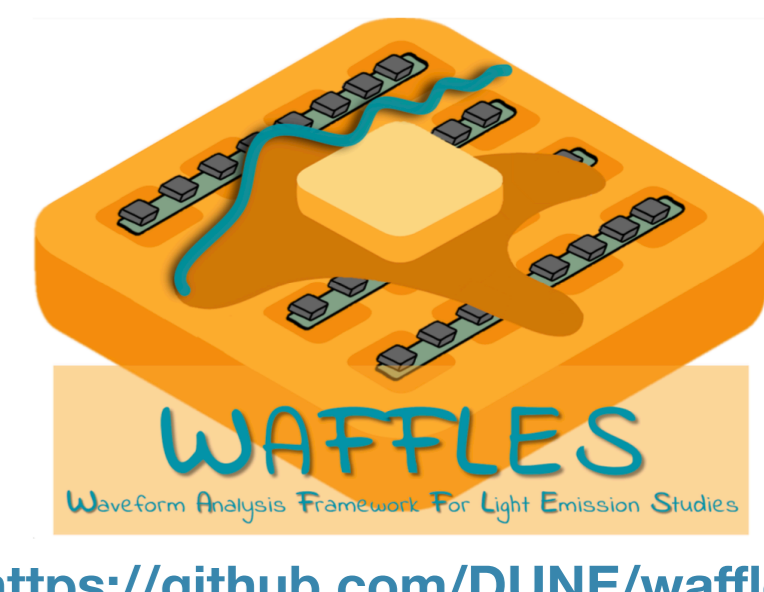


The Performance of DUNE's Vertical Drift Photon Detection System

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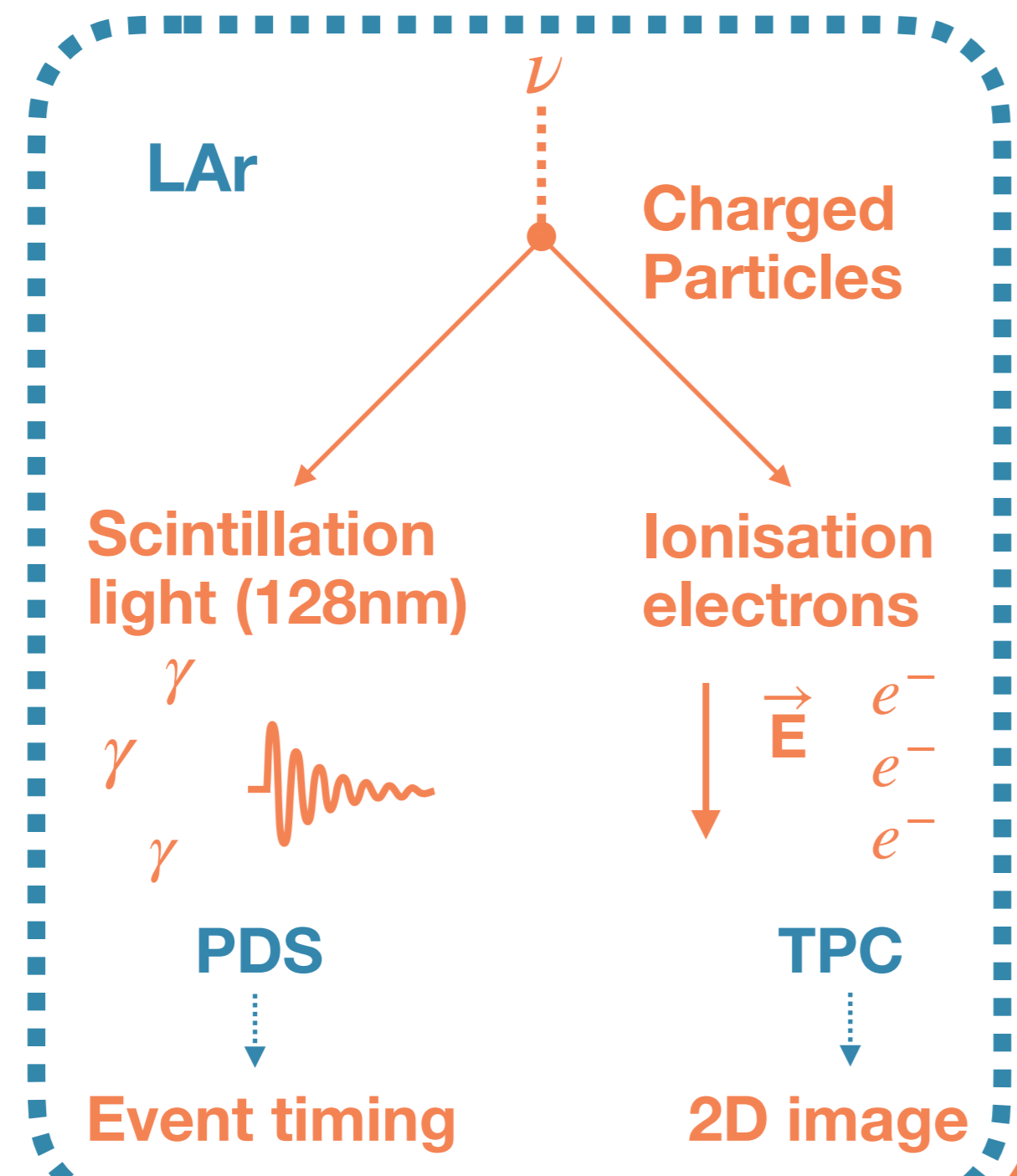
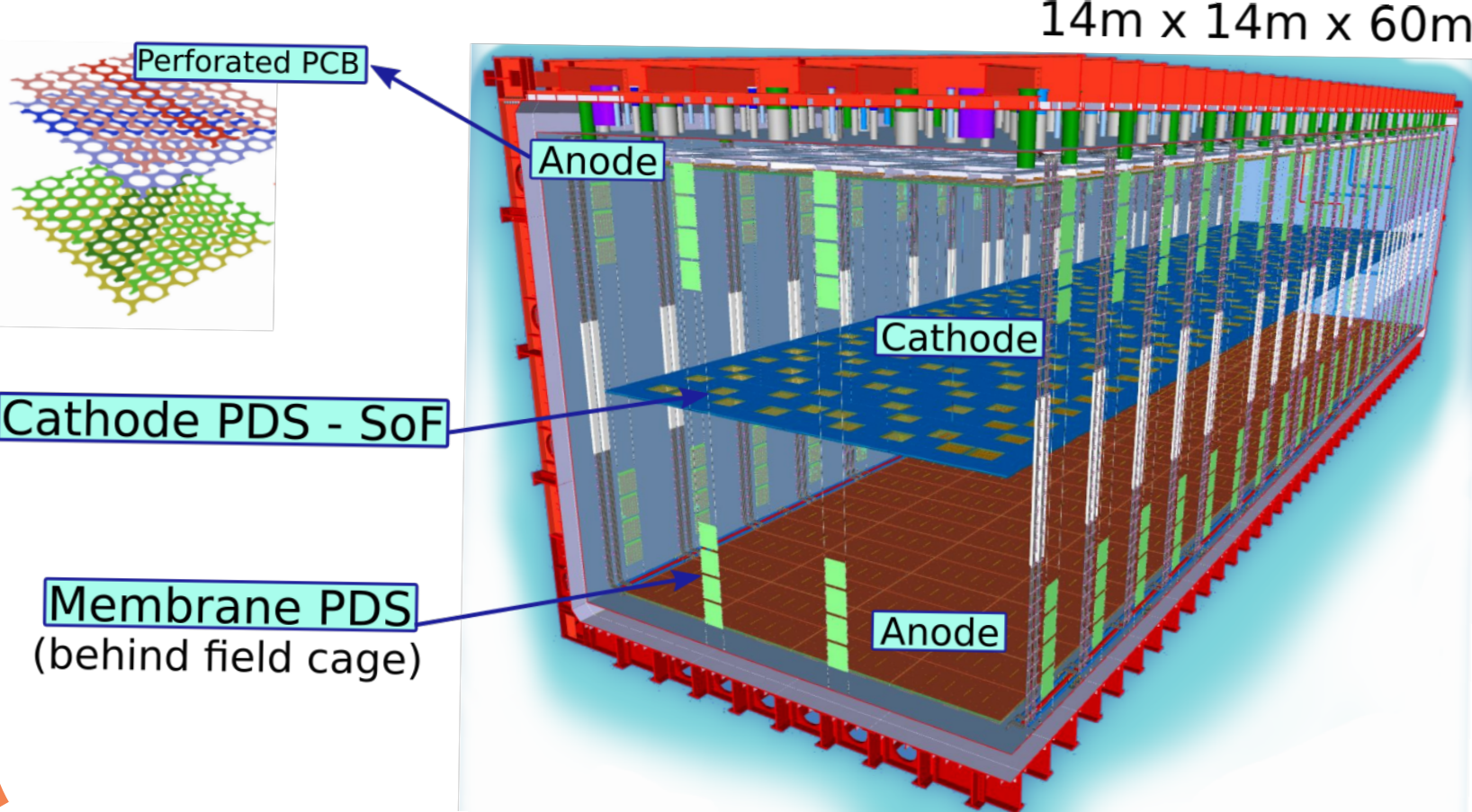


<https://github.com/DUNE/waffles>

1. Vertical Drift Far Detector

One of DUNE's Far Detectors will be instrumented with:

- Vertical Drift Liquid Argon Time Projection Chamber (VD-LArTPC).
- Photon Detection System (PDS).

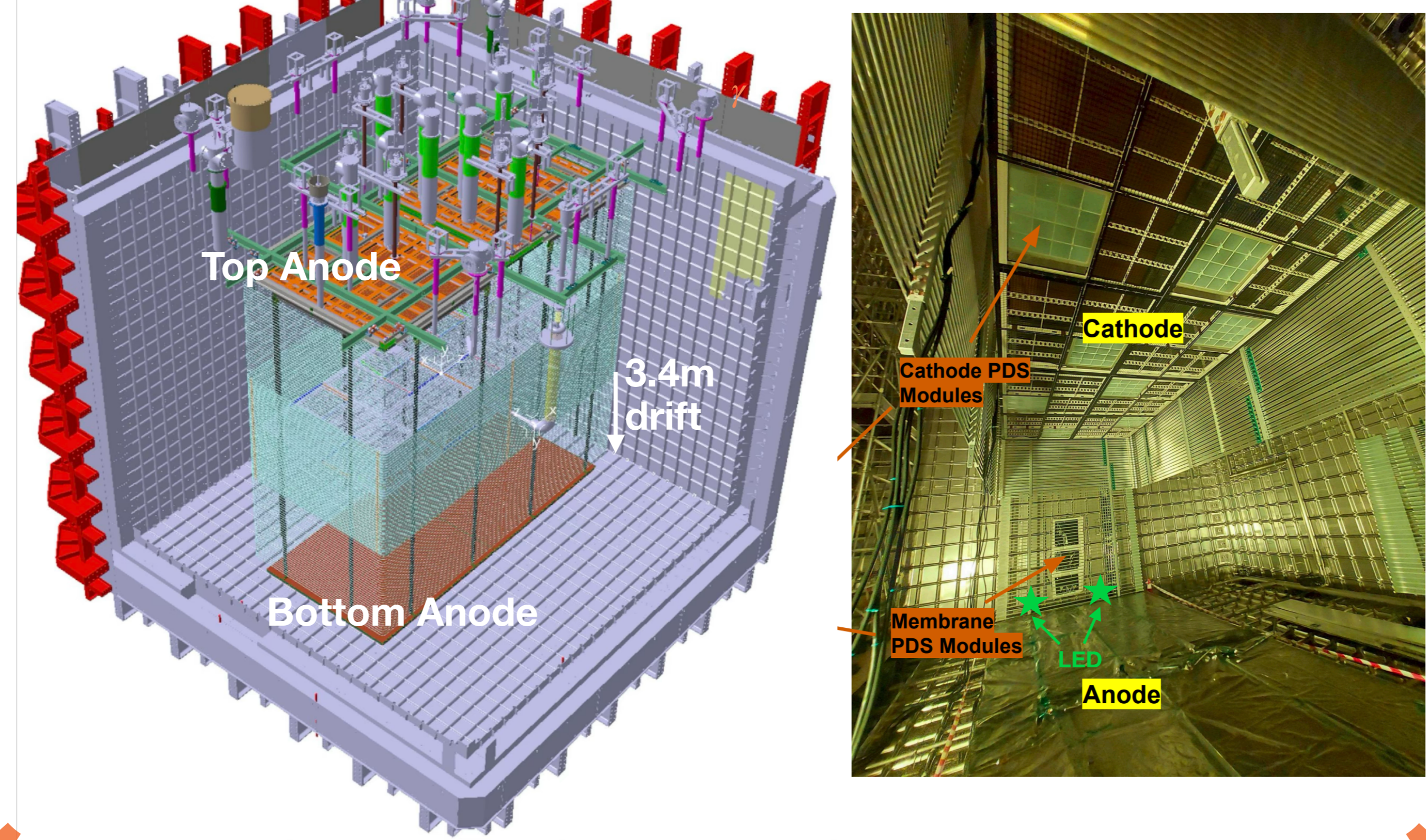


3. ProtoDUNE- VD

- 770-ton prototype of the DUNE Vertical Drift LArTPC operated at CERN Neutrino Platform.
- PDS modules installed on the cathode and detector membranes.

Validates integrated detector performance using:

- * SPS charged particle beam ($e^\pm, \pi^\pm, K^\pm, \mu^\pm, p$).
- * Laser (TPC) and LED (PDS) calibration systems.
- * Cosmic-rays (overground operation).



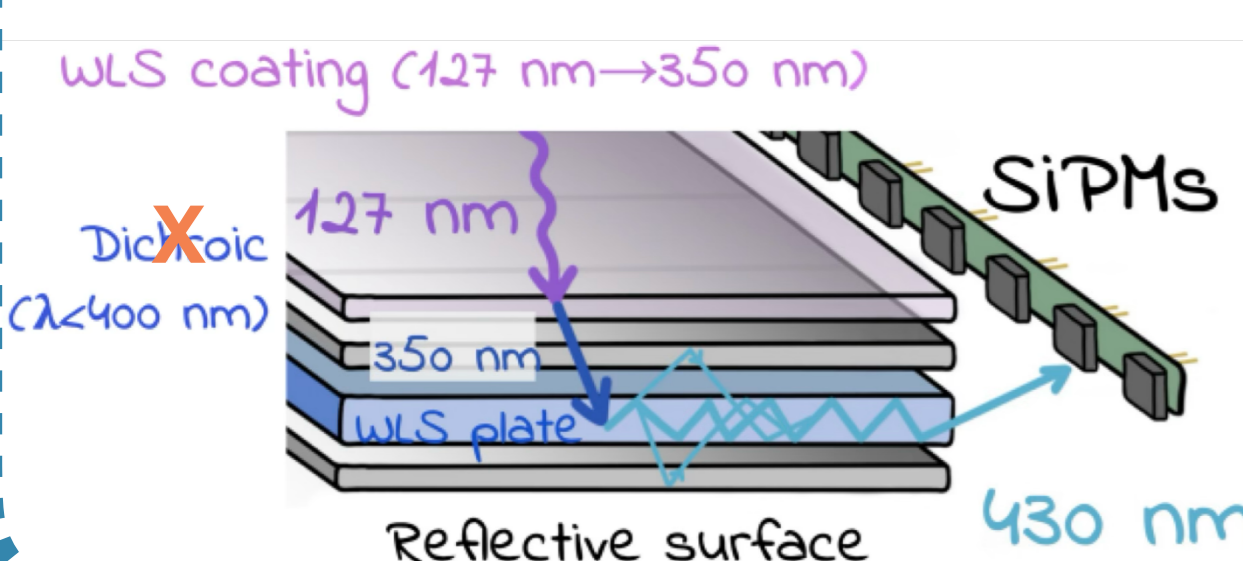
2. The Photon Detection System

Why the PDS?

- Interaction timestamp (t_0)
- Triggering and event selection
- Interaction depth
- Sensitivity from single photons to highly energetic events

The X-Arapuca

Captures 128 nm scintillation photons, shifts them to visible wavelengths, and guides them to SiPM arrays, where they are converted into electrical signals for readout [1]



Signal-over-Fiber

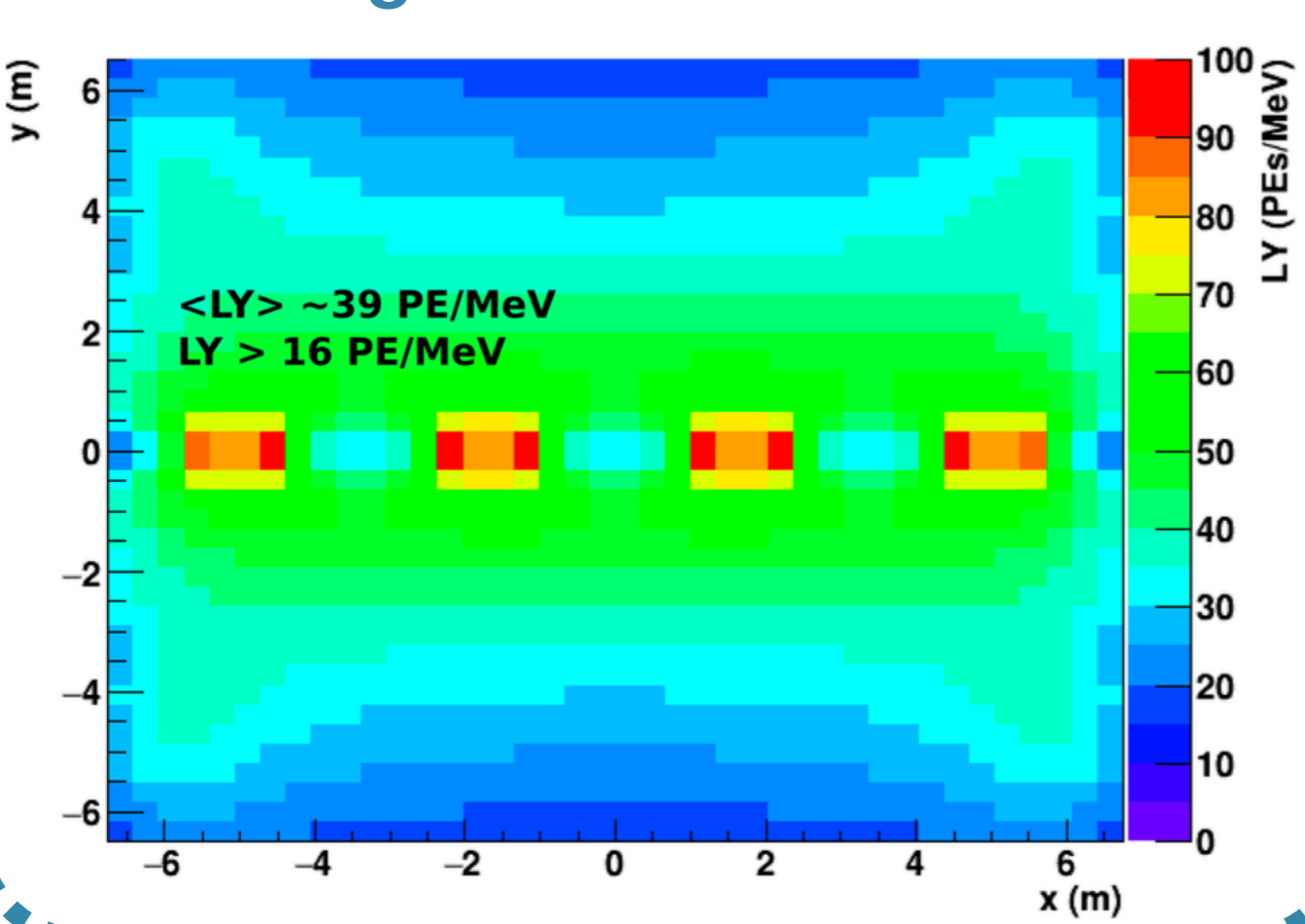
Transmits detector signals optically from the cathode to the readout system [2].

Power-over-Fiber

Delivers power optically from an infrared laser to electronics on the cathode[3].

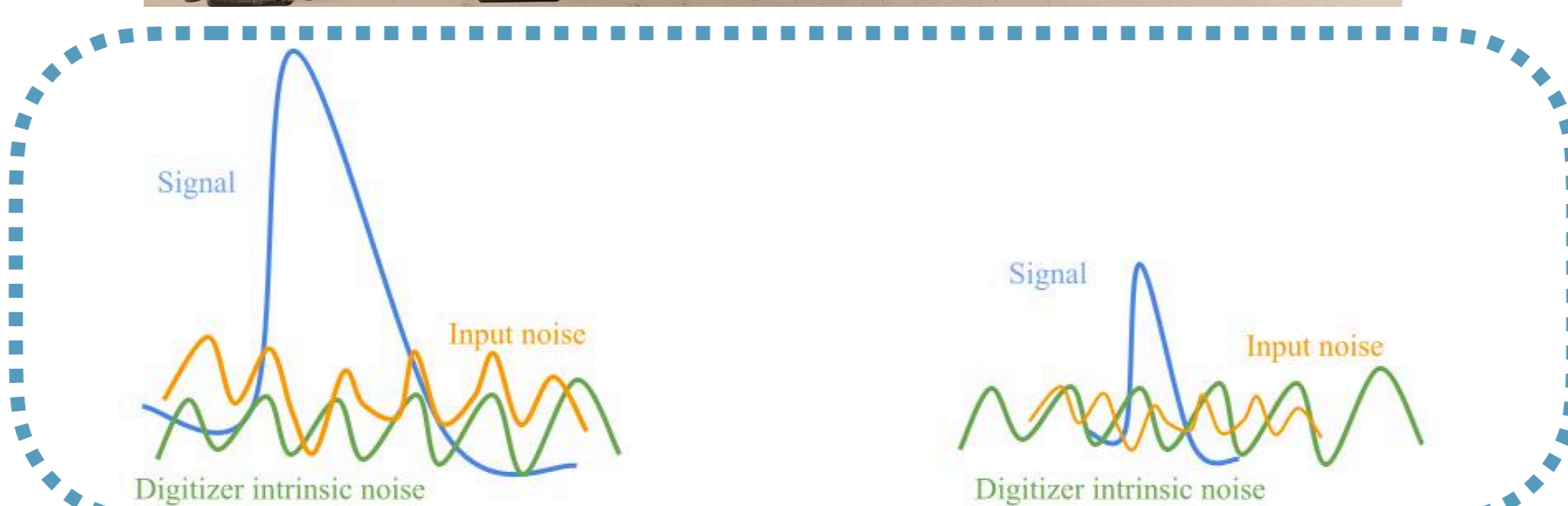
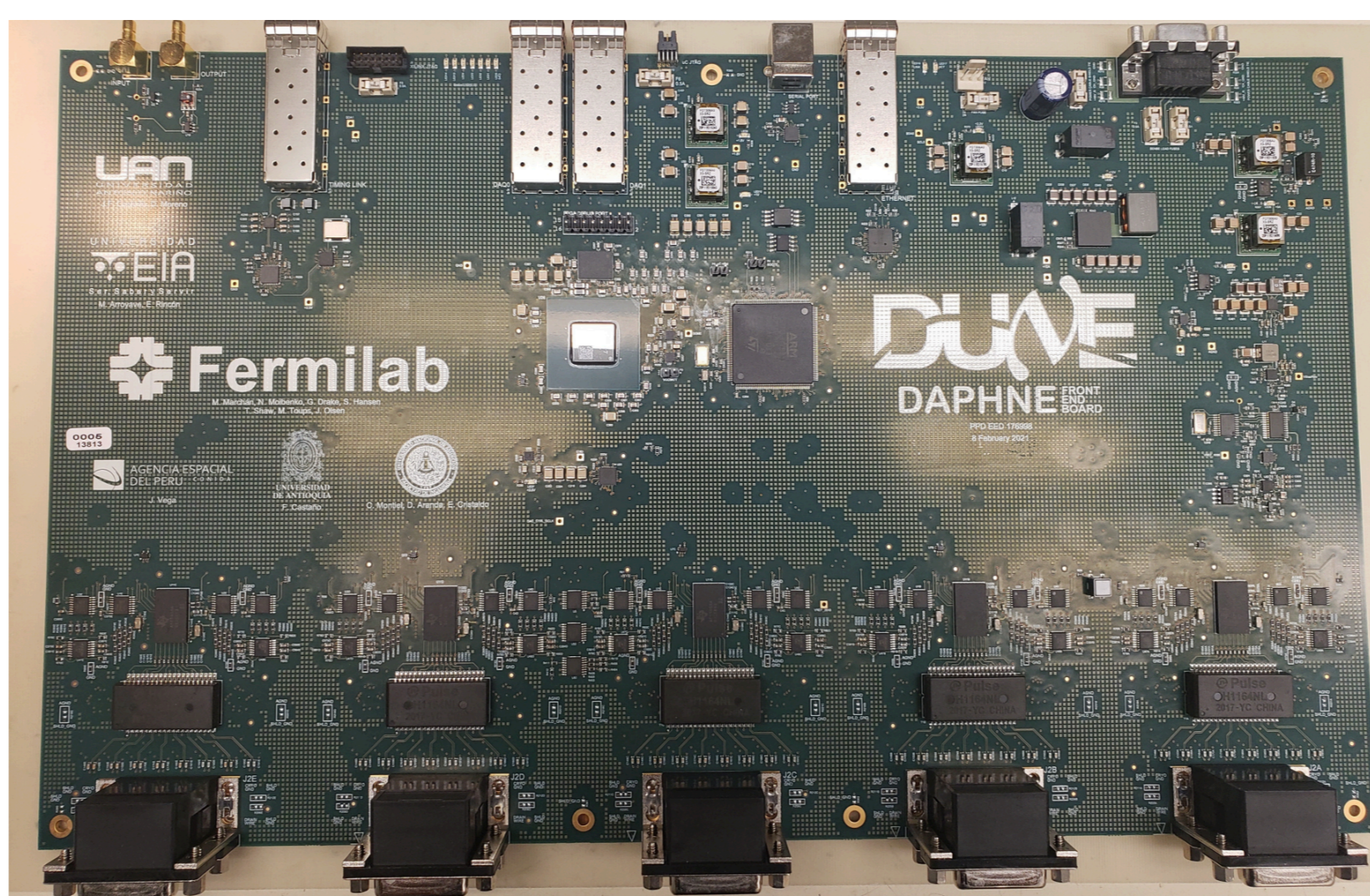
PDS- VD

To enhance light yield and uniformity, half of the photon detectors are installed on the -300 kV cathode, requiring the development of novel optical readout and powering technologies.



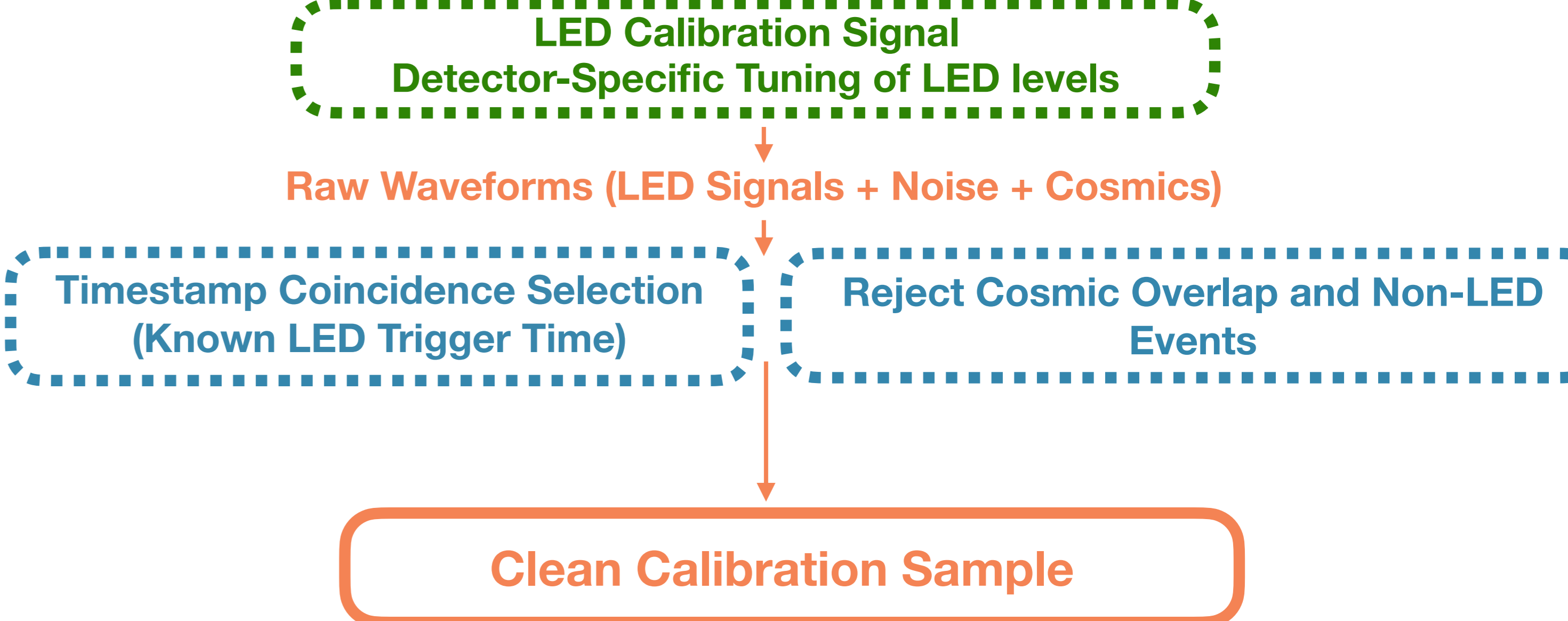
4. Signal Digitization: DAPHNE

- Developed for digitization of DUNE-PDS signals.
- Implements a 14-bit ADC with variable gain.
- > Gain selection is done to optimize the signal-to-noise ratio (SNR) and dynamic range.



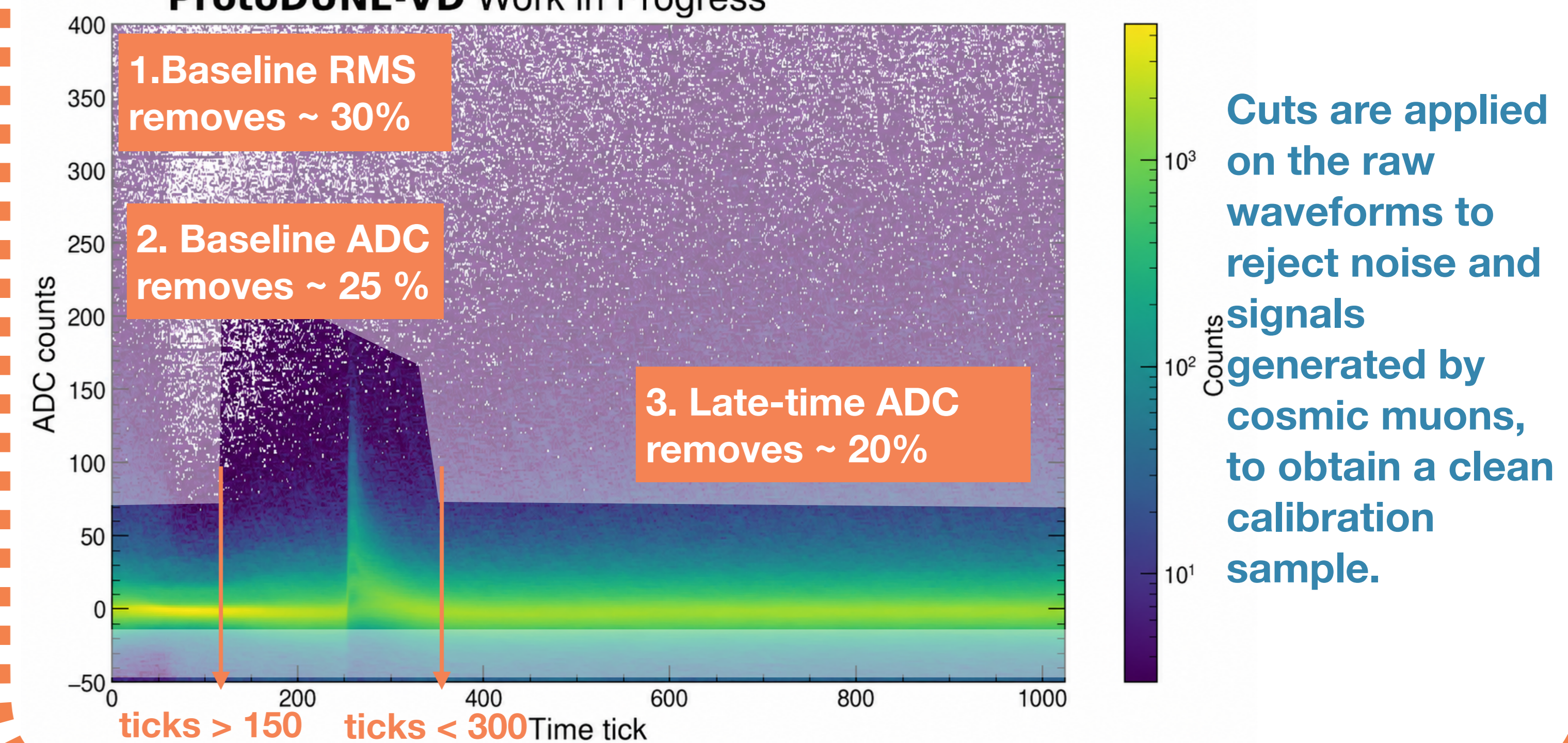
5. PDS analysis

Waffles is a Python framework for ProtoDUNE PDS analysis. It provides standardized tools for waveform processing, detector characterization, calibration and performance studies.



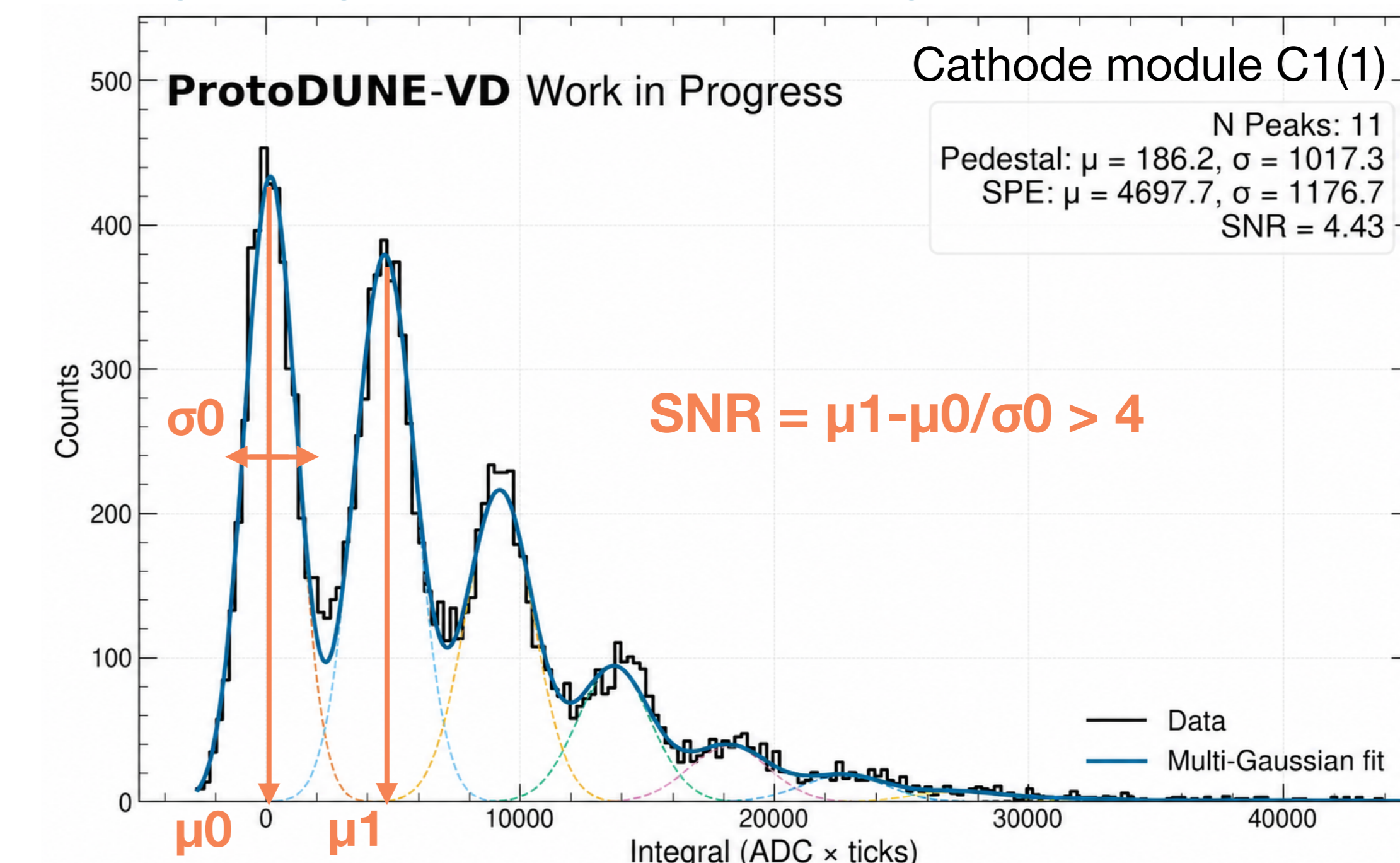
6. Signal Processing

ProtoDUNE-VD Work in Progress



7. Single-Photon Sensitivity

Charge integral of the calibration signals :



The signal-to-noise ratio (SNR) is extracted from the separation between the baseline pedestal peak and the first single-photon peak.

The SNR of the individual photon-detectors + electronics is used to evaluate how well the PDS can measure single-photon signals.

[1] A.A. Machado et al., "The X-ARAPUCA: an improvement of the ARAPUCA device," arXiv:1804.01407 (2018)
 [2] S. Sacerdoti (DUNE Collab.), "Signal and Power transmission over Fiber in the DUNE Far Detector," arXiv:2412.10177 (2024)
 [3] M. A. Arroyave et al., JINST 19, P10019 (2024), doi:10.1088/1748-0221/19/10/P10019.