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

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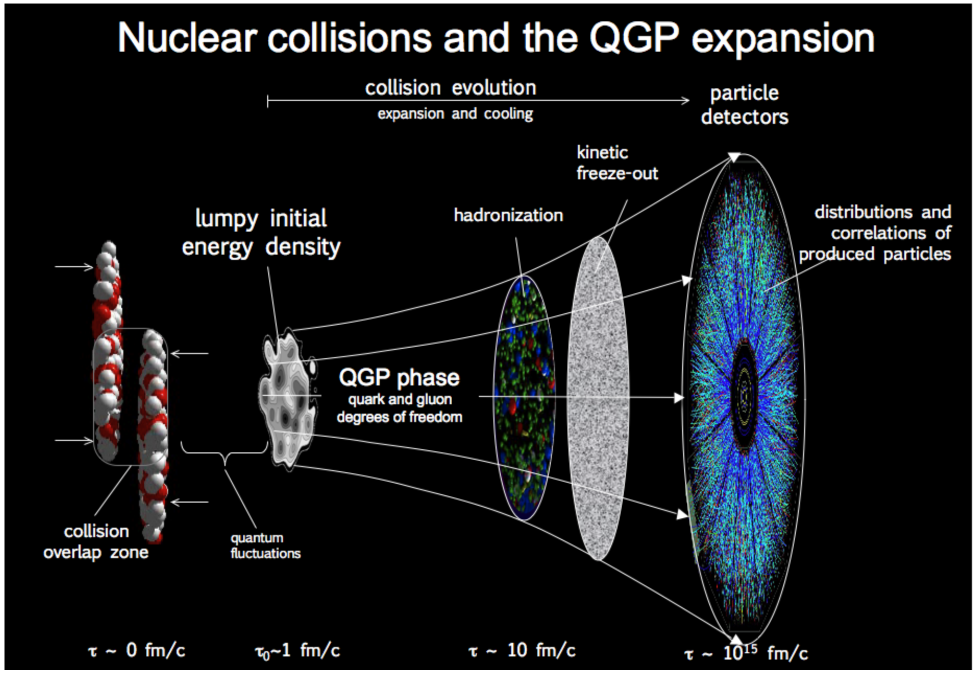
Outline

1. Motivation
2. Methods & Strategies
3. Results
    - Tuning parameters of two component model
    - Tuning fragmentation parameters
4. Next step for heavy flavor in AMPT
5. Summary

Motivation



- 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

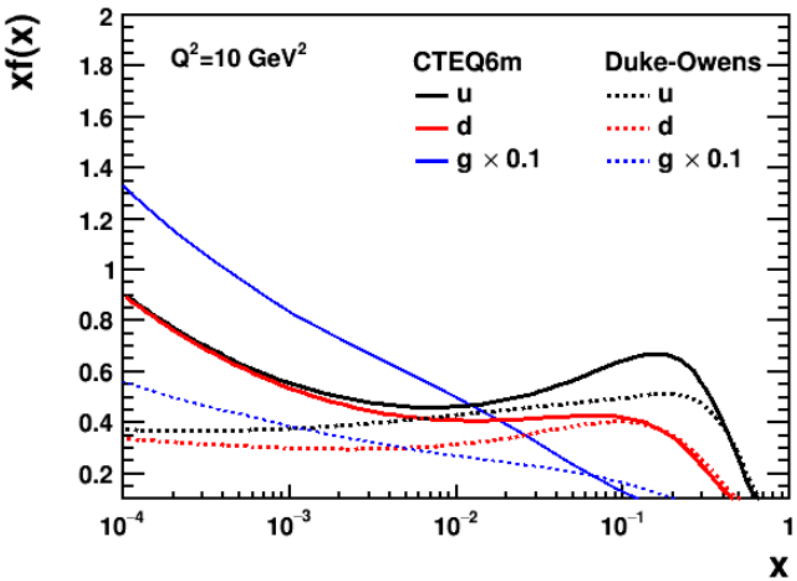
↓

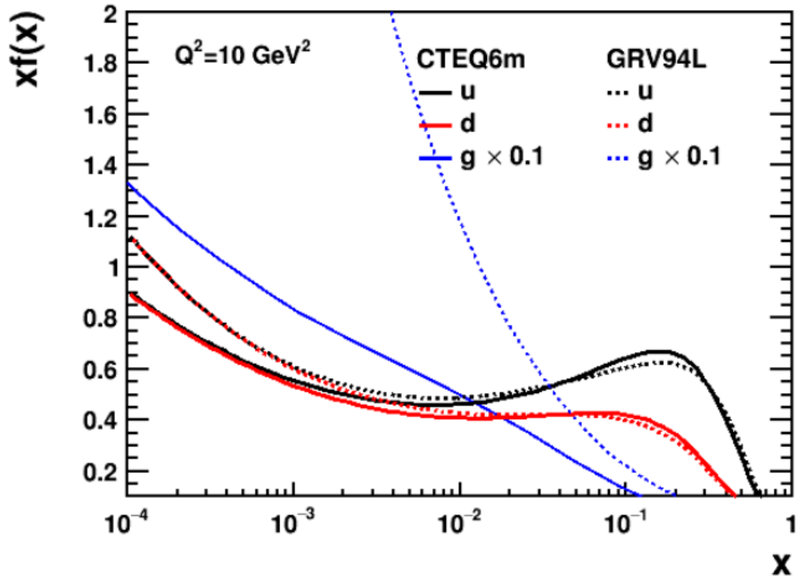
ART

↓

Final particle spectra

PDF: Parton Distribution Function





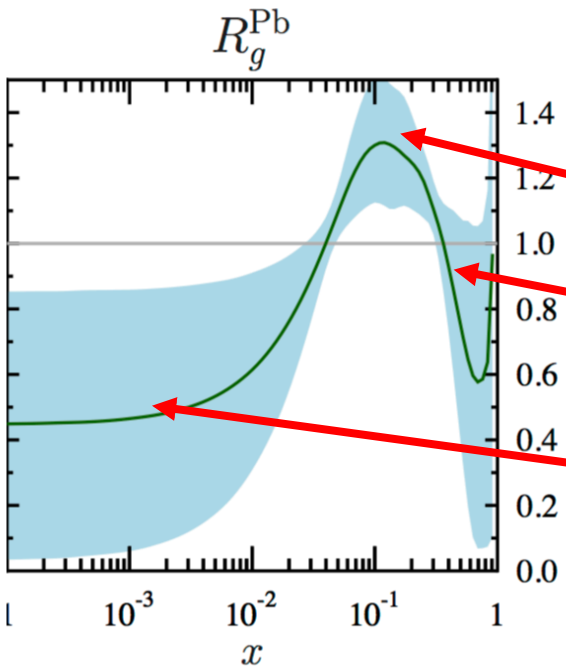
- Duke-Owens: used in the current published AMPT model. ***Outdated***
- AMPT model: valid for wide energy range, especially LHC energies when minijet production reaches to a very small-x region, where gluon distribution is much ***higher*** than Duke-Owens parametrization. ***Update the PDF*** is important.

- HIJING 2.0 work ： GRV94L PDF.

Wei-Tian Deng PHYSICAL REVIEW C **83**, 014915

Spatial Dependent Nuclear PDFs

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

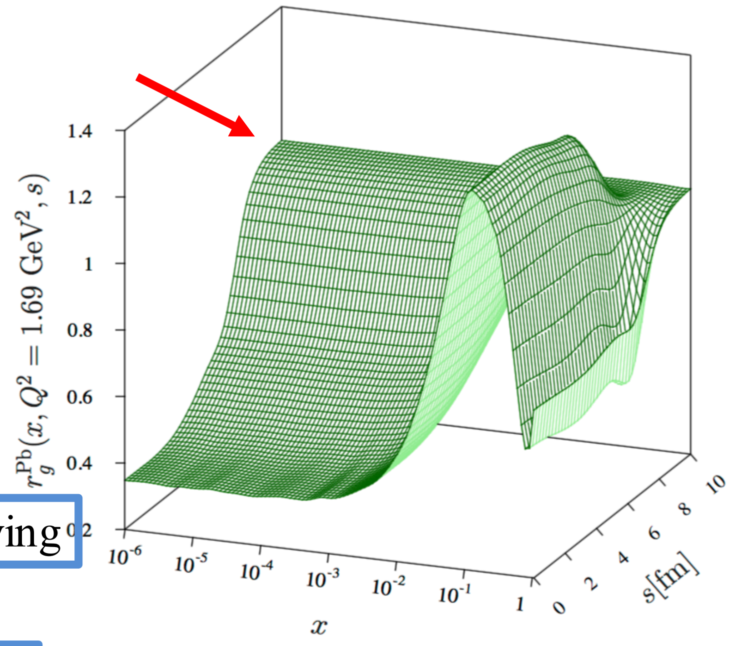


Antishadowing

EMC effect

Shadowing

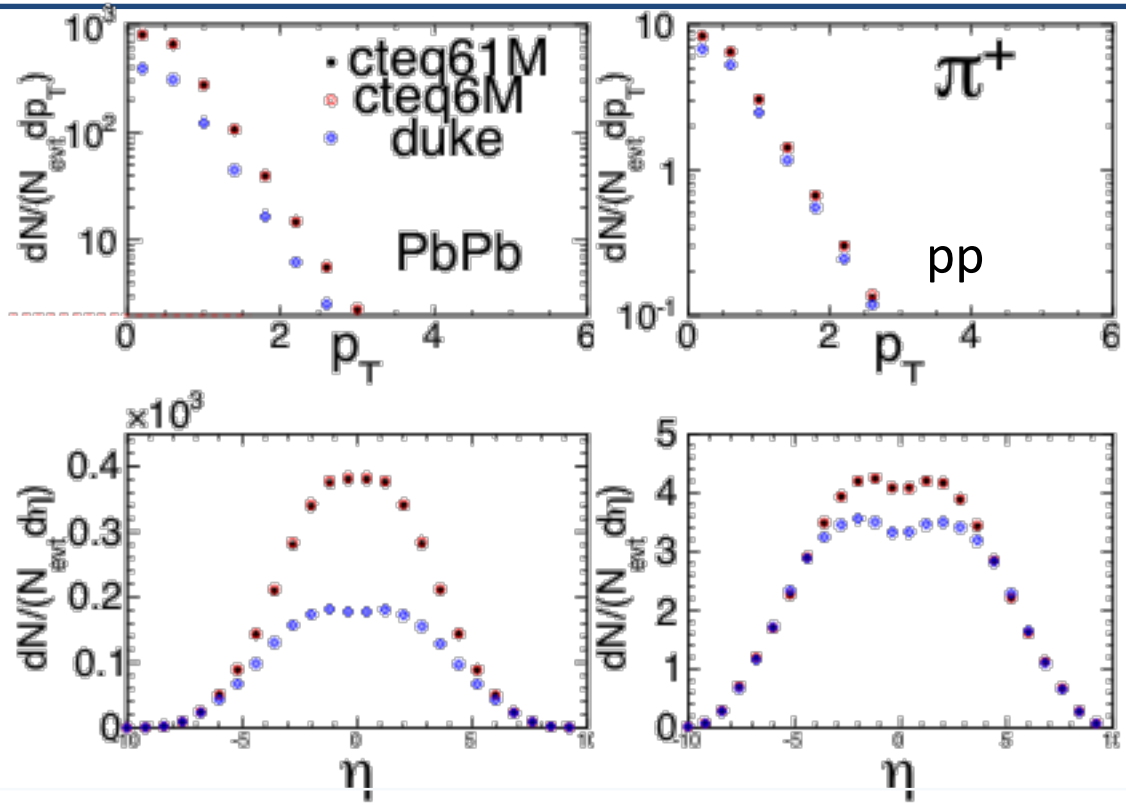
Ilkka helenius. JHEP 1207 (2012) 073



f_i^A (x,Q,center) ≠ f_i^A (x,Q,edge)

- Nuclear modifications ***vanish*** at the edge of the nucleus.

Influence of PDF and nPDFs



- PbPb collision: 2.76 TeV, a factor of ~ 3 larger for both p_T and pseudo-rapidity, mainly within |eta|<5.
- pp collision: 13 TeV, both enhancement in p_T and pseudo-rapidity, 20% increase mainly within |eta|<3.
- We need to ***tune*** the parameters.

Methods and Strategies

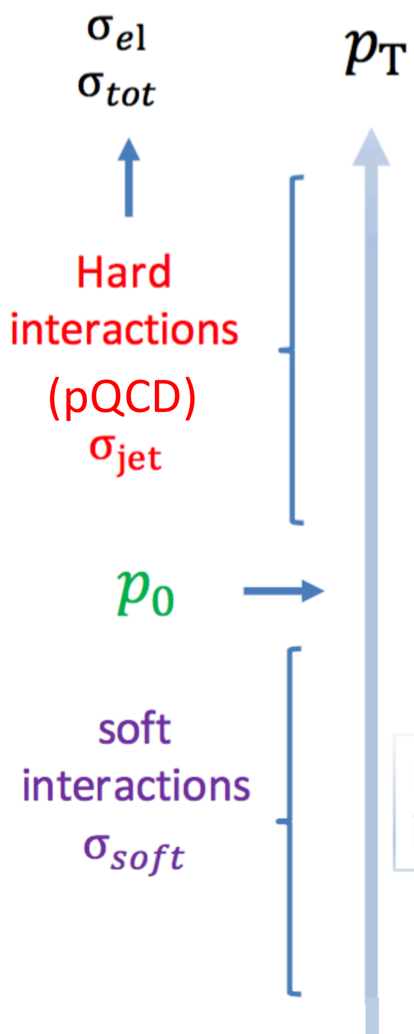
Parameter tuning strategy

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

2. Lund fragmentation parameter (***a***&***b***) tuning: use the charged particle pseudorapidity distributions and transverse momentum spectra.
$$f(z) \propto z^{-1}(1-z)^{\mathbf{a}} e^{(-\mathbf{b} m_{\perp}^2 / z)}$$

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

The HIJING Two Component Model



$$\sigma_{jet} = \int_{p_0^2}^{s/4} dp_T^2 dy_1 dy_2 \frac{1}{2} \frac{d\sigma_{jet}}{dp_T^2 dy_1 dy_2},$$

$$\frac{d\sigma_{jet}}{dp_T^2 dy_1 dy_2} = K \sum_{a,b} x_1 f_a(x_1, p_T^2) x_2 f_b(x_2, p_T^2) \frac{d\sigma^{ab}(\hat{s}, \hat{t}, \hat{u})}{d\hat{t}}$$

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

Key input parameters in the model

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

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

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

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

Tuning Method

HIJING input

↓

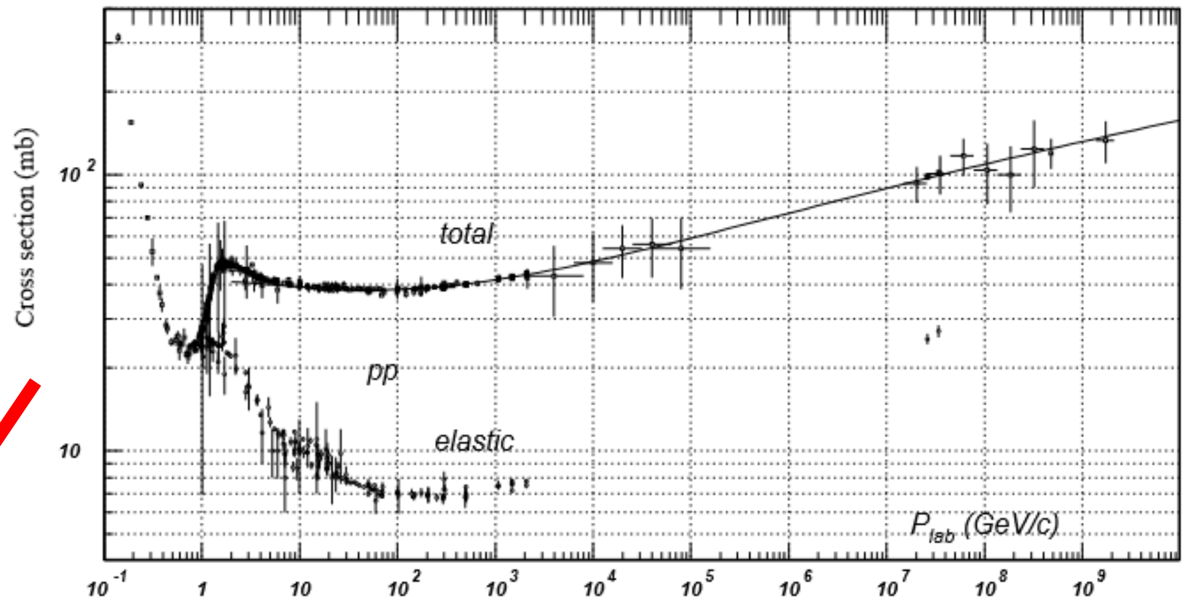
p_0 , σ_{soft}

↓

σ_{el_ampt} , σ_{tot_ampt}

↓ compare

σ_{el_fit} , σ_{tot_fit}



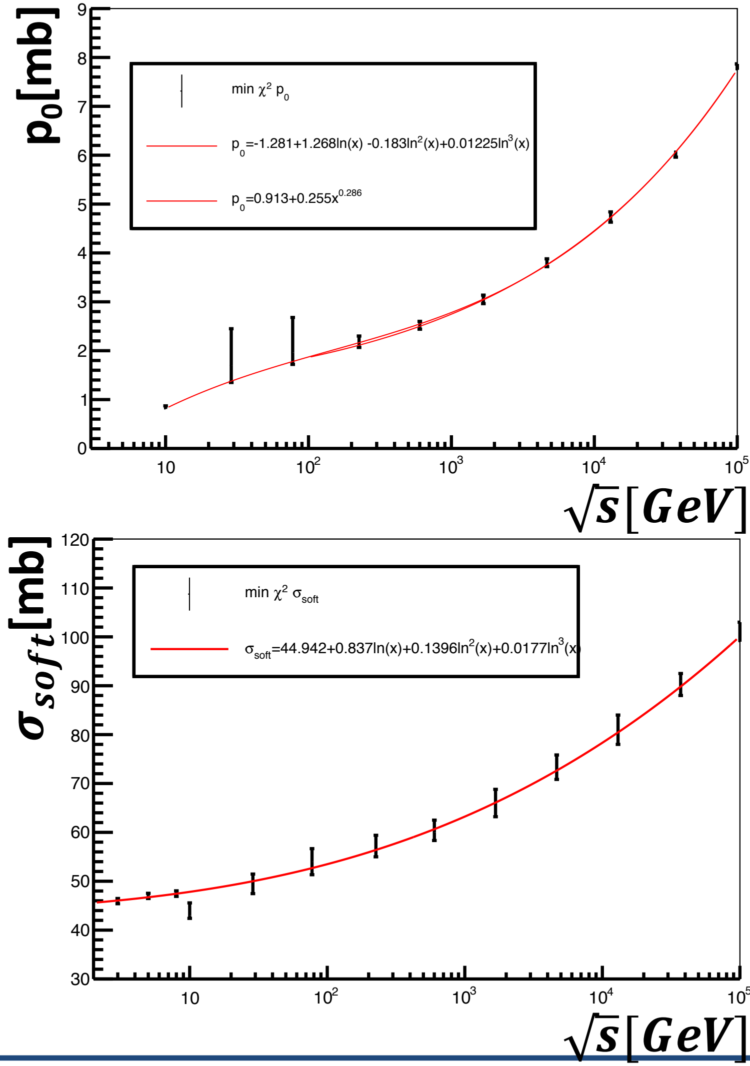
C. Patrignani et al. (Particle Data Group), Chin. Phys. C, 40, 100001 (2016).

A relative residual sum of squared is defined as the target function to be minimized allowed $\mathbf{p_0}$ *and* $\boldsymbol{\sigma_{\mathrm{soft}}}$ parameters

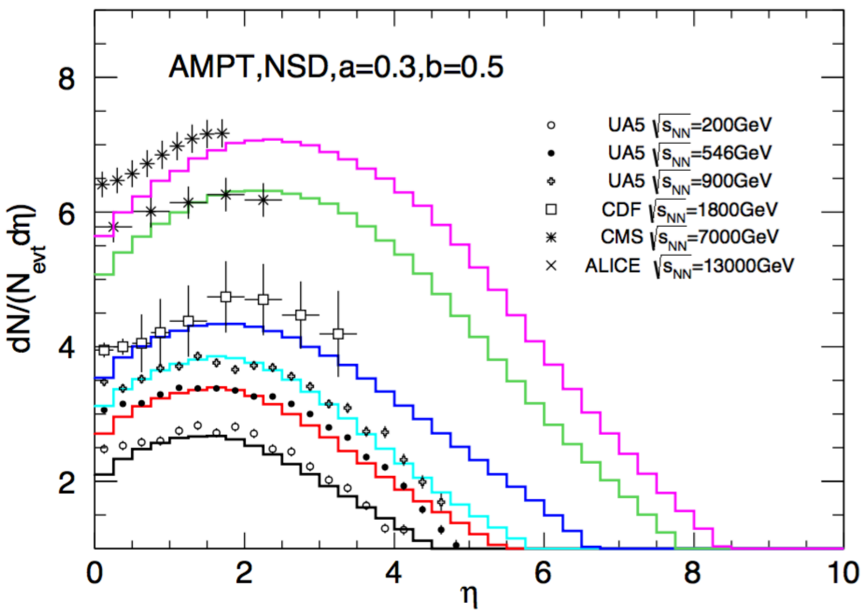
$$\text{Minimize } \chi^2 = \frac{(\sigma_{tot\_ampt} - \sigma_{tot\_fit})^2}{\sigma_{tot\_fit}} + \frac{(\sigma_{el\_ampt} - \sigma_{el\_fit})^2}{\sigma_{el\_fit}}$$

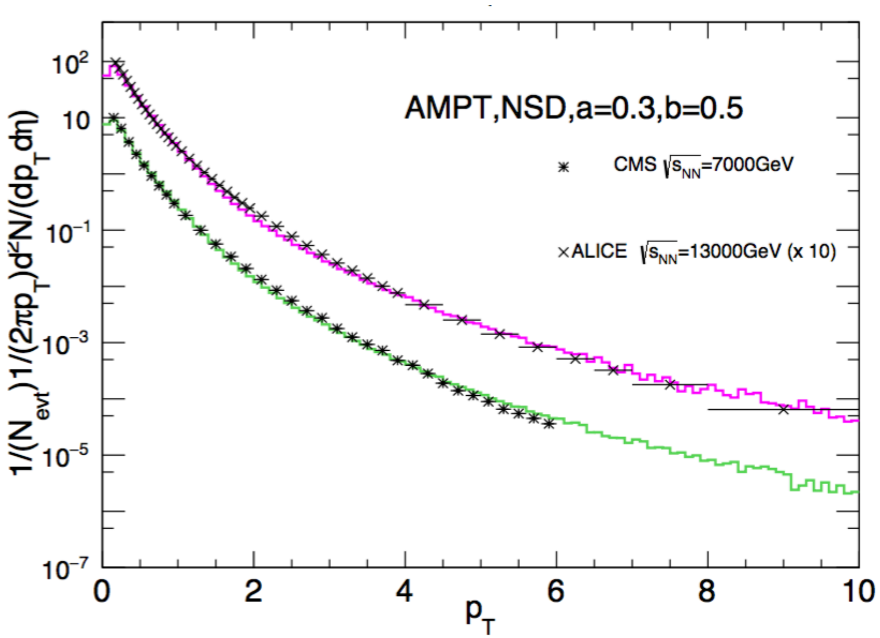
Tuning of p_0 and σ_{soft}

- $\boldsymbol{p_0}$ have strong energy dependence, while energy dependence of $\boldsymbol{\sigma_{soft}}$ is weaker.
- When collision energy $\sqrt{S_{\mathrm{NN}}}$>10 GeV, we fit both σ_{tot} and σ_{el}.
- When $\sqrt{S_{\mathrm{NN}}}$<10 GeV, we only fit the inelastic cross section, since jet cross section is completely ***switched off*** below 10 GeV in HIJING.



a&b Tuning

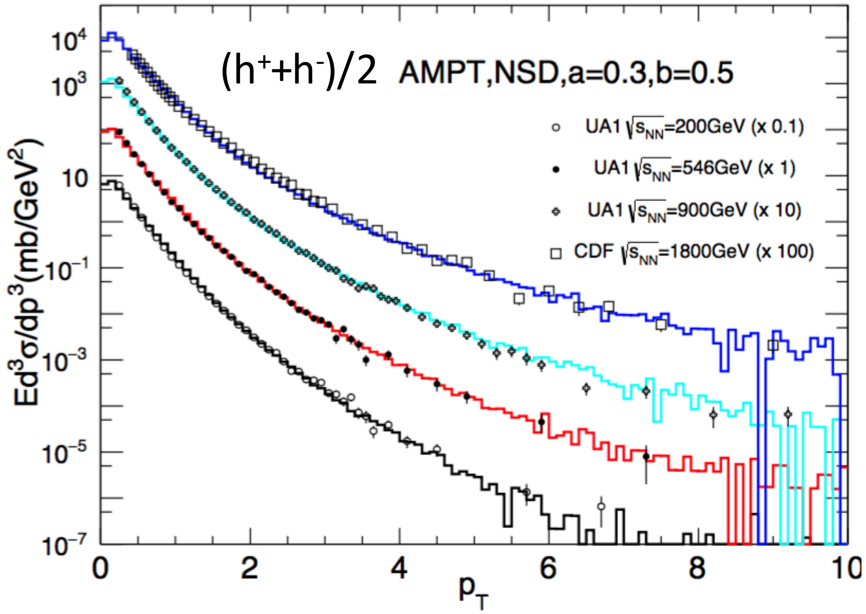


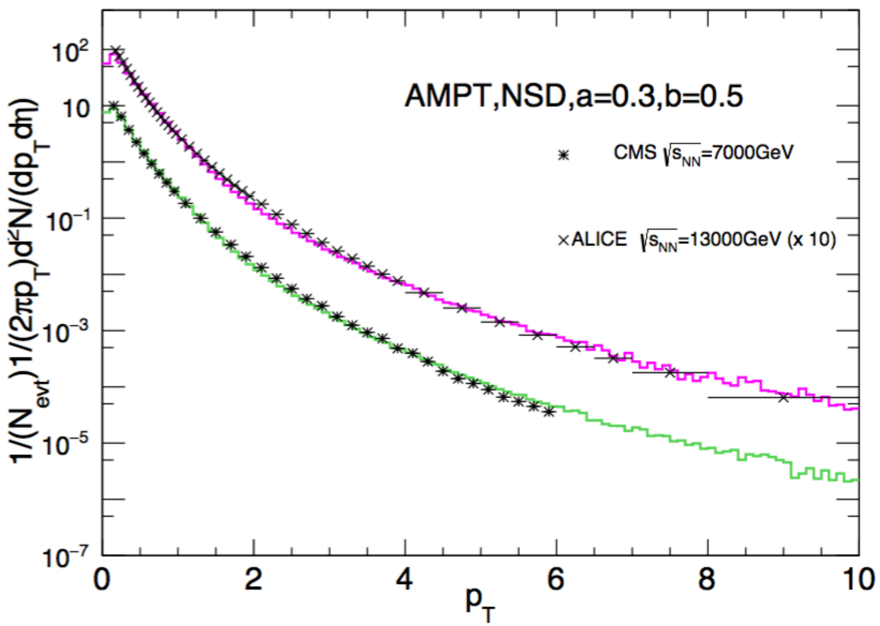


- We use charged particle pseudo-rapidity distributions and transverse momentum spectra to tune the Lund parameters ***a*** and ***b***.
- Larger ***a*** typically gives ***larger*** pseudo-rapidity distributions, smaller ***b*** typically leads to a more ***flat*** p_T spectrum.
- a=0.3 , b=0.5 agrees 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).

a&b Tuning





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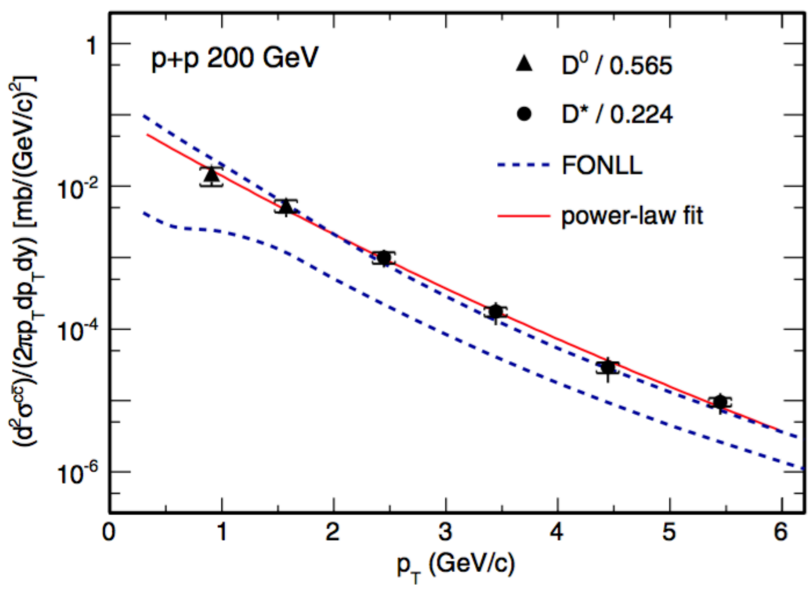
Heavy Flavor Production in AMPT

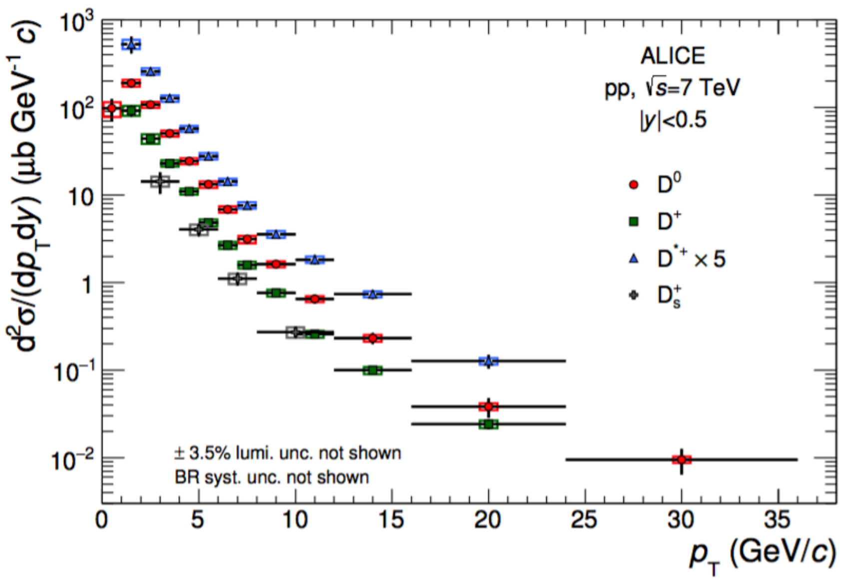
- Channel 12, 53, 81 and 82 can produce charm in current AMPT model (***double counting*** problem).

- We now only allow channels 81, 82 to produce charm, all light flavor productions are through channel 12, 53.

11	f + f' -> f + f'
12	f + fb -> f' + fb'
13	f + fb -> g + g
14	f + fb -> g + gamma
18	f + fb -> gamma + gamma
28	f + g -> f + g
29	f + g -> f + gamma
53	g + g -> f + fb
68	g + g -> g + g
81	q + qb -> Q + QB, massive
82	g + g -> Q + QB, massive

Next Step For Heavy Flavors in AMPT





STAR collaboration PHYSICAL REVIEW D 86, 072013 (2012).
ALICE collaboration Eur.Phys.J. C77 (2017) no.8, 550 .

1. No transport model have been used to describe the heavy flavors production in HIC.
2. With this updated AMPT model, we will have a better description of many observables in the experiments such as particle spectra, event anisotropy etc…

Summary

1. The ***necessity*** for updated PDF and nuclear shadowing modification to describe heavy flavors.

2. We have used a ***systematic strategy*** to determine the parameters. as well as tuning the Lund fragmentation parameters with the latest experimental data.

3. Fit the energy dependence of $\boldsymbol{p_0}$ and $\boldsymbol{\sigma_{soft}}$ as well as tuning the parameters with the latest dataset.

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THANKS for listening