UNIVERSIDAD DE GRANADA

Expected performance of the Photon Detection System in SBND

SENSE General meeting

April 1st 2025

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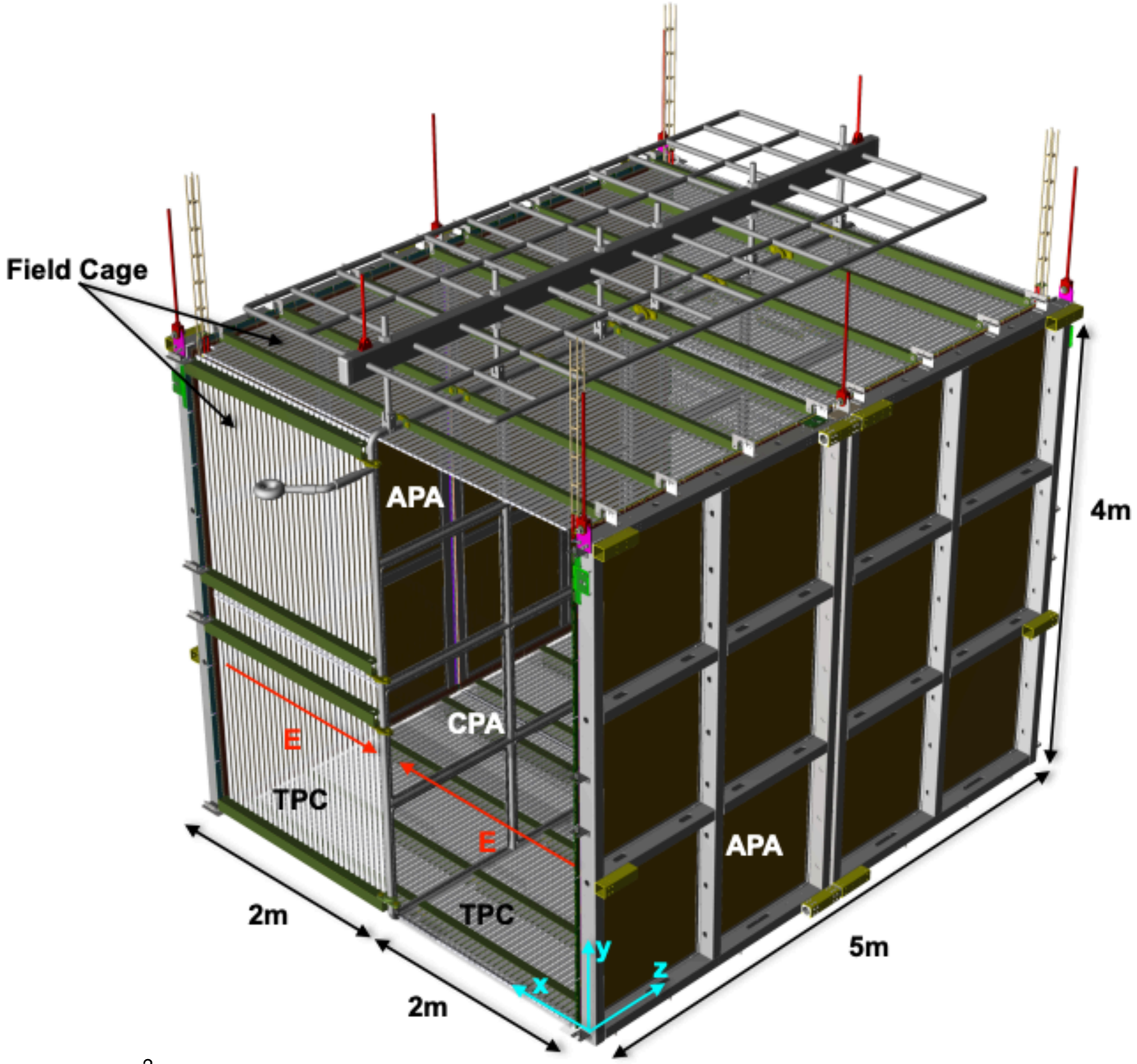
The University of Granada

SBND detector

- Drawing of the SBND TPCs:
  - Two TPCs separated by a central cathode
  - 2 m maximum drift distance
  - Field cage covering the active volume to ensure homogeneous electron field (0.5 kV/cm)
  - Note that part of the vertical field cage has been removed to reveal the active volume



Photon Detection System design

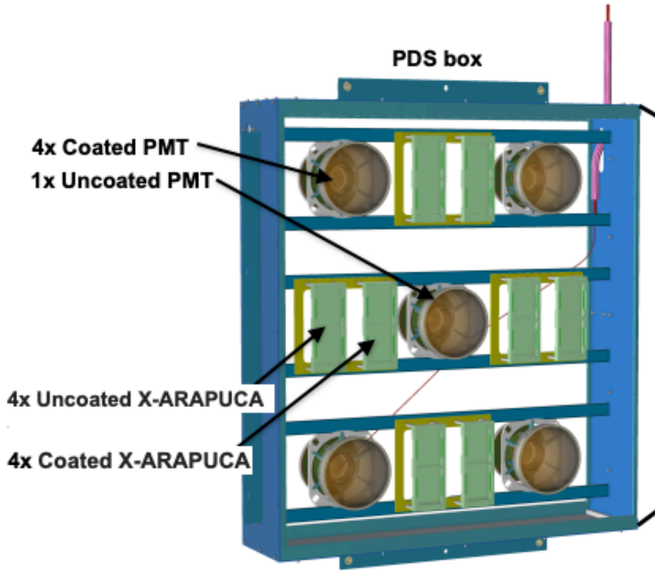
Components of the PDS:

- ***Active***: PMTs and XARAPUCAs both coated and uncoated
- ***Passive***: TPB-coated reflector foils

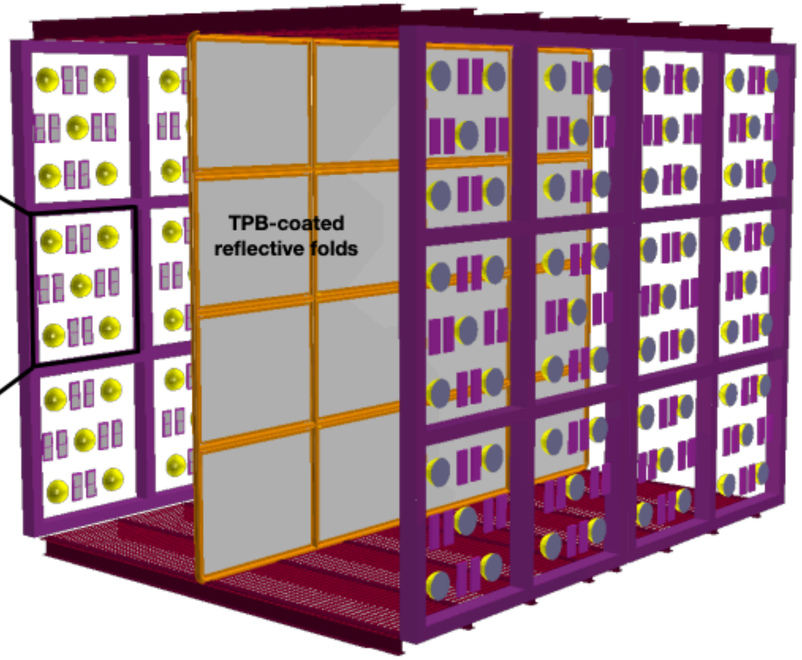
Able to detect the two different light components:

- ***Direct***: VUV photons
- ***Re-emitted***: Visible photons

PMTs and X-ARAPUCAs arrangement in the PDS-box



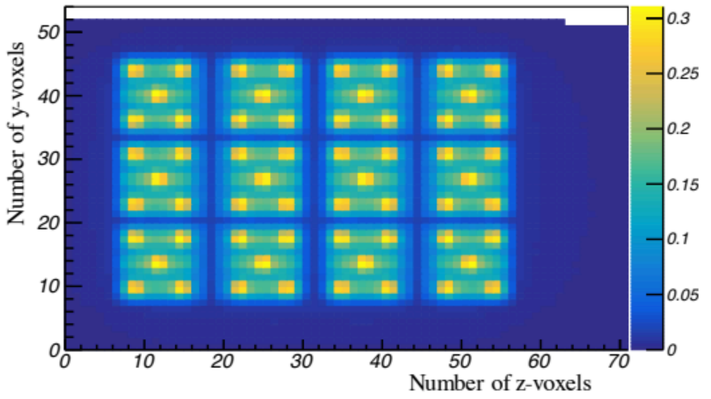
View of the SBND's photon detection system as described by the GDML package

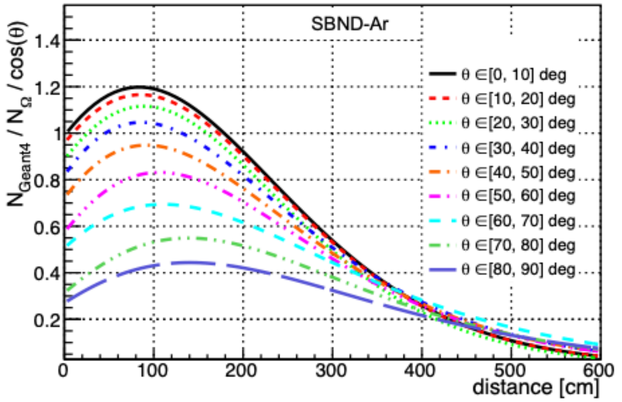


Scintillation Light Simulation

Number of photons detected

In SBND we use a **Hybrid** approach with the **Semi-Analytic** model for the active volume (inside the TPCs) and the **Optical-Library** for the LAr outside the TPCs



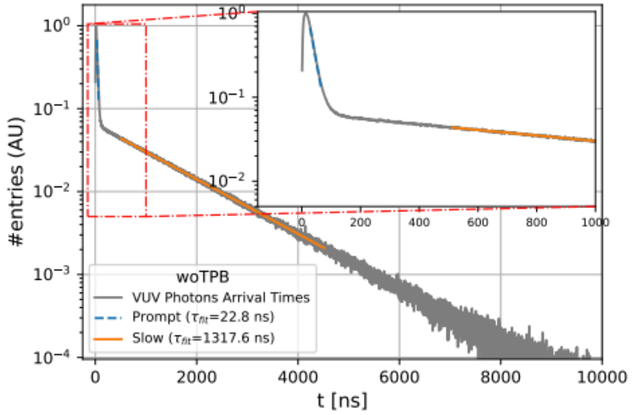


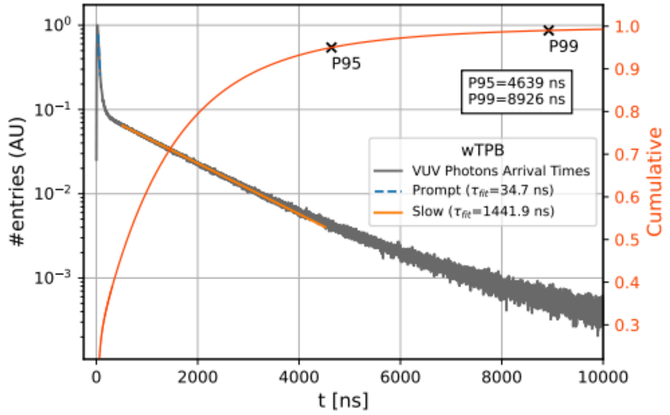
Arrival time distributions

Emission: $\tau_{fast} = 6\,ns$ and $\tau_{slow} = 1300\,ns$

Propagation: using the Semi-Analytic model

WLS delay: TPB and pTP

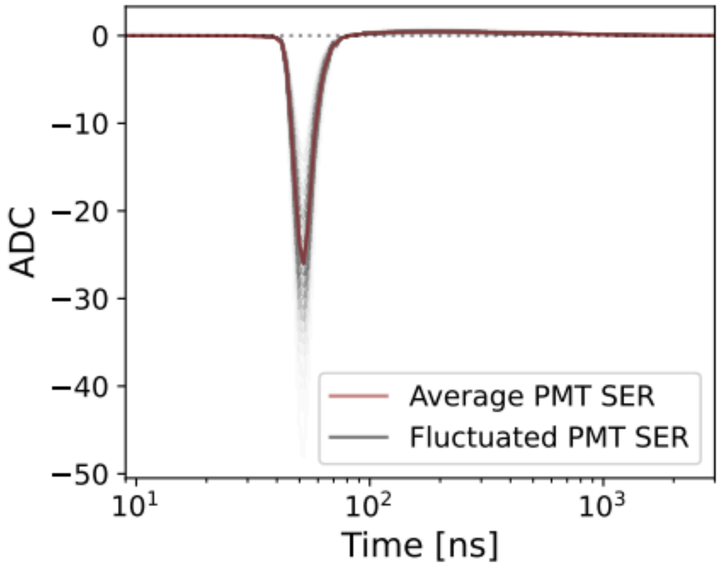


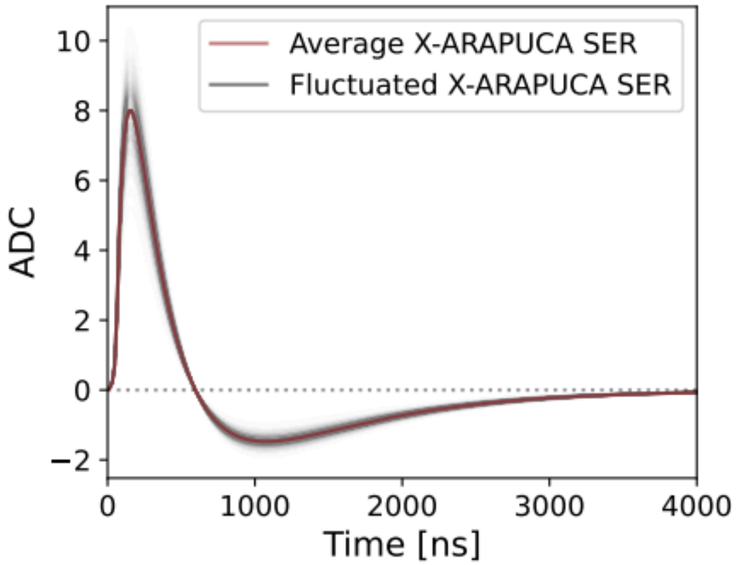


Detector Response Simulation

Detector effects simulated in our light signals:

- Photon Detection Efficiencies
- SER + fluctuations
- Baseline settings to accommodate peak and under(over)shoot
- Noise model
- PMT non linearity (curve in suplemental material)
- Transit time

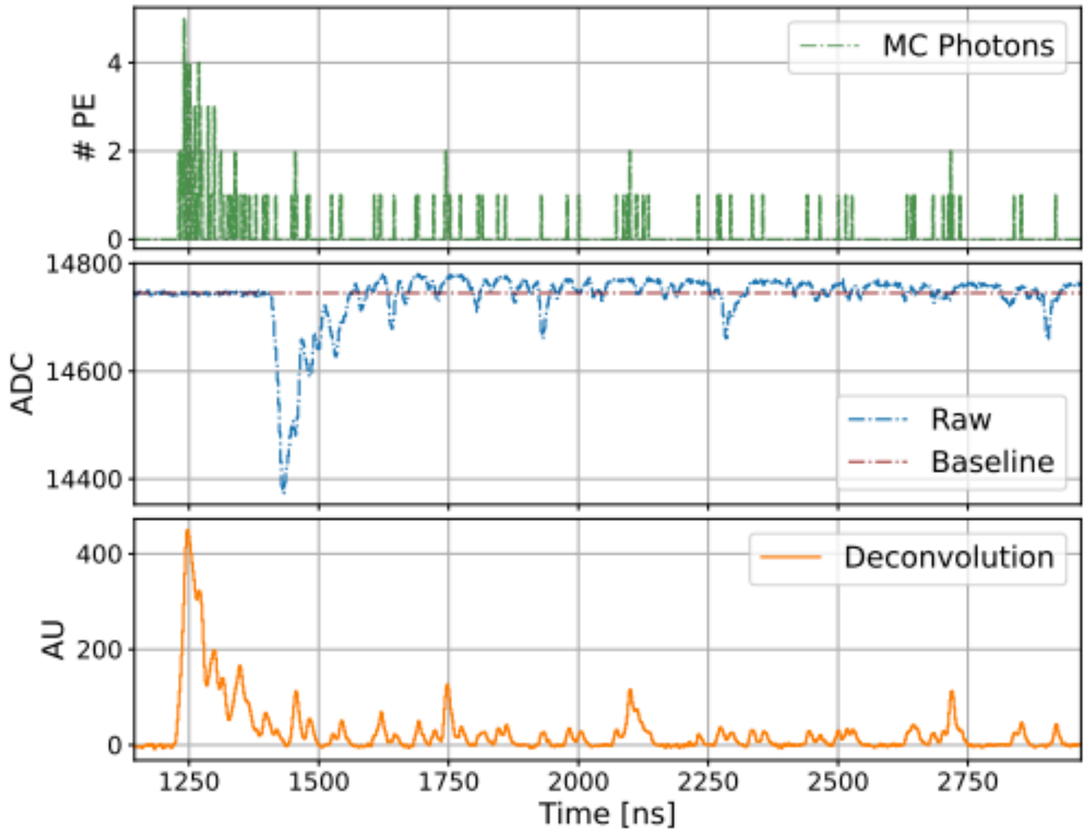


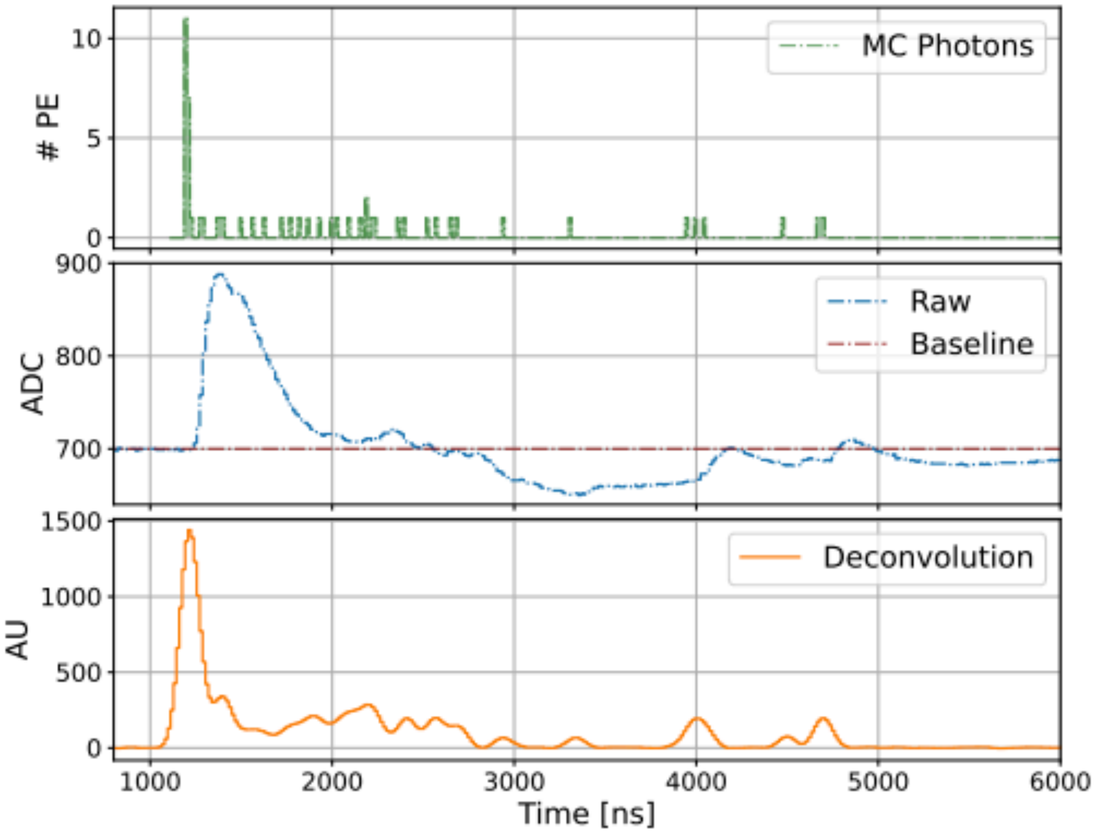


Measured Single Electron Response for the PMTs (Left) and X-ARAPUCAs (Right) in SBND

Detector Response Simulation

Example of signal processing stages for PMTs (left) and X-ARAPUCAs (right)





Waveform deconvolution to remove the signal bipolarity introduced by our AC-coupled readout

Light Signal Reconstruction

Optical Hit and Flash objects

Example of the OpHit finder algorithm performance for a PMT waveform.

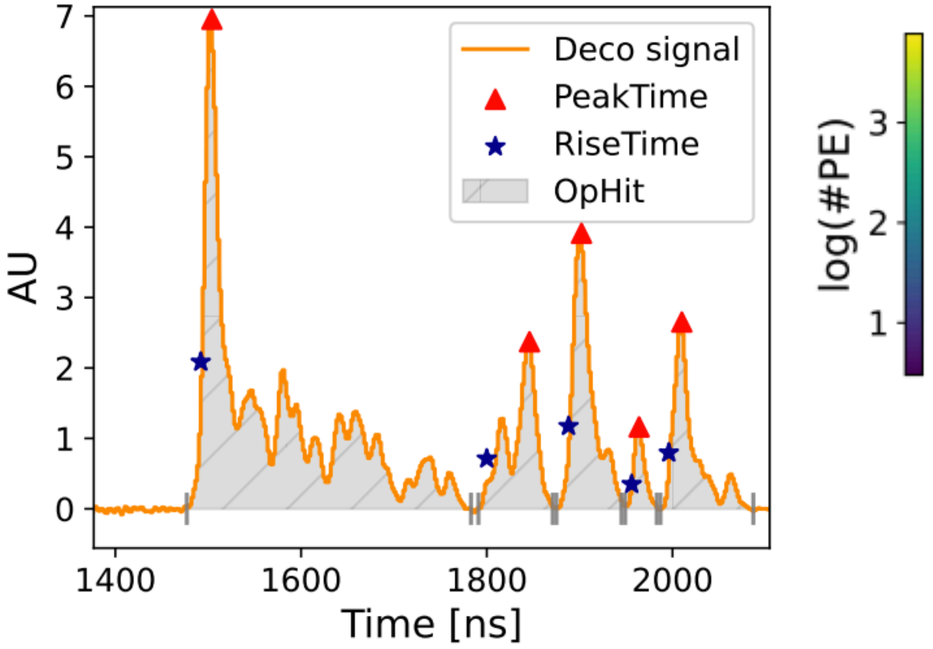
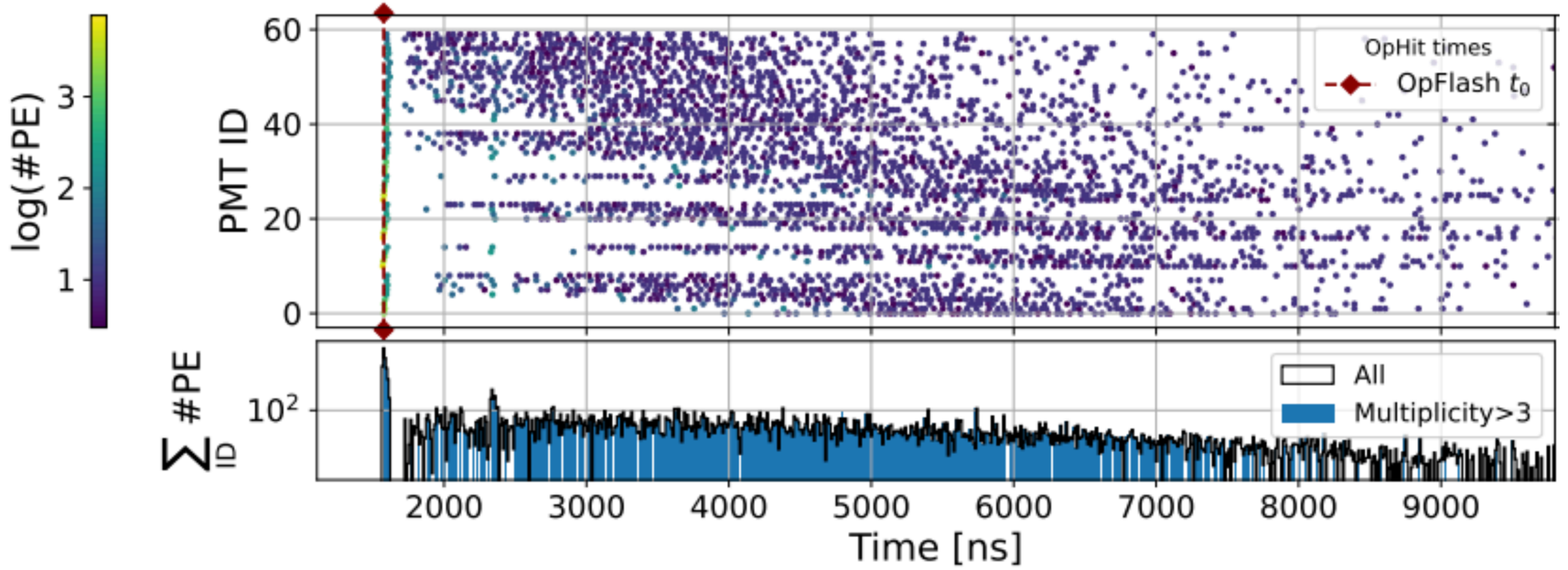


Illustration of the OpFlash finder reconstruction algorithm.

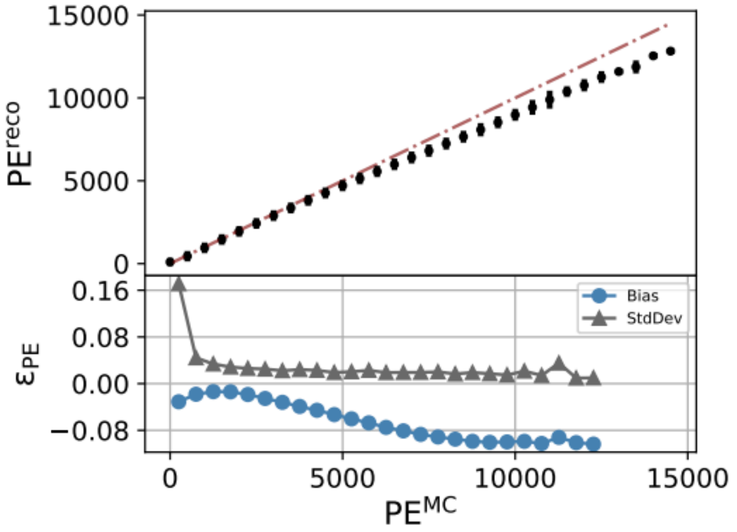


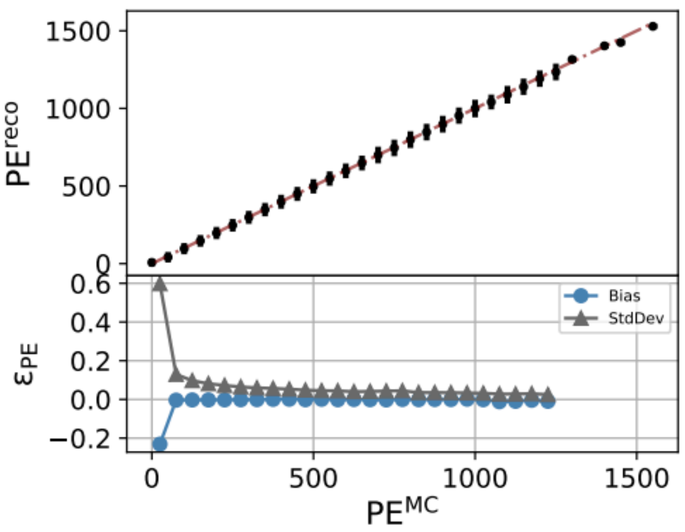
Reconstruction Performance

Calorimetry

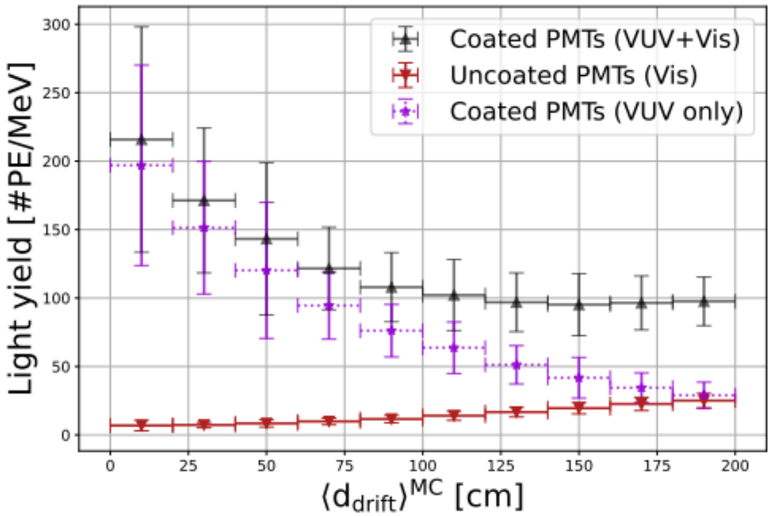
Number of reconstructed PE after deconvolution at OpHit level as a function of the total number of simulated photons within one channel

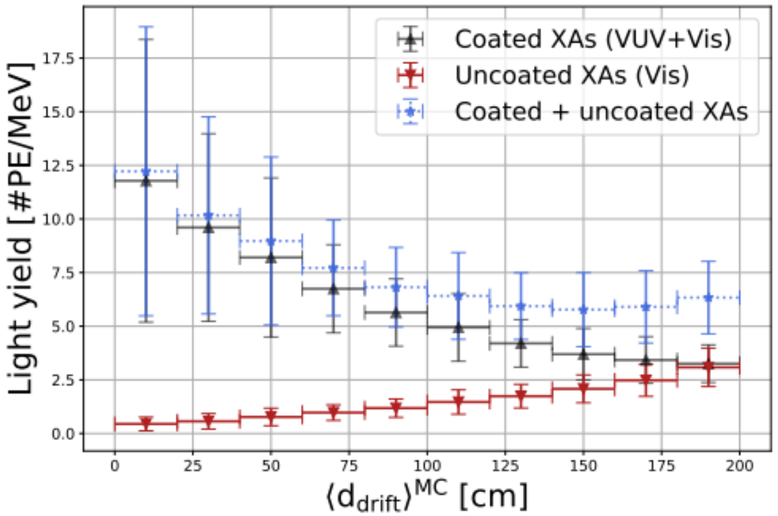
- The non-linear behaviour of PMTs is clearly visible from 3000 PEs onwards.





Expected LY in SBND as a function of the mean drift distance for the different **PMT (left)** and **X-ARAPUCA (right)** flavours

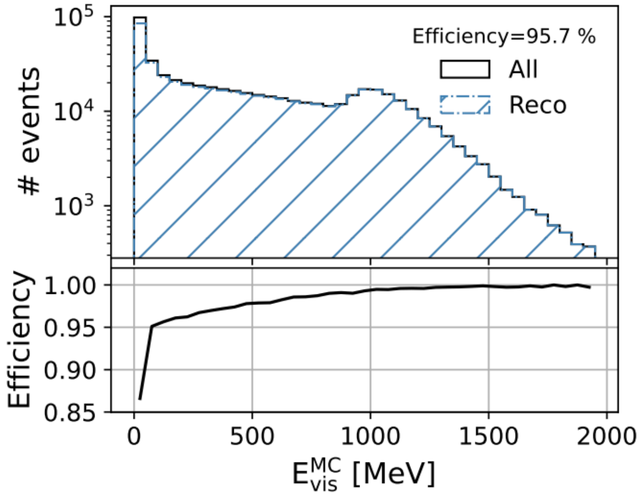


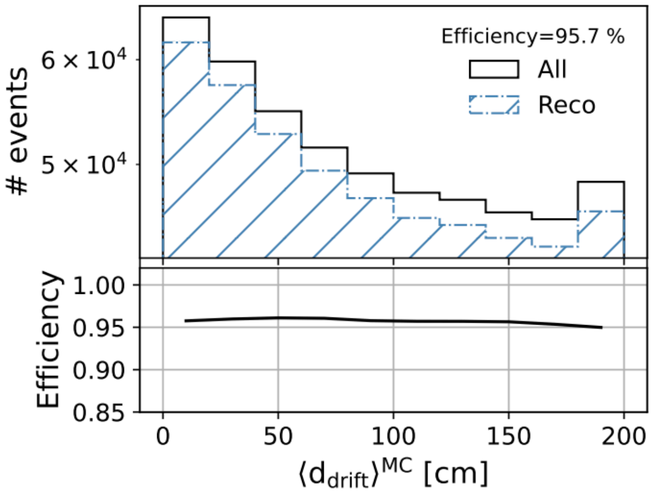


Reconstruction Performance

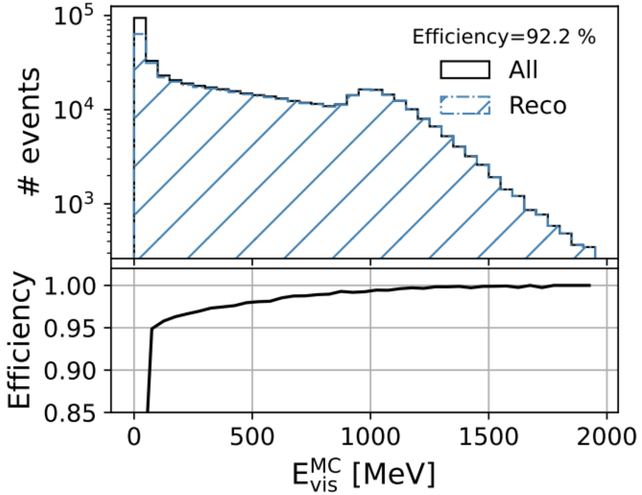
OpFlash reconstruction efficiency

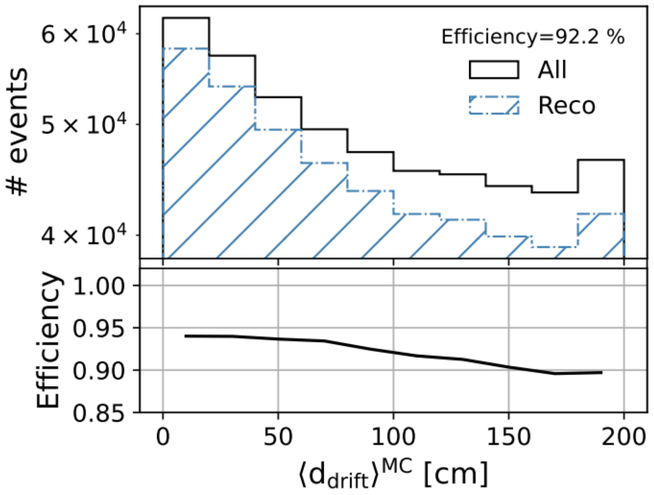
The OpFlash reconstruction efficiency is defined as the ratio between the number of interactions with a reconstructed OpFlash and the total number of interactions





OpFlash reconstruction efficiency as a function of the deposited energy (left) and drift distance (right) for **PMTs (top)** and **X-ARAPUCAs (bottom)**.

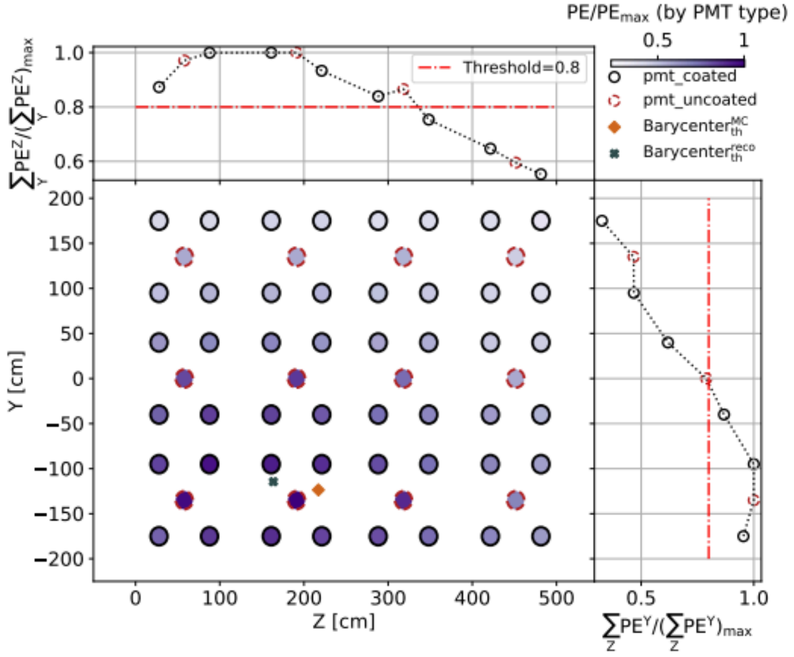


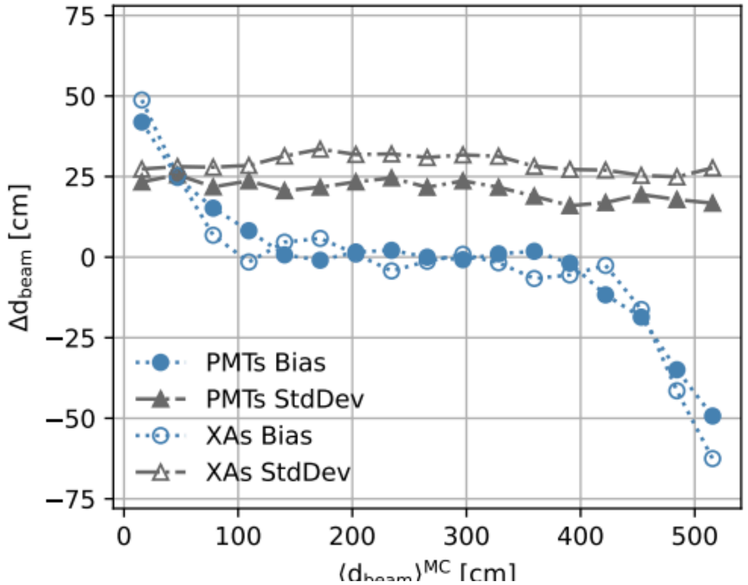


Reconstruction Performance

Position resolution

- (Y, Z) reconstruction
  - A simple threshold algorithm: we averaged the (Y, Z) coordinates of the PDs whose signal differs from the hottest one by less than a 20% ⇒ To minimize border effects





Bias and resolution in the estimation of the interaction point in the beam direction (Z) for the PMTs (full marks) and X-ARAPUCAs (empty marks) flashes

Reconstruction Performance

Position resolution

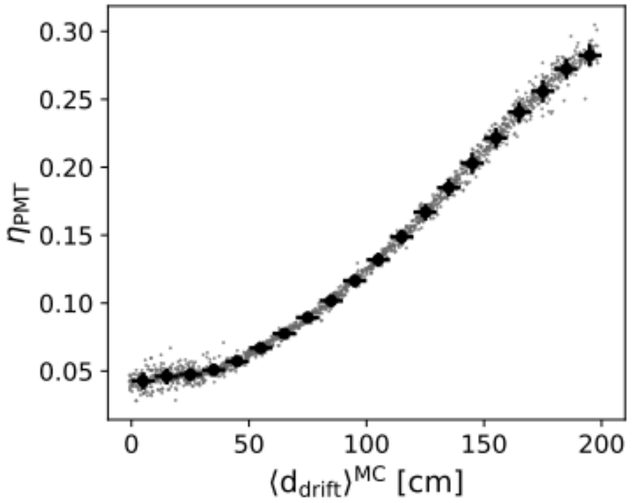
- **Drift distance** (X in our coordinates system)

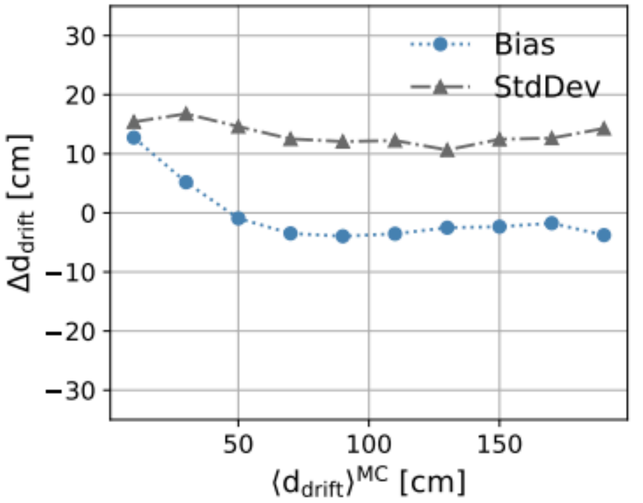
- A fairly unique feature of SBND's PDS design

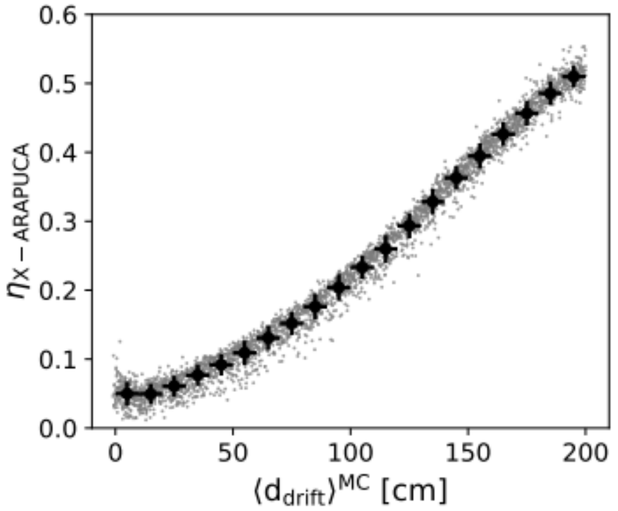
- We do it by defining the η parameter (for both PMTs and X-ARAPUCAs)

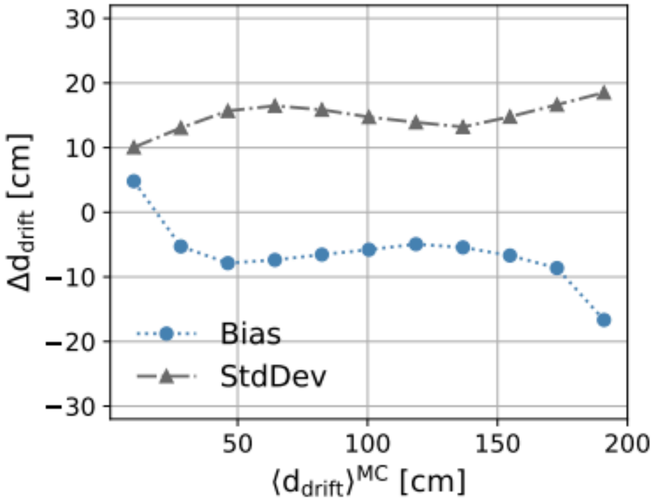
$$\eta_{\mathrm{PMT}} \equiv \frac{\#PE_{uncoated}}{\#PE_{coated}}$$

$$\eta_{\mathrm{X-ARAPUCA}} \equiv \frac{\#PE_{uncoated}}{\#PE_{coated} + \#PE_{uncoated}}$$





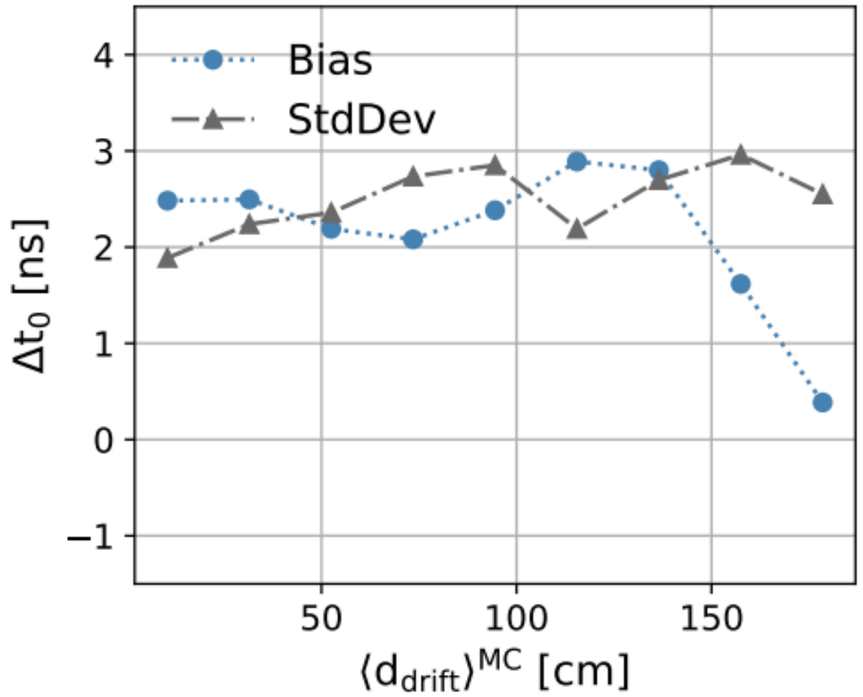


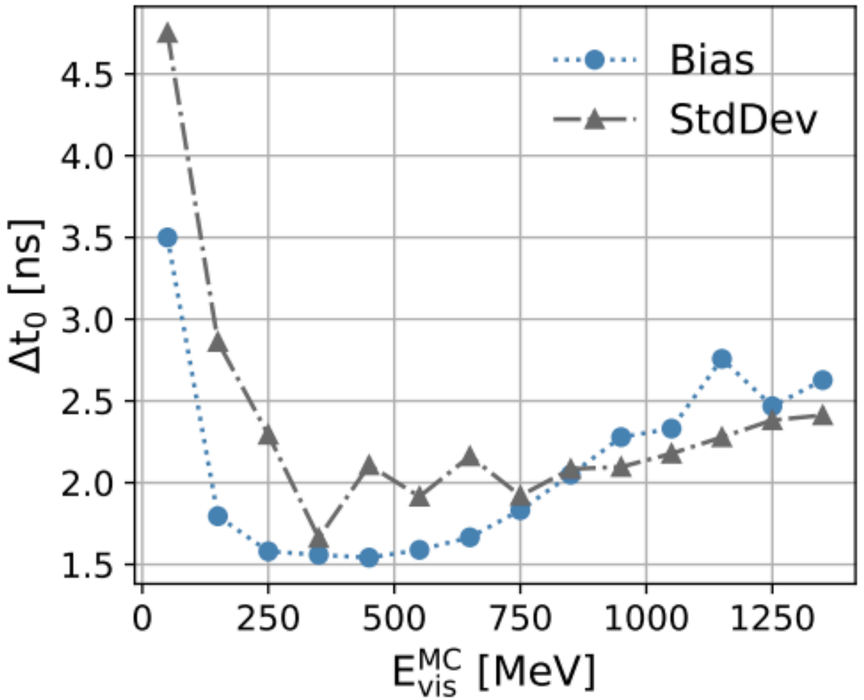


Reconstruction Performance

Time resolution

- Once $\langle X_{rec} \rangle$ has been estimated (using η curve), we can correct for the light propagation delay:





Time resolution of the **PMTs system** as a function of the drift distance and deposited energy after corrections for propagation effects

Summary

- In the LArTPC community, light signals have been traditionally used only for triggering purposes.
- SBND is the LArTPC detector using the most advanced Photon Detection System so far
  - Its innovative design allows us to explore and develop new applications of the scintillation light signals.
  - 3D reconstruction of the events (using only light signal)
  - ~1ns Time resolution
  - Calorimetry (Q+L)