DOI: 10.20396/revpibic.



# Test of X–ARAPUCA through Monte Carlo simulation in Brazil

**R.R. Sarmento*, E. Segreto, A.A. Machado, B. Gelli, H.V. Souza, M. Reggiani-Guzzo, J. Nascimento, Souza. G**

**Abstract**

DUNE[1] is a massive experiment for the study of neutrinos physics which uses liquid argon as active medium. The X-ARAPUCA is a novel technology for the detection of liquid argon scintillation light with an increased detection efficiency with respect to more standard solutions. The X-ARAPUCA light collection efficiency depends on several parameters: the Quantum Efficiency of the active photo-sensitive device, the transmissivity, and reflectivity of the dichroic filter, the shifting efficiency of the wavelength shifters, the reflectivity and shape of the box. The collection efficiency of the device can be maximized by optimizing all of these factors. The present work deals with the Monte Carlo simulation of an experimental set-up which is being used to estimate the total detection efficiency of an X-ARAPUCA. The experiment is constituted by a stainless steel cylinder which hosts the device to be tested and an alpha source. The cylinder is filled with ultra-pure liquid argon and the X-ARAPUCA detects the scintillation photons produced by the alpha particles. The comparison of the experimental spectrum of the detected number of photons with the Monte Carlo spectrum of the number of photons impinging on the X-ARAPUCA acceptance window allows to determine its total detection efficiency. The simulation is based on the GEANT4 package[2].

***Key words:***
*particle physics, ARAPUCA, monte carlo*

## Introduction

Neutrinos are elementary particles that, due to their weak interaction with matter, have a low cross section which makes their detection difficult. Large experiments have been and are being developed in order to detect this particle to solve some open problems in elementary particle physics. It is in this context that X-ARAPUCA device was introduced as an innovative device of light detection. The X-ARAPUCA has its operational principle based on the trapping of incident photons, originated from the interaction of particles with liquid argon, to increase the chance to detect them. Trapping occurs due to a combination of wavelength shifters and a dichroic filter. The purpose of the present work was to learn the basis of Monte Carlo simulation and the use of the GEANT4 package. This package was used to simulate an experimental set-up built in the Laboratory of Leptons at UNICAMP to measure the detection efficiency of an X-ARAPUCA prototype.

## Results and Discussion

The simulation of the experimental X-ARAPUCA test required the modeling of an alpha source made of an alloy of Aluminium and natural Uranium in the form of a thin metallic circle. The alpha particles that are able to exit the aluminum interact with the liquid argon producing scintillation photons. The simulation reconstructs the spectrum of the number of photons that impinge on the device acceptance window. This spectrum is compared with the experimental spectrum of the number of detected photons, measured in the test. Experimental and simulated spectra are directly proportional, with the efficiency of the detector as a scale factor. For the maximum voltage applied in the SiPM's (48.5 V) a range of 3.2 - 3.5% was obtained for the X-ARAPUCA efficiency. The analysis was performed by minimizing the $\chi 2$ between the two spectra. Image 1 shows the result of the minimization process. The agreement with the data is good, since only scaling factors and noise additions were introduced in the minimization.

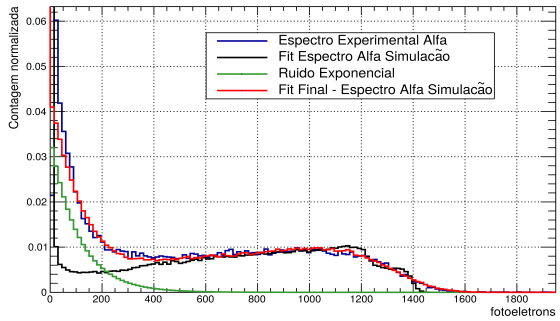


**Image 1.** Final fit of the Monte Carlo simulation data with the experimental data

## Conclusions

This Monte Carlo work contributed to measure the detection efficiency of the first X-ARAPUCA prototype tested in liquid argon. All the steps done in this project are the basis for the production of more complex simulations. The Laboratory of Leptons at UNICAMP will carry out new measures of prototypes of X-ARAPUCA. Therefore, the use of Monte Carlo simulation tools has a fundamental paper to give the completeness of these future measurements and thus to determine the efficiency of these prototypes. In this way, this work plays an important role as the basic simulation for future experiments once it has been tested successfully.

## Acknowledgement

We thank FAPESP for the scholarship and the support who encouraged this project that became my guide to academic life. (grants 2018/06982-3).

[1] Abi, B. et al. The DUNE Far Detector Interim Design Report, Volume 2: Single-Phase Module. arXiv: 1807.10327 [physics.ins-det] (2018)

[2] S. Agostinelli et al., Geant4 - A Simulation Toolkit, Nucl. Instrum. Meth. A 506 (2003) 250