The University of Texas at Austin
Department of Physics
College of Natural Sciences

A Plate Design for the LEGEND-1000 LAr Veto System

Firas Abouzahr[1], Wonseok Bae[1], Karol Lang[1], Marek Proga[1]
[1]Department of Physics, College of Natural Sciences, The University of Texas

LEGEND Large Enriched Germanium Experiment for Neutrinoless ββ Decay

Introduction

LEGEND-1000 is a proposed ^{76}Ge-based neutrinoless double beta decay (0νββ) experiment. The discovery of 0νββ, a theoretical process, would prove the majorana nature of neutrinos and demonstrate the violation of lepton number conservation. LEGEND-1000 will utilize germanium (about 90% ^{76}Ge enriched) detector strings located within a liquid argon (LAr) cryostat tank. In its current, proposed state the detectors are surrounded by a curtain of TPB-coated, wavelength shifting (WLS) optic fibers. This curtain of fibers is the LAr Veto System, which is used to reject background events originating outside of the germanium that are deposited in the LAr. The 128 nm LAr scintillation light is wavelength shifted by the fibers and detected by coupled silicon photomultipliers (SiPMs). Our research group at University of Texas at Austin is currently designing, simulating, and testing another iteration of the LAr Veto System based on TPB-coated EJ-280 plates (with coupled SiPMs) instead of optic fibers. EJ-280 plate shrouds have great potential to reach increased levels of background sensitivity beyond the fiber model's capabilities.

Research Goal

Positive identification of the 0νββ energy signature requires a virtually background-free experiment. This motivates the goal to design a background signal tagger that is as efficient as possible, surpassing the current fiber model, and ultimately aiding in the detection of neutrinoless double beta decay.

Methods

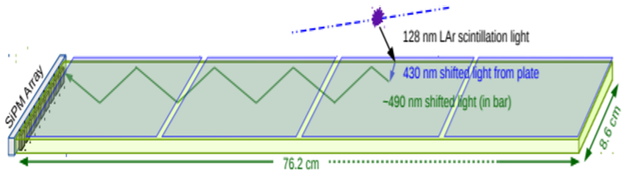

Figure 1

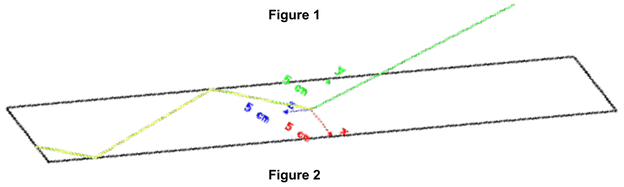

Figure 2

Fig. 1: A rendering of a single TPB-coated plate wavelength shifting 128 nm scintillation light. Fig. 2: A Geant4 simulation of a similar plate as that in Fig. 1. The proposed EJ-280 plates were tested through Geant4 Monte Carlo simulations. The simulations included all relevant physics processes (i.e., photon scattering) as well as material properties for EJ-280 and TPB (i.e., attenuation length, refractive index, etc.).

Figures and Results

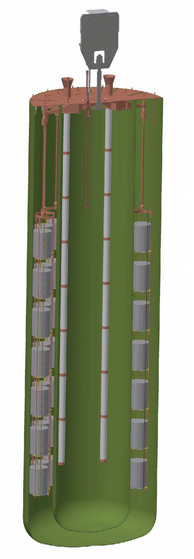

Figure 3

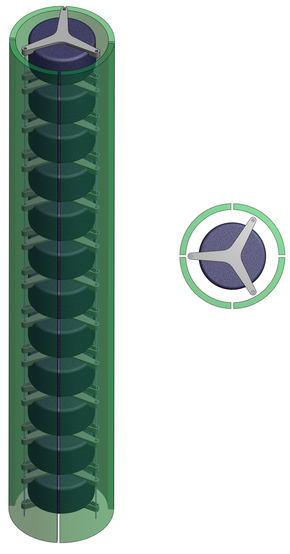

Figure 4

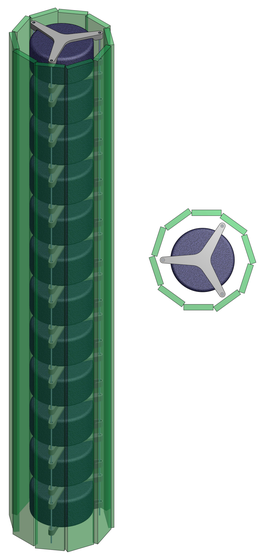

Figure 5

The plate, fiber, and other plausible geometric models were tested through Geant4 and their photodetection efficiencies (PDEs) were all compared. Fig. 3: The current, fiber model shroud surrounding germanium detector strings (PDE: 1.62%). Fig. 4: A curved plate model surrounding a single detector string and its cross section (PDE: 3.15%). Fig. 5: Our proposed plate model surrounding a single detector string and its cross section (PDE: 3.70%). A full cylindrical model was also tested (not pictured, PDE: 2.07%) The simulated photodetection efficiencies of 4 possible Veto System geometries, including the current fiber model, demonstrate that the plate geometry will provide the highest possible PDE.

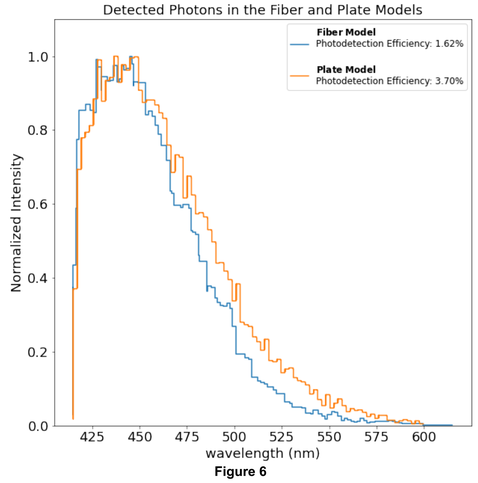

Figure 6

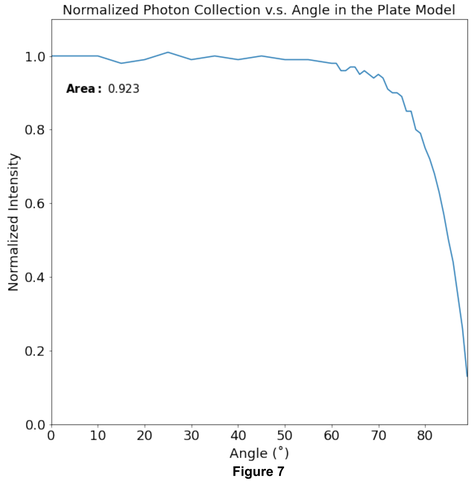

Figure 7

Fig. 6: Detected photons verses wavelength for an EJ-280 plate and a fiber curtain. Results from Geant4 simulation show that EJ-280 plates allow for LAr photon detection at an efficiency that is over 2.25 times that of the current fiber model making it a worthy design for the LAr Veto System. Fig. 7: Normalized photon collection as a function of incident angle for a single EJ-280 plate.

Conclusion

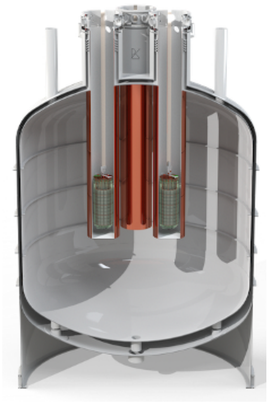

Figure 8

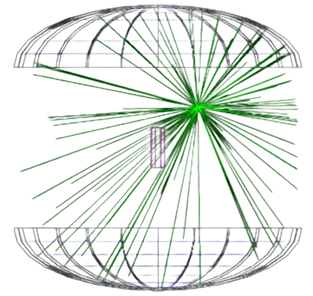

Figure 9

Fig. 8: A rendering of the LAr cryostat tank with the fiber shrouds. Fig. 9: A Geant4 simulation of the LAr cryostat tank with a single EJ-280 plate shroud. We propose an EJ-280-based plate model for the LEGEND-1000 LAr Veto System. Through Geant4 simulation, the photodetection capability of the plate model was compared to that of the fiber model as well as other geometries. Simulation results show that EJ-280 plates provide the best possible PDE, which is over double that of the current fiber model, making it a promising addition to LEGEND-1000.

Future Studies

The next phase for the plate model LAr Veto System is to experimentally test EJ-280 plates. Currently, our group is setting up a dark box experiment in which a UV light source (replicating photons originating from LAr scintillation) will irradiate a TPB-coated EJ-280 plate as well as a small-scale recreation of a fiber curtain. The collected data will then be cross checked with simulation results.

References

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