More on Validation of Geant4 Models using the MIPP Data

Outline

- ❑ Dataset used
- ❑ Results from Comparisons
  - ➢ Momentum Distribution
  - ➢ Lorentz invariant cross section
- ❑ Summary

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Debarati Roy
Sunanda Banerjee

Motivation

- Recently the Main Injector Particle Production (MIPP) experiment at Fermilab (E907) has published their first results on inclusive neutron production with proton beams at high energies (58, 84 and 120 GeV/c) on a number of nuclear targets.
- The main idea of the measurements:
  - Cross sections to be used in calculating neutrino fluxes;
  - Inclusive particle production data to facilitate proton radiography.
- Geant4 provides a large number of models to describe hadronic interactions at high energies: QGS, FTF, HEP, CHIPS. These models have been tested with limited set of thin target data. The new data will be a good testing ground for Geant4 models.

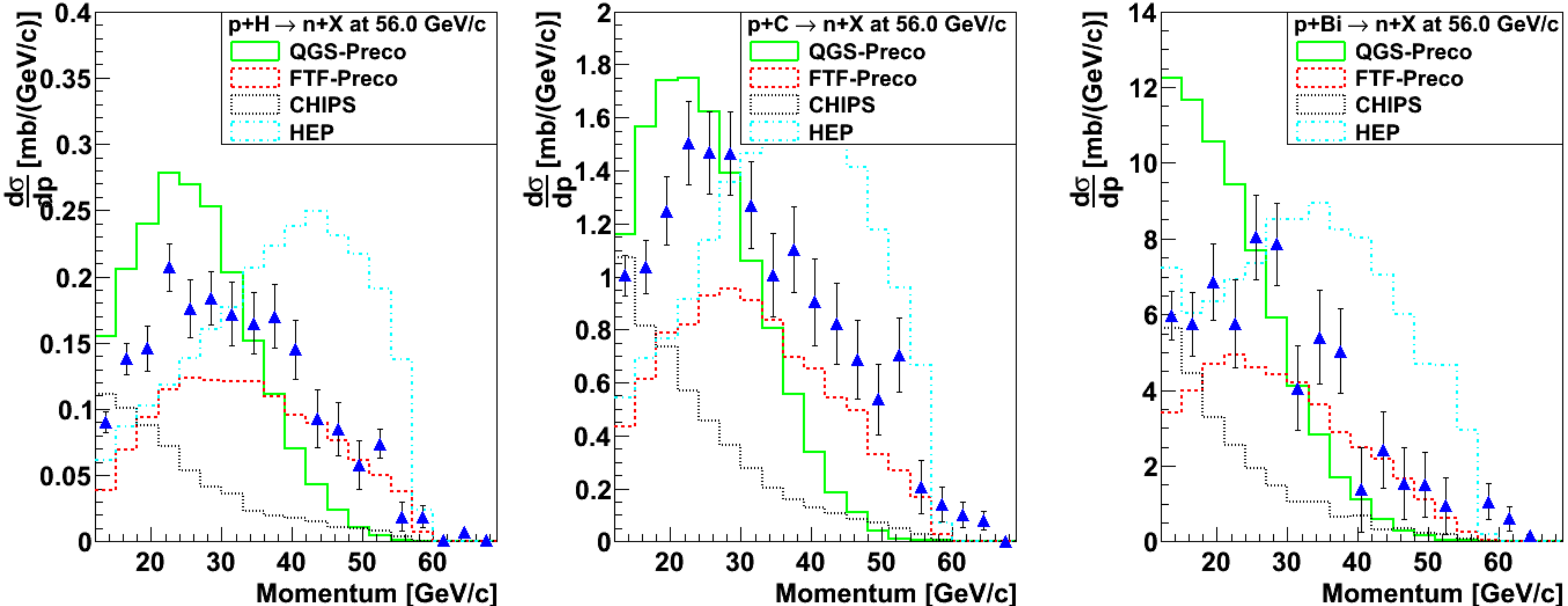
The DataSet

- The MIPP experiment has two spectrometers with TPC, drift + proportional chambers and a particle identification system using dE/dx, TOF and Cerenkov detectors.
- Two calorimeters (electromagnetic and hadron) further downstream detect photons and neutral hadrons.
- Targets used: Hydrogen, Beryllium, Carbon, Bismuth, Uranium.
- Projectile: proton beam at: 58, 59, 84 and 120 GeV/c. Beam momentum and impact point at the target are measured using an upstream spectrometer.
- Neutrons are detected in the hadron calorimeter and its energy is measured by subtracting energies of charged particles within the geometric acceptance of calorimeter.
- Background is large for low energy neutrons and inefficiency of triggering and selecting neutron events is large for high energy neutrons. So there is a low energy threshold for the data set and corrections are made due to these effects. Systematic uncertainties are dominated by these effects.

Available Measurements

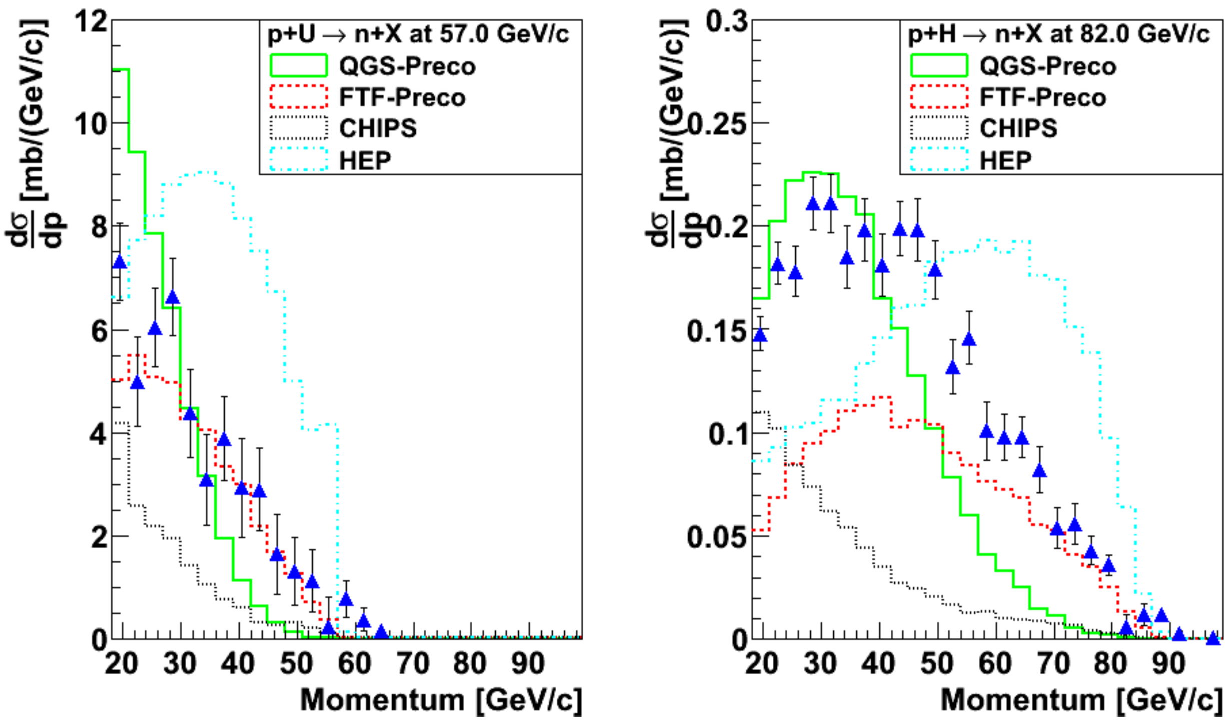
- Five types of measurements are published:
  - Total inclusive cross section of neutron production with neutron energy above a threshold and with neutrons within a fiducial volume of the detector
  - The same as above but after correcting for geometric acceptance (estimated using FLUKA/DPMJET)
  - Inclusive neutron momentum distribution without any geometric acceptance correction
  - Lorentz invariant cross section for neutron as a function of x_F without any geometric acceptance correction
  - Total inclusive cross section as a function of x_F with neutron energies above a threshold after geometric correction
- For this comparison, we use the third and the fourth set. The third set is present with statistical uncertainties only while the fourth data set is available with both statistical and systematic uncertainties.

Momentum distributions at 58 GeV/c



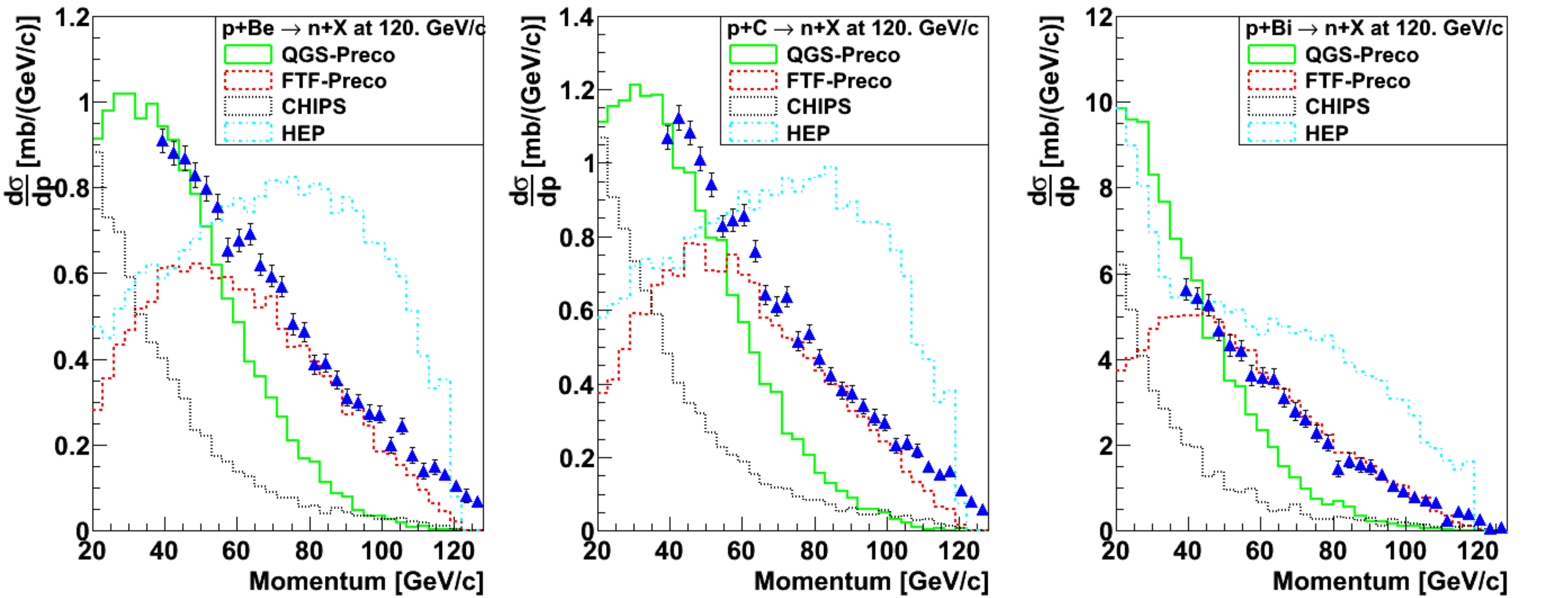
- None of the models considered here can describe the data at all regions
- For hydrogen and carbon targets the QGSP model is in agreement with the data for low momenta neutrons while the FTFP model is in better agreement with the data at high momentum.
- For bismuth (beam momentum QGSP cannot match the data even at low momenta. At higher neutron momenta the FTFP model agrees better with the data.

Momentum distributions at 59 and 84 GeV/c



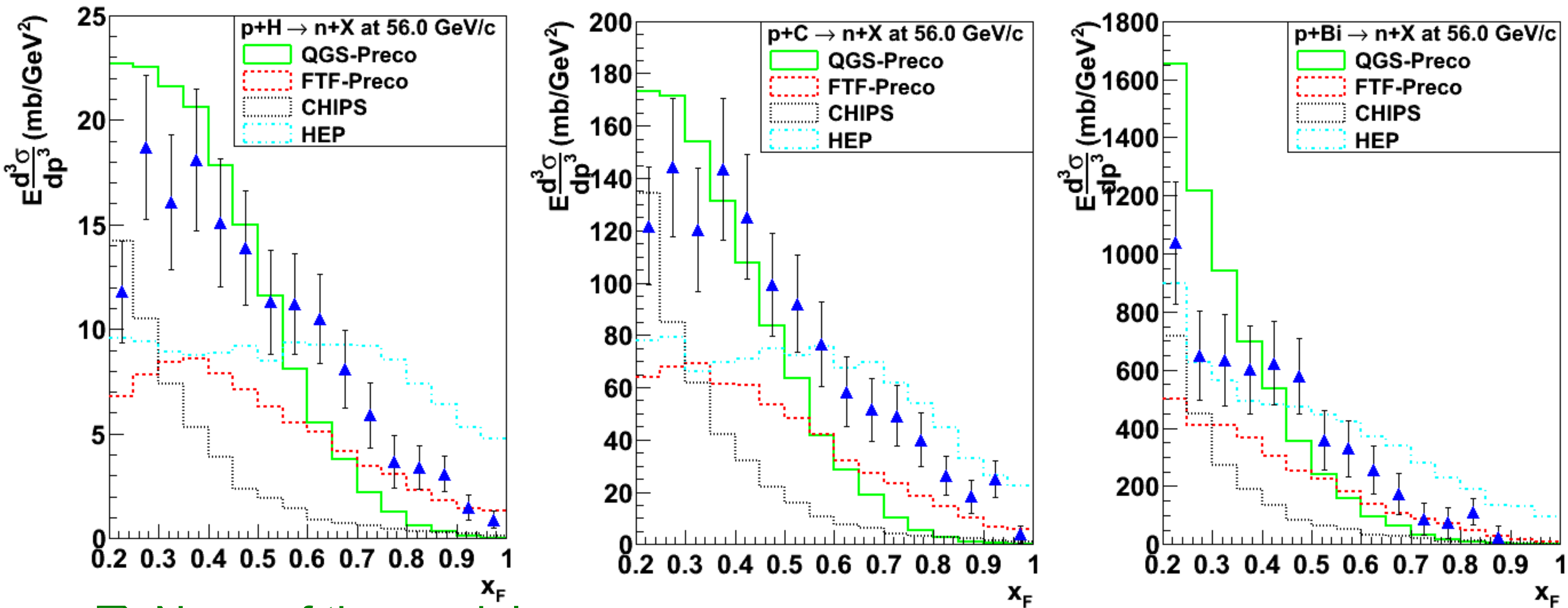
- Similar conclusion as before:
  - QGSP agrees better at lower energies
  - FTFP agrees better at higher energies
  - CHIPS or HEP do not agree with the data at both ends of the spectra

Momentum distributions at 120 GeV/c



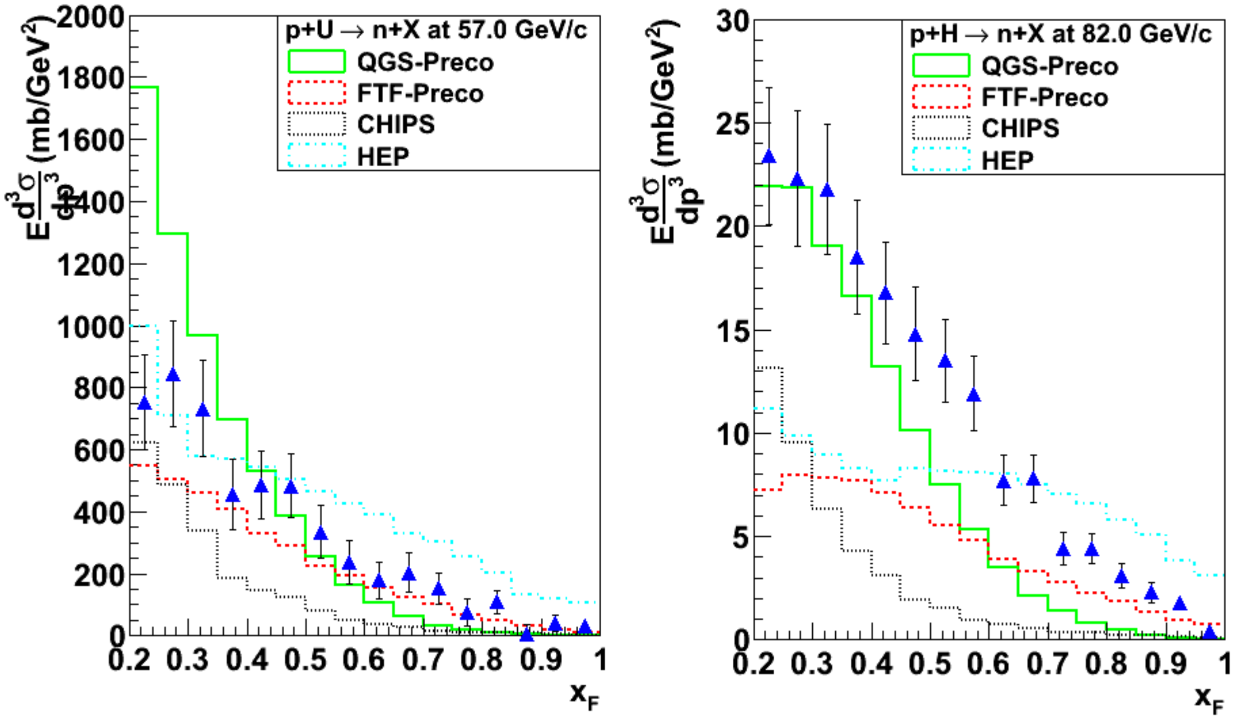
- The high momentum side of the data is better described by the FTFP model
- The low momentum side of the data are better describe by the QGSP model
- No single model can describe the entire data set well

x_F distributions at 58 GeV/c



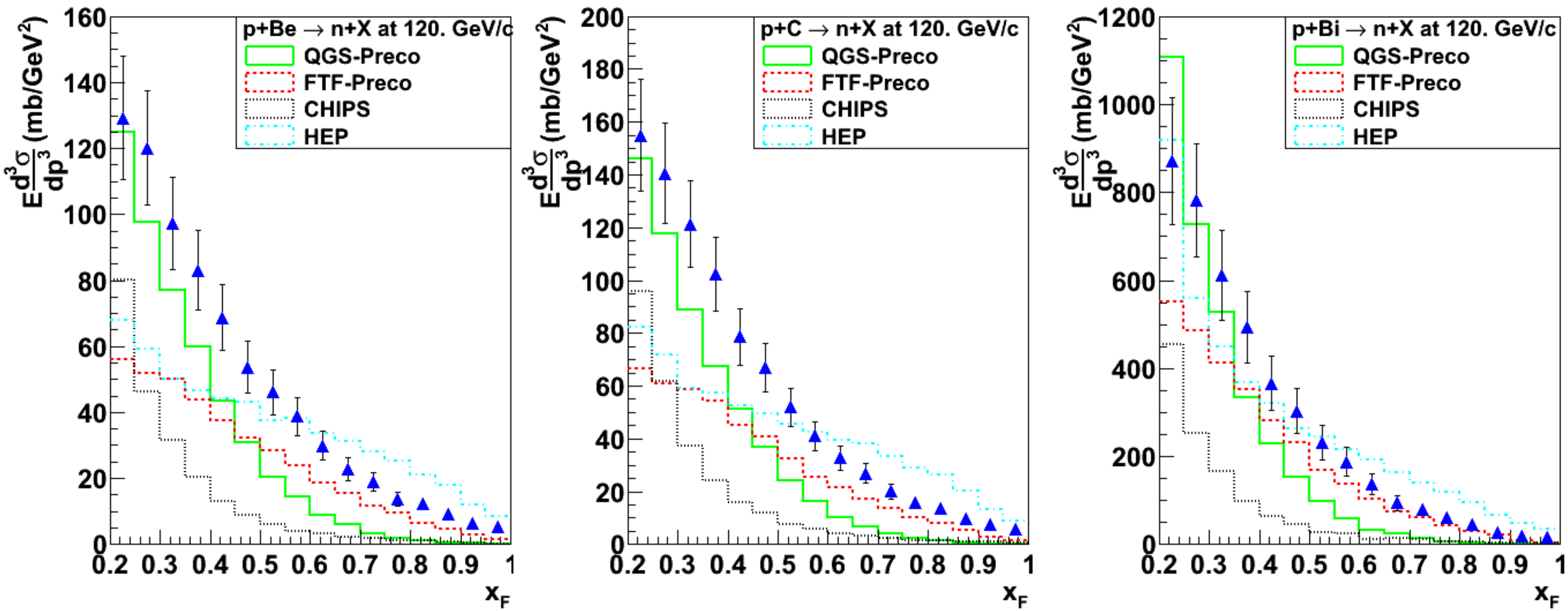
- None of the models considered here can describe the data at all regions
- For hydrogen and carbon targets the QGSP model is in agreement with the data for low x_F neutrons while the FTFP model is in better agreement with the data at higher x_F.
- For bismuth (beam momentum QGSP cannot match the data even at low x_F values. At higher values of neutron x_F the FTFP model agrees better with the data.

x_F distributions at 59 and 84 GeV/c



- Similar conclusion as before

x_F distributions at 120 GeV/c

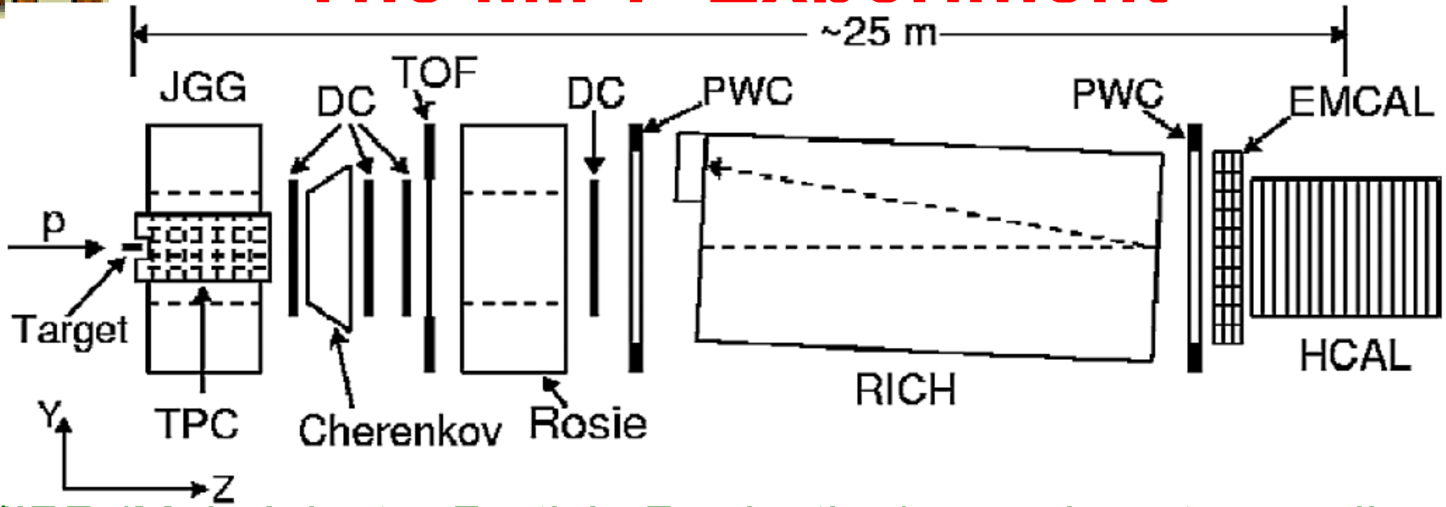


- The higher x_F side of the data is better described by the FTFP model and sometime by the HEP model
- The lower x_F side of the data are better describe by the QGSP model
- No single model can describe the entire data set well

Observations

- New set of thin target data is now available for testing the models for hadronic interactions at high energies.
- None of the existing models (among these four: QGSP, FTFP, CHIPS, HEP) can describe the experimental data well.
- These models match with the data in some regions and deviate significantly in other regions.
- So simulation of hadronic interactions within GEANT4 still needs improvement.

The MIPP Experiment



- MIPP (Main Injector Particle Production) experiment uses direct or secondary proton beams from Main Injector at Fermilab
- Several upstream counters to measure the beam momentum and identify beam particles
- Two large aperture magnetic spectrometers
- A Time projection chamber (TPC), several planes of drift chambers (DC) and proportional wire chambers to measure charged particles
- Particle identification is provided by TPC, time of flight hodoscope and Cherenkov detectors
- Electromagnetic (10 layers of Pb interspersed with proportional chambers ~10X_0) and hadron (64 layers of iron plates interspersed with plastic scintillators ~9.6λ)