Description of HARP data in Geant4 with FTF model

V. Uzhinsky, CERN and JINR

Content

- Main ingredient of the Fritiof model
- Fritiof model in Geant4
- Description of pp-interactions
- Description of pA-interactions
- Quasi-elastic scattering
- Description of HARP data
- Conclusion

2007/ Release 09-01-ref-02

1. Implementation of the original algorithm of string mass sampling;
2. Improvement of string fragmentation algorithm;
3. Improvement of small string mass “fragmentation”/2-particle decay;
4. Separate simulation of diffractive and non-diffractive interactions;
5. Attempts to improve a description of meson-nucleon interactions.

2008/ Release 09.???

1. Tuning of the parameters for the separate simulation of diffractive and non-diffractive nucleon-nucleon interactions;
2. Tuning of the parameters for q-qbar and qq-q strings fragmentation;
3. Implementation of a projectile elastic scattering on nuclear nucleons (quasi-elastic scattering);
4. Accounting of a particle formation time;
5. Experiments with combinations of the FTF model and the low energy cascade models (FTF and Binary Cascade Model works well!).

1. Short description of the models

FRITIOF model

B. Andersson et al., Nucl. Phys. B281 (1987) 289;
B. Nilsson-Almquist and E. Stenlund, Comp. Phys. Commun. 43 (1987) 387.

HIJING model

Xin-Nian Wang and Miklos Gyulassy, Phys. Rev. D44 (1991) 3501
A corresponding program has been published in: Miklos Gyulassy and Xin-Nian Wang, Comput. Phys. Commun. 83 (1994) 307, e-Print Archive: nucl-th/9502021, New – AMPT model

UrQMD model

S. A. Bass et al., Prog. Part. Nucl. Phys. 41 (1998)225.
M. Bleicher et al., J. Phys. G: Nucl. Part. Phys 25 (1999) 1859.
The corresponding code at http://th.physik.uni-frankfurt.de/~urqmd/

HSD model (new one, W. Cassing et al.)

W. Ehehalt and W. Cassing, Nucl. Phys. A 602 (1996) 449 -486
The corresponding code at http://th.physik.unifrankfurt.de/~brat/hsd.html

Some of them can be tested at special WEB-page: http://hepweb.jinr.ru/

FRITIOF model

B. Andersson et al., Nucl. Phys. B281 (1987) 289;
B. Nilsson-Almquist and E. Stenlund, Comp. Phys. Commun. 43 (1987) 387.

Hadron-hadron interactions are modeled as binary kinematics

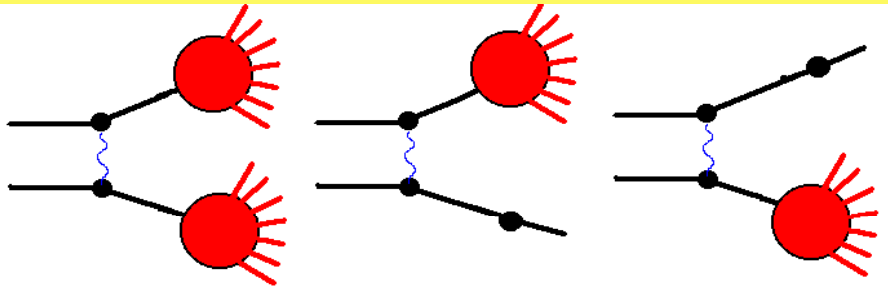
$a + b \rightarrow a' + b', \quad m_a' > m_a \quad m_b' > m_b$

where a' and b' are excited states of the initial hadrons a and b.

In hadron-nucleus interactions the excited hadrons can interact with other nucleons of nucleus and increases mass. The probability of multiple collisions is calculated in Glauber approach. The variant used in the Fritiof model is enlarged with elastic re-scatterings of hadrons. The excited states are considered as QCD-strings, and the LUND model is used for their fragmentation.

$$dW \propto dP^-_{proj} / P^-_{proj}$$

$$dW \propto dP^+_{tar} / P^+_{tar}$$



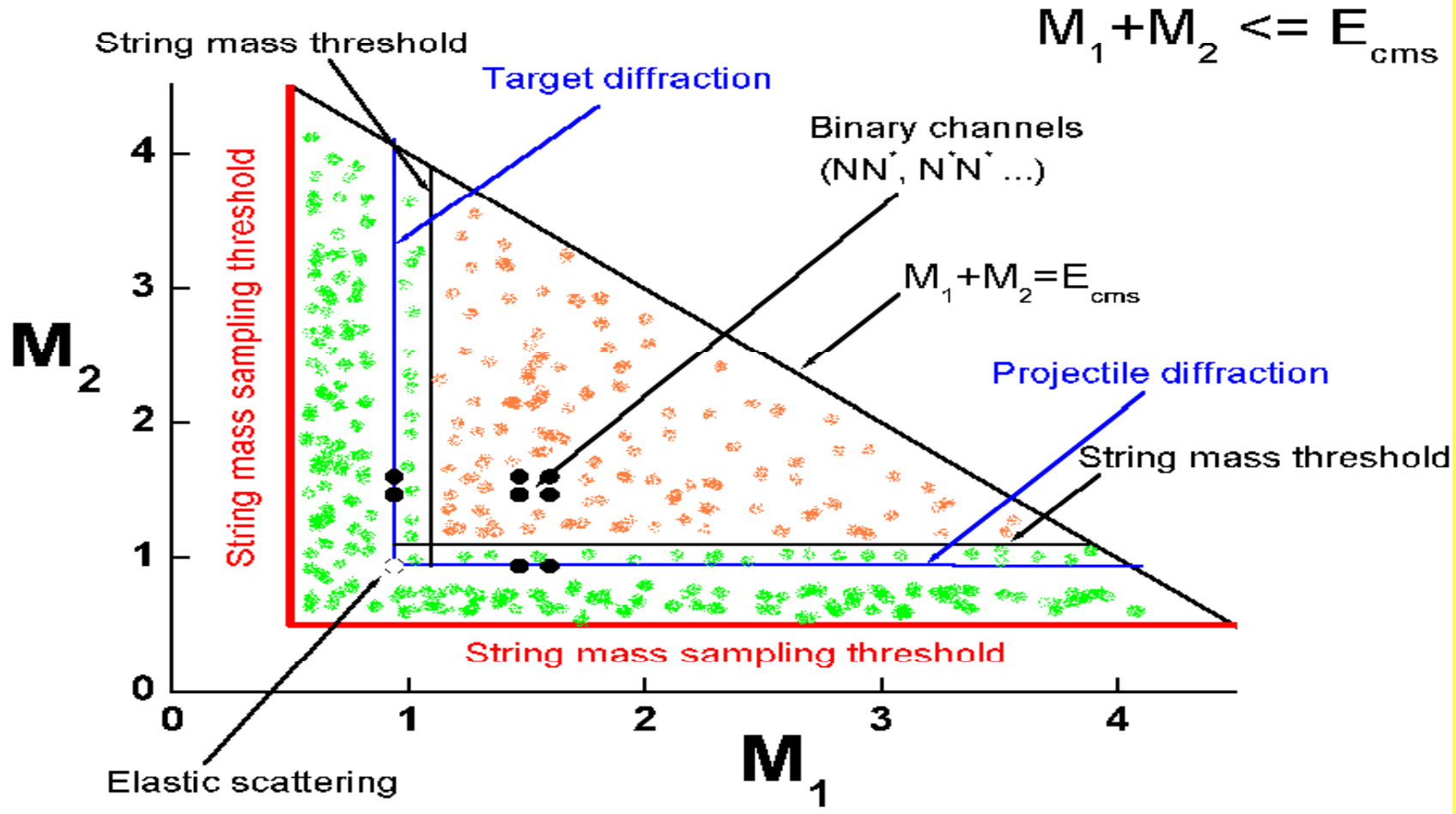
Key parameters

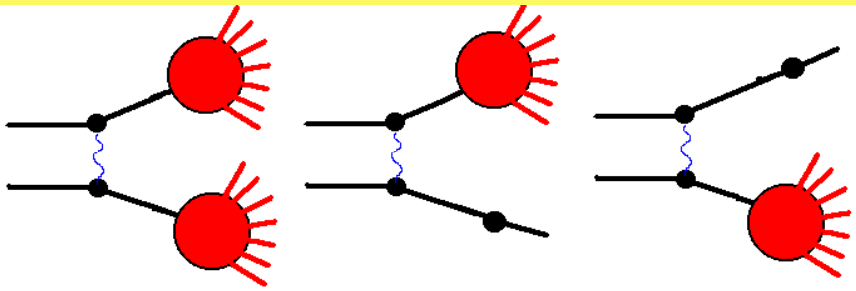
$$dW \propto \frac{dM_1}{M_1}, \qquad dW \propto \frac{dM_2}{M_2}$$

$$M_{string} = 1.1\ GeV\ (N), \quad 1\ GeV\ (\pi), \quad 1.1\ GeV\ (K)$$

$$M_{sampling} = 0.94\ GeV\ (N), \quad 0.75\ GeV\ (\pi), \quad 0.85\ GeV\ (K)$$

FRITIOF model

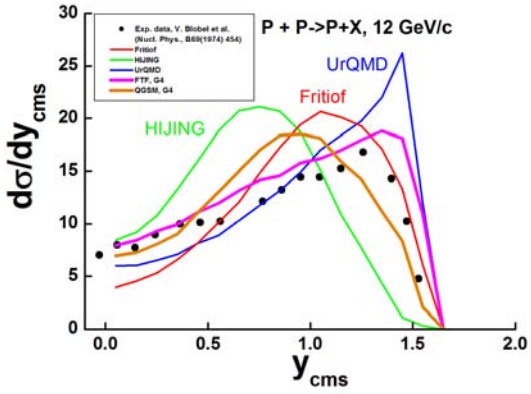


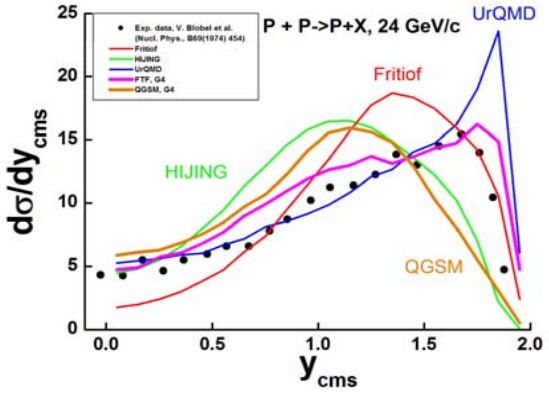


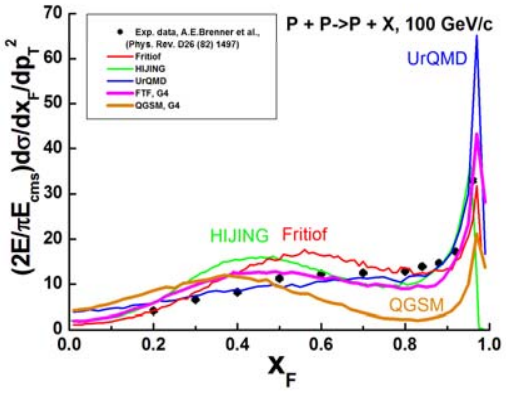
Limits are different for various implementations (UrQMD, Hijing).

Fragmentation models are different too. These lead to various predictions

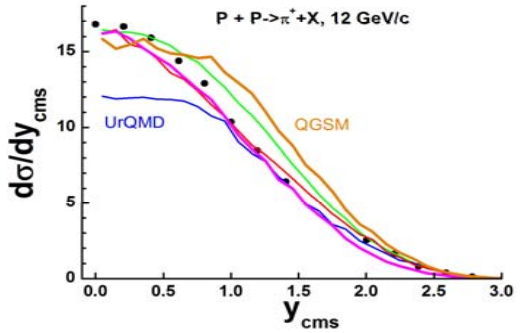
Description of baryon spectra is the problem in all MC models

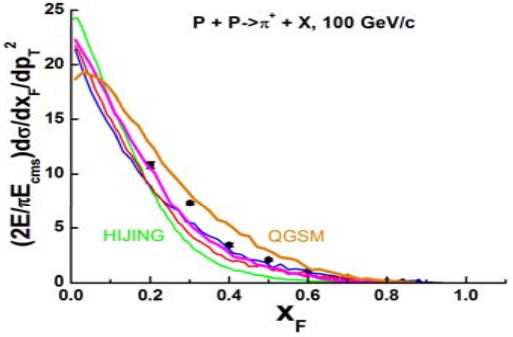


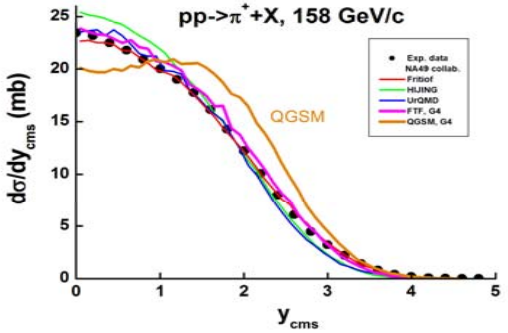


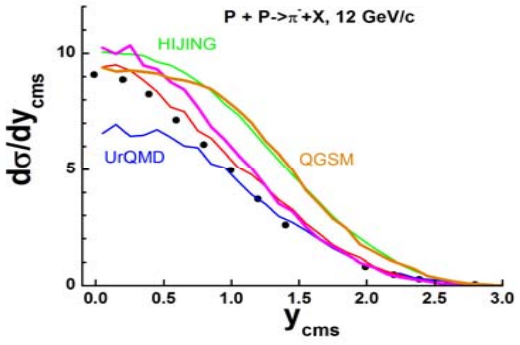


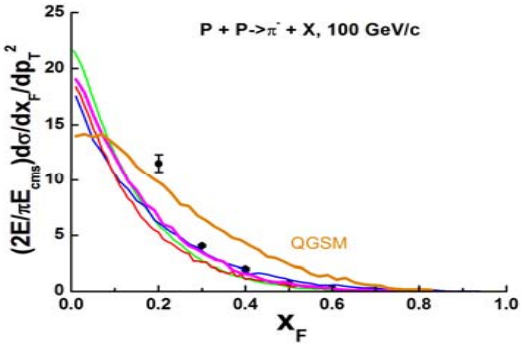
There are some problems with a description of meson spectra

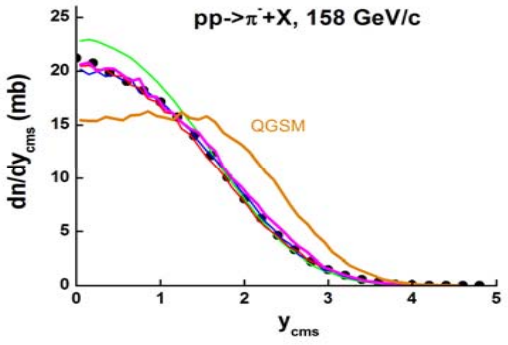




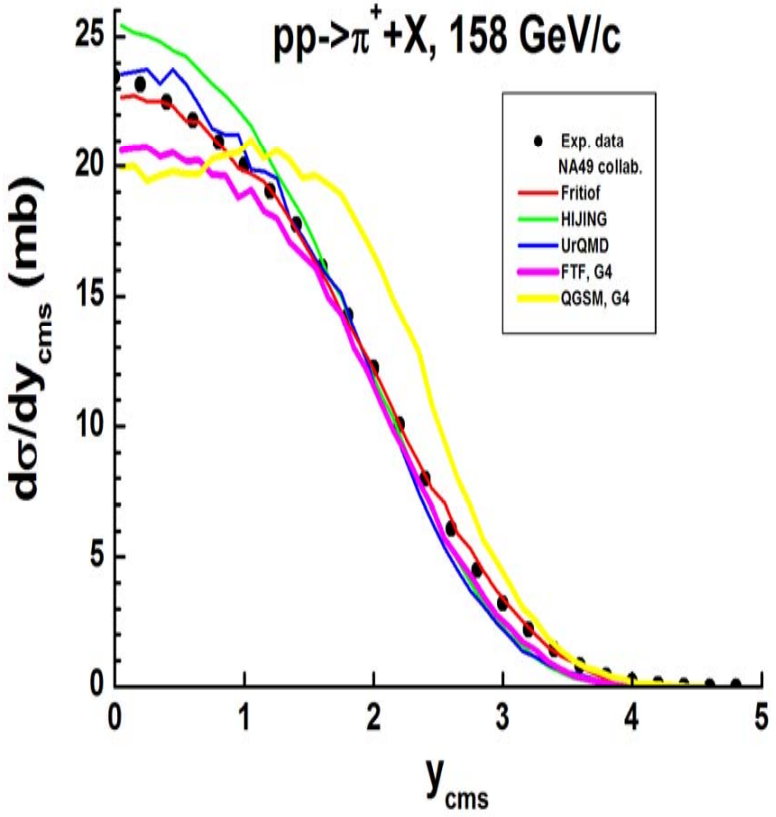


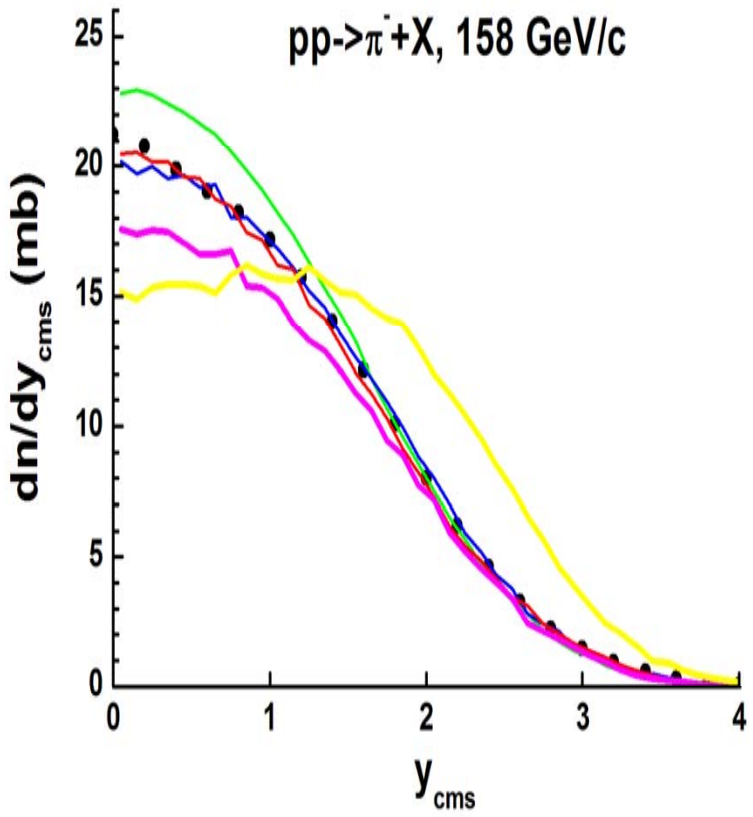






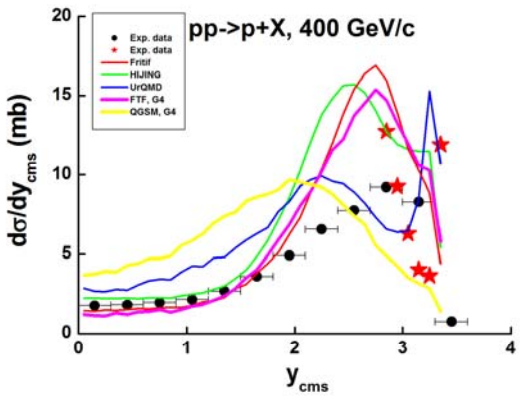
2. Description of PP-interactions, 158 GeV/c, NA-49

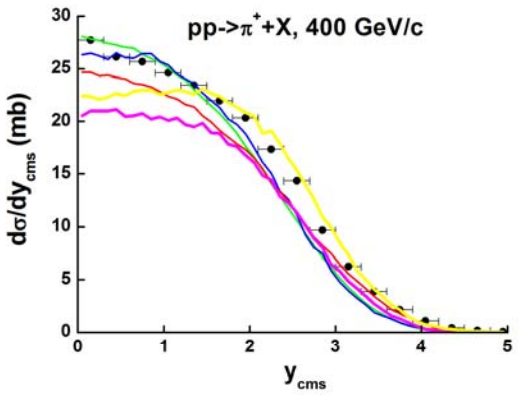


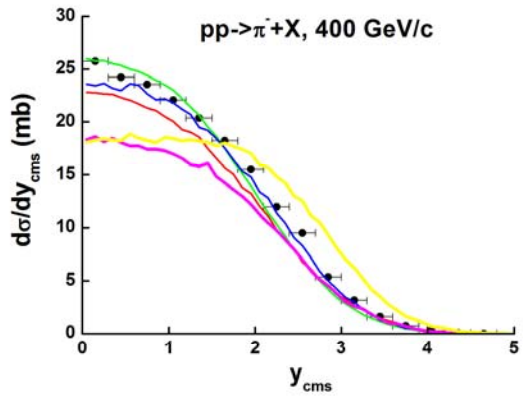


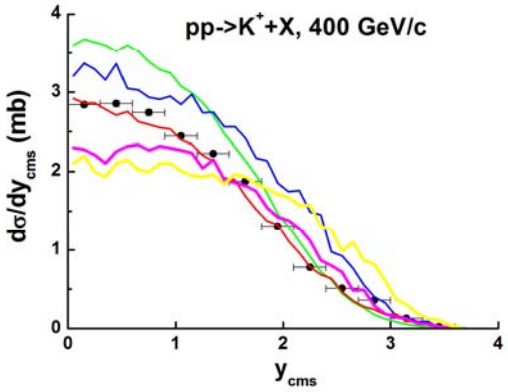
At Plab > 30 GeV/c: **UrQMD and Fritiof give good results.**
HIJING overestimate meson multiplicities,
FTF underestimates them a little bit,
Predictions of QGSM are far away from others!

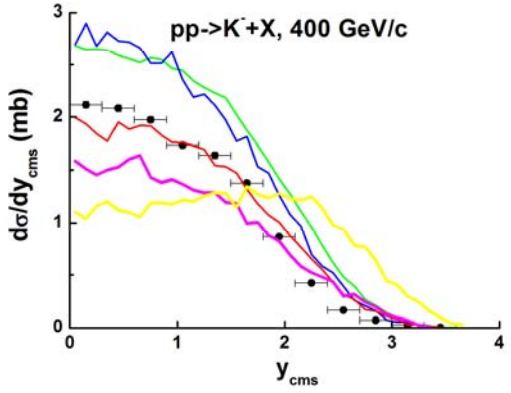
2. Description of PP-interactions, 400 GeV/c

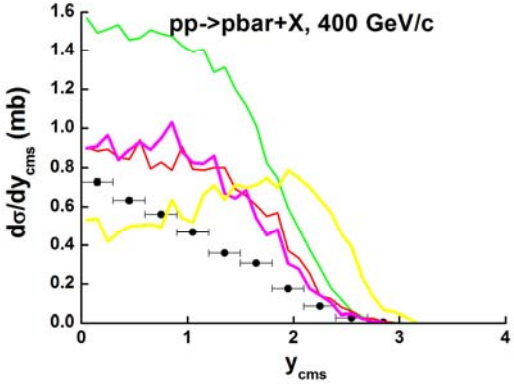






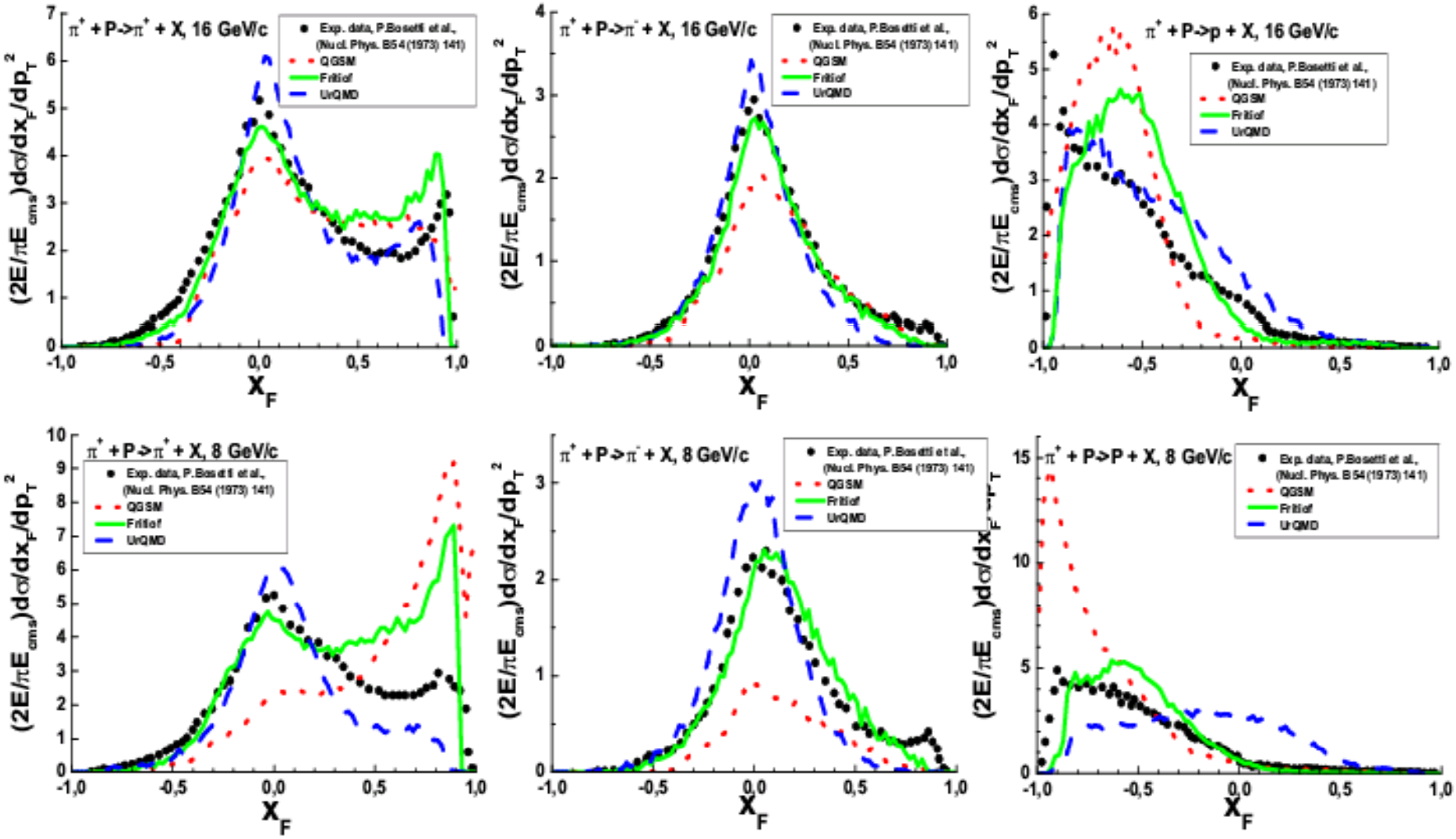




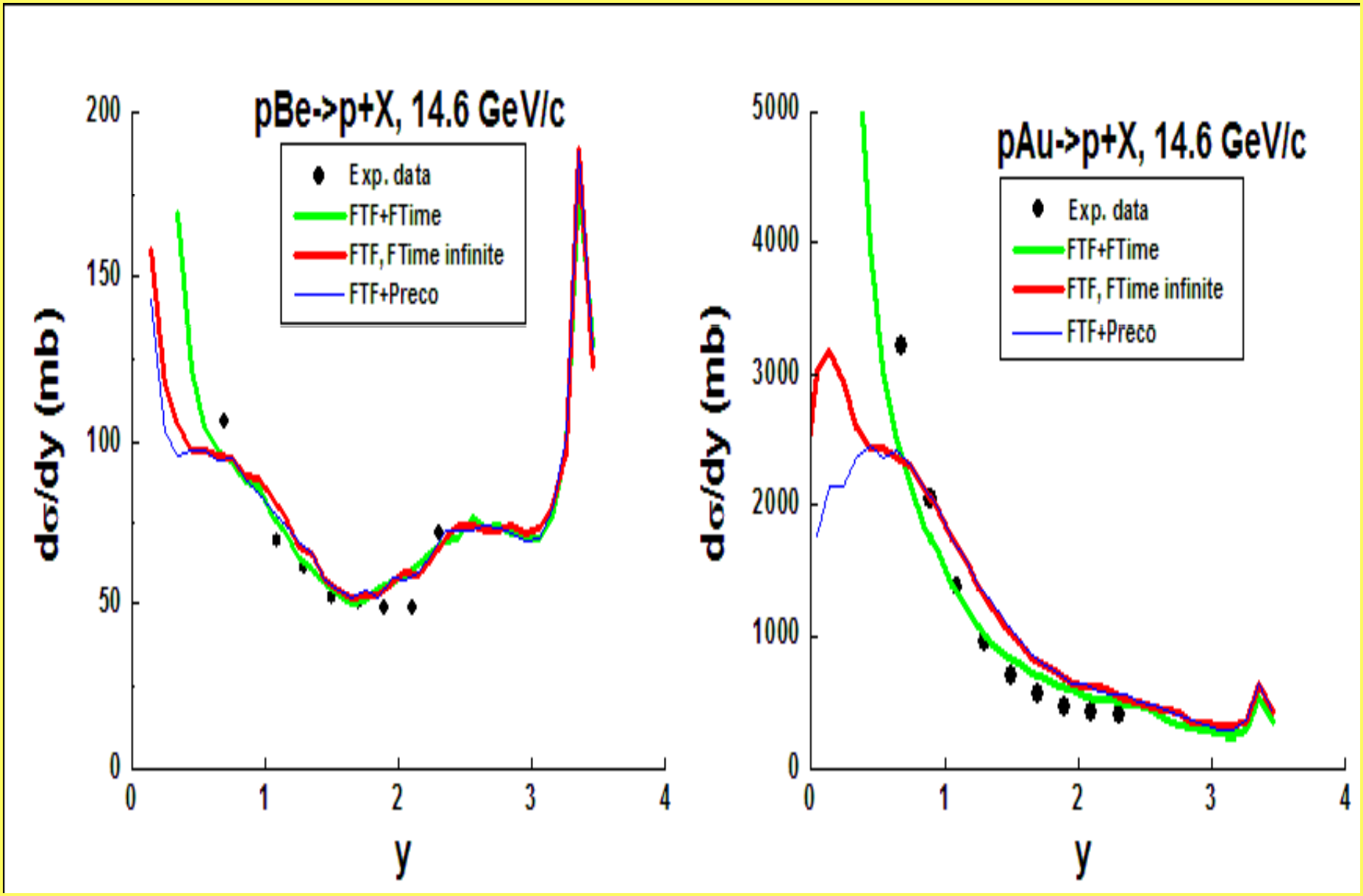


At Plab =400 GeV/c: Only HIJING and UrQMD give satisfactory results for Pi-mesons. QGSM and FTF must be improved.
For K-mesons only Fritiof works well!

3. Description of pion-nucleon interactions

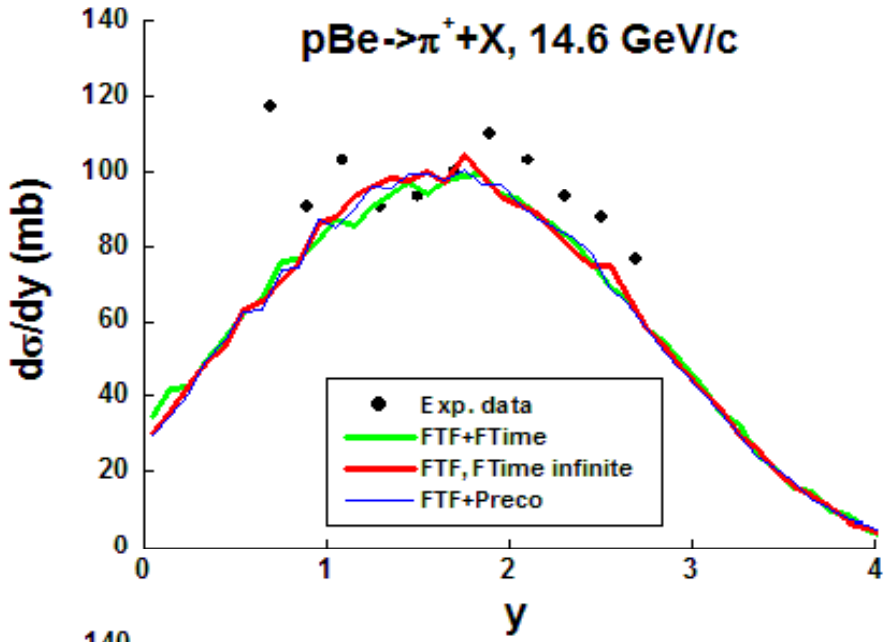


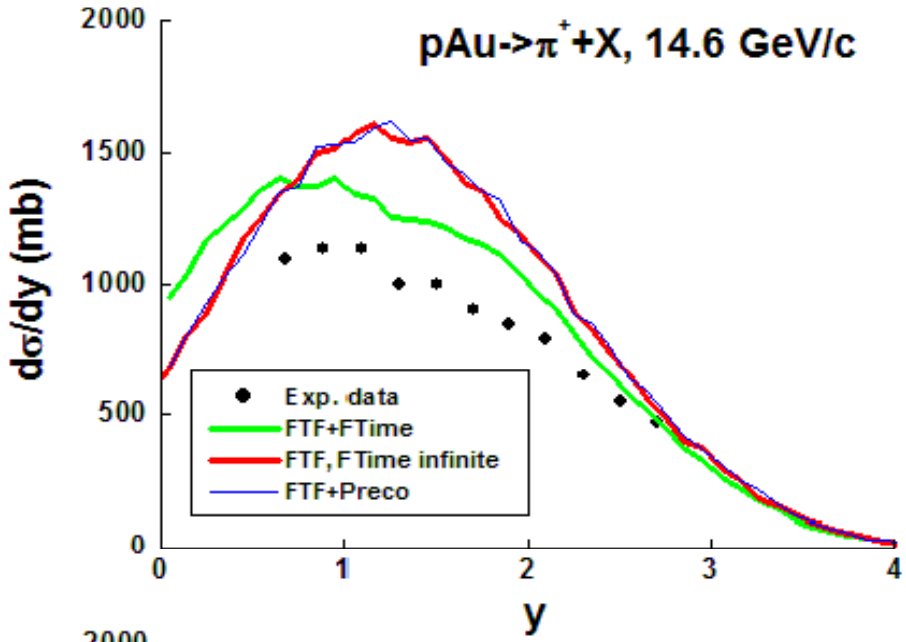
All models do not give satisfactory results!
UrQMD crushed for Pi+A interactions!

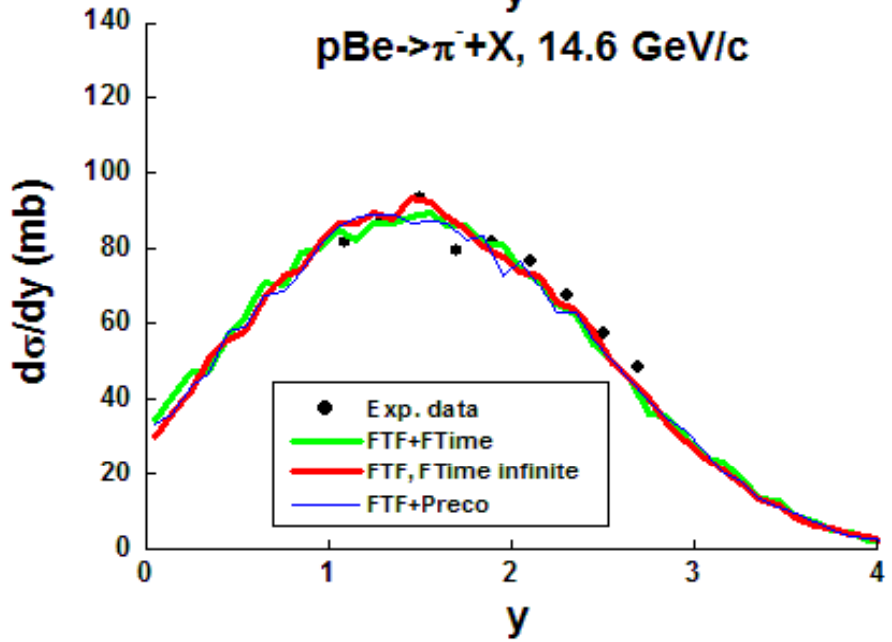


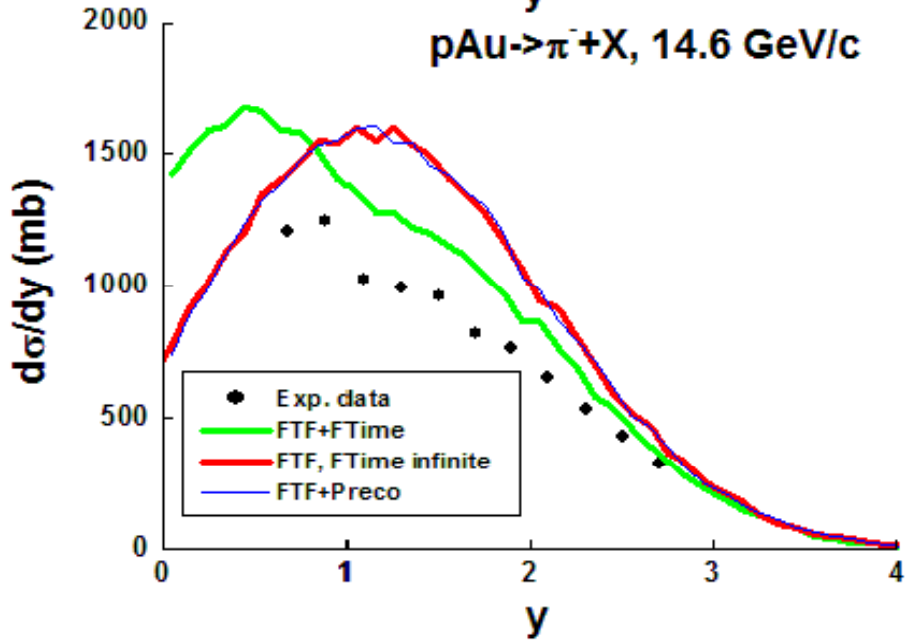
FTF + binary cascade works well!

4. Results for pA-interactions





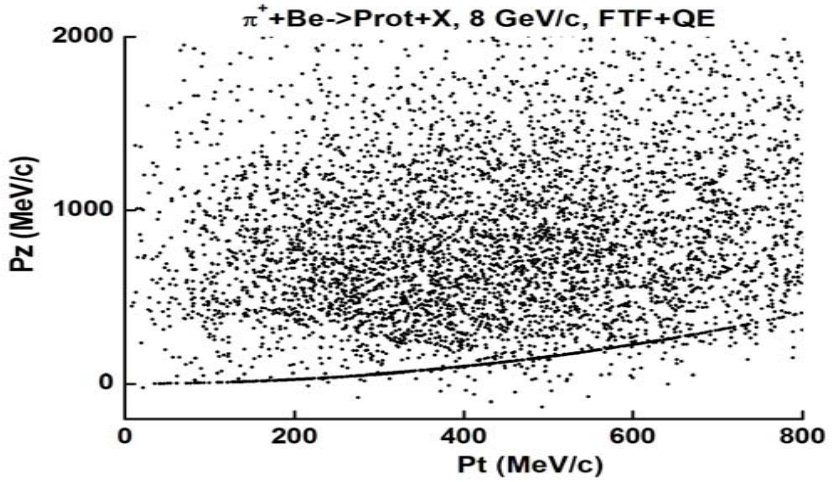


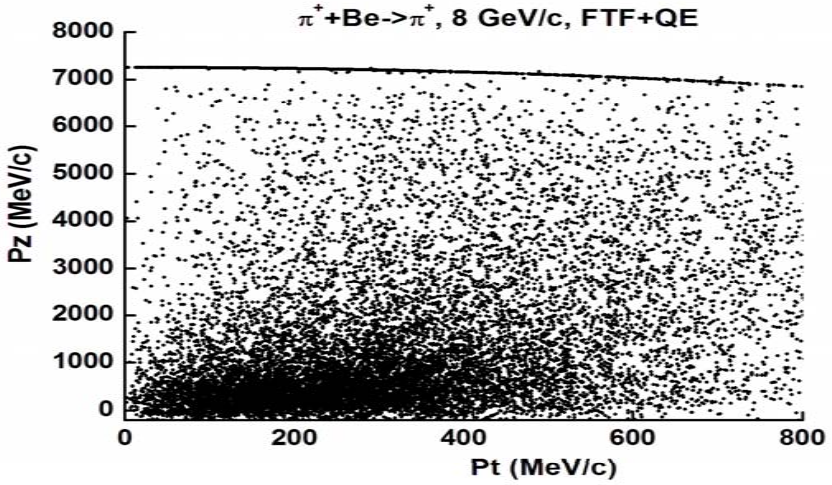


5. Results for Pi+A-interactions

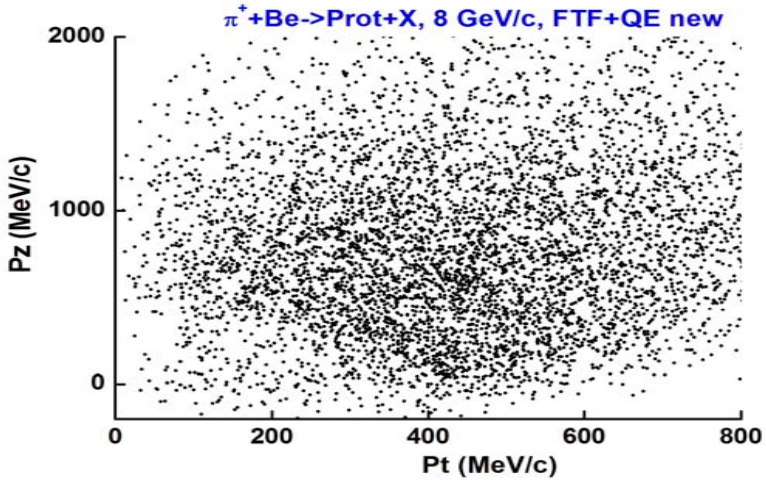
New implementation of quasi-elastic scattering

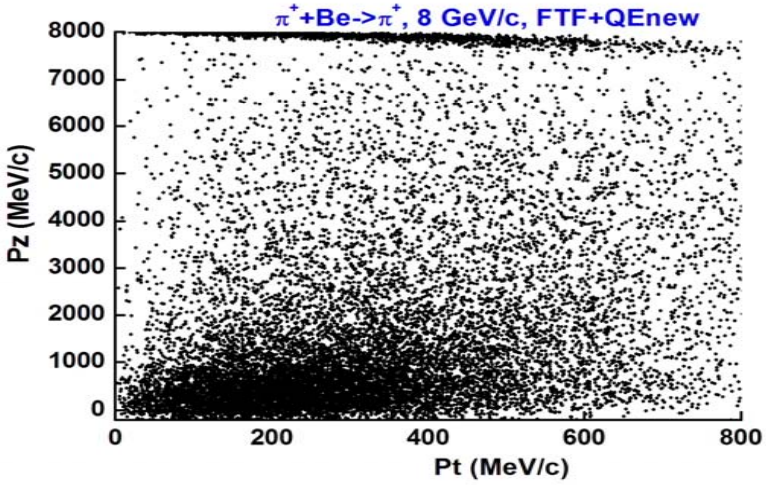
Old





New





Corresponding HARP exp. data are not published.

A correct simulation of quasi-elastic scattering is very important

Data by HARP collaboration

High Energy Physics - Experiment

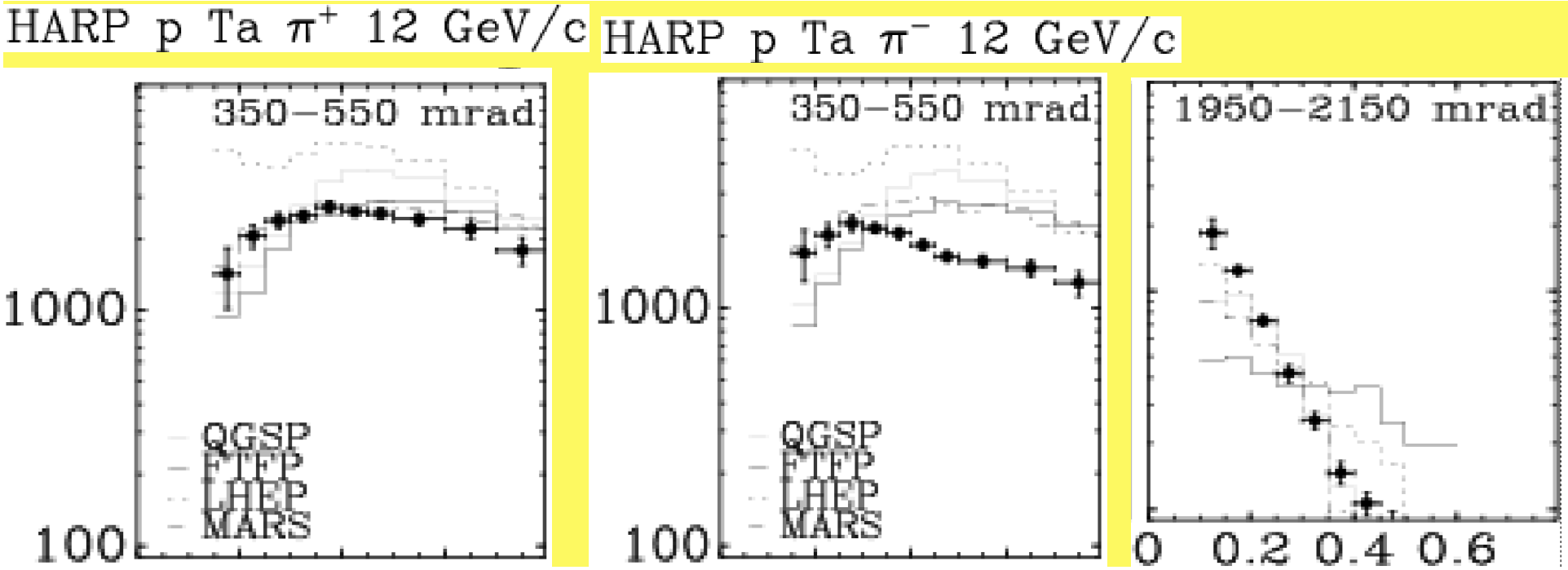
Large-angle production of charged pions with 3-12.9 GeV/c incident protons on nuclear targets

HARP Collaboration

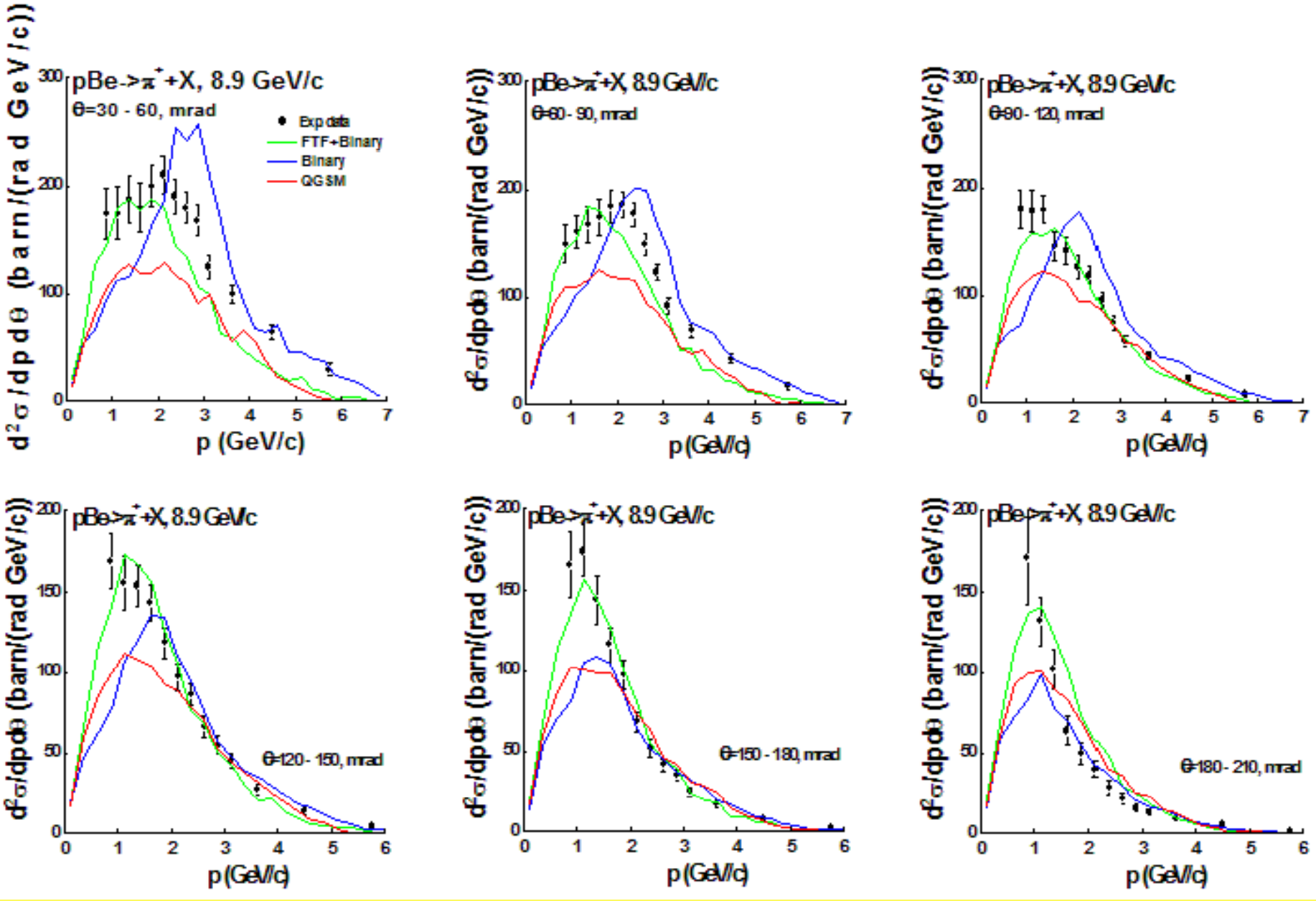
(Submitted on 19 May 2008)

Measurements of the double-differential charged pion production cross-section in the range of momentum 100 MeV/c < p < 800 MeV/c and angle 0.35 < \theta < 2.15 rad in proton-beryllium, proton-carbon, proton-aluminium, proton-copper, proton-tin, proton-tantalum and proton-lead collisions are presented. The data were taken with the large acceptance HARP detector in the T9 beam line of the CERN PS. The pions were produced by proton beams in a momentum range from 3 GeV/c to 12.9 GeV/c hitting a target with a thickness of 5% of a nuclear interaction length.

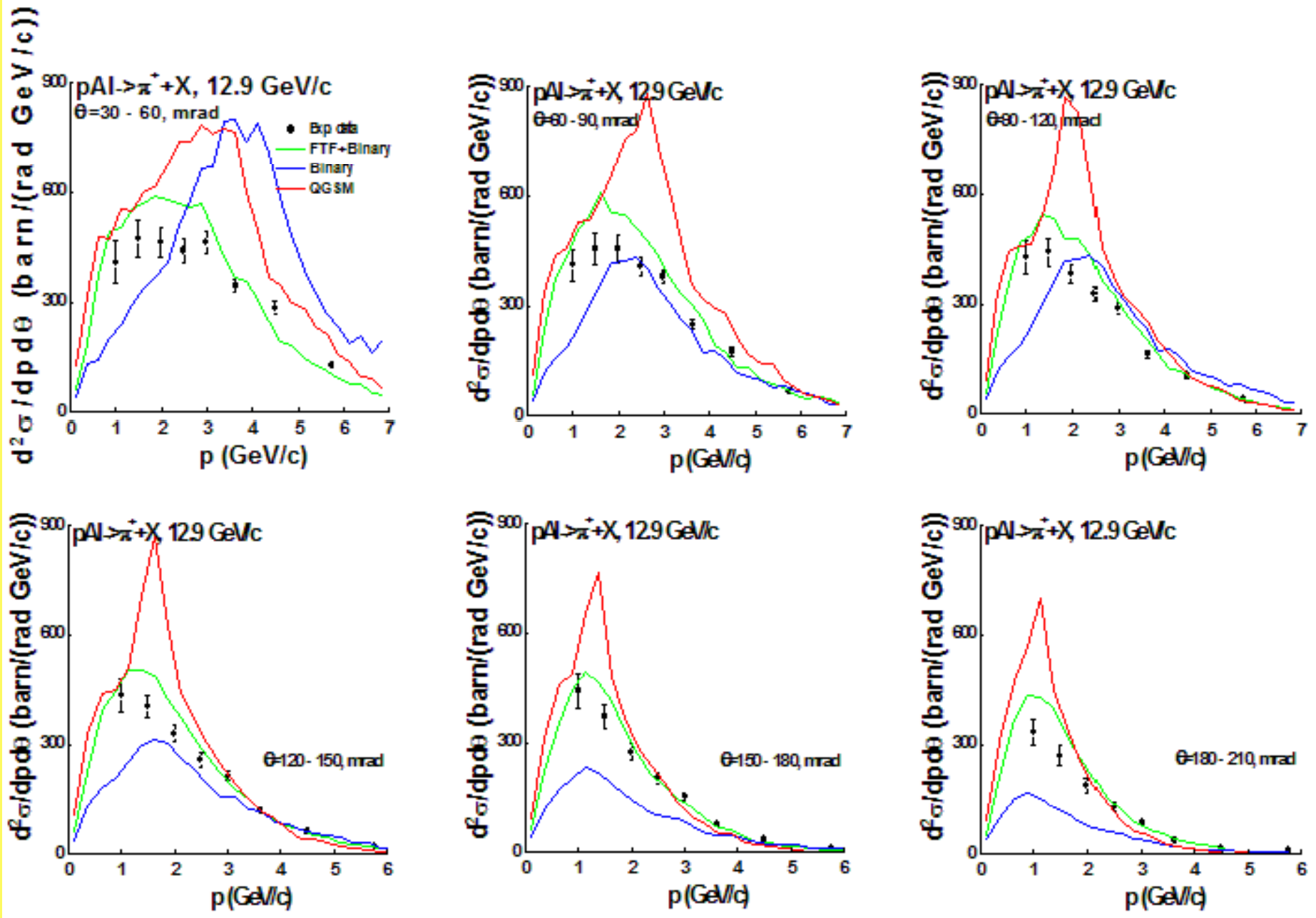
Subjects: **High Energy Physics - Experiment (hep-ex)**
Cite as: **arXiv:0805.2871v1 [hep-ex]**



Implementation of formation time in FTF, results for HARP experiment, pBe

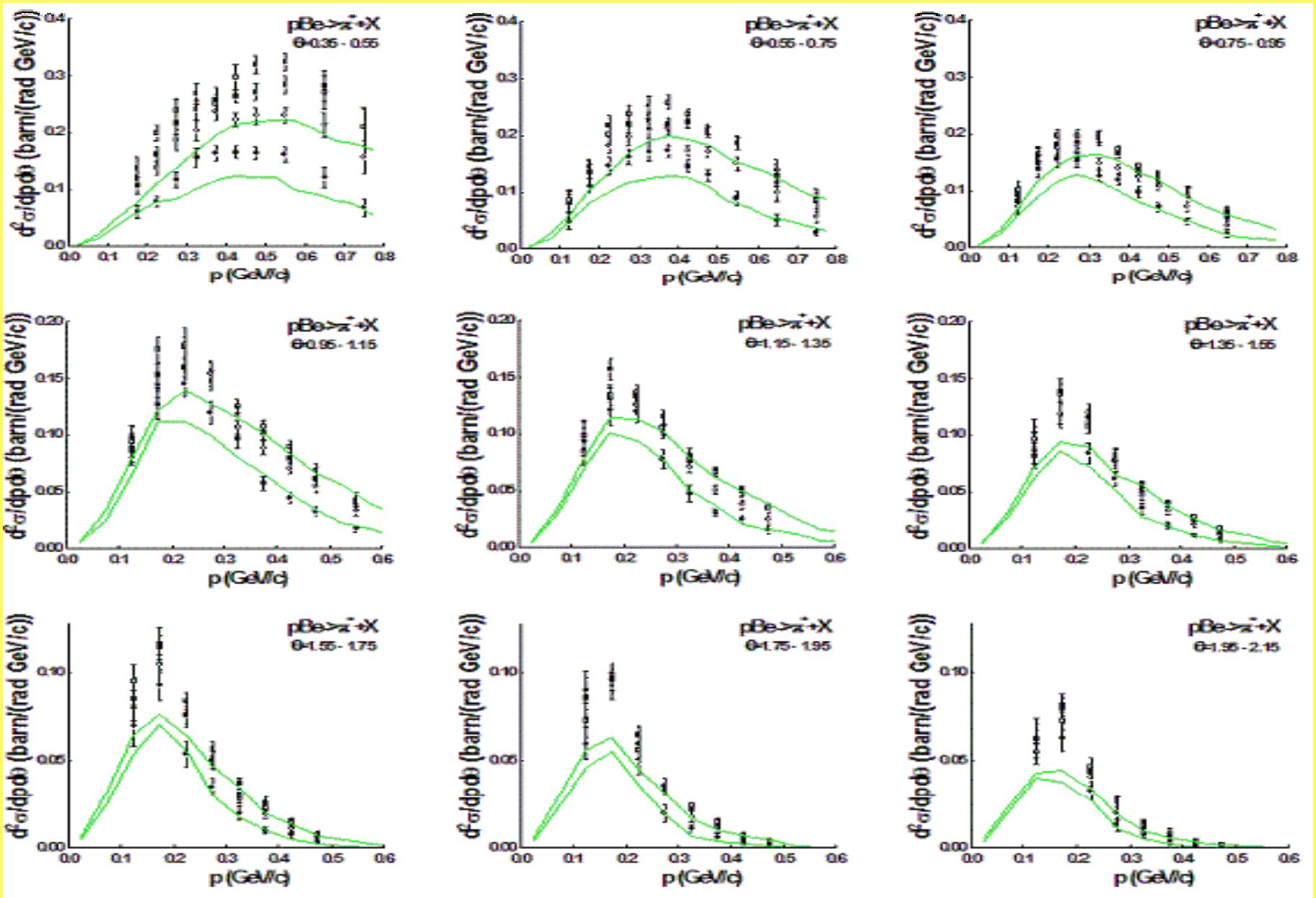


Implementation of formation time in FTF, results for HARP experiment, pAl



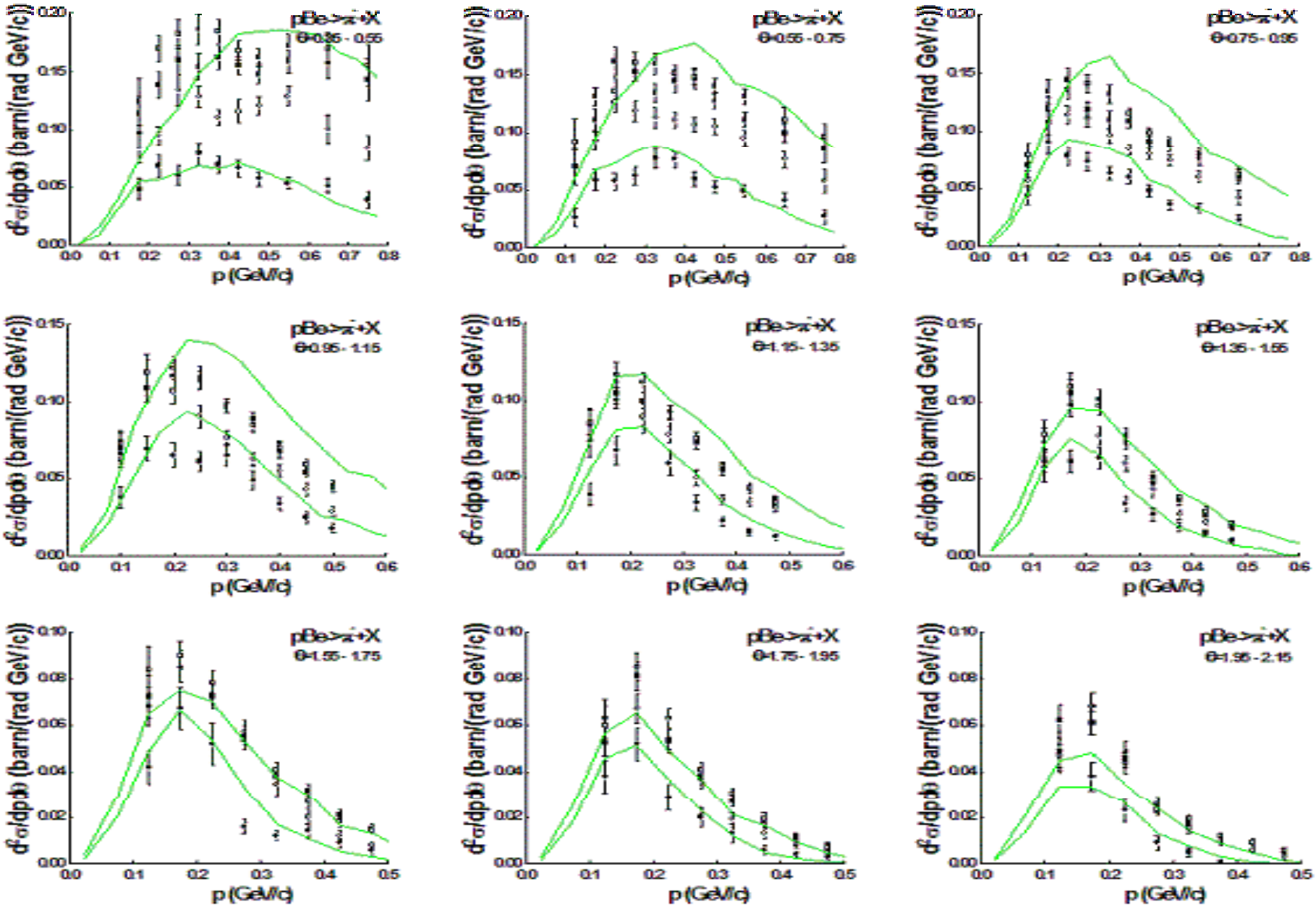
Implementation of formation time in FTF, results for HARP experiment, pBe

Large angles, Pi+

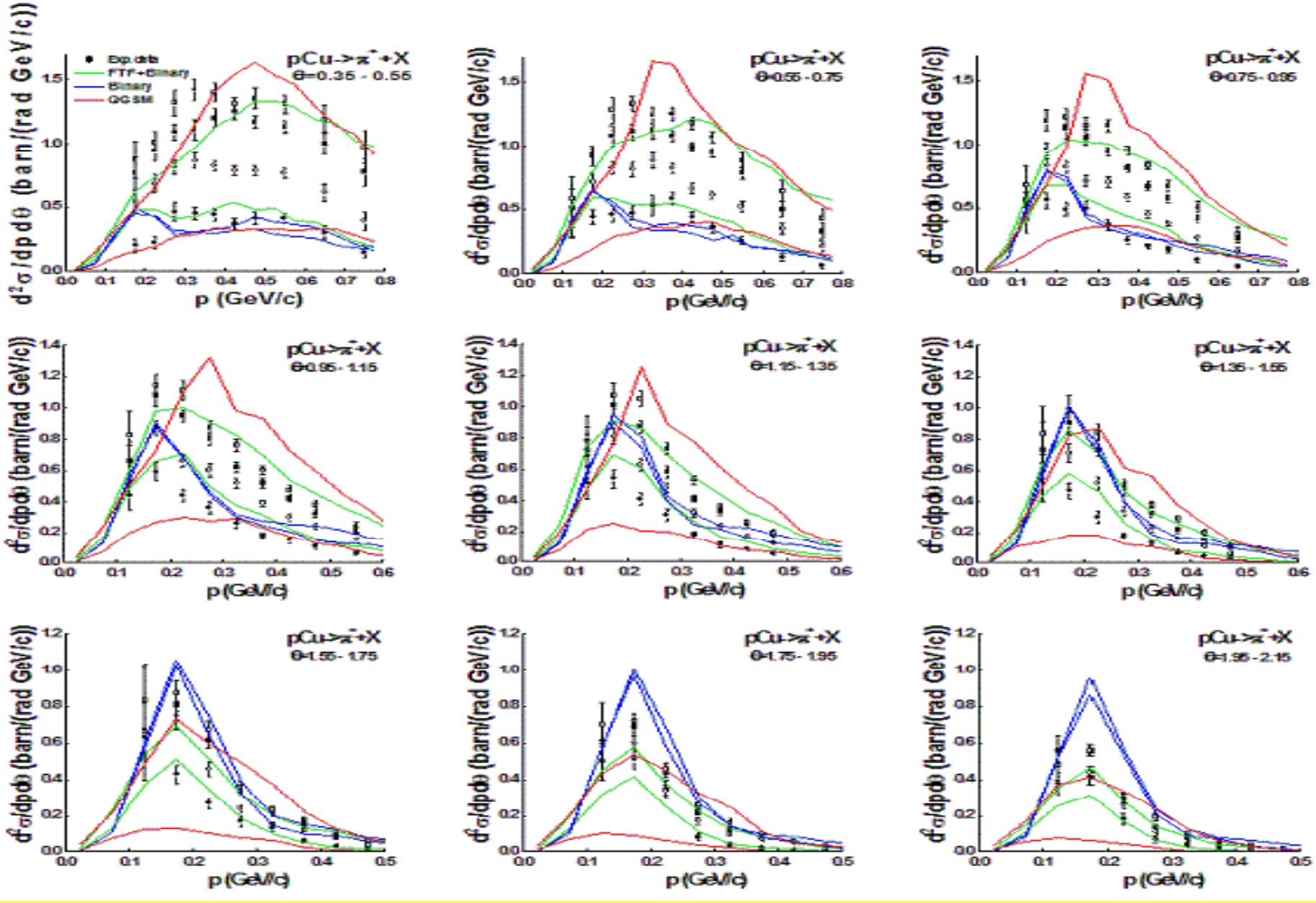


Implementation of formation time in FTF, results for HARP experiment, pBe

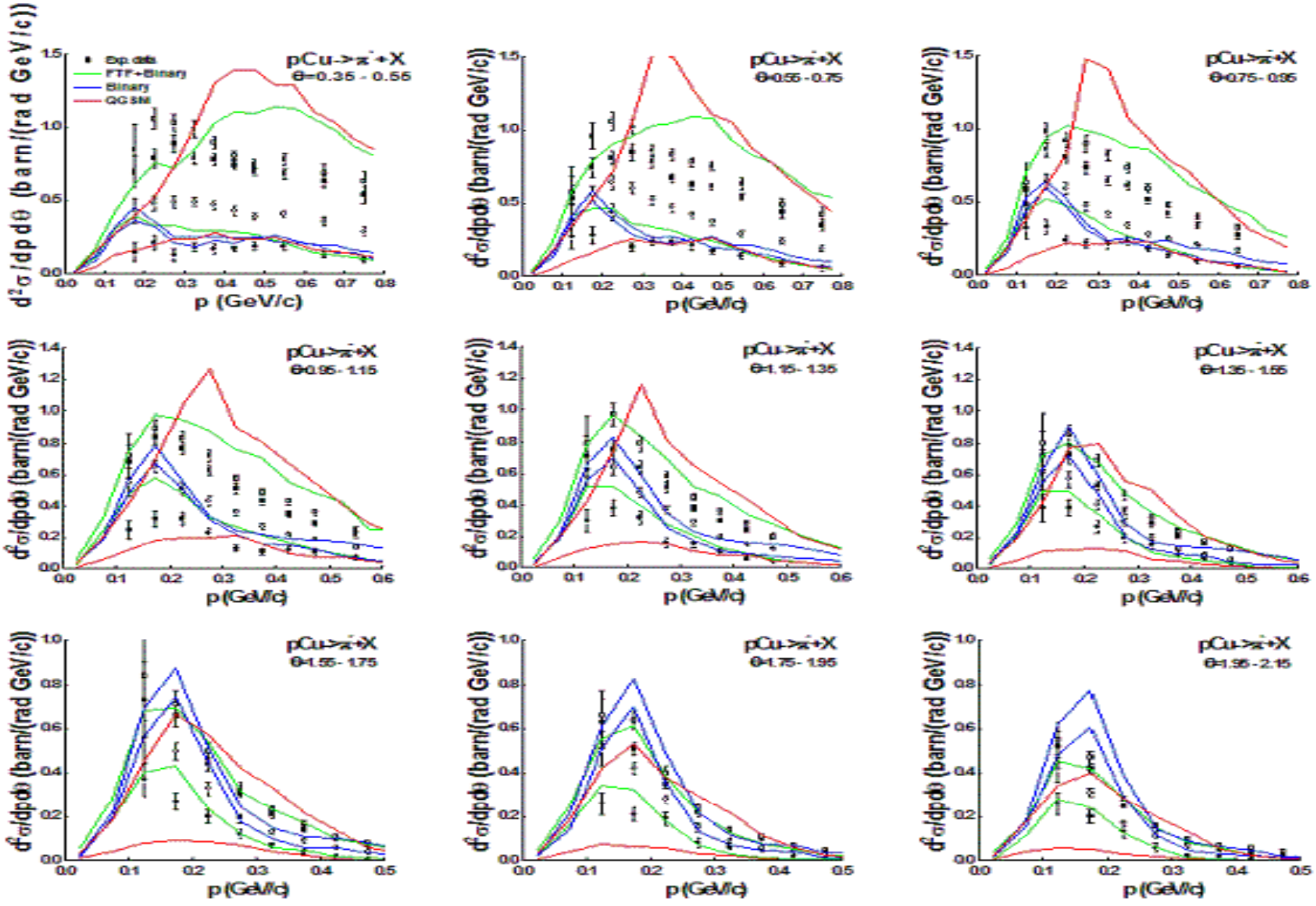
Large angles, Pi-



Implementation of formation time in FTF, results for HARP experiment, pCu

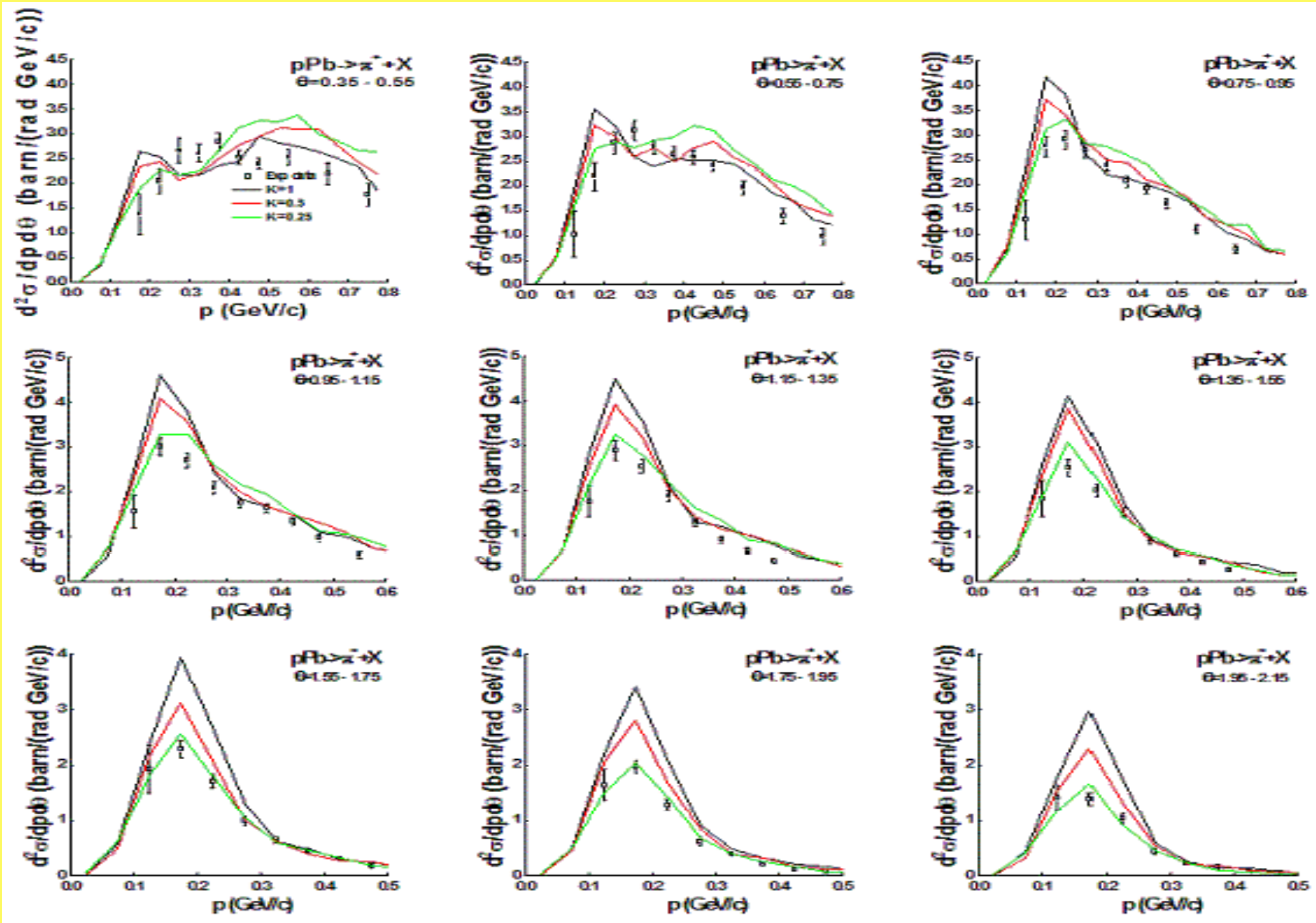


Implementation of formation time in FTF, results for HARP experiment, pCu



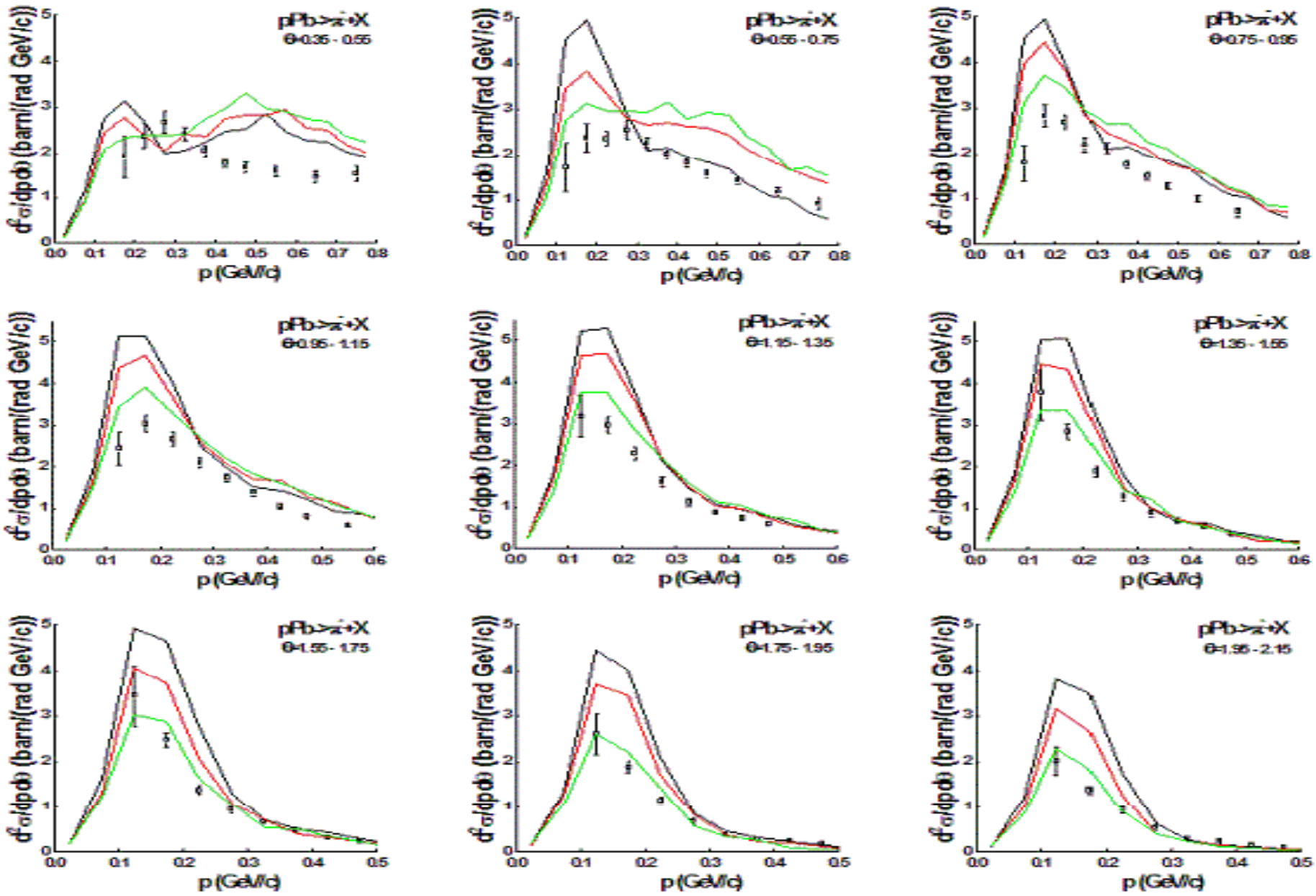
Tuning of string tension, results for HARP experiment, pPb

Large angles, Pi+



Tuning of string tension, results for HARP experiment, pPb

Large angles, Pi-



Strange results

High Energy Physics - Experiment

Comparison of Geant4 hadron generation with data from the interactions with beryllium nuclei of +8.9 GeV/c protons and pions, and of -8 GeV/c pions

A. Bolshakova, et al

(Submitted on 18 Apr 2008)

Hadron generation in the Geant4 simulation tool kit is compared with inclusive spectra of secondary protons and pions from the interactions with beryllium nuclei of +8.9 GeV/c protons and pions, and of -8.0 GeV/c pions. The data were taken in 2002 at the CERN Proton Synchrotron with the HARP spectrometer. We report on significant disagreements between data and simulated data especially in the polar-angle distributions of secondary protons and pions.

Comments: 15 pages, 13 figures
Subjects: **High Energy Physics - Experiment (hep-ex)**
Report number: CERN-PH-EP/2008-007
Cite as: arXiv:0804.3013v1 [hep-ex]

The HARP–CDP group

A. Bolshakova, I. Boyko, G. Chelkov, D. Dedovitch, A. Elagin[1], M. Gostkin, A. Guskov, Z. Kroumchtein, Yu. Nefedov, K. Nikolaev, A. Zhemchugov
Joint Institute for Nuclear Research, Dubna, Russia

F. Dydak, J. Wotschack*
CERN, Geneva, Switzerland

A. De Min[2]
Politecnico di Milano and INFN, Sezione di Milano-Bicocca, Italy

V. Ammosov, V. Gapienko, V. Koreshev, A. Semak, Yu. Sviridov, E. Usenko[3], V. Zaets
Institute for High Energy Physics, Protvino, Russia

Main result

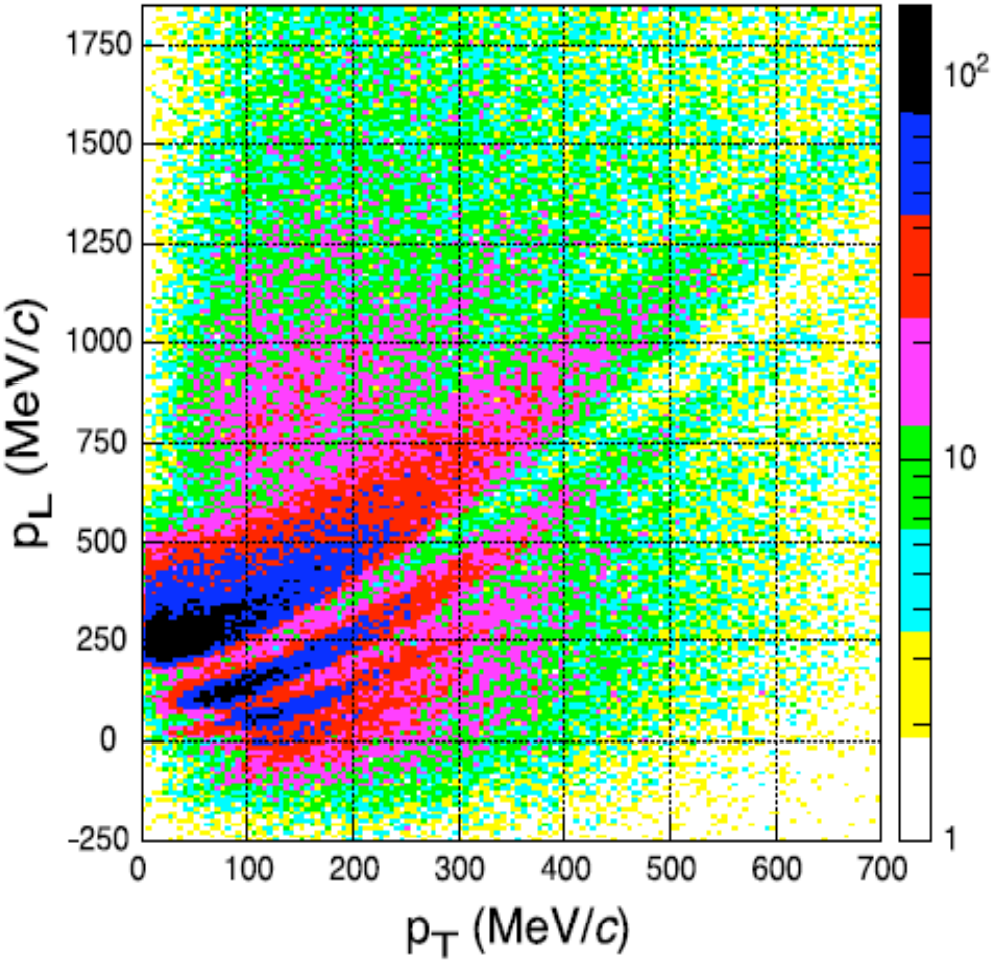


Fig. 1: Longitudinal momentum p_{L} versus transverse momentum p_{T}, as generated by Geant4's LHEP physics list for secondary π^+ from the interactions of +8.9 GeV/c beam π^+ with beryllium nuclei at rest.

Main result

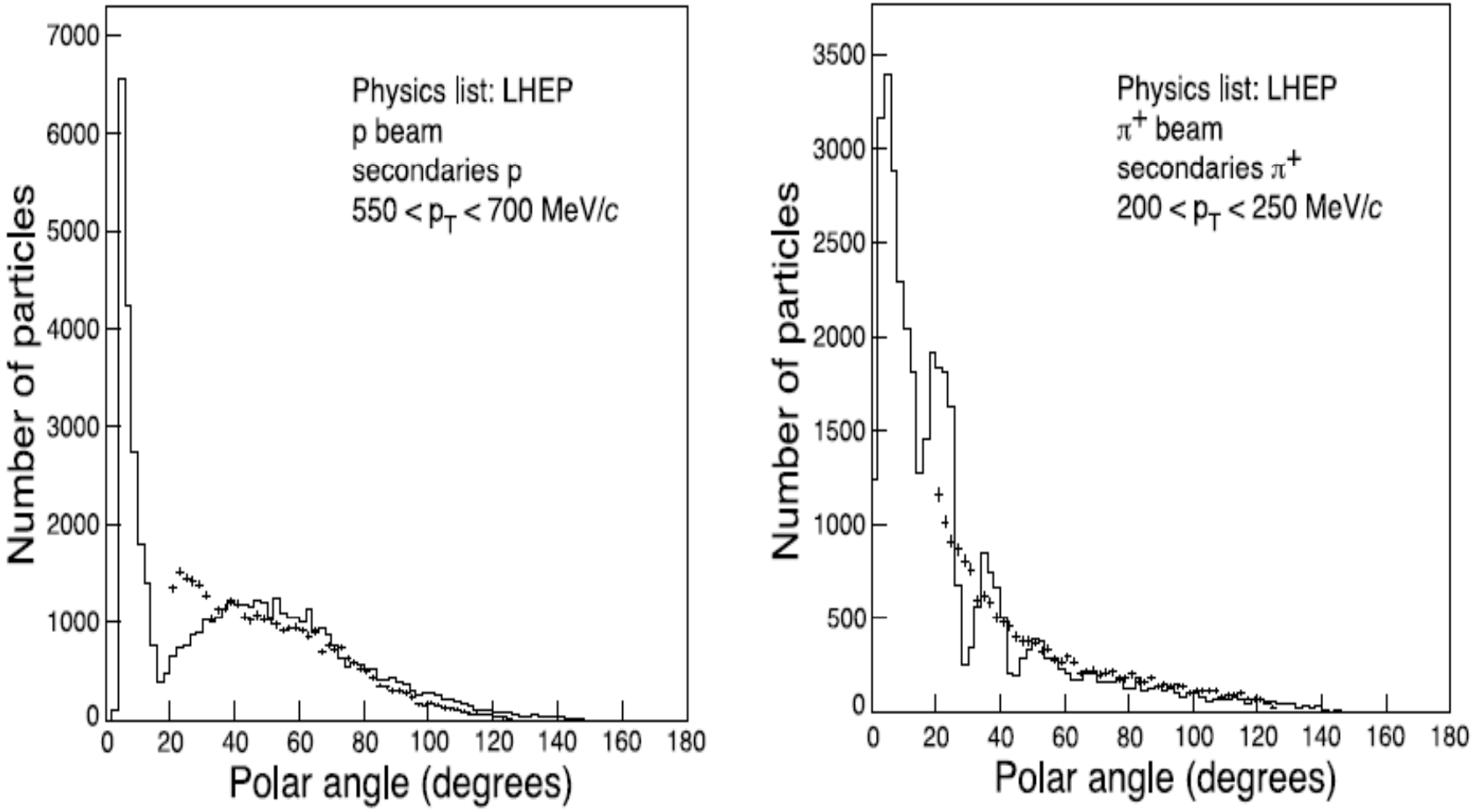


Fig. 5: LHEP physics list; polar-angle distributions of protons for incoming protons (left panel), and of π^+ for incoming π^+ (right panel).

Main result

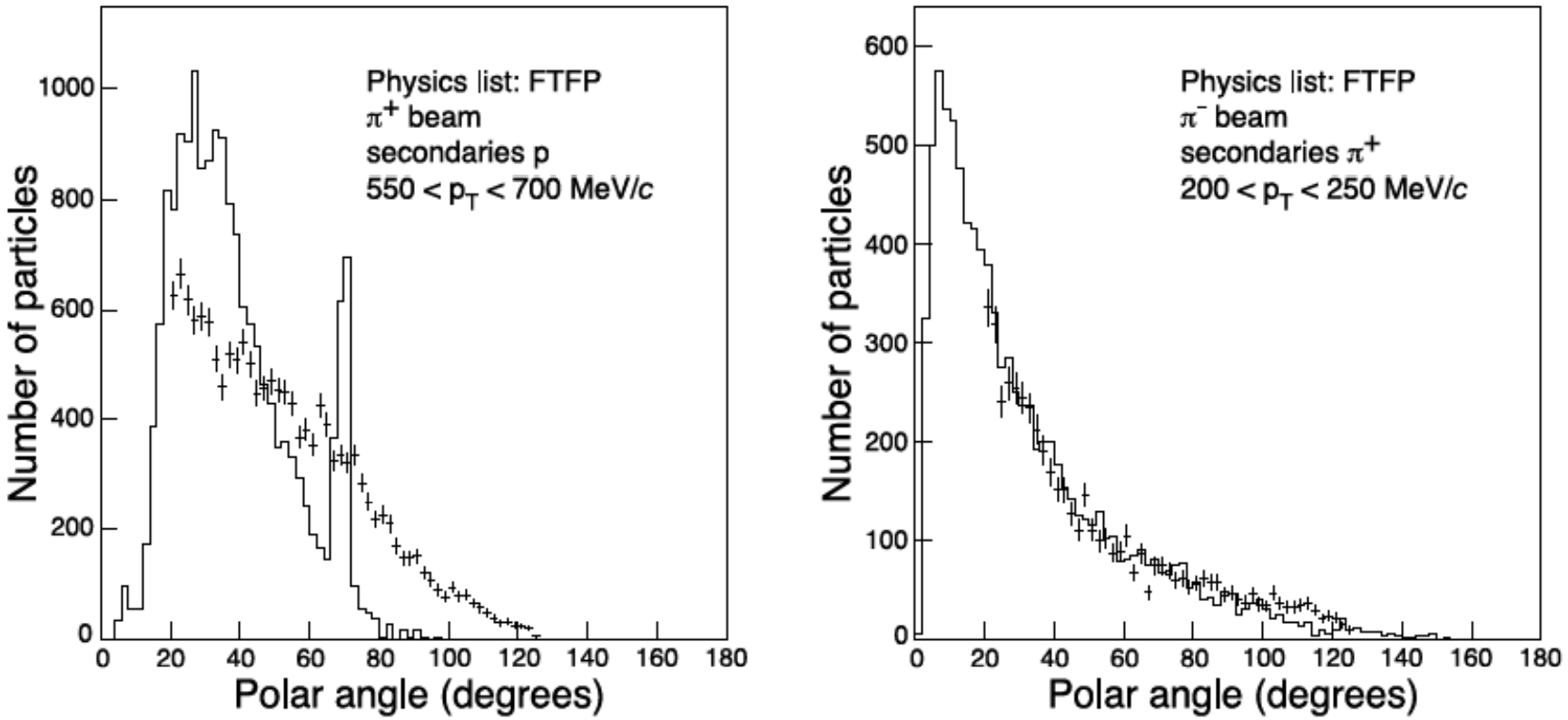
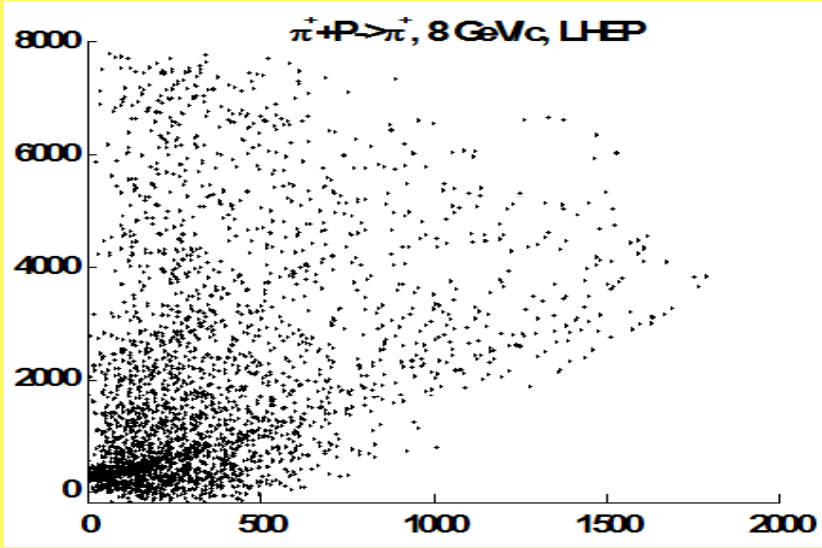


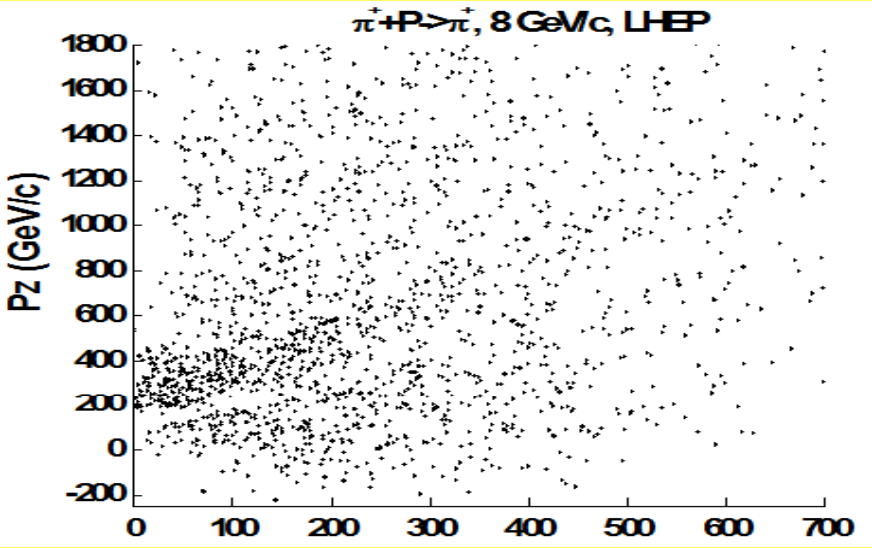
Fig. 10: FTFP physics list; polar-angle distributions of protons for incoming π^+ (left panel), and of π^+ for incoming π^- (right panel).

Questions:

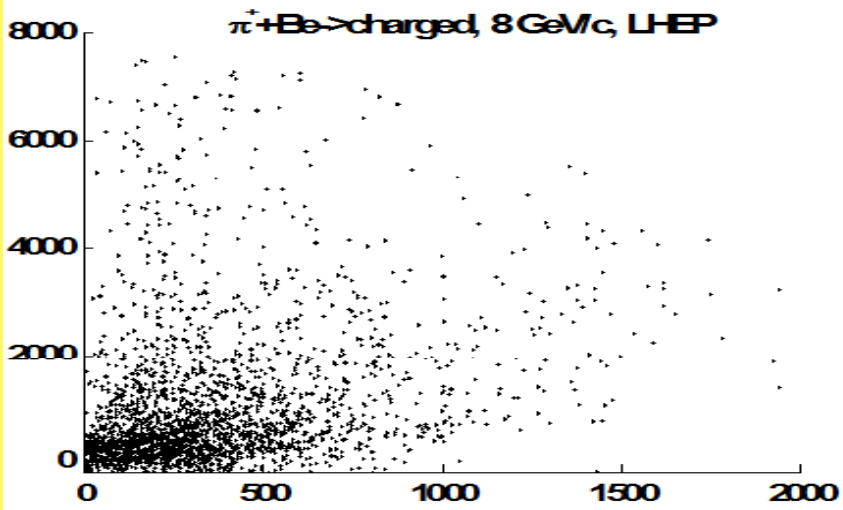
1. **What is going on for hP-interactions? (In hBe-inter. Only hN take place)**
2. **What are the properties of hA-interactions? Fist of all – multiplicity?**

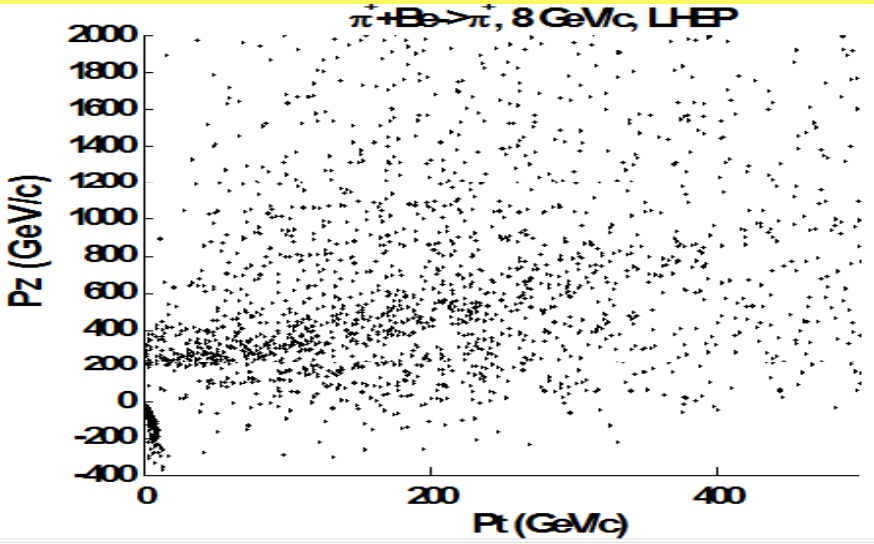
Analysis, LHEP



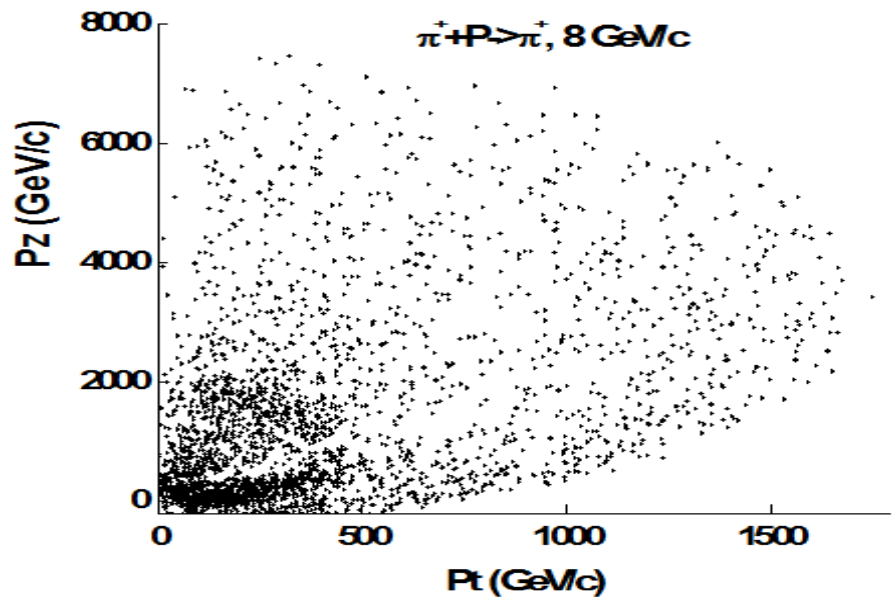


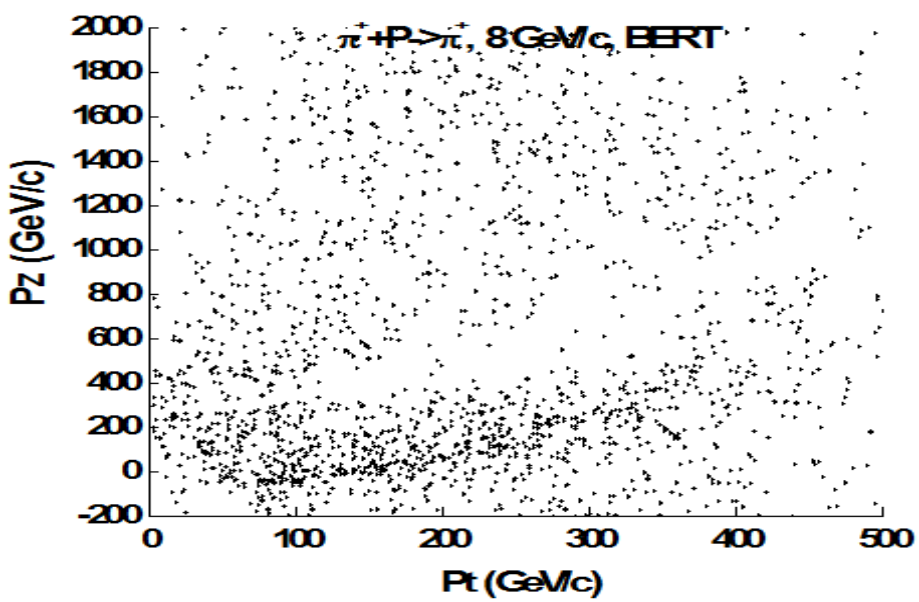
The structure is presented in hN-interactions. It is natural that it is in hBe-interactions too! LHEP must be improved.

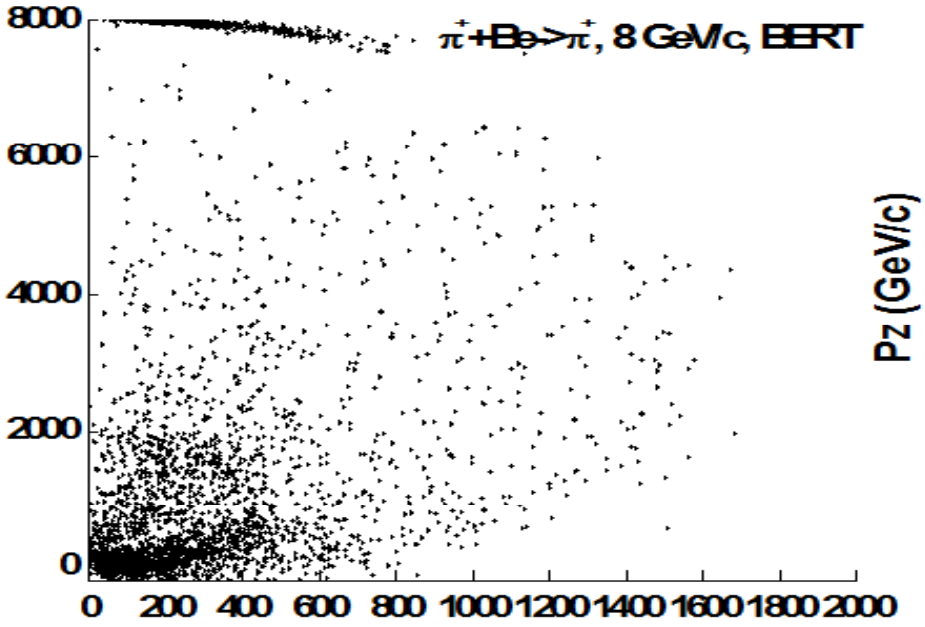


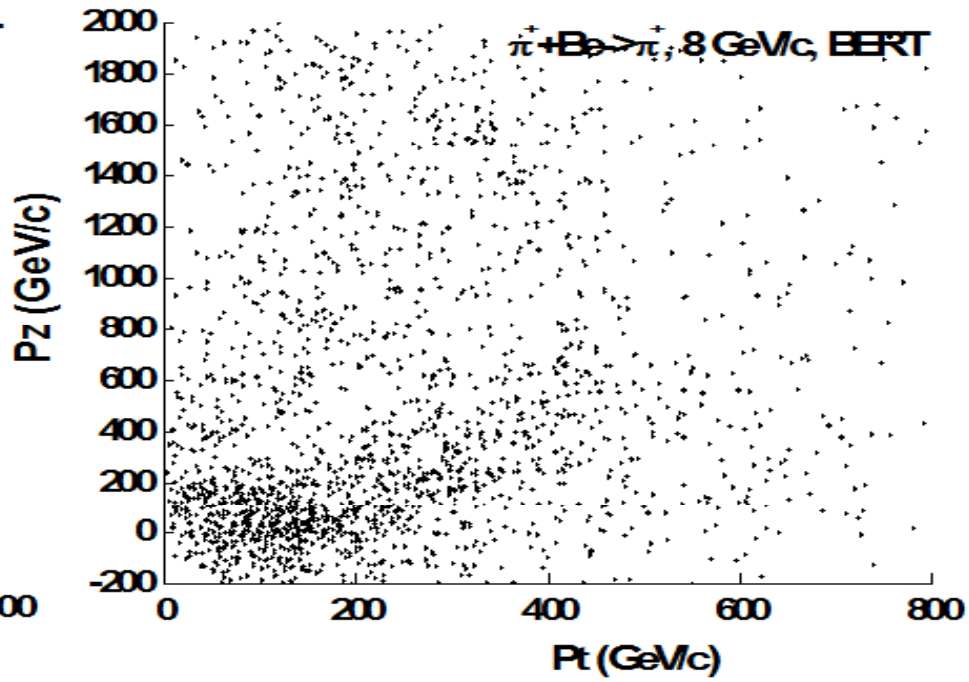


Analysis, Bertini cascade

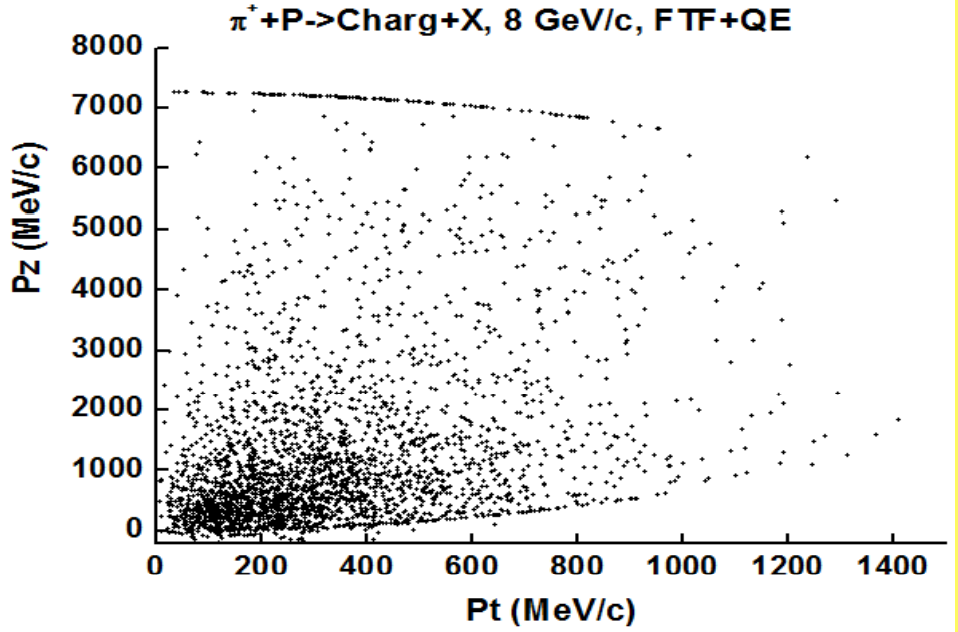


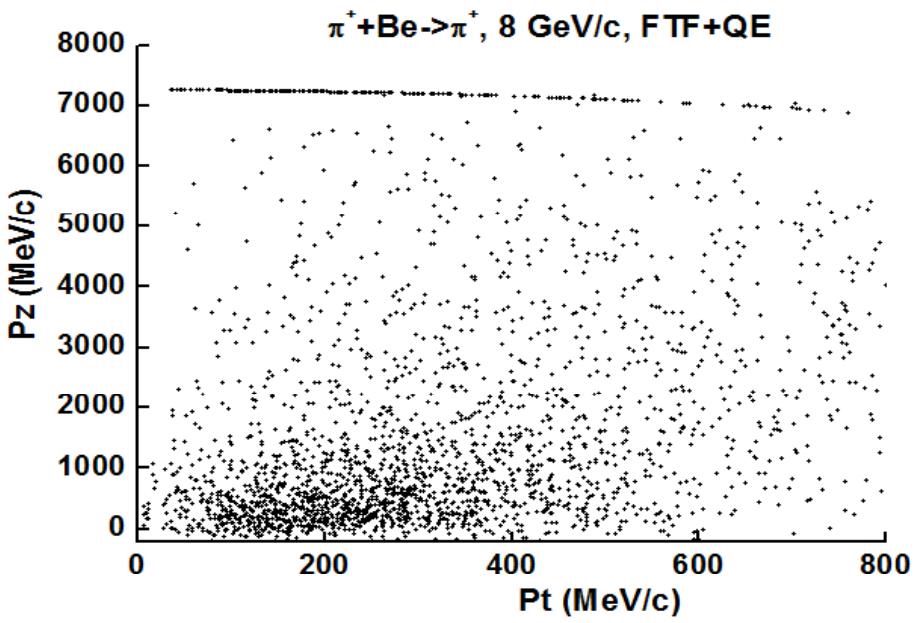


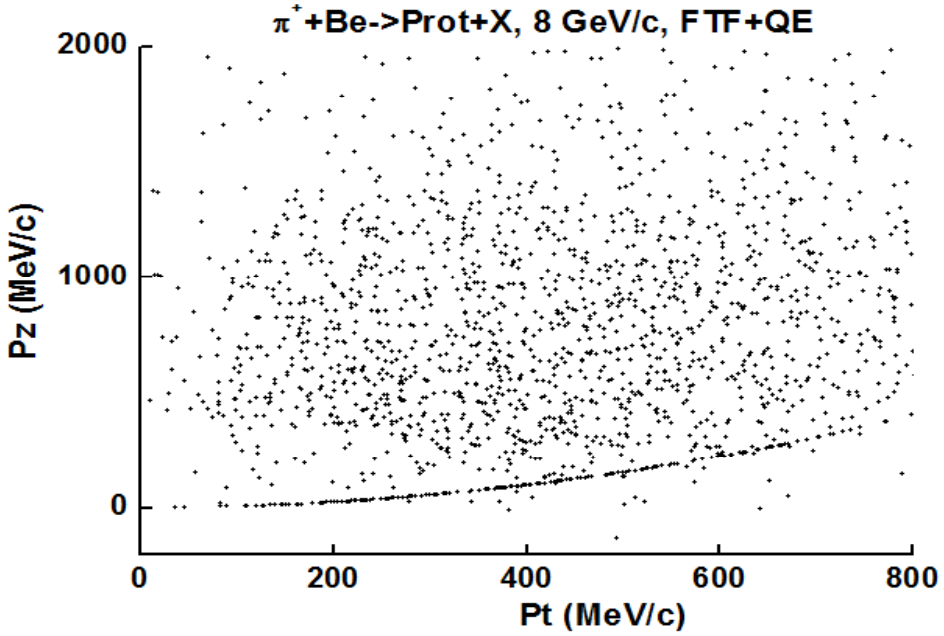


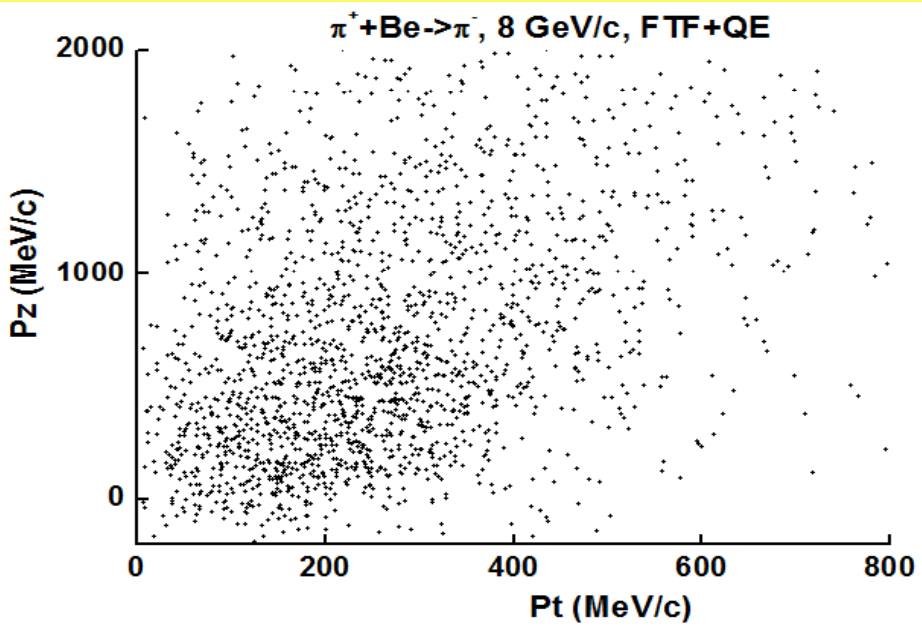


Analysis, FTF+QEI

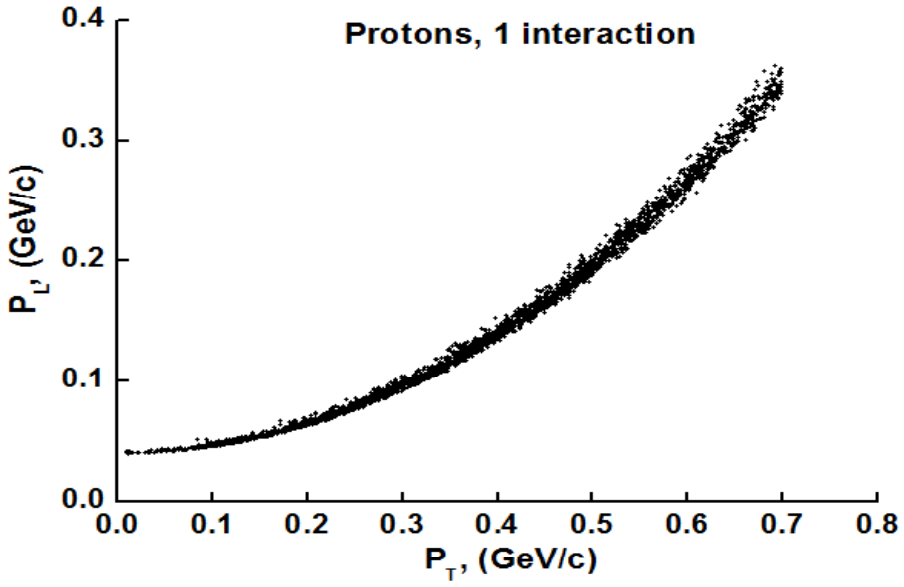


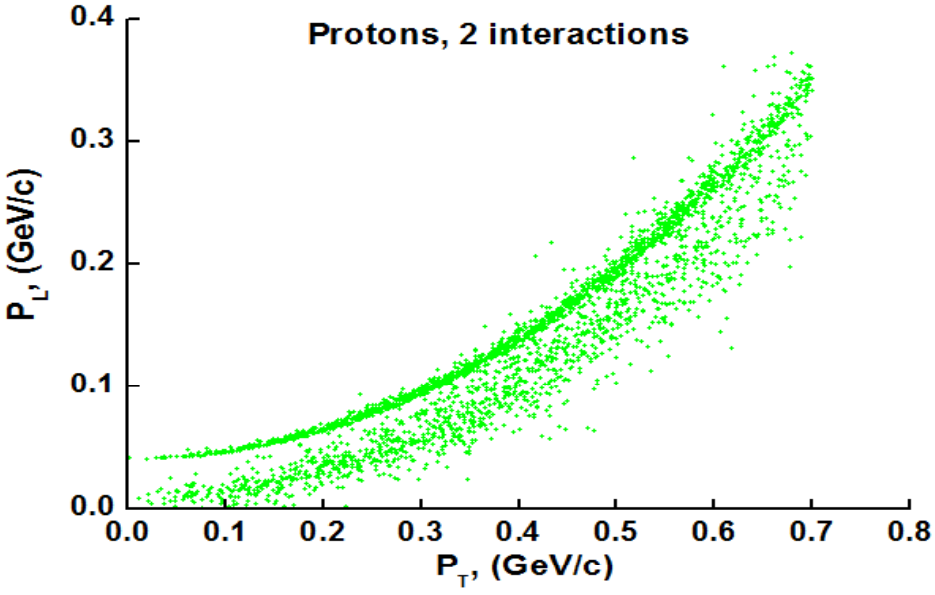


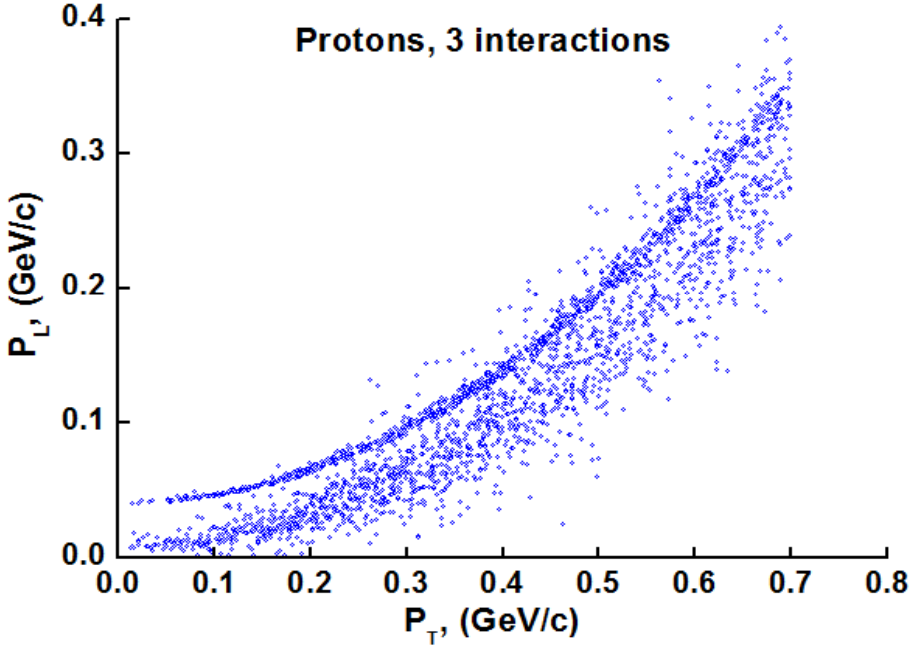




Hypothesis – the structure is connected with elastic hN-scattering!







The hypothesis works!
It can be if there is No Fermi-motion!

Resume:
A MC data must be analyzed as an experimental data! Here one has a lot of possibilitis!

Conclusion 1

Summary

- Geant4 predictions on hadron production by protons and pions at 8.9 GeV/c has been compared with experimental data
- Significant disagreements in shape of polar angle distributions have been found for all standard physics lists
- Major problems are
  - an unphysical peak for secondary protons near 70°
  - an unphysical diffraction-like pattern for secondary pions
- Situation partially improved in the recent version 4.9.1p02

1. **The “unphysical peak” has defined physical meaning!**
2. **The “diffraction-like pattern” is connected with hN simulations!**
3. **A MC data must be analyzed as an experimental data!**

Conclusion 2

1. Geant4 has the problem with a description of hN-interactions.
2. It reflects only on the interactions with light nuclei.
3. Amount of the abnormal low-energetic particle is lower then 30 %.
4. The structure for light nuclei is connected also with the first implementation of the quasi-elastic scattering in Geant4.
5. Most of the problems overcome in FTF model now.

FTF model now

1. The FTF model has been enlarged by the quasi-elastic scattering and the formation time for secondary particles.

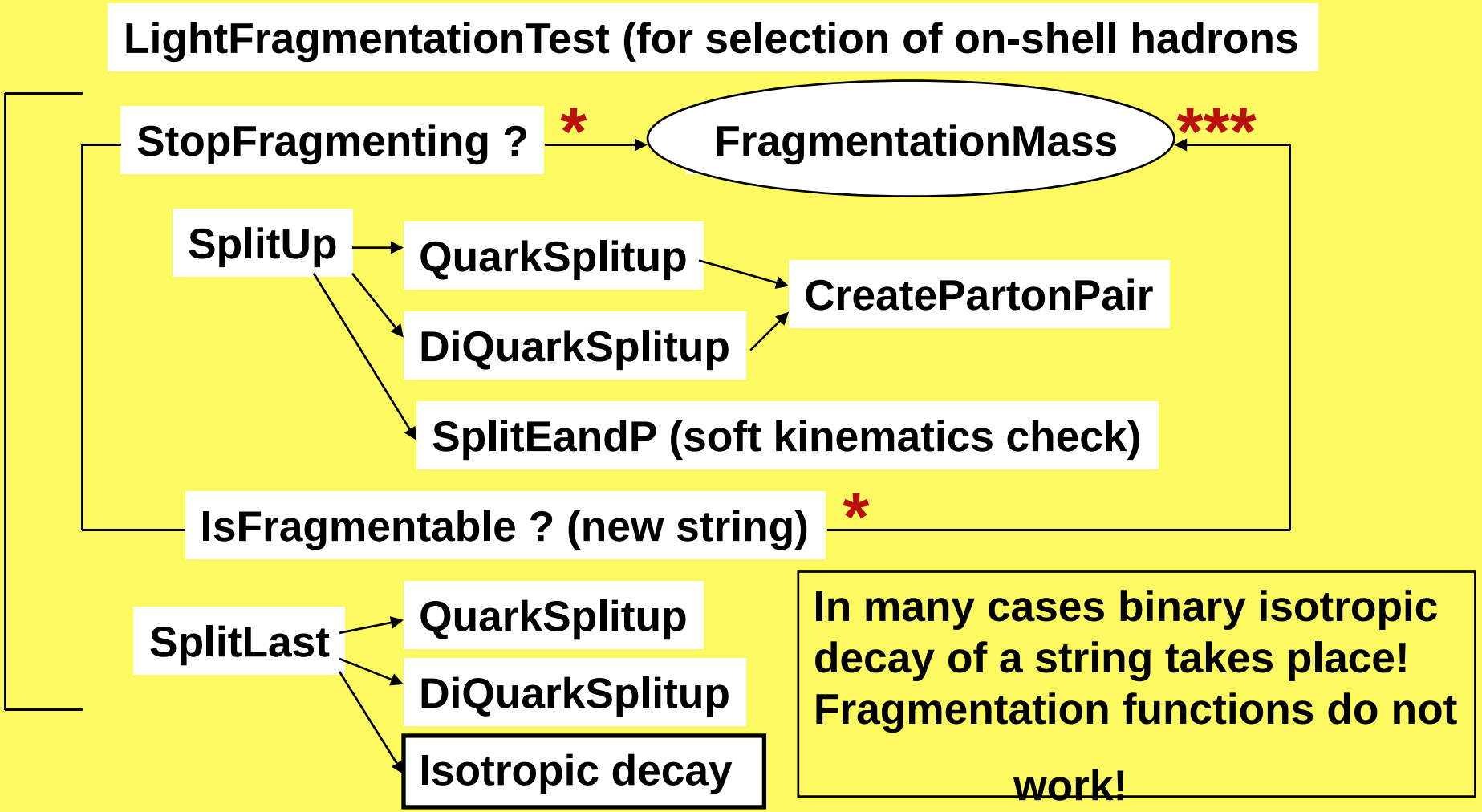
2. The model parameters have been tuned for PP- and PA-interactions.

3. The control check of the model has been performed. Satisfactory results have been obtained for the HARP experimental data.

HARP experimental data are very important and very useful for tuning and validation theoretical and Monte Carlo models!

4. Implementation of Fritiof (FTF) model in Geant-4

Main routine: FragmentString



Two different conditions for an End of fragmentation!
There is no isotropic decay in LUND fragmentation!

4. Implementation of Fritiof (FTF) model in Geant-4

Main routine: FragmentString