Geant4 Models Compared to MIPP Data

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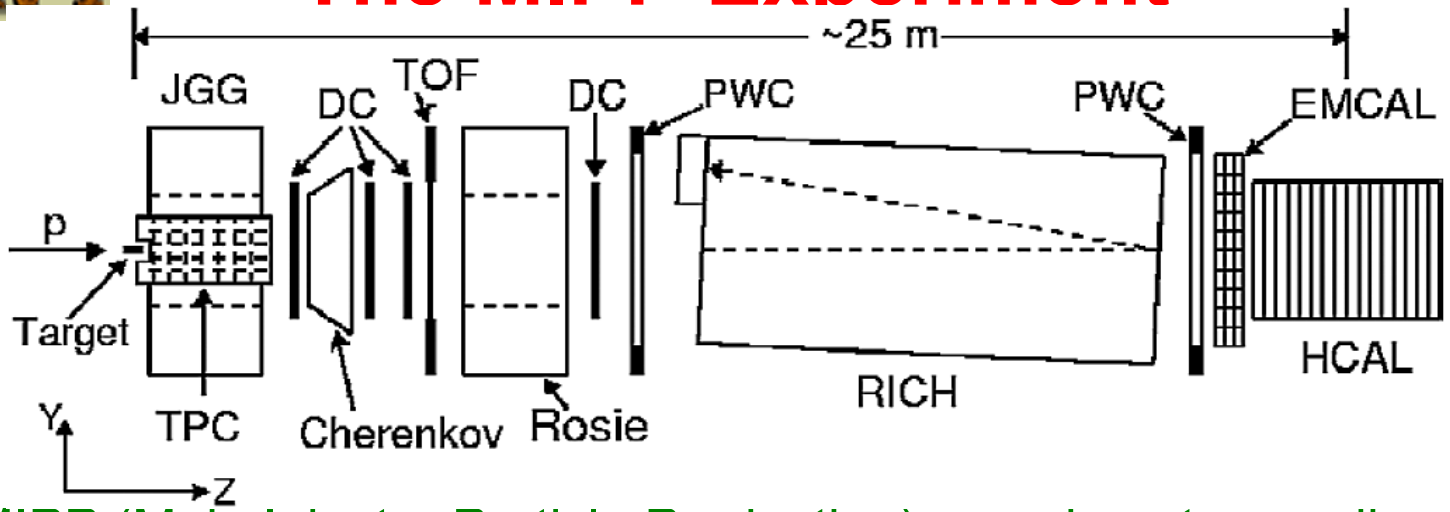
Motivation

- Recently the MIPP experiment at Fermilab has published their first results on inclusive neutron production with proton beams at high energies (>50 GeV/c) on a number of nuclear targets
- Geant4 provides a large number of models to describe hadronic interactions at high energies: QGS, FTF, HEP, CHIPS
- They have been tested with limited set of thin target data. The data from the MIPP experiment will be a good testing ground for Geant4 models

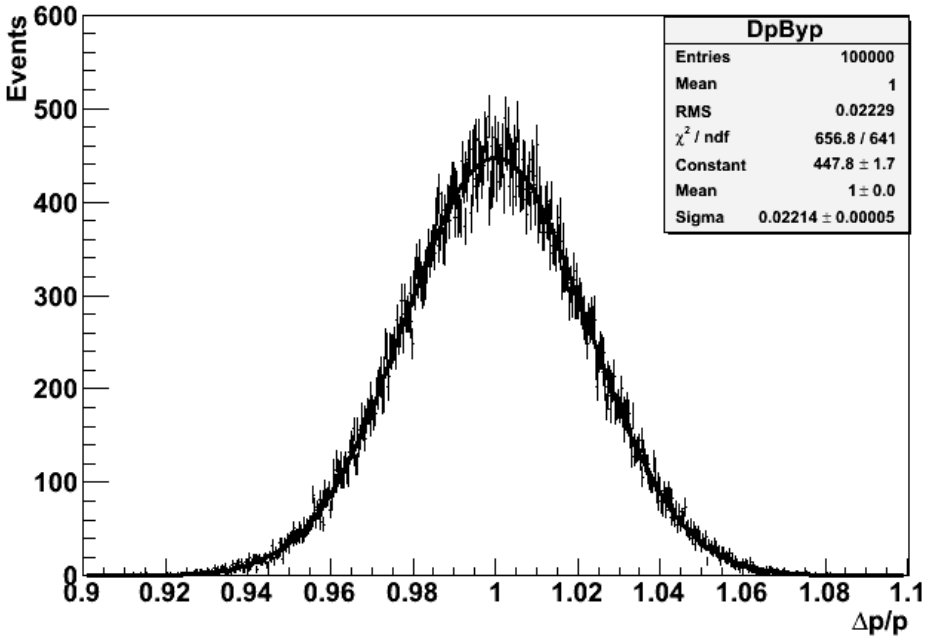
The MIPP Experiment



- 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)

Data Used

- Published results on inclusive neutron production from MIPP
- Targets used: Hydrogen, Beryllium, Carbon, Bismuth, Uranium.
- Projectile: proton beam at: 58, 59, 84 and 120 GeV/c.
- Beam momentum distribution:
  - 58 GeV/c beam: peak value (p_0) = 56.78 GeV/c, σ = 1.27 GeV/c
  - 84 GeV/c beam: peak value (p_0) = 82.56 GeV/c, σ = 3.37 GeV/c
  - 120 GeV/c beam: peak value (p_0) = 120 GeV/c, very narrow

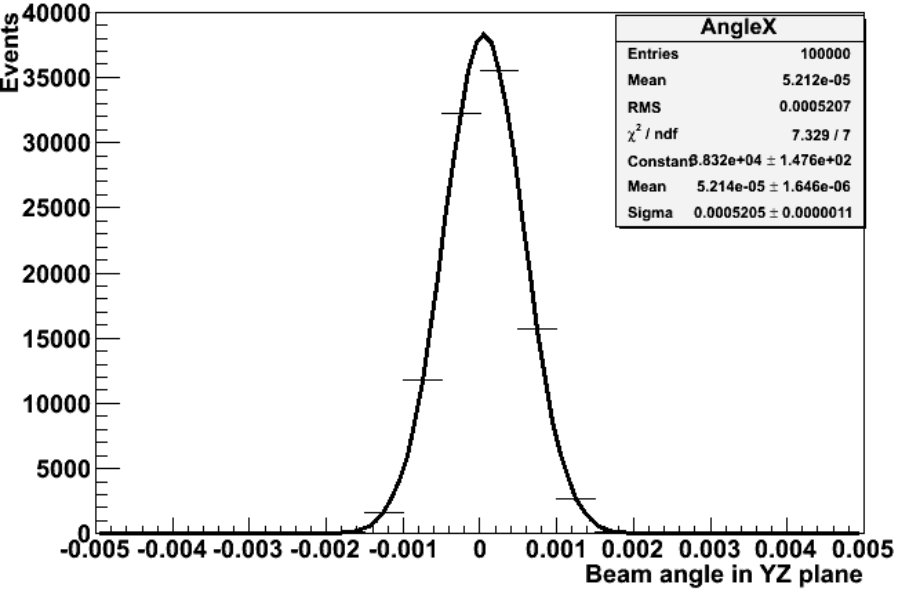


Simulate the beam momentum spread

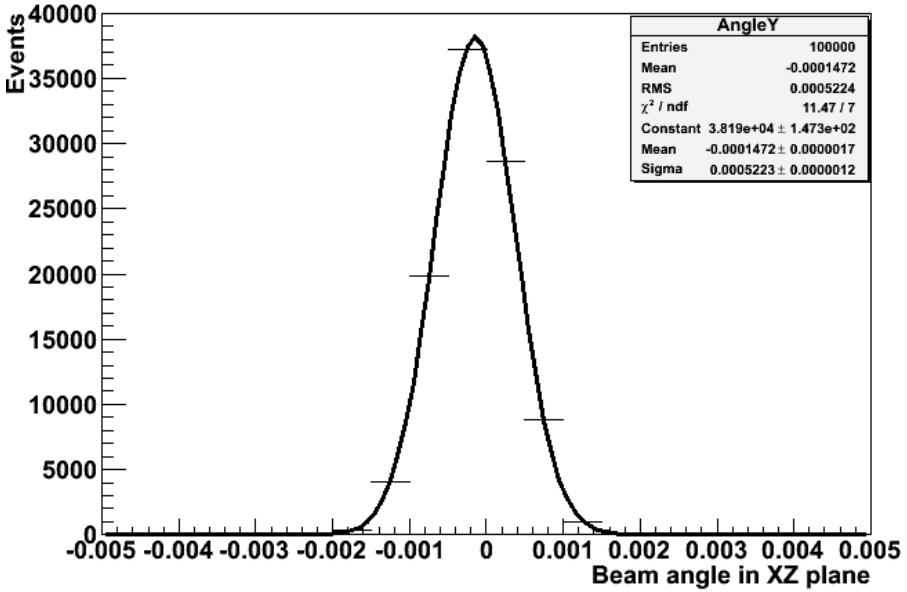
Beam Direction

- Beam direction:
  - In X view: from -0.7 mrad up to 0.8 mrad (~3σ)
  - In Y view: from -0.9 mrad up to 0.6 mrad (~3σ)

Angular divergence in yz plane

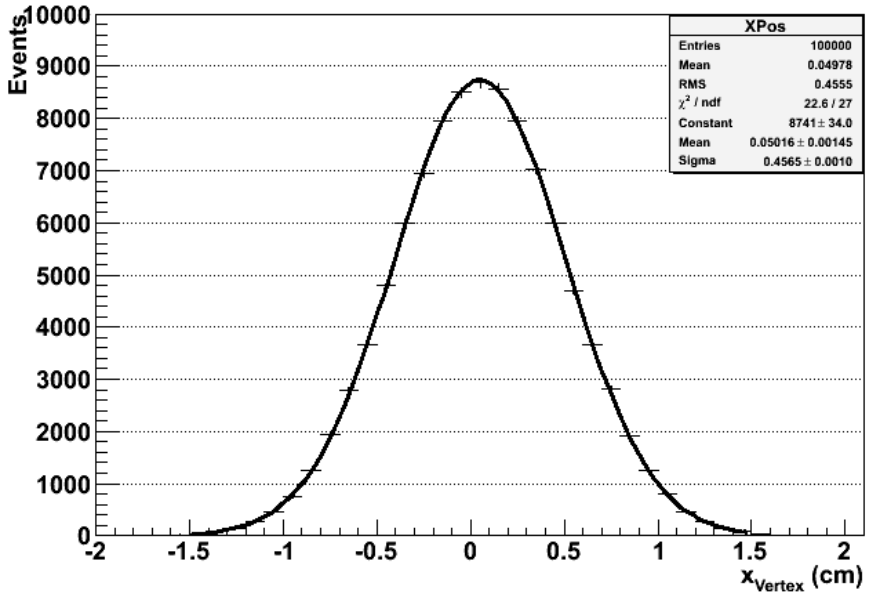


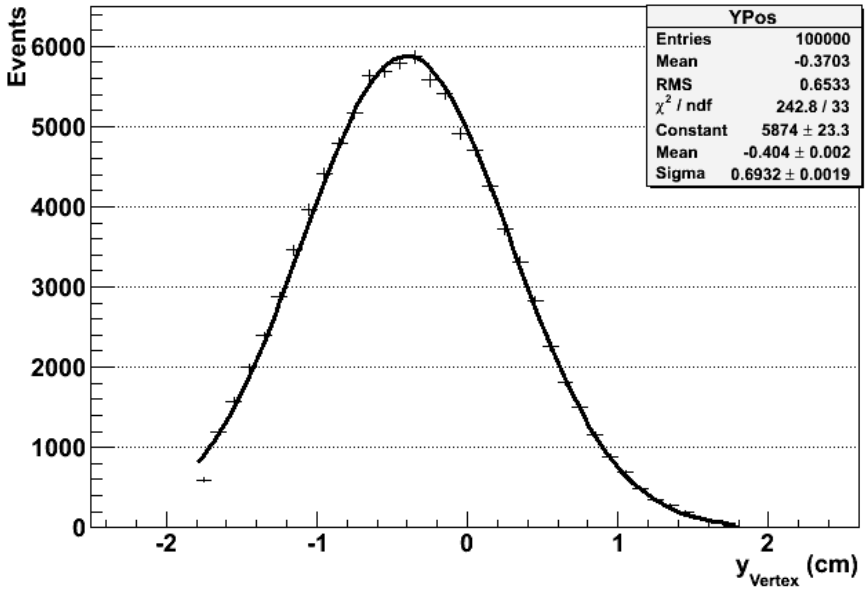
Angular divergence in zx plane



Beam Profile

Momentum (GeV/c)	x_0 (cm)	σ_x (cm)	y_0 (cm)	σ_y (cm)
58.0	0.30	0.76	0.10	0.85
84.0	0.05	0.46	-0.42	0.71
120.0	0.05	0.21	0.50	0.26

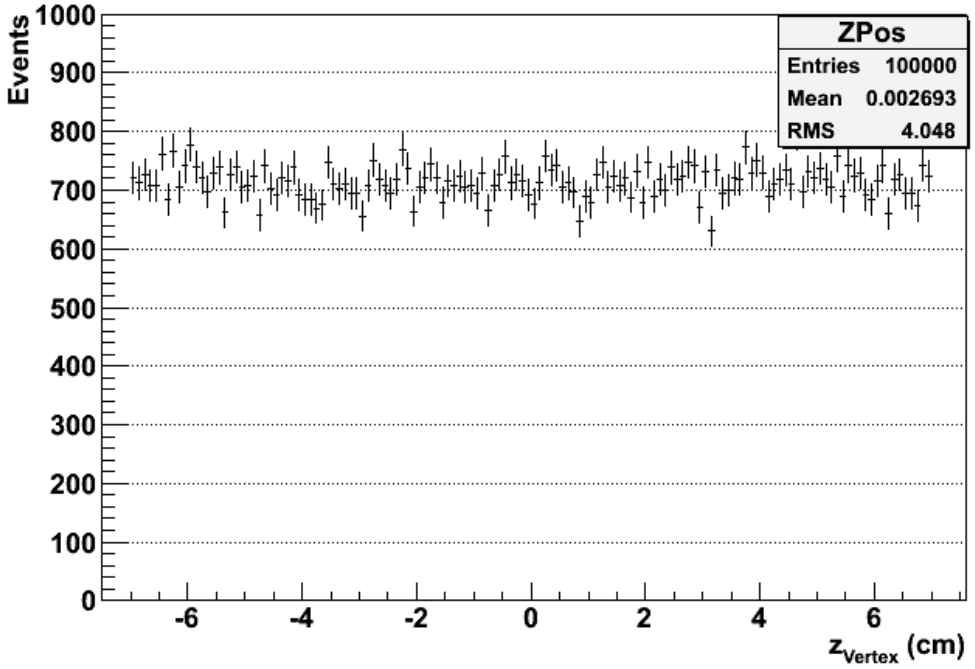




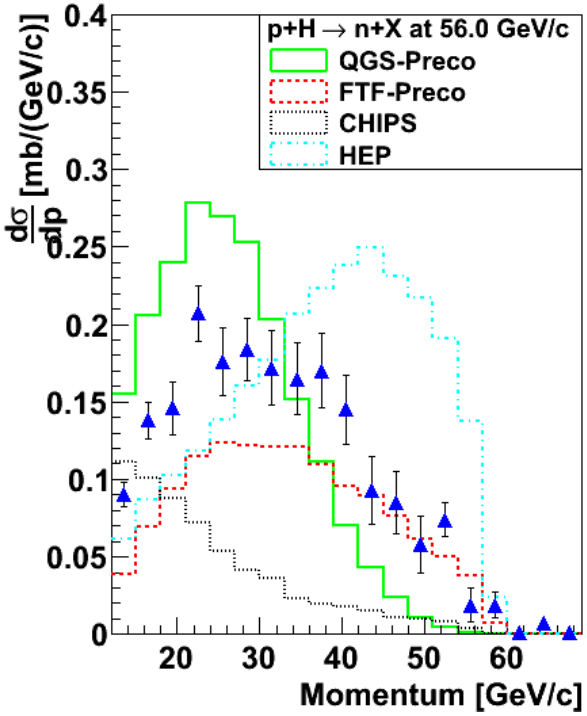
Beam position for the 84 GeV/c run

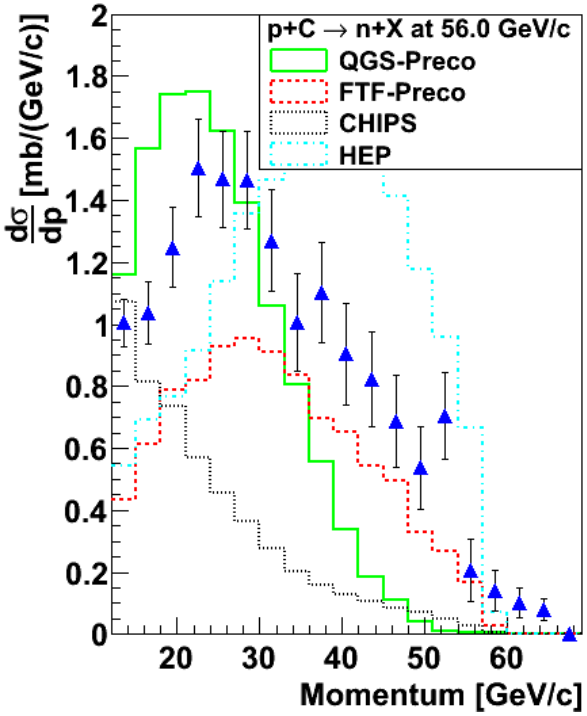
Fiducial Volume

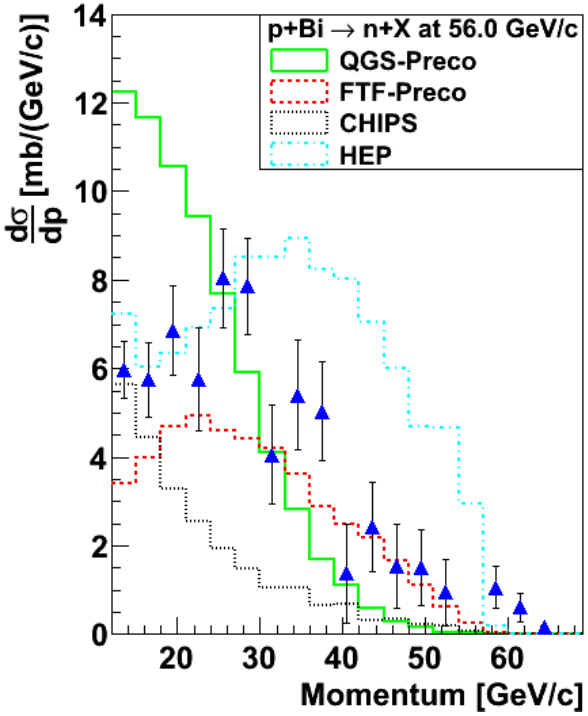
- Target size: Liquid hydrogen target is 14 cm long, the remaining targets are between 1 mm and 1 cm in thickness. The transverse size is between 3.6 and 5.0 cm in diameter. Interaction vertex is uniformly distributed along the length of the target.
- Neutrons that have passed through a rectangular region of ±49.5 cm in x and ±49.0 cm in y centred on the beam line at the Hadron Calorimeter (located 25.96m behind the target) with energies above a threshold (12/18/20 GeV for 58/84/120 GeV/c runs) are considered.



Results at 58 GeV/c

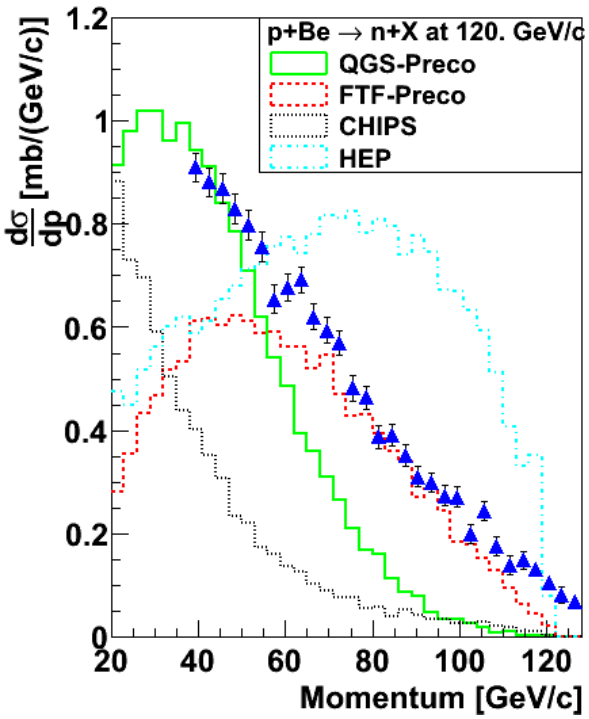


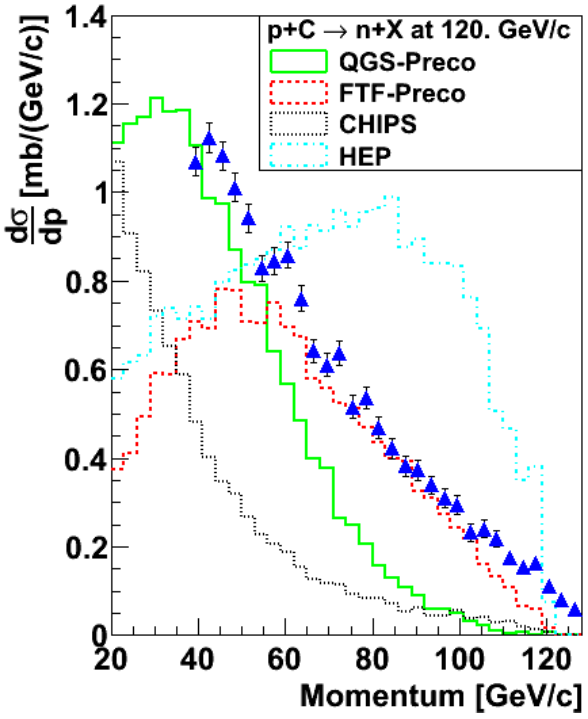


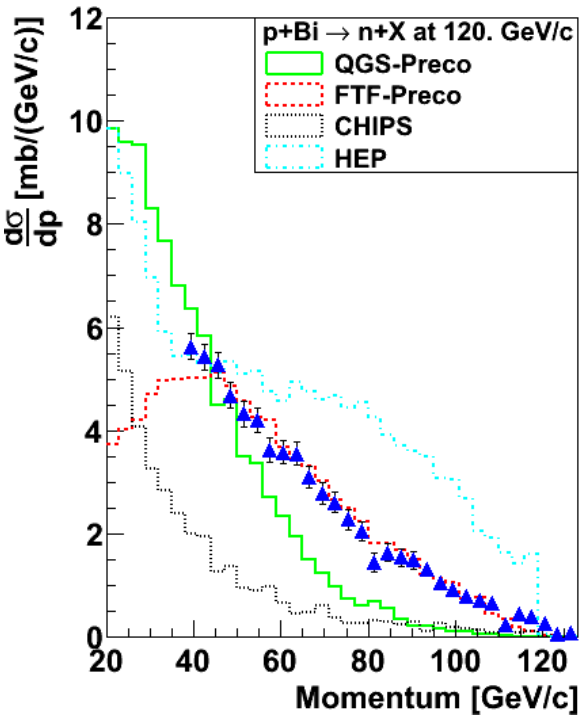


- None of the models considered here can describe the data at all regions
- For hydrogen and carbon targets the QGSP model is in agreement with the data for low momenta neutrons while the FTFP model is in better agreement with the data at high momentum.
- For bismuth (beam momentum QGSP cannot match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

Results 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

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 three: QGSP, FTFP, CHIPS) 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.