Calibration of the Photon Detection System of SBND

XVI CPAN DAYS

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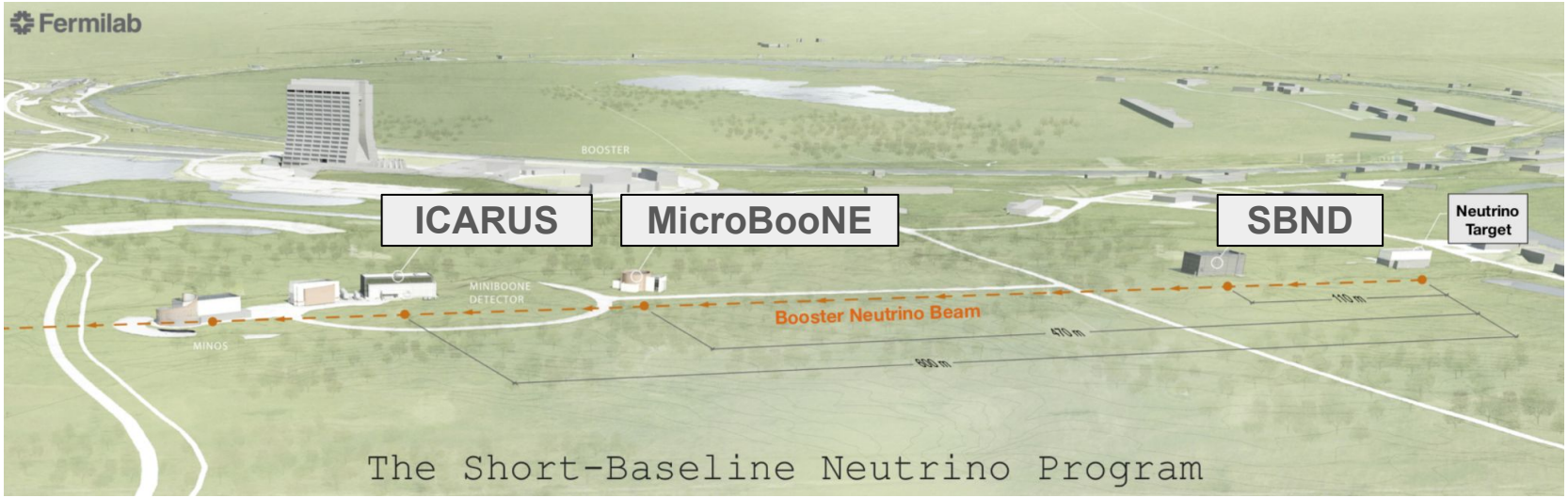
On behalf of the SBND Collaboration

November 2024

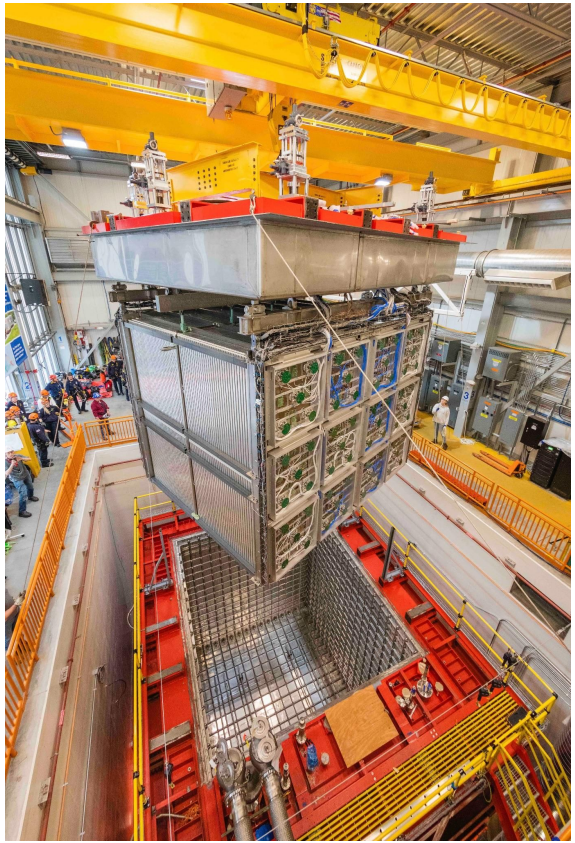
SBN Program:



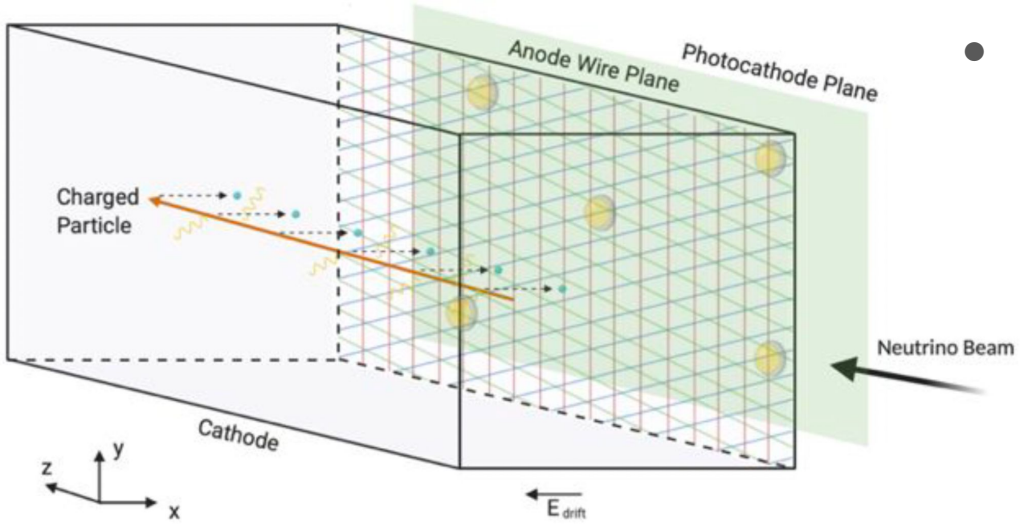
- The **S**hort **B**aseline **N**ear **D**etector (SBND) is the closest of the three detectors that integrate the Short-Baseline Neutrino Program at Fermilab.
- Three detectors based on the **L**iquid **Ar**gon **T**ime **P**rojection **C**hamber (LArTPC) technology to detect neutrinos produced at the **B**ooster **N**eutrino **B**eam (BNB).
- SBN physics goal: search for light ($\Delta m^2 \sim 1eV^2$) sterile neutrino oscillations

Short Baseline Neutrino Detector:

- SBND has a rich physics program:
  - Closest detector to the neutrino beam. It will characterize the unoscillated neutrino flux.
  - Will record ~2M neutrino interactions per year, allowing the study of interactions with unprecedented precision at ~1 GeV energies.
  - Other BSM searches (HNL, light dark matter…)
  - R&D for future LArTPC experiments (X-Arapuca, TPB-coated foils, WLS coated and uncoated detectors…)
- Data taking since July 2024



Liquid Argon Time Projection Chamber:



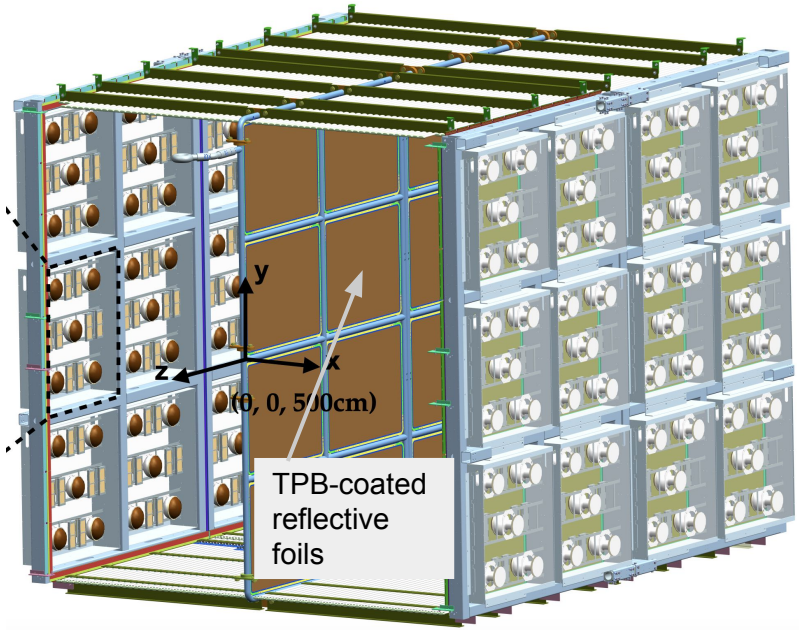
- Two complementary signals:
  - Ionization electrons: drifted through an electric field and detected at the charge readout plane.
  - Scintillation photons: detected by the photon detection system.

- Ionization signals traditionally used for calorimetric and topological reconstruction.
- Scintillation signals traditionally used for trigger purposes. Full potential of scintillation signals has not been explored yet.

SBND Photon Detection System:

- SBND Photon Detection System aims at maximizing the physics output that can be obtained from scintillation signals through an innovative design.

PASSIVE COMPONENTS

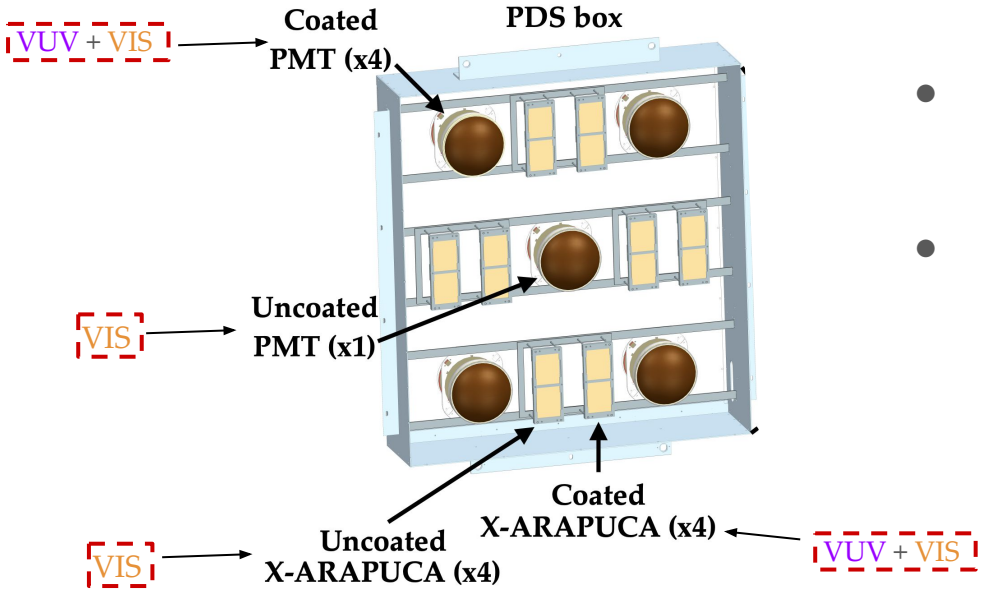


- Reflected foils coated with Tetra-PhenylButadiene (TPB) WLS installed at the cathode.
  - Absorbs VUV photons and re-emits them with a visible wavelength.
- PDS sensitive to two light components:
  - Primary: VUV (main component).
  - Reflected: Visible (extra component).

SBND Photon Detection System:

- SBND Photon Detection System aims at maximizing the physics output that can be obtained form scintillation signals through an innovative design.

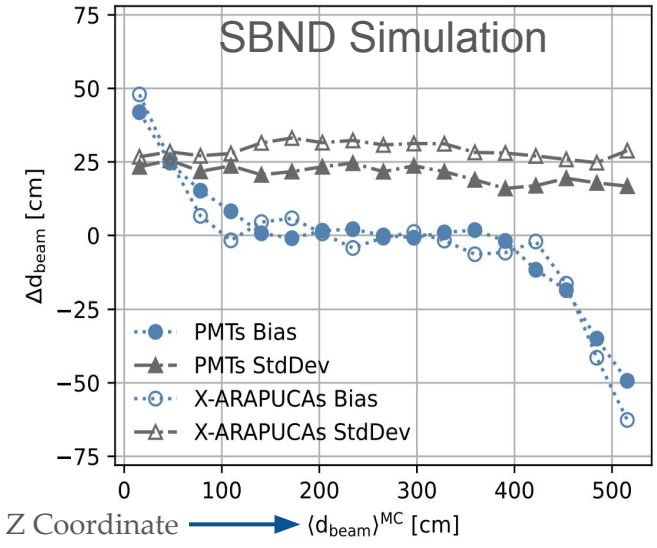
ACTIVE COMPONENTS

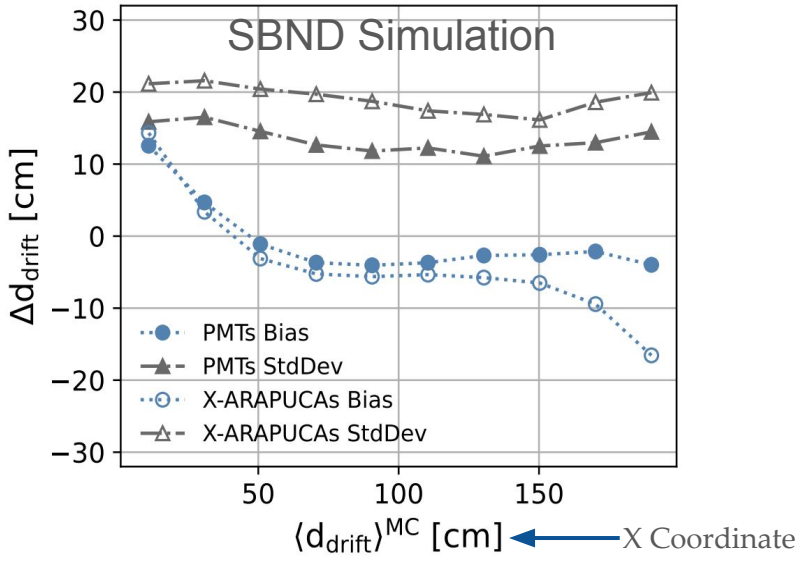


- Detection of VUV light is challenging: wavelength shifting compounds are used.
- Primary system: 120 8”Hamamatsu Photomultiplier tubes (PMTs). Well know technology.
- 192 X-ARAPUCAs: technology under development (R&D). See Jorge Romeo’s talk in the instrumentation session.
  - Acts as a light trap: WLS and dichroic filters.
  - Readout by SiPMs.

SBND Photon Detection System:

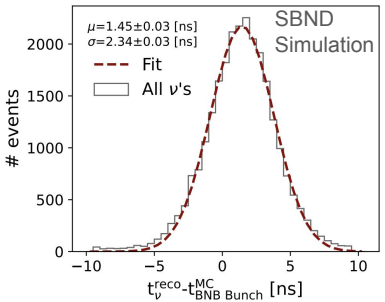
- SBND Photon Detection System allows for a 3D reconstruction using only light signals:
  - High granularity of photon detectors in the detection plane allows for YZ position estimation.
  - Being sensitive to two light components allows us to estimate the drift distance.

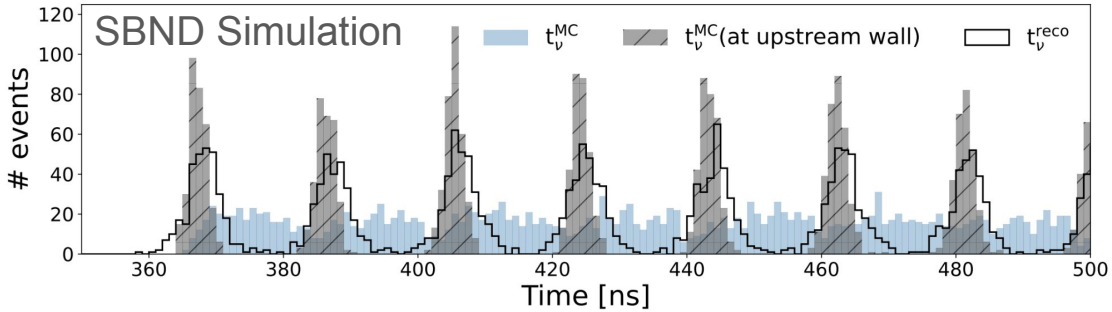




SBND Photon Detection System:

- The 3D position reconstruction capabilities combined with a ~ns timing resolution allows for the reconstruction of the BNB neutrino beam internal structure:





- The reconstruction capabilities of such an innovative PDS have been shown at the simulation level:

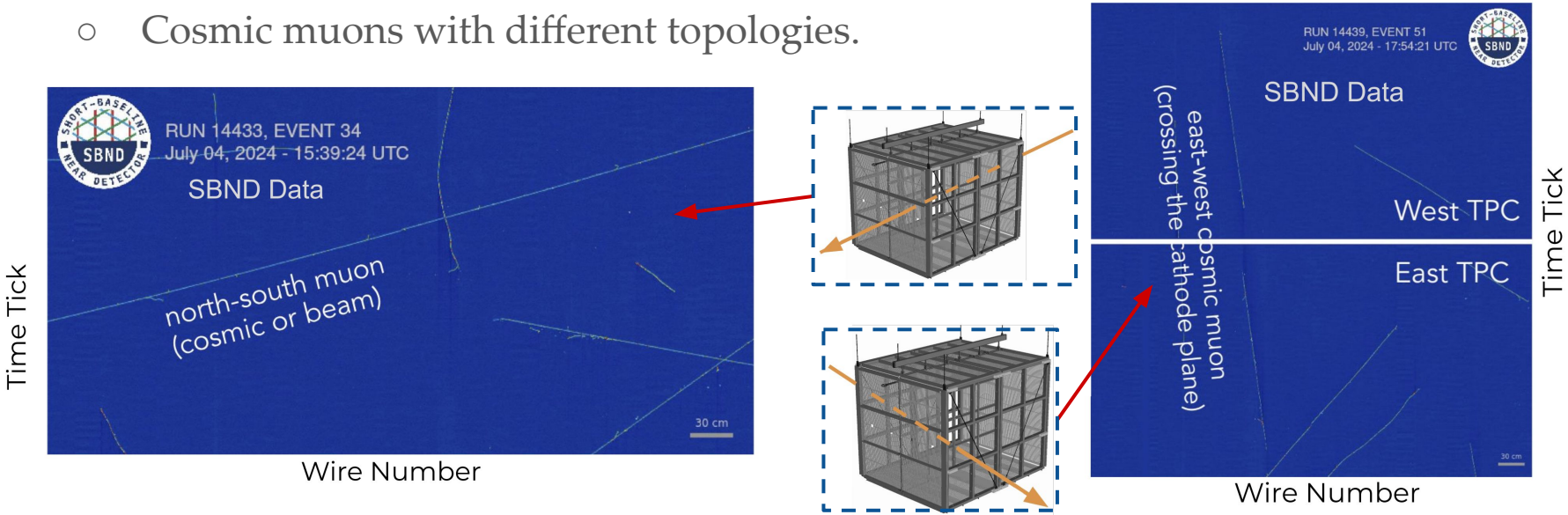
Eur. Phys. J. C (2024) 84:1046
https://doi.org/10.1140/epjc/s10052-024-13306-3
THE EUROPEAN PHYSICAL JOURNAL C
Regular Article - Experimental Physics

Scintillation light in SBND: simulation, reconstruction, and expected performance of the photon detection system

SBND Collaboration[a]

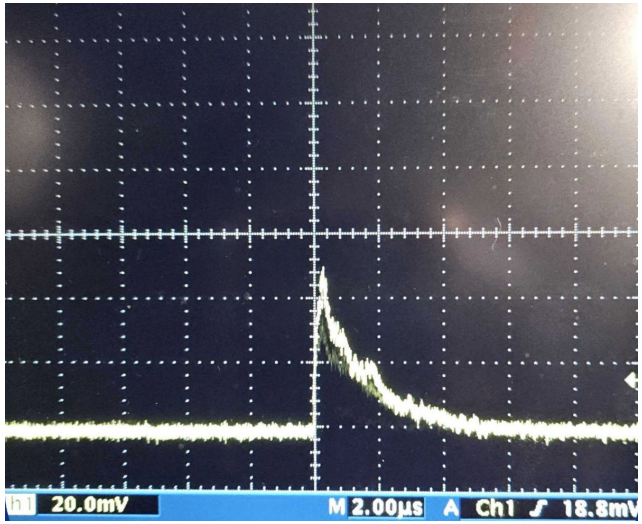
Current Status:

- Detector operating at nominal voltage (-100kV) since 3rd July. Has been collecting BNB data until the summer shutdown (July 12th).
- Data taking since July 12th until the end of BNB summer shutdown (mid-November) has been focused on commissioning and calibration:
  - Cosmic muons with different topologies.



PDS Status:

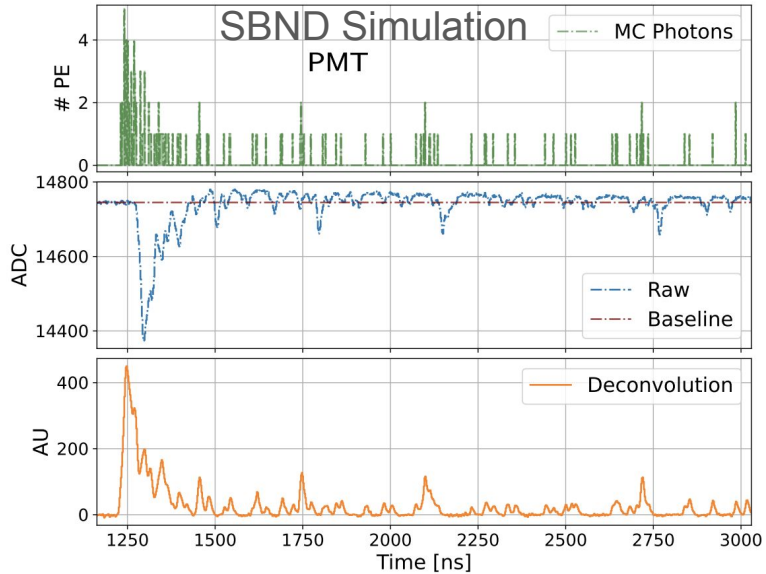
- X-ARAPUCA System:
  - First signals have been observed.
  - Now starting its commissioning phase.



- PMT System:
  - Commissioning already finished.
  - Starting calibration phase. Using cosmic data collected during summer.
  - Calibration studies includes:
    - Detector response.
    - Tuning of reconstruction algorithms.
    - Detector properties.

PMT Calibration:

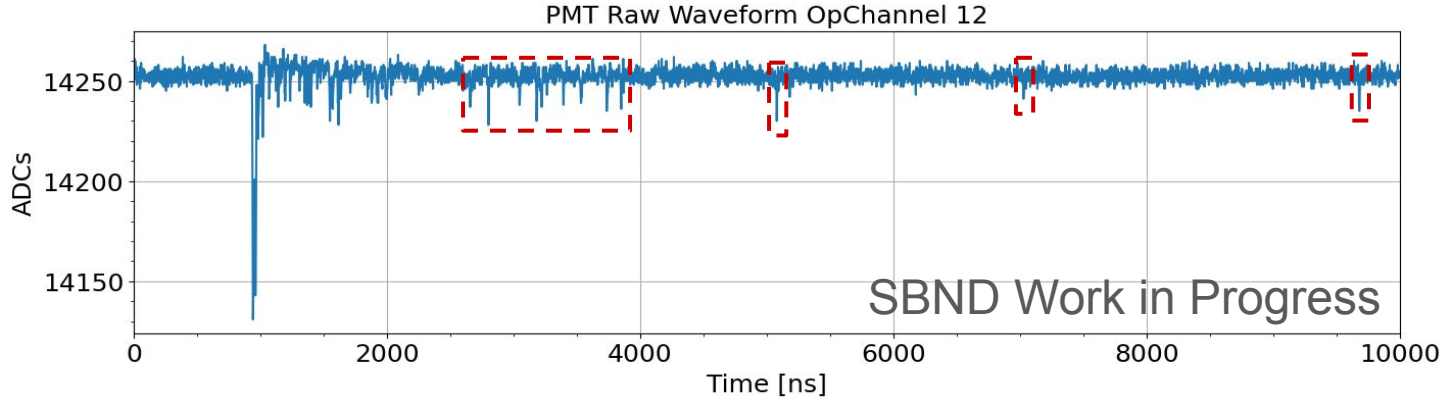
- The reconstruction of the digitized signals measured by the photon detection system is the first step in the reconstruction chain.
  - SBND uses a deconvolution-based algorithm to recover the original scintillation signal.



- The deconvolution algorithm requires the characterization of the **S**ingle **E**lectron **R**esponse (SER).
  - Response of the PMT to a single photo-electron.
  - This calibration is crucial for further reconstruction stages.

PMT Calibration:

- How is the calibration done?
  - We have developed an algorithm to find pulses corresponding to single photo-electrons on scintillation signals



- Averaging over these pulses we can obtain the response of our devices to a single photon input.
- This is just the first step in the calibration, there is much exciting work ahead!

Conclusions:

- 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.
  - Already taking data until Fermilab's accelerator long shutdown ~2027.

- A precise calibration of the devices integrating the photon detection system is crucial for exploiting the reconstruction capabilities.

Thanks for your attention!