IRN Terascale @ Marseille, Luminy

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Luminy

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Beyond the Standard Model / **1**

Light dark matter with Breit-Wigner enhanced annihilation and possible probes

Auteurs: Genevieve Belanger[1]; Sreemanti Chakraborti[2]; Yoann Genolini[1]; Pierre Salati[1]

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We study a minimal model for a light scalar dark matter (DM) with a mass of a few GeV, requiring a light dark photon mediator to interact with the Standard Model (SM) particles. We analyse the model by focusing on the Breit-Wigner resonance for DM annihilation channels, considering the thermal relic abundance condition that includes the early kinetic decoupling effect. The interactions of the mediator can be constrained by various low-energy terrestrial probes such as proton beam-dumps measuring rare meson decays or electron beam-dump experiments measuring mediator decay into leptons. On the other hand, the interactions of the DM are tested by indirect searches, which include the cosmic ray and X-ray observations, and also by the low-mass direct detection experiments. We do a systematic analysis involving the latest and future limits in each category of the experiments/observations.

Dark Universe / **2**

Primordial black holes and gravitational waves from long-range scalar forces

Auteur: Marcos M. Flores[1]

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Most of the elementary particles discovered in the past century have Compton wavelengths that are much smaller than the size of the atom, and, therefore, they cannot mediate any long-range forces between atoms. This changes in the early Universe, when the horizon size is small. The forces that mediate attractive interactions between particles, such as Yukawa forces, are of particular interest in this early era. These attractive forces exhibit an instability similar to the gravitational instability, but are generally stronger. The effect of this instability is the formation of structure, even in a radiation dominated era. Simultaneously, this same attractive interaction enables the removal of energy and angular momentum through the emission of scalar radiation which facilitates collapse. The process of early structure formation and collapse, has a rich phenomenology and has been utilized to address numerous open questions in physics. In this talk, I will demonstrate how long-range forces and scalar radiation lead to the formation of primordial black holes (PBHs) as dark matter. Furthermore, we will explore the observational consequences of early structure formation, particularly possible contributions to the stochastic gravitational wave background. Lastly, I will talk about the implications of PBHs as dark matter, with a particular focus on the interactions between PBHs and neutron stars.

Beyond the Standard Model / **3**

Accidentally light scalars from large representations

Auteurs: Felix Bruemmer[1]; Giacomo Ferrante[2]; Michele FRIGERIO[3]; Thomas Hambye Hambye[4]

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In models with spontaneous symmetry breaking by scalar fields in large group representations, we observe that some of the scalar masses can be loop-suppressed with respect to the naive expectation from symmetry selection rules. We present minimal models – the SU(2) five-plet and SU(3) ten-plet – with such accidentally light scalars, featuring compact tree-level flat directions lifted by radiative corrections. We sketch some potential applications, from stable relics and slow roll in cosmology, to hierarchy and fine-tuning problems in particle physics.

Beyond the Standard Model / **4**

Asymptotic Grand Unification

Auteurs: Aldo Deandrea[1]; Giacomo Cacciapaglia[2]

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Asymptotic Grand Unification (aGUT) is an alternative unification paradigm where coupling tend to the same UV fixed point. Models can be constructed in 5 dimensions with a single bulk gauge group. I will present a pathway to classify aGUT models, and apply it to SU(N) in the bulk. Only two models are viable, based on SU(6) and with one Higgs doublet stemming from the gauge fields. I will also briefly present how a supersymmetric E6 aGUT can unify both gauge and Yukawa coupling to the same fixed point and require three generations from anomaly cancellation. Furthermore, the aGUT scale can be as low as few TeV, hence reachable at colliders.

Dark Universe / **5**

DM annihilations from a density spike in Milkyway galaxy

Auteurs: Divya Sachdeva[1]; Filippo Sala[None]; Joseph Silk[None]; Shyam Balaji[None]

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We used H.E.S.S. gamma-ray observations of Sgr A*to derive novel limits on the Dark Matter (DM) annihilation cross-section. I will discuss their dependence on uncertainties i) in the DM halo profile, which we varied from peaked to cored, and ii) in the shape of the DM spike around Sgr A* dynamically heated by the nuclear star cluster. For peaked halo profiles and depending on the heating of the spike, our limits are the strongest existing ones for DM masses above a few TeV.

Methods and Tools / **6**

SimuNET: an open-source tool for the simultaneous fit of PDFs and SMEFT coefficients

Auteurs: Maria Ubiali[1]; Mark N. Costantini[1]

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I present a new methodology that can simultaneously fit the Parton Distribution Functions (PDFs) of the proton alongside other parameters that determine the theory predictions. The framework is particularly suited for the study of joint PDF-SMEFT interpretations, where the effects of heavy new physics (NP) are encoded in higher-dimensional operators which alter the interactions among SM particles.
SimuNET is an extension of the NNPDF4.0 methodology, characterised by a flexible neural network parameterisation that allows for extracting proton PDFs and associated uncertainties from a broad data collection. Within this framework, adding an extra layer allows for further parametric dependence in the theory predictions, enabling the simultaneous fit of SMEFT coefficients.
SimuNET can carry out state-of-the-art SMEFT analyses of Higgs, top, Drell-Yan, and electroweak data, allowing for the study of their interplay with the PDFs. It is equipped with various post-fit analysis tools, extending the inherited PDF functionalities with a toolbox for SMEFT interpretations. Further, it provides the user with a functionality designed to determine whether global PDF fits might inadvertently 'fit away' NP in the high-energy tails of the distributions.

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Is the muon a third family lepton?

Auteur: Aldo Deandrea[1]

Co-auteurs: Giacomo Cacciapaglia [2]; Shahram Vatani [3]

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We discuss a new possible family structure for the Standard Model, where the muon is assigned to the third family. This has no consequence in the Standard Model itself, were this assignment is simply a matter of convention. However in physics beyond the Standard Model this reveals potentially meaningful patterns in the masses and mixings, while pointing to precise and testable predictions for experiments.

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Staying on Top of Likelihood Analyses - Likelihoods and global SMEFT analyses in the Top sector

Auteurs: Nikita Schmal[1]; Tilman Plehn[2]

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To make proper use of the vast amount of data produced at the LHC, the presentation and publication of experimental results is vital. For many years it has been advocated to provide the full likelihood, to allow for the proper interpretation of these measurements. Following this, the ATLAS Top working

group now provides several likelihoods for measurements in the Top sector. This talk will give an overview of the uses of these published likelihoods in the context of a global SMEFT analysis in the Top sector using SFitter.

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Enhancing DM searches in LHC with ML

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Dark Matter particles can be searched for in the Large Hadron Collider in the monojet channel defined as at least one hard jet recoiling against a missing momentum and no leptons. Monojet searches are challenging for classical analyses because they require investigation of subtle differences between the jets originating from the SM background and jets accompanying the production of DM particles. Since Neural Networks have been proven to be highly effective in jet classification, we propose a new analysis relying on Graph Neural Networks and aiming at enhancing the searches for Dark Matter in the monojet channel in the LHC.

Beyond the Standard Model / **12**

Composite Hybrid Inflation : Dilaton and Waterfall Pions

Auteur: Wanda Isnard[1]

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We investigate the possibility that inflation originates from a composite field theory, in terms of an effective chiral Lagrangian involving a dilaton and pions. It is possible to find a successful hybrid inflation occurring via the dilaton as the inflaton and the pions as waterfall fields. Compositeness consistency strongly constrain the model such as the composite scale and the inflation scale are fully calculable.

Methods and Tools / **13**

MEMENNTO –Matrix Element Method with Neural Networks

Auteurs: Anja Butter[1]; Nathan Huetsch[2]; Ramon Winterhalder[3]; Theo Heimel[2]; Tilman Plehn[2]

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The matrix element method remains a crucial tool for LHC inference in scenarios with limited event data. We enhance our neural network-based framework, now dubbed MEMENNTO, by optimizing

phase-space integration techniques and introducing an acceptance function. Additionally, employing new architectures, like transformer and diffusion models, allows us to better handle complex jet combinatorics associated with initial-state radiation (ISR). These improvements are showcased again through the CP-violating phase of the top Yukawa coupling in associated Higgs and single-top production, underlining the enhanced capabilities of our revised approach.

Beyond the Standard Model / **14**

Global interpretation of EDMs

Auteurs: Margarete Mühlleitner[1]; Nina Marie Elmer[None]; Skyler Degenkolb[2]; Tanmoy Modak[2]; Tilman Plehn[2]

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We present preliminary results for a global analysis in the low-energy EDM sector. This includes eleven measurements from the paramagnetic and diamagnetic sector and the neutron measurement. Furthermore we investigate their influence on a set of seven model parameter. Tests have shown that not all measurements are constraining the parameter set equally well, with only some leading to significant changes in the parameter constraints and ranges. By dividing the measurements into two subsets we are able to get a good overview on correlations and possible constraints from future measurements. All of the results are currently presented without taking theory uncertainties into account.

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High Multiplicity with JetGPT

Auteurs: Jonas Spinner[1]; Maeve Madigan[None]; Nathanael Ediger[None]; Tilman Plehn[None]

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Generative networks are promising tools in fast event generation for the LHC, yet struggle to meet the required precision when scaling up to large multiplicities. We employ the flexibility of autoregressive transformers to tackle this challenge, focusing on Z and top quark pair production with additional jets. We demonstrate the use of classifiers in combination with the autoregressive transformer to further improve the precision of the generated distributions.

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Diffusion Models for LHC event generation

Auteurs: Anja Butter[1]; Jonas Spinner[2]; Nathan Huetsch[2]; Peter Sorrenson[3]; Sofia Palacios Schweitzer[4]; Tilman Plehn[2]

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Given the recent success of diffusion models in image generation, we study their applicability to generating LHC phase space distributions. For that purpose two specific models are chosen, which differ in their concrete diffusion architecture, a Denoising Diffusion Probabilistic Model (DDPM) and a model based on Conditional Flow Matching (CFM). We find that both achieve state-of-the-art precision. To further enhance the interpretability of our results we quantify our training uncertainty by developing a Bayesian version. In this talk, both diffusion models are introduced and discussed followed by a presentation of our findings.

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Taking aim at the wino-higgsino plane with the LHC

Auteur: Taylor Murphy[1]

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In this work we explore multiple search strategies for higgsinos and mixed higgsino-wino states in the MSSM and project the results onto the (μ, M_2) plane. Assuming associated production of higgsino-like pairs with a W/Z boson, we develop a search in a channel characterized by a hadronically tagged vector boson accompanied by missing energy. We use as our template an ATLAS search for dark matter produced in association with a hadronically decaying vector boson, but upgrade the search by implementing a joint likelihood analysis, binning the missing transverse energy distribution, which greatly improves the search sensitivity. For higgsino-like states (more than 96% admixture) we find sensitivity to masses up to 550 GeV. For well-mixed higgsino-wino states (70-30% higgsino) we still find sensitivities above 300 GeV. Using this newly proposed search, we draw a phenomenological map of the wino-higgsino parameter space, recasting several complementary searches for disappearing tracks, soft leptons, trileptons, and hadronic diboson events in order to predict LHC coverage of the (μ, M_2) mass plane at integrated luminosities of up to $3\,\mathrm{ab}^{-1}$. Altogether, the full run of the HL-LHC can exclude much of the "natural" ($\mu, M_2 < 500$ GeV) wino-higgsino parameter space.

Dark Universe / **18**

Primordial black holes as dark matter: Interferometric tests of phase transition origin

Auteur: Iason Baldes[1]

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We show that primordial black holes — in the observationally allowed mass window with $f_{\rm pbh} = 1$ — formed from late nucleating patches in a first order phase transition imply upcoming gravitational

wave interferometers will see a large stochastic background arising from the bubble collisions. As an example, we use a classically scale invariant $B - L$ model, in which the right handed neutrinos explain the neutrino masses and leptogenesis, and the dark matter consists of primordial black holes. The conclusion regarding the gravitational waves is, however, expected to hold model independently for black holes coming from such late nucleating patches.

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A model-independent likelihood function for the Belle II $B^+ \to K^+\nu\bar{\nu}$ analysis

Auteur: Lorenz Gaertner[1]

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Rare decays like $B^+ \to K^+\nu\bar{\nu}$, searched for by the Belle II collaboration, are important in particle physics research as they offer a window into physics beyond the Standard Model. However, the experimental challenges induced by the two final state neutrinos require assumptions on the kinematic distribution of this decay. Consequently, the results feature a model dependency arising from both Standard Model assumptions and from the description of the pertinent hadronic matrix element, making reinterpretation complicated without reanalysing the underlying data.
We address this issue by deriving a model-independent likelihood function, parameterizing the theory space in terms of Wilson coefficients of the weak effective theory, and reweighting the signal template according to the predicted kinematic signal distribution. This enables us to derive exclusion limits in the space of Wilson coefficients.
Once public, the model-independent likelihood function will be a useful tool for the particle physics community to perform tests on existing theoretical models.

Dark Universe / **20**

Cosmological simulations of Milky-Way like galaxies

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Dark Universe / **21**

Cosmological simulations of Milky-Way like galaxies

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Cosmological simulations of Milky-Way like galaxies

Beyond the Standard Model / **22**

Trend and novelty on tools used for BSM searches at LHC

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Probing Lorentz invariance with top quarks at CMS

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Methods and Tools / **24**

Data Preservation in High Energy Physics : a 10 years perspective

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At the end of their data taking, experiments in HEP enter a period of data analysis that can be prolonged and made more effective if dedicated data preservation projects are designed and executed. Those projects enable in fact a cost-effective way of doing fundamental research by exploiting unique data sets in the light of the continuously increasing theoretical understanding. This talk summarizes the status of data preservation in high energy physics, with a perspective of more than ten years of experience with a structured effort at international level. The status and the scientific return related to the preservation of data accumulated at large collider experiments are presented, together with an account of ongoing efforts to ensure long-term analysis capabilities for ongoing and future experiments.

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Scientific management committee meeting

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Higgs / **26**

Additional Higgs Bosons near 95 and 650 GeV in the NMSSM

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Review of Vector Boson Scattering analyses

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Polarized WZ production observation by ATLAS

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HH->bbyy search with ATLAS

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Evidence for H -> Zy in the combination of ATLAS and CMS results

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Exotic Higgs decays: Present Status and Future Prospects at the LHC

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Measurement of Higgs mass in H → yy with ATLAS

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how to get to the restaurant from Luminy