GENIE Adaptations for Electron Beam and Simulation Comparisons

Thomas Barbera, University of Notre Dame

Background

E4nu Experiment

The goal of the electron-for-neutrino (e4nu) collaboration is to simulate neutrino nuclear interactions via electrons due to the similarity between their interactions within a nucleus in order to minimize uncertainty in neutrino analysis.

ROOT

ROOT is a C++-based "Data Analysis Framework" created by CERN that is specifically designed for statistical analyses of large datasets. Because of its large systematic capabilities, ROOT is used in many test beam facilities.

GENIE

GENIE, a neutrino simulation program, is widely used to further the understanding of neutrino interactions. Recently, GENIE has been expanded to electron simulations because of the similarities between the nuclear interactions of electrons and neutrinos.

Project Goals

Determine the overlap of GENIE electron simulations with electron cross-section data collected from the e4nu experiment in order to analyze the accuracy of GENIE simulations

References

1) *Data releases*. e4nu. (n.d.). Retrieved July 22, 2022, from https://www.e4nu.com/data-releases

2) *Genie document 2-V7*. Genie. (n.d.). Retrieved July 22, 2022, from https://genie-docdb.pp.rl.ac.uk/cgi-bin/ShowDocument?docid=2

3) Khachatryan, M., Papadopoulou, A., Ashkenazi, A., Hauenstein, F., Nambrath, A., Hrnjic, A., Weinstein, L. B., Hen, O., Piasetzky, E., Betancourt, M., Dytman, S., Mahn, K., & Coloma, P. (2021, November 24). *Electron-beam energy reconstruction for neutrino oscillation measurements*. Nature News. Retrieved July 28, 2022, from https://www.nature.com/articles/s41586-021-04046-5

4) *Mc.org*. genie. (n.d.). Retrieved July 22, 2022, from http://www.genie-mc.org/

5) *The MicroBooNE experiment*. MicroBooNE. (2021, October 27). Retrieved July 22, 2022, from https://microboone.fnal.gov/

6) team, R. O. O. T. (n.d.). *Analyzing petabytes of data, scientifically*. ROOT. Retrieved July 22, 2022, from https://root.cern/

Project Goals

Selection Criteria

The program was first developed to designate events based on specific criteria and filter out all other events. The selection was based on the acceptance range of the detectors and the interest in analyzing 1-proton final states.

1) Sample of selection code
2) List of selection criteria used to determine desired events
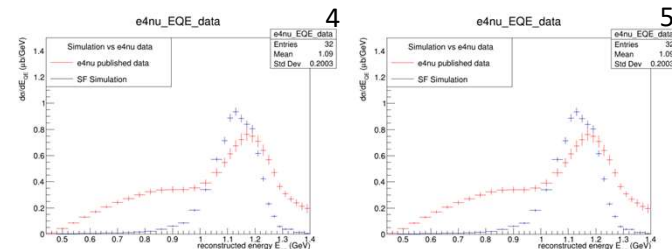

Cross-section Analysis

A separate program was then developed to analyze and plot electron beam data from previous test beams in the e4nu collaboration. This was done in order to create a baseline for the comparison between the electron beam simulations and the experimental data.

3) Sample of analysis code

NUISANCE Comparison

The selection criteria and cross-section plotting were then implemented into NUISANCE, a program designed to compare and tune event generators such as GENIE to cross section data. NUISANCE was then used to compare the selected simulation data to cross section data collected via e4nu.

Results and Conclusions

After finalizing the selection criteria for the GENIE output and completing a cross-section analysis of e4nu data, the two datasets were overlayed in order to determine the accuracy of the simulation. The lower range of the simulation appears to neatly overlay the e4nu data, while the peak energy tends to overestimate the differential cross section. Alternatively, the Spectral Function (SF) data better approximates the peak while mostly neglecting the overall shape of the distribution

4) Overlay of GENIE simulation output with e4nu published data

5) Overlay of SF GENIE simulation against e4nu published data

Future Directions

➢ Further comparisons with other e4nu datasets

➢ Generalize zero error solution to apply to all bins

➢ Statistical analysis to complete comparison of simulation and cross section

Acknowledgements

Fermi National Accelerator Laboratory

Fermilab · U.S. DEPARTMENT OF ENERGY