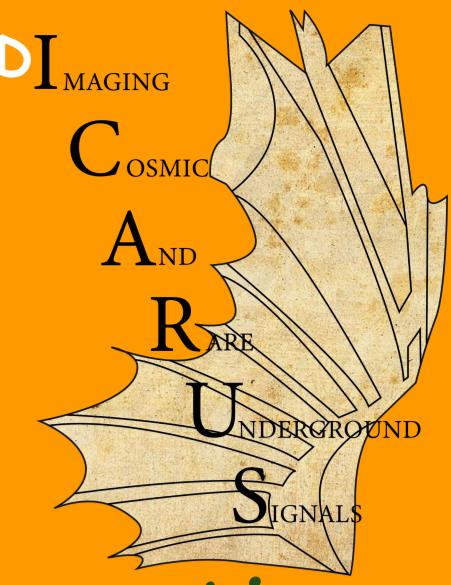




Status of ICARUS-NuMI interaction cross-section analysis

FERMILAB-POSTER-24-0097-PPD



Promita Roy¹, Minerba Betancourt², Bruce Howard², Jaesung Kim³, Guadalupe Moreno⁴, Jack Smedley³

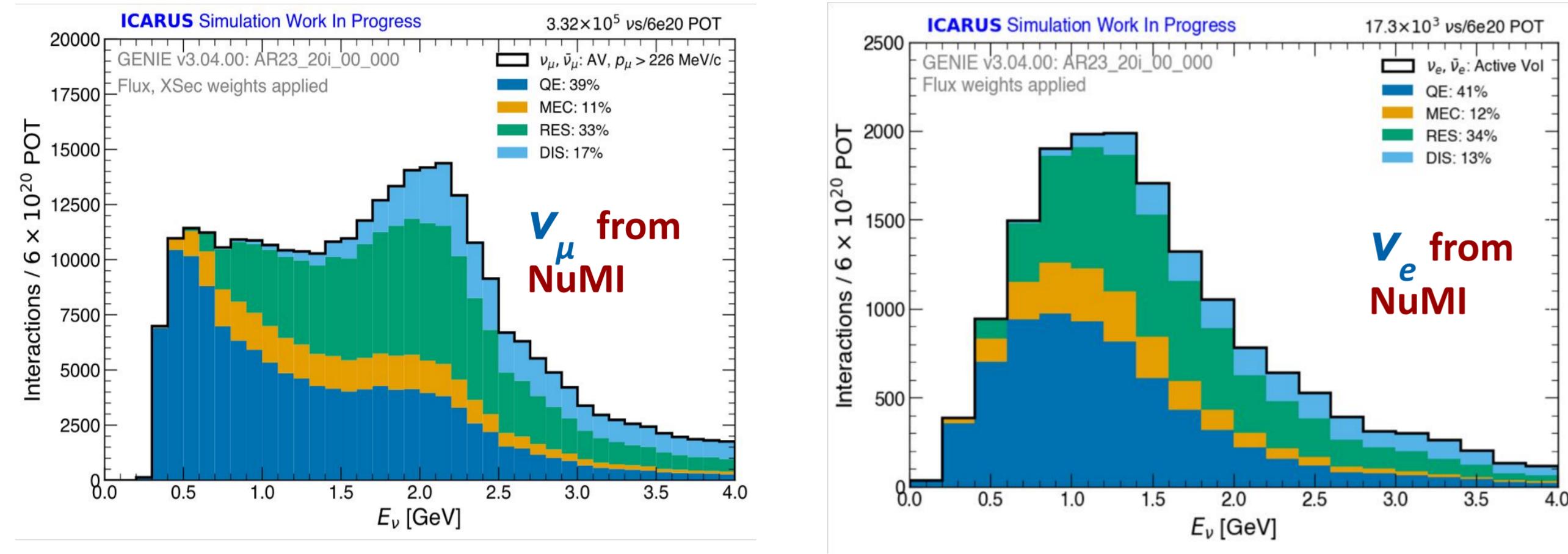
¹Virginia Tech, ²Fermilab, ³University of Rochester, ⁴CINVESTAV

For the ICARUS Collaboration

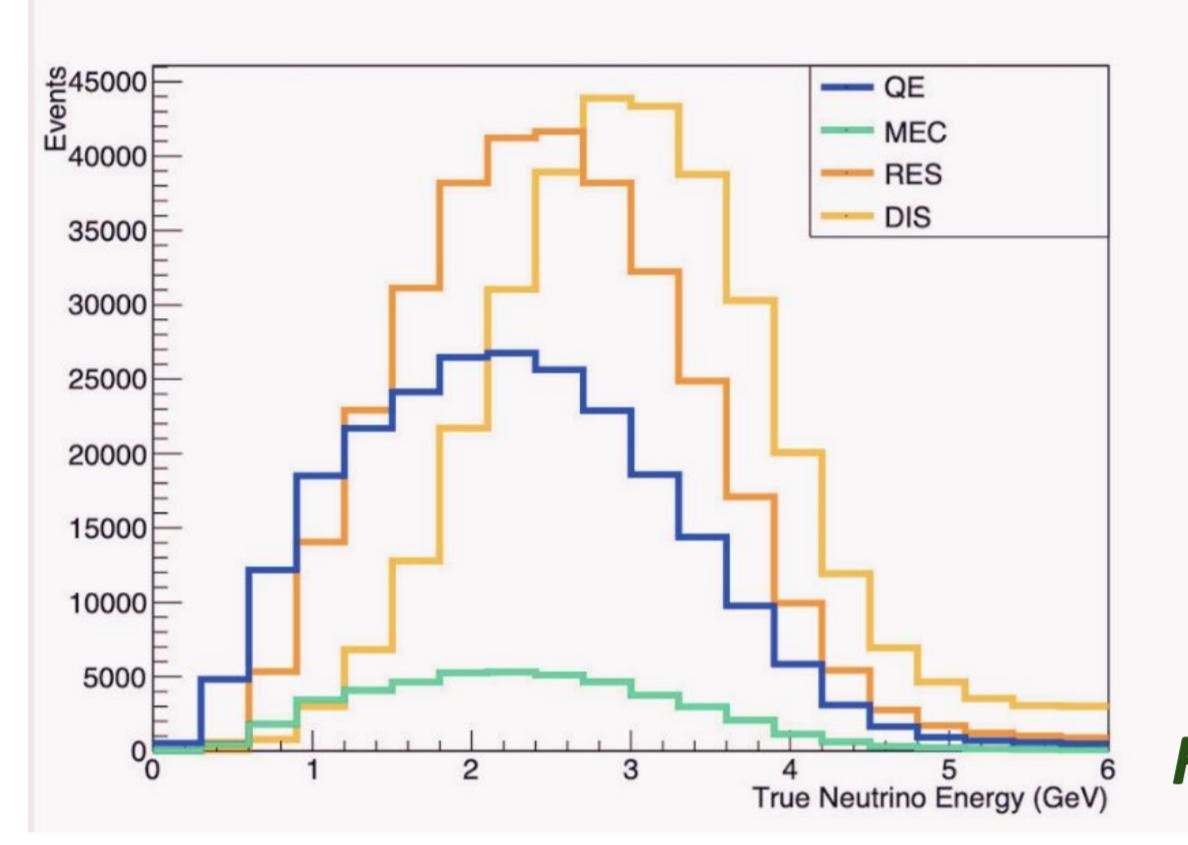
Contribution ID: 44, Email: promita@vt.edu

A Introduction and motivation

- The ICARUS experiment [1], utilizing LAr TPC, has been installed at Fermilab in Chicago.
- Primary objective is to function as the far detector of the SBN program, seeking sterile neutrino signatures [2].
- Offers diverse physics capabilities- searches beyond the standard model and measurements of cross-sections.
- In addition to being exposed to the common Booster Neutrino (BNB) beamline, it also receives off-axis neutrinos from the Main Injector (NuMI) beam.



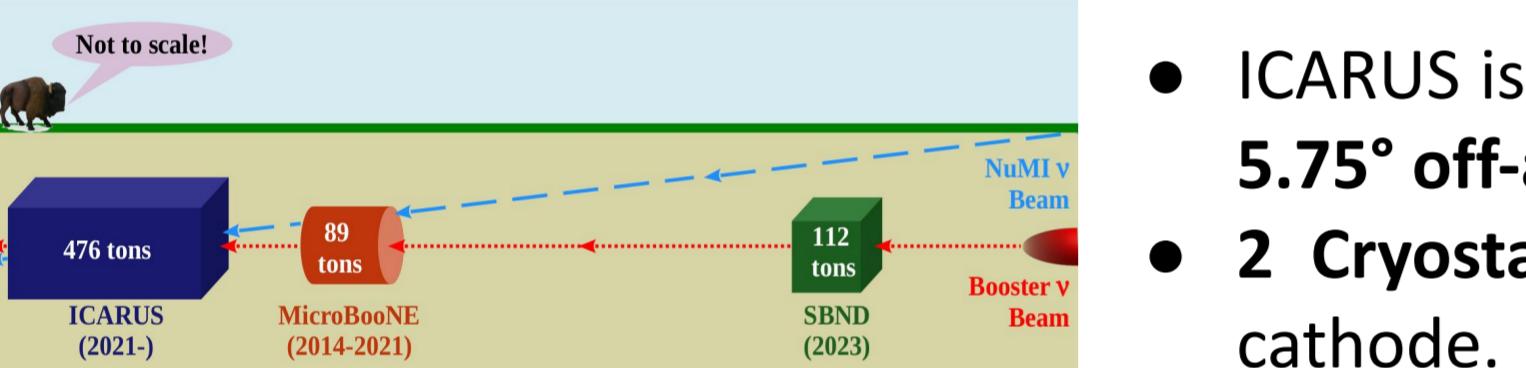
- The energy range of NuMI ν_μ interactions in ICARUS is in a similar energy range to that expected by DUNE.
- ν_e spectrum from NuMI at ICARUS covers first oscillation peak and provides good coverage of the relevant phase space for the DUNE.



- ν_e flux is distributed to probe regions - we expect the largest ν_e/ν_μ differences (dominant systematic for DUNE-CP violation measurements)

Ref: NuINT talk by Minerba Betancourt

B ICARUS detector at Fermilab

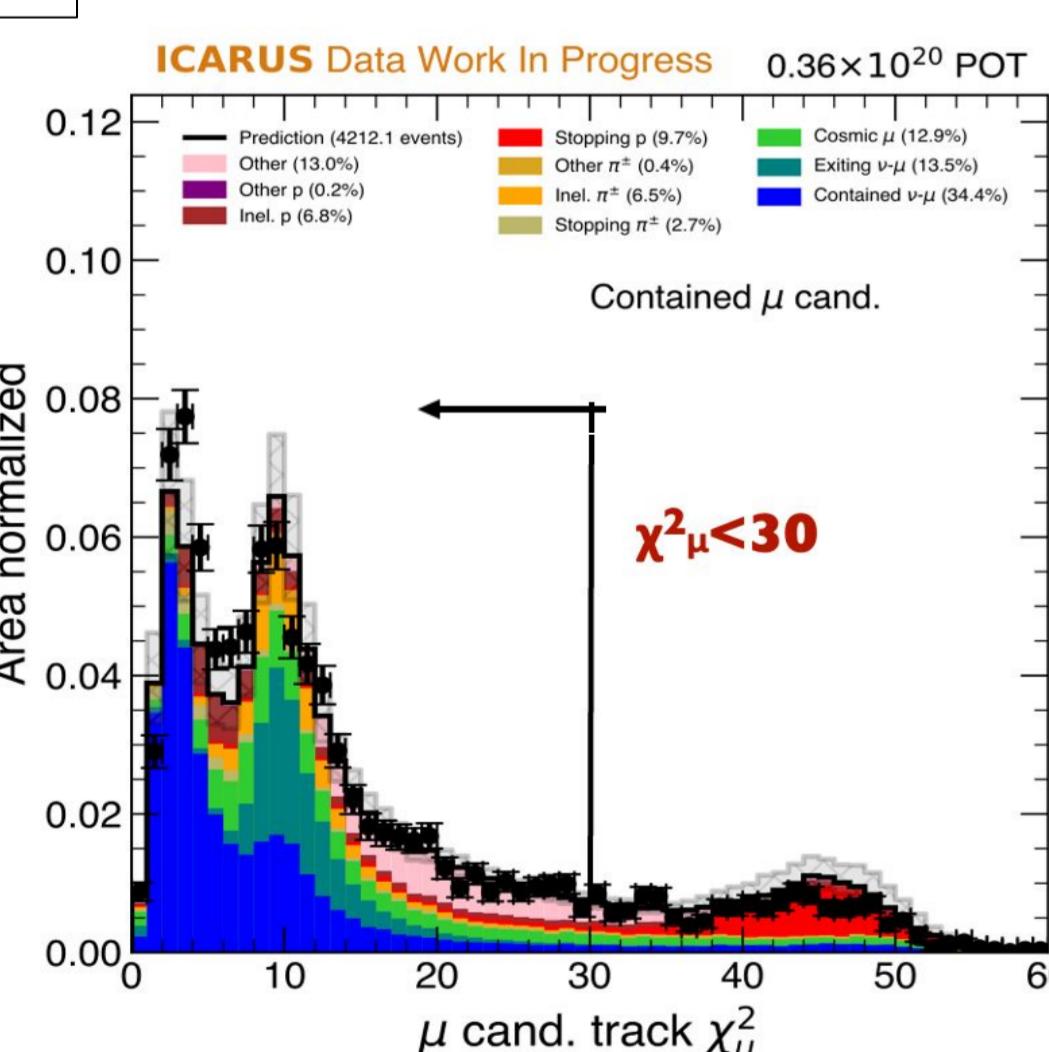


- ICARUS is located on-axis from the Booster beam and **5.75° off-axis** from the NuMI beam [1].
- 2 Cryostats with 2 TPCs per module with central cathode.**
- 3 readout wire planes** (2 induction+collection) per TPC.
- 360 (8" PMTs)**: Scintillation light detected to provide ns event time and trigger.
- 4π coverage with CRTs**: Bottom CRT, Side CRT and Top CRT and 3 m concrete overburden (6m water equivalent)



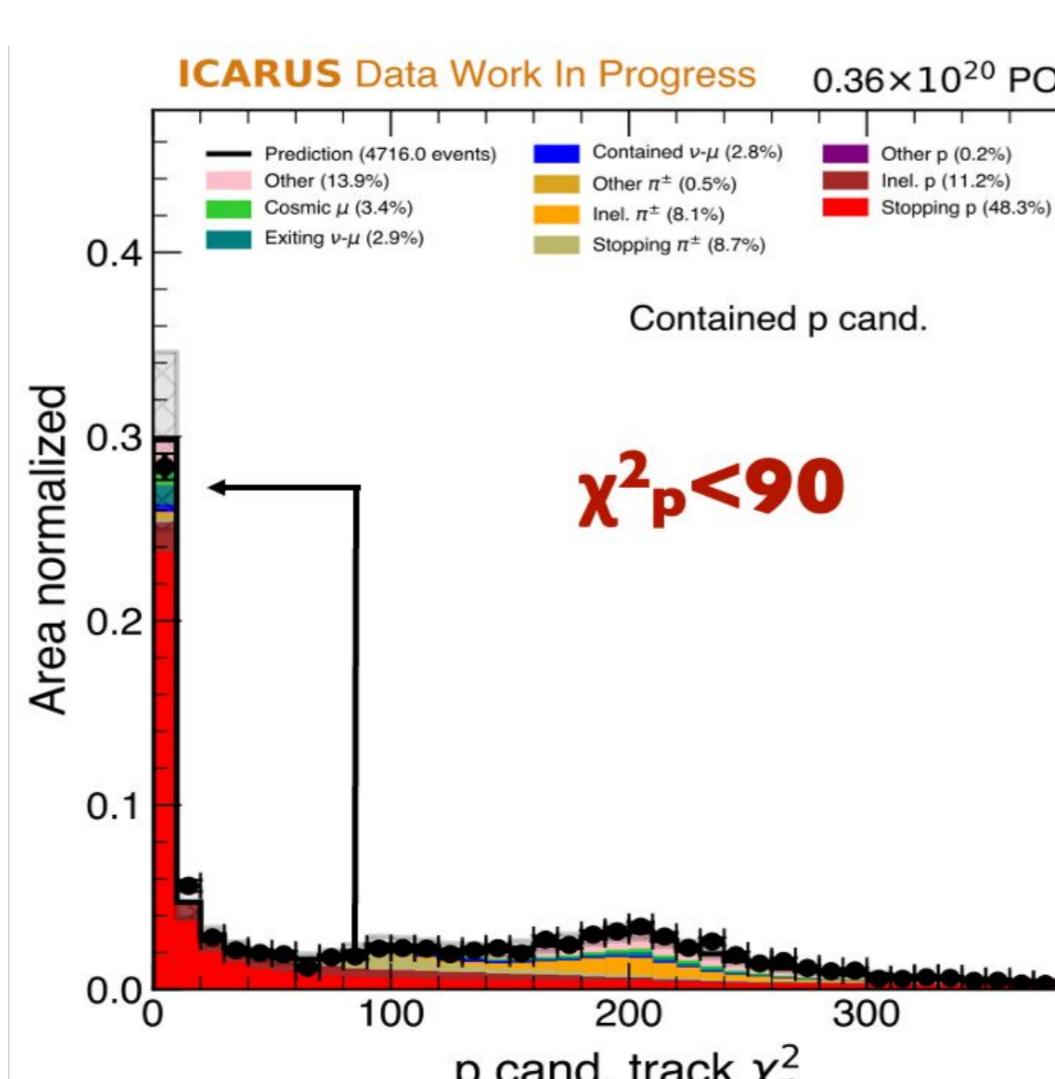
One of the ICARUS modules

C CC 0π event selection



Selecting events with muons

- Vertex to be in fiducial volume (25 cm on sides and top/bottom, 30 cm upstream and 50 cm downstream)
- Events tagged as clear cosmics by Pandora [4] rejected
- At least two primary tracks
- χ^2 PID scores consistent with a muon over a proton



Conclusion

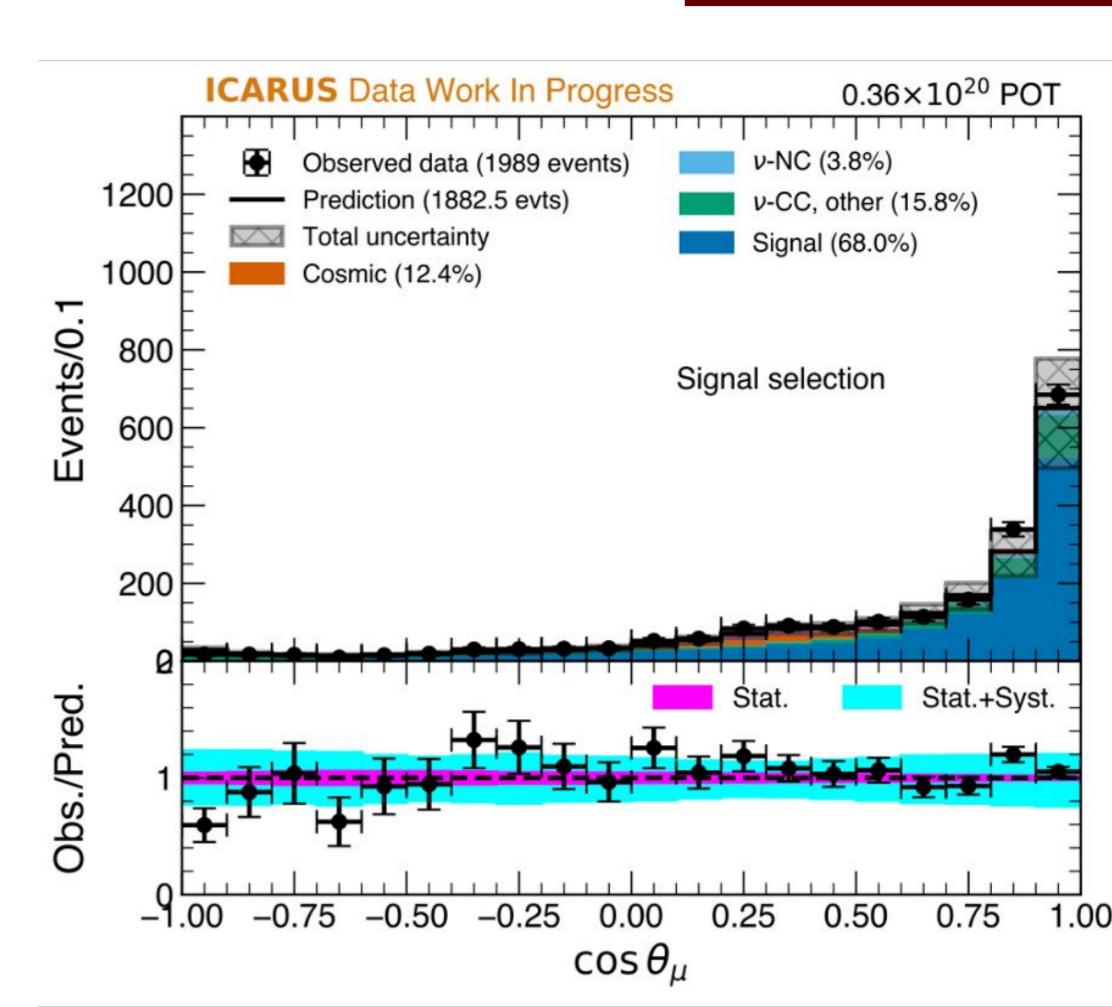
- ICARUS at Fermilab underwent a period of commissioning and first operations.
- Rich physics program for neutrino-argon scattering measurements using NuMI.
- Conducting neutrino cross-section and interaction measurements neutrinos from NuMI beam in a similar kinematic regime as DUNE: Opportunity to test and constrain models to be used in DUNE.

This document was prepared by the ICARUS Collaboration using the resources of the Fermi National Accelerator Laboratory (Fermilab), a U.S. Department of Energy, Office of Science, Office of High Energy Physics HEP User Facility. Fermilab is managed by Fermi Research Alliance, LLC (FRA), acting under Contract No. DE-AC02-07CH11359.

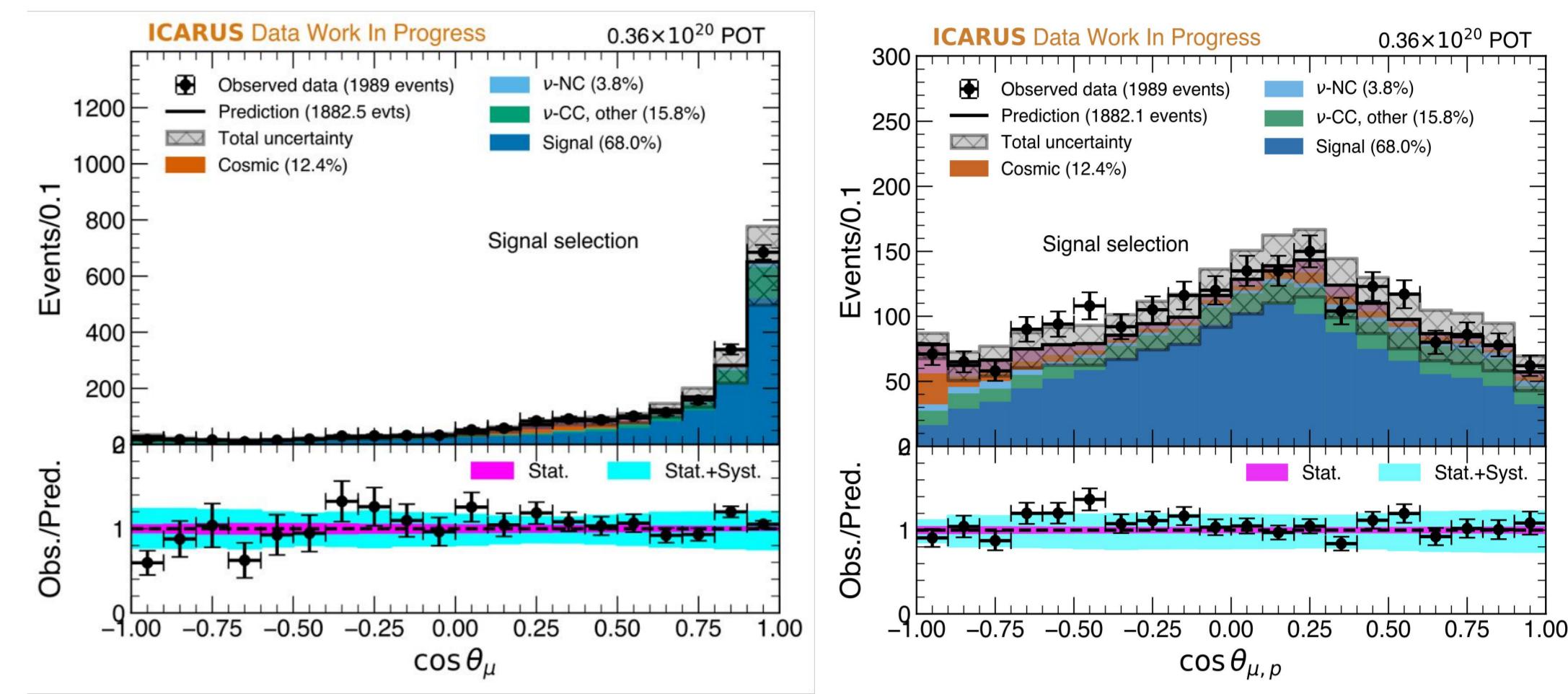
D CC 0π+Np: Our first Cross-section Analysis

CC 0π selected events

- First analysis:** $1\mu+N\text{proton}+0\pi$
- Signal:** One muon with $\mathbf{p}_{\mu\text{muon}} > 226 \text{ MeV}/c$, any proton with $400 \text{ MeV}/c < \mathbf{p}_{\mu\text{proton}} < 1 \text{ GeV}/c$, no charged or neutral pions in the final state.

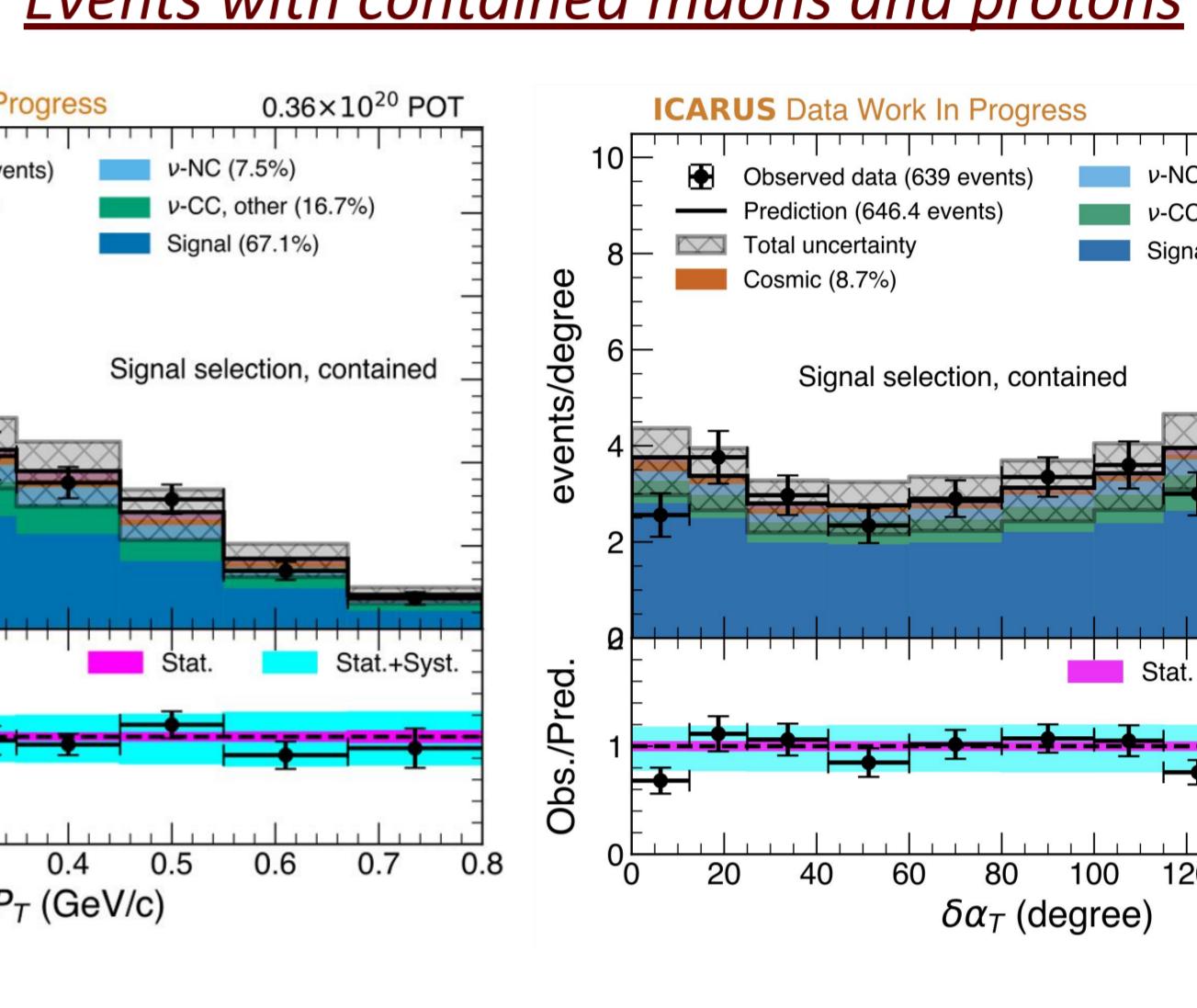
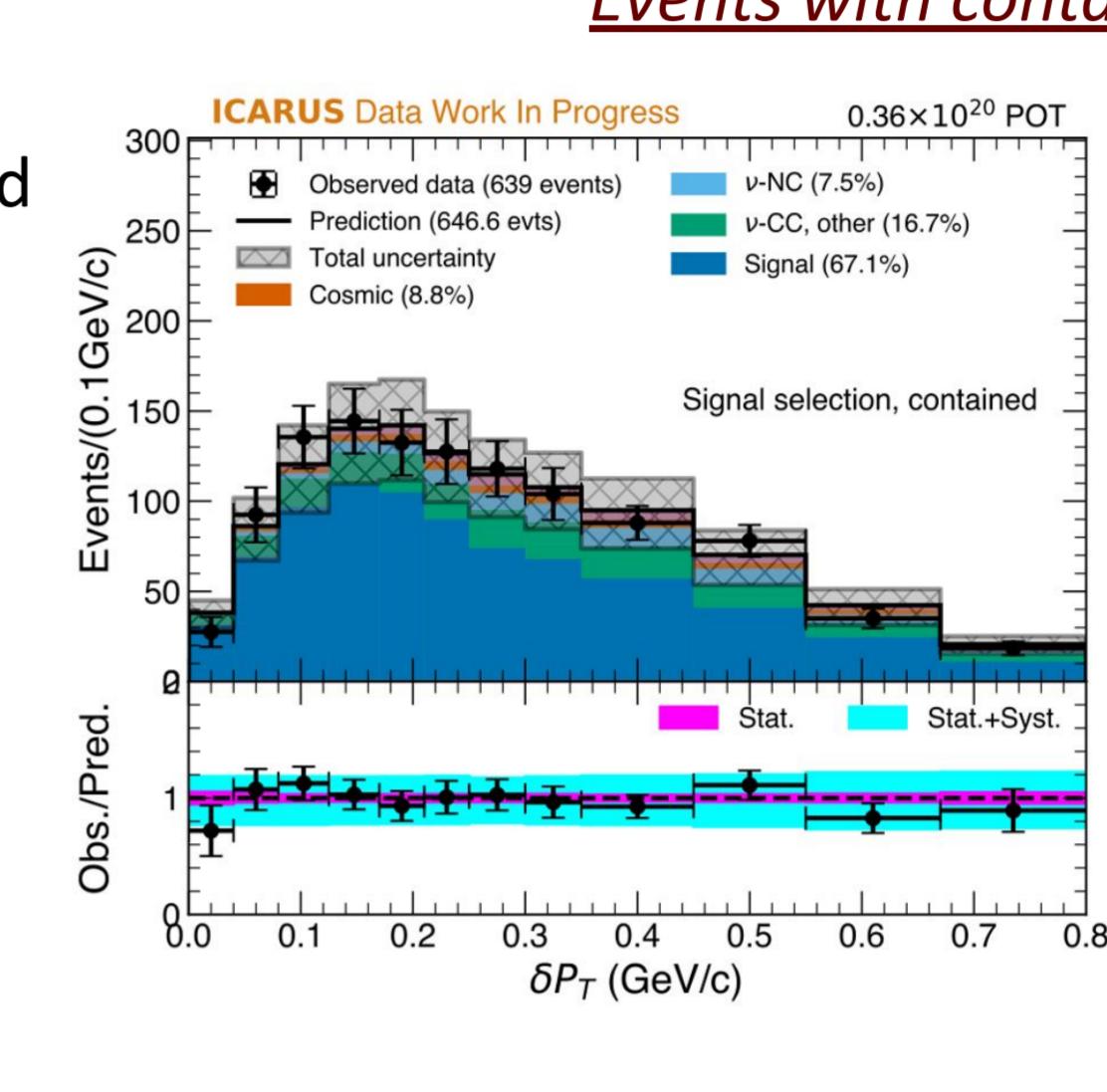
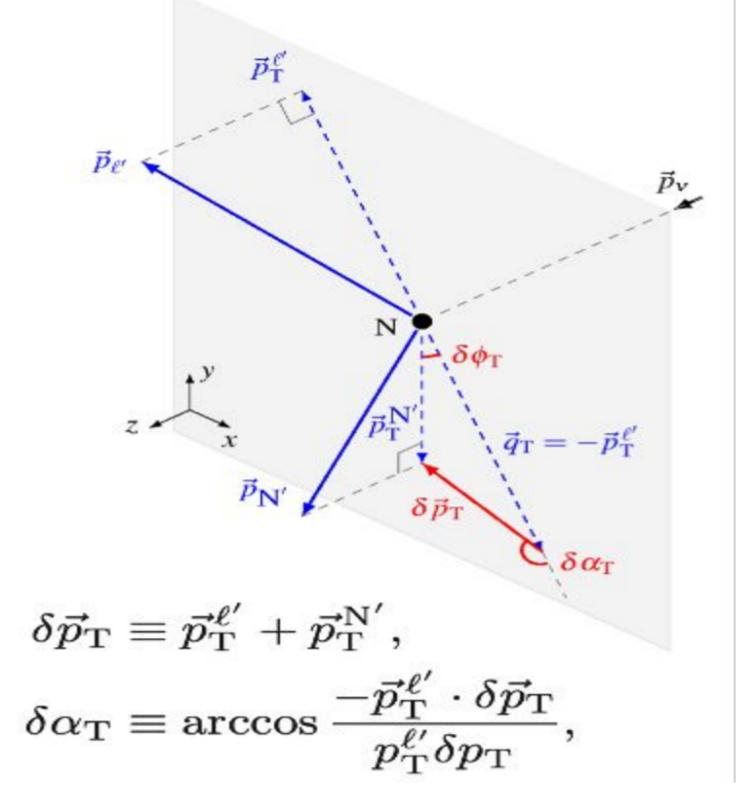


Events with contained and exiting muons

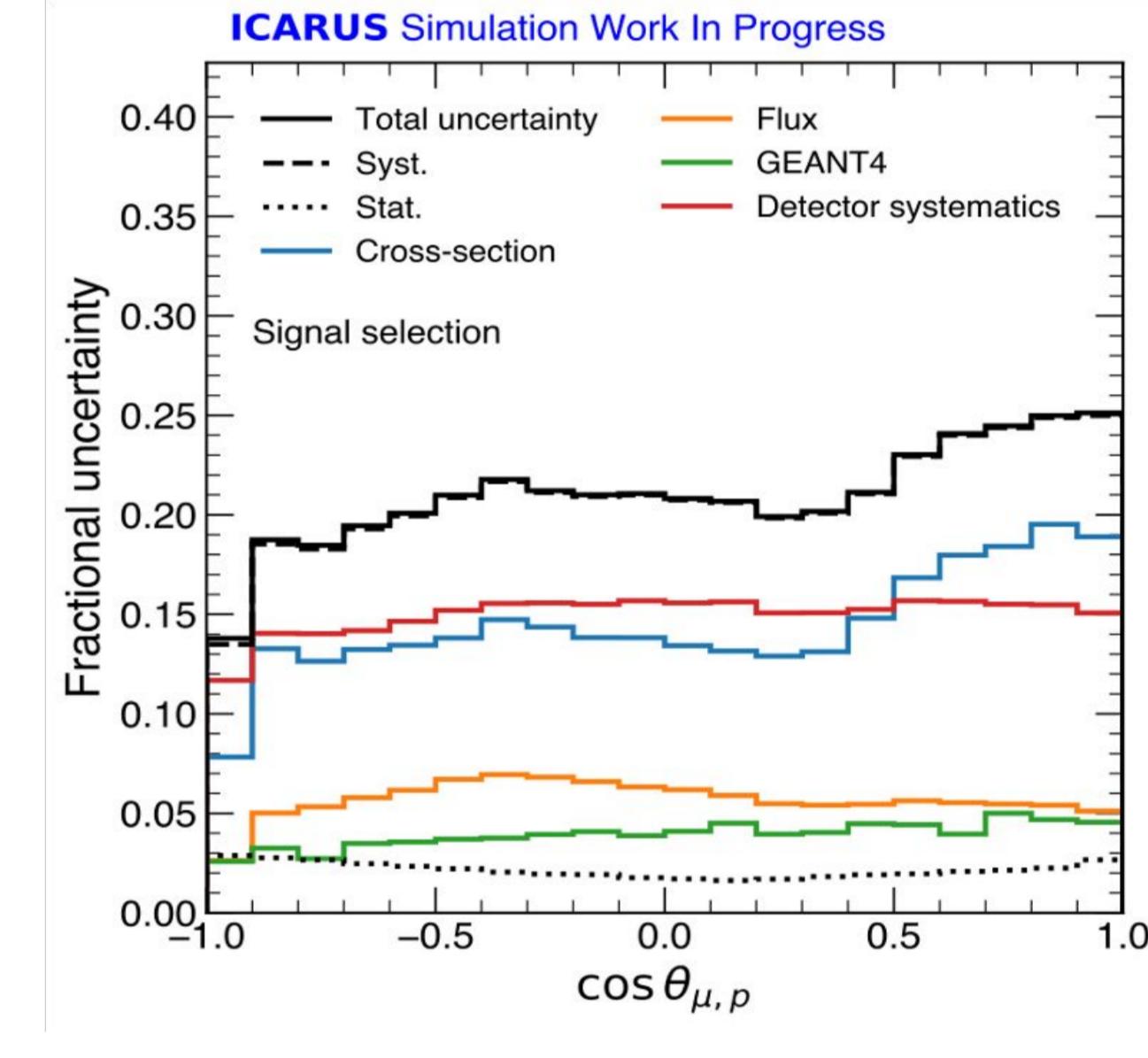


CC 0π Event Selection for fully contained Events

- Transverse kinematic imbalance observables δP_T and $\delta \alpha_T$ studied using the leading proton.
- Main background is pions.



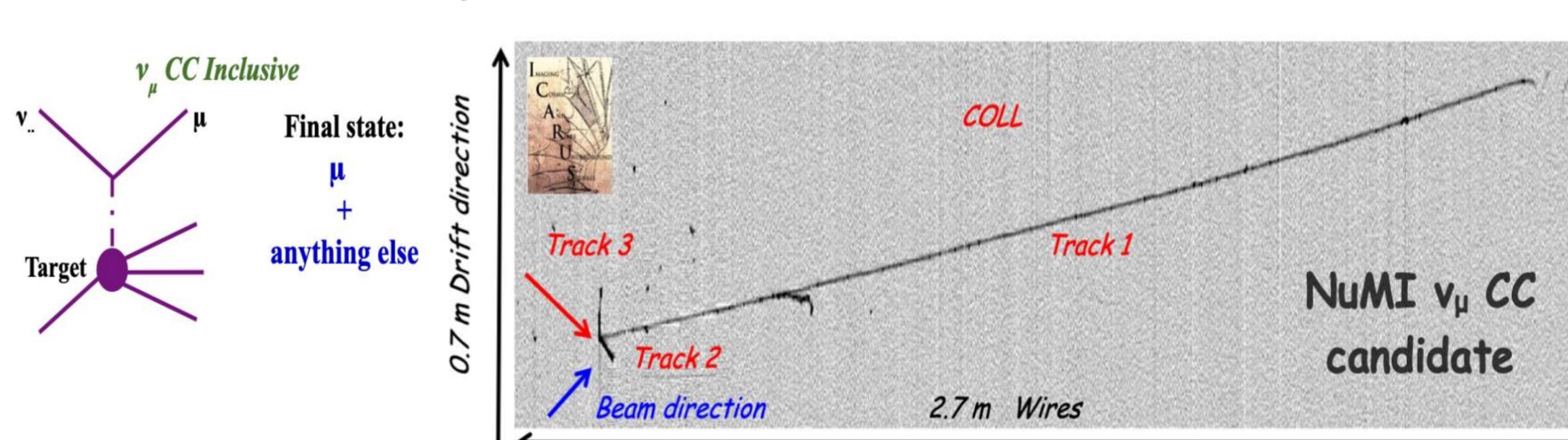
Systematic uncertainties



Several systematics uncertainties evaluated: **Flux systematics, Geant4 and detector systematics.**

E Other Ongoing Analyses: ν_μ CC Inclusive and CC 0π+2p

ν_μ CC Inclusive analysis



ν_μ CC Inclusive event selection

- Events tagged as Pandora clear cosmic rejected.
- Vertex in Fiducial Volume (FV).
- A cut on the longest track's Y-direction: $\text{Cosine} \theta_{\text{LongestCRY}} > -0.7$
- Barycenter Flash Matching $< 1\text{m}$
- Muon track: Distance from Vertex $< 10\text{ cm}$
 - Contained: Length $> 50\text{cm}$
 - Exiting: Length $> 100\text{cm}$

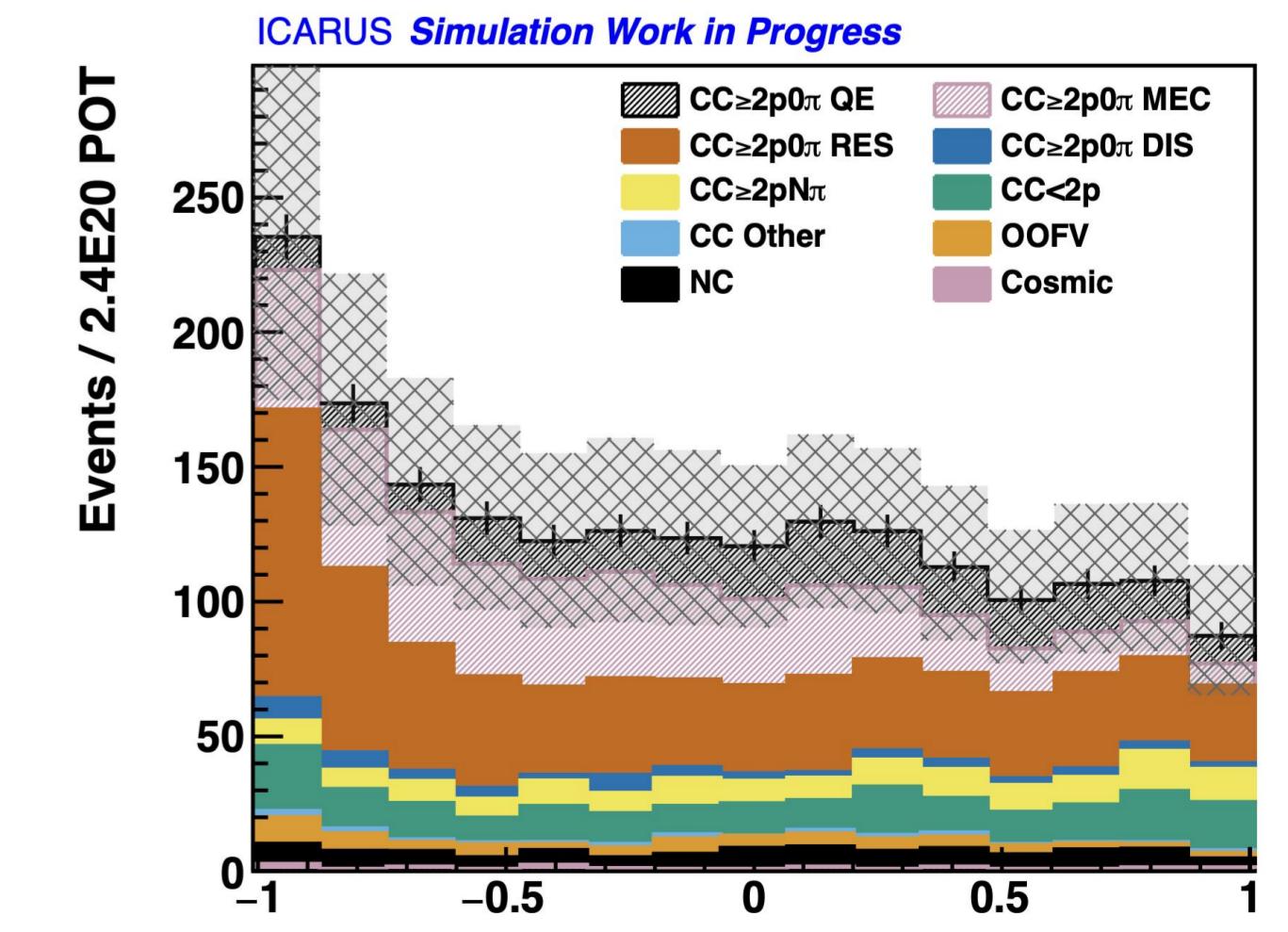
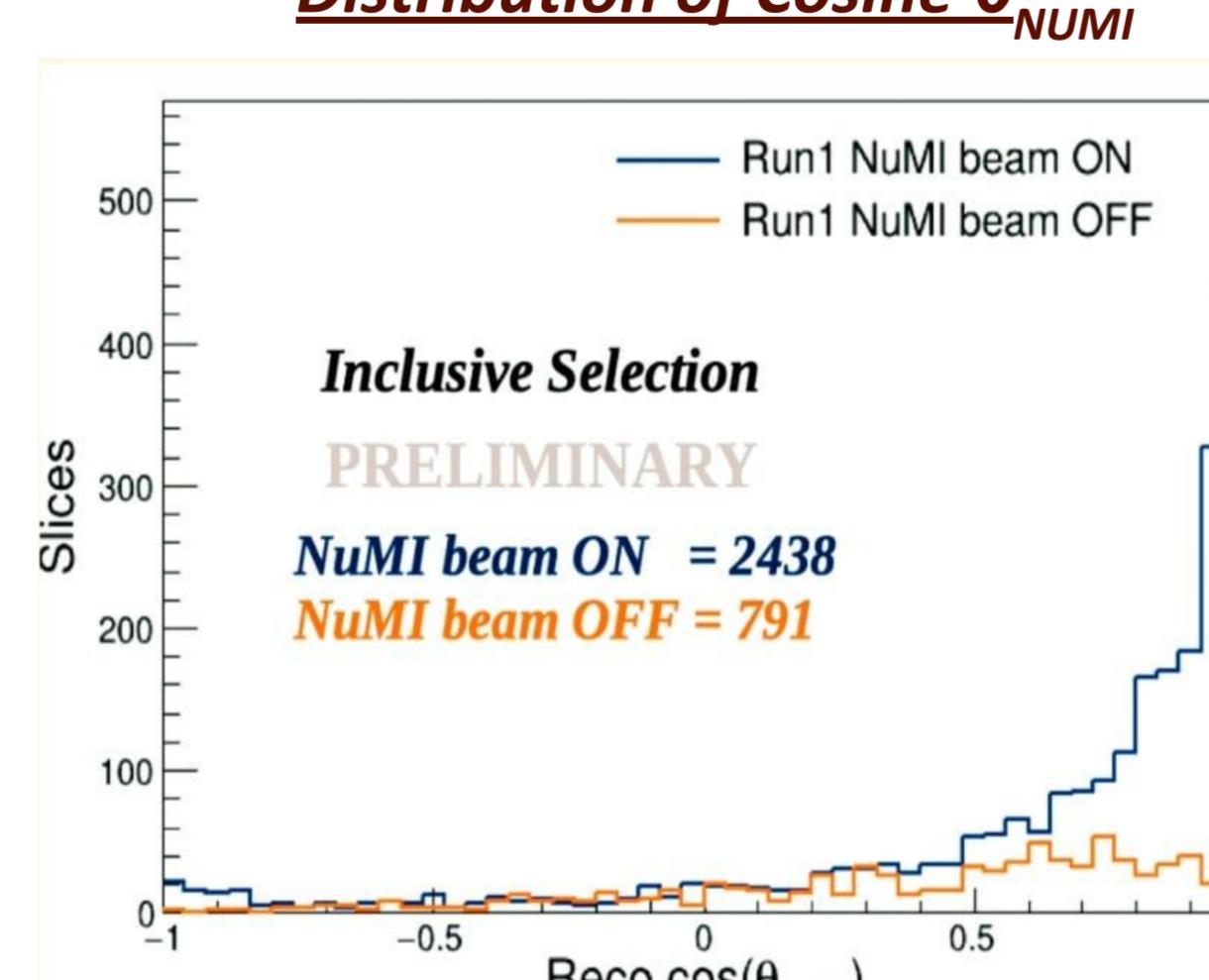
CC 0π with 2 protons



Event selection for CC 0π 2p

- Vertex in FV and not Clear Cosmic.
- All selected tracks tagged as primary and start $< 10\text{cm}$ from the vertex.
- Muon candidate track: at least 50 cm long
- Proton candidate tracks: At least 2 of them, Reco momentum $> 350\text{MeV}/c$
- Hadronic system is fully contained

Distribution of Cosine θ_{NuMI}



REFERENCES

- [1] Abratenko, P. et al. Eur. Phys. J. C 83, 467 (2023)
- [2] P. Machado, O. Palamara, D. Schmitz. Annu. Rev. Nucl. Part. Sci. (2019). doi: 10.1146
- [3] The DUNE Collaboration. arXiv:2006.16043
- [4] Acciari, R., Adams, C., An, R. et al. Eur. Phys. J. C 78, 82 (2018)

ACKNOWLEDGMENTS

