Probing Resonant Interactions and Nuclear Effects with Neutral Pion Production in MicroBooNE

UC SANTA BARBARA

Fan Gao (fangao@ucsb.edu) on behalf of the MicroBooNE Collaboration (microboone_info@fnal.gov)

FERMILAB-POSTER-26-0117-PPD

Motivation

Neutral pion (π^0) production is:

- An important component of neutrino interaction energy determination in DUNE.
- A sensitive probe of resonant production and nuclear effects, providing important constraints on physics models in neutrino event generators.

Rev. Mod. Phys. 84, 1307 (2012)

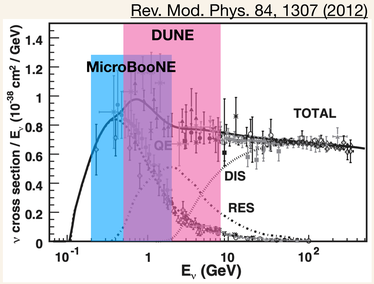
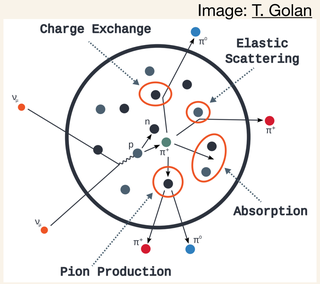
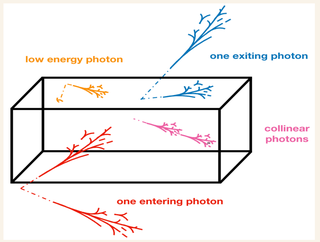


Image: T. Golan



- A key background to ν_e appearance signal for DUNE's precision oscillation measurements.
- A key background to a variety of BSM searches involving electromagnetic final states, especially those with single photons.



Overview

MicroBooNE has performed extensive measurements of π^0 production in neutrino interactions across multiple channels:

- Charged-current π^0 (**CCπ^0**) [1]

$\nu_\mu + Ar \rightarrow \mu^- + \pi^0 + 0\pi^\pm + X$

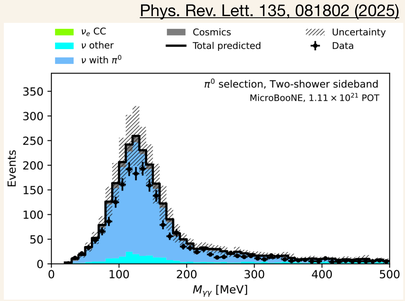
X: residual nucleus and any number of ejected protons or neutrons

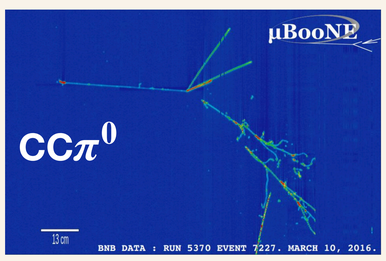
- Neutral-current π^0 (**NCπ^0**) [2]

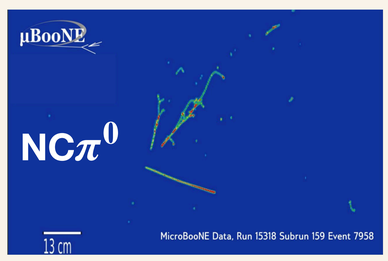
$\nu_l + Ar \rightarrow \nu_l + \pi^0 + \mathrm{N}p/0p + X$

$\mathrm{N}p/0p$: with/without protons in the final states

Phys. Rev. Lett. 135, 081802 (2025)



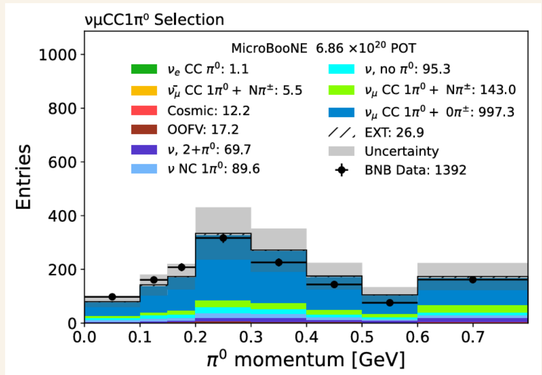




Data Samples

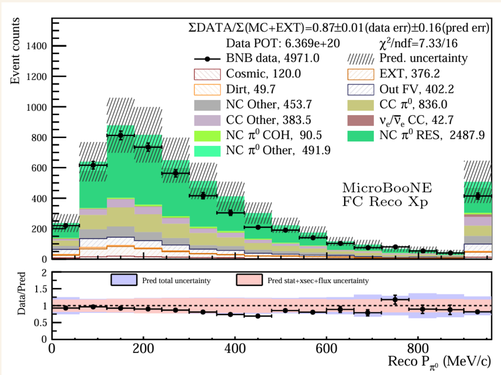
CCπ^0

- POT: 6.86 × 10^{20}
- Efficiency: 8.5%
  Purity: 69%
- First single-differential cross section of CCπ^0 production on argon:
  - π^0 kinematics
  - μ kinematics
  - μ-π^0 opening angle



NCπ^0

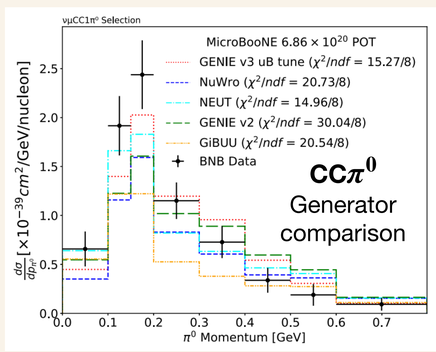
- POT: 6.37 × 10^{20}
- Efficiency: 35%
  Purity: 54%
- First double-differential cross section of NCπ^0 production on argon.
- Single-differential cross section in final states of Np/0p.
  - Proton kinetic energy threshold: 35 MeV

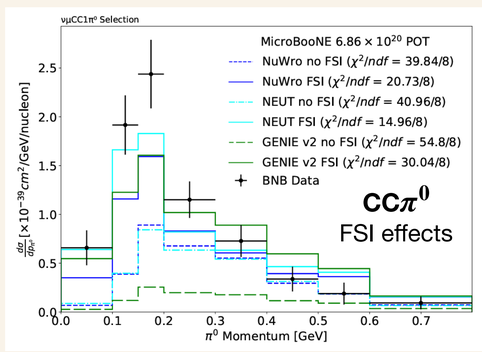


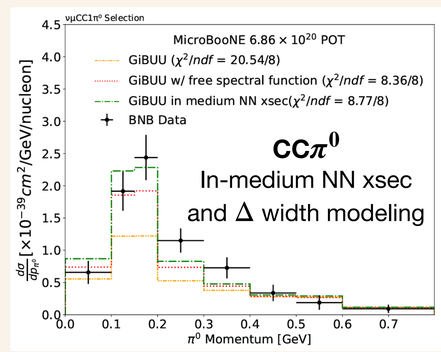
Results

CCπ^0:

- Generators underpredict the measured cross section in the 100-200 MeV π^0 momentum region.
- Sensitive to final-state interactions (FSI), particularly to in-medium nucleon-nucleon (NN) cross sections and Δ resonance width.



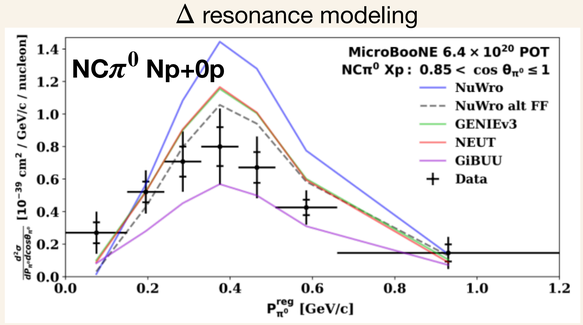




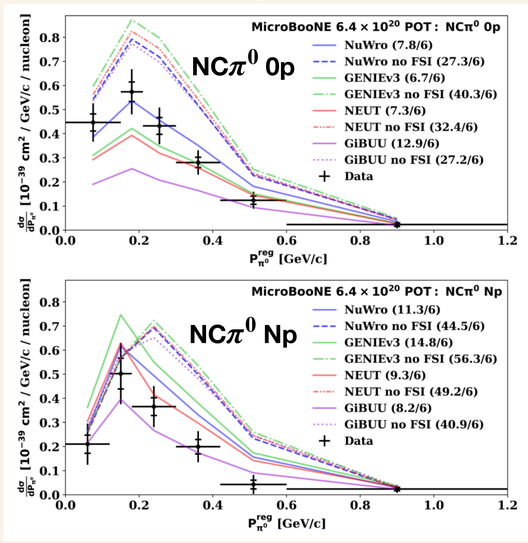
NCπ^0:

- Most generators overpredict the measured Np-channel cross section in the 0.2-0.5 GeV π^0momentum region.
- Sensitive to FSI.
- Provides sensitivity to Δ resonance modeling by comparing data to predictions with alternative form factors in NuWro.

Δ resonance modeling



Generator comparison + FSI effects



Outlook

Measure π^0 production using the full MicroBooNE dataset:

- ν_μCC1p1π^0 differential cross section in TKI variables (1.11 × 10^{21} POT) (Poster 145)
- ν_μCC1p1π^0 differential cross section in hadronic invariant mass W to probe higher order resonances (1.30 × 10^{21} POT) *(in development)*
- CCπ^0/NCπ^0 cross section ratio *(in development)*

[1] Phys. Rev. D 110, 092014 (2024)
[2] Phys. Rev. Lett. 134, 161802 (2025)

Fermilab · U.S. DEPARTMENT of ENERGY | Office of Science · SWISS NATIONAL SCIENCE FOUNDATION · NSF · Science & Technology Facilities Council · THE ROYAL SOCIETY · UK Research and Innovation · The NSF Institute for Artificial Intelligence and Fundamental Interactions