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Book of Abstracts

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Searches for baryon number violation in free neutron transformations at the European Spallation Source

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Baryogenesis, the process that is theorised to have happened in the beginning of the Universe which produced the observed baryonic asymmetry, remains one of the most fundamental problems in physics. Baryon number violation (BNV) is ordinarily required for baryogenesis, but so far, all searches for it came back negative. The HIBEAM/NNBAR program is a two stage set of experiments (HIBEAM then NNBAR) to search for BNV-only processes: neutron conversions to sterile neutrons and antineutrons, using free neutrons. Due to the enormous advances in neutron reflectometry and high intensity of neutrons that will be available at the European Spallation Source, Sweden, where the measurements are to take place, the searches can achieve unprecedented sensitivity, surpassing the last search by three orders of magnitude. In this talk I will give an overview of the current stage of the experiment showing the fast progress that has been achieved, in particular in the last two years, in all areas of the experimental program.

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Dark sector freeze-out due to a non-Boltzmann suppression

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Commonly known as Boltzmann suppression is the key ingredient to create chemical imbalance for thermal dark matter. In a degenerate/quasi degenerate dark sector chemical imbalance can also be generated from a different mechanism which is analogous to the radioactive decay law, known as co-decaying dark matter. In this work, we have studied the dynamics of a multicomponent thermally decoupled degenerate dark sector in a hidden $U(1)_X$ extension of the Standard Model. We compute the relic density and the temperature (T') evolution of the hidden sector by considering all possible $2 \to 2$ and $3 \to 2$ processes. We find that the production of energetic particles from $3 \to 2$ processes increase the temeprature of the dark sector whereas the rate of growth of temperature is decelerated due to the presence of $2 \to 2$ processes and expansion of the Universe. We also study the prospect of detecting neutrino and γ-ray signals from DM annihilation via one step cascade processes. We find that in the present scenario, all the existing indirect detection constraints arising from measured fluxes of atmosheric neutrinos by Super-Kamiokande and diffuse γ-rays by EGRET, Fermi-LAT, and INTEGRAL respectively can easily be evaded for the degenerate dark sector. However for the quasi degenerate scenario the constraints are significant.

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Imprint of the Seesaw Mechanism on Feebly Interacting Dark Matter and the Baryon Asymmetry

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We show that the type-I seesaw, responsible for generating the light neutrino mass, itself is capable of accommodating one of the three right handed neutrinos as a freeze-in type of dark matter (DM) where the required smallness of the associated coupling is connected to the lightness of the (smallest) active neutrino mass. It turns out that (a) the non-thermal production of DM having mass $\leq \mathcal{O}(1)$ MeV (via decays of W, Z bosons and SM Higgs) consistent with relic density as well as (b) its stability determine this smallest active neutrino mass uniquely $\sim \mathcal{O}(10^{-12})$ eV. On the other hand, study of flavor leptogenesis in this scenario (taking into account the
latest neutrino data and Higgs vacuum stability issue) fixes the scale of two other right handed neutrinos.

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Emergence of kinematic space from quantum modular geometric tensor

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We generalize the Quantum Geometric Tensor by replacing a Hamiltonian with a modular Hamiltonian. The symmetric part of the Quantum Geometric Tensor provides a Fubini-Study metric, and its anti-symmetric sector gives a Berry curvature. Our generalization dubbed Quantum Modular Geometric Tensor gives the metric and curvature of a Kinematic Space. We also use the result of the identity Virasoro block to relate the connected correlator of two Wilson lines to the two-point function of a modular Hamiltonian. This relation realizes a novel holographic entanglement formula for two intervals of a general separation. This result also provides a new interpretation to the connected correlators as the mutual information. Our study remains valid at the quantum level. Hence it provides an opportunity to explore the Kinematic Space in a generic case without conformal symmetry.

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No-scale hybrid inflation with broken R-symmetry

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We consider hybrid inflation models in the framework of no-scale supergravity. $U(1)_R$ symmetry can be broken on the renormalizable level or by Planck suppressed non-renormalizable operators. We show that a Starobinsky like inflation can be realized with asymptotically flat potentials for specific region of parameter space. A connection to the low energy physics as well as the neutrino masses is addressed in a realistic GUT model.

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Electroweak Phase Transition in the Z_3-invariant NMSSM Implications of LHC and Dark matter Searches and Prospects of Detecting the Gravitational Waves

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We study in detail the viability and the patterns of a strong first-order electroweak phase transition as a prerequisite to electroweak baryogenesis in the framework of Z_3-invariant Next-to-Minimal Supersymmetric Standard Model (NMSSM), in the light of recent experimental results from the Higgs sector, dark matter (DM) searches and those from the searches of the lighter chargino and neutralinos at the Large Hadron Collider (LHC). For the latter, we undertake thorough recasts of the relevant, recent LHC analyses. With the help of a few benchmark scenarios, we demonstrate that while the LHC has started to eliminate regions of the parameter space with relatively small $\mu_{\rm eff}$, that favors the coveted strong first-order phase transition, rather steadily, there remains phenomenologically much involved and compatible regions of the same which are yet not sensitive to the current LHC analyses. It is further noted that such a region could also be compatible with all pertinent theoretical and experimental constraints. We then proceed to analyze the prospects of detecting the stochastic gravitational waves, which are expected to arise from such a phase transition, at various future/proposed experiments, within the mentioned theoretical framework and find them to be somewhat ambitious under the currently projected sensitivities of those experiments.

SUSY and String models / **13**

Scale-separated Type IIA AdS3 vacua and O6-plane backreaction

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We discuss flux compactifications of massive Type IIA string theory on G2 spaces with O2/O6-planes to three dimensions. We start by presenting the setup of allowed fluxes, internal geometry and equations of motion and after compactification we achieve N=1 and N=0 AdS_3 vacua with scale that can be parametrically decoupled from the KK modes. We use the smeared approximation description for our sources. The solutions we find are at weak coupling and large volume regime while the moduli are fully stabilized at the classical level. Next, utilizing the equations of motion including varying warp factor and dilaton we evaluate the backreaction of O6-planes. Using the appropriate flux scaling we show that the corrections to the various background fields and moduli are controlled and subleading when going from smeared to localized sources. Similarly, the backreaction corrections to the scalar potential are parametrically small in the scale-separation limit, assuming always that the near-O6-plane singularities will find a resolution within string theory, even in the presence of a Romans mass.

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Dark matter freeze-out and freeze-in beyond kinetic equilibrium

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In the usual approach to the determination of the dark matter thermal relic abundance, both from freeze-out and freeze-in mechanisms, one takes into account only 0-th moment of the Boltzmann equation, i.e. the equation for the particle number density. In case of freeze-out this comes from the assumption of local thermal equilibrium, while for freeze-in from neglecting annihilation processes. In this talk I will discuss how to go beyond this assumption and introduce DRAKE —a numerical precision tool that can trace not only the DM relic density, but also its velocity dispersion and full phase space distribution function. I will review the general motivation for this approach and highlight several examples of classes of models where processes responsible for kinetic and chemical equilibriation are intertwined in a way that can impact the value of the relic density by as much as an order of magnitude. Finally, I will comment on relevance and applicability of this approach to more involved DM models, like the MSSM.

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conformal superalgebra GUT

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We present a GUT model based on the conformal superalgebra su(2,2|N). The model is based on an implementation of supersymmetry where matter fields are in the adjoint representation. We will discuss some of the particularities of the model and we will compare to other susy and nonsusy GUT schemes.

SUSY: Phenomenology and Experiment / **18**

SUSY-QCD corrections to squark annihilation into gluons and light quarks

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We discuss the one-loop SUSY-QCD corrections to the neutralino relic density for pMSSM scenarios with light stops where we focus on stop annihilation into gluons and light quarks including Sommerfeld enhancement effects. These corrections are important as stop (co)-annihilation becomes the dominant contribution to the relic density for scenarios with a small mass difference between the neutralino and the stop which are favored by current LHC searches and consistent with the observation of a 125 GeV Higgs boson.

To allow for the efficient analytic cancellation of infrared divergences between the real and the virtual corrections, we extend the dipole formalism by Catani and Seymour to massive initial states and verify our results through comparison with the phase space slicing approach.

The corrections have been implemented in the dark matter precision tool DM@NLO and the impact of the one-loop corrections on the cosmologically favored parameter region for relevant scenarios is analyzed.

Higgs theory and experiment / **19**

Probing electroweak and top quark physics at the FCC-he

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Despite its immense success, the standard model fails to answer issues such as the stability of the electroweak vacuum or matter dominance over antimatter in the Universe. The Higgs boson and top quark sector hold the key to the answer. We need precise values of their couplings for the correct theoretical description of the said issues. Through a framework of the effective theory, we address the potential of the proposed Future Circular Colliders (FCC) for the Higgs boson self-coupling measurements. We further discuss the probe for the top quark flavour-changing neutral current (FCNC) at the Large Hadron-Electron Collider (LHeC).

Flavour physics: Theory and Experiment / **20**

Recent Beyond-the-Standard-Model results and prospects from MicroBooNE

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MicroBooNE is an 85-tonne active mass liquid argon time projection chamber (LArTPC) at Fermilab. It has excellent calorimetric, spatial and energy resolution and is exposed to two neutrino beams, which make it a powerful detector not just for neutrino physics, but also for Beyond the Standard Model (BSM) physics. The experiment has competitive sensitivity to heavy neutral leptons possibly present in the leptonic decay modes of kaons, and also to scalar bosons that could be produced in kaon decays in association with pions. In addition, MicroBooNE serves as a platform for prototyping searches for rare events in the future Deep Underground Neutrino Experiment (DUNE). This talk will explore the capabilities of LArTPCs for BSM physics and highlight some recent results from MicroBooNE.

Particle cosmology: Theory and Experiment / **22**

Cosmological Stasis in the Early Universe

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One signature of an expanding universe is the time variation of the cosmological abundances of its different components. For example, a radiation-dominated universe inevitably gives way to a matter-dominated universe, and critical moments such as matter-radiation equality are fleeting. In this talk, I will stress that this lore is not always correct and that it is possible to obtain a form of "stasis"in which the cosmological abundances of the different components remain unchanged over extended cosmological epochs, even as the universe expands. For example, critical moments such as moments of matter-radiation equality can persist over an arbitrarily large number of e-folds. Moreover, as I will demonstrate, such situations are not fine-tuned, but are actually global attractors within certain cosmological frameworks, with the universe naturally evolving towards such long-lasting periods of stasis for a wide variety of initial conditions. The existence of this kind of stasis, therefore, gives rise to a host of new theoretical possibilities across the entire cosmological timeline, ranging from potential implications for primordial density perturbations, dark-matter production, and structure formation all the way to early reheating, matter-dominated eras, and even the age of the universe.

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Cosmic Strings, Inflation and Gravitational Waves

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We investigate the impact of Coleman-Weinberg inflation on the stochastic gravitational wave background spectrum emitted by intermediate-scale cosmic strings. The string network is partially inflated and reenters the horizon at later times after the end of inflation, such that the short string loops are not produced. This leads to a significant modification of the gravitational wave spectrum that we explore in detail. We find that Coleman-Weinberg inflation can help to satisfy the Parkes Pulsar Timing Array (PPTA) bound for dimensionless string tension values in the range $G\mu > 1.1 \times 10^{-10}$. We also identify the modified gravitational wave spectra which, in the case of inflation, are compatible with the North American Nanohertz Observatory for Gravitational Waves (NANOGrav) data.

Particle cosmology: Theory and Experiment / **24**

Capture of DM in Compact Stars

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Neutron stars harbour matter under extreme conditions, providing a unique testing ground for fundamental interactions.

Dark matter can be captured by neutron stars via scattering, where kinetic energy is transferred to the star.
This can have a number of observational consequences, such as theheating of old neutron stars to infra-red temperatures.
Previous treatments of the capture process have employed various approximation or simplifications.
We present here an improved treatment of dark matter capture, valid for a wide dark matter mass range, that correctly incorporates all relevant physical effects.
These include gravitational focusing, a fully relativistic scattering treatment, Pauli blocking, neutron star opacity and multi-scattering effects.
We provide general expressions that enable the exact capture rate to be calculated numerically, and derive simplified expressions that are valid for particular interaction types or mass regimes and that greatly increase the computational efficiency.
Our formalism is applicable to the scattering of dark matter from any neutron star constituents, or to the capture of dark matter in other compact objects.
We apply these results to scattering of dark matter from neutrons, protons, leptonic targets, as well as exotic Baryons.
For leptonic Targets, a relativistic description is essential. Regarding Baryons, we outline two important effects that are missing from most evaluations of the dark matter capture rate in neutron stars.
As dark matter scattering with nucleons in the star involves large momentum transfer, nucleon structure must be taken into account via a momentum dependence of the hadronic form factors.
In addition, due to the high density of neutron star matter, we should account for nucleon interactions rather than modeling the nucleons as an ideal Fermi gas.
Properly incorporating these effects is found to suppress the dark matter capture rate by up to three orders of magnitude.

We find that the potential neutron star sensitivity to DM-lepton scattering cross sections greatly exceeds electron-recoil experiments, particularly in the sub-GeV regime, with a sensitivity to sub-MeV DM well beyond the reach of future terrestrial experiments.
We present preliminary results for DM-Baryons scatterings in Neutron stars, were the sensitivity is expected to greatly exceed current DD experiments for the spin-dependent case in the whole masse range, and for spin-independent in the low and high mass range.
Regarding White Dwarfs, for dark matter-nucleon scattering, we find that white dwarfs can probe the sub-GeV mass range inaccessible to direct detection searches, with the low mass reach limited only by evaporation, and can be competitive with direct detection in the 1 GeV – 10 TeV range.
White dwarf limits on dark matter-electron scattering are found to outperform current electron recoil experiments over the full mass range considered, and extend well beyond the ~ 10 GeV mass regime where the sensitivity of electron recoil experiments is reduced.

Alternative theories to SUSY / 25

Sifting through the SM for the hints of an ALP

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Axion-like particles (ALPs) are at the forefront of physics research, especially at the intensity frontier, dealing with light weakly coupled particles. A plethora of different experiments searches for signals of the ALP in many different final states using innovative search strategies. We present a different perspective on ALP searches, concentrating on the modifications that such a particle causes to the known Standard Model (SM) results. The presence of a low lying ALP modifies the SM in non-trivial ways. We systematically derive the leading order chiral lagrangian in the presence of an ALP (A□PT). Then, using the derived A□PT, we systematically discuss three distinct modifications to SM physics—which arise at the tree level itself: i) those to the meson mass spectrum, ii) those to hadronic form

factors, leading to modified to partial decay rate distributions of the mesons, and iii) those to the sum rules constructed out of meson decay amplitudes. As a proof of concept example of our program, we analyse semi-leptonic Kaon decay data collected by the NA48/2 collaboration to find bounds on the ALP parameter space.

Flavour physics: Theory and Experiment / **29**

Grand Unified Origin of Gauge Interactions and Families Replication

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I would like to present an intriguing new perspective into such fundamental questions as 1) the origin of the gauge interactions in the Standard Model (SM), and 2) the origin of the quark, lepton and neutrino families' replication and their fundamental properties experimentally observed in Nature. These questions can be addressed by tying together in a common framework both flavour physics and Grand Unification, which are typically treated on a different footing. Furthermore, I will elaborate on New Physics scenarios that are expected to emerge at phenomenologically relevant energy scales as sub-products of the Trinification-based Flavoured GUT that naturally explain neutrino masses and observed hierarchies in the fermion sectors of the SM as well as the emergence of observed flavour anomalies.

Particle cosmology: Theory and Experiment / **31**

A Dark Matter WIMP That Can Be Detected and Definitively Identified with Currently Planned Experiments

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We have proposed a dark matter candidate which is consistent with all current experiments, and observable in the near or foreseeable future through a wide variety of direct, indirect, and collider detection experiments [1,2]. This particle is unique in that it has (i) precisely defined couplings and (ii) a well-defined mass of about 72 GeV/c^2, providing specific cross-sections and other experimental signatures as targets for clean experimental tests. It has not yet been detected because it has no interactions other than second-order gauge couplings, to W and Z bosons. However, these weak couplings are still sufficient to enable observation by direct detection experiments which should be fully functional within the next few years, including XENONnT, LZ, and PandaX. The cross-section for collider detection at LHC energies is small – roughly 1 femtobarn – but observation may ultimately be achievable at the high-luminosity LHC, and should certainly be within reach of the even more powerful colliders now being planned. It is possible that the present dark matter candidate has already been observed via indirect detection: Several analyses of gamma rays from the Galactic center, observed by Fermi-LAT, and of antiprotons, observed by AMS-02, have shown consistency with the interpretation that these result from annihilation of dark matter particles having approximately the same mass and annihilation cross-section as the present candidate. Finally, there is consistency with the observations of Planck, which have ruled out many possible candidates with larger masses. The present theory also requires supersymmetry at some energy scale [3], and the lightest supersymmetric particle (as a subdominant component) can stably coexist with the present dark matter candidate.

[1] Reagan Thornberry, Maxwell Throm, Gabriel Frohaug, John Killough, Dylan Blend, Michael Erickson, Brian Sun, Brett Bays, and Roland E. Allen. "Experimental signatures of a new dark matter WIMP", EPL (Europhysics Letters) 134, 49001 (2021), arXiv:2104.11715 [hep-ph].
[2] Caden LaFontaine, Bailey Tallman, Spencer Ellis, Trevor Croteau, Brandon Torres, Sabrina Hernandez, Diego Cristancho Guerrero, Jessica Jaksik, Drue Lubanski, and Roland E. Allen, "A Dark Matter WIMP That Can Be Detected and Definitively Identified with Currently Planned Experiments", Universe 7, 270 (2021), arXiv:2107.14390 [hep-ph].
[3] Roland E. Allen, "Predictions of a fundamental statistical picture", arXiv:1101.0586 [hep-th].

Particle cosmology: Theory and Experiment / **33**

Amplification and oscillations in the power spectrum from features in the potential of single-field inflation

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We discuss features of the inflaton potential that can lead to a strong enhancement of the power spectrum of curvature perturbations. Such features may be either inflection points or steep decreases of the potential and enhance the power spectrum of the curvature perturbations by several orders of magnitude at certain scales. In particular, steep step-like features also produce prominent oscillatory patterns. We also see that the induced tensor power spectrum inherits the distinctive oscillatory profile of the curvature spectrum and is potentially detectable by near-future space interferometers. The enhancement of the power spectrum may trigger the production of a sizeable number of primordial black holes. This talk is based on the two following papers: "Features of the inflaton potential and the power spectrum of cosmological perturbations", K. Kefala, G.P. Kodaxis, I.D. Stamou, N. Tetradis, Phys. Rev. D 104, 023506 (2021) and "Spectrum oscillations from features in the potential of single-field inflation", I. Dalianis, G.P. Kodaxis, I.D. Stamou, N. Tetradis, A. Tsigkas-Kouvelis, Phys. Rev. D 104 (2021).

Higgs theory and experiment / **35**

A 96 GeV Higgs Boson in the 2HDM plus Singlet

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We discuss a $\sim 3\,\sigma$
signal (local) in the light Higgs-boson search
in the diphoton decay mode at ~ 96 GeV as reported by
CMS, together with a $\sim 2\,\sigma$ excess (local)
in the $b\bar{b}$ final state
at LEP in the same mass range.
We interpret this possible signal as a Higgs boson in the
2ˆHiggs Doublet Model type¯II with an additional Higgs singlet, which can be either complex (2HDMS) or real (N2HDM), where the 2HDMS so far has never been analyzed as an explanation of these excesses. An emphasis of our work are the differences between and the possible distinction of the two models in this context.
We find that the lightest CP-even Higgs boson of the two models can
equally yield a perfect fit to both excesses simultaneously, while the second lightest

state is in full agreement with the Higgs-boson measurements at
125 GeV, and the full Higgs-boson
sector is in agreement with all Higgs exclusion
bounds from LEP, the Tevatron and the LHC as well as other theoretical and
experimental constraints.
We derive bounds on the 2HDMS and N2HDM Higgs sectors from a fit to both excesses and describe how this signal can be further analyzed at
future e^+e^-colliders, such as the ILC. We analyze in
detail the anticipated precision of the coupling measurements of the
96 GeV Higgs boson at the ILC. We find that these Higgs-boson measurements at the LHC and the ILC cannot distinguish between the two Higgs-sector realizations.

Higgs theory and experiment / **36**

Phenomenology of the Dark Matter sector in the Two Higgs Doublet Model with Complex Scalar Singlet extension

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Extensions of the Two Higgs Doublet model with a complex scalar singlet (2HDMS) can accommodate all current experimental constraints and are highly motivated candidates for Beyond Standard Model Physics. It can successfully provide a dark matter candidate as well as explain baryogenesis and provides gravitational wave signals. In this work, we focus on the dark matter phenomenology of the 2HDMS with the complex scalar singlet as the dark matter candidate. We study variations of dark matter observables with respect to the model parameters and present representative benchmark points in the light and heavy dark matter mass regions allowed by existing experimental constraints from dark matter, flavour physics and collider searches. We also compare real and complex scalar dark matter in the context of 2HDMS. Further, we discuss the discovery potential of such scenarios at future colliders.

SUSY: Phenomenology and Experiment / **38**

Confronting Muon g-2 with Sleptons at LHC

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Inspired by the latest measurement of muon anomalous magnetic moment (muon g-2) by FermiLab we explore the implications about muon g-2 of supersymmetric grand unified theories (GUTs) in a class with non-universal gaugino masses at the GUT scale. The discrepancy between the Standard Model (SM) predictions and the experimental results in muon g-2 can be solved by the contributions from the supersymmetric particles, and the fundamental parameter space compatible with the muon g-2 solution typically favors light sleptons (<~ 800 GeV), charginos (<~ 900 GeV) and LSP neutralino (<~ 600 GeV). In addition to resolve the muon g-2 problem, these mass scales for sleptons, charginos

and neutralinos are in reach of LHC currently, and it is expected to have a stronger impact from LHC-Run3. We find that the chargino mass can be probed up to about 600 GeV, and LHC-Run3 is expected to test chargino up to about 700 GeV. Even though there is no direct impact on the slepton masses, these experiments are able to probe the sleptons up to about 350 GeV. However, these scales depend on the handedness of light slepton states, and one can still realize solutions with lighter charginos when the lighter slepton is mostly right-handed. The strongest impact from chargino-neutralino productions is observed when LSP is Bino-like and the chargino is Wino-like, which leads to chargino-neutralino coannihilation scenario, even though the NLSP may happen to be a lighter slepton state. The spectra of SUSY particles involving relatively light chargino, slepton together with LSP neutralino yield also interesting results which can be tested at the current dark matter experiments. In this talk, we present prospects in probing the muon g-2 resolution together with sleptons and charginos at the upcoming LHC experiments and confront it with the current and projected results from the direct dark matter detection experiments.

Flavour physics: Theory and Experiment / **39**

Probing the Lμ-Lτ Gauge Boson at the MUonE Experiment

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This talk is based on our recent paper arXiv:2109.10093.
The MUonE collaboration intends to assess the hadronic vacuum polarization contribution to the muon $g-2$ via the elastic scattering process $\mu e \to \mu e$. I will discuss the prospects of probing the $L_\mu - L_\tau$ gauge boson at the MUonE experiment. The $L_\mu - L_\tau$ gauge boson Z , which can explain the reported muon $g-2$ discrepancy, can be produced at the MUonE experiment through the process $\mu e \to \mu e Z$. The background events coming from the elastic scattering $\mu e \to \mu e$ as well as radiative process $\mu e \to \mu e \gamma$ can be removed by the kinematical cuts on the muon scattering angle and the electron energy, in addition to a photon veto. With our selection criteria, the number of signal events $\mu e \to \mu e Z$ is found to be as large as 10^3 in the parameter region motivated by the muon $g-2$ discrepancy. Our result shows that the MUonE experiment is also sensitive to new physics and therefore it can serve a double purpose.

Flavour physics: Theory and Experiment / **40**

First Results from MicroBooNE's Low Energy Excess Search and Constraints on eV-Scale Sterile Neutrino Oscillations

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The MicroBooNE collaboration recently released a series of measurements aimed at investigating the nature of the excess of low energy electromagnetic interactions observed by the MiniBooNE collaboration. In this talk, we will present the latest results from both a search of single photons in MicroBooNE, as well as a series of three independent analyses leveraging different reconstruction paradigms which look for an anomalous excess of electron neutrino events. We additionally will highlight new results that use these well-understood selections to perform a search for an eV scale sterile neutrino in the 3+1 oscillation framework. Constraints are presented for regions of sterile neutrino oscillation parameter space relevant to the Gallium/Reactor ν_e disappearance anomaly and LSND/MiniBooNE ν_e appearance anomalies.

Plenary / **41**

A toy model of holography: sparse SYK, wormholes, and chaos

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The Sachdev-Ye-Kitaev (SYK) model is a quantum mechanical model that is strongly interacting, chaotic and solvable. It is known to have a gravity dual and exhibit black hole
physics. Recently, a sparse version of SYK was proposed. These sparse SYK models can be obtained by randomly pruning the couplings of the all-to-all SYK or defined by random regular hypergraphs. The sparsity makes these models amenable to efficient computer simulations, making possible calculations out of reach in the all-to-all SYK. In this talk, I will review the sparse SYK and present results regarding two coupled sparse SYK systems –the holographic dual of a traversable wormhole–and the spectral form factor of the sparse SYK.

SUSY: Phenomenology and Experiment / **42**

MoEDAL, MAPP and the lifetime frontier

Co-author: Laura Patrizii [1]

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The unprecedented collision energy of the LHC has opened up a new discovery regime. The first LHC dedicated search experiment, MoEDAL, has inaugurated the lifetime frontier being optimised for searches of long-lived particles. MoEDAL is designed to search highly ionising particle avatars of new physics, such as magnetic monopoles and dyons, using proton and heavy-ion collisions at the LHC. The upgrade for MoEDAL at Run 3 - the MAPP detector (MoEDAL Apparatus for Penetrating Particles) - will extend the physics reach to include feebly interacting, long-lived messengers of physics beyond the Standard Model. This will allow us to explore a number of models of new physics, including dark sector models, in a complementary way to that of the main LHC detectors. The presentation will focus on recent results on magnetic monopoles, dyons, and highly charged particles, and plans for the LHC Run 3.

SUSY: Phenomenology and Experiment / **44**

Multiboson production in CMS

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This talk reviews recent measurements of multiboson production using CMS data. Inclusive and differential cross sections are measured using several kinematic observables.

SUSY: Phenomenology and Experiment / 45

Electrically charged stable particles in MoEDAL

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The MoEDAL experiment at the LHC has been designed to search for highly ionising avatars of New Physics such as magnetic monopoles and dyons. Hypothetical stable particles of single or multiple electric charge, that arise in models of supersymmetry, quirks, strangelets, Q-balls, or as black-hole remnants, can be detected in MoEDAL. The recent analysis of a prototype nuclear track detector has set limits on electric charges, extending previous bounds set by other experiments towards high charges. Studies on supersymmetric models and neutrino mass scenarios have demonstrated the MoEDAL potential to discover long-lived particles with charge in the range from one to several electrons. All these aspects of the MoEDAL experiment will be discussed in the presentation.

MoEDAL search: arXiv:2112.05806 [hep-ex]
Prospects: Eur.Phys.J.C 80 (2020) 5, 431
Eur.Phys.J.C 80 (2020) 6, 572
Eur.Phys.J.C 81 (2021) 8, 697
arXiv:2204.03667 [hep-ph]

SUSY: Phenomenology and Experiment / 46

Search for electroweak SUSY in hadronic final states with the CMS detector

Author: Noah Alexander Zipper[1]

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Results from the CMS experiment are presented for electroweak production of supersymmetric partners in hadronic final states. The searches use proton-proton collision data with luminosity up to 138 fb-1 recorded by the CMS detector at center of mass energy 13 TeV during the LHC Run 2.

Flavour physics: Theory and Experiment / 47

Anapole Moment of Majorana Fermions and Implications for Direct Detection of Neutralino Dark Matter

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In many theories dark matter is assumed to be a Majorana fermion, for which the electromagnetic anapole moment can induce an effective interaction with targets in direct detection experiments. After discussing briefly the experimental limit on the anapole moment of a DM candidate using direct detection data, we will formalize theoretical predictions for this coupling for general P breaking interactions between the Majorana fermion, a charged fermion and a scalar or vector.

This formalism is then applied to the lightest neutralino of the MSSM, for which we will present numerical results for both simplified limits and the full pMSSM. We find that the anapole moment can be enhanced by either allowing light sfermions in the spectrum or by considering a mixed neutralino state. Although the enhancement in the former case is typically larger, for the latter case the vector contribution can still lead to sizeable values of the anapole moment testable by next generation direct detection experiments.

Flavour physics: Theory and Experiment / **48**

Phenomenology of LNV in SMEFT at dimension 7

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If Majorana neutrino masses are not generated via the dimension 5 Weinberg operator, the next simplest solution would be to generate them at dimension 7. We present a comprehensive analysis of dimension 7 lepton number violating (LNV) SMEFT operators and their phenomenological consequences for a range of experimental searches. Comparing low-scale observables such as flavour violating rare decays and neutrinoless double beta decay with collider searches as well as neutrino mass constraints, we show limits on each of the different $\Delta L = 2$ SMEFT operators at dimension 7. Furthermore, we systematically consider all possible tree-level UV-completions of these operators in a covariant derivative expansion framework, leading to the identification of the most phenomenologically promising New Physics scenarios as well as capturing the effect of a hierarchy in the internal heavy degrees of freedom.

SUSY: Phenomenology and Experiment / **49**

Searches for top squarks and gluinos with the CMS detector

Author: Andrea Trapote Fernandez[1]

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Recent results on searches for supersymmetric partners of top quarks and gluons with the CMS detector are presented. The results are based on proton-proton collisions recorded at $\sqrt{s} = 13\,TeV$ with the CMS detector using the full Run 2 dataset of $138\ fb^{-1}$.

Particle cosmology: Theory and Experiment / **50**

Testing the mean field description of scalar field dark matter

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The nature of dark matter, one of the major components of the cosmic standard model, remains one of the outstanding problems in physics. One interesting model is scalar field dark matter (SFDM), which fits naturally into observations in both particle physics and cosmology. Simulations and calculations using SFDM often use a classical field approximation (MFT) of the underlying quantum field theory. And while it is suspected that large occupation numbers make this description good in the early universe, it is possible that this approximation fails during nonlinear structure growth and begins to admit important quantum corrections. To investigate this possibility, we compare simulations using the MFT to those that take into account these corrections. By studying their behavior as we scale the total number of particles in the system we can estimate how long the MFT remains an accurate description of the system. We estimate that quantum corrections begin to become important around 300 Myr. In this talk we will explain how these simulations are performed, as well as their results, and their potential implications.

Flavour physics: Theory and Experiment / **51**

Explaining lepton-flavor non-universality and self-interacting dark matter with L_mu-L_tau

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Experimental hints for lepton-flavor universality violation in the muon's magnetic moment as well as neutral- and charged-current B-meson decays require Standard-Model extensions by particles such as leptoquarks that generically lead to unacceptably fast rates of charged lepton flavor violation and proton decay. We propose a model based on a gauged $U(1)_{L_\mu - L_\tau}$ that eliminates all these unwanted decays by symmetry rather than finetuning and efficiently explains $(g-2)_\mu$, $R_{K^{(*)}}$, $R_{D^{(*)}}$, and neutrino masses. The $U(1)_{L_\mu - L_\tau}$ furthermore acts as a stabilizing symmetry for dark matter and the light Z' gauge boson mediates velocity-dependent dark-matter self-interactions that resolve the small-scale structure problems. Lastly, even the Hubble tension can be ameliorated via the light Z' contribution to the relativistic degrees of freedom.

Particle cosmology: Theory and Experiment / **54**

Dark Matter Data Center

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The quest for Dark Matter (DM) and its nature has been puzzling scientists for nearly a century. This puzzle has engendered theories that span nearly hundred orders of magnitude in mass scales with widely contrasting nature. It has also motivated decades of experimental efforts correspondingly different in the wide variety of their target masses, observables, technologies and interpretations. The last two decades have seen no less than twenty experiments designed to directly detect the Weakly Interacting Massive Particle (WIMP) paradigm of DM alone. Their sensitivities span five orders of magnitude and use Ionization, Scintillation, Heat, Sound, Images and several combinations of these as their detection methods. In addition, WIMPS are also searched for at Indirect Detection and Collider experiments. This labyrinth of theories and experiments make their analyses and combination a daunting task. The Dark Matter Data Center (DMDC) is an ORIGINS Excellence Cluster initiative,

supported by the Max Planck Computation and Data Facility (MPCDF). It aims at bringing together the large amount of recorded data and theories in a unified platform, making it easily accessible for the DM community. It offers a repository where data, methods and code are clearly presented in a unified interface for comparison, reproduction, combination and analysis. The DMDC is a forum where Experimental Collaborations can directly publish their data and Phenomenologists the implementation of their models, in accordance to Open Science principles. Alongside the repositories, it also offers easy online visualization of the hosted data. It offers an online simulation of signal predictions for experiments using model data supplied by the users, all in a friendly web-based GUI. The DMDC also hosts guidance tools from the Collaborations illustrating the usage and analysis of their data through Binders that run online and support all popular programming platforms. It hosts a continuously growing compendium of ready-to-use, copy-pastable code examples for inference and simulations. It can also provide support and computational power for comparison of model and experimental observations as well as the combination of these results using modern and robust statistical tools through similar Binders. We are already online with more databases and features being added continuously! Find us at https://www.origins-cluster.de/odsl/dark-matter-data-center

Gravity and Supergravity / 56

De Sitter vacua in gauged Supergravity and the Swampland

Author: Matteo Morittu[1]

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I will show that critical de Sitter points of gauged Supergravity are typically in conflict with the Weak Gravity Conjecture when the gravitino has a vanishing or parametrically small mass. This puts all known stable de Sitter vacua of the N=2 theory in the Swampland.

Flavour physics: Theory and Experiment / 57

A closer look at the extraction of $|V_{ub}|$ from $B \to \pi l \nu$..

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The Cabibbo-Kobayashi-Maskawa (CKM) element V_{ub} is an important input parameter for the theoretical predictions of many observables in the flavor sector as it is responsible for the CP violating phase within the Standard Model. There exists a long standing tension between the tree-level determinations using the inclusive $B \to X_u l \nu$ decays (where X_u refers to sum over all final state hadrons containing an up quark) and exclusive decays like $B \to \pi l \nu$, known as the inclusive-exclusive puzzle. We relook into the precision extraction of the CKM matrix element $|V_{ub}|$ from the tree level semileptonic $b \to u l \nu_l$ ($\ell = e, \mu$) decays, incorporating all the available inputs (data and theory) on the $B \to \pi l \nu$ ($\ell = e, \mu$) decays including the newly available inputs on the form-factors from light cone sum rule (LCSR) and Lattice QCD (LQCD) approach. We have reproduced and compared the results with the procedure taken up by the Heavy Flavor Averaging Group (HFLAV), while commenting on the effect of outliers on the fits. After removing the outliers and creating a comparable group of data-sets, we mention a few scenarios in the extraction of $|V_{ub}|$. Our best results for $|V_{ub}|^{exc.}$ are $(3.94 \pm 0.14) \times 10^{-3}$ and $(3.93^{+0.14}_{-0.15}) \times 10^{-3}$ in frequentist and Bayesian approaches, respectively, which are consistent with the most recent estimate for $|V_{ub}|^{inc.}$ from Belle-II within 1 σ confidence interval.

Particle cosmology: Theory and Experiment / 58

Novel Quark Dark Matter from Broken Twin Color

Author: Christopher Verhaaren[1]

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The twin Higgs framework offers an explanation of the little hierarchy problem while remaining consistent with the bounds on new colored states. This scenario also offers a concrete model of richly varied hidden sectors. Typically, the twin sector includes a SU(3) confining force which binds the twin quarks into hadrons. I outline how twin color can be spontaneously broken. In this case the component of the quark fields along the direction of twin color breaking can become an asymmetric dark matter candidate. I explain how this dark matter can be produced through the same mechanism as the standard model baryons and the resulting phenomenology.

Higgs theory and experiment / **59**

Hidden patterns of new physics within the Higgs Yukawa Couplings

Author: Lorenzo Diaz-Cruz[None]

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In this talk we discuss briefly some of the main lessons that have been learned from the LHC about the profile of the Higgs boson. Then, we discuss possible patterns that models of new physics could leave on the couplings of the Higgs boson. In particular we discuss the dependence of the Higgs-Yukawa couplings on the fermion masses, an argue that in multi-Higgs type models, instead of a single-line, as in the Standard Model, these couplings display multiple lines, which could be used as discriminants for these models.

Flavour physics: Theory and Experiment / **60**

The role of JUNO in leptonic unitarity test

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The Jiangmen Underground Neutrino Observatory (JUNO) is a 20 kton multi-purpose underground liquid scintillator detector currently under construction at a baseline of about 52.5 km from eight nuclear reactors in the Guangdong Province of South China. By featuring a 78% photon sensor coverage achieved via a primary calorimetry system consisting of 17,612 20-inch PMTs and an additional calorimetry system of 25,600 3-inch PMTs, JUNO is expected to enable an unprecedented 3% energy resolution at 1 MeV scale, aiming at the determination of the neutrino mass ordering. Besides its main ambitious goal, JUNO's extensive physics program includes studies of neutrinos from the Sun, the atmosphere, supernovae, and planet Earth, as well as explorations of physics beyond the Standard Model.

In this respect, thanks to its unparalleled size and energy resolution, JUNO will enable the simultaneous observation of the Δm^2_{31}, Δm^2_{21}, $\sin^2\theta_{12}$, and $\sin^2\theta_{13}$ oscillation parameters and is expected to determine the first three to a world-leading precision better than 0.6% within six years of data taking. The unmatched sub-percent precision on the oscillation parameters will permit JUNO to scrutinize the unitarity of the 3×3 Pontecorvo-Maki-Nakagawa-Sakata matrix describing neutrino

mixing, fundamental to probe and constrain the flavor mixing parameters associated to possible new physics, and possibly shedding light on the underlying dynamics responsible for neutrino mass generation and lepton flavor mixing. In this talk I will present the role of JUNO in a new era of precision in the neutrino sector which will pave a way to potentially discover physics beyond the Standard Model.

SUSY: Phenomenology and Experiment / **62**

Searches for top squarks in compressed scenarios

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Results are presented from searches for the pair production of the lightest supersymmetric partner of the top quark (stop) targeting compressed scenarios, including four-body decays of the stop. The final states are challenging because of the low momentum of visible decay products. A variety of techniques, including multivariate approaches, are used to address the challenges. The results are based on proton-proton collisions recorded at sqrt(s) = 13 TeV with the CMS detector using the full Run 2 dataset of 137 fb-1.

SUSY: Phenomenology and Experiment / **63**

Search for SUSY in tau lepton final states with the CMS experiment

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Results from the CMS experiment are presented for searches for supersymmetric particle production with tau leptons in the final state. The searches use proton-proton collision data with luminosity up to 138 fb-1 recorded by the CMS detector at center of mass energy 13 TeV during the LHC Run 2.

Flavour physics: Theory and Experiment / **64**

Searching for Proton Decay in JUNO

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Proton Decay is a main consequence of Baryon Number Violation and is predicted in several Grand Unified Theories (GUTs). It is one of the conditions to explain the asymmetry of matter and antimatter in our universe. One of the main proton decay channels favored by supersymmetric GUTs is p to K^+ and $\bar{\nu}$. By now, Super-Kamiokande has set a lower lifetime limit of 5.9×10^{33} years for this channel. The Jiangmen Underground Neutrino Observatory (JUNO) is a 20 kton liquid scintillator

detector currently under construction in China and is expected to reach the order of 10^{34} years after ten years of data taking.

In this talk, I present a general strategy of JUNO for the search of the proton decay and main background reactions due to atmospheric neutrinos will be discussed. One open issue is the still unknown quenching behavior of the K^+ in the scintillator of JUNO, which we aim to solve in dedicated experiments at accelerators.

Higgs theory and experiment / **65**

Search for a susy heavy neutral Higgs boson at the LHC in the BLSSM

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The Higgs sector of the supersymmetric $B-L$ extension of the Standard Model (BLSSM) consists of 4 neutral CP-even bosons, 2 neutral CP-odd bosons and one charged Higgs boson. In this model, We show that the lightest CP-even Higgs boson, which is like the standard model Higgs boson, and the next lightest Higgs boson are generated from the neutral components of the two electroweak Higgs doublets. We also show that the mass of the next lightest Higgs boson can be of an order of a few hundred GeVs. We analyze the detection of the next lightest Higgs boson, h', at the Large Hadron Collider (LHC) for a center-of-mass energy $\sqrt{s} = 14$ TeV and integrated luminosity $L_{\rm int} = 300\ fb^{-1}$ via di-Higgs channel: $h' \to hh \to b\bar{b} + 2\gamma$ and also in both, the ZZ channel: $h' \to ZZ \to 4\ell$ and WW-channel with missing energy (MET) in the final state: $h' \to WW \to 2\ell + \text{MET}$ ($\ell = e, \mu$). We consider three benchmark points for this analysis in the quite low, moderate and high scale of mass ranges with $m_{h'} = 250, 400$ GeV, and $m_{h'} = 600$ GeV. We show that promising signals with good statistical significances can be obtained in di-Higgs channel, with diphoton and $2b$-jets final states and the final leptonic decay ZZ- and WW-channels.

SUSY: Phenomenology and Experiment / **66**

Digging deeper into SUSY parameter space with the CMS experiment

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Since the classic searches for supersymmetry have not given any strong indication for new physics, more and more supersymmetry searches target the more difficult, unconventional, or specific scenarios. This talk focuses on searches looking for signatures of stealth and R-parity-violating supersymmetry as well as SUSY models with long-lived particles or with compressed mass spectra that require dedicated analysis techniques. The results are based on proton-proton collisions recorded at $\sqrt{s}$ = 13 TeV with the CMS detector.

Particle cosmology: Theory and Experiment / **68**

Light thermal dark matter and its possible probes

Authors: Shigeki Matsumoto[1]; Sreemanti Chakraborti[2]; Tobias Binder[1]; Yu Watanabe[1]

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We study a minimal model for light scalar dark matter (DM) which requires a light scalar mediator to address the core-cusp problem as well as to interact with the standard model. We focus on the Breit-Wigner resonance for the DM annihilation and self-scattering channels. The thermally-averaged annihilation cross-section of DM has strong temperature dependence, whereas its energy exchange by elastic scattering with the thermal bath particles is suppressed. This leads to the early kinetic decoupling of DM and modifies the standard calculation of the relic density. A systematic analysis of the model is done involving the latest and future constraints such as the CMB observations, indirect dark matter detection and the collider searches of the invisibly decaying mediator. In particular, we address the indirect search prospects for dark matter of mass range from sub-GeV to a few GeV with cosmic ray and gamma/X-ray observations.

Higgs theory and experiment / 69

New constraints on extended Higgs sectors from the trilinear Higgs coupling

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The trilinear Higgs coupling λ_{hhh} is a crucial tool to investigate the structure of the Higgs potential and to probe possible effects of physics beyond the Standard Model (SM). Focusing on the Two-Higgs-Doublet Model (2HDM) as a concrete example, I will discuss the calculation of the leading two-loop corrections to λ_{hhh}, and show that this coupling can be significantly enhanced with respect to its SM prediction in certain regions of parameter space. I will show that the current experimental bounds on λ_{hhh} are already sufficient to rule out significant parts of the 2HDM parameter space that would otherwise be unconstrained. Finally, I will present a benchmark scenario illustrating the interpretation of the current results and future measurement prospects of λ_{hhh}.

Higgs theory and experiment / 70

External-leg corrections as an origin of large logarithms

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Obtaining precise theoretical predictions for both production and decay processes of heavy new particles is of paramount importance to constrain the allowed parameter space of BSM models and to properly assess the sensitivity for discoveries and for discriminating between different BSM scenarios. In this context, it is well known that large logarithmic corrections can appear in the presence of widely separated mass scales.
In this talk, I will point out the existence of a new class of possible large, Sudakov-like, logarithms,

appearing in external-leg corrections of heavy scalars. In constrast to usual Sudakov logarithms, these can furthermore potentially be enhanced by large trilinear couplings. I will show that such large logarithms are associated with infrared singularities and examine several techniques to address these. In addition to a discussion at one loop, I will also present the derivation of the two-loop corrections containing this type of large logarithms, pointing out in this context the importance of adopting an on-shell renormalisation scheme. I will illustrate this discussion with examples of decay processes involving heavy scalars in the Minimal Supersymmetric Standard Model (MSSM) and the singlet-extended Two-Higgs-Doublet Model (N2HDM).

Gravity and Supergravity / **71**

Dynamically induced Planck scale and inflation in Palatini quadratic gravity

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In this talk we will consider a model of infation in the Palatini formulation of gravity with the addition of quadratic in curvature terms in the usual Einstein-Hilbert action.
The model under consideration corresponds to a two-field scalar-tensor theory, that involves the Higgs field and an extra scalar field stemming from a gauge U(1)_X extension of the Standard Model, which contains an extra gauge boson and three right-handed neutrinos. By means of the Gildener-Weinberg approach, we describe the infationary dynamics in terms of a single scalar degree of freedom along the flat direction of the tree-level potential. The one-loop effective potential in the Einstein frame exhibits plateaus on both sides of the minimum and thus the model can accommodate both small and large field inflation. The Planck scale is dynamically generated when the scalar field coupled to gravity develop their vacuum expectation values. The infationary predictions are found to comply with the latest bounds set by the Planck collaboration.

Plenary / **72**

A challenge for the cosmological standard model

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The standard model of cosmology is based on the assumption that the universe is (statistically) isotropic and homogeneous. The dipole anisotropy of the CMB must then be attributed to our peculiar motion, due to local inhomogeneity, wrt the cosmic rest frame in which the CMB looks isotropic. If so, there should be a corresponding dipole in the skymap of high redshift sources. Using catalogues of radio sources & quasars we find however that the observed dipole is ˜twice what is expected. This calls into question the assumption of the FLRW metric and the consequent inference that the universe is dominated by dark energy.

SUSY: Phenomenology and Experiment / **73**

Search for electroweak SUSY in leptonic final states with the CMS detector

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Results from the CMS experiment are presented for electroweak production of supersymmetric partners in leptonic final states. Searches are performed for a wide range of SUSY spectra including so-called compressed spectra. The searches use proton-proton collision data with luminosity up to 138 fb-1 recorded by the CMS detector at center of mass energy 13 TeV during the LHC Run 2.

Flavour physics: Theory and Experiment / **74**

Assessment of the Dimension-5 Seesaw Portal and Impact on Non-Pointing Photon Searches from Exotic Higgs Decays

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The Dimension-5 Seesaw Portal is a Type-I Seesaw model extended by d=5 operators involving the sterile neutrino states, leading to new interactions between all neutrinos and the Standard Model neutral bosons. In this work we focus primarily on the implications of these new operators at the GeV-scale. In particular, we recalculate the heavy neutrino full decay width, up to three-body decays. We also review bounds on the dipole operator, and revisit LEP constraints on its coefficient. Finally, we turn to heavy neutrino pair production from Higgs decays, where the former are long-lived and disintegrate into a photon and a light neutrino. We probe this process by recasting two ATLAS searches for non-pointing photons, showing the expected event distribution in terms of arrival time t_γ and pointing variable $|z_\gamma|$.

Gravity and Supergravity / **75**

Ising Universe

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We consider a real scalar field in de Sitter background and compute its thermal propagators.
We propose that non-trivial thermal effects in the |out⟩ vacuum can be encoded in the anomalous dimensions of the d = 3 Ising model. One of these anomalous dimensions, the critical exponent η, fixes completely a number of cosmological observables, which we compute.

Higgs theory and experiment / **76**

Trilinear Higgs self-coupling in supersymmetric models

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The Higgs self-coupling is the only Standard Model parameter that has not been measured directly. On the other hand the self-coupling is related to the Higgs mass. In the MSSM the Higgs self-coupling is practically fixed and hence allows no large deviations from the SM, while nonminimal models can have different ways of achieving the 125 GeV Higgs mass, which can then lead to a non-SM-like Higgs self-coupling. I shall discuss which models allow a larger or smaller Higgs trilinear coupling and what would these mean for di-Higgs production.

Particle cosmology: Theory and Experiment / **77**

Primordial black holes and Gravitational waves from inflationary models based on supergravity.

Author: Ioanna Stamou[1]

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We study models of cosmic inflation in order to explain the production of primordial black holes (PBHs), which can amount of a significant fraction of dark matter (DM) in the universe and the induced gravitational waves (GWs). In particular, we present mechanisms which lead to an enhancement of the scalar power spectrum at small scales. This amplification can explain the generation of PBHs and GWs at the radiation dominated era because of the previous epoch of inflation.
The models which we present are based on supergravity theories. Specifically, in the first mechanism we present models, where their potential has an inflection point. These models are based on no-scale theory. Secondly, we refer a model based on alpha-attractors and the corresponding mechanism of the enhancement is sharp features in the potentials. Finally, we present a hybrid model with a waterfall trajectory which can lead to a significant enhancement of scalar power spectrum. In the last mechanism we have imposed supergravity corrections. All models presented are in complete consistent with the constraints of inflation given by the Planck collaboration.

Particle cosmology: Theory and Experiment / **81**

PBHs and GWs from an early matter era

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A low reheating temperature is predicted by many supersymmetric extensions of the Standard Model. This implies that an extended early matter domination era (eMD) might have occurred in the universe during the first seconds of the cosmic evolution. In this talk I will present how the density perturbations grow and primordial black holes (PBHs) can form during eMD. Emphasis will be given to the production of the associated gravitational wave (GW) signal, its particular spectral characteristics and the detection prospects that can be also seen as a probe of the eMD cosmological scenario.

SUSY: Phenomenology and Experiment / **82**

Measurements of top quark production cross sections in CMS

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Recent measurements of inclusive and differential cross sections for top quark pair or single top productions are presented using the data collected by the CMS detector. The differential cross sections are measured multi-differentially as a function of various kinematic observables of top quarks, jets, leptons of the event final state. Results for ttbar cross sections are compared to precise theory calculations, among them also MINNLO+PS for the first time. The single top quark analyses investigate separately the production of top quarks via the associated production with a W boson (tW) or via the s-channel.

Flavour physics: Theory and Experiment / 83

Muon g-2 and lepton flavor violation in SUSY-GUT theories.

Authors: Cem Salih Un[1]; Magda Lola[None]; Mario E. Gomez[None]; Qaisar Shafi[None]

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We found SUSY contribution to the muon g-2 can be compatible with its observed value. In models where Supersymmetry is broken though Supergravity this can be achieved if the soft masses are generated by TeV gaugino masses and light gravitinos. These scenarios provide a natural explanation for not observing lepton flavor violation (LFV) on charged leptons , even if the soft scalar masses are flavor dependent at the GUT scale. In this work we study SUSY models with SU(4)_cxSU(2)_LXSU(2)_R unification extended with an additional family symmetries to explain flavor. We find that the kind of models explaining muon g-2 can have as well LFV predictions of experimental interest.

Plenary / 84

Precision Higgs Physics at Current and Future Colliders

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Studying the properties of the Higgs boson can be an important window to explore the physics beyond the Standard Model. In this work, we present studies on the implications of the Higgs precision measurements at future Higgs Factories on various types of two Higgs Doublet Models. We perform a global fit to various Higgs search channels to obtain the 95% C.L. constraints on the model parameter spaces of 2HDMs. We also compare the sensitivity of various future Higgs factories, namely, Circular Electron Positron Collider (CEPC), Future Circular Collider (FCC)-ee and International Linear Collider (ILC). We explore the discovery potential based on the hypothetical deviations in the precision data for the 2HDMs up to one-loop level.

Higgs theory and experiment / **85**

2HDM Neutral Scalars under the LHC

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Two Higgs Doublet Models (2HDM) provide a simple framework for new physics models with an extended Higgs sector. The current LHC results, including both direct searches for additional non-Standard Model (SM) Higgs bosons, as well as precision measurements of the SM-like Higgs couplings, already provide strong constraints on the 2HDM parameter spaces. In this work, we examine those constraints for the neutral scalars in the Type-I and Type-II 2HDM. In addition to the direct search channels with SM final states: H/A→ff,VV,Vh,hh, we study in particular the exotic decay channels of H/A→AZ/HZ once there is a mass hierarchy between the non-SM Higgses. We found that H/A→AZ/HZ channel has unique sensitivity to the alignment limit region which remains unconstrained by conventional searches and Higgs precision measurements. This mode also extends the reach at intermediate tanβ for heavy mA that are not covered by the other direct searches.

SUSY: Phenomenology and Experiment / **86**

Vector boson scattering results in CMS

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Vector boson scattering is a key production process to probe the electroweak symmetry breaking of the standard model, since it involves both self-couplings of vector bosons and coupling with the Higgs boson. If the Higgs mechanism is not the sole source of electroweak symmetry breaking, the scattering amplitude deviates from the standard model prediction at high scattering energy. Moreover, deviations may be detectable even if a new physics scale is higher than the reach of direct searches. Latest measurements of production cross sections of vector boson pairs in association with two jets in proton-proton collisions at sqrt(s) = 13 TeV at the LHC are reported using a data set recorded by the CMS detector. Differential fiducial cross sections as functions of several quantities are also measured.

Higgs theory and experiment / **87**

Two-loop investigation of new physics effects on the W-boson mass from a doublet extension of the SM Higgs sector

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Recently, the CDF collaboration has reported a new precision measurement of the W-boson mass M_W, exhibiting a large deviation from the value predicted by the Standard Model (SM).
In this talk, I will investigate possible new physics contributions to M_W from extended Higgs sectors, focusing on the Two-Higgs-Doublet Model (2HDM) as a concrete example. Employing predictions for the electroweak precision observables in the 2HDM at the two-loop level and taking into account further theoretical and experimental constraints, I will identify parameter regions of the 2HDM in which the prediction for M_W is close to the new CDF value. I will additionally discuss the compatibility of these regions with precision measurements of the effective weak mixing angle and the total width of the Z boson.

Higgs theory and experiment / **88**

Search for rare and exotic decays of the Higgs boson in ATLAS

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The study of the Higgs boson properties provides a unique window for the discovery of new physics at the LHC. New phenomena can in particular be revealed in the search for rare, lepton-flavor-violating or exotic decays of the Higgs boson, as well as in its possible couplings to hidden-sector states that do not interact under Standard Model gauge transformations. This talk presents recent searches by the ATLAS experiment for rare decays of the Higgs boson where enhanced rates would be a sign of new physics, and searches for decays of the Higgs boson to new particles, using collision data at sqrt(s) = 13 TeV collected during the LHC Run 2.

Higgs theory and experiment / **89**

Measurements of the Higgs boson couplings and their interpretations with the ATLAS experiment

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Very detailed measurements of Higgs boson properties and its interactions can be performed with the full Run 2 pp collision dataset collected at 13 TeV, shining light over the electroweak symmetry breaking mechanism. This talk presents the latest measurements of the Higgs boson coupling properties by the ATLAS experiment in various decay bosonic and fermionic channels, as well as their combination. Results on production mode cross sections, Simplified Template Cross Sections, and their interpretations are presented. Specific scenarios of physics beyond the Standard Model are tested, as well as a generic extension in the framework of the Standard Model Effective Field Theory, and in the framework of an Effective Field Theory.

Higgs theory and experiment / **90**

Measurement of Higgs boson fiducial and differential cross sections with the ATLAS detector

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With the pp collision dataset collected at 13 TeV, detailed measurements of Higgs boson properties can be performed. The Higgs kinematic properties can be measured with increasing granularity

and interpreted to constrain beyond-the-Standard-Model phenomena. This talk presents the measurements of the Higgs boson fiducial and differential cross sections exploiting various Higgs boson decays, as well as their combination and interpretations.

Higgs theory and experiment / **91**

Measurements of the mass, width and coupling CP structure of the Higgs-boson with the ATLAS detector

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Measurements of the fundamental properties of the Higgs boson are presented, including its mass, width, and the CP properties of its coupling in various production modes and decay channels.

Higgs theory and experiment / **92**

Probing the nature of electroweak symmetry breaking with Higgs boson pair-production at ATLAS

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In the Standard Model, the ground state of the Higgs field is not found at zero but instead corresponds to one of the degenerate solutions minimising the Higgs potential. In turn, this spontaneous electroweak symmetry breaking provides a mechanism for the mass generation of nearly all fundamental particles. While the Standard Model makes a definite prediction for the Higgs boson self-coupling and thereby the shape of the Higgs potential, enhanced rates and modified kinematic properties of Higgs boson pair (HH) production are a smoking-gun signature for new physics. In the case of SUSY, this may appear as new loop contributions in non-resonant HH production or via new scalar resonances decaying to HH. In this talk, the latest searches for Higgs boson pairs by the ATLAS experiment are reported, with emphasis on the results obtained with the full LHC Run 2 dataset at 13 TeV. In the case of non-resonant HH searches, results are interpreted both in terms of sensitivity to the Standard Model and as limits on the Higgs boson self-coupling. Extrapolations of recent HH results towards the High Luminosity LHC upgrade are also discussed. Search results on new resonances decaying into pairs of Higgs bosons are also reported.

Higgs theory and experiment / **93**

Searches for additional Higgs bosons in ATLAS

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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 to solely explain some observations. Many extensions of the Standard Model addressing such shortcomings, including several SUSY benchmark models, introduce additional Higgs-like bosons which can be either neutral or charged. The current status of searches for additional low- and high-mass Higgs bosons based on the full LHC Run 2 dataset of the ATLAS experiment at 13 TeV are presented.

SUSY: Phenomenology and Experiment / 94

Searches for strong production of supersymmetric particles with the ATLAS detector

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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 for weak-scale supersymmetry favour supersymmetric partners of the gluons and third generation quarks with masses light enough to be produced at the LHC. 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. It covers both R-parity conserving models that predict dark matter candidates and R-parity violating models that typically lead to high-multiplicity final states without large missing transverse momentum.

SUSY: Phenomenology and Experiment / 95

Searches for electroweak production of supersymmetric particles with the ATLAS detector

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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 lead to difficult searches, despite relatively clean final states. 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. Models are targeted in both R-parity conserving as well as R-parity violating scenarios.

SUSY: Phenomenology and Experiment / 96

ATLAS searches for supersymmetry with long-lived particles

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Various Supersymmetry (SUSY) scenarios, including split SUSY and anomaly or gravity-mediated SUSY-breaking scenarios, lead to signatures with long-lived particles. Searches for these processes may target either the long lived particle itself or its decay products at a significant distance from the collision point. These signatures provide interesting technical challenges due to their special reconstruction requirements as well as their unusual backgrounds. This talk will present recent results in long-lived SUSY searches using ATLAS Run 2 data.

SUSY: Phenomenology and Experiment / 97

Search for long-lived particles with large ionisation energy loss

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This talk presents a search for long-lived particles with the ATLAS detector at the LHC based on the full Run 2 dataset. Such particles would move slower than the speed of light and can be identified using their high transverse momenta and large specific ionisation losses (dE/dx). Using the dE/dx measurement from the pixel detector layer provides sensitivity to particles with lifetimes down to approximately 1 ns with a mass ranging from 100 GeV up to 3 TeV. Interpretations for pair-production of long-lived R-hadrons, charginos and staus are presented, with sensitivity that significantly surpasses that of previous searches.

SUSY: Phenomenology and Experiment / 98

Searches for dark matter with the ATLAS detector

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The presence of a non-baryonic Dark Matter (DM) component in the Universe is inferred from the observation of its gravitational interaction. If Dark Matter interacts weakly with the Standard Model (SM) it could be produced at the LHC. The ATLAS experiment has developed a broad search program for DM candidates in final states with large missing transverse momentum produced in association with other particles (light and heavy quarks, photons, Z and H bosons, as well as additional heavy scalar particles) called mono-X searches. The results of recent searches on 13 TeV pp data, their interplay and interpretation will be presented.

SUSY: Phenomenology and Experiment / 99

Searches for new physics with leptons using the ATLAS detector

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Many theories beyond the Standard Model predict new phenomena, such as Z', W' bosons, or heavy leptons, in final states with isolated, high-pt leptons (e/mu/tau). Searches for new physics with such signatures, produced either resonantly or non-resonantly, are performed using the ATLAS experiment at the LHC. This includes a novel search that exploits the lepton-charge asymmetry in events with an electron and muon pair. Lepton flavor violation (LFV) is a striking signature of potential beyond the Standard Model physics. The search for LFV with the ATLAS detector focuses on the decay of the Z boson into different flavour leptons (e/mu/tau). The recent 13 TeV pp results will be reported.

SUSY: Phenomenology and Experiment / 100

Searches for BSM physics using challenging and long-lived signatures with the ATLAS detector

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Various theories beyond the Standard Model predict new, long-lived particles with unique signatures which are difficult to reconstruct and for which estimating the background rates is also a challenge. Signatures from displaced and/or delayed decays anywhere from the inner detector to the muon spectrometer, as well as those of new particles with fractional or multiple values of the charge of the electron or high mass stable charged particles are all examples of experimentally demanding signatures. The talk will focus on the most recent results using 13 TeV pp collision data collected by the ATLAS detector.

SUSY: Phenomenology and Experiment / **101**

Searches for new phenomena in final states with 3rd generation quarks using the ATLAS detector

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Many theories beyond the Standard Model predict new phenomena, such as heavy vectors or scalar, vector-like quarks, and leptoquarks in final states containing bottom or top quarks. Such final states offer great potential to reduce the Standard Model background, although with significant challenges in reconstructing and identifying the decay products and modelling the remaining background. The recent 13 TeV pp results, along with the associated improvements in identification techniques, will be reported.

Flavour physics: Theory and Experiment / **102**

ATLAS measurements of CP violation and rare decay processes with beauty mesons

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The ATLAS experiment has performed measurements of B-meson rare decays proceeding via suppressed electroweak flavour changing neutral currents, and of mixing and CP violation in the neutral B_s^0 meson system. This talk will focus on the latest results from the ATLAS collaboration, such as rare processes $B_s^0 \to \mu\mu$ and $B_d^0 \to \mu\mu$, and CP violation in $B_s^0 \to J/\psi\ \phi$ decays. In the latter, the Standard Model predicts the CP violating mixing phase, ϕ_s, to be very small and its SM value is very well constrained, while in many new physics models large ϕ_s values are expected. The latest measurements of ϕ_s and several other parameters describing the $B_s^0 \to J/\psi\ \phi$ decays will be reported.

SUSY: Phenomenology and Experiment / **104**

Exploring Parameter Spaces with Artificial Intelligence and Machine Learning Black-Box Optimisation Algorithms

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Validating Beyond the Standard Model (BSM) theories usually involves scanning highly multi-dimensional parameter spaces and check observable predictions against experimental bounds and theoretical constraints. Such task is often timely and computationally expensive, namely when the BSM model is severely constrained leading to very low random sampling efficiency. In this work we tackled this challenge using Artificial Intelligence and Machine Learning search algorithms used for Black-Box optimisation problems. Using the cMSSM and the pMSSM parameter spaces, we considered both the Higgs mass and the Dark Matter Relic Density constraints to study their sampling efficiency and parameter space coverage. We find our methodology to produce orders of magnitude improvement of sampling efficiency whilst reasonably covering the parameter space.

Particle cosmology: Theory and Experiment / **105**

Low-mass dark matter in the complex NMSSM

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The Higgs sector of the Next-to-Minimal Supersymmetric Standard Model can accommodate explicit CP-violating phases at the tree level, unlike the minimal scenario. In particular, the phase of the parameter that governs the singlet-singlino mass is relevant for the phenomenology of the dark matter in the model also, when R-parity is conserved. A small magnitude of this parameter can yield a fairly light, $O(1)$ GeV, singlino-dominated neutralino dark matter, which still satisfies the observed relic abundance of the Universe. We performed a detailed investigation of the impact of the CP-violating phase on the properties of such a dark matter, in parameter space regions of the model that are consistent with a variety of current experimental data.

SUSY: Phenomenology and Experiment / **106**

Recent HL-LHC projections from CMS

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Recent HL-LHC studies that were performed by CMS within Snowmass activities are presented. Updates cover different physics topics including also NP processes.

Particle cosmology: Theory and Experiment / **107**

Heterodyne Detection of Axion Dark Matter in an RF Cavity

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I will present a recently proposed approach to detect photon-coupled dark matter axions in an RF cavity. The approach relies on axion-mediated transitions between nearly-degenerate resonant modes, leading to parametrically enhanced signal power for light axions. We will discuss how a resonant signal is generated, and how it compares with traditional haloscope searches. We will also discuss noise sources. This approach could probe axion masses across fifteen orders of magnitude, all in a metre-scale cavity.
Time permitting, I will comment on the parallels between axion and gravitational wave detection.

Plenary / 108

Recent results from the MicroBooNE experiment

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The MicroBooNE collaboration recently released a series of measurements aimed at investigating the nature of the excess of low energy electromagnetic interactions observed by the MiniBooNE collaboration. In this talk, we will present the latest results from both a search of single photons in MicroBooNE, as well as a series of three independent analyses leveraging different reconstruction paradigms which look for an anomalous excess of electron neutrino events in the Fermilab Booster neutrino beam. This talk will present details of these recent results including event selection, background estimation, systematic uncertainty analysis and cross-checks to demonstrate the robustness of analysis.

Flavour physics: Theory and Experiment / 109

Predictions for flavorful Z' searches from asymptotic safety

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We use the framework of asymptotically safe quantum gravity to derive predictions for New Physics (NP) models with an extra U(1)' symmetry as a solution to the b $\to$ s flavor anomalies. We study three different (but similar) models with vector-like (VL) fermions and a scalar whose vev breaks the U(1)' symmetry. The flavor-violating coupling of the new gauge boson Z' with the b and s quarks is generated via the mixing with the VL quarks. The coupling of Z' with muons is obtained either by the mixing with VL leptons, or directly by identifying U(1)' with a $L_\mu - L_\tau$ symmetry.

The presence of an interactive UV fixed point in the system of gauge and Yukawa couplings of our NP models imposes a set of boundary conditions at the Planck scale, which allows one to determine low-energy values of the NP Yukawa vector elements. As a consequence, the allowed NP mass range consistent with the solution to the b-s anomalies can be significantly narrowed down.

We also confront the models with the null results of the LHC searches for VL fermions and the new gauge boson Z'.

Flavour physics: Theory and Experiment / **110**

A Tale of Flavor Anomalies and the Origin of Neutrino Mass

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Experimental hints for lepton flavor universality violation in beauty-quark decay both in neutral- and charged-current transitions require an extension of the Standard Model for which scalar leptoquarks (LQs) are the prime candidates. Besides, these same LQs can resolve the long-standing tension in the muon and the recently reported deviation in the electron $g-2$ anomalies. These tantalizing flavor anomalies have discrepancies in the range of $2.5\sigma - 4.2\sigma$, indicating that the Standard Model of particle physics may finally be cracking. In this Letter, we propose a resolution to all these anomalies within a unified framework that sheds light on the origin of neutrino mass while satisfying all constraints from collider searches, including those from flavor physics.

SUSY and String models / **111**

Hybrid inflation and waterfall field in string theory from D7-branes

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In this talk, I will present an explicit string realisation of a cosmological inflationary scenario within the framework of type IIB flux compactifications in the presence of three magnetised D7-brane stacks. Inflation takes place around a metastable de Sitter vacuum. The scalar potential of the inflaton, identified with the volume modulus, exhibits a very shallow minimum. Inflation ends due to the presence of "waterfall" fields that drive the evolution of the Universe from a nearby saddle point towards a global minimum with tuneable vacuum energy describing the present state of our Universe. Such implementation of hybrid inflation, explained in detail in a toroidal orbifold case, is generic to models where the inflaton is identified with a Kähler modulus and does not necessarily restrict to our particular setup.

Gravity and Supergravity / **112**

New Methods for Old Problems: Vacua of Supergravity Theories

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Charting and analysing vacua of supergravity theories is a fundamental task to find which models can be related to String Theory as well as to understand supersymmetry breaking, the possible mechanisms to generate critical points with a positive value of the cosmological constant and which supergravities lead to Anti-de Sitter (AdS) vacua with an interesting holographic dual. Among all possible theories, the maximally supersymmetric ones stand out for their fixed matter content and the limited number of possible deformations. In this talk I will present some new techniques, borrowed from Cryptography and AI, to tackle this problem in five and seven space-time dimensions. I will also discuss how to recover analytical results starting from numerical analysis.

SUSY: Phenomenology and Experiment / **114**

Exploring nearly degenerate higgsinos using mono-Z/W signal

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We propose a new search strategy for higgsinos. Assuming associated production of higgsino-like pairs with a W or Z boson, we search in the missing energy plus hadronically-tagged vector boson channel. We place sensitivity limits for (HL-)LHC searches assuming O(1–3.5 GeV) mass differences between the lightest neutral and charged states. We point out that using the $E_T^{\rm miss}$ distribution significantly increases the sensitivity of this search. We find the higgsinos up to 110 (210) GeV can be excluded with 139 (300) fb−1 data. The full data of the HL-LHC will exclude (discover) the higgsinos up to 520 (280) GeV. This work is based on arXiv:2110.04185 published in PLB.

Particle cosmology: Theory and Experiment / **116**

Supersymmetry and dark matter extensions of Higgs-R2 model

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Recently, the Higgs-R2 inflation model has been intensively studied as a UV completed model of Higgs inflation. In this talk, we discuss two directions on extensions of this model. One is supersymmetric embedding of the Higgs-R2 inflation, which provides a further UV completion. We investigate several conditions for the original successful inflation to be kept after supersymmetrization, and also discuss supersymmetry breaking and its phenomenological consequence. Another direction is DM extension. Adopting a singlet scalar dark matter, we discuss the freeze-in production of dark matter both from the non-thermal scattering during reheating and the thermal scattering after reheating.

Gravity and Supergravity / 117

Curvature invariants for accelerating, rotating and charged black holes in (anti-)de Sitter spacetime

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The curvature scalar invariants of the Riemann tensor are important in General Relativity because they allow a manifestly coordinate invariant characterisation of certain geometrical properties of spacetimes such as, among others, curvature singularities, gravitomagnetism. We calculate explicit analytic expressions for the set of Zakhary-McIntosh curvature invariants for accelerating Kerr-Newman black holes in (anti-)de Sitter spacetime as well as for the Kerr-Newman-(anti-)de Sitter black hole.
These black hole metrics belong to the most general type D solution of the Einstein-Maxwell equations with a cosmological constant.
Explicit analytic expressions for the Euler-Poincare density invariant, which is relevant for the computation of the Euler-Poincare characteristic $\chi(M)$, and the Kretschmann scalar are also provided for both cases.
We perform a detailed plotting of the curvature invariants that reveal a rich structure of the spacetime geometry surrounding the singularity of a rotating, electrically charged and accelerating black hole . These graphs also help us in an exact mathematical way to explore the interior of these black holes.
Our explicit closed form expressions show that the above gravitational backgrounds possess a non-trivial Hirzebruch signature density. Possible physical applications of this property for the electromagnetic duality anomaly in curved spacetimes that can spoil helicity conservation are briefly discussed.

Flavour physics: Theory and Experiment / 118

Seesaw mechanism in the R-parity violating supersymmetric standard model with the gauged flavor $U(1)_X$ symmetry

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This talk is based on arXiv:2112.10337. We study the seesaw mechanism in the supersymmetric standard model (SSM) with the Z_3 symmetry called Matter triality (M_3). The Abelian discrete symmetry prohibits the baryon number violation operators at the (non-)renormalizable level, which ensures the proton longevity. The cubic coupling by the right-handed neutrinos generates the Majorana mass term after right-handed sneutrinos develop into the vacuum expectation values. Due to the R-parity violation, the active neutrinos masses can be generated not only from the mixing angles with right-handed neutrinos but also from the ones with MSSM-neutralinos. In this setup, we propose a model where M_3 is embedded into the gauged flavor symmetry. Then, the flavor charges are constrained by the anomaly cancellation conditions and the requirements to realize the fermion masses and mixing angles in the quark and lepton sectors. We analyze the assignments of the flavor charge and show that the sterile neutrinos masses are allowed to be below the soft SUSY breaking scale, which contribute to the neutrinoless double beta decay.

SUSY: Phenomenology and Experiment / 119

LHC constraints on monojet signatures from electroweakino DM and coloured-superpartner decays

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We revisit LHC searches for heavy invisible particles by exploiting QCD initial-state radiation. In the first part, we recast a monojet and a dijet signal region in a general multijet plus missing transverse momentum analyses by ATLAS. We find non-trivial mass limit can already be obtained for the Wino and Higgsino LSP scenarios with the present data of 139 fb^{-1} thoroughly from hadronic channels; $m_{\widetilde{W}} > 160$ GeV for Wino and $m_{\widetilde{h}} > 100$ GeV for Higgsino, depending on the chargino-neutralino mass splitting. We also study simplified dark matter scenarios with scalar and axial-vector mediators and derive limits on the coupling vs mediator mass planes.

In the second part , we study the application of the mono-jet channel at the LHC as a mean of searching for squarks and gluinos. We consider two separate scenarios. In the first scenario the lighter of the squark and gluino is almost mass degenerated with the lightest neutralino, which is assumed to be the lightest supersymmetric particle and stable due to the R-parity. The associated squark-gluino production, $pp \to \tilde{q}\tilde{g}$ then leads to a distinctive mono-jet signature, where the high p_T jet is produced from the decay of the heavier coloured particle into the lighter one ($\tilde{q} \to q + \tilde{g}$ for $m_{\tilde{q}} > m_{\tilde{g}}$ and $\tilde{g} \to q + \tilde{q}$ for $m_{\tilde{g}} > m_{\tilde{q}}$), and the lighter coloured particle is registered as the missing transverse energy due to the mass degeneracy with the neutralino. We recast an existing mono-jet analysis for this scenario and find non-trivial exclusion limits on the squark-gluino mass plane with heavy neutralinos. In the second scenario we assume large mass hierarchy between the squarks and the lightest electroweakino ($\tilde{\chi}$). The associated squark-wino production, $pp \to \tilde{q}\tilde{\chi}$ then leads to a mono-jet signature, where the high p_T jet is originated from the squark decay, $\tilde{q} \to q + \tilde{\chi}$. Comparing projected sensitivity of the mono-jet analysis to the associated squark-wino production and that of the standard multi-jet analysis to the squark pair production, we find that the former may be superior or at least competitive to the latter at the high-luminosity LHC if the lightest electroweakino is Wino-like.

SUSY and String models / 120

Non-local S-matrix in a solvable model

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We study implications of non-local interactions, assuming an effective gaussian localization of interaction vertices. We present the analytical form of a transition amplitude, and discuss possible phenomenological applications of this approach.

Particle cosmology: Theory and Experiment / 121

Axion dark matter from frictional misalignment

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We study the impact of sphaleron-induced thermal friction on the axion dark-matter abundance due to the interaction of an axion-like particle (ALP) with a dark non-abelian gauge sector in a secluded thermal bath. Thermal friction can either enhance the axion relic density by delaying the onset of oscillations or suppress it by damping them. We derive an analytical formula for the frictional adiabatic invariant, which remains constant along the axion evolution and which allows us to compute the axion relic density in a general set-up. Even in the most minimal scenario, in which a single gauge group is responsible for both the generation of the ALP mass and the friction force, we find that the resulting dark-matter abundance from the misalignment mechanism deviates from the standard scenario for axion masses ma 100 eV. We also generalize our analysis to the case where the gauge field that induces friction and the gauge sector responsible for the ALP mass are distinct and their couplings to the axion have a large hierarchy as can be justified by means of alignment or clockwork scenarios. We find that it is easy to open up the ALP parameter space where the resulting axion abundance matches the observed dark-matter relic density both in the traditionally over- and underabundant regimes. This conclusion also holds for the QCD axion

Alternative theories to SUSY / 123

Sky Meets Laboratory via RGE: Light Higgs Inflation, Axion and Gravitational Waves

Author: Anish Ghoshal[1]

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We investigate in a conformally extended B–L scenario radiative plateau Higgs inflation while dynamically generating the Electroweak and Seesaw scale. The inflationary flat potential is a result of cancellations of quantum corrections between the gauge and Yukawa couplings. We show the theoretically consistent parameter space regions in LHC searches for this particle as well as in CMB.

In the second part of the talk, as a solution to the SM hierarchy problem, we will discuss model-building with classical scale invariance in 4-dimensional QFT satisfying Total Asymptotic Freedom (TAF): the theory holds up to infinite energy, where all coupling constants flow to zero and is devoid of any Landau poles. Such principles if beyond the reach of LHC (TeV scale) can be tested via Gravitational Waves (GW) in LIGO, etc. As an example, we will discuss a QCD axion in the TAF scenario, with strong first order Peccei-Quinn phase transitions and produces GW.

Thus we will conclude by promoting RGE as a novel connection to complement laboratory searches of BSM with cosmological observables as probes of BSM models.

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Dynamical Generation of Dark Matter and Electroweak Scales

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The Standard Model (SM) of particle physics suffers from the hierarchy problem which can be ameliorated if all the scales that we observe in nature are considered not to be fundamental but generated

dynamically in nature. As examples, we will discuss freeze-out and freeze-in production of vector dark matter (DM) in a classically scale invariant theory, where the Standard Model (SM) is augmented with an extended gauge symmetries that are spontaneously broken due to the non-zero vacuum expectation value (VEV) of a scalar. Generating the SM Higgs mass at 1-loop level, it leaves only two parameters in the dark sector, namely, the DM mass mX and the gauge coupling gX as independent. For freeze-in, which require very feeble coupling to satisfy the relic, the scenario is testable in several light dark sector searches (e.g., in DUNE and in FASER-II) as well as direct detection probes in a complementary manner courtesy to the underlying scale invariance of the theory.

SUSY and String models / **125**

Connected vacua in string models

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Global consistency condition of string theory plays important role in obtaining vacua of string theory.
It does not only restrict possible vacua, but also suggest that many vacua are connected, if the systems are protected by SUSY.
We visit some examples in heterotic orbifold and F-theory, focusing on the small instanton transitions and their duals.

Particle cosmology: Theory and Experiment / **126**

How to produce observable primordial gravitational waves

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A toy-model is presented, which considers two flat directions meeting at an enhanced symmetry point such that they realise the usual hybrid inflation mechanism. The kinetic term of the waterfall field features a pole at its Planckian vacuum expectation value (VEV), as in alpha-attractors. Consequently, after the phase transition which terminates hybrid inflation, the waterfall field never rolls to its VEV. Instead, it drives a period of "kination", where the stiff barotropic parameter of the Universe w=1/2 results in a mild spike in the spectrum of primordial gravitational waves, which will be observable by the forthcoming LISA mission.

Alternative theories to SUSY / **127**

Goldstone Boson Decays and Chiral Anomalies

Author: Priyanka Lamba[None]

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Martinus Veltman was the first to point out the inconsistency of the experimental value for the decay rate of \pi^0\rightarrow\gamma\gammaπ
0
→γγ and its calculation by J. Steinberger with the very successful concept of the pion as the (pseudo)Nambu-Goldstone boson of the spontaneously broken global axial symmetry of strong interactions. That inconsistency has been resolved by J. Bell and R. Jackiw in their famous paper on the chiral anomalies. We review the connection between the decay amplitudes of an axion into two gauge bosons in Abelian vector-like and chiral gauge theories. The axion is the Nambu-Goldstone boson of a spontaneously broken axial global symmetry of the theory. Similarly as for the vector-like gauge theory, also in the chiral one the axion decay amplitude is determined by the anomaly of the current of the axial symmetry in its non-linear realization. Certain subtlety in the calculation of the anomaly in chiral gauge theories is emphasised.

Plenary / **130**

Highlights of searches for long-lived particles at the LHC

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Plenary (ATLAS+CMS)

Plenary / **131**

New experimental results on BSM searches from ATLAS and CMS

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Plenary / **132**

The Dark Dimension and the Swampland

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We explain how the Swampland criteria combined with observational data and in particular a small dark energy, leads to the prediction of a single mesoscopic dimension of length in the micron range. We also explain how this can lead to a unification of cosmological and electroweak hierarchies.

Plenary / **133**

From UV to IR and back

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Plenary / **134**

Higgs Vacuum Decay and Primordial Black Holes

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Plenary / **135**

Tachyons and Misaligned Supersymmetry

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Plenary / **136**

Topological Defects, Inflation & Gravity Waves

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Plenary / **137**

Dark Matter candidate particles in Supergravity based models

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In this talk we will revisit supergravity models with dark matter candidate particles like neutralino and gravitino. Moreover, we will discuss the possibility that primordial black holes play the role of the dark matter of the Universe.

Plenary / **138**

A unified model for solving big problems of the Standard Model

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Although the Standard Model (SM) is currently the best theory for describing elementary particle phenomena, it still suffers from several problems, such as neutrino masses and mixings, dark matter, cosmic inflation, the origin of the matter-antimatter asymmetry, and the strong CP-problem. I will discuss a unified model that can offer a solution to them.

Plenary / **139**

Challenges of an accelerating universe in string theory

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Plenary / **140**

The Gravitino and the Swampland

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Plenary / **141**

Massive gravity and string theory

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Plenary / **142**

Supersymmetry and the muon g-2 anomaly

Corresponding Author: moroi@phys.s.u-tokyo.ac.jp

Plenary / **144**

Light from the dark sector: gravity, axions graviphotons and neutrinos

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Plenary / **145**

Themes in Celestial CFT

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We present the motivation for the celestial holography program, recent progress, and ongoing questions!

Plenary / **146**

Wavefunction of the universe: Diffeomorphism invariance and field redefinitions

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Plenary / **147**

The anapole moment of a charged lepton in softly-broken Supersymmetric QED

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Plenary / **148**

String-inspired Running Vacuum Inflationary Cosmologies with gravitational anomalies

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I discuss a framework in which a low-energy effective Chern-Simons (CS) modification of General relativity emerges as a viable cosmological model from string theory. Condensation of CP-violating primordial gravitational waves can lead to non-trivial CS anomaly condensates, which drive inflation without external inflaton fields, of running vacuum model type.
The string-model independent axion field, which couples to the gravitational CS anomalies, is responsible for providing a slow-roll field during inflation, but, although at an effective action level, one obtains a linear axion potential in the condensate phase (similar to that obtained in string/brane-inspired axion-monodromy inflationary models), nonetheless the axion itself does not drive inflation in this model. Inflation is driven in this scenario by the dominant non-linear terms, quartic in the Hubble parameter, that characterise the vacuum energy density. It is worthy of stressing that the gravitational anomaly condensates lead to spontaneous violation of Lorentz and CPT symmetries, which may have important implications for unconventional leptogenesis at the early stages of the post-inflationary radiation epoch of this string-inspired Cosmology.

Plenary / **149**

Nonthermal Dark Matter Production

Corresponding Author: drees@th.physik.uni-bonn.de

Plenary / **150**

Hints of new paths toward Unification from Flavour Physics

Corresponding Author: gino.isidori@cern.ch

Plenary / **151**

Modular flavor and CP symmetry from a top-down perspective

Corresponding Author: nilles@th.physik.uni-bonn.de

Plenary / **152**

Glimpses of SUSY?

Corresponding Author: john.ellis@cern.ch

Plenary / **153**

Gravitational Waves: observational forays into fundamental physics

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With a rapidly increasing catalog of detected gravitational wave (GW) events since 2015, we have developed new ways of probing fundamental aspects of gravity and matter in extreme conditions. A violation of our current understanding of fundamental physics may manifest itself in ways that are testable by GW observations of astrophysical sources. In this talk I will summarise some of the recent results from GW experiments that are most relevant to this endeavour.

Plenary / **154**

New Higgs Bosons around the Corner (with and without SUSY)

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Plenary / **155**

New opportunities for Electroweak Baryogenesis

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Plenary / **156**

Flat asymptotics, charges and dual charges - What the Cotton can do

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Plenary / **157**

Gauge group topology and higher-form structures in quantum gravity

Corresponding Author: cvetic@physics.upenn.edu

Plenary / **158**

Causality, nonlinear supersymmetry and inflation

Corresponding Author: emilian.dudas@polytechnique.edu

Plenary / **159**

Cosmology and Phenomenology of the Superstring derived No-Scale Flipped SU(5)

Corresponding Author: dimitri@physics.tamu.edu

Plenary / **160**

Leptogenesis

Corresponding Author: apostolos.pilaftsis@manchester.ac.uk

Plenary / **162**

Spinor-vector duality and the swampland

Corresponding Author: alon.faraggi@liv.ac.uk

Plenary / **163**

Anomalies in Particle Physics

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I review the deviations from the Standard Model predictions observed in low energy precision measurements. This includes the anomalous magnetic moment of the muon, semi-lepton B meson decays, the Cabibbo Angle anomaly, the mass of the W boson and searches for very high-energetic lepton pairs. I then discuss the implications of these anomalies for possible extensions of the Standard Model.

Plenary / **164**

Superspace approach to the M5 brane

Corresponding Author: laura.andrianopoli@polito.it

Plenary / **165**

Non-linear SUSY, Vacuum Energy and Inflation

Corresponding Author: f.quevedo@damtp.cam.ac.uk

Plenary / **166**

Gravitational Portals and Particle Production during Reheating.

Corresponding Author: olive@physics.umn.edu

Plenary / **167**

Heavy KK Modes Hunting from Gravitational Waves

Corresponding Author: quiros@ifae.es

Plenary / **168**

Third Family Hypercharge

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Plenary / **169**

The unreasonable effectiveness of Genetic Algorithms as a search tool in the string landscape

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I discuss the use of Genetic Algorithms (GAs) as a search method in string theory. I will describe work showing that, despite intense recent developments in more conventional machine learning methods, GAs remain remarkably effective. Indeed comparison with Reinforcement Learning (RL) shows them to be in some respects superior. I also discuss how GAs and RL can be used in conjunction to make qualitative conclusions about the global structure of the string landscape that are not possible with either method alone.

Plenary / **170**

Higher-spin states of the superstring in an electromagnetic background

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Plenary / **174**

Neutrino and Flavour Models, from the Planck Scale to the Electroweak Scale

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We discuss various approaches to the flavour problem of the Standard Model, including the LFU violation anomalies in B decays, in which the Yukawa couplings may be determined by symmetry or anarchy and may be renormalizable or effective. If the Yukawa couplings are effective, in principle the flavour scale can be anywhere from the Planck scale to the Electroweak scale, where SUSY/GUTs suggest a high scale theory, while LFU anomalies in B decays require a low flavour scale. In the symmetry approach, large neutrino mixing suggests the use of non-Abelian symmetry, possibly due to a finite modular symmetry, and we such discuss examples of this. We also discuss an anarchical example of fermion masses based on the Twin Pati-Salam gauge group, where the effective low scale Yukawa couplings arise from exchange of fourth family vector-like fermions, which also mediate the couplings to TeV scale vector leptoquarks which could be responsible for the LFU violation anomalies.

Plenary / **175**

LHCb (in)direct searches for physics beyond the SM

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Plenary / **176**

Solution to EDGES anomaly with a millicharge of possible string origin

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SUSY: Phenomenology and Experiment / **178**

Muon g-2 in SUSY scenarios with unstable neutralinos

Author: Rafal Maselek[None]

Co-authors: Jong Soo Kim [1]; Kazuki Sakurai [2]; Manimala Chakraborti [3]; Sho Iwamoto [4]

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We investigate the possibility to explain the observed discrepancy between the observed value of anomalous magnetic moment of a muon and Standard Model predictions. We start by reviewing MSSM and confront it with the latest experimental constraints from LHC and DM experiments. Next, we move on to unorthodox scenarios in which neutralinos are unstable. We consider R-parity violation and GMSB scenarios, and we find out the parameter space for which SUSY can explain muon g-2 and simultaneously evade current experimental constraints.

SUSY and String models / **179**

Dynamical restoration of conformal invariance in sigma-models

Author: Konstantinos Siampos[1]

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We consider a class of integrable deformations of current algebra/coset CFTs by current/parafermion bilinears, known as \lambda-deformed models. We dynamically promote the deformation parameters by introducing time as an extra coordinate and we enforce conformal invariance at one-loop order. The derived model obeys a system of non-linear second-order ordinary differential equations and by appropriate choosing the initial conditions we interpolate between the RG fixed points of the parental model as the time varies from the far past to the far future.

SUSY and String models / **180**

Emergent fields from hidden sectors

Author: Pascal Anastasopoulos[1]

[1] *University of Vienna*

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This talk focuses on a collection of ideas that explain why the Standard Model (SM) should be completed by a graviton, graviphotons, axions, and neutrinos (and maybe other stuff) emerging from a hidden sector.
This task will be accomplished in a novel framework, where the SM is coupled to a holographic theory. The new particles will be composites and, in almost all cases, are distinct qualitatively from what has been considered so far.

Higgs theory and experiment / **182**

Yukawa coupling unification in non-supersymmetric SO(10) GUT models with an intermediate scale

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We will discuss the possibility of unifying in a simple and economical manner the Yukawa couplings of third-generation fermions in a non-supersymmetric SO(10) model with an intermediate symmetry breaking, focusing on two possible patterns with intermediate Pati-Salam and minimal left-right groups. For this purpose, we start with a two Higgs doublet model at the electroweak scale and assume a minimal Yukawa sector at the high energy scales. We first enforce gauge coupling unification at the two-loop level by including the threshold corrections in the renormalization group running which are generated by the heavy fields that appear at the intermediate symmetry breaking scale. We then study the running of the Yukawa couplings of the top quark, bottom quark, and tau lepton at twoloops in these two breaking schemes, when the appropriate matching conditions are imposed. We find that the unification of the third family Yukawa couplings can be achieved while retaining a viable spectrum, provided that the ratio of the vacuum expectation values of the two Higgs doublet fields is large, tan $\beta \approx 60$.

Plenary / **183**

Minimal SUSY Models confront Experiment

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colloquium / **184**

Twistronics: a new platform for physics and applications using 2D materials

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Particle cosmology: Theory and Experiment / **185**

Status of the LUX-ZEPLIN (LZ) Experiment

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LUX-ZEPLIN (LZ) is a direct detection dark matter experiment hosted in the Davis Campus of the Sanford Underground Research Facility in Lead, South Dakota. LZ's central detector is a dual-phase time projection chamber containing 7 tonnes of liquid xenon (LXe), 5.6 tonne fiducial mass, and is aided by a LXe "skin"detector and liquid scintillator-based outer detector to veto events inconsistent with dark matter. LZ aims to collect 1000 live days of data, allowing sensitivity to a WIMP-nucleon spin-independent cross-section of $1.4 \times 10^{-48} cm^2$ for a $40 GeV/c^2$ mass. This talk will provide an overview of the experiment and report on its status.

Flavour physics: Theory and Experiment / 186

Flavour Anomalies Meet Flavour Symmetry

Authors: Claudia Hagedorn[None]; Innes Bigaran[1]; Michael Schmidt[2]; Tobias Felkl[3]

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There is growing evidence for lepton-flavour non-universality, notably due to recent measurements of the magnetic moment of the muon and the LFU ratios $R(D)$ and $R(D^\star)$. We propose a model involving a scalar leptoquark which can ameliorate the tensions with the SM prediction in either case, while accommodating the mass hierarchies and mixing of the charged SM fermions. Crucially, the interaction structure of the model is entirely fixed via a discrete flavour symmetry. We find that the most stringent constraints on the parameter space arise from the experimental bounds on BR($\tau \to \mu\gamma$) and BR($\mu \to e\gamma$). Apart from these radiative cLFV decays, an explanation of the anomalous magnetic moment of the muon might be accompanied by signals in upcoming searches for $\mu \to 3e$ and $\mu - e$ conversion in aluminium, as well as $\tau \to 3\mu$ if the leptoquark is sufficiently light. We also highlight opportunities to further test and potentially constrain our model in the near future, including searches for the electric dipole moment of the muon and measurements of the axial-vector coupling of the Z boson to muons.

Plenary / 188

Opening

SUSY: Phenomenology and Experiment / 189

Higgs-mass constraints on a supersymmetric solution of the muon g-2 anomaly

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Explaining the muon (g-2) anomaly, reported by Fermilab in 2021, imposes constraints on various Beyond Standard Model theories. In our work with Pietro Slavich (arXiv 2109.15277), we focus on a supersymmetric extension to the SM with four Higgs doublets. We show how the interplay between a correct Higgs mass prediction - calculated in the EFT approach - and explaining the muon (g-2) anomaly constrains the parameter space of this model.

Alternative theories to SUSY / 190

Goldstino condensation and anti-brane uplift instability

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We investigate the formation of composite states of the goldstino in theories with non-linear supersymmetry and show that the pure Volkov-Akulov model has an instability towards goldstino con-

densation. We discuss the limitations and implications of our findings for string models involving anti-brane uplifts.