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Development of innovative devices for liquid Argon scintillation light detection. Simulation and Data Analysis.

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Abstract

There are a lot of questions that still open in neutrino physics and in order to address those questions, huge experiments are being designed to detect those particles. One of the most exploited technique to detect them needs to detect scintillation light. In this context, an innovative device called ARAPUCA, has been designed to improve the scintillation light detection efficiency. This study aimed to simulate, to analyze the data and to help to answer what is the best geometry for this revolutionary device.

Key words:

Liquid Argon, scintillation light, neutrinos.

Introduction

One of the biggest experiments in the world, the Deep Underground Neutrino Experiment (DUNE), will explore very important questions that still open in neutrinos physics. For this, it is necessary to detect those particles and one of the most exploited techniques to detect them is the one of liquid argon time projection chambers (LarTPC). The detection of its scintillation light represents a very important part of the experimental technique.

ARAPUCA¹ is a totally innovative device which has been designed to improve the collection and detection efficiency of the scintillation photons. This device has a very simple design and it is made basically of highly reflective materials, and a Dichroic filter combined with two wavelength shifters (WLS) in a way that photons are allowed to enter but not to leave the equipment. Once the photon is trapped inside ARAPUCA, it will be reflected until it is collected by a Silicon Photomultiplier (SiPM).

This study can be divided in two parts and before each of them could be started, it was necessary to learn how to use two software: ROOT Data Analysis Framework and GEANT4. The first part focused on analyzing some data collected from a prototype test using ROOT and the second aimed to help to answer what is the best setup to optimize the apparatus efficiency, for example, find out which is the best geometry and material of the device and the best number and positions of the SiPMs. For this, Monte Carlo simulations were performed based on GEANT4 packages and their data were used to estimate the real efficiency.

Results and Discussion

1. Data Analysis:

In the first part, 40 waveforms were collected from the prototype efficiency tests and each of them consisted of 10,000 output voltage values vs. time. This analysis aimed to find the electrical signals generated due to the detection of a single photon and calculate their energy. Since these signals were too small, it was necessary to filter the data in order to make it possible to differentiate such signals from the background noise. The applied filter consists of replacing a value by the mean between it and the values close to it.

Image 1. Left: Graphic of one waveform. Black: data collected from the test; Red: data after being filtered; the offset is just to make easier the comparison. Right: Histogram to calculate the average noise of one waveform.

2. Geometry simulation:

The main simulation was a box, with one SiPM (6x6 cm²). All the photons were launched inside the box and more than 20% of them hit the SiPM. It is still necessary to simulate the WLS and the Dichroic filter to calculate the total efficiency of the device.

Image 2. Left: Simulation interface with 3 photons. Blue: Teflon; green: photon trace; red: SiPM. Right: prototype.

Conclusions

Even though it hasn't been possible to determine the best setup yet, the simulation results already showed how revolutionary this device is and how it can improve the collection and detection efficiency of scintillation light.

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¹ Machado, A.A.; Segreto, E.; ARAPUCA a new device for liquid argon scintillation light detection, Journal of Instrumentation, Vol. 11, Feb. 2016.