Measurements of the X-Arapuca single-cell light detection efficiency

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H. V. Souza, on behalf of the DUNE collaboration

UNIVERSITY OF CAMPINAS – IFGW

In this work, we present the first characterization of the photon detection efficiency of an X-Arapuca prototype sizing 10 x 7.5 cm² in Brazil, where the X-Arapuca was exposed to alpha particles, cosmic muons and gammas in liquid argon. Operating the SiPMs at +5 and +5.5 V over the breakdown voltage, an efficiency ranging from 2.2% to 2.3% and from 2.7% to 3.1% was found, respectively.

Introduction

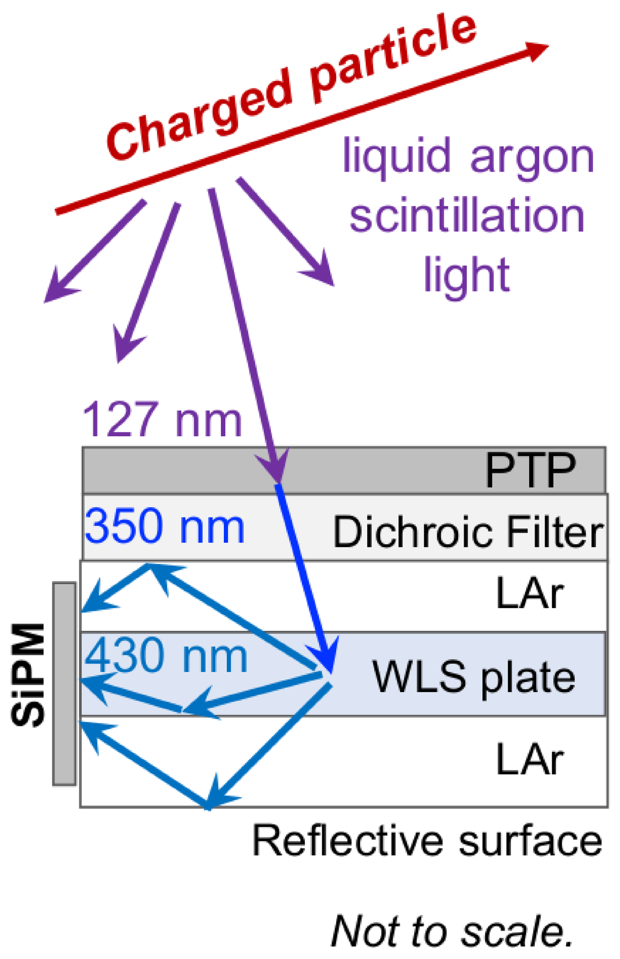

Fig. 1 - The X-Arapuca concept scheme.

The X-ARAPUCA device uses two wavelength shifters (WLS) in combination with a dichroic filter to efficiently detect liquid argon scintillation light (127 nm). The first wavelength shifter is the para-Terphenyl (PTP), which downshifts the 127 nm light to a spectrum peaking at 350 nm. The dichroic filter has a high transmittance to wavelengths below a 400 nm cutoff, allowing the PTP downshifted photons to enter the device, but high reflectivity to wavelengths above the cutoff. Inside, a WLS plate (EJ-286 from Eljen) downshifts again the photons to a spectrum peaking around 430 nm, which are trapped inside the X-ARAPUCA due to the dichroic filter reflectivity (together with the reflective surface) and due to total internal reflection inside the WLS plate.

Procedures

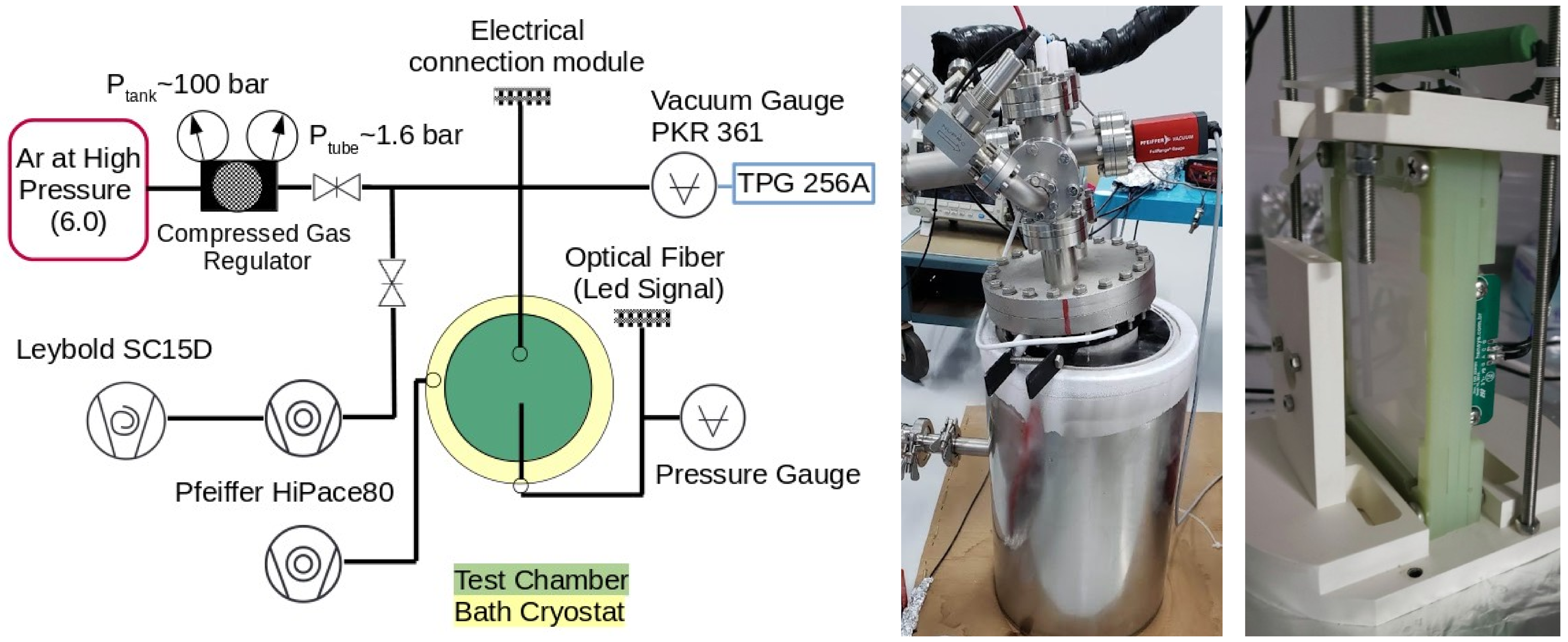

Fig. 3 – (Left) Cryogenic setup for the liquid argon tests. Gas argon 6.0 is liquefied inside the test chamber (in green). (Middle) Picture of the outside cryostat filled with liquid argon for thermal bath, the testing chamber with the X-Arapuca prototype can be seen inside it. (Right) Picture of the X-Arapuca device (100 x 80 mm²), two channels of 4 SiPMs Hamamatsu model S13360-6050VE (6 x 6 mm²). The device was exposed to an natural Uranium alpha source (seen in the picture), to a ^{60}Co gamma source and to cosmic muons in three separate runs.

Calibration

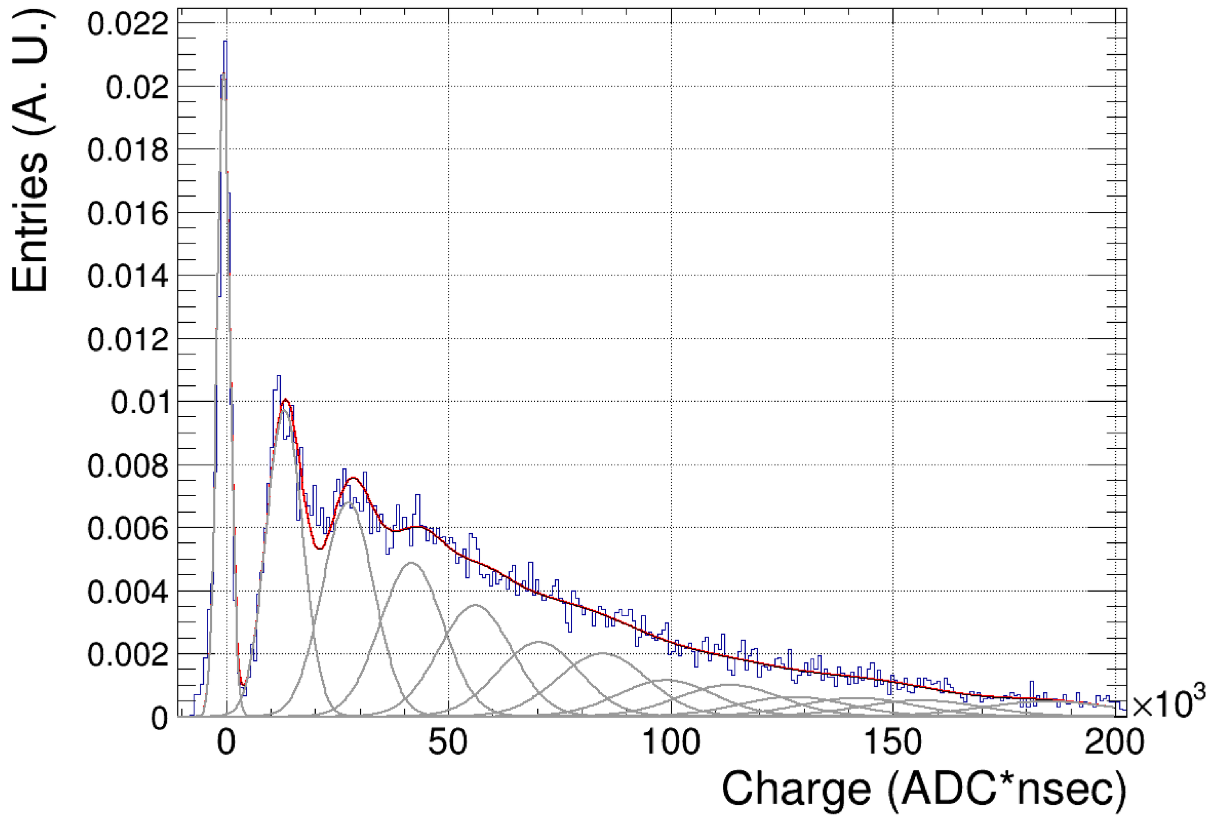

Fig. 4 - Single photo-electron spectrum extracted. The fit function is the sum of five Gaussians. The pedestal (n=0) and the fist peak (n=1) have three free parameters, the n=2 peak the standard deviation fixed at √n · σ1. For n>2 peaks both means and standard deviations are fixed at n · G and √n · σ1, respectively.

Conclusions

	Ionizing radiation
Overvoltage	α-source
+5 V	2.2 ± 0.4 %
+5.5 V	3.0 ± 0.6 %
	γ-source
+5 V	2.3 ± 0.5 %
+5.5 V	2.7 ± 0.5 %
	Cosmic muons
+5 V	2.3 ± 0.5 %
+5.5 V	3.1 ± 0.6 %

Table 1 - Summary of the results achieved. Efficiencies for +5 V and +5.5 V overvoltage between the three different ionizing radiations are compatible considering the uncertainties.

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Efficiency

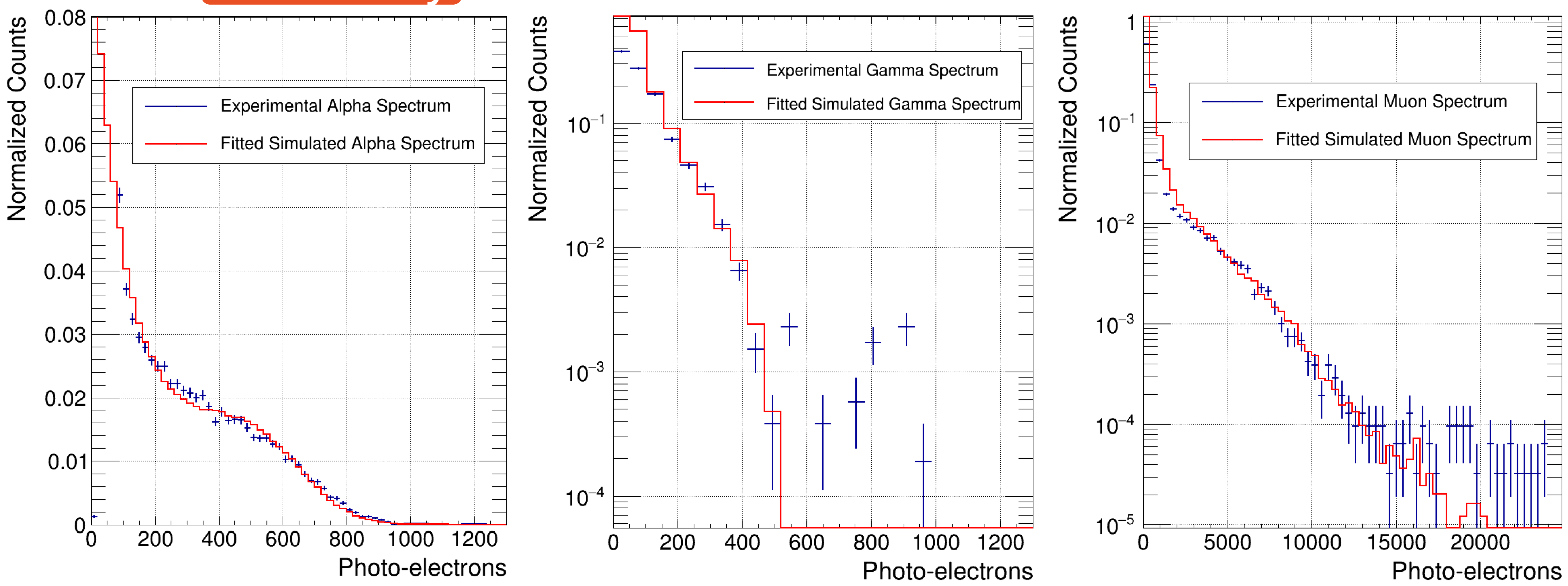

Fig.6 - Monte carlo spectrum (red) fitted in the experimental spectrum (blue) for α-particles (left), γ-rays (center) and cosmic muons (right).

Simulation

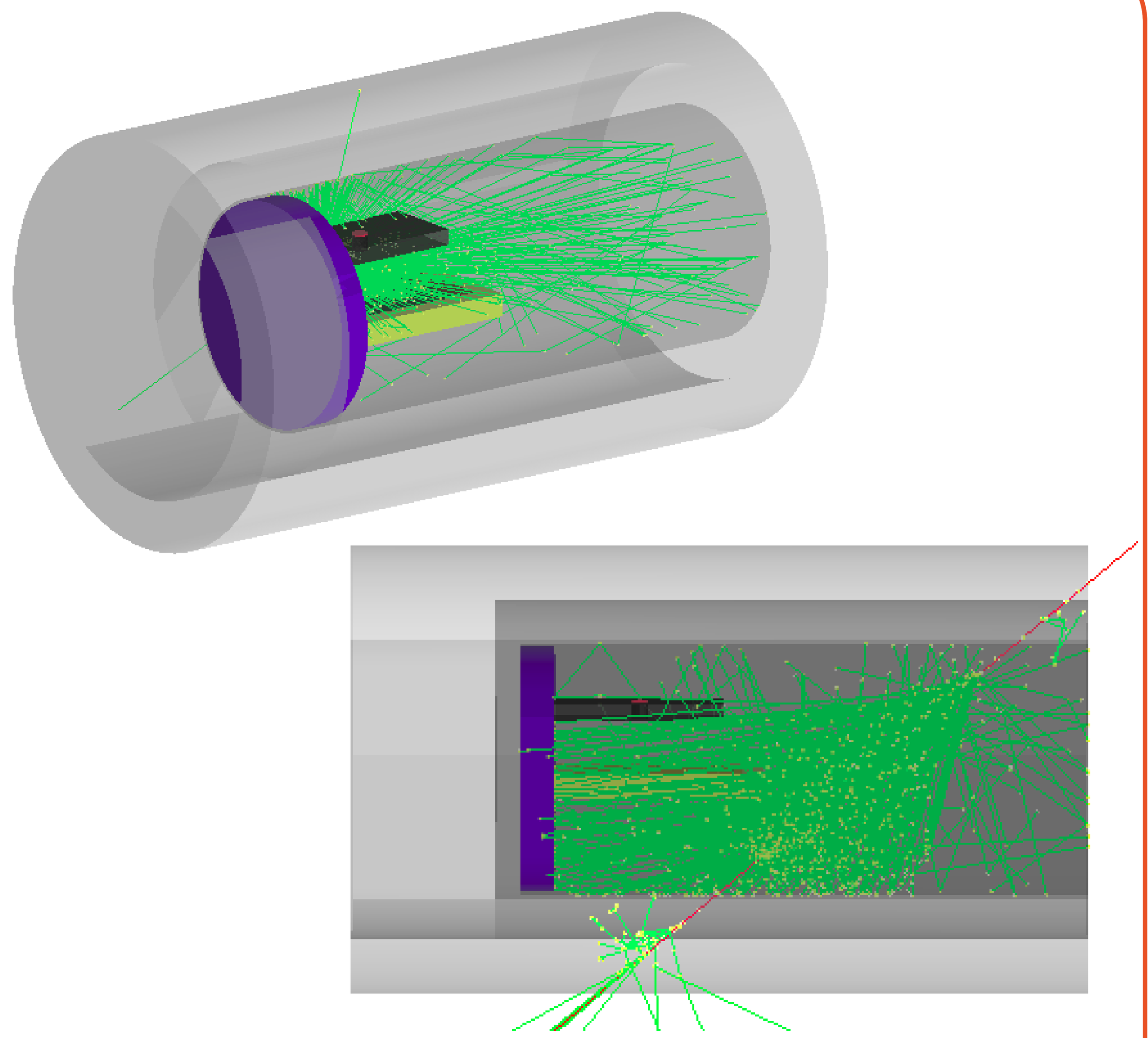

Fig. 5 – A Geant4 Monte Carlo simulation of the experimental setup was created for the three different ionizing radiations. The liquid argon light yield was set to 50 photons/keV, with a quenching of 0.78 for electrons and muons and 0.71 for alpha particles.

Acknowledgement

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