X ARAPUCA

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on behalf of the X-ARAPUCA development team

LIDINE 2017: LIght Detection on Noble Elements 22-24 September SLAC NAtional Accelerator Laboratory

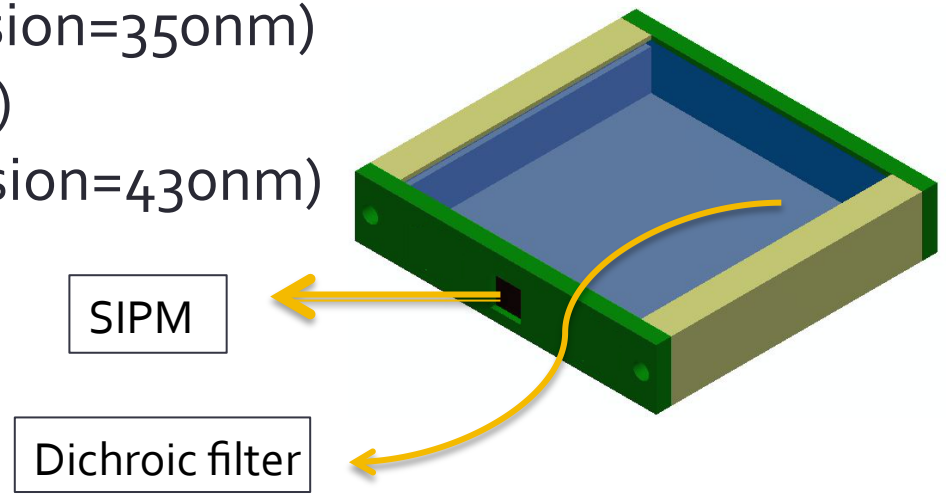
Motivation

- Develop an efficient technology for light detection in large LArTPC experiments.
- The idea of the **ARAPUCA** presented in **LIDINE2015** had a great success and the R&D tests done until now have confirmed a good efficiency of this device.

- **Would it be possible to increase this efficiency even more ?**

ARAPUCA review

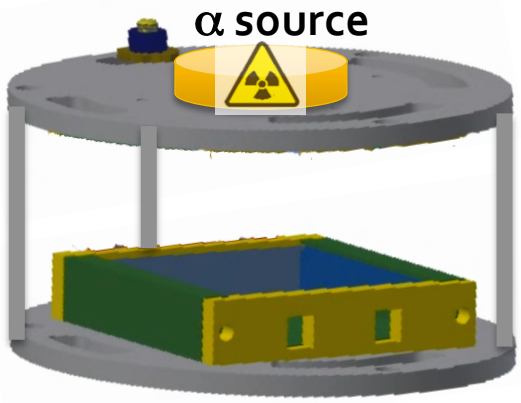
- **LIDINE2015** → Idea of a new device for light detection was presented as a device for "**trapping**" photons to increase the effective area of SiPM.
- Walls of **highly reflectivity material** (Teflon,VIKUITI,Tyvek,…)
- Acceptance window composed of
  - pTP wavelength shifter (emission=350nm)
  - Dichroic filter (cutoff 400nm)
  - TPB wavelength shifter (emission=430nm)



April 2016

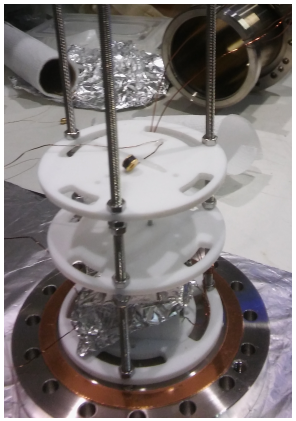
- First prototype tested in LAr using SCENE cryostat at FERMILAB:
  - Acceptance window **5x5cm²**
  - Read-out by **2 SiPM** (SensL C60035)
    - 6X6mm² active area each
  - Exposed to an alpha source:
    (**^{241}Am** → 5.4 MeV monochromatic particles)

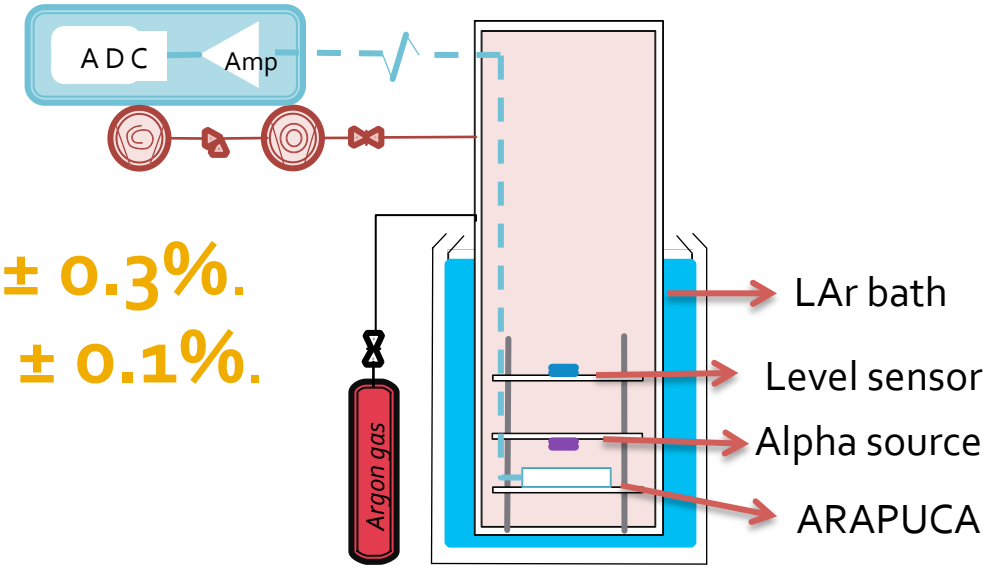
- Estimated **efficiency** of about **1%**, (factor 2 below the expectation)
  - Tickness of the teflon walls
  - Quality of the evaporation



Dicember 2016

- First test done in Brazil at the Synchrotron Light National Laboratory
  - Acceptance window **2.5 X 3.6cm²**
  - Read-out by **1 SiPM** (SensL C60035) 6X6mm²
  - Exposed to an alpha source – (4.2 MeV)
  - Teflon thickness: 1cm



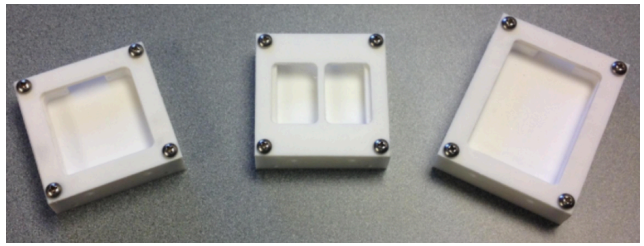


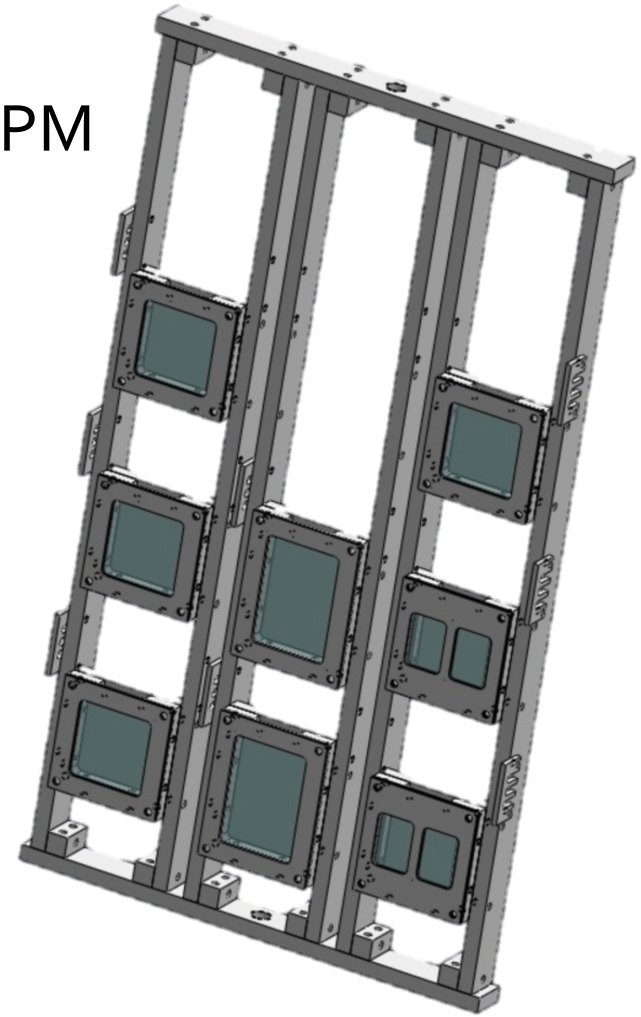
- Eff. measured = **1.8% ± 0.3%.**
- MC simulation = **1.7% ± 0.1%.**

January 2017

- Tests in TallBo
  - Two 6X6mm² (SensL C60035) SiPM per ARAPUCA cell

  Compared:
  - Different ARAPUCA sizes
  - Different internal reflectors
  - Different filters producers





- Efficiency around 0.3 → 1%
- Data analysis is ongoing

September 2017

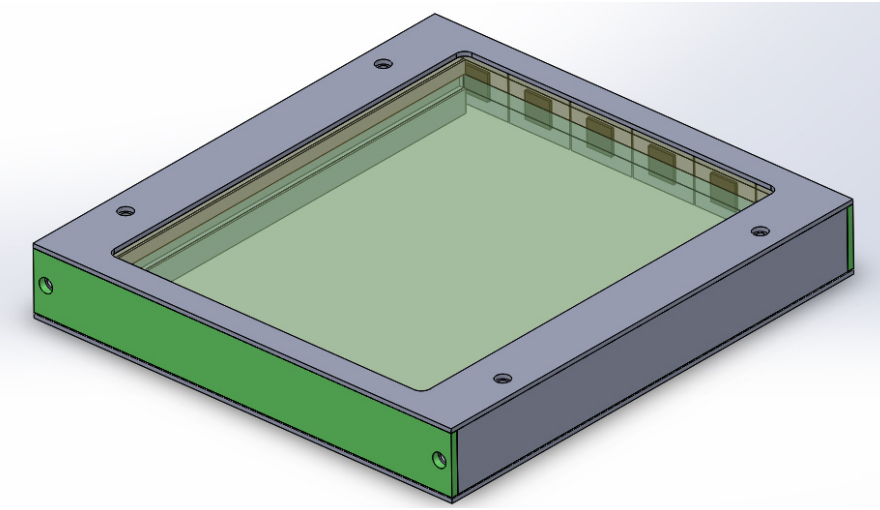
- Current testing underway at Fermilab in the TallBo cryostat
- Comparative test of two technologies
  - ARAPUCA
  - ProtoDUNE Light guide bars -- IU version --

X-ARAPUCA

- The **X-ARAPUCA** is a development of the original ARAPUCA concept, in which the combination of different well-established technologies can work together **to produce an even more efficient device.**
- The fundamental principle is the same: trap a VUV photon inside a box with highly reflective internal surfaces, using a dichroic filter with a combination of wavelength shifters.
- In order to minimize the number of reflections on the internal walls a **light guide is placed inside the box to direct photons on SiPMs.**

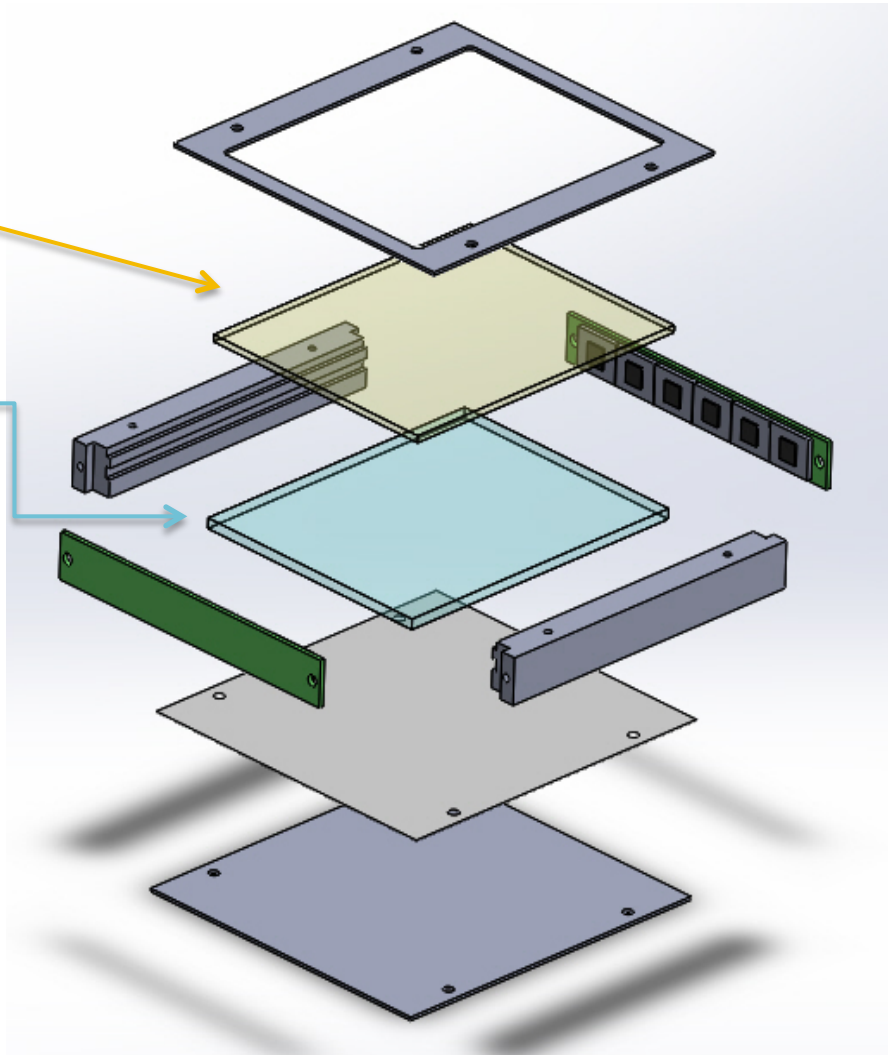
Components

- Walls of highly reflective material
- Acceptance window composed of
  - pTP wavelength shifter (350nm)
  - Dichroic filter (cutoff 400nm)
- Light guide slab
  - TPB doped (430nm)
- Photon detector array (SIPM)



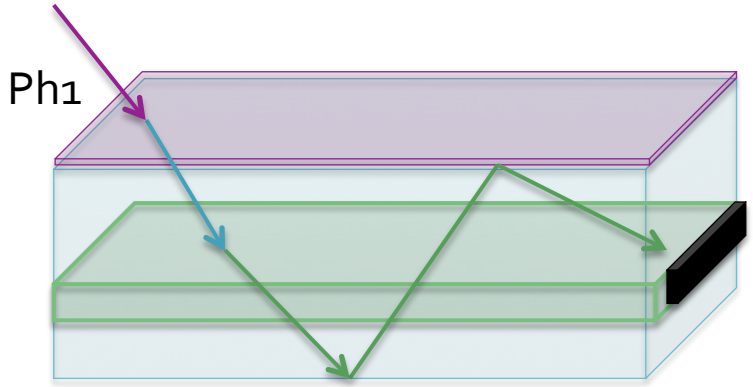
Components

- The top gray piece is G-10.
- The yellowish piece is the **filter** plate, 2mm X 100mm X 80mm
- The blue piece in the middle is a 3mm **thick slab of WLS**, 100mm X 80mm
- The **green PCBs** on each end each hold 6 Hamamatsu cryogenic **SiPMs each** , active area 6X6 mm^2 each (all 12 passively ganged)
- The gray blocks on the side are G-10
- Next layer is Vikuity highly reflective film
- Bottom layer is a G-10 mechanical support backplane



3 Ways to Detect : 1

- A VUV photon hits the front filter plate coating and is converted. This photon enters the box, is converted by the WS light guide plate and is captured inside the ARAPUCA.
- After few reflections it is detected by the SiPM array.



  - It is trapped by the **usual ARAPUCA** scheme

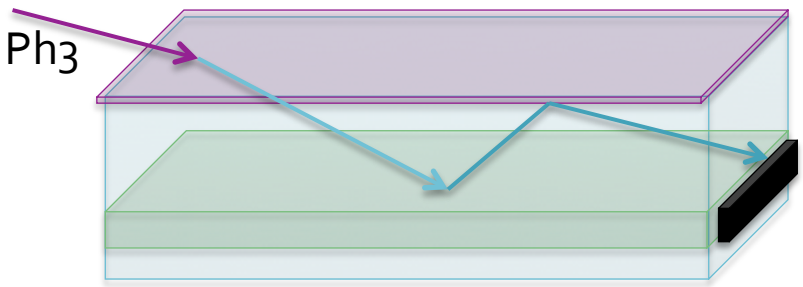
3 Ways to Detect : 2

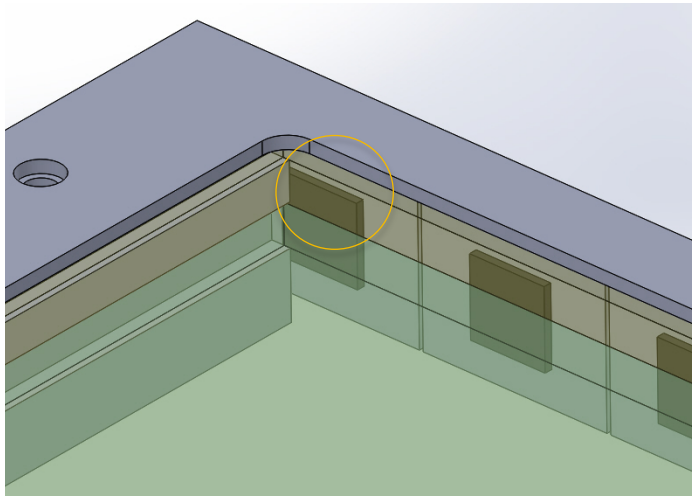
- A VUV photon hits the front face of the box, it is converted by the WS on the filter and the light guide, it is trapped by the light guide and it is **guided to the SiPM.**

  - This is the first improvement of the **X-ARAPUCA**

3 Ways to Detect : 3

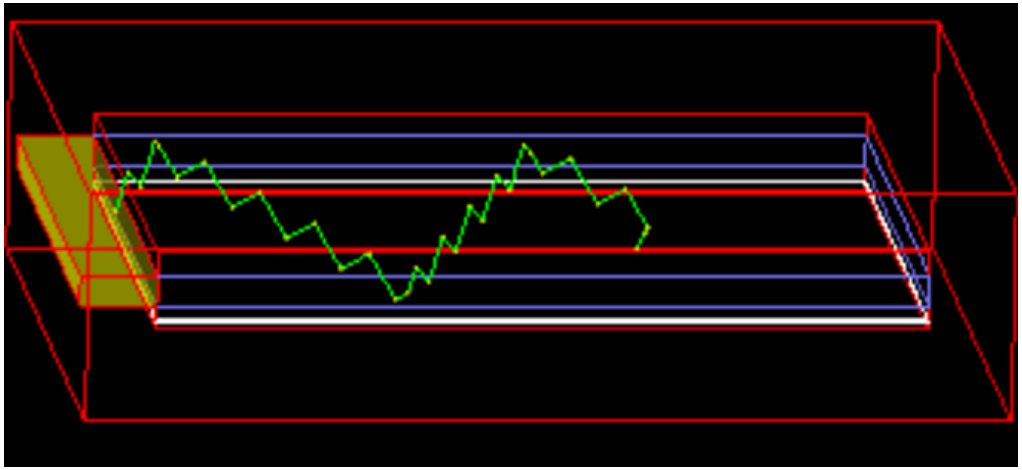
- A photon with **high incidence angle** inside the box, is trapped in the liquid argon **gap** between the filter and light guide (refractive index of LAr (350nm) = 1.2 - refractive index of fused silica and acrylic ≈ 1.5 →high reflectivity at large angles).





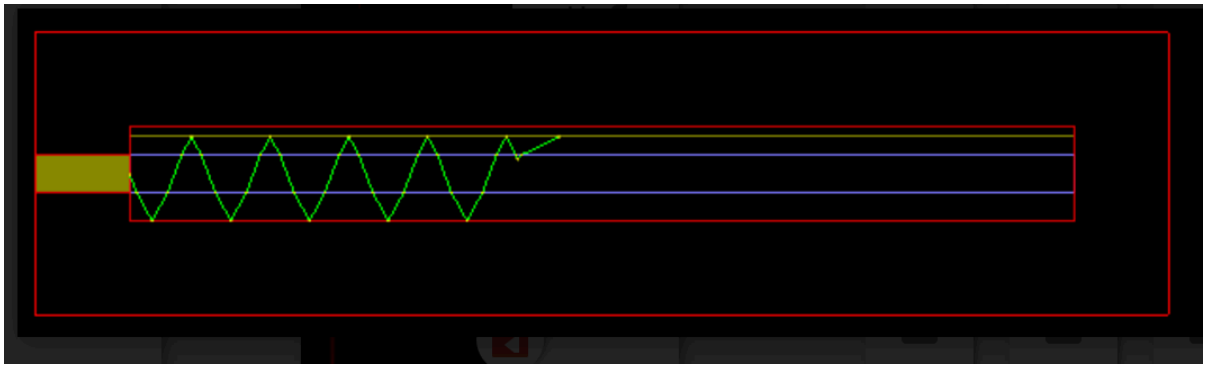
MC Simulation

- Teflon box
- Acrylic light guide doped with TPB
- Internal Geometry: 8X10X1 cm^3
  - (very close to protoDUNE ARAPUCA dimensions)
- Light guide size: 8X10X0.4 cm^3
- SiPM array: 8X1X0.4 cm^3
- SiPM acceptance area: 8X0.4 cm^2

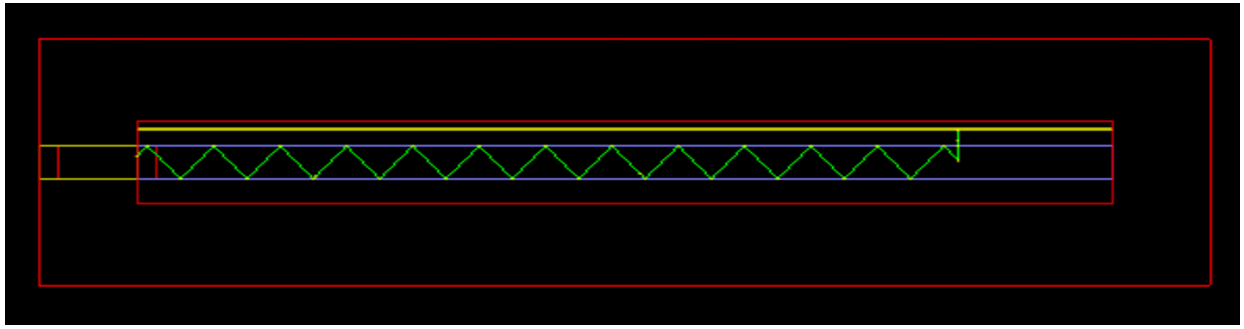


MC Simulation

- Event trapped as a usual ARAPUCA



- Event guided by the guiding slab



Preliminary Results

- Two simulation have been made: one with the guiding slab (**X-ARAPUCA**), and another without (ARAPUCA), in order to estimate the improvement in the gain.

- ARAPUCA
  - **Trapping** efficiency = **0.38651**
  - Average Time if flight = 1.71851 ns
  - # of events = 100000

- **X-ARAPUCA**
  - **Trapping** efficiency = **0.53618**
  - Average Time if flight = 2.09964 ns
  - # of events = 100000

Summary

- ARAPUCA has been shown in prototype testing in LAr to be a good candidate for large LArTPC scintillation light read-out.
- **X-ARAPUCA** improves the ARAPUCA concept by combining the standard ARAPUCA principle with a guiding slab to facilitate photon collection on the SiPM.
- Preliminary **MC simulation** results confirms that **X-ARAPUCA** can significantly improve the light trapping efficiency (40% in our simulation).

THANK YOU FOR YOUR ATTENTION !!!

X-ARAPUCA is a possible way of bringing **experts in different technologies to**

Work Together

for a same objective: improve the photon detection efficiency.

Let's play Frescobol !

Why X ?

- You can choose

10 as a Roman number, is it possible to reach a 10% of detection efficiency ???

- Or…

a mutation of the original idea that detects photons through three different trapping mechanisms.