First Measurement of Sub-GeV ν_μ Charged-Current Coherent Pion Production on Argon in MicroBooNE

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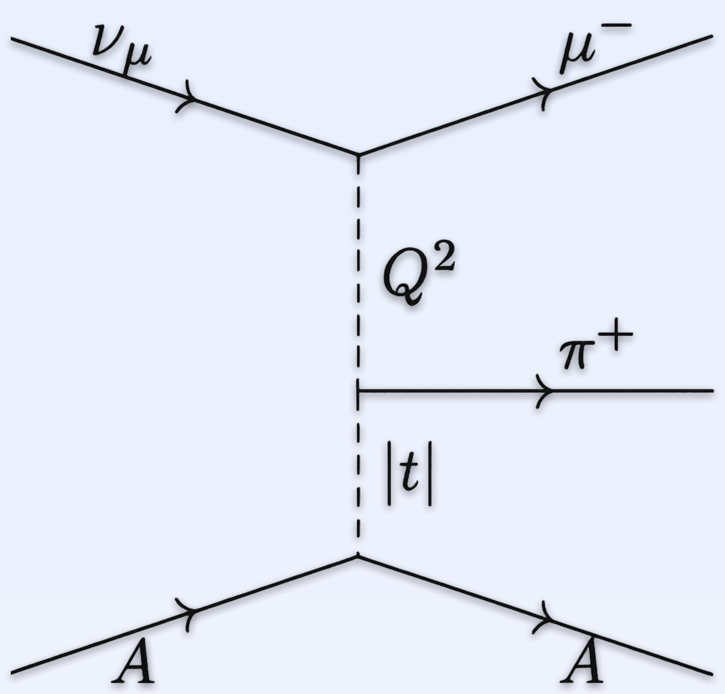
FERMILAB-POSTER-26-0118-PPD

1. Introduction

- In ν_μ induced charged-current coherent pion ($\nu_\mu CC\pi_c^+$) production, the neutrino interacts with the entire nucleus, which remains intact due to minimal momentum transfer.
- The resulting muon and pion emerge in the forward direction with a small opening angle between them.
- This process is rare, with only ~1 in 670 neutrino interactions in MicroBooNE predicted to be a $\nu_\mu CC\pi_c^+$ event.

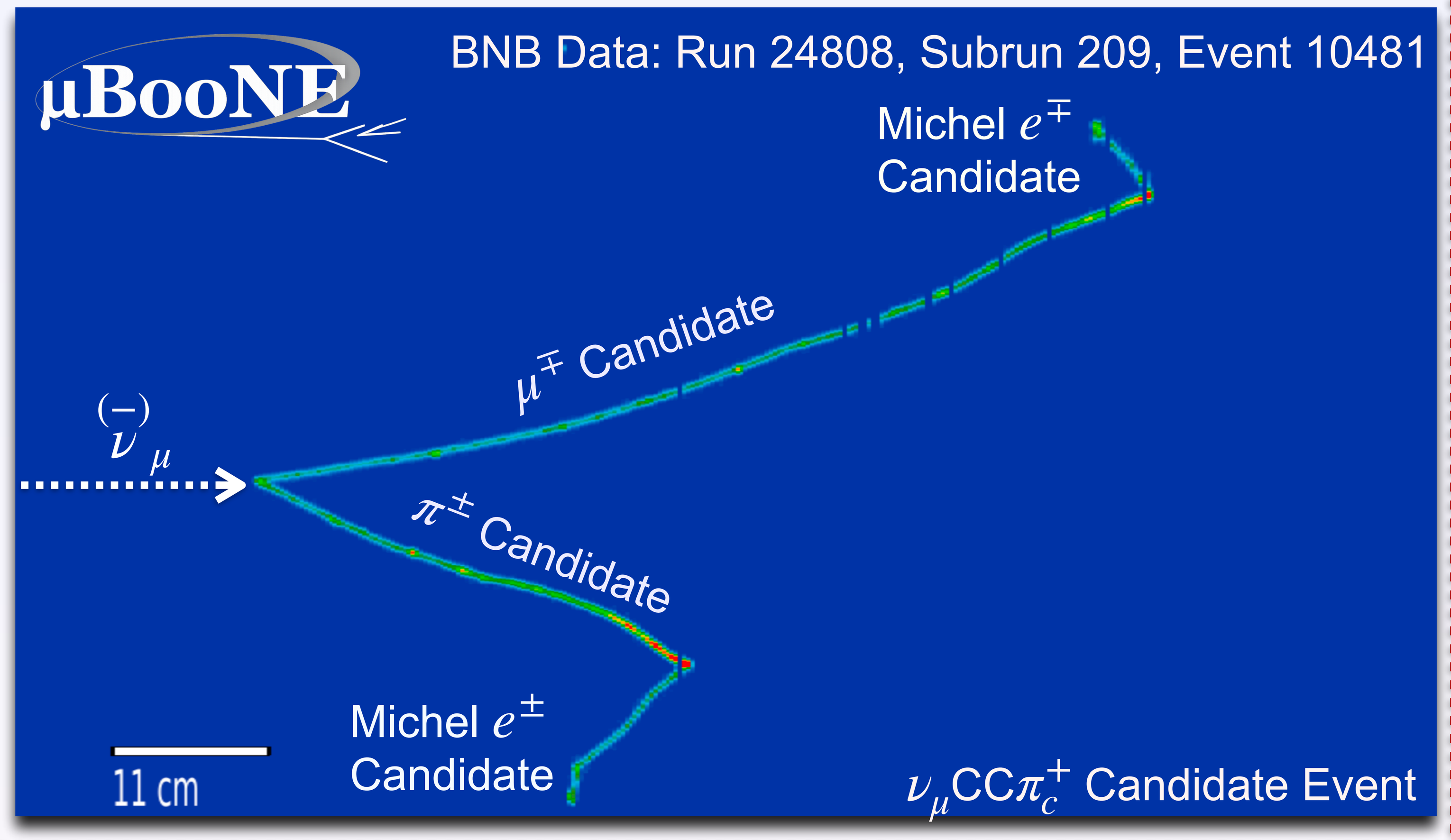


2. Motivation for this Study

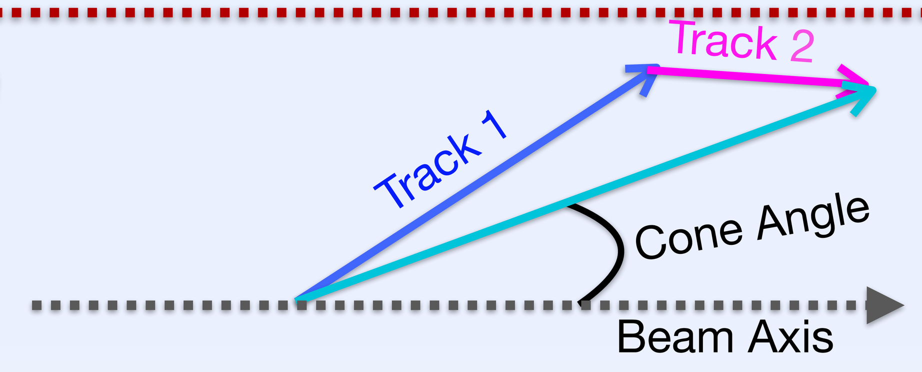
- Coherent pion production has relatively well-controlled theoretical uncertainties compared to other neutrino interaction channels.
- Potential as a "Standard Candle" for Neutrino Flux [1]

3. Signal Definition

- ν_μ charged-current interaction
- One Muon with momentum > 150 MeV
- One Pion with momentum > 150 MeV
- Zero π^0 or heavier mesons
- Muon-pion opening angle < 55°



4. Cone Angle

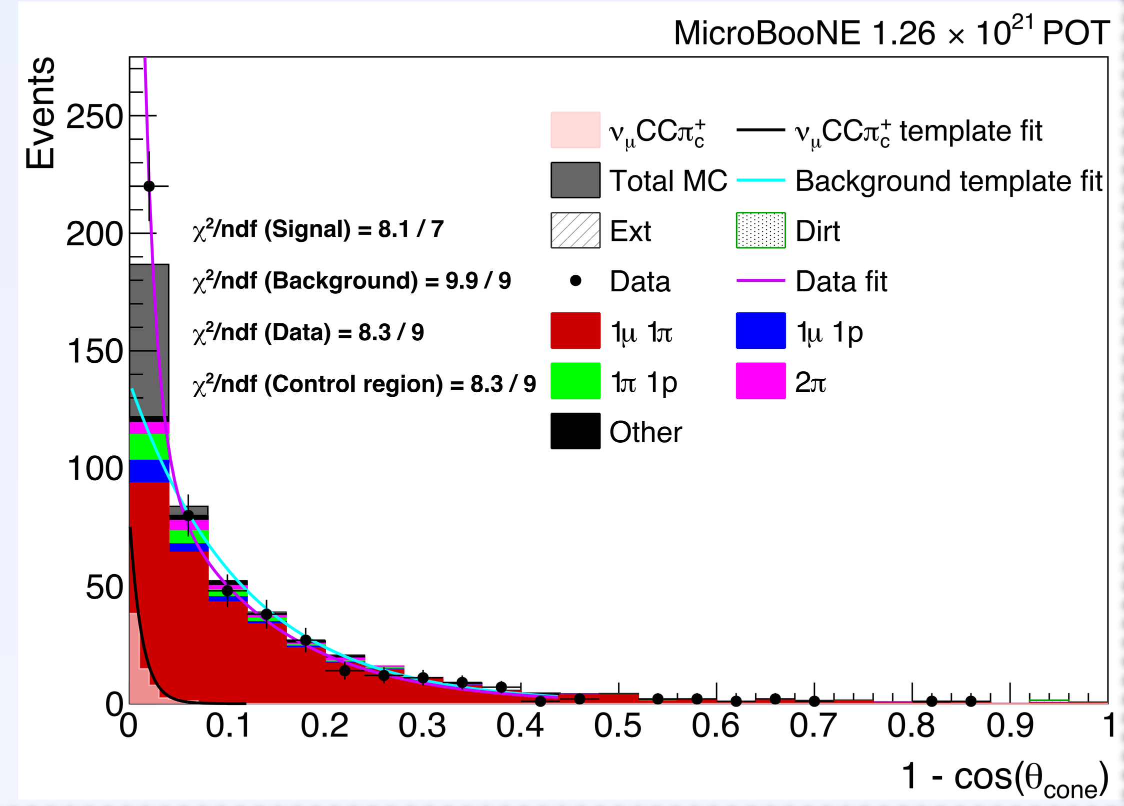


- The $\nu_\mu CC\pi_c^+$ signal produces a sharper forward peak than the background, enabling signal extraction through template fitting.
- MC signal and background samples are fit separately to determine the template shape parameters (p_1 and q_1).

$$Y_{signal}(\theta) = \frac{p_0 e^{p_1\theta}}{\int e^{p_1\theta}} \qquad Y_{background}(\theta) = \frac{q_0 e^{q_1\theta}}{\int e^{q_1\theta}}$$

- The data fit (Y_{data}) fixes these shapes and extracts the signal (S) and background (B) normalizations.

$$Y_{data} = S \cdot \frac{Y_{Signal}(\theta)}{\int Y_{Signal}\, d\theta} + B \cdot \frac{Y_{Background}(\theta)}{\int Y_{Background}\, d\theta}$$

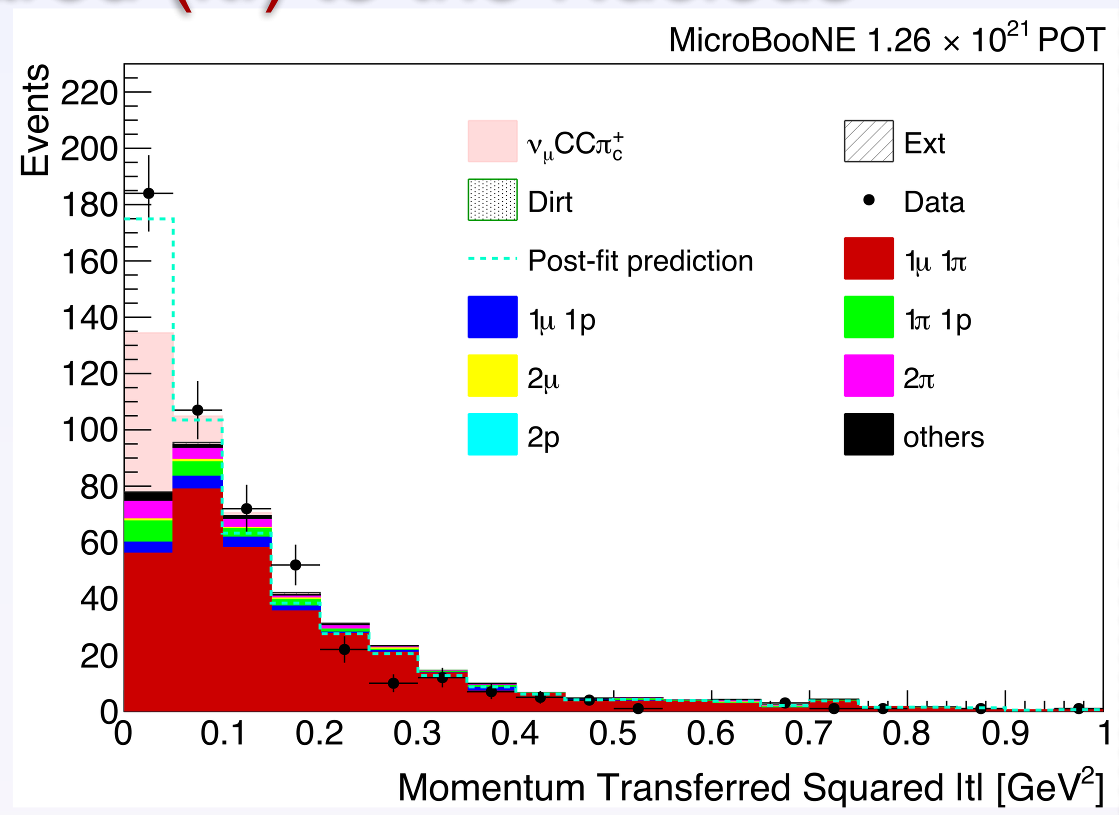


5. Momentum Transferred Squared (|t|) to the Nucleus

- $\nu_\mu CC\pi_c^+$ interactions are expected to occur at low |t|, corresponding to minimal momentum transfer to the nucleus.

$$|t| \equiv |(p_\nu - p_\mu - p_\pi)^2|$$

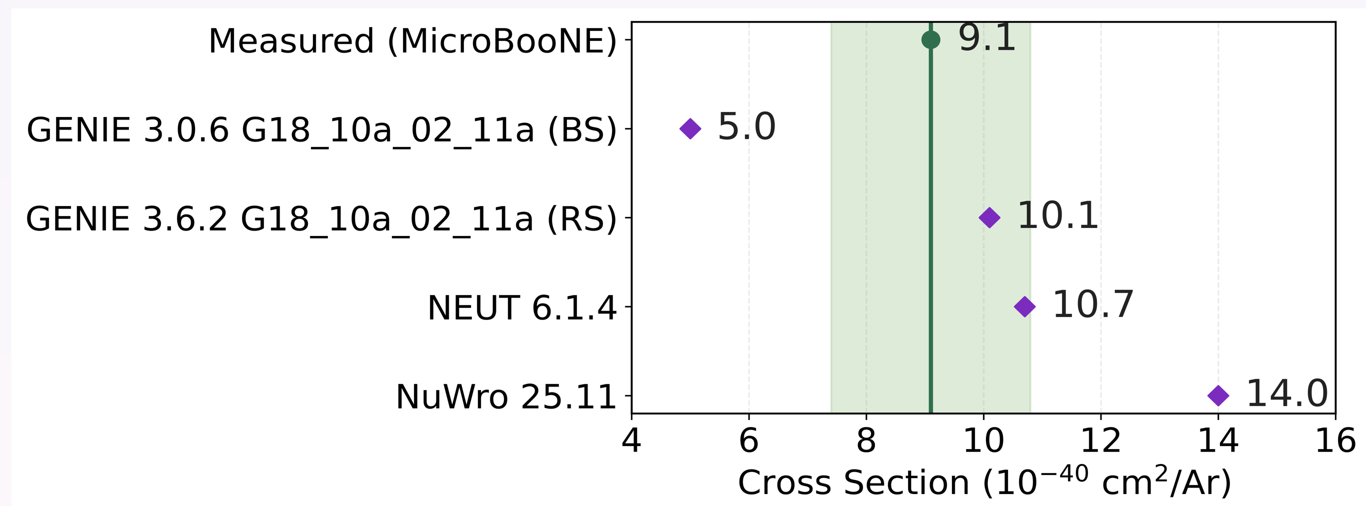
- The fitted signal and background normalizations extracted from the cone-angle analysis are used to predict the |t| distribution.



6. Results

- The total flux-integrated $\nu_\mu CC\pi_c^+$ production cross section on argon is measured [2] to be:

$$\sigma = (9.1 \pm 1.2_{stat} \pm 1.2_{syst}) \times 10^{-40}\ \mathrm{cm^2/Ar}$$



- The measured cross section is in good agreement with the NEUT and GENIE Rein-Sehgal (RS) predictions, while the GENIE Berger-Sehgal (BS) and NuWro predictions show increasing tension with the data.

7. References

[1] Jung, Pandey, Putnam, Schmitz, arXiv preprint (2025), arXiv:2502.02576v1 [hep-ph]

[2] First Measurement of Sub-GeV ν_μ Charged-Current Coherent Pion Production on Argon in MicroBooNE, arXiv preprint (2026), arXiv:2606.13613 [hep-ex]