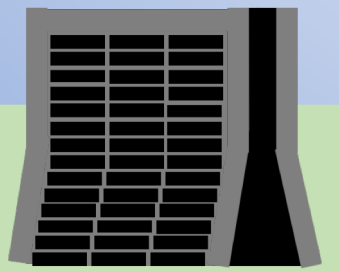
MANCHESTER 1824
The University of Manchester

μBooNE

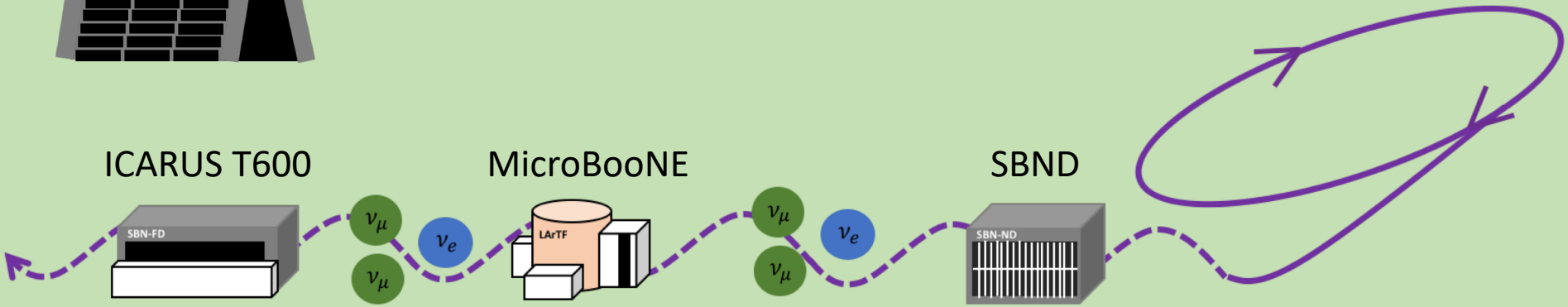
# Towards the measurement of the charged-current $\nu_e$ inclusive cross-section on argon in MicroBooNE

10 June 2019

**Krishan Mistry**, Colton Hill



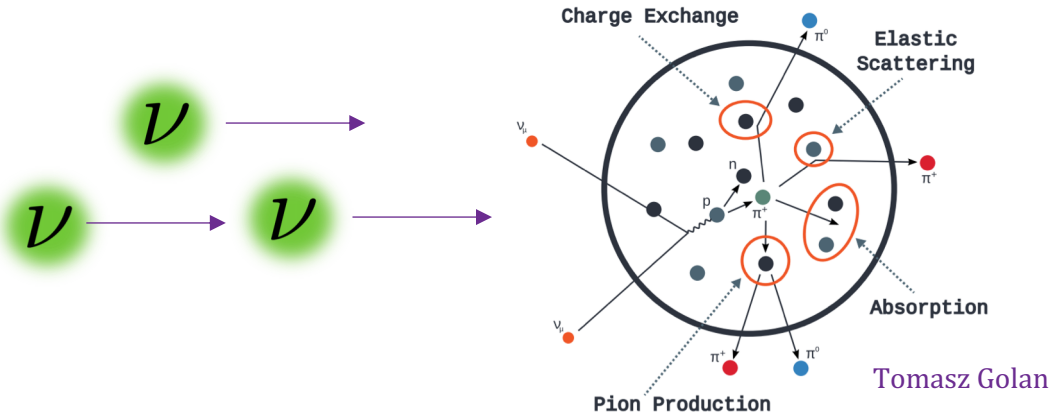
New Perspectives 2019



# Why Measure the $\nu_e$ – Ar Cross Section?

- $\nu_e$ appearance is the golden channel for experiments such as DUNE, SBN (incl. MicroBooNE!)
  - This measurement is important for these oscillation experiments!

- Measurements of this cross section exist on other targets, but never on argon
  - With argon we can get complex nuclear effects due to the many protons and neutrons in the argon nucleus



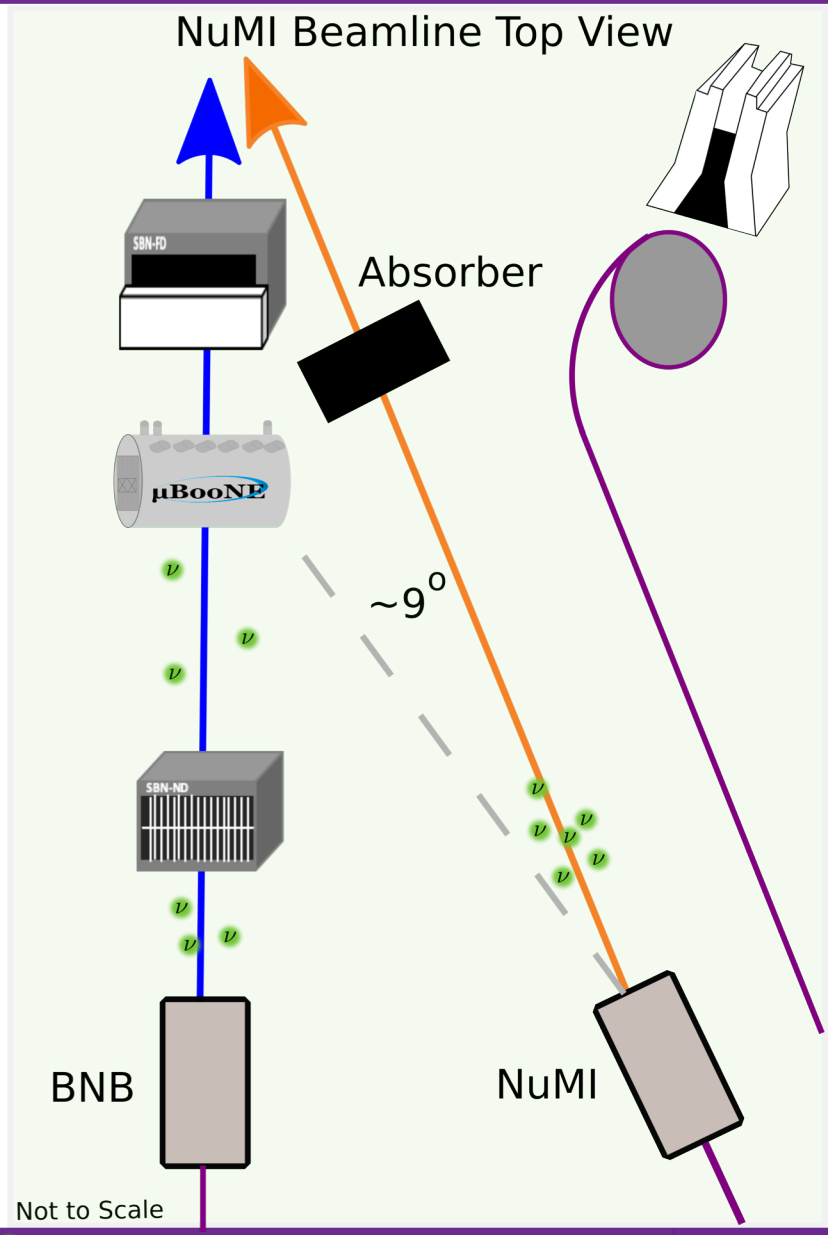
# The NuMI Beamline

- The NuMI beamline provides beam to NO$\nu$A, MINER$\nu$A, MINOS+
  - Much higher energy proton beam
  - Higher fraction of kaons produced leading to a higher electron neutrino content

| Beam | Proton Energy | <Energy $\nu_e + \overline{\nu_e}$> | $\nu_e$ fraction |
|---|---|---|---|
| BNB | 8 GeV | ~900 MeV | 0.5% |
| NuMI | 120 GeV | ~640 MeV | 5% |

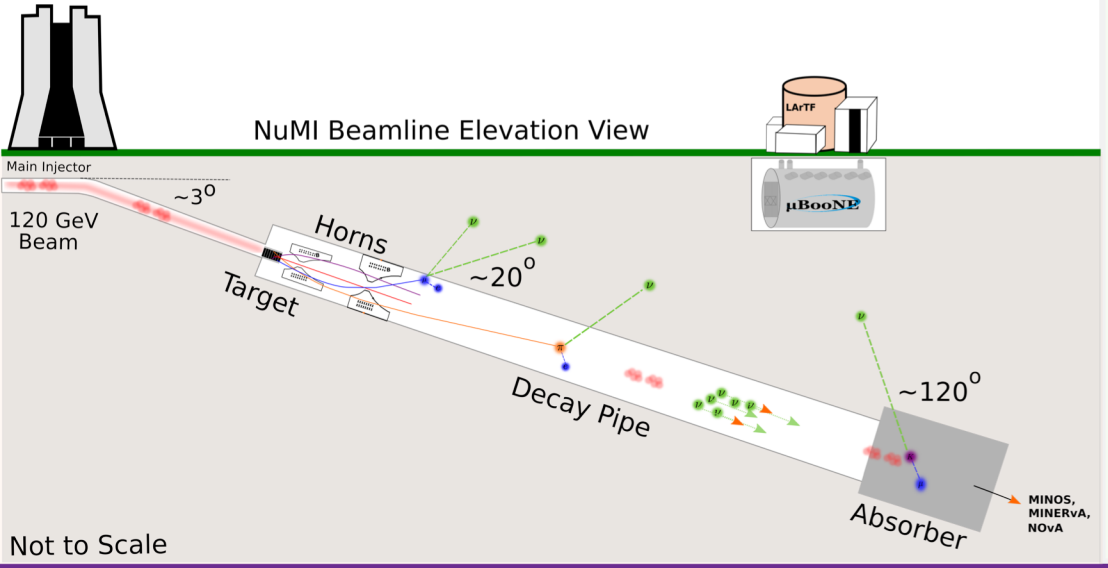
(at MicroBooNE)

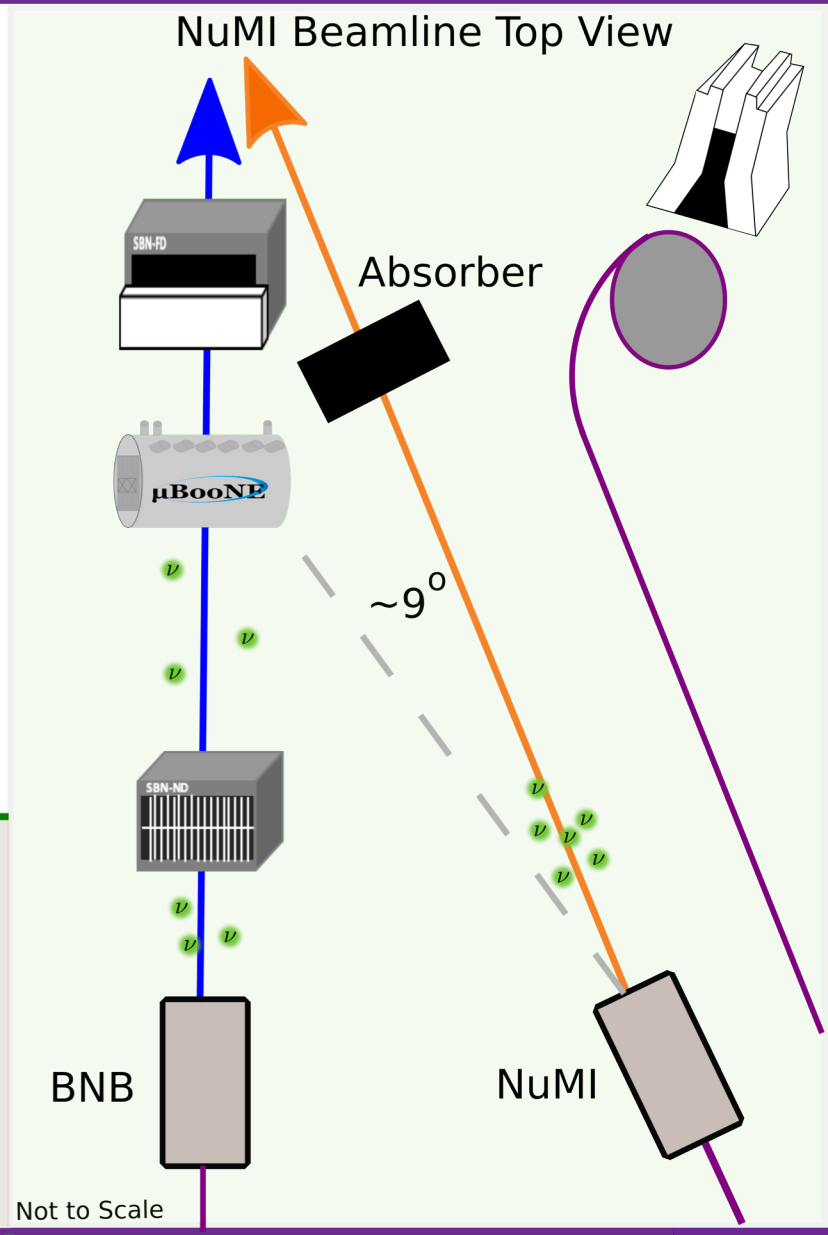
- ICARUS will also see neutrinos from NuMI



# NuMI Flux at MicroBooNE

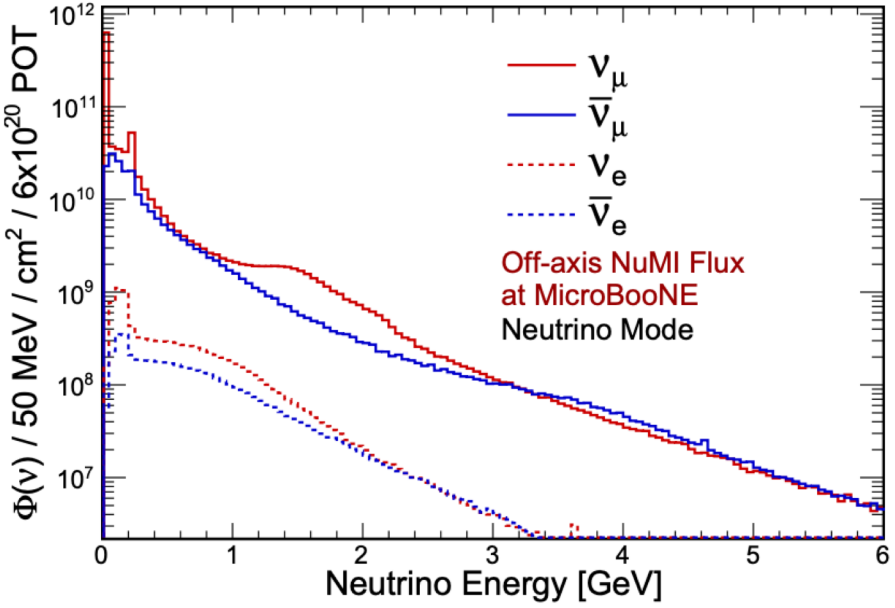
- MicroBooNE sees highly off-axis neutrinos from a range of angles
  - Neutrinos from the target ~8°
  - Backwards going neutrinos from the absorber ~120°
  - Neutrinos from all angles in-between from decay pipe

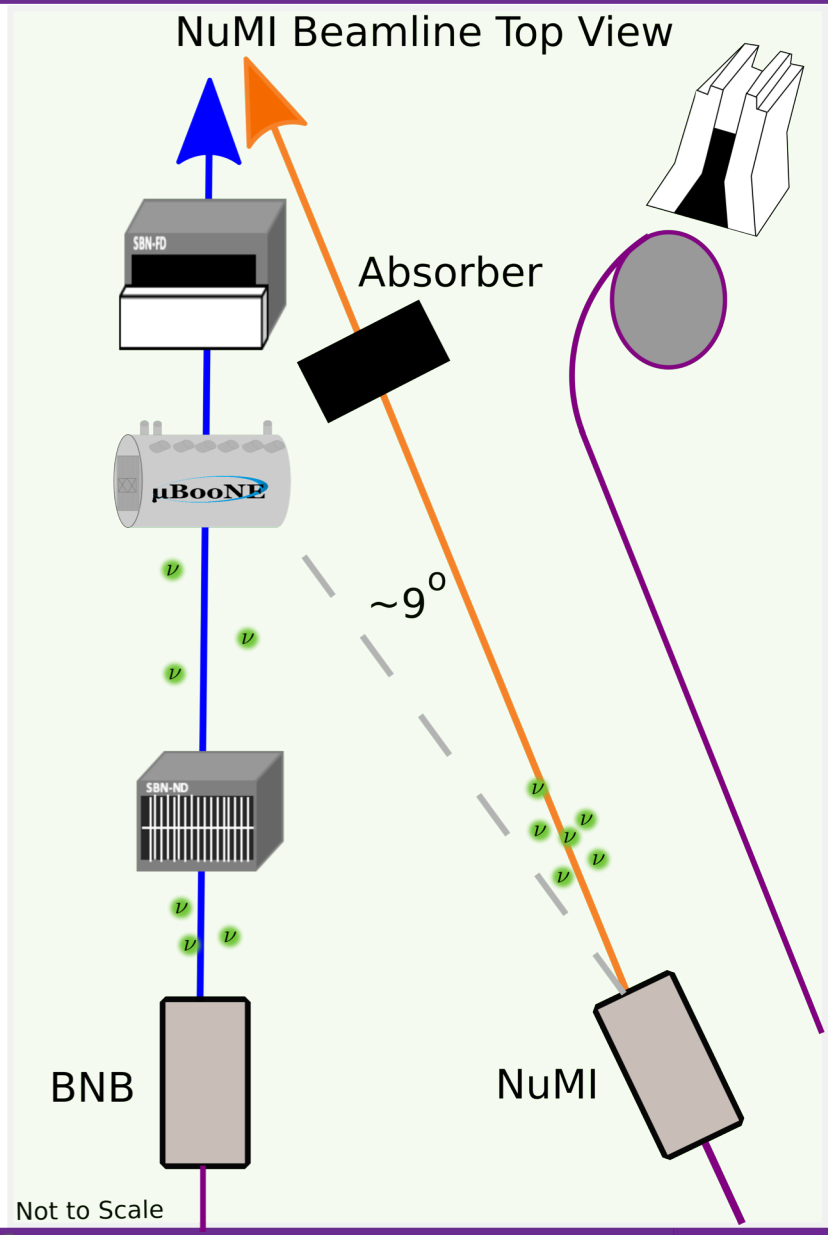


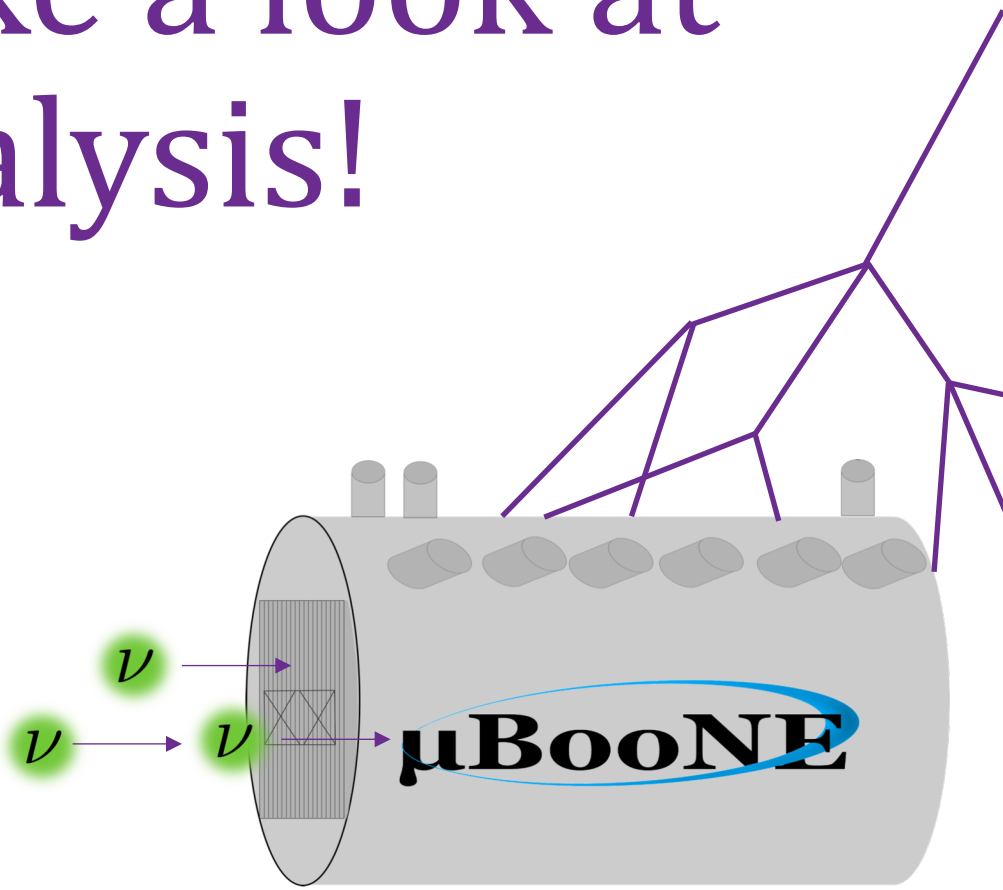
# NuMI Flux at MicroBooNE

- Large span of neutrino energy available
- Large flux of low-energy neutrinos from decays at rest



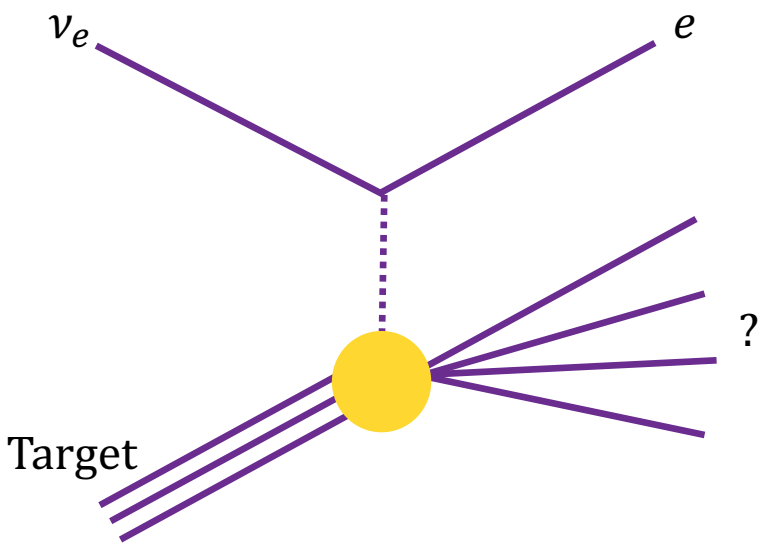



# Now lets take a look at the analysis!



# The Analysis

- Inclusive analysis with all $\nu_e + \overline{\nu_e}$ CC topologies:
  - Have no requirements on the number of tracks or additional showers




- Flux Integrated
  - Differential cross section will be the next stage

- Fully automated reconstruction and event selection:
  - Uses the Pandora reconstruction framework [1]

$$\sigma = \frac{N - B}{\epsilon \times N_{\text{Targets}} \times \phi_{\nu_e + \overline{\nu_e}}}$$

[1] arxiv 1708.03135

# Selection Chain

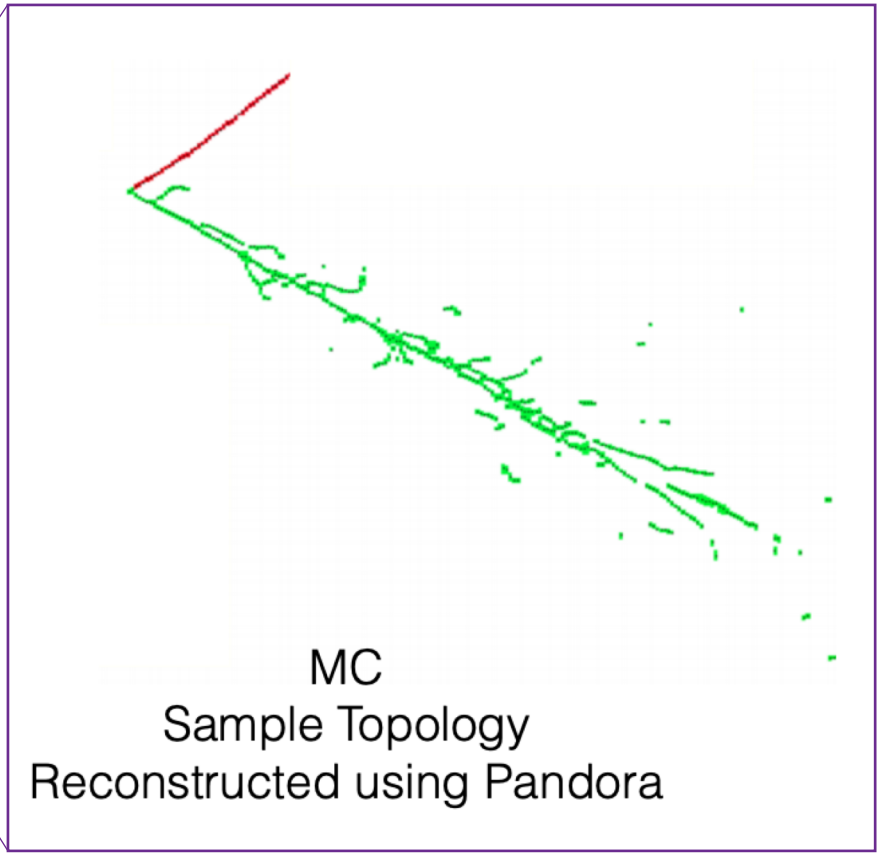
Simple Cuts → Flash Matching → Reconstruction Quality → Shower Hit Thresholds → Electron Showers → Final Tuning

- First construct the signal definition

In-time with Beam

In Fiducial Volume

Pandora Reco $\nu_e$



MC
Sample Topology
Reconstructed using Pandora

See MICROBOONE-NOTE-1054-PUB for more details!

# Selection Chain

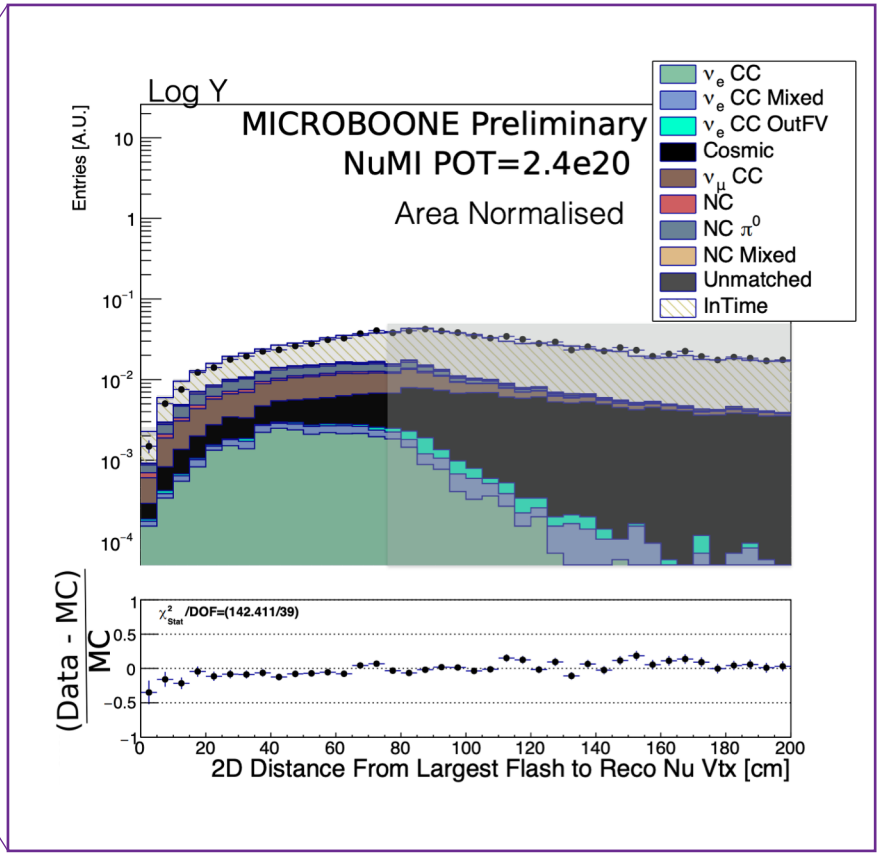
Simple Cuts → **Flash Matching** → Reconstruction Quality → Shower Hit Thresholds → Electron Showers → Final Tuning

- Utilise the optical information

Flash PE

Flash to Vertex

e.g. Distance between reconstructed optical centre and neutrino centre




See MICROBOONE-NOTE-1054-PUB for more details!

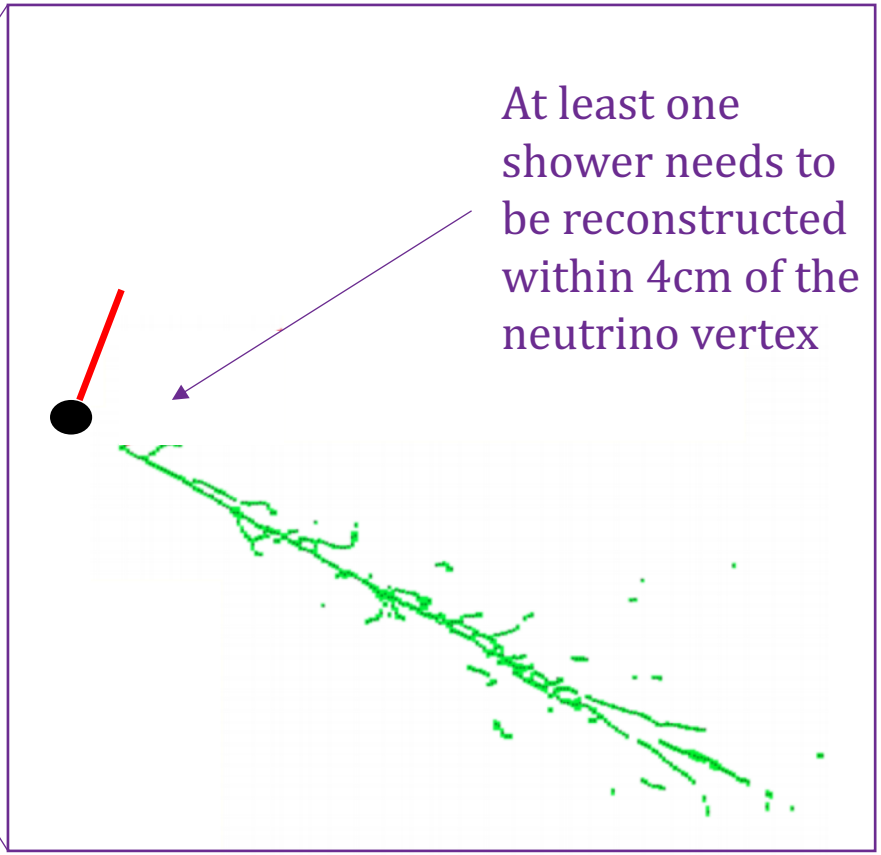
# Selection Chain

Simple Cuts → Flash Matching → **Reconstruction Quality** → Shower Hit Thresholds → Electron Showers → Final Tuning

- Remove showers and tracks far from the neutrino vertex

Shower-Vertex Distance

Track-Vertex Distance




See MICROBOONE-NOTE-1054-PUB for more details!

# Selection Chain

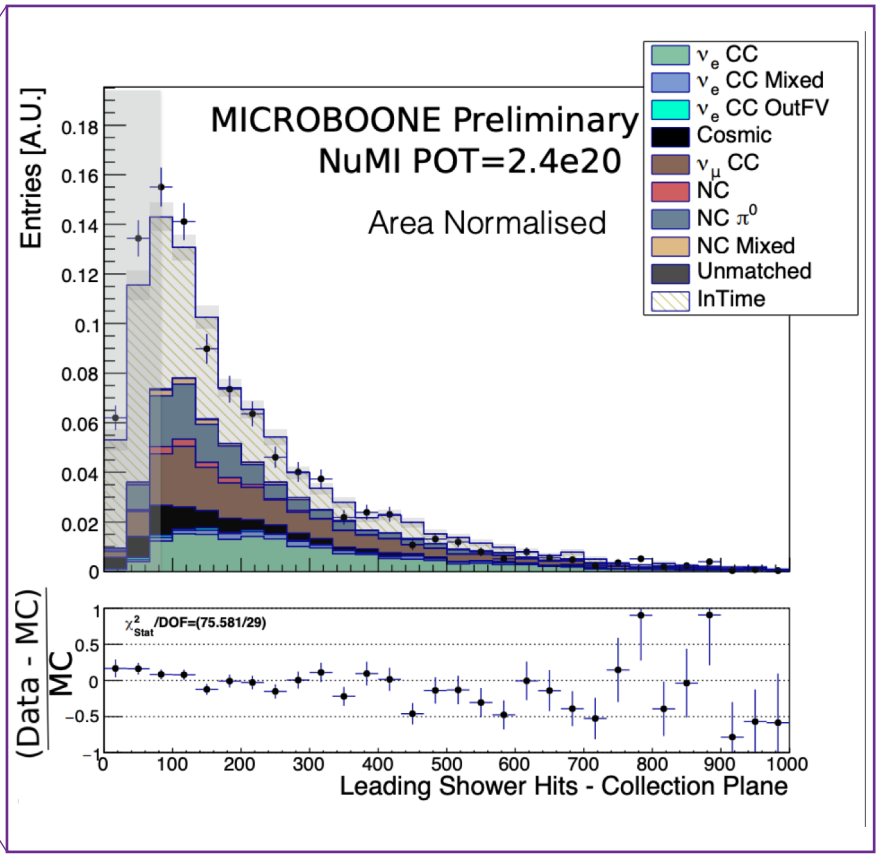
Simple Cuts → Flash Matching → Reconstruction Quality → Shower Hit Thresholds → Electron Showers → Final Tuning

- Target cosmic backgrounds and improve quality of reconstructed showers

Leading Shower All Planes

Leading Shower Coll. Plane

e.g. Number of collection plane hits for the leading shower (shower with most hits) to be greater than 80




See MICROBOONE-NOTE-1054-PUB for more details!

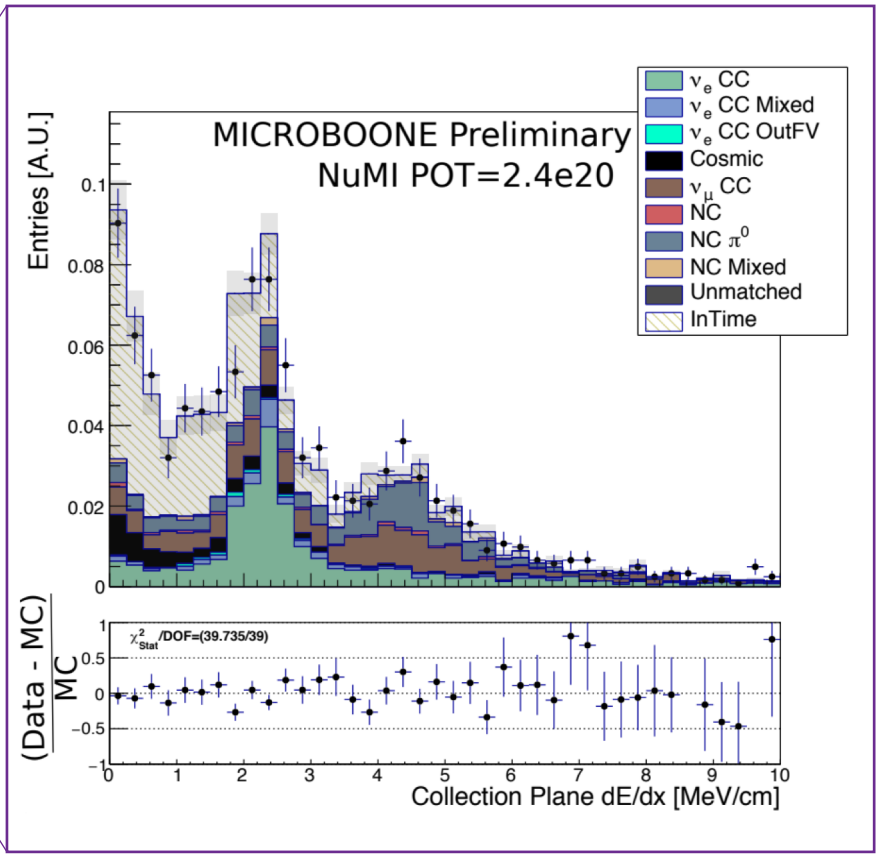
# Selection Chain

Simple Cuts → Flash Matching → Reconstruction Quality → Shower Hit Thresholds → Electron Showers → Final Tuning

- Photon induced backgrounds are challenging to remove in a $\nu_e$ selection

Leading Shower Open Angle

Leading Shower dE/dx




- Demonstration of **MicroBooNE**'s ability to differentiate electron-like and photon-like showers

See MICROBOONE-NOTE-1054-PUB for more details!

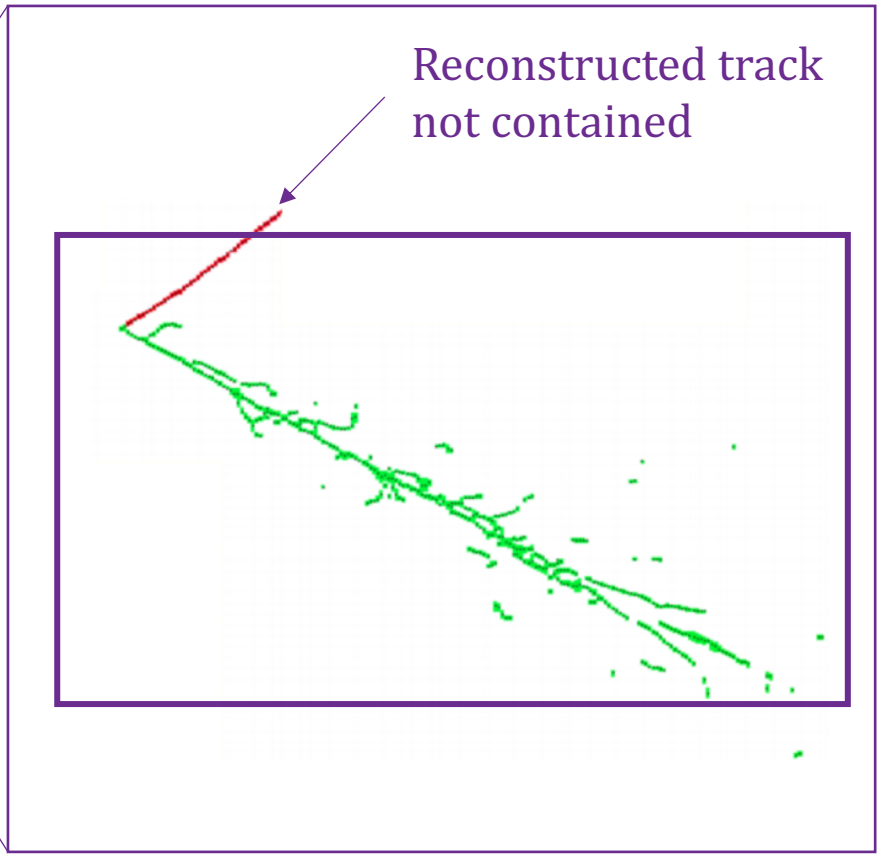
# Selection Chain

Simple Cuts → Flash Matching → Reconstruction Quality → Shower Hit Thresholds → Electron Showers → Final Tuning

- Finalisation cuts

Track-Shower Length Ratio
Secondary Shwr Distance
Hits / Length
Track Containment

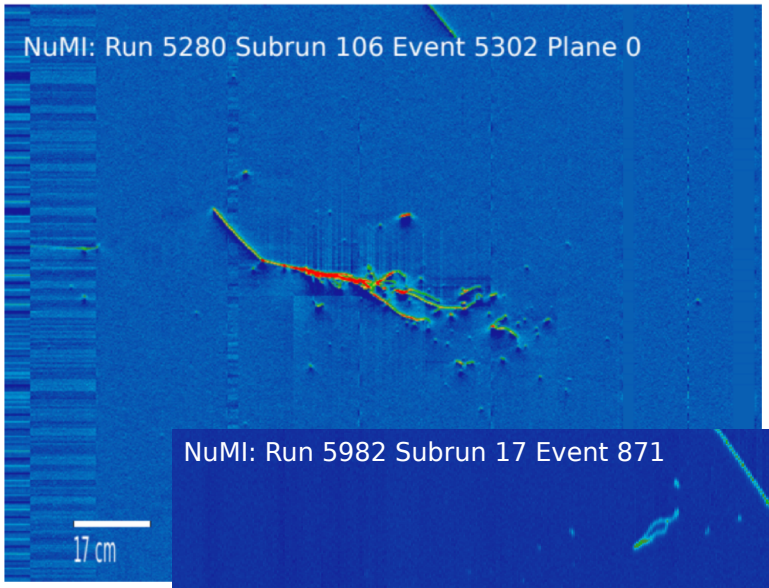
e.g. Require all tracks associated with a neutrino interaction to be contained within the fiducial volume

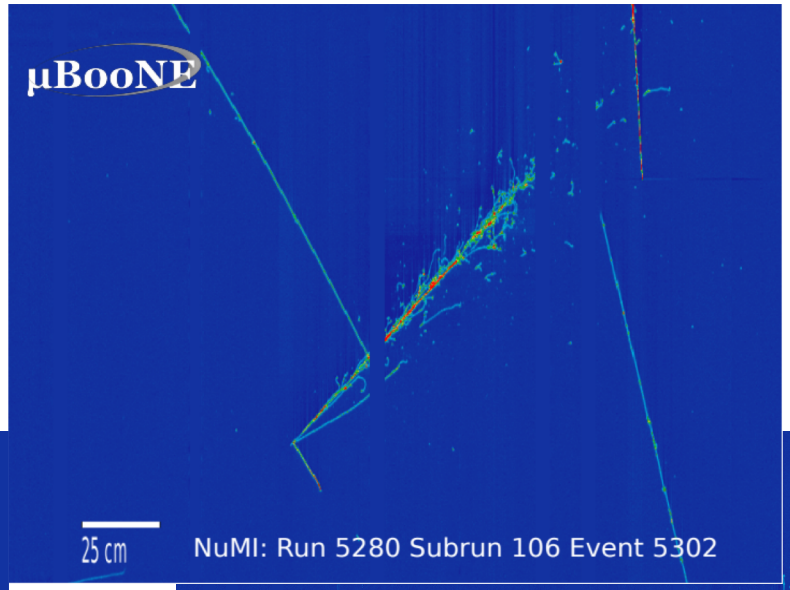


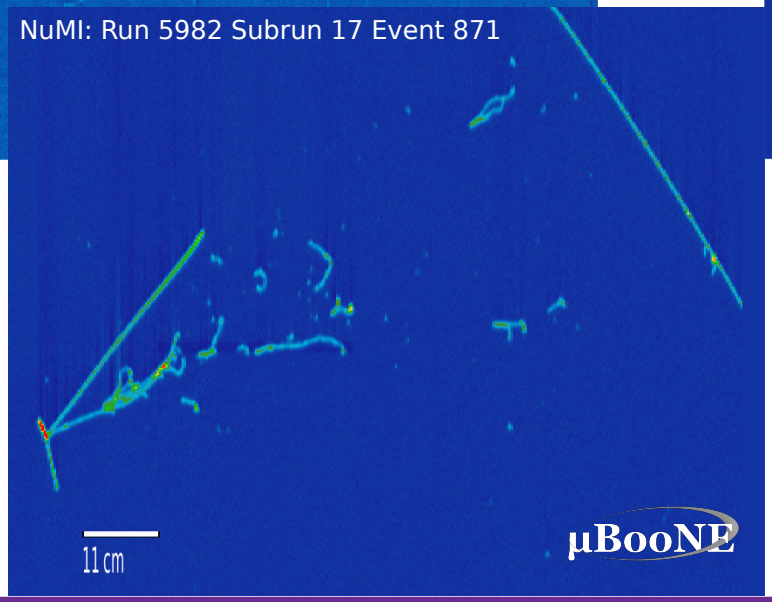

See MICROBOONE-NOTE-1054-PUB for more details!

# MicroBooNE Event Displays

- Data events that pass the selection
- NuMI direction is from the bottom left to top right



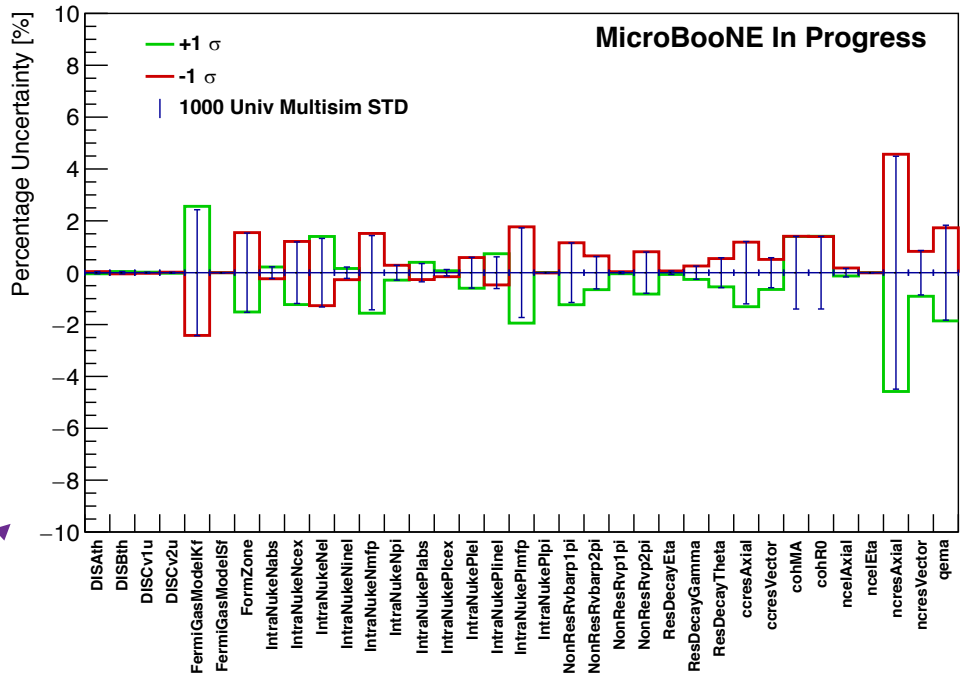




# Systematic Uncertainties

- Systematic uncertainties are being finalised

- Adopted the PPFX package used by NuMI experiments for flux systematics
  - Flux uncertainty is expected to be the most significant contribution

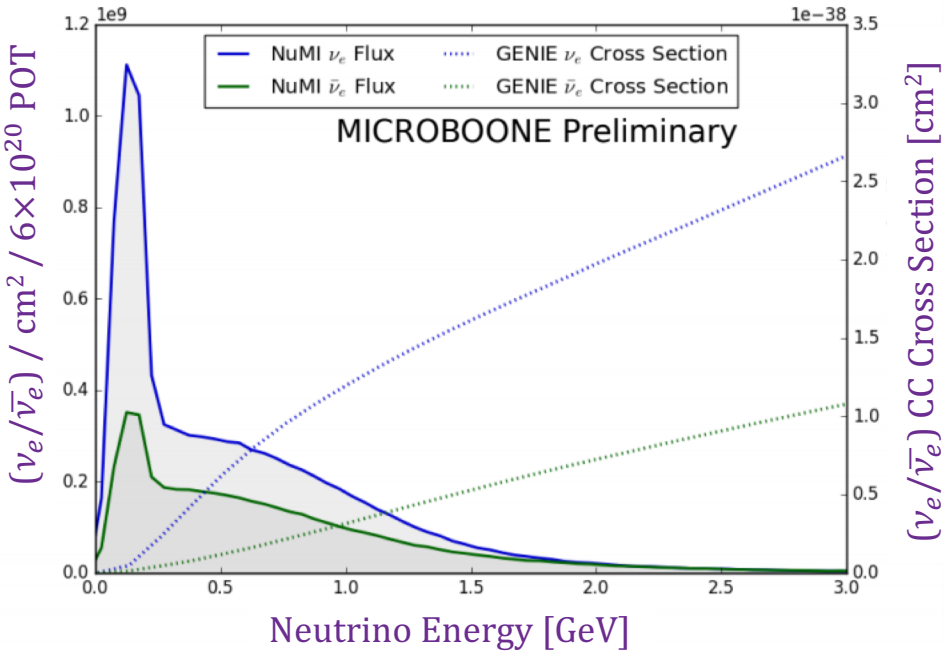
- Preliminary cross section systematics have been evaluated

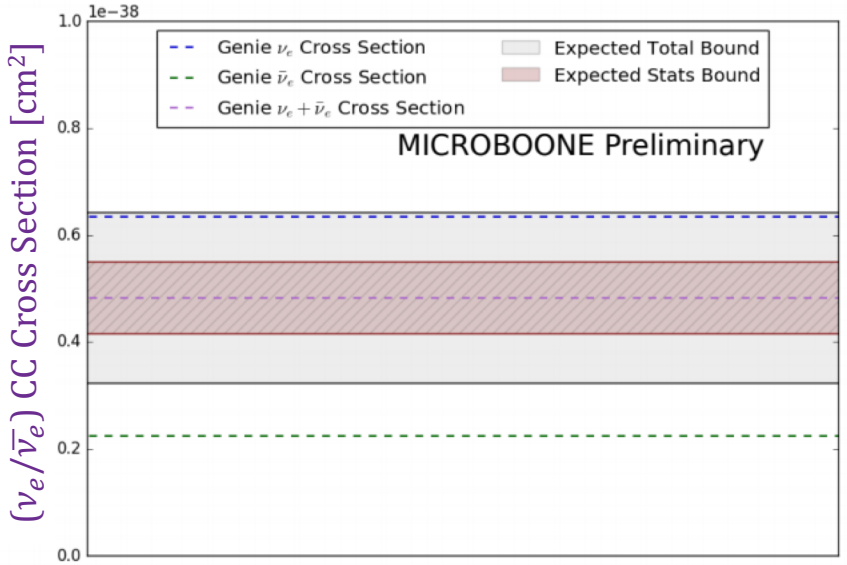


# MC Cross Section Closure Test

- Can run full selection on MC to get a representation of what the final result will be

- Total error band shows the expected sensitivity for data cross section

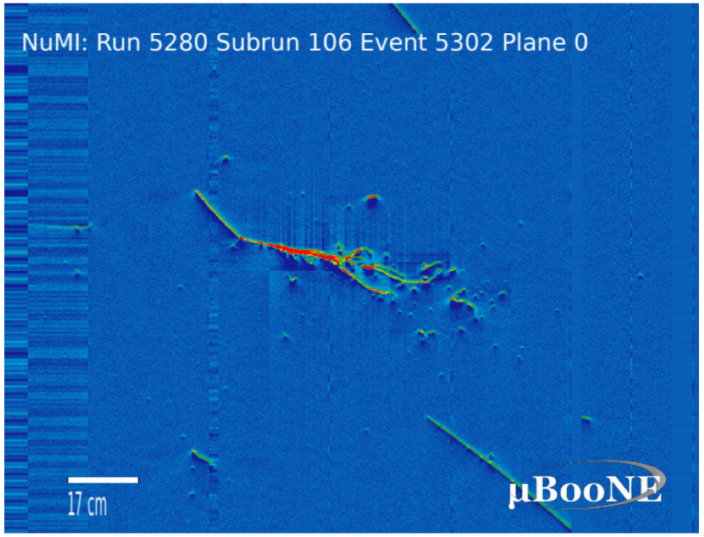


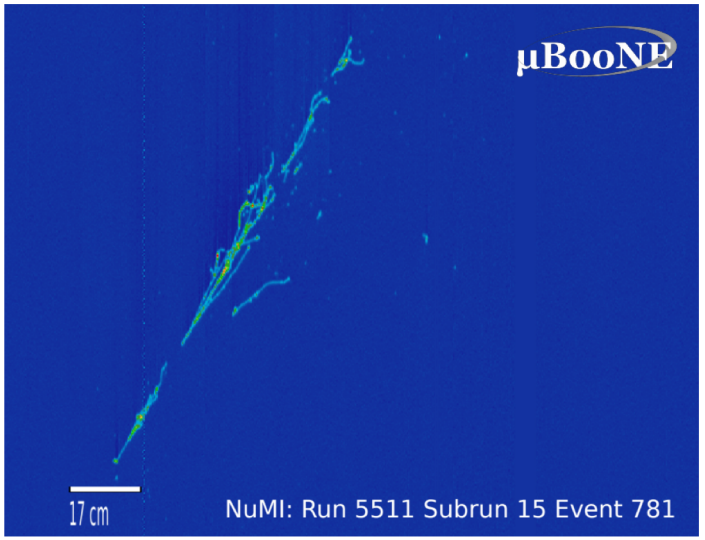



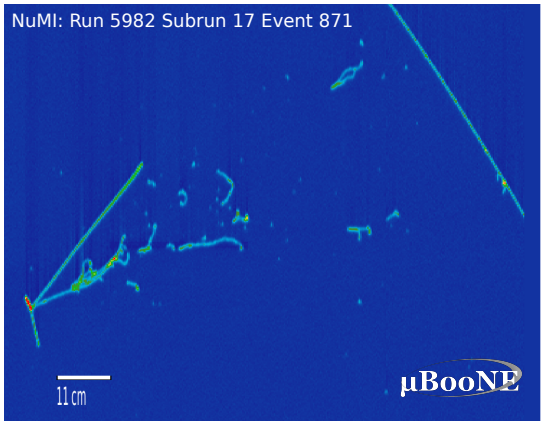
# Conclusion

- Demonstrated one of LAr most powerful capabilities:
  - Separating electron-like and photon-like showers based on calorimetric information

- Final steps towards the measurement are being completed
  - Data cross section will be coming soon!






Thanks for listening!

# Questions?