

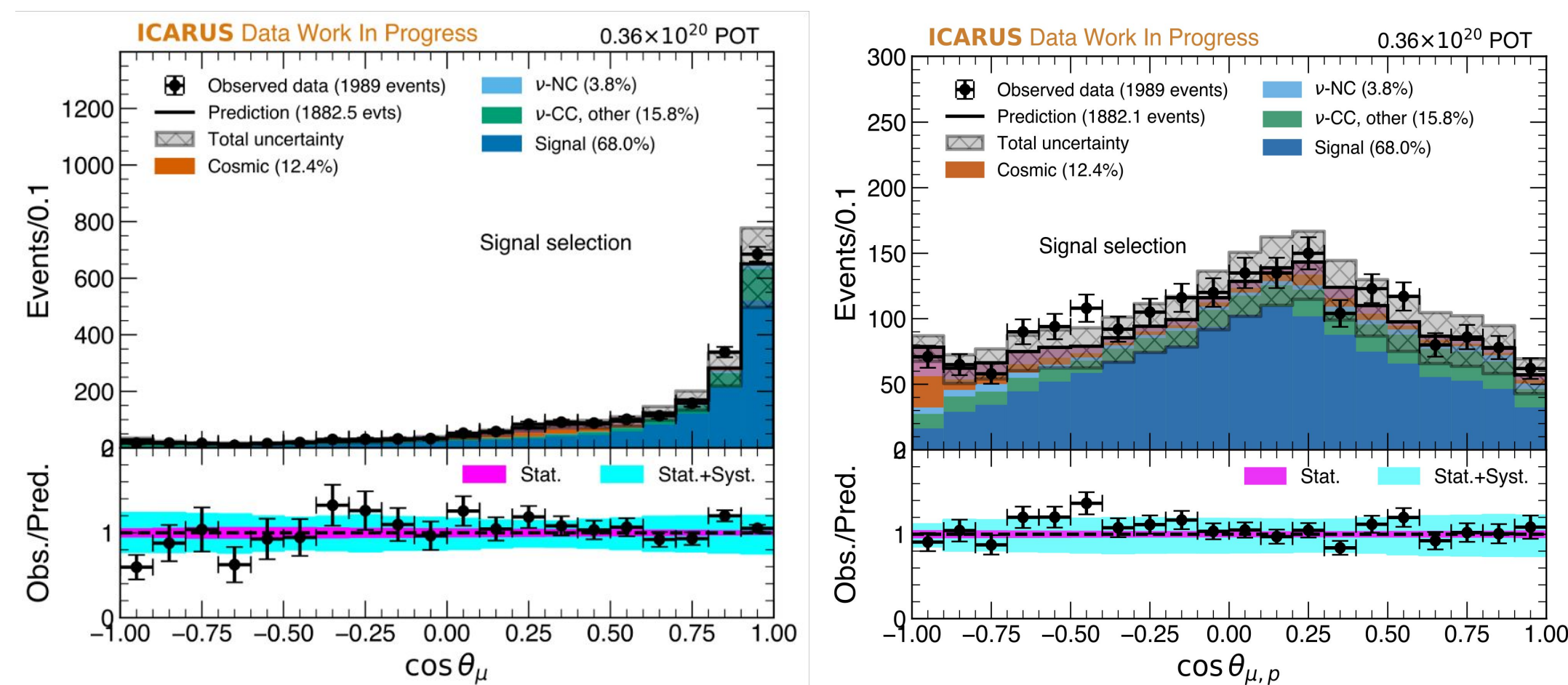
## FERMILAB-POSTER-24-0097-PPD IMAGING

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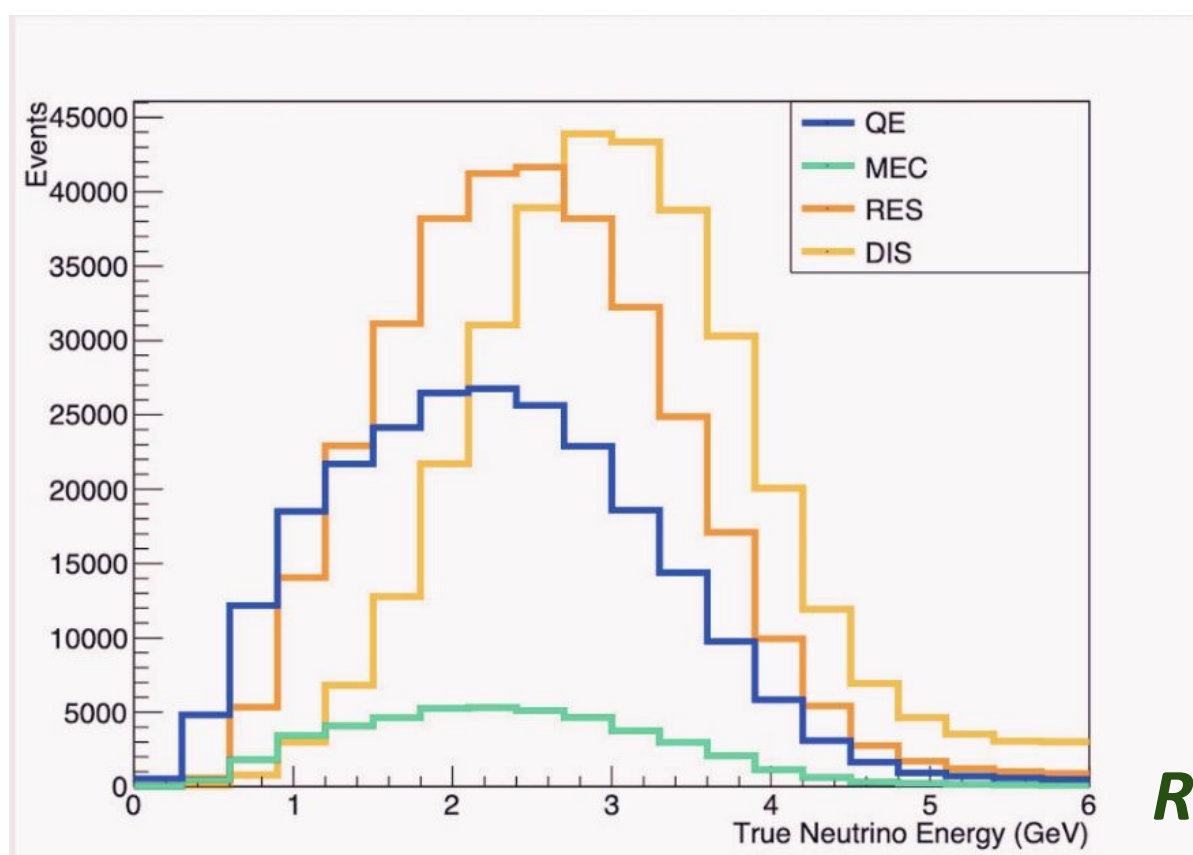
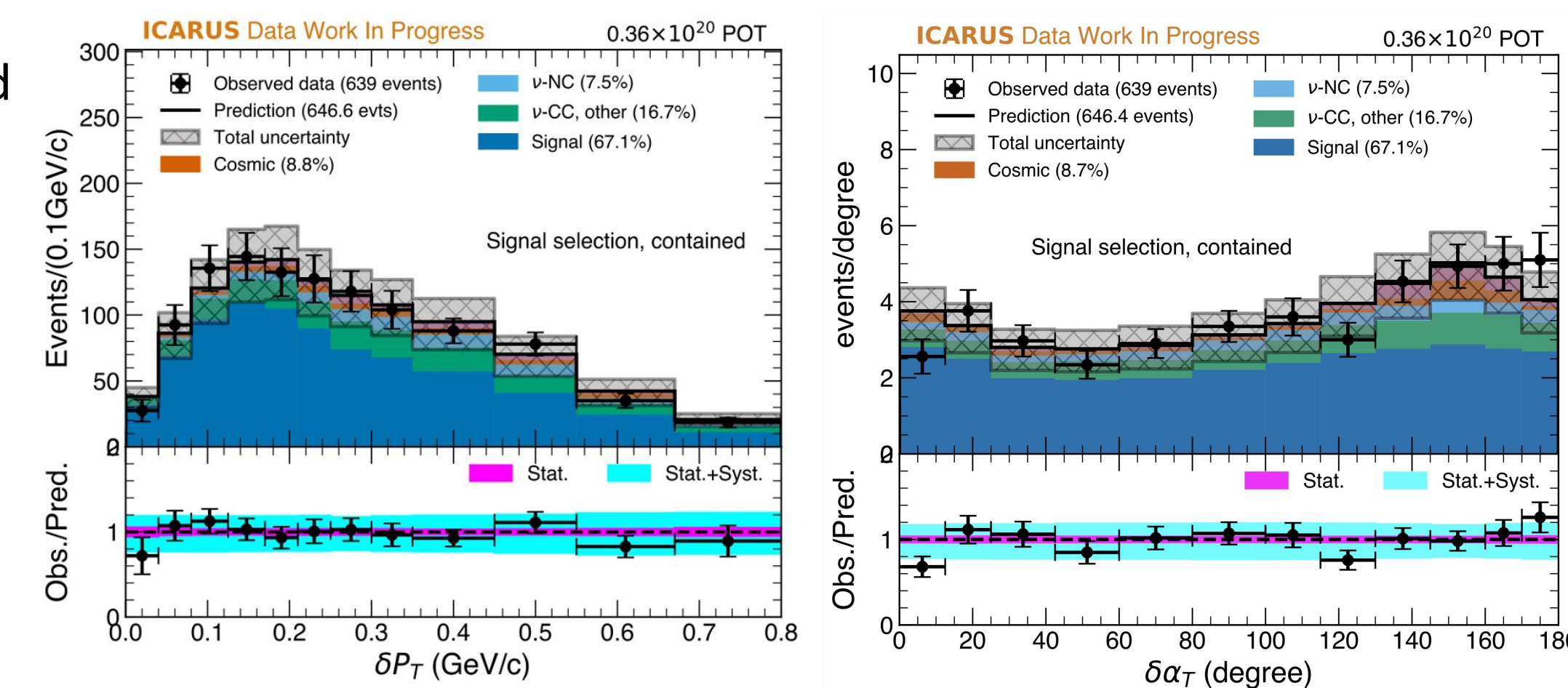
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## D

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



- ### CC $0\pi$ Event Selection for fully contained Events



- Ref: NuINT talk by Minerba Betancourt**

### Reconstructed vs True

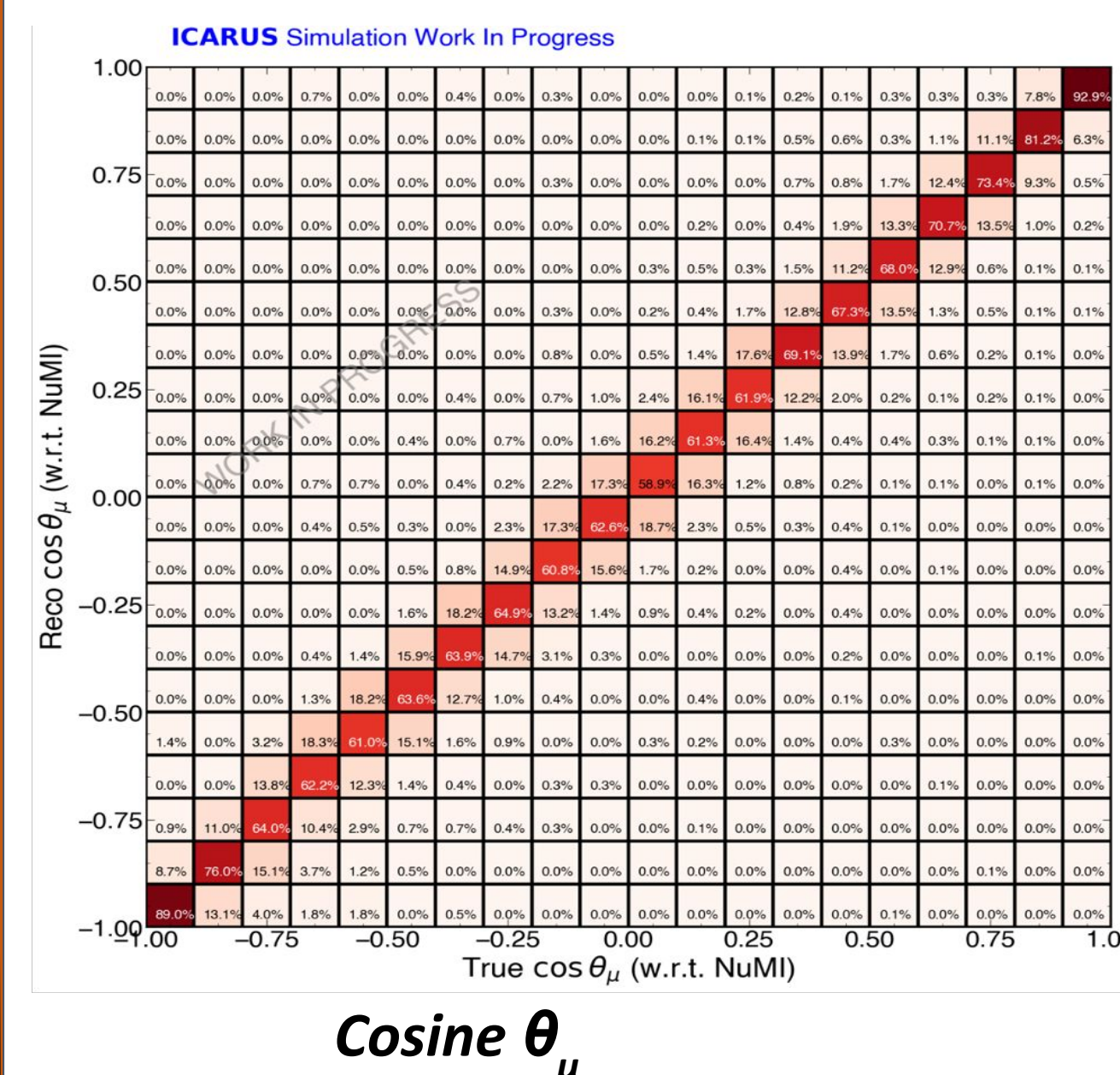
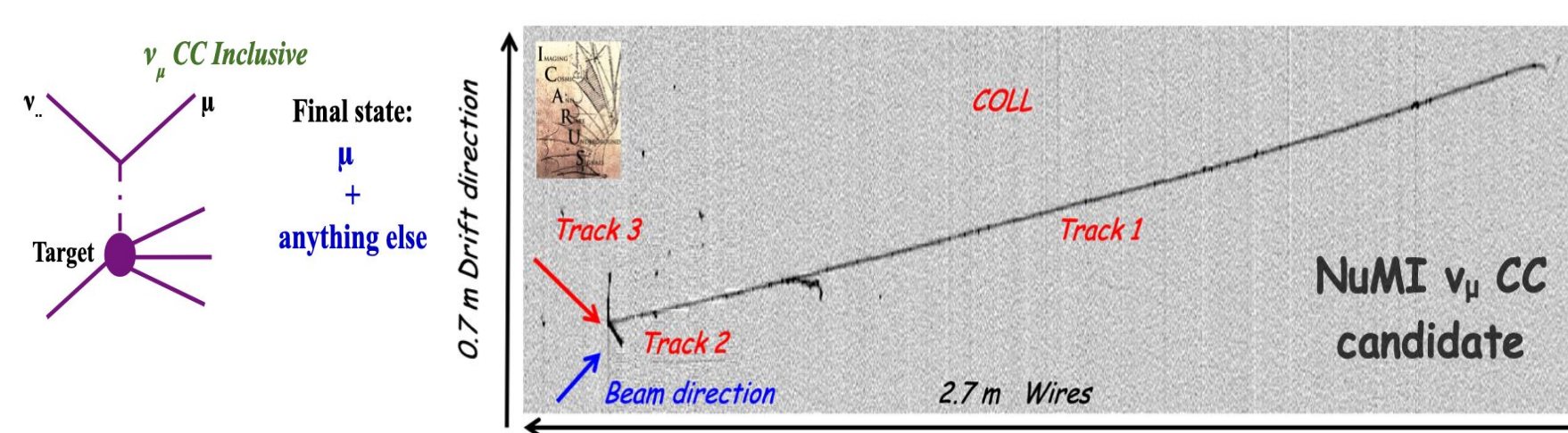


Figure 1 is a line plot titled "ICARUS Simulation Work In Progress". The y-axis is labeled "Fractional uncertainty" and ranges from 0.00 to 0.40. The x-axis is labeled " $\cos \theta_{\mu,p}$ " and ranges from -1.0 to 1.0. The plot shows several uncertainty components for the ICARUS simulation. The "Total uncertainty" (solid black line) is the highest, starting around 0.14 at  $\cos \theta_{\mu,p} = -1.0$  and increasing to about 0.25 at  $\cos \theta_{\mu,p} = 1.0$ . The "Syst." (dashed black) and "Stat." (dotted black) components are much lower, both around 0.02. The "Cross-section" (solid blue line) starts at 0.14, dips to 0.12, and then rises to 0.20. The "Flux" (solid orange line) starts at 0.04, rises to 0.07, and then falls to 0.05. The "GEANT4" (solid green line) starts at 0.03, rises to 0.05, and then falls to 0.04. The "Detector systematics" (solid red line) starts at 0.14, rises to 0.16, and then falls to 0.15. The text "Signal selection" is present in the plot area.

E

**V<sub>CC</sub> Inclusive analysis**



CC  $0\pi$  with 2 protons



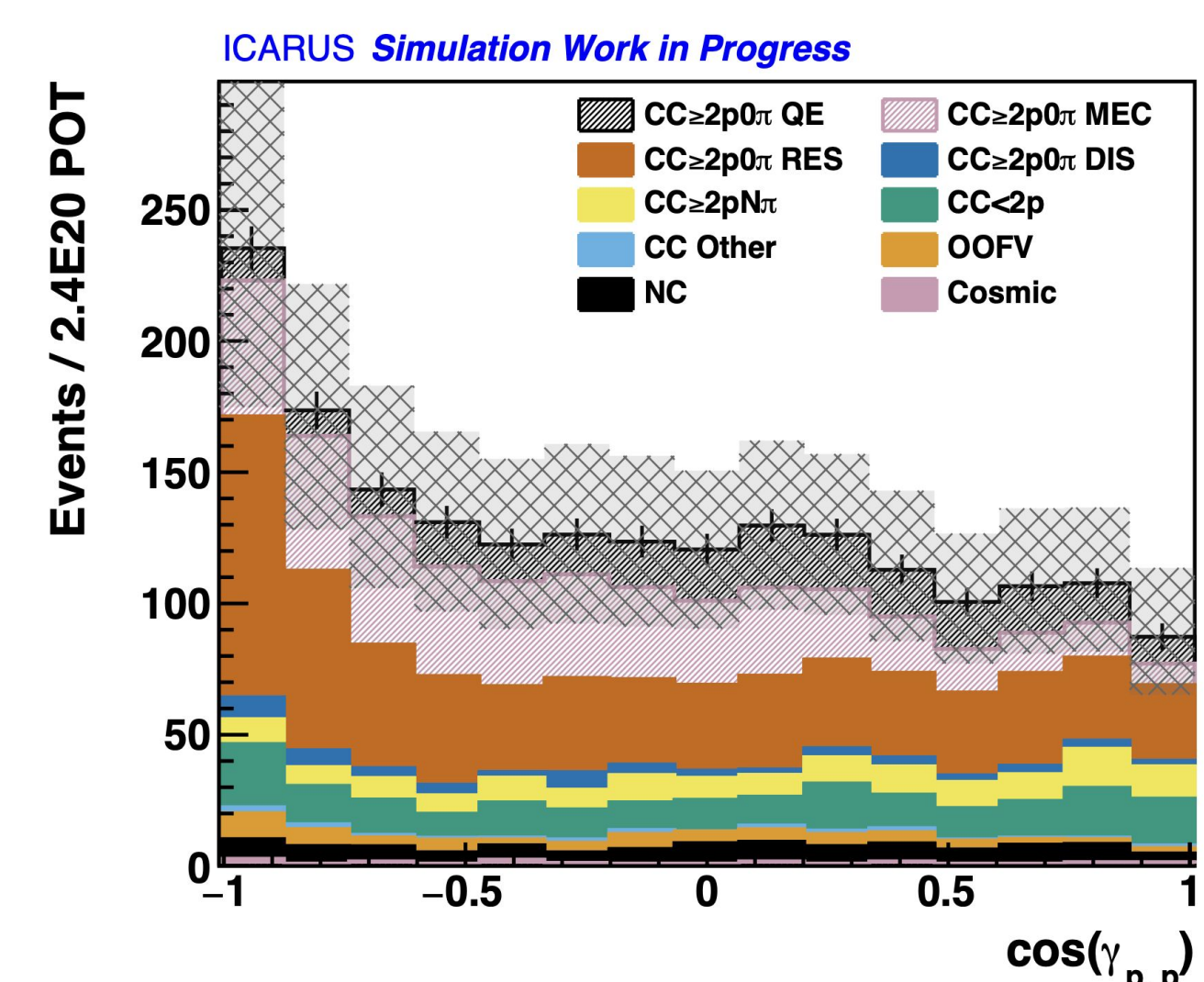
$v_\mu$  CC Inclusive event section

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

### Event selection for CC $0\pi 2p$

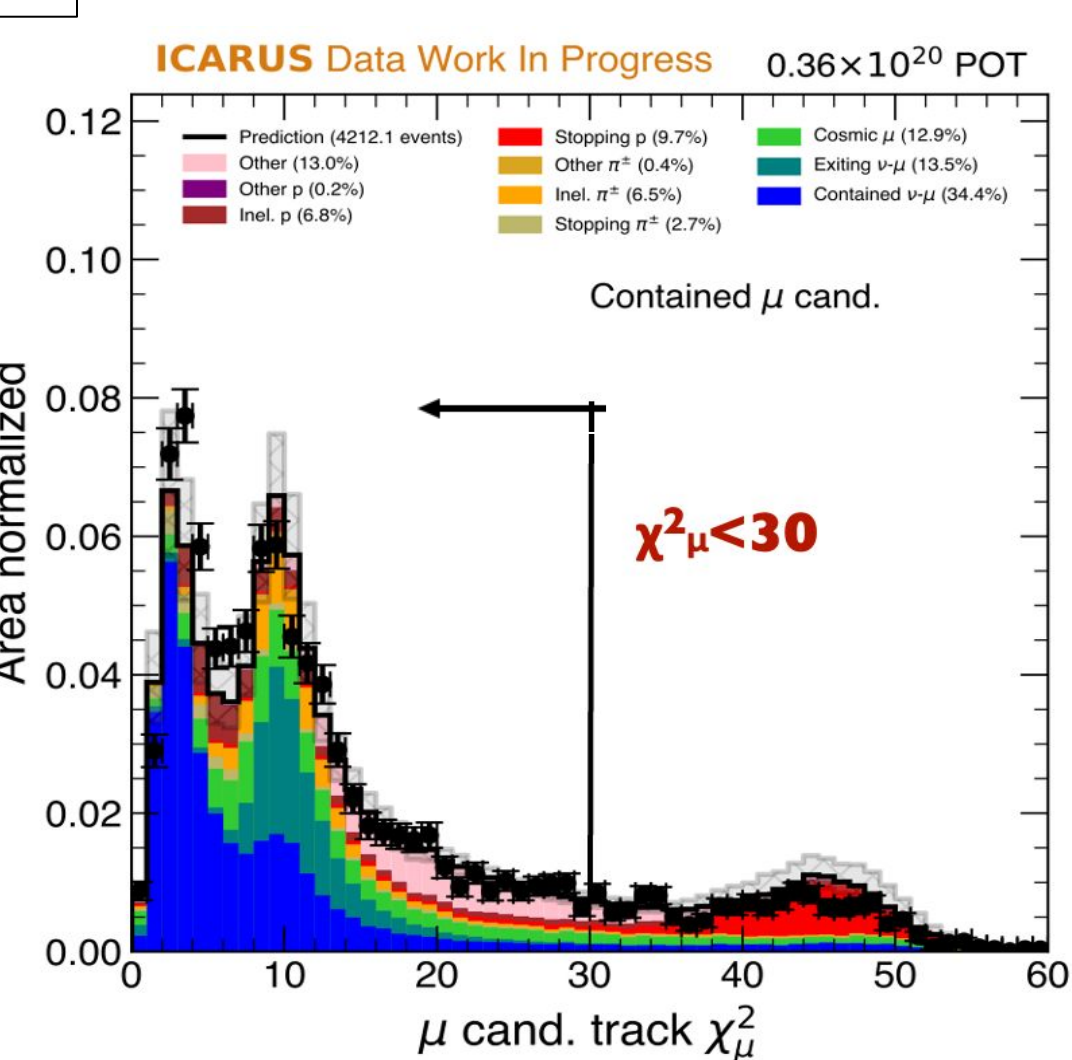
- Vertex in FV and not Clear Cosmic.
- All selected tracks tagged as primary and start  $< 10\text{cm}$  from the vertex
- **Muon candidate track:** at least 50 cm long
- **Proton candidate tracks:** **At least 2 of them, Reco momentum  $> 350\text{MeV}/c$**
- Hadronic system is fully contained

### 2protons opening angle distribution



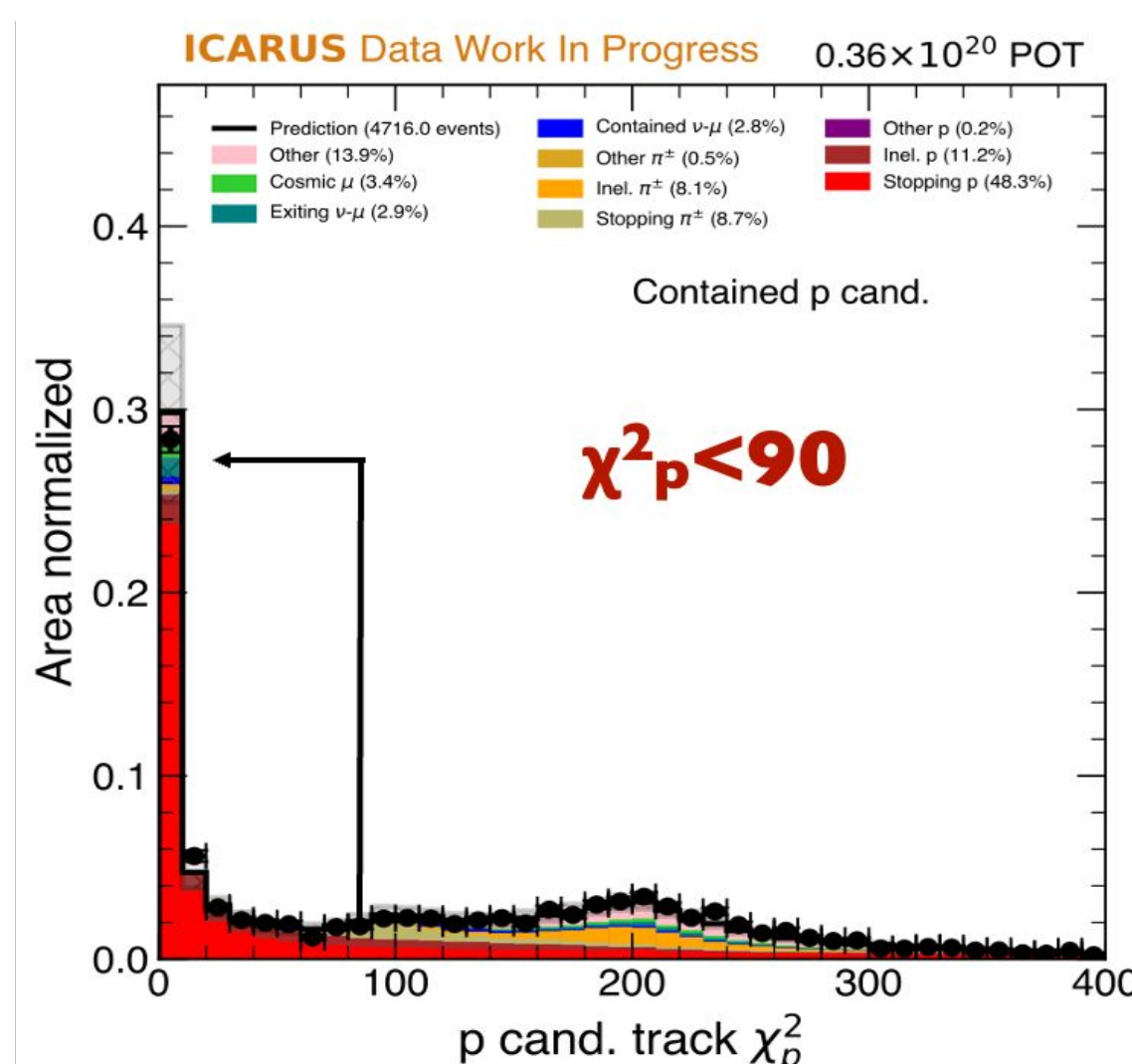
### Selecting events with muons

- 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
- $\chi^2$  PID scores consistent with a muon over a proton



### Selecting events with muons and protons

- Vertex in fiducial volume
- Events tagged as Pandora clear cosmics are rejected
- At least two primary tracks
- Muon track: **same as above**
- Proton track:  $\chi^2$  PID scores consistent with a proton, **proton momentum > 0.4 GeV/c and < 1 GeV/c, the longest such track is the leading proton candidate**



## 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 using neutrinos from NuMI beam in a similar kinematic regime as *DUNE*: Opportunity to test and constrain models to be used in *DUNE*.
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## 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] Acciarri, R., Adams, C., An, R. et al. Eur. Phys. J. C 78, 82 (2018)

## ACKNOWLEDGMENTS

