Studies for the selection of fully contained ν_μCC events in the ICARUS T600 detector at Fermilab

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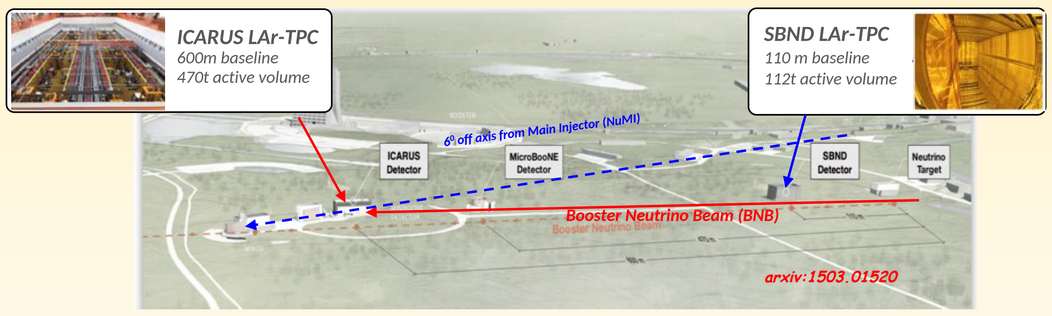
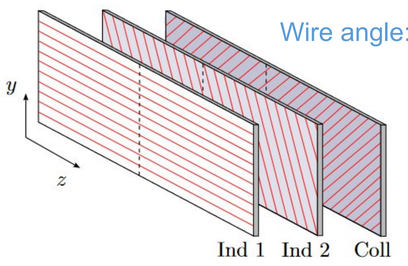
Short-Baseline Neutrino

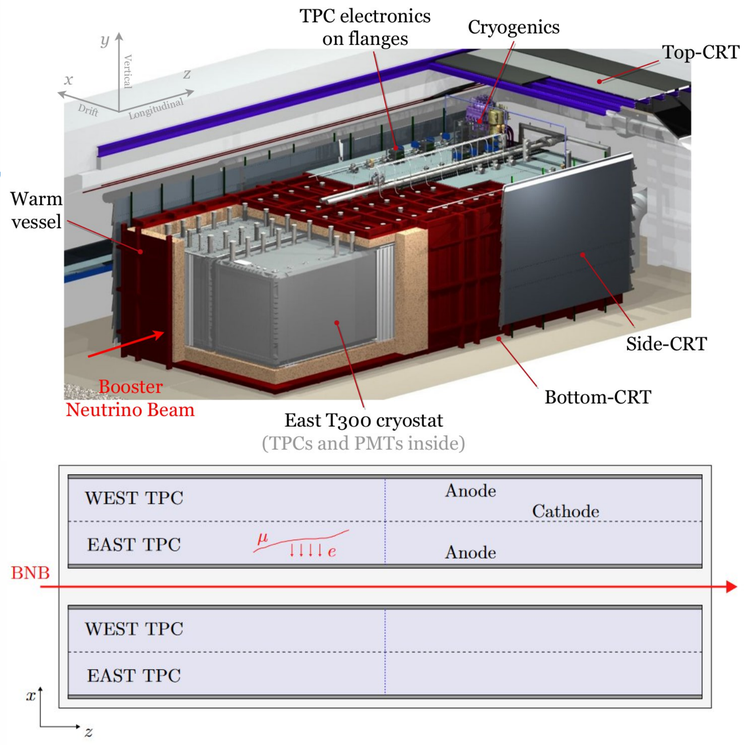


- The SBN Program includes two detectors exposed to the Booster Neutrino Beam: SBND and ICARUS, and they are all based on very similar Liquid Argon Time Projection Chamber (LArTPC) technology. Its main goal is to investigate the possible existence of 1 eV mass scale ***sterile neutrinos***.
- The ICARUS T600 detector is the first large scale LArTPC ever realized and actively taking data. It allows to perform a three-dimensional and calorimetric reconstruction of ***particle trajectories*** in ultra-pure liquid Argon active volume. ICARUS data taking for physics within SBN started on June 9th 2022.

ICARUS T600

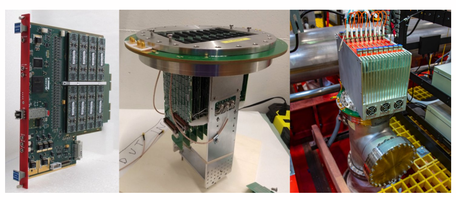
- 600 m from the beam source
- 476 tons of LAr as active volume
- Two identical (3.6 x 3.9 x 19.6 m³) modules, and each module houses two TPCs separated by a common cathode
- Three wire planes that read ionization charge in each TPC
- 360 PMTs for timing and trigger
- CRT systems to identify cosmic particles
- ~3m concrete overburden

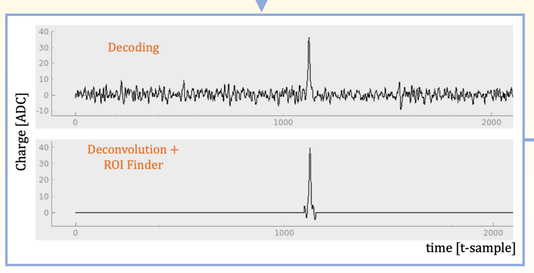




Event Reconstruction

Data Collected





Hit ID

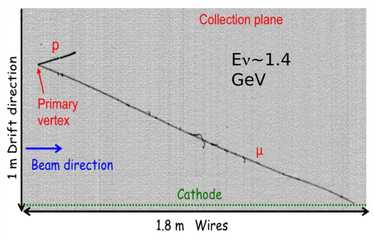
3D Reco

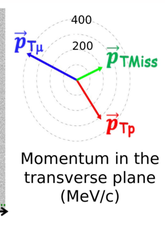
candidate 3D points from 2D hits on the planes

Pandora Pattern Recognition

identification of interactions (slices) and removal of clear cosmic particles

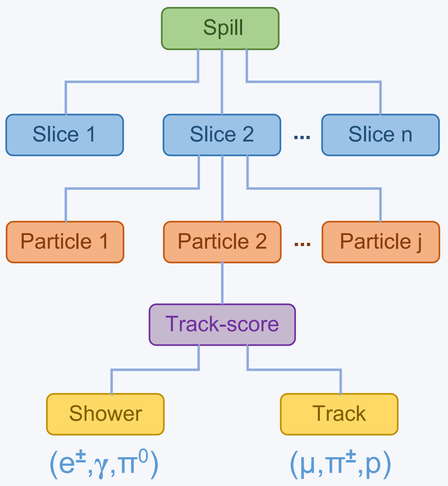
Analysis





- Reconstruction products are stored in Common Analysis Framework (CAF) files for high-level data analysis
- Events grouped in ***hierarchies***

Particle Interaction Hierarchy



Signal Definition

- **ν_μCC interaction** with vertex in Fiducial Volume
- 1 muon > 50cm at the vertex
- fully contained

Basic Selection

Selection based on a ***series of cuts*** on variables associated to the event by Pandora:

- SPILL -

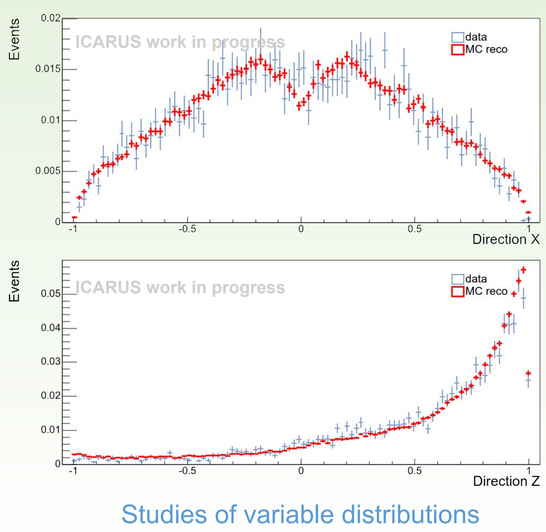
- No CRT signal in 1.6μs beam spill window

- SLICE -

- vertex in Fiducial Volume
- charge and light barycenters within 1m
- containment of all tracks (>5cm from edge)

- PARTICLE -

- muon identification based on dE/dx vs residual range along the track
- μ is primary particle and longest in slice
- length μ > 50cm



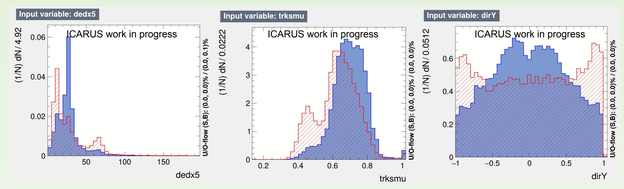
Studies of variable distributions

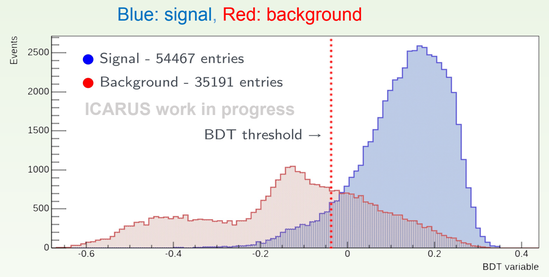
Boosted Decision Tree (BDT) Selection

Selection based on ***machine learning*** methods.

BDT training on Monte Carlo (MC) samples to discriminate signal from background using many variables, to name a few:

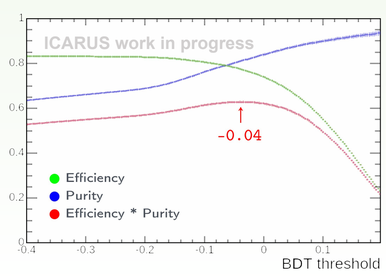
- muon track-score
- dist. vertex-μ_{start}
- muon length
- vertex Y coord
- muon end Y coord
- muon dir. along Y&Z
- energy deposited in the last 5-10-15-20 cm





Selection procedure:

- ***Pre-selection*** to identify potential ν_μCC candidates (similar to basic selection but with looser cuts)
- Use BDT generated ***weights*** to discriminate between signal and background



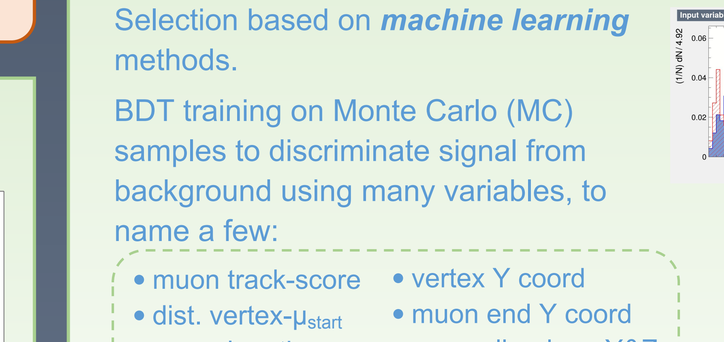
BDT threshold to maximize **eff * pur**

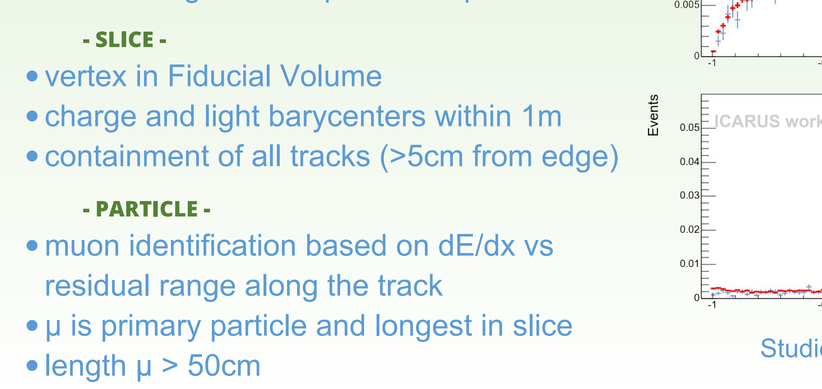
Selection Results

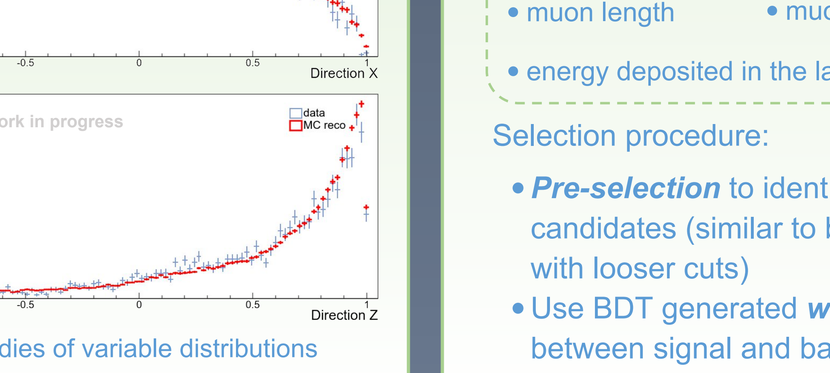
Basic Selection	BDT Selection
Efficiency = 75.7%	Efficiency = **76.6%**
Purity = 83.3%	Purity = **86.1%**

- BDT bonus: provide a ***stronger reduction*** (almost a factor of 2) of background associated to cosmics and to neutrino events with the primary vertex outside the active volume.

Comparison of the muon length in the events selected by the two procedures, considering both MC events and a reduced data statistics (corresponding to 1.9E19 proton on target)







Comparison of the selection efficiency of the two procedures as a function of different variables

What's Next?

- Validation of the selection procedures using a ***visual study*** of selected events.
- Study of the reconstructed ***neutrino energy*** in ν_μCC interactions.