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

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MAYORANA School 2025, 19 - 25 June

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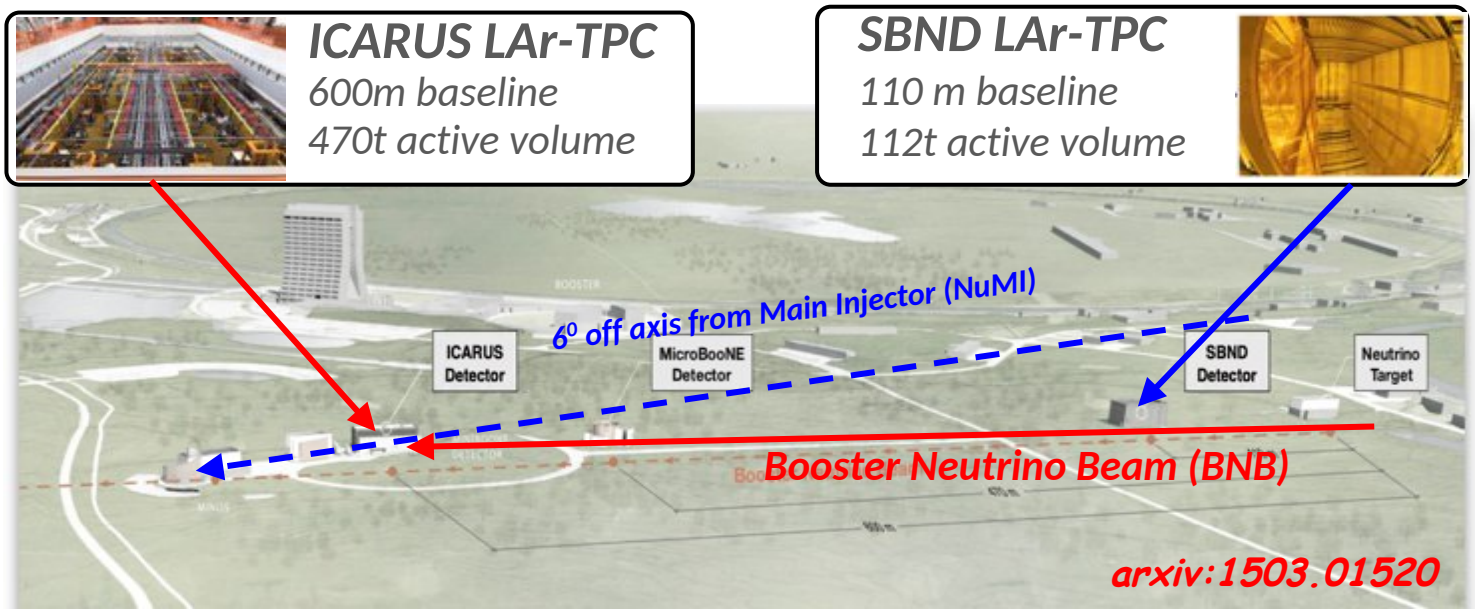
Short-Baseline Neutrino

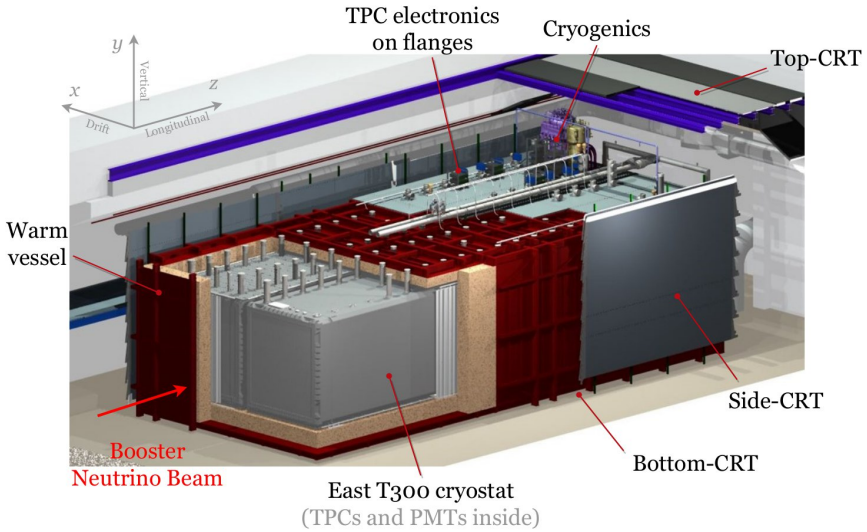


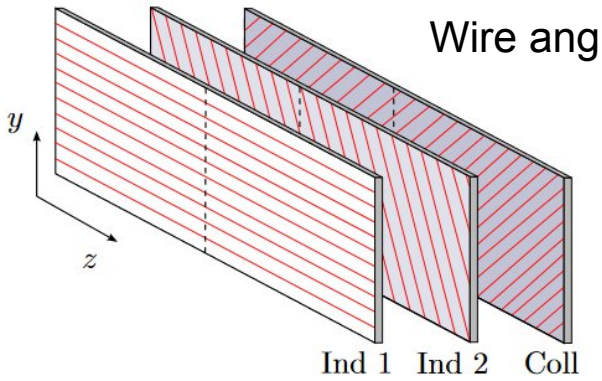
- The **SBN Program** includes two detectors exposed to the Booster Neutrino Beam: SBND and ICARUS, and they are all based on very similar Liquid Argon Time Projection Chamber (**LArTPC**) technology.
- LArTPCs allow to perform three-dimensional and calorimetric reconstructions of **particle trajectories** in ultra-pure liquid Argon active volume
- Its main goal is to investigate the possible existence of 1 eV mass scale ***sterile neutrinos***.

ICARUS T600

The ICARUS T600 detector is the **first large scale LArTPC** ever realized and actively taking data. ICARUS data taking for physics within SBN started on June 9th 2022.

- 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

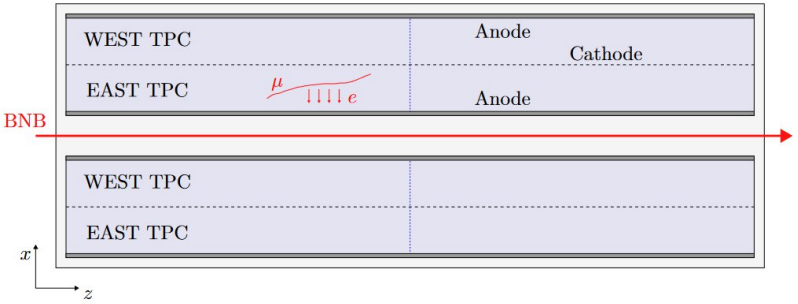




Wire angle: 0°, -60°,+60°

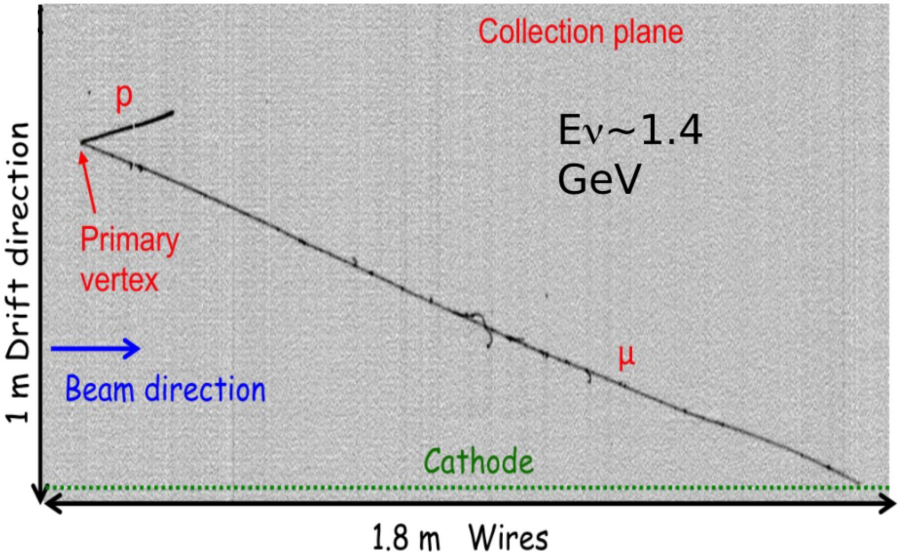
E = 500V/cm

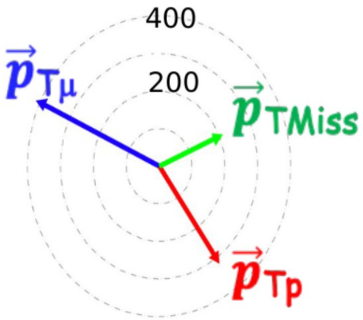
t_{drift} = ~1ms



Event Reconstruction

- **Data collection**
- Decoding
- Deconvolution
- ROI Finder
- Hit ID
- 3D Reconstruction
- Pandora Pattern Recognition
- **Analysis**





Momentum in the transverse plane (MeV/c)

Goal of this study:

- development of selection procedures to discriminate between signal and background

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 -

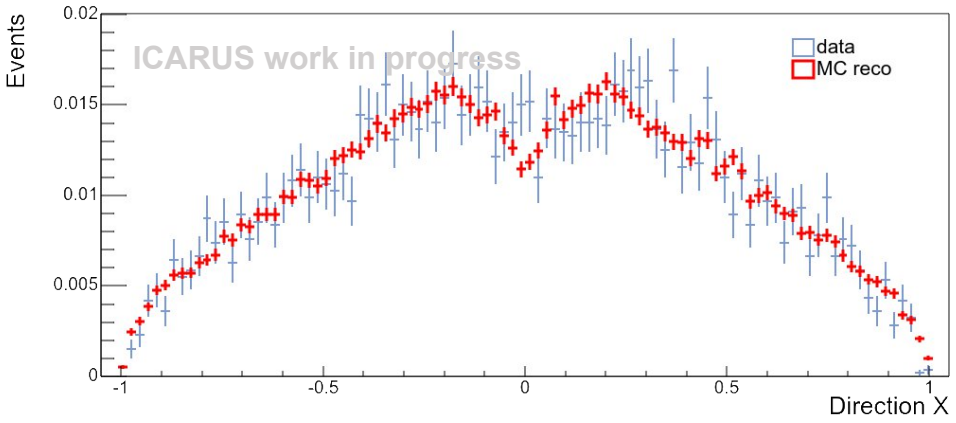
- No CRT signal in 1.6μs beam spill window

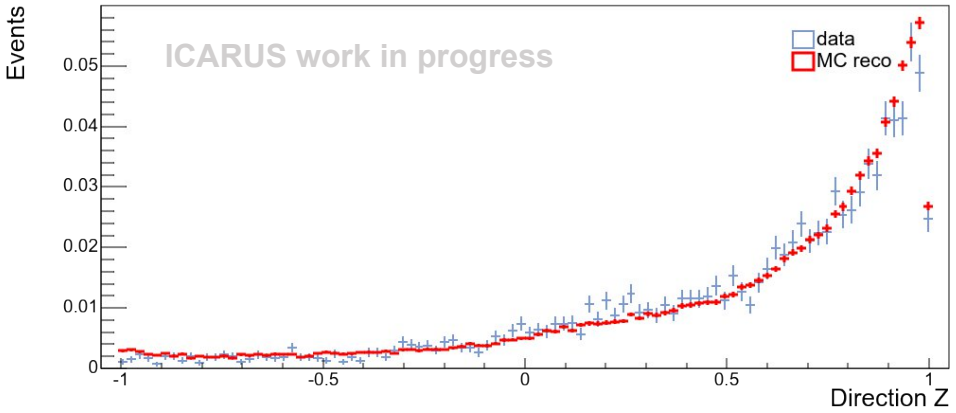
- SLICE -

- 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

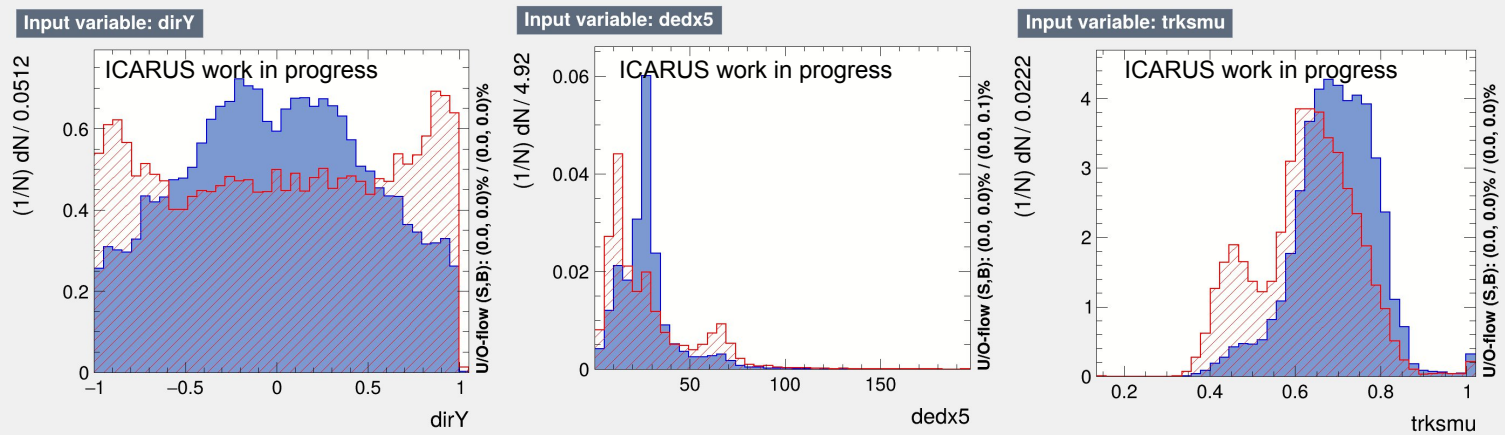
BDT Selection

Boosted Decision Tree (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.



Blue: signal, Red: background

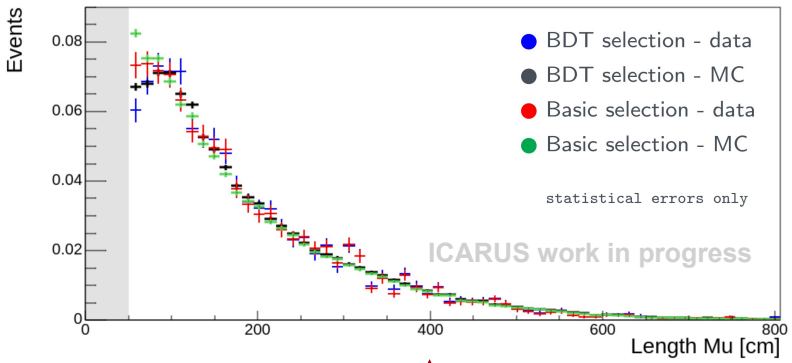
Results

Basic Selection

Efficiency = 75.7%
Purity = 83.3%

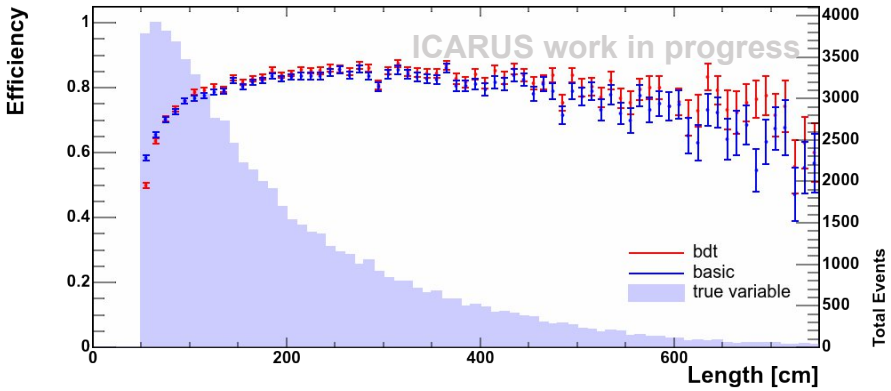
BDT Selection

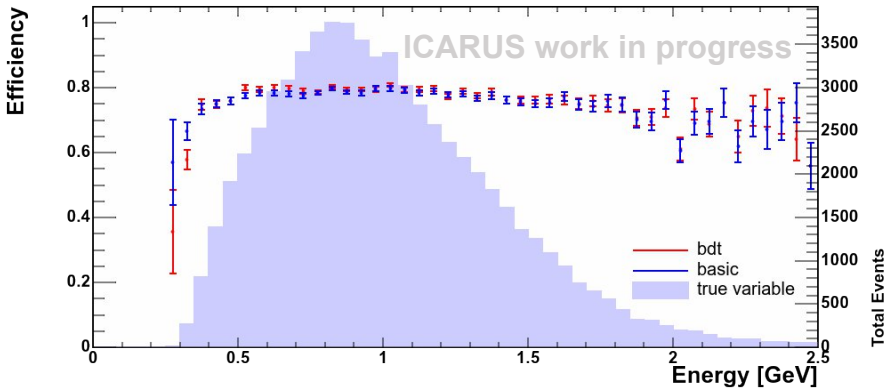
Efficiency = **76.6%**
Purity = **86.1%**



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.

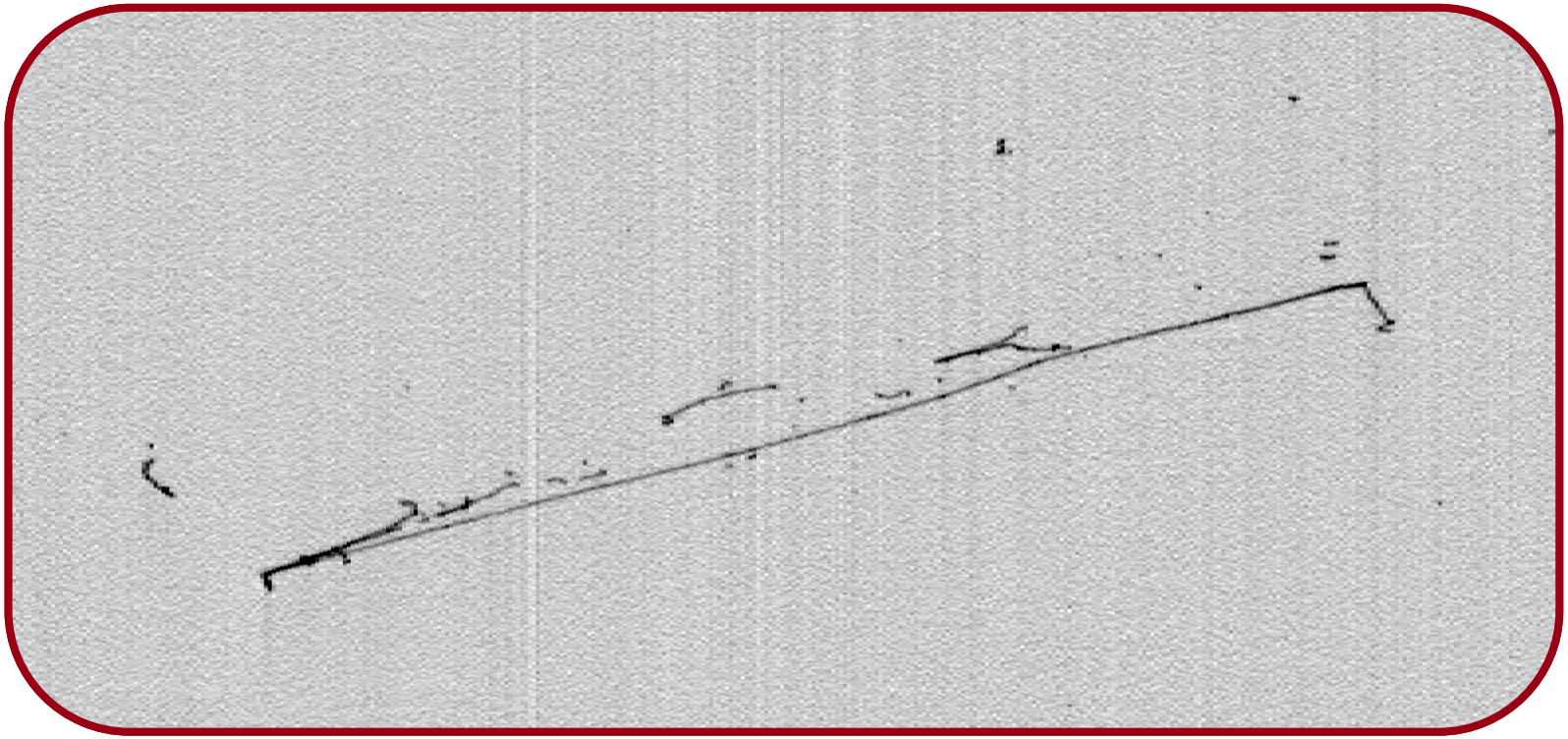
Comparison of the muon length in the events selected by the two procedures.



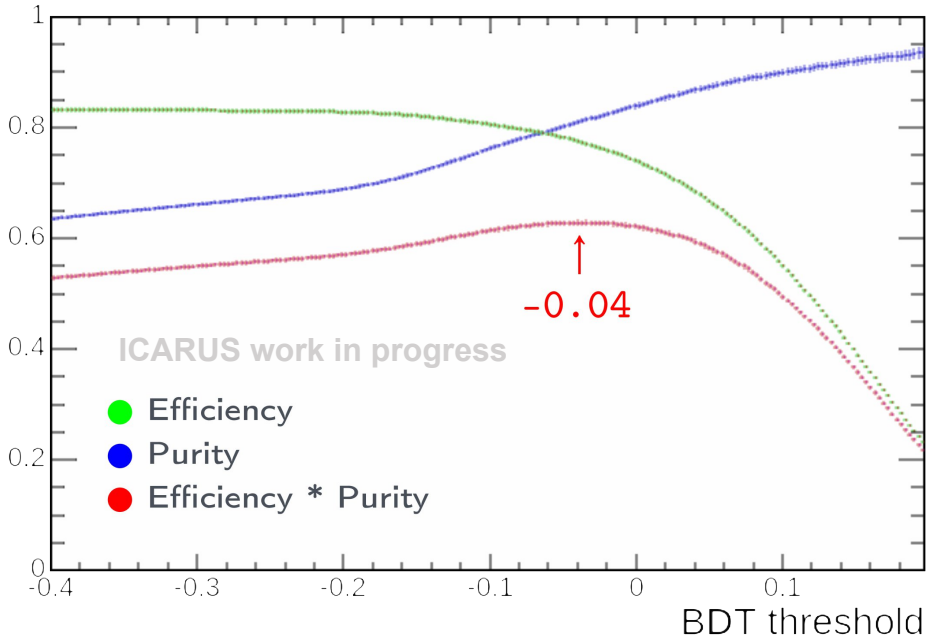


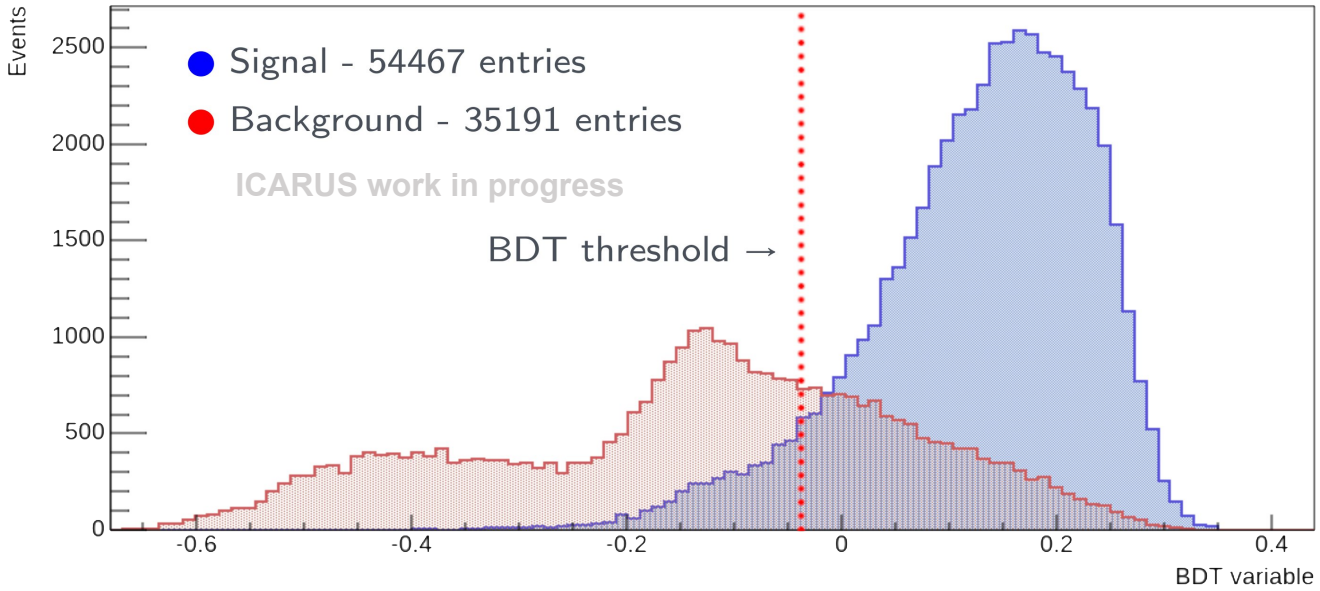
What's Next?

- Validation of the selection procedures using a ***visual study*** of selected events.
- Study of the reconstructed ***neutrino energy*** in ν_μCC interactions: essential to see evidence of **neutrino oscillations**.



Thank you!


1
0.8
0.6
0.4
0.2
0
-0.4
-0.3
-0.2
-0.1
0
0.1
-0.04
ICARUS work in progress
Efficiency
Purity
Efficiency * Purity
BDT threshold


Events
2500
2000
1500
1000
500
0
Signal - 54467 entries
Background - 35191 entries
ICARUS work in progress
BDT threshold →
-0.6
-0.4
-0.2
0
0.2
0.4
BDT variable