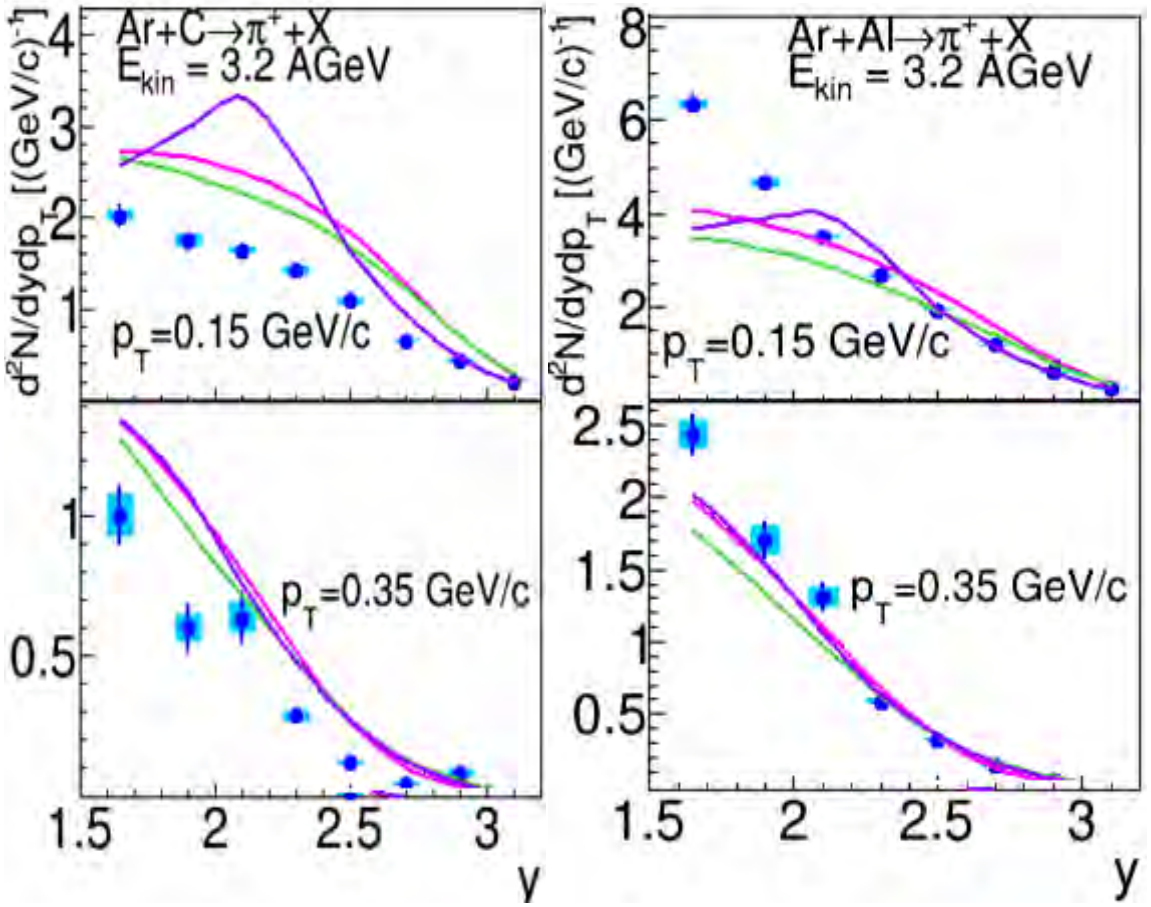
Is there diffraction dissociation of nuclear nucleons in nucleus-nucleus interactions?

V. Uzhinsky, A. Galoyan, A. Ribon, 3 July 2024

1 BMN results for Ar + A inter. at 3.2 A GeV

Production of Pi_+ and K_+ mesons in argon-nucleus interactions at 3.2 AGeV

JHEP 07 (2023) 174



It was interesting for us, how does Geant4 FTF model describe the data?

Some details of the Geant4 FTF will be given and considered.

2 NA61/SHINE results for Ar + Sc inter. at 13, 19, 30, 40, 75 and 150 A GeV/c

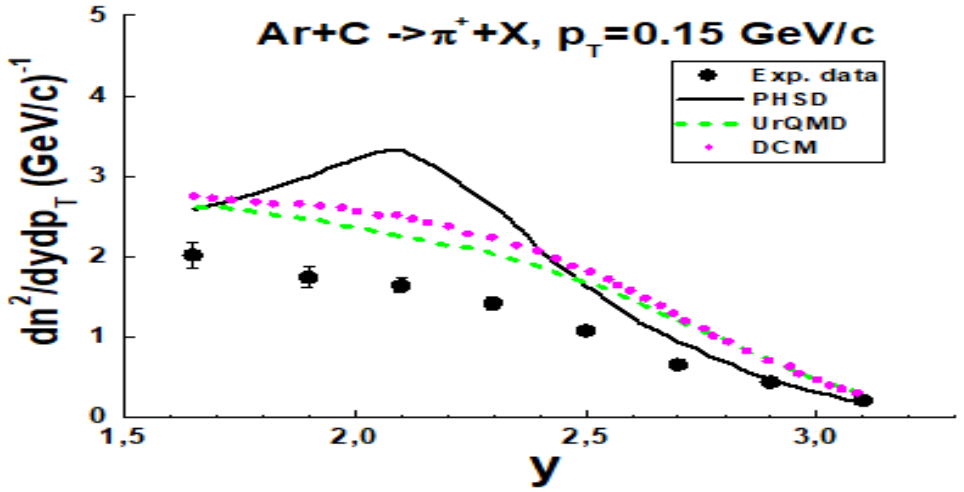
3 NA61/SHINE results for Be-7 + Be-9 inter. at 19, 30, 40, 75 and 150 A GeV/c

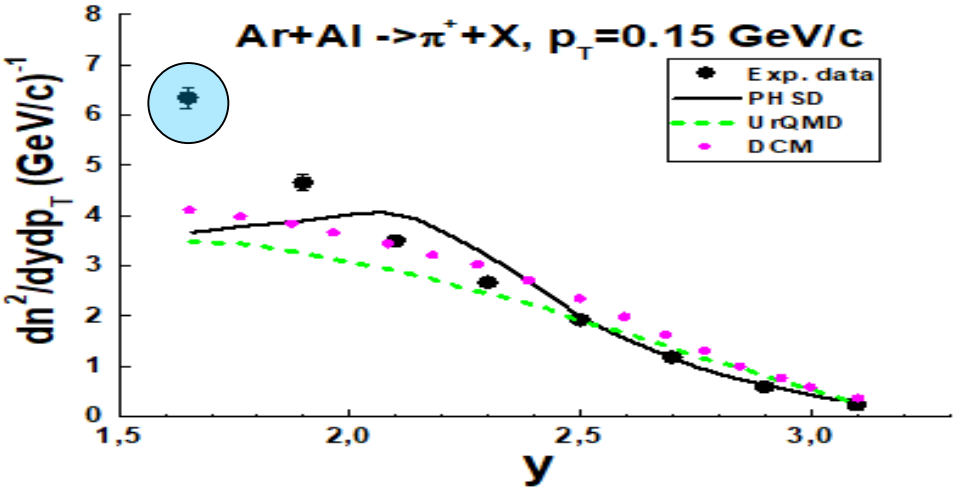
Ongoing BMN publication

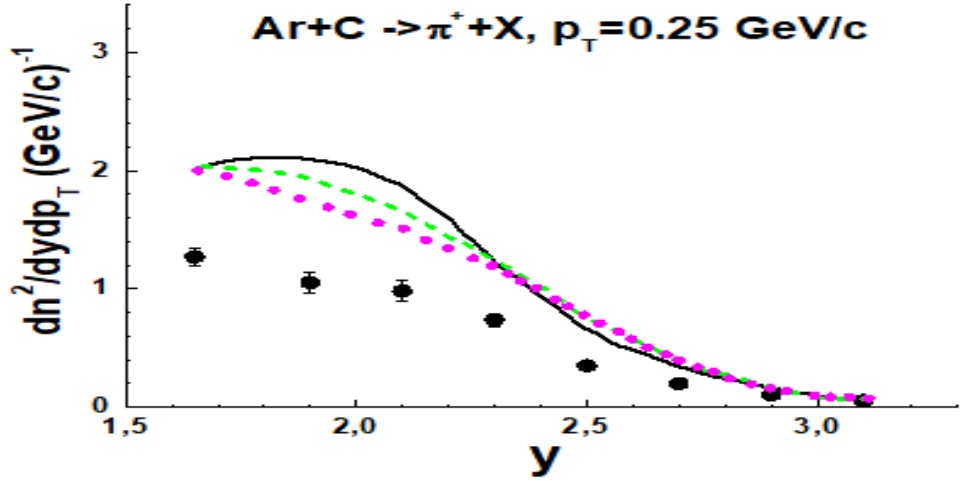
Production of protons, deuterons, tritons in argon-nucleus interactions at 3.2 AGeV BM@N Collaboration

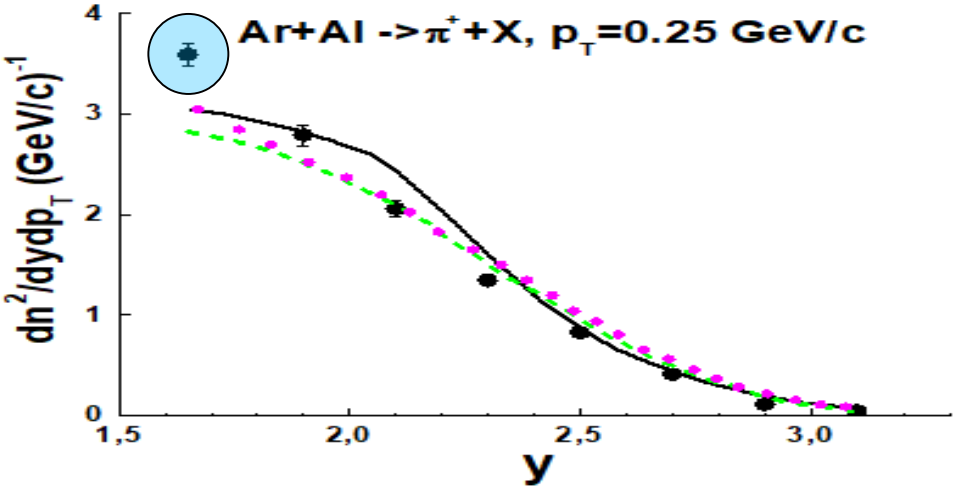
It was presented by V.Plotnikov at the RAS session, *1 – 5 April 2024. JINR, Dubna*

BMN results for Ar + C and Ar + Al









DCM/AGT model: local simulations of NN channel cross sections like P+P -> N Pi+ P. No Deltas! (P+P -> P + Δ+ -> P + N + Pi+)

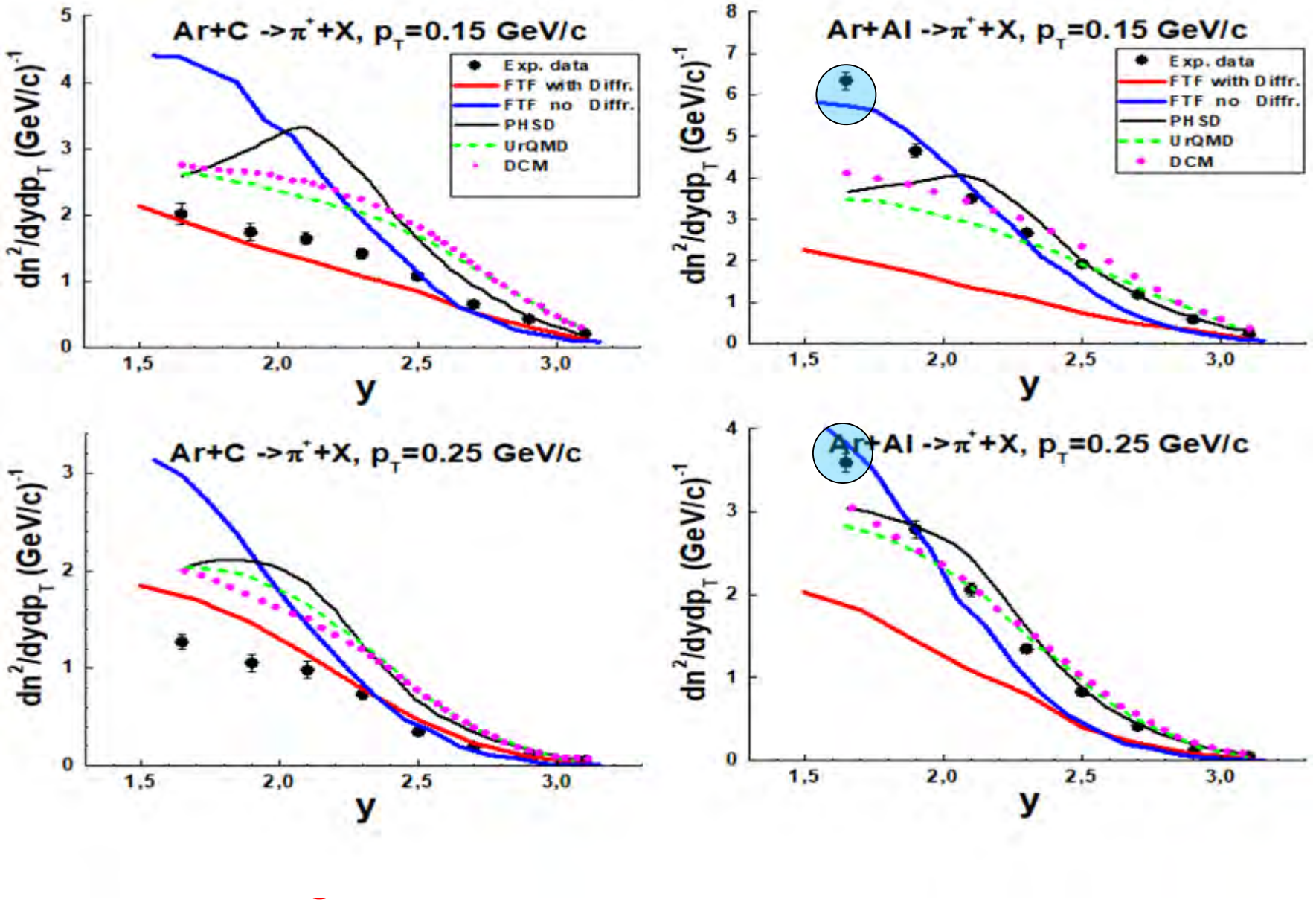
UrQMD local simulations of NN inter. Using matrix elements.

No Delta formation time and size!

PHSD based on Fritiof 7.0 at high energies and UrQMD at low energies.

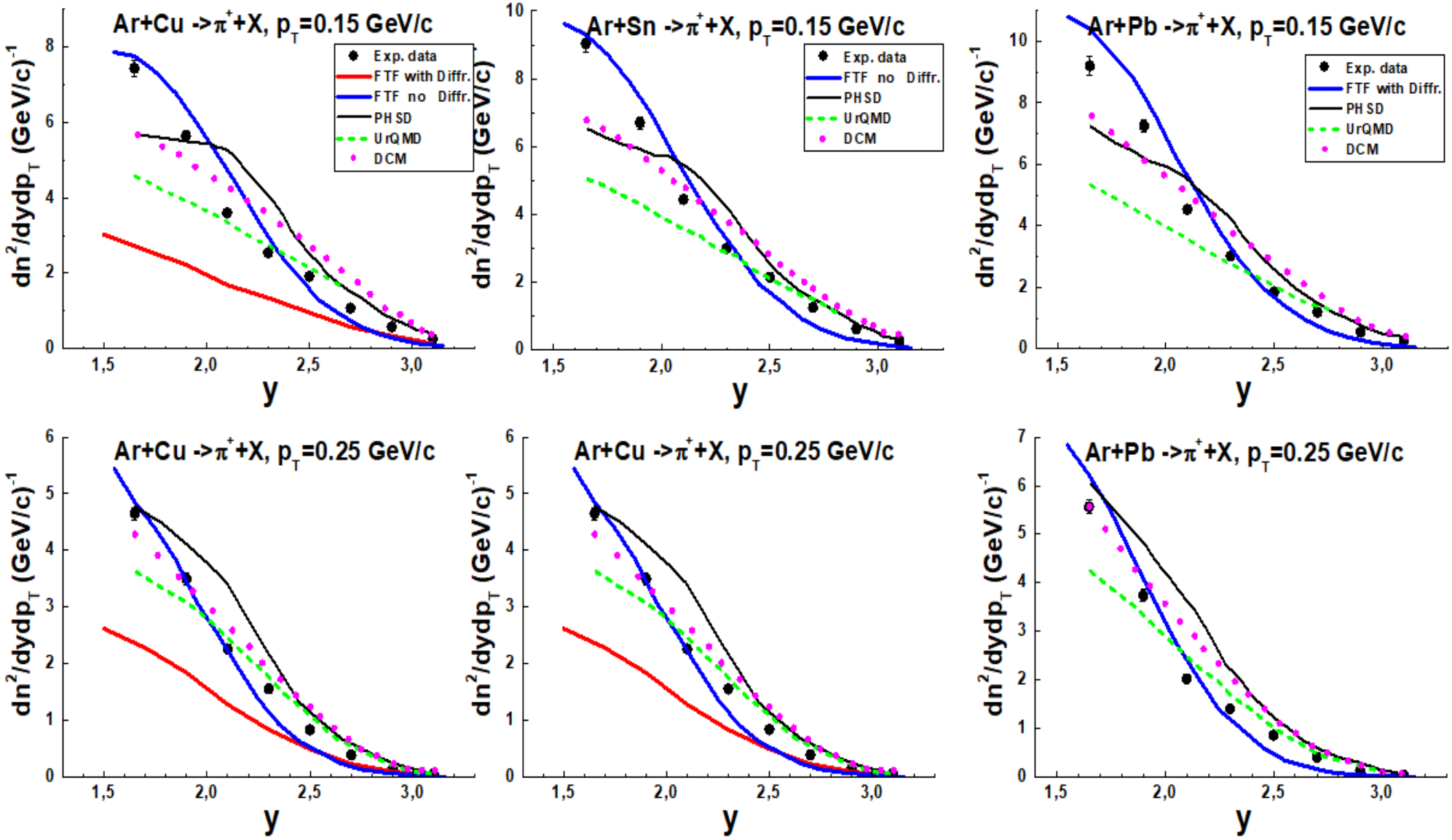
BMN results for Ar + C and Ar + Al

Red lines – default FTF model, blue ones – new FTF



Blue lines (suppressed DD) – OK for Al and heavy A!

BMN results for Ar + Cu, Sn and Pb
Red lines – default FTF model, blue ones – new FTF



New FTF works better than other models.

Geant4 FTF model : basic assumptions

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

Fig. 1: Processes of string's creations considered in the FTF model.

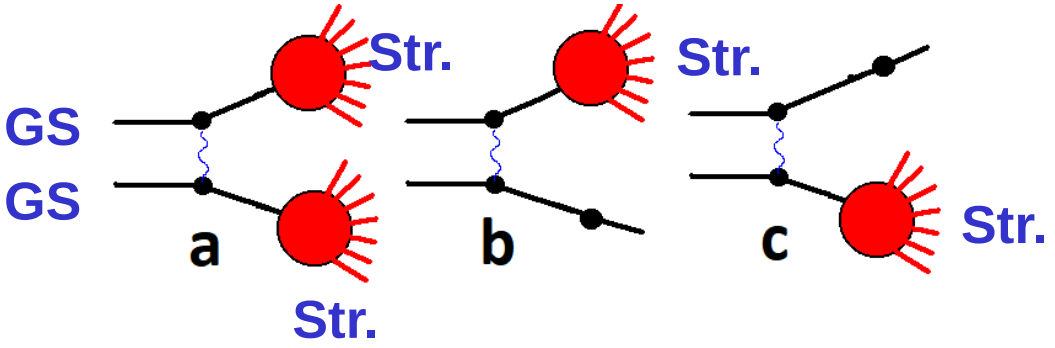
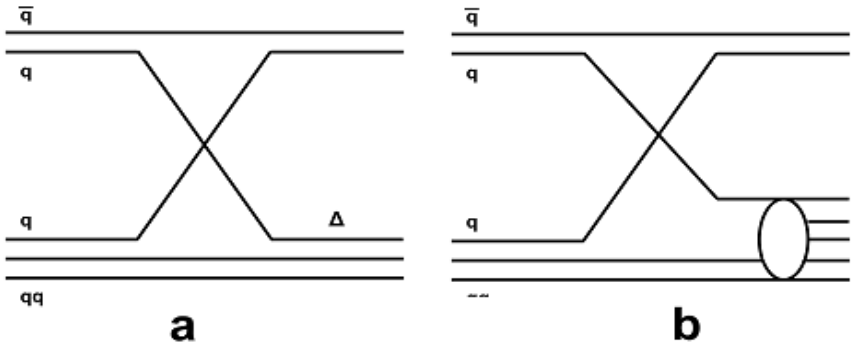


Fig. 2 Additional quark exchange processes in the FTF model.



String mass distribution

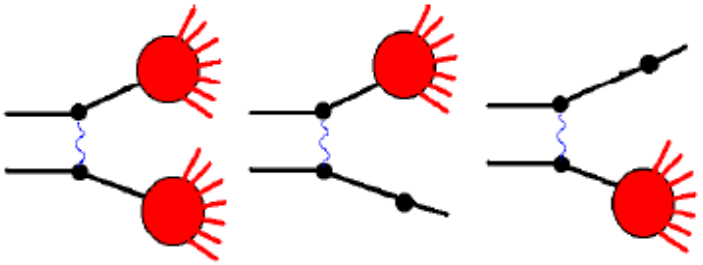
$$dW/dP^- = (1-f)\frac{1}{\ln\left(P^-_{max}/P^-_{min}\right)}\,1/P^- + f\frac{1}{P^-_{max}-P^-_{min}},$$

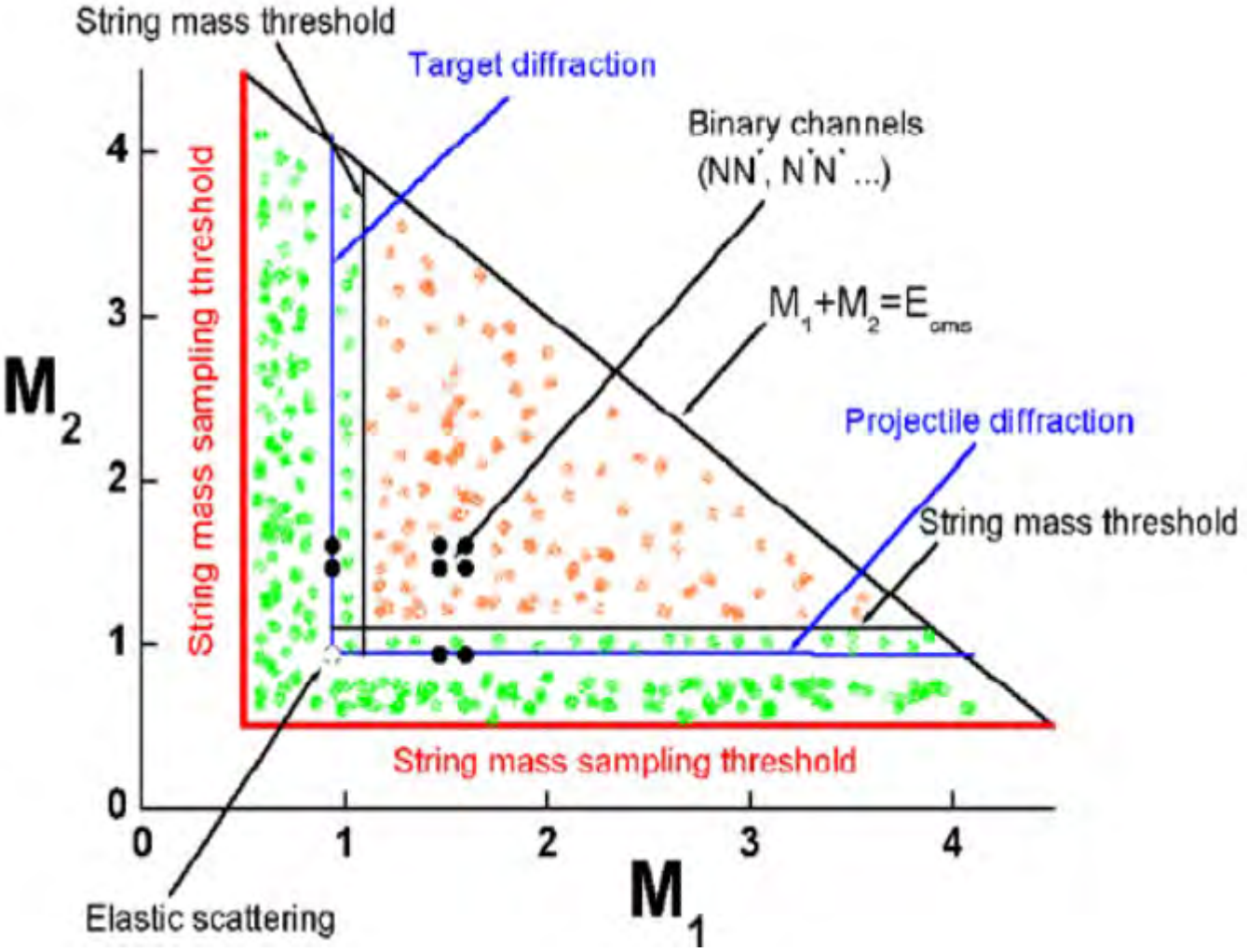
$$P^- = \sqrt{M^2+P_T^2+P_z^2} - P_z \simeq (M^2+P_T^2)/2\,P_z\ (P_z\to\infty) \qquad f = 0.55$$

Simulation of inelastic nucleon-nucleon interactions

Fritiof model

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





$$NN \to N\Delta_{1232}$$
$$NN \to NN^*$$
$$NN \to N\Delta^*$$
$$NN \to \Delta_{1232}N^*$$
$$NN \to \Delta_{1232}\Delta^*$$
$$NN \to \Delta\Delta \text{ excitation}$$

UrQMD Md=1.46

Fritiof 1.6 Md=1.2
Fritiof 7.0 Md=1.2
Hijing Md~2;
FTF – 1.16

Diffraction processes in PP interactions

Diffractive Production Mechanisms A.B. Kaidalov, Phys. Rept. 50 (1979) 157, cited 289!

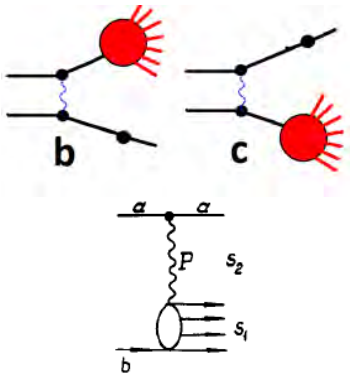


Fig. 2.8. Graph of diffraction dissociation of particle b.

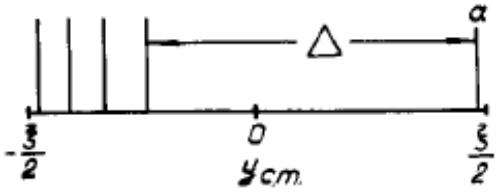


Fig. 2.9. Rapidity distribution for diffractive production of particles.

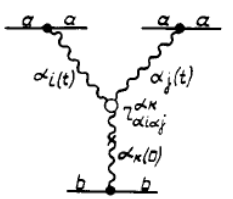


Fig. 2.12. Triple-Regge diagram.

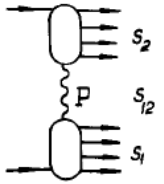


Fig. 2.15. Graph of double diffractive dissociation.

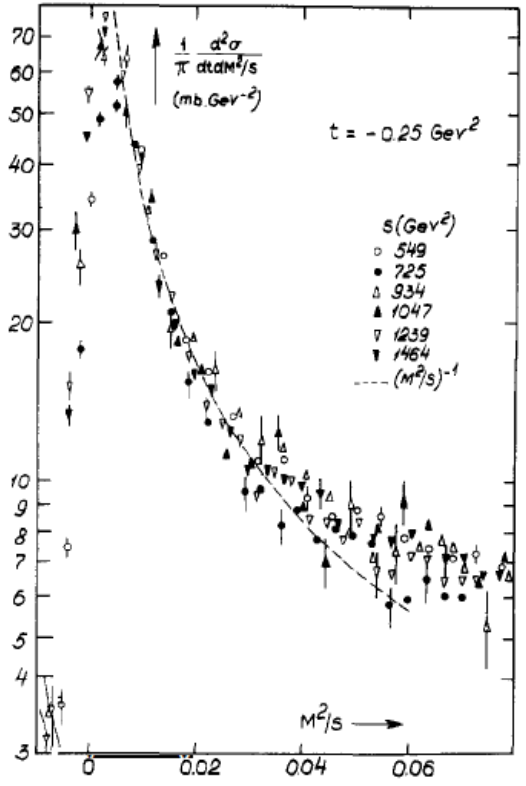
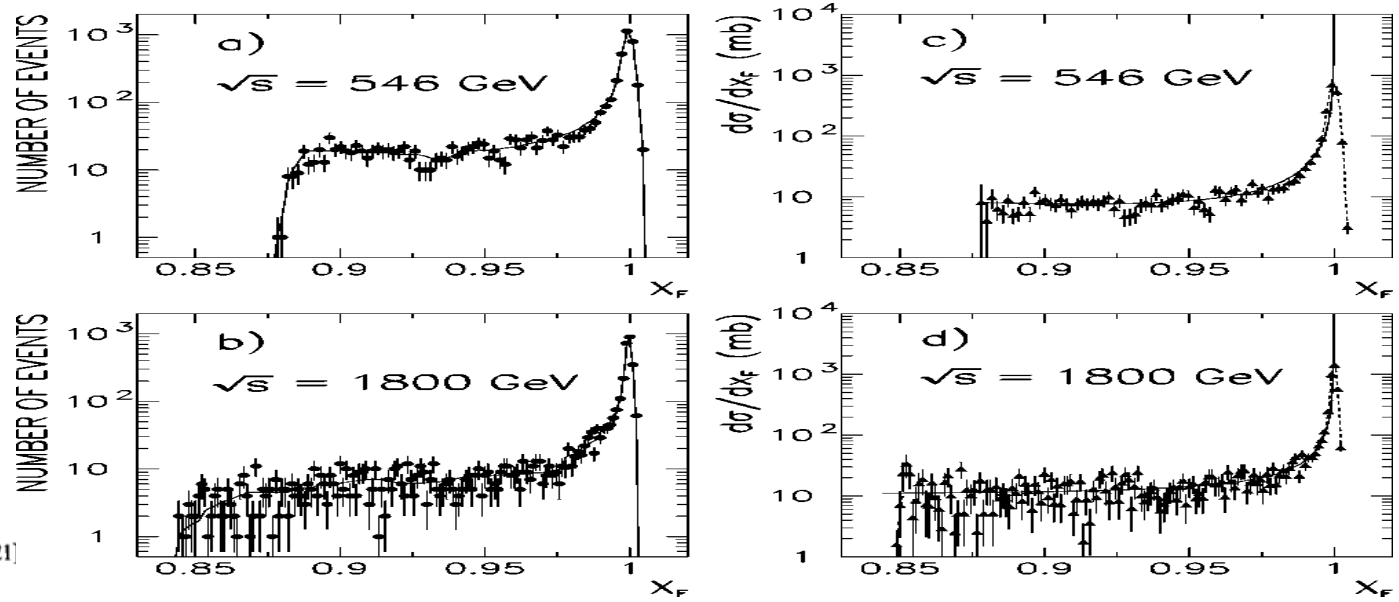


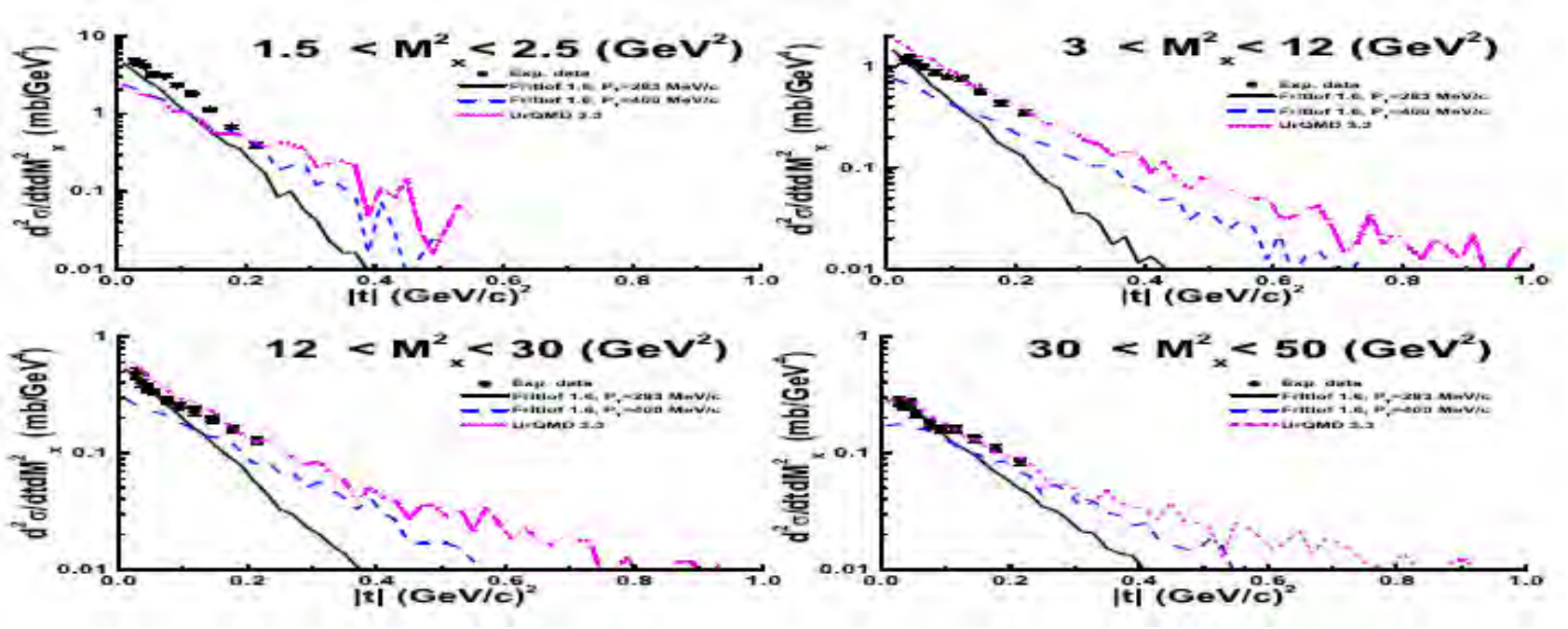
Fig. 3.19. Inclusive cross sections for the reaction pp→pX at ISR [121]

This is the triumph of the Pomeron theory

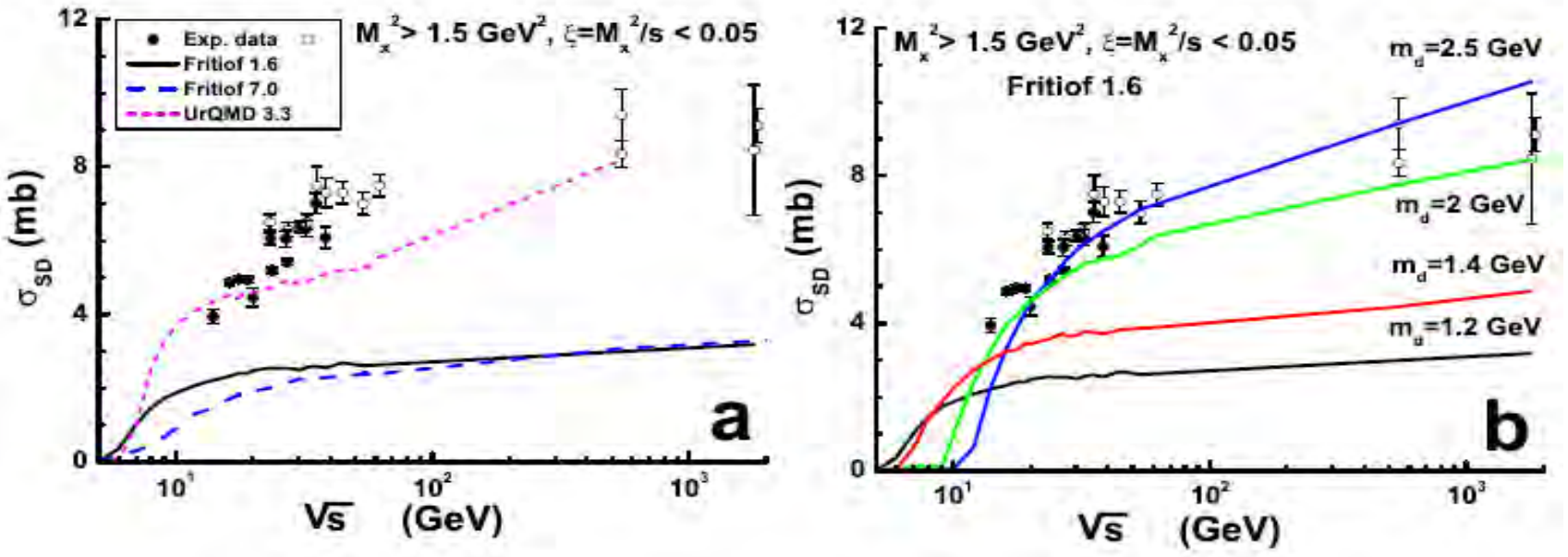
K. Goulianos and J. Montanha, Factorization and scaling in hadronic diffraction, Phys. Rev., D 59 (1999) 114017



CDF data, Solid lines -- calculations

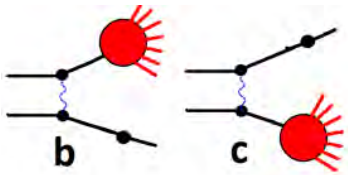


Дифракция с малыми передачами не воспроизводится в UrQMD!



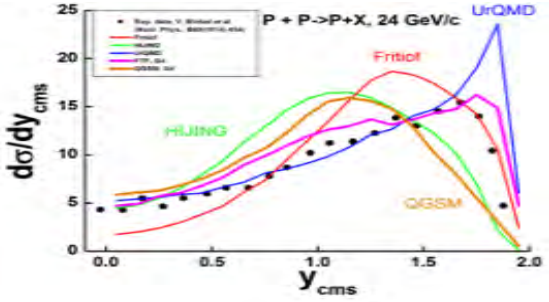
Дифракция в большие массы воспроизводится в UrQMD!

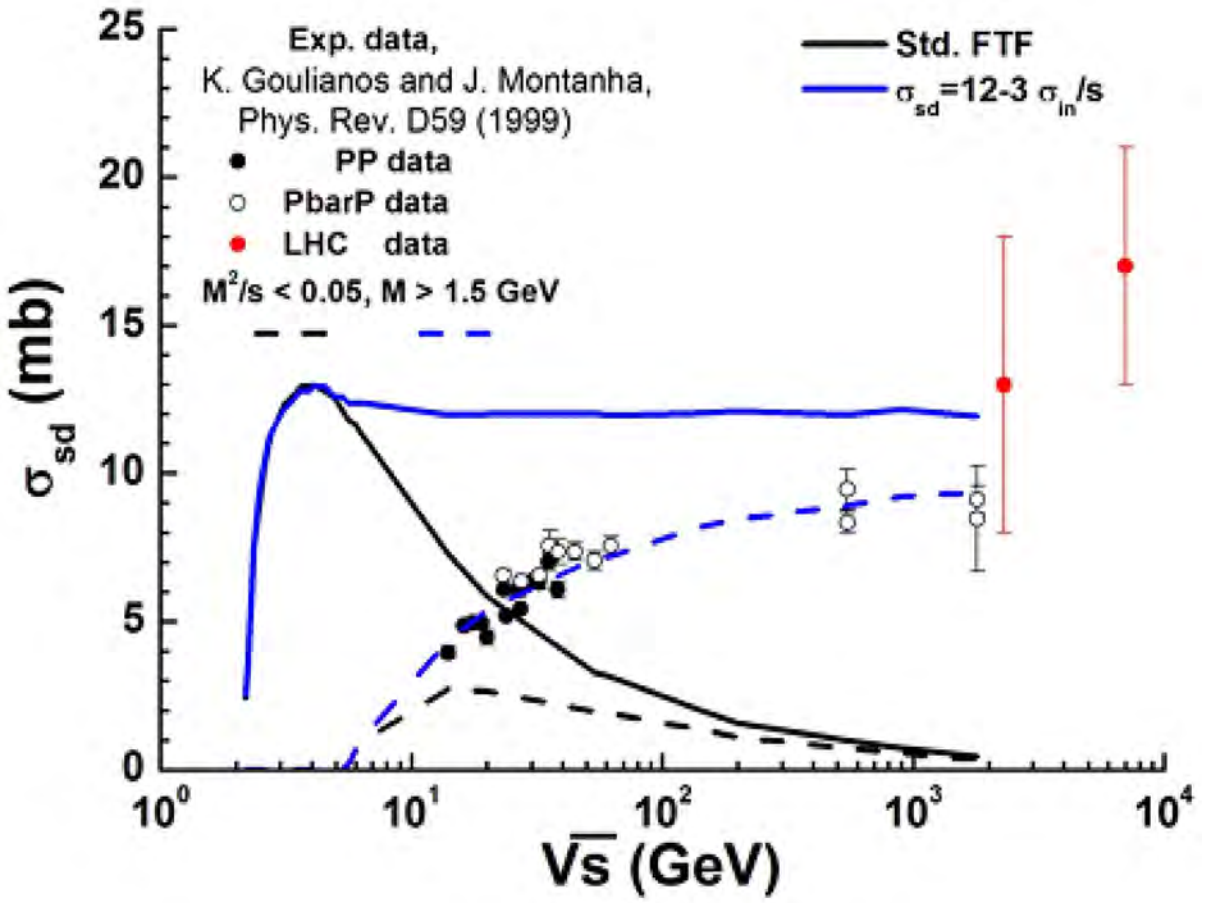
Diffraction processes in PP interactions



$$\sigma_{pp}^{pd} = \sigma_{pp}^{td} = 6 + \sigma^{in}\frac{1.5}{s} \quad (\text{mb})$$

Diffractive processes (~ 40 %) and quark exchange ones are very important at low energies (NICA)!

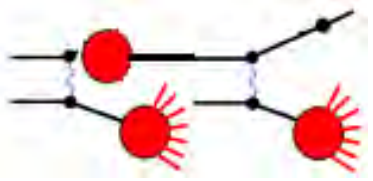




Single diffraction dissociation cross section in pp-interactions. Points are data gathered by K. Goulianos and J. Montanha [GM99]. Lines are FTF model calculations. (**Physics Reference Manual, Release 11.1 Geant4 Collaboration Rev7.0: December 9th, 2022**
https://geant4-userdoc.web.cern.ch/UsersGuides/PhysicsReferenceManual/html/index.html)

What has to be done in nucleus-nucleus interactions?

States of hadrons in FTF



Secondary Interactions?

1. Quark exchange (GS + GS, QE)
2. Quark exchange with excitation (GS + TrD or PrD + GS, QE)
3. Projectile diffractive excited (PrD)
4. Target diffractive excited (TrD)
5. Non-diffractive interactions (Str. + Std., ND)

Target/ Project.	GS	PrD	Str.
GS	Qe PrD TrD ND	PrD TrD ND	ND
TrD	PrD TrD ND	PrD TrD ND	ND
Str..	ND	ND	ND

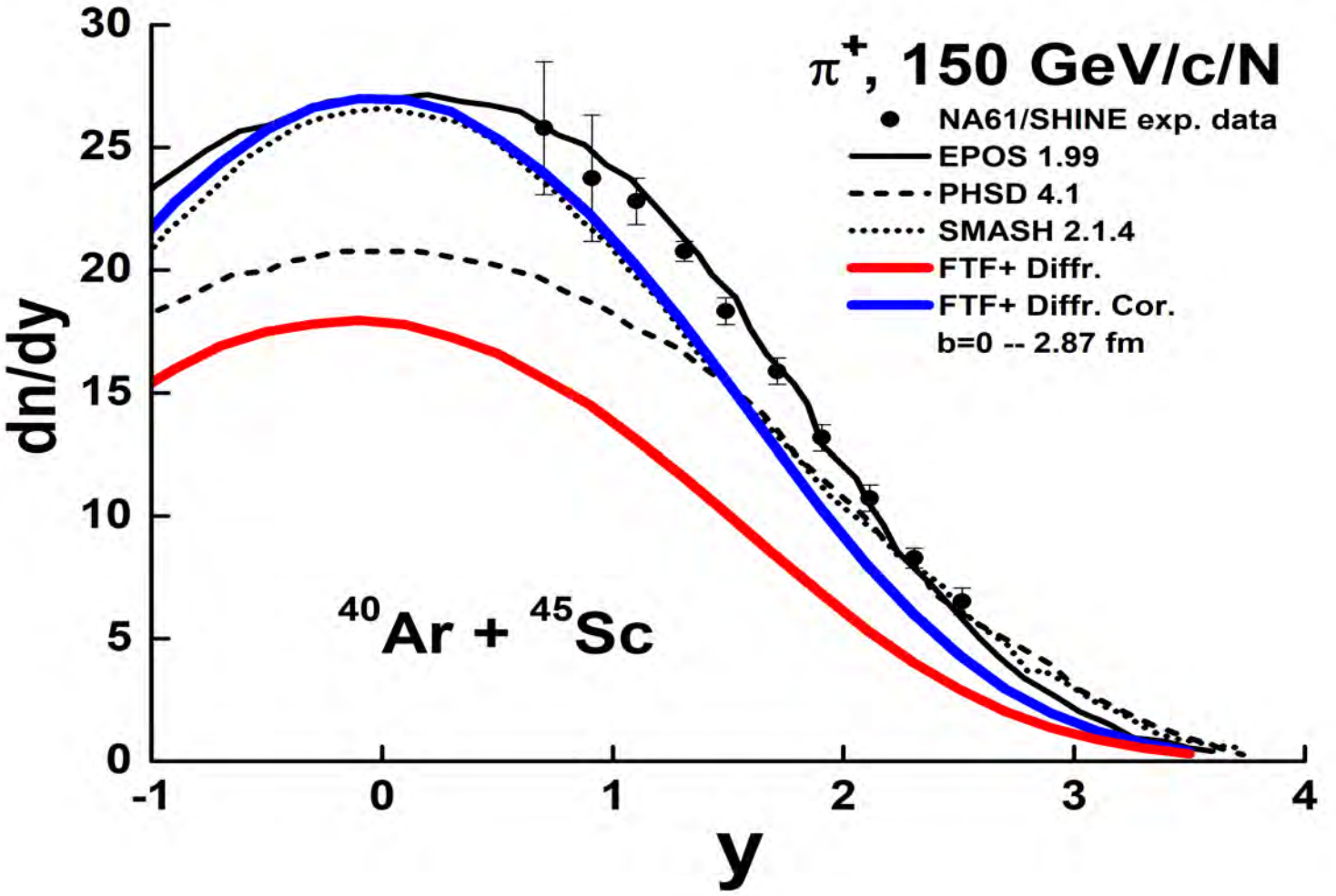
New algorithm of DD accounting

NA61/SHINE data on Ar-40 + Sc-45 and FTF model
10 % centrality. Bmax = 2.87 fm

Measurements of $\pi^{\pm}$, $K^{\pm}$, p and anti-p spectra in ^{40}Ar+^{45}Sc collisions at 13A to 150A GeV/c

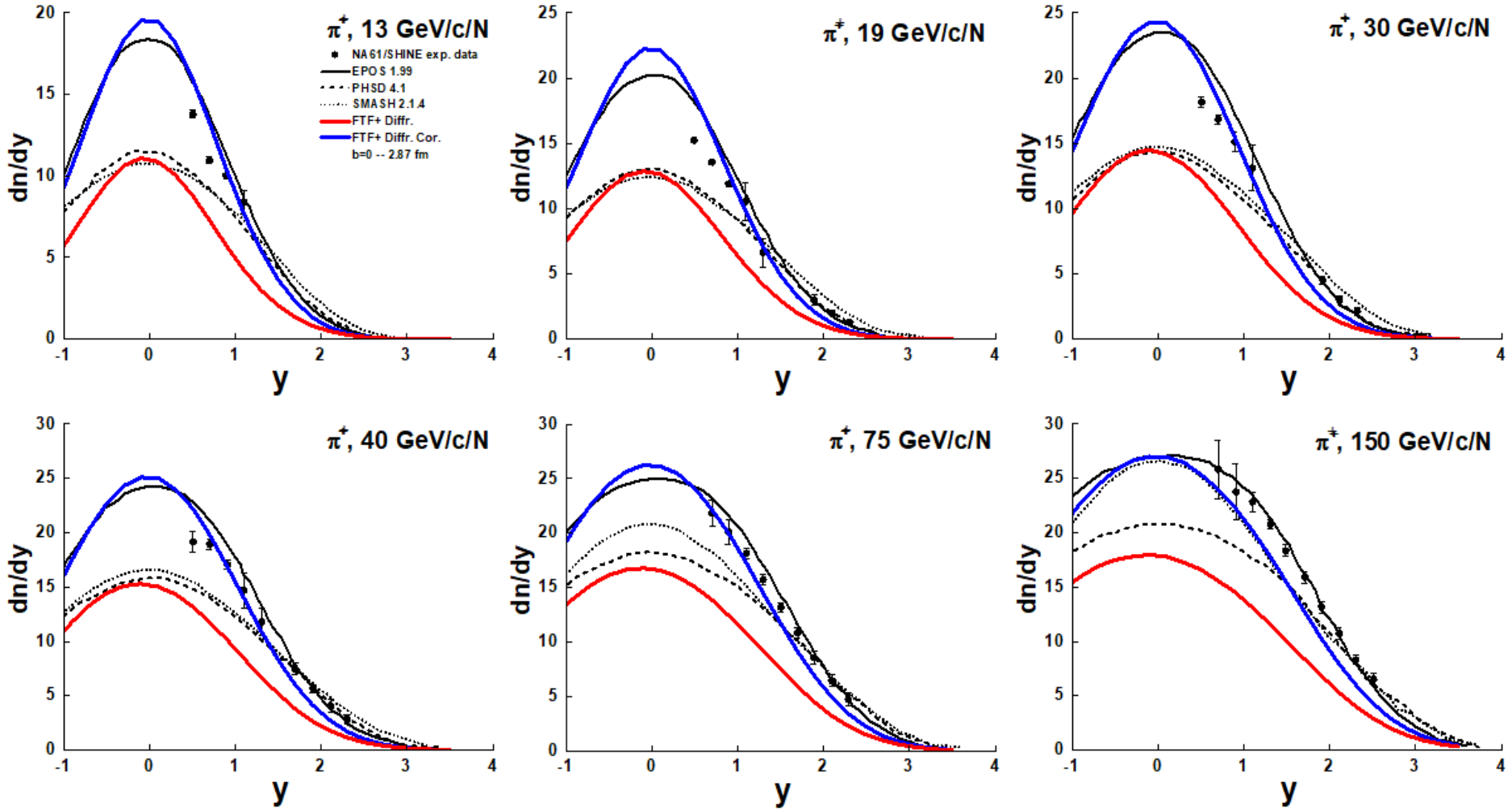
•NA61/SHINE Collaboration (H. Adhikary et al.) ***Eur. Phys. J.C* 84 (2024) 416**

These first results encouraged us!



Now we can reproduce (~) results of other model in Geant4 FTF one! It is very good!

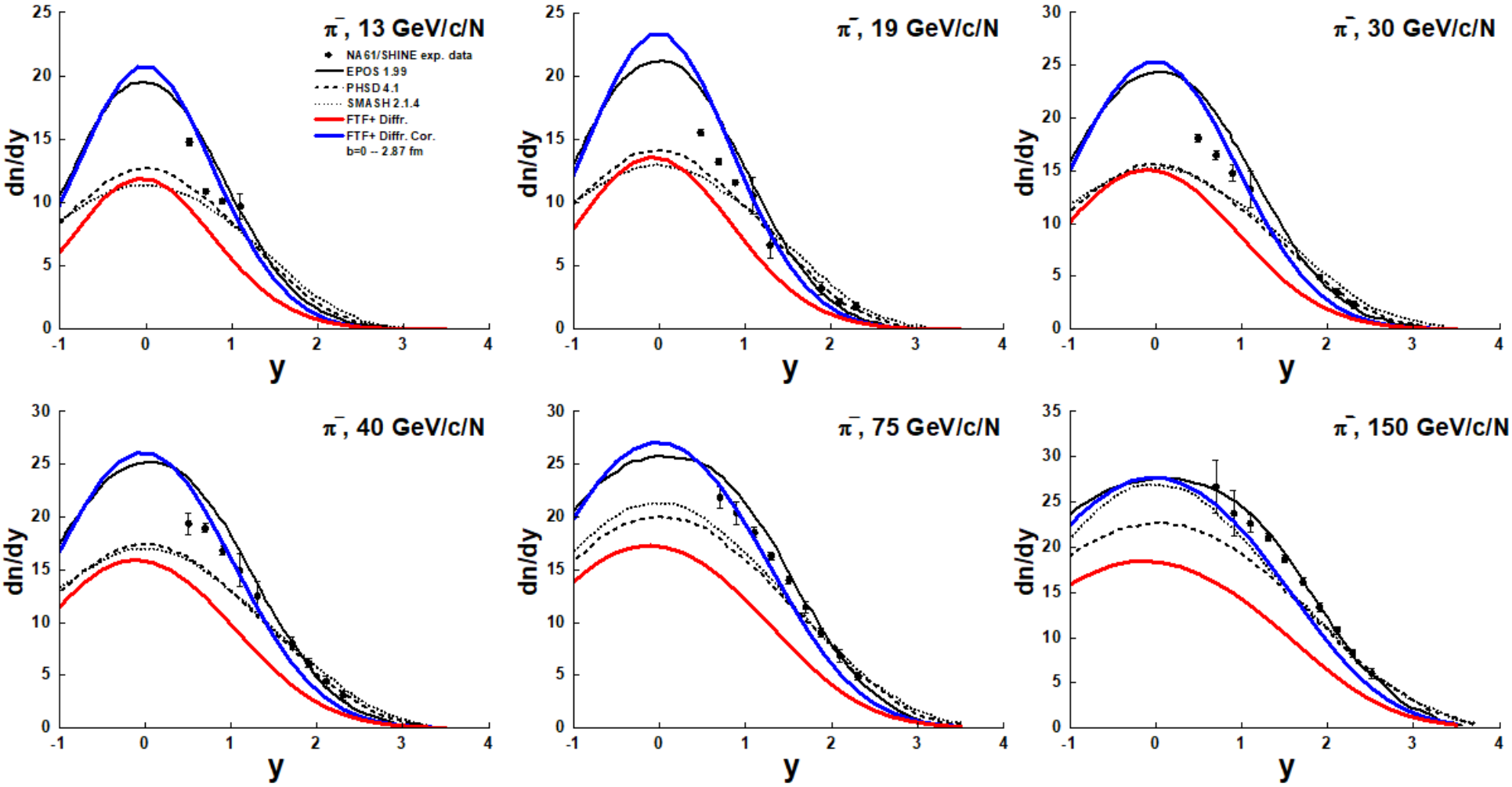
NA61/SHINE data on Ar-40 + Sc-45 and FTF model
10 % centrality. Bmax = 2.87 fm, Pi+



Now we can reproduce (~) results of other model in Geant4 FTF one! It is very good!

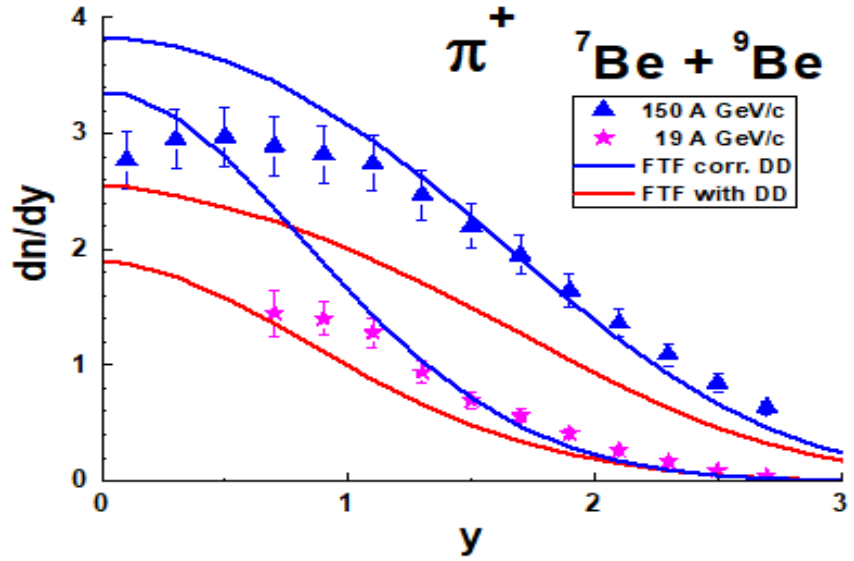
Of course, it is not good that the data do not cover the central region.

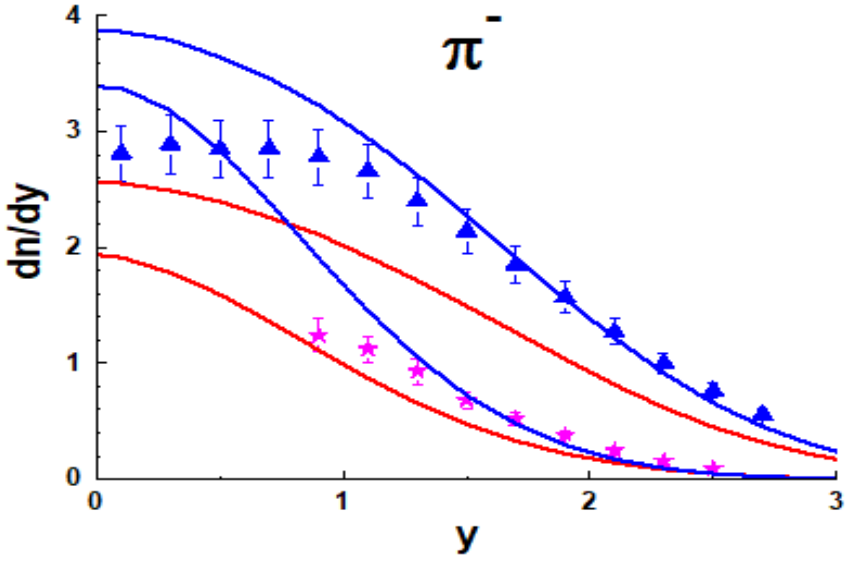
NA61/SHINE data on Ar-40 + Sc-45 and FTF model
10 % centrality. Bmax = 2.87 fm, Pi-

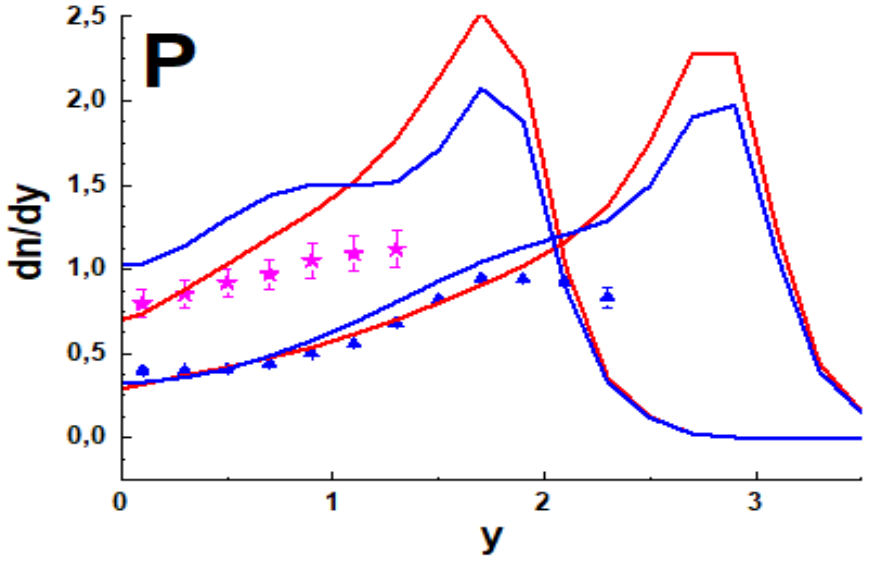


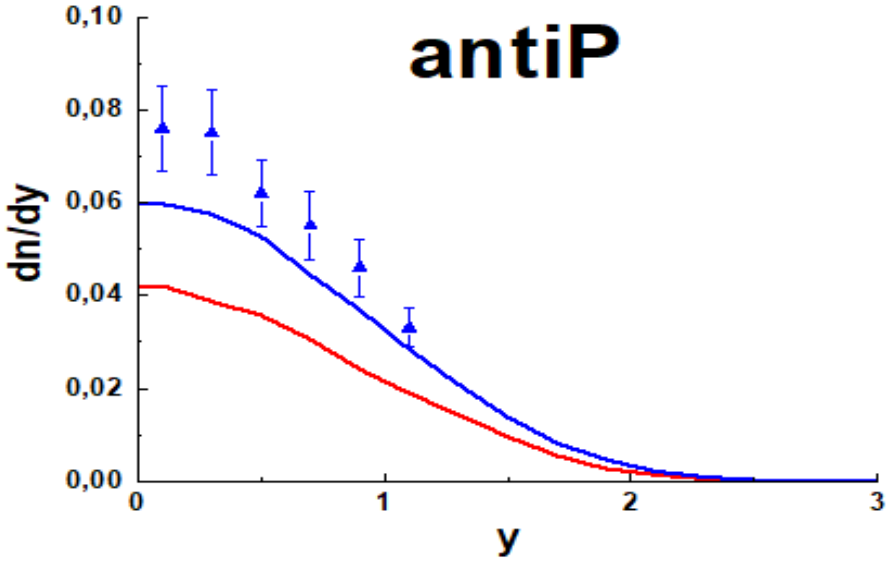
Now we can reproduce (~) results of other model in Geant4 FTF one! It is very good!

NA61/SHINE data on Be-7 + Be-9 and FTF model
20 % centrality. Bmax = 1.92 fm, Pi, Protons





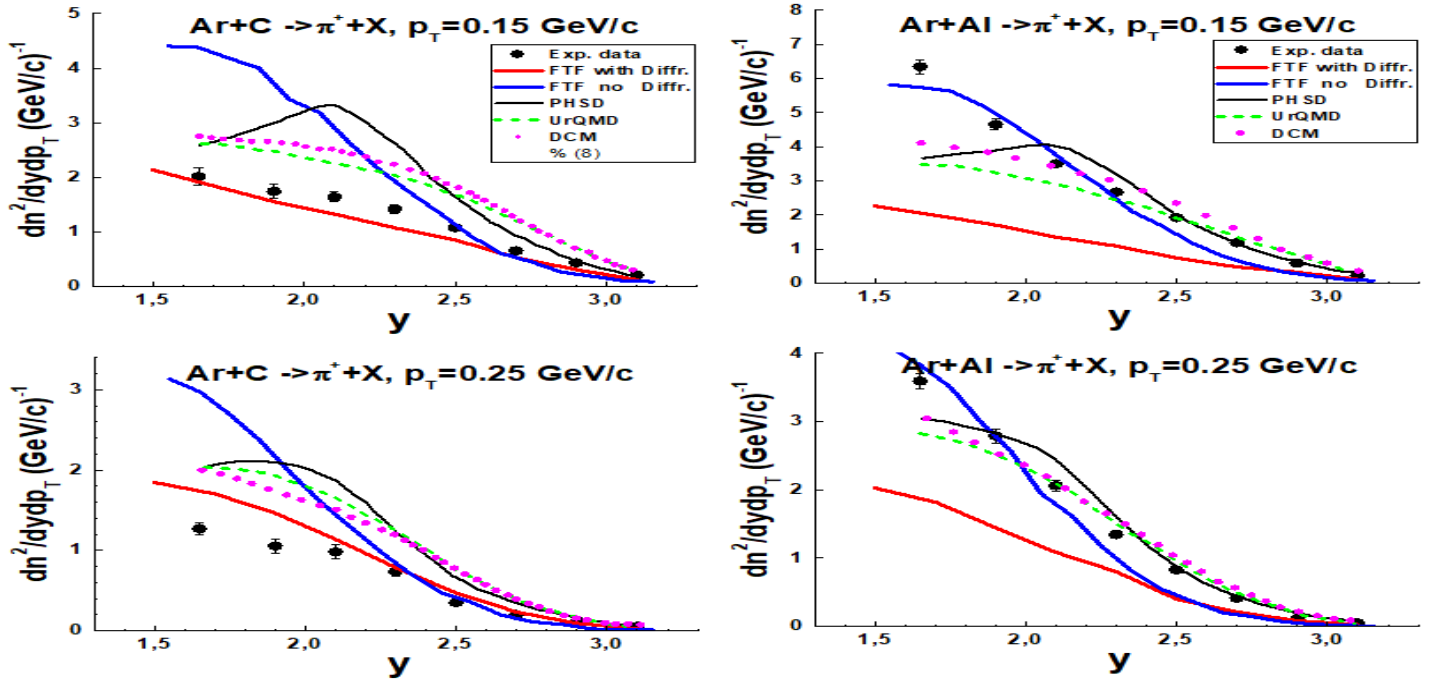




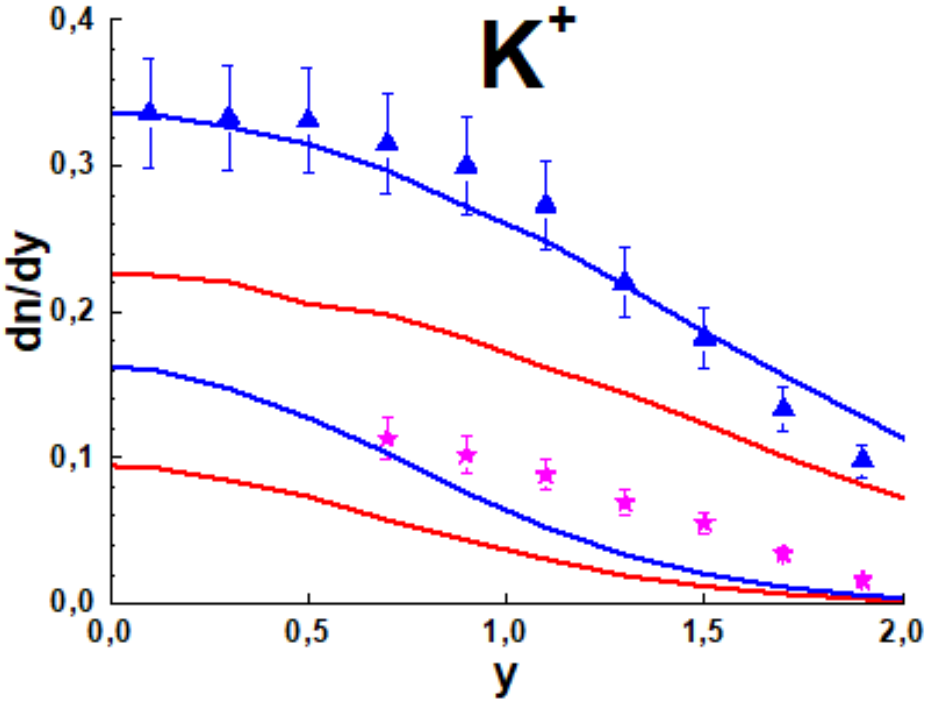
There is a space for improvement of the Geant4 FTF model.

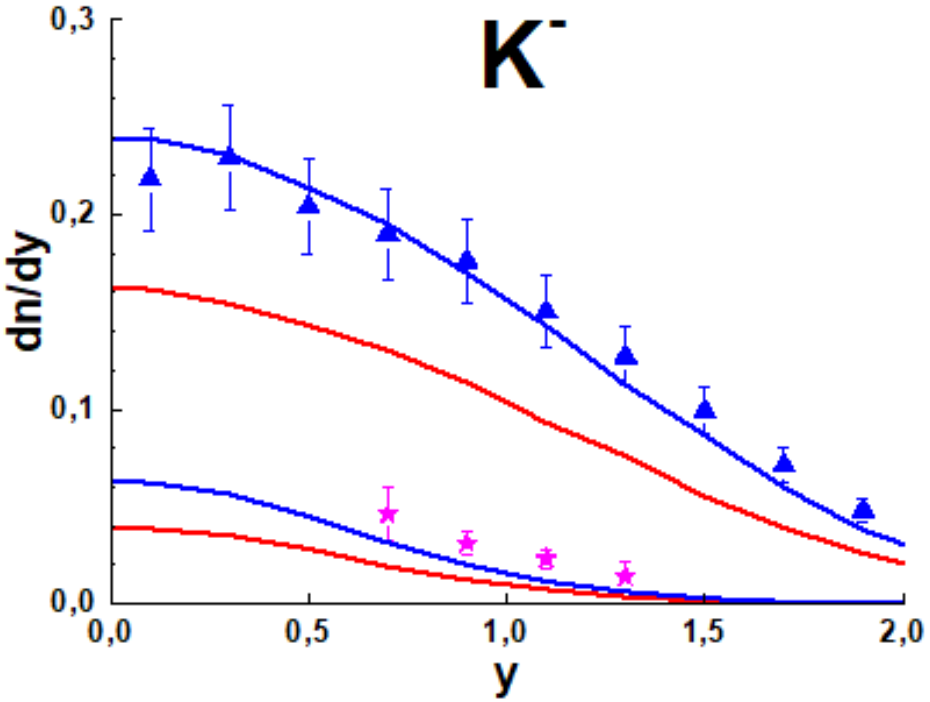
Summary

1. The new algorithm of accounting of the nuclear nucleon diffraction dissociation in nucleus-nucleus interactions has been proposed. It allows to improve FTF results.
2. Good results have been obtained for heavy nuclei.
3. There is a problem of description of interactions with light nuclei.
4. It is almost unclear, how to reach a description of K-meson production in Ar-40 + Sc-45 interactions?



NA61/SHINE data on Be-7 + Be-9 and FTF model
20 % centrality. Bmax = 1.92 fm, Pi, Protons





We hope a small tuning will be need for a description of the data!

Questions to think about

1. Model predictions for Ar + C?
2. Exp. points at y = 1.65?
3. Large scattering of model predictions for K mesons in Ar + A interactions? What about Pi- and K- (Propan)?
4. Strong leading particle effect in FTF for proton production?
5. Pauli blocking in QGSM and FTF?
6. DD and Pauli blocking in models?
7. K meson production in Ar + Sc?
8. Condensed baryonic matter?