MicroBooNE

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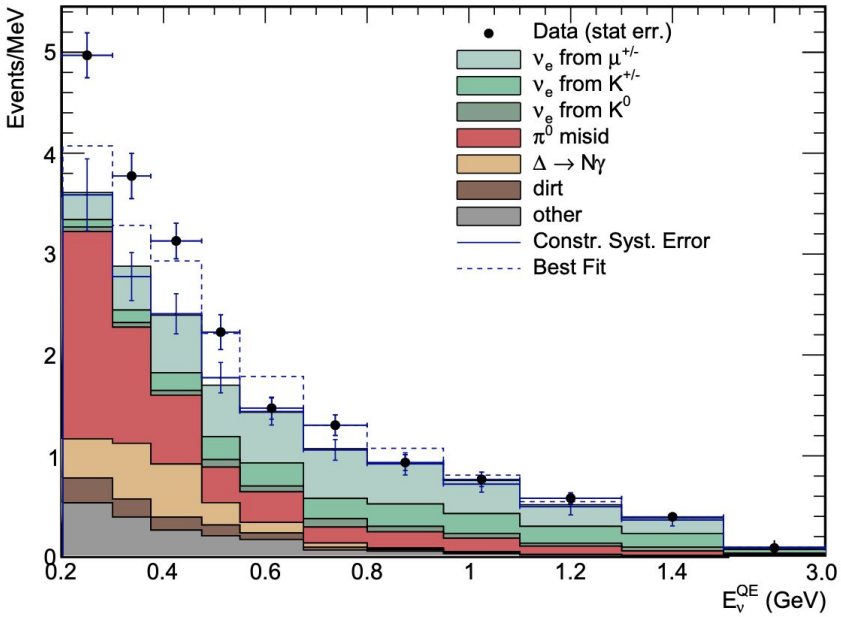
On behalf of the MicroBooNE Collaboration

June 13, 2019

U.S. DEPARTMENT OF ENERGY | Office of Science

Main Physics Goals

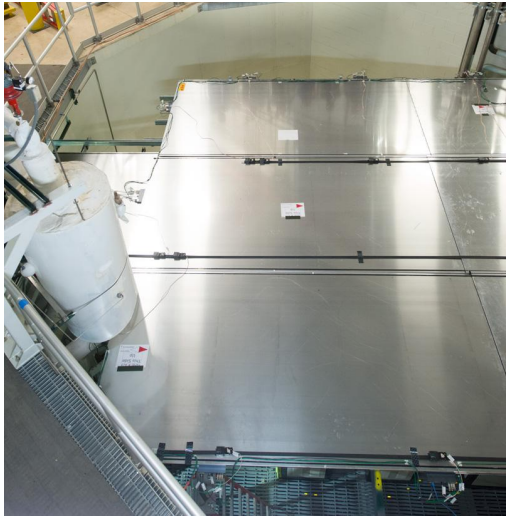
- Investigation of Low Energy Excess (LEE) seen by MiniBooNE
- Neutrino-Ar cross section measurements
- Beyond Standard Model (BSM) searches
- Detector R&D



Phys.Rev.Lett. 121 (2018) no.22, 221801

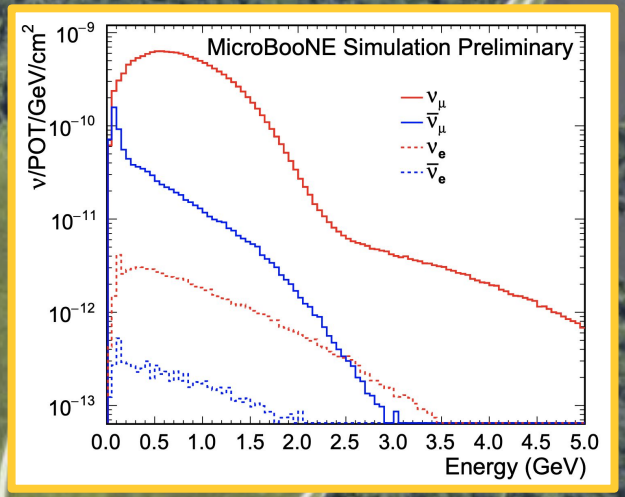
MicroBooNE

- 85 ton active mass, surface-based LArTPC
- 8192 wires, 32 PMTs
- UV laser calibration system
- Start taking data in Fall 2015
- Cosmic ray tagger installed in 2016-2017

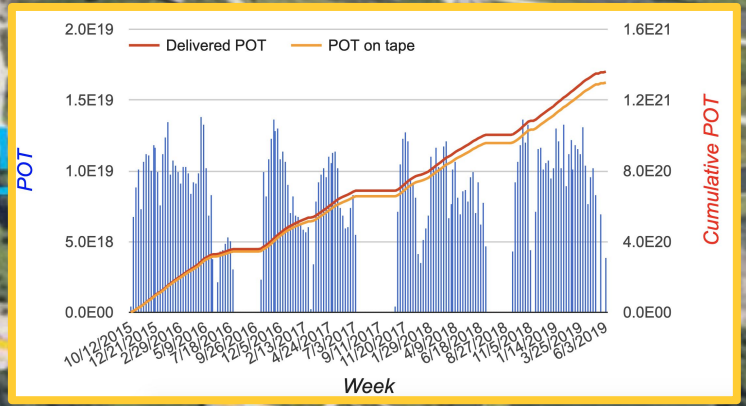


Neutrino Beams

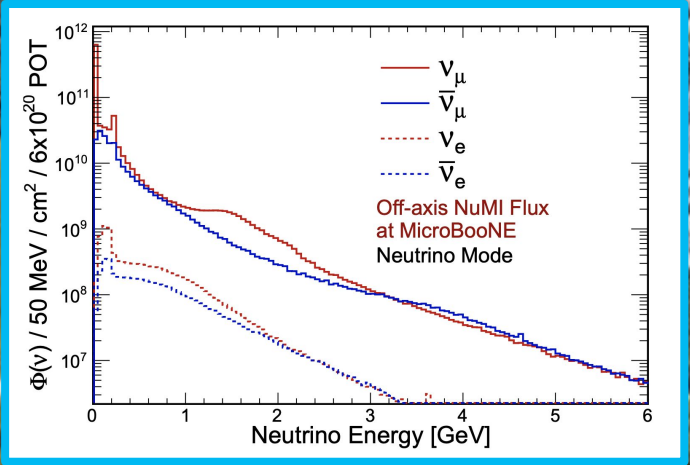
Neutrino Beams



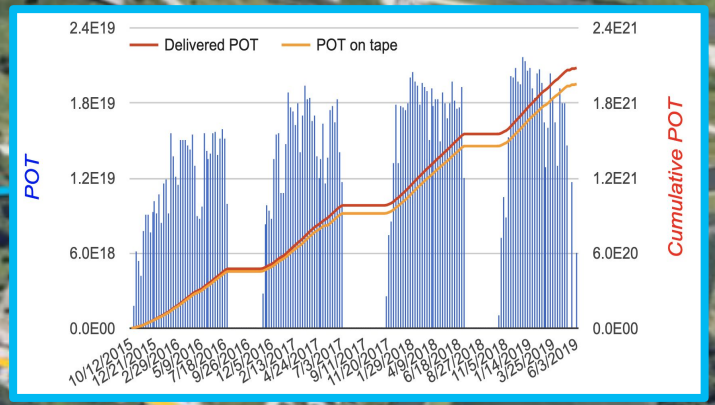
- MicroBooNE is 470 m from the target
- BNB ν_μ flux peaks at 0.8 GeV
- We have collected 1.3×10^{21} Protons On Target (POT) since October 2015
  - ~ 200,000 neutrino events



Neutrino Beams



- MicroBooNE also receives off-axis NuMI beam
- About 680 m from the target
- We have collected 2×10^{21} POT since October 2015
- Larger fraction of ν_e than BNB



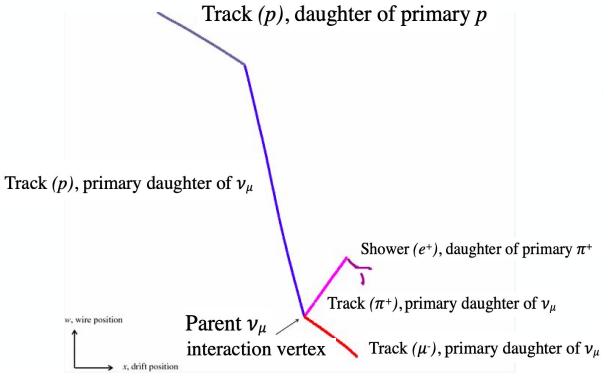
We would like to thank Fermilab for the excellent support of neutrino beams, detector operation and computing infrastructure !

Automated Reconstruction

3 independent reconstruction methods

Pandora

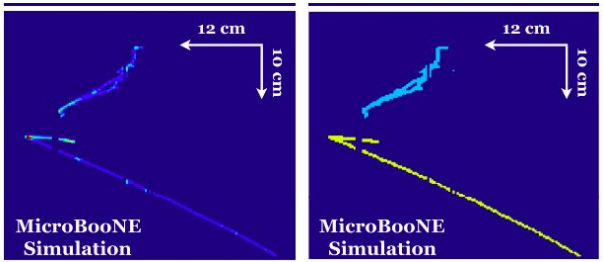
Pattern recognition in 2D to build 3D reconstruction



EPJC 78, 1, 82 (2018)

Deep Learning

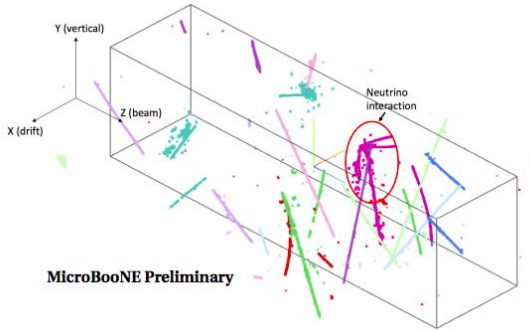
Use Convolutional Neural Network (CNN) to label tracks and showers from input pixel images



JINST 12, P03011 (2017)
PRD 99, 092001 (2019)

WireCell

Directly reconstruct 3D space points and perform clustering in 3D

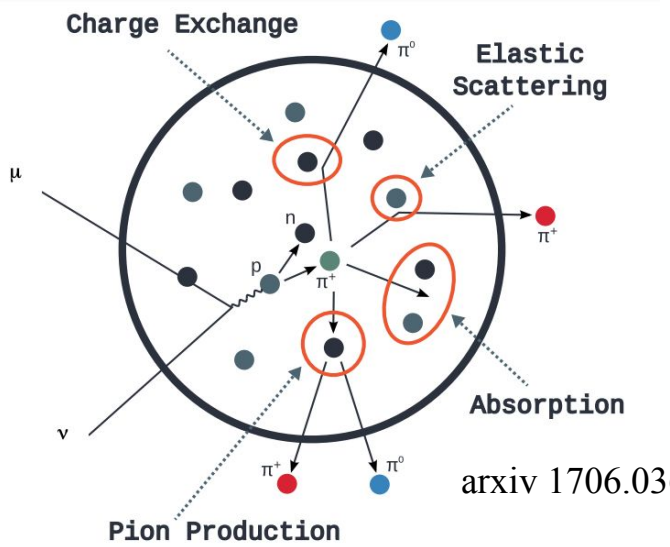


JINST 13 (2018) no.05, P05032
MICROBOONE-NOTE-1040-PUB

Neutrino Cross Section Measurements

- BNB (ν_μ)
  - Charged-current (CC) Inclusive
    arXiv:1905.09694, submitted to PRL
  - CC Quasi-Elastic (QE)
    arXiv:1812.05679, submitted to EPJC
  - CC N-Proton MICROBOONE-NOTE-1056-PUB
  - CC 2-Proton MICROBOONE-NOTE-1056-PUB
  - CC π^0 PRD 99, 091102(R) (2019)
  - CC π^+
  - CC Coherent Pion Production
  - CC Kaon Production
  - NC π^0
  - NC Elastic MICROBOONE-NOTE-1053-PUB
  - Track Multiplicity EPJC 79, 248 (2019)
  - ...

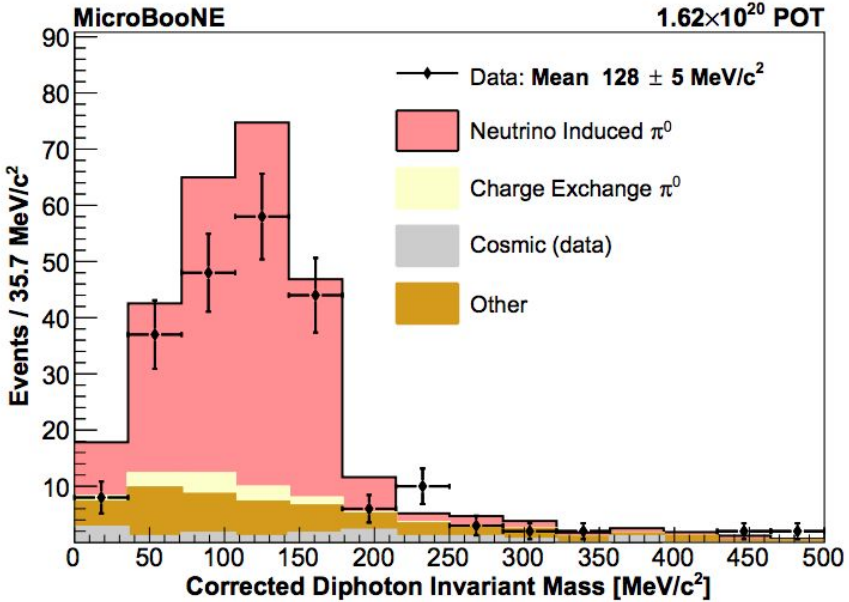
- NuMI
  - ν_e CC Inclusive MICROBOONE-NOTE-1054-PUB
  - ν_e CC 0-Pion
  - Kaon Decay-At-Rest (KDAR)



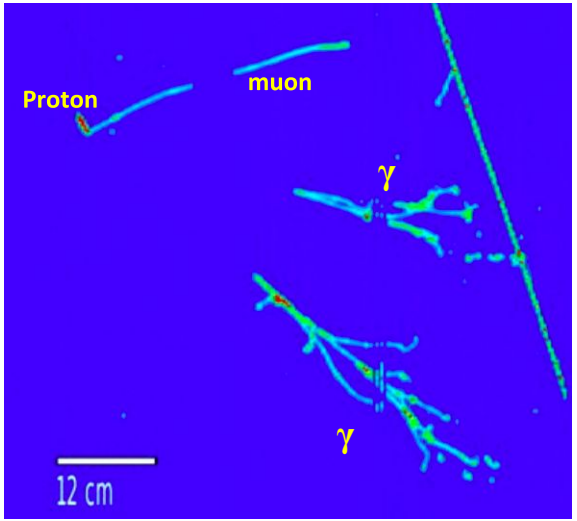
arxiv 1706.03621

Charged-Current Neutral Pion Production

- First absolute cross section measurement from MicroBooNE
- First π^0 cross section on argon to use fully automated shower reconstruction
- Challenging background of ν_e appearance
- Selected events reproduce expected π^0 invariant mass

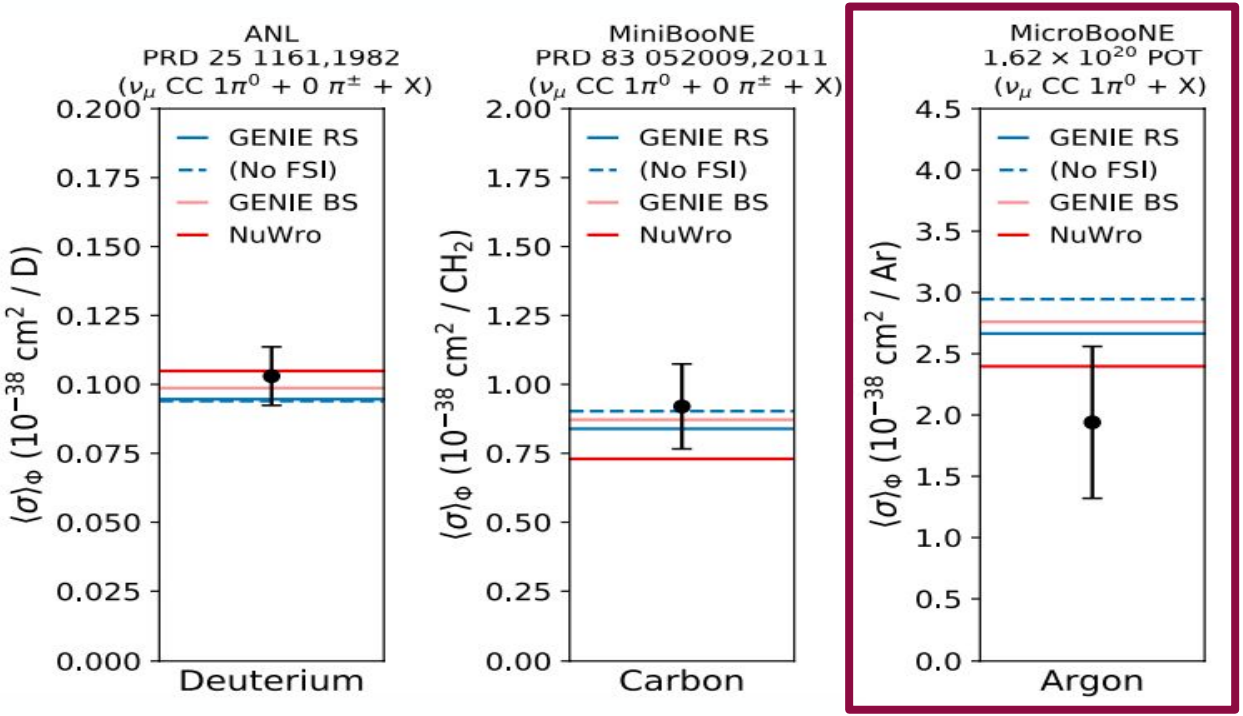


$$\nu_\mu + Ar \rightarrow \mu^- + \pi^0 + X$$



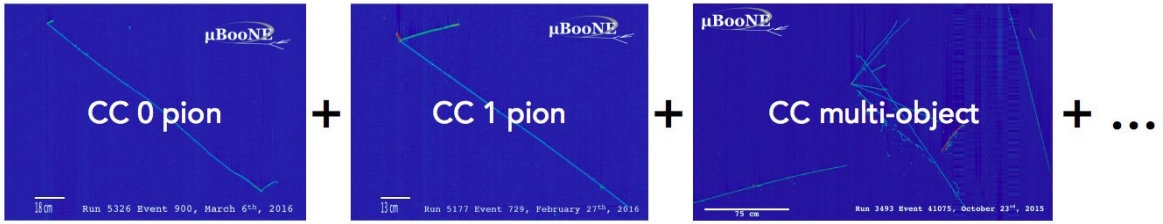
Charged-Current Neutral Pion Production

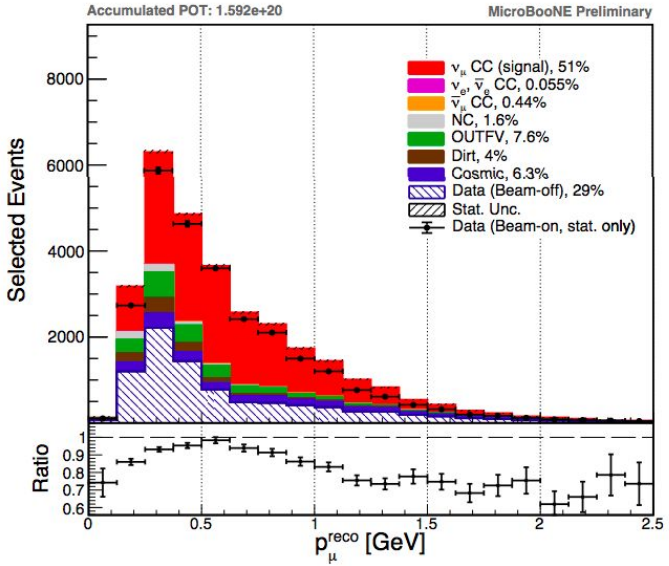
- Verified that the scaling used in models for larger nuclei is consistent with our data

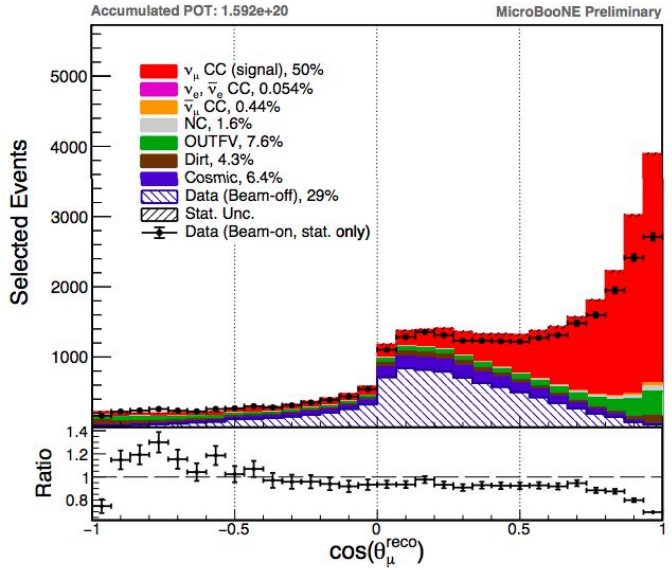


$$\langle\sigma\rangle_\Phi = 1.9 \pm 0.2\ (\text{stat}) \pm 0.6\ (\text{syst}) \times 10^{-38}\ \frac{\text{cm}^2}{\text{Ar}}$$

ν_μ CC Inclusive Cross Section

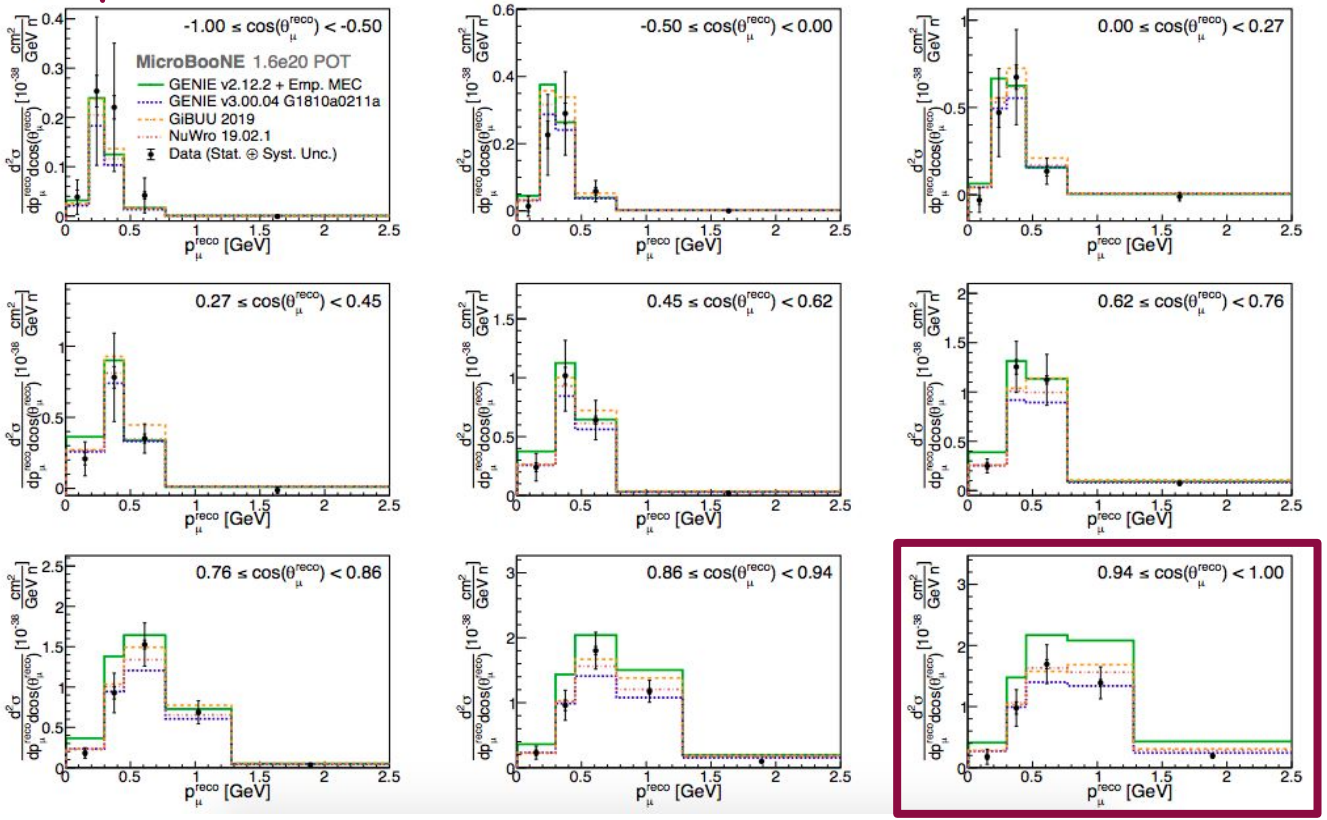






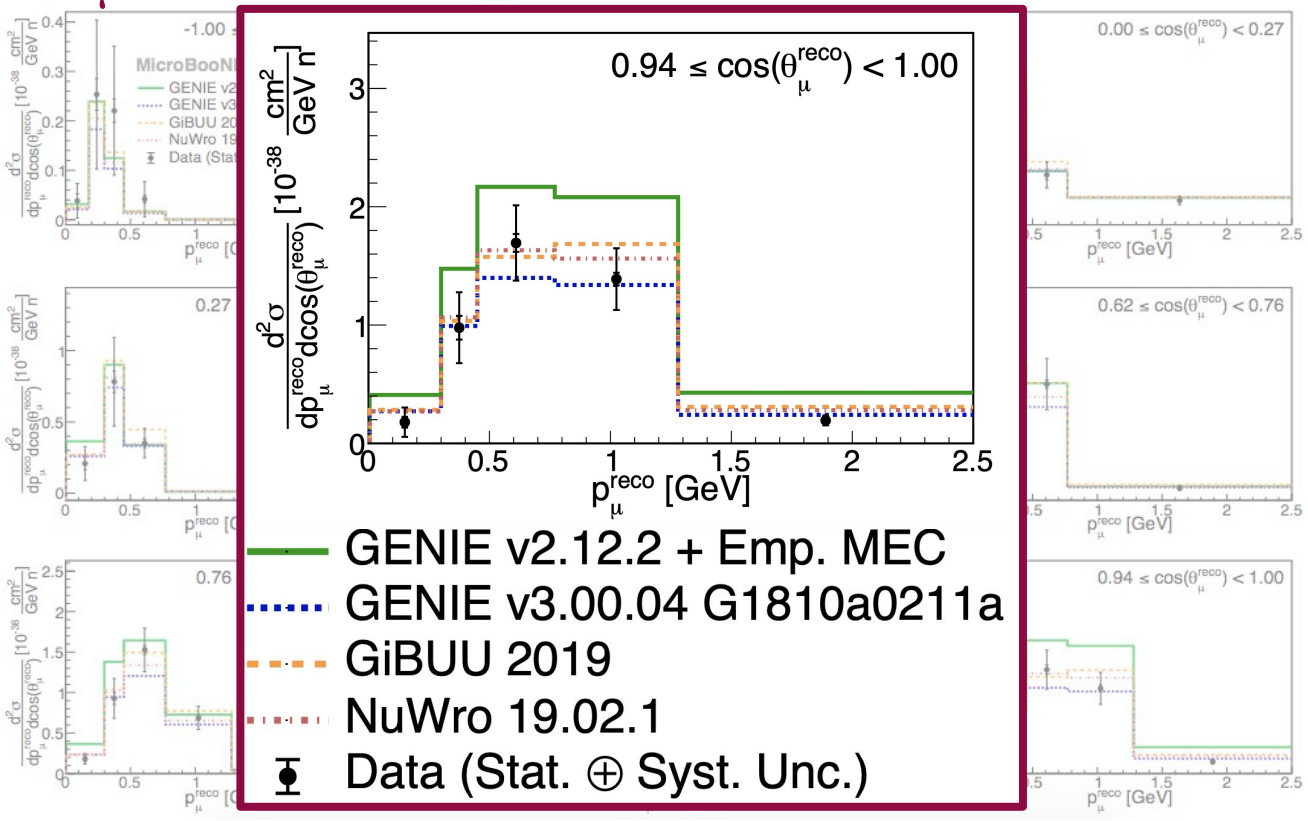
- Full momentum coverage
  - Using Multiple Coulomb Scattering (MCS) for momentum reconstruction
- Full angular coverage
- Cross section measured as a function of muon momentum and muon angle with respect to the beam direction

ν_μ CC Inclusive Cross Section



- First ν_μ-Ar double differential cross section measurement
- Compared with 4 different model sets
- Favors GENIE 3 G1810a0211a
- Uncertainty is dominated by:
  - Detector model (16.2%)
  - Beam flux (12.2%)
  - Out-of-FV neutrino modeling (10.9%)

ν_μ CC Inclusive Cross Section



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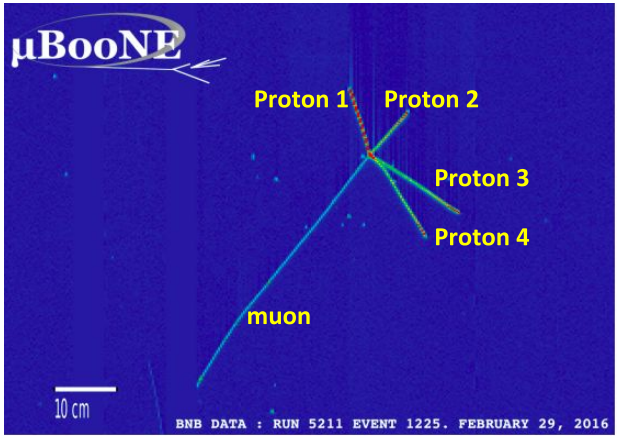
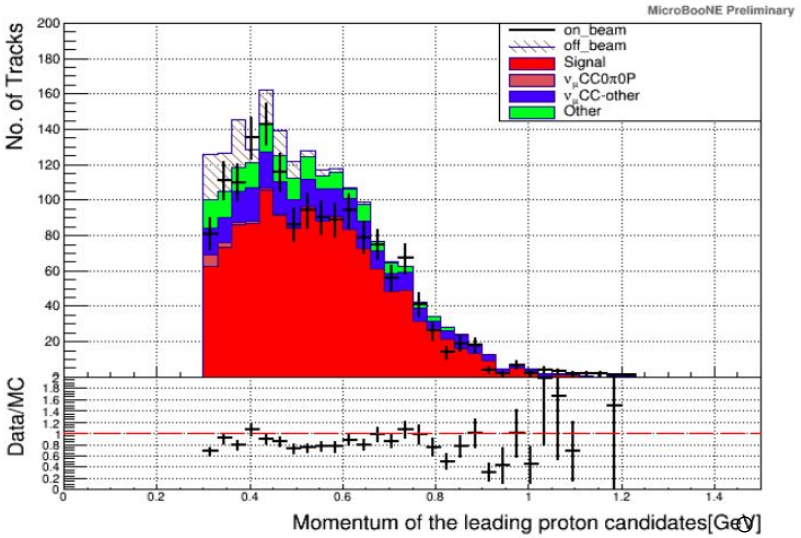
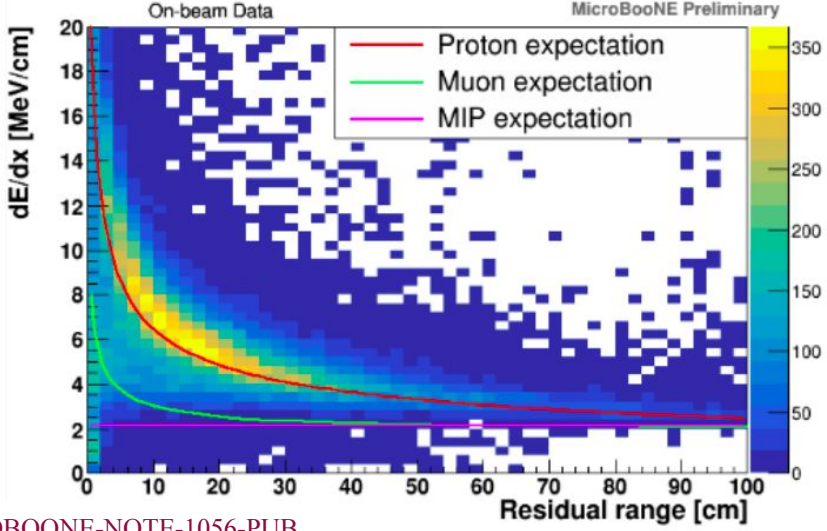
CC N-Proton Analysis

- Use CC Inclusive as pre-selection
- Final state has 1 muon and no pions
- Important for understanding Final State Interaction (FSI) and nucleon correlations
- Paper in preparation







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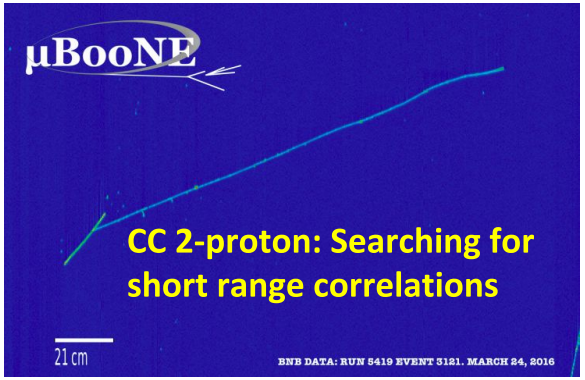
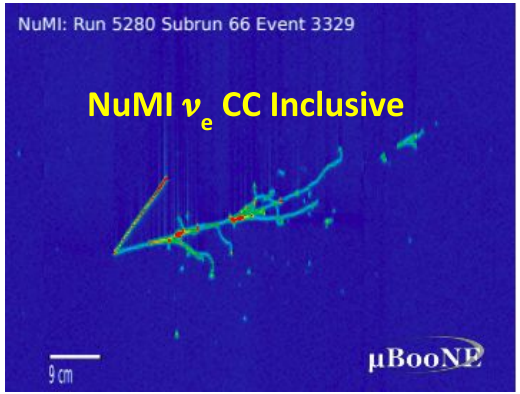
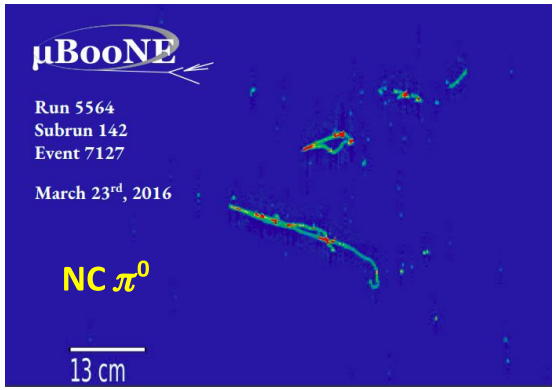
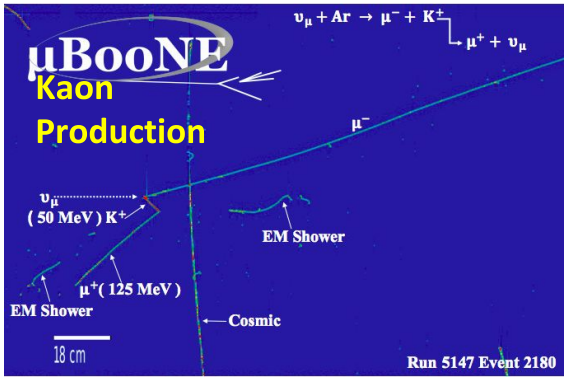
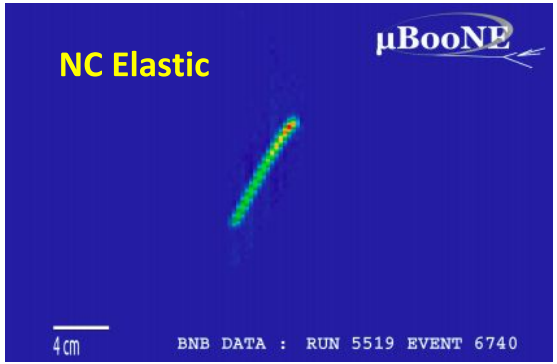
Other On-going Cross Section Measurements









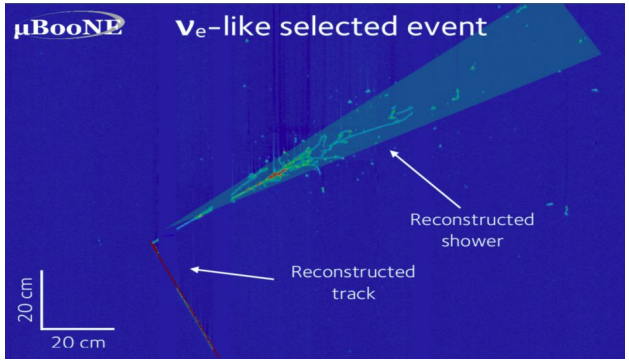


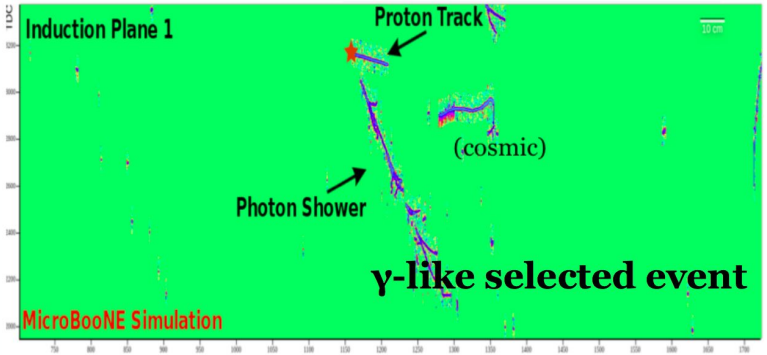
Please find all our latest results at

https://microboone.fnal.gov/public-notes/

Towards a Low Energy Excess Result

- Independent e-like and γ-like searches targeting two different models for the MiniBooNE excess

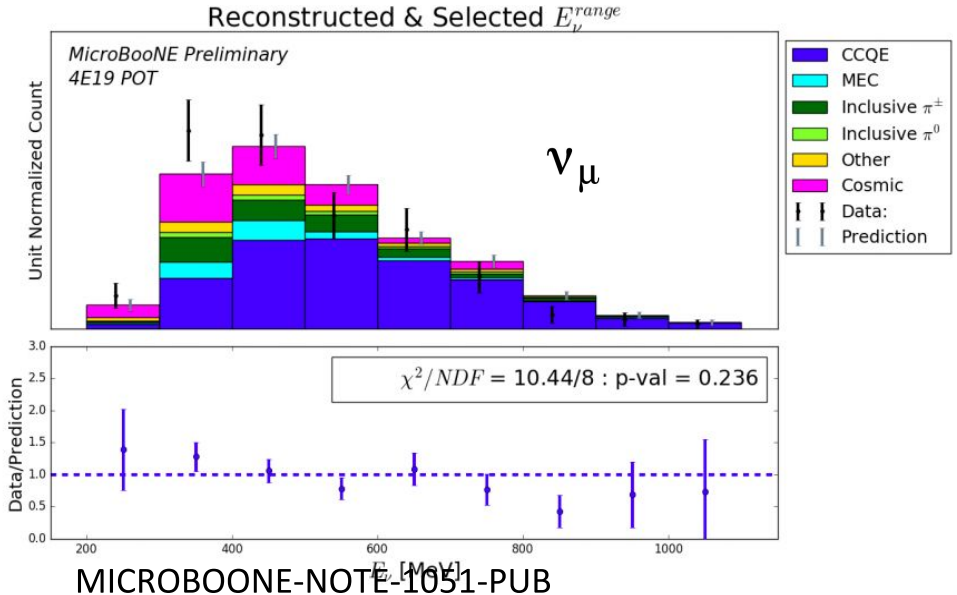




- e-like: 1e+X, 1e+1p, 1e+Np
- γ-like: 1γ+0p, 1γ+1p

Towards a Low Energy Excess Result

- Blind search - only a small fraction of first year data is open for developing analyses
- Simultaneous ν_e — ν_μ fit to constrain flux and cross section uncertainties
- Background constraints from data using sidebands



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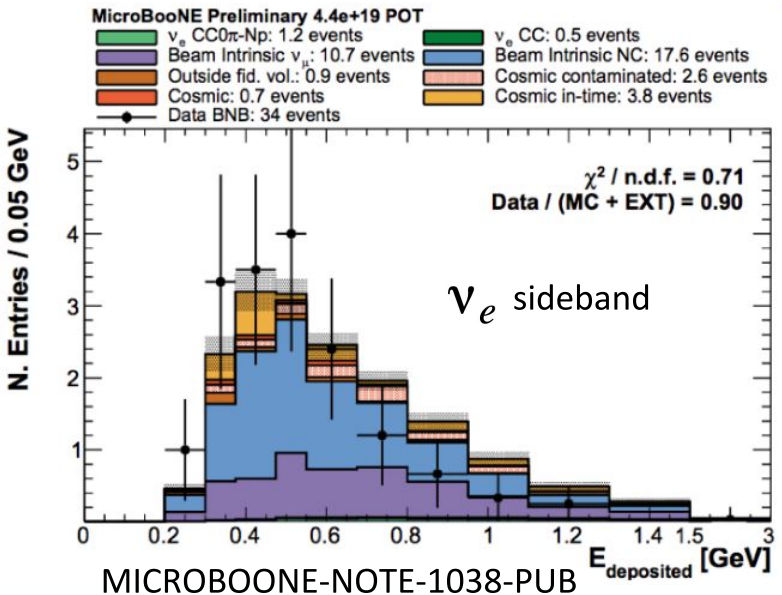


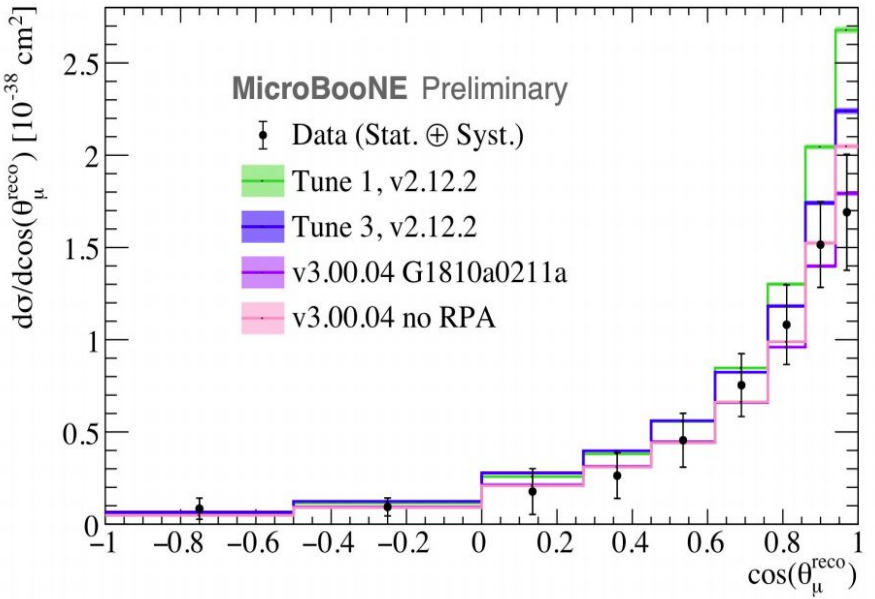
MICROBOONE-NOTE-1038-PUB

Towards a Low Energy Excess Result

- We have completed first iteration of ν_e and single photon selections

Towards a Low Energy Excess Result

- We have completed first iteration of ν_e and single photon selections
- We have been working on integrating analysis and simulation improvements in the last 12 months
  - GENIE 2 → GENIE 3
  - "2D Deconvolution"
  - Integrated calibrations into detector simulation
  - Integrating cosmic ray tagger into analyses



Summary

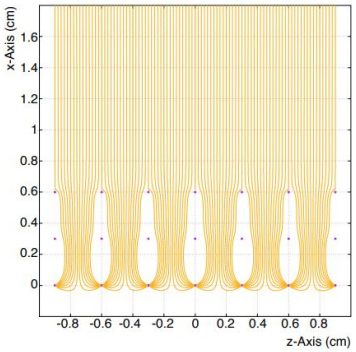
- MicroBooNE has been running smoothly since October 2015
- We have collected 1.3×10^{21} POT BNB data
- We have published our first neutrino cross sections
- Pioneering work on calibrations, simulations, neutrino event reconstruction and analysis which is paving the way for neutrino measurements in liquid argon
- **Stay tuned for more exciting results from MicroBooNE!**

Thank you!

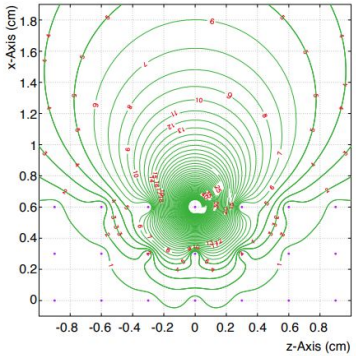
Backup

ν_μ CC Inclusive Cross Section

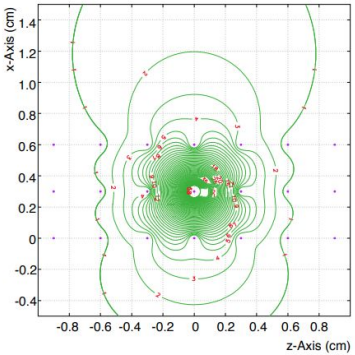
JINST 13 (2018) no.07, P07006



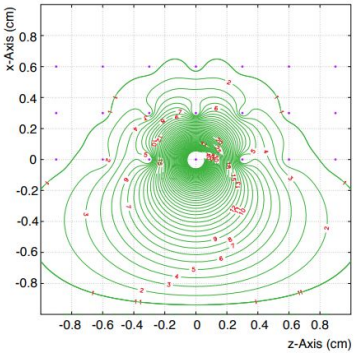
(a) Electron drift paths.



(b) Weighting potential on a U wire.



(c) Weighting potential on a V wire.



(d) Weighting potential on a Y wire.

Systematic Sample	Relative Uncertainty [%]
Induced Charge Effect	13.0
Light Yield Model	4.7
Channel Saturation	4.3
Space Charge Effect	3.7
TPC Visibility	3.7
Electron Lifetime	2.9
Misconfigured Channels	1.8
Longitudinal Diffusion	1.7
Transverse Diffusion	1.6
PE Noise	0.4
Wire Response	0.2
Wire Noise	0.1
Electron Recombination	0.1

Charged-Current Neutral Pion Production