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

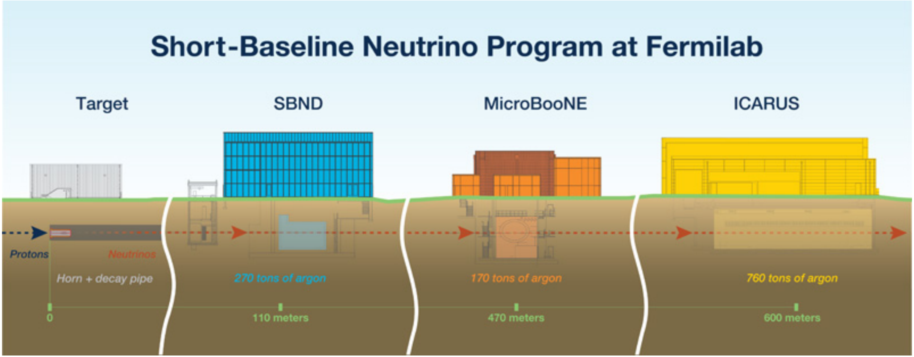
Edward Tyley

University of Sheffield

IOP 2021

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

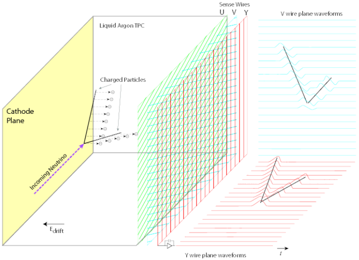


Diagram demonstrating how a LArTPC works: arXiv:1503.01520

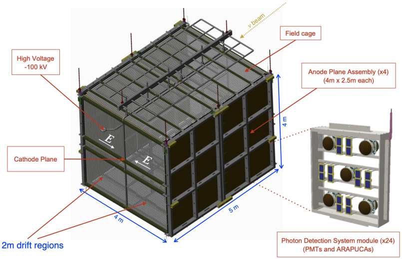
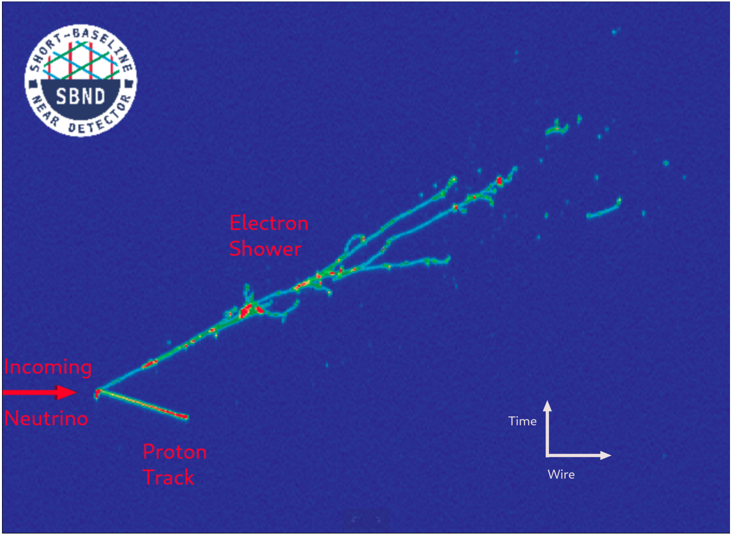


Diagram of the SBND LArTPC and it's Photon Detection System

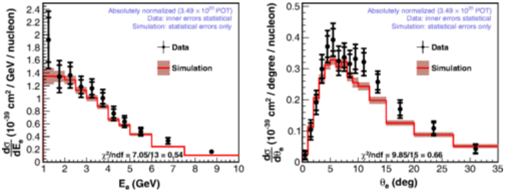
Liquid Argon Time Projection Chambers



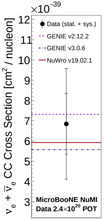
A simulated ν_e CC interaction in SBND

SBND Cross Section Measurements

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



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

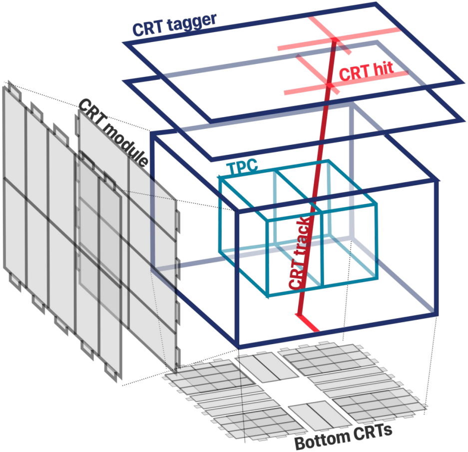


MicroBooNE collaboration
arXiv:2101.04228

Selection Introduction

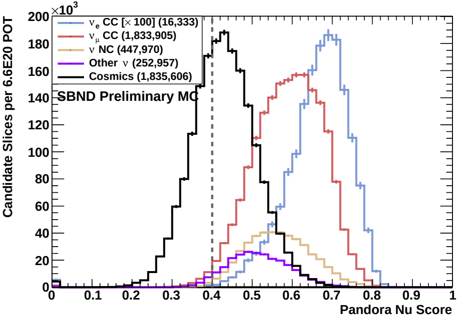
- To meet SBND's physics goals it is crucial to be able to select ν_e CC interactions
- As a surface level detector SBND has a huge cosmic background to reject
  - Intime cosmics: Cosmics that trigger the detector by entering during the beam spill
  - Out-of-time cosmics: Cosmics overlaying on neutrino interactions
- The Booster Neutrino Beam (BNB) has a low fraction of intrinsic ν_e (0.5%)
- This makes the ν_e CC selection particularly challenging
- Many aspects of common selection between cross-section, oscillation and BSM physics programmes
- Define our signal as ν_e CC interactions within the fiducial volume where $E_{Electron}^{True} > 200 MeV$

Cosmic Removal: Cosmic Ray Tagger (CRT) Hit Veto



- SBND has almost 4π CRT coverage
- The majority of cosmics will induce a CRT hit
- The majority of ν_e CC interactions will not
- Veto events with a hit within the beam spill window
- Removes 74% of In-time cosmics and 5% ν_e CC

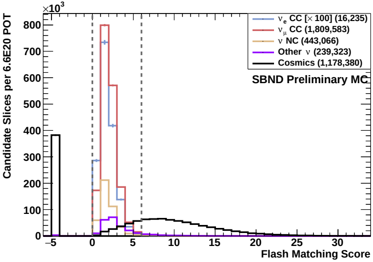
Cosmic Removal: Nu Score Cut



MVA Score representing how neutrino-like a slice is

- Pandora pattern recognition divides the event up into slices from a single origin:
  - Comsic Rays
  - Neutrino Interactions
- 92% of cosmics as unambiguously cosmic (99.4% efficiency for ν_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% ν_e CC interactions

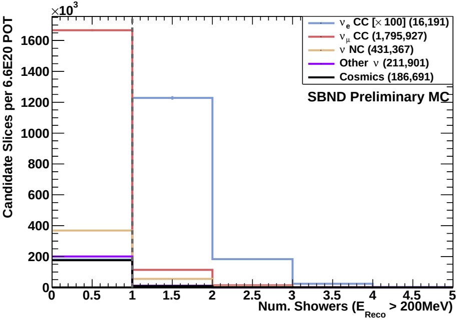
Cosmic Removal: Flash Score Cut



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% ν_e CC
- Peak at -5 is for incompatible matched

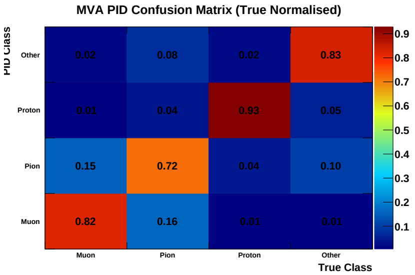
Reco Selection: Shower Energy Cut



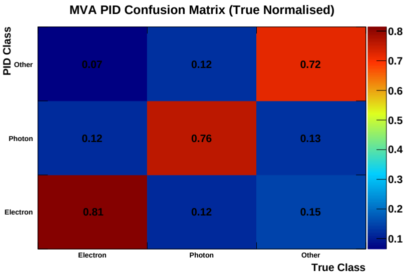
- Reject slices where there are no showers above 200 MeV
- Removes 90% of backgrounds and 15% ν_e CC interactions
- Reconstruction improvements will increase the efficiency in the future

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

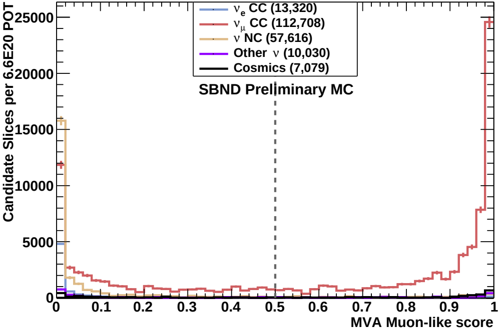


MVA Track PID Confusion Matrix



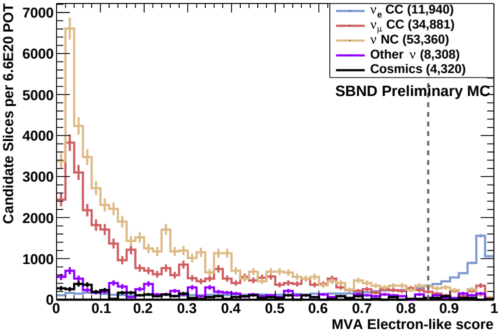
MVA Shower PID Confusion Matrix

Track Selection



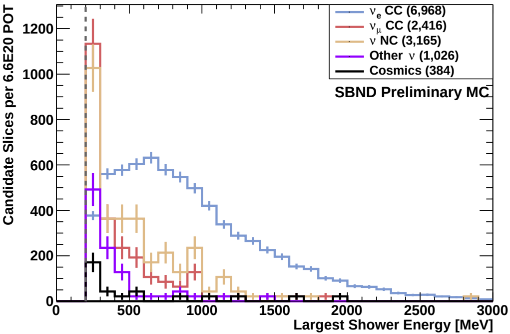
- Aim to remove any ν_μ CC interactions by searching for muon-like tracks
- Define the muon candidate as the longest track in the slice
- Remove any slices where the candidate track has a muon-like score above 0.5
- Removes 70% of ν_μ CC interactions
- Lose only 10% of ν_e CC

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 a electron-like score below 0.85
- Lose 40% of ν_e CC
- Reject over 93% of remaining backgrounds

All Cuts: Purity

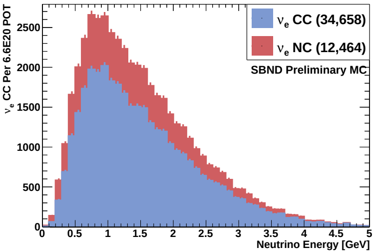


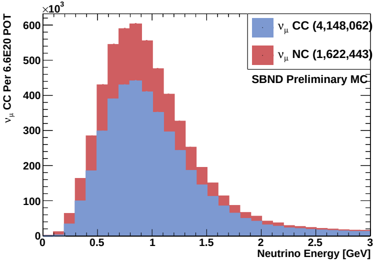
- Reject over 99.9% of all backgrounds
- Integrated efficiency of 38%
- Backgrounds dominate at low energy
- Largest remaining background in ν NC interactions

Conclusions

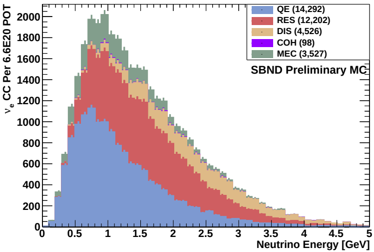
- A full end-to-end ν_e CC selection has been performed
- Utilising the powerful subsystems we can reject 99.998% of cosmics
- Reject 99.9% (99.7%) of ν_μ CC (NC) backgrounds
- Integrated efficiency of 38%
- Work to improve the reconstruction and selection is ongoing
- Next steps will propagate this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

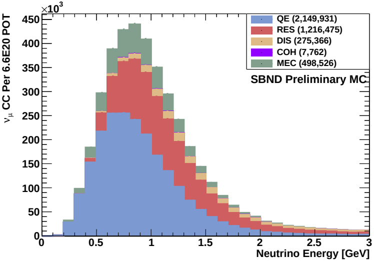
SBND Cross Section Measurements



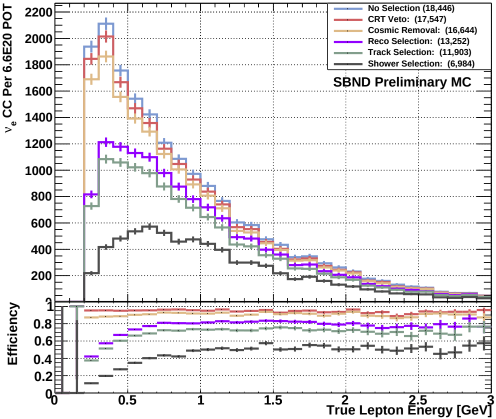


SBND Cross Section Measurements





All Cuts: Efficiency



- Lowest efficiency is at low lepton momentum (In particular when requiring a 200MeV shower)
- Biggest efficiency loss is at Full selection (Track + Shower Cuts)

SBND Cross Section Measurements