Triggering First SBND Events

ICHEP, 19th July 2024

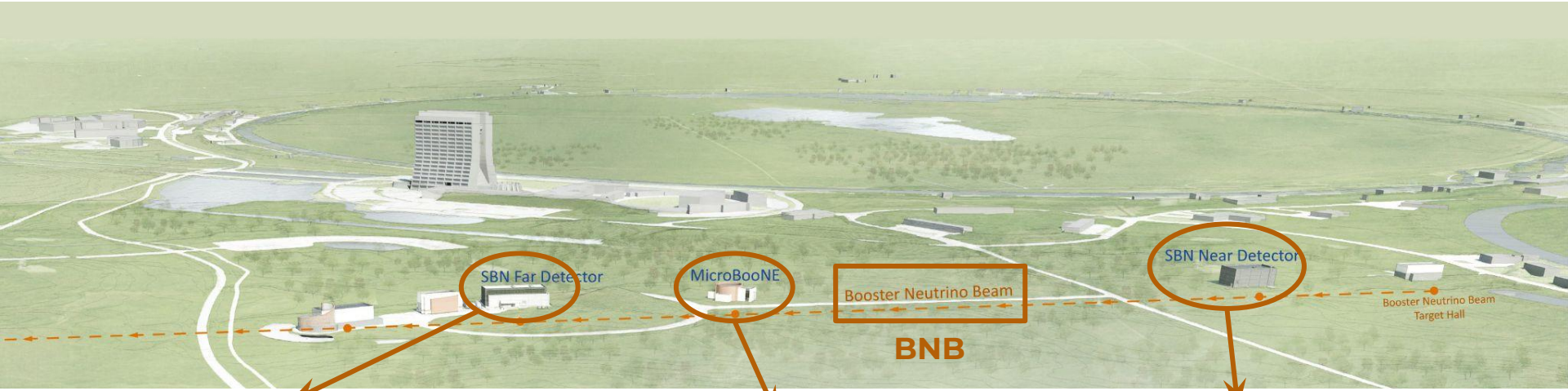
Tereza Kroupová
SBND Collaboration

Penn
University of Pennsylvania

SHORT-BASELINE NEAR DETECTOR
SBND

Short-Baseline Neutrino Program at Fermilab

Three detectors of the same technology along the same neutrino beam



ICARUS

476 tons active volume
L = 600 m
“Far detector”

MicroBooNE

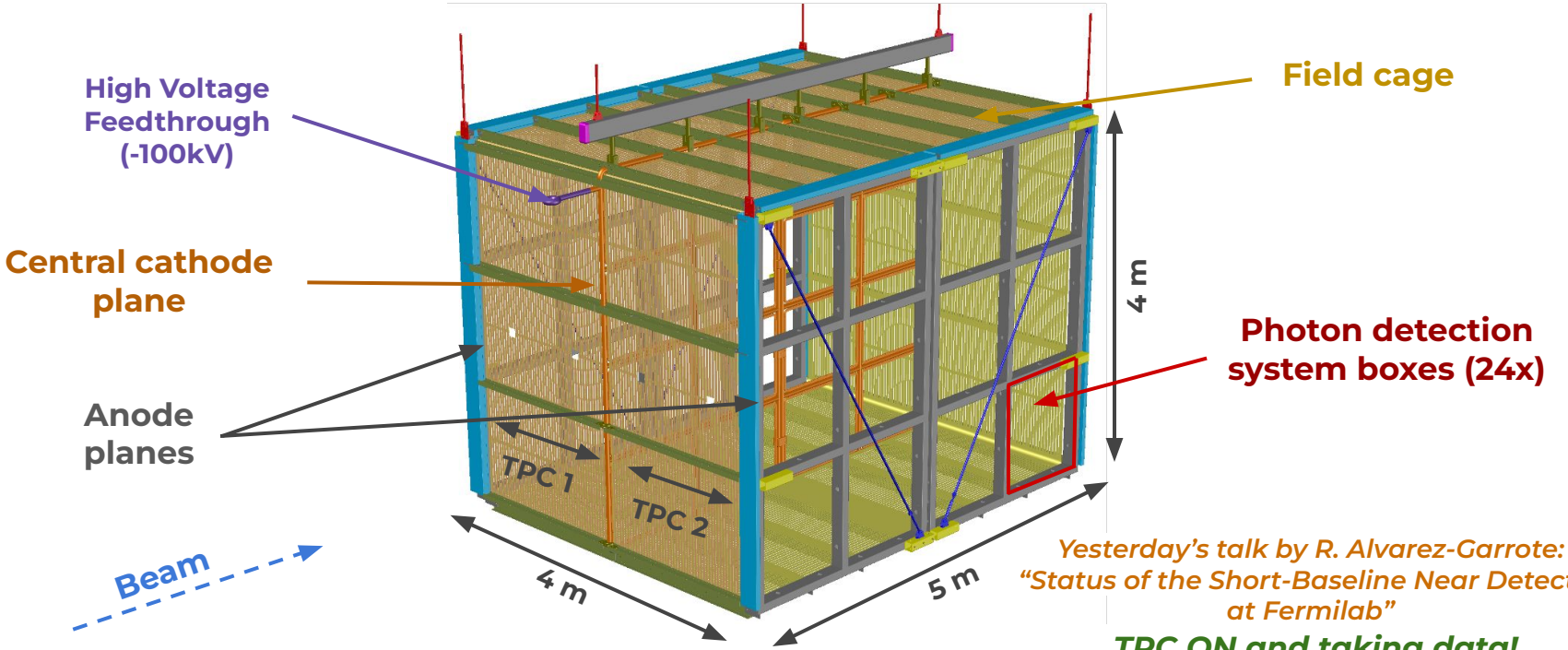
85 tons active volume
L = 470 m

SBND

112 tons active volume
L = 110 m
“Near detector”

The SBND Experiment

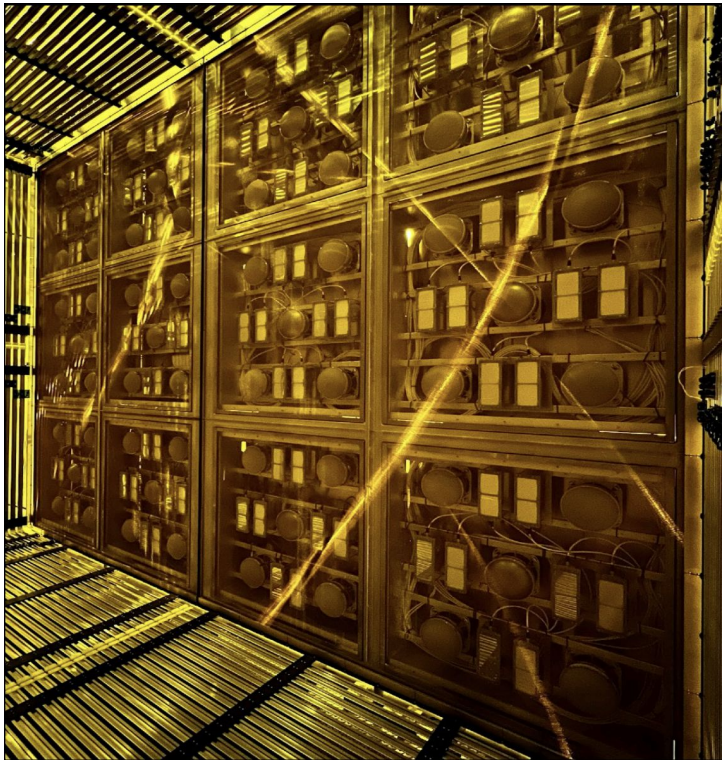
112 tons of LAr between two drift volumes separated by central cathode



Yesterday's talk by R. Alvarez-Garrote: "Status of the Short-Baseline Near Detector at Fermilab"

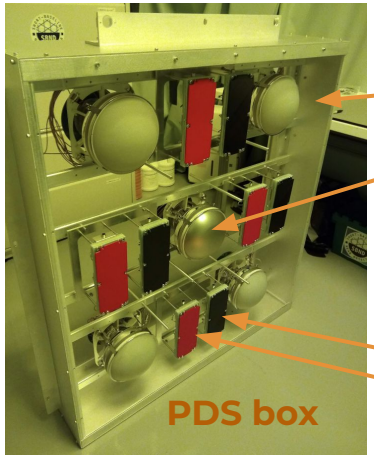
TPC ON and taking data!

Photon Detection System (PDS)



PDS system behind each anode plane to detect **fast LAr scintillation light**

- Direct and cathode reflected light
- Uses CAEN digitisers to readout waveforms
- **Nanosecond timing and trigger**



120 PMTs

96 TPB coated

24 uncoated

ON and taking data!

192 X-ARAPUCAs

Light guides with dichroic filters and wavelength shifter coupled to SiPMs

50% PTP coated

50% uncoated

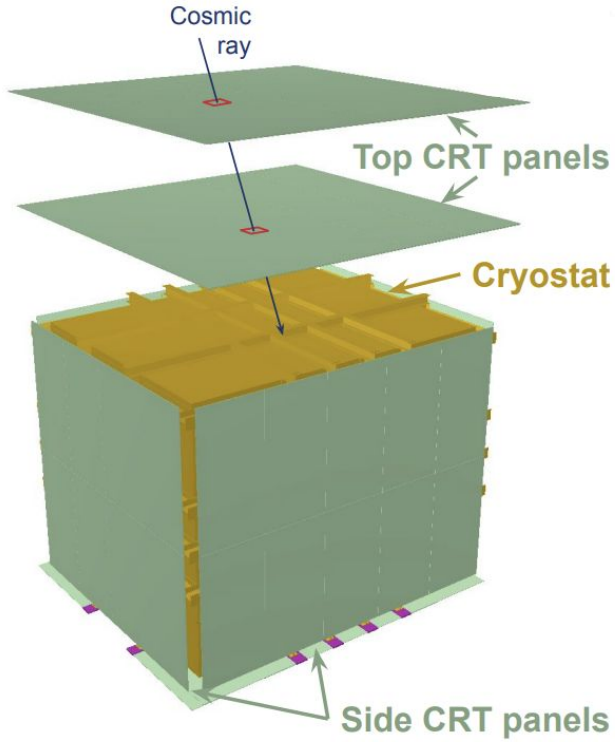
Cosmic Ray Tagger (CRT)

Cryostat surrounded by plastic scintillator panels coupled to SiPMs

- near 4π coverage
- time resolution of a few nanoseconds

Cosmic tagging for background rejection and creating samples useful for commissioning

Side and bottom panels installed and operational, top panels to be installed later this year



SBND Hardware Trigger

TPC events beautiful but large - event rate for analysis restricted to ~Hz
SBND will receive 20-30x higher LAr statistics than currently available

SBND data:

- BNB rate of 5Hz
- Neutrino event every ~20 beam spills
- Potential beam-related BSM signatures
- kHz of cosmics on surface

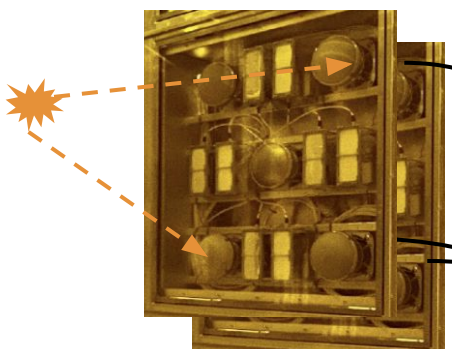
Trigger on light activity across the detector
(localised or spread out)
paired with programmable logic
(beam coincidence, prescaled spills, CRT triggers, ...)

Master Trigger Card Analog (MTC/A)

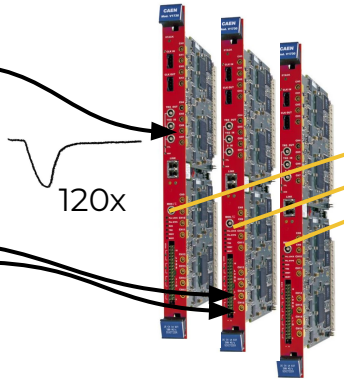
Penn/Photon Trigger Board (PTB)

Efficient trigger allows for **lower energy thresholds** while keeping manageable data rate
Important for low energy cross-section measurements and BSM physics

Main Hardware Trigger Path

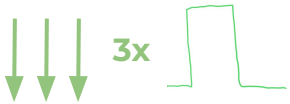


120x PMTs



8x 16 channel CAEN V1730
PMT waveform digitisation
Outputs # of channel pairs over threshold/board

Master Trigger Card Analog (MTC/A)
Analog sum of all inputs
3 comparators with programmable thresholds

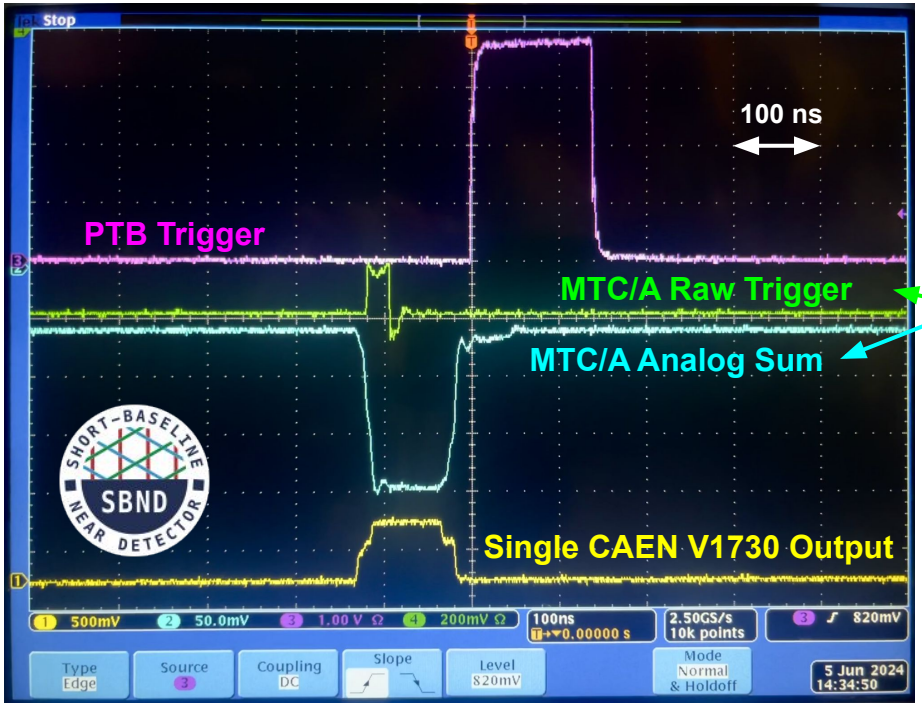


Penn/Photon Trigger Board (PTB)

Readout triggers issued and distributed to sub-systems: TPC trigger board, DAQ, PDS

Overall latency O(100ns)

Main Hardware Trigger Path

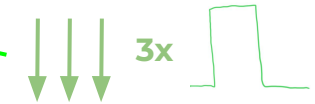


Triggers on PMT light operational

Master Trigger Card Analog (MTC/A)

Analog sum of all inputs

3 comparators with programmable thresholds

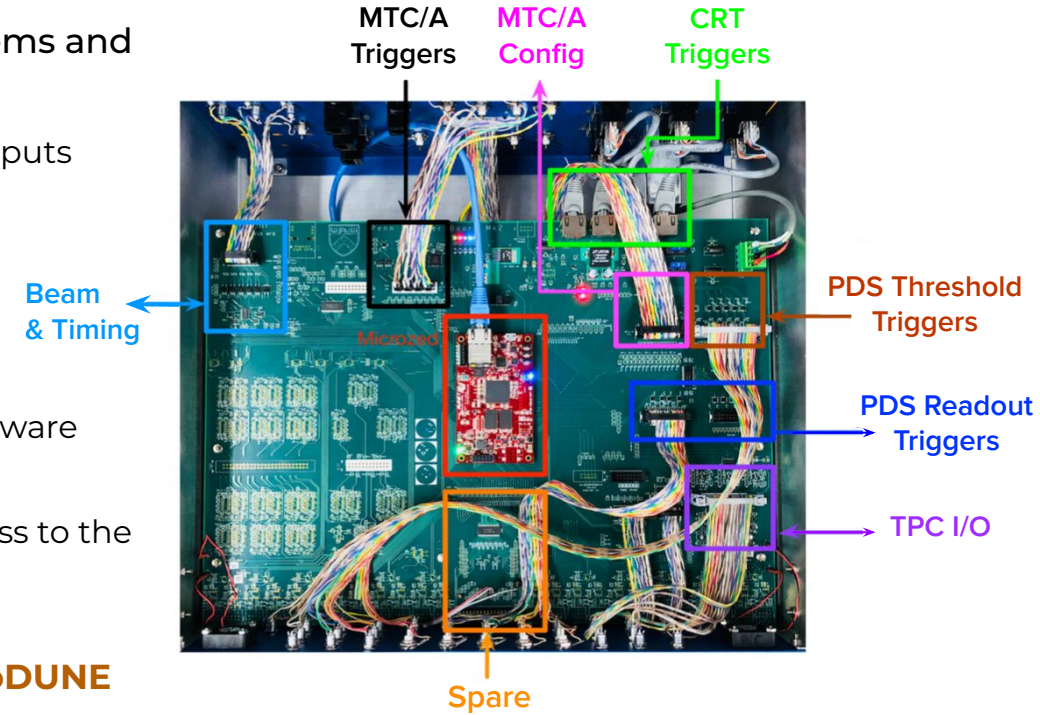


Penn/Photon Trigger Board (PTB)

Penn/Photon Trigger Board (PTB)

PTB receives signals from different subsystems and issues readout triggers and other signals

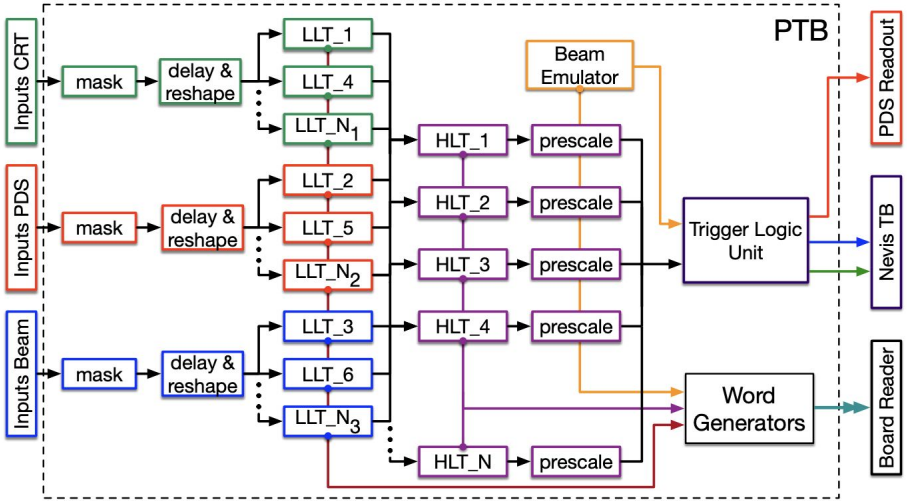
- Highly **flexible inputs** (ECL/TTL/...) and outputs from various subsystems
- ~100 I/Os total
- MicroZed with with Zynq-7Z020 SoC (System-on-Chip)
- **Programmable logic** - FPGA running firmware containing all HW trigger logic
- Linux **processing system** with direct access to the FPGA



Version of PTB used in DUNE 35t, protoDUNE SBND and EOS experiments

PTB Architecture and Capabilities

Firmware architecture allows high flexibility by employing Low Level Triggers (LLTs) and High Level Triggers (HLTs)



All LLTs and HLTs timestamped and recorded

Low level triggers from single subsystem

High level triggers across subsystems

Logic of each trigger configurable at run time

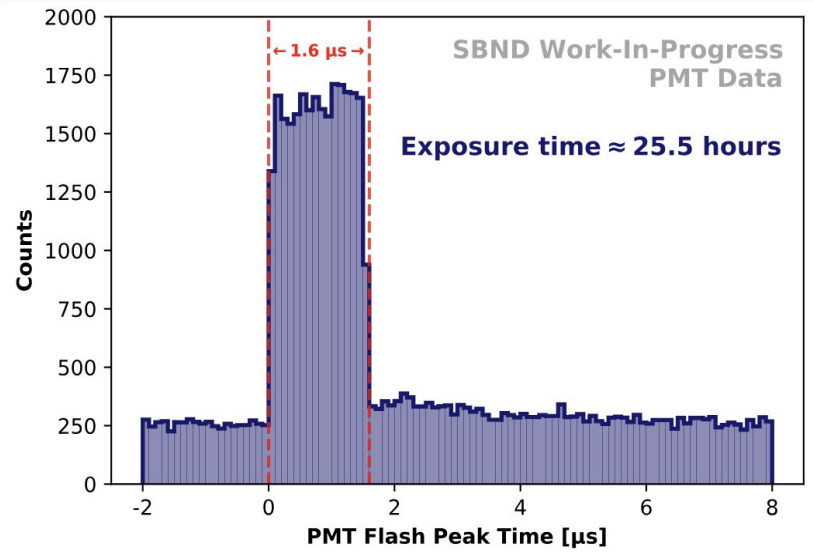
- **Coincidences and vetos**
- **Counting triggers**
- **Fake beam triggers for cosmics**

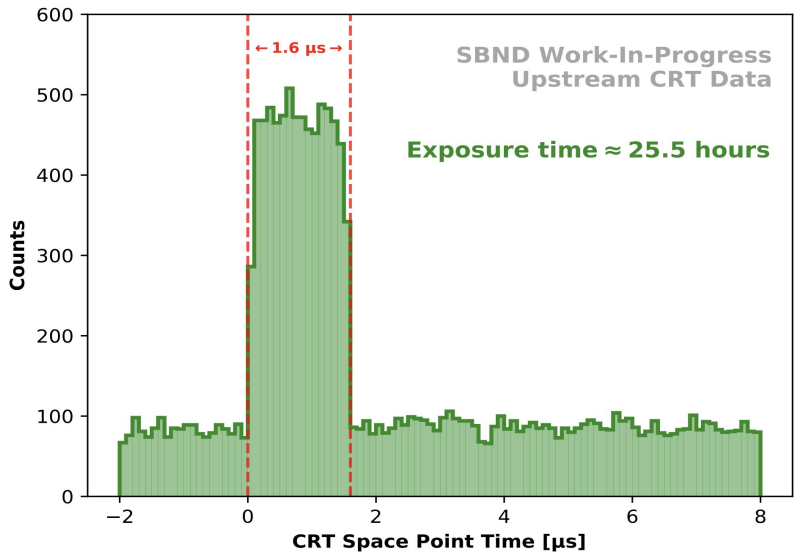
Also:
Inhibits & resets to avoid subsystem deadtimes
Multiple PDS “flash” triggers/TPC trigger, …

Triggering BNB Events

BNB ran until July 12th- maximised beam data by triggering on every beam spill

Increased event rates in coincidence with beam demonstrated



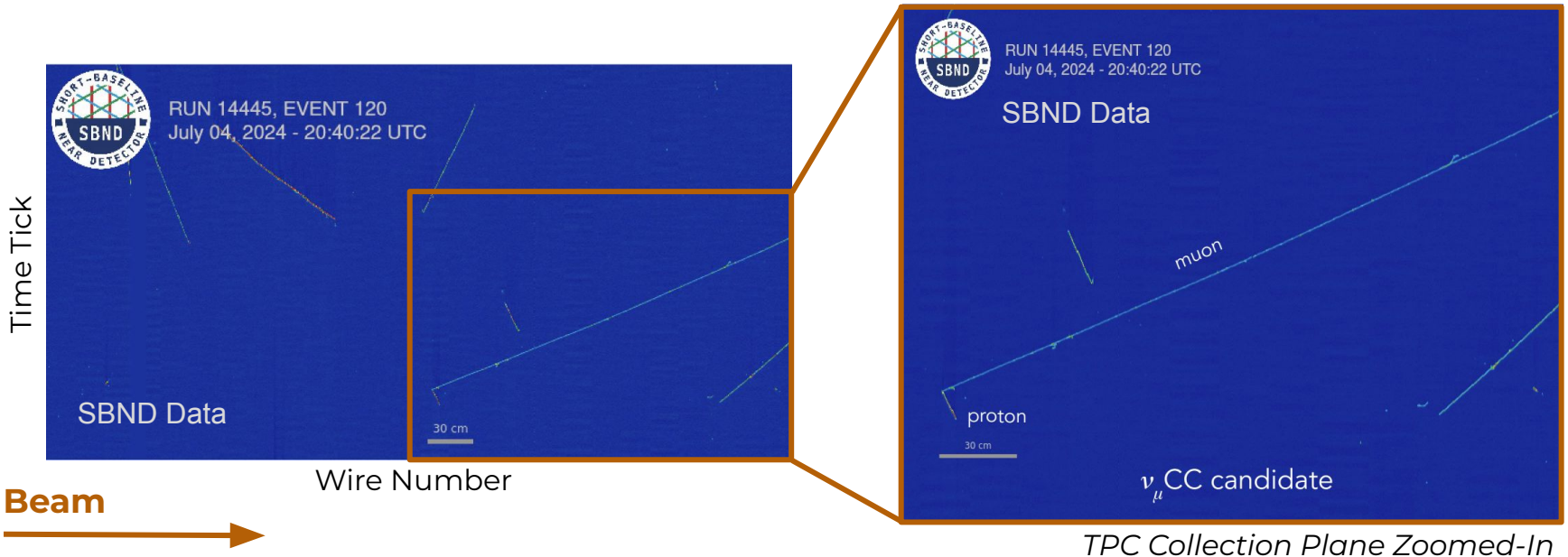


PMT and CRT event rates referenced to the start of BNB spill,
readout with respect to the PTB trigger on beam signal delayed to ~1 μs before the spill

Triggering BNB Events

BNB ran until July 12th- maximised beam data by triggering on every beam spill

TPC on high voltage since July 3rd and seeing neutrino candidate events

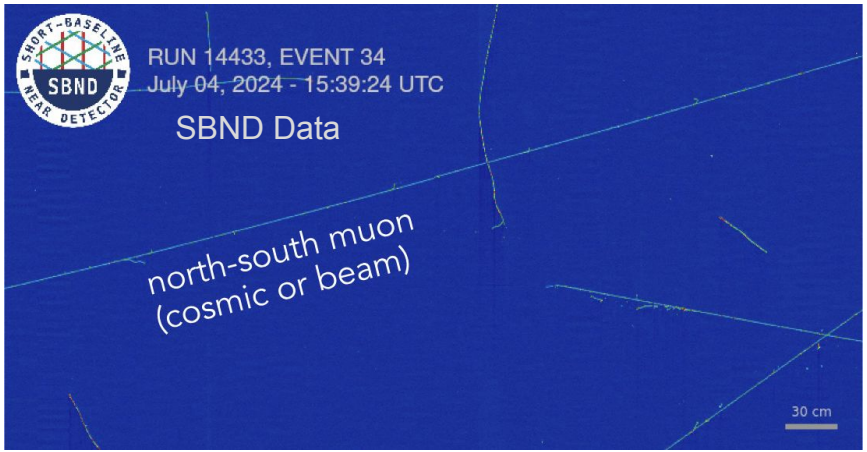


TPC Collection Plane Zoomed-In

Triggering Crossing Muon Events

Calibration and commissioning samples during beam downtime
Prioritisation logic in the PTB for data taking alongside neutrino data when beam returns

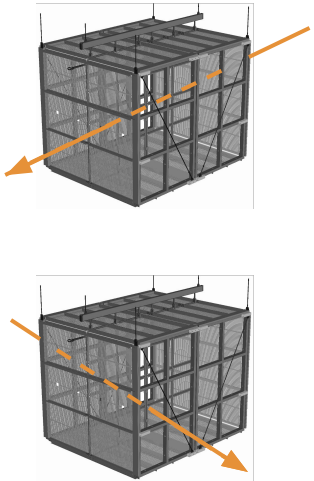
North/South CRT Coincidence Trigger



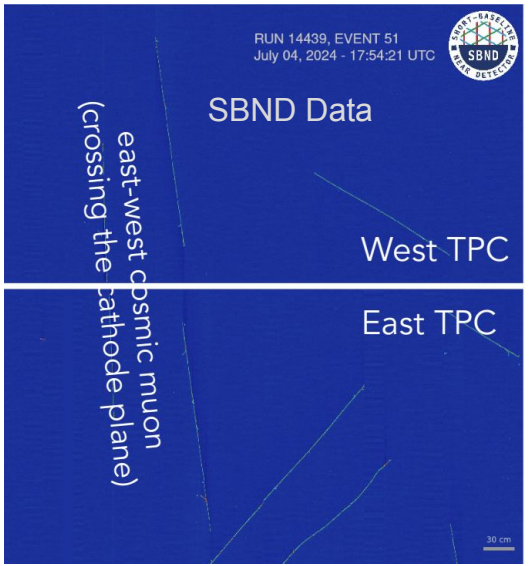
Time Tick

Wire Number

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



East/West CRT Coincidence Trigger



Time Tick

Wire Number

Looking Ahead & Conclusions

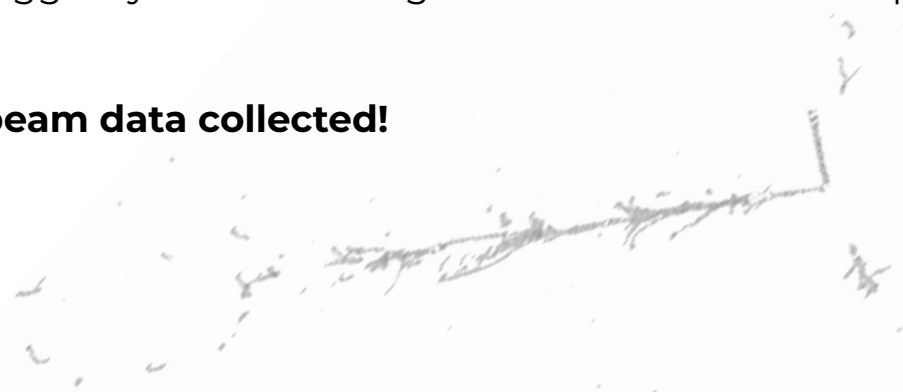
SBND highest statistics of any neutrino LAr experiment to date will provide opportunity for measuring **neutrino cross-sections** and potential **BSM physics**

Definitive answer on existence of **eV-scale sterile neutrinos** as part of the SBN program

Efficient and configurable hardware trigger to optimise readout for maximal physics sensitivity given data size restrictions

The SBND hardware trigger system including the PTB is a flexible and powerful solution for SBND trigger needs

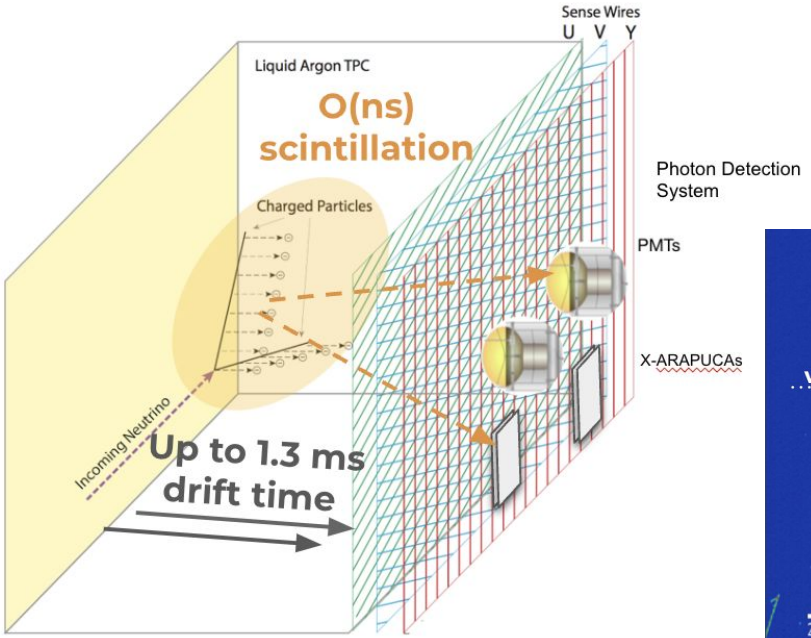
First beam and non-beam data collected!



Thank you for your attention!

Děkuji za pozornost!

Back up: SBND Events



LAr ionisation from charged particle passage **millisecond drift times** to anode

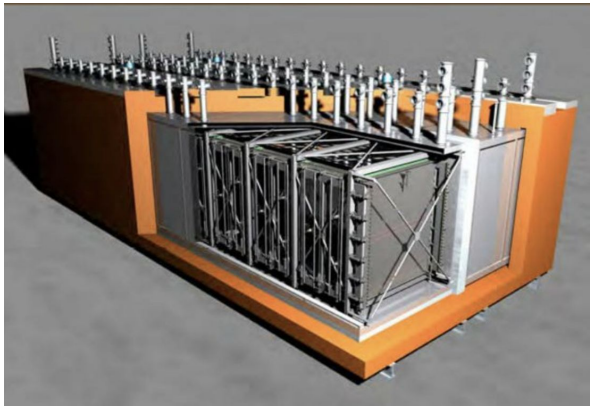
→ **Multi-dimensional event topology**
→ **Particle Identification via dE/dx**

Fast **scintillation light** from LAr detected by photon detection system

→ **Nanosecond timing and trigger**

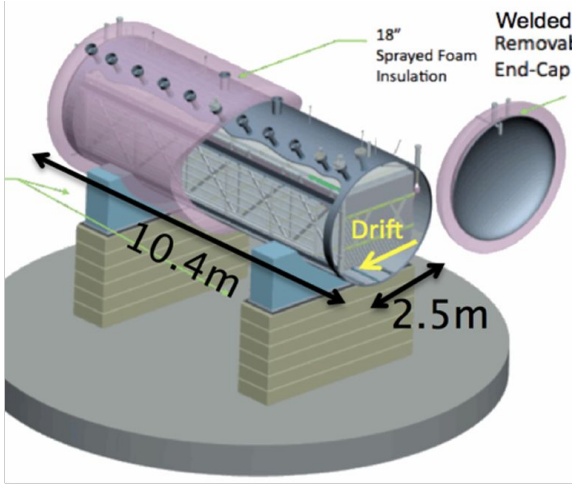
Back up: SBN Detectors

Three detectors of the same technology along the same neutrino beam



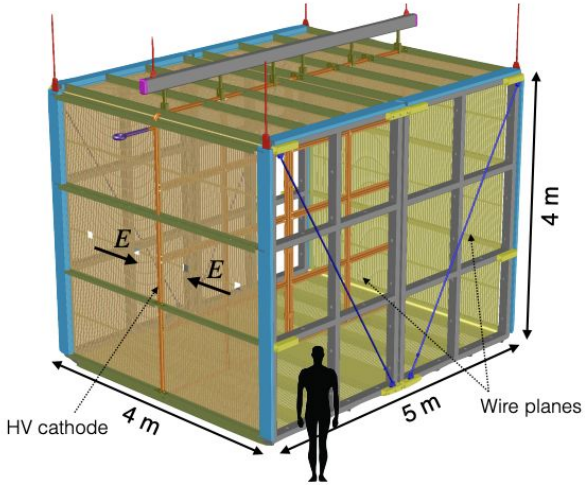
ICARUS

476 tons active volume
L = 600 m
“Far detector”



MicroBooNE

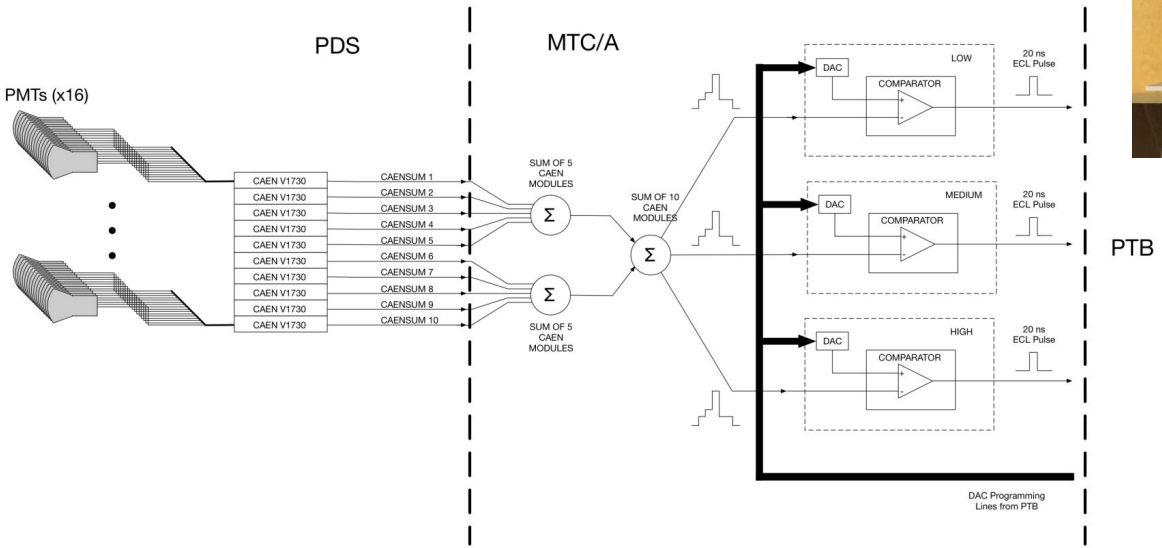
85 tons active volume
L = 470 m

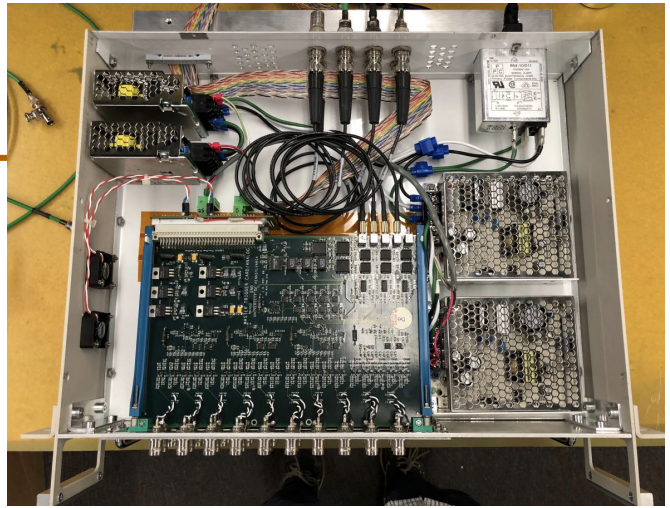


SBND

112 tons active volume
L = 110 m
“Near detector”

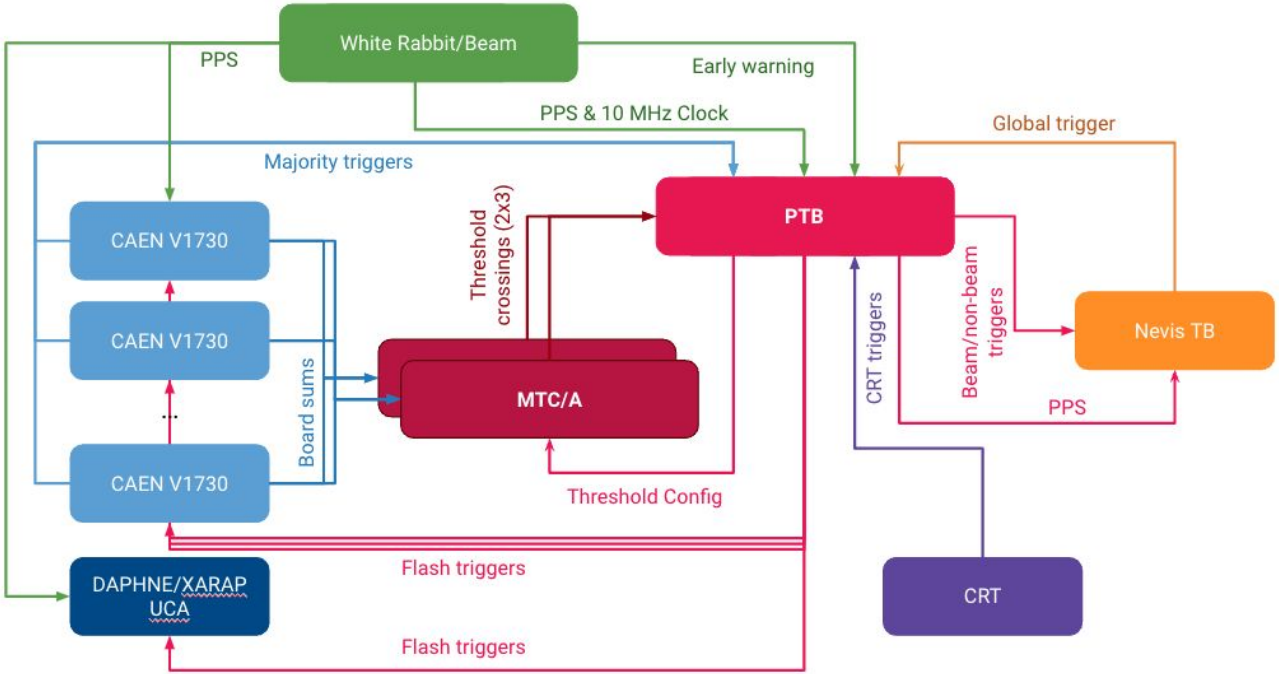
Back up: MTC/A Detail





MTC/As used in the SNO experiment

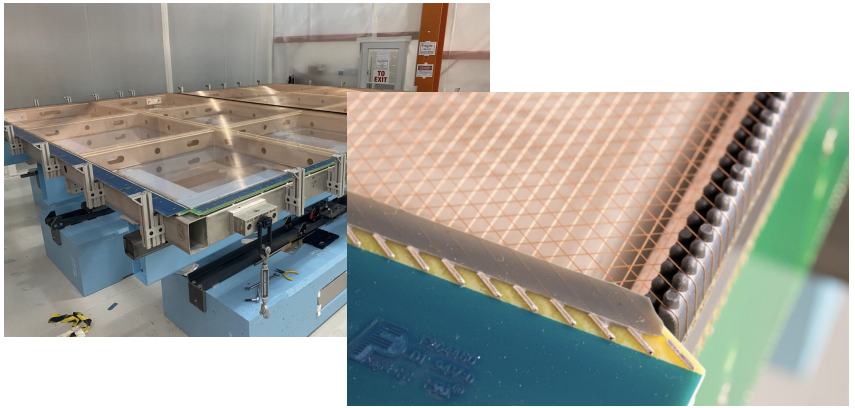
Back up: SBND PTB connections



Back up: SBND TPC

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

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



Back up: SBND Cryostat

Stainless steel membrane cryostat to allow for LAr operation