Hadron Physics Validation Using HARP Data

Geant4 Validation Workshop
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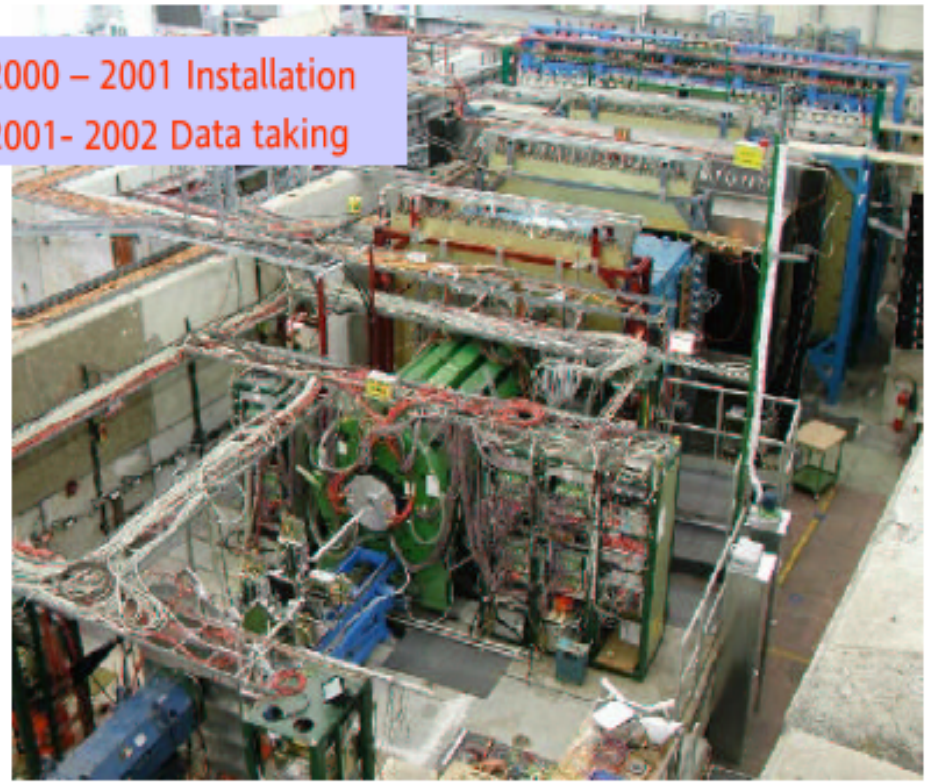
For HARP collaboration

Outline

- HARP experiment
- test35
- Test results for g4 8.1
  - Pion production by 12.9 GeV/c in Al
  - Pion production by 8.9 GeV/c in Be
- Summary

Physics goals of HARP

2000 – 2001 Installation
2001- 2002 Data taking



Systematic study of hadron production:
Beam momentum: 1.5-15 GeV/c
Target: from hydrogen to lead
·Acceptance over full solid angle
·Final state particle identification

·Input for prediction of neutrino fluxes for the MiniBooNE and K2K experiments

·Pion/Kaon yield for the design of the proton driver of neutrino factories and SPL- based super-beams

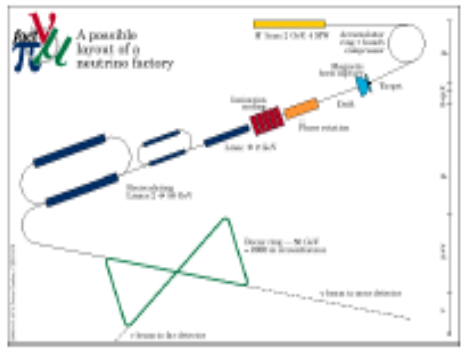
·Input for precise calculation of the atmospheric neutrino flux

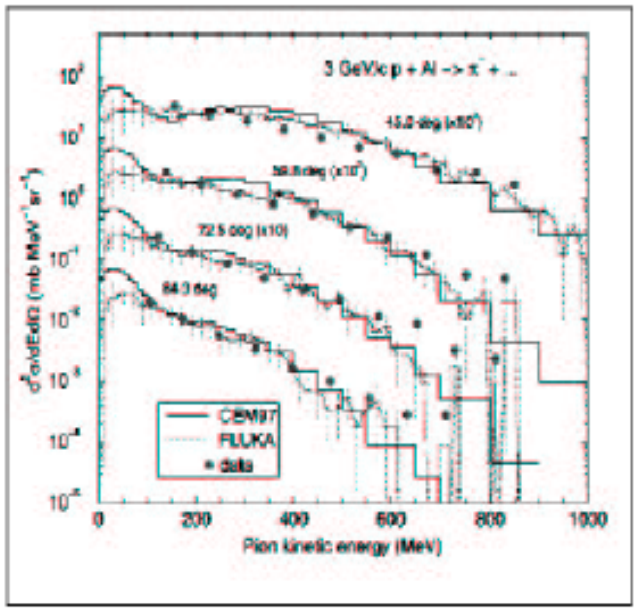
·Input for Monte Carlo generators (GEANT4, e.g. for LHC or space applications)

ν factory design

- maximize $\pi^+(\pi^-)$ production yield as a function of:
  - proton energy
  - target material
  - geometry
  - collection efficiency (p_L,p_T)
- but different simulations show large discrepancies for π production distributions, both in shape and normalization. Experimental knowledge is rather poor (large errors: poor acceptance, few materials studied)

  ⇒ aim: measure p_T distribution with high precision (< 5%) for high Z targets





ν beams flux prediction

- Energy, composition, geometry of a neutrino beam is determined by the development of the hadron interaction and cascade ⇒ needs to know π spectra, K/ π ratios

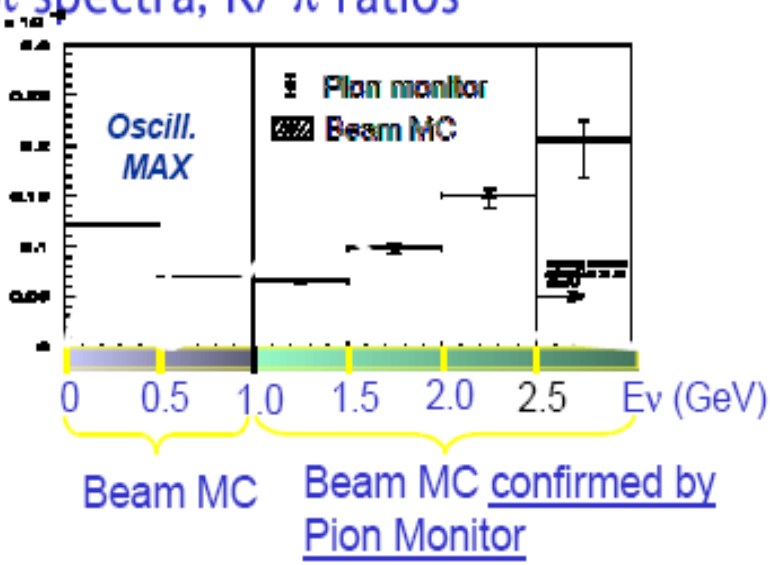
•K2K : Al target, 12.9 GeV/c

Al targets 5%, 50%, 100% λ (all p_{beam}), K2K target replica (12.9 GeV/c)

➡ special program with K2K replica target aiming at
Δ (Far/Near)/(Far/Near) < 3%

•MiniBooNE:Be target 8.9 GeV/c

Be targets: 5%, 50%, 100% λ, MiniBoone target replica



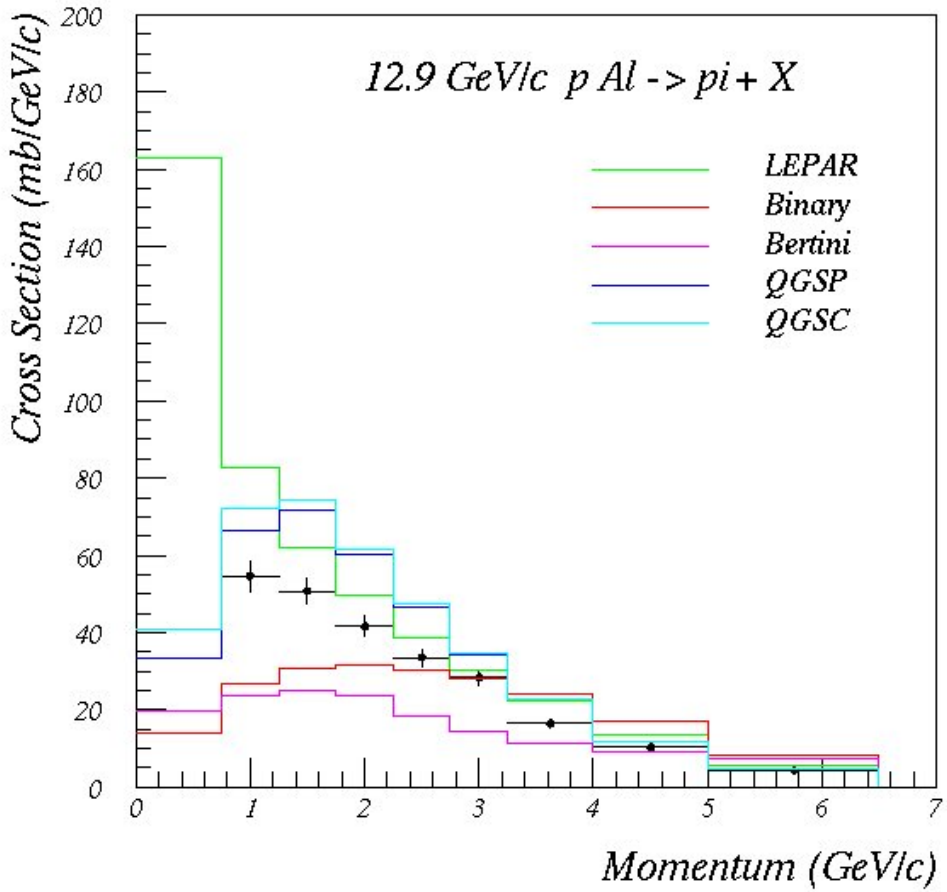
Precise p_T and p_L spectra for extrapolation to far detectors and comparison between near and far detectors

test35

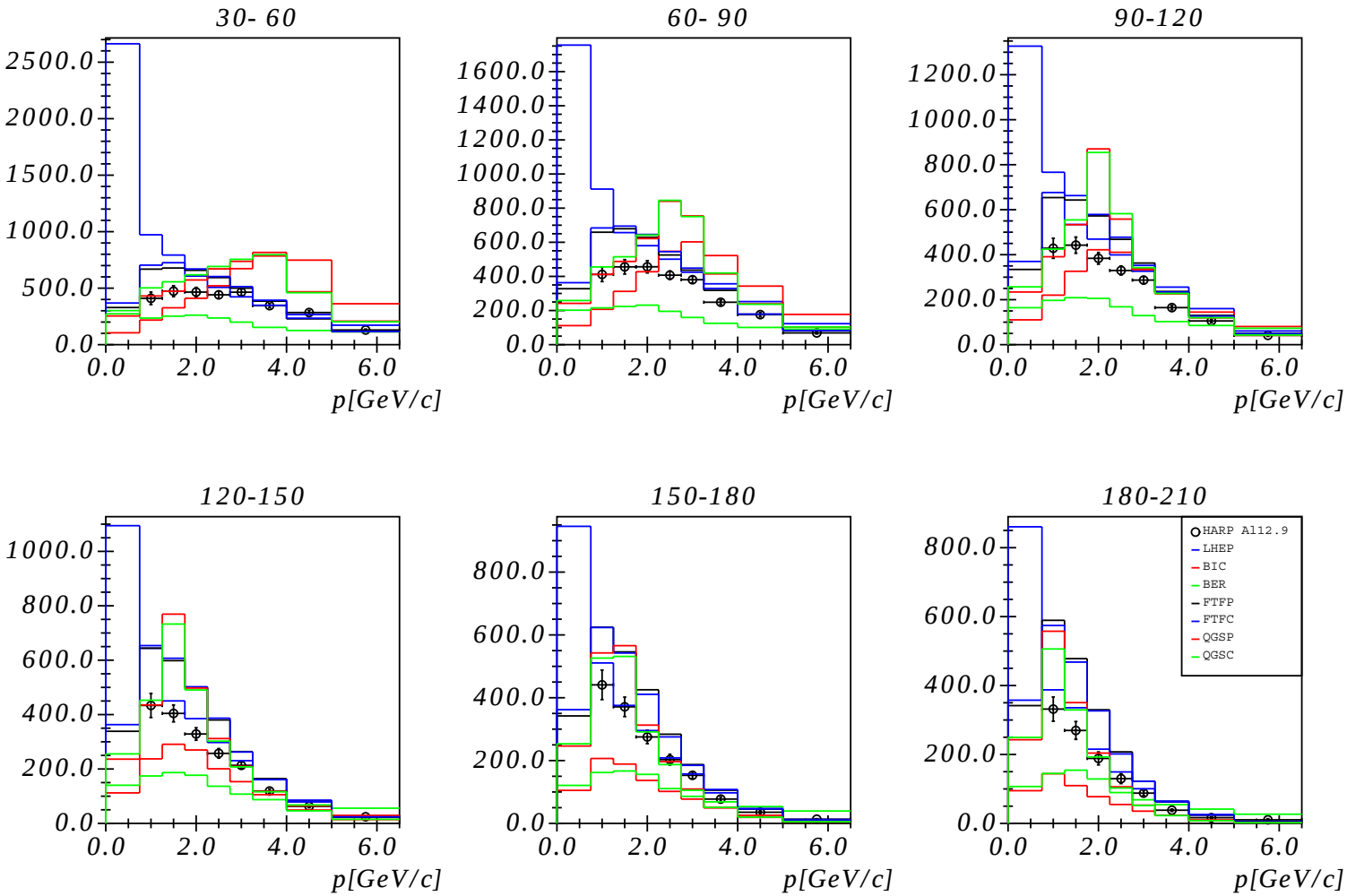
- Was reorganized for G4 8.1
  - Data and test results at afs
  - Directory structure as for test30
  - Scripts for running at LXBATCH
- Focus on charged pion production in proton and pion beams with momentum (1.5 – 15) GeV/c
- 2 setting have been used for recent releases
  - 8.9 GeV/c p + Be forward (MiniBooNE setup)
  - 12.9 GeV/c p + Al forward (K2K setup)
- Other settings are running without comparison with the data
  - 3, 5, 8 GeV/c p + Ta large angles (neutrino factory)
  - 3 GeV/c p + C forward (background study)
- Models under study:
  - Binary, Bertini, LHEP, QGSP, QGSC, FTFP, FTFC
  - Model applicability range extended to cover HARP energy range

Forward π^+ Production in Al by 12.9 GeV/c Proton Beam

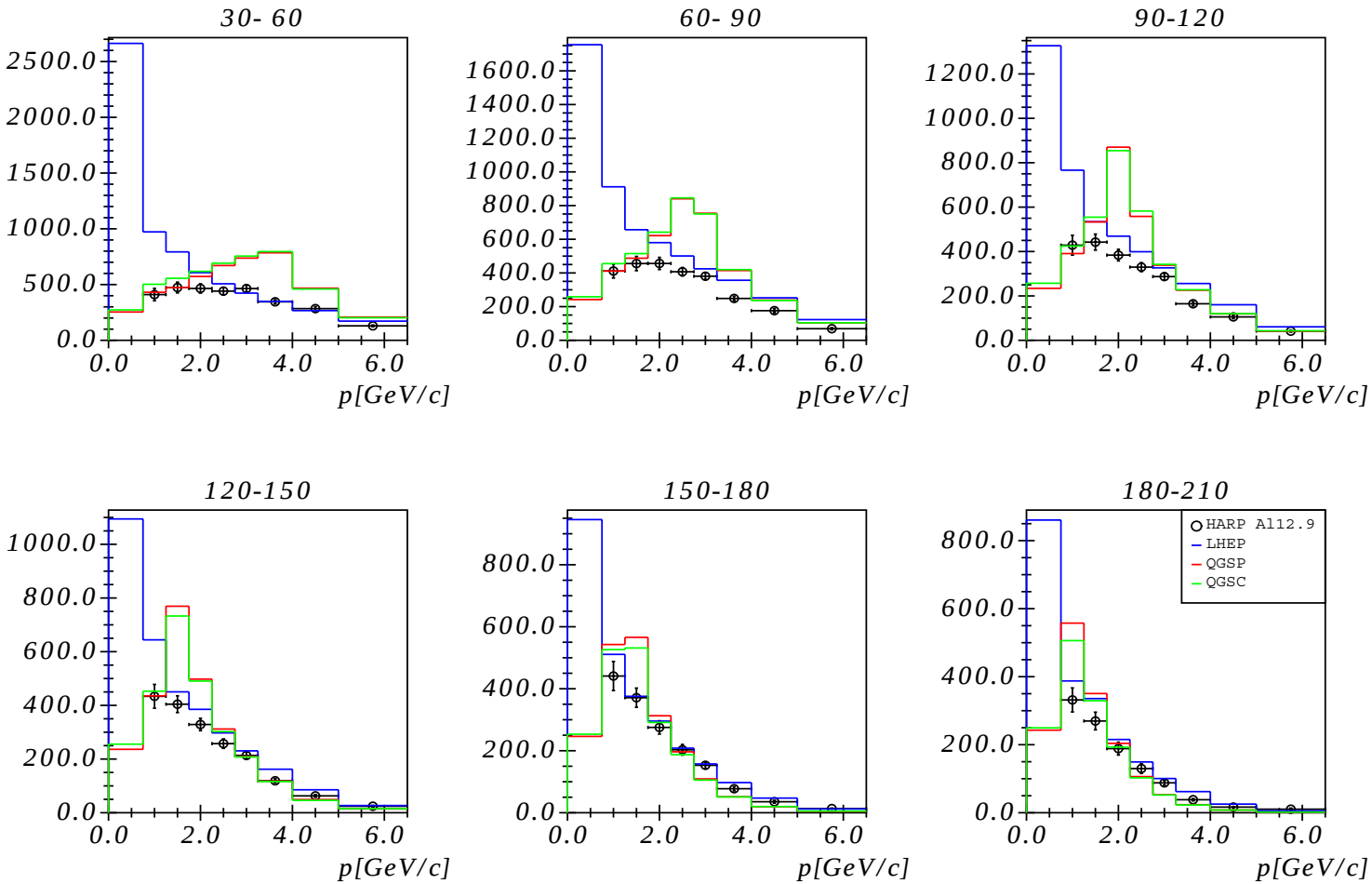
- $0.03 < \theta < 0.21$ rad
- LHEP has obvious problem producing too many low energy pions
- QGS model seems to predict pion yield the most closed to the data
- Both cascade models underestimate low energy pion production



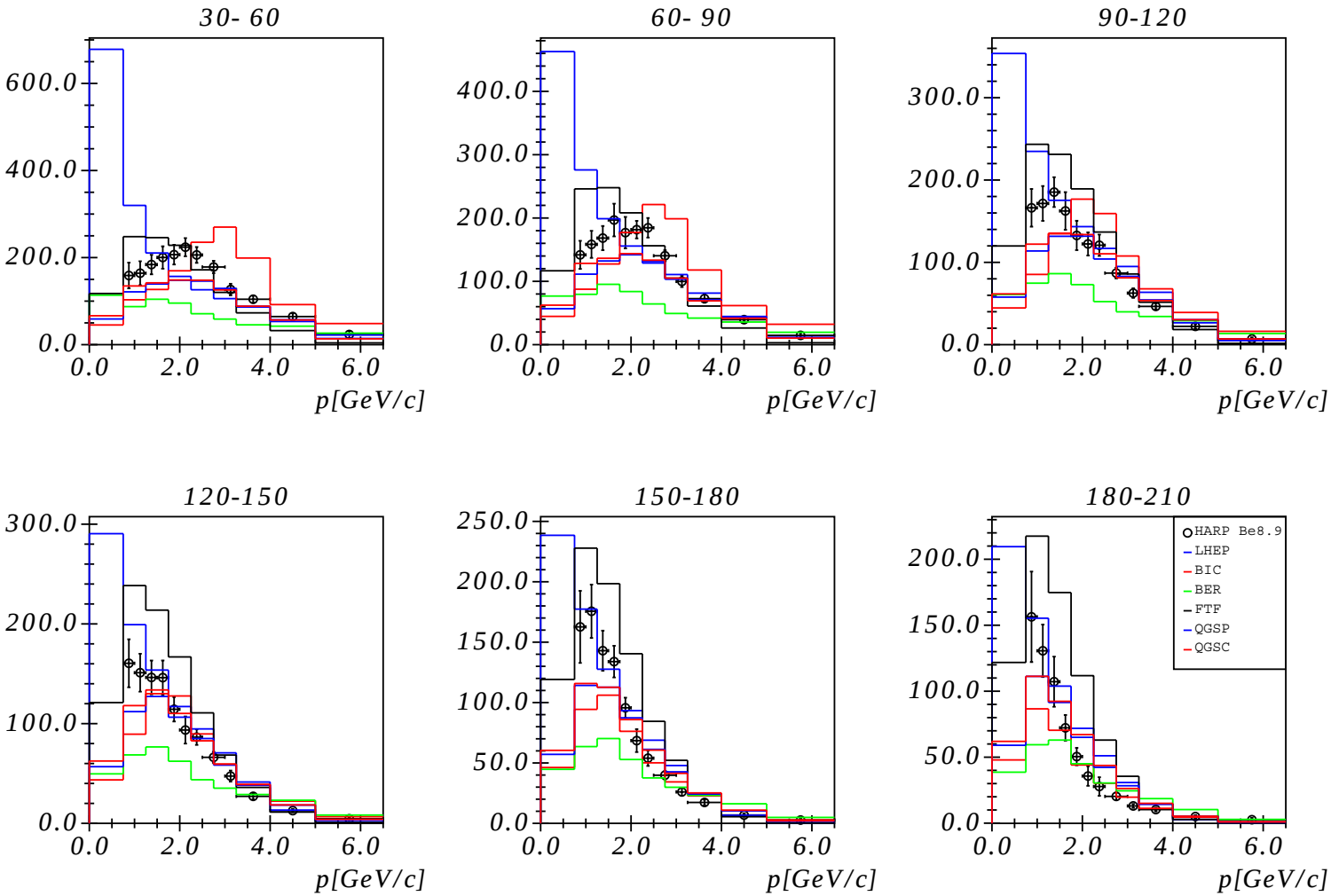
Double Differential Cross Section of π^+ Production by 12.9 GeV/c Protons in Al



Double Differential Cross Section of π^+ Production by 12.9 GeV/c Protons in Al



Double Differential Cross Section of π^+ Production by 8.9 GeV/c Protons in Be



Comparison on base of Geant4 application and pre-packaged Physics Lists

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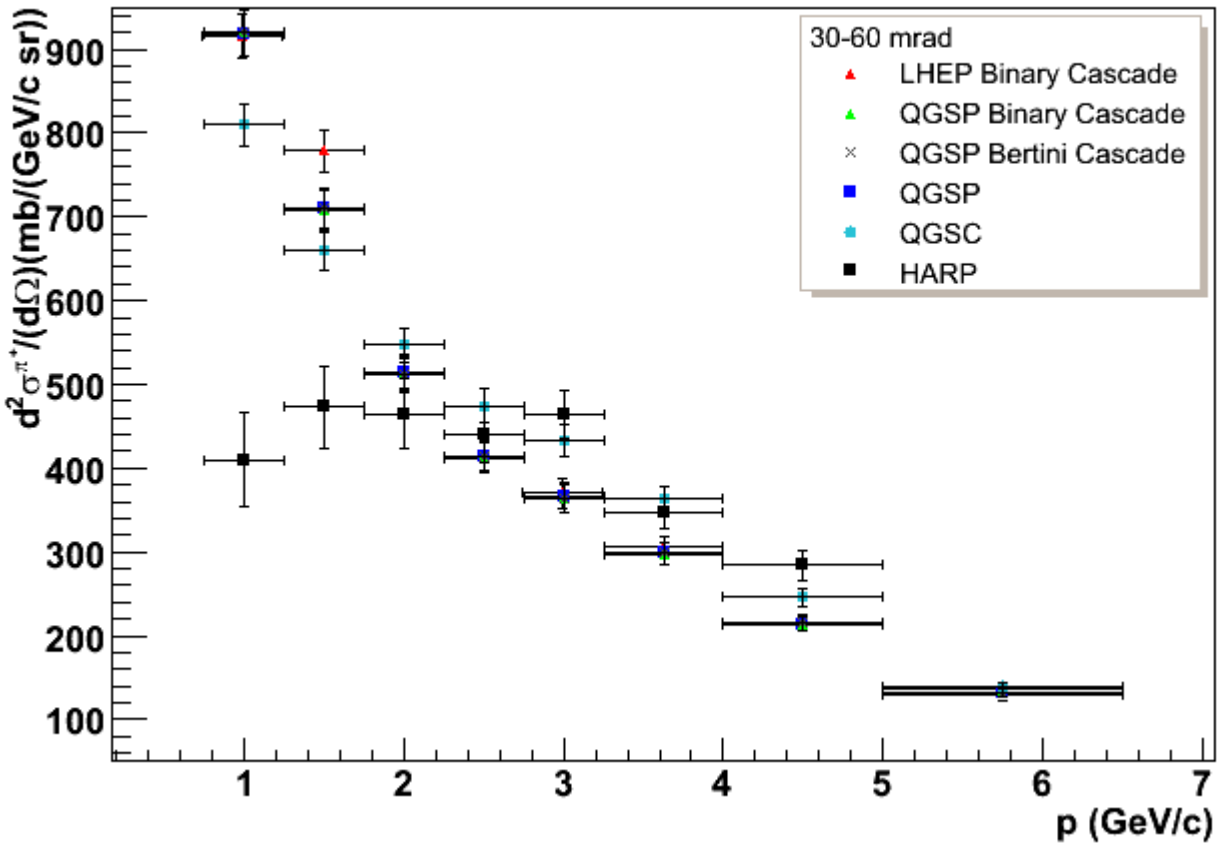
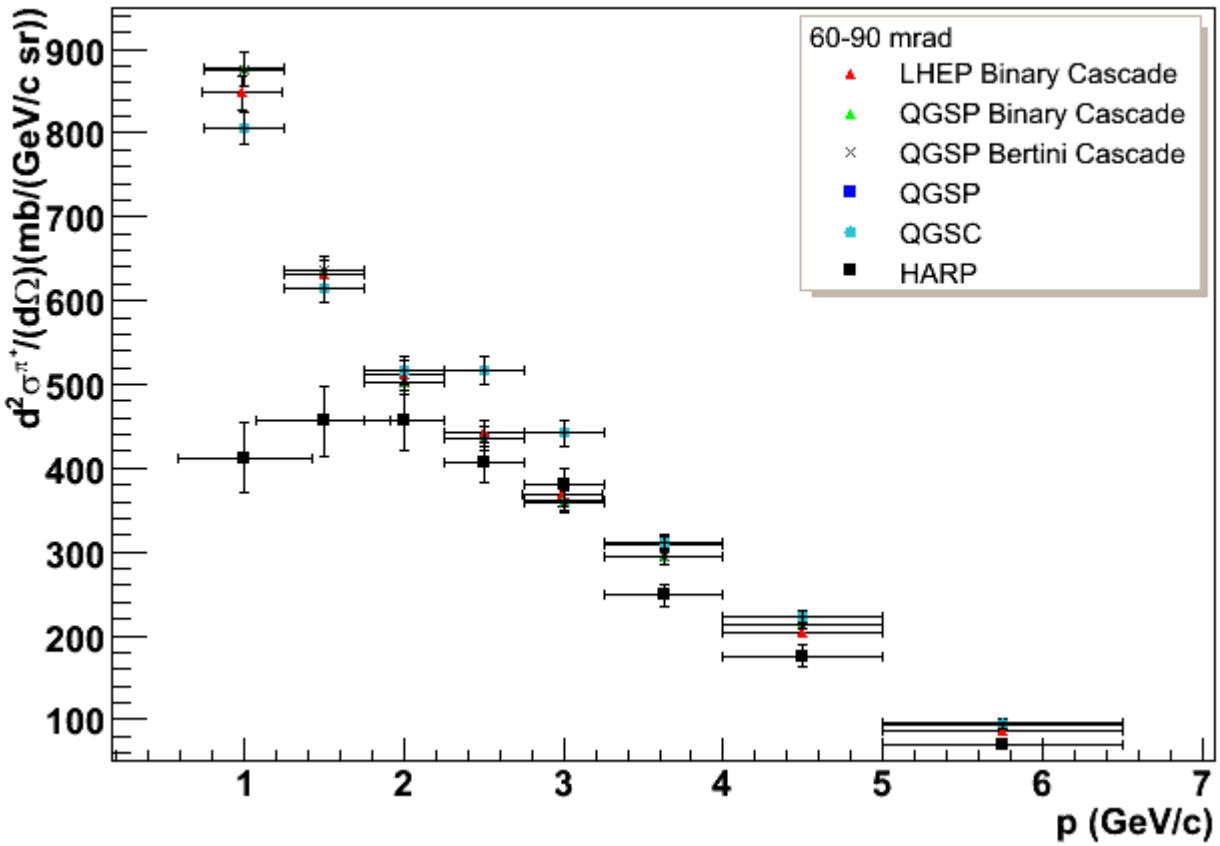
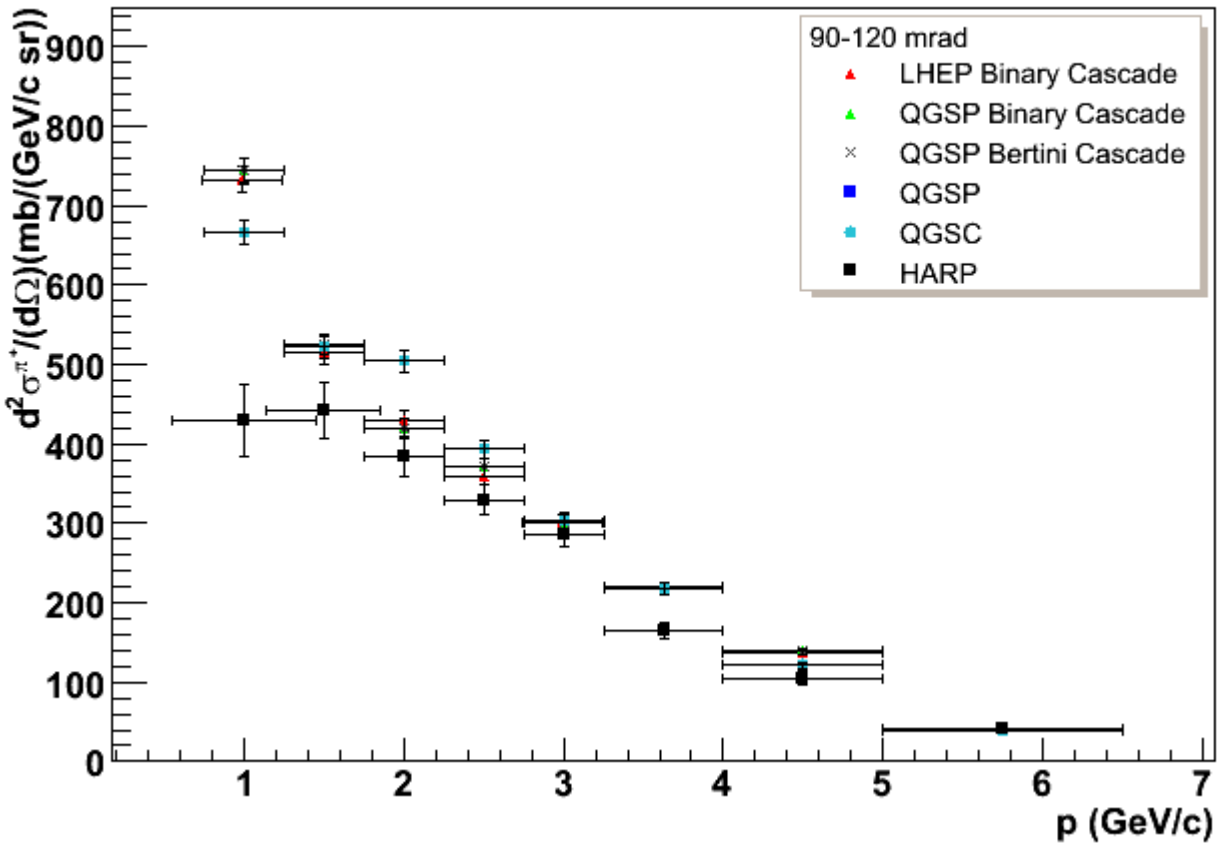
Forward π^+ Production in Al by 12.9 GeV/c Proton Beam
30 mrad < θ < 60 mrad



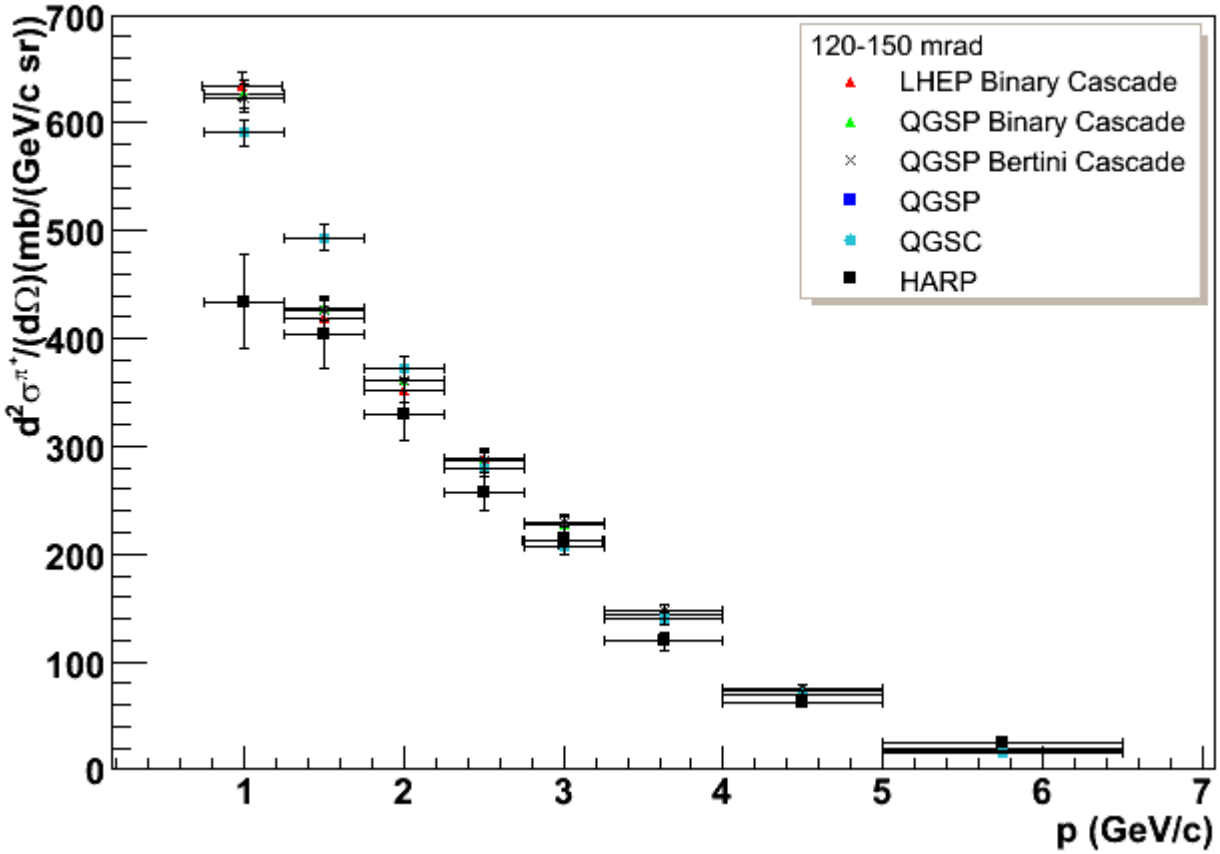
Forward π+ Production in Al by 12.9 GeV/c Proton Beam
60 mrad < θ < 90 mrad



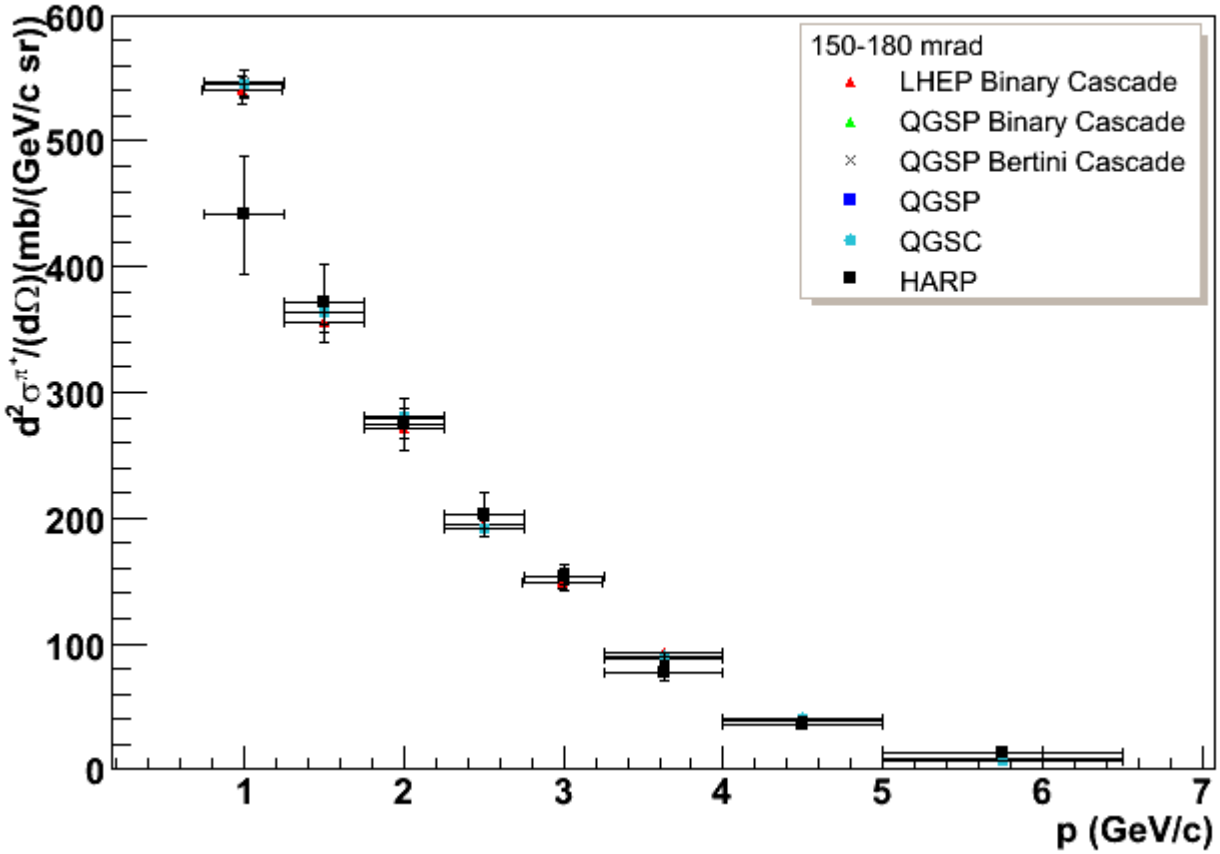
Forward π+ Production in Al by 12.9 GeV/c Proton Beam
90 mrad < θ < 120 mrad



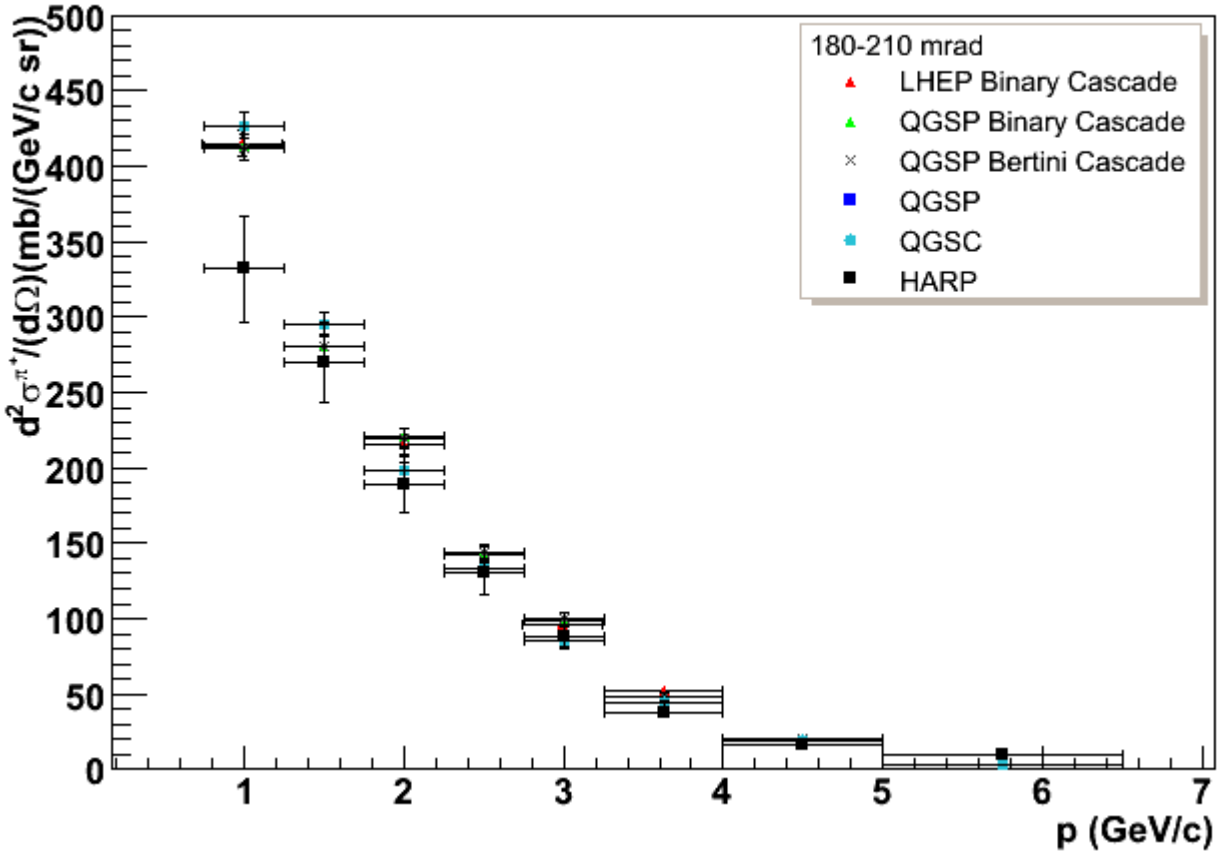
Forward π+ Production in Al by 12.9 GeV/c Proton Beam
120 mrad < θ < 150 mrad



Forward π+ Production in Al by 12.9 GeV/c Proton Beam
150 mrad < θ < 180 mrad



Forward π+ Production in Al by 12.9 GeV/c Proton Beam
180 mrad < θ < 210 mrad



Summary

- Routine procedure for verification of hadron generators in the energy range (1.5 – 15) GeV is established
- The reorganization is provided for G4
- There are a number of concerns to all Geant4 generators
  - The most significant problem in LHEP
  - QGS/FTF angular/momentum distribution
  - Cascades underestimate pion yield
- HARP data are already used by K2K and MiniBooNE collaborations
- The results of data/G4 comparisons will be shown in coming conferences