Update of a Multi-Phase Transport Model with Modern Parton Distribution Functions and Nuclear Shadowing

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PHYSICAL REVIEW C **99**, 064906 (2019)

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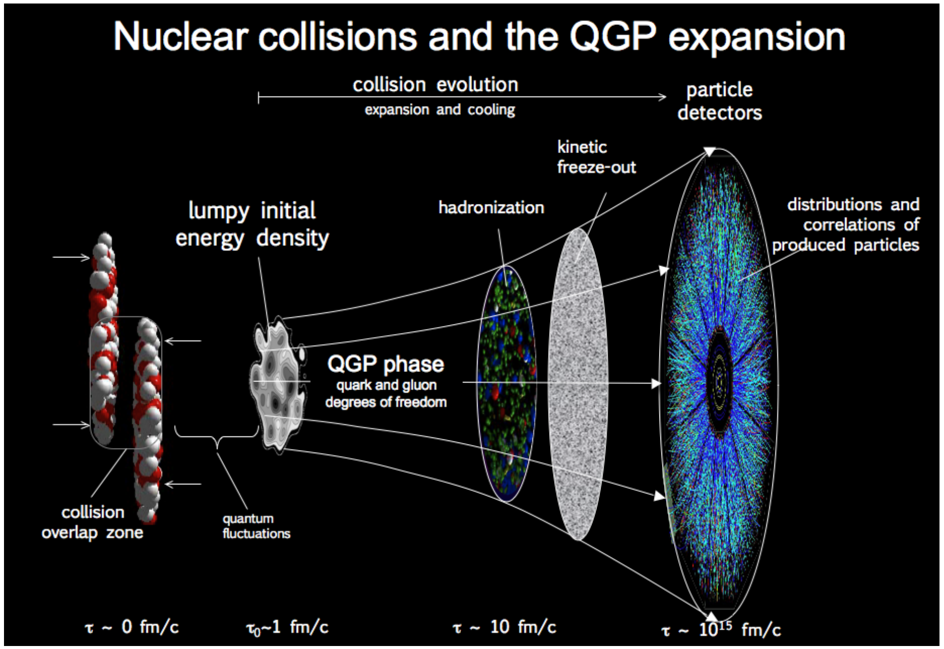
Introduction



- The ***heavy flavor*** production is sensitive to the gluon distribution (according to pQCD calculation).
- Upgrade the parton distribution function (***PDF***) in initial condition is important.

Structure of AMPT (string melting)

A+B → ***PDF Cteq6M***

↓

HIJING

↓

ZPC

↓

Quark Coalescence

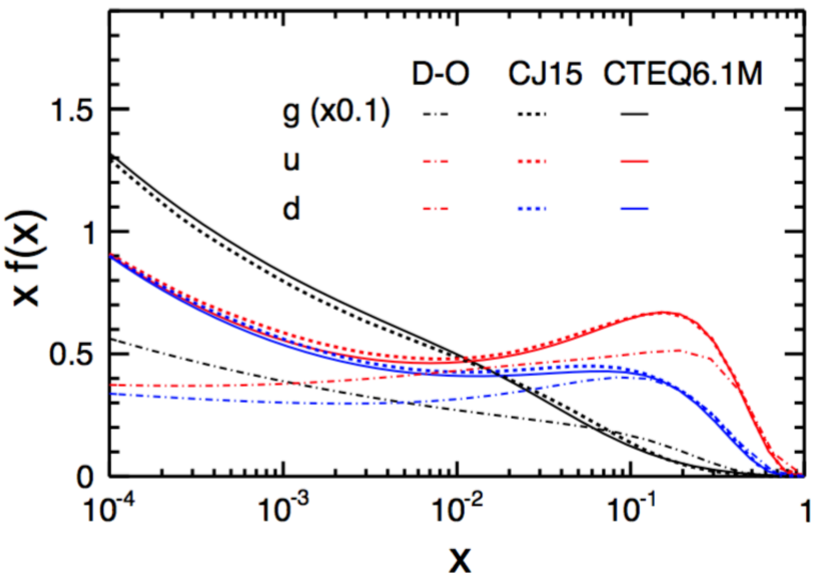
↓

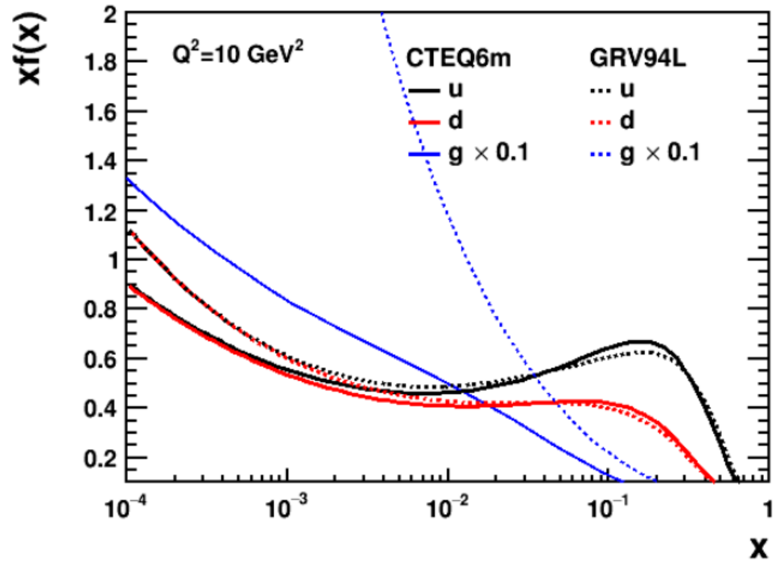
ART

↓

Final particle spectra

Parton Distribution Function



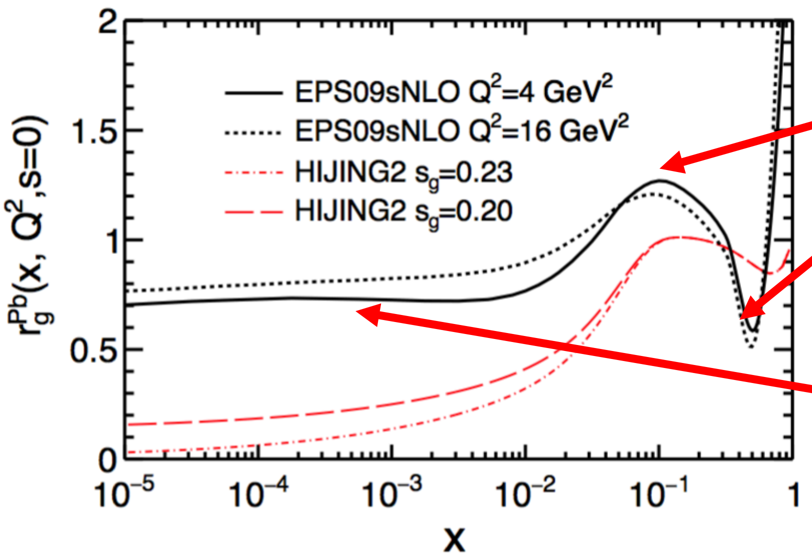


- *Duke-Owens*: used in the current published AMPT model. ***Outdated;***
  CJ15: experiments data at LHC utilized, ***modern PDF***.
  GRV94L: HIJING 2.0 work.
- AMPT model: valid for wide energy range, especially LHC energies when minijet production reaches to a very small-x region, where gluon distribution is much ***higher*** than Duke-Owens parameterization. ***Update of the PDF*** is important.

Wei-Tian Deng PHYSICAL REVIEW C **83**, 014915 ; A. Accardi, Phys. Rev. D 93, no. 11, 114017 (2016).

Spatial-Dependent nPDFs

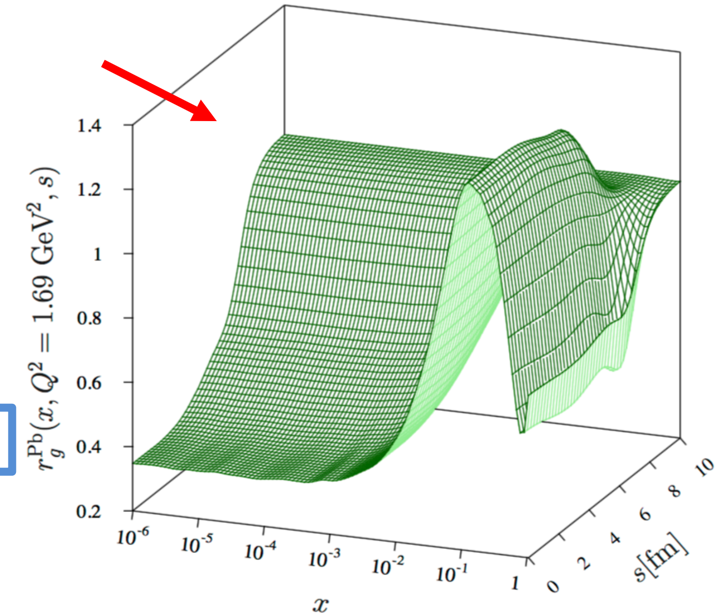
$$f_i^A(x,Q^2) \equiv R_i^A(x,Q^2) f_i^{\mathrm{CTEQ6.1M}}(x,Q^2)$$



Anti-shadowing

EMC effect

Shadowing



Ilkka helenius. JHEP 1207 (2012) 073

- Incorporate modern PDF and nPDFs improve the AMPT model for heavy flavor and high p_T observables.

The HIJING Two-Component Model

σ_{el}

σ_{tot}

p_T

Hard interactions (pQCD)

σ_{jet}

p_0

soft interactions

σ_{soft}

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

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

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

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

Key input parameters in the model

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

Tuning Method

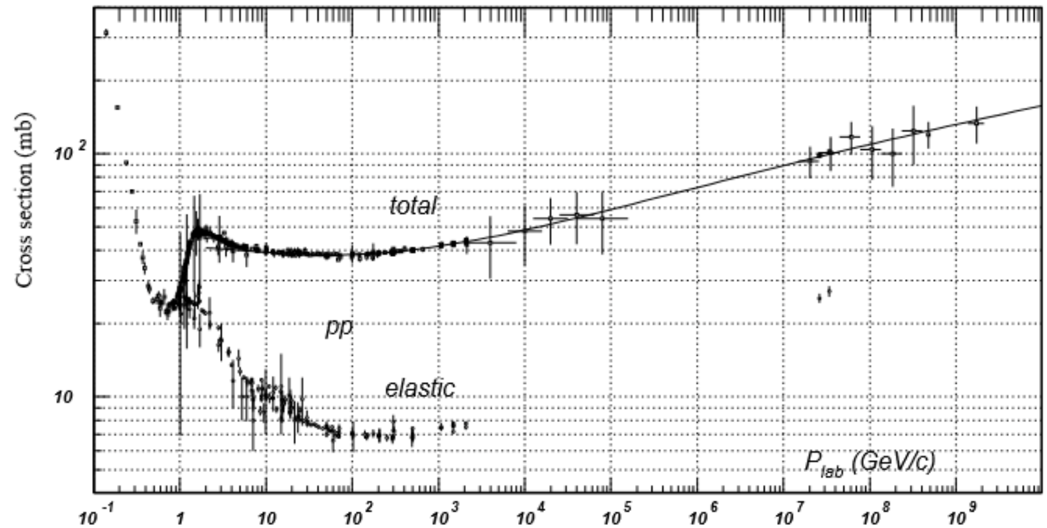
$p_0 \quad \sigma_{soft}$

↓

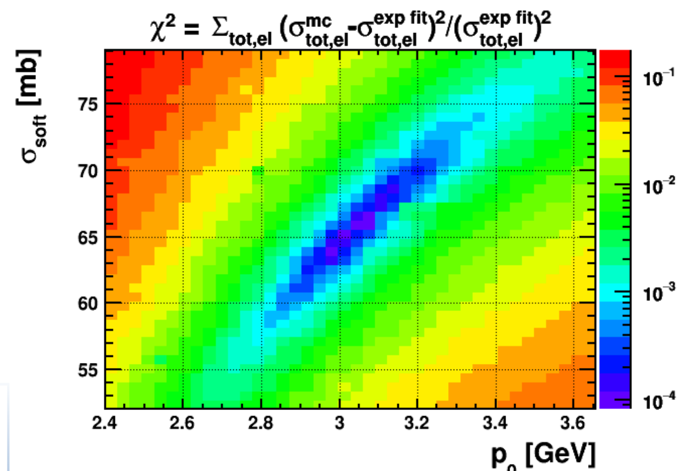
$\sigma_{el\_ampt} \quad \sigma_{tot\_ampt}$

↓ compare

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

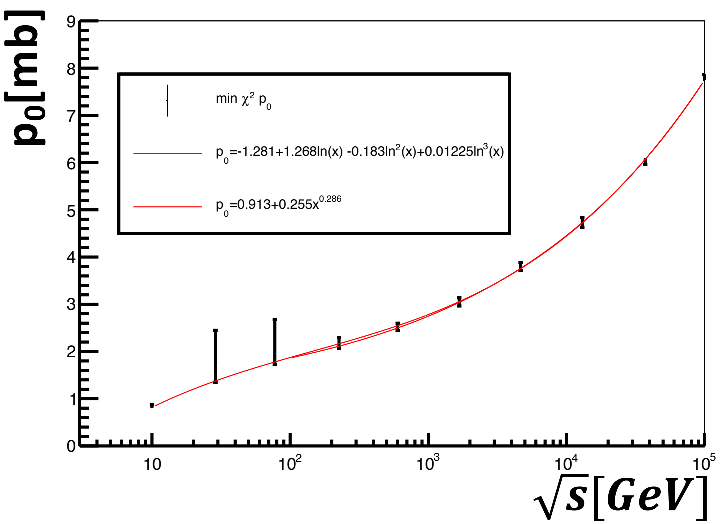


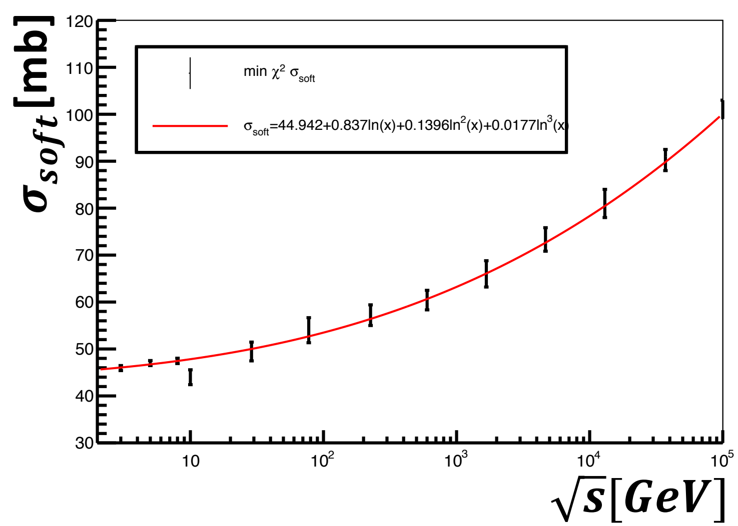
A relative residual sum of squared is defined as the target function to be minimized allowed p_0 *and* σ_{soft} parameters

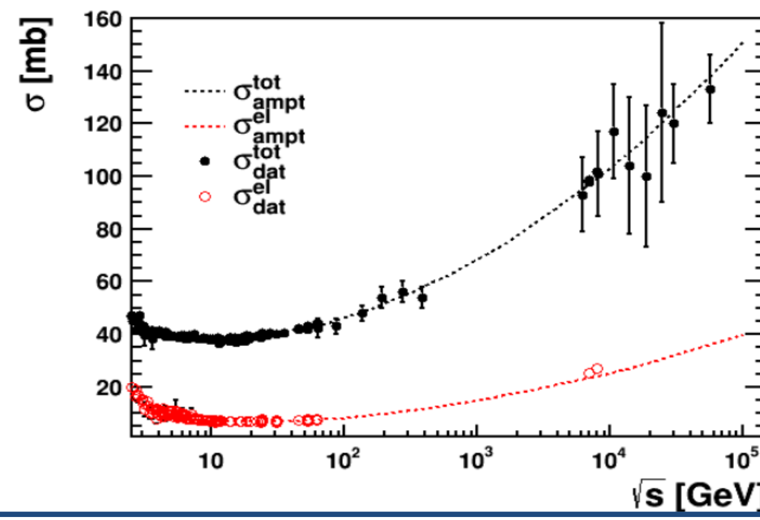


$$\text{Minimize } \chi^2 = \frac{(\sigma_{tot\_ampt} - \sigma_{tot\_fit})^2}{(\sigma_{tot\_fit})^2} + \frac{(\sigma_{el\_ampt} - \sigma_{el\_fit})^2}{(\sigma_{el\_fit})^2}$$

Tuning of p_0^{pp} and σ_{soft}

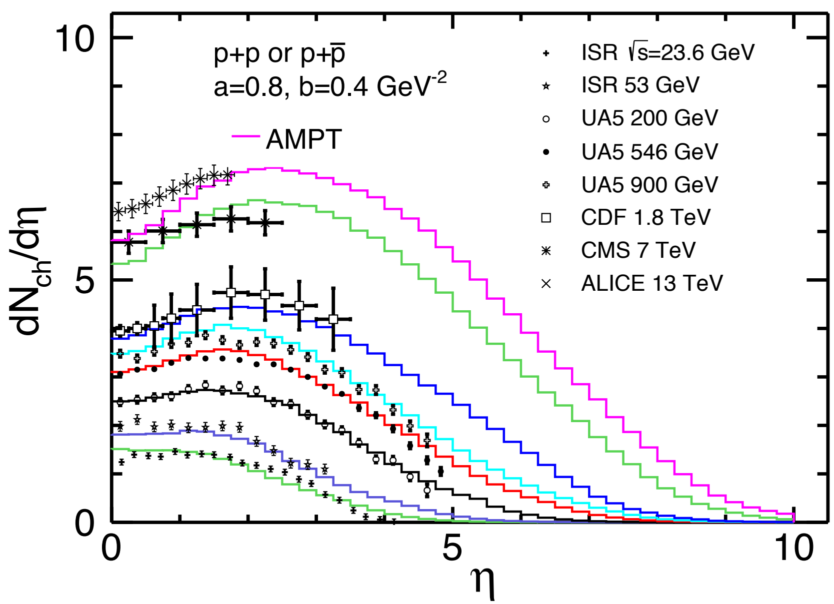


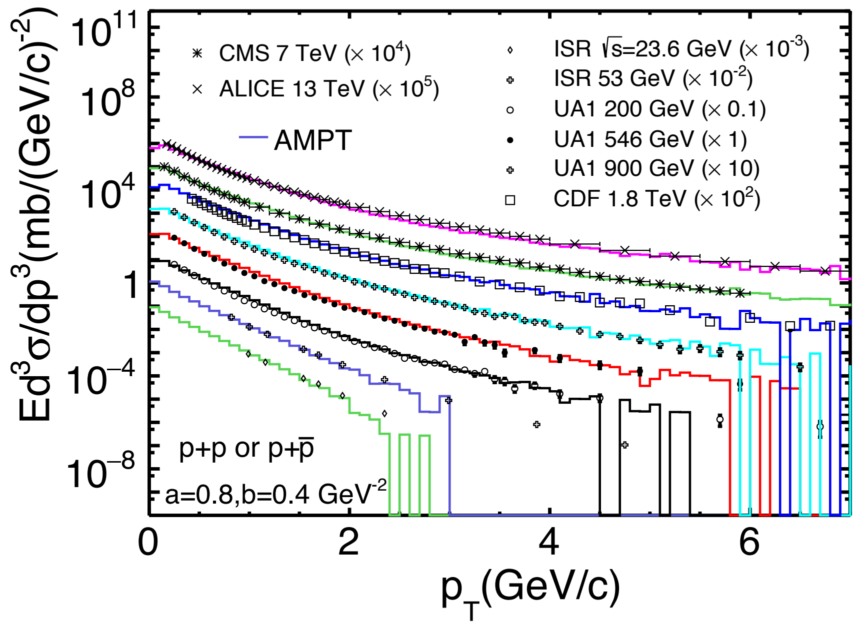




- Tuning the p_0^{pp} and σ_{soft} by fitting the experimental data of total and inelastic cross section.

N_{ch} in pp Collisions



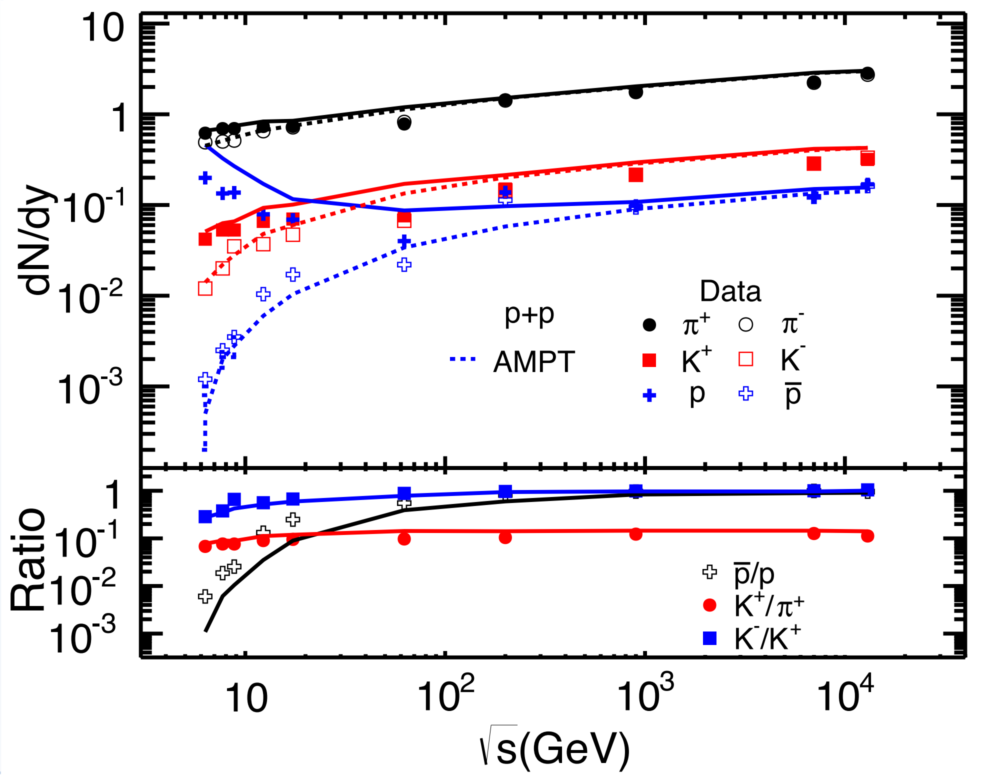


- Larger lund ***a*** typically gives larger pseudo-rapidity distributions, smaller ***b*** leads to a more flat p_T spectrum.
- Lund ***a***=0.8 , ***b***=0.4 agrees with data in general.

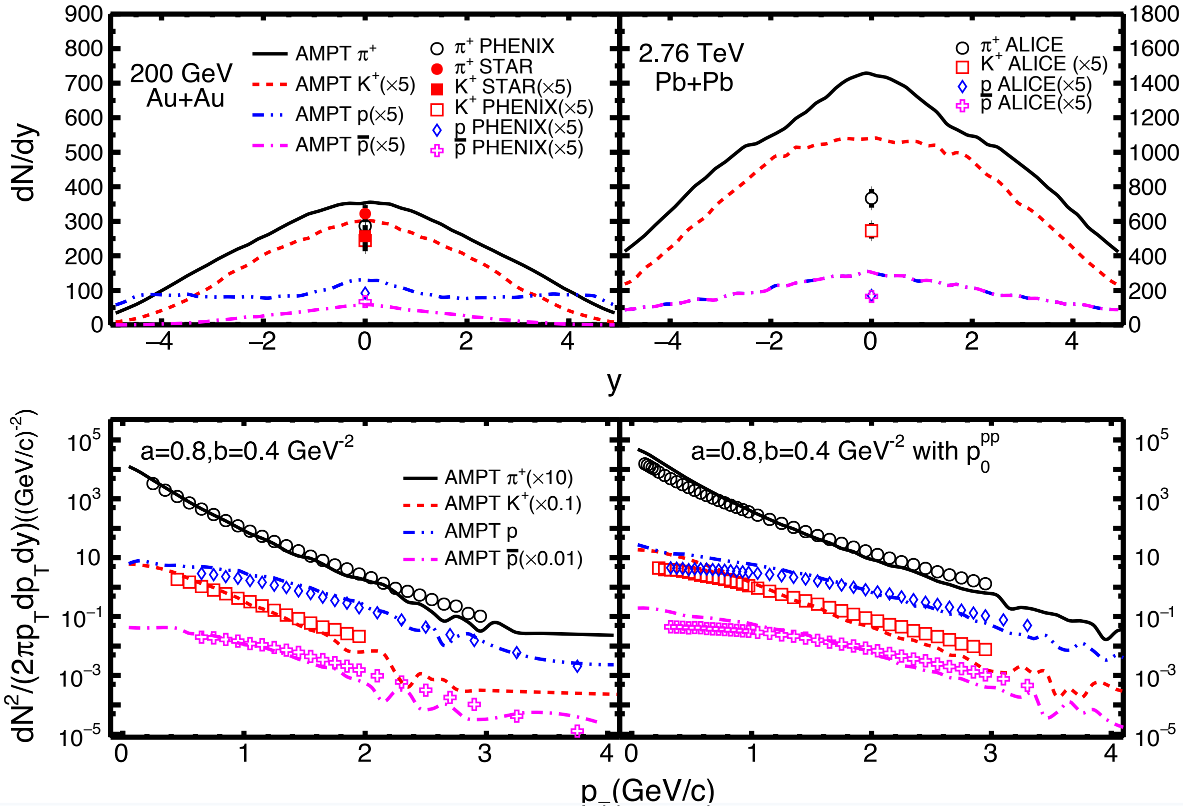
UA5 Collaboration, Z. Phys. C – Particles and Fields 33, 1-6(1986). CDF Collaboration, Phys. Rev. D 41, 2330 (1990).
CMS Collaboration, PRL 105, 022002 (2010). ALICE Collaboration, Physics Letters B 751 (2015) 143–163 .
UA1 Collaboration, C. Nuclear Physics B335 (1990) 261-287. CDF *Collaboration,* Phys. Rev. Lett. **61**, 1819 (1988).

π/k/p Production

- Energy dependence of the identified particles dN/dy at mid-rapidity.
- Charged π and k productions from the AMPT model show good consistency with data.
- AMPT underestimates the anti-proton yields and overestimates the proton yields at low colliding energies.

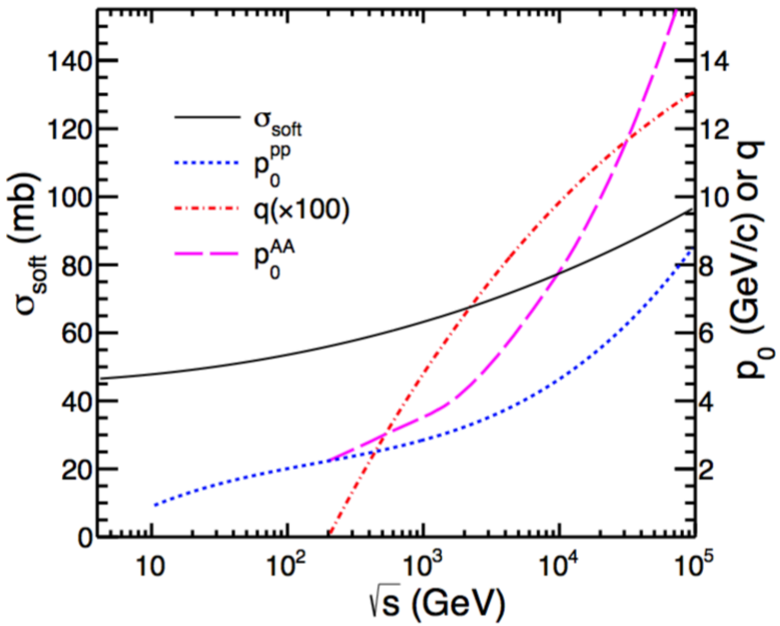


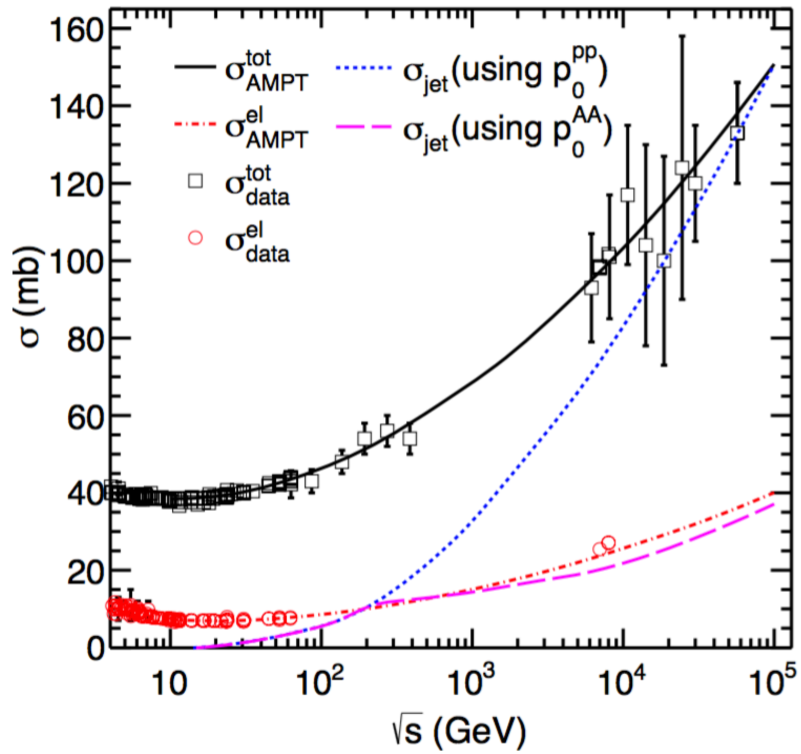
Particle Production in AA Collision



- AMPT string-melting version with lund a=0.8 & b=0.4 and p_0^{pp} minijet cutoff.
- Overestimates the yields of most of these particles, the $\mathrm{p_T}$ spectra from the AMPT model are mostly softer than data.

A-scaling of p₀ (p_0^{AA})



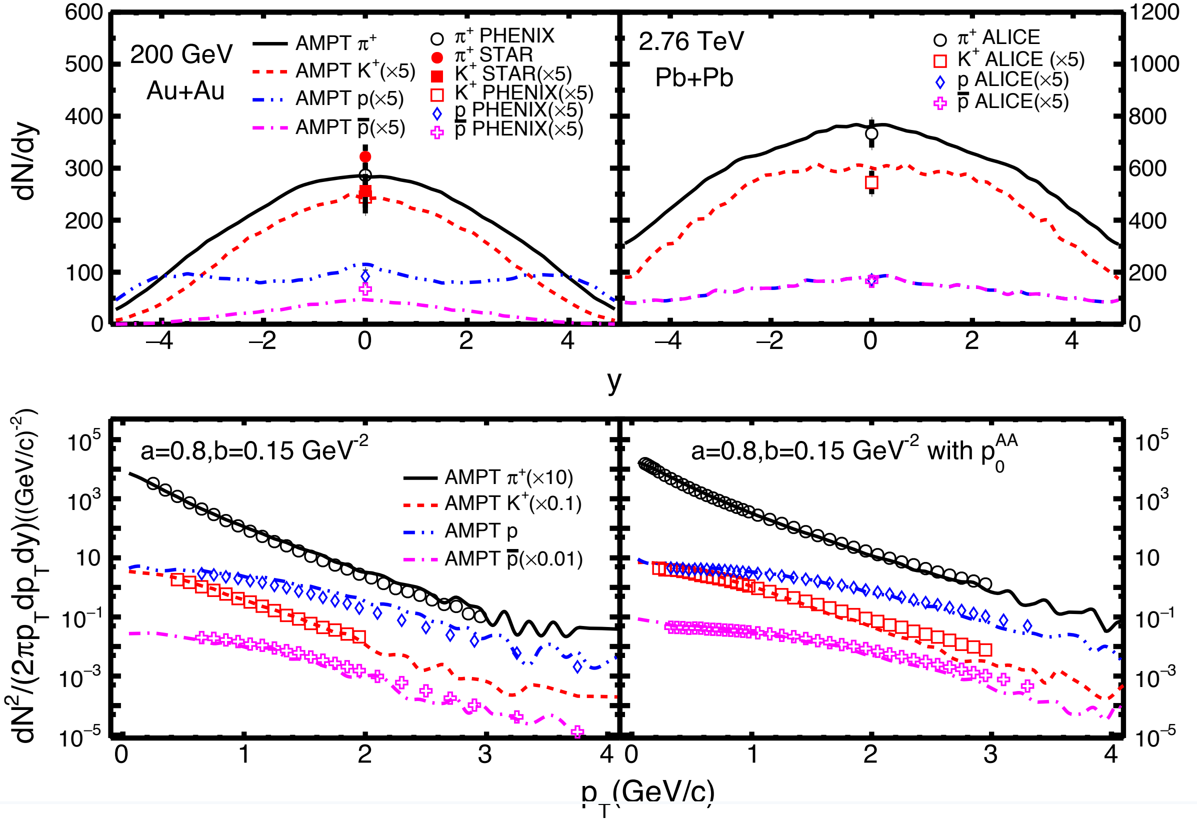


$$p_0^{AA} = p_0^{pp} A^{q(s)},$$

$$q(s) = 0.0334\, ln\left(\frac{\sqrt{s}}{200}\right) - 0.00232\, ln^2\left(\frac{\sqrt{s}}{200}\right) + 0.0000541\, ln^3\left(\frac{\sqrt{s}}{200}\right), \text{for } \sqrt{s} \geq 200 \text{ GeV}$$

- The nuclear scaling of the minijet momentum cutoff scale *p0* is motivated by the physics of final state saturation model(EKRT etc.)

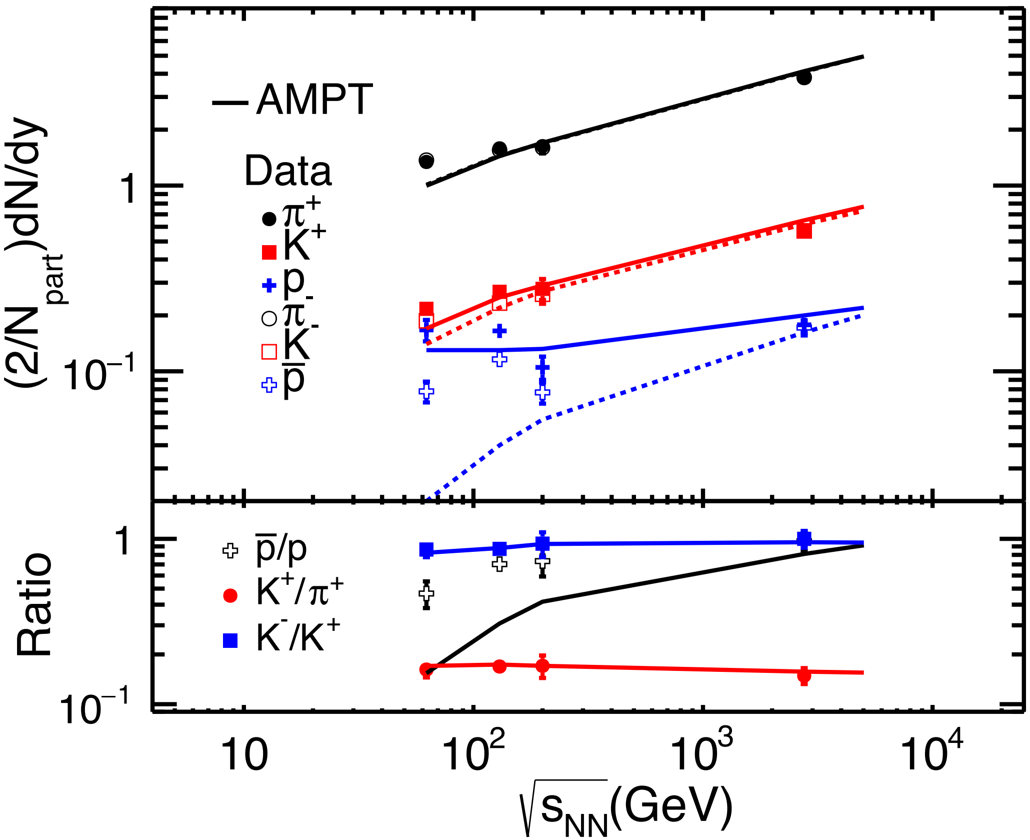
Particle Production with p_0^{AA}



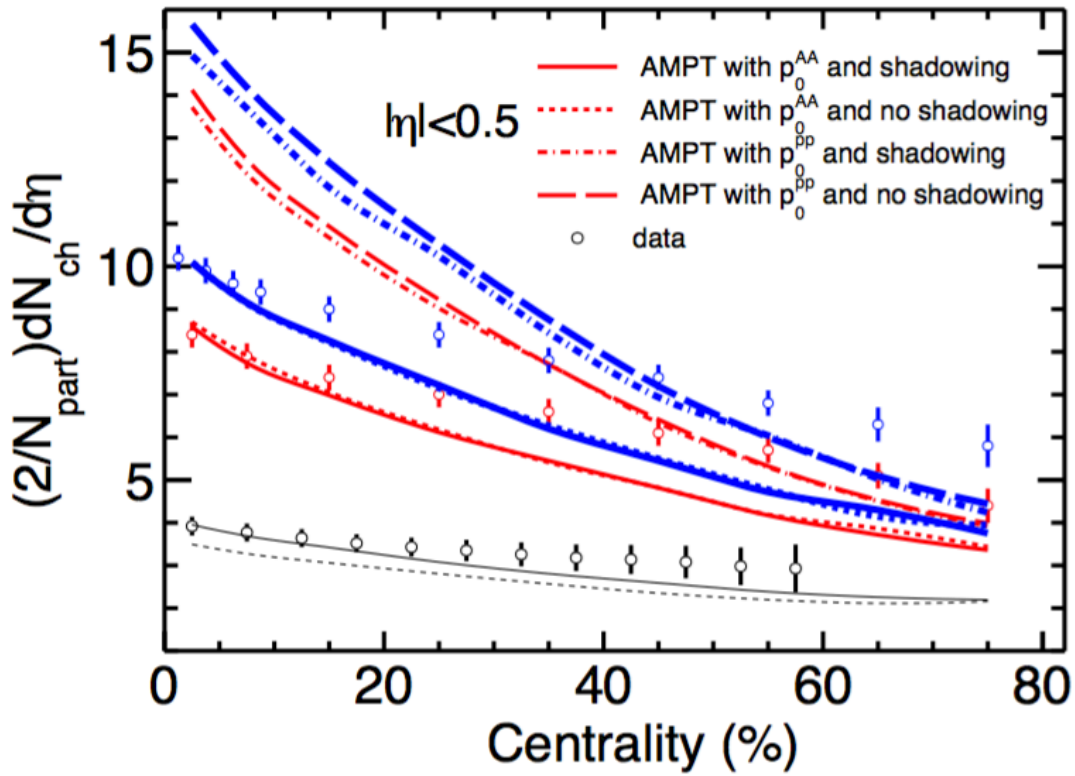
- AMPT string-melting version with lund $\boldsymbol{a}$=0.8 & $\boldsymbol{b}$=0.15 and p_0^{AA} minijet cutoff.
- The update AMPT model can reasonably reproduce the data at RHIC and LHC energies.

π/k/p Production with p_0^{AA}

- Energy dependence of identified particles $\frac{2}{\mathrm{Npart}} * \frac{\mathrm{dN}}{\mathrm{dy}}$ at mid-rapidity for AA collision.
- The AMPT model can reproduce charged π and k productions, however, underestimates the anti-proton yields.



Centrality Dependence of N_{ch}



- The nuclear shadowing has a small effect on charged particle yields at all centralities due to large p_0 cutoff.
- p_0^{AA} suppress the particle production especially at central collisions.

Summary

1. We update the AMPT model with modern PDF and nPDFs.
2. We use a systematic strategy to determine the p_0^{pp} and σ_{soft} for pp collisions, introduced A-scaling of p_0 for AA collisions.
3. We show for both charged and identified particles production in pp and AA collisions using this update AMPT model.

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THANKS for listening