LIDINE2013: LIght Detection In Noble Elements

Wednesday 29 May 2013 - Friday 31 May 2013

Book of Abstracts

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Low Radioactivity Argon from Underground Sources

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The cosmogenic $^{3}9$Ar concentration in atmospheric argon is $8.1x10^{-16}$, which amounts to 1Bq of $^{3}9$Ar decays in a kg of atmospheric argon. This decay rate can limit the size of liquid argon dark matter detectors due to pile-up. The cosmic ray shielding by the earth means that argon from deep underground should not contain $^{3}9$Ar. CO_2 wells in Southwestern Colorado have been found to contain approximately 500ppm of argon as a contamination in the CO_2. We have developed an extensive system of processes to extract the low radioactivity underground argon (UAr) from the CO_2 and purify it for use in the Darkside 50 experiment. Through chromatography, our plant in Colorado extracts an UAr/He/N_2 mixture from the CO_2, which, to date, has produced more than 170 kg of UAr. At Fermilab we have developed cryogenic plants that: separate helium at high pressure, remove residual organic contamination (CO_2, C_4H_10, C_5H_12, etc.), and finally purify the argon from the nitrogen through cryogenic distillation. We are also trapping residual argon in our waste streams to maximize UAr retention. In this talk I will discuss each of these plants and their performance, as well as the status of UAr purification.

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Comparison of TPB and bis-MSB as VUV Waveshifters

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Future neutrino and dark matter experiments require the detection of scintillation photons from detectors that use liquid noble elements as the active detector medium. These scintillation photons are generated in the VUV region (< 200 nm) of the spectrum.
We present here the results of comparative studies of the absorption spectra in the VUV of the waveshifters bis-MSB (p-bis(o-methylstyryl)benzene) and TPB (1,1,4,4-tetraphenyl-1,3-butadiene). We obtained these results using prototype light guides designed to detect scintillation photons in the liquid argon TPC of the proposed Long Baseline Neutrino Experiment (LBNE). We compare our measurements longward of 200 nm with spectra we found in the literature.

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Characterization of the R5912-02 MOD Photomultiplier Tube at Cryogenic Temperatures

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Hamamatsu's R5912-02 MOD is an 8 inch diameter cryogenic photomultiplier tube of interest for light detection in large liquid noble dark matter and neutrino detectors. The R5912-02 MOD will be used in the MiniCLEAN single phase liquid argon dark matter detector and has been tested and characterized at cryogenic temperatures in the single photoelectron regime. A detailed model of the single photoelectron timing properties, pulse shape, and charge distribution will be described. The model extracts these parameters from fits to the unique multi-component timing structure of the R5912-02 MOD pulses.

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Introduction

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VUV-VIS optical characterization of Tetraphenyl-butadiene films on glass and specular reflector substrates from room to liquid Argon temperature

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The use of efficient wavelength-shifters from the vacuum-ultraviolet to the photosensor's range of sensitivity is a key feature in detectors for Dark Matter search and Neutrino physics based on liquid argon scintillation detection. Thin film of Tetraphenyl-butadiene (TPB) deposited onto the surface delimiting the active volume of the detector and/or onto the photosensor optical window is the most common solution in current and planned experiments. Detector design and response can be evaluated and correctly simulated only when the properties of the optical system in use (TPB film + substrate) are fully understood.
The main features of TPB coatings on different, commonly used substrates is reported, Measured features include TPB emission spectra with lineshape and relative intensity variation recorded as a function of the film thickness
and for the first time down to LAr temperature,
as well as optical reflectance and transmittance spectra of the TPB coated substrates in the wavelength range of the TPB emission.

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Conclusion and Close of Conference

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For those who wish to attend, the Fermilab Wine and Cheese seminar will take place at 15:30 after the close of the conference. All conference speakers and delegates are most welcome, and encouraged, to attend.

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Large Area Picosecond Photodetectors for Use in Liquid Noble Detectors

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The development of large-area imaging photodetectors with sub-nanosecond time resolutions and millimeter-level spatial resolutions allows detailed track reconstruction based on the precise transit times and position of individual photons. The Large Area Picosecond Photodetector (LAPPD) collaboration has developed large area microchannel plate-based photodetectors with such high resolutions using scalable, industrial batch processes. In this talk we present a discussion of the LAPPD concept, recent developments in the project, and progress towards commercialization. We also discuss possible applications of these photosensors in the context of neutrino experiments using Cherenkov and scintillation light in liquid-noble detector systems.

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WLS Gasses for High-Pressure Xenon Detectors

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In either liquid xenon or high-pressure xenon gas, scintillation occurs in a band centered at 175 nm, a region directly accessible to PMTs, without the need for an intermediate wavelength-shifting (WLS) step. However, this generally requires a reflective surface such as teflon and directly positioning the PMTs, with all their radioactive burden, to stare directly into the active volume of rare event detectors. However, in room temperature xenon gas, it appears possible to use a fluorescent Penning molecule, such as trimathylamine (TMA), to wavelength-shift in the gas to a band centered near 300 nm, which providentially appears to be the region of maximum excitation efficiency for commercial plastic WLS materials. The entire interior surface of a large TPC may be covered in WLS plastic, maximizing optical efficiency.This may facilitate a novel approach to determine directionality in nuclear recoils for direct WIMP searches in a monolithic symmetric TPC approaching ton-scale active mass.

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WLS R&D for the Detection of Noble Gas Scintillation at LBL: seeing the light from neutrinos, to dark matter, to double beta decay

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Radiation detectors with noble gasses as the active medium are becoming increasingly common in experimental programs searching for physics beyond the standard model. Nearly all of these experiments rely to some degree on collecting scintillation light from noble gasses. The VUV wavelengths associated with noble gas scintillation mean that most of these experiments use a fluorescent material to shift the direct scintillation light into the visible or near UV band. We present an overview of the R&D program at LBL related to noble gas detectors for neutrino physics, and dark matter. This program ranges from precise measurements of the fluorescence behavior of wavelength shifting films, to the prototyping of large are VUV sensitive light guides for multi-kiloton detectors. We will provide some background information as well as recent progress on each branch of this program, as well as plans for future work and connections to existing or planned experimental programs.

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The SNS neutron electric dipole moment experiment

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Experimental searches for a permanent electric dipole moment (EDM) of the neutron provide an extremely sensitive probe for CP violation beyond the standard model. A new neutron EDM measurement is under development for installation at the Oak Ridge Spallation Neutron Source. The experiment will use ultracold neutrons (UCN) produced in superfluid helium, along with He3 that will act as a neutron spin analyzer and comagnetometer. The UCN and liquid helium will be contained in an acrylic measurement cell. Neutron spin precession detection will be provided by spin direction dependent neutron capture on He3, which will produce scintillation light in the liquid helium. The UV scintillation light will be downconverted by deuterated TPB on the cell walls. The acrylic cell walls also act as light guides for PMT detectors outside of the liquid helium volume. An overview of the experiment will be given, focussing on measurement cell development and light detection issues.

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Experiences Using TPB to Detect Scintillations in Liquid Helium

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In an experiment to measure the neutron beta-decay lifetime using magnetically trapped ultracold neutrons, neutron decays are detected using the scintillation process in liquid helium. When a neutron decays, the decay electron deposits on average 250 keV within the liquid. The helium then scintillates in the extreme ultraviolet, producing ˜5500 EUV photons. The trap walls are coated with evaporated TPB which converts the EUV light to visible blue light that is guided and is detected using room temperature photomultiplier tubes. I will review our early work in measuring the fluorescence efficiency of TPB and other fluors, as well as discussing several geometries we investigated as part of our detector development.

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TPB-coated Light Guides for Liquid Argon TPC Light Detection Systems

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I will discuss work on a system for light detection in Liquid Argon TPCs utilizing acrylic lightguides coated with a thin fim of TPB embedded in acryic. This system provides solutions to some of the issues we expect to face when scaling existing light collection systems to the scale of future detectors. While there is still room for improvement, we show that the current results are sufficient for triggering in a large detector.

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Results from the Bo Argon Scintillation Test Stand at Fermilab

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In this talk I will discuss some recent results from the Bo test stand at the Proton Assembly Building, Fermilab. This test stand has been used to characterize elements of the MicroBooNE optical system as well as to perform studies of processes affecting argon scintillation light such as scintillation quenching and optical absorption by impurities.

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PMT Triggering and Readout for MicroBooNE Experiment

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In this talk I will discuss the PMT readout and triggering system that will be used in the MicroBooNE LArTPC experiment. Triggering schemes have been designed to study beam neutrino events as well as fully characterize background cosmic rays. In addition, exploration of important physics applications including "late" scintillation light in Argon and Michel electrons will be possible. Various types of triggers and how they will be implemented in the combined PMT+TPC readout electronics system will be discussed.

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MicroBooNE photon detection system

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The MicroBooNE experiment is a liquid argon time projection chamber (LArTPC) at Fermilab.
Behind of its wire plane, the MicroBooNE photon detection system is located.
It consists of 32 8-inch cryogenic PMTs and 4 14.5-inch light guides coupled with 2-inch cryogenic PMTs.
These PMTs provide a trigger information through the detection of
the fast component of the scintillation light to the TPC, while light guides provide larger surface coverage with fewer channels
and they offer an option for a light detection system of future large liquid argon detector, such as LBNE.
In this talk, I would like to describe the general features of the system and the current status.

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R11410-21 3-Inch Photomultiplier Tube for XENON1T Dark Matter Experiment.

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To satisfy the requirements of the next generation of dark matter detectors based on the dual phase TPC, Hamamatsu, has developed the R11410-21 photomultipler tube. We present the results of the detailed measurements of various PMT characteristics. High QE (>30%) accompanied by a low dark count rate (50 Hz at 0.3 PE) and high gain (10^7) with good single PE resolution have been observed. A comprehensive screening measurement campaign is ongoing while the manufacturer quotes a radioactivity of 20 mBq/PMT. Several tests in LXe were performed in environments similar to a dark matter detector setup. These measurements show the R11410-21 to be particularly suitable for the forthcoming zero background liquid xenon detectors.

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QUartz Photon Intensifying Detector (QUPID): a possible alternative for noble liquid experiments

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Dark matter and double beta decay experiments require extremely low radioactivity within the detector materials. For this purpose, the University of California, Los Angeles and Hamamatsu Photonics have developed the QUartz Photon Intensifying Detector (QUPID), an ultra-low background photodetector based on the Hybrid Avalanche Photo Diode (HAPD) and entirely made of ultraclean synthetic fused silica. In this work we present the basic concept of the QUPID and the testing measurements on QUPIDs from the first production line. Screening of radioactivity at the Gator facility in the Laboratori Nazionali del Gran Sasso has shownthat the QUPIDs safely fulfill the low radioactive contamination requirements for the next generation zero background experiments set by Monte Carlo simulations. The quantum efficiency of the QUPID at room temperature is >30% at the xenon scintillation wavelength. At -100C, the QUPID shows a leakage current smaller than 1 nA and a global gain of 1E5. In these conditions, the photocathode and the anode show >95% linearity up to 1uA for the cathode and 3 mA for the anode. The photocathode and collection efficiency are uniform to
80% over the entire surface. In parallel with single photon counting capabilities, the QUPIDs have a good timing response: 1.8+-0.1 ns rise time, 2.5+-0.2 ns fall time, 4.20+-0.05 ns (FWHM) pulse width, and 160+-30 ps (FWHM) transit time spread. The QUPIDs have also been tested in a liquid xenon environment, and scintillation light from 57Co and 210Po radioactive sources was observed.

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Exploring LXe's scintillation response at the 1 keV level

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Many dark-matter models have been invoked to attempt to explain the observed annual modulation in the event rate of the DAMA/LIBRA experiment. While most models focus on WIMP-like dark matter that produces nuclear recoil signals, axion-like particles have been proposed that could produce the observed ˜2-5 keV peak in the data. Dark-matter searches using germanium have been able to exclude some, but not all, of the parameter space available under this interpretation. Liquid xenon (LXe) could, in principle, probe much of the remaining parameter space, but a direct measurement of LXe's scintillation response in this energy range has only recently been achieved. I present the results of a study that probes LXe's response to electronic recoils down to 1.5 keV, both with and without applied electric fields (as used in most LXe dark matter searches), and show how our results can be used to calculate the energy thresholds of some current LXe experiments.

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Effect of Exposure to Optical and Near UV Light on Waveshifter Efficiency

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Current and future neutrino and dark matter experiments use waveshifters to detect the VUV scintillation photons from liquid noble elements. The efficiency of these waveshifters can be affected by exposure to optical and near UV light. We have compared the degradation of the absorption efficiency of bis-MSB (p-bis(o-methylstyryl)benzene) and TPB (1,1,4,4-tetraphenyl-1,3-butadiene) on prototype light guides designed to detect scintillation photons in the liquid argon TPC of the proposed Long Baseline Neutrino Experiment (LBNE). We obtained these results by exposing light guides made with either TPB or bis-MSB to optical and (optical + near UV) light and then comparing them to unexposed light guides. We tested the efficiency of the waveshifters in a dark box at 245 nm. The experimental results reported here were obtained over a month of exposure.

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Optical Simulations of Wavelength Shifting Fibers

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We have constructed a GEANT4-based detailed software model of photon transport in polystyrene-based clear and wavelength shifting fibers. We have validated the model using data from several experiments and test bench studies using LEDs. In the model, we account for all spectral properties of materials such as bulk absorption and (re)emission and refractive indices. In this talk, I will present features of the general model and input components. I will then demonstrate that by accounting for the spectral properties of all detector components, the model accurately predicts the light response for a broad range of fiber lengths, diameters, and configurations. This model serves as a useful tool for optimization of the next generation plastic scintillator-based particle detectors and can be easily extended to study other fluorescence based materials including coumarins and TPB.

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Status of The Solid Xenon Project at Fermilab

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The solid (crystalline) phase of xenon possesses many of the same advantages of liquid xenon as a particle detector material including good transparency and ionization drift, self-shielding, low intrinsic background, and high scintillation light yield. Many of the properties of solid xenon have been measured previously employing small volumes and thin films. However, few systematic studies have been successfully produced using large volumes of solid xenon. Two major R\&D issues must be addressed to make a solid xenon particle detector; the demonstration of the scalability of solid xenon and the capability to readout solid xenon signals. Both issues are being addressed with a dedicated cryogenic system at Fermilab. The first phase of this project entailed growing approximately a kilogram of transparent solid phase xenon and was successfully completed in 2010 at Fermilab. The second phase of this project is underway where the signals from scintillation light and electron drift

in solid xenon will be measured. These measurements are expected to be completed this year. In this talk, we will discuss the recent progress of solid xenon detector R&D performed at Fermilab.

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DarkSide Search for Dark Matter

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The DarkSide staged program utilizes a dual-phase time projection chamber (TPC) with underground liquid argon as the target material for the scattering of dark matter particles. Efficient background rejection is achieved using several experimental handles such as pulse shape, ratio of ionization over scintillation signal, 3D event reconstruction, active neutron and muon veto. The scintillation light yield is a particularly important parameter as it sets the energy threshold for the pulse shape discrimination technique. The DarkSide-10 prototype detector performance will be presented, focusing on its light response, together with the status of the DarkSide-50 detector featuring a 50kg active mass and designed to reach sensitivity of 10^{-45} cm^2 for dark matter scattering cross section.

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Light Detection in XENON100 and Small-Scale LXe R&D Detectors

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The XENON100 experiment, installed underground at the Laboratori Nazionali del Gran Sasso in Italy, aims at detecting dark matter weakly interacting massive particles (WIMPs) scattering off nuclei within its 62 kg liquid xenon (LXe) target by simultaneously measuring the scintillation and ionization signals produced by nuclear recoils. These two signals allow the three-dimensional localization of events with millimeter precision and the ability to
fiducialize the target volume, yielding an inner core with a very low
background. I will discuss the performance of the XENON100 light detection system, based on the Hamamatsu R8520 PMT, as well as the design and performance of other special-purpose detectors built to measure the response of liquid xenon to low-energy nuclear and electronic recoils.

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Pressurized xenon as scintillator for gamma spectroscopy

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Xenon detectors have been used and are in use for a number of applications, in particular for the detection of gamma rays. They are also preeminent in the field of Dark Matter searches, neutrinoless double beta decay and searches of rare processes.
Xenon is an attractive material for gamma ray detection, in particular thanks to its high atomic number and, as a consequence, large cross-section for photoelectric absorption.
While a number of works presenting high-pressure Xe ionization chambers can be found in the literature, very few are available that discuss the properties of high-pressure Xe as a scintillator.
In this talk I will present the experimental study of the properties of high-pressure Xe as a scintillator, in the context of developing a gamma ray detector for the detection of Special Nuclear Materials.
Our first goal has been to study experimentally the light yield and energy resolution from a high-pressure Xe tube, studying the dependence on thermodynamic conditions as well.
We measured a light yield near 2 photoelectrons per keV for xenon at 40 bar and an energy resolution of about 9% (FWHM) at 662 keV.

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Status of the ArDM experiment

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The ArDM experiment is a ton-scale double phase argon Time Projection Chamber designed for direct Dark Matter searches.
It combines the detection of scintillation light together with the ionization charge in order to discriminate the background (electron recoils) from the WIMP signals (nuclear recoils).
The ArDM light readout was newly redesigned and produced, improving the light collection efficiency. It consists of two arrays of PMT, i.e. one at the bottom of the detector, immersed in the liquid, and one on top, in the argon vapor.
The charge is measured by the top PMT array via the proportional scintillation in the gas phase.
ArDM has recently been installed to the Laboratorio Subterráneo de Canfranc, and the commissioning phase is ongoing.
In this talk I will report the status of the experiment and recent results from measurements with the detector filled with argon gas using radioactive sources.

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Photon Detection in CAPTAIN

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The Cryogenic Apparatus for Precision Tests of Argon Interactions with Neutrinos (CAPTAIN) is being built at Los Alamos National Lab. A 2m x 2m hexagonal TPC with a 1m drift will be constructed inside a cryostat containing 7,700L of liquid argon. CAPTAIN will be used to test interactions using beams of neutrons and neutrinos. It will serve as a test bed for various options for LBNE including in the photon detection system. The current photon detection system will be described and future options discussed. The system is composed of 16 R8520 Hamamatsu photomultiplier tubes with an wavelength shifting coating on acrylic in front of the PMT. Various WLS coatings can be examined with the current default of TPB. CAPTAIN is currently looking for collaborators to assist in its construction and operation.

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AGING STUDIES OF THIN TPB FILMS

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Tetra Phenyl Butadiene (TPB) is the most commonly used compound to wave-shift the 128 nm scintillation light of liquid Argon down to the visible spectrum. We present a study on the loss of conversion efficiency of thin TPB films evaporated on reflective foils when exposed to light and atmosphere. The efficiency of the films is measured and monitored with a dedicated set-up that uses gaseous Argon excited by alpha particles to produce 128 nm photons and working at room temperature. In particular we performed a two years long exposure of the samples to lab diffuse light and atmosphere. We also performed more controlled aging tests to investigate the effect of storing samples in a inert atmosphere and how sample's thickness influences degradation.

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AN ANALYTIC TECHNIQUE FOR THE ESTIMATION OF THE LIGHT YIELD OF A SCINTILLATION DETECTOR

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A simple model for the estimation of the light yield of a scintillation detector is developed under general assumptions and relying exclusively on the knowledge of its optical properties. The model allows to easily incorporate effects related to Rayleigh scattering and absorption of the photons. The predictions of the model are benchmarked with the outcomes of Monte Carlo simulations of specific scintillation detectors. The case of a real liquid argon based detector is explicitly treated and the predicted light yield is compared with the measured value.

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Liquid argon scintillation read-out with silicon devices

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Silicon photosensors actually represent a viable alternative to standard photomultipliers in fields such as communications and medical imaging. We explored the interesting possibility of using these sensors in combination with liquid Argon (LAr) for astroparticle physics applications such as neutrino, dark matter and double beta decay experiments. In fact, silicon photosensors have detection efficiencies comparable with those of the most performing PMTs and can be manufactured with high level of radiopurity.
In particular within the on-going R&D activity of the SILENT project (Low background and low noise techniques for double beta decay physics funded by ASPERA) a large area SiPM (Hamamatsu S11828-3344M – 1.7 cmˆ2 area) has been installed in a LAr scintillation chamber of 0.7 liters volume together with a cryogenic photomultiplier tube (Hamamatsu R11065) used as a reference. The LAr chamber has been exposed to many gamma sources of different energies and single photoelectron response and light yield for the SiPM and PMT have been measured and compared.
In this contribution the results of the tests, the ongoing R&D to optimize the SiPM for cryogenic and for ultralow backgrounds applications, will be presented, as well as the possible application in the GERDA experiment on Double Beta Decay Searches of Ge-76.

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Status of the MiniCLEAN Dark Matter Experiment

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The MiniCLEAN dark matter experiment is a low background, single phase, liquid argon dark matter experiment at SNOLAB. With a projected fiducial volume of 150 kg, MiniCLEAN will perform a dark matter search and demonstrate several of the technologies and analysis techniques required to build and operate liquid argon and neon detectors at the 100 ton scale for dark matter and precision solar neutrino measurements. I will discuss the current status of MiniCLEAN construction, and highlight some of the reconstruction techniques that are specific to noble liquid scintillation detectors.

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The LArIAT Light Readout System

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Most neutrino experiments using liquid argon as a detector medium focus on obtaining information about the interaction from ionization electrons and choose to use the scintillation light as a trigger or an indication of interaction time. On the other hand, experiments investigating lower energy ranges, i.e. Dark Matter searches have shown that there is a wealth of information in the scintillation light, which by itself allows calorimetric reconstruction and particle identification based on the shape of the light signal. LArIAT is a an experiment set to calibrate the LAr Time Projection Chamber technology by placing the detector on a beam of charged particles of known type and momemntum. One of its goals is to test a Dark Matter search-like light collection system, which could supplement the calorimetric and particle identification capabilities of the LArTPC. The plans to implement this setup in the LArIAT detector will be presented as well as a test set up being constructed to test the components.

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NEST: The Noble Element Simulation Technique

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A comprehensive model for explaining the scintillation and electroluminescence yields, and pulse shapes, in liquid and gaseous noble elements will be presented which informs an exhaustive simulation code called NEST (Noble Element Simulation Technique). All available liquid xenon data on electron and nuclear recoils have been incorporated, and significant progress has been made on extending NEST's applicability to argon. Results will be shown from Geant4 implementations for 1- and 2-phase xenon and argon detectors. The quasi-empirical NEST approach can lead to a better understanding of detector calibrations and performance verification and aid in the design and optimization of future detectors for dark matter, neutrinos, or other applications, and assist in the data analysis stage of present detectors.

Summary:

NEST is a both a powerful collection of models, and simulation computer code which implements said models. It has strong postdictive power, explaining XENON10 and ZEPLIN results, and has demonstrated incredible predictive power for more recent experiments like LUX and XENON100. It is already used or is under consideration by numerous dark matter experiments (LUX, XENON, PANDA-X, DEAP/CLEAN, DarkSide) and is being considered for LBNE.

Scintillation Light from Noble Elements - R&D Efforts / **19**

Photodegradation Mechanisms of Tetraphenyl Butadiene Coatings for Liquid Argon Detectors

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We report on studies of degradation mechanisms of tetraphenyl butadiene (TPB) coatings of the type used in neutrino and dark matter liquid argon experiments. Using gas chromatography coupled to mass spectrometry we have detected the ultraviolet-blocking impurity benzophenone. We monitored the drop in performance and increase of benzophenone concentration in TPB plates with exposure to ultraviolet (UV) light, and demonstrate the correlation between these two variables. We show promising results obtained by adding a free radical inhibiting stabilizing compound, which improves the initial performance of LBNE style light-guide coatings by up to 20% and significantly improves their UV stability.

Scintillation Light from Noble Elements - R&D Efforts / **10**

Development of a Wavelength-Shifting Fiber-Based Photon Detector for LBNE

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The proposed LBNE experiment will use liquid argon TPCs for the far detector. We are developing a prototype photon detector for potential use in the LBNE far detector. This prototype is based on wavelength shifting fibers and will utilize silicon photomultipliers for readout. In this talk I will describe progress and plans on the prototype development. I will also provide an update on the latest
development of our cryogenic detector development test facility, which includes a 500 L cryostat designed for testing full-scale photon detector components for LBNE.