NEUTRINO RECONSTRUCTION ANALYSIS AT ICARUS DETECTOR

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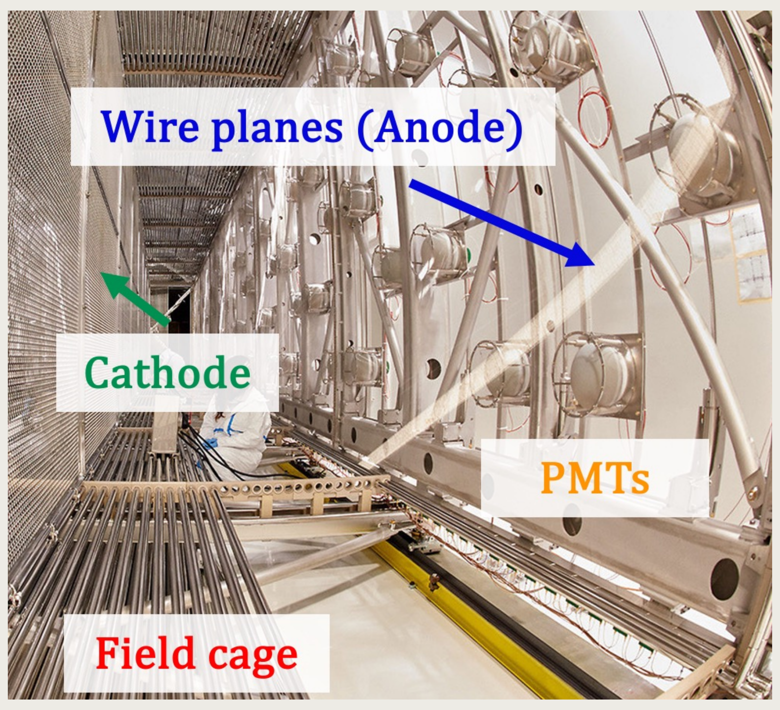
1. ICARUS AT FERMILAB

ICARUS liquid argon time projection chamber (LArTPC) is a high granularity uniform self-triggering detector with 3D imaging and calorimetric capabilities, ideal for ν physics.

With 476 t of active mass and placed at 600 m from target, ICARUS operates at shallow depth as the far detector in the Short-Baseline Neutrino (SBN) Program.

It consists of three large LArTPCs sitting along the Booster Neutrino Beam (BNB) line searching for sterile neutrino oscillations in both appearance and disappearance channels (at $\sim eV^2$ mass scale).

More details here!

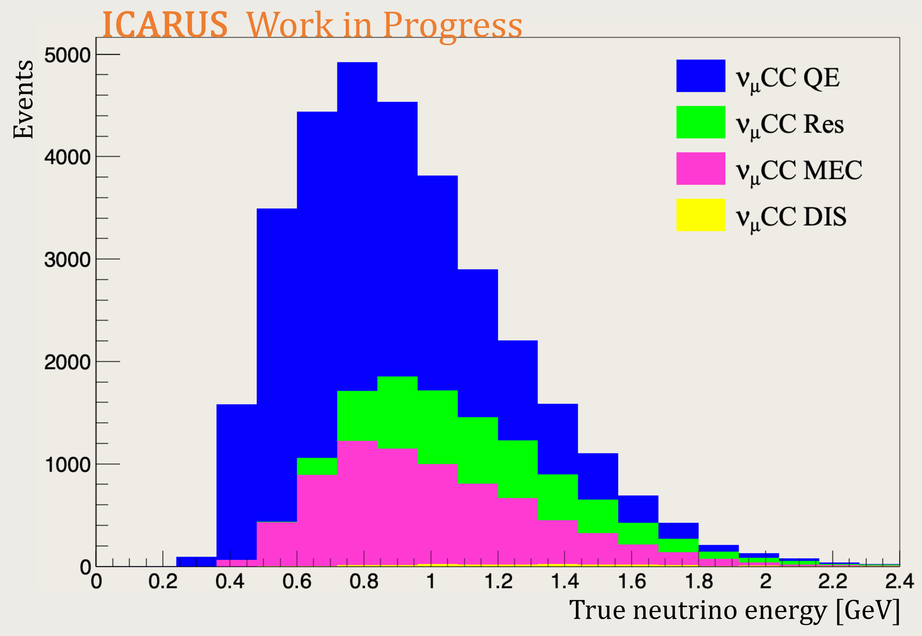


- ⋆ 2 identical cryostats with 2 TPC divided by a common central cathode
- ⋆ 2 Induction + 1 Collection anode planes per TPC
- ⋆ 360 PMTs providing fast signals for timing and triggering purposes
- ⋆ ~4π external Cosmic Ray Tagger (CRT) + 3 m concrete overburden

2. SIGNAL DEFINITION – 1μNp ν_μCC events

A first step towards a BNB ν_μ disappearance analysis is the study of 1μNp ν_μCC events fully contained. Their true signal definition was implemented requiring (at true level):

- ⇢ ν_μCC with vertex inside the fiducial volume
- ⇢ 1 muon of length > 50 cm
- ⇢ At least 1 proton with deposited energy E_{dep} > 50 MeV (~2.3 cm)
- ⇢ No photons with E_{dep} >25 MeV and 0 charged pions
- ⇢ All charged particles contained within 5 cm from TPC active borders



$\sim 2.5 \times 10^{20}$ POT collected with BNB during the entire physic runs

Contribution	2.5×10^{20} POT
ν_μ CC QE	62.4%
ν_μ CC MEC	22.7%
ν_μ CC Res	14.3%
ν_μ CC DIS	0.6%
Total events	~ 32.3k

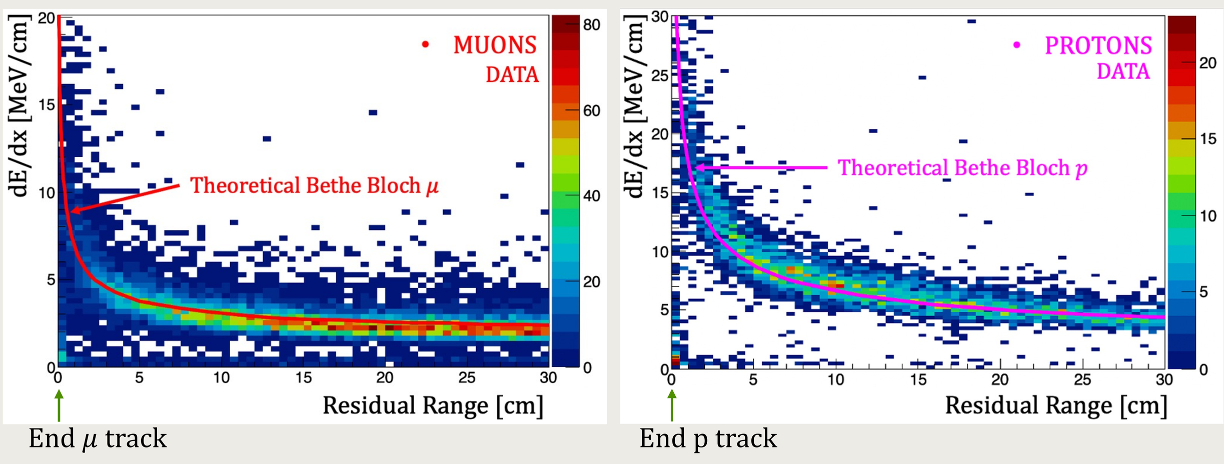
⋆ Fiducial volume definition: >25 cm from the lateral TPC walls and 30/50 cm from the upstream/downstream walls

3. AUTOMATIC SELECTION

ν in ICARUS must be recognized among ~ 11 kHz of cosmic rays ⟶ **Pandora**, a pattern recognition tool, was used to develop an automatic selection procedure, where consistent conditions were applied to match the true signal definition:

1. No CRT signal inside the 1.6 μs beam spill window
2. Reconstructed vertex inside the fiducial volume
3. Require charge and light barycenter to be within 1 m
4. All interaction reconstructed objects within 5 cm from the TPC active volume
5. Longest track ($\geq$ 50 cm) classified as a μ by the Particle identification tool (PID)
6. At least 1 proton of 50 MeV of kinetic energy (range-based measurement)
7. No other pions or showers with E > 25 MeV

The PID algorithm relies on the comparison between the measured dE/dx vs residual range along the track and the mean theoretical profiles from different particles (μ, p, K, π).



A small sample of data (~ 2×10^{18} POT) was visually scanned to evaluate selection efficiency and purity and compare it with MC:

	Efficiency	Purity
Data	48%	84%
Simulation	48%	81%

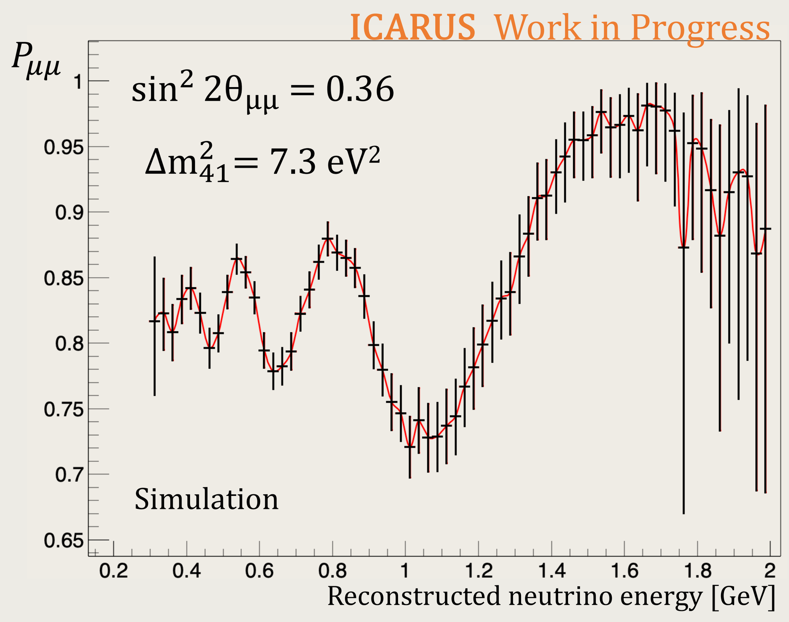
$$\text{Efficiency} = \frac{\textit{Selected signal}}{\textit{True signal}}$$

$$\text{Purity} = \frac{\textit{Selected signal}}{\textit{All selected}}$$

Hypothetical example of ν_μ disappearance assuming the reported values of Neutrino-4 $\bar{\nu}_e$.

$$P(\nu_\mu \to \nu_\mu)_{SBL} \simeq 1 - \sin^2 2\theta_{\mu\mu} \sin^2 1.27 \frac{\Delta m^2_{41} L}{E_{\nu_\mu, true}}$$

The oscillation pattern due to the neutrino active-sterile mixing is not spoiled when the precision of reconstructed neutrino energy is accounted for.



⋆ Only statistical errors are shown

4. RESULTS – 1μNp

In view of the blinding policy towards a final ν_μ disappearance oscillation analysis, a small fraction of data (~ 1.9×10^{19} POT) was used to obtain the following data – MC comparisons.

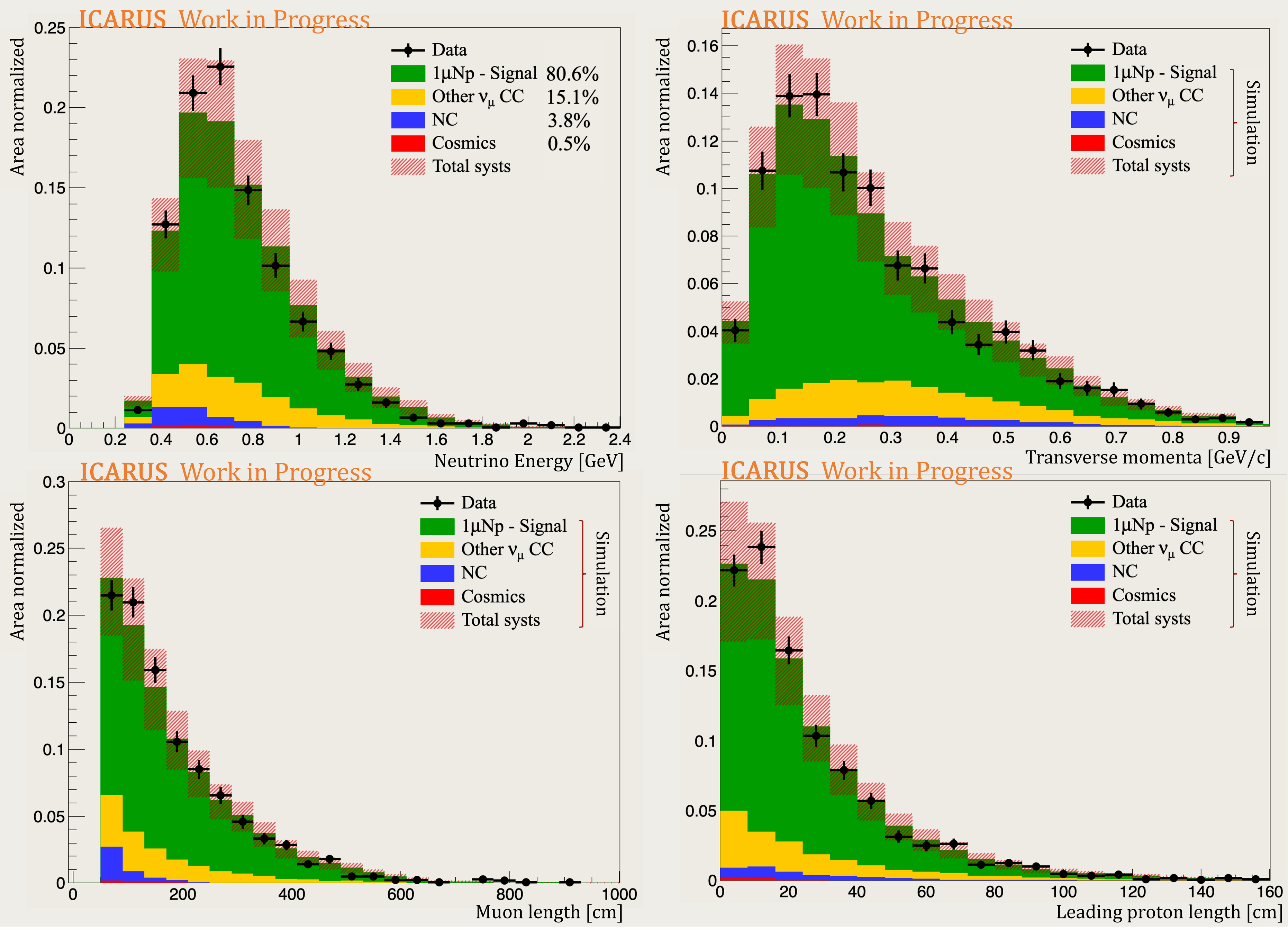
> Shape only analysis are shown with full treatment of systematic uncertainties including flux, cross section, detector and POT errors.

> Conservative systematics are considered, expected to be reduce in the near future. For instance, cross section errors with a new GENIE retuning and more detailed detector systematics.

See poster #259 for more on detector systematics!

Huge effort is ongoing to improve the **efficiency** and **purity** of the automatic selection, as well as to optimize all the selection cuts applied.

Common systematic uncertainties are expected to be substantially reduced when combining **near** and **far** detector data in future analysis.



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