PROCEEDINGS OF SCIENCE

The Short Baseline Neutrino Program at Fermilab

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The Short-Baseline Neutrino (SBN) program at Fermilab is a short-baseline neutrino experiment with the main goal of performing definitive search for neutrino oscillations in the 1 eV^2 mass-splitting scale. The SBN consists of three liquid argon time projection chamber (LAr-TPC) detectors, the Short-Baseline Near Detector (SBND), MicroBooster Neutrino Experiment (MicroBooNE), and Imaging Cosmic And Rare Underground Signals (ICARUS), situated in the Booster Neutrino Beam-line (BNB). In addition to its main physics goal, having three LAr-TPC detectors in the neutrino beam-line, SBN will also perform precise measurements on neutrino-argon interactions. Moreover, the experience of constructing and running LAr-TPC detectors together with the ongoing R&D activities in the SBN program will help to realize the next generation long-baseline neutrino oscillation experiment DUNE. This paper discusses the physics potentials of the program, its current status and ongoing activities.

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1. SBN Program at Fermilab

In the last two decades, measurements from neutrino oscillation experiments have proved mixing and oscillation among three active flavors [1, 2]. However, electron like excess from the LSND [3] and the MiniBooNE experiments [4], together with $\bar{\nu}_e$ disappearance from the nuclear reactors and radioactive sources [5] can not be explained with the standard three flavor oscillations and require the existence of sterile neutrino with a mass range of 1 eV.

The Fermilab Short-Baseline Neutrino program (SBN) [6] was designed to provide a definitive answer as to whether the short-baseline anomalies can be associated with high Δm^2 sterile neutrino oscillations. SBN is a three detector setup with a new near detector, SBND, MicroBooNE and a large far detector, ICARUS. These detectors will sit on-axis in the Booster Neutrino Beam (BNB), which has 0.7 GeV neutrino energy peak and well known 0.5 % ν_e contamination. As shown in the schematic view in Figure 1, SBND will be situated at 100 m from the BNB target, followed by MicroBooNE at 470 m and ICARUS be at 600 m.

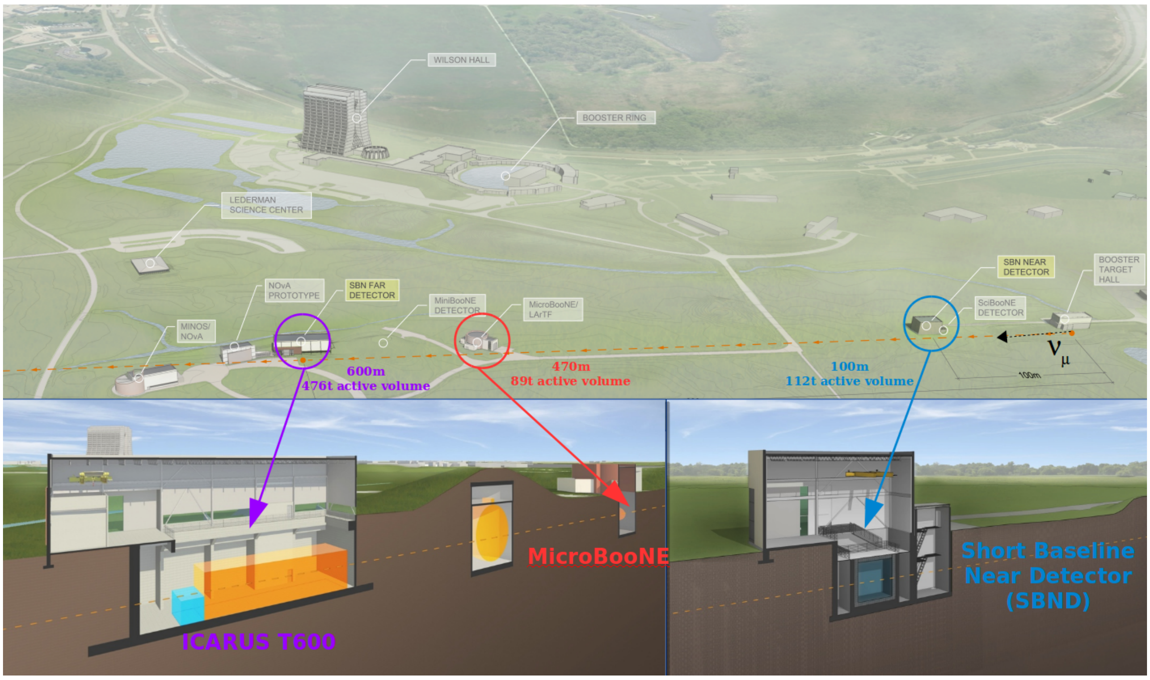

Figure 1: Schematic view of the SBN complex at Fermilab.

2. SBN Physics Program

The main physics goal of the SBN program is to search for sterile neutrinos and perform a definitive test for the MiniBooNE/LSND sterile neutrino oscillation interpretation. SBN has ability to address this question in both electron neutrino appearance and muon neutrino disappearance using the LAr-TPC technology [7]. LArTPC provides millimetric spatial resolution and precise measurement of calorimetric information, which helps to reduce neutral-current induced photon production background, which in turn is the dominant background for electron neutrino experiments. For the electron neutrino appearance, combining 3 experiments with 19.8×10^{20} protons on target(p.o.t) in total, SBN will cover 99 % of the LSND allowed region with more than 5σ significance. In the case of muon neutrino disappearance, SBN will extend the search by an order of magnitude beyond the combined analysis of SciBooNE and MiniBooNE [8]. Figure 2 shows the SBN sensitivities for both electron neutrino appearance and muon neutrino disappearance.

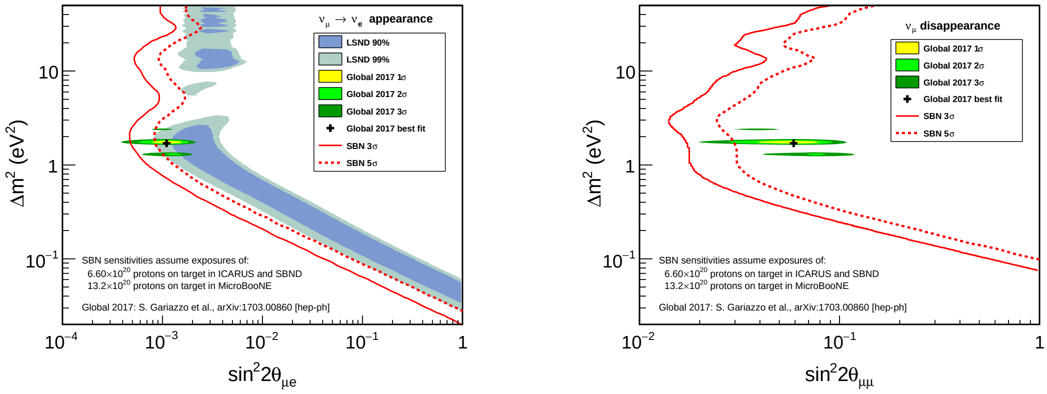

Figure 2: Sensitivities for electron neutrino appearance (left) and muon neutrino disappearance (right).

Precise measurement of ν-Ar nucleus cross-section is crucial for the correct interpretation of the experimental results, including sterile neutrino studies and the future liquid argon long-baseline physics goals. SBN provides an ideal venue to conduct precision cross section measurements in the sub-GeV and few GeV range. MicroBooNE has already collected more than 6.1×10^{20} p.o.t and data analysis is ongoing. SBND will collect more than 2 million neutrino interactions per year with 2.2×10^{20} p.o.t. 1.5 million of these will be muon neutrino charged current interactions along with 12,000 electron neutrino charged current, 250,000 neutral current and a few hundred elastic interactions. In addition to low energy BNB neutrinos, off-axis neutrinos from Main Injector, or NuMi [9], will provide cross section studies for the different energy regions. With its 476 tons of active volume, ICARUS is expected to detect 100,000 events per year originating from NuMi beam.

3. Status of the SBN Program

The first experiment that has been realized in the SBN program is MicroBooNE. Its main purpose is to address the MiniBooNE low energy access [4]. The detector installation was completed in 2014 and MicroBooNE has been collecting data since October 2015. Currently, data analysis for its main physics goal is ongoing and MicroBooNE is doing the groundwork for LAr-TPC calibration, simulation, reconstruction and analysis tool development for the future LAr-TPC neutrino experiments [10, 11, 12, 13, 14, 15, 16, 17].

The near detector in the SBN program will provide a detailed characterization of the beam before oscillation. In addition, since it will be located 100 m far from the neutrino source, SBND will collect a large neutrino data sample and allow us to study ν-argon interactions extensively. Besides its physics goals, LAr-TPC technology developed and used in this experiment will be an important step towards the future detectors for long-baseline neutrino experiment. The main component of SBND will be a Time Projection Chamber (TPC). The design of the TPC has been finalized and currently its components are under construction. Once the construction is finalized, it will be placed inside a membrane cryostat which will located in the new SBND building at Fermilab. The construction of the SBND building has been finalized and it can be seen in the picture of the right hand side of Figure 3.

The ICARUS experiment is going to be the far detector of the SBN program. ICARUS was operational at the Gran Sasso Underground Laboratory in Italy from 2010 to 2013, as the first large scale LAr-TPC. Then, it was shipped to CERN where it underwent upgrades for two years. After the upgrades, two TPC modules inside the cold vessels were shipped to Fermilab and safely arrived there on July 26, 2017. Meanwhile, as can be seen in the picture of the left hand side of Figure 3, the detector building at Fermilab has been finalized. Inside the building, a warm vessel installation, which will hold the cold vessels, has also been finalized and is waiting for the cold vessel installations. Commissioning of the ICARUS is expected to start in the second half of 2018.

Figure 3: The SBND(left) and ICARUS (right) buildings at Fermilab.

4. Conclusions

The SBN program, consisting of SBND, MicroBooNE and ICARUS experiments, will study the baseline dependence of the low energy excess in both neutrino appearance and disappearance modes. Having three LAr-TPC neutrino detectors in the BNB neutrino beam-line will also allow performing high precision measurements on ν-argon cross-section in addition to the development of LAr-TPC technology for future large neutrino experiments like DUNE. MicroBooNE experiment is currently collecting data, while SBND is making excellent progress in construction of the detector pieces and ICARUS is under installation at Fermilab.

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