

Recent development of FTF model, and validation of FTFP and BERT models

V. Uzhinsky, 25 July 2017

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Smearing of resonance masses

From: Johan Messchendorp [j.g.messchendorp@rug.nl]

Sent: 24 May 2017 14:00

To: Makoto Asai; verderi@in2p3.fr; Alberto Ribon; dwright@slac.stanford.edu

Cc: Vladimir Uzhinsky; Galoyan Aida; Karin Schöning

Subject: Request from the Panda collaboration

Dear members of the Geant4 Collaboration,

The PANDA experiment aims to harvest data in the fields of hadron spectroscopy (especially, search for gluonic excitations, charmonium spectroscopy, D meson spectroscopy, baryon spectroscopy), hadrons in matter (medium modifications of hadrons embedded in hadronic matter), hypernuclei, and nucleon structure. To reach our physics goals, a measurement of the properties of hadronic resonances is of vital importance. The corresponding setups and physics performances are now under investigation using the Geant4 toolkit, especially, the QGSP-BERT physics list.

By running Monte Carlo simulations, we observed that Geant4 produces resonances with no width, which for our studies can be problematic. It would be desirable for us to take properly into account the Breit-Wigner mass distributions of the various resonances, thereby accounting for the natural width of the states, while respecting momentum and energy conservation. We, therefore, like to ask you whether you could implement such a "smearing" scenario in Geant4. This would be highly appreciated by our physics working groups.

More information about our experiment can be found at

<http://www.fair-center.eu/public/experiment-program/antiproton-physics/panda.html>

<https://panda.gsi.de/>

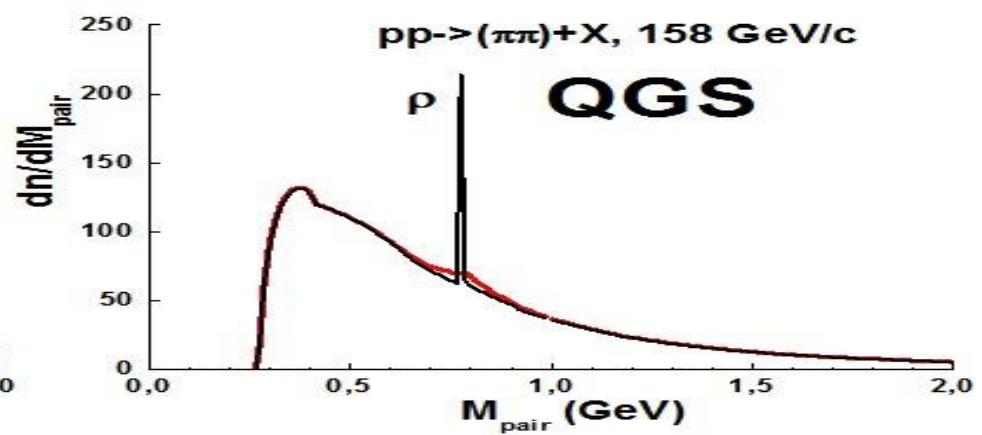
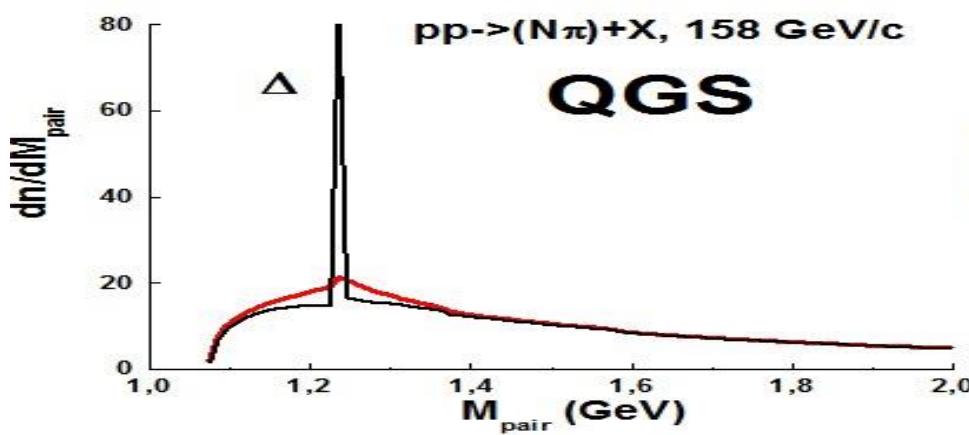
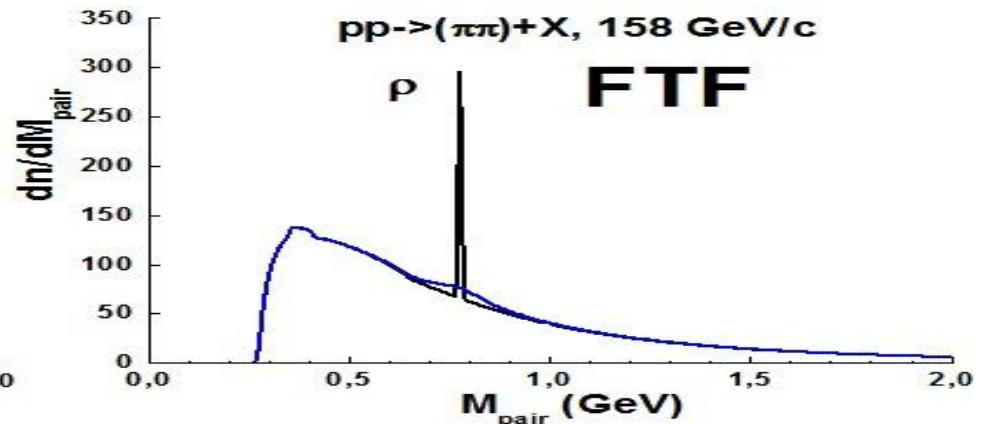
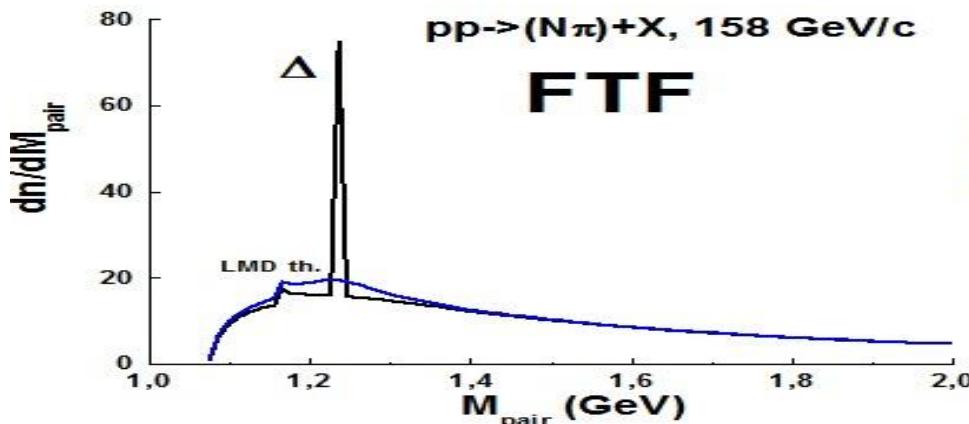
Thank you in advance!

Sincerely yours,

The PANDA Collaboration

Johan Messchendorp
Physics coordinator PAND

1. Smearing of resonance masses



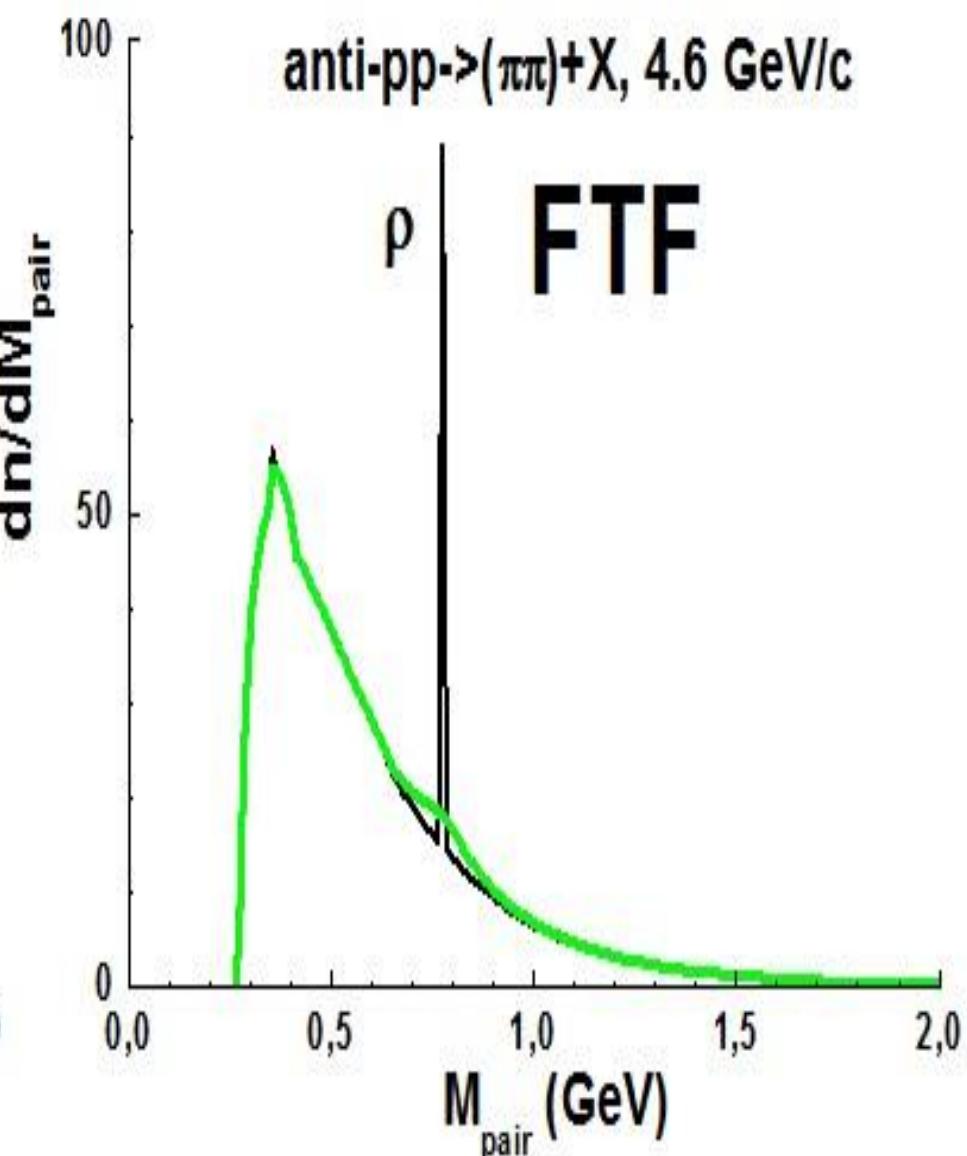
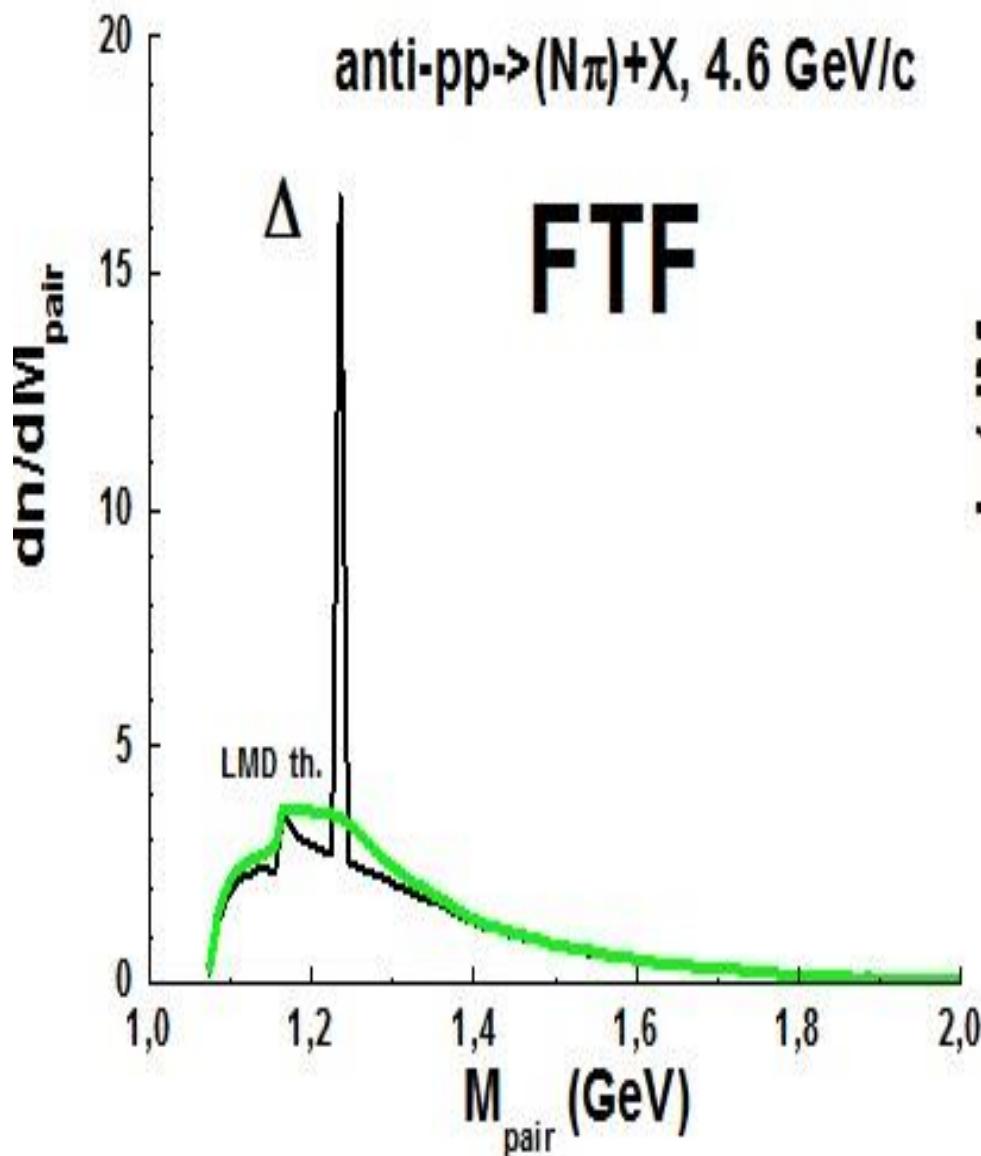
Class G4ExcitedStringDecay:

```
// ----- Sampling mass of unstable hadronic resonances ----- Uzhi July 2017
TrackDefinition = (*generatedKineticTracks)[aTrack]->GetDefinition();

if(TrackDefinition->IsShortLived())
{
    G4double NewTrackMass = BrW.SampleMass( TrackDefinition,
        TrackDefinition->GetPDGMass() + 5.0*TrackDefinition->GetPDGWidth() );
    G4LorentzVector Tmp=G4LorentzVector((*generatedKineticTracks)[aTrack]->Get4Momentum());
    Tmp.setE(std::sqrt(sqr(NewTrackMass) + Tmp.vect().mag2()));

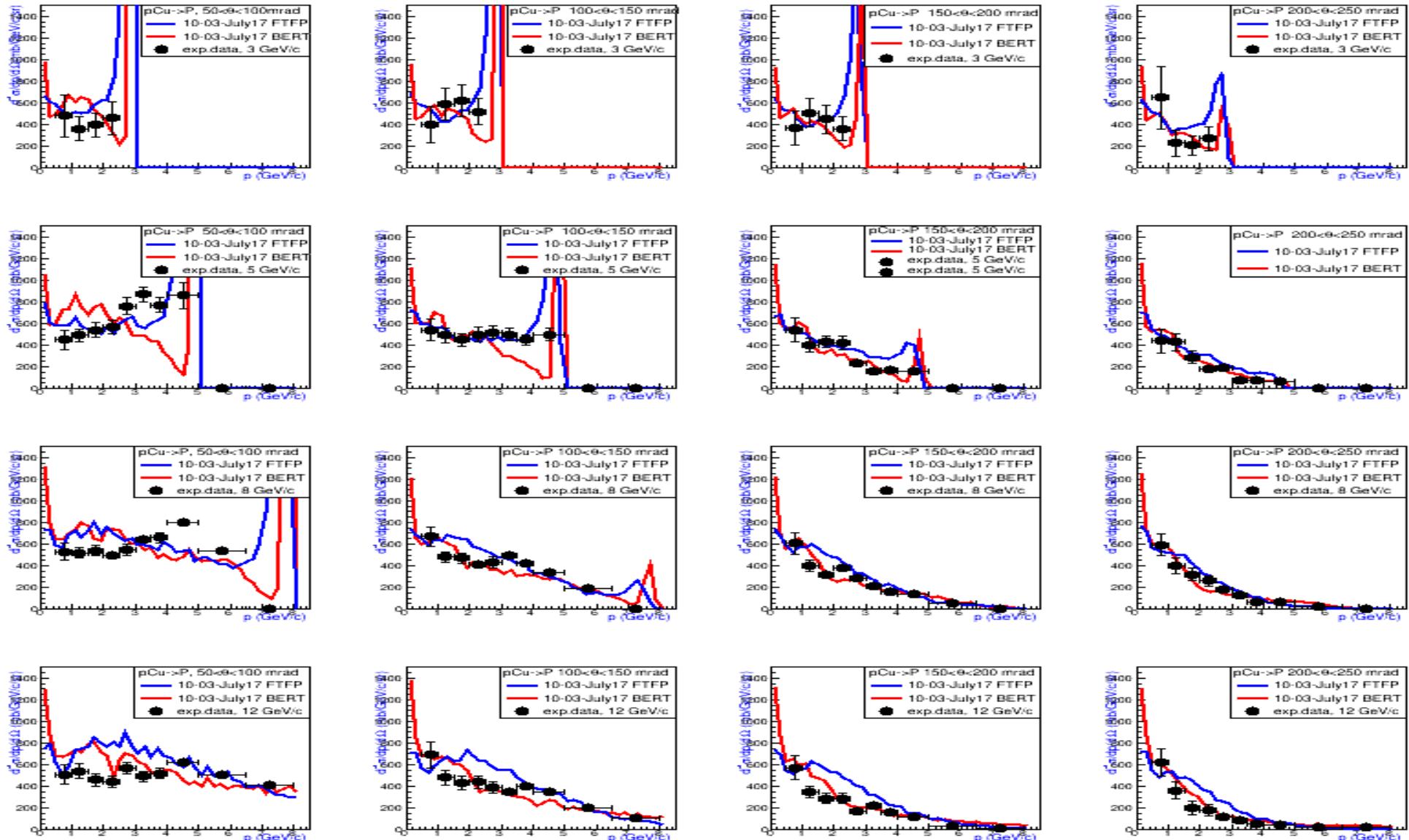
    (*generatedKineticTracks)[aTrack]->Set4Momentum(Tmp);
}
```

1. Smearing of resonance masses



DONE!

2. Bertini and FTF for HARP experiment, p+Cu->P

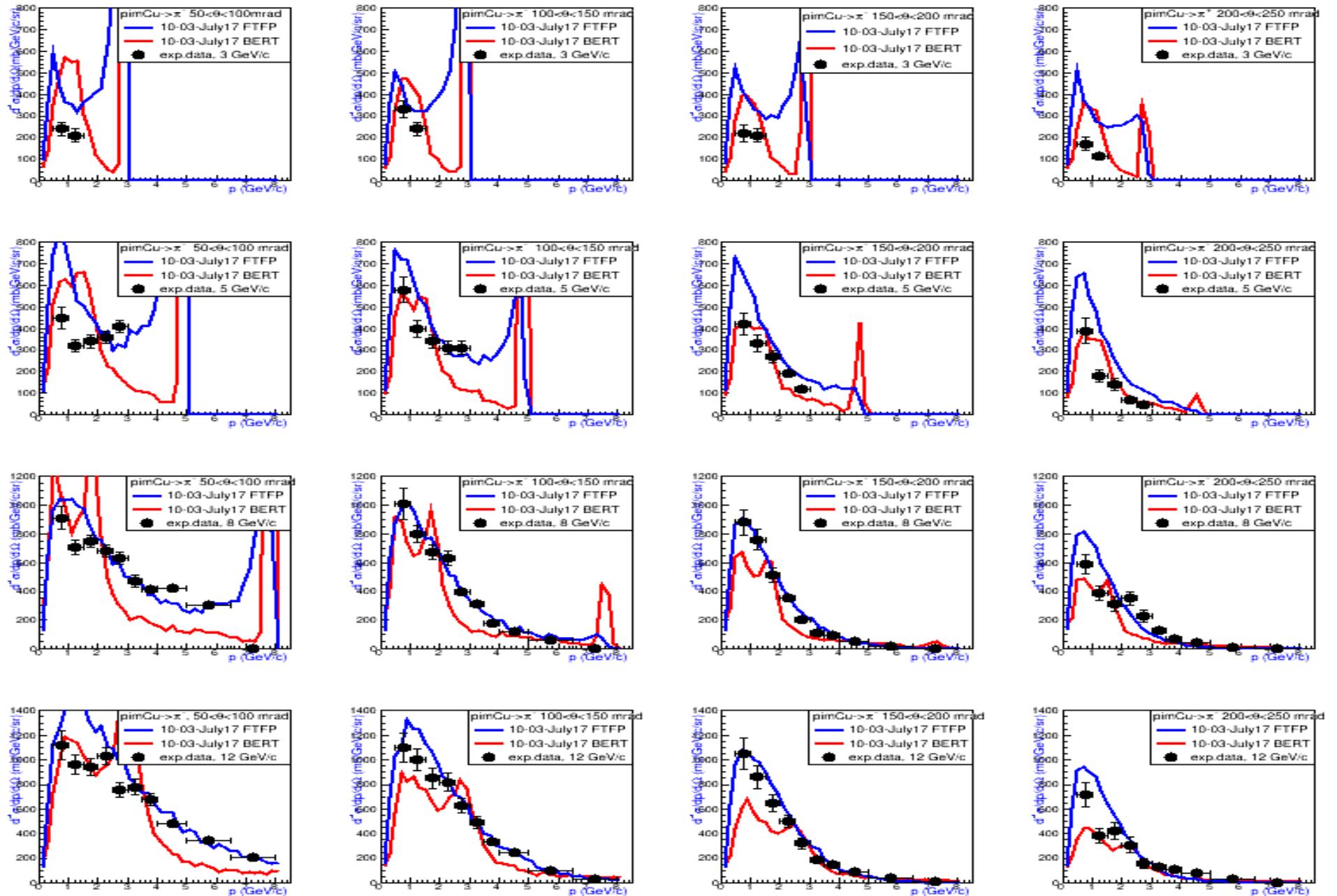


Abnormal peak at large P in bertini for light nuclei. Quasi-elastic?

Too wide peak at large P in FTF for light nuclei.

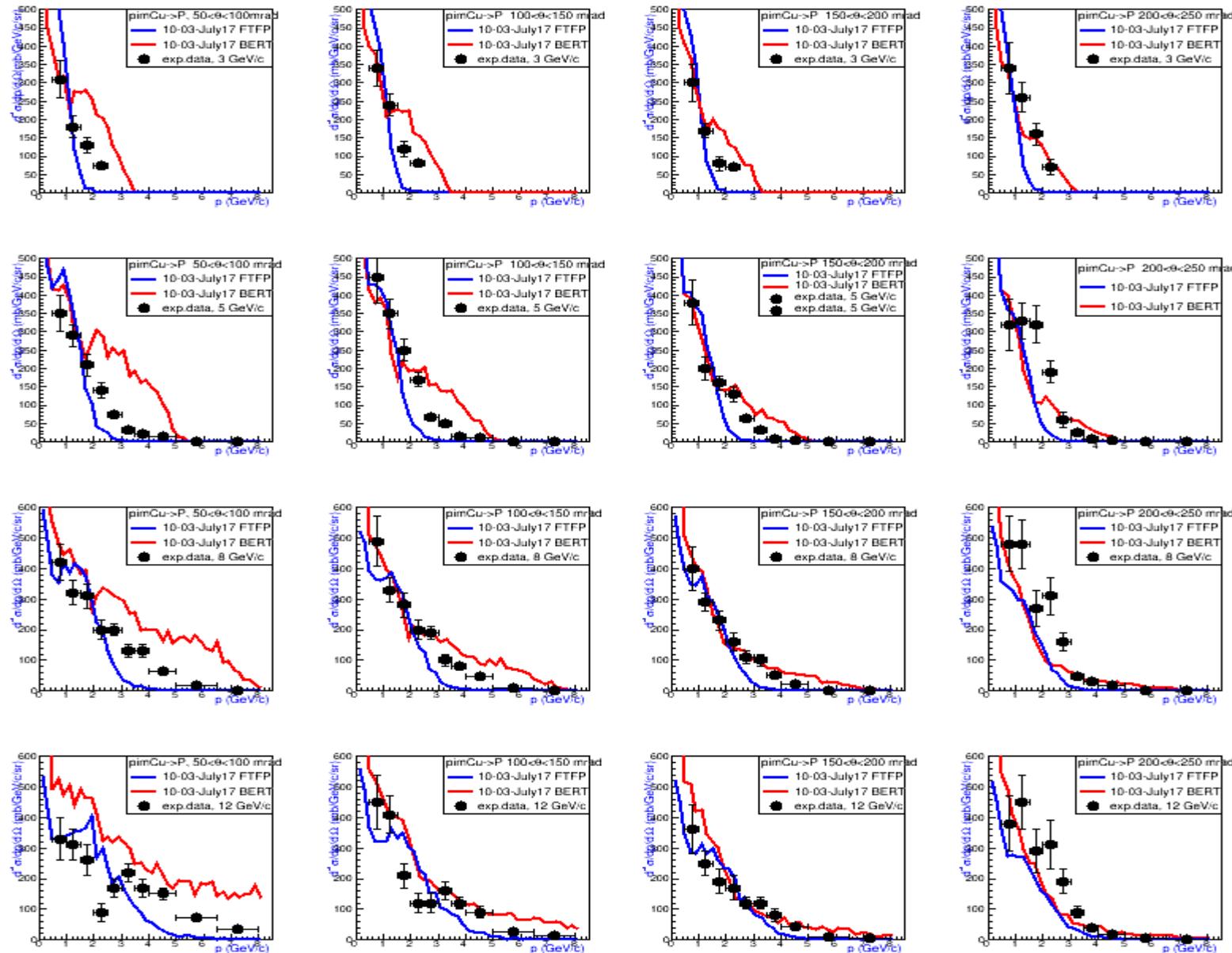
Overestimation of proton production in FTF at large projectile energies.

Bertini and FTF for HARP experiment , $\text{Pi}+\text{Cu} \rightarrow \text{Pi}-$



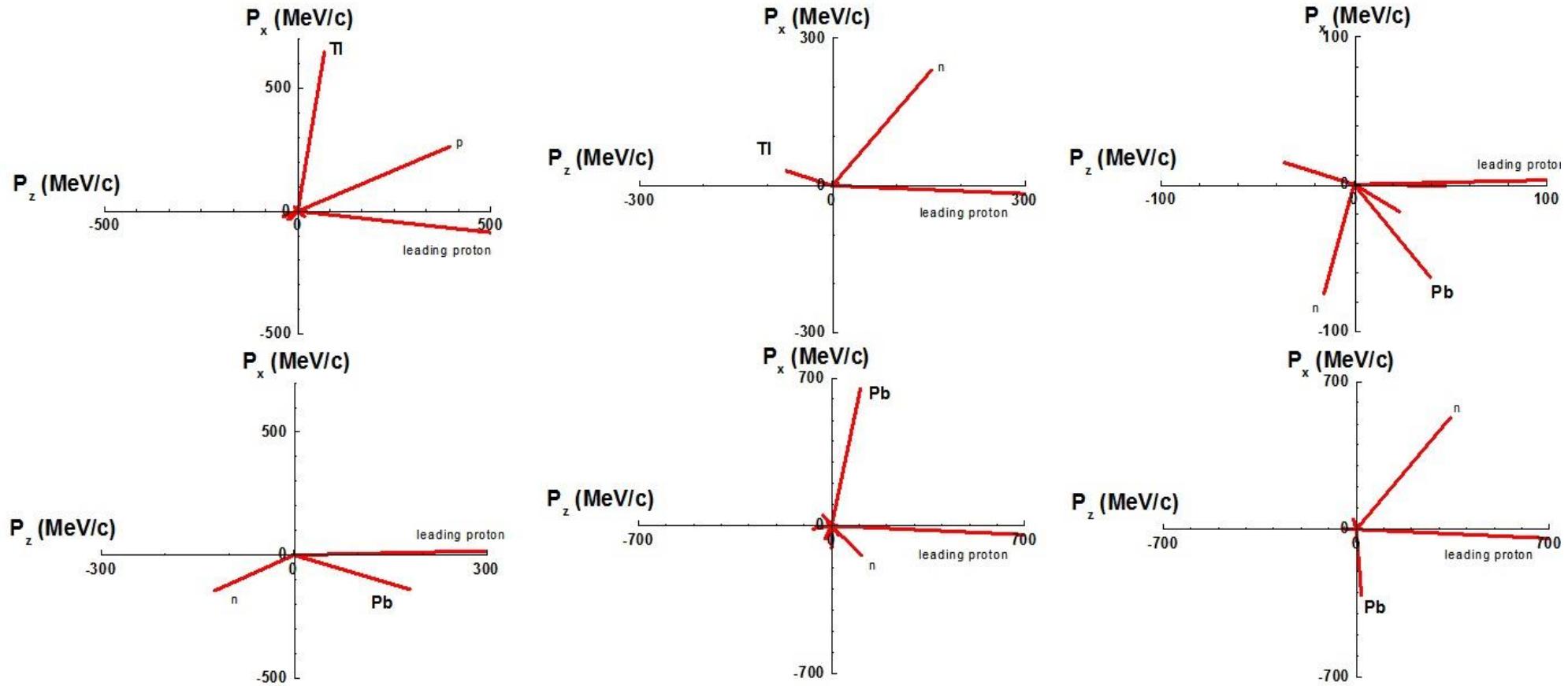
Overestimation of meson production in FTF at low energies.
Very strange structures in Bertini!

Bertini and FTF for HARP experiment , Pi+Cu->P



Form of the distributions in bertini at $P \geq 5 \text{ GeV}/c$ is not right.
Underestimation of meson production in FTF at 3 GeV/c.

3. Problem of bertini, p+Pb, 5 GeV/c



It seems to me that nuclear residuals obtain TOO LARGE recoil momenta in the Bertini model!
Simplest checking – increase or decrease pot. well.
I am afraid that it is a common drawback of cascade models.

3. Problem of bertini, p+Pb, 5 GeV/c

Class G4CollisionOutput

```
void G4CollisionOutput::setOnShell(G4InuclParticle* bullet,
                                   G4InuclParticle* target) {

    mom_non_cons = ini_mom - out_mom;
    G4double pnc = mom_non_cons.rho();
    G4double enc = mom_non_cons.e();

    // Adjust "last" particle's four-momentum to balance event
    // ONLY adjust particles with sufficient e or p to remain physical!

    if (npart > 0) {
        for (G4int ip=npart-1; ip>=0; ip--) {
            if (outgoingParticles[ip].getKineticEnergy() + enc > 0.) {
                last_mom = outgoingParticles[ip].getMomentum();
                last_mom += mom_non_cons;
                outgoingParticles[ip].setMomentum(last_mom);
                break;
            }
        }
    }

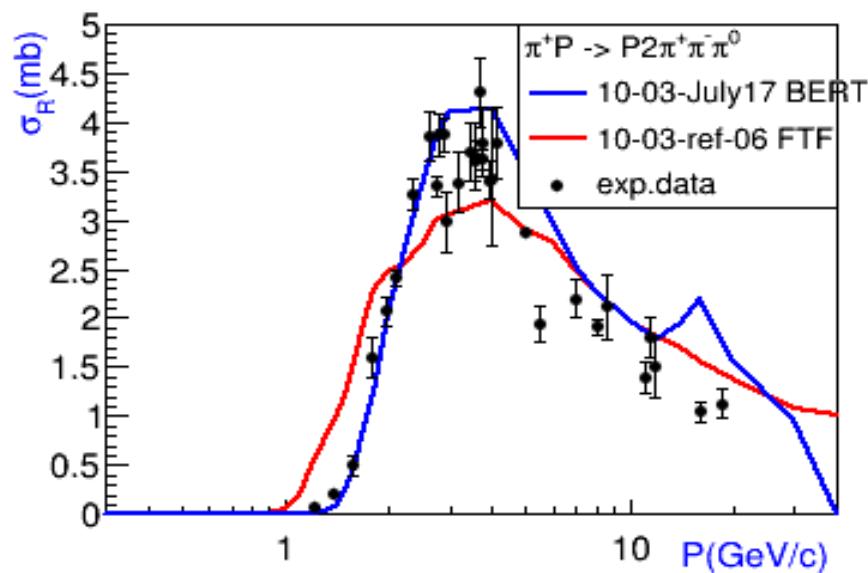
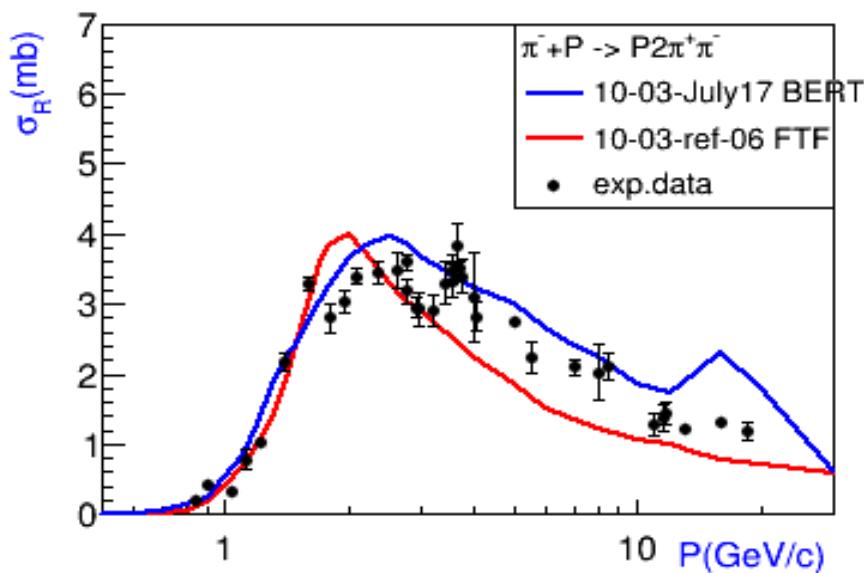
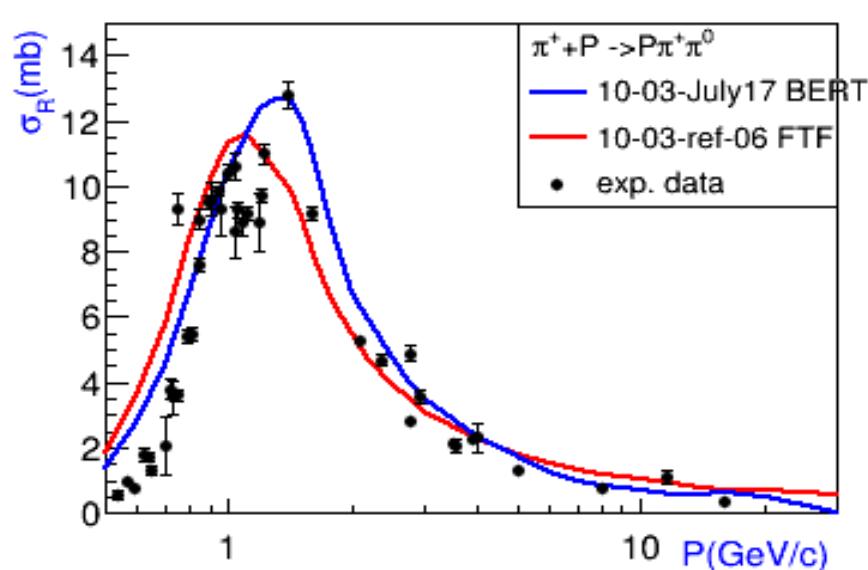
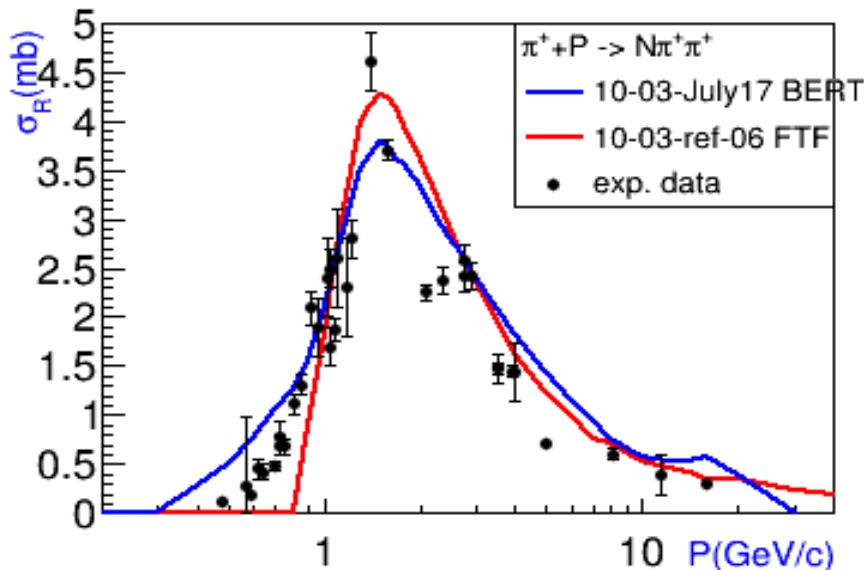
    // Recompute momentum non-conservation parameters

    // Momentum (hard) tuning required for energy conservation

    std::pair<std::pair<G4int, G4int>, G4int> tune_par = selectPairToTune(enc);

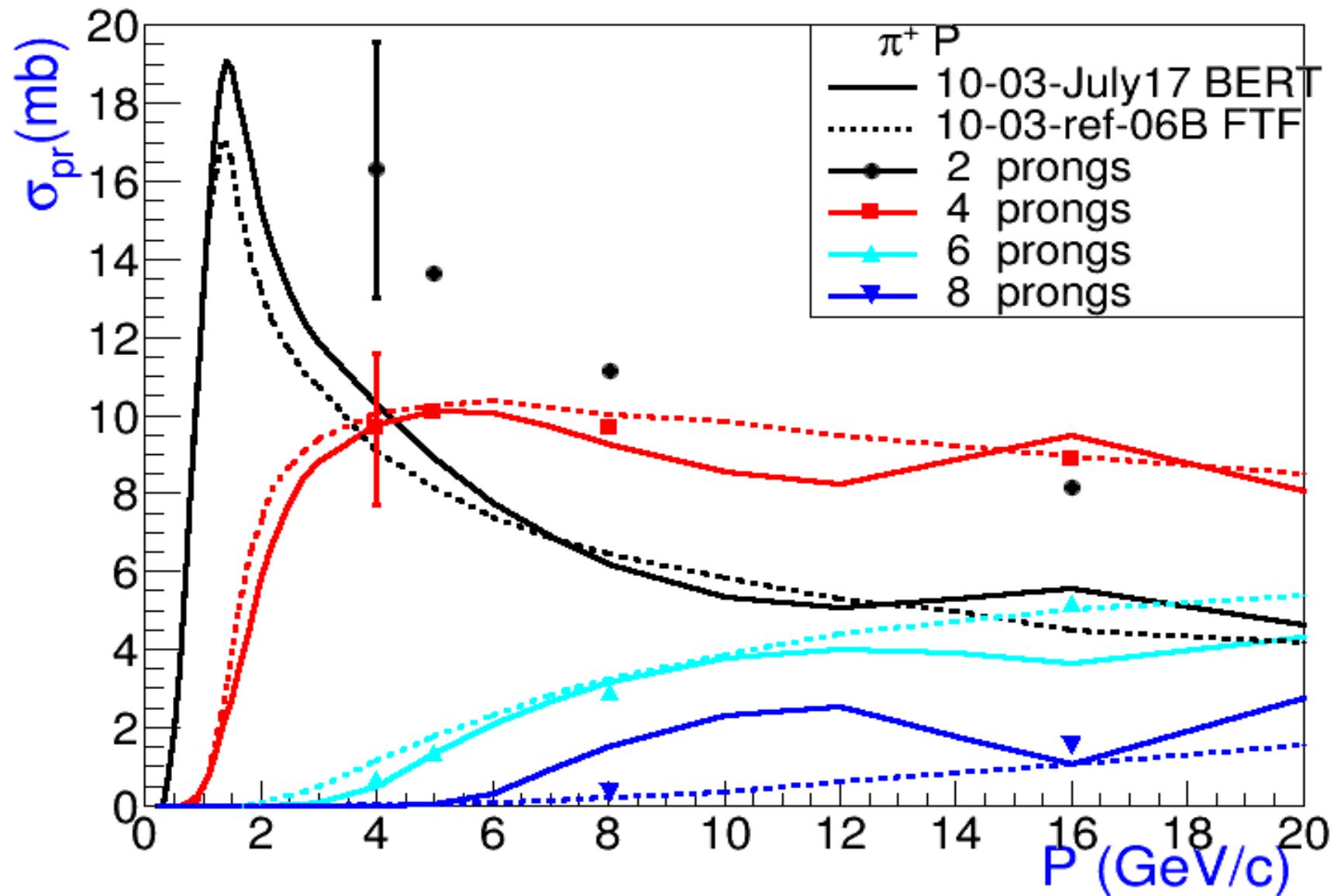
    if (tuneSelectedPair(mom1, mom2, mom_ind)) {
        outgoingParticles[tune_particles.first].setMomentum(mom1);
        outgoingParticles[tune_particles.second].setMomentum(mom2);
    }
}
```

4. Pi+ Nucleon reaction cross-sections



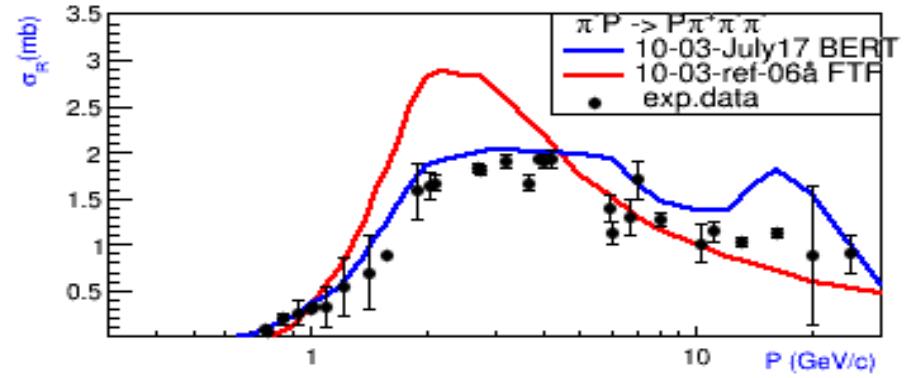
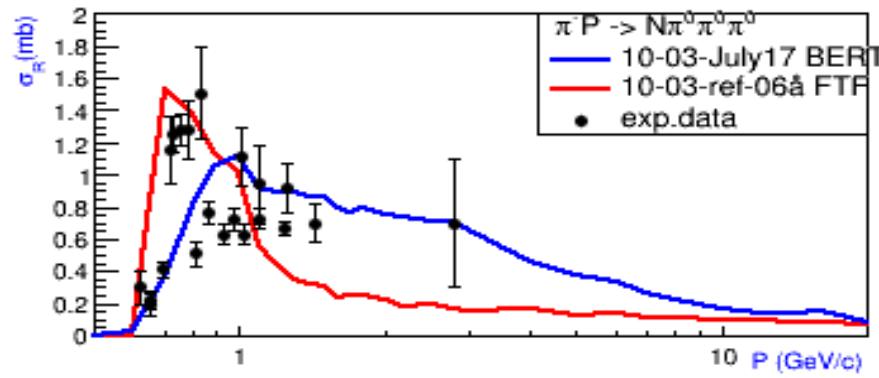
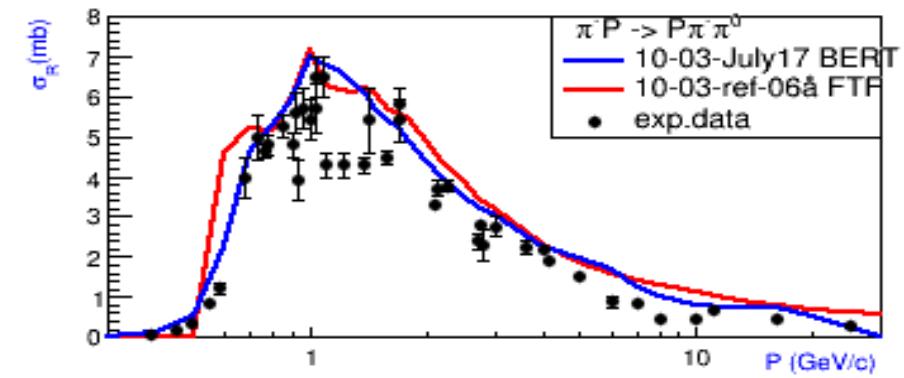
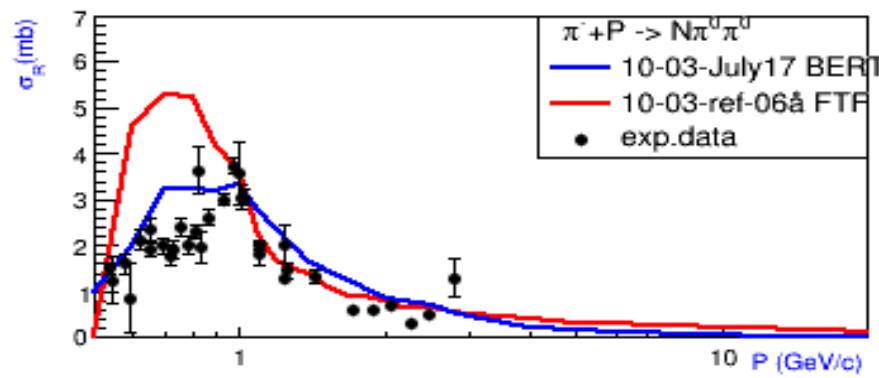
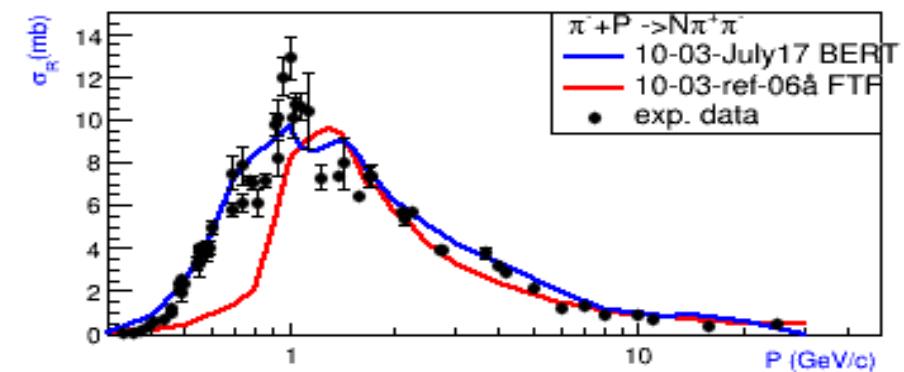
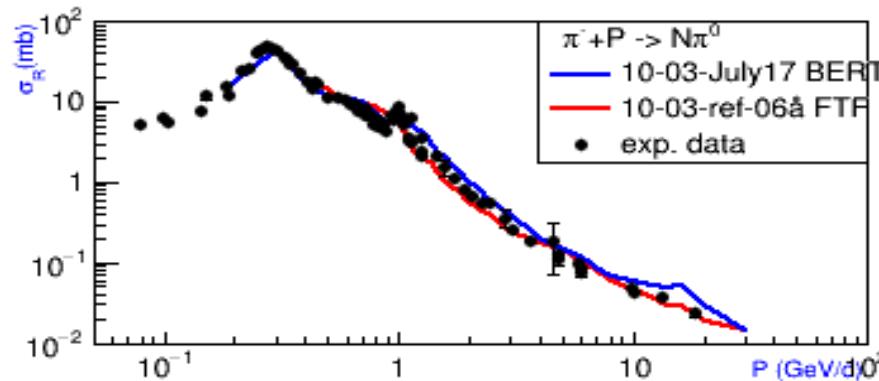
Strange peak in Bertini at 16 GeV/c!

4. π^+ Nucleon reaction cross-sections



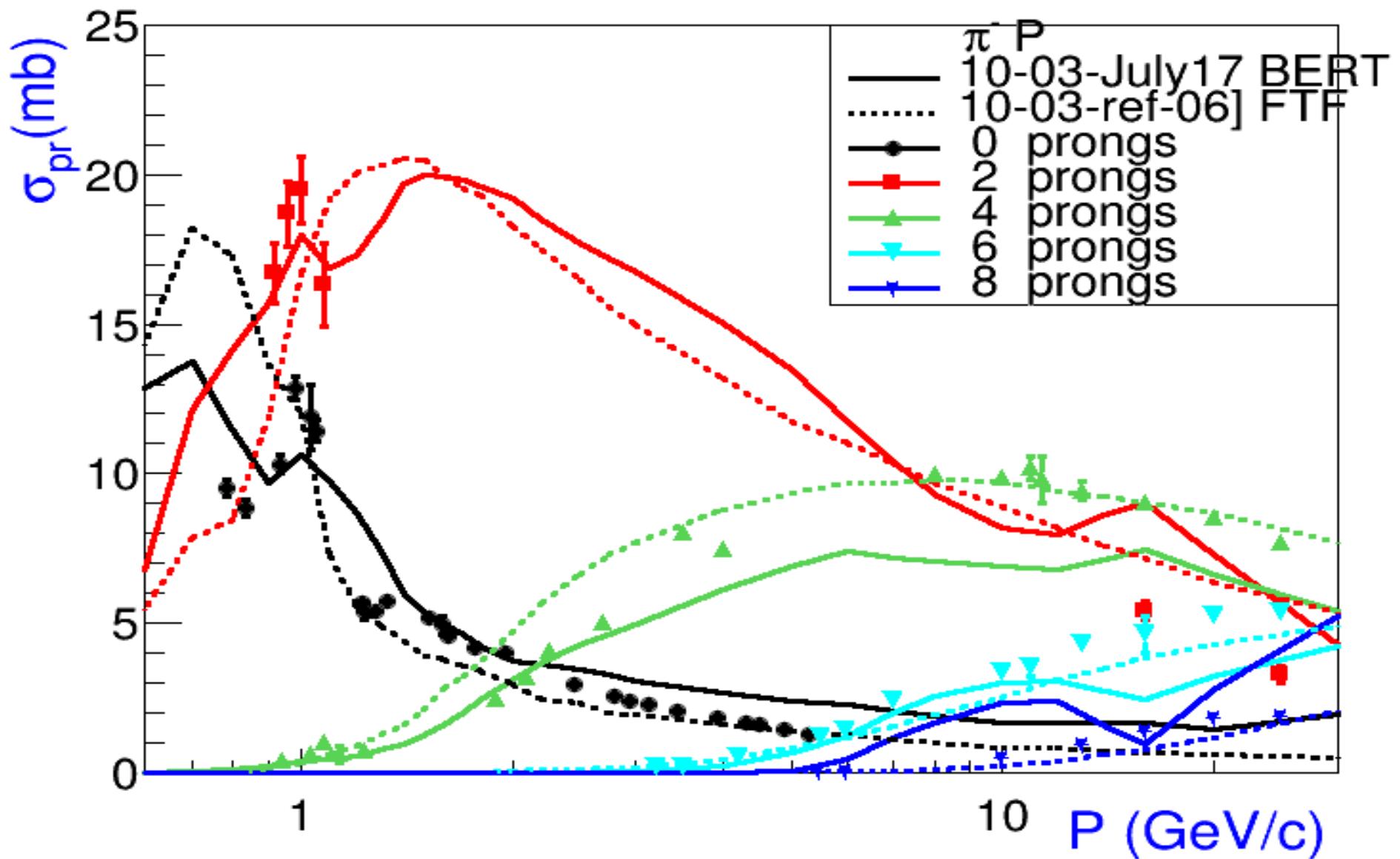
Overestimation of 8 prong events in Bertini at 12 GeV/c!

4. Pi- Nucleon reaction cross-sections



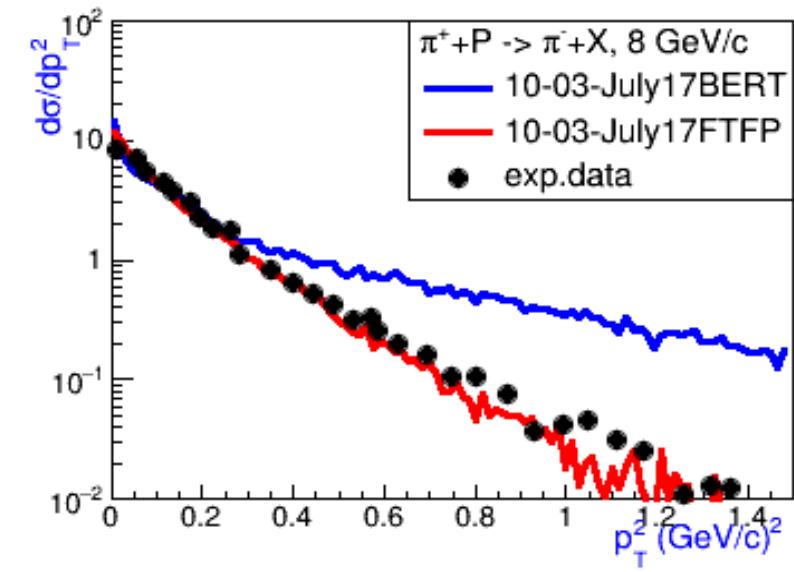
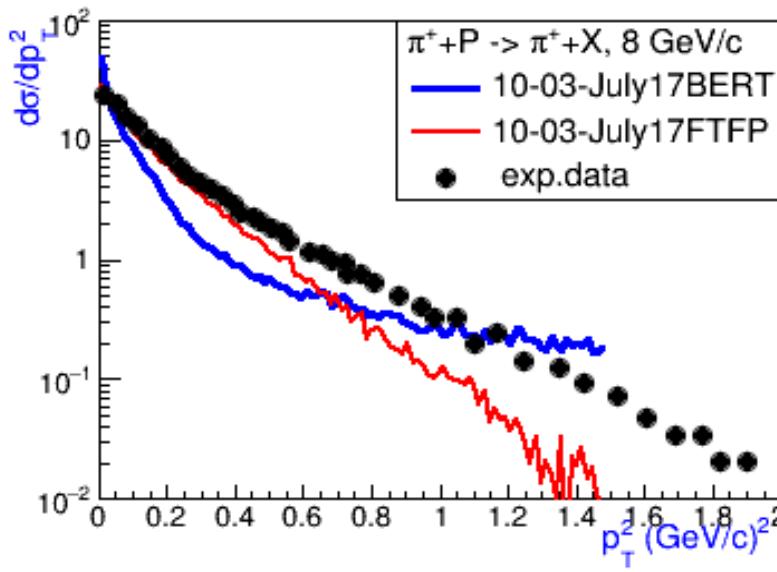
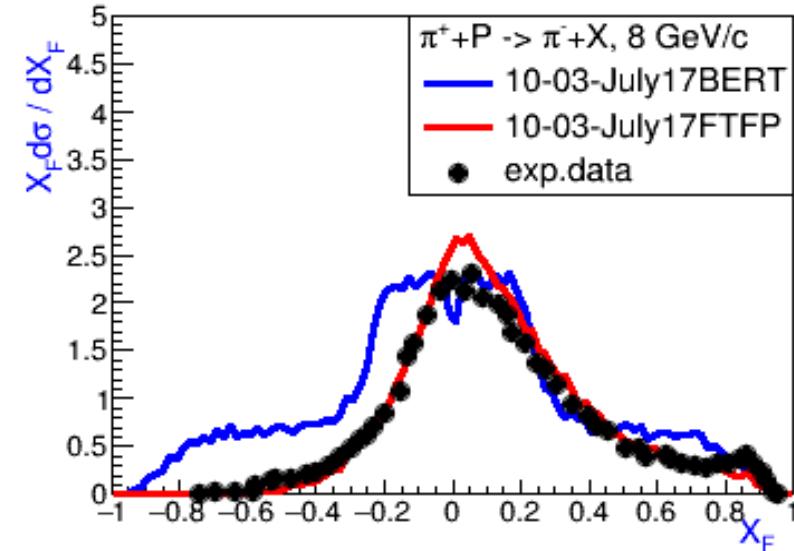
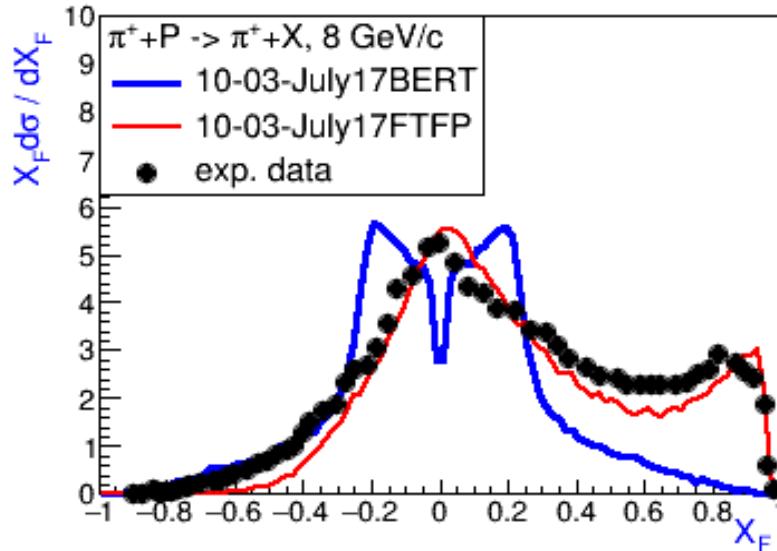
Strange peaks in Bertini at $P_{lab} > 10$ GeV/c!

4. Pi- Nucleon reaction cross-sections



Underestimation of 4 prong events in Bertini at $P_{lab} > 3$ GeV/c!
It would be well to check the Bertini model at low energies.

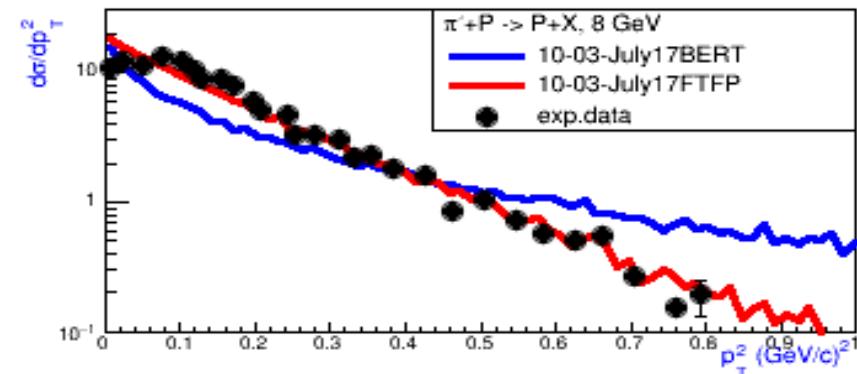
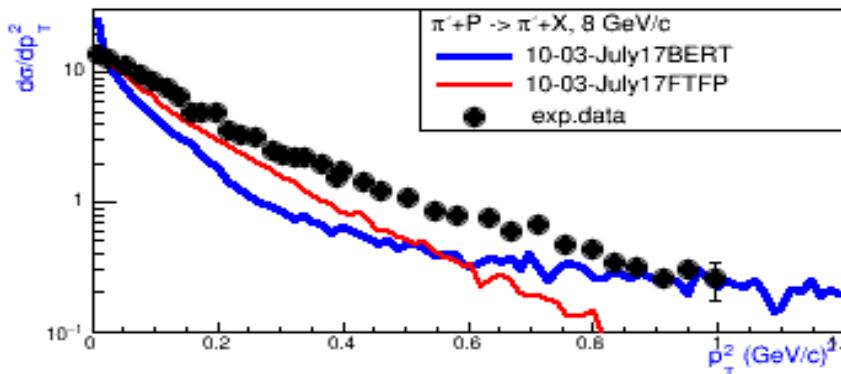
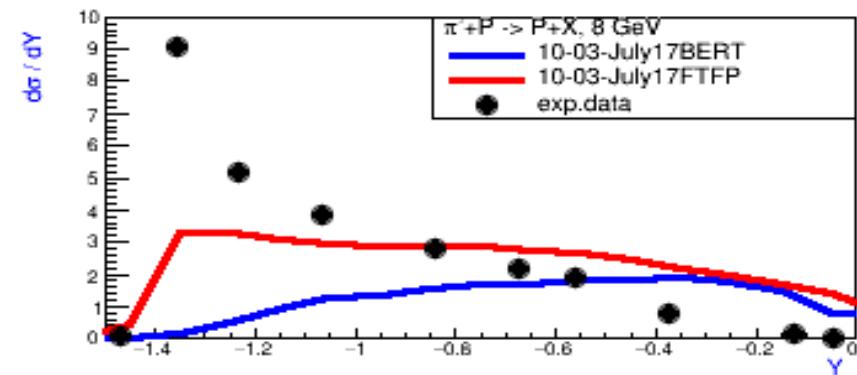
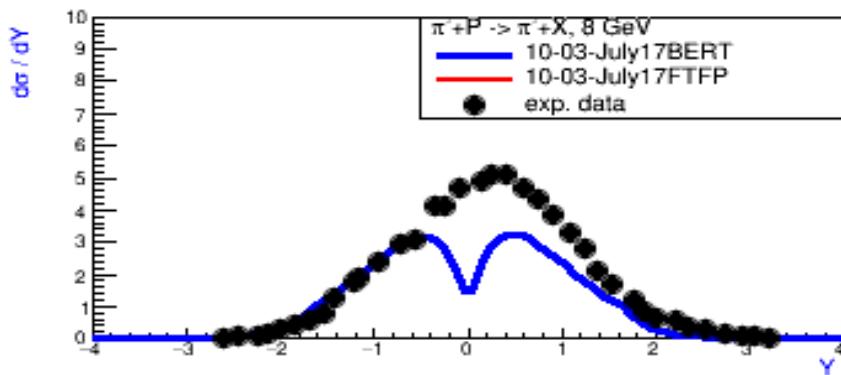
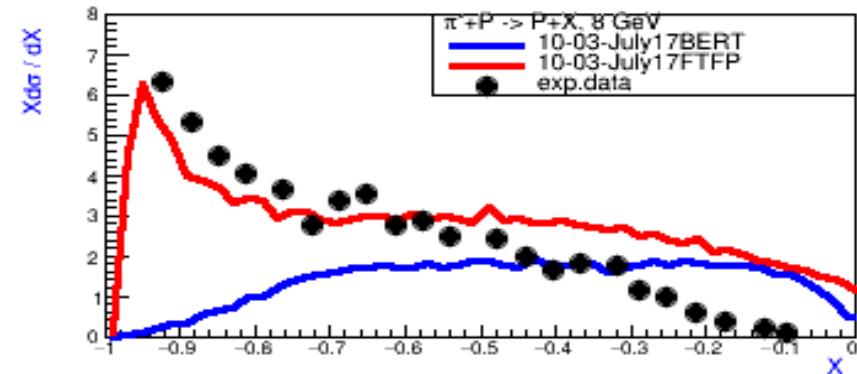
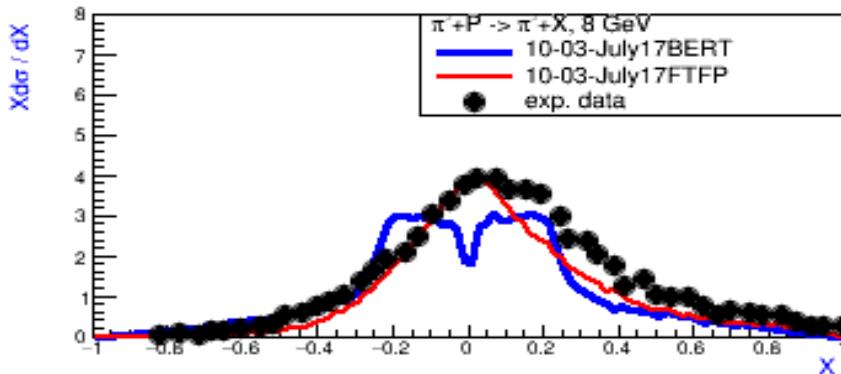
4. Pi+ Nucleon reaction cross-sections



Very strange structure in X_F distributions!

It would be well to check the Bertini model at low energies.

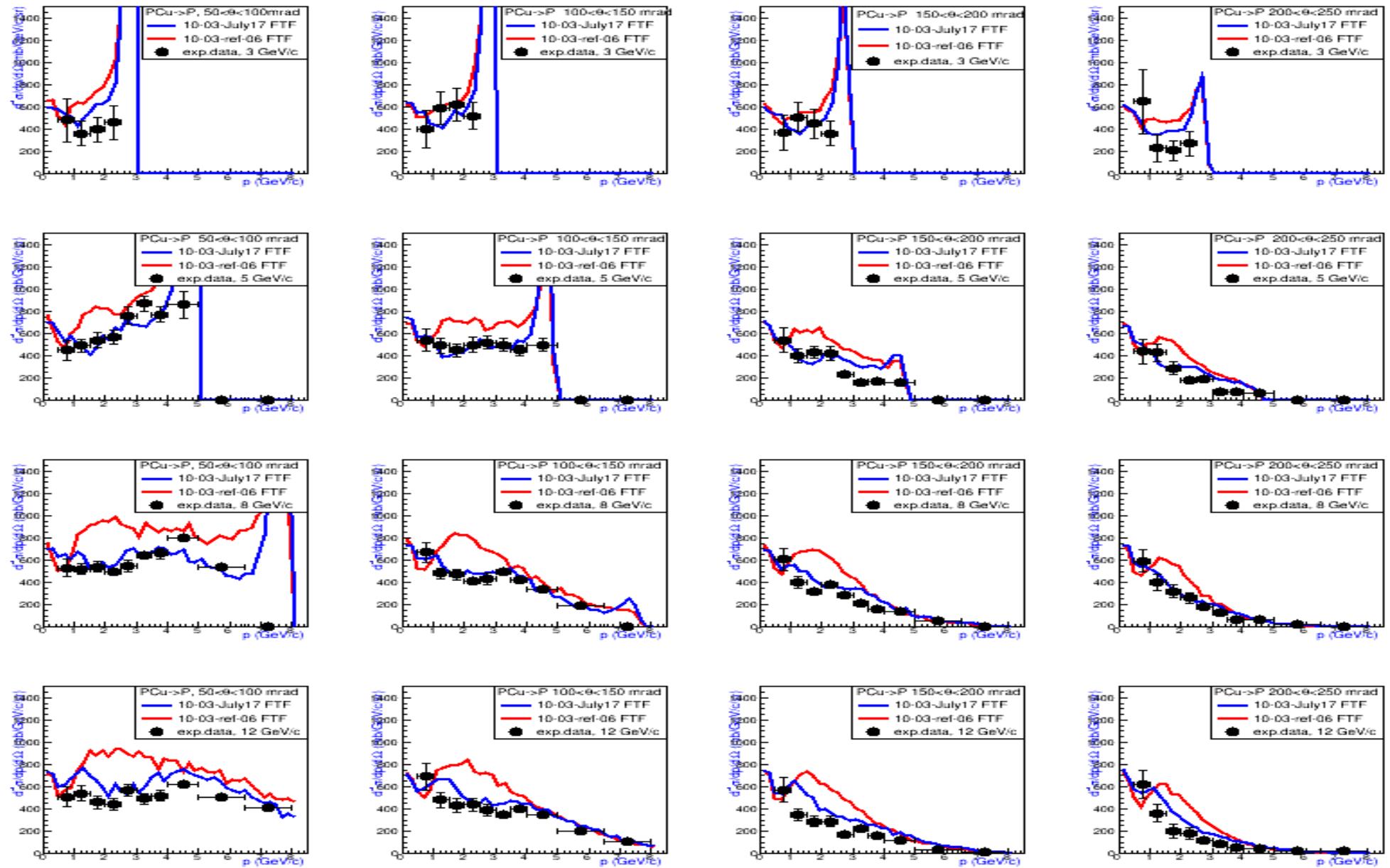
4. Pi- Nucleon reaction cross-sections



Very strange structure in Xf distributions!

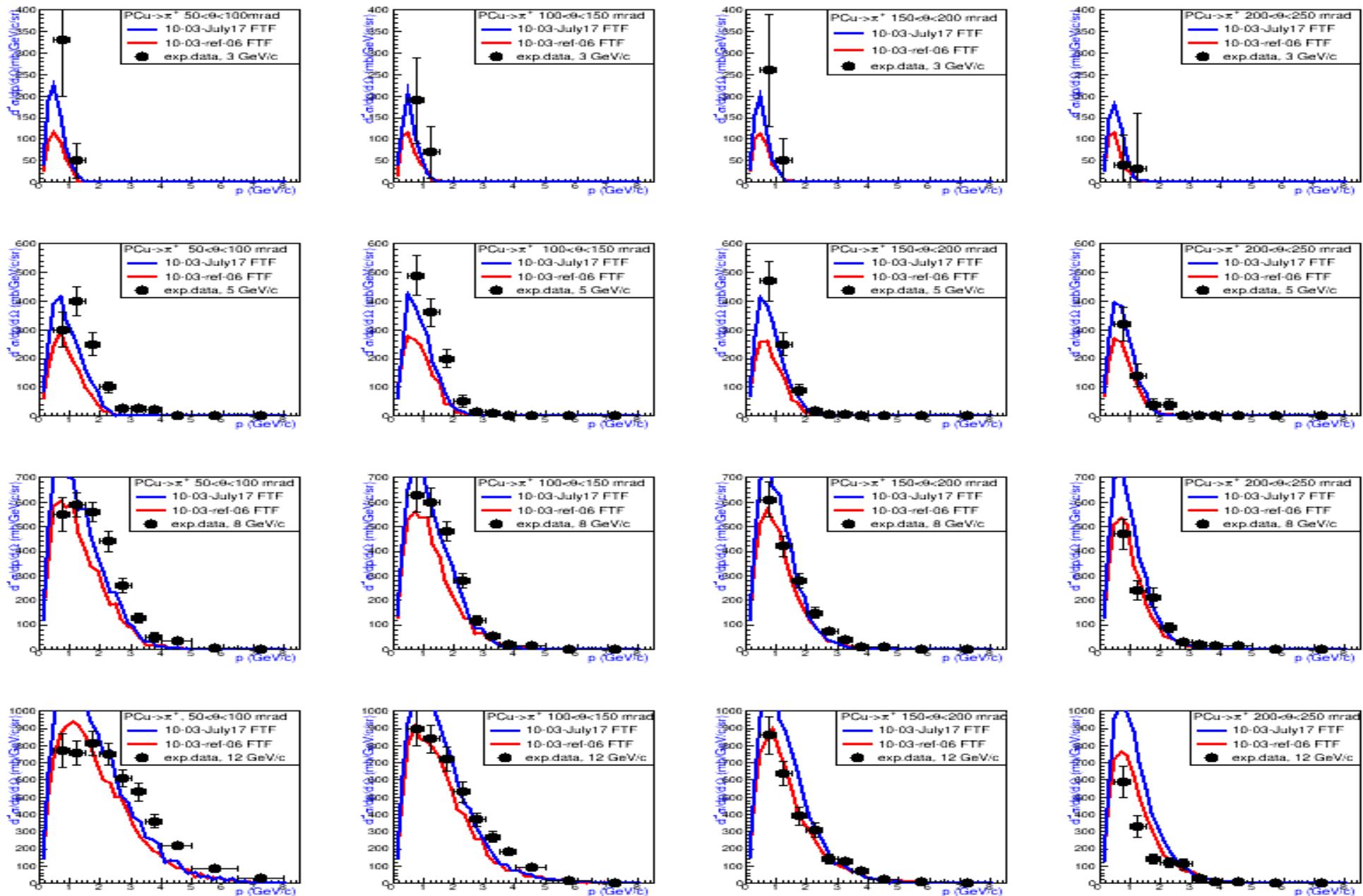
It would be well to check the Bertini model at low energies.

Improved FTF for HARP experiment , p+Cu->P



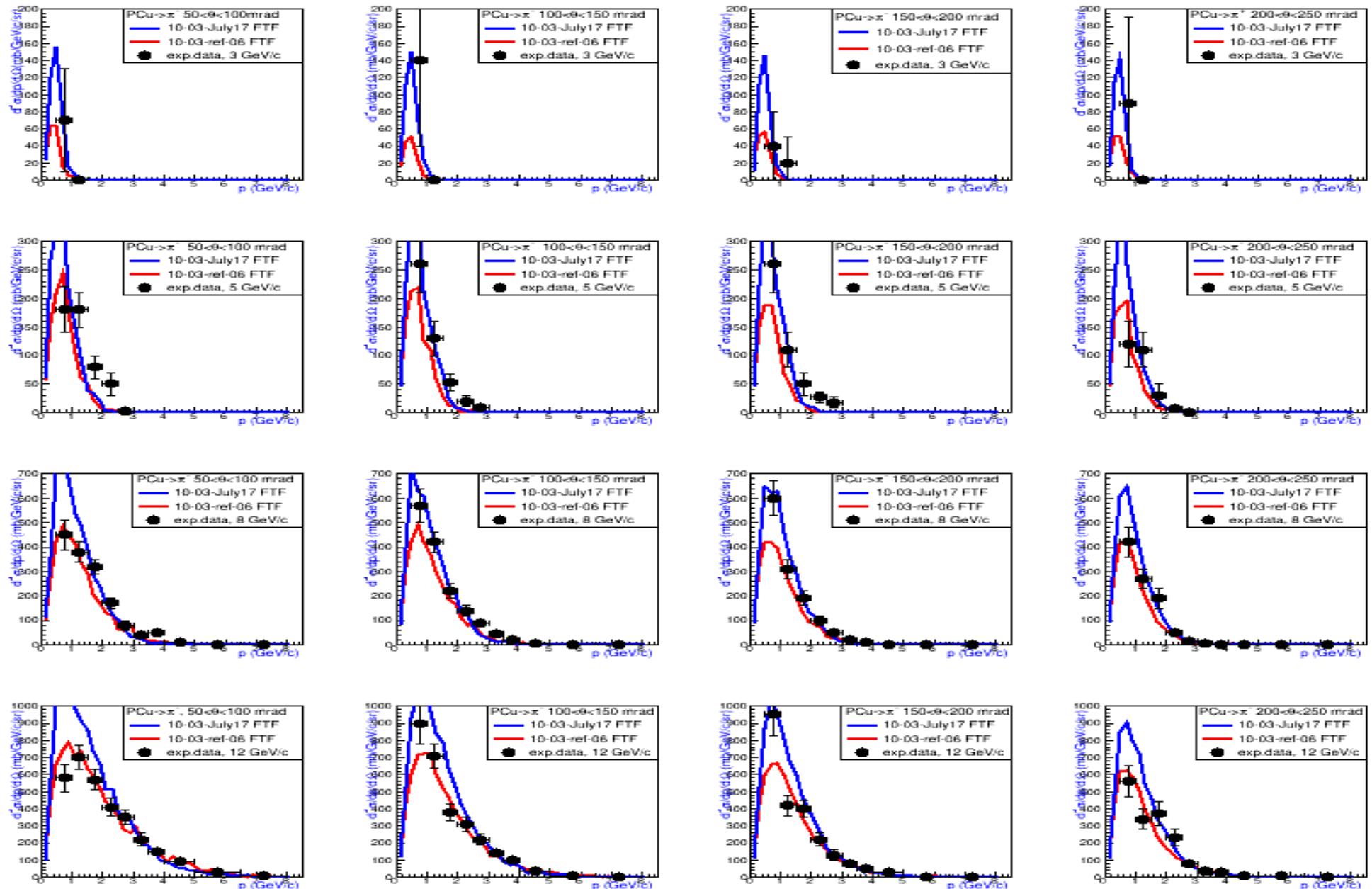
Essential improvement of proton spectra!

Improved FTF for HARP experiment , p+Cu->Pi+



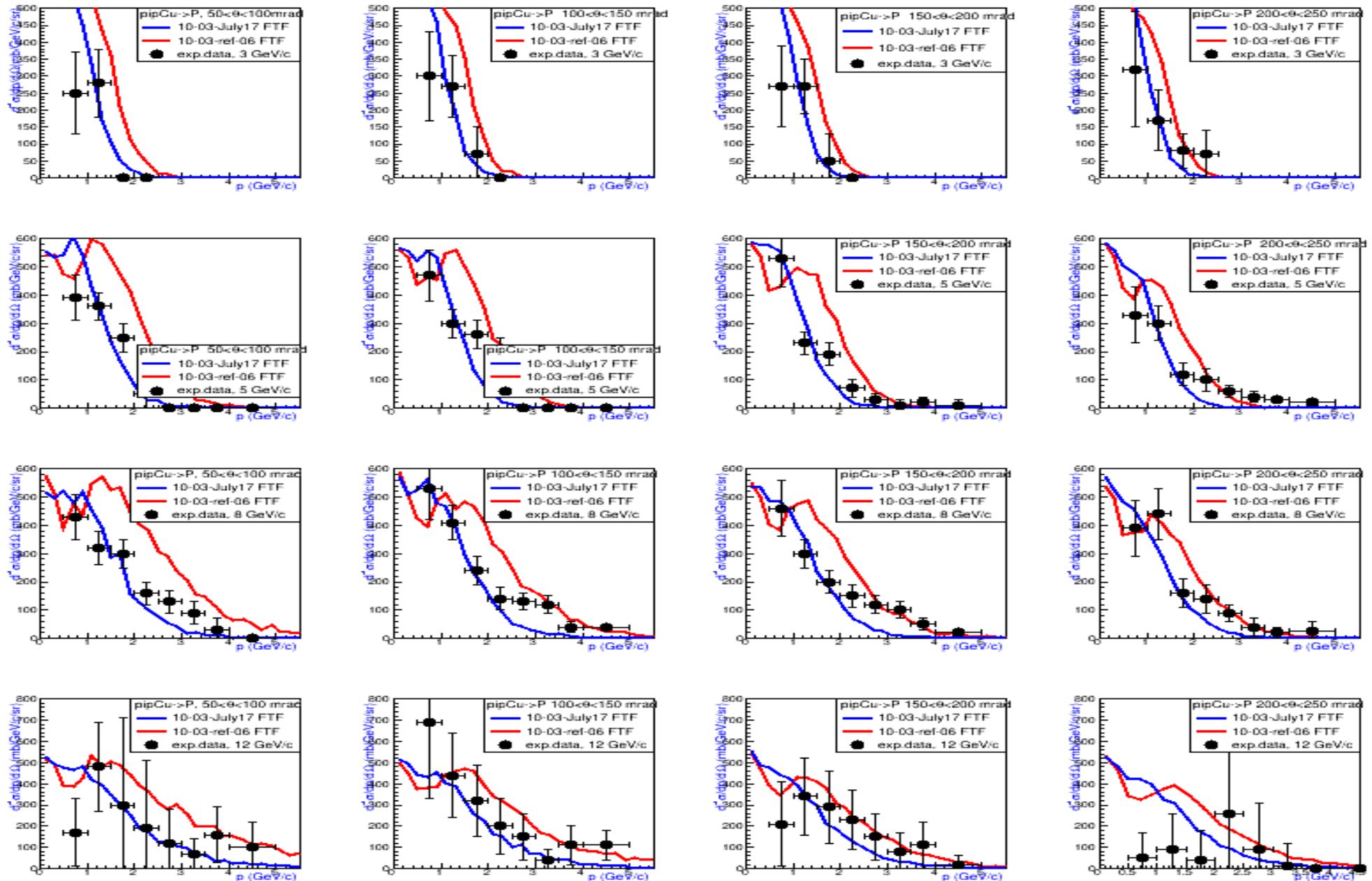
Essential improvement of the Pi+ spectra!

Improved FTF for HARP experiment , p+Cu->Pi-



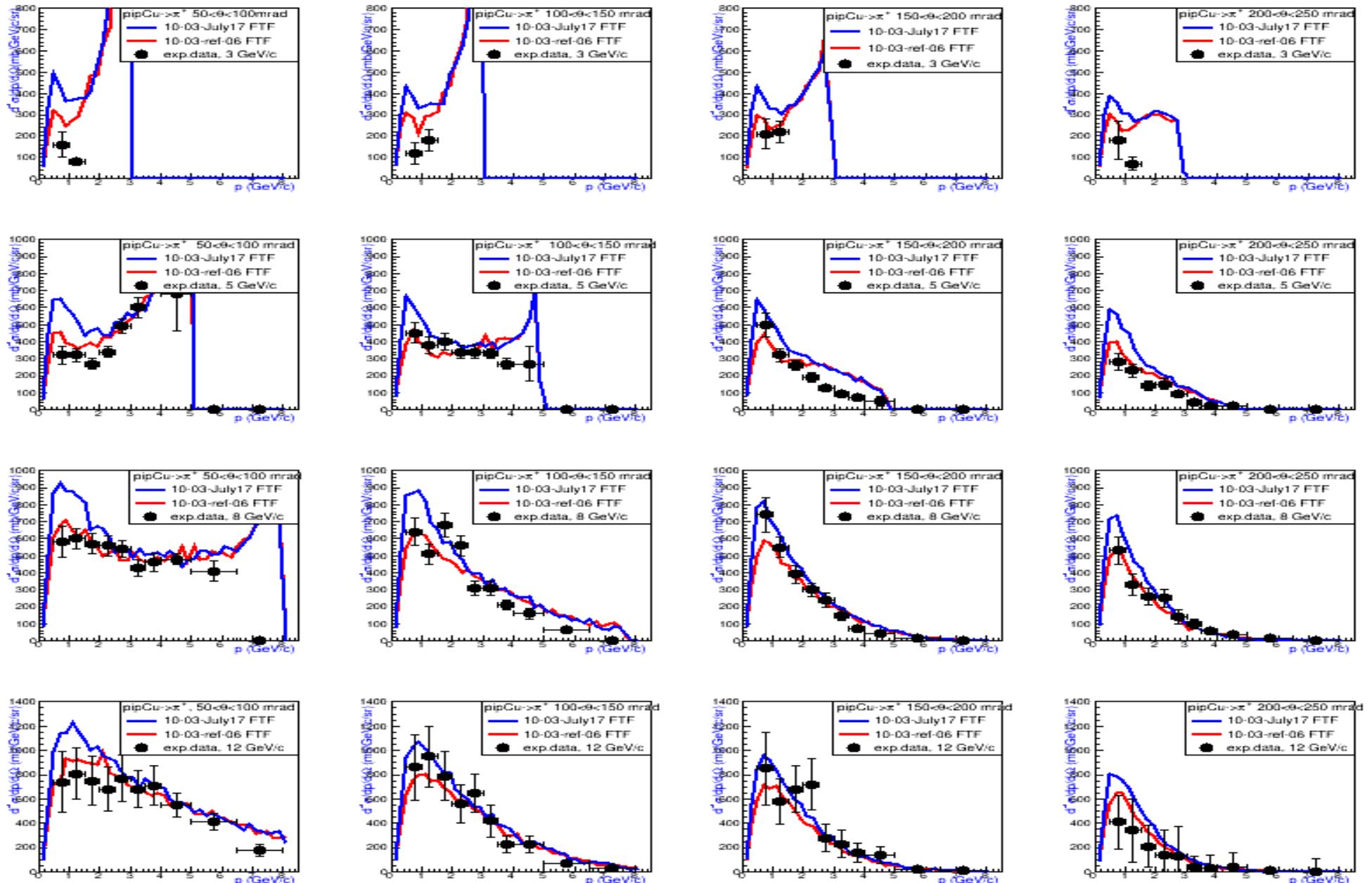
Essential improvement of the Pi- spectra!
Maybe, too many mesons?

Work with Pi+ +Cu->P



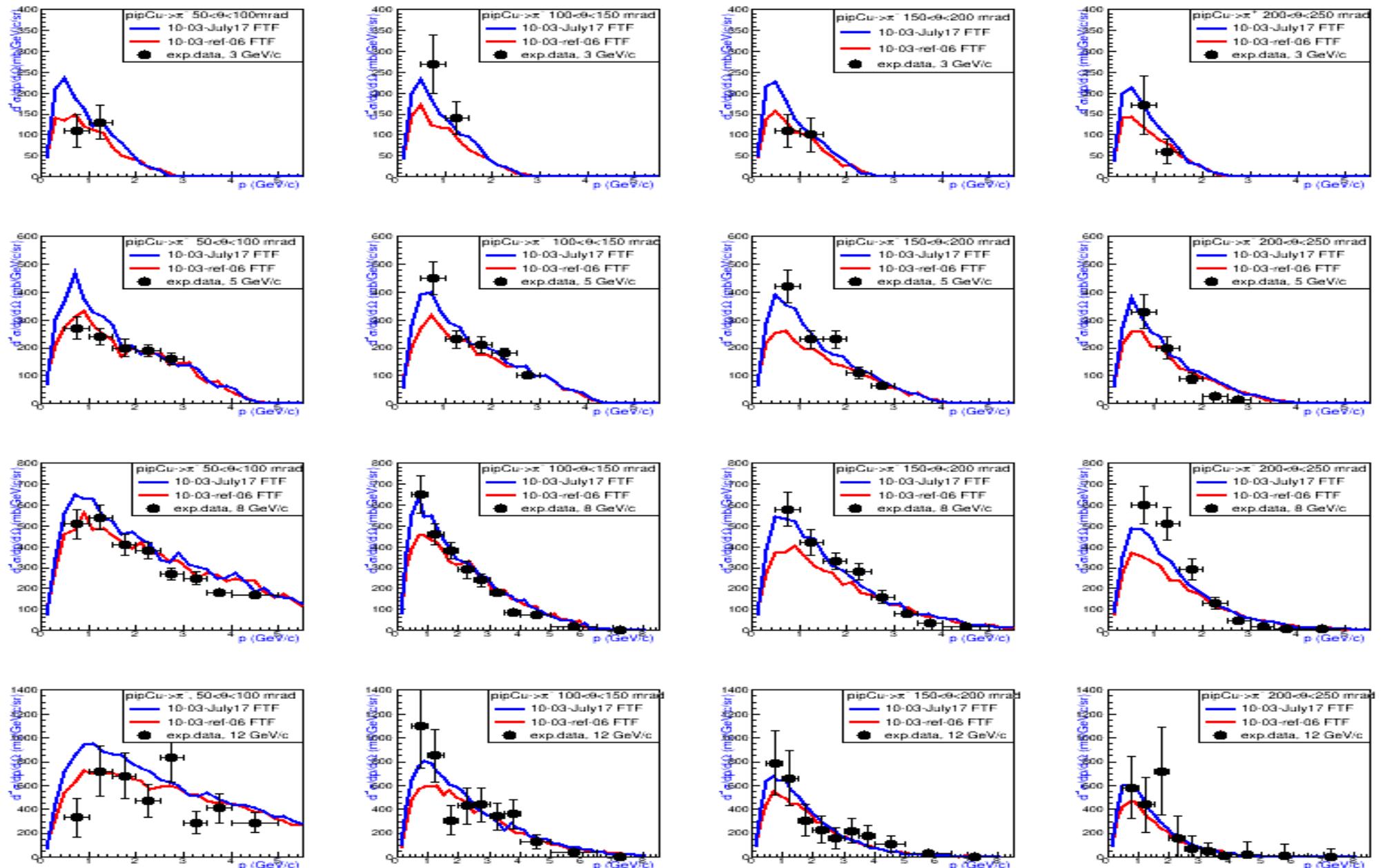
In general, better than it was before!

Work with Pi+ +Cu->Pi+



Not bad!

Work with $\text{Pi}^+ + \text{Cu} \rightarrow \text{Pi}^-$



Not bad!

Nucleus-nucleus interactions at 2-8 GeV/N

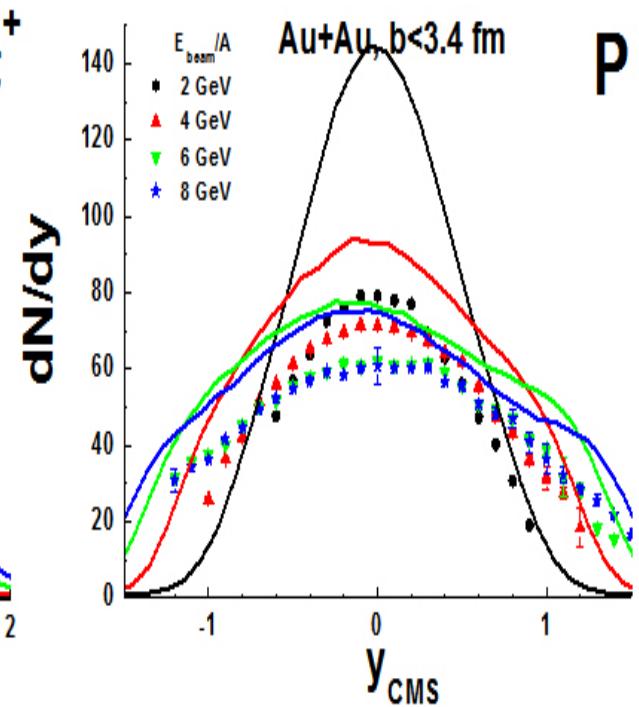
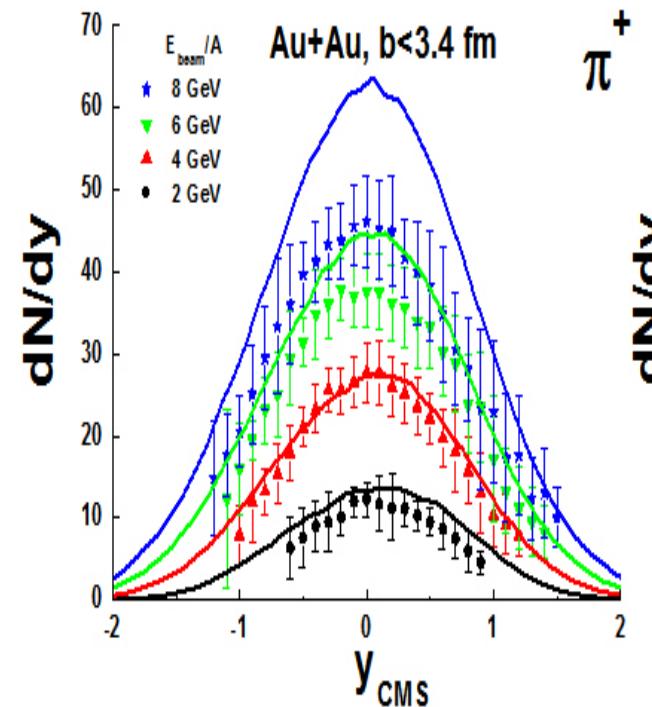
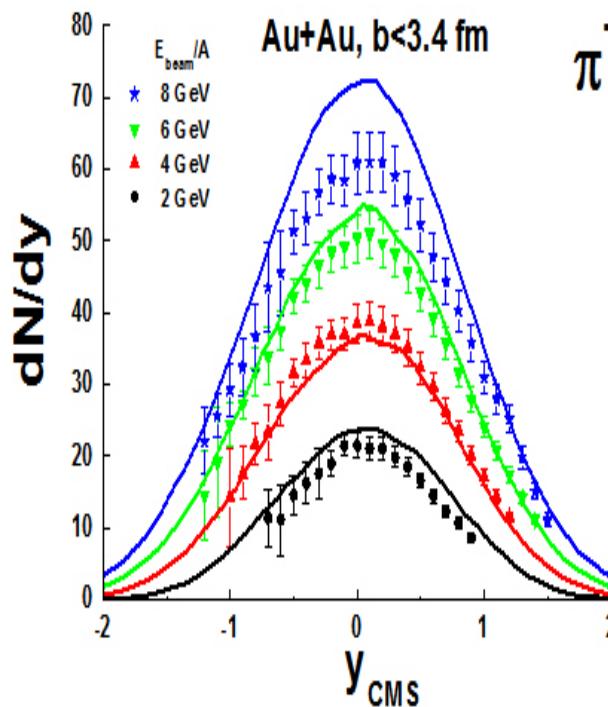
Charged pion production in 2 to 8 A GeV central au+au collisions

E-0895 Collaboration (J.L. Klay (UC, Davis) *et al.*).
Phys. Rev. C68 (2003) 054905

Longitudinal flow from 2-A-GeV to 8-A-GeV Au+Au collisions
at the Brookhaven AGS

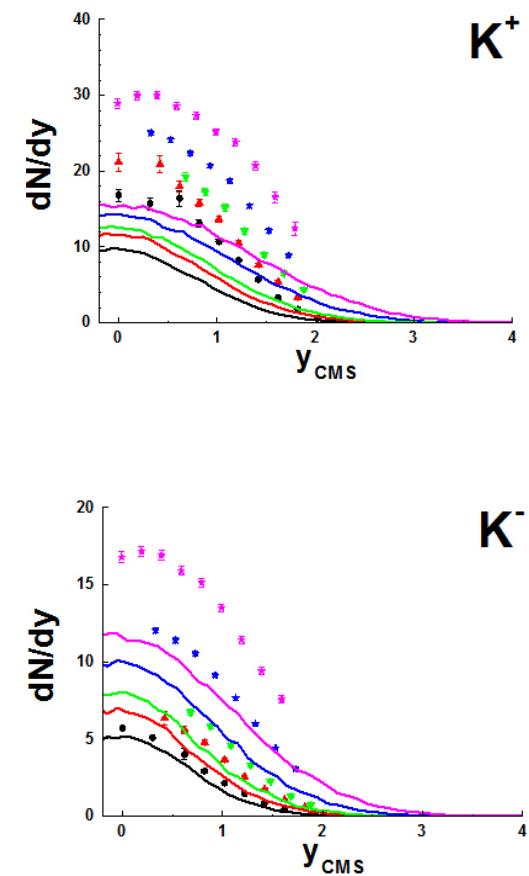
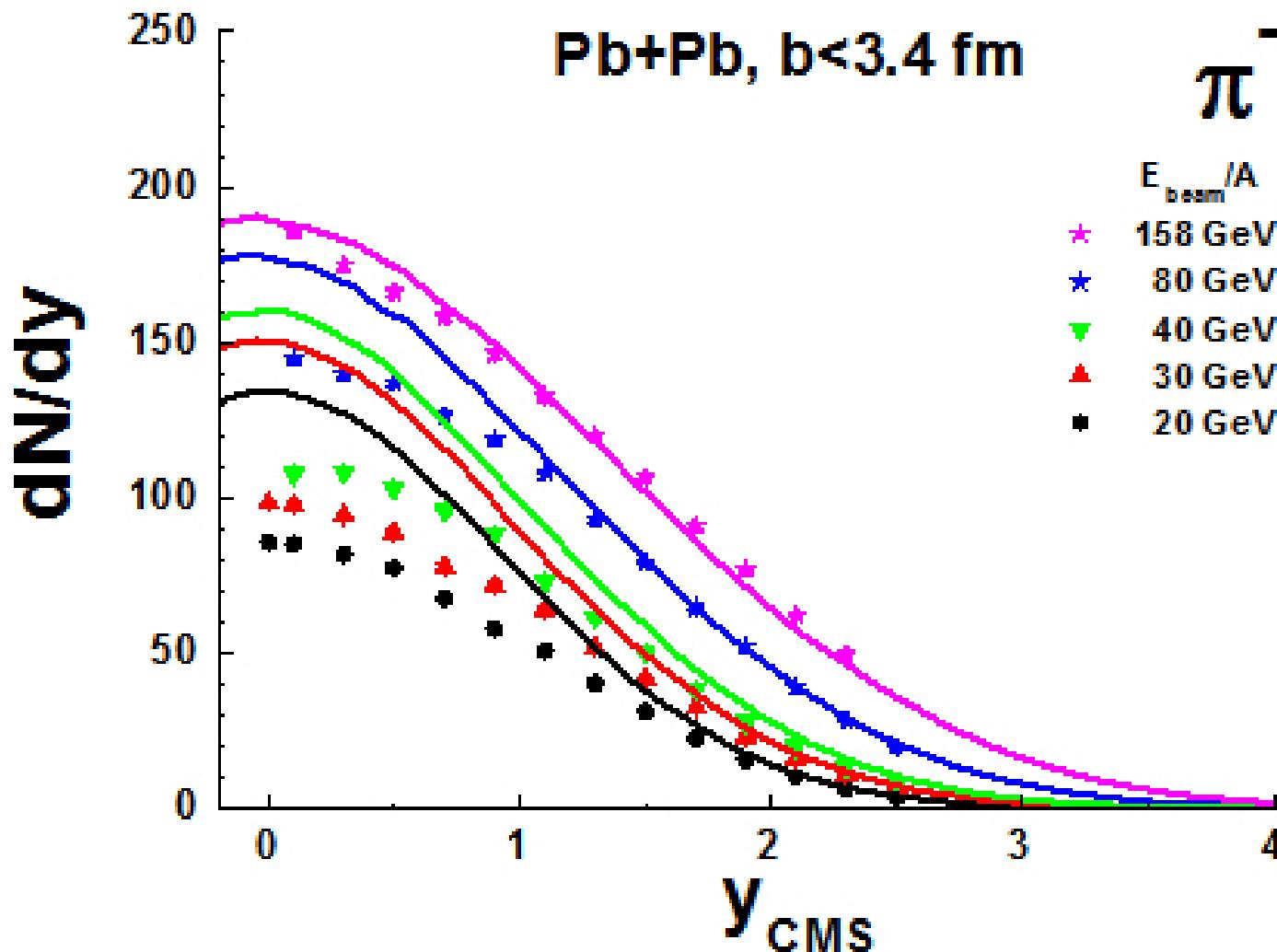
E895 Collaboration (J.L. Klay (UC, Davis) *et al.*).
Phys.Rev.Lett. 88 (2002) 102301

FTF calculations



Nucleus-nucleus interactions at 20-158 GeV/N

FTF calculations for Pb+Pb, NA49 data



Conclusion

Smearing of resonance masses is introduced!

**Small angle HARP experimental data are described
in Bertini and FTF models. Improved FTF gives good
results.**

**There are some problems in Bertini model.
Recoil momenta of nuclear residuals are too large.
It would be well to check the Bertini model at
low energies, and improve it, if possible.**

<http://vuzhinsk.web.cern.ch/vuzhinsk>

Geant4 Bertini and FTF model description of the HARP data

$p/\pi^+/\pi^- + Al$ interactions, 3 - 12 GeV/c

$p/\pi^+/\pi^- + Cu$ interactions, 3 - 12 GeV/c

$p/\pi^+/\pi^- + Pb$ interactions, 3 - 12 GeV/c

**Operation of FTF for nucleus –nucleus interactions
is started!**