IOP Joint APP and HEPP 2019

Background removal for ν_μ CC selections in SBND

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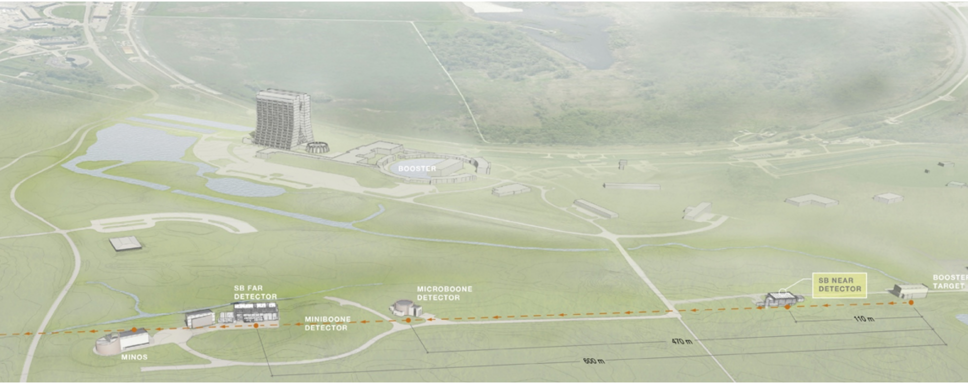
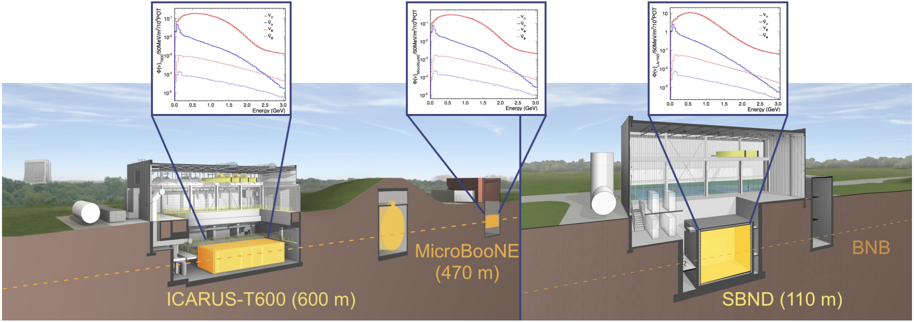


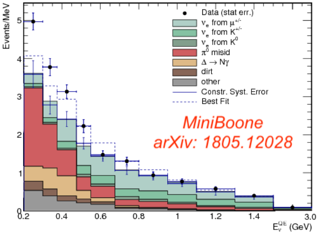
The Short-Baseline Near Detector

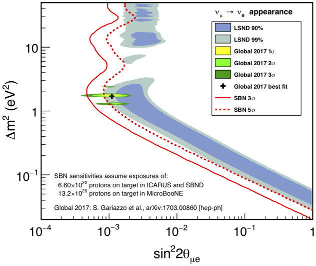
- The near detector of the Short-Baseline Neutrino (SBN) Program at Fermilab.
- A 112 ton liquid-argon time projection chamber (LArTPC) with two drift regions.
- In the Booster Neutrino Beam.
- Instrumented with cosmic ray tagger (CRT) and photon detection (PDS) systems to improve background removal and event selection.



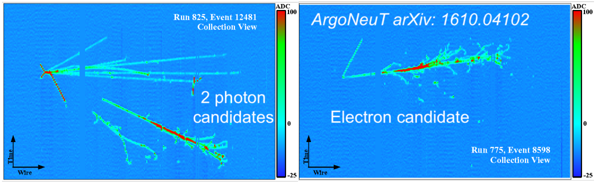
Physics program

SBN





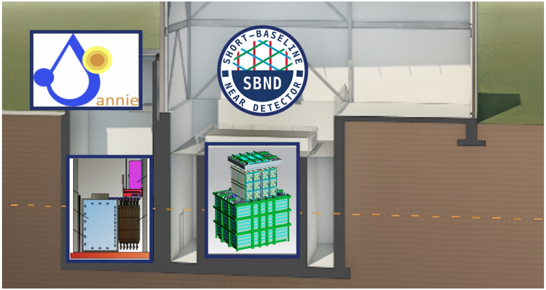
- Some experiments have observed an excess of low energy ν_e-like events.
- Possible explanation: short-baseline oscillations driven by an eV scale sterile neutrino.
- Tension with exclusion limits from other experiments.
- LArTPCs are able to distinguish between electron and photon showers.



Physics program

Cross sections

- Near detector $= \nu - Ar$ cross section measurements with highest statistics ever.
- Will reduce systematic uncertainties in DUNE and explore rare channels.
- Compare water and argon cross sections in the same beam with the annie detector.



Hadronic Final State	**GENIE (G17_01b) prediction for 6.6×10^{20} POT ($\approx$ 3 years)**
Charged Current	
ν_μ Inclusive	5,389,168
$\rightarrow 0\pi$	3,814,198
$\longrightarrow 0p$	27,269
$\longrightarrow 1p$	1,261,730
$\longrightarrow 2p$	1,075,803
$\longrightarrow \geq 3p$	1,449,394
$\rightarrow 1\pi^+ + X$	942,555
$\rightarrow 1\pi^- + X$	38,012
$\rightarrow 1\pi^0 + X$	406,555
$\rightarrow 2\pi + X$	145,336
$\rightarrow \geq 3\pi + X$	42,510
$\rightarrow K^+K^- + X$	521
$\rightarrow K^0\bar{K}^0 + X$	582
$\rightarrow \Sigma_c^{++} + X$	294
$\rightarrow \Sigma_c^{+} + X$	98
$\rightarrow \Lambda_c^{+} + X$	672
ν_e Inclusive	**$\approx$ 36,000**
Neutral Current	
ν_μ Inclusive	2,170,990
$\rightarrow 0\pi$	1,595,488
$\rightarrow 1\pi^\pm + X$	231,741
$\rightarrow \geqslant 2\pi^\pm + X$	343,760
$\rightarrow e(^-)$	374

The detector

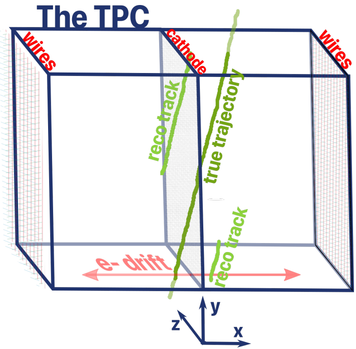
Status

- SBND is under construction.
- All TPC components are at Fermilab and are currently being assembled.
- Data taking will start in 2020, and we will see 7 million events in three years.
- Need to be ready to perform full analyses as soon as possible.

The detector

Principle of operation

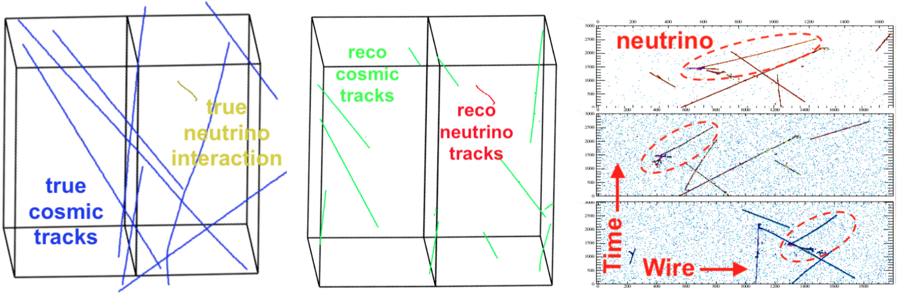
- Charged particles leave tracks of ionisation in the argon volume.
- Ionisation electrons are drifted in a strong electric field and collected on a series of wire planes.
- Readout is triggered by flashes in the PDS in time with the BNB.
- Three dimensional images can be reconstructed with excellent position resolution and calorimetry.



The detector

Cosmic backgrounds

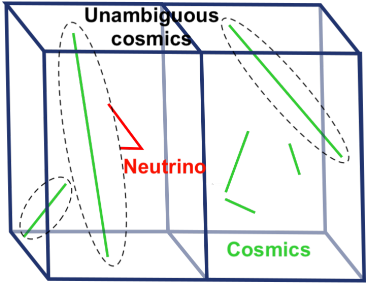
- SBND is located near the surface with a small overburden so there will be a high flux of muons from cosmic rays.
- These muons can be a significant background because the electron drift velocity is low.
- We expect ≈ 10 cosmic muons per readout window.
- If a particle crosses the detector before or after the trigger time (t_0) the TPC reconstructed X-position will be shifted.

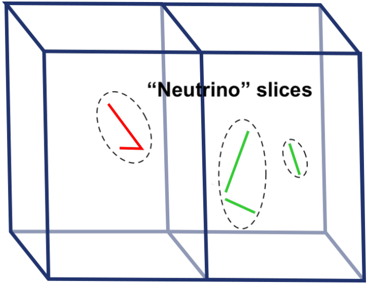


Reconstruction

Time projection chamber - Pandora

- The Pandora multi algorithm pattern recognition software is used to reconstruct tracks and showers from charge deposited in the TPC.
- Unambiguous cosmic ray muon tracks are removed.
- The remaining events are reconstructed as if they are neutrino interactions (a vertex is identified and a particle hierarchy is created).
- We are left with 3-4 cosmic muons per neutrino interaction in an event.

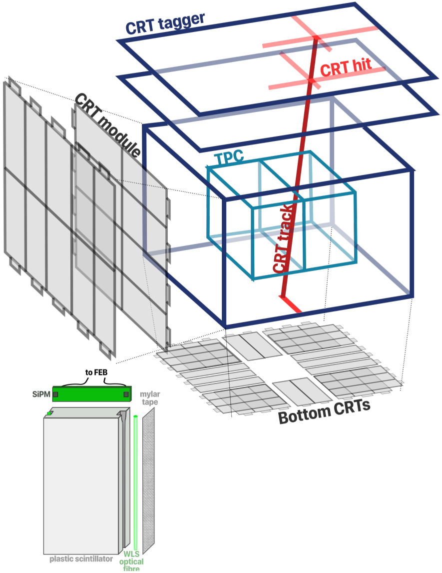




Reconstruction

Cosmic ray tagger

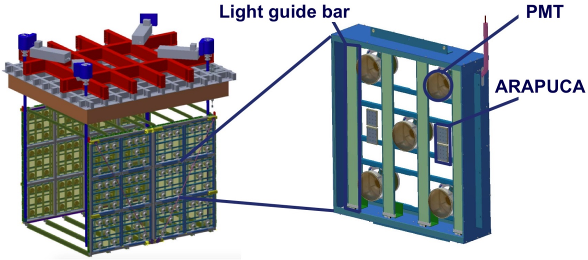
- SBND has seven cosmic ray taggers, one on each side and the bottom and two in a telescopic array on the top.
- We reconstruct particle-tagger intersections and times as CRT hits.
- We reconstruct the trajectory of through-going particles as CRT tracks.
- TPC reconstructed tracks can be matched with CRT hits and tracks to calculate their true times.



Reconstruction

Photon detector system

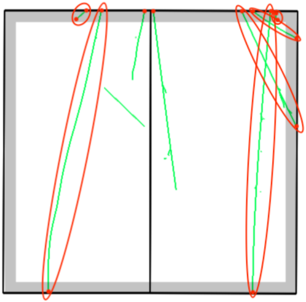
- There are 60 PMTs on each side of the detector.
- SBND will also have light guide bars, ARAPUCAs and reflector foils on the central cathode.
- The full simulation chain is still under development so some conservative assumptions about the reconstruction are made:
  - **Assumption 1:** The PDS can be used to get an unmatched list of times of particles crossing the detector.
  - **Assumption 2:** The drift region that the neutrino interaction occurred in can be determined due to the reflectors on the cathode.



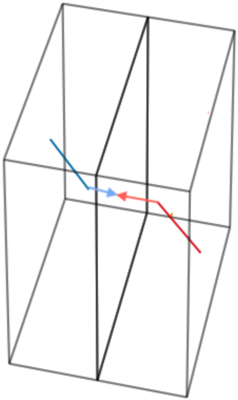
Cosmic ID

Selection cuts

- **Reconstructed position:** remove particles reconstructed outside of volume allowed by wires and PDS.
- **Fiducial volume:** remove particles which start and end outside of 10 cm from all walls.



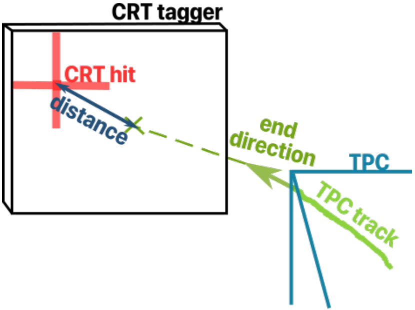
- **Cathode crossing:** tag the times of tracks by matching across the cathode.

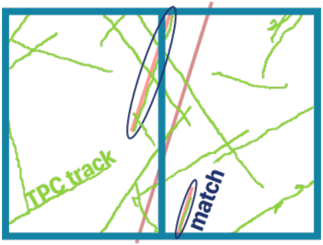


Cosmic ID

Selection cuts

- **Stopping particle:** use calorimetry to remove particles which enter the TPC and stop.
- **CRT hit matching:** project TPC tracks on to CRTs to match times.
- **Wire crossing:** use the PDS times to match particles which cross the wire planes.
- **CRT track matching:** match angle and position of TPC and CRT tracks.



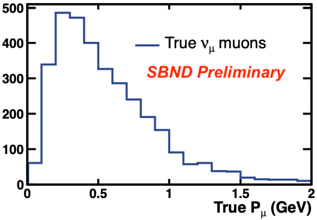


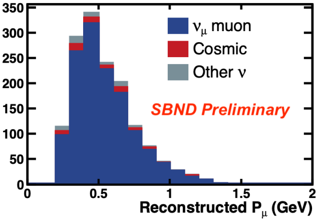
ν_μ selection

Performance

- Performance evaluated with a sample of 5,000 BNB neutrino events with a cosmic overlay.
- Apply simple ν_μ selection criteria:
  - Vertex inside stricter fiducial volume (80 cm from back, 15 cm from all other walls), contained tracks longer than 50 cm, exiting tracks longer than 100 cm, longest track is muon candidate.

Stage	ν_μ	Cosmics	Other ν
Pandora	2,865	9,216	547
Cosmic ID	2,429	218	447
Selection	1,388	68	32





Conclusions and next steps

- It has been demonstrated that (almost) the entire reconstruction chain is operational.
- We can remove the majority of cosmic backgrounds to charged current ν_μ interactions using the TPC, CRT and conservative PDS assumptions.
- The analysis is in the early stages and there are still some improvements in the neutrino reconstruction to be made.
- **Next steps:**
  - Tune the reconstruction to improve muon tracking efficiency.
  - Develop a more sophisticated selection measurement.

Thanks for listening!