CPAD Workshop 2023

Tuesday, 7 November 2023 - Friday, 10 November 2023
SLAC

Book of Abstracts
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CrystaLiZe: Pushing Dark Matter Detection to the Limit with Solid Xenon

Author: Scott Kravitz

1 University of Texas at Austin

Corresponding Author: skravitz@utexas.edu

We present the crystalline xenon time projection chamber (TPC), a promising novel technology for next-generation dark matter searches. Initial tests have established that it maintains many of the benefits of the liquid xenon TPC while also effectively excluding radon, the dominant background in currently-running xenon dark matter experiments such as LZ. This offers the potential for greatly improved sensitivity to dark matter through a crystal xenon upgrade to an existing experiment. This talk will discuss instrumental performance, comparison with respect to liquid phase detectors, and plans for establishing its scalability.

Early Career:
Yes

The Capabilities of the Liquid Xenon Proportional Scintillator Counter for Low-energy Event Detection

Author: Jianyang Qi

Corresponding Author: jiq019@ucsd.edu

The Liquid Xenon Proportional Scintillation Counter (LXePSC) is a single-phase liquid xenon detector capable of producing electroluminescence directly in the liquid phase. In doing so, we are able to disregard the extraction efficiency, as seen in dual phase LXeTPCs, and simplify the detector design and operation by not needing to maintain a liquid-gas interface. In this talk, we will present our recently published results, which include the detection of low-energy electronic recoils down to ~1 keV, as well as evidence of single-electron signals from photo-induced electron emission of cathode surfaces. Furthermore, we will present preliminary results of our recent run, which includes a potential for nuclear and electronic recoil discrimination using the LXePSC, and an improved energy calibration using activated xenon lines.

Early Career:
Yes

Characterization of Delayed Ionization Backgrounds in the LZ Experiment

Author: Eli Mizrachi

1 University of Maryland, Lawrence Livermore National Laboratory
Corresponding Author: emiz@umd.edu

Dual-phase noble liquid time projection chambers (TPCs) are known to experience delayed ionization backgrounds which persist for at least a second after an ionization event occurs. Their rate has been observed by some experiments to exhibit a characteristic power law in time, but the cause is not yet understood. This work presents an analysis of delayed ionization backgrounds from different regions of the LZ TPC. The dependence of these backgrounds on various detector conditions is discussed, revealing features which may have been overlooked by previous studies.

Early Career:
No

RDC1 / 26

Calibration Systems of the Multi-Tonne Scale Xenon Detector in LZ

Author: Qing Xia

LBNL

Corresponding Author: qingxia@lbl.gov

The LUX-ZEPLIN (LZ) experiment utilizes 7 tonnes of active liquid xenon to search for dark matter at the Sanford Underground Research Facility (SURF) in Lead, South Dakota, USA. The core of the LZ detector is a dual-phase xenon time projection chamber, primarily designed for detecting Weakly Interacting Massive Particles (WIMPs). In this talk, I will discuss the novel features and performance of the LZ calibration systems, which played a crucial role in enabling LZ's world-leading WIMP search results and will facilitate its broad scientific program in the future. The description of the LZ calibration systems presented in this talk will be a valuable reference for future calibration efforts in direct dark matter search experiments.

Early Career:
Yes

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Experimental search for the Migdal Effect in a compact liquid xenon TPC

Author: Brian Lenardo

SLAC

Corresponding Author: blenardo@slac.stanford.edu

Direct dark matter searches have reported dramatically increased sensitivity to sub-GeV parameter space by taking into account the "Migdal Effect", a predicted inelastic process in which a neutral particle scattering with a nucleus results in the ejection of a bound electron from the recoiling atom. However, the Migdal Effect has never been experimentally observed, and should be confirmed and characterized before a potential dark matter signal in this channel can be reliably discovered. In this talk, we report on a dedicated experimental campaign to search for the Migdal Effect using neutron scattering in a small liquid xenon detector at Lawrence Livermore National Laboratory.
Scattered neutrons are detected by a ring of liquid scintillator detectors at fixed angle, providing a high-statistics sample of 7+/−1.5 keV nuclear recoils in the liquid xenon. We search for nuclear recoil events with an electronic recoil component consistent with atomic excitation from the Migdal Effect. We find no evidence for a signal consistent with predictions, and discuss possible explanations for this discrepancy. Our results, while inconclusive, provide important input into future experimental studies of the Migdal Effect.

Early Career:
Yes

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Studies of Xenon-Doped Argon with the CHILLAX Experiment

Authors: Eli Mizrachi¹; Ethan Bernard²; James Kingston³; Jingke Xu⁴; Teal Pershing²

¹ University of Maryland
² LLNL
³ UC Davis / LLNL
⁴ Lawrence Livermore National Laboratory

Corresponding Authors: emiz@umd.edu, jwkingston@ucdavis.edu, bernard5@llnl.gov, pershing1@llnl.gov, jingkexu@llnl.gov

Xenon and argon are widely used target media for low cross-section experiments including neutrino physics and dark matter searches. Xenon-doping of dual phase argon time projection chambers (TPCs) at the O(1%) level may substantially improve detector sensitivity. However, the large temperature discrepancy between the argon and xenon phase transition points can cause instabilities in a xenon-doped argon detector such as unwanted xenon distillation. The CHILLAX experiment at LLNL is investigating the challenges and benefits of xenon-doping of argon. We discuss the results of various stability experiments conducted within CHILLAX, which have thus far culminated in housing liquid argon doped with 2.35% xenon mole fraction with excellent stability. We also discuss recent work aiming to quantify the scintillation, ionization, and electroluminescence performance of argon from xenon-doping.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory (LLNL) under Contract DE-ACS2-07NA27344.

Early Career:
Yes

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Status and Development of nEXO's Charge Readout System

Author: Glenn Richardson¹

¹ SLAC

Corresponding Author: glenn96@slac.stanford.edu
The nEXO detector, a 5-tonne liquid xenon time projection chamber enriched to 90% in Xe-136, will search for the hypothetical decay process known as neutrinoless double beta decay with a half-life sensitivity > $10^{28}$ years. As part of this search, the nEXO collaboration is developing a radiopure charge readout system which will help reach nEXO’s sub-percent energy resolution goal and its requirement for positional reconstruction and topological discrimination. In this talk I will outline nEXO’s design for the charge readout system, which consists of an array of fused silica tiles with a specially designed electrode pattern, as well as share results from prototype tiles and readout electronics.

Early Career:
No

66

Resistive Field Shells for Liquid Noble Time Projection Chambers

Author: Francois Drielsma1

1 SLAC

Corresponding Author: drielsma@slac.stanford.edu

We present a novel approach to continuous electric field shaping for liquid noble gas time projections chambers. Conventional detectors utilize discreet field-shaping rings between a cathode and an anode to maintain a uniform electric field. Our approach employs planes formed of a highly resistive, O(10) GOhm/square, carbon-loaded layer applied to a fiberglass substrate. The use of continuous resistive material reduces the energy release rate in the case of a high-voltage discharge, minimizing the risk to readout electronics. A fiberglass substrate provides a substantial dielectric shield, 200 kV/cm, which reduces the need for large high-voltage clearance volumes around the detector, maximizing active volume. The reduced component count of this method serves to simplify detector design and construction. We report studies of the electrical properties measured in cryogens and at high voltage for periods of several months. We find that the resistance dependence on the applied voltage follows the hopping-transportation model, with an exponential decay with respect to the square root of the electric field. We also characterize the change in resistance as a function of temperature and over time.

Early Career:
Yes

85

DarkSide-20k: Advancing dark matter search with dual-phase Argon TPC

Author: Tianyu Zhu1

1 UC Davis

Corresponding Author: tiiy@ucdavis.edu

The DarkSide-20k (DS20k) experiment is currently under construction at LNGS, Italy. The DS20k detector boasts a dual-phase time projection chamber (TPC) filled with Underground Argon (UAr),
depleted by a factor of ~1500 in Ar39. The TPC features an anode and cathode of low-background pure acrylic coated with conductive polymer films. The TPC’s lateral walls, constructed with Gd-loaded acrylic, enhance background neutron tagging. The active volume is viewed by two large arrays of Silicon Photo Multipliers (SiPM) from the top and bottom. Additionally, smaller arrays of SiPM placed strategically around the TPC monitor the optically isolated neutron Veto volume. The inner detector is then housed within a sealed stainless steel vessel submerged in a ProtoDUNE-like membrane cryostat, filled with liquid atmospheric argon (AAr) acting as a shield and outer veto. The DS20k project aims for an exposure of ≈ 200 tonne-years with near-zero instrumental background, setting the stage for world-leading sensitivity in detecting dark matter with a mass above 1 TeV/c² over a 10-year run.

Early Career:
Yes

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Progress on a novel coextruded high-voltage feedthrough concept for DarkSide-20k

Author: Tyler Erjavec
Co-authors: Emilija Pantic; Tianyu Zhu

1 University of California Davis
Corresponding Author: terjavec@ucdavis.edu

As noble liquid time projection chambers get larger, so does the high voltage (HV) requirements required to maintain strong electric drift fields. HV feedthrough (FT) designs become increasingly complex given limitations imposed by cryogenic temperatures, HV, and cryostat geometry. In this talk, progress on a novel HV FT using a coextruded multi-layered coaxial cable is presented for DarkSide-20k, emphasizing design considerations implemented to the unique, fully-plastic cable construction.

DarkSide-20k is a 49.7 ton active volume dual-phase underground argon time projection chamber (TPC) that will perform the search for dark matter reaching the sensitivity 4.9e10-48cm² with for 90% C.L. exclusion for a 1 TeV/c² over a 10yr run.

Early Career:
No

100

A novel approach to purification in small-scale noble liquid systems

Author: Stephen Greenberg
Co-authors: Andrew Lambert; Brooke Russell; Dan Dwyer; Kevin Wood

1 University of California, Berkeley and Lawrence Berkeley National Lab
2 Lawrence Berkeley National Laboratory
The inert-behavior, high nuclear mass, and scintillating properties of liquid Argon and Xenon make them attractive for use in a variety of sensitive experiments. However, great care must be taken to remove electronegative impurities which reduce light yield from scintillation, and degrade the resolution of ionization-charge imaging. An external purification circuit is generally beyond the capabilities of smaller systems devoted to detector R&D, where instead various creative pumping approaches have been developed. We present progress towards the development of a novel, mechanically inactive, submerged pump and purification system for liquid Argon developed at Lawrence Berkeley National Laboratory. This system is low noise, low power, pressure safe, low cost, and achieves nearly continuous O(liters/min) flow rates using only a resistive heater as the primary energy input.

Early Career:
Yes

R&D program for Doped Liquid Argon TPCs

LArTPCs are the technology of choice for current and future neutrino experiments. This technology provides sensitivity to GeV signals like accelerator neutrinos down to the 10s of MeV, covering part of the supernova neutrino spectrum. Expanding the reach of LArTPCs to the 1-10 MeV range would substantially enhance the flagship analyses of experiments like DUNE, while enabling low-energy analyses.

We outline the R&D pathway for Ar + Xe + photosensitive dopants, whose introduction into the LAr, has the potential to substantially enhance ionization yields of LAr detectors. This scalable R&D
program will demonstrate the feasibility and impacts of introducing doped LAr into current and future neutrino detectors at the kTon scale.

Early Career:
Yes

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TinyTPC - A test stand for photosensitive dopants

Author: Hannah LeMoine
Co-author: Fernanda Psihas
Corresponding Authors: lemoi023@d.umn.edu, psihas@fnal.gov

LArTPCs are designed to explore signals with energies as low as 10s of MeV. To improve the LArTPC’s energy resolution at the MeV range, photosensitive dopants may be used. These dopants convert light to charge and have the potential to increase ionization yields. We built a LArPix test stand, TinyTPC, to demonstrate this technology and study potential enhancements for next generation LArTPCs. We plan to compare TinyTPC’s energy resolution with and without dopants for radioactive sources and determine optimal doping strategies. This presentation will describe the status and progress of the TinyTPC test stand and analysis.

Early Career:
Yes

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2023 DPF Instrumentation Award

Corresponding Authors: gorham@hawaii.edu, dsaltzbe@ucla.edu

“For their experimental proof and subsequent characterization of radio emission from high-energy particle cascades, the Askaryan Effect, which has been used in searches for the highest energy astrophysical (PeV and EeV) neutrinos. They have utilized the lunar regolith, Antarctic ice sheet, salt and other dielectrics as detector materials. In addition, they have studied the radio signatures of magnetic emission from the highest energy cosmic rays. And finally, for development of calorimeters and timing planes for future high energy physics collider detectors utilizing the Askaryan effect.”

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2023 DPF Instrumentation Early Career Award

Corresponding Author: dadwyer@lbl.gov

“For his work on 3D pixelated readout technology for liquid argon time projection chambers (LArPix). This low power, low noise custom ASIC with dynamic i/O, capable of running in liquid argon, has helped open the field to advanced systems on chips. Such technologies underpin the modular DUNE
ND-LAr near detector which will need to make precise measurements in a high flux environment with event pileup for the ultimate measurements of neutrino oscillations and CP violation in the neutrino sector.”

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2023 DPF Instrumentation Awards

Corresponding Author: petra@fnal.gov
https://cpad-dpf.org/?page_id=750

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2023 GIRA Awards

Corresponding Author: kurinsky@slac.stanford.edu
https://cpad-dpf.org/?page_id=750#temporaryId12

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A Qubit Inspired Ion Sensor for Barium Tagging in Neutrinoless Double-Beta Decay Searches

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Development of Quantum Optomechanical Sensors for Dark Matter and Sterile Neutrino Searches

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First Definitive Demonstration of Electron Counting in Three Dimensions

Corresponding Author: majd@hawaii.edu

Status and Development of nEXO’s Charge Readout System
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