LIDINE 2022: LIght Detection In Noble Elements

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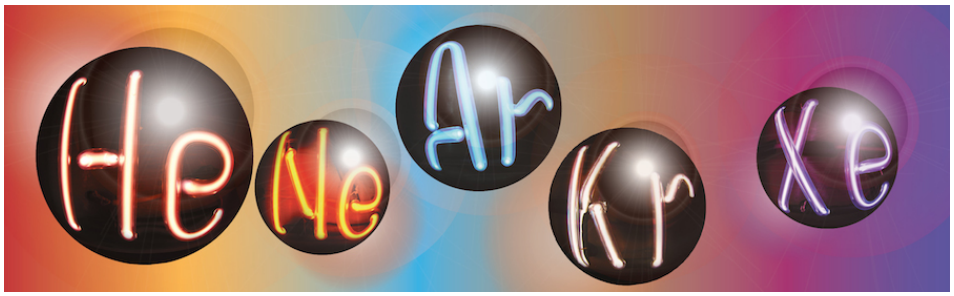

Book of Abstracts

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Poster session / **1**

Muon Energy reconstruction and neutrino astronomy with the DUNE far detector.

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DUNE (Deep Underground Neutrino Experiment) is a proposed long-baseline neutrino oscillation experiment located in the United States. The main physics objectives of DUNE are to characterize neutrino oscillations, search for nucleon decay, and observe supernova neutrino bursts. The DUNE far detector will be located 4850' underground at the Sanford Underground Research Facility in Lead, South Dakota. It will house the world's largest liquid-argon time projection chamber. The DUNE far detector can detect high-energy muons that arise from interactions of cosmogenic neutrinos and search for neutrinos originating in the decay of Weakly Interacting Massive Particles (WIMPs). Selecting upward-going muons reduces the background from cosmic-ray muons. The muon energy is estimated from the electromagnetic showers accompanying the muon, a technique that allows energy reconstruction up to a few hundred TeV. This work discusses the DUNE far detector's potential for neutrino astronomy.

Properties of noble liquids / **2**

Lindhard integral equation with binding energy apply to light and charge yields nuclear recoils in noble liquid detectors

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We present a model for the ionization efficiency, or quenching factor, for low energy nuclear recoils based on a solution to Lindhard's integral equation with binding energy and apply it to the calculation of the relative scintillation efficiency and charge yield for noble liquid detectors. The quenching model incorporates a constant average binding energy together with an electronic stopping proportional to the ion velocity, and is essential input into an analysis of charge recombination processes to predict the ionization and scintillation yields. Our results are comparable to NEST simulations of LXe and LAr and are in good agreement with available data. These studies are relevant for current and future experiments using noble liquids as targets for neutrino physics and direct searches for dark matter.

Applications / **3**

Detection efficiency measurement and operational tests of the X-Arapuca for the first module of DUNE Far Detector

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The Deep Underground Neutrino Experiment (DUNE) is a dual-site experiment for long-baseline neutrino oscillation studies, able to resolve the neutrino mass hierarchy and measure δ_{CP}.
DUNE will also have sensitivity to supernova neutrinos and to processes beyond the Standard Model, such as nucleon decay searches.
The Far Detector (FD) will consist of four liquid argon TPC (17.5kton total mass) with systems for the detection of charge and scintillation light produced by an ionization event.
The charge detection system permits both calorimetry and position determination.
In addition, the photon-detection system (PDS) enhances the detector capabilities for all DUNE physics drivers. The PDS of the first FD module consists of light collector modules placed in the inactive space between the innermost wire planes of the TPC anode. The light collectors, the so-called X-Arapucas, are functionally a light trap that captures wavelength-shifted photons inside boxes with highly reflective internal surfaces where they are guided to Silicon Photo-multipliers (SiPM) by wavelength-shifting bars. Functionality and operational tests of the X-Arapucas to be installed in ProtoDUNE-phase II (FD DUNE prototype at the scale 1:20), as well as the measurement of their absolute detection efficiency will be shown in this presentation.

Light and charge readout / **4**

Scintillation Light Detection Performance for the DUNE ND-LAR 2x2 Modules

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The Deep Underground Neutrino Experiment (DUNE) will be using a liquid argon time projection chamber (LAr TPC) with optically separated modules in the Near Detector (ND) complex. A prototype experiment for these modules, DUNE ND-LAr 2x2, is currently commissioning and constructing four test modules. These modules detect ionization charge through a pixel-based readout and scintillation light through fibers in Light Collection Modules and light traps called ArCLights. This presentation will discuss the light detection performance for two modules of DUNE ND-LAr 2x2 that took cosmic ray data at the University of Bern. The talk will discuss the role of DUNE ND-LAr 2x2 in DUNE and the reconstruction capabilities of its light detectors in terms of energy thresholds and timing resolution.

Light and charge readout / **5**

Production and Testing of the Large-Area Photon Detector ArCLight

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Compact large-area dielectric photon detectors ensure modular noble liquid detectors can sense scintillation light signals for triggering and reconstruction purposes with minimal decreases to the overall target volume of the module. ArCLight is a small volume, sizeable sensitive area detector that consists of a light trap covered in a thin layer of TPB that can be placed along a time projection chamber's electric field. These sensors are planned for the Deep Underground Neutrino Experiment Near Detector liquid argon (DUNE ND-LAr) modules. They are constructed and tested at the University of Bern and will be used for the prototype experiment, DUNE ND-LAr 2x2. The talk will discuss the details of assembling ArCLights, the quality control methods developed, and the test studies done with LEDs to assess their performance.

Photosensors / 6

Correlated noises for NUV-HD-Cryo SiPMs

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Silicon Photomultipliers (SiPM) represent an established solution for the light detection of large particle detectors. The NUV-HD-Cryo family from Fondazione Bruno Kessler exhibits a very attractive solution at liquid argon temperature, being stable with large overvoltages with a primary dark count rate below a few count per second per square centimeter. On the other hand, for those SiPMs the optical cross-talk (oCT) can reach very high values. Part of the oCT remains confined in the silicon bulk and accounts for the internal cross-talk (iCT). Escaping photons can be detected by other SiPM in the particle detector, in a process named external cross-talk (eCT). The interaction between iCT and eCT creates a positive feedback that leads to a noisy photon-detection gain extended to the full experiment, which can easily exceed 1.5-3.
In this contribution, measurements and models of the internal and external cross-talk will be presented. Furthermore, the effects on broadening resolution of the photon-detection for cryogenic experiments will be discussed.

Long-term light yield stability / 7

X-ARAPUCA long term test

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The photon detection system of the DUNE experiment is based on the X-ARAPUCA light trap. The basic constituents of the X-ARAPUCA are: dichroic filters coated with wavelength shifter (para-Therphenyl), a waveshifting plate and an array of SiPMs which detects the trapped photons. A small scale prototype of the X-ARAPUCA has been installed in LAr in a dedicated facility at INFN-Napoli and exposed to alpha, gamma particles and cosmic muons. In order to stress mechanically the optical components (the thin para-Terphenyl layer and the wave shifting plate) few thermal cycles from room to liquid argon temperature were performed. The overall stability of the device was monitored by measuring its detection efficiency on a daily basis.

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Analysis of the purity of the argon used by the MicroBooNE experiment by ICPMS technique

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Mass spectrometry is typically used to measure U and Th contamination of the materials used to build a low-background detector. However, this technique has the potential to provide essential information about the purity of the gas used by argon-based rare event research experiments. The CIEMAT-DM group has shown that, by ICPMS, it is possible to identify and quantify contaminants in the argon, a piece of information that is typically not exploited. We did preliminary tests with the gas extracted from the ArDM experiment at LSC, proving this technique's viability and identifying the mercury contamination in the argon used in this experiment. This unexpected contamination had to be accounted for in the experiment's light propagation model.
A more recent analysis has been performed with the gas extracted from the MicroBooNE detector. We identified some typical argon contaminants in this case and compared the ICPMS results with commercially available argon gas.
This talk will present the idea behind this technique, the preliminary results, and some prospects for future experiments.

Signal reconstruction / **9**

Prediction of supernova neutrino signals by detectors and its future challenges

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Supernova neutrinos produced during a core-collapse of a massive star, carries 99% of the energy produced during the violent phenomenon. These neutrinos are weakly interacting massive particles, and can provide useful information for both particle physics (neutrino oscillations parameters) and astrophysics (explosion mechanism) that can be used to explore physics beyond the standard model. Neutrinos escape from the supernova core hours before the light, so a neutrino signal providing information about supernova direction can enable early observation. The current generation of detectors, like, Super-Kamiokande (Super-K), LVD, Borexino, KamLAND, and IceCube, as well as HALO, Daya Bay and NOvA, have ability to detect only a few orders of magnitude of events and the next generation, like, Hyper-Kamiokande (Hyper-K), DUNE, and JUNO will have yet another order of magnitude in reach, as well as richer flavor sensitivity. This work will present a monte carlo based study using the SNOwGLoBES package, that is used to estimate the event rate using folded fluxes, cross-sections, and detector smearing to determine mean expected neutrino interaction signals in multiple current and future detectors. A study is carried out for the calculation of core-collapse neutrino event rates in realistic detectors for different flux models, effects of different parameters on flux and its variation with time. This work will also discuss the future challenges and technology needed to advance neutrino astronomy.

Poster session / **10**

DAPHNE digitizing system for DUNE SP-PD

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The Deep Underground Neutrino Experiment (DUNE) will be an experiment in neutrino physics and proton decay studies. DUNE will consist of two parts, The Long-Baseline Neutrino Facility, located at the Fermi National Accelerator Laboratory, and the Far Detector at Sanford Underground Research Facility, the latter consists of liquid argon tanks used as scintillators for neutrino detection. The PD consortia are using SiPMs sensors for photon detection and those analog signals are amplified and digitized by a system named DAPHNE. The DAQ system we have designed is capable of digitizing 40 channels of signals coming from the silicon sensors, sending data at high speed via Gigabit Ethernet or fiber optics using the FullMode protocol to the receiving DAQ systems. This card works as an interface between the analog signals, part of the cold electronics, and the digital signals, part of the warm electronics.
DAPHNE system is under development and testing by a group of Latin American institutions and Fermilab. Other works running in the collaboration are the SiPM signal amplification system, timing interface, and DAQ for system validation.

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Measurement of SiPM external cross-talk in a liquid xenon detector

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Silicon photomultipliers (SiPMs) are the photo-detection technology of choice for future noble-liquid scintillator rare-event search experiments, both in neutrino-less double beta decay and dark matter. The high radio-purity and exceptional gain of SiPMs along with a high VUV detection efficiency make them ideal for these applications. The Light only Liquid Xenon (LoLX) experiment is a small-scale R&D liquid xenon (LXe) detector located at McGill University. LoLX operates 96 Hamamatsu VUV4 SiPMs in a cylindrical geometry submerged in LXe. Of particular importance, is the characterization of SiPM external cross-talk in a LXe detector with similar geometric acceptance as future planned experiments. During the SiPM avalanche process photon detection, NIR photons are emitted and can transport to other SiPMs and may produce correlated hits on other devices [1], this process is called SiPM external cross-talk (eXT). In this talk, we will present the measurement of SiPM eXT detection within LoLX, with comparisons to GEANT4 eXT simulations informed by ex-situ measurements of SiPM photon emission characteristics.

1 - McLaughlin JB, et al., Characterisation of SiPM Photon Emission in the Dark. Sensors (Basel). 2021 Sep 4/21 (17):5947, doi: 10.3390/s21175947

Properties of noble liquids / **12**

Calibrating the scintillation and ionization responses of xenon recoils for high-energy dark matter searches

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Liquid xenon-based direct detection dark matter experiments have recently expanded their searches to include high-energy nuclear recoil events as motivated by effective field theory dark matter and inelastic dark matter interaction models, but few xenon recoil calibrations above 100 keV are currently available. In this presentation, we show our measurements of the scintillation and ionization yields of xenon recoils up to 426 keV. The experiment uses 14.1 MeV neutrons to scatter off xenon in a compact liquid xenon time projection chamber and produce quasi-monoenergetic xenon recoils between 39 keV and 426 keV. We present the xenon recoil responses and their electric field-dependence for recoil energies up to 306 keV; due to the low event statistics and the relatively mild field dependence, the yield values at higher energies are reported as the average of xenon responses for electric fields between 0.2-2.0 kV/cm. This result will enable xenon-based dark matter experiments to significantly increase their high energy dark matter sensitivities by including energy regions that were previously inaccessible due to lack of calibrations.

Applications / **13**

3DΠ scanner, an application in medical physics of the DarkSide collaboration

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This project is based on the emerging technology from the field of direct dark matter searches for weakly interacting massive particles (WIMPs), in which Liquid Argon (LAr) time projection chambers are used to identify different particle interactions for WIMP detection. The Darkside Collaboration has demonstrated the true power of the advancing LAr detector technology. They are also making significant strides in low-radioactivity argon procurement and cryogenic photosensor development and fabrication. With these advances in hand, the principle of 3DΠ has been developed. It is a novel design of a Time Of Flight (TOF) Total-Body (TB) scanner for Positron Emission Tomography (PET) using Xenon-doped liquid Argon (LAr) as a scintillator. By doping the LAr with Xenon, the long-lifetime component of the LAr scintillation light can be suppressed, allowing the scanner to handle higher data rates and hence higher patient doses if required for a given application. Since the de-excitation process in the mixture can be accomplished with direct energy transfer from argon excimers to xenon and direct emission of xenon light, it will be faster than the fluorescence processes of a wavelength shifter (WLS). Additionally, it has been shown that reducing the operating temperature of SiPMs down to the temperature of LAr significantly reduces the dark count rate within the SiPM.

The preliminary results of the Monte Carlo simulation demonstrate that the scanner's system performance, according to the NEMA NU 2-2018 standardized guide, is comparable to commercial scanners.

Detector techniques / **14**

Spectroscopy measurements to enhance readout of xenon TPCs

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Over the past several decades, the dual-phase xenon time projection chamber (TPC) has risen to the forefront of the race to directly detect dark matter (DM). The technology utilizes photomultiplier tubes (PMTs), or other light detection devices, to readout scintillation produced promptly after a particle scatters in the liquid and electroluminescence generated when electrons freed by the interaction are drifted into a gaseous amplification region. The scintillation spectrum has been well measured under the cryogenic operating conditions of these detectors, but the electroluminescence spectrum has only been measured at room temperature. A precise unbiased investigation is required to improve response models of xenon to the scattering of particles and decrease systematic uncertainty in future DM searches. This talk describes an R&D setup designed to make such measurements.

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Novel VUV Light Detection in a Pixelated Liquid Argon Time Projection Chambers

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Projective readout technologies currently used in Liquid Argon Time Projection Chambers come with a set of challenges from the construction of the wire planes themselves to the continuous readout of the system required to accomplish the physics goals of proton decay searches and supernova neutrino sensitivity. Additionally, the reconstruction techniques required for these projective readouts become complex and difficult for complex neutrino interaction topologies. As such, research into reading out LArTPC's using true 3D pixel based schemes has recently garnered a lot of interest. This new charge readout poses a problem for detection of the scintillation light. In the wire based readout, the wires are transparent to the photons and thus photon detectors (PMT's and SiPM's) coated in wavelength shifting materials (TPB and PEN) can be deployed. However, pixel planes are opaque to the light and thus other methods of detection may be required. A number of novel ideas could be pursued to allow the pixel design to be an integrated tracking/photo-detector. One such notion is the exploration of coating the dielectric surface with a type of photo-conductor which would respond to the VUV light incident on the surface. When struck by a VUV photon, the photoconductor would have electrons elevated into the conduction band and move in the electric field toward a pixel button. We will present some early results and initial R&D being done into the realization of such an integrated tracking/photo-detector for pixel based LArTPCs and future plans for testing currently underway.

Applications / **16**

The Scintillating Bubble Chamber: Overview and Status

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As conventional liquid noble experiments push towards lower energy thresholds, separation between electron and nuclear recoils becomes increasingly difficult. The Scintillating Bubble Chamber (SBC) Collaboration is combining the well-established bubble chamber and liquid argon scintillator technologies, building a detector specifically suited to quasi-background-free measurement of low energy nuclear recoils. This relies on the principle that nuclear recoils cause bubble formation (nucleation), while electron recoils do not. SBC plans to operate at nucleation thresholds as low as 100 eV, while the scintillation signal will be used to tag and reject higher energy nucleation events. This yields performance suitable for a competitive WIMP dark matter search in the 1GeV mass region and sensitivity to reactor CEvNS. Currently the collaboration is constructing two similar chambers: one for calibration data at Fermilab and a second low background version to be operated at SNOLAB. The active volume consists of 10kg of superheated liquid argon contained within two fused silica vessels, surrounded by 32 silicon photomultipliers for scintillation light detection. SBC also plans to investigate performance with xenon doped liquid argon and to study the effects of electric field on nucleation efficiency. This talk will discuss detector function, current status and calibration techniques, along with the advantages and challenges unique to SBC.

Long-term light yield stability / **18**

Reduction in Light Collection Efficiency Over Time in LUX's Second Science Run

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Between its first and second WIMP-search runs (Run03 and Run04) the LUX (Large Underground Xenon) detector at SURF (Sanford Underground Research Facility) observed a ~15% sharp drop in its primary scintillation detection efficiency (g1), with an O(5%) further slow drop over the course of the 300+ live-days of Run04. Different possibilities for the cause(s) will be reviewed, including "natural" PMT photocathode degradation over time as well as "scorching" of the VUV-reflective PTFE panels from the inter-runs grid-wire conditioning campaign with the goal of increasing the magnitude of the drift electric field, for better nuclear recoil (NR) signal versus electron recoil (ER) background discrimination. Another focus will be how it was possible to track the changes in g1 as well as g2 (gain factor for the secondary scintillation channel, from ionization) with time in situ not only with mono-energetic sources such as 83mKr but also with spectra continuous in energy, from a D-D neutron calibration source for NR and a novel 14C beta high-energy ER calibration source, comparing the data from these sources to Monte Carlo computer simulations driven by LUXSim (Geant4-based), the precursor to LZ's BACCARAT, as well as NEST (the Noble Element Simulation Technique).

Applications / **19**

Recent results from DEAP-3600

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DEAP-3600 is the largest running dark matter detector filled with liquid argon, set at SNOLAB, in Sudbury, Canada, 2 km underground. The experiment holds the most stringent exclusion limit in argon for WIMPs above 10 GeV/c^2. In the published analysis the background events due to alpha-inducing scintillation in the neck of the detector limited the sensitivity. Both the hardware upgrades and the multivariate analysis are going to decrease this background and eventually improve the the detector sensitivity in the next upcoming WIMP search.
Moreover, the WIMP analysis has been revisited in terms of a non-relativistic effective field theory framework and explored the impact of possible substructures in the galactic dark matter halo, motivated by the latest results from Gaia and the Sloan Sky Digital Survey, setting the world best exclusion limit for xenon-phobic dark matter scenarios. Finally, a custom-developed analysis has recently pointed out the extraordinary sensitivity also to ultra-heavy, multi-scattering dark matter candidates, that has resulted in world leading exclusion limits on two composite dark matter candidates with masses up to the Planck-scale.

Applications / **20**

Search for low mass WIMP dark matter with DarkSide-50

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DarkSide-50 is a direct WIMP dark matter detection experiment at Laboratori Nazionali del Gran Sasso (LNGS) that uses argon as the target material. Exploiting the ionization signal from a dual-phase time projection chamber (TPC) filled with low radioactivity argon from an underground source, it has set the strongest limit against WIMP with a mass in the GeV/c2 region. A new analysis has recently been carried out with a larger exposure coupled with an improved understanding of the detector response. In this talk, we give the new result for the low mass WIMP search. We also highlight the latest status of an advanced analysis exploiting event rate modulation.

Light and charge readout / **21**

Rugged and radiopure amplification structures for large-area xenon chambers read out through electroluminescence

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Large scintillation gaps are desirable for electroluminescence chambers with ultimate energy resolution and single-electron counting characteristics, whereas large-area amplification structures are needed for next-generation ton-scale experiments. We present systematic studies of a custom designed structure (Field-Assisted Transparent Gas Electroluminescence Multiplier, or FAT-GEM), consisting of a hole matrix on an acrylic plate. The structures, produced at CERN and ASTROCENT workshops following different fabrication techniques, are radiopure and mechanically robust, allow manufacturing on large areas and are amenable to tiling in a seamless manner (i.e., no dead-regions). In this presentation we will present a systematic characterization with an x-ray source and comparison with simulations for different FAT-GEM architectures.
As a self-supported structure allows for optimization of the point-spread function, increasing the light collection efficiency and implementing wavelength-shifting capabilities, the potential of this

technological solution is very broad. We will present first results of such 'active' designs and prospects, including the use of PEN, TPB and ESR reflectors incorporated into the structure.

Poster session / **22**

Charge Flash Matching in SBN's near and far detectors to discard cosmic ray backgrounds

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The SBN program consists of three surface liquid argon time projection chambers (LArTPC) detectors on the Booster Neutrino Beam line at Fermilab, devoted to probe neutrino oscillations at the $\sim 1\mathrm{eV}^2$ scale. SBND is the near detector, located at 110 m from the source, with a mass of 112 tons. Because of the inherent long readout times of LArTPCs and the lack of shielding, cosmic rays are the main source of background. Charge particles traversing the detector ionise the media, creating electrons and scintillation light. This talk describes a reconstruction algorithm that associates the electrons and the scintillation from interactions. We present the simulated performance to discard cosmic induced interactions, and finish with a method to use the scintillation light to aid with the charge reconstruction of challenging events.

Application overview / **23**

Particle Dark Matter searches, the next generation

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The cosmological Dark Matter particle remains as elusive as ever. Experiments looking for signals from direct interactions of galactic Dark Matter particles in detector targets have so far ruled out only a small number of theoretical possibilities within the vast parameter space Dark Matter could be found in. To probe unexplored regions in parameter space for signs of these particles, we continue to re-define what is possible in terms of detector size, energy threshold, and radio-purity.
In this contribution, we look at the role of noble gases in shaping current and upcoming detector generations, and at the role of these detectors in the wider field.

Signal reconstruction / **24**

Measurement of the Light-Yield in MicroBooNE with Isolated Protons

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The MicroBooNE detector is an 85-ton active mass Liquid Argon Time Projection Chamber (LArTPC) located on-axis along the Booster Neutrino Beam (BNB). It serves as a part of the Short-Baseline Neutrino (SBN) program at Fermilab, which was primarily designed to address the Miniboone low-energy excess. The primary signal in the LArTPC is ionisation, but the argon also emits large quantities of scintillation light. Prompt scintillation light in MicroBooNE is recorded with an array of 32 PhotoMultiplier Tubes (PMTs). The scintillation light is used to determine the timing of neutrino interactions and to reject cosmic-ray activity. We present a new method of measuring the light-yield using isolated proton events, which enables a position-dependent light-yield measurement to map the response of the detector across its volume. This method can be used to calibrate the light response in large-scale LArTPC detectors as well as to test assumptions used in simulating scintillation light.

Light and charge readout / **25**

The Photon Detection System of SBND

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SBND is the near detector of the Short Baseline Neutrino program at Fermilab. Its near location (110 m) to the neutrino source and relatively large mass (112 ton active volume) will allow studying neutrino interactions on argon with unprecedented precision.
This talk focuses on the SBND Photon Detection System. It represents a major R&D opportunity for the LArTPC technology. Its design is a hybrid concept combining a primary system of 120 photomultiplier tubes, and a secondary system of 192 XARAPUCA devices, all of them located behind the anode plane. Furthermore, covering the cathode plane with highly reflective panels coated with a wavelength shifting compound recovers part of the light emitted towards the cathode, where no optical detectors exist. This new design provides high light-yield and more uniform detection efficiency, an excellent time resolution and an independent position reconstruction (including the drift coordinate) using only the scintillation light.

Applications / **26**

The DARWIN observatory: Physics potential for Dark Matter and beyond

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The nature of Dark Matter is one of the most urgent unsolved questions of modern physics. The DARWIN observatory is a future experiment to search directly for Dark Matter and to shine light on its properties. DARWIN will consist of a dual-phase time-projection chamber with 40 tons of liquid xenon in its active volume and will be surrounded by external veto detectors for background suppression. The large detector size and the stringent background requirements pose a multitude of challenges. At the same time it provides ample opportunities to address a variety of physics topics. This talk will discuss the physics reach of DARWIN in the area of Dark Matter and beyond.

Photosensors / **27**

Studies of event burst phenomenon with SiPMs at cryogenic temperature

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Silicon photomultipliers (SiPMs) are used to collect scintillation photons in many cryogenic noble liquid detectors deployed around the world, such as DarkSide, nEXO, MEGII, ProtoDUNE and DUNE. An event burst phenomenon was observed during routine characterization on many models of SiPMs operated in liquid nitrogen. These bursts of consecutive pulses are initiated by an intense dark photoelectron pulse with an event rate much lower than the time-uncorrelated thermal dark pulse. Although the occurrence of these event bursts pulse rate is very low, it can potentially compromise some dedicated rare physics event searches which are also anticipated to be of extremely low rate. Here, we systematically study the behavior of the event burst phenomenon and identify the probable cause of the phenomenon. This investigation is important on the selection of SiPMs for use in noble liquid detectors, high energy physics experiments, and industrial applications where SiPMs are used in cryogenic environment.

Optics and wavelength shifters / **28**

Fluorescence of optical materials down to 4 K – acrylic, TPB, pyrene

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Many noble liquid-based particle detectors contain the medium in an acrylic vessel. The acrylic may be coated by a wavelength shifter if the scintillation light produced from particle interactions with the medium is outside the wavelength range of the photodetectors. In the case of liquid argon, the 128 nm scintillation light must usually pass through a wavelength shifter to be detected by standard photodetectors which are more sensitive to visible wavelengths. We have investigated the temperature dependence of fluorescence properties for pyrene-polystyrene coatings which can be used as a wavelength shifter to complement 1,4,4-tetraphenyl-1,3-butadiene (TPB), a common wavelength shifter for noble liquid detectors. Pyrene has a much longer fluorescence time than TPB which could be useful for pathological background rejection in a detector. The fluorescence properties of pyrene-polystyrene coated acrylic were studied using samples with different concentrations and fluorescence grades of pyrene. In addition, we have studied the fluorescence of the acrylic itself, as it could form a background in rare-event searches and compared the relative light yield of acrylic to TPB at different temperatures. All these materials were excited with 285 nm UV light and studied at various temperatures between 4 K and 300 K to cover the operating temperatures of most particle detectors. We present the changes in the spectra and light yields of all these materials with temperature and discuss an additional analysis of the temperature dependence of the pyrene fluorescence time constants. These results are reported in recent publications (H. Benmansour et al 2021 JINST 16 P12029 & E. Ellingwood et al 2022 NIM-A 1039 167119) and we are currently working towards a similar fluorescence analysis of Clevios coated acrylic.

Light and charge readout / **29**

Light detection with power and signal transmission over fiber.

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The Deep Underground Neutrino Experiment (DUNE) is be a massive long baseline (1300 km) neutrino experiment that aims to shade light on some of the major open questions in neutrino physics. The neutrino beam measurements will be performed by a near detector (ND) and far detector (FD). The far detector will consist of four modules, installed 1,5 km deep underground, based Liquid Argon Time Projection Chamber (LArTPC) technology to detect particles.

The Vertical Drift (VD) LArTPC is a recent technology proposed by the DUNE Collaboration for the second FD module. In vertical drift, light collection will be optimized by installing photon detectors in the LArTPC's cathode, which is biased at -300 kV. This imposes a constrain that the Photon Detection System (PDS) must have power and signal transmission through non conductive materials. The proposed solution is to use Power-over-Fiber (PoF) and Signal-over-Fiber (SoF). An intense validation of the system is being performed by the Collaboration at the CERN Neutrino Platform, this talk will present the matured design and results of the data collected over the first half of 2022.

Light and charge readout / **30**

SiPM array of Xenoscope, a full-scale DARWIN vertical demonstrator

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The DARWIN project aims to build and operate a next-generation observatory for dark matter and neutrino physics, featuring a time projection chamber (TPC) with a proposed active target of 40 t of liquid xenon (LXe). As an R&D facility to test fundamental components of the future detector, Xenoscope, a full-scale vertical demonstrator with 350 kg of LXe and up to 2.6 m electron drift length was built at the University of Zurich. Its main objective is to demonstrate electron drift over unprecedented distances in LXe, first in a purity monitor setup with charge readout, followed by a dual-phase TPC. In this second phase, an array of 192 VUV-sensitive 6x6 mm2 SiPMs (Hamamatsu VUV4 MMPCs) with a 12-channel readout will be placed above the active target and operated as light readout for the proportional scintillation signals in the TPC.
This talk will present the design and development of the SiPM top array of Xenoscope, from the structural and electronic design, up to the characterization of the SiPM sensors, their installation and performance.

Detector techniques / **31**

Stabilization of High-concentration Xenon Doping in Liquid Argon

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Doping liquid argon with small (< 0.1%) concentrations of xenon improves its performance as a detection medium by shifting primary scintillation light to longer wavelengths. At high doping levels, the concentration of xenon in the gas phase is sufficient to modify the electroluminescence chemistry analogously to that of the primary scintillation. However, conventional cryostat and circulation designs of liquid argon TPCs lead to unwanted concentration and separation of the xenon, even at small doping levels. We describe the successful operation of a system specifically designed to thermodynamically stabilize xenon-argon mixtures. This method allows mixtures to be stabilized for multiple days without separation, with operation demonstrated at 2% concentration. Consequently, the S2 light of dual-phase TPCs using this mixture can be conveniently sensed at longer wavelengths and over shorter timescales, allowing for more efficient detection of low-energy ionization signals.

Optics and wavelength shifters / **32**

Assessing the performance of metalenses to enhance the light collection of silicon photomultipliers

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A metalens is an emerging type of flat optical metamaterial that presents several advantages over a traditional lens, such as reduced cost and reduced bulkiness. We developed a set of software tools and fabrication procedures for the rapid development and characterization of new metalens designs. A large field-of-view centimeter-scale metalens was fabricated, and its performance compared with GEANT4-based predictions. We explored the potential in using this metalens to gain an increase in SiPM light collection in a variety of detector geometries.

Properties of noble liquids / **33**

Light production in liquid and gaseous argon

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It has been known that noble elements, when excited by ionizing radiation, emit light not only in the vacuum ultraviolet (VUV) region but also at longer wavelengths, up to the near-infrared (NIR). Many questions remain on the exact nature of this scintillation both in terms of its atomic/molecular origin as well as its full characterization as regards the light yield, spectral and time structure. In this contribution we report results from a dedicated experiment in gaseous and liquid argon, sensitive to both the VUV as well as the non-VUV light, which addresses some of these questions. Our experimental setup houses an Am241 alpha source and employs four SiPMs with different spectral sensitivities which together cover a wide spectral region from the VUV to the NIR, in an arrangement that is compact and impervious to stray light.

Properties of noble liquids / **34**

Simulation results for a low energy NR yields measurement in liquid xenon using the MiX detector

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To increase sensitivity of liquid xenon (LXe) experiments to light WIMPs, the response of the LXe medium to sub-keV nuclear recoils must be characterized. We study the feasibility for an ultra-low energy nuclear-recoil yield measurement in LXe using neutron capture. The measurement strategy uses the recoil energies imparted to xenon nuclei during the de-excitation process following neutron capture, where promptly emitted γ cascades can provide the nuclei with up to 0.3 keV_{nr} of recoil energy due to momentum conservation. In this talk we will present simulation results and the current status of the Michigan Xenon (MiX) detector, a small sub-kilogram dual-phase xenon TPC, that is being prepared to carry out this measurement.

Detector techniques / **35**

Filling of the LEGEND cryostat - Liquid argon optical properties study

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In the LEGEND experiment, approximately 90 tons (65 m^3) of liquid argon (LAr) serve as a cooling medium for the germanium detectors and as an instrumented shielding. To achieve optimal performance of the liquid argon detector system, the LAr was purified by a dedicated system during the cryostat's initial filling. The LEGEND LAr purification System (LLArS) performance was studied and monitored during cool down and filling of the cryostat by three systems: A scintillation analyzer for probing the argon scintillation properties by triplet state lifetime measurements; simultaneously, a direct measurement of the concentrations of impurities, such as water, oxygen, and nitrogen was performed with a sensitivity of 0.1 ppm. Additionally, the optical properties of argon filled inside the

cryostat are constantly monitored by the LEGEND Liquid Argon Monitoring Apparatus (LLAMA). Thanks to the employment of LLArS, the achieved argon triplet lifetime ($_3$) measured inside the 70%-filled LEGEND-200 cryostat was 1.3 µs. It dropped to 1.1 µs after adding LAr of poor quality. The delivered LAr had a too high nitrogen content, which could not fully be removed by LLArS. However, this accidental nitrogen doping gave an opportunity to study optical properties of liquid argon at low nitrogen concentrations. The nitrogen content increased by 0.9 ppm in the course of several hours. Thanks to the argon monitoring system good quality data was collected and analyzed. The liquid argon purity in the cryostat can be recovered by implementing LLArS into an argon circulation system.
We will present the design, construction, and performance of the LLArS system capable of efficiently purifying 65 m^3 of liquid argon to a sub-ppm level for the LEGEND-200 experiment. Additionally, we show the evolution of the measured light yield and effective triplet lifetime during the filling and at low nitrogen concentrations.

Light and charge readout / **36**

The light detection system of the ICARUS detector in the Short Baseline Neutrino program at Fermilab.

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The Short Baseline Neutrino (SBN) program at the Fermi National Laboratory in the US is an extensive experimental programme based on three Liquid Argon Time Projection Chambers (LAr-TPCs) aiming at searching for sterile neutrino(s), whose existence is one of the fundamental open questions of neutrino physics. The SBN program aims to study neutrino oscillations and interactions in the hundreds-of-MeV to a few GeV energy range, using the Booster Neutrino Beam (BNB) and some off-axis neutrinos from the NuMI (Neutrinos at the Main Injector) beam. The SBN detectors, working near the Earth's surface, are also exposed to a substantial cosmic background, which can mimic genuine neutrino interactions. Thus, it is fundamental to distinguish the signals related to the neutrino beams from those induced by the cosmic rays. The subject of this talk is related to the ICARUS detector with a focus on its light detection system. The ICARUS detector is equipped with 360 8" R5912 Hamamatsu Photomultiplier Tubes (PMTs) to detect VUV photons produced after the passage of ionizing particles in LAr. This system is fundamental for the TPC operation, providing an efficient trigger and contributing to the 3D reconstruction of events.
Moreover, the light detection system allows for the time reconstruction of events, contributing to the identification and selection of neutrino interactions within the beam spill gates. The light detection system calibration and further development of the trigger system, aiming at increasing their efficiencies for physics data taking, had been performed for the final detector configuration during the detector commissioning at Fermilab. The trigger system effectively exploits the information given by the scintillation light detection system. This contribution also presents a way of using the PMT information for filtering neutrino interactions and cosmic muons by applying a Convolutional Neural Network (CNN) to the simulated data. The results show that with this method, the cosmic background can be reduced by up to 76% with a neutrino selection efficiency of 99%. However, this work aims at filtering the real data cases, which are usually not identical to the simulated ones. Thus, a way to mitigate biases from imperfect simulations will also be presented by applying Domain Adversarial Neural Networks (DANNs). The results demonstrate that adversarial training through a DANN can alleviate the loss of efficiency at a relatively low cost of reduced background rejection. This is the first application of DANN for CNN as an event classifier for a LAr TPC.

Applications / **37**

CCM Experiment

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CCM is a 10 ton liquid argon scintillation detector located at Los Alamos National Lab. The prototype detector CCM120 was fabricated in 2017, which utilized 120 PMTs, and now the upgraded detector CCM200, with 200 PMTs, has collected data in the 2021 run cycle. The physics program of CCM comprises searches for new particles in the weak sector, including Dark Photons, Axion-like Particles (ALPs), and neutral heavy leptons in the keV to MeV mass range, extending the coverage of open parameter space for these searches at the order of magnitude level.

Optics and wavelength shifters / **38**

Development of coated electrodes with low quantum efficiency for future direct dark matter experiments with liquid xenon

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In direct dark matter experiments using liquid xenon (Xe), scintillation and ionization signals are produced by an interaction between Xe and dark matter. A scintillation photon can produce an electron through photoelectric effect on electrodes, which is one of the major backgrounds for low-mass dark matter searches. For future direct dark matter experiments using liquid Xe, we are developing coated electrodes with low quantum efficiency (QE) to reduce such background. In this talk, I will present about the results of QE measurements for some electrodes (ex:Au, Pt, Al, SUS304) and also some insulators (ex:PTFE, Quartz, PEEK) in vacuum, liquid Xe, and gas Xe.

Signal reconstruction / **39**

Monte Carlo Pulse Shape Discrimination model and fitter for liquid Argon dark matter detectors.

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Pulse Shape Discrimination is a powerful tool to distinguish WIMP signals from electronic recoil background in liquid Argon detectors.
In order to accurately evaluate the expected rate of background events with uncertainty, a robust background model that can be tuned to the detector data and reliably extrapolated orders of magnitude beyond the available background statistics, is needed. We have developed a physics-driven toy simulation to model the complete detection process from scintillation to light detection. Since high statistics simulations are computationally expensive the model has been implemented in python using PyTorch framework, which significantly reduces the computation time using parallelization on multiple GPUs. On a single GPU, PyTorch implementation is 2 orders of magnitude faster than the ROOT based implementation. We'll discuss the model and its application to analyse the DEAP-3600 data.

Poster session / **40**

Xenoscope - a full scale vertical demonstrator for the DARWIN observatory

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The DARWIN observatory is a proposed next generation experiment for dark matter detection and neutrino physics. DARWIN will feature a 50 tonne liquid xenon (LXe) target enclosed in a dual phase time projection chamber. The realisation of this multi-ton scale detector requires to address a series of technological challenges, to this end, a full scale vertical demonstrator, Xenoscope, was built at the University of Zurich. The Xenoscope facility will be used to demonstrate the drift of electrons in LXe over to 2.6 m distance, as well as to study electron cloud diffusion studies and measurement of the LXe optical properties. We present an overview of the Xenoscope facility, the current status and the future measurement campaigns.

Applications / **41**

First dark matter search results from the LZ experiment

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The LUX-ZEPLIN (LZ) experiment is a dark matter detector centred on a dual-phase xenon time projection chamber operating at the Sanford Underground Research Facility in Lead, South Dakota, USA. Results from LZ's first search for Weakly Interacting Massive Particles (WIMPs) with an exposure of 60 live days using a fiducial mass of 5.5 tonnes were recently published. A profile-likelihood analysis shows the data to be consistent with a background-only hypothesis, setting new limits on spin-independent WIMP-nucleon cross-sections for WIMP masses above 9 GeV/c^2. The most stringent limit is set at 30 GeV/c^2, excluding cross-sections above 5.9×10^{-48} cm^2 at the 90% confidence level. This talk will give an overview of the LZ detector, a description of the first results, and a brief look at the science program that is now accessible with the LZ experiment.

Detector techniques / **43**

Monitoring 39Ar Background for DarkSide-20k with DArT in ArDM

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The current landscape for the hunt of particle Dark Matter (DM) requires us to achieve state of the art ability to mitigate and account for the various backgrounds. DarkSide-20k, a 20-tonn scale double phase TPC, will commission its voyage for the DM with an exclusion sensitivity to spin-independent WIMP-nucleon interaction of 6.3×10^{-48} cm^2 (90% C.L.) @ 1 TeV/c^2 with a 200 t $\times$ year exposure. Thorough material assays campaign is being carried out to report and avoid various instrumental background, leaving aside the background contribution of ^{39}Ar from the total mass of LAr inside the TPC itself. With purpose of solving this, the project DArT in ArDM is almost ready for commissioning at LSC, Spain with a sensitivity to measure UAr depletion factor exceeding 1000 with statistical accuracy better than 10% in one week of counting time. At present, the primary detector is taking data in a test setup.

Properties of noble liquids / **44**

Experimental study of Ar ion drift and feedback from gas to liquid phase

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A large positive volume charge can distort the drift field and quench the charge signal in a massive argon time projection chamber, thus the study of the dynamics of the positive ions created by particle interactions in liquid argon is essential for the characterization of the new generation of experiments planned for the dark matter direct search and neutrino physics. We have constructed a 1 L liquid argon chamber (ARION: ARgon ION experiment), which is able to produce a sizeable volume charge by injecting, in a controlled manner, an ion current into the argon drift region. This chamber allows the space charge effects to be studied systematically by reading the charge collected in different locations using a multichannel digital picoamperimeter. In this talk, new experimental results regarding positive ion dynamics in LAr are presented with the direct demonstration of ion feedback from the gas to the liquid. In addition, a novel technique to measure the drift velocity of the argon ions is introduced.

Detector techniques / **45**

A versatile cryogenic system for liquid argon detectors

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Detectors for direct dark matter search using noble gases in liquid phases as detection medium need to be coupled to liquifying, purifying and recirculation systems.
In the framework of the DarkSide experiment the Proto-0 system, a double phase liquid Argon TPC as reduced scale prototype version of the DarkSide-20k detector, has been built with the aim of the study of the position of the scintillation and ionization signals detected by a large SiPM's arrays.
The detector is connected to a dedicated cryogenic system to liquefy and purify the gaseous argon used as the scintillator.

The cryogenic system is mainly composed of double wall cryostat hosting the TPC, a purification stage to reduce the impurities below the parts per billion level, a condenser to liquefy the argon, a recirculation gas panel connected to the TPC cryostat equipped with a custom gas pump.
The system has been built and has been operated at the INFN-Laboratory of the Naples since October 2021.
Main features of the cryogenic system will be presented. Performances, long term operations and stability in terms of the most relevant thermodynamic parameters will be reported. Future plans and upgrades will be discussed.

Photosensors / **46**

A large facility for photosensors test at cryogenic temperature

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Silicon based photo-detectors are innovative light collecting devices and represent a successful technology in the field of direct dark matter search detectors based on liquified noble gases.
The DarkSide collaboration started a dedicated development and customization of SiPM technology for its specific needs resulting in the design, production and assembly of a large surface module of 20x20 cm^2 to be used as PhotoDetectionUnit (PDU) in the DarkSide-20k experiment.
Production of a large number of such devices, as needed to cover about 15 m^2 of active surface inside the DarkSide-20k detector, requires a robust testing and validation process.
In order to match this requirement a dedicated test facility for the PDU tests was designed, integrated and commissioned at INFN Naples laboratory. The first commissioning test was successfully performed in 2021. Since then a number of testing campaigns were performed.
Results of these tests as well as a detailed description of the facility will be presented and discussed. Possible upgrades on the system will be also reported.

Applications / **47**

First Science Results from the XENONnT experiment

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The XENONnT experiment is a dark matter detector centered on a dual-phase xenon time projection chamber operating at the INFN Laboratori Nazionali del Gran Sasso. XENONnT has achieved unprecedented purity both for electronegative contaminants, with an electron lifetime exceeding 10 ms, and for radioactive 222Rn, with an activity of 1.72±0.03 Bq/kg. This talk will give an overview and the first science results of the XENONnT experiment.

Properties of noble liquids / **48**

Update on Delayed Electron Emission in DarkSide-50

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Dual-phase noble gas Time Projection Chambers (TPCs) suffer from spurious electron background events at the lowest detectable energy region. This background is reported in liquid xenon TPCs and some of the causes are discussed in the literature. Understanding its origin is of paramount importance as this background sets the analysis threshold and affects the most sensitive part of the region of interest for low mass dark matter searches.

We present an update of the study of the spurious electron events observed in the liquid argon TPC in the DarkSide-50 experiment. Our analysis indicates a significant fraction of the spurious electron events is related to the impurities in the TPC. While a full understanding of spurious electron emissions will require dedicated R&D, possible mechanisms and mitigation strategies are discussed, in light of what we know from observations in DarkSide-50. The differences from the spurious electron emission in the liquid xenon TPCs are discussed.

Application overview / **49**

Application of noble gases in searches for neutrino-less double beta decay

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Noble gases, like Xr or Ar in their liquid or gaseous phase, are becoming increasingly common in experimental programs searching for physics beyond the standard model. This includes the searches for the neutrino-less double beta decay. Noble gases may be used either as targets or can also serve as passive and/or active shields. In the first case one can use as an example the Xe-based detectors (like EXO or NEXT) applying gas enriched in the Xe-136 isotope. In the second case the LEGEND experiment can be presented, where LAr is used as the passive and the active shield, having strong impact on the background reduction.
Clear advantages of the detectors using noble gases are their high radio-purity, which can be relatively easy achieved by gas-phase purification, high scalability and good energy resolution. All this makes it possible to build ultra-sensitive detectors with active targets with masses of several tonnes and almost zero background level.
In the talk various experiments searching for the neutrinoless double beta decay and utilizing noble gases will be presented. Their construction, detection principle, background reduction techniques, expected/achieved sensitivities and prospects will be discussed.

Applications / **50**

Present status of the LEGEND experiment

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The Large Enriched Germanium Experiment for Neutrinoless Double Beta (0vbb) Decay (LEGEND) is designed to answer one of the highest priority questions in fundamental physics: is the neutrino Majorana or Dirac particle, is the lepton number conserved, and what is the neutrino mass ?
In the first phase of the project the LEGEND-200 detector is under construction at the Laboratori Nazionali del Gran Sasso (LNGS) in Italy. Up to 200 kg of bare high purity germanium (HPGe) detectors enriched in Ge-76 up to about 90 % will be deployed in liquid argon (LAr). The LAr will serve as cooling medium for the detectors as well as a passive and active shield. The LAr instrumentation will be composed of light guiding fibers connected to silicon photomultipliers detecting scintillation light of argon. It has been already shown in the GERDA experiment that the LAr veto was a very powerful tool for background rejection and minimization. By combining the lowest background levels with the best energy resolution in the field, LEGEND-200 will perform a quasi-background-free search for 0vbb decay and after collecting of about 1 ton*year of data it can make a discovery of neutrinoless double-beta decay with just a handful of counts for the Ge-76 half-life of about 10^(27) years.
In the presentation the present status of LEGEND-200 will be discussed, as well as the perspectives for construction of the full-scale detector based on 1000 kg of Ge-76. LEGEND-1000 is designed to probe Neutrinoless Double Beta Decay with a discovery sensitivity in the Ge-76 half-life of about 10^(28) years, corresponding to an effective Majorana mass upper limit in the range of 9-21 meV to cover the inverted-ordering neutrino mass scale with 10 years of live time.

Photosensors / **51**

Rapid characterization of SiPMs for noble liquid experiments

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Silicon photomultipliers (SiPMs) are emerging as the photodetector technology to be used in upcoming noble liquid experiments. Newly developed SiPMs sensitive to vacuum ultraviolet (VUV) light will be directly used for the readout of scintillation photons (λ = 175nm) from liquid xenon in future tonne-scale experiments such as nEXO searching for neutrinoless double beta decay in 136Xe. In this research project, VUV-SiPMs from two different vendors are characterized using current-voltage (IV) and pulse-level measurements performed at TRIUMF, from room temperature to liquid xenon temperature. These data are analysed to extract the SiPM's features like breakdown voltage, gain, crosstalk, afterpulsing and dark noise rates. The IV and pulse-level results are compared. A method is proposed for rapid quality control of large numbers of SiPM using IV measurements.

Signal reconstruction / **52**

Energy Resolution of LZ detector to High Energy Electron Recoils

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The LUX-ZEPLIN (LZ) detector is a 10-ton liquid xenon dual-phase time projection chamber operating at the SURF laboratory (South Dakota, USA). As reported in June 2022, after 60 live days of the search for Weakly Interacting Massive Particles (WIMPs), LZ demonstrates a world record sensitivity to spin-independent WIMP-nucleon interactions for WIMP masses above 9 GeV [1]. Given its

large target mass and low backgrounds, the LZ scientific program also includes the search for the neutrinoless double beta decay of 136Xe, highlighting the importance of achieving a good energy resolution at 136Xe Qββ value of 2.46 MeV.
This work presents the detector's energy resolution for single scatter interactions emphasising the high energy search region (>2 MeV). The detector demonstrates a linear response to electron recoils in the 160–2700 keV energy range. A novel technique to correct the non-uniformity of the light collection in a scintillation detector, based on the knowledge of the light response functions of individual photosensors, will be described. With this technique, we report, at a very early phase of the detector operations, a state-of-the-art performance on the energy resolution for the whole fiducial volume. The comparison of the measured energy resolution in the 160–2700 keV energy range with other liquid xenon particle detectors and the predictions of the NEST model will also be presented.

References
[1] Aalbers, J., et al. "First Dark Matter Search Results from the LUX-ZEPLIN (LZ) Experiment". vol. 33, 2022. Available: http://arxiv.org/abs/2207.03764

Signal reconstruction / **54**

Latest Development of the Noble Element Simulation Technique (NEST)

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We will report the latest development of NEST, a comprehensive simulation package for noble liquid experiments. It has achieved increasingly accurate predictions of energy spectrum and discrimination between electronic and nuclear recoils for a large range of drift fields in liquid xenon and is used by leading dark matter experiments such as LZ and XENONnT. Opportunities to use this software package to inform the design of the next generation liquid xenon observatory for nuclear, particle and astrophysics will be discussed.

Poster session / **55**

Measurements on refractive index of wavelength shifters

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A common practice when detecting high-energy scintillation photons in noble gas experiments is the use of wavelength shifters. These compounds convert the high-energy photons to a less energetic spectrum, simplifying the detection process. The use of wavelength shifters in combination with other optical elements allows the construction of light traps, which can greatly increase the capacity of photon detection systems. Although their importance, some optical parameters of these compounds are still not known. This is the case for the refractive index, which is a key value when designing a multi-layer device.
In this work, we measured the Refractive Index for a wide wavelength range of commonly used wavelength shifters. This was performed using two different techniques, Total Transmittance, and Ellipsometry, to ensure the precision of the results.

Optics and wavelength shifters / 56

MagLITe - a multi-layer approach to wavelength shifter thin films

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Many photodetection systems of liquid noble experiments are comprised of an external wavelength shifter film, deposited over an optical element. Although this technique has many advantages, the expose external wavelength shifter is delicate and is subjected to problems, for instance, cross-contamination, mechanical and chemical stresses, and photobleaching. To help with these drawbacks, our group developed MagLITe (Magnesium fluoride Light collection Improvement technique). This technique consists in covering the external wavelength shifter with a layer of a material that is transparent to VUV light, while also being hard, durable, and compatible with the underlying layer. By carefully designing the top layer, MagLITe is not only able to solve the described drawbacks but also acts as an anti-reflective coating, significantly increasing the efficiency.
In this work, we will discuss the in-depth concept of this technique, measurements of key parameters, and the first result of this new multi-layer implementation.

Poster session / 57

Optical simulation study and Testing of ASIC chip

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The functionality and radiopurity of SiPM-based photodetectors with integrated electronics, which will meet the demanding requirements for radio pure detectors looking for dark matter. ASIC (application-specific integrated circuit) readout electronics have the potential to replace discrete electronic components and to reduce the radioactivity of photo sensor frontend electronics. For future dark matter experiments, we will need to scale-up the photo sensor coverage area, which will call for the development of integrated electronics with digital readout, capable of operation at cryogenic temperatures. ASIC uses Time-over-Threshold (ToT) method, which is a time-width signal processing method. This method has an advantage in its simplicity because it does not need a complicated ADC (Analogue to Digital Converter) circuit. Its disadvantage is the nonlinearity, which causes distortions in energy spectra. We used Geant4 simulations for uniformly generating recoiling electrons inside the TPC, with different energies i.e. 0.3, 0.7, and 1.1 keV. For the analysis, we used different segmentation sizes for each PDM (Photo detector module) i.e. 5x5 cm^2, 2x2 cm^2, 1x1 cm^2 and 0.5x0.5 cm^2. The 1x1 cm^2 shows promising results as most of the channels see 1 photon while fewer channels see 2,3, or more photons. We are working on a small scale setup at AstroCeNT. We will perform tests using ASIC digital readout for SiPM (Silicon photo-multiplier) at cryogenic temperature.

Applications / 58

The PETALO project

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PETALO (Positron Emission TOF Apparatus with Liquid xenOn) is a new technique that uses liquid xenon (LXe) together with a SiPM-based readout and fast electronics to provide a significant improvement in PET-TOF technology. Liquid xenon allows to build a continuous detector with a high stopping power for 511-keV gammas and provides a uniform response avoiding most of the geometrical distortions of conventional detectors based on scintillating crystals. In addition, SiPMs enable a fast and accurate measurement of the energy with a small dark count rate at the low temperatures required from LXe. PETit, the first PETALO prototype built at IFIC (Valencia), started operation in July 2021. It consists of an aluminum box with one volume of LXe and two planes of SiPMs that register the scintillation light emitted in xenon by the gammas coming from a Na22 radioactive source. In this talk I will review the potential of the LXe technology for full-body PET scanners and present the first measurements performed with PETit.

Long-term light yield stability / **59**

Scintillation Light in MicroBooNE After 5 Years of Data Taking

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The MicroBooNE experiment is a Liquid Argon Time Projection Chamber (LArTPC) placed along Booster Neutrino Beam (BNB) at Fermilab. Its primary physics goal is to contribute to addressing the elusive short-baseline MiniBooNE low energy excess. MicroBooNE records and utilises both the ionisation charge and scintillation light produced inside the TPC to select and reconstruct its events. The scintillation light collected through a plane of PhotoMultiplier Tubes (PMTs) is also used for accurate event timing and cosmic muon rejection with the latter being an important driver for detectors, such as MicroBooNE, located on the surface. A good understanding of light modeling and its related systematic uncertainties is crucial to evaluate their impact on physics analyses. The experience acquired from MicroBooNE regarding how the stability of the scintillation light behaves and evolves during the 5 years of the primary physics run will be discussed. This will help inform the next many years long running Short-Baseline Neutrino (SBN) and DUNE programmes to properly understand the physics of the scintillation light in LArTPCs.

Properties of noble liquids / **60**

What surfaces in operation of dual-phase dark matter detectors

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Abstract.
Dual-phase noble liquid time-projection chambers have a long application history in searches for rare low-energy events like interactions with dark matter particles. Because of scalability and existing support infrastructure, they are expected to serve in large future projects. Our analysis of data and models for electrons and ions extraction from the liquid into the gas phase and data for the dwelling time of unextracted electrons at the liquid surface indicates that several remarkable

effects, including Wigner crystallization of unextracted electrons on the liquid surface, which can be present. Not checking for these effects could lead to systematic uncertainties in particle physics results analysis. Though additional studies on the detector's physics are required, we can suggest some detector design improvements.
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. LLNL-ABS-834584-DRAFT

Light and charge readout / **61**

Progress with the bubble-free Liquid Hole-Multiplier for dual-phase scintillation- & electroluminescence-photon detectors

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The bubble-free Liquid Hole-Multiplier (bf-LHM) has been proposed as a novel sensor for recording both scintillation- and electroluminescence-photons in dual-phase detectors. The new concept follows that of the bubble-assisted one investigated over the past years.

In this contribution, we will discuss the progress made with this new, simpler concept – in which the gas bubble is replaced by a liquid-to-vapor interface located between two perforated (e.g. THGEM) electrodes. The bottom one, fully immersed in the liquid (L-THGEM), has a CsI VUV photocathode deposited on its bottom face, while the top (uncoated) THGEM is located in the gas (G-THGEM), with photo-sensors above. Ionization electrons deposited in the drift volume below the L-THGEM and S1-induced photoelectrons emitted from the photocathode are focused into the holes and transmitted through with nearly no losses. An intense field between the two electrodes (taking here the role of the "gate" in conventional dual-phase TPCs) ensures efficient transmission of the electrons into the vapor phase, where they induce fast EL signals (after being collected) primarily within the G-THGEM holes.

The main advantages of this concept are
- the independence of any liquid-to-gas interface fluctuations and instabilities and the detection capability of both ionization electrons and single-VUV photons (the latter with expected high PDE)
- the possibility of using SiPMs or CMOS sensors as the single-photon induced electroluminescence flashes are expected to be far above the dark noise of current photo-sensors.

We will describe the basic operation principles of the new concept and summarize our current experimental results in LXe. We will demonstrate the high transfer efficiency of ionization electrons and photoelectrons from CsI across the L-THGEM as well as their detection efficiency in the gas phase. Although preliminary, the results already demonstrate a significant improvement in the sensitivity of this detector concept to VUV photons compared to the bubble-assisted LHM.

Signal reconstruction / **62**

An ASIC for Real Time Analog Pulse Shape Discrimination

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Pulse shape discrimination (PSD) is a powerful tool for separating gamma induced interactions from those induced by fast neutrons. It relies on the fact that various excited modes have different decay constants, and are excited differently by neutrons and gammas. This is especially true for liquid argon targets. We have designed and developed a custom integrated circuit that reads out scintillation pulses and performs PSD in real time. The ASIC also provides a fast output for time of arrival and an analog level representing the total pulse area. The method has been tested using various scintillators coupled to silicon photomultipliers, however, the ASIC can be deployed in a wide variety of instruments. Some key revisions will allow this ASIC to be functional at liquid argon temperatures.

Light and charge readout / **63**

Novel electron & photon sensing concepts of single-phase noble-liquid detectors

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Novel electron & photon sensing concepts of single-phase noble-liquid detectors

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Abstract
Some novel ideas of ionization-electron and scintillation-photon sensing concepts in single-phase noble-liquid detectors are presented. They rely on immersed micro-structured electrodes, undercoated with VUV photocathodes. Both radiation-induced electrons from the liquid and primary-scintillation photoelectrons emitted by the photocathode are collected on thin anode strips printed on appropriate insulators, or on nanostructured surfaces. This results in combined electroluminescence and small charge multiplication in the liquid. The resulting fast UV-photon flashes are detected by nearby photo sensors, e.g. SiPM or CMOS arrays. The multiplied single-photon light flashes should be detected above the dark noise of such sensors. Some of the proposed concepts, that permit both vertical and horizontal deployment of liquid-TPCs, are expected to resolve current liquid-to-gas interface issues in large-area dual-phase detectors in future Particle- and Astroparticle physics applications and in other fields.

Light and charge readout / **64**

Floating Hole Multiplier – a novel concept for dual-phase noble liquid detectors

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We describe a novel concept for dual-phase noble liquid detectors, the Floating Hole Multiplier (FHM). It consists of a perforated electrode freely floating on the surface of the liquid. The concept has been validated with a Thick Gas Electron Multiplier (THGEM) on the surface of liquid xenon.

First experimental results will be reported showing that the electrons, liberated in liquid xenon due to ionization by alpha-particles, are focused into the THGEM holes, extracted under the electric field from liquid to gas and generate electroluminescence of the gas in the hole and its vicinity. Both primary scintillation of the liquid and secondary scintillation in the gas were measured with a quartz window photomultiplier thus showing the potentiality of operation of this configuration in the regime used in the noble liquid dual-phase time projection chambers for low background experiments such as WIMP search and neutrino physics. The advantages of the new concept of floating electrodes will be discussed in view of its application in both liquid xenon and liquid argon detectors, among which are the complete absence of the electrode sagging (critical for large detectors), no need for a fine tilt and liquid level control, significant reduction of surface mechanical and electrical instabilities, reduction of single electron noise from the surface.

Properties of noble liquids / **65**

Nucleation efficiency of a liquid xenon bubble chamber

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Bubble chambers using liquid xenon (and liquid argon) have been operated (resp. planned) by the Scintillating Bubble Chamber (SBC) collaboration for GeV-scale dark matter searches and CEvNS from reactors. This requires a robust calibration program of the nucleation efficiency of low-energy nuclear recoils in these target media. Such experiments were performed with a liquid xenon test chamber, gathering data in varying operating conditions and from different neutron sources. The obtained bubble formation efficiency in liquid xenon as a function of recoil energy and thermodynamic state is presented. Parametric monte carlo studies were also carried out to validate the model paradigm.

Applications / **66**

Status and prospects of the NEXT experiment

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NEXT is an experimental program aimed at the detection of neutrinoless double beta ($\beta\beta0\nu$) decay in 136Xe. The collaboration has recently concluded the operation of NEXT-White: a 50-cm diameter and length TPC holding Xe at 10 bar. The experiment, hosted at the Laboratorio Subterráneo de Canfranc, under the Spanish Pyrenees, has demonstrated the two key features of the NEXT technology: an excellent energy resolution (≤1% FWHM at $Q\beta\beta$) and an efficient topology-based background suppression capability. Furthermore, the data collected with NEXT-White has yielded an independent measurement of the half-life of the two-neutrino mode of the decay using a unique model-independent background subtraction method.

The collaboration is currently beginning the construction of the next stage of development: NEXT-100. This TPC, twice as large as NEXT-White in every dimension, will hold 100 kg of 136Xe-enriched gas at 15 bar. This apparatus will serve as a large-scale demonstrator, with a $\beta\beta0\nu$ half-life sensitivity in excess of 1025 y.

In parallel, the collaboration is running an R&D program to develop the technology to be implemented in a tonne-scale detector succeeding NEXT-100 in about five years, with a sensitivity on the

scale of 1027 y. In addition, extensive research focuses on developing the capability of detecting the 136Ba ion resulting from the ββ decay that could make NEXT an essentially background-free experiment, promoting the sensitivity of the detector to 1028 y.

This talk will summarize the status of the NEXT program, present the most recent results and outline the road to the following stages of the experiment.

Application overview / **67**

Noble liquid based neutrino detectors

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The understanding of neutrino physics has made impressive advances in the last two decades thanks to the development of detectors for studying the phenomenon of oscillation. Next generation of experiments will perform precision measurements of the oscillation parameters, measure the mass hierarchy, the CP violation phase, and assess the possible existence of a fourth neutrino flavor. Noble liquid detectors, in particular liquid argon time projection chambers (LArTPCs), are playing a central role in this enterprise thanks to their capability of performing high quality measurements of neutrino interactions with 3D topological and calorimetric reconstruction and particle identification. A review of the most relevant experiments adopting LArTPC technique for detecting neutrino interactions in short and long baseline programs is presented.

Parallel discussion session / **68**

Scale up challenges

Parallel discussion session / **69**

New technologies, ideas, R&D priorities

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Summary of parallel discussions

Opening / **71**

Welcome

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Closing remarks

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ECFA Detector R&D Roadmap Implementation, Liquid Detectors Task Force Call for Community Input

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