IDM 2018

Sunday, July 22, 2018 - Friday, July 27, 2018

MacMillian

Book of Abstracts

Contents

2.4 Theory / 1

Probing Velocity Dependent Self Intereacting Dark Matter with Neutrino Telescopes.

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In this talk velocity dependent self-interacting dark matter models (vdSIDM) will be considered. A brief discussion on how dark matter self interactions might alleviate potential CDM problems at small scales will be presented. Following it will be shown that data already collected by the IceCube-DeepCore neutrino telescopes can probe most of the interesting vdSIDM parameter space. Finally that indirect detection through neutrinos can compete with the strong existing limits from direct detection experiments, specially in the case of isospin violation.

1.3 Direct Detection / 2

Doping LXe TPCs with helium for light dark matter

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Next generation liquid xenon TPCs are poised to increase our sensitivity to dark matter by more than an order of magnitude over a wide range of possible dark matter candidates. In this talk I will describe an idea to expand the reach and flexibility of such detectors even further, by adding helium to the xenon to enable searches for very light dark matter and combining high and low Z targets in the same detector. The reach of a He-doped xenon dark matter detector can potentially extend down to ~50 MeV dark matter masses. In this talk, I will describe an experimental program to develop helium doping as an upgrade to a next generation xenon detector and model the expected sensitivity of such an upgrade.

1.6 Theory / 3

Long-lived particles at the LHC: catching them in time

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We explore the physics potential of using precision timing information at the LHC in the search for long-lived particles (LLP). In comparison with the light Standard Model particle produced from the hard interactions, the decay products of massive LLPs arrives at detectors with sizable time delay. We propose new strategies to take advantage of this property, using the initial state radiation jet for timestamping the event and only requiring a single LLP to decay inside the detector. This search strategy can be effective to a broad range of models. In addition to outlining the general

approach of using timing information, we demonstrate its effectiveness with the projected reach for two benchmark scenarios: Higgs decaying into a pair of LLPs, and pair production of long-lived neutralinos in the gauge mediated supersymmetry breaking scenario. Our strategy increases the sensitivity to the lifetime of the LLP by orders of magnitude and exhibits better behavior particularly in the large lifetime region compared to traditional LLP searches at colliders. The timing information greatly reduces the Standard Model background and therefore provides a powerful new dimension for LLP searches.

2.1 Plenary Session / 4

Recent PandaX-II Results on Dark Matter Search and PandaX-4T Upgrade Status

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PandaX experiment, located at China JinPing underground Laboratory (CJPL), is a 500kg scale liquid xenon dark matter direct detection experiment. With recent data, PandaX-II experiment obtained stringent upper limits on the spin-independent (SI) and spin-dependent (SD) WIMP-nucleon elastic scattering cross sections. Alternative models of dark matter are also explored using this data. Meanwhile, PandaX collaboration has launched an upgrade plan to build PandaX-4T detector with 4-ton liquid xenon in the active volume. The PandaX-4T experiment will be relocated to CJPL-II and is expected to run after 2020. Detailed simulation indicates that the sensitivity on SI WIMP-nucleon scattering cross section could reach $10^{-47} cm^2$ after two-year's running.

2.2 Plenary Session / 5

XENONnT - The next step in XENON Dark Matter Search

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The XENON series of experiments has been highly successful in pushing the limits of WIMP direct searches for more than a decade. With the currently most sensitive DM experiment XENON1T still taking data, the collaboration is preparing the next step, the upgraded and upscaled XENONnT. This new experiment is making use of many infrastructures and systems built for XENON1T, located at the LNGS underground laboratory in Italy. The goal of XENONnT is to explore parameter space for spin-independent WIMP interactions down to of 2×10^{-48} cm^2 by lowering the background level by an order of magnitude compared to XENON1T, and increasing exposure up to 20 ton years. This talk will provide an update on status and prospects of the XENONnT phase.

2.1 Plenary Session / 6

Projected WIMP sensitivity of the LUX-ZEPLIN dark matter experiment

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LUX-ZEPLIN (LZ) is a next generation dark matter direct detection experiment that will operate 4850 feet underground at the Sanford Underground Research Facility (SURF) in Lead, South Dakota, USA. Using a two-phase xenon detector with an active mass of 7 tonnes, LZ will search primarily for low-energy interactions with Weakly Interacting Massive Particles (WIMPs), which are hypothesized to make up the dark matter in our galactic halo. LZ builds upon the demonstrated response to keV nuclear recoils and the excellent self-shielding properties of liquid xenon and scales the TPC design beyond all existing experiments. In addition, an optically separated and instrumented xenon skin layer and a surrounding external liquid scintillator detector provide powerful rejection of gamma-rays and neutrons from internal sources. Materials screening and in-house purification of the liquid xenon then ensure that LZ meets the strict radioactivity constraints needed to achieve world leading WIMP search sensitivity. In this talk, I will describe the projected WIMP sensitivity of LZ, based on the latest background estimates and simulations of the detector. With construction well underway, LZ is on track for underground installation at SURF in 2019 and will start collecting data in 2020.

5.6 Detection Theory / **7**

The Impact of antiproton and antimatter nuclei measurements on dark matter searches

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We study the AMS-02 antiproton/proton ratio spectral-measurement in light of the recent advances done in parametrizing the impact of solar modulation of cosmic-rays, the antiproton production uncertainties from inelastic proton-proton collisions in the Galaxy as well as the interstellar medium uncertainties that pertain to the propagation of cosmic-rays in the Milky Way. We confirm previous claims on a GeV bump in antiprotons. Including all the relevant astrophysical uncertainties there is a ~3 sigma significance of a feature in the antiproton/proton ratio that if interpreted as a signal of dark matter annihilation, it would be suggestive of a 50-100 GeV dark matter particle with a partial annihilation cross-section to hadrons that is in the range of $\sigma v : 1 - 10 \times 10^{-26}$ cm^3/s. We also discuss the impact that the recent discovery of anti-helium 3 and 4 nuclei by AMS-02 has on the dark matter searches in antimatter cosmic-rays.

1.5 Direct Detection / **8**

Dark matter annual modulation with SABRE

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The interaction rate of hypothesized dark matter particles in an Earth bound detector is expected to undergo an annual modulation due to the planet's orbital motion. The DAMA experiment has observed such a modulation with high significance in an array of scintillating NaI(Tl) crystals, however this results demands a model independent verification.
SABRE aims to perform a higher sensitivity measurement with NaI(Tl) crystals able to clarify the claim, but also to investigate the nature of dark matter interaction and the characteristics of the halo. SABRE will have a lower background in the signal region and a lower energy threshold thanks to high purity crystals and a 4π active background rejection with liquid scintillator. We present here the progresses ongoing in the construction of the Proof-of-Principle phase at LNGS (Laboratori Nazionali del Gran Sasso, Italy), our future design including a pair of twin detectors at LNGS and SUPL (Stawell Underground Physics Laboratory, Australia) and we detail the background and the sensitivity to dark matter interaction that we anticipate.

1.2 Plenary Session / 9

Cosmological signatures of decaying dark matter

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Cosmological probes have a lot to tell us about the nature of the Dark Matter (DM) in our Universe. In this talk, I would like to review in particular how CMB temperature and polarization anisotropies can be used to look for signatures of decaying particles composing part (or all of) the DM. Moreover, I will discuss the great complementarity with CMB spectral distortions and Big Bang Nucleosynthesis studies. Finally, I will illustrate how the 21cm signal, one of the main target of future experiments, could be used in order to improve (but not always!) over current sensitivity.

2.4 Theory / 10

Looking for ultra light axion-like particles in the CMB

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In this talk, I would like to review how the CMB (in particular its temperature and polarization anisotropies) can be used to look for ultra light axion-like particles (ULAs).
Such ULAs are naturally numerous in the axiverse scenario and can play many role in cosmology, from Dark Matter to Dark Energy. Moreover, they have been invoked to solve several recent cosmological tensions. In particular, ULAs can potentially be used to solve the tension between the LCDM prediction of H0 extracted from Planck data and that deduced by direct observations of cepheids and SNIa at low-redshift. They have also been suggested as an explanation of the EDGES anomaly — the observation of a puzzling absorption feature in the global 21cm signal. While the standard axion potential leads to ULA behaving like DM when their mass is large enough, a simple generalization of this potential leads to ULAs diluting with arbitrary rate (i.e. they can be chosen to dilute like matter, radiation or at even faster rate).
I will explain why such ULAs are phenomenologically very interesting and describe how such generic ULAs can be accurately modeled on cosmological scales thanks to a newly derived fluid approximation that generalizes former work. Finally, I will discuss constraints arising from Planck data on these models, as well as the implications of these constraints for the puzzling cosmological tensions.

2.3 Direct Detection / 11

(Now combined) Dark matter search with a light mediator at PandaX-II experiment

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One of the primary goals of many direct dark matter (DM) experiments have been focused on detecting weakly interacting massive particles (WIMPs). Usually, these searches assume a point-like contact interaction between DM and nucleons. However, it is possible that they interact with the exchange of a light mediator with masses comparable to the momentum transfer of the process involved, in which case the contact interaction assumption is no longer valid.

In this talk, we present experimental cross section limits on DM-nucleon interaction via a light mediator in PandaX-II, a direct detection experiment in China JinPing underground Laboratory. We use data collected in 2016 and 2017 runs, corresponding to a total exposure of 54 ton day, the largest published data set of its kind to date. In the context of a few benchmark self-interacting dark matter models with a light mediator mixing with nucleons, we set strongest limits on the mediator mass for DM masses ranging from 5 GeV/c^2 to 10 TeV/c^2.

3.1 Plenary / 12

SnowBall Chamber: Supercooled Water for Low-Mass Dark Matter

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We have all heard of the cloud and bubble chambers of course, and the latter in the context of direct WIMP dark matter detection even. However, no one has explored a third phase transition, into solid, until now that is. This talk will introduce the snowball chamber, which utilizes a supercooled liquid, just purified water in the prototype. An incoming particle triggers nucleation in the liquid, forming a solid. We will present the world's first definitive evidence that radiation can trigger freezing in metastable cold water, an effect never before observed, and in particular share AmBe neutron source calibration data, wherein multiple nucleation sites could be observed during the neutron source runs, another world first, making our device act just like a reverse bubble chamber. Because the reaction is exothermic not endothermic as in a bubble chamber however the energy threshold should be lower, perfect for sub-GeV dark matter searches, for which we will show the measured gamma discrimination, high as in a bubble chamber, and the projected sensitivity, showing our new technology reaching the neutrino floor, with a smaller, more cost-effective detector than many of the competing new technologies. The crystallization may even have directionality which we will show preliminary evidence for: this would mean higher-density directional detectors than in gas, capable of not just reaching the neutrino floor but punching through it, at masses less than 10 GeV/c^2 at least.

2.3 Direct Detection / 13

The future PICO programme

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After the successful conclusion of the PICO 60 experiment, the new "right-side-up", or inverted bubble chamber, PICO 40L, will start operation later in 2018. We will present the current status and the experimental plans for PICO 40L.

The PICO collaboration is also in the design and early procurement phase for the PICO 500 experiment, a tonne scale dark matter bubble chamber that aims to cover the remaining phase space above the neutrino floor with C_3F_8 as active liquid. We will report the latest detector design and the plans for installation and operation at SNOLAB.

2.3 Direct Detection / 14

DARWIN – The Ultimate WIMP Detector

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The DARWIN (DARk matter WIMP search with liquid xenoN) experiment will be the next-to-next generation direct search dark matter detector. Featuring a 40 t target mass liquid xenon time projection chamber it will reach a sensitivity to WIMP nuclear recoil cross-sections at the level of the "ultimate" irreducible background induced by coherent scattering of solar and atmospheric neutrinos. Hence DARWIN will probe the entire experimentally accessible parameter space for WIMP masses above a few GeV/c2. Besides its excellent sensitivity to WIMP dark matter, DARWIN will explore a plethora of science channels in astroparticle and nuclear physics, e.g., the neutrinoless double beta decay of 136Xe.

This talk reviews the DARWIN science program for dark matter searches and beyond. An overview of the detectors baseline design and the ongoing R & D program is provided and some of the technological alternatives currently under study are showcased briefly. The technical challenges owed to the detector size as well as its requirements in terms of detector backgrounds will be addressed.

4.6 Theory / 15

Astrophysical Signatures of Dark Matter Accumulation in Neutron Stars

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Over the past few decades, terrestrial experiments have placed increasingly strong limits on the dark matter-nucleon scattering cross-section. However, a significant portion of the standard dark matter parameter space remains beyond our reach. Due to their extreme density and huge gravitational fields, neutron stars stand as optimal targets to probe dark matter-neutron interactions. As an example, over the last few years, the existence of Gyr-age neutron stars has placed strong limits on models of asymmetric dark matter. In this talk, I will discuss novel methods which utilize neutron stars to potentially detect dark matter interactions by studying the galactic morphology of neutron stars, as well as electromagnetic signals which may be produced via neutron star collapse. Intriguingly, these observations can probe extremely generic dark matter models spanning from MeV - PeV energies, and including troublesome portions of parameter space such as pure-Higgsino dark matter.

5.4 Indirect Detection / 16

Multiwavelength analysis of annihilating dark matter as the origin of the gamma-ray emission from M31

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Indirect detection of dark matter through multiwavelength astronomical observations provides a promising avenue for understanding the particle nature of dark matter. In the case of dark matter consisting of weakly-interacting massive particles (WIMPs), self-annihilation ultimately produces a variety of observable products including gamma-rays that can be detected directly, as well as electron/positron pairs that can be detected by radio emission from synchrotron radiation, or X-rays and soft gamma rays from inverse Compton scattering. A major focus of study for astrophysical signs of dark matter is in the Galactic center (GC) of the Milky Way, due in large part to an observed excess of gamma-rays that could be dark matter. A recent observation by the Fermi-LAT collaboration of a similar gamma-ray excess in the central region of the Andromeda galaxy (M31) leads us to explore the possibility of a dark matter-induced signal in that system as well. In this talk, I will present the results from a multi-frequency analysis of dark matter annihilation as a potential source of the emissions in M31, discussing the relevant astrophysical modeling, and considering these results in relation to galactic center dark matter studies.

1.6 Theory / 17

Exposing Dark Sector with Future Z-Factories

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We investigate the prospects of searching dark sector models via exotic Z-boson decay at future e+e− colliders with Giga Z and Tera Z options. Four general categories of dark sector models: Higgs portal dark matter, vector portal dark matter, inelastic dark matter and axion- like particles, are considered. Focusing on channels motivated by the dark sector models, we carry out a model independent study of the sensitivities of Z-factories in probing exotic decays. The limits on branching ratios of the exotic Z decay are typically O(10^−6−10^−8.5) for the Giga Z and O(10^−7.5 −10^−11) for the Tera Z, and they are compared with the projection for the high luminosity LHC. We demonstrate that future Z-factories can provide its unique and leading sensitivity, and highlight the complementarity with other experiments, including the indirect and direct dark matter search limits, and the existing collider limits. Future Z factories will play a leading role to uncover the hidden sector of the universe in the future.

2.4 Theory / 18

Sexaquark and other uds-quark Dark Matter

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A stable sexaquark (S) composed of uuddss is a compelling Dark Matter candidate and would not have been discovered in accelerator experiments to date. I will briefly review its particle properties, why the S would have eluded searches for an H-dibaryon, and analyses of Upsilon decay and LHC data suitable to discovering it (as are now underway by BABAR, Belle, CMS and LHCb). The main focus of the talk will be direct detection constraints on S Dark Matter, and two major almost model-independent cosmological consequences: predicted Omega_DM/Omega_b = 4.5-6, in excellent agreement with the 5.3 +- 0.1 observed, and 7Li abundance in agreement with observation (which is ~10sigma below the standard LCDM prediction). The Omega_DM/Omega_b prediction follows from statistical physics at the QGP-hadronization transition and approximately applies also for strange quark nuggets, but the 7Li result requires sexaquark DM. For the relevant parameter space of S interactions with nucleons via omega-phi and f0 meson exchange, Born Approximation does not apply, requiring a complete re-evaluation of Direct Detection experiments, as will be reported. Time permitting, new direct detection limits for generic hadronically interacting Dark Matter forming an atmosphere within and around Earth will be given, and additional astrophysical consequences of HIDM will be discussed.

4.2 Plenary / 19

First Results from the ADMX-G2 Axion Search

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We report on results from the first run of the ADMX-G2 experiment, a haloscope search for dark matter axions. The search excludes the range of axion-photon couplings predicted by the DFSZ model for masses between 2.66 and 2.81 μeV. This unprecedented sensitivity is achieved by operating a large-volume haloscope at sub-kelvin temperatures, thereby reducing thermal noise as well as the excess noise from the ultra-low-noise SQUID amplifier used for the signal power readout. Future runs will extend sensitivity over a wide range of axion masses.

5.1 Plenary / 20

Recent results from the COSINE-100 experiment

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COSINE-100 is a dark matter direct detection experiment that uses low-background NaI(Tl) crystals to test the DAMA collaboration's claimed detection of the dark matter annual modulation. The first phase of the experiment, situated at the Yangyang Underground Laboratory in South Korea, consists of eight NaI(Tl) crystals with a total mass of 106 kg and 2000 liters of liquid scintillator as an active veto. The physics run of the experiment began in September 2016 and several analyses are being performed based on the current energy threshold of 2 keV, with a background rate of $\sim$3 counts/kg/keV/day in the energy region between 2 and 6 keV. The performance of the detector and recent results will be presented.

5.1 Plenary / 21

Direct search for light dark matter with the CRESST-III experiment

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In absence of an unambiguous dark matter signal direct searches need to cover a wide range of potential dark matter particle masses. Thanks to their low energy thresholds, cryogenic experiments push the low-mass frontier with CRESST opening up the sub-GeV/c^2 regime.
CRESST-III employs scintillating $CaWO_4$ crystals as target material operated at mK temperatures. The phonon signal allows for a very precise measurement of the deposited energy while the simultaneously acquired scintillation light provides particle discrimination on an event-by-event basis. In early 2018 CRESST-III completed an initial data taking campaign reaching nuclear recoil thresholds of well below 100eV. This unprecedented low threshold provides a significant boost in sensitivity beyond CRESST-II which achieved a threshold of 0.3keV allowing for the first time to probe dark matter masses as low as 500MeV/c^2. New results of CRESST-III will be presented accompanied by a brief status update on the ongoing CRESST-III measurement campaign started in May 2018.

4.3 Direct Detection / 22

COSINUS: Probing the DAMA/LIBRA claim with NaI-based cryogenic detectors

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Dark matter is a main ingredient of the cosmos, its nature however is still in the dark. At present, after enormous progress in direct dark matter searches, the situation of this key question of today's particle physics is controversial: DAMA/LIBRA observes an annual modulation signal at high confidence matching the expectation for dark matter. In the so-called standard scenario, however, the DAMA/LIBRA signal is incompatible with the null-results of numerous other direct searches.

COSINUS aims to disentangle this inconsistency by providing a fully model-independent clarification of the DAMA claim. To exclude material effects, COSINUS will use crystals of sodium iodide, just as the DAMA/LIBRA experiment. Yet, COSINUS will not operate them as mere scintillation detectors, but as so-called cryogenic scintillating calorimeters at milli-Kelvin temperatures providing a coincident, independent measurement of both the temperature signal and the scintillation light signal caused by a particle interaction. Since the amount of produced light depends on the particle type (light quenching), this yields identification of the type of interacting particle on an event-by-event basis.

In this contribution we will present the recent achieved performance of first generation detectors. Furthermore, we will report first results on light quenching of nuclear recoils events in comparison to electron/gamma events measured at milli-Kelvin temperatures. We will conclude with a discussion on future steps and prospects.

5.1 Plenary / 23

Review on directional direct dark matter search with gaseous detectors

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A directional signal is thought to constitute strong evidence for dark matter detection. Consequently, substantial work on directional dark matter detection has been pursued and planned by the community. Directionality is also important for studying the nature of the dark matter once a discovery has been made. Gaseous detectors are prime candidates for directional detectors, due to their ability to track recoils and to assign event times.
In this talk, I will summarize current directional detection work, covering individual works, and within the wider CYGNUS collaboration CYGNUS.

5.3 Direct Detection / 24

NEWAGE

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NEWAGE is a direction-sensitive direct dark matter search experiment. NEWAGE uses a micro-TPC with a detection volume of 30 by 30 by 41 cm^3 read by one of the MPGD variations, \mu-PIC. We have been performing underground measurement since 2013 with a new detector NEWAGE-0.3b'. The results from 430 days' measurement will be presented. In order to improve the sensitivities, we are developing a low-radioactive \mu-PIC and a negative-ion TPC and its readout electronics. These recent activities to improve the sensitivity will also be reported.

5.1 Plenary / 25

Directional Search for Dark Matter Using Nuclear Emulsion

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A variety of experiments have been developed over the past decades, aiming at the detection of Weakly Interactive Massive Particles (WIMPs) via their scattering in an instrumented medium. The sensitivity of these experiments has improved with a tremendous speed, thanks to a constant development of detectors and analysis methods. Detectors capable of reconstructing the direction of the nuclear recoil induced by the WIMP scattering are opening a new frontier to possibly extend Dark Matter searches beyond the neutrino background. Exploiting directionality would also give a proof of the galactic origin of dark matter making it possible to have a clear and unambiguous signal to background separation. The NEWSdm experiment, based on nuclear emulsions, is a new experiment proposal intended to measure the direction of WIMP-induced nuclear recoils with a solid-state detector, thus with a high sensitivity. We discuss the discovery potential of a directional experiment based on the use of a solid target made of newly developed nuclear emulsions and novel read-out

systems achieving nanometric resolution. We also report results of a technical test conducted in Gran Sasso.

4.6 Theory / 26

MADMAX: A new way to search for QCD Axion Dark Matter with a Dielectric Haloscope

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Light Dark Matter candidates have increasingly come under the focus of scientific interest. In particular the QCD axion is also able to solve other fundamental problems such as CP-conservation in strong interactions. Galactic axions and axion-like particles can be converted to photons at boundaries between materials of different dielectric constants under a strong magnetic field. Combining many such surfaces, one can enhance this conversion significantly using constructive interference and resonances. The proposed MADMAX setup containing 80 high dielectric disks in a 10 T magnetic field could probe the well-motivated mass range of $40 - 400\,\mu$eV, a range which is at present inaccessible by existing cavity searches. The experimental idea and the proposed design of MADMAX will be discussed. Among recent R&D results from finite element simulations and proof-of-principle prototype measurements, the prospects of reaching sensitivity to the QCD axion will be presented.

5.5 Direct Detection / 27

Modelling of electromagnetic backgrounds in the CRESST experiment

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CRESST searches directly for dark matter (DM) with $\mathrm{CaWO_4}$ crystals operated as cryogenic calorimeters. It established leading limits for the spin-independent DM-nucleon scattering cross-section down to DM-particle masses of $350\,\mathrm{MeV/c^2}$. At this mass regime, the rejection power against electromagnetic background starts to degrade.

The background in the region of interest is mainly caused by beta and gamma decays of radioactive contaminations in the $\mathrm{CaWO_4}$ crystals and their Cu surrounding. To gain a reliable understanding of these background components a detailed Geant4 model of the contaminations is under development.

With this contribution we report the current status of the simulation used to validate the model. We discuss the absolute normalization of the simulation via sideband measurements of alpha decays. Finally, we show a preliminary comparison with experimental reference data.

I am also submitting an abstract to the track Direct Detection.

2.2 Plenary Session / 28

One year of XENON1T

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The XENON1T experiment is a direct dark matter search that has been operating in stable conditions at the Gran Sasso Underground Laboratory since December 2016. With an unprecedented target mass and a world-record low-background level, XENON1T is the largest liquid xenon time projection chamber operated up to date and it is uniquely placed to explore uncharted territory, further probing the WIMP paradigm as well as other dark matter models. In this talk, I will present the results of the WIMP search performed on data collected during the last year of data taking.

5.3 Direct Detection / 29

Directional Dark Matter search with optical readouts and the CYGNO project

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We are going to present the project for CYGNO, a 1kg gaseous TPC Dark Matter directional experiment, to be hosted at Laboratori Nazionali del Gran Sasso. CYGNO (a CYGNus TPC with Optical readout) fits into the context of the wider CYGNUS collaboration, for the development of a Galactic Nuclear Recoil Observatory at the ton scale with directional sensitivity. The most innovative CYGNO's features will be the exploitation of sCMOS cameras and PMTs, coupled to GEMs amplification of an He:CF4 gas mixture at atmospheric pressure. Compared to other optical approaches, these choices provide an improved signal/noise ratio, thanks to the 1-2 e-/pixel noise of sCMOS and high GEMs gains, combined with full 3D reconstruction, including head-tail, exploiting the large PMT signals. We will discuss the results of the Italian R&Ds with a 10 L detector prototype, demonstrating 3D tracking and background discrimination capabilities for O(100) keV nuclear and electron recoils, with O(100) um spatial resolution over 20 cm drift distance. In parallel, we will illustrate the complementary work with low pressure CF4 gases and CCDs readout by our collaborators of the University of New Mexico, showing 10^-5 gamma rejection at 10 keVee, and their recent results with CF4-SF6 negative ion drift mixtures. We will conclude with the foreseen CYGNO-1kg experiment performances and sensitivity.

4.3 Direct Detection / 30

(Poster) Results from the CRESST-III experiment

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CRESST is a direct dark matter detection experiment operating $CaWO_4$ target crystals as particle detectors at cryogenic temperatures. The third generation of CRESST detectors features nuclear recoil energy thresholds below $100eV$ combined with a sophisticated veto system for holder and surface related backgrounds in addition to the standard scintillation light based event-by-event particle discrimination technique. This allows to push the low-mass frontier for direct dark matter detection well into the sub-GeV/c^2 range.

The poster will focus on new results from the last data taking campaign obtained with an updated analysis scheme and a down to threshold analysis.

2.1 Plenary Session / 31

Status of the LZ dark matter search

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LUX-ZEPLIN (LZ) is a WIMP dark matter search under construction at the 4850' level of the Sanford Underground Research Facility in Lead, South Dakota. The centerpiece of the experiment is a two-phase TPC containing seven active tonnes of liquefied xenon. Rejection of backgrounds is enhanced by a set of veto detectors, including a liquid scintillator Outer Detector. LZ has been designed to explore much of the parameter space available for WIMP models, with excellent sensitivity for WIMP masses between a few GeV and a few TeV. This talk will review the current status of the experiment, and the plans for integration and commissioning in 2018 and 2019. First data is expected in 2020.

5.4 Indirect Detection / 32

GAPS: Cosmic-ray antinuclei for dark matter searches

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The GAPS Antarctic balloon payload is the first experiment optimized specifically for low-energy antideuteron and antiproton cosmic-ray signatures. Low-energy antideuterons have been recognized as an extraordinarily low-background signature of new physics, and low-energy antiprotons are probes of both light dark matter and cosmic-ray propagation models. Together, these signatures open new discovery space in cosmic rays, providing complementary coverage with direct detection, collider, and other indirect dark matter searches. GAPS is currently scheduled by NASA for its first Antarctic flight in late 2020. The experiment uses a novel detection technique, based on exotic atom capture and decay, to be sensitive to antinuclei in an unprecedented low energy range (<0.25 GeV/n) and to provide high rejection factors for rare antideuteron searches. The heart of GAPS will be 10 planes of lithium-drifted Si (Si(Li)) detectors, surrounded on all sides by a plastic scintillator time-of-flight. In this contribution, I will present the design, status, and discovery potential of the GAPS scientific program.

1.3 Direct Detection / 33

Electron Recoil Bubble Nucleation in PICO Bubble Chambers

Author: Daniel Baxter[1]

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The primary advantage of the bubble chamber technology for dark matter detection, as used by the PICO collaboration, is its simultaneous sensitivity to nuclear recoils from dark matter interactions and insensitivity ($\sim 10^{-10}$) to electron recoil backgrounds. Previously published data in CF_3I indicated that the probability of nucleation for a single electron recoil scales with the thermodynamic threshold of the detector. More recent calibrations in C_3F_8 suggest that this may not be the case, indicating that the nucleation mechanisms in the two fluids may be different. I present separate nucleation models for energy deposition in C_3F_8 and on heavy atomic targets like iodine. These models fit existing PICO calibration data reasonably well, and should allow for more accurate prediction of electron recoil background rates in future PICO dark matter searches.

2.5 Direct Detection / 34

First results of high voltage breakdown studies with XeBrA

Author: Lucie Tvrznikova[1]

Co-authors: Daniel McKinsey ; Ethan Bernard [2]; Scott Krawitz [2]; Quentin Riffard [2]; James Watson [3]; William Waldron [4]; Glenn Richardson [3]

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As noble liquid time projection chambers grow in size, their high voltage requirements increase, and detailed, reproducible studies of breakdown and electroluminescence are needed to inform their design. The Xenon Breakdown Apparatus (XeBrA) is a 5-liter cryogenic apparatus designed to study high voltage behavior in noble liquids located at Lawrence Berkeley National Laboratory. This talk will present the motivation for XeBrA and its first results in liquid argon and liquid xenon. Since experimental evidence suggests a correlation between electric field breakdown and electrode area in liquid argon, XeBrA was designed to characterize this behavior in both liquid argon and liquid xenon and allow for a direct comparison between measurements in these two noble liquids. Electrodes may be tested up to 30 cm2 in area, cathode-anode separation from 0 to 10 mm, and cathode voltages reaching -75 kV.

2.4 Theory / 35

(Withdrawn) Concentrated Dark Matter and Primordial Black Holes

Author: Scott Watson[1]

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I will discuss a new mechanism for the primordial creation of dark matter, 'co-decay', where hidden sector particles comprising the dark matter have little or no interaction with the Standard Model. So how does one detect it? The hidden sector leads to a matter-dominated phase before Big Bang Nucleosynthesis, which results in enhanced growth of dark matter on small scales and the production of primordial black holes. If the enhanced sub-structure survives until today it implies interesting implications for indirect detection experiments. Whereas a more provocative result is that the mass of the most populated black holes resulting from this epoch is within the mass range recently detected by LIGO. I will also discuss how the hypothesis that part of the dark matter is primordial black holes can be tested.

2.4 Theory / 36

Atomic Aspects of Light Dark Matter Searches

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Low-threshold detectors at sub-keV levels open windows to directly search for light dark matter (LDM) particles and constrain their possible interactions with electrons. As the energy and momentum scales of such scattering processes overlap with typical atomic scales, the many-body physics plays an important role in interpreting experimental data. In this talk, we present our approach and results of various scattering processes involving LDM or neutrinos with germanium or xenon, and discuss their implications for direct LDM searches and neutrino detection.

4.6 Theory / 37

The Cosmic Axion Spin Precession Experiment

Authors: Matthew Lawson[1]; Jan Conrad[2]; Alfredo Davide Ferella[1]; Dmitry Budker[3]; Derek Kimball[4]; Arne Wickenbrock[None]; Marina Gil Sendra[None]; Gary Centers[None]; Nathan Figueroa Leigh[None]; John Blanchard[None]; Antoine Garcon[None]; Martin Engler[None]; Deniz Aybas[None]; Peter Graham[None]; Surjeet Rajendran[None]; Alexander Sushkov[None]; Lutz Trahms[None]; Tao Wang[None]; Teng Wu[None]

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The Cosmic Axion Spin Precession Experiment (CASPEr) is a direct
Axion Like Particle (ALP) search. We use techniques analogous to Continuous Wave (CW)
Nuclear Magnetic Resonance to set limits on the axion-nucleon coupling.
The axion field can exert a torque on nuclear spins either by the axion wind
effect or by inducing a time-varying Electric Dipole Moment (EDM) in the nucleon.
We here report on the progress of the construction of the CASPEr-wind apparatus,
and discuss anticipated sensitivity.

4.2 Plenary / 38

The Status of Interpretations of the Galactic Center Excess

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I will summarize the evidence and arguments in favor of dark matter and pulsars as the source of the gamma-ray excess observed from the Inner Milky Way. The evidence in favor of a pulsar origin includes the observed small scale power in the gamma-ray emission from this region, and possible correlations between this emission and the distribution of stars. In opposition to this conclusion are the lack of bright pulsar-like gamma-ray sources and bright low-mass X-ray binaries in this direction of the sky. I will also comment on the implications of HAWC's TeV-halos for pulsar interpretations of this excess.

1.4 Astrophysics Dynamics / 39

A Particle Physicist's Perspective on the EDGES Anomaly

Author: Samuel McDermott[1]

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In a recent pair of Nature papers, Bowman et al. claimed a detection of an anomalously low 21 cm brightness temperature at a redshift of 17, and Barkana interpreted this as evidence of cold dark matter that was scattering with baryons at that cosmic epoch. In this talk, I will discuss constraints available in the particle physics literature, and future directions for particle, astro, and nuclear physics in the wake of the EDGES observation. A number of independent groups have found that cosmological constraints limit only a subdominant fraction of the dark matter particles to be able to participate in this scattering, and that even this limited scenario is strongly bounded by complementary terrestrial considerations. The prospects for investigating this small remaining region of viable parameter space are discussed in both terrestrial and astrophysical contexts.

2.2 Plenary Session / 40

Updated Dark Matter Search Results from the PICO-60 Bubble Chamber

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The PICO-60 experiment, located in the SNOLAB underground laboratory, is the largest bubble chamber operated to date by the PICO collaboration, filled with 52 kg of superheated C_3F_8. Initial dark matter search results were reported in 2017 based on operation at a 3.3 keV threshold. I will report new dark matter search results from increased exposure and lowered operational threshold, with improved sensitivity to low-mass WIMPs. I will also report on a new analysis of neutron calibration experiments performed by the PICO collaboration using neutron beams and low-energy (γ,n) sources, resulting in an improved measurement of the energy dependence of the nuclear recoil detection efficiency.

4.3 Direct Detection / 41

DANAE – A new attempt to search for Dark Matter with DEPFET-RNDR detectors

Author: Holger Kluck[1]

Co-authors: Johannes Treis [2]; Hexi Shi [3]; Jochen Schieck [4]; Jelena Ninkovic [5]; Alexander Bähr [6]

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Motivated by various theoretical models, the direct search for dark matter (DM) at the sub-GeV/c² mass scale gained special interest during the last years. In case of individual DM-electron interactions in Si-semiconductor devices, this requires a readout noise level of less than 1e- RMS.

The *Depleted P-channel Field Effect Transistor* (DEPFET) with *Repetitive Non Destructive Readout* (RNDR) is one possible technique which promise a sub-electron noise level. Such a low noise level was successfully demonstrated with a single pixel DEPFET-RNDR prototype [1]. DANAE is a new follow-up project aiming to apply the DEPFET-RNDR technique to the direct search for DM-electron interactions. This intends the assembly of a setup with a detector matrix of 64x64 pixels as well as an optimization of the dark current and the readout frequency.

In this contribution we will introduce the DEPFET-RNDR technique and the DANAE project. Afterwards, the status of the ongoing R&D work will be reported which is currently focused on the setup construction and the investigation of the temperature dependence of the dark current. Finally we will discuss future prospects of DANAE.

[1] A. Bähr, H. Kluck, J. Ninkovic, J. Schieck and J. Treis, Eur. Phys. J. C77 (2017) 905, arXiv:1706.08666

I am also submitting an abstract to the track Low Background Techniques.

42

(Duplicate) Astrophysical Signatures of Dark Matter Accumulation in Neutron Stars

Author: Tim Linden[None]

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Over the past few decades, terrestrial experiments have placed increasingly strong limits on the dark matter-nucleon scattering cross-section. However, a significant portion of the standard dark matter parameter space remains beyond our reach. Due to their extreme density and huge gravitational fields, neutron stars stand as optimal targets to probe dark matter-neutron interactions. As an example, over the last few years, the existence of Gyr-age neutron stars has placed strong limits on models of asymmetric dark matter. In this talk, I will discuss novel methods which utilize neutron stars to potentially detect dark matter interactions by studying the galactic morphology of neutron stars, as well as electromagnetic signals which may be produced via neutron star collapse. Intriguingly, these observations can probe extremely generic dark matter models spanning from MeV - PeV energies, and including troublesome portions of parameter space such as pure-Higgsino dark matter.

1.4 Astrophysics Dynamics / 43

21-cm Implications for Dark Matter: Results

Authors: Hongwan Liu[1]; Tracy Slatyer[None]

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Measurements of the temperature of the baryons at the end of the cosmic dark ages can potentially set very precise constraints on energy injection from exotic sources, such as annihilation or decay of the dark matter. However, additional effects that lower the gas temperature can substantially weaken the expected constraints on exotic energy injection, whereas additional radiation backgrounds can conceal the effect of an increased gas temperature in measurements of the 21-cm hyperfine transition of neutral hydrogen. Motivated in part by recent claims of a detection of 21-cm absorption from a redshift of 17 by the EDGES experiment, we derive the constraints on dark matter annihilation and decay that can be placed in the presence of extra radiation backgrounds or effects that modify the gas temperature, such as dark matter-baryon scattering and early baryon-photon decoupling. We find that if the EDGES observation is confirmed, then constraints on light dark matter decaying or annihilating to electrons will in most scenarios be stronger than existing state-of-the-art limits from the cosmic microwave background, potentially by several orders of magnitude. More generally, our results allow mapping any future measurement of the global 21-cm signal into constraints on dark matter annihilation and decay, within the broad range of scenarios we consider.

2.6 Theory / 44

Complete CMB Constraints for Millicharged Dark Matter

Authors: Daniel Pfeffer[None]; Kimberly Boddy[1]; Vivian Poulin[None]

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In this work we look at the complete cosmic microwave background (CMB) constraints on a millicharged dark matter (DM) model. Millicharged DM models have regained a lot of interest after the discovery of an anomalous 21cm signal by EDGES which can potentially be explained by the presence of scattering between DM and baryons. We focus on the simplest millicharged model that involves adding an unbroken U(1) symmetry to the Standard Model (SM). This addition to the SM adds a massive fermion that gets charged under the SM electric charge as well as a new gauge boson. The new gauge boson behaves as a massless dark photon.

Previous works mainly considered the implications from individual effects while we look at the impact of all of the interactions of the millicharged DM. We consider: scattering with photons, baryons and the dark photons as well as annihilations into SM particles. We rank the importance of each effect depending on region of the parameter space. By considering all of the effects we place constraints on the coupling of the DM to the standard model, the coupling of the dark matter to the dark photon as well as the redshift to the decoupling of the dark photons from the SM. We compare our cosmological constraints to these arising from other probes.

2.3 Direct Detection / 45

A combined energy scale for WIMP searches in liquid argon with the DarkSide-50 detector

Author: Luca Pagani[1]

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The DarkSide-50 detector aims to directly detect WIMPs using a liquid argon time-projection chamber.
Understanding the energy scale for WIMP interactions is important since it directly maps to a quantitative understanding of WIMP sensitivity.
A combined energy variable is developed where anti-correlation between ionization and scintillation produced by an interaction in liquid argon is taken into account.
This variable can better probe micro-physics parameters relevant for modeling liquid argon detectors.
Preliminary results on electron recombination probability, charge yield, and light yield for electronic recoil energies between 2.8 and 565 keV will be presented and compared to PARIS, the custom-made liquid argon response model.

4.2 Plenary / 46

Aspects of Dark Matter Axion Clumps

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In this talk I begin by reviewing how dark matter axions can undergo Bose-Einstein condensation and why this is captured by classical field theory. I explain that such condensates are spatially localized clumps, as they are organized by gravitation and self-interactions, and they may populate the galaxy. I discuss both the ground state and finite angular momentum states. Also, I comment on using ultra-light axions to resolve the cusp-core problem at the center of galaxies. I then discuss the possibility of parametric resonance of these axion clumps into electromagnetic waves, which may leave an astrophysical signature.

4.4 Axions / 47

The Stochastic Axion Scenario

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For the minimal QCD axion model it is generally believed that overproduction of dark matter constrains the axion mass to be above a certain threshold, or at least that the initial misalignment angle must be tuned if the mass is below that threshold. We demonstrate that this is incorrect. During inflation, if the Hubble scale is low, the axion tends toward an equilibrium. This means the minimal QCD axion can naturally give the observed dark matter abundance in the entire lower part of the mass range, down to masses ~10^{12} eV (or f_a up to almost the Planck scale). The axion abundance is generated by quantum fluctuations of the field during inflation. This mechanism generates cold dark matter with negligible isocurvature perturbations. In addition to the QCD axion, this mechanism can also generate a cosmological abundance of axion-like particles and other light fields.

2.5 Direct Detection / 48

Simulations for the LUX-ZEPLIN Experiment

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The LUX-ZEPLIN experiment will use a seven tonne dual-phase xenon TPC for the direct detection of WIMP dark matter. Backgrounds that can affect the experiment's sensitivity must be well understood. Simulations are essential to estimate these and thus to develop effective strategies to mitigate them. They are also useful in assessing detector performance, and planning calibration and analysis schemes. I will describe the LZ simulations framework and give details of how its output is used to inform these applications.

5.2 Plenary / 49

Searching for Dark Matter at the Cosmic Dawn

Author: Julian Munoz Bermejo[1]

Co-authors: Abraham Loeb [2]; Cora Dvorkin

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Current and upcoming 21-cm measurements during the cosmic dawn can provide a new arena on the search for the cosmological dark matter. This era saw the formation of the first stars, which coupled the spin temperature of hydrogen to its kinetic temperature—producing 21-cm absorption in the CMB. The strength of this absorption acts as a thermostat, showing us if the baryons have been cooled down or heated up by different processes. In particular, during the cosmic dawn, the baryon-dark matter fluid is the slowest it will ever be, making it ideal to search for dark matter elastically scattering with baryons through massless mediators, such as the photon. I will describe how dark-matter particles with an electric millicharge can significantly alter the baryonic temperature, and thus explain the anomalous 21-cm depth observed by the EDGES collaboration.

1.2 Plenary Session / 50

The COHERENT collaboration and its first observation of CEνNS

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The Coherent Elastic Neutrino-Nucleus Scattering (CEνNS) has been observed at a 6.7-sigma confidence level by the COHERENT collaboration using a 14.6-kg CsI[Na] scintillator at Oak Ridge National Laboratory. The CEνNS process predicted by the standard model is a neutral-current weak interaction where the cross section is enhanced by N^2, where N is the number of neutrons in the nucleus. This indicates a new way to build compact neutrino detectors and unlocks new channels to test the standard model. More detectors are being and will be deployed at Oak Ridge to further test CEνNS including a single-phase liquid argon detector, a p-type point contact germanium detector

array and a NaI[Tl] detector array. The result, present status and future plans of the COHERENT collaboration will be presented.

2.6 Theory / 51

Capture and decay of electroweak WIMPonium

Authors: Pouya Asadi[None]; Matthew Baumgart[1]; Patrick Fitzpatrick[2]; Emmett Krupczak[3]; Tracy Slatyer[3]

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The spectrum of Weakly-Interacting-Massive-Particle (WIMP) dark matter generically possesses bound states when the WIMP mass becomes sufficiently large relative to the mass of the electroweak gauge bosons. The presence of these bound states enhances the annihilation rate via resonances in the Sommerfeld enhancement, but they can also be produced directly with the emission of a low-energy photon. I will present a calculation of the rate for SU(2)-triplet dark matter (the wino) to bind into WIMPonium – which is possible via single-photon emission for wino masses above 5 TeV for relative velocity v < \mathcal{O}\left(10^{-2} \right) – and the subsequent decays of these bound states. I will also present results with applications beyond the wino case, e.g. for dark matter inhabiting a general nonabelian dark sector.

5.3 Direct Detection / 52

NEWS-G Light dark matter searches with a Spherical Proportional Counter

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NEWS-G (New Experiments With Spheres-Gas) proposes a new concept for the dark matter search, based on a spherical gaseous detector, the Spherical Proportional Counter (SPC). The detector has a large volume and single electron detection sensitivity and may be filled with light gaseous targets such as hydrogen, helium, and neon. The capabilities of the detector permit the extension of dark matter searches to candidates with a mass from 0.1 GeV to few GeV which are out of the range of liquid noble gas TPCs and complementary to some solid state detectors using heavier elements as targets. Dark matter searches in the low mass range are well motivated by the recent non-findings in the higher mass region and the richness of theoretical models that predict candidates in the low mass range, opening a window to non-standard model physics. NEWS-G already operates a SPC of this type (SEDINE), a 60cm diameter sphere, placed in the underground laboratory of Modane (France), which acts as the current main detector but also as a testing ground. The full-scale detector, 140 cm in diameter, will be installed in SNOLab (Canada) by March 2019. In this talk, I will present the first NEWS-G results with neon as target nuclei, which exclude at 90% confidence level (C.L.) cross-sections above $4.4 \cdot 10^{3\ 7}$ cm^2 for a 0.5 GeV/c^2 WIMP based on 9.7 kg·days of exposure.
I will also discuss the status of the second phase of SEDINE based on helium gas mixtures along with the status of the NEWS-G/SNOLAB project and the prospects for the future.

5.4 Indirect Detection / 53

Dwarf galaxies J-factors without priors: a frequentist Jeans analysis consistent with indirect Dark Matter searches

Authors: Andrea Chiappo[1]; Jan Conrad[2]; Johann Cohen-Tanugi[3]; Louis Strigari[4]; Nils Håkansson[5]

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Dwarf spheroidal galaxies (dSphs) are considered promising targets for indirect Dark Matter (DM) identification. The (mostly frequentist) analyses of gamma-ray photons originating from dSphs have allowed to set stringent limits on the DM self-annihilation cross-section. Conventional search strategies rely on quantifying the abundance of DM by calculating the so-called J-factor. This quantity can be estimated from the kinematic properties of the stellar population of dSphs by means of Bayesian methods, which introduce significant systematic uncertainties due to the inevitable influence of priors. Here we describe a fully frequentist method for deriving J-factors and their uncertainties, which improves upon previous studies by making the statistical treatment of J consistent with most gamma-ray analyses. We investigate the statistical properties of the frequentist approach by validating our method on the simulation suite released by Gaia Challenge. The technique is applied on kinematic samples from 9 dSphs producing profile likelihoods of J, a subset of which is implemented to derive new upper limits on the DM annihilation cross-section. The new limits and the implications of these findings for DM searches are discussed.

4.6 Theory / 54

Future prospects for axion haloscopes: Multiple cavities and really strong magnets

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The Axion Dark Matter eXperiment (ADMX) is conducting a search for axions within the dark-matter halo of our Galaxy. The power emitted from the ADMX cavity is proportional to B2V, where B is the strength of the magnetic field threading the cavity and V the cavity volume. ADMX has achieved its goal of reaching the DFSZ limit, receiving ~100 yW power, which near-quantum-limited detectors can detect in 10—100 sec integration times. The search has set limits in the 2.6. to 2.8 microeV range and continues to scan towards higher frequencies. As frequency goes up, either the volume of the simple cylindrical cavity must decrease or one must go to multiple cavities or more complex shapes. ADMX will use a 4-cavity array in its generation-2 search to cover 5-9 microeV Performance of prototypes of this cavity, including a Pound-locking scheme, will be presented. To extend to higher frequencies, ADMX should procure a new magnet. The magnet would be smaller in volume but higher in field; B2V is the factor to maintain. With Heising-Simons support and in collaboration with the NHMFL and Oxford instruments, we have made a design study for such a magnet. Using high-temperature superconductors, a field of 32 T in a volume of about 7 liters could be achieved. Compared to the present ADMX magnet and cavity, the square of the magnetic field increases by a factor of 16 and the volume is decreased by a factor of 20. The power emitted from a four-cavity array would be in the 120 yW range and the system would be able to tune 8 to 25 microeV. The practical details of such a magnet will be discussed.

3.1 Plenary / 55

(Withdrawn) Underground Laboratory of Modane (LSM) ; Multi-disciplinarily and Rare events experiments cozy host

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The LSM is Located in the middle of the French/Italy " Fréjus " tunnel , below Fréjus peak mountain under 1700 m (4800 m.w.e) rock and it is a cozy place to look for rare process such as WIMP research or double beta decay detection.
The low radioactive environment of the LSM, characterize it as an exceptional place for experiments requiring low radioactivity conditions in Particle and Astroparticle Physics, Germanium gamma ray spectrometry, environmental sciences, biology and nano-electronics. The LSM hosts also facilities such as clean deradonized room (class 5) and anti-Radon facility.
The LSM structure and briefly review of all experiments installed at LSM will be presented.

3.1 Plenary / 56

Direct dark matter search with CDEX at CJPL

Authors: Ma Hao[1]; Qian Yue[1]; Litao Yang[None]; Hao Jiang[None]; Zhi Zeng[None]; Jianping Cheng[None]

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The China Dark Matter Experiment (CDEX) aims at direct searches of light Weakly Interacting Massive Particles (WIMPs) at the China Jinping Underground Laboratory (CJPL) with an overburden of about 2400m rock. Results from CDEX-1B and CDEX-10 phase, and related technical development are reported. In addition, the progress of CJPL-II extension project will be introduced.

5.5 Direct Detection / 57

Material Informatics for Dark Matter Detection

Authors: Alexander Balatsky[1]; Matthias Geilhufe[2]; Alfredo Ferella[3]; Felix Kahlhoefer[4]; Jan Conrad[3]; Timo Koski[5]; Bart Olsthoorn[6]

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A promising path to detect dark matter is given by direct detection, i.e., detecting the recoil of dark matter particles in a target material by measurement of the energy deposited, as light, charge or heat. For the case of light dark matter (below 1 GeV) this approach is strongly connected to the highly non-trivial task of identifying appropriate materials having the necessary target properties, such as, optimal band gap, chemical stability, large single crystal sizes, or, specific magnetic and dielectric

properties. Motivated by the exponential growth of computational power and the resulting data, we recently witness novel approach towards functional materials prediction in the framework of materials informatics. Here, methods adapted from computer science based on data-mining and machine learning are applied to identify materials with requested target properties. In our contribution, we outline the approach for finding target materials for light dark matter detection using the electronic structure database OMDB.

2.3 Direct Detection / 58

The Spin-independent analysis of one tonne-year of XENON1T data

Author: Knut Morå[None]

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The XENON1T collaboration has completed a search for Weakly Interacting Massive Particles using a total of 1 tonne-year of exposure. This talk will detail the analysis performed of the combined XENON1T dataset dearching for spin-independent scatters in a fiducial mass of 1.3 tonnes.

1.5 Direct Detection / 59

Testing DAMA/LIBRA result with ANAIS-112 experiment at the Canfranc Underground Laboratory

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The ANAIS (Annual modulation with NaI(Tl) Scintillators) experiment aims at the confirmation or refutation of the DAMA/LIBRA positive annual modulation signal in the low-energy detection rate using the same target and technique at the Canfranc Underground Laboratory (LSC) in Spain. Several 12.5 kg NaI(Tl) modules produced by Alpha Spectra Inc. have been operated in Canfranc during the last years in various set-ups. All of them have shown an outstanding light collection at the level of 15 photoelectrons per keV, which allows triggering at 1 keV of visible energy, and their background has been fully characterized. The ANAIS-112 set-up consisting of nine detectors in a 3x3 matrix configuration with a total mass of 112.5 kg was commissioned at LSC in the first semester of 2017. The dark matter run started on August, the 3rd and is running smoothly since then. The ANAIS-112 experimental plan is to take data for two years and in parallel, to explore a possible experiment upgrade. ANAIS-112 sensitivity will allow exploring the DAMA/LIBRA singled-out WIMP parameter region at 3 sigma in 5 years of data taking. Discovery potential of ANAIS-112 in present conditions is high if WIMPs are responsible of the DAMA/LIBRA annual modulation signal.
Here, the latest results on the detector performance (light collection, low energy calibration, event selection, stability..) and on the background model of all the detectors will be presented and the physics potential of the experiment will be discussed.
I am also submitting an abstract to the track: Direct Detection

5.3 Direct Detection / 60

Status of the TREX-DM experiment at the Canfranc Underground Laboratory

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TREX-DM (TPC Rare Event eXperiment for Dark Matter) is an approved experiment by the Canfranc Underground Laboratory (LSC) in Spain, intended to look specifically for low-mass WIMPs (<10 GeV) that could be pervading the galactic dark halo. This requires the use of light elements as target and detectors with very low energy threshold; TREX-DM is conceived to fulfil these requirements using a gas time projection chamber (TPC) equipped with novel micromesh gas structures (Micromegas) readout planes. The detector can hold, in the fiducial volume, ~20 litres of pressurized gas up to 10 bar, which corresponds to ~300 g of Ar, or alternatively, ~160 g of Ne. The Micromegas are highly segmented and read with a self-triggered acquisition, allowing for effective thresholds below 0.4 keV (electron equivalent). An exhaustive material screening campaign has allowed to design and construct the detector and shielding with the state-of-the art radiopurity specifications. The background model developed by Monte Carlo simulations suggests that levels of the order of 1-10 counts keV-1 kg-1 d-1 are expected in the region of interest, making TREX-DM competitive in the search for low mass WIMPs. After completion of a series of measurements at ground level, the commissioning at the LSC facilities is almost finished and the start of the data taking is expected for this summer. Operation with Ne first and (depleted) Ar afterwards is foreseen. Here, the description of the background model, the status of the installation and first operation in Canfranc, and the expected WIMP sensitivity will be presented.

I am also submitting an abstract to the track: Direct Detection

4.3 Direct Detection / 61

Detector Stability of COSINE-100

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COSINE-100 is a direct detection dark matter experiment consisting of 106 kg of low-background NaI(Tl) crystal detectors located at the Yangyang Underground Laboratory in South Korea. One of the primary physics goals of COSINE-100 is to search for a WIMP-induced annual modulation signal to confirm or refute DAMA/LIBRA's claim of dark matter discovery. The search for an annual modulation signal requires a thorough understanding of time-dependent environmental effects and a high degree of detector stability. To achieve the required level of stability, COSINE-100 has developed a monitoring system to measure operating conditions, such as temperature, radon levels, and muon rates, over time. Here, I will present the COSINE-100 monitoring system and discuss the achieved stability of the COSINE-100 detector.

4.5 Direct Detection / 62

First Evidence for Radon Daughter Solubility in Liquid Xenon

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Dual phase liquid/gas xenon time projection chambers (TPCs) currently set the worlds most sensitive limits on weakly interacting massive particles (WIMPs), a favored dark matter candidate. Radon and radon daughters produce problematic backgrounds for these searches. During detector construction, 222Rn and daughters plate out onto detector surfaces. While 222Rn has a half-life of 3.8 d, the long-lived daughter 210Pb (half life ~22.3 y) can be a source of background events in even the longest running searches. Of particular concern for liquid xenon dark matter detectors are the 'naked beta' decays of 210Pb and 210Bi. Rejection of these backgrounds relies solely on being able to distinguish electron recoils from nuclear recoils. Typically it is assumed that once 222Rn and daughters plate out, they remain stuck to the surface, where a fiducial volume cut will reject the 'naked beta' decays of 210Pb and 210Bi. However, evidence of 210Bi mobility has been observed in the liquid scintillator environment of the KamLAND detector. If radon daughters are soluble in liquid xenon, the 'naked beta' decays of 210Pb and 210Bi pose a serious background distributed the fiducial volume. We present first evidence of the solubility of adsorbed radon daughters in liquid xenon from a laboratory test with the 220Rn chain; we discuss possible mechanisms for this solubility, and differences in the 220Rn and 222Rn chains.

I am also submitting an abstract to the track Low Background Techniques.

4.5 Direct Detection / 63

Two Distinct Components of the Delayed Single Electron Noise in Liquid Xenon Emission Detectors

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Single electron noise which persists for many milliseconds is known to follow ionizing events in liquid/gas xenon emission detectors. This noise can span multiple event windows and can pile up in time. Therefore it can be mistaken for a genuine signal. Delayed electron noise can be a limiting background to the low-energy threshold of dark matter searches, and could prevent discovery-class searches for MeV scale hidden sector dark matter. We present a laboratory study that reveals distinct fast and slow components to the noise. The fast component is compatible with the hypothesis of delayed emission of electrons trapped below the liquid surface, and can be reduced by increasing the electric field across the liquid/gas interface. However, the slow component increases linearly with electric field. We also discuss hypotheses for the behavior of the slow component and suggest techniques for mitigation.

I am also submitting an abstract to the track Low Background Techniques.

4.3 Direct Detection / 64

Rare-event searches using the Majorana Demonstrator

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Located at the 4850' level of the Sanford Underground Research Facility (SURF) in Lead, SD, the Majorana Demonstrator (MJD) experiment is searching for neutrinoless double beta decay in Ge-76 with high-purity Germanium (HPGe) detectors. The combination of low-activity materials of the Demonstrator and careful control of cosmic-ray exposure to the enriched Ge detectors have resulted in a low-background level throughout the entire energy spectrum starting from ~1 keV. The Demonstrator has achieved excellent energy resolution and low energy thresholds for the HPGe detectors, and the experiment has a compelling low-energy physics program with sensitivity to dark matter and axion searches. Multiple competitive searches of physics beyond the standard model are carried out with the MJD commissioning data at low-energies. MJD physics datasets taken later have factor of several reduction in the background at low energy, which enables improved and additional rare-event searches. In this talk, we will discuss the status of rare-event searches of the Majorana Demonstrator with a focus on dark matter candidates.

5.5 Direct Detection / 65

Background Assessment of the COSINE-100 Experiment

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COSINE-100 is a NaI(Tl) dark matter direct detection experiment, with the goal of testing DAMA's claim of dark matter detection by looking for an annual modulation signal. It consists of eight NaI(Tl) crystals, adding to a total of 106 kg, and 2000 liters of a liquid scintillator veto. Located at the Yangyang Underground Laboratory, South Korea, COSINE-100 has been running since September 2016. The search for an annual modulation signal requires a complete understanding of the radioactive backgrounds and their time dependence. This can be achieved by conducting a full detector simulation and modeling the detector's background, in addition to studying the cosmogenic activation history of the crystals. Details of the COSINE-100 simulation, the background assessment, and the study of cosmogenic activated isotopes will be presented.

2.3 Direct Detection / 66

Sub-GeV Dark Matter Results from a Single Electron-Hole-Pair SuperCDMS Detector

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The SuperCDMS collaboration has designed a new generation of semiconductor-based dark matter detectors with sensitivity to single charge carriers and very low dark count rates. The achieved threshold of less than half of an electron-hole pair enables the detection of events with energy deposits as little as 1.2 eV (0.7 eV), the indirect bandgap energy of Si (Ge). This threshold was reached partially through the use of the Neganov-Trofimov-Luke effect where the charge carriers drift through a large electric potential, converting their potential energy into phonons. In order to take advantage of this crucial pre-amplification mechanism, a phonon detector with an energy resolution of order of 10 eV is needed - a technical challenge in its own right. In this talk I will discuss the initial science results from 0.5 g-d of exposure with a gram-scale prototype detector, and prospects for future dark matter searches employing similar detectors with further improved charge resolution and even lower backgrounds.

2.5 Direct Detection / 67

Phase 2 Upgrades for the HAYSTAC Axion Experiment

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The axion was first proposed as a solution to the strong CP problem, and also serves as a well-motivated dark matter candidate. HAYSTAC is a dark matter axion experiment designed to detect cosmic axions through their conversion into photons using a high Q microwave cavity detector. The flexibility of HAYSTAC's platform allows for the development of new microwave cavity and amplifier concepts in an operational environment, and is the first to explore the axion model band above 20 μeV. HAYSTAC has now concluded Phase 1 of the experiment and has excluded axions in the range 23.15\,< m_a\,< 24.0 μeV at with two photon coupling at $\mathrm{g}_{\alpha\gamma\gamma} > 2 \times 10^{-14}$ GeV^{-1}. I will discuss the changes to the experiment that have been made in preparation for Phase 2. These include a refurbished cavity, improved cryogenics, and the addition of a squeezed-state receiver.

1.5 Direct Detection / 68

The PTOLEMY-G experiment for light dark matter direct detection

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One of the pillars of the standard cosmological model is the undisputed existence of a relic cosmic neutrino background (CNB) that still need to be probed. Recently a new window to the direct detection of CNB has been opened with the proposal of the PTOLEMY experiment, with a prototype detector ready to be tested at an Underground site, likely the Gran Sasso Laboratory in Italy. Given the exceptional sensitivity of the detector to low energy electrons, a novel method based 2D target surfaces, fabricated from graphene, for light (MeV-scale) dark matter direct detection is proposed as a first stage to form a basis for the future large-scale relic neutrino detector. The PTOLEMY experimental program will be outlined with special focus on the light dark matter direct detection program.

2.6 Theory / 69

Dark decay of the neutron

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New decay channels for the neutron into dark matter and other particles have been suggested for explaining a long-standing discrepancy between the neutron lifetime measured from trapped neutrons versus those decaying in flight. Many such scenarios are already ruled out by their effects on neutron stars, and the decays into dark matter plus photon or electron-positron pair have been experimentally excluded. In this talk, I will present a scenario in which the neutron decays into 2 invisible particles: a dark Dirac fermion and a dark photon. This setup can be consistent with all constraints if the fermion is a subdominant component of the dark matter. I will discuss the limits on the model's parameter space that are derived from the existence of two solar mass neutron stars, direct and indirect dark matter detection, supernova observations, and cosmological considerations.

2.5 Direct Detection / 70

Background analysis in a one tonne-year dark matter search of XENON1T

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The XENON collaboration has completed a search for WIMP-nucleon Spin-Independent elastic scattering using a one tonne-year exposure of XENON1T detector. The XENON1T experiment has an electronic recoil background of ~0.2 events/(tonne-day-keVee), the lowest ever achieved in any dark matter search experiments. This talk will describe the background modeling performed in this WIMPs search analysis.

3.1 Plenary / 71

Recent Analysis Efforts of the LUX Collaboration

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LUX (Large Underground Xenon) is a retired, direct dark matter detection experiment that has published three, previously world leading limits on the spin-independent cross section for the Weakly Interacting Massive Particle (WIMP) nucleon scattering. The detector was dismantled in the Fall of 2016 and efforts were shifted to completing additional analyses with the existing WIMP-scattering and calibration data sets, some of which inform the second generation LUX-ZEPLIN (LZ) experiment. This talk describes new work that improves our understanding of radiogenic backgrounds, detector performance, and scope of dark matter models for which xenon time projection chamber detectors are competitive. Special emphasis is given to accurate characterization of backgrounds for the purpose of extracting signals at energies beyond the range of the earlier spin-independent WIMP-search analyses.

5.3 Direct Detection / 72

Dark Photon Searches with SuperCDMS Technology

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The Super Cryogenic Dark Matter Search (SuperCDMS) is a direct dark matter search experiment designed to observe nuclear recoils induced by WIMPs. However, it is also sensitive to dark photons that kinetically mix to the Standard Model photon. This mixing allows dark photons to produce electron excitations through the photoelectric absorption, depositing an energy equal to the dark photon mass. The band structure of semiconductor detectors gives this technology sensitivity to dark photon masses as small as a few eV, allowing to probe new parameter space at dark photon masses from a few eV to about 1 keV. This talk will highlight the first dark photon search results using single electron-hole-pair detector data and will discuss the prospect of a search with the upcoming SuperCDMS SNOLAB experiment.

3.1 Plenary / 73

Understanding eV-threshold calorimeters for SuperCDMS

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The state of nuclear recoil calibrations in germanium and silicon at and below 500 eV and plans for SuperCDMS will be discussed. New calibrations, and novel methods of calibration, at the ultra-low thresholds acheivable by SuperCDMS are required. Traditional calibrations using the scattering of fast neutrons will be supplemented by calibrations studying the Thompson scattering of high-energy photons and the recoils from photon emission during thermal neutron capture.

2.1 Plenary Session / 74

Low-mass WIMP searches with EDELWEISS

Authors: Veronique Sanglard[1]; EDELWEISS collaboration[None]

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The EDELWEISS collaboration is performing a direct search for WIMP dark matter in the range from 1 to 20 GeV/c2 using cryogenic germanium detectors equipped with a full charge and thermal signal readout. We present the most recent results and the currently ongoing program to reduce the experimental thresholds and gain sensitivity for low mass WIMPs, either utilizing the Neganov-Trofimov-Luke effect in the EDELWEISS-LT program, or increasing the discrimination of backgrounds with an improved ionization readout in the MELODI program. New prospects for Axion-Like Particle dark matter searches will also be presented.

1.3 Direct Detection / 75

SuperCDMS Detector Performance and Early Science from CUTE

Author: Tsuguo Aramaki[1]

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The SuperCDMS SNOLAB experiment will search for low-mass dark matter particles at SNOLAB, the deep underground laboratory near Sudbury Ontario Canada. The new generation of SuperCDMS germanium and silicon detectors will be tested for functionality in facilities operated by the SuperCDMS collaboration in laboratories above ground. However, the background radiation in these facilities is very high. Prior to deployment in the experiment, some of the detectors will therefore be operated in the Cryogenic Underground TEst facility (CUTE) at SNOLAB, which will enable performance tests that cannot be accomplished in a high-background environment. It is also expected to provide the possibility to explore some new dark matter parameter space in the low-mass region. In this talk, I will present the current status of the SuperCDMS SNOLAB detectors, as well as the goals and potential scientific reach of the measurements performed at CUTE.

2.6 Theory / 76

Early- and Late-Time Scattering of Dark Matter and Baryons in Cosmology

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There is a substantial effort in the physics community to search for dark matter interactions with the Standard Model of particle physics. Collisions between dark matter particles and baryons exchange heat and momentum in the early Universe, enabling a search for dark matter interactions using cosmological observations in a parameter space that is highly complementary to that of direct detection. Depending on the form of the interaction, scattering is most prominent either at early times or late times. In this talk, I will describe the effects of scattering in the CMB power spectra and in the matter power spectrum, and discuss the implications of late-time scattering during Cosmic Dawn.

2.2 Plenary Session / 77

Status of the DEAP-3600 dark matter search

Author: Marcin Kuzniak[None]

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DEAP-3600 is a single-phase scintillation-only detector, which searches for dark matter particle interactions with 3.3 tonnes of liquid argon, located 2 km underground at SNOLAB (Sudbury, Ontario). The argon target is contained in an ultra-pure acrylic vessel viewed by 255 photomultiplier tubes.

The first DEAP-3600 WIMP-search results from 10 tonne-days of commissioning data were published last year, demonstrating the scintillation-only technique, the best achieved electronic-recoil backgrounds rejection using pulse-shape discrimination, lowest-ever achieved radon backgrounds in a noble liquid experiment, and demonstrating scalability to the very large target masses required to reach the neutrino floor.

The detector has been running stably since November 2016 and has accumulated exposure significantly exceeding the published dataset. This talk will present an overview of the project and status of the analysis of 1 year worth of data. Future plans for larger detectors will also be discussed.

2.5 Direct Detection / 78

Production and high voltage testing of the LZ detector grids

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The LZ (LUX-ZEPLIN) dark matter search experiment is a liquid xenon time projection chamber (TPC) with a 7 tonne active xenon volume currently under construction. Four wire mesh grids of 1.5 m diameter establish electric fields in the detector to drift ionization electrons across the volume and extract them from the liquid surface. This presentation will discuss the design, construction, surface treatment, mitigation of radon exposure, and high voltage performance of the LZ grids. The high voltage testing characterizes the electron and photon emission rates of the grids at high electric fields. Three detectors contribute to the high voltage testing program including a small-scale gaseous xenon detector, a small-scale liquid xenon TPC detector to study electron extraction, and a large gaseous xenon detector to test the final LZ grids.

2.3 Direct Detection / 79

Results on sub-GeV dark matter direct detection with LUX Run 3 data by using Bremsstrahlung and Migdal-effect signal

Authors: Junsong Lin[1]; Lucie Tvrznikova[2]

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Dual-phase xenon time projection chambers have been recently suggested to be sensitive to sub-GeV dark matter if the inelastic channels of Bremsstrahlung and the Migdal effect in the nuclear interaction are taken into account. Sub-GeV dark matter is difficult to probe due to the small energy transfer in dark matter-nucleus elastic scattering and the finite energy threshold of the detector. Considering photon emissions from Bremsstrahlung or electron emissions from Migdal effect in the dark matter nucleus inelastic scattering could circumvent this difficulty. This analysis utilizes both the scintillation (S1) and ionization (S2) signals in the LUX Run 3 data. New sub-GeV parameter space in the dark matter- nucleus interaction cross-section is explored using the Profile Likelihood Ratio method.

5.4 Indirect Detection / 80

Effects of Dark Matter Distribution Uncertainties on Milky Way Satellite Galaxy Dark Matter Searches

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Milky Way satellite galaxies are compelling targets for dark matter searches due to their proximity, high dark matter content, and low astrophysical backgrounds. Detailed studies of the stellar kinematics of satellite galaxies provide information on their dark matter content and velocity distribution. In this talk, I will discuss the systematic uncertainties in determining the dark matter content and phase space distribution from stellar kinematics. They have important impacts on several dark matter constraints such as dark matter annihilation/decay cross section limits for both velocity-independent and velocity dependent models. Finally I will discuss how forthcoming survey data and future facilities will improve our understanding of satellite dark matter distributions.

1.3 Direct Detection / 81

Potassium and Dark Matter: the KDK Experiment

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The nature of the dark matter thought to make up most of the matter in the universe is unknown. It may consist of new particles from beyond the standard model. For close to two decades, the DAMA experiment has claimed to have detected such particles. This claim is controversial, in particular because there is no accepted model for the background radioactivity in DAMA. One major unknown is the contribution of the decay of potassium 40 (40K) by electron capture (EC) to ground state. The KDK (40K decay) experiment at Oak Ridge National Laboratories (ORNL) brings together groups from Queen's, ORNL, the University of Tennessee, the Max Planck Institute and TRIUMF. KDK will measure the EC branching ratio using a 40K source, a small detector to trigger on the 3 keV X-rays from EC, and a large outer detector to veto the 1.4 MeV gamma rays coming from the competing electron capture decays to an excited state. We will present the status of the experiment, including calibrations and data taking.

5.4 Indirect Detection / 82

Point Sources at the Galactic Center

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The Galactic Center GeV excess is firmly detected. While there is statistical evidence suggesting the excess originates largely from point sources, its interpretation as a signal of annihilating dark matter has not been conclusively ruled out. I will discuss the degree to which assumptions about the diffuse modeling and source populations could affect non-Poissonian template fitting methods that indicate a point-source origin for the excess.

4.5 Direct Detection / 83

Neutron production in radioactive processes relevant to underground experiments

Author: Vitaly Kudryavtsev[1]

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Neutron production in (alpha,n) reactions as one of the main contributors to the background in dark matter experiments is discussed. Several codes exist to calculate the neutron yields and spectra from the decays of naturally occurring isotopes in various materials giving sometimes quite different results. The comparison of different codes will be presented and the sources of differences between the results will be discussed, also in comparison with available measurements.

1.3 Direct Detection / 84

ER/NR Discrimination in Liquid Xenon with the LUX Experiment

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Liquid xenon is one of the most promising targets for WIMP dark matter direct detection. Above 10GeV, the most stringent limits on WIMP-nucleus cross section have been established by the LUX, XENON1T, and PANDAX-II collaborations, by using the technology of the two-phase xenon time projection chamber. In addition, several experiments using the same technology are in development, in particular LUX-ZEPLIN and XENONnT. For standard WIMP searches, our signal is composed of nuclear recoils (NR), while our background is composed of both electron recoils (ER) and NR. Measurement of the charge to light ratio offers discrimination capability between ER and NR, allowing us to reduce the background. The vast amount of LUX calibration data at different electric fields allows me to present an analysis of ER/NR discrimination and how it is affected by the electric field. Finally, I will describe the potential of future LXe experiments to probe dark matter parameter space.

1.5 Direct Detection / 85

HeRALD: direct detection with superfluid 4He

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We present the HeRALD detector concept, a staged path to meV nuclear recoil thresholds. The proposal centers on a 4He target at mK temperatures, which allows long-range ballistic propagation of the superfluid's phonon and roton excitions. On reaching a liquid-vacuum interface, such kinetic excitations liberate 4He atoms via a one-to-one process, and this signal channel of liberated atoms is then sensed via its adsorption energy onto large-area low-threshold calorimetery. We describe past R&D on this technique, along with sensitivity projections assuming various levels of technical advancement.

5.5 Direct Detection / 86

Measurement of Background Gamma Flux in the Davis Cavern for the LZ Experiment

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The LUX-ZEPLIN (LZ) experiment will search for dark matter particle interactions with a liquid xenon TPC in the Davis cavern at the Sanford Underground Research Facility, Lead, South Dakota, 4850 feet below the surface. The underground environment reduces the cosmic ray flux by a factor of 10^6, but there remains a potential background from γ-rays emitted from the decays of ^{40}K, ^{238}U and ^{232}Th naturally occurring in the rock surrounding the laboratory. In-situ γ-ray measurements were taken with a sodium iodide detector in several locations within the cavern, yielding average radioactivity levels. We will present the radioactivity levels determined with these measurements, along a first attempt at mapping non-uniformities in the γ-flux due to differences in rock composition.

1.3 Direct Detection / 87

(Withdrawn) Select Effective Field Theory Results from the 2014-2016 LUX WIMP search run

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We analyze the WIMP search data from the Large Underground Xenon (LUX) experiment 2014-2016 WIMP search run (a 33,480 kg-day exposure) under a non-relativistic effective field theory (EFT) framework. The WIMP nucleon coupling is investigated for fifteen different effective operators individually. The analysis of several of these operators motivates an expansion of the WIMP search energy range beyond that of the standard spin-independent and spin-dependent analyses. We present a 90% confidence level exclusion limit on the coupling constants of select operators obtained via the profile likelihood ratio technique.

1.4 Astrophysics Dynamics / 88

21-cm Implications for Dark Matter: Introduction

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I will demonstrate how current and future measurements of the global 21-cm signal could provide new constraints on models of p-wave annihilating dark matter (DM), over a broad range of DM masses. 21cm observations are sensitive to the baryon temperature at the end of the cosmic dark ages, and are particularly well-suited to constrain p-wave models, because the energy injection rate from p-wave annihilation increases dramatically around this time due to the formation of large gravitationally bound structures. In addition to the standard cold DM structure formation scenario, we analyze the scenario in which a component of DM obtains a nonzero temperature through its interactions with visible matter. This analysis enables us to set constraints on milli-charged scalar DM, which has been proposed as a possible explanation for the claimed 21cm signal from the EDGES

experiment, and more generally to explore the possible relationship between p-wave-annihilating DM and the deep EDGES absorption trough.

4.5 Direct Detection / 89

The Noble Element Simulation Technique (NEST) Version 2.0

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The latest release of the Noble Element Simulation Technique (NEST) is presented here. Noble element target media have become common in rare event searches, and an accurate comparison model is critical for understanding and predicting signals and unwanted backgrounds. Like its predecessors, NESTv2.0 is a simulation tool written in C++ and is based heavily on experimental data, taking into account most of the existing ionization and scintillation data for solid, liquid, and gaseous xenon. Due to the large amount of precise data for liquid xenon, most theoretical models in NEST have been replaced with simple, well-behaved, empirical formulas, such as sigmoids and power laws. NESTv2.0 also uses an empirical, non-binomial, recombination fluctuations model. In addition, NESTv2.0 simulates S1 and S2 scintillation signals with correct energy resolutions in dual-phase xenon time-projection chambers, and this is done without using an external package. While NEST can be used with GEANT, NESTv2.0 is fully capable of operating as a stand-alone command-line tool.

4.5 Direct Detection / 90

A category of extremely-fast events (EFEs) in pPCGe detectors used in CDEX

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The p-type Point Contact Germanium (pPCGe) detector is used in light WIMPs searches by the China Dark matter EXperiment (CDEX). With better rise-time resolution, a category of extremely-fast events (EFEs) can be clearly recognized and its origin had been experimentally indentified. The analysis of EFEs could help to understand the background origins, which is very important for the detector structure design and material selection in the next phase. In addition, related parameters to identify the EFEs could also be used to improve the energy resolution at high energies.

1.5 Direct Detection / 91

Search for low mass dark matter at DUNE

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Various cosmological and astrophysical observations strongly support the existence of the Dark Matter (DM) with an abundance of ≈ 27%. Recent theoretical work has highlighted the motivations for sub-GeV dark matter candidates that interact with ordinary matter through new light mediator particles, called "vector portal" model. Recently, a great deal of interest has been paid to the possibility of studying these models at low energy, fixed-target experiments. Such sub-GeV (or light) dark matter particles are difficult to probe using traditional methods of dark matter detection, but can be copiously produced in Long Baseline Neutrino Facility (LBNF). The DM particles can then be detected through neutral-current like interactions either with electrons or nucleons in the detector. Since the signature of DM events looks just like those of the neutrinos, the neutrino beam provides the major source of background for the DM signal. Several ways have been proposed to suppress neutrino backgrounds by using the unique characteristics of the DM beam. In addition, since the electrons struck by DM will be much more forward direction, the angle of these electrons may be used to reduce backgrounds, taking advantage of fine angular resolution DUNE can provide. In this talk we will discuss the capabilities of searching Dark Matter produced in high intensity proton beams at LBNF using DUNE near detector

4.3 Direct Detection / 92

Development of Cryogenic Thermal Detectors for Sub-GeV Dark Matter

Author: H Douglas Pinckney[1]

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An important topic in dark matter research is the search for sub-GeV dark matter. Direct detection searches for sub-GeV dark matter can be conducted through scattering on Silicon nuclei utilizing a detector with energy threshold on the order of 10 eV. This low threshold can be achieved by thermalizing a Transition-Edge Sensor (TES) based detector with gram scale silicon absorbers. This poster describes the design of a 10 eV threshold TES based detector as well as recent fabrication and testing progress.

5.6 Detection Theory / 93

GeV-Scale Thermal WIMPs: Not Even Slightly Dead

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Weakly Interacting Massive Particles (WIMPs) have long reigned as one of the leading classes of dark matter candidates. The observed dark matter abundance can be naturally obtained by freeze-out of weak-scale dark matter annihilations in the early universe. This "thermal WIMP" scenario makes direct predictions for the total annihilation cross section that can be tested in present-day experiments. While the dark matter mass constraint can be as high as m 100 GeV for particular annihilation channels, the constraint on the total cross section has not been determined. We construct the first model-independent limit on the WIMP total annihilation cross section, showing that allowed combinations of the annihilation-channel branching ratios considerably weaken the sensitivity. For thermal WIMPs with s-wave 2⟶2 annihilation to visible final states, we find the dark matter mass is only known to be m 20 GeV. This is the strongest largely model-independent lower limit on the mass of thermal-relic WIMPs; together with the upper limit on the mass from the unitarity bound, it defines what we call the "WIMP window". To probe the remaining mass range, we outline ways forward.

1.3 Direct Detection / 94

Dark Matter Model or Mass: Benchmark-Free Forecasting for Future Detectors

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We systematically approach the topic of signal diversity and model discrimination for a variety of future dark matter (DM) direct detection experiments. Firstly I introduce the Euclideanized signal method which will allow for a "benchmark-model-free" discussion of optimal experimental design. Secondly, I will present an intuitive way to quantify the sensitivity of experiments in terms of the number of distinctly discriminable signals and discuss a simple way to visualise these results using Infometric Venn Diagrams. In addition, I will demonstrate the technique and display the complementarity of combining a Xenon and Argon detector using a Non-Relativistic Effective Field Theory framework as well as some selected DM models. I show, using Modern clustering algorithms, that only in a small region of the parameter space is it possible to both constrain the mass of the DM and simultaneously discriminate between standard spin independent interactions and other DM-nucleon couplings for near-future Xenon and Argon detectors. Finally, I will present recent work on attempting to systematically break down model degeneracies by accounting for inelastic contributions to the DM signal

2.1 Plenary Session / 95

Status and Projected Sensitivity for SuperCDMS SNOLAB

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The SuperCDMS SNOLAB experiment, currently under construction, will seek direct detection of dark matter with mass from 0.5-10 GeV/c^2. It has been designed with an initial sensitivity to nuclear recoil cross sections ~ 10^{-43} cm^2 for a dark matter particle mass of 1 GeV/c^2, and with capacity to continue exploration to both smaller masses and better sensitivities. The experiment uses cryogenic detectors of two types (HV and iZIP) and two target materials (germanium and silicon). This mix

of detector types and targets will maximize the low-mass reach while providing understanding of the backgrounds that the experiment will encounter. The primary backgrounds are expected to be cosmogenically produced tritium and naturally occurring Si-32, with radon daughters dominating for the lowest masses probed. This talk will describe the overall experiment design, current status, and projected backgrounds and sensitivity.

4.2 Plenary / 96

A Search for Axion Dark Matter with the HAYSTAC Experiment

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The Haloscope At Yale Sensitive to Axion CDM (HAYSTAC) is a tunable microwave cavity experiment searching for axion dark matter in the galactic halo through the inverse Primakoff interaction, in which axions in a strong magnetic field are resonantly converted to microwave photons. In 2017, HAYSTAC excluded axion-photon couplings above ~2x10-14 GeV⁻¹ for the axion mass range 23.15 < m_a < 24.0 <i>mu;</i>eV, and probed new parameter space of interest to both particle physics and cosmology. HAYSTAC is now entering its second phase of operation, incorporating the improvements from the 2017 run with a new squeezed-state receiver and significant upgrades to the cryogenics system. We discuss our recent results, upgrades, the current status of HAYSTAC, and expectations for Phase II.

2.5 Direct Detection / 97

Measurements of electron extraction efficiency and low-energy electron recoil response in a two-phase xenon time projection chamber

Authors: Ethan Bernard[1]; Elizabeth Boulton[2]; Blair Edwards[2]; Nicholas DeStefano[3]; Scott Hertel[1]; Markus Horn[2]; Nicole Larsen[2]; Brian Tennyson[2]; Chris Wahl[2]; Daniel McKinsey[1]; Moshe Gai[3]

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We describe two new measurements from the PIXeY two-phase xenon time projection chamber. The extraction efficiency of quasi-free electrons from the xenon surface was measured as the field in the gas above the liquid surface was varied from 4.5 to 13.1 kV / cm. The extraction efficiency was seen to increase even at the highest fields, suggesting that the charge signals in two-phase xenon detectors can be increased if stronger fields in the gate-anode region can be suitably engineered. We also describe the response of this detector to ^{37}Ar, which provides a useful low-energy internal calibration source for WIMP direct detection experiments.

2.4 Theory / 98

Generalised dark matter and diminishing the low CMB multipole tension

Author: Tanvi Karwal[1]

Co-authors: Tristan Smith [2]; Tarun Souradeep [3]; Marc Kamionkowski

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Generalized dark matter (GDM) is a powerful framework capable of emulating the effects of a wide variety of dark matter and dark energy models. In this talk, I will discuss the GDM framework and show how it can reduce the moderate tension in the low CMB TT multipoles. The standard ΛCDM model predicts more power in the low TT multipoles than observed by Planck. This tension can be alleviated by altering the late ISW effect through a modification of the recent expansion history of the Universe, achieved here by varying the dark matter equation of state.
I will show that GDM suppresses power in low CMB multipoles, with minimal impact on a number of other cosmological observables. If dark matter exhibits such exotic behavior, our understanding of cosmic expansion history and of the nature of dark matter are far from complete.

I am also submitting an abstract to the track Theory.

4.4 Axions / 99

Early dark energy and the Hubble tension

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Although the ΛCDM model is in excellent agreement with the observed CMB, its prediction for the current rate of expansion of the universe is in tension with observations of the local universe at $> 3\sigma$. Furthermore, theoretically motivating a cosmological constant has proved difficult. In this talk, I will discuss a solution to the Hubble tension in the form of early dark energy, modeled as a scalar field in a linear potential. This behaves like a cosmological constant at early times and then decays away quickly as $(1+z)^6$ at some redshift. It therefore only influences the expansion rate over a small range in redshift. If such a field becomes dynamical before recombination, it can increase the expansion rate and decrease the angular size of the sound horizon. This precisely measured quantity can be brought back in agreement with observations by an increase in the predicted value of H_0, reducing the Hubble tension. I will present constraints to this model and discuss its effectiveness in diminishing the tension.

I am also submitting an abstract to the track Theory.

5.1 Plenary / 100

Status and plans for the DAMIC experiment at SNOLAB and Modane

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The DAMIC (Dark Matter in CCDs) experiment employs the active silicon of low-noise charge-coupled devices (CCDs) as a target to search for a variety of dark matter candidates with masses below 10 GeV. An array of seven 675-μm thick CCDs with a target mass of ~40 grams has been collecting data at SNOLAB since early 2017. The collaboration has engaged in an extensive campaign of characterization efforts to understand the response of these CCDs to low-energy nuclear recoils and their unique capabilities, including the use of high spatial resolution for both the rejection and study of backgrounds. This talk will discuss the devices and the current status of the DAMIC at SNOLAB experiment, as well as plans for the next-generation experiment, which will deploy 1 kg of improved CCDs to the Modane Underground Laboratory.

1.4 Astrophysics Dynamics / 101

Searching for Decaying Particles with Line Intensity Mapping

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The purpose of line-intensity mapping (IM), an emerging tool for extragalactic astronomy and cosmology, is to measure the integrated emission along the line of sight from spectral lines emitted from galaxies and the intergalactic medium. The observed frequency of the line then provides a distance determination allowing the three-dimensional distribution of the emitters to be mapped. A considerable intensity-mapping effort with neutral hydrogen's 21-cm line is already underway, and efforts are now afoot to develop analogous capabilities with CO and CII molecular lines, hydrogen's Lyman-alpha line (e.g., with SphereX, recently selected for a NASA Phase A MidEx study), and others. In this paper we discuss the possibility to use these measurements to seek radiative decays from dark-matter particles. The photons from monoenergetic decays will be correlated with the mass distribution, which can be determined from galaxy surveys, weak-lensing surveys, or the IM mapping experiments themselves. We discuss how to seek this cross-correlation and then estimate the sensitivity of various IM experiments in the dark-matter mass-lifetime parameter space.

2.6 Theory / 102

Dark Matter Axion Condensates: Stability and Astrophysical Properties

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We study astrophysical properties and stability under parametric resonance of photons of dark matter axion condensates. Gravitational attraction and self-interactions can cause the axion field to re-organize into a BEC of spatial localized clumps. For spherical configurations, we find that clumps which are spatially large are stable, while clumps which are spatially small are unstable and may collapse. Furthermore, there is a maximum number of particles that can be in a clump. We find generalizations of these previous results for non-spherically symmetric clumps by including finite angular momentum. Since the axion condensate is a coherently oscillating axion field, it can potentially lead to parametric resonance of photons through the axion-photon coupling, leading to an output of coherent radio waves. We study this possibility and find that while the resonance phenomenon always exists for spatially homogeneous condensates, its existence for a spatially localized clump condensate depends sensitively on three parameters: width of the clump, strength of axion-photon coupling, and clump's field amplitude. For spherically symmetric clumps the resonance is absent for typical values of the QCD axion-photon coupling. By contrast, it is present for axions with moderately large couplings, or into hidden sector photons, or from generic scalar dark matter with repulsive interactions. We extend these results to non-spherically symmetric clumps and find that even QCD axion clumps with conventional photon couplings can undergo resonant decay for sufficiently large angular momentum. We discuss possible astrophysical consequences of these results.

4.4 Axions / 103

Cosmological adiabatic conversion between QCD axion and ALP

Author: Fuminobu Takahashi[1]

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We study the adiabatic conversion between the QCD axion and axion-like particle (ALP) at level crossing
which occurs when their masses become close to each other in the early universe. This is similar to the
Mikheyev-Smirnov-Wolfenstein effect in neutrino oscillations. I explain a scenario where the ALP produced
by the adiabatic conversion of the QCD axion explains the observed dark matter abundance. Interestingly,
the ALP-photon coupling is enhanced by a few orders of magnitude, which is advantageous for the on-going
and future axion search experiments using the axion-photon coupling.

2.6 Theory / 104

Dark matter and WIMPy baryogenesis in Scotogenic Model

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We propose a scenario for the common origin of dark matter and baryon asymmetry in the present Universe in the context of scotogenic model. We show that the neutral component of a inert scalar doublet is a dark matter candidate and the baryon asymmetry is achieved from the dark matter annihilation. After showing that the minimal model in this category can not satisfy all these requirements, we study a minimal extension of this model and find that the scale of leptogenesis can be as low as 5 TeV, lower than the one in vanilla leptogenesis scenario in scotogenic model along with the additional advantage of explaining the baryon-dark matter coincidence. Due to such low scale, the model remains predictive at dark matter direct detection and rare decay experiments looking for charged lepton flavour violating processes.

1.1 Plenary Session / 105

Paleo Detectors of Dark Matter

Authors: Katherine Freese[1]; Sebastian Baum[2]; Patrick Stengel[2]; Andrzej Drukier[2]; Maciej Gorski[3]

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Paleodetectors provide an alternative approach to the detection of Dark Matter–nucleon interactions. One can search for the persistent traces left by Dark Matter scattering in ancient minerals obtained from much deeper than current underground laboratories. The sensitivity of paleo-detectors extends down to the neutrino floor for a wide range of Dark Matter masses. With readily available O(500)Myr old minerals, paleo-detectors can probe spin-independent WIMP-nucleon cross sections 2–3 orders of magnitude lower than current direct detection limits for most of the WIMP mass range.

1.1 Plenary Session / 106

Welcome to IDM and Brown University

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2.4 Theory / 107

Complementarity for Dark Sector Bound States

Authors: Hongwan Liu[1]; Yotam Soreq[1]; Tracy Slatyer[None]; Gilly Elor[None]

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We explore the possibility that bound states involving dark matter particles could be detected by resonance searches at the LHC, and the generic implications of such scenarios for indirect and direct detection. We demonstrate that resonance searches are complementary to mono-jet searches and can probe dark matter masses above 1 TeV with current LHC data. We argue that this parameter regime, where the bound-state resonance channel is the most sensitive probe of the dark sector, arises most naturally in the context of non-trivial dark sectors with large couplings, nearly-degenerate dark-matter-like states, and multiple force carriers. The presence of bound states detectable by the LHC implies a minimal Sommerfeld enhancement that is appreciable, and potentially also radiative bound state formation in the Galactic halo, leading to large signals in indirect searches. We calculate these complementary constraints, which favor either models where the bound-state-forming dark

matter constitutes a small fraction of the total density, or models where the late-time annihilation is suppressed at low velocities or late times. We present concrete examples of models that satisfy all these constraints and where the LHC resonance search is the most sensitive probe of the dark sector.

4.4 Axions / 108

Non-relativistic effective field theory of scalar field and longevity of condensates

Authors: Kyohei Mukaida[1]; Masahiro Takimoto[2]; Masaki Yamada[3]

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Ultra light bosonic dark matter like axion may form long-lived condensate. The longevity of the condensate can be understood by the approximate number conservation in the non-relativistic regime. The profile of condensate is obtained via the bounce method, just like Q-balls, as long as the number violating interaction is weak enough. I will discuss the decay processes of the condensate by the number violating interaction, namely the production of relativistic modes. I will show that there are some attractor behaviors during the evolution of condensate that enhance the lifetime.

4.4 Axions / 109

Duration of classicality of the axion dark matter condensate

Authors: Ariel Arza[1]; Sankha Chakrabarty[1]; Seishi Enomoto[1]; Yaqi Han[1]; Pierre Sikivie[1]; Elisa Todarello[1]

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Axion dark matter is commonly considered as a classical self-interacting scalar field condensate. This talk takes the axion as a quantum scalar field and shows how long the classical description is valid considering gravitational and contact self-interactions. When the axion field is homogeneus and interacts with itself by attractive forces, parametric resonance causes quanta to jump in pairs out of the condensate into all modes with wave vector less than some critical value. Although these instabilities do not occur for repulsive contact interaction in the homogeneous case, they do so for the inhomogeneous case. In every unstable case, the time of classicality is calculated.

1.4 Astrophysics Dynamics / 110

Estimating the local dark matter content using Gaia DR2

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The dark matter (DM) content in the local solar neighborhood is an important ingredient for direct detection experiments on Earth such as LZ, Xenon, PandaX, and searches for DM in charged cosmic ray data from PAMELA, AMS-02, DAMPE, and CALET. Traditionally, the local DM density has been estimated by analyzing the vertical motion of different 'tracer' stars in the solar neighborhood. These methods rely on an accurate reconstruction of the galactic potential by modeling baryonic matter, namely interstellar gas and stars, as disks with different scale heights and normalizations, and approximating the collisionless DM halo as a constant DM density at low heights above the galactic plane. However, dissipative interactions in, even a fraction of, the dark sector could lead to the formation of a thin dark disk, parametrized by its surface density and scale height, co-rotating with the baryonic disk. In this talk, we present constraints on thin dark disk parameters using the 6D phase space information of stars from the latest Gaia data release (DR2). We also determine a value of local DM density (in absence of a thin dark disk) that is consistent with those from complementary methods in the literature. Lastly, we discuss data selection in DR2, choice of tracer stars, and the robustness of our results in light of the assumptions implicit in our analysis.

1.6 Theory / 111

Lines, Boxes, and Energy Duality: Deciphering Astrophysical and Cosmological Imprints of Extended Dark Sectors

Author: Brooks Thomas[1]

Co-authors: Kimberly Boddy [2]; Keith Dienes [3]; Doojin Kim [4]; Jason Kumar [5]; Jong-Chul Park [6]

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Identifying signatures of dark matter at indirect-detection experiments is generally more challenging in non-minimal dark-matter scenarios than it is in scenarios involving a single dark particle. The reason is that the partitioning of the total dark-matter abundance across an ensemble of particles with different masses tends to "smear" the injection spectra of photons and other cosmic-ray particles produced via dark-matter annihilation or decay, leading to continuum features rather than sharp lines. In this talk, I shall discuss two strategies for identifying characteristic signatures of non-minimal dark-matter scenarios at indirect-detection experiments. One of these strategies exploits correlations that arise between different continuum spectral features associated with the same annihilation or decay process. The other involves the identification of an "energy duality" under which a single spectral feature is invariant. I shall also discuss potential implications of this latter strategy for assessing the origin of the observed excess of gamma-rays emanating from the Galactic Center within the context of the Dynamical Dark Matter framework.

1.2 Plenary Session / 112

Reaching Beyond the Standard Scenarios: From Strongly Coupled Dark Sectors and Thermal Freezeout to Cosmological Phase Transitions and the Lifetime Frontier

Authors: Keith Dienes[1]; Brooks Thomas[2]

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In this talk, I survey new non-traditional approaches to a number of topics in dark-matter physics. These include strongly coupled dark sectors, new thermal freezeout phenomenologies, new dark-matter effects emerging from cosmological phase transitions, and a new approach towards probing the dark sector with detectors that are designed to explore the so-called "lifetime frontier". As we shall see, all of these topics are connected through Dynamical Dark Matter (DDM), an alternative approach to dark-matter physics. In this talk, I provide an overview of the DDM framework and then discuss how it provides a new way of addressing a number of long-standing issues in dark-matter phenomenology.

3.1 Plenary / 113

Nigel Smith (Executive Director, SNOLAB): Development of Deep Underground Facilities

Author: Nigel Smith[1]

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Direct searches for dark matter candidates require deep underground research facilities and specialised low background infrastructure and associated capabilities. As the dark matter community develops ever more sensitive detectors, the requirements placed on deep underground facilities and these capabilities become even more stringent. This talk will review recent progress within deep underground facilities at providing these required research infrastructures, including the recent steps to provide greater coordination between the research facilities.

5.1 Plenary / 114

CYGNUS - a multi-latitude directional WIMP experiment

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The CYGNUS effort aims to produce a network of direction sensitive detectors able to probe below the neutrino floor and to reach into the low WIMP mass region with active discrimination against electron background. The new prospect of operation in both Southern and Northern hemisphere underground laboratories opens further possibilities. Latest progress with prototypes towards the goals of CYGNUS will be presented, including the new prospect of direction sensitive gas TPCs operating at atmospheric pressure using He and negative ion SF6. New background estimates and simulations of directionality and recoil identification at low energy with different charge readout technologies are presented. These underpin sensitivity calculations for a first stage 10m3 device which itself can reach the neutrino floor in principle.

4.5 Direct Detection / 115

Low background Counting Facilities at SNOLAB: Current and Future

Author: Chris Jillings[1]

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SNOLAB is working with several collaborations to develop low-background techniques and assay systems. The sensitivity of current systems and their applicability to experiments will be discussed. Sample preparation techniques, such as ashing of acrylic, will be explained. New and more sensitive tools such as an XIA alpha detector and an ultra-low background radon emanation system are under construction. Proposals for future development and SNOLAB's community consultation efforts towards new technologies are presented.

1.6 Theory / 116

Searches for Dark Matter Mediators at CMS

Author: David Yu[1]

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This talk presents results from the CMS experiment on searches for dark matter mediator particles. The searches target new bosons decaying into dijet final states. Techniques for studying low-mass resonances below the typical threshold for conventional dijet resonance searches are emphasized, including the use of data scouting, online bottom quark tagging, and boosted mediator production due to initial state radiation.

5.4 Indirect Detection / 117

Astrophysical vs. dark matter interpretations of gamma-ray observations in dwarf galaxies

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Deep, all-sky gamma-ray observations combined with recent discoveries of nearby dwarf galaxies have set the stage for the potential detection of dark matter annihilation. I will discuss a few issues, both conceptual and technical, required to rigorously establish the existence of a signal and to identify it as new physics. This includes assessing significance given limitations in our understanding of the gamma-ray background, especially regarding populations of faint astrophysical sources. I will present a new methodology that improves on flux-based test statistics and enables a new test of the dark matter hypothesis against alternatives. The emphasis is on developing a rigorous procedure which nonetheless handles partial knowledge of both the dark matter properties and of the background. Given a putative excess I will show how comparing its energy spectrum to those of conventional sources can help explain its origin. I will present these new techniques in applications to the dwarf galaxies Reticulum II and the Carina II/III pair.

4.4 Axions / 118

Dark Matter-Baryon Scattering in Global 21cm Signal

Authors: Chih-Liang Wu[1]; Tracy Slatyer[None]

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We compare several cosmological constraints on the cross section for elastic scattering between DM and baryons over a wide range of epochs in cosmological history. The result shows that given high-redshift constraints on DM-baryon scattering, long-range interactions for light DM would be sufficient to explain the deep 21cm absorption trough recently claimed by the EDGES experiment. For millicharged DM models proposed to explain the observation, where only a small fraction of the DM interacts, we estimate that a PIXIE-like future experiment measuring CMB spectral distortion could test the relevant parameter space.

119

Reception Drinks + Registration (345 Brook Street, Providence, RI 02912)

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1.1 Plenary Session / 120

(Placeholder) Phenomenology

1.1 Plenary Session / 122

(Placeholder) CMB Constraints on Dark Matter

1.2 Plenary Session / 123

(Placeholder) Micro and Milli-Lensing

1.2 Plenary Session / 124

(Placeholder) Neutrino backgrounds in dark matter detectors

4.1 Plenary / 126

The EDGES result: An update and future plans

A deeper than expected absorption of the Cosmic Microwave Background (CMB) by the 21-cm line hydrogen line at redshift 17 with flattened bottom has been observed using the Experiment to Detect the Global EoR signature (EDGES) instruments located at the Murchison Radio-astronomy Observatory in Western Australia. I will briefly describe EDGES and its calibration and how the performance has been improved leading to detection of 21 cm absorption at 78 MHz. Absorption of the CMB is expected when the hydrogen
spin temperature drops from the CMB temperature to the kinetic temperature as the result of Wouthuysen–Field coupling of the Lyman-Alpha radiation from the early stars.

I will give an update of EDGES results, the need for confirmation by other instruments, the future plans of EDGES, and list mechanisms which might explain the greater depth and flattened profile.

4.1 Plenary / 127

Interferometric 21cm and Dark Matter

4.1 Plenary / 128

21 cm Dark Matter Theory

4.1 Plenary / 129

(Placeholder) Black Hole Dark Matter

4.2 Plenary / 130

Axions Theory

5.2 Plenary / 131

(Placeholder) Dark Matter Baryon Interactions

5.2 Plenary / 132

(Placeholder) Galactic Center Gamma Excess

5.2 Plenary / 133

(Placeholder) Baryon Dark Matter Interactions

4.1 Plenary / 134

Dark Cosmology: Searching for Dark Matter in the Dark Ages using the Global 21-cm Spectrum

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After the Cosmic Microwave Background photons decoupled from baryons, the Dark Ages epoch began: density fluctuations imprinted from earlier times grew under the influence of gravity, eventually collapsing into the first stars and galaxies during the subsequent Cosmic Dawn. In the early universe, most of the baryonic matter was in the form of neutral hydrogen, detectable via its ground state's "spin-flip" transition. This line's rest frame frequency (wavelength) of 1420 MHz (21-cm) arrives today highly redshifted to low radio frequencies (<200 MHz) due to cosmic expansion. A measurement of the 21-cm spectrum maps the history of the hydrogen gas through the Dark Ages and Cosmic Dawn and up to Epoch of Reionization, when ionization of hydrogen extinguished the signal. The ground-based EDGES experiment recently reported a 78 MHz (redshift z~17) absorption trough roughly consistent with that expected from Cosmic Dawn, but ~3 times deeper than was thought possible from standard cosmology and adiabatic cooling of neutral hydrogen. Interactions between baryons and mildly-charged Dark Matter particles with a proton-like mass provide a potential explanation of this difference but many other cooling mechanisms are also being investigated.

The Cosmic Dawn trough is affected by cosmology and the complex astrophysical history of the first luminous objects. A trough representing the Dark Ages, predicted to occur at lower frequencies (higher z), however, is determined entirely by cosmological phenomena (including Dark Matter) that took place before star formation began. A new space-based experiment, the Dark Ages Polarimeter PathfindER (DAPPER), will be described that is designed to observe this pristine epoch (15-30 MHz; z~93-46) which is inaccessible from Earth due to ionospheric opacity. DAPPER will search for deviations from the trough predicted by the standard cosmological model (minimum at ~18 MHz, amplitude=40 mK). In addition to Dark Matter properties such as annihilation, decay, temperature, and interactions, the low-frequency background radiation level can significantly modify this trough. Hence, this observation constitutes a powerful, clean probe of exotic physics in the Dark Ages. The science instrument and a unique data analysis approach will also be discussed.

1.2 Plenary Session / 135

Probing the nature of dark matter with gravitational lensing

Author: Daniel Gilman[1]

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The particle nature of dark matter affects the progression of structure formation in the universe. On small scales, differences between the standard cold dark matter picture and alternatives, such as warm or self-interacting dark matter, become especially pronounced. Gravitational lensing provides a mechanism to directly probe the density profiles and overall abundance of low mass dark matter halos through their gravitational distortion of light emitted from a background galaxy. I will describe various techniques that wield data from strong lenses to probe dark matter on small scales, and forecast the constraining power of these methods in years to come.

1.6 Theory / 136

Limits on Dark Matter with masses <~ GeV.

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New and improved limits on Dark Matter interactions with baryons, for DM masses in the GeV range and below, are reported from XQC, CRESST-surface run and DAMIC (Mahdawi-Farrar 2018).
Also reported will be the recent determination of the Earth's atmosphere of DM, which provides strong new constraints for DM in this mass range from HST's orbital decay, storage times of liquid He and other cryogens, LHC beam lifetime and the thermal conductivity of the Earth's crust (Neufeld, Farrar and McKee 2018). Finally, the complexity of constraining DM interactions when Born Approximation does not apply (as natural for this regime) will be discussed and first results of an exact treatment using the Schroedinger Equation will be reported (Xu and Farrar, 2018).

1.1 Plenary Session / 137

Dark Matter neatly explains anomalous Primordial 7Li Abundance

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There is a 10-sigma discrepancy between the observed and expected abundances of primordial 7Li, which is naturally explained by a DM-nucleon interaction that is comfortably allowed by laboratory and other constraints. I first review the literature on BBN observations and the standard CDM calculation, and then report on a calculation of the modification to standard BBN when DM interactions can break up 7Be and 7Li (Farrar and Galvez, 2018). The relevant temperature when 7Be and 7Li form (T < ~80 keV) is low, and the binding energy of other primordial nuclei (4.5,5.7,22.8 MeV for 3He, 3H and 4He, resp.) is much larger than that of 7Be and 7Li (1.6, 2.5 MeV, resp.), so DM on the tail of the thermal distribution can breakup 7Be (7Li) into 4He+3He (4He+3H), with negligible impact on the excellent predictions for 4He and D abundances, bringing all predictions into consistency with observation for interesting DM-nucleon interaction cross sections. (Deuterium is formed so efficiently that a low level of additional breakup is irrelevant.) Dependence on DM mass will be discussed, as will experimental tests and other implications of this proposal.

4.6 Theory / 138

(Withdrawn) QCD Axion Dark Matter with f_a as Low as 10^8 GeV

Author: Raymond Co[None]

The QCD axion elegantly solves the longstanding strong CP problem and is well motivated dark matter candidate. To reproduce the observed dark matter abundance with axions, the decay constant f_a is considered to be around 10^12 GeV for the misalignment mechanism. On one hand, the late-time entropy production is known to allow larger f_a. On the other hand, the decay of the axion domain walls and strings can generate axion dark matter with f_a around 10^11 GeV. We propose a new mechanism for QCD axion dark matter with f_a as low as 10^8 GeV, where the axion abundance is produced from parametric resonance of the oscillating Peccei-Quinn symmetry breaking field. Several experimental efforts are currently devoted to axion searches in this range of f_a. Other potential signatures include dark radiation and warmness of dark matter. We realize this framework within various particle physics models, demonstrating complete and viable cosmologies.

5.2 Plenary / 139

Simulations of Structure Formation in CDM and Beyond

Author: Mark Vogelsberger[None]

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I will describe recent progress in structure formation and galaxy formation simulations. I will demonstrate that recent large-scale simulations are able to reproduce the observed galaxy population on large scales. Based on those simulations I will then present results on the dark matter distribution in galaxies and discuss implications for dark matter detection experiments. At the end of my talk I will also present recent results on non-CDM simulations focusing on self-interacting dark matter models.

2.2 Plenary Session / 140

DarkSide latest results and the future liquid argon dark matter program

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DarkSide-50 is a dual-phase argon time projection chamber (TPC) with a 50 kg active volume that has been operating at the Gran Sasso National Laboratory (LNGS) since mid-2015. I will present the latest dark matter search results from this detector and their implications for a next-generation experiment, DarkSide-20k, a more than 20 tonne fiducial mass TPC equipped with SiPM-based photosensors. DarkSide-20k is expected to achieve an instrumental background well below that from coherent scattering of solar and atmospheric neutrinos and achieve exclusion sensitivity to a WIMP-nucleon cross section of 10^{-47} cm^2 for a 1 TeV WIMP in a 5 year run.

2.6 Theory / 141

Inhomogeneous initial conditions and the start of inflation

Authors: Patrick Fitzpatrick[1]; David Kaiser[1]; Kiriakos Hilbert[1]; Jolyon Bloomfield[1]

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The robustness of inflation to inhomogeneous initial conditions for matter fields and the spacetime metric is under investigation. If inflationary expansion fails to begin under sufficiently inhomogeneous initial conditions, such that inflation requires fine-tuning of its initial state to occur, then its naturalness is challenged. I will present results for the range of initial conditions which give rise to inflation, based on numerical calculations which evolve the equations of motion of the scale factor and the inflaton field coupled to its quantum fluctuations and metric perturbations through a well-defined set of nonlinear interactions in the Hartree approximation. These results address to what extent inflation can occur under inhomogeneous initial conditions for a few standard slow-roll single-field inflationary models, in calculations which include effects of gravitational back-reaction of perturbations on the background dynamics and on the perturbations themselves, and which have wide applications beyond the inflationary models I will present. Our findings are consistent with recent simulations involving full (3+1) numerical relativity. However, by relying on certain well-studied approximations, our numerical approach can be applied more efficiently to a wide range of models, and can track the evolution of perturbations across a wide range of scales, thereby complementing the recent numerical-relativity simulations.

5.2 Plenary / 142

The Galactic Center Excess in Gamma Rays

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The center of the Milky Way is predicted to be the brightest source of gamma rays produced by dark matter. An excess consistent with a dark matter annihilation signal has been observed in the data collected by Fermi LAT. Although these results are intriguing, the complexity involved in modeling the foreground and background emission from conventional astrophysical sources makes a conclusive interpretation of these results challenging. In this talk, I'll summarize these results.

1.1 Plenary Session / 143

Dark Matter Phenomenology

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I will describe the status of phenomenological studies of dark matter, and how they enable searches for it using various methods.

5.2 Plenary / 144

Probing the nature of dark matter with the CMB

Author: Yacine Ali-Haimoud[1]

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The cosmic microwave background has provided the most precise measurement of the dark matter (DM) abundance, and places stringent limits on its annihilation cross section. Yet, its nature remains unknown, motivating the exploration of non-standard models. In this talk I will discuss the imprints that such non-standard DM candidates may leave on CMB spectral distortions and anisotropy measurements, focusing on elastically scattering DM and primordial black holes.

1.1 Plenary Session / 145

CMB Constraints on Dark Matter

Author: Tracy Slatyer[None]

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Non-gravitational interactions between dark and visible matter could transform the early history of our universe, heating or cooling the gas and contributing additional ionization and photons. I will describe the potential effects of energy injection from dark matter annihilation on the early universe, and the imprints it would leave in the cosmic microwave background and other observables. I will outline the resulting powerful constraints on light dark matter, and discuss some future directions.

1.2 Plenary Session / 146

Neutrino Backgrounds at Dark Matter Detectors

Author: Louis Strigari[1]

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I will discuss the prospects for identifying solar neutrinos in future direct dark matter detection experiments. I will discuss them as a background for dark matter searches, and also the implications for constraining the properties of neutrinos and their sources. I will also discuss the complementarity of these future measurements with terrestrial coherent neutrino scattering experiments.

4.1 Plenary / 147

Black-hole (and other) dark matter

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Following the announcement in March 2018 of the discovery of the first gravitational-wave signal from a black-hole-binary merger, it was suggested that ~30-solar-mass black holes could make up the dark matter. Since then, a number of astrophysical probes or constraints to the scenario have been discussed. I will summarize these constraints and identify associated caveats for some as well as those that I believe are more robust. I will also briefly discuss some other recent work related to non-black-hole dark matter.

5.2 Plenary / 148

Baryonic Effects on the Distribution of Dark Matter

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Most well-known results regarding the distribution of dark matter in the Universe are based upon dissipationless simulations of the cosmological evolution of dark matter only. I will discuss some generic ways in which baryonic processes alter the distribution of dark matter. I will begin with a discussion of the clustering of dark matter on few Mpc scales. Baryonic effects can alter dark matter clustering on Mpc scales at a non-negligible level. I will then discuss the shapes of dark matter halos and the distribution of dark matter within them. Baryonic effects may make dark matter halos more concentrated and more circular, but there remains considerable uncertainty in the magnitude of these effects. Lastly, I will discuss some aspects of dark matter halo substructure, particular dark matter subhalos and satellite galaxies about Milky Way like dark matter halos.

1.1 Plenary Session / 149

Dark matter in disequilibrium and its implications for direct detection

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In this talk, I will use the velocity distribution of accreted stars in SDSS-Gaia DR2 to demonstrate that the local dark matter halo may not be in equilibrium and that a non-trivial fraction is in substructure. Using a mixture likelihood analysis, we identify a young anisotropic population of stars that can be explained as the tidal debris of a disrupted massive satellite on a highly radial orbit, and is consistent with mounting evidence from recent studies. Simulations that track the tidal debris from such mergers find that the dark matter traces the kinematics of its stellar counterpart. If so, our results indicate that the majority of the local dark matter that is sourced by luminous satellites is in kinematic substructure referred to as debris flow. These results challenge the Standard Halo Model, which is highly discrepant with the distribution recovered from the stellar data, and have important ramifications for the interpretation of direct detection experiments.