Status of the Short-Baseline Near Detector at Fermilab

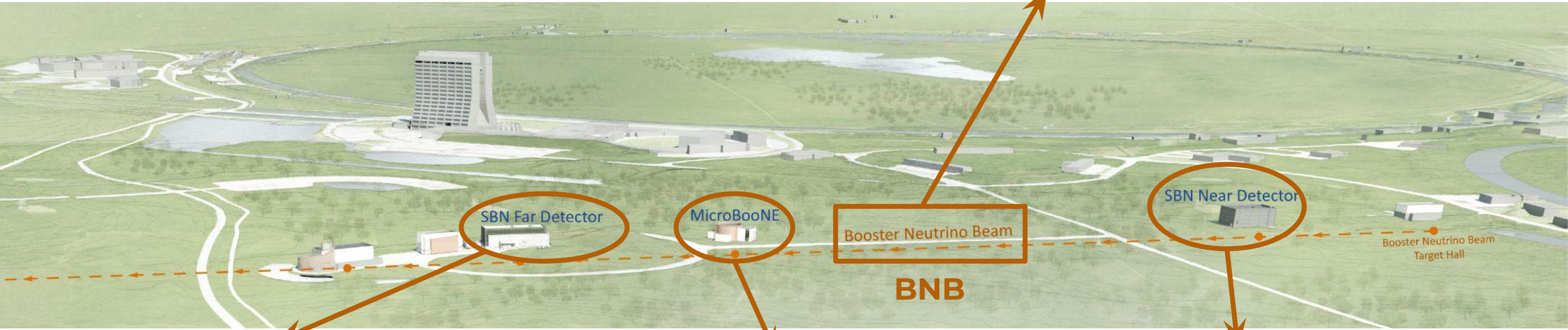
NuFACT, 19th September 2024

Tereza Kroupová
SBND Collaboration

Short-Baseline Neutrino Program at Fermilab

Three detectors of the same technology along the same neutrino beam

8 GeV protons on Be target



BNB

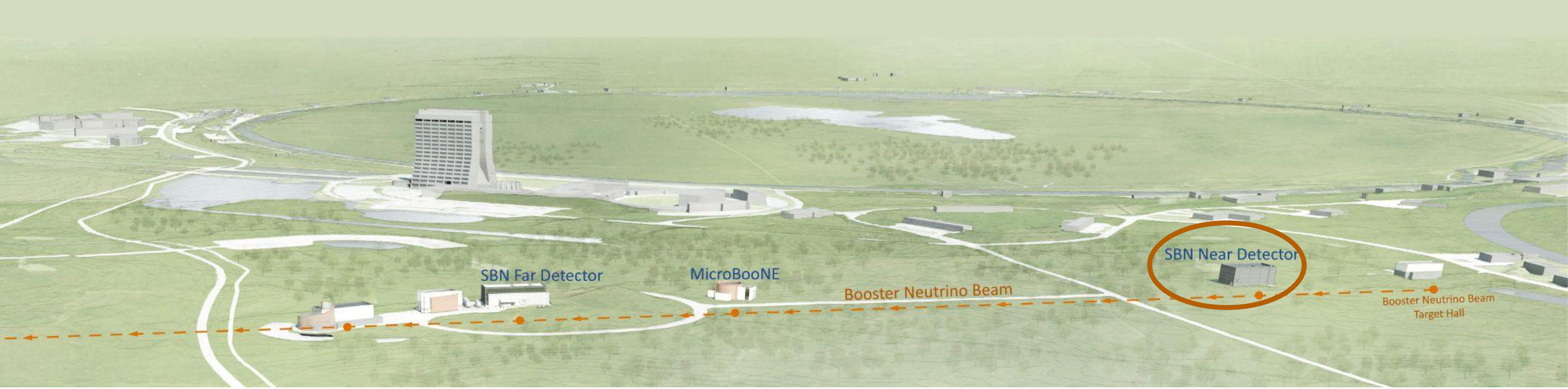
ICARUS
(2021 - now)
476 tons active volume
L = 600 m
"Far detector"

MicroBooNE
(2015 - 2021)
85 tons active volume
L = 470 m

SBND
(2024 - now)
112 tons active volume
L = 110 m
"Near detector"

Short-Baseline Neutrino Program at Fermilab

Three detectors of the same technology along the same neutrino beam



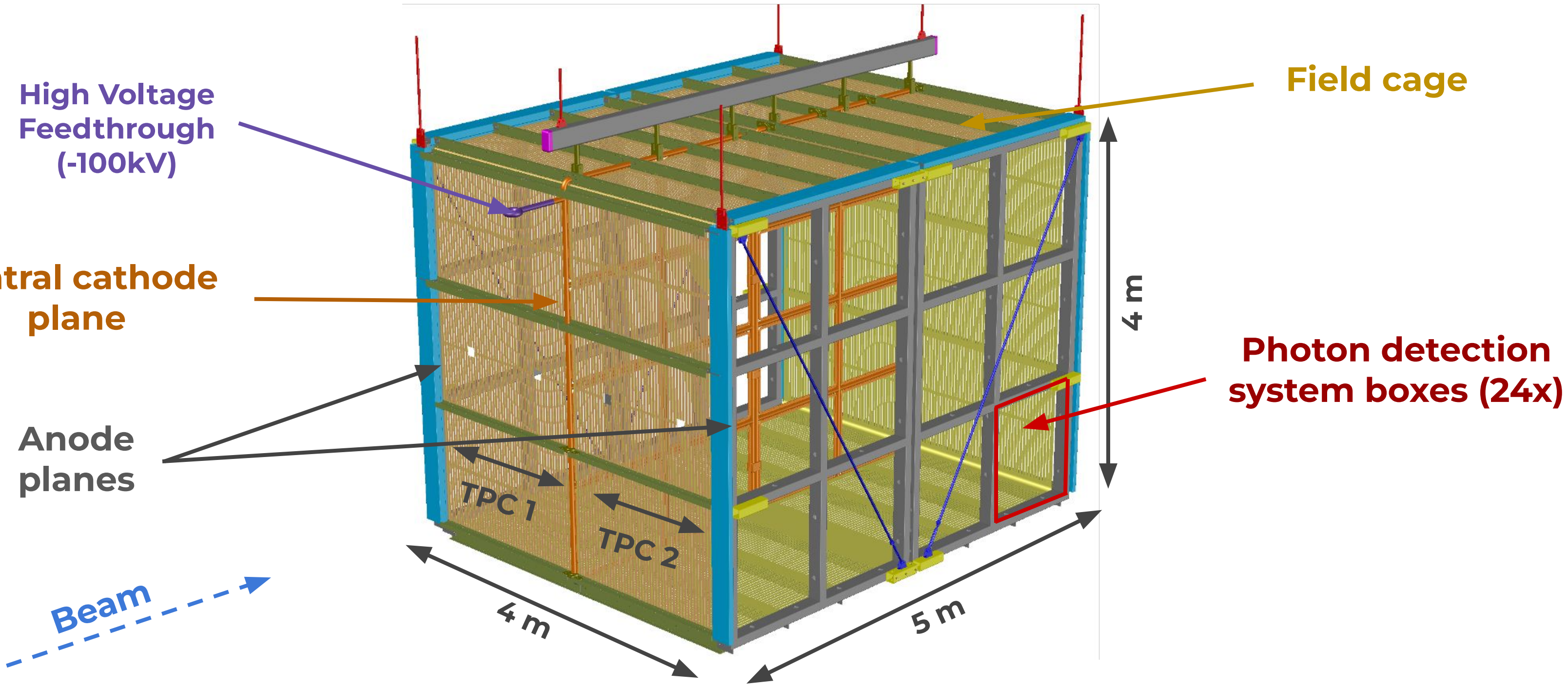
SBN Strategy

- **Systematic errors** constrained between detectors
- **Background rejection** through particle identification
- Measuring across **multiple baselines and channels**

SBND leverages high interaction rates for cross-section measurements and BSM searches

The SBND Experiment

112 tons of LAr between two drift volumes separated by central cathode

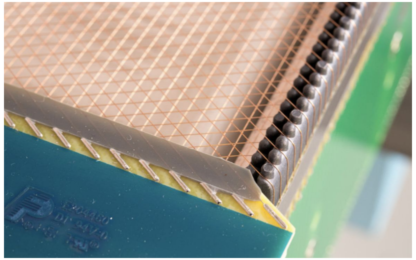


SBND TPC

TPC filled with liquid argon, at -100kV and taking data

Cathode covered in wavelength shifting (TPB) reflectors
- Two TPCs optically isolated

2 Anode Plane Assemblies per wall
- 3 wire crossing planes each
- 3 mm wire & plane pitch



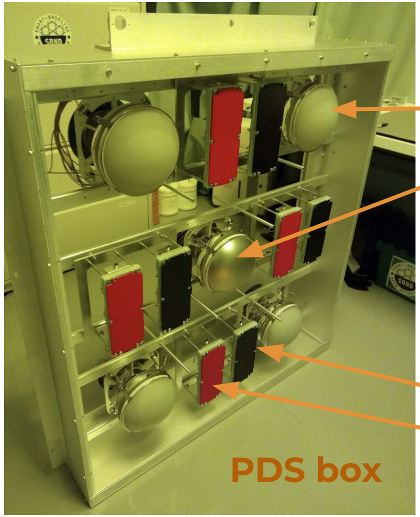
Field cage to ensure uniform electric field of 500 V/cm

Photon Detection System (PDS)

PMTs ON and taking data

PDS system behind each anode plane to detect LAr scintillation light

- Direct and cathode reflected light
- R&D for LArTPC program



120 PMTs

96 TPB coated

24 uncoated

192 X-ARAPUCAs

Light guides with dichroic filters and wavelength shifter coupled to SiMPs

50% PTP coated

50% uncoated

Photon Detection System (PDS)

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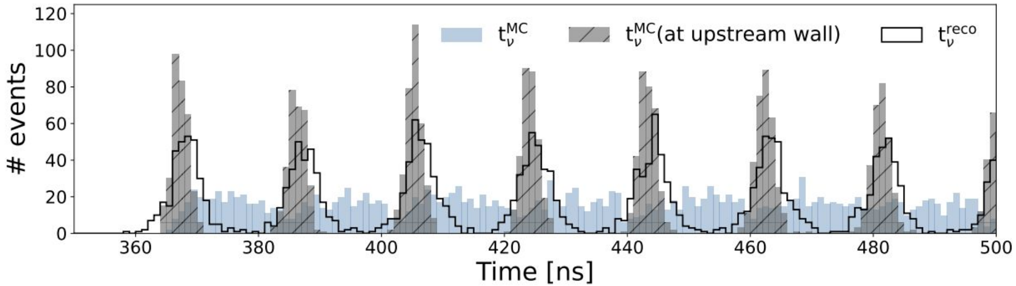
- Direct and cathode reflected light
- R&D for LArTPC program
- Nanosecond timing for reconstruction and trigger

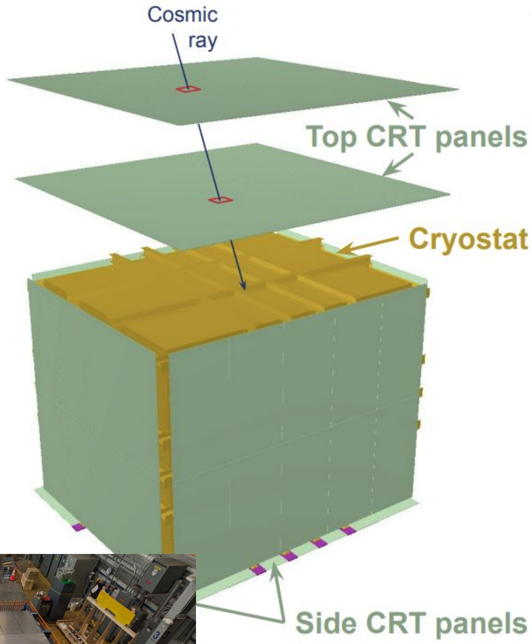


Scintillation Light in SBND: Simulation, Reconstruction, and Expected Performance of the Photon Detection System
arXiv:2406.07514

Cosmic Ray Tagger (CRT)

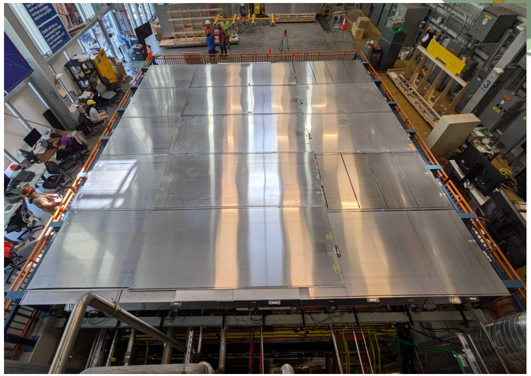
Cryostat surrounded by plastic scintillator panels coupled to SiPMs

- near 4π coverage
- time resolution of a few nanoseconds
- included in hardware trigger

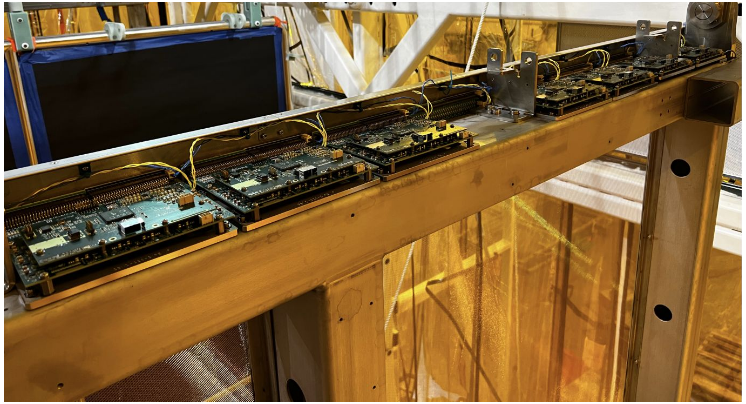


Cosmic tagging for background rejection and creating data samples for calibration and commissioning

Last panel placed on top of the cryostat 2 weeks ago



Readout electronics and Trigger



TPC cold electronics installed on anode plane frames

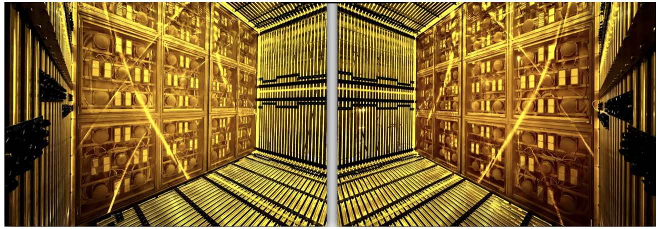
Signals pre-amplified and digitised in the cold for noise reduction

Hardware trigger primarily based on fast O(ns) PDS signals, also includes beam signals and CRT

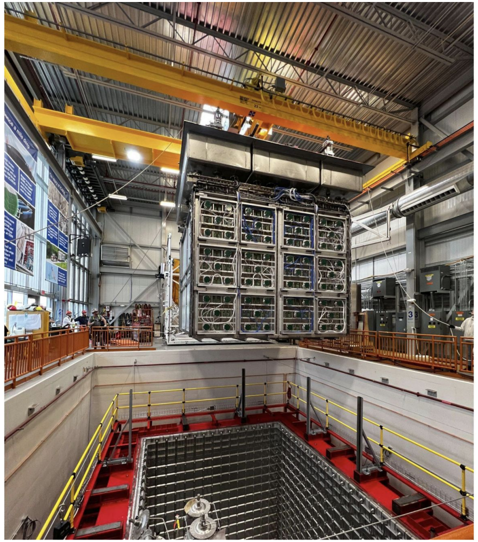
Allows for high efficiency trigger while keeping data rate manageable for analysis

SBND Timeline

September 2022
Detector assembly completed



December 2022
Detector transported to ND



April 2023
Detector lowered to cryostat

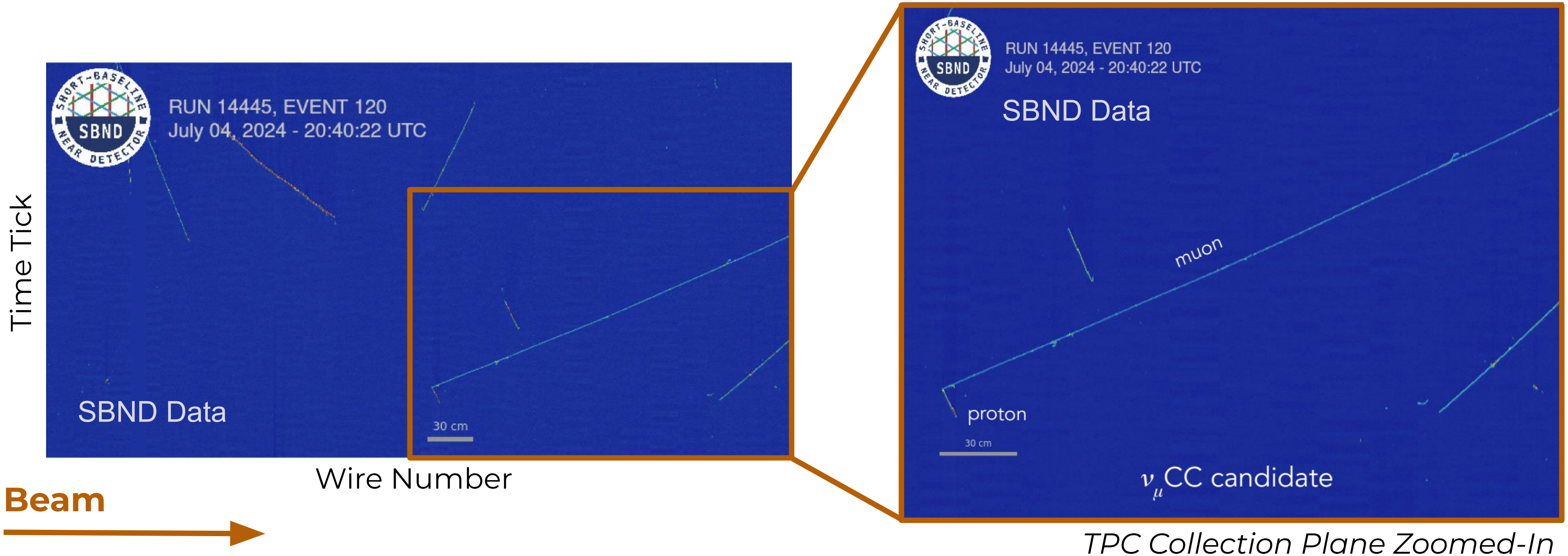
March 2024: **LAr filling complete**

July 2024
TPC high voltage ramped up

First Events: BNB

TPC high voltage operating stably since July 3rd, neutrino candidate events in the detector

BNB ran until July 12th- seen neutrino candidate events while triggering on every beam spill to maximise beam time

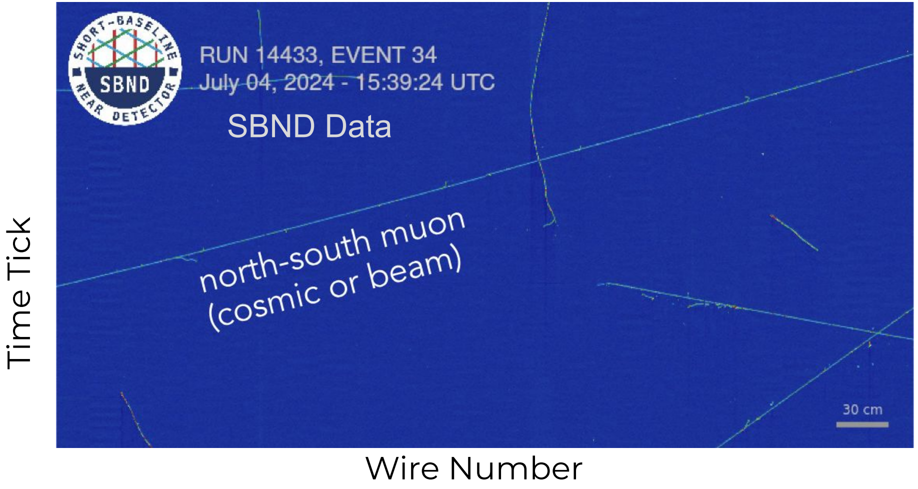


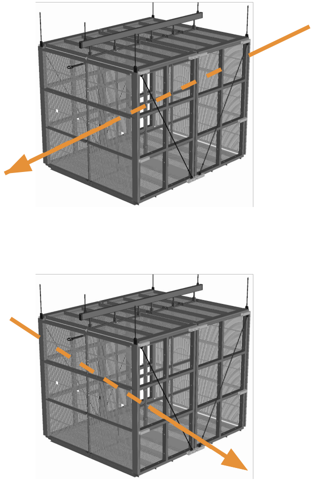
TPC Collection Plane Zoomed-In

First Events: Crossing Muons

Calibration and commissioning samples during beam downtime

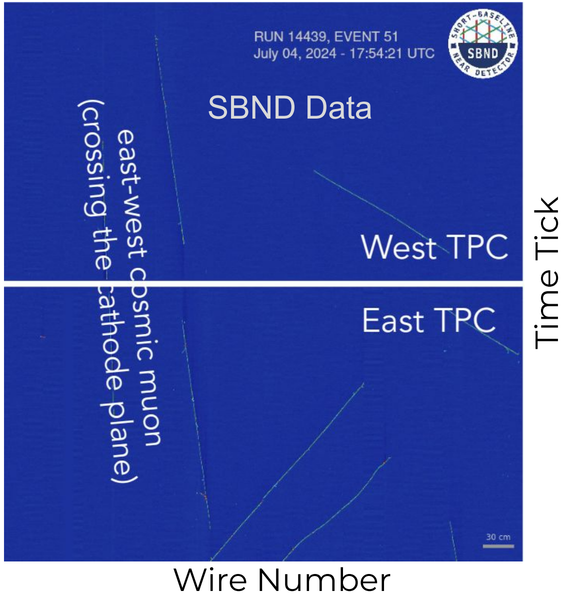
North/South CRT Coincidence Trigger





Crossing tracks observed in the TPC during crossing-muon trigger runs

East/West CRT Coincidence Trigger

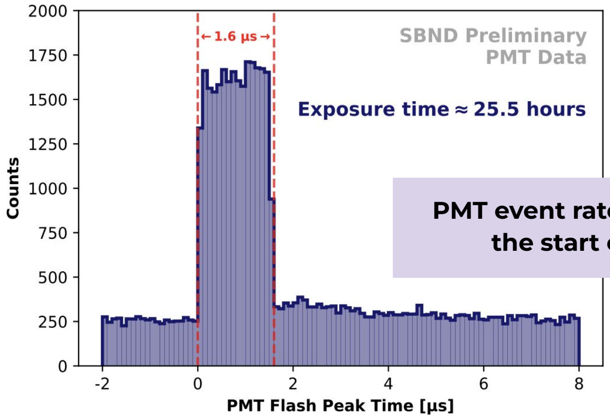


Detector Performance

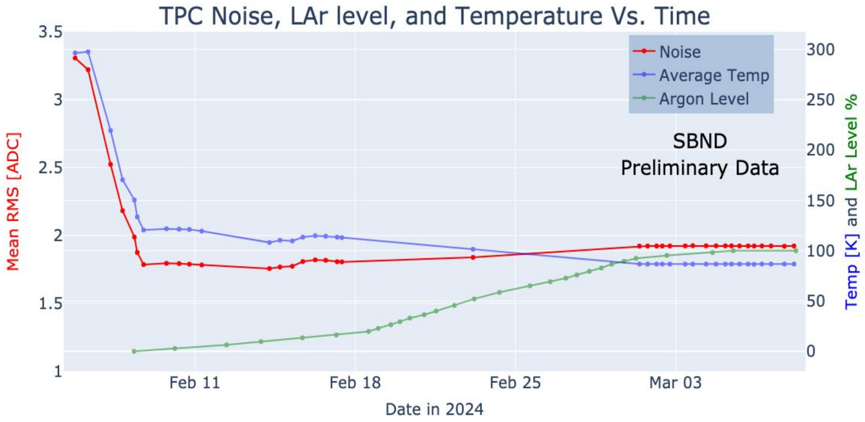
Low TPC noise of ~2 ADC for 4m wires across all active channels

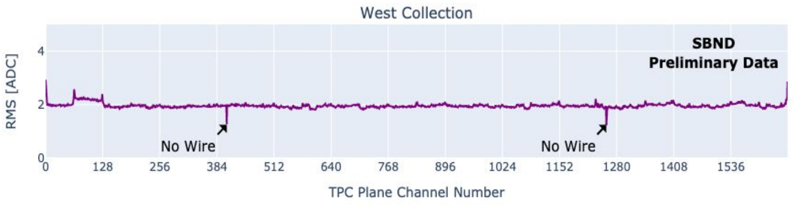
Electron lifetime meets design criteria of >3 ms

Functionality and synchronisation between PMTs, CRT, beam signals, and trigger demonstrated



PMT event rates referenced to the start of BNB spill





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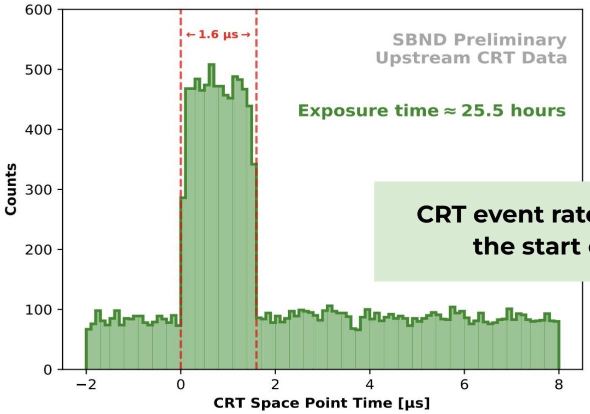
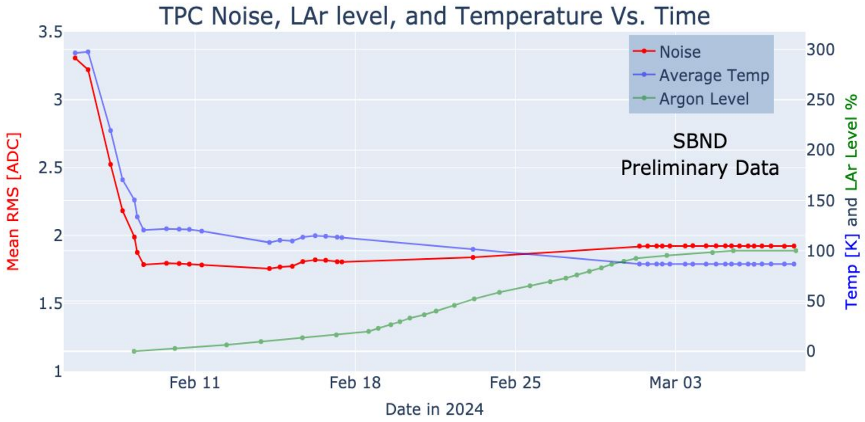
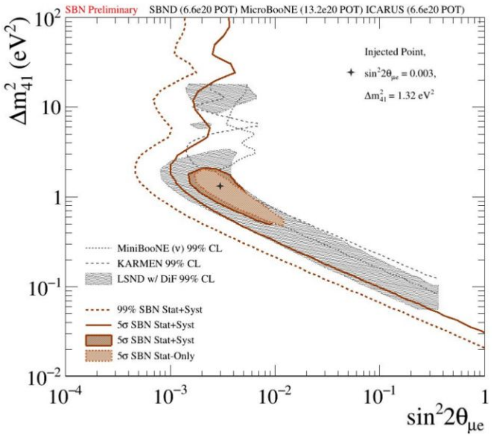


CRT event rates referenced to the start of BNB spill



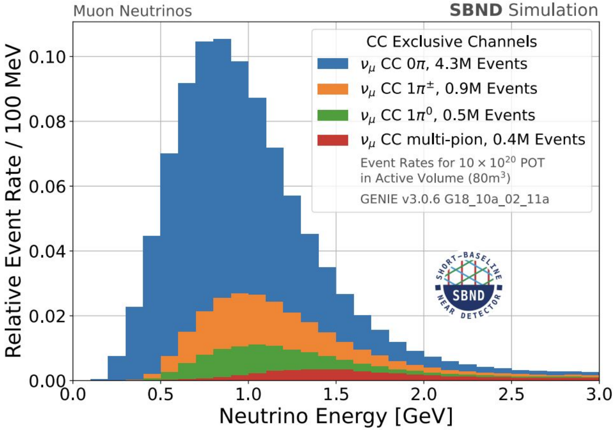
SBND Physics Goals

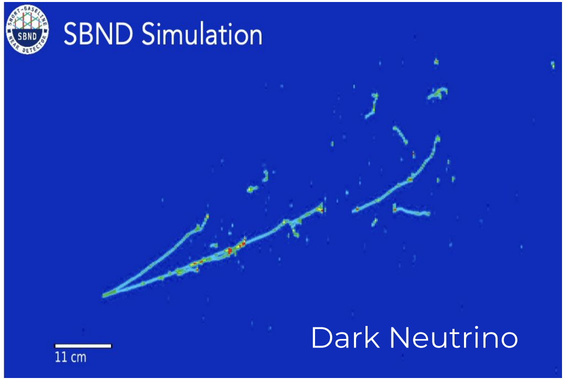


1. **eV-scale sterile neutrino** hypothesis as part of SBN (3 channels)

Tuesday's talk by S. Yadav: "Near Detector Constraint for SBND to reduce uncertainties in SBN Oscillation analysis"

2. **ν-Ar interaction cross-section** measurements

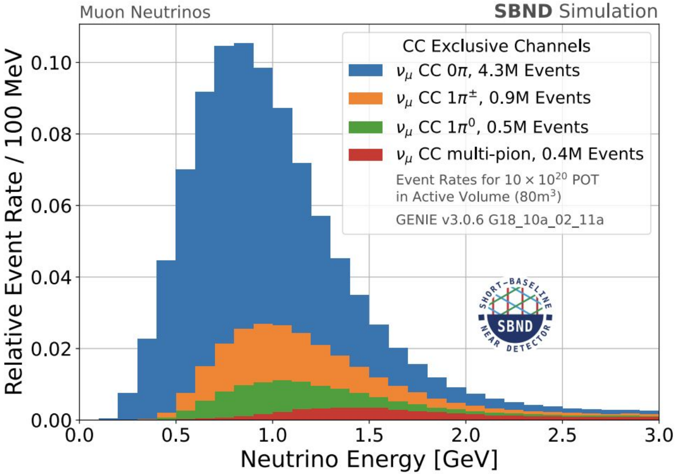


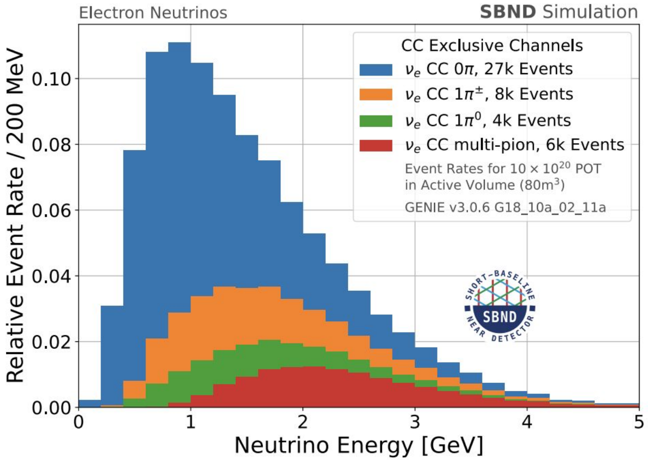


3. **Beyond the Standard Model** searches

Neutrino Interactions

BNB impacts 8 GeV protons on Be target giving neutrino beam with peak energy of ~0.7 GeV, 93.6% muon neutrinos





2M ν_μ CC events

15k ν_e CC events in 1 year

Order of magnitude higher LAr statistics than currently available!

Today's talk by L. Soplin: "Neutrino Interaction Measurement Capabilities of the SBND Experiment"

Poster by J.Paton: "An Updated Simulation of the Booster Neutrino Beam"

Poster by M. Jung: "Studying Neutrino-Nucleus Interactions at SBND with Muon Neutrino Charged-Current Pionless Events"

BSM Physics

… beyond SBN sterile neutrino search

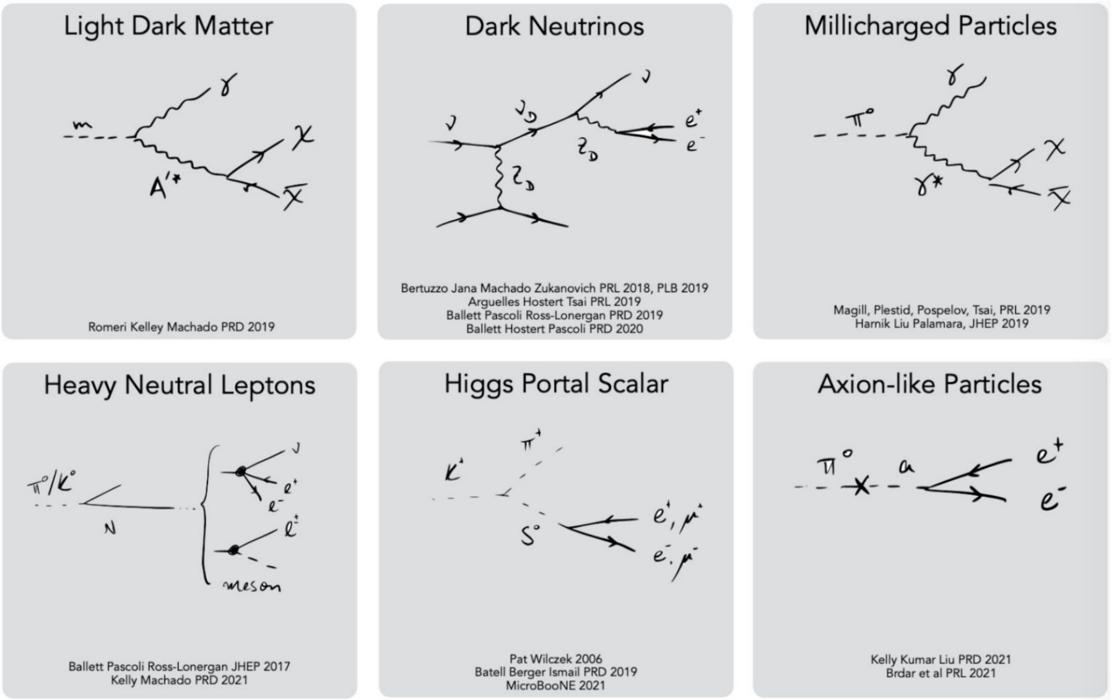


Image Credit: P. Machado and M. Del Tutto

Alternative explanations to MiniBooNE excess as well as unrelated **new physics**

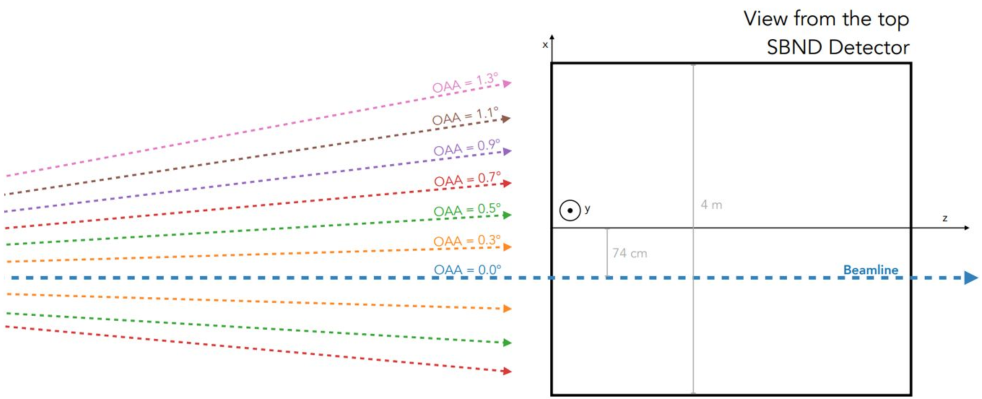
High statistics in SBND gives it unique opportunity for exotic searches

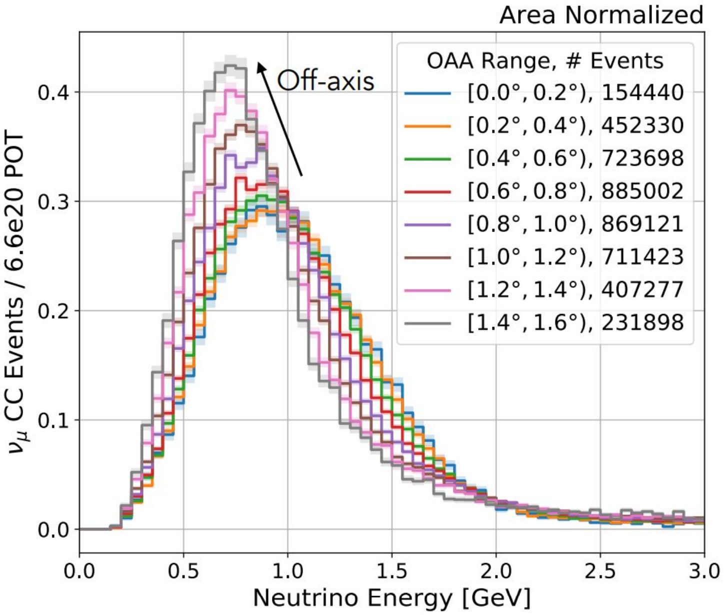
SBND PRISM will be useful for neutrino background constraint

Nanosecond timing allows leveraging time-of-flight differences

SBND PRISM

Sampling multiple off-axis fluxes with the same detector





SBND positioned ~70 cm off beam axis and only 110m from target
→ **can sample multiple angles in the same detector**

Incorporating off-axis angle to analysis provides further **constraint on systematic errors** to improve sensitivity

Conclusions

SBND has collected first data and is getting ready for BNB operations in the fall

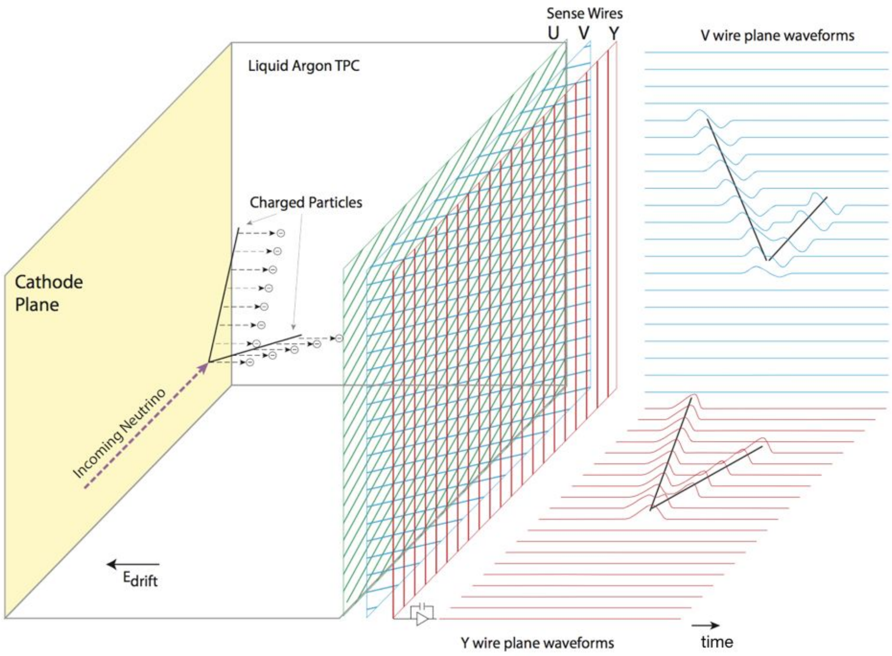
All sub-systems of SBND installed and taking data

Highest statistics of any neutrino LAr experiment to date will provide opportunity for measuring **neutrino cross-sections** and potential **BSM physics**

Thank you for your attention!

Back up: LArTPC

SBND is a Liquid Argon Time Projection Chamber



Neutrino scattering produces charged particles which **ionise LAr**

- millisecond drift times to anode

3 wire crossing planes

- 2 induction + 1 collection

Multi-dimensional event topology
Particle Identification via dE/dx

Back up: LArTPC

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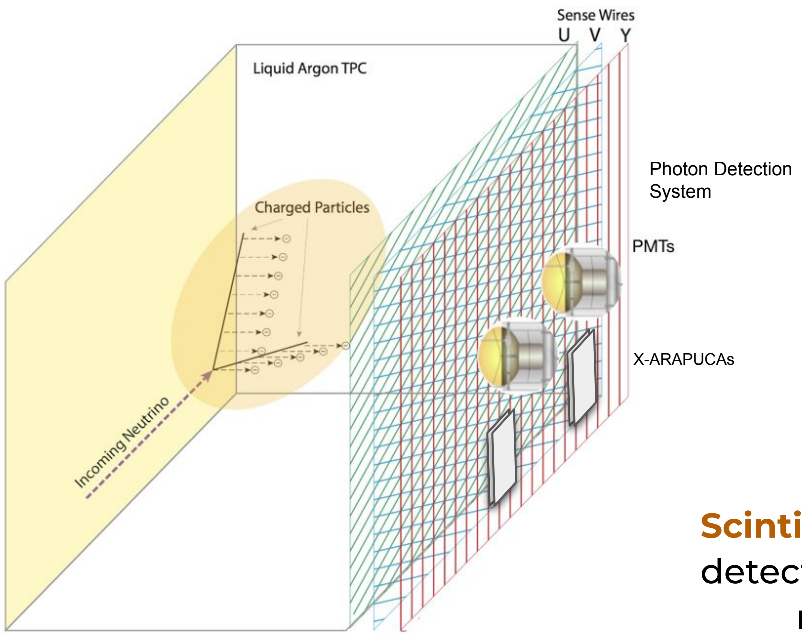

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- millisecond drift times to anode

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Multi-dimensional event topology
Particle Identification via dE/dx

Scintillation light from LAr detected by photon detection system
nanosecond timing and trigger

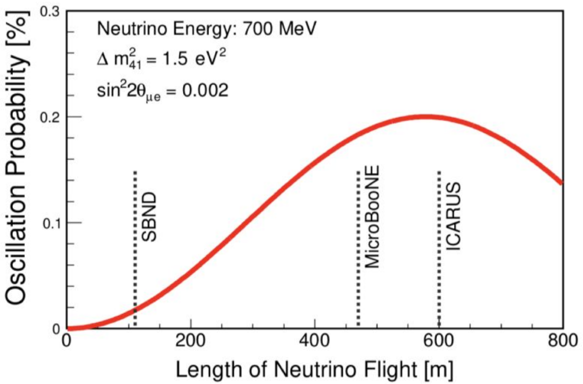
Back-up: Beam composition

Neutrino mode BNB composition:

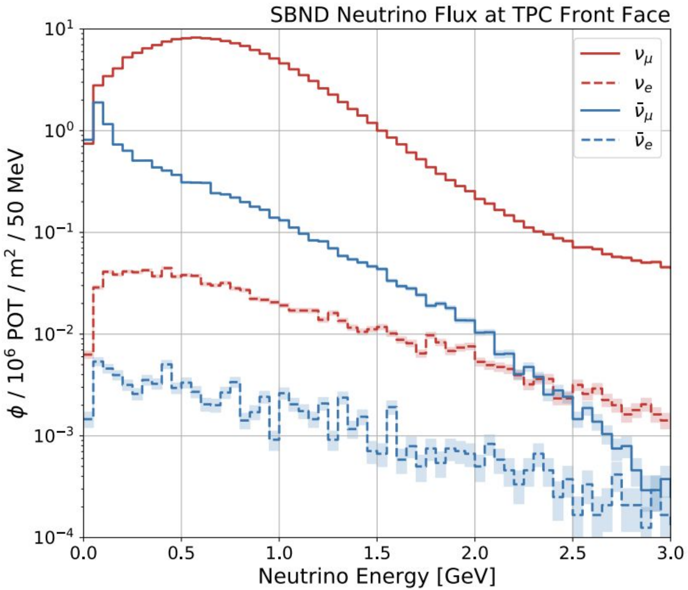
$$93.6\% \ \nu_\mu$$

$$5.9\% \ \bar{\nu}_\mu$$

$$\sim 0.5\% \ \bar{\nu}_e + \nu_e$$



Neutrino mode



Back up: X-ARAPUCAs