Phenomenology 2023 Symposium

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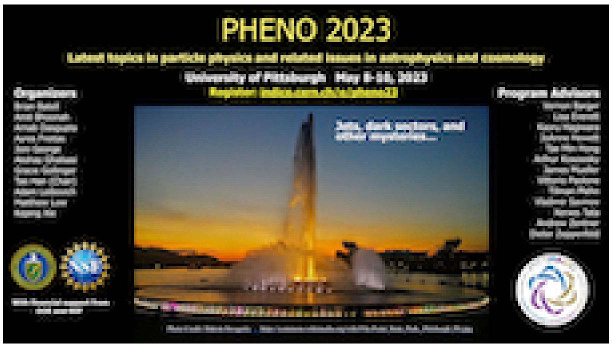

Book of Abstracts

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BSM VIII / 4

Status of negative coupling modifiers for extended Higgs sectors

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In this work, we study the status of negative coupling modifiers in extended Higgs sectors, focusing on the ratio of coupling modifiers that probes custodial symmetry violation $\lambda_{WZ} = \kappa_W/\kappa_Z$. Higgs sectors with multiplets larger than doublets are the only weakly coupled models that give tree-level modifications to λ_{WZ}, and we explore all such models allowed by the constraint from the ρ parameter and perturbative unitarity. This class of models has a custodial symmetry violating potential, while the vacuum configuration preserves the symmetry. We apply precision measurements from ATLAS and CMS and show that each data set can exclude a vast set of models with $\lambda_{WZ} < 0$ at greater than 95\% confidence level. We give evidence that $\lambda_{WZ} < 0$ is excluded in all weakly coupled models.

BSM V / 5

The Earth Mover's Distance as a Measure of CP Violation

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We introduce a new unbinned two sample test statistic sensitive to CP violation utilizing the optimal transport plan associated with the Wasserstein (earth mover's) distance. The efficacy of the test statistic is shown via two examples of CP asymmetric distributions with varying sample sizes: the Dalitz distributions of $B^0 \to K^+\pi^-\pi^0$ and of $D^0 \to \pi^+\pi^-\pi^0$ decays. The test statistic is shown to have comparable sensitivity to CP violation as the commonly used energy test statistic, but also retains information about the localized distributions of CP asymmetry over the Dalitz plot. Additionally, we introduce two alternative test statistics with similar sensitivities to CP violation but improved time and space complexity scalings. Finally, generalizations and applications to time dependent and flavor asymmetries are discussed.

Cosmology III / 6

An Effective Field Theory of 21 cm Radiation with Redshift Space Distortions

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With the prospect of detecting the cosmological 21 cm signal from the epoch of reionization just over the horizon, methods for extracting maximal cosmological information from this signal are increasingly timely. I will discuss recent work to further develop the effective field theory (EFT) for the 21 cm brightness temperature field during the epoch of reionization, incorporating renormalized bias and a treatment of redshift space distortions. To validate our theoretical treatment, we fit the predicted EFT Fourier-space shapes to the Thesan suite of hydrodynamical simulations of reionization at the field level, where the considerable number of modes prevents overfitting. We find agreement at the level of a few percent between the 21 cm power spectrum from the EFT fits and simulations over the wavenumber range $k < 0.8$ h/Mpc and neutral fraction $x_{\rm HI} > 0.4$ that is imminently measurable by the Hydrogen Epoch of Reionization Array (HERA). The ability of the EFT to describe the 21 cm signal extends to simulations that have different astrophysical prescriptions for reionization as well as simulations with interacting dark matter. We provide physical interpretations for the various bias parameters and test these interpretation against the different simulations, and find that simulations with the largest bubble sizes are perturbative over the smallest ranges of $x_{\rm HI}$.

Neutrinos I / 8

Here Comes the Sun: Solar Parameters in Long-Baseline Accelerator Neutrino Oscillations

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Long-baseline (LBL) accelerator neutrino oscillation experiments, such as NOvA and T2K in the current generation, and DUNE-LBL and HK-LBL in the coming years, will measure the remaining unknown oscillation parameters with excellent precision. These analyses assume external input on the solar parameters, θ_{12} and Δm^2_{21}, from solar experiments such as SNO, SK, and Borexino, as well as reactor experiments like KamLAND. Here we investigate their role in long-baseline experiments. We show that, without input on solar parameters, the sensitivity to detecting and quantifying CP violation is significantly, but not entirely, reduced. Thus long-baseline accelerator experiments can actually determine the solar parameters, and thus all six oscillation parameters, without input from \emph{any} other oscillation experiment. In particular, Δm^2_{21} can be determined; thus DUNE-LBL and HK-LBL can measure both the solar and atmospheric mass splittings in their long-baseline analyses alone. While their sensitivities are not competitive with existing constraints, they are very orthogonal probes of solar parameters and provide a key consistency check of a less probed sector of the three-flavor oscillation picture. Furthermore, we also show that the true values of the solar parameters play an important role in the sensitivity of other oscillation parameters such as the CP violating phase δ.

Neutrinos I / 9

High-energy neutrino cross sections

Author: Keping Xie[1]

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We present predictions of the cross section of ultrahigh-energy neutrino-nucleon scattering. The calculations are based on CT18NNLO parton distribution functions and their uncertainties. For the highest energies, we extrapolate the PDFs to small x according to several assumptions, which

affect the uncertainties at such high energies. The results can be applied to astrophysical neutrino observatories, such as IceCube currently, and proposed future detectors.

SM II / 10

Measurements of processes sensitive to quartic electroweak couplings in ATLAS

Author: John Patrick Mc Gowan[1]

[1] *ATLAS*

Measurements of multiboson production at the LHC probe the electroweak gauge structure of the Standard Model for contributions for anomalous gauge couplings. Processes involving quartic gauge couplings have become experimentally accessible at the LHC. We present recent ATLAS results of vector-boson scattering in the Zgamma channel, where the Z boson decays to neutrinos producing missing transverse momentum in the event, and the same-sign WW channel, with both W bosons decaying leptonically. In addition, inclusive and differential measurements of triboson production in Zyy channel, and recent observations of Wyy and WZy processes are presented. Results are used to constrain dimension-eight operators affecting quartic electroweak couplings in the Effective Field Theory framework. If available, additional measurements of vector-boson scattering will be discussed.

SM I / 11

Precision W and Z measurements at ATLAS

Author: Pierre-Hugues Beauchemin[1]

[1] *ATLAS*

Precision measurements of the production cross-sections of W/Z boson at LHC provide important tests of perturbative QCD, information about the parton distribution functions for quarks within the proton and fundamental parameters of the Standard Model. Extremely precise double-differential measurement of Z transverse momentum and rapidity at centre-of-mass energy of 8 TeV will be presented. This measurement is used to extract the coupling constant of the strong interactions using state-of-the-art predictions at third-order accuracy in perturbative QCD, supplemented by resummation of logarithmically-enhanced contributions in the small transverse-momentum region of the lepton pairs. In addition, the W mass is determined with a profile-likelihood fit technique which allows improvements in the precision of the mass determination by fully exploiting the information present in the 7 TeV proton-proton data. Finally, the measurement of the W, Z, ttbar cross section and their ratios at the centre-of-mass energy of 13.6 TeV using early Run3 data will be shown.

SM I / 12

Recent highlights of top-quark cross section and properties measurements with the ATLAS detector at the LHC

Author: Lorenzo Bellagamba[1]

[1] *ATLAS*

The remarkably large dataset collected with the ATLAS detector at the highest proton-proton collision energy provided by LHC allows to use the large sample of top quark events to test theoretical predictions with unprecedented precision. Recent measurements of total and differential top-quark cross sections as well properties of top-quark production are presented, including new measurements of top-quark pair production and single-top production at 5 and 13 TeV as well as first measurement of the 13.6 TeV cross-section of ttbar events. Further highlights are the new measurements of angular properties such as the W-boson polarisation in ttbar events, new top-quark mass measurements as well as distributions sensitive to colour reconnection. Several measurements are interpreted within the Standard Model Effective Field Theory, yielding stringent bounds on Wilson coefficients.

SM I / 13

Recent results on associated top quark production and searches for new top-quark phenomena with the ATLAS detector

Author: Brendon Bullard[1]

[1] *ATLAS*

The high center-of-mass energy of proton-proton collisions and the large available datasets at the CERN Large Hadron Collider allow to study rare processes of the Standard Model (SM) with unprecedented precision and search for new physics that might enhance extremely rare processes in the SM. Measurements of rare SM processes provide new tests of the SM predictions with the potential to unveil discrepancies with the SM predictions or provide important input for the improvement of theoretical calculations. Interesting processes are Flavour Changing Neutral Currents (FCNC): forbidden at tree level and highly suppressed at higher orders in the Standard Model (SM), FCNC processes can receive enhanced contributions in many extensions of the SM, so any measurable sign of such interactions is an indication of new physics. In this talk, total and differential measurements of top-quark production in association with additional bosons are shown using data taken with the ATLAS experiment at a center-of-mass-energy of 13 TeV. Strong evidence for four-top production is presented, while measurements of production asymmetries in various final states provide additional precision tests of the SM. In addition, new searches for FCNCs with the ATLAS experiment are shown, using the full data taken during Run-2 of the LHC, as well as other searches for beyond-the-Standard-Model phenomena in top-quark final states.

BSM I / 14

Searches for supersymmetric particles with prompt decays with the ATLAS detector

Author: ATLAS Collaboration[None]

Supersymmetry (SUSY) provides elegant solutions to several problems in the Standard Model, and searches for SUSY particles are an important component of the LHC physics program. This talk will present the latest results from SUSY searches conducted by the ATLAS experiment. The searches target multiple final states and different assumptions about the decay mode of the produced SUSY particles, including searches for both R-parity conserving models and R-parity violating models and their possible connections with the recent observation of the favour and muon g-2 anomalies. The talk will also highlight the employment of novel analysis techniques, including advanced machine learning techniques and special object reconstruction, that are necessary for many of these analyses to extend the sensitivity reach to challenging regions of the phase space.

BSM I / 15

Searches for BSM resonances in ATLAS

Author: ATLAS Collaboration[None]

Many new physics models predict the existence of additional particles. This talk summarizes recent ATLAS searches for Beyond-the-Standard-Model heavy resonances which decay to pairs of bosons, heavy quarks, or leptons, using Run 2 data collected at the LHC. The experimental methods are explained, including the jet substructure techniques used in some searches to disentangle the hadronic decay products in highly boosted configurations.

BSM I / 16

Searches for Dark Matter with the ATLAS Experiment at the LHC

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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 Collaboration has developed a broad search program for DM candidates in final states with large missing transverse momentum produced in association with other SM particles (light and heavy quarks, photons, Z and H bosons, as well as additional heavy scalar particles) and searches where the Higgs boson provides a portal to Dark Matter, leading to invisible Higgs decays. The results of recent searches on 13 TeV pp data from the LHC, their interplay and interpretation will be presented.

BSM XIV / 17

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

Author: ATLAS Collaboration[None]

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.

BSM I / 18

Searches for new physics with leptons using the ATLAS detector

Author: ATLAS Collaboration[None]

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Many theories beyond the Standard Model (SM) predict that New Physics (NP) will manifest by decaying into final states involving leptons. Leptoquarks are predicted by different NP theories to describe similarities between the lepton and quark sectors of the SM. Other NP theories relating to quantum gravity predict periodic signatures in dilepton final states, where tightly-spaced resonance towers detectable at LHC energies provide access to very small couplings through a mechanism coined Clockwork. This talk will present the most recent 13 TeV results of searches for leptoquarks with the ATLAS detector, covering flavour-diagonal and cross-generational final states, as well as a novel search for Clockwork signals in diphoton and dielectron final states.

SM III / 19

Measurements of Higgs boson properties (mass, width, and Spin/CP) with the ATLAS detector

Author: ATLAS Collaboration[None]

This talk presents precise measurement of the properties of the Higgs boson, including its mass, total width, spin, and CP quantum number. The measurements are performed in various Higgs boson production and decay modes, as well as their combinations. Observation of deviations between these measurements and Standard Model (SM) predictions would be a sign of possible new phenomena beyond the SM

SM III / 21

Probing the nature of electroweak symmetry breaking with Higgs boson pairs in ATLAS

Author: ATLAS Collaboration[None]

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. The Standard Model makes a definite prediction for the Higgs boson self-coupling and thereby the shape of the Higgs potential. Experimentally, both can be probed through the production of Higgs boson pairs (HH), a rare process that presently receives a lot of attention at the LHC. In this talk, the latest HH searches by the ATLAS experiment are reported, with emphasis on the results obtained with the full LHC Run 2 dataset at 13 TeV. Non-resonant HH search results are interpreted both in terms of sensitivity to the Standard Model and as limits on the Higgs boson self-coupling and the quartic VVHH coupling. The Higgs boson self-coupling can be also constrained by exploiting higher-order electroweak corrections to single Higgs boson production. A combined measurement of both results yields the overall highest precision, and reduces model dependence by allowing for the simultaneous determination of the single Higgs boson couplings. Results for this combined measurement are also presented. Finally, extrapolations of recent HH results towards the High Luminosity LHC upgrade are also discussed.

BSM I / 22

Searching for new symmetries in the Higgs sector at ATLAS

Author: ATLAS Collaboration[None]

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The discovery of the Higgs boson with the mass of 125 GeV confirmed the mass generation mechanism via spontaneous electroweak symmetry breaking and completed the particle content predicted by the Standard Model. Even though this model is well established and consistent with many experimental measurements, it is not capable of solely explaining some observations. Many extensions of the Standard Model introduce additional scalar fields to account for the electroweak symmetry breaking and thereby extra Higgs-like bosons, which can be either neutral or charged. This talk presents recent searches for additional low- or high-mass Higgs bosons, as well as decays of the 125 GeV Higgs boson to new light scalar particles, using LHC collision data at 13 TeV collected by the ATLAS experiment in Run 2.

Theory I / **26**

1+1D Hadrons Minimize their Biparton Renyi Free Energy

Authors: Pouya Asadi[1]; Varun Vaidya[2]

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I put forward a novel variation method for calculating the mass and PDF of hadrons in 1+1D models. The template functions in our method minimize a Free Energy functional composed of free partons kinetic energy and Renyi entropy of all pairs of partons. Our results suggest hadrons in these models minimize this Free Energy functional. I will comment on extending our calculation to confining theories in higher dimensions and calculating the mass and PDF of their hadrons.

DM I / **27**

An Analytic Approach to Light Dark Matter Propagation

Author: Christopher Cappiello[None]

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Although searches for GeV-scale WIMPs are sensitive to very small cross sections, constraints on sub-GeV dark matter are significantly weaker, and largely constrain moderately- or strongly-interacting dark matter. But if dark matter interacts too strongly with nuclei, it could be slowed to undetectable speeds in Earth's crust or atmosphere before reaching a detector. For sub-GeV dark matter, approximations used to model the attenuation of heavier dark matter fail, necessitating the use of computationally expensive simulations. I present a new, analytic approximation for modeling attenuation of light dark matter in the Earth. I show that our approach agrees well with Monte Carlo results, and can be much faster at large cross sections. I show how this method can be used to reanalyze recently reported constraints on sub-dominant dark matter—that is, dark matter particles that make up only a fraction of the total dark matter density.

Axion III / **28**

The inflated Chern-Simons number in spectator chromo-natural inflation

Authors: Hengameh Bagherian[None]; Linda Xu[None]; Matthew Reece[None]

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The chromo-natural inflation (CNI) scenario predicts a potentially detectable chiral gravitational wave signal, generated by a Chern-Simons coupling between a rolling scalar axion field and an SU(2) gauge field with an isotropy-preserving classical background during inflation. However, the generation of this signal requires a very large integer Chern-Simons level, which can be challenging to explain or embed in a UV-complete model. We show that this challenge persists in the phenomenologically viable spectator field CNI (S-CNI) model. Furthermore, we show that a clockwork scenario giving rise to a large integer as a product of small integers can never produce a Chern-Simons level large enough to have successful S-CNI phenomenology. We briefly discuss other constraints on the model, both in effective field theory based on partial-wave unitarity bounds and in quantum gravity based on the Weak Gravity Conjecture, which may be relevant for further explorations of alternative UV completions.

Gravity I / 29

Going Underground or Listening to the Sky?

Author: Anupam Ray[None]

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Dark Matter (DM) remains mysterious. Despite decades of experimental efforts, its microscopic identity is still unknown. Terrestrial detectors are placing stringent exclusions on various parts of the DM parameter space, however, there exist a few blind-spots. In this talk, I will demonstrate how existing GW detectors can be used to unravel the particle nature of DM. More specifically, by observing low mass black hole mergers, existing GW detectors can provide unprecedented sensitivity to the weakly-interacting heavy dark matter, a blind spot to the terrestrial DM detectors. I will also walk you through how continued existence of a variety of stellar objects can probe strongly-interacting heavy DM, a yet another blind spot.

Gravity I / 30

Planck Constraints and Gravitational Wave Forecasts for Primordial Black Hole Dark Matter Seeded by Multifield Inflation

Authors: David Kaiser[1]; Evan McDonough[2]; Sarah Geller[1]; Shyam Balaji[3]; Wenzer Qin[1]

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In my talk, I will present recent significant work on the formation of primordial black hole dark matter and the resultant
gravitational wave signal, drawing from the results of arXiv:2303.02168, with co-authors
W. Qin, S. Balaji, D.I. Kaiser, and E. McDonough, which has been submitted for peer review to Phys. Rev. D. My talk will also build on our previous results as published in (Phys.
Rev.D 106, 063535 (2022), arXiv:2205.04471). In our work, we performed a Markov Chain Monte Carlo (MCMC)
analysis of a simple yet generic multifield inflation model characterized by two scalar fields coupled to each
other and nonminimally coupled to gravity, fit to Planck 2018 cosmic microwave background (CMB) data. In
particular, model parameters are constrained by data on the amplitude of the primordial power spectrum of
scalar curvature perturbations on CMB scales As, the spectral index ns, and the ratio of power in tensor to

scalar modes r, with a prior that the primordial power spectrum should also lead to primordial black hole
(PBH) production sufficient to account for the observed dark matter (DM) abundance.
I will demonstrate that ns in particular largely controls the constraints on our class of models. Whereas
previous studies of PBH formation from an ultra-slow-roll phase of inflation have highlighted the need for at
least one model parameter to be highly fine-tuned, I will identify a degeneracy direction in parameter space
such that shifts by ~ 10% of one parameter can be compensated by comparable shifts in other parameters
while preserving a close fit between model predictions and observations. Furthermore, I will show how this
allowed parameter region produces observable gravitational wave (GW) signals in the frequency ranges to
which upcoming experiments are projected to be sensitive, including Advanced LIGO and Virgo, the Einstein
Telescope (ET), DECIGO, and LISA.

BSM XIV / 31

To profile or to marginalize - A SMEFT case study

Authors: Emma Geoffray[1]; Ilaria Brivio[2]; Michel Luchmann[3]; Nikita Schmal[1]; Nina Elmer[1]; Sebastian Bruggisser[4]; Tilman Plehn[None]

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We present an updated global SMEFT analysis in the Higgs and Electroweak sectors using the SFitter framework. We use a newly implemented marginalization procedure that allows comparison of Wilson coefficient results between profiling and marginalization methods. Marginalization is motivated by better scalability for high-dimensional analyses and provides faster numerical convergence compared to the profiling method. Moreover, the results differ especially when volume effects affect the marginalization. Our extended Run-2 dataset contains new measurements, including several high-energy kinematic distributions. Finally, we present some preliminary results for a combined global fit of the Higgs and electroweak sectors with the top sector. This top sector includes two top measurements using likelihoods made publicly available by the ATLAS top working group.

BSM XIII / 32

Exploring the Neutrino Sector of the Minimal Left-Right Symmetric Model

Authors: Chee Fong[1]; Gustavo Figueiredo Severiano Alves[2]; Luighi Leal[2]; Renata Funchal[2]

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We explore the neutrino sector of the minimal left-right symmetric model, with the additional charge conjugation discrete symmetry, in the novel regime where type-I and type-II seesaw mechanisms are equally responsible for the light neutrino masses, which can result in large active-sterile mixing. We show that unless the charged lepton mixing matrix is the identity and the right handed neutrino mass matrix has no phases, we expect sizable lepton flavor violation and electron dipole moment in this region. We use recent results from neutrino oscillation fits, bounds on neutrinoless double beta decay, $\mu \to e\gamma$,
$\mu \to 3e$, $\mu \to e$ conversion in nuclei, the muon anomalous magnetic moment, the electron electric dipole moment, the CDF II determination of W boson mass and cosmology to determine the viability of this region.

We derive stringent limits on the heavy neutrino masses and mixing angles as well as on the vacuum expectation value v_L, which drives the type-II seesaw contribution, using the current data. We discuss the perspectives of probing the remaining parameter space by future experiments.

BSM III / 33

Constraining new physics with Borexino Phase-II spectral data

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We present a detailed analysis of the spectral data of Borexino Phase II, with the aim of exploiting its full potential to constrain scenarios beyond the Standard Model. In particular, we quantify the constraints imposed on neutrino magnetic moments, neutrino non-standard interactions, and several simplified models with light scalar, pseudoscalar or vector mediators. Our analysis shows perfect agreement with those performed by the collaboration on neutrino magnetic moments and neutrino non-standard interactions in the same restricted cases and expands beyond those, stressing the interplay between flavour oscillations and flavour non-diagonal interaction effects for the correct evaluation of the event rates. For simplified models with light mediators we show the power of the spectral data to obtain robust limits beyond those previously estimated in the literature.

DM III / 34

Neutrinos from Dark Matter Annihilation versus the Diffuse Supernova Neutrino Background

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Upcoming neutrino experiments are expected to detect the Diffuse Supernova Neutrino Background (DSNB). This requires pondering all possible sources of background. Sub-GeV dark matter (DM) which annihilates into neutrinos is a potential background that has not been considered so far. We simulate DSNB and DM signals, as well as backgrounds in the Hyper-Kamiokande detector. We find that DM-induced neutrinos could indeed alter the extraction of the correct values of the parameters of interest for DSNB physics. While this opens the possibility of simultaneously characterizing the DNSB and discovering DM via indirect detection, we argue that it would be hard to disentangle the two contributions due to the lack of angular information available at low energies.

BSM II / 36

Lepton Flavor Violation at Electron-Positron Colliders

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Lepton Flavor Violation (LFV) is one of the cleanest probes of Beyond the Standard Model (BSM) Physics. In this work, we explore the sensitivity of the channel $e^+e^- \to \tau\mu$ to BSM physics above the $\sim$ TeV scale at the proposed circular electron-positron collider FCC-ee. We compute the expected cross-section $\sigma(e^+e^- \to \tau\mu)$ in the Standard Model Effective Field Theory (SMEFT) framework and assess the backgrounds to set constraints on the size of the SMEFT operators. If present, these operators also contribute to LFV tau decays at lower energies.
We find that the limits on individual operators (or on the New Physics (NP) scale Λ) from the FCC-ee are comparable to those obtained from low-energy tau decays (except for the dipole operators). In addition, we illustrate the complementarity between the sensitivities of these different processes when more than one SMEFT operator is turned on at the NP scale.

SM III / 37

Lighting up the LHC with Dark Matter

Authors: Carlos E.M. Wagner[None]; Duncan Rocha[1]; Marcela Silvia Carena Lopez[None]; Nausheen Shah[2]; Sebastian Baum[3]; Tong Ou[None]

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We show that simultaneously explaining dark matter and the observed value of the muon's magnetic dipole moment may lead to yet unexplored photon signals at the LHC. We consider the Minimal Supersymmetric Standard Model with electroweakino masses in the few-to-several hundred GeV range, and opposite sign of the Bino mass parameter with respect to both the Higgsino and Wino mass parameters. In such region of parameter space, the spin-independent elastic scattering cross section of a Bino-like dark matter candidate in direct detection experiment is suppressed by cancellations between different amplitudes, and the observed dark matter relic density can be realized via Bino-Wino co-annihilation. Moreover, the observed value of the muon's magnetic dipole moment can be explained by Bino and Wino loop contributions. Interestingly, "radiative" decays of Wino-like neutralinos into the lightest neutralino and a photon are enhanced, whereas decays into leptons are suppressed. While these decay patterns weaken the reach of multi-lepton searches at the LHC, the radiative decay opens a new window for probing dark matter at the LHC through the exploration of parameter space regions beyond those currently accessible. To enhance the strength of a potential electroweakino signal, we propose searching for a single (soft) photon plus missing transverse energy, accompanied by a hard initial state radiation jet.

Axion II / 39

Imprints of Axion's Evolution in CMB

Author: Shuyang Cao[1]

Co-author: Daniel Boyanovsky [1]

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We studied the non-equilibrium dynamics of an axion-like particle (ALP) weakly coupled to a thermal bath and misaligned initial conditions. The ALP's evolution is studied to leading order in the ALP coupling to the bath but to all orders in couplings among the bath's degrees of freedom. Results are obtained using both Langevin equation derived from in-in formalism and quantum master equation, where consistencies and discrepancies of the two methods are identified and discussed. A quantum fluctuation-dissipation relation is revealed in in-in formalism. The solution exhibits damping of the misaligned condensate and thermalization with the bath. It describes a mixed dark matter scenario where the initial (cold) component decays and the thermalized (hot) component grows. ALP-photon coupling is calculated explicitly as a specific example, in which we found an enhancement to ALP's relaxation rate, a potential inverted phase transition, and the requirement of higher order derivative terms. The back reaction of ALP to the photon bath is also investigated. Due to the special coupling form $ga\vec{E}\cdot\vec{B}$, a Chern-Simons condensate is induced by the coherent axion field. Such a condensate will leave observable imprints in both CMB's Stokes parameters and quasi-axions in condense matter physics. In particular, these effects are at the leading order of axion-photon coupling due to the coherence of the axion field.

BSM IV / 40

Cosmological gravitational particle production of massive spin-2 particles

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The phenomenon of cosmological gravitational particle production (CGPP) is expected to occur during the period of inflation and the transition into a hot big bang cosmology. Particles may be produced even if they only couple directly to gravity, and so CGPP provides a natural explanation for the origin of dark matter. In this work we study the gravitational production of massive spin-2 particles assuming two different couplings to matter. We evaluate the full system of mode equations, including the helicity-0 modes, and by solving them numerically we calculate the spectrum and abundance of massive spin-2 particles that results from inflation on a hilltop potential. We conclude that CGPP might provide a viable mechanism for the generation of massive spin-2 particle dark matter during inflation, and we identify the favorable region of parameter space in terms of the spin-2 particle's mass and the reheating temperature. As a secondary product of our work, we identify the conditions under which such theories admit ghost or gradient instabilities, and we thereby derive a generalization of the Higuchi bound to Friedmann-Robertson-Walker (FRW) spacetimes.

Cosmology I / 41

Cornering Extended Starobinsky Inflation with CMB and SKA

Authors: Benedikt Schosser[1]; Björn Malte Schäfer[1]; Lennart Röver[1]; Tanmoy Modak[None]; Tilman Plehn[1]

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Starobinsky inflation is an attractive, fundamental model to explain the Planck measurements, and its higher-order extension may allow us to probe quantum gravity effects. We show that future CMB data combined with the 21cm intensity map from SKA will meaningfully probe such an extended Starobinsky model. A combined analysis will provide a precise measurement and intriguing insight into inflationary dynamics, even accounting for correlations with astrophysical parameters.

DM I / 42

Results from sub-GeV dark matter searches with SENSEI

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SENSEI (Sub-Electron Noise Skipper Experimental Instrument) is a direct detection dark matter experiment with detectors operating at Fermilab and at the SNOLAB underground facility. The experiment consists of silicon Skipper-CCD sensors that make multiple non-destructive measurements of the charge contained in each of millions of pixels, reducing the readout noise to a level that allows for resolution of single electrons. This low energy threshold, along with low rates of events with one, two, three, and four electrons, results in competitive sensitivity for low-mass dark matter candidates that interact with electrons over a wide range of dark matter masses. In this talk, we present an overview of the SENSEI experiment, current status after the successful commissioning of the first batch of science-grade sensors at SNOLAB, as well as recent results.

DM II / 43

The dark matter profile of the Milky Way inferred from its circular velocity curve

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The circular velocity curve, one of the first pieces of evidence for dark matter (DM), is a direct probe of the Galaxy's potential, which allows studies of the nature of DM. Recent large surveys have provided valuable information for determining the Milky Way circular velocity curve. In this talk, I will describe our newly-derived circular velocity curve of the Milky Way out to ~30 kpc, which shows a sharp decline at R greater than 20 kpc. I will discuss the newly found best fit measurement of the virial mass, inner density profile, the local density, and the J-factor of the Galactic Center. We find that a cored Einasto profile with slope parameter 1.13 +/- 0.06 is a better fit to the data than a generalized or contracted Navarro-Frank-White (NFW), as was argued in previous studies. We also find the virial mass of the DM halo to be significantly lower than previous estimates, but the corresponding local DM density at the solar position is consistent with the literature. The cored profile may indicate baryonic effects such as starbursts after the central DM accretion has slowed down, or alternative DM models such as self-interacting DM. Future studies will focus on better modeling of the baryonic components and incorporating other dynamical probes such as the escape velocity. The studies will serve as a test for alternative DM models, such as self-interacting DM or dissipative models.

Higgs I / 44

Exploring CP Violation in the Higgs Sector Through Higgs Boson Production in Association of Three Jets

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In this presentation, I will explore the impact of finite top and bottom quark masses in the computation of scattering cross-sections for Higgs Boson production in association with three jets at Hadron Colliders like the CERN Large Hadron Collider. Additionally, I will offer insights into the expected outcomes for the production of a CP-violating Higgs.

Tools I / 45

MadNIS - Neural Multi-Channel Importance Sampling

Authors: Theo Heimel[1]; Ramon Winterhalder[2]; Anja Butter[3]; Joshua Isaacson[None]; Claudius Krause[4]; Fabio Maltoni[5]; Olivier Mattelaer[6]; Tilman Plehn[None]

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Theory predictions for the LHC require precise numerical phase-space integration and generation of unweighted events. We combine machine-learned multi-channel weights with a normalizing flow for importance sampling, to improve classical methods for numerical integration. We develop an efficient bi-directional setup based on an invertible network, combining online and buffered training for potentially expensive integrands. We illustrate our method for the Drell-Yan process with an additional narrow resonance. In addition to these results from the paper "MadNIS - Neural Multi-Channel Importance Sampling", MadNIS now interfaces to MadGraph to use its matrix elements and channel mappings. I will present preliminary results from our upcoming comparison between MadNIS and classical MadGraph for various LHC processes.

Theory I / 46

Corrections to Hawking radiation from asteroid mass primordial black holes: Formalism of dissipative interactions in quantum electrodynamics

Author: Makana Silva[1]

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Primordial black holes (PBHs) within the mass range $10^{17} - 10^{22}$ g are a favorable candidate for describing all of the dark matter content. Towards the lower end of this mass range, the Hawking temperature, T_H, of these PBHs is $T_H > 100$ keV, allowing for the creation of electron-positron pairs, thus making their Hawking radiation a useful constraint for most current and future MeV surveys. This motivates the need for realistic and rigorous accounts of the distribution and dynamics of emitted particles from Hawking radiation in order to properly model detected signals from high energy observations. This is the first in a series of papers to account for the $O(\alpha)$ correction to the Hawking radiation spectrum. We begin by the usual canonical quantization of the photon and spinor (electron/positron) fields on the Schwarzschild geometry. Then we compute the correction to the rate of emission by standard time-dependent perturbation theory from the interaction Hamiltonian. We conclude with the analytic expression for the dissipative correction, i.e., corrections due to the creation and annihilation of electron/positrons in the plasma.

SM III / 47

The top quark legacy of the LHC Run II for PDF and SMEFT analyses

Author: Maeve Madigan[None]

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I will present a study of the impact of top quark production at the LHC on global analyses of parton distributions (PDFs) and of Wilson coefficients in the SMEFT, both separately and in the framework of a joint interpretation. We consider the broadest top quark dataset to date containing all available measurements based on the full Run II luminosity. First, we determine the constraints that this dataset provides on the large-x gluon PDF and study its consistency with other gluon-sensitive measurements. Second, we carry out a SMEFT interpretation of the same dataset using state-of-the-art SM and EFT theory calculations, resulting in bounds on 25 Wilson coefficients modifying top quark interactions. Subsequently, we integrate the two analyses within the SIMUnet approach to realise a simultaneous determination of the SMEFT PDFs and the EFT coefficients and identify regions in the parameter space where their interplay is most phenomenologically relevant.

BSM IX / 48

Deep Learning Symmetries in Physics and Beyond

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We design a deep-learning algorithm for the discovery and identification of the continuous group of symmetries present in a labeled dataset. We use fully connected neural networks to model the symmetry transformations and the corresponding generators. We construct loss functions that ensure that the applied transformations are symmetries and that the corresponding set of generators forms a closed (sub)algebra. Our procedure is validated with several examples illustrating different types of conserved quantities preserved by a symmetry. In the process of deriving the full set of symmetries, we analyze the complete subgroup structure of the rotation groups SO(2), SO(3), and SO(4) and of the Lorentz group SO(1,3). Other examples include SO(10), squeeze mapping, and piece-wise discontinuous labels, demonstrating that our method is completely general, with many possible data science applications. In this talk, I will demonstrate finding the symmetries of the exceptional group G2 and the symmetries encoded in the MNIST digits.

DM II / 49

Constraining Dark Matter Substructure With Gaia Wide Binaries

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We use a catalogue of stellar binaries with wide separations (up to 1 pc) identified by the *Gaia* satellite to constrain the presence of extended substructure within the Milky Way galaxy. Heating of the binaries through repeated encounters with substructure results in a characteristic distribution of binary separations, allowing constraints to be placed independent of the formation mechanism of wide binaries. Across a wide range of subhalo density profiles, we find that subhalos with masses □ 65 M_□ and characteristic length scales similar to the separation of these wide binaries cannot make up 100% of the Galaxy's dark matter. Constraints weaken for subhalos with larger length scales and are dependent on their density profiles. For such large subhalos, higher central densities lead to stronger constraints. Subhalos with density profiles similar to those expected from cold dark matter must be at least ~5,000 times denser than predicted by simulation to be constrained by the wide binary catalogue.

Axion II / 51

Finding Exotic Particles with Fireballs

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Compact transients such as supernovae and binary neutron star mergers can produce enormous fluxes of exotic particles. One way to look for them is through fireballs, a dense expanding photon electron plasma formed when exotic particles escaping a compact source quickly decay to Standard Model particles. Fireballs produce a unique signal, allowing us to observe new parts of dark photon and axion parameter space. Fireballs formation changes the previously predicted axion signal from SN 1987a and may produce new constraints on axions with masses between 1 MeV and 1 GeV emitted in the binary neutron star merger GW 170817.

BSM XII / 52

Cosmological Constraints on Long Lived Supersymmetric Particles

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We provide a comprehensive analysis of constraints on Supersymmetric gravitinos and axinos originating from spectral distortion, BBN and Lyman-alpha considerations. We analyze the current status and future prospects of such scenarios from cosmological probes. Furthermore, we provide the complementary constraints from collider data and assess the future discovery prospects.

BSM III / 53

Detecting Nanometer-Scale New Forces with Coherent Neutron Scattering

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Significant effort has been devoted to searching for new fundamental forces of nature. At short length scales (below approximately 10 nm), the strongest experimental constraints come from neutron scattering from individual nuclei in gases. The leading experiments at longer length scales instead measure forces between macroscopic test masses. We propose a hybrid of these two approaches: scattering neutrons off of a target that has spatial structure at nanoscopic length scales. Such structures will give a coherent enhancement to small-angle scattering, where the new force is most significant. This can considerably improve the sensitivity of neutron scattering experiments for new forces in the 0.1 - 100 nm range. We discuss the backgrounds due to Standard Model interactions and a variety of potential target structures that could be used, estimating the resulting sensitivities. We show that, using only one day of beam time at a modern neutron scattering facility, our proposal has the potential to detect new forces as much as four orders of magnitude beyond current laboratory constraints at the appropriate length scales.

DM III / 54

Searching for ultralight dark matter using radio telescopes

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Ultralight axions and dark photons are compelling candidates for dark matter. In this talk, I will provide an overview of my recent work (arXiv:2207.05767, 2301.03622) on detecting radio-frequency axions and dark photons using radio telescopes. The detectability relies on two distinct underlying mechanisms. One mechanism involves local dark photon dark matter inducing harmonic oscillations of electrons within the antenna of radio telescopes. This process results in a local radio electromagnetic (EM) signal that can be captured by telescope receivers. The other mechanism is the resonant conversion of dark photons into EM waves in the solar corona when their mass matches the solar plasma frequency. This mechanism is also applicable to axions due to the presence of the solar magnetic field. The resulting radio EM waves can be detected by radio telescopes designed for solar observations, although the detectability for axions is suppressed due to the relatively weak solar magnetic field. By analyzing data from radio telescopes such as FAST and LOFAR, we have obtained constraints on the kinetic mixing constant between dark photons and photons, surpassing existing bounds in multiple radio-frequency ranges.

Tools I / 55

Feature selection using distance correlation

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Choosing which properties of the data to use as input to multivariate decision algorithms – a.k.a. feature selection – is an important step in solving any problem with machine learning. While there is a clear trend towards training sophisticated deep networks on large numbers of relatively unprocessed inputs (so-called automated feature engineering), for many tasks in physics, sets of theoretically well-motivated and well-understood features already exist. Working with such features can bring many benefits, including greater interpretability, reduced training and run time, and enhanced stability and robustness. We develop a new feature selection method based on Distance Correlation (DisCo), and demonstrate its effectiveness on the tasks of boosted top- and W-tagging. Using our method to select features from a set of over 7,000 energy flow polynomials, we show that we can match the performance of much deeper architectures, by using only ten features and two orders-of-magnitude fewer model parameters.

Gravity I / 58

Freezing-In Gravitational Waves

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The thermal plasma in the early universe produced a stochastic gravitational wave (GW) background, which peaks today in the microwave regime and was dubbed the cosmic gravitational microwave background (CGMB). In previous works only single graviton production processes that contribute to the CGMB have been considered. In this talk we also investigate graviton pair production processes and show that these can lead to a significant contribution if the ratio between the maximum temperature and the Planck mass, $T_{\rm max}/m_{\rm p}$, divided by the internal coupling in the heat bath is large enough. As the dark matter freeze-in production mechanism is conceptually very similar to the GW production mechanism from the primordial thermal plasma, we refer to the latter as "GW freeze-in production". We also show that quantum gravity effects arising in single graviton production are smaller than the leading order result by a factor $(T_{\rm max}/m_{\rm p})^2$.

BSM V / 59

Proton decay from quark and lepton compositeness

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Within a chiral SU(15) gauge theory in which the Standard Model fermions are bound states of massless preons, we show that proton-decay operators are likely induced at the compositeness scale, $\Lambda_{\rm pre}$. Our estimate of the limit imposed by searches for proton decays is $\Lambda_{\rm pre} > 10^4$ TeV, dependent on an 8-prebaryon operator induced by SU(15) dynamics and the mass of a composite vectorlike quark. The latter has a lower limit related to the mass of a composite vectorlike lepton, which in turn is required by LHC searches to be above 1 TeV. We point out that exotic proton decay modes, into a π^+ and a heavy right-handed neutrino, could be observed using the Super-Kamiokande or DUNE detectors.

BSM V / 60

Asymptotically safe dark matter with gauged baryon number

Authors: Christopher Carone[1]; Jens Boos[1]; Mikkie Musser[1]; Noah Donald[1]

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We propose an asymptotically safe extension of the standard model with gauged baryon number that is spontaneously broken at the TeV scale. Among the new heavy fermions is a potential dark matter candidate which is rendered stable by an unbroken Z_2 subgroup of the baryon number gauge group. After taking into account gravitational effects above the Planck scale, we study the ultraviolet fixed points of this theory and determine a subset of the model's parameter space at the TeV scale which renders the theory asymptotically safe. Asymptotic safety is a framework in which theories can be validly extrapolated to infinitely high energy scales. Working within this subspace of parameters at the TeV scale, we show that the correct dark matter relic density can be calculated while also ensuring that these parameter choices are consistent with bounds placed by direct detection experiments.

SM IV / 61

CPV Searches @ COLLIDERS

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Due to naturalness arguments we must continue our quest for CPV at all frontiers. This is of course esp. so @ LHC. New experimental efforts with additional expt. + theory inputs will be highlighted.

BSM IV / 62

Vectorlike Fermions as Portals into Higgs Vacuum Stability

Authors: Daniel Litim[1]; Gudrun Hiller[2]; Tim Höhne[None]; Tom Steudtner[None]

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This talk addresses the notorious metastability of the Standard Model and promotes it to a model building task. We explore the ingredients required to stabilize the SM up to the Planck scale without encountering sub-Planckian Landau poles. Using the SM extended by vectorlike fermions, we chart out the corresponding landscape of Higgs stability. We find that the "gauge portal mechanism", triggered by new SM charge carriers, opens up sizable room for stability in a minimally invasive manner. We also find models with Higgs criticality and Yukawa portals opening up at stronger coupling. Several models allow for vectorlike fermions in the TeV range, which can be searched for at the LHC. For nontrivial flavor structure, severe flavor-changing neutral current constraints arise that complement those from stability and push lower fermion masses up to order 10^3 TeV.

BSM IV / 63

EFT for Heavy Dark Matter of Arbitrary Spin

Authors: Emmanuel Stamou[1]; Fady Bishara[2]; Joachim Brod[3]; Jure Zupan[3]; Sandra Kvedaraite[None]

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We construct an effective field theory for non-relativistic heavy dark matter of arbitrary spin based on the Little group formalism. We present the most general HDMEFT basis up to dimension seven involving scalar (spin 0), vector (integer spin) and fermionic (half-integer spin) dark matter fields. We also discuss the matching onto the non-relativistic EFT.

Axion I / 64

Discovering the QCD Axion with Polarization Haloscopes

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The QCD axion is a well-motivated extension of the Standard Model which dynamically relaxes away strong CP violation. However, to date most searches for the axion have instead focused on its model-dependent coupling to photons. I will present a new idea for axion detection that directly targets its defining coupling to gluons, by resonantly amplifying the oscillating currents from time-varying atomic electric dipole moments. If these effects are enhanced by large nuclear Schiff moments, such as in octupole-deformed nuclei, our proposal could be sensitive to the QCD axion's defining coupling at the most motivated GHz frequencies.

BSM II / 65

Probing New Physics with $\mu^+\mu^- \to bs$ at a Muon Collider

Authors: Sri Aditya Gadam[None]; Stefano Profumo[1]; Stefano Profumo[None]; Wolfgang Altmannshofer[2]

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We show that bottom-strange production at a high energy muon collider, $\mu^+\mu^- \to bs$, is a sensitive probe of new physics. We consider the full set of four fermion contact interactions that contribute to this process at dimension 6, and discuss the complementarity of a muon collider and rare B meson decays that probe the new physics.
If a signal were to be found at a muon collider, the forward-backward asymmetry of the b-jet provides diagnostics about the underlying chirality structure of the new physics.
In the absence of a signal at a center of mass energy of 10˜TeV, $\mu^+\mu^- \to bs$ can indirectly probe

new physics scales as large as 86~TeV. We also discuss the impact that beam polarization has on the muon collider sensitivity.

Gravity I / 66

The Primordial Black Holes that Disappeared: Connections to Dark Matter and MHz-GHz Gravitational Waves

Authors: Thomas Gehrman[1]; Barmak Shams Es Haghi[2]; Kuver Sinha[1]; Tao xu[1]

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Light primordial black holes(PBHs) form in the early universe through a variety of formation mechanisms. These PBHs can Hawking evaporate before BBN to produce SM particles and in our scenario also generate the dark matter(DM) relic abundance. High frequency gravitational waves in the MHz-GHz regime are produced during the formation of these light PBHs. In this talk I will present two different classes of PBHs: those originating from curvature perturbations generated by inflation, and those originating from false vacuum collapse. I will show ultra-high frequency GWs is a new way to probe cosmology of very light PBHs

BSM IX / 67

On two-body and three-body spin correlations in leptonic $t\bar{t}Z$ production and anomalous couplings at the LHC

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We study the anomalous $t\bar{t}Z$ couplings in the $t\bar{t}Z$ production in leptonic final state at the 13 TeV LHC. We use the polarizations of top quarks and Z boson, two-body and three-body spin correlations among the top quarks and Z boson, and the cross section to probe the anomalous couplings. We estimate one parameter and simultaneous limits on the couplings of the effective vertex as well as the effective operators for a set of luminosities 150 fb^{-1}, 300 fb^{-1}, 1000 fb^{-1}, and 3000 fb^{-1}. The polarizations and the spin correlations are found to be helpful on top of the cross section to better constrain the anomalous couplings.

Axion III / 68

Zero Modes from Massive Fermions and Axion Strings

Authors: Hengameh Bagherian[None]; John Stout[1]; Katherine Fraser[2]; Samuel Homiller[2]

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In recent years, there has been renewed interest in the physics of axion strings since they naturally arise in axion models and can have a dramatic impact on cosmological observations. It is well-known that axion strings superconduct since massless chiral excitations can propagate along them. Aside from anomaly inflow, a common explanation for why these modes exist is that a bulk fermion becomes massless in the core of the string, and so excitations can propagate at the speed of light as long as they are confined to this region. In this talk, we reexamine this intuition and show such zero modes exist even when the fermion remains massive in the core of the string. Counterintuitively, these zero modes become less and less localized around the string the higher this mass is, up until a critical value in which case the zero modes disappear.

SM IV / 69

Determining the CP Property of the $ht\bar{t}$ Coupling via a Gluon Jet Anisotropy Substructure

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Determining the CP property of the Higgs boson is important for a precision test of the Standard Model as well as for the search for new physics. We propose a novel jet substructure observable based on the azimuthal anisotropy in a linearly polarized gluon jet that is produced in association with a Higgs boson at hadron colliders, and demonstrate that it provides a new CP-odd observable for determining the CP property of the Higgs-top interaction. We introduce a factorization formalism to define a polarized gluon jet function with the insertion of an infrared-safe azimuthal observable to capture the linear polarization.

Axion III / 70

Hybrid Cosmological Collider of Axion

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If a light axion is present during inflation and becomes part of dark matter afterwards, its quantum fluctuations contribute to dark matter isocurvature. In this article, we introduce a whole new suite of cosmological observables for axion isocurvature, which could help test the presence of axions, as well as its coupling to the inflaton and other heavy spectator fields during inflation such as the radial mode of the Peccei-Quinn field. They include correlated clock signals in the curvature and isocurvature spectra, and mixed cosmological-collider non-Gaussianities involving both curvature and isocurvature fluctuations with shapes and running unconstrained by the current data. Taking into account of the existing strong constraints on axion isocurvature fluctuations from the CMB, these novel signals could still be sizable and potentially observable. In some models, the signals, if observed, could even help us significantly narrow down the range of the inflationary Hubble scale, a crucial parameter difficult to be determined in general, independent of the tensor mode.

BSM II / 71

Isosinglet vectorlike leptons at e^+e^- colliders

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Vectorlike leptons are an intriguing possibility for physics beyond the Standard Model. This talk is concerned with the example of weak isosinglet vectorlike leptons that decay through a small mixing with the tau lepton, for which the discovery and exclusion reach of the Large Hadron Collider and future proposed hadron colliders is limited. For this minimal model, I will argue that an e^+e^- collider may act as a discovery machine, and discuss the prospects for observing a mass peak if they are indeed discovered.

SM II / 72

AFB in High Invariant-Mass Drell-Yan: Implications for SMEFT Fits

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We study the impact of LHC forward-backward asymmetry (AFB) measurements at high invariant mass in the Drell-Yan process on probes of semi-leptonic four-fermion operators in the Standard Model effective field theory (SMEFT). In particular, we study whether AFB measurements can resolve degeneracies in the Wilson coefficient parameter space that appear when considering invariant mass and rapidity measurements alone. We perform detailed fits of the available high energy and high luminosity ATLAS and CMS data for both invariant mass distributions and AFB. While each type of measurement separately exhibits degeneracies, combining them removes these blind spots in some cases. In other situations it does not, highlighting the importance of incorporating future data sets from other experiments to fully explore this sector of the SMEFT. We investigate the impact of contributions quadratic in the Wilson coefficients on the description of Drell-Yan data, and discuss when such terms are important in joint fits of the AFB and invariant mass data.

BSM VII / 73

Heavy Neutral Lepton at Future Muon Collider

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The future high-energy muon colliders, featuring both high energy and low background, could play a critical role in our searches for new physics. The smallness of neutrino mass is a puzzle of particle physics. Broad classes of solutions to the neutrino puzzles can be best tested by seeking the partners

of SM light neutrinos, dubbed as heavy neutral leptons (HNLs), at muon colliders.
We can parametrize HNLs in terms of the mass m_N and the mixing angle with ℓ-flavor U_ℓ. In this work, we focus on the regime $m_N > O(100)$ GeV and study the projected sensitivities on the $|U_\ell|^2 - m_N$ plane with the full-reconstructable HNL decay into a hadronic W and a charged lepton. The projected reach in $|U_\ell|^2$ leads to the best sensitivities in the TeV realm.

BSM V / 74

A natural model of spontaneous CP violation

Author: Motoo Suzuki[None]

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We examine the possibility of building a natural non-supersymmetric model of spontaneous CP violation equipped with the Nelson-Barr (NB) mechanism to address the strong CP problem. Our approach is to utilize a doubly composite dynamics where the first confinement of the CFT occurs at the scale of spontaneous CP violation (SCPV) and the second confinement at the TeV scale. A holographic dual description of this 4D set-up via a warped extra dimension with three 3-branes provides an explicit realization of this model, radiative corrections to the strong CP phase are well under control, and the coincidence of mass scales, which we generally encounter in NB models, is addressed. Our model also provides an explanation to the quark Yukawa hierarchies, and a solution to the gauge hierarchy problem just as in the usual Randall-Sundrum model with the Higgs being localized on the TeV brane.

Cosmology I / 75

Gauged quintessence

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We introduce the gauged quintessence model, in which the dark energy field (quintessence) has a U(1) gauge symmetry. This is the first quintessence model under a gauge symmetry. We identify the real part of the complex scalar as the dark energy field (quintessence), while the imaginary part is the longitudinal component of a new gauge boson. It brings interesting characters to dark energy physics. The U(1) gauge boson can affect the quintessence dynamics, and the solicited dark energy properties can constrain the gauge coupling constant. While the uncoupled quintessence model severely suffers from the Hubble tension, the gauged quintessence might alleviate the situation.

BSM IX / 76

Anomalies, Representations and Self-Supervision

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Autoencoders are an effective analysis tool for model-agnostic searches at the LHC. Unfortunately, it is known that their OOD detection performance is not robust and heavily depends on the compressibility of the signals. Even if a neural network can learn the physical content of the low-level data, the gain in sensitivity to features of interest can be hindered by redundant information already explainable in terms of known physics. This poses the problem of constructing a representation space where known physical symmetries are manifest and discriminating features are retained. I will present ideas in both directions. I will introduce a Machine Learning framework, known as Contrastive Learning, that allows for the definition of observables invariant to transformations and show how to use them for Autoencoders-based anomaly detection.

Cosmology II / 77

Baryogenesis in a Parity Solution to the Strong CP Problem

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Space-time parity can solve the strong CP problem and introduces a spontaneously broken $SU(2)_R$ gauge symmetry. We investigate the possibility of baryogenesis from a first-order $SU(2)_R$ phase transition similar to electroweak baryogenesis. We consider a model with the minimal Higgs content, for which the strong CP problem is indeed solved without introducing extra symmetry beyond parity. Although the parity symmetry seems to forbid the $SU(2)_R$ anomaly of the $B{-}L$ symmetry, the structure of the fermion masses can allow for the $SU(2)_R$ sphaleron process to produce non-zero $B{-}L$ asymmetry of Standard Model particles so that the wash out by the $SU(2)_L$ sphaleron process is avoided. The setup predicts a new hyper-charged fermion whose mass is correlated with the $SU(2)_R$ symmetry breaking scale and hence with the $SU(2)_R$ gauge boson mass, and depending on the origin of CP violation, with an electron electric dipole moment. In a setup where CP violation and the first-order phase transition are assisted by a singlet scalar field, the singlet can be searched for at future colliders.

Cosmology II / 78

Nonrelativistic vector dark matter nonminimally coupled to gravity

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Vector dark matter (VDM) is a good candidate of dark matter with rich phenomenology. In this work, we study nonminimal couplings to gravity for VDM in the wave regime, where the particle mass is below $30\mathrm{eV}$. In the nonrelativistic limit, the nonminimal coupling with the lowest mass dimension leads to effective self-interactions that affect the mass-radius relation of vector solitons, growth of linear perturbations during structure formation, and the speed of gravitational waves (GWs). Based on current limits on the GW speed, we constrain the dark matter mass and nonminimal coupling strength to be within the range $-2\times10^{46}\mathrm{eV}^{-2} < \xi_2/\mathrm{m}^2 < 2\times10^{49}\mathrm{eV}^{-2}$.

SM III / 79

Measurements of Higgs boson production and decay rates and their interpretation with the ATLAS experiment

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The event rates and kinematics of Higgs boson production and decay processes at the LHC are sensitive probes of possible new phenomena beyond the Standard Model (BSM). This talk presents precise measurements of Higgs boson production and decay rates, obtained using the full Run 2 and partial Run 3 pp collision dataset collected by the ATLAS experiment at 13 TeV and 13.6 TeV. These include total and fiducial cross-sections for the main Higgs boson processes as well as branching ratios into final states with bosons and fermions. Differential cross-sections in a variety of observables are also reported, as well as a fine-grained description of the Higgs boson production kinematics within the Simplified Template Cross-section (STXS) framework. Combinations of such measurements are also presented, as well as their interpretation in terms of Higgs boson couplings and in the context of Effective Field Theory (EFT) frameworks and specific BSM models.

BSM III / 80

Earth-Catalyzing Detection of Magnetic Inelastic Dark Matter

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Inelastic dark matter with moderate splittings, $\mathcal{O}(\text{few to }150)$ keV, can upscatter to an excited state in the Earth, with the excited state subsequently decaying, leaving a distinctive monoenergetic photon signal in large underground detectors. I'll show that proposed large volume gaseous detectors (CYGNUS) will have excellent sensitivity to this signal. I'll compare and contrast the photon signal to the standard nuclear recoil signal (from, in this case, upscattering) that Xenon detectors are sensitive.

BSM XIV / 81

A new picture for scalar boson superpartners, with only second-order gauge couplings and reduced cross-sections

Author: Roland Allen[1]

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A new fundamental theory [1] unavoidably predicts supersymmetry, SO(N) grand unification, and a new description of all fundamental scalar bosons. As discussed in our previous papers [2-5] and many recent talks, this last feature in turn unavoidably predicts a dark matter WIMP which is consistent with all experimental and observational constraints, and which should be observable via direct detection (within the next few years), collider detection (within about 15 years), and indirect detection (for which there is already evidence). Here we point out another important consequence: It is not possible to form the usual sfermions described by the 16 of SO(10), and instead it is necessary to form real scalar boson fields with the same basic character as the higgsons of our earlier papers, having no interactions other than (1) second-order gauge couplings and (2) the usual Higgs coupling. This means that the scalar boson partners of fermions will be harder to produce and observe than is

currently expected, and the same will be true of gauginos and Higgsinos via processes which also involve scalar boson superpartners. One then has a different version of natural supersymmetry, with superpartners at ˜ a few hundred GeV which are more difficult to observe, and which have modified experimental signatures.

[1] Roland E. Allen,"Some unresolved problems from a fresh perspective", arXiv:2302.10241.
[2] Reagan Thornberry et al., EPL [European Physics Letters] 134, 49001 (2021), arXiv:2104.11715 [hep-ph].
[3] Caden LaFontaine et al., Universe 7, 270 (2021), arXiv:2107.14390 [hep-ph].
[4] Bailey Tallman et al., ICHEP-2022 proceedings, arXiv:2210.05380 [hep-ph].
[5] Bailey Tallman et al., Letters in High Energy Physics LHEP-342 (2023), doi.org/10.31526/lhep.2023, arXiv:2210.15019 [hep-ph].

DM I / 82

Ab-initio all-electron calculation of dark matter–electron scattering rates with emphasis on theoretical uncertainties.

Authors: Cyrus Dreyer[1]; Marivi Fernandez-Serra[1]; Rouven Essig[1]; Aman Singal[1]; Cheng Zhen[None]

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We present a new calculation of dark matter-electron scattering rates in semiconductors using atomic centered gaussian basis sets within the framework of density functional theory. We treat both core and valence orbitals similarly and compare with prior results, emphasizing the importance of all-electron effects, which enhance dark-matter electron scattering rates at high recoil energies. We also carefully test systematic uncertainties from the choice of basis sets, exchange correlation functionals, and numerical modelling.

Neutrinos I / 83

What can the upcoming large neutrino detectors tell us about flavor transitions of galactic supernova neutrinos?

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We present a method to verify Mikheyev-Smirnov-Wolfenstein effect during the propagation of SN neutrinos from the SN core to the Earth. The non-MSW scenarios to be distinguished from the MSW one are the incoherent flavor transition probability for neutrino propagation in the vacuum and the flavor equalization induced by fast flavor conversions. Our approach involves studying time evolution of neutrino event rates in liquid Argon, liquid scintillation and water Cherenkov detectors. Using currently available simulations for SN neutrino emissions, the time evolution of electron-neutrino capture by Argon and electron anti-neutrino inverse beta-decay event rates and the corresponding cumulative event fractions are calculated up to t=100 ms in DUNE, JUNO and Hyper-Kamiokande detectors, respectively. It is shown that the area under the cumulative time distribution curve from t=0 to t=100 ms in each detector and their ratio can be used to discriminate different flavor transition scenarios of SN neutrinos.

Higgs I / 84

Top Yukawa Coupling Measurement at High Energy Muon Collider

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Top Yukawa coupling is deeply connected to many fundamental puzzles in Higgs and Electroweak physics. In this study, we seek to measure the Top Yukawa coupling at the future high-energy muon colliders utilizing the Higgs unitarization in the $V_L V_L \to t\bar{t}$ process. If the Top Yukawa coupling deviates from the Standard Model (SM) value, the amplitude of the
processes with gauge bosons and top quarks $VV \to t\bar{t}$ will be increasing and it will deviate from the SM rate as a function of the $t\bar{t}$ center of mass energy. We show that using a muon collider with 10TeV energy and 10ab^{-1} integrated luminosity, the collider can probe the Top Yukawa with a precision better than 1.5%. This is a significant improvement from the projected high-luminosity LHC (HL-LHC) limit of 3.2% and the $t\bar{t}H$ process sensitivity at muon colliders.

Cosmology I / 85

Seeing highly anisotropic gravitational wave backgrounds from phase transitions

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Anisotropies of gravitational wave background (GWB) from a first-order phase transition could provide a new map of primordial inhomogeneities, analogous to the CMB. In multi-field inflation, this map could differ significantly from CMB if its inhomogeneities are sourced by a quantum field different from the one sourcing CMB (adiabatic) inhomogeneities. While a highly anisotropic GWB could provide valuable new information about light fields from inflation, its isotropic component is expected to be small due to the isocurvature constraints from CMB. In this talk, I will propose a model that makes this tradeoff less severe by including an additional period of matter dominance in the early universe. I will show improvement in the detection prospect of GWB with large anisotropies and elaborate on other interesting features of this model such as the production of primordial black holes.

BSM IV / 86

FIMP Dark matter from Flavor models

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We investigate the phenomenology of a non-thermal dark matter (DM) in the context of flavor models that explain the hierarchy in the masses and mixings of quarks and leptons via the Froggatt-Nielsen (FN) mechanism. A flavor-dependent $U(1)_{FN}$ symmetry explains the fermion mass and mixing hierarchy, and also provides a mechanism for suppressed interactions of the DM, assumed to be a Majorana fermion, with the Standard Model (SM) particles, resulting in its FIMP (feebly interacting massive particle) character. Such feeble interactions are mediated by a flavon field through higher dimensional operators governed by the $U(1)_{FN}$ charges. We point out a natural stabilizing mechanism for the DM within this framework with the choice of half-integer charge for the DM fermion and integer charges for the SM fermions and the flavon field. In this scenario, the DM is non-thermally produced from the decay of the flavon in the early universe, and becomes a relic through the freeze-in mechanism. We explore the allowed parameter space for this DM candidate from relic abundance by solving the relevant Boltzmann equations. We find that there is some preference for sub-MeV range for the DM mass since the experimental and theoretical constraints are less stringent in this range.

Cosmology III / 87

Dark Radiation from Neutrino Mixing after Big Bang Nucleosynthesis

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In this talk, I will motivate the study of models of dark radiation. Dark radiation models might have a rich phenomenology, with imprints on cosmological observables. Upcoming CMB and LSS measurements will be sensitive to different signals, which makes the exploration of Dark radiation imprints timely. Moreover, we recently showed that Dark radiation might be an asset in solving the Hubble and S_8 tensions.

I will concretely show how a light ($m_{\nu D} \underset{\backslash sim}{<}$ MeV) dark fermion mixing with the Standard Model neutrinos can naturally equilibrate with the neutrinos via oscillations and scattering. In the presence of dark sector interactions, the production of dark fermions is generically suppressed above BBN, but then enhanced at later times. Over much of the parameter space, we find that the dark sector equilibrates, even for mixing angles θ_0 as small as 10^{-13}, and equilibration naturally occurs at most a few orders of magnitude above the dark fermion mass. The implications of this are twofold: one, light states are often only constrained by the CMB and LSS without leaving an imprint on BBN, and two, such sectors that equilibrate before recombination will typically have a mass threshold before recombination. Different regimes of parameter space, as well as different spectra and interactions of the dark sector, have different and model-dependent signatures on the CMB and LSS, opening the door for future studies.

BSM IV / 88

Anomaly Mediated Supersymmetry Breaking for Chiral Gauge Theories

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Anomaly Mediated Supersymmetry Breaking or AMSB is a promising new technique that allows one to use the solvability of SUSY chiral theories and translate that in a standard way into non-SUSY theories. I will discuss how this new method works and apply it to a certain set of chiral gauge theories with fields in the fundamental, antifundamental and antisymmetric representations. I find that this set of theories obtains a stable minima and passes many nontrivial checks such as t 'Hooft anomaly cancellation.

BSM IV / 89

Mass-varying gauge boson that couples to the dark energy field

Authors: Hye-Sung Lee[1]; Jaeok Yi[None]; Jiheon Lee[1]; Kunio Kaneta[None]

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We study the dark gauge boson in the gauged quintessence model. The gauged quintessence is the dark energy field under a gauge symmetry, and therefore its mass varies as the quintessence scalar value changes. The change of the dark gauge boson mass brings interesting consequences. The evolution of the universe is sensitively affected by the mass-varying dark gauge boson. We study various phenomenology of the dark gauge boson, including its production, evolution, and other implications.

DM I / 90

Directional detection of dark matter with anisotropic response functions

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Direct detection for sub-GeV dark matter is developing rapidly, with many novel experimental ideas and theoretical methods emerging. In this work, we extend the dielectric formalism for dark matter scattering to incorporate anisotropic material responses, enabling directionally-sensitive experiments with a broad class of target materials. Using a simple model of an anisotropic electron gas, we demonstrate the importance of many-body effects such as the plasmon, and show that even when the dark matter kinetic energies are much smaller than the plasmon energy, the tail of an anisotropic plasmon can still produce a sizeable daily modulation. We highlight the relevant experimental techniques required to establish the target response, as well as the challenges in extracting a response function which is truly free of modeling uncertainties.

Tools I / 91

Decision tree autoencoder anomaly detection on FPGA at L1 triggers

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We present a decision tree-based implementation of autoencoder anomaly detection. A novel algorithm is presented in which a forest of decision trees is trained only on background and used as an anomaly detector. The fwX platform is used to deploy the trained autoencoder on FPGAs within the latency and resource constraints demanded by level 1 trigger systems. Results are presented with two datasets: a BSM Higgs decay to pseudoscalars with a 4l final state, and the LHC physics dataset for unsupervised New Physics detection. Finally, the effects of signal contamination on the training set are presented, demonstrating the possibility of training on data.

This work is detailed in 2304.03836.

BSM IV / 92

New Horizons in the Holographic Phase Transition

Authors: Bharath Sambasivam[None]; Cem Eröncel[1]; Gabriele Rigo[2]; Jay Hubisz[1]; Seung J. Lee[3]

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We consider dynamical fully 5-Dimensional cosmological solutions of the holographic dilaton to study an out-of-equilibrium alternative to the thermal Randall-Sundrum conformal phase transition. It is well known that this transition is typically strongly first order, with the requirement of a perturbative 5D gravity theory obstructing completion of the transition. We comment on a class of initial conditions that generically leads to completion of the phase transition with increased perturbative control of the 5D theory associated with higher likelihood of success.

DM III / 95

Evaporation Barrier for Dark Matter in Celestial Bodies

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The minimum testable dark matter (DM) mass for almost all DM signatures in celestial bodies is determined by the rate at which DM evaporates. DM evaporation has previously been calculated assuming a competition between the gravitational potential of the object, and thermal kicks from the celestial-body matter. I will point out a new effect, where mediators with a range larger than the

interparticle spacing induce a force proportional to the density gradient of celestial objects, forming an evaporation barrier for the DM. This effect can be so significant that evaporation does not occur even for sub-MeV DM, in stark contrast to previous calculations. This opens up a wide range of new light DM searches, many orders of magnitude in DM mass below the sensitivity of direct detection.

DM III / 96

Visible Signatures of Dark Photon Decays in LDMX

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The constituents of dark matter are still unknown, and the viable possibilities span a very large mass range. Specific scenarios for the origin of dark matter sharpen the focus to within about an MeV to 100 TeV. Most of the stable constituents of known matter have masses in the lower range, and a thermal origin for dark matter works in a simple and predictive manner in this mass range as well. The Light Dark Matter eXperiment (LDMX) is a planned electron beam fixed-target experiment at SLAC that will probe a variety of dark matter models in the sub-GeV mass range using a missing momentum technique. Although optimized for this technique, LDMX is effectively a fully instrumented beam dump experiment, making it possible to search for visibly decaying signatures. This would provide another outlet for LDMX to probe complementary regions of dark matter phase space for a variety of models, provided that the additional technical challenges can be met. This contribution will give an overview of the motivations for LDMX and focus on the technical challenges of searches for visible signatures at LDMX.

BSM XII / 97

Limits on Dark Matter Annihilation from the Shape of Radio Emission in M31

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Well-motivated scenarios of thermally-produced dark matter often result in a population of electrons and positrons within galaxies produced through dark matter annihilation – often in association with high-energy gamma rays. As they diffuse through galactic magnetic fields, these $e^{\pm}$ produce synchrotron radio emission. The intensity and morphology of this signal depends on the properties of the interstellar medium through which the $e^{\pm}$ propagate. Using observations of the Andromeda Galaxy (M31) to construct a model of the gas, magnetic fields, and starlight, we set constraints on dark matter annihilation to $b\bar{b}$ using the morphology of 3.6˜cm radio emission. As the emission signal at the center of M31 is very sensitive to the diffusion coefficient and dark matter profile, we base our limits on the differential flux in the region between 0.9-6.9˜kpc from the center. We exclude annihilation cross sections $> 3 \times 10^{-25}$ cm^3/s in the mass range $10 - 500$ GeV, with a maximum sensitivity of 7×10^{-26} cm^3/s at $20 - 40$ GeV. Though these limits are weaker than those found in previous studies of M31, they are robust to variations of the diffusion coefficient

SM II / 98

Challenges with Internal Photons in Constructive QED

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We find the correct spinor amplitude for a simple photon-mediated process and show that, in contrast, the result for the same process using the standard constructive techniques do not agree with Feynman diagrams when the fermions are massive.

SM II / 99

Impact of dimension-eight SMEFT operators in the EWPO and Triple Gauge Couplings analysis in Universal SMEFT

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We perform a complete study of the electroweak precision observables and electroweak gauge boson pair production in terms of the SMEFT up to
$\mathcal{O}(1/\Lambda^4)$ under the assumption of universal, C and P conserving new physics. We show that the analysis of data from those two sectors allows us to obtain closed constraints in the relevant parameter space in this scenario. In particular we find that the Large Hadron Collider data can independently constrain the Wilson coefficients of the dimension-six and -eight operators directly contributing to the triple gauge boson vertices. Our results show that the impact of dimension-eight operators in the study of triple gauge couplings is small.

DM III / 100

Dark photon conversion in the presence of multiple level crossings

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Dark photons can oscillate into SM photons via kinetic mixing in a way that is analogous to neutrino oscillations. Much like the MSW effect for neutrinos in environments of varying density, the probability for dark photons to convert to photons depends on the properties of the ambient background (density, electromagnetic fields, etc.) Resonances are even possible when there is a level-crossing between the dark photon and background-dependent photon states. The Landau-Zener approximation is used widely in the field, but we will show that it breaks down when there are multiple level-crossings where phase effects can cause interference between the resonance points. In some relevant cases, the breakdown is at the level of a few orders of magnitude. We present a new analytic approximation that is valid in this regime and that can accurately predict the conversion probabilities in a wide range of astrophysical environments, from the dense interiors of stars to the rarefied intergalactic medium.

BSM II / 101

CP Violating Top Higgs Coupling at the Future Muon Collider

Authors: Ian Lewis[None]; KC Kong[None]; Morgan Cassidy[None]; Yajuan Zheng[None]; Yanzhe Zhang[None]; Zhongtian Dong[None]

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We study a CP violating top-Higgs coupling at the future muon collider. We consider the processes tth, $tth\nu\nu$, and $tbh\mu\nu$. Using energies of 1, 3, 10, and 30 TeV, we discuss cross section dependence on the CP phase and show how different processes dominate at different benchmark energies. We give projected bounds on the CP phase at 95% CL and discuss the required luminosity for 5σ discovery and 2σ exclusion for different CP phases. We conclude with a comparison of the muon collider results to other future colliders.

BSM VIII / 102

The Light Dark Matter eXperiment (LDMX)

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The constituents of dark matter are still unknown, and the viable possibilities span a very large mass range. Specific scenarios for the origin of dark matter sharpen the focus on a narrower range of masses: the natural scenario where dark matter originates from thermal contact with familiar matter in the early Universe requires the DM mass to lie within about an MeV to 100 TeV. Considerable experimental attention has been given to exploring Weakly Interacting Massive Particles in the upper end of this range (few GeV –˜TeV), while the region ˜MeV to ˜GeV is largely unexplored. Most of the stable constituents of known matter have masses in this lower range, tantalizing hints for physics beyond the Standard Model have been found here, and a thermal origin for dark matter works in a simple and predictive manner in this mass range as well. It is therefore a priority to explore. If there is an interaction between light DM and ordinary matter, as there must be in the case of a thermal origin, then there necessarily is a production mechanism in accelerator-based experiments. The most sensitive way, (if the interaction is not electron-phobic) to search for this production is to use a primary electron beam to produce DM in fixed-target collisions. The Light Dark Matter eXperiment (LDMX) is a planned electron-beam fixed-target missing-momentum experiment that has unique sensitivity to light DM in the sub-GeV range. This contribution will give an overview of the theoretical motivation, the main experimental challenges and how they are addressed, as well as projected sensitivities in comparison to other experiments.

Cosmology III / 103

CMB Bounds from Primordial Black Hole Accretion

Author: Gregory Suczewski[1]

Co-authors: Daniele Gaggero [2]; Dominic Agius [3]; Francesca Scarcella [4]; Mauro Valli [1]; Rouven Essig [1]

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Primordial black holes (PBHs) are a well motivated, macroscopic alternative to particle-like dark matter. If present in the early universe, PBHs will accrete matter, producing high energy photons. The injection of high energy photons during the Dark Ages affects the thermal and ionization histories of the universe, leading to noticeable impacts on the CMB power spectra. In this talk, I will provide an overview of the early universe physics that controls the thermal and ionization histories and the CMB bounds obtained from PBH accretion. In particular, I will present updated constraints on the PBH abundance using the Park-Ricotti accretion model, which incorporates the formation of ionization fronts.

Cosmology II / 104

Parity-violating signals from cosmological collider

Authors: Liantao Wang[None]; Yiming Zhong[None]; Yunjia Bao[1]; Zhong-Zhi Xianyu[2]

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Cosmological parity violation offers a unique way to probe the primordial non-Gaussianity. Recent studies have indicated that measuring parity-violating signals from large-scale structure observations are possible. These signals can arise naturally through the exchange of heavy spinning particles, with chemical potential enhancement, during cosmic inflation. In this talk, we will present a systematic pipeline that relates the primordial trispectra of such cosmological collider processes to the observables in the galaxy surveys. In particular, we focus on several toy models and a full spin-1 model that exhibit parity violation, using the Schwinger-Keldysh formalism and isotropic function formalism to compute the trispectra and corresponding four-point correlation functions, respectively. Our results highlight the need for further studies to provide more precise predictions for cosmological parity-violating signals from the perspective of particle physics.

BSM VI / 105

Precision Cosmological Constraints on Atomic Dark Matter

Author: Jared Barron[None]

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Atomic dark matter (aDM) is a simple but highly theoretically motivated possibility for an interacting dark sector that could constitute some or all of dark matter. We perform a comprehensive study of precision cosmological observables on minimal atomic dark matter, exploring for the first time the full parameter space of dark QED coupling and dark electron and proton masses $(\alpha_D, m_{e_D}, m_{p_D})$ as well as the two cosmological parameters of aDM mass fraction f_D and temperature ratio ξ at the time of SM recombination. We also show how aDM can alleviate the (H_0, S_8) tension from late-time measurements, leading to a significantly better fit than ΛCDM or ΛCDM + dark radiation. Furthermore, including late-time measurements leads to strikingly tight constraints on the parameters of

atomic dark matter. An aDM fraction $f_D > 0.1$ is preferred, with a dark recombination around $z = 2 \times 10^4$.

DM II / 106

Solar reflection of light dark matter with light mediators

Authors: Hailin Xu[None]; Rouven Essig[None]; Timon Emken[None]

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We consider halo dark matter particles whose energy is boosted by colliding with the hot solar plasma. This "solar-reflected"dark matter (SRDM) halo component extends the sensitivity of terrestrial direct detection experiments to lower dark matter masses. In this study, we use a Monte-Carlo simulation to model the propagation and scattering of dark matter particles. We study the properties of the SRDM flux, obtain exclusion limits for various direct-detection experiments, and provide projections for future experiments. We extend previous work on SRDM by focusing on dark matter that interacts with light mediators and implementing a new simulation method that includes the thermal effects in the Sun. Using our updated modeling of the SRDM flux and of the interaction of dark matter particles in terrestrial detectors, we show how SRDM can probe the freeze-in benchmark for sub-MeV dark matter masses.

DM III / 107

More Ways to (Be) Cool: Compact Objects from Inelastic Dark Matter

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A dissipative dark sector can result in the formation of astrophysical compact objects. In this work, we investigate the formation of exotic compact objects assuming a subdominant inelastic dark matter model, and study the resulting landscape of these objects. Inelastic transitions introduce radiative processes which can impact the formation of compact objects via mutliple cooling channels. In particular, we consider cooling from dark Bremsstrahlung and a rapid decay process after inelastic upscattering. We find that having multiple cooling processes can result in a notably unique landscape of compact objects when compared to a scenario with only one cooling channel. The resulting distribution of these astrophysical compact objects and their properties can be used to further constrain and differentiate between dark sectors.

BSM V / 108

Cogenesis of Baryon asymmetry and gravitational dark matter from primordial black holes

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We propose a scenario where dark matter (DM) with a wide mass range from a few keV to PeV can be produced solely from evaporating primordial black holes (PBH), while being consistent with the required free streaming length for structure formation. If DM does not have any other interactions apart from gravity and the universe has a PBH dominated phase at early epoch, then PBH evaporation typically leads to overproduction of DM in this mass range. By incorporating this gravitational DM within a Type-I seesaw scenario with three right handed neutrinos (RHN), we bring the abundance of PBH generated DM within observed limits by late entropy injection due to decay of one of the RHNs, acting as the diluter. The diluter, due to its feeble coupling with the bath particles, gets produced primarily from the PBH evaporation thereby leading to the second stage of early matter domination after the end of PBH dominated era. The other two RHNs contribute to the origin of light neutrino mass and also lead to the observed baryon asymmetry via leptogenesis with contributions from both thermally and PBH generated RHNs. The criteria of DM relic and baryon asymmetry can be satisfied simultaneously if DM mass gets restricted to a ballpark in the MeV-GeV regime with the requirement of resonant leptogenesis for heavier DM mass in order to survive the large entropy dilution at late epochs.

DM II / 109

Neutrino and Gamma Ray Annihilation Signatures From Inelastic Dark Matter Around Neutron Stars

Authors: Javier Acevedo[1]; Joseph Bramante[2]; Qinrui Liu[2]; Narayani Tyagi[3]

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This study investigates the capture and thermalization of inelastic dark matter outside neutron stars. While the possibility of capture, thermalization and annihilation has been studied in some detail in the literature, this has assumed dark matter thermalizes to a trajectory lying inside neutron stars. I will show that some inelastic dark matter models imply thermalization timescales long enough that a substantial fraction of dark matter annihilation can occur outside the star, resulting in potentially observable signatures in the form of neutrinos or gamma rays.
The analysis is carried out for a distribution of neutron stars and dark matter densities in the Milky Way, showing that for a few cases, current ground-based neutrino telescopes could be used to detect such signals.

DM I / 110

Recent Developments in Measuring the Migdal Effect

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The Migdal effect, ionization induced by a nuclear recoil, is an important atomic process for pushing conventional dark matter searches into the MeV mass range. The Migdal effect has of yet not been definitively observed using standard model probes. We have studied the viability of measuring the neutron induced Migdal effect in liquid xenon, silicon, and liquid argon. We present the results of these calculations as well as preliminary results of a measurement done in a two-phase xenon TPC done at LLNL.

BSM XI / 111

Precision electroweak measurements and SMEFT studies at the EIC

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The EIC's high luminosity, wide kinematic coverage, availability of proton and isoscalar deuteron targets, and ability to polarize both the lepton and hadron beams, allows for unique opportunities for precision tests of the electroweak sector of the Standard Model and constraining beyond the Standard Model physics in a manner that complements efforts at the LHC and low energy experiments. In particular, neutral current parity violating DIS allows for a precision extraction of the weak mixing angle over the previously unexplored range of $10\ \mathrm{GeV} < Q < 70\ \mathrm{GeV}$. Furthermore, the various PVDIS asymmetries at the EIC can constrain new physics using the model-independent techniques such as Standard Model Effective Field Theory (SMEFT) analysis. In this talk, we will present an overview of these different topics and provide projection results based on recently carried out realistic EIC simulation studies.

Neutrinos I / 112

Recent Results from MicroBooNE's Low Energy Excess Search

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MicroBooNE is a neutrino experiment that utilizes a single-phase liquid argon time projection chamber (LArTPC) located on-axis in the Booster Neutrino Beam at Fermilab. One of its primary goals is to investigate the nature of the excess of low-energy electromagnetic-like events observed by the MiniBooNE collaboration. In this talk, I will present the recent results from MicroBooNE's low energy excess (LEE) search based on a search of single photons in MicroBooNE and a series of three independent analyses leveraging different reconstruction paradigms which look for an anomalous excess of electron neutrino events. I will also discuss the interpretation of these results in the context of the 3+1 oscillation framework under a light sterile neutrino model, as well as ongoing efforts for other BSM explanations of the MiniBooNE anomaly.

SM IV / 113

Precision Electroweak Tensions and a Wide Dark Photon

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The dark photon is a well-motivated and well-studied extension to the Standard Model. The strongest bounds on a dark photon with a mass near the Z pole come from precision electroweak analysis while for higher masses, collider bounds dominate. Existing tensions involving the heavy flavor observables, the W boson mass, and the muon magnetic moment motivate a revisiting of the precision electroweak bounds, and the collider bounds can be relaxed if the dark photon has a nontrivial branching ratio to a dark sector. In this talk, I discuss the effects of different data combinations on the precision electroweak fit and the viable dark photon parameter space. I also discuss the complementarity between collider searches and precision electroweak bounds for a wide dark photon.

BSM XI / 114

Neutral-current SMEFT studies with EIC and LHeC DIS pseudo data

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We study the potential of DIS measurements at the Large Hadron-electron Collider (LHeC) and the Electron-Ion Collider (EIC) to probe physics beyond the Standard Model. Our study is performed in the context of the Standard Model Effective Field Theory (SMEFT). We find that future measurements at both machines can improve existing SMEFT fits to precision electroweak data by resolving blind spots in fits that utilize LEP and SLC data. We further show that the LHeC can probe semi-leptonic four-fermion operators to the 7 TeV level in some cases, improving upon the LHC reach.

SM II / 115

Some applications of the Eikonal model with Coulomb and curvature corrections in pp and $\bar{p}p$ scattering

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Using a simple eikonal approach to the treatment of Coulomb-nuclear interference and form-factors effects and taking into account the curvature effects in high-energy pp and $\bar{p}p$ scattering, we determine the basic parameters B, ρ, and $\sigma_{\rm tot}$ from fits to experiment at $W = \sqrt{s} =$ 53 GeV, 62.3 GeV, 8 TeV, and 13 TeV. We then investigate the differential cross sections in the dip region for pp and $\bar{p}p$ elastic scattering at $W =$ 53 GeV and 1.96 TeV. We find that i) the results of the basic parameters calculated using the simple eikonal approach agree well with the values determined in other analyses and ii) Coulomb effects are significant in the dip region at 53 GeV and 1.96 TeV, and must be taken into account in searches for odderon effects through cross section differences in that energy region.

Axion III / 116

MAGPI: Measurement of Axion Gradients with Photon Interferometry

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I will present a novel search technique for axions with a CP-violating monopole coupling $\tilde{g}_Q$ to bulk SM charges $Q \in \{B, L, B-L\}$. Gradients in the static axion field configurations sourced by matter induce achromatic circular photon birefringence via the axion-photon coupling $g_{\phi\gamma}$. Circularly polarized light fed into an optical or (open) radio-frequency (RF) Fabry-Perot (FP) cavity develops a phase shift that accumulates up to the cavity finesse: the fixed axion spatial gradient prevents a cancellation known to occur for an axion dark-matter search. The relative phase shift between two FP cavities fed with opposite circular polarizations can be detected interferometrically. This time-independent signal can be modulated up to non-zero frequency by altering the cavity orientations with respect to the field gradient. Multi-wavelength co-metrology techniques can be used to address chromatic measurement systematics and noise sources. I will discuss how, with Earth as the axion source, we project reach beyond current constraints on the product of couplings $\tilde{g}_Q g_{\phi\gamma}$ for axion masses $m_\phi < 10^{-5}$eV. If shot-noise-limited sensitivity can be achieved, an experiment using high-finesse RF FP cavities could reach a factor of $\sim 10^6$ into new parameter space for $\tilde{g}_Q g_{\phi\gamma}$ for masses $m_\phi < 10^{-10}$eV.

Tools I / 117

The Physics of Neural Networks

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Neural networks (NNs) have gained significant attention in the physics community because of their ability to find non-trivial patterns in large datasets. However, developing a theory of NN learning has proven to be quite challenging because of the vast number of degrees of freedom in a typical NN. But fortunately, statistical field theory already provides tools for analyzing similar many-body problems. Infinite-width NNs correspond to free field theories, while finite widths give rise to interactions; signals propagating through a network can be thought of as a renormalization group flow where the marginal couplings are hyperparameters of the network tuned to criticality to prevent exponential growth or decay of signals. We study the effect of initializing a network with weights sampled from an orthogonal matrix distribution and find several key features which indicate that networks with orthogonal initialization might perform better than those with Gaussian initialization throughout training.

BSM I / 118

Dark Photons from Charged Pion Bremsstrahlung at Proton Beam Experiments

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Secondary charged particles in proton beam dump experiments offer a new production mechanism for new particles like dark photons. Proton beam dump experiments produce a multitude of secondary charged pions. As the charged pions travel down the beam path, they scatter off of the target's nuclei and can radiate a dark photon. We use chiral perturbation theory to calculate the production of dark photons through secondary charged pion bremsstrahlung. We find that the mass reach of SpinQuest is significantly extended compared to estimates based on dark photon production through proton bremsstrahlung or meson decay for the planned high-luminosity upgrade of the experiment.

BSM VIII / 119

Extending the Discovery Potential for Inelastic-Dipole Dark Matter with FASER

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Neutral particles are notoriously difficult to observe through electromagnetic interactions. As a result, they naturally elude detection in most collider detectors. In this talk, I will point out that neutral particles that interact through a dipole interaction can nevertheless be detected in far-forward detectors designed to search for long-lived particles (LLPs). In contrast to previous analyses that focused on neutral particles with elastic interactions, we consider inelastic interactions. This naturally leads to LLPs, and we demonstrate that FASER (and future experiments at the Forward Physics Facility) will be able to probe substantial regions of the associated parameter space. In particular, we find that FASER is capable of probing the region of parameter space wherein thermal freeze-out gives rise to an $\mathcal{O}$(GeV)dark-matter candidate with the appropriate relic abundance, as well as regions of parameter space that are difficult to probe at fixed-target experiments. FASER and its successor experiments may therefore play a critical role in the discovery of such a dark-matter candidate.

Gravity I / 120

Constraining Electromagnetic Signals from Black Holes with Hair

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We constrain a broad class of "hairy"black hole models capable of directly sourcing electromagnetic radiation. We assume this emission is triggered by a catastrophic event, such as a binary black hole merger. This signal is generic and model-independent since it depends only on the black hole mass and the proportion of that mass released as radiation (denoted by ϵ). In the most energetic regime, this mechanism triggers pair- production to produce a gamma-ray burst. Since the Fermi Gamma-ray Space Telescope has not observed a gamma-ray burst from a binary black hole merger,

we constrain ϵ to be $< 10^{-4}$ (10^{-5}) for a 10 (30) $M_\odot$ black hole. These constraints will improve as Fermi continues to monitor the sky. In the less energetic regime, ambient charged particles are rapidly accelerated to nearly the speed of light by the strong electromagnetic field. For 1-30 $M_\odot$ black holes and ϵ ranging from 10^{-20} to 10^{-7}, the typical proton energies were ~ $20{-}10^4$ GeV and electron energies were ~ 0.01–10 GeV. At these energies, cosmic ray protons and electrons quickly diffuse into the Milky Way's background magnetic field, making it difficult to identify a point source producing them. Overall, constraining ϵ in this less energetic regime becomes difficult and future constraints may need to consider specific models of "hairy"black holes.

Neutrinos I / 121

First Measurement of Inclusive Muon Neutrino Charged Current Triple-Differential Cross Section on Argon

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The MicroBooNE detector is a Liquid Argon Time Projection Chamber (LArTPC) located along the Booster Neutrino Beam at Fermilab. One of MicroBooNE's key physics goals is the measurement of neutrino-argon cross sections. The MicroBooNE detector's fully active volume and precision reconstruction and calorimetry allow for accurate measurements of lepton kinematics as well as visible hadronic energy produced in a neutrino interaction. This information is leveraged through Wiener SVD unfolding to produce the first neutrino-argon triple-differential cross section measurement, targeting inclusive charged-current final states. A series of constrained goodness of fit tests are used to demonstrate the validity of MicroBooNE's model in describing the distribution of reconstructed kinematics seen in data to ensure the accuracy of unfolding.

SM II / 122

Unpolarized Transverse-Momentum-Dependent Parton Distributions of the Nucleon from Lattice QCD

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We present a first calculation of the unpolarized proton's isovector transverse-momentum-dependent parton distribution functions (TMDPDFs) from lattice QCD, which are essential to predict observables of multi-scale, semi-inclusive processes in the standard model. We use a $N_f = 2 + 1 + 1$ MILC ensemble with valence clover fermions on a highly improved staggered quark sea (HISQ) to compute the quark momentum distributions in large-momentum protons on the lattice. The state-of-the-art techniques in renormalization and extrapolation in correlation distance on the lattice are adopted. The one-loop contributions in the perturbative matching kernel to the light-cone TMDPDFs are taken into account, and the dependence on the pion mass and hadron momentum is explored. Our results are qualitatively comparable with phenomenological TMDPDFs, which provide an opportunity to predict high energy scatterings from the first principles.

SM III / 123

A Guide to Anomaly-Mediated Supersymmetry Breaking QCD

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Recently it has been demonstrated that anomaly-mediated supersymmetry breaking (AMSB) is a valuable tool for understanding the low-energy phases of non-SUSY gauge theories. For example, applying AMSB to SUSY SU(N) gauge theories with quarks in the fundamental leads to scalar potentials with chiral symmetry breaking minima. Furthermore, the application of AMSB to a class of SUSY SO(N) gauge theories gave the first analytic demonstration of confinement, via the dual Meissner effect, and continuous chiral symmetry breaking in a non-SUSY gauge theory. In this talk I will review these developments and then begin an exploration of the rich moduli space structure of AMSB-deformed SU(N) gauge theories. In particular, SUSY-broken gauge theories often possess baryonic runaways to incalculable minima with field VEVs of order Lambda_QCD. For a large class of theories, we instead find that the naive tree level runaways are stabilized by AMSB loop effects. This provides good evidence that the chiral symmetry breaking minima found in the small SUSY breaking limit are in fact global minima.

Axion I / 124

Heavy QCD axions via dimuon final states

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Heavy QCD axions are well-motivated extensions of the QCD axion that address the quality problem while still solving the strong CP problem. Owing to the gluon coupling, critical for solving the strong CP problem, these axions can be produced in significant numbers in beam dump and collider environments for axion decay constants as large as PeV, relevant for addressing the axion quality problem. In addition, if these axions have leptonic couplings, they can give rise to long-lived decay into lepton pairs, in particular, dominantly into muons above the dimuon threshold and below the GeV scale in a broad class of axion models. Considering existing constraints, primarily from rare meson decays, we demonstrate that current and future neutrino facilities and long-lived particle searches have the potential to probe significant parts of the heavy QCD axion parameter space via dimuon final states.

BSM V / 125

Bubble profile and baryon asymmetry in the C2HDM

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Electroweak baryogenesis is a popular mechanism to generate baryon asymmetry at the electroweak scale. The key ingredient in the estimation of baryon asymmetry during electroweak baryogenesis

is the bubble profile. In EWBG studies, it is a routine practice to parametrize the bubble profile by the kink profile using the tanh function. A more refined estimation of the bubble profile can be obtained by solving the tunnelling equation. In the talk, I will present the viability of the kink profile assumption in the framework of CP violating 2HDM. In the bulk of parameter space points, the kink profile predicts the correct order of asymmetry as obtained from the tunnelling profile. There are instances where the kink profile cannot capture the tunnelling profile, thereby showing a significant difference in the asymmetries. I will discuss a few benchmark situations illustrating these differences. I will also discuss the key factors triggering strong first-order phase transition in CP-violating 2HDM parameter space.

Cosmology II / 126

Gravitataional Wave and Parity Odd Signals at the Cosmological Collider

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- Introduce a Chern-Simons term that inflaton is coupled with a gauge boson and show that the gauge boson can be sufficiently produced during inflation.
- Constrain the mass and chemical potential of the gauge boson and the most stringent constraint is the non-Guassianity of the equilateral bispectrum.
- Show three signals of the gauge boson: oscillation with respect to the mass in the squeezed bispectrum, parity violation in the trispectrum, and gravitational waves.

Axion III / 128

The Irreducible Axion Background

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Searches for dark matter decaying into photons constrain its lifetime to be many orders of magnitude larger than the age of the Universe. A corollary statement is that the abundance of any particle that can decay into photons over cosmological timescales is constrained to be much smaller than the cold dark-matter density. We show that an irreducible freeze-in contribution to the relic density of axions is in violation of that statement in a large portion of the parameter space. This allows us to set stringent constraints on axions in the mass range 100 eV – 100 MeV. At 10 keV our constraint on a photophilic axion is almost three orders of magnitude stronger than the bounds established using horizontal branch stars; at 100 keV our constraint on a photophobic axion coupled to electrons is almost four orders of magnitude stronger than present results. Although we focus on axions, our argument is more general and can be extended to, for instance, sterile neutrinos.

BSM XI / 129

Resolving CDF-W mass shift and CKM unitarity puzzle in Left-Right Symmetric Models with Universal Seesaw

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We explore the possibility of resolving the W mass shift observed by the CDF collaboration and the apparent deviation from unitarity in the first row of the CKM matrix simultaneously in a class of left-right symmetric models with universal seesaw. A unique non-trivial solution to the two anomalies was obtained, where the down quark mixing with vector-like quarks˜(VLQ) resolves the CKM unitarity problem, while top mixing with VLQ explains the positive shift in W mass. This leads to testable predictions in the model.

SM IV / 130

Amplitude/Operator Basis for Chiral Perturbation Theory

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The problem of enumerating a complete and independent set of operators for an effective field theory has been solved systematically by the Young Tensor method. In this talk, I am going to present the method adapted for Chiral Perturbation Theory, which introduces the Adler's zero condition to account for the nonlinearly realized symmetry associated with Goldstone bosons. Several subtleties are clarified, including the nonlinear constraint from the Gram determinant, the Cayley-Hamilton theorem for finite N_f, and the inclusion of CP-odd operators. Mesonic operators up to N^3LO with multiplicity 6 are presented together with the corresponding amplitude basis. Finally I will show the technique applied to the HEFT to obtain the NLO and NNLO operator basis.

SM III / 131

Multi-photon decays of the Higgs boson at the LHC

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Many new physics scenarios predict multi-photon Higgs resonances. One such scenario is the dark axion portal. The primary decay chain that we study is the Higgs to dark photon (γ_D) pairs that subsequently decay into a photon and an axion-like particle (a). The axion-like particles then decay into photon pairs. Hence, the signal is a six-photon Higgs decay: $h \to \gamma_D\,\gamma_D \to 2\,\gamma 2\,a \to 6\gamma$. However, depending on the relevant kinematics, the photons can become well-collimated and appear as photon-jets (multiple photons that appear as a single photon in the detector) or ξ-jets (non-isolated multi-photon signals that do not pass the isolation criterion). These effects cause the true six-photon resonance to appear as other multi-photon signals, e.g., four or two photons. The four photon signal is particularly interesting. These events mainly occur when the photons from the axion are collimated into a photon jet. The apparent decay of the dark photon is then $\gamma_D \to \gamma a \to \gamma + \gamma$-jet. This decay seems to violate the Landau-Yang Theorem at the detector level since the dark photon appears to decay into a pair of massless photons. We explore and examine the multi-photon signals

that could appear at the Large Hadron Collider (LHC). The mass regions where two, four, and six-photon resonances dominate are determined. Some additional signal categories involving ξ-jets are considered. All of these multi-photon signals provide excellent footing to explore new physics at the LHC and beyond.

Axion I / 132

Searching for a fifth force with atomic and nuclear clocks

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We consider the general class of theories in which there is a new ultralight scalar field that mediates an equivalence principle violating, long-range force. In such a framework, the Sun and Earth act as sources of the scalar field, leading to potentially observable location-dependent effects on atomic and nuclear spectra. We determine the sensitivity of current and next-generation atomic and nuclear clocks to these effects and compare the results against the existing laboratory and astrophysical constraints on equivalence principle violating fifth forces. We show that, in the future, the annual modulation in the frequencies of atomic and nuclear clocks in the laboratory caused by the eccentricity of Earth's orbit around the Sun may offer the most sensitive probe of this general class of equivalence principle violating theories. Even greater sensitivity can be obtained by placing a precision clock in an eccentric orbit around Earth and searching for time variation in the frequency, as is done in anomalous redshift experiments. In particular, an anomalous redshift experiment based on current clock technology would already have a sensitivity to fifth forces that couple primarily to electrons at about the same level as the existing limits. Our study provides well-defined sensitivity targets to aim for when designing future versions of these experiments.

Tools I / 133

Reducing MC Variance One Control Variate at a Time

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In HEP, we preform multidimensional integrals to compute observables to compare with experimental data. To do so, we use Monte Carlo integration – it scales well with dimensionality but it suffers from a slow convergence rate. As such, it is important to reduce the variance of the result as much as possible and so many techniques have been created for this task. In this talk I will introduce one such method called "control variates" which, when applied to the existing vegas algorithm, returns better results than vegas alone.

Cosmology II / 134

Dynamics of Dark Matter Misalignment Through the Higgs Portal

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A light singlet scalar field feebly coupled through the super-renormalizable Higgs portal provides a minimal and well-motivated realization of ultra-light bosonic dark matter. We study the cosmological production of dark matter in this model by elucidating the dynamics of two sources of scalar field misalignment generated during the radiation era. We compare our relic abundance predictions with constraints and projections from equivalence principle and inverse square law tests, stellar cooling, resonant molecular absorption, and observations of extra-galactic background light and diffuse X-ray backgrounds. New experimental ideas are needed to probe most of the cosmologically motivated regions of parameter space.

BSM III / 135

Constraining light dark Z with low-energy experiments

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In this talk, we will present a study on the effects of the dark Z model in current and future low-energy parity-violating experiments. In particular, we will give the constraints from electroweak pole observables, CEvNS, BaBar, and the future sensitivity for SoLID. We will also present a re-analysis of other existing or upcoming low-energy experiments, such as E158, Qweak, P2, MOLLER, and Atomic Parity Violation, among others.

Gravity I / 136

Detecting Dark Compact Objects in Gaia DR4: A Data Analysis Pipeline for Transient Astrometric Lensing Searches

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The Gaia satellite is cataloging the astrometric properties of an unprecedented number of stars in the Milky Way with extraordinary precision. This provides a gateway for conducting extensive surveys of transient astrometric lensing events caused by dark compact objects. In this work, we establish a data analysis pipeline capable of searching for such events in the upcoming Gaia Data Release 4 (DR4). We use Gaia Early Data Release 3 (EDR3) and current dark matter and astrophysical black hole population models to create mock DR4 catalogs containing stellar trajectories perturbed by lensing. Our analysis of these mock catalogs suggests that Gaia DR4 will contain about 4 astrometric lensing

events from astrophysical black holes at a 5σ significance level. Furthermore, we project that our data analysis pipeline applied to Gaia DR4 will result in leading constraints on compact dark matter in the mass range $1 - 10^3\ M_\odot$ down to a dark matter fraction of about one percent.

BSM VIII / 137

LLPs from photons and charged mesons at beam dumps

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We utilize photon and charged meson fluxes at proton beam targets to produce long lived particles (LLPs) via scattering and decay mechanisms. These particles encompass light scalars and gauge bosons that appear in theories like extended Higgs sectors, $U(1)_{L_\mu - L_\tau}$, $U(1)_{T3R}$ etc. We look at the sensitivities of the above in the context of experiments like ArgoNeuT, MicroBooNe, SBND, ICARUS and the upcoming DUNE experiment. For scenarios that contain muonphilic scalars and/or vectors, these experiments can probe parameters that can explain the current discrepancy in the anomalous magnetic moment of muons. Further, when applied to Higgs Portal Scalars, we see that upcoming experiments are sensitive to masses beyond the current bounds.

BSM XIII / 138

Neutrino masses and self-interacting dark matter in a Z-Z' mixing model

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In this talk we will discuss the possibility that a gauged U(1)' symmetry mediates dark matter self interactions. The breaking of this symmetry induces a Z-Z' mass mixing term, connecting the dark and visible sectors. After symmetry breaking of the U(1)', the fermion content of the dark sector is divided into right handed neutrinos and a stable dark matter candidate. We discuss the neutrino and dark matter phenomenology of this setup.

SM II / 139

Master Integrals for Electroweak corrections to gg → $\gamma\gamma$

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We present a calculation of the master integrals (MI's) required for the calculation of the Electroweak corrections to $gg \to \gamma\gamma$ production in which the process contains a light quark loop.
The integrals can be broken down into four categories based on the flow of the heavy vector bosons throughout the loop. Two of the families are planar, and two are non-planar. We determine a canonical basis for each family which allows an efficient solution of the resulting differential equations via iterated integrals. We compute the families in relevant physical kinematics and obtain an efficient numerical evaluation based on an implementation of Chen-iterated integrals.

Axion II / 140

Search for sub-MeV axion-like particles from horizontal branch stars

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Axion-like particles (ALPs) coupled to photons are produced inside stars via the Primakoff process and photon coalescence. They spontaneously decay into two gamma-ray photons that escape from the stellar interior only if decays occur outside the photosphere. Owing to their hot and dense plasma and small radius of the photosphere, horizontal branch stars are promising astrophysical objects to detect the gamma-ray flux from ALP decays. We estimate the detectability of the ALP-induced gamma-ray flux at future MeV gamma-ray telescopes such as AMEGO-X and APT.

BSM XII / 141

Probing the Sun for BSM Physics using RHESSI

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The nuclear processes within the sun could lead to the production of Beyond the Standard Model (BSM) particles of MeV scale. If these particles are long-lived, they could escape from the Sun and decay into observable particles en route to the Earth.

We use data available from the RHESSI Spectrometer to explore scenarios involving these solar long-lived particles. In particular, we study heavy neutral leptons that couple to neutrinos either through a dipole transition moment or additional elements in the PMNS matrix. We also consider the signal from a heavy axion produced from pp-chain nuclear processes.

DM I / 142

Probing Dark Matter Substructure with Pulsar Timing Arrays

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Pulsar timing arrays (PTAs) are a powerful tool to study dark matter (DM) substructure. Transiting lumps of DM can induce shift in pulsar timings due to Doppler and Shapiro effects. In this talk we first briefly review the principle of DM detection with PTAs. We then show the projected reach using the projected subhalo mass function and density profile of DM substructure from various models. We also discuss constraints on DM substructure obtained using pulsar timing data from the North American Nanohertz Observatory for Gravitational Waves (NANOGrav) and the corresponding Bayesian analysis framework. Finally, we discuss constraints on a Yukawa fifth force interaction between DM and baryons derived from both PTA, and observation of the coldest known neutron star, which limits the interaction strength due to kinetic capture and heating of DM by the neutron star.

BSM X / 143

Search for inelastic dark matter with the CMS detector

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A new paradigm for dark matter searches, allows to focus not only on the coupling between dark matter and the Standard Model, but also on the interactions between dark matter constituents themselves. The LHC is in a unique position to investigate such a rich dark sector which is otherwise difficult to probe with direct and indirect detection techniques. In this talk, a recently published search for dark matter with the CMS detector, using inelastic dark matter (iDM) predictions as a guide, is presented.

BSM VII / 144

What if cLFV was only manifest in tau decays?

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Motivated by flavour symmetry models, one may construct theories based on a low-energy limit featuring lepton flavour triality that have the flavour-violating decays $\tau^\pm \to \mu^\pm\mu^\pm e^\mp$ and $\tau^\pm \to e^\pm e^\pm \mu^\mp$ as the main phenomenological signatures of BSM physics. These decay modes are expected to be probed in the near future with increased sensitivity by the Belle II experiment at the SuperKEKB collider. I will discuss the motivation, model-building and phenomenology of simple extensions to the SM featuring doubly-charged scalars, for which the smoking-gun would be a detection of cLFV in these tau decay channels.

DM III / 145

Stellar Binary Hardening: A Novel Method to Probe Sub-Solar Mass Primordial Black Holes

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Stellar binaries have historically provided a rich target in the search for exotic compact objects such as primordial black holes (PBHs) or MACHOs. A sufficiently heavy compact object flying sufficiently close to a binary will disrupt or soften it, an effect that will show up in binary data as sparseness at large separation bins. While most studies have focused on the softening of wide binaries, we point out that compact objects that are lighter than the binary components would instead cause the binary to become tighter, following Heggie's Law. The hardening of binaries perturbed by light PBHs opens up the possibility to probe sub-solar mass PBHs. The hardening effect would manifest itself as an excess of binaries at separations ~ 10ˆ4 – 10ˆ6 AU, and such separations therefore constitute an important target for Gaia. A future challenge is to distinguish such an excess over uncertainties emanating from the initial distribution of binaries. A way forward could be to compare data between two classes of binaries that have similar initial distributions but different interaction rates with PBHs.

DM I / 146

The Molecular Migdal Effect

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Nuclear scattering events with large momentum transfer in atomic, molecular, or solid-state systems may result in electronic excitations. In the context of atomic scattering by dark matter (DM), this is known as the Migdal effect, but the same effect has also been studied in molecules in the chemistry and neutron scattering literature. Here we present two distinct Migdal-like effects from DM scattering in molecules, which we collectively refer to as the molecular Migdal effect: a center-of-mass recoil, equivalent to the standard Migdal treatment, and a non-adiabatic coupling resulting from corrections to the Born-Oppenheimer approximation. The molecular bonds break spherical symmetry, leading to large daily modulation in the Migdal rate from anisotropies in the matrix elements. Our treatment reduces to the standard Migdal effect in atomic systems but does not rely on the impulse approximation or any semiclassical treatments of nuclear motion, and as such may be extended to models where DM scatters through a long-range force. We demonstrate all of these features in a few simple toy models of diatomic molecules, namely H_2^+, N_2, and CO, and find total molecular Migdal rates competitive with those in semiconductors for the same target mass. We discuss how our results may be extended to more realistic targets comprised of larger molecules which could be deployed at the kilogram scale. Furthermore, we present results from an upcoming paper on ionization in H_2 molecular clouds that demonstrate comparable sensitivity to electronic scattering.

BSM XIII / 148

Discovering the Origin of Neutrino Masses at SHiP

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In $U(1)_R$ extensions of supersymmetric models, the bino and its Dirac partner, the singlino, can play the role of right-handed neutrinos. The bino and the singlino form a pseudo-dirac pair, dubbed the 'biνo', which can generate Standard Model neutrino masses via the inverse seesaw mechanism. We investigate the prospects for detecting long-lived biνos at SHiP, where GeV scale biνos can be copiously produced in the decays of mesons. We show that SHiP can probe new regions of parameter space that are complementary to searches for the lepton flavor-violating decay $\mu \to e\gamma$. This scenario provides a well-motivated benchmark for future experiments of a right-handed neutrino that mixes with all Standard Model neutrinos, and is directly related to the generation of neutrino masses.

SM I / 149

Jet SIFT-ing: a new scale-invariant jet clustering algorithm for the substructure era

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We describe a new jet clustering algorithm named SIFT (Scale-Invariant Filtered Tree) that maintains the resolution of substructure for collimated decay products at large boosts. The scale-invariant measure combines properties of kT and anti-kT by preferring early association of soft radiation with a resilient hard axis, while avoiding the specification of a fixed cone size. Integrated filtering and variable-radius isolation criteria block assimilation of soft wide-angle radiation and provide a halting condition. Mutually hard structures are preserved to the end of clustering, automatically generating a tree of subjet axis candidates. Excellent object identification and kinematic reconstruction for multi-pronged resonances are realized across more than an order of magnitude in transverse energy. The clustering measure history facilitates high-performance substructure tagging, which we quantify with the aid of supervised machine learning. These properties suggest that SIFT may prove to be a useful tool for the continuing study of jet substructure.

BSM IV / 150

Vector boson dark matter in a classically conformal U(1) extension of the Standard Model

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We consider a classically conformal $U(1)$ extension of the Standard Model (SM). The $U(1)$ symmetry is radiatively broken by the Coleman-Weinberg mechanism, after which the $U(1)$ Higgs field ϕ drives electroweak symmetry breaking through a mixed quartic coupling with the SM Higgs doublet with coupling constant λmix. The conformal system features a suppressed coupling $g_{h_1 h_2 h_2} \sim \lambda_{mix} v_h$ (v_h = 246 GeV), likely due to the unique nature of the classically conformal potential, leading to a suppressed $h \to \phi\phi$ process which may evade future experimental limits. We consider the gauge boson of the new $U(1)$ gauge sector, Z', to be the dark matter candidate in the absence of kinetic mixing, and interpret constraints on the conformal model in the context of observed values for dark matter abundance.

Gravity I / 151

Spinor Bose Einstein Condensates : From Cosmos to Laboratory

Author: Mudit Jain[None]

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I will describe spatially localized Bose Einstein condensates (BECs) composed of non-zero spin particles, that carry huge amounts of intrinsic spin angular momentum. Such objects are naturally present in the spectrum of a massive integer spin field theory admitting attractive self-interactions, and are relevant both in cosmology and laboratory setups. In the cosmological scenario, they are relevant in dark photon dark matter and can form at different epochs in the history of our Universe depending on the formation mechanism of the vector field. In dark matter halos, such BECs/solitons arise inevitably via kinetic condensation. In laboratory setups, spinor BECs comprise of ultracold atoms, with various hyperfine levels serving as effective spin quantum numbers. Time permitting, I will also present an interesting setup of atoms trapped under a uniform bias magnetic field + a sinusoidal quadrupole magnetic field, leading to the formation of Dirac strings.

BSM V / 152

Dirac dark matter, neutrino masses, and dark baryogenesis

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We present a gauged baryon number model as an example of models where all new fermions required to cancel out the anomalies help to solve phenomenological problems of the standard model (SM). Dark fermion doublets, along with the isosinglet charged fermions, in conjunction with a set of SM-singlet fermions, participate in the generation of small neutrino masses through the Dirac-dark Zee mechanism. The other SM-singlets explain the dark matter in the Universe, while their coupling to an inert singlet scalar is the source of the CP violation. In the presence of a strong first-order electroweak phase transition, this "dark"CP violation allows for a successful electroweak baryogenesis mechanism.

BSM IX / 153

Drell-Yan Bound on Continuum Spectra from Extra Dimensions

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We present bounds on 5D theories that have a mass gap followed by a continuous spectrum. These theories involve a metric with a warp factor and are controlled by a single parameter ρ. Using Drell-Yan data simulated from MadGraph, Pythia8, and Delphes for charged lepton and dilepton events we perform a χ2 analysis for the differential cross section predicted by the 5D theory and measured by the Standard Model.

BSM XI / 154

The role of dimension-8 operators in an EFT for the 2HDM

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The Standard Model effective field theory (SMEFT) is a standard tool for parametrizing the effects of new physics. The ordiinary approach to SMEFT is to use the truncation at dimension-6, which would typically be the leading contribution beyond the Standard Model. We perform the matching to dimension-8 in the two-Higgs-doublet model (2HDM) and critically examine the dimension-6 and dimension-8 truncations. We find that the dimension-6 truncation fails to capture important physics contributions in the 2HDM.

Higgs I / 155

Non-resonant di-Higgs searches in four b final state at CMS

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In this talk, we will discuss about the results of searches for Higgs pair production in the four-bottom-quark final state via gluon fusion (ggF), vector boson fusion (VBF) and the one associated with an additional vector boson (VHH) with the CMS detector. In addition to the analysis strategy and limits on the production cross section of this process, constraints on the Higgs boson self-coupling and the coupling between two Higgs bosons and two vector bosons will be presented.

BSM VI / 156

Simulating Atomic Dark Matter in Milky Way Analogues

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Dark sector theories naturally lead to multi-component scenarios for dark matter where a sub-component can dissipate energy through self-interactions, allowing it to efficiently cool inside galaxies. We present the first cosmological hydrodynamical simulations of Milky Way analogues where the majority of dark matter is collisionless Cold Dark Matter (CDM), but a sub-component (6%) is strongly dissipative minimal Atomic Dark Matter (ADM). The simulations, implemented in GIZMO and utilizing FIRE-2 galaxy formation physics to model the standard baryonic sector, demonstrate that the addition of even a small fraction of dissipative dark matter can significantly impact galactic evolution despite being consistent with current cosmological constraints. We show that ADM gas with roughly Standard-Model-like masses and couplings can cool to form a rotating "dark disk" with angular momentum closely aligned with the visible stellar disk. The morphology of the disk depends sensitively on the parameters of the ADM model, which affect the cooling rates in the dark sector. The majority of the ADM gas gravitationally collapses into dark "clumps" (regions of black hole or mirror star formation), which form a prominent bulge and a rotating thick disk in the central galaxy. These clumps form early and quickly sink to the inner ˜kpc of the galaxy, affecting the galaxy's star-formation history and present-day baryonic and CDM distributions.

DM I / 157

Search for prompt production of a GeV scale resonance decaying to a pair of muons using data scouting at CMS

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Several BSM predicted particles could give rise to resonant particle pair production. We will present the results of a search for prompt low-mass dimuon resonances based on proton-proton collision data at a center-of-mass energy of 13 TeV collected by CMS. The search exploits a high-rate trigger ("scouting") stream to record events with two muons and looks for narrow peaks in the dimuon mass spectrum below 10 GeV.

Theory I / 158

Constructing Operator Basis in Supersymmetry

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We will talk about a Hilbert series approach to build the operator basis for a N = 1 supersymmetry theory with chiral superfields. We give explicitly the form of the corrections that remove redundancies due to the equations of motion and integration by parts. In addition, we derive the maps between the correction spaces. This technique allows us to calculate the number of independent operators involving chiral and antichiral superfields to arbitrarily high mass dimension.

SM IV / 159

A new statistical model for estimating PDF uncertainties

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Parton distribution functions (PDFs) form an essential part of particle physics calculations. Currently, the most precise predictions for these non-perturbative functions are generated through fits to global data. One difficulty that several PDF fitting groups encounter is the presence of tension in data sets that appear to pull the fits in different directions. Several methods to capture the uncertainty in PDFs in presence of seemingly inconsistent data sets have been proposed and are currently in use. These methods are important to ensure that the uncertainty in PDFs are not underestimated. Here we propose to update these methods by introducing a generalized statistical model inspired by unsupervised machine learning techniques, namely the Gaussian Mixture Model (GMM).
Using a toy model of PDFs, we demonstrate how the GMM can be used to faithfully reconstruct the probability distribution function in PDF space which can in turn be used to accurately determine the uncertainty on PDFs.
We further show how this statistical model reduces to the usual likelihood function for a consistent data set.

Theory I / 160

What UV Evolution Can Tell Us About The Dark Sector

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We analyze the UV breakdown of sub-GeV Dark Matter Models that live in a new, dark U(1) sector. Many of these models include a scalar field, which is either the Dark Matter itself or a dark Higgs field that generates mass terms for the Dark Matter particle via Spontaneous Symmetry Breaking. A quartic self coupling of this scalar field is generically allowed, and we show that its running is largely governed by the strength of the U(1) gauge field. Furthermore, it consistently has a lower Landau pole than the gauge coupling. We consider the implication of this Landau pole from three perspectives: what are the most reasonable low energy parameters, at what energies are novel UV completions needed, and where might one expect to discover Standard Model charged particles associated with the dark sector?

BSM X / 161

Search for long-lived particles decaying to trackless jets with advanced machine learning techniques at CMS

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Novel techniques, using trackless and delayed jet information combined in a deep neural network discriminator, can be employed to identify decays of long-lived particles. In this talk we present how such techniques could be exploited to search for long-lived particles decaying in the outer regions of the CMS silicon tracker or in the calorimeters. The results, obtained using the full Run-II dataset collected at the LHC, are interpreted in a simplified model of chargino-neutralino production, where the neutralino is the next-to-lightest supersymmetric particle, is long-lived, and decays to a gravitino and either a Higgs or Z boson.

Cosmology III / 162

NGC 1068 and Neutrino Self-Interactions

Author: Jeffrey Hyde[1]

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Recently IceCube announced the observation of high-energy neutrinos from the active galaxy NGC 1068. Due to the potential for scattering between signal neutrinos and cosmic background neutrinos, this observation is sensitive to neutrino self-interactions mediated by a massive scalar. In this talk I will present bounds based on the data, highlight the role that detector physics plays in this result, and discuss future possibilities.

Axion III / 163

A new production mechanism for dark photons

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We introduce a mechanism by which a misaligned ALP can be dynamically converted into a dark photon in the presence of a background dark magnetic field. An abundance of non-relativistic ALPs will produce dark photons with momentum of order the inhomogeneities in the background field; therefore a highly homogeneous field will produce non-relativistic dark photons without relying on any redshifting of their momenta. The analysis naturally splits into two regimes. In the large field regime the dark photons exhibit the 'gliding' phenomena in which their energy density decays slower than matter. In the smaller field regime the energy density converts to dark photons, and

during a time in which one would naively assume the field is frozen by Hubble friction, the energy density decays like radiation.

Cosmology II / 164

Dark Matter Distribution in the Shapley Supercluster

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We consider the possibility of constraining the dark matter distribution in the Shapley Supercluster from the velocity distribution of galaxy clusters and galaxies with in it.

BSM VI / 165

Distortion of neutrino oscillations by dark photon dark matter

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A weakly coupled and light dark photon coupling to lepton charges $L_\mu - L_\tau$ is an intriguing dark matter candidate that could modify the dynamics of neutrino flavor conversions. By analyzing data from the T2K, SNO, and Super-Kamiokande experiments, limits are obtained on the dark photon gauge coupling for masses below $\sim 10^{-11}\,\mathrm{eV}$. Degeneracies between shifts in the neutrino mass-squared differences and mixing angles and the new physics effect significantly relax the current constraints on the neutrino vacuum oscillation parameters.

BSM XIII / 166

Gravitational waves from phase transitions and cosmic strings in neutrino mass models with multiple Majorons

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The origin of Majorana neutrino masses in a Majoron model provide a well-motivated scenario for the generation of identifiable primordial stochastic background of gravitational waves. In this talk I will discuss how a spectrum with a joint contribution both from a strong first order phase transition and from global cosmic strings can emerge naturally in these models. Moreover, the interplay between multiple Majorons can enhance the signal making it detectable at planned experiments and even give rise to a double peaked spectrum.

Gravity I / 167

Relativistic Signatures of Flux Eruption Events Near Black Holes

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The black hole images released by the Event Horizon Telescope have opened up a multitude of opportunities to improve our understanding of gravity in strongly curved spacetimes, as well as elucidate the dynamics of turbulent plasma. In this talk, I will connect these two phenomena by demonstrating that the intrinsic variability of reconnection-driven flares in the accretion flow can introduce prominent associated changes in the relative brightness of the lensed emission. Using a combination of numerical and semi-analytic models of flux eruption events, I will show that the "photon ring"formed by multiply imaged emission exhibits a characteristic "loop"in the space of relative brightness versus total flux density. This loop arises from a combination of gravitational lensing, Doppler boosting, and magnetic field structure near the event horizon. I will discuss the ways in which we hope to observe and analyze this feature in supermassive black holes with the next-generation Event Horizon Telescope.

Axion II / 168

Spectral distortions of astrophysical blackbodies as axion probes

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Recent studies reveal that more than a dozen of white dwarfs displaying near-perfect blackbody spectra in the optical range have been lurking in the Sloan Digital Sky Survey catalog. We point out that, in a way analogous to the Cosmic Microwave Background, these stars serve as excellent testbeds for new physics. Specifically, we show how their observed lack of spectral distortions translate into limits on the parameter space of axions with electromagnetic coupling.

BSM XI / 169

Modifying Froggatt Nielsen : An EFT approach

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Froggatt Nielsen (FN) mechanism, when employed to explain the SM flavor hierarchy, introduces a systematic power counting for BSM physics couplings in the IR. While the power counting in the IR is generally robust to UV details, nonetheless there can be visible deviations from a naïve FN counting owing to specificities of the underlying UV model. In this work, we propose a systematic way to account for these deviations (wrinkles) in the EFT by correlating the power counting of new spurions to that arising from FN. We demonstrate this via an explicit UV realization of these wrinkles in a model of a scalar leptoquark coupled to the SM.

BSM IX / 170

Drell-Yan tails as flavour probes of new physics

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The study of high-p_T tails at the LHC can be a complementary probe to low-energy observables when investigating the flavour structure of the Standard Model and its extensions. The Mathematica package HighPT allows to compute Drell-Yan cross-sections for dilepton and monolepton final states at the LHC. The observables can be computed at tree-level in the SMEFT, including the relevant operators up to dimension-eight, with a consistent expansion up to $\mathcal{O}(\Lambda^{-4})$. Furthermore, hypothetical TeV-scale bosonic mediators can be included at tree-level in the computation of the cross-sections, thus allowing to account for their propagation effects. Using the Run-2 searches by ATLAS and CMS, the likelihood for all possible leptonic final states can be constructed within the package, which therefore provides a simple framework for high-pT Drell-Yan analyses. We introduce the main functionalities of HighPT, by deriving constraints on semileptonic operators in the SMEFT, and comparing these to low-energy and electroweak data.

BSM III / 171

Searching for Dark Matter Annihilation with IceCube and P-ONE

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We present a new search for weakly interacting massive particles utilizing neutrino telescopes. We consider galactic and extra-galactic dark matter and analyze ten years of public IceCube data, setting stringent bounds on massive dark matter annihilation. In addition, we make predictions for P-ONE, a new neutrino telescope in the Pacific Ocean, showing that its sensitivity may even exceed bounds set by gamma-ray experiments. We then present estimates for future searches.

BSM VII / 172

Lepton Flavor Portal Matter I

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The paradigm of portal matter represents a well-motivated extension to models with kinetic mixing/vector portal dark matter. We present a minimal toy model construction using leptonic portal matter that addresses the muon $g-2$ anomaly through chiral enhancement. We further explore a realization of this construction with an extended dark gauge sector in which SM and portal matter fields exist as members of the same dark gauge multiplets, which provides a natural extension of simple portal matter models.

BSM II / 173

Testing Lepton Flavor Universality at Future Lepton Colliders

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As one of the hypothetical principles in the Standard Model (SM), lepton flavor universality (LFU) should be tested with a precision as high as possible such that the physics violating this principle can be fully examined. The run of Z factory at a future e^+e^- collider such as CEPC or FCC-ee provides a great opportunity to perform this task because of the large statistics and high reconstruction efficiencies for b-hadrons at Z pole. In this paper, we present a systematic study on the LFU test in the future Z factories. The goal is three-fold. Firstly, we study the sensitivities of measuring the LFU-violating observables of $b \to c\tau\nu$, i.e., $R_{J/\psi}$, R_{D_s}, $R_{D_s^*}$ and R_{Λ_c}, where τ decays muonically. For this purpose, we develop the strategies for event reconstruction, based on the track information significantly. Secondly, we explore the sensitivity robustness against detector performance and its potential improvement with the message of event shape or beyond the b-hadron decays. A picture is drawn on the variation of analysis sensitivities with the detector tracking resolution and soft photon detectability, and the impact of Fox-Wolfram moments is studied on the measurement of relevant flavor events. Finally, we interpret the projected sensitivities in the SM effective field theory, by combining the LFU tests of $b \to c\tau\nu$ and the measurements of $b \to s\tau^+\tau^-$ and $b \to s\bar{\nu}\nu$. We show that the limits on the LFU-violating energy scale can be pushed up to $\sim \mathcal{O}(10)$ TeV for $\sim \mathcal{O}(1)$ Wilson coefficients at Tera-Z.

Axion II / 174

Detecting Axion-Like Particles with Primordial Black Holes

Authors: Bhaskar Dutta[None]; Jae Hyeok Chang[1]; Kaustubh Agashe[None]; Steven Clark[2]; Tao Xu[None]; Yuhsin Tsai[3]

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Asteroid-mass primordial black holes (PBH) can make up a fraction or all of dark matter. Their Hawking radiation process offers a novel channel to produce new particles, which is especially interesting if these particles are mostly secluded from the Standard Model sector. Future gamma-ray

experiments, such as the e-ASTROGAM and AMEGO telescopes, provide exciting prospects for detecting the Hawking radiation signal. In this talk, I will introduce the indirect detection search for PBHs and discuss the potential to distinguish the signal from PBH-produced axion-like particles in the gamma-ray spectrum.

BSM II / 175

Invisible Higgs from forward muons at a muon collider

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In this talk I will propose to probe the Higgs boson decay to invisible particles at a muon collider by observing the forward muons that are produced in association with the Higgs in the Z-boson fusion channel. I will argue that an excellent sensitivity is possible provided a forward muon detector is installed. We find that the resolution on the measurement of the muon energy and angle will be the main factor limiting the actual sensitivity, which poses tight requirements on the forward muon detector design.

BSM I / 176

Secluded dark matter in gauged $B - L$ model

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We consider the gauged $B - L$ model which is extended with a secluded dark sector, comprising of two dark sector particles. In this framework the lightest Z_2-odd particle is the dark matter candidate, having a feeble interaction with all other SM and BSM states. The next-to-lightest Z_2-odd particle in the dark sector is a super-wimp, with large interaction strength with the SM and BSM states. We analyse all the relevant production processes that contribute to the dark matter relic abundance, and broadly classify them in two different scenarios, a) dark matter is primarily produced via the non-thermal production process, b) dark matter is produced mostly from the late decay of the next-to-lightest-odd particle. We discuss the dependency of the relic abundance of the dark matter on various model parameters. Furthermore, we also analyse the discovery prospect of the BSM Higgs via invisible Higgs decay searches.

Axion I / 177

Probe axion-like particles at the electron-ion collider

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The electron-ion collider (EIC), a new powerful high-luminosity
facility, will be able to open up new windows of opportunities to explore new physics. In this paper, we study the potential of the EIC to probe the coupling between axion-like particles (ALPs) and photons in coherent scattering, where the ion stays intact, resulting in a cross section enhancement proportional to the square of the proton number. The ALPs can be produced via photon fusion and decay back to two photons inside the EIC detector. In the prompt-decay searches, we find the EIC can set the most stringent bound for ma ⊠ 10 GeV and can reach the effective coupling 1/Λ at 10−6 GeV−1 level. For the displaced decay, we are able to probe GeV ALPs with 1/Λ = 10−7 GeV−1.

BSM II / 178

Searching for Lepto-philic Z'at Future Lepton Colliders

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With simplest extension of SM symmetry by adding one extra U(1) symmetry, we introduce a new particle Z'. From the collider kinematic variable distribution, we can measure the deviation of the new model from background, with the sensitivity equation, we plot the constraints. Compare to current weak experimental constraints, we have better constraints in our lepton collider processes.

BSM IV / 179

What Can Generalized Symmetries Do For You

Author: Seth Koren[None]

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Models of particle physics that you care about have generalized symmetries, and understanding them can lead to new insights into these theories. I'll give a brief overview of the sorts of questions one might try to address with this technology.

BSM X / 180

Searches for electroweak production of SUSY particles with the CMS experiment

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The latest results from searches for electroweak production of SUSY particles with the CMS experiment will be presented. The analyses are based on the full dataset of pp collisions recorded at sqrt(s) = 13 TeV during the LHC Run 2. Searches are performed in multiple final states and the combination of those searches will be also discussed.

BSM X / 181

Searches for BSM interactions with top quarks and EFT interpretations at CMS

Author: Brent Yates[1]

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The top quark is hypothesized in many BSM models to have enhanced, non-standard or rare interactions with other SM or BSM particles. This presentation covers the latest CMS direct results in this regard, including the tests of lepton flavor violations and baryon number violations. It does not cover FCNC searches.

Higgs I / 182

Effects of EFT operators on off-shell production of the Higgs boson

Author: Lucas Kang[1]

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We present simulation of the dominant off-shell Higgs production mechanisms (gluon fusion, vector boson fusion, and associated production with a vector boson) with subsequent decay to two Z bosons. Effects of Effective Field Theory (EFT) operators on kinematic distributions are modeled for the signal and interfering background diagrams.

BSM XIV / 183

Inevitable Large non-Gaussianity from Curvaton Models

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Curvatons are light (compared to Hubble during inflation) spectator fields that potentially contribute adiabatic curvature perturbations post-inflation. They can thereby alter CMB observables such as

the spectral index n_s, the tensor-to-scalar ratio r, and the local non-Gaussianity $f_{\rm NL}^{\rm (loc)}$. We systematically explore the observable space of a curvaton with a quadratic potential. We find that when the underlying inflation model does not satisfy the n_s and r observational constraint but can be made viable with a significant curvaton contribution, a large $f_{\rm NL}^{\rm (loc)}$ is inevitable without fine-tuning, therefore a lack of observation of said $f_{\rm NL}^{\rm (loc)}$ in next generation experiments will rule out these models. On the other hand, when the underlying inflation model already satisfies the n_s and r observational constraint, $f_{\rm NL}^{\rm (loc)}$ cannot be distinguished from the single-field inflation prediction in general.

BSM VII / 184

Lepton Flavor Portal Matter -2

Authors: GEORGE WOJCIK[None]; Lisa Everett[None]; RICARDO ALEXANDRE DOS SANTOS XIMENES FILHO[1]; SHU TIAN EU[None]

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The paradigm of portal matter represents a well-motivated extension to models with kinetic mixing/vector portal dark matter. In previous work, we constructed a simple leptonic portal matter model in which the portal matter fields could mediate a new physics correction to the anomalous magnetic moment of the muon consistent with the observed discrepancy between the measured value for this quantity and the SM prediction. Here, we present a version of this mechanism by constructing a model with an extended dark gauge sector in which SM and portal matter fields exist as members of the same dark gauge multiplets, which provides a natural extension of simple portal matter models. We find a rich phenomenology in this extended model, including nontrivial novel characteristics that do not appear in our earlier minimal construction, and discuss current experimental constraints and future prospects for this model. We find that a multi-TeV muon collider has excellent prospects for constraining or measuring the crucial parameters of this model.

Tools I / 185

Resolving Combinatorial Ambiguities in the tt Event Topologies with Quantum Algorithms

Authors: Jacob Scott[None]; K.C. Kong[None]; Zhongtian Dong[1]

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We revisit the combinatorial problem at the LHC, taking $t\bar{t}$ production as an example. The combinatorial ambiguity in this case can be reformulated in terms of a quadratic unconstrained binary optimization problem. Finding the solution to the combinatorial problem becomes equivalent to finding the ground state of the Ising Hamiltonian. We explore several variational quantum algorithms to find the global minimum of the problem Hamiltonian and compare our results against the existing methods.

BSM VII / 186

Heavy Neutrino Decay:Detection Sensitivity and Decay Width

Authors: Jeffrey Berryman[1]; Patrick Huber[None]; Yulun Li[None]

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We investigate the decay of MeV-scale sterile neutrinos into e+e- pairs, which is a signature that can be exploited by current solar neutrino and future dark matter experiments to set stringent limits in mass-mixing parameter space. We present a closed-formed cross-section correctly accounting for the neutral/charged current interference and rederive Borexino bounds based on this result. We also comment on future sensitivities.

Cosmology III / 187

Higgsed dark photons without isocurvatures

Authors: Andrea Tesi[1]; Liantao Wang[None]; Wen Han Chiu[None]

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We show how dark photons originating from an abelian Higgs model can be produced from the decay of the radial mode that acts as the curvaton, a light field during inflation that generates (part of) the adiabatic large scale cosmological primordial fluctuations.

BSM X / 188

SUSY searches in photonic final states with CMS

Author: Manfred Paulini[1]

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We summarize current results for searches of the production of supersymmtric particles decaying to photons in the final state using LHC data collected with the CMS detector. The latest results on a SUSY search with diphotons and large missing momentum as well as a stealth supersymmetry search involving diphotons and low missing momentum are presented.

Tools I / 189

Measuring Galactic dark matter through unsupervised machine learning

Authors: Matthew Buckley[None]; Sung Hak Lim[1]; Eric Putney[2]; David Shih[None]

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Measuring the density profile of dark matter in the Solar neighbourhood has important implications for both dark matter theory and experiment. In this work, we apply autoregressive flows to stars from a realistic simulation of a Milky Way-type galaxy to learn –in an unsupervised way –the stellar phase space density and its derivatives. With these as inputs, and under the assumption of dynamic equilibrium, the gravitational acceleration field and mass density can be calculated directly from the Boltzmann equation without the need to assume either cylindrical symmetry or specific functional forms for the galaxy's mass density. We demonstrate our approach can accurately reconstruct the mass density and acceleration profiles of the simulated galaxy, even in the presence of Gaia-like errors in the kinematic measurements.

DM II / 190

Heating of Neutron Stars through Scattering and Capturing of Inelastic Dark Matter with Ultra-Relativistic Targets

Author: Mehrdad Phoroutan-Mehr[1]

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Our research focuses on studying the heating mechanism of neutron stars through the capture of inelastic dark matter. Due to the high density of neutron stars, infalling dark matter particles are accelerated to relativistic speeds. To analyze the scattering between ultra-relativistic targets in the neutron star and quasi-relativistic infalling dark matter, we employ relativistic kinematics. This approach enables us to impose strong constraints that were previously unattainable through direct detection and collider searches. Furthermore, we derive an analytic equation for the maximum mass splitting between two species of dark matter

BSM III / 191

IceCube at the frontier of macroscopic dark matter direct detection

Authors: Mrunal Korwar[None]; Yang Bai[None]; Joshua Berger[1]

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For a class of macroscopic dark matter models, inelastic scattering of dark matter off a nucleus can generate electromagnetic signatures with GeV-scale energy. The IceCube detector, with its kilometer-scale size, is ideal for directly detecting such inelastic scattering. Based on the slow particle trigger for the DeepCore detector, we perform a detailed signal and background simulation to estimate the discovery potential. For order 1 GeV deposited energy in each interaction, we find that IceCube can probe the dark matter masses up to one gram.

Cosmology I / 192

Chiral Plasma Instability in the Early Universe

Author: Tina Kahniashvili[None]

Co-authors: Axel Brandenburg ; Emma Clarke ; Andrew Long ; Guotong Sun

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In my talk I will address possible parity symmetry violation as manifested through prefered chirality in the early universe and its imprints on cosmological observables. I will discuss the chiral plasma instability (CPI) induced in primordial plasma and driven by chiral magnetic effect. My particular interest will be to estimate the gravitational wave signal sourced by CPI and to determine its spectral characteristics and detection prospects.

BSM VI / 193

Probing Atomic Dark Matter using Simulated Galactic Subhalo Populations

Author: Caleb Gemmell[1]

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Atomic dark matter (ADM) is a simple extension to the Standard Model that is motivated by considerations in both particle and astrophysics. ADM can alter structure formation on subgalactic scales due to its ability to dissipate energy through cooling mechanisms, but is also one realisation of a possible complex dark sector. These dark sectors have been previously studied as a solution to the little hierarchy problem. Recently the first N-body simulations were completed, studying the effects of cold dark matter with a ADM subcomponent (6%) and are only beginning to be analysed. In this talk I present how the dissipative nature of ADM affects both the distribution and structure of subhalos in a Milky Way analogue, and outline how we may hope to constrain and probe the ADM parameter space.

Axion II / 194

Probing Axionic Instabilities in the late Universe via CMB-B mode

Author: Subhajit Ghosh[1]

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We study the cosmological signatures of a completely secluded dark sector consisting of axion-like particles (ALPs) with anomalous coupling to a dark Abelian gauge boson. The lighter ALP starts rolling during matter domination and produces dark photons through tachyonic instabilities. The resulting exponential growth in dark photon quanta sources tensor and scalar perturbations which are uncorrelated with the inflationary initial perturbation. These perturbations generate temperature and polarization (E and B mode) anisotropies in the CMB. We constrain the parameter space of the ALP-dark photon system using the CMB measurement from Planck and B mode constraints from the BICEP-Keck array. For most of the viable parameter space, the B mode signal is well within the reach of future B mode experiments. Additionally, this scenario exhibits intrinsic CP violation and produces non-zero EB correlation in the CMB spectrum. We analyze the CP violating signature in light of the recent measurement of cosmic birefringence from Planck data which shows striking deviation from CP symmetry.

BSM VI / 195

Dark photons as boosted dark matter

Authors: Ian Shoemaker[1]; Michael Graesser[None]; Robert Gustafson[1]; Varun Mathur[None]

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While most of dark matter needs to be cold and nonrelativistic, as we look at dark sectors, a subcomponent could be boosted. We have looked for indirect detection of boosted dark matter at intensity frontier experiments like Super-K, Hyper-K. We propose a simple scenario of looking for dark photons as the boosted subcomponent of dark matter. This can be used to place competitive constraints on a popular dark matter model, where dark matter is charged under a dark U(1) which kinetically mixes with the photon. We find that Xenon n-ton, Borexino and Super-K and can place very strong contraints on boosted dark photons which can compete with self interaction and direct detection bounds for dark photon mediator.

BSM X / 196

New search strategies for exotic decays of the Higgs boson to four bottom quarks using vector boson fusion

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Co-authors: Christopher Robyn Hayes [2]; Stephen Roche [3]; Tae Min Hong [4]

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Searching for Higgs boson decays to four bottom quarks is a challenging and critical benchmark for LHC experiments. This final state is predicted by a variety of beyond the Standard Model theories, and current LHC searches focus on the associated production of a Higgs boson with a W or Z boson that subsequently decays to leptons which can be used for triggering. We evaluate the sensitivity of two Higgs production modes that have not yet been explored in detail for this final state: the vector boson fusion (VBF) channel and the VBF channel with an associated photon. We also provide guidance for designing new triggers for the current LHC data-taking period and beyond.

Cosmology III / 197

Learning about the early universe from dips in the gravitational wave spectrum

Author: Joshua Berger[1]

Co-authors: Amit Bhoonah [2]; Biswajit Padhi [1]

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When gravitational waves propagate through a medium with a changing equation of state, their spectrum distorts. A changing equation of state results from massive particles decoupling from the cosmic plasma as the temperature decreases. For low-frequency stochastic gravitational waves, this leads to deviations from the standard k^3 scaling. Interestingly, low-frequency waves emitted from short-duration phase transitions are affected only after they enter the horizon, making them sensitive to the thermal history of the universe. An example of a model with a changing equation of state is the weak confined standard model (WCSM). The WCSM is a phase in which the SU(2) component of the electroweak force is strongly coupled. This phase could have possibly existed in the early universe at temperatures much greater than 100 GeV. Propagating through the WCSM phase causes distortions in the spectrum of gravitational waves that can be detected with space-based detectors such as LISA.

Axion I / 198

From SuperMAG to SNIPE Hunt: Using the Earth to search for ultralight dark matter

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Ultralight bosonic particles, including axionlike particles and kinetically mixed dark photons, can be promising dark matter candidates. It was recently shown that the Earth can act as a transducer for ultralight dark matter detection, by converting the dark matter into an oscillating monochromatic magnetic field signal across the Earth's surface. This occurs because the ground and ionosphere both act as good conductors, forming a (non-resonant) cavity similar to those in shielded laboratory experiments, like DM Radio. In this talk, I review the Earth transducer effect and recent searches for the effect at low frequencies using geomagnetic field data from the SuperMAG collaboration. I also discuss recent and ongoing efforts by the SNIPE Hunt collaboration to search for this effect at higher frequencies, by measuring the magnetic field in radio-quiet locations. In particular, I focus on how environmental effects lead to large uncertainties in the signal, and how these can be avoided by measuring the local curl of the magnetic field.

BSM VI / 199

The continuum dark matter zoo

Author: Ameen Ismail[None]

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I will describe some dark matter models, based mainly on 2210.16326, where the dark matter is described by a gapped continuum, rather than by ordinary particles. The unique kinematics of continuum states leads to a strong suppression of direct detection cross sections, rendering minimal WIMP-like continuum Z-portal models phenomenologically viable. Continuum states can decay to lighter continuum states, which has interesting ramifications for the cosmology and collider physics of these models.

Axion III / 200

Stellar Axion Background

Authors: Erwin Tanin[1]; Ngan Nguyen[None]

Co-author: Marc Kamionkowski

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We characterize in detail the diffuse axion background sourced by all the stars in the universe throughout the cosmic history and discuss the feasibility of probing this background via its decay to X-ray. We focus on main sequence stars and base our calculations on the stellar interior profiles from MESA along with recent models of star formation history and stellar initial mass function.

SM IV / 201

Variant Nelson-Barr Mechanism with Minimal Flavor Violation

Authors: GEORGE WOJCIK[None]; Yang Bai[None]

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Within the general framework of using spontaneous CP violation to solve the strong CP problem, we construct a variant Nelson-Barr model in which the Standard Model (SM) quark contribution to the strong CP phase is cancelled by new heavy QCD-charged fermions. This cancellation is ensured by choosing conjugate representations for the new colored states under the same global flavor symmetry of SM quarks. Choosing the global flavor symmetry to be that of minimal flavor violation, we suppress higher-order corrections to the strong CP phase to well below current experimental constraints. More than two dozen massless Goldstone bosons emerge from spontaneous flavor symmetry breaking, which yield strong astrophysical constraints on the symmetry breaking scale. In the early universe, the Goldstone bosons can be thermally produced from their interactions with the heavy colored fermions and contribute to ΔNeff at a measurable level. As a function of reheating temperature, the predicted ΔNeff shows an interesting plateau behavior we dub the "flavor stairway", which encodes information about the SM quark flavor structure.

Cosmology I / 202

Cosmic Stasis from Primordial-Black-Hole Evaporation and Its Phenomenological Implications

Author: Brooks Thomas[None]

Co-authors: Keith Dienes [1]; Lucien Heurtier [2]; Fei Huang [3]; Doojin Kim [4]; Tim M.P. Tait [5]

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Cosmic stasis is a phenomenon in which the abundances of multiple cosmological energy components —components such as matter, radiation, or vacuum energy —remain effectively constant despite the expansion of the universe. One mechanism which can give rise to an extended period of

cosmic stasis is the evaporation of a population of primordial black holes (PBHs). In this talk, I review how PBH evaporation can lead to a stasis epoch and examine the observational consequences of such a modification to the cosmic expansion history. These include implications for inflationary observables, for the stochastic gravitational-wave background, and for the production of dark matter and dark radiation.

BSM XI / 203

Flavor-changing light bosons with accidental longevity

Authors: Kunfeng Lyu[1]; Maxim Pospelov[None]; Yohei Ema[None]; Zhen Liu[None]

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We consider a model with a complex scalar field that couples to (e, μ) or (μ, τ) within the "longevity" window: $[|m_{l_1} - m_{l_2}|, m_{l_1} + m_{l_2}]$ in which l_1 and l_2 are the two different charged leptons. Within such a mass window, even a relatively large coupling ({\em e.g.} of the size commensurate with the current accuracy/discrepancy in the muon $g-2$ experiment) leads to long lifetimes and macroscopic propagation distance between production and decay points.
We propose to exploit several existing neutrino experiments and one future experiment to probe the parameter space of this model. For the $\mu - e$ sector, we exploit the muonium decay branching ratio and the production and decay sequence at the LSND experiment, excluding the parametric region suggested by $g_\mu - 2$ anomaly. For the $\tau - \mu$ sector, we analyze three main production mechanisms of scalars at beam dump experiments: the Drell-Yan process, the heavy meson decay, and the muon scattering. We explore the constraints from the past CHARM and NuTeV
experiments, and evaluate sensitivity for the proposed beam dump experiment, SHiP.
The latter can thoroughly probe the parameter space relevant for the $g_\mu - 2$ anomaly.

BSM VII / 204

Vectorlike leptons and long-lived bosons at the LHC

Author: Elias Bernreuther[1]

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Long-lived particles are a prime target of searches in current and upcoming LHC runs. In my talk, I will discuss a renormalizable theory that includes a heavy weak-singlet vectorlike lepton that decays into a long-lived pseudoscalar boson and a tau lepton. I will show that this can be the dominant decay mode of the vectorlike lepton provided the pseudoscalar couplings deviate from the case of a Nambu-Goldstone boson. The electroweak production of vectorlike leptons leads to a rich phenomenology at colliders, including signals with many taus or photons. I will analyze in detail the case where the pseudoscalar has a decay length of a few meters and thus would typically deposit energy in the muon chambers of the CMS or ATLAS detectors.

BSM VI / 205

A Twin Higgs Model with SU(4) Color

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Twin Higgs models address the hierarchy problem and can provide interesting dark matter possibilities. However, the cosmology of these models can be problematic.

I present a new twin Higgs model in which the usual color group originates from the spontaneous breaking of a gauged SU(4) symmetry in the visible sector. In the hidden sector the SU(4) is not broken leading to new dark matter possibilities. I present the signals necessary to observe this model in collider experiments, and address its cosmological effects on $N_{effective}$.

Theory I / 206

Oscillation Phenomena in Nambu Quantum Mechanics

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In canonical quantum mechanics (QM), energy eigenstates can be thought of as evolving in the phase space of a classical harmonic oscillator. Nambu quantum mechanics is a particular generalization of canonical QM whereby this phase space is extended to that of an asymmetric top, introducing two "deformation parameters". Canonical QM can then be interpreted as the limiting case where both of them vanish. We will discuss the motivation for and a few consequences of such a generalization, including the possibility of constraining the aforementioned parameters using experimental data on particle oscillation.

BSM XII / 207

Characterizing the Galactic Center gamma-ray Excess using differentiable probabilistic programming

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The Galactic Center gamma-ray Excess (GCE) is a puzzling excess of gamma-ray photons in the inner galaxy, broadly consistent with annihilating dark matter signals, but can also be explained by unresolved astrophysical point sources (PSs) such as millisecond pulsars. Non-Poissonian Template Fitting (NPTF) has been used to study its origin; however, it has proven susceptible to systematic biases, partially arising from degenerate morphologies between different emission components in the GCE region.

In this work, we introduce a novel approach to study the GCE using differentiable probabilistic programming, which enables us to probe spatially varying templates as well as hybrid templates for PS and diffuse components within a single inference framework. This method prepares us to more rigorously and systematically investigate the biases and uncertainties in non-poissonian analyses of the GCE.

Cosmology II / 208

Constraints on Scalar Dark Matter Production from the Inflaton

Author: Sarunas Verner[1]

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In this talk, I discuss the production of a spectator scalar dark matter field that directly couples to the inflaton. Two specific inflationary potentials, the Starobinsky and T-model of inflation, are considered, which satisfy the constraints on the scalar tilt (n_s) and tensor-to-scalar ratio (r) as measured by the Planck satellite. Excitation of the light scalar dark matter during inflation can lead to significant isocurvature perturbations. However, they can be avoided by inducing a sizable effective dark matter mass during the inflationary phase. For purely gravitational production, the Planck isocurvature constraints require that the dark matter mass must be greater than the Hubble scale at the horizon exit, with m_{chi} > H_*. It is argued that these constraints can be extended to a broad range of single-field slow-roll inflation models. Additionally, isocurvature, dark matter abundance, and Lyman-α constraints on the direct coupling and bare dark matter mass are derived. Finally, I briefly discuss the models with non-minimal coupling.

BSM VIII / 209

Doped Semiconductor Devices for sub-MeV Dark Matter Detection

Authors: Peizhi Du[None]; Daniel Egana-Ugrinovic[1]; Rouven Essig[None]; Mukul Sholapurkar[None]

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Dopant atoms in semiconductors can be ionized with ~ 10 meV energy depositions, allowing for the design of low-threshold detectors. We propose using doped semiconductor targets to search for sub-MeV dark matter scattering or sub-eV dark matter absorption on electrons. In this talk, I will show that currently unconstrained cross sections could be tested with a 1 g-day exposure in a doped detector with backgrounds at the level of existing pure semiconductor detectors, but improvements would be needed to probe the freeze-in target.

BSM VI / 210

A Colorful Mirror Solution to the Strong CP Problem

Author: Claudio Andrea Manzari[1]

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I will discuss theories of a complete mirror world with parity (P) solving the strong CP problem. P exchanges the entire Standard Model with its mirror copy and two new mass scales arise: v' where parity and mirror electroweak symmetry are spontaneously broken, and v3 where the color groups break to the diagonal strong interactions. The strong CP problem is solved even if v3 « v' and the breaking of P gives negligible contributions, starting at three-loop order. I will discuss the energy

scales of the model, its minimal particle content and technicolor-like models which can realize the symmetry breaking dynamically and without additional hierarchy problems.

BSM XII / 211

Constraining Ultralight Scalar Dark Matter with Quadratic Couplings from Big Bang Nucleosynthesis

Authors: Philip Sørensen[1]; Tien-Tien Yu[2]; Tom Bouley[None]

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In this talk I present recent work, deriving constraints on ultralight dark matter form Big Bang Nucleosynthesis. The work shows that the presence of ultralight dark matter can modify the effective values of fundamental constants during Big Bang Nucleosynthesis, affecting the predicted abundances of the primordial elements such as Helium-4. The dark matter evolution is influenced by interactions with the Standard Model, leading to novel phenomenology that must be accounted for to correctly estimate the effect on the Helium-4 abundance. It's shown that Big Bang Nucleosynthesis provides strong constraints of ultralight dark matter with quadratic couplings to the Standard Model for a large range of masses as compared to other constraints.

BSM VIII / 212

Keep it Simple: Simplified Frameworks for Long-Lived Particles at Neutrino Facilities

Authors: Brian Batell[1]; Kevin Kelly[2]; Wenjie Huang[None]

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Modern-day accelerator neutrino facilities are excellent venues for searches for new-physics particles. Many distinct new-physics models predict overlapping signatures and phenomenology in these experiments. In this work, we advocate for the adoption of simplified frameworks when studying these types of new-physics signatures, which are characterized by a small number of primary variables, including particle masses, lifetimes, and production and decay modes/rates that most directly control signal event rates and kinematics. In particular, taking the example of long-lived particles that decay inside a neutrino detector as a test case, we study formulate and study simplified frameworks in the context of light scalars/fermions produced in kaon decays which then decay into final states containing an electron-positron pair. We show that using these simplified frameworks can allow for individual experimental analyses to be applicable to a wide variety of specific model scenarios. As a side benefit, we demonstrate that using this approach can allow for the T2K collaboration, by reinterpreting its search for Heavy Neutral Leptons, to be capable of setting world-leading limits on the Higgs-Portal Scalar model. Furthermore, we argue the simplified framework interpretation can serve as a bridge to model identification in the hopeful detection of a new-physics signal. As an illustration, we perform a first determination of the likelihood that, in the presence of a new-physics signal in a detector like the DUNE ND-GAr, multiple different new-physics hypotheses (such as the Higgs-Portal Scalar and Heavy Neutral Lepton ones) can be disentangled. We demonstrate that this model discrimination is favorable for some portions of detectable new-physics parameter space but for others, it is more challenging.

BSM VII / 213

Searching for Heavy Neutral Leptons at A Future Muon Collider

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As the planning stages for a high energy muon collider enter a more concrete era, an important question arises as to what new physics could be uncovered. A TeV-scale muon collider is also a vector boson fusion (VBF) factory with a very clean background, and as such it is a promising environment to look for new physics that couples to the electroweak (EW) sector. In this paper, we explore the ability of a future TeV-scale muon collider to search for Majorana and Dirac Heavy Neutral Leptons (HNLs) produced via EW bosons. Employing a model-independent, conservative approach, we present an estimation of the production and decay rate of HNLs over a mass range between 200 GeV and 9.5 TeV in two benchmark collider proposals with $\sqrt{s}$=3,10 TeV, as well as an estimation of the dominant Standard Model (SM) background. We find that exclusion limits for the mixing between the HNLs and SM neutrinos can be as low as $\mathcal{O}(10^{-6})$. Additionally, we demonstrate that a TeV-scale muon collider allows for the ability to discriminate between Majorana and Dirac type HNLs for a large range of mixing values.

SM I / 214

Hadronization Fractions and Exotic Heavy Flavor at CMS

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Measurements of heavy quark hadronization fractions, or the probabilities f_q that a bottom quark forms one of the weakly decaying B hadrons, are essential for precision measurements of B branching fractions made at hadron colliders and potentially limit searches for new physics in B_s decays. Although once thought to be universal, recent measurements have suggested an environmental and p_T dependence of the ratio f_s/f_u which is examined in detail by new measurements made by the CMS experiment using 62 fb^{-1} of pp collision data at the LHC. Large samples of J/ψ decays have been collected for this purpose using dedicated triggers, which also allow for the reconstruction of exotic charm states decaying to J/ψ J/ψ. While the nature of these states remains unclear, CMS confirms the observation of the X(6900) state, and observes two new states denoted X(6600) and X(7300) with significance of 6.5 and 4.1 standard deviations, respectively.

DM II / 215

Dark Matter-Induced Baryonic Feedback in Galaxies

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In this talk, we discuss a baryonic feedback mechanism induced by dark matter ignition of white dwarf populations, and its potential effects on galaxy evolution and star formation. Previous works have shown that Type Ia supernova ignitions of sub-Chandrasekhar white dwarfs may be caused by asymmetric dark matter captured within white dwarfs, leading to the formation and subsequent collapse of a dark matter core. These dark matter-induced supernovae become an additional source of baryonic feedback in the galaxy. We implement this dark feedback mechanism in a simulation of an isolated galaxy, using the galaxy evolution code GIZMO, and discuss preliminary results of the effects of dark feedback on star formation and dark matter profiles.

BSM VIII / 216

Quirky Signals at Colliders

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Exploring less studied signals of beyond the standard model physics can optimize the LHC's discovery potential and address open questions. Quirks are particles charged under a new $SU(N)$ color group with masses much larger than their confinement scale. This makes their collider signal qualitatively different from many standard searches and leads to interesting signals. I outline families of quirky signals motivated by the Higgs hierarchy problem and how they can be discovered at the LHC.

BSM XI / 217

Probing type-II seesaw mechanism in alternative U(1)$_X$ model

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We investigate a pair production of doubly-charged scalars ($\Delta^{\pm\pm}$)
at the High-Luminosity LHC in the recently proposed alternative U(1)$_X$ extension
of the Standard Model with the type-II seesaw mechanism. We focus on the $\Delta^{\pm\pm}$
production mediated by U(1)$_X$ gauge boson (Z') and find an enhancement of
the production cross section via Z' resonance compared with that through
the Standard Model gauge interaction.

Neutrinos I / 218

Neutrino forces in neutrino backgrounds

Authors: Bingrong Yu[1]; Mitrajyoti Ghosh[2]; Walter Tangarife[3]; Xunjie Xu[1]; Yuval Grossman[4]

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In the non-relativistic limit, scattering of two particles by boson exchange can be described using a static potential, i.e, that of a force between them. The exchange of two fermions can also lead to a force, as if the two fermions behave like an effective boson. These forces are called "quantum forces", and the range of these forces is inversely proportional to the mass of the fermions being exchanged. Thus, the exchange of neutrinos leads to the longest-ranged fermion exchange force since neutrinos are the lightest fermions in the Standard Model. In this talk, I will briefly review the neutrino force. I will then talk about scenarios where the effects due to the neutrino force can be enhanced significantly due to a neutrino background, potentially providing sensitivity to neutrino physics parameters that have so far eluded us.

Theory I / 219

Kerr Blackhole Perturbation and Metric Reconstruction Problem in a Horizon-Penetrating Coordinates

Authors: Dejan Stojkovic[1]; Mohamed Fawzi[1]

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We investigate the Teukolsky equations in horizon-penetrating coordinates to study the behavior of perturbation waves crossing the outer horizon. For this purpose, we use the null ingoing/outgoing Eddington-Finkelstein coordinates. We find that the radial equation is a confluent form of Heun' s differential equation in both ingoing/outgoing coordinates, with three singularities. The radial function satisfies the physical boundary conditions without imposing any regularity conditions. We also observe that the Hertz-Weyl scalar equations preserve their angular and radial signatures in these coordinates. Using the angular equation, we construct the metric perturbation for a circularly orbiting perturber around a black hole in Kerr spacetime. Furthermore, we complete the missing metric pieces due to the mass and angular momentum perturbations. We also provide an explicit formula for the metric perturbation as a function of the radial part, its derivative, and the angular part of the solution to the Teukolsky equation.

BSM IX / 220

Entangled Taus at Colliders

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Studies of entanglement and other quantum information measures at colliders have recently been proposed to probe fundamental interactions at high energies. Inspired by these results, we examine tau pair productions at both lepton and hadron colliders, to probe dimension-6 dipole operators in the Standard Model Effective Field Theory (SMEFT).

The SMEFT contributions are found to be sizable in some regions of parameter space, if quadratic contributions are considered, prompting a comparison with other known indirect constraints on the tau dipole operators. We also find interesting patterns of entanglement across the phase spemphasized textace, feeding into previous discussions on quantum information in the context of EFTs.

Cosmology III / 221

Cosmologically Varying Kinetic Mixing

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The portal connecting the invisible and visible sectors is one of the most natural explanations of the dark world. However, the early-time dark matter production via the portal faces extremely stringent late-time constraints. To solve such tension, we construct the scalar-controlled kinetic mixing varying with the ultralight CP-even scalar's cosmological evolution. To realize this and eliminate the constant mixing, we couple the ultralight scalar within the mass range 10−33eV«m0«eV with the heavy doubly charged messengers and impose the Z2 symmetry under the dark charge conjugation. Via the varying mixing, the keV−MeV dark photon dark matter is produced through the early-time freeze-in when the scalar is misaligned from the origin and free from the late-time exclusions when the scalar does the damped oscillation and dynamically sets the kinetic mixing. We also find that the scalar-photon coupling emerges from the underlying physics, which changes the cosmological history and provides the experimental targets based on the fine-structure constant variation and the equivalence principle violation.

BSM IX / 222

Entanglement and Bell's inequalities with boosted semi-leptonic top quarks at the LHC

Authors: Alberto Navarro[None]; Dorival Goncalves[None]; Kyoungchul Kong[None]; Zhongtian Dong[None]

The Large Hadron Collider provides an excellent environment to study quantum entanglement and Bell's inequality at high energies. We explore the possible observation of entanglement and violation of Bell's inequality in the semi-leptonic channel of top quark pair production. We show that boosted top quarks are required to ensure they are spacelike separated. The density matrix of the top-pair system is reconstructed using an optimal hadronic polarimeter and NN-inspired reconstruction methods.

BSM XIII / 223

Neutrino Long-Range Self-Interaction and its impact on Cosmic Structure Formation

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In the late universe, the massive cosmic neutrino background alters the growth of structure, providing a unique opportunity to study physics beyond the standard model. In this talk, I will show

that neutrinos with long-range self-interaction can significantly affect late-time cosmological observables, with coupling strengths a few orders of magnitude stronger than gravity.

BSM X / 224

Prospects of Heavy Higgs scalar in the natural SUSY at LHC upgrades

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Under supersymmetry (SUSY) models with low electroweak naturalness (natSUSY), which have been suggested to be the most likely version of SUSY to emerge from the string landscape, we examine the viabilities of future search for the heavy SUSY Higgs bosons H, A, Hˆ\pm through various their decay signatures in LHC. The traditional H, A -> tautau, as well as Hˆ\pm -> tau+nu, t+b, with a spectator top-jet channels are considered. In particular, we also examine H/A/Hˆ\pm -> W/Z/h + MET. These decay channels only come from natSUSY, in which the higgsinos are expected at the few hundred GeV scales whilst electroweak gauginos inhabit the TeV scale, such that for TeV-scale heavy SUSY Higgs bosons as the current LHC limits required, their decays modes into gauggino plus higgsino are kinematically open. We evaluate these signals against several Standard Model backgrounds to get both the 95% CL exclusion and 5σ discovery reach in the mA vs. tan β plane for the future high luminosity LHC (HL-LHC) with 3000 fbˆ-1 of integrated luminosity.

BSM V / 225

Dark Matter Induced Nucleon Decay Signals in Mesogenesis

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I introduce and study the first class of signals that can probe the dark matter in Mesogenesis which will be observable at current and upcoming large volume neutrino experiments. The well-motivated Mesogenesis scenario for generating the observed matter-anti-matter asymmetry necessarily has dark matter charged under baryon number. Interactions of these particles with nuclei can induce nucleon decay with kinematics differing from sponanteous nucleon decay. I calculate the rate for this process and develop a simulation of the signal that includes important distortions due to nuclear effects. I estimate the sensitivity of DUNE, Super-Kamiokande, and Hyper-Kamiokande to this striking signal.

Higgs I / 226

Unfolding Higgs-top CP measurement

Authors: Dorival Gonçalves[1]; Jona Ackerschott[2]; Rahool Kumar Barman[1]; Theo Heimel[2]; Tilman Plehn[None]

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We explore CP-violation in Higgs-top interactions via the semileptonic $pp \to t\bar{t}h$ channel with $h \to \gamma\gamma$ at the high luminosity LHC with machine learning-based unfolding techniques. We invert the event simulation chain, unfolding the detector-level events to construct and encode observables in their relevant partonic reference frame to improve CP sensitivity.

BSM XII / 227

Neutrino pair radiation from pulsar binaries

Author: Margarita Gavrilova[1]

Co-authors: Mitrajyoti Ghosh [2]; Tien-Hsueh Tsai [3]; Walter Tangarife [4]; Yuval Grossman [2]

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Pulsar binaries can be used for robust probes of new physics. There are two main reasons for this. First, there exists an abundance of high precision experimental data on orbital period decays of pulsar binaries. Second, pulsars are extreme astrophysical objects for which BSM effects can be significantly enhanced by large particle number densities. In my talk, I will discuss the use of pulsar binaries for new physics searches. As a particular example, I will talk about the neutrino pair radiation by pulsar binaries in a gauged $L_\mu - L_\tau$ scenario.

BSM XIII / 228

Detecting Superradiant Dark Photon Strings in Gravitational Wave Experiments

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Black hole superradiance is a phenomenon in which, purely through gravitational interactions, light bosons are spontaneously produced outside spinning black holes. Through this effect, an exponentially growing Bose-Einstien condensate cloud forms around the black hole. In the case of dark photon superradiance, the cloud can form into strings of magnetic flux analogous to Abrikosov vortices in type II superconductors. Once formed, these strings are ejected from the black hole as loops of flux in a "stringy bosenova" event and travel across the galaxy at relativistic speeds. We discuss the prospects of detecting such a string here on earth. In particular, we consider the effect of a broken $U(1)_{B-L}$ gauge boson string passing through gravitational wave detectors such as LIGO and MAGIS. We show that the effect of the string on the detector is independent of the gauge couping,

g, and argue that, in some regions of the parameter space, these strings can produce a noticeable signal in the detector.

BSM X / 229

Searches for non-conventional signatures at CMS

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Non-conventional signatures like exotic long-lived particles can naturally arise from many beyond-the-standard-model scenarios, which are closely connected to some of the most important puzzles in particle physics, including hierarchy problem, the nature of dark matter, the origin of neutrino mass, and the origin of matter-antimatter asymmetry. Searches for non-conventional signatures also usually face unique experimental challenges, calling for continuous innovations in trigger, reconstruction, offline analysis, and detector technologies. In this talk, I'll discuss the current status and some future prospects of such searches at CMS, which provide powerful tools to address these long-standing puzzles in particle physics, and have many exciting physics potentials ahead.

BSM XIV / 230

Cosmological challenges for dark sectors with new gauge forces

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New gauge forces in nature are among the most well-studied proposed ingredients for particle models of the dark sector. The popularity of such scenarios is driven by the simplicity of the low-energy effective theory needed to describe the associated phenomenology ranging from collider physics, astrophysical systems, and physics of the early universe. However, the origin of the parameters in the effective theory is often overlooked. From this perspective, I will argue that dark sectors with new gauge forces naturally suggest the existence of new heavy particles and discuss the implied challenges for their thermal history in the early universe and their direct detection.

BSM VII / 231

Probing Lepton Number Violation and Majorana Nature of Neutrinos at the LHC

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Observation of lepton number (L) violation by two units at colliders would provide evidence for the Majorana nature of neutrinos. We study signals of L-violation in the context of two popular models

of neutrino masses, the type-II seesaw model and the Zee model, wherein small neutrino masses arise at the tree-level and one-loop level, respectively. We focus on L-violation signals at the LHC arising through the same-sign dilepton plus jets within these frameworks. We obtain sensitivity to L-violation in the type-II seesaw model for triplet scalar masses up to 700 GeV and in the Zee model for charged scalar masses up to 4.8 TeV at the high-luminosity LHC with an integrated luminosity of 3 ab−1

Axion I / 232

Searching for the DFSZ Axino in Collider Experiments

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Although a direct search for the QCD axion at colliders may not be viable due to the feebleness of the axion couplings to the standard model, collider experiments may be sensitive to signatures of the axino, the supersymmetric partner of the axion. The couplings of the axion and axino are related to the axion decay constant f_a, and so collider searches for the axino may be a way to set model-dependent limits on the QCD axion itself. We have extended the minimal supersymmetric standard model with the addition of Dine-Fischler-Srednicki-Zhitnitsky (DFSZ) axion using tools like SARAH and FeynRules. As a first test of this model implementation, we have simulated the case in which the axino is the lightest supersymmetric particle and thus appears in the decays of heavier supersymmetric particles to produce displaced vertex and missing energy signatures. We will discuss the sensitivity of ATLAS and CMS to such signatures in light of our simulation results.

Tools I / 233

Highly Improved Direct Detection Rate Calculation

Author: Ben Lillard[1]

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I introduce a new method for calculating the dark matter (DM) scattering rate in a directionally sensitive detector, which for the most complicated analyses can be multiple orders of magnitude faster than previous approaches. The new method projects each ingredient of the rate calculation, such as the DM velocity distribution, onto a basis of orthogonal functions. This reduces the rate calculation to an exercise in matrix multiplication, where previously it required high-dimension numeric integration. Thanks to this factorization, it is easy to perform the rate calculation on an ensemble of velocity distributions: e.g. to propagate the astrophysical uncertainties to the constraints on DM models, or to use results from galactic scale N-body simulations. I conclude with a preview of the soon-to-be released code that performs the needed calculations.

BSM IX / 234

Exploring the Flavor Symmetry landscape of Composite Higgs models

Authors: Lorenzo Ricci[None]; Alfredo Glioti[None]; Riccardo Rattazzi[None]; Luca Vecchi[None]

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Flavor and CP violating observables strongly constrain new Physics at the TeV scale. This is the case for Composite Higgs models, where "standard"constructions only partially screen dangerous flavor effects, pushing up the new physics scale far from the LHC reach.

Specific assumptions for the flavor structure of the composite sector suppress unwanted effects, allowing for a lower new physics scale. We systematically explore this landscape of symmetry-based scenarios and we show that few clever setups are compatible with new physics near the LHC reach.

Interestingly, B-physics might play a central role in the exclusion/discovery of these models in the "near"future.

DM III / 235

Probing Dark Matter-Neutrino Interactions via Supernova Neutrinos

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We consider the effect of interactions between supernova neutrinos and dark matter. As these neutrinos travel towards Earth through a column density of dark matter, they could interact via dark mediator, deflecting after the process. Depending on the location of the supernova with respect to Earth, the attenuation of the neutrino flux from a local supernova could be observable by neutrino detection experiments like DUNE, Hyper-K, and JUNO. For this talk, we choose a model of Dirac fermion dark matter and scalar mediator with various benchmark points, showing skymaps of the survival rate for a fixed neutrino energy and the expected event rate of observed neutrinos.

DM I / 236

Detecting Ultralight Dark Photon Dark Matter Using Optomechanical Sensors

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Dark matter may exist as an ultralight bosonic particle, leading to the formation of an ever-present field that could interact with us via a new long-range fifth force. Recently, quantum sensing techniques have been shown to be promising avenues with which to detect such a dark matter candidate. However, these studies did not entirely capture the stochastic nature of the field, which is important to construct realistic exclusion limits and discovery regions. In this talk, I will show how an experiment employing an array of optomechanical sensors can be used to place leading bounds on ultralight dark photon dark matter via an improved statistical treatment. I will highlight the different statistical regimes required depending on how long the dark matter field is observed. I will then derive a general exclusion limit on ultralight dark photon dark matter through the paradigm of the canonical optomechanical light cavity, further interpreting this limit in the context of concrete, well-motivated dark photon models. Our results demonstrate that an array of optomechanical sensors would form a powerful probe of ultralight dark matter.

BSM VIII / 237

Reconstruction, Trigger Efficiency and Exclusion Studies for MATHUSLA

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MATHUSLA (MAssive Timing Hodoscope for Ultra-Stable neutraL pArticles) is a proposed detector at the LHC to search for Long Lived Particles (LLP). We present various trigger and efficiency studies crucial to determining the final design and sensor geometry of the detector. We also present exclusion plots for BSM models taking into account the actual expected geometric acceptance of MATHUSLA.

Cosmology I / 238

Enhancing CMB acoustic phase shift with dark matter loading

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The acoustic peaks in the CMB power spectrum contain valuable information for studying particle physics. A shift in the position of these peaks corresponds to a phase shift in the acoustic oscillations of the photon-baryon fluid before recombination, which only corresponds to specific types of dark sector physics. As such, it provides a clean cosmological signature for identifying new physics models. For example, if compared against the lambda-CDM model plus free-streaming radiation, the acoustic peaks shift to shorter wavelength modes if the radiation is self-interacting. The maximum phase shift from scattering radiation is typically considered due to the radiation effect. However, in this talk, I will show that such a phase shift can be significantly enhanced by an observable amount if the dark radiation scatters with a fraction of dark matter (DM). The DM-loading effect further suppresses the dark fluid sound speed, shifting the peaks to even shorter wavelength modes. We use neutrino-DM interactions as an example to show that this DM-loading effect can be well-described by a simplified model consisting of two coupled oscillator equations for the photon and neutrino perturbations. The simplified model provides a semi-analytical approach to understanding the origin of the CMB phase shift.

BSM XII / 239

Low-Energy Supernovae Bounds on Sterile Neutrinos

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Sterile neutrinos can be produced through mixing with active neutrinos in the hot and dense core of a collapsing supernova (SN). The standard SN bounds on the active-sterile mixing (θ) arise from the SN1987A energy-loss argument. In this talk, I will discuss a novel and stringent bound on θ arising from the energy deposition through the decays of sterile neutrinos inside the SN envelope.

BSM XII / 240

Probing ultralight dark-photon dark matter with asteroids

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Ultralight dark-photon dark matter coupled to the Standard Model (through e.g. B or $B-L$ charges) would supply a new force that oscillates with a frequency set by the dark photon mass. Such forces result in fluctuations in the separation between inertial test masses, a physical quantity tracked in many gravitational-wave (GW) detectors. A recent GW detection proposal based on monitoring the separation of certain asteroids in the inner Solar System would be sensitive to frequencies in the experimentally-challenging μHz band. In this talk, I discuss how that proposal would also enable access to new parameter space for dark-photon dark matter, well beyond current best limits.

Cosmology III / 241

Light Stepped Dark Sectors Face Cosmological Data Sets

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Light dark relativistic sectors may undergo changes in the number of their relativistic species during the cosmological history (due e.g. to mass thresholds and/or phase transitions), similarly to the visible sector. When such changes occur around recombination, the stringent bound on the effective number of neutrino species, N_{eff}, can be relaxed and the value of the Hubble rate inferred from the early Universe raised. Such models have been considered in the literature to alleviate tensions in cosmological data. We search for such sectors in the latest cosmological data sets, including BOSS galaxy clustering data. We present a detailed analysis, accounting for choice of prior boundaries and including the possibility of dark sector interactions with (a fraction of) the dark matter. We discuss the impact of these models on alleviating observational tensions in the value of the Hubble rate and the matter-clustering parameter S_8.

SM II / 242

A phenomenological study of Higgs Jets at a Muon Collider

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A muon collider provides an interesting opportunity to test various aspects of Higgs physics and potential BSM models. For a muon collider, Vector-boson fusion provides the dominant channel for the production of Higgs bosons. We calculate the lowest and higher order Higgs jet distribution as a function of jet invariant mass for the super-renormalizable splitting $h \to hh$ and compare it to the background QCD jet distribution calculated from the NLL resummed cross section for e^+ e^- annihilation. The qualitative difference between the two distributions shows up distinctly at collider center of mass energies greater than 10 TeV as the peak of the QCD jets is pushed off to higher invariant jet masses, making it easier to observe the super-renormalizable and ultra-collinear $h \to hh$ jet distribution. This can also prove to be an important channel to test potential BSM models.

Theory I / 243

Radion Stabilization with Bulk Fields

Authors: Barry Dillon[1]; Robert Clemenson[2]; Stephan Huber[2]

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The Randall-Sundrum model has been a great source of interest to theorists
and phenomenologists for over two decades, both for its novel solution to the hierarchy problem, and its phenomenological consequences. The modulus field associated with the warped extra dimension of this model requires stabilization. In this talk I will present ongoing work to investigate the feasibility of stabilizing the fifth dimension of the RS model using alternate mechanisms to the standard Goldberger-Wise scenario. I will also discuss how the rate of the phase transition between the high and low temperature phases of the RS model is affected by the specific details of the radion stabilization mechanism.

BSM III / 244

Repurposing Precision SM Measurements to Constraint New Physics

Authors: Deepak Sathyan[None]; Doojin Kim[None]; Kaustubh Agashe[None]; Lorenzo Ricci[None]; Roberto Franceschini[1]; Sagar Airen[None]

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We show how precision SM measurements can be repurposed to constraint certain types of new physics (NP) without invoking SMEFT. Motivated by highly precise measurement of W mass by the CDF collaboration, we demonstrate our proposal for the specific case of W mass data. W boson gives lepton + MET final state, which makes it special because it cannot be reconstructed completely. Any NP, which can give the same final state, can pollute W mass data. W mass is measured by fitting p_T^l,

M_T and p_T^{miss} spectra, using templates calculated using SM. Any new contribution to the spectra can change the shapes. Hence, any deviations in the observed spectra from the expectation could give us a hint of NP. On the flip side, agreement between the measured shapes and the SM expectation can give constraints on NP. We consider multiple BSM scenarios that can creep into W data, find expected constraints and measure them against best existing bounds on the models we analyze.

DM II / 245

Probing the Local Dark Matter Halo with Neutrino Oscillations

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Dark matter particles can form halos gravitationally bound to massive astrophysical objects. The Earth could have such a halo where depending on the particle mass, the halo either extends beyond the surface or is confined to the Earth's interior. We consider the possibility that if dark matter particles are coupled to neutrinos, then neutrino oscillations can be used to probe the Earth's dark matter halo. In particular, atmospheric neutrinos traversing through the Earth can be sensitive to a small size, interior halo that is otherwise inaccessible. The constraint on the dark matter-neutrino coupling depends on the halo mass and neutrino energy.

SM III / 246

Non-resonant di-Higgs searches in bbtt, bbgg, bbZZ, bbWW, WWgg, and multilepton final states at CMS

Author: Vivan Nguyen[1]

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We discuss the latest status of searches for nonresonant di-Higgs production with the CMS detector. In addition to the analysis strategy and limits on the production cross section of this process, constraints on the Higgs boson self-coupling and the coupling between two Higgs bosons and two vector bosons will be presented.

BSM XIV / 247

Light Neutrinophilic Dark Matter from Scotogenic Model

Authors: Johannes Herms[1]; Sudip Jana[1]; shaikh saad[2]; vishnupk Padmanabhan Kovilakam[None]

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We present a minimal UV-complete model for sub-GeV thermal Dark Matter (DM) that primarily interacts with neutrinos and contributes to the generation of neutrino masses and mixings through quantum loop corrections at the one-loop level. In this configuration, DM can solely annihilate into SM neutrinos without affecting the Cosmic Microwave Background anisotropies. We find that the rate of neutrinoless double beta decay can be enhanced through loop corrections involving light-dark matter exchange. Moreover, we emphasize that detecting extra neutrino flux from dark matter annihilations with neutrino telescopes in the galaxy is the most effective means of testing the scenario.

Tools I / 249

Normalizing flows and uncertainty quantification in hadronization simulations

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The hadronization process plays a crucial role in Monte Carlo event generators, where quarks and gluons are combined into observable hadrons. However, while current phenomenological models have been quite successful overall in simulating this process, there remain phenomenological areas where they still lack accuracy in describing the underlying physics. Recent research has taken a new approach by utilizing machine-learning (ML) techniques based on generative models for simulating the hadronization process. However, the recently presented architectures have their own set of limitations.

In this talk, we present an updated version of our MLHad pipeline that overcomes most of the limitations by incorporating normalizing flows (NFs). Our updated approach conditions NFs on different hadron masses and initial configuration energies, which in principle enables the emission of different mesons.

Furthermore, the utilization of NFs grants us access to the kinematical probability distribution of the generated mesons. This allows for the implementation of a reweighting technique, which assigns a weight to each emitted meson, enabling us to estimate the uncertainties associated with the process. We demonstrate the capability of the reweighting technique to evaluate the uncertainty of our model.

DM II / 250

Measuring Dark Matter in the Solar Neighborhood using Normalizing Flows and Gaia DR3

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Density estimation utilizing normalizing flows enables novel data-driven analyses of galactic dynamics. We train Masked Autoregressive Flows on the kinematic coordinates of 6 million nearby bright stars from the Gaia DR3 catalog within 4 kpc of the Solar location to learn their underlying phase space distribution f(x,v). Assuming dynamic equilibrium, we use f to estimate the local acceleration and mass density field via the collisionless Boltzmann equation. We present a minimal-assumption and model-free measurement of the gravitational acceleration and dark matter mass density in the solar neighborhood.

Neutrinos I / 253

Towards precise predictions of the diffuse supernova neutrino background

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The isotropic signal of neutrinos from all past core-collapse supernovae, known as the diffuse supernova neutrino background (DSNB), is close to being detected in Super-Kamiokande. The most optimistic models are already disfavored with current upper limits so improving our theoretical understanding of the DSNB is crucial in the next few years, especially with upcoming detectors. We discuss the importance of understanding the late phase neutrino emission during core collapse. We also discuss strategies for estimating this phase, given the prohibitive computational cost for long term simulations. Finally, we show how recent measurements of the star formation rate up to redshift 2 have improved and can result in precise DSNB flux predictions, in time for next generation experiments.

Axion II / 254

Distinguish axion models with SPARC

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In this talk I will first discuss how rotation-dominated galaxies can be used to constrain the size of solitons inside galaxy dark matter halos. I will discuss how this confronts the theoretical expectation, which leads to a robust constraint on the fraction of ultralight dark matter in a wide mass range from 10^{-24} eV to 10^{-20} eV. I will then discuss how this bound is affected by the Peccei-Quinn scale and its sensitivity to the type of axion potential. The talk will be based on the work 2111.03070 as well as work in preparation.

BSM VI / 257

Magnetic Moments of Dark Baryons

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Dark matter could be dark baryons made from underlying vector-like quarks which interact with the standard model as an electroweak multiplet. If the lightest dark baryon is electrically neutral with vanishing hypercharge, the leading interaction with the SM is anticipated to be through its magnetic dipole (for fermionic dark baryons). Using the non-relativistic quark model, which becomes exact in the large N_c limit, we calculate the spin-flavor wave functions and magnetic moments of spin-½ baryons arising from a confined $SU(N_c)$ gauge group with N_f flavors. For every N_c and N_f considered, we find that the magnetic moment vanishes for most baryons that are the potential dark matter candidates. This suggests bounds from direct detection experiments lead to considerably weaker constraints on strongly-coupled baryonic dark matter, opening up new possibilities for dark matter at TeV and higher scales.

Higgs I / 258

Higgs boson physics: an update

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SM I / 259

Understanding the W-boson mass

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Axion I / 260

Physics with axions and axion-like particles

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BSM XIV / 261

Probing BSM physics with Solar and Atmospheric Neutrinos in Dark Matter Experiments

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We demonstrate the ability of future dark matter experiments to probe beyond the standard model (BSM) effects in neutrino scattering of solar and atmospheric origin in models with heavy scalar and vector mediated interactions. Mapping the effective four-Fermi vertex of a scalar NSI to the well studied model of leptoquarks, we find that near future detectors can probe parameter space beyond the reach of current and planned collider facilities. Using this formalism, we place constraints on the S1 leptoquark using preliminary data from LUX-ZEPLIN (LZ). We comment on the effects of the diffuse supernova neutrino background and discuss the ability of leptoquarks to explain neutrino masses and (g − 2)μ motivating experimental probes of such models.

BSM XI / 262

Lepton Flavor Specific Extended Higgs Models

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In multi-Higgs models, a discrete symmetry in the quark sector is needed to avoid tree-level flavor-changing neutral currents. Although a similar symmetry is usually considered with the lepton sector, this symmetry is not necessary. We consider a multi-Higgs doublet model in which one Higgs doublet couples to quarks and three other doublets couple to the electron, muon and tau respectively. Our analysis is broken into two benchmark models: one where quark-tau sector decouples from the muon-tau sector, and one in the alignment limit. Constraints from boundedness, perturbativity, and oblique parameters are considered. We also incorporate bounds from meson-antimeson mixing, radiative B-decays, diphoton Higgs decay rate. For a wide range of parameters, the lightest additional scalar, pseudoscalar, and charged scalar can have substantial decays into electrons and muons.

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Physical Review Journals

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Perspectives on flavor physics

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Physics results from LHCb

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Beyond-the-Standard Model theories

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Astrophysical probes for BSM new physics

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Unraveling Dark Matter with Gaia

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Particle cosmology

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Early discoveries with JWST

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Progress and prospects in dark matter direct detection

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New approaches on dark matter detection

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Generalized symmetry in particle physics

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Weak gravity conjecture and particle physics

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Visions in particle physics

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SM IV / 283

Timing coincidence search for supernova neutrinos with optical transient surveys

Author: Sean Heston[1]

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Neutrinos allow us to probe the interiors of stars during core collapse, and detecting them can teach us about the different stages and processes in the collapse. To date, only 24 supernova neutrinos have been detected all originating from a single event, SN1987A. Since then, most studies have focused on two different distance regimes of supernovae neutrinos: Galactic/local events and all past cosmic supernovae neutrinos forming the diffuse supernova neutrino background. We instead focus on an intermediate distance regime that can be thought of as "un-diffusing" the diffuse supernovae neutrino background. We make predictions for an offline, optical timing coincidence search method of neutrinos at Hyper-Kamiokande in tandem with optical supernova surveys. We find that detection prospects require approximately 10 years of operation. We discuss how pinpointing the time of core collapse with optical surveys to within the timescale of hours is vital for confident neutrino detections.

SM II / 284

NLO-SM physics simulation with Whizard

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Whizard is a universal program for computing observables and simulated event samples in multi-parton high-energy collider processes. While it has been developed as a tool for e+e- physics studies, it also covers LHC physics and new collider concepts such as a muon collider. Physics models are supported intrinsically and via the UFO format. Whizard version 3 accounts for the full Standard Model at next-to-leading order. I present recent results and plans for further development.

Axion II / 286

The Flavor of QCD axion dark matter

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There exists a whole landscape of QCD axion models. However, if this particle is to make up the dark matter, the absence of catastrophic domain walls and exotic strongly interacting relics singles out two minimal versions of hadronic axions as the only viable possibilities. I argue that these models generically predict sizeable flavor-violating axion couplings to quarks that can be probed at terrestrial rare meson decay experiments. In particular, kaon decay experiments like NA62 and KOTO are sensitive to QCD axions with masses down to $10\,\mu$eV, well into the mass region where the QCD axion can make up the whole dark matter abundance via the standard post-inflationary misalignment mechanism.

Axion III / 287

CMB birefringence from cosmic axion strings

Axion-like particles (ALPs) can form a network of cosmic strings and domain walls that survives after recombination and leads to anisotropic birefringence of the cosmic microwave background (CMB). This effect provides a unique way of probing ALPs with masses in the range $3H_0$
$lesssim m_a$
$lesssim 3H_{\mathrm{cmb}}$. In this talk I discuss the two-point statistics of birefringence from axion string networks and using measurements of CMB birefringence from several telescopes, I find no evidence for axion-defect-induced anisotropic birefringence of the CMB. I extract constraints on the model parameters that include the ALP mass m_a, ALP-photon coupling $\mathcal{A} \propto g_{a\gamma\gamma} f_a$, the domain wall number N_{dw}, and parameters characterizing the abundance and size of defects in the string-wall network. Considering also recent evidence for isotropic CMB birefringence, I find it difficult to accommodate this with the non-detection of anisotropic birefringence under the assumption that the signal is generated by an ALP defect network.

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SM physics at the LHC

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Searches for new physics at the LHC

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Bread & butter physics at the LHC

BSM XIV / 295

Title: Baryogenesis in Mirror Twin Higgs

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Abstract: The Twin Higgs framework is a solution to the hierarchy problem that is compatible with LHC null results for colored top partner searches. The Higgs mass is stabilized via a hidden sector related to the SM by a Z2 symmetry that is softly broken in the IR to give the hidden Higgs a larger vev f, with f/v ~ 3-7 in the natural range. The Minimal Twin Higgs has an unacceptable cosmological history, generating DeltaNEff of order a few, which can be ameliorated by including a source of asymmetric reheating to dilute the hidden sector. We investigate baryogenesis within an asymmetrically reheated twin Higgs framework. Hidden Baryons implement a version of the Atomic Dark Matter scenario. The discrete symmetry relates the hidden baryon asymmetry to the SM baryon asymmetry, and we find that astrophysically interesting and not excluded for atomic dark matter fractions < O(10%) which are naturally generated. This has important theoretical implications for

astrophysical and cosmological studies of atomic dark matter, and their possible connection to the hierarchy problem.

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Theories of neutrino masses

Plenary / 297

Experimental status of neutrino physics

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Machine learning for particle physics

BSM XIII / 299

Collider Signatures of Near-Continuum Dark Matter

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I will describe the collider phenomenology of near-continuum dark matter, a model that gives rise to a gapped tower of Kaluza-Klein (KK) states. The model is coupled to the Standard Model via a Z-portal coupling, and the unique experimental signatures of this model include a cascade decay with large displaced vertices, a characteristic fermion energy spectrum, and more, all of which will be shown at a benchmark point of a 500 GeV lepton collider. I will also comment on the phenomenological aspects of the continuum limit of this model, where the dark matter spectrum approaches a gapped continuum of KK states.

Higgs I / 300

Muon Yukawa couplings at the high-energy muon collider

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We take multiple boson production at high-energy muon colliders to probe the Higgs-muon coupling in the Standard Model Effective Feild Theory (SMEFT) and Higgs Effective Feild Theory (HEFT) framework.