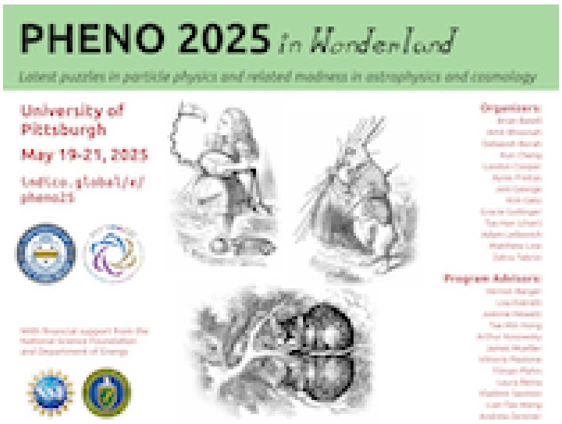
Phenomenology 2025 Symposium

Monday 19 May 2025 - Wednesday 21 May 2025

University of Pittsburgh



Book of Abstracts

Contents

Cosmology / **1**

BBN Constraint on Heavy Neutrino Production and Decay

Authors: Yu-Ming Chen[1]; Yue Zhang[None]

[1] *Carleton University*

Corresponding Author: yumingchen@cmail.carleton.ca

We explore the big-bang nucleosynthesis (BBN) constraint on heavy neutrino that is a mixture of gauge singlet fermion and active neutrinos in the Standard Model. We work in the minimal model with only two parameters, the heavy neutrino mass m_4 and the mixing parameter $|U_{a4}|^2$, where $a = e$, μ, or τ stands for the active neutrino flavor. We show that both the early universe production mechanism and decay products of the heavy neutrino are determined by m_4 and $|U_{a4}|^2$, with little room for further assumptions. This predictability allows us to present a portrait of the entire BBN excluded parameter space. Our analysis includes various effects including temporary matter domination, energy injections in the form of pions, photons and light neutrinos. The BBN constraint is complementary to terrestrial search for heavy neutrinos (heavy neutral leptons) behind the origin of neutrino masses and portal to the dark sector.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / **2**

Photon Proliferation Effect from N-body ultralight DM annihilation

Author: Shaoping Li[1]

[1] *Osaka University*

Corresponding Author: lisp@het.phys.sci.osaka-u.ac.jp

I will demonstrate a general photon proliferation effect from N-body ultralight dark matter (DM) annihilation in the early Universe, which can induce a drastic photon-temperature shift after neutrino decoupling. For pseudoscalar DM mass below the eV scale, I will show that the photon proliferation effect becomes significant as the mass approaches the ultralight end, presenting the leading constraints on the DM-photon coupling, DM self-interaction, and DM-electron coupling.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Cosmology / **3**

Possible imprints of non-thermal leptogenesis on the CMB observables

Author: Dibyendu Nanda[1]

Co-authors: Abhijit Kumar Saha [2]; Anish Ghoshal [3]

[1] *Korea Institute for Advanced Study*
[2] *Indian Association for the Cultivation of Science*
[3] *University of Warsaw, Poland*

Corresponding Author: dnanda.physics@gmail.com

I will discuss the possible imprints of high-scale non-thermal leptogenesis on cosmic microwave background (CMB) from the measurements of inflationary observables such as spectral index (n_s) and tensor-to-scalar (r) ratio, which otherwise is inaccessible to the conventional laboratory experiments. I will argue that non-thermal production of baryon (lepton) asymmetry from subsequent decays of inflaton to heavy right-handed neutrinos (RHN) and RHN to SM leptons is sensitive to the reheating dynamics in the early Universe after the end of inflation. Such dependence provides detectable imprints on the n_s - r plane which is well constrained by the Planck experiment.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

New Physics at Future Colliders / 4

W' Searches at Future Muon Collider

Authors: Cosmos Dong[1]; KC Kong[1]; Miguel Angel Soto Alcaraz[None]; Talal Ahmed Chowdhury[None]

[1] *University of Kansas*

Corresponding Author: brossmiguelsa@gmail.com

Discovering that neutrinos have mass has left question regarding their origin. One possible model of their origin are Left-Right models, which add a SU(2) group with a right handed neutrino and a new heavy charged boson W'. Searches at the LHC for this heavy boson have not been successful, meaning that larger and more energetic colliders are needed. This analysis searches for the W' at 6.5 TeV at a 20 TeV muon collider, and is complemented by Machine Learning algorithms. Lorentz Boost Networks and Deep Neural Networks are used and compared, both having a good discrimination between the signal and background events.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / 5

Top tagging with Tensor network

Authors: Jack Y. Araz[1]; K.C. Kong[None]; Zhongtian Dong[2]

[1] *Stony Brook University*
[2] *University of Kansas*

Corresponding Author: cdong@ku.edu

Tensor Networks, originally developed for quantum many-body systems, offer powerful representations of high-dimensional data. When applied to discriminate top quark signals from QCD backgrounds, the entanglement entropy of the tensor network model can give us insight into the correlations it has learned. Moreover, our study shows tensor network model is more resilient to detector effects and pile-up.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

New Developments in Theory / 6

Cheshire θ terms, Aharonov-Bohm effects, and axions

Authors: Aleksey Cherman[1]; Gongjun Choi[1]; Maria Neuzil[1]; Shi Chen[1]

[1] *University of Minnesota*

Corresponding Author: choi0988@umn.edu

We discuss unusual θ terms that can appear in field theories that allow global vortices. These "Cheshire θ terms" induce Aharonov-Bohm effects for some particles that move around vortices. For example, a Cheshire θ term can appear in QCD coupled to an axion and induces Aharonov-Bohm effects for baryons and leptons moving around axion strings. We point out a potential experimental signature left on the spectrum of gravitational waves from axion cosmic string network by the Cheshire θ term.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Cosmology / 7

Inflation from Purgatory

Author: Scott Watson[None]

Corresponding Author: gswatson@syr.edu

In this talk, we revisit motivation from String Theory for new phases of cosmology –prior to inflation. Cosmic inflation offers a causal way to predict initial conditions for the growth of structure and density fluctuations in the cosmic microwave background and large scale structure formation. However, asymptotic deSitter space possesses a past cosmological (physical) singularity implying the theory cannot be complete. In this talk, I will discuss how investigations into QCD led to an idea that could prevent the past singularity, or at least give a way to calculate predictions precisely on curved space-time backgrounds. This paradigm would lead to cosmologies that do not begin (Big Bang) or repeat (Ekpyrotic / Cyclic scenario) but instead begin from sitting around –a period of "lingering", as inspired by Lemaître, Hagedorn, and COVID.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / 8

Spin-Dependent Dark Matter Rates from Neutron Scattering

Authors: Asher Berlin[1]; Alex Millar[1]; Tanner Trickle[None]; Kevin Zhou[2]

[1] *Fermilab*

[2] *UC Berkeley / LBNL*

Corresponding Author: kzhou7@gmail.com

For many spin-dependent dark matter-electron couplings, the DM's scattering rate in a target material can be written in terms of its dynamical magnetic susceptibility. This quantity can be inferred from neutron scattering data, without requiring a microscopic model of the material. As a proof of principle, I will show that an existing dataset can be used to find the DM scattering rate in yttrium iron garnet.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Gravitational Waves / 9

Single-step first order phase transition and gravitational waves in a SIMP dark matter scenario

Author: Himadri Roy[1]

[1] *POST DOCTRAL RESEARCHER*

Corresponding Author: himadri027roy@gmail.com

We investigate the non-zero temperature dynamics of a sub-GeV dark matter scenario freezing-out via self-interactions. As a prototype, we take up the case of a scalar dark matter species undergoing $3 \to 2$ number changing annihilations catalysed by another scalar. We study the shape of the thermal potential of this scenario in a parameter region accounting for the observed relic abundance. An analysis reveals the possibility of a first order phase transition with bubble nucleation occurring at sub-GeV temperatures. This finding can be correlated with the typical sub-GeV masses in the framework. The gravitational wave spectra associated with such a phase transition is subsequently computed.

Mini Symposia (Invited Talks Only):

Mini Symposia (Invited Talks Only)

Plenary (Invited talks only):

10

Signature of a sterile neutrino in Flavor Anomalies

Author: Alakabha Datta[None]

Corresponding Author: datta@olemiss.edu

I will consider the signature of a light sterile neutrino to resolve certain flavor anomalies. First I will consider the recent evidence for B-> K invisible by Belle II and describe a framework to explain the measurement and also to explain the MiniBooNE anomaly. I will then discuss how a sterile neutrino signatures can be explored in experiments like Belle II and FASER

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Neutrino / 11

A Hybrid Type I + III Inverse Seesaw Mechanism in $U(1)_{R-L}$-symmetric MSSM

Authors: Cem Murat Ayber[1]; Seyda Ipek[1]

[1] *Carleton University*

Corresponding Author: cemayber@cmail.carleton.ca

We show that, in a $U(1)_{R-L}$-symmetric supersymmetric model, the pseudo-Dirac bino and wino can give rise to three light neutrino masses through effective operators, generated at the messenger scale between a SUSY breaking hidden sector and the visible sector. The neutrino–bino/wino mixing follows a hybrid type I+III inverse seesaw pattern. The light neutrino masses are governed by the ratio of the $U(1)_{R-L}$–breaking gravitino mass, $m_{3/2}$, and the messenger scale Λ_M. The charged component of the $SU(2)_L$–triplet, here the lightest charginos, mix with the charged leptons and generate flavor-changing neutral currents at tree level. We find that resulting lepton flavor violating observables yield a lower bound on the messenger scale, Λ_M
$gtrsim(500 - 1000)$ TeV for a simplified hybrid mixing scenario. We identify interesting mixing structures for certain $U(1)_{R-L}$–breaking singlino/tripletino Majorana masses. For example, in some parameter regimes, bino or wino has no mixing with the electron neutrino. We also describe the rich collider phenomenology expected in this neutrino-mass generation mechanism.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

New Developments in Theory / 12

Field-Theory Action for the Constructive Standard Model

Author: Neil Christensen[1]

[1] *Illinois State University*

Corresponding Author: neil.christensen.qft@ilstu.edu

We introduce a field-theory framework in which fields transform under the little group, rather than the Lorentz group, specific to each particle type. By utilizing these fields, along with spinor products and the x factor, we construct a field-theory action that naturally reproduces the vertices of the constructive standard model (CSM). This approach eliminates unphysical components, significantly reduces the degrees of freedom compared to traditional field theory, and offers deeper insights into the power of constructive amplitudes. Our action is momentum-conserving, Lorentz-invariant, Hermitian, and nonlocal. We also discuss this as a framework for developing new constructive field theories, discussing their essential properties and potential applicability in renormalization theory and nonperturbative calculations.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Neutrino / 13

Global Extraction of the Electromagnetic Response Functions ($calR_L$ and $calR_T$) for ^{12}C, ^{40}Ca and ^{56}Fe and Comparisons to Nuclear Theory and Neutrino/Electron Monte Carlo Generators

Author: Arie Bodek[1]

[1] *University of Rochester (US)*

Corresponding Author: bodek@pas.rochester.edu

We perform a global extraction of the ^{12}C, ^{40}Ca and ^{56}Fe longitudinal ($calR_L$) and transverse ($calR_T$) nuclear electromagnetic response functions from an analysis of all available electron scattering data on these nuclei. The response functions are extracted for energy transfer ν, spanning the nuclear excitation, quasielastic (QE) scattering with one nucleon (1p1h) and two nucleon (2p2h) final states, and the resonance and inelastic continuum. We extract $calR_L$ and $calR_T$ as functions of ν for both fixed values of Q^2 and also for fixed values of 3-momentum transfer **q**. Given the nuclear physics common to both electron and neutrino scattering from nuclei, extracted response functions from electron scattering spanning a large range of Q^2 and ν also provide a powerful tool for validation and tuning of neutrino Monte Carlo (MC) generators. For ^{12}C we compare the measurements to theoretical predictions including Energy Dependent-Relativistic Mean Field(ED-RMF), Green's Function Monte Carlo (GFMC), Short Time Approximation Quantum Monte Carlo(STA-QMC), an improved superscaling model (SuSAv2), Correlated Fermi Gas"(CFG), as well as the Nuwro and Achilles generators. For ^{12}C we find that combining the ED-RMF-QE-1p1h predictions with the SuSAv2-MEC-2p2h predictions provides a good description of $calR_L$ and $calR_T$ for both single nucleon (from QE and nuclear excitations) and two nucleon final states over the entire kinematic range. For ^{40}Ca and ^{56}Fe we focus on comparisons of the measurements to the predictions of ED-RMF and SuSAv2.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / 14

Singlet-Doublet Fermionic Dark Matter in Gauge Theory of Baryons

Authors: Kirtiman Ghose[1]; Rameswar Sahu[1]; Sudhanwa Patra[2]; Taramati Guruwani[2]; Utkarsh Patel[2]

[1] *IOP Bhubaneshwar*

[2] *IIT Bhilai*

Corresponding Author: taramatiguruwani570@gmail.com

We are considering a minimal $U(1)_B$ extension of the Standard Model (SM) by promoting the baryon number as a local gauge symmetry to accommodate a stable dark matter (DM) candidate. The gauge theory of baryons induces non-trivial triangle gauge anomalies, and we provide a simple anomaly-free solution by adding three exotic fermions. A scalar S spontaneously breaks the $U(1)_B$ symmetry, leaving behind a discrete Z_2 symmetry that ensures the stability of the lightest exotic fermion originally introduced to cancel the triangle gauge anomalies. Scenarios with weakly interacting DM candidates having non-zero hypercharge usually face stringent constraints from experimental bounds on the DM spin-independent direct-detection (SIDD) cross-section. In this work, we consider a two-component singlet-doublet fermionic dark matter scenario, which significantly relaxes the constraints from bounds on the DM SIDD cross-

section for suppressed single-doublet mixing. We show that the model offers a viable parameter space for a cosmologically consistent DM candidate that can be probed through direct detection searches, collider experiments, and gravitational wave (GW) experiments.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Cosmology / 15

New Sensitivity to Dark Photons from the 21-cm Power Spectrum

Authors: Ethan Baker[1]; Hongwan Liu[1]

[1] *Boston University*

Corresponding Author: bakerethan47@gmail.com

Dark photons are dark massive vector gauge bosons that are one of the simplest extensions of the Standard Model. Through a kinetic mixing term, visible photons resonantly convert into dark photons when the plasma mass of an ionized gas is equal to the dark photon mass $m_{A'}$. This disappearance of Standard Model photons leaves a striking signature in a map of the 21-cm signal and enhances the 21-cm power spectrum. In this work, we analytically model the conversions from visible to dark photons in dark matter halos between $0.005 < z < 4$ and use 21cmFAST to simulate conversions that occur between $5 < z < 35$. We forecast sensitivities from HERA and SKA and demonstrate leading limits to dark photons with masses between 10^{-14} and 10^{-13} eV.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Gravitational Waves / 16

Gravitational wave signals from transitions of Gravitational atoms in Black Hole Binaries

Author: Antonios Kyriazis[1]

Co-authors: Fengwei Yang [1]; Hyeonseok Seong [2]

[1] *University of Florida*

[2] *DESY*

Corresponding Author: antokyr42@gmail.com

Superradiance offers a unique link between particle and black hole physics. Through this process, a cloud of light particles can build up around a spinning black hole that resembles the hydrogen atom. If the black hole is part of a binary system, the cloud can be disrupted and the particles transition from one state of the atom to another. In this talk, I will analyze a new gravitational signal that originates from the time dependent quadrupole moments of the gravitational atom and discuss observational prospects with the future space-based interferometer LISA.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / **17**

First High-Throughput Search for Dark Matter Detector Materials

Author: Bethany Suter[1]

Co-authors: Benjamin Lehmann [2]; Rotem Ovadia [3]; Ruo Xi Yang [4]; Sinead M. Griffin [4]; Wayne Zhao [4]; Yonit Hochberg [5]

[1] *UC Berkeley*

[2] *Massachusetts Institute of Technology*

[3] *Cornell University*

[4] *Lawrence Berkeley National Lab*

[5] *Hebrew University*

Corresponding Author: bethany_suter@berkeley.edu

We perform the first high-throughput search for materials that can serve as excellent low-mass dark matter detectors. Using properties of over one thousand materials from the *Materials Project* database, we project the sensitivity in dark matter parameter space for experiments constructed from each material, including both absorption and scattering processes between dark matter and electrons. Using the anisotropic materials in the dataset, we further compute the daily modulation rate of known materials, which highlight materials with prospects to detect a directional dark matter wind. Our methods provide the basic tools for data-driven design of dark matter detectors, and our findings lay the groundwork for the next generation of highly optimized direct searches for dark matter as light as the keV scale.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / **19**

Colliding light to measure tau g–2

Author: Jesse Liu[1]

[1] *New York University*

Corresponding Author: jesse.liu@cern.ch

The electron and muon anomalous magnetic moment (g–2) are among the most precisely tested quantities in nature. But what about tau-leptons? Long overlooked, tau g–2 is so poorly constrained it cannot even test Schwinger's landmark $\alpha/2\pi \simeq 0.0012$ prediction from 1948. This leaves striking room for new physics where taus enjoy 280 times greater sensitivity than muons. Creative proposals to measure tau g–2 via photon collisions are initiating an exciting new LHC program using unconventional tracking. These advances open tests of quantum electrodynamics in uncharted regimes that could reveal novel discoveries. Based on 2403.06336

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / 20

A Brief History of Mass

Author: Scott Willenbrock[1]

[1] *University of Illinois at Urbana-Champaign*

Corresponding Author: willen@illinois.edu

It has been known since the 1950's that an unstable particle is associated with a complex pole in the propagator. This had to be rediscovered twice: in the early 1970's in the context of hadronic resonances, and in the early 1990's in the context of the Z boson. The physical mass of the particle is the real part of the pole in the complex energy plane. In hadronic physics, this replaced the "Breit-Wigner mass," which was found to depend on the parameterization of the "energy-dependent width." In Z physics, it replaced the "on-shell" mass, which was found to be gauge dependent. Although the mass defined from the complex pole position has been widely discussed in the literature, it has not yet made its way into quantum field theory textbooks.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

New Physics at Future Colliders / 21

Light Axion-Like Particles at Future Lepton Colliders

Author: Yang Ma[1]

Co-authors: Hong Zhang [2]; Keping Xie [3]; Shou-shan Bao [2]; Yongcheng Wu [4]

[1] *UCLouvain*

[2] *Shandong University*

[3] *Michigan State University*

[4] *Oklahoma State University*

Corresponding Author: mayangluon@pitt.edu

We study the interactions between light axion-like particles (ALPs) and the Standard Model electroweak gauge bosons at future lepton colliders. In the long-lived ALP regime, mono-photon and mono-Z production channels are exploited, while for ALPs with shorter lifetimes, non-resonant vector boson scattering processes are used. Our combined analysis shows that future lepton colliders can significantly improve the constraints on the ALP–boson couplings.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / 22

The Cross-Disciplinary Hunt for Dark Matter: Machine Learning and Material Science Meet Astroparticle Physics

Author: Carlos Blanco[None]

Corresponding Author: carlosblanco2718@gmail.com

The age of WIMP-like dark matter direct detection is drawing to a close due to their non-detection at exquisitely sensitive liquid-noble detectors. However, models where the dark matter is lighter than the mass of a proton remain largely inaccessible to existing probes. Recently, molecular targets have emerged as particularly well-suited detector materials to look for this sub-GeV dark matter. In this talk, I will show how theoretical techniques from chemistry and material science can be used to design searches that are sensitive to the best-motivated models of sub-GeV dark matter. I will review the latest development in molecule-based direct detection techniques and introduce how machine learning can be used to explore the vast and intractable space of potential materials, optimizing for theoretically-motivated electronic properties relevant to dark matter interactions. I will then present new constraints on sub-GeV dark matter from searches of molecular UV and IR signatures in gas and ice giants in the solar system. These astrophysical searches provide powerful new probes of unexplored parameter space and complement existing strategies for detecting dark matter.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

New Developments in Theory / 23

Understanding Strongly Coupled Theories with AMSB

Author: Bea Noether[1]

[1] *UC Berkeley*

Corresponding Author: bea_noether@berkeley.edu

I will review developments in applying Anomaly Mediated SUSY Breaking (AMSB) as a theoretical tool for understanding the dynamics of strongly coupled gauge theories. After reviewing the general properties of AMSB, I will show what we have been able to learn when applying it to a variety of examples. Many non-trivial consistency conditions are satisfied. In the case of QCD, I will show how we can establish the presence of chiral symmetry breaking vacua, explicitly calculate condensates, derive the chiral lagrangian, and even obtain the low-lying spectrum of hadrons in qualitative agreement with QCD. I will conclude with an example of a phenomenological application in composite axion models.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / 24

Loop-induced contributions to the dark matter annihilation cross section in a simplified model of dark matter with colored mediator

Authors: Ambresh Shivaji[1]; Radhika Vinze[2]; Warsimakram Katapur[3]

[1] *IISER Mohali*

[2] *Indian Institute of Science Education and Research, Mohali, India*

[3] *Indian Institute of Science Education and Research Mohali*

Corresponding Author: radhikavinze@iisermohali.ac.in

We consider a simplified model of dark matter which contains a scalar dark matter candidate χ and a coloured scalar mediator ϕ. The model parameter space contains dark matter mass m_χ, mediator mass m_ϕ, the dark matter coupling with the mediator λ_d and the color representation r of the mediator ϕ. In this model, we investigate the phenomenology of loop-induced contributions to dark matter annihilation into gluons and quarks. At leading order, the dark matter annihilation in gluon channel is a one-loop process whereas in quark channel, it is a two-loop process. By calculating next-to-leading order QCD corrections in the gluon channel and leading order contribution in quark channel for dark matter annihilation, we study the dependence of annihilation cross section on the model parameters. The obvious constraints on the parameters of the model are from the relic density measurements. Taking into account the running of the strong coupling parameter α_s, we scan the model parameter space and derive bounds on the masses and couplings of dark matter and mediator particles.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / **25**

Did IceCube discover Dark Matter around Blazars?

Authors: Alessandro Granelli[1]; Andrea Giovanni De Marchi[1]; Filippo Sala[1]; Jacopo Nava[1]

[1] *Università di Bologna and INFN*

Corresponding Author: andreagiovanni.demarchi@unibo.it

Blazars are a subclass of active galactic nuclei (AGN), the brightest continuously emitting sources in the Universe, powered by accreting supermassive black holes (SMBH). Their defining characteristic is the presence of powerful, back-to-back relativistic jets of protons and electrons, with one jet closely aligned in the direction of Earth. This offers a unique opportunity to probe physics Beyond the Standard Model. The jet can in fact interact with the surrounding Dark Matter in the host galaxy' s halo, where the presence of the SMBH induces a spike in density, offering compelling direct and indirect detection prospects. A key signature of this interaction is the production of high-energy neutrinos, as secondary products of the proton disintegrating in the collision. The resulting outgoing neutrino flux is qualitatively and quantitatively different from the one expected via Standard Model processes alone and, notably, provides a better fit to observations for a large region of unexplored light Dark Matter parameter space. This raises the intriguing question of whether high-energy neutrino observations from blazars could represent the first indirect detection of Dark Matter.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / **26**

Velocity-dependent cross-sections and gravothermal evolution of self-interacting dark matter halos

Author: Bashi Mandava[None]

Corresponding Author: bashitha567@gmail.com

Self-interacting dark matter (SIDM) provides an intriguing alternative to collisionless dark matter, especially when it comes to resolving small-scale structure problems. I will present our preliminary findings on gravothermal collapse in SIDM halos using an extended version of the Gravothermal-SIDM code, now capable of incorporating velocity-dependent cross sections from the CLASSICS repository and going beyond the Born limit for the Yukawa potential. This framework allows us to systematically explore a wide range of velocity dependencies and help us understand how these dependencies impact the onset and progression of gravothermal collapse. We specifically investigate scenarios involving light mediators, which naturally produce velocity-dependent interactions and I will discuss the potential to establish new limits based on the expected stage of gravothermal collapse these halos are in.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

27

Efficient track reconstruction with linear attention Transformer and Mamba

Authors: Cheng Jiang[1]; Sitian Qian[2]

[1] *University of Edinburgh*

[2] *Peking University (CN)*

Corresponding Author: c.jiang-19@sms.ed.ac.uk

The HL-LHC poses significant challenges for tracking with machine learning models, demanding both robust stability while requiring minimal computational overhead. While most previous studies have relied on graph-based methods that are often highly effective, they frequently encounter difficulties with computational complexity on large scale point cloud. In this study, we adopted several linear complexity model, and new class state space model, Mamba to further improve the throughput while having the same performance. We first evaluate per-point classification DBSCAN to assign track IDs, measuring both physics performance and embedding quality. Building on this, a new design with semantic or instance segmentation to support a wide range of downstream applications.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / 28

Renormalization Group Evolution and Phenomenology of Dimension-8 SMEFT

Author: Supratim Das Bakshi[1]

[1] *Argonne National Laboratory*

Corresponding Author: sdasbakshi@anl.gov

Recent SMEFT studies emphasize the consistent inclusion of $\frac{1}{\Lambda^4}$ terms in SMEFT predictions. In this presentation, we explore SMEFT up to $\frac{1}{\Lambda^4}$, incorporating renormalization group evolution (RGE) effects from the running of SMEFT Wilson coefficients (WCs), including dimension-8 contributions.

We discuss the current status of dimension-8 renormalization and recent advancements in RGE computations for SMEFT WCs. Additionally, we examine the phenomenological implications of WC running in both a bottom-up framework and a model-specific top-down approach. Finally, we present future collider projections that account for dimension-8 corrections.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

New Physics at Future Colliders / 29

COmpact DEtector for EXotics at LHCb: CODEX-b

Authors: Jacob Pfaller[1]; Juliette Alimena[2]; Philip Ilten[3]

[1] *University of Cinncinatti*

[2] *DESY*

[3] *University of Cincinnati (US)*

Corresponding Author: jacob.pfaller@cern.ch

The COmpact DEtector for EXotics at LHCb (CODEX-b) is a particle physics detector dedicated to displaced decays of exotic long-lived particles (LLPs), compelling signatures of dark sectors Beyond the Standard Model, which arise in theories containing a hierarchy of scales and small parameters. The CODEX-b detector is a cube with 10m per side with two internal sections, planned to be installed near the LHCb interaction point. It is built of a new generation of high performance RPCs triplet chambers, derived from the ATLAS upgrade RPC technology, providing a space x time resolution of a few mm x 300 ps per individual detector layer. It will have a near-zero background environment, hence complementing the new-searches program of other detectors like ATLAS or CMS. A demonstrator detector, CODEX-⊠, has been installed to take data beginning in 2025. It will validate the design and physics case for the future CODEX-b. CODEX-⊠ will be responsible for validating the background estimations for CODEX-b, demonstrating integration in the LHCb readout system, and showing the suitability of the baseline tracking and its mechanical support. This talk will present the latest developments and will focus on the status and plans for CODEX-⊠.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / 30

Upper Bound on The Parity Breaking Scale of WIMP Dark Matter Models

Authors: Isaac Wang[None]; Keisuke Harigaya[None]; Matthew Baldwin[None]

Corresponding Author: mjbaldwin@uchicago.edu

We consider weakly interacting massive particle (WIMP) dark matter in a parity solution to the strong CP problem. The WIMP phenomenology is drastically affected by the presence of parity partners of WIMP and electroweak gauge bosons. We focus on a parity extension of $SU(2)_L$-doublet fermion dark matter, identify the viable parameter space, and derive the predictions of the theory. We find that the parity symmetry breaking scale is generically bounded from above, with the bound given by $O(10)$ TeV, depending on the details of the model. The High-Luminosity Large

Hadron Collider, future colliders, and direct detection experiments will probe this parameter space further.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / 31

Detecting dark matter with asteroids, planetary rings, and craters

Author: ZACHARY PICKER[None]

Corresponding Author: zpicker@physics.ucla.edu

Macroscopic, composite, and ultraheavy dark matter remains one of the most intriguing dark matter candidates. Along with primordial black holes, this includes quark nuggets, Fermi balls, Q-balls, and more. I will motivate these candidates and discuss their formation mechanisms, before discussing here my recent work which places constraints on a wide and previously unconstrained area of the macroscopic dark matter parameter space by considering the interaction of these massive objects within our Solar System. Macroscopic dark matter could destroy asteroids, planetary rings, and lead to excessive cratering on the Earth or other rocky bodies.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / 32

Impact of Galactic Dark Matter Velocity Distribution on Single Phonon Scattering Rate

Authors: Navaneetha Valsan[1]; Xuxiang Li[1]; Zhengkang Zhang[1]

[1] *University of Utah*

Corresponding Author: navaneetha.valsan@utah.edu

In this work, we investigate the dependence of dark matter (DM) direct detection results, specifically single phonon scattering observables, on the astrophysical properties of the local DM halo. We analyze the impact of uncertainties in DM halo velocity distributions on both total cross-sections and daily modulation in single phonon excitation rates. Employing the Standard Halo Model (SHM), Tsallis model, and an empirical model, we explore the effects of varying key astrophysical parameters, including the local circular velocity (v_0), escape velocity (v_{esc}), and earth's velocity (v_E). We find that the uncertainties of these parameters cause substantial deviations in direct detection projected reach for DM-single phonon scattering, with the impact being highly pronounced for low DM masses. Our findings underscore the paramount importance of accurately determining astrophysical inputs for a reliable interpretation of experimental efforts targeting DM detection via single phonon excitations.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

New Ideas in Baryogenesis, Inflation / 33

Warm Inflation with the Standard Model

Author: Kim Berghaus[1]

Co-authors: Marco Drewes ; Sebastian Zell [2]

[1] *California Institute of Technology*

[2] *LMU Munich*

Corresponding Author: berghaus@caltech.edu

We show for the first time that warm inflation is feasible with Standard Model (SM) gauge interactions alone. Our model consists of a minimal extension of the SM by a single scalar inflaton field with an axion-like coupling to gluons and a monomial potential. The effects of light fermions, which were previously argued to render warm inflation with the SM impossible, are alleviated by Hubble dilution of their chiral chemical potentials. Our model only features one adjustable combination of parameters and accommodates all inflationary observables. We briefly discuss implications for axion experiments, dark matter, and the strong CP-problem.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

New Ideas in Baryogenesis, Inflation / 34

Is the SM CP Violation ever enough to produce the BAU?

Authors: Gilly Elor[None]; Martha Ulloa[1]; Racehl Houtz[None]; Seyda Ipek[None]

[1] *University of Florida*

Corresponding Author: m.ulloacalzonzin@ufl.edu

Is the Standard Model Charge-Parity (CP) violation ever enough to generate the observed baryon asymmetry? Yes! In this talk, I will discuss our most recent work: baryogenesis together with a dark matter production mechanism that can generate the entire observed baryon asymmetry of the universe using only the CP violation within the Standard Model. We introduced baryogenesis along with a dark sector dynamics involving a morphon field that shifts the mass of the particles mediating the decay responsible for baryogenesis. This enhances baryon production while evading present-day collider constraints. The CP violation comes entirely from Standard Model contributions to neutral meson systems. Meanwhile, the dark dynamics generate gravitational waves that may be searched for with current and upcoming Pulsar Timing Arrays.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

New Ideas in Baryogenesis, Inflation / 35

Testing leptogenesis models through the measurement of leptonic CP violation at the LHC

Authors: Nicolas Sanfaçon[1]; David London[None]; Fatemeh Najafi[2]; Jacky Kumar[3]; Jean-Francois Fortin[4]; Mariana Frank[2]

[1] *Université de Montréal*

[2] *Concordia University*

[3] *Los Alamos National Laboratory*

[4] *Laval University*

Corresponding Author: nicolas.sanfacon@umontreal.ca

Leptogenesis provides a compelling explanation of the baryon asymmetry of the Universe. It uses lepton-number-violating (LNV) decays of heavy right-handed neutrinos, which also generate neutrino masses. These neutrinos can, in fact, be light enough to be produced in low-energy processes. If their LNV decays can be observed, this would directly constrain the parameter space of leptogenesis models. We calculate the CP asymmetries and branching ratios for various LNV decays, identifying viable parameter regions where collider signals are compatible with constraints on leptogenesis models. Using analytical methods and MadGraph simulations, we find that lower neutrino masses are tightly constrained, while the 30–100 GeV range remains promising. To extend these tests, we are exploring higher-mass regimes through scattering processes, providing a quantitative framework to test leptogenesis models at colliders.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Gravitational Waves / **36**

Self Consistent Thermal Resummation: A Case Study of the Phase Transition in 2HDM

Authors: Carlos E.M. Wagner[None]; Pedro Bittar[None]; Subhojit Roy[1]

[1] *Argonne National Laboratory*

Corresponding Author: subhotheory@gmail.com

An accurate description of the scalar potential at finite temperature is crucial for studying cosmological first-order phase transitions (FOPT) in the early Universe. At finite temperatures, a precise treatment of thermal resummations is essential, as bosonic fields encounter significant infrared issues that can compromise standard perturbative approaches. The Partial Dressing (or the tadpole resummation) method provides a self consistent resummation of higher order corrections, allowing the computation of thermal masses and the effective potential including the proper Boltzmann suppression factors and without relying on any high-temperature approximation. We systematically compare the Partial dressing resummation scheme results with the Parwani and Arnold Espinosa (AE) ones to investigate the thermal phase transition dynamics in the Two-Higgs-Doublet Model (2HDM). Our findings reveal that different resummation prescriptions can significantly alter the nature of the phase transition within the same region of parameter space,confirming the differences that have already been noticed between the Parwani and AE schemes. Notably, the more refined resummation prescription, the Partial Dressing scheme, does not support symmetry non-restoration in 2HDM at high temperatures observed using the AE prescription. Furthermore, we quantify the uncertainties in the stochastic gravitational wave (GW) spectrum from an FOPT due to variations in resummation methods, illustrating their role in shaping theoretical predictions for upcoming GW experiments. Finally, we discuss the capability of the High-Luminosity LHC and proposed GW experiments to probe the FOEWPT-favored region of the parameter space.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

37

Testing the lepton content of the proton at HERA and EIC

Authors: Anibal Medina[1]; Carlos E.M. Wagner[None]; Leandro Da Rold[2]; Subhojit Roy[3]

[1] *The University of Melbourne*

[2] *Comision Nac. de Energia Atomica Centro Atomico Bariloche (AR)*

[3] *Harish-Chandra Research Institute, INDIA*

Corresponding Author: subhotheory@gmail.com

Although protons are baryons with an overall vanishing lepton number, they possess a non-trivial leptonic content arising from quantum fluctuations which can be described by lepton parton distribution functions (PDFs) of the proton. These PDFs have been recently computed and can be used to define lepton-induced processes at high-energy colliders. In this article, we propose a novel way to test the computation of lepton PDFs of the proton by analyzing both non-resonant di-lepton and resonant Z gauge boson production processes induced by leptons within the proton at proton-electron colliders like HERA and EIC. Despite the fact that lepton PDFs of the proton are known to be small, this work demonstrates that both processes imply a measurable yield of events at HERA and EIC, which could be used to test these PDFs.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / 38

Axion strings from string axions

Authors: Christos Litos[1]; James Cline[2]; Wei Xue[1]

[1] *University of Florida*

[2] *McGill University, (CA)*

Corresponding Author: c.litos@ufl.edu

A favored scenario for axions to be dark matter is for them to form a cosmic string network that subsequently decays, allowing for a tight link between the axion mass and relic abundance. We discuss an example in which the axion is protected from quantum gravity effects that would spoil its ability to solve the strong CP problem: namely a string theoretic axion arising from gauge symmetry in warped extra dimensions. Axion strings arise following the first-order Randall-Sundrum compactification phase transition, forming at the junctions of three bubbles during percolation. Their tensions are at the low scale associated with the warp factor, and are parametrically smaller than the usual field-theory axion strings, relative to the scale of their decay constant. Simulations of
string network formation by this mechanism must be carried out to see whether the axion mass-relic density relation depends on the new parameters in the theory

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Flavor / 39

Radiative correction to $B \to \ell\nu$

Authors: Claudia Cornella[1]; Matthias König[2]; Matthias Neubert[None]; Max Ferré[3]

[1] *CERN*

[2] *JGU (Mainz)*

[3] *PRISMA Cluster of Excellence \& Mainz Institute for Theoretical Physics\\ Johannes Gutenberg University,*

Corresponding Author: ferremax@uni-mainz.de

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

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Cosmology / 40

Cosmology and New Physics with Big-Bang Nucleosynthesis

Authors: Cara Giovanetti[1]; Hongwan Liu[2]; Joshua Thomas Ruderman[1]; Mariangela Lisanti[3]; Siddharth Mishra-Sharma[4]

[1] *NYU*

[2] *Boston University*

[3] *Princeton University*

[4] *MIT*

Corresponding Author: hongwan@bu.edu

I will review the importance of Big-Bang Nucleosynthesis to cosmology and the search for new physics, and explain how to perform parameter inference with LINX, a fast and differentiable BBN code package.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Flavor / 41

Electron EDM and $\Gamma(\mu \to e\gamma)$ in the 2HDM

Authors: Wolfgang Altmannshofer[1]; Ben Assi[None]; Joachim Brod[2]; Nick Hamer[1]; J. Julio[3]; Patipan Uttayarat[None]; Daniil Volkov[4]

[1] *UC Santa Cruz*

[2] *University of Cincinnati*

[3] *BRIN*

[4] *University of Cinccinati*

Corresponding Author: volkovdi@mail.uc.edu

We present the first complete two-loop calculation of the electric dipole moment of the electron, as well as the rates of the lepton-flavor violating decays μ → e + γ and τ → e/μ + γ, in the unconstrained two-Higgs doublet model. We include the most general Yukawa interactions of the Higgs doublets with the Standard Model fermions up to quadratic order, and allow for generic phases in the Higgs potential.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Astro-particle / **42**

Axions from magnetized plasma: effects of plasma dispersion

Author: Nirmalya Brahma[1]

[1] *McGill University*

Corresponding Author: nirmalya.brahma@mail.mcgill.ca

Some of the most stringent constraints on axions arise from considerations of it's emission from astrophysical plasmas. However, many studies assume that particle production occurs in an isotropic plasma environment. This condition is rarely (if ever) met in astrophysical settings, for instance due to the ubiquitous presence of magnetic fields. The effects of the magnetic fields are only taken into consideration for writing down the coupling g^2B^2 while their impact on plasma dispersion are less explored in the context of axion production. In magnetized plasmas, the equations of motion are not diagonal in the usual polarization basis of transverse and longitudinal modes, causing a mixing of these modes and breaking the degeneracy in the dispersion relation of the two transverse modes. This behavior is captured by projecting the response tensor of the plasma $\Pi^{\mu\nu}$ into mode space, whose eigenvectors and eigenvalues are related to the normal modes and their dispersion relations. In this talk, I will discuss a general formalism for determining the normal modes of propagation that are coupled to axions in an anisotropic magnetized plasma. I will provide analytic approximations for the normal modes and their dispersion relations assuming various plasma conditions that are relevant to astrophysical environments. Finally, I will briefly discuss how these modified dispersion properties affect the axion production rate in a magnetized plasma.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / **43**

Weak bosons as partons below 10 TeV partonic center-of-momentum

Author: Richard Ruiz[1]

[1] *Institute of Nuclear Physics (IFJ) PAN*

Corresponding Author: richard.physics@gmail.com

Due to the inclination for forward gauge radiation, lepton colliders beyond a few TeV are effectively electroweak boson colliders, suggesting the treatment of electroweak bosons as constituents of high-energy leptons. In this talk, we summarize the status of electroweak boson parton distribution functions, present new theoretical progress on their implementation, and give a brief outlook for their realistic implementation in TeV-scale hadron-hadron collisions.

Based on arXiv:2502.07878

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Neutrino / 44

New Physics versus Quenching Factors in Coherent Neutrino Scattering

Author: Yulun Li[None]

Co-authors: Gonzalo Herrera [1]; Patrick Huber

[1] *TUM, MPP*

Corresponding Author: yulunl@vt.edu

We investigate the impact of quenching factor uncertainties on the Coherent Elastic Neutrino-Nucleus Scattering (CEνNS) cross section measurements. From the recent results of Dresden-II, CONUS+, and COHERENT, we present that no choice of quenching factor can bring these three data sets into mutual agreement. We further present the quenching factor dependence on sensitivity of these experiments to a large neutrino magnetic moment, finding that the constraints can vary up to an order of magnitude. Our work highlights the importance of reducing this uncertainty on quenching factors in order to probe new physics from neutrinos at the low-energy frontier.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / 45

The Dark Matter Diffused Supernova Neutrino Background

Author: R. Andrew Gustafson[1]

Co-authors: Garv Chauhan [2]; Gonzalo Herrera [1]; Ian Shoemaker [1]; Taj Johnson [3]

[1] *Virginia Tech*

[2] *Virginia Tech, Arizona State University*

[3] *Virginia Tech, Cornell College*

Corresponding Author: gustafr@vt.edu

Dark matter (DM) - neutrino interactions will necessarily lead to a time-delayed flux of neutrinos from transient sources. Considering Milky Way supernovae, we find scattering with DM can lead to neutrino time delays on the order of thousands of years. Multiple supernovae are expected to occur on such timescales, meaning we expect a nearly continuous diffuse neutrino flux. We call this the Dark Matter Diffused Supernova Neutrino Background. We show that current DSNB flux upper bounds can set limits DM-neutrino cross sections at $/m_{DM}$ ~ $10^{-24} cm^2 GeV^{-1}$, one order of magnitude stronger than SN 1987A for DM masses above 100 MeV.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / 46

Higgs CP properties and EFT measurements from ATLAS

Authors: ATLAS Collaboration[None]; Cheng Jiang[1]

[1] *University of Edinburgh*

Corresponding Author: c.jiang-19@sms.ed.ac.uk

This talk presents precise measurement of the CP properties of the Higgs boson using the full dataset collected in pp collisions at 13 TeV during Run 2 and at 13.6 TeV during Run 3 of the LHC. 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.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

New Developments in Theory / 47

Precision QED: how to handle electrons with boundaries

Authors: Asher Berlin[1]; Gerald Gabrielse[None]; Hannah Day[None]; Roni Harnik[None]; Shashin Pavaskar[None]; Yonatan Kahn[None]

[1] *Fermilab*

Corresponding Author: hjday2@illinois.edu

The anomalous magnetic dipole moment ($g-2$) of the electron is one of the most precisely measured quantities in the world. To push precision beyond the current record, we can no longer assume the electron is in free space. We calculate $g - 2$ for an electron in a cylindrical cavity and demonstrate that the boundary correction can be measured in a near-future experiment.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Flavor / 48

Jet cross-section and sub-structure measurements in ATLAS

Author: Yuzhan Zhao[1]

[1] *Carleton University (CA)*

Corresponding Author: yuzhan.zhao@cern.ch

This talk reports recent measurements of jet production cross-sections and the sub-structure properties inside jets in ATLAS. These measurements provide important inputs to understand Quantum Chromodynamics at the high energy regime.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / 49

Recent diboson measurements in ATLAS

Author: Greg Myers[1]

[1] *University of Michigan (US)*

Corresponding Author: greg.myers@cern.ch

This talk reports recent precision measurements of diboson production and the study of anomalous Gauge boson self couplings (and constraints on EFT wilson coefficients) in ATLAS. These results offer further insights into the structure of electroweak interactions and provide greater sensitivity to new physics effects with improved measurement precision.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

New Developments in Theory / 50

Maximal Magic in Two-Qubit States

Authors: Qiaofeng Liu[1]; Ian Low[2]; Zhewei Yin[3]

[1] *Northwestern University*

[2] *Argonne National Lab/Northwestern Univ*

[3] *Northwestern University and Argonne National Laboratory*

Corresponding Author: zhewei.yin@northwestern.edu

Recent years have seen growing interest in exploring quantum information principles within particle scattering processes, both in theoretical and experimental physics. Magic, a resource that quantifies computational advantages in quantum systems, offers a distinct measure of quantumness beyond conventional metrics like entanglement. As researchers investigate the role of magic in scattering final states, determining the fundamental limits of magic attainable in physical systems has

emerged as a critical challenge. By employing the stabilizer Rényi entropy as a measure of magic, we establish—for the first time—the maximum achievable magic in a two-qubit system. We identify all states saturating this bound as fiducial states belonging to Weyl-Heisenberg mutually unbiased bases (MUBs), thereby connecting magic optimization to foundational quantum structures. Furthermore, we demonstrate the nuanced interplay between magic and entanglement in these states. These findings offer critical guidance for probing quantum field theories with enhanced quantum computational properties, advancing the intersection of high-energy physics and quantum information science.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / 51

Recent results on measurements of the Higgs boson in ATLAS

Author: Man Yuan[1]

[1] *University of Michigan (US)*

Corresponding Author: m.yuan@cern.ch

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 the most recent results in the 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. Additionally, several rare Higgs boson processes predicted in the SM, such as decays to a Z boson and a photon, and decays to a pair of muons will be discussed. The observation of one of these processes could open new windows for the study of Higgs boson couplings, or provide evidence for physics beyond the Standard Model.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / 52

Latest New Physics Searches using Leptons at ATLAS

Author: Emily Anne Thompson[1]

[1] *Lawrence Berkeley National Lab (US)*

Corresponding Author: emily.anne.thompson@cern.ch

The Standard Model of Particle Physics explains many natural phenomena yet remains incomplete. Many new physics models (such as leptoquarks, W'/Z', or heavy neutral leptons) could manifest in final states involving multiple leptons. This talk will summarise the latest results from ATLAS in searches involving final states with leptons.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / 53

Probing a Quarkophobic W' at the High-Luminosity LHC via Vector Boson Fusion and Lorentz-Equivariant Point Cloud Learning

Author: Umar Sohail Qureshi[1]

Co-authors: Alfredo Gurrola [2]; Jose Ruiz [3]

[1] *Vanderbilt University*

[2] *Vanderbilt University (US)*

[3] *Universidad de Antioquia (CO)*

Corresponding Author: umar.sohail.qureshi@vanderbilt.edu

The addition of a heavy charged vector gauge boson W' to the Standard Model (SM) with negligible quark couplings (”quarkophobic”) and triple gauge couplings can address issues with the SM, such as the B-meson anomalies and recent discrepancies in the W boson mass measurements. Such a model featuring a large W' decay width has not yet been explored at the LHC and would be challenging to probe using conventional methods, necessitating the development of innovative search strategies. In this talk, we present a novel study probing W' production through weak boson fusion in proton-proton collisions at the LHC, operating under a simplified model with a large W' decay width and considering final states with two jets, large missing transverse momentum, and one light lepton. Notably, we use point cloud learning for the first time in a BSM search—specifically, a novel Lorentz-Equivariant Geometric Algebra Transformer—providing significant improvement in signal sensitivity compared to traditional methods. Using our methodology, a quarkophobic W' with triple gauge couplings decaying to a lepton and neutrino can be probed with masses up to 4.45 TeV, depending on the couplings to SM leptons and weak bosons.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Flavor / 54

Recent heavy flavour results from ATLAS

Author: Ioannis Michail Maniatis[1]

[1] *Weizmann Institute of Science (IL)*

Corresponding Author: giannis.maniatis@cern.ch

Studying heavy-flavour hadron properties provides a extensive tests for various QCD predictions as well as a means to probe the Standard Model validity. ATLAS experiment, being a general-purpose detector at LHC, is particularly successful in such measurements with final states involving muons, thanks to large collected integrated luminosity and precise muon reconstruction and triggering. This talk will overview the recent ATLAS results on heavy-flavour hadron production and decay properties and spectroscopy of exotic states.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Gravitational Waves / **55**

Holographic phase transitions via thermally-assisted tunneling

Authors: Arpon Paul[None]; Tony Gherghetta[None]; Andrey Shkerin[None]

Corresponding Author: paul1228@umn.edu

We construct the thermal bounce solution in holographic models that describes first-order phase transitions between the deconfined and confined phases in strongly-coupled gauge theories. This new, periodic Euclidean solution represents transitions that occur via thermally-assisted tunneling and interpolates between the $O(4)$-symmetric vacuum bubble at zero temperature and the high temperature $O(3)$-symmetric critical bubble associated with classical thermal fluctuations. The exact thermal bounce solution can be used to obtain the bounce action at low temperatures which allows for a more accurate determination of vacuum decay rates, significantly improving previous estimates in holographic models. In particular, provided the phase transition is sufficiently supercooled, new predictions are obtained for the gravitational wave signal strength for critical temperatures ranging from the TeV scale up to 10^{12} GeV, some of which are within reach of future gravitational wave detectors.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / **56**

ATLAS results on associated top quark production (Top+X)

Author: Nilima Nilesh Akolkar[1]

[1] *University of Bonn (DE)*

Corresponding Author: nilima.nilesh.akolkar@cern.ch

The high center-of-mass energy of proton-proton collisions and the large available datasets at the CERN Large Hadron Collider allow the study of rare processes of the Standard Model with unprecedented precision. 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. In this contribution, total and differential measurements of associated top-quark production are shown using data taken with the ATLAS Experiment at a center-of-mass-energy of 13 TeV. These measurements provide important bounds on the electroweak couplings of the top quark, often with Effective Field Theory interpretations and constrain backgrounds that are important in searches for Higgs production and for new phenomena beyond the SM.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / **57**

Differential inclusive single W (also off-shell) measurements in ATLAS

Author: Jerry Ling[1]

[1] *Harvard University (US)*

Corresponding Author: jerry.ling@cern.ch

This talk reports recent differential measurements of single W boson in ATLAS for both on-shell and off-shell scenarios, which provide sensitive inputs to improve the constraints on PDFs and relevant EFT wilson coefficients.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

New Physics at Future Colliders / 58

Heavy QCD axions at Muon Collider

Authors: Peiran Li[1]; Ravneet Bedi[1]; Soubhik Kumar[2]; Tony Gherghetta[None]; Zhen Liu[None]

[1] *University of Minnesota*

[2] *UC Berkeley*

Corresponding Author: li001800@umn.edu

We study the physics potentials of heavy QCD axions at 3/10 TeV muon colliders (MuC). These heavy QCD axions differ from typical ALPs as they solve the Strong CP puzzle, and their phenomenology is driven by the $aG\tilde{G}$ couplings. Different realizations of heavy QCD axions have different implications, and we show comprehensively how muon colliders can uniquely probe them with a huge parameter space. Additionally, we find a set of vector-boson-scattering channels at MuC that dominate the axion production rate rather than the usual vector-boson-fusion channel.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / 59

Recent VBS and Triboson Measurements in ATLAS

Author: Mark Neubauer[1]

[1] *Univ. Illinois at Urbana Champaign (US)*

Corresponding Author: msn@illinois.edu

This talk reports recent measurements of vector boson scattering and triboson processes in ATLAS. These results provide stringent tests of the Higgs mechanism, as well as the Gauge sector of the electroweak theory (through studying anomalous Gauge boson couplings), and offer a new avenue for precision tests of the SM as well as MC modelling. In addition, the investigation of boson polarization states in VBS processes can bring further sensitivity for the test of SM and new physics phenomena, with recent progress covered in the talk.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Cosmology / 60

Breaking Free from the Swampland of Impossible Universes through the DESI Portal

Author: Luis Anchordoqui[None]

Corresponding Author: luis.anchordoqui@gmail.com

We propose a simple, well-motivated, and robust model of slow-roll thawing quintessence, which is consistent with current observations of dark energy and naturally satisfies the conjectured swampland constraints.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / 61

Almost Minimal Dark Matter

Author: Spencer Griffith[1]

[1] *Ohio State University*

Corresponding Author: griffith.1037@osu.edu

Numerous models of particle dark matter have been proposed, many of which remain viable given current experimental and observational constraints. Minimal dark matter is an extremely attractive option since it envisions the addition of a single SU(2) multiplet to the standard model, rather than a complicated array of particles and interactions. However, experimental limits already rule out a subset of minimal dark matter possibilities and are approaching the predicted phase space of the remaining candidates. We consider extensions to the minimal dark matter paradigm, particularly a combination of two multiplets with a Higgs coupling, and the non-perturbative effects which may alleviate this experimental pressure.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / 62

Searches for supersymmetric particles with the ATLAS detector

Author: Tomas Davidek[1]

[1] *Charles University (CZ)*

Corresponding Author: tomas.davidek@cern.ch

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. The direct production of electroweak SUSY particles, including sleptons, charginos, and neutralinos, is a particularly interesting area with connections to dark matter and the naturalness of the Higgs mass. Naturalness arguments also favour supersymmetric partners of the gluons and third-generation quarks with masses light enough to be produced at the LHC. This talk will highlight the most recent results of searches performed by the ATLAS experiment for supersymmetric particles, considering both electroweak and strong production modes. With increasing mass bounds on more classical MSSM scenarios other variations of supersymmetry become increasingly interesting. Results for compressed, non-minimal, and R-parity violating scenarios and recent interpretations in the context of the pMSSM are also presented.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Cosmology / 63

Stasis from a single Annihilating particle species

Authors: Brooks Thomas[None]; Jonah Barber Not Supplied[None]; Keith Dienes[1]

[1] *University of Arizona*

Corresponding Author: jbarber2@arizona.edu

Stasis is a cosmological phenomena in which the abundances of the different energy components in the universe (such as matter, radiation, etc.) remain fixed for an extended period even though they are affected differently by expansion. Many of the mechanisms that lead to stasis revolve around a tower of states, which emerge in many BSM theories. In this talk, I will describe a realization of stasis that does not involve a tower. Instead of a tower of decaying states, this realization has a single species of particle undergoing annihilation. These particles form a thermal population and the temperature influences the cross section of annihilation. If this cross section depends on the temperature in a certain way than this process can lead to stasis.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Machine Learning / 64

Baryon number violation searches with CUORE

Author: Vivek Sharma[1]

[1] *University of Pittsburgh*

Corresponding Author: vsharma2510@gmail.com

The conservation of baryon number in the Standard Model originates from an empirical symmetry and does not derive from first principles. Any discovery of a phenomenon that indicates that this

symmetry is broken would have far-reaching consequences for our understanding of the universe, in particular the origin of the matter-antimatter asymmetry. A proposed process that can violate baryon number is the tri-nucleon decay, which involves three nucleons in a nucleus decaying simultaneously. The products of this decay are emitted with GeV-scale energy, which can serve as an excellent signal in CUORE. We will present the details on the search signatures, the associated backgrounds and the analysis techniques employed. Other possible baryon number violation studies with CUORE will also be discussed.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Flavor / 65

SU(3)-flavour symmetry breaking in B->DP decays.

Authors: Bhubanjyoti Bhattacharya[1]; David London[2]; Rida Boumris[2]

[1] *Lawrence Technological University*

[2] *Montreal university*

Corresponding Author: rida.boumris@umontreal.ca

The latest measurements of branching ratios, related to hadronic decays of B mesons to charm and pseudo-scalar final states (DP), showed disagreements with theoretical predictions based on QCD factorization. Meanwhile, SU(3) symmetry-breaking was found in recent studies to exceed the Standard Model threshold of 20% (in B decays to two pseudo-scalars). In the light of these results, an analysis of SU(3)-flavour symmetry in B-> DP decays is essential to quantify the degree of the symmetry-breaking and to look for possible 'New Physics' in the charm sector as well.
To achieve that, we consider both decay channels: DC=1 and DC=-1. We use decay observables: Branching ratios, direct and indirect CP asymmetries. We then perform a global fit while computing the Chi-square.
The best fit results have shown that a symmetry-breaking of 20% is sufficient to account for the data. Moreover, we were able to find the sizes of the diagrams and to make observable predictions for certain decays, which are hard to measure otherwise.

Mini Symposia (Invited Talks Only):

Mini Symposia (Invited Talks Only)

Plenary (Invited talks only):

Plenary (Invited Talks Only)

Machine Learning / 66

NomAD: Real-Time Unsupervised Anomaly Detection at the ATLAS Level-1 Trigger

Author: Rajat Gupta[1]

[1] *University of Pittsburgh (US)*

Corresponding Author: rajat.gupta@cern.ch

We present NomAD (Nanosecond Anomaly Detection), an unsupervised machine learning algorithm developed for real-time anomaly detection in the ATLAS Level-1 Topological (L1Topo) trigger during Run 3. Combining a Variational Autoencoder with Decision Tree Regression, NomAD identifies rare and unconventional events in FPGA-based trigger hardware with low latency. Applied to dimuon events, the algorithm captures signals beyond standard selections, achieving up to a 21% increase in unique acceptance using B-Physics benchmarks. The anomaly detection trigger operates at a tunable rate, with around 1.8 kHz observed at a representative AD score threshold. This flexibility enables integration into existing trigger menus while maintaining sensitivity to new physics. This talk will cover the algorithm's design, performance, and its potential to enhance real-time event selection in high-energy physics.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / 67

HH searches and Higgs-self couplings measurements by ATLAS

Author: Sayuka Kita[1]

[1] *University of Tsukuba (JP)*

Corresponding Author: sayuka.kita@cern.ch

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. Additionally, extrapolations of recent HH results towards the High Luminosity LHC upgrade are also discussed. Many new physics models predict the existence of resonances decaying into two bosons, including the Higgs boson or new scalar S bosons making these important signatures in the search for new physics. Searches for HH or SH resonances have been performed in various final states. In some of these searches, jet substructure techniques are used to disentangle the hadronic decay products in highly boosted configurations.Recent ATLAS searches with Run 2 data collected at the LHC and explains the experimental methods used, including vector- and Higgs-boson-tagging techniques are presented.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Flavor / 68

High Quality Axion from Gauged Flavor Symmetry

Authors: Ks Babu[1]; Sai Charan Chandrasekar[2]; Zurab Tavartkiladze[None]

[1] *Oklahoma State University*

[2] *PhD Student at Oklahoma State University*

Corresponding Author: sai.sekar@okstate.edu

We show how the axion quality problem resulting from the violation of global symmetries by quantum gravity can be solved in presence of a gauged $U(1)_F$ flavor symmetry in a class of models. The gauged $U(1)_F$ explains the hierarchical structure of fermion masses and mixings via the Froggatt-Nielsen mechanism. The axion is realized as a byproduct of an accidental $U(1)$ symmetry with a QCD anomaly present in these models, with the gauged $U(1)_F$ safeguarding the axion potential. Three models, which are generalizations of the Dine-Fischler-Srednicki-Zhitnitsky (DFSZ) axion model, are presented realizing this idea. The axion acts as a flavon (flavaxion or axiflavon) in these models, which can be tested in flavor-changing decays of mesons. These models provide an understanding of the hierarchical structure of the fermion masses, solve the strong CP problem, and also explain the dark matter relic abundance in axion without inducing a cosmological domain wall problem.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / **69**

Unconventional Searches using the ATLAS Detector

Author: Kenneth Johns[1]

[1] *University of Arizona (US)*

Corresponding Author: kenneth.johns@cern.ch

Many theories beyond the Standard Model (SM) have been proposed to address several of the SM shortcomings. Some of these beyond-the-SM extensions predict new particles or interactions directly accessible at the LHC, but which would leave unconventional signatures in the ATLAS detector. These unconventional signatures require special techniques and reconstruction algorithms to be developed, enabling analysers to perform unique searches for new physics. Conversely, some searches for more standard models also make use of unconventional workflows to improve sensitivity. This talk will cover several such recent searches at ATLAS.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / **70**

ATLAS results on top quark cross section measurements

Author: Laura Pintucci[1]

[1] *Universita degli Studi di Udine (IT)*

Corresponding Author: laura.pintucci@cern.ch

The exceptionally large dataset collected by the ATLAS detector at the highest proton-proton collision energies provided by the LHC enables precision testing of theoretical predictions using an extensive sample of top quark events. Measurements of the inclusive top quark production rates at the LHC have reached a precision of several percent and test advanced Next-to-Next-to-Leading Order predictions in QCD. Differential measurements in several observables are important to test SM predictions and improve Monte Carlo generator predictions.Recent measurements include total and differential top quark cross sections, as well as detailed studies of top quark production at various center-of-mass energies. This contribution presents the latest highlights from the ATLAS top quark physics program, including key measurements from Run II, and new results using Run III data.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Cosmology / 71

Small-scale cosmology with DESI Lyman-alpha forest

Author: Naim Karacayli[1]

[1] *The Ohio State University*

Corresponding Author: karacayli.1@osu.edu

The Lyman-alpha forest enables the study of cosmic structure on scales much smaller than those probed by baryon acoustic oscillations (BAO). While the BAO feature appears at 150 Mpc, the Lyman-alpha forest can resolve structure down to 1 Mpc, limited primarily by spectrograph resolution. This sensitivity makes it a powerful probe of small-scale clustering, which is influenced by the mass of neutrinos and hypothetical dark matter particles. However, this advantage comes with the requirement of a careful study of instrumental systematics. We quantify the small-scale clustering using the one-dimensional flux power spectrum (P1D). In this talk, I will present our P1D measurements from DESI Data Release 1 and outline our strategy for mitigating systematics related to CCD defects. By the time of the symposium, I expect to have preliminary cosmological insights from this analysis.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / 72

Recent Heavy resonances searches (including new scalars & BSM Higgs decays)

Author: Yuichiro Hayashi[1]

[1] *University of Tokyo (JP)*

Corresponding Author: yuichiro.hayashi@cern.ch

Though the Standard Model (SM) of particle physics has been a very successful theory in explaining a wide range of measurements, there are still many questions left unanswered such as incorporation of gravity into SM, neutrino masses, matter-antimatter asymmetry, supersymmetry, or existence of dark matter candidates. One of the possible solutions to address these challenges is the extension of

the SM with the presence of additional, heavy BSM particles; including scalar (H/S), pseudoscalar (A), or charged (H+-/H++--) BSM Higgs bosons. This is accounted for in multiple possible new physics models predicting the existence of these new, heavy particles. This talk summarises recent ATLAS searches for Beyond-the-Standard-Model heavy resonances, using the full Run 2 dataset.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Cosmology / 73

PBH formation via junction conditions

Author: Mudit Rai[1]

Co-authors: Bhaskar Dutta ; James Dent [2]

[1] *Texas AM University*

[2] *Sam Houston State University*

Corresponding Author: muditrai@tamu.edu

We analyse the formation criteria for PBH formation via the Israel-Junction conditions. We find that the usual overdensity condition is a weaker condition when compared to the more fundamental junction conditions. In addition, we look into the PBH formed in fermi-ball scenarios and compare it with known results in the literature.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Astro-particle / 74

A ν look at the Sun: Probing the conditions of the solar core using ^{8}B neutrinos

Author: Melanie Zaidel[1]

Co-author: John Beacom [1]

[1] *Ohio State University*

Corresponding Author: melaniezaidel7@gmail.com

In the coming age of precision neutrino physics, neutrinos from the Sun become robust probes of the conditions of the solar core. Here, we focus on ^{8}B neutrinos, for which there are already high precision measurements by the Sudbury Neutrino Observatory and Super-Kamiokande. Using only basic physical principles and straightforward statistical tools, we calculate projected constraints on the temperature and density of the ^{8}B neutrino production zone compared to a reference solar model. We outline how to better understand the astrophysics of the solar interior using forthcoming neutrino data and solar models. Our code is publicly available on Github.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Flavor / 75

Uncovering Hidden Symmetries in 4HDM: New Tools and Classifications

Author: Jiazhen(Jan) Shao[1]

[1] *Washington University in St. Louis*

Corresponding Author: jan.shao@wustl.edu

Multi-Higgs-doublet models (NHDMs) has been gaining increasing popularity in beyond Standard Model (BSM) research, and people have been using it to address problems like dark matter, fermion mass hierarchies, and neutrino mass. Among these, there is steady growing literature (reaching a hundred) discussing the Four-Higgs-Doublet Model (4HDM). Finite symmetries play a pivotal role in NHDMs, yet many studies in 4HDM rely on ad hoc choices due to the absence of systematic study of all global symmetry options. In this work, we present the first systematic classification of global symmetry groups in the 4HDM. We developed new purely group-theoretic and computational methods that go beyond the more widely-used representation theory. These methods enrich the toolbox for NHDM studies, and offer a new, purely group-theoretic perspective for exploring BSM phenomenology.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Flavor / 76

Probing New Physics through Right-Handed Neutrinos in Semileptonic $\bar{B}$ Decays

Authors: Alakabha Datta[1]; Bhubanjyoti Bhattacharya[2]

Co-authors: Kumar Pandey [1]; Thomas Browder [3]; Nilakshi Das [4]; Alexei Sibidanov [3]; Tejhas Kapoor [5]

[1] *University of Mississippi*

[2] *Lawrence Technological University*

[3] *University of Hawaii*

[4] *Indian Institute of Technology Gandhinagar*

[5] *Universit´e Paris-Saclay*

Corresponding Author: kpandey@go.olemiss.edu

More evidence of New Physics (NP) has been observed in charged current decays of $\bar{B} \to D^* \ell \bar{\nu}$, as measured by the BaBar, Belle, and LHCb experiments. Curiously, the observable R_{D^*} has been found to exceed Standard Model (SM) expectations, with a combined significance of 3.4σ. Moreover, there is further motivation for NP in the muon sector due to persistent anomalies in the muon anomalous magnetic moment ($(g-2)_\mu$) and in neutral current processes such as $b \to s\mu^+\mu^-$.In this work, we investigate the differential decay distributions of $\bar{B} \to D^* \ell \bar{X}$, where X is a heavy right-handed neutrino. To explore NP signatures associated with such a neutrino, we employ a newly developed Monte Carlo event generator built upon the EvtGen framework, tailored specifically to simulate beyond-the-Standard-Model processes.
Our study includes an analysis of angular observables and kinematic distributions, with particular emphasis on forward-backward asymmetries, such as $\Delta A_{\text{FB}} = A^{\mu}_{\text{FB}} - A^{e}_{\text{FB}}$, among others. These observables offer valuable insight into potential deviations from SM predictions and represent a promising avenue for probing the existence of right-handed neutrinos in semileptonic B-meson decays.

Mini Symposia (Invited Talks Only):

Mini Symposia (Invited Talks Only)

Plenary (Invited talks only):

Dark Matter / 77

New approach to using optomechanically levitated sensors to detect ultralight dark matter

Author: Louis Hamaide[1]

Co-author: Hannah Banks [2]

[1] *INFN Naples*

[2] *U. of Cambridge - DAMTP*

Corresponding Author: louis.hamaide@na.infn.it

Optically levitated quantum sensors have recently been increasingly popular in proposals to detect ultralight dark matter and gravitational waves due to their world-leading sensitivities to forces. Although historically less optimized to search for many DM couplings than e.g. magnetic traps, optical traps can reach much higher frequencies (kHz-to-GHz). After outlining the necessary concepts in optomechanical quantum sensing, we compare sensitivities to ultralight dark matter couplings with currently used optical traps versus a newly proposed optimised setup, improving these sensitivities by several orders of magnitude and reaching new dark matter parameter space. We also discuss near-future prospects of improving this by reaching the on-resonance standard quantum limit to explore the ultimate sensitivity of these novel detectors.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

78

Dark matter effective theory for any spin

Author: Joachim Brod[1]

[1] *University of Cincinnati*

Corresponding Author: joachim.brod@uc.edu

Direct detection via scattering on atomic nuclei remains one of our best hopes to shed light on the mystery of dark matter. Several effective theory frameworks exist that try to capture most of the physics without committing to a specific model. I will present the "ultimate effective theory" for direct detection, valid for non-relativistic dark matter of any spin.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Flavor / 79

Towards an NNNLO prediction of indirect CP violation in kaon decays

Author: Joachim Brod[1]

[1] *University of Cincinnati*

Corresponding Author: joachim.brod@uc.edu

Indirect CP violation in kaon decays is measured with a precision at the permil level. In this talk, I briefly review the status of the standard model prediction, including current efforts to calculate the four-loop QCD corrections using the MaRTIn code.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Gravitational Waves / 80

On the Feasibility of Detecting the Graviton Mass in PTAs: A Novel Approach from the Massive Dispersion Relation

Author: Chris Choi[1]

Co-author: Tina Kahniashvili [2]

[1] *Carnegie Mellon University*

[2] *Carnegie Mellon*

Corresponding Author: minyeonc@andrew.cmu.edu

In massive gravity, we expect a modification to the dispersion relation for gravitational waves and the angular correlation in pulsar timing arrays (PTAs) due to the five polarization modes that arise. We consider the lower bound for graviton mass constraints from the dispersion relation for future PTA observations and scrutinze the possibility of detection via the effective overlap reduction function. We find that the predicted overlap reduction function for such a graviton mass lies outside the standard deviation of the observed angular correlation, even in the best case scenario. Future PTA observation campaigns therefore are not able to detect these additional modes of polarization and cannot be effectively used to constrain the graviton mass.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Neutrino / 81

Neutrino force at all length scales

Author: Bingrong Yu[1]

[1] *Cornell University*

Corresponding Author: bingrong.yu@cornell.edu

The exchange of a pair of neutrinos can mediate a long-range force. This "neutrino force" is a unique quantum force predicted by the Standard Model; it is also sensitive to the nature of the neutrino mass. Yet, this force is too weak to be detected so far. In this talk, I will introduce our recent progress in detecting the neutrino force from two aspects.

(1) At the **microscopic** scale, since the neutrino interaction breaks the parity symmetry, we propose to use the atomic parity violation (APV) to probe the neutrino force. We derive a new formula for the neutrino force that is valid at all distances and apply it to study APV effects in different atomic systems. We find that the neutrino force effect is significant compared with the current sensitivity of APV experiments. It also has an important effect on the atomic measurement of the Weinberg angle. The first part is based on [2410.19059].

(2) At the **macroscopic** scale, the neutrino force can be coherently enhanced by a neutrino background. We calculate the finite-temperature correction to the neutrino force in the background of cosmic neutrinos and solar/reactor neutrino flux. We find the background correction can significantly change the scaling behavior of the neutrino force at long distances, greatly enhancing the chance to detect this force. The second part is based on [2209.07082].

(3) Finally, if I have time, I will briefly discuss the BSM extension, that is, using our strategy to probe the quantum force from other exotic light particles (e.g., axion), which is based on [2504.00104].

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Flavor / 82

Autonomous Model Building Neutrino Flavor Theories with Reinforcement Learning

Authors: Aishik Ghosh[1]; Daniel Whiteson[1]; Jake Rudolph[2]; Jason Baretz[2]; Max Fieg[None]; Victoria Knapp Perez[2]; Vijay Ganesh[3]

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

[2] *UCI*

[3] *Georgia Tech*

Corresponding Author: vknapppe@uci.edu

Model building in particle physics relies heavily on the intuition of theorists to select appropriate symmetry groups, particle content, and representation assignments. However, the space of viable models is vast. Exploring the space is usually computationally expensive. The challenge lies in the combinatorial complexity of symmetry and representation choices and the computational effort required to evaluate and compare a model's predictions with experimental data. In this talk, we present the development of an Autonomous Model Builder (AMBer), a reinforcement learning framework designed to search these spaces efficiently. We apply our framework to construct neutrino flavor models that reproduce the observed mass spectrum and mixing angles while maintaining minimal field content. We apply our agent to well-studied symmetry group spaces and discover new models within spaces that have not been previously explored.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

New Developments in Theory / 83

Discrete Symmetry of Magnetic Monopole with Spinor Helicity Formalism

Authors: Hsing-Yi Lai[None]; John Lee Kenneth Terning[1]

[1] *University of California (UCD)*

Corresponding Author: hylai@ucdavis.edu

Spinor helicity formalism and modern amplitude techniques are powerful tools receiving strong attention. In this talk, we will show that the discrete symmetries, parity and charge conjugation, can be applied and determined completely within the spinor helicity language. We will further apply it to the production amplitude of magnetic monopoles by annihilating electric particles. On-shell techniques and implications to the phenomenology of the Large Hadron Collider will also be discussed.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Neutrino / 84

Unveiling the Neutrino Magnetic Moment: Constraints from Colliders

Authors: Samiur R. Mir[1]; Vedran Brdar[2]; Ying-Ying Li[3]; Yi-Lin Wang[4]

[1] *Oklahoma State University*

[2] *Oklahoma State University (US)*

[3] *Institute of High Energy Physics, , Chinese Academy of Sciences*

[4] *Interdisciplinary Center for Theoretical Study, University of Science and Technology of China*

Corresponding Author: samiur.mir@okstate.edu

The transition magnetic moment between active and sterile neutrinos is theoretically well-motivated scenario beyond the Standard Model, which can be probed in cosmology, astrophysics, and at terrestrial experiments. In this talk, we focus on the latter by examining such an interaction at proposed lepton colliders. Specifically, in addition to revisiting LEP, we consider CEPC, FCC-ee, CLIC, and the muon collider, motivated by the potential realization of any of them. Within the effective field theory framework, we present parameter regions that can be probed, highlighting the dependence on the lepton flavor interacting with the sterile neutrino. By including several new processes with large sterile neutrino production cross sections at high-energy lepton colliders, we find that the expected sensitivity for the active-to-sterile neutrino transition magnetic moment can reach $d_\gamma \simeq \mathcal{O}(10^{-7})$ GeV^{-1}.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Neutrino / 85

Towards a Robust Exclusion of the Sterile-Neutrino Explanation of Short-Baseline Anomalies

Authors: Bryce Littlejohn[None]; IBRAHIM SAFA[1]; Kevin Kelly[2]; Matheus Hostert[None]; Ohana Benevides[None]; Pedro Machado[3]; Tao Zhou[2]

[1] *University of Wisconsin - Madison*

[2] *Texas A&M University*

[3] *Fermilab*

Corresponding Author: taozhou@tamu.edu

The sterile neutrino interpretation of the LSND and MiniBooNE neutrino anomalies is currently being tested at three Liquid Argon detectors: MicroBooNE, SBND, and ICARUS. It has been argued that a degeneracy between $\nu_\mu \to \nu_e$ and $\nu_e \to \nu_e$ oscillations significantly degrades their sensitivity to sterile neutrinos.
Through an independent study, we show two methods to eliminate this concern. First, we resolve this degeneracy by including external constraints on ν_e disappearance from the PROSPECT reactor experiment. Second, by properly analyzing the full three-dimensional parameter space, we demonstrate that the stronger-than-sensitivity exclusion from MicroBooNE alone already covers the entire 2σ preferred regions of MiniBooNE at the level of $2-3\sigma$. We show that upcoming searches at SBND and ICARUS can improve on this beyond the 4σ level, thereby providing a rigorous test of short-baseline anomalies.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / 86

Illuminating Very Heavy Dark Matter in the Earth with Tau Neutrinos

Authors: Ali Kheirandish[1]; Qinrui Liu[2]; Tianyi Ding[1]

[1] *University of Nevada, Las Vegas*

[2] *Queen's University*

Corresponding Author: tianyi.ding@unlv.edu

Dark matter continuously accumulates at the Earth's core through DM–nucleon scattering as Earth traverses the Milky Way's dark matter halo. With higher dark matter density in the Earth's core, potential annihilations of these dark matter particles into Standard Model particles, like tau neutrinos and tau leptons, offer an intriguing observational target for indirect dark matter searches. Large-volume neutrino telescopes, with their expansive detection capabilities across wide energy spectra, have opened a new front in identifying dark matter signals originating from Earth's center. Conventional studies have predominantly focused on dark matter masses below a PeV due to Earth' s opacity to very-high-energy neutrinos.
In this talk, we reexamine the role of tau regeneration, which enables dark matter annihilation signals from the Earth's center to reach the surface. By focusing on annihilation channels into tau leptons or tau neutrinos, we show that neutrino observatories, like IceCube, can probe much heavier dark matter than previously accessible. Using 7.5 years of IceCube high-energy starting event data, this study sets stringent new upper limits on the spin-independent dark matter–nucleon cross-section, pushing the accessible dark matter mass range from 10^5 GeV to as high as 10^{10} GeV. Our results highlight the potential of current and future neutrino observatories to explore the high-mass regime of Earth-bound dark matter annihilation.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / 87

From Neutron Stars to Beam Dumps: 2-to-3 Process with Single Photon Final State

Authors: Ankur Verma[1]; Anupam Ray[2]; Aparajitha Karthikeyan[1]; Bhaskar Dutta[1]; Debopam Goswami[1]

[1] *Department of Physics & Astronomy, Texas A&M University*

[2] *University of California, Berkeley*

Corresponding Author: debopam22@tamu.edu

In this work, we focus on the 2-to-3 scattering process between dark matter (DM) and nuclei, mediated by the Standard Model (SM) photon and a scalar particle with its mass spanning from 10 keV to 100 GeV. This process provides an efficient channel for producing energetic photons in the final state. These photons serve as a powerful probe in multiple contexts: they investigate unexplored regions of parameter space, and their distinctive energy spectrum offers a means to isolate potential signal from background channels. We explore the viable parameter space by combining constraints from both astrophysical observations—such as neutron star heating—and terrestrial searches. In particular, we present predictions for this process at proton beam dump experiments, such as at the ongoing Short-Baseline Neutrino (SBN) program at Fermilab.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Machine Learning / 88

Isolating Unisolated Upsilons with Anomaly Detection in CMS Open Data

Author: Rikab Gambhir[1]

Co-authors: Ben Nachman [2]; Jesse Thaler [1]; Radha Mastandrea [3]

[1] *MIT*

[2] *Lawrence Berkeley National Lab. (US)*

[3] *University of California, Berkeley*

Corresponding Author: rikab@mit.edu

We present the first study of anti-isolated Upsilon decays to two muons ($\Upsilon \to \mu+\mu-$) in proton-proton collisions at the Large Hadron Collider. Using a machine learning (ML)-based anomaly detection strategy, we "rediscover" the Υ in 13 TeV CMS Open Data from 2016, despite overwhelming anti-isolated backgrounds. We elevate the signal significance to 6.4σ using these methods, starting from 1.6σ using the dimuon mass spectrum alone. Moreover, we demonstrate improved sensitivity from using an ML-based estimate of the multi-feature likelihood compared to traditional "cut-and-count" methods. Our work demonstrates that it is possible and practical to find real signals in experimental collider data using ML-based anomaly detection, and we distill a readily-accessible benchmark dataset from the CMS Open Data to facilitate future anomaly detection developments.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Astro-particle / 89

Predicting the Diffuse Supernova Neutrino Background

Author: Andrew Caruso[1]

Co-authors: Shunsaku Horiuchi ; Tomoya Kinugawa [2]; Volodymyr Takhistov [3]

[1] *Virginia Tech*

[2] *ICRR, University of Tokyo*

[3] *QUP, KEK*

Corresponding Author: adcaruso110@gmail.com

We predict the expected flux of anti-electron flavor neutrinos in the diffuse supernova neutrino background (DSNB) with the inclusion of both failed and successful supernovae and binary stellar systems. Using simulations from the Garching Core-collapse Supernova Archive of single star progenitors and their neutrino energy spectra for a variety of explosion models, we determine an optimal criterion to determine which progenitors yield failed or successful supernovae. By synthesizing the binary stars and applying the optimized criterion, we can distinguish failed and successful supernovae and thereafter compute the expected flux of the DSNB from their contribution across multiple binary synthesis models. Our results extend previous predictions by incorporating failed supernovae and improving the collective endeavor to model the DSNB relevant for detection at the Super-Kamiokande gadolinium-doped experiment.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

New Physics at Future Colliders / 90

Colored Particle Production at High-Energy Muon Colliders

Author: Arthur Wu[None]

Corresponding Author: tow39@pitt.edu

A high-energy muon collider provides a wide variety of mechanisms for the production of new heavy particles. In this talk, I will first show how the PDFs for quarks, gluons and photons can be applied on muon collider, and then present production cross sections for a large variety of colored particles, including color triplet fermions and scalars and color sextet diquarks, leptoquarks, leptogluons and color octet scalars, fermions and vectors. Compared to LHC, we find muon collider has better sensitivity for many of the colored BSM particles.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Machine Learning / 91

Jet calibration with in-situ pileup suppression

Author: Stephen Roche[1]

Co-authors: Benjamin Carlson [2]; Michael Hemmett [2]; Tae Min Hong [3]

[1] *Saint Louis University*

[2] *Westmont College*

[3] *University of Pittsburgh (US)*

Corresponding Author: stephen.thomas.roche@cern.ch

We present a method to suppress pileup and calibrate hadronic jet energy at L1 triggers using boosted decision trees for regression and classification. The fwX platform is used for implementation of BDTs on FPGA within the necessary timing and resource constraints. The in-situ pileup suppression can improve trigger performance in the high pileup environment of the HL-LHC.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Neutrino / **92**

Dark Matter-enhanced Probe of Relic Neutrino Clustering

Authors: Anna Suliga[1]; Bhupal Dev[2]; Vedran Brdar[3]; Writasree Maitra[2]

[1] *New York University*

[2] *Washington University in St. Louis*

[3] *Oklahoma State University (US)*

Corresponding Author: m.writasree@wustl.edu

The existence of relic neutrino background is a strong prediction of the Big Bang cosmology. But because of their extremely small kinetic energy today, the direct detection of relic neutrinos remains elusive. On the other hand, we know very little about the nature of dark matter. In this work, we are putting constraint on the overdensity of the cosmic neutrino background by using them as the scatterers to the neutrinos coming from decaying heavy dark matter (with mass in the range of 10^9 to 10^{15} GeV). For a particular choice of constraint on dark matter lifetime, these attenuated neutrino fluxes are potentially observable at the next-generation ultra-high energy neutrino telescopes (such as IceCube-Gen2).

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Astro-particle / **93**

A Search for Cosmic Ray Signatures in the RNO-G Experiment

Author: Alisa Nozdrina[1]

[1] *CCAPP OSU*

Corresponding Author: alisanozdrina@gmail.com

Neutrinos produced by interactions between ultra-high-energy (UHE) cosmic rays and the cosmic microwave background can help trace the origins of these particles and investigate the mechanisms driving their extreme acceleration.

The detection of neutrinos above the PeV scale requires instruments capable of monitoring several cubic kilometers of dense material, as the neutrino flux drops sharply at these energies. This has led to the development of new detection techniques searching for Askaryan radiation —coherent radio pulses produced by neutrino induced particle showers that can propagate over kilometer-scale distances through dielectric media.

The Radio Neutrino Observatory in Greenland (RNO-G) is a particle detector utilizing a sparse array of antennas embedded within the glacier ice. In addition to detecting Askaryan radiation from neutrinos, RNO-G is also sensitive to radio emissions generated by cosmic ray interactions, which present a challenging background to isolate. However, the detection of cosmic rays would mark the first observation of Askaryan radiation in natural ice and serve as validation of the detection technique. This talk will discuss the progress made in identifying cosmic ray signatures within the RNO-G dataset.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / 94

Measurements of electroweak penguin decays at Belle and Belle II

Author: . Renu[None]

Corresponding Author: renu2@andrew.cmu.edu

The Belle and Belle II experiments have collected a 1.1 ab^{-1} sample of $e^+e^- \to B\bar{B}$ collisions at a centre-of-mass energy corresponding to the $\Upsilon(4S)$ resonance. These data, with low particle multiplicity and constrained initial state kinematics, are an ideal environment to search for rare electroweak penguin and radiative B decays. Results include those related to the following decays: $b \to s^+\nu\bar{\nu}$; $B \to K^{(*)}\tau^+\tau^-$; and $B^0 \to K^0_S\tau^+\ell^-$, where ℓ is an electron or muon.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / 95

Latest New Physics Searches using Top Quarks at ATLAS

Author: Rongqian Qian[1]

[1] *Michigan State University (US)*

Corresponding Author: qianron1@msu.edu

As the heaviest known fundamental particle, the top quark plays a pivotal role in the search for new physics. Many beyond-the-Standard-Model theories predict interactions between the top quark and yet undiscovered particles. With the LHC becoming a top quark factory, it offers unprecedented opportunities to study top quark properties and explore potential signs of new physics. In this talk, the latest ATLAS results from searches for new physics with top quarks will be highlighted.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Neutrino / 96

Enhancing Solar Neutrino Sensitivity with Neutron Tagging

Author: Obada Nairat[1]

Co-authors: John Beacom ; Shirley Li [2]

[1] *The Ohio State University*

[2] *UC Irvine*

Corresponding Author: nairat.2@osu.edu

Solar neutrinos provide crucial insights into the Sun's fusion processes and neutrino oscillations in matter. However, detecting them requires effective suppression of backgrounds. One of these is spallation backgrounds—beta decays of unstable isotopes produced by cosmic-ray muons—which pose a major challenge above 6 MeV. We show that neutron tagging, made possible by the recent addition of dissolved gadolinium, provides a powerful new method to identify and reject these backgrounds. This technique is particularly relevant for future shallower detectors like Hyper-Kamiokande and JUNO.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Astro-particle / 97

Blue Loops, Cepheids, and Forays into Axions

Authors: Edward Walsh[1]; Kaleb Anderson[2]; Kuver Sinha[1]; Pearl Sandick[3]; Thomas Gehrman[1]

[1] *University of Oklahoma*

[2] *Brown University*

[3] *University of Utah*

Corresponding Author: thomas.gehrman@ou.edu

I will discuss the blue loop stage of intermediate mass stars as a type of "magnifying glass", where even seemingly small effects in prior stages of evolution, as well as assumptions about stellar composition, rotation, and convection, produce discernible changes. As such, blue loops, and especially the existence and properties of Cepheids, can serve as a laboratory where feebly connected Beyond Standard Model particles such as axions can be gainfully studied. Our simulations, performed with \texttt{MESA}, place bounds on the axion-photon coupling using the galactic Cepheid S Mus, with dynamically-determined mass of $6M_\odot$, as a benchmark. Less conservative (but more stringent) bounds on the axion-photon coupling are given for a $9M_\odot$ model, which is the heaviest that can

be simulated if overshoot is incorporated, and tentative projections are given for a $12M_\odot$ model, which is approximately the heaviest tail of the mass distribution of galactic Cepheids determined by pulsation models using Gaia DR2. The main message is that the reliable simulation and observation (ideally, through dynamical mass determination) of massive Cepheids constitutes an important frontier in axion searches.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Cosmology / 98

Growth Through Stasis: The Evolution of Matter Perturbations During a Stasis Epoch

Author: Brooks Thomas[1]

Co-authors: Keith R. Dienes [2]; Lucien Heurtier [3]; Daniel Hoover [1]; Fei Huang [4]; Anna Paulsen [5]

[1] *Lafayette College*

[2] *University of Arizona*

[3] *King's College London*

[4] *Weizmann Institute*

[5] *Brown University*

Corresponding Author: thomasbd@lafayette.edu

Cosmological stasis is a phenomenon wherein the abundances of multiple cosmological energy components with different equations of state remain constant for an extended period despite the expansion of the universe. This stasis phenomenon can give rise to cosmological epochs in which the effective equation-of-state parameter $\langle w \rangle$ for the universe is constant, but differs from the canonical values associated with matter, radiation, vacuum energy, *etc.* Indeed, during such a stasis epoch, the spatial average of the energy density of the universe evolves in precisely the same manner as it would have evolved if the universe were instead dominated by a perfect fluid with an equation-of-state parameter equal to $\langle w \rangle$. In this talk, however, I demonstrate that this equivalence is broken at the perturbation level. As an example, I show that the density perturbations associated with a spectator matter component with an exceedingly small energy density exhibit power-law growth during an epoch of matter/radiation stasis. This growth can potentially lead to significant enhancements of structure at small scales. Such enhancements are not only interesting in their own right, but may also provide a way of observationally distinguishing between a stasis epoch and an epoch of perfect-fluid domination.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Neutrino / 99

Tau Tridents at Accelerator Neutrino Facilities

Author: Diego Lopez Gutierrez[1]

Co-authors: Bhupal Dev [2]; Innes Bigaran [3]; Pedro Machado [4]

[1] *Washington University in St Louis*

[2] *Washington University in St. Louis*

[3] *Fermilab and Northwestern University*

[4] *Fermilab*

Corresponding Author: d.lopezgutierrez@wustl.edu

We present the first detailed study of Standard Model neutrino tridents involving tau leptons at the near detectors of accelerator neutrino facilities. These processes were previously thought to be negligible, even at future facilities like DUNE. However, our full $2 \to 4$ calculation, including both coherent and incoherent scatterings, reveals that
the DUNE near detector will actually get a non-negligible number of tau tridents, which is an important background to new physics searches. We identify promising kinematic features that may allow distinction of tau tridents from the usual neutrino charged-current background at DUNE, and thus could establish the observation of tau tridents for the first time. We also comment on the detection prospects at other accelerator and collider neutrino experiments.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Machine Learning / 100

Learning the energy dependence and source brightness distribution of the Galactic Center Excess

Authors: Eve Schoen[1]; Florian List[2]; Florian Wolf[3]; Nicholas Rodd[None]; Yujin Park[None]

[1] *UC Berkeley*

[2] *The University of Sydney*

[3] *University of Vienna*

Corresponding Author: eve_schoen@berkeley.edu

An excess of gamma rays from the Galactic center is observed by the *Fermi* Space Telescope. The two leading hypotheses for the cause of this excess are millisecond pulsars or dark matter. Generically, we expect the statistics of these two sources to differ. We train a graph convolutional neural network (NN) to accurately determine the relative flux contribution of point sources to the Galactic center excess (GCE), training the model on the energy dependent data for the first time. The NN method allows us to avoid biases that have been attributed to existing likelihood based techniques and we show training on energy dependent data predicts sources that are indistinguishable from Poisson emission. We determine that we cannot rule out any of the flux of the GCE as Poisson-like and we need at least order $O(100{,}000)$ point sources to explain the observed excess.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / 101

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

Author: Wasikul Islam[1]

Co-author: ATLAS Collaboration of CERN

[1] *University of Wisconsin-Madison (US)*

Corresponding Author: wasikul.islam@cern.ch

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

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / **102**

Decoding SBN Anomalies with Dark Matter and Neutrinos

Authors: Adrian Thompson[None]; Aparajitha Karthikeyan[1]; Bhaskar Dutta[None]; Doojin Kim[None]; Richard Van de Water[2]

[1] *Department of Physics and Astronomy, Texas A&M University*

[2] *Los Alamos National Laboratory*

Corresponding Author: aparajitha_96@tamu.edu

We propose new solutions to accommodate both the MiniBooNE electron-like and MicroBooNE photon low-energy excesses, based on interactions involving light dark matter and/or neutrinos. The novelty lies in the utilization of a photon arising from 2-to-3 scattering processes between a nucleus/nucleon and a neutrino and/or dark matter ($\nu/\chi + N \to \nu/\chi + N + \gamma$) via exchanges of light mediators. We find that viable regions exist in the coupling and mass parameter space of the mediators and light dark matter that can simultaneously explain the observed excesses and remain consistent with current experimental constraints. We also highlight that these scenarios can be probed with upcoming data from various ongoing experiments.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / **103**

Effect of Axion Dark Matter on g-2 of the Electron

Authors: Jason Evans[1]; Junyuan Lyu[2]

[1] *Shanghai Jiaotong University/TDLI*

[2] *Tsung-Dao Lee Institute*

Corresponding Author: lvjunyuan@sjtu.edu.cn

If dark matter is ultralight, the number density of dark matter is very high and the techniques of zero-temperature field theory are no longer valid. The dark matter number density modifies the

vacuum giving it a non-negligible particle occupation number. For fermionic dark matter, this occupation number can be no larger than one. However, in the case of bosons the occupation number is unbounded. If there is a large occupation number, the Bose enhancement needs to be taken into consideration for any process involving particles which interact with the dark matter. Because the occupation number scales inversely with the dark matter mass, this effect is most prominent for ultralight dark matter. If we consider axion-like particles, the corrections to the electron anomalous magnetic moment from the Bose enhancement effect would provide new constraints on the axion electron and axion photon couplings.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Neutrino / **104**

From the Mediterranean to Antarctica, via New Physics?

Authors: Dibya S. Chattopadhyay[1]; Vedran Brdar[1]

[1] *Oklahoma State University*

Corresponding Author: dibya.chattopadhyay@okstate.edu

The KM3NeT collaboration recently reported the observation of KM3-230213A, a neutrino event with an energy of 220 PeV, nearly an order of magnitude more energetic than the highest-energy neutrino in IceCube's catalog. Despite its larger effective area and longer data-taking period, IceCube has not observed similar events, leading to a tension quantified between ˜2σ and 3.5σ, depending on the type of neutrino source.

The 220 PeV neutrino detected at KM3NeT has traversed approximately 147 km through rock and sea, whereas neutrinos from the same location in the sky would cross only about 14 km of ice to reach IceCube. In this talk, I will show how differences in propagation distance can help resolve this tension. Specifically, I will present a scenario where the source emits sterile neutrinos that partially convert to active neutrinos via oscillations. I will present two such mechanisms: one where a new physics matter potential induces a resonance in sterile-to-active transitions, and another involving off-diagonal neutrino non-standard interactions. In both cases, oscillations over ˜100 km enhance the active neutrino flux at KM3NeT with respect to the flux at IceCube. Overall, we propose the exciting possibility that neutrino telescopes have already started detecting signatures of physics beyond the Standard Model.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / **105**

ATLAS results on top quark mass and properties

Author: Haruka Asada[1]

[1] *Nagoya University (JP)*

Corresponding Author: haruka.asada@cern.ch

The top-quark mass is one of the key fundamental parameters of the Standard Model that must be determined experimentally. Its value has an important effect on many precision measurements and

tests of the Standard Model. The Tevatron and LHC experiments have developed an extensive program to determine the top quark mass using a variety of methods. In this contribution, the top quark mass measurements by the ATLAS experiment are reviewed. These include measurements in two broad categories, the direct measurements, where the mass is determined from a comparison with Monte Carlo templates, and determinations that compare differential cross-section measurements to first-principle calculations. In addition, new ATLAS results on top-quark properties are shown. This includes the first observation of quantum entanglement in top-quark pair events and tests of lepton-flavour universality.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / 106

New Constraints of ALPs from EDM of Leptons and Nucleons with Background

Author: Nan Li[1]

Co-author: Junyuan Lyu [1]

[1] *Tsung-Dao Lee Institute*

Corresponding Author: nanli2000cn@sjtu.edu.cn

We consider new contributions of lepton and nucleon EDM, which are
given by background effects of ultralight bosons. We calculate EDM contributions up to two loop diagram for CP-violating ALPs interactions with photon, lepton and nucleon. These new contributions will give new constraints on couplings, and constraints would be stronger if ALP mass is smaller than 10^{-11} eV.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Machine Learning / 107

Frequentist Uncertainties on Neural Density Ratios with wifi Ensembles

Author: Sean Benevedes[1]

[1] *Massachusetts Institute of Technology*

Corresponding Author: seanbenevedes@gmail.com

We propose $w_i f_i$ ensembles, a novel framework to obtain asymptotic frequentist uncertainties on density ratios in the context of neural ratio estimation. In the case where the density ratio of interest is a likelihood ratio conditioned on parameters, for example a likelihood ratio of collider events conditioned on parameters of nature, it can be used to perform simulation-based inference on those parameters. We show how uncertainties on a density ratio can be estimated with $w_i f_i$ ensembles and propagated to determine the resultant uncertainty on the estimated parameters. We then turn to an application in quantum chromodynamics (QCD), using $w_i f_i$ ensembles to estimate the likelihood ratio between generated quark and gluon jets. We use this learned likelihood ratio to estimate the

quark fraction in a mixed quark/gluon sample, showing that the resultant uncertainties empirically satisfy the desired coverage properties.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Flavor / 108

Anomalies in Hadronic B decays: an Update

Authors: Alexandre Jean[1]; Bhubanjyoti Bhattacharya[2]; Christopher MacKenzie[2]; David London[3]; Luke Hudy[2]; Marianne Bouchard[None]

[1] *Université de Montréal*

[2] *Lawrence Technological University*

[3] *Montreal university*

Corresponding Author: marianne.bouchard.5@umontreal.ca

The decays B->PP, where the pseudoscalar P is a pi or K, have been studied under the assumption of flavor SU(3) symmetry. The global fit reveals a 3.6 sigma discrepancy with the Standard Model. Separate fits for Delta S = 0 and Delta S = 1 decays find parameter sets that differ by a factor of 10, indicating a flavor SU(3) breaking of 1000%, significantly larger than the 20% breaking expected in the Standard Model.
An extended study is being conducted, including final states with eta and eta' mesons. The resulting global fit, once again under the assumption of flavor SU(3) symmetry, is worse, with a 4.1 sigma deviation from the Standard Model. When theoretical constraints |C/T| = 0.2 or A = 0 are imposed, the fits worsen, with the discrepancy approaching 5 sigma.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / 109

On Gauge Theories of Neutrino Masses and Dark Matter

Authors: Hridoy Debnath[None]; Pavel Fileviez Perez[1]

[1] *Case Western Reserve University*

Corresponding Author: hridoy.debnath@case.edu

We discuss the predictions in the simplest theory for neutrino masses based on the spontaneous breaking of local lepton number. This theory provides a simple theoretical framework to understand the possible relation between the origin of neutrino masses and the nature of the dark matter. In this theory, one of the fields needed for anomaly cancellation is a dark matter candidate and the local lepton number is broken at the low scale. We discuss in great detail the dark matter properties showing the allowed parameter space by the relic density bounds and the predictions for direct detection.
The predictions for gamma and neutrino lines from dark matter annihilation are investigated. In the case of Dirac neutrinos, the bound on the effective number of relativistic degrees of freedom plays an important role and the predictions for gamma lines could be tested in the near future. We

discuss the predictions in the case of Majorana neutrinos where the dark matter candidate has extra annihilation channels and compare all the predictions to the case with Dirac neutrinos.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Cosmology / 110

Alleviating the Hubble Tension Through Black Hole Superradiance

Authors: Bhaskar Dutta[None]; Iain Bisset[1]; James Dent[2]; Tao Xu[3]

[1] *Texas A&M University*

[2] *Sam Houston State University*

[3] *The University of Oklahoma*

Corresponding Author: ibisset@tamu.edu

The long-standing discrepancy between late and early-time measurements of the Hubble parameter has given rise to a tension that has been resistant to a satisfactory theoretical explanation, even as the statistical tension has grown to about 4-6σ. In this work, we present a novel idea designed to alleviate this tension. Taking dark matter to consist of a population of primordial black holes of asteroid mass or greater with high initial spin, the process of superradiance can facilitate conversion of the black holes' angular momentum into relativistic particles that escape the black holes' influence. We demonstrate that this process leads to a unique effect on cosmological evolution that can modify the present day value of the Hubble parameter.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

111

Sensitivity of the IceCube Neutrino Observatory to Primordial Black Hole Evaporation

Authors: Bhaskar Dutta[1]; Iain Bisset[1]; James B. Dent[2]; Masoom Singh[1]

[1] *Texas A&M University*

[2] *Sam Houston State University*

Corresponding Author: masoom.ruchi@gmail.com

Primordial black holes remain compelling candidates for dark matter and could produce detectable high-energy neutrino fluxes through Hawking radiation. We extend beyond previous analytical frameworks by implementing a comprehensive examination of various black hole mass distribution models and their corresponding neutrino emission characteristics. Through detailed simulations of detector response, we derive projected exclusion contours in both the mass-abundance $(M - f_{\mathrm{PBH}})$ parameter space using IceCube and project future discovery potential for the IceCube-Gen2 configuration. Additionally, we map these constraints onto the neutrino flavor triangle, providing insight into how flavor composition measurements can further constrain PBH properties. Our multi-dimensional approach demonstrates improved constraints compared to previous analyses, potentially advancing our understanding of these primordial relics and their neutrino signatures.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / 112

A general mass variable flavor number scheme for Z boson production in association with a heavy quark at hadron colliders

Author: Keping Xie[1]

[1] *Michigan State University*

Corresponding Author: xiekepi1@msu.edu

We present a methodology to streamline implementation of massive-quark radiative contributions in calculations with a variable number of active partons in proton-proton collisions. The methodology introduces subtraction and residual heavy-quark parton distribution functions (PDFs) to implement calculations in the Aivazis-Collins-Olness-Tung (ACOT) factorization scheme and its simplified realization in various processes up to the next-to-the-next-to-leading order in the QCD coupling strength. Interpolation tables for bottom-quark subtraction and residual distributions for CT18 NLO and NNLO PDF ensembles are provided in the common LHAPDF6 format. A numerical calculation of Z-boson production with at least one b jet at the Large Hadron Collider beyond the lowest order in QCD is considered for illustration purposes.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Flavor / 113

Spin and symmetry properties of all-charm tetraquarks

Author: Zhiyuan Huang[1]

[1] *Johns Hopkins University (US)*

Corresponding Author: zhiyuan.huang@cern.ch

The traditional quark model accounts for the existence of baryons, like protons and neutrons, which consist of three quarks, as well as mesons, composed of a quark and antiquark pair. Only recently has substantial evidence started to accumulate for exotic states composed of four or five quarks or antiquarks. In this study, the CMS Collaboration investigates the recently discovered family of three tetraquark candidates composed of four charm quarks and antiquarks. The exact nature of their internal structure remains uncertain. They could either be tightly bound states of true tetraquarks, similar to quarks bound within protons and neutrons, or molecules composed of two familiar mesons, loosely bound like protons and neutrons in a nucleus, with other potential configurations still being considered. Angular analysis techniques for decay products, developed for the discovery and characterization of the Higgs boson, are now being applied to the new exotic states. The quantum numbers for parity P and charge conjugation C symmetries are found to be +1. The spin J of these exotic states is most consistent with J = 2h, a value that is uncommon for such particles, while the J = 0h and 1h are excluded at 95% and 99% confidence level, respectively. The J^PC = 2++ quantum numbers match the expected values for tetraquarks with specific configurations of spin and angular momenta of its components, which helps in narrowing down the tetraquark's internal structure.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / 114

Probing light gauge bosons using the muon (g-2)

Author: Kushan Panchal[1]

[1] *University of Maryland, College park*

Corresponding Author: kushu23@umd.edu

The anomalous magnetic moment of the muon, i.e. $(g-2)$, is one of the versatile and promising probes of new physics at the GeV scale, particularly for Z' gauge bosons that couple to both leptons and quarks. Due to inputs from experiments, lattice QCD as well as theory collaborations, one can constrain such BSM theories using various combinations of these inputs. Based on this idea, in this talk, I will introduce two tests related to the $(g-2)$, and the Hadronic Vacuum Polarisation (HVP) contribution to $(g-2)$, which provide two independent ways to constrain new physics. I will highlight some of the key field theoretic aspects of the tests, along with the differences in the $(g-2)$ and HVP numbers from experiment, lattice and data-driven calculations, and their impact on these tests. I will then demonstrate their utility by applying them to two simple BSM extensions: the Dark Photon and the Baryon Number Gauge Boson. These tests could be used in a way akin to existing collider bounds (such as those from LHCb, BaBar etc)

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

New Ideas in Baryogenesis, Inflation / 115

Real-time simulation of CP violation in electroweak baryogenesis

Authors: Tong Ou[None]; Marcela Carena[1]; Ying-Ying Li[2]; Hersh Singh[3]

[1] *Perimeter Institute for Theoretical Physics*

[2] *Institute of High Energy Physics, Beijing*

[3] *Fermilab*

Corresponding Author: tongou@uchicago.edu

Baryogenesis is a dynamical out-of-equilibrium process generating the baryon asymmetry of the Universe. Focusing on the mechanism of electroweak baryogenesis, where baryon number is generated through CP-violating scattering of the fermions with the bubble wall during a first-order electroweak phase transition, perturbative calculations for the relevant processes are known to suffer from various issues, motivating the development of lattice calculations. However, conventional lattice calculations based on Euclidean formulation in the imaginary time domain are limited to equilibrium dynamics. Real-time simulation is necessary for proper understanding of the out-of-equilibrium dynamics of baryogenesis. In our work, we focus on the fermion scattering process during electroweak baryogenesis, and develop a real-time simulation framework by mapping the fermions onto a spin system. Using tensor network methods, we perform numerical simulations

and systematically analyze lattice artifacts. Our studies take a first step towards real-time simulation of baryogenesis, and are expected to shed light on real-time non-perturbative calculations of general out-of-equilibrium processes in the early Universe.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Neutrino / **116**

Probing New Physics from Neutrino Interactions at MeV and GeV

Author: Sam Carey[1]

[1] *Wayne State University*

Corresponding Author: samcarey@wayne.edu

As neutrino experiments become more precise and explore a wide range of energies, studying how neutrinos interact with matter has become an important way to test the Standard Model and search for new physics. In this talk, I will present our work on neutrino interactions at both low (MeV) and high (GeV) energy scales. At low energies, we consider coherent elastic neutrino–nucleus scattering (CEνNS) at current and upcoming neutrino facilities. CEνNS allows to extract key Standard Model parameters like the weak mixing angle and to explore possible new physics effects such as non-standard neutrino interactions (NSI), neutrino magnetic moment, and charge radius. At energies relevant for DUNE, neutrinos interacting with nuclei or electrons can have enhanced couplings to photons if light scalar mediators are present, resulting in a potentially measurable neutrino polarizability. We identify two possible experimental signatures of such coupling—one or two separated electromagnetic showers with no associated hadronic activity—and show the projected sensitivity for the DUNE Near Detector.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / **117**

BEC vortices as an observational signature of Ultra-light bosonic dark matter

Authors: Man Hei Leung[1]; Ming Chung Chu[2]; RongZi Zhou[3]; Sheung Chi Poon[3]

[1] *The Ohio State University*

[2] *The Chinese University of Hong Kong (HK)*

[3] *The Chinese University of Hong Kong*

Corresponding Author: leung.253@osu.edu

Ultra-light bosonic dark matter (ULDM) is an interesting dark matter candidate. While the wave-like nature of ULDM has been widely studied in the literature, we explore another distinctive feature of ULDM as Bose-Einstein Condensate (BEC) in this paper: the emergence of vortices in rotating

BEC-ULDM halos. Using numerical solution of the GPP equation, we demonstrate that a vortex lattice would form naturally in such systems given the Milky Way-like parameters. Furthermore, we study the gravitational lensing by these vortices as a possible observational signature of BEC-ULDM.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

New Physics at Future Colliders / 118

Accidental Suppression of Wilson Coefficients in Higgs Coupling

Authors: Chi Shu[1]; Jiayin Gu[2]; Liantao Wang[None]; Yunjia Bao[1]; Zhen Liu[None]

[1] *University of Chicago*

[2] *Fudan University*

Corresponding Author: yunjia.bao@uchicago.edu

Higgs couplings are essential probes for physics beyond the Standard Model (BSM) since they can be modified by new physics, such as through the Higgs portal interaction $|H|^2\mathcal{O}$. These modifications influence Higgs interactions via dimension-6 operators of the form $\left(\partial|H|^2\right)^2$ and $|H|^6$, which are generally expected to be of comparable size. This talk discusses a phenomenon of accidental suppression, where the $|H|^6$ coupling is significantly smaller than $\left(\partial|H|^2\right)^2$. This suppression, arising from the truncation of the tree-level effective potential, lacks a clear symmetry explanation but persists in portal models. This talk aims to inspire further studies on additional instances of accidental suppression without symmetry explanations or a general framework to characterize such suppression. We also discuss constraints, at the HL-LHC and future colliders, on the Wilson coefficients of the two dimension-6 operators for various benchmark scenarios of the concrete model.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / 119

Opening up New Parameter Space for Sterile Neutrino Dark Matter

Authors: Aaroodd UR[None]; Bhupal Dev[1]; Bhaskar Dutta[None]; Srubabati Goswami[2]; Jianrong Tang[1]

[1] *Washington University in St. Louis*

[2] *Physical Research Laboraotory*

Corresponding Author: aaroodd@wustl.edu

Sterile neutrinos are compelling dark matter candidates, yet the minimal Dodelson-Widrow (DW) production mechanism is excluded by astrophysical observations. We propose a scenario where heavy scalar-mediated non-standard interactions (NSI) between active and sterile neutrinos not only alter the DW mechanism but also generate new production channels, such as $\nu_a\nu_a \to \nu_s\nu_s$. This framework enables efficient sterile neutrino production at smaller mixing angles and opens new viable regions of parameter space.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

New Ideas in Baryogenesis, Inflation / 120

Warm Inflation with Pseudo-scalar Couplings

Authors: Anson Hook[1]; Edward Broadberry[2]; Sagnik Mondal[3]

[1] *University of Maryland*

[2] *University of Maryland, College Park*

[3] *Maryland Center for Fundamental Physics, Department of Physics, University of Maryland, College Park, MD 20742, U.S.A.*

Corresponding Author: sagnik@umd.edu

Inflaton couplings during warm inflation result in the production of a thermal bath. Thermal friction and fluctuations can dominate the standard de Sitter analogues, resulting in a modified slow-roll scenario with a new source of density fluctuations. Due to issues with back-reaction, it is advantageous to consider inflaton couplings with the thermal bath that are pseudo-scalar in nature, e.g., derivative interactions or topological $F\tilde{F}$ couplings. We demonstrate in the context of a perturbative toy model that the model-dependent chemical potentials modify the fluctuation-dissipation theorem, making the relationship between the thermal friction and thermal fluctuations model-dependent. In extreme cases, these chemical potentials can cause the friction term to vanish while thermal fluctuations remain non-zero. We demonstrate how to calculate the chemical potentials, thermal friction, and thermal fluctuations using both the Boltzmann equations and by calculating thermal expectation values, showing explicitly that the two approaches give the same result.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Flavor / 121

Exploring Low-Scale Quark-Lepton Unification

Authors: Kaladi S. Babu[1]; Shaikh Saad[2]; Sumit Biswas[1]

[1] *Oklahoma State University*

[2] *Stefan Inst., Ljubljana*

Corresponding Author: sumit.biswas@okstate.edu

We propose an E_6 inspired Pati-Salam (PS) model that naturally accommodates multi-TeV leptoquark gauge bosons, X, with a softly broken discrete Z_2 symmetry. Standard Model (SM) fermions are Z_2-even in this framework, whereas exotic fermions are Z_2-odd. An interesting feature of the model is that the PS gauge bosons are Z_2-odd, enabling them to couple exclusively between ordinary and exotic fermions, except in the down-type sector, where mixing arises due to the soft breaking of Z_2. This structure leads to helicity suppression of meson decays at the tree level, with unsuppressed contributions appearing only at the one-loop level, which allows a lower PS breaking scale. Such a scale offers exciting collider prospects, particularly for probing leptoquark gauge bosons, as well as the distinctive signature of a vector-like down-type quark carrying a fractional baryon number of -$\frac{2}{3}$.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Neutrino / 122

Probing Quantumness at Long Baseline Neutrino Experiments

Authors: Murshed Alam[1]; Vedran Brdar[1]; Dibya S. Chattopadhyay[1]

[1] *Oklahoma State University*

Corresponding Author: murshed.alam@okstate.edu

The Leggett-Garg Inequality (LGI) offers a way to test for the violations of classicality in a system by studying how its measurements are correlated over time. Long-baseline neutrino oscillation experiments provide some of the longest distances over which the quantum behavior of any system can be tested. In my talk, I will present comprehensive results on LGI in connection to 3 existing experiments (MINOS, NOvA, T2K) and I will also discuss projections for DUNE. I will also present the results for the recently proposed quantum mismatch measure and compare against the corresponding results from the Leggett-Garg measure. Our results highlight the importance of a careful, systematic approach to testing quantum behavior in both current and future long-baseline experiments.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Flavor / 123

Baryon number violation through derivative operators

Authors: Diana Sokhashvili[None]; Julian Heeck[None]

Corresponding Author: bkq5jz@virginia.edu

Baryon number violation is our most sensitive probe of physics beyond the Standard Model, conveniently encoded in higher-dimensional effective operators. Operators involving derivatives are usually ignored in phenomenological analyses since they are generically suppressed compared to non-derivative operators. We will study exceptions to this statement and explore scenarios in which derivative operators are important. Along the way, we also show how derivative operators arise in UV-complete models.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Cosmology / 124

Cosmological constraints on majoron dark matter in vanilla leptogenesis

Author: Swapnil Dutta[None]

Co-authors: Akshay Ghalsasi [1]; Arnab Dasgupta [2]; Brian Thomas Batell

[1] *Harvard University*

[2] *PITT-PACC*

Corresponding Author: swd20@pitt.edu

In this talk, we look at some cosmological constraints on majoron dark matter in the singlet Majoron model. We consider two scenarios: pre-inflationary and post inflationary spontaneous lepton number symmetry breaking, while simultaneously demanding thermal leptogenesis to happen, and neutrino masses being generated by the type I seesaw mechanism. We derive the constraints and future prospects to probe majoron dark matter over a broad mass range.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Neutrino / **125**

Probing dark matter –neutrino interaction from the double beta decay at PandaX

Authors: Michael Ramsey-Musolf[None]; PandaX collaboration[1]; Van Que Tran[2]; Yihong Zhong[3]

[1] *TDLI - SJTU*

[2] *NCTS, National Taiwan University*

[3] *Shanghai Jiao Tong University*

Corresponding Author: yihong-z@sjtu.edu.cn

The neutrinoless double beta decay experiments not only give great prospects for us to understand the nature of neutrinos, but also a efficient way to test the dark matter –neutrino interactions. We analyze the double beta decay data at PandaX to probe the dark matter –neutrino interaction. We compute the nuclear matrix element with the presence of this new interaction. We found that the nuclear matrix element for double beta decay with massive dark matter emission differs significantly from the standard one. The latest data from PandaX put a stringent bound on the parameter space of the light mediator scenario at the mediator mass around 1 MeV.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Plenary / **126**

Welcome

Corresponding Author: zentner@pitt.edu

Plenary / 127

APS and Physical Review Journals

Corresponding Author: jsayre@aps.org

Flavor / 128

Proton decay into light new particles

Author: Julian Heeck[None]

Corresponding Author: heeck@virginia.edu

Light new particles could be emitted in nucleon decays if they have baryon-number-violating couplings. Even though they usually leave the detector as missing energy, interesting signatures can arise in such decays in underground detectors such as Super-Kamiokande and DUNE. In the particularly simple case of light sterile neutrinos, nucleon decays can even be an efficient production mechanism that leads to characteristic displaced decay signatures.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Cosmology / 129

Dark matter, gravitational waves, and primordial black holes from domain-wall annihilation

Authors: Graciela Beatriz Gelmini[1]; Jonah Hyman[2]; ZACHARY PICKER[None]

[1] *University of California Los Angeles (US)*

[2] *University of California, Los Angeles*

Corresponding Author: jthyman@ucla.edu

The symmetry breaking of a scalar particle (axion-like particle) in the early Universe produces a rich cosmology. In this cosmology, different patches of the Universe with different energies are separated by a network of domain walls. When the Universe cools, the domain walls annihilate as the lowest-energy patches become dominant. The annihilation process ("catastrogenesis") produces axion-like particles, gravitational waves, and possibly primordial black holes. Depending on the properties of the model, the axion-like particles or primordial black holes could constitute the dark matter, and the gravitational waves could be visible in present or future detectors. (Based on arXiv:2303.14107, arXiv: 2307.07665, and forthcoming work.)

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Flavor / 130

The Quark-Lepton Portal

Author: Katherine Schwind[1]

[1] *The Ohio State University*

Corresponding Author: schwind.44@osu.edu

Light exotics effective field theory (LEX-EFT) focuses on the idea that there may be light BSM particles that are so far undiscovered. This talk will focus on a specific portal to new physics, the quark-lepton portal. This portal encompasses all possible interactions, up to dimension six, that a quark, lepton, and LEX field (with or without additional SM fields) can have. Within this portal, we can access fields with unusual combinations of baryon and lepton number, along with particles with a wide array of SU(3) and SU(2) charges. The implications of this are large, as there have been very few in-depth studies done on fields with higher representations under these gauge groups. Many of these particles would create very unusual signatures, and the implications of these signatures at both current and future colliders will be discussed.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Astro-particle / 131

Too Fast Less Furious: Three-Body Interaction with Fast Low-Mass PBHs

Authors: Badal Bhalla[1]; Benjamin Lehmann[2]; Kuver Sinha[1]; Tao Xu[3]

[1] *University of Oklahoma*

[2] *Massachusetts Institute of Technology*

[3] *The University of Oklahoma*

Corresponding Author: badalbhalla@ou.edu

Stellar binaries have historically provided a rich target in the search for exotic compact objects such as primordial black holes (PBHs) or MACHOs. In a three-body interaction involving a PBH and a binary star system, the binary can either lose or gain a significant amount of energy from the PBH, leading to a change in its orbital period. A standard lore has been that if the perturber velocity is large compared to the orbital velocity of the binary components, as is typical for PBHs, the perturbation only produces a small shift in the binary energy, and hence is undetectable. We point out that the standard lore is only true if the number of perturber interactions with the binary is statistically large. If the number of perturber interactions is small, the net effect is more akin to shot noise. We apply our formalism to PBHs producing perturbations in the binding energy of binary pulsar systems, which provides the most optimistic scenario to capture shot noise, given the extraordinary precision of binary pulsar timing.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Cosmology / 132

Nambu-Goldstone boson phenomenology in Domain-Wall Standard Model

Author: PUJA DAS[None]

Corresponding Author: pdas1@crimson.ua.edu

We discuss the Domain-Wall Standard Model formulated in five-dimensional spacetime. In this framework, all Standard Model (SM) particles are localized within a finite region (domain) along a non-compact extra spatial dimension. This scenario predicts the existence of a Nambu-Goldstone (NG) boson associated with the spontaneous violation of translational invariance in the extra dimension. The NG boson couples to the SM fermions (zero modes) as well as their Kaluza-Klein excitations. We explore the phenomenology of this NG boson and derive constraints from LHC experiments, stellar cooling, and Big Bang Nucleosynthesis.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / 133

Quantum Information Observables at Lepton Colliders

Authors: Yu-Chen Guo[1]; Tao Han[2]; Matthew Low[2]; Youle Su[3]

[1] *Liaoning Normal University & PITT PACC*

[2] *University of Pittsburgh*

[3] *Fudan University*

Corresponding Author: ycguo@lnnu.edu.cn

The interpretation of multi-particle spin systems produced at colliders as quantum states has shown the potential to obtain quantum information at colliders. For instance, top quark or lepton pairs produced at colliders exhibit correlated spin states. Fermion pair production at lepton colliders presents an ideal source for comprehensive quantum tomography of the production process, enabling high-precision measurements of quantum entanglement and Bell nonlocality. In this presentation, I will introduce our recent work concerning the measurement of quantum information observables in the τ+τ−,μ+μ−,and ttbar systems at future lepton colliders.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Astro-particle / 134

Supermassive black hole formation in the initial collapse of axion dark matter

Authors: Pierre Sikivie[None]; Yuxin Zhao[None]

Corresponding Author: yuxinzhao@ufl.edu

How the supermassive black holes form has been an enduring puzzle. Recent discoveries of active galactic nuclei near cosmic dawn by James Webb Space Telescope suggests that SMBHs may have formed as early as z 10. We propose a mechanism that SMBHs form naturally near the cosmic dawn if the dark matter is axion or ALPs. Axion dark matter thermalizes by gravitational self-interactions and forms a Bose-Einstein condensate. We show that the rethermalization of the axion fluid during the initial collapse of large scale overdensities near cosmic dawn transports angular momentum outward sufficientlly fast that black holes form with masses ranging from approximately 10^5 to $10^{10} M_\odot$.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / 135

Probing neutral Higgs Boson with all-top and same-sign top final states at LHC

Authors: Chenyu Fang[None]; Chung Kao[None]; Phillip Gutierrez[1]

[1] *University of Oklahoma (US)*

Corresponding Author: chenyu.fang@ou.edu

A general two Higgs doublet model is adopted to study flavor changing neutral Higgs (FCNH) interactions in $pp \to t\phi \to t(tc)$ at the Large Hadron Collider, where ϕ is either the CP-even Higgs scalar (H) or the CP-odd Higgs pseudoscalar (A). We considered two final states, (i) single lepton: $ttc \to bjjcb\ell\nu$, and (ii) same sign di-lepton: $ttc \to bbc\ell\ell\nu\nu$ where $\ell = e$ or μ and $\nu =$ neutrino, and t represents either a top quark or an anti-top quark. We evaluated the cross sections for the FCNH signal and for the dominant physics backgrounds. Realistic acceptance cuts are applied to investigate the discovery potential. In addition, we have applied b tagging and c tagging at the event level using the ATLAS and CMS tagging and mis-tagging efficiencies. Promising results have been obtained for the single lepton top quark final states to reconstruct the Higgs mass. Furthermore, we employ the Higgs mass from the single lepton analysis to develop selection criteria for the same sign di-lepton final state, which is almost background free. Since the discovered light Higgs scalar behaves like the standard model Higgs boson, we expect $H \to tc$ and $A \to tc$ to offer great promise to search for new physics beyond the Standard Model.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / 136

On the sensitivity of nuclear clocks to new physics

Author: Gil Paz[1]

[1] *Wayne State University*

Corresponding Author: gilpaz@wayne.edu

The recent demonstration of laser excitation of the 8 eV isomeric state of thorium-229 is a significant step towards a nuclear clock. The low excitation energy likely results from a cancellation between the contributions of the electromagnetic and strong forces. Physics beyond the Standard Model could disrupt this cancellation, highlighting nuclear clocks' sensitivity to new physics.

It is challenging to accurately predict the different contributions to nuclear transition energies and therefore of the sensitivity of a nuclear clock to new physics. We improve upon previous sensitivity estimates. First, by revisiting a classical geometric model of thorium-229. Second, by proposing a new d-wave halo model, inspired by effective field theory. For both approaches we show that poor

sensitivity to new physics is unlikely. For the halo model we find that the nuclear clock's sensitivity to variations in the effective fine structure constant is enhanced by a factor of order 10,000.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Flavor / 137

Cabibbo-Kobayashi-Maskawa matrix related measurements at Belle and Belle II

Author: Kimika Arai[1]

[1] *University of Pittsburgh (US)*

Corresponding Author: kia33@pitt.edu

The Belle and Belle˜II experiments have collected a 1.1˜ab^{-1} sample of $e^+e^- \to B\bar{B}$ collisions at a centre-of-mass energy corresponding to the $\Upsilon(4S)$ resonance. These data allow measurements of CP violation and the Cabibbo-Kobayashi-Maskawa matrix elements in B-meson decay. In particular, we measure the CP-violating phase ϕ_1/α and $|V_{cb}|$. In addition, we present constraints on the branching fractions of $B^+ \to \ell^+\nu$ ($\ell = \mu,\ \tau$), which are related to $|V_{ub}|$.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / 138

Dark gauge-mediated supersymmetry breaking

Authors: Brian Thomas Batell[None]; Yechan Kim[1]; Hye-Sung Lee[1]; Jiheon Lee[1]

[1] *KAIST*

Corresponding Author: anffl0101@kaist.ac.kr

We investigate *dark gauge-mediated supersymmetry breaking* with an unbroken $U(1)_D$ symmetry and a massless dark photon. Messengers charged under both Standard Model and dark gauge groups generate new soft SUSY-breaking terms via gauge kinetic mixing. Large mixing significantly alters superpartner spectra compared to standard GMSB, reduces the μ parameter, and predicts a relatively light Higgsino detectable at the LHC. Simple messenger scenarios yield a very light bino-dark photino state observable in exotic Higgs decays at future colliders. The cosmological and phenomenological effects of stable, fractionally charged messenger states are also explored.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Cosmology / 139

Large-Scale Correlated Magnetic Fields from Primordial Seeds

Author: Sayan Mandal[1]

Co-authors: Molly Abramson [1]; Tina Kahniashvili [1]

[1] *Carnegie Mellon University*

Corresponding Author: sayanm@andrew.cmu.edu

The origin of large scale magnetic fields in the Universe is widely thought to be from early Universe processes, like inflation or phase transitions. These magnetic fields evolve via magnetohydrodynamic processes till the epoch of recombination. When structures begin to form in the later Universe, the conservation of magnetic flux amplifies the magnetic fields via the adiabatic collapse of gravitationally bound gas clouds hosting the magnetic fields, and moves them to smaller scales. In this work, we have semi-analytically studied this forward cascade effect, considering simple models of gravitational collapse of structures. We find that this simple model is able to reproduce the general qualitative features of the evolution of the magnetic field spectrum as seen from magnetized cosmological simulations.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / 140

Lattice Simulations of the ZN Axion

Author: Owen Leonard[1]

Co-authors: Raymond Co [1]; Taegyu Lee [1]

[1] *Indiana University*

Corresponding Author: owleonar@iu.edu

Axion-like particles are currently among the most popular dark matter candidates. Considerable theoretical efforts have gone into expanding the parameter window of the quantum chromodynamics (QCD) axion beyond the narrow QCD band. The $Z_\mathcal{N}$ QCD axion model is the only such model which reduces the QCD axion mass naturally. The $Z_\mathcal{N}$ model invokes a discrete $Z_\mathcal{N}$ symmetry through which the axion field is coupled to $\mathcal{N}$ QCD dark sectors, yielding an effective potential with $\mathcal{N}$ degenerate minima. Lattice simulations provide a robust means for gauging the viability of analytical and semi-analytical approximations, and for generating accurate predictions when they are insufficient. Having conducted the first lattice simulations of $Z_\mathcal{N}$ scenarios, we find their phenomenology to be significantly influenced by nonlinear phenomena such as parametric resonance and back-reaction. From these simulations, we present dark matter abundances as well as insights into whether or not $Z_\mathcal{N}$ axions can actually solve the strong CP problem.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Cosmology / 141

Reionization and the Hubble Constant: Correlations in the Cosmic Microwave Background

Authors: Itamar J. Allali[1]; JiJi Fan[1]; Lingfeng Li[1]; Praniti Singh[2]

[1] *Brown University*

[2] *Brown University (US)*

Corresponding Author: praniti_singh@brown.edu

Recently, the James Webb Space Telescope (JWST) has found early galaxies producing photons from more efficient ionization than previously assumed. This may suggest a reionization process with a larger reionization optical depth, τ_{reio}, in some mild disagreement with that inferred from measurements of cosmic microwave background (CMB). Intriguingly, the CMB would prefer larger values of τ_{reio}, more consistent with the recent JWST hint, if the large-scale measurements (i.e. $\ell < 30$) of E-mode polarization are removed. In addition, τ_{reio} has an indirect correlation with today's Hubble constant H_0 in ΛCDM. Motivated by these interesting observations, we investigate and reveal the underlying mechanism for this correlation, using the CMB dataset without the low-ℓ polarization data as a proxy for a potential cosmology with a larger τ_{reio}. We further explore how this correlation may impact the Hubble tension between early and late universe measurements of H_0, in ΛCDM as well as two proposals to alleviate the Hubble tension: the dark radiation (DR) and early dark energy (EDE) models. We find that the Hubble tension gets further reduced mildly for almost all cases due to the larger τ_{reio} and its positive correlation with H_0, with either the Baryon Acoustic Oscillations (BAO) data before those from the Dark Energy
Spectroscopic Instrument (DESI) or the DESI data.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / **142**

Multiboson production in CMS

Author: Kelci Ann Mohrman[1]

[1] *University of Florida (US)*

Corresponding Author: kelci.mohrman@cern.ch

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

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Flavor / **143**

Probing new physics with dedicated data streams at CMS

Author: Ali Eren Simsek[1]

[1] *Catholic University of America (US)*

Corresponding Author: ali.eren.simsek@cern.ch

Signatures of new physics at the LHC are varied and, by nature, often very different from those of Standard Model processes. Novel experimental techniques, including dedicated data streams, are exploited to enhance the sensitivity of the CMS Experiment to search for such signatures. In this talk, we highlight the most recent CMS results, obtained using the data collected at the LHC Run-2 and Run-3 through the so-called "Data Scouting" and "Data Parking" strategies. These approaches have allowed us to set some of the strongest constraints to date for low-mass resonances in both prompt and long-lived signatures.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / **144**

Search for heavy BSM particles coupling to third-generation quarks at CMS

Author: Atanu Pathak[1]

[1] *Purdue University Northwest (US)*

Corresponding Author: atanu.pathak@cern.ch

We present results from searches for resonances with enhanced couplings to third generation quarks, based on proton-proton collision data at a center-of-mass energy of 13 TeV recorded by CMS. The signatures include single and pair production of vector-like quarks and heavy resonances decaying to third-generation quarks. A wide range of final states, from multi-leptonic to entirely hadronic is covered. Jet substructure techniques are employed to identify highly boosted heavy SM particles in their hadronic decay modes.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Neutrino / **145**

Continuum-mediated self-interacting neutrinos

Authors: Kevin Kelly[1]; Mudit Rai[2]; Saeid Foroughi-Abari[3]; Yue Zhang[None]

[1] *Texas A&M University*

[2] *Texas AM University*

[3] *Carleton University*

Corresponding Author: saeidf@physics.carleton.ca

Testing new interactions in the neutrino sector, both in current and upcoming experiments, is essential for uncovering the nature of neutrinos. In many extensions of the Standard Model (SM), active neutrinos may engage in self-interactions via the exchange of a new light particle, often motivated by the need to explain empirical puzzles such as the origin of neutrino mass. Cosmological data also point toward an effective Fermi constant significantly larger than what the SM offers. However, much of the parameter space for sizable neutrino self-interactions mediated by a light neutrinophilic scalar has already been tightly constrained by complementary terrestrial, astrophysical, and cosmological probes. In this talk, I present a novel approach in which neutrino self-interactions are mediated by a field with a continuous spectral density. I show that a gapped unparticle mediator can open up significant regions of parameter space for strong neutrino self-interactions relevant to cosmology, providing a well-motivated target for upcoming experiments. (2501.02049)

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Cosmology / 146

Dynamical Dark Energy, Dual Spacetime, and DESI

Authors: Djordje Minic[1]; Michael Kavic[2]; Sunhaeng Hur[1]; Tatsu Takeuchi[1]; Vishnu Jejjala[3]

[1] *Virginia Tech*

[2] *SUNY Coll., Old Westbury*

[3] *Witwatersrand U.*

Corresponding Author: sunhh@vt.edu

We discuss possible consequences of a manifestly non-commutative and T-duality covariant formulation of string theory on dark energy, when the correspondence between short distance (UV) and long distance (IR) physics is taken into account. We demonstrate that the dark energy is dynamical, time-dependent, and we compute the allowed values of w_{0} and w_{a} given by w(a)=w_{0}+(1-a)w_{a}, which compare favorably to the most recent observations by DESI. From this point of view, the latest results from DESI might point to a fundamentally new understanding of quantum spacetime in the context of quantum gravity.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Cosmology / 147

The One-loop Scalar Chemical Potential at the Cosmological Collider

Authors: Arushi Bodas[None]; Edward Broadberry[1]; Raman Sundrum[None]; Zhaohui Xu[1]

[1] *University of Maryland, College Park*

Corresponding Author: zhxu1226@umd.edu

We study the one-loop model of a pair of charged scalars with chemical potential mechanism in cosmological collider physics. We evaluate the one-loop amplitude analytically using spectral decomposition in de Sitter. Compared to previous analysis, our result predicts the correct power dependence on scalar masses and the chemical potential for both the signal and the background. Using these results, we further demonstrate that a signal strength $f_{\mathrm{NL}} \sim \mathcal{O}(0.01 - 0.1)$ can be obtained in the bispectrum within perturbative regime, which is potentially reachable by the 21 cm tomography.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Flavor / **148**

New Physics from Light Scalars from Rare Kaon Decay

Author: Rahul Pradeep[1]

Co-author: Jure Zupan [1]

[1] *University of Cincinnati*

Corresponding Author: pradeerl@mail.uc.edu

We introduce and investigate the effects of a light scalar interacting with the short-lived kaon and the $K_S \to^{+-}$ decay. We use the results of searches performed at kaon factories as well as the Standard Model predictions for this decay to constrain the couplings of a ϕ particle with a mass m of the order of MeV. We also examine the time evolution of the kaon beams with the full mixing considered and the effect of its lifetime on extractable experimental parameters.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

New Ideas in Baryogenesis, Inflation / **149**

Second leptogenesis for large baryon-lepton asymmetry discrepancy

Authors: YeolLin ChoeJo[1]; Kazuki Enomoto[2]; Yechan Kim[3]; Hye-Sung Lee[3]

[1] *Korea Advanced Institute of Science and Technology*

[2] *National Taiwan University*

[3] *KAIST*

Corresponding Author: cj7801@kaist.ac.kr

We study a novel leptogenesis scenario with the temperature-dependent mass of heavy Majorana neutrino by the wave dark matter to explain the matter-antimatter asymmetry of the Universe. The leptogenesis happens twice in this scenario: the first leptogenesis occurs above the electroweak scale, while the second leptogenesis occurs below it. The sphaleron process converts the lepton asymmetry to the baryon asymmetry during the first leptogenesis, but not for the second leptogenesis due to the sphaleron decoupling at the electroweak scale. This mechanism potentially explains the significant discrepancy between baryon and lepton asymmetries, which is recently reported by EMPRESS. This talk is based on JHEP 03 (2024) 003 and PRD 111, 055026 (2025).

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Machine Learning / **150**

The bias-variance-correlation tradeoff and its implications for ML applications in HEP

Author: Prasanth Shyamsundar[1]

[1] *Fermi National Accelerator Laboratory*

Corresponding Author: prasanth@fnal.gov

The bias-variance tradeoff is a well-recognized phenomenon in statistics and machine learning. In this talk, I will discuss an extension, dubbed the bias-variance-correlation tradeoff. Roughly speaking, as the flexibility of a model decreases, the correlations in the outputs of a trained model for different inputs increases. Such correlations have implications for several applications of machine learning in high energy physics, e.g., the use generative models for event generation. In particular, I will argue that claims in the literature of data amplification by generative models stem from ignoring important correlations between the model's outputs for different inputs.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Machine Learning / 152

Synaptic Field Theory

Authors: Donghee Lee[1]; Hye-Sung Lee[1]; Jaeok Yi[1]

[1] *KAIST*

Corresponding Author: wodhr1541@kaist.ac.kr

Theoretical understanding of deep learning remains elusive despite its empirical success. In this study, we propose a novel "synaptic field theory" that describes the training dynamics of synaptic weights and biases in the continuum limit. Unlike previous approaches, our framework treats synaptic weights and biases as fields and interprets their indices as spatial coordinates, with the training data acting as external sources. This perspective offers new insights into the fundamental mechanisms of deep learning and suggests a pathway for leveraging well-established field-theoretic techniques to study neural network training.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / 153

Sommerfeld Enhancement from Quantum Forces for Dark Matter

Authors: Bingrong Yu[1]; Maxim Perelstein[1]; Steven Ferrante[1]

[1] *Cornell University*

Corresponding Author: sef87@cornell.edu

I will discuss the Sommerfeld enhancement of scattering cross sections due to quantum forces. Quantum forces are forces which arise only at loop level. Since they are subject to corrections from a background with finite temperature or number density, there will also be an important contribution to the Sommerfeld enhancement in the presence of a background. In particular this can be applied to any dark matter (DM) model with quadratically coupled mediators. For certain models we find phenomena not previously observed in the literature on Sommerfeld enhancement, such as having both enhancement and suppression effects in the same model with different masses, and resonance peaks for massless mediators. I then point out and discuss some direct applications to DM phenomenology, including its effects on DM freeze-out and CMB distortions.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

New Developments in Theory / 154

'Here be dragons': Is there new physics beyond quantum theory?

Authors: Djordje Minic[1]; Nabin Bhatta[1]; Tatsu Takeuchi[1]

[1] *Virginia Tech*

Corresponding Author: nabinb@vt.edu

"New"physics can potentially be witnessed in two ways: firstly, by making familiar experiments more precise, and secondly, by looking for phenomena outside the familiar domain. Even though quantum mechanics (QM) has been extremely well-tested, there is room for novel, although necessarily tiny, effects.

In this talk, I will describe a framework that modifies QM slightly, using parameters that can be experimentally bound, effectively constraining the deviations from QM. Not intended as an empirical competitor to QM in any way, this exercise can help us a) better appreciate the rigidity of the aspects that were modified and b) more interestingly, provide hints for describing phenomena beyond QM. Therefore, this can be a way to explore both the aspects mentioned above: precision tests of QM and novel phenomena beyond QM.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

New Physics at Future Colliders / 155

Visible Collider Signals of Natural Quirks

Author: Joshua Forsyth[1]

Co-authors: Carson Tenney [1]; Christopher Verhaaren [1]; Matthew Low [2]

[1] *Brigham Young University*

[2] *University of Pittsburgh*

Corresponding Author: jdfors21@byu.edu

New electroweak states with masses below the TeV scale can still be discovered at the LHC. We show that motivated electroweak particles that are confined by a new gauge group could have masses as

low as 100 GeV and still be consistent with LHC searches. Additionally, we introduce a new search strategy to discover such particles at the high-luminosity LHC.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Neutrino / **156**

Hadron Production in Neutrino Beams Through the Looking-Glass

Author: George Parker[1]

Co-authors: Joachim Kopp [2]; Julia Gehrlein [3]; Margot MacMahon [4]

[1] *Johannes Gutenberg-Universität Mainz*

[2] *CERN*

[3] *Colorado State University (US)*

[4] *University College London*

Corresponding Author: geparker@uni-mainz.de

At upcoming neutrino oscillation experiments, a precise understanding of the neutrino flux is imperative for oscillation studies with sub-percent precision, even with a near detector. Current uncertainties on the neutrino flux are dominated by hadron production uncertainties, making their precise determination crucial. We propose a novel approach to investigate hadron production using near detectors.
Our approach leverages the angular distributions of mesons with different masses - lighter pions will remain along the beam axis compared to heavier kaons. This property creates a distinct off-axis angle dependence in the resulting neutrino flux which, when measured at multiple off-axis positions, can reveal valuable information about the underlying hadron flux composition.
As a case-study we focus on DUNE-PRISM, the movable near detector complex of DUNE, and demonstrate that this approach can enhance the precision of the standard oscillation parameter measurements.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Gravitational Waves / **157**

Analysis of kinematic anisotropies with pulsar timing array

Author: Murman Gurgenidze[1]

Co-authors: Axel Brandenburg [2]; Emma Clarck [1]; Tina Kahniashvili [1]

[1] *Carnegie Mellon University*

[2] *The Nordic Institute for Theoretical Physics*

Corresponding Author: mgurgeni@andrew.cmu.edu

Recent observations from pulsar timing-array collaborations have provided compelling evidence for the existence of a stochastic gravitational wave background (SGWB). While astrophysical sources such as mergers of supermassive black hole binaries are likely contributors, additional signals may arise from early-universe phenomena or modified gravity theories. These different origins are expected to exhibit distinct anisotropic features: astrophysical sources are anticipated to produce a highly anisotropic SGWB, whereas cosmological sources would result in a more isotropic background with small fluctuations. The goal of the present work is to analyze the anisotropies of the SGWB. More specifically, we aim to provide estimates for anisotropies and perform distinction between intrinsic anisotropies of the background and those induced kinematically by our relative motion, similar to the kinematic dipole observed in the Cosmic Microwave Background (CMB). This analysis could provide an independent test of the CMB dipole.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / 158

Searches in CMS for long-lived particles

Author: Pritam Palit[1]

[1] *Carnegie-Mellon University (US)*

Corresponding Author: pritampalit@gmail.com

Many models beyond the standard model predict new particles with long lifetimes. These long-lived particles (LLPs) decay significantly displaced from their initial production vertex thus giving rise to non-conventional signatures in the detector. Dedicated triggers and innovative usage of the CMS detector are exploited in this context to significantly boost the sensitivity of such searches at CMS. We present recent results of searches for long-lived particles obtained using data recorded by the CMS experiment during the completed Run 2 and the ongoing Run 3 of the LHC.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Machine Learning / 159

Deep Learning Reveals Structure in Fast Radio Burst Signals

Author: Rohan Arni[1]

Co-authors: Anirudh Prabhu [2]; Carlos Blanco [3]

[1] *High Technology High School*

[2] *Princeton Center for Theoretical Science*

[3] *Pennsylvania State University*

Corresponding Author: roarni@ctemc.org

While the nature of fast radio bursts (FRBs) remains unknown, population-level analyses can elucidate underlying structure in these signals. In this study, we employ deep learning methods to both classify FRBs and analyze structural patterns in the latent space learned from the Blinkiverse FRB Survey dataset. We adopt a Supervised Variational Autoencoder (SVAE) architecture which combines the representational learning capabilities of Variational Autoencoders (VAEs) with a supervised classification task, thereby improving both classification performance and the interpretability of the

latent space. We construct a learned latent space in which we perform further dimensionality reduction to find underlying structure in the data. Our results demonstrate that the SVAE model achieves state-of-the-art classification accuracy for FRB repeaters and reveals structured clusters within these binary classifications, suggesting meaningful representations of FRB properties. Furthermore, using K-Nearest Neighbors analysis we identify outlier FRB signals in the latent space.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Flavor / 160

Exploring the truth and beauty of theory landscapes with machine learning

Authors: Konstantin Matchev[1]; Katia Matcheva[2]; Pierre Michel Ramond[3]; Sarunas Verner[4]

[1] *University of Alabama (US)*

[2] *University of Alabama*

[3] *University of Florida (US)*

[4] *University of Florida*

Corresponding Author: kmatchev@ua.edu

Theoretical physicists describe nature by i) building a theory model and ii) determining the model parameters. The latter step involves the dual aspect of both fitting to the existing experimental data and satisfying abstract criteria like beauty, naturalness, etc. We use the Yukawa quark sector as a toy example to demonstrate how both of those tasks can be accomplished with machine learning techniques. We propose loss functions whose minimization results in true models that are also beautiful as measured by three different criteria —uniformity, sparsity, or symmetry.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / 161

Light in the Shadows: Primordial Black Holes Making Dark Matter Shine

Author: Steven Clark[None]

Corresponding Author: sclark@hood.edu

While dark matter does not interact strongly with the standard model, for some models, this darkness can be attributed to a low population of a critical participant of a standard model active interaction. This ultimately leads to the formation of a bottleneck which prevents a discernible signal from being produced. On the other hand, small black holes produce all particles, whether in the standard model or a dark sector, through Hawking radiation. In this work, we consider primordial black holes (PBHs) producing this missing ingredient. This activates the otherwise inert ambient dark matter to produce a measurable signal which can then be used to gain information about both the dark matter and the PBHs. Finally, we investigate the capabilities of future gamma-ray detectors measuring this signal as well as distinguishing between different models.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Cosmology / 162

Observing Late Cosmological Phase Transitions with Scalar Perturbations

Authors: Daven Wei Ren Ho[None]; Kylar Greene[1]; Soubhik Kumar[2]; Yuhsin Tsai[3]

[1] *University of New Mexico*

[2] *NYU*

[3] *University of Notre Dame*

Corresponding Author: dho2@nd.edu

Cosmological first order phase transitions proceed via the random nucleation and expansion of bubbles throughout space. This inherently stochastic process leads to statistical fluctuations across causally disconnected patches from which super-horizon curvature perturbations emerge. I will discuss how such phase transitions generate scalar perturbations that follow a universal power-law scaling in the phase transition parameters. By numerically modelling the resulting curvature perturbation, we can set constraints on the phase transition parameters in light of cosmological data such as CMB, Lyman-alpha, and the observation of dynamical heating in ultra-faint dwarf galaxies. This gives us a handle on constraining cosmological phase transitions even if they occur in a dark sector that interacts with us only gravitationally.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Neutrino / 163

Probing scalar non-standard interaction of supernova neutrinos in DUNE

Authors: Sudipta Das[1]; Mary Hall Reno[None]

[1] *University of Iowa*

Corresponding Author: sudipta-das@uiowa.edu

A new neutrino-matter interaction can potentially affect neutrino propagation through matter. In this work, we explore the impact of a flavor-conserving scalar-mediated non-standard neutrino interaction in the supernova neutrino flux. We observe that the presence of scalar interaction involving muon and tau neutrinos (parameterized as $\eta_{\mu\mu}$ and $\eta_{\tau\tau}$, respectively) can invert the neutrino mass eigenstate in which three neutrino flavor states are produced inside the Supernova core, resulting in a significant modification of the electron neutrino flux from supernova reaching the Earth. In the context of the DUNE experiment, we estimate the number of supernova neutrino events in the presence of scalar non-standard neutrino interaction $\eta_{\mu\mu}$ or $\eta_{\tau\tau}$ and contrast with the case without scalar-mediated non-standard interactions. Our results indicate that such scalar interactions introduce a new source of uncertainty in the measurement of neutrino mass ordering from supernova neutrinos.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Neutrino / 164

Diffuse Boosted Cosmic Neutrino Background

Authors: Gonzalo Herrera[1]; Ian Shoemaker[2]; Shunsaku Horiuchi[None]; Xiaolin Qi[2]

[1] *VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY*

[2] *Virginia Tech*

Corresponding Author: xiaolinq76@vt.edu

Cosmic neutrino background (CνB) is notoriously difficult to detect due to its low energy. We investigate the scenario in which CνB is scattered off by energetic cosmic rays throughout the history of the Universe, yielding a diffuse flux boosted to higher energies. The non-observation of this flux with current high-energy neutrino experiments already excludes an average cosmic neutrino background overdensity larger than ~ 10ˆ4 1.

In this talk, I will present how the boosted flux is calculated, and discuss results from both a previous paper and our recent work.

1 Herrera, G., Horiuchi, S. and Qi, X., 2025. Diffuse boosted cosmic neutrino background. Physical Review D, 111(6), p.063016.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Machine Learning / 165

Jet Image Generation using Score Based and Consistency Diffusion Models

Authors: Victor Martinez[1]; Vidya Manian[1]

Co-author: Sudhir Malik [1]

[1] *University of Puerto Rico, Mayaguez*

Corresponding Author: vidya.manian@upr.edu

Score based and consistency diffusion models are presented for generating jet images, focusing on high-fidelity synthesis for high energy Physics applications. Using the JetNet dataset, the diffusion models are trained to learn the visual representation of jet kinematics. The results demonstrate that consistency models achieve significantly lower Fréchet inception distance measures compared to score-based models, indicating improved image quality and generation stability. Unlike methods based on latent distributions, this approach operates directly in image space. Furthermore, the efficacy of jet image generation is demonstrated using jet tagging and other metrics to highlight the strengths of image-based jet generative modeling.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Gravitational Waves / 166

Millisecond Pulsars In Galactic Center

Author: Shengyi Liu[None]

Corresponding Author: l690683728@icloud.com

The Galactic-Center Excess, a surplus of gamma rays at the Milky Way's core, has sparked debate over its origins, with two main theories suggesting either dark matter annihilation or emissions from mil-
lisecond pulsars as potential sources. This study utilizes data from the Laser Interferometer Gravitational-

Wave Observatory (LIGO) to explore the presence of millisecond pulsars in the galactic center. Employ-
ing PyFstat, an MCMC tool optimized for continuous gravitational wave detection, we analyzed gravi-
tational wave signals emitted by millisecond pulsars, revealing significant insights into their distribution
and activities. Our findings suggest that expanding the search aperture in future LIGO observation runs
could enhance the detection of these pulsars, contributing to a better understanding of the Galactic-Center
Excess and the nature of energetic processes within our galaxy's nucleus.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

New Developments in Theory / 167

Exceptional Unification

Author: Kaladi Babu[None]

Corresponding Author: babu@okstate.edu

Realistic grand unified theories based on the exceptional group E_6 will be presented and their phenomenological implications explored. These include fermion masses, neutrino oscillations, proton decay and a GUT-stabilized dark matter candidate.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

New Developments in Theory / 168

Geometry of Effective Field Theories on Functional Manifolds

Authors: Tim Cohen[1]; Xiaochuan Lu[2]; Xu-Xiang Li[3]; Zhengkang Zhang[3]

[1] *CERN*

[2] *University of California, San Diego*

[3] *University of Utah*

Corresponding Author: jukcoeng@gmail.com

Field redefinitions in effective field theories (EFTs) can involve derivatives, introducing redundancies that cannot be captured by the traditional geometry of field space based solely on two-derivative terms in the Lagrangian. To accommodate these derivative-dependent transformations, we present a geometric framework that extends beyond conventional field space to the functional manifold. Within this setting, we demonstrate that tree-level scattering amplitudes can be constructed from on-shell covariant building blocks. As an example, we show that amplitudes in up-to-two-derivative theories depend solely on the curvature, potential, and their covariant derivatives. Our results provide a step toward a fully geometric formulation of EFTs, potentially offering new tools for organizing and understanding their physical content.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

New Developments in Theory / 169

What is the Geometry of Effective Field Theories?

Authors: Tim Cohen[1]; Xiaochuan Lu[2]; Xu-Xiang Li[3]; Zhengkang Zhang[3]

[1] *CERN*

[2] *University of California, San Diego*

[3] *University of Utah*

Corresponding Author: z.k.zhang@utah.edu

One of the fundamental difficulties in the Lagrangian formulation of effective field theories (EFTs) is that one can redefine the fields in a theory without changing the physical predictions, e.g. scattering amplitudes. The freedom to perform field redefinitions to change the form of the Lagrangian can often obscure the physical content of an EFT. This is in fact a familiar situation in any physical theory, where one can pick different coordinate systems for the dynamical degrees of freedom. In the case of classical Hamiltonian mechanics, this corresponds to choosing different coordinates for the same symplectic geometry. What is the analogous geometric picture for EFTs? Is it possible to characterize and classify EFTs by the geometric properties of their associated manifolds? In this talk, we present recent progress towards answering these ambitious questions.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / 170

Kaluza-Klein portal dark matter models

Authors: Dipan Sengupta[1]; Elizabeth Simmons[2]; George Sanamyan[None]; Joshua Gill[None]; Kirtimaan Mohan[3]; R. Sekhar Chivukula[4]; Xing Wang[4]

[1] *University of New South Wales, Sydney, Australia*

[2] *University of California, San Diego*

[3] *Michigan State University*

[4] *UC San Diego*

Corresponding Author: kamohan@msu.edu

We revisit the phenomenology of dark matter (DM) scenarios within radius-stabilized Randall-Sundrum models. Specifically, we consider models where the dark matter candidates are Standard Model (SM) singlets confined to the TeV-brane and interact with the SM via spin-2 and spin-0 gravitational Kaluza-Klein (KK) modes. We compute the thermal relic density of DM particles in these models by applying recent work showing that scattering amplitudes of massive spin-2 KK states involve an intricate cancellation between various diagrams. Considering the resulting DM abundance, collider searches, and the absence of a signal in direct DM detection experiments, we show that spin-2 KK portal DM models are highly constrained. In particular, we confirm that within the usual thermal freeze-out scenario, scalar dark matter models are essentially ruled out. In contrast, we show that fermion and vector dark matter models are viable in a region of parameter space in which dark matter annihilation through a KK graviton is resonant.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Neutrino / **171**

Probing a HN through vector boson fusion and machine learning techniques

Authors: Alfredo Gurrola[1]; Yin-Fa Shen[1]

[1] *Vanderbilt University (US)*

Corresponding Author: yin-fa.shen@vanderbilt.edu

We propose a novel strategy to probe heavy neutrinos with non-universal fermion couplings at the Large Hadron Collider (LHC) using vector boson fusion (VBF) processes. Focusing on proton-proton collisions at $\sqrt{s} = 13\,\mathrm{TeV}$, we investigate final states characterized by a muon, missing energy, and two forward/backward jets, originating from a virtual heavy neutrino. Unlike resonant production channels, the VBF process maintains sensitivity at higher masses due to reduced kinematic suppression. We simulate both signal and Standard Model background events and apply gradient-boosted decision trees (BDTs) to optimize event classification. Our results, assuming $3000\,\mathrm{fb}^{-1}$ of integrated luminosity, demonstrate that heavy neutrino masses in the range of 250-5000 GeV can be probed with a mixing parameter sensitivity of approximately 0.1. This approach enhances the discovery potential for heavy neutrinos and provides a complementary pathway to existing search strategies.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Flavor / **172**

Charged Lepton Flavor Violation in a Lepton Flavor Portal Matter Model

Authors: Lisa Everett[None]; RICARDO ALEXANDRE DOS SANTOS XIMENES FILHO[1]

[1] *University of Wisconsin - Madison*

Corresponding Author: dossantosxim@wisc.edu

Increasing attention has been given recently to the theory and phenomenology of portal matter (PM) models —a BSM framework in which the standard model (SM) local gauge symmetry group is augmented by a local dark group $U(1)_D$, of which the mediator is the dark photon, and kinetic mixing between $U(1)_D$ and the SM hypercharge is generated at one loop by the PM fields. The case in which the PM are vector-like leptons (VLL) is of particular interest for the study of precision measurements of the leptonic sector: We have recently studied a simple realization of this $U(1)_D$ model that addresses the potential $(g-2)_\mu$ anomaly 1 and a TeV-scale completion in which the $U(1)_D$ is embedded into a larger non-Abelian dark group, allowing the SM and PM fields to exist as members of the same dark gauge multiplets [2] and resulting in the introduction of new $U(1)_D$-neutral vector-like leptons. Here we study models with leptonic PM and additional $U(1)_D$ neutral vector-like leptons. We analyze the minimal particle content that such a simplified model can have and still produce a sizable correction to the charged lepton flavor-conserving process $(g-2)_\mu$, which shows that only certain combinations of PM and $U(1)_D$-neutral VLL are required, in agreement with [3]. Moreover, given the current stringent constraints on muonic charged lepton flavor violation (CLFV), we study the CLFV processes $\mu^+ \to e^+ + \gamma$, $\mu^+ \to e^+ + e^- + e^+$, and μ to e conversion in nuclei up to one loop level and examine how current and future experiments can constrain its parameter space [4].

1 George N. Wojcik, Lisa L. Everett, Shu Tian Eu, and Ricardo Ximenes. "Portal Matter, Kinetic Mixing, and Muon g-2." Physics Letters B 841 (2023): 137931.
[2] George N. Wojcik, Lisa L. Everett, Shu Tian Eu, and Ricardo Ximenes. "Lepton flavor portal matter." Physical Review D 108.5 (2023): 055033.
[3] George N. Wojcik, Shu Tian Eu, and Lisa L. Everett. "Graph reinforcement learning for exploring model spaces beyond the standard model." Physical Review D 111.3 (2025): 035007.
[4] George N. Wojcik, Lisa L. Everett, Shu Tian Eu, and Ricardo Ximenes. "Charged Lepton Flavor Violation in a Lepton Flavor Portal Matter Model" - In preparation.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / 173

Rescaling Microlensing Results for Novel Dark Compact Objects

Author: Joel Cortez Osuna[1]

[1] *Pennsylvania State University*

Corresponding Author: jjc7342@psu.edu

We present a framework to model microlensing signatures of novel compact object populations beyond the traditional stellar evolution path. A compelling model to investigate is the dissipative dark matter scenario, in particular, the atomic dark matter model, which can form dark black holes (DBHs) from the gravitational collapse of fragmented dark hydrogen gas. DBHs have unique mass ranges and spatial and velocity distributions, distinguishing them from stellar-origin black holes, making them strong candidates for microlensing searches. To estimate their detectability, we rescale results from Population Synthesis for Compact Object Lensing Events (PopSyCLE), which simulates baryonic compact object microlensing events across different surveys, to predict the DBH microlensing signatures. These predictions are then compared to the gravitational wave merger rates of DBH binaries as a function of the fraction of dark matter in DBHs, offering a way to constrain novel populations with multiple gravitational probes.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Cosmology / 174

Free streaming of warm wave dark matter

Author: Moira venegas villa[None]

Corresponding Author: mvenegasvilla@gmail.com

In models of warm dark matter, there is an appreciable population of high momentum particles in the early universe, which free stream out of primordial over/under densities, thereby prohibiting the growth of structure on small length scales. The distance that a dark matter particle travels without obstruction, known as the free streaming length, depends on the particle's mass and momentum, but also on the cosmological expansion rate. In this way, measurements of the linear matter power spectrum serve to probe warm dark matter as well as the cosmological expansion history. In this work, we focus on ultra-light wave wave dark matter (WWDM) characterized by a typical comoving momentum q_* and mass m. We derive constraints on the WWDM parametermspace (q_*,m) using Lyman-αforest observations due to a combination of the free-streaming effect and the white-noise effect.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Neutrino / 175

Measuring the Neutrino Mass with the Project 8 Experiment

Author: Luiz de Viveiros[1]

[1] *Pennsylvania State University*

Corresponding Author: ldeviveiros@gmail.com

The Project 8 experiment seeks to determine the electron-weighted neutrino mass via the precise measurement of the electron energy in beta decays, with a sensitivity goal of $40\,\mathrm{meV/c^2}$. We have developed a technique called Cyclotron Radiation Emission Spectroscopy (CRES), which allows single electron detection and characterization through the measurement of cyclotron radiation emitted by magnetically-trapped electrons produced by a gaseous radioactive source. We have successfully demonstrated the use of the technique to measure the tritium spectrum on a small scale. I will present a brief overview of the Project 8 experimental program, and the development of novel technologies for performing CRES using tritium atoms in a multi-cubic-meter volume. I will focus on the design of a Low-Frequency Apparatus (LFA) that deploys a cylindrical resonant cavity to capture the electron's cyclotron radiation, increasing the signal-to-noise ratio and sensitive volume. The LFA will demonstrate the scalability of the CRES technique to the cubic-meter scale and reach sub-eV sensitivity to the neutrino mass.

This work is supported by the US DOE Office of Nuclear Physics, the US NSF, the PRISMA+ Cluster of Excellence at the University of Mainz, and internal investments at all collaborating institutions.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / 176

Recent highlights of dark matter searches from CMS

Author: Allison Reinsvold Hall[1]

[1] *Fermilab*

Corresponding Author: ahall@fnal.gov

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

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Astro-particle / 177

Could We Observe an Exploding Black Hole in the Near Future?

Author: Aidan Symons[1]

[1] *University of Massachusetts Amherst*

Corresponding Author: asymons@umass.edu

The observation of an exploding black hole would provide the first direct evidence of primordial black holes, the first direct evidence of Hawking radiation, and definitive information on the particles present in nature. However, indirect constraints suggest that direct observation of an exploding Schwarzschild black hole is implausible. We introduce a dark-QED toy model consisting of a dark photon and a heavy dark electron. In this scenario a population of light primordial black holes charged under the dark $U(1)$ symmetry can become quasi-extremal, so they survive much longer than if they were uncharged, before discharging and exhibiting a Schwarzschild-like final explosion. Addressing the question posed in the title, we find the answer to be "yes".

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Cosmology / 178

Shining a Light on (Non-)Minimal Dark Sectors With 21-cm Cosmology

Author: Federico Cima[1]

Co-author: Francesco D'Eramo [2]

[1] *Caltech*

[2] *University of Padua*

Corresponding Author: fcima@caltech.edu

Future observations of the sky-averaged 21-cm signal during the cosmic dawn promise unprecedented measurements of the gas temperature in this epoch. Such measurements can place extremely strong constraints on the lifetime of dark matter. We revisit the projected bounds on minimal decaying dark matter scenarios and present new constraints for theoretically motivated non-minimal dark sectors, specifically focusing on axion-like particle sub-components and inelastic dark matter.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / 179

Ultralight dark matter detection with trapped-ion interferometry

Author: Leonardo Badurina[1]

Co-authors: Diego Blas [2]; John Ellis [3]; Sebastian Ellis [4]

[1] *California Institute of Technology*

[2] *ICREA/IFAE*

[3] *CERN*

[4] *Universite de Geneve (CH)*

Corresponding Author: badurina@caltech.edu

We explore how recent advancements in the manipulation of single ionic wave packets open new avenues for detecting weak magnetic fields sourced by ultralight dark matter. By leveraging the entanglement between the ion's spin and motional degrees of freedom, proposed trapped-ion matter-wave interferometers enable the measurement of the dynamical Zeeman phase shift accrued by the ion over its trajectory, which results in a parametrically enhanced sensitivity to weak magnetic fields. Considering the relevant boundary conditions, we demonstrate that a single trapped ion can probe unexplored regions of kinetically-mixed dark photon dark matter parameter space in the 10^{-15} eV
$lesssimm_{A'}$
$lesssim10^{-14}$ eV mass window. We also show how these table-top quantum devices will serve as a complementary probe of axion-like particle dark matter in the same mass window.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / 180

New Directions in Dark Matter Detection

Author: Ben Lillard[1]

[1] *University of Oregon*

Corresponding Author: blillard@uoregon.edu

Experiments with directional sensitivity are ideal for discovering a dark matter signal even in the presence of irreducible backgrounds. Crystalline trans-stilbene ($C_{14}H_{14}$) is an excellent first example, with O(10%) amplitudes in its daily modulation signals. In this talk, I present a simple, universal

measure for quantifying the statistical power of a directionally sensitive counting experiment, to guide the search for target materials that are even more effective than trans-stilbene. I also provide an update on the multi-gram-scale prototype experiment currently being assembled at Fermilab.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

181

New Physics Searches at the LHC through Event based Anomaly Detection and Development of ADFilter Web-tool

Authors: Nicholas Luongo[1]; Sergei Chekanov[1]; Wasikul Islam[2]

[1] *Argonne National Laboratory (US)*

[2] *University of Wisconsin-Madison (US)*

Corresponding Author: wasikul.islam@cern.ch

This work presents advancements in model-agnostic searches for new physics at the Large Hadron Collider (LHC) through the application of event-based anomaly detection techniques utilizing unsupervised machine learning. We discuss the advantages of Anomaly detection approach, as demonstrated in recent ATLAS analysis, and introduce ADFilter, a web-based tool designed to process collision events using autoencoders based on deep unsupervised neural networks. ADFilter calculates loss distributions for input events, aiding in determining the degree to which events can be considered anomalous. Real-life examples are provided to demonstrate how the tool can be used to reinterpret existing LHC results, with the goal of significantly improving exclusion limits. Furthermore, we present a comparative study between anomaly detection and supervised machine learning techniques, using the search for heavy resonances decaying into two or more Higgs bosons as a representative case to demonstrate the application and effectiveness of these methods.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Neutrino / 182

Right-Handed Neutrino Masses from the Electroweak Scale

Authors: Amit Bhoonah[1]; Brian Batell[1]; Wenjie Huang[None]

[1] *University of Pittsburgh*

Corresponding Author: weh68@pitt.edu

We explore the possibility that the right-handed neutrino Majorana mass originates from electroweak symmetry breaking. Working within an effective theory with two Higgs doublets, nonzero lepton number is assigned to the bilinear operator built from the two Higgs fields, which is then coupled to the right-handed neutrino mass operator. In tandem with the neutrino Yukawa coupling, following electroweak symmetry breaking a seesaw mechanism operates, generating the light SM neutrino masses along with right-handed neutrinos with masses below the electroweak scale. This scenario leads to novel phenomenology in the Higgs sector, which may be probed at the LHC and at future colliders. There are also interesting prospects for neutrinoless double beta decay and lepton flavor violation. We also explore some theoretical aspects of the scenario, including the technical naturalness of the effective field theory and ultraviolet completions of the right-handed neutrino Majorana mass.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

New Developments in Theory / 183

A lapse-Wick rotation on curved backgrounds: admissible complex metrics and the generalized heat kernel

Author: Rudrajit Banerjee[1]

[1] *Okinawa Institute of Science and Technology*

Corresponding Author: rudrajit.banerjee@oist.jp

On generic (non-stationary) curved backgrounds, the link between Euclidean and Lorentzian signature QFT via a Wick rotation is not fully understood. In this talk, I will present a generalization to curved spacetimes of a variant of Wick rotation originally due to Zimmermann. This construction interpolates between Lorentzian and Riemannian metrics on the same underlying smooth real manifold, passing through admissible complex metrics dampening the exponential of the action of a real scalar field. Next, motivated by the central role of the heat kernel in both one-loop perturbation theory and non-perturbative functional renormalization group methods in Euclidean QFT, I will briefly discuss the generalized heat semigroup and kernel associated to the Wick rotated metric, as well as the strict Lorentzian limit. This talk is based on joint work with Max Niedermaier, appearing in the papers: Class.Quant.Grav. 42 (2025) and J.Funct.Anal. 289 (2025).

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

New Developments in Theory / 184

Dynamical Condensates and the Problem of the Finite Temperature Effective Potential

Author: Nathan Herring[1]

Co-authors: Daniel Boyanovsky [2]; Shuyang Cao [2]

[1] *Hillsdale College*

[2] *University of Pittsburgh*

Corresponding Author: nathanmherring@gmail.com

We study the applicability of the usual finite temperature effective potential in the equation of motion of a homogeneous "misaligned" scalar condensate , and find important caveats that severely restrict its domain of validity: i:) the assumption of local thermodynamic equilibrium (LTE) is in general not warranted, ii:) a direct relation between the effective potential and the thermodynamic entropy density entails that the entropy becomes a non-monotonic function of time, iii:) parametric instabilities in both cases with and without spontaneous symmetry breaking lead to profuse particle production with non-thermal distribution functions, iv:) in the case of spontaneous symmetry

breaking spinodal instabilities yield a complex effective potential, internal energy and entropy, an untenable situation in thermodynamics. All these caveats associated with dynamical aspects, cannot be overcome by finite temperature equilibrium resummation schemes. We argue that the dynamics of the condensate leads to decoupling and freeze-out from (LTE), and propose a closed quantum system approach based on unitary time evolution. It yields the correct equations of motion without the caveats of the effective potential, and provides a fully renormalized and thermodynamically consistent framework to study the dynamics of the "misaligned" condensate, with real and conserved energy and entropy amenable to numerical study.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / 185

Quantum Entanglement is Quantum: ZZ Production at the LHC

Author: Alberto Navarro[1]

[1] *Oklahoma State University*

Corresponding Author: alberto.navarro_serratos@okstate.edu

We discuss systematic limitations of entanglement measurements in particle production processes at collider experiments. Using the example of $pp \to ZZ$ production at the Large Hadron Collider, we study the distinct contributions that arise at leading and higher orders, which can affect the interpretation of the system as a two-qutrit ZZ system.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

New Physics at Future Colliders / 186

Axion-like Particles at the Electron-Ion Collider

Authors: Brian Thomas Batell[None]; Keping Xie[1]; Monica Leys[None]

[1] *Michigan State University*

Corresponding Author: mpl47@pitt.edu

The Electron-Ion Collider (EIC) will have the capability to collide various particle beams with large luminosities in a relatively clean environment, surrounded by a large angular coverage detector. Our analysis focuses on the EIC's sensitivity to Axion-like particles (ALPs) that are created via photon fusion and promptly decay to photons. We explore this predominantly through coherent electron-ion scattering in the 0.1-50 GeV ALP mass range, which has the potential to extend reach to untouched ALP-photon coupling parameter space.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / 187

Gravitational Particle Production as a Mechanism for Generating Dark Matter

Author: Marcell Howard[1]

[1] *University of Pittsburgh*

Corresponding Author: mah455@pitt.edu

The lack of direct detections for weakly interacting massive particles has led theorists to think about more exotic scenarios for producing DM in the early Universe. One viable alternative is gravitational particle production i.e. the creation of particles through due to the presence of a sufficiently strong gravitational field. In this talk, I will go over how this mechanism can be used to produce a viable free scalar field dark matter candidate and how these results can be extended to a self-interacting scalar field.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Neutrino / 188

Energy Reconstruction for the Project 8 Experiment

Author: Ehteshamul Karim[1]

[1] *University of Pittsburgh*

Corresponding Author: ehk22@pitt.edu

Project 8 is designed to directly measure the electron neutrino mass using cyclotron radiation emission spectroscopy (CRES). Using cyclotron frequency as a proxy for kinetic energy, the β-decay electron endpoint spectrum for magnetically-trapped electrons produced by a gaseous tritium source can be measured with high precision using CRES. Following the successful demonstration of CRES with waveguides, the upcoming phase of Project 8 will demonstrate the first realization of the CRES technique in cylindrical cavities using Cavity CRES Apparatus (CCA) with the goal to further improve energy resolution by an order of magnitude. Further, a cubic-meter scale volume apparatus called Low-Frequency Apparatus (LFA) is planned to increase statistics. This talk will describe the development of CRES energy reconstruction techniques for the upcoming Project 8 detectors.

This work is supported by the US DOE Office of Nuclear Physics, the US NSF, the PRISMA+ Cluster of Excellence at the University of Mainz, and internal investments at all institutions.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / 189

Magnetic Levitation for Fundamental Physics: From Dark Matter to Non-Newtonian Gravity

Author: Dorian Amaral[1]

[1] *Rice University*

Corresponding Author: dorian.amaral@rice.edu

Magnetic levitation technology offers force and displacement sensitivities at the quantum frontier, making it an attractive platform for probing the feeble interactions expected of beyond the Standard Model physics. Despite its promise, the case for magnetic levitation in fundamental physics applications is only just being built. In this talk, I will demonstrate how a setup based on the Meissner levitation of a ferromagnet within a superconducting trap will have world-leading sensitivity to three fundamental physics problems: the search for ultralight dark matter, ultraheavy dark matter, and a non-Newtonian gravitational fifth force. In the first of these cases, I will present the first limit on ultralight dark matter using magnetic levitation technology around the dark matter mass $m_{\mathrm{DM}} \sim 10^{-13}\,\mathrm{eV}/c^2$. Our results highlight the promise of this developing technology within the fundamental physics community and pave the way for exciting future applications.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Astro-particle / **190**

Multi-messenger Astronomy with Quenched Superradiance

Authors: Indra Kumar Banerjee[1]; Soumya Bonthu[None]; Ujjal Kumar Dey[1]

[1] *Indian Institute of Science Education and Research, Berhampur*

Corresponding Author: bsoumya@okstate.edu

We propose a novel method to study the ultra-light bosons, where compact rotating objects undergo the phenomenon of quenched superradiance to create gravitational waves and neutrino flux signals. The neutrino flux results from appropriate coupling between the ultra-light bosons and the neutrinos. We consider a heavy sterile neutrino generation from ultralight scalar, which later results in active neutrino flux through neutrino oscillations, whereas we consider active neutrino generation directly from the vector bosons. We study the intertwining of gravitational waves and neutrino flux signals produced from a single source and elaborate if and when the signals can be detected in existing and upcoming experiments in a direct manner.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / **191**

Quantum Entanglement is Quantum: $\mathbf{h \to VV^*}$

Author: dorival Gonçalves[1]

[1] *Oklahoma State University*

Corresponding Author: dorival@okstate.edu

Driven by the increasing interest in probing spin structure and quantum entanglement in diboson processes, we study polarization and spin correlations in Higgs → VV decays. We show that higher-order electroweak corrections are crucial for accurately determining these coefficients and discuss their impact on proposed entanglement measurements.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Neutrino / 192

Neutrino Force and Its Implications for Atomic Measurement of the Weinberg Angle

Authors: Bingrong Yu[1]; Chinhsan Sieng[1]; Mitrajyoti Ghosh[2]; Yuval Grossman[1]

[1] *Cornell University*

[2] *Florida State University*

Corresponding Author: cs2284@cornell.edu

The Standard Model predicts a long-range force mediated by a pair of neutrinos, commonly referred to as the "neutrino force". This force scales as G_F^2/r^5, where G_F is the Fermi constant. However, this scaling breaks down at distances r
$lesssim\sqrt{G_F}$, where the four-Fermi approximation becomes invalid. In this talk, I present a complete expression for the neutrino force that is valid at all distances. We examine its implications for atomic parity violation (APV) experiments, emphasizing that the neutrino force, due to its long-range nature relative to atomic scales, cannot be treated as a simple correction to the tree-level Z-exchange without accounting for atomic wavefunctions. Applying our result to muonium and positronium, we find that the neutrino force contributes approximately 4 % and 16 %, respectively, compared to the leading Z-exchange contribution. These findings have important consequences for the detection of the neutrino force and precision measurements of the weak mixing angle.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Machine Learning / 193

Truth, beauty, and goodness in grand unification: A machine learning approach

Author: Nobuchika Okada[1]

Co-author: Shinsuke Kawai [2]

[1] *University of Alabama*

[2] *Yamagata University*

Corresponding Author: okadan@ua.edu

We investigate the flavour sector of the supersymmetric SU(5) Grand Unified Theory (GUT) model using machine learning techniques. The minimal SU(5) model is known to predict fermion masses that disagree with observed values in nature. There are two well-known approaches to address this issue: one involves introducing a 45-representation Higgs field, while the other employs a higher-dimensional operator involving the 24-representation GUT Higgs field. We compare these two approaches by numerically optimising a loss function, defined as the ratio of determinants of mass matrices. Our findings indicate that the 24-Higgs approach achieves the observed fermion masses with smaller modifications to the original minimal SU(5) model.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Astro-particle / 194

Twin Peak Dark Matter and Gravitational Wave Signal

Author: Brenda Gomez Cortes[1]

Co-authors: Arnab Dasgupta ; Akshay Ghalsasi [2]; Monica Leys [1]

[1] *University of Pittsburgh*

[2] *Harvard University*

Corresponding Author: bdg43@pitt.edu

We explore a conformal dark matter model based on the gauge group $SU(N_c) \times U(1)_D$, from which we can obtain confinement of bound-state dark matter at a dark QCD scale, and a WIMP and self-interacting dark matter at a higher energy scale, around 1 TeV, along with the possibility of gravitational wave (GW) production from strong first-order phase transitions at both scales. We expect that the predicted GW spectra will have sensitivity strong enough to be probed at the frequency range windows observable with NANOGrav and LISA, respectively.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Astro-particle / 195

Axion dark radiation in a neutron star magnetosphere

Author: Andrew Long[1]

[1] *Rice University*

Corresponding Author: andrewjlong@rice.edu

I'll discuss the conversion of relativistic axion dark radiation into terahertz electromagnetic radiation via a novel resonance that is only accessible in a neutron star magnetosphere thanks to the strong magnetic field. Based on 2408.04551 with Enrico Schiappacasse.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Flavor / 196

Systematic Study of U-spin Amplitude Sum Rules Predictions for Physical Observables

Authors: Guglielmo Papiri[1]; Margarita Gavrilova[2]; Yuval Grossman[None]

[1] *Cornell University*

[2] *Cornell*

Corresponding Author: gp343@cornell.edu

Theoretical predictions for hadronic decays are extremely challenging due to the non-perturbative nature of QCD. The SU(3) approximate flavor symmetry of QCD can be used to derive relations between hadronic decay amplitudes. We perform a systematic study on how the SU(2) flavor symmetry amplitude sum rules can be used to give predictions for physical observables. In particular, we show a general strategy to derive all the rate sum rules for a system of hadron decays that are related by the U-spin symmetry, for every order in the symmetry breaking. We provide novel examples of relations between decay rates that hold at higher order in the breaking and that can be studied experimentally in precision physics.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / 197

Long-lived ALPs from electromagnetic cascades

Authors: Ryan Plestid[None]; Samuel Patrone[1]

[1] *California Institute of Technology*

Corresponding Author: spatrone@caltech.edu

I will present some preliminary results from our study on Axion-Like Particles (ALPs) production from electromagnetic showers in beam dump experiments, focusing on SHiP as a relevant benchmark example. Existing projections for SHiP's sensitivity to ALPs have focused on production from either the primary photon beam or the (high-energy) photons produced by $\pi 0 \longrightarrow \gamma\gamma$. In this work, we study the subsequent production of axions from the full electromagnetic shower initiated by each of these photons.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Cosmology / 198

CMB constraints on non-minimally coupled ultralight dark matter

Author: Subhajit Ghosh[1]

[1] *The University of Texas at Austin*

Corresponding Author: sghosh@utexas.edu

In this talk, I will present bounds on the variation of fundamental constants from the cosmic microwave background (CMB). In our theoretically motivated model, the variation is modulated by a scalar field that behaves as an ultralight dark matter (ULDM). We self-consistently compute the effects of the variation of constants on big bang nucleosynthesis (BBN) and propagate those effects to the computation of the CMB spectra. We explore the degeneracies between various effects, such as changes in primordial Helium fraction (Y_p), changes due to modified recombination, and the effects on the ULDM. I will present the bounds on the variation of the electron mass and fine structure constant. I will also discuss the implications of the Hubble tension in this context.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Cosmology / 199

Analytic formulation of Leptogenesis with neutrino oscillation data employing the general parametrization for neutrino mass matrix

Authors: Digesh Raut[1]; Nobuchika Okada[None]

[1] *St. Mary's College of Maryland*

Corresponding Author: theeguess@gmail.com

Type-I seesaw scenario is arguably the simplest scenario to generate the observed neutrino oscillation data and the observed baryon asymmetry in the universe via leptogenesis. Based on the Casas–Ibarra general parametrization, we derive analytic expressions for the CP asymmetry parameter in the leptogenesis with two and three generations of right-handed Majorana neutrinos, reproducing the neutrino oscillation data. We examine both thermal and non-thermal leptogenesis scenarios to obtain bounds on Majorana neutrino masses for successful leptogenesis.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

New Ideas in Baryogenesis, Inflation / 200

Testable Flavored TeV-scale Resonant Leptogenesis with MeV-GeV Dark Matter

Author: Kairui Zhang[1]

Co-author: Peisi Huang

[1] *University of Oklahoma-Norman*

Corresponding Author: kzhang25@ou.edu

We explore flavored resonant leptogenesis embedded in a neutrinophilic 2HDM. Successful leptogenesis is achieved by the very mildly degenerate two heavier right-handed neutrinos˜(RHNs) N_2 and N_3 with a level of only $\Delta M_{32}/M_2 \sim \mathcal{O}(0.1\% - 1\%)$. The lightest RHN, with a MeV–GeV mass, lies below the sphaleron freeze-out temperature and is stable, serving as a dark matter candidate. The

model enables TeV-scale leptogenesis while avoiding the extreme mass degeneracy typically plagued conventional resonant leptogenesis. Baryon asymmetry, neutrino masses, and potentially even dark matter relic density can be addressed within a unified, experimentally testable framework.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / 201

Dark Matter and Gravitational Wave Production in 2HDMS

Authors: Brenda Gomez Cortes[1]; Matthew Knauss[2]

[1] *University of Pittsburgh*

[2] *William & Mary*

Corresponding Author: mhknauss@wm.edu

We investigate dark matter and gravitational wave production in a type II 2HDM with the addition of an inert complex singlet. A Z_2' symmetry is imposed under which the doublets are even and the singlet is odd to ensure the stability of the dark matter candidate. Before the first order phase transition, finite temperature effects provide a window where thermal bath interactions produce dark matter through channels kinematically forbidden at zero temperature. At zero temperature, the lightest dark matter candidate is stable. The gravitational waves produced by this phase transition could be observed by future experiments.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Dark Matter / 202

Can the LHC be sensitive to Light Dark Mediators?

Author: Deepak Sathyan[None]

Co-authors: Aparajitha Karthikeyan [1]; Bhaskar Dutta ; Doojin Kim ; Hyunyong Kim [2]

[1] *Department of Physics and Astronomy, Texas A&M University*

[2] *Texas A & M University (US)*

Corresponding Author: dsathyan@tamu.edu

We propose a novel method to obtain sensitivity to dark mediators and dark sectors at the LHC with masses of ~ 10 MeV $- 10$ GeV, providing complementarity with beam dump experiments. For this talk, we consider dark photons, which can be produced at the LHC by neutral meson decays, bremsstrahlung off baryons, or directly produced in correlation with a jet. We then consider visible decays to muon pairs as the signal channel and provide methods to control backgrounds. We show a range of sensitivities dependent on various estimates of backgrounds and different signal threshold requirements.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / 203

Entanglement maximization and mirror symmetry in Two-Higgs-Doublet-Models

Authors: Carlos E.M. Wagner[None]; Guglielmo Coloretti[1]; Ian Low[None]; Marcela Carena[2]; Mira Littmann[3]; Wanqiang Liu[None]

[1] *University of Zurich (UZH) / Paul Scherrer Institute (PSI)*

[2] *Perimeter Institute for Theoretical Physics*

[3] *University of Chicago*

Corresponding Author: wanqiangl@uchicago.edu

We consider 2-to-2 scatterings of Higgs bosons in a CP-conserving two-Higgs-doublet model (2HDM) and study the implication of maximizing the entanglement in the flavor space, where the two doublets Φ_a, $a = 1, 2$, can be viewed as a qubit: $\Phi_1 = |0\rangle$ and $\Phi_2 = |1\rangle$. More specifically, we compute the scattering amplitudes for $\Phi_a\Phi_b \to \Phi_c\Phi_d$ and require the outgoing flavor entanglement to be maximal for a full product basis such as the computational basis, which consists of $\{|00\rangle, |01\rangle, |10\rangle, |11\rangle\}$. In the unbroken phase and turning off the gauge interactions, entanglement maximization results in the appearance of an $U(2) \times U(2)$ global symmetry among the quartic couplings, which in general is broken softly by the mass terms. Interestingly, once the Higgs bosons acquire vacuum expectation values, maximal entanglement enforces an exact $U(2) \times U(2)$ symmetry, which is spontaneously broken to $U(1) \times U(1)$. As a byproduct, this gives rise to Higgs alignment as well as to the existence of 6 massless Nambu-Goldstone bosons. The $U(2) \times U(2)$ symmetry can be gauged to lift the massless Goldstones, while maintaining maximal entanglement demands the presence of a discrete Z_2 symmetry interchanging the two gauge sectors. The model is custodially invariant in the scalar sector, and the inclusion of fermions requires a mirror dark sector, related to the standard one by the Z_2 symmetry.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

New Ideas in Baryogenesis, Inflation / 204

Electroweak Baryogenesis in the Real Singlet Model

Authors: Morgan Cassidy[None]; Ian Lewis[1]; Brian Batell[2]; Arnab Dasgupta[2]

[1] *University of Kansas*

[2] *University of Pittsburgh*

Corresponding Author: mec400@pitt.edu

Electroweak Baryogenesis is a commonly studied mechanism to explain the baryon asymmetry of the universe. By introducing a real scalar singlet to the Standard Model, the electroweak phase transition can become strongly first order and satisfy the out-of-equilibrium Sakharov condition. Additionally, contributions from the scalar to the top quark mass term can provide the necessary CP violation. In this talk, I will go over the methods used to compute relevant quantities needed to determine the asymmetry for this model. The relevant quantities will include the critical temperature, bounce action, nucleation temperature, field profiles, wall velocity, and wall width.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Astro-particle / 205

Testability of Dynamical Inflection Point Inflation at Collider Experiments

Author: Francis Burk[None]

Co-authors: Arnab Dasgupta [1]; Brian Batell [1]; Keping Xie [2]; Swapnil Dutta ; Tao Han

[1] *University of Pittsburgh*

[2] *Michigan State University*

Corresponding Author: frb25@pitt.edu

The growth of large-scale structure in the early universe remains unexplained to this day. Originally proposed by Alan Guth, inflation, which posits a brief period of rapid cosmological growth, stands as a potential explanation to this puzzle. Inflationary models use "slow roll parameters"to align predictions with cosmological constraints fixed by data from the CMB and other such experiments. Due to the constraining nature of slow roll parameters, most inflationary models are only testable at energies far from the reach of particle colliders. However, recently Yang Bai and Daniel Stolarski have proposed an interesting new inflationary model with energies falling within the detection range of current and upcoming particle colliders. We introduce a minimal setup to achieve dynamical inflection point inflation, utilizing a minimal framework. Our approach examines collider constraints on inflationary parameters using the same field composition. Specifically, we incorporate an dark SU(2)D gauge sector featuring a dark scalar doublet as the inflaton, accompanied by particle content akin to the Standard Model but with degenerate masses. This configuration facilitates the realization of multiple inflection points in the inflaton potential. Notably, all vector-like particles in the exotic content possess identical Standard Model charges, enabling the inflaton's decay into the visible sector for reheating the universe. Our study establishes a vital link between collider constraints and their implications on inflationary parameters.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Gravitational Waves / 206

Gauge-Invariant Observables for Gravitational Waves from a First-Order Electroweak Phase Transition

Authors: Leon Friedrich[1]; Manuel Díaz[2]; Michael Ramsey-Musolf[2]; Michael Ramsey-Musolf[None]

[1] *The University of Melbourne*

[2] *U. Massachusetts Amherst*

Corresponding Author: manueldiaz@umass.edu

We employ a gauge-invariant perturbative framework to analyze the next-to-leading order (NLO) effective action of the SU(2)-Higgs model at finite temperature. This involves utilizing a specific power counting scheme, which allows us to compute gauge-invariant observables for primordial gravitational waves arising from a thermal first-order electroweak phase transition. Finally, we then compare our results with findings from pre-existing non-perturbative analyses, effectively benchmarking the framework's validity and assessing its implications on the need to reevaluate the validity of predictions by BSM models in the literature about the detectability of these primordial gravitational waves by forthcoming experiments such as LISA.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Neutrino / 207

LIQUIDating the Gallium Neutrino Anomaly

Author: Garv Chauhan[1]

Co-author: Patrick Huber

[1] *Arizona State University*

Corresponding Author: garv.chauhan@gmail.com

The Gallium Anomaly (GA) currently stands at a global significance of greater than 5σ. Most viable BSM solutions quickly run into strong tensions with reactor and solar neutrino data. In this talk, I'll argue that the GA resolution requires the ability to probe spectral features and oscillation behavior, therefore requires a new detection strategy for low-energy neutrinos. Firstly, I'll discuss the most viable and currently promising solution involving sterile neutrinos and a tuned MSW resonance. Secondly, I'll show that solar neutrino measurements based on ν-e scattering cannot probe the fine-tuned parameter regions for GA. Finally, we propose a new setup with an opaque scintillator detector such as LiquidO, to detect such narrow resonances, which can completely test the GA at more than 5σ in about 100 days with a 3.2 MCi ^{51}Cr source. We also highlight that such a unique detector will open unexplored avenues in low-energy neutrino spectroscopy.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Cosmology / 208

Primordial Black Holes from First-Order Phase Transition in the xSM

Authors: AJAY Kaladharan[None]; Yongcheng Wu[1]; dorival Gonçalves[1]

[1] *Oklahoma State University*

Corresponding Author: kaladharan.ajay@okstate.edu

Supercooled first-order phase transition (FOPT) can lead to the formation of primordial black holes (PBHs). This scenario imposes stringent requirements on the profile of the effective potential. In this work, we use the singlet extended Standard Model (xSM) as a benchmark model to investigate this possibility at the electroweak scale. The PBHs formed during a supercooled FOPT have a narrow mass distribution around the mass of Earth. This distribution is closely tied to the temperature at which the PBHs form, corresponding to the FOPT at the electroweak scale. This scenario can be probed with microlensing experiments, space-based gravitational wave detectors, and collider experiments. I will also show the possible gravitational signals due to PBH mergers in this model.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / 209

The Importance of Higgs Yukawa Measurements at the LHC: 2HDM and Beyond

Author: Duncan Rocha[1]

[1] *University of Chicago*

Corresponding Author: drocha@uchicago.edu

Since the discovery of the Higgs Boson at the Large Hadron Collider, much progress has been made in characterizing its couplings to the Electroweak bosons and the third generation of fermions. In this talk, I will discuss the LHC constraints in the leptonic sector of a flavor-violating 2HDM, a well-motivated model which is also constrained by precision measurements. I will also characterize the capabilities of future experiments, such as the HL-LHC and FCC, in constraining the 2HDM and other simple BSM extensions.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / 210

General Form of Effective Operators from Hidden Sectors

Authors: Aqeel Ahmed[1]; Can Kilic[None]; Ina Flood[2]; Saereh Najjari[None]; Zackaria Chacko[3]

[1] *Max-Planck-Institut für Kernphysik, Heidelberg*

[2] *University of Maryland College Park*

[3] *University of Maryland, College Park*

Corresponding Author: iflood@umd.edu

We perform a model-independent analysis of the dimension-six terms that are generated in the low energy effective theory when a hidden sector that communicates with the Standard Model (SM) through a specific portal operator is integrated out. We work within the Standard Model Effective Field Theory (SMEFT) framework and consider the Higgs, neutrino and hypercharge portals. We find that, for each portal, the forms of the leading dimension-six terms in the low-energy effective theory are fixed and independent of the dynamics in the hidden sector. For the Higgs portal, we find that two independent dimension-six terms are generated, one of which has a sign that, under certain conditions, is fixed by the requirement that the dynamics in the hidden sector be causal and unitary. In the case of the neutrino portal, for a single generation of SM fermions and assuming that the hidden sector does not violate lepton number, a unique dimension-six term is generated, which corresponds to a specific linear combination of operators in the Warsaw basis. For the hypercharge portal, a unique dimension-six term is generated, which again corresponds to a specific linear combination of operators in the Warsaw basis. For both the neutrino and hypercharge portals, under certain conditions, the signs of these terms are fixed by the requirement that the hidden sector be causal and unitary. We perform a global fit of these dimension-six terms to electroweak precision observables, Higgs measurements and diboson production data and determine the current bounds on their coefficients.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Astro-particle / 211

High-Energy Neutrinos from Scalar Decays in Primordial Black Hole Evaporation

Author: SUJAY SHIL[1]

[1] *University of Sao Paulo*

Corresponding Author: sujayshil1@gmail.com

We investigate the potential of evaporating primordial black holes (PBHs) as unique astrophysical sources of high-energy neutrinos originating from the decays of heavy beyond-Standard-Model (BSM) scalars. In their final stages, PBHs can attain temperatures sufficient to emit CP-even (H2), CP-odd (⊠), and charged Higgs bosons (⊠±). In specific regions of parameter space, ⊠2 and A predominantly decay into neutrinos, yielding distinctive spectral features. We compute the resulting neutrino fluxes, incorporating greybody factors and detailed kinematic distributions, and demonstrate that such signals may be observable at detectors like IceCube. These results position PBH evaporation as a promising probe of hidden scalar sectors and new physics beyond the Standard Model.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

New Developments in Theory / 212

Bubble wall velocity from Kadanoff-Baym equations: fluid dynamics and microscopic interactions

Author: Jiang Zhu[1]

[1] *University of Massachusetts-Amherst*

We establish a first principles, systematic framework for determining the bubble wall velocity during a first order cosmological phase transition. This framework, based on non-local Kadanoff-Baym equations, incorporates both macroscopic fluid dynamics and microscopic interactions between the bubble wall and particles in the plasma. Previous studies have generally focused on one of these two sources of friction pressure that govern the wall velocity. As a precursor, we utilize background field quantum field theory to obtain the relevant local Boltzmann equations, from which we derive the forces associated with variation of particle masses across the bubble wall and the microscopic wall-particle interactions. We subsequently show how these equations emerge from the Kadanoff-Baym framework under various approximations. We apply this framework in the ballistic regime to compute the new friction force arising from the $2 \to 2$ scattering processes in scalar field theory. We obtain a linear relationship between this force and the Lorentz factor γ_w that would preclude runaway bubbles with such effects.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Neutrino / 213

Old neutron stars as a new probe of relic neutrinos and sterile neutrino dark matter

Authors: Amarjit Soni[None]; Bhupal Dev[None]; Saurav Das[None]; Takuya Okawa[1]

[1] *Washington University*

Corresponding Author: o.takuya@wustl.edu

We study the kinetic cooling (heating) of old neutron stars due to coherent scattering with relic neutrinos (keV sterile neutrino dark matter) via Standard Model neutral-current interactions by taking into account coherent enhancement, gravitational clustering, neutron degeneracy, Pauli blocking and weak potential. We find that the anomalous cooling of neutron stars due to relic neutrino scattering is difficult to observe. However, the anomalous heating of neutron stars due to coherent scattering with keV-scale sterile neutrino dark matter may be observed by current and future telescopes operating in the optical to near-infrared frequency band, such as the James Webb Space Telescope (JWST), which would probe hitherto unexplored parameter space in the sterile neutrino mass-mixing plane.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / 214

Mini-Review: Update on Muon g-2: White Paper Version 2

Corresponding Author: thomas.blum@uconn.edu

Machine Learning / 215

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Machine Learning / 216

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Machine Learning / 217

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Electroweak / 218

Searches for dark sector particles at Belle and Belle II

Author: Haruki Kindo[1]

[1] *VPI/KEK*

Corresponding Author: kindo@post.kek.jp

The Belle and Belle II experiment have collected samples of e^+e^- collision data at centre-of-mass energies near the $\Upsilon(nS)$ resonances. These data have constrained kinematics and low multiplicity, which allow searches for dark sector particles in the mass range from a few MeV to 10 GeV. Using a 426 fb^{-1} sample collected by Belle II, we search for inelastic dark matter accompanied by a dark Higgs. Using a 711 fb^{-1} sample collected by Belle, we search for $B \to h + \text{invisible}$ decays, where h is a π, K, D, D_s or p, and $B \to Ka$, where a is an axion-like particle.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

New Developments in Theory / 219

Solving Contact Term Ambiguities for Massive Helicity Amplitudes

Author: Zhen Liu[1]

[1] *University of Minnesota*

Corresponding Author: zliuphys@umn.edu

Recursive constructions in amplitudes are a strong feature that requires careful analytic continuation with momentum shift to yield the full, correct, physical amplitudes. If not done systematically, an undetermined contact term would arise. We study the All-Line Transverse (ALT) shift, which we developed for on-shell recursion of amplitudes for particles of any mass. Our method allows for a nice and clean determination of the constructibility of the underlying theory. We apply the shift to the QED, electroweak theory, and higher-spin Compton scattering. The ALT shift framework allows consistent treatment in dealing with contact term ambiguities for renormalizable massive and massless theories, which we show can be useful in studying real-world amplitudes with massive spinors.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Electroweak / 220

Mini-review: Quantum Information Processing Meets Collider Physics

Corresponding Authors: ilow@northwestern.edu, ilow@anl.gov

Electroweak / 221

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Flavor / 222

-

New Developments in Theory / 223

A First Look at ”Continuous Spin” Gravity – Time Delay Signatures

Author: Shayarneel Kundu[1]

[1] *Stanford*

Corresponding Author: skundu4@stanford.edu

We consider the possibility that gravity is mediated by “continuous spin”particles, i.e. massless particles whose invariant spin scale ρg is non-zero. In this case, the primary helicity-2 modes of gravitational radiation on a Minkowski background mix with a tower of integer-helicity partner modes under boosts, with ρg controlling the degree of mixing. We develop a formalism for coupling spinless matter to continuous spin gravity at linearized level. Using this formalism, we calculate the time delay signatures induced by gravitational waves in an idealized laser interferometer detector. The fractional deviation from general relativity predictions is $O(\rho g/\omega)$ for gravitational wave frequencies $\omega > \rho g$, and the effects of waves with ω ⊠ ρg are damped.

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Flavor / 224

-

Astro-particle / 225

Mini-Review: Novel Astrophysical Probes of the Dark Universe

Corresponding Author: hongwan@bu.edu

Flavor / 226

Measurements of τ decays at Belle and Belle II

Author: Vladimir Savinov[1]

[1] *University of Pittsburgh*

Corresponding Author: vladimirsavinov@gmail.com

TBA

Mini Symposia (Invited Talks Only):

Plenary (Invited talks only):

Plenary / **227**

Recent Results from DESI and Precision Cosmology

Plenary / **228**

Recent Results from DESI and Precision Cosmology

Plenary / **229**

Physics with Deep Underground Dark Matter Detectors

Corresponding Author: jianglai.liu@sjtu.edu.cn

Plenary / **230**

Phenomenological Cosmology

Corresponding Author: karwaltanvi@gmail.com

Plenary / **231**

Selected Results from LHCb

Corresponding Author: michael.k.wilkinson@cern.ch

Plenary / **232**

Heavy Flavor Physics

Corresponding Author: mpapucci@caltech.edu

Plenary / 233

Deep Learning in Particle Physics

Corresponding Author: claudius.krause@oeaw.ac.at

Plenary / 234

Recent LHC Results

Corresponding Author: philip.chang@cern.ch

Plenary / 235

HL-LHC and Future Perspectives

Corresponding Author: alessandro.tricoli@cern.ch

Plenary / 236

BSM Higgs Physics

Corresponding Author: kanemu@het.phys.sci.osaka-u.ac.jp

Plenary / 237

Physics at IceCube

Corresponding Author: halzen@icecube.wisc.edu

Plenary / 238

Gravitational Waves and the Early Universe

Corresponding Author: sk5348@nyu.edu

Plenary / 239

New Technologies in Probing Dark Sectors

Corresponding Author: aberlin@fnal.gov

Plenary / 240

Recent Results in Neutrino Physics

Corresponding Author: jessie.micallef@tufts.edu

Plenary / 241

Theories of Neutrino Masses

Corresponding Author: ibarra@tum.de

Plenary / 242

Noninvertible Symmetry in Particle Physics

Corresponding Author: htlam@mit.edu

Plenary / 243

Physics at the EIC

Corresponding Author: hewett@slac.stanford.edu

Plenary / 244

Physics at Future Colliders: Higgs and Beyond

Corresponding Author: shomiller@cornell.edu

Plenary / 245

Discovery Opportunities in High Energy Physics

Corresponding Author: rschivukula@ucsd.edu