Fermilab

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SBND Detector Commissioning and Early Performance

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U.S. DEPARTMENT of ENERGY

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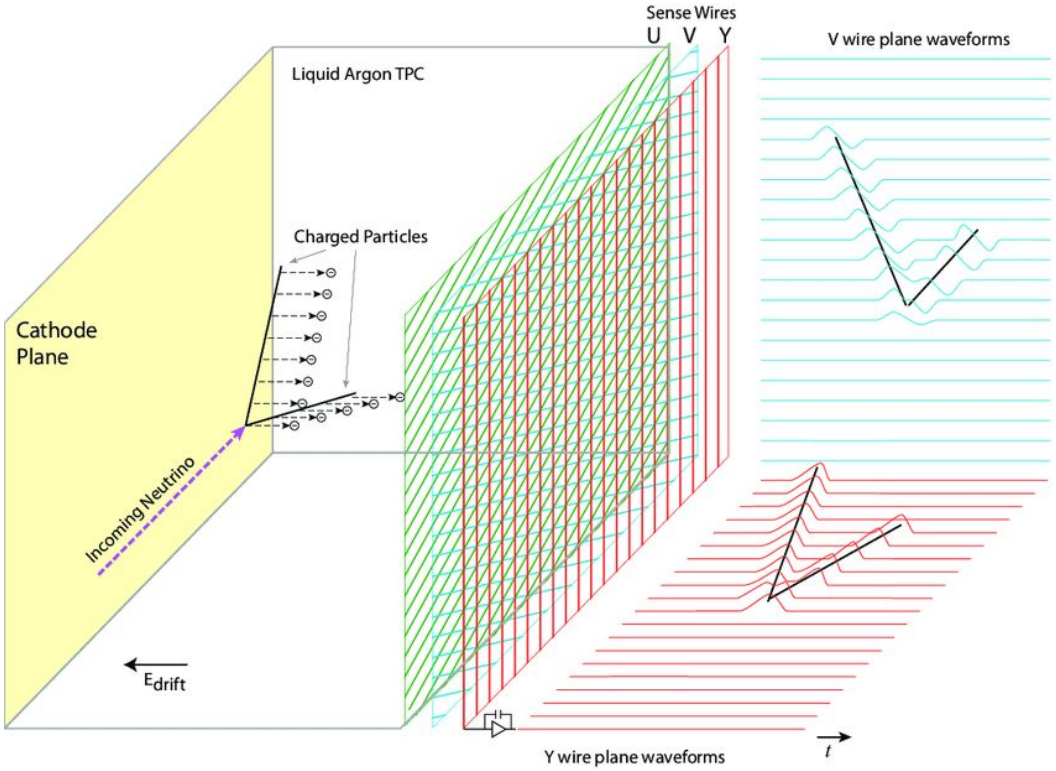
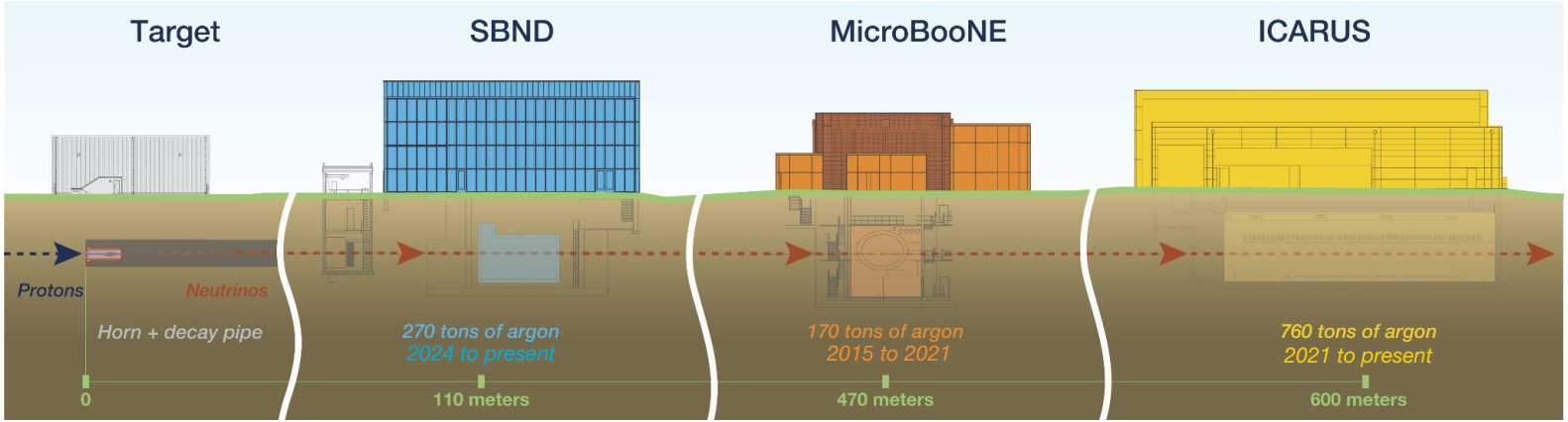
Detecting Neutrino Interactions with LArTPCs



- LArTPC detectors are highly-capable, fully-active tracking calorimeters with mm-scale spatial resolution
- Enables disentangling complex final states with low thresholds and excellent particle identification
- Precise timing information also available via scintillation light

Short Baseline Neutrino Program at Fermilab



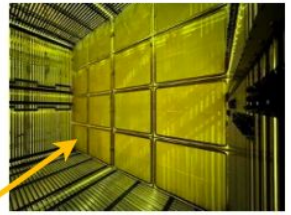
- Consists of liquid argon time projection chambers (LArTPCs) located at different baselines in Fermilab's Booster Neutrino Beam (BNB), aiming to conclusively address short-baseline neutrino oscillations at the eV-scale
  - SBND has a critical role in enabling this as the program's near detector
- SBND also has a rich single-detector physics program including neutrino–argon cross section measurements and new and rare physics searches
- We have been stably collecting physics-quality neutrino data since December 2024

The SBND Detector: TPC

LArTPC

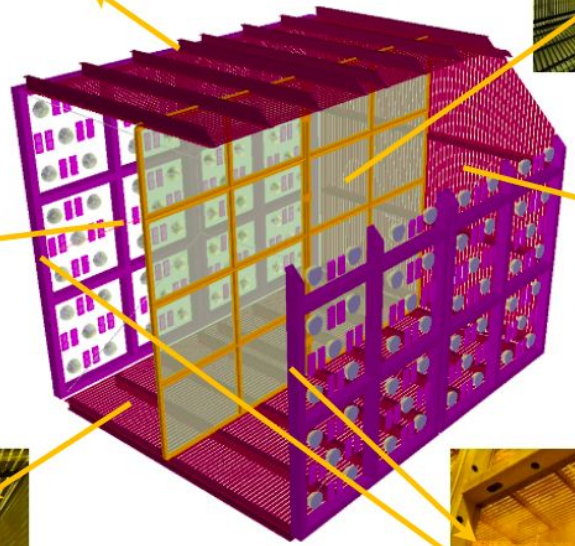
Active mass is 112 t
Active vol. is 4×4×5 m^3

Cold Electronics (in LAr)
pre-amplify and digitize
TPC wire signals

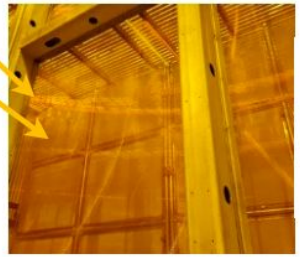


Cathode Plane at –100kV
divides the detector into
two drift volumes

Drift distance is 2m,
max. drift time is ~1.28ms



Field Cage wraps around
the two TPCs to step down
the voltage and ensure a uniform
electric field of 500 V/cm



Anode Plane on either side,
each with three wire planes
with 3 mm wire spacing and
different orientation per plan

Total of 11,260 wires

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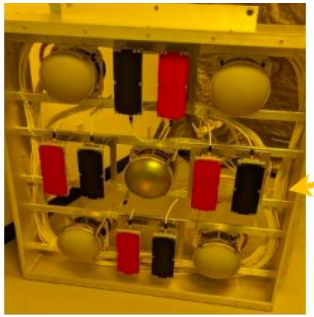
The SBND Detector: PDS, CRT, & Trigger

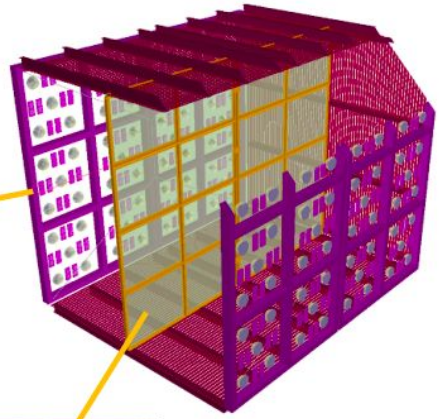
Photon Detection System



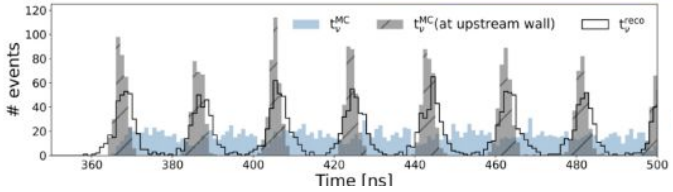
24 PDS Boxes
Behind the anode wire planes

5×24 = **120 8” PMTs**
80% TPB-coated,
20% uncoated

8×24 = **192 X-ARAPUCAs**
Half with wavelength shifting



Cathode Plane with TPB-coated reflective foils mounted behind mesh panels

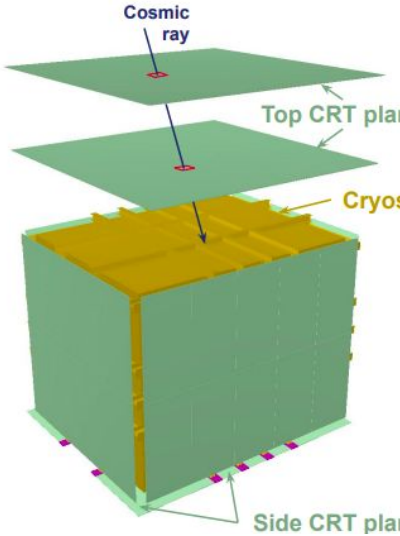


Sophisticated PDS reconstruction techniques developed on simulation demonstrate ns-scale timing

EPJ C **84**, 1046 (2024)

Hardware trigger system capable of incorporating inputs from PMTs and CRT, plus beam signals

Trigger System



Scintillator strips with SiPM readout

Two layers with perpendicular strips for accurate positions

142×32 channels

Cosmic Ray Tagger

Detector Commissioning

Detector commissioning was the process of activating all subsystems, and verifying their operational parameters were set to be sufficient for SBND's physics running

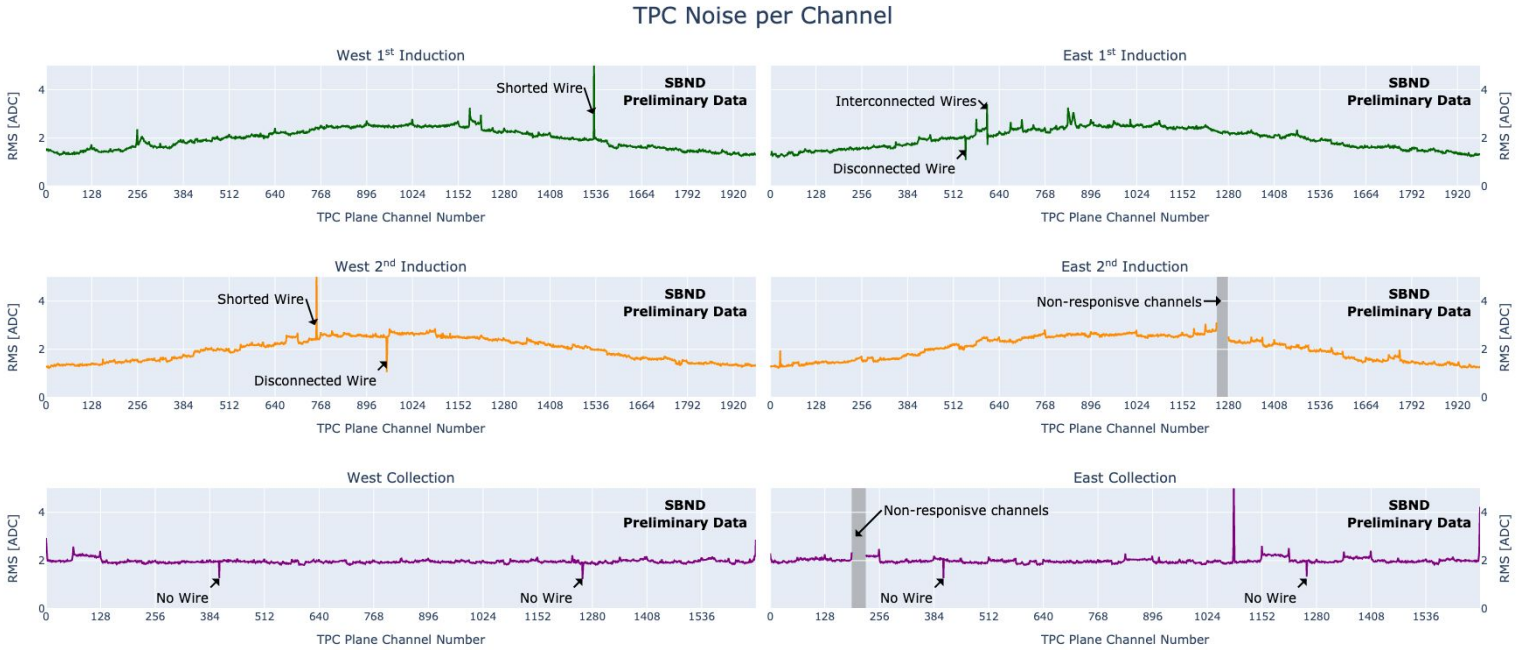
I will give brief descriptions of a few selected commissioning topics:

- TPC electronics noise
- PMT gain equalization
- CRT system activation and timing
- DAQ, trigger, and timing systems verification

There are many other aspects, and you're welcome to ask me questions if there's something else you'd like to hear about!

TPC Electronics Noise

SBND's TPC electronics noise is close to the intrinsic floor, resulting in excellent signal-to-noise ratio on all planes — comparable to others after their noise filtering



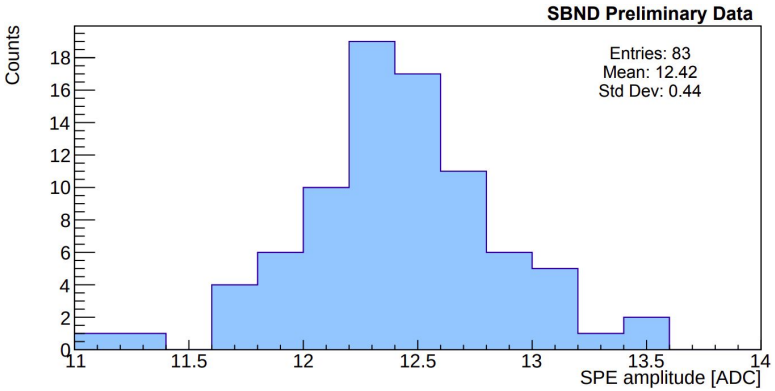
PMT Gain Equalization

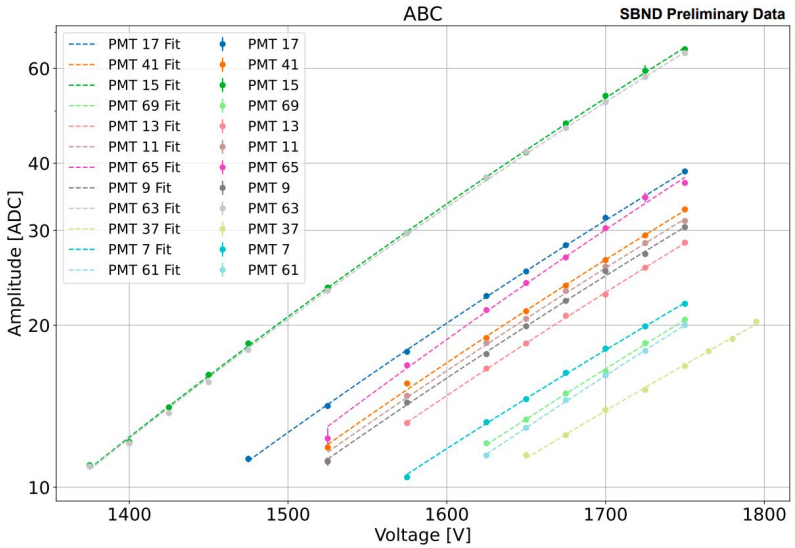
PMT gain equalization is an essential prerequisite to a light-based trigger

Performed a voltage scan and then set each channel to the bias voltage that provides a gain of about 12.5 ADC/PE

Balancing gain with PMT longevity

Resulting distribution of PMT gains for is shown below, equalized to ~5% level



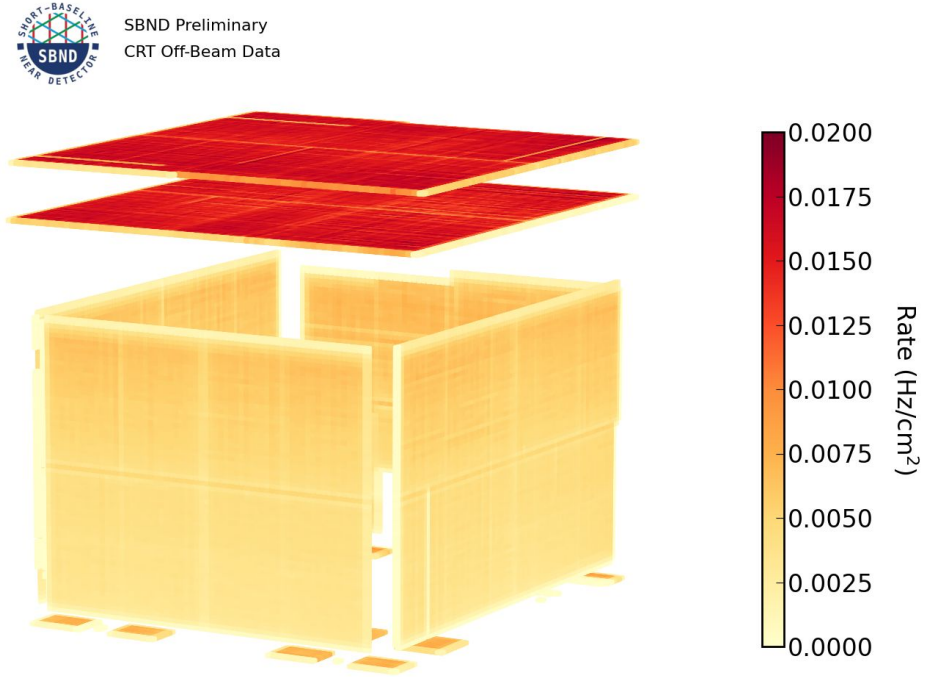


CRT Commissioning

Rejecting cosmic backgrounds is important for many analyses

Tagging cosmics can be useful for calibration analyses, as the CRT can provide a known time and position for through-going muons

Can also measure the cosmic ray rate around the detector

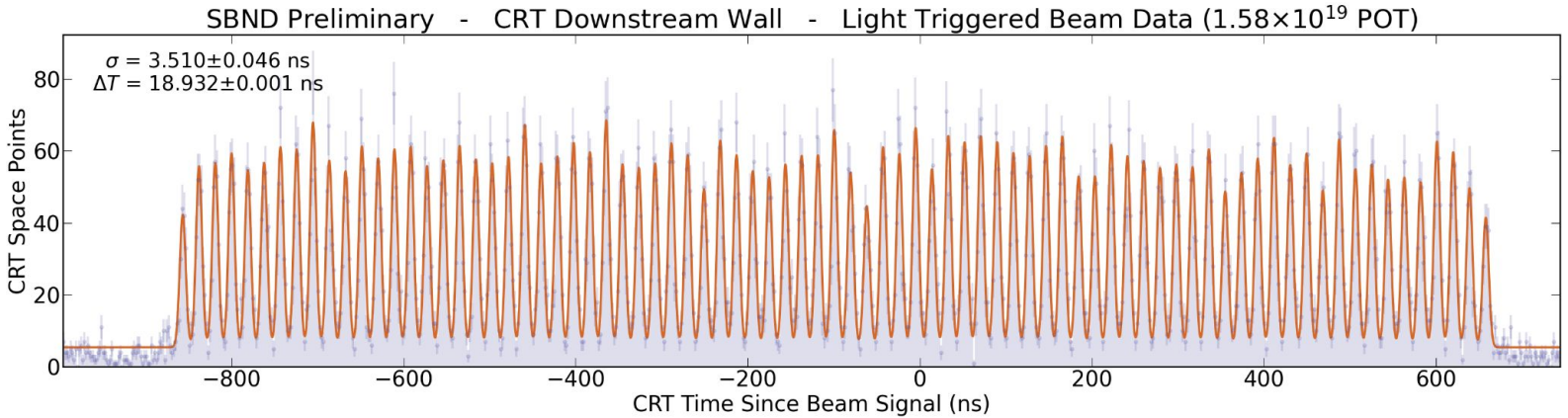


CRT Timing

CRT system is designed to have timing resolution of O(1 ns), and we have already been able to demonstrate that in SBND data

We can observe this bucket structure in the CRT activity, and buckets have an measured width of about 3.5ns

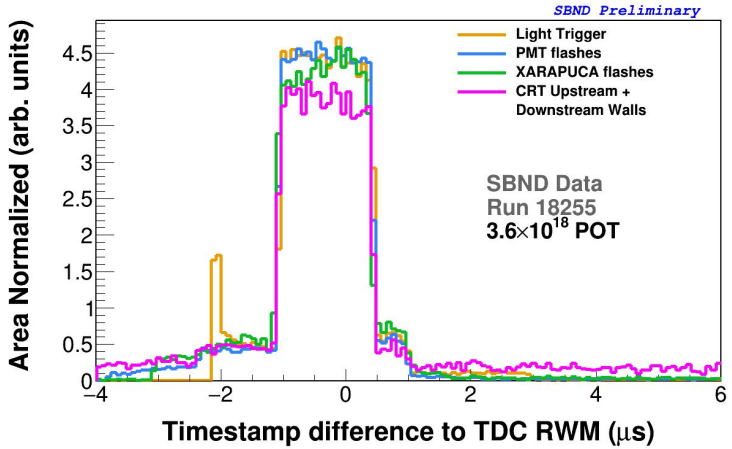
Precise timing can help distinguish entering cosmics vs. exiting neutrinos

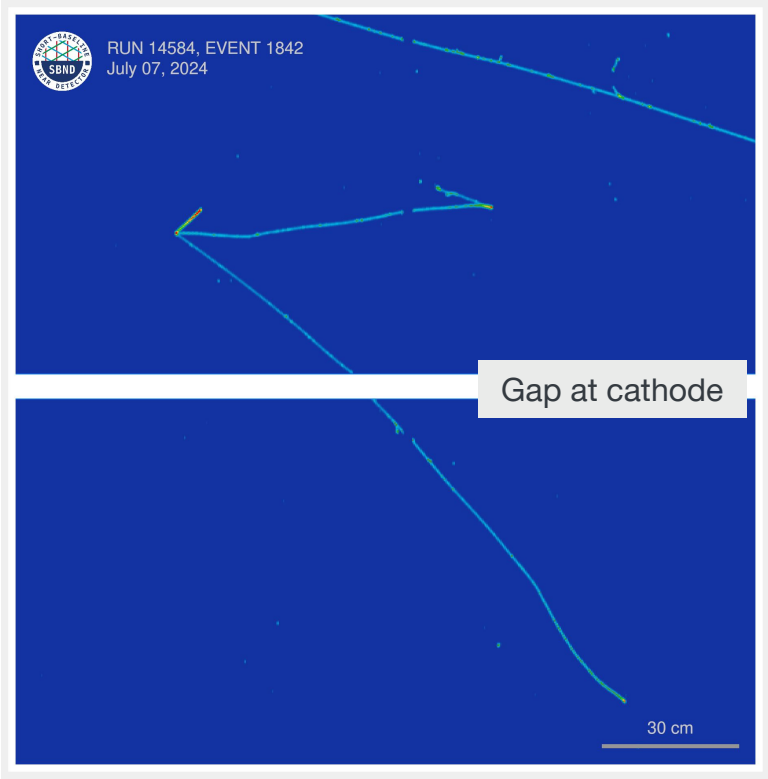


Data Acquisition & System Synchronization

For the PDS, CRT, and trigger, system synchronization can be verified by seeing the beam activity appears at the same time

For the TPC, we can look at event displays, and check that we see neutrino topologies consistent with in-time interactions

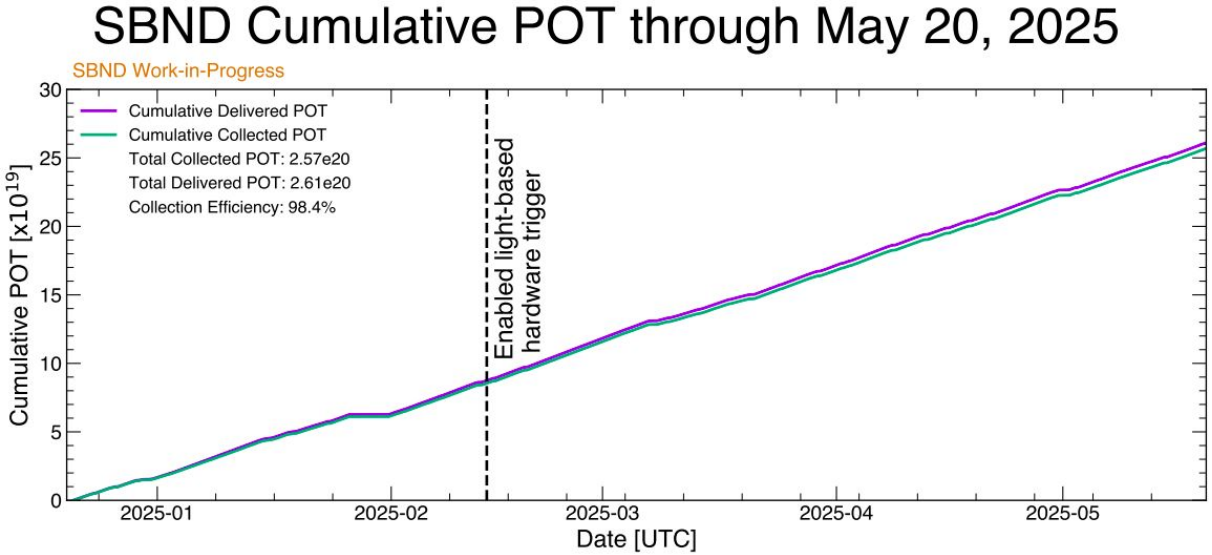




SBND Operations to Date

SBND has been smoothly collecting physics-quality neutrino data since December, and implemented our light-based hardware trigger in February (>98% uptime)

To date, have collected more than 2.5e20 POT, which corresponds to an expectation of more than 2 million neutrino interactions in the detector



Summary & Outlook

SBND detector commissioning is complete and we are stably collecting physics-quality data, having already accumulated world-leading statistics for neutrino–argon interactions

Our early detector performance is outstanding, with all systems consistently meeting or exceeding their design requirements

We are making great progress in understanding and calibrating our detector, which is an important step towards high-precision physics measurements

See Lynn Tung's talk

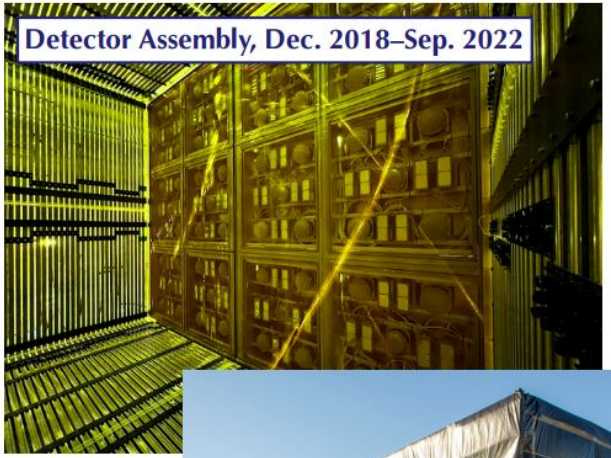
We have an exciting physics program that will keep us busy for many years to come! Stay tuned for future results to come from SBND and the SBN Program

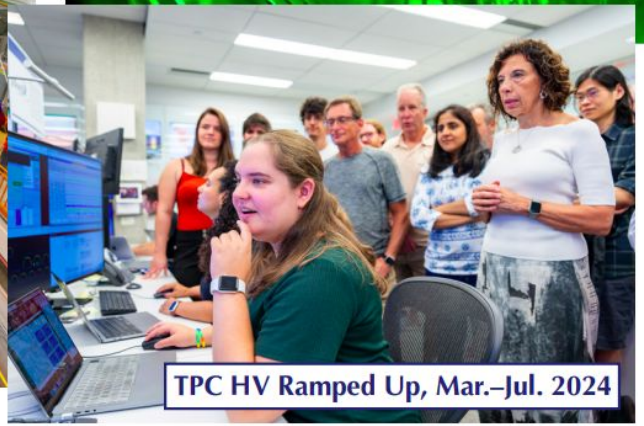
See Josie Paton, Amy Filkins, and Vincent Basque's talks

Thank you!

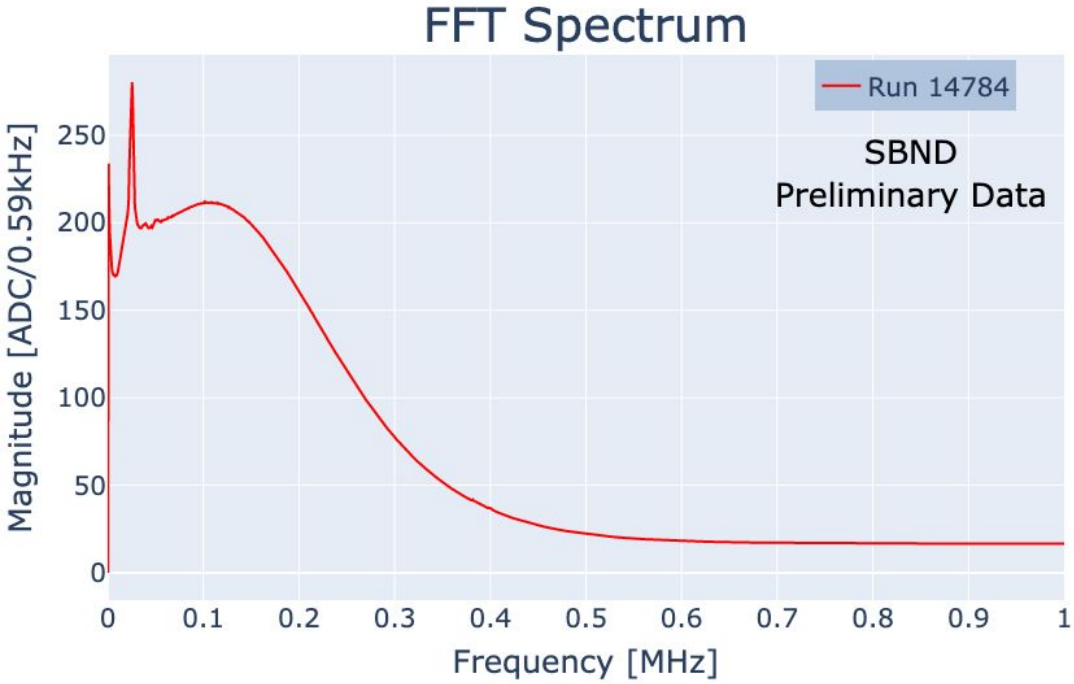
Additional Slides

SBND Timeline

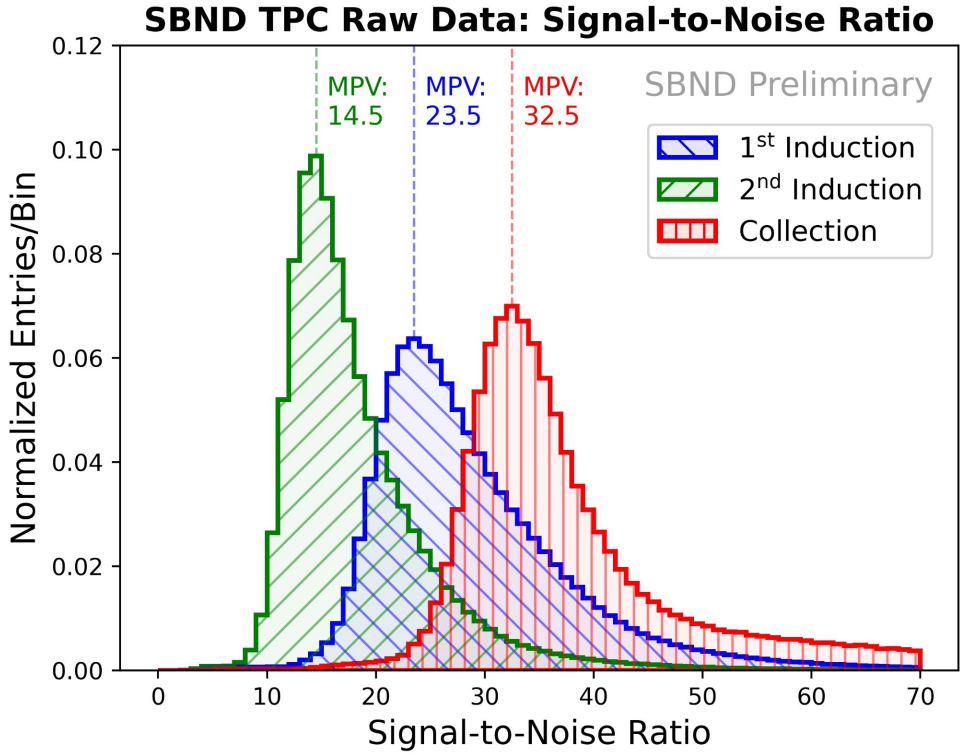




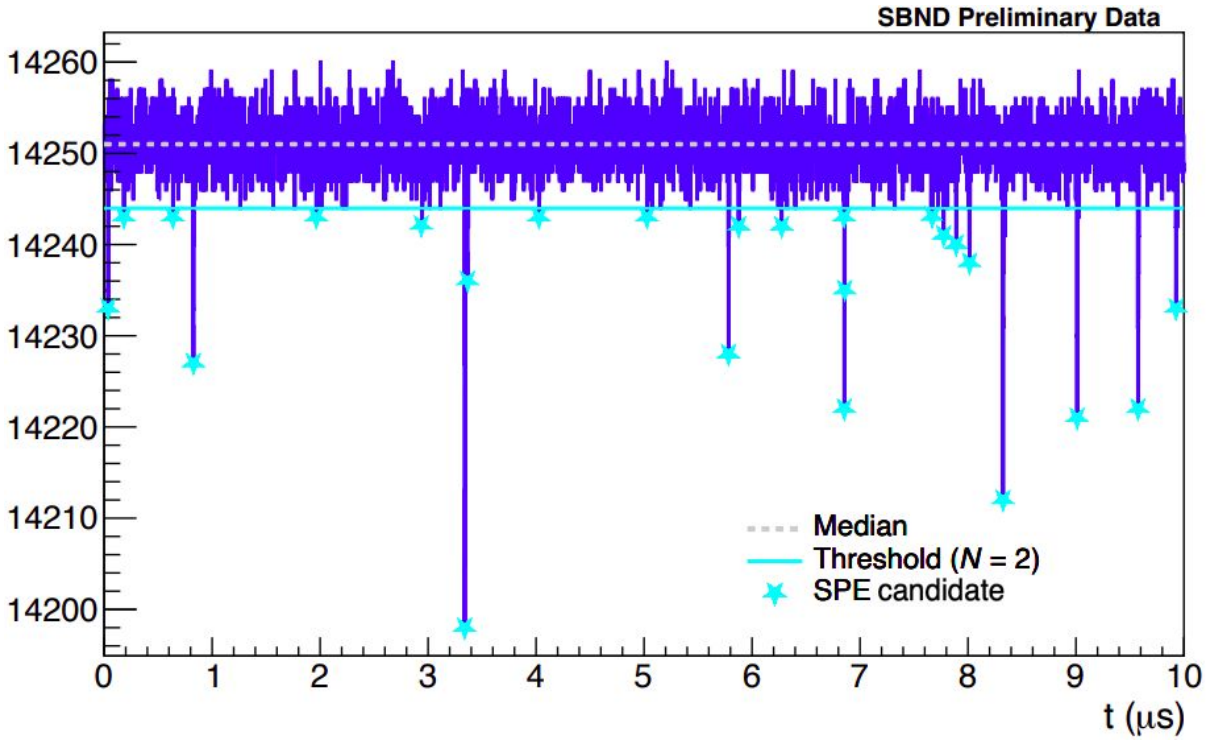
TPC Electronics Noise Spectrum



TPC Electronics Signal-to-Noise



PMT Gain Equalization: SPE-Finding



PMT Gain Equalization: SPE Fitting