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

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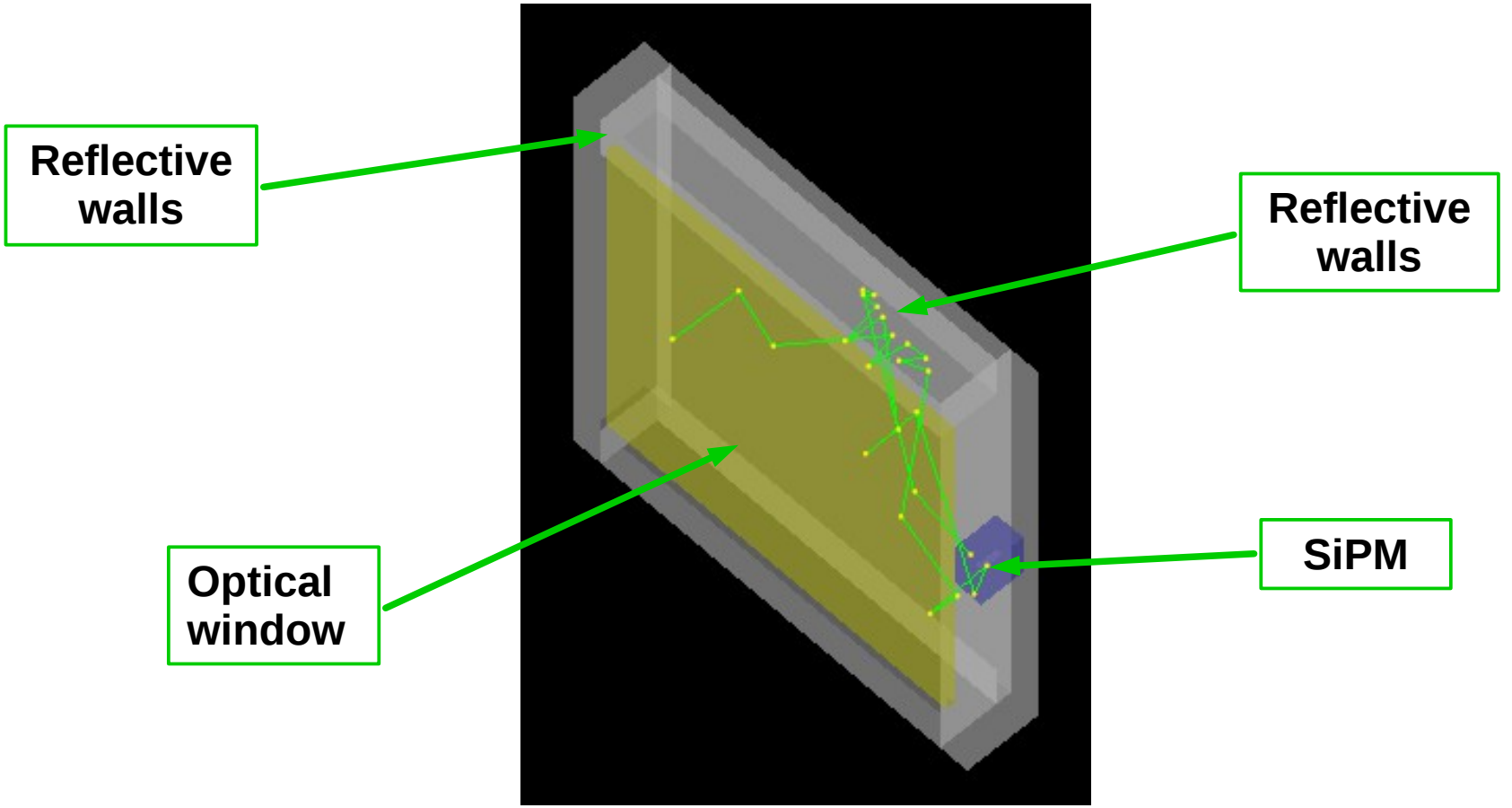
Arapuca

- Photon trap for liquid argon scintillation light
  - Optical window, reflective cavity and active sensor

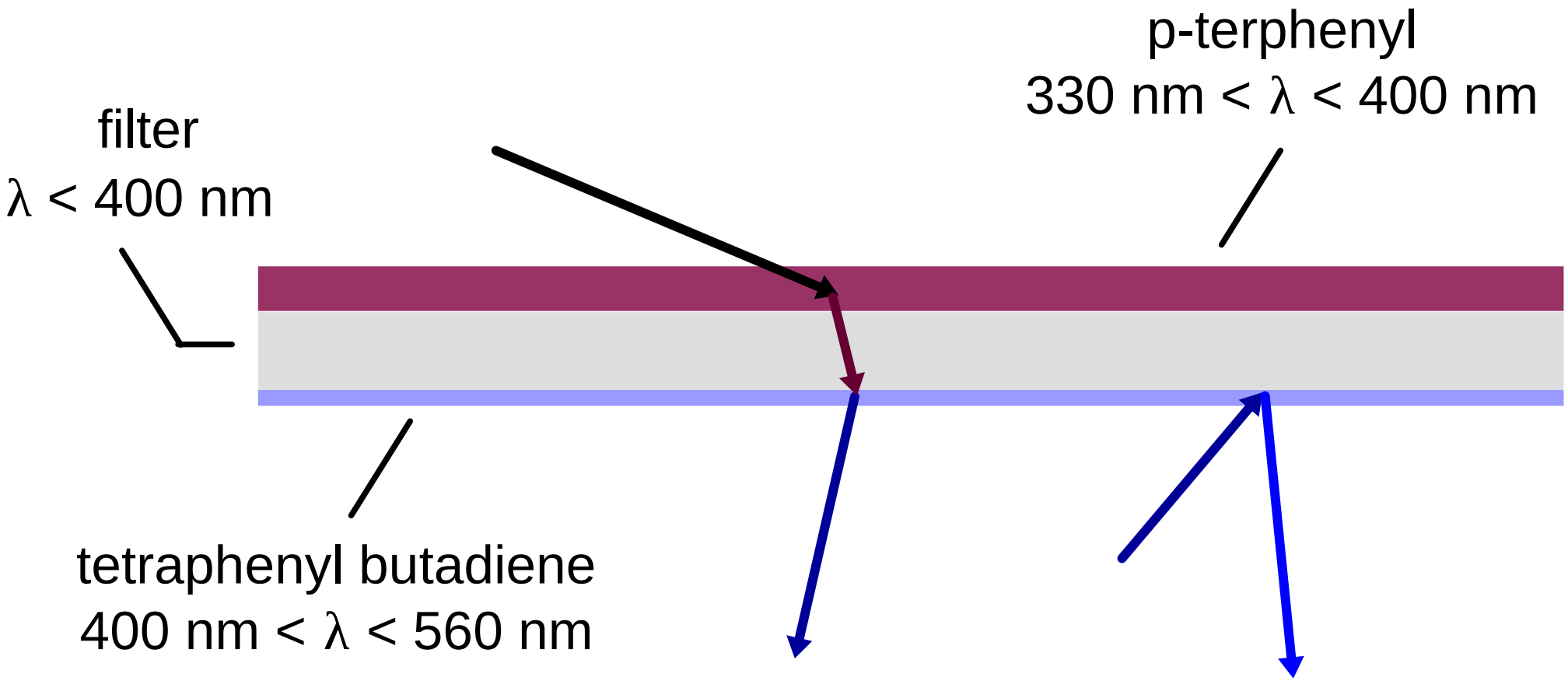


Performance vs geometry and materials

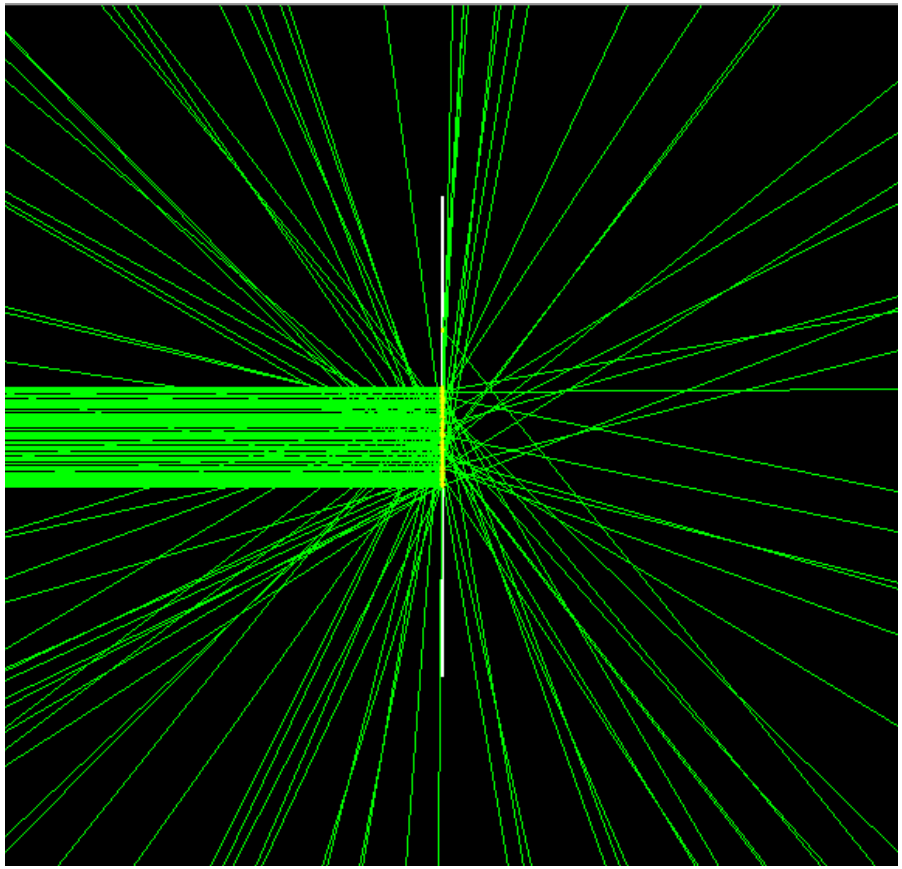
E. Segreto, A.Machado JINST 11 C02004 2016

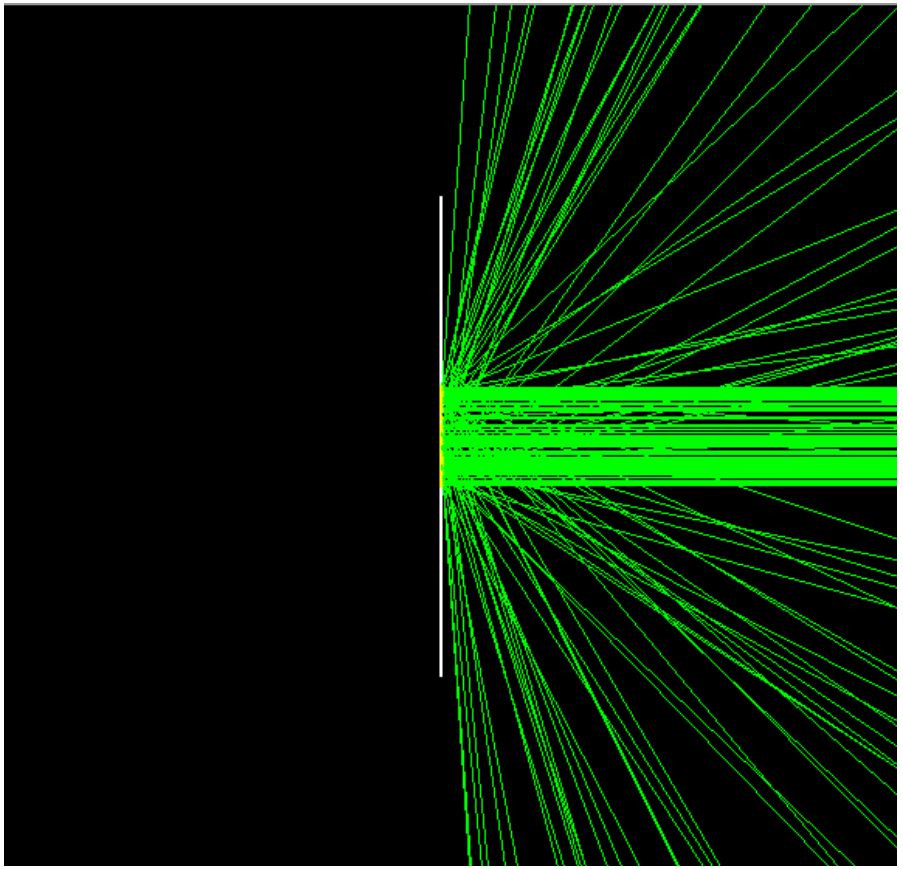
Optical Window

At least 2 WLS + dichroic filter

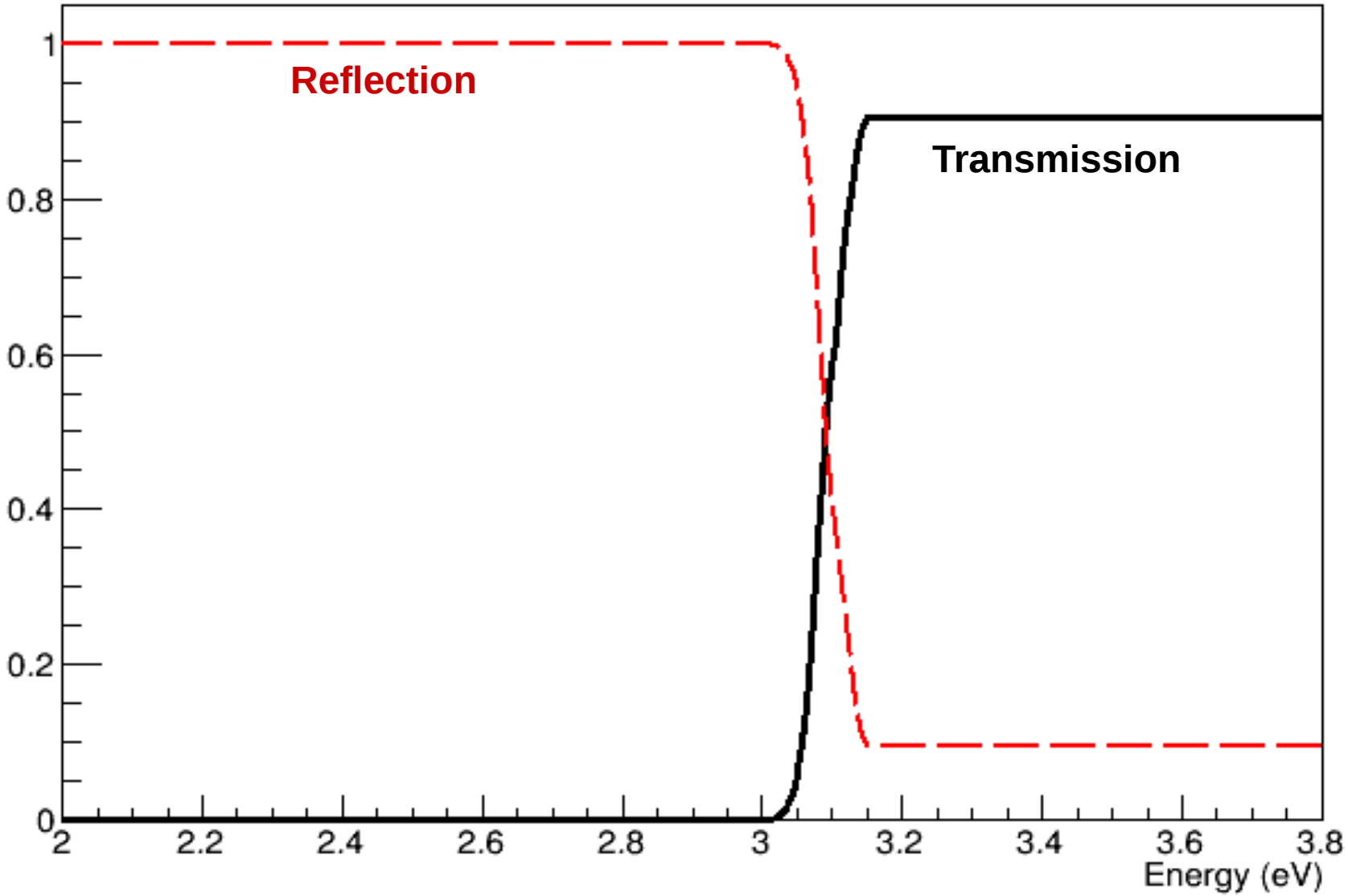


Optical Window: operation principle





Optical Window: filter



Average polarisation @ 45°

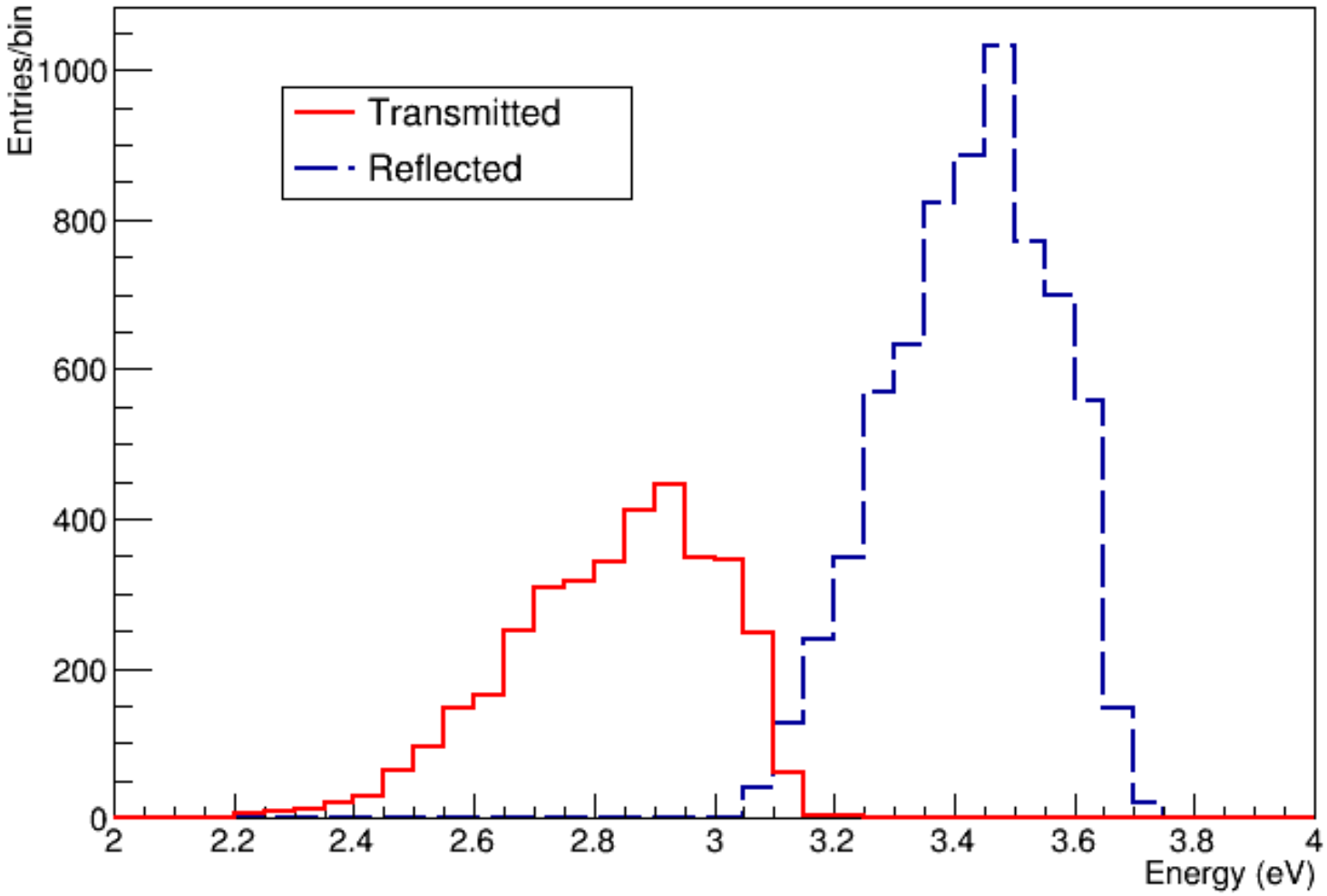
Optical Window: wavelength shifters

Acceptance efficiency

$$\varepsilon_{acceptance} = \frac{N^{photons}_{accepted}}{N^{photons}_{total}}$$

$$= 35.4 \pm 6.0\,\%$$

$$\approx \frac{1}{2}\varepsilon_{ptp} \times T_f \times \varepsilon_{tpb}$$



Emission spectrum structure at LAr temperature

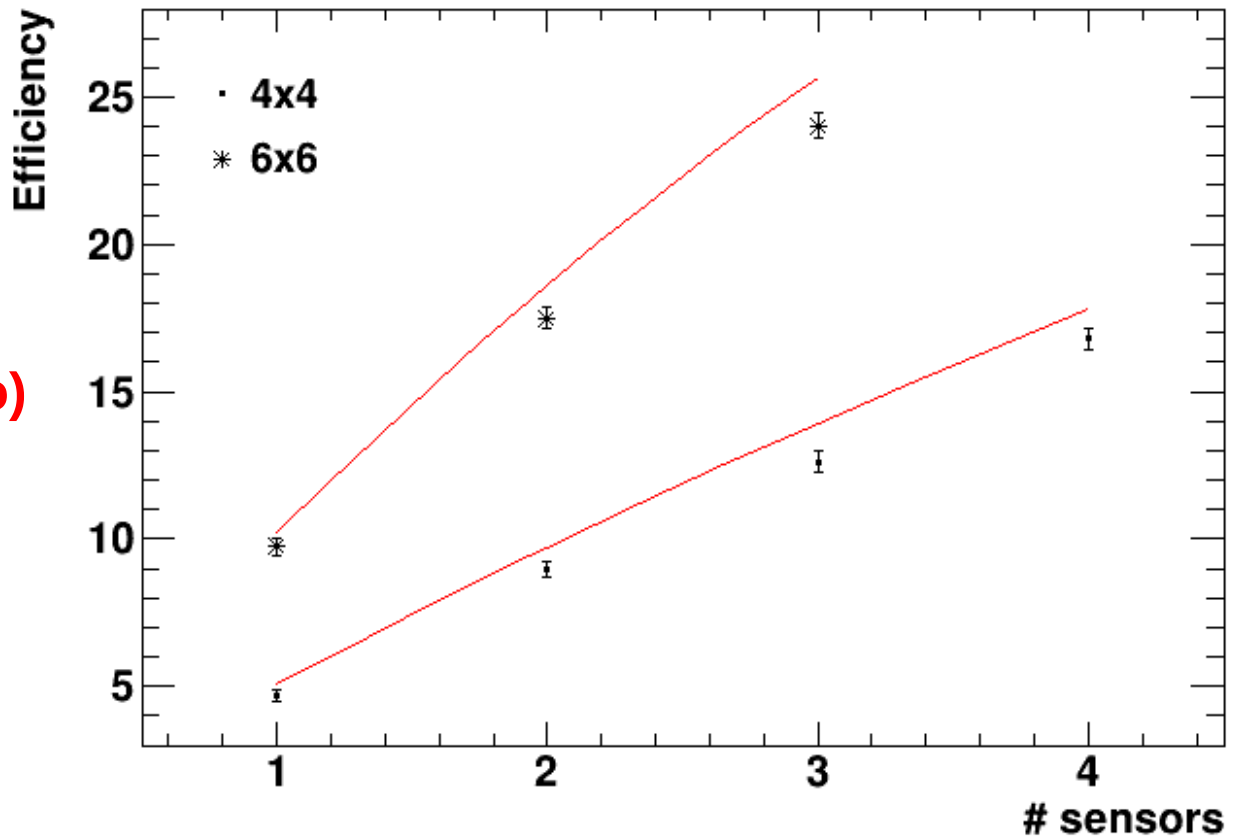
Reflective Cavity: collection efficiency

$$\varepsilon_{collection}^{analytic} = \frac{f}{1 - R(1-f)}$$

f: active coverage
R: average reflectivity
(see arXiv:1110.6370, E. Segreto)

$$\varepsilon_{collection}^{MC} = \frac{N_{collected}^{photons}}{N_{accepted}^{photons}}$$

- Internal reflections
  Lambertian (teflon), specular (vikuit), etc
- Geometry characteristics



Dimensions: 50 mm x 48 mm x 8 mm
Reflectivity: 0.95

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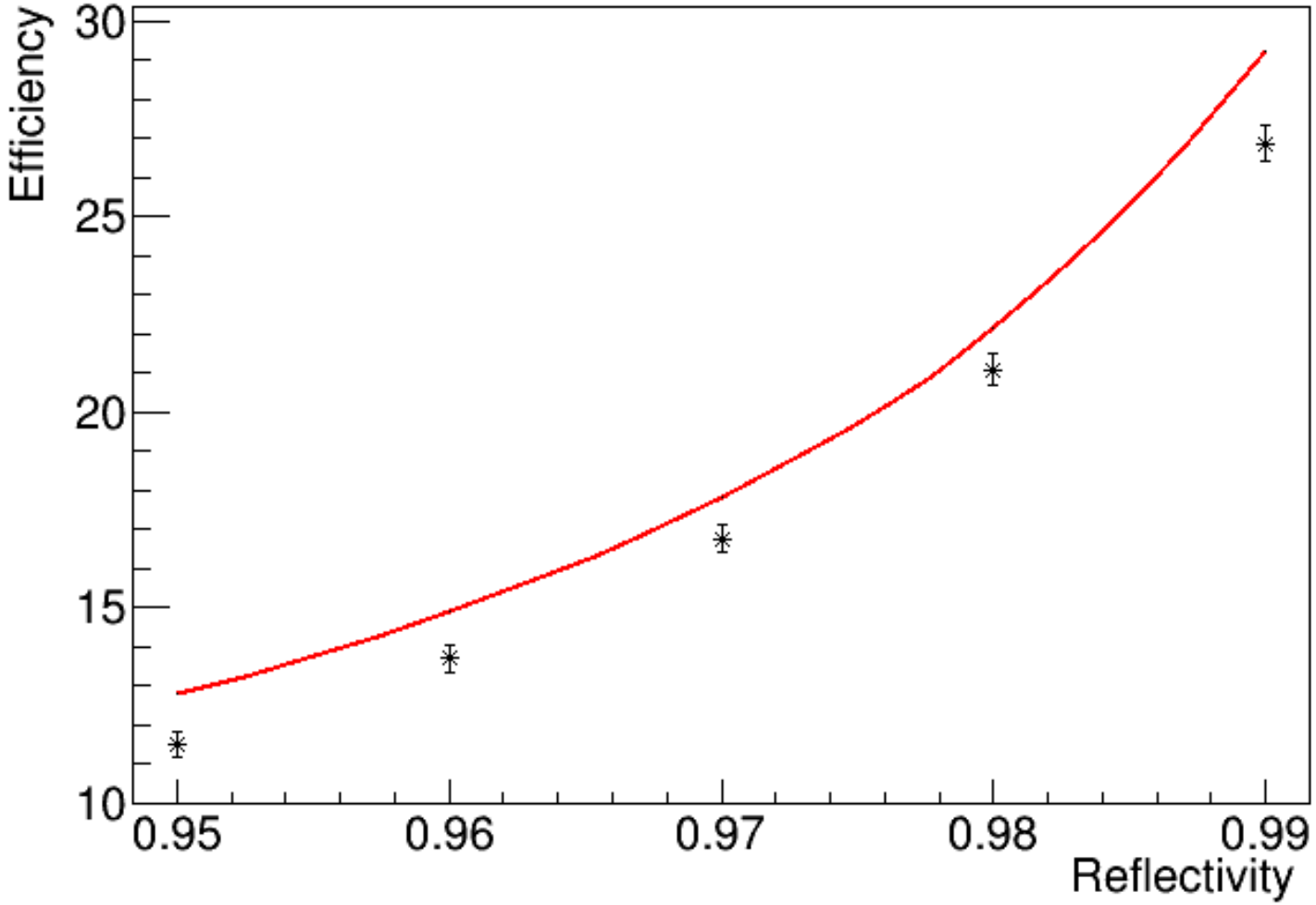
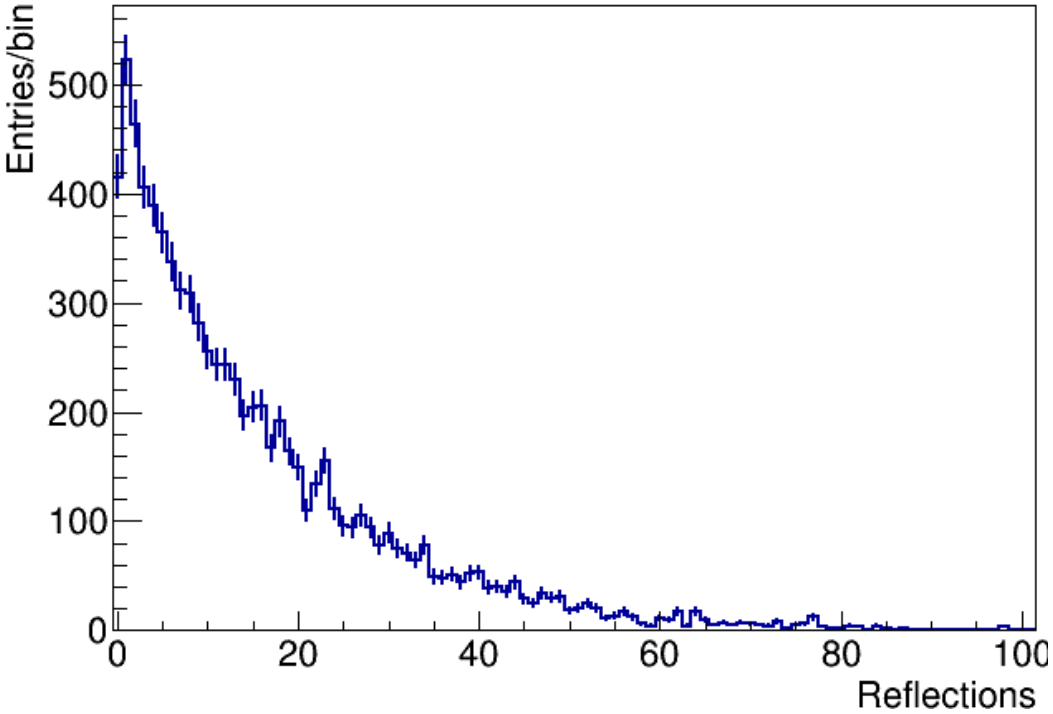
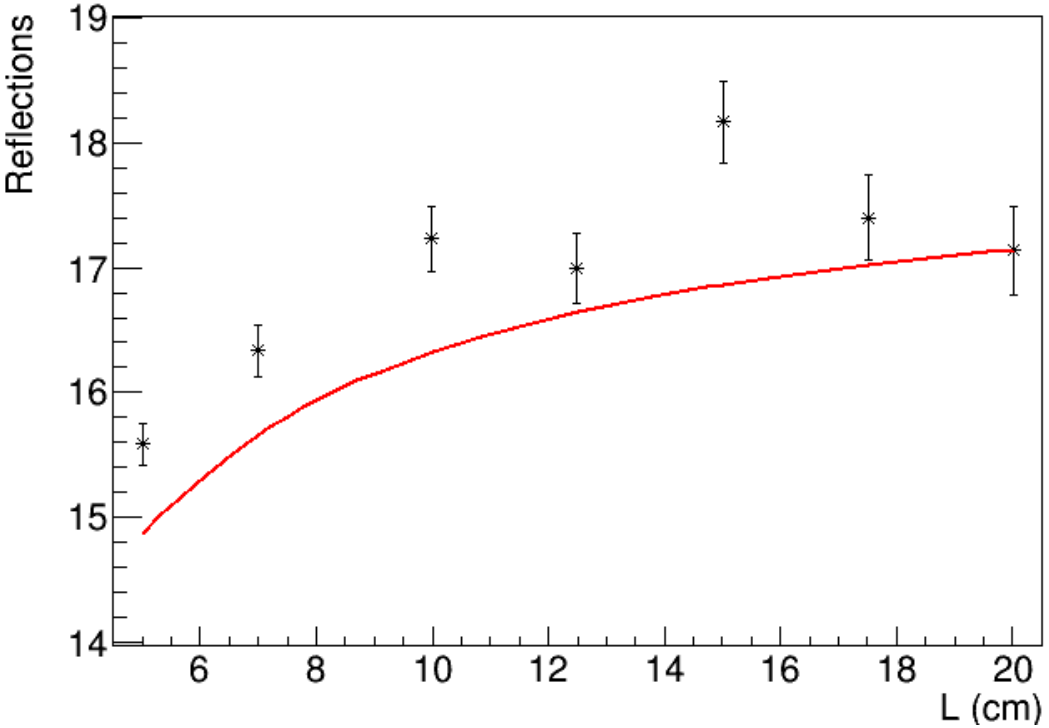
Reflective Cavity: collection efficiency



Dimensions: 50 mm x 48 mm x 8 mm, **Sensor:** 1 6x6 SiPM

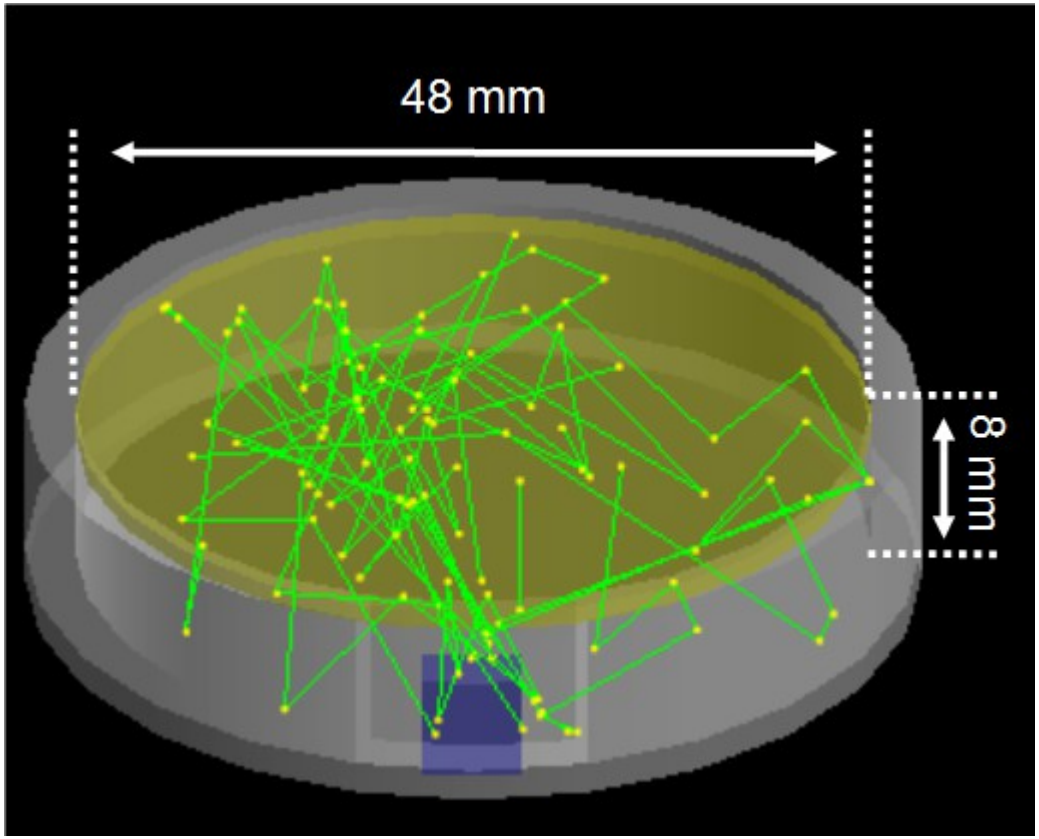
Reflective Cavity: reflections



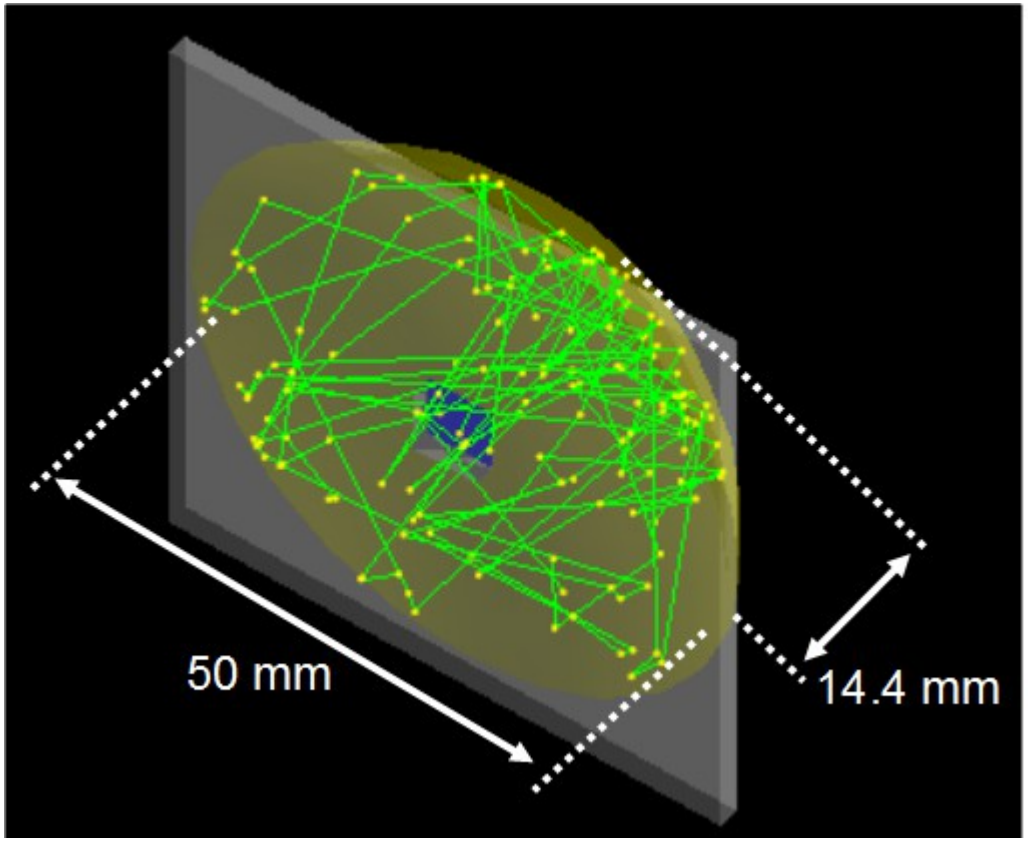


$$n_{reflections} = \frac{[(1-f)R]^2}{1-(1-f)R}$$

Reflective Cavity: geometries

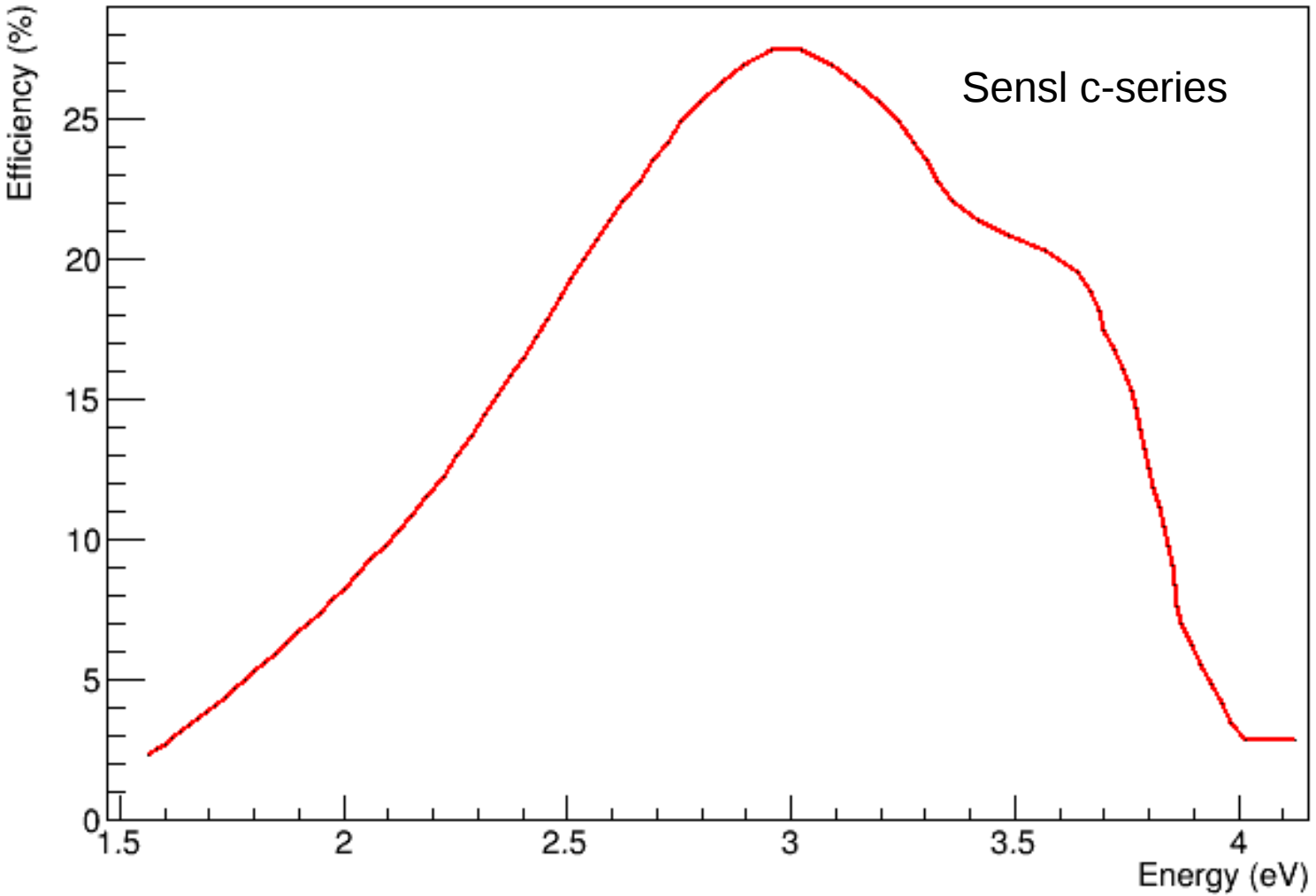


Efficiency: (14.9 ± 0.4)%
Analytic estimate: 13%



Efficiency: (16.0 ± 0.4)%
Analytic estimate: 13.7%

SiPM Sensor: efficiency



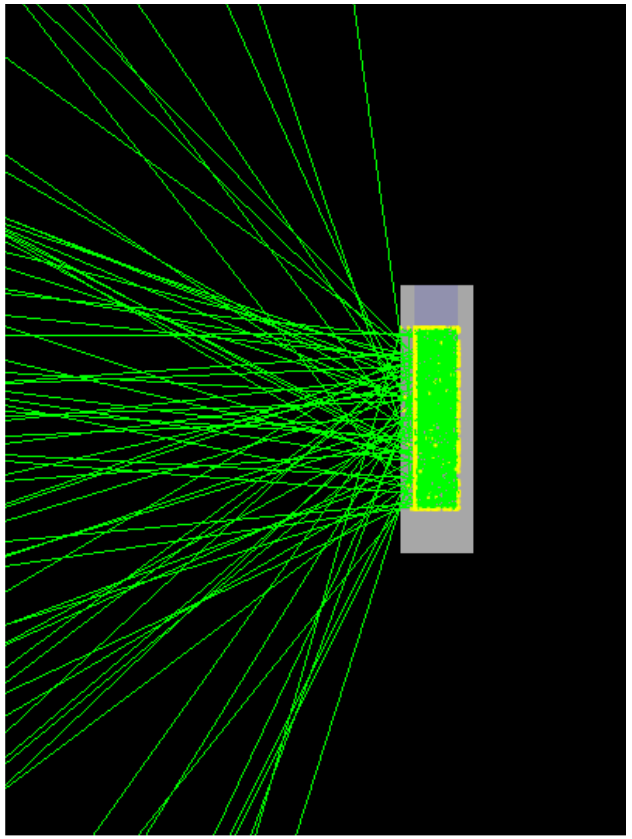
$$\varepsilon_{SiPM} = \frac{1}{N_{collected}} \int_{E_0}^{E_1} \varepsilon_{SiPM}(E) \frac{dN_{collected}}{dE} dE = 25.1 \pm 0.3\,\%$$

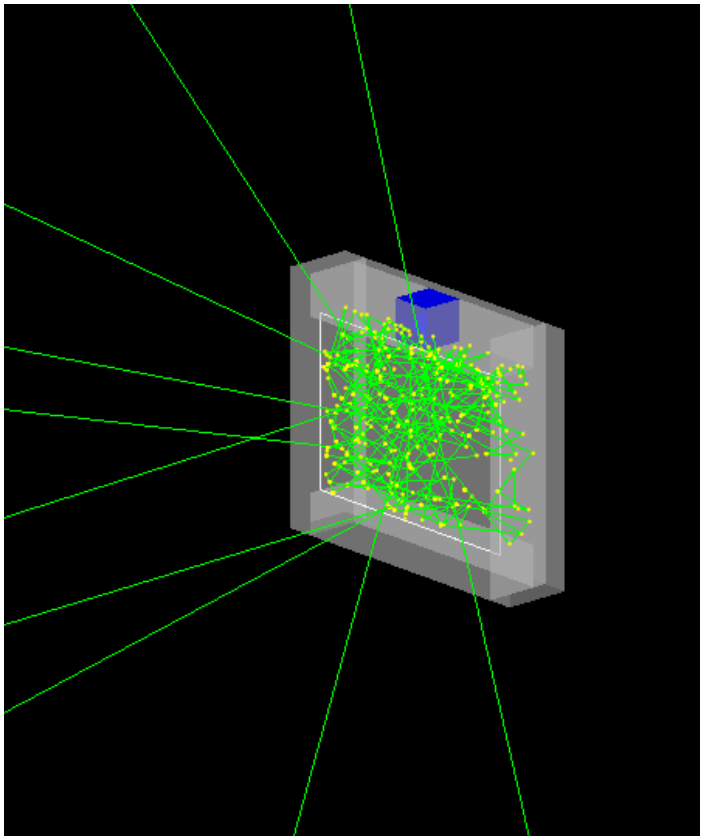
Complete setup

Dimensions:
3.6cm x 2.5cm x 0.6cm
R: 0.95 (Lambertian)

SiPM: 6x6 mm²

LNLS LAr test (α source)
Efficiency ~ 1.8 %



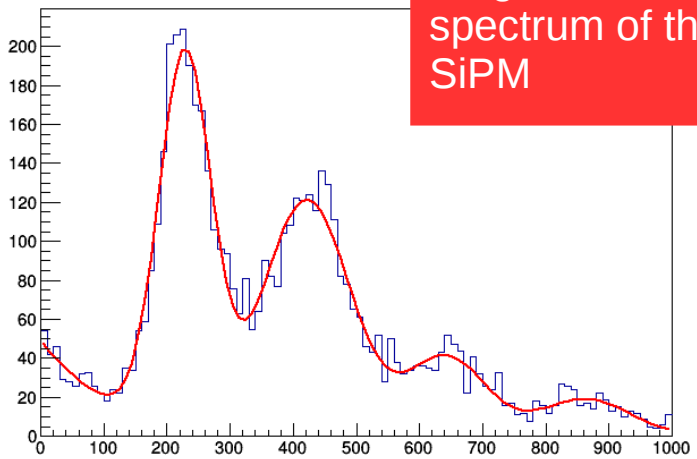


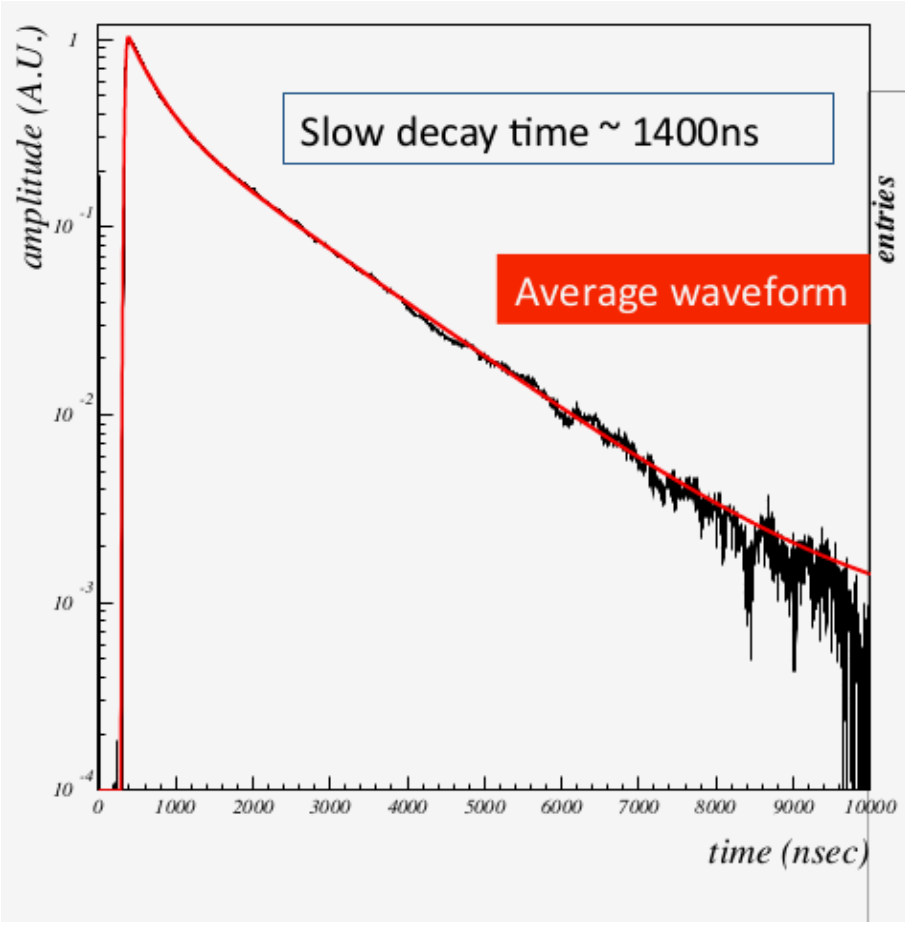
$$\varepsilon_{total} = \varepsilon_{acceptance}\,\varepsilon_{collection}\,\varepsilon_{SiPM} = \frac{N_{detected}}{N_{total}} = 1.7 \pm 0.3\,\%$$

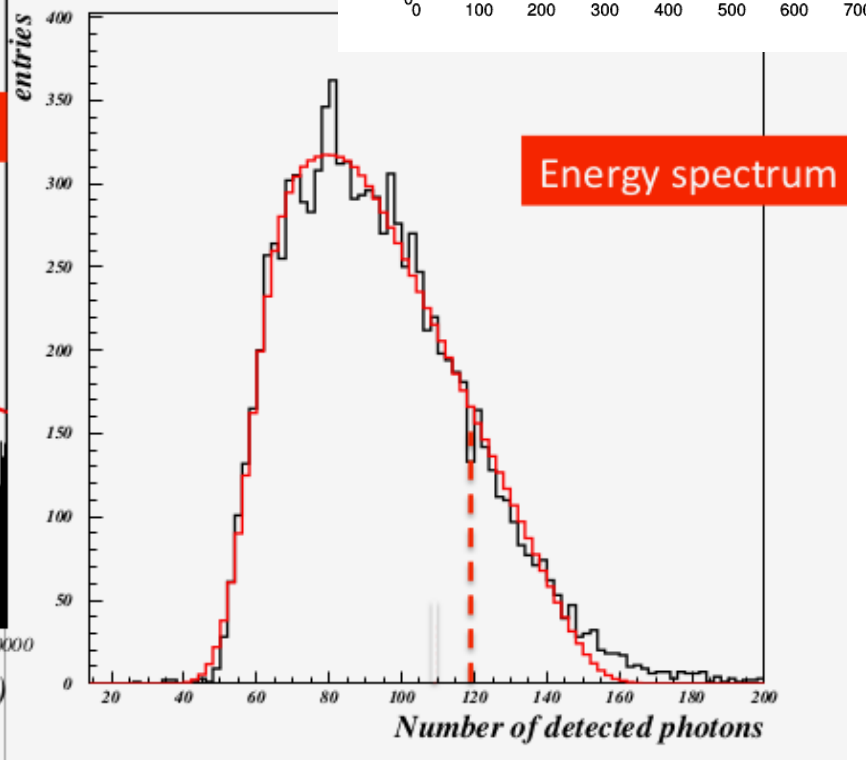
LNLS: analysis

PRELIMINARY

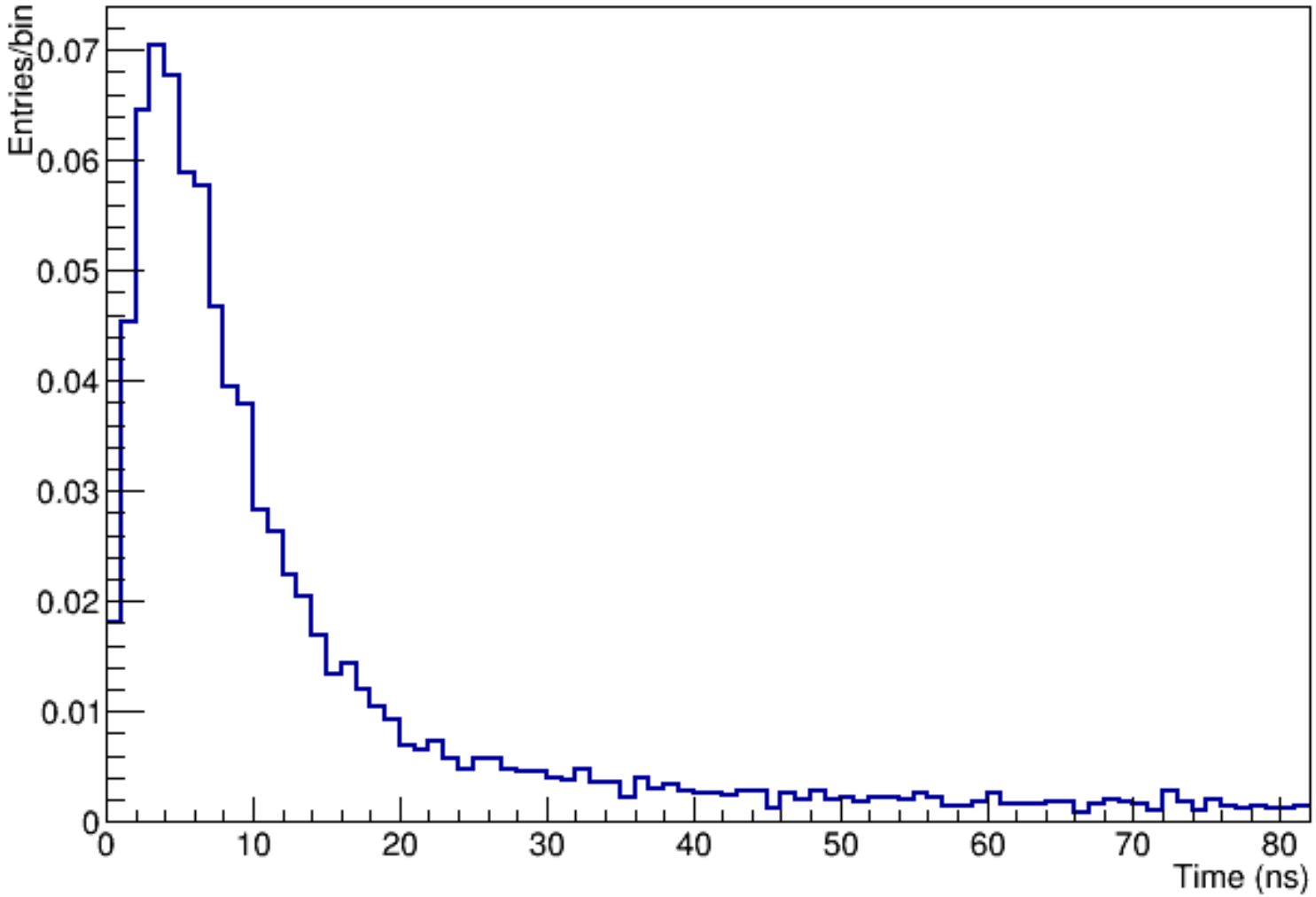
Single electron spectrum of the SiPM







Acquisition time



$$t_{acquisition} = t_{PTP} + t_{TPB} + t_{collection} \approx 4\text{ns}$$

Conclusions

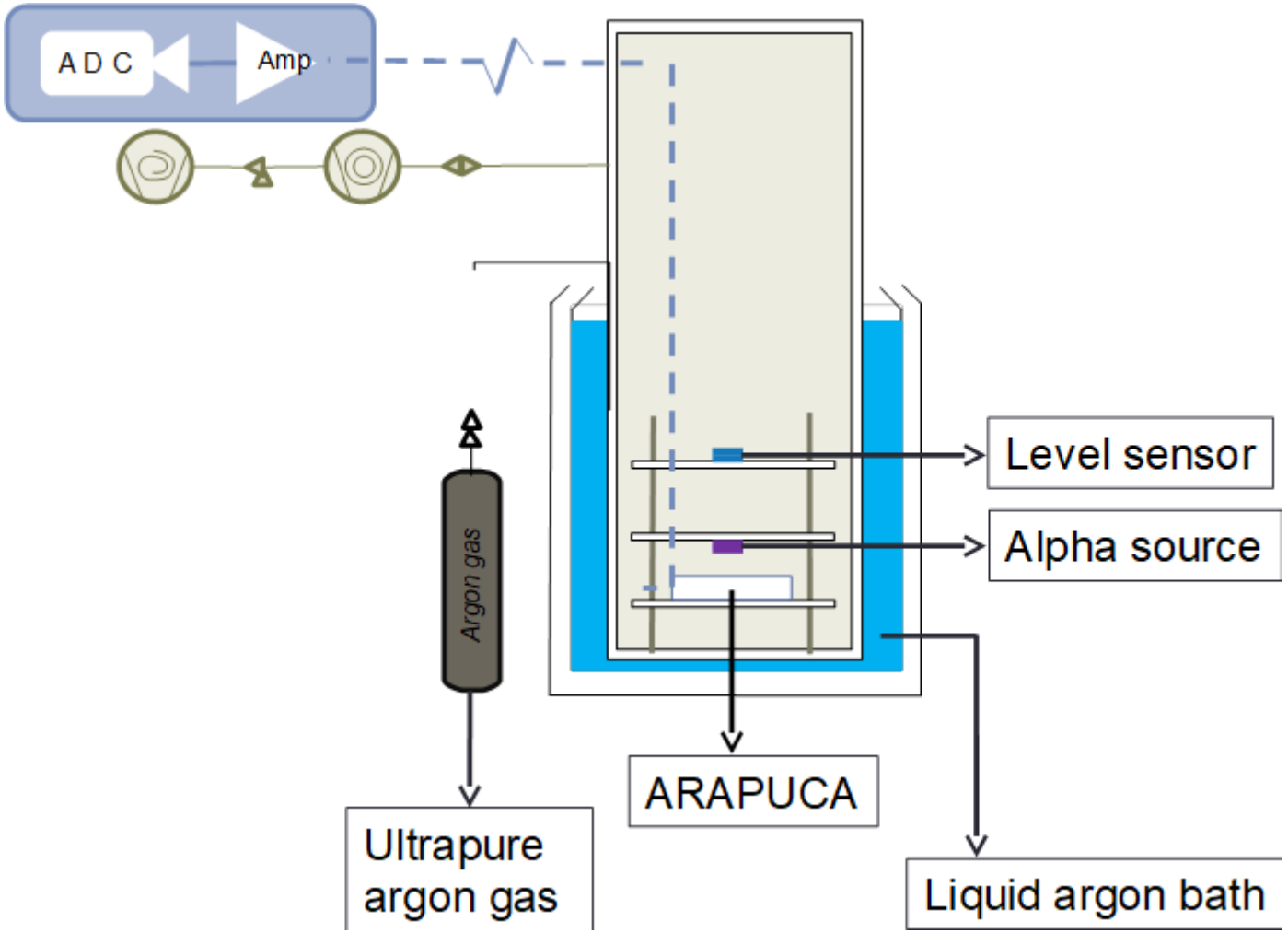
- ARAPUCA full simulation for R&D
  - Flexible for parameter settings optimization
  - Analysis macros well developed
- Acceptance window: wavelength shifters (temperature) and dichroic filter (angle)
- Reflective cavity: main surface models and geometry available
- SiPM: manufacturer specifications
- Acquisition time modelling

Perspectives

- Design for next round of cryostat tests
  - TallBo (protoDune), Scene (SBND)
- Electronics response
  - Single PE model, waveform
- Impact on physics measurements

Backup

LNLS: experimental setup



Reflective Cavity: photon detection rate