TAGGING NEUTRINO EVENTS WITH THE SBND'S PHOTON DETECTION SYSTEM

New Perspectives 23

06/26/23

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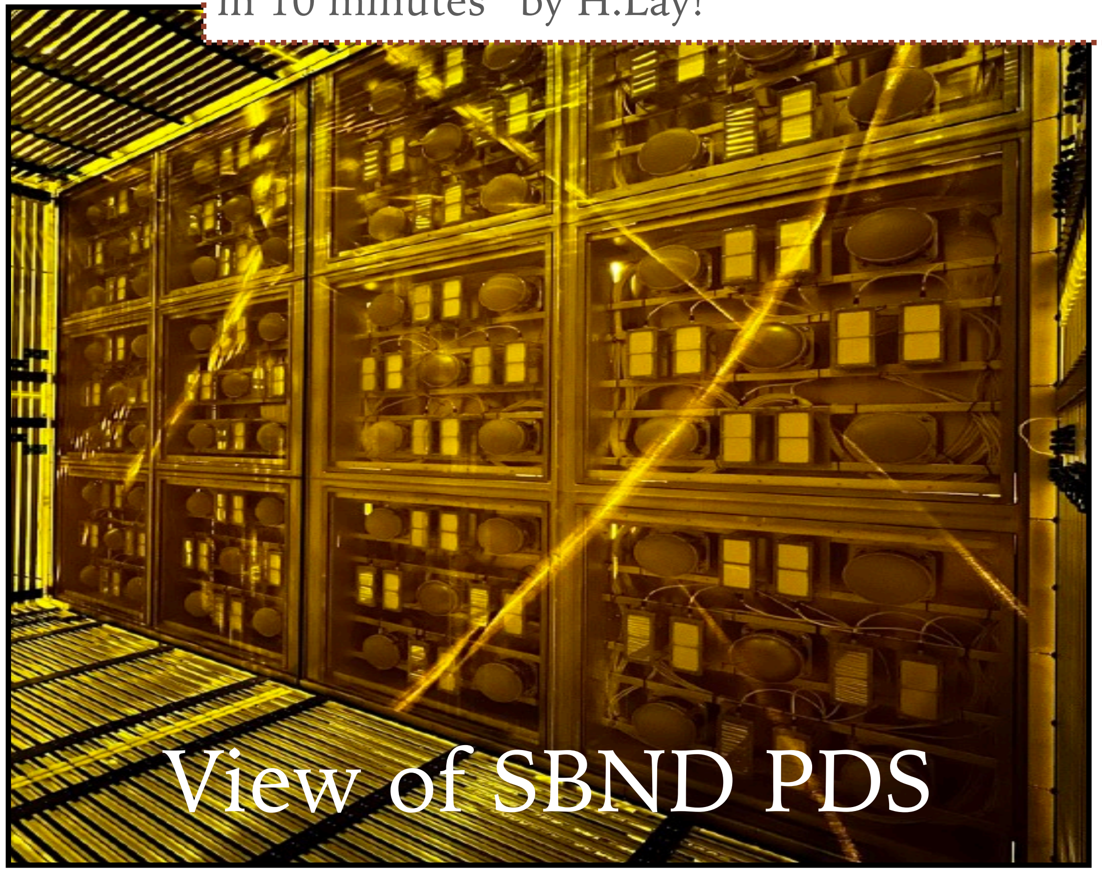
DOE report number: SLIDES-23-118-V

MOTIVATION

More details about the SBND detector in "SBND in 10 minutes" by H.Lay!

- Liquid Argon Time Projection Chambers (LArTPCs): two complementary signals
  - Ionization charge provide:
    - Near photographic images of neutrino interactions + calorimetry
  - Scintillation light: mainly used for trigger purposes *thus far*



- LAr is a **very prolific scintillator**: a similar amount of light/charge is produced at the operational electric fields
- New experiments like SBND are focusing on **harnessing the potential of the light signals with its pioneering Photon Detection System (PDS)**

OUTLINE

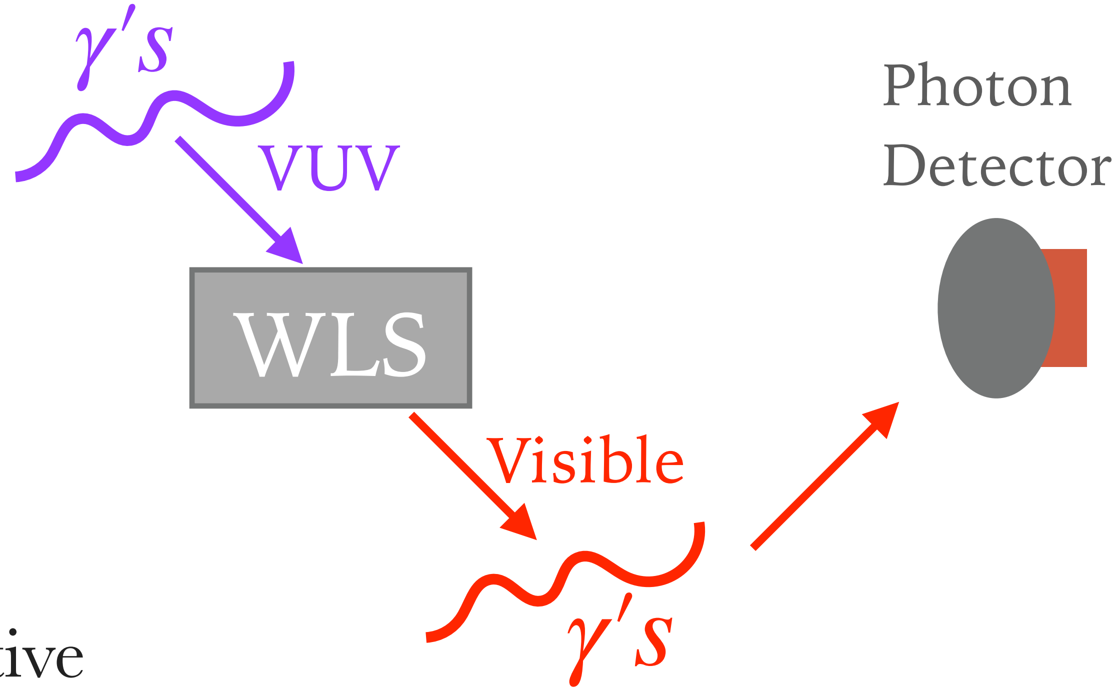
What's new?

My talk:

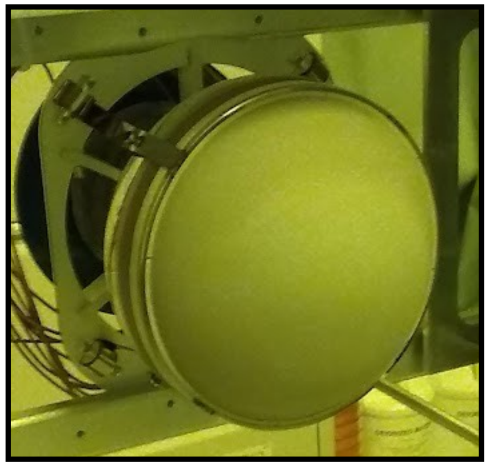
1. SBND PDS system design
2. Signal reconstruction
3. Applications

SCINTILLATION LIGHT DETECTION

- Scintillation light emission: 128 nm (VUV)
- Detection challenging: VUV light absorbed by most materials
- Common technique: wavelength shifters (WLS)
  - Re-emits photon in the visible spectrum, where most photon detectors (PD) are sensitive

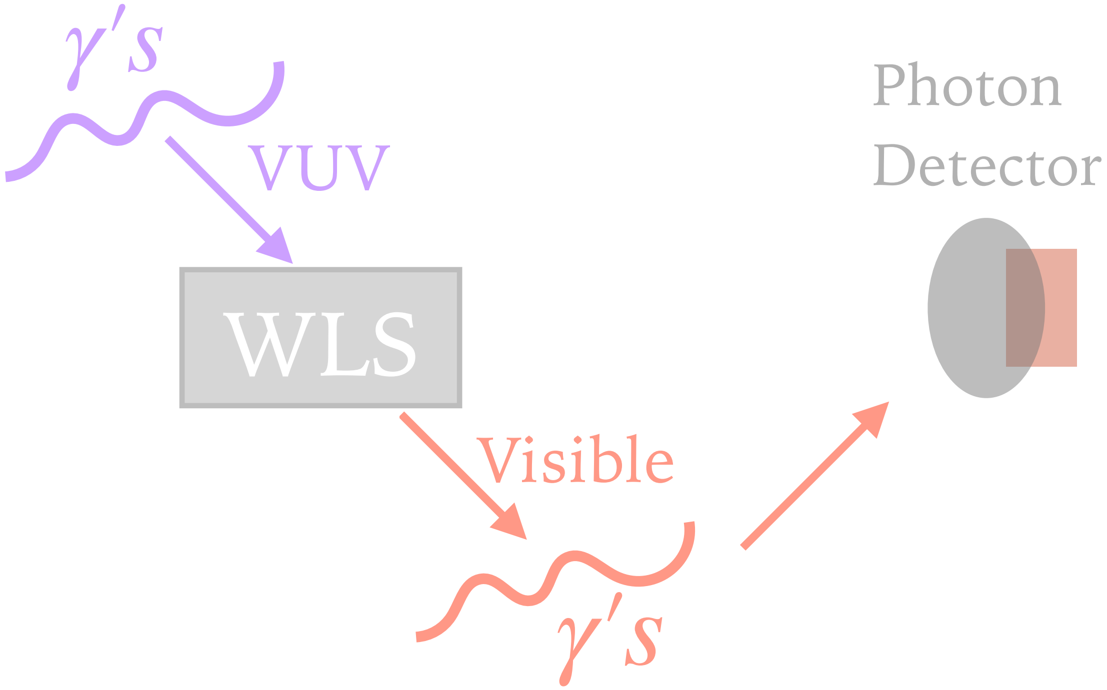


PDS components
(traditional approach)

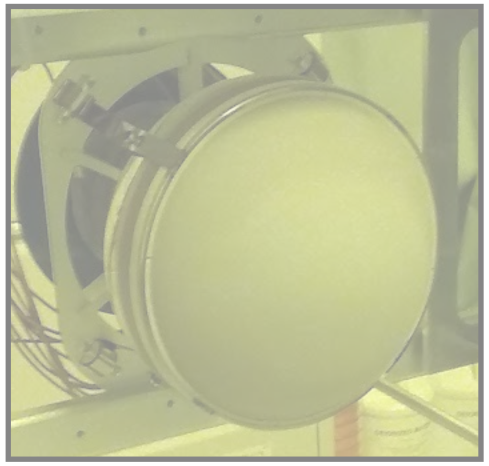


Place WLS component in front of the PD (coating, plate covers…)

The SBND PDS takes the wavelength shifting technique a step further!

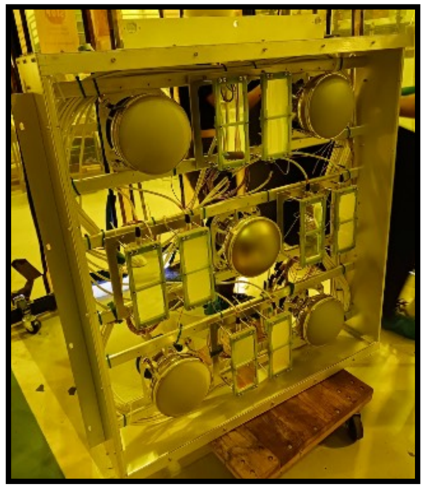


PDS components (traditional approach)

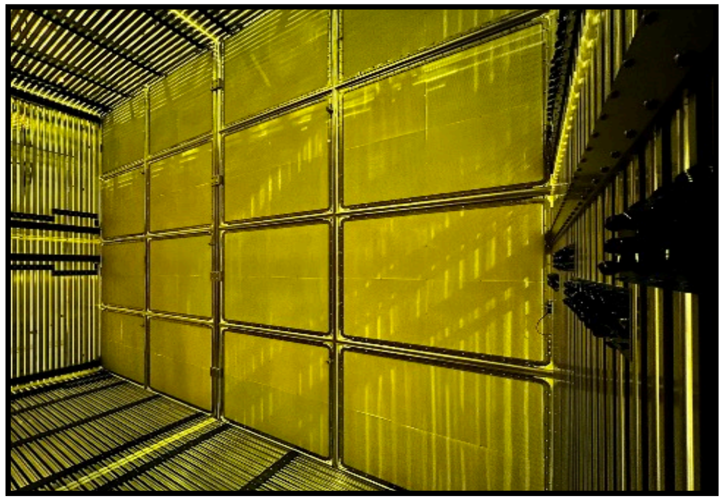


Place WLS component in front of the optical detector (coating, plate covers…)

PDS components (SBND approach)



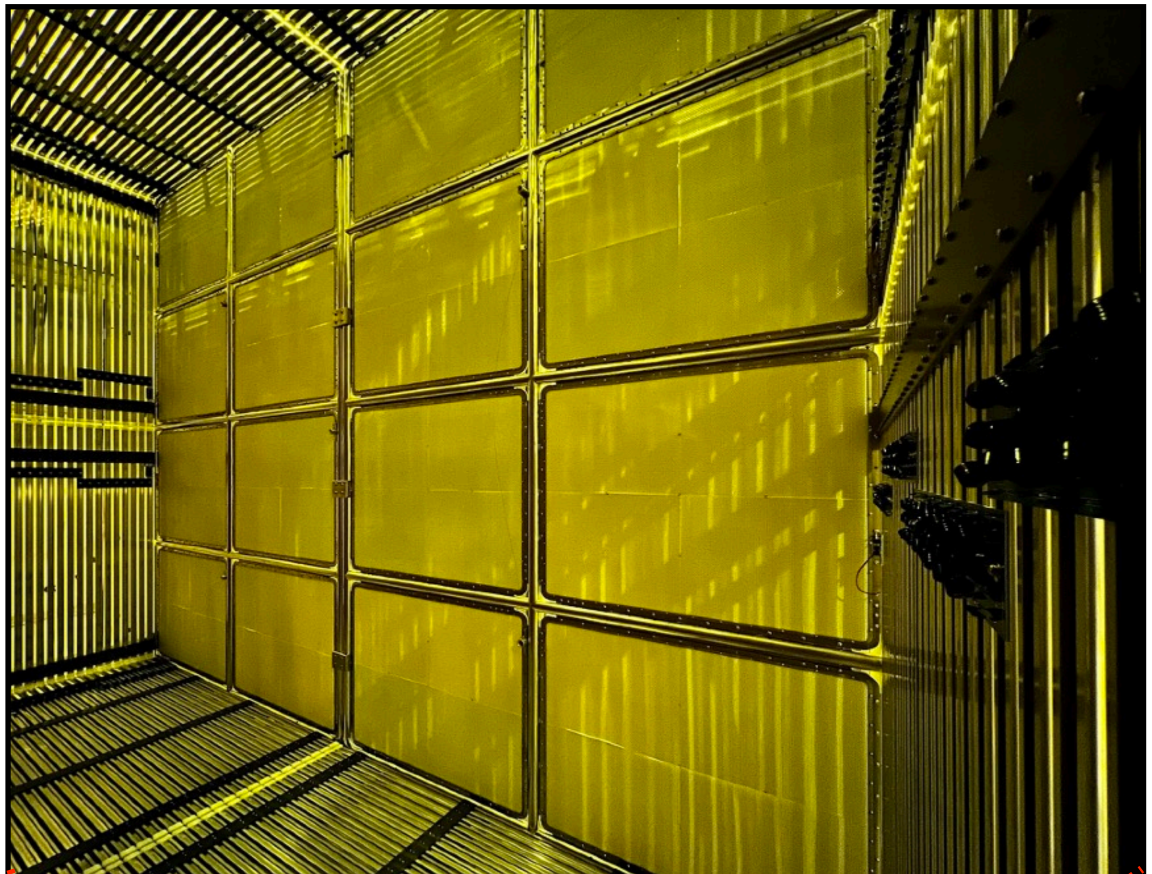
4 different flavors of optical sensors

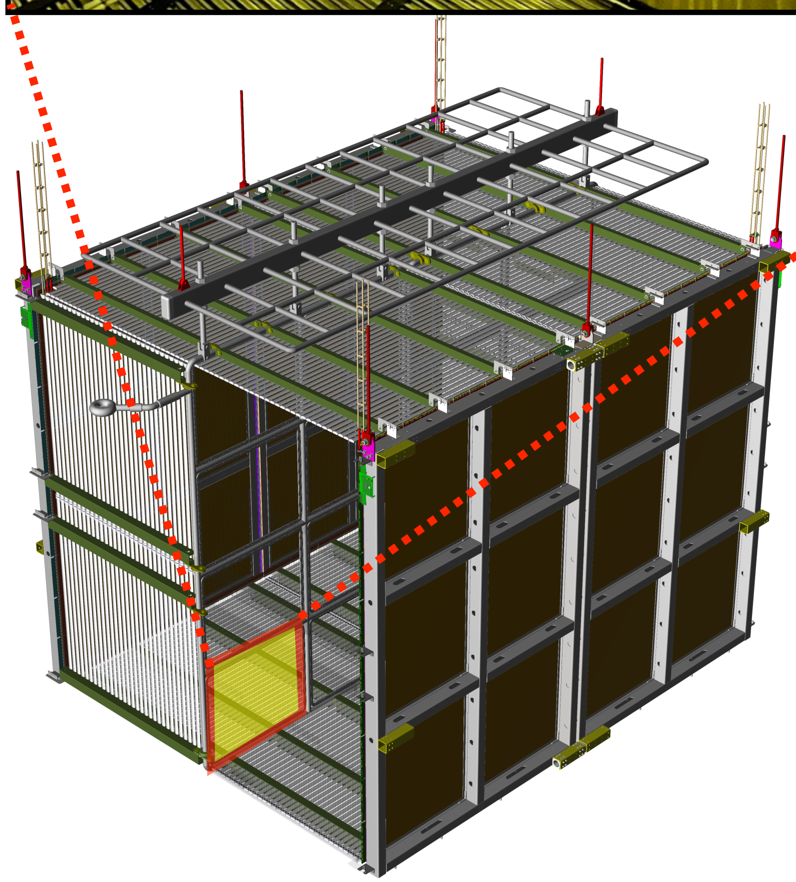


The full cathode will be acting as a WLS[1]!

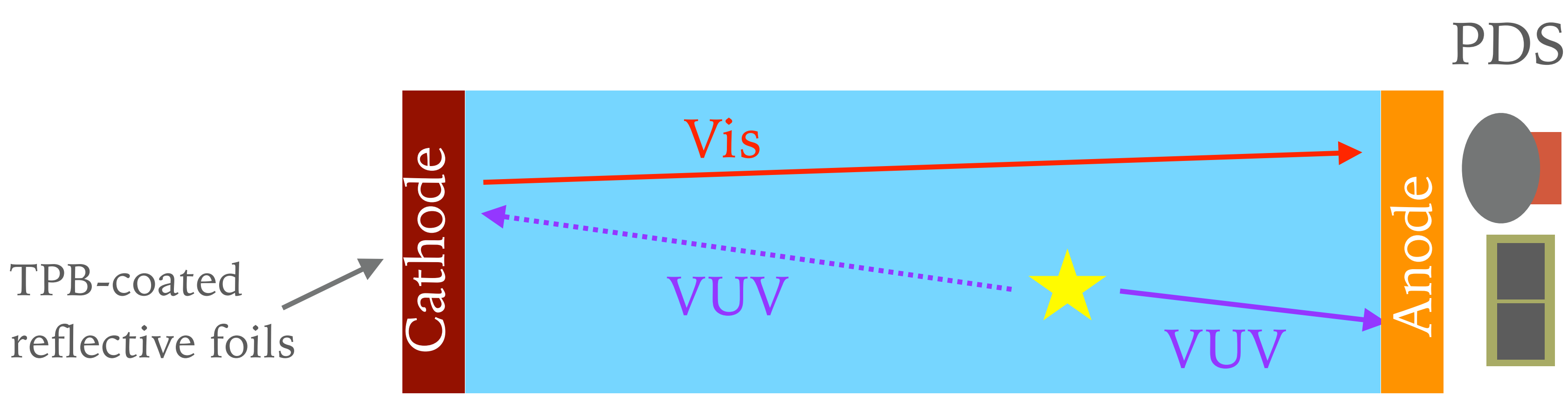
[1]Foil-based method first use by LArIAT experiment

PASSIVE ELEMENTS: CATHODE FOILS



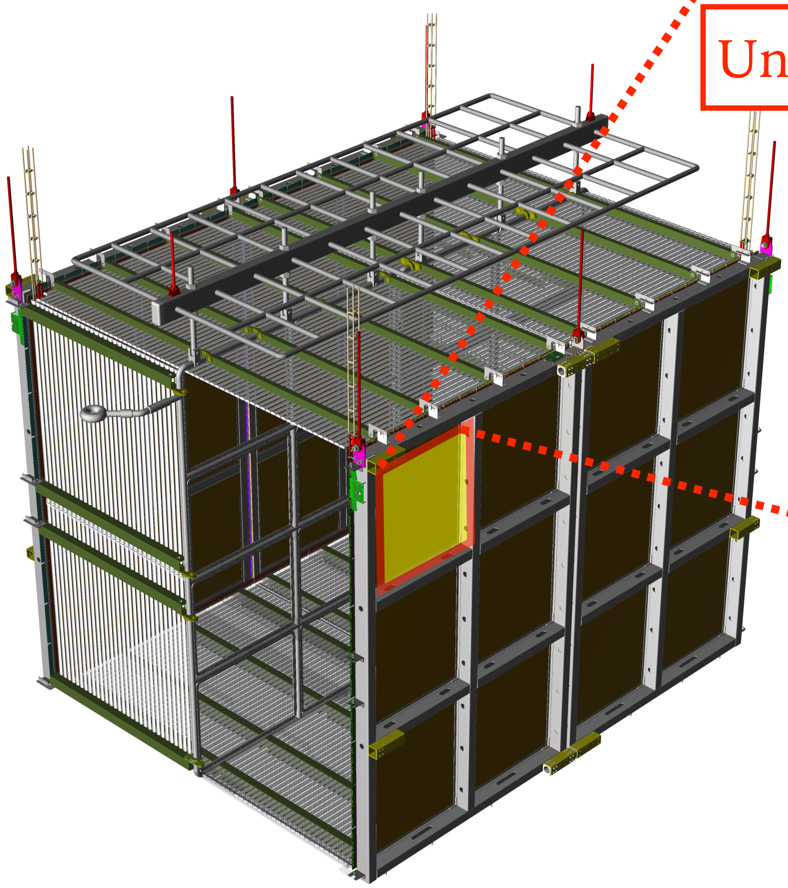


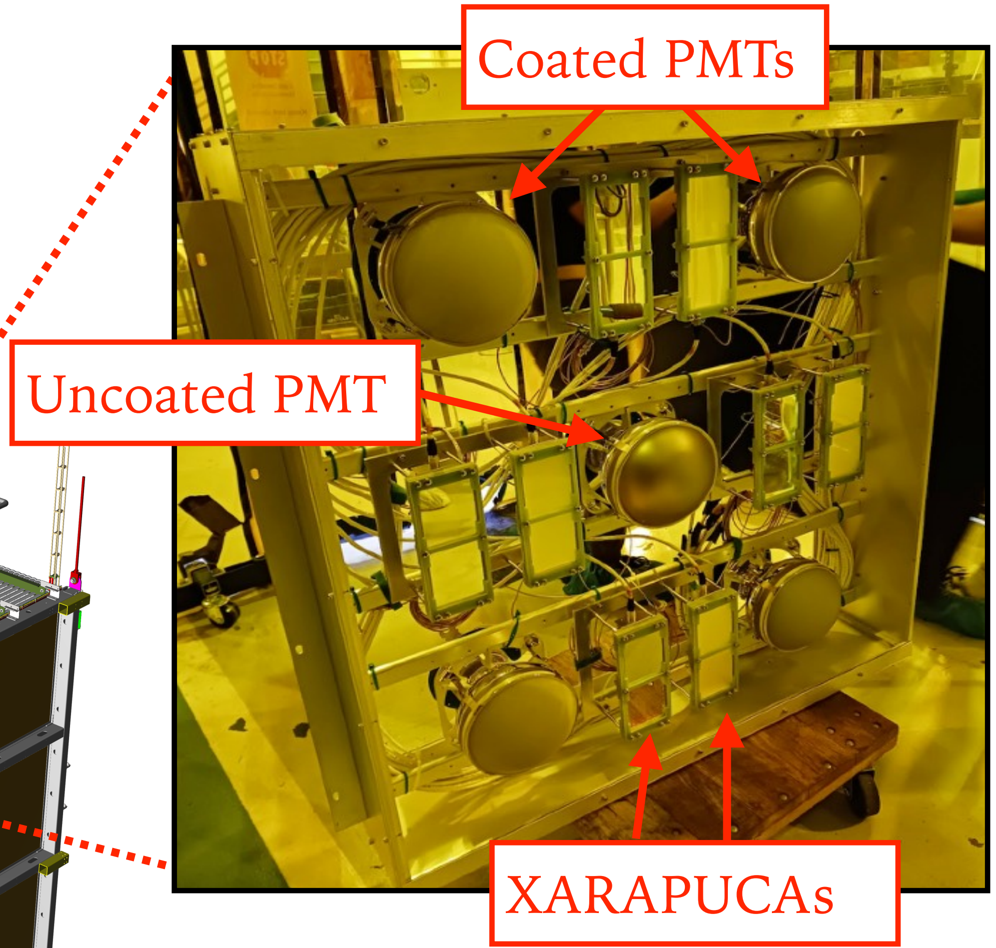
- Highly **reflective foils** installed in the cathode: recovers part of the photons
- Foils coated in Tetra-Phenyl-Butadiene (TPB) wavelength shifter: **2 light components in SBND:**
  - Primary light: VUV (standard)
  - Foil-reflected: visible (extra)
- **Passive** element in the system



- 2 detection technologies:
  - Hamamatsu R5912-mod Photomultiplier tubes (PMTs): x120
  - R&D XARAPUCAs: x196

- High granularity and detection area:
  - ~9.6 % anode coverage for PMTs
  - ~7.1 % anode coverage for XARAPUCAs



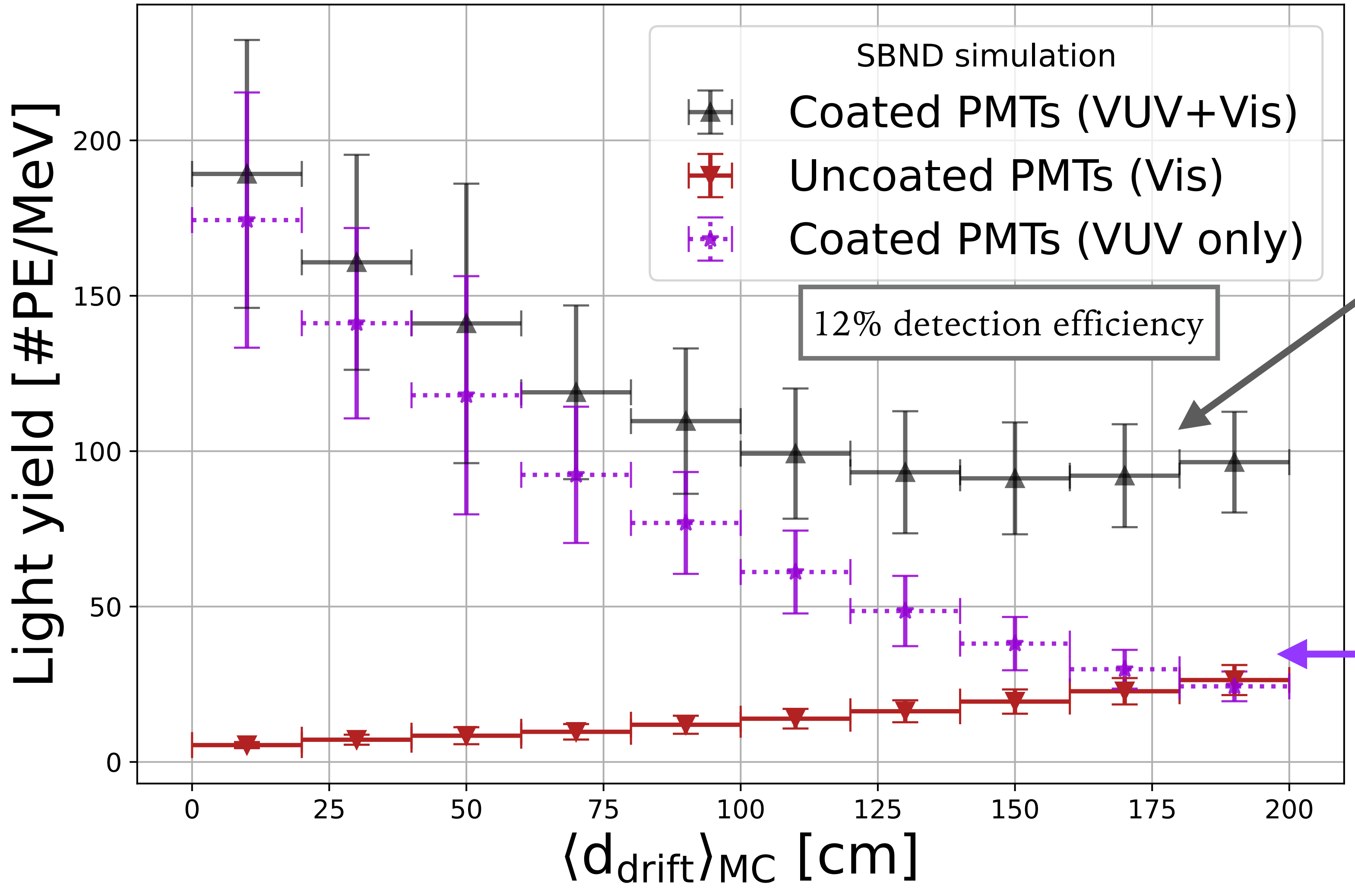


- Able to decouple the 2 light components!
- PMTs:
  - 96 **coated** (corners) in TPB: sensitive to VUV+Vis
  - 24 **uncoated** (central): sensitive only to Vis photons
- XARAPUCAs:
  - 1/2 Vis sensitive
  - 1/2 VUV+Vis sensitive

- SBND PDS design: enhances the **light collection and its uniformity** thanks to

  (i) the hight density of optical channels

  (ii) the TPB-coated reflective foils installed in the cathode



- The cathode foils minimize the effect and increase the amount of light collected

- The farther from the PDS plane, the less light yield (VUV only)

OUTLINE

What's new?

1. Cathode foils: two light components
2. High density of PDs
3. Different flavors of PDs: able to distinguish between the two wavelengths

My talk:

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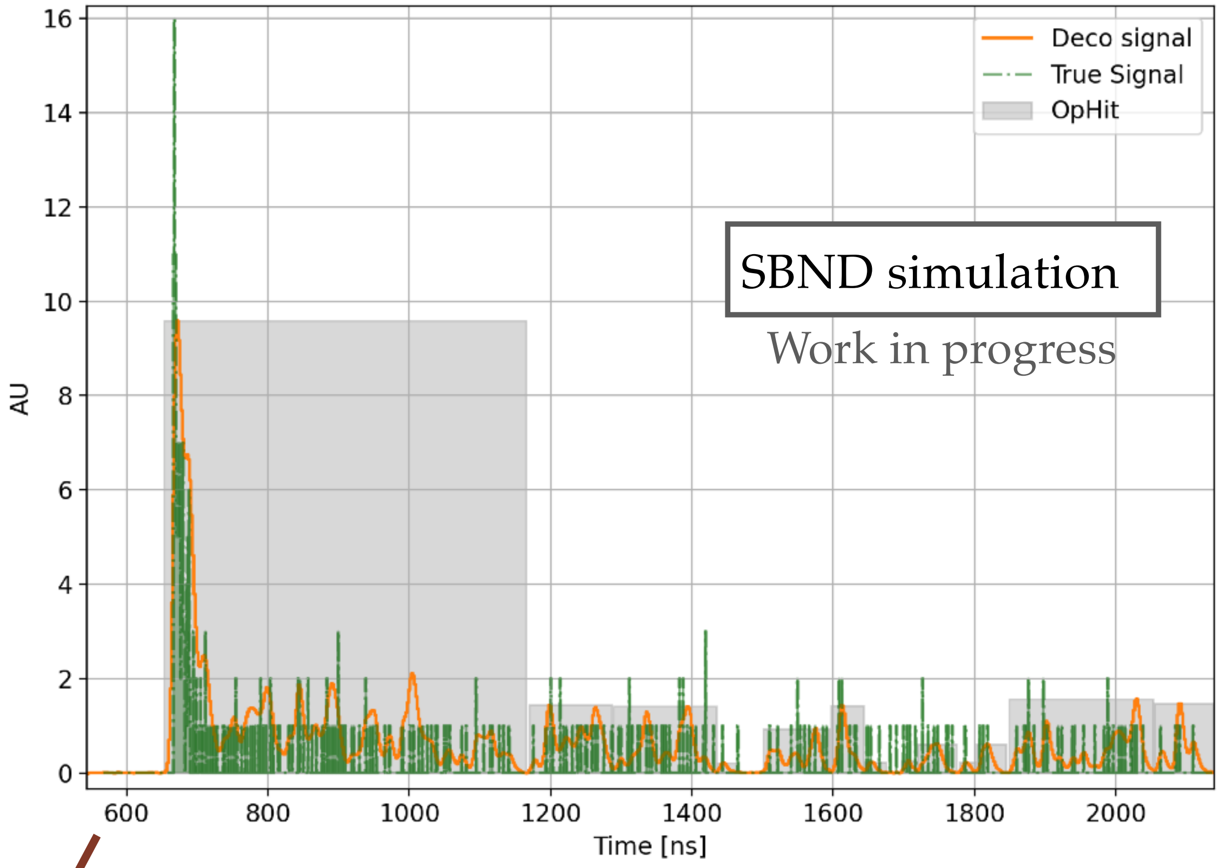
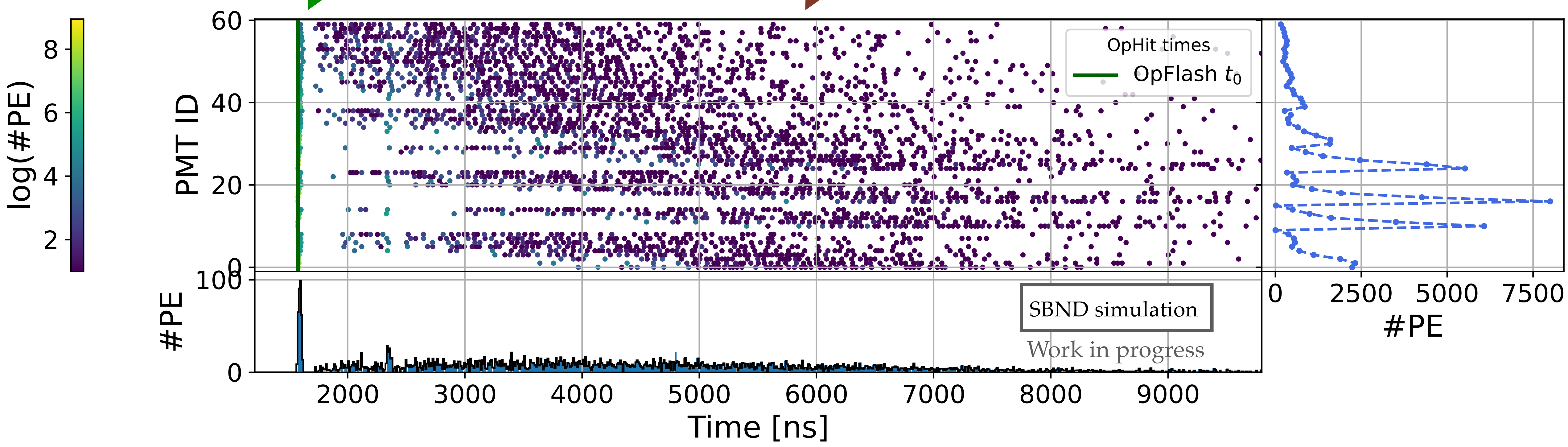
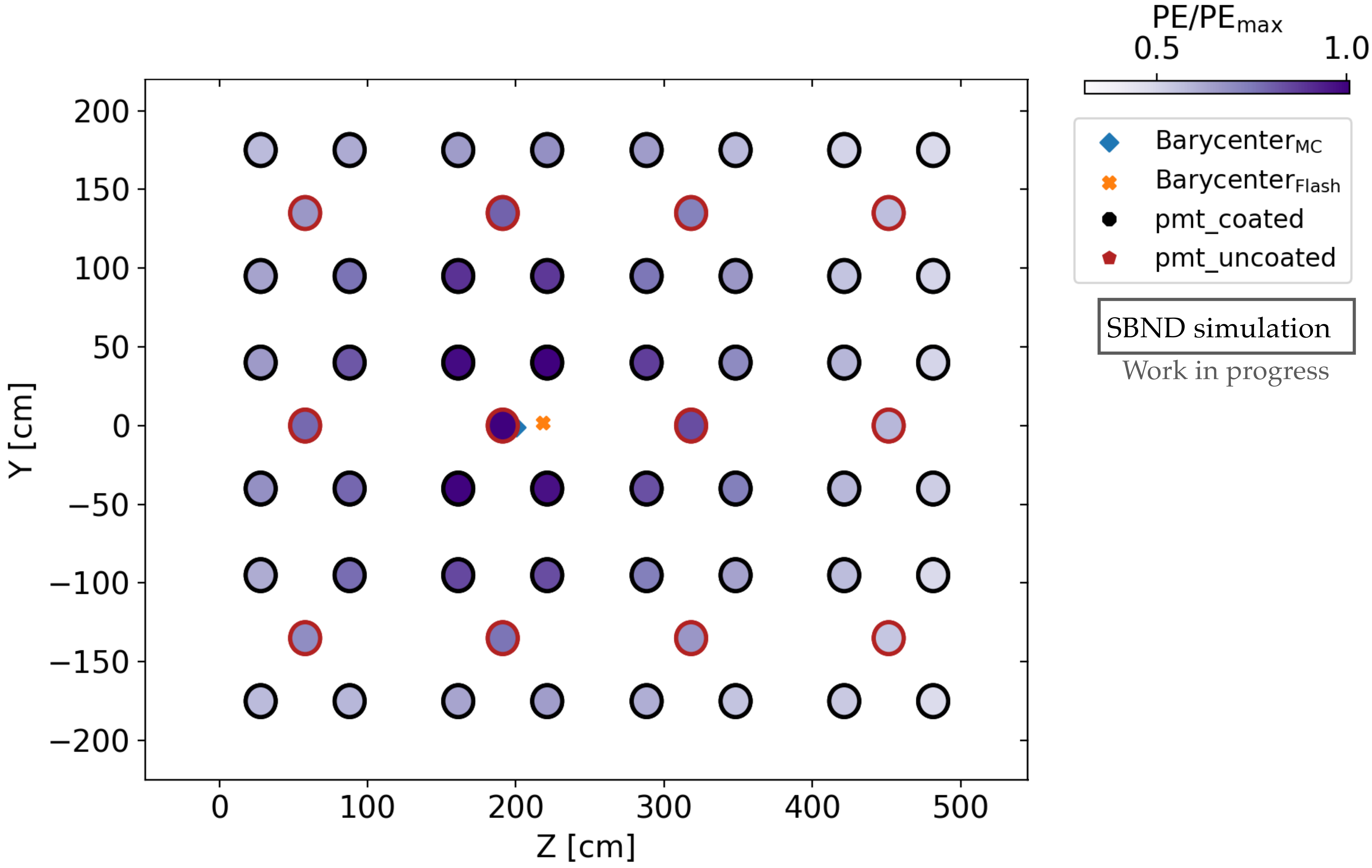
- Step 1: signal deconvolution (gaussian filter) + **hit** finding
- Step 2: hit clustering among different PDs
  - "**flash of light**"
  - Provides **interaction time** (≡ t_0)



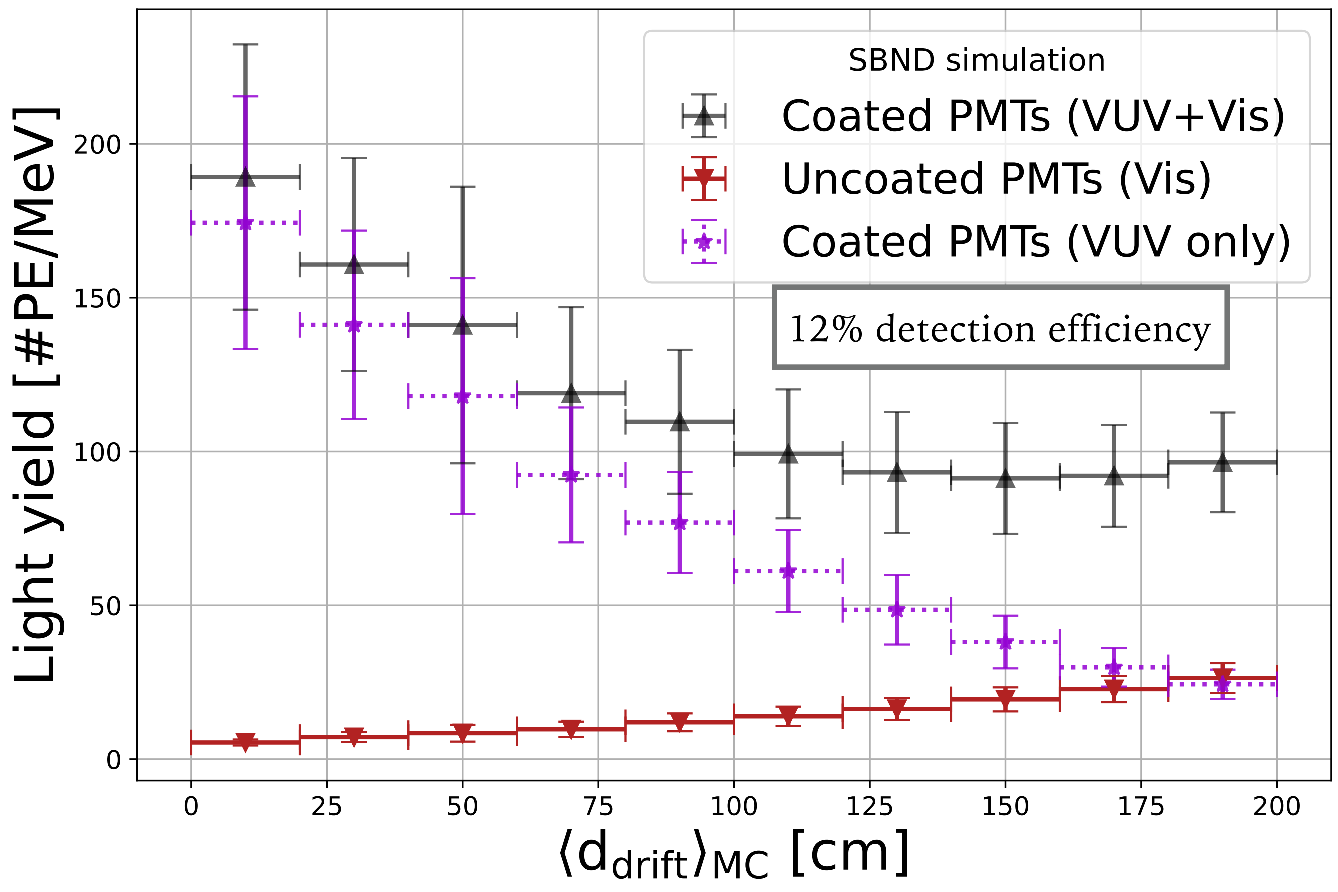


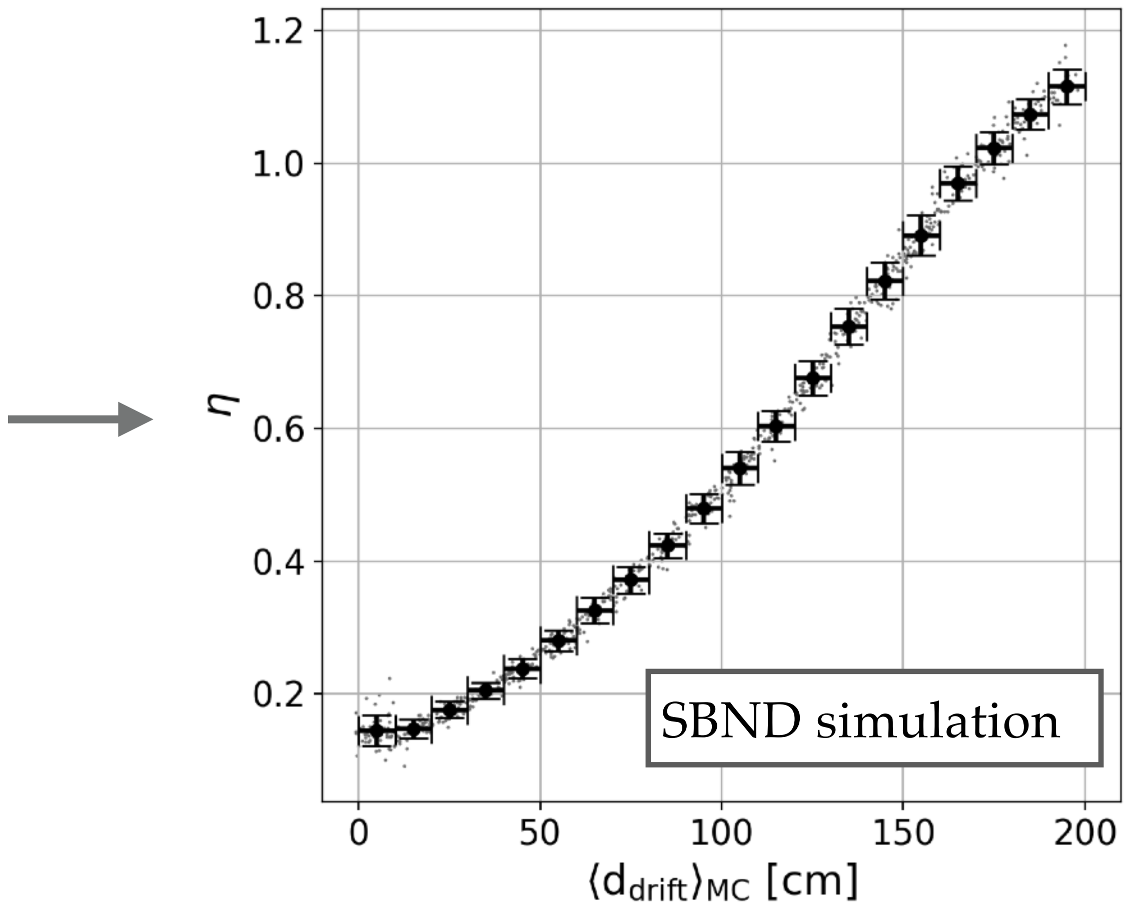
- PDS high granularity: estimate the position in the anode plane (Y-Z)



WHAT ABOUT THE DRIFT?

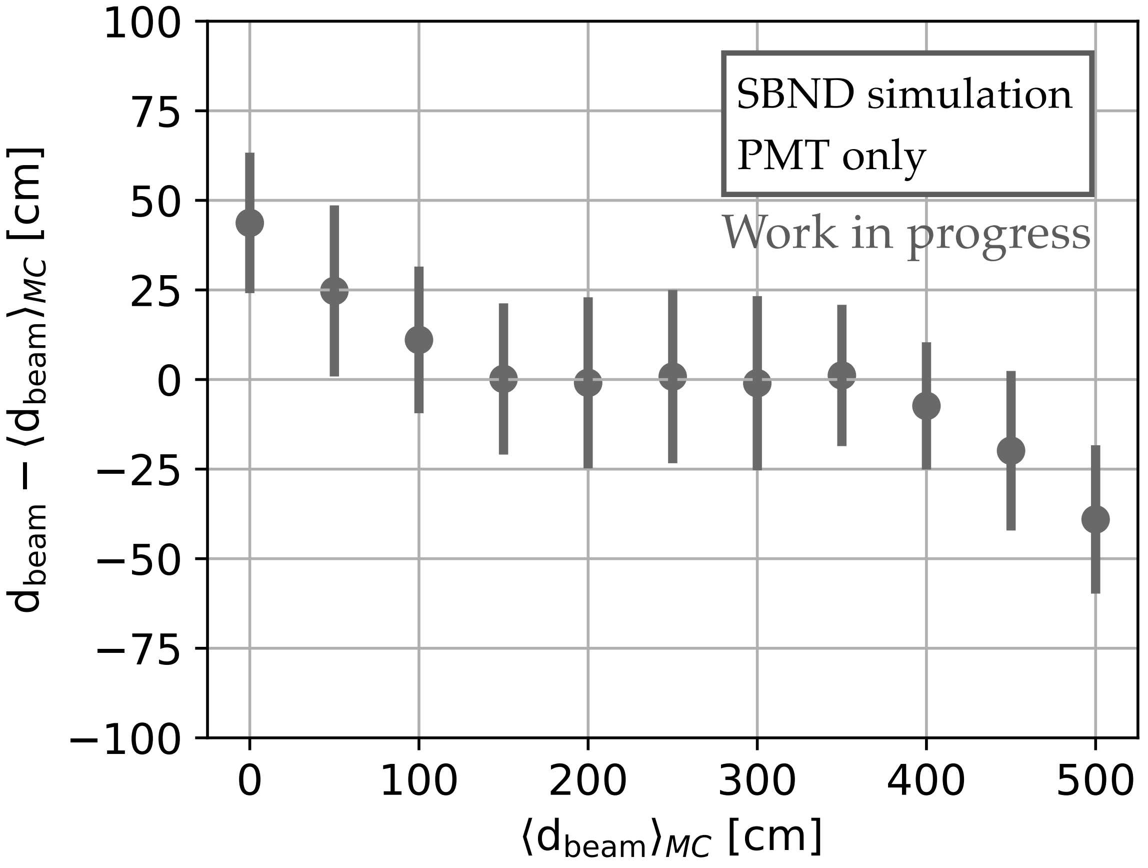
- Reminder: <u>two light components, that can be decoupled by our PDs</u>
  - The closer to the cathode, the more visible light
  - Parameter that correlates with the drift position: ratio of light seen by uncoated and coated PMTs ($\equiv \eta$)
- Calibration curve accesible with data thanks to the Cosmic Ray Tagger (~2 cm position resolution)

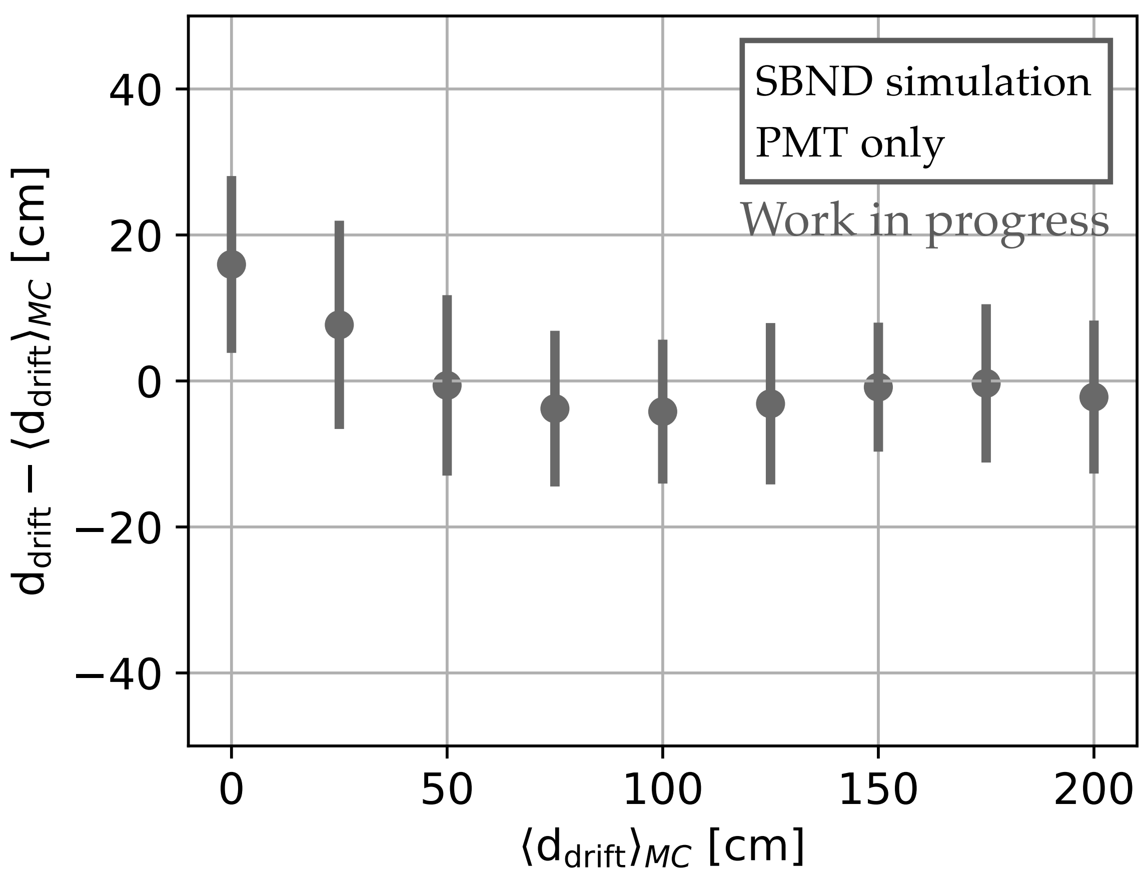




POSITION RESOLUTION

- SBND PDS provides an **independent 3D position reconstruction**
- Expected resolution:
  - Drift: ~15 cm
  - Beam direction (Z): ~25 cm





OUTLINE

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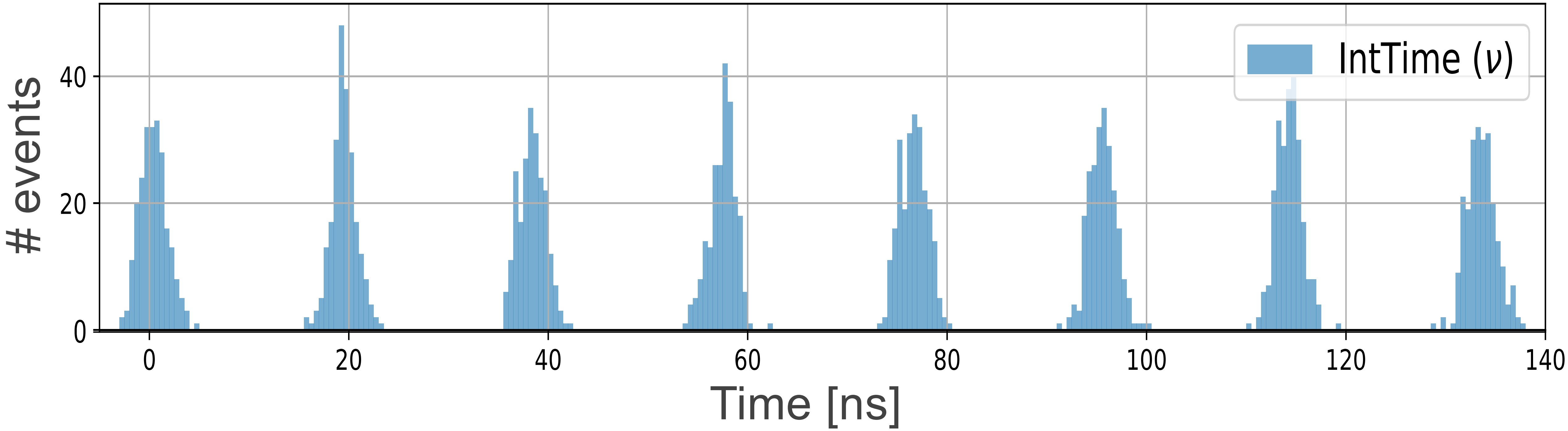
Using only light signals:

1. Flash t_0: neutrino interaction time
2. 3D position reconstruction

How can it be helpful in physics analysis?

TAGGING NEUTRINO EVENTS

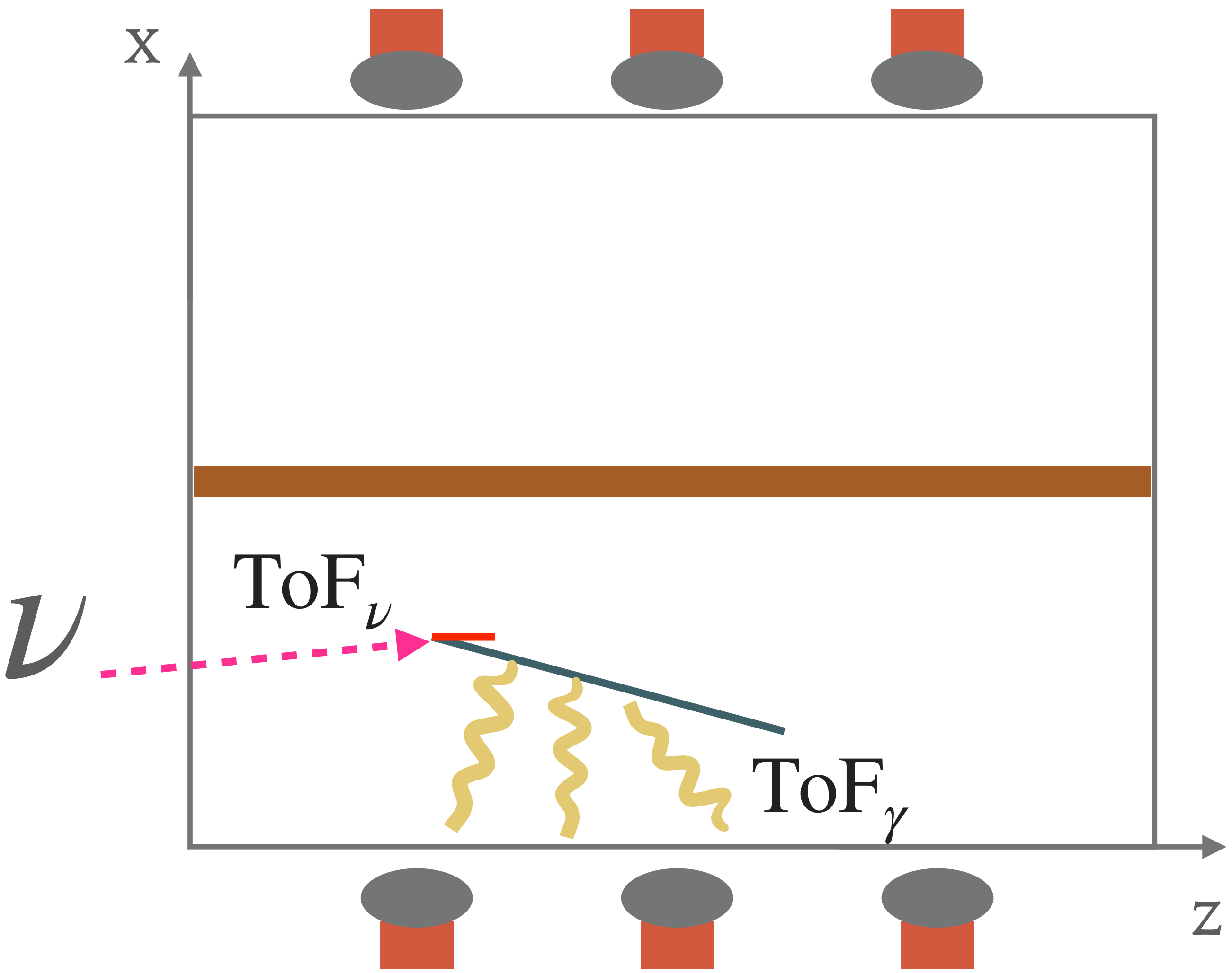
- Booster Neutrino Beam (BNB) neutrinos produced in a 1.6 μs time window (beam spill)
  - ν's produced in "packets": ~2 ns width, ~19 ns gap



- Method for tagging neutrino events: can we correlate the **flash** t_0 with the BNB inner structure?

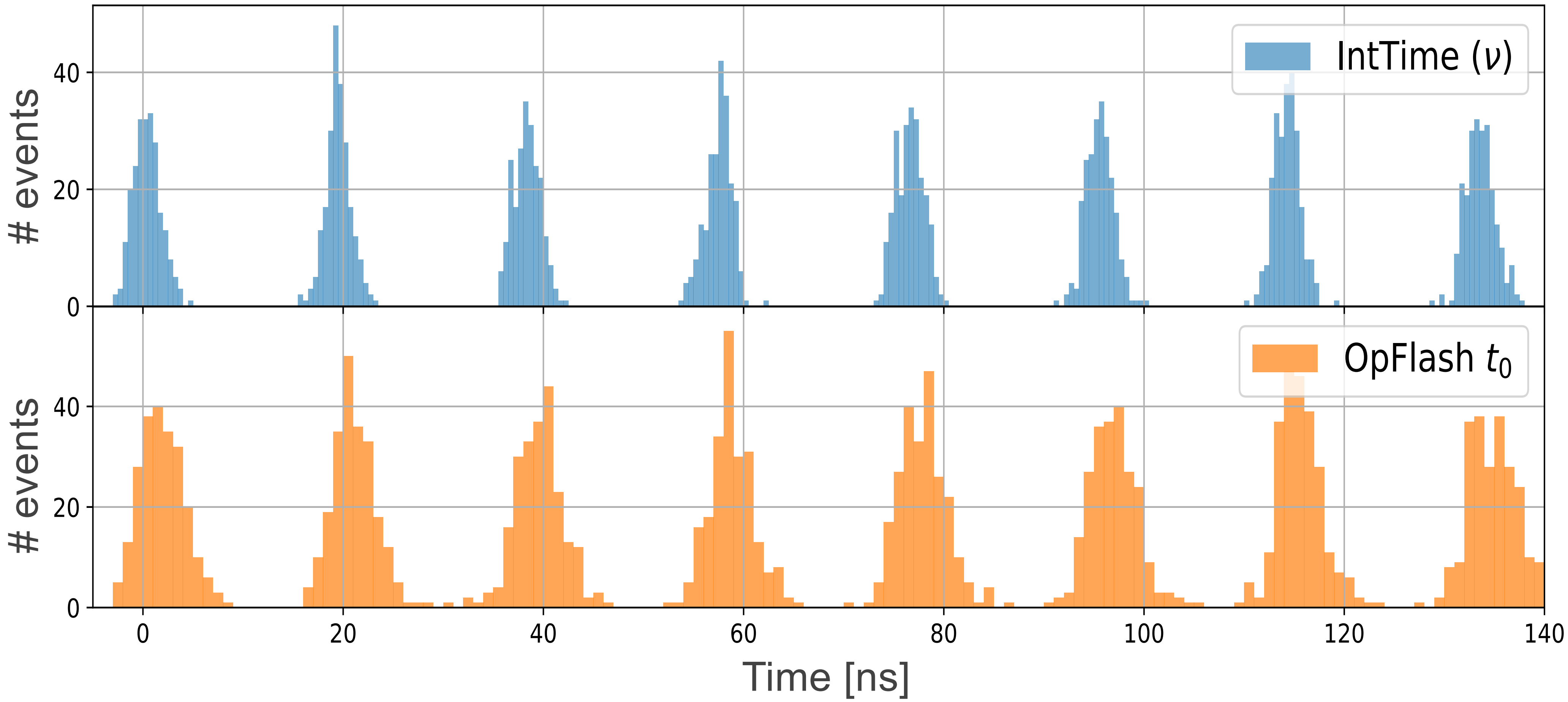
TAGGING NEUTRINO EVENTS

- We need to account for two additional time delays:
  - ToF_{ν}: Neutrino time of flight inside the detector (~17 ns)
  - ToF_{γ}: Scintillation photons time of flight (~15 ns)
- Both time of flights can be corrected using only the SBND PDS



- ToF_{ν}: we can correct using the flash Z barycenter
- ToF_{γ}: we can correct using the drift coordinate estimation from the η parameter

- ν reconstructed times from the light signals:
  - t_0 from the flash of light
  - ToF_γ and ToF_ν subtracted using the flash position



Top: simulated neutrino arrival time distribution at SBND

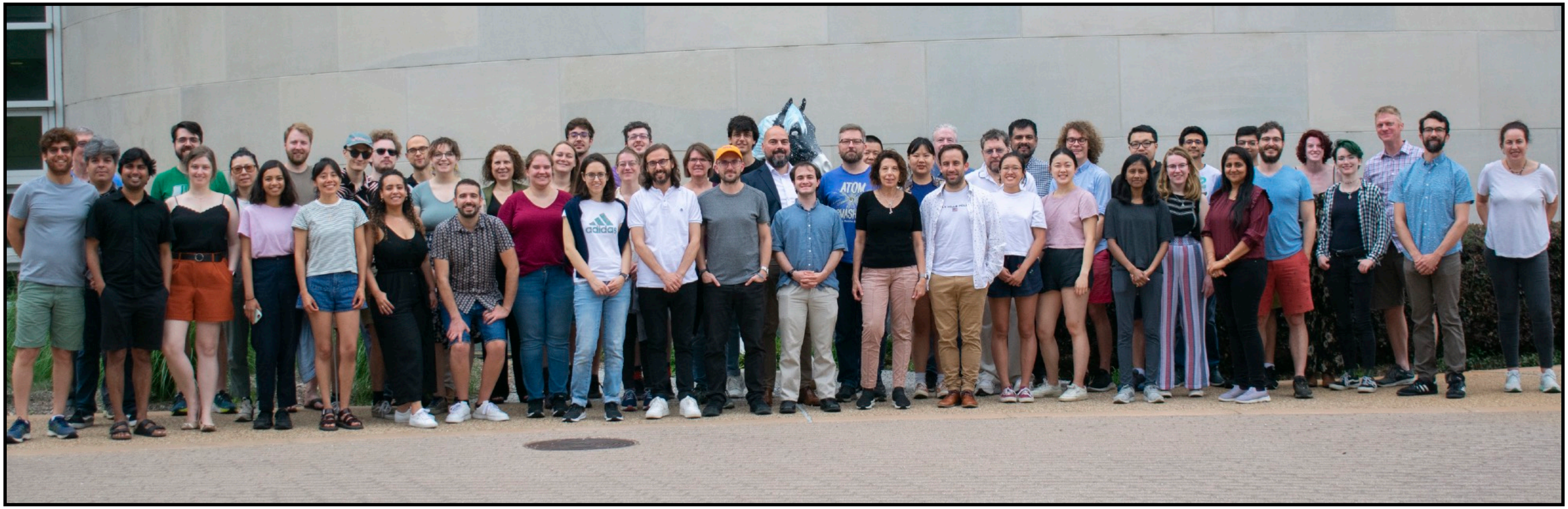
Bottom: neutrino times from light signals (PDS-only reconstruction)

Multiple applications! Example:

- Heavy Neutral Leptons searches (see L.Nguyen' talk)

- SBND PDS focuses on pushing the LArTPC technology beyond its current limitations, maximizing the physics output and detector performance by an innovative design including:
  A. TPB-coated reflective foils installed in the cathode
  B. Having a large number of optical detectors, able to **distinguish between the two light components**
- This design aims to:
  (I) Enhance the **light collection and its uniformity**
  (II) Provide an independent 3D reconstruction, allowing SBND to retrieve the BNB inner structure using only scintillation light

Thank you!



Backup

Charge (Q) vs Light (L)

Number of electrons (Q) and scintillation photons (L) per unit of absorbed energy vs electric field