CETUP* 2024

Monday, June 17, 2024 - Friday, July 19, 2024

Lead/Deadwood Middle School

THE INSTITUTE
FOR UNDERGROUND SCIENCE
AT SURF

Book of Abstracts

Contents

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Charged-current (anti)neutrino-nucleon scattering and QED nuclear medium effects

Author: Oleksandr Tomalak[1]

[1] *Los Alamos National Laboratory*

Corresponding Author: tomalak@lanl.gov

Charged-current quasielastic neutrino scattering is the signal process in neutrino oscillation experiments and requires precise theoretical prediction for the analysis of modern and future experimental data, starting with the nucleon axial-vector form factor. In this talk, I compare a new MINERvA measurement of this form factor with lattice-QCD calculations and deuterium bubble- chamber data, provide uncertainty projections for future extractions, present recent calculations of radiative corrections to charged-current processes, and investigate the potential of neutrino scattering data on constraining nucleon- and quark-level interactions beyond the Standard Model.
The exchange of photons with nuclear medium modifies (anti)neutrino and electron scattering cross sections. We study the distortion of (anti)neutrino-nucleus and charged lepton-nucleus cross sections, medium-induced bremsstrahlung, and estimate the QED-medium effects on the final- state kinematics and scattering cross sections. We find new permille-to-percent level effects, which were never accounted for in either (anti)neutrino-nucleus or electron-nucleus scattering. We quantitatively compute the effects of Glauber photon-mediated multiple re-scattering within the nuclear medium and find that the relativistic charged lepton acquires a momentum of order 10 MeV transverse to its direction of propagation inside the nucleus. This broadening sizably deflects expected electron and muon tracks and suppresses scattering cross sections. Precise extraction of the nucleon and nuclear structure by electron and muon probes should, thus, take the QED nuclear medium angular redistribution of particles into account.

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New Directions for ALP Searches Combining Nuclear Reactors and Haloscopes

Author: Vedran Brdar[1]

[1] *Oklahoma State University*

Corresponding Author: vedran.brdar@okstate.edu

I will discuss a recently proposed novel experimental setup for axion-like particle (ALP) searches. Nuclear reactors produce a copious number of photons, a fraction of which could convert into ALPs via the Primakoff process in the reactor core. The generated flux of ALPs leaves the nuclear power plant, and its passage through a region with a strong magnetic field results in efficient conversion to photons, which can be detected. Such a magnetic field is the key component of axion haloscope experiments. I will discuss existing setups featuring an adjacent nuclear reactor and axion haloscope and I will demonstrate that the obtained sensitivity projections complement constraints from existing laboratory experiments, e.g., light-shining-through-walls.

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CP-Violation with Neutrino Disappearance

Author: Peter Denton[1]

[1] *Brookhaven National Laboratory*

Corresponding Author: peterbd1@gmail.com

The best way to probe CP violation in the lepton sector is with long-baseline accelerator neutrino experiments in the appearance mode: the appearance of ν_e in predominantly ν_μ beams. Here we show that it is possible to discover CP violation with disappearance experiments only, by combining JUNO for electron neutrinos and DUNE or Hyper-Kamiokande for muon neutrinos. While the maximum sensitivity to discover CP is quite modest (1.6σ with 6 years of JUNO and 13 years of DUNE), some values of δ may be disfavored by $> 3\sigma$ depending on the true value of δ.

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Dark matter annihilation signals from Sagittarius analogues

Author: Nassim Bozorgnia[1]

[1] *University of Alberta*

Corresponding Author: nbozorgnia@ualberta.ca

Dwarf spheroidal galaxies such as Sagittarius are dark matter dominated, and therefore unique candidates for indirect dark matter searches. In order to accurately predict the dark matter annihilation signal from dwarf spheroidal galaxies, it is crucial to correctly model the phase space distribution of dark matter in them. Hydrodynamical simulations of galaxy formation provide important information on the dark matter distribution in dwarf spheroidal analogues. I will present the dark matter density profile and velocity distribution of the Sagittarius dwarf spheroidal galaxy extracted from state-of-the-art hydrodynamical simulations. In addition to the annihilation signals from dark matter particles bound to Sagittarius, we consider for the first time the annihilation of dark matter particles bound to the Milky Way that overlap spatially with Sagittarius. I will discuss the implications of this dark matter population for velocity-dependent dark matter annihilation models.

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Dark matter at the high mass frontier

Author: Joe Bramante[1]

[1] *Queen's University*

Corresponding Author: joseph.bramante@queensu.ca

A number of theories predict that dark matter is a supermassive particle or composite state. Discovering dark matter in this high mass regime requires different approaches. I will survey recent developments, including composite dark matter that produces unique signatures in underground experiments and dark matter detectable through thermonuclear reactions in Antarctic ice. I will also survey certain experiments from the 80s and 90s, which still provide the best sensitivity to many varieties of high mass dark matter.

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New Constraints on Neutrino-Dark Matter Interactions

Author: Bhupal Dev[1]

[1] *Washington University in St. Louis*

Corresponding Author: bdev@wustl.edu

We present a comprehensive analysis of nonstandard neutrino interactions with the dark sector in an effective field theory framework. We implement a full catalog of constraints on the parameter space of the neutrino-dark matter/mediator couplings and masses, including bounds coming from cosmology, astrophysics, as well as new laboratory constraints, such as from invisible Z decays and rare meson decays. We find that most of the benchmarks in the dark matter mass-coupling plane adopted in previous studies to get an observable effect are actually ruled out by a combination of these constraints. Finally, as an application of our results, we consider the case of galactic supernova neutrinos, identify new benchmark points for future observational prospects of the attenuation of the galactic supernova neutrino flux, compute the full set of cascade equations and sky maps for different dark matter density profiles in the Galaxy, and comment on their implications for the detection prospects in future large-volume neutrino experiments such as DUNE, Hyper-K and JUNO.

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Gravitational Wave Symphony from Oscillating Spectator Scalar Fields

Author: Yanou Cui[None]

Corresponding Author: yanou.cui@ucr.edu

Spectator scalar fields can be generically present in the early Universe,
and are potentially dark matter candidates. We investigate the prospect of such scalars loop as a generic source of stochastic gravitational wave background (SGWB) due to parametric resonance during their oscillation phase. By systematically analyzing
benchmark models through lattice simulations and considering a wide range of parameters, we demonstrate that such a scenario can lead to detectable signals in GW detectors over a broad frequency range and potentially address the recent findings by Pulsar Timing Array experiments. Furthermore, we show that these models naturally yield viable ultra-light, wave-like dark matter candidates and/or dark radiation detectable by CMB observatories. We also explore the potential for realizing low-scale baryogenesis from such an oscillating scalar system and the resultant detectable SGWB signals. This study highlights an intriguing connection between the stochastic gravitational wave background (SGWB) and terrestrial probes for low-energy new particle physics.

Request to give talk on Wednesday, July 3 in the afternoon

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Neutrinos from the Sun can discover dark matter-electron scattering

Author: Ranjan Laha[1]

[1] *Indian Institute of Science, Bengaluru, India*

Corresponding Author: ranjanlaha@iisc.ac.in

We probe dark matter-electron scattering using high-energy neutrino observations from the Sun. Dark matter (DM) interacting with electrons can get captured inside the Sun. These captured DM may annihilate to produce different Standard Model (SM) particles. Neutrinos produced from these SM states can be observed in IceCube and DeepCore. Although there is no excess of neutrinos from the Solar direction, we find that the current data-sets of IceCube and DeepCore set the strongest constraint on DM-electron scattering cross section in the DM mass range 10 GeV to 10^5 GeV. Our

work implies that future observations of the Sun by neutrino telescopes have the potential to discover DM-electron interaction.

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TALK: Dark Radiation Isocurvature from Cosmological Phase Transitions

Corresponding Author: peizhi.du@rutgers.edu

Speaker: Peizhi Du (Rutgers University)
Authors: Matthew Buckley, Peizhi Du, Nicolas Fernandez, Mitchell Weikert

Cosmological first-order phase transitions are typically associated with physics beyond the Standard Model, and thus of great theoretical and observational interest. In this talk, I will show that a broad class of non-thermal first-order phase transitions could generate distinct large-scale isocurvature in dark radiation that can be observable in the CMB. We derive constraints on ___ from phase transitions based on CMB+BAO data, which can be much stronger than that from adiabatic initial conditions. I will also demonstrate that since perturbations of dark radiation have a non-Gaussian origin, searches for non-Gaussianity in the CMB could also place a stringent bound on ___.

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Welcome by Mike Headley, Executive Director, South Dakota Science and Technology Authority/SURF

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The Institute for Underground Science at SURF Overview and Update (room 132)

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Discussion, Collaborations and Lunch

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TALK: Dark matter at the high mass frontier

Corresponding Author: joseph.bramante@queensu.ca

Author: Joe Bramante
A number of theories predict that dark matter is a supermassive particle or composite state. Discovering dark matter in this high mass regime requires different approaches. I will survey recent developments, including composite dark matter that produces unique signatures in underground experiments and dark matter detectable through thermonuclear reactions in Antarctic ice. I will also survey certain experiments from the 80s and 90s, which still provide the best sensitivity to many varieties of high mass dark matter.

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Discussion and Collaboration

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Shuttle Pickup for Underground Tour - Travel to SURF Yates Admin, 2nd Floor Vault

Pick up at the Middle School

This shuttle is only for the CETUP* participants that are going on the underground tour. Other participants not going on the tour will be able to stay at the Middle School and continue to work and carry on discussions.

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SURF Overview by Markus Horn, Research Scientist, South Dakota Science and Technology Authority/Laboratory Director, SURF

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SURF Underground Tour Safety Training, Waivers, Lunch at 11:00am, PPE, Shuttle to Ross

Corresponding Authors: lbaatz@sanfordlab.org, jmolina@sanfordlab.org

Only the CETUP* participants that are going on the underground tour will attend. Other participants not going on the tour will be able to stay at the Middle School and continue to work and carry on discussions.

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Shuttle, PPE, Return to Middle School

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TALK: Dark Matter Annihilation Signals from Sagittarius Analogues

Corresponding Author: nbozorgnia@ualberta.ca

Author: Nassim Bozorgnia
Dwarf spheroidal galaxies such as Sagittarius are dark matter dominated, and therefore unique candidates for indirect dark matter searches. In order to accurately predict the dark matter annihilation signal from dwarf spheroidal galaxies, it is crucial to correctly model the phase space distribution of

dark matter in them. Hydrodynamical simulations of galaxy formation provide important information on the dark matter distribution in dwarf spheroidal analogues. I will present the dark matter density profile and velocity distribution of the Sagittarius dwarf spheroidal galaxy extracted from state-of-the-art hydrodynamical simulations. In addition to the annihilation signals from dark matter particles bound to Sagittarius, we consider for the first time the annihilation of dark matter particles bound to the Milky Way that overlap spatially with Sagittarius. I will discuss the implications of this dark matter population for velocity-dependent dark matter annihilation models.

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TALK: (Speaker: Pearl Sandick)

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Discussions, Collaboration, and Lunch

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TALK: TBD (open slot available)

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Discussions and Collaboration

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Constraining Dwarf Galaxy Dark Matter Distributions: Spherical Jeans Analyses for Line-of-Sight and 3D Velocity Data

Corresponding Author: isgoldstein@tamu.edu

Author: Isabelle Goldstein
Co-author: Louie Strigari
The stellar kinematics in dwarf galaxies can provide a wealth of information about its underlying dark matter distribution. Using line of sight velocity measurements for six classical dwarf galaxies of the Milky Way, we study whether ultralight bosonic dark matter is consistent with the gravitational potential extracted from stellar kinematics. It shows that axion-like particles with masses of order _____ eV are inconsistent with the potential distribution in classical dwarf galaxies unless the hierarchical assembly of the Milky Way did not trace the mean evolution of Milky Way size halos. We also explore the use of three dimensional velocity measurements from Gaia data in spherical Jeans analyses to further constrain dark matter distributions.

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TALK: TBD (open slot available)

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Discussions and Collaboration

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Travel to Ethnobotanical Garden at SURF (via shuttle)

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Guest Speaker at the Ethnobotanical Gardens (Speaker: Rochelle Zens)

Corresponding Author: rzens@sanfordlab.org

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Travel to Middle School

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Discussions and Collaboration

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TALK: Analytic Results on Dark Matter Velocity Distributions

Corresponding Author: jkumar@hawaii.edu

Author: Jason Kumar
We review recent work on determining dark matter velocity distributions from analytic methods of classical mechanics, and the potential impact of these results on dark matter indirect detection strategies. In particular, we discuss velocity-dependent dark matter annihilation in subhalos and in the Galactic Center. We compare the results of these analytic methods to those obtained in large N numerical simulations, and discuss future work.

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TALK: Probing Neutrinophilic Dark Matter: From Colliders to Supernovae

Corresponding Author: dtuckler@triumf.ca

Author: Douglas Tuckler
New beyond-the-Standard Model mediators that couple predominantly to neutrinos are not yet probed by existing experimental searches. Such a neutrinophilic mediator is well motivated for addressing the origin of several neutrino-portal dark matter candidates, including thermal freeze-out and sterile-neutrino dark matter scenarios. In this talk, we explore the sensitivity to this scenario from two different approaches. In the first part of the talk we will explore the potential of the Forward Physics Facility (FPF) using the so-called "mono-neutrino signature": neutrino charged-current scattering events associated with large missing transverse momentum, and excessive apparent tau-neutrino events. We will show that with this smoking-gun signature, the FPF has excellent sensitivity to probe this model in new regions of parameter space. the In the second part of the talk we focus on astrophysical constraints on sterile neutrino DM, namely from core-collapse supernovae. Production and emission of DM can result in excessive energy loss of the supernova, leading to additional cooling. We will show that supernova cooling can constrain new regions of parameter space that complements terrestrial and cosmological probes. The results of this work present a nice complementarity among the collider and astrophysical frontiers.

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Discussion, Collaboration, and Lunch

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TALK: Decoding the Mystery of Dark Matter with Celestial Objects (Speaker: Anupam Ray)

Corresponding Author: anupam.ray@berkeley.edu

Dark Matter (DM) remains mysterious. Despite decades of experimental and theoretical efforts, its microscopic identity is still unknown to us. In this talk, I will walk you through how a variety of celestial objects can be utilised as powerful DM detectors. This astrophysical probe, complementary to the terrestrial and cosmological probes, covers a significant portion of the DM parameters (DM mass and its interaction strength with nucleons) which are otherwise remains elusive.

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TALK: Thermal Axion and Dark Radiation

Corresponding Author: fazlollah.hajkarim@ou.edu

Author: Fazlollah Hajkarim
We provide a comprehensive analysis of thermal axion production in the early universe, focusing on the KSVZ and DFSZ models. We extend our calculations to incorporate multiple mass thresholds, including the QCD phase transition, and provide a continuous production rate across these regimes. Employing updated cosmological data, we refine constraints on axion mass and examine the implications for dark radiation quantified as an effective number of additional neutrino species (ΔNeff). Our rigorous approach revisits traditional approximations in axion production, highlighting the importance of precise calculations in anticipation of future CMB surveys and large scale structure observations. Also, we examine the validity of different computational approaches for the calculation of effective number of additional neutrino species.

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TALK: The Power of the Dark Sink

Corresponding Author: rmcgehee@umn.edu

Author: Robert McGehee
We describe a simple dark sector structure which, if present, has implications for the direct detection of dark matter (DM): the Dark Sink. A Dark Sink transports energy density from the DM into light dark-sector states that do not appreciably contribute to the DM density. As an example, we consider a light, neutral fermion which interacts solely with DM via the exchange of a heavy scalar . We illustrate the impact of a Dark Sink by adding one to a DM freeze-in model in which couples to a light dark photon
which kinetically mixes with the Standard Model (SM) photon. This freeze-in model (absent the sink) is itself a benchmark for ongoing experiments. In some cases, the literature for this benchmark has contained errors; we correct the predictions and provide them as a public code. We then analyze how the Dark Sink modifies this benchmark, solving coupled Boltzmann equations for the dark-sector energy density and DM yield. We check the contribution of the Dark Sink ‘s to dark radiation; consistency with existing data limits the maximum attainable cross section. For DM with a mass between , adding the Dark Sink can increase predictions for the direct detection cross section all the way up to the current limits.

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Discussions, Collaboration, and Lunch

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TALK: Jet-SIFTing for Dark Sector Physics in a Hidden Valley

Corresponding Author: jww004@shsu.edu

Author: Joel Walker
We consider a Hidden Valley model which generates showering from strong dynamics within the dark sector followed by decays back into Standard Model states. Our interest is the limit of smaller dark pion masses, which create a high multiplicity of final states. The reconstruction of dark sector masses in such a setting is obscured by a thick combinatoric background. We apply the new SIFT (Scale-Invariant Filtered Tree) jet clustering algorithm to the reconstruction of simulated events of this type. By cutting an ordered slice through possible recombinations, the SIFT algorithm may help lift backgrounds of the described variety.

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Discussion and Collaboration

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TALK: SPLENDOR: Narrow-gap Quantum Materials for Light Dark Matter

Corresponding Author: yfkahn@illinois.edu

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TALK: SPLENDOR: narrow-gap quantum materials for light dark matter

Corresponding Author: yfkahn@illinois.edu

Author: Yonatan Kahn
Low-mass direct detection experiments based on conventional semiconductors such as silicon and germanium are achieving impressive sensitivity for dark matter masses above 1 MeV. However, to probe dark matter-electron scattering via electronic excitations for even lighter dark matter masses, more exotic materials with sub-eV band gaps are required. I will give an overview of the SPLENDOR program, which aims to develop a prototype detector for keV-MeV dark matter based on narrow-gap quantum materials. This research program involves close interdisciplinary collaboration with condensed matter theorists and experimentalists, in all stages from detector material synthesis to determining the experimental sensitivity via the density response function.

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Shuttle to Middle School for Discussion and Collaboration

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TALK: TBD

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Discussion and Collaboration

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TALK: Dynamical Generation of the Baryon Asymmetry from a Scale Hierarchy

Corresponding Author: jhchang@fnal.gov

Authors: Jae Hyeok Chang, Kwang Sik Jeong, Chang Hyeon Lee, Chang Sub Shin
We propose a novel baryogenesis scenario where the baryon asymmetry originates directly from a hierarchy between two fundamental mass scales: the electroweak scale and the Planck scale. Our model is based on the neutrino-portal Affleck-Dine (AD) mechanism, which generates the asymmetry of the AD sector during the radiation-dominated era and subsequently transfers it to the baryon number before the electroweak phase transition. The observed baryon asymmetry is then a natural outcome of this scenario. The model is testable as it predicts the existence of a Majoron with a keV mass and an electroweak scale decay constant. The impact of the relic Majoron on $\Delta N_{\rm eff}$ can be measured through near-future CMB observations.

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TALK: Gauged global strings

Corresponding Author: weixue@ufl.edu

Author: Wei Xue
I will present the string solutions and cosmological implications of the gauge U(1)Z × global U(1)PQ model. With two hierarchical symmetry-breaking scales, the model exhibits three distinct string solutions: a conventional global string, a global string with a heavy core, and a gauge string as a bound state of the two global strings. This model reveals rich phenomenological implications in cosmology. When incorporating this model with the QCD axion framework, the heavy-core global strings emit more axion particles due to their large tension. This radiation significantly enhances the QCD axion dark matter abundance, thereby opening up the QCD axion mass window. Furthermore, in contrast to conventional gauge strings, the gauge strings in this model exhibit a distinctive behavior, radiating axions.

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Discussion, Collaboration, and Lunch

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TALK: Cosmic Stability of Dark Matter from Pauli Blocking

Corresponding Author: batell@pitt.edu

Why does dark matter (DM) live longer than the age of the Universe? Here we study a novel sub-eV scalar DM candidate whose stability is due to the Pauli exclusion of its fermionic decay products. We analyze the stability of the DM condensate against decays, scatterings (i.e., evaporation), and parametric resonance, delineating the viable parameter regions in which DM is cosmologically stable. In a minimal scenario in which the scalar DM decays to a pair of new exotic fermions, we find that scattering can populate an interacting thermal dark sector component to energies far above the DM mass. This self-interacting dark radiation may potentially alleviate the Hubble tensions. Furthermore, our scenario can be probed through precise measurements of the halo mass function or the masses of dwarf spheroidal galaxies since scattering prevents the DM from becoming too dense. On the other hand, if the lightest neutrino stabilizes the DM, the cosmic neutrino background can be significantly altered from the standard cosmology and thus be probed in the future by cosmic neutrino background detection experiments.

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Discussion and Collaboration

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TALK: BSM Physics with Gravitational Wave Detectors

Corresponding Author: kuver.sinha@ou.edu

Author: Kuver Sinha
Future gravitational wave detectors probing the mHz - nHz frequency range will provide a unique opportunity for BSM physicists to study new physics. Neutron star and white dwarf mergers can serve as axion probes, while extreme mass ratio inspirals can constrain dark forces. Gravitational wave detectors will also probe early first order phase transitions. I will discuss some ongoing work and future ideas in these directions.

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Discussion, Collaboration, and Lunch

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TALK: Cosmological Stasis and Its Realization from Dynamical Scalars

Corresponding Author: thomasbd@lafayette.edu

Author: Brooks Thomas
Co-authors: Keith R. Dienes, Lucien Heurtier, Fei Huang, Timothy M. P. Tait
It has recently been realized that many extensions of the Standard Model give rise to cosmological histories exhibiting extended epochs of cosmological stasis —epochs wherein the abundances of multiple energy components (such as matter, radiation, or vacuum energy) remain effectively constant despite cosmological expansion. The emergence of a stasis epoch is not a consequence of fine-tuning in cosmologies of this sort; rather, stasis turns out to be a global attractor toward which the universe naturally evolves for a broad range of initial conditions. In this talk, I shall review the general conditions under which stasis emerges in such scenarios and explore some of its potential implications for cosmological observables such as the matter power spectrum and the stochastic gravitational-wave background. I shall also discuss a particular realization of stasis involving a collection of scalar fields, each of which dynamically transitions from a period of slow roll to a period of rapid oscillation around its potential minimum as the universe expands. As I shall demonstrate, not only does cosmological stasis arise in such scenarios, but the system of dynamical scalars also exhibits novel features not seen in previous realizations of stasis, including a tracking behavior wherein the effective equation of state for the universe as a whole evolves toward the equation of state of this energy component. The emergence of such tracking behavior has potential model-building implications in the context of dark-energy and cosmic-inflation scenarios.

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TALK: Updates on the Migdal effect and hydrogen doping for dark matter detection

Corresponding Author: jayden.newstead@unimelb.edu.au

Author: Jayden Newstead
An ongoing challenge in dark matter direct detection is to improve the sensitivity to light dark mat-

ter in the MeV–GeV mass range. One proposal is to dope a liquid noble-element direct-detection experiment with a lighter element such as hydrogen. This has the advantage of enabling larger recoil energies compared to scattering on a heavy target, while leveraging existing detector technologies. Direct-detection experiments can also extend their reach to lower masses by exploiting the Migdal effect, where a nuclear recoil leads to electronic ionization or excitation. In this work, we combine these ideas to study the sensitivity of a hydrogen-doped LZ experiment (HydroX) and a future large-scale experiment such as XLZD. We find that HydroX could have sensitivity to dark matter masses below 10 MeV for both spin-independent and spin-dependent scattering, with XLZD extending that reach to lower cross sections. Notably, this technique substantially enhances the sensitivity of direct detection to spin-dependent proton scattering, well beyond the reach of any current experiments.

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Discussion and Collaboration

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TALK: Dark Matter Raining on DUNE and Other Large Volume Detectors

Corresponding Author: joshua.berger@colostate.edu

Authors: Javier Acevedo, Joshua Berger, Peter Denton
Direct detection is a powerful means of searching for particle physics evidence of dark matter (DM) heavier than about a GeV with volume, low-threshold detectors.
In many scenarios, some fraction of the DM may be boosted to large velocities enhancing and generally modifying possible detection signatures. We investigate the scenario where 100\% of the DM may be boosted at the Earth due to new attractive long-range forces. This opens up two main improvements in detection capabilities: 1) the detection signatures are stronger opening up large-volume neutrino detectors, such as DUNE, Super-K, Hyper-K, and JUNO, as possible DM detectors, and 2) the large boost allows for detectable signatures of sub-GeV DM. At lower boosts, a modified, higher-than-usual energy signal could be accessible at direct detection experiments such as LZ. In addition, the model leads to a significant anisotropy in the signal with the DM flowing dominantly vertically at the Earth's surface instead of the typical approximately isotropic DM signal. We develop the theory behind this model and also calculate realistic constraints using a detailed GENIE simulation of the signal inside detectors.

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TALK: Gravitational Waves from Cosmic Superstrings and Gauge Strings

Corresponding Author: gnaoiypb@duck.com

Author: Danny Marfatia
We perform a phenomenological comparison of the gravitational wave spectrum expected from cosmic gauge string networks and superstring networks comprised of multiple string types.

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Discussion, Collaboration, and Lunch

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TALK: Introduction to DAMSA, A Novel Dark Matter Search Experiment at an Accelerator

Corresponding Author: jaehoonyu@uta.edu

Dark matter is thought to make up 25% of the universe. Dark sector particles (DSP) do not interact through the known forces but could be weakly coupled to Standard Model particles through a portal or a mediator. Many searches for dark matter/dark sector particles at an accelerator thus far seem to face a ceiling that the sensitivity reach is greatly limited, beyond statistical effects. DAMSA is an extremely short baseline experiment at proposes to break through this limit, taking advantage of high beam powers available at various accelerator facilities around the world, including the PIP-II Linac under construction, an essential element in providing the necessary high flux proton beams to DUNE at Fermilab. In this talk, I will describe the DAMSA (Dump produced Aboriginal Matter Search at an Accelerator) experiment. I will also discuss current status and plan for DAMSA and its expected sensitivity reach in the search of the Axion-Like Particle as an example physics case.

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Discussion and Collaboration

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TALK: Dark Matter in the Time of Gravitational Waves

Corresponding Author: tao.xu@ou.edu

The observation of gravitational waves opens a new window for exploring astrophysics and cosmology. These messengers enable the concurrent measurement of their amplitudes and phases, facilitating a precise analysis of gravitational wave production and propagation. In this talk, I will demonstrate how gravitational waves can be utilized to study the properties of dark matter. Specifically, I will use wave dark matter as an example to show that gravitational waveforms, along with further multi-messenger observations involving photon signals, reveal distinctive features. These features can be probed with the ongoing LIGO and upcoming LISA missions.

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TALK: Probing self-interacting sterile neutrino dark matter with the diffuse supernova neutrino background

Corresponding Author: asuliga@berkeley.edu

Author: Anna Suliga
Co-authors: Baha Balantekin, George Fuller, Anupam Ray
The neutrinos in the diffuse supernova neutrino background (DSNB) travel over cosmological distances and this provides them with an excellent opportunity to interact with dark relics. We show that a cosmologically-significant relic population of keV-mass sterile neutrinos with strong self-interactions could imprint their presence in the DSNB. The signatures of the self-interactions would be "dips" in the otherwise smooth DSNB spectrum. Upcoming large-scale neutrino detectors, for example Hyper-Kamiokande, have a good chance of detecting the DSNB and these dips. If no dips are detected, this method serves as an independent constraint on the sterile neutrino self-interaction strength and mixing with active neutrinos. We show that relic sterile neutrino parameters that evade X-ray and structure bounds may nevertheless be testable by future detectors like TRISTAN, but may also produce dips in the DSNB which could be detectable. Such a detection would suggest the existence of a cosmologically-significant, strongly self-interacting sterile neutrino background, likely embedded in a richer dark sector.

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Discussion, Collaboration, and Lunch

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TALK: Introduction to DAMSA, A Novel Dark Matter Search Experiment at an Accelerator

Corresponding Author: jaehoonyu@uta.edu

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Discussion and Collaboration

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TALK: Journey with Sourced Millicharged Particles and Dark Photons

Corresponding Author: zliuphys@umn.edu

Author: Zhen Liu
Hidden symmetries are widely prevalent across numerous new physics models and have garnered significant attention. These symmetries give rise to intriguing testable phenomena, such as "dark photons" as the force mediators and "millicharged" particles representing the matter content. A diverse range of physics experiments and search strategies have been developed to investigate these phenomena. In this talk, I will discuss my recent work in exploring these elusive particles, covering both theoretical foundations and experimental results. I will focus on the unique aspects of controlled search approaches, where we actively source the fields under investigation and discuss the future prospects in this exciting research area.

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TALK: Asymptotically Free E_6 GUT and the Generation of Neutrino Mass

Corresponding Author: vasja.susic@lnf.infn.it

Author: Vasja Susič
Co-authors: K.S Babu, Borut Bajc

Grand Unified Theories (GUTs) represent an attractive possibility of physics beyond the Standard Model, with implications for both proton decay and neutrinos. The most studied examples are based on unified groups SU(5) and SO(10), while the exceptional case
remains less understood. In an asymptotically free GUT, model building is essentially limited to the use of irreducible representations of dimension 27 and 78 (the fundamental and the adjoint). I will present ongoing work in non-supersymmetric models regarding the determination of the necessary ingredients for both GUT symmetry breaking and a realistic Yukawa sector. Special attention will be given to the peculiarities associated with neutrino mass generation in this type of models.

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Discussion, Collaboration, and Lunch

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TALK: TALK: Gravitational Wave Symphony from Oscillating Spectator Scalar Fields

Corresponding Author: yanou.cui@ucr.edu

Spectator scalar fields can be generically present in the early Universe, and are potentially dark matter candidates. We investigate the prospect of such scalars loop as a generic source of stochastic gravitational wave background (SGWB) due to parametric resonance during their oscillation phase. By systematically analyzing benchmark models through lattice simulations and considering a wide range of parameters, we demonstrate that such a scenario can lead to detectable signals in GW detectors over a broad frequency range and potentially address the recent findings by Pulsar Timing Array experiments. Furthermore, we show that these models naturally yield viable ultra-light, wave-like dark matter candidates and/or dark radiation detectable by CMB observatories. We also explore the potential for realizing low-scale baryogenesis from such an oscillating scalar system and the resultant detectable SGWB signals. This study highlights an intriguing connection between the stochastic gravitational wave background (SGWB) and terrestrial probes for low-energy new particle physics.

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Discussion and Collaboration

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TALK: Probing Baryon Number Violation in Neutron Stars

Corresponding Author: rouzbeh@unm.edu

Author: Rouzbeh Allaverdi
I start by presenting minimal extensions of the Standard Model that accommodate low-scale baryogenesis. These models involve fermion singlets with baryon-number-violating couplings to quarks. Then I briefly discuss the consequences of these models for low energy and high energy experiments. Finally, I mention how neutron stars can be used to tightly constrain such interactions for GeV scale fermions.

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TALK: TBD (open slot available)

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Discussion, Collaboration, and Lunch

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TALK: Does the Sun Have a Dark Disk?

Corresponding Author: m.zakeri@uky.edu

The Sun's oblateness has been measured using optical observations. Its gravitational quadrupole moment has been deduced through helioseismology and measurements of its gravitational effects on Mercury's orbit. The distribution of mass within Mercury's orbit would only impact the orbital determination, suggesting that discrepancies among various types of assessments may indicate the possible existence of a non-luminous mass. For the first time, we have developed a method to combine these differing measurements to yield new, highly sensitive constraints on the mass distribution within Mercury's orbit. In this talk, we will show that the most precise measurements indicate the existence of a non-luminous disk within Mercury's orbit, with a mass significantly heavier than the modeled mass for the circumsolar dust ring observed by the Solar TErrestrial RElations Observatory (STEREO) mission. This suggests a substantial dark matter contribution. Furthermore, the long-standing inconsistency between the element abundances determined from the spectroscopy of the Sun's surface, and those inferred from its interior through helioseismology, can be reconciled if the Sun formed within a protoplanetary disk. We will discuss how our findings limit the presence of a dark disk or a spherical halo near the Sun and highlight the potential of future orbital measurements of Mercury and near-Sun asteroids to refine these constraints further.

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Discussion and Collaboration

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TALK: TBD (open slot available)

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TALK: TBD (open slot available)

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Discussion, Collaboration, and Lunch

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Independence Day Festivities in Lead

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TBD (open slot available)

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TALK: Neutrino-nucleus interactions and the quest for new and precision physics searches in neutrino experiments

Corresponding Author: vpandey@fnal.gov

Current and future accelerator-based neutrino facilities utilizing intense neutrino beams and advanced neutrino detectors are focused on precisely determining neutrino oscillation properties and signals of weakly interacting Beyond the Standard Model (BSM) physics. Neutrino-nucleus interactions constitute one of the biggest systematics hurdle in these endeavors. This talk will focus on neutrinos spanning from tens of MeV to a few GeV energies, where neutrino interactions present a formidable multi-scale, multi-process challenge that traverses uncharted territories, encompassing low-energy nuclear physics to perturbative Quantum Chromodynamics without a known unified framework. The presentation will provide an encompassing overview of the field, spotlighting the inherent challenges associated with neutrino interactions in this energy range as well as highlight recent progress and present some examples of ongoing cross-community efforts tackling such a problem.

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Discussion, Collaboration, and Lunch

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TALK: From Neutrinos to Multimessenger Targets for Discovering New Quantum Fields

Corresponding Author: vtakhist@post.kek.jp

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Discussion and Collaboration

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The Institute for Underground Science at SURF Update

162

TALK: CP - Violation with Neutrino Disappearance

Corresponding Author: peterbd1@gmail.com

The best way to probe CP violation in the lepton sector is with long-baseline accelerator neutrino experiments in the appearance mode: the appearance of ν_e in predominantly ν_μ beams. Here we show that it is possible to discover CP violation with disappearance experiments only, by combining JUNO for electron neutrinos and DUNE or Hyper-Kamiokande for muon neutrinos. While the maximum sensitivity to discover CP is quite modest (1.6σ with 6 years of JUNO and 13 years of DUNE), some values of δ may be disfavored by $>3\sigma$ depending on the true value of δ.

163

Discussion, Collaboration, and Lunch

164

TALK: A 17 MeV pseudoscalar and the MiniBooNE, LSND and ATOMKI anomalies

In the absence of any new physics signals at the Large Hadron Collider (LHC), anomalous results at low energy experiments have become the subject of increased attention and scrutiny. We focus on three such results from the LSND, MiniBooNE (MB), and ATOMKI experiments. A 17 MeV pseudoscalar mediator can account for the excess events seen in 8Be and 4He pair creation transitions in ATOMKI. We incorporate this mediator in a gauge invariant extension of the Standard Model (SM) with a second Higgs doublet and three singlet (seesaw) neutrinos (Ni , i = 1, 2, 3). N1,2 participate in an interaction in MB and LSND which, with a ′ as mediator, leads to the production of e +e − pairs. The Ni also lead to mass-squared differences for SM neutrinos in agreement with global oscillation data. We first show that such a model offers a clean and natural joint solution to the MB and LSND excesses. We then examine the possibility of a common solution to all three anomalies. Using the values of the couplings to the quarks and electrons which are required to explain pair creation nuclear transition data for 8Be and 4He in ATOMKI, we show that these values lead to excellent fits for MB and LSND data as well, allowing for a common solution. We discuss the constraints and future tests of our proposal.

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Discussion and Collaboration

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TALK: Charged-current (anti)neutrino-nucle on Scattering and QED Nuclear Medium

Corresponding Author: tomalak@lanl.gov

Author: Oleksandr Tomalak
Charged-current quasielastic neutrino scattering is the signal process in neutrino oscillation experiments and requires precise theoretical prediction for the analysis of modern and future experimental data, starting with the nucleon axial-vector form factor. In this talk, I compare a new MINERvA measurement of this form factor with lattice-QCD calculations and deuterium bubble- chamber data, provide uncertainty projections for future extractions, present recent calculations of radiative corrections to charged-current processes, and investigate the potential of neutrino scattering data on constraining nucleon- and quark-level interactions beyond the Standard Model. The exchange of photons with nuclear medium modifies (anti)neutrino and electron scattering cross sections. We study the distortion of (anti)neutrino-nucleus and charged lepton-nucleus cross sections, medium-induced bremsstrahlung, and estimate the QED-medium effects on the final- state kinematics and scattering cross sections. We find new permille-to-percent level effects, which were never accounted for in either (anti)neutrino-nucleus or electron-nucleus scattering. We quantitatively compute the effects of Glauber photon-mediated multiple re-scattering within the nuclear medium and find that the relativistic charged lepton acquires a momentum of order 10 MeV transverse to its direction of propagation inside the nucleus. This broadening sizably deflects expected electron and muon tracks and suppresses scattering cross sections. Precise extraction of the nucleon and nuclear structure by electron and muon probes should, thus, take the QED nuclear medium angular redistribution of particles into account.

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TALK: A Modern Look at the Oscillation Physics Case for a Neutrino Factory

Corresponding Author: julia.gehrlein@colostate.edu

Author: Julia Gehrlein
The next generation of neutrino oscillation experiments, JUNO, DUNE, and HK, are under construction now and will collect data over the next decade and beyond. As there are no approved plans to follow up this program with more advanced neutrino oscillation experiments, we consider here one option that had gained considerable interest more than a decade ago: a neutrino factory. Such an experiment uses stored muons in a racetrack configuration with extremely well characterized decays reducing systematic uncertainties and providing for more oscillation channels. Such a machine could also be one step towards a high energy muon collider program. We consider a long-baseline configuration to SURF using the DUNE far detectors or modifications thereof, and compare the expected sensitivities to the three-flavor oscillation parameters to the anticipated results from DUNE and HK. We find that a neutrino factory can improve our understanding of CP violation and also aid in disentangling the complicated flavor puzzle.

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Discussion, Collaboration, and Lunch

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TALK: A SURF Low Background Module (SLoMo)

Corresponding Author: juergen.reichenbacher@sdsmt.edu

With radiopurity controls and targeted design modifications a kton-scale liquid argon time projection chamber similar to DUNE could be used for enhanced low energy physics searches. This includes improved sensitivity to supernova and solar neutrinos, and other rare event searches, such as WIMP dark matter, while simultaneously serving long-baseline neutrino physics. This talk will present simulation studies to evaluate physics sensitivities of such a module. It will also discuss R&D to develop large-scale radiopurity controls necessary to construct such a detector.

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Discussion and Collaboration

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Shuttle to Middle School

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Shuttle to Sanford Lab Visitor Center

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TALK: Probing Heavy Neutral Lepton on Muan Collider and Beam-dump Experiments

Corresponding Author: lyu00145@umn.edu

Author: Kunfeng Lyu
Broad classes of solutions to the neutrino puzzles can be best tested by seeking the partners of SM light neutrinos, dubbed as heavy neutral leptons (HNLs). It can be parameterized by the HNL mass m_N and the mixing angle U_l with the SM neutrino. In this talk, I will mainly discuss about probing two parameter space regime. One is for HNL mass larger than O(100) GeV which can be tested at future high energy muon collider. Alternatively, if the HNL is lighter than the muon, it can be produced by the decays of muons and pions. The LSND experiment and the future beam dump experiment such as PIP2-BD can be exploited to improve the sensitivity.

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Discussion, Collaboration, and Lunch

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Shuttle to Ethnobotanical Garden

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Guest Speaker at Ethnobotanical Garden - Rochelle Zens

Corresponding Author: rzens@sanfordlab.org

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Shuttle to Middle School

178

TALK: Neutrino and light dark matter physics with directional detectors

Corresponding Author: diego.aristizabal@usm.cl

Author: Diego Aristizabal
In this talk I will review a few aspects of Coherent Elastic neutrino-Nucleus Scattering (CEvNS) and light dark matter (LDM) production in meson decays. In particular, I will focus on potential measurements using neutrino beams at FNAL. I will show that, combined with directional detectors, these beams offer an avenue for CEvNS measurements as well as for LDM detection. Such measurements will provide complementary information to that coming from other CEvNS facilities as well as from other non-directional detectors looking for LDM.

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Discussion and Collaboration

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TALK: Neutron Stars as probe of cosmic neutrino background

Corresponding Author: garv.chauhan@gmail.com

Cosmic neutrino background is one of the earliest relics from time around the big bang. Its detection in terrestrial experiments remains challenging. In this talk, we will discuss the effect of CNB interacting with a neutron star and comment on possible ways to leverage this for any future detection.

181

TALK: The Scotos Side of Neutrinos

Corresponding Author: schakdar@holycross.edu

Authors: Kaladi Babu, Shreyashi Chakdar, Vishnu Padmanabhan Kovilakam
We carry out a systematic investigation for minimal Scotogenic models based on a dark
gauge symmetry, in which the neutrino masses are induced at the one-loop level and include a chiral dark matter (DM) candidate. Assuming this gauge symmetry is broken by only one Higgs singlet scalar that also generates masses to all dark fermions, we analyze the stability of the DM candidate which is ensured by a residual symmetry of
gauge symmetry. There can be different DM scenarios explored in this framework and we investigate the associated scalar and fermonic DM phenomenology of one of the minimal models.

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Discussion, Collaboration, and Lunch

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TALK:

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Discussion and Collaboration

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Coffee/Social with Students

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TALK: Direct Collapse Black Holes from Dark Matter Annihilation

Corresponding Author: flip.tanedo@ucr.edu

187

TALK: Quasi (pseudo)-Dirac Neutrinos

Corresponding Author: sheng.fong@ufabc.edu.br

Author: Chee Sheng Fong
Here we will consider quasi (pseudo)-Dirac neutrinos

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Discussion and Collaboration

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TALK: Neutrinos From the Sun Can Discover Dark Matter-electron Scattering

Corresponding Author: ranjanlaha@iisc.ac.in

Author: Ranjan Laha
We probe dark matter-electron scattering using high-energy neutrino observations from the Sun. Dark matter (DM) interacting with electrons can get captured inside the Sun. These captured DM may annihilate to produce different Standard Model (SM) particles. Neutrinos produced from these SM states can be observed in IceCube and DeepCore. Although there is no excess of neutrinos from the Solar direction, we find that the current data-sets of IceCube and DeepCore set the strongest constraint on DM-electron scattering cross section in the DM mass range 10 GeV to 10
GeV. Our work implies that future observations of the Sun by neutrino telescopes have the potential to discover DM-electron interaction.

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TALK: E6 Unification: Intermediate Symmetries, Fermion Masses and Proton Decay

Corresponding Author: borut.bajc@ijs.si

Authors: Kaladi Babu, Borut Bajc, Vasja Susič
I will present a non-supersymmetric E6 GUT with the scalar sector consisting of 650 + 351′ + 27 dimensional representations. The intermediate symmetries which turn out to be realistic under the extended survival hypothesis (with minimal fine-tuning) are trinification symmetry SU(3)C × SU(3)L × SU(3)R with either LR or CR parity, and SU(6)CR × SU(2)L. This means among others that they can reproduce correctly the light charged fermion and neutrino masses as well as the CKM and PMNS mixing matrices. Although the successful cases give a large range for proton lifetime estimates, all of them include regions consistent with current experimental bounds and within reach of forthcoming experiments.

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Discussion, Collaboration, and Lunch

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TALK: TBD (open slot available)

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Discussion and Collaboration

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TALK: Nuclear Reactors as the Gateway to Potential Discoveries

Corresponding Author: vedran.brdar@okstate.edu

Author: Vedran Brdar
I will discuss a recently proposed novel experimental setup for axion-like particle (ALP) searches. Nuclear reactors produce a copious number of photons, a fraction of which could convert into ALPs via the Primakoff process in the reactor core. The generated flux of ALPs leaves the nuclear power plant, and its passage through a region with a strong magnetic field results in efficient conversion to photons, which can be detected. Such a magnetic field is the key component of axion haloscope experiments. I will discuss existing setups featuring an adjacent nuclear reactor and axion haloscope and I will demonstrate that the obtained sensitivity projections complement constraints from existing laboratory experiments, e.g., light-shining-through-walls.

195

TALK: Decoding the Flavor Evolution of Supernova Neutrinos: Shedding Light on Neutrino Electromagnetic Properties and Supernova Dynamics

Corresponding Author: yago.porto@ufabc.edu.br

Author: Yago Porto
Two of the most important questions in neutrino astrophysics are: A) How can the extreme supernova environments, through which neutrinos propagate, be used to shed light on the new physics behind neutrino masses and mixing? B) What is the flavor evolution of supernova neutrinos in the latest stages of core collapse? In this talk, I will summarize our recent developments in these directions, emphasizing how the unique magnetic fields of supernova progenitors can modify neutrino evolution in the presence of both Dirac and Majorana neutrino magnetic moments during the first few tens of milliseconds of neutrino emission. For the rest of the neutrino emission (roughly 10 seconds), I will describe how standard matter effects can define the main features of the neutrino signal in terrestrial detectors despite the exotic neutrino-neutrino refraction that dominates in the supernova core.

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Discussion, Collaboration, and Lunch

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TALK: Unleashing the Power of EFT in Neutrino–Nucleus Scattering

Corresponding Author: ztabrizi@northwestern.edu

Author:
Zahra Tabrizi

Neutrino physics is advancing into a precision era with the construction of new experiments, particularly in the few GeV energy range. Within this energy range, neutrinos exhibit diverse interactions with nucleons and nuclei. This talk delves in particular into neutrino–nucleus quasi-elastic cross sections, taking into account both standard and, for the first time, non-standard interactions, all within the framework of effective field theory (EFT). The main uncertainties in these cross sections stem from uncertainties in the nucleon-level form factors, and from the approximations necessary to solve the nuclear many-body problem. In this talk I explore how these uncertainties influence the potential of neutrino experiments to probe new physics introduced by left-handed, right-handed, scalar, pseudoscalar, and tensor interactions. For some of these interactions the cross section is enhanced, making long-baseline experiments an excellent place to search for them. The results, including tabulated cross sections for all interaction types and all neutrino flavors, can serve as the foundation for such searches.

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Discussion and Collaboration

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TALK: Probing SUSY at Gravitational Wave Observations

Corresponding Author: shaikh.saad@okstate.edu

Author: Shaikh Saad
Under the assumption that the recent pulsar timing array evidence for a stochastic gravitational wave (GW) background at nanohertz frequencies is generated by metastable cosmic strings, we analyze the potential of present and future GW observatories for probing the change of particle degrees of freedom caused, e.g., by a supersymmetric (SUSY) extension of the Standard Model (SM). We find that signs of the characteristic doubling of degrees of freedom predicted by SUSY could be detected at Einstein Telescope and Cosmic Explorer even if the masses of the SUSY partner particles are as high as about TeV, far above the reach of any currently envisioned particle collider. We also discuss the detection prospects for the case that some entropy production, e.g. from a late decaying modulus field inducing a temporary matter domination phase in the evolution of the universe, somewhat dilutes the GW spectrum, delaying discovery of the stochastic GW background at LIGO-Virgo-KAGRA. In our analysis we focus on SUSY, but any theory beyond the SM predicting a significant increase of particle degrees of freedom could be probed this way.

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TALK: Embedding the Universal See-Saw Mechanism in Pati-Salam Model

Corresponding Author: sumit.biswas@okstate.edu

Authors: Kaladi S. Babu, Sumit Biswas
Here we explore the integration of universal see-saw mechanism within the parity-symmetric Pati-Salam framework to address fermion mass generation. Incorporating vector-like fermions and a simple Higgs sector helps realize the hierarchical mass for all generations in this unified quark-lepton model. The neutrino sector seems pretty intriguing with the lightest neutrino acquiring mass

through one-loop radiative corrections. With softly broken parity, we also see the possibility of addressing the strong CP problem in this setup.

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Discussion, Collaboration, and Lunch

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TALK: eV Sterile Neutrino Paradox

Corresponding Author: sudip.jana@okstate.edu

Authors: Sudip Jana, Lucas Puetter, Alexei Yu. Smirnov
Light sterile neutrinos are frequently featured in various theories, particularly to explain short-baseline anomalies or as candidates for dark matter. These scenarios necessitate non-zero mixing with active neutrinos, often disregarding the contributions to the active neutrino mass matrix. We demonstrate that this mixing induces contributions to the active neutrino mass matrix, thereby affecting neutrino oscillation results. We conduct a rigorous analysis and present stringent bounds on these induced masses for each entry of a active neutrino mass matrix. Furthermore, we examine whether the induced matrix can elucidate the distinctive pattern of lepton mixing and the neutrino mass spectrum, while discussing the various phenomenological implications.

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Discussion and Collaboration

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Shuttle Pickup at Hampton Inn, travel to Sanford Lab Homestake Visitor Center

The workshop will be held at the visitor center all day today.

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Shuttle Pickup at HOTEL, Travel to E&O Building

Hampton Inn Lead hotel

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SURF Overview by Jaret Heise, Science Director, South Dakota Science and Technology Authority

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SURF Underground Tour Safety, Waivers, Lunch at 11:00 w/ Cultural Awareness Committee, PPE and Shuttle to Ross

Corresponding Author: jmolina@sanfordlab.org

Only the CETUP* participants that are going on the underground tour will attend. Other participants not going on the tour will be able to stay at the Middle School and continue to work and carry on discussions.

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Shuttle, PPE, Return to Hampton Inn

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TALK: TBD (open slot available)

210

TALK: Skimming tau neutrinos and optical Cherenkov signals

Corresponding Author: mary-hall-reno@uiowa.edu

Author: Mary Hall Reno
Optical Cherenkov signals from up-going air showers show promise for detection of skimming tau neutrinos. We review the theoretical inputs to evaluating the sensitivities to transient neutrino sources of orbital and sub-orbital Cherenkov telescopes.

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Discussion, Collaboration, and Lunch

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TALK: TBD (open slot available)

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Discussion and Collaboration

214

Road Scholar Group - CETUP* Guest Speaker (Mary Hall Reno)

Corresponding Author: mary-hall-reno@uiowa.edu

Mary Hall Reno will be presenting to the Road Scholar group at 2:00 p.m. During this time other CETUP* participants are welcome to continue with discussions and collaborations.

Road Scholars is an educational tour group that comes to the visitor center to listen to a featured speaker on a science related topic and Q&A.

CETUP 2024 / 215

Dynamical Generation of the Baryon Asymmetry from a Scale Hierarchy

Authors: Chang Hyeon Lee[1]; Chang Sub Shin[1]; Jae Hyeok Chang[2]; Kwang Sik Jeong[3]

[1] *Chungnam Natl. U.*

[2] *Fermilab and UIC*

[3] *Pusan Natl. U.*

Corresponding Author: jhchang@fnal.gov

We propose a novel baryogenesis scenario where the baryon asymmetry originates directly from a hierarchy between two fundamental mass scales: the electroweak scale and the Planck scale. Our model is based on the neutrino-portal Affleck-Dine (AD) mechanism, which generates the asymmetry of the AD sector during the radiation-dominated era and subsequently transfers it to the baryon number before the electroweak phase transition. The observed baryon asymmetry is then a natural outcome of this scenario. The model is testable as it predicts the existence of a Majoron with a keV mass and an electroweak scale decay constant. The impact of the relic Majoron on ΔNeff can be measured through near-future CMB observations.

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Discussion and Collaboration

CETUP 2024 / 217

The Power of the Dark Sink

Author: Robert McGehee[1]

[1] *University of Minnesota*

Corresponding Author: rmcgehee@umn.edu

We describe a simple dark sector structure which, if present, has implications for the direct detection of dark matter (DM): *the Dark Sink*. A Dark Sink transports energy density from the DM into light dark-sector states that do not appreciably contribute to the DM density. As an example, we consider a light, neutral fermion ψ which interacts solely with DM χ via the exchange of a heavy scalar Φ. We illustrate the impact of a Dark Sink by adding one to a DM freeze-in model in which χ couples to a light dark photon γ' which kinetically mixes with the Standard Model (SM) photon. This freeze-in model (absent the sink) is itself a benchmark for ongoing experiments. In some cases, the literature for this benchmark has contained errors; we correct the predictions and provide them as a public code. We then analyze how the Dark Sink modifies this benchmark, solving coupled Boltzmann equations for the dark-sector energy density and DM yield. We check the contribution of the Dark Sink ψ's to dark radiation; consistency with existing data limits the maximum attainable cross section. For DM with a mass between MeV $- \mathcal{O}(10\text{ GeV})$, adding the Dark Sink can increase predictions for the direct detection cross section all the way up to the current limits.

CETUP 2024 / 218

Analytic Results on Dark Matter Velocity Distributions

Author: Jason Kumar[1]

[1] *University of Hawaii*

Corresponding Author: jkumar@hawaii.edu

We review recent work on determining dark matter velocity distributions from analytic methods of classical mechanics, and the potential impact of these results on dark matter indirect detection strategies. In particular, we discuss velocity-dependent dark matter annihilation in subhalos and in the Galactic Center. We compare the results of these analytic methods to those obtained in large N numerical simulations, and discuss future work.

CETUP 2024 / 219

Probing SUSY at Gravitational Wave Observatories

Author: Shaikh Saad[None]

Corresponding Author: shaikh.saad@okstate.edu

Under the assumption that the recent pulsar timing array evidence for a stochastic gravitational wave (GW) background at nanohertz frequencies is generated by metastable cosmic strings, we analyze the potential of present and future GW observatories for probing the change of particle degrees of freedom caused, e.g., by a supersymmetric (SUSY) extension of the Standard Model (SM). We find that signs of the characteristic doubling of degrees of freedom predicted by SUSY could be detected at Einstein Telescope and Cosmic Explorer even if the masses of the SUSY partner particles are as high as about 10^4 TeV, far above the reach of any currently envisioned particle collider. We also discuss the detection prospects for the case that some entropy production, e.g. from a late decaying

modulus field inducing a temporary matter domination phase in the evolution of the universe, somewhat dilutes the GW spectrum, delaying discovery of the stochastic GW background at LIGO-Virgo-KAGRA. In our analysis we focus on SUSY, but any theory beyond the SM predicting a significant increase of particle degrees of freedom could be probed this way.

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-TBD-

Author: Garv Chauhan[1]

[1] *Virginia Tech*

Corresponding Author: garv.chauhan@gmail.com

N/A

221

Gravitational waves from cosmic superstrings and gauge strings

Author: Danny Marfatia[None]

Corresponding Author: gnaoiypb@duck.com

We perform a phenomenological comparison of the gravitational wave spectrum expected from cosmic gauge string networks and superstring networks comprised of multiple string types.

222

Journey with Sourced Millicharged Particles and Dark Photons

Author: Zhen Liu[1]

[1] *University of Minnesota*

Corresponding Author: zliuphys@umn.edu

Hidden $U(1)$ symmetries are widely prevalent across numerous new physics models and have garnered significant attention. These symmetries give rise to intriguing testable phenomena, such as "dark photons" as the force mediators and "millicharged" particles representing the matter content. A diverse range of physics experiments and search strategies have been developed to investigate these phenomena. In this talk, I will discuss my recent work in exploring these elusive particles, covering both theoretical foundations and experimental results. I will focus on the unique aspects of controlled search approaches, where we actively source the fields under investigation and discuss the future prospects in this exciting research area.

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gauged global strings

Author: Wei Xue[1]

[1] *University of Florida*

Corresponding Author: weixue@ufl.edu

I will present the string solutions and cosmological implications of the gauge U(1)Z × global U(1)PQ model. With two hierarchical symmetry-breaking scales, the model exhibits three distinct string solutions: a conventional global string, a global string with a heavy core, and a gauge string as a bound state of the two global strings. This model reveals rich phenomenological implications in cosmology. When incorporating this model with the QCD axion framework, the heavy-core global strings emit more axion particles due to their large tension. This radiation significantly enhances the QCD axion dark matter abundance, thereby opening up the QCD axion mass window. Furthermore, in contrast to conventional gauge strings, the gauge strings in this model exhibit a distinctive behavior, radiating axions.

224

Probing Baryon Number Violation in Neutron Stars

Author: Rouzbeh Allaverdi[1]

[1] *University of New Mexico*

Corresponding Author: rouzbeh@unm.edu

I start by presenting minimal extensions of the Standard Model that accommodate low-scale baryogenesis. These models involve fermion singlets with baryon-number-violating couplings to quarks. Then I briefly discuss the consequences of these models for low energy and high energy experiments. Finally, I mention how neutron stars can be used to tightly constrain such interactions for GeV scale fermions.

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Welcome by Mike Headley, Executive Director, South Dakota Science and Technology Authority/SURF

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Shuttle to Hampton Inn

227

Modular Flavor Symmetry and Neutrino Oscillations

Author: Zurab Tavartkiladze[1]

[1] *Ilia State University*

Corresponding Author: zurab.tavartkiladze@iliauni.edu.ge

Extension of the SM with modular flavor symmetry will be discussed. We show that by specific assignment of the transformation properties to the fermion states, very economical and predictive lepton sector can be constructed. Details of the neutrino sector and also robustness of the obtained results will be discussed.

228

SPLENDOR: narrow-gap quantum materials for light dark matter

Author: Yonatan Kahn[1]

[1] *University of Illinois Urbana-Champaign*

Corresponding Author: yfkahn@illinois.edu

Low-mass direct detection experiments based on conventional semiconductors such as silicon and germanium are achieving impressive sensitivity for dark matter masses above 1 MeV. However, to probe dark matter-electron scattering via electronic excitations for even lighter dark matter masses, more exotic materials with sub-eV band gaps are required. I will give an overview of the SPLENDOR program, which aims to develop a prototype detector for keV-MeV dark matter based on narrow-gap quantum materials. This research program involves close interdisciplinary collaboration with condensed matter theorists and experimentalists, in all stages from detector material synthesis to determining the experimental sensitivity via the density response function.

229

Updates on the Migdal effect and hydrogen doping for dark matter detection

Author: Jayden Newstead[1]

[1] *University of Melbourne*

Corresponding Author: jayden.newstead@unimelb.edu.au

An ongoing challenge in dark matter direct detection is to improve the sensitivity to light dark matter in the MeV–GeV mass range. One proposal is to dope a liquid noble-element direct-detection experiment with a lighter element such as hydrogen. This has the advantage of enabling larger recoil energies compared to scattering on a heavy target, while leveraging existing detector technologies. Direct-detection experiments can also extend their reach to lower masses by exploiting the Migdal effect, where a nuclear recoil leads to electronic ionization or excitation. In this work, we combine these ideas to study the sensitivity of a hydrogen-doped LZ experiment (HydroX) and a future large-scale experiment such as XLZD. We find that HydroX could have sensitivity to dark matter masses below 10 MeV for both spin-independent and spin-dependent scattering, with XLZD extending that reach to lower cross sections. Notably, this technique substantially enhances the sensitivity of direct detection to spin-dependent proton scattering, well beyond the reach of any current experiments.

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Dark Radiation Isocurvature from Cosmological Phase Transitions

Authors: Matthew Buckley[1]; Peizhi Du[1]; Nicolas Fernandez[1]; Mitchell Weikert[1]

[1] *Rutgers University*

Corresponding Author: peizhi.du@rutgers.edu

Cosmological first-order phase transitions are typically associated with physics beyond the Standard Model, and thus of great theoretical and observational interest. In this talk, I will show that a broad class of non-thermal first-order phase transitions could generate distinct large-scale isocurvature in dark radiation that can be observable in the CMB. We derive constraints on $\Delta N_{\rm eff}$ from phase transitions based on CMB+BAO data, which can be much stronger than that from adiabatic initial conditions. I will also demonstrate that since perturbations of dark radiation have a non-Gaussian origin, searches for non-Gaussianity in the CMB could also place a stringent bound on $\Delta N_{\rm eff}$.

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The Scotos side of Neutrinos

Authors: Kaladi Babu[1]; Shreyashi Chakdar[2]; Vishnu Padmanabhan Kovilakam[3]

[1] *Oklahoma State University*

[2] *College of the Holy Cross*

[3] *Universität Münster*

Corresponding Authors: kaladi.babu@okstate.edu, schakdar@holycross.edu, vpadmana@uni-muenster.de

We carry out a systematic investigation for minimal Scotogenic models based on a dark $U(1)_D$ gauge symmetry, in which the neutrino masses are induced at the one-loop level and include a chiral dark matter (DM) candidate. Assuming this $U(1)_D$ gauge symmetry is broken by only one Higgs singlet scalar that also generates masses to all dark fermions, we analyze the stability of the DM candidate which is ensured by a residual symmetry of $U(1)_D$ gauge symmetry.
There can be different DM scenarios explored in this framework and we investigate the associated scalar and fermonic DM phenomenology of one of the minimal models.

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Does the Sun Have a Dark Disk

Authors: Gustavo Alves[1]; Mohammadreza Zakeri[2]; Pedro Machado[3]; Susan Gardner[2]

[1] *University Of Sao Paulo*

[2] *University of Kentucky*

[3] *Fermilab*

Corresponding Authors: pmachado@fnal.gov, gardner@pa.uky.edu, m.zakeri@uky.edu, gustavo.figueiredo.alves@usp.br

The Sun's oblateness has been measured using optical observations. Its gravitational quadrupole moment has been deduced through helioseismology and measurements of its gravitational effects on Mercury's orbit. The distribution of mass within Mercury's orbit would only impact the orbital determination, suggesting that discrepancies among various types of assessments may indicate the possible existence of a non-luminous mass. For the first time, we have developed a method to combine these differing measurements to yield new, highly sensitive constraints on the mass distribution

within Mercury's orbit. In this talk, we will show that the most precise measurements indicate the existence of a non-luminous disk within Mercury's orbit, with a mass significantly heavier than the modeled mass for the circumsolar dust ring observed by the Solar TErrestrial RElations Observatory (STEREO) mission. This suggests a substantial dark matter contribution. Furthermore, the long-standing inconsistency between the element abundances determined from the spectroscopy of the Sun's surface, and those inferred from its interior through helioseismology, can be reconciled if the Sun formed within a protoplanetary disk. We will discuss how our findings limit the presence of a dark disk or a spherical halo near the Sun and highlight the potential of future orbital measurements of Mercury and near-Sun asteroids to refine these constraints further.

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Probing Heavy Neutral Lepton at Muon Collider and Beamdump Experiments

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Broad classes of solutions to the neutrino puzzles can be best tested by seeking the partners of SM light neutrinos, dubbed as heavy neutral leptons (HNLs). It can be parameterized by the HNL mass m_N and the mixing angle U_l with the SM neutrino. In this talk, I will mainly discuss about probing two parameter space regime. One is for HNL mass larger than O(100) GeV which can be tested at future high energy muon collider. Alternatively, if the HNL is lighter than the muon, it can be produced by the decays of muons and pions. The LSND experiment and the future beam dump experiment such as PIP2-BD can be exploited to improve the sensitivity.

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Constraining non-standard neutrino interactions with neutral current events at long-baseline oscillation experiments

Author: Julia Gehrlein[1]

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Neutrino non-standard interactions (NSI) provide an attractive framework to study new physics in the neutrino sector in scattering experiments and in oscillation experiments where NSI lead to new matter effects. At long-baseline oscillation experiments, so far, constraints on NSI have been derived using charged current events. In this manuscript we explore a new channel, namely neutral-current events at long-baseline experiments to constrain vector and axial-vector NSI. We introduce a framework to parametrize the effect of NSI on the cross section and then focus, as an example, on the NOvA experiment to derive constraints on NSI using real data.

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Embedding the Universal See-Saw Mechanism in Pati-Salam Model

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

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Here we explore the integration of universal see-saw mechanism within the parity-symmetric Pati-Salam framework to address fermion mass generation. Incorporating vector-like fermions and a simple Higgs sector helps realize the hierarchical mass for all generations in this unified quark-lepton model. The neutrino sector seems pretty intriguing with the lightest neutrino acquiring mass through one-loop radiative corrections. With softly broken parity, we also see the possibility of addressing the strong CP problem in this setup.

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Asymptotically free E_6 GUT and the generation of neutrino mass

Author: Vasja Susič[1]

Co-authors: Borut Bajc ; K.S Babu [2]

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Grand Unified Theories (GUTs) represent an attractive possibility of physics beyond the Standard Model, with implications for both proton decay and neutrinos. The most studied examples are based on unified groups SU(5) and SO(10), while the exceptional case E_6 remains less understood.

In an asymptotically free E_6 GUT, model building is essentially limited to the use of irreducible representations of dimension 27 and 78 (the fundamental and the adjoint). I will present ongoing work in non-supersymmetric models regarding the determination of the necessary ingredients for both GUT symmetry breaking and a realistic Yukawa sector. Special attention will be given to the peculiarities associated with neutrino mass generation in this type of models.

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Thermal Axion and Dark Radiation

Author: Fazlollah Hajkarim[1]

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We provide a comprehensive analysis of thermal axion production in the early universe, focusing on the KSVZ and DFSZ models. We extend our calculations to incorporate multiple mass thresholds, including the QCD phase transition, and provide a continuous production rate across these regimes. Employing updated cosmological data, we refine constraints on axion mass and examine the implications for dark radiation quantified as an effective number of additional neutrino species (ΔNeff). Our rigorous approach revisits traditional approximations in axion production, highlighting the importance of precise calculations in anticipation of future CMB surveys and large scale structure observations. Also, we examine the validity of different computational approaches for the calculation of effective number of additional neutrino species.

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E6 unification: intermediate symmetries, fermion masses and proton decay

Authors: Kaladi Babu[None]; Borut Bajc[None]; Vasja Susič[None]

I will present a non-supersymmetric E6 GUT with the scalar sector consisting of 650 + 351′ + 27 dimensional representations. The intermediate symmetries which turn out to be realistic under the extended survival hypothesis (with minimal fine-tuning) are trinification symmetry SU(3)C × SU(3)L × SU(3)R with either LR or CR parity, and SU(6)CR × SU(2)L. This means among others that they can reproduce correctly the light charged fermion and neutrino masses as well as the CKM and PMNS mixing matrices. Although the successful cases give a large range for proton lifetime estimates, all of them include regions consistent with current experimental bounds and within reach of forthcoming experiments.

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Constraining Dwarf Galaxy Dark Matter Distributions: Spherical Jeans Analyses for Line-of-Sight and 3D Velocity Data

Author: Isabelle Goldstein[1]

Co-author: Louie Strigari [1]

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The stellar kinematics in dwarf galaxies can provide a wealth of information about its underlying dark matter distribution. Using line of sight velocity measurements for six classical dwarf galaxies of the Milky Way, we study whether ultralight bosonic dark matter is consistent with the gravitational potential extracted from stellar kinematics. It shows that axion-like particles with masses of order $m \sim 10^{-22}$ eV are inconsistent with the potential distribution in classical dwarf galaxies unless the hierarchical assembly of the Milky Way did not trace the mean evolution of Milky Way size halos. We also explore the use of three dimensional velocity measurements from Gaia data in spherical Jeans analyses to further constrain dark matter distributions.

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Probing Neutrinophilic Dark Matter: From Colliders to Supernovae

Author: Douglas Tuckler[1]

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New beyond-the-Standard Model mediators that couple predominantly to neutrinos are not yet probed by existing experimental searches. Such a neutrinophilic mediator is well motivated for addressing the origin of several neutrino-portal dark matter candidates, including thermal freeze-out and sterile-neutrino dark matter scenarios. In this talk, we explore the sensitivity to this scenario from two different approaches. In the first part of the talk we will explore the potential of the Forward Physics Facility (FPF) using the so-called "mono-neutrino signature": neutrino charged-current scattering events associated with large missing transverse momentum, and excessive apparent tau-neutrino events. We will show that with this smoking-gun signature, the FPF has excellent sensitivity to probe this model in new regions of parameter space. the In the second part of the talk we focus on astrophysical constraints on sterile neutrino DM, namely from core-collapse supernovae. Production and emission of DM can result in excessive energy loss of the supernova, leading to additional cooling. We will show that supernova cooling can constrain new regions of parameter space that complements terrestrial and cosmological probes. The results of this work present a nice complementarity among the collider and astrophysical frontiers.

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Neutrino Interactions/TBD

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Neutrino Interactions/TBD

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Decoding the Flavor Evolution of Supernova Neutrinos: Shedding Light on Neutrino Electromagnetic Properties and Supernova Dynamics

Author: Yago Porto[1]

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Two of the most important questions in neutrino astrophysics are: A) How can the extreme supernova environments, through which neutrinos propagate, be used to shed light on the new physics behind neutrino masses and mixing? B) What is the flavor evolution of supernova neutrinos in the latest stages of core collapse? In this talk, I will summarize our recent developments in these directions, emphasizing how the unique magnetic fields of supernova progenitors can modify neutrino evolution in the presence of both Dirac and Majorana neutrino magnetic moments during the first few tens of milliseconds of neutrino emission. For the rest of the neutrino emission (roughly 10 seconds), I will describe how standard matter effects can define the main features of the neutrino

signal in terrestrial detectors despite the exotic neutrino-neutrino refraction that dominates in the supernova core.

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TBD

Author: Tao Xu[1]

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Talk details will be updated at a later date.

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Quasi (Pseudo)-Dirac neutrinos

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Here we will consider quasi (pseudo)-Dirac neutrinos

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Dark Matter Raining on DUNE and Other Large Volume Detectors

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Direct detection is a powerful means of searching for particle physics evidence of dark matter (DM) heavier than about a GeV with $\mathcal{O}(\text{ton})$ volume, low-threshold detectors.
In many scenarios, some fraction of the DM may be boosted to large velocities enhancing and generally modifying possible detection signatures. We investigate the scenario where 100\% of the DM may be boosted at the Earth due to new attractive long-range forces. This opens up two main improvements in detection capabilities: 1) the detection signatures are stronger opening up large-volume neutrino detectors, such as DUNE, Super-K, Hyper-K, and JUNO, as possible DM detectors, and 2) the large boost allows for detectable signatures of sub-GeV DM. At lower boosts, a modified, higher-than-usual energy signal could be accessible at direct detection experiments such as LZ. In addition, the model leads to a significant anisotropy in the signal with the DM flowing dominantly vertically at the Earth's surface instead of the typical approximately isotropic DM signal. We develop the theory behind this model and also calculate realistic constraints using a detailed GENIE simulation of the signal inside detectors.

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Cosmological Stasis and Its Realization from Dynamical Scalars

Author: Brooks Thomas[1]

Co-authors: Fei Huang [2]; Keith R. Dienes [3]; Lucien Heurtier [4]; Timothy M. P. Tait [5]

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[4] *King's College London*

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It has recently been realized that many extensions of the Standard Model give rise to cosmological histories exhibiting extended epochs of cosmological stasis —epochs wherein the abundances of multiple energy components (such as matter, radiation, or vacuum energy) remain effectively constant despite cosmological expansion. The emergence of a stasis epoch is not a consequence of fine-tuning in cosmologies of this sort; rather, stasis turns out to be a global attractor toward which the universe naturally evolves for a broad range of initial conditions. In this talk, I shall review the general conditions under which stasis emerges in such scenarios and explore some of its potential implications for cosmological observables such as the matter power spectrum and the stochastic gravitational-wave background. I shall also discuss a particular realization of stasis involving a collection of scalar fields, each of which dynamically transitions from a period of slow roll to a period of rapid oscillation around its potential minimum as the universe expands. As I shall demonstrate, not only does cosmological stasis arise in such scenarios, but the system of dynamical scalars also exhibits novel features not seen in previous realizations of stasis, including a tracking behavior wherein the effective equation of state for the universe as a whole evolves toward the equation of state of this energy component. The emergence of such tracking behavior has potential model-building implications in the context of dark-energy and cosmic-inflation scenarios.

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Neutrino and light dark matter physics with directional detectors

Author: Diego Aristizabal[1]

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In this talk I will review a few aspects of Coherent Elastic neutrino-Nucleus Scattering (CEvNS) and light dark matter (LDM) production in meson decays. In particular, I will focus on potential measurements using neutrino beams at FNAL. I will show that, combined with directional detectors, these beams offer an avenue for CEvNS measurements as well as for LDM detection. Such measurements will provide complementary information to that coming from other CEvNS facilities as well as from other non-directional detectors looking for LDM.

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Direct Collapse Black Holes from Dark Matter Annihilation

Author: Flip Tanedo[1]

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Pre-stellar galactic halos are highly sensitive to soft radiation: the presence of sources of O(10 eV) Lyman-Werner radiation changes the gas chemistry and prevent the standard fragmentation of the gas. Rather than producing Population III stars, this may instead lead to direct collapse black holes. Observations of supermassive black holes at high redshift have long been suspected to be evidence for direct collapse black holes. Recent studies have explored the possibility that direct collapse may be influenced by new particle physics.

We present a simple dark matter model where resonant annihilation can dissociate molecular hydrogen and discuss the assumptions that are necessary to induce direct collapse black holes. In these models, O(10 MeV) dark matter annihilates into electron-positron pairs which produce Lyman-Werner radiation by inverse Compton scattering CMB light. We present a self-consistent modeling of H2 self-shielding that highlights the challenges when building models for direct collapse.

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Probing self-interacting sterile neutrino dark matter with the diffuse supernova neutrino background

Author: Anna Suliga[1]

Co-authors: Anupam Ray [2]; Baha Balantekin [3]; George Fuller [4]

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[3] *UW Madison*

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The neutrinos in the diffuse supernova neutrino background (DSNB) travel over cosmological distances and this provides them with an excellent opportunity to interact with dark relics. We show that a cosmologically-significant relic population of keV-mass sterile neutrinos with strong self-interactions could imprint their presence in the DSNB. The signatures of the self-interactions would be “dips” in the otherwise smooth DSNB spectrum. Upcoming large-scale neutrino detectors, for example Hyper-Kamiokande, have a good chance of detecting the DSNB and these dips. If no dips are detected, this method serves as an independent constraint on the sterile neutrino self-interaction strength and mixing with active neutrinos. We show that relic sterile neutrino parameters that evade X-ray and structure bounds may nevertheless be testable by future detectors like TRISTAN, but may also produce dips in the DSNB which could be detectable. Such a detection would suggest the existence of a cosmologically-significant, strongly self-interacting sterile neutrino background, likely embedded in a richer dark sector.

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Planting Native Plants at Sanford Lab Homestake Visitor Center

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Communicating with Media (Speakers: Ann Melti and Mike Ray, SDSTA/SURF)

Corresponding Author: ametli@sanfordlab.org

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Communicating with Media - 3 Minute Challenge (Ann Melti and Mike Ray - SDSTA/SURF)

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Career Panel

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Scientist Mentor/Student Speed Match Up and Shadow

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Communicating with Media - Ann Melti and Mike Ray (SDSTA/SURF)

Corresponding Author: ametli@sanfordlab.org

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3 Minute Challenge - Ann Melti and Mike Ray (SDSTA/SURF)

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Jet-SIFTing for Dark Sector Physics in a Hidden Valley

Author: Joel Walker[1]

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We consider a Hidden Valley model which generates showering from strong dynamics within the dark sector followed by decays back into Standard Model states. Our interest is the limit of smaller dark pion masses, which create a high multiplicity of final states. The reconstruction of dark sector masses in such a setting is obscured by a thick combinatoric background. We apply the new SIFT (Scale-Invariant Filtered Tree) jet clustering algorithm to the reconstruction of simulated events of

this type. By cutting an ordered slice through possible recombinations, the SIFT algorithm may help lift backgrounds of the described variety.

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Skimming tau neutrinos and optical Cherenkov signals

Author: Mary Hall Reno[1]

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Optical Cherenkov signals from up-going air showers show promise for detection of skimming tau neutrinos. We review the theoretical inputs to evaluating the sensitivities to transient neutrino sources of orbital and sub-orbital Cherenkov telescopes.

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Detection of cosmogenic (B)SM signals with nuclear inelastic scattering

Author: Doojin Kim[1]

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Corresponding Author: doojin.kim@tamu.edu

I will discuss the detection of sub-GeV-range cosmogenic signals at large-volume neutrino detectors such as DUNE, SK/HY, and JUNO, utilizing nuclear inelastic scattering channels featuring nuclear deexcitation gamma-ray lines. I will first briefly discuss the detection of neutrino signals and point out the potential of observing the 13-MeV oxygen line at SK. I will then propose a new approach to search for light dark matter (DM) in the range of keV-GeV in the context of cosmic-ray boosted dark matter. I will show that using a hadrophilic dark-gauge-boson-portal model as a benchmark, the nuclear inelastic channels generally provide better sensitivity than the elastic scattering for a large region of light DM parameter space.

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BSM Physics with Gravitational Wave Detectors

Author: Kuver Sinha[1]

[1] *University of Oklahoma*

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Future gravitational wave detectors probing the mHz - nHz frequency range will provide a unique opportunity for BSM physicists to study new physics. Neutron star and white dwarf mergers can serve as axion probes, while extreme mass ratio inspirals can constrain dark forces. Gravitational wave detectors will also probe early first order phase transitions. I will discuss some ongoing work and future ideas in these directions.

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eV Sterile Neutrino Paradox

Authors: Alexei Yu. Smirnov[None]; Lucas Puetter[1]; Sudip Jana[None]

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Light sterile neutrinos are frequently featured in various theories, particularly to explain short-baseline anomalies or as candidates for dark matter. These scenarios necessitate non-zero mixing with active neutrinos, often disregarding the contributions to the active neutrino mass matrix. We demonstrate that this mixing induces contributions to the active neutrino mass matrix, thereby affecting neutrino oscillation results. We conduct a rigorous analysis and present stringent bounds on these induced masses for each entry of a 3×3 active neutrino mass matrix. Furthermore, we examine whether the induced matrix can elucidate the distinctive pattern of lepton mixing and the neutrino mass spectrum, while discussing the various phenomenological implications.

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CETUP* Workshop Overview

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Discussion and Collaboration

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TALK: New Constraints on Neutrino-Dark Matter Interactions

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Author: Bhupal Dev
We present a comprehensive analysis of nonstandard neutrino interactions with the dark sector in an effective field theory framework. We implement a full catalog of constraints on the parameter space of the neutrino-dark matter/mediator couplings and masses, including bounds coming from cosmology, astrophysics, as well as new laboratory constraints, such as from invisible Z decays and rare meson decays. We find that most of the benchmarks in the dark matter mass-coupling plane adopted in previous studies to get an observable effect are actually ruled out by a combination of these constraints. Finally, as an application of our results, we consider the case of galactic supernova neutrinos, identify new benchmark points for future observational prospects of the attenuation of the galactic supernova neutrino flux, compute the full set of cascade equations and sky maps for different dark matter density profiles in the Galaxy, and comment on their implications for the detection prospects in future large-volume neutrino experiments such as DUNE, Hyper-K and JUNO.

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TALK: TBD (open slot available)

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Shuttle, Travel to Ross

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Does the Sun have a dark disk?

Authors: Gustavo Alves[1]; Susan Gardner[2]; Pedro Machado[3]; Mohammadreza Zakeri[2]

[1] *University Of Sao Paulo*

[2] *University of Kentucky*

[3] *Fermilab*

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The nature of dark matter is unknown, as are its total mass and distribution within the Solar system, though constraints from measurements of planetary orbits exist. I discuss how differing measurements of the Sun's gravitational quadrupole moment can
combine to yield new and highly sensitive constraints on the mass distribution within Mercury's orbit. The best determinations point with high confidence to the existence of a non-luminous disk coplanar with Mercury's orbit, and the mass estimates associated with known matter, although uncertain, point to a significant dark-matter contribution, for which macroscopic dark-matter models may suit best.

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TALK: Direct Collapse Black Holes from Dark Matter Annihilation

Corresponding Author: flip.tanedo@ucr.edu

Pre-stellar galactic halos are highly sensitive to soft radiation: the presence of sources of O(10 eV) Lyman-Werner radiation changes the gas chemistry and prevent the standard fragmentation of the gas. Rather than producing Population III stars, this may instead lead to direct collapse black holes. Observations of supermassive black holes at high redshift have long been suspected to be evidence for direct collapse black holes. Recent studies have explored the possibility that direct collapse may be influenced by new particle physics.

We present a simple dark matter model where resonant annihilation can dissociate molecular hydrogen and discuss the assumptions that are necessary to induce direct collapse black holes. In these models, O(10 MeV) dark matter annihilates into electron-positron pairs which produce Lyman-Werner radiation by inverse Compton scattering CMB light. We present a self-consistent modeling of H2 self-shielding that highlights the challenges when building models for direct collapse.

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TALK: TBD (open slot available)

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Discussions, Collaboration and Lunch

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Current Challenges and Opportunities in Physics Community (open discussion)

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Academia
Research
Funding
Promotion and tenure
Mentoring

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Global Scientist Social

Corresponding Author: rmcgehee@umn.edu

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SURF Underground Tour

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Discussion and Collaboration; Mentor/Student Shadow

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A SURF Low Background Module (SLoMo)

Author: Juergen Reichenbacher[1]

[1] *South Dakota School of Mines and Technology*

Corresponding Author: juergen.reichenbacher@sdsmt.edu

With radiopurity controls and targeted design modifications a kton-scale liquid argon time projection chamber similar to DUNE could be used for enhanced low energy physics searches. This includes improved sensitivity to supernova and solar neutrinos, and other rare event searches, such as WIMP dark matter, while simultaneously serving long-baseline neutrino physics. This talk will present simulation studies to evaluate physics sensitivities of such a module. It will also discuss R&D to develop large-scale radiopurity controls necessary to construct such a detector.

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The Institute for Underground Science at SURF Overview and Update (room 132)

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The Institute for Underground Science at SURF Overview and Update (room 132)

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The Institute for Underground Science at SURF Overview and Update (room 132)

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REMINDER NOTE ONLY: please make sure to bring a brown bag lunch for today

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TALK: Detection of cosmogenic (B)SM signals with nuclear inelastic scattering

Corresponding Author: doojin.kim@tamu.edu

Author: Doojin Kim
I will discuss the detection of sub-GeV-range cosmogenic signals at large-volume neutrino detectors such as DUNE, SK/HY, and JUNO, utilizing nuclear inelastic scattering channels featuring nuclear deexcitation gamma-ray lines. I will first briefly discuss the detection of neutrino signals and point out the potential of observing the 13-MeV oxygen line at SK. I will then propose a new approach to search for light dark matter (DM) in the range of keV-GeV in the context of cosmic-ray boosted dark matter. I will show that using a hadrophilic dark-gauge-boson-portal model as a benchmark, the nuclear inelastic channels generally provide better sensitivity than the elastic scattering for a large region of light DM parameter space.