NuFact 2022

The 23rd International Workshop on Neutrinos from Accelerators

Salt Lake City, Utah, United States

July 31st – Aug. 6th, 2022

Status of the Short-Baseline Near Detector at Fermilab

M.Nebot-Guinot

University of Edinburgh

on behalf of the SBND Collaboration

Fermilab

Outline

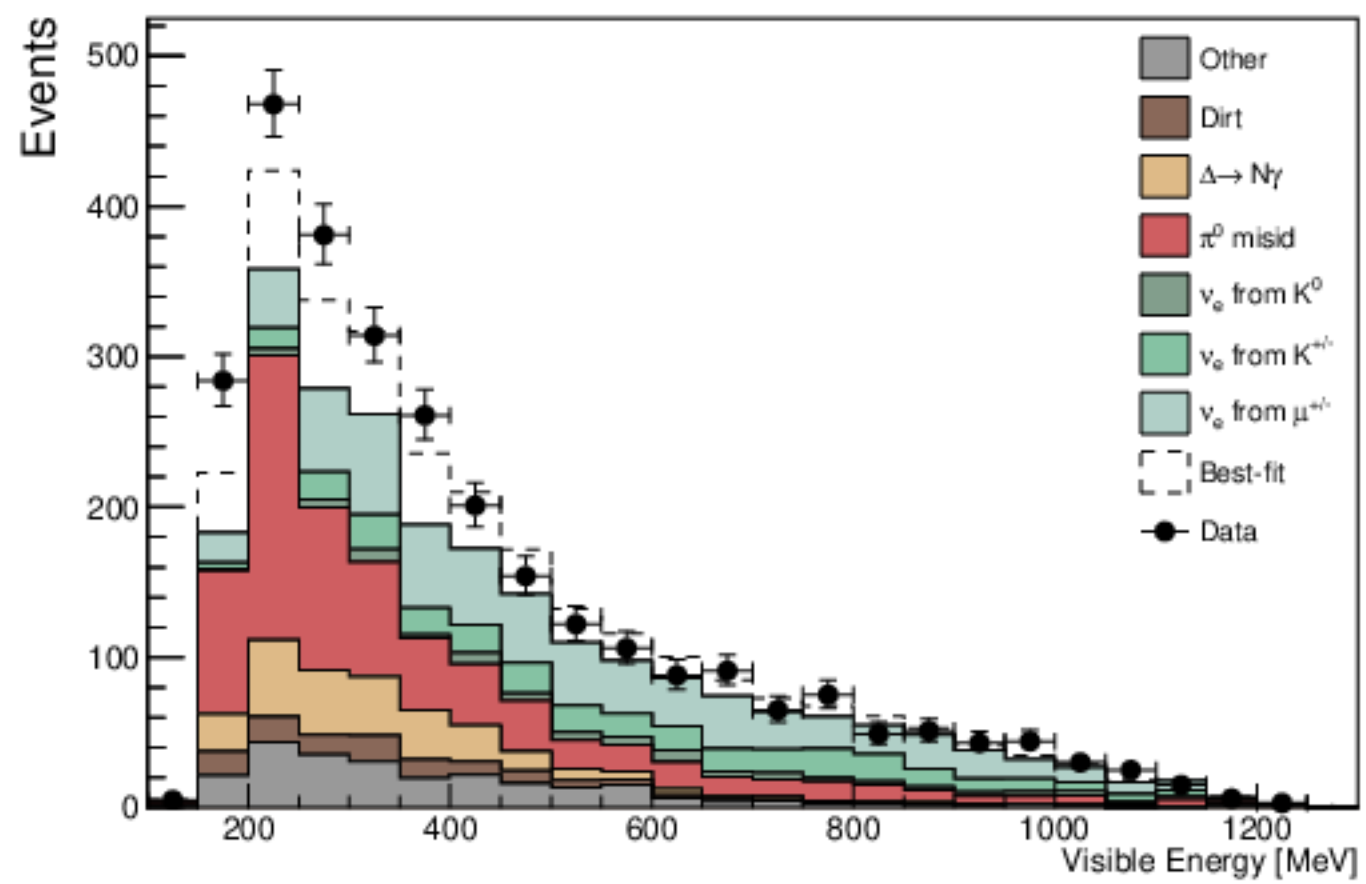
- SBND and the SBN program
- SBND Physics goals
- Current status of detector construction
  - Time Projection Chamber
  - Photon Detection System
  - Cryostat
- Conclusions

M.Nebot-Guinot

Low Energy Excess

- Evidence for an electron-like Low Energy Excess (LEE) from neutrinos from particle accelerators (the “LSND and MiniBooNE anomalies”)
- Could be explained by the possible existence of at least one sterile neutrino.
- Caveat:
  No e^- vs γ discrimination (Cherenkov detector)
- Challenge:
  Resolve the nature of the MiniBooNE like signal.

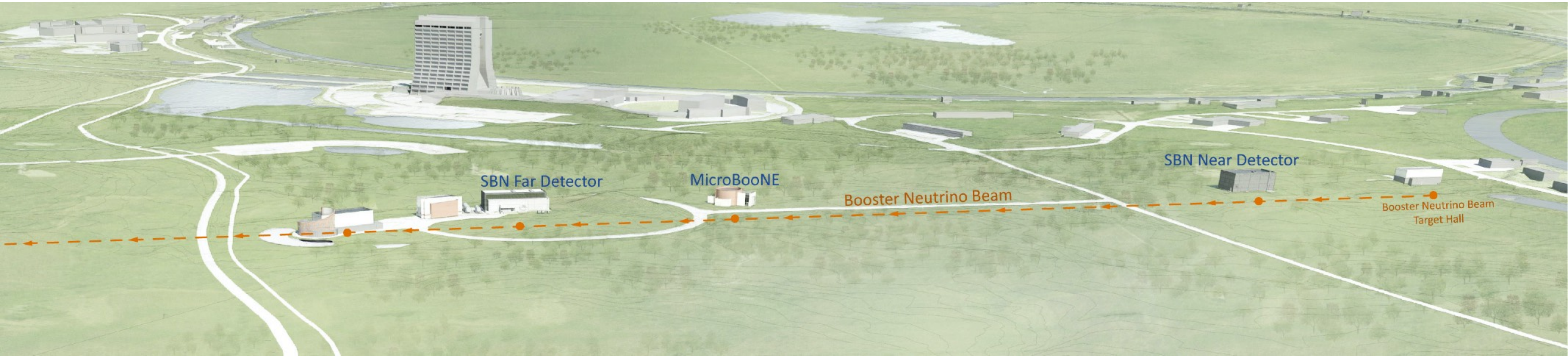
MiniBooNE ν_e



The MiniBooNE neutrino mode visible energy distributions, corresponding to the total 18.75 × 10^{20} POT data in the 200 < E_ν^{QE} < 1250 MeV energy range, for ν_e CCQE data and background.
10.1103/PhysRevD.103.052002

The Short Baseline Neutrino (SBN) program at Fermilab

- Resolve the question of the existence of sterile neutrinos.
- Perform World-leading cross-section measurements and BSM searches.
- Develop the liquid argon neutrino technology.

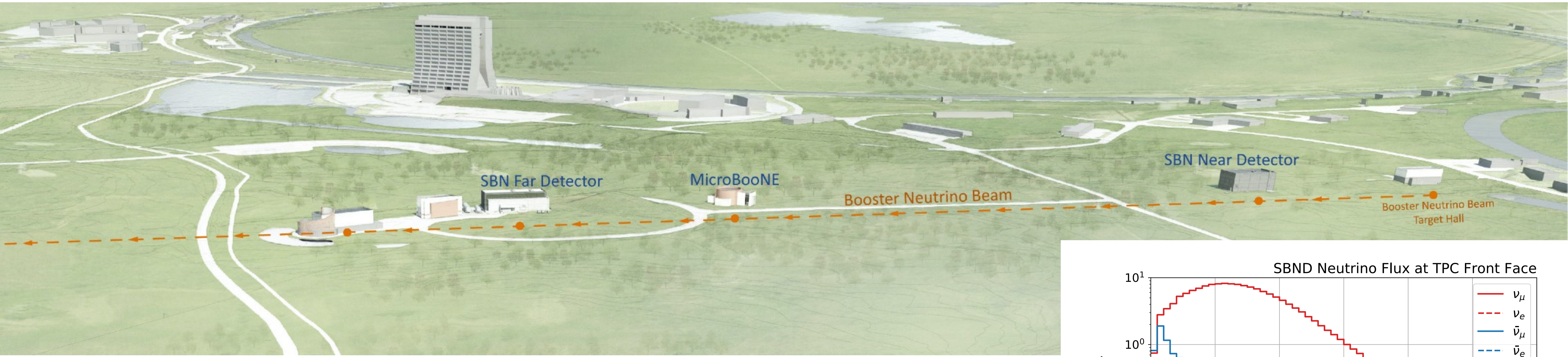


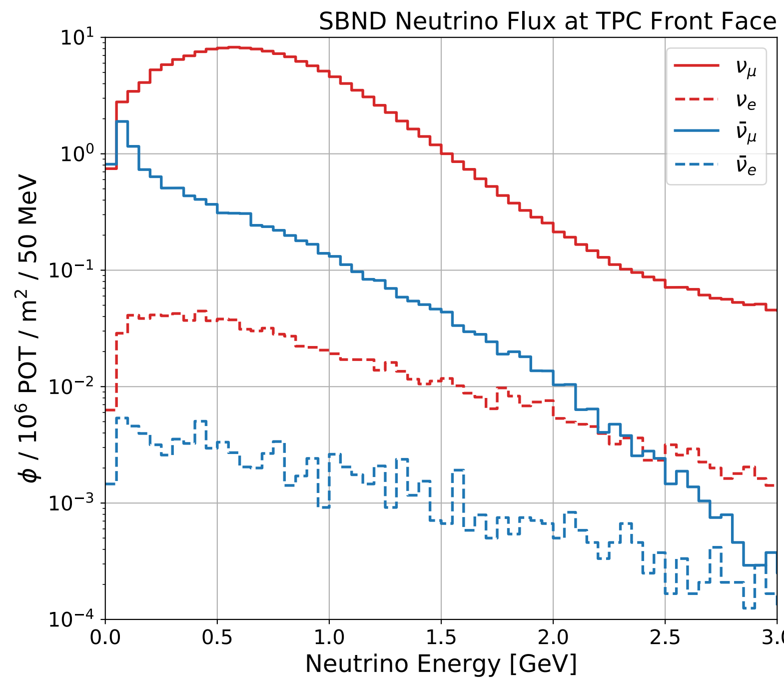
SBND and the SBN program

The Short Baseline Neutrino (SBN) program at Fermilab

A multi-detector facility on the Booster Neutrino Beam at Fermilab using the same neutrino beam, nuclear target, detector technology to reduce systematic uncertainties to the % level.

- Neutrino beam from pion decay-in-flight mostly. Well-known beam, same as MiniBooNE (PRD 79, 072002).



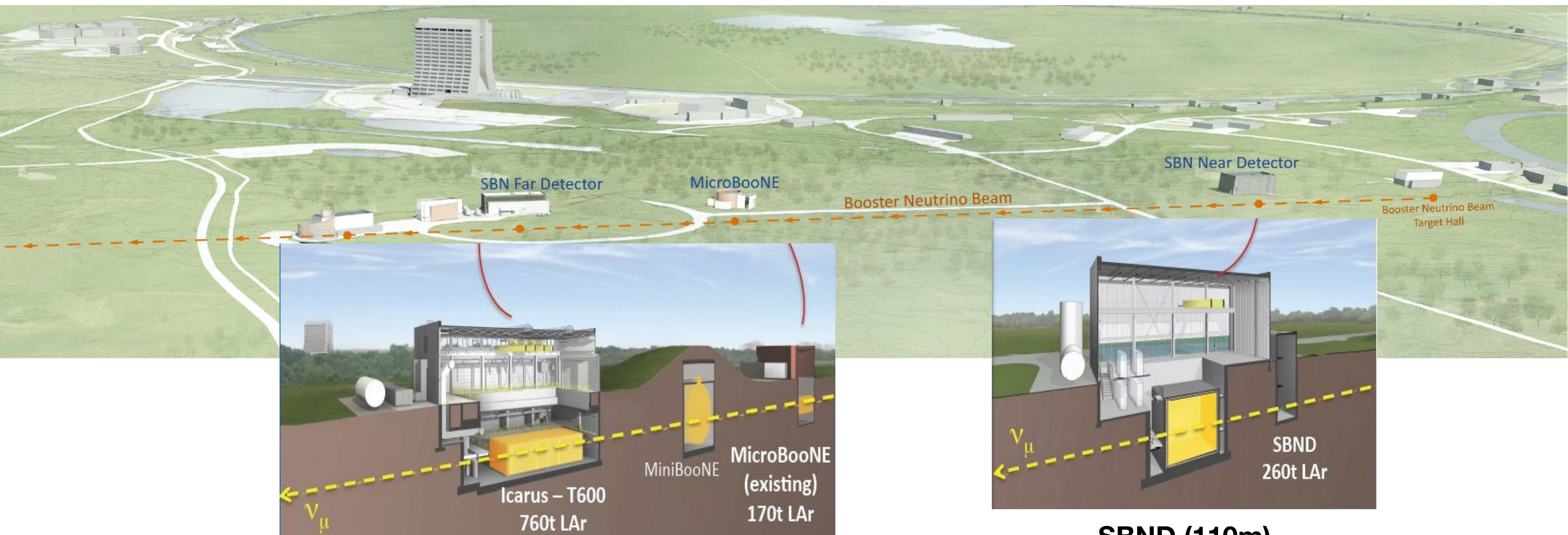


SBND and the SBN program

The Short Baseline Neutrino (SBN) program at Fermilab

A multi-detector facility on the Booster Neutrino Beam at Fermilab using the same neutrino beam, nuclear target, detector technology to reduce systematic uncertainties to the % level.

- Neutrino beam from pion decay-in-flight mostly. Well-known beam, same as MiniBooNE (PRD 79, 072002).
- 3 Liquid Argon Time Projection Chamber (LArTPC) detectors.



ICARUS (600m)
taking data

For more details see
Biswaranjan Behera's talk

MicroBooNE (470m)
finished taking data 2021

SBND (110m)
under construction

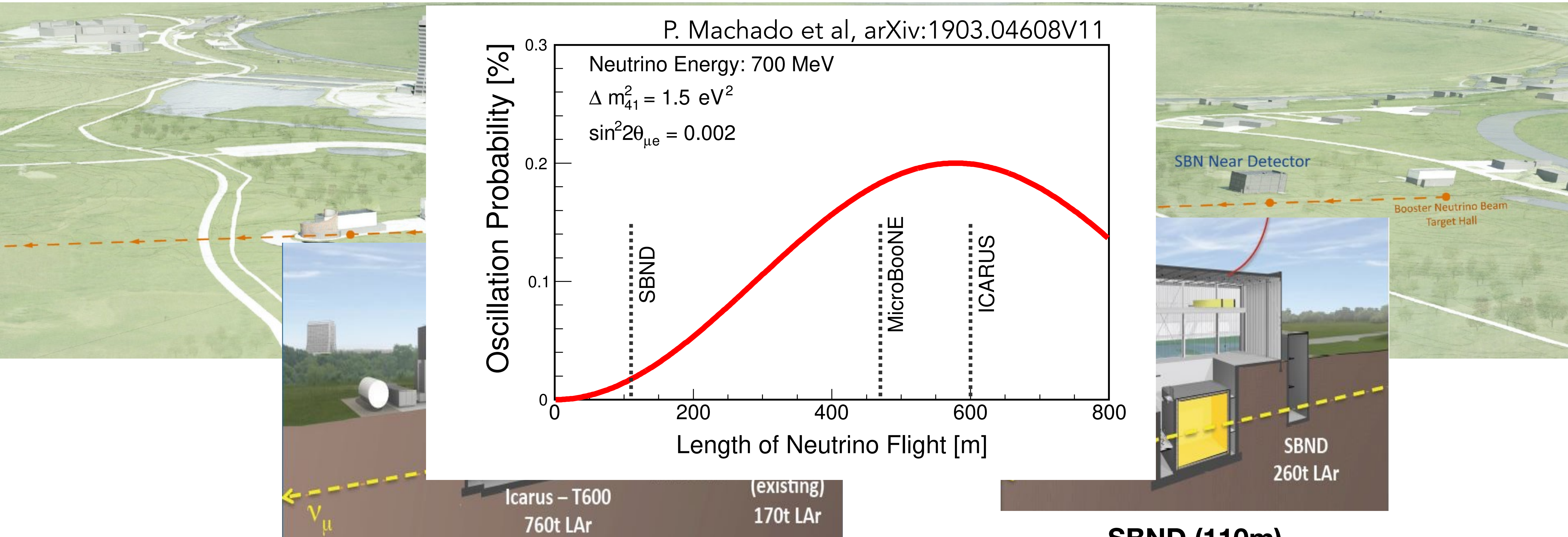
M.Nebot-Guinot

SBND and the SBN program

The Short Baseline Neutrino (SBN) program at Fermilab

A multi-detector facility on the Booster Neutrino Beam at Fermilab using the same neutrino beam, nuclear target, detector technology to reduce systematic uncertainties to the % level.

- Neutrino beam from pion decay-in-flight mostly. Well-known beam, same as MiniBooNE (PRD 79, 072002).
- 3 Liquid Argon Time Projection Chamber (LArTPC) detectors.



ICARUS (600m) taking data

For more details see Alessandro Menegolli talk

MicroBooNE (470m) finished taking data 2021

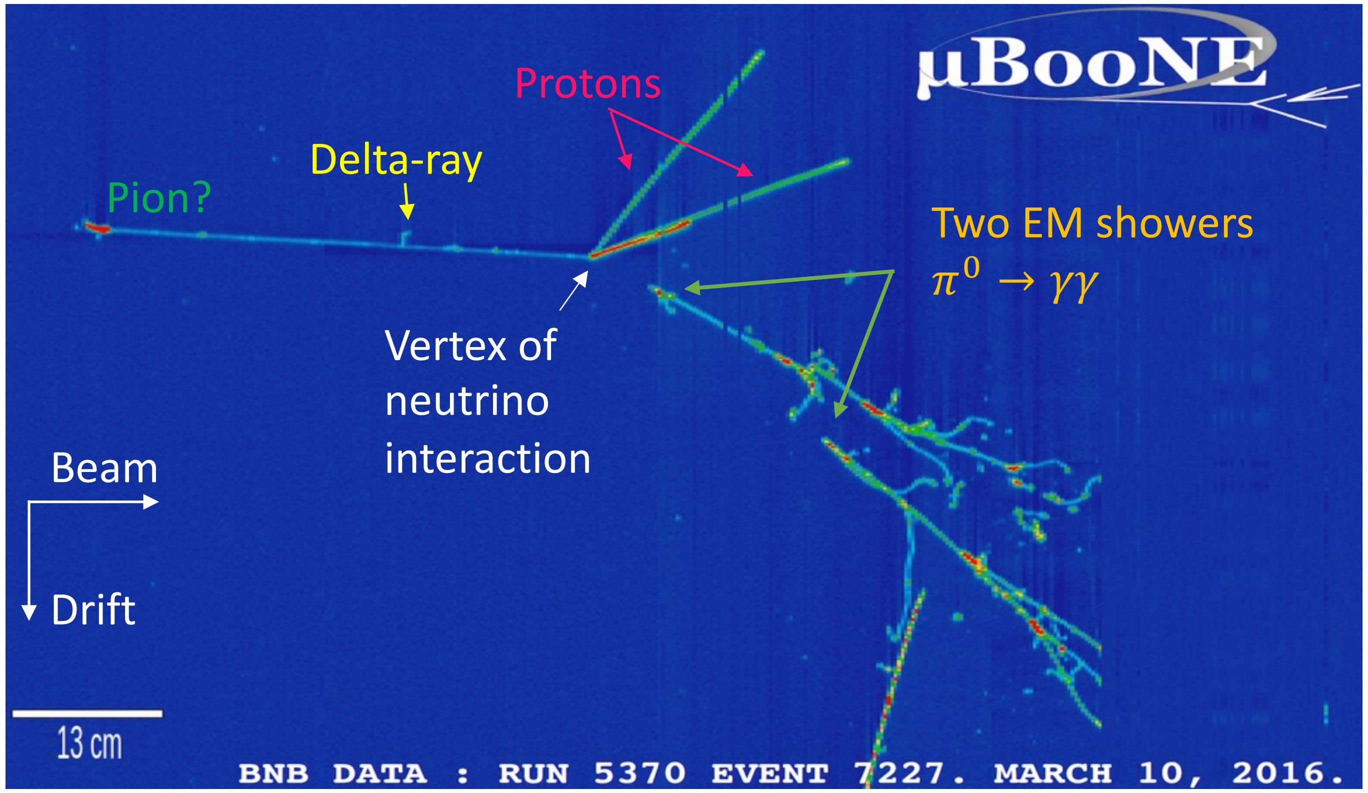
SBND (110m) under construction

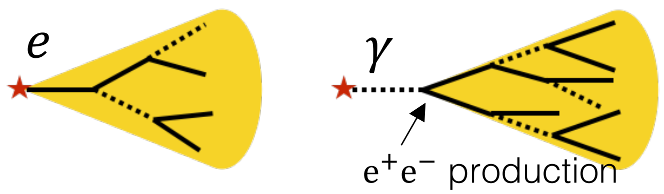
M.Nebot-Guinot

Why LArTPCs?

- Capable of identifying different species of particles and reconstructing 3D images with fine-grained information. Neutrino vertex, particle flow, track vs. shower…
- Electron vs gamma discrimination to resolve MiniBooNE anomaly.

LArTPC: fully active calorimeter + high-resolution tracking

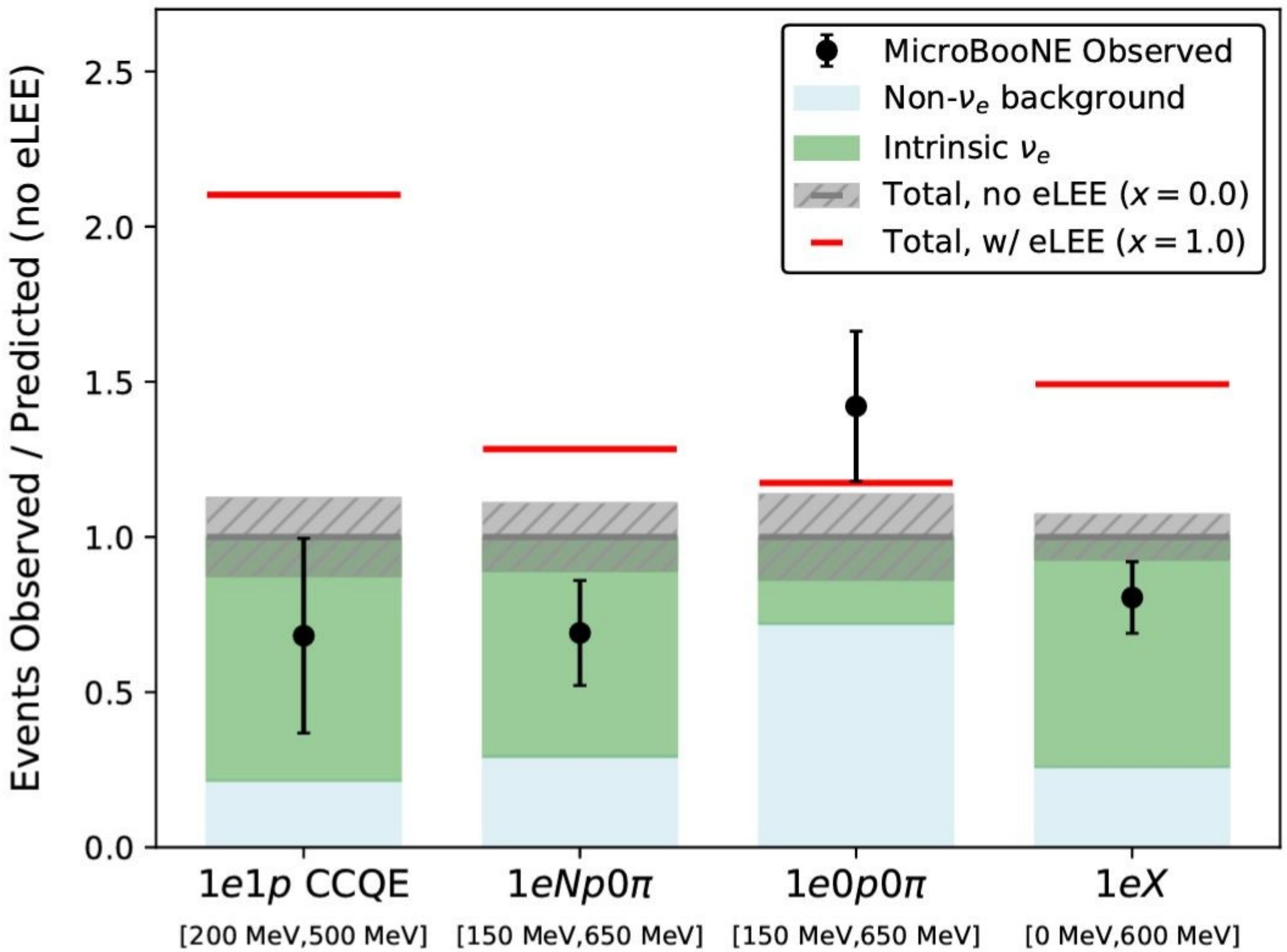




MicroBooNE results

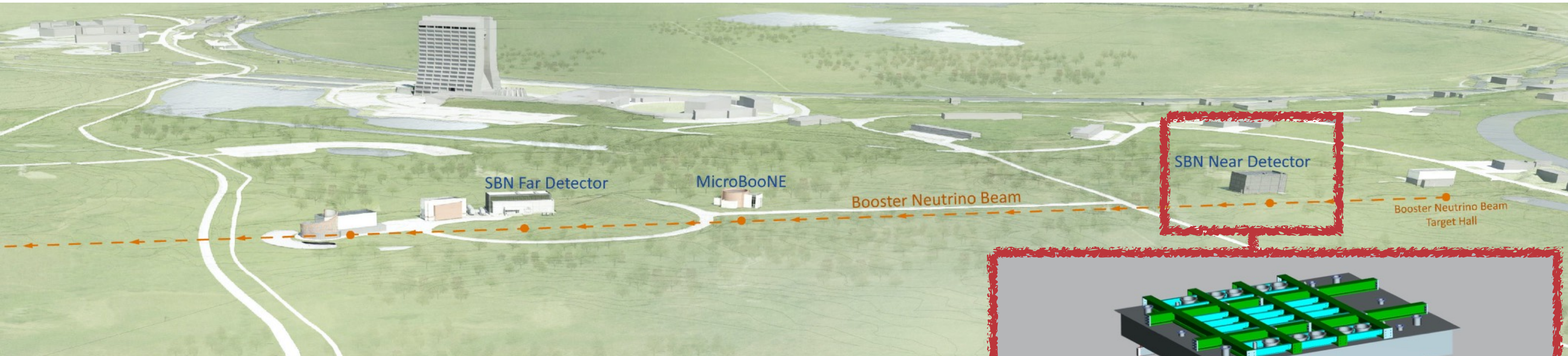
- MicroBooNE released results of their first LEE search.
  - *no low-energy excess detected*
  - *could not rule out sterile neutrino*

10.1103/PhysRevLett.128.241801

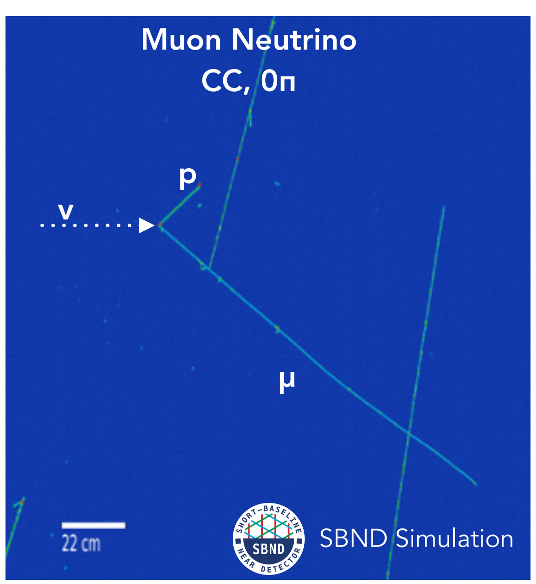


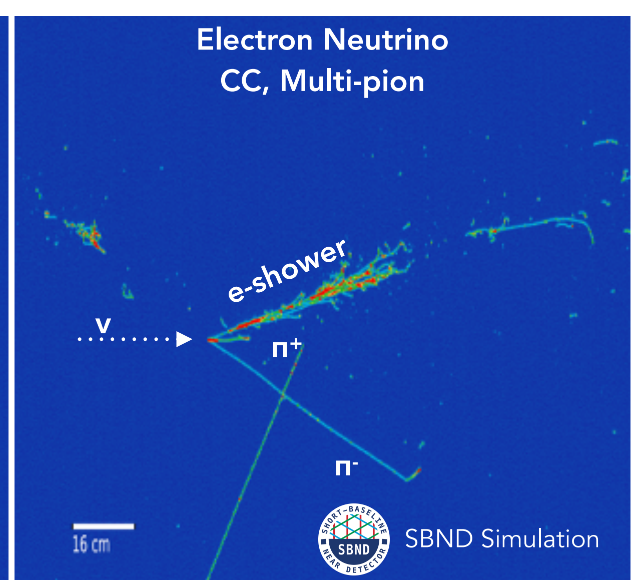
For more details see Georgia Karagiorgi, Mark Ross-Lonergan and Xiangpan Ji talks

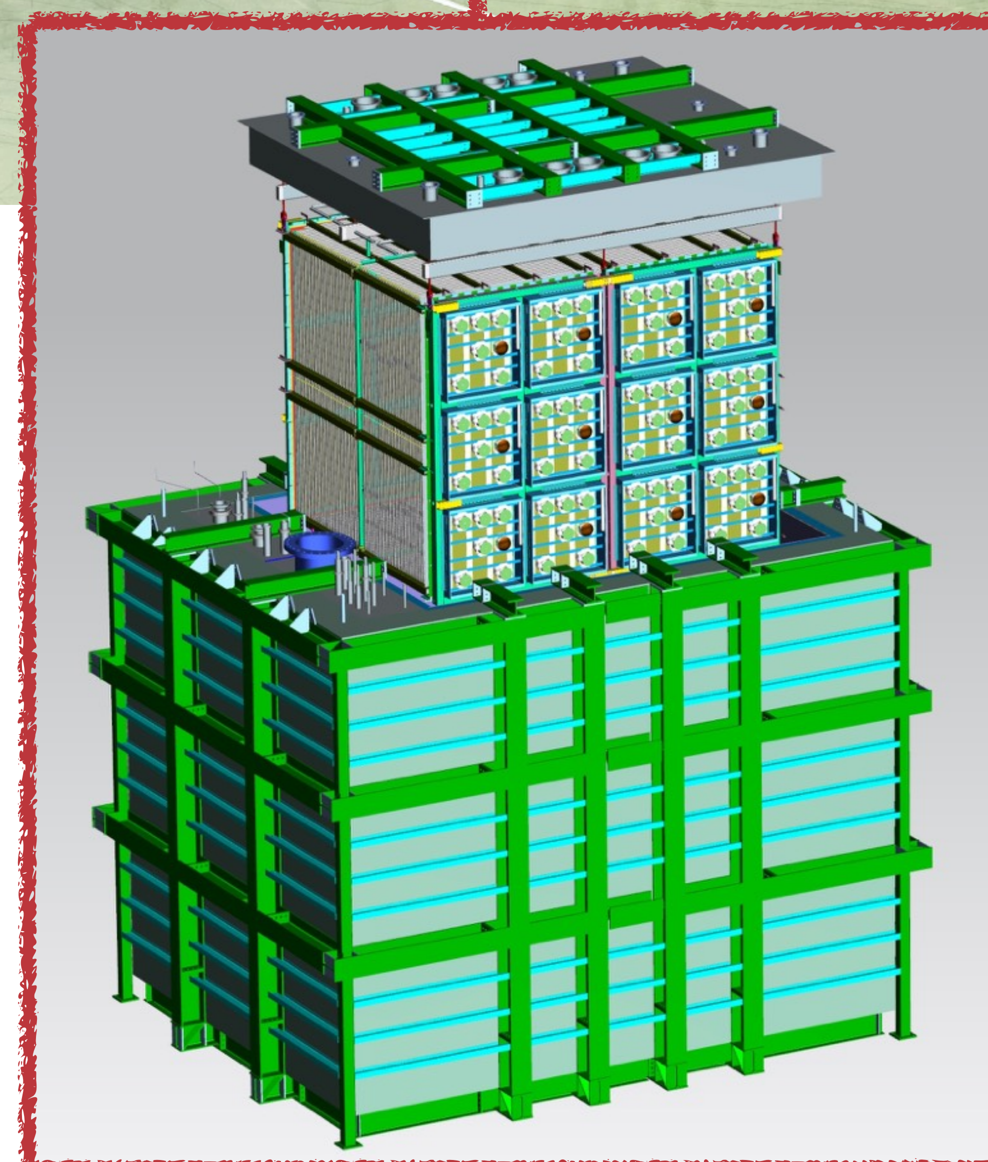
The SBN Near Detector



Short-Baseline Near Detector (SBND) is located just 110 meters from the Booster Neutrino Beam target, and has 112 tons of liquid argon within the active volume of its detection systems.



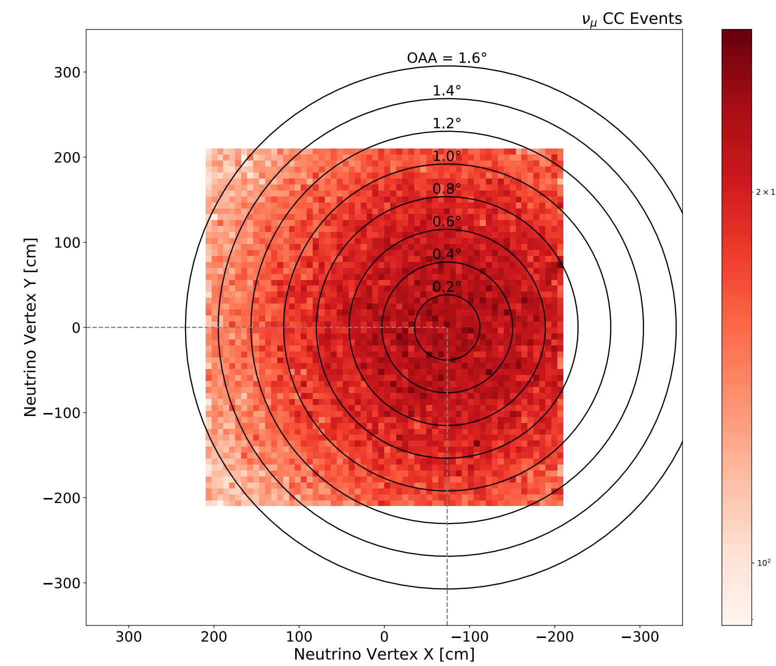




SBND physics goals

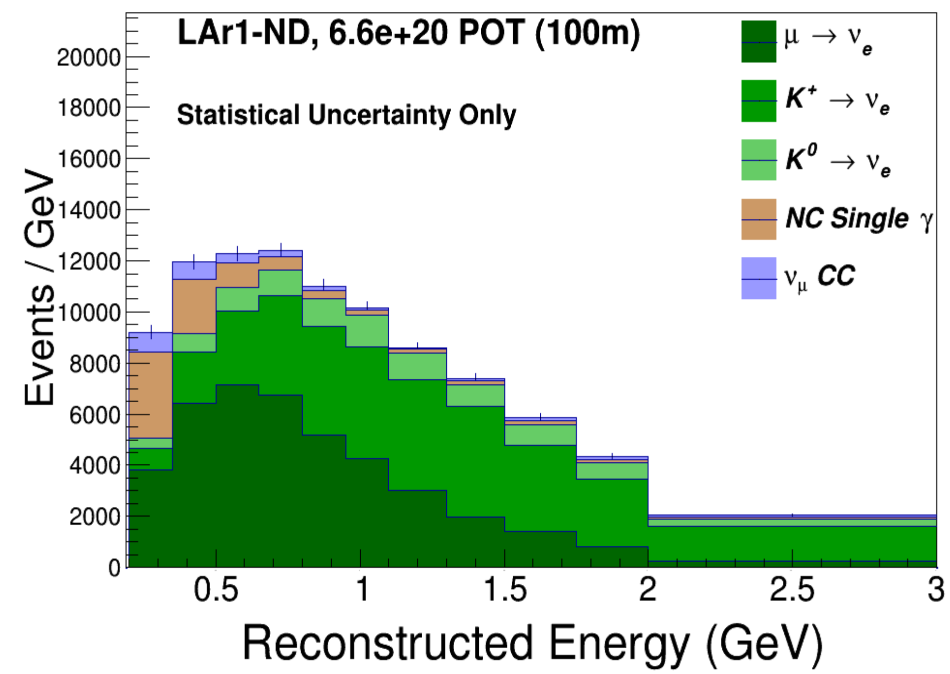
- Constrain the un-oscillated flux for sterile neutrino searches.
  The near detector plays a fundamental role on answering whether the MiniBooNE low energy excess is intrinsic to the BNB or if it appears along the beam-line.

See Marco Del Tutto's SBND-PRISM talk



- Search for new physics Beyond the Standard Model.

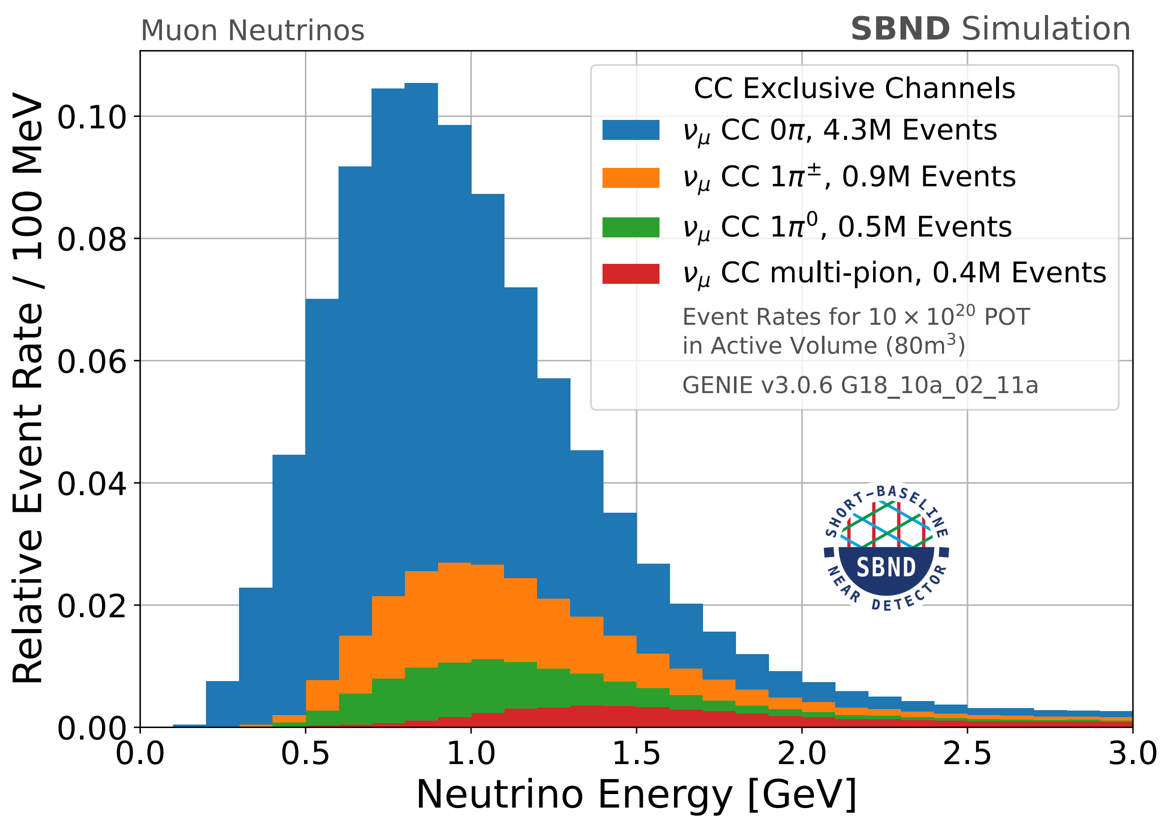
See Supraja Balasubramanian's BSM in SBND talk



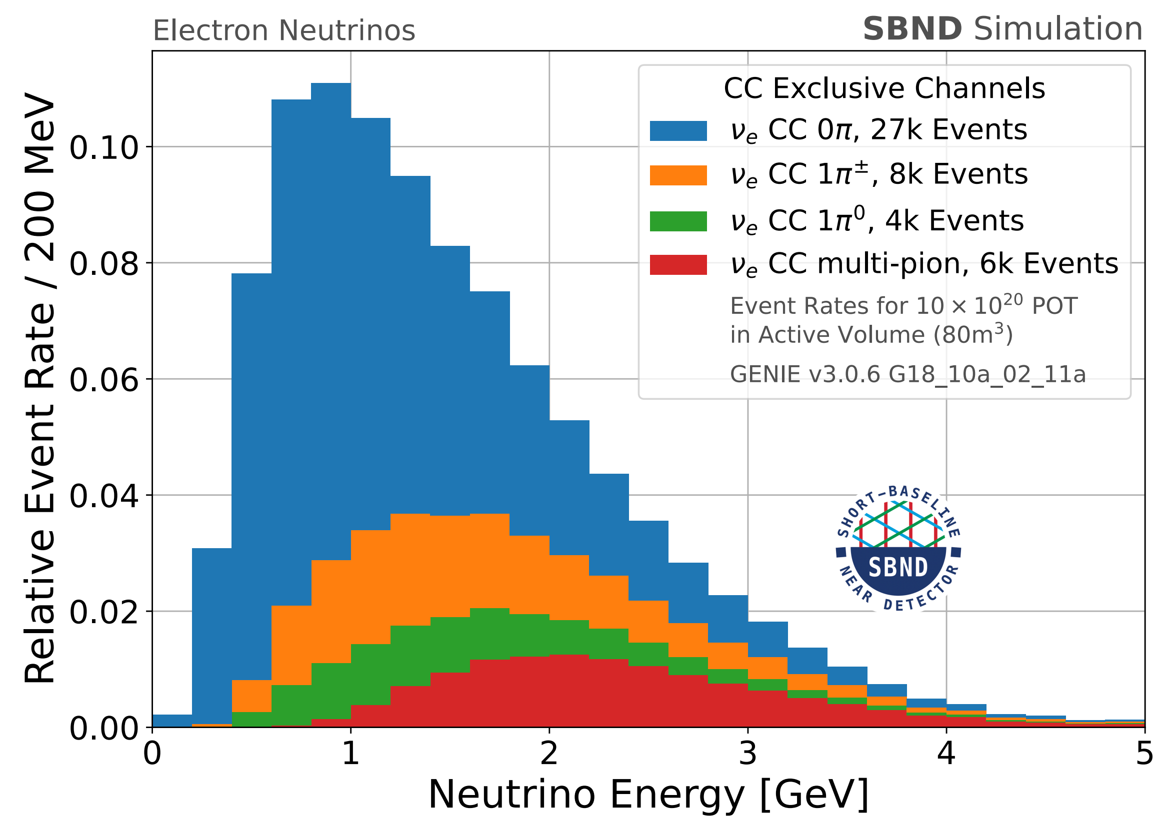
- Cross-section measurements.

M.Nebot-Guinot

Cross-section measurements



1.5M ν_μ CC events in 1 year



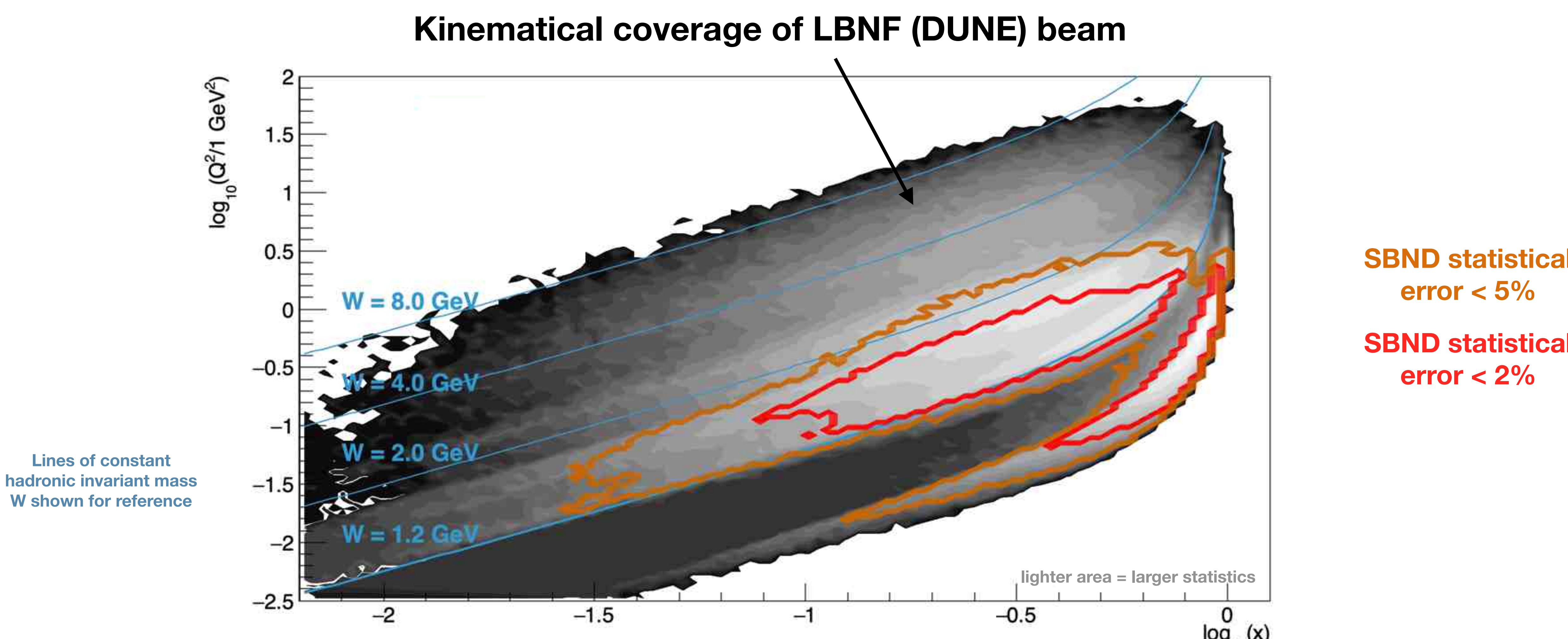
12k ν_e CC events in 1 year

- Collect the largest sample of neutrino-argon interactions to date.
- Discriminate between nuclear models to inform MC generators.
- Reduce systematic uncertainties for oscillation analysis.

SBND will observe 5000 ν-events/day!

Cross section measurements

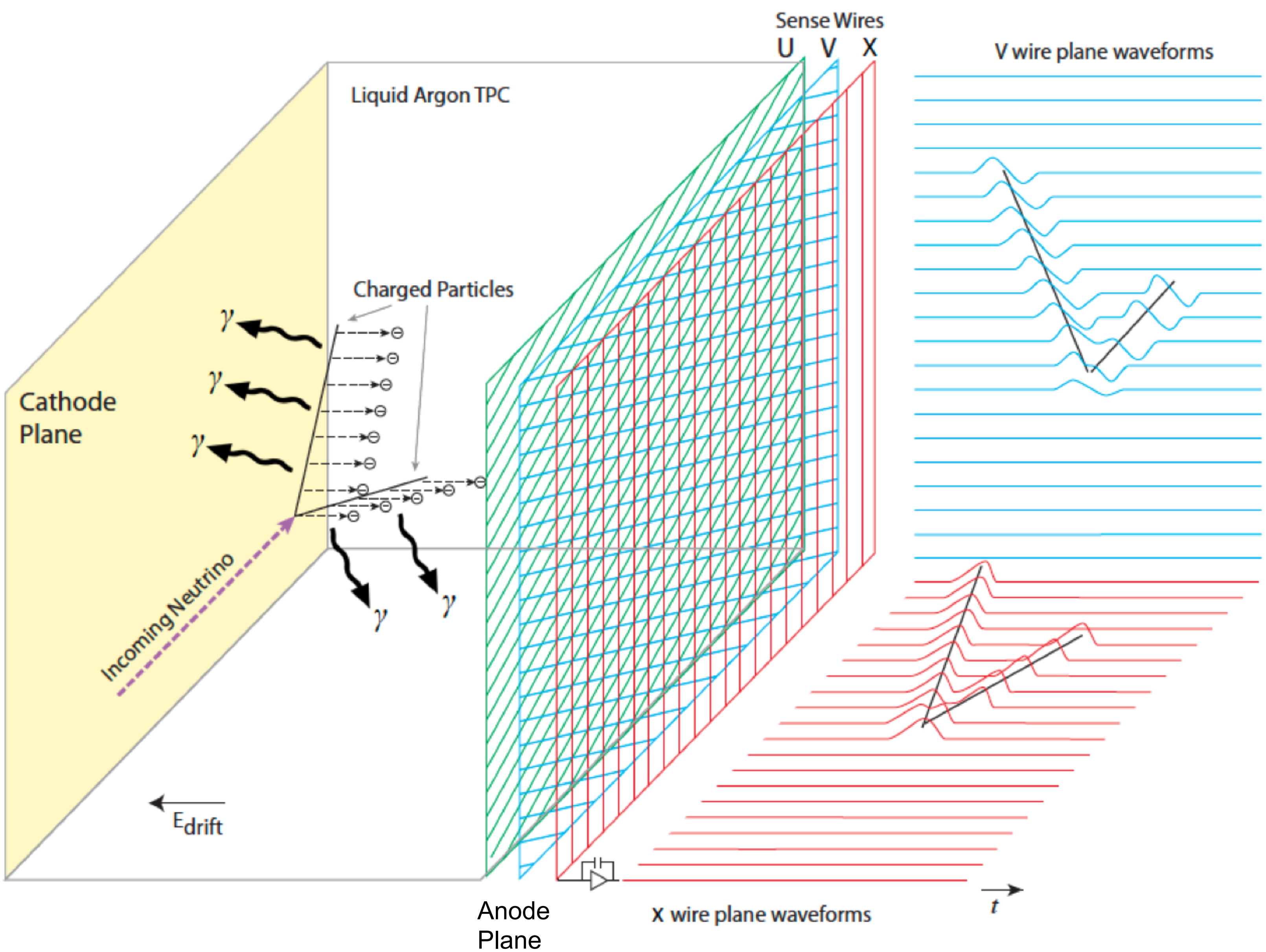
- SBND's vicinity to neutrino target it will allow measurements of many rare channels such as heavy baryons (Δ^0, Σ^+), NC coherent single photon production, etc.
- SBND covers peaks of kinematic area relevant for DUNE.



Momentum transfer Q2 vs Bjorken x - ν_μ CC events

Reconstruction in LArTPC

Homogeneous target that combines large mass with accurate spatial and calorimetric reconstruction.

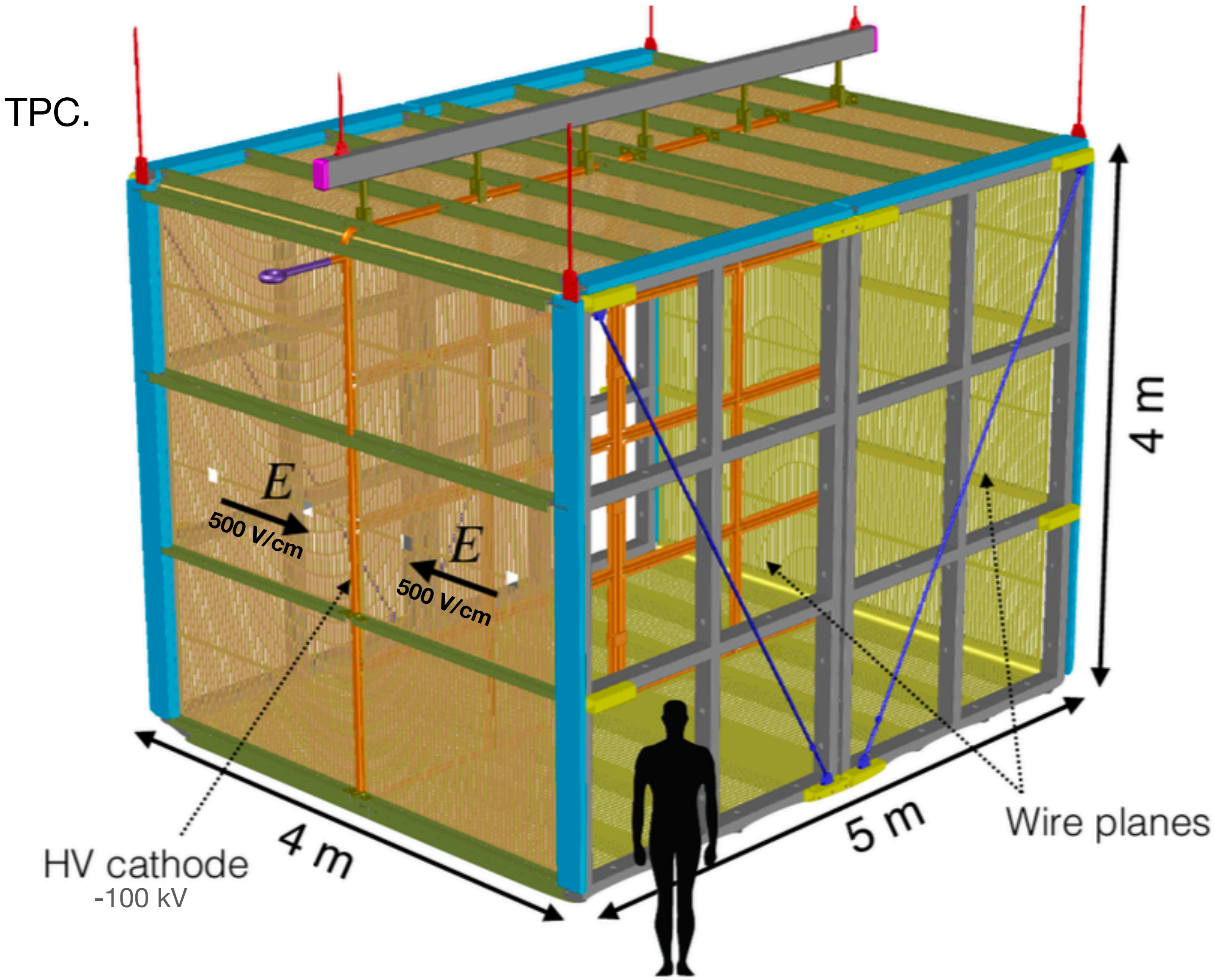


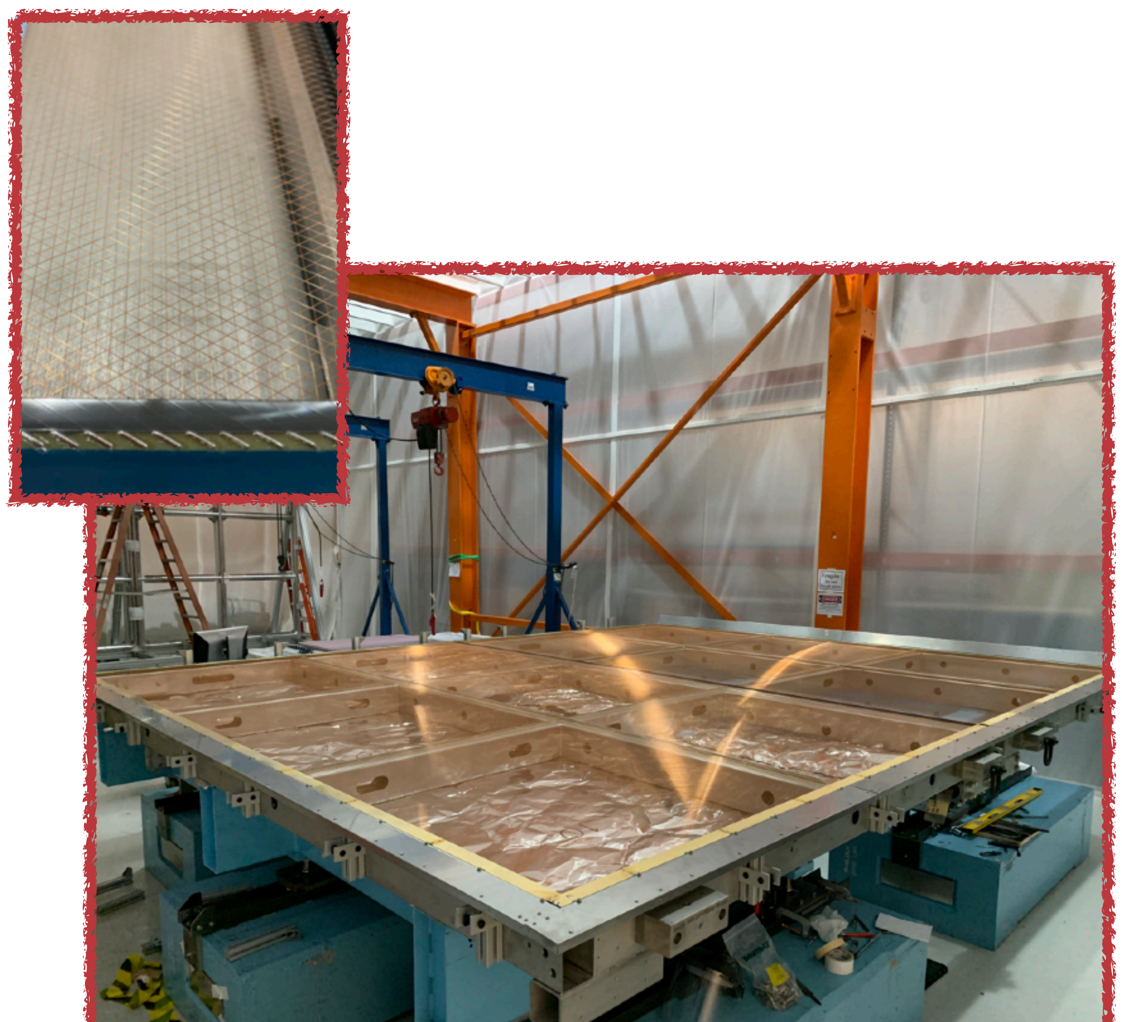
- Ionisation electrons: 42000 e^-/MeV. Drifted (E) towards wires planes. Response time = drift time (~ ms)
- λ = 128 nm scintillation light: 40000 γ/MeV Response time O(10ns), provides signals for timing/ triggering.
- 3D image reconstruction by combining coordinates on different wire planes at the same drift time.

M.Nebot-Guinot

SBND Time Projection Chamber

- Cathode Plane Assembly in the middle of the TPC.
- On both sides, Anode Plane Assemblies.
- 2 drift volumes.
  Maximum drift length: 2 m.
  Maximum drift time: 1.28 ms.





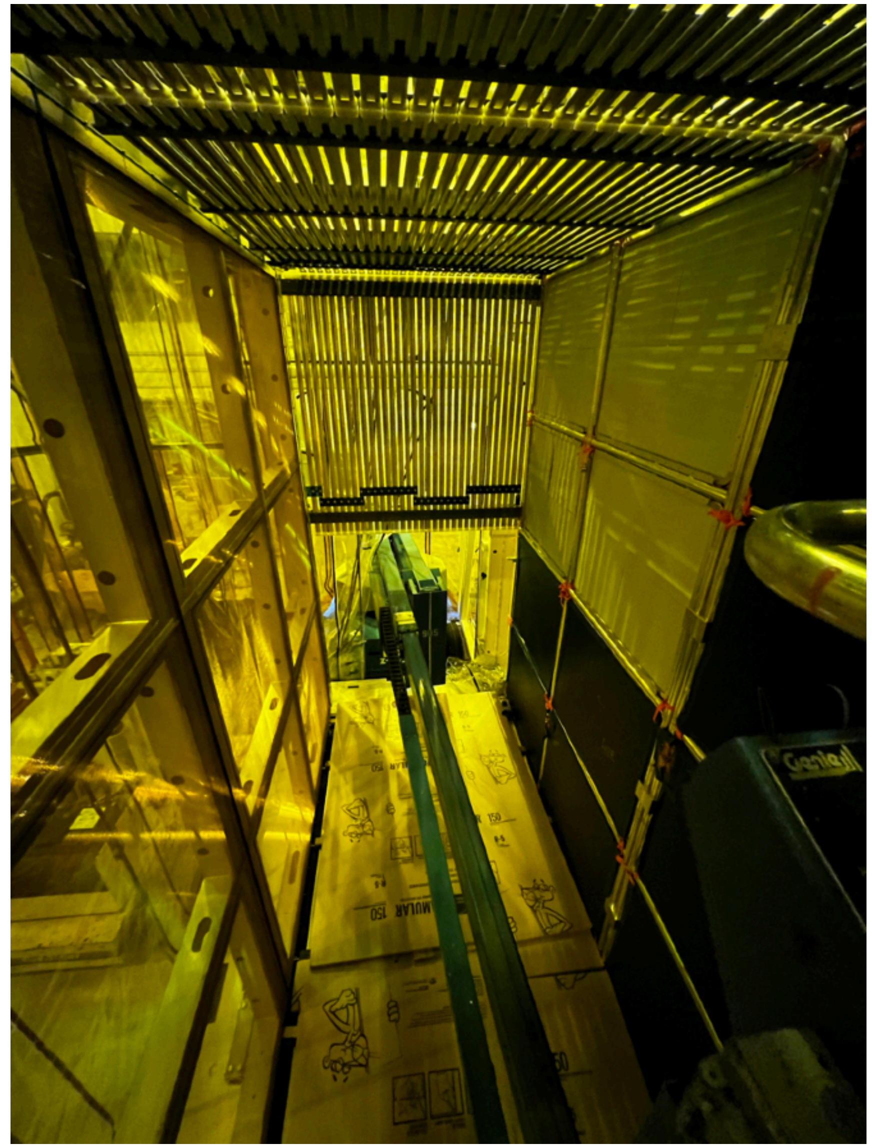
- One collection plane with vertical wires.
  Two induction planes with wires
  at ± 60^{o} from vertical.
  3 mm wire pitch.
  11264 channels.

SBND TPC assembly

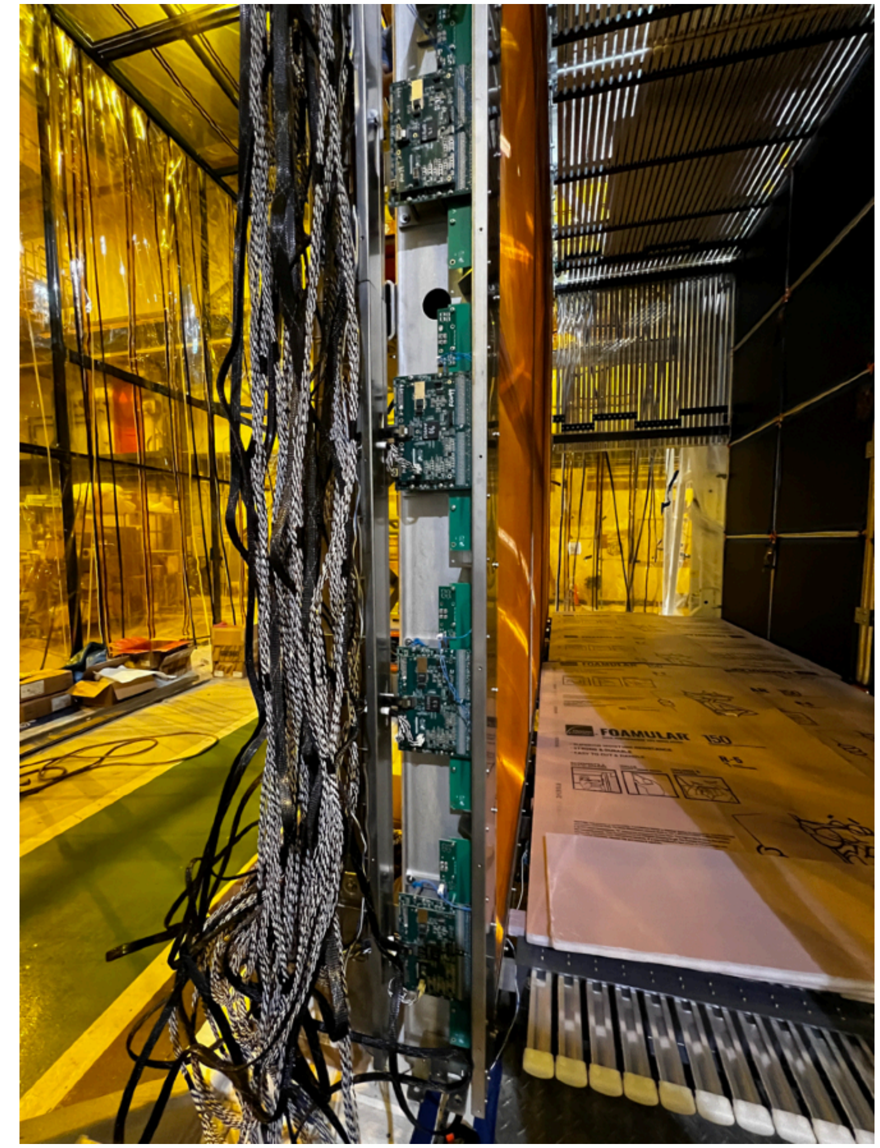
CPA assembly in place

APA installation

SBND TPC assembly



Field cage assembly

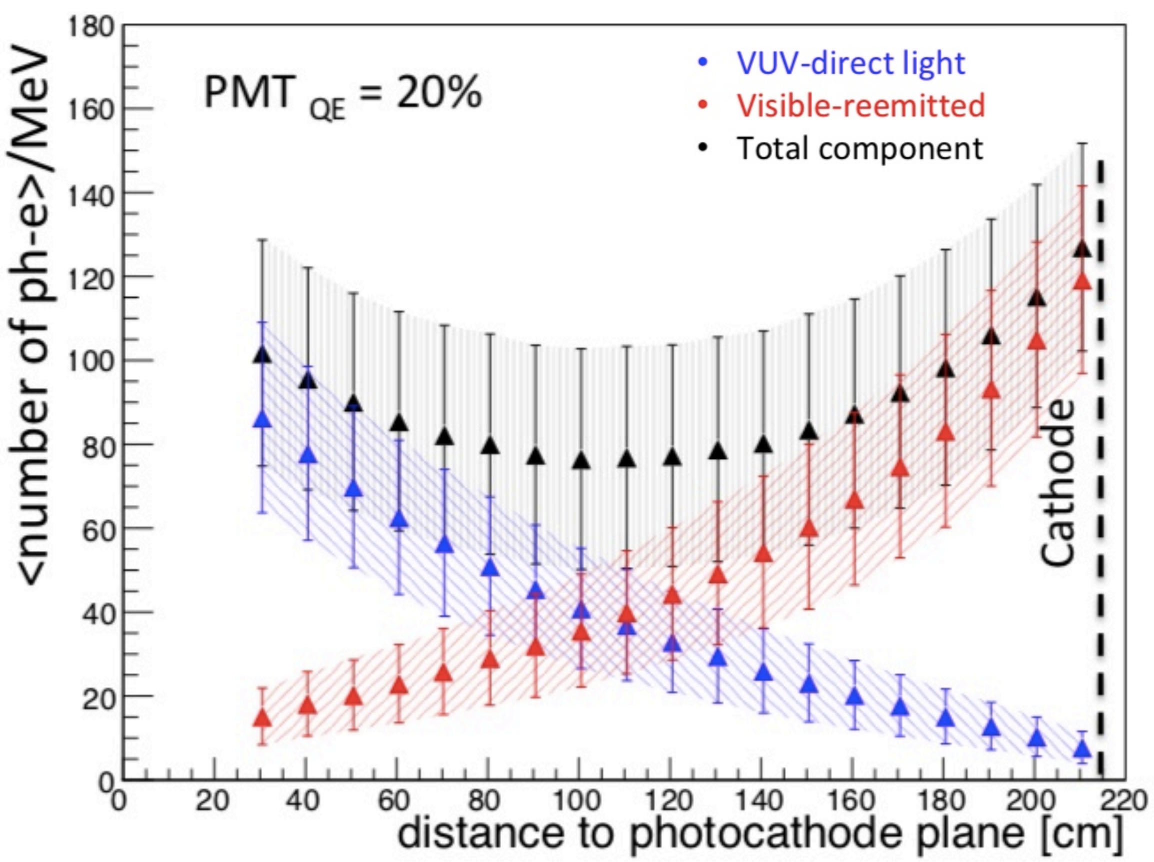


Cold electronics installation

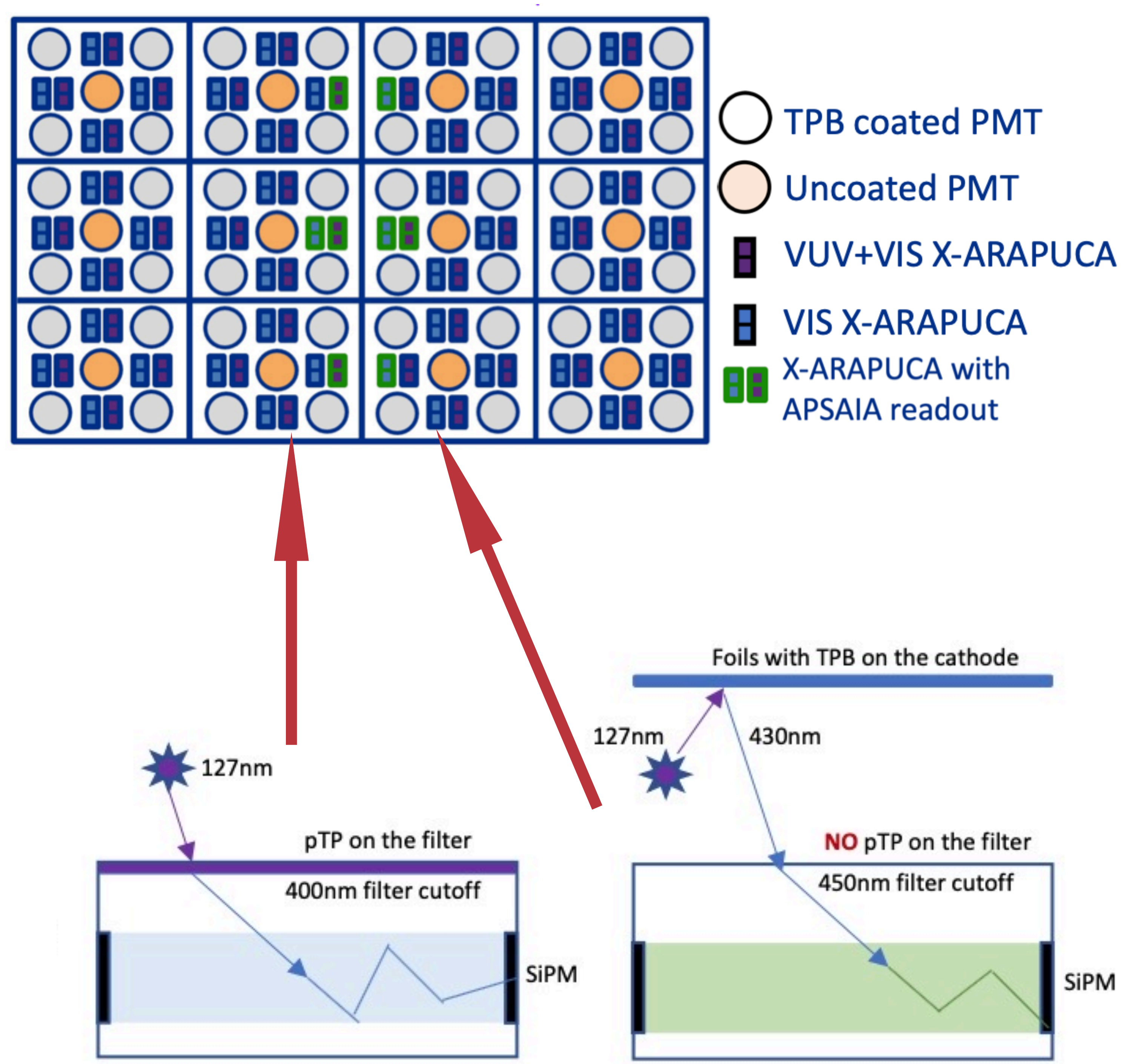
SBND TPC status

SBND Photon Detection System

Modular system behind the APAs: "looking" inside the TPC with 24 modules (12 per side) and TPB-coated reflector foils on cathode.



Scintillation & reflected light => high and uniform light yield and excellent timing resolution

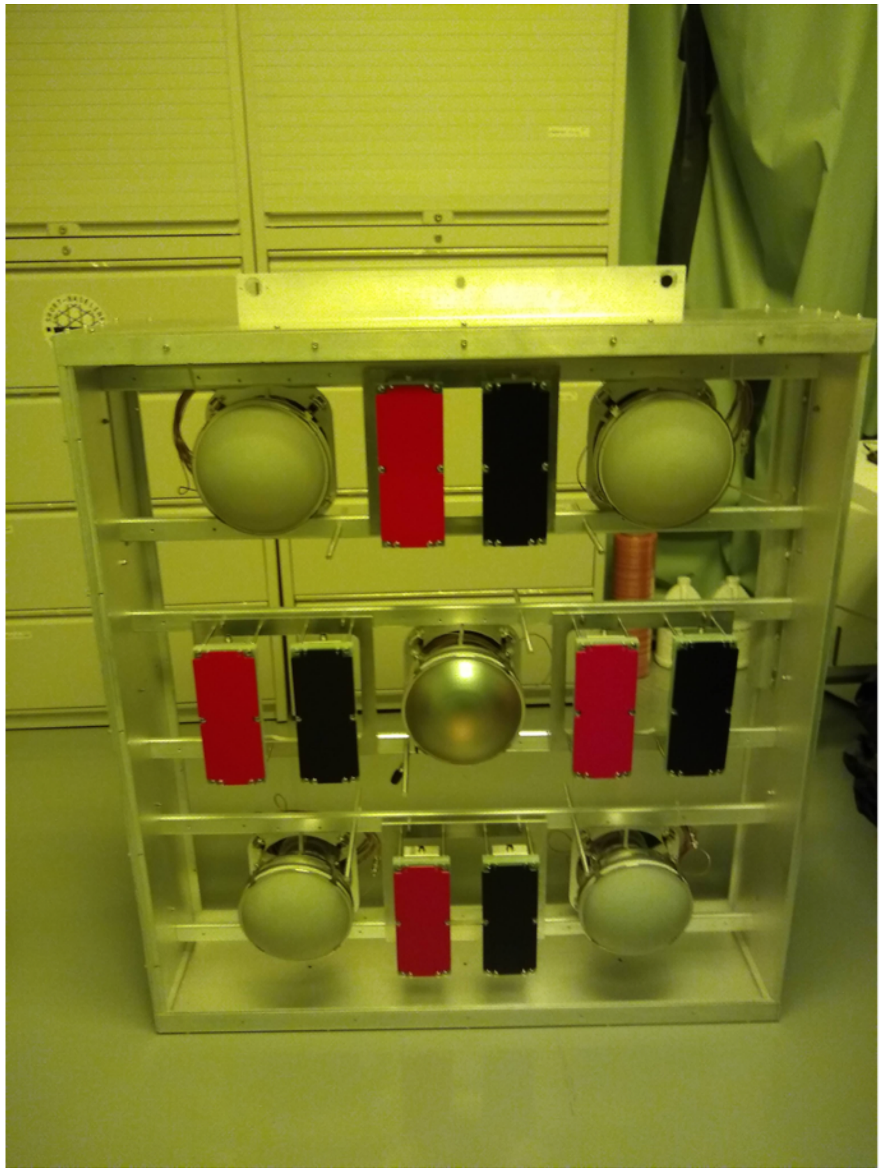


X-ARAPUCA's

M.Nebot-Guinot

SBND PDS assembly and status

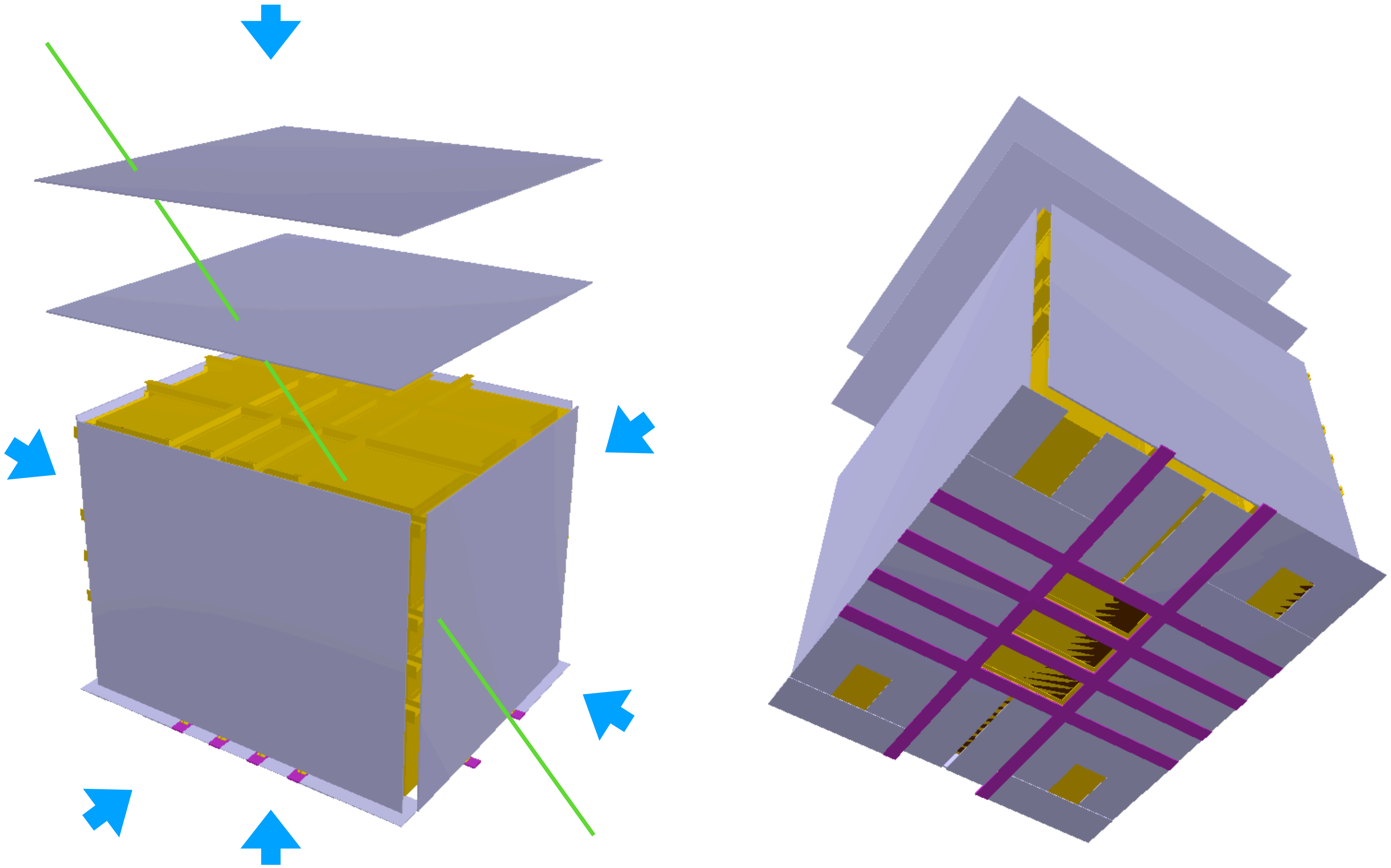
- Each module has 5 8” PMTs (120 total) and 8 X-ARAPUCAS (192 total).
- Close to completing PDS installation.



SBND Cosmic Ray Tagger

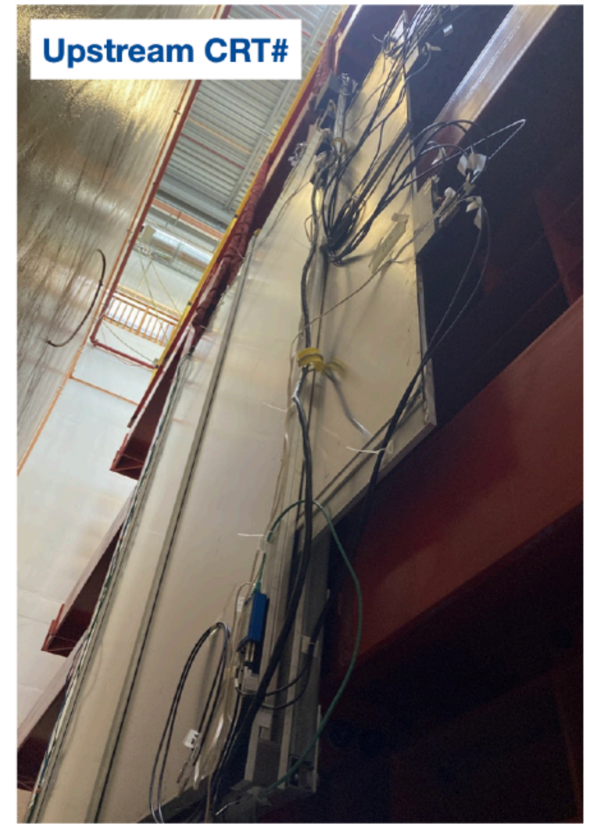
- SBND is on surface.
  In order to mitigate the cosmic ray background (identify out-of-time tracks: entering, exiting and crossing) it is equipped with a Cosmic Ray Tagger system (CRT).

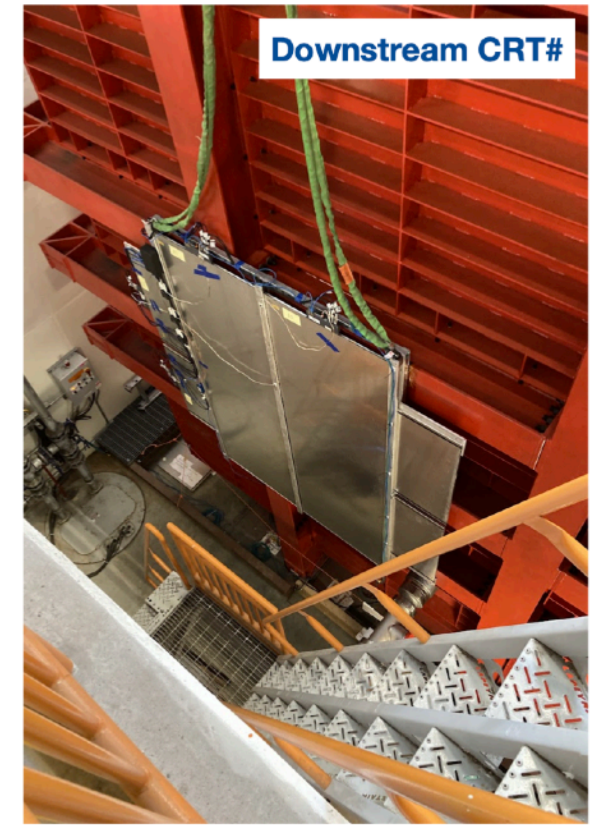
- All sides of the cryostat are surrounded by planes of extruded scintillator strips read out by SiPMs.
  - 135 single modules (from 1.80m x 1.80m to 4.5m x 1.8m)



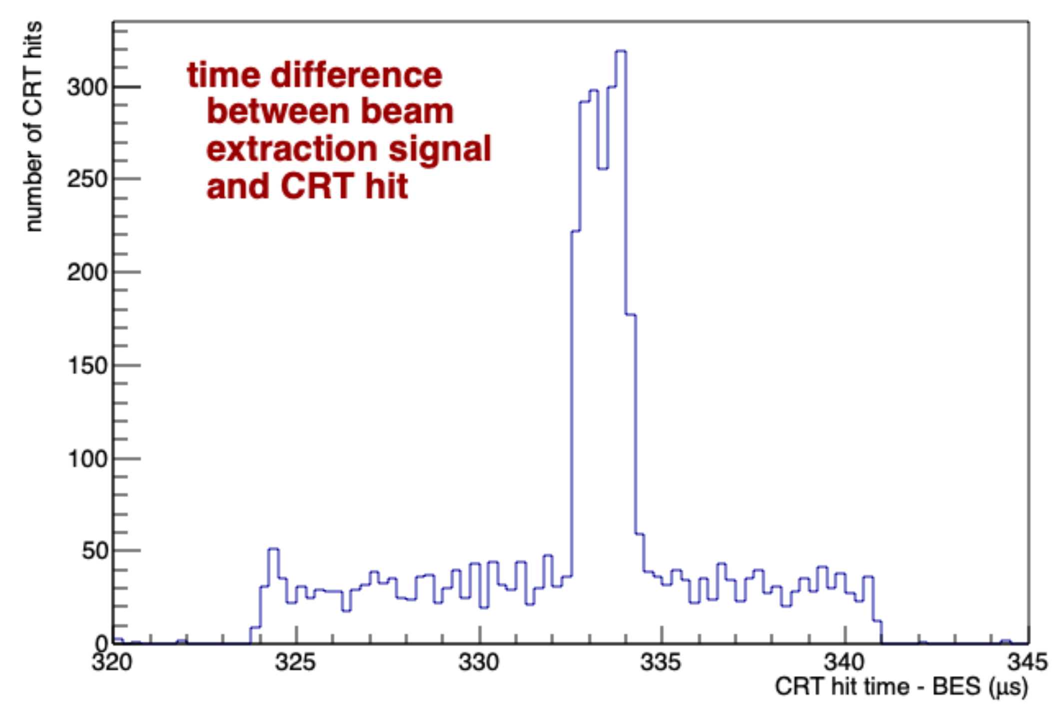
SBND CRT Assembly (head start on commissioning)

- The complete CRT will be installed and integrated last but parts can be already commissioned.
- A temporary beam muon telescope, pre-instalation of CRT modules, installed on the upstream and downstream walls of the SBND cryostat.
- This CRT enabled pre-LAr commissioning of the DAQ, CRT, Beam, Trigger and PMT electronics.

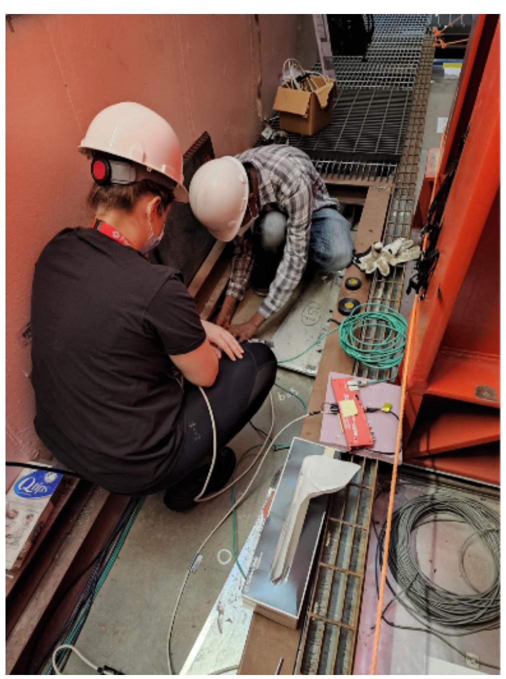


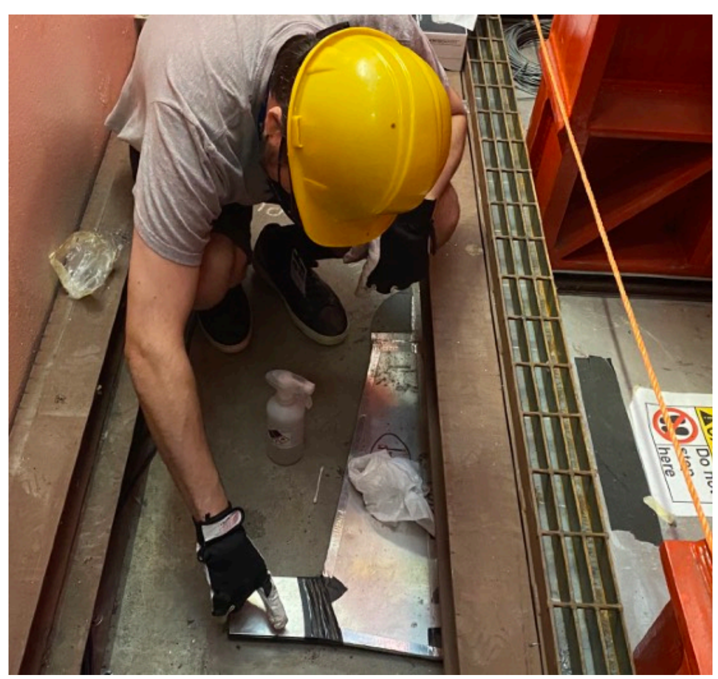


We see Beam Muons in the CRT and even do physics



beam spill duration is 1.6 us
CRT timing resolution is 1-2 ns

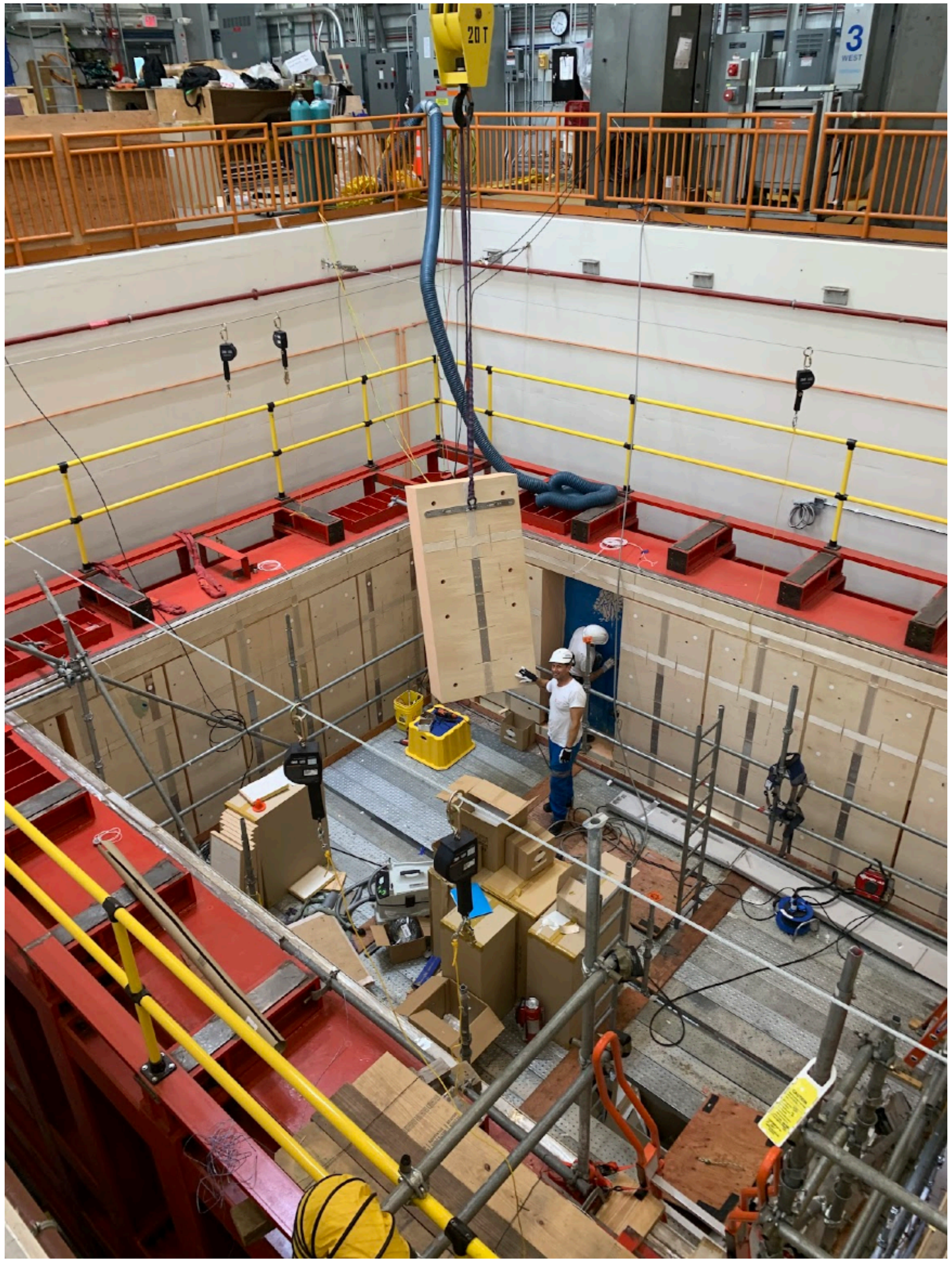




Bottom CRT installation

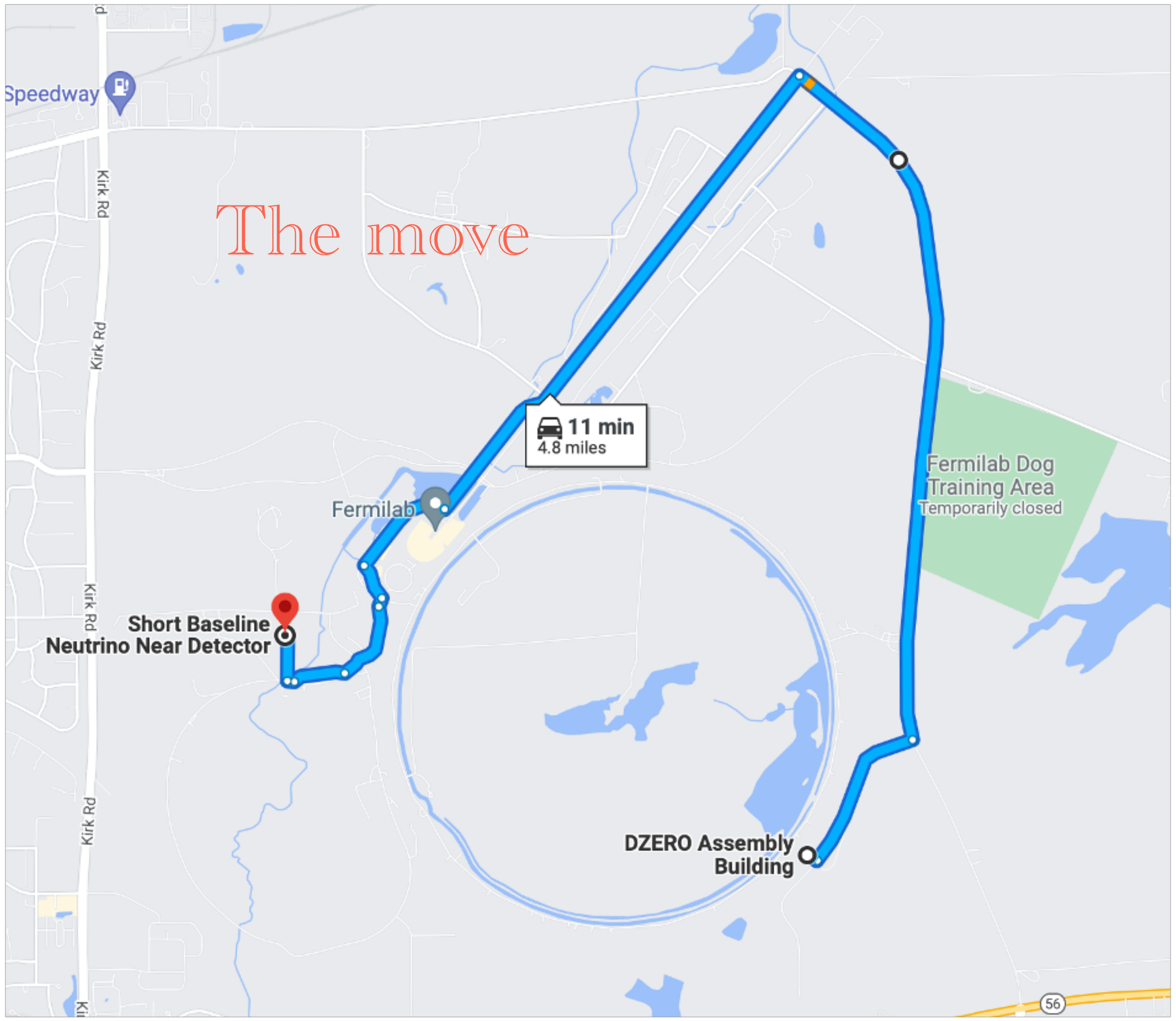
M.Nebot-Guinot

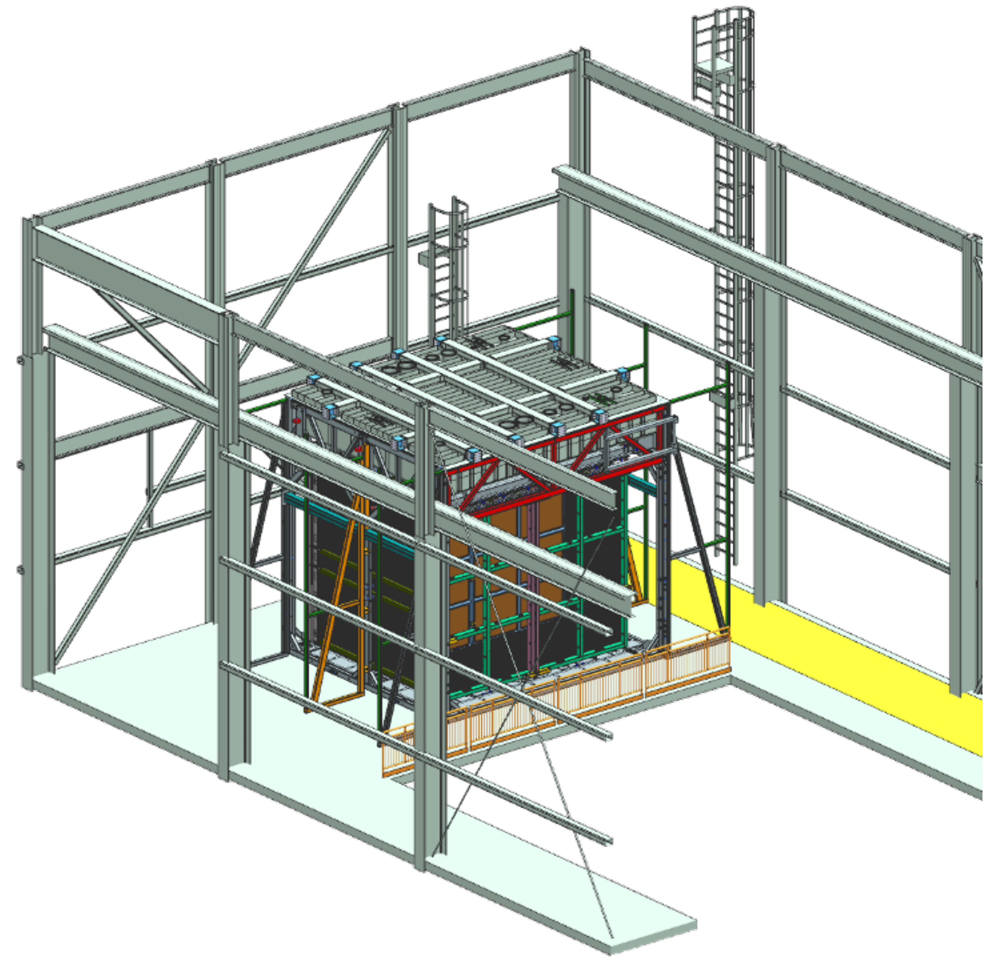
SBND cryostat assembly and status



- The SBND cryostat is a membrane type, the same as planned for the future DUNE far detectors.
- 9.3m x 7.5m x 7.6m H SS outer cryostat.
  2 layers of 40 cm insulation blocks with a secondary membrane in between. A corrugated stainless steel innermost layer as primary membrane.
- On track to finish construction in September.

Next steps towards data





- Assembled Detector will move to the ND building around fall this year.
- Detector insertion inside the cryostat is expected to take place in spring.
- Expected to be ready for cryogenic operations at the beginning of next summer.

Summary

June 2022 SBND CM (finally in person)

- SBND will constrain flux uncertainties, provide precise cross-section measurements and search for new physics.
- Great progress on SBND installation.
- This is the excellent work of many people.
- We are only a bit more than a year from taking data!

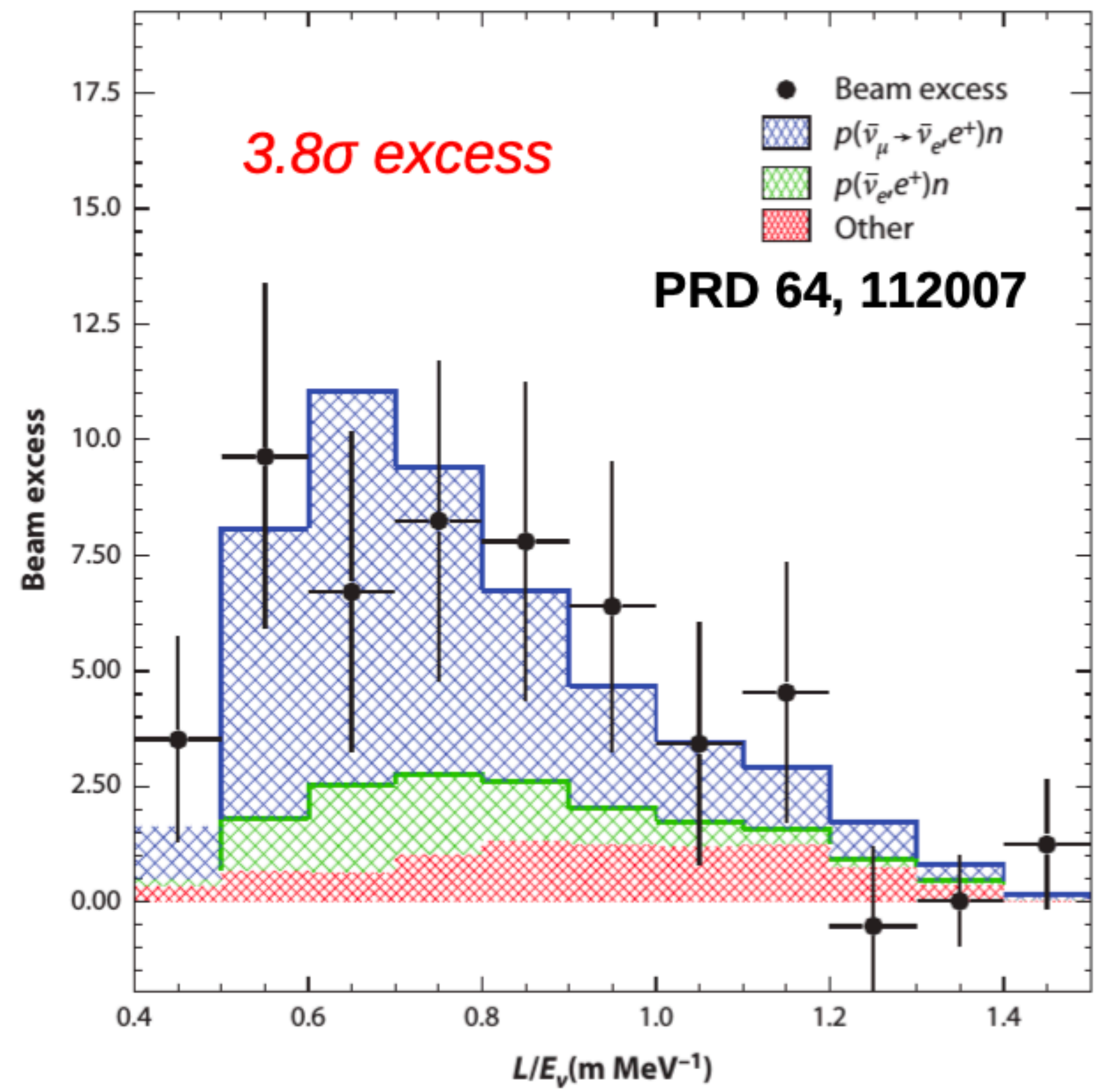
Don't miss more details of SBND:

- Gabriela Vitti Stenico: SBND Trigger System
- Marco Del Tutto: SBND-PRISM
- Supraja Balasubramanian: BSM in SBND

Backup

LSND

- Antineutrinos from μ+ decay at rest source.
- Liquid scintillator detector. Inverse β decay reaction.
- ν_e excess observed.



Electrical Installation & DAQ

- Readout racks:
  TPC racks fully installed & cabled

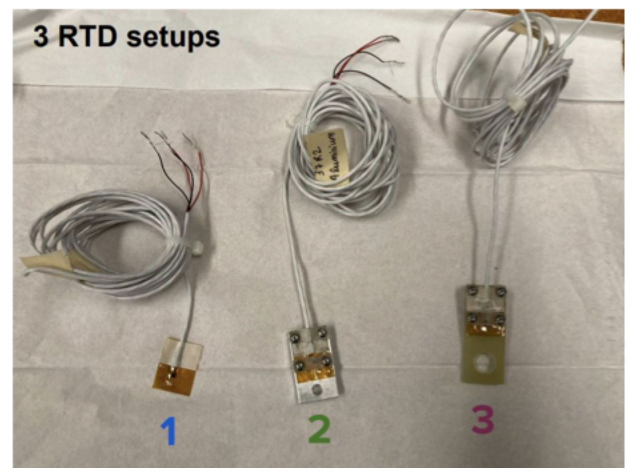
- Integration and commissioning have already begun for the DAQ and the trigger

More details in Gabriela Vitti Stenico: SBND Trigger System

M.Nebot-Guinot

Cryogenics & Instrumentation

- LAr and LN2 dewar external piping installation completed
- RTDs, mounts and cables cold tested at PAB



Purity Monitor Testing

- Purity Monitors
  SBND will have three purity monitors to check the electronegative contamination levels of the argon (especially molecules of oxygen and water).
- The purity monitors are double-gridded ion chambers immersed in the liquid argon, placed outside of the TPC.