Snowmass2021 - Letter of Interest

Precision Neutrino-Nucleus Interaction Physics and BSM Searches at the Short-Baseline Near Detector (SBND) at Fermilab

NF Topical Groups: (check all that apply ☐/■)

☐ (NF1) Neutrino oscillations
☐ (NF2) Sterile neutrinos
■ (NF3) Beyond the Standard Model
☐ (NF4) Neutrinos from natural sources
☐ (NF5) Neutrino properties
■ (NF6) Neutrino cross sections
☐ (NF7) Applications
☐ (TF11) Theory of neutrino physics
☐ (NF9) Artificial neutrino sources
☐ (NF10) Neutrino detectors
☐ (Other) *[Please specify frontier/topical group(s)]*

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On behalf of the SBND Collaboration[1]

Abstract: The Short-Baseline Neutrino (SBN) program at Fermilab, consisting of multiple Liquid Argon time projection chamber (LArTPC) neutrino detectors positioned along the Booster Neutrino Beam (BNB), presents an exciting opportunity in experimental neutrino physics [1;2]. The near detector, SBND (or the Short-Baseline Near Detector), will be a new 112 ton active mass LArTPC sited only 110 m from the neutrino production target. Beginning in 2022, SBND will record millions of neutrino charged-current and neutral-current interactions on argon, an ideal data set for understanding the challenging physics of neutrino-nucleus scattering at the GeV energy scale. Due to the large detector mass and location close to the target, the science of SBND also includes a rich program, now under active development, for using the detector and beam to search for signatures of New Physics scenarios, in addition to the light sterile neutrino framework.

[1] https://sbn-nd.fnal.gov/collaboration.html

In addition to searches for sterile neutrinos (see separate LOI on *Sensitive Tests for Sterile Neutrino Oscillations at the Short-Baseline Neutrino Program at Fermilab*), the Short-Baseline Near Detector (SBND) at Fermilab enables a broad science program of neutrino–argon interactions and searches for physics beyond the Standard Model (BSM).

SBND will provide an ideal venue to conduct precision studies of neutrino-nucleus interactions in the GeV energy range. The experiment will make the world's highest statistics cross section measurements on argon for inclusive and many exclusive ν-Ar scattering processes[2]. More than 2 million neutrino interactions will be collected per year (assuming 2.2×10^{20} protons on target), quickly reducing the statistical uncertainty to well below the percent level. The experiment was approved for a total exposure of at least 6.6×10^{20} protons on target in the FNAL Booster Neutrino Beam. In addition to the large number of ν_μ events, SBND will record around 12,000 ν_e events per year, enabling both inclusive and exclusive measurements of electron neutrino interactions as well. To place the SBND measurements into context of other liquid argon detectors, each year of exposure of SBND will provide an event sample six to seven times larger than the one available in the full MicroBooNE phase I run. Understanding neutrino-nucleus interactions is critical to the success of neutrino oscillation experiments, including the SBN sterile neutrino oscillation program and the DUNE long-baseline program, both on argon targets, and the SBND data set will be the best there is for this purpose prior to DUNE.

The liquid argon TPC technology (LArTPC), with its excellent particle identification and fine-sampling calorimetry, and SBND's large mass (112 tons) and proximity to a high intensity beam (110 m) further present opportunities for sensitive searches for new weakly-coupled physics. Many possible searches for signatures of BSM physics, from non-standard interactions to large extra dimensions to light dark matter candidates[2], are now being actively studied by the SBND collaboration, working closely with members of the theory community. In some cases, the New Physics resides in the neutrino sector itself (e.g. effects of BSM physics on neutrino oscillation), in other cases the LArTPC technology is used to search for New Physics outside the neutrino sector. The proximity to the beam target makes the SBND detector well suited for the exploration of new states that can be produced in the beam target and decay or interact inside the detector (light dark matter, heavy sterile neutrinos, dark neutrinos, millicharged particles, etc.).

Great progress has been made in the design and construction of the SBND detector since the experiment's approval in 2015. The detector components have all been completed by an international team of institutions and delivered to Fermilab where the TPC is now being assembled. Operation is scheduled to begin in early 2022, so data collection and production of physics results will reach its peak during the next 10 year period. SBND has a diverse and exciting science program and will also be an excellent training ground for an international community of physicists, especially its junior members. The physics outputs of SBND, in particular the broad program of neutrino-argon interaction measurements, will have direct application for controlling systematic uncertainties in the future long-baseline neutrino oscillation experimental program at DUNE. A range of exciting theories of New Physics in the neutrino sector and beyond will also be tested with SBND data.

References

[1] LAr1-ND, ICARUS-WA104, MicroBooNE Collaboration, M. Antonello *et al.*, "A Proposal for a Three Detector Short-Baseline Neutrino Oscillation Program in the Fermilab Booster Neutrino Beam," arXiv:1503.01520 [physics.ins-det].

[2] P. A. Machado, O. Palamara, and D. W. Schmitz, "The Short-Baseline Neutrino Program at Fermilab," *Ann. Rev. Nucl. Part. Sci.*, vol. 69, pp. 363–387, arXiv:1903.04608 [hep-ex].