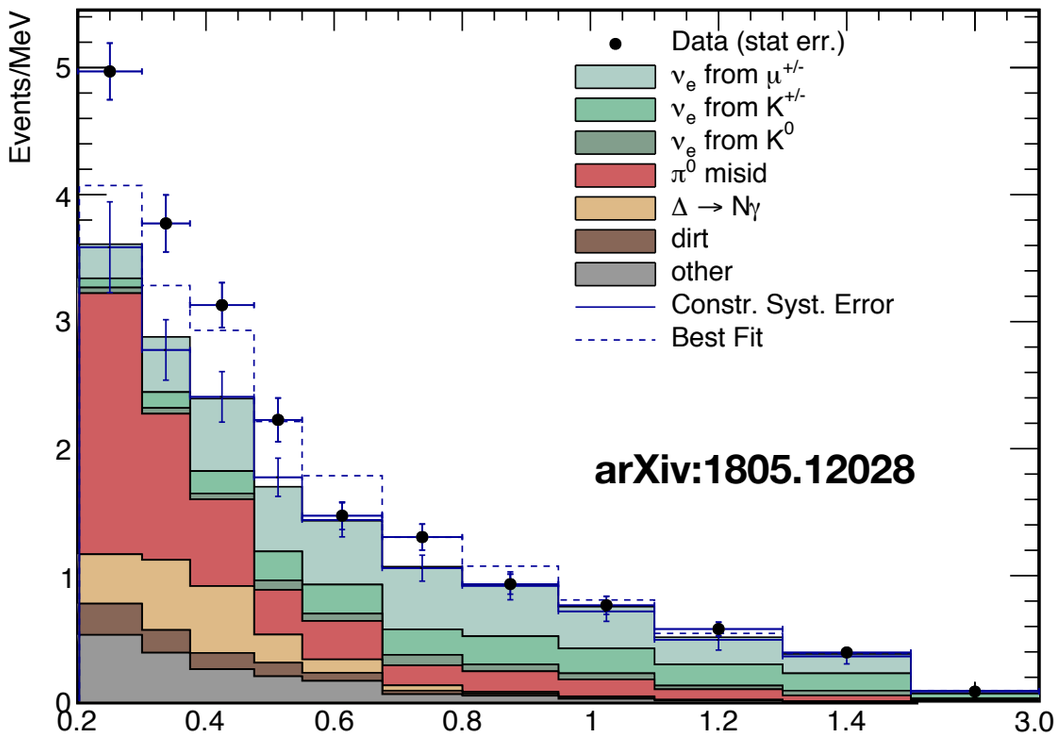
Recent Results from MicroBooNE

Wei Tang (UTK)

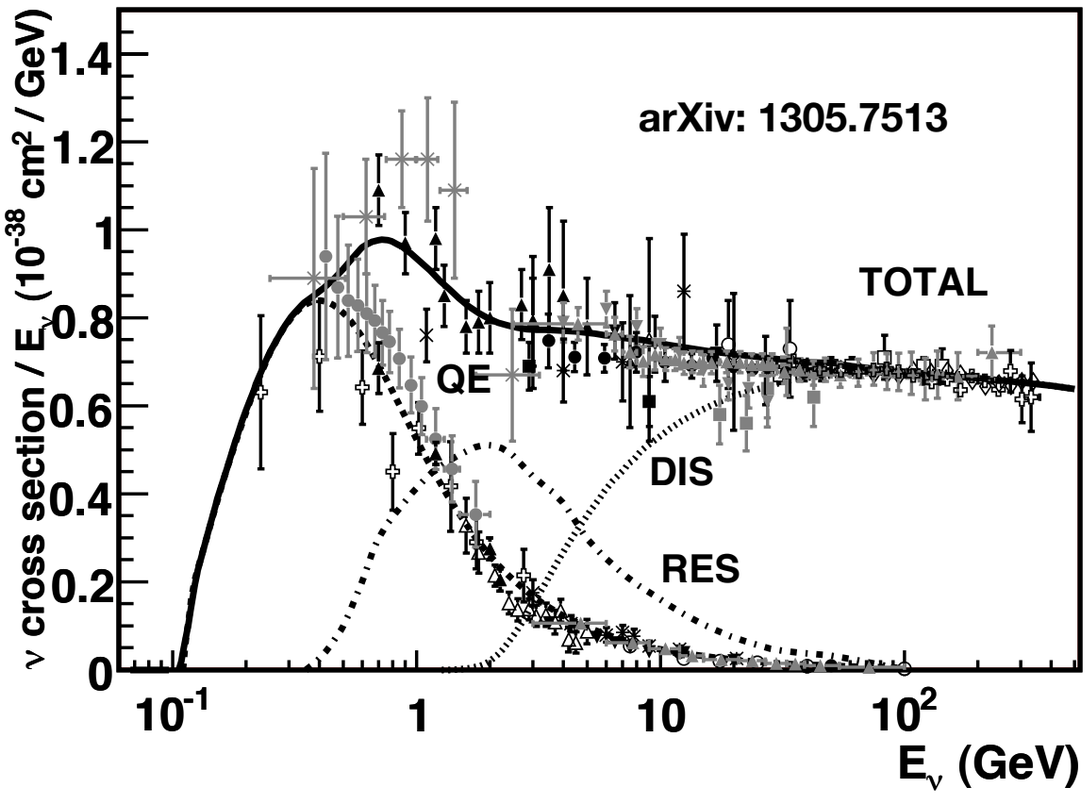
On Behalf of the MicroBooNE Collaboration

The 15th International Workshop on Tau Lepton Physics, Amsterdam, Netherlands, September, 2018

The Main Goals of the MicroBooNE



- To study short baseline neutrino oscillation, primarily the low energy electron-like excess (LEE) events observed by the MiniBooNE experiment
  - Is the LEE due to sterile neutrino(s) oscillations or backgrounds unpredicted by the MiniBooNE

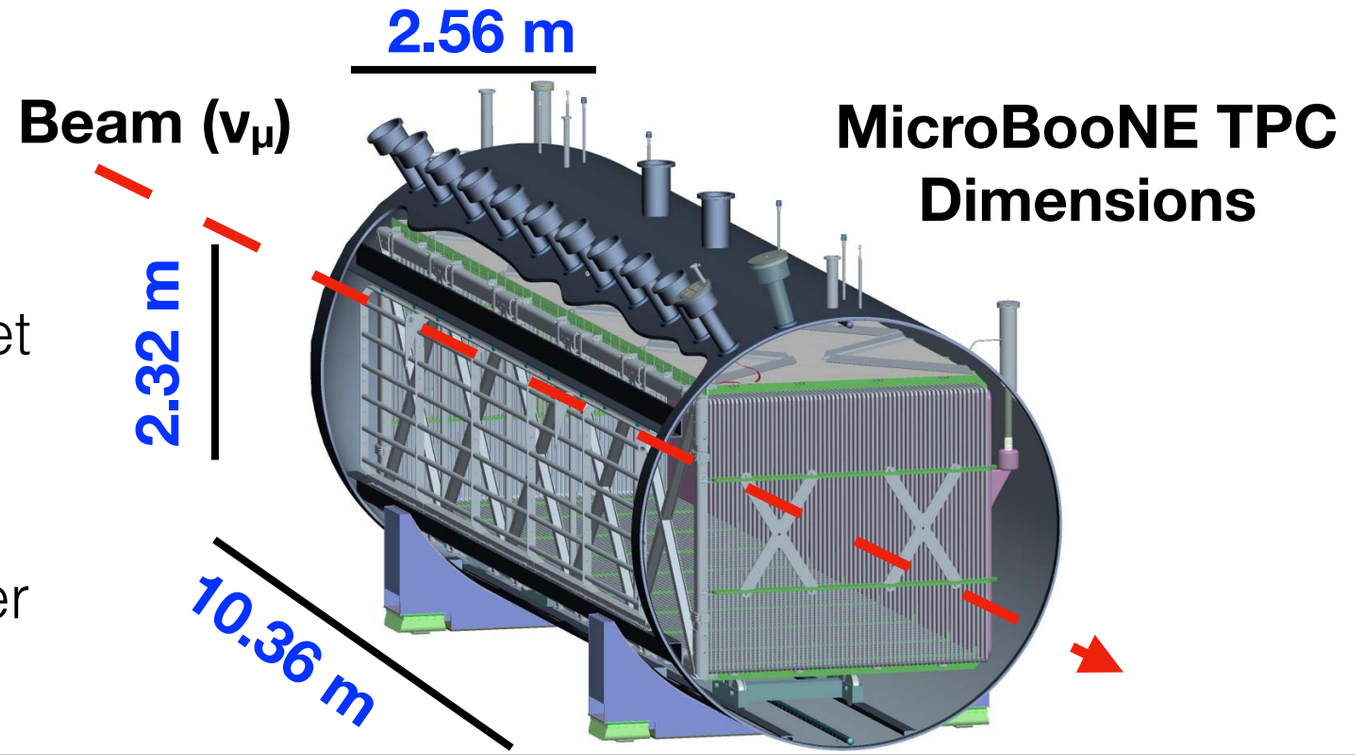


- High statistics precision measurement of ν – Ar cross sections ~ 1 GeV
  - Critical both for MicroBooNE and future LArTPC oscillation experiments

- Supernova searches and proton decay background studies

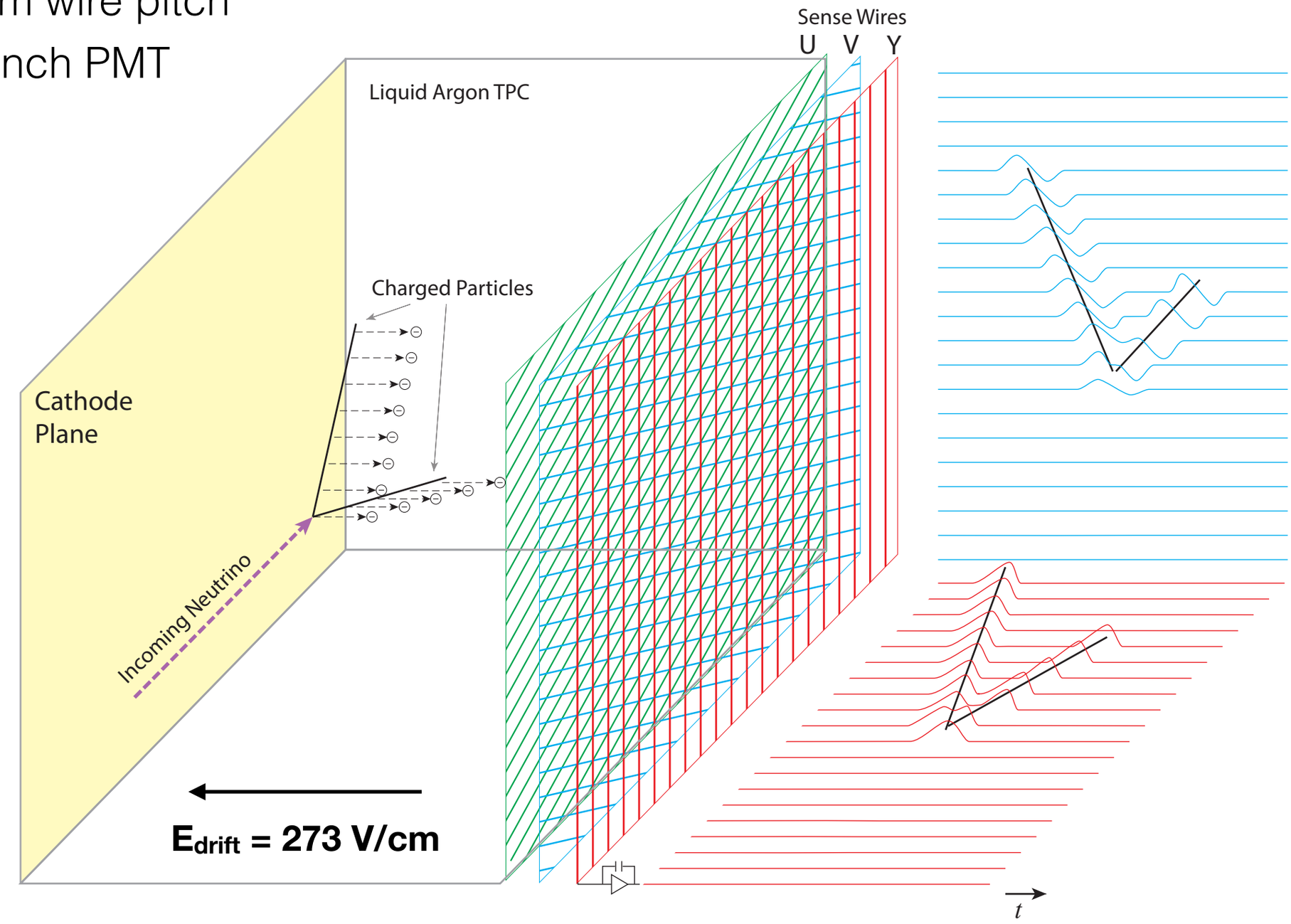
The MicroBooNE Experiment

- Accelerator ν experiment
- 8 GeV proton beam on beryllium target
- 800 MeV ν energy on average
- 470 m baseline
- Liquid Argon Time Projection Chamber (LArTPC) with 85 ton active mass

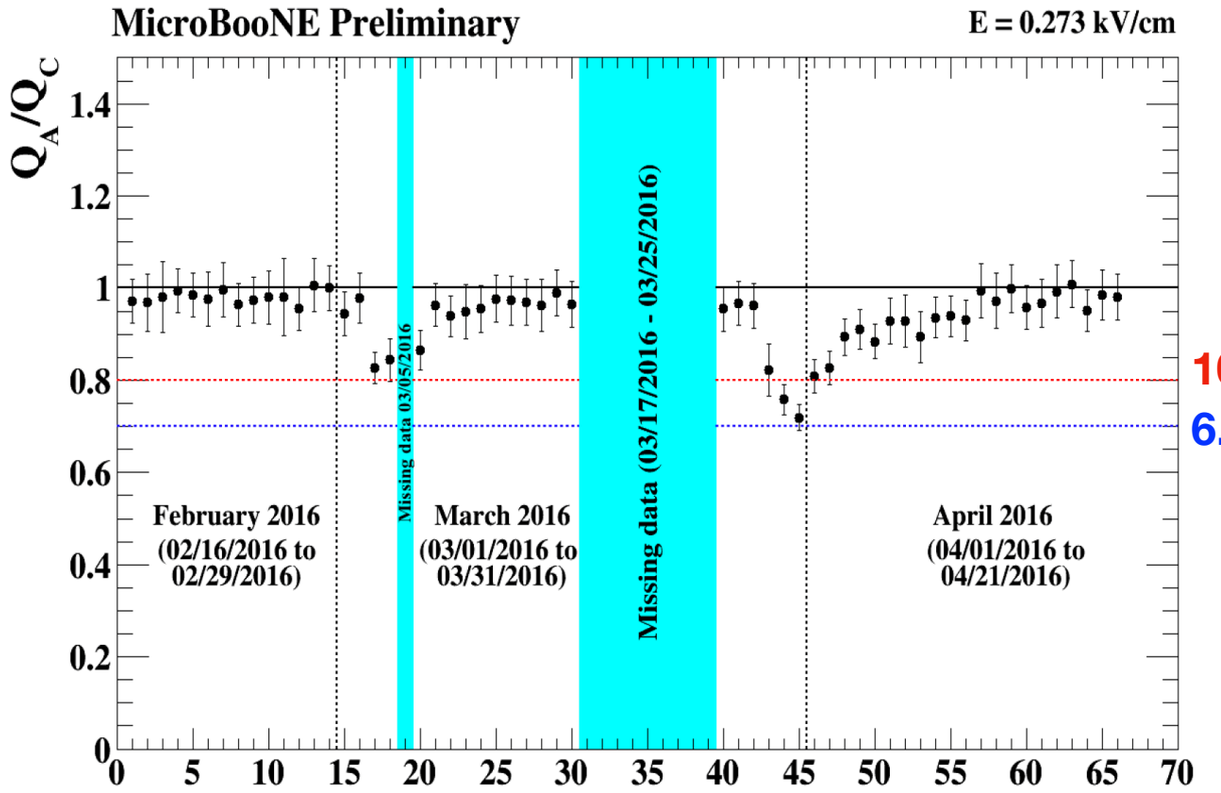


MicroBooNE Uses LArTPC Technology

- 3 wire planes with 8192 wires
  - 1 collection and 2 induction planes
  - 3 mm wire pitch
- 32 8-inch PMT

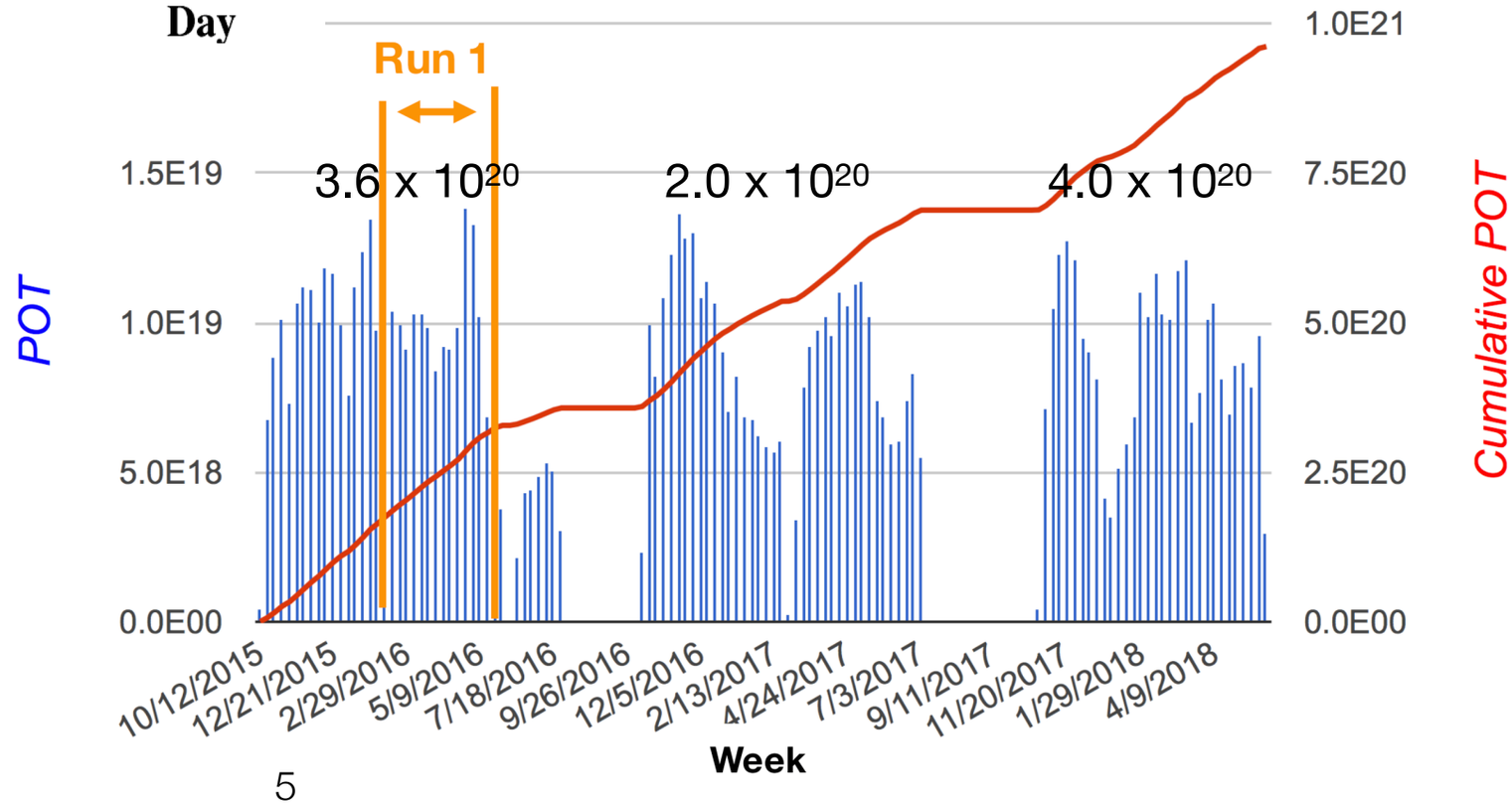


MicroBooNE Operations



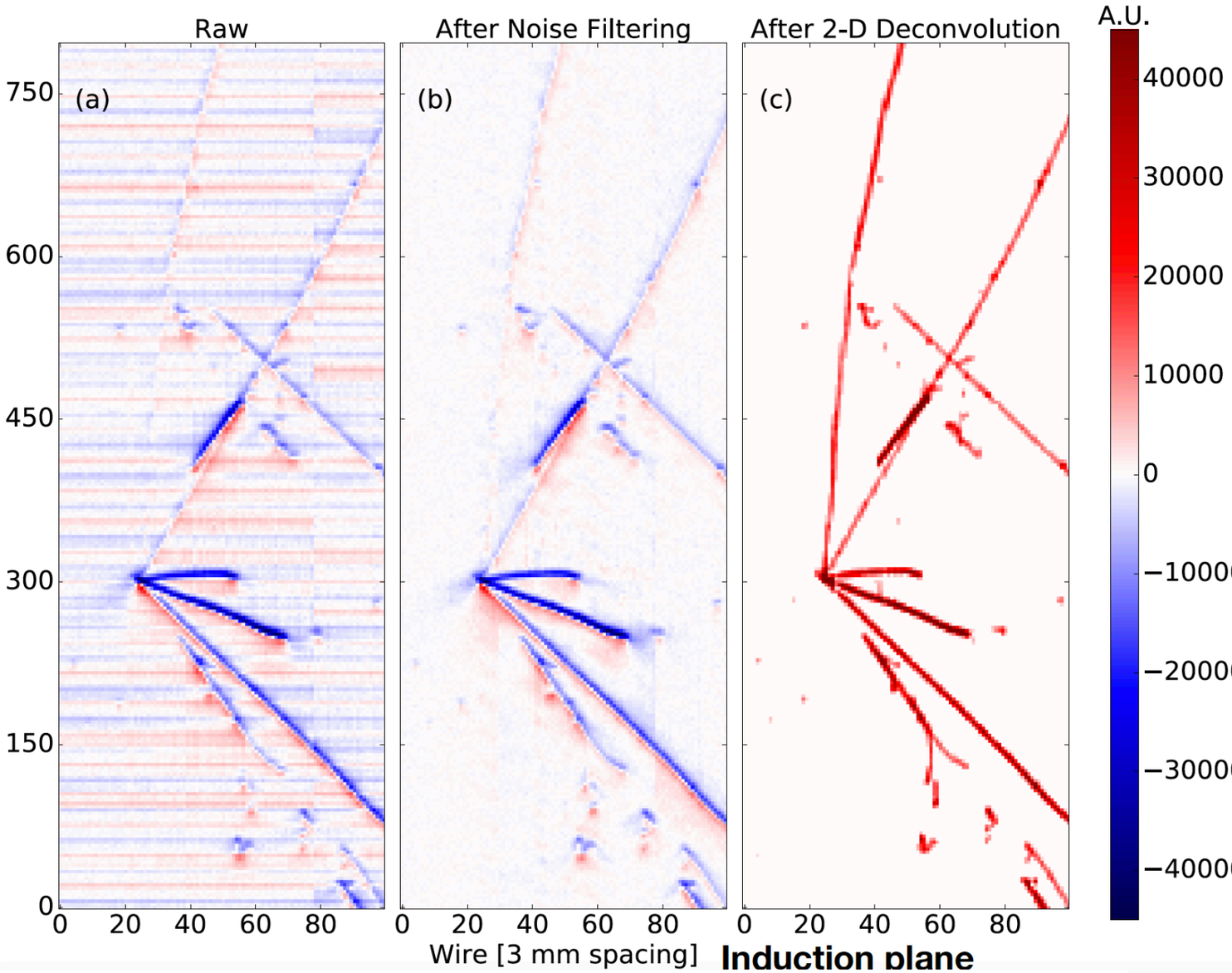
- Argon purity is critical for LArTPC operation,
  - Measured as the fraction of charge detected at its anode relative to its cathode
  - Electron lifetime is very high (steadily above 6 ms)

- Data taking started in October 2015
  - 9.6 x 10^{20} Proton On Target (POT) delivered now



Noise Filtering and Signal Processing

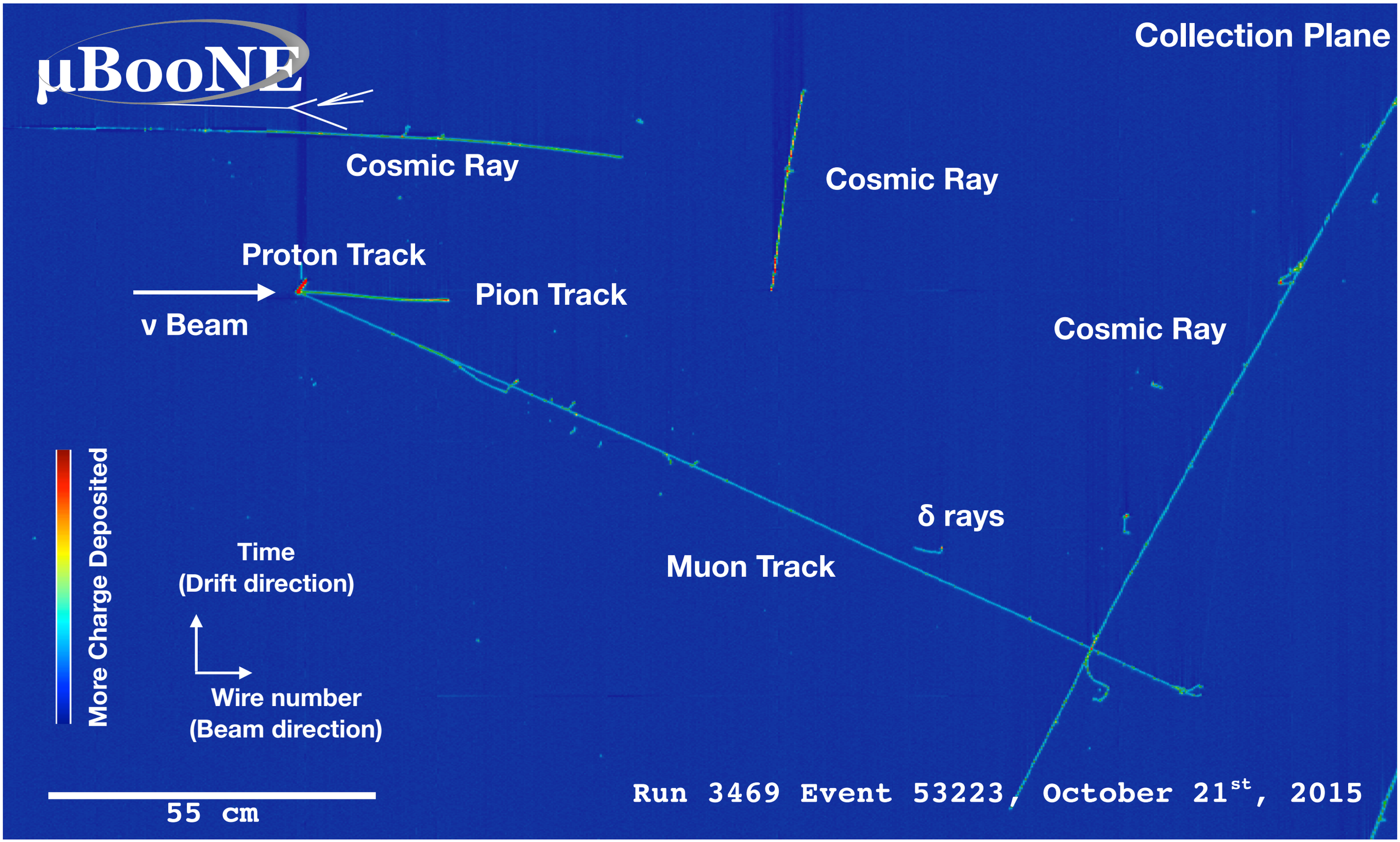
Detailed characterization of the detector is key to our Physics and to our R&D mission for future detectors



- Powerful filtering techniques can address many sources of noise
- Excellent characterization of multiple wire signal response (2d deconvolution)
- Robust signal processing allows calorimetry in all three planes (enabling induction planes)

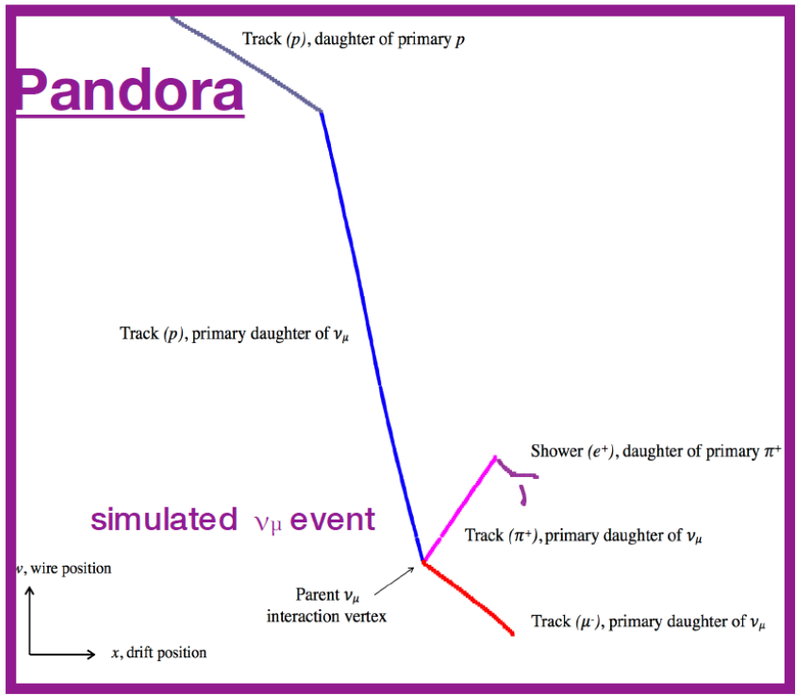
- "Ionization Electron Signal Processing in Single Phase LAr TPCs I and II, **JINST 13, P07006 (2018) & JINST 13, P07007 (2018)**
- "Noise Characterization and Filtering in the MicroBooNE Liquid Argon TPC", **JINST 12, P08003 (2017)**

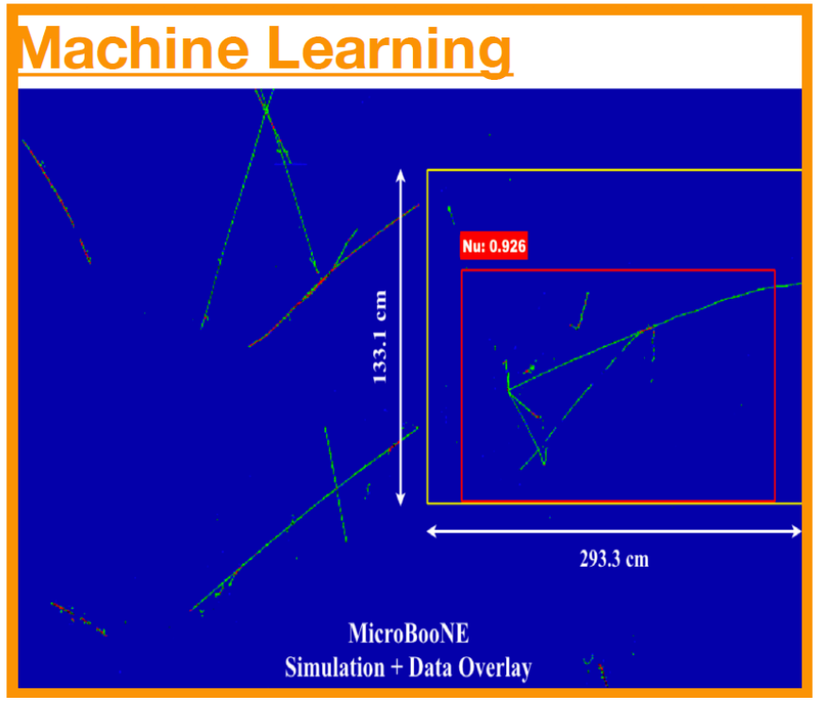
A Charged Current ν_μ Event in Data

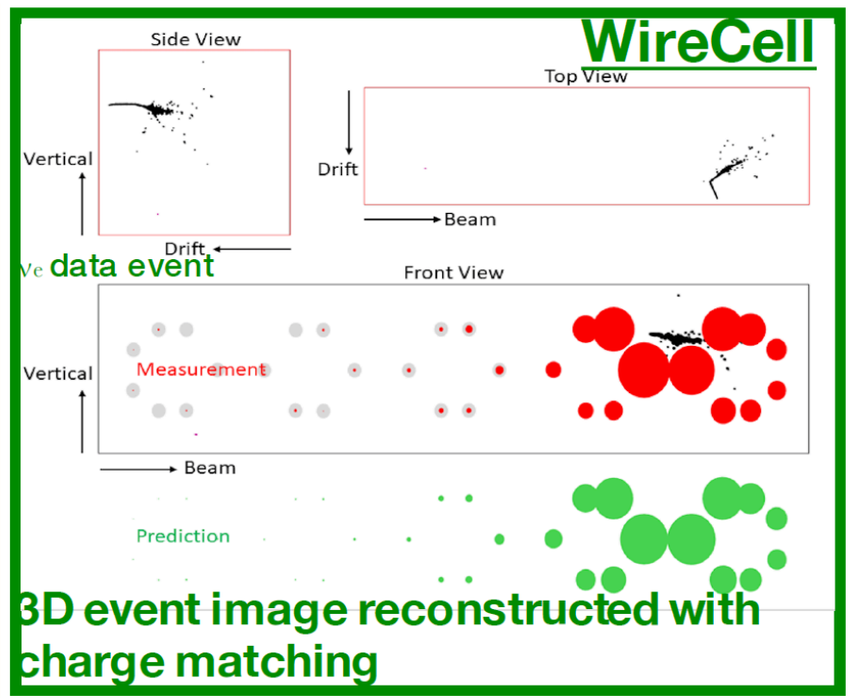


Event Reconstruction Techniques

- Different reconstruction techniques have been developed
- Reached high level of sophistication
- Essential for SBN and DUNE



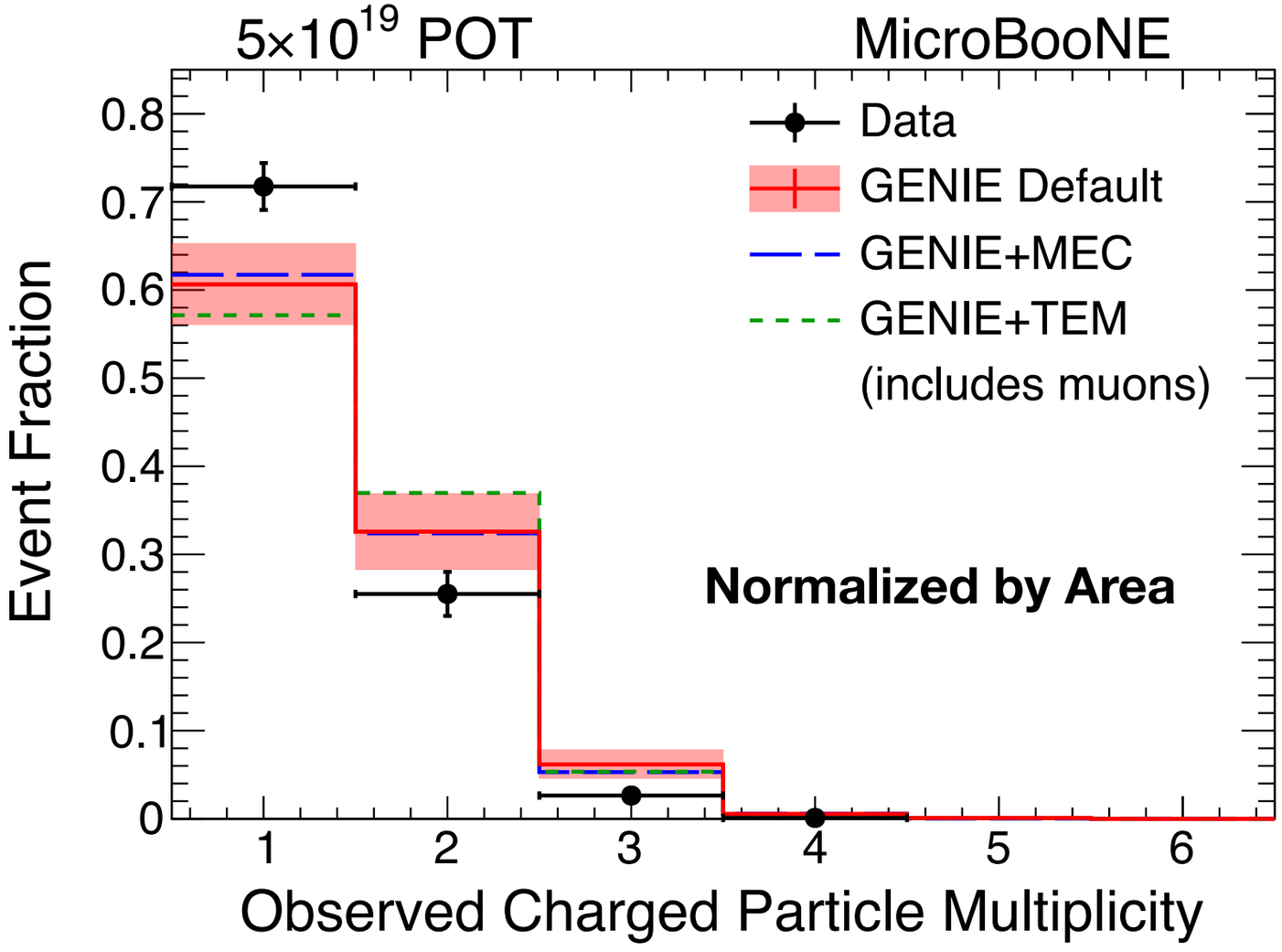




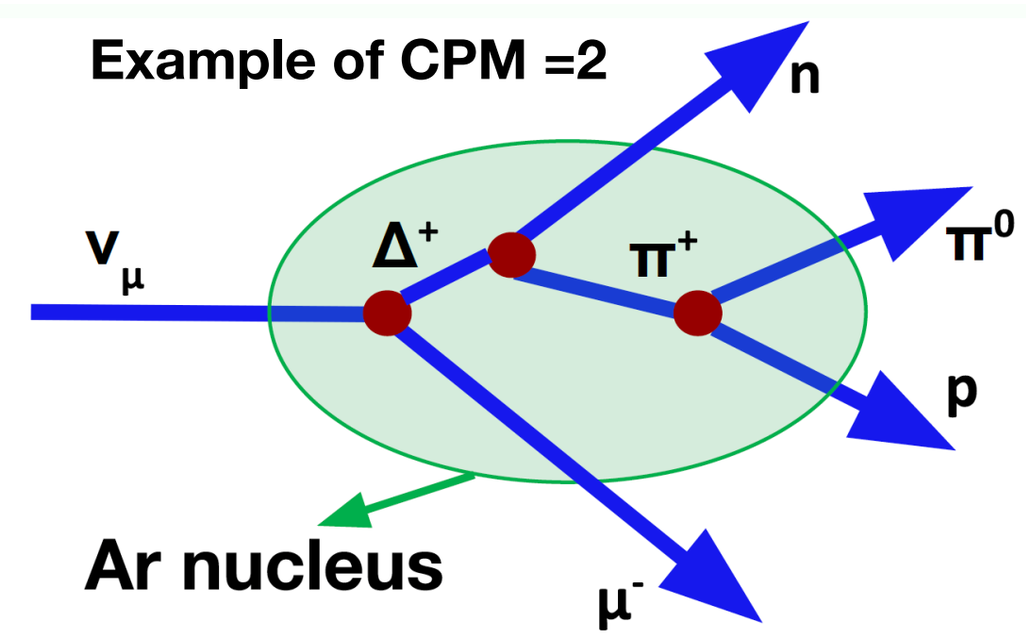
- "The Pandora Multi-Algorithm Approach to Automated Pattern Recognition of Cosmic Ray Muon and Neutrino Events in the MicroBooNE Detector", **Eur. Phys. J. C78, 1, 82 (2018)**"
- "Convolutional Neural Networks Applied to Neutrino Events in a Liquid Argon Time Projection Chamber", **JINST 12, P03011 (2017)**
- "Towards automated neutrino selection at MicroBooNE using tomorgraphic event reconstruction", **MICROBOONE-NOTE-1040-PUB, 2018**

Charge Particle Multiplicity (CPM)

- How many charged particle emerge from the nucleus in ν_μ – Ar interactions?
  - Powerful way to validate nuclear models and generators



MEC = meson exchange current (populates multi-nucleon final states)
TEM = transverse enhancement model (larger transverse QE form factor)



The Charge Particle Multiplicity of MicrobooNE data and GENIE simulation agree within 2σ

New Results

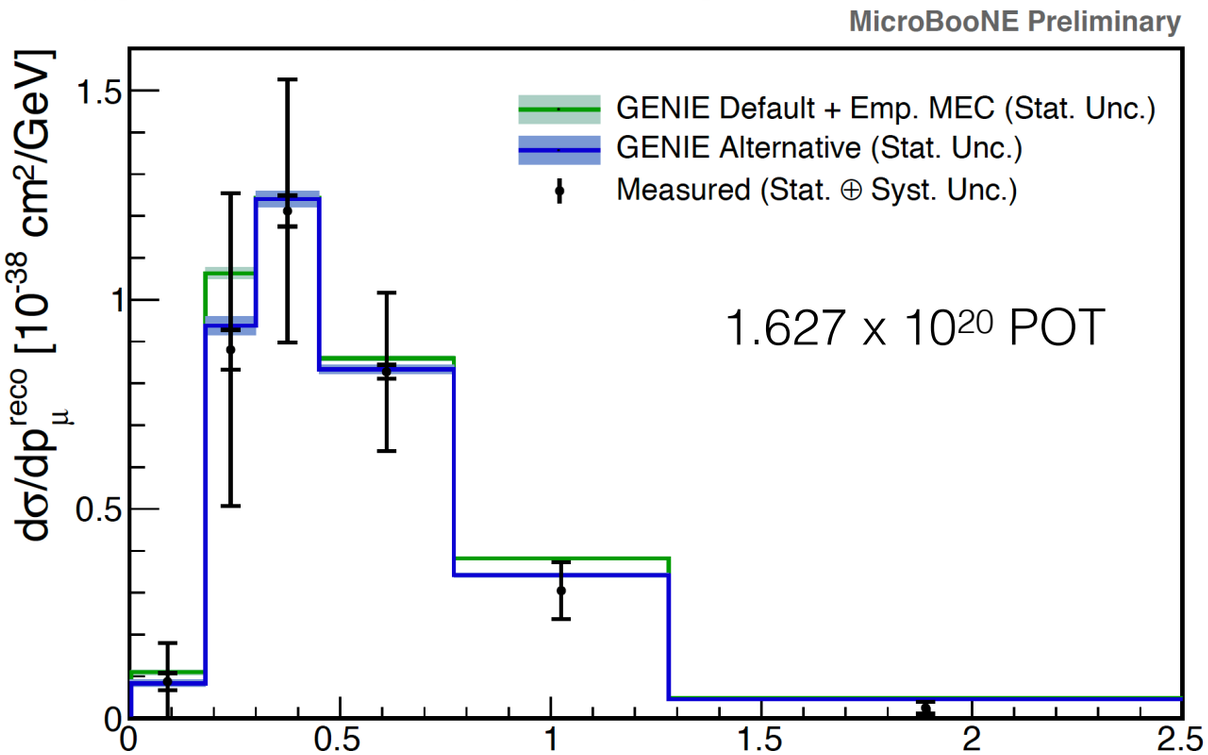
"Comparison of Muon-Neutrino-Argon Multiplicity Distributions Observed by MicroBooNE to GENIE Model Predictions" **arXiv:1805.06887**

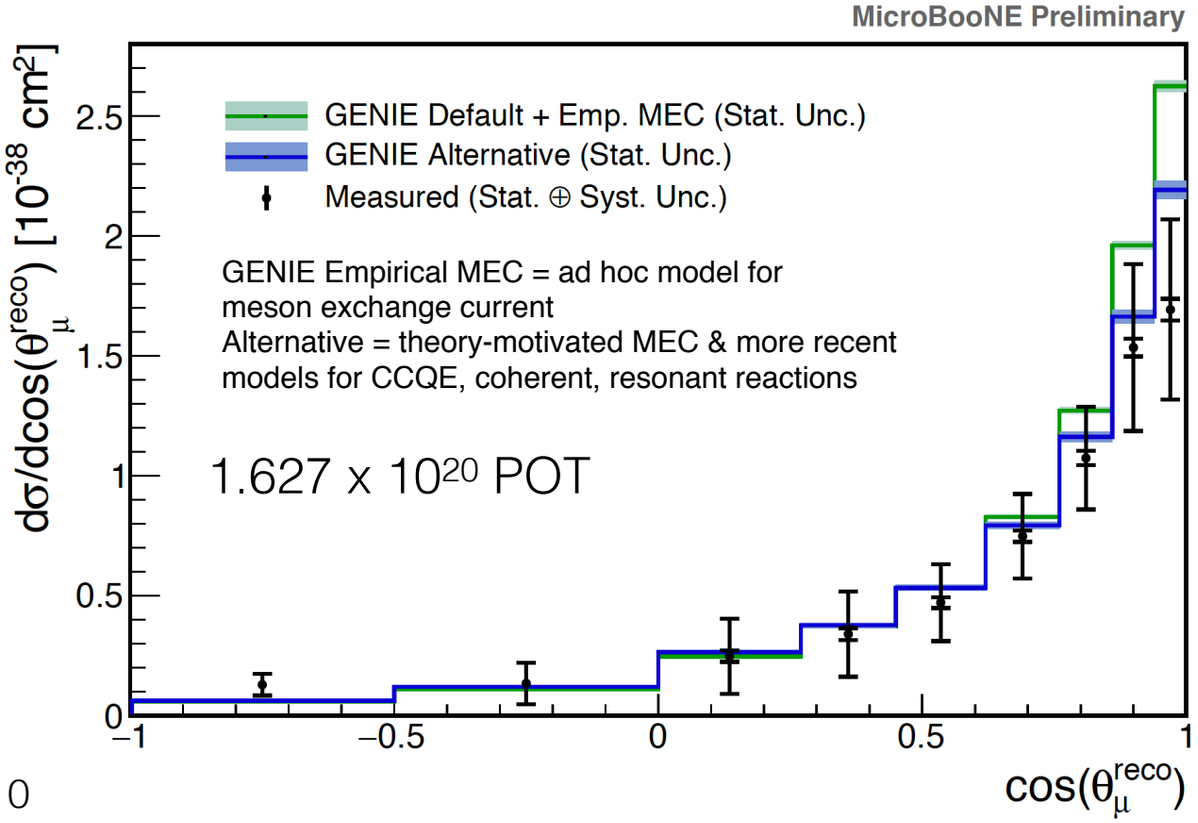
ν_μ Charge Current Inclusive Cross Section Measurement

- Charge current (CC) ν_μ on argon, inclusive of all interaction modes & final states
- Measured by many other experiments, making it a great benchmark for comparison across experiments
- Validates reconstruction techniques and provides baseline selection for other CC-based analyses
- Constrains backgrounds in oscillation analyses

First absolute cross section measurement from MicroBooNE

Public Note: MICROBOONE-NOTE-1045-PUB, 2018

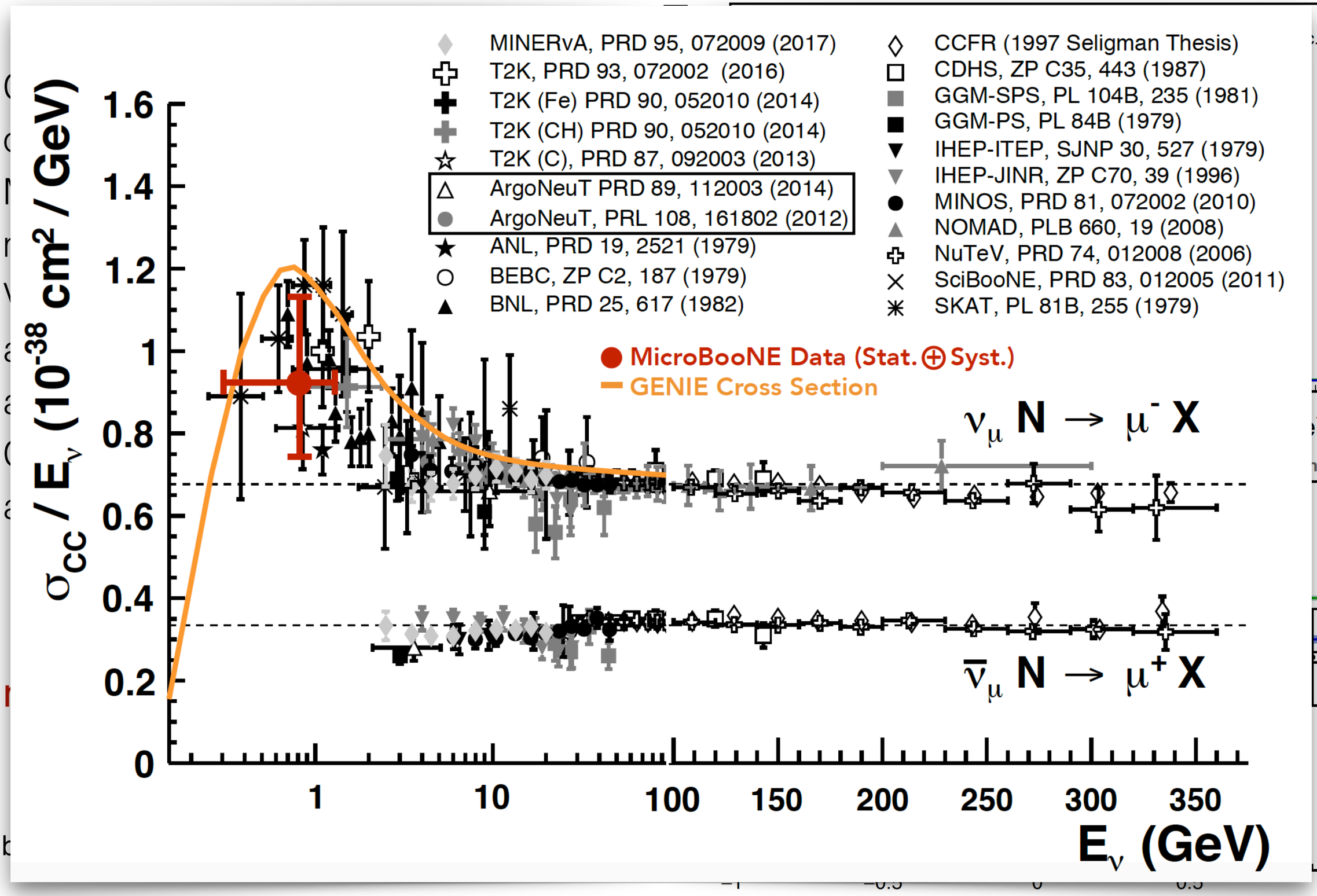




ν_μ Charge Current Inclusive Cross Section Measurement

MicroBooNE Preliminary

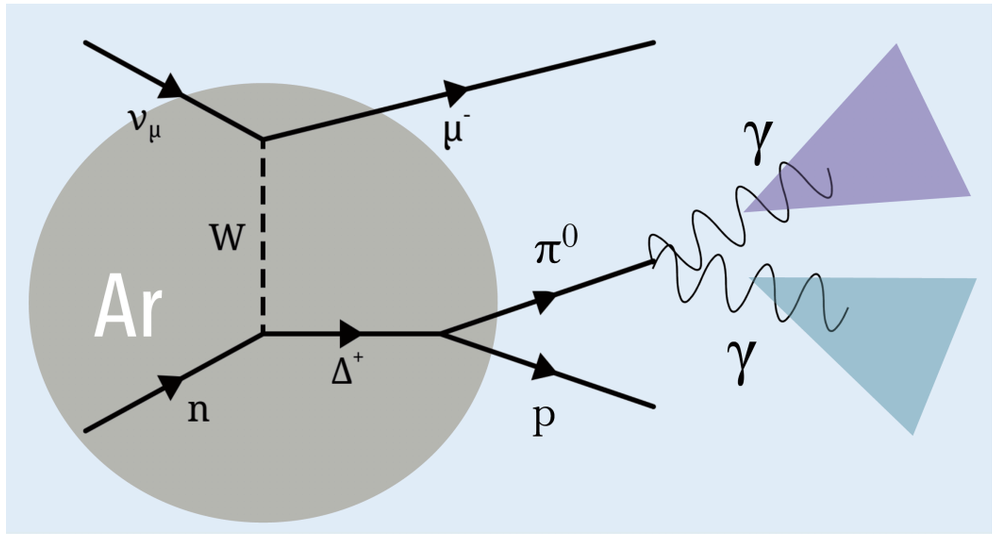
- C
- M
- V
- C

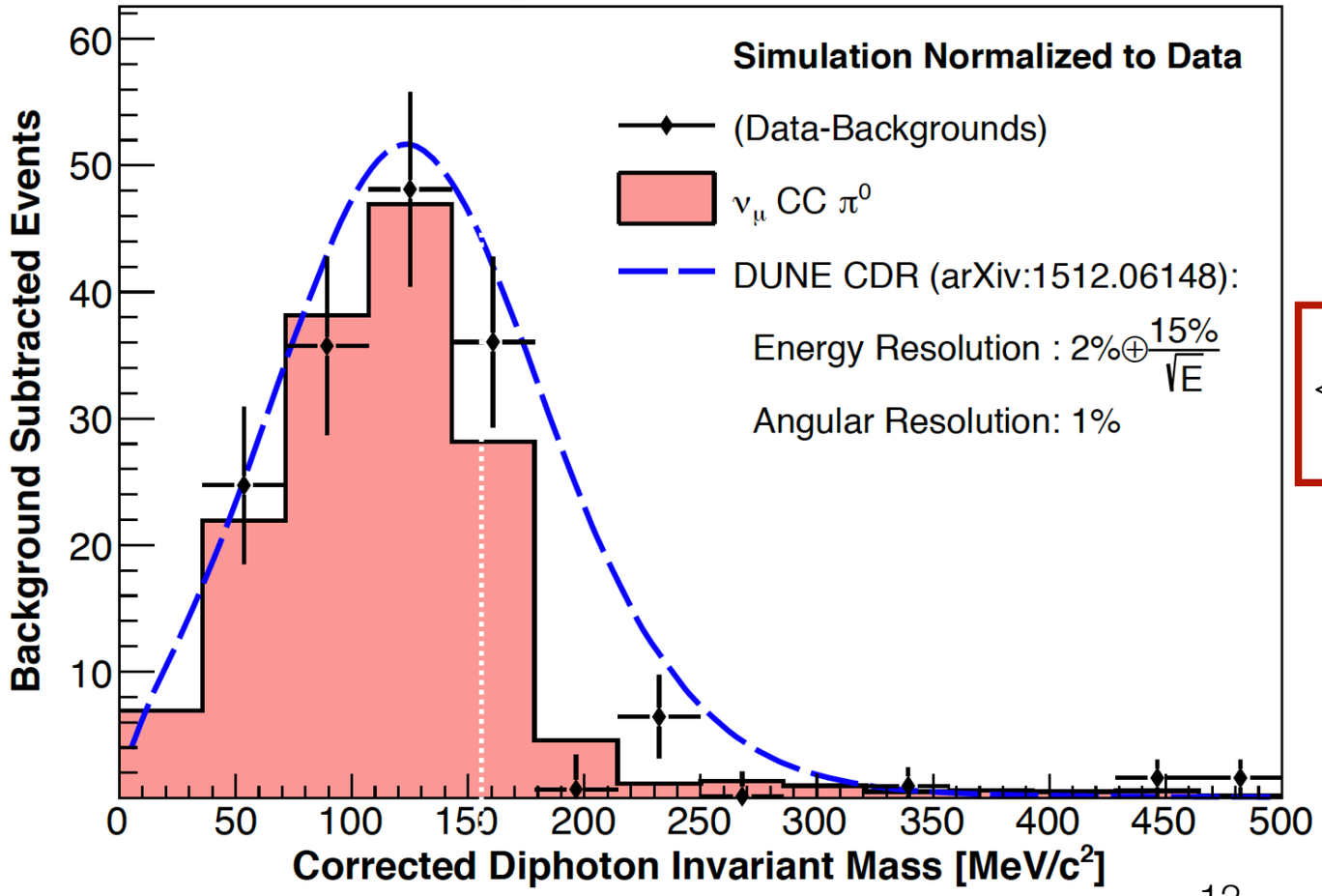


Pub

Charge Current π^0 Exclusive Cross Section Measurement

- Understanding π^0 background is a crucial step towards searching for LEE:
- Test shower reconstruction
- Validate electromagnetic shower energy resolution measured by many other experiments, making it a great benchmark





First charge current single π^0 cross sections in ν_μ + Ar interactions

Total Cross Section

$$< \sigma_{\nu_\mu}^{CC\pi^0} >_\phi = (1.94 \pm 0.16 \pm 0.60) \times 10^{-38} \frac{cm^2}{Ar}$$

"First Measurement of Muon Neutrino Charged Current Single Neutral Pion Production on Argon with the MicroBooNE LArTPC" **MICROBOONE-NOTE-1032-PUB (2018)**

Recent Publications and Public Notes

http://microboone.fnal.gov/documents-publications/

27 public notes, 10 in 2018

- **MICROBOONE-NOTE-1045-PUB** First Muon-Neutrino Charged-Current Inclusive Differential Cross Section Measurement for MicroBooNE Run 1 Data
- **MICROBOONE-NOTE-1048-PUB** Detector calibration using through going and stopping muons in the MicroBooNE LArTPC
- **MICROBOONE-NOTE-1038-PUB** Electron-neutrino selection and reconstruction in the MicroBooNE LArTPC using the Pandora multi-algorithm pattern recognition
- **MICROBOONE-NOTE-1041-PUB** The MicroBooNE Search for Single Photon Events
- **MICROBOONE-NOTE-1043-PUB** MicroBooNE low-energy excess signal prediction from unfolding MiniBooNE Monte-Carlo and data
- **MICROBOONE-NOTE-1031-PUB** Booster Neutrino Flux Prediction at MicroBooNE
- **MICROBOONE-NOTE-1049-PUB** Reconstruction Performance Studies with MicroBooNE Data in Support of Summer 2018 Analyses
- **MICROBOONE-NOTE-1050-PUB** Study of Reconstructed 39Ar Beta Decays at the MicroBooNE Detector
- **MICROBOONE-NOTE-1040-PUB** Tomographic Event Reconstruction with MicroBooNE Data
- **MICROBOONE-NOTE-1032-PUB** First Measurement of Muon Neutrino Charged Current Single Neutral Pion Production on Argon with the MicroBooNE LArTPC

11 publications, 5 in 2018

- "A Deep Neural Network for Pixel-Level Electromagnetic Particle Identification in the MicroBooNE Liquid Argon Time Projection Chamber", **arXiv:1808.07269**
- "Comparison of Muon-Neutrino-Argon Multiplicity Distributions Observed by MicroBooNE to GENIE Model Predictions", **arXiv:1805.06887**
- "Ionization Electron Signal Processing in Single Phase LAr TPCs II: Data/Simulation Comparison and Performance in MicroBooNE", **JINST 13, P07007 (2018)**
- "Ionization Electron Signal Processing in Single Phase LAr TPCs I: Algorithm Description and Quantitative Evaluation with MicroBooNE Simulation", **JINST 13, P07006 (2018)**
- "The Pandora Multi-Algorithm Approach to Automated Pattern Recognition of Cosmic Ray Muon and Neutrino Events in the MicroBooNE Detector", **Eur. Phys. J. C78, 1, 82 (2018)**
- "Measurement of Cosmic Ray Reconstruction Efficiencies in the MicroBooNE LAr TPC Using a Small External Cosmic Ray Counter", **JINST 12, P12030 (2017)**
- "Noise Characterization and Filtering in the MicroBooNE Liquid Argon TPC", **JINST 12, P08003 (2017)**
- "Michel Electron Reconstruction Using Cosmic Ray Data from the MicroBooNE LAr TPC", **JINST 12, P09014 (2017)**
- "Determination of Muon Momentum in the MicroBooNE LAr TPC Using an Improved Model of Multiple Coulomb Scattering", **JINST 12 P10010 (2017)**
- "Convolutional Neural Networks Applied to Neutrino Events in a Liquid Argon Time Projection Chamber",**JINST 12, P03011 (2017)**
- "Design and Construction of the MicroBooNE Detector", **JINST 12, P02017 (2017)**

Recent Publications and Public Notes

http://microboone.fnal.gov/documents-publications/

27 public notes, 10 in 2018

- MICROBOONE-NOTE-1045-PUB First Muon-Neutrino Charged-Current Inclusive Differential Cross Section Measurement for MicroBooNE Run 1 Data
- MICROBOONE-NOTE-1048-PUB Detector calibration using through going and stopping muons in the MicroBooNE LArTPC
- MICROBOONE-NOTE-1038-PUB Electron-neutrino selection and reconstruction in the MicroBooNE LArTPC using the Pandora multi-algorithm pattern recognition
- MICROBOONE-NOTE-1041-PUB The MicroBooNE Search for Single Photon Events
- MICROBOONE-NOTE-1043-PUB MicroBooNE low-energy excess signal prediction from unfolding MiniBooNE Monte-Carlo and Data
- MICROBOONE-NOTE-1031-PUB Booster Neutrino Flux Prediction at MicroBooNE
- MICROBOONE-NOTE-1049-PUB Reconstruction Performance Studies with MicroBooNE Data in Support of Summer 2018 Analyses
- MICROBOONE-NOTE-1050-PUB Study of Reconstructed 39Ar Beta Decays at the MicroBooNE Detector
- MICROBOONE-NOTE-1040-PUB Tomographic Event Reconstruction with MicroBooNE Data
- MICROBOONE-NOTE-1032-PUB First Measurement of Muon Neutrino Charged Current Single Neutral Pion Production on Argon with the MicroBooNE LArTPC

11 publications, 5 in 2018

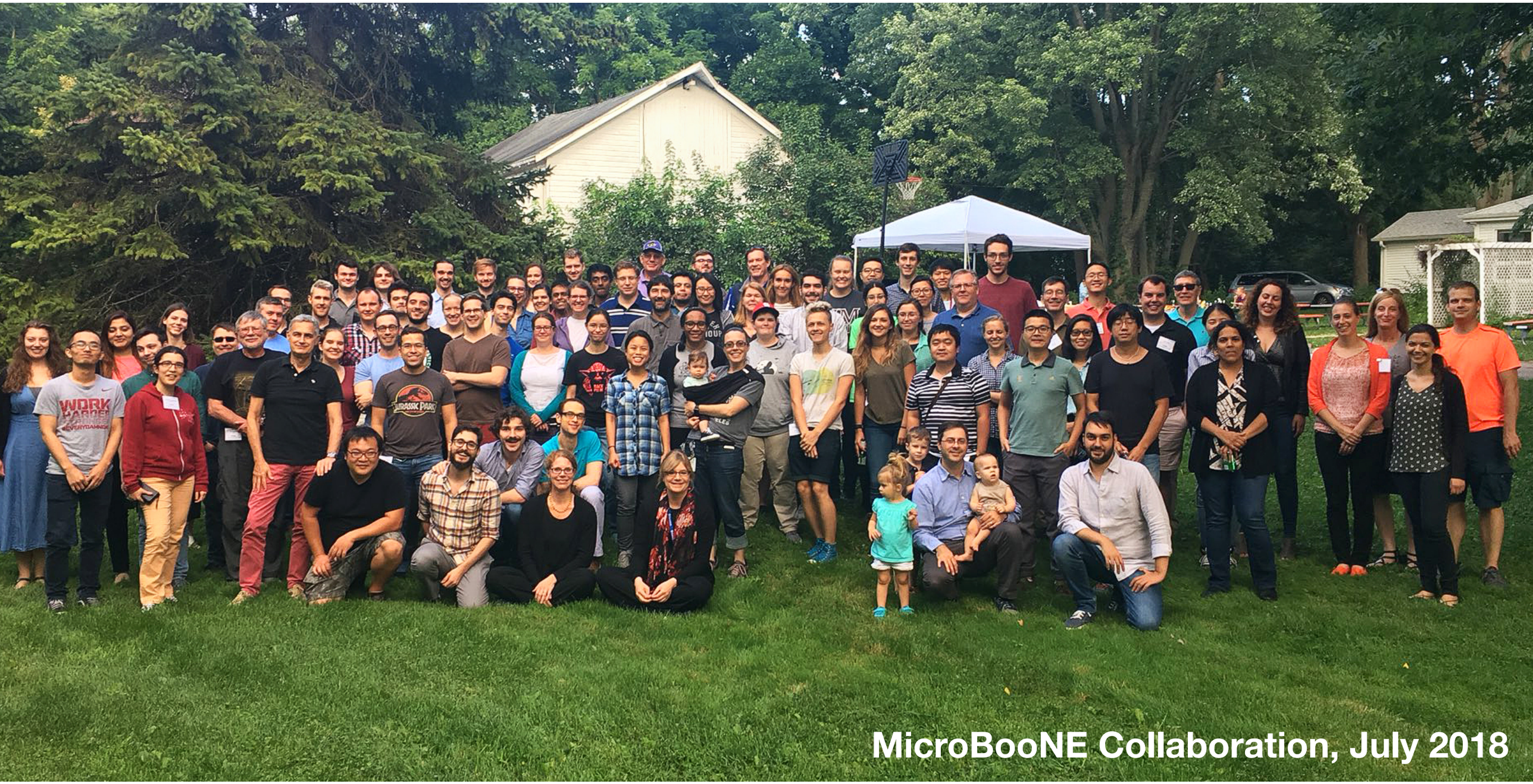
- "A Deep Neural Network for Pixel-Level Electromagnetic Particle Identification in the MicroBooNE Liquid Argon Time Projection Chamber", arXiv:1808.07269
- "Comparison of Muon-Neutrino-Argon Multiplicity Distributions Observed by MicroBooNE to GENIE Model Predictions", arXiv:1805.06887
- "Ionization Electron Signal Processing in Single Phase LAr TPCs II: Data/Simulation Comparison and Performance in MicroBooNE", JINST 13, P07007 (2018)
- "Ionization Electron Signal Processing in Single Phase LAr TPCs I: Algorithm Description and Quantitative Evaluation with MicroBooNE Simulation", JINST 13, P07006 (2018)
- The Pandora Multi-Algorithm Approach to Automated Pattern Recognition of Cosmic Ray Muon and Neutrino Events in the MicroBooNE Detector", Eur. Phys. J. C78, 1, 82 (2018)
- "Measurement of Cosmic Ray Reconstruction Efficiencies in the MicroBooNE LAr TPC Using a Small External Cosmic Ray Counter", JINST 12, P12030 (2017)
- "Noise Characterization and Filtering in the MicroBooNE Liquid Argon TPC", JINST 12, P08003 (2017)
- "Michel Electron Reconstruction Using Cosmic Ray Data from the MicroBooNE LAr TPC", JINST 12, P09014 (2017)
- "Determination of Muon Momentum in the MicroBooNE LAr TPC Using an Improved Model of Multiple Coulomb Scattering", JINST 12 P10010 (2017)
- "Convolutional Neural Networks Applied to Neutrino Events in a Liquid Argon Time Projection Chamber",JINST 12, P03011 (2017)
- "Design and Construction of the MicroBooNE Detector", JINST 12, P02017 (2017)

More results are coming !!!

Summary

- MicroBooNE has been taking data since the Fall of 2015
- MicroBooNE made enormous progress in understanding the detector and the LArTPC technology
- We have begun to utilize the full promise of the LArTPC to test our neutrino interaction models in GENIE
- We preformed our first absolute ν_μ CC inclusive cross section measurement in ν_μ + Ar interactions
- We first measured the ν_μ charged current single π^0 total cross sections in ν_μ + Ar interactions

The MicroBooNE Collaboration



Thank You!