Simulações de ARAPUCAs no DUNE

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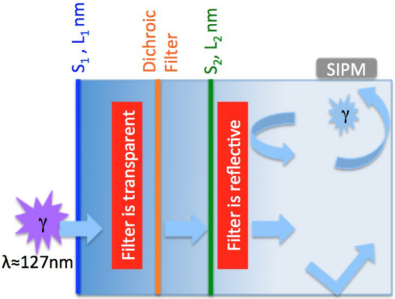
Scintillation light in LAr-based neutrino experiments

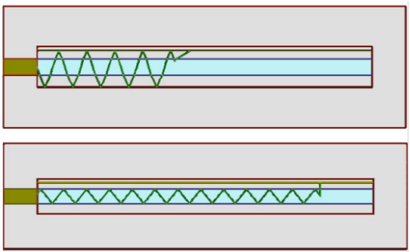
- In LAr-based experiments scintillation light is a source of important information:
  - Determination of t_0 for nucleon decay events: important to determine where the event occurred along the drift direction for event vertexing, fiducialization, and electron attenuation corrections.
  - Proper location of the event vertex and improvement of energy resolution for SuperNova Burst neutrino events.
  - Complementary triggering scheme for the burst itself.
  - Together with charge measurements allows for calorimetry reconstruction for low-energy electrons.
- The improvement of the efficiency of the photodetection system is an important task for DUNE.

ARAPUCA and X-ARAPUCA

- System proposed by Dr. Ana Machado and Dr. Ettore Segreto.
- Light-trap system, where the photon is collected and confined inside a box with highly reflective internal surfaces, so that the detection efficiency of trapped photons is high even with a limited active coverage of its internal surface
- Allows to reduce the number of active devices and electronic channels.

ARAPUCA and X-ARAPUCA





ARAPUCA Optimization

- The ARAPUCA and X-ARAPUCA design must be adapted for different detectors.
- Several features can be studied:
  - Number and distribution of SiPMs
  - Dimensions of the reflective box
  - Thickness of the WLS slab (X-ARAPUCA)
  - Arrangements of ARAPUCAs inside the detector
- Our simulations **consider the geometrical propagation** of photons inside the ARAPUCA box.
- Meshes built in Python and simulated using C++ ray-tracer with an acceleration structure.
- To be compared with Geant4 simulations by Dr. Laura Paulucci, Dr. Franciole Marinho and Dr. Gustavo Valdiviesso.

Supercell

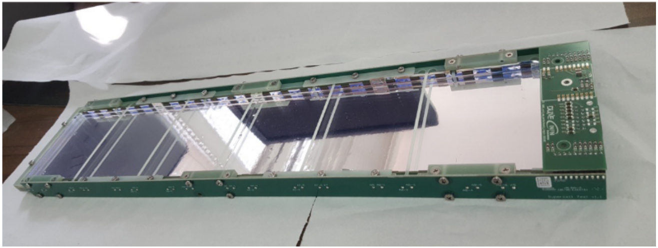
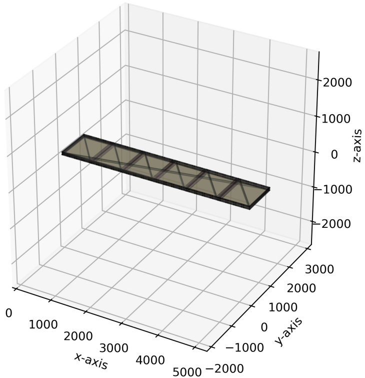


Figure: Fully assembled supercell at CIEMAT.

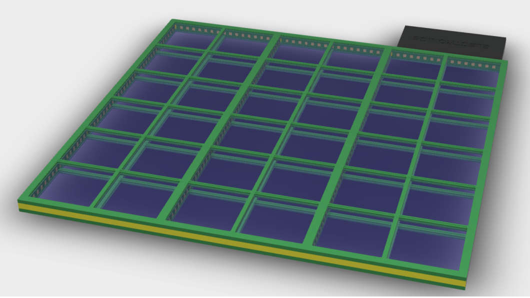
Supercell 6 x (10cm x 8cm). 1 SiPM / 10 cm^2 active area.



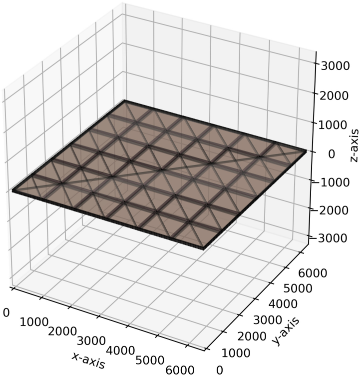
Number of SiPM = 48 (2x24)
Collection efficiency: 33.7%
Total efficiency: 34.5% x 33.7% x 45% $\approx$ 5.2%
Active area: 480 cm^2.

X-ARAPUCA Mega Cell

The X-ARAPUCA Mega Cell will be implemented in the Vertical Drift system planned for the second module of DUNE Far Detector. Our simulations are based in the current working prototype by Heriques Frandini:



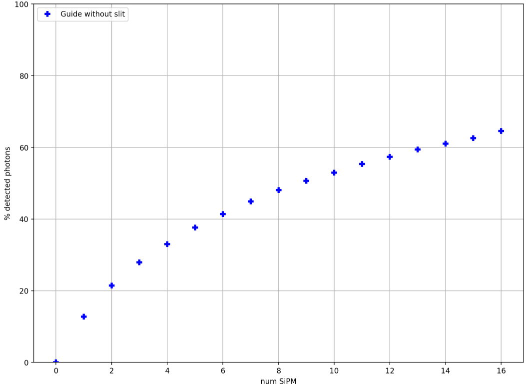
Megacell 6 x 6 x 10cm^2. 1 SiPM / 22.5 cm^2 active area.



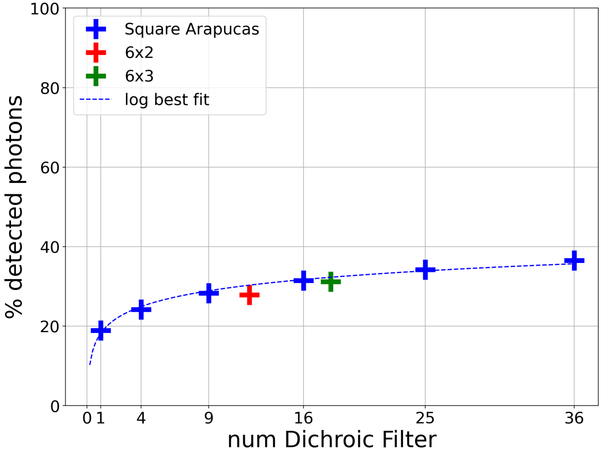
Number of SiPM = 160
Collection efficiency: 41.2%
Total efficiency: 34.5% x 41.2% x 45% ≈ 6.4%
Active area: 3600cm^2 = 7.5 x 480 cm^2.

Guide without slit

Plot of the percentage of detected photons per number of SiPM per side of dichroic filter. ($\times$ 16 per module ($\times$ 3 for the whole cell))

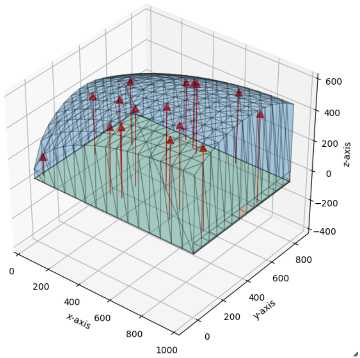


Efficiency per number of filters on each Megacell



Optimization of the reflective surface of ARAPUCA

Side project, to use Genetic Algorithms to obtain an optimized reflective surface for ARAPUCA. Some preliminary results for a parallel beam of light are obtained.



Schedule

Date	Activity
August 2021	Implementation dichroic filter
October 2021	First tests with Chroma
December 2021	Integration between Python and Geant4
June 2022	Machine Learning implementation

Costs and Resources

- Currently we are using the computational infrastructure from UTFPR. This infrastructure must be improved in medium term, as the simulations become more robust.
- In Paraná it is possible to apply for resources from CNPq and Fundação Araucária. We can apply for resources from UTFPR itself.

Conclusions

- The optimization of the ARAPUCA design using geometric propagation of photons produce consistent results, although our simulations represent an ideal case.
- We are currently working on integrating the use Geant4 in combination with our algorithms.
- The group is currently working on the improvement of the simulations implementing physical aspects, as the efficiency of the dichroic filter, etc.
- The validation of the obtained results will include comparison with other simulations and experimental results, such as the ones obtained by Cattadori et al. (arxiv - 2104.07548).
- If the incorporation of experimental data in the X-ARAPUCA simulations produces close to reality results, they could be used in full LAr chamber simulations.

Acknowledgement

This work could not have been done without the help of

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- Prof. Ettore Segreto
- Prof. Gustavo Valdiviesso
- Prof. Flavio Cavanna
- Prof. Laura Paulucci
- Prof. Carla Cattadori

The End