CIPANP 2018 - Thirteenth Conference on the Intersections of Particle and Nuclear Physics

Monday 28 May 2018 - Sunday 03 June 2018

Hyatt Regency Indian Wells Conference Center

Poster Session

Poster Session - Board: 1 / **91**

A New Symmetry of Electroweak Lagrangian

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Problems of the Standard Model, associated with the introduction of non-gauge interactions and with the introduction of an electromagnetic field as a linear combination of fields on which various gauge groups are implemented, are analyzed. It is noticed that the existing model contains U(1) – phase uncertainty of the matrix elements of the raising and lowering generators of the SU(2) group. This uncertainty creates the condition for the additional local U(1) – symmetry of the Standard Model Lagrangian with respect to the choice of various equivalent generator representations of the SU(2) group. Such symmetry is provided by a gauge electromagnetic field introduction. In this case, due to the different action of the raising and lowering generators on the fields of each generation of leptons and quarks, these fields interact with the electromagnetic field in different ways.

Poster Session - Board: 2 / **370**

Composite Higgs from Mass-Split Models

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Beyond Standard Model theories describing the electro-weak sector must exhibit a large separation of scales (or “walking") to account for a light, 125 GeV Higgs boson and the fact that so far no other resonances have been observed. Large separation of scales arises naturally and in a tunable manner in mass-split models that are built on a conformal fixed point in the ultraviolet. Splitting the fermion masses into “light” (massless) and “heavy” flavors, the system shows conformal behavior in the ultraviolet but is chirally broken in the infrared.
Due to the presence of a conformal fixed point, such chirally broken systems show hyperscaling and have a highly constrained resonance spectrum that is significantly different from the QCD spectrum. We highlight most characteristic features presenting numerical data obtained from dynamical simulations of an SU(3) gauge theory with four light and eight heavy flavors. In addition, we give an outlook on ongoing work simulating an SU(3) gauge theory with four light and six heavy flavors using a set-up well suited to explore e.g. mass-generation of Standard Model fermions via four-fermion interactions or partial compositeness.

Poster Session - Board: 3 / **372**

Results from MICE: the Muon Ionization Cooling Experiment

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The Muon Ionization Cooling Experiment (MICE) is a feasibility demonstration of a crucial emittance-reduction technique for future muon colliders and neutrino factories. MICE has studied the effect of ionization energy loss in low-Z absorber materials on a muon beam. Muons were focussed on lithium hydride and liquid hydrogen absorbers using a large-aperture solenoid. Particle tracking and identification detectors upstream and downstream of the absorber enabled the reconstruction of the phase-space coordinates of individual muons. The evolution of beam emittance was measured by studying the properties of ensembles of single muons using muon

beams with varying input emittances and momenta. Data taken in 2016 and 2017 are currently being analyzed. The current status and most recent results are presented.

Poster Session - Board: 4 / **373**

Demonstration of 3D Micro-Power Readout for Liquid Argon Time Projection Chambers

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We report the demonstration of a micro-power sensor designed for three-dimensional ionization charge detection and digital readout of liquid argon time projection chambers (LArTPCs). 3D readout is achieved using a custom-designed 32-channel system-on-a-chip ASIC (LArPix-v1), manufactured in 180 nm bulk CMOS, to uniquely instrument each pad in a charge-sensitive pad sensor array. Using a prototype sensor with 3 mm spacing between pads, we demonstrate low-noise ($< 500\ e^-$ equivalent) low-power ($< 100\ \mu$W/ch) ionization signal detection and readout of cosmic ray interactions in two LArTPCs with drift distances of 10 to 60 cm. This demonstration of 3D micro-power readout overcomes a critical technical obstacle for operation of LArTPCs in high-occupancy environments, such as the near detector site of the Deep Underground Neutrino Experiment (DUNE).

Poster Session - Board: 5 / **56**

Search for a Nuclear Magnetic Quadrupole Moment in ^{173}Yb

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The fact that the universe is made entirely out of matter, and contains no free anti-matter, has no physical explanation. While we cannot currently say what process created the matter in the universe, we know that it must violate a number of fundamental symmetries, including those that forbid the existence of certain electromagnetic moments of fundamental particles. We can search for signatures of these electromagnetic moments via precision measurements in polar molecules, whose extremely large internal electromagnetic fields can significantly amplify these moments. These effects would arise from physics beyond the Standard Model, which enables tabletop searches for new, symmetry-violating particles and forces. With modern, quantum science techniques to control polar molecules, these searches can currently reach into the TeV scale, and offer a route to the PeV scale through advanced cooling and trapping techniques. I will discuss a new cryogenic molecular beam experiment being developed at Caltech to use polyatomic ^{173}YbOH to search for hadronic CP violation via a nuclear magnetic quadrupole moment, which are sensitive to a wide variety of CP-violating sources beyond the Standard Model.

Poster Session - Board: 6 / **333**

Search for Anomalous Decay of the Free Neutron Using the UCNA Experiment: $n \rightarrow \chi + e^+ + e^-$

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The neutron lifetime is currently measured by two different types of experiments: 'beam' and 'bottle'. These two measurement techniques have a 4σ discrepancy in measured lifetime. A recent paper proposes to resolve this issue by introducing a dark sector particle, χ, that could offer an alternative decay channel for the neutron. This decay channel could resolve the discrepancy since beam experiments measure final decay products and bottle experiments measure remaining neutron population. The proposed theory allows for an e^+e^- pair produced in addition to a hypothesized χ. The UCNA (Ultra Cold Neutron Asymmetry) experiment has sensitivity to this particular decay signature, since it would appear as a mono-energetic peak over a standard β decay spectrum. In this experiment, polarized neutrons decay in a trap and their charged products are guided by a 1 T magnetic field to detectors on either side, thus effectively giving 4π detection coverage. Timing information and energy reconstruction is done on each β decay. We use results from the UCNA experiment's 2012–2013 dataset to set limits on the branching fraction of this decay channel. In the case of a candidate e^+e^- pair, the summed reconstructed energy from both sides is used to set limits on the branching ratio of this decay channel, as a function of the mass of the hypothesized χ. We present an overview of the calibration process and the limits on a neutron dark decay channel set by the UCNA experiment.

Poster Session - Board: 7 / **376**

Progress Towards Measurement of the Nuclear Anapole Moment of Ba-137 Using BaF Molecules

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Nuclear spin dependent parity violation (NSD-PV) effects in atoms and molecules arise from Z^0 boson exchange between electrons and the nucleus, and from the magnetic interaction between electrons and the parity-violating nuclear anapole moment. It has been proposed to study NSD- PV effects using an enhancement of the observable effect in diatomic molecules. Here, we demonstrate measurements of this type with sensitivity to NSD-PV effects surpassing that of any previous atomic PV measurement, using the test system $^{138}Ba^{19}F$. With ~168 hours of data, we measure the matrix element, W, of the NSD-PV interaction with combined statistical and systematic uncertainty $\delta W < 0.7$ Hz. The sensitivity we demonstrate would be sufficient to measure NSD-PV effects of the size anticipated across a wide range of nuclei. We describe the details of our method and future improvements, including an extensive study of systematic errors associated with our technique, and show that these can be controlled at least at the level of the present statistical sensitivity.

Poster Session - Board: 8 / **12**

Using X-Ray Femtoscope and X-Ray Telescope We Verified that Dark Matter Behaves as Catalyst or as Inhibitor of the Nuclear Reactions

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The X-ray femtoscope predictions: 1) Dark matter has resonances for the chemical elements Cr, Xe and Tm, which corresponds to the forces that gave the name to the WIMPs with adjustment of $R^2 = 0.996$. 2) Navier Stokes equations and solutions for the atomic nucleus are robust, since they naturally deliver the values of the following constants: neutron radius $r_n = 0.843$ fm, measured for the first time, nuclear viscosity $9.77 \times 10^{22} \leq n \leq 1.08 \times 10^{23}$ fm^2/s and Rydberg constant. 3) Dark matter produce nuclear catalysis.
The X-ray telescope proofs: 1) Fluorescent dark matter has resonances in emission and absorption at low X-ray energies (3.5 keV). 2) Gravity appears indirectly through the first analytical solution

to the millennium problem, associated with the Navier Stokes (NS) equations, which govern the stability of the incompressible nuclear fluid, and which have the range of magnitude of the gravity 10^{-30}. 3) Dark matter interacts with baryonic matter as a catalyst or as an inhibitor, so it is not consumed in the nuclear reaction for Chandra X-Ray Galaxy Clusters at $z < 1.4$.

Poster Session - Board: 9 / **368**

Introducing the SnowBall Chamber, Supercooled Water for Dark Matter and Neutron Detection

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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 poster 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, 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.

Poster Session - Board: 10 / **375**

Phases of UV Dark Matter Freeze In

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WIMPs have not yet been seen via direct detection, indirect detection, or in collider searches. Perhaps now is a good time to consider alternate mechanisms for DM production.
We investigate a new production mechanism for dark matter that consists of both a non-thermal freeze-in component as well as a hidden sector freeze-out.

Poster Session - Board: 11 / **15**

Lessons from HAWC PWNe Observations: The Diffusion Constant is Not a Constant; Pulsars Remain the Likeliest Sources of the Anomalous Positron Fraction; Cosmic Rays are Trapped for Long Periods of Time in Pockets of Inefficient Diffusion

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Recent TeV observations of nearby pulsars with the HAWC telescope have been interpreted as evidence that diffusion of high-energy electrons and positrons within pulsar wind nebulae is highly inefficient compared to the rest of the interstellar medium. If the diffusion coefficient well outside the nebula is close to the value inferred for the region inside the nebula, high-energy electrons and positrons produced by the two observed pulsars could not contribute significantly to the local measured cosmic-ray flux. The HAWC collaboration thus concluded that, under the assumption of isotropic and homogeneous diffusion, the two pulsars are ruled out as sources of the anomalous high-energy positron flux. Here, we argue that since the diffusion coefficient is likely not spatially homogeneous, the assumption leading to such conclusion is flawed. We solve the diffusion equation with a radially dependent diffusion coefficient, and show that the pulsars observed by HAWC produce potentially perfect matches to the observed high-energy positron fluxes. We also study the implications of inefficient diffusion within pulsar wind nebulae on Galactic scales, and show that cosmic rays are likely to have very long residence times in regions of inefficient diffusion. We describe how this prediction can be tested with studies of the diffuse Galactic emission.

Poster Session - Board: 12 / **199**

New Techniques in the ANITA-IV Analysis

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The ANtarctic Impulsive Transient Antenna (ANITA) is a NASA balloon-borne radio (180–1200 MHz) telescope sensitive both to impulsive Askaryan radio emission from ultra-high energy ($> 10^{18}$ eV) neutrino-initiated showers in the Antarctic ice sheet, as well as geomagnetically-induced radio emission from extensive air showers (EAS) initiated by cosmic rays or upward-going tau leptons that are created by tau neutrino interactions in the Earth. The fourth flight of ANITA completed Dec 29, 2016. I will report on the ongoing analysis of ANITA-IV data, with an emphasis on new techniques to reduce backgrounds from anthropogenic radio signals.

Poster Session - Board: 13 / **226**

Half-Lives of the Neutron-Rich $N = 82$ Isotopes ^{130}Cd and ^{131}In

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Half-lives of $N = 82$ nuclei below doubly-magic ^{132}Sn are key input parameters for calculations of any astrophysical r-process scenario and play an important role in the formation and shape of the second r-process abundance peak. In the past, shell-model calculations of neutron-rich nuclei near the $N = 82$ neutron shell closure that are not yet experimentally accessible have been performed by adjusting the quenching of the Gamow-Teller (GT) operator to reproduce the half-life of ^{130}Cd [1]. The calculated half-lives of other nuclei in the region are known to be systematically too long. Recently, a shorter half-life for ^{130}Cd was reported [2,3]. A re-scaling of the GT quenching to the new ^{130}Cd half-life by a constant factor resolved the discrepancy [2,3]. However, this GT rescaling creates a new discrepancy in the calculated half-life of ^{131}In.
The half-life measurement of ^{131}In is complicated due to the presence of three known β-decaying states with similar half-lives, making photopeak gating an ideal method to measure each of these half-lives. In this talk, the half-lives of ^{130}Cd and ^{131}In, as well as the spectroscopy of the β and $\beta - n$ decay of ^{131}In measured using the GRIFFIN γ-ray spectrometer at TRIUMF will be presented.

[1] M. Hannawald *et al.*, Nucl. Phys. A **688**, 578 (2001)
[2] R. Dunlop *et al.*, Phys. Rev. C **93**, 062801(R) (2016)
[3] G. Lorusso *et al.*, Phys. Rev. Lett. **114**, 192501 (2015)

Poster Session - Board: 14 / **339**

Neutrino Burst-Generated Gravitational Radiation from Collapsing Supermassive Stars

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We estimate the gravitational radiation signature of the e^+e^- annihilation-driven neutrino burst accompanying the asymmetric collapse of an initially hydrostatic, radiation-dominated supermassive object suffering the Feynman-Chandrasekhar instability. An object with a mass 5×10^4 $\mathrm{M_{sun}} < M < 5 \times 10^5$ $\mathrm{M_{sun}}$, with primordial metallicity, is an optimal case with respect to the fraction of its rest mass emitted in neutrinos as it collapses to a black hole: lower initial mass objects will be subject to scattering-induced neutrino trapping and consequently lower efficiency in this mode of gravitational radiation generation; while higher masses will not get hot enough to radiate significant neutrino energy before producing a black hole. The optimal case collapse will radiate several percent of the star's rest mass in neutrinos and, with an assumed small asymmetry in temperature at peak neutrino production, produces a characteristic linear memory gravitational wave burst signature. The timescale for this signature, depending on redshift, is $\sim$1 s to 10 s, optimal for proposed gravitational wave observatories like DECIGO. Using the response of that detector, and requiring a signal-to-noise ratio SNR > 5, we estimate that collapse of a 5×10^4 $\mathrm{M_{sun}}$ supermassive star could produce a neutrino burst-generated gravitational radiation signature detectable to redshift $z < 7$. With the envisioned ultimate DECIGO design sensitivity, we estimate that the linear memory signal from these events could be detectable with SNR > 5 to $z < 13$.

Poster Session - Board: 15 / **374**

Possibilities for Underground Physics in the Pyhäsalmi Mine

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The underground mining in the Pyhäsalmi mine, Finland, is coming to an end in approximately 18 months after nearly 60 years of operation. The infrastructure of the mine is in excellent condition, including 1400-metre long vertical elevator shaft and 11-km long truck-size decline for transportation, large underground storage and service halls, offices, restaurant and modern communication services.
An organization called Callio has been founded (https://callio.info) to maintain and operate the underground premises after the closure of the mine. There exists currently one dedicated laboratory hall (Lab2) for physics experiments at the deepest location of the mine. The overburden of 4100 mwe offers great possibilities for physics experiments requiring maximum shielding from cosmic muons. New excavations are possible.
Currently there are two physics experiments running in the mine. EMMA is studying the composition of cosmic rays at the knee region. The array of 11 stations is situated at the depth of 75 m. The C14 experiment is situated in the laboratory hall Lab2. It is a small-size low-background set-up to map the concentration of carbon-14 in liquid scintillators.

Poster Session - Board: 16 / **378**

In-Ice Phased Antenna Arrays for Radiodetection of Energetic Neutrinos

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Experiments such as the Askaryan Radio Array (ARA) use in-ice antennas to detect the Askaryan radio emission produced by interactions of ultra-high-energy neutrinos in glacial ice. A prototype phased array trigger was recently deployed with an ARA station this austral summer (December 2017–January 2018). The phased array trigger forms beams from multiple antennas in real time to reduce the electric field required to trigger the detector. This poster will report on the design, operation, and physics potential of the prototype.

Poster Session - Board: 17 / **379**

Visualizing Invisible Dark Matter Annihilation with the CMB and Matter Power Spectrum

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We study the cosmological signatures of Invisibly Annihilating Dark Matter (IAnDM) where DM annihilates into dark radiation particles that are decoupled from the Standard Model (SM). In a large class of dark sector models such invisible annihilation determines the relic abundance of DM via dark thermal freezeout. We demonstrate that IAnDM may reveal itself through observable, novel signatures that are correlated: scale-dependent $\Delta N_{\rm eff}$ (number of extra effective neutrinos) in the Cosmic Microwave Background (CMB) spectrum due to DM residual annihilation, while the phase of acoustic peaks shift towards the opposite direction relative to that due to SM neutrinos, resembling the effect due to scattering (fluid-like) thermal dark radiation. In addition, IAnDM induces modifications to the matter power spectrum that resemble yet are distinct from that due to warm dark matter. Current data is sensitive to IAnDM with masses up to ~ 200 keV, while future observations will improve the reach, especially if the late-time DM annihilation cross-section is enhanced relative to the standard thermal value, which can be realized in a variety of scenarios.