TAGGING NEUTRINO EVENTS WITH THE SBND PHOTON DETECTION SYSTEM

LiDINE

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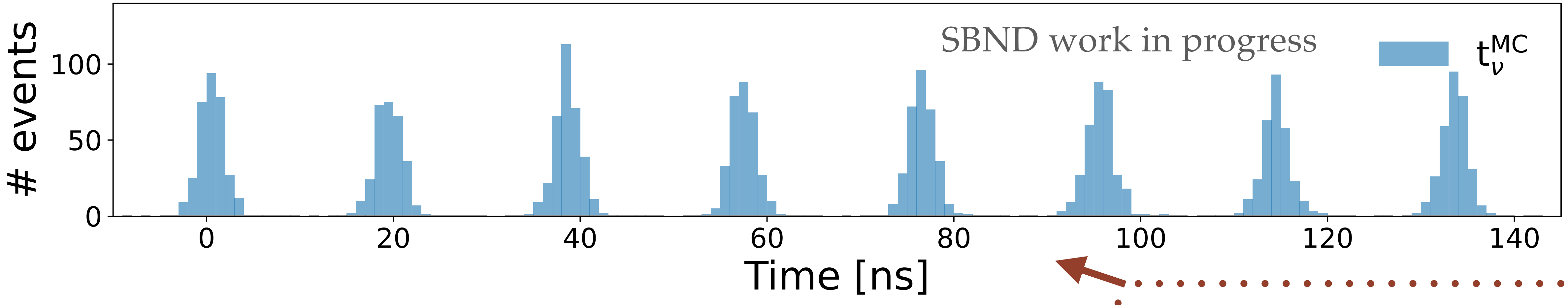
The SBND Photon Detection System (PDS) was introduced in the previous talk

This talk!

- Current status of the detector simulation and reconstruction
- What **new applications** can we explore with this innovative PDS?

- ➤ Focus on the ability to **tag neutrino events through timing information***
- ➤ SBND will detect neutrinos from the Booster Neutrino Beam (BNB):
  - ➤ With a PDS system with enough time and spatial resolution: potentially able to recover the neutrino beam inner structure using only light signals
  - ➤ In this talk: analysis based on the PMT system (but extendable to XARAPUCAs)



Neutrino arrival times at the SBND upstream wall

KEY ELEMENTS OF THE SBND PDS

- Detailed description in the talk from Rodrigo Álvarez
- Reminder: a PDS with
  - high coverage
  - able to distinguish between 2 light components

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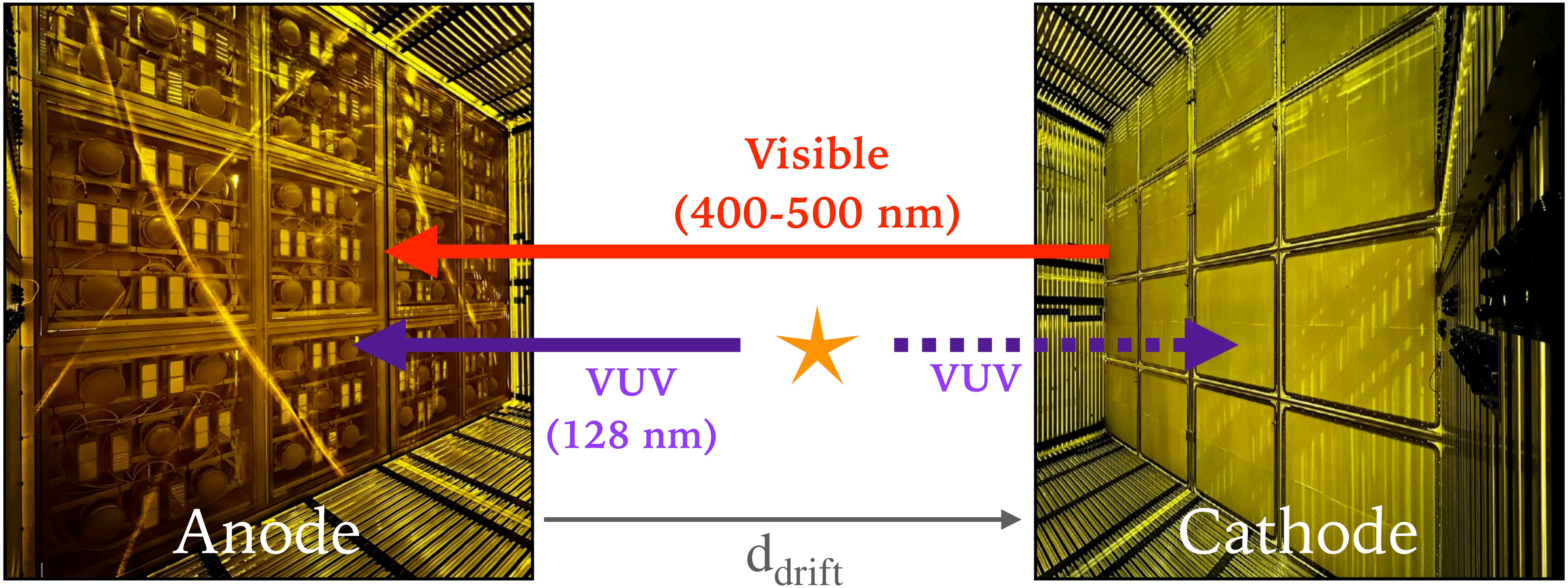
- Coated PMTs: VUV/direct + visible/reflected
- Uncoated PMTs: visible/reflected



SIMULATION WORKFLOW IN SBND

Generation

Neutrino + cosmic overlay generation: GENIE [3] + CORSIKA [4])

- A detailed detector simulation was developed for SBND:
  - Based on **Geant 4** [1] and **LArSoft** [2] packages

Propagation

- Particle tracking (Geant4)
- Photon propagation ("fast optical models")
  - LAr light emission profile
  - Photon detector geometry acceptance
  - Rayleigh scattering
  - Reflections + absorptions

Detector response

- Data driven Single Electron Response (SER)
- Detection efficiency
- Saturation + non linearities
- Noise + SER fluctuations

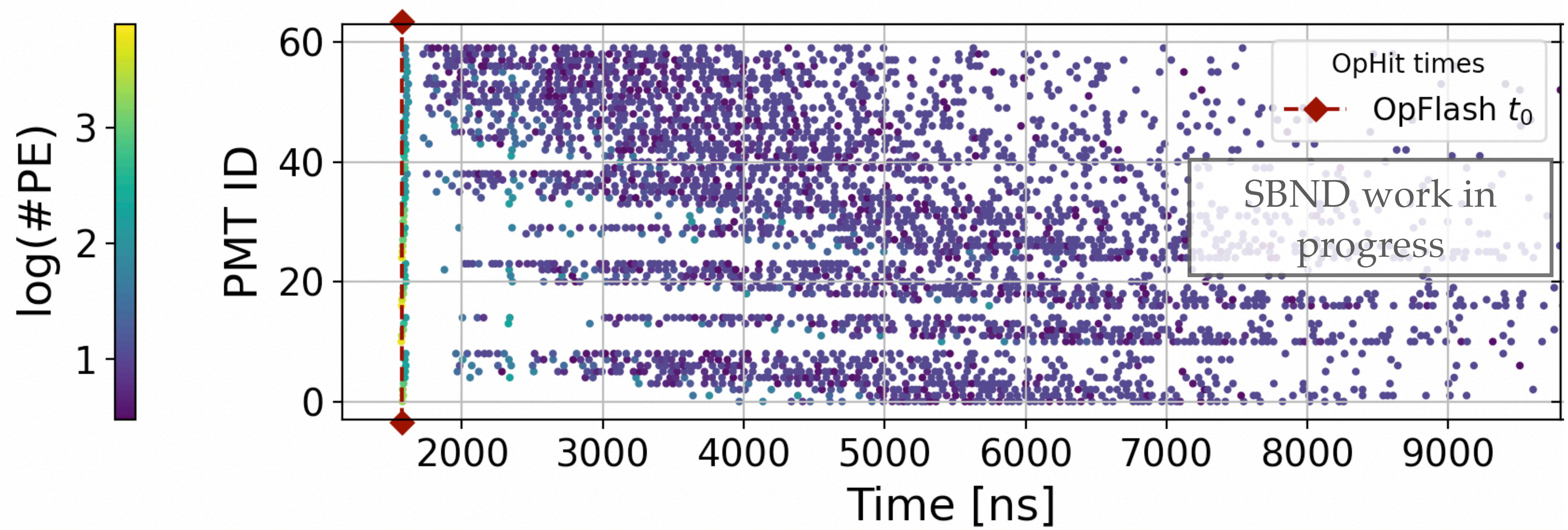
[1] S. Agostinelli *et al.*, Nucl. Instrum. Meth. A 506 (2003) 250-303

[2] E.L. Snider and G. Petrillo, J.Phys.Conf.Ser. 898 (2017) 4, 042057

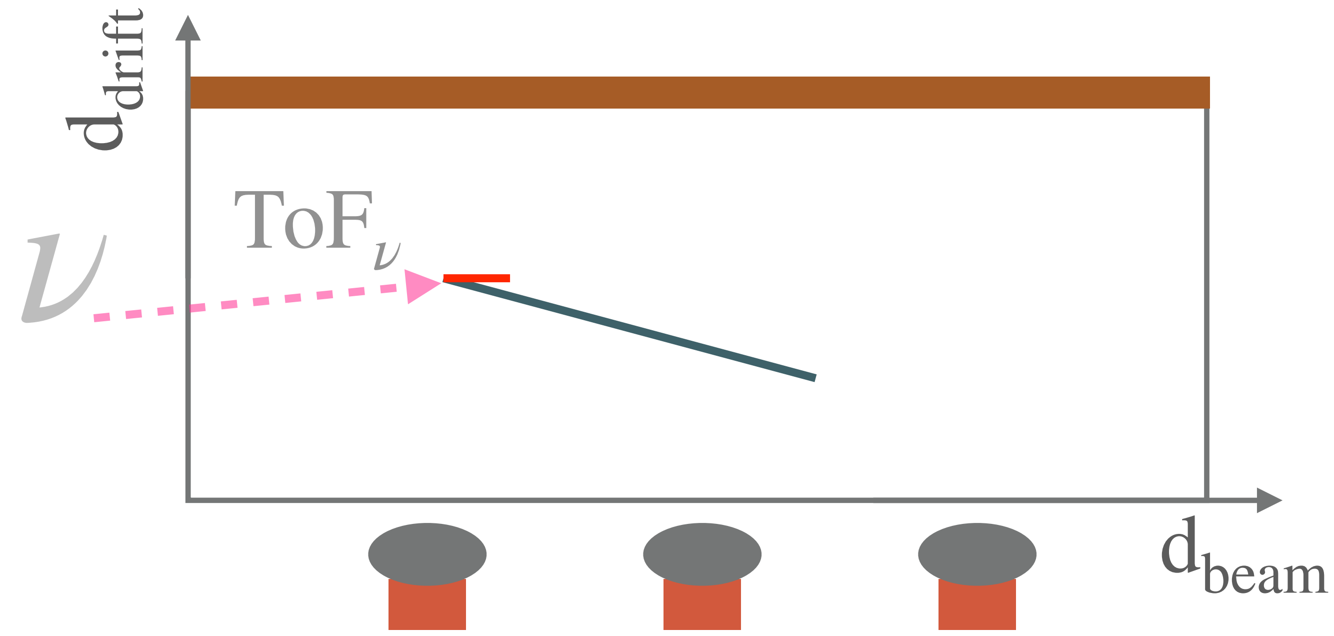
[3] C.Andreopoulos *et al.*,Nucl.Instrum.Meth.A614 (2010) 87-104

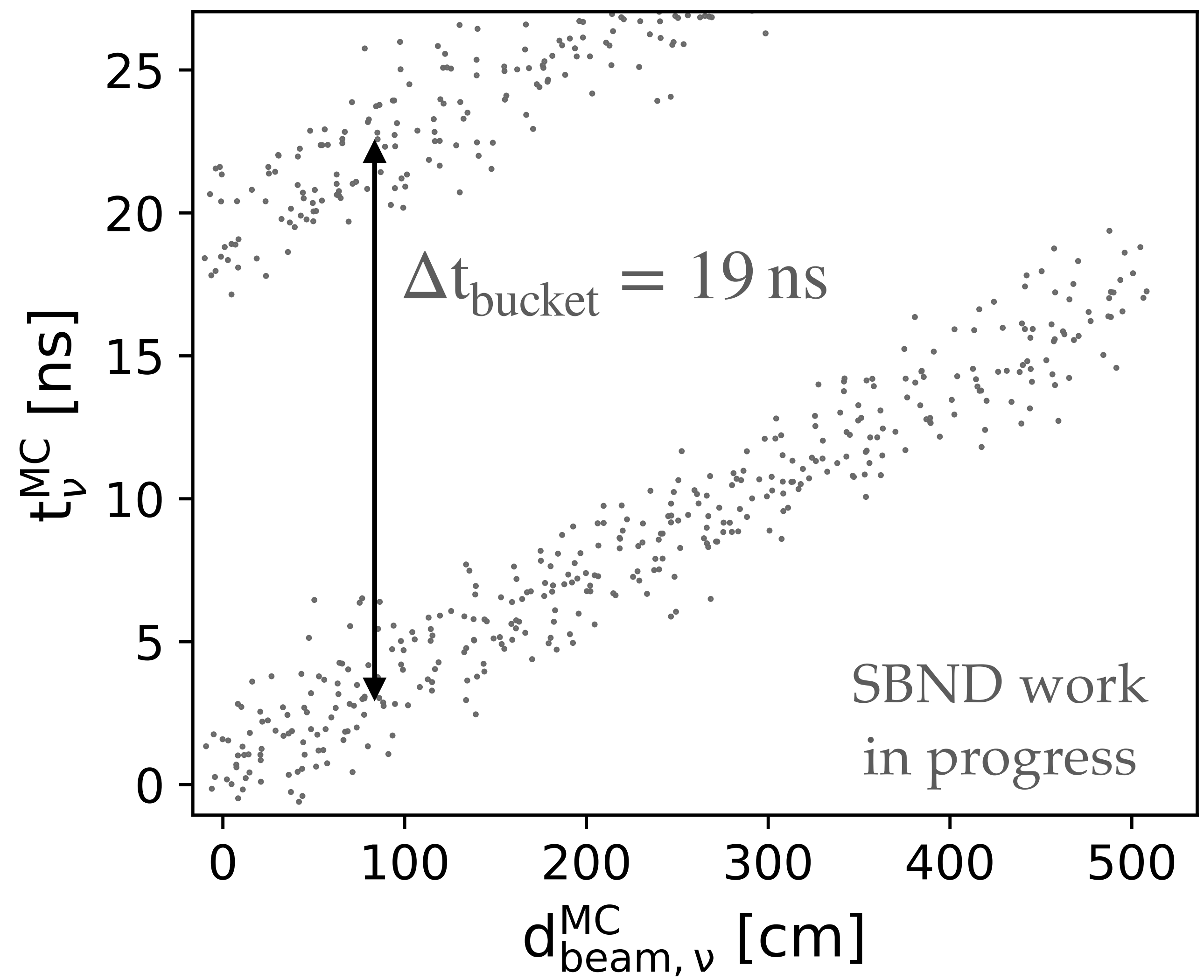
[4] D. Heck *et al.*, CORSIKA: A Monte Carlo code to simulate extensive air showers

- Reconstruction done in three steps:
  - Step 1: signal **deconvolution** (gaussian filter)
  - Step 2: **hit** finding
  - Step 3: hit **clustering** among different optical detectors:
    - “**flash of light**”
    - Provides **interaction time** ($\equiv t_0$)



- **Neutrino time of flight** (ToF_ν): they can propagate along 5 meters in the beam direction (d_{beam})
- SBND located 110 m from the target
  - At first order: 0 to 17 ns time delay for each bucket
- To match the flash time with a beam bucket: we need to correct by ToF_ν

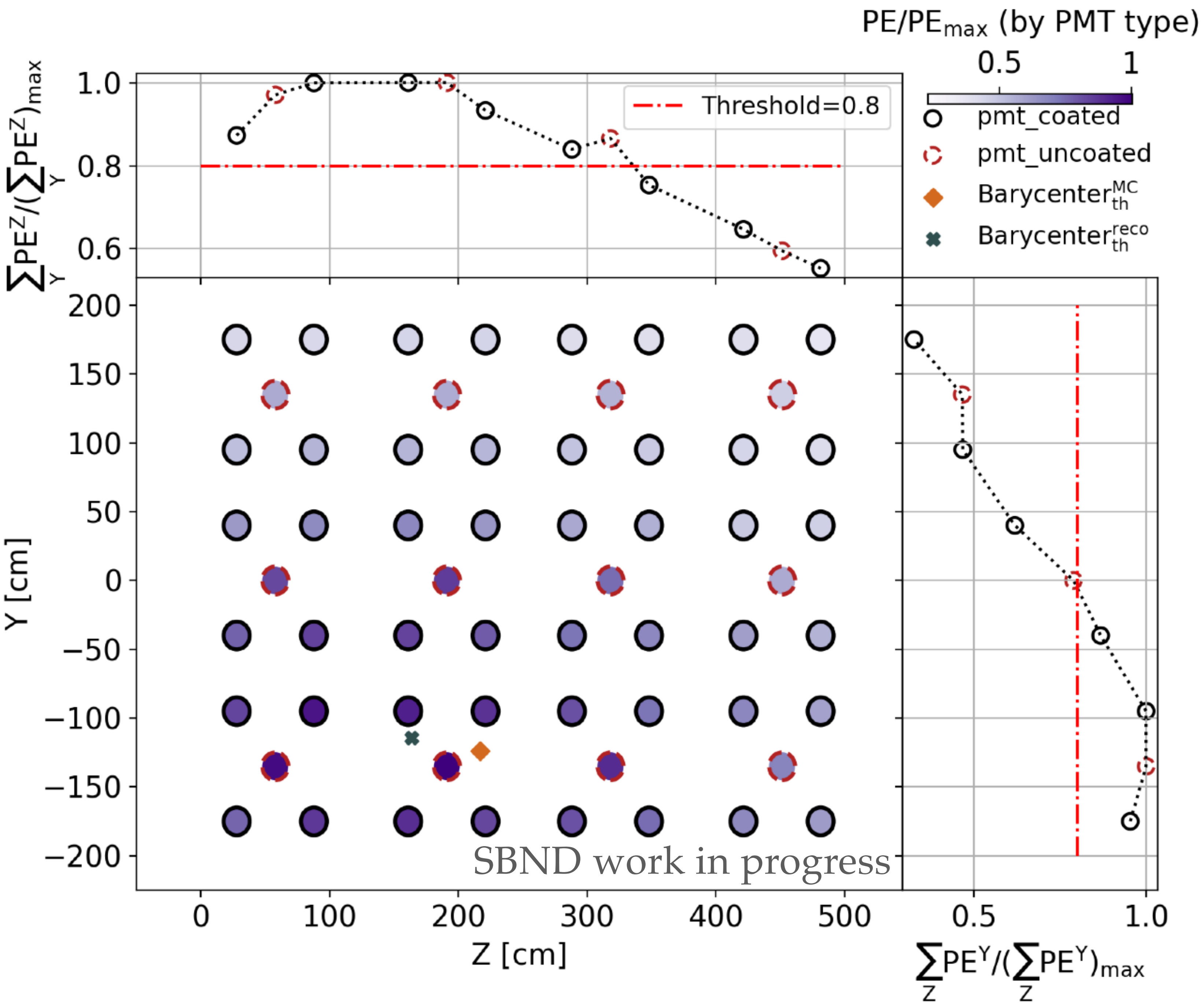




POSITION RECONSTRUCTION

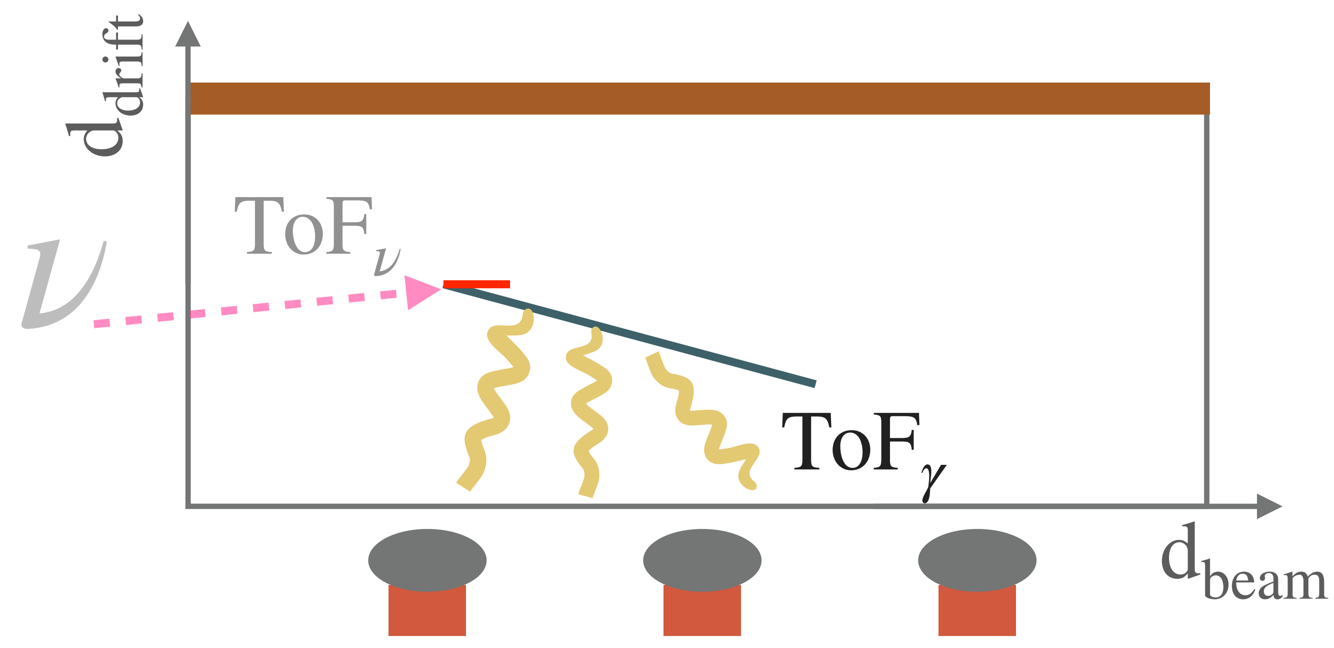
- PDS <u>high granularity</u>: estimate the ν position in the anode plane
- Threshold + barycenter-based method

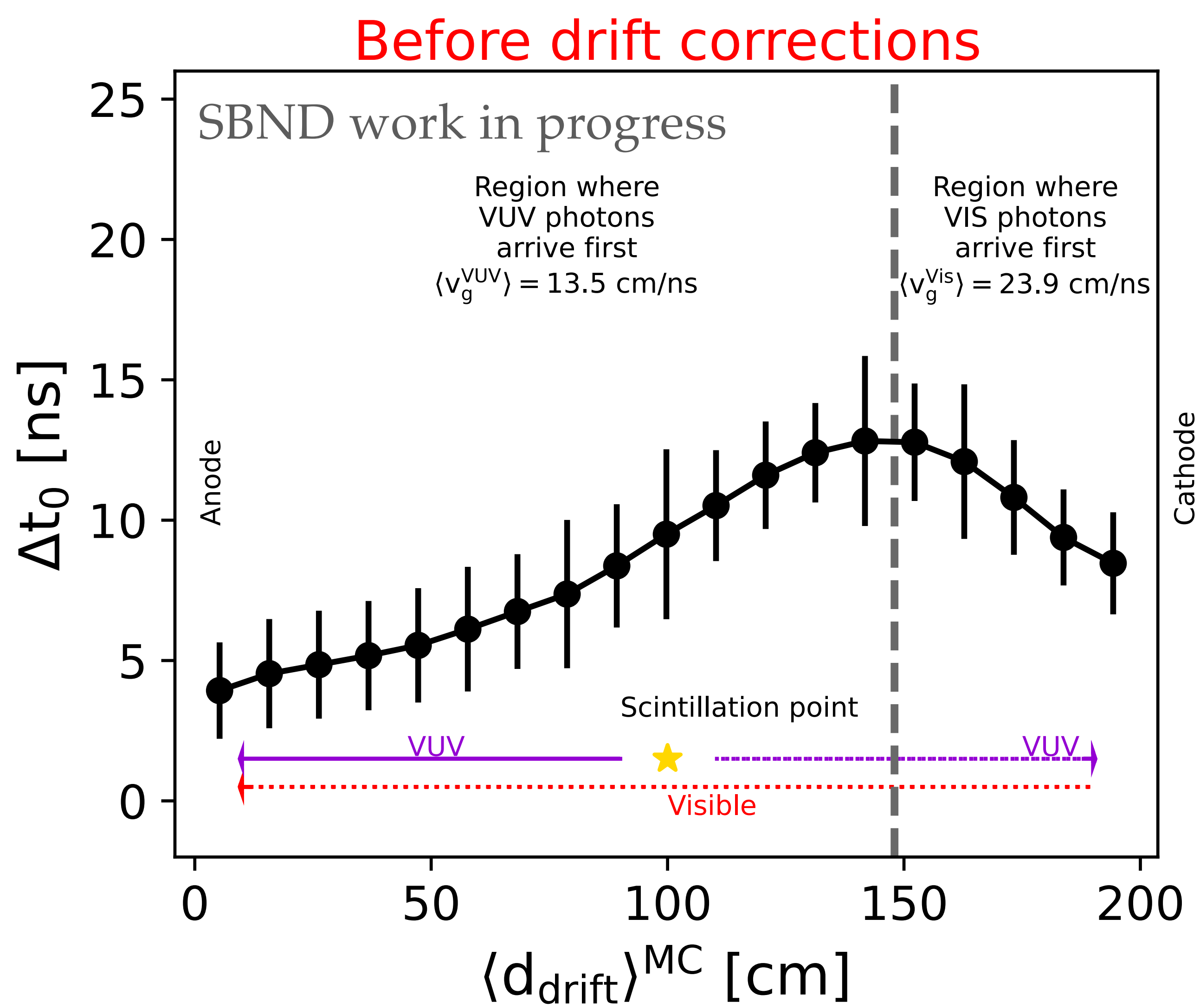
ν beam



PROPAGATION EFFECTS (II)

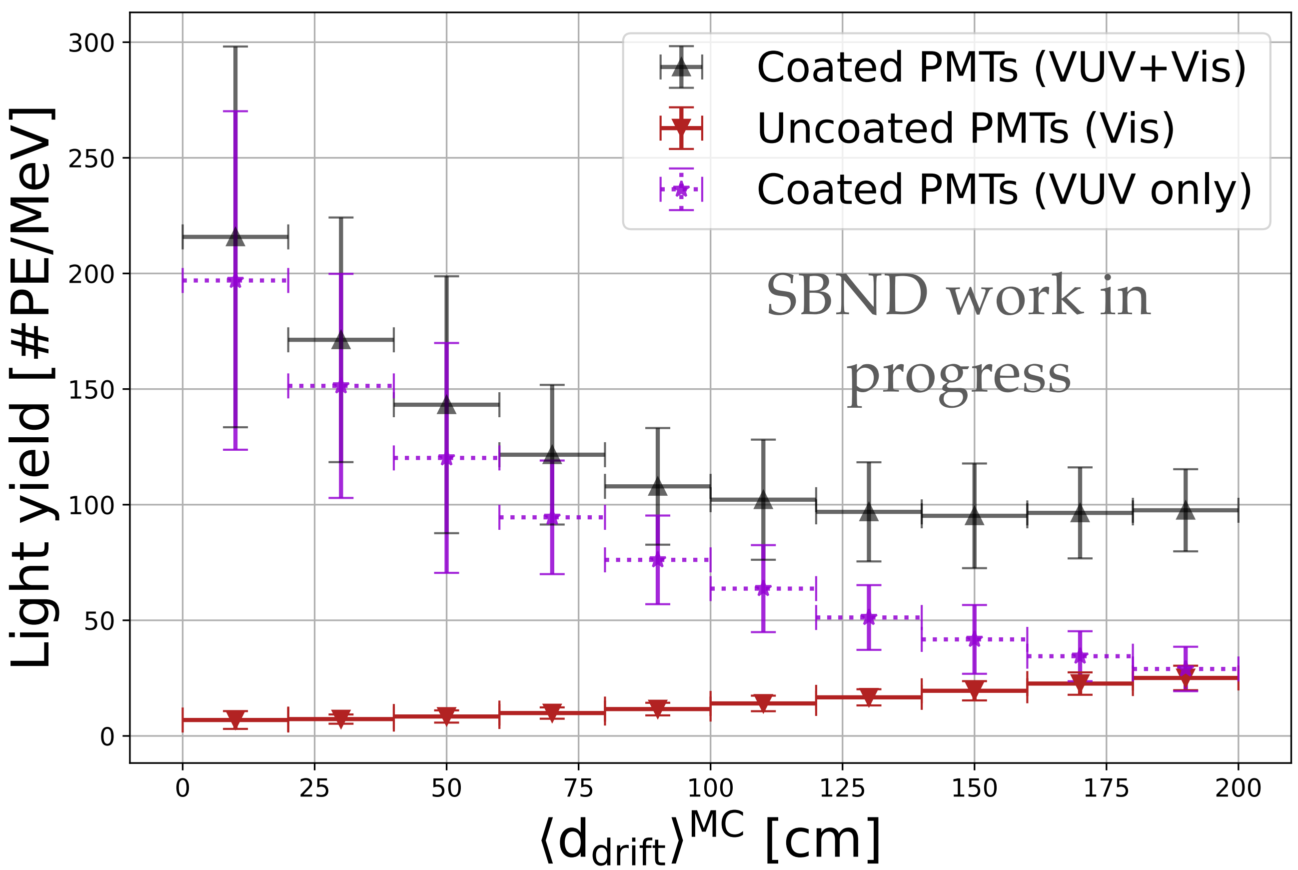
- Scintillation photons have to propagate from the energy deposition point to the PDS
- First order: dependent on the event mean <u>drift location</u>
  - Plot on the right: time resolution (Δt_0) as a function of d_{drift}
  - Up to ~ 15 ns time delay
- To pair the flash time with a beam bucket:
  - Need to correct by the photons time of flight (ToF_γ):

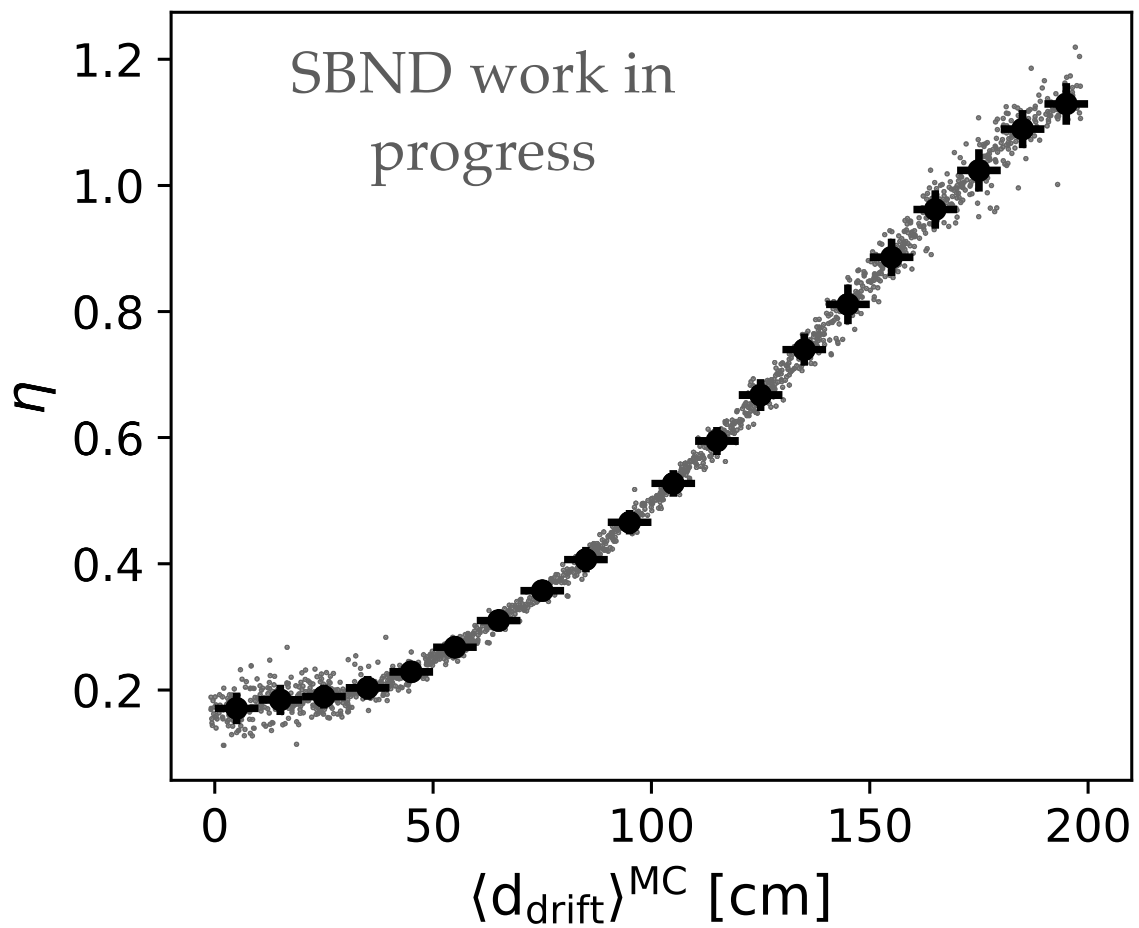




DRIFT RECONSTRUCTION

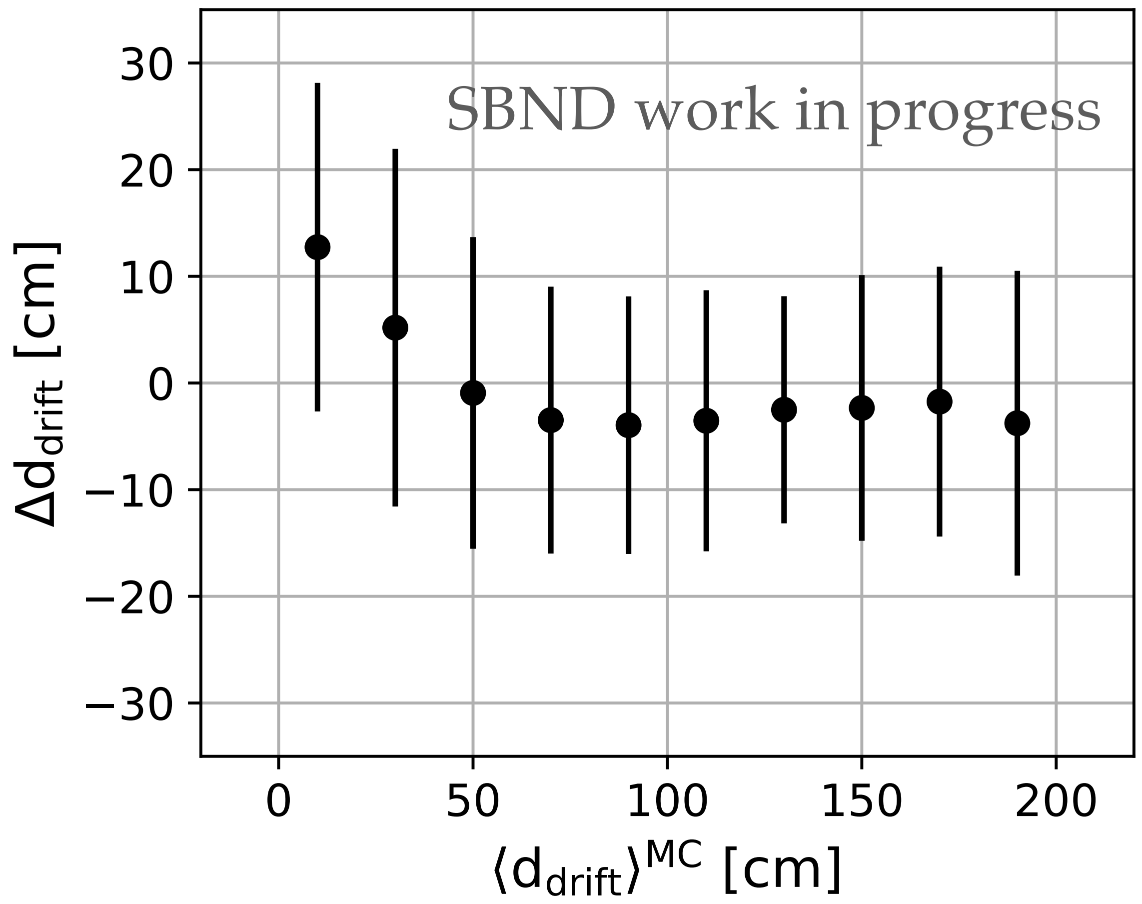
- <u>Two light components, that can be decoupled by our photon detectors</u>
- The closer to the cathode, the more visible light:
  - Ratio of light seen by uncoated and coated PMTs ($\equiv \eta$) correlates with the drift
  - SBND PDS sensitive to the drift location

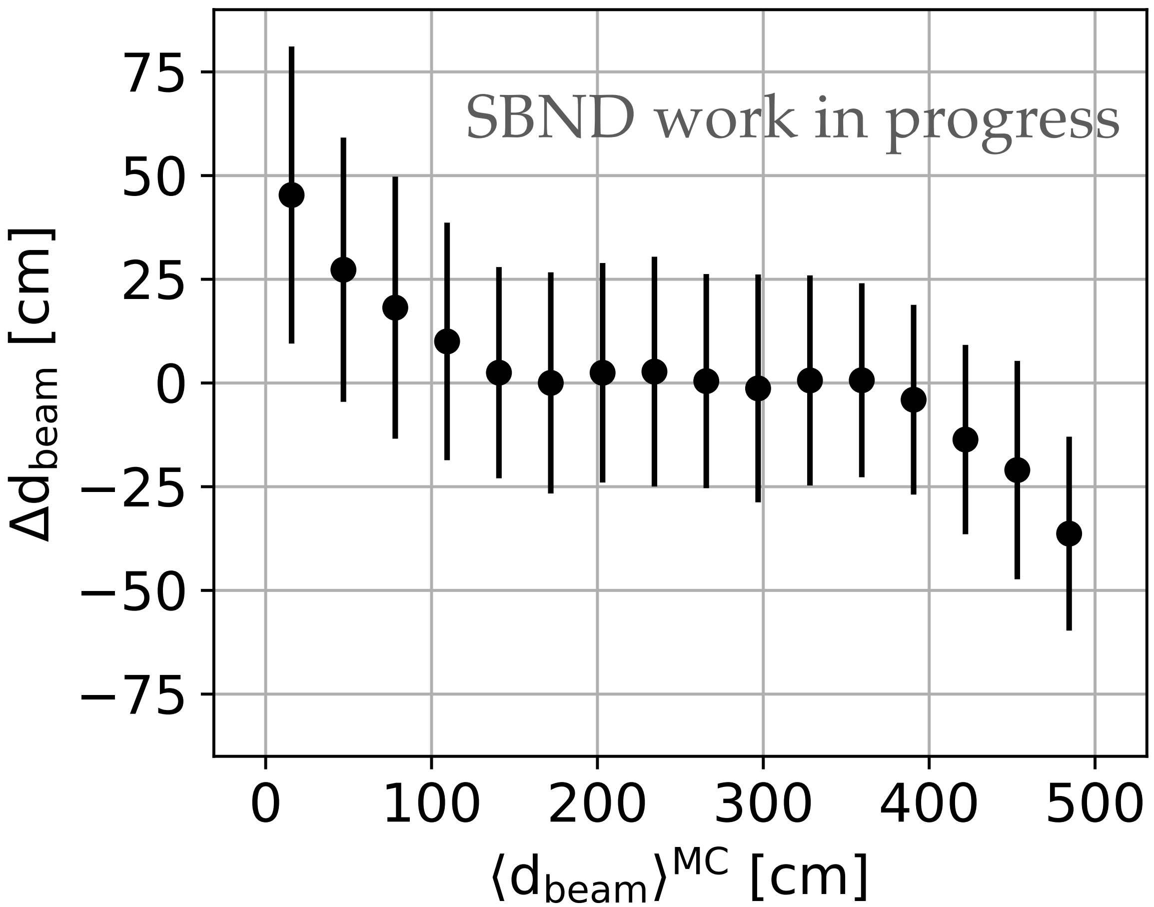




POSITION RESOLUTION

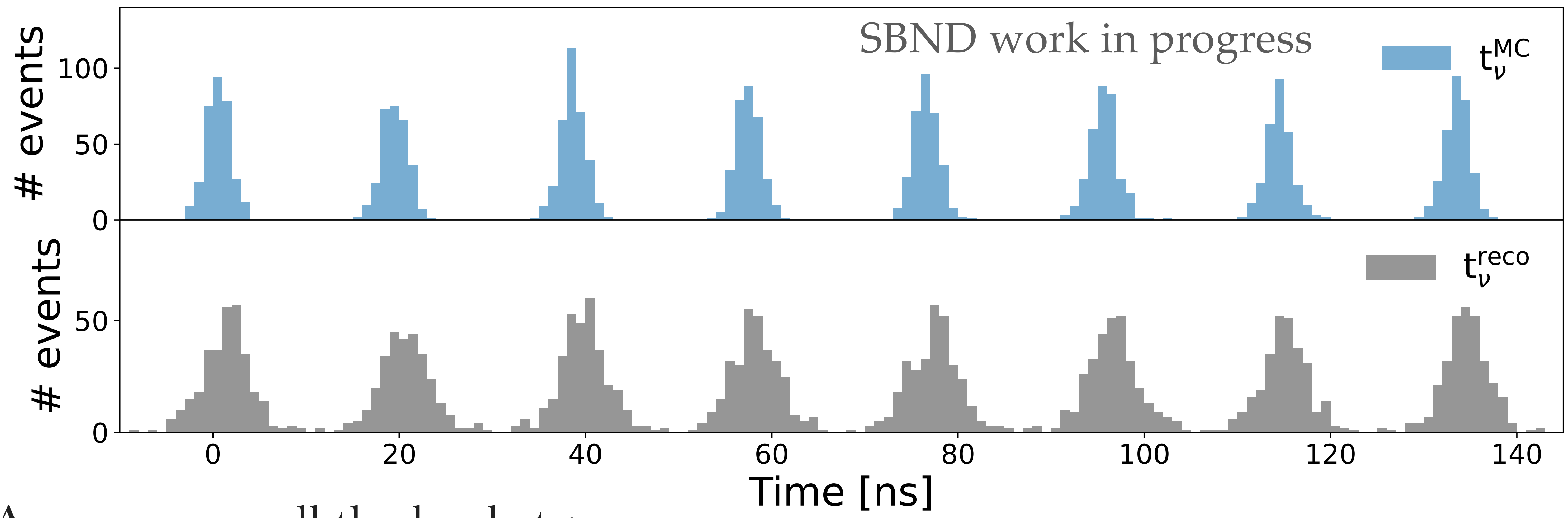
- SBND PDS provides an **independent 3D position reconstruction** using only scintillation light
- Expected resolution:
  - Drift: ~15 cm
  - Beam direction (Z): ~25 cm
- Translated to ToF: nanosecond level



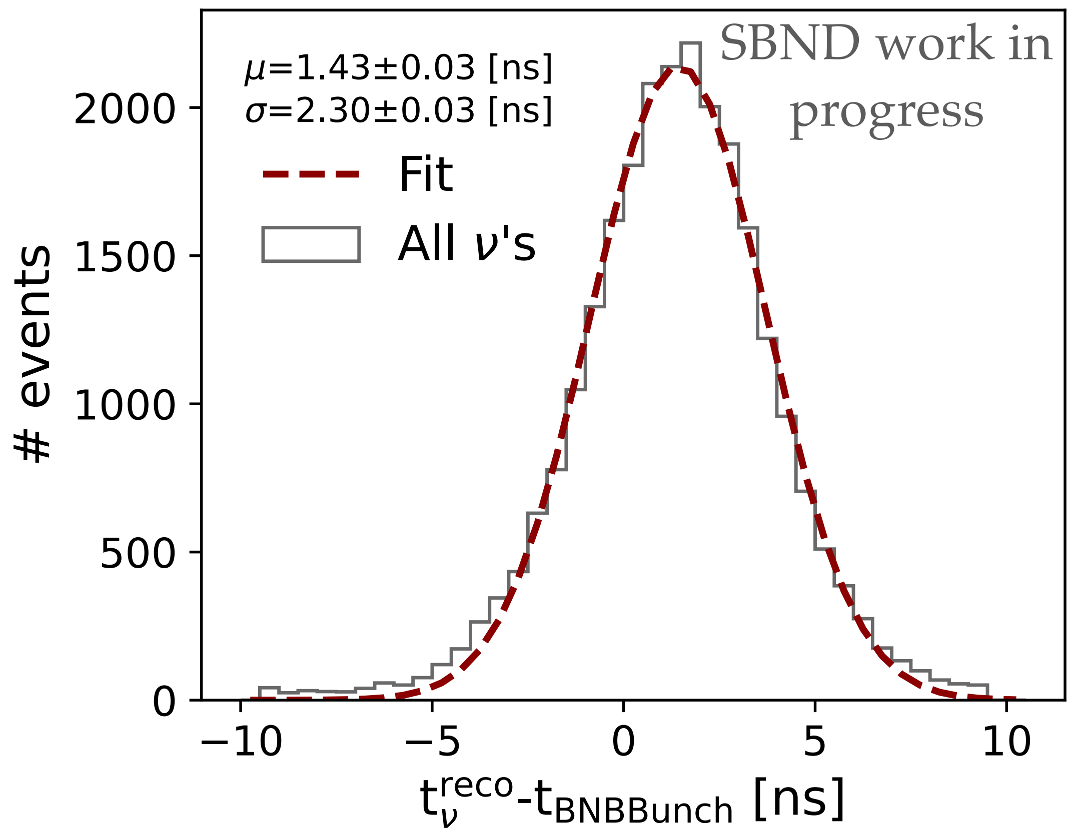


BNB RECONSTRUCTION

- True and reconstructed neutrino times after ToF_γ and ToF_ν subtraction:



- Average over all the buckets:



- This reconstruction is done using exclusively PDS information: very simple approach
- Different approaches including TPC information [already probed with data](#) by previous LArTPC experiments

SUMMARY

- The SBND PDS is potentially able to resolve the BNB inner structure using exclusively the light signals, thanks to:
  - An independent 3D reconstruction
  - $\mathcal{O}$(2 ns) time resolution
- Multiple applications:
  - Improve cosmic background discrimination
  - Exotic searches: look "between buckets" for massive long-lived particles (e.g. Heavy Neutral Leptons)

Thank you!