

# Model Tests of Inclusive CC Proton Production Over Full 5D Phase Space

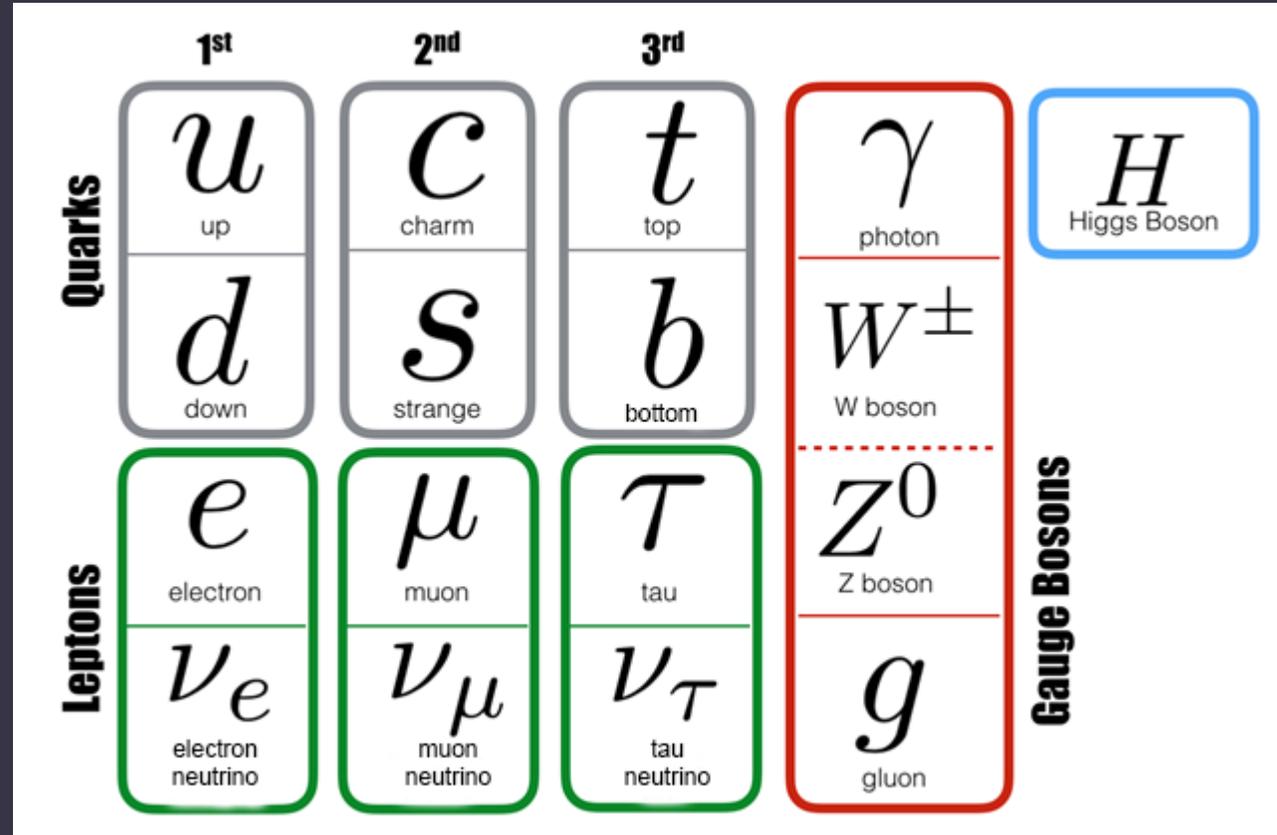
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Grace Song

Dr. Tim Bolton and Dr. Glenn Horton-Smith

# Neutrinos

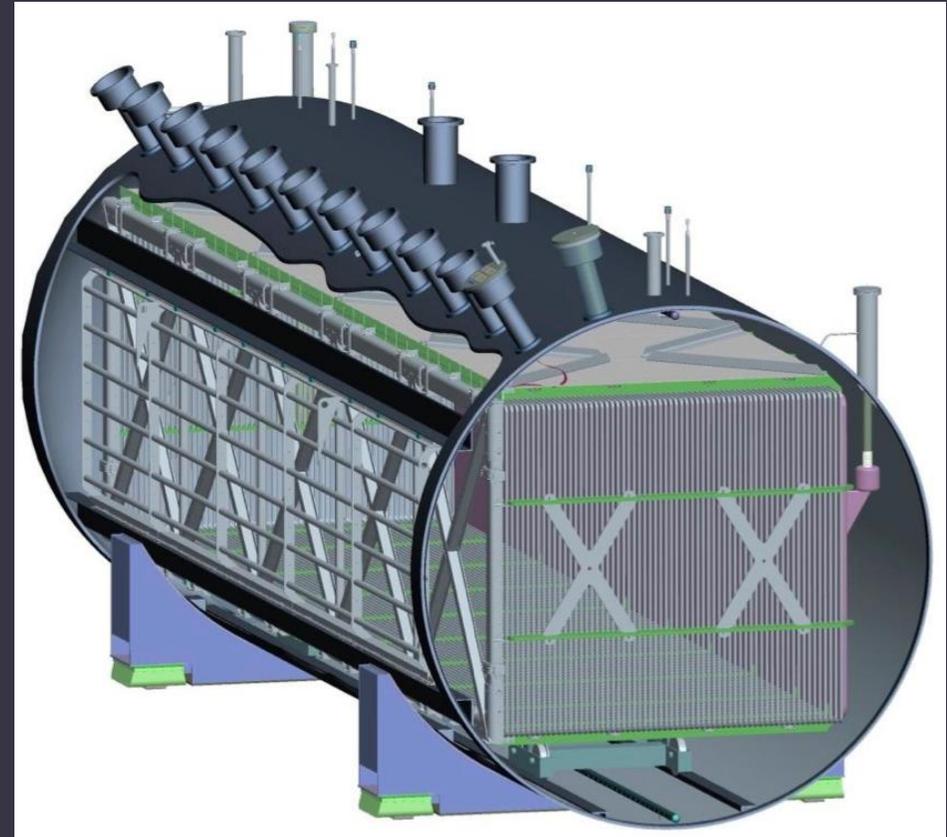
- Three flavors
- Only interact via gravity and the weak force
- Very small mass
- Suspects for CP-violation



University of Zurich: <http://www.physik.uzh.ch/en/researcharea/lhcb/outreach/StandardModel.html>

# MicroBooNE

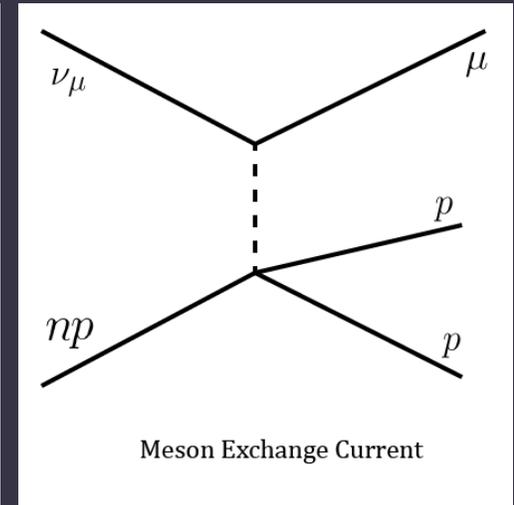
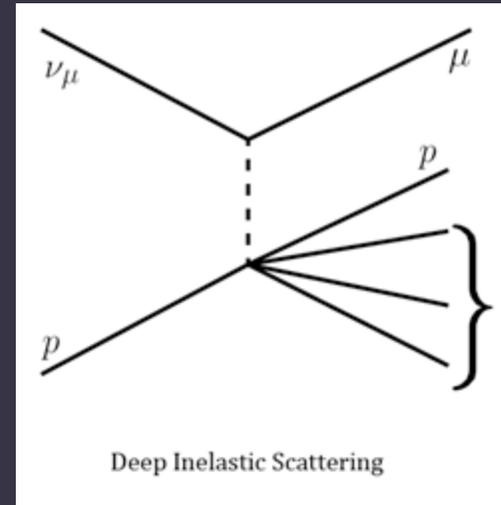
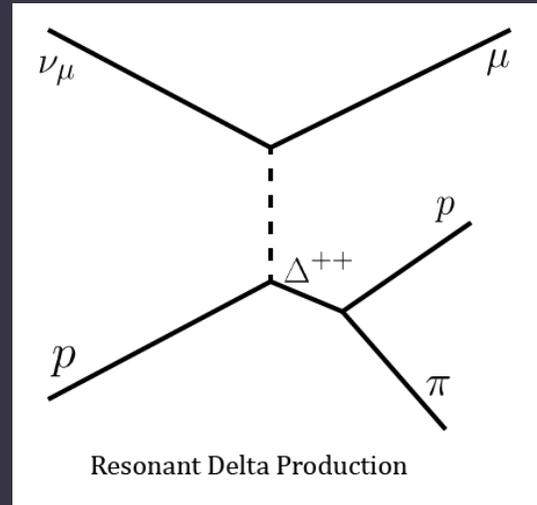
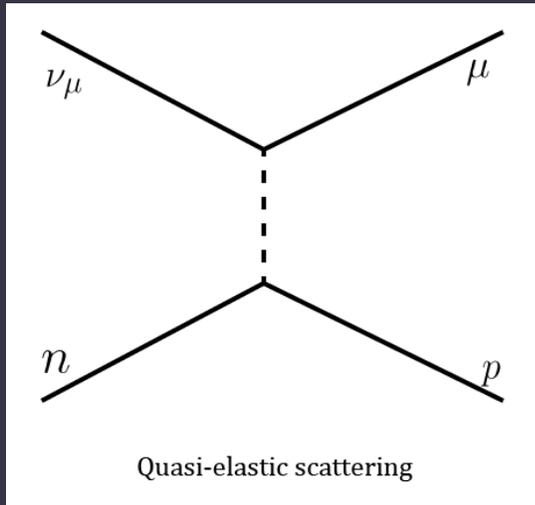
- LArTPC neutrino detector
- 170 tons of liquid argon, 87 K
- 2.325 m x 2.560 m x 10.368 m



MicroBooNE Gallery: <http://microboone.fnal.gov/images-videos/>

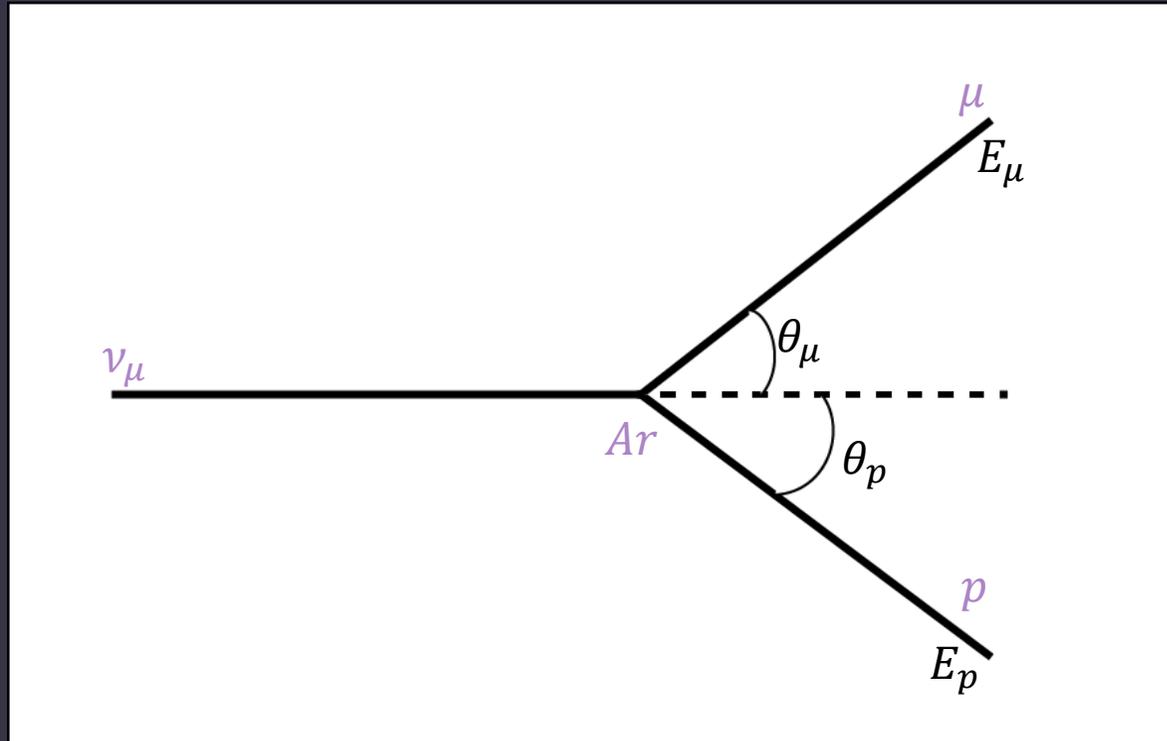
# Neutrino Interactions

$$N_{CC} = (f_{QE} + f_{RES} + f_{DIS} + f_{MEC})N_{CC}$$

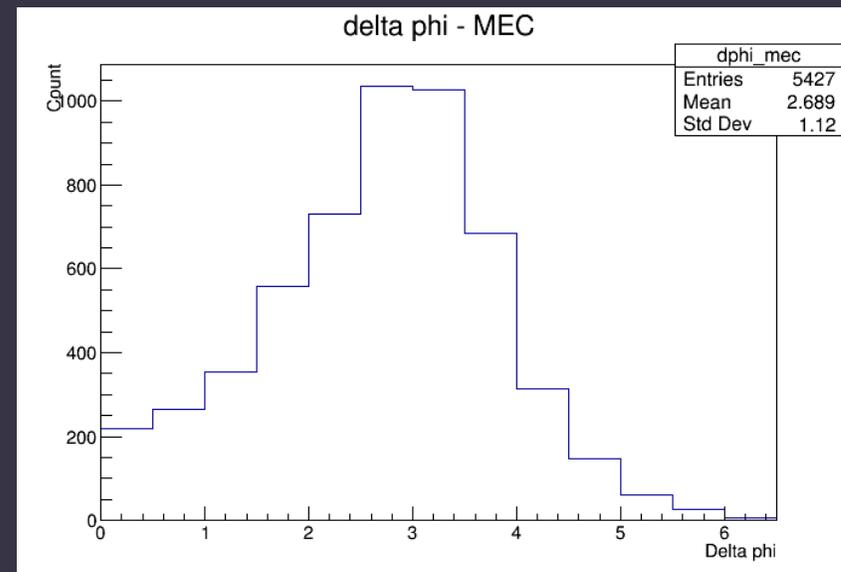
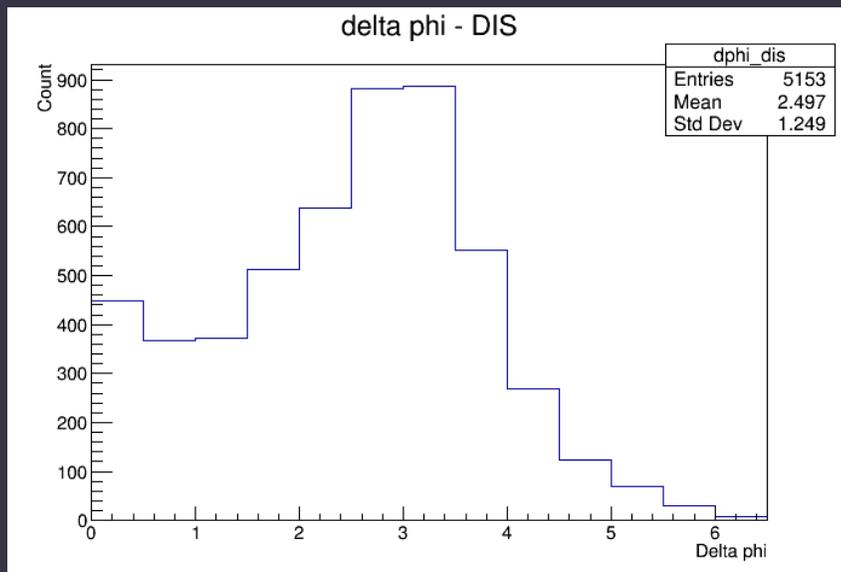
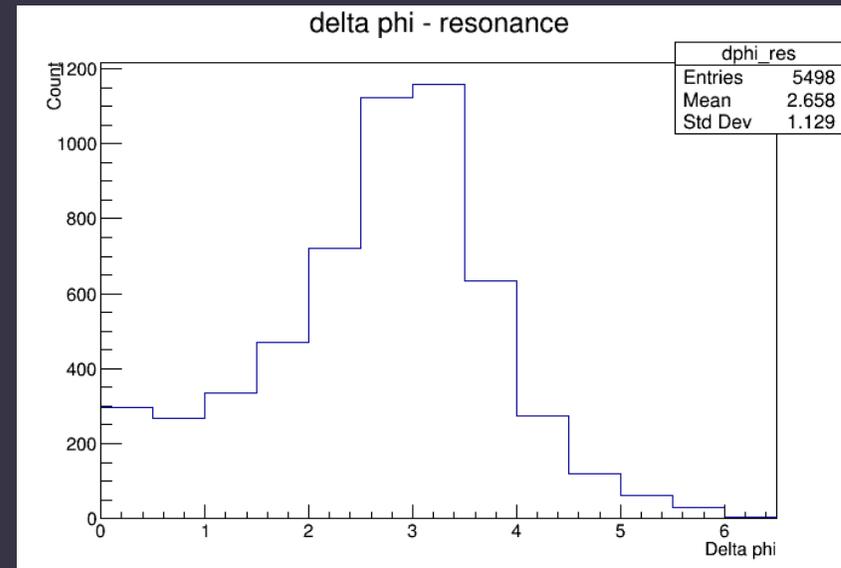
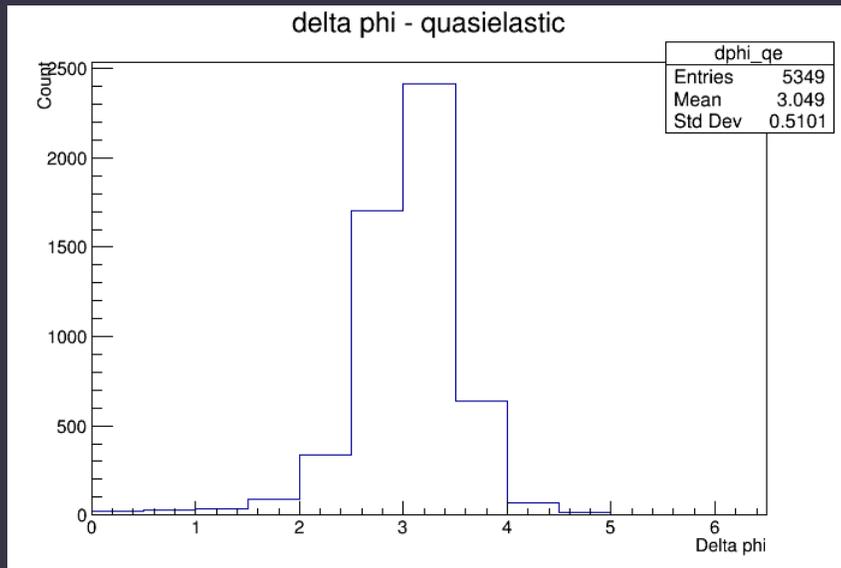


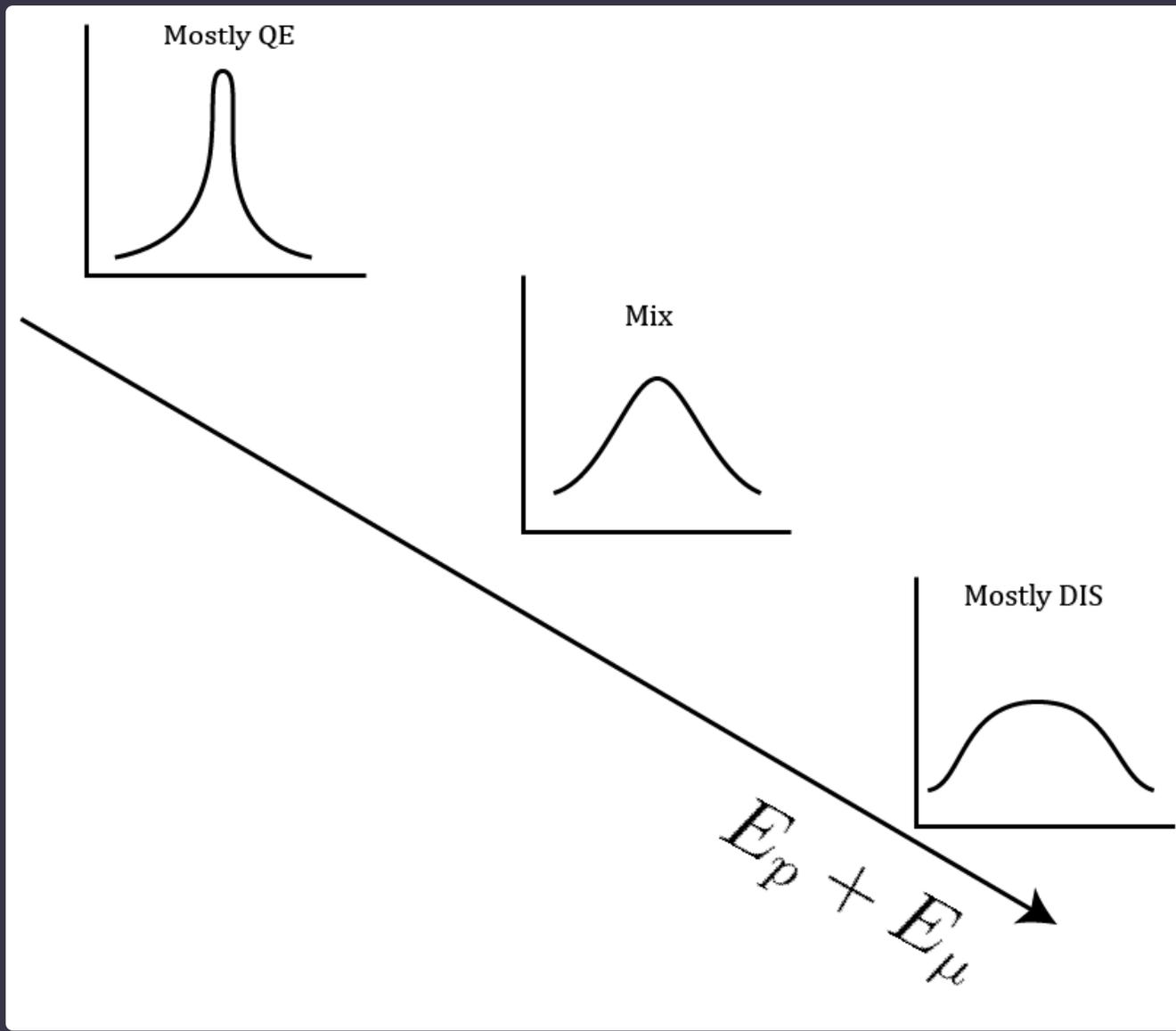
# Fitting

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$\Delta\phi$





# Idealization

- GENIE MCTruth data
- 70 MeV kinetic energy cuts on muon and proton
  - ~750,000 MC events



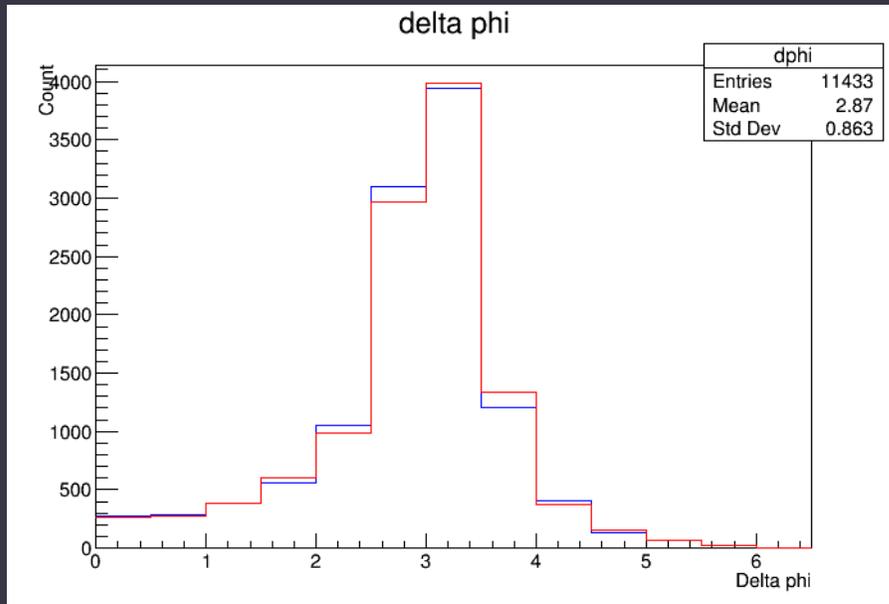
# Poisson Likelihood

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- Variable bins
  - Approx. even counts
- Wide bins
  - $n^5$  problem
  - Reduced resolution effects

$$\mathcal{L} = -\ln L \approx -\sum_i k_i \ln \lambda_i - \lambda_i$$

# 1D and 2D Fits



Model

$$f_{QE} = 0.423, \pm 0.008$$

$$f_{RES} = 0.279, \pm 0.020$$

$$f_{DIS} = 0.083, \pm 0.015$$

$$f_{MEC} = 0.215, \pm 0.011$$

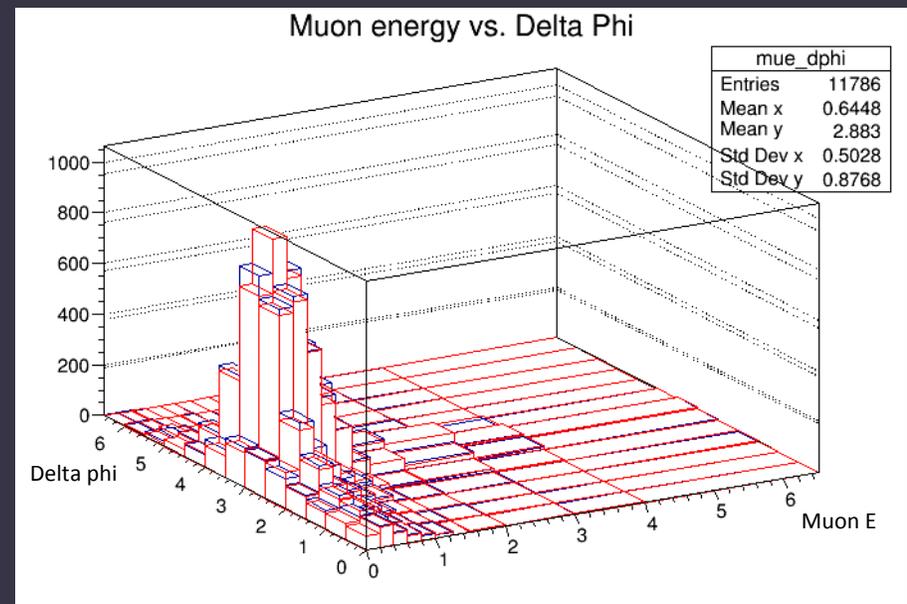
Data

$$f_{QE} = 0.437$$

$$f_{RES} = 0.288$$

$$f_{DIS} = 0.071$$

$$f_{MEC} = 0.204$$



Model

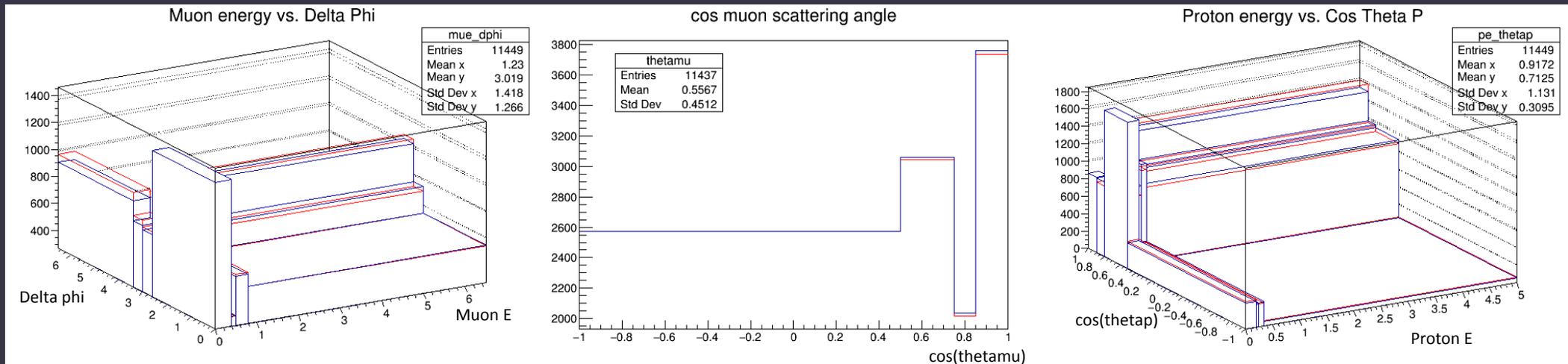
$$f_{QE} = 0.427, \pm 0.008$$

$$f_{RES} = 0.265, \pm 0.016$$

$$f_{DIS} = 0.095, \pm 0.011$$

$$f_{MEC} = 0.212, \pm 0.010$$

# 5D Fit



**Data**

$$f_{QE} = 0.387$$

$$f_{RES} = 0.314$$

$$f_{DIS} = 0.087$$

$$f_{MEC} = 0.212$$

**Model**

$$f_{QE} = 0.392, \pm 0.010$$

$$f_{RES} = 0.311, \pm 0.020$$

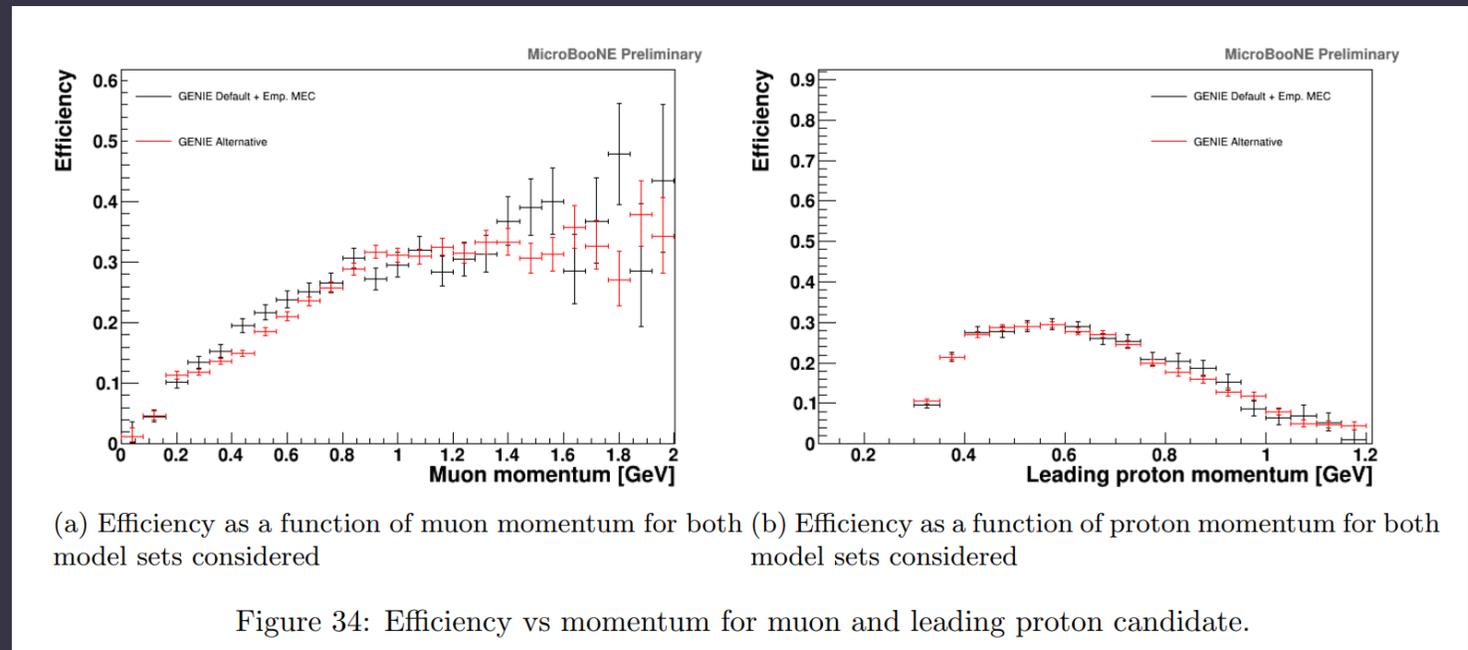
$$f_{DIS} = 0.073, \pm 0.016$$

$$f_{MEC} = 0.223, \pm 0.014$$

23- $\sigma$  difference in likelihood between 3 and 4 contributions

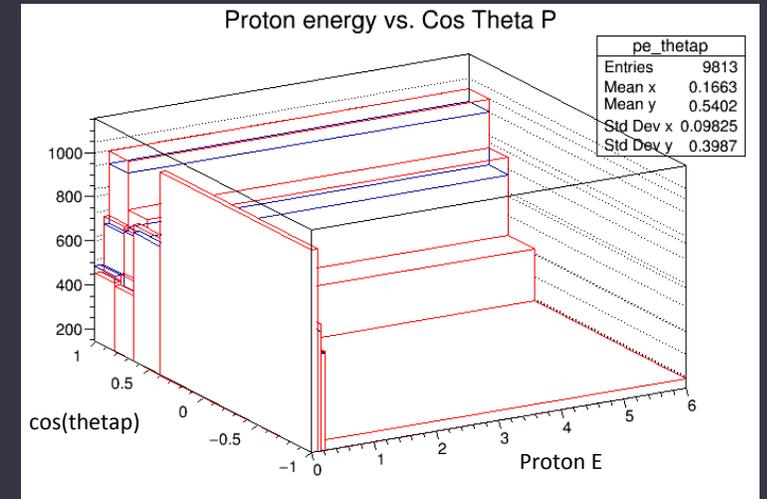
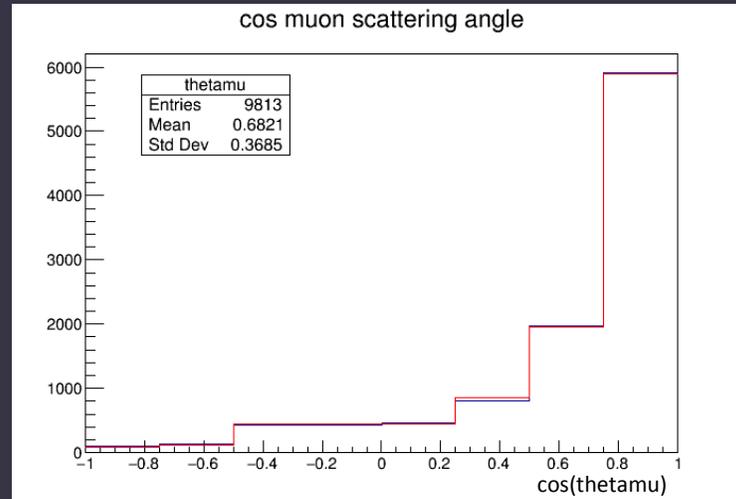
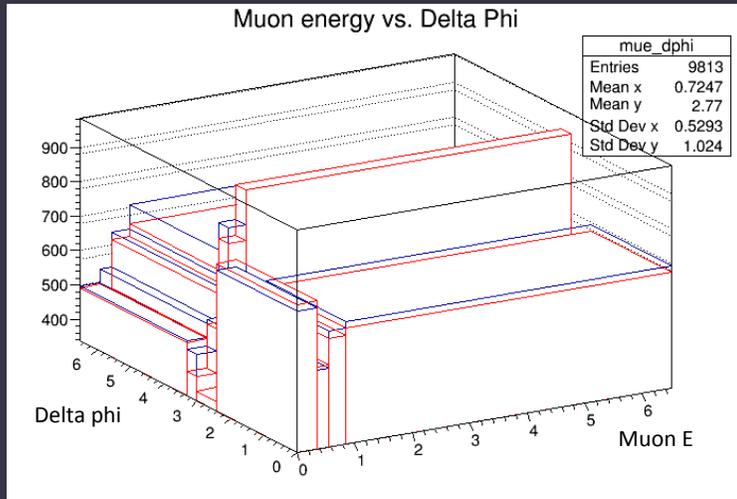
# 5D Fit w/ Efficiency Curve

- Realistic efficiency curve
  - ~70,000 MC events



“Charged Current one Muon and N Proton(N>=1) Selection and 2 Kinematic Properties Analysis in MicroBooNE” Libo Jiang, Nicholas Suarez, Steve Dytman, and Andy Furmanski

# 5D Fit w/ Efficiency Curve



Data

$$f_{QE} = 0.415$$

$$f_{RES} = 0.255$$

$$f_{DIS} = 0.064$$

$$f_{MEC} = 0.266$$

Model

$$f_{QE} = 0.416, \pm 0.009$$

$$f_{RES} = 0.207, \pm 0.017$$

$$f_{DIS} = 0.105, \pm 0.018$$

$$f_{MEC} = 0.272, \pm 0.013$$

# Conclusions

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- Able to extract GENIE parameters using 5D fit
- Currently refining the full efficiency curve implementation
- Further research:
  - Simulate resolution effects
  - Apply to detector data

# Acknowledgements

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- Dr. Glenn Horton-Smith
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