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IPHC

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Rekindling s-Wave Dark Matter Annihilation Below 10 GeV with Breit-Wigner Effects

Auteur: Margaux JOMAIN[1]

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Thermal Dark Matter (DM) below the GeV scale faces strong cosmological and astrophysical constraints, with Cosmic Microwave Background (CMB) observations excluding s-wave annihilation cross-sections for thermal DM below 10 GeV. Such limits can be evaded with velocity dependent cross-sections, for example when DM annihilates near a narrow resonance. In this work, we explore the impact of resonance effects on DM relic formation using a model-independent approach. We then derive constraints on s-wave annihilation models from CMB data and indirect detection observations, highlighting the viability and limitations of resonant production.

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Probing the general axion-nucleon interaction in water Cherenkov experiments

Auteurs: Axel Iohner[1]; Diego GUADAGNOLI[2]; Ludovico Vittorio[3]; Mael Cavan[4]; Pablo Fernández[5]

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We consider an axion flux on Earth consistent with emission from the Supernova explosion SN 1987A. Using Chiral Perturbation Theory augmented with an axion, we calculate the energy spectrum of $a + N \to N + \gamma$ as well as $a + N \to N + \pi^0$, where N denotes a nucleon in a water tank, such as the one planned for the Hyper-Kamiokande neutrino detection facility. Our calculations assume the most general axion-quark interactions, with couplings constrained either solely by experimental data, or by specific theory scenarios.
We find that even for the QCD axion – whose interaction strength with matter is at its weakest as compared with axion-like particles – the expected Čherenkov-light spectrum from neutrino-nucleon interactions is modified in a potentially detectable way. Furthermore, detectability appears significantly more promising for the $N + \pi^0$ final state, as its spectrum peaks an order of magnitude higher and at energies twice as large compared to the $N + \gamma$ counterpart. Given the rarity of SN events where both the neutrino and the hypothetical axion burst are detectable, we emphasize the importance of identifying additional mechanisms that could enhance such signals.

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OperatorToC++: Transpiling Matched EFT Coefficients to Low-Level Routines

Auteur: Suraj Prakash -[1]

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In recent years, significant progress has been made in the development of automated tools that match the parameters of new physics models and the Wilson coefficients of appropriate low-energy Effective Field Theories. This talk will shed light on an extensible, hybrid tool **OperatorToC++**, that combines the strengths of Mathematica and C++ to facilitate the next steps beyond the matching. OperatorToC++ efficiently ameliorates the complexities within the analytical matched expressions such as intricate loop-functions and lengthy sums and products involving tensor objects. It then translates and bundles the results into C++ classes and functions which provide a convenient platform for further numerical analyses.

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Baryogenesis from bubble collisions

Auteur: Kristjan Muursepp[1]

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In this talk I will discuss particle physics scenarios connecting baryogenesis with first order phase transition. In particular, I will focus on the scenario wherein the CP violation required for baryogenesis is produced by the collision of true vacuum bubbles. I will elaborate both on the case where the right handed neutrino responsible for lepton number violation is produced on-shell as well as on the case where it is produced off-shell. Finally I will present concrete particle physics models realizing this scenario.

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A Lorentz-Equivariant Transformer for All of the LHC

Auteur: Jonas Spinner[1]

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We show that the Lorentz-Equivariant Geometric Algebra Transformer (L-GATr) yields state-of-the-art performance for a wide range of machine learning tasks at the Large Hadron Collider. L-GATr represents data in a geometric algebra over space-time and is equivariant under Lorentz transformations. The underlying architecture is a versatile and scalable transformer, which is able to break symmetries if needed. We demonstrate the power of L-GATr for amplitude regression and jet classification, and then benchmark it as the first Lorentz-equivariant generative network. For all three LHC tasks, we find significant improvements over previous architectures.

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Probing a class of scotogenic models via Z- and Higgs boson decays

Auteur: Adrian Darricau[1]

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We address the phenomenological impact of a well-motivated class of scotogenic models regarding electroweak precision observables.
In particular, we carry out a full computation of the next-to-leading order corrections to leptonic Higgs and Z-boson decays. We argue how
the current bounds (and future prospects) for the latter observables, together with constraints arising from lepton flavour violating transitions
(muon and tau decays, as well as Z and Higgs decays) lead to additional constraints on the parameter space.
We further explore how the evolution in the tension between theory and observation regarding the anomalous magnetic moment of the muon
can affect previously drawn conclusions on interesting regimes in parameter space.

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Impact of Background Processes in the $H \to Z\gamma$ Decay

Auteur: Aliaksei Kachanovich[1]

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In the study of the rare $H \to Z\gamma$ process, both ATLAS and CMS collaborations reported an excess with $\mu = 2.2 \pm 0.7$ in the number of events. Initially, this was interpreted as a modification of the $HZ\gamma$ vertex. However, the $H \to Z\gamma$ process is reconstructed from the $H \to \ell\ell\gamma$ final state, and background contributions were previously neglected. In this work, we carefully analyze the background contributions to the $H \to Z\gamma$ process and propose an explanation for the excess as a new BSM physics background. We suggest an effective field theory approach, as well as a UV-complete model, both of which generate the required background to resolve this discrepancy.

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

Auteurs: Axel Iohner[1]; Claudio Toni[1]; Cristina Lazzeroni[2]; Diego GUADAGNOLI[3]; Diego Martínez Santos[4]; Joel Swallow[5]

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We analyze publicly available $K^+ \to \pi^+ \nu\bar{\nu}$ data collected by NA62 from 2016 to 2022 to constrain the fundamental vectorial coupling of the QCD axion to the down and strange quarks or, equivalently, the Peccei-Quinn scale f_a rescaled by this coupling, obtaining $|(F_V)_{23}| > 1.1 \times 10^{12}$ GeV. Under the complementary assumption that axion production is dominated by weak amplitudes, we derive a model-independent bound on f_a, namely $f_a > 1.0 \times 10^5$ 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. These constraints represent the strongest existing bounds inferred from controlled experimental setups.

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How to Unfold Top Decays

Auteurs: Alexander Paasch[1]; Dennis Schwarz[2]; Luigi Favaro[None]; Roman Kogler[3]; Sofia Palacios Schweitzer[4]; Tilman Plehn[5]

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Many physics analyses at the LHC rely on algorithms to remove detector effect, commonly known as unfolding. Whereas classical methods only work with binned, one-dimensional data, Machine Learning promises to overcome both problems. Using a generative unfolding pipeline, we show how it can be build into an existing LHC analysis, designed to measure the top mass. We discuss the model-dependence of our algorithm, i.e. the bias of our measurement towards the top mass used in simulation and propose a method to reliably achieve unbiased results.

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Profile Likelihoods on ML-Steroids

Auteur: Nikita Schmal[1]

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Global SMEFT analyses combine a vast range of LHC measurements to construct likelihoods to put constraints on physics beyond the Standard Model. However, constructing and evaluating profile likelihoods for such analyses is computationally intensive and prone to instability and noise. We show how modern numerical techniques, similar to neural importance sampling, can dramatically enhance both efficiency and stability. Specifically, we focus on datasets used in previous SFitter analyses, combining data from the Top sector with Higgs, Di-Boson, and electroweak precision measurements to simultaneously constrain up to 42 Wilson coefficients.

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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]

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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 λ_{3H}.

Due to the rarity of di-Higgs production, measuring λ_{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 at particle accelerators like the LHC.

The MEM avoids the application of strict selection requirements to the data. It accounts for the entire dataset (with minimal preselection), which is very important when dealing with such rare processes.

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. Building a MEM at LO is already a highly challenging task, and incorporating NLO formalism substantially amplifies this difficulty due to the increased computational demands and complex theoretical requirements.

To contribute to the measurement of λ_{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 in 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 λ_{3H}. This also represents the first application of the MEM using this new NLO formalism.
We have demonstrated that this NLO framework is functional and effective.

We also applied this framework to Monte Carlo (MC) simulated samples in a search for λ_{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 λ_{3H}.

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Search for emerging jets in ATLAS

Auteur: Thomas Wojtkowski[None]

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This talk will present the recent search for emerging jets performed using LHC Run 3 data collected with the ATLAS detector.
This analysis considers the production of a pair of dark quarks undergoing showering and hadronization within a dark sector, forming long-lived dark mesons that decay back to Standard Model particles. The resulting signature is a pair of jets, each one associated to several displaced vertices.

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Electroweak-inos constraints in the pMSSM with SModelS

Auteur: Leo Constantin[1]

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After LHC Run 2, a large variety of searches is able to constrain supersymmetric models. ATLAS recently presented a summary of constraints from their Run 2 analysis sensitive to electroweak-inos on a scan of the phenomenological minimal supersymmetric standard model (pMSSM). Using the SModelS reinterpretation tool, we present our results for this pMSSM scan and compare our constraints with those of ATLAS. Going further, we make use of the analysis combination feature of SModelS to explore the resulting exclusion on the pMSSM scan from CMS and ATLAS analysis combinations. In particular, we show that the combinations still allows for low mass electroweak-inos.

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Generative Unfolding with Distribution Mapping

Auteurs: Anja Butter[1]; Benjamin Nachman[2]; Nathan Huetsch[3]; Sascha Diefenbacher[4]; Sofia Palacios Schweitzer[5]; Tilman Plehn[3]; Vinicius Mikuni[4]

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Machine learning enables unbinned, highly-differential cross section measurements. A recent idea uses generative models to morph the measured distribution into the unfolded distribution. We show how to extend two morphing techniques, Schrödinger Bridges and Direct Diffusion, in order to ensure that the models learn the correct conditional probabilities. This brings distribution mapping to a similar level of accuracy as the state-of-the-art conditional generative unfolding methods. Numerical results are presented with a standard benchmark dataset of single jet substructure as well as for a new dataset describing a 22-dimensional phase space of Z + 2-jets.

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From Inclusive to Differential: Precision Measurements of ttW Production at 13 TeV

Auteur: Nihal Brahimi[1]

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The production of a top–antitop quark pair in association with a W boson ($t\bar{t}W$) is a dominant background in several measurements of rare processes, such as $t\bar{t}H$ and four-top ($t\bar{t}t\bar{t}$) production, as well as in searches for physics beyond the Standard Model. The precision, accuracy, and modeling of the $t\bar{t}W$ process represent a major limitation in the sensitivity of these analyses. Moreover, previous LHC results have shown tensions between data and Standard Model predictions, further motivating precise studies of $t\bar{t}W$ production. This talk presents the latest measurements of both the inclusive and, for the first time, differential cross sections of the $t\bar{t}W$ process, using the full Run 2 dataset of proton–proton collisions at $\sqrt{s}$ = 13 TeV recorded with the ATLAS detector at the LHC.

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From the MSSM to the SMEFT with MATCHETE

Auteur: Andre Lessa[None]

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We present the complete one-loop matching of the Minimal Supersymmetric Standard Model (MSSM) onto the Standard Model Effective Field Theory (SMEFT), considering the most general case for the MSSM with conserved R-parity, which has 124 free parameters. The matching is performed with the MATCHETE package, integrating out all superpartners at once with non-degenerate masses. We validate against existing results in the literature and present a minimal phenomenological example. Our results include all correlations among the different SMEFT Wilson coefficients that are governed by supersymmetry and thus provide a basis for future systematic and global studies of the MSSM parameter space employing EFT methods.

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The Two-Higgs Doublet Model beyond tree-level: A gauge-invariant formalism

Auteur: Thomas Guérandel[1]

[1] *LPSC*

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Keeping the gauge symmetry manifest in the two-Higgs doublet model (THDM)
has turned out to be very powerful. Stability, electroweak-symmetry breaking, basis transformations, and general symmetries can be studied concisely in terms of gauge-invariant bilinears for any THDM Higgs potential. Recently, the formalism has been extended to the complete model, including the gauge and Yukawa sectors, all in terms of gauge-invariant expressions. Now, we extend the formalism beyond the leading order where we show how bilinears can be used together with the $\hbar$-expansion formalism to derive quantum corrections. We present simple and gauge-invariant results for the one-loop corrections directly applicable to the THDM.

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Introduction to ML for particle physics in the precision era

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In the precision era of particle physics, accurate theoretical predictions and utilizing the full experimental information are key for advancing our understanding of fundamental physics. In my talk, I will show how machine learning can help us to achieve both in a controlled manner including well-calibrated uncertainties.

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LCVision and beyond

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VBS measurement in semileptonic final states with ATLAS Run-2 data

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New limits on WIMP dark matter from XENONnT

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Probing Benchmark Models of Hidden-Sector Dark Matter with DAMIC-M

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