Application of FTF model for simulations of nucleus-nucleus interactions

V. Uzhinsky, 14 Aug. 2019

1. Nuclear beams are circulating and will be circulating at RHIC, LHC, GSI and JINR. Usually, FLUKA and MARS codes are used for an ion transport in accelerator tracks. A quality of such type of simulations is unknown for me. At the same time, I know that at the LHC there is a problem with beam collimation and cleaning, especially, with erasing of beam halo. There is a hope that the problem will be solved much better than at the LHC in the Future Circular Collider. For these, a simulation of nucleus-nucleus interactions is needed.

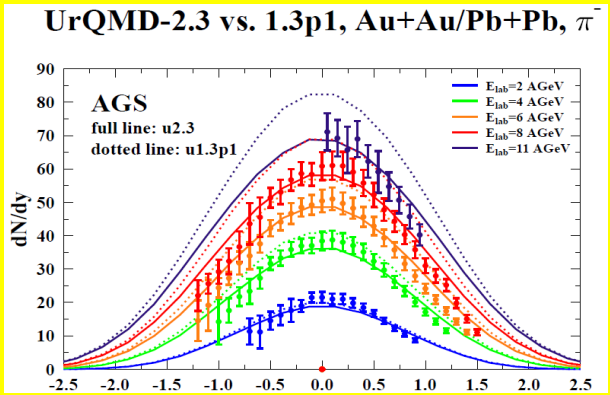
2. Experiments with nuclear beams are presented at many accelerator centers. Mainly, they are aimed on a study of the Quark-Gluon Plasma. A lot of experimental data has been collected at the moment. There is no doubt that the data contain important information about physics of nucleus-nucleus interactions. The problem is how to extract it, and what information can be useful for us?

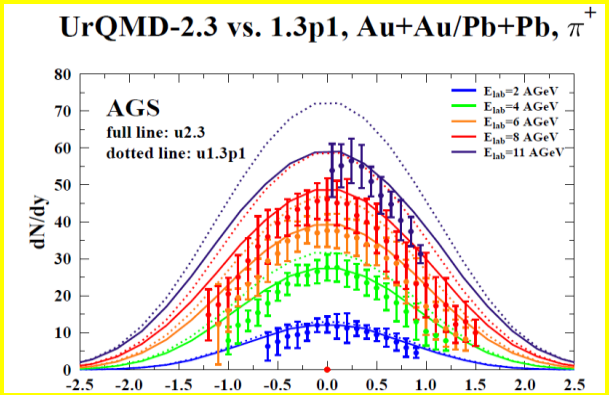
3. Nuclei are presented in cosmic rays. They produce the main damages in electronic devices restricting their time of life, and time of space missions.

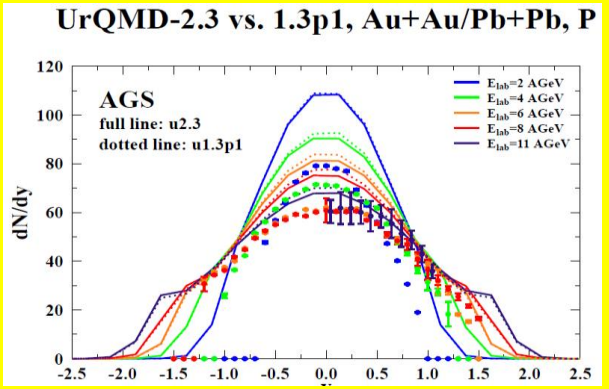
Thus it was interesting for me to study a quality of the Geant4 FTF model in application to simulations of nucleus-nucleus interactions.

There was also another aim – to look at a position of FTF model in the competition with other event generators – UrQMD, PHSD, LA QGSM, 3 fluid hydrodynamics, HIJING, AMPT and so on.

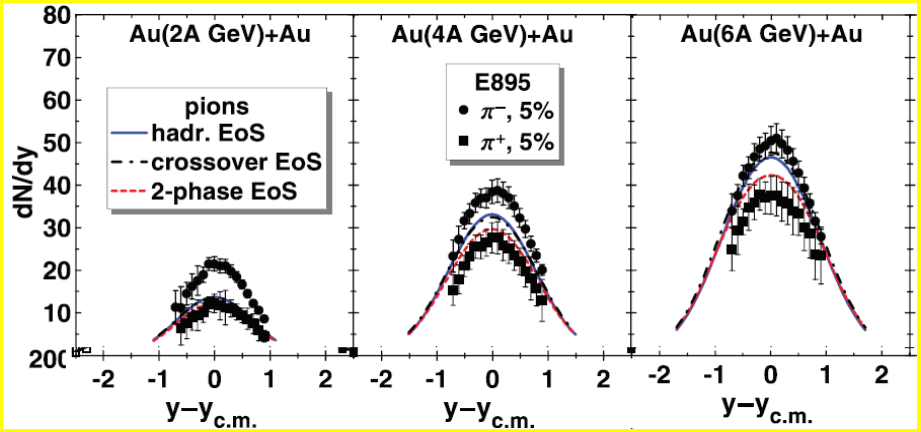
UrQMD-2.3 - Changes and Comparisons (arxiv: 0805.0567, 2008)
H. Petersen, M. Bleicher, S. A. Bass, H. Stöcker

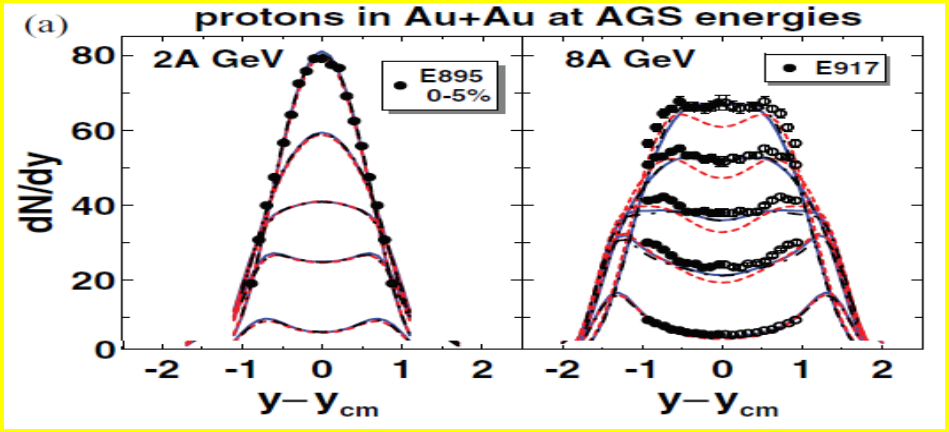






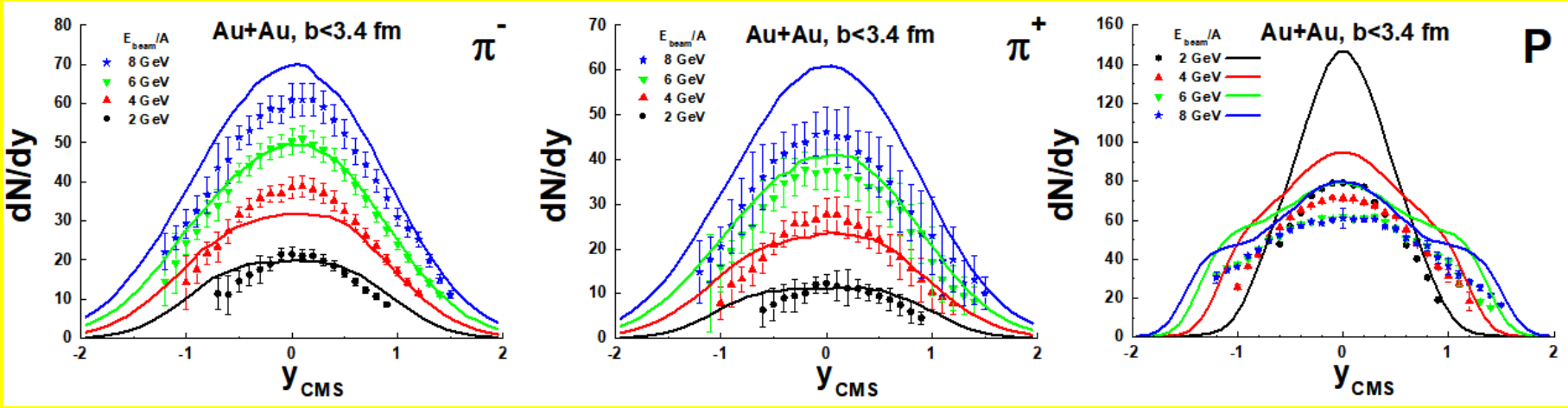
Alternative scenarios of relativistic heavy-ion collisions. II. Particle production
Yu. B. Ivanov, PRC **87**, 064905 (2013)



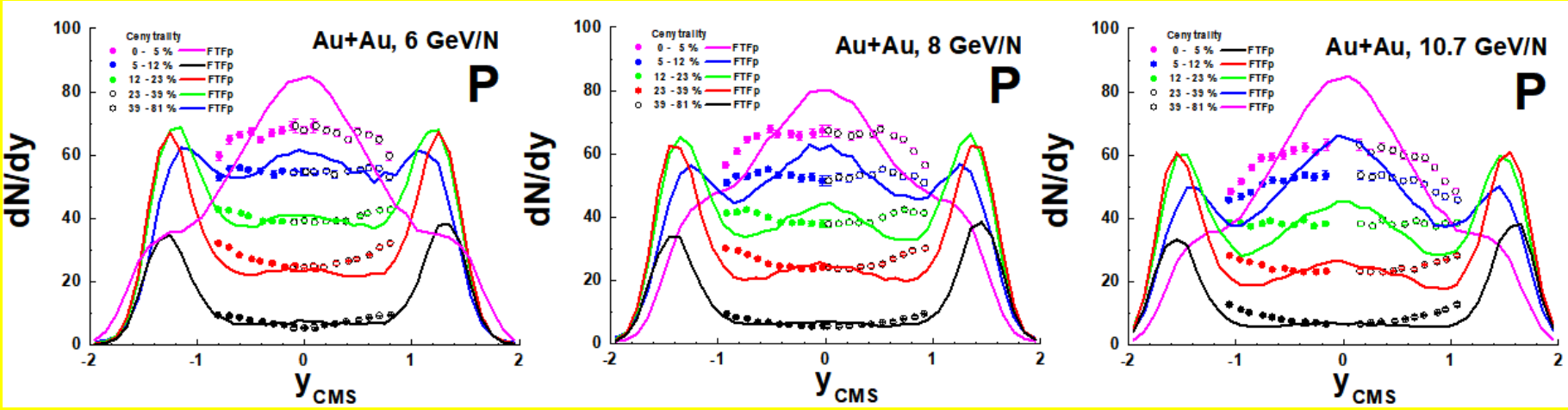


How does FTF (G4.10.5ref06) work? E895 and E917 Exp.

J. L. Klay et al., Phys. Rev C 68, 054905 (2003), Charged pion production in 2A to 8A GeV central Au+Au Collisions,
J. L. Klay et al., E895 Collaboration, Phys. Rev. Lett. 88, 102301 (2002)



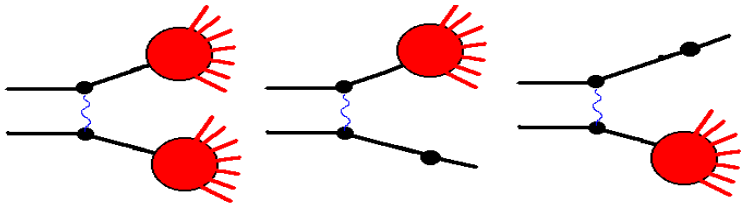
Proton emission in Au+Au collisions at 6-GeV/nucleon, 8-GeV/nucleon, and 10.8-GeV/nucleon, PRC66 , 05490 (2002), E917 Collab. (B.B. Back et al.)



Problems: Overestimation of Pi+/- mesons at highest energies and bad spectra of protons.

Changes in FTF model:

G4DiffractiveExcitation.cc -- **De-excitation of exc. Hadrons is allowed. It is very old problem of Fritiof.**



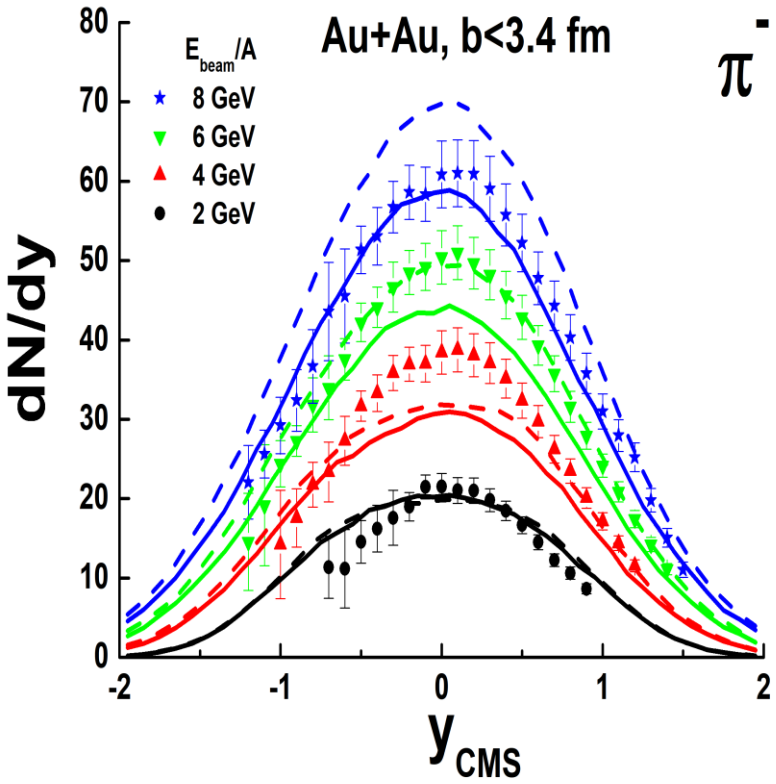
G4ElasticHNScattering.cc -- **More simple and more correct algorithm. It makes proton spectra symmetric in CMS.**

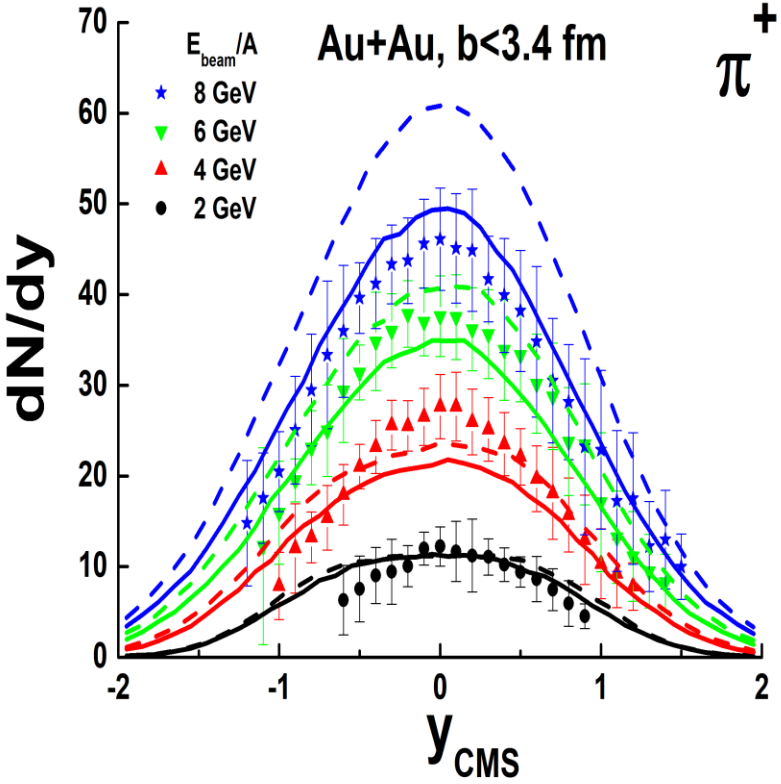
G4FTFParticipants.cc -- **Sampling of impact parameter in pre-defined range is allowed (temporary) for simulations with various centralities.**

G4FTFParameters.cc -- **E* = 0 to protect crush in G4ExcitatioHandler. I believe it is happened due to huge E*. It is needed to improve the calculation of E*.**

Results of the improvements for E895 exp.

J. L. Klay et al., Phys. Rev C 68, 054905 (2003)
Charged pion production in 2A to 8A GeV central Au+Au Collisions,

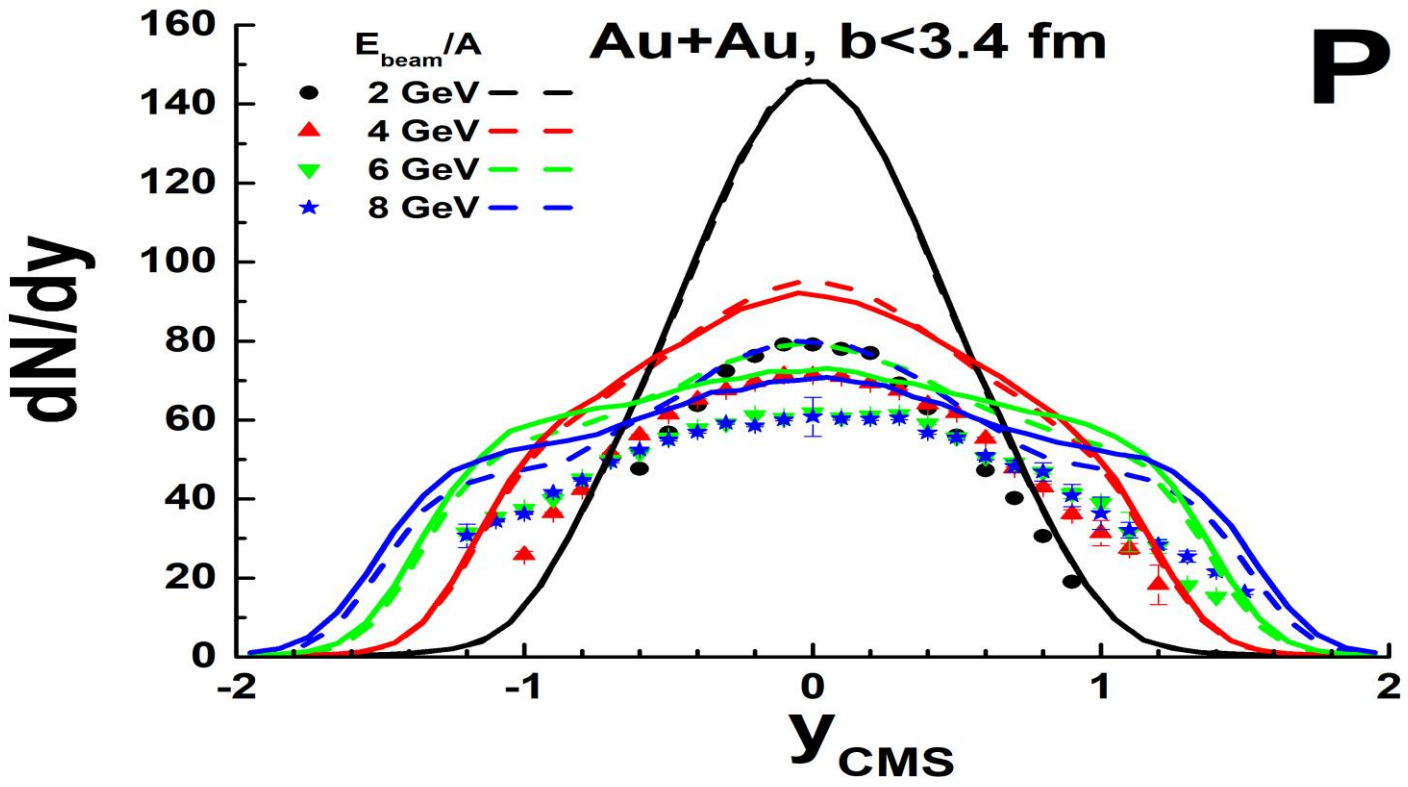




Dashed lines are previous calculations, solid ones – current results.

Results become better for high energies, T > 6 GeV.

Results of the improvements for E895 exp.

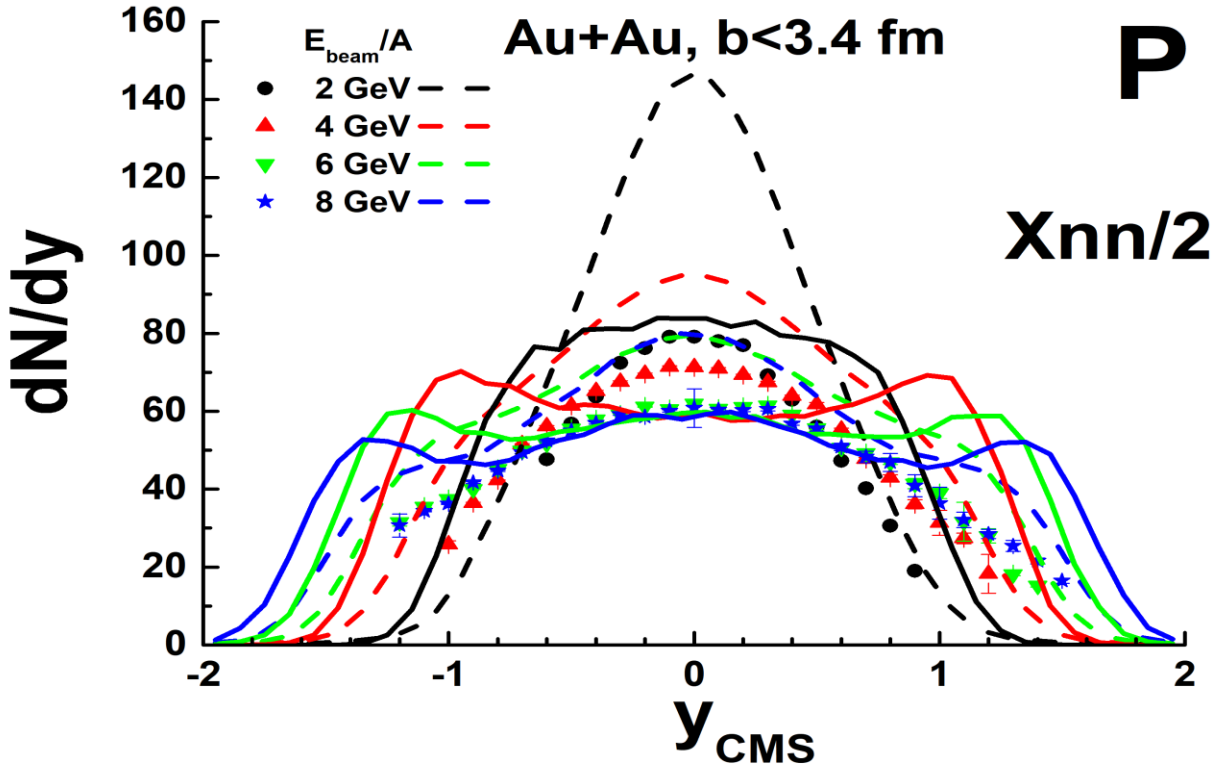


Dashed lines are previous calculations, solid ones – current results.

It is too early to make a conclusion. Exp. data are problematic.

Results of the improvements for E895 exp.

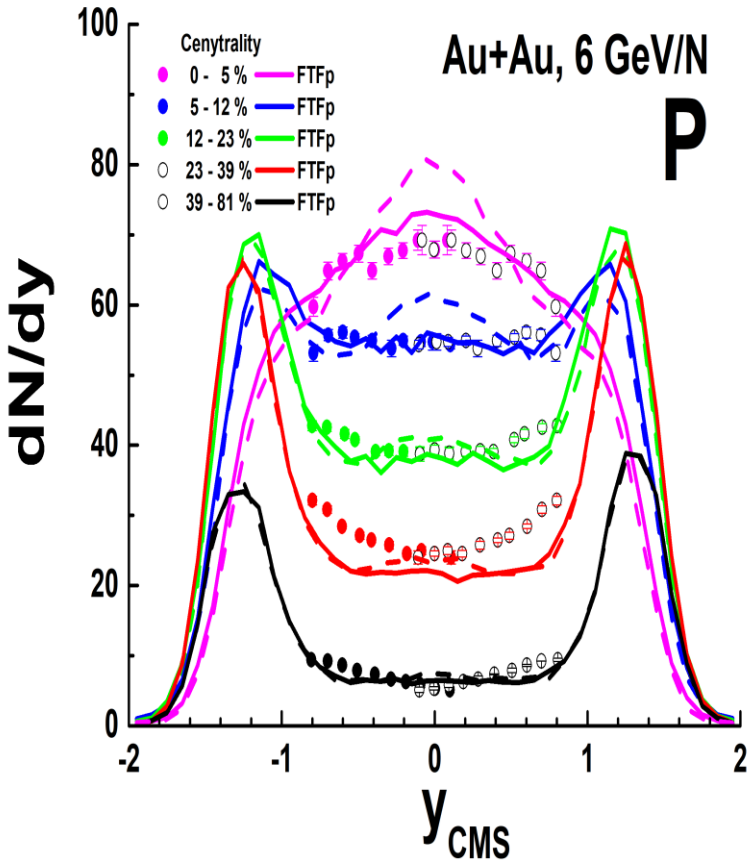
One of the possibilities to improve the results: Decrease interaction radius.

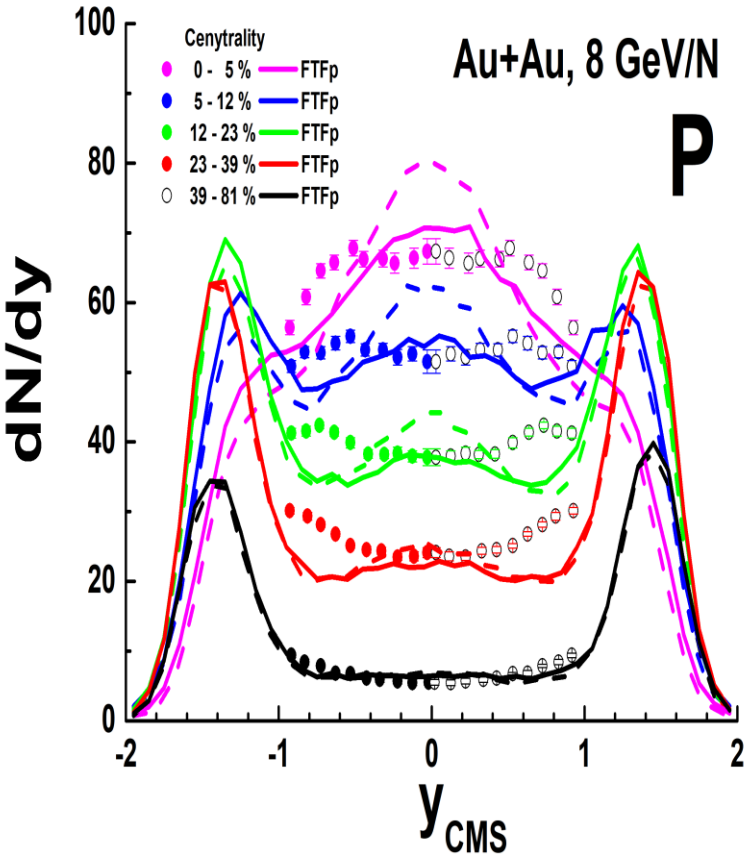


Dashed lines are previous calculations, solid ones – current results.

Results of the improvements for E917 exp.

Proton emission in Au+Au collisions at 6-GeV/nucleon, 8-GeV/nucleon, and 10.8-GeV/nucleon, PRC66 , 05490 (2002), E917 Collab. (B.B. Back et al.)





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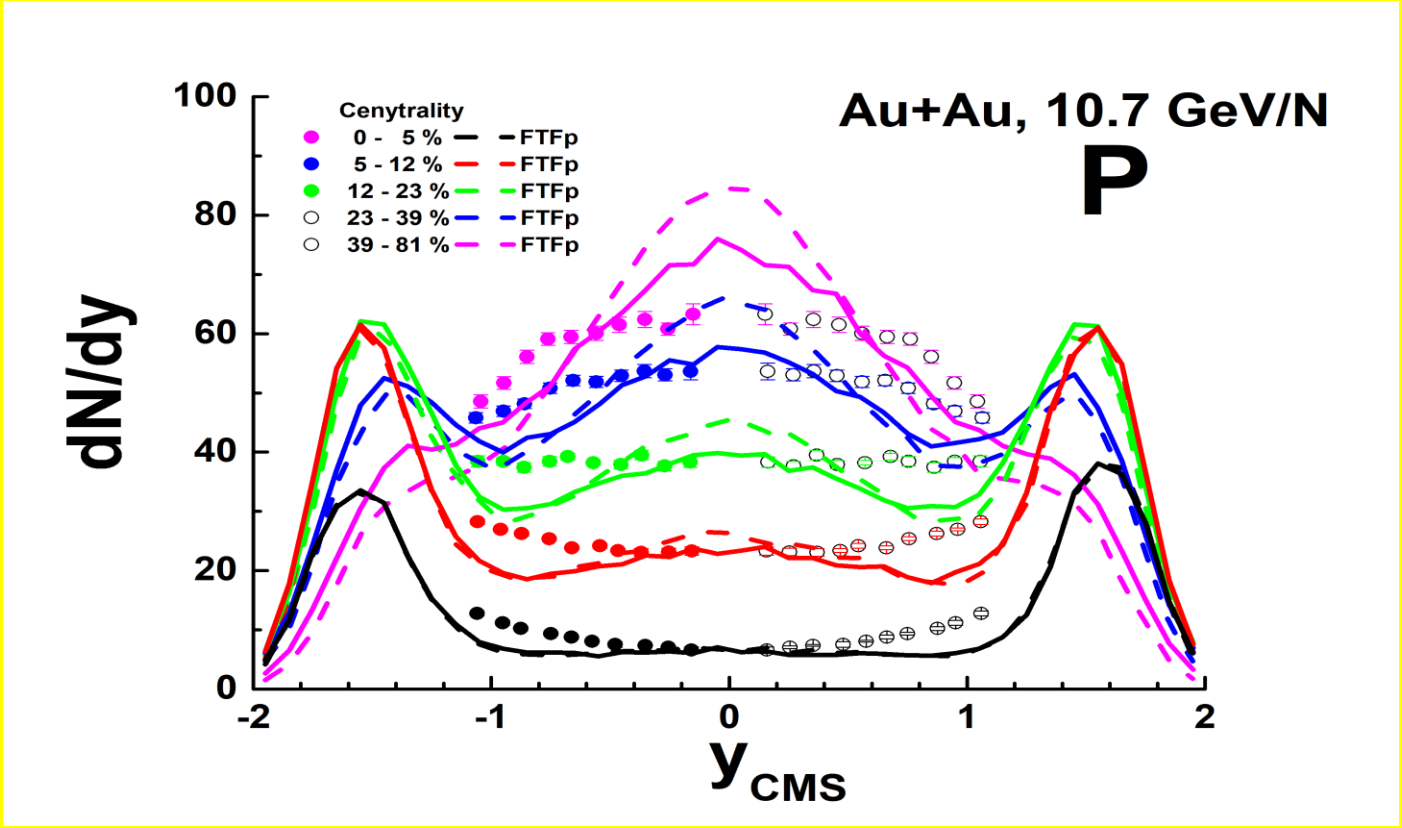


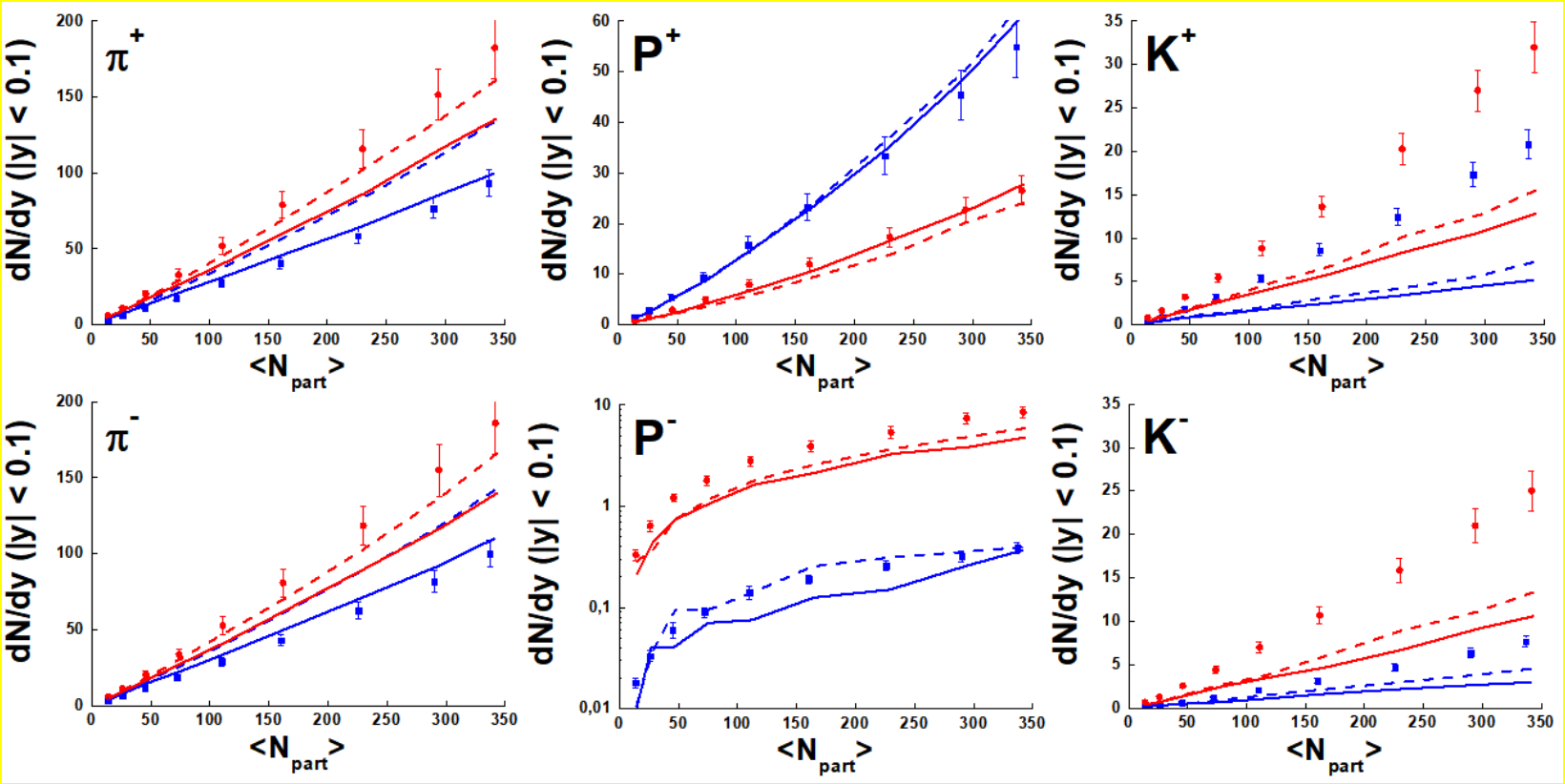
Dashed lines are previous calculations, solid ones – current results.

There is a problem for most central interactions.
A source of the disagreement at |y| ~ 0.5 – 1 is unknown!

Results of the improvements for BES of RHIC

Bulk properties of the medium produced in relativistic heavy-ion collisions from the beam energy scan program, PRC **96**, 044904 (2017)

STAR Collaboration (L. Adamczyk et al.) Ecms= 7.7, 11.5, 19.6, 27, and 39 GeV



New FTF: Pi+, Pi-, P – OK at 7.7 GeV; Pi+ and Pi- underestimated at 39 GeV. Old FTF: Pi+ and Pi- overestimated at 7.7 GeV; OK at 39 GeV.

Results of the improvements for BES of RHIC

Bulk properties of the medium produced in relativistic heavy-ion collisions from the beam energy scan program, PRC **96**, 044904 (2017)

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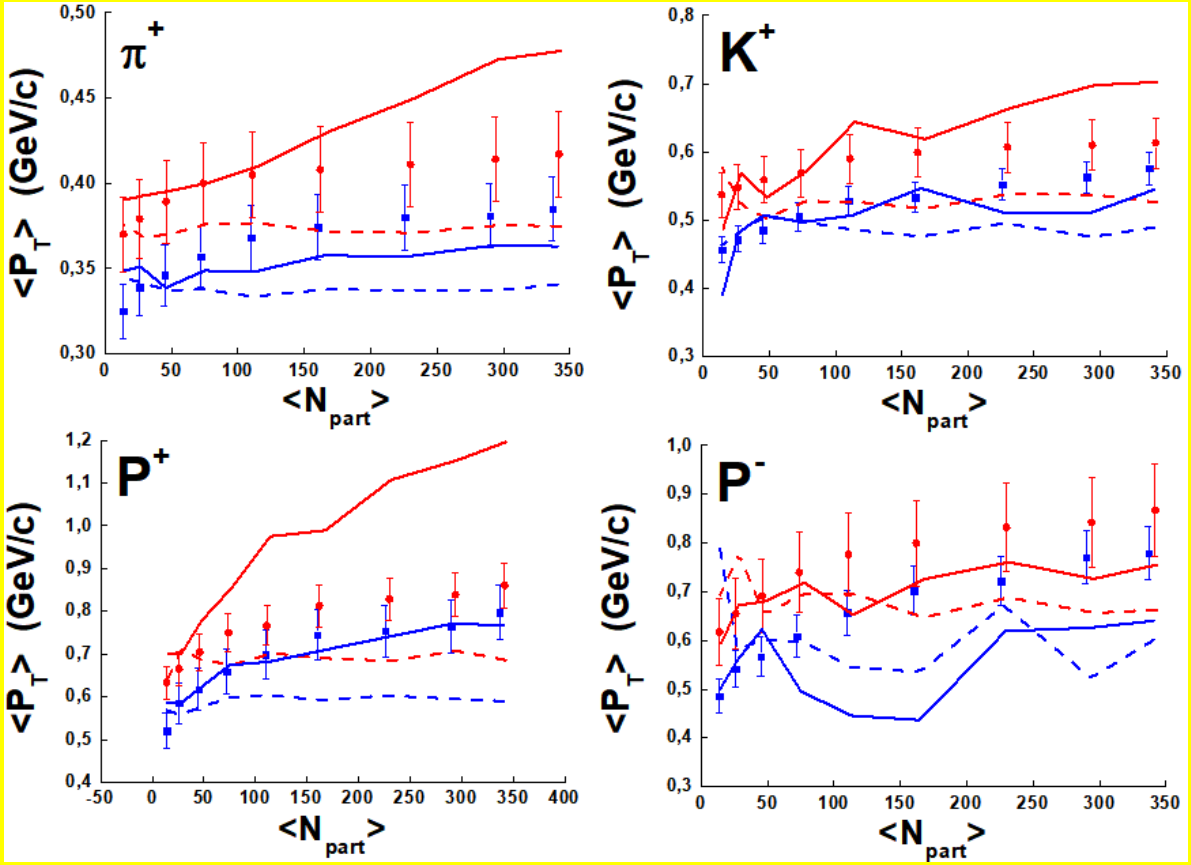


New FTF: All OK at 7.7 GeV; too large PT of protons at 39 GeV. Old FTF: too small Pt.

Results of the improvements for NA49 exp. Pb+Pb

Pion and kaon production in central Pb + Pb collisions at 20-A and 30-A-GeV: Evidence for the onset of deconfinement,

NA49 Collaboration (C. Alt *et al.*). **Phys.Rev. C77 (2008) 024903**

UrQMD-2.3 vs. 1.3p1, Au+Au/Pb+Pb, π^-

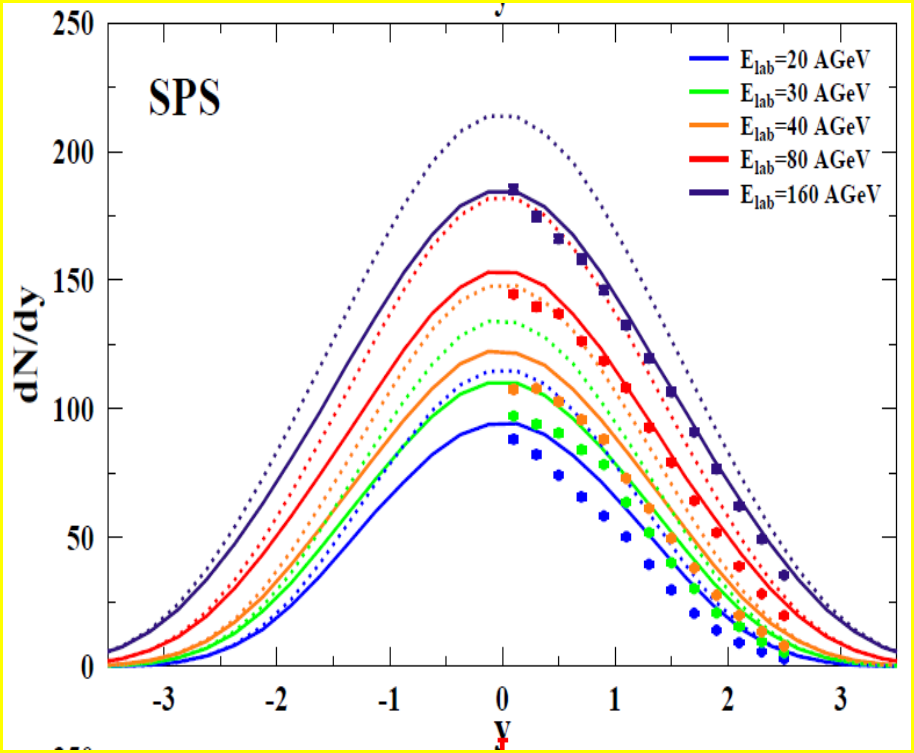
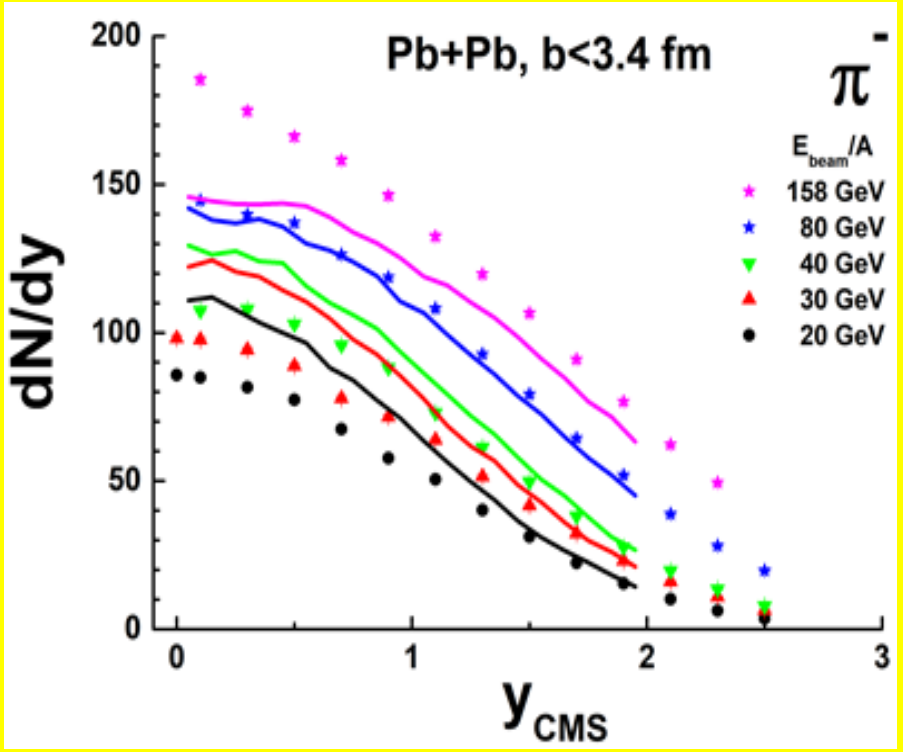


FIG. 12: (Color online) Rapidity spectra of π^- for central ($b < 3.4$ fm) Au+Au/Pb+Pb collisions from $E_{\rm lab} = 2$ AGeV to $\sqrt{s_{NN}} = 200$ GeV. UrQMD-2.3 calculations are depicted with full lines, while UrQMD-1.3p1 calculations are depicted with dotted lines.

FTF model



??????

Maybe centrality determination at the experiment (0 – 7 %) was not correct.

Results of the improvements for NA49 exp. Pb+Pb

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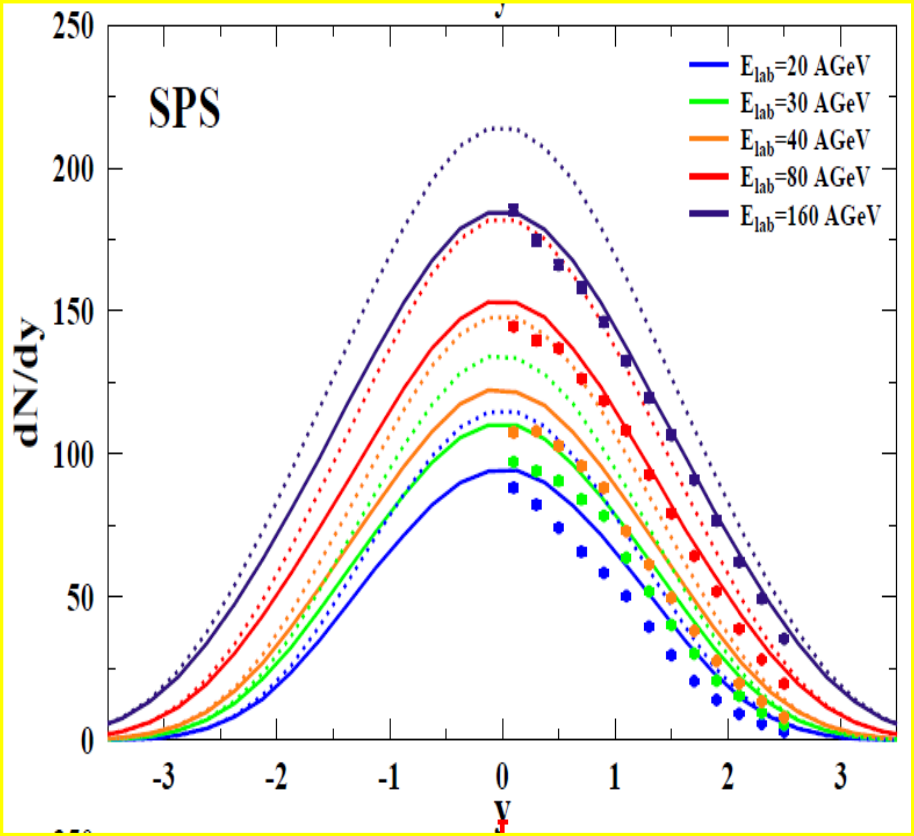
NA49 Collaboration (C. Alt *et al.*). **Phys.Rev. C77 (2008) 024903**

UrQMD-2.3 vs. 1.3p1, Au+Au/Pb+Pb, π^-



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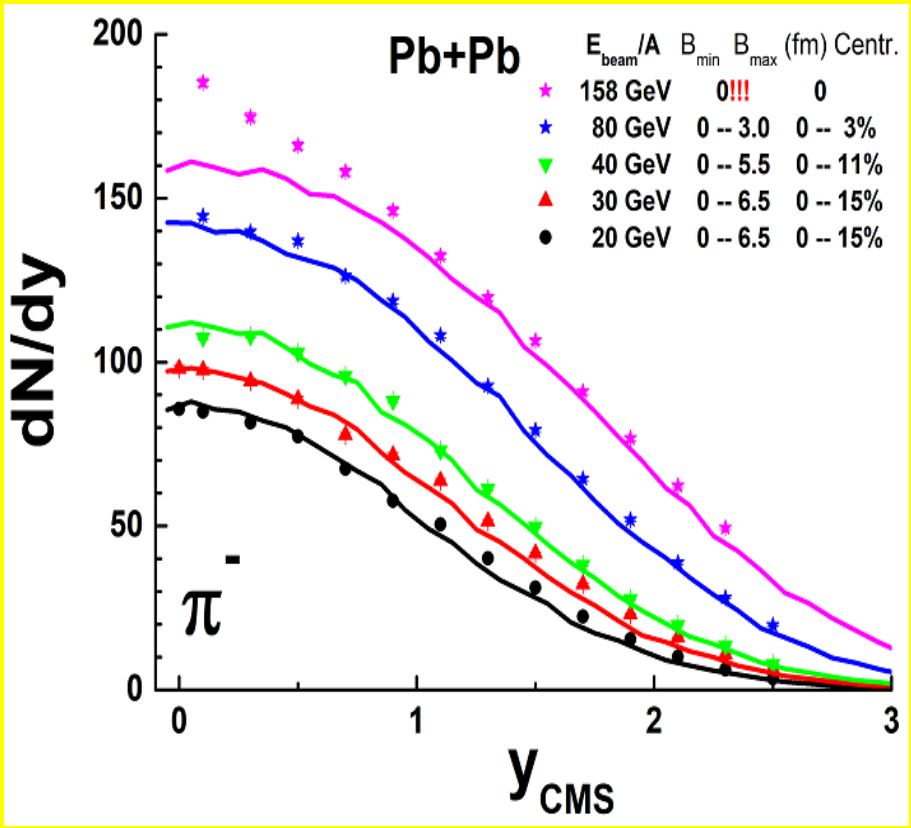


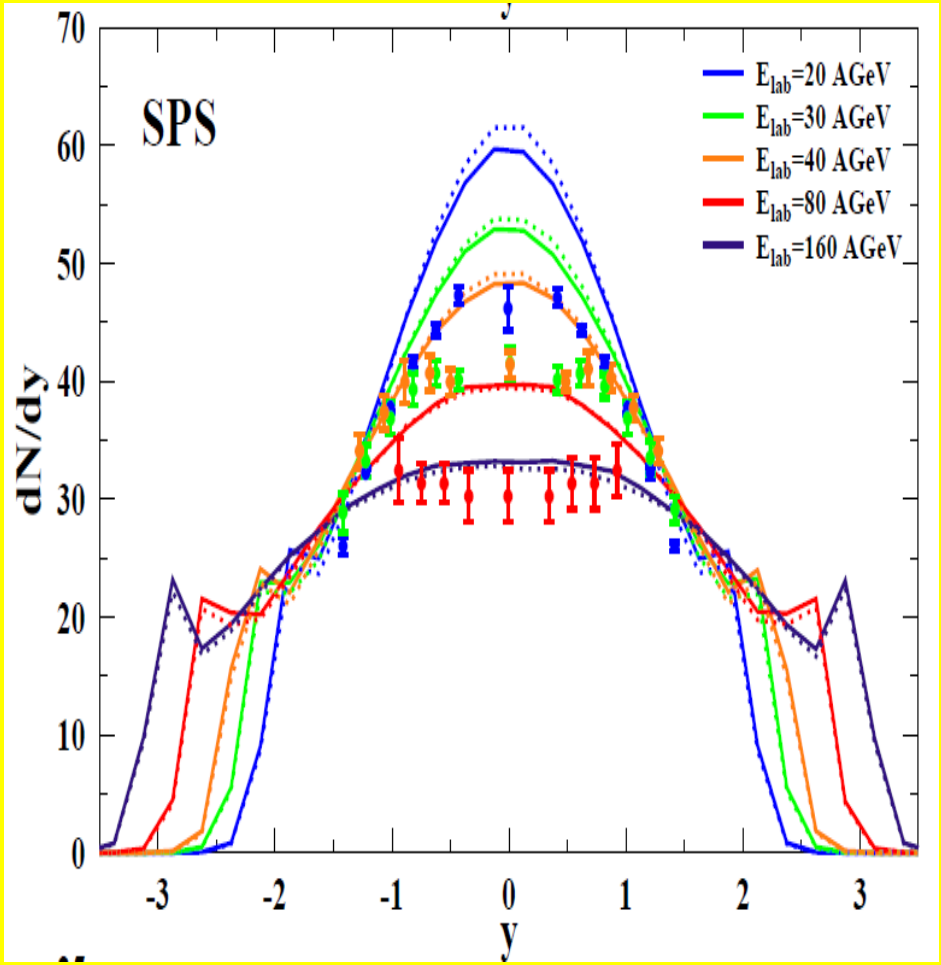
O.K.

It is unclear from exp. paper, how was the centrality determined?

Results of the improvements for NA49 exp. Pb+Pb

UrQMD-2.3 vs. 1.3p1, Au+Au/Pb+Pb, P

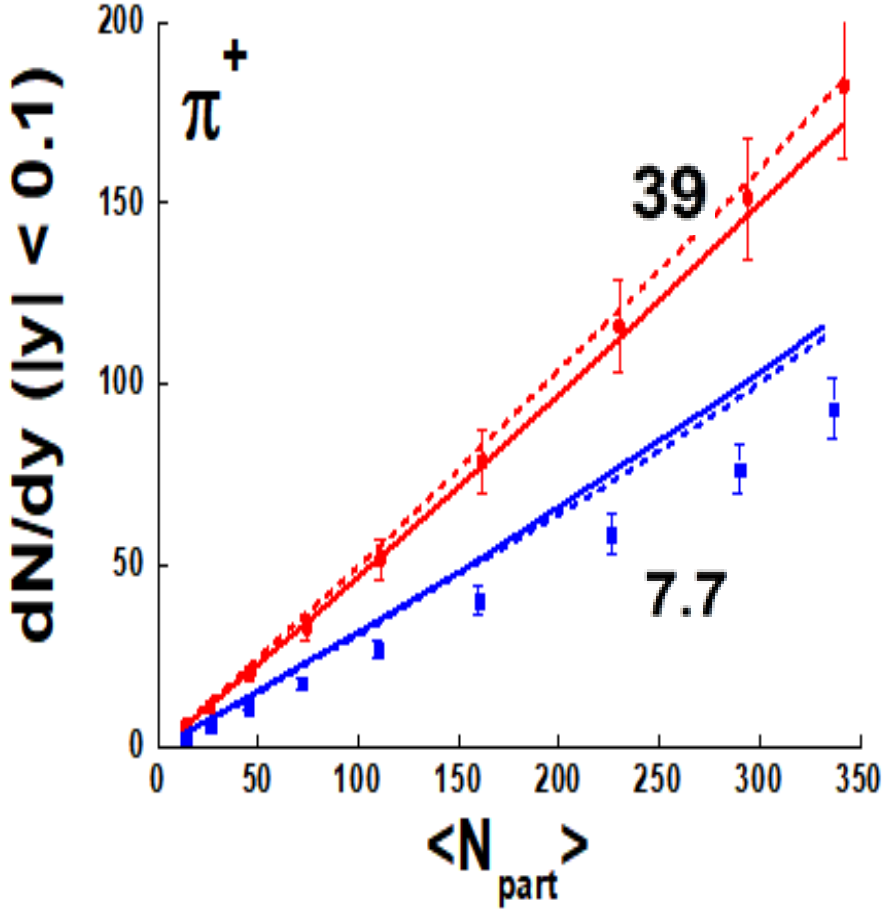
FTF model

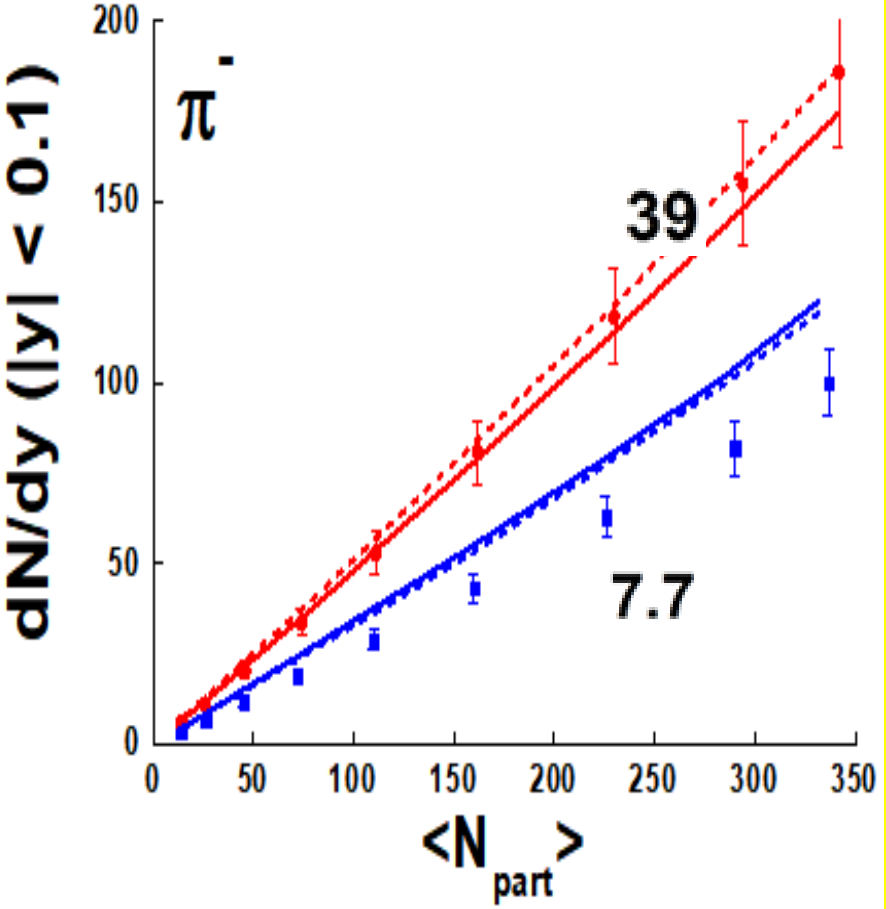


?

Exp. data are not collected by me.

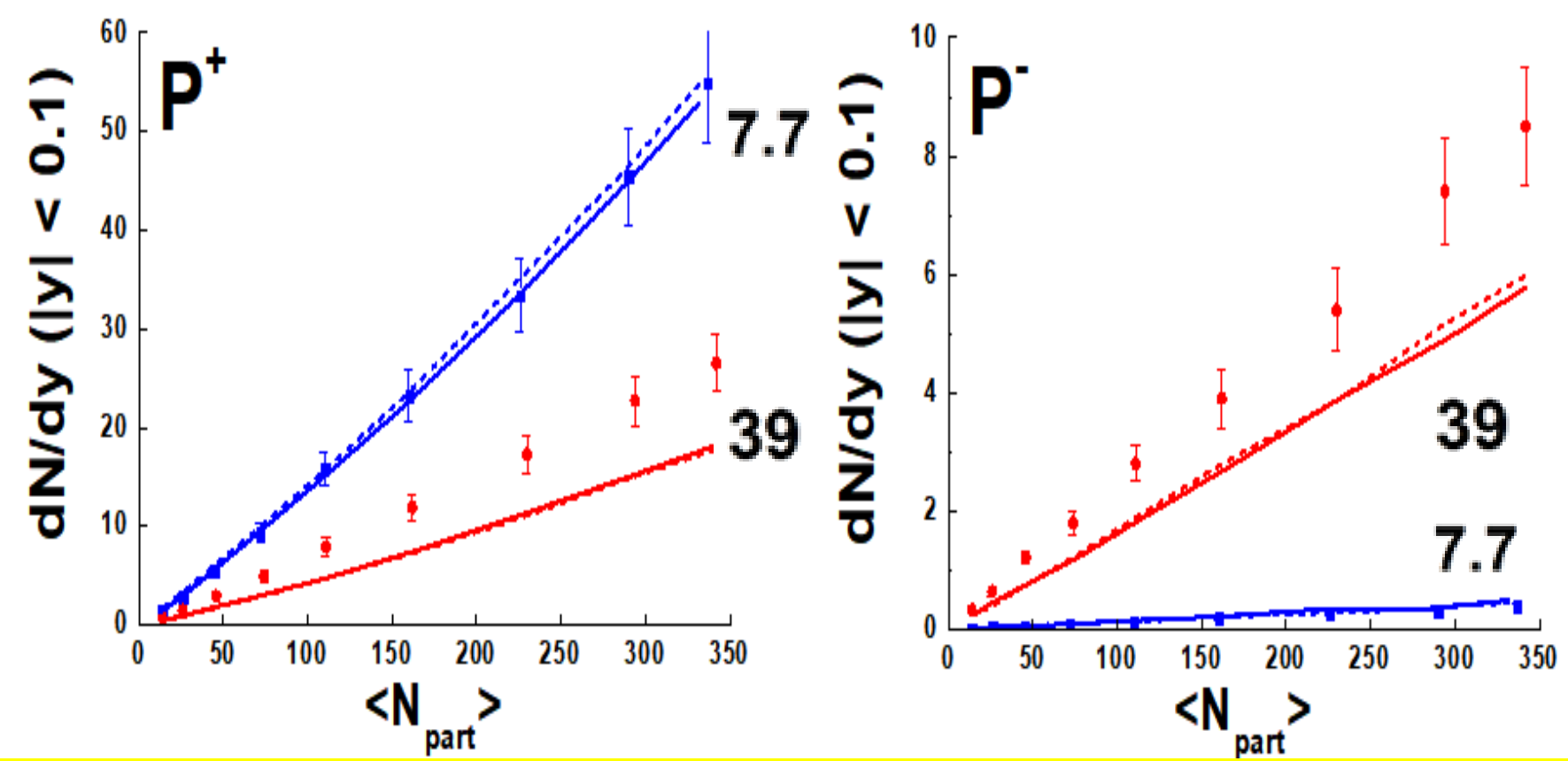
I spend 2 months trying to adjust HIJING model.
HIJING results for BES of RHIC





Red points and lines are exp. data and HIJING calculations at Ecms=39 GeV.
Blue points and lines are exp. data and HIJING calculations at Ecms= 7.6 GeV.

I spend 2 months trying to adjust HIJING model.
HIJING results for BES of RHIC



HIJING underestimates baryon production in the central region.

All in vain! It was too complicated to improve the HIJING.

Conclusion

The FTF model with small improvements gives realistic results for nucleus-nucleus interactions. Though, more detailed verification is needed.

It would be well to improve the algorithm of residual nucleus excitation energy calculation in FTF model!

We can recommend users to apply FTF model for simulation of nucleus-nucleus interactions!

It would be well to check the binary model for low energy nucleus-nucleus reactions.
Maybe, it will be useful to create the corresponding Physics List.

Maybe, it will be well to give a user a possibility to restrict impact parameter sampling for simulations of nucleus-nucleus interactions with various centralities.

In general, inclusion of QGP and hard interactions is desirable!