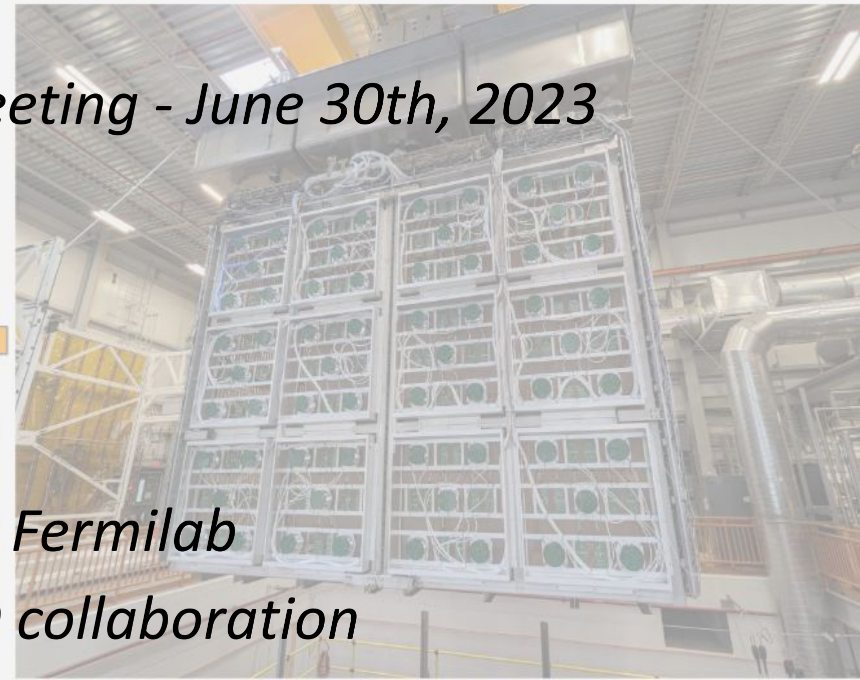
Status of the Short-Baseline Near Detector Experiment



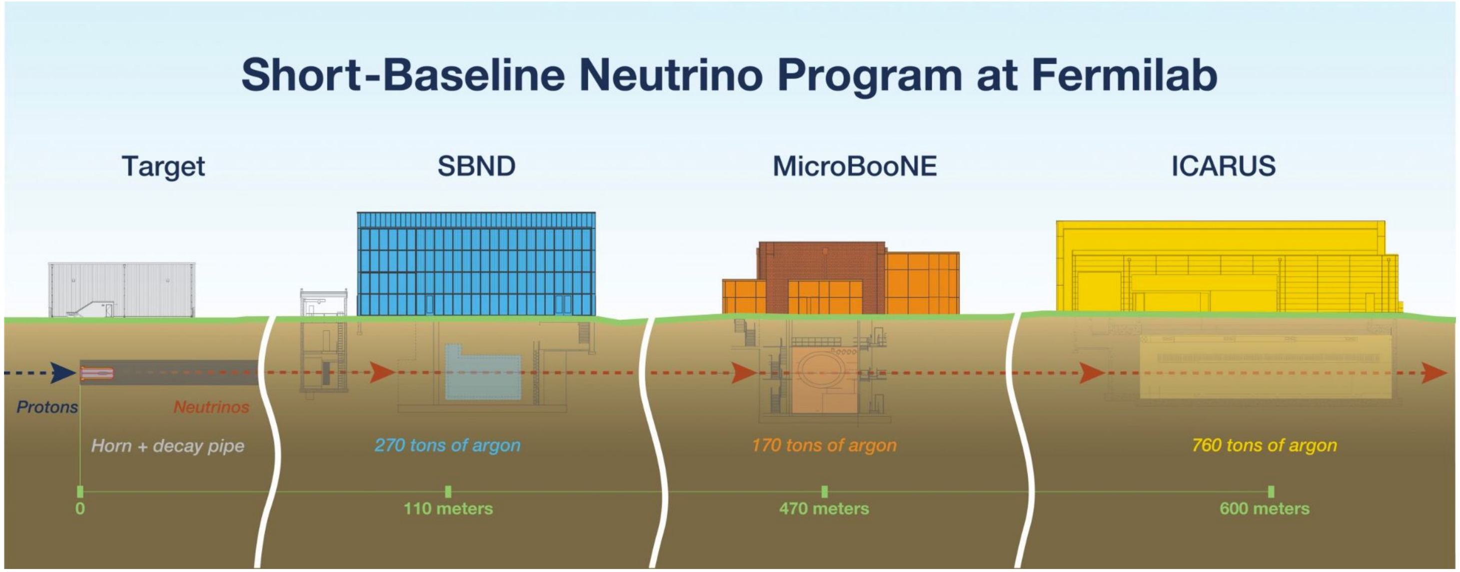
Fermilab 56th Annual Users Meeting - June 30th, 2023

Roberto Acciarri - Fermilab

On behalf of the SBND collaboration

SBN Program Introduction

- A program designed for **Sterile Neutrino searches**:
  - *same neutrino beam, nuclear target* and *detector technology* to reduce systematic uncertainties to the % level.
- Large LAr TPC detector masses and proximity to intense beams also enables a **broad physics program**, including BSM searches & high statistics cross section measurements.
- In addition, SBN is well matched with one of the recommendations of the **2014 P5** report "Building for Discovery" to realize a **world leading short-baseline experimental neutrino program** with **strong participation by the domestic and international neutrino physics communities working toward LBNF [DUNE]**



SBND expected to begin commissioning in Fall 2023

MicroBooNE data taking 2015 - 2021

ICARUS collecting data since Oct. 2021

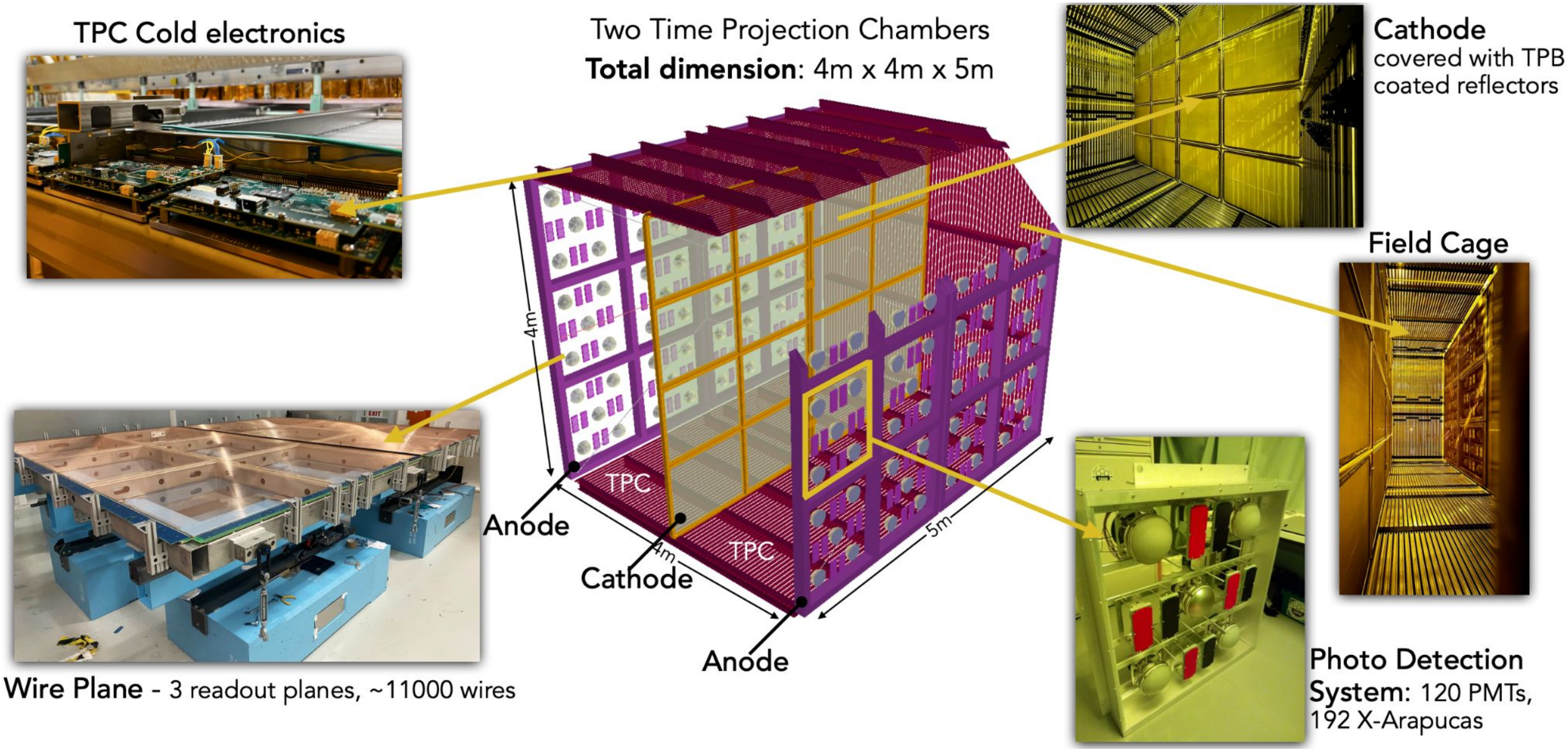
P5 report, May 2014

The SBND Detector

The design of the SBND TPC is largely based on the design of the TPC for the DUNE Far Detector 1 (FD1)

- **active volume: 112 tons**

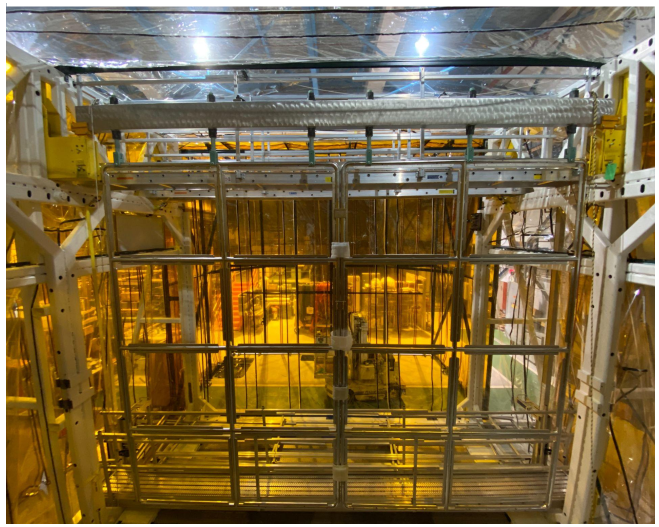
Detector components: Brazil, UK, Switzerland and US (NSF and DOE) Institutions
Cryostat and Cryogenics: CERN and FNAL (DOE)
Building and Infrastructures: FNAL (DOE)
Assembly and Installation: FNAL (DOE) and Collaboration Institutions



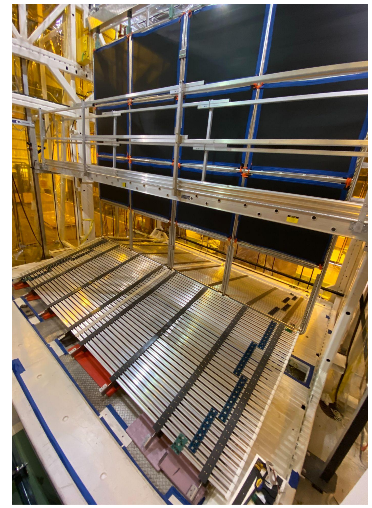
SBND Detector Assembly: 2019 - 2022

Fall 2019 *- Assembly Transport Frame Construction*

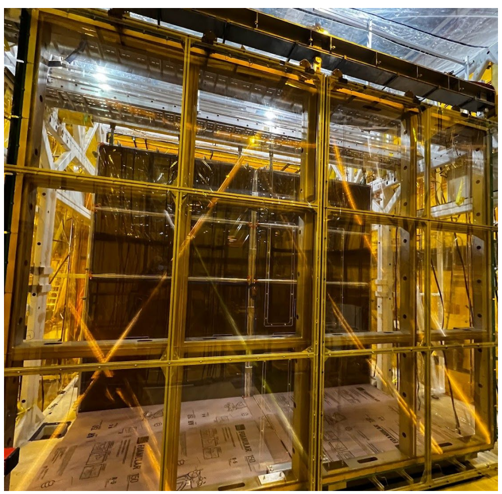
Jul 2021 *- CPA Installation*



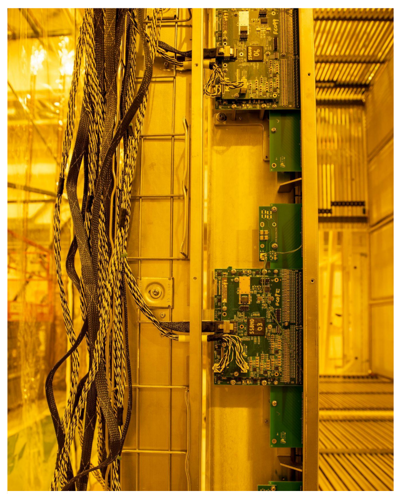
Aug 2021 *- CPA refl. window & bottom FC Installation*



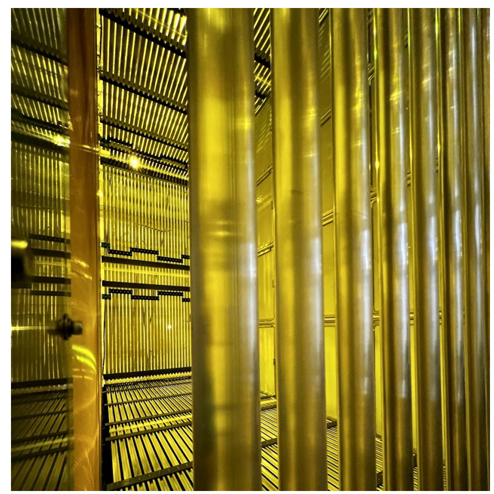
Oct & Dec 2021 *- APA Installation*



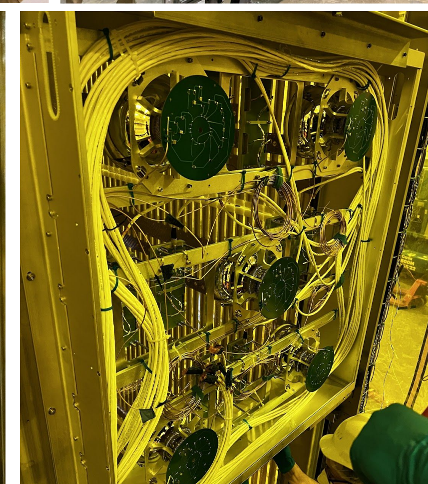
Jan 2022 *- CPA, both APAs and ground meshes installed*



Feb & May 2022 *- Cold Electronics Installation*

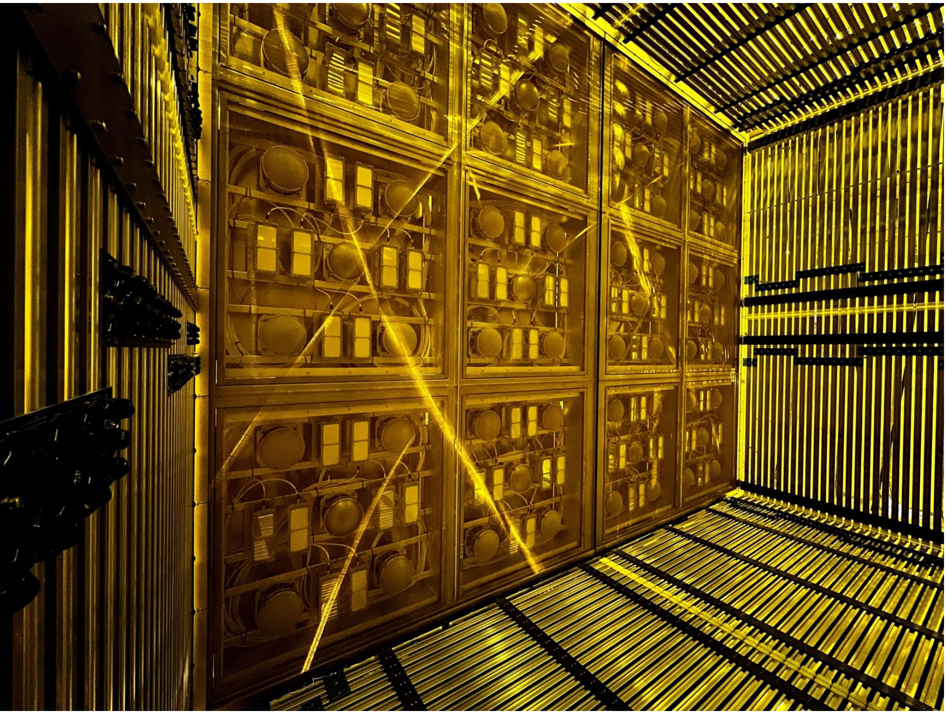


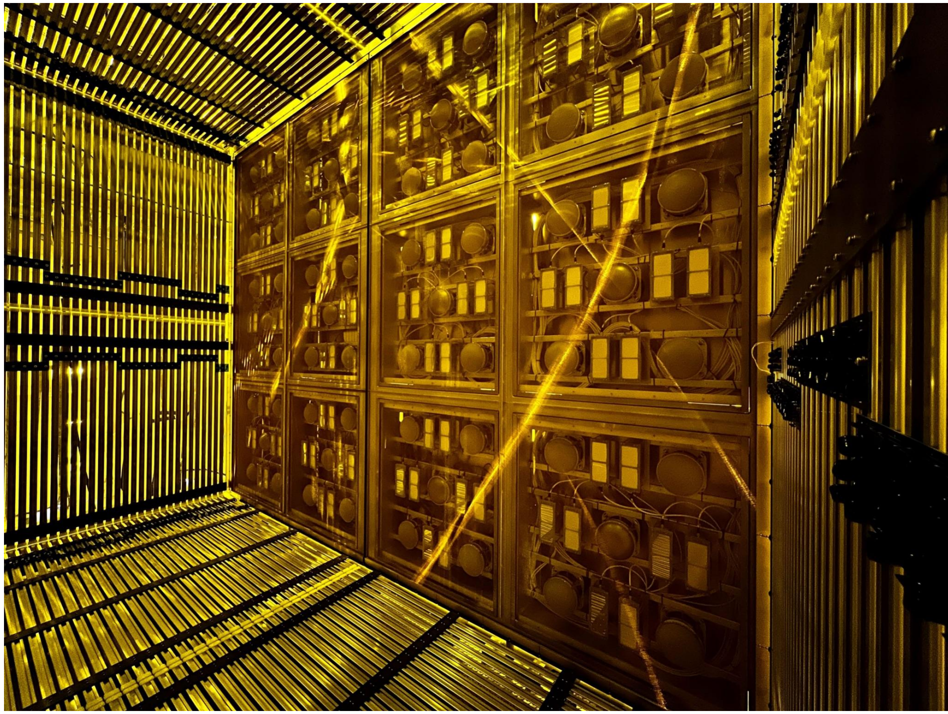
Jun 2022 *- Field Cage Closing*



Sep 2022 *- PDS Installation*

SBND Detector Assembly complete



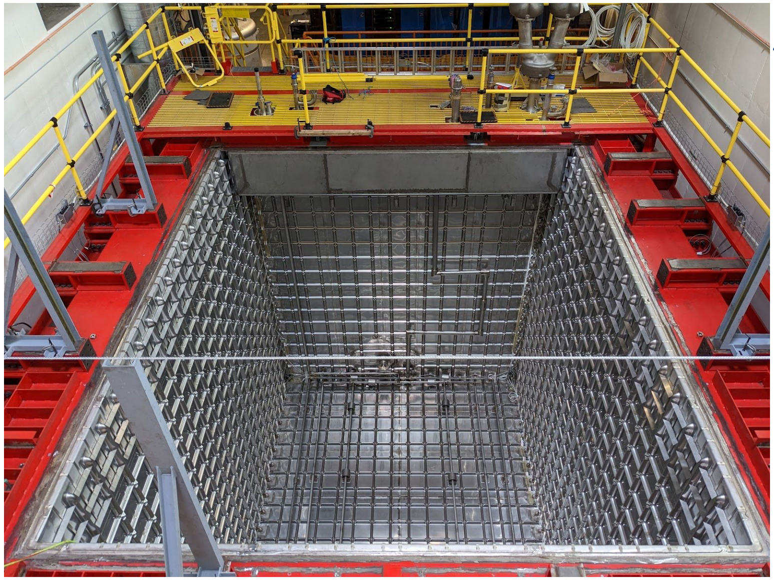


The SBND Detector Assembly was completed in October 2022 and the detector was prepped for the transport to the SBN Near Detector Building

SBND Cryostat & top cap installation

Oct/Nov '19: cryostat steel support structure installation

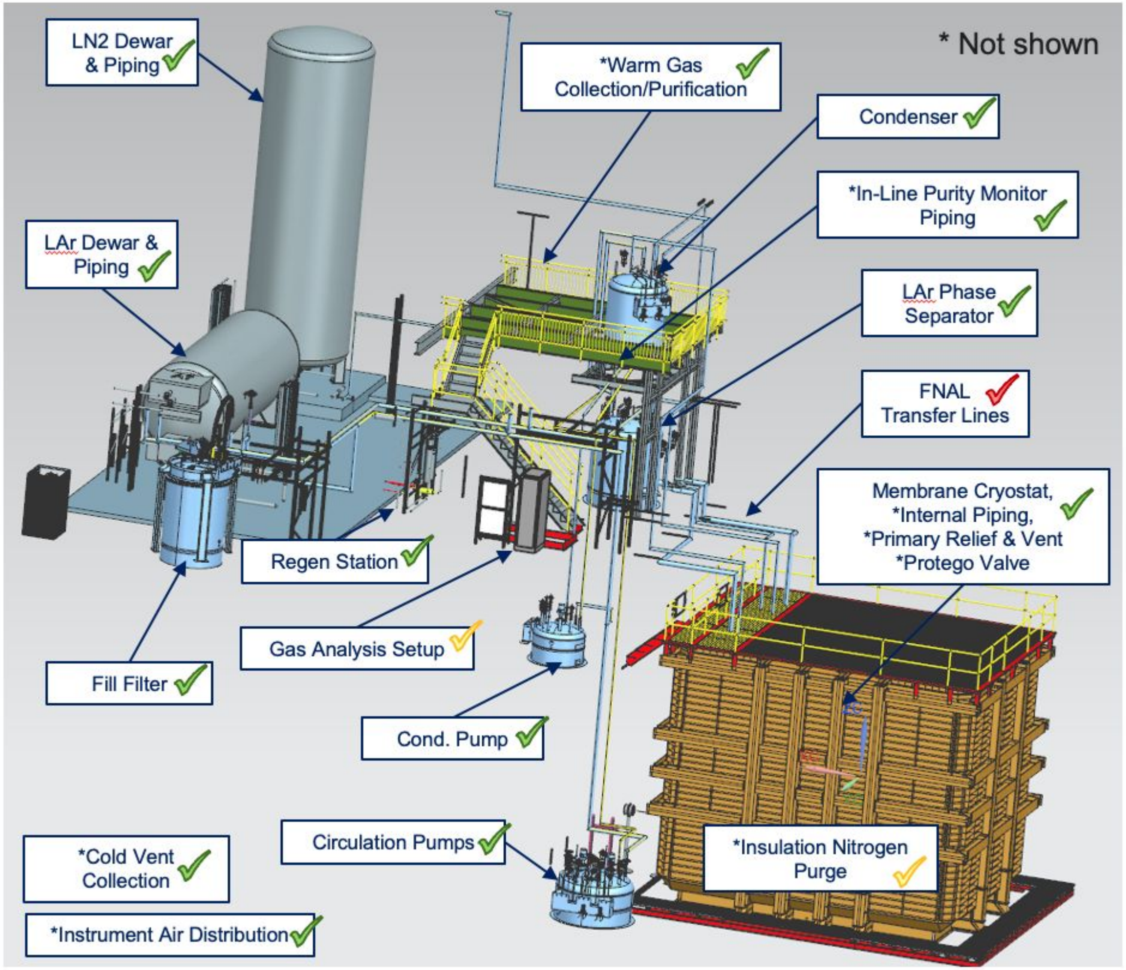
May/Jun '22: cryostat insulation installation



Jul/Aug '22: stainless steel membrane installation

Sep '22: detector top cap assembly

SBND Cryogenics System

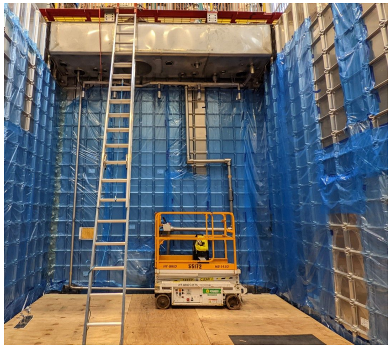


Installation Status Legend

✓ Installed ✓ In-progress ✓ Not started

Cryogenics installation is on track to complete this summer

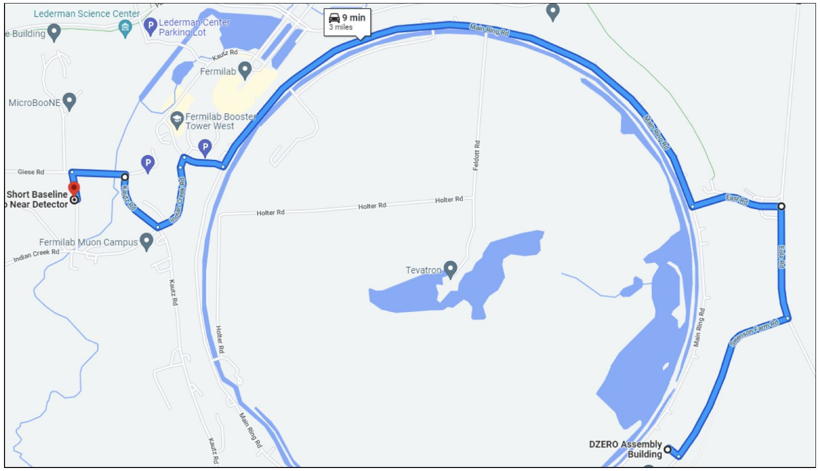
- Last remaining major installation item are the vacuum jacketed transfer lines
- Cryo controls installation & software devel. are ongoing



Detector Move from DAB to SBND

On December 1st, 2022 we transported our detector from DAB to SBND in one single long day

- The transport went very smoothly, thanks to a huge planning effort & several dry runs
- All detector subsystems checked out ok in their post-move QC testing
- Check out this YouTube video with a timelapse of the detector move



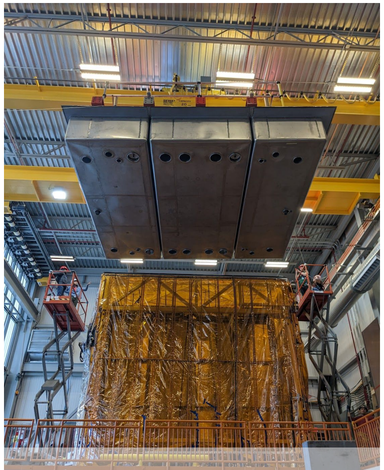
Farewell DAB!

SBND on tour

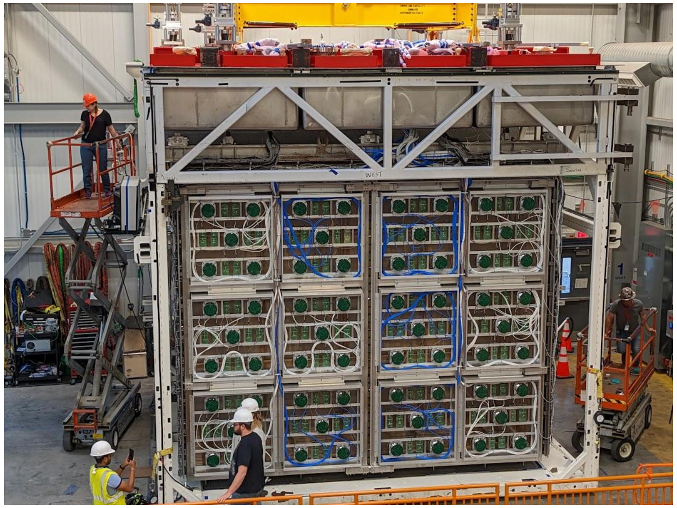
Arriving at our new home

Detector rigging

The detector was successfully lowered into the cryostat on April 25th. A timelapse video is available here, courtesy of the FNAL Visual Media Service

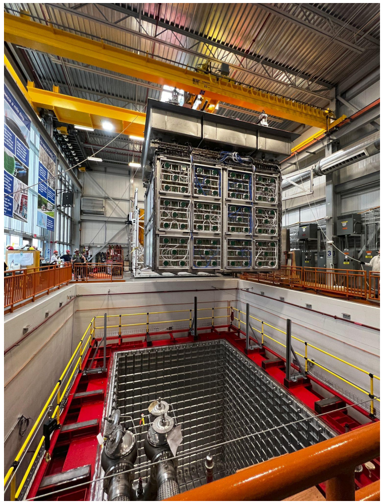


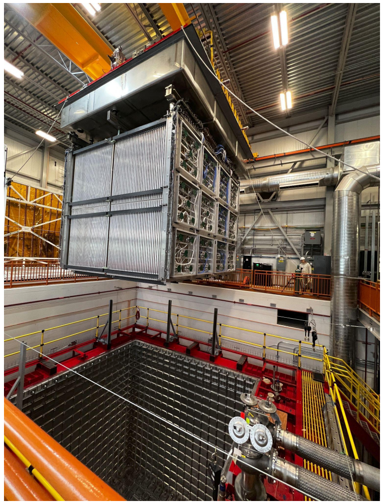
Cryostat top cap installed above detector Feb 2023

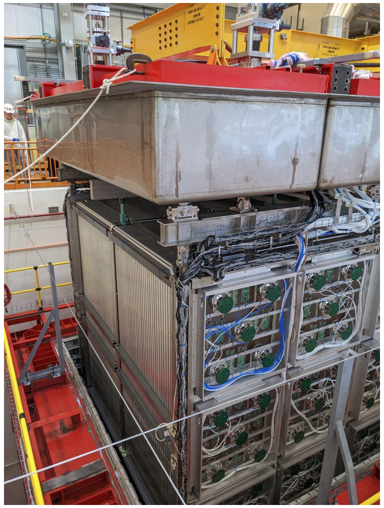


Final checks before rigging

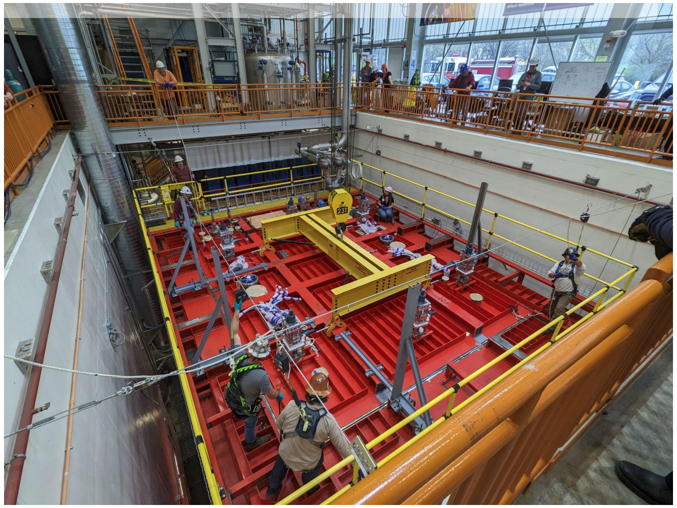
Assembly Transport Frame (ATF) door open to let detector out







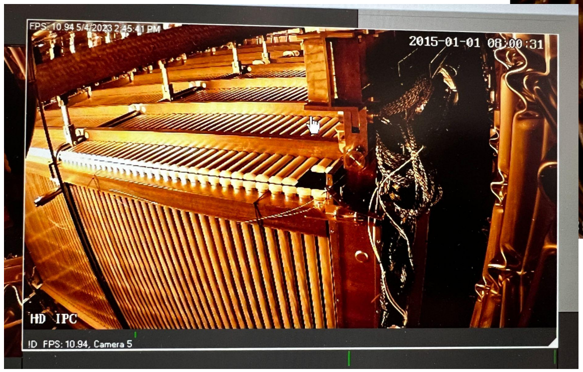
Detector extracted from ATF, rotate and inserted inside the cryostat



Detector in position!

Final Detector Installation tasks

- Currently installing remaining feedthroughs & performing QC tests on all sub-systems
  - Then we will weld the top cap to the cryostat next month
- Readout & DAQ server installation has been steadily progressing
  - Warm cabling installation in progress
  - Several readout systems have already been extensively run & tested for many months
- The detector installation will conclude in the next couple of months with the installation of the cathode HV feedthrough and cryostat-internal purity monitors



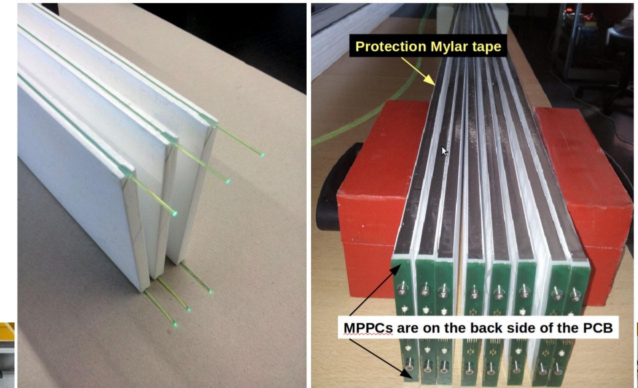
First photos from inside the cryostat after detector rigging.

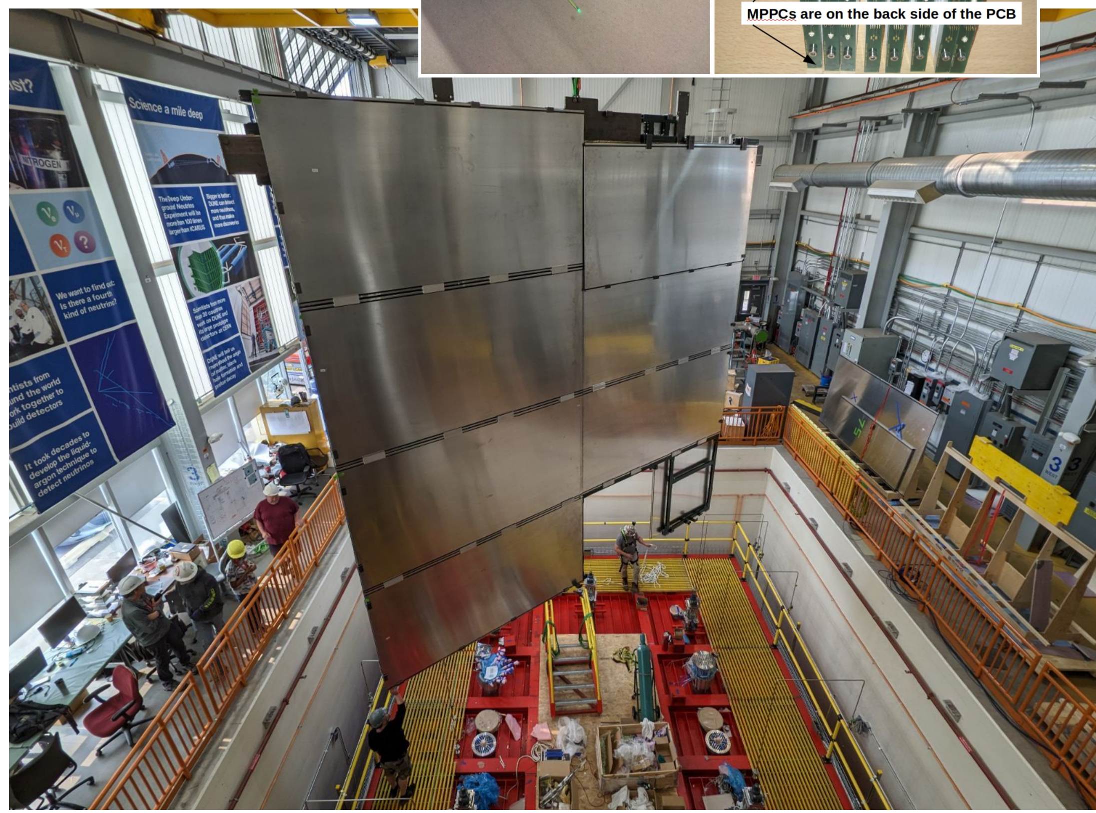
DAQ & Readout racks on the mezzanine level.

Cosmic Ray Tagger Installation

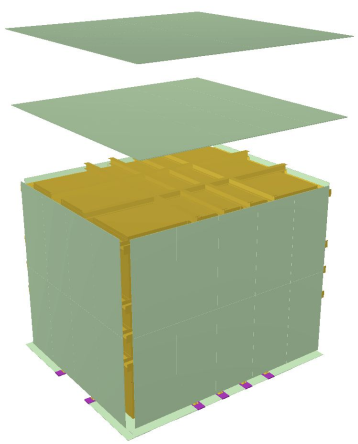
- The SBND cryostat will be surrounded by a Cosmic Ray Tagger (CRT) System
- CRT modules are made of parallel scintillator strips
- The CRT North Wall was installed last month
  - Bottom modules underneath the cryostat are already installed
  - Remaining side walls and top CRT layers will be installed after stable cryogenics operation has been established

Scintillating strip modules produced at LHEP Bern



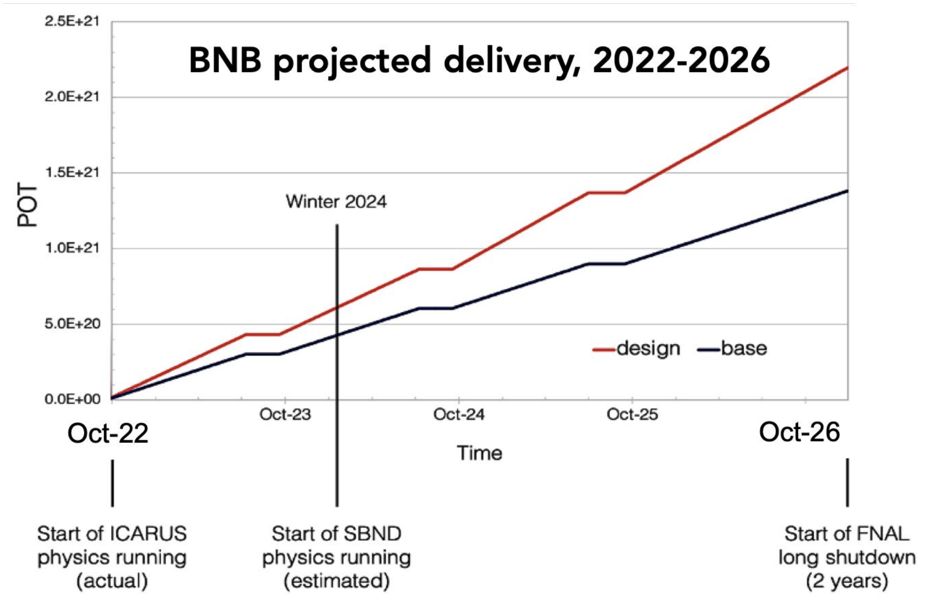


SBND CRT North Wall installed mid May 2023



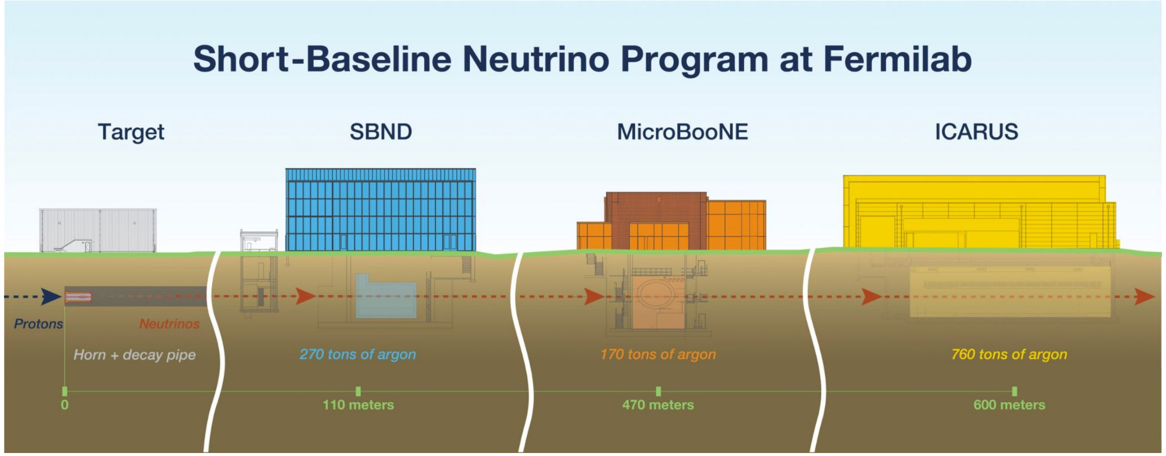
Conceptual design of the SBND CRT with one bottom, four side and two top layers

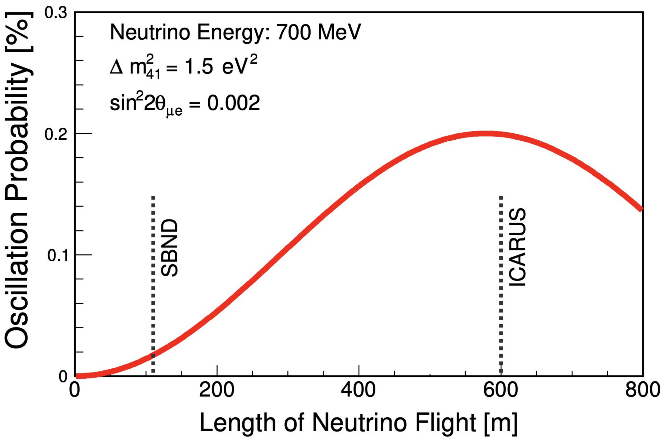
SBND Run Plan



- Cryogenics commissioning will begin at the end of Summer 2023
  - LAr delivery contract placed: 21 truckloads over ~ 3 weeks
  - Detector Commissioning proceeds in coordination with cryogenics schedule
- Running **until** the Fermilab **accelerator long-shutdown** in 2027:
  - ICARUS is expected to collect **15-22 × 10^{20} POT** from BNB
  - SBND is expected to collect **10-13 × 10^{20} POT** from BNB
  - This is x2 the assumed exposure in the SBN proposal (6.6 × 10^{20} POT)
- We have started considering the **physics potential of extending the run after the long-shutdown** (2029+). Possible scenarios:
  - Continue to run in neutrino mode
  - Run in anti-neutrino mode
  - Run in beam-dump mode

Oscillation measurement



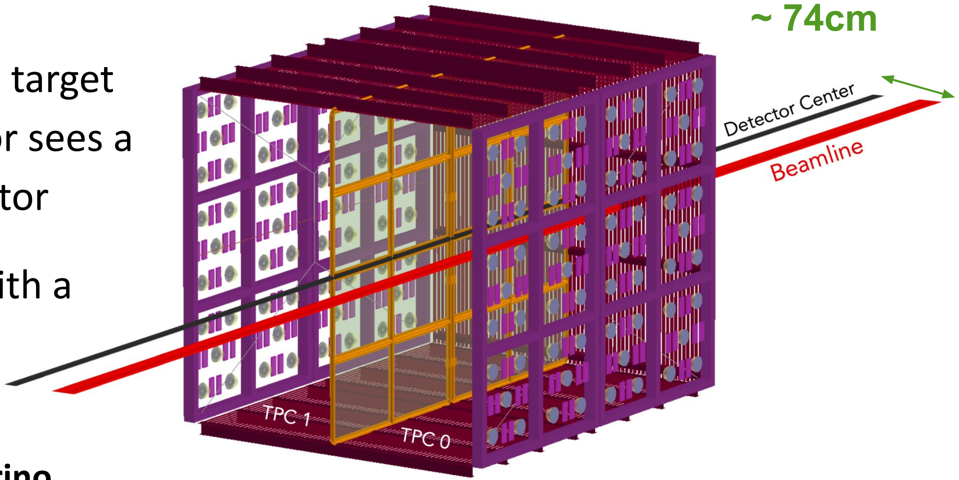


- **With SBN we have a unique ability to search for appearance of ν_e and disappearance of ν_μ within the same program**
  - current results show a 4.7σ tension between ν_e appearance and ν_μ disappearance channels
- The near detector is crucial for oscillation searches
  - It sits before oscillations turn on @eV-scale ⟶ it will **characterize the beam** and address the dominant systematic uncertainties
- Effective systematics constraint through near detector (SBND) and same detector technology in near and far detector is key
- The SBN program tests the sterile neutrino hypothesis by covering the parameter regions allowed by past anomalies at **5σ significance**

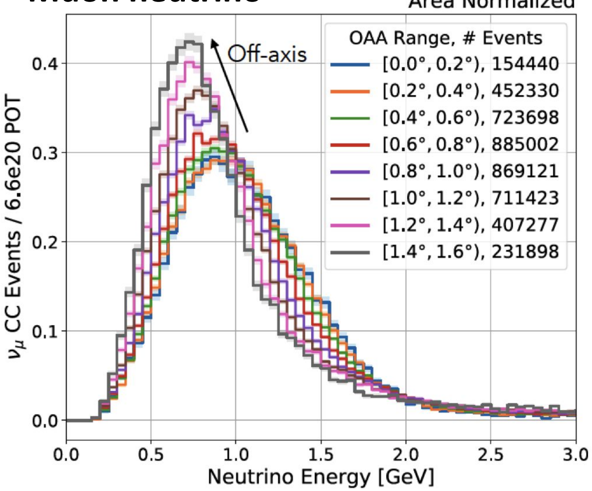
SBND-PRISM: Exploiting a slightly off-axis detector

With SBND being located very close to the beam target (110m) and slightly off-axis (~74cm), the detector sees a different flux based on position within the detector

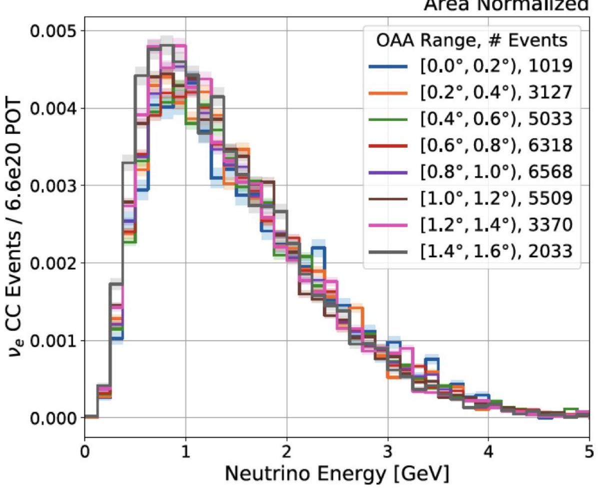
- Similar to the DUNE-PRISM concept, but with a fixed detector



Muon neutrino



Electron neutrino



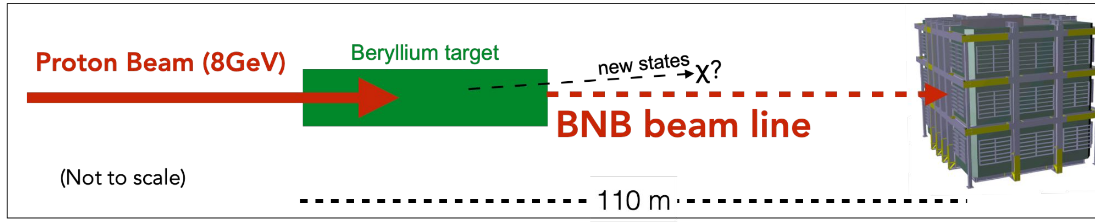
SBND-PRISM technique will enhance sensitivity for:

- Oscillation analyses
- BSM searches
- Cross section measurements

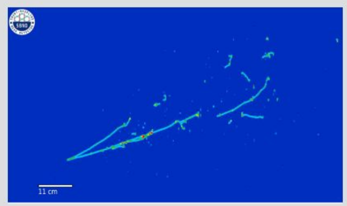
Muon and electron neutrino energy distributions are affected differently by the off-axis position

Alternative Explanations for low-energy Excess & beyond

- SBND can explore many alternative models that explain the MiniBooNE excess, and other BSM scenarios
- We are actively collaborating with theorists from Fermilab and beyond to explore possibilities for searches & capabilities of our detector
- several models already implemented in our simulation & reco

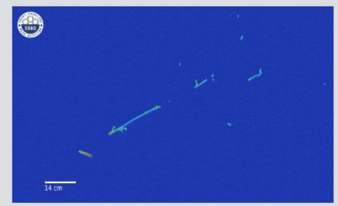


Dark Neutrinos



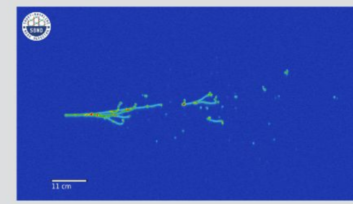
e+e- pair w/ or w/o hadronic activity

Transition Magnetic Moment



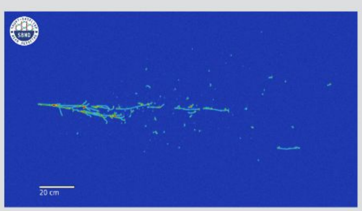
photon shower and hadronic activity

Axion-like Particles



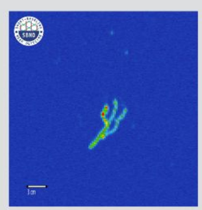
high-energy e^+e^-, $\mu^+\mu^-$

Heavy Neutral Leptons



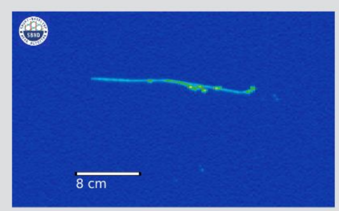
e^+e^-, $\mu^+\mu^-$, $\mu\pi$

Higgs Portal Scalar



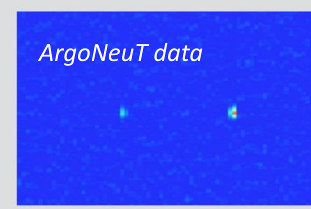
e^+e^-, $\mu^+\mu^-$, no hadronic activity

Light Dark Matter



electron scattering

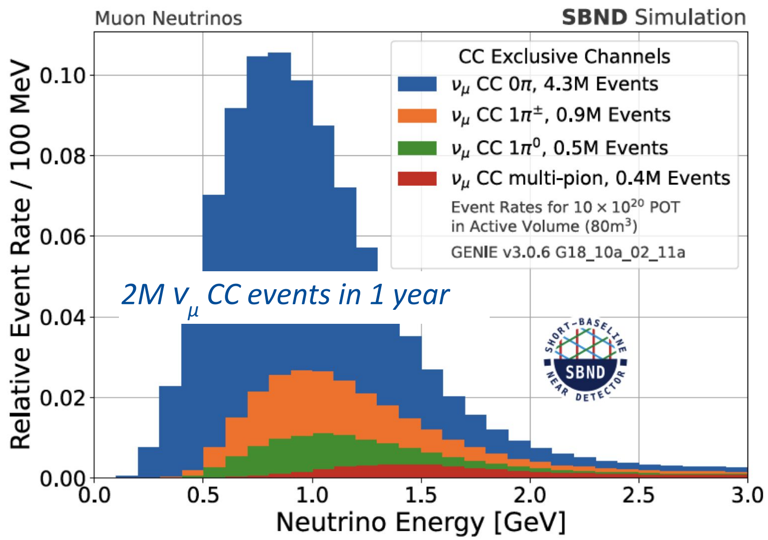
Millicharged Particles

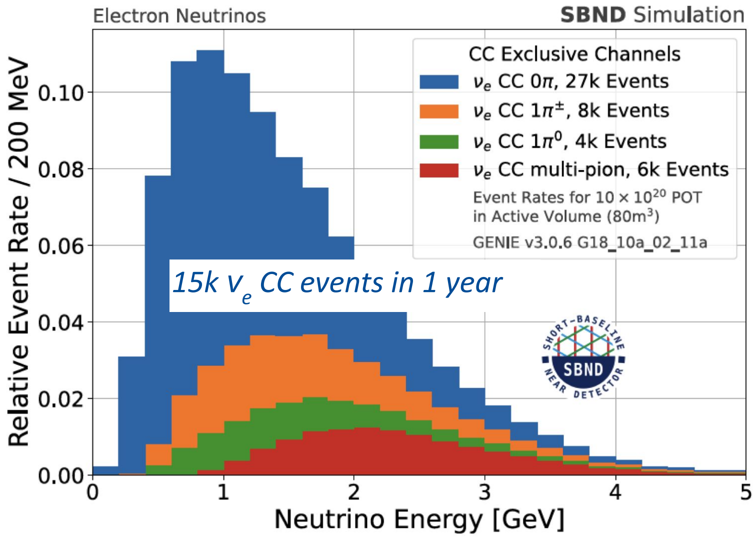


blips/faint tracks

Argoneut Paper: Phys. rev. Lett. 124, 131801

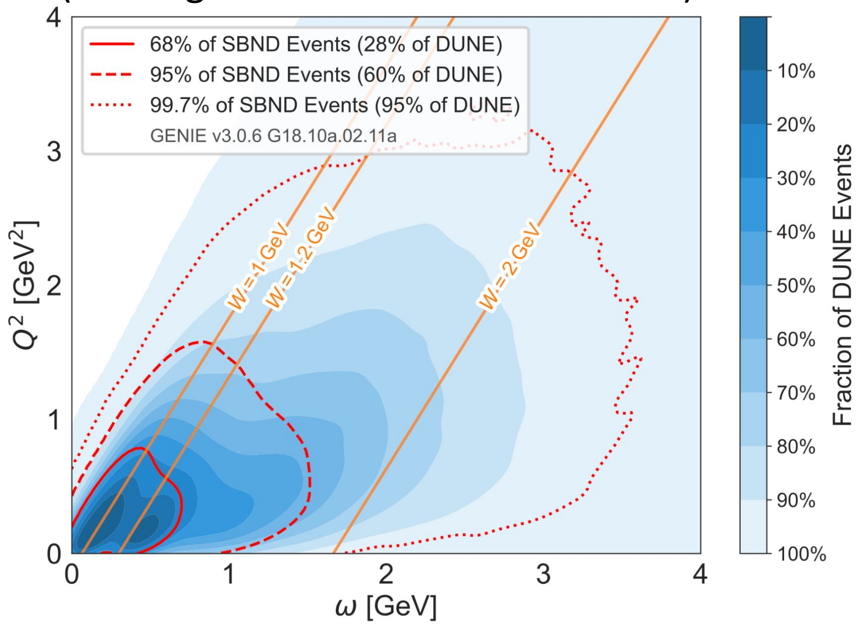
Precision Neutrino-Argon Cross Section Measurements





With its proximity to the beam target, SBND will collect neutrino interactions with unprecedented statistics

- SBND will record **20-30x more neutrino-Argon interactions** than are currently available!
- SBND will be able to advance our understanding of neutrino-Argon interactions in the GeV range (with significant relevance to DUNE!)



DUNE kinematic coverage is represented with the blue 2D histogram.
SBND kinematic coverage is shown with 3 contours, representing 68%, 95%, and 99.7% of all SBND data.

Summary

- SBND Installation has been progressing on schedule and is going to **complete this summer**
- The collaboration is ready & excited to **start Commissioning & Operations**
- SBND has a **broad science goal** as part of SBN and on its own, addressing alternative explanations of the **Short-Baseline anomalies**, **BSM** searches and precision studies of **neutrino-Argon interactions**

262 Total Collaborators

210 Scientific Collaborators
(faculty/scientists, postdocs, PhD students)

40 Institutions

5 Brazilian Universities
CERN
1 Spanish University, 1 National Laboratory
1 Swiss University
8 UK Universities, 1 National Laboratory
18 US Universities, 4 National Laboratories


obrigado
Dank U
Merci
mahalo
Köszi
спасибо
Grazie
Thank you
maururuuru
Takk
Gracias
Dziękuję
Děkuju
danke
Kiitos