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Numerical characterization of the ARAPUCA: a new approach for LAr scintillation light detection

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The ARAPUCA concept has been proposed as a simple and neat solution for increasing the effective collection area of SiPMs through the shifting and trapping of scintillation light in noble liquids, thus with great potential of improving timing and calorimetry resolution in neutrino and dark matter search experiments using time projection chambers. It is expected to achieve a single photon detection efficiency larger than 1%. The initial design consists of a box made of highly reflective internal surface material and with an acceptance window for photons composed of two shifters and a dichroic filter. The first shifter converts liquid argon scintillation light (~127 nm) to a photon of wavelength smaller than the dichroic cutoff, so the surface is highly transparent to it. When passing through the dichroic filter, it reaches the second shifter which allows the photon to be shifted to the visible region (~450 nm) and be detected by the SiPM nested inside it. When it enters the box, the photon will likely reflect a few times, including on the dichroic filter surface, before being detected. We present a full numerical description of the device using a Monte Carlo framework, including characterization of the acceptance window, models of reflection of different materials, and sensor quantum efficiency, that can now be used to further improve the detection efficiency by comparing different geometries, positions of SiPM and materials. Estimates of simulated efficiencies, number of reflections and acquisition time are presented and compared to analytical calculations. A description and preliminary results from an experimental test with a ARAPUCA prototype made in Brazil (acceptance window area of 9 cm2 and one 36 mm2 SiPM) is also presented. Those are very promising results, giving an efficiency for the detection of scintillation light in liquid argon of ~1.7+-0.1%.

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