Analysis of Neutral Current π^0 Events at MiniBooNE

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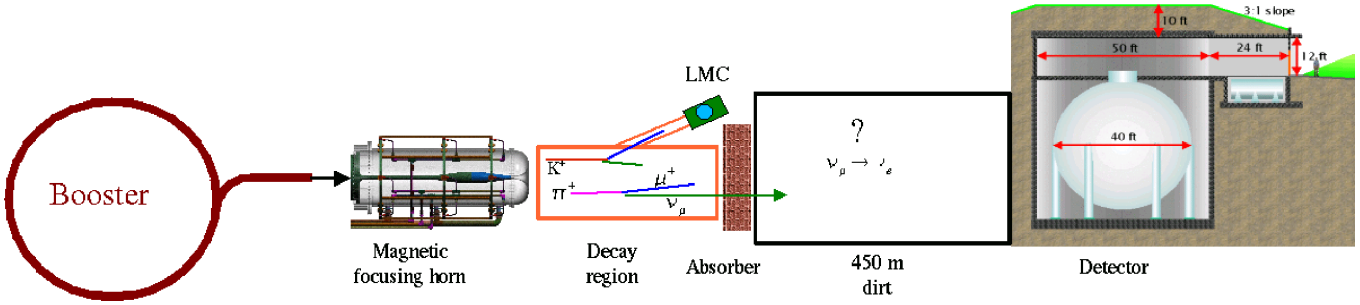
Outline

- Experiment
  - MiniBooNE Description
  - NC π^0 Overview
- Analysis
  - Selection and Reconstruction of Events
  - Rate Measurement
  - Correcting Monte Carlo w/ Data
  - Coherent Fraction Measurement

MiniBooNE

ν_e appearance search designed to confirm or refute the LSND result



The Beam

- 8 GeV p's from Booster beam directed at a Be target
  - Produced $\pi^{\pm}$'s and $K^{\pm,0}$ decay to ν_μ's and ν_e's
  - Magnetic horn focuses or defocuses charged particles to select ν_μ's or $\bar{\nu}_\mu$'s
- Collected a data sample of 5.65e20 protons on target (POT) in ν running at an average neutrino energy of 0.81 GeV and 2.30e20 POT in $\bar{\nu}$ running at $\langle E_\nu \rangle = 0.43$ GeV

MiniBooNE

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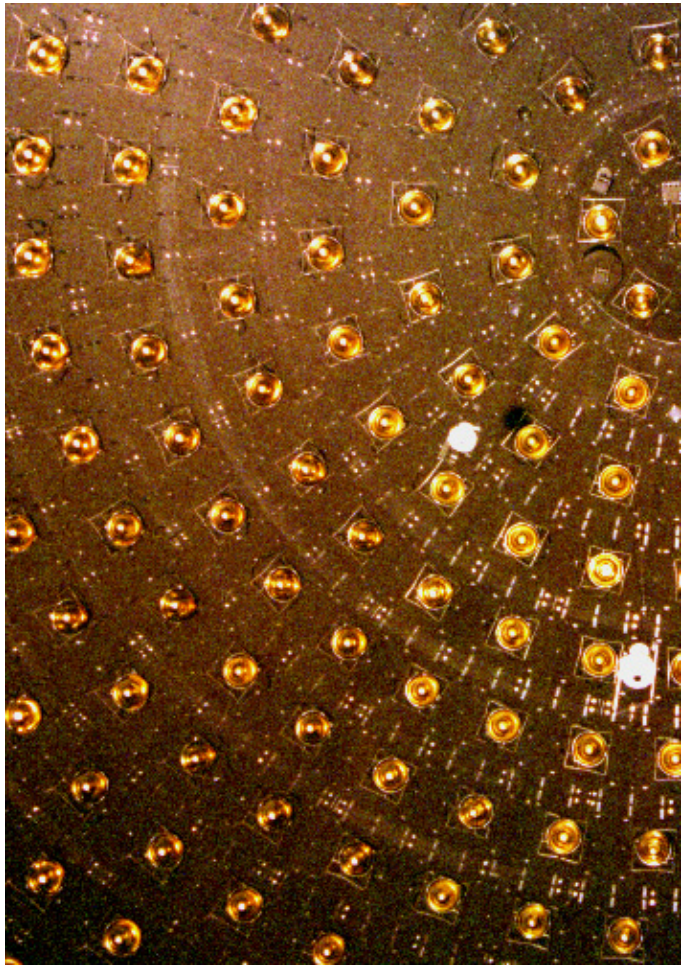
The Dectector

- 12 meter diameter tank
- 250k gallons (800 tons) of mineral oil
- 1520 PMTs – 1280 in the tank 240 in the veto region



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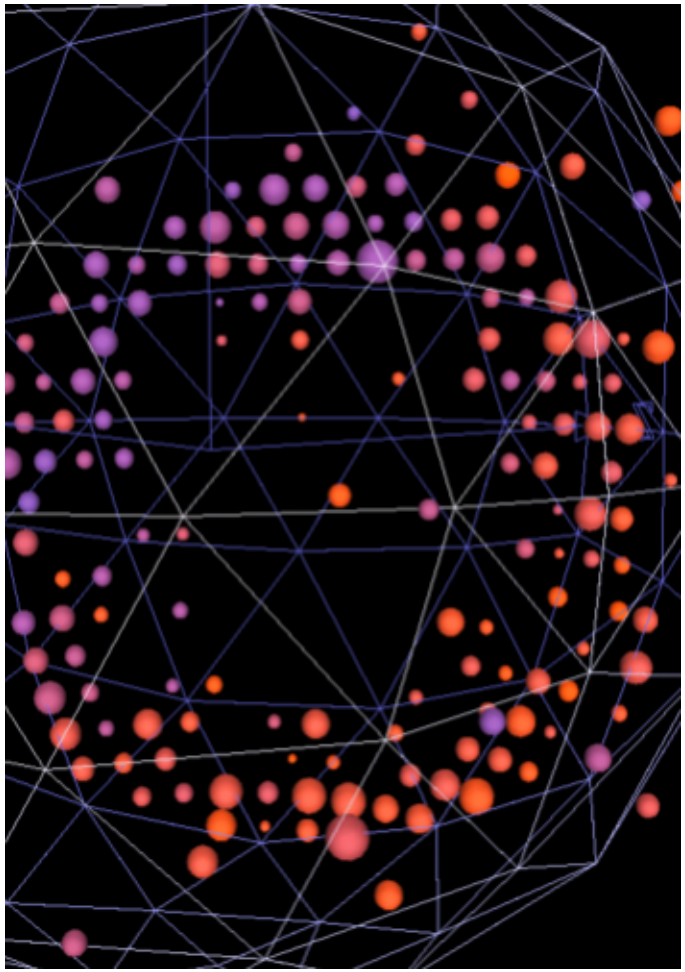
Interaction Signature

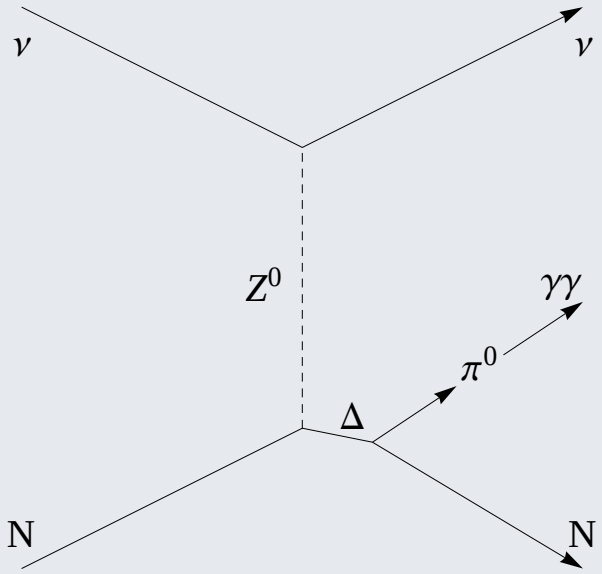
- Products of interactions cause scintillation in the detector and those above a threshold emit Cerenkov light



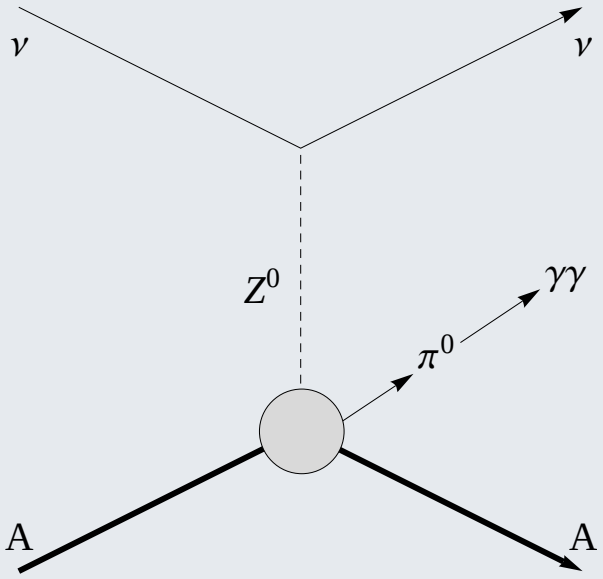
Neutral Current π^0 Interaction

Means of Production

- Resonant
  - $\nu_\mu \mathrm{N} \rightarrow \nu_\mu + (\Delta \rightarrow \mathrm{N} + \pi^0)$



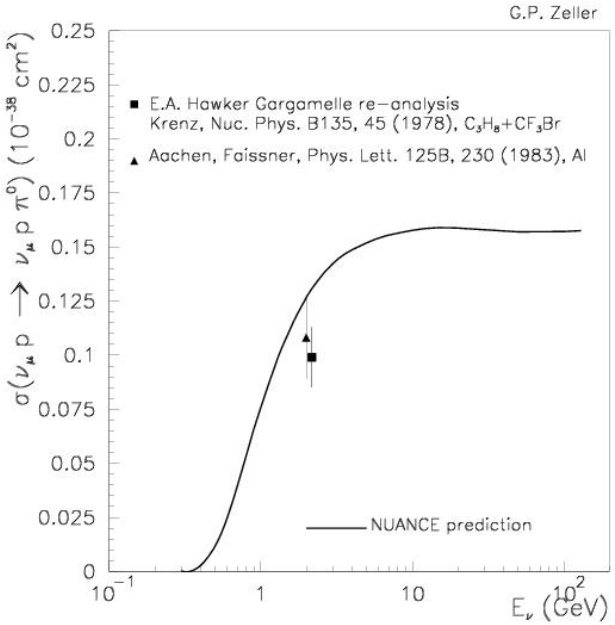
- Coherent/Diffractive
  - $\nu_\mu + \mathrm{A} \rightarrow \nu_\mu + \mathrm{A} + \pi^0$
  - Occur at lower energy, more forward peaked



Neutral Current π^0 Interaction

Why Interesting?

- Important background to many ν_e appearance searches since gammas from π^0 decay can mimic e signal
- Previous measurements of cross section are few in number and low in statistics



Neutral Current π^0 Interaction

What we do at MiniBooNE

- Need to constrain π^0 background to the oscillation search by measuring π^0 mis-ID rate
  - Need to find "effective π^0" events – any event with a decayed π^0
  - Correct Monte Carlo (MC) prediction using measurement of rate in data
- Because of large statistics, MiniBooNE is great for measuring cross sections
  - Measure the absolute effective and resonant π^0 cross sections
  - Expect NC π^0 production to account for $\sim 10\%$ of events

Selection

Starting MC Sample:

π^0's	Purity	Efficiency
Effective	9%	100%
Res. + Coh./Diff.	7%	100%

Precuts

Pre-reconstruction (N-hit) cuts used to eliminate cosmic background and begin to isolate the sample

Precut MC Sample:

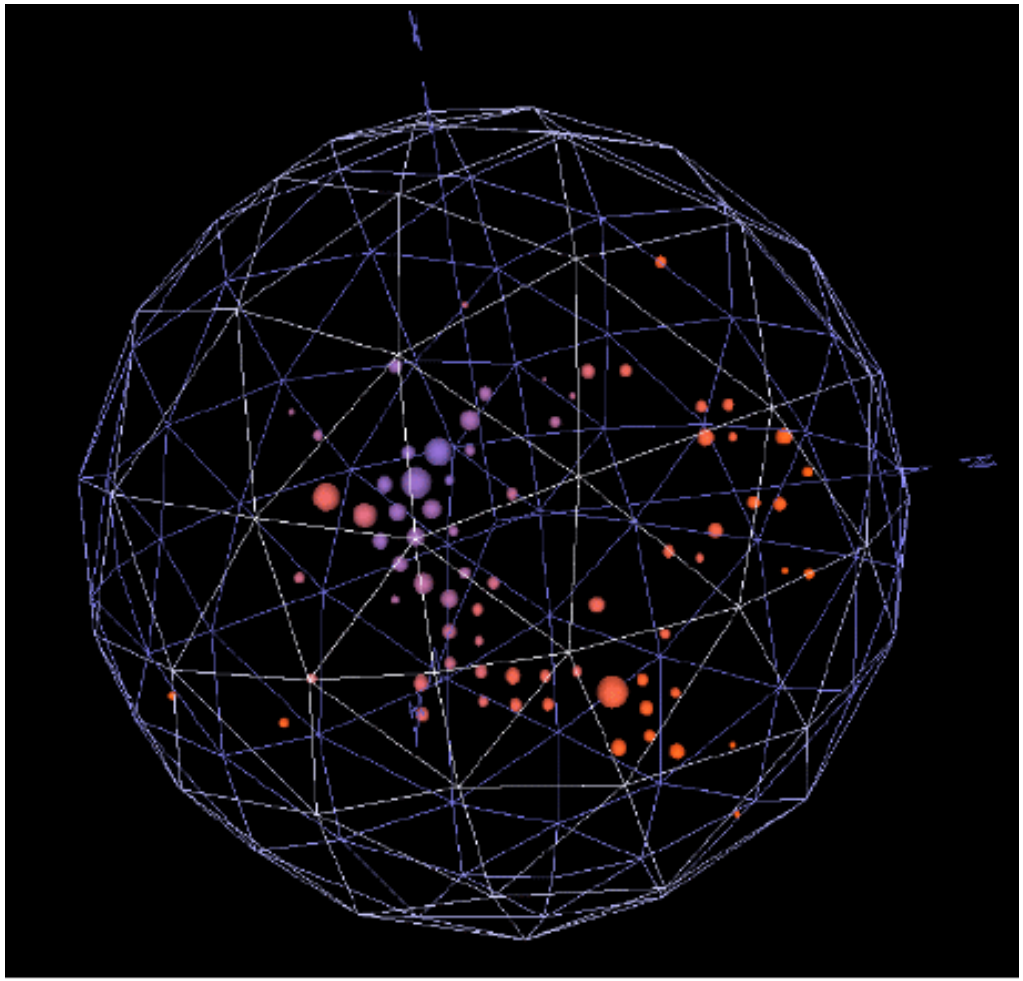
π^0's	Purity	Efficiency
Effective	50%	45%
Res. + Coh./Diff.	38%	41%

Selection

Reconstruction

Use a track-based log-likelihood fit to reconstruct events under 3 hypotheses:

- *Electron-like (Single fuzzy ring)*

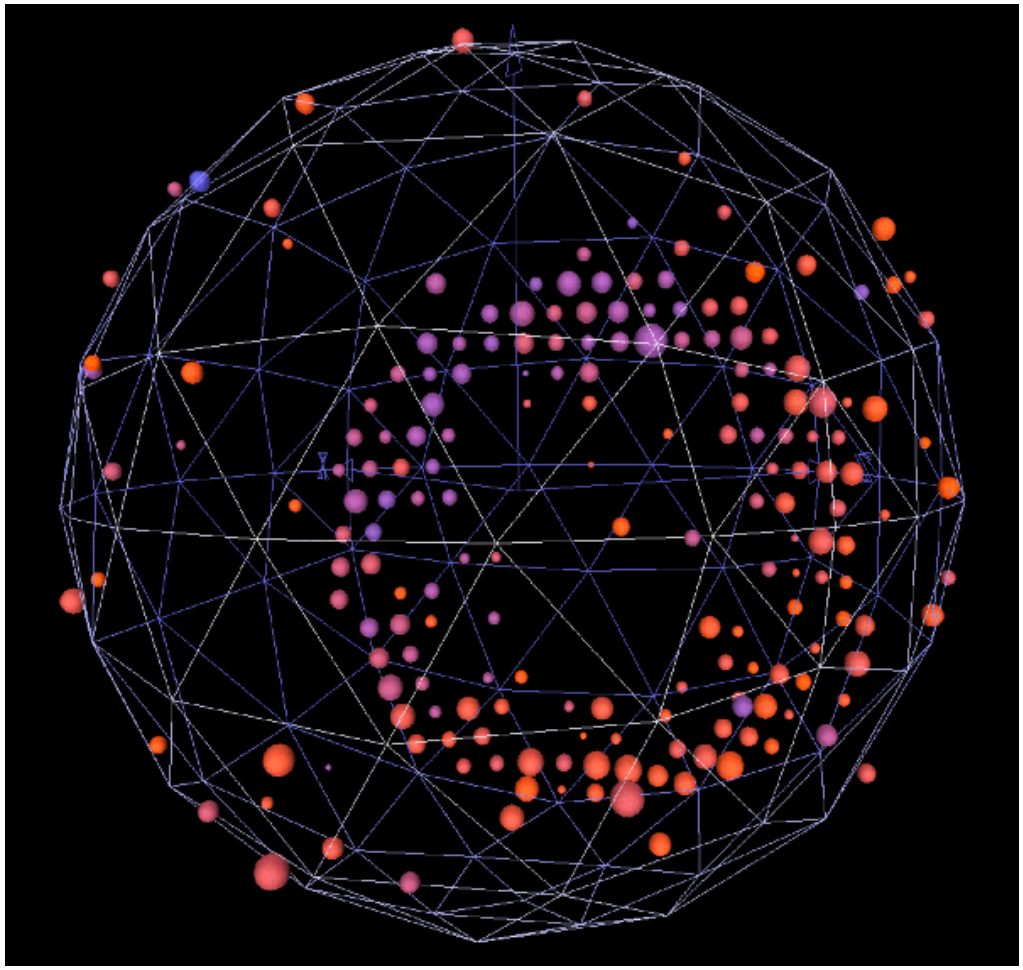


Selection

Reconstruction

Use a track-based log-likelihood fit to reconstruct events under 3 hypotheses:

- Electron-like (Single fuzzy ring)
- *Muon-like (Single sharp ring)*

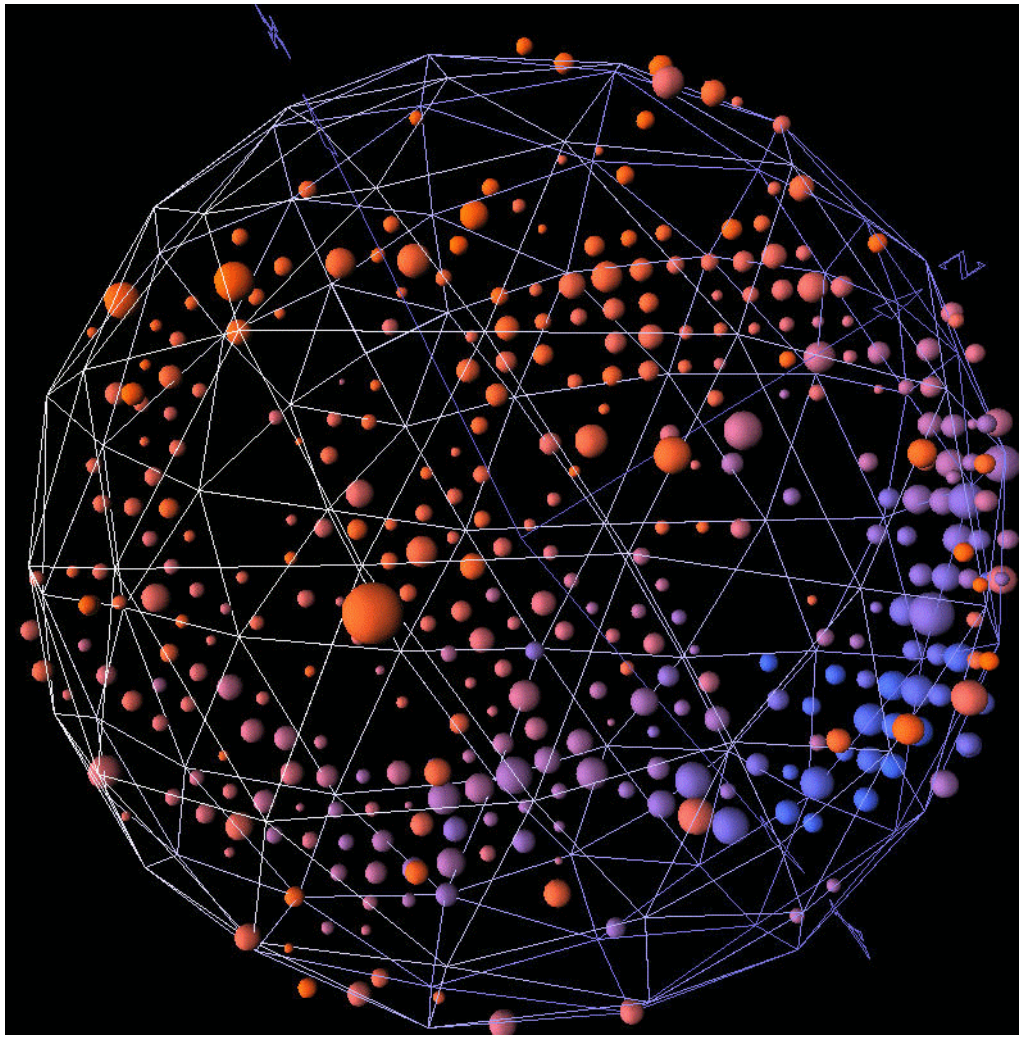


Selection

Reconstruction

Use a track-based log-likelihood fit to reconstruct events under 3 hypotheses:

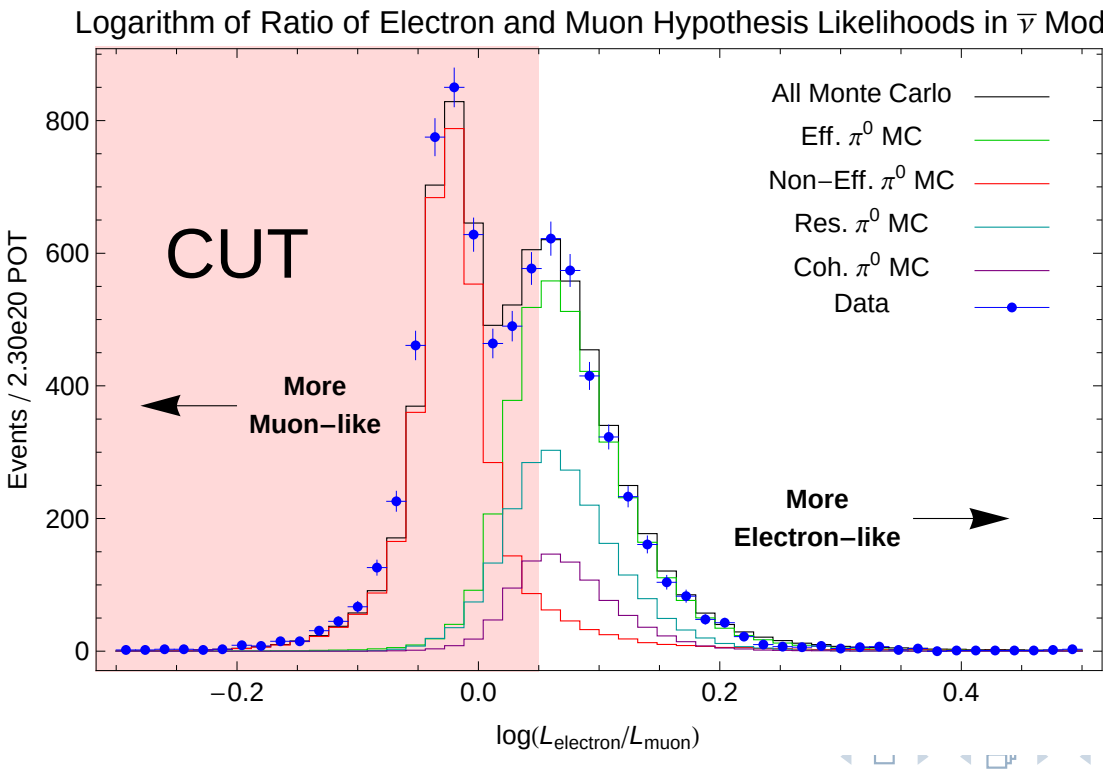
- Electron-like (Single fuzzy ring)
- Muon-like (Single sharp ring)
- *Pion-like (Double ring)*



Selection

Analysis Cuts

Analysis cuts include a fiducial volume cut, cuts comparing the likelihood of fit hypotheses, and a cut on reconstructed π^0 invariant mass



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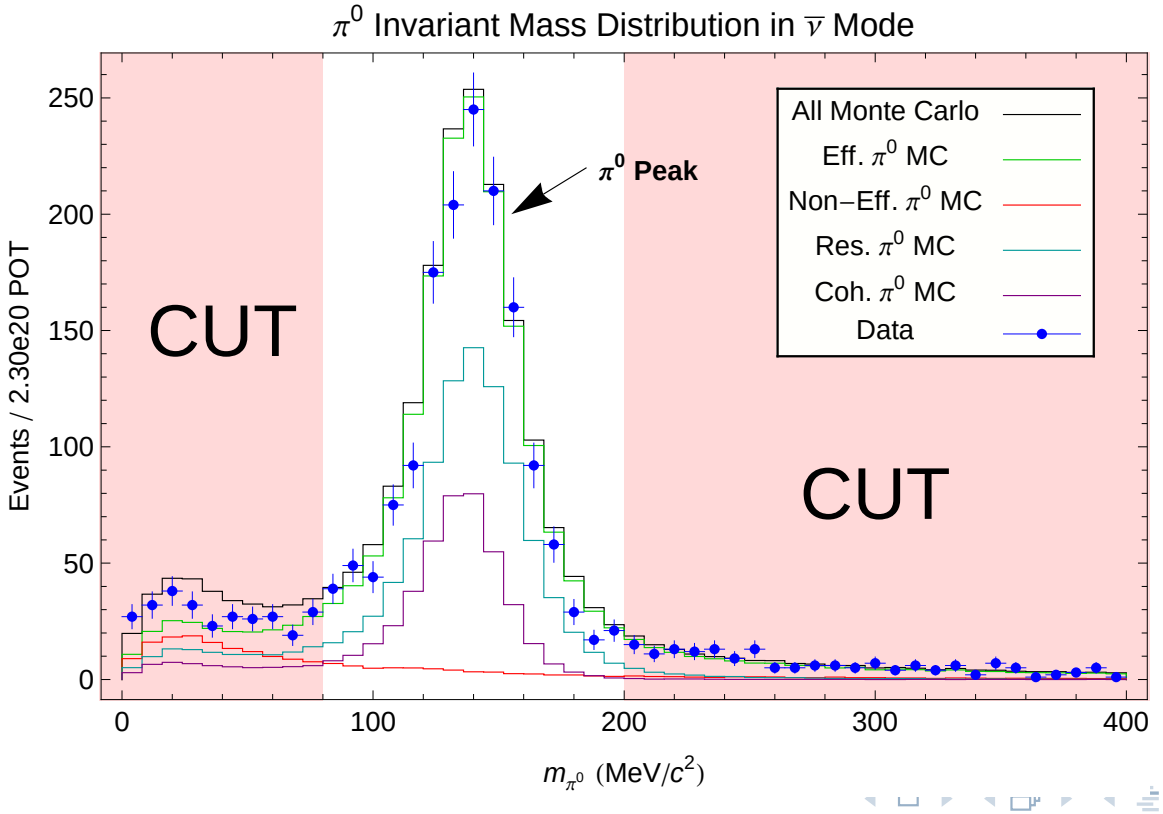


Selection

Analysis Cuts

Analysis cuts include a fiducial volume cut, cuts comparing the likelihood of fit hypotheses, and a cut on reconstructed π^0 invariant mass

Analysis MC Sample:

π^0's	Purity	Efficiency
Effective	97%	18%
Res. + Coh./Diff.	79%	18%

Running Mode	Events Passing Cuts in Data
Neutrino	~18500
Antineutrino	~1500

Rate

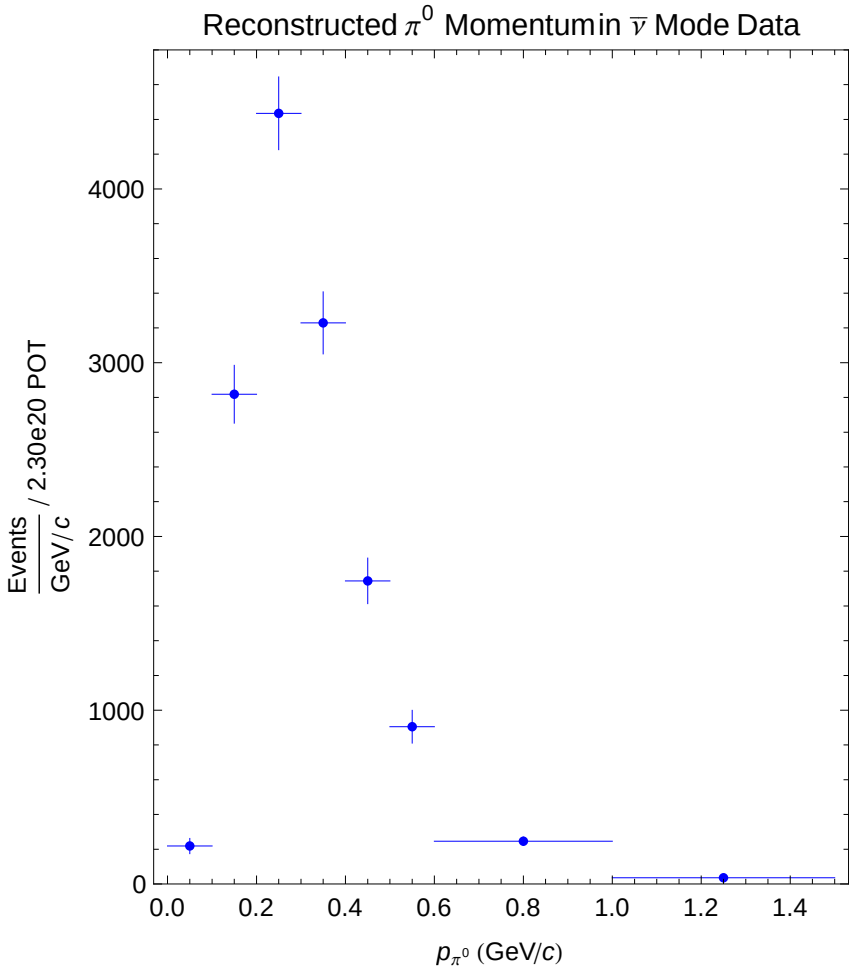
The steps to measuring the rate of π^0 production as a function of π^0 momentum

Background

Background predicted by MC in each p_{π^0} bin is subtracted from π^0 box

Unsmearing

Need to deconvolve detector effects from the measurement of p_{π^0}. Use a matrix inversion method that incorporates the probability that an event with true momentum in one bin is reconstructed in another.



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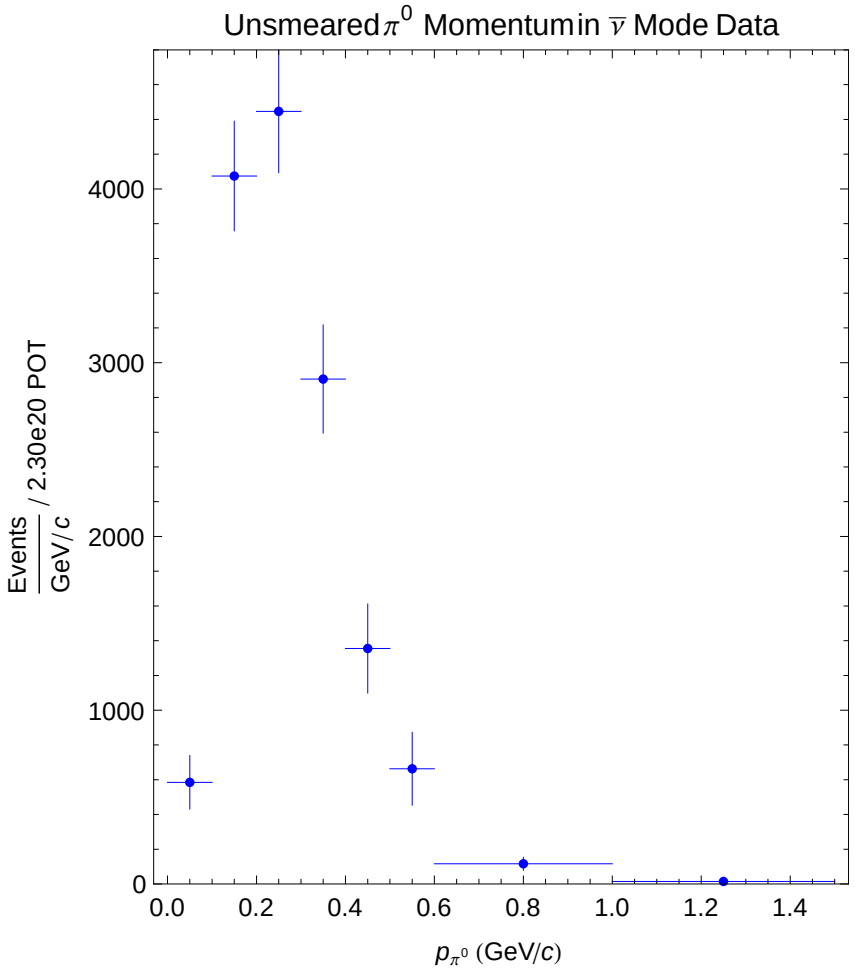

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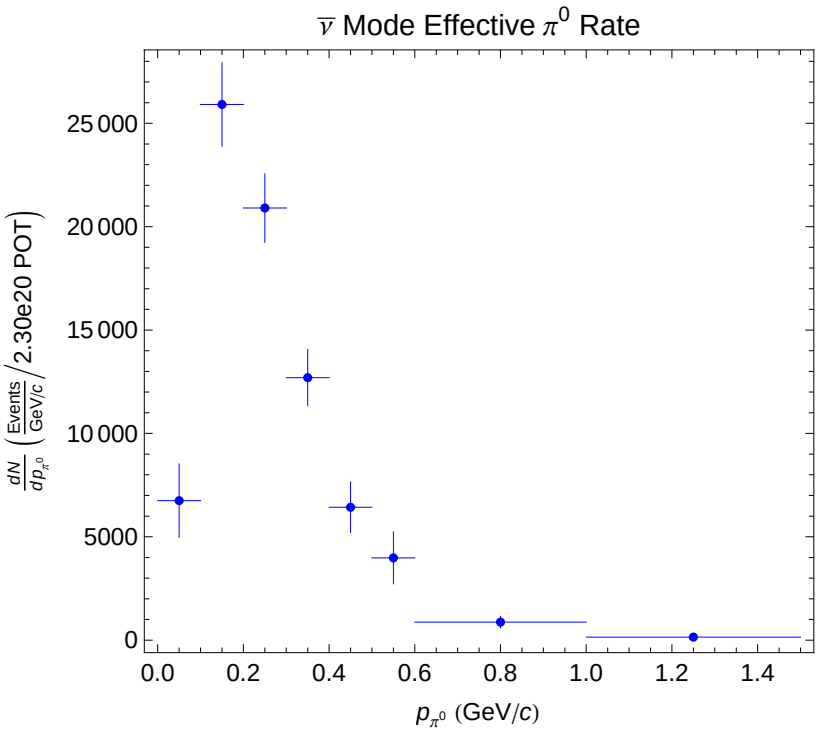
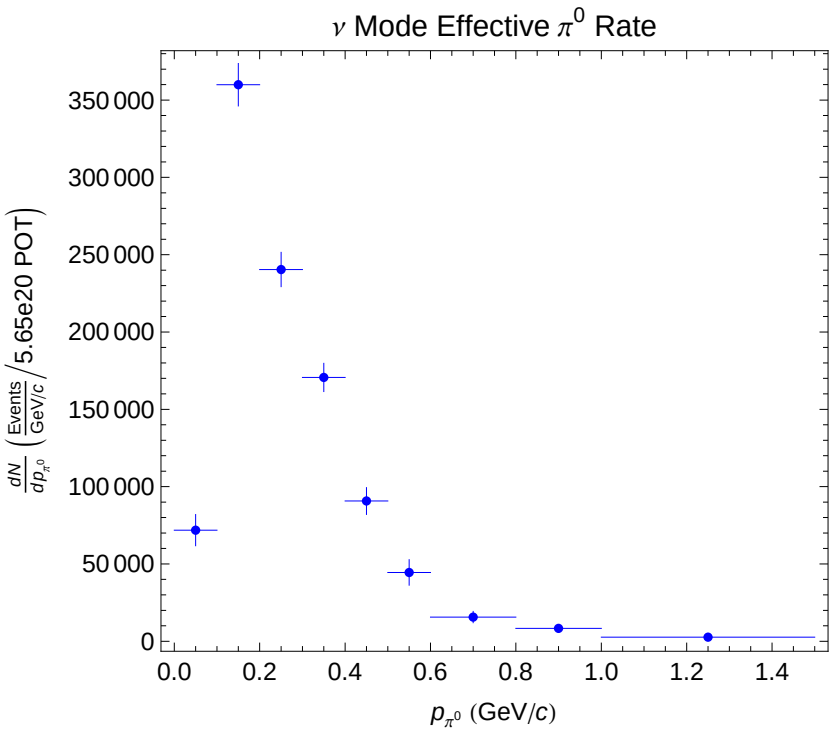




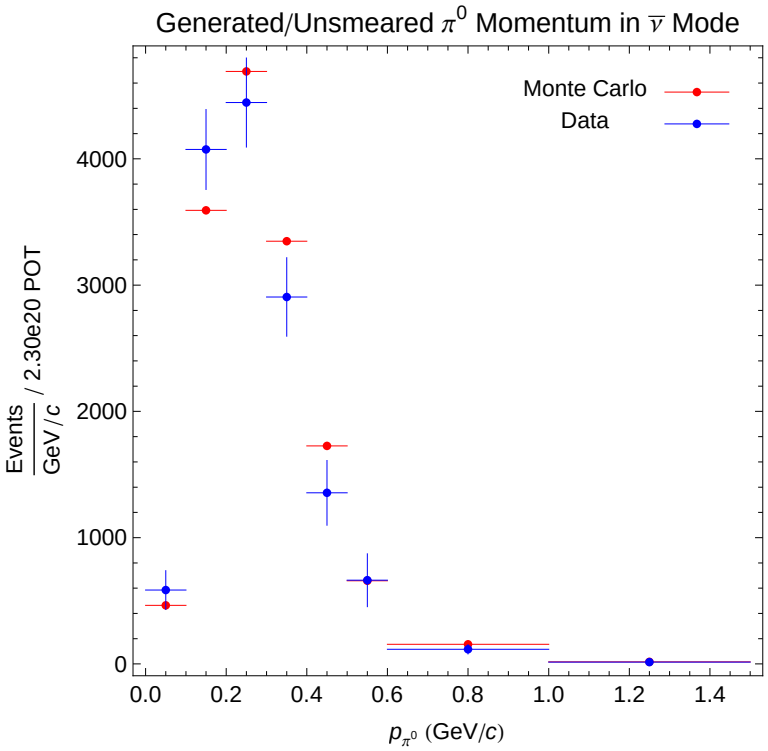
Efficiency Correction

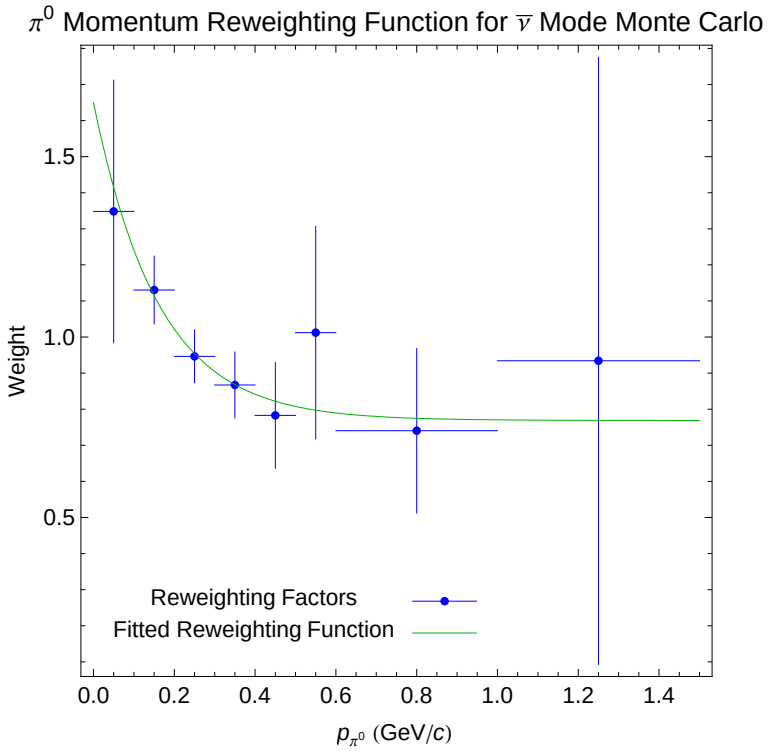
Correct the rate passing cuts back to a total rate using MC prediction of efficiency of cuts in each p_{π^0} bin

Correcting Monte Carlo

Reweighting

Dividing the unsmeared data spectrum by the generated MC spectrum yields a set of weights to apply to effective π^0 events in MC according to momentum so that the π^0 flux in MC agrees with data

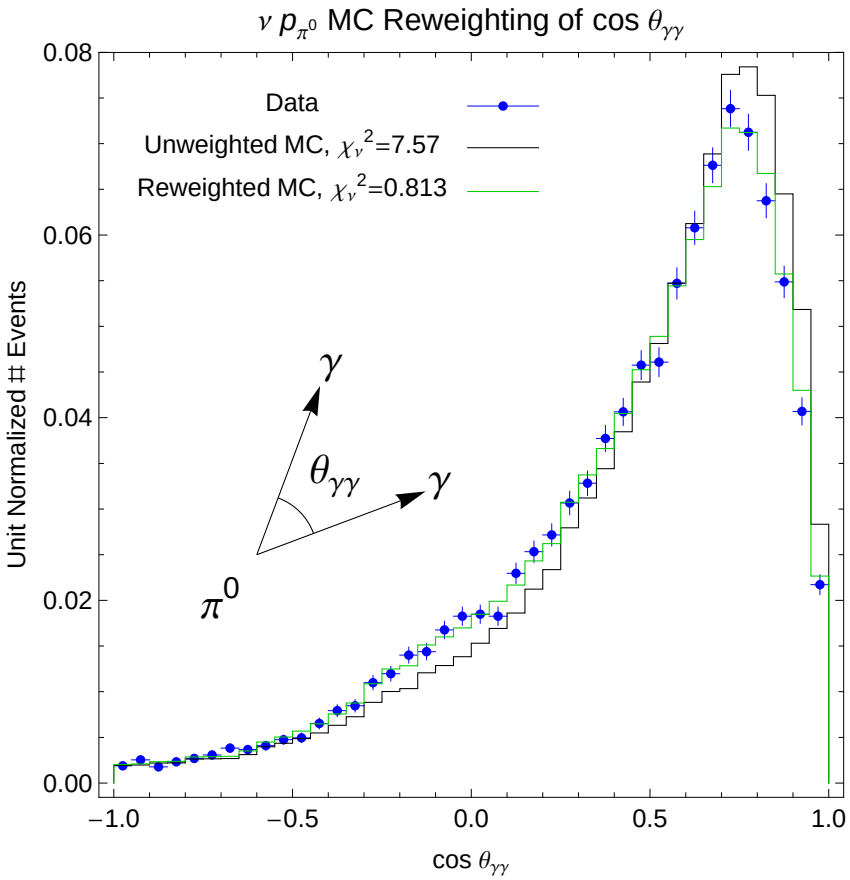


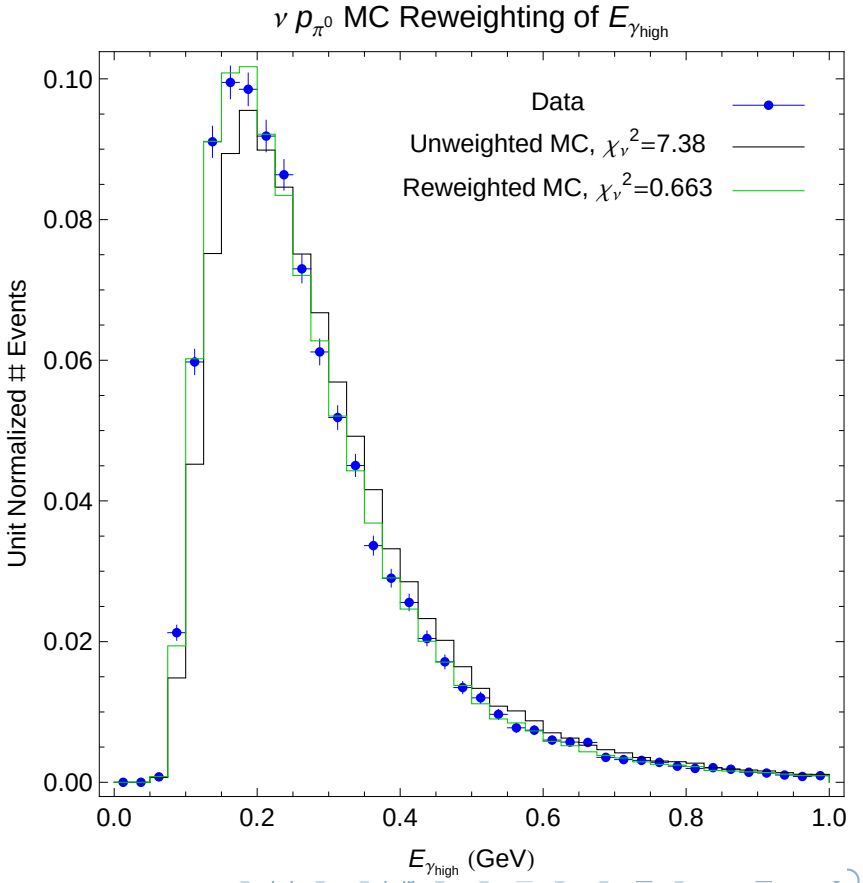


Correcting Monte Carlo

Reweighting

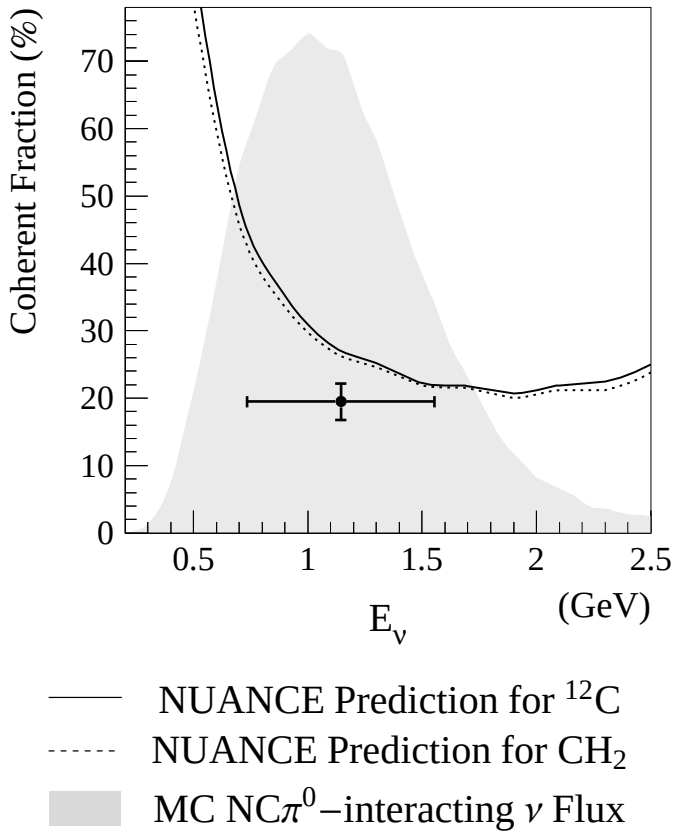
Reweighting Monte Carlo improves agreement in other π^0 variables as well





Coherent Fraction Measurement

- Corrected MC allows a reliable measurement of the coherent and resonant fractions
- 2D Coherent production, resonant production, and background shape templates are constructed from MC
- Linear combination of templates are fit to data to extract the fractional contribution of each
- A paper has been posted recently on the arXiv (arXiv:0803.3423) and submitted to *Phys. Lett. B*



Conclusion

- The rate of NC π^0-like events has been made in neutrino and antineutrino data allowing a constraint from data on an important background to the oscillation analysis
  - In the neutrino analysis, the uncertainty on the π^0 rate has been reduced from $\sim 25\%$ to $\sim 5\%$
- The first measurement of coherent NC π^0 production at an average neutrino energy under 2 GeV has been made
- Measurement of exclusive NC π^0 resonant cross sections and effective π^0 cross section in progress