ARAPUCA
Light Trap For Large Liquid Argon Time Projection Chambers

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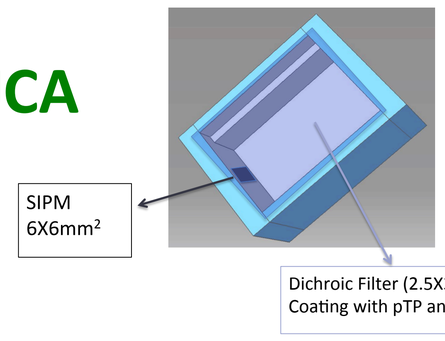
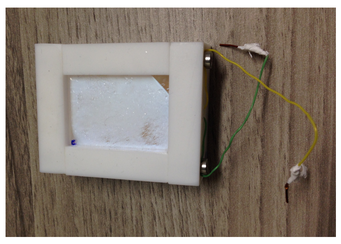
Work presented by Helio da Motta

ARAPUCA





Teflon tickness: 1cm
Internal dimensions: **2.5X3.6X0.6cm³**

The **ARAPUCA** is a "**trapping**" photon device to increase the effective area of SiPM made by:

→ Silicon Photon Sensor - **SiPM**

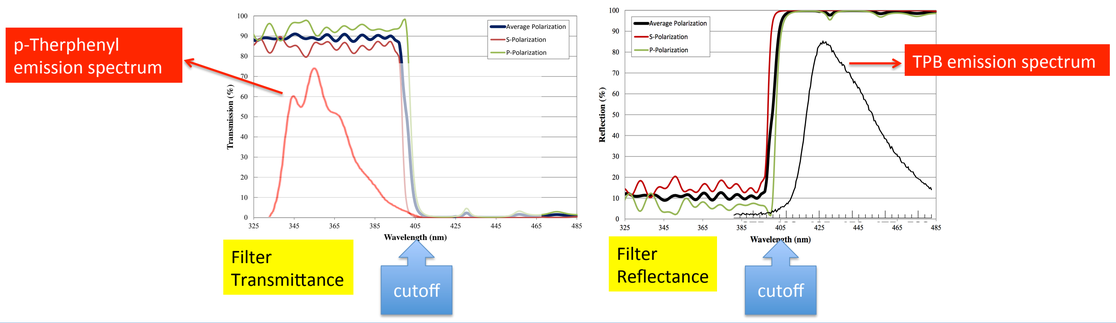
→ Walls of **highly reflectivity** material (Teflon,VIKUITI,Tyvek,…)

→ Acceptance window composed of a **dichroic filter** that has the property of **being transparen**t for certain wavelenghts (**below** the cutoff) **and reflective** for others (**above** the cutoff) – **cutoff=400nm**

→ Two different wavelength shifters:

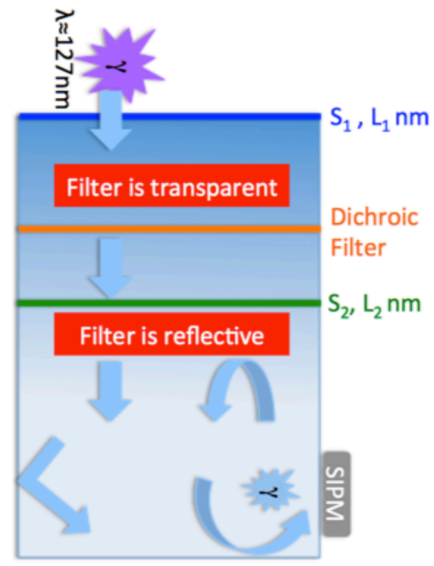
External shifter: **para-Terphenyl** (emission=350nm)

Internal shifter**: TetraPenyl Butadiene**(emission=430nm)



Working Principle

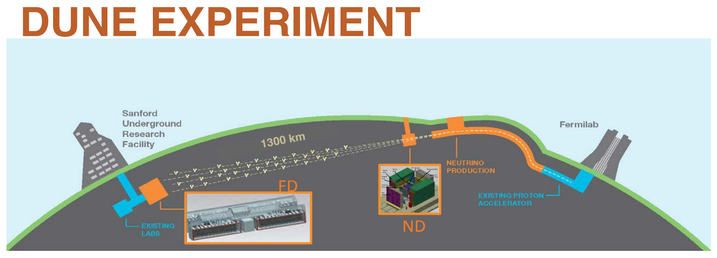
- The filter is deposited with **TWO SHIFTERS – one on each side**
- The shifter on the **external side**, S1, converts LAr scintillation light to a wavelength L1, with **L1 < cutoff**
- The shifter on the **internal side**, S2, converts S1 shifted photons to a wavelength L2, **with L2 > cutoff**
- **The internal surface** of the ARAPUCA is observed by **one or more SiPM**



ARAPUCA allows to have a reasonably **high light detection efficiency** (few percent) on large areas (hundreds of cm²) with a limited coverage of active components (SiPM). These properties make it particularly suited to be used in large liquid argon Time Projection Chambers, like the **DUNE experiment**.

Neutrino detection

DUNE EXPERIMENT



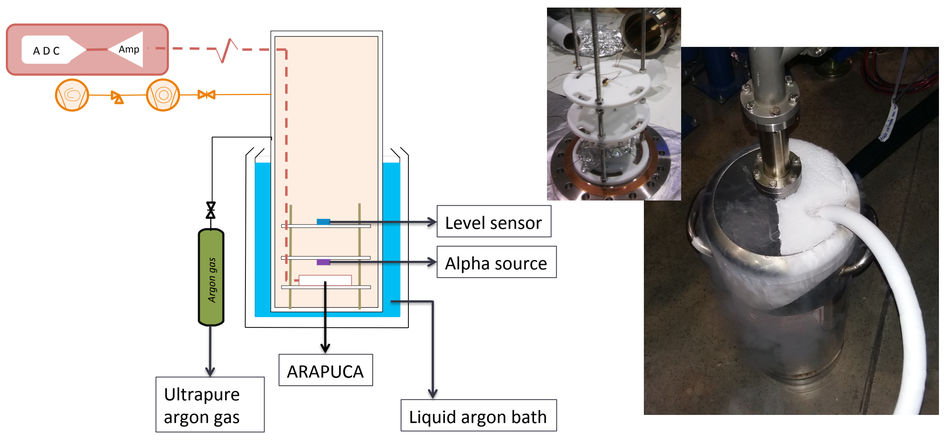
Key DUNE features:

- High-intensity wide-band neutrino beam originating at FNAL
  - 1.2 MW proton beam upgradable to 2.4 MW
- Highly capable near detector to measure the neutrino flux
- A ~40 kt fiducial mass liquid argon far detector
  - Located 1300 km baseline at SURF's 4850 ft level (2,300 mwe)
  - Staged construction of four ~10 kt detector modules. First module installation starting in 2021.

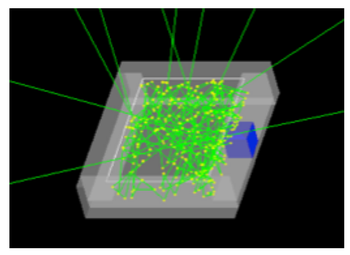
LAr scintillation used to trigger the detector and to improve energy resolution

Experimental Setup

The tests of the **ARAPUCA** using liquid argon (LAr) were performed at the facilities of the Toroidal Grating Monochromator (TGM) beamline of the Brazilian Synchrotron Light Laboratory (LNLS). In order to evaluate the ARAPUCA's efficiency, **the sensor was submerged in a chamber containing pure LAr,** in the proximity of a radioactive source (a ^{238}U-Al alloy in the form of a metallic foil, with α particles emission of 4.267 MeV). The energy loss of the energetic particles on the LAr was responsible for the production of the scintillation signal, which was collected and detected by the **ARAPUCA**.



Simulations

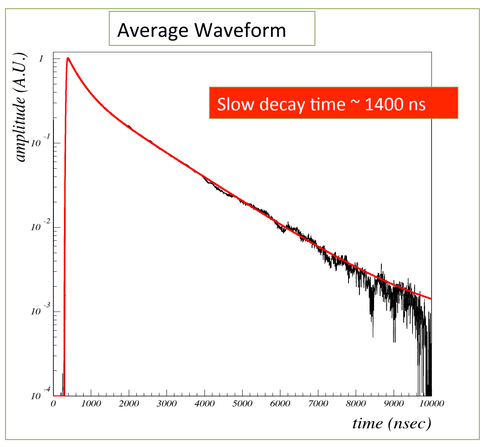


A full Monte Carlo simulation of the **ARAPUCA** was developed. It is based on the Geant4 package, and it takes into account all the main optical properties of the constituting materials.

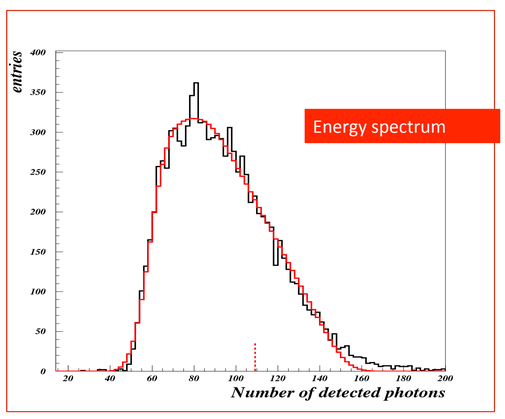
- The quantum efficiency of the sipm
- The efficiency of the WS
- Photon Tracking
- Emission and Absorption spectrum of the WS
- Reflectivity of the walls
  - Lambertian → diffusive materials (Teflon)
  - Specular → mirror

Results

The **average waveform** of the signals. Fast and slow components of scintillation light are clearly visible. The fast component decay time is dominated by the SiPM response, while the slow one by the scintillation light. Its value of 1400ns is compatible with pure liquid argon

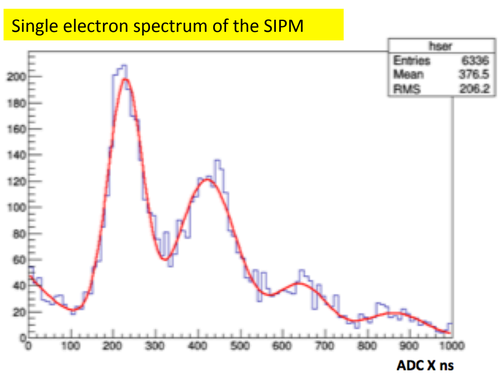


The **energy spectrum** of **the alpha source** is a continuous one, with end point at **4.2 MeV**. The number of photons detected at the spectrum end point, given the ARAPUCA solid angle, allows to estimate the detection efficiency of the device.



Calibration of the SiPM.
The peaks relative to one, two, three and four photons are clearly visible. The calibration factor is represented by the distance among the peaks

Single electron spectrum of the SIPM



The measured efficiency of the **ARAPUCA** with 9 cm² active area was **1.8% ± 0.3%**. This value is in good agreement with the Monte Carlo simulation, which gives a value of **1.7% ± 0.1%**.

Perspective

The **ARAPUCA** device **promises to have a high detection** efficiency for low energy events (supernova neutrino and proton decay) in huge LArTPC detectors (two of the three main goals of DUNE experiment).

R&D for ARAPUCA is ongoing, not only in Brazil but also in USA, Europe and other Latin America Countries.

In view of a possible design of an **ARAPUCA** for the far detector of the DUNE experiment, **a series of prototypes are being operated** (or will be operated) in existing detectors (or detector which are under construction):

- **There is** one operating ARAPUCA installed inside the LARIAT detector
- **There will be** two ARAPUCA arrays installed in the protoDUNE at CERN.
- There **is a proposal** to install few ARAPUCAs inside the SBND detector.

Acknowledgments:

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