# EPS-HEP 2025

dimanche 6 juillet 2025 - vendredi 11 juillet 2025

PALAIS DU PHARO, Marseille, France

# Recueil des résumés

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**Plenary** / **3**

## LHC status

**Auteur correspondant** helga.timko@cern.ch

**Secondary track**:

**T16** / **16**

## Towards more precise data analysis with Machine-Learning-based particle identification with missing data

**Auteur:** Lukasz Graczykowski[1]

**Co-auteurs:** Kamil Deja [1]; Maja Karwowska [1]; Malgorzata Janik [1]; Milosz Kasak [1]; Monika Jakubowska [1]

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Identifying products of ultrarelativistic collisions delivered by the LHC and RHIC colliders is one of the crucial objectives of experiments such as ALICE and STAR, which are specifically designed for this task. They allow for a precise Particle Identification (PID) over a broad momentum range.

Traditionally, PID methods rely on hand-crafted selections, which compare the recorded signal of a given particle to the expected value for a given particle species (i.e., for the Time Projection Chamber detector, the number of standard deviations in the dE/dx distribution, so-called "nσ" method). To improve the performance, novel approaches use Machine Learning models that learn the proper assignment in a classification task.

However, because of the various detection techniques used by different subdetectors (energy loss, time-of-flight, Cherenkov radiation, etc.), as well as the limited detector efficiency and acceptance, particles do not always yield signals in all subdetectors. This results in experimental data which include "missing values". Out-of-the-box ML solutions cannot be trained with such examples without either modifying the training dataset or re-designing the model architecture. Standard approaches to this problem used, i.e., in image processing involve value imputation or deletion, which may alter the experimental data sample.

In the presented work, we propose a novel and advanced method for PID that addresses the problem of missing data and can be trained with all of the available data examples, including incomplete ones, without any assumptions about their values [1,2]. The solution is based on components used in Natural Language Processing Tools and is inspired by AMI-Net, an ML approach proposed for medical diagnosis with missing data in patient records.

The ALICE experiment was used as an R&D and testing environment; however, the proposed solution is general enough for other experiments with good PID capabilities (such as STAR at RHIC and others). Our approach improves the F1 score, a balanced measure of the PID purity and efficiency of the selected sample, for all investigated particle species (pions, kaons, protons).

[1] M. Kasak, K. Deja, M. Karwowska, M. Jakubowska, Ł. Graczykowski & M. Janik, Eur.Phys.J.C 84 (2024) 7, 691

[2] M. Karwowska, Ł. Graczykowski, K. Deja, M. Kasak, and M. Janik, JINST 19 (2024) 07, C07013

**Secondary track**:

T12 - Data Handling and Computing

**T11 / 18**

## Construction and calibration of the DUCK (Detector of Unusual casKades) system modules

**Auteurs:** DUCK Collaboration[None]; Dmitriy Beznosko[1]

[1] *Clayton State University*

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In the High-Energy Physics field there is an active search of the origin and the nature of the Ultra-high energy cosmic rays. These are messengers that carry information from far into the Universe, and they might also hint on direction towards new physics. This talk presents the overall hardware and software design, and the construction and calibration of DUCK (Detector system of Unusual Cosmic-ray casKades) main modules. DUCK is a new cosmic-rays detector that is being constructed at the Clayton State University campus that has resolution at the ns-level. The main scientific direction for the DUCK project is to contribute to the approach of cosmic ray event analysis using the full waveform and detector response width. Additionally, it aims to provide an independent verification of the detection of the 'unusual'cosmic ray events that were reported by the Horizon-T detector system that may be indicating direction towards the novel physics possibilities.

**Secondary track**:

**Poster T14 / 19**

## Using Local AI with RAG for Open Educational Materials Generation for Physics Education

**Auteur:** Dmitriy Beznosko[1]

**Co-auteurs:** Alexander Iakovlev [2]; Tatiana Krivosheev [1]

[1] *Clayton State University*

[2] *Woodward Academy*

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AI nowadays is a new tool that seems to be everywhere including education. It brings convenience but also concerns - the two largest concerns with using AI by instructors are the safety of students' data and the AI lack of the specific knowledge needed in a specific class. The data safety can be addressed by using a locally run large language models model using Ollama framework, a free tool that gives user the ability to run LLM locally on your system so no data is transmitted. The approach of using the Retrieval Augmented Generation adds the user data to the as a context for the generation of the educational materials as well as homework and quiz assignments. Brief background, installation and configuration highlights with performance and use examples of different models will be presented.

**Secondary track**:

**Joint T02+T09 / 20**

## Revised phenomenology of new physics particles in GeV mass range

**Auteur:** Maksym Ovchnynikov[1]

[1] *CERN*

**Auteur correspondant** maksym.ovchynnikov@cern.ch

In this talk, I explore minimal extensions of the Standard Model that introduce new particles in the GeV mass range, with a particular focus on how they can be probed at proton accelerator experiments such as the recently approved SHiP. I present a comprehensive analysis of the phenomenology of new particles, highlighting overlooked inconsistencies in the literature as well as key theoretical uncertainties. I then show how these uncertainties substantially impact both the existing constraints on the parameter space and the reach of future experimental searches.

**Secondary track**:

T13 - Accelerators for HEP

**T01** / **21**

## Advancing our understanding of how new physics affects cosmic neutrinos

**Auteurs:** Maksym Ovchnynikov[1]; Vsevolod Syvolap[2]

[1] *CERN*

[2] *IFT Madrid*

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Understanding how new physics influences the dynamics of cosmic neutrinos is crucial in light of upcoming precise cosmological observations and the need to reconcile the complementarity between cosmological and laboratory probes. In this talk, I discuss novel insights on neutrino evolution in the presence of new physics at MeV temperatures - at the edge of the times that can be probed by BBN and CMB observations. In addition, I present a new powerful method to solve the neutrino Boltzmann equation in a model-agnostic way.

**Secondary track**:

T03 - Neutrino Physics

**T02** / **22**

## Blazar-boosted dark matter: a cosmic accelerator for dark matter particle detection

**Auteur:** Laura Manenti[1]

[1] *The University of Sydney*

The search for dark matter (DM) remains one of the most pressing challenges in modern physics. Detecting sub-GeV DM particles poses significant challenges for traditional Earth-based detectors due to their low collision energies. This talk presents a novel approach to overcome these limitations: blazar-boosted dark matter (BBDM). I will explore how active galactic nuclei (AGN) with jets oriented towards Earth, known as blazars, can serve as cosmic particle accelerators for DM. Through interactions with hadronic matter in blazar jets, DM particles in the host galaxy's halo can be significantly accelerated, potentially reaching Earth with kinetic energies high enough for detection.

This presentation will cover the theoretical framework of BBDM, including blazar selection, modeling, and the upscattering mechanism in the DM halo. Additionally, I will present the first constraints on this framework using data from leading direct detection experiments, including XENON and LZ, demonstrating how these world-class detectors can probe this novel dark matter scenario. Notably, this is the first work that brings together experimental particle physicists, astrophysicists, and theoretical physicists, representing a cross-section of different disciplines. This approach allows us to explore the potential of BBDM, potentially opening new avenues for DM research.

**Secondary track**:

**T09** / **23**

## Flavour Deconstructing the Composite Higgs

**Auteurs:** Gino Isidori[1]; Joe Davighi[2]; Marko Pesut[1]; Sebastiano Covone[1]

[1] *University of Zurich*

[2] *CERN*

**Auteur correspondant** marko.pesut@physik.uzh.ch

In the first part of the talk, we will introduce the main model building ideas, namely flavour non-universality and Higgs compositeness, that are central to our model, as well as the theoretical and experimental motivations for exploring these BSM avenues. In the second part of the talk, we present a flavour non-universal extension of the Standard Model combined with the idea of Higgs compositeness. At the TeV scale, the electroweak gauge symmetry is assumed to act in a non-universal manner on light- and third-generation fermions, while the Higgs emerges as a pseudo Nambu-Goldstone boson of a spontaneously broken global symmetry. The flavour deconstruction implies that the couplings of the light families to the composite sector are suppressed by powers of a heavy mass scale, explaining the flavour puzzle. We present a detailed analysis of the radiatively generated Higgs potential, showing how this intrinsically-flavoured framework has the ingredients to justify the unavoidable tuning in the Higgs potential necessary to separate electroweak and composite scales. The model is compatible with current experimental bounds and predicts new states at the TeV scale, which are within the reach of near future experimental searches.
Arxiv: 2407.10950

**Secondary track**:

T08 - Higgs Physics

**T11** / **25**

## Wireless power transmission for HEP

**Auteurs:** Gal Gonen[1]; Yan Benhammou[1]

[1] *Tel Aviv University*

The emergence of fully electric vehicles and autonomous systems (e.g., cars,drones), combined with advancements in long-distance power transmission (e.g.,satellites), has accelerated the development of wireless power transmission technologies. These technologies aim to address critical challenges such as reducing the reliance on extensive cabling and minimizing noise interference, especially in high-energy physics experiments. In such environments, the large quantity of copper wires not only contributes to increased material costs and complexity but also serves as a potential source of noise and signal degradation. A promising solution lies in the use of laser-based wireless power transmission systems, where optical power converters are positioned close to or directly on front-end boards.
As part of the Wireless Allowing Data and Power Transfer (WADAPT) consortium, we have undertaken a pioneering study to explore the feasibility of using laser-based wireless power systems in experimental setups. The study centers around a 10W laser coupled with a dedicated photovoltaic cell (PVC), designed to convert laser energy into electrical power efficiently. The system was rigorously tested at varying distances between the laser source and the PVC to understand the influence of distance on power transmission efficiency and overall performance.
To ensure practical application, the system was successfully integrated with a voltage and power regulator, enabling it to power a silicon photomultiplier (SiPM). The SiPM, known for its sensitivity and precision in detecting low levels of light, is a critical component in many high-energy physics experiments. Using a precise light source, we conducted a comprehensive series of tests to evaluate how this novel power source affects the sensor's performance. Key parameters such as power conversion efficiency, noise levels, signal stability, and overall sensor functionality were carefully analyzed to ensure that the wireless power system meets the rigorous demands of experimental physics.
The results of wireless power transmission for a silicon sensor will be presented, highlighting its potential to transform the way power is delivered in complex experimental environments.

**Secondary track**:

**T02** / **26**

## First searches for axion and dark photon dark matter with MADMAX

**Auteurs:** Fabrice Hubaut[1]; MADMAX Collaboration[None]

[1] *CPPM, Aix-Marseille Université, CNRS/IN2P3*

**Auteur correspondant** hubaut@in2p3.fr

The MAgnetized Disk and Mirror Axion eXperiment (MADMAX) is a future experiment aiming to detect dark matter axions from the galactic halo by resonant conversion to photons in a strong magnetic field. It uses a novel concept based on a stack of dielectric disks in front of a mirror, called booster, to enhance the potential signal from axion-photon conversion over a significant mass range. In its final version, MADMAX aims to scan the uncharted QCD axion mass range from 40 to 400 mueV, favoured by post-inflationary theories.
Several small scale prototype systems have been tested these last three years, allowing to validate the dielectric haloscope concept and perform competitive axion and dark photon dark matter searches. This talk will present the current status of the experiment and its prototypes, including the results achieved so far, the ongoing research and development and the remaining challenges.

**Secondary track**:

**Poster T06** / **27**

## Observable spectrum in the weak sector of the Standard Model

**Auteur:** Georg Wieland[1]

**Co-auteur:** Axel Maas [1]

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Strict gauge invariance dictates that physical states must be composite, even for the weak sector of the Standard Model. This field-theoretical subtlety is resolved by the Fröhlich-Morchio-Strocchi (FMS) mechanism, which suggests additional Higgs contributions in Standard Model processes. While this has been supported by theoretical investigations in the purely bosonic sector, its implications for fermionic observables require more attention —particularly as these effects could be within reach of current and future experiments.
We investigate a proxy for the weak sector that includes dynamical fermions by employing non-perturbative lattice techniques within a manifestly gauge-invariant approach. We determine the physical spectrum of the theory, collecting further evidence for the validity of the FMS mechanism. Additionally, we systematically explore the parameter space to identify suitable simulation points for calculating scattering cross sections. We also outline the next steps for deriving cross sections from lattice simulations, as has been done previously for vector boson scattering.

**Secondary track**:

T08 - Higgs Physics

**Poster T03 / 28**

## Global Extraction of the H, D, C-12, Ca-40, and Fe-56 Nuclear Electromagnetic Response Functions and Comparisons to Nuclear Theory and Neutrino/Electron Monte Carlo Generators

**Auteurs:** Arie Bodek[1]; M. E. Christy[2]

[1] *University of Rochester*

[2] *Thomas Jefferson National Accelerator Facility*

We report on a global extraction of the Hydrogen, Deuterium, C-12, Ca-40 and Fe-56 longitudinal (RL) and transverse (RT) nuclear electromagnetic response functions from an analysis of all available electron scattering data on these nuclei. Since the extracted response functions cover a large kinematic range they can be readily used for comparison to theoretical predictions as well as validation and tuning Monte Carlo (MC) generators for electron and neutrino scattering experiments. We present comparisons to several theoretical approaches and electron/neutrino MC generators (run in electron scattering mode) including: "Green's Function Monte Carlo"(GFMC), "Energy Dependent-Relativistic Mean Field"(ED-RMF), "Short Time Approximation Quantum Monte Carlo"(STA-QMC), "Correlated Fermi Gas"(CFG), the NuWro theoretical framework, the ACHILESS theoretical framework, and the Improved Superscaling Model (SuSAv2).

**Secondary track**:

T05 - QCD and Hadronic Physics

**T07 / 29**

## New measurement of $K^+ \to \pi^+\nu\bar{\nu}$ branching ratio at the NA62 experiment

**Auteur:** NA62 Collaboration[None]

**Auteur correspondant** angela.romano@cern.ch

The $K^+ \to \pi^+ \nu\bar{\nu}$ decay is a golden mode for flavour physics. Its branching ratio is predicted with high precision by the Standard Model to be less than $10^{-10}$, and this decay mode is highly sensitive to indirect effects of new physics up to the highest mass scales. A new measurement of the $K^+ \to \pi^+ \nu\bar{\nu}$ decay by the NA62 experiment at the CERN SPS is presented, using data collected in 2021 and 2022. This new dataset was collected after modifications to the beamline and detectors and at a higher instantaneous beam intensity with respect to the previous 2016-2018 data taking. Using the NA62 datasets from 2016–2022, a new measurement of $\mathcal{B}(K^+ \to \pi^+ \nu\bar{\nu}) = \left(13.0^{+3.3}_{-2.9}\right) \times 10^{-11}$ is reported, and for the first time the $K^+ \to \pi^+ \nu\bar{\nu}$ decay is observed with a significance exceeding $5\sigma$.

**Secondary track**:

T09 - Beyond the Standard Model

**T09** / **30**

## First NA62 search for long-lived new physics particle hadronic decays

**Auteurs:** Angela Romano[1]; OTHER SPEAKER[None]

[1] *University of Birmingham*

The NA62 experiment at CERN, designed to measure the highly-suppressed decay $K^+ \to \pi^+ \nu\bar{\nu}$, has the capability to collect data in a beam-dump mode, where 400~GeV protons are dumped on an absorber. In this configuration, New Physics (NP) particles, including dark photons, dark scalars and axion-like particles, may be produced and reach a decay volume beginning 80~m downstream of the absorber. A search for NP particles decaying in flight to hadronic final states is reported, based on a blind analysis of a sample of $1.4 \times 10^{17}$ protons on dump collected in 2021.

**Secondary track**:

**T07** / **31**

## Searches for hidden sectors and lepton flavour violation in kaon decays at the NA62 experiment

**Auteur:** NA62 Collaboration[None]

**Auteur correspondant** viacheslav.duk@cern.ch

Rare kaon decays are among the most sensitive probes of both heavy and light new physics beyond the Standard Model description thanks to high precision of the Standard Model predictions, availability of very large datasets, and the relatively simple decay topologies. The NA62 experiment at CERN is a multi-purpose high-intensity kaon decay experiment, and carries out a broad rare-decay and hidden-sector physics programme. NA62 has collected a large sample of $K^+$ decays in flight during Run 1 in 2016-2018, and the ongoing Run 2 which started in 2021. Recent NA62 results on searches for hidden-sector mediators and searches for violation of lepton number and lepton flavour conservation in kaon decays based on the Run 1 dataset are presented. Future prospects of these searches are discussed.

**Secondary track**:

T09 - Beyond the Standard Model

**T09** / **32**

## Heavy Higgs boson $H$ production at the future multi-TeV muon collider in the context of the $U(1)_{B-L}$ model

**Auteur:** Alejandro Gutierrez-Rodriguez[1]

[1] *Universidad Autónoma de Zacatecas*

The prospects of the Muon Collider promise an unprecedented potential for exploring the particle-physics energy frontier. Furthermore, the physics program from this future collider could provide both high-precision Higgs and Standard Model (SM) measurements and direct production of new particles predicted by various extensions of the SM. With these motivations, we consider the $\mu^+\mu^- \to (Z, Z') \to ZH \to l^\pm l^\mp W^\pm W^\mp$ signal with the subsequent decay of $Z$ to pairs of $l^\pm l^\mp$ with $l = e, \mu$ and $H$ to pairs of $W^\pm W^\mp$. The projections of new physics at the future muon collider with the benchmark center-of-mass energies of $\sqrt{s} = 3, 4, 5, 6, 7$ TeV and conservative integrated luminosities of $cal L_{\rm con} = 1, 2, 3, 4, 10\ {\rm ab}^{-1}$, is of the order of 684 expected events for $M_{Z'} = 7$ TeV, $g'_1 = 0.93$, and $cal L = 10\ {\rm ab}^{-1}$. This scenario shows that the possibility of performing measurements for the $Z'$ boson and the heavy Higgs boson $H$ is important at the future muon collider. In another scenario, we incorporate $\mu^+\mu^- \to (Z, Z') \to ZH \to l^\pm l^\mp W^\pm W^\mp$ annihilation and Vector Boson Scattering (VBS) rates of $\mu^+\mu^- \to WWZ$ into our study, as well as the Leptonic, Semi-leptonic, and Hadronic channels of the $W^\pm$ for the signal, significant impact the sensitivity of the process.

**Secondary track**:

T08 - Higgs Physics

**T09** / **33**

## Search of the heavy neutral Higgs boson H of the U(1)_{B-L} model at the future multi-TeV $\mu^+\mu^-$ collider

**Auteurs:** Alejandro Gutíerrez-Rodríguez[1]; Maria A. Hernandez-Ruiz[1]

[1] *Universidad Autónoma de Zacatecas*

The possible detection of a heavy neutral Higgs boson $H$ predicted by the $U(1)_{B-L}$ model at the future multi-TeV muon collider for the center-of-mass energies of $\sqrt{s} = 3, 6, 10, 30, 50$ TeV with integrated luminosities of $cal L_{\rm con} = 1, 2, 3, 4, 10\ {\rm ab}^{-1}$ and $cal L_{\rm opt} = 90, 250\ {\rm ab}^{-1}$, is investigated. The following production and decay channels of the heavy Higgs boson through the Vector Boson Fusion (VBF) are considered: $\mu^+\mu^- \to \nu_\mu \bar{\nu}_\mu H \to \nu_\mu \bar{\nu}_\mu W^\pm W^\mp$ and $\mu^+\mu^- \to \mu^+\mu^- H \to \mu^+\mu^- W^\pm W^\mp$, with the subsequent decay of the Higgs boson $H$ to pairs of $W^\pm W^\mp$ and $ZZ$ bosons. We show that promising signals with good statistical significances can be obtained in di-vector bosons channel, with $\nu_\mu \bar{\nu}_\mu \nu_l l^\pm \bar{\nu}_l l^\mp$ final states. For completeness, we incorporate the Higgs-strahlung process $\mu^+\mu^- \to \mu^+\mu^- H$.

**Secondary track**:

T08 - Higgs Physics

**T10** / **35**

## Composite objects in quantum (super)gravity

**Auteur:** Axel Maas[1]

[1] *University of Graz*

It has been a long entertained idea that self-bound gravitons, so-called geons, could be a dark matter candidate or form (primordial) black holes. The development of viable candidates for quantum gravity allows now to investigate these ideas. Analytic methods show that the description of geons needs to be based on composite operators made out of the graviton field. We present results from a numerical investigation into this idea using causal dynamical triangulations, an ab-initio non-perturbative definition of quantum gravity based on general relativity, and accessible in lattice-gauge-theory-like simulations. Our results suggest an interesting dependence on cosmological time and other unexpected features. We also compare the results to the expectations from analytic methods. Finally, we extend the analytic part of the setting to a supergravity scenario. This provides hints which, if confirmed, could explain why supersymmetry may in a realistic universe in principle not be observable at low (collider) energy scales.

**Secondary track**:

T01 - Astroparticles, Gravitation and Cosmology

**T01** / **38**

## Dark Energy as a Shockwave-Driven Scalar Field: Implications for Quantum Gravity and High-Energy Physics

**Auteur:** Jack Kiperman[1]

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**Auteur correspondant** jack@kiperman.us

The nature of dark energy is one of the most pressing open questions in physics. While the standard ΛCDM model assumes a static cosmological constant, alternative approaches suggest a dynamical scalar field as the source of cosmic acceleration. In this work, we propose a shockwave-driven model, where dark energy emerges as a high-energy vacuum excitation of a gravitationally coupled scalar field. This model suggests that metric fluctuations, quantum gravitational backreaction, and vacuum polarization dynamically alter the effective energy density of the universe, explaining the observed acceleration. Using a modified field-theoretic approach, we derive the time-dependent equation of state for dark energy, demonstrating how it naturally resolves the Hubble tension and predicts observable deviations from ΛCDM cosmology. This framework provides a testable link between quantum field fluctuations and large-scale structure formation, with potential constraints from CMB anisotropies, galaxy surveys, and gravitational wave experiments. If validated, this approach could provide a first-principles explanation for the dark energy problem, bridging cosmology, quantum gravity, and high-energy physics.

Keywords: Dark Energy, Quantum Gravity, Shockwave Cosmology, Scalar Fields, Vacuum Fluctuations, High-Energy Physics, Cosmology

**Secondary track**:

T09 - Beyond the Standard Model

**T02 / 39**

## The SABRE South Experiment at the Stawell Underground Physics Laboratory

**Auteur:** Irene Bolognino[1]

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SABRE is an international collaboration that will operate similar particle detectors in the Northern (SABRE North) and Southern Hemispheres (SABRE South). This innovative approach distinguishes possible dark matter signals from seasonal backgrounds, a pioneering strategy only possible with a southern hemisphere experiment. SABRE South is located at the Stawell Underground Physics Laboratory (SUPL), in regional Victoria, Australia.
SUPL is a newly built facility located 1024 m underground (~2900 m water equivalent) within the Stawell Gold Mine and its construction has been completed in 2023.
SABRE South employs ultra-high purity NaI(Tl) crystals immersed in a Linear Alkyl Benzene (LAB) based liquid scintillator veto, enveloped by passive steel and polyethylene shielding alongside a plastic scintillator muon veto. Significant progress has been made in the procurement, testing, and preparation of equipment for installation of SABRE South. The SABRE South muon detector and the data acquisition systems are actively collecting data at SUPL and the SABRE South's commissioning is planned to be completed by the end of 2025.
This presentation will provide an update on the overall progress of the SABRE South construction, its anticipated performance, and its potential physics reach.

**Secondary track**:

**T11 / 41**

## The ALADDIN experiment at LHC

**Auteurs:** ALADDIN collaboration[1]; Paolo Gandini[2]

[1] *at CERN*

[2] *INFN - Sezione di Milano*

ALADDIN (An Lhc Apparatus for Direct Dipole moments INvestigation) is a new proposed compact fixed-target experiment at the LHC, which will enable a unique program of measurements of charm baryon electromagnetic dipole moments. The experiment relies on an innovative storage-ring layout capable of deflecting protons from the beam halo towards a solid target paired to a bent crystal where forward-boosted charm baryons are produced and channelled. Exploiting the spin precession induced by the channelling phenomena in the bent crystal, the magnetic and electric dipole moments can be measured by analysing the polarisation of the decaying charm baryons. The ALADDIN apparatus features a 4.4 m long spectrometer and a 5.0 m long RICH detector for particle identification, which could be installed at the LHC Insertion Region 3, without civil engineering and with minimal impact on the LHC machine operations, during the Long Shutdown 3 to start data taking in Run4. A proof-of-principle test at the LHC, named TWOCRYST, is currently under way to demonstrate the feasibility of the proposed experiment in 2025. The Letter Of Intent of the experiment has been submitted to the LHCC (https://cds.cern.ch/record/2905467) and the LHCC has approved the collaboration to write a technical proposal in 2025.

**Secondary track**:

T11 - Detectors

**T07** / **42**

## Anomalies in Hadronic B decays

**Auteur:** Suman Kumbhakar[1]

[1] *University of Calcutta*

In this paper, we perform fits to $B \to PP$ decays, where $B = \{B^0, B^+, B_s^0\}$ and the pseudoscalar $P = \{\pi, K\}$, under the assumption of flavor SU(3) symmetry [SU(3)$_F$]. Although the fits to $\Delta S = 0$ or $\Delta S = 1$ decays individually are good, the combined fit is very poor: there is a $3.6\sigma$ disagreement with the SU(3)$_F$ limit of the standard model (SM$_{\rm SU(3)_F}$). One can remove this discrepancy by adding SU(3)$_F$-breaking effects, but 1000\% SU(3)$_F$ breaking is required. The above results are rigorous, group-theoretically – no dynamical assumptions have been made. When one adds an assumption motivated by QCD factorization, the discrepancy with the SM$_{\rm SU(3)_F}$ grows to $4.4\sigma$.

**Secondary track**:

**T10** / **43**

## A holographic analysis of the pion

**Auteur:** Ruben Sandapen[1]

[1] *Acadia University*

Using light-front holographic QCD, we compute the pion mass, charge radius, decay constant, electromagnetic form factor and electromagnetic transition form factor. In doing so, we model the longitudinal quark dynamics using (1+1)-dimensional QCD-inspired potentials due to 't Hooft and to Li & Vary. We explore the strong degeneracy between these two potentials and note that one scenario that accords well with the data also maps onto an equation previously derived by Vegh that describes the dynamics of a four-segmented string in (2+1) Anti de Sitter spacetime.

**Secondary track**:

T10 - Quantum Field and String Theory

**T11** / **44**

## Upgrade II of the muon detector at LHCb

**Auteur:** Francesco Debernardis[None]

The LHCb experiment at CERN, operating at the LHC collider, enabled significant advances in flavor physics and electroweak studies in the forward region, demonstrating excellent performance during LHC Run 1 and Run 2. Upgrades in detectors resolution and trigger system technology were necessary to cope with the increased luminosity in Run 3, reaching a peak value of $\mathcal{L} = 2 \times 10^{33}$ cm$^{-2}$s$^{-1}$.

In order to take full advantage of the enhanced luminosity in the forthcoming LHC high-luminosity era from Run 5 in 2035, a second major upgrade (the Upgrade II) is essential. This upgrade aims to maintain optimal performance at a peak luminosity of $\mathcal{L} = 1.5 \times 10^{34}$ cm$^{-2}$s$^{-1}$, while targeting an integrated luminosity of 300 fb$^{-1}$. This presentation will discuss the current state-of-the-art and future strategies for the LHCb muon detector Upgrade II. Key challenges include high hit rates, up to 1 MHz/cm$^2$, mostly of background particles, which significantly impact on muon identification efficiency. Solutions are proposed, ranging from new detector technologies with high performance readout electronics to improvements in the signal acquisition scheme. All aimed at mitigating inefficiencies and ensuring robust performance in the HL-LHC era.

**Secondary track**:

**T03** / **45**

## Muon neutrino interaction studies with 2024 data with SND@LHC detector

**Auteur:** Giulia Paggi[1]

[1] *Università di Bologna*

**Auteur correspondant** giulia.paggi@cern.ch

The Scattering and Neutrino Detector at LHC (SND@LHC) is a compact, standalone experiment located in the TI18 tunnel, 480 meters downstream of the ATLAS interaction point, designed to observe neutrinos produced in LHC proton-proton collisions. The SND@LHC detector allows for the identification of all three flavors of neutrino interactions in the pseudorapidity region 7.2 < η < 8.4 within an unexplored energy range of 100 GeV < E < 1 TeV. The SND@LHC detector comprises three main sections: an instrumented target, a hadron calorimeter, and a muon system. All high-energy νN interactions in the target produce hadronic showers, while muon neutrino interactions are distinguished by the presence of a muon in the final state.
This talk will present the status of the ongoing analysis of 2024 data. Compared to the 2022 dataset—which enabled the first observation of accelerator neutrinos—this analysis benefits from several significant improvements. The recorded luminosity in 2024 is more than three times larger than in 2022, leading to an expected number of neutrino interactions in the detector of the order of thousands. Additionally, the installation of a veto plane during the 2023–2024 Year-End Technical Stop enhanced target coverage and significantly improves background rejection. Another key advancement is the calorimeter calibration, made possible by a dedicated test beam campaign. This calibration not only enables precise energy estimation for recorded events, but also provides an additional tool for background suppression, allowing full exploitation of the instrumented volume. As a result, this analysis benefits from substantially larger statistics compared to previous studies.

**Secondary track**:

**T11** / **46**

## Energy calibration for the SND@LHC hadronic calorimeter

**Auteur:** Filippo Mei[1]

[1] *Università di Bologna*

**Auteur correspondant** filippo.mei@studio.unibo.it

SND@LHC is a compact, standalone experiment located in the TI18 tunnel, 480 meters downstream of the ATLAS interaction point, designed to observe neutrinos produced in LHC proton-proton (pp)

collisions. The SND@LHC detector allows for the identification of all three flavors of neutrino interactions in the pseudorapidity region 7.2 < η < 8.4 within an unexplored energy range of 100 GeV < E < 1 TeV.
The detector consists of two sections: an instrumented target and a hadron calorimeter. Energetic νN collisions in the target produce hadronic showers. Reconstructing the total energy requires estimating the fractions of energy deposited in both the target and the calorimeter. To achieve this, a replica of the detector was exposed to hadron beams with energies ranging from 100 to 300 GeV at the CERN SPS H8 test beam line during the summer of 2023. The experimental setup allowed for the study of showers as a function of both energy and shower starting position within the target depth. Thanks to this calibration procedure, an energy resolution of 15-20% for the reconstruction of hadronic showers was achieved. This result enables the reconstruction of the energy spectrum of hadronic showers from muon neutrino interactions, a key ingredient for the SND@LHC physics programme.

**Secondary track**:

T03 - Neutrino Physics

**Poster T03** / **47**

## Search for muonic trident production in the SND@LHC detector

**Auteur:** Onur Durhan[1]

**Co-auteur:** Ali Murat Guler [2]

[1] *Middle East Technical University, Atilim University*

[2] *Middle East technical University*

**Auteur correspondant** onur.durhan@cern.ch

The SND@LHC experiment is designed to study neutrinos produced in proton-proton collisions at the LHC, covering an energy range from 100 GeV to 1 TeV. It explores an unexplored pseudo-rapidity region of 7.2 < η < 8.4. The compact detector is positioned 480 meters downstream from the ATLAS Interaction Point (IP1) in the TI18 tunnel. Its setup includes a veto system, a tungsten target interleaved with nuclear emulsion layers, scintillating fiber (SciFi) trackers, and a muon detection system. The high muon flux through the SND@LHC detector, originating from the particles produced at IP1, enables the search for rare processes, such as the direct production of a muon pair by a muon interacting with the field of a nucleus. Here, we present the measurement of muonic trident production in the SND@LHC detector. The Monte Carlo simulation prediction of muonic trident events is consistent with the measured values.

**Secondary track**:

T09 - Beyond the Standard Model

**T07** / **49**

## Renormalisation group evolution of the shape function $g_{17}$ in $\bar{B} \to X_s\gamma$ and $\bar{B} \to X_s\ell^+\ell^-$ at subleading power

**Auteurs:** Philipp Böer[1]; Riccardo Bartocci[1]; Tobias HURTH[2]

[1] *JGU Mainz*

[2] *Johannes Gutenberg University Mainz*

We derive and solve the renormalization-group (RG) equation for the shape function $g_{17}(\omega, \omega_1; \mu)$, which appears at subleading power in the factorization of the inclusive decays $\bar{B} \to X_s\gamma$ and $\bar{B} \to X_s\ell^+\ell^-$.

Our results provide the first key ingredient for a next-to-leading order analysis of the resolved-photon $Q_1^c - Q_{7\gamma}$ interference contribution, whose current uncertainties rank among the largest in both inclusive penguin modes.

We examine the renormalization of this function and demonstrate that, for amplitude-level soft functions, the analytic properties of the anomalous dimension enable a much simpler "reduced"evolution equation. This simplification will play a crucial role in various inclusive and exclusive B decays beyond leading power in the heavy-quark and large-energy expansions.

**Secondary track**:

T05 - QCD and Hadronic Physics

**T11** / **53**

## Crilin: a highly granular semi-homogeneous crystal calorimeter with excellent timing for future colliders

**Auteur:** Ruben Gargiulo[1]

[1] *Sapienza University of Rome*

Crilin is a concept of a semi-homogeneous calorimeter consisting in multiple layers of pure Cherenkov Lead Fluoride (PbF2) crystals interspaced with active surface-mounted UV-extended Silicon Photomultipliers (SiPMs).

This innovative design is now the baseline for the electromagnetic calorimeter of the MUSIC detector for the prospective Muon Collider. Considering the need to discriminate signal particles from the Muon Collider beam-induced background (BIB), Crilin employs an high level of granularity, both transverse (1 cm) and longitudinal ($4X_0$).
Due to the expected occupancy resulting from beam-induced backgrounds, with a photon flux of average energy of 1.7 MeV and approximately 4.5 MHz/cm$^2$ fluence, time-of-arrival measurements within the calorimeter becomes essential to reject out-of-time BIB. Thanks to its pure Cherenkov response, Crilin can not only achieve outstanding time resolutions, but also suppress part of the photon background which creates $e^+/e^-$ under or close to the Cherenkov threshold.

The high granularity and the timing properties allow 5D particle flow tecniques, essential to reach good jet energy resolutions at any future collider.

Operation within a challenging radiation environment is also a crucial point, with exposure levels reaching 1 Mrad/year total ionizing dose (TID) and a neutron fluence equivalent to $10^{14}$ $n_{1MeV-eq}$/cm$^2$/year. An exhaustive radiation hardness study on both crystals and SiPMs confirmed the Crilin capability to work effectively in these extreme conditions, in terms of both dose and neutron fluences.

A prototype (Proto-1), consisting of two layers of 3x3 PbF2 crystals each, underwent testing in 2023 using 450 MeV electrons at the LNF Beam Test Facility and 40-150 GeV electrons at CERN H2. An outstanding timing resolution of less than 50 ps for energy deposits as low as 1 GeV was measured. A comprehensive overview of the prototype's mechanics and electronics, along with the outcomes of the test beams, is presented for consideration.

We are currently in the process of constructing a larger full-containment prototype featuring a 7x7 crystal matrix and comprising 5 layers, in the framework of the DRD6 collaboration. The realization is scheduled for completion in 2025, with testing set to commence in the spring of 2026.

**Secondary track**:

**T11** / **58**

## Small Extensive Air Shower detector array –a tool for global cosmic-ray research

**Auteur:** Jerzy Pryga[1]

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The CREDO collaboration studies cosmic-ray related phenomena on a large scale, searching for so called Cosmic-Ray Ensembles (CRE) and other unusual correlations and anomalies of non local nature. Such studies require data on Extensive Air Showers (EAS) and flux of secondary cosmic-ray particles that covers large areas. To perform such measurements, a large network of inexpensive detectors working continuously is necessary, and this work presents a design of such device. It comprises several small (5 cm x 5 cm x 1 cm) scintillator detectors connected in a flat coincidence circuit, which makes it a desktop-size device. Such station is designed to work for months or even years without human intervention, as it can send collected data directly to the database through internet. Cost of construction of a complete device ranges from USD 1000 to USD 2000 depending on the number of detectors used. Results of measurements performed with the use of constructed prototype are compared with estimations based on the analysis of CORSIKA simulations of EAS with Geant4 simulation of scintillator detectors response. They indicate that the proposed device is capable to measure flux of cosmic rays with high statistics and can reliably distinguish EAS events from signals originating from various backgrounds. It is a good candidate for an element of a large-scale network that should be able to not only monitor cosmic-ray flux on large area in real time, but also provide data for studies of CRE and any other phenomena related to cosmic rays.

**Secondary track**:

T01 - Astroparticles, Gravitation and Cosmology

**T03** / **59**

## Recent results from the DsTau(NA65) experiment at the CERN-SPS

**Auteur:** Ali Murat Guler[1]

**Co-auteur:** DsTau Coll.

[1] *METU*

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The DsTau(NA65) experiment at CERN aimed to measure an inclusive differential cross-section of Ds production with decay to tau lepton and tau neutrino in proton-nucleus interactions. The DsTau detector is based on the nuclear emulsion technique, which provides excellent spatial resolution for detecting short-lived particles such as charmed hadrons. We present the first results from the analysis of data collected during the pilot run in 2018 and discuss the accuracy of reconstructing proton interaction vertices in a high track density environment. The gathered data has been compared with several Monte Carlo event generators, with a focus on the multiplicity and angular distribution of charged particles. The multiplicity distribution from p–W interactions has been tested for KNO scaling and was found to be nearly consistent. Additionally, we performed the first measurement of the

interaction length of protons in tungsten. We also present the current status of our search for Ds decay and provide preliminary estimates of the differential production cross-section of Ds.

**Secondary track**:

T05 - QCD and Hadronic Physics

**T09** / **60**

## Advancing SMEFT Global Analyses: NLO, RGE contributions, and the Role of Flavour Physics

**Auteurs:** Anke Biekoetter[1]; Riccardo Bartocci[2]; Tobias HURTH[3]

[1] *Uni Heidelberg*

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The Standard Model Effective Field Theory (SMEFT) is an essential tool for probing physics beyond the Standard Model. With New Physics signals remaining elusive, deriving constraints on SMEFT Wilson coefficients is increasingly important in order to pinpoint its low-energy effects. This talk presents comprehensive global fits of SMEFT under the Minimal Flavour Violation (MFV) hypothesis. We establish global limits on Wilson coefficients using both leading and next-to-leading order SMEFT predictions for various observables. Our findings highlight significant interactions among different observables, emphasizing the necessity of integrating diverse data from multiple energy scales in global SMEFT analyses. Even within this flavour-symmetric framework, where Flavour Changing Neutral Currents (FCNC) cannot be generated at tree-level, they significantly contribute via Renormalization Group Evolution (RGE) effects. More in general a consistent treatment of the RGE in global analyses is an often-overlooked aspect which proves to be crucial for analysing properly datasets spanning various energy scales.

**Secondary track**:

T06 - Top and Electroweak Physics

**T02** / **61**

## The DarkSide-20k experiment for WIMPs direct detection and its Photon Detection System

**Auteurs:** DarkSide Collaboration[None]; Pablo KUNZE[None]

Representing approximately 85% of the Universe's total mass, dark matter remains one of the greatest mysteries in physics. Even though evidences supporting its existence accumulate, its true nature is still unknown. A leading group of dark matter candidates is Weakly Interacting Massive Particles (WIMPs). The search for WIMPs has been an ongoing experimental challenge for over a decade, continually pushing the boundaries of detection limits. The DarkSide program is part of this direct detection effort and will advance with its next-generation experiment, DarkSide-20k.

The DarkSide-20k detector will feature a dual-phase liquid argon time projection chamber (LArTPC) enclosed within two veto systems, all housed inside an $8{\times}8{\times}8\ m^3$ cryostat. Located in the Gran Sasso underground laboratory, the experiment benefits from natural shielding against cosmic rays. The

detector is designed to minimize background noise and achieve a nearly background-free operation by employing strategies to suppress unwanted signals such as neutrons, beta particles, and gamma rays. This is made possible by liquid argon's exceptional background rejection capability, particularly through pulse shape discrimination.

A key component of the detector is the Photon Detection Units (PDUs), which are curently in production. The project will utilize cryogenic and low-background silicon photomultipliers (SiPMs), which will undergo rigorous testing before being assembled into PDUs at the Nuova Officina Assergi (NOA) cleanroom, located in the external facility near the underground site. These advancements will enable DarkSide-20k to achieve unprecedented sensitivity to the WIMP-nucleon cross-section, probing previously unexplored regions of parameter space.

**Secondary track**:

**T07** / **62**

## Global fits of the Unitarity Triangle within the Standard Model. Updates from the UTfit collaboration.

**Auteurs:** UTfit Collaboration[None]; UTfit Collaboration[None]

Flavour physics represents a unique test bench for the Standard Model (SM). New analyses performed at the LHC experiments and new results coming from Belle II are bringing unprecedented insights into CKM metrology and new results for rare decays. The CKM picture provides very precise SM predictions through global analyses.
We present here the results of the latest global SM analysis performed by the UTfit collaboration including all the most updated inputs from experiments, lattice QCD and phenomenological calculations for Summer 2025.
We also present the perspectives for future UT analyses incorporating projections of experimental results and Lattice QCD computations after High-Luminosity LHC.

**Secondary track**:

**T07** / **64**

## UTfit combined analysis of D-Dbar mixing data and extraction of the CKM angle gamma

**Auteur:** UTfit Collaboration[None]

We update our combined analysis of D meson mixing and B decays sensitive to the CKM angle gamma including the latest experimental results. We derive constraints on absorptive and dispersive CP violation by combining all available data, and discuss future projections. We also provide posterior distributions for gamma and for the observable parameters appearing in D physics.

**Secondary track**:

**T03** / **65**

## Invariants of CP violation for Majorana neutrinos in the seesaw mechanism

**Auteur:** Zhi-zhong Xing[1]

[1] *Institute of High Energy, Chinese Academy of Sciences*

**Auteur correspondant** xingzz@ihep.ac.cn

We calculate several types of commutators associated with the leptonic Yukawa coupling matrices in the canonical seesaw mechanism, which can be used to measure leptonic CP violation in both heavy Majorana neutrino decays and light Majorana neutrino oscillations **in the flavor basis**. The corresponding Jarlskog-like invariants of CP violation and their small non-unitarity effects are derived **in the mass basis** with the help of a full Euler-like block parametrization of the seesaw flavor structure. A geometrical description of leptonic CP violation in terms of the unitarity polygon in the complex plane, together with some currently available experimental constraints, is also discussed.

**Secondary track**:

T07 - Flavour Physics and CP Violation

**T03** / **67**

## Physics results from the SNO+ scintillator phase and Neutrinoless Double Beta Decay prospects

**Auteur:** Ana Sofia Inacio[1]

[1] *University of Oxford*

SNO+ is a large multi-purpose neutrino detector located 2 km underground at SNOLAB, Canada, currently in operation filled with 780 tonnes of liquid scintillator as its target mass. The high light yield, low background levels, and continually increasing livetime, allow the SNO+ collaboration to perform measurements of solar neutrinos, antineutrinos from reactors and the Earth, and searches for other rare events. The data is also being used to quantify backgrounds and understand the detector response in preparation for the search of neutrinoless double beta decay of 130Te. In a first phase, SNO+ will perform this search with 0.5% of natural tellurium by weight, for a predicted half-life sensitivity of 2e26 years (90% CL) with 3 years of livetime, followed by higher tellurium loadings, up to 3%, for sensitivities above 1e27 years. In this talk I will highlight the most recent physics results from the analysis of the SNO+ scintillator data, and will discuss the prospects for the neutrinoless double beta decay search.

**Secondary track**:

**T12** / **68**

## Muon identification with Deep Neural Network in the Belle II K-Long and Muon detector

**Auteur:** Zihan Wang[1]

[1] *the University of Tokyo*

Muon identification is crucial for elementary particle physics experiments. At the Belle II experiment, muons and pions with momenta greater than 0.7 GeV/c are distinguished by their penetration ability through the $K_L$ and Muon (KLM) sub-detector, which is the outermost sub-detector of Belle II.

In this presentation, we will firstly discuss the possible room for $\mu/\pi$ identification performance improvement and then present a new method based on Deep Neural Network (DNN). This DNN model utilizes the KLM hit pattern variables as the input and thus can digest the penetration information better than the current algorithm. We test the new method in simulation and find that the pion fake rate is reduced from 4.1% to 1.6% at a muon efficiency of 90%.

**Secondary track**:

T16 - AI for HEP (special topic 2025)

**T13 / 69**

# Gamma Factory's high intensity particle beams and their potential impact on the future accelerator-technology-driven research.

**Auteur:** Gamma Factory Collaboration[None]

New directions in science are launched by new tools more often than by new concepts.

At the present time characterised by incremental increase of the energy and intensity of particle beams, Gamma Factory (GF) proposes leaps in the intensity (up to 7 orders of magnitude), quality (low emittance, polarisation CP-tagging, flavour tagging), and precision control of several types of particle beams.

The primary(ions), secondary(photons) and tertiary (polarised positrons, muons, neutrino, neutrons, radioactive ions) GF beams can be produced with unprecedented power-plug power efficiency – outperforming the present schemes by several orders of magnitude.

GF proposes to extend the scientific programme of the LHC in multiple branches of science (particle, nuclear, atomic, astro, accelerator and applied physics) with reasonable investment costs and small environmental impact – by using the plug power which can be generated by the GF-beam-driven, waste transmuting, sub-critical nuclear reactor.

The GF beam beam-cooling techniques and new methods of producing beams of polarised muons allow to improve the measurement precision of the Standard Model parameters and to produce exclusively Higgs bosons in photon-photon collisions.

The GF experimental programme, if implemented at CERN, could follow the HL-LHC phase, and can be executed while waiting for the next, large-scale, energy-frontier accelerator project.

In this talk we plan to present both ongoing the GF R&D studies (including the very recent world record in the stored laser-photon beam power, the status of the GF proof-of-principle SPS experiment, and the results of quantitative studies of selected Gamma Factory physics applications.

**Secondary track**:

**T02 / 70**

# FORMOSA: looking forward to millicharged particles at the LHC

**Auteur:** Matthew Citron[1]

[1] *UC Davis*

The FORMOSA detector at the proposed Forward Physics Facility is a scintillator-based experiment designed to search for signatures of "millicharged particles" produced in the forward region of the LHC. This talk will cover the challenges and impressive sensitivity of the FORMOSA detector, expected to extend current limits by over an order of magnitude. A pathfinder experiment, the FORMOSA demonstrator, was installed in the FASER cavern at the LHC in early 2024 and has been collecting collisional data. Results from this demonstrator and important implications for the full detector design will be shown.

**Secondary track**:

T09 - Beyond the Standard Model

**Joint T06+T08 / 71**

## Connecting Scales: RGE Effects in the SMEFT at the LHC and Future Colliders

**Auteurs:** Alejo Rossia[1]; Eleni Vryonidou[2]; Jaco ter Hoeve[3]; Juan Rojo[4]; Luca Mantani[5]

[1] *University of Padua*

[2] *University of Manchester*

[3] *University of Edinburgh*

[4] *VU Amsterdam and Nikhef*

[5] *IFIC Valencia*

**Auteur correspondant** jterhoe@ed.ac.uk

Global interpretations of particle physics data within the framework of the Standard Model Effective Field Theory (SMEFT), including their matching to UV-complete models, involve energy scales potentially spanning several orders of magnitude. Relating these measurements among them in terms of a common energy scale is enabled by the Renormalisation Group Equations (RGEs). Here we present a systematic assessment of the impact of RGEs, accounting for QCD, electroweak, and Yukawa corrections, in a global SMEFT fit of LEP and LHC data where individual cross-sections are assigned a characteristic energy scale. We also quantify the impact of the RGE effects in projected global fits at the HL-LHC and the FCC-ee. Finally, we assess the role that RGEs play on the sensitivity at HL-LHC and FCC-ee to representative one-particle UV models matched onto SMEFT either at tree and one-loop level. Our study emphasizes the importance of a consistent treatment of energy scales to achieve the best precision and accuracy in indirect searches for heavy new physics through precision measurements.

**Secondary track**:

T09 - Beyond the Standard Model

**T11 / 72**

## The Belle II Upgrade Program

**Auteur:** Steven Robertson[1]

[1] *IPP / UofA*

The Belle II detector at the SuperKEKB accelerator complex is covering a wide range of exciting physics topics. To achieve the project's research goals, a substantial increase of the data sample to 50 $ab^{-1}$ is needed, and for that, the luminosity has to reach the ambitious goal of $6 \times 10^{35}$ $cm^{-2}$ $s^{-1}$. The progress towards the design luminosity is accompanied by research and development of the accelerator, operation methods, detector components, as well as their upgrades. In the present contribution, we will discuss the status and plans of the project, timescales for upgrades, their motivations, and opportunities, an overview of upgrade options, and finish with an outlook and perspectives.

**Secondary track**:

**T11** / **73**

# The DUNE Photon Detection System

**Auteur:** PATRICIA SANCHEZ LUCAS[1]

[1] *Universidad de Granada*

The neutrino experiment DUNE, currently under construction in the US, has a broad physics program that covers oscillation physics at the GeV scale, the search for proton decay and the observation of supernova and solar neutrinos. The DUNE far detector is based on liquid argon time projection chamber (LArTPC) technology, that allows for a 3D real-time position reconstruction of the events and their energy. This is possible thanks to collection of both electrons and scintillation photons produced after an interaction. The light signal in particular is key to provide the timing of the interactions. To fully exploit the light signal, DUNE will be equipped with a Photon Detection System (PDS). The main element of the PDS is a novel device called X-Arapuca, a light trap that detect scintillation photons with SiPMs. The X-Arapuca will enhance significantly the potential of DUNE at the lowest energies by improving the overall energy resolution. Thanks to an intense R&D campaign conducted in several labs and at the two ProtoDUNEs at CERN, the PDS system has been optimized and validated. We describe here the DUNE PDS, the latest results from test facilities, the plans for the future installation in DUNE and its role in the physics goals of DUNE

**Secondary track**:

**T09** / **74**

# The BDF/SHiP experiment at the ECN3 high-intensity beam facility at the CERN SPS

**Auteur:** SHiP Collaboration[None]

The BDF/SHiP experiment is a general purpose intensity-frontier experiment for the search of feebly interacting GeV-scale particles and to perform neutrino physics measurements at the HI-ECN3 (high-intensity) beam facility at the CERN SPS, operated in beam-dump mode, taking full advantage of the available $4 \times 10^{19}$ protons per year at 400 GeV. The Collaboration is now in the phase of TDR preparation.
The setup consists of two complementary detector systems downstream an active muon shield: the scattering and neutrino detector (SND), consisting of a light dark matter (LDM) / neutrino target with vertexing capability. and the hidden sector decay spectrometer (HSDS), consisting of a 50 m long decay volume followed by a spectrometer, timing detector, and a PID system. BDF/SHiP offers an unprecedented sensitivity to decay and scattering signatures of various new physics models and tau neutrino physics.

**Secondary track**:

T03 - Neutrino Physics

**T12** / **76**

## The ODISSEE project: Converged AI real-time data processing for SKAO and HL-LHC

**Auteur:** Vladimir GLIGOROV[1]

[1] *LPNHE*

The next decades will see a new generation of scientific facilities and experiments generate exabytes of data, requiring physics-quality inference to be performed in real time in order to reduce their volume to manageable amounts for permanent storage and final physics analysis. Two of the biggest examples of such facilities are the SKAO and HL-LHC, which also share a common scientific goal of searching for dark matter and understanding its properties. Unlocking their full potential will require significant advances in the way we process data in real-time. This is essential both in order to achieve the required computational and energy efficiency as well as to increase the reuse of common methods in order to improve the coherence of the real-time processing in light of the shared scientific objectives of the projects. The ODISSEE project is a recent initiative, funded by the European Commission under the 2024 infrastructure programme, bringing together SKAO and HL-LHC researchers together with computer scientists and a range of industry partners which seeks to address this challenge. A unique aspect of ODISSEE is the scope: it aims for an end-to-end treatment of the data processing chain, from the optimization of data centre operations and monitoring, to enabling the use of AI algorithms at scale across a range of computing architectures, as well as a simultaneous tuning of computational and energy efficiency together with physics accuracy. In this poster we will present the latest actions and results from the ODISSEE project.

**Secondary track**:

**T02** / **77**

## Status of the MilliQan Experiment during Run 3

**Auteur:** Juan Salvador Tafoya Vargas[1]

[1] *University of California Davis (US)*

**Auteur correspondant** j.tafoya.vargas@cern.ch

The MilliQan experiment is an ongoing search for millicharged particles (mCPs), which arise naturally in many Dark Sector models which offer potential Dark Matter candidates. The experiment is located just above the CMS experiment at the LHC and leverages this proximity along shielding from most standard model backgrounds to gain sensitivity to mCPs in the mass range of $0.01-45$ GeV, while having sensitivity to charges as low as $0.003e$. Two detector designs have been implemented to achieve this wide range of sensitivity, one detector featuring long scintillating bars for low charge/mass points, and the other utilizing wide scintillating slabs for high mass and high charge.

The bar detector has taken data for about two years, corresponding to more than $140\,\mathrm{fb}^{-1}$ of recorded luminosity. Over the summer of 2024 the slab detector was fully assembled and commissioning has been ongoing. Measurements of beam muons produced at the CMS interaction point with the slab detector have been made and compared with cosmic ray showers for validation.

The current status of the experiment will be presented, including a look at 2024 bar detector data. In addition, recent commissioning results of the slab detector will be discussed in relation to the slab detector's early data taken in 2025.

**Secondary track**:

**T08** / **78**

## Matching NLL to NLO in Higgs and Z plus jet at the LHC and FCC

**Auteurs:** Francesco Giovanni Celiberto[1]; Luigi Delle Rose[2]; Alessandro Papa[3]

[1] *UAH Madrid*

[2] *Università della Calabria*

[3] *Università della Calabria & INFN-Cosenza*

**Auteur correspondant** francesco.celiberto@uah.es

Recent studies of high-energy inclusive Higgs boson hadroproduction rates, incorporating fixed-order N$^3$LO QCD corrections, have demonstrated that high-energy resummation effects can contribute up to 10\% at the nominal energies of the FCC. This finding underscores the importance of resummation physics for electroweak processes at 100 TeV. We present new predictions for rapidity and transverse-momentum distributions that probe the emission of a Higgs boson in association with a jet in proton collisions. These results are computed at NLO accuracy in QCD and matched to next-to-leading logarithmic accuracy and beyond (NLL/NLO$^+$) in the high-energy regime. Additionally, we report preliminary progress in extending this approach to $Z$-boson production. To our knowledge, this work represents the first implementation of a matching procedure in the high-energy resummation framework for two-particle final states separated in rapidity. We emphasize that refining fixed-order predictions for Higgs- and Z-boson plus jet distributions is essential for accurately describing key observables in Higgs and electroweak physics at both LHC and FCC energies.

**Secondary track**:

T05 - QCD and Hadronic Physics

**Poster T05** / **79**

## Heavy-flavor (in jet) fragmentation from HF-NRevo: Towards NRFF1.0

**Auteur:** Francesco Giovanni Celiberto[1]

[1] *UAH Madrid*

**Auteur correspondant** francesco.celiberto@uah.es

We report progress on the Heavy-Flavor Non-Relativistic Evolution (HF-NRevo) setup, a novel methodology to address leading-power fragmentation of hadrons containing one or more heavy quarks at moderate to large transverse momentum. As a first step, we focus on heavy quarkonia, building on Non-Relativistic QCD (NRQCD) next-to-leading-order calculations for all parton fragmentation channels to vector states such as $J/\psi$ and $\Upsilon$, as well as pseudoscalar states $\eta_c$ and $\eta_b$, which we take as proxies for initial-scale inputs. A complete set of variable-flavor number scheme fragmentation functions, named NRFF1.0, is then built through standard DGLAP evolution. Statistical uncertainties are assessed via a Monte Carlo, replica-like approach that also accounts for Missing Higher-Order Uncertainties (MHOUs). The link between the NRFF1.0 and MCscales approaches will be discussed. Finally, we highlight the use of HF-NRevo to study the collinear fragmentation of singly and doubly heavy-flavored hadrons in jets.

**Secondary track**:

**T08** / **80**

## Precision tools for the simulation of double-Higgs production via vector-boson fusion

**Auteur:** Simon Reinhardt[1]

[1] *University of Tübingen*

**Auteur correspondant** simon.reinhardt@student.uni-tuebingen.de

We present two precision tools for the simulation of Higgs-pair production via vector-boson fusion in the kappa framework for the parameterization of non-standard Higgs couplings.
A new implementation of the process is developed in the framework of the POWHEG-BOX program that can be used to provide predictions at the next-to-leading order (NLO) of QCD matched to parton showers (PS).
In addition, the existing proVBFHH program for the computation of next-to-next-to-leading order (NNLO) QCD and next-to-next-to-next-to-leading order QCD corrections is extended to account for values of the Higgs couplings different from the expectation of the Standard Model.

We systematically compare and analyse predictions obtained with the two programs and find that the NLO+PS predictions provide a good approximation of the NNLO results for observables of the tagging jets and Higgs bosons. The results turn out to be very sensitive to the values of the modified Higgs couplings.

**Secondary track**:

**T05** / **81**

## The evolution of the parton distribution functions to percent accuracy

**Auteur:** Giulio Falcioni[1]

[1] *Università di Torino and Universität Zürich*

I present analytic results for the scale evolution of the first ten moments of the Parton Distribution Functions (PDFs) through four loops in QCD.
I discuss the evolution of the PDFs to approximate N$^3$LO accuracy, which is constructed by using input from the computed moments and from physical constraints. The N$^3$LO contributions are of the order of $1\%$ or less for $x$
$gtrsim 10^{-4}$, thus providing a highly accurate PDF evolution across an important part of the kinematic plane covered at the LHC.

**Secondary track**:

**T05** / **82**

## From 1D to 3D tomography of the proton: Gluon PDFs with small-x resummation

**Auteur:** Francesco Giovanni Celiberto[1]

[1] *UAH Madrid*

**Auteur correspondant** francesco.celiberto@uah.es

We explore recent developments in the application of small-x resummation to parton distribution functions in the proton, with a particular focus on the gluon sector. In the first part, we provide a concise overview of small-x resummed one-dimensional collinear distributions, emphasizing their interplay with their three-dimensional transverse-momentum-dependent counterparts at both small and moderate values of x, including the impact of gluon–proton spin correlations. The second part introduces a novel extraction of unintegrated gluon densities, derived within the small-x resummation framework using the HELL formalism.

**Secondary track**:

**T03** / **83**

## Exploiting KM3NeT/ORCA data to study tau neutrinos and testing the non-unitarity mixing matrix

**Auteur:** Chiara Lastoria[None]

The next generation of neutrino experiments aims to provide high-precision measurements of the neutrino oscillation parameters in order to reveal the major unknowns in neutrino physics. Among them, validating the three-neutrino flavor paradigm while testing the non-unitarity of the neutrino mixing matrix remains one of the most exciting, as it allows the exploration of new physics scenarios.

KM3NeT/ORCA is a water Cherenkov detector currently under construction in the Mediterranean Sea. Its primary physics goal is an early measurement of the neutrino mass ordering from the oscillation of atmospheric neutrinos passing through the Earth. Additionally, thanks to its huge fiducial mass, KM3NeT/ORCA will have unprecedented statistics to study tau neutrinos. This talk reports the final results obtained from the data collected with a partially instrumented volume, corresponding to 5% of the total, and 433 kton-years exposure. Studying the oscillation channel of the electron and muon atmospheric neutrino flux into tau neutrinos, a measurement of the normalisation factor, defined as the ratio between the number of observed and expected tau neutrinos, and their charge-current cross-section are discussed. Beyond the standard three-neutrinos flavor paradigm, a first test of the non-unitarity mixing matrix in the atmospheric sector is presented. A dedicated discussion on the event reconstruction and selection, the analysis strategy, and the prospects is described.

**Secondary track**:

**T03** / **84**

## Lepton Mixing and charged Lepton Flavour Violation from Inverse Seesaw

**Auteur:** Francesco Paolo Di Meglio[1]

**Co-auteur:** Claudia Hagedorn [2]

[1] *IFIC-UV*

[2] *IFIC-UV-CSIC*

**Auteur correspondant** francescopaolo.dimeglio@ific.uv.es

We discuss Charged Lepton Flavour Violating (CLFV) signals in Inverse Seesaw (ISS) scenarios with 3+3 heavy sterile states and flavour and CP symmetries.

We distinguish between two options of these scenarios, each characterised by a different spectrum of the heavy sterile states and different forms of the couplings and mass matrices. For both options, different lepton mixing patterns are predicted depending on the choice of residual groups.

Compatibility of the scenario for both options with bounds on CLFV processes is studied, and bounds on the parameters are derived.

The possibility of distinguishing between the various choices of residual symmetries, as well as between the two different options, through such signals is also considered.

**Secondary track**:

T07 - Flavour Physics and CP Violation

**Joint T06+T08** / **85**

## Capping the cone of positivity bounds: dimension-8 Higgs operators in SMEFT

**Auteurs:** Dong-Yu Hong[1]; Ken Mimasu[2]; Tong Arthur Wu[3]; Shuang-Yong Zhou[1]

[1] *University of Science and Technology of China*

[2] *Southampton University*

[3] *Pittsburgh University*

SMEFT Wilson coefficients are subject to various positivity bounds in order to be consistent with the fundamental principles of S-matrix. Previous bounds on dimension-8 SMEFT operators have been obtained using the positivity part of UV partial wave unitarity and form a (projective) convex cone. We implement UV unitarity conditions that go beyond positivity in an optimization scheme with dispersion relations in a multi-field EFT. Using Higgs scattering as an example, we demonstrate how to obtain closed bounds in the space of the three relevant dimension-8 coefficients, making use of the UV unitarity conditions as well as so-called null constraints that arise from full crossing symmetry. Specifically, we show that they are bounded by inequalities schematically going like $C < calO((4\pi)^2)$. We compare the newly obtained upper bounds with the traditional perturbative unitarity bounds from within the EFT, and discuss some phenomenological implications of the two-sided positivity bounds in the context of experimental probes of Vector Boson Scattering.

**Secondary track**:

T08 - Higgs Physics

**T10** / **86**

## Loops corrections for positivity bounds

**Auteur:** Dong-Yu Hong[None]

**Co-auteurs:** Shi-Lin Wan [1]; Shuang-Yong Zhou [1]; Zhuo-Hui Wang [1]

[1] *University of Science and Technology of China*

**Auteur correspondant** principle@mail.ustc.edu.cn

Positivity bounds, derived from fundamental S-matrix principles such as unitarity and analyticity, can impose important constraints on the space of effective field theories (EFTs). While these bounds have been extensively studied at tree level for various weakly coupled EFTs, incorporating loop corrections is crucial for extending their applicability to more general models and scenarios. We examine several aspects of one-loop effects in positivity bounds for a massive scalar EFT and beyond, using various numerical methods to address key challenges such as nonlinear optimization, strong-coupling bounds and scale dependence.

**Secondary track**:

**T10** / **87**

## Matrix moment approach to positivity bounds and UV reconstruction from IR

**Auteurs:** Shi-Lin Wan[1]; Shuang-Yong Zhou[1]

[1] *University of Science and Technology of China*

**Auteur correspondant** wsl9868@mail.ustc.edu.cn

Positivity bounds in effective field theories (EFTs) can be extracted through the moment problem approach, utilizing well-established results from the mathematical literature. We generalize this formalism using the matrix moment approach to derive positivity bounds for theories with multiple field components. The sufficient conditions for
obtaining optimal bounds are identified and applied to several example field theories, yielding results that match precisely the numerical bounds computed using other methods. The upper unitarity bounds can also be easily harnessed in the matrix case. Furthermore, the moment problem formulation also provides a means to reverse engineer the UV spectrum from the EFT coefficients, often uniquely, as explicitly demonstrated in examples such as string amplitudes and the $stu$ kink theory.

**Secondary track**:

**T03** / **88**

## Current status of the RICOCHET experiment at ILL

**Auteurs:** Louis BAILLY-SALINS[1]; RICOCHET Collaboration[None]

[1] *LPC Caen*

The RICOCHET collaboration is currently building a neutrino observatory to measure with high precision the coherent elastic neutrino-nucleus scattering (CEvNS) of low-energy (< 10 MeV) reactor antineutrinos at the Institut Laue-Langevin (ILL) in Grenoble, France. Two separate cryogenic calorimeter technologies are being developed by the collaboration: the CryoCube is an assembly of germanium targets with neutron-transmutation-doped thermistors for the heat readout and aluminum electrodes for the ionization readout, while the Q-Array relies on superconducting targets

and transition-edge sensors. To identify nuclear recoils associated to the CEνNS and reject the electron recoil background, the CryoCube combines the readout of the heat and ionization channels. In the Q-Array, the background rejection relies on the different pulse shapes for electron and nuclear recoils.

A progressive commissioning of the detector (with the CryoCube technology only) took place at ILL. In 2024, three 40-gram germanium targets were operated during several months, both in reactor ON and reactor OFF periods, with the full external and internal shieldings installed, allowing to validate cryogenics performances and measure background levels. The atmospheric muon veto operation was also validated. During the first half of 2025, the payload was extended to nine germanium targets, and the full 18-targets assembly is planned to be installed during Summer 2025, marking the start of the science data-taking period. In this contribution, the results of the commissioning phase will be presented, as well as the updated CEνNS discovery sensitivity based on the in-situ background levels and detector performance.

**Secondary track**:

**Plenary / 91**

# Highlights ATLAS

**Auteur correspondant** fabio.cerutti@cern.ch

**Secondary track**:

**Plenary / 92**

# Highlights CMS

**Auteur correspondant** roberto.salerno@cern.ch

**Secondary track**:

**Plenary / 93**

# Highlights LHCb

**Auteur correspondant** vladimir.gligorov@lpnhe.in2p3.fr

**Secondary track**:

**Plenary / 94**

# Highlights ALICE

**Auteur correspondant** igor.altsybeev@cern.ch

**Secondary track**:

**Plenary / 95**

## Highlights Belle and Belle II

**Auteur correspondant** karim.trabelsi@in2p3.fr

**Secondary track**:

**Plenary / 96**

## Cosmology

**Auteur correspondant** camille.bonvin@unige.ch

**Secondary track**:

**Plenary / 97**

## Gravitational Waves

**Secondary track**:

**Plenary / 98**

## Dark Matter theory

**Auteur correspondant** llopezho@ulb.be

**Secondary track**:

**Plenary / 99**

## Dark Matter and Axion searches

**Auteur correspondant** clara.murgui@cern.ch

**Secondary track**:

**Plenary / 100**

## Neutrino Theory

**Auteur correspondant** enrique.fernandez@csic.es

**Secondary track**:

**Plenary / 101**

## Experimental Neutrino Physics

**Auteur correspondant** schol@phy.duke.edu

**Secondary track**:

**Plenary / 102**

## Heavy Ions: Theory

**Secondary track**:

**Plenary / 103**

## Heavy Ions: Experiments

**Auteur correspondant** francesco.prino@cern.ch

**Secondary track**:

**Plenary / 104**

## QCD, Jets & Monte Carlo tools

**Secondary track**:

**Plenary / 105**

## Calculational techniques in particle theory

**Secondary track**:

**Plenary / 106**

## Recent results in Standard Model Physics

**Auteur correspondant** joshbendavid@gmail.com

**Secondary track**:

**Plenary / 107**

## Quarks and Leptons flavour theory

**Auteur correspondant** sophie.renner@glasgow.ac.uk

**Secondary track**:

**Plenary / 108**

## Highlights from flavor physics and rare decays

**Auteur correspondant** t.j.gershon@warwick.ac.uk

**Secondary track**:

**Plenary / 109**

## Standard Model/SMEFT, and Higgs Theory

**Auteur correspondant** ramona.groeber@unipd.it

**Secondary track**:

**Plenary / 110**

## Recent results in Higgs physics

**Auteur correspondant** emanuele.dimarco@roma1.infn.it

**Secondary track**:

**Plenary / 111**

## BSM Theory

**Secondary track**:

**Plenary / 112**

## Searches for New Physics at the LHC

**Auteur correspondant** tvazquez@ifae.es

**Secondary track**:

**Plenary / 113**

## Quantum field and string theory

**Secondary track**:

**Plenary / 114**

## Detector R&D and computing

**Auteur correspondant** chris.parkes@cern.ch

**Secondary track**:

**Plenary / 115**

## Accelerator R&D

**Auteur correspondant** mike.seidel@psi.ch

**Secondary track**:

**Plenary / 116**

## Outreach, Education and EDI

**Auteur correspondant** kate.shaw@cern.ch

**Secondary track**:

**Plenary / 117**

## Artificial Intelligence for HEP

**Secondary track**:

**Plenary** / **118**

## Sustainability in HEP

**Secondary track**:

**Plenary** / **119**

## Conference summary

**Auteur correspondant** andreas.hoecker@cern.ch

**Secondary track**:

**Opening** / **120**

## Opening

**T10** / **121**

## Statstics and asymptotics of subdivergence-free Feynman integrals in $\phi^4$ theory

**Auteur:** Paul-Hermann Balduf[1]

**Co-auteurs:** Johannes Thürigen [2]; Kimia Shaban [3]

[1] *University of Oxford, Mathematical Institute*

[2] *University of Münster*

[3] *University of Waterloo*

Recent algorithmic improvements have made it possible to numerically compute the value of subdivergence-free (=primitive=skeleton) Feynman integrals in $\phi^4$ theory up to 18 loops. By now, all such integrals up to 13 loops and several hundred thousand of higher loop order have been computed numerically. This data enables a statistical analysis of the typical behavior of Feynman integrals at large loop order. We find that the average value per integral grows exponentially, as expected from instanton analysis. The distribution has a largely continuous inner part but a few extreme outlier diagrams which make uniform random sampling inefficient.
The number of diagrams grows factorially with the loop order, but the value of the integral can be estimated from simple features of the diagram, such as counts of cuts and cycles, to a few percent accuracy. We used this for importance sampling on the set of diagrams and obtained approximately 1000-fold decrease in runtime compared with uniform sampling.
Thirdly, a long standing conjecture is that subdivergence-free diagrams should be the asymptotically dominant contribution to the (full) beta function in minimal subtraction at large loop order. This effect is not clearly visible even at 18 loops. The relevant counts of graphs, and their exact

asymptotics, can be computed from zero-dimensional QFT. There, one finds strikingly similar behavior to the 4-dimensional numerical data which suggests that the leading asymptotic growth rate of subdivergence-free integrals can probably only be observed upwards of 25 loops.
Based on JHEP 11 (2023) 160, JHEP11 (2024) 038 (with Kimia Shaban), and arXiv 2412.08617 (with Johannes Thürigen). Underlying data sets and Mathematica implementations are available from paulbalduf.com/research

**Secondary track**:

T12 - Data Handling and Computing

**T11** / **122**

# The OREO (ORiEnted calOrimeter) project

**Auteurs:** Alberto Gianoli[1]; Alessia Selmi[2]; Alexander Lobko[None]; Alexey Sytov[None]; Andrea Mazzolari[3]; Davide De Salvador[4]; Davide Valzani[4]; Erik Vallazza[5]; Francesco Sgarbossa[4]; Gianfranco Paternò[1]; Giorgio Zuccalà[2]; Giosuè Saibene[2]; Giulia Lezzani[None]; Korjik Mikhail[None]; Laura Bandiera[1]; Leonardo Perna[None]; Lorenzo Malagutti[1]; Marco Romagnoni[3]; Matthew Moulson[6]; Mattia soldani[None]; Michela Prest[2]; Nicola Canale[1]; Pierluigi Fedeli[7]; Pietro Monti-Guarnieri[8]; Riccardo Negrello[3]; Sofia Mangiacavalli[None]; Stefano Carsi[None]; V.G Baryshevsky[None]; Victor Tikhomirov[None]; Viktar Haurylavets[None]; Vincenzo Guidi[3]

[1] *INFN Ferrara*

[2] *Università degli Studi dell'Insubria*

[3] *Unife*

[4] *Unipd*

[5] *INFN MiB*

[6] *LNF*

[7] *Istituto Nazionale di Fisica Nucleare & University of Ferrara*

[8] *UniTS*

Inorganic scintillators are widely used to build compact and high-energy-resolution homogeneous electromagnetic calorimeters. Recent tests have shown that if the impinging angle of the particle relative to a lattice axis is smaller than one degree, the strong field experienced by electrons and photons with an energy larger than a few GeV increases the standard bremsstrahlung and pair-production cross-sections, leading to an acceleration of the electromagnetic shower.

The ORiEnted calOrimeter (OREO) collaboration (subtask 1.3.4 of the DRD6 collaboration) has assembled an electromagnetic calorimeter prototype based on oriented crystals, consisting of a $3 \times 3$ matrix of 5 radiation-length oriented PWO-UF (Ultra-Fast) crystals read out by SiPMs, followed by a layer of non-oriented crystals.

This contribution will present the results obtained during the OREO 2024 beam tests with 1–6 GeV/c electrons on the T9 beamline at the CERN PS and 40–200 GeV/c electrons on the H4 beamline at the CERN SPS. For the first time, we have demonstrated the possibility of aligning a layer of crystals along the same crystallographic direction, opening the way towards the development of a highly compact calorimeter.

In addition, we will show that this new type of calorimeter features a better energy resolution and improved $e^{\pm}$, $\gamma$/hadron discrimination capability. In fact, since the nuclear interaction length is unaffected by the lattice orientation, the oriented crystal layer of the calorimeter acts as an instrument that is sensitive to photons while being blind to hadrons.

These features make such a calorimeter highly attractive for high-energy physics experiments (e.g., forward calorimeters in colliders, fixed-target experiments) and for satellite-based $\gamma$-ray observatories.

**Secondary track**:

**T03** / **123**

## The European Spallation Source neutrino Super Beam project: Status and Prospects

**Auteur:** Tamer Tolba[1]

[1] *UNI/EXP (Uni Hamburg, Institut fur Experimentalphysik)*

**Auteur correspondant** tamer.tolba@uni-hamburg.de

ESSnuSB is a design study for a long-baseline neutrino experiment to precisely measure the CP violation in the lepton sector at the second neutrino oscillation maximum, using a beam driven by the uniquely powerful ESS linear accelerator. The ESSnuSBplus design study programme, which is an extension phase of the ESSnuSB project, aims in designing two new facilities, a Low Energy nuSTORM and a Low Energy Monitored Neutrino Beam to use them to precisely measure the neutrino-nucleus cross-section in the energy range of 0.2 −0.6 GeV, where the experimental data is very scarce. In addition, a new target station and a new water Cherenkov near-near detector will be designed to measure cross sections and serve to explore the sterile neutrino physics. An overall status of the project will be presented together with the ESSnuSB+ additions.

**Secondary track**:

**T03** / **124**

## Neutrino oscillation analysis with 715 kton-years of KM3NeT/ORCA

**Auteurs:** KM3NeT Collaboration[None]; Victor Carretero[1]

[1] *Nikhef - UvA*

KM3NeT/ORCA is a water-Cherenkov neutrino telescope currently under construction at the depths of the Mediterranean Sea. Its primary goal is to study atmospheric oscillations and to determine the neutrino mass ordering. The detector consists of a three-dimensional array of strings, each equipped with 18 digital optical modules containing 31 photomultiplier tubes. At present, 24 out of the planned 115 strings have been deployed and are actively collecting data.

A key advantage of the KM3NeT/ORCA design is its modularity, allowing for physics analyses even before full detector completion. In this contribution, we present measurements of neutrino oscillation parameters and searches for physics beyond the Standard Model using partial detector configurations with six, ten, and eleven strings, as well as comparisons with the existing worldwide measurements.

**Secondary track**:

**T07** / **125**

## Search for μ->eγ in the MEG II experiment with the highest sensitivity to date

**Auteur:** Atsushi Oya[1]

**Co-auteur:** MEG II Collaboration

[1] *The university of Tokyo*

This talk reports the result of the latest search for $\mu \to e\gamma$, which measured $1.3 \times 10^{13}$ muon decays in the MEG II data collected in 2021-2022. A sensitivity of $2.2 \times 10^{-13}$ was achieved in this search, which is factor of 2.4 higher sensitivity than the previous experiment. In addition to the result, this talk discusses the status and prospect of the MEG II experiment, which is supposed to continue the data taking until 2026.

**Secondary track**:

**T07** / **126**

## Vincia —an Antenna approach for final-state radiation

**Auteurs:** Fernando Abudinén[1]; Giacomo Morgante[2]; Peter Skands[2]

**Co-auteurs:** John Back [2]; Michal Kreps ; Thomas Latham [1]

[1] *University of Warwick*

[2] *Monash University (AU)*

**Auteur correspondant** fernando.abudinen@cern.ch

An accurate and efficient simulation of final-state radiation is key for many studies of hadron decays in view of the ever-increasing experimental precision. In this talk, we present a new simulation tool based on the Antenna parton shower, the Vincia generator, which we recently extended to simulate QED radiation from hadrons. As part of this effort, we implemented state-of-the-art tree-level matrix element corrections for various decay topologies and introduced Vincia as alternative for final-state radiation inside the EvtGen generator. We will show the results of several benchmark tests against established final-state radiation generators, comparing the physics results and the performance of the simulation.

**Secondary track**:

T07 - Flavour Physics and CP Violation

**T02** / **127**

## Search for $B$ Mesogenesis and Dark matter at $BABAR$.

**Auteur:** fabio anulli[1]

[1] *INFN*

We present the most recent $BABAR$ searches for reactions that could simultaneously explain the presence of dark matter and the matter-antimatter asymmetry in the Universe. This scenario predicts exotic $B$-meson decays into an ordinary-matter baryon and a dark-sector anti-baryon $\psi_D$ with branching fractions accessible at the $B$ factories.
The results are based on the full data set of about 430 fb$^{-1}$ collected at the $\Upsilon(4S)$ resonance by the $BABAR$ detector at the PEP-II collider.
We search, in particular, for decays like $B \to \psi_D calB$ where

$calB$ is a baryon (proton, $\Lambda$, or $\Lambda_c$). The hadronic recoil method has been applied with one of the $B$ mesons from $\Upsilon(4S)$ decay fully reconstructed, while only one baryon is present in the signal $B$-meson side. The missing mass of signal $B$ meson is considered as the mass of the dark particle $\psi_D$. Stringent upper limits on the decay branching fraction are derived for $\psi_D$ masses between 0.5 and 4.3 GeV/c$^2$.

**Secondary track**:

T09 - Beyond the Standard Model

**T09 / 130**

# New bound on the vectorial axion-down-strange coupling\\from $K^+ \to \pi^+\nu\bar{\nu}$ data

**Auteur:** Claudio Toni[1]

[1] *LAPTh*

**Auteur correspondant** claudio.toni@lapth.cnrs.fr

We analyze publicly available $K^+ \to \pi^+\nu\bar{\nu}$ data collected by NA62 from 2016 to 2022 to constrain the vectorial axion-down-strange coupling or, equivalently, the Peccei-Quinn scale $f_a$ rescaled by this coupling, obtaining $|(F_V)_{23}| > 1.1 \times 10^{12}$ GeV. We also discuss the potential of applying the same approach to $K^+ \to \pi^+\pi^0\nu\bar{\nu}$ data, from which we estimate the bound $|(F_A)_{23}| > 1.0 \times 10^8$ GeV. Finally, under the complementary assumption that these processes be dominated by weak amplitudes, we derive a model-independent bound on $f_a$, namely $f_a > 1.0 \times 10^5$ GeV. These constraints represent the strongest existing bounds inferred from controlled experimental setups.

**Secondary track**:

**T03 / 131**

# Experimental proof of principle of the Neutrino Tagging technique at NA62

**Auteur:** NA62 Collaboration[None]

**Auteur correspondant** mathieu.perrin-terrin@cppm.in2p3.fr

Neutrino tagging is a new experimental approach for accelerator based neutrino experiments. The method consists in associating a neutrino interaction with the meson decay (i.e. $\pi^\pm \to \mu^\pm\nu_\mu$ or $K^\pm \to \mu^\pm\nu_\mu$) in which the neutrino was originally produced. The properties of the neutrino can then be estimated kinematically from the decay incoming and outgoing charged particles. The reconstruction of these particles relies on the recent progress and developments in silicon particle detector technology. The method is particularly suited to study neutrino interactions at short baseline experiments, and preliminary works indicate that they could also be used to study neutrino oscillations at long baseline experiments. A proof-of-principle of this method has been performed using the NA62 experiment as a miniature tagged neutrino experiment. The intense Kaon beam of NA62 abundantly produces neutrinos through the $K^+ \to \mu^+\nu_\mu$decay. The two spectrometers of the experiment are used to reconstruct the $K^+$ and $\mu^+$ and the neutrino interaction is detected in the 20 ton of liquid krypton of the electro-magnetic calorimeter. The results of the analysis based on the data collected in 2022 are presented, where one tagged neutrino candidate has been detected for the first time in history.

**Secondary track**:

**T14** / **132**

## The Italian Summer Students Program at Fermilab and other US Laboratories

**Auteur:** Simone Donati[1]

**Co-auteurs:** Emanuela Barzi [2]; Giorgio Bellettini [3]; Marco Mambelli [4]

[1] *University of Pisa - INFN*

[2] *Ohio State University*

[3] *University of Pisa and Infn Pisa*

[4] *Fermilab*

Since 1983 the Italian groups collaborating with Fermilab (US) have been running a 2-month summer training program for Master students. While in the first year the program involved only 4 physics students, in the following years it was extended to engineering students. Many students have extended their collaboration with Fermilab with their Master Thesis and PhD.
The program has involved almost 600 Italian students from more than 20 Italian universities. Each intern is supervised by a Fermilab Mentor responsible for the training program. Training programs spanned from Tevatron, CMS, Muon (g-2), Mu2e and SBN and DUNE design and data analysis, development of particle detectors, design of electronic and accelerator components, development of infrastructures and software for tera-data handling, quantum computing and research on superconductive elements and accelerating cavities.
In 2015 the University of Pisa included the program within its own educational programs. Summer Students are enrolled at the University of Pisa for the duration of the internship and at the end of the internship they write summary reports on their achievements. After positive evaluation by a University of Pisa Examining Board, interns are acknowledged 6 ECTS credits for their Diploma Supplement. In the years 2020 and 2021 the program was canceled due to the sanitary emergency but in 2022 it was restarted and allowed a cohort of 21 students in 2022, and a cohort of 27 students in 2023, and of 13 students in 2024 to be trained for nine weeks at Fermilab. We are now organizing the 2025 program.

**Secondary track**:

**T07** / **133**

## $B \to K + invisible$ in a model with axion-like particles

**Auteurs:** Robert Ziegler[1]; Ulrich Nierste[2]; Xiyuan Gao[3]

[1] *CERN*

[2] *TTP, Karlsruhe Institute of Technology*

[3] *Institute for Theoretical Particle Physics, Karlsruhe Institute of Technology, Germany*

An axion-like particle $a$ (ALP) can explain the excess of $B \to K + invisible$ events at Belle-II. However, many analyses of ALP scenarios are over-simplified. We revisit the $B \to K + a$ transition rate in a popular minimal and UV complete model with two Higgs doublets (2HDM) and a complex singlet (DFSZ model). To this end we compare our results with previous studies which derived the $\bar{b}sa$ vertex from the $\bar{b}sA$ vertex, where $A$ is the heavy pseudoscalar of the 2HDM, in terms of an $a$-$A$ mixing angle. We find this approach to work only at one-loop level, while the two-loop contribution can no more be found in this way and furthermore can be sizable. Meanwhile, employing instead the low-energy axion effective theory leads to a divergent and basis-dependent amplitude. We clarify the ambiguities and identify which low-energy framework is consistent with the DFSZ model.

**Secondary track**:

T09 - Beyond the Standard Model

**T14 / 134**

## Alternative languages to narrate science and scientific research in schools; Art & Science across Italy

**Auteur:** Pierluigi Paolucci[1]

[1] *INFN of Napoli*

Art&Science Across Italy is a national project by INFN and CERN aimed at Italian high school students aged 16 to 18. Since its launch in 2016, more than 10,000 students have participated. The initiative is grounded in the idea that creativity and imagination are essential in both science and art. Scientists and artists alike are often called upon to look beyond what is immediately visible, to envision hidden aspects of reality, and to adopt unconventional perspectives.

The project puts into practice the core philosophy of the STEAM approach, where science, technology, engineering, and mathematics (STEM) are combined with the arts—not in competition, but in true collaboration. The goal is to engage students with scientific concepts through artistic expression, regardless of their academic background or prior knowledge. By doing so, Art&Science Across Italy fosters a deeper and more personal connection with scientific research.

**Secondary track**:

**T05 / 135**

## Towards a combined $\alpha_s$ and $m_t$ determination from a global PDF analysis

**Auteur:** Jaco ter Hoeve[1]

[1] *University of Edinburgh*

The top mass is one of the fundamental parameters of the SM and is of key importance for numerous phenomenological applications, thus requiring a precise and accurate determination. In this work, based on the NNPDF4.0 framework, we determine $m_t$ alongside the strong coupling $\alpha_s$, while faithfully propagating experimental and theoretical uncertainties. Traditional approaches often ignore the possible interplay between theory uncertainties entering the parton distributions (PDFs) and the uncertainties in predictions derived from these PDFs. We show how the Theory Covariance Method is able to overcome this limitation, thereby providing a more accurate estimate of the uncertainties. We consider a wide range of inclusive, single and double differential LHC measurements benefiting from the full NNPDF dataset. We also account for missing higher order uncertainties (MHOUs), study the impact of various kinematic observables, and compare our findings against previous results in the literature. Our results pave the way towards an efficient combined determination of the PDFs alongside the (B)SM parameters.

**Secondary track**:

T06 - Top and Electroweak Physics

**Plenary / 136**

# Highlights from Muon g-2

**Auteur correspondant** s.charity@liverpool.ac.uk

**Secondary track**:

**Plenary / 137**

# Highlights from KM3NeT

**Secondary track**:

**T02 / 139**

# Entanglement Witnesses Mediated Via Axion-Like Particles

**Auteur:** Anupam Mazumdar[1]

[1] *Van Swinderen Institute, Univesrity of Groningen*

Entanglement is solely a quantum property and it can be extremely helpful to test the physics beyond the Standard Model in tabletop experiments with the advent of future quantum technologies. In this work, we provide an entanglement-based partial positive transpose (PPT) witness for Yukawa-type potentials in the infrared regime between pairs of neutral/charged particles in a spatial quantum superposition. The entanglement is created by the interaction beyond the Standard Model such as Axion-like particle (ALP) or physics motivated by string theory such as extra dimensions in the context of gravity. We will constrain the couplings along with the decoherence rate to show what parameters can be searched for in near future entanglement-driven experiments for the search of new physics.

**Secondary track**:

T09 - Beyond the Standard Model

**T01 / 140**

# Gravitational Optomechanics: Photon-Matter Entanglement via Graviton Exchange

**Auteur:** Anupam Mazumdar[1]

[1] *Van Swinderen Institute, Univesrity of Groningen*

The deflection of light in the gravitational field of the Sun is one of the most fundamental consequences for general relativity as well as one of its classical tests first performed by Eddington a century ago. However, despite its center stage role in modern physics, no experiment has tested it in an ostensibly quantum regime where both matter and light exhibit non-classical features. This paper shows that the interaction which gives rise to the light-bending also induces photon-matter entanglement as long as gravity and matter are treated at par with quantum mechanics. The quantum light-bending interaction within the framework of perturbative quantum gravity highlights this

point by showing that the entangled states can be generated already with coherent states of light and matter exploiting the non-linear coupling induced by graviton exchange. Furthermore, the quantum light-bending interaction is capable of discerning between the spin-2 and spin-0 gravitons thus also providing a test for alternative theories of gravity at short distances and at the quantum level. We will conclude by estimating the order of magnitude of the entanglement generated by employing the linear entropy. In particular, we find that a half-ring cavity of radius 0.25 m placed around a 10 kg mechanical oscillator operating at 150 Hz, could be used to generate linear entropy of order unity using a petawatt laser source at optical wavelengths. While the proposed scheme is beyond the current experimental realities it nonetheless initiates the discussion about testing the spin of the gravitational interaction at the quantum level.

**Secondary track**:

T15 - Quantum technologies in HEP (special topic 2025)

**T05 / 141**

# $\alpha_s(m_Z)$ at approximate N$^3$LO with QED corrections and theory uncertainties

**Auteurs:** NNPDF Collaboration[None]; Roy Stegeman[1]

[1] *The University of Edinburgh*

We present an updated determination of $\alpha_s(m_Z)$ based on the global NNPDF4.0 analysis at approximate N$^3$LO QCD mixed with NLO QED accuracy. Consistent results are obtained by means of two independent methodologies, both extensively validated using closure tests. We assess the perturbative convergence of our results, the role of QED corrections and the inclusion of a photon PDF, the impact of MHOUs, the dependence on the input dataset, and the impact of $m_t$ uncertainties in the top production cross-sections. Our result provides one of the most precise determinations of the strong coupling obtained in the context of PDF fits.

**Secondary track**:

**T08 / 142**

# Approximate N$^3$LO PDFs and implications for Higgs production at the LHC

**Auteur:** NNPDF Collaboration[None]

We discussion an extension of the NNPDF4.0 parton distribution functions (PDFs) to approximate N$^3$LO. We assess the perturbative stability of the resulting PDFs and study the impact of missing higher order uncertainties, NLO QED corrections and the photon PDF, and we compare our results to the aN$^3$LO PDFs from the MSHT group. We present predictions for the total inclusive cross-section for Higgs production in gluon fusion, vector boson fusion, and associated production. For the gluon fusion and vector boson fusion channels, the corrections that arise when using correctly matched aN$^3$LO PDFs with N$^3$LO cross section calculations, compared to using NNLO PDFs, are significant, in many cases larger than the PDF uncertainty, and generally larger than the differences between the two aN$^3$LO PDF sets currently available.

**Secondary track**:

**T02** / **143**

## Recent Results from PICO-40L and the Future of the PICO Dark Matter Search

**Auteur:** Mayank Tripathi[1]

[1] *University of Chicago*

The PICO collaboration operates bubble chambers to search for WIMP dark matter, leveraging the excellent gamma rejection and long live fractions enabled by operating at a lower degree of superheat than the bubble chambers of the 1960s. This advancement allows for significantly improved background rejection while maintaining sensitivity to nuclear recoils. Located at the SNOLAB underground laboratory, these detectors use fluorinated target fluids optimized for probing spin-dependent WIMP-proton interactions.

Previous experiments, PICO-2L and PICO-60, set the world's strongest constraints on spin-dependent WIMP-proton scattering. The next-generation detector, PICO-40L, is now fully operational and actively collecting physics data. Its superheated C3F8 target provides an ideal medium to achieve world-leading sensitivity in this search. This talk will provide an overview of the detector design, analysis strategy, and initial physics results. Looking ahead, PICO-500, a 250-liter chamber currently in development, is expected to begin commissioning in 2026, further advancing the search for dark matter.

**Secondary track**:

T11 - Detectors

**T08** / **144**

## Towards HH at NNLO QCD: the $n_h^2$ contribution

**Auteur:** Marco Vitti[1]

[1] *Karlsruhe Institute of Technology - TTP and IAP*

**Auteur correspondant** marco.vitti@kit.edu

The virtual corrections for $gg \to HH$ at NLO QCD have been efficiently approximated using a Taylor expansion in the limit of a forward kinematics. The same method has been recently applied to the calculation of a subset of the NNLO corrections, which are desirable given the significant impact, at NLO, of the uncertainty due to the choice of the top mass renormalization scheme. In this talk, I will report on the progress in the calculation of another contribution at NNLO, given by diagrams in which the two Higgs bosons couple to different top quark loops. For this contribution a naive Taylor expansion cannot be used, and I will instead discuss an approach based on asymptotic expansions in different kinematic limits.

**Secondary track**:

T05 - QCD and Hadronic Physics

**T09** / **145**

## Symmetry-restoring finite counter-terms of SMEFT four-fermion operator insertions at one-loop

**Auteur:** Luiz Vale Silva[1]

[1] *UCH CEU Valencia*

**Auteur correspondant** luizva@ific.uv.es

Some effects induced by SMEFT operators at one-loop have been fully computed, in particular, the renormalization of divergences by physical operators in single insertions of dimension-six operators. Important non-logarithmically enhanced contributions remain to be calculated. We discuss dimensional regularization in the Breitenlohner-Maison 't Hooft-Veltman scheme. The goal here consists of determining in this scheme unexplored quantum effects in chiral theories at one-loop. Namely, the determination of finite counter terms that reestablish the Slavnov-Taylor identities at one-loop. These counter terms are necessary due to the presence of evanescent symmetry-breaking terms in the classical Lagrangian, that are needed to regularize fermion propagators. We consider a technique that allows an easier automation in the calculation of such finite effects. We focus on dimension-six four-fermion operators, and as expected find no obstructions to the Slavnov-Taylor identities that cannot be cured by finite counter-terms. We briefly point out phenomenological implications for higher order calculations.

**Secondary track**:

**T01 / 146**

## New symmetries of long-wavelength cosmological perturbations : Application to gravitational lensing

**Auteur:** Jibril BEN ACHOUR[1]

[1] *ENS de Lyon / Arnold Sommerfeld Center (Munich)*

The effect long wavelength cosmological perturbations (soft cosmological modes) can be captured analytically by solution-generating techniques based on large gauge diffeomorphism. This enable one to construct exact solutions of the linearized Einstein equations which described a perturbed FLRW background up to some given order in the multipole expansion of the cosmological perturbations. In this talk, I will first review this construction and I will then discuss how to identify new symmetries of these cosmological spacetimes. I will discuss that one can use these new symmetries to simplify the problem of geodesic motion and geodesic deviation in such perturbed FLRW geometry relevant for early and late time cosmology, and in particular how to go beyond the standard treatment of gravitational lensing.

**Secondary track**:

**T11 / 148**

## Super Fine-Grained Detector for the T2K long-baseline neutrino experiment

**Auteur:** SuperFGD group[None]

The Tokai-to-Kamioka (T2K) experiment is a long-baseline neutrino experiment sited in Japan. T2K obtained results that disfavor the CP conservation with a 90% confidence level so far. The (anti)neutrino

beam created at the J-PARC is characterized at the near detector before measuring neutrino oscillation parameters by the Super-Kamionde detector at 296 km away. Toward more precise measurements of neutrino oscillations, T2K experiment started operation of the fully upgraded near detector in 2024 to further reduce major systematic errors on the neutrino-nucleus interaction. An upstream part of the near detector complex, ND280, was replaced with three detectors: the Super Fine-Grained Detector (SuperFGD), two High-Angle Time Projection Chambers (HATs), and six Time of Flight detectors (ToFs). SuperFGD is a target tracker which consists of about two million 1 $cm^3$ plastic scintillator cubes packed in about 2 m x 2 m x 0.6 m dimension. Scintillation light from the cube is read out by about 56 thousand channels from three directions through wavelength-shifting fibers and photo sensors. It provides 3D track reconstruction, 4 $\pi$ angular acceptance, calorimetry, and detection capability of neutrons and low energy protons. We report SuperFGD design, construction, operation status and detector performance.

**Secondary track**:

**T11** / **149**

# CEPC Silicon Tracker Detector

**Auteur:** Qi Yan[1]

[1] *IHEP, CAS*

The Circular Electron-Positron Collider (CEPC) is designed to reach a maximum center-of-mass energy of 360 GeV for electron-positron collisions. Its primary goals are to explore the properties of the Higgs boson and search for new physics beyond the Standard Model. The CEPC silicon tracker will have a total active area of ~100 $m^2$. It is designed to measure charged particle tracks over a wide momentum range, from below 1 GeV to above 100 GeV, enabling both precision tracking of high-momentum isolated tracks and accurate reconstruction of low momentum tracks in dense jets. The required momentum resolution reaches the level of one per mille. The silicon tracker system integrates advanced pixel and microstrip sensors, readout electronics, and mechanical and cooling structures. This report will provide a comprehensive overview of the detector design, the current status of system development, and future plans.

**Secondary track**:

**T07** / **150**

# Radiative corrections to $B \to \ell\nu$

**Auteur:** Max Ferré[1]

[1] *JGU (Mainz)*

**Auteur correspondant** ferremax@uni-mainz.de

In this talk I will focus on the study of the leptonic $B \to \ell\nu$ decay at next-to-leading order in QED. The future improvements of experimental measurements of this channel require a reliable theory prediction, hence a careful theoretical estimate of QED corrections. The multi-scale character of this process requires an appropriate effective theory (EFT) construction to factorize the different contributions. In the first part of this talk, I will discuss the EFT description of the process at the partonic level, which is based on Heavy Quark Effective Theory and Soft Collinear Effective Theory. I will show how the inclusion of QED corrections demands a generalisation of the hadronic decay constant defining a new non-perturbative input. In the second part of the talk, I will discuss the EFT description below the confinement scale based on the Chiral Lagrangian including Heavy Mesons

($B$ and $B^*$). I will show that depending on the cut on final state radiation and on the lepton flavor the contribution from excited states of the B meson can become important.

**Secondary track**:

T05 - QCD and Hadronic Physics

**T02 / 151**

## keV sterile neutrino dark matter together with large neutrino mass in cosmology from a dark sector

**Auteurs:** Cristina Benso[1]; Drona Vatsyayan[2]; Thomas Schwetz-Mangold[3]

[1] *Karlsruhe Institute of Technology (KIT)*

[2] *Valencia U., IFIC*

[3] *Karlsruhe Institute of Technology*

**Auteur correspondant** cristina.benso@kit.edu

We investigate the phenomenology of a dark sector, extension of the neutrino sector, that simultaneously provides a viable dark matter (DM) candidate, reconciles cosmological constraints with active neutrino masses possibly measurable in laboratories such as KATRIN, and yields near-future testable predictions.
The dark sector comes into thermal equilibrium with Standard Model neutrinos after neutrino decoupling and before recombination via a new $U(1)$ gauge interaction in the dark sector. It contains a sterile neutrino DM candidate with mass in the $\mathcal{O}(10-100)\mathrm{keV}$ range, along with a large number of massless fermions that dilute the abundance of active neutrinos. This dilution allows for larger neutrino masses without conflicting with cosmological bounds. The DM relic abundance is determined by freeze-out within the dark sector, naturally avoiding X-ray constraints.
A key prediction of this framework is a small increase in the effective number of relativistic species, $N_{\mathrm{eff}}$, at recombination, within the sensitivity of upcoming CMB experiments - making the scenario experimentally accessible and testable in the near future.

**Secondary track**:

T03 - Neutrino Physics

**Poster T08 / 152**

## A combined test of CP violation in Higgs Boson coupling with electroweak gauge boson (W/Z)

**Auteur:** ATLAS Collaboration[None]

This poster shows a combined test of CP violation in the coupling between Higgs Boson and electroweak gauge boson (W/Z) via decay channels including H⟶γγ, ZZ, WW, ττ, and bb analysis which were conducted by ATLAS experiment using the full Run-2 pp dataset at √⊠ = 13 TeV. The constrain is set on parameters describing the strength of CP-odd component in coupling in effective field theory base. The results represent the most stringent constraints up to date on CP violation in Higgs-weak boson couplings

**Secondary track**:

**Poster T08 / 153**

## A new avenue for probing the Higgs self-coupling through Higgs pair production in multi-lepton final states with the ATLAS detector

**Auteur:** ATLAS Collaboration[None]

A search is presented for non-resonant Higgs boson pair production decaying to multi-lepton final states using 140 fb-1 of proton-proton collision data at centre-of-mass energy 13 TeV, recorded with the ATLAS detector during Run 2 of the LHC. By combining nine distinct channels characterized by varying multiplicities of electrons, muons, taus, and photons, this analysis represents a novel and competitive approach to probing the Higgs self-coupling modifier, kappa lambda. The observed (expected) limit on the signal strength is found to be 17 (11) times the Standard Model prediction. The observed (expected) 95% confidence interval constraints on kappa lambda, are -6.2 < kappa lambda < 11.6 (-4.5 < kappa lambda < 9.6), making this analysis the third most sensitive channel for constraining the Higgs self-interaction. A projection of the sensitivity of this analysis to non-resonant Higgs boson pair production to the High Luminosity LHC (LH-LHC) is also presented, assuming a centre-of-mass energy 14 TeV and integrated luminosities up to 3000 fb-1.

**Secondary track**:

**Joint T06+T08 / 154**

## Combined Higgs boson measurements and their interpretations with the ATLAS experiment

**Auteur:** ATLAS Collaboration[None]

Precision measurements of Higgs boson couplings and kinematic properties can be performed using the data collected by the ATLAS experiment, leveraging a variety of final states and production modes to probe different regions of phase space with increasing accuracy. By combining these measurements, the strengths of individual channels are maximally exploited, providing the most stringent global constraints on Higgs boson properties. This talk presents the latest combination of Higgs boson measurements by the ATLAS experiment, with results reported in terms of production modes, branching fractions, Simplified Template Cross Sections, and coupling modifiers. These combined measurements are interpreted in multiple frameworks, including targeted tests of specific beyond-the-Standard-Model scenarios and a broader interpretation using the Standard Model Effective Field Theory (SMEFT). The results are based on proton-proton collision data collected at \sqrt(s)=13 TeV during Run 2 of the LHC.

**Secondary track**:

**Poster T08 / 155**

## Implementation of a kinematic fit algorithm in the search for Higgs boson pairs in the $b\bar{b}\gamma\gamma$ final state with the ATLAS detector

**Auteur:** ATLAS Collaboration[None]

The observation of Higgs boson pairs is a fundamental step towards understanding the model of spontaneous electro-weak symmetry breaking as it represents the most direct method to estimate the cubic term of the Higgs boson potential, responsible for the tri-linear self-coupling of the boson ($\lambda_{HHH}$). The poster will discuss the status and future perspectives of the search for such events produced at the LHC and detected with the ATLAS detector in the final state $b\bar{b}\gamma\gamma$, one of the most sensitive decay channels to the tri-linear coupling of the Higgs. Although the measurements of these couplings are still subject to significant statistical uncertainties, which will be reduced with the integration of the LHC Run 3 data in the near future, considerable progress has also been made in the development and optimization of methods aimed at increasing the sensitivity of the analysis. The presentation will focus particularly on one of these methods, namely, a kinematic fit algorithm designed to increase both signal reconstruction accuracy and background rejection power.

**Secondary track**:

**T08** / **156**

## Measurements of Higgs boson coupling properties to bottom and charm with the ATLAS detector

**Auteur:** ATLAS Collaboration[None]

Probing the Yukawa couplings between the Higgs boson and fermions is essential to understanding the origin of fermion masses. Higgs boson decays into pairs of quarks offer a direct window into these couplings and broader Higgs boson properties. This talk presents ATLAS measurements of Higgs decays into bottom quark pairs and searches for decays into charm quark pairs, based on the full Run 2 dataset of proton-proton collisions at \sqrt{s} = 13 TeV, with the inclusion of available Run 3 results where relevant.

**Secondary track**:

**T08** / **158**

## Measurements of Higgs boson production with top quarks with the ATLAS detector

**Auteur:** ATLAS Collaboration[None]

The study of Higgs boson production in association with one or two top quarks offers a unique opportunity to probe the interactions between the two heaviest particles in the Standard Model. This talk presents measurements of key Higgs boson properties - specifically the production cross section and CP nature - in events produced via tH and ttH processes. The results are based on the full Run 2 dataset of proton-proton collisions at \sqrt{s} = 13 TeV, recorded by the ATLAS detector at the LHC.

**Secondary track**:

**T06** / **159**

## Top and Electroweak physics at the linear collider facility

**Auteur:** Ivanka Bozovic-Jelisavcic[1]

[1] *VINCA Institute of Nuclear Sciences*

Thanks to the extended energy range and beam polarization, the linear option for future e+e- collider facility offers unique opportunities for precision electroweak studies and top quark measurements.

Beam polarization is not only essential for many observables but also allows better control of background and reduction of systematic uncertainties. The extended energy range of the linear collider facility is especially important for the precision top quark studies above the pair production threshold, including direct measurement of the top Yukawa coupling and global analysis of the precision measurements in the EFT framework. Presented in this contribution are the results of the ILD concept group based on the ILC running scenario.

**Secondary track**:

**T08** / **160**

## Precision Higgs studies at the linear collider facility

**Auteur:** Ivanka Bozovic-Jelisavcic[1]

[1] *VINCA Institute of Nuclear Sciences*

The linear e+e- collider facility, with the energy range from the Z pole to the TeV scale offers the full exploration of the Higgs boson properties with the highest precision. Presented in this contribution are results of the detailed ILD concept group studies based on the ILC (superconducting) collider concept. Individual measurements of the Higgs properties will be discussed, including its self-coupling and possible BSM interactions, H->ssbar, as well as the impact of the Higgs and electroweak measurements on the global fits and indirect BSM constraints.

**Secondary track**:

**T09** / **161**

## BSM searches at the linear collider facility

**Auteur:** Ivanka Bozovic-Jelisavcic[1]

[1] *VINCA Institute of Nuclear Sciences*

Although the LHC experiments have searched for and excluded many proposed new particles up to masses in the TeV range, there are many scenarios that are difficult to address at a hadron collider. The linear collider facility, thanks to its staged running plan with different energy upgrade options, offers exciting new search possibilities. Reviewed in this talk are recent results, contributed by the ILD concept group to the ECFA Higgs/EW/Top factory study report, reviewing BSM prospects of the future e+e- collider assuming the International Linear Collider running conditions.

**Secondary track**:

**T11** / **162**

## The ILD Detector: A Versatile Detector for an Electron-Positron Collider at Energies up to 1 TeV

**Auteur:** Ivanka Bozovic-Jelisavcic[1]

[1] *VINCA Institute of Nuclear Sciences*

The International Large Detector, ILD, is a detector concept for an experiment at a future high energy lepton collider. The detector has been optimised for precision physics in a range of energies from 90 GeV to about 1 TeV. ILD features a high precision, large volume combined silicon and gaseous tracking system, together with a high granularity calorimeter, all inside a central solenoidal magnetic field. The paradigm of particle flow has been the guiding principle of the design of ILD. ILD is based mostly on technologies which have been demonstrated by extensive research and test programs. The ILD concept is proposed both for linear and circular lepton collider, be it at CERN or elsewhere. The concept has been developed by a group of nearly 60 institutes from around the world, and offers a well developed and powerful environment for science and technology studies at lepton colliders. In this presentation, the required performance of the detector, the proposed implementation and the readiness of the different technologies needed for the implementation are discussed.

**Secondary track**:

**T08** / **163**

# Measurements of the CP structure of Higgs-boson couplings with the ATLAS detector

**Auteur:** ATLAS Collaboration[None]

The Standard Model predicts the Higgs boson to be a CP-even scalar, but CP-odd contributions to its interactions with vector bosons and quarks are not yet strongly constrained. Various Higgs boson production and decay processes provide valuable tools to investigate the CP nature of these interactions. This talk presents the most recent measurements of the CP properties of Higgs boson interactions with vector bosons, performed by the ATLAS experiment using proton-proton collision data collected at sqrt(s) =13 TeV. These results offer important constraints on possible CP-violating effects, advancing our understanding of Higgs boson dynamics.

**Secondary track**:

**T08** / **164**

# Measurements of the Higgs boson mass and width with the ATLAS detector

**Auteur:** ATLAS Collaboration[None]

This talk presents recent precision measurements of key properties of the Higgs boson using the full dataset of proton-proton collisions at $\sqrt{s}$ = 13 TeV collected during Run 2 of the LHC by the ATLAS experiment. The Higgs boson mass is determined with high accuracy through its decays into two photons and four leptons, and the adopted analysis strategies and experimental techniques will be discussed in detail, highlighting their impact on the measurement. In addition, the talk will cover indirect determinations of the Higgs boson total width, an essential parameter for understanding the Higgs sector. While the width is too small to be directly measured at the LHC, constraints are obtained via off-shell Higgs production in ZZ and WW final states, through the 4top final state, and through interference effects in the diphoton channel. The results represent the most up-to-date measurements from ATLAS and provide important insights into Higgs boson properties.

**Secondary track**:

**Poster T08** / **167**

## Search for CP violating effects in HWW vertex in WH production channel with H ->bb in 13 TeV pp collisions with the ATLAS detector

**Auteur:** ATLAS Collaboration[None]

The Standard Model (SM) predicts the Higgs boson to be a CP-even (scalar) particle. Any deviation from a purely CP-even interaction of the Higgs boson with other SM particles would indicate physics beyond the SM. This poster presents a search for CP violating effects in Higgs boson production in association with a W boson, using proton-proton collision data collected by the ATLAS detector at the Large Hadron Collider from 2015-2018, corresponding to an integrated luminosity of 139 fb$^{-1}$ at a center-of-mass energy of 13 TeV. The analysis focuses on the Higgs boson decay to bottom quark pairs and the W boson decay to leptons: $WH$, with $H \to b\bar{b}$ and $W \to l\nu$ ($l = e, \mu$). Fiducial cross-section measurements are performed using the Simplified Template Cross Section (STXS) formalism in bins of an angular observable and the W boson transverse momentum, providing a sensitive probe to CP-violating components in the $HWW$ vertex. The results are interpreted within the Standard Model Effective Field Theory, and constraints are set on the relevant Wilson coefficient in the Warsaw basis, $c_{H\widetilde{W}}$ (CP-odd operator).

**Secondary track**:

**Poster T08** / **168**

## Search for Higgs boson pair production in the HH->bbyy final state with the full Run 2 + partial Run 3 pp collision data collected by the ATLAS Experiment

**Auteur:** ATLAS Collaboration[None]

A search for non-resonant Higgs boson pair production in the bbγγ final state is performed using the full Run 2 and partial Run 3 proton-proton collision data collected by the ATLAS experiment at the Large Hadron Collider at CERN. The data amounts to an integrated luminosity of 140 fb-1 at a center of mass energy of 13 TeV, plus 59 fb-1 at a center of mass energy of 13.6 TeV. The analysis is optimized to probe deviations from the Standard Model of both the Higgs-boson trilinear self-coupling modifier □λ as well as the quartic □□□□ (where □ = □, □) coupling modifier □2V.

**Secondary track**:

**Poster T08** / **169**

## Search for Higgs boson pair production in the 2b+2l+MET final state in pp collisions with the ATLAS detector

**Auteur:** ATLAS Collaboration[None]

The Higgs boson self-coupling is a key parameter of the Standard Model, but is still experimentally unconstrained as it requires the challenging simultaneous production of two Higgs bosons in the same event. A search for a Higgs boson pair (HH) production is presented, in which one of the Higgs bosons decays to a b-quark pair (bb) and the other decays to WW*, or ZZ*, or \tau^+ \tau^-, with in each case a final state with two leptons + neutrinos. Events are selected to have exactly two b-tagged jets and two leptons with opposite electric charge and a large transverse missing energy (MET) in the final state, which is the fourth most significant HH final state after $b\bar{b}b\bar{b}$, $b\bar{b}\tau^{\tau-}$, and multilepton. Events are classified using multivariate analysis algorithms to separate the HH events from other Standard Model processes. Upper limits on the production cross section and the self-interaction coupling parameters.

**Secondary track**:

**T08** / **170**

## Search for rare processes and lepton-flavor-violating decays of Higgs boson at the ATLAS experiment

**Auteur:** ATLAS Collaboration[None]

The Standard Model predicts several rare Higgs boson processes, including decays into a Z boson and a photon, a low-mass lepton pair and a photon, or a meson and a photon. Observing these rare decays would offer new and complementary insights into the Higgs boson's coupling structure beyond the more commonly studied channels. In addition, searches for lepton-flavor-violating decays of the Higgs boson are performed, where any observation would provide unambiguous evidence of physics beyond the Standard Model. This talk presents several recent results from the ATLAS experiment based on proton-proton collision data collected in Run2 at \sqrt{s} = 13 TeV, , with the inclusion of available Run 3 results where relevant.

**Secondary track**:

**T08** / **171**

## Searches for resonances decaying into Higgs boson pairs with the ATLAS Experiment

**Auteur:** ATLAS Collaboration[None]

Many new physics models predict the existence of resonant states decaying into two bosons, including the Higgs boson or new scalar S bosons. These processes provide crucial signatures in the search for physics beyond the Standard Model and may offer insights into the mechanism of electroweak symmetry breaking. In this talk, the latest results from searches for resonant Higgs boson pair (HH) production and Higgs-scalar (SH) production are presented, focusing on findings from the full LHC Run 2 dataset at 13 TeV, along with the inclusion of available Run 3 results where relevant.

**Secondary track**:

T09 - Beyond the Standard Model

**T08** / **172**

## Towards the full NLO electro-weak corrections in Higgs boson pair production

**Auteurs:** Augustin Vestner[1]; Gudrun Heinrich[2]; Marco Bonetti[1]; Matthias Kerner[1]; Philipp Rendler[1]; Stephen Jones[3]; Tom Stone[3]

[1] *KIT - ITP*

[2] *KIT - Karlsruhe Institute of Technology (DE)*

[3] *IPPP*

**Auteur correspondant** augustin.vestner@kit.edu

Measurement of the Higgs boson self interaction is one of the main goals at the high luminosity phase of LHC. A promising channel for this is the simultaneous production of two Higgs bosons from gluon-gluon fusion. For the interpretation of the measured data, a theoretical prediction of similar precision is needed. Following current projections this requires electroweak corrections at next-to-leading order.
This talk presents the contributions from top-Yukawa and Higgs self-interaction induced corrections as well as the first milestones towards inclusion of all electroweak effects in the calculation.

**Secondary track**:

**T15** / **173**

## Quantum Chebyshev Probabilistic Models for Fragmentation Functions

**Auteurs:** German Rodrigo[1]; Hsin-Yu Wu[2]; Jorge Juan Martinez De Lejarza Samper[None]; Michele Grossi[3]; Oleksandr Kyriienko[4]

[1] *IFIC Valencia*

[2] *University of Exeter, Pasqal*

[3] *CERN*

[4] *University of Sheffield*

We propose a quantum protocol for efficiently learning and sampling multivariate probability distributions that commonly appear in high-energy physics. Our approach introduces a bivariate probabilistic model based on generalized Chebyshev polynomials, which is (pre-)trained as an explicit circuit-based model for two correlated variables, and sampled efficiently with the use of quantum Chebyshev transforms. As a key application, we study the fragmentation functions~(FFs) of charged pions and kaons from single-inclusive hadron production in electron-positron annihilation. We learn the joint distribution for the momentum fraction $z$ and energy scale $Q$ in several fragmentation processes. Using the trained model, we infer the correlations between $z$ and $Q$ from the entanglement of the probabilistic model, noting that the developed energy-momentum correlations improve model performance. Furthermore, utilizing the generalization capabilities of the quantum Chebyshev model and extended register architecture, we perform a fine-grid multivariate sampling relevant for FF dataset augmentation. Our results highlight the growing potential of quantum generative modeling for addressing problems in scientific discovery and advancing data analysis in high-energy physics.

**Secondary track**:

**T03** / **174**

## EFT analysis of New Physics at COHERENT with Dirac neutrinos

**Auteur:** Sergio Cruz-Alzaga[1]

**Co-auteurs:** Martin Gonzalez-Alonso [2]; Suraj Prakash - [3]; Víctor Bresó-Pla [4]

[1] *IFIC (CSIC-Universidad de Valencia)*

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**Auteur correspondant** sergio.delacruz.alzaga@ific.uv.es

We study the sensitivity of COHERENT-like experiments to non-standard contributions within the so-called $\nu$WEFT framework. The latter is the most general low-energy effective field theory that includes not only the light SM fields but also additional right-handed Dirac neutrinos.

Our analysis uses the framework presented at "Consistent QFT description of non-standard neutrino interactions", which makes use of the full freedom of EFT's. This allows us, for the first time, to include flavor-general New Physics effects in neutrino production (pion and muon decays) and neutrino detection (through Coherent Elastic Neutrino-Nucleus Scattering). The versatility of this framework also allows to easyly study different NP scenarios, as was shown in the letter "Muon-decay parameters from COHERENT".

Despite the generality, the results can be written in compact form and are easy to implement in existing or future analyses using effective nuclear charges. We use current COHERENT data to set constraints on the corresponding effective operators, and we estimate the sensitivity of future measurements.

**Secondary track**:

T09 - Beyond the Standard Model

**T08** / **175**

## A novel implementation of the Matrix Element Method at next-to-leading-order (NLO) for the measurement of the Higgs tri-linear coupling in di-Higgs production at the LHC

**Auteurs:** Jan Stark[1]; Matthias Tartarin[2]

[1] *L2I Toulouse, CNRS/IN2P3, Université de Toulouse*

[2] *L2I Toulouse, Université de Toulouse, CNRS/IN2P3*

**Auteur correspondant** matthias.tartarin@l2it.in2p3.fr

One of the LHC's priorities, following the discovery of the Higgs boson, is to observe the production of Higgs pairs and to measure the Higgs tri-linear coupling $\lambda_{3H}$.

Due to the rarity of di-Higgs production, measuring $\lambda_{3H}$ has proven to be highly challenging. Exclusion limits have been observed using a variety of approaches, including cut-based methods and boosted decision trees (BDTs).
To address this difficulty from a new perspective, our work explores the application of the Matrix Element Method (MEM), a technique that has demonstrated its effectiveness in multiple analyses in which measurements were performed in processes that were rare (at the time).One can mention the primordial role of the MEM in measuring the top-quark mass at Tevatron, or its role in the first evidence for single top production in the s-channel at the LHC for example.

The MEM is a statistically optimal multivariate method that maximizes the utilization of both the experimental and theoretical information available to an analysis, making it inherently well-suited to rare process searches and Standard Model measurements.
Most MEM studies have been limited to leading-order (LO) accuracy, with extensions to next-to-leading-order (NLO) explored only in specific cases due to the additional complexities introduced by virtual and real contributions.
To contribute to the measurement of $\lambda_{3H}$ from LHC data in the $gg \to HH \to b\bar{b}\gamma\gamma$ channel, we developed a MEM framework by working on a new NLO implementation (which can be applied to many more analyses).

This MEM framework utilizes state-of-the-art Matrix Elements at NLO from the POWHEG-BOX-V2 and MG5_@NLO software packages. The framework is implemented within a modified version of MoMEMta, a software designed for managing multi-variable phase-space integration, which has been extended to incorporate this new NLO implementation.

To our knowledge, this work marks the first application of the MEM at NLO accuracy to the search for $HH$ and the measurement of $\lambda_{3H}$. This also represents the first application of the MEM using this new NLO formalism.
We also applied this framework to Monte Carlo (MC) simulated samples in a search for $\lambda_{3H}$, achieving promising results.

This study aims to introduce this new approach to the community and position the MEM (at NLO) as a competitive alternative to other established methods to determine the Higgs self-coupling $\lambda_{3H}$.

**Secondary track**:

**T11** / **176**

## Results of long-term ageing tests on Eco-Friendly Resistive Plate Chamber detectors

**Auteur:** RPC EcoGas@GIF++ Collaboration[None]

**Co-auteurs:** Alessandra Pastore [1]; Davide Piccolo [2]

[1] *Bari University & INFN*

[2] *INFN LNF*

Resistive Plate Chambers (RPCs) are particle detectors extensively used in several domains of Physics. In High Energy Physics, they are typically operated in avalanche mode with a high-performance gas mixture based on Tetrafluoroethane (C2H2F4), a fluorinated high Global Warming Potential greenhouse gas.
The RPC EcoGas@GIF++ Collaboration has pursued an intensive R&D activity to search for new gas mixtures with low environmental impact, fulfilling the performance expected for the LHC operations and for future applications.
In this talk, results obtained with new eco-friendly gas mixtures based on Tetrafluoropropene and carbon dioxide even under high-irradiation conditions will be presented. Long term ageing tests carried out at the CERN Gamma Irradiation Facility will be discussed together with their possible limits and future perspectives.

**Secondary track**:

**T07** / **177**

## Gravity induced CP violation in K and B mixing, decays and interferences experiments

**Auteur:** Jean-Marcel Rax[1]

[1] *UJCLab Universite Paris-Saclay*

The impact of earth's gravity on neutral mesons dynamics is analyzed. The main effect of a Newtonian potential is to couple the flavor oscillations with the quarks zitterbewegung oscillations. This coupling is responsible of the observed CP violations (CPV) in the three types of experiments: (i)

indirect violation in the mixing, (ii) direct violation in the decay to one final state and (iii) violation in the interference between decays with and without mixing. The three violations parameters associated with these experiments for K and B neutral mesons (epsilon, epsilon prime and beta : arXiv:2503.09465 ) are predicted in agreement with the experimental data (PDG 2024). The amplitude of the violation is linear with respect to the strength of gravity so that this new mechanism allows to consider matter dominated cosmological evolution providing the observed baryon asymmetry of the universe (BAU).

**Secondary track**:

T01 - Astroparticles, Gravitation and Cosmology

**T11** / **178**

# Luminosity determination at LHCb during Run 3

**Auteur:** LHCb Collaboration[None]

During Runs 1 and 2, the LHCb detector optimized its performance by stabilizing the instantaneous luminosity throughout each fill, adjusting the distance between the colliding beams using a hardware-based trigger system. In Run 3, the LHCb experiment underwent a major upgrade to accommodate a fivefold increase in luminosity, transitioning to a fully software-based trigger. A new luminometer, PLUME, was installed and successfully commissioned, providing enhanced real-time luminosity measurements. Furthermore, new online proxies from nearly all sub-detectors are now utilized to deliver real-time luminosity measurements, both integrated and per bunch crossing. Additionally, dedicated offline counters are recorded via a specialized data stream operating at a rate of 30 kHz, enabling precise offline luminosity calibration. This talk will provide an overview of the upgraded luminosity measurement capabilities at LHCb and of the systems employed to perform such measurements, presenting the first results obtained from data collected during 2023 and 2024, including the measurement of the ghost charge fraction using the beam-gas imaging technique.

**Secondary track**:

**T07** / **180**

# Recent results from LHCb on charged-current decays of b-hadrons

**Auteur:** LHCb Collaboration[None]

Semileptonic $b$-hadron decays proceed via charged-current interactions and provide powerful probes for testing the Standard Model and searching for New Physics effects. The advantages of studying such decays include the large branching fractions and reliable calculations of the hadron matrix elements. Several SM features may be studied, such as the CKM parameters, the properties of $b-$hadron production, form factor parameters and Wilson coefficients. In this contribution, recent LHCb results on this topic are presented.

**Secondary track**:

**T07** / **181**

# CP Violation in Baryon Decays at LHCb

**Auteur:** LHCb Collaboration[None]

While CP violation (CPV) is well established in meson decays, its observation in baryon decays remains an open challenge. The LHCb experiment, designed to study CP violation in particles containing bb quarks, has collected an unprecedented dataset, offering a unique opportunity to probe CP asymmetries in baryon decays. This talk will present the latest LHCb results on CPV in baryon decays, with a focus on charmless beauty decays, discussing their implications and prospects for future measurements.

**Secondary track**:

**T07 / 182**

## Overview of the b-to-charmonium decays in LHCb

**Auteur:** LHCb Collaboration[None]

Benefiting from the clean experimental signature of dimuon detection, the LHCb experiment collects large samples of beauty hadron decays to charmonium. This allows for precise measurements of key properties such as branching fractions, lifetimes, and CP violation. In this work, we present the latest LHCb results on these decays, with a particular focus on CP violation and branching ratio measurements.

**Secondary track**:

**T05 / 185**

## Recent results of hadron spectroscopy in B to open charm decays at LHCb

**Auteur:** LHCb Collaboration[None]

B-hadron decays with open charm hadrons in the final states provide excellent opportunities for hadron spectroscopy studies, covering both conventional and exotic states. Access to the kinematics of the full B-decay chain enables precise measurements of the properties of the intermediate resonances through the amplitude analysis technique, providing critical inputs for understanding the inner structure of these particles in theory. The LHCb experiment has made significant contributions to hadron spectroscopy with B to open charm decays in recent years. This talk will present the latest results in this area.

**Secondary track**:

**Joint T05+T07 / 186**

## CP violation measurements in B to open charm decays at LHCb

**Auteur:** LHCb Collaboration[None]

Time-integrated and time-dependent measurements of CP violation are important to test the Standard Model (SM) description. In particular, the tree-level determination of the CKM angle gamma is a standard candle measurement of CP violation in the SM. The latest CP violation measurements using beauty to open charm decays from LHCb are presented.

**Secondary track**:

**T09** / **187**

## BuSca: New Strategies for LLP Searches at 30 MHz at LHCb

**Auteur:** LHCb Collaboration[None]

The new fully software-based trigger of the LHCb experiment operates at a 30 MHz data rate, opening a search window into previously unexplored regions of physics phase space. The BuSca (Buffer Scanner) project at LHCb acquires and analyzes data in real time, extending sensitivity to new lifetimes and mass ranges thanks to the recently deployed Downstream tracking algorithm. BuSca identifies hotspots indicative of potential new particle candidates in a model-independent manner, providing strategic guidance for developing new trigger lines. To control background, regions with minimal detector material interactions are selected, and pairs of same-sign tracks are used to suppress combinatorial background. This talk presents the results from the analysis of the first data.

**Secondary track**:

T12 - Data Handling and Computing

**T05** / **188**

## Studies of Bc mesons at LHCb

**Auteur:** LHCb Collaboration[None]

The Bc meson, the heaviest among known mesons, decays through the weak interaction. Its double-heavy quark content and distinct masses present new challenges and opportunities for testing effective theories with unique decay, spectroscopy and production properties. These features offer valuable insights into heavy-quark dynamics inside hadrons and enhance our understanding of the strong interaction. This talk presents recent progress on Bc spectroscopy and decay studies obtained at LHCb.

**Secondary track**:

**T04** / **191**

## Charm and charmonia production in fixed-target collisions

**Auteur:** LHCb Collaboration[None]

The production of charm quarks and charmonium states in fixed-target collisions provides a powerful probe of QCD in cold and hot nuclear matter. The LHCb experiment has pioneered a novel fixed-target program, now enhanced for Run 3 with the SMOG2 system, which features improved gas confinement and the capability to inject non-noble gases. This upgrade significantly increases fixed-target luminosity, enabling high-statistics studies of charm production in proton-nucleus (pA) and lead-nucleus (PbA) collisions. Charm production measurements in this environment offer unique insights into cold nuclear matter effects, such as nuclear PDF modifications, parton energy loss, and intrinsic charm contributions, across small and large collision systems at the same center-of-mass energy per nucleon pair (√sNN). Additionally, these measurements provide an opportunity to investigate potential signatures of hot nuclear matter effects at lower energies. In this talk, we will present new results on open and hidden charm production using the first dataset collected with SMOG2. We will also discuss future prospects for charm studies in PbAr collisions, which will further refine our understanding of QCD in nuclear environments.

**Secondary track**:

**T05 / 192**

# Low-x physics at LHCb

**Auteur:** LHCb Collaboration[None]

The LHCb detector, with its unique forward geometry, provides unprecedented kinematic coverage at low Bjorken-x values, down to 10^-6. LHCb's excellent momentum resolution, vertex reconstruction and particle identification allow precision measurements down to very low hadron transverse momentum. In this talk, recent studies of exclusive vector boson production in proton-proton and heavy ion collisions will be presented. These studies include the central exclusive production (CEP) of charmonium vector mesons in pp collisions, as well as their production in ultraperipheral Lead-Lead collisions (UPC). Additionally, the production of exotic meson candidates in diffractive proton-proton collisions, previously observed only in B to J/ψϕK decays, is reported. Future prospects for further investigations into low-x phenomena with the LHCb detector in Run 3 are also explored.

**Secondary track**:

**T04 / 193**

# Charmonium production from small to large systems at LHCb

**Auteur:** LHCb Collaboration[None]

Modifications of quarkonia production in hadronic collisions provide an important experimental observable to probe the heavy quark interaction with the nuclear medium. The excited ψ(2S) state, with a relatively low binding energy, is especially sensitive to these effects. Different phenomena can be probed by studying the excited-to-ground state production ratio in different collision systems with increasing multiplicity. In this contribution, we will present new LHCb results on ψ(2S) / J/ψ production from pp to PbPb collisions. In addition, progress on new measurements with Run 3 data will be reported.

**Secondary track**:

**Poster T07 / 194**

# Rare charm decays at LHCb

**Auteur:** LHCb Collaboration[None]

The LHCb experiment is playing a leading role in the study of rare and forbidden decays of charm hadrons, which are sensitive to new interactions beyond the Standard Model. The latest searches

for FCNC-mediated processes and asymmetry measurements in final states with two leptons are presented.

**Secondary track**:

**T07 / 195**

## Mixing and CP violation in charm decays at LHCb

**Auteur:** LHCb Collaboration[None]

The LHCb experiment published the first observation of CP violation in the decay of charmed particles in 2019, using the decay channels $D^0 \to \pi^+\pi^-$ and $D^0 \to K^+K^-$. Additional measurements of $D^0$ mixing and of other decay channels are essential to understand whether this observation can be explained within the Standard Model, or if new sources of CP violation are needed. We present the latest measurements of mixing and CP violation in complementary decay channels, and discuss the prospects for sensitivity at the LHCb upgrades.

**Secondary track**:

**T05 / 196**

## Charmed-hadron production and decay properties at LHCb

**Auteur:** LHCb Collaboration[None]

LHCb has collected the world's largest sample of charmed-hadron decays during the LHC Run 1 and 2 (2015-2018). For Run 3 (2022-2026), the LHCb detector has been upgraded to operate at fivefold larger instantaneous luminosity. We present recent findings on the production and decay properties of charmed hadrons, including the first results based on Run 3 data.

**Secondary track**:

T07 - Flavour Physics and CP Violation

**T12 / 198**

## Performance of the real-time alignment and calibration of the LHCb detector in Run 3 of the Large Hadron Collider.

**Auteur:** LHCb Collaboration[None]

The LHCb detector has undergone a major upgrade for Run 3 of the Large Hadron Collider (LHC) to take data at a nominal instantaneous luminosity increased by approximately a factor of five. A key component of this upgrade concerns the realization of a fully software-based trigger system that performs the reconstruction of tracks and particle candidates in real time, which can directly be used for physics analysis. The new trigger system allows for a more refined and efficient event selection, made possible by the real-time alignment and calibration of the detector, ensuring a high quality of the data. This talk presents the status and performance of the real-time alignment and calibration of the LHCb detector during Run 3 of the LHC. The fully software-based trigger strategy is introduced, with a focus on the alignment and calibration procedures that have enabled its successful operation.

**Secondary track**:

**T12** / **199**

## The upgraded LHCb trigger system

**Auteur:** LHCb Collaboration[None]

Since the beginning of Run 3 of LHC the upgraded LHCb experiment is using a triggerless readout system collecting data at an event rate of 30 MHz and a data rate of 4 TB/s. The trigger system is split into two high-level trigger (HLT) stages. During the first stage (HLT1), implemented on GPGPUs, track reconstruction and vertex fitting for charged particles is performed to reduce the event rate to 1 MHz, where the events are buffered to a disk. In the second stage (HLT2), deployed on a CPU server farm, a full offline-quality reconstruction of charged and neutral particles and their selection is performed, aided by the detector alignment and calibration run in quasi-real time on buffered events. This allows to use the output of the trigger directly for offline analysis. In 2024 for the first time we ran the system at the design lumi and achieve an HLT1 output rate of 1.3 MHz. In this talk we will give a review of the implementation and challenges of the heterogenous LHCb trigger system, discuss the results with 2024 data, together with the prospects for the future.

**Secondary track**:

**T12** / **200**

## Tracking and PID performance with the upgraded LHCb detector

**Auteur:** LHCb Collaboration[None]

The LHCb experiment underwent a major upgrade in LHC Long Shutdown 2 and has been taking data in Run 3 at a five times higher instantaneous luminosity of $2 \times 10^{33}$ cm$^{-2}$ s$^{-1}$. The tracking detectors are all newly constructed and the particle identification detectors have been substantially upgraded with new frontend and backend electronics, allowing for the lowest level hardware trigger to be removed and all subdetectors to be read out at the full LHC bunch crossing rate of 40 MHz. An all-software trigger then processes the full event information in two stages, where the first stage is implemented on GPU cards and the second stage on CPUs servers. In this presentation we will cover the performance of the new track reconstruction and particle identification and show how the improved granularity of the detectors help not only to maintain but even to improve on the previous LHCb detector performance in many key areas, paving the way for precise flavor physics measurements. We will focus on the results of the 2024 data taking year, the first period where the experiment reached nominal operating conditions and recorded over 9 fb$^{-1}$ of integrated luminosity.

**Secondary track**:

T11 - Detectors

**T05** / **201**

## Two- and three-particle Bose-Einstein correlations in small collision systems at LHCb

**Auteur:** LHCb Collaboration[None]

The new results on three-pion Bose-Einstein correlations measured with the sample of proton-proton collisions recorded at the centre-of-mass energy of √s = 7 TeV will be presented, being the first study of three-particle Bose-Einstein correlations measured in the forward region provided by the LHCb detector. The results are interpreted within the core-halo model for the first time in proton-proton collisions. Together with previous LHCb results on two-pion Bose–Einstein correlations measured for the first of this in the forward rapidity region at LHC energies, it confirms the observation of collective phenomena in the small collision systems.

**Secondary track**:

**T07 / 202**

# Recent results on $b \to s\ell\ell$ analyses

**Auteur:** LHCb Collaboration[None]

Measurements involving flavour-changing neutral current $b \to s\ell^+\ell^-$ transitions are highly sensitive probes of new physics as their Standard Model contribution is both loop and CKM suppressed. Over the past decade, there has been increased interest in these decays due to a pattern of self-consistent, sizeable and persistent tensions between measurements and SM predictions. This talk will present the latest LHCb results on amplitude analyses and branching fraction measurements of $b \to s\ell^+\ell^-$ processes and discuss prospects in this field.

**Secondary track**:

**T07 / 205**

# Radiative Rare b-Hadron Decays at LHCb

**Auteur:** LHCb Collaboration[None]

Radiative rare b-hadron decays offer a unique window into potential contributions from physics beyond the Standard Model through precise measurements of branching fractions, angular distributions, CP-violating observables, and photon polarization. The LHCb experiment, with its high-efficiency trigger system, excellent tracking resolution, and advanced particle identification capabilities, provides an ideal environment for studying these decays. This talk presents the latest LHCb results on radiative rare b-hadron decays, including new precise measurements of the $b \to s\gamma$ photon polarisation and upcoming results on Cabibbo-suppressed $b \to d\gamma$ decays.

**Secondary track**:

**T07 / 206**

# Rare strange decays at LHCb: Observation of the $\Sigma^+ \to p\mu^+\mu^-$ rare decay and searches for $K_{\mathrm{S}}$ rare decays

**Auteur:** LHCb Collaboration[None]

In recent years the LHCb experiment has expanded its physics reach to searches for $K_{\mathrm{S}}$ and hyperon rare decays, and is currently the experiment with the highest yields of reconstructed decays of these particles. Particularly, searches for flavour changing neutral currents have been performed, sensitive to physics beyond the Standard Model. The $K_{\mathrm{S}} \to \mu^+\mu^-$ and $K_{\mathrm{S}} \to 4\mu$ have been searched and limits have been put orders of magnitude lower than previous experiments, tightening the space of possible new physics. With Run 2 data the $\Sigma^+ \to p\mu^+\mu^-$ decay is observed for the first time at the LHCb experiment. The HyperCP experiment years ago presented evidence of this decay with a hint of a possible unknown intermediate particle. This was excluded by LHCb already in 2018. This new measurement presents a highly significant observation, a measurement of the integrated branching fraction and of the dimuon spectrum. This is the rarest baryon decay ever observed. Additionally, the sensitivity of these observables to Chiral Perturbation Theory parameters will be discussed. Finally prospects for additional observables, such as a CP violation measurement, and additional rare strange hadron decays will also be presented.

**Secondary track**:

**Poster T03** / **208**

## Analysis and simulation of low energy Michel electrons in ProtoDUNE

**Auteur:** Thibaut Houdy[1]

[1] *IJCLab, France*

The Deep Underground Neutrino Experiment (DUNE) is a long-baseline neutrino-oscillation experiment aiming to measure CP-violation and the neutrino mass ordering. The far detector consists of four 17-kt modules based on Liquid Argon Time Projection Chamber (LArTPC) technology. The first and second DUNE modules technology are being tested with large scale prototypes (ProtoDUNE) at the CERN Neutrino Platform.

Measurements of low-energy electrons produced by electron-neutrino interactions and cosmic rays are important for neutrino oscillation measurements, the detection of supernova bursts and the search for physics beyond the Standard Model in neutrino experiments. In particular, the electrons produced by cosmic muons that decay at rest, known as Michel electrons, have well-known energy spectra below 50 MeV. They are therefore important for understanding the response of detectors to low-energy electrons.

The ProtoDUNE detectors have been taking beam and cosmic muons data in 2024 and 2025. This poster will focus on the simulation and analysis of Michel electrons in the vertical drift prototype of DUNE.

**Secondary track**:

**T06** / **209**

## LUXE: a high-precision experiment to study non-perturbative QED in electron-laser and photon-laser collisions

**Auteur:** LUXE Collaboration[None]

The Laser Und XFEL Experiment (LUXE), in planning at DESY Hamburg, is intended to study quantum electrodynamics (QED) in strong electromagnetic fields, and in particular the transition from perturbative to non-perturbative. In the non-perturbative regime, electron-positron pairs tunnel out of the vacuum in a manner akin to the Schwinger process. The experiment will make precision measurements of the photon and positron rates in collisions between a high-intensity laser pulse and the 16.5 GeV electron beam of the European XFEL, or the high-energy secondary photons it produces. This talk will provide an overview and update on the work of the LUXE collaboration, as the experiment moves towards implementation.

**Secondary track**:

**T16** / **210**

## Zero-bias new particle searches in UPCs

**Auteur:** Simone Ragoni[1]

[1] *Creighton University (USA)*

Ultra-peripheral collisions (UPC) are events characterised by large impact parameters between the two projectiles, larger than the sum of their radii. In UPCs, the protons and ions accelerated by the collider do not interact via the strong interaction and can be regarded as sources of quasireal photons, with minimal contamination from hadronic interactions.

In this talk, we present novel applications of machine learning techniques to enhance the identification of the low-multiplicity events which are characteristics of UPCs. Leveraging models for early event classification in continuous readout systems, we demonstrate the ability to significantly reduce data storage requirements while optimizing real-time event selection. We also explore the use of unsupervised learning, particularly autoencoder neural networks, to identify rare particle decays and exotic hadrons in UPCs and diffractive events. These techniques allow for the detection of anomalies in decay kinematics, potentially uncovering new exotic states and processes beyond the Standard Model.

Our approach offers a scalable solution for high-luminosity experiments like ALICE and ePIC, where managing the sheer volume of data is critical. By combining early event classification and anomaly detection, machine learning holds the promise of transforming data acquisition and analysis in the next generation of particle physics experiments.\\

**Secondary track**:

T16 - AI for HEP (special topic 2025)

**T08** / **211**

## ggxy: NLO QCD corrections to loop induced $gg$ initiated processes

**Auteurs:** Daniel Stremmer[1]; Joshua Davies[2]; Kay Schönwald[3]; Matthias Steinhauser[1]

[1] *KIT*

[2] *University of Liverpool*

[3] *University of Zuerich*

**Auteur correspondant** daniel.stremmer@kit.edu

We present the program package ggxy, which in its first version can be used to calculate partonic and hadronic cross sections to Higgs boson pair production at NLO QCD. The 2-loop virtual amplitudes are implemented using analytical approximations in different kinematic regions, while all other parts of the calculation are exact. This implementation allows to freely modify the masses of the top quark and the Higgs boson, as well as the renormalization scheme of the top-quark mass. Finally,

we discuss the status of including other processes in our framework, such as $gg \to ZH$ or $gg \to ZZ$.

**Secondary track**:

T06 - Top and Electroweak Physics

**T05** / **212**

## Precise determination of the strong coupling from hadronic tau decays including $\tau \to \pi^0\pi^-\nu_\tau$ from Belle

**Auteur:** Diogo Rodrigues Boito[1]

**Co-auteurs:** Aaron Eiben [2]; Kim Maltman [3]; Lucas Mansur [4]; Maarten Golterman [2]; Santiago Peris [5]

[1] *Universidade de São Paulo*

[2] *San Francisco State University*

[3] *York University*

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The determination of the QCD coupling, $\alpha_s$, from the analysis of inclusive hadronic tau decays is one of the most precise extractions of this fundamental parameter from experiment. For a long time, the analyses were based on the inclusive spectral functions determined by ALEPH and OPAL. These spectral functions rely on measurements of the dominant decay channels, but necessitated the inclusion of subleading mode contributions by means of Monte Carlo simulations. We have shown that, with more recent experimental results, it is now possible to obtain those subleading contributions directly from experiment, using measurements of the exclusive cross-sections for $e^+e^- \to \text{hadrons}$, related by conserved vector current (CVC), and BaBar data for the $K\bar{K}$ mode. We have thus constructed a new vector-isovector spectral function entirely based on experimental data, from the combination of the exclusive channel measurements from LEP, using an algorithm typically employed in applications to $g-2$ of the muon, with our determination of the subleading mode contributions from available experimental data. This new spectral function was the basis for an improved alpha_s determination.

In the present work, we include, for the first time, the Belle $\tau \to \pi^-\pi^0\nu_\tau$ high-statistics decay data to construct a new inclusive non-strange vector spectral function that combines more of the world's available data. From the resulting new spectral function, we obtain a new determination of $\alpha_s$ using our previously developed strategy based on finite-energy sum rules. We find, at the $Z$ mass scale, $\alpha_s(m_Z^2) = 0.1159(14)$. I will discuss the smaller central value and larger error of our new result compared to our previous result, showing the shifts to be due mainly to significant changes in updated HFLAV results for the $\pi^-3\pi^0$ decay mode. I will also discuss how future experimental data could be used to improve this determination even further.

**Secondary track**:

**T08** / **213**

## Quantum properties of H→VV*: precise predictions in the SM and sensitivity to new physics

**Auteurs:** Davide Pagani[1]; Fabio Maltoni[2]; Federica Fabbri[3]; Morgan Del Gratta[1]; Pryianka Lamba[1]

[1] *University of Bologna and INFN*

[2] *UCLouvain/Unibo*

[3] *University of Bologna/INFN*

**Auteur correspondant** federica.fabbri@cern.ch

We study the quantum properties of the Higgs-boson decays into four fermions via two vector bosons ($H \to VV^* \to 4f$). In particular, we focus on the case of two different-flavour lepton pairs ($H \to ZZ^* \to \mu^+\mu^-e^+e^-$). We compute the quantum-information observables for the corresponding two-qutrit system ($ZZ$) at next-to-leading order electroweak (NLO EW) accuracy in the SM. We find that NLO EW corrections lead to giant (order 1) effects in some specific cases and significantly alter the extraction of the observables quantifying the quantum correlations. We identify the observables that are robust and can be used to extract reliable information. Finally we discuss possible new physics (NP) effects, parametrised via an effective-field-theory approach. We show how quantum observables can increase the sensitivity to NP also for the process considered in this study.

**Secondary track**:

T15 - Quantum technologies in HEP (special topic 2025)

**T03** / **214**

## Atmospheric Neutrinos in DUNE

**Auteurs:** Camille Sironneau[1]; DUNE Collaboration[None]

[1] *APC lab*

**Auteur correspondant** sironneau@apc.in2p3.fr

The Deep Underground Neutrino Experiment (DUNE) is a next generation neutrino oscillation experiment which will target the main outstanding questions of neutrino physics, including the neutrino mass ordering and the possibility of CP violation in the lepton sector. It will make use of a suite of 4x17kt large liquid argon (LAr) time projection chambers, located 1.5 km deep underground at SURF, South Dakota and 1300 kilometers from the LBNF beamline at FNAL, Illinois. In addition to DUNE's beam physics program, the experiment presents the exciting opportunity to extend its reach towards atmospheric neutrino analyses. This will allow for the exploration of a wider range of L/E than beam data and provide great complementarity in both standard and Beyond Standard Model (BSM) oscillation analyses. The excellent event reconstruction capabilities expected in the DUNE Far Detectors (FD) will be key in performing these analyses. This talk will present the ongoing work of the DUNE Atmospherics & Exotics physics working group towards the implementation and optimization of the reconstruction of atmospheric neutrino events in the DUNE FD. It will also delve into the developments being made on the software MaCh3 allowing straightforward joint fits with other oscillation analyses. In this context, I will focus on the recent integration of broad BSM applications such as sterile neutrinos or non-standard neutrino interactions to the MaCh3 framework.

**Secondary track**:

**T11** / **215**

## Commissioning of a mobile neutron spectrometer for the LNGS underground laboratory

**Auteur:** FRANCESCO POMPA[1]

[1] *University of L'Aquila, INFN LNGS & KIT*

**Auteur correspondant** francesco.pompa@graduate.univaq.it

Neutrons constitute a major background in direct dark matter searches, yet previous measurements at LNGS have reported notable discrepancies in both flux values and energy spectra. These inconsistencies arise from variations in detector technologies, calibration methods, and energy windows used in different studies. Precise knowledge of this background is necessary to devise shielding and veto mechanisms, improving the sensitivity of underground experiments.
To address this challenge, we have developed ALMOND (An LNGS Mobile Neutron Detector): a mobile, low-flux neutron spectrometer based on a plastic scintillator array covered by gadolinium foils. ALMOND was designed and built at KIT as a stand-alone system to measure background in different locations. In this talk, we present the commissioning and calibration of the detector at KIT and at the Frascati Neutron Generator, introduce our first experimental campaign to measure the neutron background in Hall A at LNGS, and discuss future perspectives.

This project is funded by the German Federal Ministry of Education and Research (BMBF) under the grant number 05A21VK1.

**Secondary track**:

T02 - Dark Matter

**T15** / **217**

## A Quantum Adaptive Importance Sampling Algorithm for Multidimensional Integration

**Auteurs:** Germán Rodrigo[1]; Jorge J. Martínez de Lejarza[2]; Konstantinos Pyretzidis[2]

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Perturbative Quantum Field Theory is central to perform accurate theoretical predictions of observables at high-energy colliders. Fundamental concepts in this framework, such as loop Feynman diagrams and the phase-space, involve evaluating multidimensional integrals that are computationally intensive due to divergences and complex mathematical structures. To address these challenges and improve the precision of such calculations, the standard approach relies on adaptive importance sampling. The most notable example is the VEGAS algorithm, which adaptively updates a multidimensional grid. However, because the computational cost of handling each grid cell grows exponentially with the number of the integral's dimensions, the model for the probability density function (PDF) is simplified to a separable product of PDFs, factorized (or projected) along each integration variable's axis.

In this work, we present a Quantum Algorithmic workflow that performs Quantum Adaptive Importance Sampling. The workflow consists of three main elements. First, the Encoding part, in which the integration domain is discretized, and mapped into a quantum circuit. In this step it is also crucial to choose a suitable parameterized quantum circuit architecture, with adequate expressivity to efficiently capture all the complexities of the structures of the target integrand. Second, the State Preparation stage, where by adapting the parameters of the quantum circuit, we shape the PDF generated by the quantum state to approximate the desired target integrand. Third, the outcomes of the optimal circuit's quantum state tomography are processed within a dedicated statistical framework.

This framework is an adjusted version of standard importance sampling to a quantum computational system, that fulfills the quantum state tomography constraints while preserving its inherent unbiased estimation.

The central objective is to manipulate the grid in it's entirety via the quantum circuit in order to bypass the limitations of the separable PDF assumption.
Thus, being able to sample from the proposal PDFs that approximate the target integrand with higher accuracy. As an application, we look on benchmark integrals and loop Feynman integrals, and compare the precision that the best grid of VEGAS gets against that of the quantum generated proposal PDF, as a function of the number of samples.

**Secondary track**:

**T12 / 218**

# CMS FlashSim: how ML powers end-to-end simulation for HEP

**Auteur:** CMS Collaboration[None]

The CMS Collaboration developed an end-to-end ML based simulation that can speed up the time for production of analysis samples of several orders of magnitude with a limited loss of accuracy. Detailed event simulation at the LHC is crucial for physics analyses and it is currently taking a large fraction of computing budget. Because the CMS experiment is adopting a common analysis level format (the NANOAOD) for a larger number of analyses, such an event representation is used as the target of this ultra fast simulation, which we call FlashSim. Generator level events, from PYTHIA or other generators, are directly translated into NANOAOD events at several hundred Hz rate with FlashSim. We show how training FlashSim on a limited number of full simulation events is sufficient to achieve very good accuracy on larger datasets for processes not seen at training time. With this work, we aim to update the community about recent and relevant developments behind the FlashSim framework.

**Secondary track**:

**T12 / 219**

# Trigger Algorithms for Alignment and Calibration at CMS during LHC Run 3

**Auteur:** CMS Collaboration[None]

During LHC Run 3, the CMS experiment faced challenging pileup and high event rate conditions. To efficiently select events of interest for physics analysis or alignment and calibrations, the CMS collaboration utilises a two-tiered triggering system. This system consists of a firmware-based Level-1 Trigger (L1) and a software-based High Level Trigger (HLT) that runs in a computing farm. The L1 trigger utilizes coarse calorimeter and muon detector information while at the HLT level a streamlined event reconstruction using the complete detector information is performed. A critical asset of the experiment is the rapid derivation of alignment and calibration conditions for both the HLT and offline reconstruction. To achieve this, a dedicated set of triggers is integrated into the data-taking process. This contribution outlines the CMS alignment and calibration workflows and the interplay between these dedicated triggers and the derivation of conditions.

**Secondary track**:

T11 - Detectors

**Joint T06+T08 / 220**

# Effective Field Theory fits of the electroweak sector CMS data

**Auteur:** CMS Collaboration[None]

Recent results on global EFT fits of the CMS data are presented, with particular focus on the electroweak sector of the Standard Model.

**Secondary track**:

**T06 / 221**

# Multiboson production in CMS

**Auteur:** CMS Collaboration[None]

This talk reviews recent measurements of multiboson production using CMS data at sqrt(s) = 13 and 13.6 TeV. Inclusive and differential cross-sections are measured using several kinematic observables.

**Secondary track**:

**T11 / 222**

# PPS2: a new precision proton spectrometer for CMS at HL-LHC

**Auteur:** CMS Collaboration[None]

The CMS experiment has been successfully operating the Precision Proton Spectrometer (PPS) since 2016 to study central exclusive production (CEP) events, pp⟶pXp, at the LHC via the detection of the surviving protons. CEP allows unique sensitivity to physics beyond the standard model, e.g. in the search for anomalous quartic gauge couplings, axion-like particles, and in general new resonances. Currently PPS operates near beam tracking and timing detectors installed at ~200m from the interaction point inside dedicated stations. Since in the next years the accelerator will undergo a significant upgrade towards very high luminosity performances (HL-LHC), the CMS collaboration recently decided to build a new proton spectrometer (PPS2) to continue the physics program profiting of the new high luminosity regime. The talk will describe the physics motivation of PPS2, the detector design and the challenges of the integration of the apparatus inside the new accelerator facility.

**Secondary track**:

**T16 / 223**

# Advancements in the Reconstruction and Identification of Hadronically Decaying Tau Leptons at the CMS Experiment

**Auteur:** CMS Collaboration[None]

Tau leptons play a crucial role in studies of the Higgs boson and searches for Beyond the Standard Model physics at the LHC. This talk presents the latest advancements in the reconstruction and identification of hadronic decays of tau leptons at the CMS experiment. The tau identification algorithm deployed for the early Run 3 data-taking period, based on a deep convolutional neural network with domain adaptation, showcases significantly improved discrimination of genuine hadronic tau decays against mis-identified quark and gluon jets, electrons, and muons. The performance and calibration of the algorithm using early Run 3 data is presented. Many CMS physics analyses involving tau leptons are expected to benefit from these improvements. Alternative approaches to identify hadronic taus combined with jet flavour, based on graph neural networks and particle transformers, are also covered. Additionally, the dedicated techniques used to reconstruct and identify displaced tau leptons originating from long-lived particle decays using graph neural networks are discussed.

**Secondary track**:

**T09** / **224**

## Searches for vector-like quarks at CMS

**Auteur:** CMS Collaboration[None]

We present results of searches for massive vector-like top and bottom quark partners using proton-proton collision data collected with the CMS detector at the CERN LHC at a center-of-mass energy of 13 TeV. Single and pair production of vector-like quarks are studied, with decays into a variety of final states, containing top and bottom quarks, electroweak gauge and Higgs bosons. We search using several categories of reconstructed objects, from multi-leptonic to fully hadronic final states. We set exclusion limits on both the vector-like quark mass and cross sections, for combinations of the vector-like quark branching ratios.

**Secondary track**:

**T06** / **227**

## t(tt) associated production in CMS

**Auteur:** CMS Collaboration[None]

The production of an odd number of top quark events is necessarily suppressed in the SM, as it is mediated by the electroweak interactions, but naturally takes place in a number of BSM models, e.g. those involving FCNCs. As a consequence, the study of such processes is a promising tool in the search for new physics. We present a number of studies of such processes, including an observation of tWZ production, a search for 3 top production, and a measurement of t-channel single top production

**Secondary track**:

**T05** / **228**

## Observation of a family of all-charm tetraquarks with spin-2 and positive parity at CMS

**Auteur:** CMS Collaboration[None]

We present a comprehensive study of near-threshold structures in the J/\psi J/\psi mass spectrum using the fully reconstructed J/\psi J/\psi \rightarrow 4\mu final state, based on proton-proton collision data at \sqrt{s} = 13 and 13.6 TeV collected by the CMS experiment. With approximately four times more J/\psi pair candidates compared to the previous Run 2 dataset, the combined data sample enables a significantly enhanced sensitivity to rare structures. In the mass range between 6 and 8 GeV, three peaks are observed with significances well above 5σ, consistent with the previously reported tetraquark candidates X(6600), X(6900), and X(7100). Two pronounced dips, also exceeding 5σ in significance, are identified between the peaks, highlighting the presence of strong interference effects. A complementary search in the J/\psi \psi(2S) \rightarrow 4\mu final state reveals a consistent two-peak structure corresponding to the X(6900) and X(7100), with measured masses and widths compatible within uncertainties. To further investigate the nature of the observed states, a spin-parity analysis is performed using a matrix-element-based approach, testing multiple J^P hypotheses. The results favor a J^P = 2^+ assignment, offering new insights into the internal dynamics of these exotic resonances. This analysis, based on the Run 2 data, provides the most detailed picture to date of the fully-charm tetraquark landscape.

**Secondary track**:

T07 - Flavour Physics and CP Violation

**T12** / **229**

# Raw Data Reduction in the CMS Experiment for Run-3 and Phase-2

**Auteur:** CMS Collaboration[None]

Reducing event and data sizes is critical for experiments at the LHC, where high collision rates and increased detector granularity rapidly increase storage and processing requirements. In the CMS experiment, a recent development to address this challenge is the "Raw'"format: a new approach for recording silicon strip data in which only the reconstructed cluster's barycenter and average charge are stored, rather than the analog-to-digital converter counts from every strip. This format was successfully deployed online during Run-3 for PbPb collisions at CMS, achieving an event size reduction by nearly a factor of two and enabling CMS to record almost all hadronic minimum bias PbPb collisions.

To further enhance Raw', we optimized the number of bits used to encode the cluster barycenter and total charge, using tracking efficiency and resolution as benchmarks. Comparing standard RAW with Raw'shows that refining the bit precision yields stronger compression while maintaining similar performance.

Additionally, we introduce a lossless compression strategy that encodes distances between clusters instead of their absolute positions within a detector module. Unlike absolute positions, the distribution of these distances is peaked around zero, effectively reducing entropy of that variable. Consequently, LZMA compression becomes more efficient, allowing even stronger data reduction than the current Raw'algorithms without losing information integrity.

Lastly, we discuss projected data sizes for Phase-2 and explore extending these techniques to other CMS detectors, notably the High-Granularity Calorimeter, which is anticipated to generate a substantial fraction of future data.

**Secondary track**:

**T09** / **230**

# Probing new physics with dedicated data streams at CMS

**Auteur:** CMS Collaboration[None]

Signatures of new physics at the LHC are varied and by nature often very different from those of Standard Model processes. Novel experimental techniques, including dedicated datastreams are exploited to boost the sensitivity of the CMS Experiment to search for such signatures. In this talk we highlight the most recent CMS results, obtained using the data collected at the LHC Run-II and Run-III through the so-called "Data Scouting"and "Data Parking"strategies. These approaches have allowed to set some of the strongest constraints to date for low mass resonances in prompt and long-lived signatures.

**Secondary track**:

**T16** / **231**

## Advances in machine learning tools, software, and calibration for jet-flavor identification in CMS

**Auteur:** CMS Collaboration[None]

Identification of hadronic jets originating from heavy-flavor quarks is essential to several physics analyses in High Energy Physics, such as studies of the properties of the top quark and the Higgs boson and searches for new physics. Recent algorithms used in the CMS experiment are developed using state-of-the-art machine-learning techniques to distinguish jets emerging from the decay of heavy flavor (charm and bottom) quarks from those arising from light-flavor (udsg) ones. Increasingly complex deep neural network architectures, such as graphs and transformers, have helped achieve unprecedented accuracies in jet tagging. Furthermore, the models are extended also to identify jets originating from hadronic tau leptons and conduct a flavor-aware jet momentum regression. Along with these advances, we present new calibration methods using flavor-enriched selections of proton-proton collision events, which allow us to measure flavor tagging performances in Run 3 of the LHC. We also present modern software and data analysis tools, which allow for a fast and comprehensive development of machine-learning models and the analysis of ever-increasing volumes of data.

**Secondary track**:

T12 - Data Handling and Computing

**T11** / **233**

## Calibration of energy scales and resolution for muons in CMS for Run3

**Auteur:** CMS Collaboration[None]

For precise and unbiased physics analyses it is crucial that all the physics object have energy scales and resolution measured in data well described by Monte Carlo Simulations. In this talk we present the methods used to measure energy scale and resolutions for muons in CMS using Run3 data. The impact of these corrections on physics results is also assessed.

**Secondary track**:

**T11** / **234**

# Attaining the optimal performance of the CMS lead tungstate Electromagnetic Calorimeter in the Run3 of LHC

**Auteur:** CMS Collaboration[None]

The Compact Muon Solenoid (CMS) detector at the LHC requires optimal performance in electron and photon reconstruction for many physical analyses. The excellent energy resolution of its Electromagnetic Calorimeter (ECAL) is crucial for studies of Higgs boson decays with electromagnetic particles in the final state, for instance for the Higgs mass measurement in two-photons decay channel, as well as searches for very high mass resonances decaying to energetic photons or electrons. The energy and timing response of each ECAL channel is precisely calibrated; this talk will summarize the calibration techniques and the performance obtained during LHC Run3. The speaker will present also a new method for the time reconstruction with which, similarly to the amplitude reconstruction method used since Run2, the presence of out of time pile-up is taken into consideration in the modeling of the time signal. Finally, the new system, developed to automatically execute the calibration workflows during data taking, will be described; it aims to reduce the time needed to provide the best possible performance for physics analyses by one order of magnitude.

**Secondary track**:

**T11** / **235**

# The upgrade of the CMS Electromagnetic Calorimeter for the High-Luminosity LHC

**Auteur:** CMS Collaboration[None]

The High Luminosity upgrade of the LHC (HL-LHC) at CERN will provide, starting in 2030, unprecedented instantaneous and integrated luminosities of around 5 x 10^34 cm-2 s-1 and 3000/fb, respectively. The expected average of 140 to 200 collisions per bunch-crossing (pileup) represents a severe challenge for the detectors. While the endcap part of the calorimeters will be replaced by a new detector, the ECAL barrel's lead tungstate crystals and photo detectors are expected to sustain the new conditions.

The Very Front End electronics will be equipped with two already produced custom ASICs per crystal: a dual gain trans-impedance amplifier and an ASIC providing two 160 MHz ADC channels, gain selection, and data compression. The noise increase in the photo detectors, due to radiation-induced dark current, will be mitigated by reducing the ECAL operating temperature from 18 ℃ to 9 ℃. The trigger primitive formation will be moved off-detector and performed by powerful and flexible FPGA processors. The upgrade of the ECAL electronics will allow maintaining the excellent energy resolution of the detector and, in addition, greatly improves the time resolution of electrons and photons above 10 GeV, down to a few tens of picoseconds.

The final design of the full ECAL barrel readout chain and the status of the individual component R&D will be presented and results from recent test beam campaigns at the CERN SPS, using electron beams with energies of up to 250 GeV, will be summarised. In particular, we will present measurements of the energy and timing resolution performance of the latest HL-LHC ECAL readout electronics prototypes.

**Secondary track**:

**T08** / **237**

# Absolute Higgs boson cross section, mass, and width at FCC-ee

**Auteur:** Markus Klute[1]

[1] *KIT*

The FCC-ee programme is uniquely positioned to provide unprecedented precision on the fundamental properties of the Higgs boson. At the center-of-mass energies 240 and 365 GeV, the FCC-ee will produce millions of Higgs bosons via Higgs-strahlung and vector boson fusion. The clean experimental environment allows a model-independent measurement of the absolute ZH cross-section to better than per-mil accuracy, directly determining the Higgs coupling to Z bosons. Utilizing the recoil-mass technique in leptonic and hadronic Z decays, the Higgs boson mass will be measured with a precision of a few MeV. Combining these measurements with precise determinations of exclusive branching ratios will yield the total Higgs width at percent-level precision. These measurements will significantly advance our understanding of the Standard Model and guide the search for new physics.

**Secondary track**:

**T05** / **238**

## Determination of the strong coupling and its running from measurements of inclusive jet production at CMS

**Auteur:** CMS Collaboration[None]

The value of the strong coupling αS is determined in a comprehensive analysis at next-to-next-to-leading order accuracy in quantum chromodynamics. The analysis uses double-differential cross section measurements from the CMS Collaboration at the CERN LHC of inclusive jet production in proton-proton collisions at centre-of-mass energies of 2.76, 7, 8, and 13 TeV, combined with inclusive deep-inelastic data from HERA. The value αS(mZ) = 0.1176+0.0014−0.0016 is obtained at the scale of the Z boson mass. By using the measurements in different intervals of jet transverse momentum, the running of αS is probed for energies between 100 and 1600 GeV.

**Secondary track**:

**T08** / **239**

## Higgs boson couplings to hadrons, invisible, and rare decays at FCC-ee

**Auteur:** Markus Klute[1]

[1] *KIT*

The FCC-ee collider will deliver unparalleled sensitivity in Higgs boson decays, including couplings to quarks, gluons, and searches for invisible and rare decay modes. By employing advanced jet flavour tagging algorithms and exploiting a clean experimental environment, FCC-ee will measure the Higgs branching fractions to b, c, and gluon jets with sub-percent to few-percent accuracy. It will also provide stringent constraints on couplings to strange quarks and extremely rare or flavour-violating decays, improving current limits by one order of magnitude. Additionally, the FCC-ee will achieve exceptional sensitivity to invisible Higgs decays, with expected limits at the $10^{-4}$ level, thus probing possible dark matter candidates or new hidden sectors.

**Secondary track**:

**T08** / **240**

## Higgs precision at FCC-hh

**Auteur:** Markus Klute[1]

[1] *KIT*

The FCC-hh, operating at a centre-of-mass energy of 84 TeV, will produce unprecedentedly large samples of single and double Higgs bosons, enabling detailed studies of rare decays and precise measurements of the Higgs self-coupling. With billions of single-Higgs events, FCC-hh will measure rare decays such as H⟶μμ, H⟶γγ, and H⟶Zγ with percent-level precision. It will also significantly enhance sensitivity to invisible decays, reaching branching fractions as low as $10^{-4}$. It will also probe to top Yukawa interaction with unprecedented precision via the ttH production mechanism. Furthermore, with tens of millions of Higgs pairs events, the FCC-hh will precisely determine the Higgs self-coupling, crucial for understanding electroweak symmetry breaking and vacuum stability, with an expected precision at the few-percent level. These measurements will provide complementary information to FCC-ee and test the Higgs sector to unprecedented accuracy.

**Secondary track**:

**Joint T06+T08** / **241**

## Differential and STXS cross section measurements at CMS, combination and EFT interpretation

**Auteur:** CMS Collaboration[None]

We will discuss the latest differential measurements of Higgs boson cross sections with the CMS detector in both bosonic and fermionic decay channels. Both fiducial, differential cross section measurements and measurements in the simplified template cross section framework will be presented. Both the data collected during Run 2 of the LHC and the early data collected in Run3 by the CMS experiment are used. We also present a combination of Run2 cross section measurements and their interpretations as constraints on constraints of Wilson coefficients of beyond Standard Model operators in the framework of Effective Field Theories.

**Secondary track**:

**T06** / **242**

## Top quark physics at FCC-ee and FCC-hh

**Auteur:** Markus Klute[1]

[1] *KIT*

The Future Circular Collider (FCC) programme provides unique opportunities for comprehensive and precise studies of top quark physics. At the FCC-ee, operating at and slightly above the top pair threshold, a precise measurement of the top quark mass with a statistical and systematic accuracy down to the MeV level can be achieved through a threshold scan. Furthermore, the FCC-ee run at 365 GeV allows precise determinations of top quark electroweak couplings, particularly the ttZ vertex with sub-percent precision, and enables stringent constraints on flavor-changing neutral currents (FCNC), such as the Vts coupling. At the FCC-hh, the unprecedented center-of-mass energy of 84 TeV enables precise differential measurements of top quark production processes at very high momentum transfer, such as top quark pairs and rare four-top final states. These high Q2 measurements provide critical sensitivity to new physics effects at multi-TeV scales and will complement precision measurements from FCC-ee, thus offering a comprehensive exploration of the top quark sector.

**Secondary track**:

**T08** / **243**

## Higgs boson cross sections and coupling measurements at CMS - bosonic channels

**Auteurs:** CMS Collaboration[None]; CMS Collaboration[None]

In this talk, the latest results from the CMS experiment on inclusive, differential and simplified template cross section measurements of the Higgs boson are discussed. We cover the latest measurements for the bosonic decay channels in this presentation. Measurements of the Higgs boson couplings in the bosonic Higgs boson decay channels are also presented.

**Secondary track**:

**T08** / **245**

## Measurements of the Higgs boson mass and width at CMS

**Auteur:** CMS Collaboration[None]

An important aspect of the Higgs boson physics programme at the LHC is to determine all the properties of this particle, including its mass, which is a free parameter in the SM, and its width. This presentation will discuss the latest developments in measurements of the Higgs boson mass and width, with data collected by the CMS experiment at a centre of mass energy of 13 TeV. Both direct and indirect constraints on the Higgs boson width will be shown.

**Secondary track**:

**T13** / **246**

## Progress in the center-of-mass energy calibration at FCC-ee

**Auteur:** Markus Klute[1]

[1] *KIT*

The Future Circular Collider electron-positron (FCC-ee) is being designed to enable high energy physics experiments from the Z-pole up to above the top-pair-threshold, corresponding to center-of-mass energies from 91.2 to 365 GeV. This demands a precise knowledge of the center-of-mass energy and collision boosts at all interaction points. Center-of-mass energy measurements are envisaged being performed by resonant depolarization of transversely polarized pilot bunches in combination with a polarimeter. The center-of-mass energy itself depends on the beam energies, the crossing-angle, beamstrahlung, longitudinal impedance, the Earth tides, opposite sign dispersion and possible collision offsets. Thanks to the high collision rate, especially at the Z- and W-pair-energy, a statistical precision of 4 and 100 keV is predicted. Thus, it is aimed to reduce the systematic uncertainty to the same order of magnitude allowing performing particle physics experiments at an unprecedented precision. At the ZH- and top-pair-mode resonant depolarization is no longer possible and thus it is aimed at exploiting information obtained from various di-fermion events. Complementary, applying monochromatization schemes at a certain beam energy regime to reduce the collision energy spread are studied. These crucial challenges are being addressed within the FCC-ee energy calibration, polarization and monochromatization (EPOL) working group and its current status, research highlights and open questions are presented here.

**Secondary track**:

T13 - Accelerators for HEP

**T08** / **247**

## Higgs Anomalous couplings and CP properties at CMS

**Auteur:** CMS Collaboration[None]

To fully characterize the Higgs boson, it is important to establish whether it presents coupling properties that are not expected in the Standard Model of particle physics. These can probe BSM effects, such as CP conserving or CP violating couplings to particles with masses not directly accessible at the LHC through virtual quantum loops. In this talk we will present the most recent searches from the CMS experiment for anomalous Higgs boson interactions with vector bosons (HVV) or in effective interactions via the gluon-fusion production (ggH). Combination of the results from different channels will be presented, and interpreted as constraints on Wilson coefficients of BSM operators.

**Secondary track**:

**T11** / **248**

## The IDEA detector concept for FCC-ee

**Auteur:** Markus Klute[1]

[1] *KIT*

The electron-positron stage of the Future Circular Collider (FCC-ee) provides exciting opportunities that are enabled by next generation particle physics detectors. We present IDEA, a detector concept optimized for FCC-ee and composed of a vertex detector based on DMAPS, a very light drift chamber, a silicon wrapper, a high resolution dual redout crystal electromagnetic calorimeter, an HTS based superconducting solenoid, a dual readout fiber calorimeter, and three layers of muon chambers embedded in the magnet flux return yoke. In particular, we discuss the physics requirements and the technical solutions chosen to address them. We then describe the detector R&D currently in progress, test-beam results, and show the expected performance on some key physics benchmarks.

**Secondary track**:

**T08** / **249**

## Searches for rare Higgs boson processes with the CMS detector

**Auteur:** CMS Collaboration[None]

The full set of data collected by CMS experiment at a centre of mass energy of 13 TeV allows searches for rare production modes of the Higgs boson, subdominant with respect the ones already observed at the LHC, by using a variety of decay modes profiting of the ones with largest expected branching fractions. We also discuss rare Higgs boson decay channel searches with the CMS experiment. Searches of decays into quaronia final states can help constrain Yukawa couplings to light and charm quarks. While the expected rate is still limited with the collected data, these modes become enhanced in several BSM theories and can be used to constrain such models. Other rare Higgs boson decay channels, such as H->mumu or H->Zgamma, will also be discussed.

**Secondary track**:

**T08** / **251**

## Di-Higgs searches at CMS

**Auteur:** CMS Collaboration[None]

The measurement of the production of Higgs boson pairs (HH) at the LHC allows the exploration of the Higgs boson interaction with itself and is thus a fundamental test of the Standard Model theory and has a key role in the determination of the Higgs boson nature. The most recent results from the CMS collaboration on measurements of non-resonant HH production using different final states and their combination using the data set collected by the CMS experiment at a centre of mass energy of 13 TeV or 13.6 TeV will be presented. The combination of all available research channels give the possibility to constrain the self-coupling parameters that determine the shape of the Higgs boson potential. These results will be also presented, in the context of the SM and in extension of it.

**Secondary track**:

**T08** / **254**

## Constraints on Higgs to heavy flavour couplings (CMS)

**Auteur:** CMS Collaboration[None]

The discovery of the Higgs boson ten years ago and successful measurement of the Higgs boson couplings to third generation fermions by ATLAS and CMS mark great milestones for HEP. The much weaker coupling to the second generation quarks predicted by the SM makes the measurement of the Higgs-charm coupling much more challenging. With the full run-2 data and with the advent of ML flavour tagging techniques, a lot of progress has been made to constrain the couplings of the Higgs to c-quarks and b-quarks. In this talk, we present the latest results of direct and indirect Higgs to heavy flavour couplings by the CMS experiment. Prospects for future improvements are also given.

**Secondary track**:

**T05** / **255**

## High-precision QCD physics at FCC-ee

**Auteur:** Markus Klute[1]

[1] *KIT*

The electron-positron stage of the Future Circular Collider (FCC-ee) is aiming at direct and indirect searches for physics beyond the SM in a new 91-km tunnel at CERN. In addition, the FCC-ee offers unique possibilities for high-precision studies of the strong interaction in the clean environment provided by $e^+e^-$ collisions, thanks to its broad span of center-of-mass energies, ranging from the Z pole to the top-pair threshold, and its huge integrated luminosities yielding $O(5 \times 10^{12})$ and $O(2 \times 10^8)$ jets from Z and W bosons decays respectively, $O(2 \times 10^5)$ pure gluon jets from Higgs boson decays, as well as O(2\times10^6) top quarks. In this contribution, we will summarize the impact that the FCC-ee will have on our improved knowledge of the strong force including: (i) QCD coupling determinations with permil uncertainties, (ii) ultraprecise studies of parton radiation and jet properties (ligh-quark/heavy-quark/gluon discrimination, jet substructure, etc.); and (iii) accurate scrutiny of nonperturbative QCD phenomena (color reconnection, hadronization, final-state hadron interactions,…).

**Secondary track**:

**T11** / **256**

## Jet performance and tagging in Run3 at CMS

**Auteur:** CMS Collaboration[None]

Jets are collimated sprays of particles resulting from the hadronization of high-energy quarks and gluons. When heavy bosons (W, Z, or Higgs) decay hadronically, the resulting quarks can be reconstructed as separate thin-radius jets. At the same time, if the bosons are produced with high transverse momentum, they can be reconstructed as a single highly collimated large-radius jet. In both scenarios, to ensure accurate measurements of particle properties, CMS applies jet energy scale corrections, which account for detector effects and calibration biases. Additionally, regression techniques, based on machine learning, are used to improve the resolution of the jet energy measurement, by incorporating additional jet substructure information. Once jet energies are corrected, CMS uses several jet flavor tagging algorithms, exploiting sophisticated machine learning techniques, to identify the particle from which the jet originates and to distinguish hadronically decaying resonances from the large QCD multijet background. The accurate determination of jet properties plays a fundamental role in Standard Model measurements, as well as in searches for new physics phenomena. This talk presents an overview of recent developments in terms of jet energy scale and resolution, substructure techniques, and jet flavour tagging algorithms.

**Secondary track**:

**T09** / **257**

## BSM physics opportunities at the FCC-ee

**Auteur:** Markus Klute[1]

[1] *KIT*

The electron-positron stage of the Future Circular Collider (FCC-ee) is a precision frontier factory for Higgs, electroweak, flavour, top quark, and QCD physics. It is designed to operate in a 91-km circular tunnel built at CERN, and will serve as the first step towards O(100 TeV) proton-proton collisions. In addition to an essential Higgs program, the FCC-ee offers unique and powerful opportunities to answer fundamental open questions and explore unknown physics beyond the Standard Model. Direct searches for long-lived particles, and indirect probes of new physics sensitive to several tens of TeV scale, will be particularly fertile in the high-luminosity Z run, where $8 \times 10^{12}$ Z bosons are expected.

The large data samples of Higgs bosons, W bosons, and top quarks in very clean experimental conditions will offer additional opportunities for discoveries at other collision energies. Three concrete physics cases with promising signatures at FCC-ee will be discussed: heavy neutral leptons (HNLs), axion-like particles (ALPs), and exotic decays of the Higgs boson. These three well-motivated cases motivate out-of-the-box optimization of experimental conditions and analysis techniques that could lead to improvements in other searches for new physics.

**Secondary track**:

**T06** / **258**

## Measurements of top quark properties in CMS

**Auteur:** CMS Collaboration[None]

Precision measurements of top quark properties are of paramount importance for our understanding of the SM. We present several measurements of asymmetries in top quark production and of its spin correlations. These measurements allow us to test the fundamentals of quantum mechanics at the highest energies achieved so far and also serve as an excellent probe for physics beyond the Standard Model.

**Secondary track**:

**T06** / **259**

## Electroweak Precision Physics at the FCC-ee

**Auteur:** Markus Klute[1]

[1] *KIT*

The electron-positron stage of the Future Circular Collider (FCC) will provide measurements of the Z and W bosons couplings and masses 1–3 orders of magnitude better than the present state-of-the-art. With the run around the Z pole, where the integrated luminosity is expected to be about six orders of magnitude larger than at LEP, the Z boson mass and width, as well as the $Z \to b\bar{b}$ partial width, and the forward-backward asymmetries for leptons and quarks will be measured with ppm-scale precision. As a result, the effective weak mixing angle and the electromagnetic coupling at the Z pole can be extracted with $O(10^{-5})$ relative uncertainties. Similarly, the $2 \times 10^8$ W boson pairs expected close to the threshold, will deliver top-notch precision determinations of the W boson mass and width at the level of few hundred keV. This new level of experimental accuracy requires a proactive study of accelerator operation and detector design beyond anything that has so far been achieved at colliders. Such studies have begun and welcome new ideas and participants. Via electroweak loop corrections or mixing of new physics with the SM particles, the indirect discovery potential for new weakly interacting particles extends up to energy scales of around 50 TeV, or down to couplings of $10^{-11}$.

**Secondary track**:

**T07** / **261**

## Quark & Lepton flavour physics opportunities at FCC-ee

**Auteur:** Markus Klute[1]

[1] *KIT*

The Future Circular Collider (FCC) is a post-LHC project aiming at direct and indirect searches for physics beyond the SM in a new 91 km tunnel at CERN. The abundant production of beauty and charm hadrons in the $8 \times 10^{12}$ Z boson decays expected in e+e- collisions at FCC-ee offers outstanding opportunities in flavour physics with b and c hadron samples that exceed those available at Belle II by a factor of 20, and are complementary to the LHC heavy-flavour programme. A wide range of measurements will be possible in heavy-flavour spectroscopy, rare decays of heavy-flavoured particles and CP-violation studies, which will benefit from the low-background experimental environment, the high Lorentz boost, and the availability of the full spectrum of hadron species. The tau pairs production in the Tera-Z phase will be 3 times larger than at Belle II, and thanks to more favorable experimental conditions (better tau - hadrons separation, better tau hemispheres separation, higher momentum tracks) it will be possible to significantly improve the determinations of the tau-lepton properties − lifetime, leptonic and hadronic widths, and mass − allowing for important tests of lepton universality. Furthermore, it will be possible to extend the searches for Lepton-Flavour-Violating tau decays, and, via the measurement of the tau polarisation, FCC-ee can access a precise determination of the neutral-current couplings of electrons and taus. These measurements present strong experimental challenges to exploit as far as possible statistical uncertainties $O(10^{-5})$, raising strict detector requirements. This contribution will present an overview of the broad potential of the FCC-ee flavour physics program and also some preliminary results from recent analyses.

**Secondary track**:

**T07** / **262**

## Lepton flavour (universality) violation studies with heavy flavor at CMS

**Auteur:** CMS Collaboration[None]

Results are presented on LF(U)V tests through precise measurements of decays involving heavy mesons and leptons, which are compared to the standard model predictions. The measurements use pp collision data collected by the CMS experiment at the LHC.

**Secondary track**:

**T07** / **263**

## Recent Heavy Flavour Physics results by the CMS experiment

**Auteur:** CMS Collaboration[None]

In this talk we aim to summarize and give an overview of the status of heavy flavour related searches and measurements in CMS. The results will include analyses from rare decays, lepton flavour violation, and measurements of production cross sections.

**Secondary track**:

**T11** / **264**

## Design, performance and future prospects of vertex detectors at the FCC-ee

**Auteur:** Markus Klute[1]

[1] *KIT*

The Future Circular Collider electron-positron (FCC-ee) is designed as an electroweak, flavour, Higgs and top factory with unprecedented luminosities. Many measurements at the FCC-ee will rely on the precise determination of the vertices, measured by dedicated vertex detectors. All vertex detector designs use Monolithic Active Pixel Sensors (MAPS) with a single-hit resolution of ≈3 µm and a material budget as low as 0.3% $X/X0$ per detection layer, which is within specifications for most of the physics analyses. This contribution presents the status of the fully engineered vertex detectors, their integration with the collider beam pipe, and discusses their predicted performance using DD4hep full simulation. A concept for an ultra-light vertex detector using curved wafer-scale MAPS is also presented, which allows reducing the material budget to nearly one-fifth. This improves the vertexing capabilities, especially for heavy flavour decays, such as $B^0 \to K^{*0+-}$ .

**Secondary track**:

**T06** / **265**

## Top quark production at the ttbar threshold at CMS

**Auteur:** CMS Collaboration[None]

Near the top quark pair production threshold, non-relativistic QCD predicts an enhancement of ttbar production in pseudoscalar states. Color-singlet contributions are expected to produce a distinct resonance just below the tt threshold, offering a unique testable signature at the LHC. In this talk, we present the first observation of such a contribution in the dileptonic final state. In addition, we will discuss the first results in the lepton+jets channel, providing further evidence. These findings mark the beginning of a new chapter in top quark physics and open up a novel avenue for studying bound-state effects involving top quarks.

**Secondary track**:

**T06** / **266**

## Measurements top quark production associated with a W boson or a photon at CMS

**Auteur:** CMS Collaboration[None]

Precision measurements of top quark production cross sections are crucial for validating the Standard Model and investigating potential new physics. In this talk, we present both inclusive and differential measurements of top quark production in association with a photon or a W boson, using CMS data from 13 TeV pp collisions. Our results achieve improved precision, and we report, for the first time, measurements of several differential cross sections in these channels.

**Secondary track**:

**T06** / **267**

# Searches for new physics breaking the CP and flavor symmetries in the top quark sector at CMS

**Auteur:** CMS Collaboration[None]

The top quark plays an important role in a number of new physics models, some of which introduce violations to some of the accidental symmetries of the SM, such as the lepton number conservation or introduce additional sources of others already broken, such as the CP symmetry. A set of measurements is presented that probe violation of these symmetries in processes involving the top quark, in association with additional particles.

**Secondary track**:

**T06** / **268**

# Measurements of rare top production and their BSM interpretations with CMS

**Auteur:** CMS Collaboration[None]

The study of rare top quark production modes opens the gate to a number of new physics models that introduce large contributions to them. Among those, the production of four top quarks could be affected by the direct or indirect production of top-philic heavy resonances or be modified by anomalous Yukawa interactions between the top quark and the Higgs boson. A set of measurements is presented searching for new physics enhancing the production of four top quarks and the production of top quarks in association with additional leptons.

**Secondary track**:

T09 - Beyond the Standard Model

**T11** / **269**

# Upgrade plans of the CMS Muon System for High Luminosity LHC

**Auteur:** CMS Collaboration[None]

The CMS Muon System Upgrade is a significant part of the overall upgrade strategy for the Compact Muon Solenoid (CMS) experiment at the Large Hadron Collider (LHC), particularly for the High Luminosity LHC (HL-LHC) phase, which is expected to start around 2030. The HL-LHC will increase the LHC's luminosity by a factor of 5–7 beyond its original design, allowing it to collect more data and observe rarer processes but it also brings challenges like higher radiation levels and more pile-up events. The key goals of Muon system upgrade is to maintain high reconstruction efficiency, improve trigger capabilities, in addition expanding muon detector coverage into the forward region (high pseudorapidity) to improve physics reach. The muon system upgrades include enhancements to both the front-end and back-end electronics for the Drift Tubes (DT) and Cathode Strip Chambers (CSC), as well as back-end electronics for the Resistive Plate Chambers (RPC). Additionally, new detectors, such as improved Resistive Plate Chambers (iRPC) and Gas Electron Multipliers (GEM), are being introduced. This talk will provide an overview of the current progress, challenges, and test results, illustrating the readiness of the CMS Muon System for HL-LHC.

**Secondary track**:

**T11** / **270**

## An update on the CMS High Granularity Calorimeter

**Auteur:** CMS Collaboration[None]

Calorimetry in the upcoming High Luminosity LHC (HL-LHC) era has two enormous problems, particularly in the forward direction: radiation tolerance and unprecedented in-time event pileup. To overcome these problems, the CMS Collaboration is getting ready to replace its current endcap calorimeters with a high-granularity calorimeter (HGCAL), featuring a previously unrealized transverse and longitudinal segmentation, for both the electromagnetic and hadronic compartments, with 5D information (space-time-energy) read out. The current design uses silicon sensors for the electromagnetic section and high-irradiation regions of the hadronic section, while in the low-irradiation regions of the hadronic section plastic scintillator tiles equipped with on-tile silicon photomultipliers (SiPMs) are used. The full HGCAL will have approximately 6 million silicon sensor channels and over 200 thousand channels of scintillator tiles. This will facilitate particle-flow-type calorimetry, where the fine structure of showers can be measured and used to enhance particle identification, energy resolution and pileup rejection. In this talk we present the ideas behind the HGCAL, the current status of the project, the evolution of the detector systems with what is learned from the beam tests as well as the design and operation of test systems and the challenges that lie ahead.

**Secondary track**:

**T09** / **271**

## The MoEDAL-MAPP Facility at the LHC –Status Report

**Auteur:** James Pinfold[1]

[1] *University of Alberta*

**Auteur correspondant** jpinfold@ualberta.ca

Phase-0 of the MoEDAL-MAPP Facility began with installing the MoEDAL detector at IP8 on the LHC ring in 2010. In 2021, as part of Phase-1, CERN approved MoEDAL's reinstallation for Run-3 with key upgrades: a tenfold lower detection threshold, a fivefold luminosity increase, and a center-of-mass energy boost from 13 TeV to 13.6 TeV. MoEDAL will continue searching for highly ionizing particles (HIPs) predicted by beyond the Standard Model (BSM) theories such as, enhanced SM models, supersymmetry, neutrino mass models, and left-right symmetry. Also, in Phase-1, the MoEDAL Apparatus for Penetrating Particles (MAPP-1) was installed in the UA83 tunnel, 100 meters from IP8, and will begin data collection in 2025. MAPP-1 can detect feebly ionizing particles with charge or effective charge as low as 0.001e. The MAPP-1 Outrigger, designed to enhance MAPP-2's sensitivity to fractionally charged particles such as millicharged particles(> 0.01e), is awaiting approval and is expected to take data in 2026. MAPP-1 and the Outrigger also have some sensitivity to neutral long-lived particles (LLPs). In Phase-2, the MAPP-2 upgrade is planned for the HL-LHC and will be installed in the UGC1 gallery near IP8, radically improving MoEDAL-MAPP's ability to detect neutral LLPs decaying into charged particles and photons

**Secondary track**:

T02 - Dark Matter

**T09** / **273**

## Searches for Supersymmetry with compressed scenarios

**Auteur:** CMS Collaboration[None]

Results from the CMS experiment are presented for supersymmetry searches targeting so-called compressed spectra, with small mass splittings between the different supersymmetric partners. Such a spectrum presents unique experimental challenges. This talk describes the new techniques utilized by CMS to address such difficult scenarios and presents results based on these techniques.

**Secondary track**:

**T09** / **274**

## Recent searches for SUSY particles with CMS with MET

**Auteur:** CMS Collaboration[None]

A wide variety of searches for Supersymmetry have been performed by experiments at the Large Hadron Collider. In this talk, we focus on searches for Supersymmetric particles in events with missing energy signatures.

**Secondary track**:

**Joint T02+T09** / **275**

## Searches for dark matter with CMS in mono-X signatures

**Auteur:** CMS Collaboration[None]

Determination of the nature of dark matter is one of the most fundamental problems of particle physics and cosmology. This talk presents recent searches for dark matter particles from the CMS experiment at the Large Hadron Collider in mono-X signatures.

**Secondary track**:

T09 - Beyond the Standard Model

**T11** / **278**

## CMS RPC System status and performance in Run3

**Auteur:** CMS Collaboration[None]

The Compact Muon Solenoid (CMS) Experiment is a multi-purpose detector, located at the Large Hadron Collider (LHC) in CERN. It is equipped with several sub-detector systems to reconstruct high-energy collision particles. Resistive Plate Chambers (RPC), known for their fast response and good timing resolution, are used as one of the sub-detectors for muon detection within the CMS Muon System. RPCs detect ionizing particles through gas avalanches between resistive plates, producing signals on readout strips. During 2024, the CMS Experiment recorded over 112 $fb^{-1}$ of proton-proton collision data, bringing the total for Run 3 (2022–present) to more than 180 $fb^{-1}$. To secure good data quality throughout this period, the performance and stability of the RPC System are continuously monitored, and the latest results will be presented.

**Secondary track**:

**T11** / **279**

# Highlights on Searches for Environmentally Friendly Gases in the CMS RPC System

**Auteur:** CMS Collaboration[None]

The Resistive Plate Chambers (RPC) of the CMS experiment operate with a gas mixture composed of 95.2% $C_2H_2F_4$, a greenhouse gas with high Global-Warming Potential (GWP). In recent years, several eco-friendly alternatives, such as hydrofluoroolefins (HFOs), have been investigated to identify sustainable replacements that preserve the detector performance. Another promising approach is to partially substitute $C_2H_2F_4$ with $CO_2$, potentially reducing the GWP of the mixture by 30–40%. These studies are being carried out at the CERN Gamma Irradiation Facility (GIF++), which replicates the conditions expected during the High-Luminosity Phase-2 data taking at the Large Hadron Collider (HL-LHC), using an 11.5 TBq gamma source and a muon beam. This contribution presents updated results on the performance of two 1.4 mm gap RPC chambers operating with various eco-gas and $CO_2$-based mixtures under high-rate gamma irradiation. In addition, it highlights the latest results in aging studies, providing a deeper insight into the long-term behavior and stability of these alternative gas mixtures for the future of the RPC.

**Secondary track**:

**T09** / **280**

# Searches for additional Higgs bosons (high & low mass) at CMS

**Auteur:** CMS Collaboration[None]

We present searches from the CMS experiment, performed with data collected during LHC Run 2 at a centre-of-mass energy of 13 TeV, for additional Higgs bosons. A variety of states are searched for, at masses both above and below 125 GeV.

**Secondary track**:

T08 - Higgs Physics

**T12** / **281**

# Run Dependent Monte Carlo at Belle II

**Auteur:** Belle II collaboration[None]

The Belle II experiment at the SuperKEKB accelerator in Tsukuba, Japan, searches for physics beyond the Standard Model, with a focus on precise measurements of flavor physics observables. Highly accurate Monte Carlo simulations are essential for this endeavor, as they must correctly model the variations in detector conditions and beam backgrounds that occur during data collection. To meet this requirement, the "run-dependent" Monte Carlo has been developed. This approach incorporates time-dependent detector conditions and beam-induced backgrounds collected via random triggers, allowing for different conditions with a granularity of just a few hours. In this talk, we will discuss the procedures and challenges associated with producing run-dependent Monte Carlo simulations for Belle II. We will also highlight the improvements these simulations offer over traditional "run-independent" Monte Carlo methods.

**Secondary track**:

**T11** / **282**

## New timing Multi-Strip Multi-Gap Resistive Plate Chamber architecture with aging suppression for high counting rate experiments

**Auteur:** Mariana Petris[1]

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A long time operation of Multi-Gap Resistive Plate Chambers with gas mixtures based on $C_2H_2F_4$ and $SF_6$ leads to aging effects reflected in an increase of the dark current and dark counting rate, with impact on the chamber performance. Moreover, the higher noise rate leads to an artificial increase of the data volume in a free-streaming data acquisition operation used in high counting rate experiments. For the mitigation of the gas pollution effects observed in high counting rate Multi-Strip Multi-Gap Resistive Plate Chambers (MSMGRPCs) exposed to high irradiation doses, a new MSMGRPC architecture based on discrete spacers and direct flow of the gas mixture through the gas gaps was designed and assembled. The aging investigations of the chambers with the new design demonstrated negligible aging effects even for rather low gas flow rate. Prototypes with such a direct flow architecture were tested in real operation conditions, in an in-beam test performed at the SIS18 accelerator of GSI Darmstadt with reaction products. The obtained results demonstrate the performance of the prototypes in terms of efficiency (>95%) and time resolution (~55 ps). Therefore, such direct flow MSMGRPCs will be implemented in the modular configuration of the low polar angle region of the TOF wall (inner wall) of the CBM experiment at the FAIR facility in Darmstadt, where a challenging counting rate up to 30 kHz/cm$^2$ is anticipated. The modular architecture of the CBM-TOF inner wall encompasses 12 modules staggered in space such to assure an uniform detection area. Details about the implementation of the direct flow MSMGRPCs of different granularities in the first module of CBM-TOF inner wall, the most complex one whose assembling is in progress, are included.

**Secondary track**:

**T02** / **284**

## The CYGNO experiment, a Gaseous TPC for directional Dark Matter searches

**Auteurs:** CYGNO Collaboration[None]; Davide Fiorina[1]

[1] *GSSI and INFN*

The CYGNO/INITIUM project introduces an innovative approach to directional Dark Matter detection using a gaseous Time Projection Chamber (TPC). Targeting low mass (0.5-50 GeV) WIMPs-like Dark Matter, the experiment uses a He/CF4 gas mixture sensitive to both spin-dependent and spin-independent interactions at atmospheric pressure with optical readout. Building on the success of our 50 L prototype, LIME, we aim to deploy a 0.4 m³ demonstrator, CYGNO04, at Laboratori Nazionali del Gran Sasso (LNGS) between 20245 and 2026 to validate the technology's performance and scalability.
In CYGNO detectors, particle interactions ionize the gas, creating electrons that drift to the amplification stage, consisting of three Gas Electron Multipliers (GEMs). The readout system combines a scientific CMOS (sCMOS) camera and Photomultiplier Tubes (PMTs) to detect light produced during electron avalanches. This light is captured in a two-dimensional (X-Y) projection by the sCMOS camera and a time profile (dZ) by the PMTs, enabling 3D reconstruction of ionizing events. High granularity and rapid response allow detailed energy deposition mapping, supporting topology, directional, and head-to-tail recognition.
Results from LIME, which conducted data taking at the underground LNGS labs, show significant advancements in particle identification and 3D tracking capabilities.

Recent progress on the CYGNO-04 status will be presented, highlighting its role in the project's future. The CYGNO/INITIUM project will contribute substantially to Dark Matter detection, and the possibility that this same detector could perform neutrino measurements sets the stage for future large-scale experiments.

**Secondary track**:

T11 - Detectors

**T11** / **285**

## The upgrade of the CMS Tracker for the High-Luminosity LHC

**Auteur:** CMS Collaboration[None]

In order to fulfill the requirements of the high luminosity and hard radiation in HL-LHC, CMS is upgrading most of the sub detectors. In this talk, the current status of the phase-2 upgrade of CMS Inner and Outer Tracker detectors will be presented.

**Secondary track**:

**T16** / **286**

## Machine-learning based particle-flow algorithm in CMS

**Auteur:** CMS Collaboration[None]

The particle-flow (PF) algorithm aims to provide a global event description for each collision in terms of the comprehensive list of final-state particles. It is of central importance to event reconstruction in the CMS experiment at the CERN LHC, and has been a focus of developments in light of planned high-luminosity running conditions with increased pileup and detector granularity. Existing implementations rely on extrapolating tracks to the calorimeters, correlating them with calorimeter clusters, subtracting charged particle energy, and inferring neutral particles from significant energy deposits. The high-luminosity LHC upgrade entails new challenges, including extending the algorithm to new detectors, maintaining computational efficiency under high detector occupancy, and porting to heterogeneous computing architectures to improve throughput. Recently, end-to-end machine learning approaches for event reconstruction have been proposed that directly optimize for the physical quantities of interest, are reconfigurable to new conditions, and can be deployed in heterogeneous accelerators. One such approach, the machine-learned particle-flow (MLPF) algorithm, consists of training a transformer model to infer the full particle content of an event from the reconstructed tracks and calorimeter clusters in a single pass. We discuss progress in CMS towards an improved implementation of the MLPF reconstruction, describing the dataset generation, the ML approach, the metrics used to assess event reconstruction quality and the integration with offline reconstruction software. We find that the ML-based approach converges to results consistent with the existing PF algorithm. We benchmark the throughput of the ML-based algorithm on GPU architectures in the full reconstruction software (aka CMSSW) and report on the possible throughput under Run3 conditions.

**Secondary track**:

T11 - Detectors

**Joint T06+T08 / 287**

## Measurements of photon-induced processes with the CMS detector

**Auteur:** CMS Collaboration[None]

Measurements of photon-induced processes are presented, using data collected in Run-2.

**Secondary track**:

T06 - Top and Electroweak Physics

**T16 / 288**

## Classifying hadronic objects in ATLAS with ML/AI algorithms

**Auteur:** ATLAS Collaboration[None]

Hadronic object reconstruction & classification is one of the most promising settings for cutting-edge machine learning and artificial intelligence algorithms at the LHC. In this contribution, highlights of ML/AI applications by ATLAS to QCD and boosted-object identification, MET reconstruction and other tasks will be presented.

**Secondary track**:

**T08 / 289**

## Non-resonant Higgs boson pair production and self-coupling determination with the ATLAS experiment

**Auteur:** ATLAS Collaboration[None]

Higgs boson pair production (HH) plays a central role in probing the Higgs boson self-interactions, which are key to understanding the shape of the Higgs potential and the mechanism of electroweak symmetry breaking. This talk presents the latest results from the ATLAS experiment on non-resonant Higgs boson pair production, based on the full Run 2 dataset collected at\sqrt{s} = 13 TeV, with the inclusion of available Run 3 results where relevant. These analyses provide sensitivity to the Higgs boson self-coupling and the quartic VVHH coupling, offering key tests of the Higgs sector beyond single-Higgs measurements. Constraints are also derived from higher-order electroweak corrections to single Higgs boson production, and a combination of single and di-Higgs results is used to obtain the most precise determination of the self-coupling to date. The talk further includes projections for future sensitivity at the High-Luminosity LHC, outlining the expected improvements and challenges ahead.

**Secondary track**:

**T05 / 290**

## A Precise Determination of the strong coupling from the Heavy Jet Mass Distribution

**Auteur:** VICENT MATEU BARREDA[1]

**Co-auteurs:** Andre Hoang [2]; Arindam Bhattacharya [3]; Iain Stewart [4]; Matthew Schwartz [3]; Miguel Benitez-Rathgeb [1]; Xiaoyuan Zhang [3]

[1] *University of Salamanca*

[2] *University of Vienna, Faculty for Physics*

[3] *Harvard*

[4] *MIT*

Our work resolves a long-standing problem in particle physics: the inability for theory to agree with the spectrum of heavy-jet mass data, particularly at the Z-pole, leading to unreliable strong-coupling fits and exclusion of this high-quality experimental data. Our key theoretical improvements include high-precision large-log resummation in both the dijet and shoulder regions, a rigorous treatment of dijet non-perturbative corrections, and introducing a second non-perturbative parameter in the far tail. A crucial ingredient that leads to stable global fits is including —for the first time in this context—a theory covariance matrix for perturbative uncertainties.

**Secondary track**:

T06 - Top and Electroweak Physics

**T16** / **291**

## Expected Tracking Performance of the ATLAS ITk GNN Track Reconstruction Chain

**Auteur:** ATLAS Collaboration[None]

The HL-LHC upgrade of the ATLAS inner detector (ITk) brings an unprecedented challenge, both in terms of the large number of silicon hit cluster readouts and the throughput required for budget-constrained track reconstruction. Applying Graph Neural Networks (GNNs) has been shown to be a promising solution to this problem with competitive physics performance at sub-second inference time. In this contribution, the expected physics and computational performance of the GNN4ITk [1,2] track reconstruction chain will be presented, with emphasis on the latest available developments improving graph construction, edge scoring and graph segmentation. 1 Torres, H., Burleson, J., Caillou, S., Calafiura, P., Chan, J., Collard, C., Ju, X., Murnane, D., Neubauer, M., Pham, T., Rougier, C., Stark, J., & Vallier, A. (2024, March 7). Physics Performance of the ATLAS GNN4ITk Track Reconstruction Chain. Connecting The Dots Workshop 2023 (CTD2023), Toulouse (France). https://doi.org/10.5281/zenodo.15178159 2 ATLAS Collaboration, Computational Performance of the ATLAS ITk GNN Track Reconstruction Pipeline, 2024, ATL-PHYS-PUB-2024-018, https://cds.cern.ch/record/2914282

**Secondary track**:

**Poster T05** / **292**

## Measurement of electromagnetic transition form factors in two-photon collisions at BESIII

**Auteur:** BESIII Collaboration[None]

Electromagnetic transition form factors of light mesons are important inputs to the calculations of the hadronic light-by-light scattering contribution to the Standard Model prediction of the anomalous magnetic moment of the muon. However, data in the relevant regions of momentum transfer are scarce. The BESIII experiment at the $e^+e^-$ collider BEPCII has collected the world's largest data sets in the $\tau$-charm energy region, including, but not limited to more than $20\,\mathrm{fb}^{-1}$ of data at a center-of-mass energy of 3.773 GeV/$c^2$. The data are analyzed for two-photon collisions in events of the type $e^+e^- \to e^+e^-P$, with $P = \pi^0, \eta^{(\prime)}, f_1(1285), \pi^0\pi^0$, and $\pi^+\pi^-$. The aim is to study the momentum dependence of the respective space-like electromagnetic transition form factors. In this presentation we discuss recent results and prospects of ongoing analyses.

**Secondary track**:

**Poster T05 / 293**

## Measurement of the relative phase between strong and EM decays at BESIII

**Auteur:** BESIII Collaboration[None]

The strong and electromagnetic interactions are two main decay mechanisms in charmonium decays.
The relative phase between them is a basic parameter in understanding the decay dynamics, especially for the precise measurements. In this talk, we present the direct measurement with resonance scan method. By introducing the EM amplitude from continuum decay, the interference between EM and strong mechanism is measured in $J/\psi$ decays to several final states.

**Secondary track**:

**T09 / 294**

## The equivalent Electric Dipole Moment in SMEFT

**Auteurs:** Marco Ardu[1]; Nicola Valori[1]

[1] *IFIC (University of Valencia - CSIC)*

**Auteur correspondant** nicola.valori@uv.es

The Electric Dipole Moment of the electron (eEDM) is typically investigated in experiments using paramagnetic molecules. However, the physical observable in these searches consists of a linear combination of CP-violating interactions, rather than the eEDM alone, which is commonly referred to as the equivalent EDM of the system. Assuming the presence of new CP-odd physics from heavy degrees of freedom, I parametrize its effects within the Standard Model Effective Field Theory (SMEFT) framework. In this talk, I will present the contributions to the full low-energy direction probed by EDM searches, focusing on leading-order effects at dimension six and one-loop level, while also discussing selected two-loop and dimension-eight contributions. I will highlight that eEDM experiments are sensitive to a broader class of SMEFT operators than previously recognized.

**Secondary track**:

T07 - Flavour Physics and CP Violation

**T05** / **295**

## Precision measurement of the branching fraction for the decay $\psi(2S) \to \tau^+\tau^-$ at BESIII

**Auteur:** BESIII Collaboration[None]

Using $(2259.3 \pm 11.1) \times 10^6$ $\psi(2S)$ events acquired with the BESIII detector, the branching fraction of $\psi(2S) \to \tau^+\tau^-$ is measured with improved precision to be $\mathcal{B}_{\psi(2S)\to\tau^+\tau^-} = (3.240 \pm 0.023 \pm 0.081) \times 10^{-3}$, where the first and second uncertainties are statistical and systematic, respectively, which is consistent with the world average value within one standard deviation. This value, along with those for the branching fractions of the $\psi(2S)$ decaying into $e^+e^-$ and $\mu^+\mu^-$, is in good agreement with the relation predicted by the sequential lepton hypothesis. Combining the branching fraction values with the leptonic width of the $\psi(2S)$, the total width of the $\psi(2S)$ is determined to be (287 $\pm$ 9) keV.

**Secondary track**:

T06 - Top and Electroweak Physics

**T02** / **296**

## New Directions in Inelastic Dark Matter

**Auteurs:** Felix Kahlhoefer[1]; Giovani Dalla Valle Garcia[2]; Maksym Ovchnynikov[3]; Thomas Schwetz-Mangold[1]

[1] *Karlsruhe Institute of Technology*

[2] *IAP - KIT*

[3] *CERN*

**Auteur correspondant** giovani.garcia@student.kit.edu

Models of inelastic (or pseudo-Dirac) dark matter commonly assume an accidental symmetry between the left-handed and right-handed mass terms in order to suppress diagonal couplings. Moreover, they often introduce a gauge symmetry spontaneously broken by the introduction of a dark sector version of the Higgs mechanism. Removing the requirement of such an accidental ad-hoc symmetry instead relaxes the relic density constraint and provides a smooth transition between pseudo-Dirac and Majorana dark matter. It also allows for a minimal definition of inelastic dark matter models in which only a real scalar field is required along the pseudo-Dirac particle.

In the talk, I will introduce a simple UV-complete framework realizing the new asymmetric set-up. I discuss the viable regions of parameter space still solving the dark matter problem and comment on how they could be probed with future experiments.

**Secondary track**:

T09 - Beyond the Standard Model

**T11** / **297**

## Precision Luminosity Measurements in CMS with Run 2 and Run 3 Data

**Auteur:** CMS Collaboration[None]

Luminosity determination is a cornerstone of precision physics at the CMS experiment. In this talk, we present the latest luminosity measurements from CMS, covering both proton-proton and heavy ion collisions recorded during Run 2 and Run 3. Emphasis is placed on recent advances in reducing systematic uncertainties associated with the absolute luminosity scale from van der Meer scans, as well as methods to correct for instrumental effects impacting luminometer stability and linearity. We also highlight the use of dimuon yields as a standard candle to cross-check and validate luminosity estimates across data sets. These developments are key to improving the precision of cross section measurements and enhancing the overall sensitivity of the CMS physics program.

**Secondary track**:

**T12** / **298**

## Advancing the CMS Level-1 Trigger: Jet Tagging with DeepSets at the HL-LHC

**Auteur:** CMS Collaboration[None]

At the Phase-2 Upgrade of the CMS Level-1 Trigger (L1T), particles will be reconstructed by linking charged particle tracks with clusters in the calorimeters and muon tracks from the muon station. The 200 pileup interactions will be mitigated using primary vertex reconstruction for charged particles and a weighting for neutral particles based on the distribution of energy in a small area. Jets will be reconstructed from these pileup-subtracted particles using a fast cone algorithm. For the first time at the CMS L1T, the particle constituents of jets will be available for jet tagging. In this work we present a new multi-class jet tagging neural network (NN). Targeting the L1T, the NN is a small DeepSets architecture, and trained with Quantization Aware Training. The model predicts the classes: light jet (uds), gluon, b, c, tau_h+, tau_h-, electron, muon. The model additionally predicts the pT of the object. The new model enhances the selection power of the L1T for important processes for CMS at the High Luminosity LHC such as di-Higgs and Higgs production via Vector Boson Fusion. We present the model including its performance at object tagging and deployment into the L1T FPGA processors, and showcase the improved trigger capabilities enabled by the new tagger.

**Secondary track**:

**T12** / **299**

## The CMS W Mass Analysis as a Blueprint for Efficient HL-LHC Data Handling

**Auteur:** CMS Collaboration[None]

The unprecedented volume of data and Monte Carlo simulations at the HL-LHC poses increasing challenges for particle physics analyses, demanding computation-efficient analysis workflows and reduced time to insight. The recent W mass measurement by CMS exemplifies these challenges and demonstrates the application of cutting-edge techniques essential for future analyses. We present a comprehensive analysis framework that leverages RDataFrame, Eigen, Boost Histograms, and the Python scientific ecosystem, with particular emphasis on the interoperability between ROOT and Python tools and output formats (ROOT and HDF5). Our implementation spans from initial event processing to final statistical interpretation, featuring optimizations in C++ and RDataFrame that achieve favorable performance scaling for billions of events. The framework incorporates interfaces to TensorFlow for fast and accurate complex multi-dimensional binned maximum likelihood calculations and robust minimization. We will discuss the validation and reproducibility of the complete analysis pipeline, ensuring reliable results from event processing through statistical interpretation —critical components for precision measurements in the HL-LHC era.

**Secondary track**:

**T07 / 300**

# The hadronic decays of charmed mesons at BESIII

**Auteur:** BESIII Collaboration[None]

BESIII has collected 20.3 and 7.33 $fb^{-1}$ of $e^+e^-$ collision data samples at 3.773 and 4.128-4.226 GeV, which provide the largest dataset of $D\bar{D}$ and $D_sD_s$ pairs in the world, respectively.
We will present the measurement of branching fractions of fifteen $D_s^+$ hadronic decays using a global fit and highlight our recent advancements in amplitude analyses of $D^+ \to K_s\pi^+\eta$, $D \to \pi\pi\eta$, $D^+ \to K_sK_s\pi^+$, $D^+ \to K^-\pi^+\pi^+\pi^0$, $D_s^+ \to \pi^+\pi^+\pi^-\pi^0$, and $D_s^+ \to \pi^+\pi^+\pi^-\pi^0\pi^0$.
In these amplitude analyses, we observe the $D^+ \to K_sa_0(980)^+$, $D \to a_0(980)\pi$, and $D_s^+ \to \omega\rho^+$ decays, along with deviations in the branching fractions of $\phi$ decays from the PDG average.

**Secondary track**:

**T05 / 302**

# Study of scalar, vector, and axial-vector mesons in the semileptonic D decays at BESIII

**Auteurs:** BESIII Collaboration[None]; BESIII Collaboration[None]

BESIII has collected 20.3 and 7.33 $fb^{-1}$ of $e^+e^-$ collision data samples at 3.773 and 4.128-4.226 GeV, respectively. This provides a unique opportunity to investigate the non-perturbative nature of QCD in the charm sector.
In this presentation, we will discuss the recent progresses in amplitude analyses and branching fraction measurements of $D_{(s)} \to hhl^+\nu$ and $hhhl^+\nu$ processes. On the hadron spectrum, scalar ($a_0$, $f^0$, $\sigma$), vector ($K^*$, $\phi$), axial vector ($K_1$, $b_1$) particles are studied. The measurements of $D \to a^0(980)$, $D \to \sigma$, D -> K*, $D_s \to f^0(980)$, and $D_s \to \phi$ form factors will be presented.

**Secondary track**:

T07 - Flavour Physics and CP Violation

**T07 / 304**

# Quantum-correlation of neutral charmed mesons at BESIII

**Auteur:** BESIII Collaboration[None]

BESIII has recently accumulated a large data sample at the $\psi(3770)$ energy point corresponding to an integrated luminosity of 20 $fb^{-1}$. The neutral $D\bar{D}$ pairs produced at $\psi(3770)$ are in a C-odd correlated state, providing a unique laboratory to measure the strong-phase differences between $D^0$ and $\bar{D}^0$ decays. These parameters are essential inputs to CP violation studies in heavy flavour physics, especially the determination of the CKM angle gamma and charm mixing parameters, and the search for indirect CP violation in the charm sector. In this presentation, we will report the recent progress of new and improved measurements of the strong-phase differences in different neutral D decays at BESIII with the increased data set, along with the CP-even fraction of $D^0 \to \pi^+\pi^-\pi^0$,

$K^+K^-\pi^0$, $K^+K^-\pi^+\pi^-$, and $\pi^+\pi^+\pi^-\pi^-$. We will also discuss the uncertainties contributed by the strong-phase inputs to CKM angle $\gamma$ determination.

**Secondary track**:

T05 - QCD and Hadronic Physics

**T09** / **306**

## Model-independent searches and anomaly detection at the CMS experiment

**Auteur:** CMS Collaboration[None]

In the absence of direct evidence for new physics in targeted searches, model-independent strategies are becoming increasingly important. In this talk, we present recent results of model-agnostic searches that are facilitated by advanced machine learning techniques, opening a new avenue for unbiased detection of potential new physics signals.

**Secondary track**:

**T09** / **307**

## Searches for new physics in CMS in events with photons and leptons in the final state

**Auteur:** CMS Collaboration[None]

Many new physics models such as compositeness, extra dimensions, extended Higgs sectors, supersymmetry, and dark sectors are expected to manifest themselves in the final states with photons and/or leptons. This talk presents searches in CMS for new phenomena in such final states, focusing on the recent results obtained using the full Run-II and Run-III data-set collected by the CMS Experiment at the LHC.

**Secondary track**:

**T07** / **310**

## Measurements of lepton-flavour universality in semileptonic $B$ decay at Belle II

**Auteur:** Steven Robertson[1]

[1] *IPP / UofA*

The first run of the Belle II experiment collected a 365 fb$^{-1}$ sample of $e^+e^- \to B\bar{B}$ collisions at a centre-of-mass energy corresponding to the $\Upsilon(4S)$ resonance. These data, with low particle multiplicity, constrained initial state kinematics and excellent lepton identification, are an ideal environment to study lepton-flavour universality in semileptonic decays of the $B$ meson. We present results on the ratios of semitauonic decay rates compared to those to light leptons in both exclusive and

inclusive $B$ decay. These include new measurements of the ratios for exclusive $B \to D^{(*)}\ell\nu$ decays $R(D^{(*)})$ in events tagged by a semileptonic $B$ decay.

**Secondary track**:

T09 - Beyond the Standard Model

**T07 / 311**

# Measurements of electroweak penguin and lepton-flavour violating $B$ decays to final states with missing energy at Belle and Belle II

**Auteur:** Steven Robertson[1]

[1] *IPP / UofA*

The Belle and Belle II experiments have collected a 1.2 ab$^{-1}$ sample of $e^+e^- \to B\bar{B}$ collisions at a centre-of-mass energy corresponding to the $\Upsilon(4S)$ resonance. These data, with low particle multiplicity and constrained initial state kinematics, are an ideal environment to search for rare electroweak penguin $B$ decays and lepton-flavour-violating $B$ decays to final states with missing energy from neutrinos. Results from $b \to s\nu\bar{\nu}$ processes and their interpretation are presented. In addition, we present searches for the processes $B \to K^{(*)}\tau^+\tau^-$. Finally, we present our search for the lepton-flavour violating decay $B^0 \to K^{*0}\tau^\pm\ell^\mp$, where $\ell$ is an electron or muon.

**Secondary track**:

T09 - Beyond the Standard Model

**T07 / 312**

# Measurements of time-dependent $CP$ violation in $B$ decay at Belle and Belle II

**Auteur:** Steven Robertson[1]

[1] *IPP / UofA*

The Belle and Belle II experiment have collected a 1.2 ab$^{-1}$ sample of $e^+e^- \to B\bar{B}$ decays at a centre-of-mass energy corresponding to the $\Upsilon(4S)$ resonance. The SuperKEKB collider is asymmetric, providing a boost to the $B$ mesons in the laboratory frame, so we can perform measurements of time-dependent $CP$ violation. Among the new results, we measure $CP$-violating parameters related to the determination of the least well-known angle of the unitarity triangle $\alpha$ using the decay $B^0 \to \rho^+\rho^-$. In addition, we present a measurement of $B^0 \to K^0_S\pi^+\pi^-\gamma$, which is sensitive to beyond-the-standard-model physics.

**Secondary track**:

**T07 / 313**

## Measurements of hadronic $B$ decay rates at Belle and Belle II

**Auteur:** Steven Robertson[1]

[1] *IPP / UofA*

The Belle and Belle II experiments have collected a 1.2 ab$^{-1}$ sample of $e^+e^- \to B\bar{B}$ collisions at a centre-of-mass energy corresponding to the $\Upsilon(4S)$. The study of hadronic $B$ decays in these data allow the precise measurement of absolute branching fractions and angular distributions of the decay products. These measurements provide tests of QCD and allow the generation of more realistic simulation samples. We present measurements of the decays $\bar{B}^0 \to D^+\pi^-\pi^0$ and $B$ decays to baryons. In addition, we search for the decays $B \to D^{(*)}\eta\pi$, which can be related to poorly known $B \to X_c\ell\nu$ decays that include an $\eta$ meson in the final state.

**Secondary track**:

**T07 / 314**

## Mixing and $CP$-violation measurements with $D$ mesons at Belle and Belle II

**Auteur:** Steven Robertson[1]

[1] *IPP / UofA*

The Belle and Belle II experiments have collected a 1.6 ab$^{-1}$ sample of $e^+e^-$ collision data at centre-of-mass energies near the $\Upsilon(nS)$ resonances. These samples contain a large number of $e^+e^- \to c\bar{c}$ events that produce charmed mesons. We present measurements of charm-mixing parameters from flavour-tagged $D^0 \to K^0_S\pi^+\pi^-$ decays. Direct $CP$ violation is searched for in $D^0 \to K^0_S K^0_S$ decays and $D$ meson decays to two or three pions.

**Secondary track**:

**T07 / 315**

## Rare and baryonic decays of charmed hadrons at Belle and Belle II

**Auteur:** Steven Robertson[1]

[1] *IPP / UofA*

The Belle and Belle II experiments have collected a $1.6\mathrm{ab}^{-1}$ sample of $e^+e^-$ collision data at centre-of-mass energies near the $\Upsilon(nS)$ resonances. These samples contain a large number of $e^+e^- \to c\bar{c}$ events that produce charmed mesons and baryons. We present searches for rare flavour-changing neutral current processes and measure several radiative decays of the $D_{(s)}$ meson. Further, we study several decays of the $\Xi_c$ baryon to determine branching fractions, $CP$ asymmetries and decay asymmetries.

**Secondary track**:

T05 - QCD and Hadronic Physics

**T07 / 316**

## Searches for lepton-flavour violation in $\tau$ decays at Belle and Belle II

**Auteur:** Steven Robertson[1]

[1] *IPP / UofA*

The Belle and Belle II experiments have collected a 1.6 $\mathrm{ab}^{-1}$ sample of $e^+e^-$ collision data at centre-of-mass energies near the $\Upsilon(nS)$ resonances. This sample contains approximately 1.5 billion $e^+e^- \to \tau^+\tau^-$ events, which we use to search for lepton-flavour violating decays. We present searches for $\tau \to \ell\gamma$, tau decay to three charged leptons, $\tau^- \to K^0_{\mathrm{S}}\ell^-$, $\tau^- \to \ell^-\alpha$, where $\alpha$ is an invisible scalar particle.

**Secondary track**:

T09 - Beyond the Standard Model

**Joint T02+T09 / 317**

## Searches for dark sector particles at Belle and Belle II

**Auteur:** Steven Robertson[1]

[1] *IPP / UofA*

The Belle and Belle II experiment have collected samples of $e^+e^-$ collision data at centre-of-mass energies near the $\Upsilon(nS)$ resonances. These data have constrained kinematics and low multiplicity, which allow searches for dark sector particles in the mass range from a few MeV to 10 GeV. Using a 365 fb$^{-1}$ sample collected by Belle II, we search for inelastic dark matter and an $Z'$ that decays to invisible particles. Using a 711 fb$^{-1}$ sample collected by Belle, we search for $B \to h + \mathrm{invisible}$ decays, where $h$ is a $\pi$, $K$, $D$, $D_s$ or $p$, and $B \to Ka$, where $a$ is an axion-like particle.

**Secondary track**:

T02 - Dark Matter

**Joint T05+T07 / 318**

## Belle~II measurements from an centre-of-mass energy scan near the $\Upsilon(10753)$ resonance

**Auteur:** Steven Robertson[1]

[1] *IPP / UofA*

The Belle II experiment collected a 19.2 fb$^{-1}$ sample of data at centre-of-mass energies near the $\Upsilon(10753)$ resonance. We present several results related to the following processes: $e^+e- \to \Upsilon(nS)\eta$, $e^+e- \to \gamma X_b(\chi_{bJ}\pi^+\pi^-)$, and $e^+e^- \to \chi_{bJ}(1P)\gamma$. These results provide additional information about the nature of the $\Upsilon(10753)$ resonance and nearby structures.

**Secondary track**:

T05 - QCD and Hadronic Physics

**Joint T05+T07 / 319**

## Studies of hadron spectroscopy at Belle and Belle II

**Auteur:** Steven Robertson[1]

[1] *IPP / UofA*

The Belle and Belle II experiments have collected a $1.6\ \mathrm{ab}^{-1}$ sample of $e^+e^-$ collision data at centre-of-mass energies near the $\Upsilon(nS)$ resonances. We present a measurement of the $B^0$ and $B^+$ meson mass difference and a measurement of $\sigma\left(e^+e^- \rightarrow J/\psi p\bar{p}\right)$ over a range of centre-of-mass energies accessed via initial-state radiation.

**Secondary track**:

T05 - QCD and Hadronic Physics

**T05 / 320**

## A precise $\alpha_s$ determination from the R-improved QCD Static Energy

**Auteurs:** José Manuel Mena Valle[1]; Pablo García Ortega[2]; Vicent Mateu Barreda[2]

[1] *Universidad de Salamanca*

[2] *University of Salamanca*

**Auteur correspondant** jmmena@usal.es

The strong coupling $\alpha_s$ is the most important parameter of Quantum Chromodynamics (QCD) and therefore it is essential to determine it with high precision. This work presents an improved approach for extracting $\alpha_s$ comparing numerical lattice QCD simulations to the perturbative expansion of the QCD color-singlet static energy. We "R-improve" the $\mathcal{O}(\alpha_s^4)$ fixed-order prediction by removing the $u = 1/2$ renormalon and summing up the corresponding large logarithms at N$^3$LL. We also resum large ultrasoft logs to N$^3$LL accuracy using renormalization group equations. A new and more flexible parametrization of the renormalization scales has been implemented, allowing us to extend perturbation theory to distances of the order of 1 fm. Perturbative uncertainties are estimated randomly varying the parameters that specify the various renormalization scales. Performing R-evolution in different subtractions schemes such as the MSR, the PS mass, and the RS mass, we show that the extracted value of $\alpha_s$ is strongly correlated with the prediction for the residue of the $u = 1/2$ singularity in the Borel plane. Finally, we combine Lattice data from different simulations into a single dataset, thus simplifying the fitting procedure. Using this approach, we determine the strong coupling with a precision comparable to that of the world average.

**Secondary track**:

**T01 / 321**

## Antiproton Flux and Properties of Elementary Particle Fluxes in Cosmic Rays Measured with the Alpha Magnetic Spectrometer on the ISS

**Auteur:** Hannah Taylor Anderson[1]

[1] *Massachusetts Institute of Technology*

**Auteur correspondant** hannah.taylor.anderson@cern.ch

Precision measurements by AMS reveal unique properties of cosmic charged elementary particles. In the absolute rigidity range ~60 to ~500 GV, the antiproton flux and proton flux have nearly identical rigidity dependence. This behavior indicates an excess of high energy antiprotons compared with secondary antiprotons produced from the collision of cosmic rays. More importantly, from ~60 to ~500 GV the antiproton flux and positron flux show identical rigidity dependence. The positron-to-antiproton flux ratio is independent of energy and its value is determined to be a factor of 1.98 ± 0.03 ± 0.05. This unexpected observation indicates a common origin of high energy antiprotons and positrons in the cosmos. Below 60 GV the antiproton spectrum can not be explained by cosmic rays collisions and above 60 GV the antiproton spectrum can not be explained by latest theoretical models.

**Secondary track**:

**T06** / **322**

## The three-loop jet function for boosted heavy quarks

**Auteur:** VICENT MATEU BARREDA[1]

**Co-auteurs:** Alberto Martín Clavero [2]; Maximilian Stahlhofen [3]; Robin Bruser [3]

[1] *University of Salamanca*

[2] *Universidad de Salamanca*

[3] *University of Freiburg*

Previous studies have shown that a class of observables for massless $e^+e^-$ colliders producing primary top quarks can be used to measure the top quark mass with a precision smaller than $\Lambda_{\rm QCD}$. The maximal sensitivity to the top mass is attained in the peak of the distribution, where several Effective Field Theories (EFTs) are applicable. The use of EFTs allows for the factorization of the differential cross section for various observables, separating contributions from different physical scales. The jet function —previously known at two loops—emerges as a common ingredient in many factorization theorems, which motivates the need for computing this matrix element at higher perturbative orders.

In this talk I will outline the workflow for a fixed-order calculation and present our analytic result for the three-loop jet function for boosted heavy quarks. This result can be used to improve the calibration of the top quark mass parameter in parton-shower Monte Carlo generators and contributes to enhance the accuracy of jet invariant-mass distributions for reconstructed top quarks, which can be employed for a precise top mass determination at future lepton colliders.

**Secondary track**:

T05 - QCD and Hadronic Physics

**T10** / **323**

# AsyInt for massive multi-loop Feynman integrals in asymptotic limits

**Auteur:** Hantian Zhang[1]

[1] *PSI*

In this talk, I will present the analytic tool AsyInt 1 for solving massive multi-loop Feynman integrals in asymptotic limits. AsyInt is currently optimized for high-energy (small-mass) expansions of massive two-loop four-point integrals and their analytic evaluations. Recently, AsyInt has been successfully employed to perform analytic two-loop electroweak calculations for double Higgs production at the LHC. In these calculations, highly non-trivial integrals involving the top quark, Higgs boson, and vector bosons are computed analytically at high energies, uncovering new elliptic constants as a by-product. This development represents the state-of-the-art in analytic electroweak calculations. I will outline the methodology and workflow of AsyInt, demonstrating its applicability to important LHC phenomenology.

1 Hantian Zhang, "Massive two-loop four-point Feynman integrals at high energies with AsyInt", JHEP 09 (2024) 069. (GitLab repository: https://gitlab.com/asyint/asyint-public)

**Secondary track**:

T08 - Higgs Physics

**T12** / **324**

# The evolution of the CMS Computing model towards the HL-LHC

**Auteur:** CMS Collaboration[None]

With the approaching High Luminosity phase of the LHC programme, scheduled to start in 2030, the Offline Software and Computing group of the CMS collaboration is reviewing the experiment' s computing model to ensure its readiness for the computing challenges the HL-LHC poses. An in-depth revision of the current model, tools and practices is being carried out, along with a programme of R&D activities to evolve them, with the goal of effectively managing the available computing resources towards a successful exploitation of the data abundance provided by the HL-LHC.

This evolution includes a review of the data management and workflow management systems, to ensure their scalability to the growing data volumes and level of resources required to store, process and analyze them. Larger and more heterogeneous computing resources, both from grid and high-performance computing centers, are being integrated to the global CMS computing pool. Critical progress is being made also in the adoption of new data analysis infrastructures and paradigms. Additionally, further integration of novel technologies in multiple computing areas is being explored. This contribution will present the status of the CMS computing model evolution in the aforementioned key areas, among others.

**Secondary track**:

**T14** / **325**

# CMS outreach overview

**Auteur:** CMS Collaboration[None]

The CMS experiment is one of the largest international scientific collaborations in history, involving more than 6000 particle physicists, engineers, technicians, students and support staff from 250+ institutes in 55+ countries. The physics program and technical achievements of CMS are of great interest to a wide range of stakeholders, ranging from the general public, other scientists, journalists to politicians. We summarise the ongoing activities within the framework of Communications/Outreach, including: Visits (in-person and virtual); Web-based articles covering physics analysis, operations and upgrades; Exhibitions; Social Media (stories, blogs, photos, videos) and the use of technologies such as Virtual Relaity. We also overview Educational activities such as Masterlasses and detailed analysis using Open Data.

**Secondary track**:

**T11** / **326**

## Physics Object Performance in CMS

**Auteur:** CMS Collaboration[None]

The CMS experiment relies on high-precision reconstruction of particles to access a wide range of analyses. This talk presents recent developments in the reconstruction and performance of key objects using early Run 3 data. Advances include improved calibration techniques, machine learning-based identification, and improved pileup mitigation strategies.

**Secondary track**:

**T02** / **327**

## Search for new physics in low energy electron recoil signals in LZ WS2022+2024 combined dataset

**Auteurs:** LZ Collaboration[None]; YONGHENG XU[1]

[1] *Universitetet i Oslo*

LUX-ZEPLIN (LZ) is a direct detection dark matter experiment located at the Sanford underground research facility in Lead, South Dakota, USA. LZ utilizes a dual-phase time projection chamber containing 7 tonnes of active xenon surrounded by veto systems to search for signals induced by WIMP dark matter candidates. Recently, the experiment announced world-leading WIMP results achieved over 280 live days of science operation. Besides its leading sensitivity to WIMPs, LZ is also sensitive to other dark matter candidates and new physics beyond the Standard Model using electronic recoil (ER) signatures. In this talk, I will present results of the LZ search for new physics leading to ER events based on an exposure of 4.2±0.1 tonne-years. Our search includes several models, including solar axion-like particles, hidden photons, mirror dark matter models, bosonic dark matter absorption, and the exotic electromagnetic interactions of solar neutrinos.

**Secondary track**:

T03 - Neutrino Physics

**T07** / **328**

## Combination and checks of highly correlated measurements of the muon precession frequency in magnetic field for the final FNAL measurement of the muon magnetic anomaly

**Auteur:** Alberto Lusiani[1]

[1] *SNS and INFN Pisa*

We describe how several highly correlated measurements of the muon precession frequency in magnetic field by multiple independent analysis groups were checked for consistency and averaged, for the final measurement of the muon magnetic anomaly by the FNAL muon g-2 experiment. With a significant improvement with respect to the past data analyses of the experiment, we planned the use of common data events bootstrap samples in order to obtain reliable and comprehensive estimates of the correlation between alternative measurements, greatly improving the reliability of the consistency checks, which are a critical step of the whole measurement procedure.

**Secondary track**:

T05 - QCD and Hadronic Physics

**T07** / **329**

## Lepton Flavour Universality tests and determination of Vus using the tau branching fractions fit

**Auteur:** Alberto Lusiani[1]

[1] *SNS and INFN Pisa*

The results of the tau branching fraction fit performed by HFLAV (also reported in the PDG Review of Particle Physics) are used to update the Lepton Universality tests and to calculate Vus using tau measurements. The lepton universality tests that rely on the leptonic tau branching fractions are updated to the 2nd order QED radiative corrections, in preparation for future improved precision measurements by Belle II and FCC. Recent lattice QCD caluclations are used to compute Vus.

**Secondary track**:

**T16** / **330**

## Mind the Gap: Safely Navigating Inference through Transport Maps

**Auteurs:** Chris Pollard[1]; Francesco Armando Di Bello[None]; Malte Algren[2]; Tobias Golling[3]

[1] *Warwick*

[2] *Unige*

[3] *University of Geneva*

Machine Learning has enabled enormous gains in sensitivity at the LHC and beyond. Much of this progress has relied on excellent simulations of a wide range of processes. However, due to the sophistication of modern machine learning algorithms, discrepancies between simulation and experimental data can significantly limit their effectiveness.

In this work, we present a novel calibration approach based on optimal transport, which enables continuous calibration of high-dimensional simulations.
We demonstrate the performance of our approach through jet tagging, using a CMS-inspired dataset.
Our method can correct a 128-dimensional jet representation learned from a general-purpose classifier.
Using this calibrated high-dimensional representation, powerful new applications of jet flavor information can be utilized in LHC analyses.
This continuous calibration framework also serves as a guide for deriving high-dimensional corrections of continuous distributions via transportation maps, with applications across the sciences.

**Secondary track**:

**T06** / **332**

## Luminosity Measurements with the ATLAS Inner Detector in Run 3 of the LHC

**Auteur:** ATLAS Collaboration[None]

A high-precision measurement of luminosity is essential for all ATLAS physics analyses, with the luminosity uncertainty limiting precise cross-section measurements of W, Z, and top-quark processes. The preliminary ATLAS luminosity calibration in Run 3 of the LHC is presented, with a particular focus on measurements using the Inner Detector. Methods exploiting the multiplicity of reconstructed charged-particle tracks play a key role in transferring the van der Meer scan-based calibration to standard physics data-taking conditions and ensuring long-term stability. Building on the techniques optimised for the ultra-precise Run-2 luminosity measurement, ATLAS aims to maintain sub-percent precision in Run 3.

**Secondary track**:

T11 - Detectors

**T11** / **333**

## Overview of ATLAS muon detectors: status and performance

**Auteur:** ATLAS Collaboration[None]

The ATLAS Muon Spectrometer, the largest muon system ever built at colliders, now comprises both legacy gaseous detectors—Monitored Drift Tubes (MDT), Thin Gap Chambers (TGC), and Resistive Plate Chambers (RPC)—which have been in operation for over 15 years, as well as newer technologies like Micromegas and small-strip TGCs in the NSW. These new systems are now in stable operation following an extensive phase of construction and commissioning, providing enhanced muon tracking and trigger capabilities.
This presentation will cover the status and performance of the Muon system, focusing on the stability of the legacy detectors over time, their ability to handle increasing luminosity and associated irradiation levels, and studies on detector ageing. Emphasis
will be placed on the NSW upgrade, including the strategies adopted for simulation, alignment, track reconstruction, and trigger.

**Secondary track**:

**T11** / **334**

## ATLAS Muon Detectors upgrades for High Luminosity LHC

**Auteur:** ATLAS Collaboration[None]

The muon spectrometer of the ATLAS detector will undergo a substantial upgrade during the Phase-II upgrade to meet the operational demands of the High- Luminosity LHC. Most of the electronics for the Monitored Drift Tube (MDT) chambers, Resistive Plate Chambers (RPC), and Thin Gap Chambers (TGC) will be replaced to ensure compatibility with the higher trigger rates and extended latencies required for the new level-0 trigger.
The MDT chambers will be integrated into the level-0 trigger to sharpen the momentum threshold. Additional RPC chambers will be installed in the inner barrel layer to enhance the acceptance and robustness of the trigger. Some MDT chambers in the inner barrel layer will be replaced with new small-diameter MDTs to optimize performance. New TGC triplet
chambers will be installed in the barrel-endcap transition region, replacing the current TGC doublets to reduce the high trigger rate caused by random coincidences in this area.
Additionally, the power systems for the RPC, TGC, and MDT chambers, along with their associated electronics, will be replaced due to component obsolescence, ageing, and radiation damage.
This contribution will provide an overview of the upgrade challenges, the current status of the projects, prototype and production results.

**Secondary track**:

**T11** / **335**

## Overview of ATLAS forward proton detectors: status, performance and new physics results

**Auteur:** ATLAS Collaboration[None]

A key focus of the physics program at the LHC is the study of head-on proton-proton collisions. However, an important class of physics can be studied for cases where the protons narrowly miss one another and remain intact. In such cases, the electromagnetic fields surrounding the protons can interact producing high-energy photon-photon collisions. Alternatively, interactions mediated by the strong force can also result in intact forward scattered protons, providing probes of quantum chromodynamics (QCD).
In order to aid identification and provide unique information about these rare interactions, instrumentation to detect and measure protons scattered through very small angles is installed in the beam pipe far downstream of the interaction point. We describe the ATLAS Forward Proton AFP Detectors, including their performance to date, covering Tracking and Time-of-Flight Detectors as well as the associated electronics, trigger, readout, detector control and data quality monitoring. Finally, a glimpse on the newest results will be given.

**Secondary track**:

**T11** / **336**

## The ATLAS High-Granularity Timing Detector for the HL-LHC : project status and results

**Auteur:** ATLAS Collaboration[None]

The increase of the particle flux (pile-up) at the HL-LHC with instantaneous luminosities up to L ⍰ 7.5 × 10^(34) cm^(−2)s^(−1) will have a severe impact on the ATLAS detector reconstruction and trigger performance. The end-cap and forward region where the liquid Argon calorimeter has coarser granularity and the inner tracker has poorer momentum resolution will be particularly affected. A High Granularity Timing Detector (HGTD) will be installed in front of the LAr endcap calorimeters for pile-up mitigation and luminosity measurement. The HGTD is a novel detector introduced to augment the new all-silicon Inner Tracker in the pseudo-rapidity range from 2.4 to 4.0, adding the capability to measure charged-particle trajectories in time as well as space. Two silicon-sensor double-sided layers will provide precision timing information for minimum-ionising particles with a resolution as good as 30 ps per track in order to assign each particle to the correct vertex. Readout cells have a size of 1.3 mm × 1.3 mm, leading to a highly granular detector with ~3.7 million channels. Low Gain Avalanche Detectors (LGAD) technology has been chosen as it provides enough gain to reach the large signal over noise ratio needed. The requirements and overall specifications of the HGTD will be presented as well as the technical design and the project status. The R&D effort carried out to study the sensors, the readout ASIC, and the other components, supported by laboratory and test beam results, will also be presented.

**Secondary track**:

**T11** / **337**

## Operational Experience and Performance with the ATLAS Pixel detector at the Large Hadron Collider at CERN

**Auteur:** ATLAS Collaboration[None]

The tracking performance of the ATLAS detector relies critically on its 4-layer Pixel Detector, with a sensitive area of ~1.9 m2 and 92 million pixels. Its original part, consisting in 3 layers of planar pixel sensor is continuously operating since the start of LHC collisions in 2008, while Its innermost layer, the Insertable B Layer (IBL) at about 3 cm from the beam line, was installed in 2015 before the start of LHC Run2 and consists of both planar and 3D pixel sensors, with FE-I4 readout frontends at 130nm CMOS technology.
As the closest detector component to the interaction point, this detector is subjected to a significant amount of radiation over its lifetime. At present, before the start of 2025 Run 3 LHC collisions, ATLAS Pixel Detector on innermost layers is operating after integrating fluence of O(10**15) 1 MeV n_eq cm^(-2). In this talk the key status and performance metrics of the ATLAS Pixel Detector are summarised, putting focus on performance and operating conditions at a over performing LHC, with special emphasis to radiation damage and mitigation techniques adopted, with prediction of their evolution until the end of LHC Run3 in 2026.
These results provide useful indications for the optimisation of the operating conditions for the new generation of pixel trackers under construction for HI-LHC upgrades.

**Secondary track**:

**T11** / **338**

## ATLAS ITk Pixel Detector Overview

**Auteur:** ATLAS Collaboration[None]

In the high-luminosity era of the Large Hadron Collider, the instantaneous luminosity is expected to reach unprecedented values, resulting in up to 200 proton-proton interactions in a typical bunch crossing. To cope with the resulting increase in occupancy, bandwidth and radiation damage, the ATLAS Inner Detector will be replaced by an all-silicon system, the Inner Tracker (ITk). The innermost part of the ITk will consist of a pixel detector, with an active area of about 13 m^2. To deal with the changing requirements in terms of radiation hardness, power dissipation and production yield, several silicon sensor technologies will be employed in the five barrel and endcap layers. As a timeline, it is facing to production of components, sensor, building modules, mechanical structures

and services. The pixel modules assembled with RD53B readout chips have been built to evaluate their production rate. Irradiation campaigns were done to evaluate their thermal and electrical performance before and after irradiation. A new powering scheme –serial –will be employed in the ITk pixel detector, helping to reduce the material budget of the detector as well as power dissipation. This contribution presents the status of the ITk-pixel project focusing on the lessons learned and the biggest challenges towards production, from sensors and mechanics structures, and it will summarize the latest results on closest-to-real demonstrators built using module, electric and cooling services prototypes.

**Secondary track**:

**T11 / 339**

## Construction of the ATLAS ITk strip detector for the HL-LHC era

**Auteur:** ATLAS Collaboration[None]

The inner detector of the present ATLAS experiment has been designed and developed to function in the environment of the present Large Hadron Collider (LHC). For the next LHC upgrade to High Luminosity, the particle densities and radiation levels will exceed the current levels by a factor of ten. The instantaneous luminosity is expected to reach unprecedented values, resulting in up to 200 proton-proton interactions in a typical bunch crossing, corresponding to an instantaneous luminosity of 7 × 10^(34) s^(-1) cm^(−2). For these reasons, the new detectors must be faster and more highly segmented. The sensors need to be far more resistant to radiation and have a much greater power delivery to the front-end (FE) systems. At the same time, they cannot introduce excess material that could undermine the tracking performance. For this upgrade, the ATLAS detector will replace its existing inner detector with a full silicon and larger Inner Tracker (ITk).

The new ITk detector consists of several layers of silicon particle detectors: the innermost parts are pixel detectors, and a strip detector surrounds them. This poster focuses on the strip region. The ITk-Strip detector contains four layers in the barrel and six in each of the two endcaps, covering pseudorapidity (⊠) range of |⊠| < 2.7. The silicon sensors along with application specific integrated circuits (ASICs) and the high and low voltage power controls for the sensors are integrated in a module. These modules are placed on staves in the barrel and petals in the end-caps, providing mechanical support for the modules and host the common electrical, optical and cooling services. The FE of the ITk-Strip detector, the ABCStar chip, is an ASIC with 256 channels that read outs the hit information collected on each silicon strip. The production of modules and the structures that support them is now well underway, with the testing and integration setups for final assembly being finalised. This poster gives a general overview of the future ITk strip detector, presenting its structures, final designs and detecting technologies. Current status, performance results and future plans are discussed.

**Secondary track**:

**T11 / 340**

## Expected Tracking performance of the ATLAS ITk detector for HL-LHC

**Auteur:** ATLAS Collaboration[None]

The increased instantaneous luminosity levels expected to be delivered by the High-Luminosity LHC (HL-LHC) will present new challenges to High-Energy Physics experiments, both in terms of detector technologies and software capabilities. The current ATLAS inner detector will be unable to cope with an average number of 200 simultaneous proton-proton interactions resulting from HL-LHC collisions. As such, the ATLAS collaboration is carrying out an upgrade campaign, known as Phase-II upgrade, that foresees the installation of a new all-silicon tracking detector, the Inner Tracker (ITk), designed for the expected occupancy and fluence of charged particles. The new detector will provide a wider pseudorapidity coverage and an increased granularity. In this contribution the expected performance of the ITk detector will be presented, with emphasis on the improvements on track reconstruction based on the latest available developments since the ITk technical design reports 1.

1 https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/IDTR-2023-01/

**Secondary track**:

**T16** / **341**

## Machine Learning for Real-Time Processing of ATLAS Liquid Argon Calorimeter Signals with FPGAs

**Auteur:** ATLAS Collaboration[None]

The Phase-II Upgrade of the LHC will increase its instantaneous
luminosity by a factor of 7 leading to the HL-LHC era. At the HL-LHC, the number of proton-proton collisions in one bunch crossing, pileup, increases significantly, putting stringent requirements on the LHC detectors electronics and real-time data processing capabilities.

The ATLAS LAr calorimeter measures the energy of particles produced in LHC collisions. It also feeds the ATLAS trigger to identify interesting events. To enhance the ATLAS physics discovery potential at HL-LHC, an excellent energy resolution and an accurate time detection is crucial.

The computation of the deposited energy is performed using electronic boards based on FPGAs. Currently this computation is done using optimal filtering algorithms that are adapted to situations with limited pileup. With the increased luminosity and pileup, the performance of the optimal filter algorithms decreases.

The off-detector electronic boards for the LAr Phase-II Upgrade will use the next generation of INTEL FPGAs with increased processing power and memory. This will allow the use on these boards of more complex algorithms. We developed several neural networks (NNs) with significant performance improvements with respect to the optimal filtering algorithms.

Five NN algorithms will be presented. The improvement of the energy resolution and the accuracy of the deposited time compared to the legacy filter algorithms will be discussed.
The implementation of these networks in firmware will be shown.

**Secondary track**:

T16 - AI for HEP (special topic 2025)

**T11** / **343**

## Operation and performance of the new ATLAS LAr Calorimeter Trigger

**Auteur:** ATLAS Collaboration[None]

The Liquid Argon Calorimeters are employed by ATLAS for all electromagnetic calorimetry in the pseudo-rapidity region |eta| < 3.2, and for hadronic and forward calorimetry in the region from |eta|

= 1.5 to |eta| = 4.9. They also provide inputs to the first level of the ATLAS trigger. In 2022 the LHC started its Run-3 period with an increase in luminosity and pile-up of up to 60 interactions per bunch crossing.

To cope with these harsher conditions, a new trigger readout path has been installed. This new path significantly improved the triggering performances on electromagnetic objects with lower pT thresholds, but also lower rates. This was achieved by increasing the granularity of the objects available at trigger level by up to a factor of ten.

The installation of this new trigger readout chain also required the update of the legacy system. More than 1500 boards of the precision readout have been extracted from the ATLAS cavern, refurbished and re-installed. The legacy analog trigger readout that will remain during the LHC Run-3 as a backup of the new digital trigger system has also been updated.

For the new system, 124 new on-detector boards have been added. Those boards that are operating in a radioctive environment are digitizing the calorimeter trigger signals at 40MHz. The digital signal is sent to the off-detector system and processed online to provide the measured energy value for each unit of readout. In total up to 31Tbps are analyzed by the processing system and more than 62Tbps are generated for downstream reconstruction. To minimize the triggering latency the processing system had to be installed underground.The limited available space imposed a very compact hardware structure. To achieve a compact system, large FPGAs with high throughput have been mounted on ATCA mezzanine cards. In total no more than 3 ATCA shelves are used to process the signal from approximately 34000 channels.

Given that modern technologies have been used compared to the previous system, all the monitoring and control infrastructure is being adapted and commissioned as well.

This contribution will present the challenges of the commissioning and operation, the performance and the milestones still to be achieved towards the full operation of the new digital trigger system.

**Secondary track**:

**T11 / 344**

## Development of the ATLAS Liquid Argon Calorimeter Readout Electronics for the HL-LHC

**Auteur:** ATLAS Collaboration[None]

A new era of hadron collisions will start around 2030 with the High-Luminosity LHC which will allow to collect ten times more data than what has been collected during last 10 years of operation at LHC. This will be achieved by higher instantaneous luminosity at the price of a higher number of collisions per bunch crossing.

In order to withstand the high expected radiation doses and the harsher data taking conditions, the ATLAS Liquid Argon Calorimeter readout electronics will be upgraded.

The electronic readout chain is composed of four main components:

1: New front-end boards will allow to amplify, shape and digitise the
calorimeter's ionisation signal on two gains over a dynamic range
of 16 bits and 11 bit precision. Low noise below Minimum Ionising
Particle (MIP), i.e. below 120 nA for 45 ns peaking time, and
maximum non-linearity of two per mille is required. Custom preamplifiers
and shapers are being developed to meet these requirements using 65 nm
and 130 nm CMOS technologies. They shall be stable under irradiation
until 1.4kGy (TID) and 4.1x10^13 new/cm^2 (NIEL). Two concurrent
preamp-shaper ASICs were developed and, "ALFE", the best one has been chosen. "COLUTA", a new ADC chip is also being designed. A production test setup is being prepared and integration tests of

the different components (including lpGBT links developed by CERN) on a 32-channels front-end board are ongoing.

2: New calibration boards will allow the precise calibration of all 182468 channels of the calorimeter over a 16 bits dynamic range. A non-linearity of one per mille and non-uniformity between channels of 0.25% with a pulse rise time smaller than 1ns shall be achieved. In addition, the custom calibration ASICs shall be stable under irradiation with same levels as preamp-shaper and ADC chips. The HV SOI CMOS XFAB 180nm technology is used for the pulser ASIC, “CLAROC”, while the TSMC 130 nm technology is used for the DAC part, “LADOC”.

3: New ATCA compliant signal processing boards (“LASP”) will receive the detector data at 40 MHz where FPGAs connected through lpGBT high-speed links will perform energy and time reconstruction. In total, the off-detector electronics receive 345 Tbps of data via 33000 links at 10 Gbps. For the first time, online machine learning techniques are considered to be used in these FPGAs.

4: A new timing and control system, “LATS”, will synchronise with the aforementioned components. Its current design status will also be shown.

**Secondary track**:

**T11 / 345**

# LUCID, the ATLAS luminosity detector in LHC Run-3 and its upgrade for HL-LHC

**Auteur:** ATLAS Collaboration[None]

The LUCID-2 detector is the main luminometer of the ATLAS experiment and the only one able to provide a reliable luminosity determination in all beam configurations, luminosity ranges and at bunch-crossing level. During LHC Run-2 ATLAS has measured luminosity with a precision of 0.8%, the most precise ever among all experiments running at a hadron collider. LUCID-2 is now providing ATLAS with the luminosity measurement also in LHC Run-3. Preliminary results on the acquired datasets will be presented, suggesting that a similar precision can be obtained.
The ATLAS physics program at High Luminosity LHC (HL-LHC) calls for a precision in the luminosity measurement of 1%. To fulfill such requirement in an environment characterized by up to 140 simultaneous interactions per crossing (200 in the ultimate scenario), ATLAS will feature several luminosity detectors. At least some of them must be both calibratable in the van der Meer scans at low luminosity and able to measure up to its highest values. LUCID-3, the upgrade of LUCID will fulfill such a condition. In this contribution, two options for LUCID-3 under study are presented: the first is based on photomultipliers (PMT), as for LUCID-2, located farther from the beam-pipe to reduce the acceptance and avoid the detector saturation; the second is based on optical fibers acting as Cherenkov radiators and read-out by PMTs located in a low radiation area. All PMTs will be monitored by a radioactive 207Bi source to ensure long-term stability to better than 1%. An upgrade of the readout electronics will also be needed. The status of the analysis of the data acquired in Run-3 with prototypes of both technologies installed in ATLAS will be presented focusing on the possible final LUCID-3 design.

**Secondary track**:

**T11 / 346**

# Measurements and rejection strategies for non-collision backgrounds at the ATLAS experiment.

**Auteur:** ATLAS Collaboration[None]

During nominal LHC collisions, protons can interact with residual gas in the beam pipe or with upstream collimators, producing showers of background particles known as Beam-Induced Backgrounds (BIB). These particles do not originate from the actual proton-proton interaction point. BIB can significantly impact detector performance and mimic signals in searches for missing energy or for certain types of new physics, such as neutral long-lived particles. The ATLAS Non-Collision Background group plays a key role in developing tools to identify and reject these backgrounds.
This talk will provide an overview of the ATLAS BIB online monitoring system, the new monitoring triggers introduced for Run 3, and recent results based on measurements from LHC Run 2 data.

**Secondary track**:

**T12 / 347**

# The ATLAS Trigger System

**Auteur:** ATLAS Collaboration[None]

The ATLAS experiment in the LHC Run 3 uses a two-level trigger system to select events of interest to reduce the 40 MHz bunch crossing rate to a recorded rate of up to 3 kHz of fully-built physics events. The trigger system is composed of a hardware based Level-1 trigger and a software based High Level Trigger. The selection of events by the High Level Trigger is based on a wide variety of reconstructed objects, including leptons, photons, jets, b-jets, missing transverse energy, and B-hadrons in order to cover the full range of the ATLAS physics programme.
We will present an overview of improvements in the reconstruction, calibration, and performance of the different trigger objects, as well as computational performance of the High Level Trigger system.

**Secondary track**:

**T12 / 348**

# Status and testing of the MDT Trigger Processor for the ATLAS Level-0 Muon Trigger at HL-LHC

**Auteur:** ATLAS Collaboration[None]

The Monitored Drift Tube Trigger Processor (MDT-TP) will improve the rate capabilities of the first-level muon (L0 Muon) trigger of the ATLAS Experiment during the operation of the HL-LHC.
The information of the trigger candidate, obtained by other muon trigger subsystems, will be combined with the precision of the MDT chambers in order to improve the resolution on the muon momentum measurement, while limiting the trigger rate to an acceptable level in the high-pileup environment of HL-LHC.
The MDT-TP trigger logic is implemented on a AMD VU13P FPGA, where MDT hits are extracted around the region-of-interest identified by the trigger candidate and are used to perform muon reconstruction and transverse momentum estimation. For accepted events, MDT hits are transmitted by the MDT-TP to the ATLAS data acquisition system via FELIX. Monitoring, configuration and interfaces with other ATLAS subsystems are implemented via services running on a Zynq SoC.
Several tests of the MDT-TP are being conducted, including the configuration and monitoring of the MDT-TP and the on-detector electronics, communication with other L0 Muon trigger boards and readout via FELIX. The current status of the prototype testing and the recent updates on firmware and software developments will be presented.

**Secondary track**:

**T12 / 350**

## The phase-1 upgrade of the ATLAS level-1 calorimeter trigger

**Auteur:** ATLAS Collaboration[None]

The ATLAS level-1 calorimeter trigger is a custom-built hardware system that identifies events containing calorimeter-based physics objects, including electrons, photons, taus, jets, and total and missing transverse energy.

In Run 3, L1Calo has been upgraded to process higher granularity input data. The new trigger comprises several FPGA-based feature extractor modules, which process the new digital information from the calorimeters and execute more sophisticated trigger algorithms. The design of the system will be presented along with an analysis of the improved performance of the upgrade in the increasingly challenging Run-3 LHC pile-up environment.

**Secondary track**:

**T12 / 351**

## Enhancing the ATLAS Level-1 endcap muon trigger with New Small Wheel integration in Run 3

**Auteur:** ATLAS Collaboration[None]

The Level-1 muon endcap trigger in the ATLAS experiment utilises signals from the Thin Gap Chambers (TGCs) located in the outer muon stations. A significant challenge for this system has been the high background rate caused by particles not originating at the interaction point, which increased the Level-1 trigger rate. To address this issue, the New Small Wheel (NSW) detectors, installed at the inner muon stations during Long Shutdown 2, were integrated into the Level-1 endcap muon trigger system for Run3 operations. In 2024, the full integration of the NSW sectors into the Level-1 trigger decision was successfully completed. By cross-checking the consistency between muon candidates identified by TGC signals and those by the NSW, the system achieved a significant improvement in the discrimination between muons and background particles. This advancement reduced the Level-1 trigger rate by approximately 15 kHz, effectively decreasing the load on the Trigger and DAQ systems and substantially enhancing the data-taking efficiency of the ATLAS experiment.

**Secondary track**:

**T12 / 353**

## Fast rejection of jets from pile-up in the ATLAS HLT using DIPZ

**Auteur:** ATLAS Collaboration[None]

DIPZ is a machine learning algorithm aiming to re-purpose the Deep Impact Parameter Sets (DIPS) jet-flavour taggers to instead regress the jet's origin vertex position along the beam-line axis. Deployed at the ATLAS High Level Trigger (HLT), the DIPZ labels of each jet in an event are then used in an HLT jet algorithm to construct an event-wide likelihood-based discriminant variable (MLPL), which is used to select events compatible with targeted multi-jet signature selection. This is an HLT algorithm that takes superROI tracking information at the preselection step as inputs (prior to full-scan tracking) and performs fast rejection of jets from pile-up. The main goal for Run 3 is to

reduce input to full scan tracking in an attempt to reduce the CPU consumption in the HLT while maintaining acceptable event rates and not compromising on signal efficiency for multi-jet signatures.

**Secondary track**:

T16 - AI for HEP (special topic 2025)

**T12** / **354**

## The upgrade of the ATLAS Trigger and Data Acquisition system for the High Luminosity LHC

**Auteur:** ATLAS Collaboration[None]

The ATLAS experiment at CERN is constructing upgraded system for the "High Luminosity LHC", with collisions due to start in 2030. In order to deliver an order of magnitude more data than previous LHC runs, 14 TeV protons will collide with an instantaneous luminosity of up to 7.5 x 10e^(34) cm^(-2)s^(-1), resulting in much higher pileup and data rates than the current experiment was designed to handle. While this is essential to realise the physics programme, it presents a huge challenge for the detector, trigger, data acquisition and computing. The detector upgrades themselves also present new requirements and opportunities for the trigger and data acquisition system.

The design of the TDAQ upgrade comprises: a hardware-based low-latency real-time Trigger operating at 40 MHz, Data Acquisition which combines custom readout with commodity hardware and networking to deal with 4.6 TB/s input, and an Event Filter running at 1 MHz which combines offline-like algorithms on a large commodity compute service with the potential to be augmented by commercial accelerators . Commodity servers and networks are used as far as possible, with custom ATCA boards, high speed links and powerful FPGAs deployed in the low-latency parts of the system. Offline-style clustering and jet-finding in FPGAs, and accelerated track reconstruction are designed to combat pileup in the Trigger and Event Filter respectively.

This contribution will report recent progress on the design, technology and construction of the system. The physics motivation and expected performance will be shown for key physics processes.

**Secondary track**:

T12 - Data Handling and Computing

**T11** / **355**

## Performance and upgrade of the ATLAS Hadronic Tile Calorimeter

**Auteur:** ATLAS Collaboration[None]

The Tile Calorimeter (TileCal) is a sampling hadronic calorimeter covering the central region of the ATLAS experiment, with steel as absorber and plastic scintillators as active medium. The scintillators are read-out by the wavelength shifting fibres coupled to the photomultiplier tubes (PMTs). The analogue signals from the PMTs are amplified, shaped, digitized by sampling the signal every 25 ns and stored on detector until a trigger decision is received.

The upcoming High-Luminosity phase of the LHC (HL-LHC), starting in 2030, will increase the nominal instantaneous luminosity by a factor of 5 to 7.5, alongside an upgraded ATLAS Trigger and Data Acquisition architecture. This upgrade necessitates a complete redesign of the readout electronics and power systems of TileCal. Both the on- and off-detector TileCal electronics will be replaced during the shutdown of 2026-2030. PMT signals from every TileCal channel will be digitized and sent directly to the back-end electronics, where the signals are reconstructed, stored, and sent to the first level of trigger at a rate of 40 MHz. This will provide better precision of the calorimeter signals used by the trigger system and will allow the development of more complex trigger algorithms.

The TileCal upgrade program has included extensive research and development, including test beam studies and the construction of a Demonstrator module. The Tile Demonstrator module with reverse compatibility with the existing system was inserted in ATLAS in July 2019 for testing in actual detector conditions.

A summary of first LHC Run 3 performance results including the calibration, stability, absolute energy scale, uniformity and time resolution will be presented. This talk will also include the ongoing HL-LHC developments for on- and off-detector systems, together with expected performance characteristics and results of test-beam campaigns with the electronics prototypes.

**Secondary track**:

**Poster T16 / 356**

## Fast Simulation in ATLAS for LHC Run 3 and Beyond

**Auteur:** ATLAS Collaboration[None]

In view of the high luminosity campaign of the LHC (HL-LHC), the computational requirements of the ATLAS experiment are expected to increase remarkably in the coming years. In particular, simulation of Monte Carlo events is immensely demanding from the computational point of view and their limited availability is one of the major sources of uncertainty in many analyses. The main bottleneck in detector simulation is the detailed simulation of electromagnetic and hadronic showers in the ATLAS calorimeter system with the Geant4 software.
In order to increase Monte Carlo statistics and better employ available resources, the ATLAS Collaboration has put into production the AtlFast3 fast simulation system. This tool combines approaches based either on parametrisations or Machine Learning to run simulation of events in the ATLAS detector in reduced time with respect to Geant4, guaranteeing at the same time good accuracy.
This contribution presents the results obtained with the version of AtlFast3 currently in production for LHC Run 3, discussing its physics performance, improvements in computing resource usage and the benefit AtlFast3 brings to ATLAS analyses; the latest updates on the development of its future version are also presented, together with ideas and plans for the future of fast simulation in ATLAS also in view of HL-LHC.

**Secondary track**:

T12 - Data Handling and Computing

**T11 / 358**

## Triple-GEM detectors for the ME0 system of the CMS Phase-2 Upgrade

**Auteur:** CMS Collaboration[None]

The High-Luminosity LHC will increase proton-proton collision rates to 5-7.5 times the nominal LHC luminosity, resulting in 140-200 pp-interactions per bunch crossing. To ensure effective muon triggering and reconstruction in this high-rate environment, the forward Muon spectrometer of the CMS experiment will be upgraded with Gas Electron Multiplier (GEM) detectors.

The ME0 station will consist of six-layer stacks of triple-GEM detectors, designed to extend the muon system's pseudorapidity coverage up to $|\eta| < 2.8$. The operating environment for ME0 will be characterized by extremely high rates, with simulations predicting approximately 150 kHz/cm². To guarantee optimal performance in this challenging setting, a thorough study of its rate capability and timing performance is essential.

This talk provides an overview of the ME0 project and its current progress. Specifically, we present the integration of a final-design prototype for a six-layer ME0 stack and share performance measurements related to muon segment reconstruction efficiency and timing. We discuss results from cosmic ray measurements as well as rate capability tests conducted under high-rate gamma background conditions at the CERN Gamma Irradiation Facility (GIF++). Our findings confirm that the ME0 design meets the Phase-2 CMS muon system upgrade requirements.

**Secondary track**:

**T11** / **360**

## Signal and Power transmission over Fiber in the DUNE Far Detector

**Auteur:** Sabrina Sacerdoti[1]

**Co-auteur:** DUNE Collaboration

[1] *APC-Paris,France*

The Vertical Drift Far Detector of the Deep Underground Neutrino Experiment (DUNE) will be instrumented with a Vertical Drift Time Projection Chamber (LAr TPC) and a Photon Detection System (PDS). The PDS installed alongside a TPC provides the time-stamp for off-beam physics, and can further contribute with precise timing information and calorimetry for energy reconstruction. The expected performance of the PDS in the VD LArTPC is improved thanks to an increase in coverage, through the installation of photo-detectors on the high voltage surface of the cathode. The Signal and Power over fiber technologies have been developed within the DUNE Collaboration in order to enable the operation of these photon detectors, by using only non-conductive materials (optical fibers) for transmission of signals and power in a cryogenic environment. This talk/poster presents a detailed account of this technological development and the latest results from the prototype testing at the CERN Neutrino Platform.

**Secondary track**:

**T01** / **361**

## Searches for ultra-high-energy photons with the Pierre Auger Observatory

**Auteurs:** Nicolas Martin Gonzalez Pintos[1]; The Pierre Auger Collaboration[None]

[1] *Universitá degli studi di Torino - INFN Sezione di Torino*

**Auteur correspondant** ngonzale@to.infn.it

The Pierre Auger Observatory, the largest air-shower experiment in the world designed to investigate ultra-high-energy (UHE, E
$gtrsim10^{17}$ eV) cosmic rays, offers unparalleled sensitivity to UHE photons. These are expected from interactions of UHE cosmic rays with background radiation fields, as well as from more exotic scenarios such as the decay of super-heavy dark matter (SHDM) particles. They may also originate in the environment of cosmic-ray sources, making their detection instrumental for multi-messenger studies of cosmic-ray acceleration and transient astrophysical phenomena. In this contribution, we present the search for photons above $10^{16.7}$ eV exploiting high-quality data from the Pierre Auger Observatory. These analyses yield the most stringent upper limits on the diffuse flux of UHE photons, placing strong constraints on astrophysical models and exotic scenarios such as SHDM decay. We also report on targeted searches in coincidence with gravitational wave events detected by LIGO/Virgo, underscoring the pivotal role of the Observatory in advancing multi-messenger astronomy at the highest energies. Improved sensitivity is foreseen by exploiting the new data from the Pierre Auger Observatory upgrade, AugerPrime.

**Secondary track**:

**T01** / **362**

# A Search for Stochastic Gravitational Waves Backgrounds in the O1-O3 LVK Data Motivated by Domain Walls Behaviour in the Early Universe

**Auteurs:** Catalina-Ana Miritescu[1]; Fabrizio Rompineve[1]; Mario Martinez-Perez[1]; Oriol Pujolas[1]

[1] *IFAE*

**Auteur correspondant** cmiritescu@ifae.es

Several theories beyond the Standard Model predict the occurrence of Domain Walls (DW), topological defects expected to arise from the breaking of a discrete symmetry in the early universe. The motion and the eventual annihilation of these objects are expected to generate a stochastic background of gravitational waves (SGWB), that could in principle be probed by ground-based GW detectors. In this work we build upon our previous search for a double-peaked domain wall motivated SGWB in the O1-O3 LVK data by introducing a novel multi-break power law function, in addition to a more intuitive parametrization of the double peak signal. We follow this mathematical implementation with a phenomenological approach, in order to place constraints on the physical parameters characterizing the DWs and to determine new parameter exclusion zones.

**Secondary track**:

**T14** / **363**

# From Real-Life Astrophysics Research Questions to Olympiad Problems

**Auteur:** Catalina-Ana Miritescu[1]

[1] *IFAE*

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Data analysis tasks are a key component of the International Olympiad on Astronomy and Astrophysics, a prestigious competition for high school students. Each participating country has its own selection process, open to students with an interest in Astronomy. Exam questions are an excellent way to introduce students to novel topics, provided the required knowledge to solve them is

within the high school level. As a former competitor in Romania and one of the current organizers of the national selection, I created three problems based on real-life research projects. One problem presents noise sources characterization in gravitational wave detectors while it also assesses students'understanding of logarithmic scales and their ability to fit data using the least squares method. One exercise uses real spectra of galaxies in the COSMOS field for Doppler shift and spectral line strength calculations. Data from the citizen science website Zooniverse.org is used in the third problem, presenting this novel way of research while testing pupils'knowledge about error propagation and transiting exoplanets. Although the short-term goal is to select the best competitors to represent Romania at the International Olympiad, the long-term aim is to teach all participants about current topics and methodologies in Astrophysics research.

**Secondary track**:

**T09** / **364**

# Minimal scalar leptoquark model for RD(*)

**Auteurs:** Damir BECIREVIC[1]; Lovre Pavičić[2]; Nejc Kosnik[3]; Svjetlana Fajfer[4]

[1] *IJCLab - Pôle Théorie*

[2] *Jožef Stefan Institute*

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**Auteur correspondant** lp79064@student.uni-lj.si

Motivated by the long-standing discrepancy in lepton flavor universality ratios $R_D$ and $R_{D^*}$ we assess the status of scalar leptoquark states $R_2$, $\widetilde{R}_2$ and $S_1$ which can in principle provide a desired enhancement of $\mathcal{B}(B \to D^{(*)}\tau\nu)$ in a minimal setup with two Yukawa couplings only. We consider unavoidable low-energy constraints, $Z$-pole measurements as well as high-$p_T$ constraints. After setting mass of each leptoquark to $1.5$ TeV we find that of all considered states only $S_1$ leptoquark, coupled to both chiralities of leptons and quarks, is still a completely viable solution. On the other hand, the scenario with $R_2$ is in growing tension with $\Gamma(Z \to \tau\tau)$ and with the LHC constraints on the di-tau tails at high-$p_T$ while the $\widetilde{R}_2$ scenario is in tension with the $\mathcal{B}(B \to K^{(*)}\nu\nu)$ observable. We comment on the future experimental tests of $S_1$ scenario. Furthermore, a scenario of the $S_1$ leptoquark coupled exclusively to right-handed SM fermions and a right-handed neutrino $N_R$ is also investigated as a potential solution for the $R_{D^{(*)}}$ with possible effects also in $\mathcal{B}(B \to K^{(*)}\nu\nu)$.

**Secondary track**:

**T05** / **367**

# Cross-Sections of $e^+e^-$ Annihilation into Hidden Charm States at BESIII

**Auteurs:** BESIII Collaboration[None]; BESIII Collaboration[None]; BESIII Collaboration[None]

In this presentation, we'll discuss the recent measurements of the
cross-sections for $e^+e^-$ annihilation into hidden charm states at BESIII. These
measurements include: 1) A precise measurement of the $e^+e^- \longrightarrow \pi^+\pi^-$ $h_c$cross section
line shape at center-of-mass energies from 4.009 to 4.950 GeV. A plateau-like shape
between 4.3 and 4.45 GeV, followed by a sharp drop near 4.5 GeV, reveals three
resonant structures for the first time. 2) A search for the process $e\ e \to K_s K_s h_c$ is conducted at 13
center-of-mass energies ranging from 4.600 to 4.950 GeV. No
significant signal is observed, and the upper limits of the Born cross-sections at

each center-of-mass energy are presented; 3) The observation of the process $e\ e \to K_s K_s(3686)$ at eight center-of-mass energies from 4.682 to 4.951 GeV, with an
integrated luminosity of 4.1 fb⁻¹. This process is reported for the first time with
a statistical significance of 6.3σ, and the cross-sections at each center-of-mass
energy are measured; 4) The inclusive cross-sections for prompt J/ψ and ψ(3686)
production at center-of-mass energies ranging from 3.808 to 4.951 GeV, based on 22
fb⁻¹ of annihilation data. Average cross-section values for J/ψ and ψ(3686) are
determined within specific energy ranges.

**Secondary track**:

T07 - Flavour Physics and CP Violation

**T05** / **371**

# Light Baryon Spectroscopy at BESIII

**Auteurs:** BESIII Collaboration[None]; BESIII Collaboration[None]; BESIII Collaboration[None]; BESIII Collaboration[None]

Based on the large samples of 10 billion J/ψ and 2.7 billion ψ(3686) events collected by the BESIII detector, the recent progresses on baryon spectroscopy, including the amplitude analyses of $(3686) \to p\bar{p}\pi^0$, $(3686) \to p\bar{p}\eta$, and $(3686) \to \Lambda\bar{\Sigma}\pi$, will be presented. The perspectives on the baryon spectroscopy at BESIII will also be discussed.

**Secondary track**:

**T03** / **372**

# Physics Prospects of JUNO

**Auteur:** Mariangela Settimo[1]

[1] *SUBATECH Nantes, CNRS/IN2P3*

The Jiangmen Underground Neutrino Observatory (JUNO) is a 20 kiloton multi-purpose liquid scintillator (LS) detector located in South China. With detector construction complete in late 2024, JUNO is currently taking data during the liquid scintillator filling phase, and the operation with full liquid scintillator is expected in the second half of 2025.
JUNO's primary goal is to determine the neutrino mass ordering, with an expected significance of 3 - 4 $\sigma$ in about six years, by observing the modulations in the energy spectrum of reactor electron antineutrinos from two nuclear power plants at 53 km. Additionally, JUNO's unprecedented energy resolution and target volume, will enable sub-percent precision measurements of oscillation parameters with just a few months of data and the observation of neutrinos from natural sources, including atmospheric, solar, astrophysical, and geo-neutrinos.
As JUNO prepares for full operation, this talk will explore its physics potential and the scientific opportunities ahead.

**Secondary track**:

**Joint T02+T09** / **373**

# Search for dark sector at BESIII

**Auteurs:** BESIII Collaboration[None]; Zhijun Li[1]

[1] *Sun Yat-sen University*

The BESIII experiment is taking data at a symmetric $e^+e^-$ collider operating at the center of mass energies from 2.0 to 4.95 GeV. With the world's largest on-threshold production data set of $J/\psi$ (10 billion), $\psi$(3686) (2.6 billion), and 20 $fb^{-1}$ of $\psi(3770)$ decaying into D meson pairs, we are able to search for various dark sectors particles produced in $e^+e^-$ annihilation and meson decay processes. In this talk, we report the search for BSM particles in $\Sigma$ decay and Axion-like particle search with $J/\psi$ data. The search for massless dark photon through the FCNC process $D^0 \to \omega\gamma$' and $D^0 \to \gamma\gamma$', and $K_s^0$ invisible decay will also be presented.

**Secondary track**:

T09 - Beyond the Standard Model

**T09** / **374**

# Search for new physics with charm rare decays at BESIII

**Auteur:** BESIII Collaboration[None]

The BESIII experiment has collected 2.6 billion $\psi(3686)$ events, 10 billion $J/\psi$ events, 20 $fb^{-1}$ of D meson pairs at 3.773 GeV, and 7.33 $fb^{-1}$ of $D_sD_s^*$ events from 4.128 to 4.226 GeV. The huge data samples allow us to search for rare processes in charm hadron decays. In this talk, we report searches for FCNC decay $J/\psi \to D^0\mu^+\mu^-$ and $D_s^+ \to h(h')e^+e^-$. The searches for $J/\psi$ weak decays containing a D meson and for $J/\psi \to \gamma D^0$ will also be presented.

**Secondary track**:

T07 - Flavour Physics and CP Violation

**T09** / **375**

# Search for Baryon/Lepton number violation processes at BESIII

**Auteur:** BESIII Collaboration[None]

The observed matter-antimatter asymmetry in the universe is a serious challenge to our understanding of nature. BNV/LNV decays have been searched for in many experiments to understand this large-scale observed fact. In this talk, we present the recent results from the BESIII experiment on the searches for baryon number violation via $\Lambda - \bar{\Lambda}$ oscillation in $J/\psi \to \Lambda\bar{\Lambda}$ decay. The searches for lepton number violating processes $D_s^+ \to h^-h^0e^+e^+$ and $\phi \to \pi^+\pi^+e^-e^-$ will also be discussed.

**Secondary track**:

**T06** / **376**

## Determination of the first-generation quark couplings at the Z-pole

**Auteurs:** Aleksander Filip Zarnecki[1]; Daniel Jeans[2]; Junping Tian[3]; Jürgen Reuter[4]; Krzysztof Mekala[5]

[1] *University of Warsaw*

[2] *KEK / IPNS*

[3] *University of Tokyo*

[4] *DESY Hamburg, Germany*

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**Auteur correspondant** k.mekala@uw.edu.pl

Electroweak Precision Measurements are stringent tests of the Standard Model and sensitive probes to New Physics. Accurate studies of the Z-boson couplings to the first-generation quarks, which are currently only constrained from LEP data, could reveal potential discrepancies from the theory predictions. Future $e^+e^-$ colliders running at the $Z$-pole would be an excellent tool for an analysis based on a comparison of radiative and non-radiative $Z$ boson decays.

We present the corresponding method to extract the values of the $Z$ couplings to light quarks and discuss the uncertainty of the measurement, including contributions from various systematic effects. We show that systematic uncertainty in the heavy-flavour tagging performance is the key factor in the analysis and reducing it to a sub-permille level might be crucial to fully profit from the high luminosity of future $e^+e^-$ machines. In such a case, the measurement could improve the LEP results by at least an order of magnitude.

**Secondary track**:

T07 - Flavour Physics and CP Violation

**T16** / **377**

## Some applications of machine learning and quantum computing in jet reconstruction

**Auteur:** Chen Zhou[1]

[1] *Peking University*

To enhance the scientific discovery power of high-energy collider experiments, we propose and realize the concept of jet-origin identification that categorizes jets into five quark species (u, d, s, c, b), five antiquarks, and the gluon. Using state-of-the-art algorithms and simulated ννH, H ⟶ jj events at 240 GeV center-of-mass energy at the electron-positron Higgs factory, the jet-origin identification simultaneously reaches jet flavor tagging efficiencies ranging from 67% to 92% for bottom, charm, and strange quarks and jet charge flip rates of 7%–24% for all quark species. We apply the jet-origin identification to Higgs rare and exotic decay measurements at the nominal luminosity of the Circular Electron Positron Collider and conclude that the upper limits on the branching ratios of H ⟶ ss, uu, dd and H ⟶ sb, db, uc, ds can be determined to 0.02%–0.1% at 95% confidence level. The derived upper limit for H ⟶ ss decay is approximately 3 times the prediction of the standard model, which improves by more than a factor of 2 upon previous studies.

Exploring the application of quantum technologies to fundamental sciences holds the key to fostering innovation for both sides. In high-energy particle collisions, quarks and gluons are produced and immediately form collimated particle sprays known as jets. Accurate jet clustering is crucial as it retains the information of the originating quark or gluon and forms the basis for studying properties of the Higgs boson, which underlies the mechanism of mass generation for subatomic particles. For the

first time, by mapping collision events into graphs—with particles as nodes and their angular separations as edges—we realize jet clustering using the Quantum Approximate Optimization Algorithm (QAOA), a hybrid quantum-classical algorithm for addressing classical combinatorial optimization problems with available quantum resources. Our results, derived from 30 qubits on quantum computer simulator and 6 qubits on quantum computer hardware, demonstrate that jet clustering performance with QAOA is comparable with or even better than classical algorithms for a small-sized problem. This study highlights the feasibility of quantum computing to revolutionize jet clustering, bringing the practical application of quantum computing in high-energy physics experiments one step closer.

**Secondary track**:

T15 - Quantum technologies in HEP (special topic 2025)

**T06** / **378**

## The MC generator Whizard for future collider studies

**Auteurs:** Pia Bredt[1]; Marius Höfer[2]; Wolfgang Kilian[1]; Nils Kreher[1]; Krzysztof Mekala[3]; Maximilian Löschner[4]; Thorsten Ohl[5]; Jürgen Reuter[6]; Tobias Striegl[1]; Aleksander Filip Zarnecki[7]

[1] *University of Siegen*

[2] *KIT*

[3] *University of Warsaw / DESY*

[4] *Deutsches Elektronen-Synchrotron DESY*

[5] *University ofWürzburg*

[6] *DESY Hamburg, Germany*

[7] *University of Warsaw*

Monte Carlo generators are at the core of LHC data analyses and will remain crucial for future lepton colliders offering unprecedented energies and luminosities. With a Higgs factory on the horizon and ongoing studies on the physics potential of a muon collider, the development of the generators must be continuously supported to meet the anticipated experimental precision.

We give a status report on recent advancements in the WHIZARD event generator, an efficient tool for simulating exclusive and inclusive multi-particle processes, and one of the major codes used by the lepton-collider community. Notable new features comprise NLO electroweak automation (incl. Powheg-type matching and extensions to BSM processes and SMEFT studies), loop-induced processes and improvements to the UFO interface. We highlight work in progress and further plans, such as new developments in the context of collinear approximation used in the Equivalent Vector-Boson Approximation and electroweak PDFs.

**Secondary track**:

T09 - Beyond the Standard Model

**T09** / **379**

## A measurement of the high-mass tautau production cross-section at sqrt(s) = 13 TeV with the ATLAS detector and constraints on new particles and couplings

**Auteur:** ATLAS Collaboration[None]

The first measurement of the high-mass $\tau\tau$ production cross section is presented, performed by the ATLAS Collaboration with the dataset of 140 fb-1 of pp collisions at sqrt(s) = 13 TeV. This process is also exploited to constraint new physics models affecting the Standard Model flavour sector. A fit to the $\tau$-lepton pair invariant mass distribution is performed as a function of b-jet multiplicity to constrain the non-resonant production of new particles described by an effective field theory or in models containing leptoquarks or heavy Z'bosons that couple preferentially to the third family of leptons. Constraints on leptoquark models improve on previous results and exclude scenarios proposed to interpret the flavour anomalies in B-hadron decays. Constraints on effective field theory operators include those affecting g-2 of the ⊠ lepton.

**Secondary track**:

**T09 / 380**

## A search for emerging jets at 13 TeV with the ATLAS detector using the Run 2 dataset

**Auteur:** ATLAS Collaboration[None]

A search is presented for emerging jets, novel detector objects that could be evidence of hidden or dark sectors with structures and symmetries similar to those in quantum chromodynamics (QCD). In some models of dark QCD, dark quarks undergo dark showering similar to QCD in the Standard Model (SM), leading to a high multiplicity of long-lived dark hadrons that subsequently decay to SM particles with varying displacements and mostly collimated with SM hadronic activity. Such activity yields jet-like detector objects but with multiple displaced vertices of varying displacements within the jet cone. Pair-production of a new scalar mediator that connects the dark sector with the SM and decays to a SM quark and a dark quark resulting in a four-jet final state of two QCD jets and two emerging jets. The search uses the full dataset of proton-proton collisions at center of mass energy of 13 TeV, collected by the ATLAS experiment at the LHC during Run 2 in 2015-2018. The area of dark QCD phase spaces probed by the analysis includes emerging jets produced in the inner detector from dark scalar mediators with masses between 600 and 2200 GeV and dark pions with proper lifetimes between 0.5 and 1000 mm.

**Secondary track**:

**T09 / 381**

## Search for long-lived massive particles in events with displaced vertices and muons at sqrt(s) = 13.6 TeV using the ATLAS detector

**Auteur:** ATLAS Collaboration[None]

We present a search for massive long-lived particles (LLPs) in events with displaced vertices and muons, using proton-proton collision data at sqrt(s) = 13.6 TeV recorded by the ATLAS detector. This study focuses on event signatures where LLPs decay within the ATLAS Inner Detector, producing displaced vertices and muon tracks. It is sensitive to an array of new physics scenarios, including electroweak-scale SUSY particles that decay via small R-Parity violating couplings. It leverages new capabilities of the ATLAS detector in Run 3 to reconstruct and trigger on displaced Standard Model objects. A dedicated secondary vertexing algorithm is employed to expand the fiducial volume for displaced vertices, enhancing sensitivity to shorter LLP lifetimes. Background contributions are estimated with fully data-driven techniques.

**Secondary track**:

**T09 / 382**

## Searches for unusual signatures in hadronic channels with the ATLAS detector

**Auteur:** ATLAS Collaboration[None]

Various theories beyond the Standard Model predict new, long-lived particles with unique signatures involving jets, which are difficult to reconstruct and for which estimating the background rates is also a challenge. These include emerging jets, semi-visible, and soft unclustered energy patters. The talk will focus on the most recent results from ATLAS

**Secondary track**:

**T11 / 383**

## Wavelength shifting fibers with high photon capture rate

**Auteur:** Bastian Keßler[1]

[1] *JGU - Institut für Physik*

**Auteur correspondant** bakessle@uni-mainz.de

Wavelength-shifting optical fibers are commonly used to collect light from large detector volumes and guide towards photosensors, making them particularly interesting for water Cherenkov or scintillator based detectors. However, one problem is their low photon capture rate, leading to a degradation in the energy resolution of fiber-based detectors.

Building on previous work, it was shown that the photon capture rate can be increased by optimizing the design of the photon absorption zone. In this work, this concept was applied to wavelength shifting fiber to increase the light output of the hybrid opaque scintillator experiment NuDoubt++.

However, the first prototype fibers suffer still from a relative high attenuation, losing this advantage for fiber lengths over 2 meters and losing efficiency compared to commercial fibers. On this poster the further development of the fibers and the effect of adapted production methods on the attenuation length will be shown.

**Secondary track**:

T03 - Neutrino Physics

**T03 / 384**

## CLOUD: fundamental reactor antineutrino physics using the novel LiquidO detection technology

**Auteur:** The CLOUD collaboration[None]

The CLOUD collaboration is pioneering the first fundamental research reactor antineutrino experiment using the novel LiquidO technology for event-wise antimatter tagging. CLOUD's program is a potential byproduct of the AntiMatter-OTech EIC/UKRI-funded project focusing on industrial reactor innovation. The experimental setup is envisioned to be an up to 10 tonne detector, filled with an opaque scintillator and crossed by a dense grid of wavelength-shifting fibres. The detector is planned to be located at EDF-Chooz at around 35 m from the core of one of the most powerful European nuclear plants, with minimal overburden. Detecting of order 10,000 antineutrinos daily and with a high (≥100) signal-to-background discrimination, CLOUD aims for the highest precision of the absolute flux, along with explorations of beyond the Standard Model physics. Subsequent phases plan to exploit metal-doped opaque scintillators for further detection demonstration, including exploring the potential for surface detection of solar neutrinos.

**Secondary track**:

T11 - Detectors

**T09 / 385**

## Searches for Beyond Standard Model Higgs boson decays (including low mass resonances)

**Auteur:** ATLAS Collaboration[None]

The discovery of the Higgs boson with the mass of about 125 GeV completed the particle content predicted by the Standard Model. Even though this model is well established and consistent with many measurements, it is not capable of explaining some observations by itself. Many extensions of the Standard Model addressing such shortcomings introduce beyond-the-Standard-Model couplings to the Higgs boson. In this talk, the latest searches in the Higgs sector are reported, with emphasis on the results obtained with the full LHC Run 2 dataset at 13 TeV and including a series of searches for low-mass resonances in merged or boosted topologies.

**Secondary track**:

**T09 / 386**

## Searches for electroweak production of supersymmetric particles with the ATLAS detector

**Auteur:** ATLAS Collaboration[None]

The direct production of electroweak SUSY particles, including sleptons, charginos, and neutralinos, is a particularly interesting area with connections to dark matter and the naturalness of the Higgs mass. The small production cross-sections and challenging experimental signatures, often involving compressed spectra, lead to difficult searches. This talk will highlight the most recent results of searches performed by the ATLAS experiment for supersymmetric particles produced via electroweak processes, including analyses targeting small mass splittings between SUSY particles, and including both in R-parity-conserving and R-parity-violating scenarios. Recent results involving the combination of searches are also presented.

**Secondary track**:

**T09 / 387**

## Searches for heavy resonances (including new scalars & BSM Higgs decays)

**Auteur:** ATLAS Collaboration[None]

Though the Standard Model (SM) of particle physics has been a very successful theory in explaining a wide range of measurements, there are still many questions left unanswered such as incorporation of gravity into SM, neutrino masses, matter-antimatter asymmetry, supersymmetry, or existence of dark matter candidates. One of the possible solutions to address these challenges is the extension of the SM with the presence of additional, heavy BSM particles; including scalar (H/S), pseudoscalar (A), or charged (H+-/H++–) BSM Higgs bosons. This is accounted for in multiple possible new physics models predicting the existence of these new, heavy particles. This talk summarises recent ATLAS searches for Beyond-the-Standard-Model heavy resonances, using the full Run 2 dataset.

**Secondary track**:

**T09 / 388**

## Searches for new phenomena in hadronic final states using the ATLAS detector

**Auteur:** ATLAS Collaboration[None]

Many theories beyond the Standard Model predict new phenomena giving rise to multijet final states. These jets could originate from the decay of a heavy resonance into SM quarks or gluons, or from more complicated decay chains involving additional resonances that decay e.g. into leptons. Also of interest are resonant and non-resonant hadronic final states with jets originating from a dark sector, giving rise to a diverse phenomenology depending on the interactions between the dark sector and SM particles. This talk presents the latest ATLAS results.

**Secondary track**:

**T09 / 389**

## Searches for new phenomena in leptonic final states using the ATLAS detector

**Auteur:** ATLAS Collaboration[None]

Many theories beyond the Standard Model predict new phenomena, such as Z', W' bosons, KK gravitons, vector-like leptons or heavy leptons, in final states with isolated, high-pT leptons (e/mu/tau) or photons. Searches for new physics with such signatures, produced either resonantly or non-resonantly, are performed using the ATLAS experiment at the LHC.. The most recent ATLAS results will be reported.

**Secondary track**:

**T09 / 390**

## Searches for strong production of supersymmetric particles with the ATLAS detector

**Auteur:** ATLAS Collaboration[None]

Supersymmetry (SUSY) provides elegant solutions to several problems in the Standard Model, and searches for SUSY particles are an important component of the LHC physics program. Naturalness arguments favour supersymmetric partners of the gluons and third-generation quarks with masses light enough to be produced at the LHC. With increasing mass bounds on more classical MSSM scenarios other variations of supersymmetry, including non-minimal particle content, become increasingly interesting. This talk will present the latest results of searches conducted by the ATLAS experiment which target gluino and squark production, including stop and sbottom, in a variety of decay modes. Recent interpretations in the context of the pMSSM are also presented.

**Secondary track**:

**Joint T02+T09 / 391**

## Radion Portal Dark Matter in Stabilized Warped Extra-Dimensions

**Auteurs:** R. Sekhar Chivukula[1]; Joshua Gill[2]; Kenn Shern Goh[3]; Kirtimaan Mohan[4]; George Sanamyan[3]; Elizabeth Simmons[1]; Dipan Sengupta[2]; Xing Wang[5]

[1] *University of California*

[2] *The University of New South Wales*

[3] *University of Adelaide*

[4] *Michigan State University*

[5] *Università degli studi Roma Tre*

We analyze dark matter (DM) annihilation in a stabilised Randall-Sundrum (RS) model, where the radion—the lightest spin-0 Kaluza-Klein state—acts as a portal between DM and the Standard Model (SM).

By recasting limits from axion-diphoton couplings and collider searches for spin-0 resonances, we constrain the radion's parameter space and demonstrate that Weakly Interacting Massive Particles (WIMPs) in the 100–500 GeV mass range can satisfy the observed relic abundance while evading direct detection and collider bounds.

Furthermore, the theoretical framework of RS models mandates a sub-TeV radion mass, ergo distinguishing it from ad-hoc dilaton portals where the radion mass is a free parameter.

**Secondary track**:

T02 - Dark Matter

**T03 / 392**

## Measurement of the CP violation in neutrino flavour oscillations with Hyper-Kamiokande

**Auteurs:** Claire Dalmazzone[1]; Hyper-Kamiokande Collaboration[None]

[1] *LPNHE*

Long baseline neutrino oscillation experiments have a high sensitivity to the CP violation phase of the neutrino mixing matrix through the $\nu\mu \longrightarrow \nu e$ and $\bar{\nu}\mu \longrightarrow \bar{\nu}e$ appearance channels. For instance, the measurements of the T2K experiment in Japan, using Super-Kamiokande as a far detector, favour a close to maximal CP violation and excluded the CP conserving values at a 90% CL. However, these

results are largely limited by statistics. With a fiducial volume approximately 8 times larger than the existing Super-Kamiokande, the future water Cherenkov detector Hyper-Kamiokande (HK) being built in Japan is one example of a next generation of long-baseline neutrino experiment. It will use the same neutrino beam from the J-PARC accelerator facility, but three times more intense, and the same baseline as the current T2K experiment to improve on the measurements of neutrino oscillation parameters thanks to a larger far detector and an upgraded beam facility. With this increased statistics, the CP violation phase measurement will require a much better understanding of systematic effects among which the neutrino interaction modelling is a major source of uncertainties. This talk will address the plans of the Hyper-Kamiokande experiment to perform the measurement of the CP violation phase. The plan is based on studying in depth the systematics impacting the measurements and on potentially upgrading the near detectors used to constrain the neutrino flux and cross-section before oscillations. In particular, this talk will emphasize how HK plans to constrain the νe and ν̄e cross-sections, that are expected to be a major source of uncertainty for the measurement of the CP violation phase, with a new intermediate water Cherenkov detector at about 1 km from the neutrino beam production and an upgraded near detector from the T2K experiment (ND280 at 280 m from the neutrino production target). Depending on the true value of the CP violation phase, the measurement could also be impacted by degeneracy with the neutrino Mass Ordering. The talk will also explain how this obstacle could be overcome using the combined analysis of accelerator and atmospheric neutrinos in HK.

**Secondary track**:

**T09** / **393**

## Long-Lived Particle Searches at a Future Higgs Factory with the ILD experiment

**Auteur:** Jan Klamka[1]

**Co-auteur:** Aleksander Filip Zarnecki [2]

[1] *University of Warsaw (PL)*

[2] *University of Warsaw*

**Auteur correspondant** jan.klamka@fuw.edu.pl

Future $e^+e^-$ colliders provide a unique opportunity for long-lived particle (LLP) searches. We present a full simulation study of LLP searches using the International Large Detector (ILD), a detector concept for a future Higgs factory, with a gaseous time projection chamber as its main tracking device. Signatures of displaced vertices and kinked tracks are explored. We study challenging final states involving both very soft displaced tracks and boosted, nearly collinear tracks. Backgrounds from beam-induced interactions and other Standard Model processes are considered. We present expected exclusion limits for a model-independent analysis, as well as for Higgs boson decays to LLPs, for a range of LLP lifetimes.

**Secondary track**:

**T13** / **394**

## Bent Crystal Channeling for Optimized Beam Shadowing and Proton Extraction at Mu2e

**Auteur:** Pierluigi Fedeli[1]

**Co-auteurs:** Alexey Sytov ; Andrea Mazzolari [2]; Gianfranco Paternò [3]; Laura Bandiera [3]; Lorenzo Malagutti [3]; Marco Romagnoni [4]; Nicola Canale [5]; Riccardo Negrello [2]; Vincenzo Guidi [2]

[1] *Istituto Nazionale di Fisica Nucleare & University of Ferrara*

[2] *Unife*

[3] *INFN Ferrara*

[4] *Universita‘ degli Studi di Ferrara*

[5] *INFN - Ferrara*

**Auteur correspondant** fdlplg@unife.it

The Mu2e experiment is designed to investigate the CLFV through the observation of a neutrinoless muon-to-electron conversion in the field of an Al nucleus. The observation of such a process would be clear evidence of physics beyond the standard model. Due to the rarity of this process, a cutting-edge, intense muon beam is required to achieve an improvement of the current single-event sensitivity by 4 orders of magnitude. To achieve this goal, a primary proton beam with 8 GeV is extracted from the Fermilab Delivery Ring using the slow resonant extraction technique. Mu2e requires ~ 3.6 × 10^20 protons-on-target to meet its goal; hence, it is crucial to minimize the extraction losses. An important source of such losses are the particles impacting on the electric septum blade. A very promising solution to the problem lies in the beam shadowing scheme tested at CERN SPS. In this approach, a bent crystal is strategically placed upstream of the septum, deflecting particles from the blade at a precise angle via the phenomenon of channeling. As a result, a zone with reduced particle flux is created downstream of the crystal, safeguarding the septum anode by minimizing interactions with the beam. This work explores the optimization of beam shadowing design and the process in the manufacturing and characterization of the bent crystal sample. It emphasizes the promising role of channeling in bent crystals, and it underscores the significant potential of channeling in bent crystals to assist the Mu2e experiment.

**Secondary track**:

**T03 / 395**

## LEGEND-1000: A Ton-Scale Search for Neutrinoless Double-Beta Decay with Germanium Detectors

**Auteur:** Malgorzata Haranczyk[1]

[1] *Jagiellonian University*

LEGEND-1000 is a next-generation experiment designed to search for the neutrinoless double-beta (0νββ) decay. The observation of 0νββ decay of $^{76}$Ge isotope would establish the Majorana nature of neutrinos, providing insight into the mechanism of neutrino mass generation and the matter-antimatter asymmetry of the universe.
To achieve an unprecedented discovery sensitivity to 0νββ half-lives beyond $10^{28}$ years, the LEGEND Collaboration will deploy 1000 kg of high-purity germanium detectors enriched to over 90% in $^{76}$Ge, operated in an instrumented liquid argon active shield at a deep underground facility, with a reference design at Laboratori Nazionali del Gran Sasso in Italy. The experiment will probe an effective Majorana neutrino mass in the range of 9–24 meV, covering the inverted neutrino mass ordering. LEGEND-1000 builds on technologies from GERDA, the Majorana Demonstrator, and the ongoing LEGEND-200 deployment, incorporating innovations such as pulse shape analysis, multi-detector segmentation, and LAr scintillation detection. These techniques enable exceptional background suppression, with a targeted rate below $1 \times 10^{-5}$ cts/(keV·kg·yr), enabling a quasi-background-free search where even a few observed events could establish discovery.

**Secondary track**:

T09 - Beyond the Standard Model

**T15 / 396**

# Quantum Diffusion Models for HEP

**Auteur:** Amir Azzam[1]

[1] *PhD stdudent*

Diffusion models have recently emerged as powerful generative tools, capable of learning and synthesizing high-dimensional data distributions. In high-energy physics (HEP), these models provide an innovative route to address complex inverse problems—most notably, reconstructing the true particle-level signals from detector-smeared measurements. Traditional unfolding methods, which attempt to invert detector effects, often struggle with high-dimensional correlations and tend to depend on strong prior assumptions. In contrast, diffusion models employ an iterative denoising process that transforms random noise into samples drawn from the target distribution, thereby naturally capturing the intricate structures and uncertainties of HEP data. This inherent flexibility positions diffusion models as promising candidates for both simulating realistic detector responses and enhancing analysis techniques for precise signal recovery.
In our approach, we propose to harness the potential of analog quantum computing to construct a quantum diffusion framework. This framework is designed to emulate the iterative denoising process of classical diffusion models within a quantum setting, leveraging the analog quantum system's natural ability to perform continuous transformations and process complex, high-dimensional data. Central to our method is Quantum Reservoir Computing (QRC), which utilizes the rich, nonlinear dynamics of a high-dimensional quantum reservoir to effectively denoise noisy inputs.
We study the impact of channeling the data through this reservoir, and we anticipate that the quantum system can filter out unwanted noise requiring fewer denoising steps and simpler network architectures compared to classical approaches.

**Secondary track**:

**T04 / 397**

# Factorization and virtuality evolution of jets in QCD medium

**Auteurs:** Carlos Lamas Rodríguez[None]; Carlos Salgado[1]; Bin Wu[2]

[1] *Universidade de Santiago de Compostela*

[2] *IGFAE, Universidade de Santiago de Compostela*

**Auteur correspondant** bin.wu@usc.es

We discuss factorization of jet cross sections in heavy-ion collisions. First, using Glauber modelling of heavy nuclei, a factorized formula for jet cross sections is derived, which involves defining a virtuality-dependent jet functions in QCD medium. Then, we generalize the BDMPS-Z formalism to evaluate the jet function initiated by a parton with virtuality $m_J^2$. At the end, we disucss the interplay between vacuum-like and medium-induced radiation in the evoluton of jets at fixed order.

**Secondary track**:

**T03 / 398**

# Status, plans, and physics potential of the Hyper-Kamiokande experiment

**Auteur:** Justyna Łagoda[1]

[1] *National Centre for Nuclear Research*

Hyper-Kamiokande is a next-generation underground water Cherenkov detector currently under construction in Japan. Thanks to a fiducial volume more than eight times larger than that of the currently operating Super-Kamiokande, and enhanced detection capabilities, Hyper-Kamiokande is expected to significantly surpass the sensitivities of its predecessors, Super-Kamiokande and T2K.
The project offers a comprehensive and ambitious science program. The experiment will investigate neutrino oscillations, using neutrinos from both natural sources - such as the Sun and cosmic ray interactions in the Earth's atmosphere - and an upgraded, intense neutrino beam produced at J-PARC, for which Hyper-Kamiokande will serve as the far detector. In addition, the experiment will explore neutrinos from astrophysical sources, including galactic core-collapse supernovae and the diffuse supernova neutrino background (relic supernova neutrinos). Hyper-Kamiokande will also conduct searches for rare processes such as proton decays.
The talk will provide an overview of the Hyper-Kamiokande experiment, including its design, physics goals, projected sensitivities, and current status.

**Secondary track**:

**T12** / **399**

# Inclusive flavour tagging at LHCb

**Auteur:** LHCb Collaboration[None]

We present a new algorithm for tagging the production flavour of neutral $B^0$ and $B_s^0$ mesons in proton-proton collisions. It is based on a deep neural network, DeepSets, and exploits a comprehensive set of tracks associated with the hadronization process. The algorithm is calibrated on data collected by the LHCb experiment at a centre-of-mass energy of 13 TeV. This inclusive approach enhances the flavour tagging performance beyond the established same-side and opposite-side tagging methods.The gains in tagging power offer significant benefits for precision measurements of $CP$ violation and mixing in the neutral $B$ meson systems.

**Secondary track**:

T07 - Flavour Physics and CP Violation

**Joint T02+T09** / **400**

# How LHCb is shedding light on the existence of dark sector portals

**Auteur:** LHCb Collaboration[None]

Although suggested by cosmological and astrophysical observables, no dark matter candidate has been observed to date. Potential mediators between the visible and dark sectors are receiving more and more attention since they offer the opportunity of discovering the nature of dark matter at collider experiments. The LHCb experiment, originally built for $b$- and $c$-physics, has proven to be uniquely sensitive to low-mass resonances. A focus is set on the search for Dark Photons in leptonic decays, hidden-sector bosons, and the newly published search for axion-like-particles. The prospects for those searches with the large Run 3 dataset will be shown as well.

**Secondary track**:

T02 - Dark Matter

**T11** / **401**

## Characterization of the Electronic Noise in the Readout of Resistive Micromegas in the High-Angle Time Projection Chambers of the T2K Experiment

**Auteurs:** David Henaff[1]; Denis Calvet[2]; Jean-Francois LAPORTE[3]; Philippe Schune[4]; Shivam Joshi[5]; samira Hassani[6]

[1] *DPhP, CEA*

[2] *IRFU CEA Paris -Saclay*

[3] *CEA*

[4] *CEA-Saclay, IRFU*

[5] *CEA Saclay / IRFU / DPhP*

[6] *IRFU-SPP/CEA Saclay*

T2K is a long-baseline neutrino oscillation experiment that utilizes a beam of muon neutrinos or antineutrinos produced at the Japan Particle Accelerator Research Centre (J-PARC). To fully capitalize on J-PARC's enhanced beam intensity, T2K's ND280 near detector has been upgraded with three new sub-detectors: a high-granularity detector composed of two million scintillating cubes, time-of-flight detectors, and two time-projection chambers.

The time-projection chamber readout employs innovative Micromegas resistive chamber technology, where the anode consists of a resistive layer that diffuses charge after amplification. The diffused charge is read via capacitive coupling through a layer of metal pads positioned beneath the resistive anode. These pads are connected to custom electronics based on AFTER chips.

A detailed physical model has been developed to describe the signal formation in resistive Micromegas, incorporating primary ionization, charge diffusion during drift, charge diffusion on the anode, and the response of the electronics. We will briefly introduce this model and highlight some of its key applications. In this context, we will present a thorough characterization of the readout chain noise and its modeling (arXiv:2504.07759). This modeling enables Monte Carlo simulations of noise to study systematic effects in signal processing. The developed model accurately reproduces the observed noise, and the resulting Monte Carlo simulations show excellent agreement with experimental data.

**Secondary track**:

**T03** / **402**

## First results from LEGEND-200: searching for neutrinoless double beta decay in $^{76}$Ge

**Auteur:** Giovanna Saleh[1]

[1] *University & INFN Padova, University of Zurich*

Neutrinoless double beta decay ($0\nu\beta\beta$) is a rare process which could take place if neutrinos are Majorana fermions. Its discovery would not only shed light on the nature of neutrinos, but would also provide unambiguous evidence for the existence of new Physics Beyond the Standard Model, as it entails a two unit lepton number violation.

The LEGEND Experiment (Large Enriched Germanium Experiment for Neutrinoless $\beta\beta$ Decay) searches for $0\nu\beta\beta$ employing active HPGe detectors enriched beyond 86% in $^{76}$Ge. LEGEND's experimental program is articulated in two phases: LEGEND-200, currently ongoing, and LEGEND-1000, the next generation development.

LEGEND-200 started operating in 2023 at Laboratori Nazionali del Gran Sasso (LNGS) and ran in a stable physics data taking regime for about one year with 142 kg of detectors installed. With a target background index of $2 \cdot 10^{-4}$ counts/(keV kg yr) at $Q_{\beta\beta}$ = 2039 keV and a final exposure of 1 ton·yr, LEGEND-200 aims to reach a $3\sigma$ discovery sensitivity for a $0\nu\beta\beta$ half-life of $10^{27}$ yr.

In this contribution, the LEGEND-200 experiment will be presented, with a focus on its current status and on the results obtained with the first year of data.
In particular, the employed analysis routines will be introduced, the signal identification and background suppression performance will be discussed, and the background appearing in the region of interest around $Q_{\beta\beta}$ will be analyzed. Finally, a first LEGEND-200 $0\nu\beta\beta$ half life estimate will be presented, together with a joint GERDA + MJD + LEGEND-200 result.

This work is supported by the U.S. DOE and the NSF, the LANL, ORNL and LBNL LDRD programs; the European ERC and Horizon programs; the German DFG, BMBF, and MPG; the Italian INFN; the Polish NCN and MNiSW; the Czech MEYS; the Slovak RDA; the Swiss SNF; the UK STFC; the Canadian NSERC and CFI; the LNGS and SURF facilities.

**Secondary track**:

**T15** / **403**

## Quantum sensor R&D for particle physics: the DRD5 collaboration

**Auteurs:** DRD5 Collaboration[None]; Michael Doser[1]

[1] *CERN*

In the context of the ECFA detector roadmap, several collaborations have been formed with a view towards carrying out the necessary detector R&D for future particle physics experiments. Among these, the DRD5 collaboration focuses on R&D on quantum sensors and related topics, specifically working along five technological axes (Quantum systems in traps and beams; Low-dimensional quantum materials; Superconducting quantum devices; Macroscopic scaled-up quantum systems; Quantum techniques for sensing) and one overarching capacity-developing axis. This presentation will give an overview with examples of the range of DRD5's activities and goals and will highlight its relevance to both low and high energy particle physics.

**Secondary track**:

**T03** / **404**

## Latest results of the DSNB search at Super-Kamiokande

**Auteur:** Rudolph Rogly[1]

[1] *CNRS*

'DSNB'stands for Diffuse Supernova Neutrino Background, i.e. the continuous flux of neutrinos and antineutrinos emitted by all core-collapse supernovae (CCSNe) that have occurred in the observable universe. This elusive signal has yet to be observed and, with an estimated rate of ~1 Hz of CCSNe in the universe, it bears information on e.g. the explosion mechanism of supernovae, intrinsic neutrino properties, or the star and black hole formation history of the universe.
The detection of this signal is a primary step to accessing this rich phenomenology and is one of the main goals of the Super-Kamiokande (SK) experiment. Owing to its 39.3 m x 41.4 m tank filled with 50 kton of water, few DSNB electron antineutrinos are expected to interact in the fiducial volume

via the inverse beta decay (IBD) channel. Since 2020, the DSNB search is a flagship program of the so-called SK-Gd experiment, that has been loading the water of the SK tank with gadolinium (Gd) in order to enhance the detection capability of the delayed signal stemming from the capture of the IBD neutron. To capitalize on the enhanced capability of this detector upgrade, a continuous effort is also deployed in refining the reconstruction routines to better discriminate signal from background. In this talk, we propose to review all these efforts and report the latest hints for the DSNB signal at SK since 2021 and the analysis of the data of the pure water phase, with in particular a 2.3 sigma rejection of the no-DSNB hypothesis.

**Secondary track**:

**T08** / **405**

## Precise predictions for $b\bar{b}H$ production at the LHC

**Auteur:** Aparna Sankar[1]

[1] *TUM*

With the growing precision of experimental measurements, combining fixed-order perturbative calculations with parton-shower effects becomes essential for an accurate description of LHC phenomenology. In this talk, we present novel calculations of Higgs production in association with bottom quarks ($b\bar{b}H$), computed at NNLO accuracy and matched to parton showers (NNLO+PS), using the MiNNLOPS method. We consider both the five-flavor scheme (5FS) with massless bottom quarks and the four-flavor scheme (4FS) with massive bottom quarks. We provide a detailed comparison of the two schemes and their respective predictions. And we show that NNLO corrections in the 4FS solve the long-standing issue of discrepancies between 4FS and 5FS predictions. Possible approaches to consistently combine 4FS and 5FS NNLO+PS predictions in the future at the fully exclusive level will also be discussed.

**Secondary track**:

**T02** / **406**

## GeV scale strongly-interacting dark sectors at beam dump experiments

**Auteur:** Nicoline Hemme[1]

**Co-auteurs:** Elias Bernreuther [2]; Felix Kahlhoefer [3]; Suchita Kulkarni [4]

[1] *KIT*

[2] *University of California San Diego*

[3] *Karlsruhe Institute of Technology*

[4] *Graz University*

A natural dark matter candidate in many theories of strongly-interacting dark sectors is the dark pion $\pi_D$, which is a composite particle that is expected to have a mass close to or below the GeV scale. In many cases, these theories also contain a light vector meson, $\rho_D$ , that can be produced together with dark pions through dark showers created in particle collisions. Cosmological and astrophysical arguments favor the scenario $m_{\rho_D} < 2m_{\pi_D}$, which implies visible decays of the $\rho_D$ mesons and makes the model testable at accelerators. In this talk I will show that beam-dump experiments sensitive to feebly-interacting long-lived particles can be a valuable tool for probing such strongly-interacting dark sectors and present the projected sensitivity of the upcoming SHiP experiment.

**Secondary track**:

**Poster T03** / **407**

## Electromagnetic shower reconstruction in the ICARUS liquid argon time projection chamber detector

**Auteur:** Riccardo Triozzi[1]

[1] *University of Padova & INFN Padova*

The ICARUS-T600 liquid argon time projection chamber (LArTPC) detector is taking data at shallow depth as the far detector of the Short Baseline Neutrino (SBN) program at Fermilab, to search for a possible sterile neutrino signal at $\Delta m^2 \approx 1$ eV$^2$ with the Booster (BNB) and Main Injector (NuMI) neutrino beams at $\sim 0.8$ GeV and $\sim 2$ GeV average energies respectively.

The LArTPC technology, developed by the ICARUS collaboration and now a standard in neutrino physics, offers impressive charged-particle imaging capabilities with $\sim 1$ mm spatial resolution, enabling efficient discrimination between track-like signatures (e.g., from muons, pions, and protons) and electromagnetic showers (from electrons and photons). Moreover, electron and photon signatures can be distinguished both with the calorimetric measurement of local energy depositions at the shower start and with the cm-scale conversion gap signature of photons.

This contribution discusses event reconstruction at ICARUS focusing on Pandora, a multi-algorithm pattern recognition software widely used in LArTPC experiments.
Over a hundred Pandora algorithms and tools are used to reconstruct cosmic rays and neutrino interactions in the ICARUS detector. Recent developments have focused on the reconstruction of electromagnetic shower signatures, crucial to ensure a robust and efficient reconstruction of charged-current $\nu_e$ interactions, which serve as a key signature of sterile neutrino oscillations at SBN.
In this contribution, recent improvements to the reconstruction are discussed, focusing on the discrimination between tracks and electromagnetic showers using neutrino simulations and data.

**Secondary track**:

**T09** / **408**

## Diquark scalar production of a vectorlike quark pair at the LHC

**Auteur:** Ioana Duminica[1]

**Co-auteurs:** Bogdan Dobrescu [2]; Calin Alexa [3]; Ioan-Mihail Dinu [3]; Matei-Stefan Filip [4]

[1] *University of Bucharest*

[2] *Fermilab*

[3] *IFIN-HH*

[4] *IFIN-HH and University of Bucharest*

We study the discovery potential of LHC experiments for resonantly produced vectorlike quarks ($\chi$), when the s-channel resonance is an ultraheavy diquark scalar particle ($S_{uu}$) of mass in the $7 - 8.5$ TeV range. Given that the $S_{uu}$ resonance can be reconstructed when both $W^+$ bosons decay hadronically, we focus on the 6-jet final state arising from the $pp \to S_{uu} \to \chi\chi \to (W^+b)(W^+b)$ process. The signal selection study is done by employing Machine Learning algorithms to construct a multidimensional signal-from-background discriminator. Our results indicate that ATLAS or CMS searches in the above 6-jet final state with a luminosity of 3000 fb$^{-1}$ may discover or rule out a diquark scalar of mass near 8 TeV even when its yukawa coupling to up quarks is as small as $y_{uu} \approx 0.2$. We also discuss preliminary results on the 4-jet final state of $pp \to S_{uu} \to u\chi \to u(W^+b)$.

**Secondary track**:

**T09** / **409**

## Froggatt-Nielsen ALP

**Auteur:** Alessandro Valenti[1]

[1] *University of Basel*

Froggatt-Nielsen models typically predict the existence of a light axion-like particle, pushing the new dynamic to a very high scale.
In this talk I will focus on models based on $Z_N$ discrete symmetries, which are counterexamples in which the new scale might in fact be much lower.
I will first chart the allowed parameter space from a set of theoretical considerations, and then focus on a minimal model based on $Z_4$ symmetry. For this, I will introduce an explicit renormalizable UV completion and study the model's phenomenology in detail, highlighting the interplay between the effects of the ALP and of the UV fields.

**Secondary track**:

**Poster T16** / **410**

## Real-time muon identification in CMS L1 Trigger using FPGA-based graph neural networks

**Auteurs:** Andrea Cardini[1]; Pelayo Leguina[2]; Santiago Folgueras[3]

[1] *Deutsches Elektronen-Synchrotron DESY*

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[3] *Universidad de Oviedo*

**Auteur correspondant** pelayo.leguina.lopez@cern.ch

The Overlap Muon Track Finder (OMTF) is a key subsystem of the CMS L1 Trigger, identifying muon tracks in the transition region between the barrel and the endcap. For the Phase-2 upgrade, we are exploring new approaches and leveraging machine learning (ML) to enhance its performance. In this project, we focus on integrating a Graph Neural Network (GNN) to improve the OMTF's ability to accurately determine the transverse momentum and position of muons. Starting with an existing GNN model built with PyTorch, we carefully design and fine-tune each layer to ensure it runs efficiently on hardware. By converting the GNN from its original high-level framework to High-Level Synthesis (HLS), we can deploy it on specialized FPGA architectures, specifically using Xilinx UltraScale+ FPGAs housed in ATCA boards. Additionally, there is a proposal of implementing the same design on the AI cores of a Xilinx Versal ACAP device, aiming to compare the performances of both implementations. This adaptation transforms the model's graph-based calculations into parallel hardware processes, meeting the real-time processing needs of the trigger system. Future tests are planned to demonstrate that the HLS-converted GNN can maintain the original model's accuracy while providing the necessary speed and performance required for the CMS detector's operations, as well as exploring the AI capabilities of the Versal device.

**Secondary track**:

T11 - Detectors

**T12 / 411**

## Accelerating MC simulations using FPGAs and ACAPs

**Auteurs:** Alberto Valero[1]; Carlos Vico[2]; Francisco Hervás[1]; Hector Gutierrez[1]; Luca Fiorini[1]; Pelayo Leguina[2]; Santiago Folgueras[3]

[1] *Univ. of Valencia*

[2] *University of Oviedo*

[3] *Universidad de Oviedo*

The ever-increasing need of event generation in particle physics that is required by physics analysis of the LHC data requires innovative techniques to reduce both time and power consumption. We present a study to demonstrate the use of FPGAs and ACAPs to accelerate event generation using MadGraph. We evaluate the performance in terms of the execution time and the power consumption, as the tested devices have a potential of reducing both when compared to other acceleration hardware such as GPUs. The inherent complexity of high-precision event generation suggests that not all the acceleration is well-suited for FPGAs, however certain calculations may benefit from the use of these technologies. Experimental evaluation is ongoing, but preliminary assessments suggest a promising results compared to CPU/GPUs implementations. This potential improvement could enable the execution of more complex simulations within shorter time frames.

**Secondary track**:

T13 - Accelerators for HEP

**T01 / 412**

## Overview of the Cosmic Ray studies with the KM3NeT detectors

**Auteurs:** Andrey Romanov[1]; KM3NeT Collaboration[None]

[1] *LPC-Caen*

The KM3NeT Collaboration is currently deploying two neutrino telescopes deep in the Mediterranean Sea. Both detectors share the same technology but are different in their size due to their different physics goals. The KM3NeT/ARCA telescope is located at about 3.5 km depth off-shore Sicily, Italy, while KM3NeT/ORCA is at about 2.5 km depth close to Toulon, France. The detectors are currently taking data while being under construction with 33 and 24 lines installed at the ARCA and ORCA sites, correspondingly. Down-going atmospheric muons produced in the cosmic ray air showers are the vast majority of the reconstructed events in KM3NeT. The measurement of the properties of such muons allows for probing cosmic ray interactions and composition in the phase space complementary to the ground-based observatories. Moreover, atmospheric muons are used for calibration purposes in KM3NeT. In this contribution, the current status of the cosmic ray studies with KM3NeT is presented and its perspectives are discussed.

**Secondary track**:

T03 - Neutrino Physics

**T01 / 413**

## Unique Properties of Cosmic Rays measured by the Alpha Magnetic Spectrometer

**Auteurs:** AMS Collaboration[None]; Zhaomin Wang[1]

[1] *Shandong Institute of Advanced Technology*

We present high-precision measurements of cosmic ray nuclei spectra spanning elements from Z=1 (protons) through Z=20 (calcium), and including Z=26 (iron) and Z=28 (nickel), as measured by the Alpha Magnetic Spectrometer. The analysis reveals new properties concerning both primary and secondary cosmic rays, with particular emphasis on their distinctive spectral structures. These findings provide significant insights into cosmic ray origin, acceleration mechanisms, and propagation through the interstellar medium.

**Secondary track**:

**Poster T03 / 414**

## Searches for physics beyond SM at DANSS

**Auteurs:** DANSS Collaboration[None]; Mikhail Danilov[None]

In a search for Large Extra Dimensions (LED) the best fit point in a model with one large LED has a statistical significance of 2 standard deviations only. Therefore, no statistically significant evidence for LED was found. The established upper limits on the model parameters (the size of the extra dimension and the mass of the lightest neutrino) are the best in the world in some areas. They exclude a large fraction of parameters preferred by the LED interpretation of the Gallium anomaly and Reactor anomaly including the best fit points. The limits are based on the comparison of the Inverse beta decay spectra at 10.9 and 12.9 meters from the reactor core center. Therefore, they do not depend on the assumptions about the reactor antineutrino spectrum. Searches for sterile neutrinos were updated using additional 1 million of neutrino events. Limits obtained in a model independent way exclude practically all sterile neutrino parameters preferred by the recent BEST results for $m^2$ below 5 $eV^2$. Using model predictions for the neutrino flux DANSS excludes practically the whole sterile neutrino parameter space preferred by the BEST experiment. The Inverse Beta Decay(IBD) spectrum dependence on the 239Pu fission fraction is presented. It agrees with the predictions of the Huber-Mueller model. Using this dependence, the ratio of cross sections for 235U and 239Pu was extracted. It also agrees with the Huber-Mueller model and somewhat larger than in other experiments. The reactor power was measured using the IBD event rate during 7.5 years with a statistical accuracy of 1.0% in a week and with the relative systematic uncertainty of less than 0.8%. The fraction of the reactor antineutrino yield with energies above 10 MeV was measured. Such antineutrinos are important for searches of neutrino coherent scattering. Fission fractions of 239Pu and 235U during reactor campaigns were measured using a fit of the IBD positron spectra. Antineutrino spectra from 239Pu and 235U were reconstructed.

**Secondary track**:

**T01 / 415**

## X-ray polarization from astrophysical sources. Development and early results of a large vol-ume Time Projection Chamber (TPC) from HypeX project

**Auteur:** Giorgio Dho[1]

[1] *INFN - LNF*

X-ray polarimetry is an observational technique with the potential to enrich our understanding of high-energy astrophysics by enabling the measurement of the polarization of X-rays emitted by exotic cosmic phenomena such as black holes, neutron stars, Gamma-Ray Bursts and more. This technique provides crucial insights into the magnetic field geometries, intensities, and emission mechanisms of these sources, offering valuable in-formation that could improve the current knowledge of these astrophysical objects significantly.
Currently, the IXPE space observatory, which features a photoelectric polarimeter with an active volume of 6.75 cm3, is the only instrument providing X-ray polarimetric measurements, in the range from 2 to 8 keV. The Xray-CMOS subproject of the PRIN project "HypeX: High Yield Polarimetry Experiment in X-rays", developed by a collaboration of GSSI, INFN and INAF researchers, aims to apply more modern experimental techniques for applications in X-ray polarization measurements in the energy range between 8 and 40 keV. Xray-CMOS subproject inherits the knowhow and detector concept from the CYGNO/INITIUM directional dark matter experiment optimizing it to the photoelectric polarization measurement. The technology, a TPC with triple-GEM amplification stage and optical readout exploiting the sensitivity and granularity of sCMOS cameras and PMTs, aims to achieve 3D reconstruction of photoelectrons and an active volume significantly larger—about 100 times—than the current state of the art. The prototype TPC, with a cylindrical active vol-ume of radius of 3.7 cm and height of 6 cm, was employed in several tests at the INAF-IAPS calibration facility in Rome, Tor Vergata. The aim was to assess the instrument's sensitivity to low-energy X-ray polariza-tion and optimize parameters such as gas mixtures, amplification structures, and detector geometry. I will show the results of these data campaigns where we achieved complete reconstruction of photoelectrons in the 8-60 keV range with angular resolutions down to 15°. In addition, I will talk about the first measurements with a polarized X-rays beam which suggested modulation factors above 0.35 are possible at 17 keV.

**Secondary track**:

T11 - Detectors

**T16 / 416**

## Hyperparameter Optimisation in Deep Learning from Ensemble Methods: Applications to Proton Structure

**Auteur:** Roy Stegeman[1]

[1] *The University of Edinburgh*

Deep learning models are defined in terms of a large number of hyperparameters, such as network architectures and optimiser settings. These hyperparameters must be determined separately from the model parameters such as network weights, and are often fixed by ad-hoc methods or by manual inspection of the results. An algorithmic, objective determination of hyperparameters demands the introduction of dedicated target metrics, different from those adopted for the model training. Here we present a new approach to the automated determination of hyperparameters in deep learning models based on statistical estimators constructed from a ensemble of models sampling the underlying probability distribution in model space. This strategy requires the simultaneous parallel training of up to several hundreds of models and can be effectively implemented by deploying hardware accelerators such as GPUs. As a proof-of-concept, we apply this method to the determination of the partonic substructure of the proton within the NNPDF framework and demonstrate the robustness of the resultant model uncertainty estimates. The new GPU-optimised NNPDF code results in a speed-up of up to two orders of magnitude, a stabilisation of the memory requirements, and a reduction in energy consumption of up to 90\% as compared to sequential CPU-based model training. While focusing on proton structure, our method is fully general and is applicable to any deep learning problem relying on hyperparameter optimisation for an ensemble of models.

**Secondary track**:

**T04 / 417**

## Probing bottom quark mass effects in jet substructure with CMS using a novel technique to cluster the b-hadron decays

**Auteur:** CMS Collaboration[None]

The study of jet substructure has given rise to a new era of precision quantum-chromodynamics (QCD) measurements related to the evolution of the parton shower. In order to better understand the role of the quark mass, the decay kinematics of the heavy flavor hadrons need to be isolated from the QCD branchings. This talk presents new CMS results on the groomed jet radius Rg and momentum balance zg of bottom quark jets (b jets) in proton-proton collisions by employing a novel technique that partially reconstructs the b hadron from its charged-particle decay daughters. This approach provides direct access to the dead cone of the b quark for the first time. The jet fragmentation function, defined as the fraction of the charged-particle component of the transverse momentum of the jet held by the partially reconstructed be hadron is also presented. The results are compared to predictions from two Monte-Carlo generators, which show varying degrees of agreement.

**Secondary track**:

T05 - QCD and Hadronic Physics

**T04 / 418**

## First measurement of Top quark pair production in Run3 PbPb collisions at 5.36 TeV with CMS

**Auteur:** CMS Collaboration[None]

The production of top quarks in heavy ion collisions serves as a novel tool for investigating nuclear parton distribution functions at high Bjorken-x. Although being a quark, the top has a short lifetime, decaying predominantly to a W boson and b quark pair, before hadronizing. Leptonic final states from the subsequent W boson decay are thus effectively electroweak probes of the medium they traverse before reaching the detector. The CMS collaboration has reported evidence of top quark pair ($\mathrm{t\bar{t}}$) production using data from lead-lead (PbPb) collisions during Run 2. This talk will present the first measurement of $\mathrm{t\bar{t}}$ production utilizing $1.63\ \mathrm{nb}^{-1}$ of PbPb data collected by CMS at 5.36 TeV in 2023 and derived using kinematic variables from leptons and jets.

**Secondary track**:

**T05 / 419**

## Production of heavy flavours at CMS

**Auteur:** CMS Collaboration[None]

Recent CMS results on production of heavy hadrons is presented, including the measurement of total charm cross section in pp collisions at 7 TeV and the observation of simultaneous production of Y(1S) meson and Z boson in pp collisions at 13 TeV.

**Secondary track**:

**T06 / 420**

## First evidence of ZZγ triboson production

**Auteur:** CMS Collaboration[None]

Observation of the electroweak production of four charged leptons and a photon, and first evidence at the LHC for the triboson process ZZγ with the fully leptonic decays of the Z-bosons using pp collision data collected by the CMS experiment during the LHC Run 2 at 13 TeV, corresponding to an integrated luminosity of 138 /fb.

**Secondary track**:

**T09 / 421**

## Searches for New Resonances in CMS

**Auteur:** CMS Collaboration[None]

The quest for new physics is a major aspect of the CMS experimental program. This includes a myriad of theoretical models involving resonances that can decay to massive bosons, photons, leptons or jets. This talk presents an overview of such analyses with an emphasis on new results and the novel techniques developed by the CMS collaboration to boost the search sensitivity. The searches are carried out with data of the Run-II and Run-III of the LHC in proton-proton collisions with the CMS detector.

**Secondary track**:

**T01 / 423**

## Origin of Cosmic Positrons and Electrons in the TeV Region

**Auteur:** Dimitrii Krasnopevtsev[1]

[1] *Massachusetts Inst. of Technology (US)*

The precision measurements of the cosmic-ray positron and electron fluxes collected by the Alpha Magnetic Spectrometer on the International Space Station are presented. The positron flux exhibits complex energy dependence. It is described by the sum of a term associated with the positrons produced in the collision of cosmic rays, which dominates at low energies, and a new source term, which dominates at high energies and is associated with either dark matter or an astrophysical origin. The positron source term also manifests itself in the measured electron spectrum. This is the first indication of the existence of an identical charge symmetric source term both in the positron and in the electron spectra and, as a consequence, the existence of new physics.

**Secondary track**:

**Poster T04 / 424**

## Probing QCD collectivity at the smallest scale through high multiplicity jets in pp at CMS

**Auteur:** CMS Collaboration[None]

Recent CMS data revealed intriguing long-range correlations within high-multiplicity jets produced in proton-proton collisions, suggesting the potential onset of collective behavior, typically associated with heavy-ion collisions, at much smaller scales. Two-particle correlations in the “jet frame”show a surprising rise in elliptic flow harmonics, v2*, at large pseudorapidity separations (*$\Delta\eta > 2$), in jets with high charged-particle multiplicities, a trend not reproduced by event generators like Pythia and Sherpa. In this talk, we present new measurements on the long-range near-side correlations in the jet frame, along with the transverse momentum and $\Delta\eta^*$ dependence of elliptic and triangular flow, across a wide range of jet multiplicity and transverse momentum. We further explore the role of jet substructure in driving the observed long-range azimuthal correlations. By selecting jets exhibiting prominent two-prong structures and comparing the results with models incorporating final-state rescatterings, we investigate the potential connection to the geometry of the initial-state jet system. These results offer fresh insights into collective effects at the smallest scales, potentially reshaping our understanding of QCD dynamics in its nonperturbative regime.

**Secondary track**:

**T01** / **425**

## Effect of the spatial curvature on light bending and time delay in a curved Einstein-Straus–de Sitter spacetime

**Auteur:** Mourad Guenouche[1]

[1] *Laboratoire de Physique Théorique, Université Constantine 1, Algeria, and Département Sciences de la Matière, Université de Khenchela, Algeria.*

**Auteur correspondant** guenouche_mourad@umc.edu.dz

A method of general applicability has been developed, whereby the null geodesic equations of the Einstein-Straus-de Sitter metric can be integrated simultaneously in terms of the curvature constant k. The purpose is to generalize the computation of light deflection and time delay by a spherical mass distribution. Assuming a flat Universe with most recent measurements of the Hubble constant $H_0$ and the cosmological constant $\Lambda$, five time delays between four bright images of the lensed quasar SDSS J1004+4112 have been forecasted and compared to others in the field, $\Delta t_{DC}=(3250\pm64)$days (8.90yr ), $\Delta t_{DA}=2049_{-58}^{+59}$days (5.61yr ), $\Delta t_{AC}=(1269\pm77)$days (3.47yr ), $\Delta t_{BC}=1176_{-77}^{+78}$days (3.22yr ), and $\Delta t_{AB}=(93\pm70)$days . This set of time delays constrains the galaxy cluster mass to be $M=(2.447\pm0.73)\cdot10^{13}M_{\boxtimes}$. In addition, I have reviewed the question of the possible contribution of a positive $\Lambda$ to reduce the light bending and concluded that the changes are seemingly too small to be appreciable on cosmological scale. The same conclusion has been reached regarding the time delay. Having addressed the question of the effect of spatial curvature in both closed and open Universe, I have found that the strong lensing is slightly affected by the expected small curvature density $\Omega_{k0}$ of the current Universe within its error bar $|\Omega_{k0}|\circledcirc0.001$, in such a way that it may safely be neglected. However, it’s only if $\Omega_{k0}$ gets quite larger that the effect being noticeable. While it is only theoretically possible for $\Omega_{k0}$ to be higher, it’s worthwhile to stress that this should impact the light bending and time delay, causing them to decrease or increase depending upon whether the spatial curvature is positive or negative. Furthermore, one can infer that the observed light deflection and time delay independently, which are found to be significantly deviated from from those of the flat Universe, may serve as a useful means to provide constraints on $\Omega_{k0}$, thus making the approach employed in this work more promising than others.

**Secondary track**:

**T05** / **426**

## Studies of N3LO Fits to DIS Data Using xFitter

**Auteurs:** Alexander Glazov[1]; Developer xFitter[None]

[1] *DESY*

We investigate the impact of recently computed N3LO corrections to QCD splitting and DIS coefficient functions on global fits of parton distribution functions (PDFs) using the xFitter framework. By comparing fits performed at different perturbative orders, we analyze the modifications introduced to PDFs and their associated uncertainties, incorporating correlated experimental errors. Additionally, the effects of various approximations for splitting functions are assessed, providing a basis for estimating theoretical uncertainties. The results show the importance of the N3LO corrections and the need for further theoretical refinement in the low-x regime.

**Secondary track**:

**T05** / **427**

# Conventional and exotic heavy quarkonium production and spectroscopy in ATLAS

**Auteur:** ATLAS Collaboration[None]

This talk will present recent results from the ATLAS experiment on measurements of the production of charmonium states and studies of heavy-flavour states spectroscopy, including that of exotic quarkonium.

**Secondary track**:

**Joint T06+T08** / **428**

# EFT results in the top sector with the ATLAS detector

**Auteur:** ATLAS Collaboration[None]

Many-parameter fits to precise measurements in the framework of the Standard Model Effective Field Theory are becoming a standard interpretation of LHC and other collider data. In this contribution an overview is given of state-of-the-art EFT interpretations in ATLAS with particular emphasis on results in the top quark sector.

**Secondary track**:

**T07** / **429**

# Heavy flavour production and decay in ATLAS

**Auteur:** ATLAS Collaboration[None]

This talk will present the recent results from ATLAS experiments on open-charm meson production measurements and various studies of b hadron decays, including the most precise measurement of the $B^0$ lifetime.

**Secondary track**:

**T06** / **430**

## Measurements at the ttbar threshold with the ATLAS detector

**Auteur:** ATLAS Collaboration[None]

The exceptionally large dataset collected by the ATLAS detector at the highest proton-proton collision energies provided by the LHC enables precision testing of theoretical predictions using an extensive sample of top quark events. This wealth of data has opened the door to new measurements of top quark properties including those particularly sensitive to the ttbar threshold region, such as quantum entanglement, which were previously beyond reach. This contribution presents the latest highlights in this area from the ATLAS top quark physics.

**Secondary track**:

**T04** / **431**

## Observation of top-quark pair production in heavy-ion collisions with the ATLAS detector

**Auteur:** ATLAS Collaboration[None]

Measurements of top-quark pairs in heavy-ion collisions are expected to provide novel probes of nuclear parton distribution functions as well as to bring unique information about the time evolution of strongly interacting matter. We report the observation of top-quark pair production in proton-lead collisions at the centre-of-mass energy of 8.16 TeV in the ATLAS experiment at the LHC. Top-quark pair production is studied in the lepton+jets and dilepton channels, and the nuclear modification factor is measured for the first time for the top-quark pair process. Also, the first observation of top-quark production in Pb+Pb collisions at the centre-of-mass energy of 5.02 TeV is presented. Top-quark pair production is measured in the eμ channel, with a significance of 5.0 standard deviations. The results are compared to theory predictions based on different nuclear PDF sets.

**Secondary track**:

**T04** / **432**

## Tau-lepton pair production via di-photon fusion in ultra-peripheral heavy-ion collisions at the ATLAS detector

**Auteur:** ATLAS Collaboration[None]

In ultra-relativistic heavy-ion collisions, high rates of $\gamma\gamma$ processes occur through the interaction of the large electromagnetic fields of the heavy nuclei. For large impact parameters between the nuclei, i.e. interaction distances larger than the nuclei's radii, the di-photon interaction can be the only one taking place, leading to very clean signatures in the detector. One of the possible signatures in these ultra-peripheral collisions (UPCs) is the production of a $\tau$-lepton pair. The outgoing $\tau$-leptons are back-to-back in the transverse plane, which allows a precise and efficient identification. Processes beyond the Standard Model (BSM) can influence the production cross sections for this process, through modifications of the $\gamma\tau\tau$-vertex, allowing to probe for and constrain their existence. This talk presents the most recent measurement of di-$\tau$ production in UPC-events at a centre-of-mass energy of 5.02 TeV, performed using data from the second running period (Run 2) of the Large Hadron Collider (LHC) and recorded with the ATLAS detector. Using final states where one of the $\tau$-leptons decays involving a muon, fiducial differential cross sections for $\gamma\gamma \to \tau\tau$ production are measured for the first time and compared to currently most advanced theory predictions. Constraints on the

electromagnetic moments of the $\tau$-lepton which influence the $\gamma\tau\tau$ vertex contained in $\gamma\gamma \to \tau\tau$ production are extracted and the implications on BSM contributions discussed.

**Secondary track**:

**T06** / **433**

## Top quark (including associated production) cross section measurements with the ATLAS detector

**Auteur:** ATLAS Collaboration[None]

The exceptionally large dataset collected by the ATLAS detector at the highest proton-proton collision energies provided by the LHC enables precision testing of theoretical predictions using an extensive sample of top quark events. Recent measurements include total and differential top quark cross sections, as well as measurements of associated top quark production. This contribution presents the latest highlights from the ATLAS top quark physics program, including key measurements from Run II, and new results using Run III data.

**Secondary track**:

**T06** / **434**

## Top quark mass and properties with the ATLAS detector

**Auteur:** ATLAS Collaboration[None]

The top-quark mass is one of the key fundamental parameters of the Standard Model that must be determined experimentally. Its value has an important effect on many precision measurements and tests of the Standard Model. The Tevatron and LHC experiments have developed an extensive program to determine the top quark mass using a variety of methods. In this contribution, the top quark mass measurements by the ATLAS experiment are reviewed. These include measurements in two broad categories, the direct measurements, where the mass is determined from a comparison with Monte Carlo templates, and determinations that compare differential cross-section measurements to first-principle calculations. The exceptionally large dataset collected by the ATLAS detector at the highest proton-proton collision energies provided by the LHC also enables precision testing of theoretical predictions using an extensive sample of top quark events. New results on top-quark properties including tests of lepton-flavour universality are also shown.

**Secondary track**:

**T09** / **435**

## Probing BSM with High-Multiplicity Muon Decays

**Auteur:** Ajdin Palavrić[1]

[1] *University of Basel*

We discuss a class of exotic muon decay signatures that extend beyond the well-studied lepton flavor-violating channels such as $\mu \to e\gamma$ and $\mu \to eee$. We focus on rare processes featuring final states with $2m+1$ electrons and $n$ photons, exploring their theoretical origin and experimental relevance.

Our analysis begins in the framework of the Standard Model Effective Field Theory (SMEFT), where we examine the conditions under which an EFT description remains valid for such processes. We then identify the minimal single-particle EFT interactions capable of inducing these decays and investigate explicit ultraviolet completions that give rise to the relevant operators. Finally, we present a simple numerical study assessing the experimental prospects for observing these muon decay channels.

**Secondary track**:

**Joint T12+T16** / **436**

## Faster, more efficient, more robust: the impact of machine learning and AI on LHCb's real-time processing

**Auteur:** LHCb Collaboration[None]

The LHCb experiment has deployed machine learning and artificial intelligence models in its real-time data processing from the start of Run 1 datataking. Contrary to common fears when the LHC was starting up, these models have proven to not only be more powerful than "classical" alternatives but in many cases also more robust to changing detector performance. Their judicious use has also made the real-time processing faster, over time enabling LHCb to deploy its physics-analysis-quality reconstruction in the second stage of its real-time processing. We will describe the development of machine learning and AI models and algorithms within LHCb's real-time community, the early use of quantised machine learning and models which explicitly learned to be insensitive to physics quantities of interest, and place this work in the context of the physics breakthroughs which it has enabled. Looking towards the future, the LHCb collaboration is proposing to build a second upgrade of its detector, an ultimate flavour factory with unparalleled breadth of reach for heavy flavour and forward physics at the LHC. We will sketch the unprecedented challenges this proposal will pose to the real-time reconstruction and selection of physics-quality signals and the ways in which we anticipate machine-learning and AI models playing a central role in allowing LHCb to rise to this challenge.

**Secondary track**:

**T07** / **437**

## Refining Tau Identification with Domain Adaptation Techniques at CMS

**Auteur:** CMS Collaboration[None]

**Auteur correspondant** niki.saoulidou@cern.ch

Hadronically decaying tau leptons are a challenging signature to study given it can be mimicked by quark and gluon jets, electrons, or muons. The identification of this signature via a convolutional neural network performed by CMS during the LHC Run 2 brought a massive improvement with respect to previous strategies. To further improve the identification and reconstruction of hadronic decays of tau leptons, CMS has deployed, as of the start of Run 3, a new algorithm: DeepTau v2.5. This poster presents the performance resulting from these improvements in the network architecture using early Run 3 data and showcases the use of domain adaptation techniques to improve the modelling of data.

**Secondary track**:

**Poster T14 / 439**

## Creating a living archive of an active experiment: the CMS experienc

**Auteur:** CMS Collaboration[None]

**Auteur correspondant** niki.saoulidou@cern.ch

Going through an incredible amount of change right now in preparation for the Hi-Lumi phase of CMS, it is very important to make sure all the work of the collaboration is captured in audiovisual media. To do this for a collaboration of over 6000 people across 250 institutes is a large challenge, but it is essential for future-proofing the history of CMS. In fact, there is more audiovisual information than ever before - it just lives on personal phones, google drives, and the like. In this poster we explore our ongoing campaigns to attempt to capture and preserve the important aspects of the NOW for the future.

**Secondary track**:

**T16 / 441**

## AI and Machine Learning Applications at the Near Detector of the T2K Experiment

**Auteur:** T2K Collaboration[None]

**Co-auteur:** Anaelle Chalumeau

**Auteur correspondant** achalume@lpnhe.in2p3.fr

The T2K experiment has recently started a dedicated AI/ML working group for its Near Detector (ND280) to coordinate and support machine learning applications across its physics program. This talk presents an overview of the current efforts and developments within the collaboration, highlighting how state-of-the-art machine learning techniques are being employed to improve event reconstruction, particle identification, unfolding and systematic modeling.

Several standard machine learning architectures are currently in use or under development, including boosted decision trees, convolutional and sparse neural networks, PointNet, and transformers. These methods are applied to tasks such as PID, electromagnetic shower ID, e/γ separation in the T2K near detector (ND280). Some tools—like a transformer-based PID model—are now fully integrated into the analysis software. More advanced techniques are also described including ML-assisted unfolding with OmniFold and the use of normalizing flows for modeling complex systematic uncertainties. New levels of flexibility and performance, particularly in multidimensional and unbinned contexts, can therefore be reached.

A roadmap for the working group concludes this talk, which includes further integration of ML-models into reconstruction software such as track fitting using RNNs/transformers and vertex activity analysis, as well as finding strategies for systematic uncertainty propagation. Overall, these developments reflect how machine learning algorithms are helping T2K sharpen its tools, pushing further the precision frontier in neutrino physics.

**Secondary track**:

T03 - Neutrino Physics

**T11 / 442**

# CMS Silicon Strip Tracker Performance in Run 3

**Auteurs:** CMS Collaboration[None]; Jindrich Lidrych[1]

[1] *Université Catholique de Louvain*

The CMS tracking system is the world's largest silicon tracker, comprising 1856 pixel and 15148 strip modules. The silicon strip tracker features inner and outer barrel layers, inner discs, and endcaps, which close off the tracker on either end. In this poster, we present the performance of the silicon strip tracker during data taking in LHC Run 3, based on proton-proton collisions at the center-of-mass energy of 13.6 TeV. Key performance metrics as signal-to-noise ratio, hit efficiency and resolution, evolution of bad module components will be shown. The results demonstrate that the tracker maintained excellent performance throughout Run 3, ensuring high-quality tracking crucial for CMS physics analyses.

**Secondary track**:

**T14** / **443**

# Paving the way for Open Data –10 years of releases from CMS

**Auteur:** CMS Collaboration[None]

In November 2014, CMS made history by releasing its first batch of open data, comprising approximately 27 terabytes of proton-proton collision data collected in 2010 at a 7 TeV center-of-mass energy. This groundbreaking release marked the beginning of a new era in particle physics at the LHC, where researchers, educators, and enthusiasts worldwide could access and analyse real collider data. The collaboration has consistently adhered to its policy of making 50% of its analyzable data publicly available after six years of collection; ten years after collection 100% of the data is to be released. This dedication has resulted in the release of nearly 5 petabytes of data, including both real collision data and simulated events. Last year, 10 years after its first release of open data, CMS released over 70 terabytes of 13 TeV collision data from 2016, and 830 terabytes of corresponding simulations. This talk gives an overview of the CMS open data initiative, what is has been used for so far, and where it plans to go in the future.

**Secondary track**:

**T14** / **446**

# Humanising Science through CMS Outreach initiatives

**Auteur:** CMS Collaboration[None]

In the increasingly fragmented media landscape where there is an overload of information reaching any one member of the public, it is a human connection that cuts through. In order for our experiments to speak to people, to keep people engaged in the ongoing process of science, we need to humanise it where possible. In this talk we show how CMS outreach tries to platform a diverse set of people as much as possible, and take our audiences through our journey with us.

**Secondary track**:

**T14** / **447**

## CMS Communications Strategy for external audiences

**Auteur:** CMS Collaboration[None]

Communicating the breadth of research—from fundamental physics to cutting-edge detector upgrades—to non-expert audiences is a key challenge for the 6,000-strong CMS collaboration. Recognizing this, the CMS External Communication team embarked on a comprehensive strategic review - approved by the collaboration last year. Through extensive collaborative sessions, core team members defined key messages, identified target audiences, and evaluated past and ongoing outreach initiatives. This process culminated in the development of a refined communication strategy, encompassing new project proposals and a robust and sustainable framework for mapping and engaging the vast collaboration. This talk will detail the key conclusions of this strategic review, outlining the identified target audiences and the core messages prioritized for public dissemination, and addressing the mechanisms implemented to maintain real-time awareness of various activities. Furthermore, this presentation will showcase the initial results and impact of the implemented changes, highlighting the successes and lessons learned in fostering a more cohesive and impactful communication network for the CMS experiment.

**Secondary track**:

**Poster T03 / 448**

## An alternative approach to the CP effects in neutrino oscillation

**Auteur:** Shao-Hsuan Chiu[1]

[1] *Chang Gung University, Taoyuan, Taiwan*

The elements of a general mass matrix, together with its eigenvalues and that of its submatrices, can be correlated to the squared elements of the mixing matrix, $W = [|V_i|^2]$. It follows that alternative expressions for the Jarlskog invariant $J$ can then be deduced from $W_i$ and the matrix elements of its cofactors, $w_i$, with $w^T W = (detW)I$. The results lead to a straightforward and consistent way of calculating $J$ from rephasing-invariant combinations of $W_i$ and $w_i$. In addition, we also obtain certain invariants consisting of $W_i$ and the eigenvalues of the mass matrix as neutrinos propagate in matter. With a proper parametrization of the matrix $W$, this formulation may be useful in providing hints to the study of leptonic CP effects for neutrino oscillation in matter.

**Secondary track**:

T07 - Flavour Physics and CP Violation

**T03 / 449**

## Recent T2K neutrino-nucleus cross section results

**Auteur:** Xingyu Zhao[1]

[1] *ETH Zurich*

The measurement of CP-violation in the leptonic sector offers an opportunity to probe the physics beyond the Standard Model. Currently this measurement can be achieved by the accelerator long-baseline neutrino experiments like T2K, where the differences between neutrino and antineutrino oscillations are investigated. The oscillation probabilities are measured by comparing the neutrino spectra at the near and far detectors, where the neutrino energies are reconstructed based on the

neutrino-nucleus interactions observed in the detectors. However, the neutrino energy reconstruction is usually biased and smeared due to the nuclear effects which occur during the neutrino-nucleus interactions. These effects contribute to the largest systematic uncertainty in the CP-violation measurement.
In this talk, the latest cross section measurements at the T2K near detector ND280 will be presented. Focus will be put on the CCQE-like interactions where no pion and at least one proton observed in the final state in the detector. The main goal is to probe the nuclear effects. This measurement was performed jointly on the carbon and oxygen targets combining with the double differential transverse kinematic imbalances for the first time. Besides, new measurements of neutrino-nucleus interactions with pion or kaon in the final state will also be shown.

**Secondary track**:

**Poster T03 / 450**

## Status and Prospects of NvDEx, a Se TPC detector for 0n2b decays

**Auteurs:** Emilio Ciuffoli[1]; NvDEx Collaboration[None]

[1] *Institute of Modern Physics, Chinese Academy of Sciences*

NvDEx (No Neutrino Double beta decay Experiment) is a Se TPC detector that will be located in China Jinping Underground Laboratory (CJPL), looking for neutrinoless double beta decays. In this talk, I will present the current status of the experiment and the prospects for future developments. The first phase of the experiment will be NvDEx-100, using 100 kg of $SeF_6$: due to the large overburden (2,400 m rock) and the high Q-value of $^{82}$Se (2.996 MeV) the background rate will be very low, which ensures excellent prospects for scalability. On the other hand, since $SeF_6$ is an electronegative gas, any free electron will be captured almost immediately, and negative ions will be drifting in the chamber, which prohibits the use of traditional electron-sensing TPC detectors. For this reason, a new kind of chip has been developed: it will allow us to observe the negative ions and reconstruct the energy of the events with great precision, even without electron avalanche multiplication. A third tapeout of the chip (V2) has been produced and it's currently being tested using a prototype TPC on the surface. The tracks of alpha particles were successfully detected during the test and the equivalent noise charge was measured to be about $58e^-$, approaching the requirement of $45e^-$.

**Secondary track**:

**T09 / 451**

## The cosmic origin of matter from exact proton stability

**Auteur:** Xavier Ponce Diaz[1]

[1] *University of Basel*

**Auteur correspondant** xavier.poncediaz@unibas.ch

In this talk, we revisit a class of lepton-flavor non-universal gauge extensions of the Standard Model that provide a compelling framework for generating neutrino masses and mixing angles via a high-scale seesaw mechanism, while ensuring exact proton stability to all orders in the effective field theory. This setup naturally accommodates minimal thermal leptogenesis, offering a robust explanation for the observed matter-antimatter asymmetry. A feature of this construction is the prediction of a light pseudo-Nambu-Goldstone boson, the majoron, whose properties and couplings we examine in the context of dark matter, cosmology, and ongoing experimental searches. Remarkably, the model also yields a lower bound on the mass of the lightest neutrino and makes concrete predictions for the Majorana phases. These in turn lead to a testable prediction for neutrinoless double beta decay, providing a powerful experimental probe of the underlying theory.

**Secondary track**:

**T01 / 452**

# The Euclid Mission

**Auteur:** Cristobal Padilla Aranda[1]

[1] *IFAE-Barcelona*

Euclid is a mission of the European Space Agency designed to constrain the properties of dark energy and gravity via weak gravitational lensing and galaxy clustering. After its launch in July 1st, 2023 it is carrying out a wide area imaging and spectroscopy survey (the Euclid Wide Survey: EWS) in visible and near- infrared bands, covering approximately 15000 deg2 of extragalactic sky in six years. Euclid is equipped with a 1.2 m diameter Silicon Carbide (SiC) mirror telescope made by Airbus (Defence and Space) feeding 2 instruments, VIS and NISP, built by the Euclid Consortium : a high quality panoramic visible imager (VIS), a near infrared 3-filter (Y, J and H) photometer (NISP-P) and a slitless spectrograph (NISP-S). This talk will present the satellite and its instruments, which are optimised for pristine point spread function and reduced stray light, producing very crisp images, as well as the survey strategy, the global scheduling, the commissioning results, its progress and the preparation of the Science Data Centers to produce scientific data

**Secondary track**:

**T01 / 453**

# Euclid: performance on main cosmological parameter science

**Auteur:** Cristobal Padilla Aranda[1]

[1] *IFAE-Barcelona*

Euclid will observe 15000 deg2 of the darkest sky that is free of contamination by light from our Galaxy and our Solar System. Three "Euclid Deep Fields"covering around 40 deg2 in total will be also observed extending the scientific scope of the mission the high-redshift universe. The complete survey represents hundreds of thousands images and several tens of Petabytes of data. About 10 billion sources will be observed. With these images Euclid will probe the expansion history of the Universe and the evolution of cosmic structures by measuring the modification of shapes of galaxies induced by gravitational lensing effects of dark matter and the 3-dimension distribution of cosmic structures from spectroscopic redshifts of galaxies and clusters of galaxies. This talk will present the implications for cosmology and cosmological constraints of this unprecedented data set. Of particular interest are expected constraints on neutrino properties, neutrino masses and the nature of dark energy.

**Secondary track**:

**T01 / 454**

## Euclid Legacy Science prospects

**Auteur:** Cristobal Padilla Aranda[1]

[1] *IFAE-Barcelona*

With the immense number of images, data and sources that Euclid will deliver, the consortium will be in a unique position to create/provide/construct legacy catalogs, with exquisite imaging quality and superb Near Infrared Spectroscopy, with impact on may areas of galaxy science. This talk will review the current results and prospects that Euclid will be able to achieve in areas of Galaxy an AGN Evolution, the Local Universe, studies of the Milky Way and stellar populations, SNe and Transients, Solar System Objects, Planets, etc⋯The first data release with a small fraction of the sky boserved so far has been made public. This talk will present the first images that have been analysed in these areas and the first scientific results.

**Secondary track**:

**Poster T06 / 455**

## Recent measurements of top-associated cross sections in low pileup conditions in pp collisions at 5.02 TeV

**Auteur:** Javier Del Riego Badas[1]

[1] *Universidad de Oviedo - ICTEA (ES)*

We present the most recent measurements of top production cross sections in proton-proton collisions at a center-of-mass energy of 5.02 TeV. The dataset used was recorded by the CMS experiment at the LHC in special runs recorded in 2017, featuring a low-pileup environment, which offers a clean setting for precise cross-section measurements. Results are compared with state-of-the-art theoretical predictions, providing valuable insights into the behavior of the strong and electrowak interactions at high energies. These measurements enhance our understanding of top quark production mechanisms and test the precision of Standard Model predictions in a previously unexplored energy regime.

**Secondary track**:

**T12 / 456**

## Innovations in Simulation Tools for the CMS Experiment leading to the HL-LHC

**Auteur:** Natascha Krammer[1]

[1] *Institute of High Energy Physics, ÖAW*

The Monte Carlo simulation landscape for the CMS experiment has been enriched in view of the challenges for the High Luminosity(HL)-LHC. In addition to the very different functions of Full Simulation and Fast Simulation, a new player, FlashSim, is gaining in importance. Full Simulation scores with a precise simulation based on the Geant4 detector simulation, but at the expense of runtime. The other tool, Fast Simulation, wins with significantly higher speed through the use of parametric particle-material interactions, but has the disadvantage of lower accuracy. New developments for these tools focus on compensating for these drawbacks to achieve faster or more accurate results. For the LHC a new decade of operation begins with a major upgrade, the HL-LHC. This requires also a significant upgrade of the CMS detector, whereby parts of the detector are replaced by new and more complex ones. The simulation toolkit Geant4 is constantly being improved to achieve faster and more accurate results, and the detector description must be expanded and adapted to the new parts and geometries. The new challenges are met with the use of machine learning (ML) techniques and processing jobs on graphics processing units (GPUs) to speed up the time-consuming simulations. FlashSim is an ML-based simulation framework that is trained for general use on a variety of different analyses and combines speed and accuracy. This contribution reports on the latest innovations and developments in the field of Full and Fast Simulation and points to other promising simulation tools such as FlashSim to fulfil the significantly increased requirements for the future of CMS.

**Secondary track**:

**T09** / **457**

# Status of the Muon g-2/EDM Experiment at J-PARC

**Auteur:** Graziano Venanzoni[1]

[1] *University of Liverpool and INFN Pisa*

The muon magnetic anomaly, ,a_mu= (g −2)/2, can be both measured and computed to a very high precision, making it a powerful probe to test the Standard Model of particle physics and search for new physics. At the beginning of the 2000s, the E821 experiment at Brookhaven (USA) measured with a precision of 0.54 parts per million (ppm), finding a discrepancy of about three standard deviations with the theoretical prediction of the Standard Model. In recent years (2021-2023), the Muon g−2 Experiment at Fermilab has measured a_mu with an improved precision of 0.21 ppm, showing good agreement with the previous experimental result at Brookhaven, and a new result at 140 ppb accuracy with the full statistics is expected this year. While the comparison with the Standard Model is currently limited by tensions in the theory, a new measurement of a_mu with a different approach will be crucial for independently verifying the current prediction of the muon anomaly and exploring possible new physics beyond the Standard Model. The Muon g-2/EDM Experiment at J-PARC will employ a novel way to measure a_mu, by using a low-emittance beam of positive muons stored in a compact muon storage magnet. The experimental method includes new technologies such as a three-dimensional spiral injection, an MRI-type storage magnet with superb field uniformity, and a positron tracking detector. The experiment aims at an initial accuracy of 450 ppb corresponding to 2 years of data taking. The experiment also aims to measure the muon EDM with a sensitivity of 1.5 x10^-21 e cm. Currently, the experiment is in the construction phase, with key components such as the storage magnet and beam injection system undergoing final optimizations. First beam tests have been conducted successfully, validating the feasibility of the novel injection method. I will present the current status of the experiment, ongoing tests and design optimizations, and the plans for improvements of the experimental precision.

**Secondary track**:

T07 - Flavour Physics and CP Violation

**T14** / **458**

# Exographer: A Video Game for Particle Physics Outreach

**Auteur:** Raphael GRANIER DE CASSAGNAC[1]

[1] *Laboratoire Leprince-Ringuet*

Exographer is a particle-physics inspired video game released on September 26, 2024, on Steam (for PC and Mac), Xbox, PlayStation 5, and Nintendo Switch. Developed by a team assembled around a particle physicist from the CMS collaboration at École Polytechnique (France), the game aims to introduce fundamental concepts of particle physics to new and curious audiences.
Players explore a richly imagined world using tools inspired by bosons —such as gluonic boots or W-waves —while gradually uncovering all the particles of the Standard Model. Each level draws inspiration from real-world and historical experiments, ranging from cathode-ray tubes to massive colliders, cosmic observatories, and underground neutrino detectors.
The narrative follows the remnants of a lost civilization guided by characters inspired by iconic scientists like Marie Curie and Steven Weinberg, unfolding across a timeline shaped by actual scientific milestones.
In this talk, I will present the development process behind Exographer, the scientific ideas it conveys, its potential for outreach and education, and the reception it has received since launch.
Exographer on Steam: https://store.steampowered.com/app/2834320/Exographer/

**Secondary track**:

**Joint T04+T05 / 459**

## Recent results from NA61/SHINE strong interaction program.

**Auteur:** Grzegorz Stefanek[1]

[1] *Jan Kochanowski University*

NA61/SHINE is a multipurpose fixed-target experiment located at CERN SPS. Its research program includes studies of strong interactions as well as reference measurements for neutrino and cosmic-ray physics.
One of its main goals is to study the phase diagram of strongly interacting matter.
For this purpose, a unique two-dimensional scan in beam momentum 13A-150(8)A GeV/c and the system size, including p+p, p+Pb, Be+Be, Ar+Sc, Xe+La, and Pb+Pb collisions, was performed. The main goal of the strong interaction program is to understand the onset of deconfinement and locate the critical point of strongly interacting matter.

The latest results from the NA61/SHINE strong interaction program will be reviewed, focusing on hadron spectra and fluctuations in various collisions. The new results on strangeness production, particularly the ratio of positively charged kaons to pions, will be presented, including the first results for Pb+Pb collisions at 30A GeV.
The presentation will also review the recent NA61/SHINE results on proton and negatively charged hadrons intermittency to search for the QCD critical point. The NA61/SHINE data will be compared with other experimental results and predictions from theoretical models like EPOS, PHSD, UrQMD, and confronted with Power-law model predictions. The discussion will also cover the first D0 + anti-D0 measurement in heavy-ion collisions at SPS energies and an unexpected excess of charged over neutral K meson production in central Ar+Sc collisions. Finally, NA61/SHINE plans will be presented.

**Secondary track**:

T05 - QCD and Hadronic Physics

**T11 / 460**

## Estimation of backgrounds from jets misidentified as tau leptons using the Universal Fake Factor method with the ATLAS detector

**Auteur:** ATLAS Collaboration[None]

Physical processes with one or more τ-lepton in the final state play an important role in several analyses of the ATLAS experiment physics program. The usage of hadronic channels, in which τ-leptons decay into one or more pions, enables to exploit the large statistics associated with hadronic τ-lepton decays, but also requires a precise estimate of a sizable background of hadronic jets mis-reconstructed as fake τ-leptons. This poster will present a new technique developed by the ATLAS Collaboration to estimate the fake τ-lepton background from data - the Universal Fake Factor method. This technique improves on previous methodologies as it enables a more solid validation of the estimated background. Details on how to implement this methodology will be given as well as on its validation with single and di-τ final states. Information on ATLAS physics analyses that successfully exploited this technique will also be given.

**Secondary track**:

**T05** / **461**

## New techniques for reconstructing and calibrating hadronic objects with ATLAS

**Auteur:** ATLAS Collaboration[None]

The precision and reach of physics analyses at the LHC is often tied to the performance of hadronic object reconstruction & calibration, with any incremental gains in understanding & reduced uncertainties being impactful on ATLAS results. Recent refinements to the reconstruction and calibration procedures for jets & missing energy by the ATLAS collaboration has resulted in reduced uncertainties, improved pileup stability and overall performance gains. In this contribution, highlights of these developments will be presented.

**Secondary track**:

**T11** / **462**

## Quark-Gluon Constituent-Based Jet Taggers for the HL-LHC

**Auteur:** ATLAS Collaboration[None]

Jet constituents provide a more detailed description of the radiation pattern within a jet compared to observables summarizing global jet properties. In Run 2 analyses at the LHC using the ATLAS detector, transformer-based taggers leveraging low-level variables outperformed traditional approaches based on high-level variables and conventional neural networks in distinguishing quark- and gluon-initiated jets. With the upcoming High-Luminosity LHC (HL-LHC) era, characterized by higher luminosity and increased center-of-mass energy, the ATLAS detector has undergone significant upgrades. These include a new inner detector with extended coverage into the most forward region, previously inaccessible to tracking, as well as the addition of the High Granularity Timing Detector (HGTD) to mitigate the effects of pile-up. This study assesses how these advancements enhance jet tagger accuracy and robustness. These improvements are crucial for processes such as vector boson fusion, vector boson scattering, and supersymmetry, where precise jet identification in the most forward region enhances background discrimination.

**Secondary track**:

**T11** / **463**

# Results from muon reconstruction performance with the ATLAS experiment at the LHC using Run-3 proton-proton collision data

**Auteur:** ATLAS Collaboration[None]

Muon reconstruction performance plays a crucial role in the precision and sensitivity of the Large Hadron Collider (LHC) data analysis of the ATLAS experiment. Accurately measuring the muon performance of the ATLAS detector is of paramount importance to provide fundamental input to physics analyses involving muons. Furthermore, the ATLAS Muon Spectrometer was significantly upgraded for LHC Run-3, most notably with the New Small Wheel upgrade project, including new muon detectors with innovative design; measuring the performance of this upgrade on real data is therefore extremely important. Using di-muon resonances we are able to characterize and calibrate with high accuracy the detector response for muons in terms of muon identification and isolation efficiency and muon momentum measurement. An overview of the state-of-the-art methods for muon performance measurement and on the results obtained on Run-3 proton-proton collision data at a center-of.mass energy of 13.6 TeV is presented here.

**Secondary track**:

**T09** / **464**

# Searches for unusual signatures in leptonic/missing energy channels with the ATLAS detector

**Auteur:** ATLAS Collaboration[None]

Various theories beyond the Standard Model predict new, long-lived particles with unique signatures involving leptons or missing energy, which are difficult to reconstruct and for which estimating the background rates is also a challenge. These include displaced have neutral leptons, SUSY models involving displaced electron/muon pairs, heavy charged particles, and displaced vertices.. The talk will focus on the most recent results from ATLAS

**Secondary track**:

**T09** / **465**

# The LHC as Lepton–Proton Collider: Search for the Resonant Production of Leptoquarks

**Auteur:** ATLAS Collaboration[None]

Searches for leptoquarks are a key component of the LHC program probing physics beyond the Standard Model. These hypothetical particles couple to a lepton and a quark and are predicted by many extensions of the Standard Model such as Grand Unified Theories. The existing leptoquark searches at the LHC currently mostly consider production modes via quark and/or gluon interactions. However, the small but non-zero lepton content of the proton allows to also study the significantly less explored s-channel, resonant leptoquark production. This production mode gives rise to lepton-plus-jet signatures. Thus, leptoquarks would emerge as distinctive peaks over the smoothly falling Standard Model background in the invariant mass spectrum of the lepton-plus-jet system. The poster will give an overview of the first ATLAS analysis searching for this new process in four separate final states involving light leptons plus either jets originating from light quarks or from bottom quarks. It will especially focus on the details of the search for the electron-plus-jet signature. The general analysis strategy and the results of this search will be discussed. Probing the resonant, s-channel production shows competitive and complementary sensitivity to existing searches for e.g. the pair production of leptoquarks, particularly for leptoquarks with a high coupling to fermions.

To maximize the sensitivity reach, the full ATLAS Run2 dataset is combined with the partial Run3 dataset of 2022 and 2023 for this search.

**Secondary track**:

**T08** / **466**

## Prospects for light exotic scalar measurements at the e+e- Higgs factory

**Auteurs:** Mikael Berggren[1]; Bartlomiej Brudnowski[2]; María Teresa Núñez Pardo de Vera[3]; Kamil Zembaczynski[2]; Aleksander Filip Zarnecki[4]

[1] *LPNHE Paris VI&VII*

[2] *Faculty of Physics, University of Warsaw*

[3] *DESY*

[4] *University of Warsaw*

**Auteurs correspondants:** zarnecki@fuw.edu.pl, b.brudnowski@student.uw.edu.pl, maria-teresa.nunez-pardo-de-vera@desy.de

Extra light scalars are still not excluded by the existing experimental constraints, provided their coupling to the SM gauge bosons is sufficiently suppressed. They could be produced at the $\mathrm{e}^+\mathrm{e}^-$ Higgs factory in a scalar-strahlug process, analogous to the Higgs-strahlung process being the dominant production channel for the 125 GeV Higgs boson. This was selected as one of the focus topics of the ECFA Higgs/Top/EW factory study. As the couplings of such a light scalar can be different from the SM predictions, various search strategies have to be considered. Presented are the expected cross section limits from the decay-mode independent search and from the search in the $b\bar{b}$ decay channel, based on a full simulation of the International Large Detector (ILD), supplemented with the expected sensitivity in di-tau and invisible decay channels, based on the fast simulation in the DELPHES framework, assuming 250 GeV ILC running scenario.

**Secondary track**:

T09 - Beyond the Standard Model

**T05** / **467**

## Radiative corrections to $e^+e^- \to \pi^+\pi^-$ charge asymmetry

**Auteur:** Andrea Gurgone[1]

[1] *University of Pisa and INFN*

The $e^+e^- \to \pi^+\pi^-$ process at flavour factories plays a crucial role in the data-driven determination of the hadronic contribution to the muon $g-2$. The recent CMD-3 measurement of the pion form factor via energy scan displays a significant discrepancy with the previous experimental determinations. In this contribution, a new fully differential calculation of the $e^+e^- \to \pi^+\pi^-$ scattering, including next-to-leading order corrections matched to a fully exclusive parton shower, is presented. The calculation is implemented in an updated version of the BabaYaga@NLO event generator. To achieve a correct combination between perturbative QED corrections and non-perturbative QCD contributions, particular attention is paid in the treatment of the pion form factor in the computation of loop amplitudes, going beyond the commonly used factorised sQED approach. This is obtained

by employing two alternative approaches, one based on the generalised vector meson dominance model, the other on the dispersion relation. In particular, both methods lead to a consistent theoretical description of the forward-backward (or charge) asymmetry, which perfectly agrees with the CMD-3 data, unlike the prediction obtained through the traditional factorised sQED method. This is a crucial step forward in understanding the discrepancy between the data-driven determinations of the muon $g-2$ and the lattice predictions.

References:
1 E. Budassi et al., Pion pair production in $e^+e^-$ annihilation at next-to-leading order matched to Parton Shower [2409.03469].
2 R. Aliberti et al., Radiative corrections and Monte Carlo tools for low-energy hadronic cross sections in $e^+e^-$ collisions [2410.22882].

**Secondary track**:

**T07 / 468**

## The Three-loop hadronic vacuum polarization in chiral perturbation theory

**Auteur:** Pierre Vanhove[1]

[1] *IPhT CEA-Saclay*

This work achieves the first analytical determination of the three-loop hadronic vacuum polarization contribution to the muon's anomalous magnetic moment ($g$—2). Leveraging cutting-edge amplitude techniques within chiral perturbation theory, the effective field theory for low-energy QCD, we present this infinite volume calculation. Our result is crucial for accurately estimating finite volume errors at this order and represents a significant advancement in high-precision $g$—2 calculations.

Work done in collaboration with Laurent Lellouch, Alessandro Lupo, Mattias Sjö et al.

**Secondary track**:

T05 - QCD and Hadronic Physics

**Poster T14 / 470**

## A series of short outreach videos about Particle Physics in Portuguese

**Auteur:** Diogo Rodrigues Boito[1]

**Co-auteurs:** Ana Ferreira Choueiri [2]; Maria Eduarda Cavini Garbossa [3]

[1] *Universidade de São Paulo*

[2] *Universidade Federal de Sao Carlos*

[3] *University of Sao Paulo*

**Auteur correspondant** boito@ifsc.usp.br

I will present our experience with the production, recording, and publication of a series of 15 short outreach videos about Particle Physics, in Brazilian Portuguese, in the format of Instagram reels. The

videos cover different aspects of our research work at the University of Sao Paulo (Brazil), where I lead a group dedicated to QCD and Particle Physics. We produced videos with different emphases, covering very basic topics (such as "What is an atom made of?", or "What is anti-matter?"), intermediate topics (such as "What is QCD?"or "What is the relation between Einstein's $E = mc^2$ formula and your weight.") up to more advanced subjects, such as describing recent results obtained by us in the context of the muon anomalous magnetic moment. Some of the videos also contain interviews with the students working in the research group, and are aimed at showing glimpses of the life as a researcher. The videos last between 1:30 and 4 minutes. We are publishing one video per week in an Instagram account that was created mainly with this purpose in mind (instagram.com/fisicadeparticulas/). The production of the videos was funded by the Sao Paulo Research Foundation (FAPESP) through two scholarships for undergraduate students, for 8 months. In our case, one of the students was a Physics major who was responsible, in part, for the scientific content and for part of the video editing, while the other student was a Media arts major and was mostly responsible for the technical aspects of the videos. In partnership with a media conglomerate, training was offered to the students involved in the form of online master classes. The videos were produced, in part, in a studio recently equipped for this purpose at the Sao Carlos Physics Institute of the University of Sao Paulo.

In the talk, I will present an analysis of the data available in Instagram in order to discuss how the different types of videos succeed (or not) with our audience of followers and non-followers and what types of videos lead to more or less engagement.

**Secondary track**:

**T09** / **471**

# Analysing the B->Kvv momentum transfer spectra in terms of light new physics

**Auteur:** Martín Novoa-Brunet[1]

**Co-auteurs:** Jernej Kamenik [2]; Patrick Bolton [3]; Svjetlana Fajfer [4]

[1] *IFIC*

[2] *Jozef Stefan Institute*

[3] *IJS*

[4] *Institute Jozef Stefan and Ljubljana University*

**Auteur correspondant** martin.novoa@ific.uv.es

Motivated by the recent evidence of an excess in the rare decay $B \to KE_{\text{miss}}$ presented by the Belle II collaboration we discuss possible new physics (NP) scenarios in which light invisible states participate in flavour-changing $b \to s$ transitions. Based on a model-independent EFT framework to describe the new light states, we study the signatures given by the differential distribution of the $B \to KE_{\text{miss}}$ measurement and we present the most likely scenarios. We then describe the potential effects in the $B \to K^*E_{\text{miss}}$ branching and longitudinal polarisation fractions showing these observables have a high discrimination power among the different NP explanations. Lastly, we discuss the importance of analysing the momentum transfer spectra when probing extensions of the Standard Model that feature new light degrees of freedom.

**Secondary track**:

T07 - Flavour Physics and CP Violation

**T10** / **473**

## Convergent perturbative series via finite path integral limits

**Auteur:** Ariel Edery[1]

[1] *Bishop's University*

Perturbation theory is used extensively for solving problems in quantum mechanics and quantum field theory. In most cases, the perturbative series in powers of the coupling is an asymptotic series (it ultimately diverges). This is not an issue at weak coupling where one can make precise predictions by computing a few lower orders. However, this procedure fails completely at strong coupling. In this work, we show that one can obtain an absolutely convergent perturbative series in powers of the coupling if one uses finite path integral limits. Therefore, it can be used at strong coupling (just more terms are needed). Remarkably, one can prove in some cases that there is a duality between the perturbative series and a different series based on inverse powers of the coupling (which converges quickly at strong coupling). We illustrate the procedure for λϕ^4 theory in lower dimensions: a basic integral involving quadratic and quartic terms and the more dynamical scenario of the quantum anharmonic oscillator.

**Secondary track**:

**T10** / **475**

## Generalized dispersion relations, primal construction and bounds on glueball scattering

**Auteurs:** Claudia de Rham[1]; Andrew J. Tolley[1]; Zhuo-Hui Wang[2]; Shuang-Yong Zhou[2]

[1] *Imperial College*

[2] *University of Science and Technology of China*

**Auteur correspondant** wzh33@mail.ustc.edu.cn

We derive a family of generalized dispersion relations with new integration kernels, and use them to bootstrap the amplitudes with full unitarity and analyticity systematically employed. These dispersion relations, combined with the primal construction method, can be used to analyze the interplay between the Regge behavior of amplitudes and low-energy scattering data. As an illustrating example, we apply this framework to constrain glueball scattering amplitudes using a generalized ansatz that accounts for bound-state poles in partial waves.

**Secondary track**:

**T01** / **476**

## Causality bounds on scalar-tensor EFTs

**Auteurs:** Dong-Yu Hong[1]; Hao Xu[1]; Shuang-Yong Zhou[1]; Zhuo-Hui Wang[1]

[1] *University of Science and Technology of China*

We compute the causality/positivity bounds on the Wilson coefficients of scalar-tensor effective field theories. Two-sided bounds are obtained by extracting IR information from UV physics via dispersion relations of scattering amplitudes, making use of the full crossing symmetry. The graviton t-channel pole is carefully treated in the numerical optimization, taking into account the constraints with fixed impact parameters. It is shown that the typical sizes of the Wilson coefficients can be estimated by simply inspecting the dispersion relations. We carve out sharp bounds on the leading

coefficients, particularly, the scalar-Gauss-Bonnet couplings, and discuss how some bounds vary with the leading $(\partial\phi)^4$ coefficient and as well as phenomenological implications of the causality bounds. Causality bounds on the scalar-tensor effective field theories that include parity-violating operators are also calculated. Some parity-violating coefficients are found to be upper bounded by the parity-conserving counterparts, or the higher order parity-conserving coefficients. While the observational constraints on parity-violating coefficients are weaker than the parity-conserving counterparts, the causality bounds are of comparable strength and thus may play a more prominent role in constraining strong gravity effects in upcoming observations.

**Secondary track**:

**T11** / **477**

## Development of a High-Pressure Scintillator Test Cell for Double Beta Experiments

**Auteur:** Magdalena Eisenhuth[1]

[1] *Johannes Gutenberg-Universität Mainz*

The investigation of two-neutrino and neutrino-less double beta decay is crucial for understanding the Dirac or Majorana nature of neutrinos.

In this context, the krypton isotope Kr-78 (Q=2.88 MeV) stands out as a promising candidate for a first detection of two-neutrino ECb+ and 2b+ decays.

Detectors like the proposed NuDoubt++ experiment featuring opaque scintillator or an upgrade of the OSIRIS detector with hybrid scintillator can profit from solving the krypton gas in the scintillator at high pressure to increase the loading factor.

This poster explores the loading process and challenges in a small-scale scintillator test cell and the characterization techniques for determining the loading factor.

**Secondary track**:

T03 - Neutrino Physics

**Poster T06** / **478**

## BSM interpretations of four-top production at LHC

**Auteur:** Cristina Giordano[1]

[1] *Austrian Academy of Sciences*

Four-top quark production (tttt) is a rare yet intriguing process which has been observed by both the CMS and ATLAS collaborations at LHC, CERN. It provides a unique window into the exploration of new physics scenarios, since many Beyond Standard Model (BSM) theories predict the existence of heavy resonances which, coupling to the top quark, modify the Standard Model (SM) tttt production. This poster highlights the importance of this process in BSM searches, reviewing the latest results from CMS in the context of heavy top-philic resonances decaying into ttbar pairs, hence possibly enhancing the tttt production cross section

**Secondary track**:

T09 - Beyond the Standard Model

**T09 / 479**

## The Electric Dipole Moment of the electron in the decoupling limit of the aligned Two-Higgs Doublet Model

**Auteurs:** Juan Manuel Dávila Illán[1]; Emilie Passemar[2]; Antonio Pich[3]; Luiz Vale Silva[4]; Anirban Karan[3]

[1] *IFIC (UV - CSIC)*

[2] *IFIC-University of Valencia*

[3] *IFIC*

[4] *UCH CEU Valencia*

**Auteur correspondant** juandai@ific.uv.es

We present a discussion of model-independent contributions to the EDM of the electron.
We focus on those contributions that can emerge from an extended heavy scalar sector, and in particular we explore the decoupling limit of the aligned 2HDM.
In this model, Barr-Zee diagrams with a fermion loop produce logarithmically-enchanced contributions that are proportional to potentially large sources of CP violation. In the decoupling limit these contributions are generated by effective dimension-6 operators via the mixing of four-fermion operators into the EW dipole operator.
Some of these logarithmic contributions are not present in more constrained versions of the 2HDM where a $\mathcal{Z}_2$ symmetry is imposed. Thus, the $\mathcal{Z}_2$ symmetry provides a suppression mechanism.
We then study how does the experimental constraints oelectron EDM affect the extended set of parameters of the aligned 2HDM.

**Secondary track**:

T09 - Beyond the Standard Model

**T08 / 480**

## Electroweak corrections to Higgs boson production via weak boson fusion at the future LHeC

**Auteurs:** Bowen Wang[None]; Hou[None]; Qian[None]; Wang[None]; Xiong[None]; Xu[None]

In this talk I will present our recent precision calculation of Higgs boson production via weak boson fusion (WBF) processes at the planned LHeC collider. This is the first calculation including the full electroweak effects for the WBF in electron-proton collisions at the one-loop level. For a center-of-mass energy of 1.98 TeV, the magnitudes of the relative corrections for the total cross sections at next-to-leading (NLO) order are respectively ~10% and ~20%, in the two renormalization schemes adopted. The NLO terms play more significant roles in changing the differential distributions of certain observables. I will discuss the phenomenological impact of these corrections in both charged and neutral current WBF processes.

**Secondary track**:

T06 - Top and Electroweak Physics

**Joint T08+T16 / 481**

## Fair Universe HiggsML Uncertainty Challenge

**Auteurs:** David Rousseau[1]; RAGANSU CHAKKAPPAI[2]

**Co-auteurs:** Aishik Ghosh [3]; Benjamin Nachman [4]; Chris Harris [5]; Elham Khoda [4]; Ihsan Ullah [6]; Isabelle Guyon [6]; Jordan Dudley [4]; Paolo Calafiura [4]; Peter Nugent [4]; Po-Wen Chang [4]; Sascha Diefenbacher [7]; Shih-Chieh Hsu [8]; Steven Farrell [7]; Wahid Bhimji [7]; Yuan-Tang Chou [9]; Yulei Zhang [4]

[1] *IJCLab, Université Paris-Saclay*

[2] *IJCLab-Orsay*

[3] *UCI*

[4] *LBNL*

[5] *NERSC*

[6] *Chalearn*

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**Auteur correspondant** ragansu.chakkappai@ijclab.in2p3.fr

Measurements and observations in Particle Physics fundamentally depend on one's ability to quantify their uncertainty and, thereby, their significance. Therefore, as Machine Learning methods become more prevalent in HEP, being able to determine the uncertainties of an ML method becomes more important. A wide range of possible approaches has been proposed, however, there has not been a comprehensive comparison of individual methods.
To address this, the Fair Universe project organized the Fair Universe HiggsML Uncertainty Challenge (https://fair-universe.lbl.gov/ and the white paper introducing to the competition https://arxiv.org/abs/2410.02867 ), which took place from Sep 2024 to 14th March 2025, and was accepted as an official NeurIPS2024 competition. The goal of the challenge was to measure the Higgs to tau+ tau- cross-section, using a dataset of particle 4-momenta. Participants were evaluated on both their ability to precisely determine the correct cross-section, as well as on their ability to report correct and well-calibrated uncertainty intervals.
In this talk, we present an overview of the competition itself and of the infrastructure that underpins it. Further, we present the winners of the competition and discuss the performance of their winning uncertainty quantification approaches.
The dataset and associated metric will serve as a permanent benchmark for further developments.

**Secondary track**:

T08 - Higgs Physics

**T07 / 482**

## Full NNLO QCD corrections to B meson mixing

**Auteur:** Pascal Reeck[None]

**Auteur correspondant** pascal.reeck@kit.edu

In this talk I will discuss recent advances made in the calculation of the NNLO QCD corrections to the width difference between B and anti-B mesons. This work focuses on the perturbative high-energy part of the calculation, more specifically the matching coefficients between the $\Delta B = 1$ effective operators of the Weak Interaction and the $\Delta B = 2$ transition operator are calculated as a deep expansion in $m_c/m_b$.

This calculation yields novel results for the NNLO contributions with penguin operators which had not been considered previously at this order. Moreover, the NNLO contributions with two current-current operators, which were previously only known up to $O(m_c^2/m_b^2)$ are calculated to a higher precision.

**Secondary track**:

**T14 / 483**

## AggiornaMenti: an INFN project for the education of junior high-school teachers

**Auteurs:** Alessandra Toncelli[None]; Andrea Beraudo[1]; Andreotti Mirco[None]; Barbara Sciascia[2]; Francesco Longo[None]; Giuseppe Tagliente[None]; Grazia D'Agostino[None]; Marina Passaseo[None]; Marzia Nardi[None]; Matteo De Gerone[None]; Sandra Zavatarelli[None]; Stefano Marcellini[None]; Susanna Bertelli[3]; Valentina Bologna[None]; Viviana Fanti[None]

[1] *INFN Torino*

[2] *INFN*

[3] *INFN Frascati National Laboratory*

AggiornaMenti is a national INFN project started in 2017 and devoted to the education of junior high-school science teachers. So far, about 800 science and technology teachers have attended our courses, in which they receive a practical training on how to propose a lecture based on hands-on activities with low-cost materials, which can be easily found at home. This, by the way, conveys the important message that science is not something accessible only in few advanced laboratories, but rather enters into any aspect of our every-day life.
Innovative methods to build a STEM lecture or set of lectures are proposed, like Inquiry Based Science Education (IBSE) or Investigative Science Learning Environment (ISLE), under the coordination of researchers with a specific expertise in these fields.
Each year the impact of our project is evaluated through a feedback questionnaire, with a specific focus on how the contents proposed during the course have affected the lectures proposed at school.

**Secondary track**:

**T04 / 484**

## Taming scale uncertainties in exclusive quarkonium photoproduction and gluon PDFs at small x

**Auteur:** Christopher Alexander FLETT[1]

[1] *IJCLab*

**Auteur correspondant** christopher.flett@ijclab.in2p3.fr

We present a complete one-loop study of exclusive vector quarkonium photoproduction off protons in Collinear Factorisation (CF), including GPD evolution. The notoriously large scale instability of the cross section at high energies at next-to-leading order (NLO) is confirmed and resolved by resumming leading-logarithmic QCD corrections via High-Energy Factorisation (HEF) in the Doubly-Logarithmic Approximation (DLA), matched to CF. Our NLO CF + DLA HEF results agree with HERA data and show reduced scale dependence compared to Born-level predictions. Quark contributions are shown to be subleading to those from gluons. Implications for HERA, EIC, LHC, and future experiments are explored. Time permitting, we will also discuss an alternative approach that mitigates the previously noted large scale dependence of the NLO CF result. We will then perform a parton

fit analysis using this approach within the PDF fitting tool xFitter to determine the gluon PDF at moderate-to-low values of $x$ based on ultraperipheral collision (UPC) measurements from the LHC. We emphasise that a combined fit to exclusive heavy-quarkonium production data from multiple collision systems will not only enhance our understanding of the underlying theoretical mechanisms at play in UPCs, but also significantly improve our knowledge of the gluon distribution in protons and heavy nuclei at small $x$.

**Secondary track**:

T05 - QCD and Hadronic Physics

**T07** / **485**

## Precision calculation of muon decay asymmetry for EDM searches

**Auteur:** Andrea Gurgone[1]

[1] *University of Pisa and INFN*

The search for a non-zero electric dipole moment (EDM) of the muon is a sensitive tool to test the Standard Model, as it would indicate a further violation of the charge-parity (CP) symmetry. The current best upper limit, established by the E821 experiment at BNL, is $d_\mu < 1.8 \times 10^{-19}\ e \cdot \mathrm{cm}$ at 95% of confidence level. The forthcoming $\mu$EDM experiment at PSI aims to improve this limit by four orders of magnitude by using the frozen-spin technique within a compact storage trap. Since the muon EDM is extracted by measuring the time evolution of the directional asymmetry of the emitted positrons, an accurate calculation of the muon decay asymmetry is needed. This contribution presents an improved theoretical computation of the $\mu^+ \to e^+ \nu_e \bar{\nu}_\mu$ decay for arbitrarily polarised muons, focusing on the boosted positron energy spectrum and the corresponding positron asymmetry. The calculation includes complete QED corrections at $\mathcal{O}(\alpha^2)$ with full mass effects, as well as logarithmically enhanced terms at higher orders. In particular, logarithms due to collinear emissions are computed with a next-to-leading logarithmic accuracy up to $\mathcal{O}(\alpha^4)$ by solving order-by-order the QED evolution equation. At the endpoint of the energy spectrum, soft photon emissions result in large logarithms that are resummed with a next-to-next-to-leading logarithmic accuracy via analytic exponentiation. The calculation is applied to the kinematic configuration of the $\mu$EDM experiment to study the impact of such radiative corrections on the experimental sensitivity.

References:
1 A. Adelmann et al., A compact frozen-spin trap for the search for the electric dipole moment of the muon [2501.18979].
2 P. Banerjee et al., High-precision muon decay predictions for ALP searches [2211.01040].

**Secondary track**:

**T11** / **486**

## Performance of the backward hadronic calorimeter (nHCal) of the ePIC experiment at EIC based on simulations

**Auteurs:** Subhadip Pal[1]; on behalf of ePIC Collaboration[None]

[1] *Czech Technical University in Prague*

**Auteur correspondant** palsubha@fjfi.cvut.cz

The planned Electron Ion Collider will be a unique, high-luminosity, high-precision accelerator to yield collisions of electrons and protons/nuclei. The ePIC experiment will be the first general-purpose detector planned for EIC. It will cover a wide area in $x - Q^2$ plane at different center of mass energies. Low-$x$ physics are going to be central to the EIC mission of probing gluon saturation and the 3D structure of nucleons and nuclei. The backward hadronic calorimeter, here called nHCal (meaning Negative-eta/Neutral Hadronic Calorimeter) will be crucial for studying the low-$x$ physics, diffractive processes, and neutral hadron detection. To be installed in the electron-going negative-z direction as a tail catcher, this detector will enhance hermeticity, improve scattered electron tagging by serving as a hadronic veto, and facilitate studies of diffractive events such as vector meson and dijet production.

To meet these objectives, the nHCal must provide extensive coverage in the backward direction, efficient separation of muons and pions, high detection efficiency for low-energy neutrons, and excellent spatial resolution for distinguishing neutral and charged clusters. In this presentation, we explain the design of this backward hadronic calorimeter made of layers of steel and plastic scintillator tiles. We also report ongoing Monte-Carlo studies of the properties of the calorimeter. Studies of the neutron and pion separation and response have been conducted using simulations. Preliminary results indicate that neutral and charged hadron shower energies can be distinguished when their respective clusters are approximately 30 cm apart.

**Secondary track**:

**T03** / **487**

## Neutrino-argon cross-section measurements from the MicroBooNE experiment

**Auteur:** MicroBooNE collaboration[None]

MicroBooNE is a liquid argon time projection chamber (LArTPC) neutrino detector located along the Fermilab Booster Neutrino Beam and 8 degrees off-axis to the Neutrinos at the Main Injector beam. MicroBooNE collected data from both beams accumulating a large neutrino-argon scattering dataset with a mean neutrino energy of approximately 0.8 GeV. Understanding neutrino-argon interactions is crucial for the next generation of neutrino oscillation experiments including DUNE. MicroBooNE has developed pioneering methodologies and novel reconstruction tools in order to benchmark models at very high sensitivity across the interaction phase space, including for ultra-rare channels. This talk will give an overview of the most recent MicroBooNE neutrino interaction results. These measurements provide invaluable datasets for constraining backgrounds and improving the modelling of neutrino scattering critical for the broader LArTPC neutrino physics program.

**Secondary track**:

**T03** / **488**

## Searches for physics beyond the Standard Model with the MicroBooNE experiment

**Auteur:** MicroBooNE collaboration[None]

MicroBooNE is an 85-tonne active mass liquid argon time projection chamber (LArTPC) at Fermilab. The detector, which has an excellent calorimetric, spatial and energy resolution, has collected beam data from two different beamlines between 2015 and 2020, as well as cosmic ray data when no neutrino beam was running. These characteristics make MicroBooNE a powerful detector not just to explore neutrino physics, but also for Beyond the Standard Model (BSM) physics. Additionally, MicroBooNE is investigating the observed low energy excess (LEE) of single electromagnetic shower events reported by the MiniBooNE experiment with various searches across a number of channels the anomalous excess may originate in. This talk will discuss various newly published BSM and LEE search results as well as explore future MicroBooNE searches.

**Secondary track**:

**T02** / **489**

## Neutrino constraints on inelastic dark matter captured in the Sun

**Auteur:** Ina Sarcevic[1]

[1] *University of Arizona*

We study the possibility for large volume underground neutrino experiments to detect the neutrino flux from captured inelastic dark matter in the Sun. The neutrino spectrum has two components: a mono-energetic "spike" from pion and kaon decays at rest and a broad-spectrum "shoulder" from prompt primary meson decays. We focus on detecting the shoulder neutrinos from annihilation of hadrophilic inelastic dark matter with masses in the range 4-100 GeV. We find the region of parameter space that these neutrino experiments are more sensitive to than the direct-detection experiments. For dark matter annihilation to heavy-quarks, the projected sensitivity of DUNE is weaker than current (future) Super (Hyper) Kamiokande experiments, while for the light-quark channel, only the spike is observable and DUNE will be the most sensitive experiment.

**Secondary track**:

T03 - Neutrino Physics

**Joint T12+T16** / **490**

## Anomaly Detection in the ATLAS Trigger System

**Auteur:** Shreya Saha[1]

[1] *University of Adelaide*

The application of machine learning techniques in particle physics has accelerated the development of methodologies for exploring physics beyond the Standard Model. This talk will present an overview of anomaly detection, an unsupervised machine learning technique, and its potential to enhance the detection of new physics within data collected by the ATLAS detector at CERN. The talk will discuss the adaptation and real-time deployment of anomaly detection algorithms, integrated into the detector's trigger system. Additionally, a novel analysis strategy will be outlined for detecting non-resonant anomalies in a model - agnostic manner, utilizing autoencoders, which are based on deep neural networks. The presentation will include signal sensitivity studies for anomalous events, along with background estimation studies, based on the performance of the autoencoders.

**Secondary track**:

T09 - Beyond the Standard Model

**T03 / 491**

## Bridging Experiments, Narrowing Uncertainties: When DUNE Meets T2HK to unveil insights into 2–3 Oscillation Sector

**Auteur:** Ritam Kundu[1]

**Co-auteurs:** Masoom Singh [2]; Sanjib Kumar Agarwalla [3]

[1] *Institute of Physics, Bhubaneswar*

[2] *Utkal University, Bhubaneswar, India*

[3] *Institute of Physics, Bhubaneswar, India*

A meticulous determination of $\Delta m^2_{31}$ and $\theta_{23}$ is indispensable for accurately evaluating the Earth's matter effect in long-baseline experiments, a key element in resolving the neutrino mass ordering conundrum and in measuring the CP phase in the $3\nu$ paradigm. By reviewing the footprints of previous and ongoing experiments and considering the anticipated sensitivities from the upcoming IceCube Upgrade and KM3NeT/ORCA, we examine the expected advancements in the precision of 2–3 oscillation parameters that the next-generation long-baseline experiments, DUNE and T2HK, are set to provide, either independently or in combination. We underscore the significance of the complementarity between these two experiments, which substantially enhances the sensitivity to deviations from maximal mixing in $\theta_{23}$, decisively excludes the wrong-octant solutions for $\theta_{23}$, and enables exceptionally refined measurements of the 2–3 oscillation parameters, surpassing the capabilities of each experiment when considered in isolation. Our analysis shows that, for the current best-fit values of the oscillation parameters and assuming normal mass ordering (NMO), the combination of DUNE and T2HK can confirm a non-maximal $\theta_{23}$ and exclude the wrong octant solution with a statistical significance of approximately $7\sigma$ with their nominal exposures. Furthermore, we find that DUNE and T2HK together can enhance the existing $1\sigma$ precision on $\sin^2\theta_{23}$ and $\Delta m^2_{31}$ by factors of 7 and 5, respectively, assuming NMO. Given the financial hurdles and the prolonged commitment required for the full 10-year operation of DUNE and T2HK, our study highlights that even with less than half of their nominal exposures, the collaboration between DUNE and T2HK can still achieve sensitivities in our phenomenological analyses that are on par with those expected from their full exposures individually. Finally, we highlight how the synergistic interplay between DUNE and T2HK can offer more stringent constraints on the ($\sin^2\theta_{23}$, $\delta_{\mathrm{CP}}$) plane, outstripping the reach of the standalone experiments.

**Secondary track**:

T09 - Beyond the Standard Model

**T08 / 492**

## Enhanced Charged Higgs Signal at the LHC

**Auteur:** Chung Kao[1]

[1] *University of Oklahoma*

A general two Higgs doublet model (G2HDM) is adopted to study
$pp \to bH^\pm \to bbc + X$ at the Large Hadron Collider (LHC),
where $H^\pm$ is a charged Higgs boson,
$b$ represents a bottom quark or an anti-bottom quark,
and $c$ is a charm quark or an anti-charm quark.
In two Higgs doublet models with Type-II Yukawa interactions,

$g_{H^+bc}$ is suppressed by $V_{cb} \simeq 0.042$.
This coupling can become significantly large with the dominant contribution
$g_{H^+bc} \propto \rho_{tc} V_{tc} \simeq \rho_{tc}$ in a G2HDM.
We have evaluated cross sections for the charged Higgs signal and for the dominant processes of physics background. Realistic acceptance cuts are applied to investigate the discovery potential.
In addition, we have applied $b$ tagging and $c$ tagging at the event level with ATLAS and CMS tagging and mis-tagging efficiencies.
Promising results have been obtained for $\rho_{tc} > 0.3$ with an integrated luminosity $L = 1000$ fb$^{-1}$ for ATLAS or CMS at the LHC.

**Secondary track**:

T09 - Beyond the Standard Model

**T03 / 493**

# Status of the JUNO Detector

**Auteurs:** JUNO Collaboration[None]; Runze Zhao[1]

[1] *Institute of High Energy Physics, Chinese Academy of Science*

The Jiangmen Underground Neutrino Observatory (JUNO) is a multipurpose neutrino experiment filled with 20k tons of liquid scintillator (LS) and equipped with more than 40000 photosensors. It is designed to observe neutrinos and anti-neutrinos from various sources such as nuclear reactors, the Earth, atmosphere, the Sun and Supernovae. The detector construction was finished in 2024. It is currently at the commissioning stage: exchange of water by liquid scintillator and simultaneous data taking. This talk will introduce the detector components and report the recent commissioning progress and status of the detector.

**Secondary track**:

**Poster T14 / 495**

# Engaging CERN's Non-Scientific Staff in Particle Physics

**Auteur:** Fabiola Cacciatore[1]

[1] *IPPOG*

Since 2022, IPPOG has adapted its successful International Masterclasses (IMC) to involve CERN' s non-scientific personnel. These sessions offer an accessible introduction to particle physics for colleagues in administration, communication and other non-research departments, helping them connect with CERN's core mission.
Following the positive response to the first edition, further sessions were held using ATLAS, ALICE and CMS experiments data, with two more planned for 2025. The format, now condensed into four hours, is designed to fit within working hours and is supported by CERN's training center.
This poster presents the development and impact of this new initiative, including collaborations with internal groups like Women in Technology.

**Secondary track**:

**T03** / **496**

## Neutrinoless double beta decay in Left-Right symmetric model

**Auteur:** Jing-yu Zhu[1]

[1] *Institute of Modern Physics, Chinese Academy of Sciences*

In this talk, I will mainly discuss the neutrinoless double beta decay ($0\nu\beta\beta$) within the Left-Right Symmetric Model (LRSM), focusing on three critical aspects: (1) the enhancement or suppression of $0\nu\beta\beta$ rates in specific parameter spaces of new physics (NP) degrees of freedom, (2) constraints on NP parameters from current and future experiments, and (3) the impact of nuclear matrix element (NME) uncertainties on interpreting these constraints.
To be specific, I will talk about
**1. Parameter-Dependent Contributions of NP in LRSM**
The LRSM introduces multiple mechanisms: the standard light neutrino mass term ($m_\nu$), the η-mechanism (mediated by right-handed currents and heavy neutrinos), and the λ-mechanism (driven by $W_L - W_R$ mixing). We systematically study the enhancement or suppression of $0\nu\beta\beta$ rates by NP degrees of freedom in different parameter spaces.
**2.Experimental Constraints and Future Sensitivities**
We combine current $0\nu\beta\beta$ experiments (KamLAND-Zen, GERDA, CUORE, etc.) to derive the constraints of LRSM parameters and compare them with those from collider and cosmology searches. Similarly, the sensitivities of future $0\nu\beta\beta$ experiments to LRSM parameters will also be discussed quantitatively.
**3.Nuclear Matrix Element Uncertainties**
In deriving experimental constraints or future sensitivities, we consider the impact of the NME uncertainties, arising from approximations in nuclear structure models (e.g., QRPA, shell model) and short-range correlations, which alter the constraints of NP parameters by one order of magnitude at most. In LRSM, the η- and λ-mechanisms depend differently on NMEs, leading to degeneracies in parameter constraints. Multi-isotope studies (e.g., $^{76}$Ge, $^{130}$Te, $^{136}$Xe) are proved to be critical to mitigate these uncertainties, as they provide complementary information to disentangle NP contributions.
In summary, the LRSM offers a dynamic framework where NP contributions are modulated by $M_{W_R}$ and $m_N$. Current experiments constrain TeV-scale NP, while future $0\nu\beta\beta$ campaigns will probe deeper into the parameter space, contingent on improved NME calculations. Resolving the interplay between NP mechanisms, nuclear theory uncertainties, and multi-channel experimental data quanlitatively is essential to advance our understanding of neutrino properties and fundamental symmetries.

**Secondary track**:

**T14** / **497**

## Latest releases of ATLAS Open Data for Education and Research

**Auteur:** Steven Goldfarb[1]

[1] *University of Michigan*

The ATLAS Collaboration has recently, for the first time, released a large volume of data for use in research publications, with its use being now extended via a new education-focused release. The 2015 and 2016 proton collision datasets, along with a large quantity of matching simulated data, in a light format, PHYSLITE, for research purposes, and in a simplified version for educational purposes, are now available, allowing for a wide coverage of use cases. In order to allow this, all the corresponding software has been made public, along with extensive documentation targeting several different levels of users, from those who are new to particle physics to experienced researchers that need only an introduction to the ATLAS-specific details of the data. This contribution describes the data, the

corresponding metadata and software, and the documentation of the open data, along with the first interactions with non-ATLAS researchers and highlights of the new educational release.

**Secondary track**:

**Poster T14 / 498**

## Short video formats to communicate big physics

**Auteur:** Steven Goldfarb[1]

[1] *University of Michigan*

As audiences increasingly favour visual content, the ATLAS Collaboration at CERN has embraced short video formats as a key tool for communicating scientific results. These videos —typically under three minutes and optimised for social platforms such as Instagram —distill complex research into accessible narratives, supported by strong visual storytelling. Designed to complement paper briefings, they offer a new entry point into the science behind ATLAS publications. We present newly compiled statistics on audience reach, engagement levels, and content performance, offering a data-driven reflection on the growing role of short-form video in connecting high-energy physics with broader audiences.

**Secondary track**:

**Poster T14 / 499**

## Science Communication in a Fragmented Media Landscape

**Auteur:** Steven Goldfarb[1]

[1] *University of Michigan*

In 2025, the landscape of science communication is shifting dramatically. Once-dominant social media platforms are in decline, fractured by distrust, misinformation, and algorithmic echo chambers. For large-scale scientific collaborations, this creates both challenges and opportunities to take new approaches. Traditional social media outreach is losing effectiveness, requiring new strategies to engage the public, policymakers, and the next generation of scientists. In this divisive media environment, humanising scientists is more critical than ever. To adapt, ATLAS Outreach is exploring new approaches like interactive virtual events, in-person engagement, and decentralised digital platforms to keep its science communication engaging, relevant, and resilient.

**Secondary track**:

**T14 / 500**

## Building ATLAS with LEGO

**Auteur:** Nathan Readioff[1]

[1] *Laboratoire de Physique Subatomique & Cosmologie*

**Auteur correspondant** readioff@lpsc.in2p3.fr

A new LEGO model of the ATLAS detector has been developed to aid and enhance educational outreach. Comprising over 21,000 LEGO elements and measuring over 1m in length, this accurate 1/50 scale model depicts ATLAS as it will appear in the High-Luminosity LHC (HL-LHC) era. Cutaway walls clearly reveal every component of the real detector, from the muon chambers down to the ITk Strip Detector and Pixel Sensors at the very heart of ATLAS. A fully modular structure facilitates group building events and the exploration of individual detector components. The accompanying CAD model, parts list, and detailed step-by-step instructions will allow this engaging and accurate LEGO representation to serve as a powerful tool for demystifying particle physics at CERN and inspiring future generations.

**Secondary track**:

**T05** / **502**

## NNLOCAL: completely local subtractions for color-singlet production in hadron collisions

**Auteur:** Flavio Guadagni[1]

[1] *University of Zurich*

**Auteur correspondant** flavio.guadagni@physik.uzh.ch

The computation of higher-order corrections to cross-sections relevant at LHC involves the evaluation of phase-space integrals that exhibit soft and collinear divergences. The subtraction of these divergences is a key ingredient to obtain fully-differential predictions for physical observables. We discuss a subtraction method to handle these divergences based on the construction of universal local counterterms. The integration of the counterterms is carried out analytically, giving a strong control on the numerical stability of our predictions. We implement our method in a numerical program, that we dub NNLOCAL, and validate it by computing the fully-differential NNLO cross-section for Higgs boson production in gluon-gluon fusion.

**Secondary track**:

**T12** / **503**

## Triggering on muon showers in the Barrel Muon Trigger of the CMS experiment for the HL-LHC upgrades

**Auteurs:** Carlos Vico[1]; Daniel Estrada Acevedo[2]; Javier Prado[2]; Santiago Folgueras[2]

[1] *University of Oviedo*

[2] *Universidad de Oviedo*

Phase-2 CMS will replace the trigger and data acquisition system in preparation for the HL-LHC. This upgrade will allow a maximum accept rate of 750kHz and a latency of 12.5us. To achieve this, new electronics and firmware are being designed. We describe the first version of an algorithm capable of detecting and identifying muon showers, running in the first layer of the trigger system. It was designed to be implemented on FPGAs with minimum resource utilisation, increasing the robustness of the current algorithm. This will allow to recover efficiency compared to the current algorithm at high pt muons.

**Secondary track**:

**T14 / 504**

## From the renovation of a laboratory to the training of teachers

**Auteur:** Beatrice Panico[1]

[1] *UNINA - INFN Na*

**Auteur correspondant** bpanico@na.infn.it

Lab2GO is a project to establish a closer contact between school and experimental sciences created by the Istituto Nazionale di Fisica Nucleare (INFN) and the University of Rome "La Sapienza". The goal is the spread of laboratory practice among students and teachers in high schools. In this contribution two different experiences will be described. In the first case, a museum laboratory present in a school in Naples that had never been used was returned to the school. Students worked together to identify the instruments, clean them, and create cards illustrating how they worked. The catalogue of instruments and the explanatory video are available to teachers and students throughout the institute, making the laboratory an integral part of the school's teaching activities.
In the second case, a teacher from a classical high school in Potenza involved in the project for several years became an active protagonist. Through the production of material and the online and offline support of the Lab2GO tutor, the teacher was able to guide his class along an innovative laboratory path. The students were motivated and enthusiastic, producing several contributions presented in the national event that will be held at the University La Sapienza in Rome.

**Secondary track**:

**Poster T05 / 505**

## Measurement of associated production of electrons and muons from heavy-flavour decays in pp collisions with ALICE

**Auteur:** Maolin ZHANG[1]

[1] *LPCA*

Measurements of the production of open heavy-flavour hadrons in high-energy heavy-ion collisions provide unique access to the transport properties of heavy quarks (charm and beauty) in the quark-gluon plasma (QGP). Charm and beauty measurements in small collision systems, such as proton–proton (pp) and proton–Pb (p–Pb) collisions, serve as a crucial test of perturbative quantum chromodynamics (pQCD) calculations. They also help explore cold nuclear matter effects and act as a baseline for interpreting results in heavy-ion collisions. In ALICE, open heavy-flavour measurements can be conducted via semimuonic decays at forward rapidity and semielectronic decays at midrapidity, offering key input for studying charm and beauty production.

Associated production of electrons and muons from heavy-flavour decays enable the study of different production mechanisms such as single-parton scattering (SPS), where both heavy quarks are produced in the same hard scattering process, and double-parton scattering (DPS), where the two quarks originate from independent parton–parton interactions within the same collision. These two mechanisms exhibit distinct patterns in angular, rapidity, and invariant-mass distributions. In particular, contributions from DPS are expected to be more pronounced at large rapidity separations between the electron and the muon detected in ALICE. Taking advantage of these kinematic features, the study of electron–muon pairs serves as a powerful tool to investigate heavy-quark production mechanisms. Furthermore, the associated production of electrons and muons from heavy-flavour decays is particularly valuable for probing correlated charm and beauty production. Unlike other dilepton channels, they are largely unaffected by contaminations from resonance decays, thermal radiation, or Drell–Yan processes, thus directly reflecting the original heavy-quark correlations.

In this poster, the status of the first measurement of correlated charm and beauty production via the invariant mass analysis of unlike-sign electron–muon pairs in pp collisions at $\sqrt{s}$ = 13.6 TeV collected during LHC Run 3 with the upgraded ALICE detector is reported. Model calculations incorporating both SPS and DPS contributions are also presented.

**Secondary track**:

**T09** / **506**

## Probing for light new particles with the LUXE experiment

**Auteur:** LUXE Collaboration[None]

The proposed LUXE experiment (LASER Und XFEL Experiment) at DESY, Hamburg, using the electron beam from the European XFEL, aims to probe QED in the non-perturbative regime created in collisions between high-intensity laser pulses and high-energy electron or photon beams. This setup also provides a unique opportunity to probe physics beyond the standard model. In this talk we show that by leveraging the large photon flux generated at LUXE, one can probe axion-like-particles (ALPs) up to a mass of 350 MeV and with photon coupling of $3 \times 10^{-6}$ GeV$^{-1}$. This reach is comparable to the background-free projection from NA62. In addition, we will discuss the ongoing optimisation of the experimental setup for the ALP search.

**Secondary track**:

**T06** / **507**

## Tackling the muon g-2 anomaly with the MUonE experiment at CERN

**Auteurs:** Giovanni Abbiendi[1]; MUonE Collaboration[None]

[1] *INFN (Bologna)*

The MUonE experiment at CERN aims to determine the leading-order hadronic contribution to the muon g-2 by an innovative approach, using elastic scattering of 160 GeV muons on atomic electrons in a low-Z target. The method relies on the measurement of the hadronic contribution to the running of the QED coupling, $\Delta\alpha_{had}(t)$, which can be extracted from a precise measurement of the shape of the differential cross section of the $\mu e$ elastic process. The M2 beam line at CERN provides the necessary intensity needed to reach the statistical goal in few years of data taking. The experimental challenge relies in the precise control of the systematic effects.
A first run with a minimal prototype setup was carried out in 2023. A pilot run has been approved to be held in 2025 with a reduced setup of the full detector components. We will present the first preliminary results from the test runs, and discuss the future plans.

**Secondary track**:

**T09** / **508**

## Stau searches at future e+e- colliders

**Auteurs:** Jenny List[1]; María Teresa Núñez Pardo de Vera[1]; Mikael Berggren[1]

[1] *DESY*

**Auteur correspondant** maria-teresa.nunez-pardo-de-vera@desy.de

The direct pair-production of the superpartner of the $\tau$-lepton, the $\widetilde{\tau}$,
is one
of the most interesting channels to search for SUSY in:
the $\widetilde{\tau}$ is
likely to be the lightest of the scalar leptons,
and is one of the most experimentally challennging ones.
The current model-independent $\widetilde{\tau}$ limits come from LEP,
while limits obtained at the LHC do extend to higher masses, but are model-dependent.
The future Higgs factories will be powerful facilities for SUSY searches, offering advantages
with respect to previous electron-positron colliders as well as to hadron machines.
In order to quantify the capabilities of these future $e^+e^-$ colliders,
the "worst-case" scenario for $\widetilde{\tau}$ exclusion/discovery has been studied, taking
into account the effect of the $\widetilde{\tau}$ mixing on $\widetilde{\tau}$ production
cross-section and detection efficiency.
To evaluate the latter, the ILD concept, originally developed for the International
Linear Collider (ILC), and the ILC beam conditions at a centre-of-mass energy of
500\,GeV have been used for detailed simulations.
The obtained exclusion and discovery reaches extend to only a few GeV below the kinematic limit
even in the worst-case scenario.
A recast of the results of the detailed simulation study to ILC at different CM energies,
and to the experimental environment of other proposed Higgs factory projects is also
presented.

**Secondary track**:

**T11** / **509**

# The MUonE detector at CERN

**Auteurs:** Giovanni Abbiendi[1]; MUonE Collaboration[None]

[1] *INFN (Bologna)*

The MUonE experiment at CERN has been proposed as a novel way to solve the muon anomaly puzzle, by a precise measurement of the differential cross section of the $\mu e$ elastic scattering. This can be obtained by using the intense 160 GeV SPS muon beam onto atomic electrons of a light target. The project has been developing in the last few years by tests of increasing complexity. The first performance results will be presented, from analysis of the 2023 Test Run, which employed a minimal prototype setup, recording events in triggerless mode during a one-week data taking. The final test has been approved to be held in 2025, in a four-week run with a reduced setup of the full detector components, including three tracking stations, electromagnetic calorimeter, and new subdetectors: a spectrometer measuring the incoming muon momentum event-by-event, scintillator planes to probe the dependency on the muon arrival time, and a muon filter to identify the scattered muon. All the subdetectors will be operated by a newly developed DAQ system, with real-time processing and online selection based on FPGA at a frequency of 40 MHz. The status of the Phase-1 pilot run and the future plans will be presented.

**Secondary track**:

**T10** / **511**

# Alien operators for PDF evolution

**Auteur:** Sam Van Thurenhout[1]

**Co-auteurs:** Franz Herzog ; Giulio Falcioni [2]; Sven-Olaf Moch [3]

[1] *HUN-REN Wigner RCP*

[2] *Università di Torino and Universität Zürich*

[3] *UHH*

**Auteur correspondant** sam.van.thurenhout@wigner.hu

Understanding the scale dependence of parton distribution functions is vital for precision physics at hadron colliders. The well-known DGLAP evolution equation relates this scale dependence to the QCD splitting functions, which can be calculated perturbatively in terms of the anomalous dimensions of leading-twist gauge-invariant operators. The computation of the latter in general requires one to take into account contributions of gauge-variant (or alien) operators. In this talk, we discuss the systematic study of these alien operators at arbitrary spin. Specifically, using generalized BRST symmetry relations, we derive the one-loop couplings and Feynman rules of the aliens necessary to perform the operator renormalization up to four loops in QCD. This provides an important step towards the determination of the four-loop splitting functions which will be of significant phenomenological importance at future colliders.

**Secondary track**:

T10 - Quantum Field and String Theory

**T05** / **512**

## Extensions of MadGraph5_aMC@NLO for QCD studies

**Auteur:** Alice Colpani Serri[1]

[1] *Warsaw University of Technology*

**Auteur correspondant** 01186009@pw.edu.pl

In this talk, I will present our recent developments in MadGraph5_aMC@NLO for elementary-particle production in asymmetric systems, including photoproduction and proton–nucleus collisions. I will also discuss the first implementation of bound-state production, specifically quarkonia, the simplest bound states in QCD. Indeed, we have extended the support of radiative corrections at Next-to-Leading Order (NLO) to simulations of asymmetric collisions, such as electron–nucleus, proton–nucleus, pion-hadron and nucleus-nucleus collisions. I will present extensive validation results for charm and beauty production, Drell–Yan, and electroweak boson production, along with predictions for various observables across the multiple collision systems that are relevant for measurements at the LHC and the future Electron–Ion Collider. I will also report on our ongoing efforts regarding the extension of MadGraph5_aMC@NLO to quarkonium states. I will outline our results to extend its capabilities for inclusive and associated quarkonium production, starting at Leading-Order (LO). I will present a comprehensive benchmarking of our LO tool against HELAC-Onia, followed by a demonstration of its expanded capabilities, enabling studies going beyond the current state-of-the-art phenomenology. This work provides the community with an all-encompassing tool for quarkonium-production studies in QCD, delivering reliable, efficient and fast automated computations and lays the foundation for our future NLO extensions.

**Secondary track**:

**T11** / **513**

## The commissioning and operational experience of LHCb - Upstream Tracker

**Auteurs:** LHCb Collaboration[None]; Wojciech Krupa[1]

[1] *Syracuse University (US)*

The LHCb detector has undergone a significant upgrade, enabling the experiment to acquire data with an all-software trigger, made possible by real-time front-end readout and fast, efficient online reconstruction. The Upstream Tracker (UT), a four-plane silicon microstrip detector located in front of the dipole magnet, is crucial for charged particle trajectory reconstruction. The UT is essential for the reconstruction of long-lived particles that decay outside the acceptance of the LHCb vertex detector. The UT was installed in LHCb in early 2023. The commissioning phase was challenging due to data synchronisation issues related to the GBTx properties. We report the lessons learned during the commissioning phase and operational experience from the first year of run 3 data taking at LHCb when the UT performance with beams was extensively studied.

**Secondary track**:

**T16** / **514**

## Hypergraph learning for full event reconstruction at pp and e+e- colliders

**Auteurs:** Etienne Dreyer[1]; Nilotpal Kakati[1]

[1] *Weizmann Institute of Science*

Particle flow reconstruction algorithms lay the foundation for physics analysis at collider experiments. Enhancing these algorithms with deep learning offers a unique opportunity to improve experimental sensitivity at the LHC and future facilities. In this talk, we present HGPflow, a deep learning approach based on hypergraphs that provides a physics-motivated framework for the energy assignment problem in particle reconstruction. We demonstrate that HGPflow can reconstruct full proton-proton and electron-positron collisions while offering gains in both accuracy and interpretability over existing methods. We further highlight the importance of preserving locality when training on full collision events and propose a strategy to ensure that the model does not learn global event features.

**Secondary track**:

T12 - Data Handling and Computing

**T09** / **515**

## Fundamental Physics with HIBEAM at the ESS

**Auteur:** Alexander Burgman[1]

**Co-auteur:** HIBEAM/NNBAR Collaboration

[1] *Stockholm University*

**Auteur correspondant** alexander.burgman@fysik.su.se

One of the great open questions in modern physics is the origin of the matter-antimatter asymmetry. This requires baryon-number violation, which has never been experimentally observed. Baryon-number violation may arise in the neutron sector as the direct conversion between neutrons and antineutrons, or with a sterile/mirror neutron.
This process will be probed with the proposed HIBEAM/NNBAR program, a two-stage experiment at the European Spallation Source. The initial stage of the program, HIBEAM, will present opportunities to search for baryon-number violation in neutron conversion to antineutrons, or to sterile neutrons (as a disappearance search) or to sterile neutrons and into neutrons/antineutrons, with discovery potential reaching a factor of ten higher than previous experiments. HIBEAM also presents unprecedented sensitivity for direct searches for low mass axions as a dark matter candidate, surpassing previous results by two-to-three orders of magnitude for axion masses between 10^-22 eV to 10^-16 eV. Additionally, HIBEAM presents opportunities to search for a nonzero neutron electric charge as well as an electric dipole moment of the neutron with world-leading sensitivity.
In this talk we present the fundamental physics opportunities of HIBEAM at the European Spallation Source.

**Secondary track**:

**T09** / **516**

## The BSM potential of Momentum-dependent Widths and Propagators

**Auteur:** Wrishik Naskar[1]

[1] *University of Glasgow*

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Incorporating self-energy corrections via Dyson resummation can quantify the deviations from the fixed-width approximation, to an extent such that one can assess their implications on the myriad of collider observables. In this talk, I shall highlight the BSM reach of momentum-dependent particle widths and propagators of gauge and Higgs bosons, and the top quark using the SMEFT framework. While effects on the Higgs boson are negligible and the $W$ boson shows percent-level deviations in reconstructed transverse mass distributions, the top quark exhibits significant sensitivity near its mass threshold. Future lepton colliders, e.g., electron-positron machines or muon colliders, can offer sensitivity to these effects, enabling a novel avenue of constraining SMEFT Wilson coefficients. Momentum dependencies can indeed provide additional sensitivity at precision-era experiments, enhancing the potential for discovering new physics there.

**Secondary track**:

**T14** / **517**

## How to support early career scientists in a large collaboration such as ATLAS

**Auteurs:** Christian Appelt[1]; Steven Goldfarb[2]

[1] *Tel Aviv University*

[2] *University of Michigan*

**Auteur correspondant** christian.appelt@cern.ch

Equity, diversity and inclusion are vital for effective collaboration within an organisation like ATLAS, and the Early Career Scientists Board (ECSB) is an essential part of ATLAS's efforts in this area.

The ECSB's mandate includes advising the administrative bodies of the ATLAS collaboration, gathering regular feedback, and proposing specific action items that improve early-career scientists' integration and general well-being. To do so, the ECSB continuously organises workshops and events to provide a platform for early-career scientists to develop their skills and careers in science more effectively and works to identify and eliminate possible obstacles that may hinder the growth of early-career researchers in the ATLAS collaboration. But it's not just about career development: the ECSB believes personal development should happen regardless of individual background, and everyone in ATLAS should feel heard, respected, and valued. This presentation highlights the importance of supporting young scientists in creating an inclusive community.

**Secondary track**:

**T11 / 518**

# Operational experience and performance of the Silicon Vertex Detector after the first long shutdown of Belle II

**Auteur:** Jim Libby[1]

[1] *IIT Madras*

In 2024 the Belle II experiment resumed data taking after its Long Shutdown 1, which was required to install a two-layer pixel detector and upgrade components of the accelerator. We describe the challenges of this upgrade and report on the operational experience during the subsequent data taking. With new data, the SVD confirmed high hit efficiency, large signal-to-noise and good cluster-position resolution. SuperKEKB's instantaneous luminosity is expected to increase significantly, resulting in a larger SVD occupancy caused by beam-related background. Considerable efforts have been made to improve the SVD-reconstruction software by exploiting the excellent SVD hit-time resolution to determine the collision time and reject out-of-time hits caused by the beam-related background. A novel procedure to group SVD hits event-by-event, based on their time, has been developed by using the grouping information during reconstruction, significantly reducing the fake rate, while preserving the tracking efficiency. The front-end chip (APV25) is operated in "multi-peak" mode, reading six samples. During data taking, we tested a 3/6-mixed acquisition mode, based on the timing precision of the trigger, that reduced background occupancy, trigger dead-time and data size. Studies show a moderate radiation-induced increase in sensor current and strip noise. However, such damage will not degrade the performance during the lifespan of the detector.

**Secondary track**:

**T01 / 519**

# Cosmological constraints from ACT Data Release 6

**Auteur:** Adrien LA POSTA[1]

[1] *Oxford University*

In March 2025, the Atacama Cosmology Telescope (ACT) released its last cosmological analysis along with a new cosmic microwave background (CMB) dataset. The sixth data release (DR6), including data collected from 2017 to 2022, covers 40% of the sky at arcminute resolution providing the most precise maps of CMB temperature and polarization. In this talk, I will give an overview of the ACT DR6 analysis and describe its constraints on fundamental assumptions of the standard cosmological model and extensions to it, including constraints on particle physics.

**Secondary track**:

**T01 / 520**

# Inference of the Mass Composition of Cosmic Rays with energies between 3 and 100 EeV using the data of the Pierre Auger Observatory and Deep Learning

**Auteur:** Berenika Čermáková[1]

[1] *Karlsruhe Institute for Technology*

One of the open questions of astrophysics is the mass composition of ultra-high-energy cosmic rays (UHECRs). The flux of UHECRs is extremely low, demanding large observatories for indirect measurements of cosmic-ray air showers, cascades of secondary particles created by interactions of the cosmic ray with the atmosphere.
Located in Argentina, the Pierre Auger Observatory is the largest cosmic-ray observatory on Earth. The Observatory is a hybrid detector employing different detection principles to observe multiple components of air showers. The core part of the detector is the Surface Detector (SD), which comprises $1\,600$ water-Cherenkov detectors with $1.5\,\mathrm{km}$ spacing in an area of $3000\,\mathrm{km}^2$. The highly sensitive Fluorescence Detector (FD) overlooks the area above the SD. Since the FD can only operate on moonless nights, its duty cycle is limited to approximately 15%.
The indirect nature of measurements of the Pierre Auger Observatory poses several challenges. For example, estimating the mass of a primary cosmic ray. The atmospheric depth of the shower maximum $X_{\max}$ is a mass-sensitive observable. The FD observes the $X_{\max}$ directly but can measure only a subset of the detected events due to its duty cycle.
On the contrary, the SD of the Pierre Auger Observatory, operating almost at 100% duty cycle, allows for a significant increase in the data. In this contribution, we present the $X_{\max}$ reconstruction based on deep neural networks that extend the energy range and statistics. We probe the energy evolution of the mean and standard deviation of the reconstructed $X_{\max}$, which reflect the changes in the mass composition. The features found in the average $X_{\max}$ rate suggest a heavier and purer mass composition with increasing energy.

**Secondary track**:

**T09 / 523**

# The X17 search at the MEG II experiment

**Auteur:** Voena Cecilia[1]

[1] *Sapienza Università di Roma & INFN*

The MEG II experiment at the Paul Scherrer Institute primarily aims to search for Physics beyond the Standard Model through the investigation of charged lepton flavor violation in the $\mu^+ \to e^+\gamma$ process.
However, it is also capable of searching for new particles.

We present a search for the X17, a hypothetical particle proposed to explain a resonant structure observed at ATOMKI in the opening angle of the electron-positron pairs, produced following the excitation of nuclei such as $^8$Be, $^4$He and $^{12}$C by proton beams.

MEG~II has a CW accelerator that delivers protons with a kinetic energy up to 1.1 MeV. These protons impinge on a Li-based target, inducing nuclear transitions that produce photons used for the calibration of the Xenon calorimeter in the MEG~II detector.

By using dedicated targets (with thicknesses up to several $\mu$m) the $^7$Li(p,e$^+$e$^-$)$^8$Be process is being studied with a magnetic spectrometer including a cylindrical drift chamber and a system of fast scintillators.

This aims to achieve a higher resolution than previous experiments and to study X17 production with greater acceptance, thereby providing deeper insight into the nature of this observation.

The results of the first four-weeks data-taking run conducted in 2023 and future prospects will be presented.

**Secondary track**:

**T09** / **524**

## Beautiful Majorana Higgses at Colliders

**Auteur:** Jonathan Kriewald[1]

**Co-auteurs:** Benjamin Fuks [2]; Fabrizio Nesti [3]; Miha Nemevšek [4]

[1] *Jožef Stefan Institute*

[2] *LPTHE Paris / Sorbonne Université*

[3] *Università dell'Aquila/INFN Gran Sasso*

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**Auteur correspondant** jonathan.kriewald@ijs.si

We investigate a novel collider signature within the minimal Left-Right Symmetric Model, featuring a Higgs sector composed of a bi-doublet and two triplets. Our study focuses on a region of the parameter space where the $SU(2)_R$ charged gauge boson $W_R$ lies in the multi-TeV regime (3-100 TeV) and the additional Higgs states play a significant role. In this scenario, a heavy neutral Higgs boson $\Delta$ with a dominant $SU(2)_R$ triplet component can be produced in association with either a Standard Model Higgs boson or a massive weak boson. The subsequent decay of the heavy Higgs into Majorana neutrinos $N$ results in displaced lepton signatures, providing a striking manifestation of lepton number violation. Additionally, we explore how the production of $b$-jets in these processes can enhance hadron-collider sensitivity to such signals. A particularly compelling channel, $pp \to b\bar{b}NN$, offers the exciting possibility of simultaneously probing the spontaneous mass origin of both Dirac fermions and Majorana states. Based on an optimised event selection strategy and state-of-the-art Monte Carlo simulations, we outline the expected reach at the HL-LHC and future colliders. Our findings demonstrate that this channel probes a region of parameter space where the neutral Higgs triplet and heavy neutrino masses are relatively light ($m_\Delta$
$lesssim 250$ GeV, $m_N$
$lesssim 80$ GeV), indirectly constraining the $W_R$ boson to the deep multi-TeV domain, with sensitivity extending up to 70-80 TeV, effectively turning the LHC into a precision machine.

**Secondary track**:

**T01** / **525**

## Investigating upward-going showers using the Fluorescence Detector of the Pierre Auger Observatory

**Auteur:** Emanuele De Vito[1]

**Co-auteur:** Pierre Auger Collaboration

[1] *Università del Salento & INFN Lecce*

**Auteur correspondant** emanuele.devito@le.infn.it

The Pierre Auger Collaboration has performed a dedicated search for upward-going air showers using the Fluorescence Detector (FD), motivated by the two "anomalous" radio pulses reported by the ANITA experiment that are difficult to reconcile with expectations from the Standard Model. While ultrahigh-energy (UHE) neutrinos can traverse the Earth and initiate Earth-skimming showers interacting just beneath the surface, the steep exit angles observed in the ANITA events are inconsistent with this mechanism. To investigate a possible connection, we carried out extensive simulations to estimate the FD sensitivity to upward-going signals. Also, we used downward-going proton-initiated air showers to model the background due to not well-reconstructed showers. In this contribution, we present the methodology adopted for signal and background modelling and report the search results based on approximately 14 years of FD data collected between 2004 and 2018. We found only one candidate, consistent with the expected background, enabling us to set an upper limit on the flux of upward-going air showers. A comparison of the Auger exposure and an analytical estimate of the ANITA exposure shows that over eight events would be expected, even assuming a conservative $E^{-5}$ spectrum. This tension disfavours the interpretation of ANITA "anomalous" events as upward-going air showers, placing constraints on Beyond Standard Model explanations.

**Secondary track**:

T03 - Neutrino Physics

**T06** / **526**

## First observation of tWZ production

**Auteur:** CMS Collaboration[None]

We present the first observation of single top quark production in association with a W and a Z boson in proton-proton collisions using 13 and 13.6 TeV data recorded with the CMS detector corresponding to integrated luminosities of 138 and 61.9 fb-1, respectively. Events are selected if they contain three or four charged leptons, which can be electrons or muons. State-of-the-art machine learning algorithms and sophisticated reconstruction methods result in an unprecedented sensitivity to tWZ production. We report the first observation of this rare process with a significance of more than five standard deviations.

**Secondary track**:

**T13** / **528**

## A Linear Collider Vision for the Future of Particle Physics

**Auteur:** Ivanka Bozovic-Jelisavcic[1]

[1] *VINCA Institute of Nuclear Sciences*

We review linear e+e− colliders with a special focus on high centre-of-mass energies and beam polarisation, take a fresh look at the various accelerator technologies available or under development and, for the first time, discuss how a facility first equipped with a technology mature today could be upgraded with technologies of tomorrow to reach much higher energies and/or luminosities. In addition, we will discuss alternative collider modes, as well as opportunities for beyond-collider experiments and R&D facilities as part of a linear collider facility (LCF). The material of this presentation will support all plans for e+e− linear colliders and additional opportunities they offer, independently of technology choice or proposed site, as well as R&D for advanced accelerator technologies. This joint perspective on the physics goals, early technologies and upgrade strategies has been developed by the LCVision team. It heavily builds on decades of achievements of the global linear collider community, in particular in the context of ILC, CLIC and C3, and recent highlights of the projects will also be presented.

**Secondary track**:

**Poster T04 / 529**

## Exploring the hadronic phase with momentum and azimuthal distribution of short-lived resonances and understanding the internal structure of exotic resonances with ALICE

**Auteur:** ALICE Collaboration[None]

**Auteur correspondant** alice-cc-chairs@cern.ch

Hadronic resonances are crucial probes to understand the various phases of matter created during relativistic heavy-ion collisions. Due to their short lifetimes, the yields of these resonances can be affected by competing rescattering and regeneration mechanisms in the final hadronic phase. Rescattering can alter the momentum of the resonance decay products, limiting their reconstruction through the invariant-mass technique, while pseudo-elastic scattering can regenerate them. Final state observables such as elliptic flow, transverse momentum spectra, and measured yields of resonances could be significantly modified due to the interaction in the hadronic phase. By contrasting the yields of longer-lived resonances, such as the ϕ-meson with shorter-lived ones, such as the K*(892), it is possible to obtain information about the properties and timescales of the hadronic phase. This contribution will present new results on production yields, spectra, and flow harmonics for K*(892) and ϕ(1020) in Pb–Pb collisions obtained by the ALICE Collaboration. The results will be compared with state-of-the-art models to interpret which underlying mechanism can describe the experimental observations.

In addition to probe hadronic phase, the study of resonances also offers valuable insights into the non-perturbative regime of Quantum Chromodynamics (QCD). Resonances such as the f0(980) and f1(1285) challenge the traditional quark model. Their structure is yet unknown as they could potentially be tetraquark states or meson-meson molecules. Proposed Glueball candidates like the f2(1270), f'2(1525), and f0(1710) also provide opportunities to explore the gluonic bound states predicted by lattice QCD. Utilizing its excellent particle identification capabilities ALICE has recently conducted detailed studies of the exotic resonance production in pp collisions data at $\sqrt{s}$ = 13 and 13.6 TeV. This contribution will present new measurements of exotic resonances such as f0(980), f1(1285), and the glueball candidates to get more insight into their internal structure.

**Secondary track**:

**Poster T04 / 531**

## System size dependence of light-flavor hadron production: from the smallest to the largest collision system at the LHC with ALICE

**Auteur:** ALICE Collaboration[None]

**Auteur correspondant** alice-cc-chairs@cern.ch

Recent measurements in pp and p-Pb collisions at the LHC showed that the production of light-flavour hadrons relative to pions increases with the charged particle multiplicity of the event already in small systems. This smooth evolution connects different collision systems almost independently of the collision energy. This extends to the strangeness sector, where the enhanced production of strange hadrons in high-multiplicity pp events is reminiscent of heavy-ion phenomenology in the case of quark-gluon plasma formation. With the wealth of data collected in Run 2 and Run 3 with the ALICE experiment, it is possible to bridge the gap in multiplicity between small and large systems, exploring for the first time the systems size dependence of light-flavour particle production at the same multiplicity values for pp and AA. This contribution presents new results on the production of light flavour hadrons in pp collisions up to a centre-of-mass energy of 13.6 TeV and in Pb-Pb collisions up to an energy of 5.36 TeV. A dedicated high multiplicity trigger is used in pp collisions to reach values up to those of peripheral Pb–Pb collisions. The light flavour particle production is also investigated versus multiplicity and as a function of the event shape, with the transverse spherocity and flattenicity estimators. Moreover, for the first time at the LHC, the system size dependence is explored down to values smaller than in pp collisions using ultra-peripheral γ–Pb reactions. The system size dependence in light-flavour production is probed from the smallest system (γ–Pb) to the largest one (Pb–Pb) at the LHC, enabling testing the statistical hadronization picture at its limits. This contribution will present new light-flavour hadron measurements covering three orders of magnitude in multiplicity. These results are discussed within the context of state-of-the-art QCD and statistical hadronization models.

**Secondary track**:

**T04 / 532**

# Production and properties of hypernuclei with ALICE

**Auteur:** ALICE Collaboration[None]

**Auteur correspondant** alice-cc-chairs@cern.ch

Hypernuclei are bound states of nucleons and hyperons. The measurement of the production of hypernuclei with mass number A=3 and 4 in heavy-ion collisions is a powerful tool to investigate the hyper-nucleosynthesis mechanism. In the coalescence model, the production yields are sensitive to the interplay between the spatial extension of the nucleus wavefunction and the baryon-emitting source size, whereas, in the statistical hadronization model, the nuclear structure does not come into play in the production. Hypernuclei span over a wide range of wavefunction radii, from about 2 fm for A=4 hypernuclei to about 10 fm for the hypertriton, making them ideal probes to test such models. In addition, the study of hypernuclei properties provides information on the nucleon-hyperon interactions, complementing the results obtained through femtoscopy correlation measurements. The strength of such interactions is a fundamental input to calculate the equation-of-state of the high-density nuclear matter found inside neutron stars. This contribution presents recent measurements of 3ΛH, 4ΛH, and 4ΛHe based on the data samples collected by ALICE during the LHC Run 2 and Run 3. The results are compared with expectations from state-of-the-art models on production through coalescence and thermal production.

**Secondary track**:

**T04 / 533**

# Charged-particle production in pp collisions at 13.6 TeV and Pb-Pb collisions at 5.36 TeV with ALICE

**Auteur:** ALICE Collaboration[None]

**Auteur correspondant** alice-cc-chairs@cern.ch

The pseudorapidity dependence of charged particle production provides information on the partonic structure of the colliding hadrons. It is especially interesting at LHC energies, as this observable is sensitive to the non-linear QCD evolution of the initial state. For the Run 3 of LHC, ALICE has upgraded its detectors, increasing its pseudorapidity coverage and tracking of charged particles over a wider range of pseudorapidity ($-3.6 < \eta < 2$) by combining the information from the upgraded Inner Tracking System (ITS) and the newly installed Muon Forward Tracker (MFT). These new detectors enable the exploration of particle production mechanisms by addressing the charged-particle pseudorapidity densities, measured over a wide $\eta$ range, in pp and Pb–Pb collisions. This contribution

presents new results from Run 3 on charged-particle multiplicity, allowing us to investigate the evolution of particle production with energy and system size. The measurement will be compared with models based on various particle-production mechanisms and different initial conditions at mid and forward rapidities.

**Secondary track**:

**T08** / **535**

## Exploring Background Contributions in $H \to Z\gamma$ Decay

**Auteur:** Aliaksei Kachanovich[1]

[1] *Université libre de Bruxelles*

The rare decay process $H \to Z\gamma$ has been investigated by both the ATLAS and CMS collaborations, with both reporting an event excess characterized by $\mu = 2.2 \pm 0.7$. This anomaly was initially attributed to potential modifications of the $HZ\gamma$ vertex. However, since the $H \to Z\gamma$ signal is reconstructed via the $H \to \ell\ell\gamma$ channel, background effects-particularly those from processes mimicking the final state-may have been underestimated. In this work, we re-examine these background contributions in detail and propose that the observed excess can be explained by an additional BSM - induced background. We present both an effective field theory framework and a UV-complete model that account for the necessary contributions and offer a consistent interpretation of the observed data.

**Secondary track**:

T09 - Beyond the Standard Model

**T14** / **536**

## ATLAS On the Air! - Measuring the Success of the ATLAS Virtual Visit Programme

**Auteur:** Steven Goldfarb[1]

[1] *University of Michigan*

Since 2010, ATLAS Virtual Visits have revolutionised HEP outreach by connecting its collaboration members with audiences worldwide. The Virtual Visit model brings inspiring scientific outreach events to visitors who would otherwise not have such an opportunity. Over the years, by offering the visits in a variety of languages and using a variety of online platforms, we have expanded their scope, engaging a broad and diverse audience, including parliaments, businesses, festivals, retirement homes, experiments, and even prisons. The visits, presented in front of the detector or the control room, stimulate audience engagement and offer excellent communication training to members of the collaboration. We present newly compiled statistics describing the growth, geographical, and demographical reach of the programme.

**Secondary track**:

**T04** / **538**

# Probing sound propagation in the QGP via relativistic ultra-central collisions with ALICE

**Auteur:** ALICE Collaboration[None]

**Auteur correspondant** alice-cc-chairs@cern.ch

Relativistic heavy-ion collisions create a hot, dense state of QCD matter called Quark–Gluon Plasma (QGP). In ultra-central collisions, the QGP volume saturates and remains constant; instead, entropy fluctuations cause temperature variations in the system. This property can be probed by measuring the correlation between the average transverse momentum ($\langle p_{\mathrm{T}} \rangle$) and the multiplicity of charged hadrons. This contribution shows the latest ALICE measurements of charged-hadron $\langle p_{\mathrm{T}} \rangle$ and its higher-order cumulants in ultra-central Pb–Pb collisions. Results are in close agreement with state-of-the-art hydrodynamic models. Furthermore, by fitting the relative increase of $\langle p_{\mathrm{T}} \rangle$ to the relative change in the average charged-particle density at midrapidity, it is possible to extract the speed of sound ($c_s$) in the QGP, which indicates how fast compression waves propagate through the QGP medium. The extracted $c_s$ shows a strong dependence on the choice of the centrality estimators used to select ultra-central collisions, highlighting the sensitivity of this measurement to experimental biases. This observation suggests a need for careful reassessment of methods for determining cs from heavy-ion data. The measurements are compared with predictions from state-of-the-art models in ultra-central events.

**Secondary track**:

**T11** / **539**

# Improving the Quality Control of new detector components using Machine-Learning-based Anomaly Detection techniques

**Auteur:** Louis Vaslin[1]

**Co-auteurs:** Daniela Bortoletto [2]; Yu Nakahama [3]

[1] *KEK / QUP*

[2] *Univ. Oxford / KEK-QUP*

[3] *KEK*

**Auteur correspondant** lovaslin@post.kek.jp

New detector concepts are necessary in order to uncover the physics Beyond the Standard Model. As the need for optimal detector performance increases, ensuring the best Quality Control (QC) for the new components is more important than ever. Among the aspects of detector QC, the Visual Inspection of components is a major procedure both in term of time and complexity. This is especially the case when the number of measurement channels is expected to increase as the resolution of detectors is improving.

I propose a new framework for the Visual Inspection of new detector components based on ML-based Anomaly Detection techniques. Since it relies on the analysis of high resolution component images, AI techniques inspired by Computer Vision algorithms are good candidates to improve this process. This framework is implemented and tested in the context of the production of the new Inner Tracker (ITk) to be deployed in the ATLAS experiment for the High Luminosity upgrade. The objective is to improve the efficiency and reliability of the Visual Inspection of components, ensuring a better overall quality of the future detector while shortening the analysis time of the images. I will show the latest results and developments, as well as the future prospects offered by such a framework.

**Secondary track**:

T16 - AI for HEP (special topic 2025)

**T04** / **540**

## Longitudinal polarization of hyperons in Run 3 Pb-Pb collisions with ALICE

**Auteur:** ALICE Collaboration[None]

**Auteur correspondant** alice-cc-chairs@cern.ch

Particle production in heavy-ion collisions exhibits collective behavior known as collective flow, arising from the pressure-driven expansion of the quark-gluon plasma (QGP) formed in these collisions. Anisotropies in the azimuthal distribution of final-state particles can generate local vorticities in the QGP along the beam axis. Through spin-orbit coupling, these vorticities are expected to induce a longitudinal polarization of hadrons along beam axis. The longitudinal polarization of produced hadrons offers valuable insights into the shear and bulk viscosities of the QGP medium.
This contribution presents the first measurement of $\Xi$ longitudinal polarization at LHC energies, utilizing the high-statistics dataset from Run 3 Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.36 TeV. The results are compared with the longitudinal polarization of $\Lambda$ baryons to investigate the spin hierarchy of longitudinal polarization in heavy-ion collisions.

**Secondary track**:

**T04** / **541**

## Strangeness enhancement with effective energy in pp collisions at the LHC with ALICE

**Auteur:** ALICE Collaboration[None]

**Auteur correspondant** alice-cc-chairs@cern.ch

The enhanced production of strange hadrons in heavy-ion collisions relative to that in pp collisions is historically considered one of the signatures of the formation of the quark-gluon plasma. At the LHC, the ALICE experiment observed that the yield ratios of strange to non-strange hadrons increase with the charged-particle multiplicity at midrapidity, evolving smoothly across all systems over more than three orders of magnitude in multiplicity. The understanding of the origin of this effect in small systems remains unsolved.
This contribution will present the measurement of (multi-)strange hadron yields in proton–proton collisions at $\sqrt{s} = 13$ TeV as a function of the local charged-particle multiplicity in the pseudorapidity interval $|\eta|$<0.5 and of the very-forward energy measured with the ALICE Zero-Degree Calorimeters. The latter provides information on the effective energy, i.e. the energy effectively available for particle production in the collision once the energy carried by the leading particles is subtracted from the centre-of-mass energy. The yields of strange and multi-strange per charged particle are measured by exploiting a multi-differential approach to decouple the dependence on the local multiplicity and effective energy. These results provide new insights into the interplay between global properties of the collision, such as the initial available energy in the event, and the locally produced final hadronic state connected to the charged-particle multiplicity at midrapidity. A strong increase of strange baryon production with effective energy is observed for fixed charged-particle multiplicity at midrapidity. These results are discussed within the context of existing phenomenological models of hadronisation implemented in different tunes of the PYTHIA 8 event generator.

**Secondary track**:

T05 - QCD and Hadronic Physics

**T03** / **542**

## A short-baseline neutrino experiment at CERN for high-precision cross-section measurements

**Auteur:** Fabio Pupilli[None]

The limited knowledge on neutrino cross-sections at the GeV scale will represent the main source of systematic uncertainty for the next-generation generation neutrino oscillation experiments. Building on the ideas and R\&D efforts of ENUBET and NuTag, SBN@CERN is a proposal for a high-precision neutrino cross-section experiment.
The experiment is driven by slow extracted proton beam enabling the operation of instrumentation along the beamline and in the decay tunnel. This setup allows for percent-level monitoring of both electron and muon neutrino fluxes, individual tagging of muon neutrinos, and precise measurement of the neutrino energy independently of final-state particle reconstruction in the neutrino detector. As a result, the SBN@CERN eliminates the two primary sources of systematic uncertainty in cross-section measurements: flux normalization and energy bias caused by nuclear effects. We will discuss the design of the beamline, the proposed technology for its instrumentation together with results of prototyping activities, and possible scenarios for its implementation at CERN. We will also highlight the physics potential of this facility, with a focus on cross-sections relevant to DUNE and Hyper-Kamiokande.

**Secondary track**:

**T05** / **543**

## Testing perturbative QCD calculations with beauty-meson production in proton–proton collisions with ALICE

**Auteur:** ALICE Collaboration[None]

**Auteur correspondant** alice-cc-chairs@cern.ch

Due to their large mass, beauty quarks are always produced in hard-scattering processes, and hence their production can be computed with perturbative quantum chromodynamics (pQCD) calculations. The production cross section of beauty hadrons can be theoretically described with the factorisation approach as a convolution of the parton distribution functions of the incoming projectiles, the perturbative partonic cross section, and the fragmentation functions describing the transition from quarks to hadrons. Measurements of the production cross section of beauty hadrons in proton–proton (pp) collisions are therefore excellent tests of pQCD calculations. Measurements down to low transverse momenta are also fundamental ingredients for the estimation of the $\mathrm{b\overline{b}}$ production cross section. Moreover, the relative abundances of different beauty-hadron species also give insights into the beauty-quark hadronisation mechanisms.
Finally, measurements of beauty-hadron production cross sections in pp collisions provide a reference for Pb–Pb collisions, where modifications due to the creation of the quark–gluon plasma are expected.

In this contribution, measurements of B mesons fully reconstructed via their decay channels into a D meson and a charged pion are presented. In particular, the production cross section of $\mathrm{B}^0$-mesons in pp collisions at $\sqrt{s} = 13.6$ TeV collected by the ALICE experiment during the LHC Run 3 is presented. The measured production cross section is compared with state-of-the-art pQCD calculations with next-to-leading order accuracy plus all-order resummation of next-to-leading logarithms. Additionally, the status of the measurements of $\mathrm{B}^+$-meson and $\mathrm{B}^0_\mathrm{s}$-meson production on the same data sample is also discussed.

**Secondary track**:

**T01** / **544**

## Gravitational and Structural Modifications of Compact Objects due to Quadrupole Moments in General Relativity

**Auteurs:** Amina Sadu[1]; Saken Toktarbay[1]

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Gravitational and Structural Modifications of Compact Objects due to Quadrupole Moments in General Relativity

This study investigates the gravitational behavior of compact astrophysical objects, specifically white dwarfs and neutron stars, within Einstein's General Relativity framework. We incorporate the quadrupole moment in a first-order approximation to analyze how deviations from spherical symmetry influence their internal structure.

The Einstein field equations for a perfect fluid are given by:
$R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} = 8\pi[(\rho + p)U_\mu U_\nu - pg_{\mu\nu}]$

where $\rho$ and $p$ represent the density and pressure, respectively. The interior metric includes quadrupole corrections 1:
$ds^2 = e^{2\nu}(1 + qa)dt^2 -$
$dfrac(1 + qc + qb)1 - dfrac2mrdr^2 - (1 + qa + qb)r^2 d\theta^2 - (1 - qa)r^2 \sin^2\theta d\varphi^2$

Here, $\nu = \nu(r)$, $a = a(r)$, $c = c(r)$, $b = b(r, \theta)$, and $q$ is the quadrupole parameter.

We compare two fundamental equations of state (EoS), the Chandrasekhar and Salpeter EoS, to examine their impact on mass distributions and pressure gradients. The Chandrasekhar EOS is given by [2,3]:
$p_{\text{Ch}} =$
$dfrac43\left(dfracm_e m_n\right)^4 K_n\left[y(2y^2 - 3)\sqrt{1 + y^2} + 3\ln(y + \sqrt{1 + y^2})\right]$

while the Salpeter EoS includes electrostatic corrections:
$p_{\text{Sal}} = p_{\text{Ch}} + p_C + p_{TF}$

Numerical solutions of the Einstein equations reveal that quadrupole-induced modifications significantly alter the gravitational field and structural properties of these stars.

References:
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2Chandrasekhar, S. The Maximum Mass of Ideal White Dwarfs. Astrophys. J. 1931, Vol 74, No. 81.
[3] Rotondo M., Rueda J. A., Ruffini R., Xue S. S. Phys. Rev. D, 2011, Vol. 84, No. 8, p. 084007.

**Secondary track**:

**T04** / **545**

## Investigating charm-quark dynamics in the QGP via the charm-hadron elliptic flow in Pb–Pb collisions with ALICE

**Auteur:** ALICE Collaboration[None]

Heavy quarks (charm and beauty) are useful probes for investigating the properties of the quark-gluon plasma (QGP) generated in ultra-relativistic heavy-ion collisions. Their participation in the collective motion of the medium can be assessed by measuring the prompt and non-prompt charm-hadron elliptic-flow coefficient $v_2$, originating from the initial-state spatial asymmetry in non-central heavy-ion collisions. These measurements provide fundamental inputs to constrain theoretical models describing the heavy-quark transport in the QGP, as well as its possible thermalization in the medium. In addition, the comparison between meson and baryon $v_2$ can provide further insights into medium-induced phenomena, such as the radial flow and the heavy-quark hadronization via coalescence.

In this contribution, the first measurements of prompt- and non-prompt $\mathrm{D}^0$-, $\mathrm{D}^+$-, $\mathrm{D}_\mathrm{s}^+$-meson and $\Lambda_\mathrm{c}^+$-baryon $v_2$ in different centrality intervals of Pb–Pb collisions at $\sqrt{s_\mathrm{NN}} = 5.36$ TeV collected by the ALICE experiment during the LHC Run 3 are shown. The measurements are compared to model predictions that incorporate various implementations of heavy-quark interaction and hadronization with the QGP constituents. Moreover, the status of the measurement of the $\mathrm{D}^0$-meson elliptic flow in pp collisions is presented.

**Secondary track**:

**Poster T04 / 546**

# Measuring EECs in small to large collision systems with ALICE

**Auteur:** ALICE Collaboration[None]

**Auteur correspondant** alice-cc-chairs@cern.ch

Energy-energy correlators (EECs) provide a powerful tool to study the evolution of scattered partons into final-state hadrons. Defined as the energy-weighted cross section of the angle between particle pairs, EECs provide insight into the transition of the perturbative and non-perturbative regimes of Quantum Chromodynamics (QCD). Utilizing the ALICE precision charged-particle tracking, we present the evolution of the EECs across a variety of collision systems, measured down to low jet transverse momentum. In pp collisions, the angular dependence of the EEC cross section shows a distinct separation of the perturbative and non-perturbative regimes, revealing the partonic dynamics of jet formation and the confinement of partons into hadrons. In p–Pb collisions, the EECs can probe modifications to the dynamics of jet evolution in the presence of cold nuclear-matter effects. Finally, in Pb–Pb collisions, EECs probe the interactions of the jet with the quark-gluon plasma, highlighting the scale dependence of strong interactions in a many-body QCD system.

**Secondary track**:

**T04 / 547**

# Jet modification studies down to low $p_T$ and large radius with ALICE

**Auteur:** ALICE Collaboration[None]

**Auteur correspondant** alice-cc-chairs@cern.ch

The energy-loss of high-momentum jets, as they traverse the hot and deconfined quark-gluon plasma (QGP) produced in heavy-ion collisions, is one of the key observables used to characterize medium properties. In particular, the ability of the medium to dissipate the lost energy of the jet provides vital information on the transport properties of the QGP. The dissipative power of the medium can be probed by comparing the energy loss of jets with different radii. In this talk, we present new ALICE measurements in Pb–Pb collisions at $\sqrt{s_\mathrm{NN}}$ = 5.02 TeV, extending the reach of large radius jets to low transverse momenta, using an event-mixing method to correct the uncorrelated background. Comparison of these measurements to theoretical calculations provide new insight into the mechanisms underlying jet quenching and the transport of energy in the QGP medium.

**Secondary track**:

**T04 / 549**

# Quarkonia collectivity in large collision systems with ALICE

**Auteur:** ALICE Collaboration[None]

**Auteur correspondant** alice-cc-chairs@cern.ch

Quarkonium production has long been identified as one of the golden probes to study the quark-gluon plasma (QGP). Among many observables, the measurement of azimuthal anisotropies in quarkonium production has a special role to shed light on the collective behavior of particles in a strongly interacting medium. In particular, the magnitude of the J/$\psi$ elliptic flow measured at the LHC in Pb-Pb collisions is interpreted as a signature of the charm-quark thermalization in the QGP, supporting the scenario of charmonium (re)generation at low $p_{\mathrm{T}}$. Interestingly, the observation of collective-like effects in high-multiplicity pp and p-Pb collisions raises questions about the minimal conditions needed for QGP formation. In this contribution, measurements of quarkonium flow coefficients from small (pp) to large (Pb-Pb) collision systems carried out by the ALICE collaboration will be presented. New results on J/$\psi$ $v_2$ in Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.36$TeV using event-plane and scalar product methods as a function of $p_{\mathrm{T}}$ and rapidity will be discussed. In addition, multi-particle cumulant J/$\psi$ $v_2\{4\}$ will be shown, allowing further insight into charm quark thermalization into the QGP and, for the first time, access to flow fluctuations.

**Secondary track**:

**T04 / 551**

# Particle production in inelastic photonuclear interactions in ultra-peripheral Pb-Pb collisions with ALICE

**Auteur:** ALICE Collaboration[None]

**Auteur correspondant** alice-cc-chairs@cern.ch

Ultra-peripheral collisions enable a variety of two-photon and photonuclear interactions to be studied. Earlier analyses have mostly focused on exclusive photonuclear vector meson production and on two-photon interactions. This presentation will be on photonuclear interactions where the target nucleus breaks up. The cross sections for these interactions are huge in Pb-Pb collisions at the LHC. The transverse momentum and rapidity distributions of pions, kaons, and protons will be presented. The results will be compared to model calculations. These interactions provide an additional measure of cold nuclear matter effects, which have previously been probed in proton-nucleus interactions.

**Secondary track**:

**T04 / 552**

# Dielectron production in pp and Pb-Pb collisions with ALICE in Run 3

**Auteur:** ALICE Collaboration[None]

**Auteur correspondant** alice-cc-chairs@cern.ch

The measurement of dielectron production is a fundamental piece of the puzzle in the understanding of the hot and dense matter produced in ultra-relativistic heavy-ion collisions. The dielectron spectrum provides information that penetrates the veil of final-state hadronic interactions and provides direct access to the early phases of the collision. However, the interpretation of the measured

spectra relies on a precise understanding of all the contributing sources.
In this talk, we present the measurement of dielectron production in the high-precision proton-proton data collected with the upgraded ALICE detector at $\sqrt{s} = 13.6$ TeV. This establishes a crucial baseline for all measurements of dielectron production in larger collision systems. Utilizing the new inner tracking system, dielectron pairs from semi-leptonic decays of heavy-flavor hadrons are identified and subtracted using a data-driven approach.
The possibilities of using the extracted spectrum of prompt dielectrons over a wide mass range are discussed in the context of a possible onset of thermal radiation or the production of dielectron pairs via the Drell-Yan process in a regime where no reliable calculations based on perturbative QCD are available. We will in addition show the status of the analysis of the Pb-Pb data collected during LHC Run 3.

**Secondary track**:

**Poster T04 / 553**

## Thermal radiation from small to large systems via low-mass dielectrons with ALICE

**Auteur:** ALICE Collaboration[None]

**Auteur correspondant** alice-cc-chairs@cern.ch

Electromagnetic probes are a unique tool for studying the space-time evolution of the hot and dense matter created in ultra-relativistic heavy-ion collisions. Dielectron pairs are emitted during the entire evolution of the medium created in such collisions, allowing the extraction of the real direct photon fraction at vanishing mass and providing access to thermal radiation from the early hot stages of the collision. The measurement of dielectron and direct photon production in minimum-bias pp collisions serves as a crucial baseline for the studies in heavy-ion collisions, whereas pp collisions with high charged-particle multiplicities allow the search for interesting phenomena such as the possible presence of QGP in small systems.
This talk will present the final LHC Run 2 ALICE results on the direct-photon production in pp and central Pb–Pb collisions using the virtual-photon method. The results from central Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV are compared to theoretical models that include hot medium effects such as thermal radiation and chiral symmetry restoration. Different approaches to disentangle the background from semi-leptonic heavy flavour decays are presented and discussed. To study the possible onset of the formation of a hot medium, we also report the results on the direct-photon production in pp collisions at $\sqrt{s}$ = 13 TeV as a function of charged-particle multiplicity. For the first time at LHC energies we observe a significant yield of direct photons in pp collisions at low $p_{\mathrm{T}}$. The results are compared to theoretical models that include a contribution from a thermalised source.

**Secondary track**:

**T03 / 556**

## CUPID, the next-generation 0νββ bolometric experiment

**Auteur:** collaboration CUPID[None]

**Co-auteur:** Pia Loaiza [1]

[1] *LAL*

Neutrinoless double-beta decay (0νββ) is a key process to address some of the major outstanding issues in particle physics, such as the lepton number conservation and the Majorana nature of the neutrino. Several efforts have taken place in the last decades in order to reach higher and higher sensitivity on its half-life. The next-generation of experiments aims at covering the Inverted-Ordering

region of the neutrino mass spectrum, with sensitivities on the half-lives greater than $10^{27}$ years. Among the exploited techniques, low-temperature calorimetry has proved to be a very promising one, and will keep its leading role in the future thanks to the CUPID experiment. CUPID, CUORE Upgrade with Particle Identification, will search for the neutrinoless double-beta decay of $^{100}$Mo and will exploit the existing cryogenic infrastructure as well as the gained experience of CUORE, at the Laboratori Nazionali del Gran Sasso in Italy. Thanks to scintillating $Li_2^{100}MoO_4$ crystals coupled to light detectors, CUPID will have simultaneous readout of heat and light that will allow for particle identification, and thus a powerful alpha background rejection. With a background index of $10-4$ counts/keV/kg/y, 240 kg isotope mass, 5 keV FWHM energy resolution and 10 live-years of data taking, CUPID will have a 3σ discovery sensitivity of $1.10^{27}$yr, corresponding to a $m_{\beta\beta}$ range of 12 –21 meV.
In our talk, we will present the current status of CUPID and outline the forthcoming steps towards the construction of the experiment.

**Secondary track**:

**T15** / **557**

## Simulating Meson Scattering in (1+1)D $\mathbb{Z}_2$ Lattice Gauge Theory: Efficient Operator Construction and Quantum Circuit Implementation

**Auteurs:** Stefan Kuehn[1]; Yahui Chai[2]; Yibin Guo[2]

[1] *Deutsches Elektronen-Synchrotron DESY*

[2] *DESY*

Scattering processes in gauge theories are fundamental to high-energy physics but remain challenging for classical simulations due to the sign problem and entanglement growth in real-time dynamics. Quantum computing offers a promising alternative for simulating such processes.

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In this work, we study meson scattering in a (1+1)-dimensional \protect $\mathbb{Z}_2$ lattice gauge

Furthermore, we propose an efficient quantum circuit decomposition for meson wave packet preparation
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**Secondary track**:

**T16** / **559**

## Accurate Surrogate Amplitudes with Calibrated Uncertainties

**Auteur:** Henning Bahl[1]

[1] *Universität Heidelberg*

**Auteur correspondant** ve298@uni-heidelberg.de

Neural networks for LHC physics have to be accurate, reliable, and controlled. Using surrogate loop amplitudes as a use case, we first show how activation functions can be systematically tested with KANs. For reliability and control, we learn uncertainties together with the target amplitude over phase space. Systematic uncertainties can be learned by a heteroscedastic loss, but a comprehensive learned uncertainty requires Bayesian networks or repulsive ensembles. We compute pull distributions to show to what level learned uncertainties are calibrated correctly for cutting-edge precision surrogates.

**Secondary track**:

**Poster T05 / 560**

## Measurement of $\Lambda$ baryon balance function in pp collisions at $\sqrt{s} = 13.6$ TeV at ALICE

**Auteur:** Yash Patley[1]

[1] *Indian Institute of Technology Bombay*

This work presents the study of the strange baryon balance function in proton-proton (pp) collisions at $\sqrt{s} = 13.6$ TeV at LHC with ALICE.

Balance functions of strange baryons are sensitive to production and transport of strange quarks and their hadronization to baryons during the evolution of hot QCD matter formed in heavy-ion collisions. They are also sensitive to the diffusion of up, down and strange quarks produced in QCD matter as well as strangeness and baryon susceptibilities.

In this work, the balance function of $\Lambda$ baryons is measured for different multiplicity classes in pp collisions at $\sqrt{s} = 13.6$ TeV. The evolution of the widths of the near-side peak and integral of the balance function from low to high multiplicity classes are susceptible to the production of $s\bar{s}$ quark pairs and their hadronization to hadrons. They could also possibly be sensitive to the presence of the QGP phase in very high multiplicity pp collisions at top LHC energies.

The results are compared with Monte Carlo models which shall put significant constraints on the model parameters and our understanding of the possibility of the existence of a QGP phase in pp collisions.

**Secondary track**:

**T11 / 561**

## The silicon tracking system of the future ALICE 3 experiment at the LHC

**Auteur:** ALICE Collaboration[None]

ALICE 3 is the next generation heavy-ion experiment proposed for the LHC Runs 5 and 6. Its tracking system will be based on a vertex detector, integrated in a retractable structure inside the beam pipe to achieve a pointing resolution of better than 10 microns for $p_{\mathrm{T}}$>200 MeV/c, and a very-large-area tracker, surrounding the vertex detector and covering 8 units of pseudorapidity ($|\eta|$<4). The tracking system will be based on Monolithic Active Pixel Sensor (MAPS) technology and will leverage the sensor developments carried out for the recently upgraded ALICE Inner Tracking System and for the future ALICE ITS3.

An intensive R&D program has already started to meet the challenging detector requirements: the innermost vertex detector layer, placed at 5 mm from the interaction point, must withstand an integrated radiation load of 9x10$^{15}$ 1 MeV neq/cm$^2$ NIEL and 288 Mrad TID; the tracker will cover more than 50 m$^2$ of surface, extending to a radius of 0.8 m and a total longitudinal length of about 8 m.

This contribution will discuss the detector requirements and target sensor specifications, the ideas for mechanics and integration, and the main R&D challenges expected for the implementation of the ALICE 3 tracking system. In addition, the expected performance for novel heavy-flavour studies, ranging from D-Dbar angular and momentum correlations to the reconstruction of multicharm baryons, will be presented.

**Secondary track**:

**T03 / 562**

# A limit on neutrino mass with the first HOLMES dataset

**Auteur:** Matteo De Gerone[1]

**Co-auteurs:** Adriano Bevilacqua [2]; Alessandro Cattaneo [3]; Alessandro Cian [4]; Alessandro Irace [4]; Andrea Giachero [5]; Angelo Nucciotti [6]; Benno Margesin [4]; Bradley Alpert [7]; Carl Reintsema [7]; Dan Schmidt [7]; Daniel Becker [8]; Daniel Swetz [7]; Danilo Labranca [6]; Douglas Bennett [7]; Elena Ferri [5]; Emilio Maugeri [9]; Enrico Bogoni [4]; Eugenio Monticone [10]; Fabio Siccardi [2]; Federica Mantegazzini [4]; Federico Malnati [10]; Felix Ahrens [4]; Flavio Gatti [11]; Gene Hilton [7]; Giancarlo Ceruti [5]; Gianluigi Pessina [5]; Giovanni Gallucci [2]; Hobey Garrone [10]; Joel Ullom [7]; John Gard [8]; John Mates [7]; Joseph Fowler [7]; Leila Vale [7]; Lorenzo Ferrari Barusso [11]; Luca Origo [5]; Luigi Parodi [2]; Marco Balata [12]; Marco Faverzani [6]; Marco Gobbo [6]; Matteo Borghesi [3]; Maurizio Lusignoli [13]; Mauro Rajteri [10]; Nicolo' Crescini [4]; Pietro Campana [3]; Pietro Manfrinetti [14]; Roberto Moretti [6]; Rodolfo Carobene [3]; Sara Gamba [6]; Stefano Nisi [12]; Stefano Ragazzi [6]; Ulli Köster [15]; Zeynep Talip [9]

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The precise determination of the mass scale of (anti)neutrinos remains a fundamental open question in particle physics, carrying major implications ranging from sub-atomic physics to cosmological model.
The only model-independent approach to the measurement of neutrino mass is based on the analysis of the endpoint of beta or electron capture (EC) decay spectra, relying purely on kinematic constraints.
The spectrometric approach, which has historically been the cutting edge technology for these studies since 1970, is going to reach its sensitivity limit around 0.3 eV/c$^2$ due to technological constraints with the upcoming final DAQ campaign of the KATRIN experiment, which is currently setting the best upper limit on electron neutrino mass ($m_\nu$ < 0.45 eV @ 90% CL) by using a tritium source.
A promising strategy to circumvent this limit involves the adoption of a calorimetric technique, where the radioactive source is integrated directly into the detector. This configuration allows the measurement of all released energy except for that eventually carried away by the neutrino, thereby significantly reducing the systematic uncertainties.
The HOLMES experiment employs this approach, aiming to a sub-eV sensitivity on neutrino mass. It currently deploys arrays of Transition Edge Sensors based micro-calorimeters, embedded with ~0.5 Bq $^{163}$Ho atoms and readout based on microwave SQUID multiplexing.
The EC decay of $^{163}$Ho has been proposed as a channel for such a measurement due to its low Q-value

(2.86 keV) and relatively short half-life (~4570 years). HOLMES employs arrays of 64x Ho-implanted micro-calorimeters, achieving an average energy and time resolutions of 6 eV (FWHM) and 1.5 μs, respectively.
HOLMES recently completed its first physics data-taking run, by collecting ~$7\times10^7$ decay events over a two-month period. Analysis of the resulting spectrum led to a Bayesian upper limit on the effective electron neutrino mass of m⊠ < 27 eV/$c^2$ at 90% confidence level. Even if still far from the current best limit, this result proved the viability of $^{163}$Ho calorimetry for future neutrino mass experiments and highlighted the potential of TES-based micro-calorimeters as a scalable and robust technology. Currently HOLMES is approaching a new experimental phase called HOLMES+, by developing larger arrays with increased single-pixel activity, enhancing statistical sensitivity and paving the way toward sub-eV measurements in the next decade.

**Secondary track**:

**T02** / **563**

## The CRESST experiment for Light Dark Matter Search

**Auteur:** Stefano Di Lorenzo[1]

[1] *Max Planck Institut für Physik*

The CRESST (Cryogenic Rare Event Search with Supercoduncting Thermometers) experiment located in the underground facility of the Laboratori Nazionali del Gran Sasso (LNGS) aims to measure dark matter particles through their elastic scattering off nuclei in scintillating crystals. The target crystals are equipped with Transition Edge Sensor (TES) thermometers and operated at mK temperature as cryogenic calorimeters. CRESST achieved outstandingly low nuclear recoil thresholds (~10 eV) yielding world-leading sensitivity for light dark matter particles for mass below 1.7 GeV/$c^2$.The current sensitivity is limited by an excess of events rising exponentially below the 200 eV, known as the Low Energy Excess (LEE), whose origin remains unclear. The most recent results, together with future plans will be presented and discussed.

**Secondary track**:

**T11** / **564**

## Design and expected performance of ALICE ITS3 tracker upgrade

**Auteur:** ALICE Collaboration[None]

During LHC LS3 (2026-29) ALICE is replacing its innermost three tracking layers by a new detector, “ITS3”. It will be based on newly developed wafer-scale monolithic active pixel sensors, which are bent into truly cylindrical layers and held in place by light mechanics made from carbon foam. Unprecedented low values of material budget (0.07% per layer) and closeness to interaction point (19 mm) lead to a factor two improvement in pointing resolutions from very low $p_{\mathrm{T}}$ (O(100 MeV/c), achieving, for example, 20 $\mu$m and 15 $\mu$m in the transversal and longitudinal directions, respectively, for 1 GeV/c particles. After a successful R&D phase 2019-2023, which demonstrated the feasibility of this innovational detector and led to the Technical Design Report (https://cds.cern.ch/record/2890181), the final sensor and mechanics are being developed right now. This contribution will review the conceptual design and the main R&D achievements, as well as the current activities and road to completion and installation. It concludes with a projection of the improved physics performance, in particular for heavy-flavour mesons and baryons, as well as for thermal dielectrons, that will come into reach with this new detector installed.

**Secondary track**:

**T11 / 565**

# ALICE Forward Calorimeter upgrade (FoCal): physics program and expected performance

**Auteur:** ALICE Collaboration[None]

The FoCal is a high-granularity forward calorimeter to be installed as an ALICE upgrade during the LHC Long Shutdown 3 and take data in Run 4.
It will cover a pseudorapidity interval of $3.2 < \eta < 5.8$, allowing to explore QCD at unprecedented low Bjorken-$x$ of down to $\approx 10^{-6}$ – a regime where non-linear QCD dynamics are expected to be sizable.
The FoCal consists of a compact silicon-tungsten sampling electromagnetic calorimeter with pad and pixel readout to achieve high spatial resolution for discriminating between isolated photons and decay photon pairs. Its hadronic component is constructed from copper capillary tubes with scintillator fibers.
The detector design allows measuring a multitude of probes, including direct photons, jets, as well as photo-production of vector mesons in ultra-peripheral collisions and angular correlations of different probes.
After the recent completed of the Technical Design Report (https://cds.cern.ch/record/2696471), the FoCal project is entering the production phase in view of installation in 2028.
We will give an overview of the FoCal physics programme, of the detector design and of its expected performance using results from recent test beams of small-scale prototypes.

**Secondary track**:

**T12 / 566**

# The new ALICE asynchronous software trigger processing

**Auteur:** ALICE Collaboration[None]

During the LHC Run 3 data taking period, ALICE is reading out a factor of 600 more proton–proton collisions compared to Run 2, generating a data stream to the CERN T0 of over 30 GB/s —the highest among all LHC experiments. This dramatic increase was made possible through major upgrades to both the detector systems and the underlying data processing infrastructure.

The full data stream is continuously compressed and written to disk, then passed through the ALICE calibration and reconstruction pipeline. A flexible software trigger is applied afterward to identify and retain the relevant events for analysis.

Thanks to this efficient processing model, in 2024, ALICE collected and processed over 53 $pb^{-1}$ of data —more than ever before in the experiment's history. From an initial 200 PB of raw data, just 8 PB were retained for analysis. Remarkably, the full trigger chain —including final physics reconstruction — was completed within just eight weeks of data taking, with datasets already available for analysis. This enabled a broad range of results based on 2024 data to be presented at conferences that same year.

This presentation will provide an overview of ALICE's upgraded processing chain with a focus on the new asynchrounous software trigger strategy, and demonstrate how these innovations are maximizing the experiment's physics reach in Runs 3 and 4.

**Secondary track**:

**Poster T05 / 567**

# Light neutral meson production at the LHC energies with ALICE

**Auteur:** ALICE Collaboration[None]

This talk presents a complete overview of ALICE measurements of $\pi^0$, $\eta$, and $\omega$ meson production in pp and p–Pb collisions using the Run 2 data, from $\sqrt{s}$ = 900 GeV up to 13 TeV, over an unprecedented transverse momentum range. The ALICE measurements of neutral meson production give constraints on parton distribution functions (PDF) and fragmentation functions (FF), and provide essential background corrections for direct photon and dilepton analyses. The results in pp collisions at $\sqrt{s}$ = 13 TeV are furthermore shown as a function of the event charged-particle multiplicity and the correlation of the $\pi^0$ and $\eta$ meson with jets.
Measurements in high-multiplicity pp collisions have revealed similarities to Pb–Pb collisions for observables that were previously attributed to the formation of a QGP, suggesting a continuous evolution from small to large collision systems. In addition, the correlation of neutral mesons and jets measured in pp collisions provides further constraints on the meson FF. The status of the analysis of the high-statistics Run 3 data using the upgraded ALICE detector will also be presented.

**Secondary track**:

**T09 / 568**

# Searches for long-lived particles with displaced jets at CMS

**Auteur:** CMS Collaboration[None]

Many extensions of the standard model predict new particles with macroscopic lifetimes. Such particles produce different kinds of non-conventional signatures in the detector, for example, jets originating away from the primary proton-proton (pp) interaction vertex, known as displaced jets. Searches exploring the lifetime frontier using displaced jet signatures have become increasingly prominent at the LHC, and they often require specialized reconstruction and identification techniques, such as, state-of-the-art machine learning models. This talk will summarize the diverse approaches and results of recent long-lived particles searches using displaced jets at CMS, with 13 and 13.6 TeV pp collision datasets.

**Secondary track**:

**Poster T05 / 569**

# Bottomonia production and polarization in pp collisions with ALICE

**Auteur:** ALICE Collaboration[None]

Quarkonium production in high-energy hadronic collisions is sensitive to both perturbative and non-perturbative aspects of quantum chromodynamics (QCD) calculations. From a theoretical point of view, the production of the heavy-quark pair is described by perturbative QCD while the formation of the bound state is a non-perturbative process, treated in different ways by the available theoretical models. In this context, quarkonium polarization measurements represent a powerful tool to discriminate among the different theoretical predictions. In particular, the study of the anisotropies in the angular distribution of the decay production with respect to a given quantization axis is sensitive to the quarkonium hadronization mechanism, even if the very small values measured at the LHC have been challenging the commonly-used theoretical models. Moreover, the possibility to investigate effects related to the formation of a strongly interacting medium in ultra-relativistic heavy-ion collisions requires a precise determination of the proton-proton reference cross section and polarization.

The ALICE collaboration has measured the $\Upsilon(1S)$ cross section and polarization at different center-of-mass energies and in this contribution we will present the recent measurements in pp collisions at $\sqrt{s} = 13$ TeV at forward rapidity (2.5 < y < 4) in the dimuon channel. In addition, thanks to the upgraded detector and the large data sample collected in LHC Run 3 the preliminary measurement of $\Upsilon$(2S)-to-$\Upsilon$(1S) ratio both at mid ( |y| < 0.9) and forward rapidity (2.5 < y < 4) will be presented for the first time at $\sqrt{s} = 13.6$ TeV in the $e^+e^-$ and $\mu^+\mu^-$ decay channel respectively.

**Secondary track**:

**Poster T05 / 570**

## Charmonium production in jets and as a function of multiplicity with ALICE

**Auteur:** ALICE Collaboration[None]

The study of charmonium production in hadronic collisions is a valuable test for models of quantum chromodynamics (QCD) as both perturbative and non-perturbative processes need to be taken into account in the calculations. At LHC energies, several parton interactions may occur in a single pp collision. Multi-parton interactions (MPI) influence the production of light quarks and gluons, affecting the total event multiplicity, but also hard processes as charmonium production. Therefore the event-multiplicity dependent production of charmonium has the potential to give new insights on the interplay between the hard and soft mechanisms in charmonium production. Another topic of interest in hadronic collisions is the measurement of the $J/\psi$ production in jets, which can shed light into the mechanisms governing the hadronization of a c-$\bar{c}$ pair into a $J/\psi$. In this contribution the prompt and non-prompt $J/\psi$ fragmentation functions in charged jets measured at midrapdity are presented and compared with models. Moreover, the $J/\psi$ production at midrapdity and forward rapidity as a function of the relative charged-particle multiplicity, respectively at midrapidity and forward rapidity will be shown, and compared with models.

**Secondary track**:

**T02 / 572**

## ANUBIS: Projected Sensitivities and Initial Results from the proANUBIS demonstrator with Run 3 LHC data

**Auteurs:** Oleg Brandt[1]; Paul Swallow[2]; Théo REYMERMIER[3]

[1] *U. Heidelberg, Kirchhoff Institute for Physics*

[2] *University of Cambridge*

[3] *IP2I Lyon + LPSC*

**Auteurs correspondants:** ps983@cam.ac.uk, oleg.brandt@cern.ch, t.reymermier@ip2i.in2p3.fr

Despite the success of the Standard Model (SM) there remains behaviour it cannot describe, in particular the presence of non-interacting Dark Matter. Many models that describe dark matter can generically introduce exotic Long-Lived Particles (LLPs). The proposed ANUBIS experiment is designed to search for these LLPs within the ATLAS detector cavern, located approximately 20-30 m from the IP. A prototype detector, proANUBIS, has taken data within the ATLAS detector cavern since 2024, corresponding to 104 fb-1 of pp data. We report on the potential sensitivity of ANUBIS to a selection of LLP models, i.e. Higgs Portal and Heavy Neutral Leptons, as well as future planned studies. Additionally, we will show the first results of the proANUBIS demonstrator, and how it will be used to study the expected backgrounds for the ANUBIS detector.

**Secondary track**:

**Poster T02 / 573**

## Exploring the Projected Sensitivity of the ANUBIS detector to exotic LLP models

**Auteurs:** Oleg Brandt[1]; Paul Swallow[2]; Théo REYMERMIER[3]

[1] *U. Heidelberg, Kirchhoff Institute for Physics*

[2] *University of Cambridge*

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**Auteurs correspondants:** ps983@cam.ac.uk, oleg.brandt@cern.ch, t.reymermier@ip2i.in2p3.fr

Despite the success of the Standard Model (SM) there remains behaviour it cannot describe, in particular the presence of non-interacting Dark Matter, which composes a significant fraction of the Universe's matter. Many models that describe dark matter can generically introduce exotic Long-Lived Particles (LLPs). The proposed ANUBIS experiment is designed to search for these LLPs within the ATLAS detector cavern alongside the ATLAS detector, located approximately 20-30 m from the IP. We report on the potential sensitivity of ANUBIS to a selection of LLP models, i.e. Higgs Portal and Heavy Neutral Leptons, as well as future planned studies.

**Secondary track**:

**T11 / 574**

## The Charge Readout Planes of the DUNE Vertical Drift TPC

**Auteurs:** DUNE Collaboration[None]; Fatma Boran[1]

[1] *Indiana University (US)*

The Deep Underground Neutrino Experiment (DUNE) is a next-generation, long-baseline neutrino oscillation experiment. Its primary goals include measuring the neutrino CP-violating phase, determining the neutrino mass ordering, and conducting a broad physics program, including studies of supernova neutrinos, low-energy interactions, and searches for physics beyond the Standard Model. DUNE's far detector complex will consist in its first phase of two large liquid-argon time projection chambers (LArTPCs) with distinct designs. One employs a well-established single-phase Horizontal Drift TPC with wire-based charge readout. The second is based on an innovative Vertical Drift TPC, where the wires are replaced by copper strips on perforated printed circuit boards for charge collection. The charged detector modules are called Charge Readout Planes (CRPs). This design maintains excellent tracking and calorimetry performance while significantly simplifying the TPC construction.
Building on the success of small-scale prototypes, full-scale CRP demonstrators have been developed and extensively tested at the CERN Neutrino Platform, validating key aspects of this novel technology for the future DUNE far detector.
In this talk, I will present an overview of the CRP's developments, from the prototype construction to operation in liquid argon in TPC mode.

**Secondary track**:

T11 - Detectors

**T06 / 575**

## Status of Radiative Corrections and Monte Carlo Generators for low-energy e+e- into leptons and hadrons final states: the RadioMonteCarLow2 effort.

**Auteur:** Jeremy Paltrinieri[1]

**Co-auteurs:** Adrian Signer ; Andrzej Kupsc [2]; Graziano Venanzoni [3]; Yannick Ulrich [1]

[1] *University of Liverpool*

[2] *Uppsala University*

[3] *University of Liverpool and INFN Pisa*

Robust and precise Monte Carlo generators are paramount to the analysis of low-energy $e^+e^-$ scattering experiments at electron-positron colliders, which are essential for precision tests of the Standard Model, such as the dispersive evaluation of the hadronic vacuum polarization contribution to the muon $g-2$. As part of the community-driven initiative RadioMonteCarlow2, we aim to collect these Monte Carlo tools and facilitate their access. This initiative has been working on providing the community with codes that are able to produce differential cross-section distributions for processes related to $e^+e^- \to$ leptons and hadrons at center-of-mass energies of a few GeV. In this talk, I will report on the results of Phase I of this effort, published as arXiv:2410.22882, which presents a detailed comparison of Monte Carlo codes for $e^+e^-$ scattering into muon, pion, and electron pairs, both for energy-scan and radiative-return experiments. This first phase is a theoretical study which focuses on comparisons without reference to experimental data, aiming to clarify the importance of different physics effects and approaches in realistic experimental setups.

**Secondary track**:

T05 - QCD and Hadronic Physics

**Poster T16 / 576**

## AI-assisted analysis to enhance discovery potential in High-Energy Physics

**Auteurs:** Asrith Krishna Radhakrishnan[1]; Lorenzo Rinaldi[2]; Maximiliano Sioli[3]

[1] *Phd student*

[2] *Associate Professor, Department of Physics and Astronomy, University of Bologna*

[3] *Full Professor, Department of Physics and Astronomy, University of Bologna*

**Auteur correspondant** asrith.radhakrishna2@unibo.it

Unsupervised anomaly detection has become a pivotal technique for model-independent searches for new physics at the LHC. In high-energy physics (HEP), anomaly detection is employed to identify rare, outlier events in collision data that deviate significantly from expected distributions. A promising approach is the application of generative machine learning models, which can efficiently detect such deviations without requiring labeled data.

In this study, we develop a Transformer-based reconstruction model, trained exclusively on Standard Model (SM) background data, to identify events that exhibit significant deviations. The method is applied to ATLAS Open Data from Run 2 (2015–2016), focusing on the identification of rare and potential Beyond the Standard Model (BSM) processes. Our architecture utilizes a modified Transformer, optimized to handle high-dimensional tabular input, comprising low-level physics observables, such as jet kinematics, lepton and photon energy, MET, electromagnetic and hadronic calorimeter energy deposits, as well as event topology variables.

The Transformer model is trained to learn the inherent patterns in SM background data, effectively modeling the normal event distributions. We use a Tab-Transformer with weighted loss, which captures the intricate relationships within the background data. When the trained model is tested on rare and BSM Monte Carlo (MC) samples (e.g., SUSY, Exotic), it exhibits excellent reconstruction performance for background events while generating large reconstruction losses for anomalous events. This ability to identify outliers is crucial for anomaly detection in HEP.

Compared to conventional Variational Autoencoders (VAEs), our Transformer-based architecture demonstrates superior background modeling, with enhanced sensitivity to anomalies. The method operates directly on low-level physics observables, making it highly interpretable and scalable. Additionally, it allows for searches in pre-selection regions without introducing biases from selection cuts, offering a more flexible approach to identifying new physics. We are also planning to extend the analysis using more detector-level observables to further improve the sensitivity and scalability of the method.

**Secondary track**:

**T05** / **577**

# Prompt/Non-prompt J/ψ production in pp collisions at forward and midrapidity with ALICE

**Auteur:** ALICE Collaboration[None]

Quarkonium production in high-energy hadronic collisions is sensitive to both perturbative and non-perturbative aspects of quantum chromodynamics (QCD) calculations. Charmonium cross section can be split into prompt and non-prompt components, the first corresponding to directly produced charm-anticharm pairs, the second originating from the decay of beauty hadrons. Both components are relevant for the investigation of the properties of the quark-gluon plasma (QGP), with the latter allowing a study the mass dependence of heavy-quarks in-medium energy-loss mechanism. In this contribution the recent measurement of prompt and non-prompt $J/\psi$ carried out by the ALICE Collaboration in pp and Pb–Pb collisions at midrapidity (|y| < 0.8) will be shown, including the newest results from LHC Run 3. Moreover, thanks to the installation of the new muon forward tracker (MFT), prompt/non-prompt charmonium separation is now possible in LHC Run 3 at forward rapidity (2.5 < y < 3.6). Using pp collisions at $\sqrt{s} = 13.6$ TeV, performances for the prompt and non-prompt $J/\psi$ separation at forward rapidity will be discussed. For the first time, preliminary results on the prompt/non-prompt $J/\psi$ fraction will be presented.

**Secondary track**:

**T14** / **578**

# The Early Career Researchers'Input to the 2026 Update of the European Strategy for Particle Physics

**Auteurs:** Abdelhamid Haddad[1]; Alexander Burgman[2]; Armin Ilg[3]; Elizabeth Long[4]; Krzysztof Mekala[5]

[1] *LPCA, Université Clermont-Auvergne, CNRS/IN2P3 (FR)*

[2] *Stockholm University*

[3] *University of Zürich*

[4] *Charles University, Prague, Czech Republic*

[5] *University of Warsaw / DESY*

The future of particle physics is inseparable from the well-being, engagement, and career development of today's early career researchers (ECRs) —the very scientists who will lead the field forward.

Yet, many ECRs face structural challenges including short-term contracts, limited job security, under-recognition, and frequent relocations. These issues create uncertainty and threaten the sustainability of the field. At the same time, fostering an inclusive, supportive, and equitable research culture is essential for retaining talent and enabling innovation.

In light of the ongoing efforts toward the European Strategy for Particle Physics Update (ESPPU), ECRs from across Europe (and beyond) have come together to provide a formal input in the form of 55 key recommendations supported by a detailed 100-page white paper (arXiv:2503.19862). Grounded in a community-wide survey of over 800 ECRs, this work identifies the most pressing challenges faced by early career scientists. It offers a holistic perspective on the ECR experience—addressing not only the uncertainties surrounding future collider projects and the growing role of beyond-collider experiments but also broader aspects such as career development, mental well-being, science communication, and long-term planning for the field.

This talk will provide a brief overview of the initiative, highlight the key findings and recommendations, and discuss concrete actions proposed to help build a more inclusive, sustainable, and inspiring future for the next generation of particle physicists.

**Secondary track**:

**T05** / **579**

# Inclusive and semi-inclusive jet cross-section measurements in pp collisions at $\sqrt{s}$=13.6 TeV with ALICE

**Auteur:** ALICE Collaboration[None]

In this talk we present new measurements of inclusive and semi-inclusive jet production in pp collisions, using the high-statistics data sample of Run 3 collected by ALICE. The inclusive jet sample is composed of charged-particle jets, whilst the semi-inclusive sample has the additional constraint that the jets are recoiling from a high-pT charged hadron trigger. For the semi-inclusive sample we also report the prospects for the measurement of the acoplanarity observable, $\Delta\varphi$, defined as the azimuthal angle between the trigger and the recoiling jet, as well as the jet-axis difference $\Delta R$. These measurements can probe higher-order corrections to pQCD calculations, as well as constrain Monte-Carlo models describing the evolution of high momentum objects. An outlook to performing these measurements in Pb−Pb collisions in Run 3 is also presented, detailing the response of the upgraded ALICE detector to jet physics in heavy-ion collisions.

**Secondary track**:

**T04** / **580**

# Shedding light on the baryon production via angular correlation studies with ALICE

**Auteur:** ALICE Collaboration[None]

**Auteur correspondant** alice-cc-chairs@cern.ch

One of the most effective techniques for investigating the mechanism of baryon production is the study of angular correlations between two particles. Angular correlations represent a convolution of various physical processes, such as mini-jets, Bose-Einstein quantum statistics, conservation of momentum, resonances, and other phenomena that contribute to the unique behavior observed for different particle species.

Experimental results from proton-proton collisions at 7 TeV have revealed a pronounced anticorrelation —a phenomenon that has not been replicated by Monte Carlo models. This discovery triggered a series of studies that led to the formulation of what is now referred to as the "baryon correlation puzzle".

This work presents ALICE measurements of angular correlation functions for identified particles. Correlations involving $\pi^{\pm}$, $K^{\pm}$, and $p(\bar{p})$ are reported for different multiplicity ranges for all three collision systems—pp, p–Pb, and Pb–Pb —while correlations for $p$–$\Lambda$, $\Lambda-\bar{\Lambda}$, $p$–$\phi$, $p$–$\Xi$, and $\Lambda$–$\Xi$ pairs are presented for pp collisions, based on both LHC Run 2 and Run 3 data. The inclusion of $p$–$\phi$ correlations provides a crucial test case for evaluating the role of particle mass in the manifestation of anticorrelations. In addition, we report on $p$–$\Lambda_c$ correlation measurements, offering novel insight into baryon-baryon dynamics in the charm sector.

**Secondary track**:

**T04 / 581**

## Probing the low-x structure of protons and nuclei with ALICE using isolated prompt photons

**Auteur:** ALICE Collaboration[None]

This talk presents new measurements of prompt-photon production in pp, p–Pb and Pb-Pb collisions by ALICE. We present the first determination of the nuclear modification factor of isolated prompt-photon production in p–Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV. Together with a recent analysis at $\sqrt{s_{\mathrm{NN}}}$ 8.16 TeV, this new measurement constrains the low-x structure of matter in a regime inaccessible to previous prompt-photon measurements, extending the previous low-x reach by a factor of two to a regime where cold nuclear matter effects are expected to be sizeable. We also present the first ALICE measurement of isolated prompt photon production in Pb-Pb collisions. The measurement is carried out for the first time using multiple isolation cone radii, which allows gauging the contribution of fragmentation photons to the total physical cross section.

**Secondary track**:

T04 - Ultra-relativistic Nuclear Collisions

**T05 / 582**

## Differentially investigating flavour effects in QCD showers and hadronisation with heavy-flavour jets in ALICE

**Auteur:** ALICE Collaboration[None]

The evolution of parton showers in QCD is underpinned by the flavour of their initiating partons. Casmir colour effects (different for quarks vs gluons) and mass effects (driven by the dead cone of heavy quarks), impact the properties of the resultant showers. In this talk we present a suite of measurements of heavy-flavour tagged jets in pp collisions, tagged by the presence of a reconstructed $\mathrm{D}^0$ meson, which probe these effects. These include measurements of the first perturbative splitting selected by the Soft Drop algorithm, which map onto the properties of the charm splitting function. We further present measurements of the energy-energy correlator, which allow us to separately probe these flavour effects at the perturbative and non-perturbative scales, and the difference between a variety of jet-axis definitions which vary in their sensitivity to soft emissions in jets. In addition to these observables, we also present measurements of the longitudinal-momentum fraction carried by jets tagged with $\Lambda^{+c}$ baryons and $\mathrm{D}^0$ mesons. Such measurements probe the non-universalities observed in baryonisation between hadronic and leptonic collisions.

**Secondary track**:

**T09** / **585**

## Exotic h → Z a Higgs decays into tau leptons

**Auteurs:** Camila Ramos[None]; José Miguel No[None]; José Zurita[None]; María Cepeda[None]; Rosa María Sandá Seoane[1]

[1] *IFT*

**Auteur correspondant** rosa.sanda@uam.es

Exotic Higgs decays are among the most promising areas to be explored at the High-Luminosity LHC, given the unprecedentedly large amount ($\sim 3 \times 10^8$) of 125 GeV Higgs bosons that will be produced. In this context, we propose a new search channel for which the Higgs boson decays to a (leptonically decaying) $Z$ boson and a light BSM pseudoscalar $a$, which subsequently decays to a pair of $\tau$-leptons ($h \to Za \to \ell\ell\tau\tau$). After performing a validation of existing ATLAS and CMS exotic Higgs decay searches in related channels, we analyze the HL-LHC projected sensitivity of our $a \to \tau\tau$ search, targeting the kinematic region where the exotic Higgs decay is two-body. We are able to probe pseudoscalar masses $m_a \in [5, 33]$ GeV by leveraging both leptonic and hadronic $\tau$ decays, and establish model-independent 95\% C.L. sensitivity projections on the branching fraction $\mathrm{BR}(h \to Za) \times \mathrm{BR}(a \to \tau\tau)$. These $a \to \tau\tau$ projections yield a competitive probe of light pseudoscalars, which depending on the model can become significantly more sensitive than projections from existing experimental searches in $a \to \mu\mu$ and $a \to \gamma\gamma$ final states. Finally, we explore the potential of our search to probe an Axion-Like-Particle (ALP) solution to the muon $(g-2)$ anomaly (when taken face-value), finding that our proposed $h \to Za$, $a \to \tau\tau$ search can provide valuable constraints on such ALP scenario, in complementarity with existing $h \to Za$, $a \to \gamma\gamma$ experimental searches.

**Secondary track**:

T08 - Higgs Physics

**T10** / **586**

## Six-point ChPT amplitude for pions and kaons

**Auteur:** Mattias sebastian SJO[1]

**Co-auteur:** Johan Bijnens [2]

[1] *CPT Marseille*

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Recently [1,2], chiral perturbation theory (ChPT) has been used to predict the finite-volume spectrum of systems of three pions via the K-matrix formalism, in agreement with existing lattice data. The formalism relates the $n$-particle spectrum is related to the elastic $n$-to-$n$ scattering amplitude, and therefore requires a six-point amplitude as input. Furthermore, it has been found that a one-loop amplitude is necessary in order to obtain reasonable agreement with data.

With the pionic cases covered, the inclusion of kaons is a logical next step. The formalism groundwork has been laid, and solid lattice results are beginning to appear [3]. While previous six-point

ChPT calculations [4,5] have explored a variety of chiral symmetry breaking patterns, they have employed a single meson mass, limiting their hadron spectrum applications to systems with only pions. We describe how to solve the complications caused by distinct pion, kaon and $\eta$ masses while retaining as much as possible of the technology used to simplify the cumbersome six-point amplitude, and present the result to one-loop order.

**Secondary track**:

T07 - Flavour Physics and CP Violation

**T05** / **587**

## Studying charm-quark hadronization and charm-baryon production measurements in pp at the LHC

**Auteur:** ALICE Collaboration[None]

Precise measurements of charm-hadron production in proton–proton (pp) collisions at the LHC are fundamental to investigate the charm-quark hadronization and test perturbative QCD-based calculations. Recent advances in charm-meson spectroscopy have led to the discovery of several excited charm-strange states, whose production yields in hadronic collisions are unmeasured. Quantifying these yields provides valuable insights into charm-quark hadronization, given the significant contribution to the ground-state charm-hadron yields from their decays. Recent measurements in pp collisions show baryon-to-meson ratios significantly larger than those in $\mathrm{e^+e^-}$ collisions, challenging the validity of theoretical calculations based on the factorization approach and assuming universal fragmentation functions across collision systems. Several QCD-inspired models and Monte Carlo generators use different approaches to describe the charm-quark hadronization. However, most of them do not manage to simultaneously describe the production of strange and non-strange charm baryons. Precise measurements of those states are thus crucial to understand the mechanisms of charm-quark hadronization in pp collisions.

This contribution presents various measurements exploiting the large data sample of pp collisions at $\sqrt{s} = 13.6$ TeV collected from the start of LHC Run 3. In particular, the production yield ratios of $\mathrm{D_s}^+$ to $\mathrm{D}^+$ mesons in pp collisions at $\sqrt{s} = 13.6$ TeV as a function of charged-particle multiplicity are shown and compared to state-of-the-art model predictions. New production measurements of the orbitally excited charm-strange mesons $\mathrm{D_{s1}}(2536)^+$ and $\mathrm{D_{s2}}^*(2573)^+$ in pp collisions at $\sqrt{s} = 13.6$ TeV are also reported. Their production-yield ratios relative to ground-state $\mathrm{D_s}$ mesons are presented, extending recent final results from proton-proton collisions at $\sqrt{s} = 13$ TeV. In addition, the first measurements of the production of charm-baryons $\Lambda_\mathrm{c}^+$, $\Sigma_\mathrm{c}^{0,+,++}(2455)$, $\Sigma_\mathrm{c}^{0,+,++}(2520)$ are presented and compared with model predictions. An outlook on the production measurements of the charm-strange baryons ($\Xi_\mathrm{c}^{0,+}$, ($\Xi_\mathrm{c}^+(3055)$), ($\Xi_\mathrm{c}^+(3080)$) and $\Omega_\mathrm{c}^0$) in pp collisions at $\sqrt{s} = 13.6$ TeV is reported.

**Secondary track**:

**T09** / **588**

## LHC prospects for low mass ALP searches via bb final state

**Auteurs:** Amit Adhikary[1]; Aoife Bharucha[2]; Lorenzo Feligioni[3]; Michele FRIGERIO[4]

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The current Large Hadron Collider (LHC) data shows no clear indication of new physics yet and only incremental improvements are anticipated in the foreseeable future. LHC has been constraining TeV scale physics but new physics could be hiding below the electroweak scale. There are well-motivated dark matter models which predict a light mediator, coupled with Standard Model (SM) fermions and dark matter. In particular, the light resonance, axion-like particle (ALP), is expected to decay dominantly into bb final state if the mass is O(10) GeV. A measurement for this kind of signature is challenging due to trigger requirements at the LHC. In this talk, I will discuss on probing these light resonances in bb final state using jet substructure techniques. I will also demonstrate strategies to improve the sensitivity by modifying trigger requirements at the LHC.

**Secondary track**:

**T05** / **589**

## Investigating excited N states via the measurement of $\rho^0$-p final-state interaction with ALICE

**Auteur:** ALICE Collaboration[None]

Experimental data on the interaction between vector mesons and nucleons are a crucial input for understanding the pattern of in-medium chiral symmetry restoration (CSR) and dynamically generated excited nucleon states. However, accessing these interactions is hampered by the short-lived nature of the vector mesons, making traditional scattering experiments unfeasible. In recent years the ALICE Collaboration performed femtoscopy studies with particle pairs produced in nucleus–nucleus collisions to investigate the interactions on challenging systems like ϕ—p.
Leveraging the excellent PID capabilities of the ALICE experiment, coupled with the copious production of $\rho^0$ mesons and protons at the LHC in pp collisions, ALICE presents the first-ever measurement of the $\rho^0$–p correlation function as a function of the relative momentum. The data are interpreted employing calculations within the framework of unitarised chiral perturbation theory in a coupled-channel ansatz. This measurement represents an unprecedented opportunity to study the nature of the excited N, in particular N(1700) and N(1900), unveiling if these states are molecular in nature and shedding light on possible signatures of CSR at LHC energies

**Secondary track**:

**T05** / **590**

## Accessing Three-Body Dynamics with p–d and Λ–d Correlations in pp Collisions at 13.6 TeV with ALICE

**Auteur:** ALICE Collaboration[None]

Femtoscopic correlations between hadrons provide valuable insight into the short-range dynamics of hadronic interactions, with significant implications for fundamental physics and astrophysical phenomena. The composition of neutron stars depends on the interplay between two- and three-body forces involving nucleons and hyperons. Knowledge about the latter is scarce, mainly derived from hypernuclei data. New experimental efforts are needed to constrain three-body dynamics.

The ALICE Collaboration presents new results for proton-deuteron ($p$–$d$) and Lambda-deuteron ($\Lambda$–$d$) femtoscopy in high-energy proton-proton (pp) collisions at $\sqrt{s}$ = 13.6 TeV, collected during Run 3 of the LHC. While $p$–$d$ correlations have been previously measured, the results presented benefit from 20 times more statistics, thanks to the larger dataset available in Run 3, enabling a more detailed exploration of the $p$–$d$ system's three-body dynamics. Additionally, the $\Lambda$–$d$ femtoscopy presented here is the first-ever measurement in ultra-relativistic pp collisions at 13.6 TeV, extending previous studies at lower energies and offering new insights into the interaction between $\Lambda$ hyperons and deuterons. The measured correlation functions are compared with theoretical models, providing unique access to the short-range dynamics of these three-body systems. In this work, we discuss these results and their broader implications, particularly for advancing our understanding of the role of three-body interactions in the structure of neutron stars.

**Secondary track**:

**T09** / **591**

## Machine Learning Analysis for Dark Matter Detection via Photon Signatures at the LHC

**Auteurs:** Andrés Perez[None]; Carlos Wagner[None]; Ernesto Arganda[None]; Martín de los Rios[None]; Rosa María Sandá Seoane[1]; Subhojit Roy[None]

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**Auteur correspondant** rosa.sanda@uam.es

The search for weakly interacting massive particles (WIMPs) remains a central goal of the High Luminosity Large Hadron Collider (HL-LHC). In this work, we explore radiative neutralino decays within the framework of the $Z_3$-invariant Next-to-Minimal Supersymmetric Standard Model (NMSSM), focusing on scenarios where the lightest supersymmetric particle (LSP) is a singlino-dominated neutralino. In this setting, the correct dark matter relic density can be achieved through coannihilation with higgsino- or bino-like states, while also evading current direct detection bounds via blind spot conditions. In particular, in singlino–higgsino coannihilation scenarios, radiative decays of the heavier neutralinos into the singlino LSP and a photon can be significantly enhanced, motivating dedicated searches at the HL-LHC. These decays yield challenging final states characterized by a soft photon, a lepton, and large missing transverse energy, typically accompanied by a hard initial-state radiation jet. We investigate the HL-LHC sensitivity to such signatures by employing both cut-based and machine learning (ML) analysis techniques. Our results demonstrate that the use of ML classifiers significantly improves the discrimination power against Standard Model backgrounds, offering promising discovery potential in this well-motivated dark matter scenario

**Secondary track**:

T16 - AI for HEP (special topic 2025)

**T11** / **592**

## EPSI R&D: Developing an Innovative Electron-Positron Discrimination Technique for Space Applications

**Auteur:** Eugenio Berti[1]

[1] *INFN - Firenze*

The direct detection of antimatter in cosmic rays is essential for understanding the mechanisms behind their acceleration and propagation, and serves as a powerful tool in the indirect search for dark matter. Traditionally, charge sign discrimination rely on magnetic spectrometers. However, these instruments are not ideal for extending measurements to higher energies in a short time frame. As

current and upcoming space experiments targeting the high-energy domain are primarily based on large-scale calorimeters, there is a strong need for an alternative method of charge sign discrimination compatible with such systems.

This is the primary objective of the Electron Positron Space Instrument (EPSI) project - a two year R&D initiative funded in Italy through the PRIN (Projects of Relevant National Interest) program. The project aims to revive a concept proposed long time ago: using synchrotron radiation emitted by charged particles traversing Earth's geomagnetic field. By simultaneously detecting the lepton with an electromagnetic calorimeter and its associated synchrotron photons with an X-ray detector, it is possible to distinguish between electrons and positrons on an event-by-event basis. The central challenge lies in developing an X-ray detection array that features a large active area, high detection efficiency, a low energy threshold, and compatibility with space constraints.

In this presentation, we explore the feasibility of implementing this technique in future space missions. We outline a preliminary instrument design and discuss the difficulties posed by astrophysical background. Furthermore, we introduce the proposed X-ray detector concept, which involves a detection cell composed of a small scintillator, coupled to a large-area SiPM, wrapped with enhanced specular reflector apart from a thin aluminum layer used as entrance window. Various configurations of these components and geometries are currently undergoing testing through laboratory experiments and comprehensive simulations.

We will report on the current status of the EPSI R&D project and outline the next steps toward achieving its objectives.

**Secondary track**:

T01 - Astroparticles, Gravitation and Cosmology

**T11 / 593**

## Development of the muon beam monitor for COMET experiment using SiC detector

**Auteur:** Kenya Okabe[1]

**Co-auteurs:** Eitaro Hamada [2]; Hajime Nishiguchi [2]; Kazutoshi Kojima [3]; Masayoshi Shoji [2]; Ryoji Kosugi [3]; Satoshi Mihara [4]; Tetsuichi Kishishita [5]; Yasunori Tanaka [3]; Yoshiki Yamaguchi [6]; Yoshinori Fukao [7]; Youichi Igarashi [2]; Yowichi Fujita [2]

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The COMET experiment aims to search for the muon-to-electron $\mu - e$ conversion process, one of the lepton flavour violation processes, with a sensitivity better than $10^{-16}$ in J-PARC. To achieve this sensitivity, precisely controlling the secondary muon beam and suppressing the backgrounds is essential. The muon beam monitor will measure the muon beam profile directly, and monitor its stability and intensity. This provides key information for beam control and suppressing the background caused by sudden beam fluctuation. However, since this monitor will be exposed to a high-intensity muon beam, the radiation level is expected to become a 1-MeV equivalent neutron fluence of $1.6 \times 10^{13}/\mathrm{cm}^2$and ionising radiation of 1.2 MGy. The standard silicon sensors will lose their functionality in such an environment. Therefore, we utilise silicon carbide (SiC) for detectors, which is a

wide-bandgap semiconductor with higher radiation tolerance than silicon. Our SiC detectors were fabricated by the National Institute of Advanced Industrial Science and Technology (AIST). In this beam monitor system, SiC detectors are read out by ASIC, which KEK is developing. The overall system is under development for installing the actual experiment.
To investigate the response of SiC detectors to the pulsed muon beam, we performed a beam test at the J-PARC MLF D2 line, which provides the pulsed muon beam with the same momentum region as in the COMET experiment. In this beam test, we used a commercial preamplifier instead of ASIC, which was under development. As a result of the analysis, we found that our SiC detector can detect a single muon by employing the waveform fitting and also confirming the sufficient linearity up to around 35 incident muons.
This beam monitor is planned to be installed upstream of the primary detector system. This provides the information on the shape of the muon beam entering the detector. However, its installation will cause a reduction in the muon yield and an increase of background rates in the detector. In contrast, a downstream installation will preserve the muon yield and enhance the maintainability of the beam monitor system. We are conducting further simulation analysis to determine realistic installation locations and optimal designs. We report the results of the performance evaluation of the SiC muon beam monitor prototype based on the analysis of the beam test and the development for its implementation in the experiment.

**Secondary track**:

**T11** / **594**

# Progresses towards a Silicon-Tungsten ECAL for Higgs Factory Detectors

**Auteur:** Vincent BOUDRY[1]

[1] *LLR - CNRS, École polytechnique/IPP Paris*

**Progresses towards a Silicon-Tungsten ECAL for Higgs Factory Detectors**

One way to achieve instrumental precision at future Higgs factories,
where multi-jets events represent the majority of the final states, is to conceive detectors based on the Particle Flow approach. This is the assumption followed by ILD(LC), SiD, CLICdet, ILD(CC), CLD and the baseline detectors concepts for the ILC, CLIC, FCC and CEPC colliders.
The Particle Flow approach requiring to disentangle the individual calorimetric contributions from charged and neutral particles, a highly granular calorimeter system is mandatory.
The SiW-ECAL is the most advanced design to date; it features large Silicon diodes as sensors, combined with Tungsten absorbers for compactness (and easier particle separation), with voxels of ~$5 \times 5 \times 5\,\mathrm{mm}^3$, for a total number of channel close to 70M.
Its design, though from the start to include scalability for quality insurance and construction, tackles many technical challenges on relating to instrumentation, thermal dissipation, readout, etc. The design has been progressively refined for the ILD concept at ILC, and is now being ported for the FCC-ee and CEPC.
We will present the recent progress on the DRD6 prototype building and testing, with a new version on the active layers and hybridisation procedure. The scaling of the readout electronics required for the circular colliders, and a possible solution for an integrated cooling system will be exposed. Finally, ongoing work on the inclusion of a precision timing and future plans will be sketched.

**Secondary track**:

**T05** / **595**

# Quarkonium production at ultra-high transverse momentum at

# the LHC

**Auteurs:** Jean-Philippe Lansberg[1]; Kate Lynch[2]; Valerio Bertone[3]

[1] *IJCLab - Université Paris-Saclay - CNRS (FR)*

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**Auteur correspondant** jean-philippe.lansberg@ijclab.in2p3.fr

I will present our novel study of quarkonium-production at ultra-high transverse momentum at the LHC. We have performed a complete computation at NLO ($\alpha_s^3$)+ NLL ($\alpha_s^{n+1} \ln^n(p_T/m_H)$) using leading-power Fragmentation Functions (FFs). We have performed a thorough analysis of the theoretical uncertainties including those from the FF modelling, the scales ($\mu_R, \mu_F, \mu_{frag.}$) and the PDF uncertainties. We have revisited all the channels previously studied with FFs at LO+LL. Our analysis of the recent CMS and ATLAS data seems to reveal a different scaling behaviour between 50 and 300 GeV.

**Secondary track**:

**T04** / **596**

# Differential measurements of the particle-emitting source via proton-proton femtoscopy in pp and Pb-Pb collisions in LHC Run 3 with ALICE

**Auteur:** ALICE Collaboration[None]

**Auteur correspondant** alice-cc-chairs@cern.ch

Correlation femtoscopy is a well-known tool used in nucleus-nucleus collision experiments for studying space-time properties of the particle-emitting source via momentum correlations based on the laws of quantum statistics, Coulomb and strong interactions. In this talk, the most recent results of femtoscopic analysis of identical proton pairs measured by ALICE in various collision systems (pp at $\sqrt{s_{\mathrm{NN}}}$ = 0.9 and 13.6 TeV, Pb-Pb at $\sqrt{s_{\mathrm{NN}}}$ = 5.36 TeV) using Run 3 LHC data are presented.
Indeed, the large datasets collected by ALICE during the ongoing Run 3 provide an unprecedented opportunity to perform a scan of proton-emitting source from the smallest to largest systems currently available at the LHC. The multiplicity dependence of the extracted source size is discussed as well as the $m_{\mathrm{T}}$-dependence of the radii.
The measurements are also essential for coalescence models addressing nuclear cluster production and serve as a crucial reference for high-precision studies of interaction potentials in hadron–hadron pairs using ALICE Run 3 data.

**Secondary track**:

**T15** / **598**

# Dynamics of an Electric Flux String Across the Roughening Region in a (2+1)D Lattice Gauge Theory

**Auteurs:** Francesco Di Marcantonio[1]; Sunny Pradhan[1]; Sofia Vallecorsa[2]; Mari Carmen Bañuls[3]; Enrique Rico Ortega[2]

[1] *EHU/UPV*

[2] *CERN*

[3] *MPQ*

The realm of particle physics is full of astonishing phenomena and open problems. One is confinement, typical of QCD in (3+1)D with SU(3) gauge group. Lattice Gauge Theory (LGT) enables us to study it numerically with Tensor Networks. We focus on the pure $Z_2$ LGT in (2+1)D, dual to the quantum Ising model, which preserves criticality while reducing degrees of freedom. Our numerical investigations delve into confinement and the dynamical characterization of electric flux strings. We have confirmed critical values in the vacuum sector through finite-size scaling of entropy and analysis of a t'Hooft electric string using Matrix Product States (MPS). The introduction of two static charges generates an electric fluxtube, that is, the static potential. As we vary $g$ in the confined phase, we observe Lüscher corrections to the potential in the rough region, where the string becomes less rigid and its width increases.
A novel aspect of this work is the dynamical study of Pure Gauge $Z_2$ theory, enabled by MPS versatility in time evolution. In the confined phase, both entropy of the system and string width increase slowly. In the roughening region, we see variable growth rates in string width as a function of $g$, while entropy growth remains consistent and independent of coupling and string length. Our results align with the linear entropy growth predicted for bosonic string model. These insights significantly enhance our understanding of rough phase dynamics and lay a strong groundwork for exploring other sectors of the theory and various lattice gauge theories.

**Secondary track**:

T05 - QCD and Hadronic Physics

**T14** / **601**

## IMPROVING TEACHING THROUGH RESEARCH EXPERIENCE

**Auteurs:** Andrea Gozzelino[1]; Elisa Velcani[2]; Giorgio Chiarelli[3]; Giulia Pagliaroli[4]; Giuseppe Rapisarda[5]; Liliana Mou[1]; Luisa Pegoraro[1]; Manuela Cavallaro[5]; Massimo Mannarelli[4]; Silvia Miozzi[6]; Vincenzo Napolano[7]

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The need for constant, high-quality professional development for high school teachers (HST) has been widely recognized as essential to address society's evolving needs and to motivate and retain teachers. This is particularly critical in STEM fields, where there is a shortage of educators alongside growing job opportunities outside the education system. As highlighted by OECD since 2005 (Teachers Matter) teacher quality is the single most important factor influencing student outcomes. We present Programma INFN per Docenti (PID), a residential professional development course aimed at improving HST knowledge of cutting edge physics research, creating a strong link with scientists, and motivating them to innovate classroom activities.
Bringing science teachers into a research environment fosters improvement in their work experience by provinding hands-on experience of research, both as methodology (i.e. scientific inquiry being applied daily), and operational (teamwork), update their knowledge of frontier research and related technological development, increase awareness of opportunities available for their pupils. Moreover the format fosters the creation of informal networks among participants and with researchers involved in the program. Since 2018 more than 300 teachers took part.
Each course lasts from Monday to Friday for a total of 40 hours and includes both lectures and hands-on laboratories, where participants (divided into groups) rotate. Teachers perform -in collaboration with scientists- actual measurements, directly derived from the research activity of the host institute. The goal is to translate what they've learned into classroom activities using their creativity and

skills.
Through discussion with peers and scientists, they share ideas, and experience to develop teaching paths that can be brought in the classroom. The methodology emphasizes "learning by doing" where lessons are tied to laboratory activities. By leveraging the complementary research conducted at the involved facilities (three Nat. Lab. and a Gravitational Wave Observatory), teachers gain broad knowledge of the Institute's research in Italy, strengthen (or acquire) laboratory skills, and build direct relationships with researchers.
We will present results of surveys performed both at the end of the courses, and one year later, demonstrating the positive impact on participants' didactic and personal self-reliance, and also report on the increased opportunities for pupils.

**Secondary track**:

**T02** / **602**

# Liquid He tuning of dark matter axion haloscopes

**Auteurs:** Arthur Talarmin[1]; Frédéric Gay[1]; Pierre Perrier[1]; Rafik Ballou[2]; Thierry Grenet[2]

**Co-auteur:** GrAHal collaboration

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Haloscopes are sensitive detectors used for dark matter axion search in the microwave energy range. They rely on the axion to photon conversion in a static magnetic field, and its amplification by resonance with a cavity electromagnetic mode. While simple cylinder cavities working below below 1 GHz can provide large volume detectors of typically a hundred liters or more (GrAHal-CAPP), searches at higher frequencies are plagued by the decrease of the cavity volume, hence of the detector sensitivity. Several strategies can be used to increase the mode frequency without a detrimental loss of volume, like using multiple (ADMX), meta-material filled (ALPHA) or dielectric (MADMAX) cavities. In each case the mode frequency tuning, necessary to scan broad axion mass ranges, is challenging.
In this contribution we report on the investigation of mode tuning by filling a cavity with liquid He at 4K. Applied to a simple cylinder cavity with its TM010 mode resonating close to 6 GHz, the dielectric constant of the liquid allows to tune the mode frequency over 120 MHz. We simulate and measure the mode localization induced by the non-homogeneity of the dielectric constant in the cavity during the filling. We show that a very good mode stability and controlled slow filling can be achieved. As an illustration, the results of an axion search in the 6,23-6,33 GHz range are presented. Finally, we discuss how the mode localization can be mitigated, and the new method used for more complex cavity designs and at lower temperatures using superfluid He.

**Secondary track**:

T11 - Detectors

**T02** / **603**

# Phenomenology of extended axion models

**Auteur:** Théo BRUGEAT[1]

[1] *cnr*

Efforts for axion's search have been reinforced in the past decades, motivated by its rich phenomenology allowing for various ways to probe its parameter. Axions provide a solution to the Strong CP puzzle while being a dark matter candidate. In a spirit of minimality, we attempt to have it solve additional puzzles. We are particularly interested in coupling the axion to the sector of Baryogenesis and a scalar sector from conformal symmetry.
First, axion is the Goldstone of an internal $U(1)$ which easily mixes with other flavor symmetries such as Baryon and Lepton numbers. Scenarii of dark matter carrying a baryon number of two open up a new BSM sector that we could probe in neutron-antineutron oscillations. In particular, for light dark matter with mass in the micro-eV range, such coupling induces Rabi resonances in the oscillations. Although the tuning of the magnetic field required to reach the resonance makes the resonant regime unrealistic, this could significantly enhance the signal. For true QCD axions, the resonances are generated by a derivative coupling, and hence strongly attenuated. However, this remains a relevant sector to investigate for ALP's and scalar dark matter 1.
Second, being the Goldstone boson of the conformal group, the dilaton couples anomalously to the kinetic gauge operator. The similarities with the axion coupling to gauge bosons motivate our analysis of axion-dilaton models. The phenomenology of the dilaton has specific features as it emerges from a space-time symmetry. Yet, a correct understanding of axion-dilaton phenomenology can be enlightening both for the experimental search and for model building of such particles 2.

1 Théo Brugeat and Christopher Smith, JHEP 01 (2025), 132, arXiv:2412.06434 [hep-ph] Théo Brugeat and Christopher Smith, in preparation.

**Secondary track**:

T07 - Flavour Physics and CP Violation

**T06** / **604**

## PrecisionSM: an annotated database for low-energy positron-electron hadronic cross sections

**Auteurs:** Alberto Lusiani[1]; Anna Driutti[2]; Fedor Ignatov[None]; Graziano Venanzoni[3]; Lorenzo Cotrozzi[None]

[1] *SNS and INFN Pisa*

[2] *University and INFN Pisa*

[3] *University of Liverpool and INFN Pisa*

PrecisionSM is an annotated database that compiles the available data on low-energy cross sections of electron-positron collisions into hadronic channels. This database organizes and collects data samples from $e^+e^-$ experiments, which are used as input for the data-driven theoretical evaluation of the muon anomalous magnetic moment, $a_\mu$, serving as a precise test of the Standard Model when compared to the experimental measurements of $a_\mu$. The database is accessible through a custom website (https://precision-sm.github.io) which contains details about the data samples, such as the treatment of radiative corrections, as well as links to papers on Inspire and to tables on HEPdata.
The PrecisionSM database was developed within a Joint Research Initiative in the group application of the European hadron physics community, STRONG2020, and is now incorporated into the RadioMonteCarLow2 Working Group (RMCL2 WG) activities, which have the more general goal of improving the theoretical description of scattering processes at $e^+e^-$ colliders. The results of Phase I of the new RMCL2 WG have been published in https://arxiv.org/abs/2410.22882.
In this poster, we will report on the status of the PrecisionSM database, which currently contains a list of the dominant $2\pi$ channel, and the ongoing work for the other channels.

**Secondary track**:

T05 - QCD and Hadronic Physics

**T01 / 605**

## Cosmic rays results with the High Energy Particle Detector 01 (HEPD-01) on board the China Seismo-Electromagnetic Satellite

**Auteurs:** Beatrice Panico[1]; on behalf of Limadou Collaboration[None]

[1] *UNINA - INFN Na*

**Auteur correspondant** bpanico@na.infn.it

The High-Energy Particle Detector 01 (HEPD-01) is one of the payloads on board the China Seismo-Electromagnetic Satellite (CSES-01). CSES-01 was the first multi-channel space observatory of a series of planned missions devoted to monitoring perturbations in electromagnetic fields, plasma and charged particle fluxes induced by natural sources and artificial emitters in near-Earth space. It was launched in February 2018 into a Sun-Synchronous orbit at an altitude of about 500 km. The second satellite, CSES-02, will host a new optimized particle detector, HEPD-02, and is scheduled for launch in June 2025.
HEPD-01 was optimized to detect charged particles, electrons (3-100 MeV), protons (30-300 MeV), and light nuclei (up to a few hundreds of MeV) with high energy resolution and wide angular acceptance. It has provided new measurements on different research fields; in this contribution the latest scientific results obtained with the HEPD-01 detector will be presented, focusing on the measurements of the cosmic rays spectrum and its modulation. These results provide crucial new information for the physical models of the transport and diffusion of cosmic rays and, together with the measurements in the South Atlantic Anomaly, will give new insight in the Earth's magnetosphere modeling, which will be further improved by the next HEPD-02 experiment.

**Secondary track**:

**T05 / 606**

## Measurement of multi-jets and boson plus jets production with ATLAS

**Auteur:** ATLAS Collaboration[None]

Production of multiple jets or bosons plus jets at the LHC offers an unprecedented opportunity to study QCD in the high-energy regime. As experimental precision advances, thorough QCD studies are enabled by measurements of a variety of different observables, including different topological configurations between vector bosons and jets, jet substructure observables, and heavy-flavor jets. In addition, these measurements are key ingredients for the precise determination of the strong coupling constants. This talk summarizes recent from ATLAS on this topic.

**Secondary track**:

T06 - Top and Electroweak Physics

**T03 / 607**

## Joint measurement of the reactor antineutrino spectrum and investigation of the light sterile neutrino sector with STEREO, PROSPECT and Daya Bay

**Auteur:** Rudolph Rogly[1]

[1] *CNRS*

Over the past decades, anomalies in short-baseline neutrino oscillation experiments triggered rich experimental programs to investigate the existence of light sterile neutrinos as a primary explanation. Amongst these, the so-called reactor antineutrino anomaly has played a major role since 2011. It consisted in an alleged deficit of electron antineutrinos emitted by nuclear reactors and observed at short baseline from the source. These antineutrinos originate from the beta decay of fission products of either uranium 235 in case of research nuclear cores Highly-Enriched in Uranium 235 (HEU), or isotopes of uranium and plutonium for commercial nuclear cores Lowly-Enriched in Uranium 235 (LEU).
STEREO and PROSPECT are prominent experiments that were able to provide world-leading precision measurements of the antineutrino spectrum emitted by HEU reactors, while putting stringent constraints on the existence of an eV-scale sterile neutrino by operating at a baseline of a few to ten meters from the reactor. On the other hand, the Daya Bay experiment measured with an outstanding precision the spectrum emitted by LEU reactors, while constraining the oscillation parameters of a sub-eV-scale sterile neutrino, due to operating at longer baselines from a few hundred of meters to the kilometer scale.
In this talk, we present the status of the analysis stemming from a cross-collaboration between these three experiments, in view of improving their constraints in the parameter space of the light sterile neutrino sector, and providing benchmark measurements for the reactor antineutrino spectrum.

**Secondary track**:

**T11** / **608**

## Status of the Hyper-Kamiokande far detector and timing system

**Auteur:** Mathieu Guigue[1]

[1] *LPNHE Sorbonne Université*

The Hyper-Kamiokande experiment, currently under construction in Japan, is scheduled to complete its new Cherenkov far detector by 2027, with operations set to begin in 2028. This next-generation detector will be approximately eight times larger than its predecessor Super-Kamiokande, enabling a significant increase in statistical sensitivity—crucial for precise measurements of CP violation in neutrino oscillations.
This scale-up introduces several technical challenges, including large-scale cavern excavation, the construction of the massive water tank, and the underwater installation of advanced readout electronics. Among the most critical challenges is the need to synchronize over 20,000 photodetectors in the tank with sub-100 picosecond precision. Additionally, achieving better-than-100-nanosecond synchronization with the neutrino beam production site at J-PARC is essential for accurate long-baseline time tagging and event selection. High precision synchronization with UTC is crucial for multi-messenger astrophysics measurements.
This presentation will provide a broad overview of the ongoing construction, with a particular focus on the technical aspects and solutions being developed for the timing and synchronization systems.

**Secondary track**:

**T06** / **609**

## Measurements of Drell-Yan processes with ATLAS

**Auteur:** ATLAS Collaboration[None]

Precision measurements of Drell-Yan processes, including on-shell and off-shell W- and Z-boson production, offer key input to improve the understanding of QCD and the accuracy of PDFs. In addition, Drell-Yan measurements are instrumental for precision measurements of fundamental electroweak parameters, such as W boson mass measurement. This talk summarizes recent results from ATLAS on this topic.

**Secondary track**:

**T06 / 610**

## Measurements of diboson production and precision EFT constraints with ATLAS

**Auteur:** ATLAS Collaboration[None]

Measuring diboson final states is a unique opportunity at the LHC, as they provide precision tests of QCD and EW predictions at unprecedented accuracies, shedding light on the non-Abelian structure of the SM EW theory, and leading to stringent constraints on Effective Field Theory Wilson coefficients. This talk summarizes recent results from ATLAS on this topic.

**Secondary track**:

**T16 / 611**

## Optimized Fast Machine Learning Inference using TMVA SOFIE

**Auteurs:** Sanjiban Sengupta[1]; Lorenzo Moneta[2]

[1] *CERN, The University of Manchester*

[2] *CERN*

**Auteur correspondant** sanjiban.sengupta@cern.ch

While the development of machine learning models for analyzing physical processes—such as simulations, reconstruction, and triggers—has progressed rapidly, efficient inference remains a major challenge. Despite the availability of popular frameworks like TensorFlow and PyTorch for model development, training, and evaluation, experiments at CERN face difficulties during inference due to issues such as limited flexibility, integration complexity, heavy dependencies, and high latency during single-event evaluation.

Addressing these challenges, the ML4EP team at CERN has developed **SOFIE** (System for Optimized Fast Inference code Emit)—a tool that translates externally trained deep learning models in ONNX format, or those developed in Keras or PyTorch, into an intermediate representation, which is then used to generate highly optimized C++ code for fast inference. The generated code has only BLAS as an external dependency, making it easy to integrate into the data processing workflows of high-energy physics experiments.

SOFIE's IR can be stored in .root format, providing flexibility for storing and transporting large models as compressed files. SOFIE integrates with the ROOT ecosystem, offering a Python interface and support for multi-threaded evaluation via RDF slots. However, it does not depend explicitly on other ROOT libraries, enhancing its portability and ease of use.

SOFIE now supports a wide range of ML operators as defined by the ONNX standard, along with user-defined functions. It also enables inference for in-memory graph neural network models trained using DeepMind's Graph Nets.

We present the recent developments in SOFIE, including space optimizations through a custom memory allocator, operator fusion, kernel-level optimizations, and improvements in processing time—that significantly reduces inference latency.

**Secondary track**:

T12 - Data Handling and Computing

**T06** / **612**

## Measurements of rare electroweak processes including vector boson scattering and triboson production with ATLAS

**Auteur:** ATLAS Collaboration[None]

Measurements of rare processes in the electroweak sector provide unprecedented constraints of the SM theory, and unique sensitivity to study the electroweak symmetry breaking (VBS processes) and the quartic boson self-couplings (VBS and triboson processes). In addition to cross-section measurements, studies of boson polarization states in VBS processes are being actively pursued to bring further sensitivity to new phenomena. This talk summarizes recent results from ATLAS on this topic.

**Secondary track**:

**T06** / **613**

## Run-2 high-mass Drell-Yan differential cross-section measurements with the ATLAS detector

**Auteur:** ATLAS Collaboration[None]

High-mass Drell–Yan differential cross-section measurements as a function of dilepton mass and other variables in the electron and muon channels are presented. The measurements utilise the full LHC Run-2 dataset at $\sqrt{s}$ = 13 TeV, recorded by the ATLAS detector. These measurements focus on the region above the Z boson mass and take advantage of the large number of precisely reconstructed light lepton pairs produced at the LHC to perform stringent tests of the Standard Model. The ratio of the measurement in both channels is used to test the Lepton Flavour Universality and an Effective Field Theory interpretation of these measurements is performed to probe potential phenomena beyond the Standard Model

**Secondary track**:

**T05** / **614**

## Study of soft QCD phenomena and double parton interactions with ATLAS

**Auteur:** ATLAS Collaboration[None]

Despite the success of perturbative QCD predictions in the high-energy regime, QCD itself remains mysterious at its nominal non-perturbative QCD scale. The LHC offers rich opportunities to probe the core of QCD related questions, by studying minibias events, double parton interactions, small-x and diffractive processes, as well as correlations in hadronization processes. This talk summarizes recent results from ATLAS on this topic

**Secondary track**:

**T08** / **615**

## Functional determinants and lifetime of the Standard Model

**Auteur:** Katarina Trailović[1]

**Co-auteurs:** Miha Nemevšek ; Pietro Baratella ; Yutaro Shoji ; Lorenzo Ubaldi

[1] *Jožef Stefan Institute*

**Auteur correspondant** katarina.trailovic@ijs.si

Accurately computing the decay rate of metastable vacua in quantum field theory hinges on a precise evaluation of functional determinants arising from quantum fluctuations. In this presentation, we explore recent advances in the regularisation and evaluation of these determinants. The first part introduces a streamlined method to regularize functional determinants for fields of spin 0, 1/2, and 1 in four-dimensional Euclidean space, by using familiar Feynman diagrammatic techniques with a double expansion in interactions and masses, together with dimensional regularisation in momentum space. After a Fourier transform to coordinate space, we end up with a simple regularisation prescription in terms of single integrals over the Euclidean radius of field-dependent masses and their derivatives. We demonstrate the effectiveness of this procedure with a full treatment of the Standard Model. In the second part, we refine the electroweak vacuum decay rate by revisiting the one-loop prefactor, focusing on gauge field contributions. Using group theory, we correct an overcounting in the transverse gauge modes, leading to a 6% shift in their contribution and a slightly reduced—but still cosmologically safe—vacuum lifetime. Together, these results offer improved theoretical control over vacuum decay calculations and broader insights into functional determinant techniques in gauge theories.

**Secondary track**:

T01 - Astroparticles, Gravitation and Cosmology

**T11** / **616**

## A big step towards ATLAS ITk: Performance Characterization of the very first Loaded Local Support Structures

**Auteur:** Anna Swoboda[None]

**Auteur correspondant** anna.swoboda@cern.ch

To meet the demands of the High-Luminosity LHC (HL-LHC), the ATLAS Inner Detector will be replaced with the all-silicon Inner Tracker (ITk), designed for enhanced granularity, reduced material budget, and coverage up to $|\eta| < 4$. A critical step in this transition is validating the performance of the detector's smallest feature-complete building block - the Loaded Local Support (LLS).
An LLS is a lightweight carbon-fiber structure hosting up to 36 hybrid silicon modules. The LLS makes use of several novel technologies: powering of the front-end ASICs via Serial-Powering (SP-) chains, and evaporative $CO_2$ cooling via embedded titanium pipes - concepts used for the first time on such a large scale.

To qualify these innovations, a dedicated test environment has been developed, including a complete readout and control chain (electrical signals up to 1.2 Gbit/s), optical conversion, a PLC processing interlock signals, and a Detector Control System (DCS), which allows for comprehensive hardware controlling and monitoring.
This contribution reports on the commissioning of this test setup, the qualification procedures applied to LLS structures, and results from the very first pre-production LLS. These include performance metrics such as noise, data integrity, thermal response, and robustness under repeated thermal cycling (from -55℃ to 40℃).
These results mark major milestones in validating the LLS concept with production-type components and allowing to start eventually with the detector production. They provide valuable insight into the performance of the future ITk, ensuring the system's robustness and reliability, thus standing out as one of the key-components in the efforts of the ATLAS Phase-II upgrade.

**Secondary track**:

**T09** / **617**

# Sensitivity study of $\mu^+ \to e^+ a\gamma$ cLFV decay with the MEG~II apparatus

**Auteur:** Elia Giulio Grandoni[1]

[1] *INFN Pisa*

The MEG II experiment, located at the Paul Scherrer Institute in Switzerland, operates with the highest continuous muon beam intensity currently achievable, reaching up to $10^8 \ \ \mu^+/s$. The MEG II experiment has been dedicated for several years to the search for the charged lepton flavour violating (cLFV) decay $\mu^+ \to e^+\gamma$, setting the world's most stringent upper limits on the Branching Ratio for this process.
In this study, we investigate the Single Event Sensitivity (SES) of the MEG II apparatus for a cLFV three-body decay involving an axion-like particle (ALP). Such a decay—and the existence of ALPs—is not predicted by the Standard Model but is featured in various Beyond the Standard Model scenarios. Therefore, its observation would serve as compelling evidence for New Physics. We focus on the decay channel: $\mu^+ \to e^+ a\gamma$ assuming a vector-minus-axial (V–A) chirality structure and a light ALP mass ranging from 0 eV up to few MeV. The study is based on detailed Monte Carlo simulations using the GEANT4 toolkit, with data analysis performed using the ROOT-CERN framework. Our analysis shows that operating the muon beam at a reduced intensity, compared to MEG II working point, of approximately $1 \times 10^6 \ \mu^+/s$, together with a relaxed trigger selection on events, significantly improves the experimental efficiency and SES for the muon ALP decay. Under these optimized conditions, only a few weeks of data collection would be sufficient to achieve competitive sensitivity compared to current best experimental limits on this decay. Taking into account the dataset accumulated by the MEG II collaboration over the past four years—corresponding to roughly 10 days of data-taking at low beam intensity—we estimate that the sensitivity to the ALP decay constant could reach a level comparable to the best current limit, which was set by the TWIST experiment in 2015.
In conclusion, our results highlight that the MEG II apparatus, under optimized operating conditions, provides a powerful platform for probing rare ALP-mediated decay channels. This study demonstrates MEG II's strong potential to contribute significantly to the search for physics beyond the Standard Model.

**Secondary track**:

T02 - Dark Matter

**T14** / **618**

## From students to experts: an example of flipped classroom during the INFN-INSPYRE International School

**Auteurs:** Adriana Postiglione[1]; Catalina Curceanu[None]; Susanna Bertelli[1]

[1] *INFN Frascati National Laboratory*

**Auteur correspondant** adriana.postiglione@lnf.infn.it

Outreach activities carried out by Research Institutions and Universities play a key role in bringing the public closer to scientific culture, and particularly, when aimed at younger audiences, in encouraging inspirations for STEM careers. In this context, numerous studies have highlighted that the most effective initiatives are those that allow students to immerse in the research setting and interact firsthand with researchers, but also to be involved in laboratory or hands-on activities 1. The INternational School on Modern PHYsics and REsearch INSPYRE of the Italian National Institute for Nuclear Physics (INFN) has been a virtuous example of this for several years 2. Organized since 2011 at the INFN Frascati National Laboratory, the School reached almost 700 high school students from all over the world. From 2025, the School is also held at the Legnaro National Laboratory. With its plenary lectures, interactions with researchers, and hands-on laboratory activities, the school provides participants the opportunity to explore the latest topics in modern and contemporary physics, while also highlighting the most recent studies and real-life applications. Strengthened by this long experience, this year we introduced a new activity that ensured a different involvement of students: a flipped classroom. In a first phase, we provided students a set of materials on dark matter to study before coming to the school. Then, during the school, we held parallel sessions with researchers in the field, during which students, divided in groups, could ask questions and share doubts. Finally, divided in 5 groups, they presented various topics to their peers. In this talk we will describe the flipped classroom and offer a reflection that may be useful in other similar contexts.

1 B. Habig, P. Gupta, B. Levine, and J. Adams, An informal science education program's impact on STEM major and STEM career outcomes, Research in Science Education, 50(3), 1051–1074, 2020

2 A. Postiglione, S. Bertelli, C. Curceanu, S. Arnone, D. Bifaretti, E. Patrignanelli, S. Reda, E. Santinelli (2023) Let's get INSPYREd: the impact of the "International School on Modern Physics and Research"on high school students'STEM career aspirations, EDULEARN23 Proceedings, pp. 4127-4135.

**Secondary track**:

**T16** / **619**

## Towards a foundation model for jet physics

**Auteurs:** Congqiao Li[1]; Huilin Qu[2]; Qibin Liu[3]; Shudong Wang[4]

[1] *Peking University (CN)*

[2] *CERN*

[3] *Tsung-Dao Lee Institute (CN) & Shanghai Jiao Tong University (CN)*

[4] *Chinese Academy of Sciences (CN)*

**Auteur correspondant** huilin.qu@cern.ch

A rising paradigm in AI in recent years is the foundation model, which refers to a model trained on broad data and adaptable to a wide range of downstream tasks. In this work, we present a new approach to learning powerful jet representations directly from unlabelled data. The method employs a Particle Transformer to predict masked particle representations in a latent space, overcoming the need for discrete tokenization and enabling it to extend to arbitrary input features beyond the Lorentz four-vectors. We demonstrate the effectiveness and flexibility of this method in several downstream tasks, including jet tagging and anomaly detection. Our approach provides a new possible path towards a foundation model for jet physics.

**Secondary track**:

**T11 / 620**

## Water Cherenkov Detectors in Hyper-K and the Photogrammetry

**Auteur:** Hyper Kamiokande Collaboration[None]

The Hyper Kamiokande (Hyper-K) is a long baseline neutrino experiment, being constructed in Japan. Besides the huge water Cherenkov (WC) far detector, an intermediate WC detector (IWCD) will also be built in smaller dimension nearer to the source, to aid in reducing the systematic uncertainties in the measurement of the neutrino oscillation parameters in Hyper-K. However, smaller WC detectors require additional measures to reduce their measurement uncertainties. So, a prototype called Water Cherenkov Test Experiment (WCTE) is being operated at CERN, to validate the performance of the various new detector and calibration elements to be used in the IWCD. The photogrammetry is one of them, used primarily for the calibration purposes, and I'll discuss the goals, details and the progress of the same in my talk.

**Secondary track**:

**T07 / 622**

## B-Meson Anomalies: Effective Field Theory Meets Machine Learning

**Auteurs:** Alejandro Mir Ramos[1]; Jorge Alda[2]; Siannah Peñaranda[1]

[1] *CAPA, Universidad de Zaragoza*

[2] *INFN, CAPA, Università degli Studi di Padova*

**Auteur correspondant** amir@unizar.es

Discrepancies between experimental measurements and Standard Model predictions in B-meson decays, especially in lepton flavor universality ratios like $R_{D^{(*)}}$, $R_{J/\psi}$ and branching ratios for processes like $B \to K^* \nu\bar{\nu}$, suggest possible new physics (NP). In this study, we use an effective field theory framework, assuming NP effects only affect a single generation in the interaction basis, leading to non-universal mixing when rotating to the mass basis. We perform a global fit to the current experimental data, exploring three scenarios characterized by different mixing patterns and constraints. Our analysis finds that the best fit involves mixing between the second and third quark generations, with no lepton sector mixing and independent coefficients for singlet and triplet four-fermion operators. To accurately capture the non-Gaussian nature of the resulting parameter distributions, we use a machine learning-based Monte Carlo algorithm, enabling the generation of representative samples that reflect the true underlying distributions. This work highlights the valuable role of machine learning in accurately modeling intricate parameter distributions in particle physics analyses.

**Secondary track**:

T09 - Beyond the Standard Model

**T11 / 623**

## Advancements in Drift Chamber Design and Particle Identification for the IDEA Experiment

**Auteurs:** MARCELLO ABBRESCIA[1]; for the IDEA collaboration[None]

[1] *University of Bari*

**Auteur correspondant** marcello.abbrescia@uniba.it

The design of tracking chambers for future $e^+e^-$ colliders presents several challenges in terms of achieving high precision while maintaining low material budget and efficient particle identification. This presentation focuses on the development of a novel helium-based drift chamber for the IDEA (Innovative Detector for an Electron-positron Accelerator) experiment. The chamber, featuring a 4 m length and 4 m diameter, offers exceptional tracking performance with an ultra-low of material budget of ~0.016X0 in the barrel region and ~0.05X0 in the end-caps. Key innovations include the application of Cluster Counting/Timing techniques for improved particle identification, providing better separation between pions and kaons over a wide momentum range. We will also discuss new advancements in materials for the drift chamber wires, soldering techniques, and gas mixture selection. Furthermore, the potential of cluster counting for achieving superior particle identification, with a resolution two times better than the traditional dE/dx method, will be explored through simulation results and beam test validation conducted at CERN.

**Secondary track**:

**T11** / **624**

## Statistical Limits to Time Resolution in Resistive Plate Chambers: A new approach

**Auteur:** MARCELLO ABBRESCIA[1]

[1] *University of Bari*

**Auteur correspondant** marcello.abbrescia@uniba.it

The pursuit of high time resolution in Resistive Plate Chambers (RPCs) continues to drive innovation across fields such as particle physics and medical diagnostics. While technological improvements remain essential, it is equally important to recognize the intrinsic statistical limitations imposed by the stochastic nature of particle detection and signal formation in these detectors. This presentation will present an original approach to evaluate limits on time resolution deriving from the fundamental statistical factors that rule the multiplication processes in parallel plate detectors. With this original approach, we will analyze the primary sources of temporal uncertainty and discuss how these insights can inform both the interpretation of experimental results and the development of next-generation detector technologies. Strategies for minimizing the distance from these theoretical bounds will also be considered.

**Secondary track**:

**T05** / **625**

## Probing spin correlations, entanglement, and Bell nonlocality in bottom quark pairs at the LHC

**Auteur:** Yevgeny Kats[1]

[1] *Ben-Gurion University*

While spin correlations and spin entanglement have been measured for top quarks at the LHC, they remain unexplored for other quark flavors. We propose analysis strategies for measuring spin correlations, entanglement, and Bell nonlocality in $b\bar{b}$ samples using the partial preservation of the spin information in $\Lambda_b$ baryons from bottom quark fragmentation. We find that certain measurements are feasible with existing datasets, while others will become possible at the HL-LHC. The proposed measurements will also provide new information on the currently poorly known polarized fragmentation functions.

**Secondary track**:

**T11 / 626**

## The ACROMASS project: study of the charged components of the atmospheric cosmic radiation

**Auteurs:** Carlo Cialdai[1]; Catalin Frosin[2]; Chiara Volpato[2]; Diletta Borselli[2]; Lorenzo Bonechi[1]; Massimo Bongi[2]; Monica Scarigella[1]; Oscar Adriani[3]; Paolo Paini[1]; Raffaello D'Alessandro[4]; Roberto Ciaranfi[1]; Sebastiano Detti[1]; Sergio Ricciarini[5]

[1] *INFN Section of Florence, Italy*

[2] *University of Florence and INFN*

[3] *University of Florence and INFN Sez. di Firenze*

[4] *Università di Firenze - INFN Firenze*

[5] *CNR-IFAC, Florence, Italy*

Although various measures of atmospheric muons have been conducted between the 60s and 80s of the last century, the study of these particles is still of interest in two fields of physics. The first one is related to neutrinos. A precise measurement of the parameters describing the phenomenon of oscillation between the three families of neutrinos known so far, through the study of atmospheric neutrinos, requires a detailed knowledge of the production spectra of these particles. This can be obtained with detailed simulations calibrated with precise measurements of atmospheric muons spectra. The second one, of an applied nature, is muon radiography, an imaging technique that uses atmospheric muons to produce radiographic representations of enormous volumes of materials and which requires the use of reliable simulations of the fluxes of atmospheric muons and their absorption inside materials.

Between the late 90s and the beginning of the 2000s, the INFN section of Florence and the Department of Physics of the University of Florence developed the ADAMO magnetic spectrometer, a test system for the preparation of the PAMELA satellite experiment. ADAMO was used in 2004 for a measurement of the inclusive momentum spectrum of cosmic rays at ground level at several zenith angles in the momentum range between 100 MeV/c and 130 GeV/c.

The ACROMASS project, started in 2024, was funded in Italy by INFN for the development of a compact, transportable detector based on a magnetic spectrometer with an MDR of approximately 260 GV/c, complemented with two auxiliary systems for particle identification. Its purpose is a precise study of atmospheric cosmic rays at different locations and altitudes. This development, which takes advantage of the experience gained with the previous PAMELA and ADAMO projects, is mainly aimed at precise measurements of the muon production spectrum at an altitude of 3500-4000 m a.s.l. for calibrating the simulations used for the estimation of the atmospheric neutrino spectra. This is important both to improve the measurements of the oscillation parameters and to improve the estimation of the atmospheric neutrinos background for neutrinos coming from outside of the Earth atmosphere.

Detector's construction will be finalized in 2025 and the apparatus will be tested at CERN PS and SPS by the end of the year. We have already contacts for a first measurement in a laboratory at an altitude of 3580 m, to be implemented in the next years.

**Secondary track**:

T03 - Neutrino Physics

**T15** / **627**

## Quantum Generative Modeling for Calorimeter Simulations in Noisy Quantum Device

**Auteur:** Saverio Monaco[1]

**Co-auteurs:** Dirk Kruecker [1]; Florian Rehm [2]; Jamal Slim [1]; Kerstin Borras [1]; Moritz Scham [1]

[1] *DESY*

[2] *CERN*

**Auteur correspondant** saverio.monaco@desy.de

Quantum-based generative models offer an alternative route for simulating intricate phenomena in high-energy physics. One notable example is the simulation of calorimeter showers, which involve highly stochastic and high-dimensional data crucial for determining particle types and reconstructing energy in experiments such as those conducted at the LHC. As the complexity and scale of these simulations grow, classical computing methods face increasing limitations, highlighting the potential of quantum strategies. In this work, we explore the capabilities of parameterized quantum circuits deployed on Noisy Intermediate-Scale Quantum (NISQ) platforms to replicate calorimeter shower patterns and evaluate their potential in practical applications.

A major component of the study is the impact of quantum noise—one of the key limitations in near-term quantum systems. Although variational circuits can partially mitigate such effects through training, the broader implications of noise in quantum generative modeling remain relatively underexplored. To address this, we introduce the Quantum Angle Generator (QAG), a variational quantum model trained with a Maximum Mean Discrepancy (MMD) loss function to generate images through the intrinsic probabilistic outputs of quantum circuits.

We carry out a thorough investigation of hyperparameters and benchmark QAG against a standard feed-forward neural network, comparing their respective performance under different noise conditions. Our results, based on both simulation and execution on real quantum hardware, indicate that QAG models trained directly on quantum devices can adapt to hardware-induced noise, resulting in stable and high-quality outputs even under significant noise levels and calibration variability.

**Secondary track**:

**T01** / **629**

## On the Potential Galactic Origin of the Ultra-High-Energy Event KM3-230213A

**Auteur:** Mischa Breuhaus[1]

[1] *CPPM*

This year, the KM3NeT observatory published the detection of the most energetic neutrino candidate ever observed, with an energy between 72 PeV and 2.6 EeV at the 90% confidence level. This extreme energy makes the observed neutrino event very likely being of cosmic origin and not produced within the Earth's atmosphere. However, the exact origin is unknown. In this talk, the possibility that the neutrino was produced within the Milky Way is discussed. Considering the low flux of the Galactic diffuse emission at these energies, the lack of a nearby potential Galactic particle accelerator

aligned with the event's direction, and the theoretical challenges of accelerating particles to such high energies in Galactic systems, we conclude that an extragalactic origin of the event is more probable.

**Secondary track**:

T03 - Neutrino Physics

**Poster T03 / 630**

## Commissioning and performance of the TOF detector for the T2K ND280 Upgrade

**Auteur:** Emanuele Villa[1]

[1] *CERN, University of Geneva*

**Auteur correspondant** emanuele.villa@cern.ch

T2K is a long-baseline neutrino oscillation experiment in Japan, featuring SuperKamiokande as a far detector and a near detector complex. The primary near detector, ND280, has recently undergone an upgrade, incorporating three new sub-detectors: the SuperFGD (SFGD), two High-Angle TPCs (HATs), and a Time-Of-Flight (TOF) system.

In this poster, we present the TOF detector, which consists of six planes of plastic scintillator bars enclosing the SFGD and HATs, and the first analyses performed on TOF data. After a development and commissioning phase at CERN, the installation at the Japan Proton Accelerator Research Centre (J-PARC) was carried out between 2023 and 2024, and the whole ND280 upgrade has been taking data since June 2024. Already during the commissioning phase, the first data have been analyzed, including both beam neutrinos and cosmics.

The time resolution has been assessed to be 180ps, a value that can be further improved with more precise calibration measurements, but already close to the nominal resolution computed in a preliminary study in https://arxiv.org/pdf/2109.03078. Such resolution enables efficient background rejection for out-of-fiducial-volume interactions and particle identification (PID) by time of flight. In this poster, we present these and other analyses on the data collected in 2024 and 2025, already demonstrating the capabilities of the TOF detector.

**Secondary track**:

T11 - Detectors

**T09 / 631**

## Search for a new heavy particle with exclusive couplings to top quarks in multiple-top-quarks final states

**Auteur:** Gabriele Milella[None]

**Auteur correspondant** gabriele.milella@desy.de

A search for a new heavy particle produced in association with top quarks and exclusively decaying into a top quark pair is presented, based on proton-proton collision data taken with the CMS experiment from 2016 to 2018 at 13 TeV and 2022 at 13.6 TeV.

The two top quarks from the new particle are expected to be highly Lorentz-boosted. The particle mass is reconstructed from a pair of special jets resulting from a variable-radius jet clustering algorithm. These jets are identified as originating from hadronically decaying top quarks using a machine learning algorithm. The signal region is defined by events that also contain opposite-sign leptons and b-tagged jets.

Various scenarios, characterized by different particle masses in the range 500 GeV to 4 TeV, are tested by searching for local excesses in the reconstructed mass spectrum.

**Secondary track**:

**Joint T12+T16 / 632**

## Low-latency Jet Tagging for HL-LHC Using Transformer Architectures

**Auteurs:** Abhijith Gandrakota[1]; Alexander Tapper[2]; Arianna Cox[2]; Benedikt Maier[2]; Chang Sun[3]; Filip Wojcicki[2]; Jennifer Ngadiuba[1]; Lauri Laatu[2]; Zhiqiang Que[2]

[1] *Fermilab*

[2] *Imperial College London*

[3] *Caltech*

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Transformers are the state-of-the-art model architectures and widely used in application areas of machine learning. However the performance of such architectures is less well explored in the ultra-low latency domains where deployment on FPGAs or ASICs is required. Such domains include the trigger and data acquisition systems of the LHC experiments.

We present a transformer-based algorithm for jet tagging built with the HGQ2 framework, which is able to produce a model with heterogeneous bitwidths for fast inference on FPGAs, as required in the trigger systems at the LHC experiments. The bitwidths are acquired during training by minimizing the total bit operations as an additional parameter. By allowing a bitwidth of zero, the model is pruned in-situ during training. Using this quantization-aware approach, our algorithm achieves state-of-the-art performance while also retaining permutation invariance which is a key property for particle physics applications

Due to the strength of transformers in representation learning, our work serves also as a stepping stone for the development of a larger foundation model for trigger applications.

**Secondary track**:

**Poster T16 / 633**

## B-hadron identification in b-jets using novel deep learning technique in pp and PbPb collisions in CMS

**Auteur:** CMS Collaboration[None]

Advancements in geometric deep learning offer powerful tools to study the internal structure of jets initiated by heavy quarks, particularly in the context of dead-cone effect and jet quenching. The kinematics of b-hadron decays present a challenge for substructure measurements with inclusive b-jets, which are essential for quantum chromodynamics (QCD) studies. We propose an approach using graph-based deep learning that utilises charged decay products of the jets represented as point

clouds to simultaneously identify tracks associated with b-hadron decay and perform b-jet tagging. The method is demonstrated in simulated p-p ($\sqrt{s} = 5.02\ TeV$) and Pb-Pb ($\sqrt{s} = 5.36\ TeV$) collisions passed through the CMS detector framework, in both Run 2 and Run 3 conditions. We benchmark our method against traditional boosted decision tree classifiers, showcasing significant performance improvements in b-hadron identification of tracks.

**Secondary track**:

**T08** / **634**

## BSM Higgs physics at the Photon collider

**Auteur:** Marten Berger[1]

**Co-auteurs:** Georg Weiglein [2]; Gudrid Moortgat-Pick [3]; Johannes Braathen [4]

[1] *University Hamburg*

[2] *DESY*

[3] *DESY and University of Hamburg*

[4] *Deutsches Elektronen-Synchrotron DESY*

High-energy $\gamma\gamma$- and $e\gamma$-collisions offer a rich phenomenological programme, complementary to $e^+e^-$ collisions at a linear collider both in kinematic as well as physics reaches. In particular, $\gamma\gamma$ collisions offer a unique setting to investigate properties of the Higgs boson(s). High polarisation of the photon beams (produced via Compton back-scattering) can be achieved and adjusted by flipping the polarisation of the incident laser. Furthermore, prospects for di-Higgs production at a $\gamma\gamma$ collider are particularly promising, and could open the way to a direct measurement of the trilinear Higgs self-coupling, at lower centre-of-mass energies than at an $e^+e^-$ collider.
In this talk we will present new results about the di-Higgs production process at the $\gamma\gamma$ collider, comparing different running scenarios (with different types of incident laser). We will discuss the possibility of measuring the trilinear Higgs coupling, also making use in this context of photon polarisations to disentangle different contributions to di-Higgs production.

**Secondary track**:

**T04** / **635**

## Imaging the nuclear structure at the TeV energy scale using reverse engineering

**Auteur:** You Zhou[1]

[1] *Niels Bohr Institute, University of Copenhagen*

One of the main challenges in nuclear physics is studying the structure of the atomic nucleus. Recently, it has been shown that relativistic nuclear collisions at RHIC and the LHC can complement low-energy experiments. Relativistic nuclear collisions provide a snapshot of the nuclear distribution at the time of collisions, offering a precise probe of the nuclear structure.

In this talk, I present our latest developments in nuclear structure studies using reverse engineering, connecting the multi-particle correlations technique to the nuclear structure at relativistic energies. Specifically, I will demonstrate how to constrain the quadrupole deformation and triaxial structure of $^{129}$Xe and showcase new opportunities to discover nuclear shape phase transition in Xe-Xe collisions at the LHC [1]. These can be done using a new multiparticle correlation algorithm that allows us

to study genuine multi-particle correlations of the anisotropic flow, $v_n$, and the mean transverse momentum, $[p_\mathrm{T}]^{[2]}$. Furthermore, I will show a unique opportunity to discover the $\alpha$-clustering structure of $^{16}$O in the coming $^{16}$O-$^{16}$O collisions at the LHC, based on the AMPT studies[3,4]. These latest developments have vast potential in the coming data-taking in 2025 at the LHC. They will be a crucial component in spanning the bridge between the fields of low-energy nuclear physics at the MeV energy scale and high-energy heavy-ion physics at the TeV energy scale.

Relevant works:
1 Phys. Rev. Lett. 133, 192301 (2024);
2 arXiv: 2504.03044;
[3] arXiv: 2501.14852;
[4] arXiv: 2404.09780.

**Secondary track**:

**T10** / **636**

# On-shell amplitude approach to spinning binaries in GR and beyond

**Auteur:** Panagiotis Marinellis[1]

[1] *Paris-Saclay University, IJCLab*

The detection of gravitational waves by the LIGO-VIRGO collaboration has marked a transformative era in astronomy, providing groundbreaking insights into the cosmos and creating new pathways for exploration. At the same time, advancements in the classical limit of quantum scattering amplitudes, particularly through the KMOC formalism, have enriched our understanding of compact binary systems.

In this talk, we will discuss the application of these techniques to scalar-tensor theories of gravity, where long range interactions are mediated by a massless scalar in addition to the graviton. Such theories are of both theoretical and phenomenological interest, with examples including the Einstein-scalar-Gauss-Bonnet and Dynamical Chern-Simons theories. We will start by providing an overview of how amplitude techniques are used to derive predictions for gravitational waves from binary systems of black holes and neutron stars. We will then proceed to give a purely "on-shell" description of arbitrarily spinning bodies with and without scalar hair, an effect which is often present in these theories and can lead to important modifications in the gravitational wave signal. We will discuss how all the required amplitudes can be calculated in a straightforward manner by using the on-shell and spinor-helicity techniques, which can be in turn used to directly compute waveforms for spinning binary systems.

**Secondary track**:

T01 - Astroparticles, Gravitation and Cosmology

**T05** / **637**

# KNO scaling in quark and gluon jets at the LHC

**Auteurs:** Bin Wu[1]; Carlos Salgado[2]; Guo-Liang Ma[3]; Lin CHEN[4]; Xiang-Pan Duan[5]

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The Koba-Nielsen-Olesen (KNO) scaling of hadron multiplicity distributions, empirically confirmed to hold approximately in $e^+e^-$ collisions and Deep Inelastic Scattering, has been observed to be violated in hadron-hadron collisions. In this work, we show that the universality of KNO scaling can be extended to hadron-hadron collisions when restricted to QCD jets. We present a comprehensive study of KNO scaling in QCD jets produced in proton-proton collisions at the LHC. Using perturbative QCD calculations in the double logarithmic approximation and PYTHIA simulations, we find that KNO scaling approximately holds for both quark and gluon jets across a broad jet $p_T$ range, from $0.1$ TeV to $2.5$ TeV, at both the parton and hadron levels. Especially, we highlight characteristic differences between the KNO scaling functions of quark and gluon jets, with the quark-jet scaling function lying above that of gluon jets at both low and high multiplicities. This distinction is essential for interpreting inclusive jet data at the LHC. Furthermore, we propose direct experimental tests of KNO scaling in QCD jets at the LHC through quark-gluon discrimination using jet substructure techniques, as demonstrated by applying energy correlation functions to PYTHIA-generated data.

**Secondary track**:

**T02 / 638**

## Searching for cosmic-ray antinuclei with the GAPS experiment

**Auteurs:** GAPS Collaboration[None]; Sydney Feldman[1]

[1] *University of California, Los Angeles*

The General Anti-Particle Spectrometer (GAPS) is a long duration balloon experiment scheduled for its first launch from Antarctica during the austral summer of 2025-26, with a total of three planned flights. GAPS is optimized to detect cosmic-ray antinuclei at energies below 0.25 GeV per nucleon, a yet-unexplored energy regime with characteristically low astrophysical backgrounds. The experiment will measure the antiproton spectrum at lower energies and higher sensitivities than any previous detector, which will provide an interesting exploration into the potential antiproton excess. GAPS is also the first experiment sensitive to cosmic-ray antideuterons and antihelium in this energy range; antideuterons in particular are predicted by many dark matter models, but their backgrounds due to known astrophysical processes are so small that any detection would be a "smoking gun"indication of new physics.

GAPS uses a novel detection method involving exotic atom formation, de-excitation, and annihilation in order to identify antinuclei species. The innermost detector component is a silicon tracker, which acts as both the target nucleus for incoming antinuclei and an x-ray detector to measure de-excitation and annihilation products. The tracker is cooled by an oscillating heat pipe thermal system and surrounded on all sides by the time-of-flight (TOF) detector utilizing plastic scintillator material. The TOF performs precision timing measurements and provides the trigger for the experiment. The GAPS instrument is fully constructed and commissioned at NASA's long-duration ballooning facility in Antarctica and is ready for launch as early as possible during the 2025-26 Antarctic balloon season. This talk will give an overview of the instrument and discuss potential science impacts of the GAPS program on dark matter research.

**Secondary track**:

**T01 / 639**

# First very-high-energy joint likelihood analysis of the region around the second most powerful pulsar in our galaxy with H.E.S.S. and HAWC Observatories

**Auteur:** Pauline Chambery[1]

**Co-auteurs:** H.E.S.S. Collaboration ; HAWC Collaboration ; Hugo Ayala [2]; Miguel Mostafa [3]; Priyadarshini Bangale [4]; Quentin REMY ; Rishi Babu [5]

[1] *College of Science and Technology at Temple University*

[2] *PSU/Temple University*

[3] *Penn State Univ.*

[4] *Temple University*

[5] *Michigan State University*

The Galactic plane is full of bright gamma-ray sources whose astrophysical nature remains unknown. The region surrounding the second most powerful pulsar in our galaxy, PSR J1813-1749, hosts one of such intriguing sources. Multiwavelength observations of this region show a multitude of sources, including a pulsar wind nebula (PWN) embedded in a supernova remnant (SNR) in X-rays and also SNRs and a star-forming region (SFR) in radio. In 2024, a very-high-energy detailed spectro-morphological analysis of this complex region was performed with H.E.S.S. telescope array data from hundreds of GeV to tens of TeV. The study highlighted one previously detected compact emission believed to be associated with the PWN and unveiled one new extended emission using an improved background method. The latter could be the TeV halo created by electrons escaping from the PWN, which is supported by a leptonic model fitted on the multiwavelength data. However, these systems are observed around middle-aged pulsars, whereas PSR J1813-1749 is young. On the other hand, the possible hadronic scenario of proton acceleration in SNRs or/and a SFR does not explain the large size of the emission. Further investigations are required to conclude on the physical mechanisms at-play.

We conducted a new study of this mysterious region to determine the origin of the emissions. Here we present the first spectro-morphological analysis with very-high-energy data from the HAWC observatory, which is more sensitive from ten to hundreds of TeV. We also report two emissions of which the extended one displays different characteristics from the H.E.S.S. results. Finally, we present the first H.E.S.S./HAWC joint likelihood analysis across the entire energy range of both telescope arrays, which benefits of the good spatial resolution of H.E.S.S. and the wider energy range of the HAWC. This study constrains gamma-ray morphologies and sheds light on non-thermal radiation processes arising from particle acceleration to such high energies. In addition, the joint likelihood technique, possible with gammapy software, has proven very efficient and will be essential for the future of multi-wavelength and multi-messenger astronomy.

**Secondary track**:

**T10 / 640**

# Symmetric Mass Generation

**Auteur:** Oliver Witzel[1]

[1] *University of Siegen*

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In recent years tantalizing signs for a novel phase have been reported that is chirally symmetric but nevertheless exhibits massive bound states. The necessary condition for such a phase, referred to

as Symmetric Mass Generation (SMG), is the cancellation of all (continuous and discrete) 't Hooft anomalies. In 3+1 dimensions this occurs in systems containing a multiple of 16 massless Weyl fermions. SMG was originally discovered in lower dimensional condensed matter systems.
We present results investigating four dimensional field theories with gauge group SU(3). Our findings suggest that SU(3) with $N_f = 8$ fundamental fermions exhibits an SMG phase not only on the lattice but also in the infinite cutoff continuum limit. If confirmed, SMG could provide a new UV completion of the standard model and give rise to new scenarios for beyond standard model physics.

**Secondary track**:

**T11 / 641**

## Performance of the High-Angle Time Projection Chambers in the T2K Near Detector Upgrade

**Auteur:** Merlin Varghese[1]

[1] *IFAE, BARCELONA*

The T2K experiment in Japan is a long-baseline neutrino oscillation experiment searching for the CP violation in the leptonic sector. To improve the precision of measurements in CP terms, the Near Detector complex (ND280) has undergone a significant upgrade, which includes the installation of new **High Angle Time Projection Chambers** (HA-TPCs). These new HA-TPCs are required to provide 4π acceptance of charged particles and to enhance particle tracking during neutrino interaction.
The HA-TPCs have a novel **lightweight composite field cage** that allows thinner walls while maximising the tracking volume and reducing the detector's material budget. Its readout system, **Encapsulated Resistive Anode Micromegas** (ERAMs), uses innovative resistive Micromegas technology, which enhances the detector's stability and robustness without compromising the spatial resolution. These technologies have been studied during several test beams and cosmic ray campaigns.
These detectors were installed in the 2023 Autumn and 2024 Spring at the J-PARC complex. Following a commissioning phase using cosmic rays and a neutrino beam, in June 2024, HA-TPCs began taking data with the fully upgraded ND280. Using the ND280 reconstruction software in T2K, these collected data are reconstructed, and the initial performance achieved by HA-TPC is studied.
The key performance results include measurements of *spatial, momentum, and energy resolution* and a comparison with MC simulation. These results demonstrate that the HA-TPCs meet the desired goals of the **ND280 upgrade** and have a strong potential for application in the Hyper-Kamioakande experiment. In addition to the performance results, ongoing studies on the *electric field homogeneity, alignment, and performance of ERAMs*, which confirm the robustness of HA-TPCs for long-term operation, are highlighted.

**Secondary track**:

**T11 / 643**

## Resistive High Granularity Micromegas for Future Detectors

**Auteurs:** Camilla Di Donato[1]; Fabrizio Petrucci[2]; Givi Sekhniaidze[None]; Kacper Chmiel[3]; Marco Sessa[4]; Maria Grazia Alviggi[None]; Maria Teresa Camerlingo[None]; Massimo Della Pietra[None]; Mauro Iodice[None]; Michela Biglietti[3]; Paolo Iengo[None]; Roberto Di Nardo[None]; Romano Orlandini[3]; Simone Perna[5]

[1] *INFN Napoli*

[2] *Universita' Roma Tre - Dipartimento di Fisica*

[3] *INFN Roma Tre*

[4] *INFN Roma Tor Vergata*

[5] *Universita' di Napoli Federico II*

This contribution presents recent advancements in single-stage pixelised resistive Micromegas detectors for precision tracking and muon system applications in future collider experiments. These detectors combine high-rate capability, excellent spatial and timing resolution, and robust spark protection, making them well-suited for operation in demanding experimental environments.
The detectors, featuring pad-based readout with mm²-scale granularity, have demonstrated stable operation at particle rates up to 10 MHz/cm², achieving spatial resolutions below 100 µm and timing resolutions under 10 ns. These performance parameters can be tuned to match specific experimental requirements, from high-precision tracking to more cost-effective solutions with reduced granularity, such as those foreseen for FCC-ee.
More specifically, for low- to medium-rate environments, detectors with capacitive charge-sharing anodes allowing a reduction in the number of readout channels while preserving adequate precision, are explored. For high-rate scenarios, robust resistive layouts with fast charge evacuation, ensuring discharge stability and efficiency, are under testing. The resistive protection is implemented through different schemes and integration strategies, tailored to optimise performance under various conditions.
More recently, together with small and medium-size prototypes, detectors with active areas up to 40 × 50 cm² have been realised and tested, validating the concept in terms of uniformity, robustness, and rate performance across increasing detector sizes. The results demonstrate the scalability of the technology toward large-area coverage, a key requirement for future high-energy physics experiments.

**Secondary track**:

**T05** / **644**

## Exploring Photoproduced $\eta^{(\prime)}\pi^0$ Systems in the Search for Exotic Hadrons at GlueX

**Auteur:** Zachary Baldwin[1]

[1] *Carnegie Mellon University*

**Auteur correspondant** zbaldwin@andrew.cmu.edu

Probing the non-perturbative regime of Quantum Chromodynamics (QCD) remains a critical challenge in hadron spectroscopy, particularly concerning the role of gluonic excitations in shaping the hadronic spectrum. The GlueX experiment at Jefferson Lab is designed to address this challenge through the search for exotic hybrid mesons, states predicted by QCD to include gluonic degrees of freedom beyond the conventional quark-antiquark framework. This presentation highlights the ongoing amplitude analyses of the $\eta\pi$ and $\eta'\pi$ systems, produced via photoproduction with a polarized photon beam. Recent efforts involve refining resonance modeling through the usage of mass-dependent parameterizations that embed proper physics constraints. These developments aim to enhance the robustness of amplitude fits and improve their sensitivity to potential underlying exotic contributions. The resulting analyses offer a clearer window into hadronic structure and provide a step forward in the experimental exploration of QCD's predicted exotic hadrons.

**Secondary track**:

**T12** / **645**

## Fast Online Trigger System for COMET Phase-I

**Auteurs:** Chihiro Yamada[1]; Kazuki Ueno[1]; Kou Oishi[2]; Masaki Miyataki[None]; MyeongJae Lee[None]; Ryo Nagai[None]; Shoji Masayoshi[2]; Shunya Ueda[None]; Siyuan Sun[None]; Yu Nakazawa[None]; Yuki Fujii[3]

[1] *Osaka University*

[2] *KEK*

[3] *Imperial College London*

The COMET experiment aims to search for the coherent neutrinoless conversion of a muon to an electron in an aluminum atomic nucleus, one of the processes of charged Lepton Flavor Violation, which has never been observed. The experiment is being conducted in two phases. The first phase, Phase-I, targets a single event sensitivity of $3\times10^{-15}$, an improvement by a factor of 100 over the current upper limit on the branching ratio. To achieve this sensitivity, a high-intensity proton beam is used to produce a large number of stopped muons.
The Cylindrical Detector System (CyDet), which is the main detector system in COMET Phase-I, consists of the Cylindrical Drift Chamber (CDC) for momentum measurement and the Cylindrical Trigger Hodoscope (CTH) for primary trigger generation and timing measurement. The trigger system is required to operate with a latency below 7 µs due to hardware limitations and a maximum trigger rate of 20 kHz limited by the data acquisition system. Under the high-intensity beam, a large number of background hits occur, leading to a high rate of accidental triggers in the CTH. To address this, the CDC trigger, which uses CDC hit information, has been developed. The trigger logic is implemented as a multi stage system with FPGA-based electronics boards. The CDC trigger is generated by using 86 CDC readout boards, 10 trigger front-end boards, and one merger board. The production of all boards for the CDC trigger has been completed, and the construction and performance testing are ongoing.
The trigger latency was measured to be 3.2 µs in a test setup, satisfying the requirement. The CDC trigger system has now been fully assembled by connecting all readout boards to the CDC detector and all trigger boards. We confirmed that all board communications were successful without any errors. The measured upper limit of the communication error rate was $4.6\times10^{-5}$ errors per second, satisfying the requirement of maintaining a data acquisition livetime above 99% with a 95% confidence level. The system is currently under evaluation in its full configuration to finalize its performance verification.

**Secondary track**:

**T02** / **646**

# Constraints on the Dark Sector from Electroweak Precision Observables

**Auteurs:** Anthony Thomas[1]; Anthony Williams[2]; Bill Loizos[2]; Martin White[2]; Xuan-Gong Wang[2]

[1] *University of Adelaide*

[2] *Adelaide University*

**Auteur correspondant** bill.loizos@adelaide.edu.au

The dark photon is a popular choice when considering a portal between the Standard Model and the dark sector. In this work, we revisit the exclusion constraints on the dark photon, using the latest electroweak precision data from the Particle Data Group, and explore the impact on these constraints due to the CDF measurement of the W boson mass. In addition, we set upper bounds directly on dark photon couplings to dark matter particles, focusing on Dirac fermion and scalar scenarios. We also extend relic abundance constraints into the heavy mass region, and identify regions of parameter space that are consistent with both electroweak and dark matter density constraints.

**Secondary track**:

T09 - Beyond the Standard Model

**T07 / 647**

# The muEDM experiment at PSI

**Auteur:** Angela Papa[1]

[1] *PSI&INFN-UniPi*

Electric dipole moments (EDMs) of elementary particles violate time-reversal symmetry. According to the CPT theorem, this also implies the violation of combined charge-conjugation and parity-inversion (CP) symmetry, making EDMs powerful tools for probing physics beyond the current Standard Model (SM) of particle physics.

The muEDM experiment at PSI aims at setting the ground for a new direct electric dipole moment (EDM) search using muons. The experiment will perform this dedicated search using the frozen-spin technique for the first time worldwide, aiming at improving the current sensitivity by more than three orders of magnitude to better than 6 × 10−23 e cm, an astonishing jump. This search is a unique opportunity to probe previously uncharted territory and to test theories Behind Standard Model physics.

The experiment will be performed in two phases.

Phase I: In this exploratory phase, we will set up an experiment to demonstrate the frozen-spin method and collect a first data sample. Although the sensitivity to a muon EDM will be sufficient to improve the current best measurement, the main purpose is to establish all necessary techniques and methods for a measurement with the highest possible sensitivity.

Phase II: In this second phase we aim at integrating all lessons
learned from Phase I and push the sensitivity down to 10−23 e cm.

The first data taking is expected by 2026. We will present the status and key features of the experiment.

**Secondary track**:

T09 - Beyond the Standard Model

**T11 / 648**

# Performance degradation of SiPM sensors and recovery via high-temperature annealing

**Auteurs:** Nicola Rubini[1]; Roberto Preghenella[1]

[1] *INFN Bologna*

The performance of silicon photomultipliers (SiPMs) degrades significantly when exposed to high-energy hadrons (neutrons or protons) that induce defects in the silicon lattice. A moderate level of radiation leads to an increase in dark current and dark count rates (DCR) and potentially affects the single-photon detection capability due to pile-up and limitations in the readout electronics. At very high doses, radiation damage can also modify operational parameters (breakdown voltage, gain) and decrease photon detection efficiency (PDE). Nevertheless, several studies show that high-temperature annealing can significantly accelerate the recovery of radiation-induced defects, thereby lowering dark current and DCR.
In this talk we present a summary of the studies and the main results achieved in the context of the R&D for the dual-radiator RICH (dRICH) detector at the future Electron-Ion Collider (EIC), where a large number of SiPMs were tested for usability in single-photon applications in a moderate radiation environment. Proton irradiation was performed up to integrated fluences of 10^{11} 1-MeV n_{eq}/cm^{2} and at different proton energies from 18 to 138 MeV. Neutron and gamma irradiations

were performed as well. The sensors have characterised before and after irradiation and underwent various annealing procedures to measure their recovery capability from radiation damage. Particular attention was given to an annealing procedure exploiting the Joule effect, where high temperatures were achieved via self-heating of the sensor. Repeated irradiation and annealing cycles were performed to simulate a realistic experimental scenario and to assess the robustness of the sensors against such procedures.

**Secondary track**:

**T11 / 651**

## Development of the ALLEGRO Noble Liquid Calorimeter for FCC-ee

**Auteur:** Jana Faltova[None]

**Auteur correspondant** jana.faltova@cern.ch

The first stage of the Future Circular Collider (FCC-ee), operating as an electron-positron collider, offers an ambitious physics program that sets high demands on detector performance. It is designed for precision measurements in the electroweak sector and for probing potential new physics through the detection of particles with weak couplings to the Standard Model particles. ALLEGRO is among the proposed detector concepts being developed to meet these requirements.

A key component of ALLEGRO is its electromagnetic calorimeter (ECAL), which is based on noble liquid technology currently being developed within the Detector R&D Collaboration for Calorimeters (DRD6). The calorimeter design is tailored to FCC-ee specifications, employing a multilayer readout with straight electrodes to achieve fine segmentation. Such granularity is essential for employing advanced event reconstruction approaches, such as particle flow and machine learning-based techniques. Performance from test measurements of the readout electrode prototypes will be presented and discussed.

The ongoing R&D also encompasses the design and prototyping of the mechanical components of the ECAL, including absorber layers, structural supports, and spacers. Progress toward constructing a beam test prototype will be discussed. Furthermore, the integration of the ALLEGRO detector model and reconstruction tools into the key4hep software framework will be shown, together with projections for its performance.

**Secondary track**:

**Poster T05 / 653**

## Deciphering the Hadronic Phase through Resonance Production in ALICE Run 3 pp Collision

**Auteur:** Hirak Kumar Koley[1]

[1] *Jadavpur University*

**Auteur correspondant** hirak.koley@cern.ch

The study of hadronic resonances provides valuable information about the final state interactions and the system evolution in ultra-relativistic nuclear collisions. Due to their short lifespan, comparable with the duration of the hadronic phase, resonances can be affected by the competing rescattering and regeneration mechanisms. In particular, their decay daughters interact elastically/pseudo-elastically with other hadrons, altering their transverse momentum ($p_T$) distributions and affecting the measured resonance yields. Measurements of their yield ratios to stable hadron yields provide valuable insight about hadronic phase lifetime. The ALICE experiment in the LHC Run 3 is suited for resonance measurements because of its excellent tracking and PID capabilities over a broad momentum range.

In this contribution, we present the new ALICE results on resonance production at midrapidity using the hadronic decay channels for LHC Run 3 pp data collected with the upgraded ALICE detector, making use of the higher statistics compared to previous data-taking periods, which may offer new perspectives on the underlying dynamics in the hadronic phase.

**Secondary track**:

**T02** / **654**

# Long lived particle searches at FASER

**Auteur:** FASER Collaboration[None]

The FASER experiment at the LHC is designed to search for light, weakly-coupled new particles, and to study high-energy neutrinos. The experiment has been running since 2022, and has collected nearly 200/fb of pp collision data. FASER has released a search for long-lived dark photons, and long lived axion-like-particles (also interpreted in several other scenarios). This talk will summarise the long-lived BSM particle search program and discuss future prospects.

**Secondary track**:

T02 - Dark Matter

**T03** / **655**

# Neutrino results at the FASER experiment

**Auteur:** FASER Collaboration[None]

The FASER experiment at the LHC is designed to search for light, weakly-coupled new particles, and to study high-energy neutrinos. The experiment has been running since 2022, and has collected nearly 200/fb of pp collision data. FASER has released several neutrino results including the first observation of electron and muon neutrinos at a particle collider, the first measurement of the muon and electron neutrino interaction cross sections in the TeV energy range, and the first differential measurement with muon neutrinos and anti-neutrinos. This talk will summarise the FASER experiment, the neutrino results, and discuss future prospects for FASER neutrino results.

**Secondary track**:

T05 - QCD and Hadronic Physics

**T15** / **656**

# A general approach to quantum integration of cross sections in high-energy physics

**Auteurs:** Ifan Williams[1]; Mathieu Pellen[2]

[1] *Quantinuum*

[2] *University of Freiburg*

Monte Carlo integration lies at the heart of theoretical predictions in high-energy physics (HEP), underpinning the simulation of scattering processes at facilities like the Large Hadron Collider. However, as the complexity of target processes grows, classical methods rapidly become computationally demanding, consuming billions of CPU hours annually. In this talk, I will present a general-purpose framework for quantum-enhanced integration of cross sections in HEP, focusing on universal "building blocks"that are based on Fourier Quantum Monte Carlo Integration. Leveraging Quantinuum's Quantum Monte Carlo Integration engine, this approach offers an efficient, extendable methodology for generating quantum circuits that calculate these integrals, with a quadratic improvement in root mean-squared error convergence compared to classical Monte Carlo methods.

I will outline how complex, multi-dimensional cross-section integrands can be decomposed into separable products of fundamental components—monomial functions and relativistic Breit-Wigner distributions—that can themselves be naturally mapped to efficient quantum circuits. Special attention will be given to state-preparation strategies for encoding the relativistic Breit-Wigner distributions on quantum hardware, comparing two different techniques, and analysing their trade-offs in terms of scalability, circuit depth, and preparation fidelity.

To illustrate the practicality of this framework, I will walk through a concrete example: the $1 \longrightarrow 3$ decay process of the tau lepton into three fermions (at tree level). Through this case study, I will show how the framework effectively incorporates experimental selection criteria through quantum thresholding operations, and achieves integral estimations with tunable precision. Additionally, I will present performance benchmarks, including resource assessments for this example for both near-term (NISQ) devices and future fault-tolerant quantum architectures.

Beyond this example, I will discuss the pathway toward scaling to more complex processes, such as multi-boson production or higher-order corrections in perturbative QCD, and outline how these quantum-enhanced techniques could reshape the computational landscape of HEP. This work represents a significant step toward practical quantum advantage in scientific computing, offering a vision for how quantum processors may help augment classical HPC infrastructure in future HEP analysis pipelines.

**Secondary track**:

**T04 / 657**

## EPOS4 model predictions for global observables in Pb–Pb collisions at $\sqrt{s_{NN}}$ = 5.36 TeV

**Auteur:** Hirak Kumar Koley[1]

**Co-auteur:** Subikash Choudhury [1]

[1] *Jadavpur University*

**Auteur correspondant** hirak.koley@cern.ch

The study of the Quark-Gluon Plasma (QGP), a deconfined state of nuclear matter, remains a central focus of high-energy heavy-ion collision experiments. Light-flavor hadrons act as essential probes of the QGP, offering insights into its bulk properties. In particular, the pseudorapidity density of charged particles, which reflects the energy density achieved in such collisions, serves as a key global observable. Its dependence on the number of participant nucleons ($N_{part}$) provides sensitivity to the underlying particle production mechanisms, characterized by the interplay between soft-QCD processes scaling with $N_{part}$ and hard-QCD processes, which scale with the number of

binary collisions ($N_{coll}$).
The transverse momentum ($p_T$) spectra of identified hadrons further elucidate the system's transverse expansion and constrain the kinetic freeze-out conditions of the fireball. Mean $p_T$ and integrated particle yields probe the interplay between particle production and collective dynamics. At high $p_T$, the observed suppression of hadrons in nucleus–nucleus (A–A) collisions relative to proton–proton (pp) collisions, quantified via the nuclear modification factor $R_{AA}$, is consistent with substantial energy loss of hard-scattered partons traversing the QGP.

In this study, we present EPOS4 model predictions for Pb–Pb collisions at $\sqrt{s_{NN}}$ = 5.36 TeV, focusing on the pseudorapidity density of charged particles across a wide range and for various centralities. We also report transverse momentum spectra, mean $p_T$, yields, and $R_{AA}$ for pions, kaons, and (anti-)protons as functions of centrality. Kinetic freeze-out parameters are extracted using combined Blast-Wave fits to the identified hadron spectra. Where available, our results are compared with the experimental data at $\sqrt{s_{NN}}$ = 5.02 TeV and recent measurements at 5.36 TeV from ALICE and CMS; in other cases, predictions are provided. The centrality dependence of these observables reveals trends that are consistent with those observed at lower energy collisions at RHIC and the LHC.

**Secondary track**:

**T02** / **658**

# Constraining self-interacting scalar field dark matter with strong gravitational lensing?

**Auteurs:** Emmanuel Nezri[1]; Eric Jullo[2]; Marceau Limousin[1]; Raquel Galazo[1]

[1] *Laboratoire d'Astrophysique de Marseille*

[2] *LAM*

We present a method to investigate the properties of solitonic cores in the Thomas-Fermi regime under the self-interacting scalar field dark matter framework. Using semi-analytical techniques, we characterize soliton signatures through their density profiles, gravitational lensing deflection angles, and surface mass density excess in the context of strong lensing by galaxy clusters. Focusing on halos spanning two mass scales —$M_{200} = 2\ 10^{15} M$ and $2\ 10^{14} M$ —we compute lensing observables to assess the viability of the SFDM model. Our analysis establishes constraints on the soliton core mass, directly probing the self-interaction parameter space of scalar field dark matter. This work bridges semi-analytical predictions with astrophysical observations, offering a lensing-based framework to test ultralight dark matter scenarios in galaxy cluster environments.

**Secondary track**:

T01 - Astroparticles, Gravitation and Cosmology

**T05** / **660**

# QCD at the LHeC

**Auteur:** Nestor Armesto[1]

[1] *Universidade de Santiago de Compostela*

The Large Hadron electron Collider (LHeC) is the proposal to deliver electron-proton/nucleus collisions at CERN using the LHC hadron or nuclear beams and a 50 GeV electron beam from an Energy Recovery Linac (ERL) in racetrack configuration. While the 2021 update of its CDR 1 contemplated

concurrent operation of electron-hadron and hadron-hadron collisions at the HL-LHC followed by standalone electron-hadron collisions, we propose, in view of the current HL-LHC schedule, an LHeC program extending the regular HL-LHC program with only a standalone electron-hadron operation phase 2. In this way, the LHeC becomes a bridge from the HL-LHC to the next flagship project at CERN.
In this talk we review the QCD studies at the LHeC. The impact of DIS on the extraction of parton densities of proton and nuclei and on the determination of $\alpha_s$ is analysed. The implications for such extraction on EW parameters and Higgs couplings at the HL-LHC, and on the extension of high-mass searches, is discussed. The combination with EIC data is also shown. Finally, the possibilities for unraveling the existence of a new non-linear regime of QCD are discussed.
1 P. Agostini et al. (LHeC/FCC-he Study Group), J. Phys. G 48, 110501 (2021), arXiv:2007.14491 [hep-ex].
2 F. Ahmadova et al., e-Print: 2503.17727 [hep-ex].

**Secondary track**:

T04 - Ultra-relativistic Nuclear Collisions

**T06** / **661**

# Top and EW physics at the LHeC

**Auteur:** Nestor Armesto[1]

[1] *Universidade de Santiago de Compostela*

The Large Hadron electron Collider (LHeC) is the proposal to deliver electron-proton/nucleus collisions at CERN using the LHC hadron or nuclear beams and a 50 GeV electron beam from an Energy Recovery Linac (ERL) in racetrack configuration. While the 2021 update of its CDR 1 contemplated concurrent operation of electron-hadron and hadron-hadron collisions at the HL-LHC followed by standalone electron-hadron collisions, we propose, in view of the current HL-LHC schedule, an LHeC program extending the regular HL-LHC program with only a standalone electron-hadron operation phase 2. In this way, the LHeC becomes a bridge from the HL-LHC to the next flagship project at CERN.
In this talk we review the EW and top physics studies at the LHeC. We present new results on the extraction of the Weinberg angle and top, Z and W masses, together with the impact of the improved determination of PDFs+$\alpha_s$ at the LHeC on their extraction at the HL-LHC. We also present the possibilities for the determination of neutral current vector and axial couplings to light quarks, and for constraining parameters in SMEFT analyses. Concerning top physics, we present the determination of $|V_{td}|$ and $|V_{ts}|$ and of anomalous couplings, including FCNC $\gamma tq$ and $Ztq$, and of magnetic and electric dipole moments.
1 P. Agostini et al. (LHeC/FCC-he Study Group), J. Phys. G 48, 110501 (2021), arXiv:2007.14491 [hep-ex].
2 F. Ahmadova et al., e-Print: 2503.17727 [hep-ex].

**Secondary track**:

**T08** / **662**

# Higgs physics at the LHeC

**Auteur:** Nestor Armesto[1]

[1] *Universidade de Santiago de Compostela*

The Large Hadron electron Collider (LHeC) is the proposal to deliver electron-proton/nucleus collisions at CERN using the LHC hadron or nuclear beams and a 50 GeV electron beam from an Energy Recovery Linac (ERL) in racetrack configuration. While the 2021 update of its CDR 1 contemplated concurrent operation of electron-hadron and hadron-hadron collisions at the HL-LHC followed by standalone electron-hadron collisions, we propose, in view of the current HL-LHC schedule, an LHeC program extending the regular HL-LHC program with only a standalone electron-hadron operation phase 2. In this way, the LHeC becomes a bridge from the HL-LHC to the next flagship project at CERN.
In this talk we review the Higgs physics studies at the LHeC. We present the standalone determination of the Higgs couplings. We then explore the impact of the improved extraction of PDFs+$\alpha_s$ at the LHeC on Higgs coupling determination at the HL-LHC, as well as the implications on the Higgs mass extracted in EW fits, and on the cross section through gluon-gluon fusion. We finally discuss the comparison of the extraction of couplings in different combinations of future accelerators, highlighting the role of the combination HL-LHC+LHeC.
1 P. Agostini et al. (LHeC/FCC-he Study Group), J. Phys. G 48, 110501 (2021), arXiv:2007.14491 [hep-ex].
2 F. Ahmadova et al., e-Print: 2503.17727 [hep-ex].

**Secondary track**:

**T09** / **663**

## BSM physics at the LHeC and the FCC-eh

**Auteur:** Nestor Armesto[1]

[1] *Universidade de Santiago de Compostela*

The Large Hadron electron Collider (LHeC) is the proposal to deliver electron-proton/nucleus collisions at CERN using the LHC hadron or nuclear beams and a 50 GeV electron beam from an Energy Recovery Linac (ERL) in racetrack configuration. While the 2021 update of its CDR 1 contemplated concurrent operation of electron-hadron and hadron-hadron collisions at the HL-LHC followed by standalone electron-hadron collisions, we propose, in view of the current HL-LHC schedule, an LHeC program extending the regular HL-LHC program with only a standalone electron-hadron operation phase 2. In this way, the LHeC becomes a bridge from the HL-LHC to the next flagship project at CERN.
In this talk we review the possibilities for BSM studies at the LHeC and FCC-eh. We highlight the possibilities for scenarios that are difficult to constrain in hadron colliders, particularly those implying short-lived displaced vertices. The case for ALPs, dark photons, sterile neutrinos and scalars from Higgs are shown. We also discuss the impact of the improved determination of PDFs+$\alpha_s$ at the LHeC and FCC-eh on the extension of high-mass searches at the HL-LHC and future hadron colliders.
1 P. Agostini et al. (LHeC/FCC-he Study Group), J. Phys. G 48, 110501 (2021), arXiv:2007.14491 [hep-ex].
2 F. Ahmadova et al., e-Print: 2503.17727 [hep-ex].

**Secondary track**:

**T11** / **664**

## A detector for top energy DIS

**Auteur:** Nestor Armesto[1]

[1] *Universidade de Santiago de Compostela*

The Large Hadron electron Collider (LHeC) is the proposal to deliver electron-proton/nucleus collisions at CERN using the LHC hadron or nuclear beams and a 50 GeV electron beam from an Energy Recovery Linac (ERL) in racetrack configuration. While the 2021 update of its CDR 1 contemplated concurrent operation of electron-hadron and hadron-hadron collisions at the HL-LHC followed by standalone electron-hadron collisions, we propose, in view of the current HL-LHC schedule, an LHeC program extending the regular HL-LHC program with only a standalone electron-hadron operation phase 2. In this way, the LHeC becomes a bridge from the HL-LHC to the next flagship project at CERN.
In this talk we review the status of the design of a detector for the LHeC, and its extension to the FCC-eh. We present the present technology choices with their expected performance. We also analyse the possible synergies with future projects like ePIC, ALICE3 and detectors for $e^+e^-$ colliders. Finally, we review the feasibility and cost of such detector.
1 P. Agostini et al. (LHeC/FCC-he Study Group), J. Phys. G 48, 110501 (2021), arXiv:2007.14491 [hep-ex].
2 F. Ahmadova et al., e-Print: 2503.17727 [hep-ex].

**Secondary track**:

**T13 / 665**

# The LHeC collider as a bridge between major colliders at CERN

**Auteur:** Nestor Armesto[1]

[1] *Universidade de Santiago de Compostela*

The Large Hadron electron Collider (LHeC) is the proposal to deliver electron-proton/nucleus collisions at CERN using the LHC hadron or nuclear beams and a 50 GeV electron beam from an Energy Recovery Linac (ERL) in racetrack configuration. A first phase with concurrent operation of electron-hadron and hadron-hadron collisions at the HL-LHC, followed by a second phase of standalone electron-hadron collisions, was considered in the 2021 update of its CDR 1. In view of the current HL-LHC schedule, we propose an LHeC program extending the regular HL-LHC program with only a standalone electron-hadron operation phase 2. The high-energy high-luminosity electron-proton collisions enable a multi-purpose experiment leveraging the HL-LHC proton beams.
In this talk we describe the accelerator aspects of the proposal, including design, parameters, performance, feasibility, sustainability and cost. Besides, we discuss how the accelerator technology deployed in the ERL for the LHeC is a major stepping-stone for the performance, cost reduction and training for future colliders, e.g., with the use of the racetrack as an injector for FCC-ee.
1 P. Agostini et al. (LHeC/FCC-he Study Group), J. Phys. G 48, 110501 (2021), arXiv:2007.14491 [hep-ex].
2 F. Ahmadova et al., e-Print: 2503.17727 [hep-ex].

**Secondary track**:

**Poster T03 / 666**

# Gamma background model for the Ricochet Experiment

**Auteur:** Ricochet Collaboration[None]

**Co-auteur:** Renaud SERRA [1]

[1] *LPSC, ILL*

The RICOCHET experiment is currently being deployed at the ILL –Institut Laue Langevin (France), a research nuclear reactor. It is aiming at measuring precisely the $CE\nu NS$ - Coherent Elastic Neutrino-Nucleus Scattering process : at the neutrino energy available at the ILL (0-8 MeV), the coherence mechanism is maximal and the cross section fully benefits from the enhancement by a factor $N^2$, where N denotes the number of neutrons of the nucleus. A ∼1 kg scale sensitive detector is therefore sufficient for a measurement.

In the final configuration of RICOCHET, two cryogenic detector concepts will be deployed : an array of 18 germanium bolometers, ∼40 g each, and 9 super-conducting zinc crystals inserted in a cryostat operating at a temperature of 10 mK. In the initial commissioning phase, up to 9 germanium crystals were installed.

The raw background level is significant due to the proximity of the reactor core (neutron and gamma) and to the positioning of the detector on the surface (cosmic background). To fight against the backgrounds, a three-fold strategy is used: an active muon veto, a passive shielding of lead and polyethylene to mitigate the gamma and neutron backgrounds, and the simultaneous measurement of ionization and heat to discriminate electron and nuclear recoils.

Prior to the installation of the RICOCHET cryostat, a campaign of measurement of the radiogenic and reactogenic gamma background was carried out inside the detector shielding with a dedicated HPGe detector (High Purity Germanium). This contribution will present the gamma background model elaborated from these measurements and highlight some comparisons with data recorded in the commissioning phase.

**Secondary track**:

**T13** / **667**

## Energy recovery linacs: from PERLE to the LHeC

**Auteur:** Jorgen D'Hondt[1]

**Co-auteur:** Nestor Armesto [2]

[1] *Nikhef*

[2] *Universidade de Santiago de Compostela*

The development of Energy Recovery Linacs is one of the objectives of the ECFA Accelerator R&D Roadmap established in the 2021 European Strategy for Particle Physics. In this talk we present the development of ERLs with a focus on their application to high-energy accelerators. We discuss the present status and technical challenges of ERL, from PERLE at IJCLab, Orsay, to the proposal of the LHeC as a project to bridge the HL-LHC to the next flagship at CERN, for which the successful demonstration of high-current multi-turn ERL at PERLE is an essential milestone.

**Secondary track**:

**T09** / **669**

## Quark-lepton correlations in gauge anomaly free abelian extension of the Standard Model

**Auteur:** Fulvia De Fazio[1]

[1] *INFN Sezione di Bari*

**Auteur correspondant** fulvia.defazio@ba.infn.it

We consider a NP scenario with a new heavy neutral gauge boson Z'and the associated gauge symmetry U(1)'. The heavy Z'gauge boson has flavour non-universal quark and lepton couplings fixed in a such a way that the gauge anomalies generated by the presence of an additional U(1)'gauge symmetry cancel. This implies correlations between FCNC processes within the quark sector, within the lepton sector and most interestingly between quark flavour and lepton flavour violating processes. We describe in details the features of this model and work out predictions for lepton flavor violating rare and forbidden decays, as well as correlations among them.

**Secondary track**:

T09 - Beyond the Standard Model

**T16 / 670**

## Conditional Deep Generative Models for Simultaneous Simulation and Reconstruction of Entire Events

**Auteurs:** Benjamin Nachman[1]; Dmitrii Kobylianskii[2]; Eilam Gross[3]; Etienne Dreyer[2]; Vinicius Mikuni[4]

[1] *LBNL*

[2] *Weizmann Institute of Science*

[3] *WIS*

[4] *Lawrence Berkeley National Laboratory*

We present an extension of the Particle-flow Neural Assisted Simulations (*Parnassus*) framework to enable fast simulation and reconstruction of full collider events. Specifically, we employ two generative AI (genAI) approaches—conditional flow matching and diffusion models—to generate reconstructed particle-flow objects conditioned on stable truth-level particles from CMS Open Simulations. While previous iterations focused on individual jets, our enhanced methods now support all particle-flow objects in an event, incorporating particle-level features such as type and production vertex coordinates. The framework is fully automated, implemented in Python, and optimized for GPU execution. Evaluations across various LHC physics processes demonstrate that the extended *Parnassus* generalizes beyond its training data and surpasses the performance of the widely used *Delphes* tool.

**Secondary track**:

**T11 / 671**

## The Forward Physics Facility at the LHC

**Auteur:** Jamie Boyd[1]

[1] *CERN*

The Forward Physics Facility (FPF) is a proposal developed to exploit the unique scientific potential made possible by the intense hadron beams produced in the far-forward direction at the high luminosity LHC (HL-LHC). Housed in a well-shielded cavern 627 m from the LHC interactions, the facility will enable a broad and deep scientific programme which will greatly extend the physics capability of the HL-LHC. Instrumented with a suite of four complementary detectors – FLArE, FASER$\nu$2, FASER2 and FORMOSA – the FPF has unique potential to shed light on neutrino physics, QCD, astroparticle physics, and to search for dark matter and other new particles. This talk will

briefly summarize some of the key scientific drivers for the facility, the conceptual design of facility and the experiments.

**Secondary track**:

T03 - Neutrino Physics

**T03 / 673**

## Latest Results from the ICARUS Experiment at the Short-Baseline Neutrino Program

**Auteur:** ALESSANDRO MENEGOLLI[1]

[1] *University and INFN Pavia*

The ICARUS Collaboration is now entering its fifth year of continuing operations of the 760-ton liquid argon T600 detector. The T600 was overhauled at CERN after operations at the LNGS underground laboratory in Italy and moved to its present location at FNAL - as part of the Short-Baseline Neutrino (SBN) program - where it successfully completed its commissioning phase in June 2022. At FNAL ICARUS collects neutrino interactions from both the Booster Neutrino Beam (BNB) and off-axis from the Main Injector Neutrino beam (NuMI). To date, ICARUS has accumulated approximately $5.2 \cdot 10^{20}$ protons on target (POT) with the BNB and about $6.2 \cdot 10^{20}$ POT with NuMI. Within the SBN program ICARUS will search for evidence of short-baseline oscillations, potentially explained by eV-scale sterile neutrinos, jointly with the Short-Baseline Near Detector (SBND). In addition, ICARUS is performing stand-along oscillation searches in disappearance mode and measuring neutrino cross sections on argon with both the BNB and NuMI beams. It is also performing searches for additional Beyond the Standard Model signatures. Preliminary results from the ICARUS experiment, using data from the BNB and NuMI neutrino beams, will be presented.

**Secondary track**:

T09 - Beyond the Standard Model

**T11 / 674**

## Construction status and performance evaluation of the Straw-Tube Tracker for the COMET experiment

**Auteur:** Masaaki Higashide[1]

**Co-auteurs:** Hajime Nishiguchi [2]; Junichi Suzuki [2]; Kazuki Ueno [3]; Kou Oishi [2]; Satoshi Mihara [4]

[1] *The Graduate University for Advanced Studies, SOKENDAI*

[2] *KEK*

[3] *Osaka University*

[4] *KEK, IPNS*

**Auteur correspondant** higashim@post.kek.jp

The muon-to-electron (μ-e) conversion corresponds to the charged lepton flavor violating process, in which a muon captured by an atom converts into a single electron with constant momentum of 105 MeV/$c$ in the case of an aluminum target. The COMET (COherent Muon-to-Electron Transition) experiment at J-PARC is going to search for μ-e conversion in aluminum, aiming for a sensitivity of

$10^{-17}$, improving the current limit by a factor of 10,000.

The COMET experiment uses a tracking detector known as the Straw-Tube Tracker to measure the momentum of electrons emitted from muonic atoms formed in the muon stopping target. To discriminate such signals from background events, the Straw-Tube Tracker is designed to provide a momentum resolution better than 200 keV/*c* around 105 MeV/*c*. The detector consists of 5 stations; each station is composed of 480 proportional counters (straw-tube chambers) made of 20 μm thick aluminized Mylar, each with a diameter of 10 mm, arranged with 240 tubes in both the horizontal and vertical directions. The electronics of the detector are called ROESTI (Read-Out Electronics for Straw Tube Instruments) and 30 ROESTI boards are installed per station. These boards are cooled by the chamber gas ($Ar/C_2H_6$) itself. The use of this low-mass detector in vacuum further enables strong suppression of multiple scattering.

Construction of the first and second stations has been completed, and 30 ROESTI boards have been implemented in the first station. Construction of the other stations is also underway, and all of the stations are planned to be constructed within fiscal year 2025.

The commissioning of the first station using the COMET beamline has been conducted, successfully achieving the first signal acquisition. Upgrades to the first station are underway to address the issues identified in the commissioning. Fundamental performance (e.g., gas amplification factor, intrinsic spatial resolution) of the first station was also evaluated. To achieve the required momentum resolution, a spatial resolution better than 200 μm is needed and the full-scale prototype achieved ~110 μm. To reach this in the first station, specific noise must be reduced. An offline analysis achieved a ~45% noise reduction. Further improvements in the first station's readout system are underway, and the required spatial resolution is expected after these upgrades.

The construction status and the details of performance evaluation studies will be reported.

**Secondary track**:

**T10** / **675**

## Evolution of the chiral condensate in AdS/QCD with time-dependent temperature

**Auteur:** Floriana Giannuzzi[1]

[1] *INFN Bari*

The behaviour of the chiral condensate at finite temperature computed in AdS/QCD with a time-dependent background is shown. Two different scenarios are analysed: in the first a general power-law time dependence is assumed for the temperature, while in the second the energy-momentum tensor at late times reproduces the one found in viscous hydrodynamics. Depending on how quickly the temperature changes over time, the chiral transition shifts towards lower temperatures if the system is cooling, and higher temperatures if it is heating. In some cases, oscillations around the equilibrium values are observed before thermalization. A prethermalization stage is found in the chiral limit if the initial condition is set at a temperature close to the critical one.

**Secondary track**:

**T11** / **677**

## First operation of the FAMU experiment at the RIKEN-RAL high intensity muon beam facility

**Auteurs:** ALESSANDRO MENEGOLLI[1]; Riccardo Rossini[None]

[1] *University and INFN Pavia*

The FAMU experiment targets a high-precision measurement of the ground-state hyperfine splitting (1S-hfs) in muonic hydrogen, aiming for an accuracy of $10^{-5}$. This will enable extraction of the proton Zemach radius with <1% uncertainty, offering key insights into proton structure and testing QED contributions.
Being carried out the ISIS RIKEN Port1 beamline at the Rutherford Appleton Laboratory (UK), the experiment uses a 55 MeV/c pulsed negative muon beam injected into an 8-bar hydrogen gas target. After thermalisation, muonic hydrogen atoms are irradiated with tunable mid-infrared laser light (~6788 pm) to induce the 1S-hfs transition.
If the transition happens, the atom is left with a residual kinetic energy, which enhances the probability of ceasing the muon to another atom. For this reason, the gaseous target contains also 1.5% oxygen, and the observable is the laser-enhanced number of muonic oxygen X-rays. This variable is measured as a function of the laser wavelength, looking for a resonance.
The X-ray detector system is based on a set of 34 custom $LaBr_3$:Ce scintillators, optimized for timing and energy resolution. Six of them are read-out by fast PMTs, whereas the remaining 28 have a SiPM readout. A dedicated muon beam monitor ensures accurate beam diagnostics and data normalization. Initial results, systematics, and detector performance are presented, demonstrating the experiment's potential for advancing precision muon physics.

**Secondary track**:

T05 - QCD and Hadronic Physics

**T11 / 678**

## Innovative track reconstruction algorithms and performances of the new High-Angle Time Projection Chambers in the upgraded T2K Near Detector

**Auteur:** Ulysse Virginet[1]

[1] *LPNHE, Sorbonne Université, IN2P3/CNRS*

T2K (Tokai to Kamioka) is a long-baseline neutrino oscillation experiment that has taken data since 2010. After having obtained the first hints of CP violation in the leptonic sector, it has entered a second phase with an upgrade of its accelerator beam line and suite of near detectors. Among the different elements of this upgrade, two High-Angle Time Projection Chambers (HA-TPC) were installed. Each endplate of these HA-TPC is equipped with Encapsulated Resistive Anode MicroMegas (ERAM). This innovative technology owes its originality to the use of a layer of insulator and a layer of glue to engender charge spreading on the detector's pads. Several test beam and cosmics data taking campaigns have validated these HA-TPC and showed an even better spatial resolution than the Bulk MicroMegas technology that equips the vertical TPC already present for the first phase of T2K. New reconstruction algorithms had to be developed to fully exploit the capabilities of these detectors. These are presented in this talk together with the first performances they allowed to obtain

**Secondary track**:

**T09 / 679**

## Investigating New Physics Signatures with High-Energy Neutrino Events at NOvA

**Auteurs:** Chinmay bera[1]; Deepthi Kuchibhatla[1]

[1] *Ecole Centrale College of Engineering, Mahindra University*

The NuMI Off-Axis $\nu_e$ Appearance (NOvA) experiment is a long-baseline neutrino oscillation experiment primarily designed to study $\nu_e$, $\bar{\nu}_e$ appearance as well as $\nu_\mu$ and $\bar{\nu}_\mu$ disappearance in the energy range of $1 < E\nu < 4$ GeV. Interestingly, the NOvA far detector also records a non-negligible number of high-energy $\nu_e$ and $\bar{\nu}_e$ events in the extended range of $4 < E\nu < 20$ GeV. These events, although sub-dominant in standard oscillation analyses, open a window to probe physics beyond the Standard Model.

In this work, we explore the potential of NOvA to constrain new physics scenarios specifically, non-standard neutrino interactions (NSIs) and environmental decoherence, using the high-energy event spectrum observed at the far detector.

**Secondary track**:

T03 - Neutrino Physics

**T09 / 680**

# Accuracy Complements Energy: Impact of Electroweak Precision Tests on the Higgs Self-Coupling at FCC-ee

**Auteurs:** Benjamin Stefanek[1]; Tevong You[2]; Victor Maura Breick[2]

[1] *IFIC Valencia*

[2] *King's College London*

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A Tera-Z factory, such as FCC-ee or CEPC, will have indirect sensitivity to heavy new physics up to the tens of TeV scale through higher-order loop contributions to precision measurements at the Z-pole. These provide complementary sensitivity to potential deviations from the Standard Model typically thought to best be constrained at leading order at higher energies above the Z-pole, leading to improved projected sensitivities for models such as the real singlet scalar, weakly interacting massive particles or the custodial quadruplet. The entanglement between the Z-pole and higher energy runs has a profound impact on the extraction of a bound on the Higgs Self-Coupling at FCC-ee, which is probed at next-to-leading order (NLO) via Single Higgs production. We determine the FCC-ee sensitivity to Higgs self-coupling modifications $\delta\kappa_\lambda$ within the SMEFT framework, including for the first time flavour, LEP, LHC, and FCC-ee observables in a global analysis with all leading NLO effects via one-loop renormalisation group evolution, as well as incorporating finite NLO contributions to electroweak precision and ZH observables. We find that, under reasonable assumptions, FCC-ee sensitivity to $\delta\kappa_\lambda$ can exceed that of the HL-LHC.

**Secondary track**:

**T01 / 681**

# The POEMMA-Balloon with Radio Mission: a pathfinder for space-based multi-messenger astrophysics

**Auteurs:** Angela Olinto[1]; Giuseppe Osteria[None]; Valentina Scotti[2]

[1] *University of Chicago*

[2] *Università di Napoli Federico II & INFN Napoli*

**Auteur correspondant** valentina.scotti@na.infn.it

The POEMMA-Balloon with Radio (PBR) mission is a pathfinder project for the Probe Of Extreme Multi-Messenger Astrophysics (POEMMA), a proposed dual-satellite observatory designed to explore the highest energy regimes in the Universe. Scheduled for launch in Spring 2027 from Wanaka, New Zealand, PBR will fly aboard a NASA Super-Pressure Balloon for a mission duration of up to 50 days over the Southern Ocean.
PBR will employ a novel hybrid focal surface that consists of a Fluorescence Camera and a Cherenkov Camera, augmented by radio antennas, to address three main scientific objectives: to observe Ultra-High-Energy Cosmic Rays via the fluorescence technique from suborbital altitudes, to detect horizontal high-altitude air showers with energies above the cosmic ray knee (E > 3 PeV) using a pioneering combination of optical and radio measurements, and to follow up on multi-messenger alerts from astrophysical transients, such as gamma-ray bursts, in the search for Very-High-Energy Neutrinos.
This contribution presents an overview of the PBR payload and current developments, highlighting its expected performance and role in the future of high-energy cosmic observations.

**Secondary track**:

T11 - Detectors

**T03 / 683**

## Direct neutrino mass measurement at the KATRIN experiment

**Auteur:** Jaroslav Storek[1]

[1] *KIT*

The KArlsruhe TRItium Neutrino experiment (KATRIN) is performing a high precision spectroscopy of the tritium beta spectrum becay to search for the signature of the neutrino mass. It combines a high-intensity gaseous molecular tritium source with a high-resolution electrostatic spectrometer with magnetic adiabatic collimation which allowes KATRIN to reach a sub-eV sensitivity to the neutrino mass. This talk gives an overview of the latest neutrino mass results as well as results of the sterile neutrino searches based on the 25% of the total anticipated dataset of KATRIN. The talk concludes with an outlook on the future prospects of KATRIN.

**Secondary track**:

**T11 / 684**

## The dRICH detector at the future ePIC experiment

**Auteur:** Luisa Rosa Maria Occhiuto[1]

[1] *University of Calabria and INFN Cosenza*

The ePIC detector is designed as a general-purpose detector to enable the entire physics program of the future Electron-Ion Collider (EIC) at BNL, USA. A key feature will be particle identification (PID). A PID system covering a wide pseudorapidity range [-3.3, 3.5] is critical for accurately separating electrons from hadrons such as pions, kaons, and protons.
PID in the forward region will be provided by a dual Radiator Ring Imaging Cerenkov (dRICH) detector. Photons will be focused by spherical mirrors and detected by silicon photomultiplier sensors placed on six spherical tiles.

This presentation aims to provide a concise overview of the dRICH. The latest studies of the achievable pion-kaon separation efficiency will be shown, exploring its dependence on particle momentum and selected pseudorapidity intervals. Furthermore, GEANT4-based simulation studies will be presented, with a particular emphasis on one of the two radiators integrated in the dRICH, the aerogel, which enables a detailed investigation of particle behavior at the low-momentum regime. The detector's performance, based on chosen geometries, will also be discussed.

**Secondary track**:

**Poster T08 / 685**

## Measurement of the Higgs Boson mass and width at CMS and projections for HL-LHC

**Auteur:** Neha Rawal[1]

[1] *University of Florida*

The Higgs boson mass and width are key free parameters of the Standard Model and must be determined experimentally. This poster presents the measurement of the Higgs boson mass in the $H \to ZZ \to 4\ell$ decay channel, using 138 $fb^{-1}$ of proton-proton collision data collected by the CMS experiment at a centre-of-mass-energy of 13 TeV. Constraints on the Higgs boson on-shell width are also presented. The analysis strategy, and systematic uncertainties are described in detail. In addition, projections for the mass measurement at HL-LHC and the forthcoming challenges in the analysis are shown.

**Secondary track**:

**T16 / 686**

## EveNet: Towards a Generalist Event Transformer for Unified Understanding and Generation of Collider Data

**Auteurs:** Bai-Hong Zhou[1]; Benjamin Nachman[2]; Haoran Zhao[3]; Qibin Liu[4]; Shih-Chieh Hsu[3]; Shu Li[1]; Ting-Hsiang Hsu[5]; Vinicius Mikuni[6]; Wang Wei-Po[None]; Yuan-Tang Chou[7]; Yue Xu[3]; Yulei Zhang[3]

[1] *Tsung-Dao Lee Institute*

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[5] *National Taiwan University*

[6] *Lawrence Berkeley National Laboratory*

[7] *University of Washington, Seattle (US)*

With the increasing size of the machine learning (ML) model and vast datasets, the foundation model has transformed how we apply ML to solve real-world problems. Multimodal language models like chatGPT and Llama have expanded their capability to specialized tasks with common pre-train. Similarly, in high-energy physics (HEP), common tasks in the analysis face recurring challenges that demand scalable, data-driven solutions. In this talk, we present a foundation model for high-energy physics. Our model leverages extensive simulated datasets in pre-training to address common tasks across analyses, offering a unified starting point for specialized applications. We demonstrate the benefit of using such a pre-train model in improving search sensitivity, anomaly detection, event reconstruction, feature generation, and beyond. By harnessing the power of pre-trained models, we could push the boundaries of discovery with greater efficiency and insight.

**Secondary track**:

**T02 / 687**

## A dark matter direct detection search in DarkSide-20k

**Auteur:** Zoe Balmforth[1]

[1] *University of Hamburg*

The DarkSide-20k detector, currently under construction at the INFN Gran Sasso National Laboratory in Italy, consists of a 51 tonne dual-phase Liquid Argon Time Projection Chamber aiming to directly detect GeV –TeV mass WIMPs. WIMPs are one of the most promising dark matter candidates, but no direct detection experiment has yet observed evidence sufficient to claim a WIMP discovery. Therefore, the parameter space yet to be explored is the focus of next-generation detectors such as DarkSide-20k. Building on the successful use of underground argon in the DarkSide-50 detector, DarkSide-20k is designed to be free of instrumental backgrounds. It aims to achieve unprecedented sensitivity for direct dark matter detection of 7.4 x10^-48 cm² for 1 TeV/c² WIMPs in a 200 tonne year exposure. Several novel technologies will be exploited, including the use of ultra-low radioactivity underground argon and large-area Silicon Photomultiplier readout. This talk will give an overview of the status of construction, discussing some of the novel technologies used in DarkSide-20k. This talk will also give an overview of the physics program of DarkSide-20k, highlighting recent low-mass sensitivity projections.

**Secondary track**:

**Poster T16 / 688**

## Deep learning techniques for high-precision neutral meson reconstruction in the LHCf experiment

**Auteurs:** Giuseppe Piparo[1]; LHCf Collaboration[None]

[1] *INFN Catania section*

**Auteur correspondant** giuseppe.piparo@ct.infn.it

In this contribution, we present the machine learning-based strategy to improve the reconstruction of neutral meson events within the Large Hadron Collider forward (LHCf) experiment. The LHCf experiment is uniquely positioned in the very forward region of the LHC to investigate the hadronic interactions relevant to high-energy cosmic ray air shower simulations by measuring forward-produced neutral particles in proton-proton and proton-ion collisions at the LHC.

A primary challenge for the experiment is accurately and efficiently reconstructing neutral mesons from their decay photons. The particles of interest, specifically $\pi^0$, $\eta$ and $K^0{}_s$, predominantly decay into multiple photons, two for $\pi^0$ and $\eta$ mesons and four for $K^0{}_s$, produced via the secondary decay of two $\pi^0$ mesons. This increased photon multiplicity complicates event reconstruction, resulting in complex event topologies and overlapping calorimetric signals. Traditional reconstruction methods struggle to distinguish closely spaced photon clusters, reducing resolution and efficiency. These complexities are particularly pronounced in reconstructing $K^0{}_s$ mesons due to the higher photon multiplicity from their secondary decay chain.

To overcome these limitations, we developed a deep learning pipeline comprising several models optimized for specific reconstruction tasks. The pipeline involves sequential stages for event tagging, particle identification, and precise estimation of photon energies and positions. Each model within

this pipeline leverages multimodal input, fully exploiting the sensor design of the LHCf Arm2 detector. This multimodal strategy integrates calorimetric energy deposits and silicon tracking detector signals, enhancing the accuracy of meson decay vertex reconstruction, particularly for complex $K^0_s$ events.

Models were trained and evaluated using detailed Monte Carlo simulations that replicate the geometry and response of the LHCf Arm2 detector, incorporating realistic detector effects. Preliminary validation results using simulated data demonstrate the effectiveness and promise of the deep learning approach developed. These findings highlight the significant potential of deep learning methods for enhancing event reconstruction capabilities in the LHCf experiment, opening new opportunities for precise studies in cosmic ray physics and laying the groundwork for further developments and applications in upcoming experimental analyses.

**Secondary track**:

T05 - QCD and Hadronic Physics

**T01 / 689**

## EW Vacuum Decay Induced by Domain Walls in the N2HDM

**Auteur:** Mohamed Younes Sassi[1]

**Co-auteur:** Gudrid Moortgat-Pick

[1] *University of Hamburg, 2.Institut für Theoretische Physik*

The Next-to-Two-Higgs-Doublet model (N2HDM) has a rich vacuum structure where multiple electroweak (EW) breaking minima, as well as CP and electric-charge breaking minima, can coexist. These minima can be deeper than the electroweak vacuum $v_{ew} \approx 246$ GeV of our universe, making our vacuum metastable. In such a case, one needs to calculate the tunneling rate from the EW vacuum to the deeper minimum. If the decay rate is larger than the universe's age, our vacuum is deemed long-lived, and the parameter point is in principle allowed. If the decay rate is smaller than the universe's age, then our vacuum is unstable and the parameter point is ruled out. However, domain walls (DW) in the N2HDM can substantially alter this picture. We show in this work that inside the DW, the barrier between our electroweak minimum and the deeper minimum can disappear, leading the scalar fields to classically roll over to the deeper minimum that nucleates inside the DW and then expands outside of it everywhere in the universe. We show that such behavior can happen to parameter points where the lifetime of our vacuum is several orders of magnitude larger than the age of the universe, making these parameter points with very long-lived EW minimum ruled out.

**Secondary track**:

T01 - Astroparticles, Gravitation and Cosmology

**T01 / 690**

## Electroweak Symmetry Restoration in the N2HDM via Domain Walls

**Auteur:** Mohamed Younes Sassi[1]

**Co-auteur:** Gudrid Moortgat-Pick

[1] *University of Hamburg, 2.Institut für Theoretische Physik*

Domain walls are a type of topological defect that can arise in the early universe after the spontaneous breaking of a discrete symmetry. This occurs in several beyond Standard Model theories with an extended Higgs sector, such as the Next-to-Two-Higgs-Doublet model (N2HDM). In this talk, I will discuss the domain wall solution related to the singlet scalar of the N2HDM as well as demonstrate the possibility of restoring the electroweak symmetry in the vicinity of the domain wall. Such symmetry restoration can have profound implications on the early universe cosmology as the sphaleron rate inside the domain wall would, in principle, be unsuppressed compared with the rate outside the wall. We also demonstrate the possibility of having a hypercharge field condensate localized at the center of the wall starting from random initial conditions for the Goldstone modes after the electroweak phase transition.

**Secondary track**:

T08 - Higgs Physics

**T15** / **691**

## Hamiltonian approach to Parton Distribution Functions in the Schwinger model

**Auteurs:** C.-J. David Lin[1]; Krzysztof Cichy[2]; Manuel Schneider[1]; Mari Carmen Bañuls[3]

[1] *National Yang Ming Chiao Tung University*

[2] *Adam Mickiewicz University*

[3] *Max-Planck-Institut für Quantenoptik*

**Auteur correspondant** manuel.schneider@nycu.edu.tw

Parton distribution functions (PDFs) describe universal properties of hadrons. They provide insights into the non-perturbative internal structure of bound states and are highly significant for experiments. Calculating PDFs involves evaluating matrix elements with a Wilson line in a light-cone direction. This poses significant challenges for Monte Carlo methods in Euclidean formulation of lattice gauge theory, where the light cone cannot be directly accessed. In contrast, the PDF can, in principle, be calculated directly from light-cone matrix elements in the Hamiltonian formalism. This seems particularly appealing since recent developments in quantum computing and tensor network approaches allow for an efficient treatment of states in Hilbert space. Using the quantum-inspired tensor network ansatz, we introduce a new strategy to obtain the PDFs directly in the Minkowski formalism, and apply it to the Schwinger model. We present the PDF for different fermion masses in the continuum limit. This shows the feasibility of tensor networks for dynamical calculations in gauge theories and represents a first step towards such computations for QCD. The approach can also be implemented in quantum simulations and with quantum computers in the future.

**Secondary track**:

T05 - QCD and Hadronic Physics

**T11** / **693**

## MPGD-HCAL for future collider experiments: status and perspectives

**Auteurs:** Angela Zaza[None]; Anna Colaleo[None]; Anna Stamerra[None]; Antonello Pellecchia[None]; Daryna Zavazieva[None]; Eraldo Olivieri[None]; Federica Maria Simone[1]; Givi Sekhniaidze[None]; Lisa Generoso[None]; Luca Moleri[None]; Luigi Longo[None]; Marcello Maggi[None]; Marco Buonsante[None]; Maria Grazia Alviggi[None]; Maria Teresa Camerlingo[None]; Marina Borysova[None]; Massimo Della Pietra[None]; Mauro Iodice[None]; Michela Biglietti[None]; Michele Bianco[None]; Muhammad

Ali[None]; Paolo Iengo[None]; Piet Verwilligen[None]; Raffaella Radogna[None]; Roberto Di Nardo[None]; Rosamaria Venditti[2]

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[2] *Bari University and INFN*

The next generation of calorimeters for experimental facilities at future colliders, as FCC-ee or Muon Collider, should offer excellent spatial, time and energy resolution. This is essential to fulfil the 5D calorimetry paradigm, ensuring detectors suitable for particle-flow (PF) techniques which guarantee unprecedented precision in jet energy resolution. Such advancements will enable the measurement of Higgs couplings to quarks with sub-percent accuracy. In pursuit of this objective, we propose a novel hadron calorimeter (HCAL) utilizing resistive Micro Pattern Gaseous Detectors (MPGD). MPGD HCAL is particularly ideal for PF due to its high-granularity readout capabilities (on the order of $cm^2$), and is well-suited to the Muon Collider's challenging background conditions, being a radiation-hard technology with high-rate tolerance (up to 10 $MHz/cm^2$). Additionally, resistive MPGDs, including resistive Micromegas and μ-RWELL, provide excellent spatial resolution, operational stability (with discharge quenching), and uniformity, making them highly suitable for calorimetry. In this contribution, we will present the latest developments in the project, including simulation studies using GEANT4 and Pandora Particle Flow reconstruction within the Muon Collider framework. We will also share recent results from test beam campaigns, which focus on evaluating the performance of the MPGD active layers, such as efficiency, uniformity, time resolution, and the initial studies on the hadronic-shower response of a 8 layers MPGD-HCAL prototype using pion beams with energies up to 10 GeV.

**Secondary track**:

**T03** / **694**

## Status of the Short-Baseline Near Detector at Fermilab

**Auteur:** Nicola McConkey[1]

[1] *Queen Mary University of London*

The Short-Baseline Near Detector (SBND) is one of the Liquid Argon Time Projection Chamber (LArTPC) neutrino detectors positioned along the axis of the Booster Neutrino Beam (BNB) at Fermilab, and is the near detector in the Short-Baseline Neutrino (SBN) Program. The detector completed commissioning and began taking neutrino data in the summer of 2024. SBND is characterized by superb imaging capabilities and will record around 2 million neutrino interactions per year. Thanks to its unique combination of measurement resolution and statistics, SBND will soon carry out a rich program of neutrino interaction measurements and novel searches for physics beyond the Standard Model (BSM). As the near detector, it will enable the full potential of the SBN sterile neutrino program by performing a precise characterization of the unoscillated event rate and constraining BNB flux and neutrino-argon cross-section systematic uncertainties. In this talk, the physics reach, current status, and future prospects of SBND are discussed.

**Secondary track**:

**Joint T02+T09** / **695**

## Search for Dark Matter in 2HDM+complex singlet at LHC and future Lepton Colliders

**Auteur:** JAYITA LAHIRI[1]

**Co-auteurs:** Cheng Li [2]; Farah Tabira Sheikh [1]; Gudrid Moortgat-Pick [1]; Juhi Dutta [3]; Julia Ziegler [1]

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We investigate the phenomenological prospects of the Two Higgs Doublet and Complex Singlet Scalar Extension (2HDMS) in the context of dark matter (DM) and Higgs phenomenology. The 2HDMS provides an enlarged Higgs sector along with a DM candidate. In this work, we perform an exhaustive scan to find representative benchmarks which are consistent with all theoretical and experimental constraints. We choose benchmarks with light, intermediate and massive DM masses and in some cases, also accommodate the 95 GeV excess in $b\bar{b}$ and $\gamma\gamma$ channels observed at the Large Electron-Positron Collider (LEP) and Large Hadron Collider (LHC). We focus on the relevant signatures at the LHC and at proposed future lepton colliders, including electron-positron and muon colliders. Using a cut and count analysis, we show that while the High Luminosity LHC (HL-LHC) may give a hint of new physics, future lepton colliders prove to be efficient discovery probes for the 2HDMS.

**Secondary track**:

T02 - Dark Matter

**T14** / **696**

## Physics on the Infinite Canvas, A new tool for popularization and pedagogy

**Auteurs:** Elisabeth Petit[1]; Jérôme Charles[2]; Magali DAMOISEAUX[3]; Paola Bertelli[4]; Simon Rouvet[5]; Thierry Masson[6]; William Gillard[7]; Yohann Lebouazda[5]

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[7] *Aix-Marseille Université, CNRS/IN2P3, CPPM, Marseille*

"Physics on the Infinite Canvas"("La Fresque des deux infinis"in French) is a fun, collaborative workshop based on collective intelligence, created in 2024 by physicists from CPPM and CPT. This original tool aims to popularize theoretical and experimental physics at both the infinitely small and the infinitely large scales. Its goal is to introduce major physics discoveries across these two domains by highlighting key theoretical and experimental breakthroughs. Besides science outreach, it also serves as an educational resource for teachers in schools and universities.

The collaborative workshop is built around a set of printed cards featuring texts and illustrations. These are divided into several categories: Scientific cards, Open question cards, Scientist cards, Technological application cards, Scientific instrument cards, Research career cards, and Science fiction "technology"cards.

In the full version, each session, led by a facilitator, lasts around three hours and involves a group of 5 to 9 participants. It is structured in two parts: mapping and debriefing. During the mapping phase, participants collaboratively arrange the scientific cards into a "canvas,"with time on the horizontal axis and the physical scale on the vertical axis, connecting the cards through logical, physical, and historical links. This phase relies on the group's collective intelligence. The debriefing phase then aims to spark interest in science, from raising public awareness to inspiring students to pursue scientific careers. The facilitator uses the completed canvas to launch discussions using the thematic

card sets: scientists, instruments, applications, and/or careers. A shorter "quiz"version, lasting about twenty minutes, uses a smaller set of pre-arranged cards displayed on a printed canvas for a quick, interactive session.

To promote gender parity, the scientist cards highlight the contributions of women in physics. Facilitators are trained to be mindful of these issues and to encourage young women to consider careers in science.

This presentation will outline the main features of the workshop and introduce our open-source project to distribute it via a Git repository containing scripts and LaTeX files. We will explain how to contribute to its international development as a facilitator, developer, or content creator.

**Secondary track**:

**T11 / 698**

## Superconducting quantum detectors for applications in direct dark matter search with low-mass and luminosity measurement at FCCee

**Auteur:** Ilya Charaev[None]

The detection of individual quanta of light is important for quantum computation, fluorescence lifetime imaging, single-molecule detection, remote sensing, correlation spectroscopy, and more. Thanks to their broadband operation, high detection efficiency, exceptional signal-to-noise ratio, and fast recovery times, superconducting nanowire single-photon detectors (SNSPDs) have become a critical component in these applications.
Initially developed for deep-space communication and quantum information science, SNSPDs possess specific characteristics that make them particularly suited for applications in high-energy physics, in particular, dark matter search 1 and particle detection.

**Dark matter search**
The QROCODILE experiment 2 uses a microwire-based SNSPDs as a target and sensor for dark matter scattering and absorption, and is sensitive to energy deposits as low as 0.11 eV. We introduce the experimental configuration and report new world-leading constraints on the interactions of sub-MeV dark matter particles with masses as low as 30 keV. The thin-layer geometry of the system provides anisotropy in the interaction rate, enabling directional sensitivity. In addition, we leverage the coupling between phonons and quasiparticles in the detector to simultaneously constrain interactions with both electrons and nucleons.

**Luminosity measurement at FCCee**
The demonstration of high-efficiency direct relativistic particle detection via SNSPDs opens up a new detector technology for consideration in the FCC. One of the leading potential use cases is the luminosity measurement at FCCee. These detectors are capable of sub-10-ps RMS timing resolution, which will enable collision localization and high-rate background rejection. The energy threshold of the detectors is tunable via their bias current, which can lead to significant energy background rejection.
Furthermore, SNSPDs are also considered for other FCC science cases, such as calorimetry or tracking if coupled to scintillating fibers, long-lived searches, and an ALP detector in the forward region.

*1 Y. Hochberg, I. Charaev, S. W. Nam, V. Verma, M. Colangelo, and K. K. Berggren, Detecting Sub-GeV Dark Matter with Superconducting Nanowires, Phys Rev Lett, vol. 123, no. 15, 2019, doi: 10.1103/PhysRevLett.123.151802.*
*2 Laura Baudis and et. al., A New Bite Into Dark Matter with the SNSPD-Based QROCODILE Experiment, arXiv:2412.16279, 2025.*

**Secondary track**:

T02 - Dark Matter

**T15** / **700**

## High frequency gravitational wave sensing with superconducting microwave cavities

**Auteurs:** Can Dokuyucu[None]; Giovanni Marconato[None]; Gudrid Moortgat-Pick[1]; Krisztian Peters[2]; Marc Wenskat[None]; Tom Krokotsch[3]

[1] *DESY and University of Hamburg*

[2] *DESY*

[3] *Universität Hamburg*

A promising way to probe physics beyond the Standard Model is to
search for gravitational wave (GW) signals at high frequencies where
known astrophysical sources can not obscure the signal. Similar to the
search for dark matter, microwave cavity resonators can be used to
detect faint effects from GWs. We will report on the progress of our project to operate such a detector and highlight improvements we are planning in the future. This includes quantum enhancement techniques like vacuum squeezing which will allow future detectors to operate beyond the standard quantum limit.

**Secondary track**:

T01 - Astroparticles, Gravitation and Cosmology

**T08** / **701**

## Renormalization-group improved Higgs to two gluons decay rate

**Auteurs:** Astha Jain[1]; Gauhar Abbas[1]; Neelam Singh[1]; Vartika Singh[1]

[1] *Indian Institute of Technology (BHU)*

**Auteur correspondant** vartikasingh.rs.phy19@itbhu.ac.in

We investigate the renormalization group scale and scheme dependence of the $H \to gg$ decay rate at the order N$^4$LO in renormalization-group summed perturbative theory, which employs the summation of all renormalization-group accessible logarithms including the leading and subsequent four sub-leading logarithmic contributions to the full perturbative series expansion. The main advantage of this approach is the closed-form analytic expressions, which represent the summation of all RG-accessible logarithms in the perturbative series that is known to a given order. The new renormalization-group summed expansion for the $H \to gg$ decay rate shows an improved behaviour by exhibiting a reduced sensitivity to the renormalization-group scale. Moreover, we study the higher order behaviour of the $H \to gg$ decay width using the asymptotic Pad\'e approximant method in four different renormalization schemes. Furthermore, the higher order behaviour is independently investigated in the framework of the asymptotic Pad\'e-Borel approximant method where generalized Borel-transform is used as an analytic continuation of the original perturbative expansion. The predictions of the asymptotic Pad\'e-Borel approximant method are found to be in agreement with that of the asymptotic Pad\'e approximant method.

**Secondary track**:

T08 - Higgs Physics

**Poster T05 / 702**

## Transverse-Spin Dependent Azimuthal Asymmetries in Drell-Yan at COMPASS

**Auteurs:** COMPASS Collaboration[None]; Malgorzata Niemiec[1]

[1] *University of Warsaw*

**Auteur correspondant** malgorzata.rozalia.niemiec@cern.ch

The study of transverse-spin dependent azimuthal asymmetries in the Drell-Yan process provides crucial insights into the spin-dependent structure of nucleons. In combination with semi-inclusive deep inelastic scattering, it provides a key test of the restricted universality of transverse-momentum dependent parton distribution functions, which predict that the Sivers and Boer–Mulders functions have opposite signs in these reactions. During the 2015 and 2018 data-taking periods, the COMPASS Collaboration at CERN measured the $\pi^-\mathrm{p} \rightarrow \mu^+\mu^- X$ reaction, using a 190 GeV/$c$ pion beam and a transversely polarized $NH_3$ target. We examined asymmetries in the Drell-Yan process, introducing a novel weighting method that applies powers of the dimuon system's transverse momentum relative to the beam, in this way avoiding the convolution present in conventional asymmetries. This approach enables the direct extraction of specific $k_\mathrm{T}^2$ moments of the transverse-momentum dependent parton distribution functions. The combined results from weighted and unweighted analyses will be presented, focusing on the $M_{\mu\mu}$ mass range of 4–9 GeV/$c^2$.

**Secondary track**:

**T01 / 703**

## Baryogenesis and Preheating in Starobinsky-Higgs Inflation

**Auteur:** Yann Cado[1]

[1] *LPTHE*

Cosmological inflation is nowadays a well established paradigm to solve the classical problems of the standard model of Cosmology and to generate the primordial density perturbations giving rise to the present Universe structure. The achievements of inflation usually require the presence of one or several scalar field, the inflaton, giving rise to physics beyond the Standard Model (SM) of particle physics. Starobinsky-Higgs inflation currently stands out as one of the best-fit models of Planck data.
Using a doubly-covariant formalism for the inflationary dynamics and the production of helical gauge fields, I will show how to derive the relevant dynamics of preheating and how the observed baryon asymmetry of the Universe can be obtained when this model is supplemented by a dimension-six CP-violating term in the hypercharge sector.
The results include the full SM SU(2)×U(1) gauge dynamics in a complete analysis of the perturbations at the linear order.

**Secondary track**:

T09 - Beyond the Standard Model

**T11 / 704**

## Design and Optimisation of a Novel Light-Guiding Water Cherenkov Photodetector

**Auteur:** Jazmin Stewart[1]

[1] *University of Leicester*

This project explores a novel photodetector configuration for water Cherenkov detection by integrating smaller photomultiplier tubes (PMTs) with wavelength shifting (WLS) plates, which aims to improve the photon detection efficiency cost-effectively. A custom-built water tank at the University of Leicester will be used to test a range of modifications for this design and assess the impact on light collection. The small PMT is partially embedded in the centre of a WLS plate, designed to absorb UV Cherenkov photons and re-emit them at longer wavelengths, which will match more closely with the PMT's optimal sensitivity. The WLS plate will guide the re-emitted light towards the edge of the PMT's photocathode via total internal reflection and additional reflective edges.
This investigation will evaluate the influence that the WLS plate positioning has on the PMTs' photon detection efficiency. We aim to quantify the gain in detected signal due to changes in angular acceptance by varying the WLS plates' vertical height on the photocathode. Furthermore, we will test the effects of reflective coatings on the WLS plate to determine the optimal configuration for maximising light guiding toward the PMT.
This configuration will specifically focus on atmospheric muon detection and selectively trigger on these with a prototype muon telescope. The system comprises two 6×6 mm² silicon photomultipliers (SiPMs) - used for the CTA Small-Sized Telescope (SST) selection process - coupled to small WLS scintillator blocks, vertically aligned and separated with a thin lead sheet. The lead will act as a low-energy background radiation veto, favouring muons. Coincidence logic is used to identify events where both SiPMs have been simultaneously triggered, generating a logic pulse that serves as an external trigger for the Oscilloscope to monitor the PMT output. This system will improve the signal-to-noise ratio by measuring only muon-induced signals.
This study aims to determine the feasibility of this configuration in water Cherenkov detectors for application in high-energy astroparticle physics. This technique could offer a cost-effective alternative to the traditionally used larger PMTs in these systems.

**Secondary track**:

T01 - Astroparticles, Gravitation and Cosmology

**T09 / 705**

## Heavy sterile Neutrinos from B decays and new QCD corrections to their semi-hadronic decay rates

**Auteurs:** Florian Bernlochner[1]; Marco Fedele[2]; Markus Prim[1]; Tim Kretz[3]; Ulrich Nierste[4]

[1] *University of Bonn*

[2] *U. Mainz - PRISMA*

[3] *KIT - TTP*

[4] *TTP, Karlsruhe Institute of Technology*

**Auteur correspondant** tim.kretz@kit.edu

In modern experiments on flavour physics it is possible to search for the decays of $B$'s, $D$'s, or $\tau$'s into final states with heavy neutrinos $N$ (a.k.a. heavy neutral leptons). I present a common study of theorists and experimentalists from Belle II on constraints on $B \to D^* \ell N$. Next I discuss the status of the theory predictions of the various $N$ decay rates. In scenarios in which $N$ interacts with SM particles only through sterile-active neutrino mixing, the dependence of

the lifetime on the relevant mixing angles is important to determine whether $N$ decays in the detector or outside. To calculate the inclusive decay rate into semi-hadronic final states reliably one needs to include radiative QCD corrections. I present analytic results for the QCD-corrected decay rates and discuss their phenomenological impact.

**Secondary track**:

**T05** / **707**

## Intrinsic-kt and soft-gluons in Monte Carlo generators

**Auteurs:** Aleksandra Lelek[None]; Francesco Hautmann[None]; Laurent Favart[None]; Louis Moureaux[None]

**Auteur correspondant** louis.moureaux@uni-hamburg.de

The talk addresses the interplay of perturbative and non-perturbative physics in Monte Carlo (MC) generators.

We summarize the studies carried out so far within the TMD parton branching (PB) approach on the extraction of intrinsic transverse momentum (intrinsic-kt) from Drell-Yan (DY) predictions at different center-of-mass energies and in different ranges of invariant mass of the lepton pair. The recent PB study shows a striking difference in the center-of-mass energy dependence of intrinsic-kt compared to standard Monte Carlo (MC) generators: whereas the PB approach finds basically no energy dependence, the standard MCs show a strong dependence. This difference can be associated with the radiation modelling and with the interplay of the effects related to soft-gluon emission and intrinsic-kt distribution. We comment on the possibility of the flavor dependence of the intrinsic-kt distribution.

**Secondary track**:

**T14** / **708**

## The intersection of Diversity & CMS Communications

**Auteur:** CMS Collaboration[None]

**Auteur correspondant** niki.saoulidou@cern.ch

It is more important than ever to not only have a diverse community within science, but to show it to those outside who provide support and resources, as well as to young people hoping to make a career in this field. Allowing our audiences to see themselves reflected in members of our community, or to aspire to people we show them is a powerful way of connecting to them. In this poster, we, as CMS Communications, touch on a couple of different campaigns that aim to reach more diverse audiences by platforming that diversity from our collaboration of 6000 people.

**Secondary track**:

**T09** / **709**

## Dataset-wide Graph Neural Networks for BSM Searches at the LHC

**Auteurs:** Anna Mullin[1]; Holly Pacey[2]; Maggie Chen[2]; Sebastian Rutherford Colmenares[1]

[1] *University of Cambridge*

[2] *University of Oxford*

**Auteur correspondant** ajm351@cam.ac.uk

We present a new application of Graph Neural Networks (GNNs) for LHC searches that aims to improve event classification by representing entire datasets as graphs, with events as nodes and kinematically similar events connected by edges. The strategy builds from our development of graph convolutions and graph attention mechanisms, where we apply scalable solutions for training various GNN models on large graphs with robust background validation. By merit of the search style and graph design, the GNN obtains extensive information from topological network structures such as clusters, helping to distinguish signal from background through their distinct characteristic connectivity. This work extends our previous proof of concept for dataset-wide graphs in BSM searches [JHEP 2021, 160 (2021)], which demonstrates a promising baseline of signal-background separation. Since our recent extension to include GNNs, we confirm further sensitivity improvements with a leptoquark BSM benchmark beyond a conventional DNN approach. In addition, we present a second result extending the method to anomaly detection, exploiting the new format of a dataset-wide GNN in an example unsupervised search, calculating the event-by-event anomaly score.

**Secondary track**:

T16 - AI for HEP (special topic 2025)

**T14** / **711**

## Japanese-Style Compact Cosmic-Ray Muon Detector for Outreach and Education

**Auteurs:** Chihiro YAMADA[1]; Haruki Iiyama[None]; Kazuki Ueno[1]; Kenya Okabe[2]; Masaaki Higashide[2]; Masayoshi Shoji[3]; Nakamori Takeshi[None]; Shota Takahashi[None]; Yaegashi Dai[None]; Yoshioka Tamaki[None]

[1] *Osaka University*

[2] *The Graduate University for Advanced Studies, SOKENDAI*

[3] *KEK*

For many students and members of the public interested in particle physics and astrophysics, direct access to real research is limited due to the need for expensive and large-scale equipment such as accelerators and telescopes. However, recent advances in technology have made it feasible to develop low-cost detectors, and several groups have started creating simple yet functional instruments for outreach and educational purposes.
We have developed a compact and low-cost cosmic-ray muon detector named **OSECHI** (Outreach & Science Education Cosmic-ray Hunting Instrument). The detector is housed in a Japanese-style tiered lunch box, *Jubako*, and consists of three layers of 3D-printed plastic scintillators. These are capable of detecting coincident muon events with a single unit. Light from the scintillators is collected by silicon photomultipliers (SiPMs), and the signals from the SiPMs are processed by a custom-designed electronics board, which records both charge and timing information. The board includes LEDs that light up in real time when muons pass through the corresponding scintillators, offering an intuitive way for users to visualize cosmic-ray events. It operates via a USB power source and includes a DC-HV converter for SiPM bias. Additional sensor interfaces, such as GPS and temperature monitors, are also supported. Signal processing is fully handled by an onboard microcontroller.
We have produced and evaluated prototype versions of the OSECHI detector, conducted several hands-on workshops with students and educators, and incorporated the feedback to improve the design.
In this presentation, we will describe the design and performance of the OSECHI detector, and share examples of its successful use in outreach and educational activities.

**Secondary track**:

**T06** / **713**

## Measurement of the electroweak production of one photon and two jets in proton-proton collisions at sqrt(s)=13 TeV in CMS detector

**Auteur:** CMS Collaboration[None]

We present the first observation of electroweak production of a photon in association with two forward jets in proton-proton collisions using 13 TeV data recorded by the CMS experiment corresponding to an integrated luminosity of 138 fb-1 The analysis is performed in a region enriched with vector boson fusion (VBF) production, with a requirement on the transverse momentum of the leading photon to exceed 200 GeV. The cross section is measured in the VBF fiducial region, at a significance concerning the null hypothesis that exceeds five standard deviations, and in agreement with the standard model prediction. Differential cross sections are measured as a function of various observables. Limits are set on effective field theory operators that contribute to the WWy vertex at dimension-six. The 95% confidence intervals for cW and cHWB are [0.11, 0.16] and [-1.6, 1.5], respectively.

**Secondary track**:

**T01** / **714**

## Gamma-ray astronomy: latest results and prospects

**Auteur:** Federica BRADASCIO[1]

[1] *IJCLab, Université Paris-Saclay*

Gamma-ray astronomy offers a unique window into the most extreme environments of the Universe, enabling the study of cosmic particle acceleration, high-energy emission mechanisms, and potential signatures of dark matter and fundamental physics. In recent years, the field has witnessed significant progress, driven by observations from space-based instruments such as Fermi-LAT and ground-based Cherenkov telescopes including H.E.S.S., MAGIC, and VERITAS, and wide-field observatories like HAWC and LHAASO. This talk will present recent highlights from gamma-ray observations across a range of astrophysical sources, focusing on new detections and multi-wavelength and multi-messenger synergies. I will also discuss the challenges and opportunities ahead, and outline the expected impact of next-generation observatories such as the Cherenkov Telescope Array Observatory (CTAO) on the future of the field.

**Secondary track**:

**T08** / **715**

## Assessing uncertainties arising in the interpretation of single-Higgs-production observables as a measurement of the triple Higgs coupling

**Auteurs:** Georg Weiglein[1]; Henning Bahl[2]; Jenny List[1]; Johannes Braathen[3]; Murillo Rebuzzi Ardións Vellasco[4]; Philip Bechtle[1]; Sven Heinemeyer[5]

[1] *DESY*

[2] *Universität Heidelberg*

[3] *Deutsches Elektronen-Synchrotron DESY*

[4] *Physikalisches Institut, Universität Bonn*

[5] *IFCA (CSIC-UC, Santander)*

e+e- colliders operating at energies below the di-Higgs production threshold can provide information on the trilinear Higgs self-coupling lambda via its loop contributions to single Higgs production processes and electroweak precision observables. We investigate how well a non-SM value of lambda can be determined indirectly via its loop contributions to a global EFT fit. Using a doublet extension of the SM Higgs sector as an example for a scenario of physics beyond the SM that could be realised in nature, we find that the results for lambda obtained from the global EFT fit differ significantly from the actual value of lambda in the considered scenarios unless additional systematic uncertainties are considered. We find that theoretical uncertainties that are connected to the treatment of loop contributions and the truncation of the EFT expansion play an important role in this mismatch. The results obtained from such an indirect determination of lambda via its loop contributions in an EFT fit, without taking additional uncertainties into account, could therefore be misleading in the quest to precisely identify the underlying physics of electroweak symmetry breaking. We furthermore discuss the role of di-Higgs production in the determination of the trilinear Higgs self-coupling.

**Secondary track**:

T06 - Top and Electroweak Physics

**T14** / **716**

## Subatomic Heroes

**Auteur:** Oliver Witzel[1]

[1] *University of Siegen*

**Auteur correspondant** oliver.witzel@uni-siegen.de

Sharing the amazing achievements of the particle physics world with the general public is at the heart of the Subatomic Heroes. Our activities range from merging art with a public physics lecture to marvelous performances at the local theater, over dedicated events for high-school students, to our Subatomic Heroes channel on instagram where you may also find out when and where our famous "hadronic ice-cream" will be served next! So let's follow us instagram.com/subatomic_heroes/

**Secondary track**:

**T06** / **717**

## Two-photon processes in future electron-hadron facilities

**Auteurs:** Hamzeh Khanpour[1]; Krzysztof Piotrzkowski[2]; Laurent Forthomme[3]

[1] *Universita degli Studi di Udine (IT)*

[2] *UCLouvain/CERN*

[3] *AGH University of Krakow (PL)*

High energy photon-photon interactions provide unique opportunity for studying with high precision the electroweak sector of particle physics at future electron-hadron colliders 1. In particular, facilities such as the LHeC [2, 3], and its proposed phase-one option at a 0.75 TeV centre-of-mass energy [4], FCC-eh, or SppC-eh, will offer very advantageous experimental conditions and at the

same time provide high $\gamma\gamma$ luminosities, for photon-photon centre-of-mass energies reaching the TeV scale.

In this talk we will give an overview of sensitivities for multiple SM, and BSM photon-induced processes at these colliders.

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1 L. Forthomme, H. Khanpour, K. Piotrzkowski, Y. Yamazaki, "High energy $\gamma\gamma$ interactions at the LHeC", paper in preparation
2 P. Agostini, H. Aksakal, et al, "The Large Hadron-Electron Collider at the HL-LHC", J. Phys. G 48 (2021) 11, 110501
[3] F. Ahmadova, K. André, et al, "The Large Hadron electron Collider as a bridge project for CERN", arXiv:2503.17727 [hep-ex]
[4] K. André, B. Holtzer, L. Forthomme, K. Piotrzkowski, "An electron-hadron collider at the high-luminosity LHC", arXiv:2503.20475 [hep-ex]

**Secondary track**:

T09 - Beyond the Standard Model

**T07 / 718**

## Heavy Meson Lifetimes

**Auteurs:** Matthew Black[1]; Oliver Witzel[2]

[1] *University of Edinburgh*

[2] *University of Siegen*

We present a novel approach to calculate heavy meson lifetimes on the lattice. To tackle this long standing problem, we utilize gradient flow in combination with the short flow time expansion to nonperturbatively renormalize our lattice results and perform a perturbative matching to the $\overline{\text{MS}}$ scheme. This paves the way to circumvent challenges on the lattice such as mixing with operators of lower mass dimension. We focus on $D_s$ mesons to establish and validate our method and plan to study $B$ mesons in the near future.

**Secondary track**:

**Joint T02+T09 / 719**

## Searches for displaced Scalar decays to dimuons: LHCb's extended reach in Run 3

**Auteur:** LHCb Collaboration[None]

A detailed study exploiting novel trigger and reconstruction techniques developed to search for Beyond Standard Model (BSM) Long-Lived Particles (LLPs) with very displaced vertices is presented. Building on feasibility studies that have successfully reconstructed Standard Model decays occurring up to 8m forward of the interaction point in LHCb's magnet region, the search for LLP particles into charged final states exploits LHCb's unique forward geometry and segmented tracking system—comprising the Vertex Locator, Upstream Tracker, and SciFi stations—to extend sensitivity into previously inaccessible regions.

The presentation will cover innovative trigger strategies implemented in LHCb's software trigger for inclusively selecting very displaced dimuon pairs, alongside advanced offline selection methods utilising multivariate analysis methods to robustly suppress background while maintaining high signal efficiency. Preliminary sensitivity estimates for Dark Higgs -> mu mu search indicate that these approaches can achieve competitive performance compared to dedicated LLP experiments. Future prospects will also be discussed. This work aims to provide a comprehensive framework for enhancing LLP discovery potential at LHCb and offers insights that could be beneficial for the broader BSM LLP search community.

**Secondary track**:

T09 - Beyond the Standard Model

**T11** / **720**

## MUSIC: a detector concept for 10 TeV $\mu^+\mu^-$ collisions

**Auteurs:** Alessio Gianelle[1]; Davide Zuliani[2]; Donatella Lucchesi[2]; Leonardo Palombini[1]; Lorenzo Sestini[3]; Massimo Casarsa[4]; Paolo Andreetto[1]

[1] *INFN Padova, Italy*

[2] *University and INFN of Padova, Italy*

[3] *INFN Firenze, Italy*

[4] *INFN Trieste, Italy*

The full exploitation of the physics potential of a multi-TeV muon collider will ultimately lie in the detector's ability to cope with unprecedented levels of machine-induced backgrounds.
This contribution introduces the MUSIC (MUon System for Interesting Collisions) detector concept and presents its performance in the context of $\sqrt{s} = 10$ TeV muon-antimuon collisions. The MUSIC detector is designed to mitigate machine-induced background effects while maintaining high efficiency and accuracy in the reconstruction of physics events, in particular in the Higgs boson sector and in the search for new physics. It features an advanced all-silicon tracking system, a semi-homogeneous lead-fluorite crystal electromagnetic calorimeter, a iron-scintillator sampling hadronic calorimeter, and a superconducting magnet providing a 5 T magnetic field.
The contribution presents the results of detailed detector simulations including the dominant machine-induced backgrounds. The results demonstrate promising tracking efficiency, photon, electron and jet reconstruction capabilities, and jet flavor identification performance, highlighting the strong potential of the detector for high-energy muon collider experiments.

**Secondary track**:

**T08** / **721**

## Higgs physics at 10 TeV Muon Collider

**Auteurs:** Alessio Gianelle[None]; Davide Zuliani[1]; Donatella Lucchesi[None]; Leonardo Palombini[None]; Lorenzo Sestini[None]; Massimo Casarsa[2]; Paolo Andreetto[None]

[1] *University and INFN of Padova*

[2] *INFN Trieste, Italy*

This contribution discusses the physics potential of a future muon collider operating at a center-of-mass energy $\sqrt{s} = 10$ TeV for precision studies in the Higgs sector. Using a detailed detector simulation that incorporates the dominant sources of machine-induced background, the expected sensitivity to key Higgs processes is evaluated. These include the measurement of production cross sections for $H \to b\bar{b}$, $H \to WW^*$, and double-Higgs production $HH \to b\bar{b}b\bar{b}$. A central focus of the study is the determination of the Higgs boson trilinear self-coupling, a critical parameter for understanding the structure of the Higgs potential and electroweak symmetry breaking. The analysis is based on the MUSIC (MUon System for Interesting Collisions) detector concept, specifically optimized for the muon collider environment, and assumes an integrated luminosity of 10 ab$^{-1}$ collected over five years. The results presented highlight the exceptional prospects of a multi-TeV muon collider for exploring the Higgs potential with a level of precision unattainable by any other proposed future collider within a comparable timeframe.

**Secondary track**:

**T05** / **722**

## Heavy Mesons to Charmed Tetraquark Decays

**Auteur:** Chun-Khiang Chua[1]

[1] *Chung Yuan Christian University*

Motivated by the recent observations of $T^*_{cs0}(2870)^0$, $T^*_{c\bar{s}0}(2900)^0$ and $T^*_{c\bar{s}0}(2900)^{++}$ charmed tetraquark states by LHCb, we study the decays of heavy mesons to these charmed tetraquark states ($T$) using a topological amplitude approach. We first obtain the $T \to DP$ and $DS$ strong decay amplitudes by decomposed them into several topological amplitudes, where $P$ is a light psedo-scalar particle and $S$ is a low-lying scalar particle. Later on, weak decay amplitudes of $\overline{B} \to D\overline{T}$, $\overline{D}T$ and $\overline{B} \to TP$, $TS$ decays are decomposed topologically. Other heavy mesons to charmed tetraquark decays are also discussed. Using these results, modes with unambiguous exotic interpretation in flavor are highlighted.

**Secondary track**:

T07 - Flavour Physics and CP Violation

**T07** / **723**

## Precision Measurement of the Muon Spin Precession Frequency ωa in the Fermilab Muon g-2 Experiment

**Auteurs:** Estifa'a Zaid[1]; Muon g-2 Collaboration[None]; TBC TBC[None]

[1] *University of Liverpool*

The Fermilab Muon $g-2$ Experiment is designed to measure the muon's anomalous magnetic moment, $a_\mu = (g-2)/2$ with a final accuracy of 140 parts per billion. This quantity is determined from two key measurements; the magnetic field and the difference between the muon's spin precession frequency and its cyclotron frequency, given by $\omega_a = \omega_s - \omega_c$, in a highly uniform 1.45 T magnetic field within a 14-meter-diameter storage ring.

In this talk, we present the methodology for determining $\omega_a$. Muons with a momentum of 3.1 GeV are injected into the storage ring, and $\omega_a$ is extracted from the time distribution of decay positrons recorded by 24 electromagnetic calorimeters placed symmetrically inwards around the ring. We will provide an overview of recent results and analysis techniques based on data collected from 2020 to 2023, including positron reconstruction and fitting procedures as well as corrections for systematic effects such as gain fluctuations, pileup, and beam dynamics.

**Secondary track**:

T09 - Beyond the Standard Model

**T10** / **724**

# The matrix model of two-color one-flavor QCD in the ultra-strong coupling regime

**Auteurs:** Nirmalendu Acharyya[1]; Prasanjit Aich[2]; Arkajyoti Bandyopadhyay[1]; Sachindeo Vaidya[2]

[1] *Indian Institute of Technology Bhubaneswar, India*

[2] *Indian Institute of Science, Bangalore, India*

**Auteur correspondant** prasanjita@iisc.ac.in

The matrix model for the two-color QCD coupled to a single quark (matrix-QCD$_{2,1}$) exhibits novel features, such as the Pauli-G\"{u}rsey symmetry. Using variational methods, we numerically investigate matrix-QCD$_{2,1}$ in the limit of ultra-strong Yang-Mills coupling ($g_{YM} = \infty$). The spectrum of the model has superselection sectors labelled by baryon number $B$ and spin $J$. We study sectors with $B = 0, 1, 2$ and $J = 0, 1$, which may be organised as mesons, (anti-) diquarks and (anti-) tetraquarks. For each of these sectors, we study the properties of the respective ground states in both chiral and heavy quark limits, and uncover a rich quantum phase transition (QPT) structure. We also investigate the division of the total spin between the glue and the quark and show that glue contribution is significant for several of these sectors. For the $(B, J) = (0, 0)$ sector, we find that the dominant glue contribution to the ground state comes from reducible connections. Finally, in the presence of non-trivial baryon chemical potential $\mu$, we construct the phase diagram of the model. For sufficiently large $\mu$, we find that the ground state of the theory may have non-zero spin, indicating a phase reminiscent of the LOFF phase in two-color QCD.

**Secondary track**:

**T07** / **725**

# Beam dynamics corrections to the measured anomalous precession frequency at the Muon g-2 experiment at Fermilab

**Auteur:** Elia Bottalico[1]

[1] *University of Liverpool*

The Fermilab Muon g-2 experiment is designed to determine the muon's magnetic moment anomaly with an unprecedented precision of 0.14 parts per million (ppm). This anomaly is extracted from the ratio of the muon's anomalous spin precession frequency within a magnetic storage ring to the magnetic field experienced by the ensemble of muons. However, the measured precession frequency is subject to systematic biases arising from muon beam dynamics. In our analysis, we account for two primary categories of systematic effects: (i) reductions in the spin precession frequency due to electric fields and vertical motion, and (ii) variations in the precession phase over the course of the measurement period. In this presentation, we outline the beam dynamics corrections implemented in the analysis of the data collected from 2020 to 2023 and provide an update on developments since the previous result announcement.

**Secondary track**:

**T01** / **727**

# Effects of Inflationary Particle Production on Local Temperature Fluctuations on the CMB

**Auteur:** Sven Ha[1]

**Co-auteurs:** Bibhushan Shakya Shakya [2]; Gudrid Moortgat-Pick [3]; Julia Ziegler [4]

[1] *DESY*

[2] *Cornell University*

[3] *DESY and University of Hamburg*

[4] *II. Theoretical Institute for Physics, University of Hamburg*

Heavy particle production through coupling with the inflaton field, during inflation, can lead to time-dependent and scale non-invariant curvature perturbations. These perturbations are preserved on superhorizon scales and imprint local temperature deviations, hot and cold spots, in the CMB.
Hot or cold spots can also be a result of tachyonic Higgs production, since the Standard Model Higgs becomes tachyonic and gets exponentially produced out of vacuum during inflation.
We take an in-depth look into potential hot or cold spot relics
in the CMB created by the high particle energy density of the Higgs to see whether these hot or cold spots can be detected. Additionally, we study potential scenarios such as hot or cold spots left by primordial black hole (PBH) production due to the collapse of local overdense Higgs regions.
Using this approach we find the
theoretical limits on the mass functions for Higgs particle production
during the inflationary epoch.

**Secondary track**:

T08 - Higgs Physics

**T02** / **728**

# COmpact DEtector for EXotics at LHCb: CODEX-b

**Auteurs:** CODEX-b Collaboration[None]; Vladimir GLIGOROV[1]

[1] *LPNHE*

The COmpact DEtector for EXotics at LHCb (CODEX-b) is a particle physics detector dedicated to displaced decays of exotic long-lived particles (LLPs), compelling signatures of dark sectors Beyond the Standard Model, which arise in theories containing a hierarchy of scales and small parameters. The CODEX-b detector is a cube with 10m per side with two internal sections, planned to be installed near the LHCb interaction point. It is built of a new generation of high performance RPCs triplet chambers, derived from the ATLAS upgrade RPC technology, providing a space x time resolution of a few mm x 300 ps per individual detector layer. It will have a near-zero background environment, hence complementing the new-searches program of other detectors like ATLAS or CMS. A demonstrator detector, CODEX-⊠, has been installed to take data beginning in 2025. It will validate the design and physics case for the future CODEX-b. CODEX-⊠ will be responsible for validating the background estimations for CODEX-b, demonstrating integration in the LHCb readout system, and showing the suitability of the baseline tracking and its mechanical support. This talk will present the latest developments and will focus on the status and plans for CODEX-⊠.

**Secondary track**:

T11 - Detectors

**T04** / **729**

## Recombination of heavy quarks for meson and baryon production in a large range of collisions systems

**Auteurs:** Salvatore Plumari[1]; Vincenzo Greco[2]; Vincenzo Minissale[3]

[1] *Università di Catania, LNS-INFN*

[2] *University of Catania, INFN-LNS*

[3] *INFN - Sezione di Catania*

**Auteur correspondant** vincenzo.minissale@lns.infn.it

Measurements of heavy baryon production in pp, pA and AA collisions from RHIC to top LHC energies have recently attracted more and more attention, currently representing a challenge for the heavy-quark hadronization theoretical understanding. In such experiments there have been many indications of the formation of a deconfined phase of quarks and gluons called the quark-gluon-plasma (QGP).
The large baryon over meson ratio $\Lambda_c/D^0 \sim O(1)$ observed in both AA collisions at RHIC and LHC 1 as well as in pp collisions at $5.02$ and $13\ \mathrm{TeV}$ has been well described by an hadronization approach based on the recombination of heavy quarks combined with fragmentation. The obtained ratio is, in general, quite larger than the one measured and expected in $e^+e^-$, $ep$ collisions.
The same approach also predicts a quite large $\Xi_c/D^0 \sim 0.15$ and $\Omega_c/D^0 \sim 0.05$ in $pp$ collisions, in quite good agreement with experimental measurements 2.
Given such successful predictions, we present here a critical assessment of the elements of the hadronization modeling that are mainly driving heavy baryon enhancement.
In addition, we discuss the extensions of the approach applied in order to supply the prediction for the multi-charmed baryon production, i.e. $\Xi_{cc}$, $\Omega_{cc}$ and $\Omega_{ccc}$, over a wide system size scan from $PbPb$ to $KrKr$, $ArAr$ and $OO$ [3], and the bottomed hadron production in $pp$ and $PbPb$ collisions [4][5].
We can compare the coalescence prediction with the one coming from a statistical hadronization approach, investigating further the impact on the production coming from non-equilibrium features in the heavy-quark distribution that comes from the solution of relativistic Boltzmann or Langevin equation that describes the QGP evolution.

[1.] S. Plumari, V. Minissale, S.K. Das, G. Coci and V. Greco, Eur.Phys.J. C 78 (2018) no.4, 348
[2.] V. Minissale, S. Plumari and V. Greco, Physics Letters B 821 (2021) 136622.
[3.] V. Minissale, S. Plumari, Y.Sun and V. Greco, Eur.Phys.J.C 84 (2024) 3, 228
[4.] M.L. Sambataro, V. Minissale, S. Plumari and V. Greco,Phys.Lett.B 849 (2024) 138480
[5.] V. Minissale, V. Greco and S. Plumari, Phys.Lett.B 860 (2025) 139190

**Secondary track**:

**T09** / **730**

## Search for the X17 particle with the PADME detector

**Auteur:** PADME Collaboration[None]

The PADME experiment at the Frascati National Laboratory of INFN has performed a search for the hypothetical X17 particle, by observing the product of the collisions of the positron beam from the DAΦNE LINAC on a diamond fixed target.
The beam energy has been varied in the range 265–300 MeV, corresponding to values of √s between 16.4 and 17.5 MeV, completely covering the the CoM region identified by the ATOMKI collaboration as significant for observing the postulated X17 particle.
The result of the analysis shows an about 2-sigma excess corresponding to the mass indicated by the ATOMKI experiment. A new data taking campaign, with an improved detector is

planned to start in the summer of 2025, with the aim of pushing forward the sensitivity of the search.

**Secondary track**:

T02 - Dark Matter

**Joint T04+T05** / **731**

## Probing of exotic multiquark states in hadron and heavy ion collisions

**Auteur:** Mikhail Barabanov[1]

**Co-auteur:** Stephen Olsen [2]

[1] *IUPAP*

[2] *UCAS*

**Auteur correspondant** bara_2009@mail.ru

The spectroscopy of charmonium-like mesons with masses above the 2_mD open charm threshold has been full of surprises and remains poorly understood. The currently most compelling theoretical descriptions of the mysterious XYZ mesons attribute them to hybrid structure with a tightly bound cc\bar diquark or cq(cq)\bar tetraquark core that strongly couples to S-wave D*D*\bar molecular like structures. In this picture, the production of a XYZ states in high energy hadron collisions and its decays into light hadron plus charmonum final states proceed via the core component of the meson, while decays to pairs of open-charmed mesons proceed via the D*D*\bar component.
These ideas have been applied with some success to the XYZ states, where a detailed calculation finds a cc\bar core component that is only above 5% of the time with the DD*\bar component (mostly D0D0*\bar) accounting for the rest. In the hybrid scheme, XYZ mesons are produced in high energy proton-nuclei collisions via its compact (r_rms < 1 fm) charmonium-like structure and this rapidity mixes in a time (t ~ ħ/δM) into a huge and fragile, mostly D0D0*\bar, molecular-like structure. δM is the difference between the XYZ meson mass and that of the nearest cc\bar mass pole core state.
The experiments with proton-proton and proton-nuclei collisions with √S_pN up to 27 Gev and luminosity up to 10^32 cm^-2s^-1 planned at NICA may be well suited to test this picture for the X(3872) and other XYZ mesons. In near threshold production experiments in the √S_pN ≈ 8 GeV energy range, XYZ mesons can be produced with typical kinetic energies of a few hundred MeV. In the case of X(3872), its decay length will be greater than 50 fm while the distance scale for the cc\bar ⟶ D0D0**\bar transition would be 2 ~ 3 fm. Since the survival probability of an r_rms ~ 9 fm "molecular"inside nuclear matter should be very small, XYZ meson production on a nuclear target with r_rms ~ 5 fm or more (A ~ 60 or larger) should be strongly quenched. Thus, if the hybrid picture is correct, the atomic number dependence of XYZ production at fixed √S_pN should have a dramatically different behavior than that of the ψ', which is long lived compact charmonium state.
The current experimental status of XYZ mesons together with hidden charm tetraquark can-didates and present simulations what we might expect from A-dependence of XYZ mesons in proton-proton and proton-nuclei collisions are summarized.

**Secondary track**:

T04 - Ultra-relativistic Nuclear Collisions

**Joint T06+T08** / **733**

## Electroweak Precision Observables, Top and Higgs physics in the SMEFT

**Auteurs:** JORGE DE BLAS[1]; Laura Reina[None]; Luca Silvestrini[2]; Mauro Valli[None]; Victor Miralles[None]

[1] *University of Granada*

[2] *INFN, Roma*

We present results from a global fit of dimension-six SMEFT operators that includes electroweak, Higgs-boson, top-quark, and flavor observables. The leading-order scale dependence of the SMEFT Wilson coefficients is consistently included in the evolution from the UV scale to the electroweak scale and the low-energy scale of flavor observables. The global fit is obtained within the HEPfit framework and is based on the state-of-the-art of both experimental results and SM theoretical predictions for all the observables considered.

**Secondary track**:

T08 - Higgs Physics

**Joint T08+T16** / **734**

## Parameter Estimation with Neural Simulation-Based Inference in ATLAS

**Auteur:** David Rousseau[1]

[1] *IJCLab, Université Paris-Saclay*

**Auteur correspondant** rousseau@lal.in2p3.fr

Neural Simulation-Based Inference (NSBI) is a powerful class of machine learning (ML)-based methods for statistical inference that naturally handle high dimensional parameter estimation without the need to bin data into low-dimensional summary histograms. Such methods are promising for a range of measurements at the Large Hadron Collider, where no single observable may be optimal to scan over the entire theoretical phase space under consideration, or where binning data into histograms could result in a loss of sensitivity. This work develops an NSBI framework that, for the first time, allows NSBI to be applied to a full-scale LHC analysis, by successfully incorporating a large number of systematic uncertainties, quantifying the uncertainty coming from finite training statistics, developing a method to construct confidence intervals, and demonstrating a series of intermediate diagnostic checks that can be performed to validate the robustness of the method. As an example, the power and feasibility of the method are demonstrated for an off-shell Higgs boson couplings measurement in the four lepton decay channel, using ATLAS experiment simulated samples. The proposed method is a generalisation of the standard statistical framework at the LHC, and can benefit a large number of physics analyses. This work serves as a blueprint for measurements at the LHC using NSBI.
This talk covers https://arxiv.org/abs/2412.01600 which is a methodology paper detailing the NSBI technique used in the physics paper https://arxiv.org/abs/2412.01548 .

**Secondary track**:

T08 - Higgs Physics

**T07** / **735**

## The role of Flavour in global SMEFT fits

**Auteurs:** JORGE DE BLAS[1]; Laura Reina[None]; Luca Silvestrini[2]; Mauro Valli[None]; Victor Miralles[None]

[1] *University of Granada*

[2] *INFN, Roma*

We discuss the role of Flavour physics in global fits of dimension-six operators in the Standard Model Effective Theory. We present results from fits with different assumptions on the SMEFT flavour structure: U(3)^5, U(3)^5 and Minimal Flavour Violation. The leading-order scale dependence of the SMEFT Wilson coefficients is consistently included in the evolution from the UV scale to the electroweak scale and to the low-energy scale of flavor observables. The Standard Model parameters, including quark masses and the CKM matrix, are simultaneously determined with the SMEFT coefficients. The impact of flavour physics in the global fit is highlighted. The global fit is obtained within the HEPfit framework and is based on the state-of-the-art of both experimental results and SM theoretical predictions for all the observables considered.

**Secondary track**:

T09 - Beyond the Standard Model

**Poster T14** / **736**

## Elementary particles for Engineers

**Auteur:** Ivan Melo[1]

[1] *University of Žilina*

Introducing elementary particles to science and engineering students (non-physics majors), poses both a challenge and an opportunity. The challenge lies in the inherently limited scope of the topic, which is usually taught as part of an elective modern physics course. The opportunity lies in being able to share the beauty of our subject with people who are motivated to learn and tend to focus more on conceptual insights and less on complex mathematical formulations.

I will describe my approach, in which I take students of an introductory course on quantum mechanics on a fascinating (and short!) journey from the classical harmonic oscillators and standing waves that everyone is familiar with to particles as excitations/waves of quantum fields. We discuss other problems that are naturally related to this framework, including the double-slit experiment, wave-particle duality, particle decays, and the quantum vacuum. After further simplification, this treatment could satisfy curiosity of talented high school students.

**Secondary track**:

**T09** / **737**

## Two-photon production of W-boson pairs at the LHeC and sensitivity to anomalous gauge couplings

**Auteurs:** Hamzeh Khanpour[1]; Krzysztof Piotrzkowski[1]; Laurent Forthomme[1]; Zahra Abdy[1]

[1] *AGH University of Krakow (PL)*

We explore the prospects of exclusive $W^+W^-$ production via
photon-photon fusion at the LHeC, operating at a center-of-mass energy

of 1.2 TeV 1. Utilizing the clean experimental environment and high luminosity of the LHeC [2,3], this process could provide a powerful probe of electroweak interactions and possible deviations from SM, particularly through anomalous quartic gauge couplings. We investigate the impact of dimension-8 operators that modify the $\gamma\gamma W^+W^-$ vertex. Signal sensitivity for semileptonic decay channels of the $W$ bosons is assessed using Monte Carlo simulations, including detector effects through Delphes. Kinematic distributions and selection strategies are optimized to suppress contributing backgrounds. Finally, a statistical analysis is performed to set 95\% CL exclusion limits on aQGC parameters.

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1 L. Forthomme, H. Khanpour, K. Piotrzkowski, Y. Yamazaki, High energy $\gamma\gamma$ interactions at the LHeC, paper in preparation.
2 F. Ahmadova, K. André, The Large Hadron Electron Collider as a bridge project for CERN, arXiv:2503.17727 [hep-ex].
[3] P. Agostini, H. Aksakal, et al, The Large Hadron-Electron Collider at the HL-LHC, J. Phys. G 48 (2021) 11, 110501.

**Secondary track**:

T06 - Top and Electroweak Physics

**T08** / **738**

# Inclusive Higgs->bb/cc with Run 2 data from LHCb

**Auteur:** LHCb Collaboration[None]

LHCb is a spectrometer that covers the forward region of proton-proton collisions, in the pseudo rapidity range from 2 to 5. Thanks to its excellent vertex reconstruction system, it has already demonstrated its capability to identify heavy flavour jets. Moreover, the b- and c-jet identification is a crucial ingredient for the search of H->bb and H->cc at LHCb. In this talk, new methods used at LHCb based on machine learning techniques that exploits the jet substructure will be presented. Particularly, the focus will be on dijet mass regression and jet flavour identification. These new methods are applied to search for H->bb and H->cc using Run 2 data. New results and prospects for inclusive searches for H->bb and H->cc at the LHCb experiment will be presented.

**Secondary track**:

**Poster T06** / **739**

# Top quark charge asymmetry in ttbar+jets events

**Auteur:** Ying An[1]

[1] *DESY*

Top quark charge asymmetry measurements in jet-associated top quark pair production are performed in proton-proton collisions at a centre-of-mass energy of 13 TeV, using a sample of events containing one electron or muon in the final state. The data were recorded with the CMS detector at the CERN LHC and correspond to an integrated luminosity of 138 $\mathrm{fb}^{-1}$. Two observables that exploit the relation between the momenta of the top quarks and the jet in the final state are measured: the energy asymmetry and, for the first time, the incline asymmetry. The analysis incorporates

top quark signatures across different kinematic regimes: at low transverse momentum, where decay products appear as distinct jets and isolated leptons, and at transverse momentum, where they become collimated and overlap. The sensitivity to charge asymmetry effects is enhanced by performing the measurements in a fiducial region defined by the scattering angle of the associated jet, ranging from $0.25\pi$ to $0.6\pi$. The measurements are corrected for detector effects to the particle level using a maximum-likelihood unfolding. The energy asymmetry deviates from zero by more than 3 standard deviations, while the incline asymmetry exhibits a deviation of 1 standard deviation. The measured asymmetries are consistent with standard model predictions calculated at next-to-leading order in quantum chromodynamics, offering new insights into top quark dynamics in jet-associated processes.

**Secondary track**:

**T01 / 740**

## The science of ultra-high energy cosmic rays after 20 years of operation of the Pierre Auger Observatory

**Auteur:** Olivier Deligny[None]

The Pierre Auger Observatory has been on the astroparticle scene for over twenty years now. It's a mature player in this field, yet it retains all its vitality to provide data whose richness sheds light not only on the origin of ultra-high-energy cosmic rays (UHECRs), but also on high-energy hadronic interactions, multi-messenger astrophysics, beyond Standard Model (BSM) physics and atmospheric electricity phenomena. An essential feature of the Observatory is its hybrid design: UHECRs are detected through the observation of the associated extensive air showers with different and complementary techniques. The analyses of the multi-detector data have enabled high-statistics and high-precision studies above ~100 PeV. The energy spectrum is falling down at UHE through a two-step change of spectral index. Mass-composition data are consistent with group elements getting heavier beyond the ankle energy and taking over one after the other so that the all-particle flux gets dominated by one specific group elements as the energy increases. While no discrete source of UHECRs has been identified so far, the extragalactic origin of the particles has been confirmed from the arrival directions above 8 EeV, and the net is closing around nearby astrophysical sites at higher energies. Also, the established upper limits on fluxes of UHE neutrinos and photons have implications not only on multi-messenger studies, but also on various phenomena of BSM physics that could occur at a high scale. The resulting constraints are summarized in this contribution

**Secondary track**:

**T04 / 741**

## Tracing early time dynamics through high energy probes

**Auteur:** Souvik Priyam Adhya[1]

[1] *Institute of Physics of the Czech Academy of Sciences, Prague*

Jets are essential hard probes for investigating the early-time dynamics and structure of the quark-gluon plasma in heavy-ion collisions. We develop an analytical framework for radiative energy loss in evolving media using resummation techniques, capturing both rare and multiple scattering regimes. Our results highlight the sensitivity of jet observables to early-time medium properties, showing that strong quenching requires the medium's equilibration time to exceed its mean free path. Next, we apply our understanding of jet-medium interactions to $\gamma$+jet correlations at forward rapidities, incorporating initial-state gluon saturation via the small-x Improved Transverse Momentum Dependent (ITMD) factorization. We present results for azimuthal correlations and nuclear modification factor with parameters tuned for upcoming forward calorimeter acceptances in experiments, in particular the ALICE FoCal detector. To further understand the signatures of pre-equilibrium phase, we explore with diffractive dijet production in pp and pA collisions at large rapidity gaps, offering a complementary perspective on QCD dynamics in dilute systems.

**Secondary track**:

T05 - QCD and Hadronic Physics

**T15** / **742**

## Quantum Computing for Track Reconstruction at LHCb

**Auteur:** Miriam Lucio Martinez[1]

[1] *IFIC and University of Valencia*

Reconstructing the trajectories of charged particles as they traverse several detector layers is a key ingredient for event reconstruction at LHC and virtually any particle physics experiment. The limited bandwidth available, together with the high rate of tracks per second O(10^10) - where each track consists of a variable number of measurements - makes this problem exceptionally challenging from the computational perspective. With this in mind, Quantum Computing is being explored as a new technology for future detectors, where larger datasets will further complicate this task.

Several quantum algorithms have been explored in this regard - e.g., Variational algorithms and HHL offering a heterogeneous set of advantages and disadvantages. In this talk, an extensive study using the Quantum Approximate Optimization Algorithm (QAOA) for track reconstruction at LHC will be presented. The robustness of QAOA to hardware noise when compared to other algorithms makes it a good candidate for the near-term utility era in Quantum Computing. In this talk, implementations with simplified simulations will be presented, both for QAOA and a modified version of the algorithm that could improve performance in comparison with Quantum annealers as per recent Q-CTRL results. Finally, a complete study of hardware requirements, prospects on improving scalability, and energy consumption for different technologies will also be discussed.

**Secondary track**:

T12 - Data Handling and Computing

**T14** / **743**

## "Warning!": from physics to an interdisciplinary project to reflect on the challenges of modern societies

**Auteur:** Sandra Leone[1]

**Co-auteurs:** Enrico Mazzoni [1]; Franco Cervelli [1]

[1] *INFN Pisa Italy*

The "Warning" project has reached its fifth edition this year. "Warning!" was born in 2020, when Pisa Foundation and the Pisa unit of the Italian Institute for Nuclear Physics (INFN) launched this initiative with the aim of developing interdisciplinary educational paths, on the topics of major planetary dangers and environmental fragility. This project was conceived as a knowledge dissemination initiative, addressing the general public at large, but with a specific focus on high-school students, that represented most of participants. Given the great success in terms of number of participants

and positive response, "Warning!" has been repeated in the following years, proposing different themes for discussion: from the scenarios that will open up in the near future following technological innovations, to the emergence of new ethical questions; from the affirmation of new professions in the job market, to an in-depth analysis of modern theories of complexity; from humanity's relationship with nature, to the ever-present questions on the origin of the Universe and the birth of life. Interdisciplinary approach, importance of cross knowledge and, above all, education on complexity, were the main features of "Warning!". The centrality of the scientific method in facing complex problems was underlined. Instead of focusing on a specific aspect, interdisciplinarity allows to approach different topics from different points of view. Each cycle was composed of four or five debates in which experts from different disciplines addressed the topic under discussion. Physics was the "fil rouge" that accompanied the participants on this journey across many fields of science. The various events took place in Pisa "Palazzo Blu" auditorium, and were streamed online allowing the participation of more than 3000 high school students. "Warning!"represents a useful educational support for students and teachers, who can integrate topics covered in school programs.
https://warning.palazzoblu.it/

**Secondary track**:

**T03 / 744**

## The SuperNEMO Demonstrator: a unique technology for high-precision measurements of ββ-decay modes

**Auteurs:** Miroslav Macko[1]; SuperNEMO Collaboration[None]

[1] *Czech Technical University in Prague*

There are still many open questions in understanding the nature of neutrinos, the most abundant matter particles in the Universe. Experimental neutrino physics is focused on measuring neutrino properties, such as absolute mass scale, the nature of neutrinos (Majorana or Dirac), and the possible violation of symmetries such as charge-parity and lepton-number conservation.

Neutrinoless double-beta decay (0νββ) is a hypothesized lepton-number-violating process whose discovery would have profound consequences for our understanding of neutrinos. Its half-life is directly dependent on the currently unknown neutrino coupling arising from beyond-the-Standard-Model physics involving Majorana neutrinos. The discovery of 0νββ is currently the only known way to prove the neutrino's Majorana nature.

The biggest challenge in searching for any rare process (such as 0νββ) is separation of signal from potential backgrounds. SuperNEMO is searching for 0νββ using a unique tracker-calorimeter detector, which tracks individual particle trajectories and energies, enabling sophisticated particle identification and associated background rejection. This full topological reconstruction allows access to observables that are not accessible to other experiments in the field, such as the angle between the two electrons emitted in ββ decay and individual particle energies, opening the possibility to precisely study nuclear processes hidden to other technologies. SuperNEMO is able to search for 0νββ to excited nuclear states, as well as some of its more exotic modes, such as 0νββ with involvement of Majoron or right-handed weak current.

To further ensure ultra-low backgrounds, the SuperNEMO Demonstrator is placed at LSM (Underground Laboratory in Modane, France), and is protected with gamma and neutron shielding and an anti-radon tent flushed with radon-free air. The SuperNEMO Demonstrator has been collecting data since April 2025, using a 6.1 kg Se-82 ββ source. Its goal is to demonstrate the possibility of a future fully topological detector, with similar sensitivity to next-generation experiments, that is background-free in the 0νββ ROI and can be used to determine the 0νββ mechanism in the event of discovery. In addition, the Demonstrator has a rich physics program of its own, searching for exotic 0νββ decays and precisely studying 2νββ decay mechanisms.

The presentation is dedicated to the introduction of the SuperNEMO technology, its unique features and its physics goals.

**Secondary track**:

T09 - Beyond the Standard Model

**T07** / **745**

## Probing Charm Baryon Dipole Moments: Advancing Physics and Experimental Innovation with ALADDIN at the LHC

**Auteurs:** Fernando Martinez Vidal[1]; Nicola Neri[2]

[1] *IFIC, University of Valencia - CSIC*

[2] *University and INFN Milano*

The ALADDIN experiment at the LHC aims to measure the electromagnetic dipole moments of charm baryons, a powerful probe of physics within and beyond the Standard Model. Utilizing the phenomenon of particle channeling in bent crystals and a novel detector setup, ALADDIN overcomes challenges posed by short-lived particles, enabling precise spin-precession measurements. This initiative not only promises groundbreaking physics insights but also drives the development of advanced detectors and experimental techniques. With a compact design and minimal impact on LHC operations, ALADDIN represents a new frontier in fixed-target experiments and instrumentation. This talk will explore its physics potential, experimental innovations, and broader implications.

**Secondary track**:

T11 - Detectors

**Joint T08+T16** / **746**

## Unbinned machine-learned measurements for the LHC with systematic uncertainties

**Auteur:** Robert Schoefbeck[None]

I present a new method for unbinned cross-section measurements and related inference problems at the LHC.
The new methodology revolves around 'refinable' machine learning of various model parameter dependencies with a particular focus on systematic effects. It shows significant performance gains in concrete applications. I will illuminate the general methodology for two realistic cases: An unbinned EFT measurement of the top quark pair production process at high pairwise mass and an unbinned cross-section measurement of the H->Tautau process. The second example also summarizes our contribution to the FAIR Universe Uncertainty Challenge.

Links:
https://www.codabench.org/competitions/2977
TTbar: https://arxiv.org/abs/2406.19076
Htautau: Submission before May 19th.

**Secondary track**:

**T15** / **747**

## A TES for ALPS II and other dark matter searches

**Auteur:** Jose Alejandro Rubiera Gimeno[1]

**Co-auteurs:** Axel Lindner [2]; Christina Schwemmbauer [2]; Elmeri Rivasto [3]; Friederike Januschek [2]; Gulden Othman [1]; Katharina-Sophie Isleif [1]; Manuel Meyer [3]

[1] *Helmut-Schmidt-Universität (HSU)*

[2] *Deutsches Elektronen-Synchrotron (DESY)*

[3] *University of Southern Denmark (SDU)*

Transition Edge Sensors (TES) are widely employed in the field of quantum sensing due to their exceptional energy resolution and sensitivity to single quanta of energy. When operated in its superconducting transition at mK temperatures, a single photon absorbed by the TES produces a significant change in its resistance, generating a measurable signal. In particular, TESs are an ideal tool for quantum optics, searches for rare events, and measurements of low energy deposits. Therefore, TESs are particularly suitable for experiments searching for light dark matter candidates, such as axions and axion-like particles. A precise understanding and control of the background sources affecting TESs is crucial, as false signals can limit the sensitivity for quantum sensing applications.
At DESY, Hamburg, we are investigating the uses of tungsten TESs, provided by NIST, for fundamental physics applications.
We have developed simulations of the expected background sources, including black body radiation, radioactivity, and cosmic rays, to better understand the observed background rates. The results of the simulations will be discussed, along with their validation with measured background data. Furthermore, we will give an overview of the current status of a direct dark matter search using our TESs, which aims to probe MeV-scale dark matter via dark matter-electron and dark matter-nucleon scattering.
In addition, these background simulation results motivated alternative design proposals to mitigate background contributions, which are currently being implemented. Preliminary results obtained with one of these newly developed modules especially dedicated for direct dark matter searches will be presented. The change in the module setup resulted in a reduction of the background rate by up to one order of magnitude.
Given our TESs sensitivity and low background rates, it is also a strong candidate for an alternative detection scheme for the Any Light Particle Search~II (ALPS~II) experiment at DESY, a light-shining-through-a-wall experiment that aims to explore the existence of axions and axion-like particles.

**Secondary track**:

T11 - Detectors

**T02** / **748**

## Lohengrin —a proposed experiment in the search for dark bremsstrahlung and a portal to the dark sector

**Auteurs:** Klaus Desch[1]; Lohengrin Study Group[None]; Matthias Hamer[2]; Philip Bechtle[1]

[1] *University of Bonn*

[2] *Uni Bonn*

The non-discovery of WIMPs at the LHC and the negative outcome of direct detection experiments have led to a steadily increasing interest in models with light dark matter. Models with a dark matter candidate that has a mass below the Lee-Weinberg bound can predict the right dark matter relic density if a new gauge interaction is introduced in addition to the dark matter candidate. The new gauge boson couples predominantly to the dark matter particle (and possibly other particles), but

also acts as a portal to the dark sector in these models thanks to a feeble coupling $\varepsilon$ to the standard model.
Dark photons $A'$, massive gauge bosons of a new broken $U(1)_D$ interaction are a prominent example for such a new gauge boson. The dark photon can mix kinetically with the standard model photon, enabling the thermal freeze-out of dark matter particles with masses well below the Lee-Weinberg bound.
Dark photons can be produced in a process called dark bremsstrahlung, for example by shooting a beam of electrons onto a thick target. In this contribution we present the proposal for an experiment at the ELSA accelerator in Bonn that will search for the production of dark bremsstrahlung: the Lohengrin experiment.
A beam of 3.2 GeV electrons is directed onto a tungsten target, placed in a strong magnetic field in the center of a tracking detector that is used for triggering and track reconstruction. Signal events are characterized by a low energy electron and a significant amount of missing momentum and energy in the final state. A fast electromagnetic calorimeter is placed behind the tracking volume to efficiently veto events with standard model bremsstrahlung. A hadron veto is used to discard events with electron-nuclear or photon-nuclear interactions producing neutral hadrons. In order to reach the sensitivity to cosmologically relevant regions in the $m_{A'} - \varepsilon$ parameter space, the key properties of the experiment are 1) a high rate of incoming electrons and 2) a highly efficient background rejection at the order of $10^(-12)$.
We will demonstrate the feasibility of the Lohengrin experiment using next-generation tracking detectors and calorimeters, and will show that the proposed experiment has the potential to conclusively probe the dark photon parameter space for dark photon masses between ~1 MeV and ~50 MeV, an interval that is not currently covered by any existing experiments.

**Secondary track**:

**T09** / **749**

# Statistically Learning New Physics from LHC Data

**Auteur:** Sahana Narasimha[1]

**Co-auteurs:** Andre Lessa ; Humberto Alonso Reyes González ; Jamie Yellen ; Mohammad Mahdi AlTakach ; Sabine Kraml [2]; Wolfgang Waltenberger

[1] *HEPHY, OeAW and University of Vienna*

[2] *CNRS - LPSC Grenoble*

**Auteur correspondant** sahana.narasimha@oeaw.ac.at

Despite the large amount of data generated by the Large Hadron Collider (LHC) so far, searches for new physics have not yet provided any clear evidence of beyond the Standard Model (BSM) physics. Most of these experimental searches focus on exclusive channels, looking for excesses in specific final states. However, new physics could manifest as a dispersed signal over many channels. It therefore becomes increasingly relevant to attempt a more global approach to finding out where BSM physics may hide. To this end, we developed a statistical learning algorithm that is capable of identifying potential dispersed signals in the slew of published LHC analyses. The algorithm is tasked with building candidate "proto-models", precursor theories to the Next Standard Model, from small excesses in the data, while at the same time remaining consistent with negative results on new physics.
In this talk, we will present our method along with key algorithmic improvements that incorporate rigorous statistical treatments, thus going beyond the initial concept published previously. We will also discuss results obtained by applying this framework to the latest SModelS database, which aggregates around 110 published experimental analyses.

**Secondary track**:

**T01** / **750**

## Crossover phase transition in hybrid compact stars

**Auteur:** ANDREA LAVAGNO[1]

[1] *Politecnico di Torino*

Lattice simulation of QCD at small net baryon densities and high temperature have revealed that the transition to hadronic phase to the deconfined quark-gluon plasma is a crossover. Recently, the structure of neutron stars have been studied with a crossover equation of state by means of a switching function to model a smooth transition from a pure neutron matter to massless quarks. The switch function parameter was constrained in order to reproduce neutron stars up to about two solar masses, with the constraint that the adiabatic sound velocity cannot exceed the speed of light. Afterwards, such a study has been extended by considering the relevance of color superconducting quarks in the cold dense matter. In this contribution, we investigate the crossover phase transition into an hybrid compact stars by means of an equation of state which incorporates hadronic matter, composed by nucleons, hyperons and $\Delta$-isobars degrees of freedom, and a quark phase with massive strange quarks in $\beta$-stable equilibrium. In this framework, we analyze the role of the strangeness content related to the bulk properties of the compact stars.

**Secondary track**:

**T11** / **752**

## A performance study of ultrathin sensor planes for a highly compact and granular electromagnetic calorimeter of the LUXE experiment.

**Auteur:** Wolfgang Lohmann[1]

[1] *DESY*

The LUXE experiment will study laser electron scattering at the European XFEL at DESY to explore an uncharted domain in Quantum Electrodynamics. To measure the number and the energy spectrum of electrons and positrons, produced in the multi-photon Breit-Wheeler process over a wide range of multiplicity, two electromagnetic calorimeters are foreseen. In Monte Carlo simulations it was demonstrated that the necessary performance can be matched by highly compact and finely segmented calorimeters.
A design is presented for a sampling calorimeter. Tungsten plates are used as absorber material, with a Moliere radius of about 9.3mm. They are interspersed with active pad sensors to form a sandwich. To keep the Moliere radius near the one of tungsten, the gap between tungsten plates must be kept small. Hence, thin sensor-planes are needed.
Here two technologies of ultra-thin sensor planes are investigated based on silicon (Si) and gallium arsenide (GaAs) pad sensors. In both, thin metal traces guide the signal on a pad to the sensor edge where the front-end ASICs are positioned. For the GaAs sensors, these traces are made of aluminium, embedded in the gaps between the pads, and for the Si case, Kapton fan-outs with copper traces are glued to the sensor. In addition, a dedicated front-end ASIC in 130 nm CMOS technology is developed for the read out.
A full system test of two considered pad-structured sensors for the LUXE ECAL is reported. The sensors are positioned in a 5 GeV electron beam at DESY. A pixel telescope is used to measure the trajectory of each triggered electron. The signal on each pad is amplified and digitised. Data preprocessing is done using FPGAs. Results are presented on the signal-to-noise ratio, the homogeneity of the response of different pads, edge effects, cross talk and signals due to the readout traces on the GaAs substrate.

**Secondary track**:

**T07 / 753**

## Lattice calculation of the hadronic light-by-light contribution to the anomalous magnetic moment of the muon and of its light meson components

**Auteur:** Antoine Gérardin[1]

[1] *CPT Marseille*

In this talk, we present a recent lattice calculation of the hadronic light-by-light scattering contribution to the anomalous magnetic moment of the muon, by the Budapest-Marseille-Wuppertal collaboration. Together with the hadronic vacuum polarization, this is the dominant source of uncertainty in the Standard Model prediction. We will compare our result with previous lattice calculations and with the data-driven dispersive determination before discussing the impact of our calculation in view of the forthcoming final result of the Fermilab experiment.

**Secondary track**:

**Poster T03 / 754**

## Reconstruction of Complex Particle Trajectories in the SuperNEMO Detector

**Auteur:** Tomas KRIZAK[None]

**Co-auteur:** SuperNEMO Collaboration

The SuperNEMO experiment is designed to search for neutrinoless double beta decay, a rare process whose discovery would confirm the Majorana nature of neutrinos and provide insight into their absolute mass scale. Unlike most detectors focused only on calorimetry, SuperNEMO uniquely combines energy measurement with a tracking system composed of 2034 Geiger-mode drift cells, enabling detailed topological reconstruction of charged particle trajectories. This dual approach enhances background rejection and allows for the study of decay kinematics, such as angular distributions and single-electron energy spectra.
This work presents a novel algorithm for particle track reconstruction tailored to SuperNEMO's tracking detector. Building on a previously developed method based on the Legendre transform, we introduce an improved reconstruction approach based on a maximum likelihood method that incorporates a tunable model of the detector's response to identify the most probable particle trajectories. This method evaluates how well candidate tracks explain the observed data, allowing for precise 3D reconstruction even with limited information.
What sets this approach apart is the unique nature of the tracking data in SuperNEMO's low-activity environment, where events typically contain only one or two tracks. Each Geiger cell provides a ring-shaped constraint on the particle's position, rather than a precise point, making trajectory reconstruction a non-trivial task. With only a few such measurements per track, the algorithm must combine this limited information as effectively as possible to accurately recover the full 3D path. To handle complex trajectories affected by scattering, the algorithm employs a polyline trajectory model, reconstructing paths as sequences of linear segments. These are identified using recursive clustering, ordered and refined through geometrical criteria, and assembled into complete trajectories. The result is a robust and accurate reconstruction method, capable of resolving both simple and complex topologies. These improvements represent a step toward achieving the experiment's ultra-low background goals and will contribute to the sensitivity of the upcoming physics run.

**Secondary track**:

T09 - Beyond the Standard Model

**T11** / **755**

## CMS track reconstruction performance during Run 3

**Auteur:** CMS Collaboration[None]

The precise reconstruction of charged particle tracks is crucial for the overall performance of the CMS experiment. In this contribution, performance measurements of the track reconstruction both in simulation and data will be presented, from the collisions occurred during the last periods of the Run 3 of data taking at the LHC. A particular focus will be given to the role and performance of the Silicon Pixel detector for the track reconstruction.

**Secondary track**:

**T07** / **757**

## Rare radiative-and-leptonic $B_s$-meson decay within and beyond the Standard Model

**Auteur:** LUDOVICO VITTORIO[1]

[1] *Sapienza Università di Roma and INFN, Sezione di Roma*

**Auteur correspondant** ludovico.vittorio@uniroma1.it

Rare radiative-and-leptonic $B_s$-meson decay is a golden channel to scrutinize hypothetical New Physics (NP) effects in $b \to s$ quark transitions. Contrarily to the purely leptonic counterpart, i.e. $B_s \to \mu^+\mu^-$, it is sensitive to a larger set of Wilson coefficients and it is not helicity suppressed. The LHCb Collaboration has set a first limit on the Branching Ratio (BR) of radiative-and-leptonic $B_s$-meson decay in the region of high squared momentum transfer $q^2$, namely $\mathcal{B}(B_s^0 \to \mu^+\mu^-\gamma)[q^2 > (4.9\,\mathrm{GeV})^2] < 2.0 \cdot 10^{-9}$, and has also recently studied this channel at low-$q^2$ by directly reconstructing the produced photon.
In this talk, I will discuss about the main features of a novel phenomenological approach to the description of hadronic form factors in this channel at high-$q^2$, connecting its results with recent computations from lattice QCD. The corresponding theoretical predictions of the BR will be compared with available experimental limits, also presenting a brief overview of the different experimental techniques currently employed to study $B_s^0 \to \mu^+\mu^-\gamma$ decay. A dedicated sensitivity study of radiative-and-leptonic $B_s$-meson channel at high-$q^2$ will be also presented, highlighting the interplay that such an analysis can have with phenomenological studies of semileptonic $B \to K^{(*)}$ and $B_s \to \phi$ transitions.

**Secondary track**:

**T13** / **758**

## The e+BOOST Project

**Auteur:** Nicola Canale[1]

**Co-auteurs:** Alberto Orso Maria Iorio [2]; Alessia Selmi [3]; Alexey Sytov ; Andrea Mazzolari [4]; Daniele Boccanfuso [5]; Davide De Salvador [6]; Davide Valzani [6]; Erik Vallazza [7]; Fahad ALHARTHI [8]; Francesco Cescato [9]; Francesco Sgarbossa [6]; Gianfranco Paternò [10]; Giorgio Zuccalà [3]; Giosuè Saibene [3]; Giulia Lezzani ; Iryna Chaikovska [11]; Laura Bandiera [10]; Leonardo Perna [12]; Lorenzo Malagutti [10]; Marco Romagnoni [4]; Mattia soldani ; Michela Prest [3]; Pierluigi Fedeli [13]; Pietro Monti-Guarnieri [14]; ROBERT CHEHAB [15]; Riccardo Negrello [4]; Simone Perna [5]; Sofia Mangiacavalli ; Stefano Carsi ; Susanna Bertelli [16]; Victor Tikhomirov ; Viktar Haurylavets ; Vincenzo Guidi [4]

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[5] *Universita' di Napoli Federico II*

[6] *Unipd*

[7] *INFN MiB*

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[9] *Università degli studi di Ferrara, INFN Ferrara*

[10] *INFN Ferrara*

[11] *IJCLab*

[12] *Gran Sasso Science Institute, INFN*

[13] *Istituto Nazionale di Fisica Nucleare & University of Ferrara*

[14] *UniTS*

[15] *IPNL/IN2P3*

[16] *INFN Frascati National Laboratory*

**Auteur correspondant** nicola.canale@fe.infn.it

The **e$^+$BOOST** (intense positron source Based On Oriented crySTals) project aims to demonstrate the effectiveness of a novel fixed-target positron source scheme enhanced by coherent phenomena in crystals. Future lepton colliders such as **FCC-ee, CLIC, and CepC** require unprecedented positron beam intensities to achieve their respective luminosity goals.

Conventional positron production schemes, based on a high-energy electron beam impinging on a solid target, are limited by the **peak energy density deposition (PEDD)** threshold, beyond which the target structure is compromised. A promising alternative is to exploit the intense coherent radiation emitted in oriented crystals, enabling a higher rate of $e^+e^-$ pair production compared to non-oriented targets, while significantly reducing the PEDD in the converter.

The proposed crystal-based positron source adopts a hybrid target configuration, consisting of a thin oriented crystal radiator followed downstream by a thicker amorphous converter, which transforms the generated photons into $e^+e^-$ pairs. This scheme, initially proposed in 1, has been successfully validated at CERN and KEK 2, and is currently under investigation within the FCC-ee injector design framework [3].

**Recent experimental results** have shown a clear enhancement in radiation yield when the crystal radiator is properly aligned with the incoming beam, as reported in [4] and [5], providing strong validation of the concept. These findings have also confirmed the reliability of the simulation framework [6], which is now being used to guide the **optimization of a crystalline positron source for FCC-ee**, as detailed in [7].

In this contribution, I will present the latest results of the e$^+$BOOST project, including both experimental outcomes and simulation studies supporting the development of future high-intensity positron sources.

1 R. Chehab *et al.*, DOI :10.5170/CERN-1989-005.105
2 R. Chehab *et al.*, DOI :10.1016/S0370-2693(01)01395-8
[3] I. Chaikovska *et al.*, DOI: 10.18429/JACoW-IPAC2019-MOPMP003
[4] N.Canale *et al.*, DOI : 10.1016/j.nima.2025.170342
[5] L.Bandiera *et al.*, DOI : 10.1140/epjc/s10052-022-10666-6
[6] A. Sytov *et al.*, DOI: 10.1007/s40042-023-00834-6
[7] F. Alharthi *et al.*, DOI : 10.1016/j.nima.2025.170412

**Secondary track**:

**T11 / 759**

# A new large-area Micromegas detector and its readout electronics for AMBER experiment at CERN

**Auteurs:** Antonio Amoroso[1]; Chiara Alice[1]; Daniele Panzieri[2]; Davide Giordano[1]; Maxim Alexeev[1]; Michela Chiosso[1]; Oleg Denisov[3]; Rui De Oliveira[4]

[1] *INFN e Univ. Torino*

[2] *INFN Torino e Univ. Piem. Orientale*

[3] *INFN Torino*

[4] *CERN*

The Apparatus for Mesons and Baryon Experimental Research (AMBER, NA66) is a high-energy physics experiment at CERN's M2 beam line, with a broad physics program extending beyond 2032. It includes studies on: antiproton production cross-sections on protons, helium and deuterium; the charge radius of the proton, and Kaon and Pion PDFs via the Drell-Yan process.
As part of medium- and long-term upgrades, aging Multi-Wire Proportional Chambers (MWPCs) will be replaced with Micro-Pattern Gaseous Detectors (MPGD). The replacement technology is the resistive bulk MICRO-MEsh-Gaseous Structure (Micromegas or MM) detector. The MM detector composed of three independent modules will cover an acceptance similar to the present MWPC. The large area of the present MWPC will be covered by three independent micromegas detector modules. Each module has an active area of 1x0.5 m², and together the three modules adjacent modules will cover 1x1.5 m² in total. Each detector has includes two readout planes in a face-to-face configuration enabling XUV coordinate measurements, the cathode cathodes are implemented on a thinner central PCB. For lateral modules A uniform 10 MΩ/sq Diamond-Like Carbon (DLC) resistive layer is applied on top of the readout strips for lateral modules.
The mechanical structure and readout planes have been designed, and the first detector was produced in October 2024. First tests comprising in-beam operation beam tests are currently ongoing both at CERN and in Torino. In parallel, a 64-channel mixed-signal front-end ASIC, named ToRA (Torino Readout for AMBER), is being developed at INFN Torino. It is optimized for time and energy measurements leveraging results from simulations and from earlier tests with Micromegas prototypes and TIGER-based electronics. Current efforts focus on characterizing detector performance, noise behavior, and integration with the ToRA ASIC. Both the detector and readout system developments will be presented.

**Secondary track**:

**T07** / **760**

# High-precision calculation of the hadronic vacuum polarization contribution to the muon anomaly

**Auteurs:** Alessandro LUPO[1]; BMW Collaboration[None]; DMZ Collaboration[None]

[1] *CPT, Aix-Marseille Université*

**Auteur correspondant** alessandro.lupo@cpt.univ-mrs.fr

Recent measurements of the anomalous magnetic moment of the muon have challenged the Standard Model, producing significant tensions between theory and experiment. Accurate theoretical predictions are difficult due to the strongly interacting nature of QCD, which is the primary source of uncertainty in the Standard Model prediction for the muon g-2. In this talk, we present a lattice QCD calculation, by the BMW-DMZ collaboration, of the leading hadronic contribution to the Standard Model prediction, achieving an unprecedented, relative precision of 0.5%.

**Secondary track**:

T05 - QCD and Hadronic Physics

**T05 / 761**

## Event shape variables in pp collisions in CMS

**Auteur:** CMS Collaboration[None]

We present recent measurements of event shape variables in proton-proton (pp) collisions with the CMS detector. Event shape variables provide insight into the final-state particle distributions, offering a detailed probe of the perturbative and non-perturbative QCD regimes.

**Secondary track**:

**T05 / 762**

## New results on jet measurements in CMS

**Auteur:** CMS Collaboration[None]

Measurements of jet properties (such as the substructure or mass) in proton-proton collisions at the LHC are essential for precise tests of both perturbative and non-perturbative QCD, improving the understanding of proton structure and the strong interaction. In this presentation, we will present the latest measurements with jets performed using data collected by the CMS experiment.

**Secondary track**:

**T06 / 763**

## Electroweak Production of Vector Bosons and Jets at CMS

**Auteur:** CMS Collaboration[None]

The study of the associated production of vector bosons and jets provides an excellent opportunity to explore the electroweak (EW) aspects of their production. Recent results from the CMS Collaboration on the differential cross sections of vector bosons produced in association with jets at 13 TeV center-of-mass energy will be presented. Differential distributions as a function of various kinematical observables are measured and compared with theoretical predictions up to NNLO. Final states with a vector boson and jets are also useful for studying EW-initiated processes, such as the vector boson fusion production of a photon, Z, or W boson, accompanied by a pair of energetic jets with large invariant mass. These processes serve as sensitive probes for new physics, searching for deviations from the Standard Model that can be parametrized in a dim-6 EFT framework.

**Secondary track**:

**T15 / 764**

## Local basis truncation for Quantum Field Theories

**Auteur:** Peter Majcen[1]

**Co-auteurs:** Giovanni Cataldi [1]; Giuseppe Magnifico [2]; Pietro Silvi [1]; Simone Montangero [1]

[1] *University of Padua/INFN Padua*

[2] *University of Bari/INFN Bari*

**Auteur correspondant** peterroland.majcen@unipd.it

While perturbative methods have led to significant insights into fundamental interactions,non-perturbative phenomena remain poorly understood—particularly in regimes where Monte Carlo (MC) techniques suffer from the sign problem, such as in dense nuclear matter and real-time dynamics in Quantum Chromodynamics (QCD). Tensor Network (TN) methods, which are not affected by the sign problem,therefore offer a suitable extension to existing techniques.
To apply TN techniques to gauge theories, we use the Hamiltonian Lattice Gauge Theory (HLGT) framework, with the dressed-site formalism to enforce Gauss's law, allowing for an efficient and gauge-invariant representation of the local Hilbert space. Building on this, we present a general-purpose library for constructing HLGTs with non-simple finite and compact Lie groups in any dimension, supporting flexible choices of background charge.

Even with this efficient encoding, the local Hilbert space can still be large. To address this, we propose an effective description of the target theory. Using cluster mean-field techniques, we estimate the reduced density matrix and project the theory onto the relevant subspace. We demonstrate this approach in purely bosonic quantum field theories, such as the sine-Gordon model in (1+1)D and the $\varphi^4$ model in (1+1)D and (1+2)D, where it is particularly effective in symmetry-broken phases and allows for accurate determination of critical exponents.
This development improves the scalability of TN simulations in higher dimensions of theories with bosonic degrees of freedom and can also be applied to quantum computation and quantum simulation.

**Secondary track**:

**T11** / **766**

## The LHCb RICH Upgrade II: the challenge of particle identification at High-Lumi LHC

**Auteurs:** LHCb RICH Collaboration[None]; Silvia Gambetta[1]

[1] *University of Edinburgh*

The High-Luminosity LHC (HL-LHC) will present unprecedented opportunities for precision flavour physics, along with new challenges for detector performance in extreme conditions. As part of the LHCb Upgrade II program, the Ring Imaging Cherenkov (RICH) detectors are undergoing a comprehensive redesign to meet the demands of increased luminosity, higher track multiplicities, and tighter timing constraints with occupancies approaching those of general-purpose detectors in the forward region.
This contribution outlines the conceptual design and ongoing R&D efforts for the RICH Upgrade II system. The upgraded detectors will feature ultra-fast photon sensors with improved spatial granularity and picosecond-level time resolution, enhanced optics to mitigate occupancy effects, and fully integrated front-end electronics capable of precision time stamping, enabling 4D particle identification reconstruction to disentangle high-density event topologies.
We will present the current status of sensor and optics development, simulation studies guiding design choices, and initial results from testbeam campaigns, demonstrating how these unprecedented technological advances are essential to realizing LHCb's physics ambitions in the HL-LHC era.

**Secondary track**:

**T15** / **767**

# Group Invariance in Quantum Fidelity Kernels for Vector Boson Scattering Identification at the LHC

**Auteurs:** Michele Grossi[1]; Santeri Laurila[1]; Väinö Mehtola[2]

[1] *CERN*

[2] *VTT Technical Research Centre of Finland, Helsinki Institute of Physics, CERN Quantum Technology Initiative*

In the high-luminosity era of particle physics, advanced computing methods are vital for tackling the unprecedented scale and complexity of data, inspiring us to explore innovative quantum approaches for data analysis. We investigate the impact of incorporating problem-specific permutation invariance into hardware-efficient quantum fidelity kernels for high energy physics data analysis in terms of classification performance and model scalability, and to demonstrate this approach, we tackle the problem of identifying rare vector boson scattering (VBS) events from the abundant QCD multijet background by exploiting the pairwise permutation invariance of the final-state jets in the kernel design. We introduce a novel quantum kernel model, Bivariate Permutation-Invariant Fidelity Quantum Kernel (BPINVFQK), alongside partially and fully symmetrized variants of the standard hardware-efficient ansatz, which embed the $S_n$ group invariance to reflect the underlying symmetries of the VBS process. The models are trained and evaluated using simulated samples from the CMS experiment at the CERN LHC. Under ideal, noise-free conditions, these symmetrized models yield statistically significant improvements in classification performance—demonstrated by higher mean AUC values and improved centered kernel alignment compared to both the baseline HEA model and classical RBF kernel. However, under realistic shot noise conditions (10,000 shots), the performance benefits significantly diminish, highlighting challenges for a NISQ-era implementation. This motivates investigation into testing the models with higher shot counts to recover and further enhance the observed performance under shot noise. Additionally, our hyperparameter analysis reveals a critical dependency on the kernel bandwidth $\gamma$: smaller $\gamma$ values promote anti-concentration up to a threshold, after which all models begin to concentrate, while BPINVFQK exhibits hints of sub-exponential scaling at higher bandwidths, indicating a promising scaling capability. Finally, experimental results gathered from VTT's Q50 quantum computer corroborate our simulation findings, underlining the practical challenges and opportunities in deploying symmetry-enhanced quantum kernels on contemporary quantum hardware.

**Secondary track**:

**T12 / 768**

# Improved Probabilistic Event Weighting via Covariance-Corrected Q-Factors for Signal Isolation

**Auteur:** Zachary Baldwin[1]

**Co-auteur:** Nathaniel Dene Hoffman [1]

[1] *Carnegie Mellon University*

**Auteur correspondant** zbaldwin@andrew.cmu.edu

In complex particle physics analyses where signal and background events are intertwined across multidimensional phase space, statistically consistent event-by-event weighting is indispensable for unbiased extraction of signal observables. However, many widely used methods can often fail to correctly estimate this separation, particularly in the presence of statistically independent variables or when key model assumptions fail.

We assess the limitations of these standard techniques with particular focus on Q-factors – an adaptive local fitting method based on k-nearest neighbors. Although Q-factors offer enhanced flexibility over global fits, it inherently assumes statistical dependence between discriminating and weighted variables, leading to a bias when this condition is violated. To address this, we introduce a corrected formalism, ${}_sQ$-factors (pronounced */skju:/*, as in "*skew*"), which integrates the local adaptivity of Q-factors with the covariance-based corrections from ${}_s\mathcal{P}$lot. This hybrid approach restores statistical

consistency across dimensions while still preserving local sensitivity, enabling unbiased signal extraction in complex, multidimensional analyses. Through Monte Carlo simulations, we demonstrate that $_sQ$-factors consistently outperform traditional methods in both signal recovery and physics parameter estimation. These studies highlight the robustness and accuracy of the method in high-dimensional analyses.

**Secondary track**:

**T11** / **770**

## Enhancing Particle Reconstruction and Identification with the MIP Timing Detector at CMS

**Auteurs:** CMS Collaboration[None]; Tiziano Pauletto[1]

[1] *Sapienza Università e INFN, Roma I*

The MIP Timing Detector (MTD) is a major component of the CMS Phase-II upgrade for the High-Luminosity LHC (HL-LHC), featuring a time resolution of O(30) ps. It comprises the Barrel Timing Layer and the Endcap Timing Layer, covering complementary regions in pseudorapidity and enabling precision timing measurements across the detector.

The MTD will significantly enhance event reconstruction during HL-LHC operations by providing powerful tools to mitigate pileup and improve particle identification (PID). By incorporating precise time-of-flight (TOF) information, the MTD enables four-dimensional vertexing and mass hypothesis testing for charged particles.

This contribution presents a detailed study of TOF-based reconstruction techniques using the MTD, including an assessment of the associated uncertainties and their impact on vertex association and PID performance. These developments will help to enhance the detector's sensitivity to both Standard Model processes and searches for new physics in the challenging HL-LHC environment.

**Secondary track**:

T12 - Data Handling and Computing

**T03** / **771**

## The T2K ND280 Detector Upgrade

**Auteur:** Anna Holin[1]

[1] *STFC RAL*

T2K is a long-baseline experiment measuring neutrino and antineutrino oscillations by observing the disappearance of muon neutrinos, as well as the appearance of electron neutrinos, over a long 295km distance. The ND280 near detector at J-PARC plays a crucial role to minimise the systematic uncertainties related to the neutrino flux and neutrino-nucleus cross-sections as it measures the neutrino beam at a ND site before it oscillates.
The ND280 detector has recently been upgraded with a new suite of sub-detectors: a high granularity SuperFGD with 2 million optically-isolated scintillating cubes read out by wavelength shifting fibres and 55000 Multi-Pixel Photon Counters; two horizontal Time-Projection Chambers instrumented with resistive Micromegas, and additionally six panels of scintillating bars for precise time-of-flight measurements.

New data using the new ND280 detector configuration, and its performance will be discussed and the improvements will be highlighted.

**Secondary track**:

T11 - Detectors

**T15** / **772**

## Scalable Readout Architecture for Large-Scale Quantum Sensor Arrays in Fundamental Physics

**Auteur:** Luis E. Ardila-Perez[1]

**Co-auteurs:** Daniel A. Crovo Pérez [1]; Frank Simon [1]; Juan M. Salum [2]; Luciano P. Ferreyro [2]; Lukas Scheller [1]; Manuel E. Garcia Redondo [2]; Manuel Platino [3]; Marvin Fuchs [1]; Oliver Sander [1]; Robert Gartmann [1]; Timo Muscheid [1]

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**Auteur correspondant** luis.ardila@kit.edu

Modern experiments in particle, astroparticle physics, and cosmology, particularly those probing for New Physics, are increasingly relying on quantum sensors to achieve unprecedented sensitivities. These include efforts to determine the absolute neutrino mass scale, search for neutrinoless double beta decay, detect potential dark matter candidates, or measure the B-mode polarization of the cosmic microwave background (CMB) to test the inflationary model of the early universe. Achieving these goals requires the development and simultaneous readout of large-scale arrays of cryogenic detectors, often ranging in the tens or hundreds of thousands. Frequency-Division Multiplexing readout techniques, such as microwave SQUID multiplexing, are critical enablers of these ambitious programs.

To support this, we are developing the Quantum Interface Controller (QIC), a modular and scalable readout system shared across several experiments in these domains. This technology is also used in quantum computing since superconducting qubit characterization and control require similar high-fidelity microwave-based instrumentation. This system supports full-stack end-to-end signal processing. The room-temperature electronics perform digital synthesis of the required microwave tones and implement real-time demodulation of the detector signals using FPGA-based firmware and a user-friendly software stack to process the results.

We present the architecture of this multi-purpose readout system, discuss the modular implementation of the signal processing firmware, and describe the supporting software tools developed for control and data handling. One part of the system is the CryoDE (Cryogenic Detector Emulator), a digital detector twin integrated directly into the firmware, which enables hardware-in-the-loop (HIL) testing of the entire signal processing chain. This feature allows for rapid iteration and validation of firmware and system performance without requiring access to the full cryogenic infrastructure. This common readout infrastructure is adaptable to the needs of each experiment; currently, it is being deployed in support of the ECHo (neutrino mass), BULLKID-DM (dark matter), and QUBIC-upgrade (CMB) experiments, improving development efficiency and long-term maintainability. This contribution provides an overview of the current status of the data acquisition systems within these efforts and will show selected results of recent tests with prototype detector systems.

**Secondary track**:

T12 - Data Handling and Computing

**T09** / **773**

## Probing Flavorful EFTs at the LHC

**Auteur:** Matheus Martines de Azevedo da Silva[1]

[1] *University of São Paulo/Laboratoire De Physique Des 2 Infinite Irène Joliot-Curie*

Under the assumption that new physics lies beyond the current energy reach of the LHC, deviations from Standard Model predictions are expected to appear in the high-energy tails of kinematic distributions that can be experimentally accessed. The Standard Model Effective Field Theory (SMEFT) provides a model-independent framework to systematically capture such deviations. In this talk, I will present an analysis based on a subset of dimension-six operators, without imposing flavor assumptions, using data from Drell-Yan, diboson production, and Higgs production processes. Additionally, I will show an explicit comparison with ultraviolet models capable of generating the relevant operators, providing insight into the range of validity of the EFT description at the LHC.

**Secondary track**:

T09 - Beyond the Standard Model

**T02** / **774**

## Improving constraints on asymmetric dark matter from neutron stars

**Auteur:** Drona Vatsyayan[1]

[1] *IFIC (UV-CSIC)*

Fermionic asymmetric dark matter (ADM) can be captured in neutron stars (NS) via scatterings with the neutron star material. The absence of DM annihilations due to their asymmetric nature would thus lead to their accumulation in the NS core, which can exceed the Chandrasekhar limit to collapse into a black hole (BH), and provide exclusion limits from observations of neutron stars today. We compute the most up-to-date constraints on the ADM scattering rate and mass for a class of fermion DM models using improved capture, thermalization, BH accretion and evaporation rates, discussing the caveats and issues with approximations and assumptions used in the literature to derive these bounds. Our results show that some of the bounds can be significantly relaxed.

**Secondary track**:

T01 - Astroparticles, Gravitation and Cosmology

**T13** / **775**

## PoPLaR; the LhARAproof of principle experiment

**Auteur:** Kenneth Long[1]

[1] *Imperial College London*

The "Laser-hybrid Accelerator for Radiobiological Applications", LhARA, is conceived as a novel, uniquely-flexible facility dedicated to the study of the biological impact of proton and ion beams. The collaboration is implementing a proof-of-principal beam-line, "PoPLaR", on the SCAPA facility at Strathclyde University. It is planned that the beam line will be commissioned over the summer and autumn of 2025. The beam-line will be used to serve the LhARA collaboration's systematic comparison of in-vitro radiobiology using laser-driven and conventional beams. The status of PoPLaR beam line will be described and its role as a test bed for LhARA will be outlined.

**Secondary track**:

**T03** / **776**

## Results from the T2K Experiment

**Auteur:** Anna Holin[1]

[1] *STFC RAL*

T2K is a neutrino experiment that measures neutrino and antineutrino oscillations using a long baseline of 295km, from the neutrino beam source at JPARC in Japan, to the Super-Kamiokande detector in Kamioka. The ND280 near detector at JPARC measures the properties of the neutrino beam prior to oscillations, while SuperK measures the beam after oscillations.
In this talk, the most recent results of neutrino oscillations will be presented, featuring world-leading sensitivities on the search of Charge-Parity violation, by comparing oscillation measurements of neutrinos and antineutrinos. Measurements of the atmospheric oscillation parameters also extracted by observing the disappearance of muon neutrinos and the appearance of electron neutrinos. Combinations with other experiments such as SuperK and NOvA are also presented.

**Secondary track**:

**T03** / **777**

## Progress on the development of the science case and simulation of nuSTORM

**Auteur:** Kenneth Long[1]

[1] *Imperial College London*

The Neutrinos from Stored Muons, nuSTORM, facility has been designed to provide intense neutrino beams with well-defined flavour composition and energy spectra. By using neutrinos from the decay of muons confined within a storage ring, a beam composed of equal fluxes of electron- and muon-neutrinos can be created for which the energy spectrum can be calculated precisely. The case for the nuSTORM facility rests on three themes: precision neutrino scattering studies; searches for new physics; and its role as a test bed for the development of high energy muon beams of high brightness. The status of the development of the physics case for nuSTORM will be described along with a summary of progress on the design and simulation of the facility.

**Secondary track**:

T13 - Accelerators for HEP

**T11 / 778**

## Status and Perspectives for FCC-ee Detector Background Studies

**Auteur:** Markus Klute[1]

[1] *KIT*

The electron-positron Future Circular Collider (FCC-ee) is a proposed high-energy lepton collider that aims to reach unprecedented precision in the measurements of fundamental particles. The high beam currents, with a top-up continous injection, and the high interaction
frequency produce machine induced backgrounds in the detector, especially at the Z peak energy. This contribution presents a study of the beam-induced backgrounds at FCC-ee.
Two main categories of backgrounds are considered reaching the detector: the single-beam related, such as synchrotron radiation and beam gas, in which photons or electrons survive the collimation and absorber system, and the luminosity backgrounds, originating
at the collision point, like the incoherent pair creation or the radiative Bhabha, with high cross-sections. In addition, to allow for high beam intensity the beam is continuously injected, potentially leading to induce backgrounds in the detector, thus giving feedback on the best injection schemes. The beam induced backgrounds are simulated with GuineaPig++, BDSIM and X-Suite and are interfaced to the turnkey software Key4HEP to estimate the occupancy levels in the detector.

**Secondary track**:

**T11 / 779**

## The CGEM-IT of the BESIII detector

**Auteur:** Michela Greco[1]

[1] *INFN and University of Torino*

BESIII is a spectrometer hosted at the leptonic collider BEPCII, at the Institute of High Energy Physics, in Beijing since 2009. Its program covers charmonium(-like), charmed and light hadrons spectroscopy, new physics and QCD studies.
Its physics program has been recently extended up to 2030. In 2024, both the accelerator and the spectrometer are undergoing an upgrade program. The inner drift chamber, which was showing aging effects, has been replaced with a new inner tracker based on the cylindrical GEM technology. The CGEM-IT will deploy three coaxial layers of cylindrical triple-GEM detectors. A dedicated electronic readout chain, based on the TIGER ASIC, and the FPGA-based GEMROC readout cards, has been thoroughly developed and tested with the final detectors.
Studies with cosmic ray data taken during a standalone commissioning show a spatial resolution better than 200 um with orthogonal tracks and tracking efficiency of 95% in each layer. The system was installed starting from October 2024.
This presentation will show the project details, the results from the standalone commissioning with cosmic rays, and the most interesting parts of the installation.

**Secondary track**:

**T07 / 780**

## Rare $B_c \to D_s \ell^+ \ell^-$ decay within the $U_1$ leptoquark model

**Auteur:** Tarun Kumar[1]

**Co-auteur:** Barilang Mawlong [1]

[1] *University of Hyderabad*

**Auteur correspondant** barilang@uohyd.ac.in

We examine the rare $B_c \to D_s \ell^+ \ell^-$ decay channel mediated by the flavor changing neutral current $b \to s\ell^+\ell^-$ transition within the $U_1$ leptoquark framework. The leptoquark couplings are taken to be complex, thus allowing for possible new CP violation sources. With a large new weak phase, a sizeable CP asymmetry may be possible. The new physics couplings are constrained using the latest experimental results in the $b \to s\ell\ell$ sector. We work with a few new physics scenarios involving the contributing Wilson coefficients $C_9^{(\prime)}(\mathrm{NP})$, $C_{10}^{(\prime)}(\mathrm{NP})$ and make predictions of the CP asymmetry for the $B_c \to D_s \mu^+ \mu^-$ mode. We also assess the impact of the complex couplings on the branching fraction and the lepton flavor universal ratio within these new scenarios.

**Secondary track**:

**T13** / **781**

## Positron Source at Future Linear Collider Designs (ILC, HALHF, CLIC)

**Auteur:** Gudrid Moortgat-Pick[1]

**Co-auteurs:** Carmen Tenholt [2]; Dieter Lott [3]; Gregor Loisch [2]; Grigory Yakopov [2]; Malte Trautwein [4]; Manuel Formela [5]; Niclas Hamann [5]; Peter Sievers [6]; Sabine Riemann [2]; Tim Lengler [3]

[1] *DESY and University of Hamburg*

[2] *DESY*

[3] *Hereon*

[4] *UHH*

[5] *DESY / UHH*

[6] *CERN*

Positron Sources for high luminosity high-energy colliders with at least a cms of 500 GeV are a challenge for all future lepton colliders as, for instance, the International Linear Collider (ILC), the Compact Linear Collider (CLIC) as well as new concepts as the HALHF collider design. In the talk new R&D developments for the undulator-based positron source are discussed. The talk includes physics requirements, target material tests, current prototypes for optic matching devices as pulsed solenoids as well as plasma lenses. The applicability of an undulator-based positron source in order to provide polarized positrons for all three collider designs is discussed.

**Secondary track**:

**T06** / **782**

## PHOKHARA at the frontier of NNLO

**Auteurs:** Pau Petit Rosàs[1]; Thomas Dave[1]; William J. Torres Bobadilla[1]

[1] *University of Liverpool*

Electron–positron annihilation into hadrons accompanied by an energetic photon provides a powerful tool to measure the hadronic cross-section across a broad energy range at high-luminosity flavour factories such as DAPHNE, CESR, PEP-II, KEK-B, SuperKEKB, and BESIII. The Monte Carlo event generator PHOKHARA has been widely used and simulates this process with next-to-leading order (NLO) accuracy, incorporating both virtual and soft photon corrections for single-photon emission, as well as events with two hard real photons.
In this talk, we present recent progress in extending PHOKHARA towards next-to-next-to-leading order (NNLO) precision. The discussion is divided into two parts: (i) we revisit the radiative return process $e^+e^- \to \pi^+\pi^-\gamma$, refining the hadronic current by incorporating the Generalised Vector Dominance Model (GVDM) as an improvement over the standard scalar QED (sQED) approximation; and (ii) we outline the preliminary evaluation of two-loop scattering amplitudes that form the building blocks of full NNLO predictions. The results presented build upon those discussed in https://arxiv.org/abs/2410.22882.

**Secondary track**:

T05 - QCD and Hadronic Physics

**Poster T06 / 783**

## Measurement of W±Z boson pair production in pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS Detector

**Auteur:** ATLAS Collaboration[None]

"New measurements of W±Z production cross-sections in pp collisions at a center-of-mass energy of 13 TeV are presented. The full Run 2 dataset recorded by the ATLAS experiment at the Large Hadron Collider, corresponding to an integrated luminosity of 140 fb−1, is used. The W±Z candidate events are reconstructed using leptonic decay modes of the gauge bosons into electrons and muons.

The inclusive W±Z production cross-section is measured in the detector fiducial region with a relative precision below 4%, the best reached so far for this channel. Cross sections for W+Z and W−Z production and their ratio are measured as well.

The W±Z cross-section is also measured differentially as a function of various observables, including new observables sensitive to CP violation effects. All measurements are compared to Standard Model predictions from MATRIX, that incorporate corrections up to NNLO in QCD and NLO in electroweak, respectively. The experimental precision reached allows in particular to test the impact of NLO electroweak corrections.

An Effective Field Theory (EFT) interpretation is performed, considering both CP-even and CP-odd dimension-6 operators impacting the W±Z production. Limits are extracted on CP-even Wilson coefficients using the transverse mass of the W±Z system. For CP-odd coefficients a novel machine learning approach is used to design an observable with enhanced sensitivity to CP violation effects. Limits set on the studied coefficients are competitive and complementary to previously existing results."

**Secondary track**:

**T11 / 784**

## The LHCb RICH Upgrade: Operations and Performance

**Auteurs:** Federica Borgato[1]; LHCb RICH Collaboration[None]

[1] *Università e INFN Padova*

The LHCb experiment is designed for precision measurements of CP violation and rare decays of beauty and charm hadrons. A key component enabling these studies is the Ring Imaging Cherenkov (RICH) system, which provides robust particle identification (PID) over a wide momentum range. With the start of Run 3 and the transition to a triggerless readout at 40 MHz, the RICH detectors have undergone a major upgrade to meet the new data-taking and performance demands. This contribution presents the design, implementation, and commissioning of the upgraded RICH system. Key features include the replacement of the Hybrid Photon Detectors with new multi-anode photomultiplier tubes (MaPMTs), the development of custom readout electronics capable of handling the increased data rate, and the re-optimization of the optical layout to maintain PID performance despite a reduced material budget. The challenging construction and installation, as well as first results from commissioning with collisions will be described. Performance metrics such as PID efficiency and stability under high occupancy conditions will be presented, demonstrating that the upgraded RICH system is fully equipped to support the LHCb physics program throughout Run 3.

**Secondary track**:

**T09** / **785**

## Impact of polarized beams for Higgs, Electroweak and Dark Matter Physics

**Auteur:** Gudrid Moortgat-Pick[1]

**Co-auteurs:** Cheng Li [2]; Florian Lika [3]; Jasmin Becks [3]; Robin Heine [3]; Sven Heinemeyer [4]

[1] *DESY and University of Hamburg*

[2] *SYSU, Guangzhou*

[3] *UHH*

[4] *IFCA (CSIC-UC, Santander)*

Future Electron-Positron Linear Collider Designs (ILC, CLIC, HALHF) offer high-energy, polarized beams and high-precision measurements. In the talk we discuss the impact of polarized beams for the detection of the Higgs couplings, CP-violation effects and Dark Matter candidates with respect to the model distinction in different Beyond the Standard Models (MSSM, 2HDMS, inflation models). The current experimental bounds have been taken into account and involved parameter scans have been performed.

**Secondary track**:

T08 - Higgs Physics

**T09** / **786**

## Axion-Higgs Criticality

**Auteurs:** Maximilian Detering[1]; Tevong You[2]

[1] *King's College London*

[2] *King's College London*

**Auteur correspondant** maximilian.detering@kcl.ac.uk

Self-organised criticality, realised through cosmological dynamics in the early universe, is an alternative paradigm for addressing the electroweak hierarchy problem. In this scenario, an unnaturally

light Higgs boson is the result of dynamics driving the electroweak vacuum towards a near-critical metastable point where the Higgs mass is bounded from above by the vacuum instability scale. To lower the vacuum instability scale close to the weak scale, previous realisations of this mechanism introduced new vector-like fermions coupled to the Higgs. Here we show that an Axion-Like Particle (ALP) coupling to the Higgs is an alternative possibility for achieving criticality with another well-motivated and naturally light candidate for new physics, thus leading to an entirely different set of testable phenomenological signatures. Our Axion-Higgs criticality model predicts an ALP in the MeV to $\mathcal{O}(10)$ GeV range. The entire natural region of parameter space can be thoroughly explored by a combination of future colliders, flavour experiments, and cosmological observatories.

**Secondary track**:

**T05** / **788**

## Measurements of transverse momentum dependent effects in SIDIS at COMPASS

**Auteur:** COMPASS Collaboration[None]

An important part of the physics programme of the COMPASS experiment at CERN consists in the measurement of transverse spin and transverse momentum effects in Semi-Inclusive Deep Inelastic Scattering (SIDIS) of high energy muons off unpolarised and transversely polarised nucleons.
In this talk, the most relevant new results on SIDIS off unpolarised protons and transversely polarised deuterons will be reviewed.
The perspectives and the implications for the extraction of transversity and of the transverse momentum-dependent parton distribution functions will also be discussed.

**Secondary track**:

**T15** / **789**

## Searching for New Physics with Nuclear Lineshape Data

**Auteur:** Fiona Kirk[None]

The exceptionally low-lying isomer thorium-229m, which had been observed via radioactive decay, was the subject of intense research for several decades due to its potential as a nuclear clock state. Recently, this state was laser-excited for the first time, bringing us an important step closer to the realisation of nuclear clocks, but also opening up new possibilities to search for new physics that couples to the QCD sector.

In this talk I will describe how new physics might affect the shape of the nuclear resonance, and explain how nuclear lineshape data can already today set competitive bounds on ultralight dark matter coupling to the QCD sector, or more generally, on the time variation of the QCD scale.

**Secondary track**:

**T07** / **790**

## On Soft Contributions to the $B \to \gamma*$ Form Factors

**Auteurs:** Aoife Bharucha[1]; Danny van Dyk[2]; Eduardo VELASQUEZ ALVAREZ[3]

[1] *CPT, Marseille*

[2] *IPPP Durham*

[3] *Centre de Physique Théorique*

The photoleptonic decay B⟶lνγ*is the simplest low-energy process that probes the substructure of the B meson. For an energetic photon, its amplitude can be accessed within the frame of collinear factorization or QCD factorization (QCDF). The factorization formula depends critically on the light-cone distribution amplitudes (LCDAs) of the B meson. The physical photoleptonic amplitude arises in the q^2 ⟶ 0 limit of the B⟶lνγ* amplitude, where q denotes the photon momentum. The amplitude involving an off-shell photon is relevant to the description of the decay B⟶lνl'l'.
Despite the light-cone dominance, the time-ordered product also receives soft contribution by field configurations with x^2 ⊠ Λ_had^2. These are not accessible within the framework of QCDF, However, an estimate using a light-cone sum rule setup.
In this talk, we will focus on the general off-shell photon case. We will first present the corresponding four form factors in a basis that is free of kinematic singularities. The absence of such kinematic singularities is a formal prerequisite for expressing these form factors through hadronic dispersion relations. Then, we will show that these form factors can actually be expressed in the form of dispersion relation. Finally, once in dispersion relation form, we will revisit the derivation of the original light-cone sum rule setup for the general off-shell case to obtain the soft corrections to the form factors.

**Secondary track**:

T05 - QCD and Hadronic Physics

**T04** / **791**

# Gluon shadowing in nuclei and the role of the $c\bar{c}g$ state in the coherent photoproduction of $J/\psi$ in nucleus-nucleus collisions

**Auteur:** Agnieszka Luszczak[1]

**Co-auteur:** Wolfgang Schaefer [2]

[1] *Cracow University of Technology*

[2] *Institute of Nuclear Physics PAN, Krakow*

We studied the diffractive photoproduction of $J/\psi$ mesons at the highest available energies.The data from ultraperipheral collisions (UPCs) are well described at high energies/small-$x$ after including additional shadowing from the $c\bar{c}g$ Fock state.
We confront our results on diffractive photoproduction of $J/\psi$ mesons with the putative gluon shadowing ratio defined as $R_g = \sqrt{\sigma(\gamma A \to J/\psi A)/\sigma_{\mathrm{IA.}}}$, where $\sigma_{\mathrm{IA}}$ is the result in impulse approximation.
Building on our earlier description of the process in the color-dipole approach, where we took into account the rescattering of $c\bar{c}$ states only, we demonstrate that the inclusion of $c\bar{c}g$-Fock states improves the description at small $x$ commonly associated with gluon shadowing. The results are published in Phys.Lett.B 856 (2024) 138917.

**Secondary track**:

T04 - Ultra-relativistic Nuclear Collisions

**T16** / **792**

## BitHEP – The Limits of Low-Precision ML in HEP

**Auteurs:** Claudius Krause[1]; Daohan Wang[2]; Ramon Winterhalder[3]

[1] *HEPHY, OeAW*

[2] *HEPHY, ÖAW*

[3] *UC Louvain*

The increasing complexity of modern neural network architectures demands fast and memory-efficient implementations to mitigate computational bottlenecks. In this talk, we present a comprehensive evaluation of the recently proposed BITNET architecture across multiple HEP tasks, including quark-gluon discrimination, SMEFT parameter estimation, and detector simulation. We assess its performance in classification, regression, and generative modeling, benchmarking it against state-of-the-art methods. Our findings indicate that BITNET achieves competitive performance in classification tasks, while its effectiveness in regression and generation depends significantly on the network configuration. These results provide insights into both the current limitations and the potential of BITNET for future HEP applications.

**Secondary track**:

T12 - Data Handling and Computing

**Poster T16 / 793**

## TrackFormers 2: Enhanced Transformer-Based Models for High-Energy Physics Track Reconstruction

**Auteurs:** Sascha Caron[1]; Nadezhda Dobreva[2]; Antonio Ferrer Sánchez[3]; José Martín-Guerrero,[3]; Uraz Odyurt[4]; Slav Pshenov[5]; Roberto Ruiz De Austri Bazan[6]; Evgeniy Shalugin[7]; Zef Wolffs[8]; Yue Zhao[9]

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[9] *SURF, The Netherlands*

High-Energy Physics experiments are rapidly escalating in generated data volume, a trend that will intensify with the upcoming High-Luminosity LHC upgrade. This surge in data necessitates critical revisions across the data processing pipeline, with particle track reconstruction being a prime candidate for improvement. In our previous work, we introduced "TrackFormers", a collection of Transformer-based one-shot models that effectively associate hits with expected tracks. In this study, we extend our earlier efforts of model development by incorporating loss functions that account for inter-hit correlations, conducting detailed investigations into (various) Transformer attention mechanisms, and a study on the reconstruction of higher-level objects. Furthermore, we discuss new datasets that allow the training on hit level for a range of physics processes. These developments collectively aim to boost both the accuracy and the potential efficiency of our tracking models, offering a robust solution to meet the demands of next-generation high-energy physics experiments.

**Secondary track**:

**Joint T08+T16 / 794**

## Higgs Signal Strength Estimation with a Dual-Branch GNN under Systematic Uncertainties

**Auteurs:** Claudius Krause[1]; Daohan Wang[2]; Minxuan He[None]

[1] *HEPHY, OeAW*

[2] *HEPHY, ÖAW*

In this talk, we present a dedicated graph neural network (GNN)-based methodology for the extraction of the Higgs boson signal strength, incorporating systematic uncertainties. The model features two branches: a deterministic GNN that processes kinematic variables unaffected by nuisance parameters, and an uncertainty-aware GNN that handles inputs modulated by systematic effects through gated attention-based message passing. Their outputs are fused via skip connections and learnable gating to produce classification scores for signal-background discrimination. During training, systematic variations are explicitly injected by scanning the nuisance parameter space and updating model parameters at each point, enabling the network to learn a smooth dependence of classifier outputs on systematic shifts. To model systematic effects, classifier outputs are recomputed under varied nuisance parameters, and the resulting weighted score distributions for signal and background are interpolated using template morphing. The resulting surrogate likelihood functions enable profile likelihood scans over signal strength, with nuisance parameters profiled out via numerical optimization. This framework yields accurate estimation of $\mu$ and its 68.27% confidence interval, achieving competitive coverage and interval widths in large-scale pseudo-experiments compared to traditional binned approaches.

**Secondary track**:

T08 - Higgs Physics

**T05 / 795**

## Diffractive dijets in $ep \to e' jet\, jet\, p$ reaction using GTMDs

**Auteur:** Marta Łuszczak[1]

[1] *University of Rzeszów*

We calculate several differential distributions for diffractive dijets production in $ep \to e' jet\, jet\, p$ in the perturbative QCD dipole approach using off diagonal unintegrated gluon distributions (generalized transverse momentum dependent distributions, GTMDs). We concentrate on the contribution from exclusive $q\bar{q}$ dijets. Results of our calculations are compared to H1 and ZEUS data, including specific experimental cuts in our calculations. In general, except for one GTMD, our results are below the HERA data. The considered mechanism is expected to gives a sizeable contribution to the ZEUS data, while it is negligible in the kinematics of the H1 measurement. This is in contrast to recent results from the literature where the normalization was adjusted to some selected distributions of the H1 collaboration and no agreement with other observables was checked. The ZEUS data provide stricter limitations on the GTMDs than the H1 data. We conclude, based on comparison to different observables, that the calculated cross sections are only a small fraction of the measured ones which contain probably also processes with pomeron remnant. Alternatively one could try to explain the experimental data by inclusion of $q\bar{q}g$ component of the photon wave function.

Published in: **Phys.Rev.D 110 (2024) 5, 054027**

**Secondary track**:

**Joint T04+T05 / 797**

## Heavy flavor correlations and Quarkonia production in high energy proton-proton collisions in the EPOS4HQ framework.

**Auteur:** Joerg Aichelin[1]

**Co-auteurs:** Jiaxing Zhao ; Klaus Werner [1]; pol bernard gossiaux [2]

[1] *SUBATECH*

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A heavy quark-antiquark ($Q\bar{Q}$) pair can be produced in several pQCD processes, which impose different correlations between the $Q$ and $\bar{Q}$. Employing the recently advanced EPOS4HQ event generator, which contains these processes, we show that they explain the measured $D\bar{D}$ and $DD$ correlations and how they influence the $p_T$ distributions of open heavy flavor mesons in pp and AA collisions. It turns out that this influence is different for D and B mesons.

These correlations have also an influence on hidden heavy flavour mesons produced in pp collisions. To explore them we present a model of quarkonia formation based on the convolution between the Wigner densities, associated to the quarkonia eigenstates (up to 3S states), and the Wigner density of the two-body $Q\bar{Q}$ pairs produced those collisions. This model allows to predict quantitatively the rapidity and $p_T$ distribution of ground states and excited states of charmonia as well as of bottomonia in pp collisions. We compare the results with experiments and identify the influence of the correlations. Finally, we extend the density matrix approach to study the production of $B_c$ mesons and compare our results with experimental data.

**Secondary track**:

**T11 / 798**

## Enhancing Particle Identification for Future Circular Collider Experiments using Cluster Counting Technique

**Auteur:** Markus Klute[1]

[1] *KIT*

Particle Identification is a critical and challenging task in high-energy physics experiments, particularly for future collider facilities such as FCC-ee and CEPC. The dE/dx method is limited by significant uncertainties in the total energy deposition, which limit its particle separation capabilities. The cluster counting (dN/dx) technique exploits the Poisson distribution of primary ionisation, offering a statistically robust approach to infer particle mass. Simulation studies using Garfield++ and Geant4 show that dN/dx can achieve twice the resolution of dE/dx in helium-based drift chambers, at the cost of detecting electron peaks and identifying ionisation clusters, a challenging task due to signal overlap in the time domain. This presentation will introduce advanced algorithms and computational tools to enable the identification of electron peaks and ionisation clusters, validated in beam tests at CERN, using several drift tubes operating with different helium gas mixtures.

The analysis results will be reported and discussed, and a comparative study of the resolutions achieved using dN/dx and dE/dx methods will be presented.

**Secondary track**:

**T15** / **799**

## 1 Particle - 1 Qubit: Particle Physics Data Encoding for Quantum Machine Learning

**Auteurs:** Aritra Bal[1]; Benedikt Maier[2]; Markus Klute[1]; Michael Spannowsky[3]

[1] *KIT*

[2] *Imperial College London*

[3] *University of Durham*

We present 1P1Q, a novel quantum data encoding approach tailored specifically for particle physics, where each particle in collision events is mapped onto an individual qubit. This method bypasses classical data compression, enabling direct and lossless representation of event-level kinematic details on quantum devices. We showcase the effectiveness of 1P1Q in two key quantum machine learning (QML) applications: unsupervised anomaly detection using a Quantum Autoencoder (QAE) and supervised classification employing a Variational Quantum Circuit (VQC).

Our results highlight that the QAE significantly outperforms classical autoencoders in distinguishing signal jets from background Quantum Chromodynamics (QCD) jets, achieving superior performance with dramatically fewer trainable parameters. Meanwhile, the VQC achieves competitive performance comparable to state-of-the-art classical methods such as Particle Transformer, yet requires minimal computational complexity and significantly fewer parameters. Additionally, we demonstrate, for the first time, successful validation of the QAE using real experimental data from the CMS detector at the LHC, confirming the practical applicability and robustness of our quantum models.

These results underscore the potential of the 1P1Q encoding strategy as a powerful and scalable quantum framework for analyzing high-energy collider data, allowing for a clear pathway towards the integration of quantum computing techniques within particle physics analyses.

**Secondary track**:

T16 - AI for HEP (special topic 2025)

**T04** / **800**

## General Linblad equation for in-QGP quarkonia evolution

**Auteur:** Aoumeur Daddi Hammou[1]

**Co-auteurs:** Jean-Paul Blaizot [2]; Thierry Gousset [1]; pol bernard gossiaux [3]

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Accurate modeling and understanding of quarkonium production in AA collisions requires a formalism that preserves the quantum properties of a microscopic $Q\bar{Q}$ system while treating the interaction of such pairs with the QGP. The open quantum system approach has recently emerged as one of the most fruitful schemes to meet such requirements. However, the quantum master equations obtained so far in this approach and currently used to make predictions for the upsilon suppression at RHIC and LHC are derived assuming a strict ordering between the QGP temperature and the energy gaps ($\Delta E$) of the upsilon bound states. This limits their predictive power as the QGP cooling interpolates between the quantum Brownian regime ($T$
$gtrsim\Delta E$) and the quantum optical regime ($T$
$lesssim\Delta E$).

In our contribution, we derive and present a more general non-abelian quantum master equation of the Linblad type, which does not suffer from these limitations and thus allows to faithfully describe the quantum evolution of the $b\bar{b}$ pairs during the whole QGP evolution. Preliminary results will be shown showing the interpolating features of our equation between the two regimes. We also establish the contact with the QME previously obtained in the QBM and QO regimes and give some concrete perspectives for its efficient solution.

**Secondary track**:

**Joint T08+T16 / 801**

## Constraining the Higgs trilinear self-coupling from off-shell production using neural simulation-based inference

**Auteur:** Tae Hyoun Park[1]

**Co-auteurs:** Aishik Ghosh [2]; Ulrich Haisch [1]

[1] *Max Planck Institute for Physics*

[2] *UC Irvine*

**Auteur correspondant** tae.hyoun.park@cern.ch

Experimental verification of the Higgs trilinear self-coupling is one of the next major challenges of particle physics. While prospects from proton-proton collisions have centred around measuring the on-shell single- and di-Higgs production processes, the off-shell Higgs production process has also been suggested as a complementary channel to resolve the degeneracy in Higgs couplings. We employ neural simulation-based inference to evaluate an expansion of the likelihood ratio that fully describes the Higgs signal under effective field theory modifications to the self-coupling, relevant backgrounds, and possible quantum interference effects between them in the $pp \to ZZ$ process. We demonstrate that NSBI approaches the best possible sensitivity and report the expected constraint at the High-Luminosity Large Hadron Collider.

**Secondary track**:

T16 - AI for HEP (special topic 2025)

**T07 / 802**

## Standard Model prediction for the muon g-2: a lattice perspective

**Auteur:** Laurent Lellouch[1]

**Co-auteur:** BMW collaboration

[1] *CNRS & Aix-Marseille U.*

This spring, Fermilab's "Muon g-2" experiment is set to unveil its final results, targeting an unprecedented precision of 0.1 parts per million in measuring the muon's anomalous magnetic moment. To fully leverage this measurement in the quest for new fundamental physics, minimizing uncertainties in the Standard Model prediction is essential. This talk will review the various contributions to this prediction, focusing on the two most uncertain ones. In particular, it will explain how lattice QCD can be employed to compute those two contributions precisely. By comparing the resulting Standard Model prediction with the world-average measurement value, the extent to which new physics could be contributing to the muon g-2 will be assessed.

**Secondary track**:

T05 - QCD and Hadronic Physics

**T04 / 803**

## Probing nPDF and fully coherent radiation through electromagnetic signals at the LHC

**Auteur:** François Arleo[1]

[1] *SUBATECH Nantes*

Prompt photon production in pA collisions has long been suggested as a sensitive probe of the nuclear gluon density. In this study, we present recent results on another cold nuclear matter effect: fully coherent radiation induced by parton multiple scattering, which may affect the nuclear dependence of prompt photon production. Medium-induced radiation effects, implemented in leading-order direct photon processes, are computed for pPb collisions at the LHC. At backward rapidity, photons are sensitive to fully coherent energy loss (FCEL) effects, while at forward rapidity, fully coherent energy gain (FCEG) plays a crucial role due to the dominance of the $qg \to q\gamma$ scattering channel. In the case of virtual photon production, the effects of fully coherent radiation become marginal, making the Drell-Yan process one of the best for probing nuclear PDFs. The power of the DY process is demonstrated through the reweighting of nPDF sets at next-to-leading order (NLO) using realistic pseudo-data from LHC Run 3.

**Secondary track**:

T05 - QCD and Hadronic Physics

**T09 / 804**

## Searching for heavy resonances via oblique parameters in non-linear effective frameworks

**Auteur:** Ignasi Rosell[1]

**Co-auteurs:** Antonio Pich [2]; Juan José Sanz-Cillero [3]

[1] *Universidad CEU Cardenal Herrera*

[2] *IFIC*

[3] *U. Complutense de Madrid & IPARCOS*

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Within the framework of a general non-linear effective field theory describing the electroweak symmetry breaking, we perform a detailed analysis of the next-to-leading contributions to the electroweak oblique parameters S and T from hypothetical heavy resonance states strongly coupled to Standard Model fields. This work extends our previous results by including parity-odd operators in the effective Lagrangian, contributions from fermionic cuts, and up-to-date experimental constraints. We demonstrate that in strongly-coupled ultraviolet completions satisfying both Weinberg Sum Rules —as is the case in asymptotically free gauge theories—the vector and axial-vector resonance masses are constrained to lie above 10 TeV. Conversely, scenarios allowing for lighter resonances with masses in the 2–3 TeV range necessarily imply a violation of the second Weinberg Sum Rule.

**Secondary track**:

T06 - Top and Electroweak Physics

**T02 / 805**

## Light Dark Matter Searches with Spherical Proportional Counters

**Auteur:** Patrick Knights[1]

**Co-auteur:** NEWS-G Collaboration

[1] *University of Birmingham*

**Auteur correspondant** p.r.knights@bham.ac.uk

The particle nature of dark matter remains a key unanswered questions in modern physics, despite it making up the majority of matter in the universe. The NEWS-G collaboration is searching for light dark matter candidates using a gaseous detector, the spherical proportional counter. The use of light gaseous targets, including H, He, Ne, etc., combined with a low energy threshold, enable access to the mass range from 0.05 to 10 GeV. The detector's simple design also facilitates radio-pure detector construction. The collaboration currently operates a 140 cm in diameter detector, constructed at the Modane Underground Laboratory (LSM) using 4N copper with 500 $\mu$m electroplated inner layer. The first direct dark matter search with this detector using a methane target will be presented, as will ongoing searches performed at SNOLAB. The potential to achieve sensitivity reaching the neutrino floor in light dark matter searches with a next generation, fully underground electroformed detector, DarkSPHERE, situated in the Boulby Underground Laboratory, will also be presented. Current efforts underway towards DarkSPHERE will be discussed, for example, establishing a high-purity copper electroforming facility in Boulby.

**Secondary track**:

**T08 / 806**

## Interference effects in resonant di-Higgs production at the LHC in the Higgs singlet extension

**Auteurs:** Daniel Winterbottom[None]; Elina Fuchs[1]; Finn Feuerstake[2]; Tania Robens[None]

[1] *Leibniz University Hannover and DESY*

[2] *Leibniz Universität Hannover*

We investigate the size of interference effects between resonant and non-resonant contributions to di-Higgs production in the singlet extension of the Standard Model, where the additional heavy scalar provides a resonant channel. We find these interference contributions to have a non-negligible effect on the cross-sections and differential distributions. In order to allow for a computationally efficient treatment of these effects via reweighting, we introduce a new tool utilising a matrix-element reweighting method: *HHReweighter*. In addition to the broadly used di-Higgs invariant mass mhh, we analyse the sensitivity to the interference terms for other kinematic variables, such as the Higgs boson transverse momentum, and find that these also can be sensitive to interference effects. Furthermore, we provide updates on the latest experimental and theoretical limits on the parameter space of the real singlet extension of the Standard Model Higgs sector.

**Secondary track**:

**T04** / **807**

## Soft and hard interactions in high multiplicity PP collisions at LHC energies

**Auteur:** Peter Levai[1]

**Co-auteurs:** Gabor Biro [1]; Gergely Gabor Barnafoldi [1]; Guy Paic [2]; Leonid Serkin [2]

[1] *HUN-REN WIGNER RCP*

[2] *Universidad Nacional Autonoma de Mexico*

Recent PP collisions at the highest available LHC energies (at 13 TeV CM energies) are performed with such a high luminosity, when the detected multiplicity dependence can be observed by high precision and its microscopical origin can be studied and discussed. Indeed, the measured hadron transverse momentum spectra differ at lower and higher final state multiplicities, which offers the opportunity of an extensive theoretical investigation of the applied microscopical models in the theoretical descriptions. We use PYTHIA 8 and EPOS 4 Monte Carlo models to reproduce the measured transverse momentum spectra and identify any observed differences. We plan to display our HIJING++ results, also. Our phenomenological analysis indicates a centre-of-mass energy invariance within the low-pT part of the hadron spectra. This observation opens the way of studying high multiplicity PP collisions with methods applied in heavy ion collisions looking for the appearance of the quark-gluon plasma state.

**Secondary track**:

T05 - QCD and Hadronic Physics

**T06** / **809**

## Recent results on EW physics at LHCb

**Auteur:** LHCb Collaboration[None]

The Electroweak sector of the Standard Model is currently being scrutinized with a extraordinary level of detail. Many of the Electroweak and QCD processes can be computed nowadays at several orders in perturbation theory, reaching an unprecedented precision. Thanks to the increasing sizes of the data samples collected at LHCb, together with the developments on the theory side, it is

possible to perform high precision measurements that push the boundaries of our understanding of fundamental interactions. The LHCb detector offers unique capabilities in order to perform high precision measurements of QCD and EW observables in the high pseudorapidity region at the LHC. In this environment, certain quantities, like the weak-mixing angle, are less affected by uncertainties from the parton distribution functions, and the more simple geometry of the detector facilitates the evaluation of experimental biases. The LHCb coverage also provides the opportunity to constrain theory uncertainties when combining the measurements with the other experiments at the LHC, allowing to obtain an almost full coverage of the proton-proton interactions.

In this presentation, the most recent results of EW measurements performed at LHCb will be covered, with a special dedication to the latest Z boson mass result, the study of the effective weak-mixing angle and the measurement of the W boson mass. In addition, prospects for the analysis of the full Run 2 data sample will be shown as well as the expectations for the analysis of the Run 3 data, which have the potential to beat previous experiments and reach uncertainties smaller than those of the current global EW fit.

**Secondary track**:

T05 - QCD and Hadronic Physics

**T09 / 811**

# Flavour hierarchies, extended groups and a composite Higgs

**Auteur:** Javier Lizana[1]

[1] *IFT, Madrid*

We present a model that extends the electroweak gauge symmetry of the Standard Model in a non-universal way to $SU(2)'_L \times U(1)_X \times SU(2)_L^{q_3} \times SU(2)_R^{\ell^3}$. This symmetry is spontaneously broken to $SU(2)_L \times U(1)_Y$ near the TeV scale by a condensate of a new composite sector. Charging appropriately the fermionic degrees of freedom of the composite sector, anomaly cancellation enforces the Standard Model fermions to be charged in such a way that the extended gauge interactions respect a $U(2)_q \times U(2)_e \times U(3)_u \times U(3)_d \times U(3)_\ell$ accidental flavor symmetry.
In addition, from the same symmetry breaking, a composite Higgs boson emerges as a pseudo-Nambu-Goldstone boson of the strong dynamics of the new sector.
Due to the extended gauge and the specific flavor symmetry, leading Yukawa couplings between Higgs and fermions can only be written for the third generation and higher dimension operators generate suppressed light-family Yukawa couplings. Furthermore, CKM mixing angles between third and light families result naturally suppressed while the PMNS ones, anarchic.
The model thus provides a unified origin for the Higgs boson and the flavor hierarchies between third and light families.

**Secondary track**:

**T09 / 812**

# Search for cLFV with COMET experiment at J-PARC

**Auteur:** Cristina Carloganu[1]

**Co-auteur:** COMET Collaboration

[1] *LPCA Clermont Ferrand*

**Auteur correspondant** carlogan@in2p3.fr

The COMET experiment at J-PARC facility in JAPAN is designed to search for charged lepton flavour violation (cLFV), one of the most promising way of looking for physics beyond the Standard Model. Specifically, it will search for the coherent, neutrinoless conversion of a muon to an electron in the field of an aluminum nucleus, a process that is forbidden in the Standard Model and highly suppressed in most of its minimal extensions that accommodate neutrino oscillations.

With a targeted single event sensitivity (SES) of the order of
$10^{-17}$, COMET aims to improve the current limit on the conversion rate by four orders of magnitude. This presentation will review the physics motivation, the experimental design, and the current status of the experiment. The focus will be on recent progress in the construction of the facility and of the detectors for the first phase of the experiment, COMET Phase-I, foreseen to start data taking in 2027.

**Secondary track**:

T07 - Flavour Physics and CP Violation

**T07 / 813**

## CP Violation and the Neutron Electric Dipole Moment from Lattice QCD

**Auteur:** Andrea Shindler[1]

[1] *RWTH - Aachen University*

The search for electric dipole moments (EDMs) remains one of the most sensitive probes of CP violation and physics beyond the Standard Model. In this talk, I will present results from lattice QCD calculations of the neutron EDM induced by the QCD $\theta$-term. I will also discuss hadronic matrix elements of CP-violating effective operators relevant to BSM scenarios—key theoretical inputs needed to connect experimental limits to new sources of CP violation. These calculations highlight both conceptual and technical challenges, including renormalization and the control over systematics. To illustrate the versatility of the underlying methodology, I will briefly present recent results on parton distribution functions (PDFs), showcasing how lattice QCD can access complementary aspects of hadron structure relevant to both low-energy and collider physics.

**Secondary track**:

T05 - QCD and Hadronic Physics

**T02 / 815**

## Results from and Status of the LUX-ZEPLIN Experiment

**Auteurs:** Amy Cottle[1]; LZ Collaboration[None]

[1] *University College London*

**Auteur correspondant** a.cottle@ucl.ac.uk

The LUX-ZEPLIN (LZ) experiment is a dark matter direct detection experiment operating almost a mile underground at the Sanford Underground Research Facility in Lead, South Dakota. LZ uses a 7 active-tonne dual-phase xenon time projection chamber primarily designed to detect weakly interacting massive particles (WIMPs), a well-motivated class of dark matter candidate. This talk will give the status of the LZ experiment, report on its latest dark matter results and discuss searches for other new physics phenomena.

**Secondary track**:

**Joint T08+T16 / 817**

## Multi-Scale Transformer Encoder for Di-Tau Invariant Mass Reconstruction at CMS

**Auteur:** CMS Collaboration[None]

With the discovery of the Standard Model (SM) Higgs boson (H) by the CMS and ATLAS experiments in 2012, the last missing elementary particle predicted by the SM was identified. Since then, extensive measurements of the Higgs boson's properties have been performed across various decay channels. One of the most important is its decay into a pair of tau leptons, the second-most frequent fermionic decay mode after the decay into bottom quarks. In such analyses, the reconstructed invariant mass of the di-tau system plays a crucial role in distinguishing signal (H) from background events. However, due to the presence of neutrinos in the final state, a portion of the energy is lost, leading to an underestimation of the invariant mass. This work proposes a novel Deep Learning (DL) model designed to enhance the reconstruction of the invariant mass by estimating the full four-momentum of each tau lepton before decay, rather than directly regressing the mass. The approach allows for !
a more precise kinematic characterization of the parent particle. The implemented model is a custom transformer encoder —an advanced DL architecture originally developed for Natural Language Processing, now proving its versatility in diverse domains. It takes as input the information from the di-tau products, the reconstructed properties of the two tau leptons, the missing transverse energy (MET), and other key event variables relevant for invariant mass reconstruction. Through learned embeddings, the model extracts meaningful features from each input source, which are then combined and processed using self-attention layers within the transformer encoder. This architecture enables the model to effectively capture correlations between inputs and recover missing contributions from neutrinos, leading to a more accurate invariant mass estimation. The performance of the proposed algorithm is benchmarked against the current standard method used in CMS (SVFit) using simulated H!
$\rightarrow \tau\tau$ events and main background processes. The results demonstrate
the potential of this novel approach in improving mass reconstruction and enhancing Higgs boson analyses.

**Secondary track**:

**T02 / 818**

## Latest results from the XENONnT experiment

**Auteurs:** Paloma Cimental Chavez[None]; XENON Collaboration[None]

**Auteur correspondant** paloma.cimentalchavez@physik.uzh.ch

The XENONnT detector, located at the INFN Laboratori Nazionali del Gran Sasso in Italy, is a leading experiment in the search for dark matter in the form of Weakly Interacting Massive Particles (WIMPs). It features a dual-phase time projection chamber with a 5.9-tonne liquid xenon active target, designed to detect rare particle interactions. Owing to its low background environment, the scientific reach of XENONnT extends beyond WIMP searches to include rare event studies such as bosonic dark matter, solar axions, rare nuclear decays, and solar neutrinos. In this talk,

I will present recent results on the first observation of Boron-8 solar neutrinos via coherent elastic neutrino-nucleus scattering (CEvNS), as well as the latest findings from the WIMP search with XENONnT.

**Secondary track**:

**T01 / 819**

# Axion Emission from Strange Matter in Core-Collapse SNe

**Auteur:** Diego Guadagnoli[None]

The duration of the neutrino burst from the supernova event SN 1987A is known to be sensitive to exotic sources of cooling, such as axions radiated from the dense and hot hadronic matter thought to constitute the inner core of the supernova. We perform the first quantitative study of the role of hadronic matter beyond the first generation – in particular strange matter. We do so by consistently including the full baryon and meson octets, and computing axion emissivity induced from baryon-meson to baryon-axion scatterings as well as from baryon decays. We consider a range of supernova thermodynamic conditions, as well as equation-of-state models with different strangeness content. We obtain the first bound on the axial axion-strange-strange coupling, as well as the strongest existing bound on the axion-down-strange counterpart. Our bound on the latter coupling can be as small as O(10^−2) for fa=10^9 GeV.

**Secondary track**:

**T01 / 820**

# Cosmological constraints from the Dark Energy Spectroscopic Instrument

**Auteur:** Etienne Burtin[1]

[1] *CEA-Saclay*

The Dark energy Spectroscopic Instrument (DESI) is measuring spectra of millions of distant galaxies and
quasars over a five-year period that started in spring 2021. A 3D map of the universe is built from the observations
and statistical methods applied to this map allows to place strong constraints on the underlying cosmological
Model. The main probe used in the data analysis is the baryonic acoustic oscillation that induces a characteristic
distance of separation between galaxies. This distance is measured across cosmic history and provides a measurement
of the history of the universe expansion. I will present the results based on the first three years of observations and
their impact on cosmology and in particular on the nature of dark energy and on the sum of neutrino masses.

**Secondary track**:

**Poster T13 / 821**

## Status and plan of the emittance tuning of the FCC-ee High Energy Booster ring

**Auteur:** Quentin Bruant[1]

**Co-auteurs:** Adnan Ghribi [2]; Antoine Chance [3]; Barbara Dalena [4]

[1] *CEA/IRFU/DACM*

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The Future Circular Collider (FCC), in its electron/positron configuration, is one of the CERN's leading proposals for its next high-energy collider. This collider aims to achieve luminosities one to two orders of magnitude higher than ever before, enabling unprecedented precision studies of Z, WW, and H bosons, as well as the largest and purest production of top/anti-top quark pairs.

Previous studies for the FCC have highlighted the need to define tolerances on magnet imperfections and develop correction strategies. This is crucial for ensuring the performance of one of the main elements in the acceleration chain: the High Energy Booster (HEB) ring.

The efficiency and overall performance of these correction strategies, as well as the magnet field quality and misalignment tolerances, directly influence the specifications of correction magnets. This, in turn, affects key parameters such as beta functions, dispersion, transverse coupling, and emittance.

We show the status of the emittance tuning for the HEB ring of the FCCee, following a method ramping the sextupole's strength.

**Secondary track**:

**T13 / 822**

## AI techniques to improve optics measurments based on the Turn-by-turn Beam Position Monitors

**Auteur:** Quentin Bruant[1]

**Co-auteurs:** Andrés Gomez [2]; Barbara Dalena [3]; Charles ndungu-ndegwa [2]; Francesca Bugiotti [4]; Hugo Le Corre [5]; Jacqueline Keintzel [6]; Jonathan Piscart [5]; Leonardo Vitileia [5]; Valérie Gautard [7]; Yasmina Nasr [5]; Yukiyoshi Ohnishi [8]

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Collider rings all around the world need to have several sensors all around the ring to operate. One kind of these sensors is the Beam Position Monitors (BPMs), that allows operators to measure if the beam travelling in their apparatus is well centered in the different magnets.

One specific category of BPMs, standing out by its very high aquisition rate, is called the Turn-by-turn BPMs (TbTBPMs). Several methods exist in order to recontruct the magnetic lattice and the

associated optical functions based on these sensors, but each of these methods needs to have several functional TbTBPMs all along the ring. In the context of the FCC, it involves several thousand of these sensors scattered along a 91-km ring operating in very adverse environment specially due to the effect of radiations on the electronics.

Therefore, in order to maximise the duty cycle in this very large scale accelerator, operation may occur even when some of its sensors are down.

It is consequently important to quickly detect and take into account the detection of faulty TbTBPMs in the study for the reconstruction of the optical functions as well as to have sufficient confidence in the actual measurement which needs to be sensitive and precise enough (i.e having a high Signal-over-Noise Ratio (SNR)) to make decision for the correction of the behavior of the multi-GeV beam. Indeed, the ability to function with very high precision in a very noisy environment is also a challenge that SuperKEKB, but also future colliders and even future lightsources, need to achieve in order to measure rapidly and with high precision the optics functions

We present several methods imported from data science and studied in the context of accelerators, to either detect faulty TbTBPMs and to denoise the TbTBPMs tracks of SuperKEKB, the largest e+/e- collider currently in operation; hoping that an efficient enough method could be scalable to the scale of the FCC accelerator.
We also show the main effect on the harmonic analysis of the different denoising methods tested.

**Secondary track**:

T16 - AI for HEP (special topic 2025)

**T16** / **823**

## Event Tokenization and Next-Token Prediction for Anomaly Detection at the LHC

**Auteurs:** Ambre Visive[1]; Clara Nellist[2]; Polina Moskvitina[1]; Roberto Ruiz de Austri[3]; Sascha Caron[4]

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Advances in Machine Learning, particularly Large Language Models (LLMs), enable more efficient interaction with complex datasets through tokenization and next-token prediction strategies, providing a novel framework for analyzing high-energy physics datasets. This talk presents and compares various approaches to structuring particle physics data as token sequences, allowing LLM-inspired models to learn event distributions and detect anomalies via next-token (or masked token) prediction in proton-proton collisions at the Large Hadron Collider (LHC). By training solely on background events, the model reconstructs expected physics processes, learning properties of the given Standard Model (SM) processes. During inference, both background and signal events are processed, with deviations in reconstruction scores flagging anomalous events—offering a data-driven approach to distinguishing processes or uncovering physics beyond the Standard Model (BSM). This technique is particularly relevant for exploring rare or unexpected signatures, such as four-top-quark production or supersymmetric (SUSY) processes. The method is tested using simulated LHC Run 2 ($\sqrt{s}$ = 13 TeV) proton-proton collision data from the Dark Machines Collaboration, replicating ATLAS conditions, specifically targeting SM and BSM four-top-quark final states. The event tokenization strategies presented in this talk not only enable anomaly detection but also represent a potential new approach for training a foundation model at the LHC. By integrating state-of-the-art ML techniques with fundamental physics principles, this approach paves the way for more adaptive data-driven methods in particle physics, potentially enhancing future searches for new physics at the LHC and beyond.

**Secondary track**:

**Poster T02 / 824**

## Feasibility to probe the dynamical scotogenic model at the LHC

**Auteur:** Gustavo Adolfo Ardila Tafurth[1]

[1] *Universidad de los Andes (CO)*

**Auteur correspondant** ga.ardila10@uniandes.edu.co

In this talk (poster), we perform a feasibility study to probe dark matter production at the LHC, using a $U_L(1)$ scotogenic model. The study is conducted considering the viable parameter space of the model allowed by experimental constraints such as neutrino masses, the Higgs to invisible branching fraction, and dark matter observables. The analysis is carried out using the Markov Chain Monte Carlo numerical method. The production of scalar and fermionic dark matter candidates, predicted by the model, is then studied under the LHC conditions for different luminosity scenarios imposing compressed mass spectra conditions between the lightest fermion and the $\mathbb{Z}_2$ odd scalar masses. We studied two production mechanisms, Drell-Yan and Vector Boson Fusion and analyzed their production cross sections within the LHC framework.

**Secondary track**:

**T16 / 825**

## QCD in Language Models: What they really know about QCD?

**Auteur:** Antonin Sulc[None]

This study presents an analysis of modern open-source large language models (LLMs)—including Llama, Qwen, and Gemma—to evaluate their encoded knowledge of Quantum Chromodynamics (QCD). Through reverse engineering of these models' representations, we uncover the naturally idiosyncratic patterns in how foundational QCD concepts are embedded within their parameter spaces. Our methodology combines targeted probing techniques and knowledge extraction protocols to assess the models' understanding of critical QCD principles like color confinement, asymptotic freedom, and the running coupling constant. We further demonstrate how these latent representations can be leveraged for "connecting dots" between important QCD concepts, potentially enabling novel insights since LLMs allow us to understand the problem holistically limited only by memory. This work provides a tool for utilizing LLMs as an assistant in theoretical physics research, while also highlighting current limitations in their representation of advanced quantum field theory concepts that future model development should address.

**Secondary track**:

**T07 / 826**

## BSM Sensitivity of Rare Kaon Decays

**Auteur:** Siavash Neshatpour[1]

[1] *IP2I Lyon*

Rare kaon decays offer a sensitive window into short-distance physics and potential signals of physics beyond the Standard Model (BSM). This work focuses on several key decay modes—namely $K^+ \to \pi^+\nu\bar{\nu}$, $K_L \to \pi^0\nu\bar{\nu}$, and $K_L \to \pi^0\ell^+\ell^-$—highlighting how new physics scenarios can influence their behavior. We perform a global analysis of current rare kaon decay data and present projections informed by potential future experimental results from CERN and KOTO-II. These results demonstrate the important role of kaon observables in probing short-distance effects and guiding the search for BSM signatures.

**Secondary track**:

**T05** / **827**

# Precise Determination of the Strong Coupling Constant from Dijet Cross Sections up to the Multi-TeV Range

**Auteur:** Daniel Britzger[None]

We determine the value of the strong coupling α_s and study its running over a wide range of scales as probed by the dijet production process at hadron colliders. The analysis is performed using the complete next-to-next-to-leading order (NNLO) predictions in perturbative QCD and is based on dijet data published by ATLAS and CMS at center-of-mass energies of 7, 8, and 13 TeV. From a large subset of these data we infer a value of α_s(m_Z)=0.1178±0.0022 for the strong coupling at the scale of the Z-boson mass m_Z.
Complementing the LHC data with dijet cross sections measured at HERA, we extend the range to test the predicted running of the strong coupling towards smaller scales. Our results exhibit excellent agreement with predictions based on the renormalization group equation of QCD. This study represents the a very comprehensive test of the asymptotic behaviour of QCD, spanning over three orders of magnitude in energy scale from 7GeV up to 7TeV. (work based on arXiv:2412.21165)

**Secondary track**:

**T15** / **828**

# Variational Quantum Eigensolver for (2+1)-Dimensional QED at Finite Density

**Auteur:** Emil Otis Rosanowski[1]

[1] *HISKP Bonn*

In this talk, we present an implementation of multiple fermion flavors in both the Kogut-Susskind and Wilson formulations for quantum simulations of (2+1)-dimensional Quantum Electrodynamics (QED). Our numerical results show a particular type of level crossing with one flavor of fermions at zero density for Wilson fermions, as expected from analytical Chern number calculations. Moving forward, we explore the multi-flavor system at finite density by including a chemical potential. Finally, we present results from inference runs executed on real quantum hardware.

**Secondary track**:

**T05** / **829**

# Measurement of the 1-jettiness event shape observable and of empty hemisphere events in deep-inelastic electron-proton scattering at HERA

**Auteur:** H1 collaboration[None]

The Breit frame provides a natural frame to analyze lepton–proton scattering events. In this reference frame, the parton model hard interactions between a quark and an exchanged boson defines the coordinate system such that the struck quark is back-scattered along the virtual photon momentum direction. In Quantum Chromodynamics (QCD), higher order perturbative or non-perturbative effects can change this picture drastically. The 1-jettiness event shape observable $\tau_1^b$ is mapping out the transition from single-jet events with $\tau_1^b = 0$ up to extreme configurations where the current hemisphere is empty and hence $\tau_1^b = 1$. The data sample was collected at the HERA $ep$ collider in the years 2003–2007 with center-of-mass energy of $\sqrt{s} = 319$ GeV, corresponding to an integrated luminosity of 351.1 pb$^{-1}$. Triple differential cross sections are provided as a function of $\tau_1^b$, event virtuality $Q^2$, and inelasticity $y$, in the kinematic region $Q^2 > 150$ GeV$^2$. Double differential cross sections are measured, in contrast, integrated over $\tau_1^b$ and represent the inclusive neutral-current DIS cross section measured as a function of $Q^2$ and $y$. The data are compared to a variety of predictions and include classical and modern Monte Carlo event generators, predictions in fixed-order perturbative QCD where calculations up to $\mathcal{O}(\alpha_s^3)$ are available for $\tau_1^b$ or inclusive DIS, and resummed predictions at next-to-leading logarithmic accuracy matched to fixed order predictions at $\mathcal{O}(\alpha_s^2)$. The fraction of inclusive neutral-current DIS events with an empty hemisphere is also determined and is found to be $0.0112 \pm 3.9\%_{\text{stat}} \pm 4.5\%_{\text{syst}} \pm 1.6\%_{\text{mod}}$ in the selected kinematic region of $150 < Q^2 < 1500$ GeV$^2$ and inelasticity $0.14 < y < 0.7$. It is also measured differentially and compared to a variety of QCD models.

**Secondary track**:

**T05** / **830**

# Machine Learning-Assisted Measurement of Lepton-Jet Azimuthal Angular Asymmetries and of the complete final state in Deep-Inelastic Scattering at HERA

**Auteur:** H1 collaboration[None]

Deep-inelastic positron-proton scattering at high momentum transfer $Q^2$ is an ideal place to study QCD effects. The H1 collaboration presents two such studies based on data collected in ep collisions at $Q^2 > 150$ GeV$^2$. The data are unfolded (corrected for detector effects) using advanced machine learning methods. This results in parallel and unbinned measurements of several observables, hence it is possible to measure quantities such as moments or variables with poor resolution. One such example are moments of the lepton-jet azimuthal angular asymmetry, sensitive to subtle gluon radiation effects which have to be pinned down accurately in order to be able measure TMDs from similar observables. The moments are presented as a function of the total transverse momentum of the lepton-jet system,
$lvert\vec{q}_\perp$
$rvert$. Another analysis is targeting a simultaneous measurement of all final state particles in these high $Q^2$ events, such that complex studies such as comparisons of different jet algorithms, or jet substructure measurements can be performed on the unfolded data, free of restrictions on the choice of observables or other technicalities such as bin boundaries. The unfolded dataset is projected for validation purposes onto a few example observables which have been measured earlier. New measurements such as comparisons of jet algorithms or energy-energy corelators are also presented.

**Secondary track**:

**T05** / **831**

# Measurement of groomed event shape observables in deep-inelastic electron-proton scattering at HERA

**Auteur:** H1 collaboration[None]

The H1 Collaboration at HERA reports the first measurement of groomed event shape observables in deep inelastic electron-proton scattering (DIS) at $\sqrt{s} = 319$ GeV, using data recorded between the years 2003 and 2007 with an integrated luminosity of 351 $\text{pb}^{-1}$. Event shapes provide incisive probes of perturbative and non-perturbative QCD. Grooming techniques have been used for jet measurements in hadronic collisions; this paper presents the first application of grooming to DIS data. The analysis is carried out in the Breit frame, utilizing the novel Centauro jet clustering algorithm that is designed for DIS event topologies. Events are required to have squared momentum-transfer $Q^2 > 150$ $\text{GeV}^2$ and inelasticity $0.2 < y < 0.7$. We report measurements of the production cross section of groomed event 1-jettiness and groomed invariant mass for several choices of grooming parameter. Monte Carlo model calculations and analytic calculations based on Soft Collinear Effective Theory are compared to the measurements

**Secondary track**:

**T12 / 832**

# Data Preservation in High Energy Physics: a collaborative perspective

**Auteur:** Cristinel Diaconu[1]

[1] *CPPM, Aix-Marseille Université, CNRS/IN2P3 (FR)*

Data preservation is essential for present and future experimental facilities, enabling cost-effective fundamental research by leveraging unique data sets as theoretical and experimental understanding advances. This contribution summarizes the status of data preservation in high energy physics from a perspective of 15 years of experience with a structured collaborative effort at international level. There is clear evidence that the data preservation enhances the scientific output of experiments during and after data acquisition, improves computational efficiency and strengthens the scientific activity. Lessons from past experiments and recent developments will be presented, as well as prospectives and recommendations.

1) DPHEP Collaboration, T. Basaglia et al., "Data preservation in high energy physics", Eur. Phys. J. C 83 no. 9, (2023) , arXiv:2302.03583 [hep-ex].

2) ESPP Submission: Data Preservation in High Energy Physics, DPHEP Collaboration • Alexandre Arbey (IP2I, Lyon) et al. e-Print: 2503.23619 [hep-ex]

**Secondary track**:

**T12 / 833**

# Advancing KM3NeT Data Management: Harnessing Snakemake and Grid Computing

**Auteur:** Anna Sinopoulou[1]

[1] *INFN - Laboratori Nazionali del Sud*

The KM3NeT collaboration is constructing two cutting-edge underwater neutrino detectors in the Mediterranean Sea: ARCA, which is optimized for the detection of astrophysical neutrinos, and ORCA, which aims to determine the neutrino mass hierarchy via the observation of atmospheric neutrinos. The increasing size of the detectors results in significant data volumes, requiring effective data processing and management strategies. To address the data handling demands, KM3NeT has implemented a hierarchical computing model similar to that of the LHC experiments, featuring a Tier structure for data processing and distribution. This model enables the integration of diverse computing resources, thereby improving data handling efficiency. KM3NeT has already integrated Snakemake, a contemporary workflow management system, to guarantee portability, reproducibility, and scalability across various computational environments. Snakemake optimizes and automates complex data processing tasks, enhancing flexibility and efficiency in data management.The last year, efforts are focused on integrating Grid Computing resources into the KM3NeT computing model to improve computational capabilities. This integration seeks to address the rigorous needs associated with detector calibration, simulation, reconstruction, and analysis. Grid Computing enables efficient management of workloads, including serial, multi-parallel, and GPU-optimized jobs, while facilitating frequent data transferring and sharing among collaborators. This presentation offers an overview of KM3NeT's data processing framework, focusing on the implementation of Snakemake and the integration of Grid Computing resources. This discussion will address the challenges faced, the solutions implemented, and the current status of our data handling and computing infrastructure.

**Secondary track**:

**T13 / 834**

## Status of the TWOCRYST project for a double-crystal fixed-target experiment in the LHC

**Auteur:** Rongrong Cai[1]

[1] *CERN*

TWOCRYST is a proof-of-concept installation in the Large Hadron Collider (LHC) at CERN to assess the feasibility of double-crystal experiments. It is designed to provide critical input to a possible future experiment aiming to measure the dipole moments of short-lived charm baryons. A first bent crystal extracts particles from the LHC beam halo onto a target, at safe distances from the circulating beam. A second crystal installed immediately downstream induces magnetic spin precession in charmed baryons produced in the target. TWOCRYST aims to demonstrate the operational feasibility of such a configuration and to characterise the performance of bent crystals, a key component for any future experiment. It features a simplified but representative setup including both crystals, a movable fixed target within the LHC vacuum, and two tracking detectors housed in Roman Pots to observe channelled particles. The experiment was successfully installed in insertion region 3 of the LHC during the End-of-Year Technical Stop 2024/25 and has recorded first data in 2025. This contribution provides an overview of the current status of the TWOCRYST project, including hardware implementation, machine development studies, and the initial results.

**Secondary track**:

**T13 / 835**

## FCC-ee: A high-luminosity lepton collider at CERN

**Auteur:** SOFIA KOSTOGLOU[1]

[1] *CERN*

The Future Circular electron-positron Collider (FCC-ee), the first phase of the broader FCC program, is a proposed next-generation lepton collider at CERN. Designed to operate in a 91 km circular tunnel, FCC-ee will run at four distinct center-of-mass energies, delivering collisions at four experimental interaction points to enable unprecedented precision measurements of the Standard Model and beyond. Achieving the luminosity targets requires significant innovations in accelerator technology and beam dynamics control. FCC-ee adopts a nano-beam collision scheme, aiming for vertical beam sizes in the nanometer range at the interaction points, which also means high sensitivity to misalignment and vibrations. In the presence of errors, displacements and noise effects, it is essential to identify a machine configuration that ensures an acceptable dynamic aperture and momentum acceptance in order to achieve sufficient beam lifetime in operation. To mitigate beam-beam effects, a crab-waist collision scheme is employed, while synchrotron radiation, including beamstrahlung generated during collisions, must be carefully controlled to preserve beam lifetime. Stable intensity in operation will be achieved through top-up injection, which requires synchronization with the High Energy Booster (HEB) located above the Collider ring. Precise energy calibration will be achieved with beam de-polarization techniques. Each of these aspects poses significant challenges and requires thorough studies, detailed simulations and technical developments.

**Secondary track**:

**Poster T08** / **836**

## Probing the Higgs-charm Yukawa coupling at CMS

**Auteur:** Felix Heyen[1]

[1] *Vrije Universiteit Brussel*

The measurement of the Higgs-charm Yukawa coupling is one
of the next milestones in Higgs physics at the LHC and serves as another
test of the consistency of the Standard Model. The Higgs-charm coupling
may be experimentally probed in different ways. These include for
example searches for signatures where a Higgs boson directly decays to a
pair of charm and anti-charm quarks or where a charm quark couples to
the Higgs boson in the initial state. This poster presents recent, novel CMS
results (1[3]) which probe such signatures and place significant
constraints on $|\kappa_c|$.
Bibliography:
1 Search for Higgs boson production in association with a charm quark
in the diphoton decay channel, CMS-PAS-HIG-23-010
2 Search for gammaH production in pp collisions at sqrt{s} = 13 and
constraints on the Yukawa couplings of light quarks to the Higgs boson
using data from the CMS detector, CMS-PAS-HIG-23-011
[3] Search for Higgs boson decay to a charm quark-antiquark pair via ttH
production, CMS-PAS-HIG-24-018

**Secondary track**:

**T01** / **837**

## Determination of Anisotropy of Elementary Particles

**Auteurs:** Iñaki Rodriguez[1]; Jorge Casaus[1]; Miguel Angel Velasco[1]; Miguel Molero[2]

[1] *CIEMAT*

[2] *IAC*

Analysis of anisotropy of the arrival directions of galactic positrons, electrons and protons has been performed with the Alpha Magnetic Spectrometer on the International Space Station. This measurement allows to differentiate between point-like and diffuse sources of cosmic rays for the understanding of the origin of high energy positrons. The AMS results of the dipole anisotropy are presented along with the discussion of the implications of these measurements.

**Secondary track**:

**T13** / **838**

## Xsuite: A Modular Accelerator Simulation Framework

**Auteur:** Frederik Van der Veken[None]

Xsuite is a recent Python framework for accelerator physics simulations developed at CERN. Since its inception in 2021, it has progressively supplanted legacy simulation tools such as SixTrack, sixtracklib, PyHEADTAIL, and COMBI. It consists of distinct, interconnected Python modules—Xobjects, Xdeps, Xtrack, Xpart, Xfields, Xcoll, and Xwakes—and seamlessly interfaces with other accelerator-specific and general-purpose scientific Python tools. This design enables rigorous symplectic treatments of particle dynamics and incorporates sophisticated models to simulate synchrotron radiation, beam impedances, space charge and beam-beam effects, electron-cloud interactions, and collimation processes. For the latter, specific interfaces to particle-matter interaction libraries such as BDSIM and Geant4 are implemented. Targeting high-performance computing, Xsuite supports both CPU and GPU architectures, significantly enhancing computational efficiency and enabling accelerated simulation workflows.

**Secondary track**:

**T01** / **839**

## The Nanohertz Gravitational Wave Background: Insights from Pulsar Timing Arrays

**Auteur:** Sonali Verma[None]

Pulsar Timing Array (PTA) collaborations use a collection of pulsars in the Milky Way to detect gravitational waves in the nanohertz band by measuring tiny shifts in pulse arrival times. In this talk, I will briefly summarise the recent strong evidence for a gravitational wave background, together with astrophysical and cosmological interpretations of the PTA observation. I will conclude by highlighting prospects for discriminating between the possible origins of the observed signal.

**Secondary track**:

**T08** / **840**

## Prospects for single- and di-Higgs measurements at the HL-LHC with the ATLAS and CMS experiments

**Auteurs:** ATLAS Collaboration[None]; CMS Collaboration[None]

The High-Luminosity LHC (HL-LHC) is expected to deliver an integrated dataset of approximately 3 $ab^{-1}$, enabling detailed studies of Higgs boson processes with unprecedented precision. Projections

based on current analyses have been performed to estimate the expected measurement accuracy and identify potential limitations. The large data sample will also significantly enhance sensitivity to di-Higgs production, providing access to the Higgs boson self-coupling. This talk will present the ATLAS and CMS experiments'prospects for Higgs and di-Higgs measurements at the HL-LHC.

**Secondary track**:

**T01 / 841**

## Cosmology with largest camera ever built: Dawn of Vera Rubin Observatory's LSST

**Auteur:** Bruno Sanchez[1]

[1] *CPPM - CNRS*

The Vera C. Rubin Observatory's Legacy Survey of Space and Time (LSST) is set to begin survey operations by the end of this year.
This groundbreaking facility will transform our understanding of the universe across a broad range of science cases in optical astronomy. LSST will perform a comprehensive inventory of Solar System objects, including the identification of potentially hazardous asteroids.

The survey's deep, wide-field imaging will reveal the properties of galaxies and their associated dark matter halos, and enable precise measurements of cosmic shear through weak gravitational lensing. In the time domain, LSST will trace the cosmic expansion history using several thousand newly discovered Type Ia Supernovae (SNe Ia), offering the most accurate constraints to date on the nature of dark energy and its possibly evolving equation of state, w.

In this talk, we will present an overview of the observatory's ongoing commissioning phase, including the status of LSSTCam—the largest astronomical camera ever built.
We will also highlight the transient detection system, describe how its performance is evaluated using synthetic sources, and discuss the implications of its performance for cosmological analyses with SNe Ia.

**Secondary track**:

**T07 / 843**

## Measurements of semileptonic and leptonic $B$ decays at Belle and Belle II

**Auteur:** Steven Robertson[1]

[1] *IPP / UofA*

The Belle and Belle II experiments have collected a combined sample of 1.2~ab$^{-1}$ of $e^+e^- \to B\bar{B}$ collisions at a centre-of-mass energy corresponding to the $\Upsilon(4S)$ resonance. These data, with low particle multiplicity and constrained initial state kinematics, are an ideal environment for studying semileptonic and leptonic decays of the $B$ meson. Combined with theoretical inputs, measurements of both inclusive and exclusive semileptonic decays yield information about the Cabibbo-Kobayashi-Maskawa matrix elements $V_{cb}$ and $V_{ub}$. Our latest results based on the Belle II data set are reviewed. We also present the first measurement of $B^+ \to \tau^+\nu$ from Belle II and a search for $B^+ \to \mu^+\nu$ using the combined Belle and Belle~II samples. These decays provide constraints on beyond-the-standard model physics and provide alternative measurements of $V_{ub}$ that complement those from semileptonic decay.

**Secondary track**:

**T07 / 844**

## Searches for New Physics in $B$-meson Decays to Vector Mesons and Charmless Final States at LHCb

**Auteur:** Paras Naik[1]

[1] *University of Liverpool*

$B$-meson decays into two vector mesons, $B \to VV$, constitute a class of decays of special interest. These decays are generally mediated by both loop and tree processes, making the measurement of their CP asymmetries, polarisation variables, and branching fractions especially interesting and challenging. For $B \to VV$ decays, any enhancement in one of those variables would be a hint for new physics. Also, searches for new decay modes and branching fraction measurements are performed in charmless decays. Measuring these branching fractions and comparing them with theoretical predictions provides valuable insights into various theoretical frameworks, contributing to refined predictions for branching fractions and CP asymmetries in other charmless decay modes. These measurements serve as tests of the Standard Model, where deviations could signal the presence of New Physics. This talk will provide an overview of recent LHCb results covering these studies.

**Secondary track**:

**T07 / 845**

## Exploring Lepton Flavour with $b$-hadron Decays at LHCb: Universality Tests and Searches for Violation

**Auteur:** Paras Naik[1]

[1] *University of Liverpool*

Lepton flavour plays a crucial role in tests of the Standard Model and searches for New Physics. Within the Standard Model, the electroweak bosons couple universally to the three lepton families, differing only by mass effects (Lepton Flavour Universality, LFU) — charged Lepton Flavour Violation (cLFV) is highly suppressed. However, several beyond-the-Standard-Model scenarios predict deviations from LFU or enhanced rates for cLFV decays, making their observation a clear indication of New Physics. Current measurements of ratios of branching fractions for $b$-hadrons decaying into final states with different lepton flavours show deviations from the Standard Model predictions at the order of $3\sigma$. The LHCb experiment, optimized for studying heavy-flavour hadrons with excellent tracking and particle identification, provides an ideal environment for probing these rare phenomena. This talk will present recent results from LHCb on tests of lepton flavour universality, specifically in $b \to c\ell\nu$ decays using hadronic or muonic $\tau$ decays, as well as results from searches for charged lepton flavour violation in $b$-hadron decays. These results contribute significantly to our understanding of potential new interactions beyond the Standard Model, offering stringent constraints on Standard Model extensions.

**Secondary track**:

**T07 / 846**

# Probing for New Physics with $b \to s\ell^+\ell^-$ and $b \to d\ell^+\ell^-$ Transitions at LHCb

**Auteur:** Paras Naik[1]

[1] *University of Liverpool*

Flavour-changing neutral current processes, such as $b \to s\ell^+\ell^-$ and $b \to d\ell^+\ell^-$ transitions, are highly sensitive probes of new physics. In the Standard Model, their contributions are both loop and CKM suppressed, with $b \to d\ell^+\ell^-$ further suppressed by small off-diagonal quark-flavour mixing couplings and forbidden at the lowest perturbative order. The $b \to s\ell^+\ell^-$ decays have drawn increased interest over the past decade due to a pattern of self-consistent, sizeable and persistent tensions between measurements and Standard Model predictions. In contrast, $b \to d\ell^+\ell^-$ processes have remained largely unexplored due to their scarcity, although they are also sensitive to non-Standard Model loop contributions that can affect associated decay rates and angular distributions. This talk will present the latest LHCb results on amplitude analyses and branching fraction measurements of $b \to s\ell^+\ell^-$ processes, alongside an overview of recent $b \to d\ell^+\ell^-$ results obtained from data collected at LHCb. Future prospects in this field will also be discussed in view of the ongoing data taking.

**Secondary track**:

**T07** / **847**

# Charmed baryon decays at BESIII

**Auteurs:** Fabrizio Bianchi[1]; Fabrizio Bianchi[2]

[1] *INFN Torino*

[2] *INFN and University of Torino*

BESIII has accumulated 4.5 fb^-1 of e+e- collision data in the 4.6 and 4.7
GeV energy range, which provides the largest dataset of Lambda_c- Lambda_c
pairs in the world.
Our presentation will include the observation of a rare beta decay of the
charmed baryon Lambda_c+ -> n e+ nu with a Graph Neural Network and the
first measurement of the decay asymmetry in the pure W-boson-exchange
decay Lambda_c+ -> 926;0 K+, as well as the branching fraction
measurements of the inclusive decays Lambda_c+->X e+ nu and Lambda_cbar-
-> nbar X.
Furthermore, we will present the results of the partial wave analysis of
Lambda_c+ to Lambda pi+ pi0, and Lambda_c+ to Lambda pi+ eta Lambda, Our
presentation will also include branching fraction measurements of
Cabibbo-suppressed decays, including Lambda_c+ to p pi0, and the
measurements of KS-KL asymmetries in the Lambda_c+ decays.

**Secondary track**:

**T13** / **848**

# Muon Colliders and their future R&D

**Auteur:** Rebecca Taylor[1]

[1] *CERN*

Muons offer a unique opportunity to build a compact high-energy electroweak collider at the 10 TeV scale. It will be a paradigm-shifting tool for particle physics representing the first collider to combine the high-energy reach of a proton collider and the high precision of an electron-positron collider. The International Muon Collider Collaboration (IMCC) has made significant progress in developing a 10 TeV centre-of-mass facility, including the proton driver, target, front-end, cooling, low and high energy acceleration, and a 10 km collider ring with two detectors. The muon collider design is sufficiently mature that R&D is now essential to guide the technological limits of simulations of the accelerator complex. A 10 year R&D plan has been proposed which would focus on developing detector technology, muon cooling technology and the superconducting magnet prototyping . This would enable a first muon collider stage with a start of operation around 2050. Its could thus be the next flagship project in Europe.
This talk highlights the overall design of the muon collider, the contributions made by the IMCC in recent years, and the aims of the proposed R&D plan.

**Secondary track**:

**T01** / **849**

## Searches for Gravitational Wave Background and Future Prospects

**Auteur:** Jishnu Suresh[None]

As of today, the LIGO-Virgo-KAGRA collaboration has cataloged nearly 200 GW detections from various compact object mergers. These discoveries began the endeavors to search for other kinds of GW sources. Among these, the Gravitational-Wave Background (GWB), arising as the superposition of individually undetectable cosmological and/or astrophysical sources, is one of the potential sources to observe with the network of ground-based GW observatories in the coming years. A cosmological GWB would carry unique signatures from the earliest epochs in the evolution of the Universe. Likewise, an astrophysical GWB would provide information about the population properties of the sources that generated it. To a first approximation, the GWB is assumed to be isotropic; one could determine its statistical properties by observing any part of the sky. However, these backgrounds can be anisotropic as well. Therefore, searches for both isotropic and anisotropic GWB have been conducted. In this talk, I will explain the search methods and the results from the most up-to-date quests for the GWB. In addition, I will outline the new analysis and searches planned for the upcoming runs of these detectors and the exciting results expected from these probes.

**Secondary track**:

**T15** / **850**

## Quantum noise reduction in gravitationnal wave detectors

**Auteur:** Edwige Tournefie[None]

Quantum noise poses a fundamental limitation to the sensitivity of second-generation terrestrial gravitational wave (GW) detectors,affecting both low and high frequencies through radiation pressure noise and shot noise, respectively. Overcomming this limitation is crucial for the improvement of the detector's sensitivities. For this reason all international collaborations have undertaken an R&D campaign aimed at overcoming the Standard Quantum Limit for GW detectors. The strategy employed is based on the use of squeezed vacuum states injected in to the output port of the interferometers. This technique has been successfully implemented in the LIGO and Virgo interferometers1.

In this talk we will present the principle of the quantum noise reduction technique and its implementation in the GW interferometers and the achieved performance in terms of noise suppres-

sion.

1 D. Ganapathy et al. Broadband Quantum Enhancement of the LIGO Detectors with Frequency-Dependent Squeezing, Phys. Rev. X 13, 041021 (2023)

2 F. Acernese et al. Frequency-Dependent Squeezed Vacuum Source for the Advanced Virgo Gravitational-Wave Detector, Phys. Rev. Lett. 131, 041403 (2023).

**Secondary track**:

**T03 / 851**

## Latest results from the XENONnT experiment

**Auteur:** Paloma Cimental[1]

[1] *Universität Zürich (UZH)*

The XENONnT detector, located at the INFN Laboratori Nazionali del Gran Sasso in Italy, is a leading experiment in the search for dark matter in the form of Weakly Interacting Massive Particles (WIMPs). It features a dual-phase time projection chamber with a 5.9-tonne liquid xenon active target, designed to detect rare particle interactions. Owing to its low background environment, the scientific reach of XENONnT extends beyond WIMP searches to include rare event studies such as bosonic dark matter, solar axions, rare nuclear decays, and solar neutrinos. In this talk, I will present recent results on the first observation of Boron-8 solar neutrinos via coherent elastic neutrino-nucleus scattering (CEνNS), as well as the latest findings from the WIMP search with XENONnT.

**Secondary track**:

**T14 / 852**

## Outreach, educational activities and communication of the ALICE collaboration

**Auteurs:** ALICE Collaboration[None]; Simone Ragoni[1]

[1] *Creighton University (USA)*

Outreach and communication with the public is an integral part of our work as researchers. A wide range of activities and platforms allow ALICE members to share, especially with the young generation, the excitement of our field. ALICE Masterclasses for high-school students, both in-person and online, are expanding, reaching a higher number of students every year. Visits to the experiment site, especially to the underground installations when the LHC schedule allows, are very popular; the large demand also serves to motivate ALICE members to get involved as guides. The surface exhibition offers a glimpse to both the physics and the variety of detectors of ALICE. Virtual visits are also popular, and the growing use of social media platforms like Instagram brings the excitement of the physics of the quark-gluon plasma to new audiences of different ages and interests.

**Secondary track**:

**T14 / 853**

# LHCb overview of outreach activities

**Auteur:** LHCb Collaboration[None]

**Co-auteur:** Sara Celani

The LHCb experiment aims to address one of the most fundamental questions in particle physics: what distinguishes matter from antimatter? This compelling scientific quest captures the imagination not only of the general public but also of policymakers, funding bodies, and the broader scientific community. In this talk, we present the wide range of outreach activities undertaken by the LHCb members to communicate the significance of our research and maintain strong engagement with diverse audiences. These efforts include the revitalization of the LHCb social media presence, active participation in international masterclasses, organized visits for the public, VIP, funding agencies and artists, as well as development of branded merchandise, creation of underground exhibitions, improved documentation and public news sharing.

**Secondary track**:

**T01 / 854**

# Unveiling the Gravitational-Wave Universe: Population Insights from the LIGO-Virgo-KAGRA Observations

**Auteur:** TBD[None]

We present the latest population-level results from the LIGO-Virgo-KAGRA (LVK) Collaboration, based on the growing catalog of gravitational-wave detections from compact binary coalescences. Leveraging data from the O1–O3 observing runs, and incorporating advanced statistical inference techniques, we explore the underlying astrophysical distributions of binary black holes (BBHs), binary neutron stars (BNSs), and neutron star–black hole (NSBH) systems. This talk will cover updated constraints on the mass and spin distributions, merger rate densities, and redshift evolution of these sources. We will also discuss the implications of these findings for stellar evolution, formation channels, and cosmology. Furthermore, we examine potential signatures of hierarchical mergers and primordial black holes, and address the presence of selection biases and detector sensitivity limits. These population studies mark a significant step toward understanding the demographics and origins of compact binaries in the gravitational-wave era.

**Secondary track**:

**T14 / 855**

# ATLAS Outreach and Education

**Auteur:** ATLAS Collaboration[None]

**Co-auteur:** Steven Goldfarb [1]

[1] *University of Michigan*

The ATLAS Experiment on the Large Hadron Collider at CERN is one of the largest most complex scientific instruments ever constructed. It has been built and operated by an international collaboration of over 5900 members of 103 nationalities from 243 institutes around the world. While the scientific goals and results of the experiment are continually reported to colleagues in the field through conferences, journals and seminars, the collaboration makes a dedicated effort to engage other key audiences with the excitement of its achievements. These audiences range from young children and students, members of the media, politicians and scientists in the same or different fields. Efforts include effective sustained online communication, development of educational material, including

Masterclasses and open data programmes, creation of exhibitions and events at festivals, hosting of local and virtual visits to the experiment, and much more. The work is led by members of the collaboration, supported by a dedicated Outreach team including expertise in education and communication. We report on recent developments and plans, as well as the challenges faced by the current fragmented media landscape.

**Secondary track**:

**T11** / **856**

## Status of the Mu2e Experiment

**Auteurs:** Kevin Lynch[None]; Pierluigi Fedeli[1]

[1] *Istituto Nazionale di Fisica Nucleare & University of Ferrara*

The Mu2e experiment is designed to investigate the CLFV through the observation of a neutrinoless muon-to-electron conversion in the field of an Al nucleus. The observation of such a process would be clear evidence of physics beyond the standard model. Due to the rarity of this process, a cutting-edge, intense muon beam is required to achieve an improvement of the current single-event sensitivity by 4 orders of magnitude. To achieve this goal, a primary proton beam with 8 GeV is extracted from the Fermilab Delivery Ring using the slow resonant extraction technique. Mu2e requires ~ 3.6 × 10^20 protons-on-target to meet its goal; hence, it is crucial to minimize the extraction losses. An important source of such losses are the particles impacting on the electric septum blade. A very promising solution to the problem lies in the beam shadowing scheme tested at CERN SPS. In this approach, a bent crystal is strategically placed upstream of the septum, deflecting particles from the blade at a precise angle via the phenomenon of channeling. As a result, a zone with reduced particle flux is created downstream of the crystal, safeguarding the septum anode by minimizing interactions with the beam. This work explores the optimization of beam shadowing design and the process in the manufacturing and characterization of the bent crystal sample. It emphasizes the promising role of channeling in bent crystals, and it underscores the significant potential of channeling in bent crystals to assist the Mu2e experiment.

**Secondary track**:

**T13** / **857**

## AWAKE: Towards high-energy electrons for particle physics experiments

**Auteur:** Michele Bergamaschi[1]

[1] *CERN*

The Advanced Wakefield Experiment, AWAKE, at CERN is an accelerator R&D experiment, which moved from a proof-of-concept experiment to a facility that develops the proton-driven plasma wakefield acceleration technology to be ready for proposing first particle physics applications in the 2030's. The AWAKE program aims to accelerate electrons to energies of 10 to 100 GeV in a single plasma source, while controlling the beam quality and demonstrating the scalability of the process.
This talk gives a summary of the recent results of the self-modulator experiments for the long proton drive bunch and presents the program, experimental layout and challenges of the electron acceleration experiment where a 150 MeV, 100pC charge, 200fs long electron bunch is externally injected into a 10m -long accelerator plasma source. In addition the development of scalable discharge and helicon plasma sources to hundreds of meters length, necessary to reach high energies, is shown.

**Secondary track**:

**T11 / 858**

# Precision Timing with the CMS MIP Timing Detector for High-Luminosity LHC

**Auteur:** CMS Collaboration[None]

The Compact Muon Solenoid (CMS) detector at the CERN Large Hadron Collider (LHC) is undergoing an extensive Phase 2 upgrade programme to prepare for the challenging conditions of the High-Luminosity LHC (HL-LHC). A new timing detector for CMS will measure minimum ionising particles (MIPs) with a time resolution of about 30-40 ps. The precise timing information from the MIP timing detector (MTD) will reduce the effects of the high levels of pileup expected at the HL-LHC, bringing new capabilities to CMS. The MTD will be composed of an endcap timing layer (ETL), instrumented with low-gain avalanche diodes and read out with the ETROC chip, and a barrel timing layer (BTL), based on LYSO:Ce crystals coupled to SiPMs and read out with the TOFHIR2 chip. This contribution will provide an overview of the MTD design and its expanded physics capabilities, describe the latest progress towards prototyping and production, and show the ultimate results demonstrating the achieved target time resolution.

**Secondary track**: