Cross Section Systematics in DUNE

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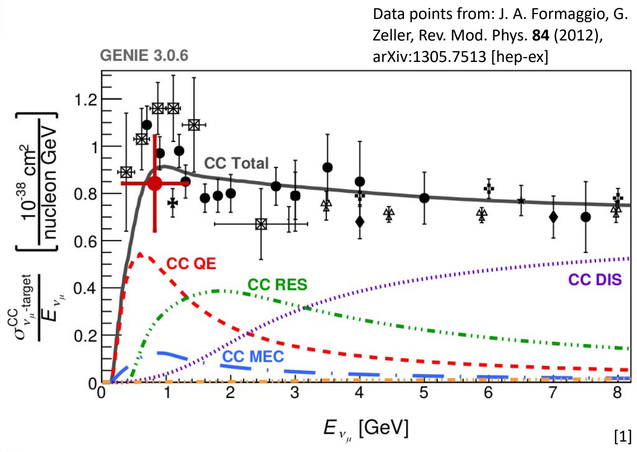
Motivation

- Problem: **Incomplete understanding** of neutrino-nucleus scattering processes and nuclear effects
- Goal: **Obtain interaction model** with associated uncertainties
- How: Design uncertainty parameters to account for model-to-model **discrepancies** in the DUNE oscillation analysis

Processes

- Charged-Current inclusive muon neutrino interactions

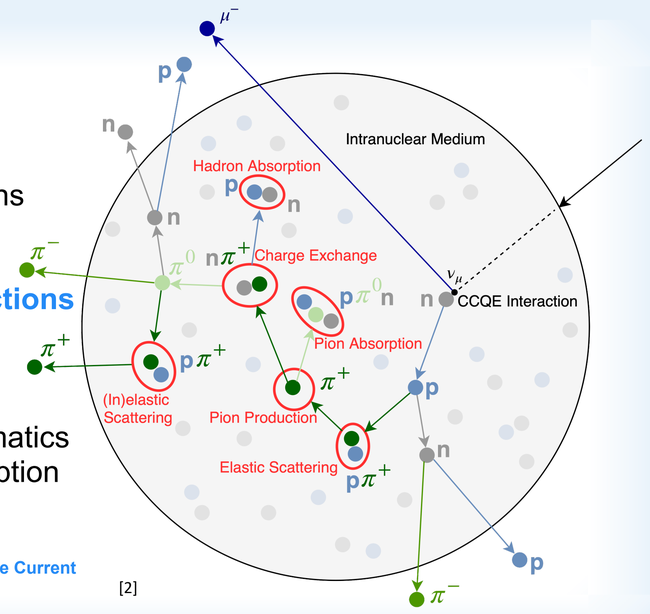


[1]

Nuclear Effects

- *Initial State Effects*:
  - Fermi Motion
  - Nuclear Binding Energy
  - Nucleon-Nucleon-Correlations
- *Nucleon Correlation Effects*:
  - 1p1h-, **2p2h-(*MEC-)interactions**
- *Final State Interactions* (FSIs):
  - Intranuclear re-scattering
  - Alteration of final state kinematics
  - Stimulation of nuclear absorption and emission

*MEC: Meson Exchange Current

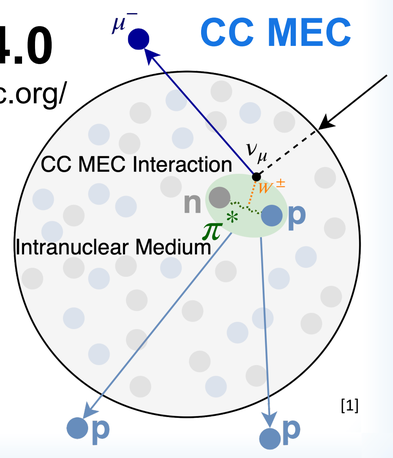


[2]

Simulation

GENIE v3.4.0
http://www.genie-mc.org/

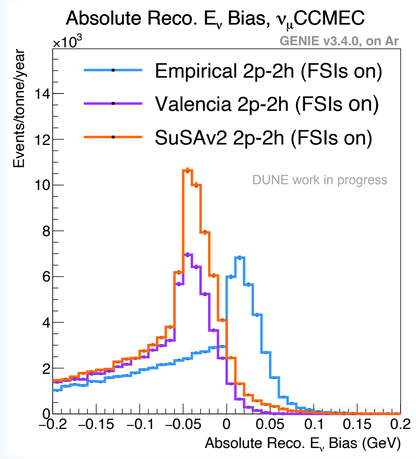
- Simulate CC MEC neutrino interactions with GENIE
- Vary parameters and compare predictions to **determine uncertainties**



[1]

Why do we want to vary systematic parameters?

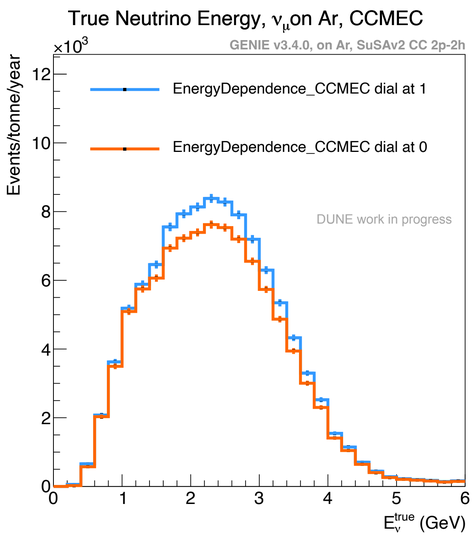
Idea



- **Clear separation** between the distributions of the Empirical and Valencia/ SuSAv2 CC 2p-2h models
- **Choose uncertainties** such that the measurement of the oscillation parameters is not biased in case the wrong model is chosen

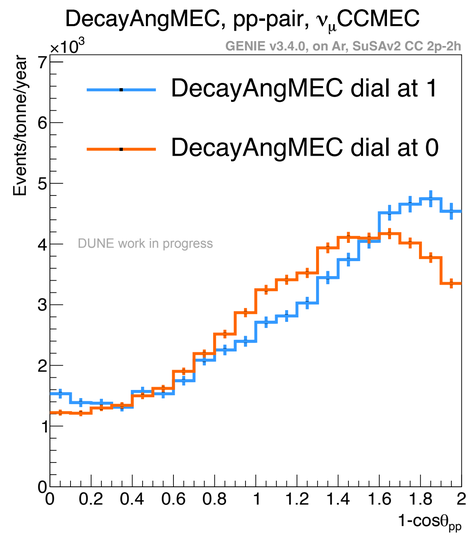
$$E_\nu^{\text{rec}} = \sum_{\text{p},\pi^\pm} E_{\text{kin}} + \sum_{\text{e}^\pm,\pi^0,\gamma} E + E_{\text{lep}}$$

Energy Dependence



- Changes the energy dependence of 2p-2h cross sections

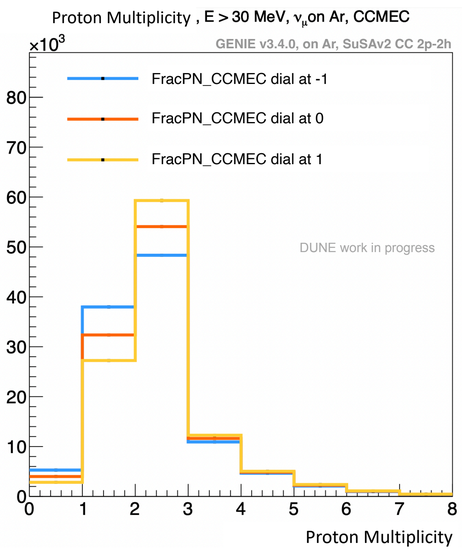
Nucleon Decay Angle



- Changes dependence of decay angle of struck nucleon pair (an ad-hoc assumption on angular distribution of outgoing nucleons) away from isotropic distribution

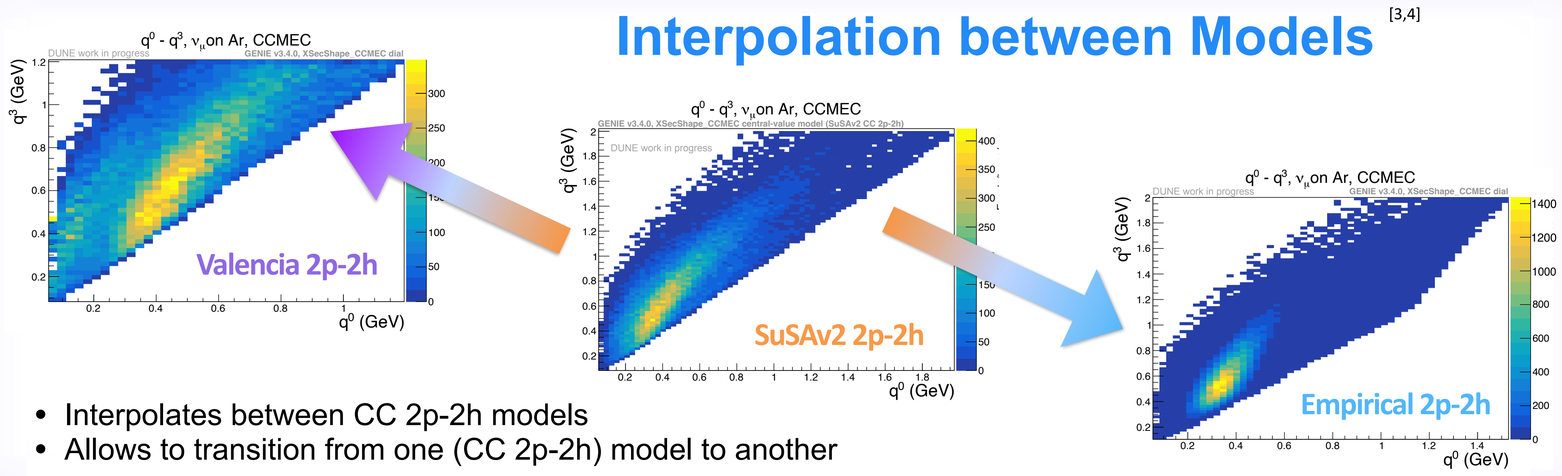
New Meson Exchange Current Model Uncertainties

Nucleon Pair Content



- Changes the pn-pair content in the initial nuclear state

Interpolation between Models [3,4]



- Interpolates between CC 2p-2h models
- Allows to transition from one (CC 2p-2h) model to another

Conclusion

- Develop systematic fit parameters to enhanced theory-driven simulation predictions
- Understanding the effect of systematic parameter dials on chosen variable distributions will allow a robust estimate of systematic uncertainties in modern and future neutrino oscillation experiments such as DUNE.

[1] L. Bathe-Peters, M.S. thesis, Harvard University and Technische Universität Berlin, 2020.
[2] L. Bathe-Peters , S. Gardiner, R. Guenette., FERMILAB-PUB-22-007-SCD, Jan. 2022. arXiv: 2201.04664 [hep-ph].
[3] P. Abratenko, R. An, J. Anthony, et al., Phys. Rev. D, 105, 7 Apr. 2022.
[4] S. Dolan, G. D.. Megias, S. Bolognesi, Phys. Rev. D, 101, 20 Feb. 2020

In collaboration with: Kirsty Duffy

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