Short-Baseline Near Detector (SBND)

Contribution to the European Strategy for Particle Physics 2026

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for the SBND Collaboration

Fermilab

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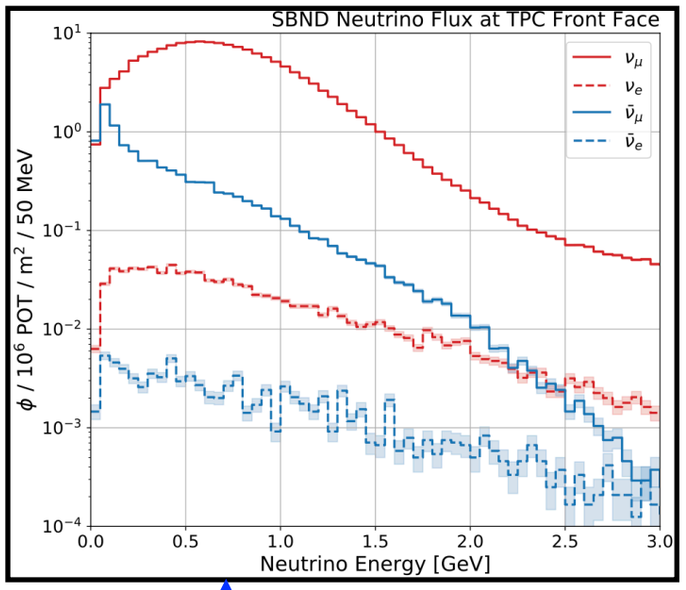
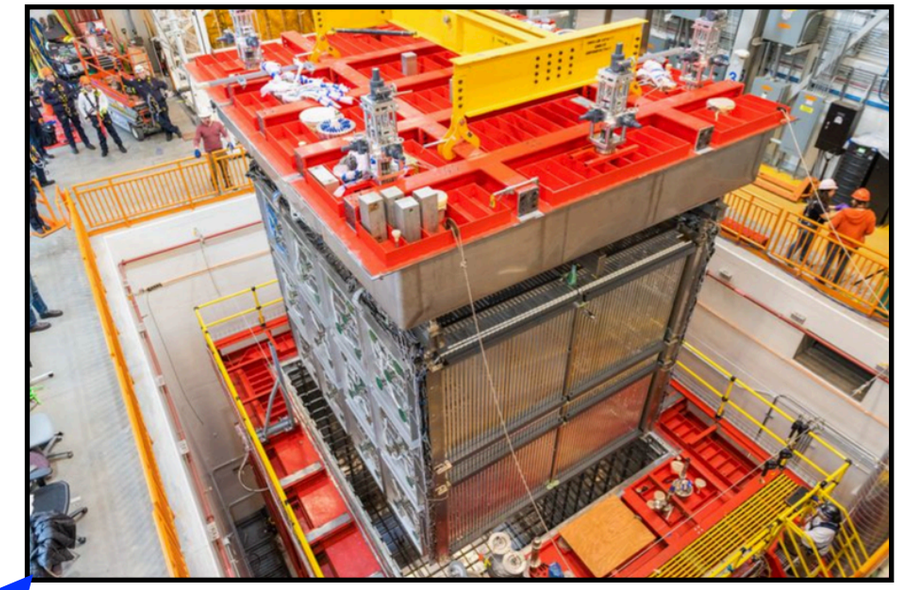
Short-Baseline Near Detector (SBND)

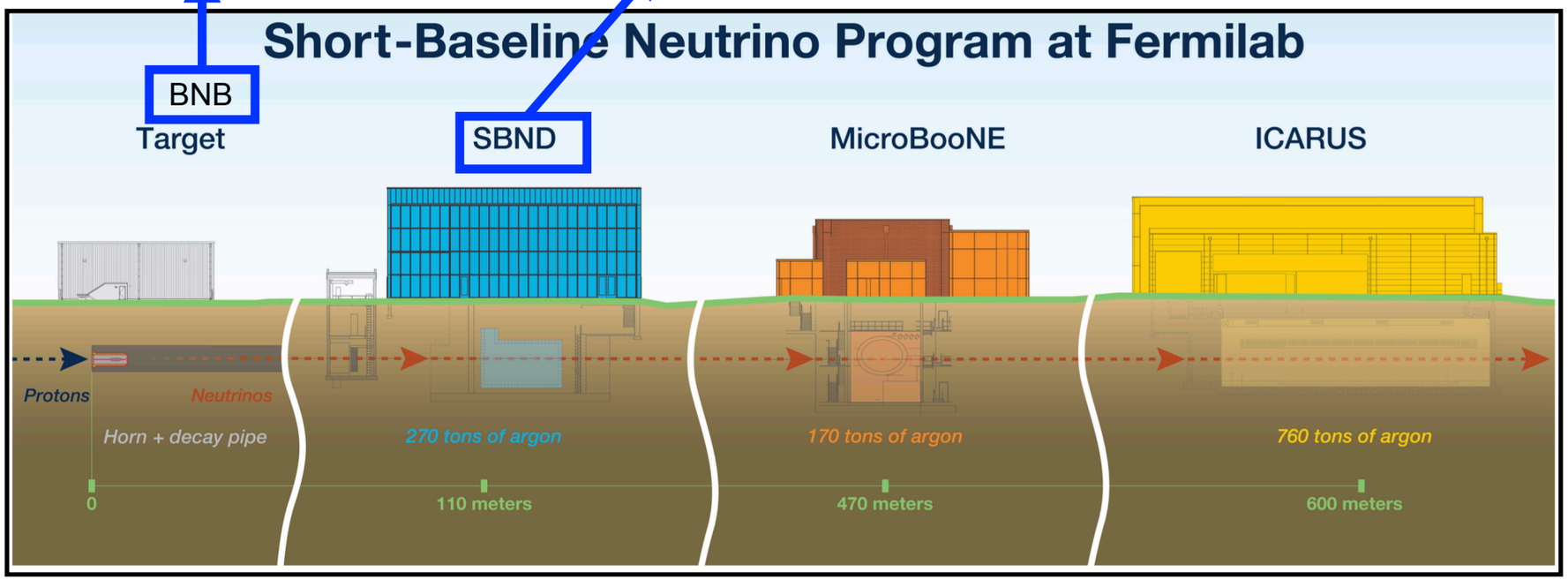
- The Short-Baseline Near Detector (SBND) is the near detector of the Short-Baseline Neutrino (SBN) program located along the Booster Neutrino Beamline (BNB) at Fermilab.
- SBND has broad science goals as part of SBN program and on its own, addressing explanations of the short-baseline anomaly, BSM searches and precision studies of neutrino-argon interactions.

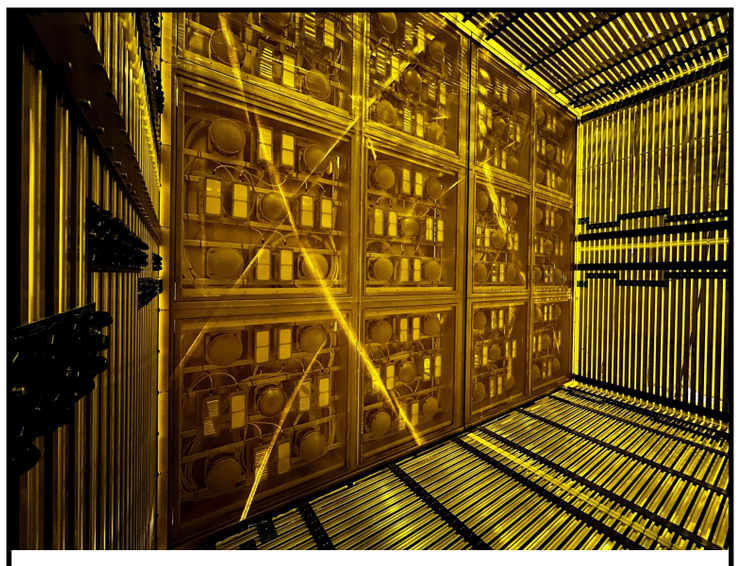




- SBND is a **LArTPC** detector combined with a **unique photon detection system**

  - Event imaging
  - Fine granularity calorimetry and particle identification
  - Good timing resolution
  - Low energy threshold





Inner view of one of the two SBND TPCs

SBND Collaboration

Argonne National Lab, USA
University of Bern, Switzerland
Brookhaven National Lab, USA
University of California, Santa Barbara, USA
University of Campinas, Brazil
CERN
University of Chicago, USA
CIEMAT, Spain
Colorado State University, USA
Columbia University, USA
University of Edinburgh, UK
Federal University of ABC, Brazil
Federal University of Alfenas, Brazil
Instituto Tecnológico de Aeronáutica, Brazil
Fermilab, USA
University of Florida, USA
University of Granada, Spain
Illinois Institute of Technology, USA
Imperial College London, UK
University of Kansas, USA
Lancaster University, UK
University of Liverpool, UK
Los Alamos National Lab, USA
Louisiana State University, USA
University of Manchester, UK
University of Michigan, USA
University of Minnesota, USA
University of Oxford, UK
University of Pennsylvania, USA
Queen Mary University, UK
Rutger University, USA
University of Sheffield, UK
University of Sussex, UK
Syracuse University, USA
Texas A&M University, USA
University of Texas, Arlington, USA
Tufts University, USA
University College London, UK
Virginia Tech, USA
University of Warwick, UK

- Strong European contributions to detector construction, commissioning and data analysis.

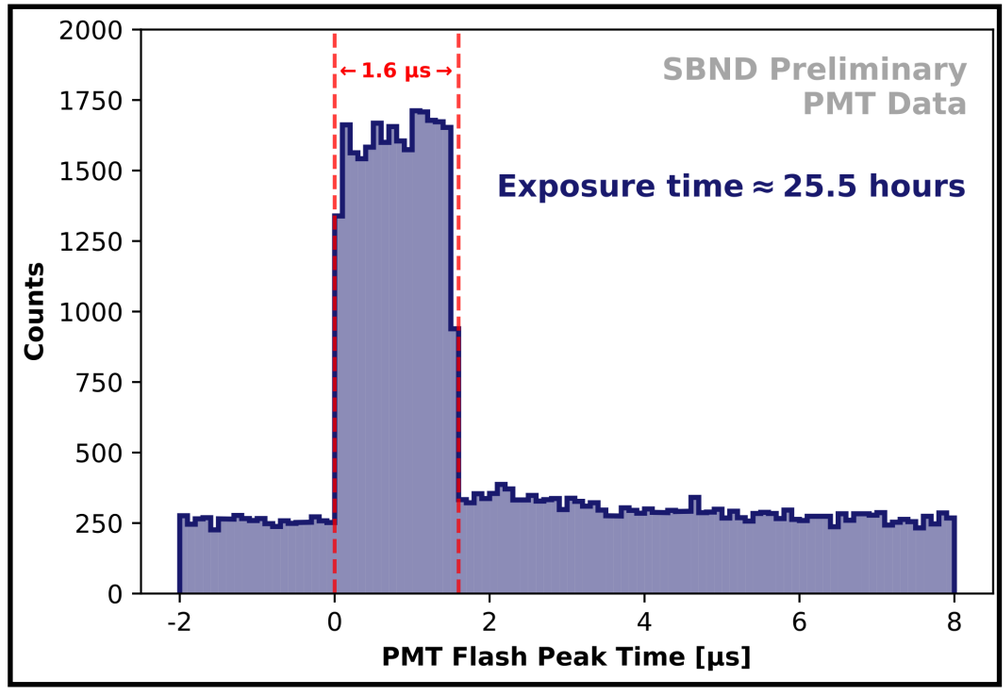
262 Total Collaborators

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

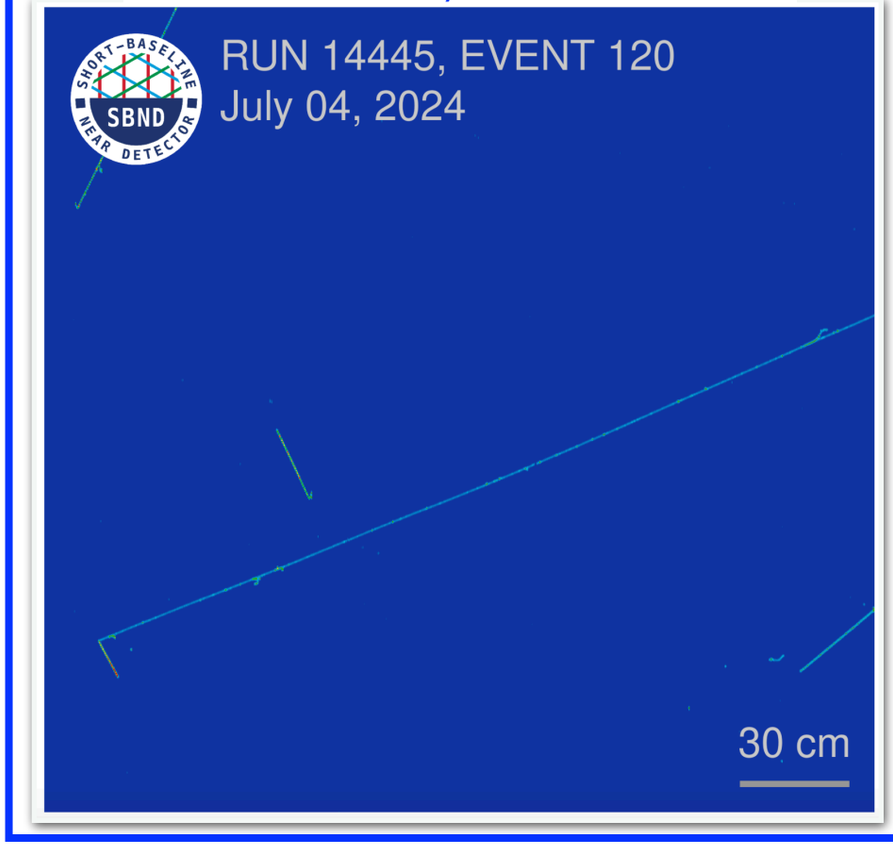
40 Institutions
4 Brazilian Universities
CERN
1 Spanish University, 1 National Laboratory
1 Swiss University
11 UK Universities
17 US Universities, 4 National Laboratories

SBND Status

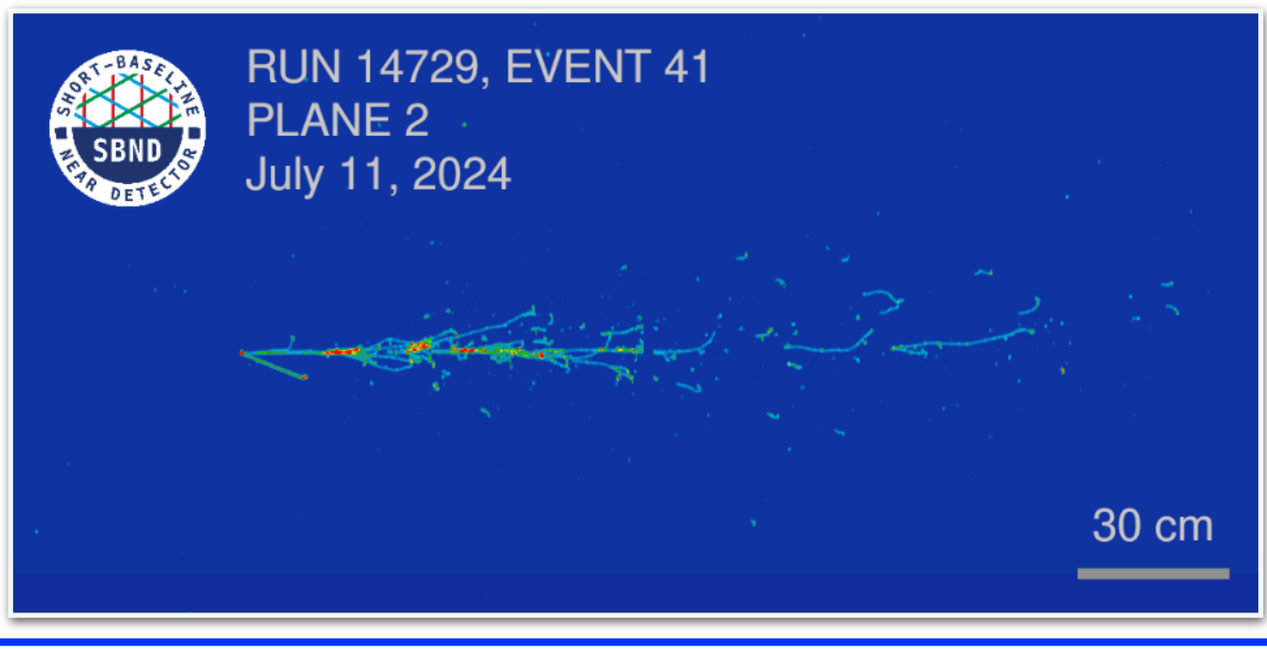
- After ~10 years of design, construction & installation, the detector is currently operating and collecting BNB data since Dec 2024.
- Already accumulated **~ 0.5 million** neutrino interactions events!
- By summer 2025, expected to accumulate **1.5-2 millions ν_μ- and 12-15 thousands ν_e -argon scattering events!**



SBND Data: ν_μ CC Candiate



SBND Data: ν_e CC Candiate



SBN(D) in the USA and European Particle Physics Strategy

2014 P5 Report

Recommended a world-leading short-baseline experimental neutrino program at Fermilab with strong participation by the domestic and international neutrino physics communities working toward LBNF [DUNE] using liquid argon detectors.

2023 P5 Report

Highlighted how the short-baseline neutrino anomalies will be conclusively tested by the current SBN program at Fermilab. It also acknowledged the crucial role **in maturing the LAr technology and analysis, and measuring neutrino-Ar interactions**

Physics Briefing Book Input for the ESPPU 2020

Mentioned **SBND and ICARUS unique position to fully address the short-baseline neutrino anomalies.**

ESPPU 2020 Recommendation

Stated that Europe, and CERN should continue to collaborate with the US towards the successful implementation of the Long-Baseline Neutrino Facility (LBNF) and the Deep Underground Neutrino Experiment (DUNE).

ESPPU 2026

We are submitting a SBND White Paper, to get continuous support for the operations & analysis phase as well as in planning and execution future prospects of the experiment.

SBND White Paper as Contribution to ESPP 2026

The Short-Baseline Near Detector White Paper

Contribution to the European Strategy for Particle Physics 2026

Contents

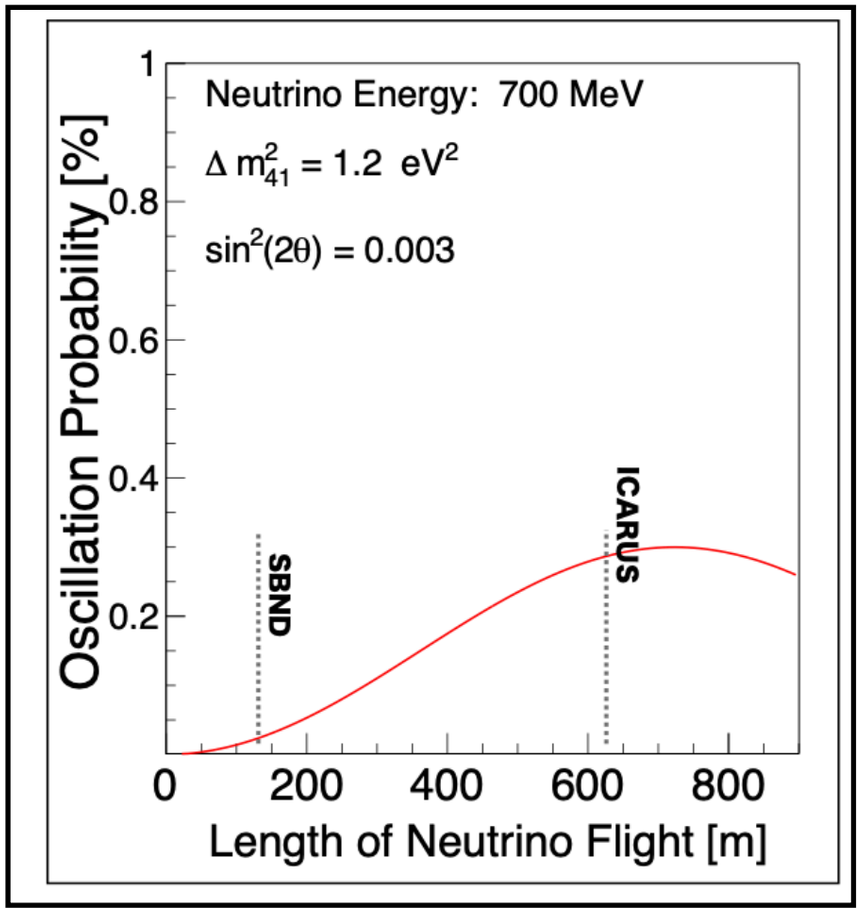
- White paper in preparation, planning to submit to ESPP by March 31 deadline. Planning to also upload on arXiv.

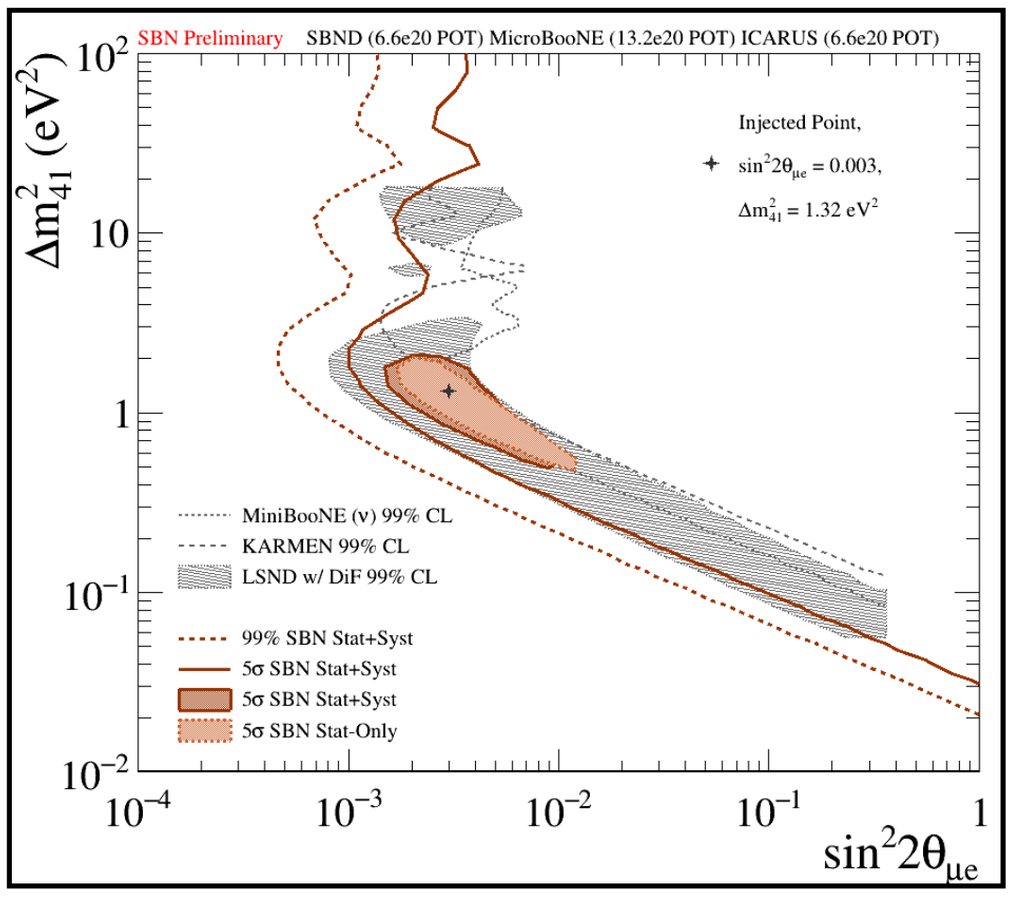
Sec 3: Physics Goals and Capabilities

■ Sec 3.1: Search for eV Scale Sterile Neutrinos as part of the SBN program

- SBN program is fully online now, and poised to tests the sterile neutrino hypothesis by covering the parameter regions allowed by past anomalies at 5σ significance.
- Complementary searches for ν_μ disappearance, ν_e appearance, ν_e disappearance, and flavor-inclusive NC disappearance.

■ As the Near Detector in the SBN Program, SBND plays a key role in mitigating large neutrino flux and cross section uncertainties since its positioned before the oscillations turns on at eV-scale.





Sec 3: Physics Goals and Capabilities

■ 3.2 Precision Measurements of Neutrino-Argon Scattering Cross Sections

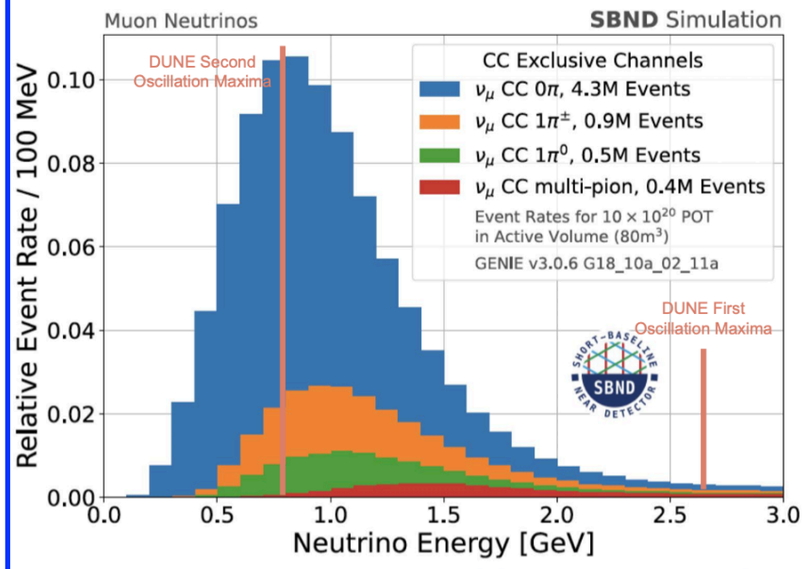
- With SBND running, the high-statistics and high-precision era in neutrino-argon cross section physics has started!
  - Already collecting **7,000 total neutrino interactions events per day**

- SBND will record ~20–30x more neutrino–argon interactions than is currently available

- SBND has a significant phase space overlap with DUNE → SBND measurements can be used to constrain some of the same physics DUNE needs to know

$\nu_\mu - {}^{40}Ar$

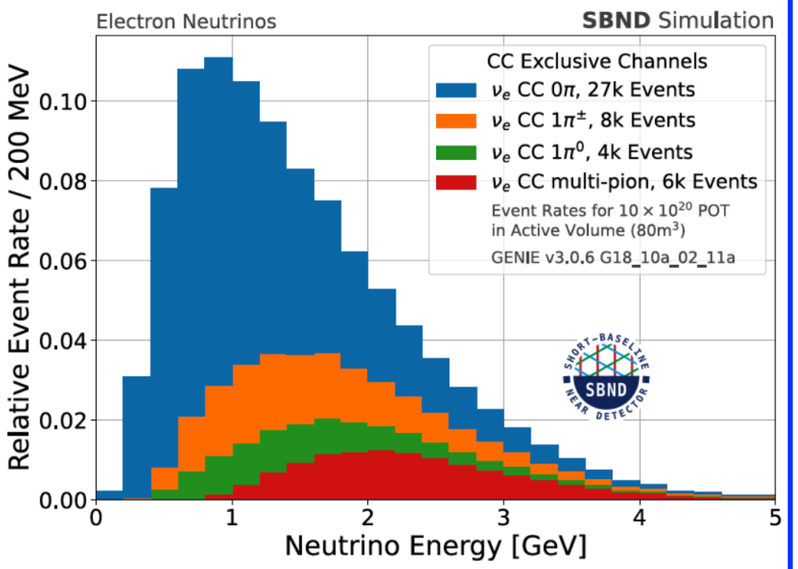
2M ν_μ CC events in 1 year



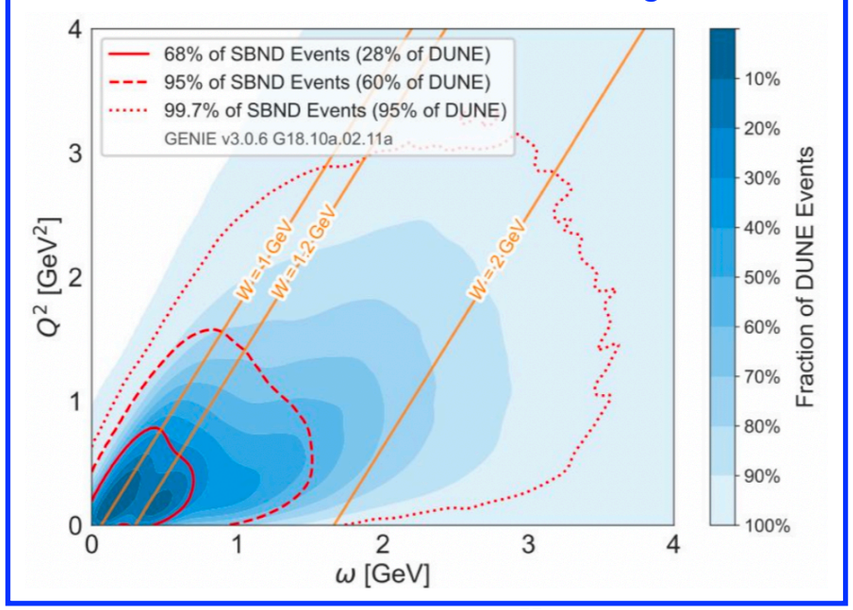
50,000 ν_μ CC events above 2 GeV

$\nu_e - {}^{40}Ar$

15k ν_e CC events in 1 year

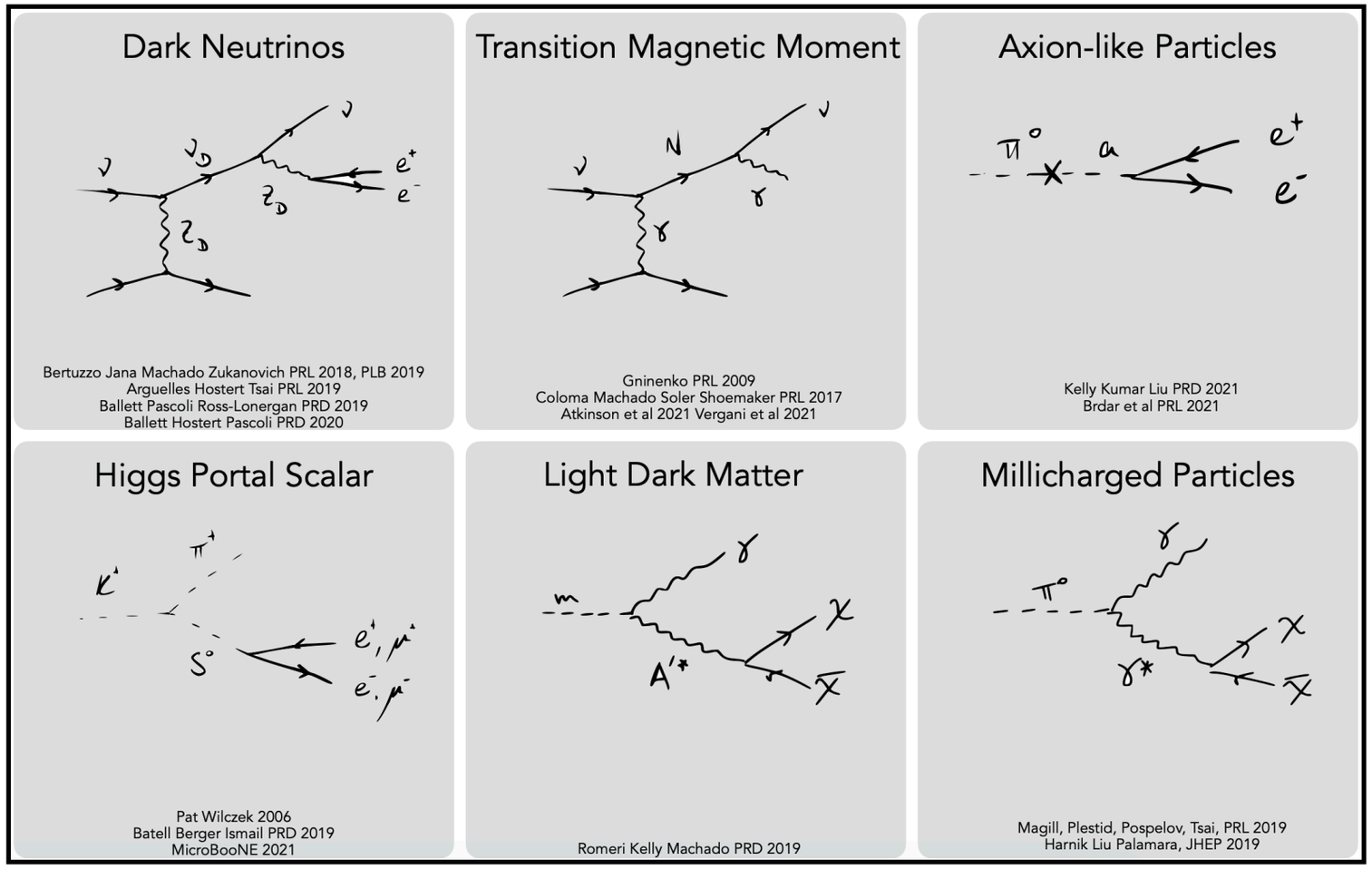


SBND kinematics coverage overlaid on the DUNE kinematics coverage



■ 3.3 Other Searches for Beyond the Standard Model Physics

- SBND's large detector mass (~100 ton), proximity to the beam target (~100 m), and high-performance detector design enables exploring many new physics scenarios in meson decays and proton-fixed target interactions.
  - Leverage LArTPC capabilities and SBND's ns-timing resolution.
  - Study alternative explanation of the short-baseline anomalies as well as other BSM scenarios.
  - Strong collaboration with theory community and many on-going model-specific and model-independent sensitivity studies and searches.



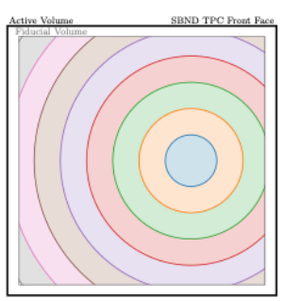
- *A non-exhaustive list of BSM new physics that could be produced in the BNB and can be detected in SBND.*

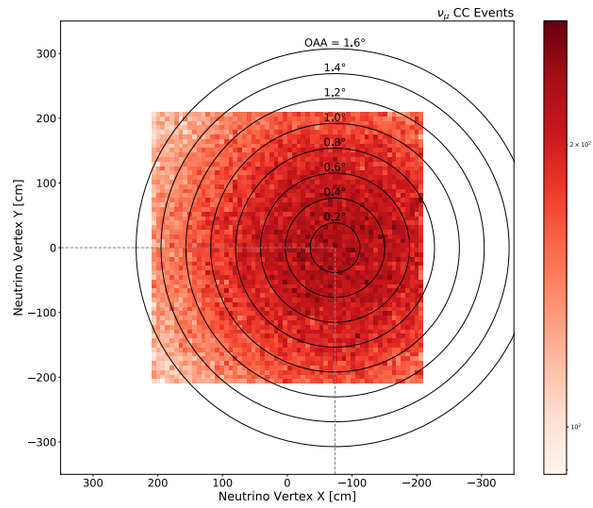
Sec 4: Features of the Beam and Detector

■ 4.1 BNB and SBND-PRISM Concept

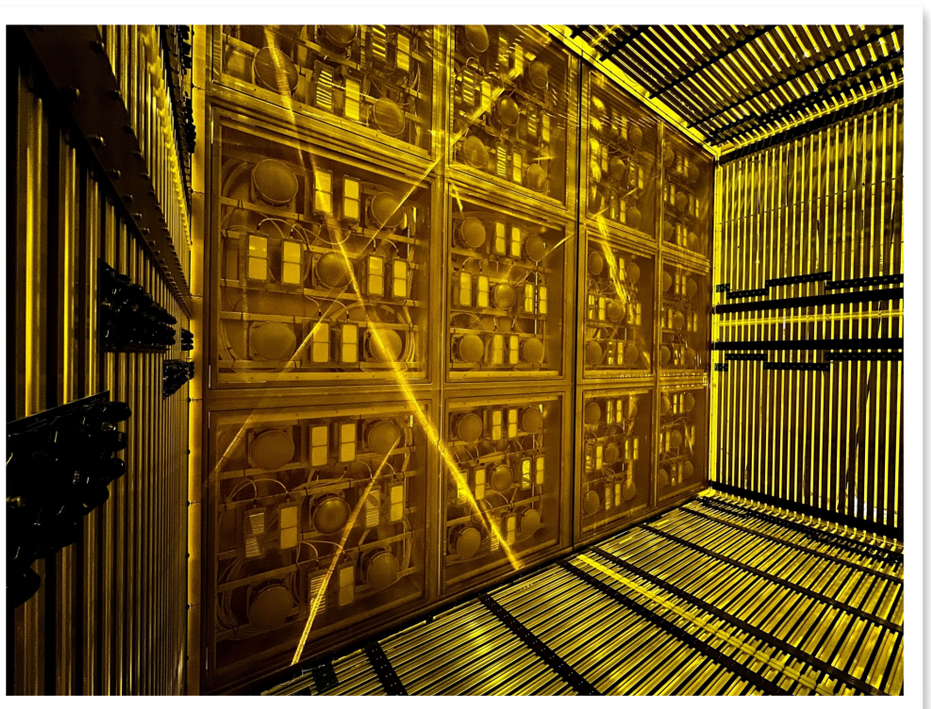
- SBND is close (110 m) to the neutrino source and is positioned offset relative to beam center that allows sampling multiple neutrino fluxes in the detector - enabling SBND-PRISM feature.

- SBND-PRISM provides unique constraints of systematic uncertainties, helps mitigate backgrounds, and expands the SBN(D) physics potentials





Similar to the nu-PRISM and DUNE-PRISM concepts, but with a fixed detector.



■ 4.2 Advancing LArTPC technology

- Two TPCs (2 m drift), similar design as DUNE FD-HD. 112 ton active mass.
- 3rd iteration towards the DUNE cryostats.
- Cold front-end TPC electronics prototypes toward final DUNE's design.
- X-ARAPUCA photodetector technology shared with DUNE. SBND will have the longest operation in liquid argon (2024 – 2027+).
- Development of data analysis pipelines for LArTPC experiments: reconstruction, calibration, systematics uncertainties as well as two LAr detector joint analysis.

■ Training next generation of LArTPC experts!

Sec 5. Current and Long-Term Operations Plans

■ 5.1 Current/Approved Operations Plans (2025 - 2027)

- Running until the Fermilab accelerator long-shutdown in ~ Fall 2027.
- Expected to collect or even exceed 10×10^{20} POT from BNB.

■ 5.2 Long-term Opportunities (after the long-shutdown ~2029+)

- **Continue to run in Neutrino Mode**
- **Run in Antineutrino Mode:**

  - Lack of antineutrino-argon scattering data.
  - It will be a significant input to DUNE's CP-violation measurement. Neutrino and anti-neutrino may behold different nuclear effects due to isospin asymmetric nature of the argon nucleus.
  - SBND can collect world's largest antineutrino-argon data in a few days.

- **Run in Beam-dump Mode:**

  - Option 1: Off-target mode (similar to MiniBooNE search), x50 reduction in neutrino rate
  - Option 2: Absorber at end of beam pipe, x1000 reduction in neutrino rate
  - Enhanced sensitive for many new physics scenarios: dark-matter, dark-photon, ALPs, …

Short-Baseline Near Detector (SBND)

- **Effort Name:** Short-Baseline Near Detector
- **Short abstract:** The Short-Baseline Near Detector (SBND) is a 112-ton active mass liquid argon time projection chamber (LArTPC) neutrino detector that sits only 110-m from the target of the Booster Neutrino Beam (BNB) at Fermilab. SBND is the near detector in the Short-Baseline Neutrino Program and has broad science goals as part of the SBN program and on its own addressing explanations of the short-baseline anomaly, beyond the Standard Model searches and precision studies of neutrino-argon interactions.
- **Contact information:** SBND Spokes: Ornella Palamara (palamara@fnal.gov)
  David Schmitz (dwschmitz@uchicago.edu)
- **Useful links:** https://sbn-nd.fnal.gov/index.html
- **White paper:** To appear on arXiv