An Electron Neutrino Selection in the Short Baseline Near Detector (SBND)

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The Short Baseline Near Detector: SBND

- 112 t active volume Liquid Argon TPC (LArTPC)
- Powerful subsystems allow for excellent cosmic removal
- Closest of three LArTPCs in the Booster Neutrino Beam at Fermilab
- Critical role in constraining uncertainties for sterile neutrino search
- Rich cross section and BSM physics programmes
- Scheduled to come online in 2022
Liquid Argon Time Projection Chambers

Diagram demonstrating how a LArTPC works: arXiv:1503.01520

Diagram of the SBND LArTPC and it’s Photon Detection System
A simulated $\nu_e$ CC interaction in SBND
SBND Cross Section Measurements

- SBND has an extremely high event rate
  - Expect over 5.5 million events in 3 years
  - Over 4 million $\nu_\mu$ CC interactions
  - Over 30,000 $\nu_e$ CC interactions
- High granularity detector allows for precision measurements
- Possibility of many exclusive final state measurements

MINERvA Collaboration:
Phys. Rev. Lett. 116, 081802

MicroBooNE collaboration
arXiv:2101.04228
To meet SBND’s physics goals it is crucial to be able to select $\nu_e$ CC interactions.

As a surface level detector SBND has a huge cosmic background to reject:
- Intime cosmics: Cosmics that trigger the detector by entering during the beam spill
- Out-of-time cosmics: Cosmics overlaying on neutrino interactions

The Booster Neutrino Beam (BNB) has a low fraction of intrinsic $\nu_e$ (0.5%).

This makes the $\nu_e$ CC selection particularly challenging.

Many aspects of common selection between cross-section, oscillation and BSM physics programmes.

Define our signal as $\nu_e$ CC interactions within the fiducial volume where $E_{\text{Electron}}^{\text{True}} > 200\text{MeV}$.
SBND has almost $4\pi$ CRT coverage.
The majority of cosmics will induce a CRT hit.
The majority of $\nu_e$ CC interactions will not.
Veto events with a hit within the beam spill window.
Removes 74% of In-time cosmics and 5% $\nu_e$ CC.
Cosmic Removal: Nu Score Cut

- Pandora pattern recognition divides the event up into slices from a single origin:
  - Cosmic Rays
  - Neutrino Interactions
- 92% of cosmics as unambiguously cosmic (99.4% efficiency for $\nu_e$ CC)
- Use an Multi Variate Analysis (MVA) to classify how neutrino-like or cosmic-like remaining slices are based on event topology
- Conservative cut at a score of 0.4 removes 36% cosmics and 0.4% $\nu_e$ CC interactions

MVA Score representing how neutrino-like a slice is
Cosmic Removal: Flash Score Cut

Flash matching score representing agreement between a slice and the light during the beam spill

- SBND has a comprehensive Photon Detection System to collect scintillation light
- This provides timing information
- Very effective at removing out-of-time cosmics
- Removes 91% of cosmics and 1.4% $\nu_e$ CC
- Peak at -5 is for incompatible matched
Reject slices where there are no showers above 200 MeV

Removes 90% of backgrounds and 15% $\nu_e$ CC interactions

Reconstruction improvements will increase the efficiency in the future
Particle Identification

- I have recently developed Boosted Decision Trees (BDTs) that perform PID on tracks and showers
- Combine topological, calorimetric and hierarchical variables
- Extremely flexible to include into selection and analyses
- Enables future work to select exclusive final states

MVA Track PID Confusion Matrix

MVA Shower PID Confusion Matrix
Aim to remove any $\nu_\mu$ CC interactions by searching for muon-like tracks

Define the muon candidate as the longest track in the slice

Remove any slices where the candidate track has a muon-like score above 0.5

Removes 70% of $\nu_\mu$ CC interactions

Lose only 10% of $\nu_e$ CC
Shower Selection

- Aim to reject photon and mis-reconstructed tracks
- Define the electron candidate as the highest energy shower in the slice
- Remove any slices where the candidate shower has an electron-like score below 0.85
- Lose 40% of $\nu_e$ CC
- Reject over 93% of remaining backgrounds
All Cuts: Purity

- Reject over 99.9% of all backgrounds
- Integrated efficiency of 38%
- Backgrounds dominate at low energy
- Largest remaining background in $\nu$ NC interactions
Conclusions

- A full end-to-end $\nu_e$ CC selection has been performed
- Utilising the powerful subsystems we can reject 99.998% of cosmics
- Reject 99.9% (99.7%) of $\nu_\mu$ CC (NC) backgrounds
- Integrated efficiency of 38%
- Work to improve the reconstruction and selection is ongoing
- Next steps will propagate this selection through to cross section analyses
SBND Cross Section Measurements

Neutrino Energy [GeV]

CC Per 6.6E20 POT $e^\nu$ $e^\nu$ CC (34,658) $e^\nu$ NC (12,464) $e^\nu$ CC (34,658) $e^\nu$ NC (12,464)

SBND Preliminary MC

Neutrino Energy [GeV]

$\mu^\nu$ CC Per 6.6E20 POT $\mu^\nu$ $\mu^\nu$ CC (4,148,062) $\mu^\nu$ NC (1,622,443) $\mu^\nu$ CC (4,148,062) $\mu^\nu$ NC (1,622,443)

SBND Preliminary MC

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SBND $\nu_e$ Selection

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Lowest efficiency is at low lepton momentum (in particular when requiring a 200MeV shower)

Biggest efficiency loss is at Full selection (Track + Shower Cuts)