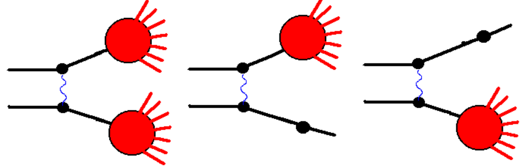


Recent developments for FTF (Fritiof model)

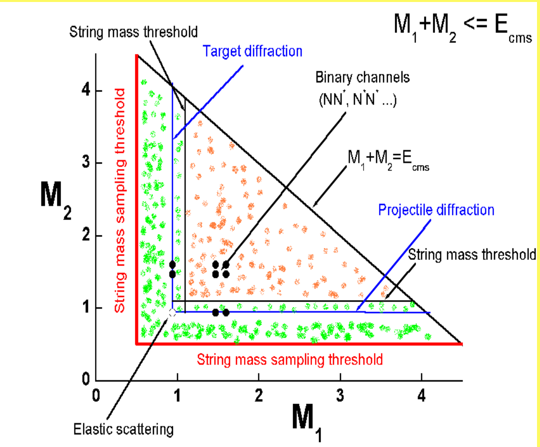
(V. Uzhinsky, CERN & JINR)

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

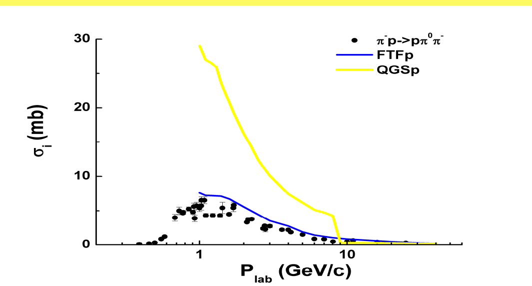
Hadron-hadron interactions are modeled as binary reactions

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

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

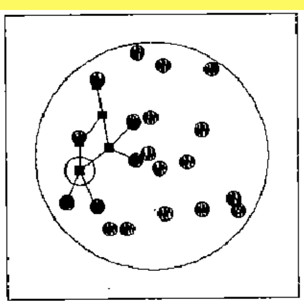


In hadron-nucleus interactions the excited hadrons can interact with other nucleons of nucleus and increases mass. The probability of multiple collisions is calculated in Glauber approach. The variant used in the Fritiof model is enlarged with elastic re-scatterings of hadrons. The excited states are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

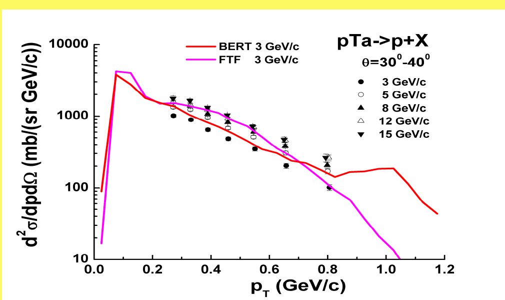


Binary reactions

FRITIOF model → HIJING model (RHIC, LHC); UrQMD model (GSI, FAIR); HSD model (GSI,FAIR, ...); GEANT4



cascading



hA-interactions

Features of the FRITIOF Model in GEANT4:

- Separate simulation of single diffraction;
- Simulation of binary reactions;
- Reggeon cascading for nuclear destruction;
- Nuclear residuals excit. and de-excitation.

FRITIOF model

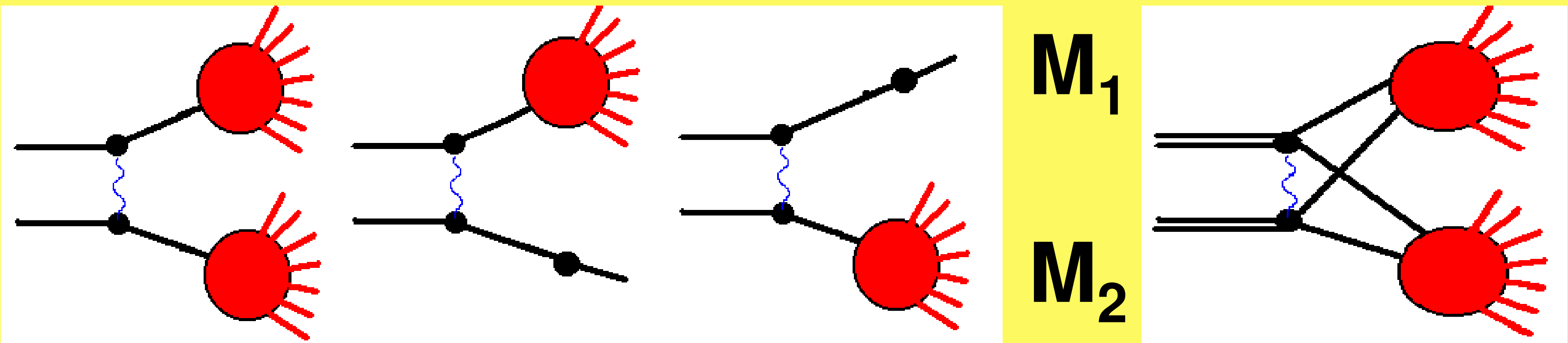
B. Andersson et al., Nucl. Phys. B281 (1987) 289;
B. Nilsson-Almquist and E. Stenlund, Comp. Phys. Commun. 43 (1987) 387.

Hadron-hadron interactions are modeled as binary kinematics

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

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

FRITIOF model QGSM



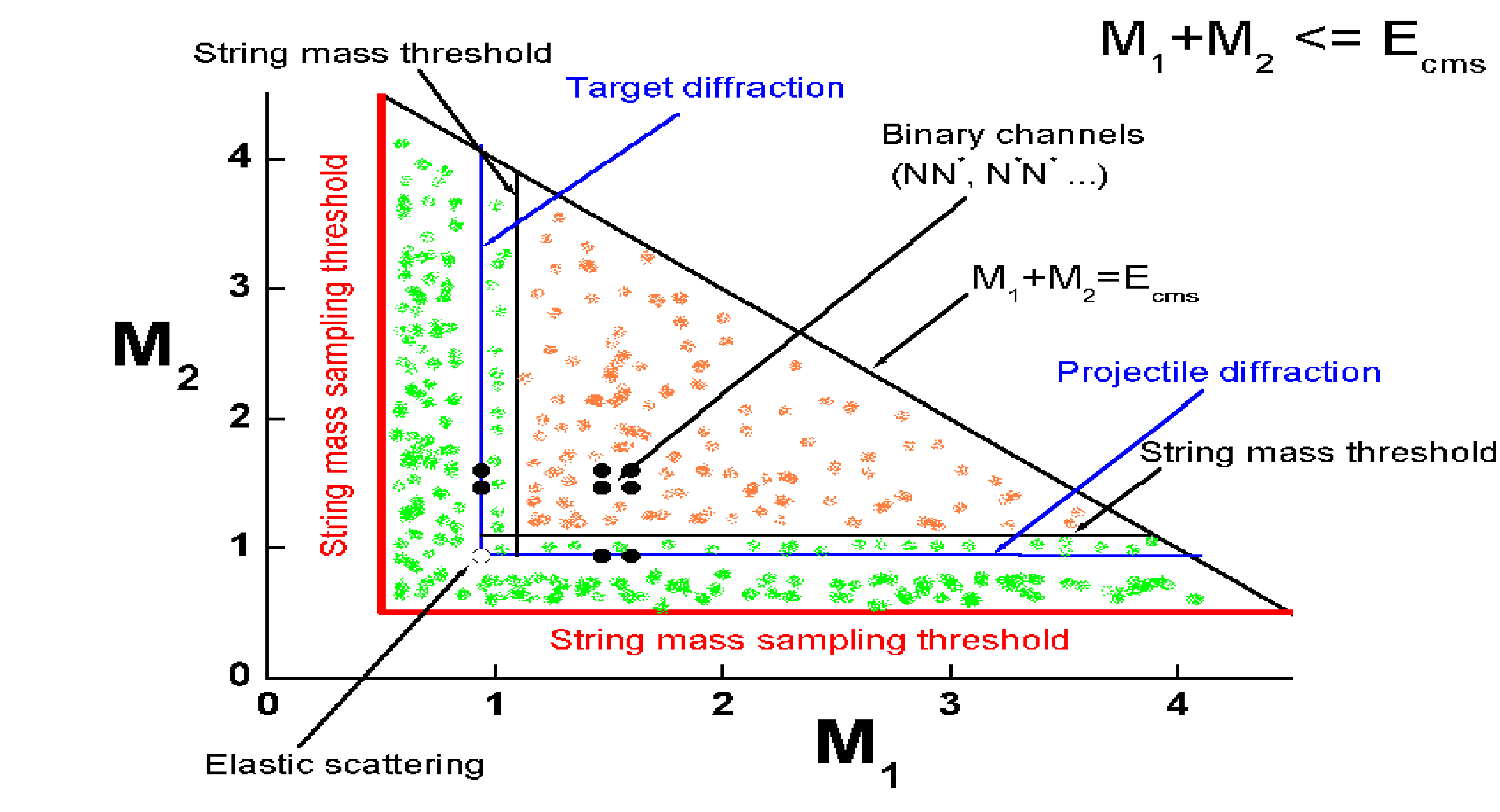
Key parameters

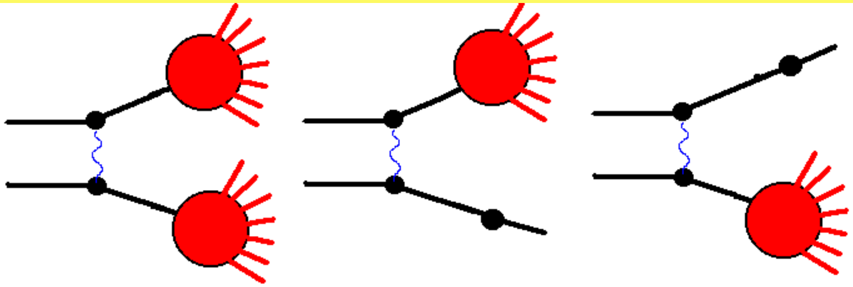
$$dW \propto \frac{dM_1}{M_1}, \qquad dW \propto \frac{dM_2}{M_2}$$

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

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

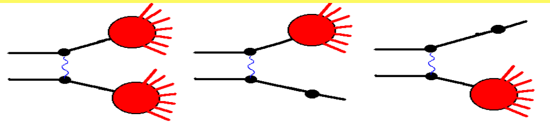
FRITIOF model



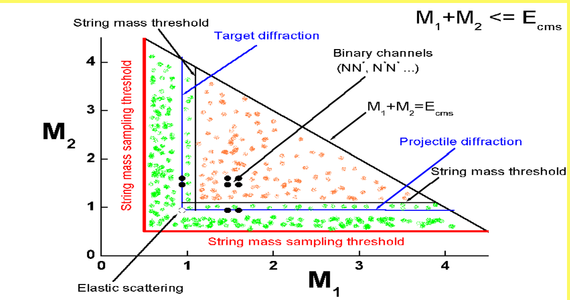


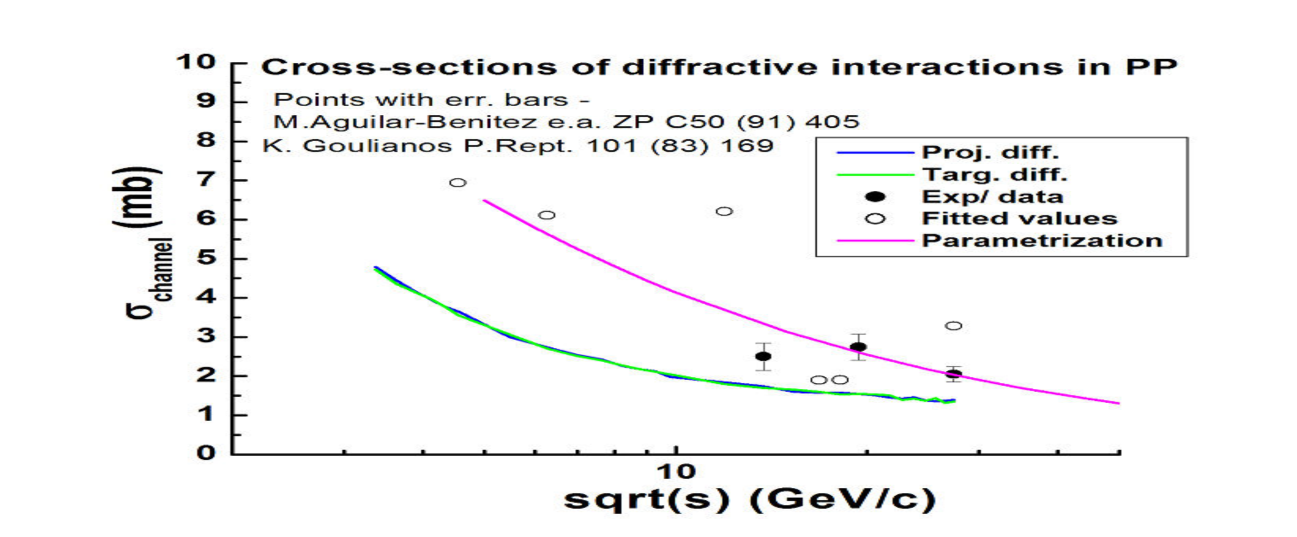
Limits are different for various implementations (UrQMD, Hijing). Fragmentation models are different too. These lead to various predictions

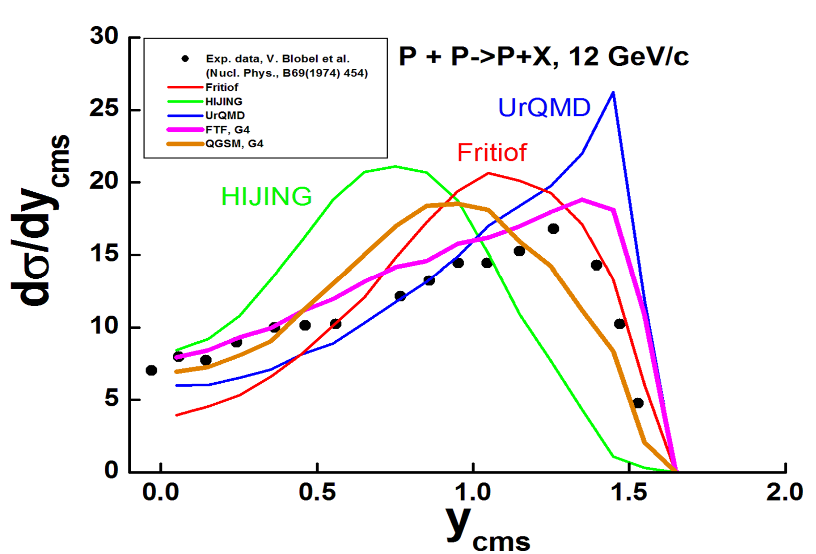
2. Separate simulation of diffractive and non-diffractive interactions

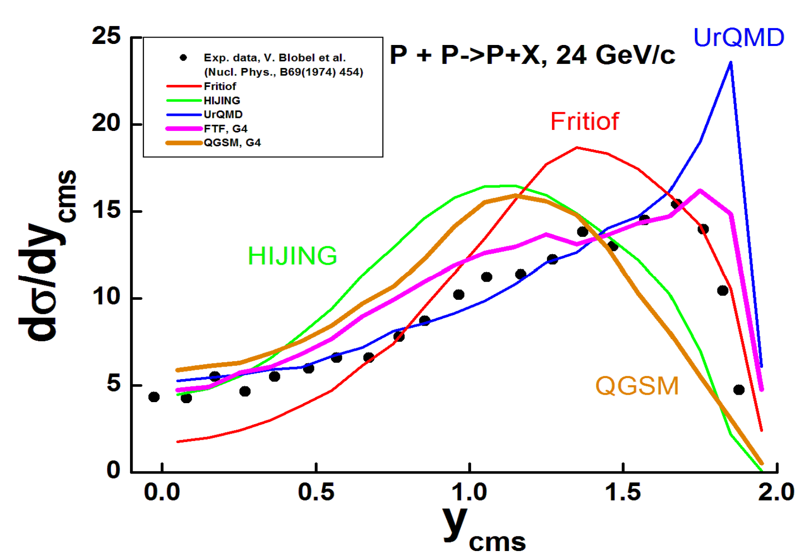


$$dW \propto \frac{dM_1}{M_1}, \qquad dW \propto \frac{dM_2}{M_2}$$



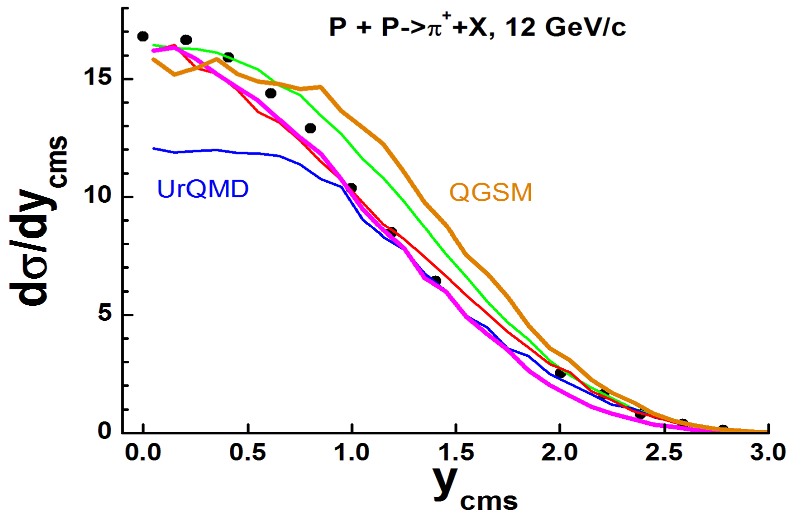


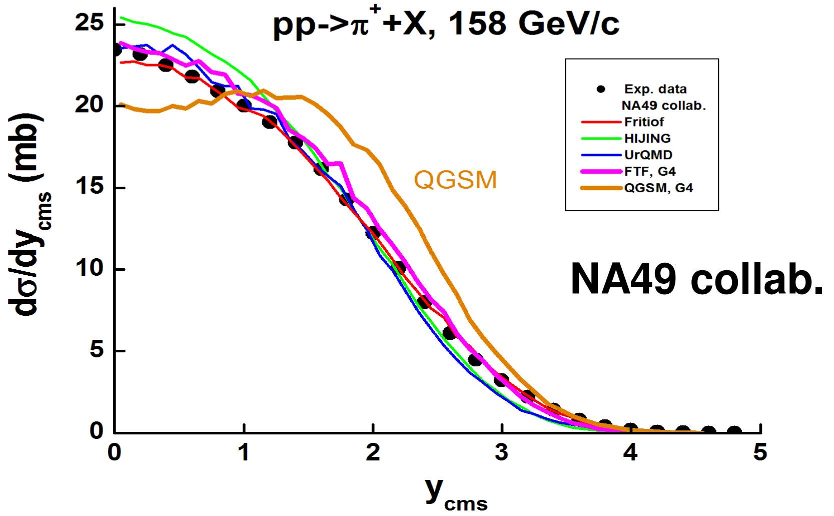


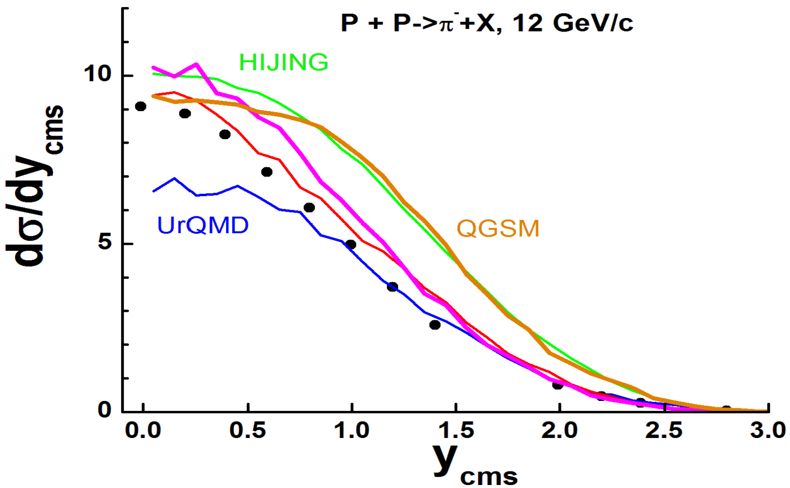


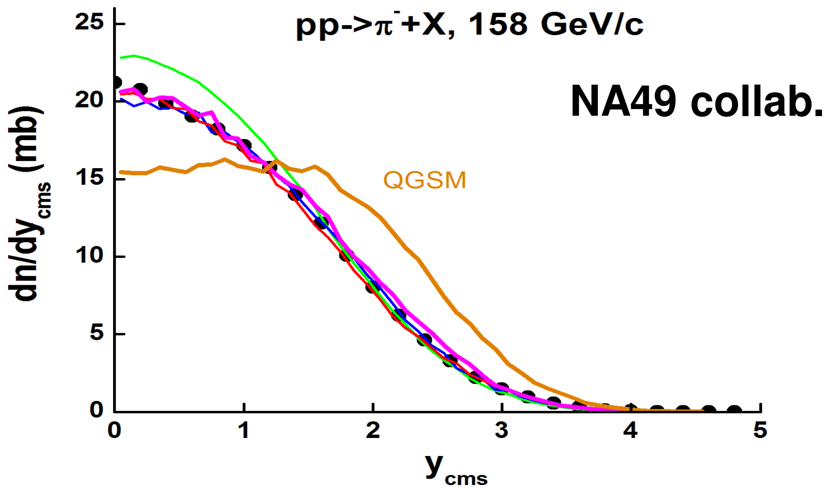
Description of baryon spectra is the problem in all MC models

2. Separate simulation of diffractive and non-diffractive interactions





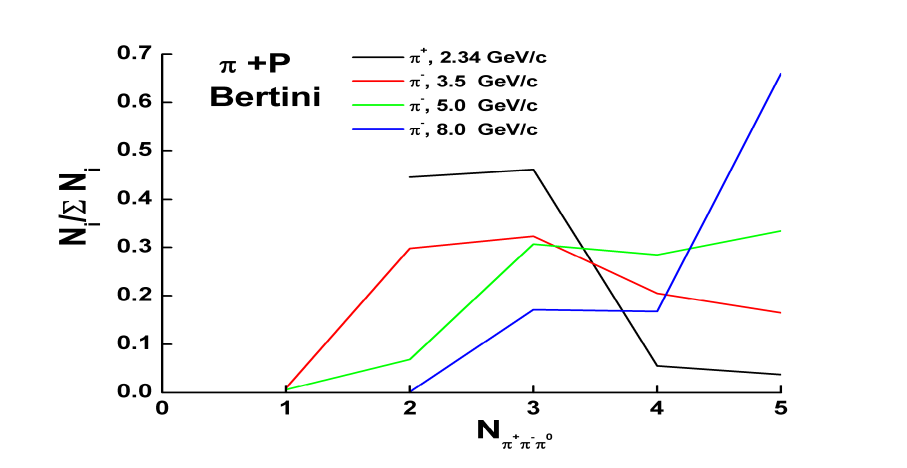


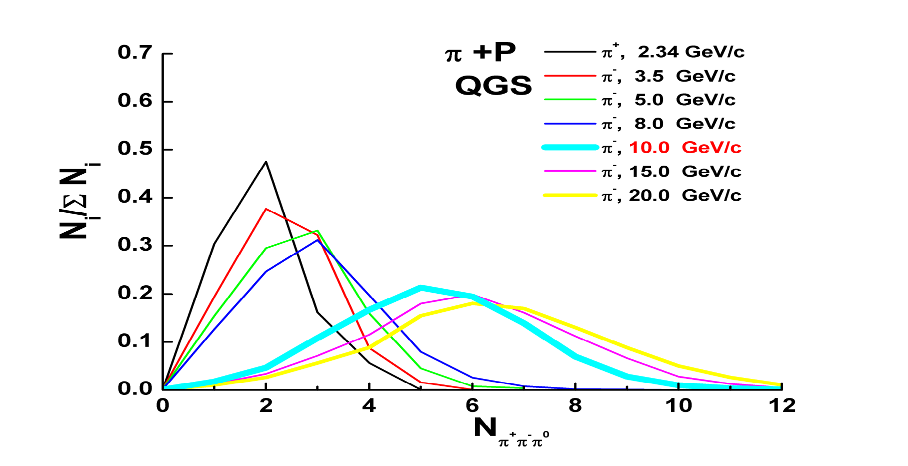


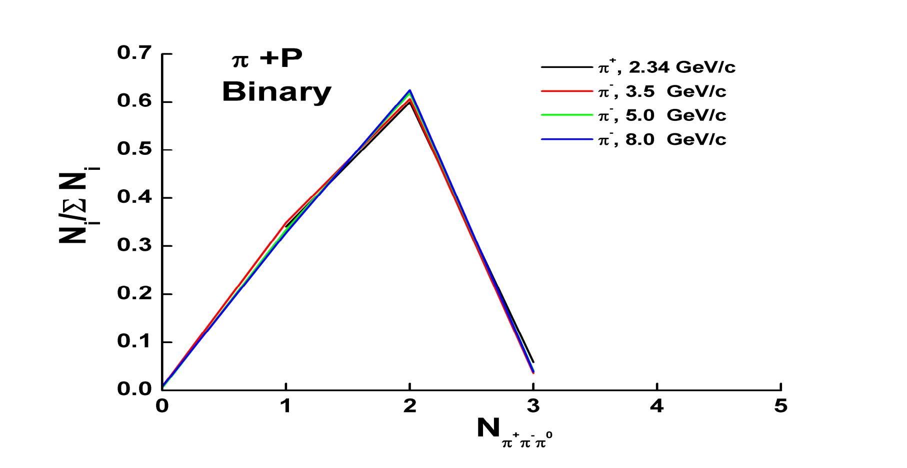
There are some problems with a description of meson spectra

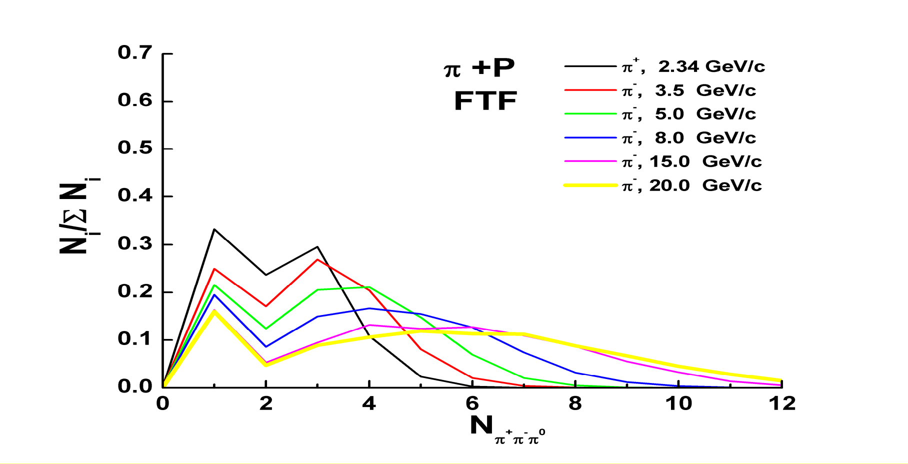
3. Simulation of binary reactions

Multiplicity distributions in πP-interactions, total meson multiplicity







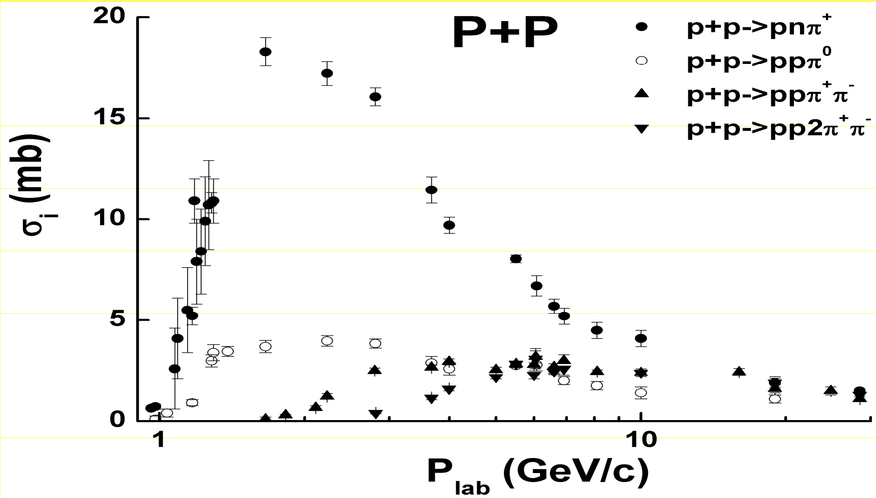


$N_{\pi+\pi-\pi0}=N_{\pi+}+N_{\pi-}+N_{\pi0}$ – total multiplicity of mesons

The Bertini and binary cascade models – Hard restriction on multiplicity!
Discontinuity of QGS model at 10 – 12 GeV/c.

3. Simulation of binary reactions

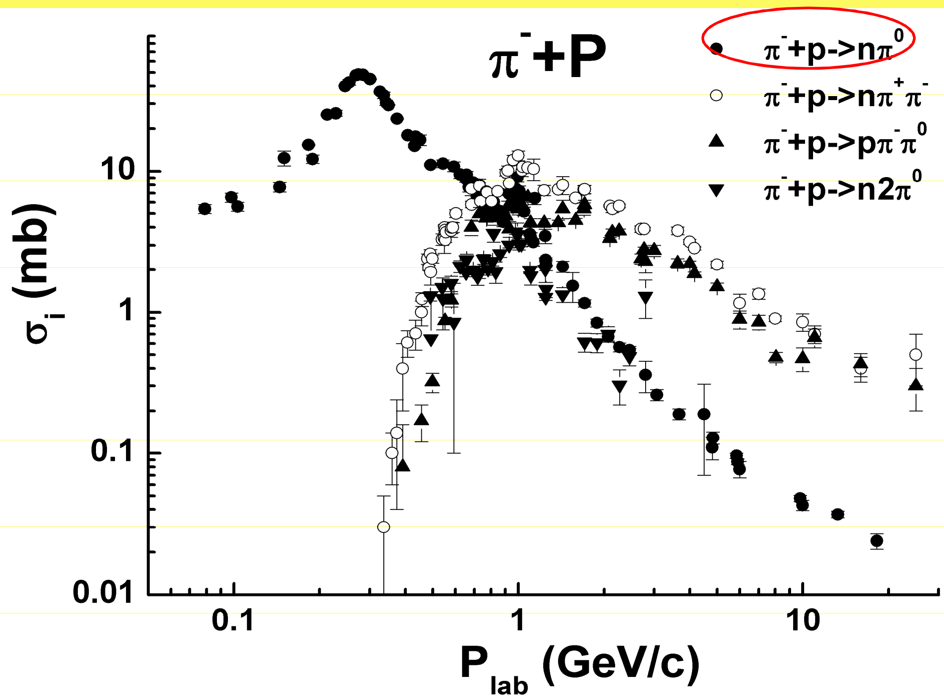
Experimental situation

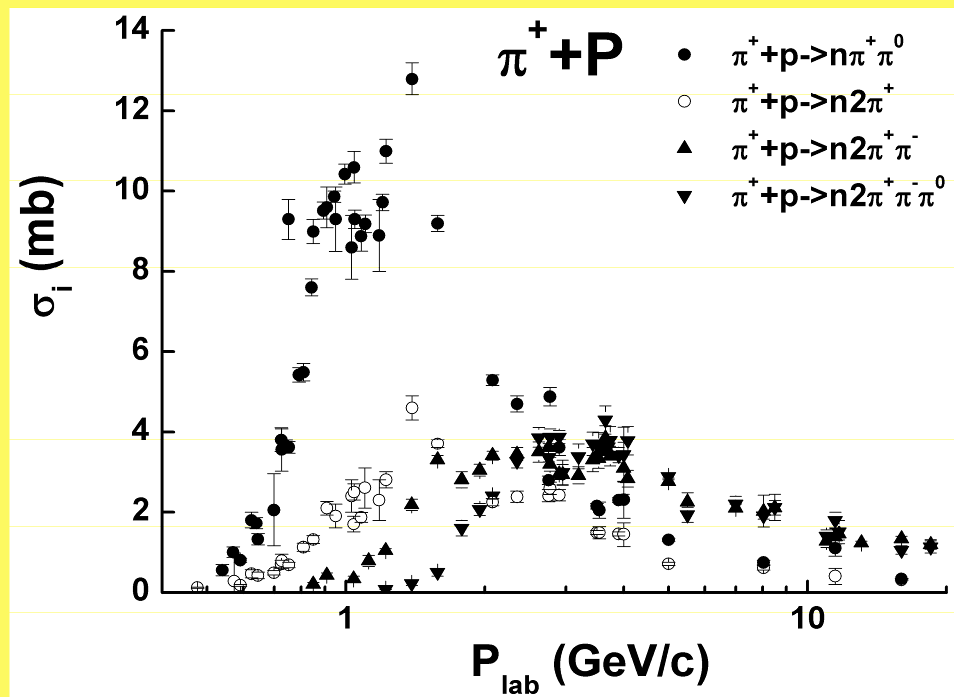


Structure of PP-interaction final states is very easy.

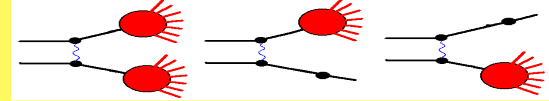
A mixture of states is presented in πP-interactions.

Most of them can be interpreted in FTF as results of the diffraction.

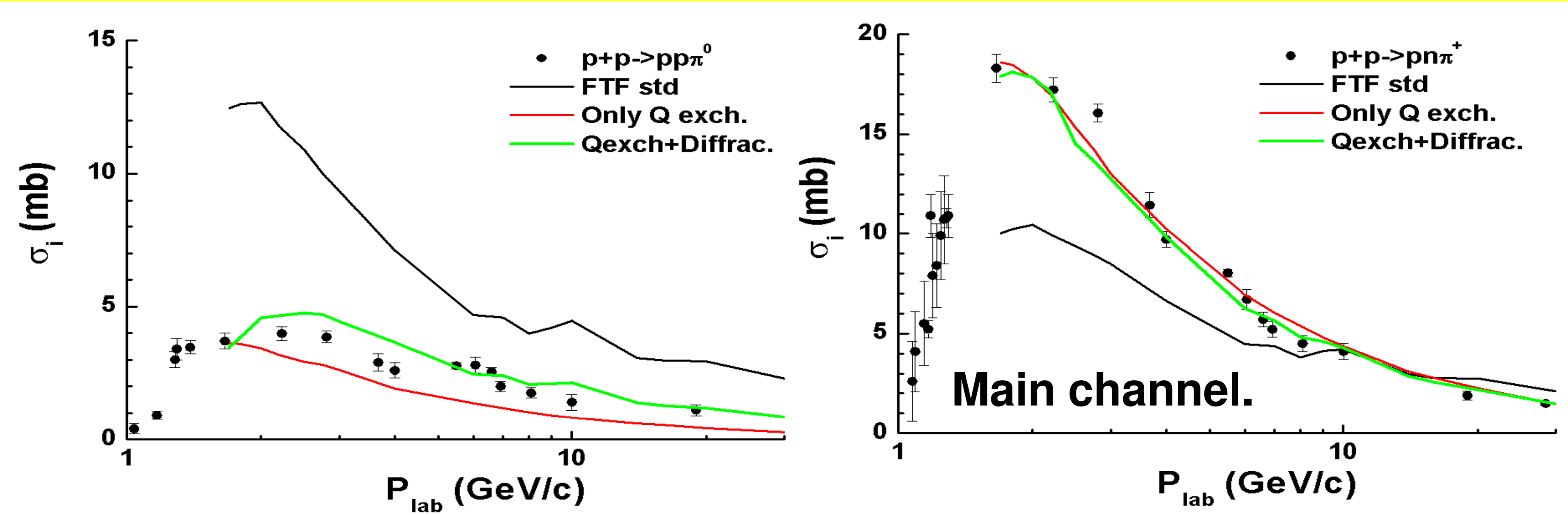




3. Simulation of binary reactions



Standard FTF approach does not give positive results

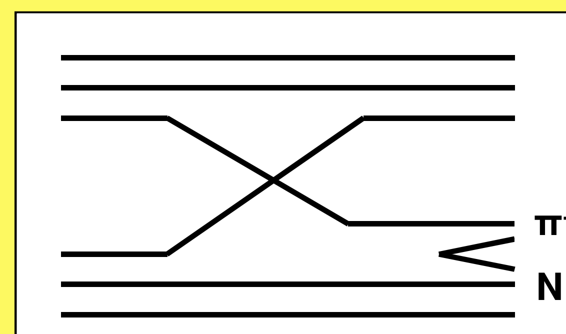


P+P->P+P*

- 2/3 ud-u string
  - 1/3 Pπ^0
  - 1/3 Nπ^+
- 1/3 uu-d string
  - 1/6 Pπ^0
  - 1/6 $\Delta^{++}\pi^-$

→ 1/3 Nπ^+, 1 /2 Pπ^0, 1/6 P$\pi^+\pi^-$

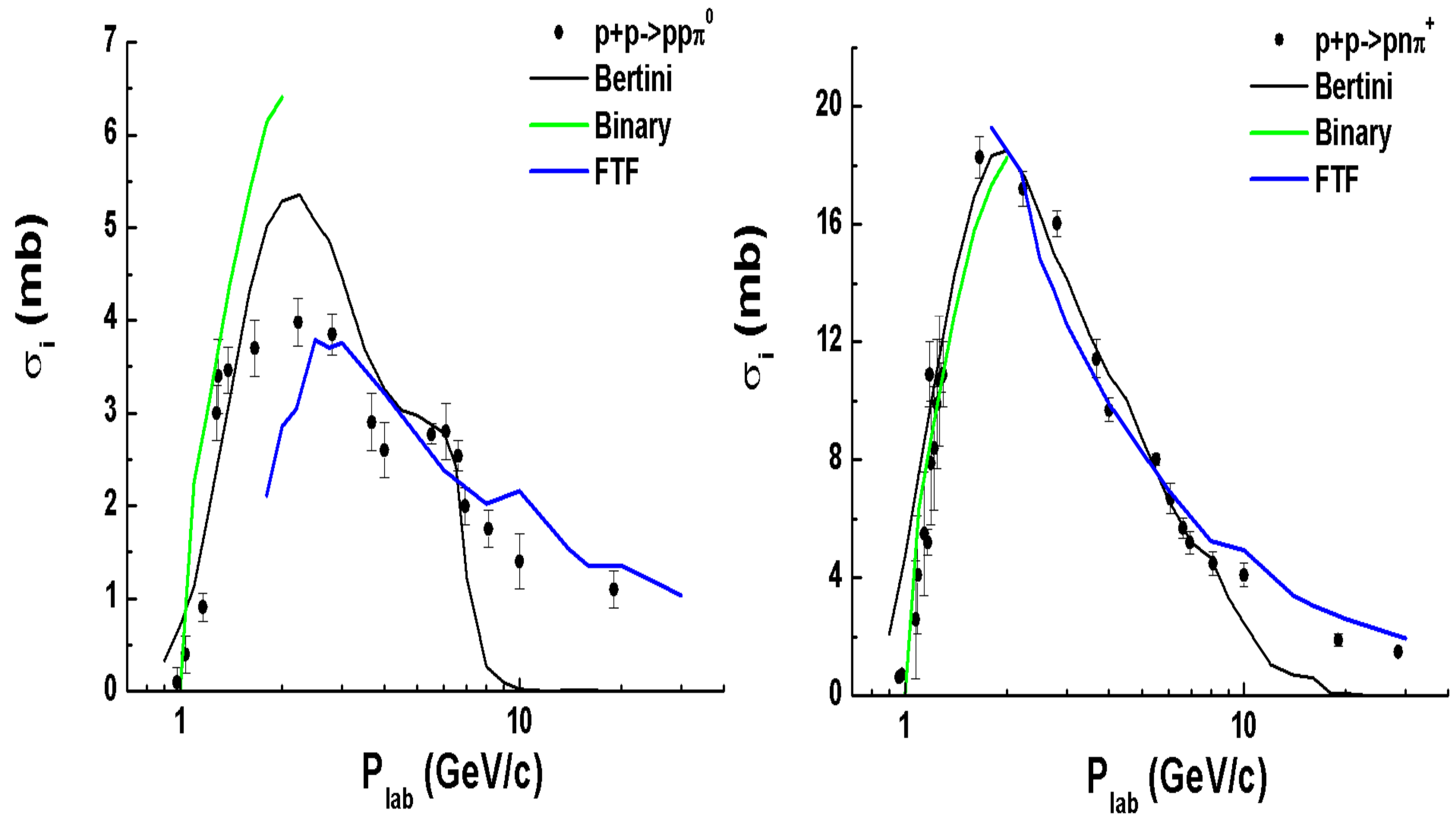
Solution – quark exchange



$$W_{q.exc.} \sim 3.4\, e^{-1.2\cdot(y_{pr}-y_{tr})}$$

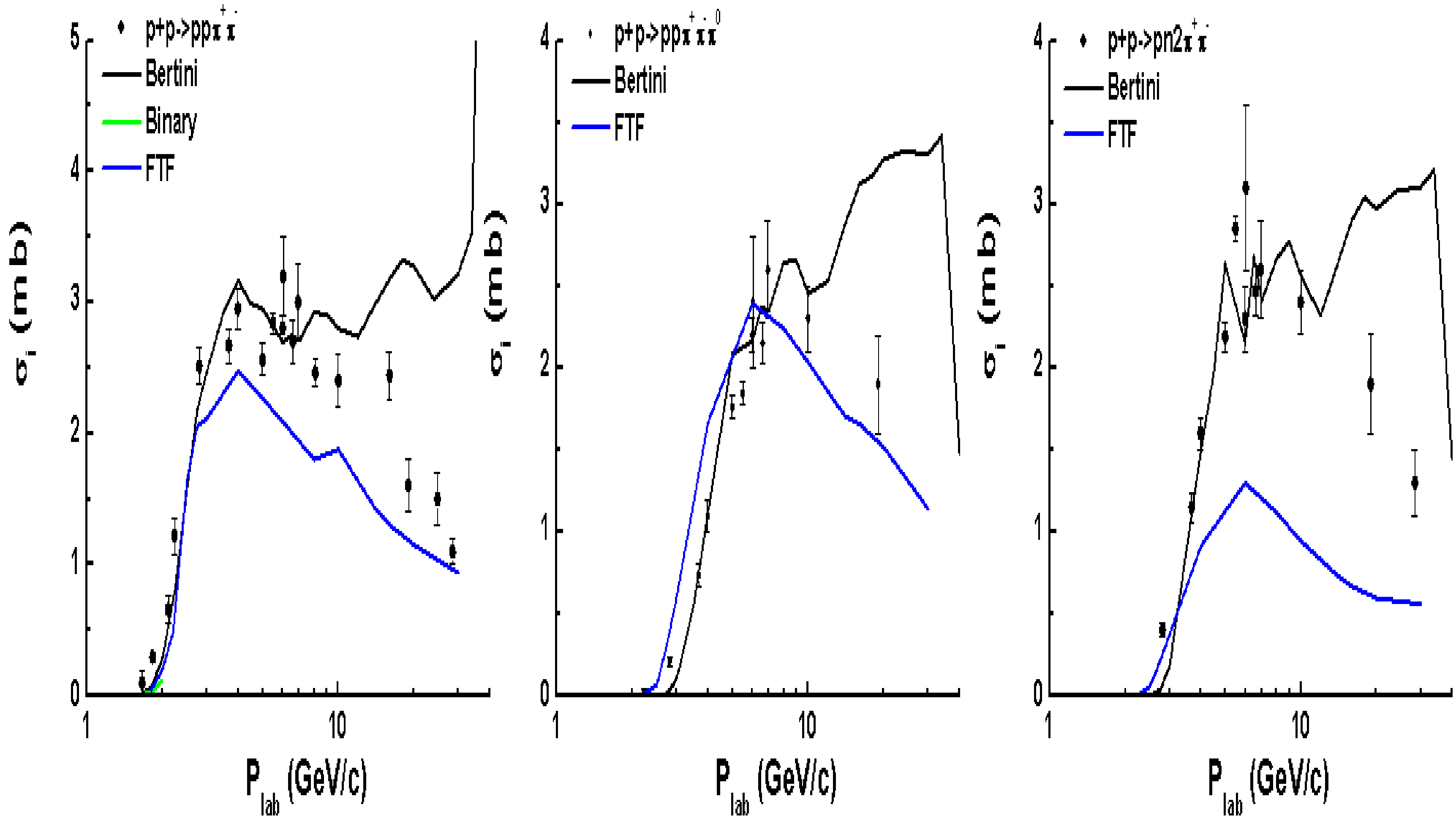
P+P-> PΔ^+, NΔ^{++}, $\Delta\Delta$

3. Simulation of binary reactions

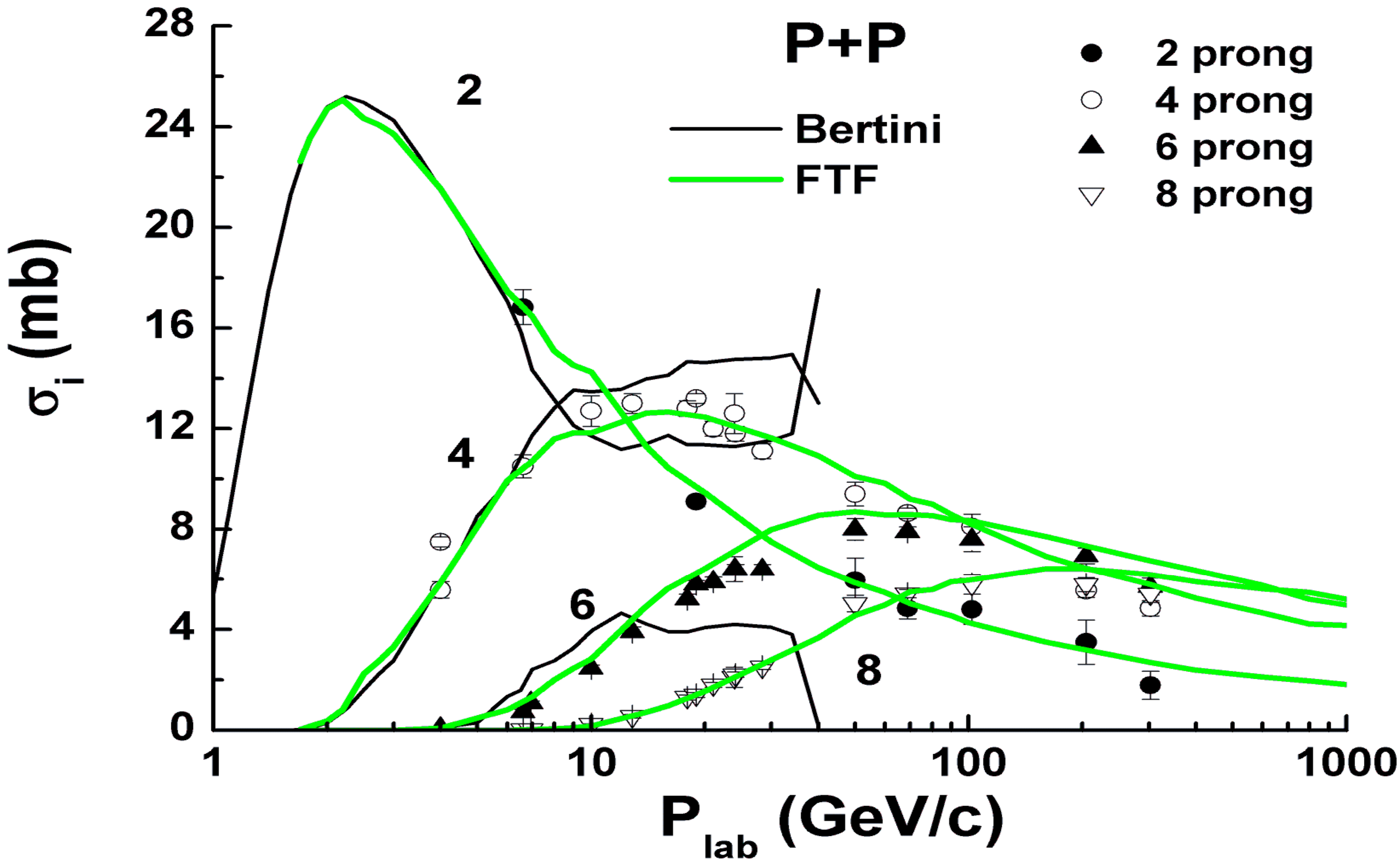


$$W_{s.d.} = 0.76\ s^{-0.35}$$

3. Simulation of binary reactions



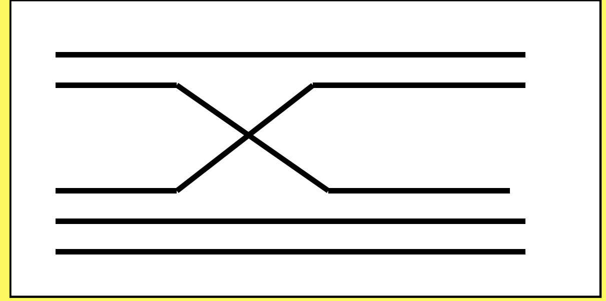
Topological cross sections in PP-interactions

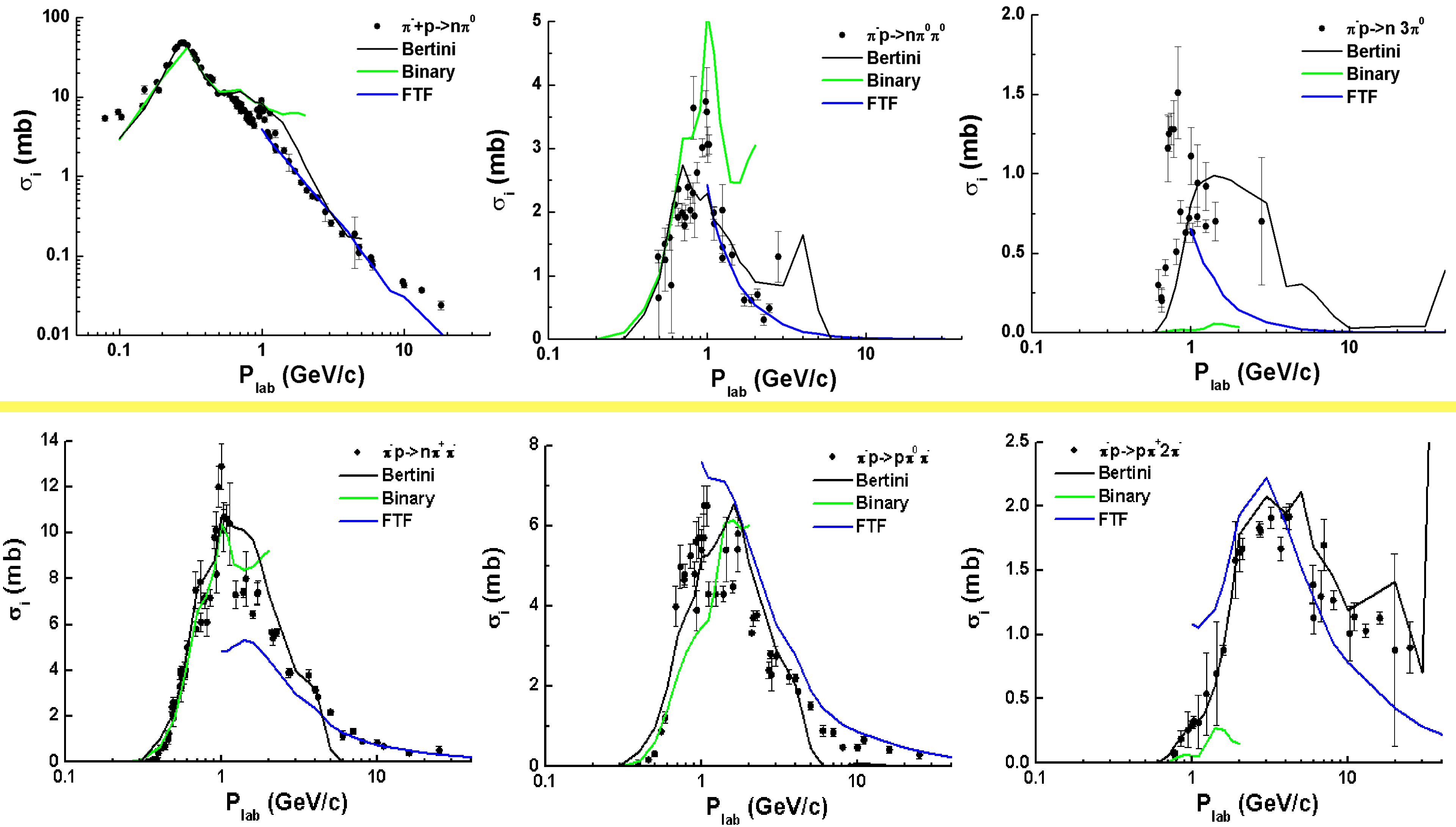


3. Simulation of binary reactions

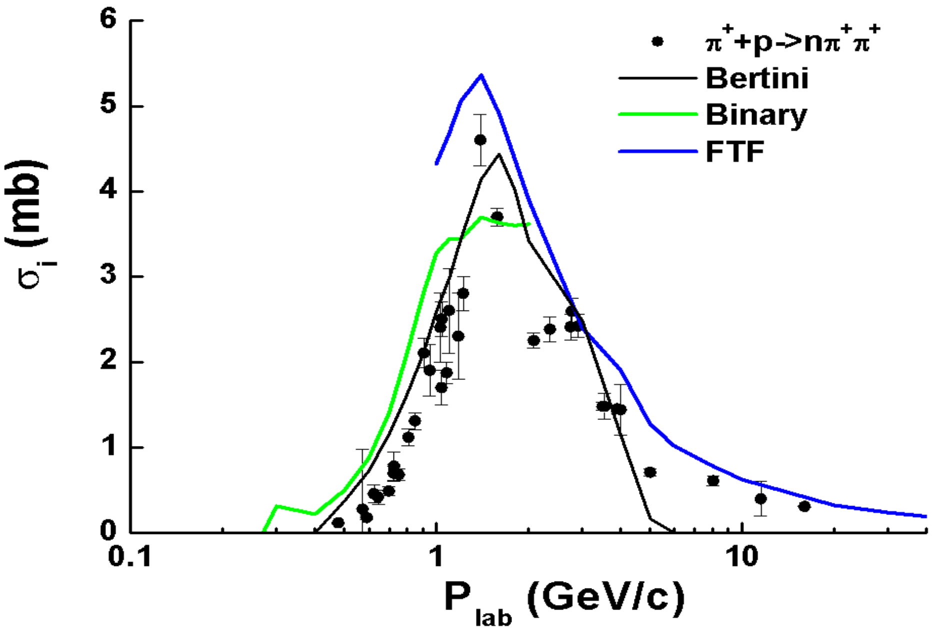
Solution – quark exchange

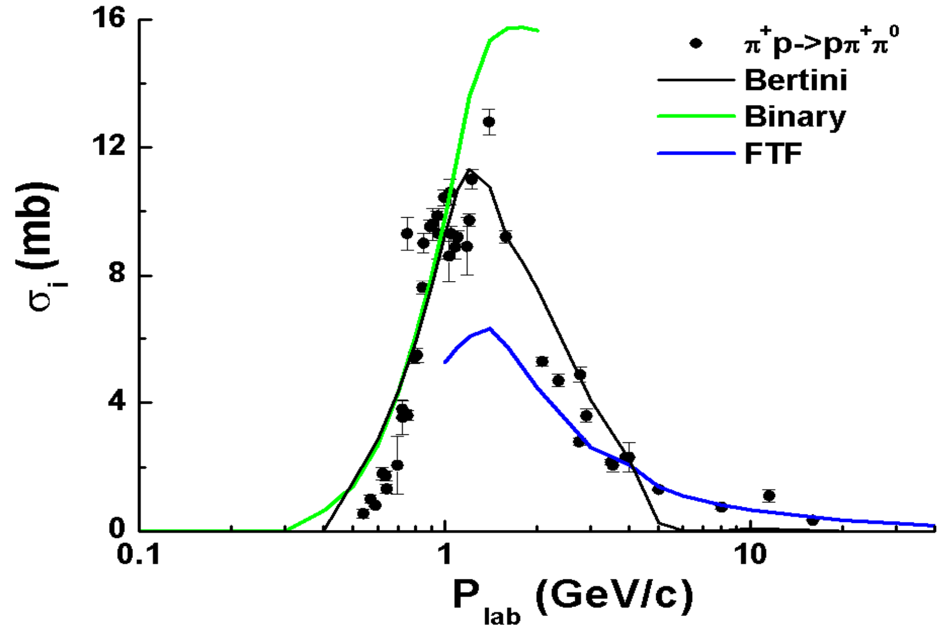
$$W_{q.exc.} \sim 120\ e^{-2\cdot(y_{pr}-y_{tr})}$$

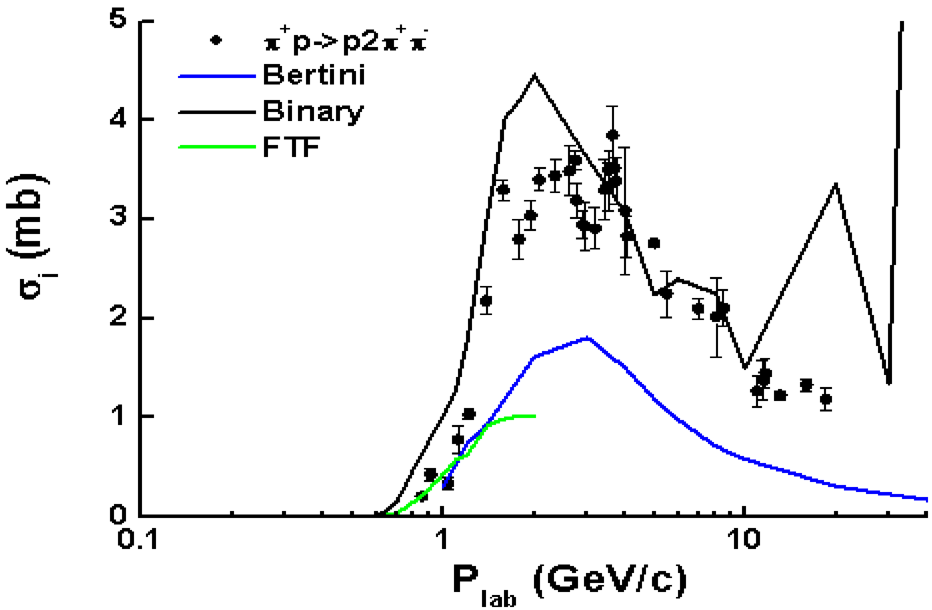


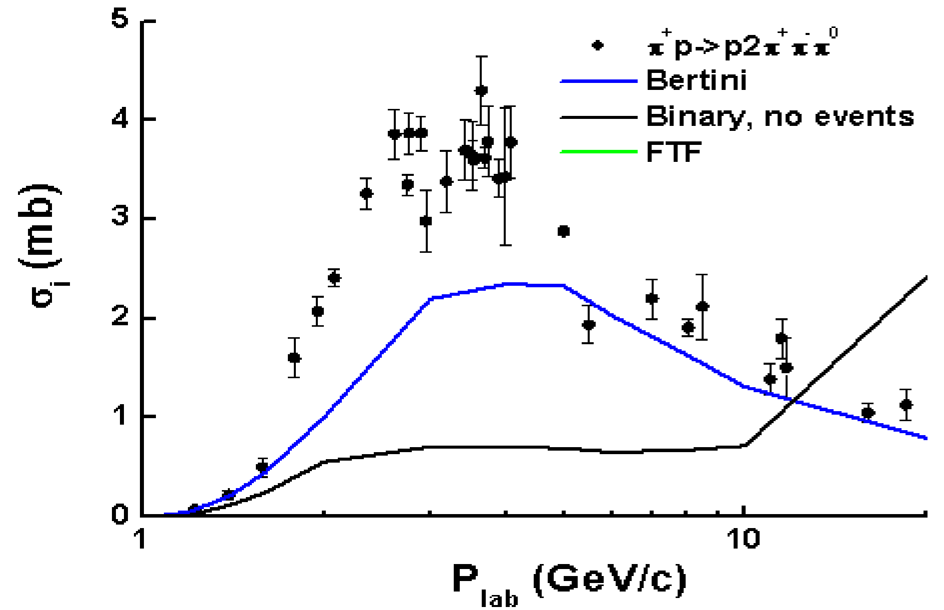


3. Simulation of binary reactions

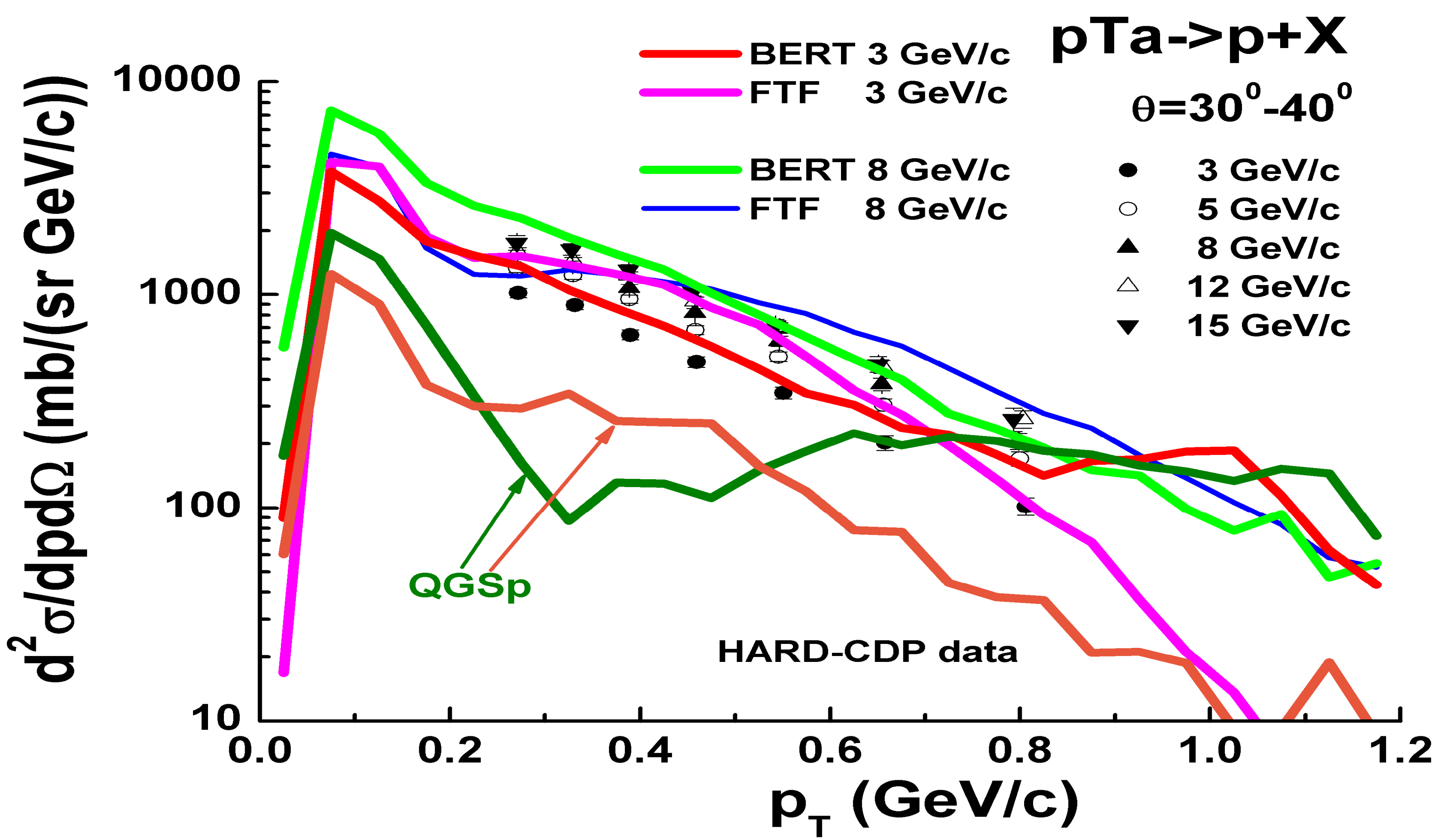






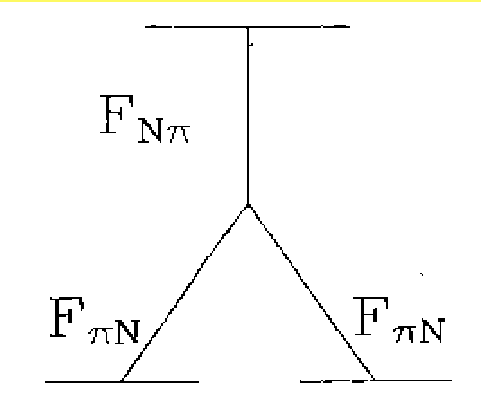


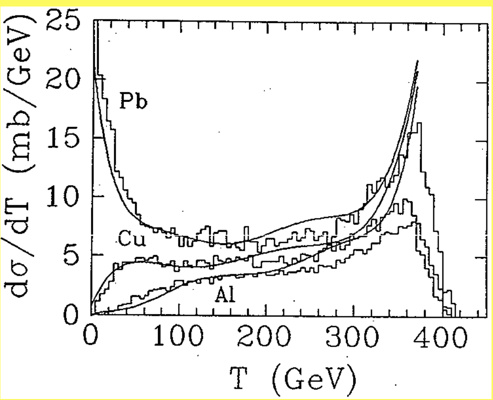
4. Reggeon cascading for nuclear destruction



Glauber aproach implemented in FTF and QGS is not sufficient for a destruction of a nucleus. Thus a reggeon cascading model of nuclear destruction was applied.

4. Reggeon cascading for nuclear destruction





Si+A, 14.7 GeV/N
T – energy in ZDC

Model of nuclear disintegration in high-energy nucleus nucleus interactions.

K. Abdel-Waged, V.V. Uzhinsky
Phys.Atom.Nucl.60:828-840,1997, Yad.Fiz.60:925-937,1997.

$$Y = G\int d\xi' d^2b' F_{N\pi}(\vec{b}-\vec{b'},\xi-\xi') \times \times F_{\pi N}(\vec{b'}-\vec{s}_1,\xi')F_{\pi N}(\vec{b'}-\vec{s}_2,\xi'),$$

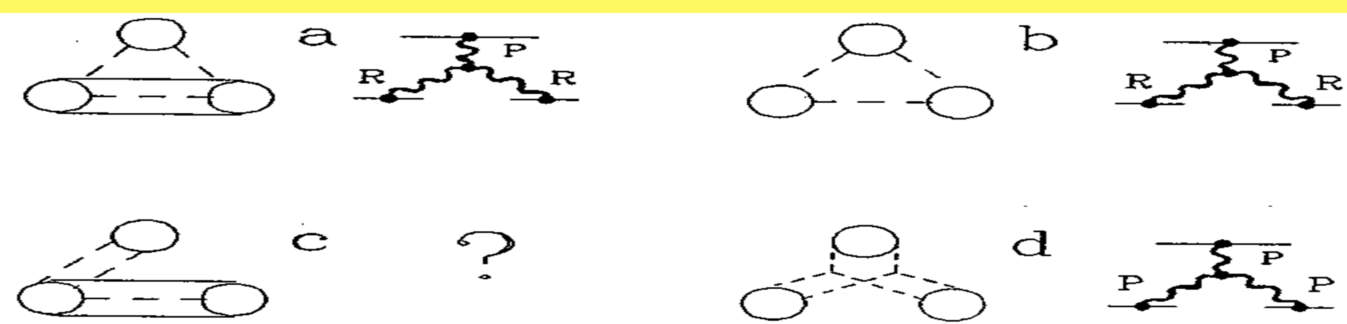
G is 3-pomeron vertex constant, $\vec{b}$- impact parameter of incident hadron, $\vec{s}_1$, $\vec{s}_2$- impact co-ordinates of nuclear nucleons. $\vec{b'}$ is the position of pomeron interactions vertex in the impact parameter plane, ξ'-its rapidity.

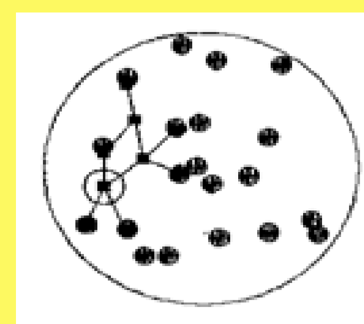
Using Gaussian parameterization for $F_{\pi N}$ ($F_{\pi N} = exp(-(|\vec{b}|^2)/(R^2_{\pi N}))$ and neglecting its dependence on energy, we have

$$Y \simeq G(\xi_0 - 2\epsilon)\frac{R^2_{\pi N}}{3} exp(-(\vec{b}-(\vec{s}_1+\vec{s}_2)/2)^2/3R^2_{\pi N}) \times \times exp(-(\vec{s}_1-\vec{s}_2)^2/2R^2_{\pi N}),$$

where $R_{\pi N}$ is the pion-nucleon interaction radius. According to (2) the contribution reaches a maximum if the nucleon coordinates $\vec{s}_1$ and $\vec{s}_2$ coincide and decreases very fast with increasing the distance between the nucleons. For reproduction of this behavior we choose ϕ as

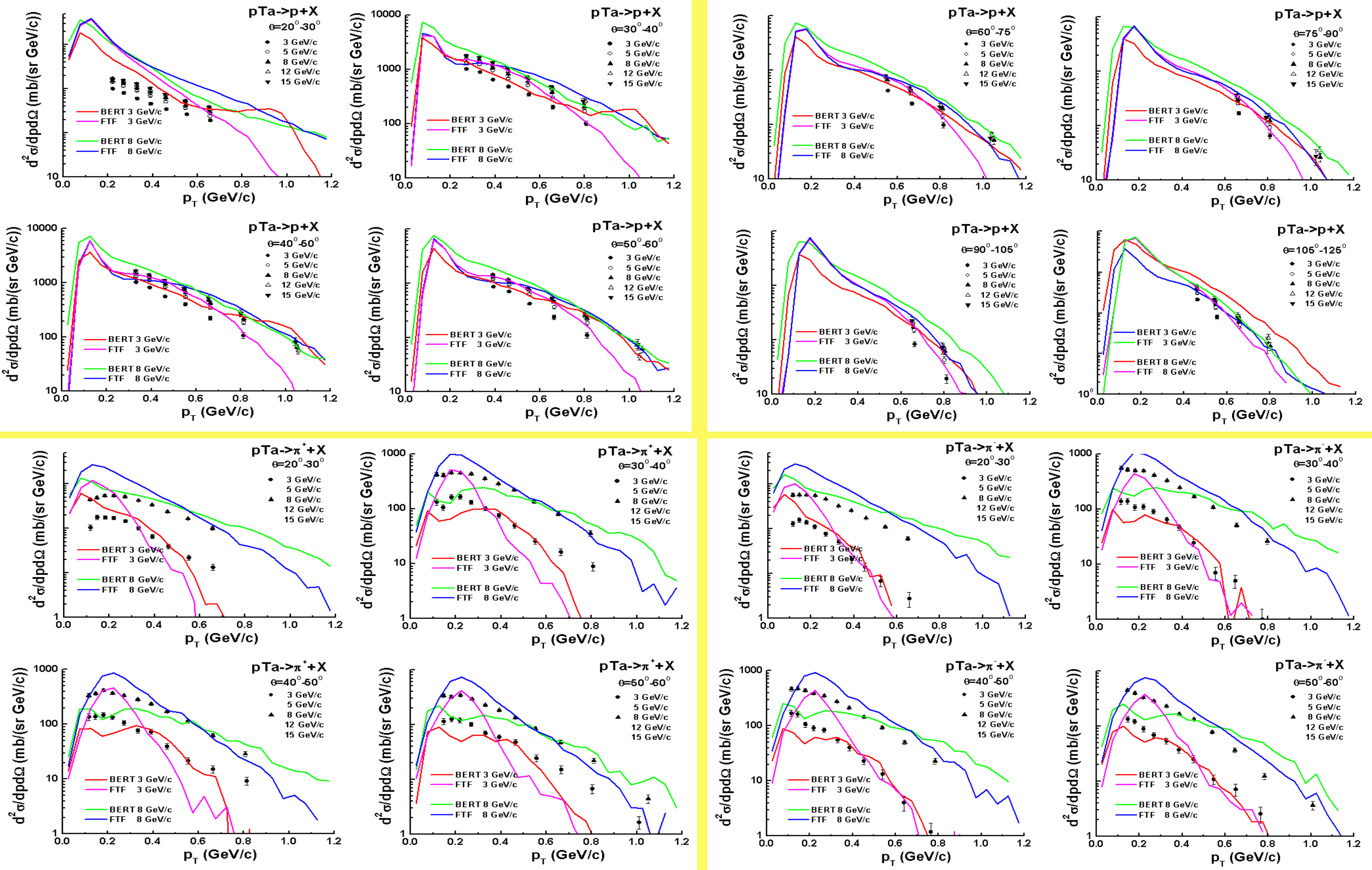
$$\phi(|\vec{s}_i-\vec{s}_j|) = C exp(-\frac{|\vec{s}_i-\vec{s}_j|^2}{r_c^2}).$$



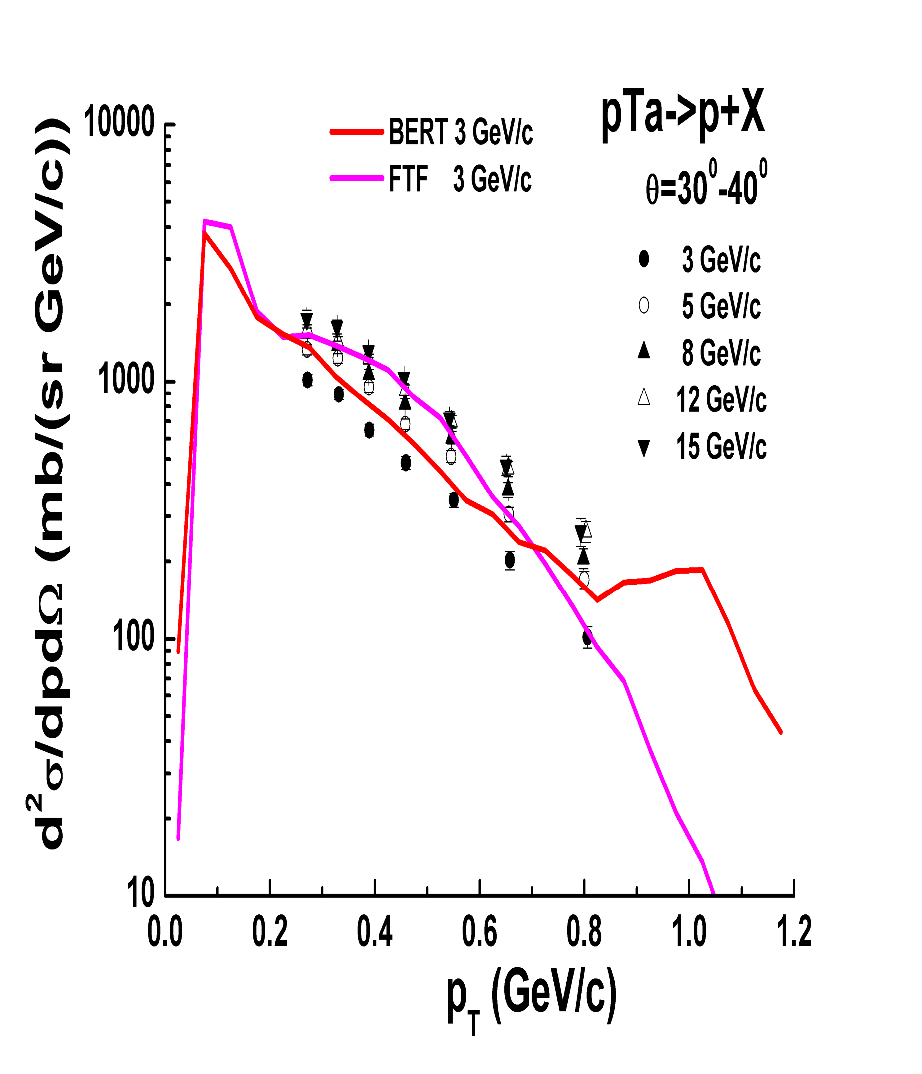


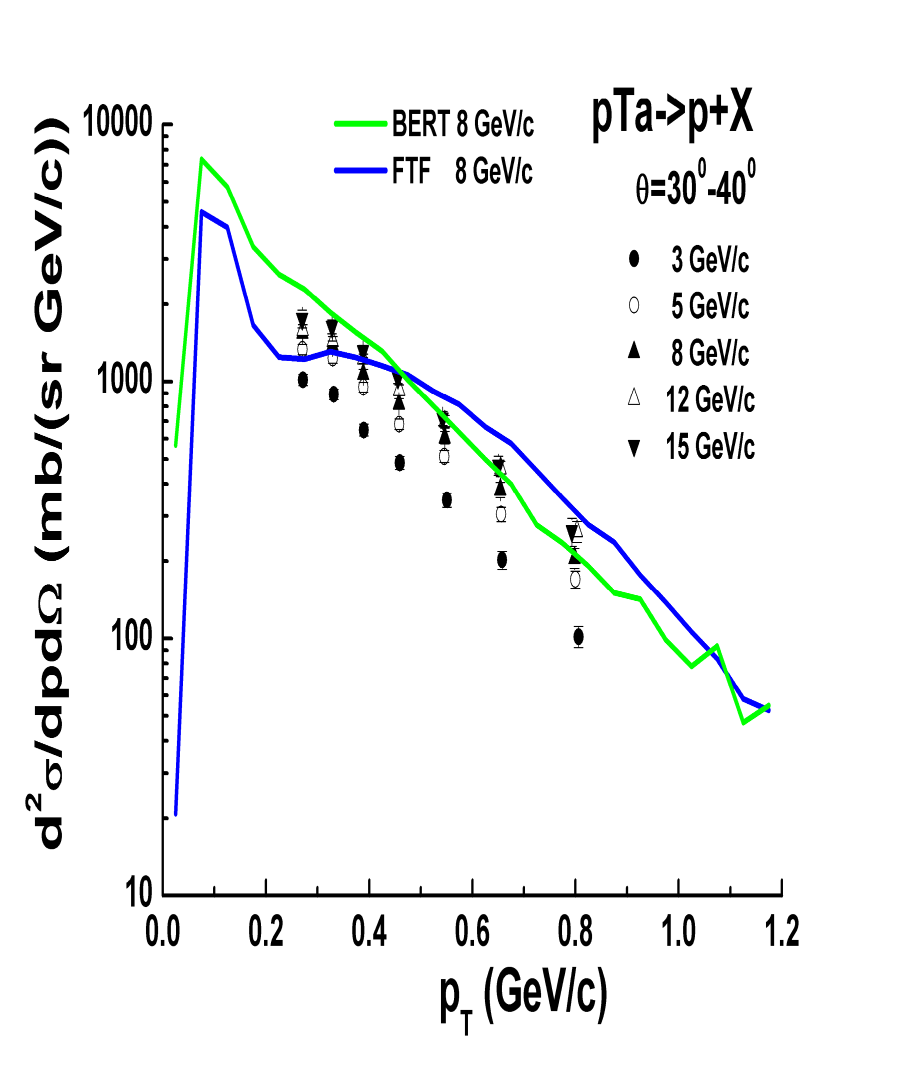
4. Reggeon cascading for nuclear destruction

Acceptable description of HARP/HARP-CDP data has been reached!



4. Reggeon cascading for nuclear destruction

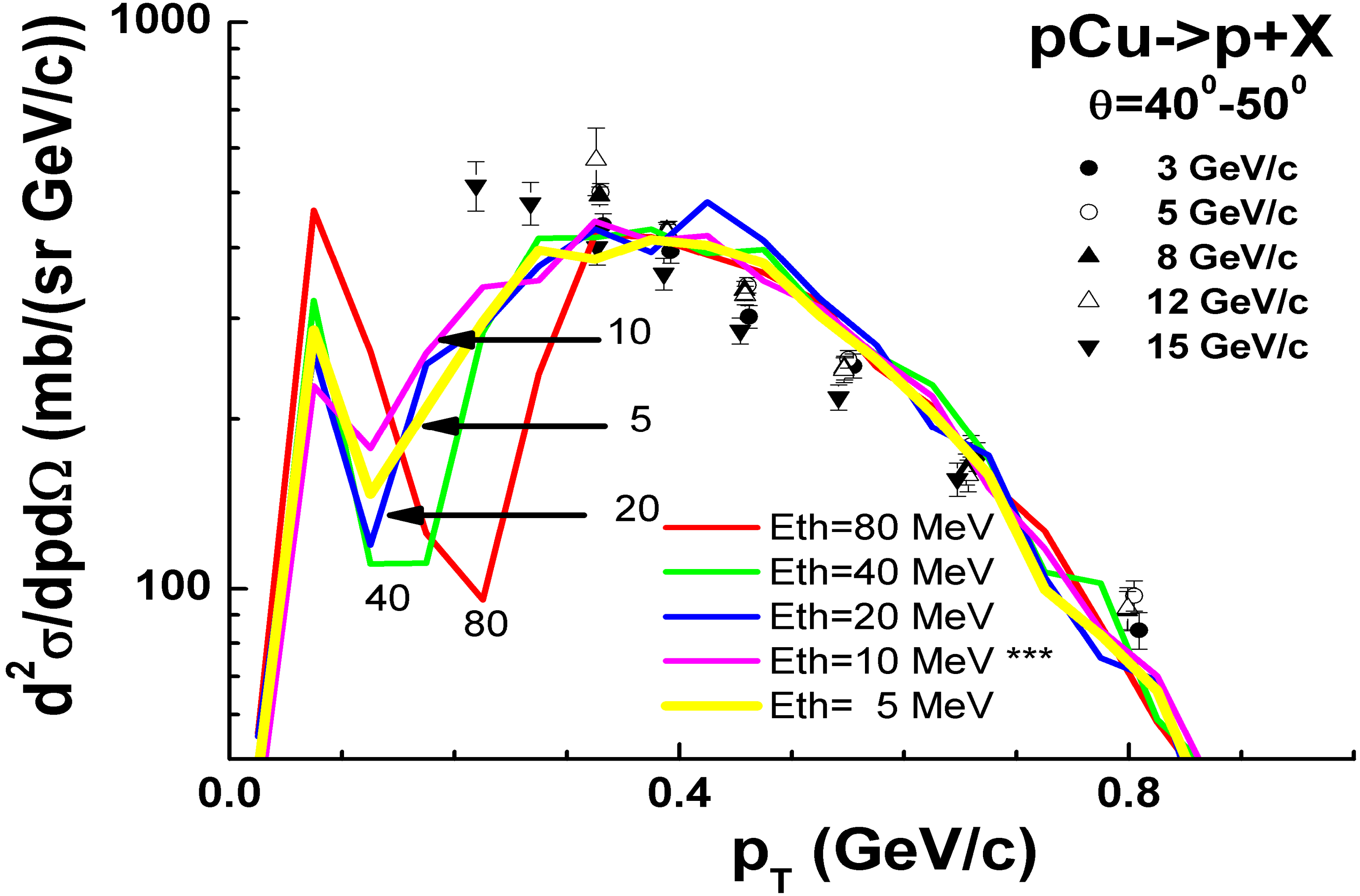




There is a good agreement with Bertini model in low energy domain.

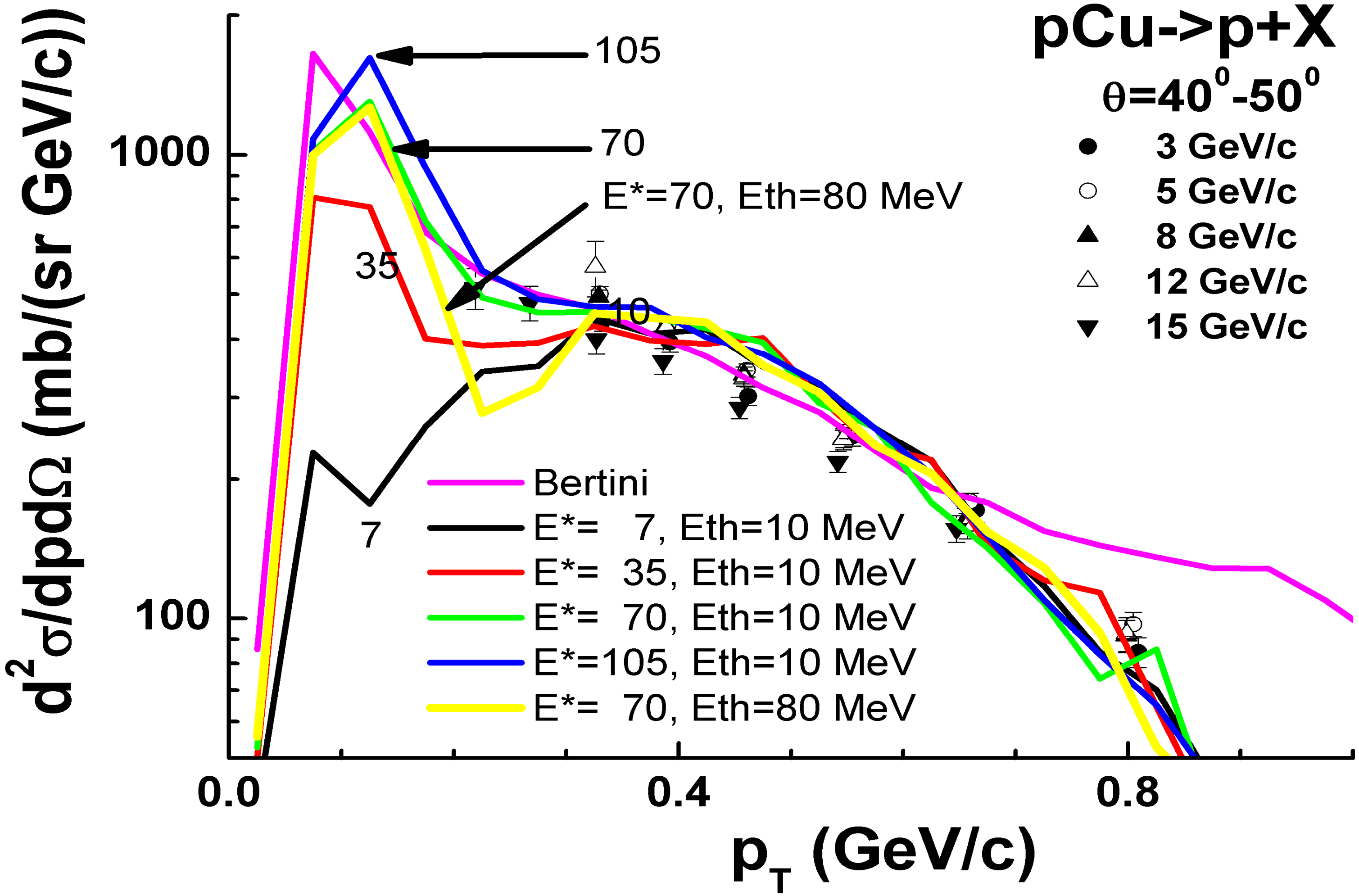
Sampling of nucleon momentum see in M.I.Adamovich et al. Z. Phys. A 358, 337-351 (1997)

5. Excitation energy of nuclear residual?



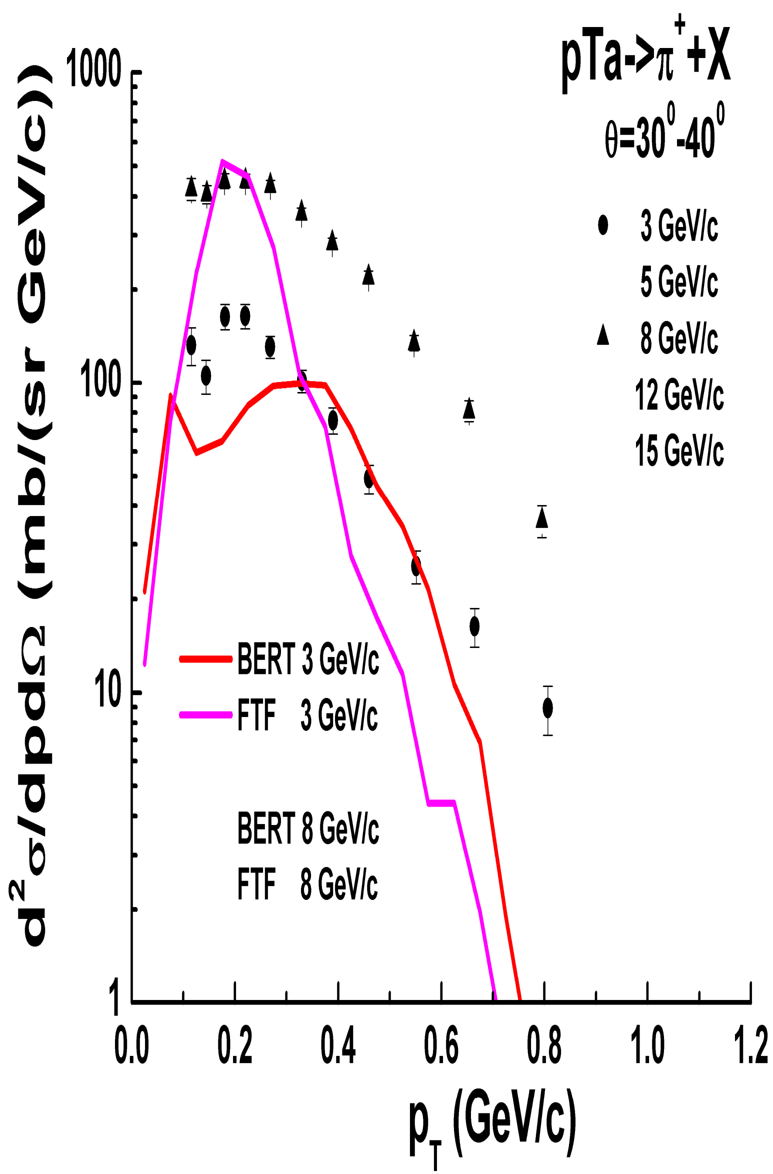
Choosing of threshold in PrecompoundModelInterFace

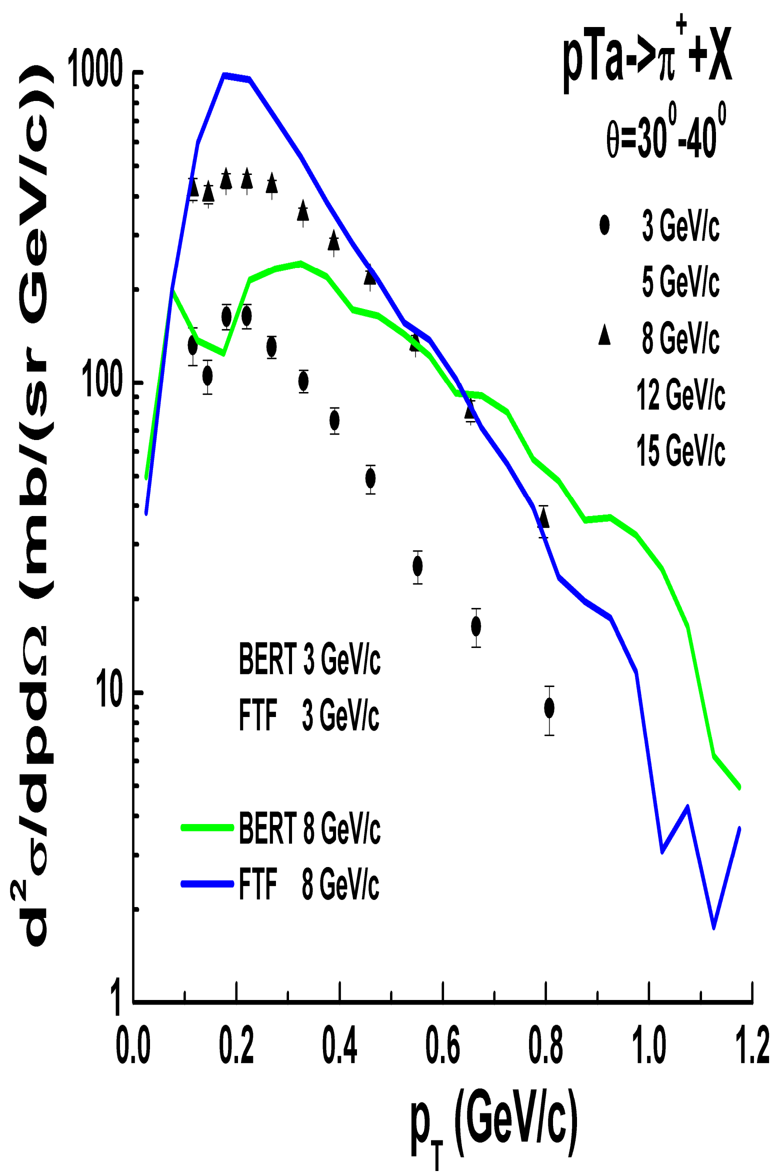
5. Excitation energy of nuclear residual?



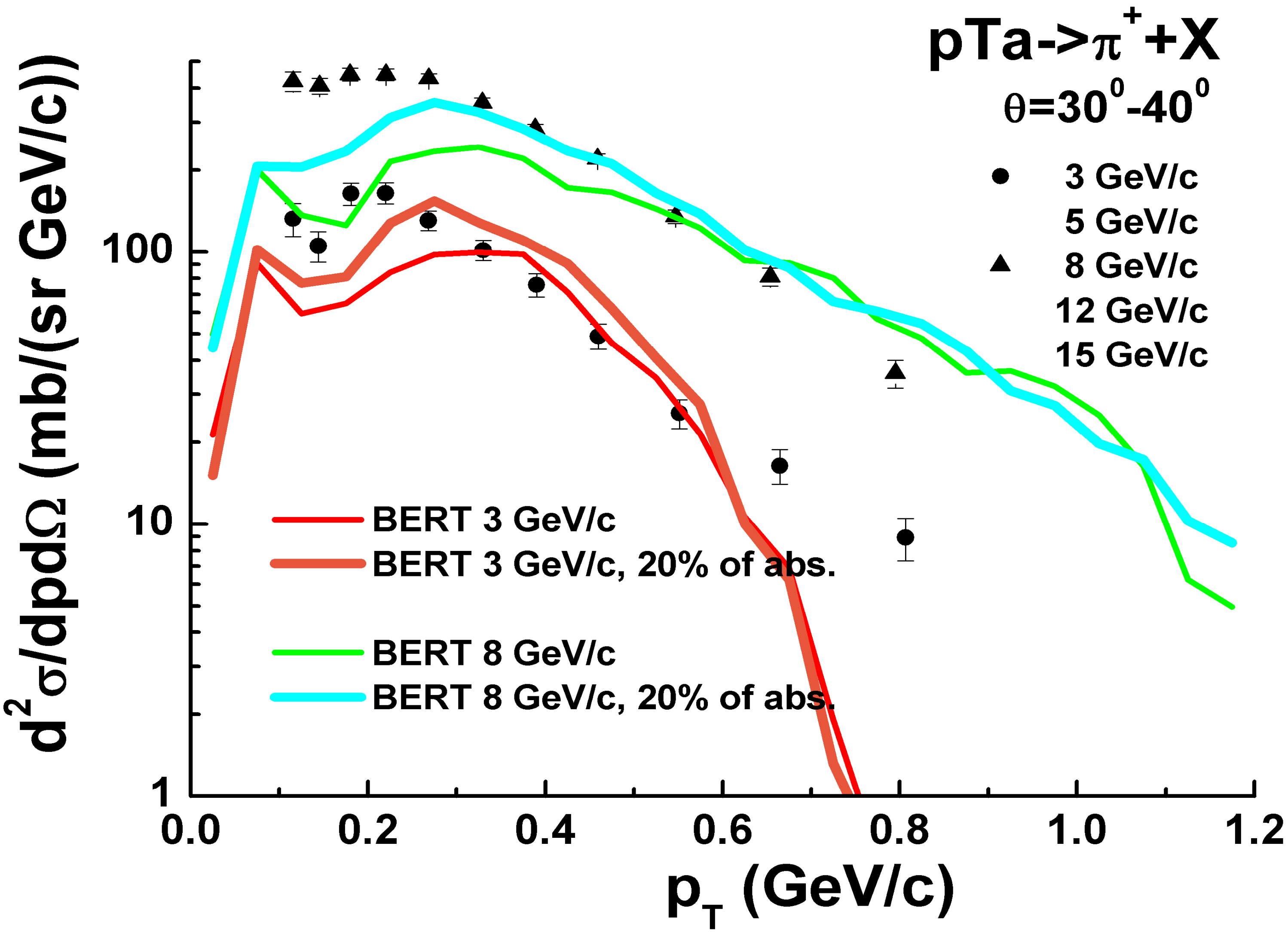
Other solutions are under the study!

6. Less important problem

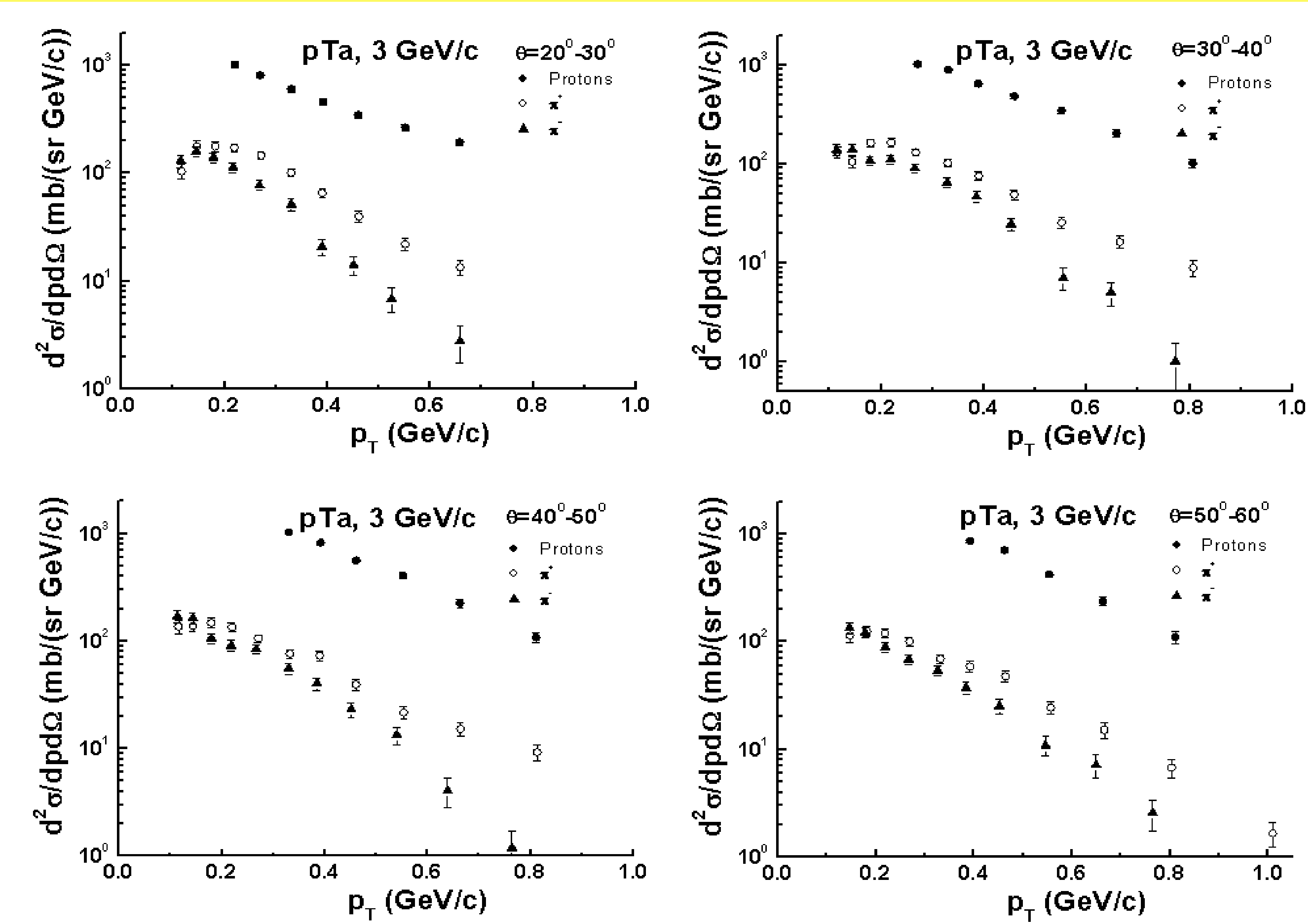




Bertini model, variation of meson absorption



6. Less important problem



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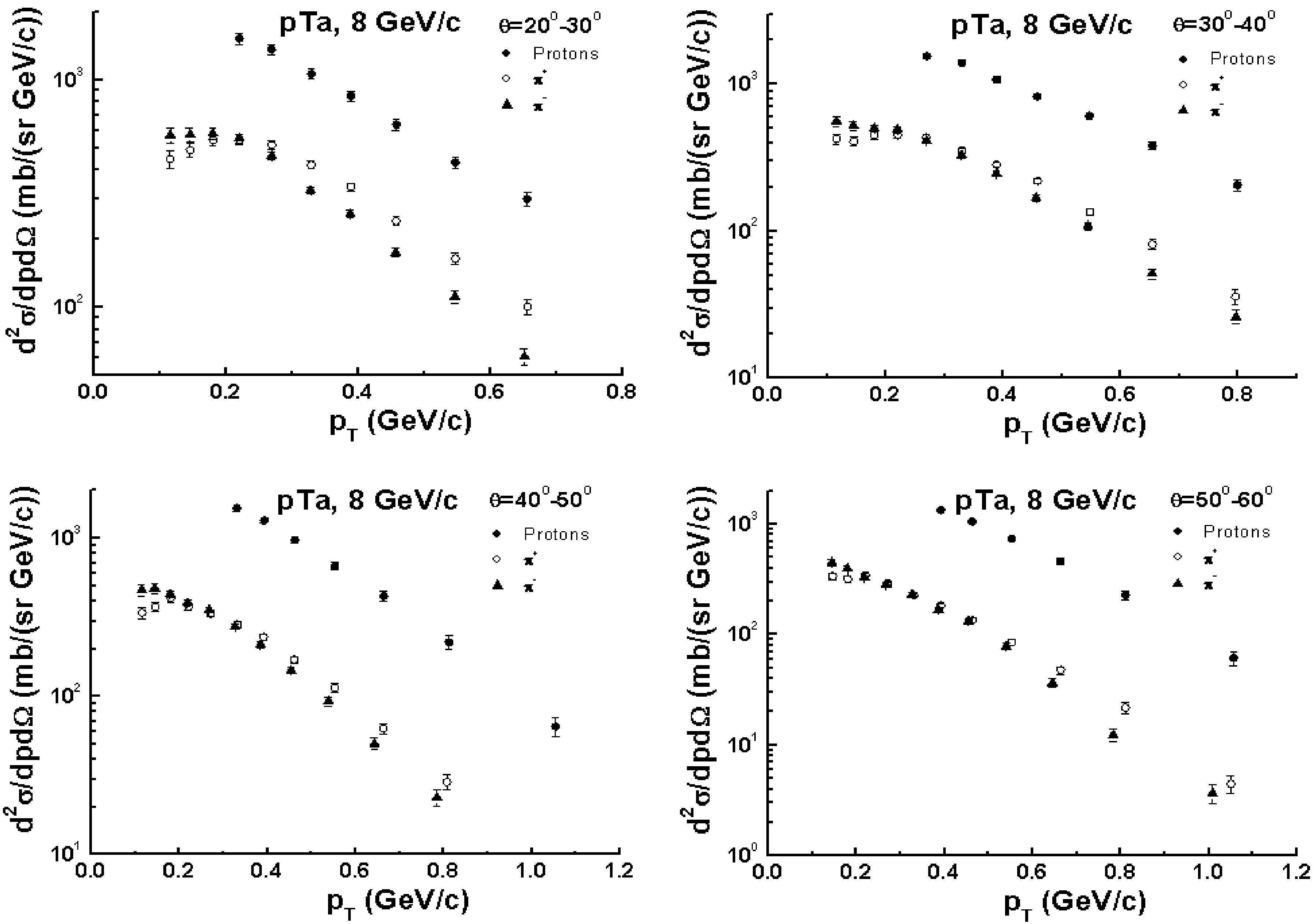

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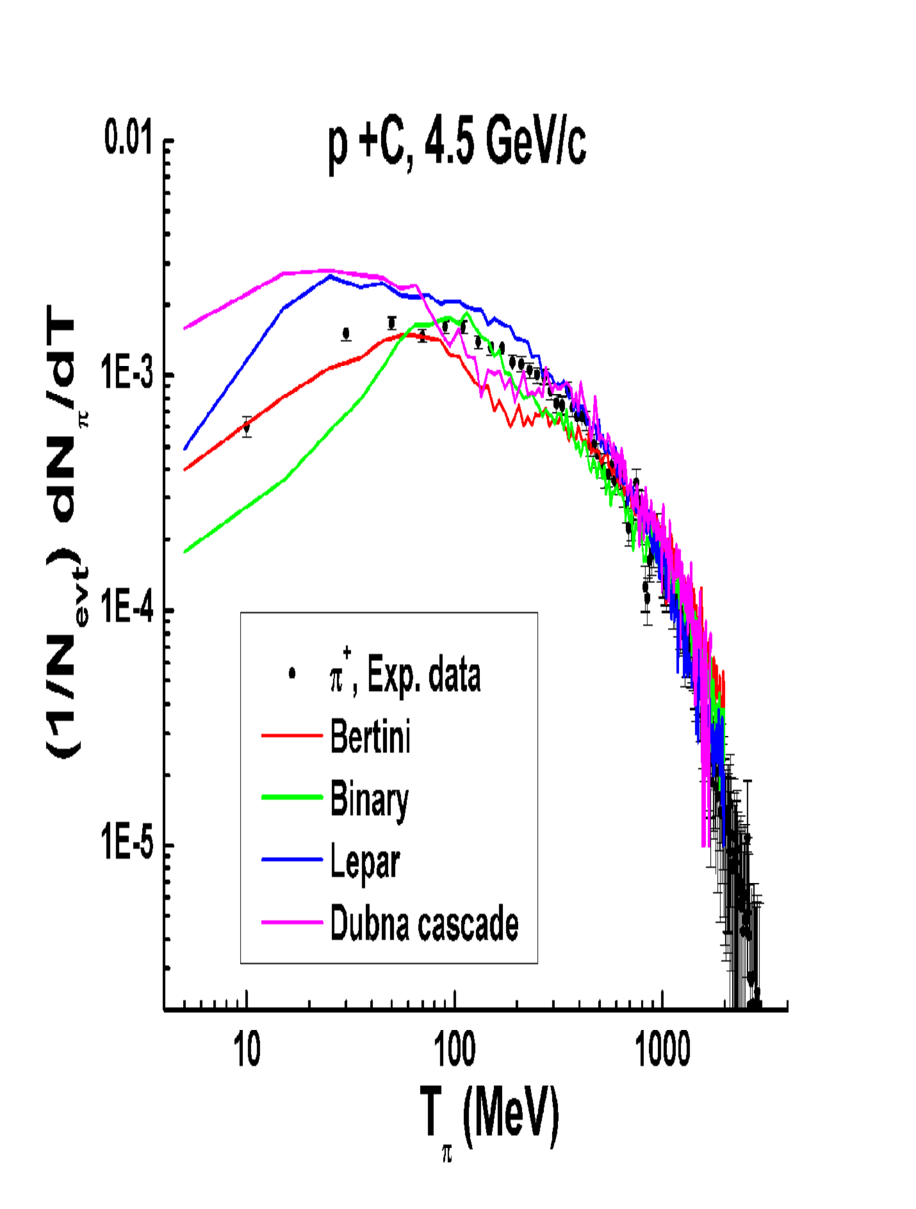
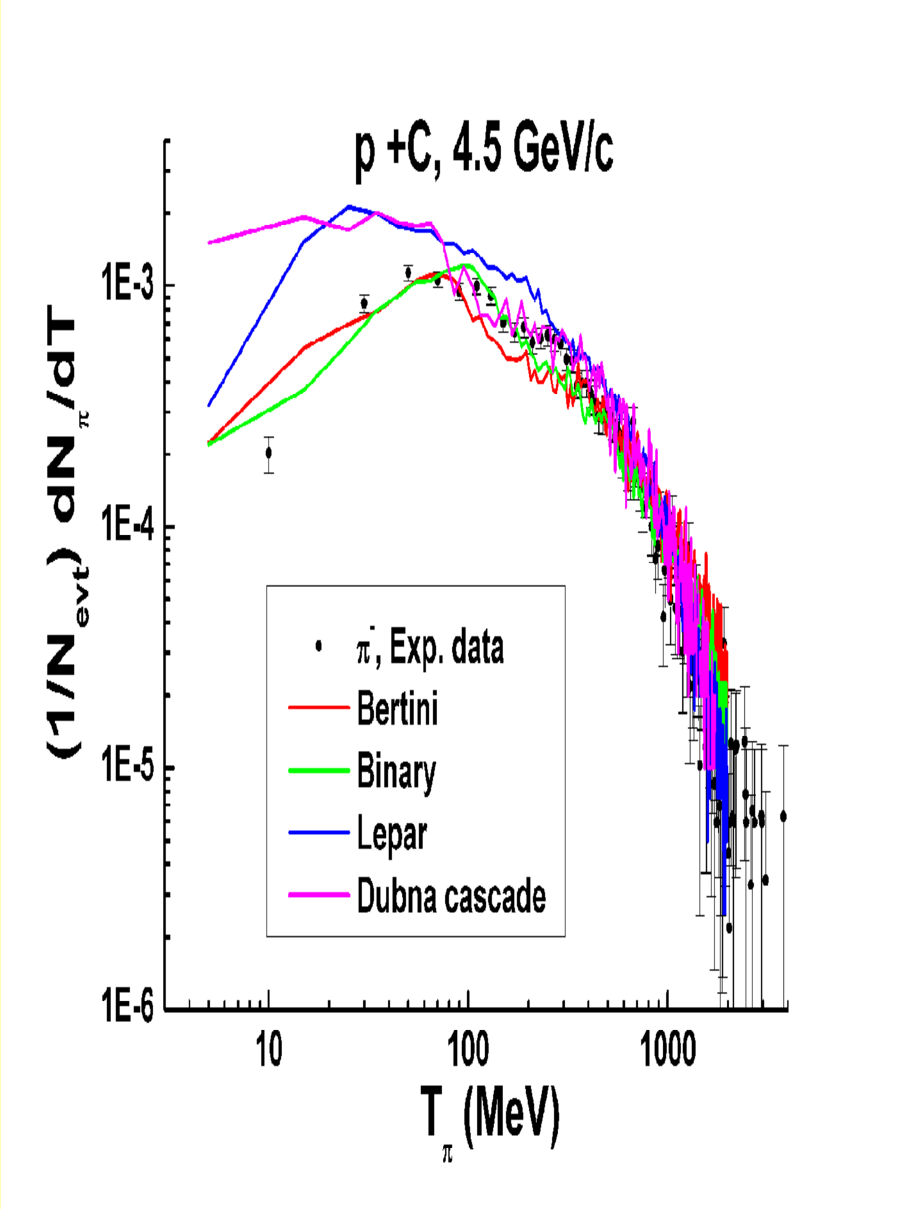
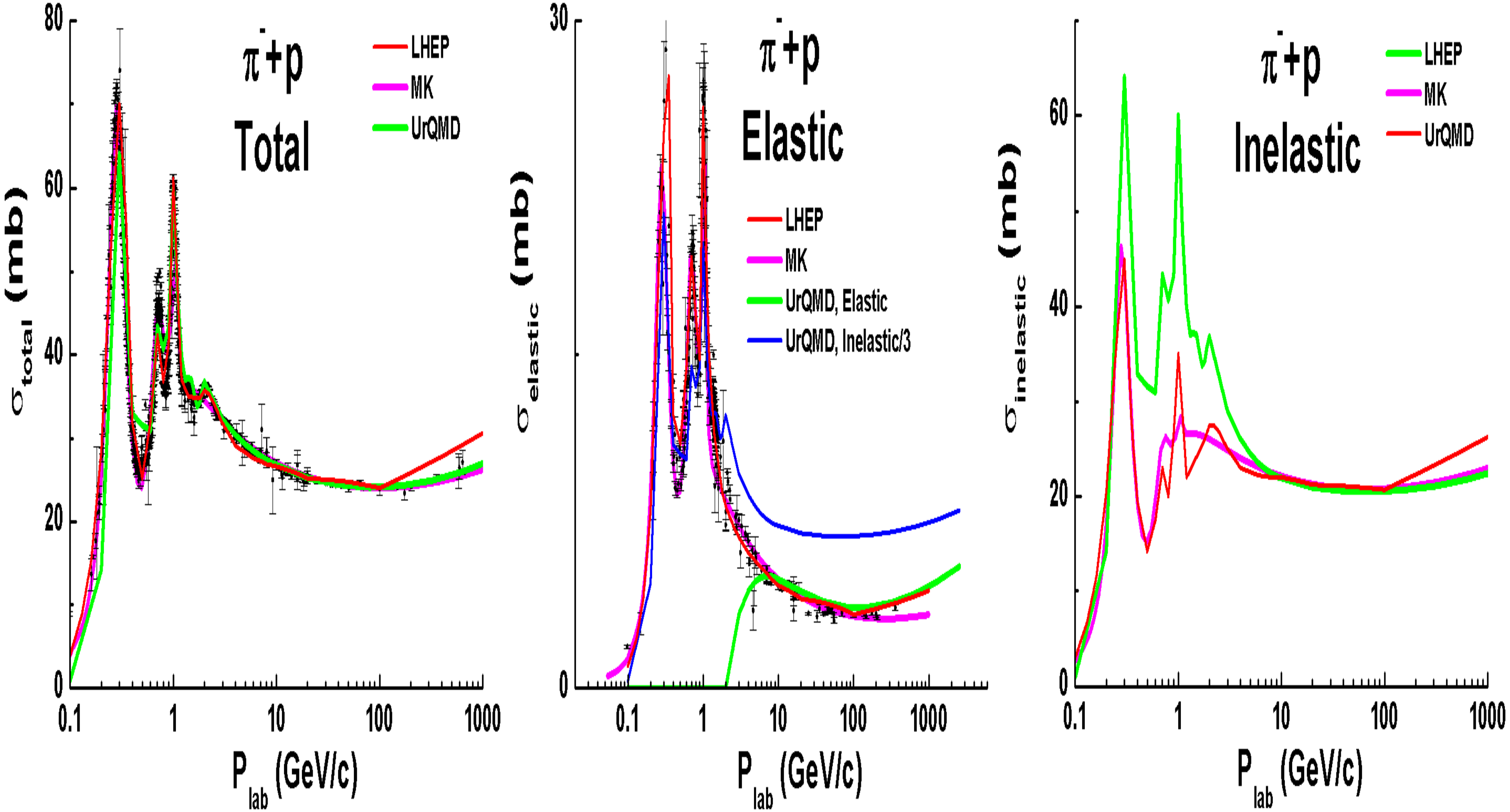




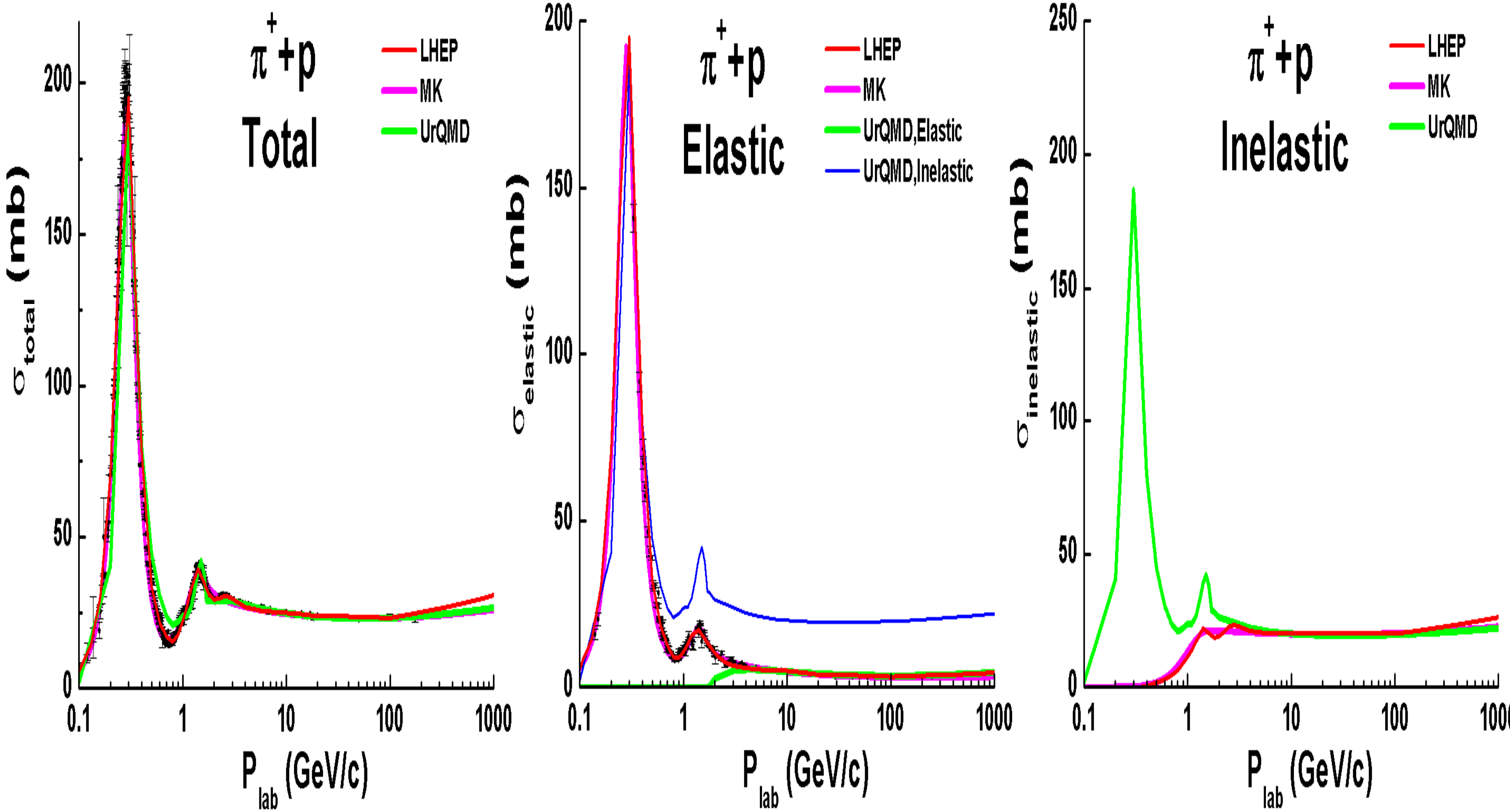
πN interaction in nuclei in region of Δ-isobar production?

6. Less important problem



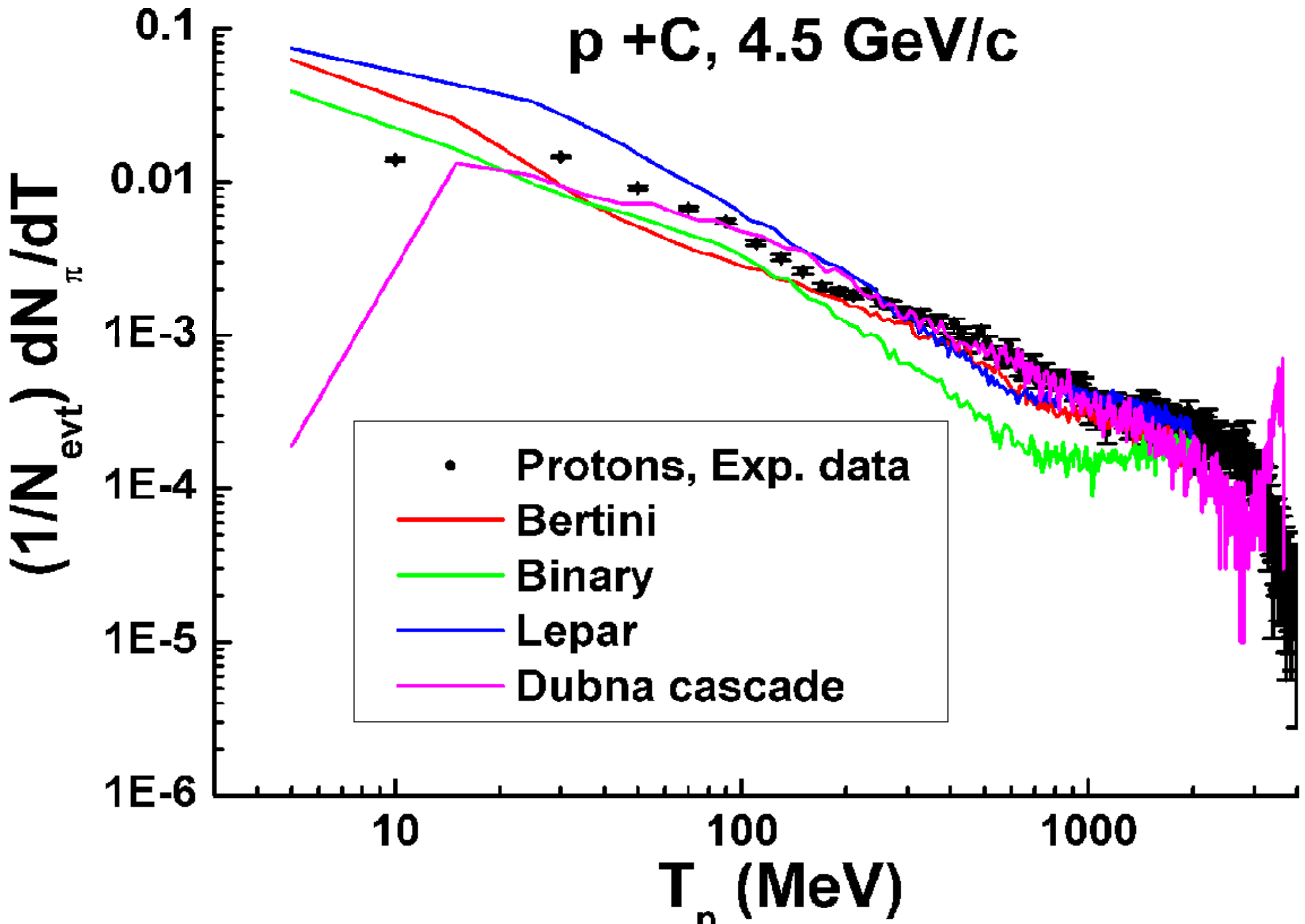
LHEP, MK and UrQMD parameterization

6. Less important problem



LHEP, MK and UrQMD parameterization

There is no problem with proton spectra in BERT



Conclusion

Quark exchange is introduced. Good description of hadron-nucleon interaction is reached.

Reggeon cascading is implemented. Good description of proton spectra is reached.

Nuclear excitation energy is estimated roughly.

Common notation:
Deficit of mesons with T=100 – 300 MeV in all hardonic models.

We urgently need a good low energy cascading model!

Improved FTF model can be smoothly coupled with the Bertini model at Plab 3 – 5 GeV/c erasing discontinuity in model predictions!

Conclusion'

The Bertini model:
Strange Pi-meson multiplicity distributions.
Restriction on the meson multiplicity.

The binary model:
No energy dependence of Pi-meson multiplicity at Plab > 5 GeV/c.
Low multiplicity of the evaporated protons.

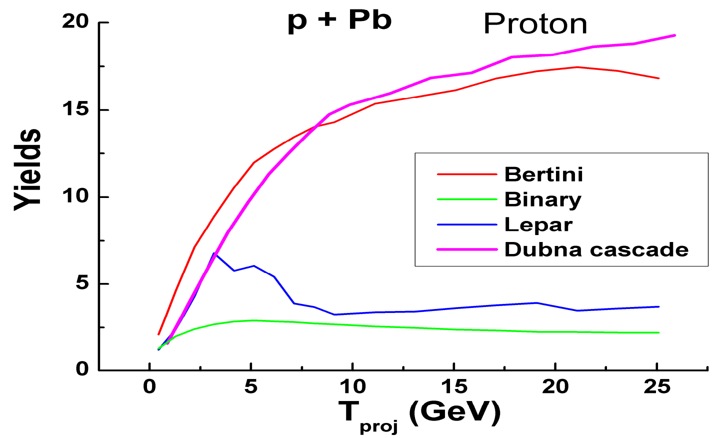
The QGS model:
Change mechanism at Plab = 10 – 12 GeV/c.

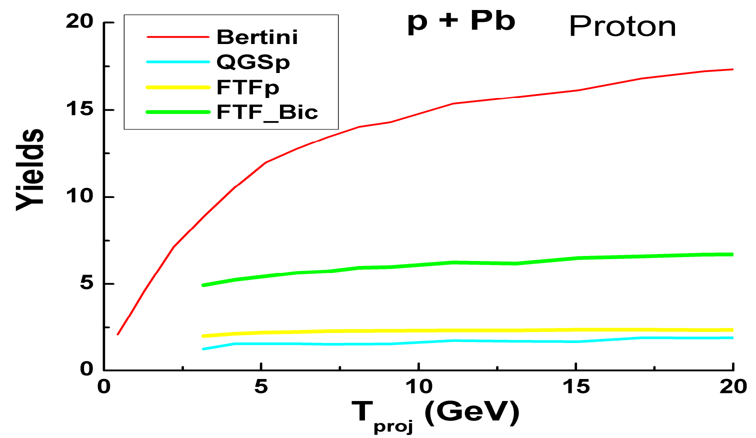
The pre-compound model interface:
Low multiplicity of protons. Absorption of baryons with T < 80 MeV.

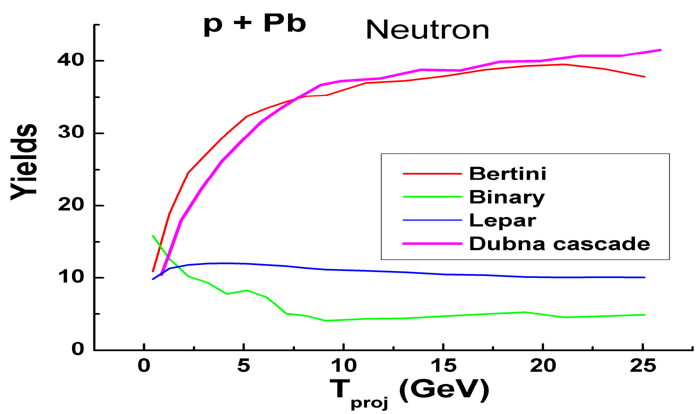
The evaporation/de-excitation model:
Stopped at large nuclear destruction. Problem at simulation of P+Be interactions. What well we do with nucleus-nucleus collisions needed for space research and future experiments where strong destruction will be presented???

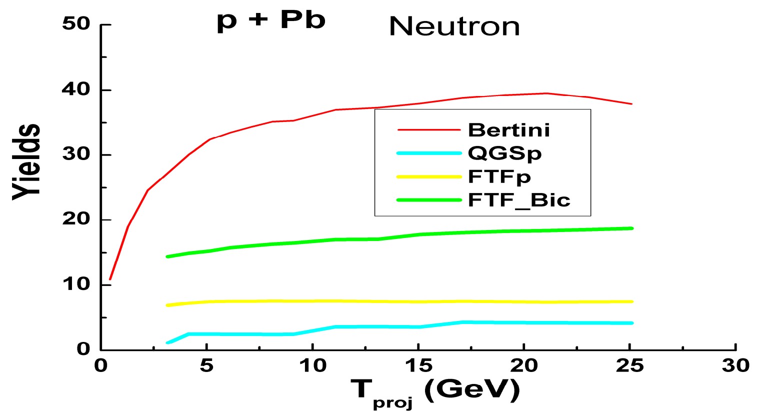
To the understanding of discontinuities in energy fractions!

Particle multiplicities and hadronic models





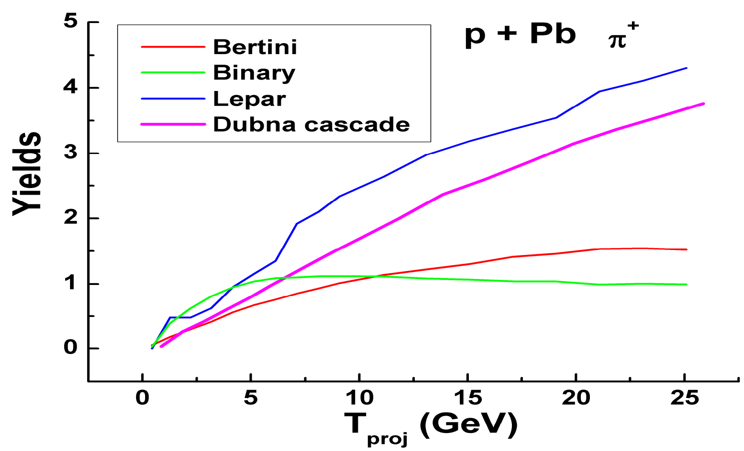


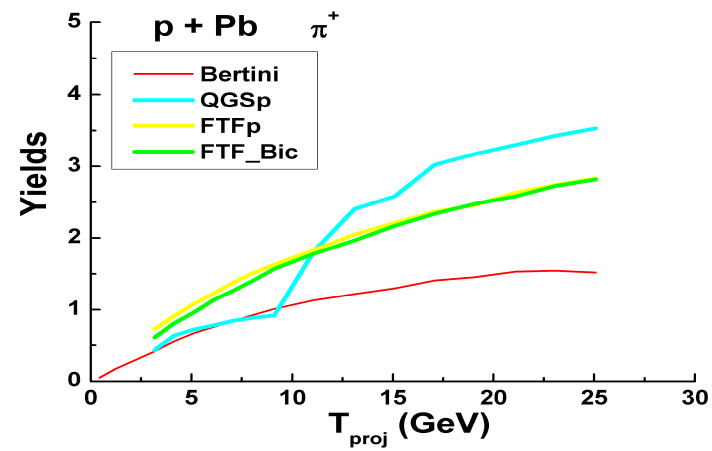


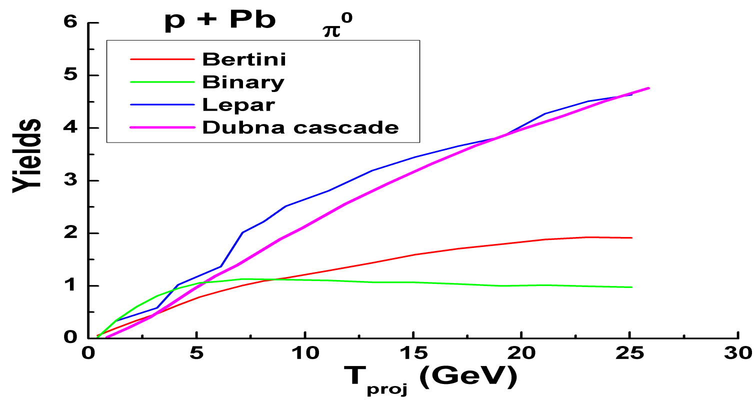
HUGE disagreement between the models!

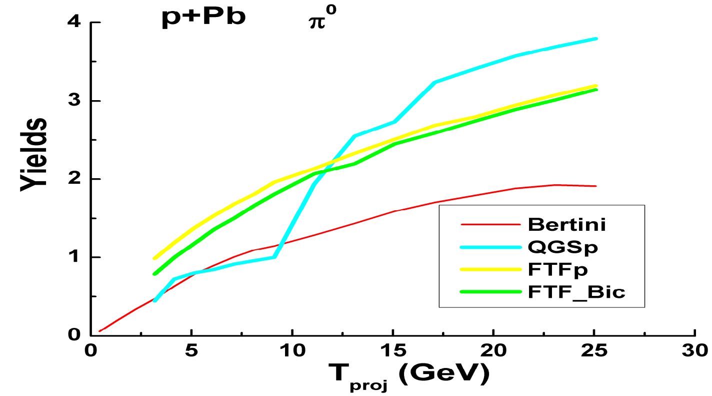
To the understanding of discontinuities in energy fractions!

Particle multiplicities and hadronic models









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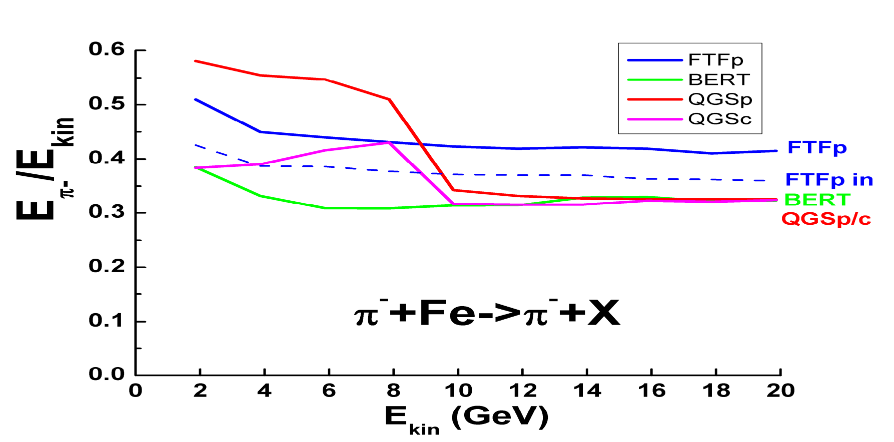
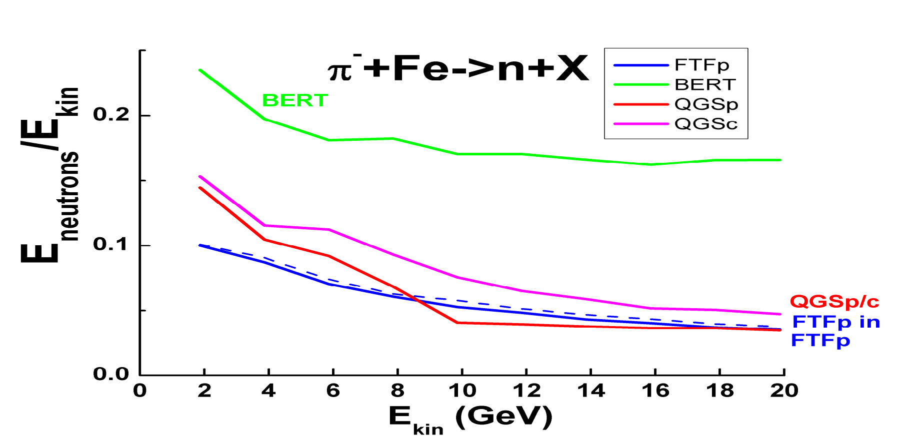
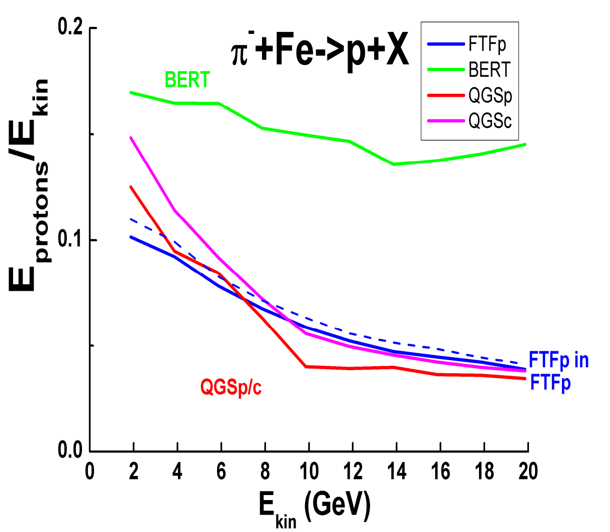
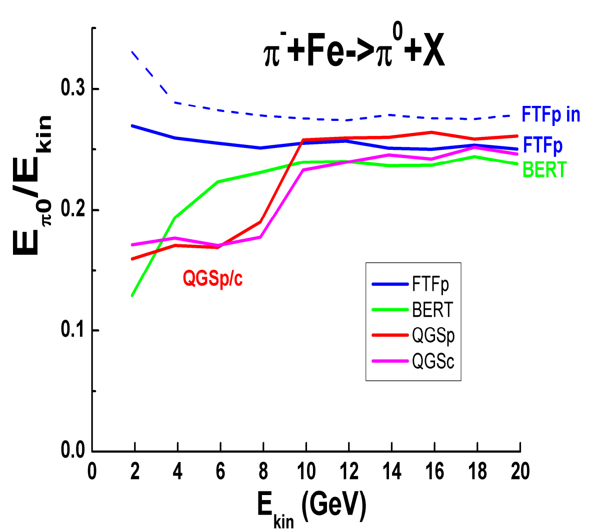
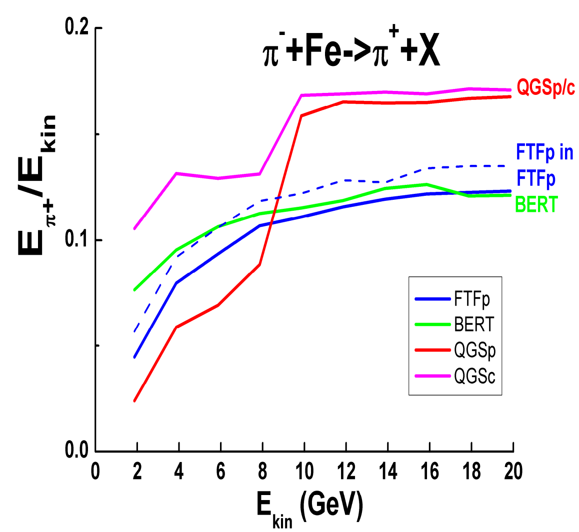
To the understanding of discontinuities in energy fractions!





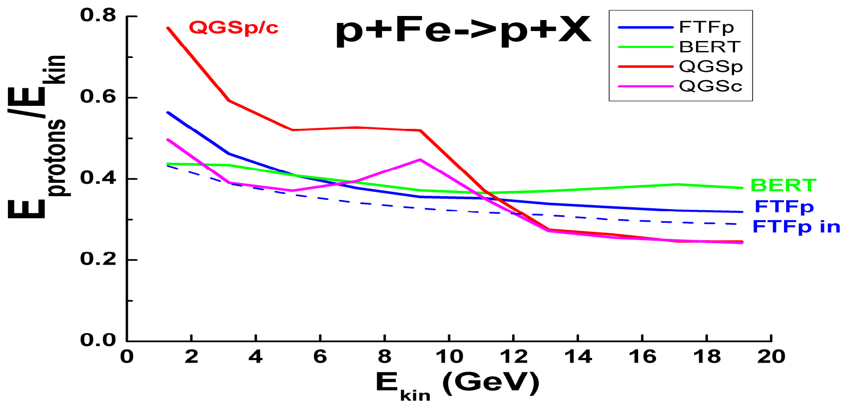


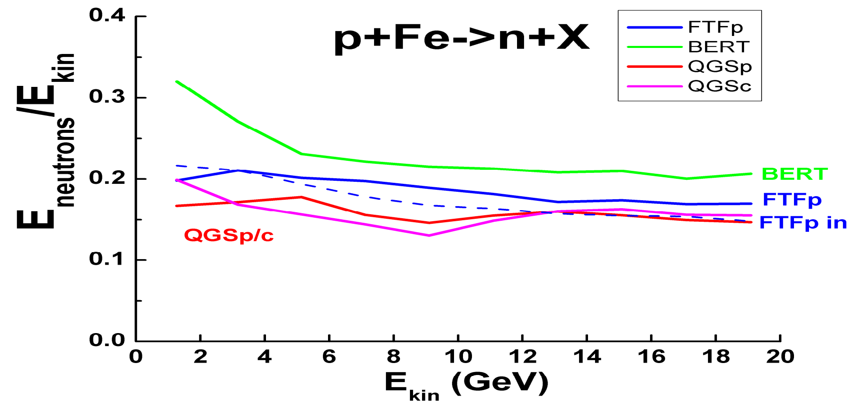


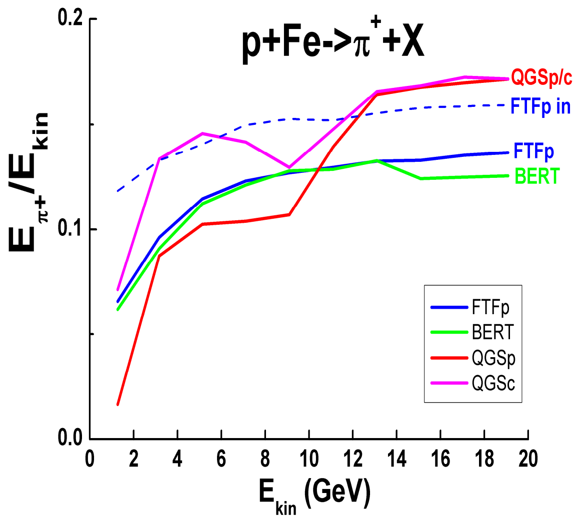


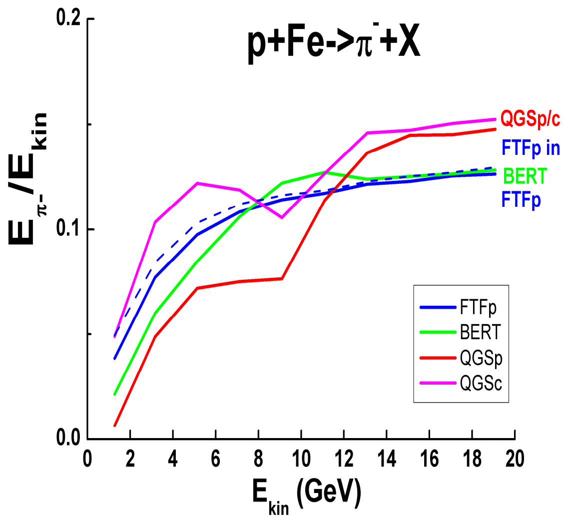
There are the discontinuities only in Quark-Gluon-String model out of range of its applicability. But it can BE IMPROVED!

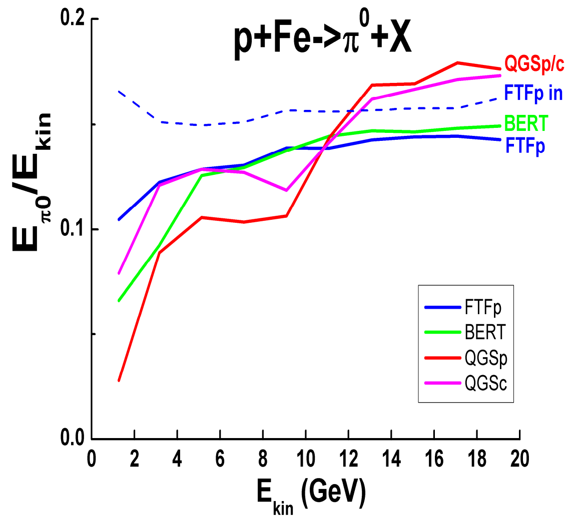
To the understanding of discontinuities in energy fractions!











There are the discontinuities only in Quark-Gluon-String model out of range of its applicability. But it can BE IMPROVED!

There are no discontinuities in energy fractions!

Improvement of FTF, Charge exchange, Wce=C*exp(-0.5*(Yproj-Ytar)), C=0.5 -1, p+Fe