FERMILAB-POSTER-26-0094-PPD

Progress toward Double-Differential Cross-Section Measurements of Single Charged-Pion Production in Charged Current Muon Neutrino Interactions on Argon with SBND

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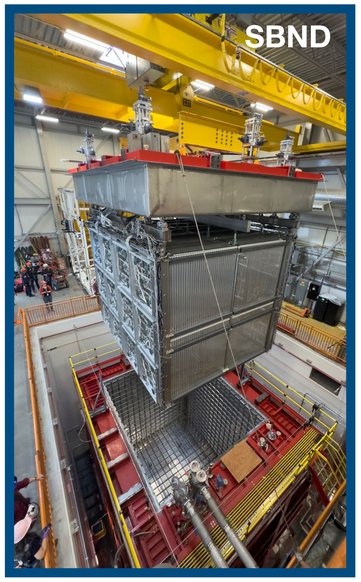
The Short-Baseline Near Detector

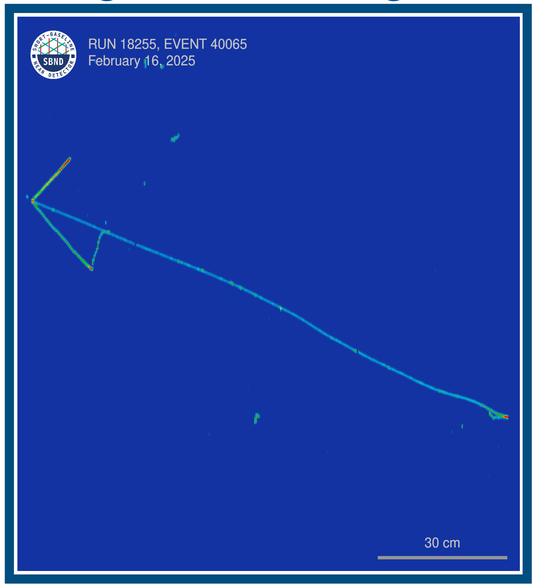
The **S**hort-**B**aseline **N**eutrino Program [1] (SBN) is a 2 detector experiment along the **B**ooster **N**eutrino **B**eam (BNB) designed to investigate the MiniBoone anomaly

The **S**hort-**B**aseline **N**ear **D**etector (SBND), taking data since 2024, is a 112 ton active volume **L**iquid **A**rgon **T**ime **P**rojection **C**hamber (LArTPC) located 110 m from the BNB target

SBND has a **broad physics program** and already **collected more than 7e20 POT,** which amounts to **~6 million neutrino** interactions



Charged Current Single Pion Production



SBND expects over 6.2 million neutrino events with **around 1 million Muon Neutrino Charged Current Single Pion** (ν_μ**CC1**π) events for 3 years of data taking

This will enable the first **double differential cross-section** measurement of this channel in Ar and a deep study of resonant processes

$$\nu_\mu \text{CC1}\pi = 1\mu^\pm + 1\pi^\pm + N_p p + N_n n$$

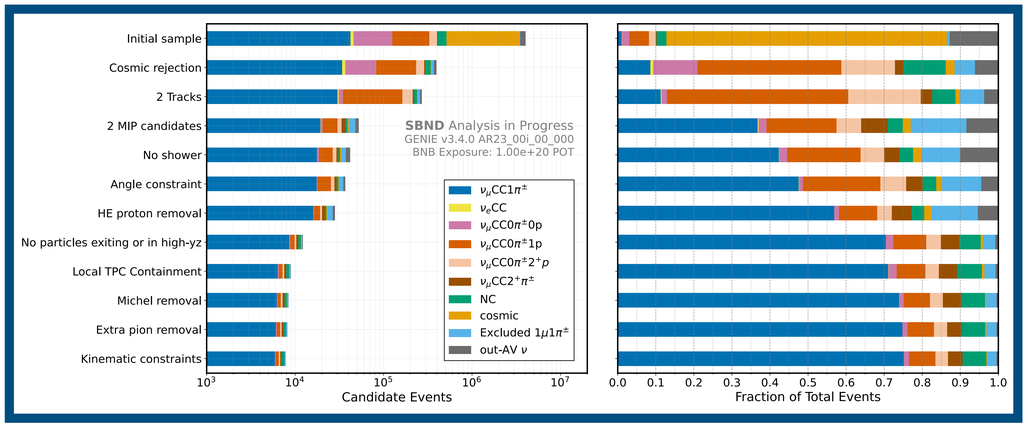
Event Selection: 1e20 POT (~3 Months of Data Taking)

We aim to select events with **two minimum ionising particle (MIP) candidates and no shower activity**, the most important steps are:

1. Cosmic removal
2. **Select 2 μ/π candidates**
3. Shower rejection
4. **High energy proton removal**
5. Michel removal
6. Containment and kinematic constraints
7. **BDT for μ/π separation**

~7800 expected events

75.2% Purity

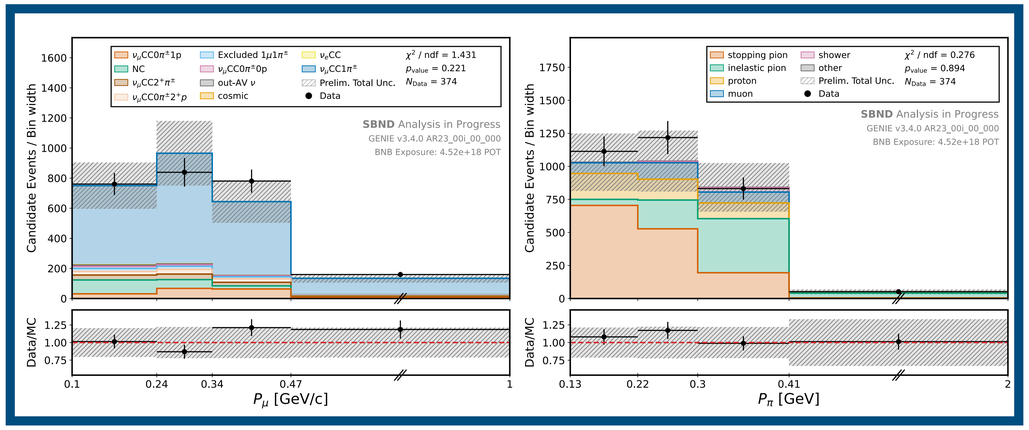


Open Sample Results (4.5e18 POT)

Selection **tested on SBND** development sample amounting to **4.5e18 POT**. **Preliminary systematics** are **included** which account for uncertainties on neutrino **cross-section, particle reinteraction**, **flux** and **detector effects**

374 selected events **in data**

354 ± 74 expected events

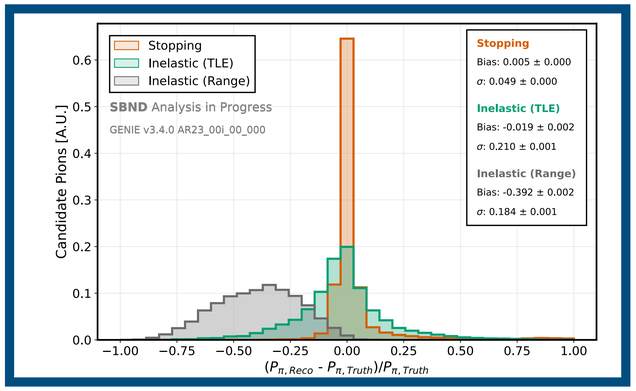


Pion Momentum Reconstruction

Pions reinteract, which makes their reconstruction **challenging** and **traditional** methods **insufficient**

This analysis marks the **first use** of the **T**rack **L**ength **E**xtension (**TLE**) method [2] in a physics measurement

Finds the most likely momentum by comparing individual energy depositions to different extended track assumptions



The method has been upgraded to include detector effects, helping it to reach **2% bias** and **21%** resolution, improving on previous estimators

The method shows **good Data/MC agreement** regardless of pion reinteraction

Summary and Outlook

- SBND has collected the biggest $\nu - Ar$ dataset to date with **more than 6 million neutrino events**
- We have developed an innovative event selection for ν_μ**CC1**π achieving **75.2%** purity and **~7800 events** for **1e20 POT**
- We are able to **reconstruct** the **pion momentum regardless of reinteractions**, due to the adoption of the Track Length Extension method
- Cross-section measurements will include muon and pion kinematics and number of protons, complete with systematics uncertainties

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[1] P. A. Machado *et al, The Short-Baseline Neutrino Program at Fermilab.* Annual Review of Nuclear and Particle Science 69, 363–387 (2019)
[2] Adam Abed Abud et al, The track-length extension fitting algorithm for energy measurement of interacting particles in liquid argon tpcs and its performance with protodune-sp data. *Journal of Instrumentation*, 20:P02021, 02 (2025).