Reducing Flux Uncertainties of NuMI Beamline

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Introduction

- NOvA is a long-baseline neutrino oscillation experiment at Fermilab.
- There are two detectors, both located 14.6 mrad off-axis from the NuMI (Neutrinos at the Main Injector) beamline, and separated by 810 km.
- For neutrino cross section measurements precise flux prediction is a critical input (existing uncertainty ~10-15%), therefore accurate modelling of flux is required.
- We report about the GEANT4-based simulation using two different models, FTFP_BERT and QGSP_BERT.
- We use a tool G4HP [1] to extract cross sections from thin target simulation.
- We plan to show the data/MC comparison study of G4HP simulation with the NA61 hadron production data.

Uncertainties in Flux Simulation and PPFX

- NuMI Simulation (G4NuMI): Geant4 v9.2.p03 with physics list FTFP_BERT.
- Hadron Production and Focusing Uncertainties are two major challenges in accurate flux prediction.
- Hadron production cross section uncertainties are the dominant contributions to the neutrino flux uncertainties.

![Hadron Production Uncertainties](image)

- The results of the simulations are corrected by external data through PPFX framework.
- Package to Predict the Flux (PPFX) is experiment independent package for NuMI beam [2].
- Constrains the underlying hadron production model used in the beamline simulation with external measurements on thin and thick targets.
- PPFX provides a central value correction and a vector of weights to calculate the Hadron Production uncertainty with “multi-universe” technique to propagate uncertainties event by event [3].
- Data from NA49 experiment is used to constrain the interactions from pC→ π X.

![Comparision of NA61 Data and MC](image)

- Comparison of NA61 data [6] with FTFP_BERT and QGSP_BERT models is shown for some angle ranges and produced pions from incident \( \pi^- \) multiplicities for Geant4 (v4.9.2.p03, (G4NuMI)) simulation by using G4HP [1].
- Significant discrepancy between data and the predictions from hadronic models
- Big difference between different hadronic models

Plan for the future

- To get better flux predictions, incorporate the data from NA61 and EMPHATIC into PPFX.

References

[1] https://cdcvs.fnal.gov/redmine/projects/g4hp