Inclusion of up-to-date parton distribution function and nuclear shadowing in the AMPT model

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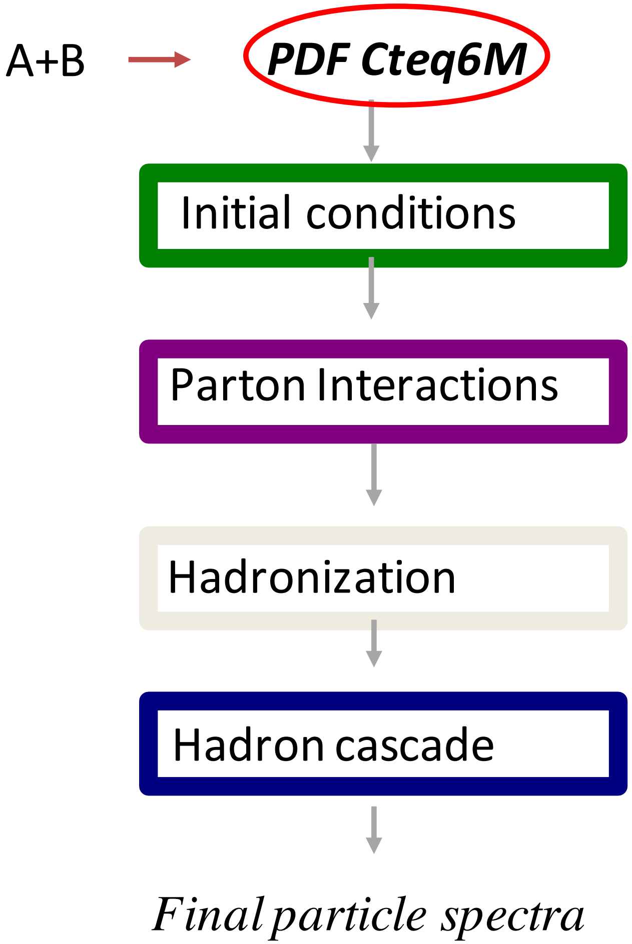
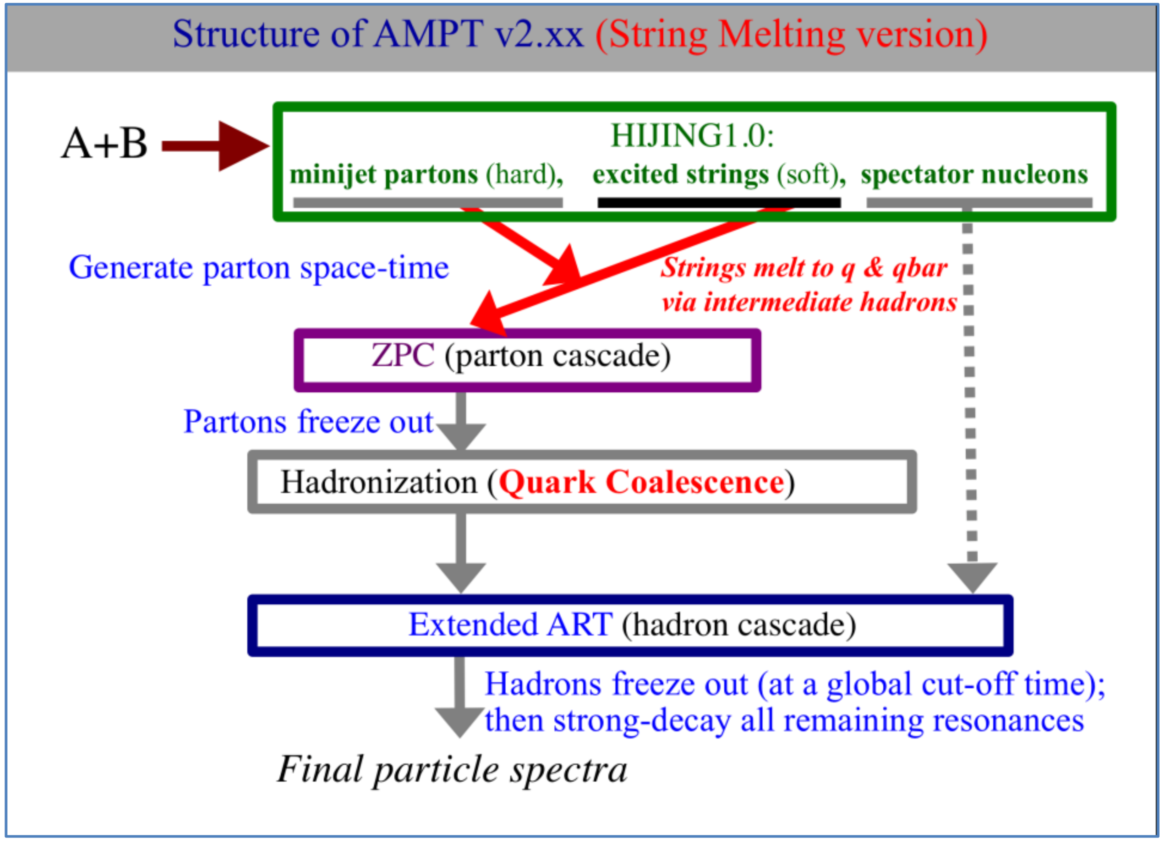
Outline

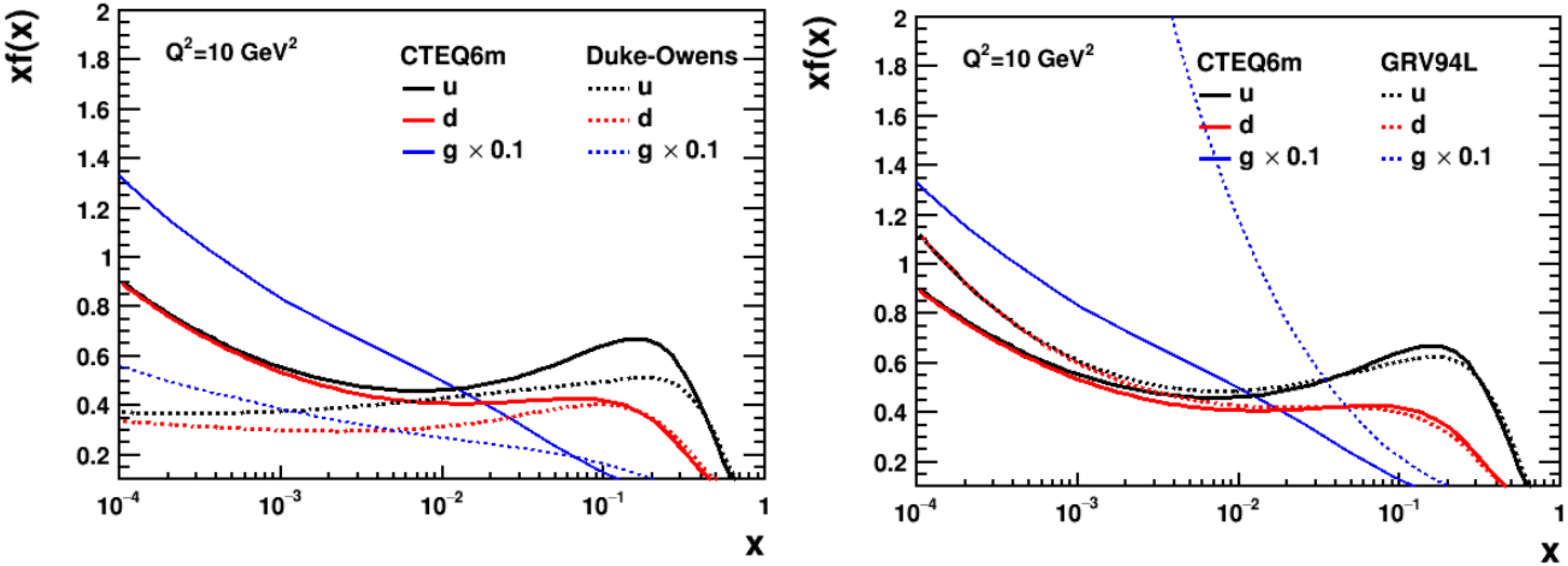
1. Motivation
2. Methods & Strategies
3. Results
   - Two component model parameter tuning
   - Fragmentation parameter tuning
4. Summary & Outlook

Motivation


A+B
PDF Cteq6M
Initial conditions
Parton Interactions
Hadronization
Hadron cascade
Final particle spectra


Structure of AMPT v2.xx (String Melting version)
A+B
HIJING1.0:
minijet partons (hard), excited strings (soft), spectator nucleons
Generate parton space-time
Strings melt to q & qbar
via intermediate hadrons
ZPC (parton cascade)
Partons freeze out
Hadronization (Quark Coalescence)
Extended ART (hadron cascade)
Hadrons freeze out (at a global cut-off time);
then strong-decay all remaining resonances
Final particle spectra

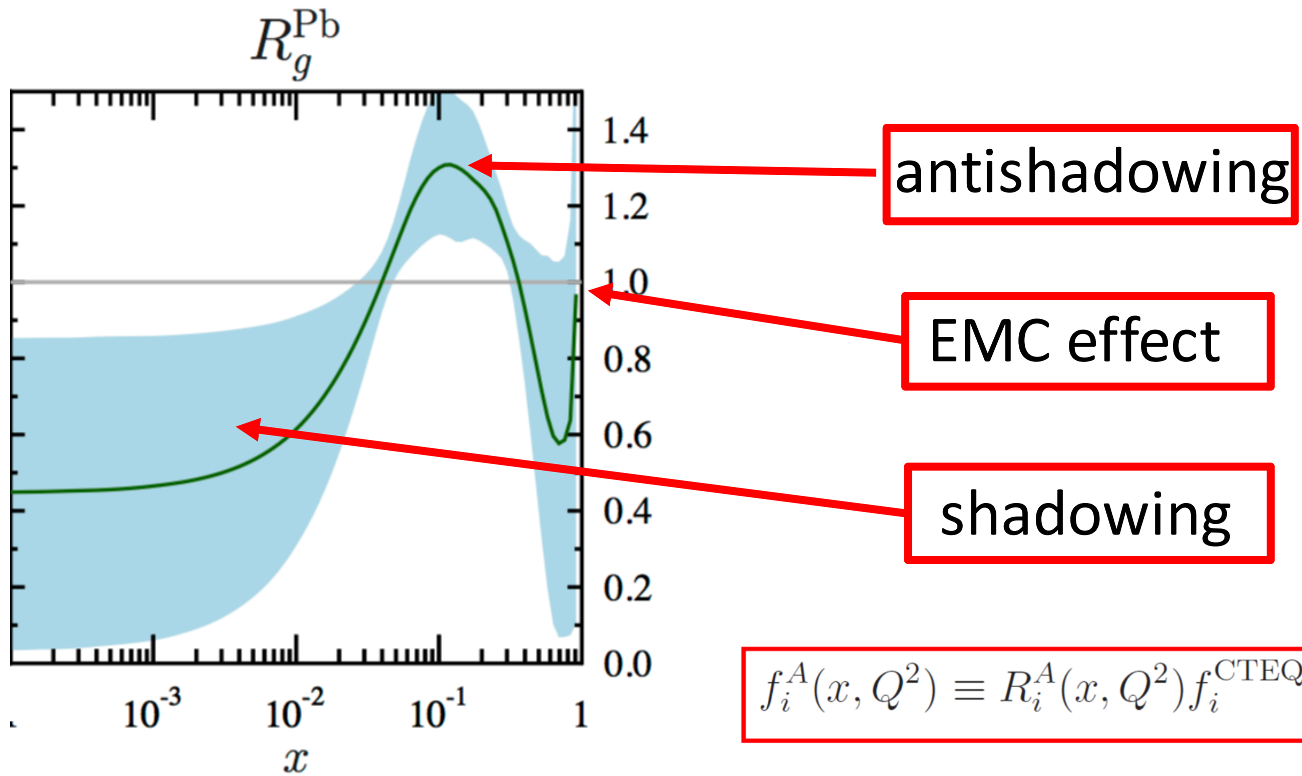
PDF: Parton Distribution Function



- Duke-Ovens: adequate for description at RHIC energies. ***Outdated***
- AMPT model: valid for wide energy range, especially LHC energies when minijet production reaches to a very small-x region, where gluon distribution is much ***higher*** than Duke-Owens parametrization. ***Update the PDF***.

- HIJING 2.0 work： GRV94L PDF.

Nuclear modification



$$f_i^A(x,Q^2) \equiv R_i^A(x,Q^2) f_i^{\mathrm{CTEQ6.1M}}(x,Q^2)$$

EPS, 0902.4154 [hep-ph]

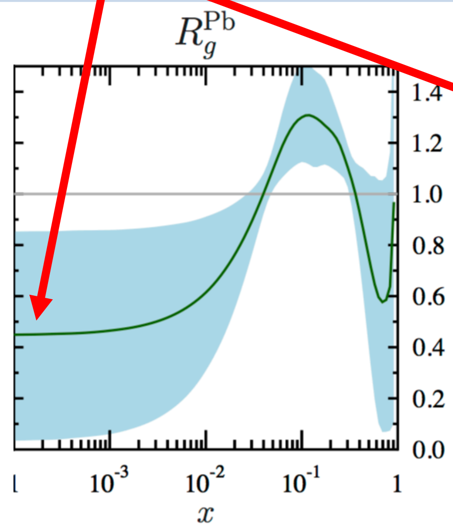
- Defined vs. CTEQ6.1M Free p PDFs.
- $R_g^{Pb}(x,Q_0^2)$: nuclear modification for gluon, obvious ***depress*** shadowing effect at small x.

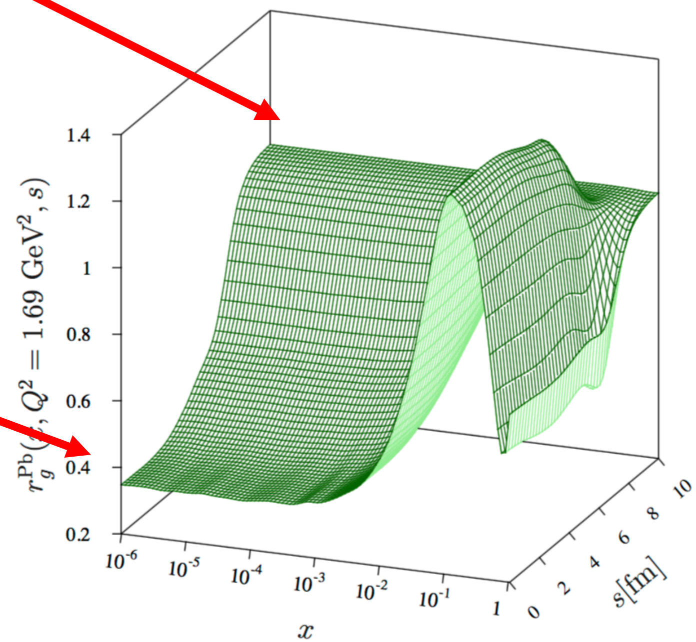
Nuclear modification factor vs. Impact parameter

$f_i^A(x,Q,\text{center}) \neq f_i^A(x,Q,\text{edge})$

By construction, nuclear modifications vanish at the edge of the nucleus.

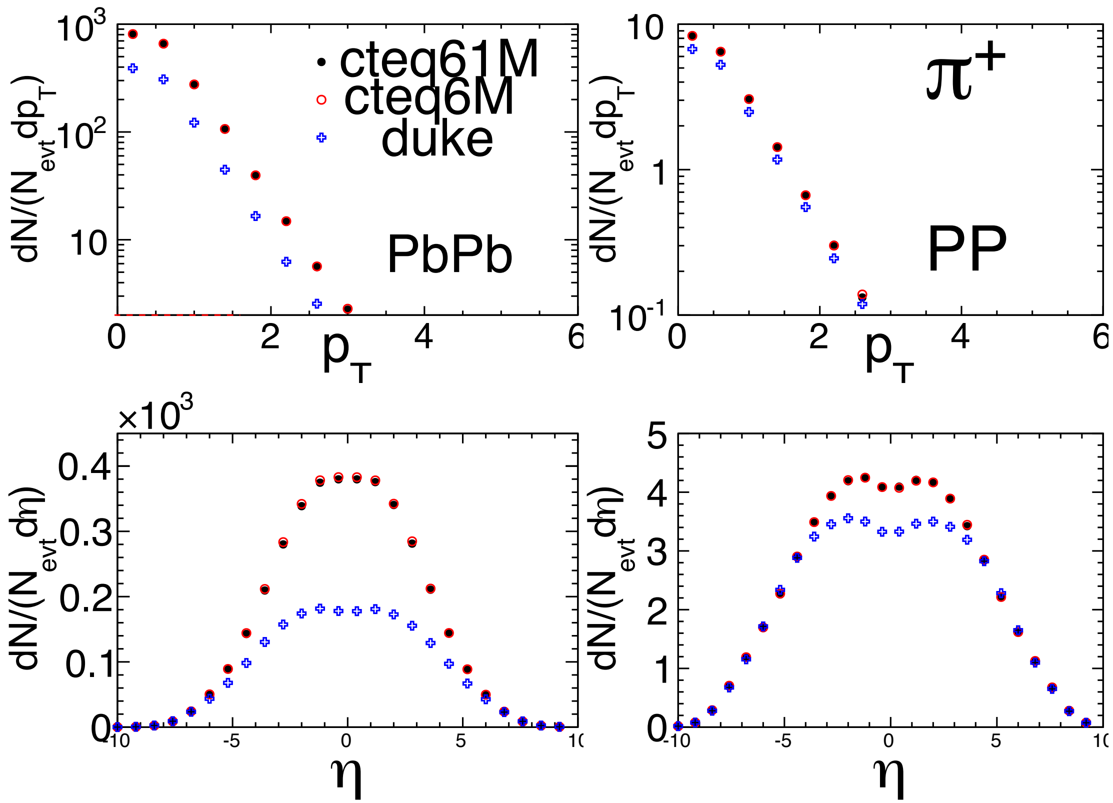
In the center of the nucleus the modifications are slightly stronger than the average.





HEHS, 1205.5359 [hep-ph]

Preliminary comparison without tuning



- PbPb collision: 2.76 TeV, Factor ~ ***3*** larger for both p_T and pseudorapidity, mainly within |eta|<5.
- PP collision: 13 TeV, No significant change vs. PbPb , 20% level increase |eta|~0.
- No significant difference between cteq61M and cteq6M.

Methods and strategies

Parameter tuning strategy

1. Total and inelastic cross section fitting: to get the key parameter input p_0 and σ_{soft} in the two component model.

2. Lund fragmentation parameter (a&b) tuning: use the charged particle pseudorapidity distribution and transverse momentum spectra.

Step 2 have no influence on the step 1,
thus we can do the step 1 first and then step 2.

Two component model

σ_{el}
σ_{tot}

p_T

Hard interactions (PQCD)
σ_{jet}

p_0

soft interactions
σ_{soft}

$$\sigma_{jet} = \int_{p_0^2}^{s/4} \mathrm{d}p_T^2 \mathrm{d}y_1 \mathrm{d}y_2 \frac{1}{2} \frac{\mathrm{d}\sigma_{jet}}{\mathrm{d}p_T^2 \mathrm{d}y_1 \mathrm{d}y_2},$$

$$\frac{\mathrm{d}\sigma_{jet}}{\mathrm{d}p_T^2 \mathrm{d}y_1 \mathrm{d}y_2} = K \sum_{a,b} x_1 f_a(x_1, p_T^2) x_2 f_b(x_2, p_T^2) \frac{\mathrm{d}\sigma^{ab}(\hat{s}, \hat{t}, \hat{u})}{\mathrm{d}\hat{t}}$$

$$\chi(b,s) \equiv \chi_s(b,s) + \chi_h(b,s) = \frac{1}{2}\left[\sigma_{soft} T_{NN}(b) + \sigma_{jet} T_{NN}(b)\right],$$

Key input parameters in the model

$$\sigma_{tot} = 2\pi \int_0^\infty \mathrm{d}b^2 \left[1 - e^{\chi(b,s)}\right]$$

$$\sigma_{el} = \pi \int_0^\infty \mathrm{d}b^2 \left[1 - e^{\chi(b,s)}\right]^2$$

$$\sigma_{in} = \pi \int_0^\infty \mathrm{d}b^2 \left[1 - e^{2\chi(b,s)}\right]$$

$$\sigma_{tot} = 2\pi \int_0^\infty \mathrm{d}b^2 \left[1 - e^{\chi(b,s)}\right]$$

PHYSICAL REVIEW C 83, 014915 (2011)

Tuning method

HIJING input

↓

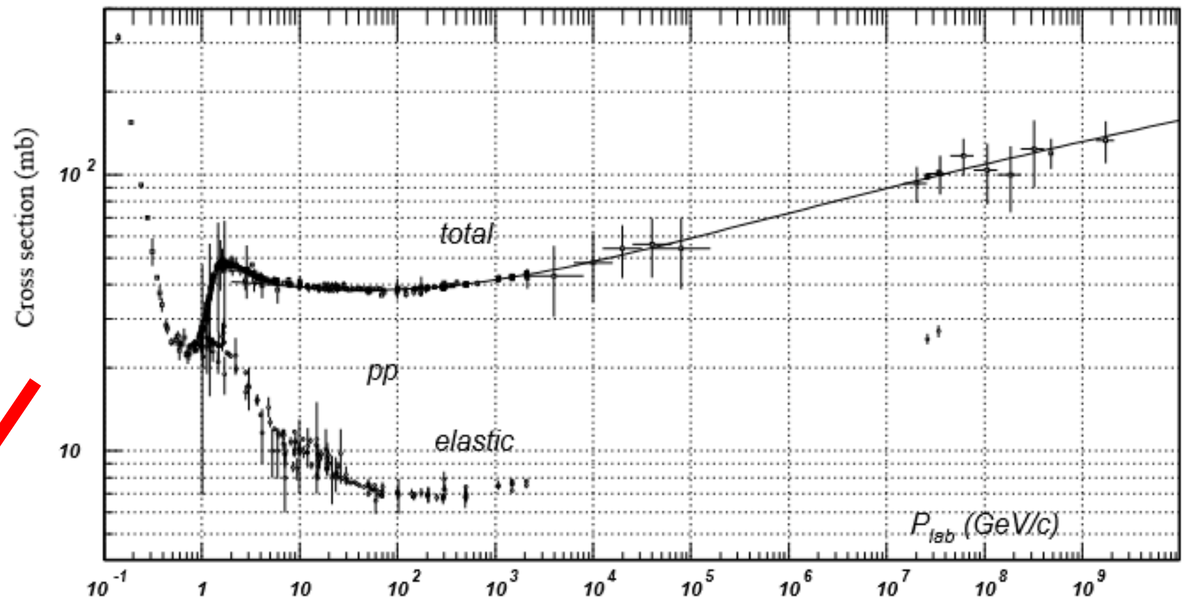
$p_0 \quad \sigma_{soft}$

↓

$\sigma_{el\_ampt} \quad \sigma_{tot\_ampt}$

↓ compare

$\sigma_{el\_fit} \quad \sigma_{tot\_fit}$

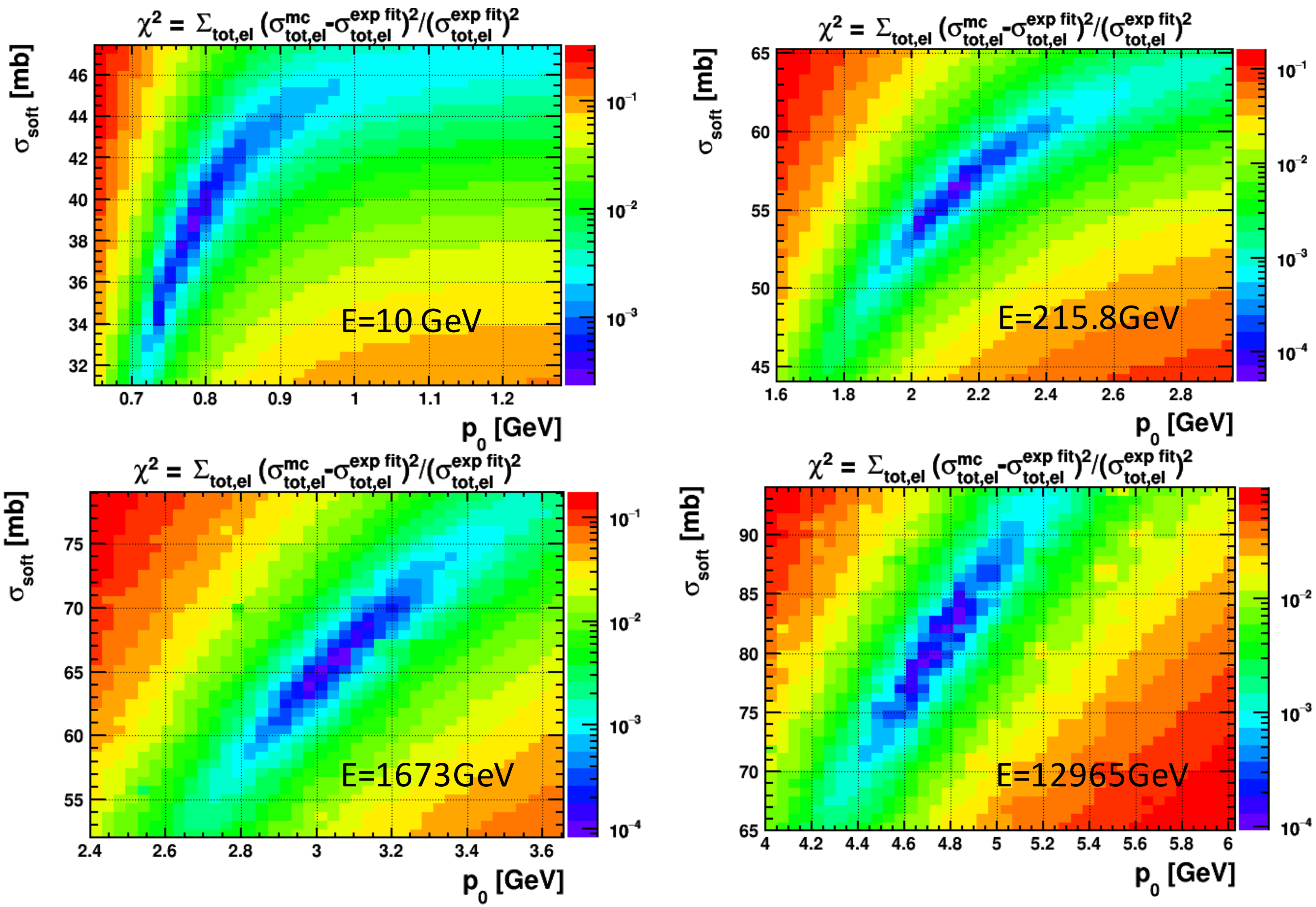


C. Patrignani et al. (Particle Data Group), Chin. Phys. C, 40, 100001 (2016).

A relative residual sum of squared is defined as the target function to be minimized allowed p_0 *and* σ_{soft} parameters

$$\text{Minimize } \chi^2 = \frac{(\sigma_{tot\_ampt} - \sigma_{tot\_fit})^2}{\sigma_{tot\_fit}} + \frac{(\sigma_{el\_ampt} - \sigma_{el\_fit})^2}{\sigma_{el\_fit}}$$

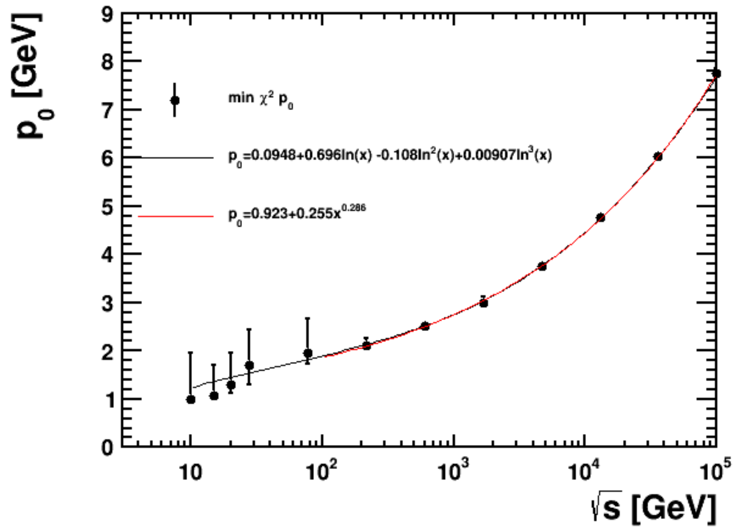
χ2 plots

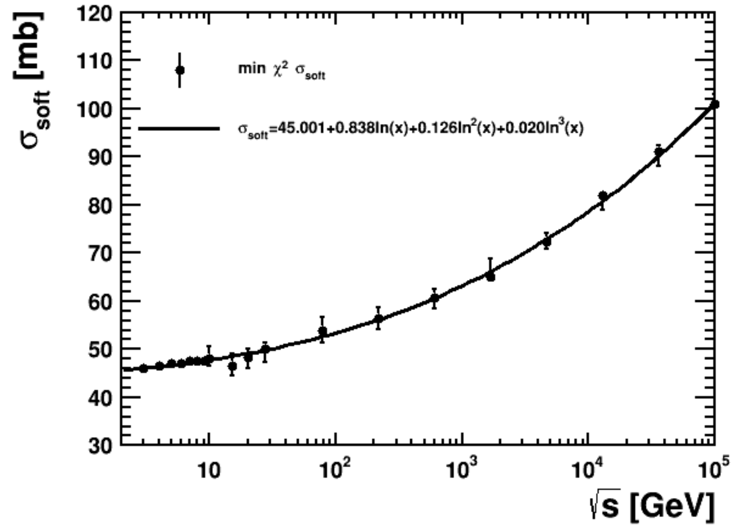


$\chi^2 = \Sigma_{tot,el}\,(\sigma^{mc}_{tot,el}-\sigma^{exp\ fit}_{tot,el})^2/(\sigma^{exp\ fit}_{tot,el})^2$
σ_{soft} [mb]
p_0 [GeV]
E=10 GeV
E=215.8GeV
E=1673GeV
E=12965GeV

p_0 and σ_{soft} tuning

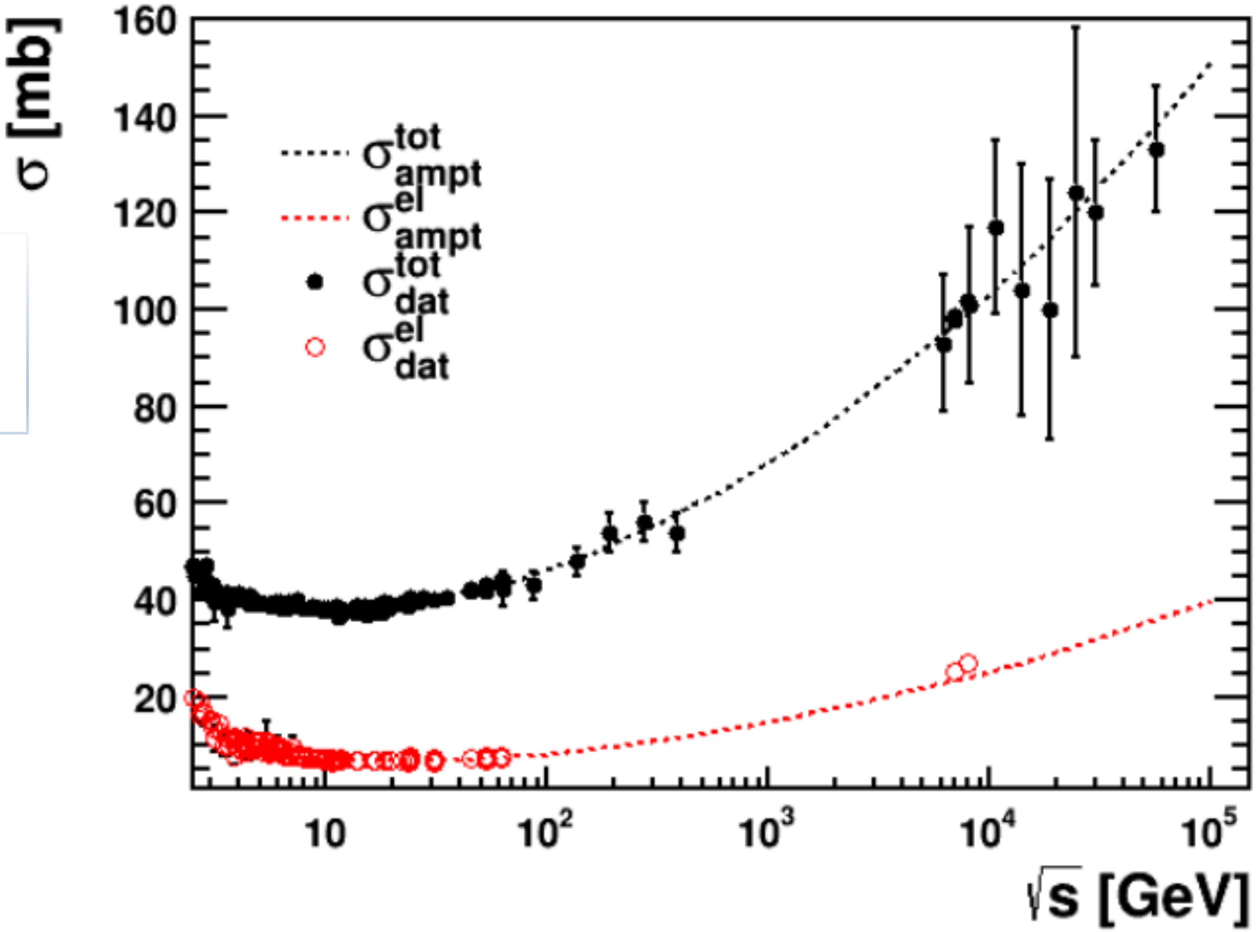
- This fit is done for the the PDF ***Cteq6m.***
- When collision energy $\sqrt{S_{\rm NN}}$ >10 GeV, it is matched with both σ_{tot} and σ_{el}, however when $\sqrt{S_{\rm NN}}$ <10 GeV, we only fit to the ***Inelastic*** cross section.
- Jet cross section is completely switched off below 10 GeV in HIJING.





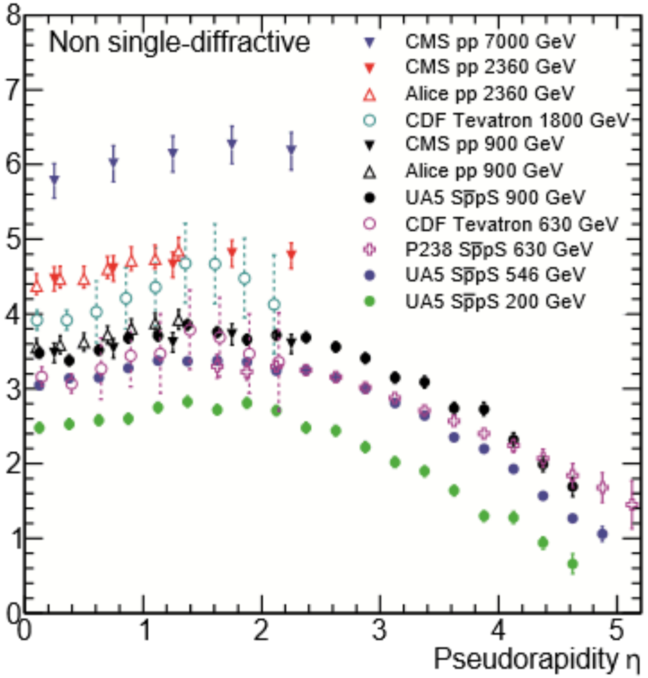
results

The ampt results compared to pp data.

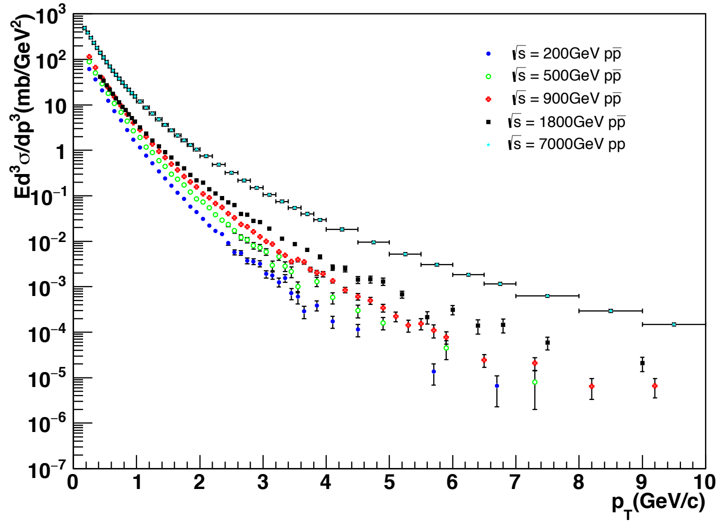


Experimental data

Charged particle pseudorapidity distributions



Invariant transverse momentum spectra



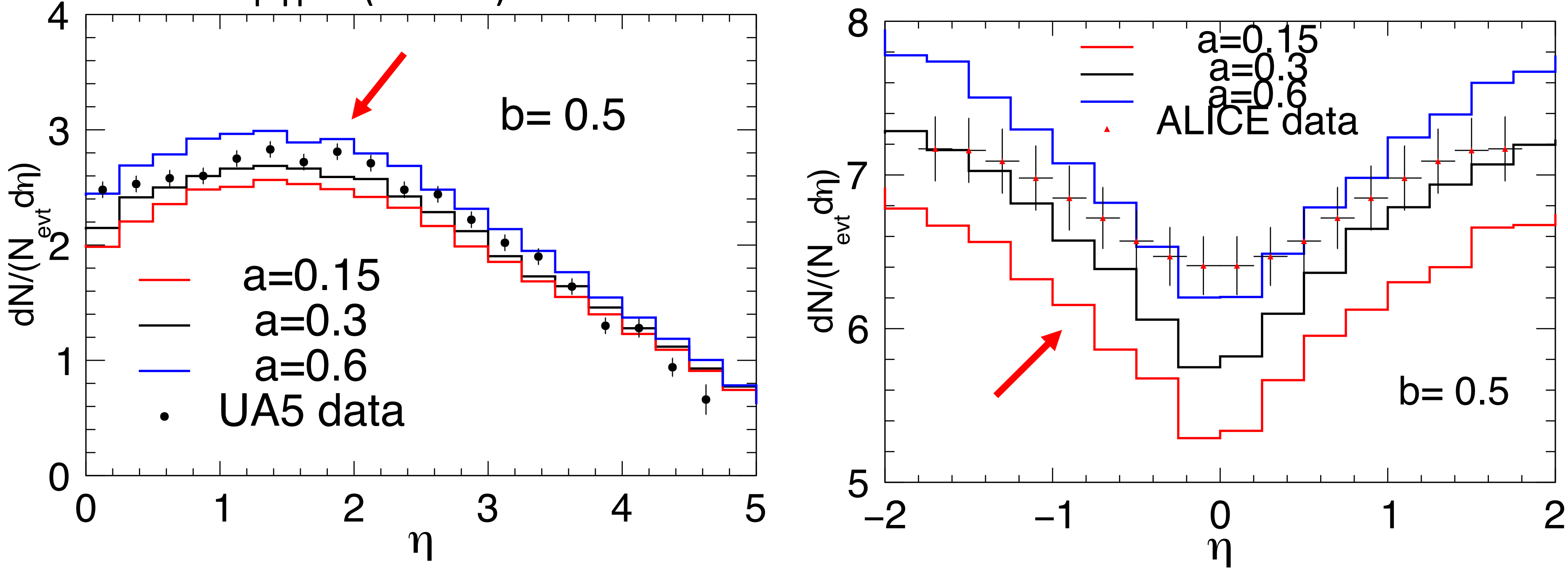
- The data were used to tune the fragmentation parameters (a&b)

Parameter (*a*) contribution to *η* distribution

Default version;
pp collision

- We fix b=0.5 and vary a=0.15 ~ 0.6 range
- Larger (a) gives overall larger charge particle density.

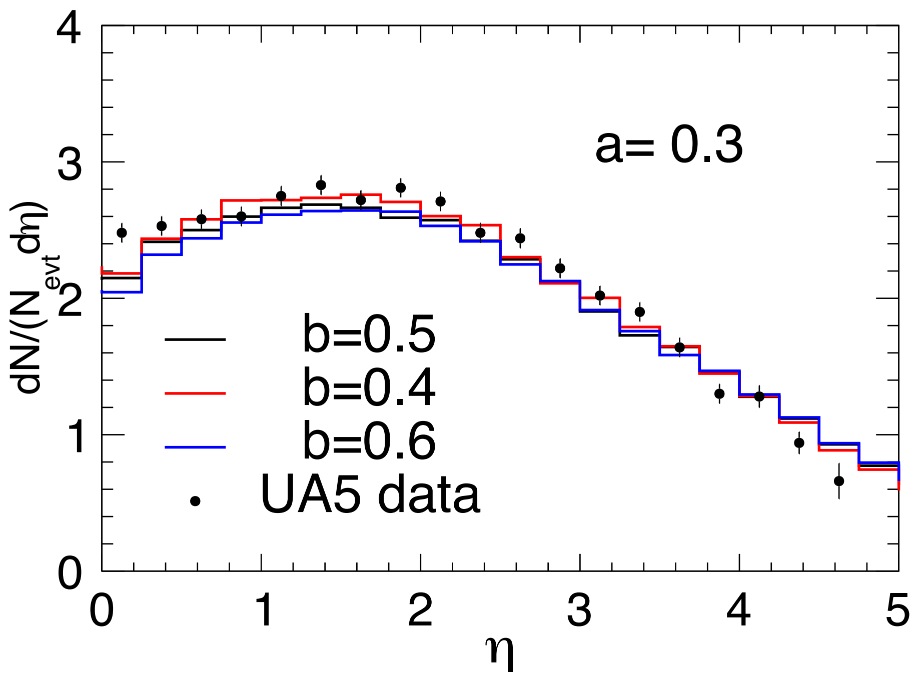
NSD cut made with 2<|η|<5 for UA5 data and at least one track within |η|<1 (INEL>0) for LHC data



Parameter (*b*) contribution to *η* distribution

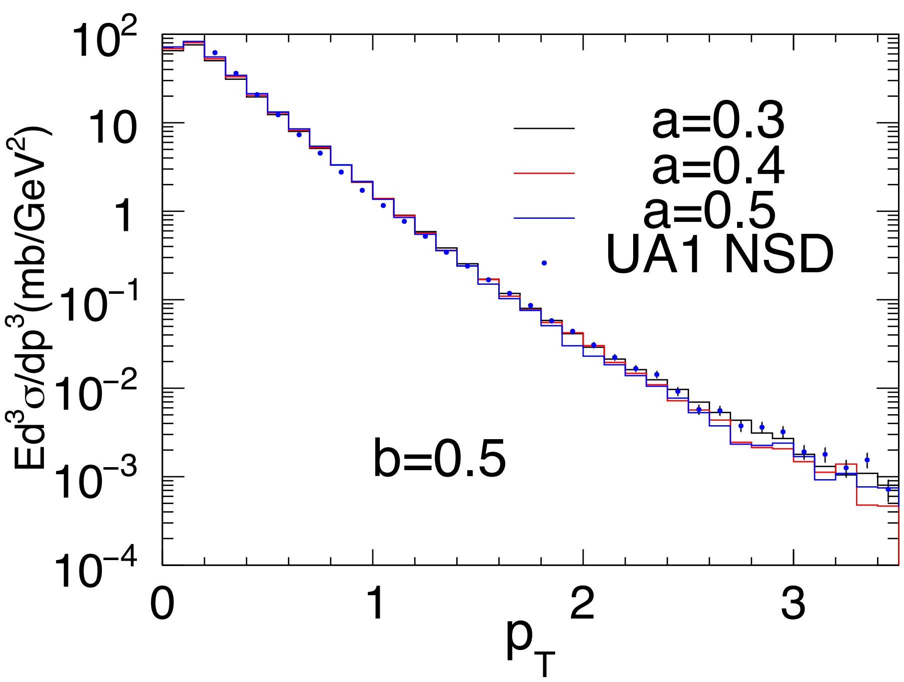
- We fix a=0.3 and vary b=0.4 ~ 0.6 range
- Charge particle density becomes slightly larger with smaller b at η~0, but the change is not strong enough to explain the difference to data from 0.4 to 0.6

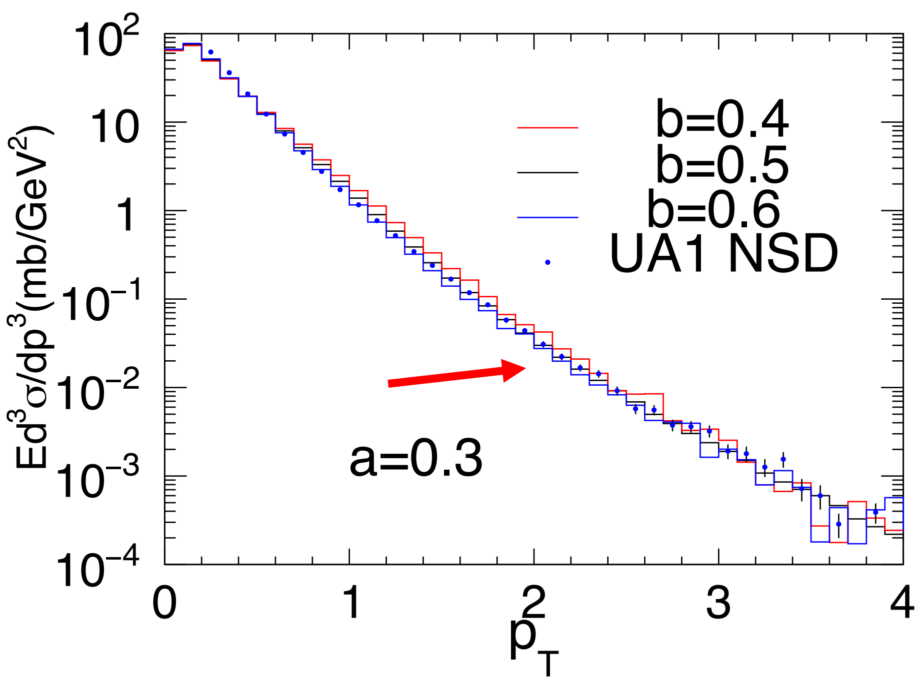
NSD cut made with both ends of 2<|η|<5 accepts charged tracks for UA5 ppbar data at 200 GeV



$a\&b$ contribution to the P_T spectra

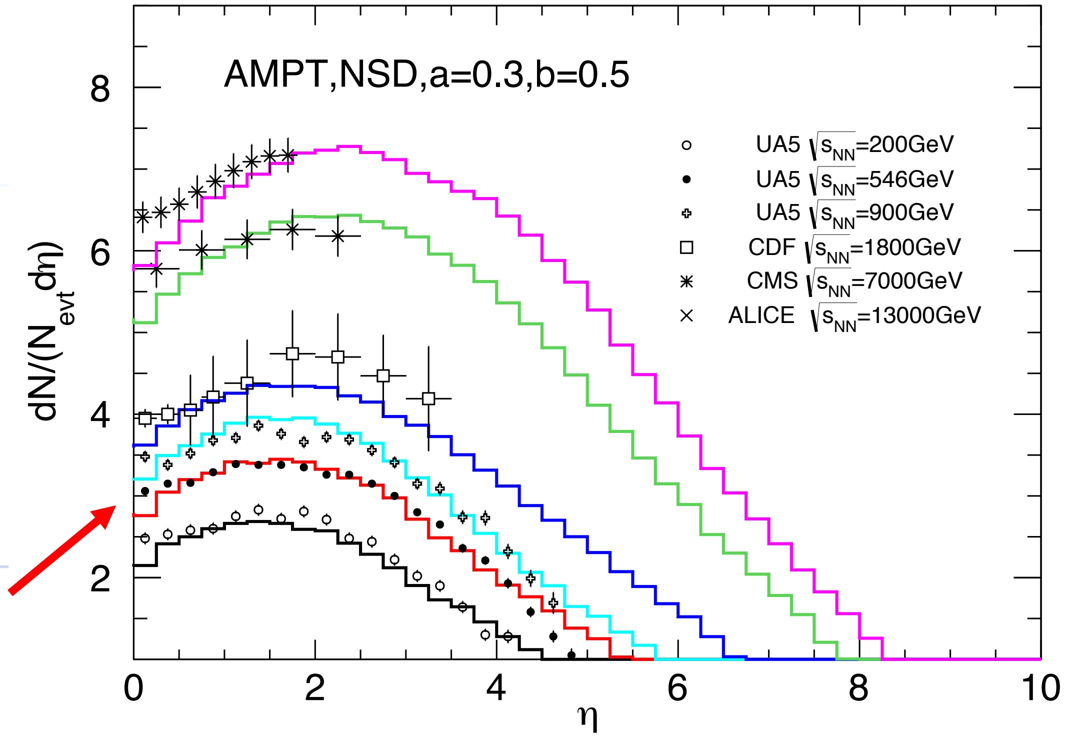
- The p_T spectra is not so sensitive to the variation of a.
- It agrees better with b=0.5; smaller b (b=0.4) leads to wider p_T tail.





a&b tuning

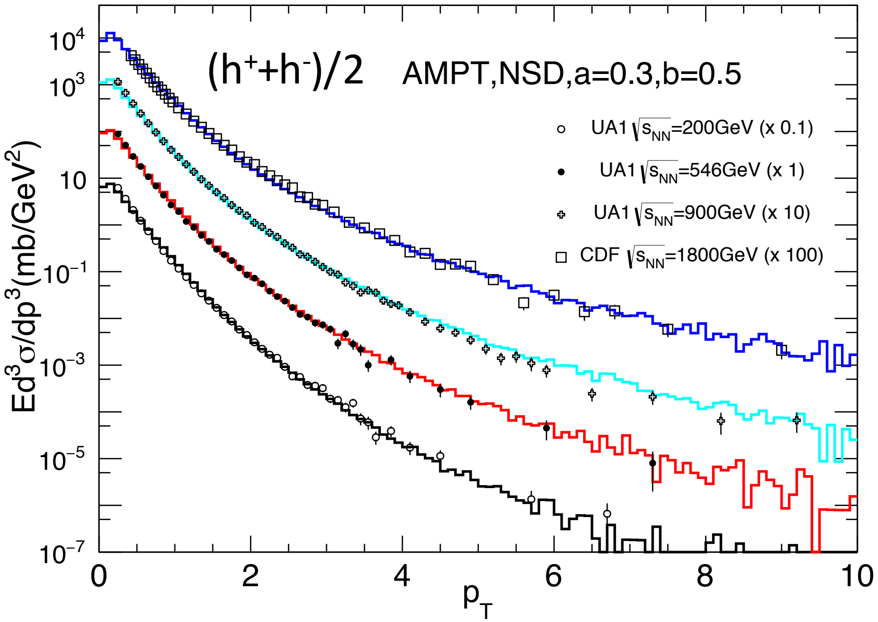
- a=0.3 , b=0.5 agrees with data in general,
- The mid-rapidity η~0 region is always smaller than data at different energy scales .

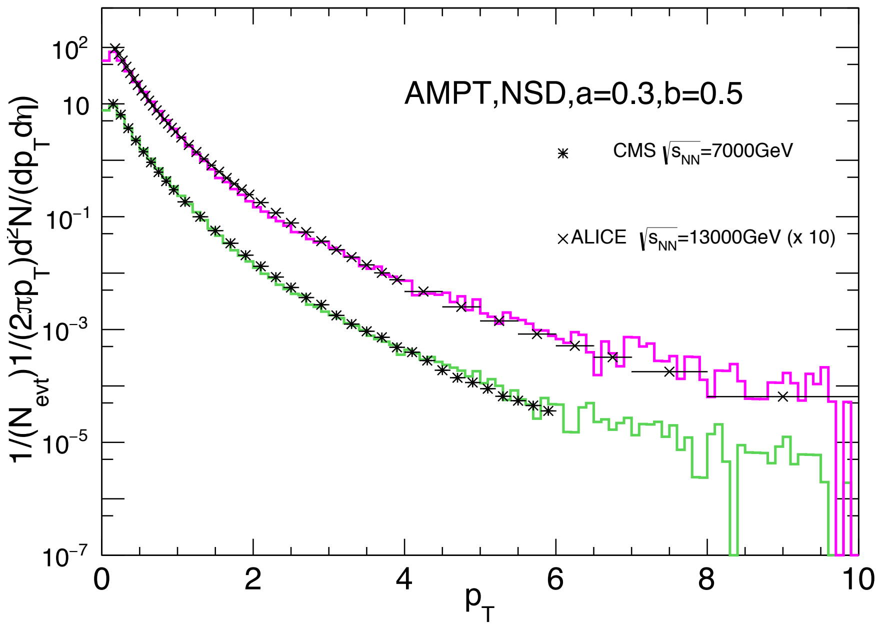


UA5 Collaboration, G.J. Alner et al. Z. Phys. C – Particles and Fields 33, 1-6(1986).
CDF Collaboration F.D. Snider et al. Phys. Rev. D 41, 2330 (1990).
CMS Collaboration V. Khachatryan et al. PRL 105, 022002 (2010).
ALICE Collaboration Physics Letters B 751 (2015) 143–163 .

a&b tuning

- The p_T spectra is consistent with data at all energies ranging from 200 GeV to 13 TeV



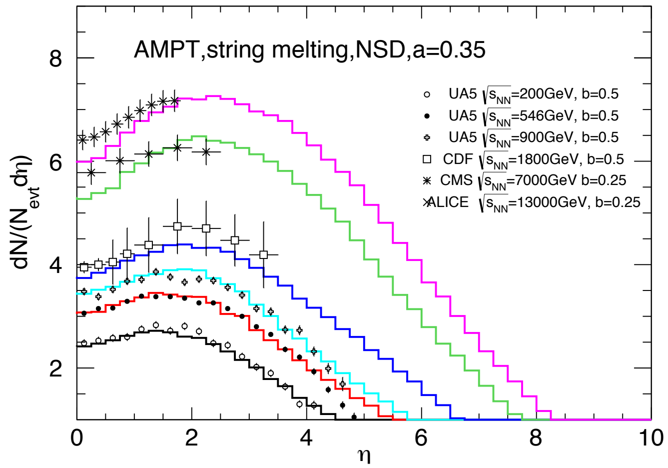


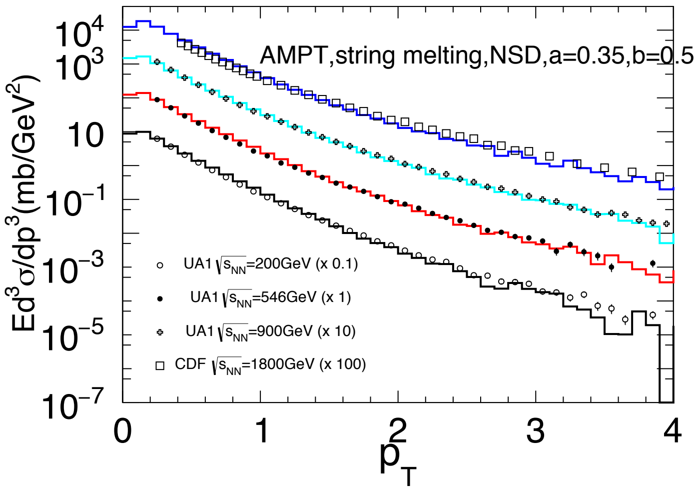
UA1 Collaboration, C. Albajar, et al.Nuclear Physics B335 (1990) 261-287
CDF *Collaboration,* F. Abe, Phys. Rev. Lett. **61**, 1819 (1988).

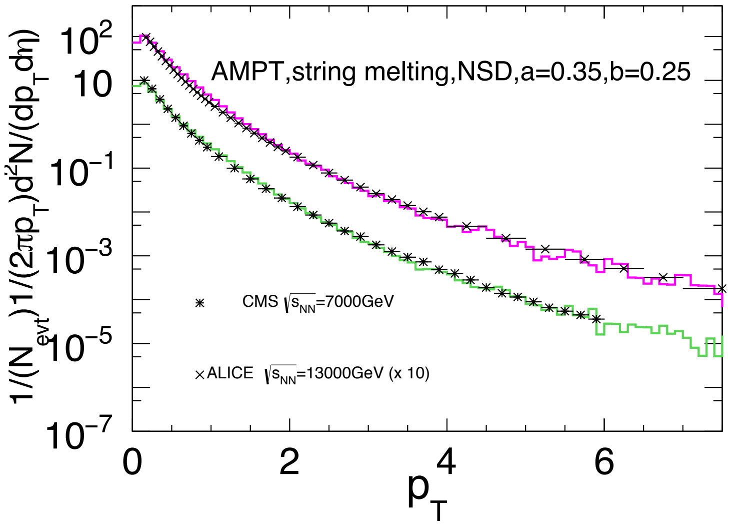
a&b tuning

String melting version;
pp collision

- a=0.35, b=0.5 for energy below 1800 GeV, b=0.25 for others.
- The overall feature agrees with data in all energies.







Summary & Outlook

Summary:

1. The necessity for updated PDF and nuclear shadowing modification.
2. Built up the systematic strategy to determine the parameter.
3. Fit the energy dependence of p_0 and σ_{soft} as well as tuning the parameters with the latest dataset.

Outlook:

1. Implement inelastic 2->2 interactions in the current ZPC model.
2. Determination of the Lund fragmentation parameter a and b for AA collision on the string melting mode.
3. Study the Heavy Flavor results with the updated AMPT model.