Workshop on Xenon Detector 0νββ Searches: Steps Towards the Kilotonne Scale

Report of Contributions

https://indico.slac.stanford.edu/e/8015

Contribution ID: **2** Type: **Lightning talk**

Solid Dreams: Advancing 0vbb and Dark Matter Detection with Crystalline Xenon TPCs

Thursday, 26 October 2023 16:07 (7 minutes)

In this talk, we present the performance of a novel crystalline/vapor xenon TPC. Compared to liquid xenon, crystal xenon demonstrates >10^3 lower activity in radon, which is a leading background source in liquid xenon dark matter experiments (Pb214 betas) and tonne-scale 0vbb detectors (Bi214 gammas). The powerful radon exclusion capability of crystal xenon enables a larger fiducial volume for 0vbb searches through the reduction of untagged radon daughters on the detector surface. Additionally, the faster electron drift observed in crystal xenon holds the potential to reduce charge signal diffusion, potentially enhancing discrimination between multiple scatters and single scatters, as well as improving the detector's energy resolution.

Primary authors: XIA, Qing (LBNL); CHEN, Hao (LBNL); GIBBONS, Ryan (LBNL/UC Berkeley); HASELSCHWARDT, Scott (LBNL); KRAVITZ, Scott (UT Austin); SORENSEN, Peter (LBNL)

Presenter: XIA, Qing (LBNL)

Session Classification: Session 1/1

Contribution ID: **3** Type: **Lightning talk**

Solar Neutrino Detection via Charged Current Interactions at the Kilotonne Scale

Thursday, 26 October 2023 16:14 (7 minutes)

Thanks to recent observations of long-lived excited Cesium-136 states, xenon detectors now have the potential to serve as solar neutrino observatories by using charged-current interactions of the form $\nu_e + ^{136} Xe \rightarrow ^{136} Cs^* + e^-$. This new detection method will be particularly potent at the kilotonne scale. In this lightning talk, I will discuss the projected capabilities of a theoretical kilotonne LXe detector to measure the CNO, pep, and ^8B solar-neutrino fluxes, as well as the energy of the ^7Be solar-neutrinos. I will also contextualize these predicted capabilities relative to the current measurements made by the Borexino and Kamland collaborations

Primary author: RICHARDSON, Glenn (Yale University)

Presenter: RICHARDSON, Glenn (Yale University)

Session Classification: Session 1/1

Contribution ID: **4** Type: **Invited talk**

NEXT-CRAB: A High Pressure Xenon Gas Time Projection Chamber with Camera Readout for Neutrinoless Double Beta Decay Searches

Friday, 27 October 2023 10:15 (25 minutes)

NEXT-CRAB (Camera Readout And Barium tagging) aims to demonstrate an ultra-high resolution tracking detector that scales elegantly to very large future detectors that can incorporate barium tagging. To do this we are employing several novel techniques, one of which is using an optical readout for direct VUV imaging of the electroluminescence. This opens up the cathode plane for incorporation of barium tagging, a novel technique developed to distinguish each time the daughter nucleus of double beta decay is within the detector volume, suppressing all anticipated radiological backgrounds and providing the possibility for zero-background detectors at very large masses, enabling measurements that probe the normal neutrino mass ordering.

Primary author: ROGERS, Leslie (argonne national laboratory)

Presenter: ROGERS, Leslie (argonne national laboratory)

Session Classification: Future Light and Charge Readout

Contribution ID: **5** Type: **not specified**

Detecting Supernova Electron-Neutrinos in Large Xenon Detectors

Thursday, 26 October 2023 16:21 (7 minutes)

Large underground xenon detectors have strong potential for detecting supernova neutrinos. For 0vBB detectors, optimized for MeV-scale signals, electron-neutrino charged-current interactions provide one means to detect the intense flux of neutrinos emitted by a supernova. There are few existing detectors capable of measuring the electron-neutrino component of the supernova neutrino flux, which provides the opportunity to gain unique insight into the dynamics of a supernova explosion. To understand the expected neutrino signature, electron-neutrino interactions with xenon nuclei must be modeled. Using a modified version of the MARLEY event generator, electron-neutrino charged-current interactions with xenon have been simulated for current detectors and future detector concepts. A summary of the progress simulating electron-neutrino charged-current interactions with xenon using MARLEY and Geant4 will be presented.

Primary author: HEDGES, Samuel (LLNL)

Presenter: HEDGES, Samuel (LLNL)

Session Classification: Session 1/1

Contribution ID: **6** Type: **Invited talk**

Single Molecule Fluorescence Imaging for Barium Tagging

Thursday, 26 October 2023 13:50 (25 minutes)

Detection of a single Ba2+ ion in many tons of xenon is a formidable technological challenge. The difficulty is exacerbated by the fact that Ba2+, the expected final state in double beta decay of gaseous 136Xe, has no visible-accessible optical transitions to use for atomic fluorescence spectroscopy. To overcome this challenge, the NEXT collaboration is developing a method of tagging individual barium ions using bespoke organic molecules that undergo fluorescence enhancement when chelating barium ions. In this talk I will describe the current state of the art and ongoing R&D toward realization of this technology, which may enable very-low-background, ultra-large 0nubb detectors.

Primary author: JONES, Ben (University of Texas at Arlington)

Presenter: JONES, Ben (University of Texas at Arlington)

Session Classification: Ba daughter tagging

Contribution ID: **7** Type: **Lightning talk**

FAT-GEM detectors for operation in noble elements

Thursday, 26 October 2023 16:28 (7 minutes)

We introduced in 2019 a new concept for electroluminescence in noble elements, based on very-thick acrylic-based perforated structures (Field-Assisted Transparent Gas Electroluminescence Multipliers, or FAT-GEMs). The structures, other than being radio pure, scalable and robust, are also transparent, opening to the possibility of enhancing light collection efficiency. In this work we present the result of the study of structures with wavelength shifting capability, thanks to the coating of the holes with TPB, which yielded up to 70% of the light collected with meshes, and energy resolutions in line with the values reported by leading experiments.

Primary authors: LEARDINI, Sara; SAA HERNANDEZ, Angela; AMEDO, Pablo; AZEVEDO, Carlos; FERNANDEZ POSADA, David; GONZALEZ DIAZ, Diego; KUZNIAK, Marcin; LUCAS, Francisco; SWOROBOWICZ, Tadeusz

Presenter: LEARDINI, Sara

Session Classification: Session 1/1

Contribution ID: **8** Type: **Invited talk**

RF carpets

Thursday, 26 October 2023 14:40 (25 minutes)

Radio frequency (RF) carpets are ion beam transport devices that have become ubiquitous in nuclear science. They first appeared in large volume gas cells where they allowed the efficient transport at pressures around 100 mbar of thermalized radioactive ions produced in-flight. Then, more recently, they started to be used at lower pressures, in the 1-10 mbar range, to dissociate molecular contaminants from radioactive ion beams, as well as part of gas catcher-based cooler and buncher devices, and in differentially pumped extraction systems of large volume gas cells. They are also projected to be used at higher pressures, in the 1-10 bar range, to transport barium ions in xenon gas. I will discuss the working principle of RF carpets as well as these various applications.

Primary author: BRODEUR, Maxime (University of Notre Dame)

Presenter: BRODEUR, Maxime (University of Notre Dame)

Session Classification: Ba daughter tagging

Contribution ID: **9** Type: **Invited talk**

Digital SiPM array for photon detection in next generation Xenon based rare event search experiments

Friday, 27 October 2023 09:00 (25 minutes)

Approaching the kiloton mass scale in rare event search experiments using Xenon places new, stringent demands on the light detection system. Aspects such as high radiopurity, low power consumption and simple mechanics are becoming as important as low noise and excellent quantum efficiency. Digital SiPMs is a light detector technology that meets all these requirements. In this technology, SPADs and CMOS logic are fabricated on the same silicon substrate so that the SPAD hits can be processed on-chip and the chip output signals are purely digital. No further readout ASIC is required and only few passive electric components are needed. This greatly reduces power consumption, system complexity and radioactivity. For rare event search experiments we developed a dedicated large area large area $(8 \times 9\,\mathrm{mm}^2)$ and high high fill factor (77%) digital SiPM array. It allows to build large detector modules controlled by seven signals. Our chip consists of a pixel matrix of 30×32 so-called macropixels of $240 \times 291\,\mu\mathrm{m}^2$ and a narrow band of synthesized readout logic. Each macropixel contains 9 SPADs and some CMOS logic which allows for disabling each SPAD in case its noise rate is too high, and a logical OR combining all SPAD signals to create a common macro-pixel hit signal. The hit signal is stored in the pixel, so that multiple coincident hits in the matrix are possible. The logic in the periphery searches the matrix for hits and stores their X- and Y-addresse as well as an associated column-wise time information $(\Delta T = 10\mathrm{ns})$. Up to 64 Chips build a serial data chain, in which the chips inject their data for readout. In total, a chip chain needs only seven signals: 3 analogue signals for power, ground and SPAD bias and 4 digital signals for clock, command and serial input and output. The SPADs are of excellent quality, offering a dark count rate of $0.02\mathrm{Hz}/\mathrm{mm}^2$ at liquid xenon temperature $(T = 165\mathrm{K})$ and $25\mathrm{kHz}/\mathrm{mm}^2$ at room temperatures. The quantum efficiency at blue light is about 40% and the manufacturer is currently optimizing it for deep VUV light.

Primary authors: KELLER, Michael (University of Heidelberg); FISCHER, Peter (University of Heidelber)

Presenter: KELLER, Michael (University of Heidelberg)

Session Classification: Future Light and Charge Readout

Contribution ID: **10** Type: **Invited talk**

Status and prospects of the AXEL experiment

Friday, 27 October 2023 10:40 (25 minutes)

A Xenon Electroluminescence (AXEL) experiment is a $0\nu\beta\beta$ search experiment using high pressure xenon gas TPC.This TPC has a unique pixelized structure(ELCC) to read out Electroluminescence(EL) light from ionized electrons.
ELCC has a rigid, pixelized structure, that can be easily scaled to larger sizes, and have the ability to reconstruct 3D tracks. EL is a linear amplification process, which reduces fluctuation associated with amplification. We constructed a 180L sized prototype detector with 12 ELCC units and acquired data in 7.6 bar xenon. The obtained energy resolution at 7.6bar is (0.82±0.11)% (FWHM) at 1836keV.
This corresponds to (0.64±0.02)% (FWHM) to (0.78±0.18)% (FWHM) of energy resolution at the Q value of ^{136}Xe $0\nu\beta\beta$. We are now developing ELCC using diamond like carbon(DLC) as electrode, Cockcroft-Walton multiplier for drift electric field, quartz glass plate coated with wave length shifter for efficient detection of scintillation light, etc. And we are preparing for our first physics search with 1000L detector at Kamioka observatory.

Primary author: AKIYAMA, Shinichi (Tohoku University)

Presenter: AKIYAMA, Shinichi (Tohoku University)

Session Classification: Future Light and Charge Readout

Contribution ID: **11** Type: **Invited talk**

When backgrounds become signal: neutrino detection with xenon detectors

Thursday, 26 October 2023 11:35 (25 minutes)

Large target masses and ultra-low background levels are now becoming commonplace for xenon-based rare event searches. As a result, current and future experiments will have unprecedented sensitivity to astrophysical neutrinos in multiple interaction channels. In this talk I will provide a brief overview of relevant neutrino sources and their interaction channels in xenon-based experiments while highlighting a subset of physics studies that can be carried out using neutrinos as a signal.

Primary author: HASELSCHWARDT, Scott (Lawrence Berkeley National Lab)

Presenter: HASELSCHWARDT, Scott (Lawrence Berkeley National Lab)

Session Classification: Physics program of multi-tonne detectors

Contribution ID: **12** Type: **not specified**

TinyTPC - A test stand for photosensitive dopants

Thursday, 26 October 2023 16:42 (7 minutes)

LArTPCs highly doped with Xenon could be interesting platforms for probing MeV- and sub-MeV physics including neutrinoless-double beta decay. A main hurdle is the small fraction of scintillation photons that are collected, which significantly impacts LArTPCs' energy resolution. One solution is the use of photosensitive dopants, which convert light to charge. A team from Rutgers University and FNAL have built a test stand (TinyTPC) with a LArPix pixelated anode plane and an active mass of 2.1 kg to study these charge enhancements. Our plan is to measure the TinyTPC' s energy resolution with and without dopants for radioactive gamma sources, which is crucial for accurate calorimetric energy reconstruction of low-energy physics signals. The doping agent that will be used is isobutylene and the radiation sources are Co-60, Y-88, and Th-228.

Primary author: ENGLEZOS, Panagiotis (Rutgers University)

Co-authors: MASTBAUM, Andrew; PSIHAS, Fernanda; ZENNAMO, Joseph (Fermilab)

Presenter: ENGLEZOS, Panagiotis (Rutgers University)

Session Classification: Session 1/1

Contribution ID: **13** Type: **not specified**

R&D for LAr + Xe + photosensitive dopants

Thursday, 26 October 2023 16:35 (7 minutes)

LArTPCs are the technology of choice for current and future neutrino experiments, including those expected to make eagerly awaited measurements of accelerator neutrino oscillations in the coming decade. This technology provides a large active volume and sensitivity to GeV signals like accelerator neutrinos all the way down to 10s of MeV, covering part of the supernova neutrino spectrum.

Expanding the reach of LArTPCs to below the 10 MeV range would substantially enhance the flagship analyses of experiments like DUNE, while potentially enabling the physics of solar neutrinos, dark matter searches, and neutrinoless double beta decay searches.

We outline the R&D pathway for photosensitive dopants, whose introduction into the LAr active medium, has the potential to substantially increase ionization yields of LAr detectors and enable the detection of low energy signals in large LArTPCs. This R&D program will demonstrate the feasibility and impacts of introducing doped LAr into current and future neutrino detectors at the kTon scale including the Xenon + photosensitive doping strategy.

Primary authors: PSIHAS, Fernanda; ENGLEZOS, Panagiotis (Rutgers University); ZENNAMO, Joseph (Fermilab)

Presenter: PSIHAS, Fernanda

Session Classification: Session 1/1

Contribution ID: **14** Type: **Invited talk**

Novel caverns and underground space scaling for giant gas TPCs

Wednesday, 25 October 2023 14:15 (25 minutes)

The natural gas industry has technologies for large-scale cryogenic gas storage on the surface (well-known to physicists since its adoption by DUNE). Less well known are the technologies for large-scale ambient-temperature underground gas storage. In this talk I will try to convince you that, with the right underground infrastructure, gas TPCs (a) can be scaled up as easily as cryogenic liquid TPCs and (b) leave room for novel gas mixes and readout strategies which my group is exploring.

Primary author: MONREAL, Benjamin (Case Western Reserve University)

Presenter: MONREAL, Benjamin (Case Western Reserve University)

Session Classification: Challenges of a program towards the kton scale

Contribution ID: **15** Type: **Invited talk**

Origin-X: A Ktonne Scale Neutrinoless Double Beta Decay Experiment with 1030yr Half-life Sensitivity.

Wednesday, 25 October 2023 09:25 (25 minutes)

Large detectors employing xenon are a leading technology in existing and planned searches for new physics, including searches for neutrinoless double beta decay (0νββ) and dark matter. While upcoming detectors will employ target masses of a ton or more, further extending gas- or liquid-phase Xe detectors to the ktonne scale would enable extremely sensitive next-generation searches for rare phenomena. The key challenge to extending this technology to detectors well beyond the ton scale is the acquisition of the xenon itself. We describe the motivation for extending xenon time-projection chambers to the kton scale and possible avenues for xenon acquisition.

Primary author: HEFFNER, mike (LLNL)

Presenter: HEFFNER, mike (LLNL)

Session Classification: Challenges of a program towards the kton scale

Contribution ID: **16** Type: **not specified**

Logistics and opening remarks

Wednesday, 25 October 2023 09:00 (25 minutes)

Primary author: MISTRY, Krishan (University of Texas at Arlington)

Presenter: MISTRY, Krishan (University of Texas at Arlington)

Session Classification: Opening Remarks

Contribution ID: **18** Type: **not specified**

Direct Air Capture of Xenon

Wednesday, 25 October 2023 09:50 (25 minutes)

Presenter: SANGIORGIO, Samuele (LLNL)

Session Classification: Challenges of a program towards the kton scale

Contribution ID: **19** Type: **not specified**

Material structures and intermolecular forces relevant to adsorption-based xenon capture

Wednesday, 25 October 2023 10:15 (25 minutes)

Given that xenon production by cryogenic distillation is prohibitory in cost and insufficient in quantity to provide for the next generation of xenon detectors, adsorption of xenon onto porous materials may be a viable alternative. Activated carbons and zeolites are possible adsorbent candidates. However, the non-specific intermolecular interactions between these materials and xenon afflict them with poor selectivity for xenon against other atmospheric gases. Intelligently designed materials containing pores tailored to the size of the xenon atom may prove to be superior adsorbents due to their high selectivity conferred by stronger attractive interactions with xenon compared to other gas species. Certain metal-organic frameworks (MOFs) with appropriately sized pores have shown promise for highly selective capture of large volumes of xenon. Several thousand MOF structures have been reported, and a combination of computational and experimental tools give insight into which MOFs warrant investigation as potential adsorbents for xenon.

Presenter: CATARINEU, Noelle (LLNL)

Session Classification: Challenges of a program towards the kton scale

Contribution ID: **21** Type: **not specified**

Design considerations for a multi-tonne Xe detector

Wednesday, 25 October 2023 11:35 (25 minutes)

Presenter: Prof. SHUTT, Tom (SLAC)

Session Classification: Challenges of a program towards the kton scale

Contribution ID: **22** Type: **not specified**

Vapor pressure measurements of xenon isotopes

Wednesday, 25 October 2023 12:00 (25 minutes)

Presenter: Prof. LICCIARDI, Caio (University of Windsor)

Session Classification: Challenges of a program towards the kton scale

Contribution ID: **23** Type: **not specified**

Landscape of current Xe supplies

Wednesday, 25 October 2023 13:25 (25 minutes)

Presenter: MARC, Amandine (Air Liquide)

Session Classification: Challenges of a program towards the kton scale

Contribution ID: **25** Type: **Invited talk**

Large-scale xenon storage

Wednesday, 25 October 2023 14:40 (25 minutes)

Presenter: MASBOU, Julien (Subatech - Nantes Université / CNRS-IN2P3 / IMT Atlantique)

Session Classification: Challenges of a program towards the kton scale

Contribution ID: **28** Type: **not specified**

Second order weak decays of 124Xe

Presenter: Dr WITTWEG, Christian (Unviersity of Zurich)

Session Classification: Physics program of multi-tonne detectors

Contribution ID: **29** Type: **not specified**

Status of nuclear matrix elements

Thursday, 26 October 2023 10:15 (25 minutes)

Presenter: Dr HOLT, Jason (TRIUMF)

Session Classification: Physics program of multi-tonne detectors

Contribution ID: **32** Type: **not specified**

Supernova neutrino detection with XLZD and the limitations therein

Thursday, 26 October 2023 12:00 (25 minutes)

Presenter: GHOSH, Sayan (Purdue University)

Session Classification: Physics program of multi-tonne detectors

Contribution ID: **34** Type: **not specified**

Double beta decay in JUNO

Presenter: Prof. WEN, Liangjian (IHEP)

Session Classification: Registration / name tag pickup

Contribution ID: **36** Type: **not specified**

Imaging of Ba/Ba+ in Xe ice

Presenter: Prof. FAIRBANK, Bill (Colorado State University)

Session Classification: Ba daughter tagging

Contribution ID: **37** Type: **not specified**

The Canadian Ba-tagging program

Thursday, 26 October 2023 15:05 (25 minutes)

Primary author: BRUNNER, Thomas (McGill University)

Co-author: Dr LENNARZ, Annika (TRIUMF)

Presenter: BRUNNER, Thomas (McGill University)

Session Classification: Ba daughter tagging

Contribution ID: **42** Type: **not specified**

Photon-to-digital converters and photodetection modules for large scale noble liquid experiments

Friday, 27 October 2023 09:50 (25 minutes)

While SiPM use is increasing, it is well accepted that the one-to-one coupling of SPAD to a CMOS quenching circuit is the best way to leverage their single photon counting and precise timing capabilities. We develop photon-to-digital converters (PDC) that expand these capabilities with embedded time-to-digital conversion and advanced signal processing. The SPAD architecture, 3D integration scheme, and CMOS readout circuit layout were engineered simultaneously for implementation in the Teledyne DALSA foundry. We designed the SPAD structure to optimize timing resolution (with 10 ps RMS as a goal) and photon detection efficiency between 350 nm and 450 nm, a range favored for wavelength shifters and scintillators. We also work at increasing detection efficiency in the VUV. While present work focuses on 180 nm CMOS readout for astroparticle physics experiments, we will also discuss the path for integration with 65 nm CMOS. I will review the progress of the SPAD array development, production and performance including our work toward photodection modules suitable for integration in large scale experiments.

Presenter: Prof. CHARLEBOIS, Serge (Université de Sherbrooke)

Session Classification: Future Light and Charge Readout

Contribution ID: **44** Type: **not specified**

Gas mixtures

Wednesday, 25 October 2023 16:00 (25 minutes)

Presenter: GONZALEZ DIAZ, Diego

Session Classification: Novel TPC ideas

Contribution ID: **45** Type: **Invited talk**

Removing Rn-222 from xenon for large-scale for large scale rare event searches

Wednesday, 25 October 2023 11:10 (25 minutes)

With ever larger detectors and the self-shielding properties of liquid xenon, the intrinsic purity of liquid xenon detectors is becoming increasingly important for rare event searches such as double neutrinoless double beta decay or dark matter. In this context, the isotope Rn-222 and its decay progenies are of particular importance.
The selection of low-activity materials and surface passivation, the construction of the detector under clean room conditions in a low radon atmosphere are the most important prerequisites to keep the radon concentration in the detector as low as possible. Continuous active removal of Rn-222 from the LXe in the detector will be the last step to decrease its concentration even further. In this talk, cryogenic *online distillation* for the removal of radioactive noble gases, especially Rn-222, from xenon will be presented. In particular, with this method new records in Rn-222 concentration below 1 µBq/kg have been achieved in the dark matter experiment XENONnT.
These methods are also suitable for removing other impurities such as krypton with its radioactive isotope Kr-85 and argon with its radioactive isotope Ar-39 and Ar-42 from xenon.

The talk will also give an outlook on how these methods can be further developed to achieve the required purity of LXe for the next generation of rare events searches such as the planned dark matter experiment DARWIN/XLZD and even neutrinoless double beta decay searches beyond nEXO. In particular, the developments just started within the ERC Advanced Grant project *LowRad* with a targeted radon purity of 1 radon atom per 100 mol xenon also aim at integrating the necessary very sensitive online diagnostic methods.

Primary author: WEINHEIMER, Christian (University of Münster)

Presenter: WEINHEIMER, Christian (University of Münster)

Session Classification: Challenges of a program towards the kton scale

Contribution ID: **46** Type: **not specified**

Scalability and optical enhancements of tracking planes for beyond-ton-scale experiments

Friday, 27 October 2023 09:25 (25 minutes)

Primary author: GUENETTE, Roxanne (Harvard)

Presenter: GUENETTE, Roxanne (Harvard)

Session Classification: Future Light and Charge Readout

Contribution ID: **47** Type: **Invited talk**

Latest result and future of neutrinoless double-beta decay search by KamLAND-Zen

Thursday, 26 October 2023 09:25 (25 minutes)

Detection of neutrinoless double-beta decay ($0\nu\beta\beta$) would be an evidence of Majorana nature of neutrino, which clue on the extremely light neutrino mass and the matter dominant universe.
The KamLAND-Zen experiment started a search for $0\nu\beta\beta$ of ^{136}Xe nuclei in 2011 (KamLAND-Zen400). The experiment was upgraded in 2019 by double amount of xenon nuclei and a tenfold reduction in uranium and thorium contamination (KamLAND-Zen 800). In addition, lots of new analytical technics including particle identification with neural network have been developed.
A combined analysis of the KamLAND-Zen 400 and 800 dataset yields a lower limit of the half life of $0\nu\beta\beta$: $T_{1/2}^{0\nu\beta\beta} = 2.3 \times 10^{26}$ years at 90% confidence level, which corresponds to the most strong upper limit on the effective Majorana neutrino mass of 36–156 meV with different nuclear matrix elements. This experiment achieved the first search of $0\nu\beta\beta$ in the inverted neutrino mass hierarchy region.
published article : https://doi.org/10.1103/PhysRevLett.130.051801

Primary author: KAWADA, Nanami (RCNS, Tohoku University)

Presenter: KAWADA, Nanami (RCNS, Tohoku University)

Session Classification: Physics program of multi-tonne detectors

Contribution ID: **54** Type: **Invited talk**

Theory perspective for large-scale xenon detectors

Thursday, 26 October 2023 11:10 (25 minutes)

Neutrinoless double beta decay (NLDBD) is the most sensitive probe of lepton number violation. Its discovery would be a clear signal of physics beyond the Standard Model, confirm the Majorana nature of neutrinos, and provide insight into scenarios of baryogenesis through leptogenesis. In this talk, I will give an overview of the kind of lepton-number violating (LNV) interactions that can be probed by NLDBD, focusing on scenarios in which LNV arises either from heavy new physics or through light sterile neutrinos. Both types of LNV sources can be described in an effective-field-theory framework, which organizes the calculation by making use of the large hierarchies between the different scales in the problem. After discussing the required steps to predict the decay rates as well as the needed hadronic and nuclear input, I will illustrate the sensitivity to the different LNV interactions.

Primary author: DEKENS, Wouter (Institute for Nuclear Theory)

Presenter: DEKENS, Wouter (Institute for Nuclear Theory)

Session Classification: Physics program of multi-tonne detectors

Contribution ID: **55** Type: **Invited talk**

Dark Matter and 0vbb physics programs of XLZD

Thursday, 26 October 2023 09:50 (25 minutes)

The dual-phase xenon time-projection chamber (TPC) has risen in recent decades as one of the best technologies to hunt for dark matter in the form of weakly interacting massive particles (WIMPs). This xenon TPC has many advantages, including self-shielding against backgrounds, low threshold, good energy resolution, potential scalability for future larger detectors which could probe the WIMP parameter space down to the neutrino fog. Beyond this sensitivity to WIMPs, larger xenon TPCs also present competitive sensitivity to neutrinoless double beta decay (0vbb) and a broad science program. A consortium was recently formed by XENON, LUX-ZEPLIN(LZ) and DARWIN collaborations to build the next generation of LXe-TPC that will serve as a multi-purpose observatory for dark matter and neutrino physics. This talk will focus on discussing this consortium, XLZD, and its science program with an emphasis on dark matter and 0vbb.

Primary author: KAMAHA, Alvine (University of California, Los Angeles)

Presenter: KAMAHA, Alvine (University of California, Los Angeles)

Session Classification: Physics program of multi-tonne detectors

Contribution ID: **56** Type: **Invited talk**

Xenon-Doped Liquid Argon TPCs as a Neutrinoless Double Beta Decay Platform

Wednesday, 25 October 2023 15:35 (25 minutes)

Next-generation large liquid argon time-projection chambers offer an unprecedented amount of active detector mass in a deep location. Modifications to the detector design could enable neutrinoless double beta decay searches, with the possibility of reaching the normal ordering region. These modifications include adding external neutron moderation, filling the detector with argon depleted in Ar42, doping with xenon, and a method to achieve percent-level energy resolution at the MeV scale. One way to achieve this desired level of energy resolution is to introduce a photosensitive dopant into the argon, converting the isotropic scintillation photons into a directional ionization signal. This would enhance the achievable energy resolution in large LArTPCs, and would lead to sizeable improvements to many facets of the broad physics program such a detector could offer.

Primary author: ZENNAMO, Joseph (Fermilab)

Presenter: ZENNAMO, Joseph (Fermilab)

Session Classification: Novel TPC ideas

Contribution ID: **57** Type: **Invited talk**

Neutrinoless double beta decay with Theia

Thursday, 26 October 2023 12:25 (25 minutes)

This talk will present plans and prospects for a next-generation neutrinoless double beta decay search with Theia, a novel hybrid Cherenkov+scintillation neutrino detector. Sensitivity to a broad program of additional physics will be presented, along with progress in R&D and technology demonstrations.

Primary author: KAPTANOGLU, Tanner (LBNL)

Co-author: Prof. OREBI GANN, Gabriel (University of California, Berkeley / LBNL)

Presenter: KAPTANOGLU, Tanner (LBNL)

Session Classification: Physics program of multi-tonne detectors

Contribution ID: **58** Type: **Lightning talk**

Cherenkov Light Separation in LXe for Improved Background Rejection

Thursday, 26 October 2023 16:00 (7 minutes)

With the development of fast sub-nanosecond photosensors and the increasing size of xenon-based detectors for neutrinoless double beta decay ($0\nu\beta\beta$) the time-of-flight difference between scintillation and Cherenkov light can be exploited for further background mitigation. This is especially crucial for the rejection of elastic scattering of solar neutrinos, which presents a major and irreducible background for a kilotonne-scale experiment. In this talk I will present some considerations for the light detection performance of a future kt-scale xenon detector searching for $0\nu\beta\beta$ based on fast GPU-based light simulations and the projected background rejection capabilities and resulting gain in sensitivity to $0\nu\beta\beta$ using the Cherenkov light separation technique.

Primary author: JAMIL, Ako (Princeton University)

Presenter: JAMIL, Ako (Princeton University)

Session Classification: Session 1/1

Contribution ID: **59** Type: **Invited talk**

Detection prospects for the double-beta decays of Xe-124

Thursday, 26 October 2023 09:00 (25 minutes)

The isotope ^{124}Xe is exceedingly rare and long-lived. Still, its two-neutrino and neutrinoless double-weak decays offer exciting opportunities for neutrino and nuclear physics. Its double-beta decays with neutrinos would provide constraints for nuclear
matrix element calculations in the proton-rich region of the nuclear chart [C. Wittweg, B. Lenardo, A. Fieguth and C. Weinheimer, EPJ C 80 (2020) 1161]. What makes ^{124}Xe special among double-beta emitters is the theoretical possibility of three different neutrinoless decay modes –either via double-electron capture in a nuclear resonance, or involving the emission of one or two positrons. Together with the observation of neutrinoless double-beta decays in other isotopes, ^{124}Xe could allow to disentangle the underlying decay mechanism. The contribution will introduce the neutrinoless and two-neutrino decays of ^{124}Xe and discuss future detection prospects.

Primary author: WITTWEG, Christian (Physik-Institut, University of Zurich)

Presenter: WITTWEG, Christian (Physik-Institut, University of Zurich)

Session Classification: Physics program of multi-tonne detectors

Contribution ID: **60** Type: **Invited talk**

Insights into the global xenon market

Wednesday, 25 October 2023 13:50 (25 minutes)

As co-spokesperson of the XENON collaboration I coordinated and purchased tons of xenon from various vendors. I noticed the talk by an Air Liquide representative, but I could add a significantly wider picture and broader insights into the global xenon market, about various market interdependencies, price evolution and many other details.

Primary author: LINDNER, Manfred (Max Planck Institute for Nucelar Physics)

Presenter: LINDNER, Manfred (Max Planck Institute for Nucelar Physics)

Session Classification: Challenges of a program towards the kton scale

Contribution ID: **61** Type: **Invited talk**

Imaging of Ba/Ba+ in Xe ice

Thursday, 26 October 2023 14:15 (25 minutes)

Our group in the nEXO collaboration is developing a cryogenic method for Ba daughter tagging in neutrinoless double beta decay in liquid 136Xe. The principle is to capture the Ba daughter from liquid xenon by trapping it in a solid xenon layer on a cryogenic probe window and then scanning the layer with a laser for 1 Ba atom/ion or 0 Ba atom/ion. We can now image single Ba atoms in a solid xenon layer and have made progress toward single Ba+ ion images. We have discovered much about the physics/chemistry of Ba atoms and Ba+ ions in solid xenon and the deposition of thin and thick solid xenon layers, but there is much still to learn in order to perfect the imaging method. I will present these results and our parallel work to date towards grabbing and detecting Ba+ ions from a liquid xenon cell.

Primary author: FAIRBANK, Bill (Colorado State University)

Presenter: FAIRBANK, Bill (Colorado State University)

Session Classification: Ba daughter tagging

Contribution ID: **62** Type: **Lightning talk**

An Atmospheric Xenon TPC for Neutrinoless Double Beta Decay

Thursday, 26 October 2023 16:49 (7 minutes)

In modern searches for neutrinoless double beta decay ($0\nu\beta\beta$) using ^{136}Xe, one possible avenue being explored by collaborations such as NEXT is the use of a high-pressure gaseous Time Projection Chamber (TPC). The principal reasons for using gas TPCs are to exploit the low intrinsic recombination of the gas and the ability to use electroluminescence as a method of stable gain amplification, resulting in competitive energy resolution performance. One of the primary behaviors of gaseous TPCs, typically seen as a disadvantage, is electron diffusion, which causes blurred track topology. Remedying this typically requires gas additives to mechanically reduce ionization electron energy or computational deconvolution algorithms to recover the original topology. Instead of eliminating diffusion, here I will discuss the possibility of utilizing this effect as a means of improving energy resolution via individual electron counting in an atmospheric-pressure gaseous TPC.

Primary author: BYRNES, Nicholas (University of Texas Arlington)

Presenter: BYRNES, Nicholas (University of Texas Arlington)

Session Classification: Session 1/1

Contribution ID: **63** Type: **Invited talk**

Material structures and intermolecular forces relevant to adsorption-based xenon capture

Given that xenon production by cryogenic distillation is prohibitory in cost and insufficient in quantity to provide for the next generation of xenon detectors, adsorption of xenon onto porous materials may be a viable alternative. Activated carbons and zeolites are possible adsorbent candidates. However, the non-specific intermolecular interactions between these materials and xenon afflict them with poor selectivity for xenon against other atmospheric gases. Intelligently designed materials containing pores tailored to the size of the xenon atom may prove to be superior adsorbents due to their high selectivity conferred by stronger attractive interactions with xenon compared to other gas species. Certain metal-organic frameworks (MOFs) with appropriately sized pores have shown promise for highly selective capture of large volumes of xenon. Several thousand MOF structures have been reported, and a combination of computational and experimental tools give insight into which MOFs warrant investigation as potential adsorbents for xenon.

Primary author: CATARINEU, Noelle (Lawrence Livermore National Laboratory)

Presenter: CATARINEU, Noelle (Lawrence Livermore National Laboratory)

Contribution ID: **64** Type: **Invited talk**

Supernova neutrino detection with XLZD and the limitations therein

In this talk I would discuss the potential detection sensitivity of XLZD towards supernova neutrino CEνNS. In addition, I would also talk on the limitations, to this detection, caused by charged current (CC) interaction of the supernova neutrinos. I would try to show that the CC interaction may in fact present a lower limit in the supernova distance that a large xenon detector can be sensitive to, without being blinded by the high energy electrons produced in the CC interactions.

Primary author: GHOSH, Sayan (Purdue University)

Presenter: GHOSH, Sayan (Purdue University)

Contribution ID: **65** Type: **Lightning talk**

MeV-scale internal calibration sources for large LXe detectors

Thursday, 26 October 2023 16:56 (7 minutes)

By design, large-scale liquid xenon TPCs enjoy powerful self-shielding; gamma rays that would create backgrounds are strongly attenuated by the liquid at the edges of the detector. This, however, presents a challenge for calibrations: calibration sources placed outside the detector will only rarely penetrate to the center of the TPC, making the most sensitive region of the experiment also the most difficult to characterize. Radioisotopes that can dissolve directly into liquid xenon can address this problem. While many such sources are already in use, they are generally either a) alpha sources, which have dramatically different light and charge response, b) continuous-spectrum beta sources, or c) they deposit energies far below the 0nuBB Q-value of 136Xe. I will discuss some possibilities for dissolvable radioisotopes that would provide O(MeV) gamma ray lines, which could be used for energy scale calibrations of large LXe detectors.

Primary author: LENARDO, Brian (SLAC)

Presenter: LENARDO, Brian (SLAC)

Session Classification: Session 1/1

Contribution ID: **66** Type: **not specified**

3He Neutron Capture in xenon gas experiments

Thursday, 26 October 2023 17:03 (7 minutes)

Helium 3 has a high neutron capture cross section and adding it to xenon can mitigate Xe136 to Xe137 capture which decays in our region of interest.

Primary author: ROGERS, Leslie (argonne national laboratory)

Presenter: ROGERS, Leslie (argonne national laboratory)

Session Classification: Session 1/1