Near Detector Selection for Neutral Current Disappearance Search at the Short-Baseline Neutrino Program

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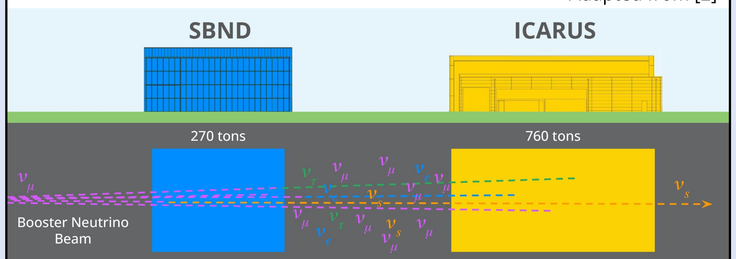
The Short-Baseline Neutrino Program

- The Short-Baseline Neutrino Program is a **multi-detector oscillation program** located at Fermilab with **world-leading sensitivity** to short-baseline neutrino oscillations [1]
- This neutral current disappearance search will use data from both **SBND and ICARUS**

Adapted from [2]



All **active** neutrino flavors interact via the neutral current interaction.

Neutral Current Disappearance

- The 3+1 model adds a single, stable, **sterile neutrino** with a mass of about 1 eV to the Standard Model [3]

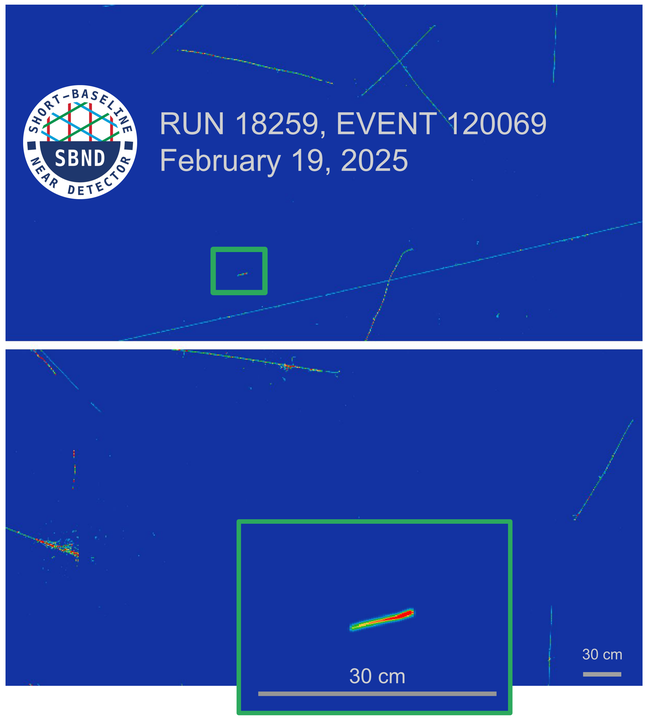
$$\begin{pmatrix}\nu_e\\ \nu_\mu\\ \nu_\tau\\ \nu_s\end{pmatrix} = \begin{pmatrix}U_{e1} & U_{e2} & U_{e3} & U_{e4}\\ U_{\mu1} & U_{\mu2} & U_{\mu3} & U_{\mu4}\\ U_{\tau1} & U_{\tau2} & U_{\tau3} & U_{\tau4}\\ U_{s1} & U_{s2} & U_{s3} & U_{s4}\end{pmatrix}\begin{pmatrix}\nu_1\\ \nu_2\\ \nu_3\\ \nu_4\end{pmatrix}$$

- Measuring **neutral current (NC) disappearance** provides unique insight and is **complementary** to charged current (CC) searches
- **CC oscillation searches** can measure how many ν_μ **disappeared** and ν_e **appeared** but ν_τ *are still unaccounted for* since ν_τ does not undergo the CC interaction at BNB energies

$$|U_{e4}|^2 + |U_{\mu4}|^2 + |U_{\tau4}|^2 + |U_{s4}|^2 = 1$$

- NC interactions are **equally sensitive to all 3 active neutrinos** [4]
  - Any change in NC interaction rate cannot be due to known flavor states
  - Disappearance in NC signal would indicate an unseen sterile flavor state in the beam

NC1p Topology

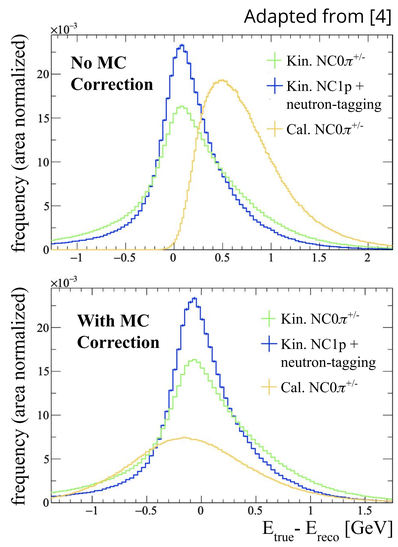


The NC1p topology is the **most common NC interaction type** at Booster Neutrino Beam energies, but is more challenging to identify than many CC final states:

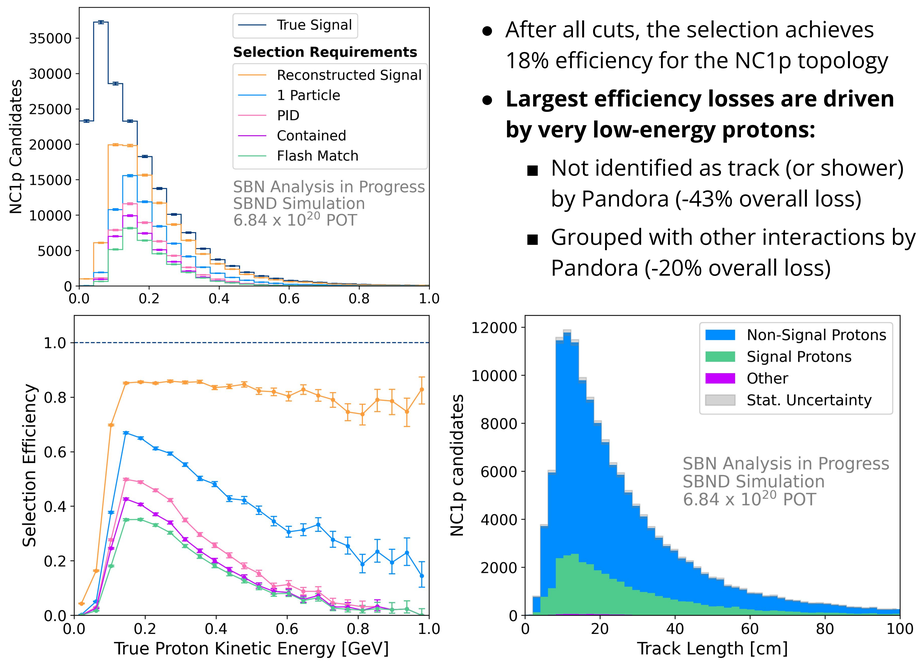
- Challenging neutrino-induced backgrounds
- No outgoing charged lepton:
  - Lower light yield
  - Identified only through the hadronic final state

This topology, however, benefits from a **dedicated neutrino energy estimator based on final-state hadronic kinematics**, which improves energy resolution and reduces bias compared to the **calorimetric method** for NC interactions. [4]

Adapted from [4]



Near Detector Selection

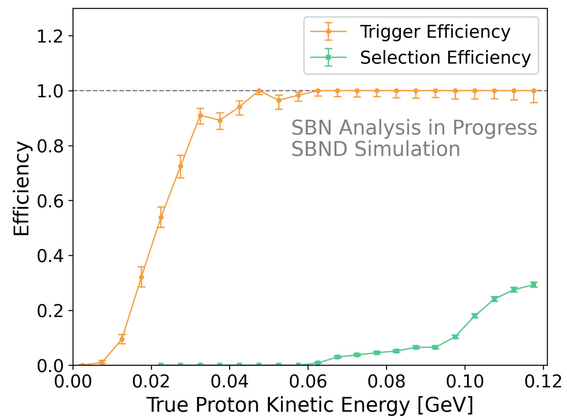


- After all cuts, the selection achieves 18% efficiency for the NC1p topology
- **Largest efficiency losses are driven by very low-energy protons:**
  - Not identified as track (or shower) by Pandora (-43% overall loss)
  - Grouped with other interactions by Pandora (-20% overall loss)
- Current selection is a **strong selection for single isolated protons from neutrino interactions:** 23% signal, but 99% protons and 96% from neutrino-induced interactions (including a mix of dirt, NC, and CC interactions)
- Future work will focus on **decreasing neutrino-induced backgrounds,** including using nanosecond timing resolution targeting dirt backgrounds

Trigger Efficiency

Low trigger thresholds and careful commissioning enable **approximately 100% trigger efficiency** for selected single protons:

- 91% trigger efficiency for 34 MeV protons (minimum kinetic energy passing current selection)
- 100% trigger efficiency for protons with ≥ 63 MeV kinetic energy (99.97% of selection)



References: **[1]** R. Acciarri, *et al.* (MicroBooNE and LAr1-ND and ICARUS-WA104 Collaborations), A Proposal for a Three Detector Short-Baseline Neutrino Oscillation Program in the Fermilab Booster Neutrino Beam, FERMILAB-LOI-2015-01 (2015). **[2]** B. Barbu, *Icarus gets ready to fly.* Fermilab News (2021). **[3]** P. A. N. Machado *et. al.*, The Short-Baseline Neutrino Program at Fermilab, Annu. Rev. Nucl. Part. S. 69 (2019). **[4]** A. Furmanski and C. Hilgenberg, Phys. Rev. D 103, 112011 (2021).

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