# Improvement for the open charm production in a multi-phase transport model

Speaker: Liang Zheng

China University of Geosciences (Wuhan)

In collaboration with: Chao Zhang (CCNU), Shusu Shi (CCNU), Ziwei Lin (ECU&CCNU)

International Workshop on Partonic and
Hadronic Transport Approaches for Relativistic
Heavy Ion Collisions
11-12 May, 2019, Dalian

# Outline

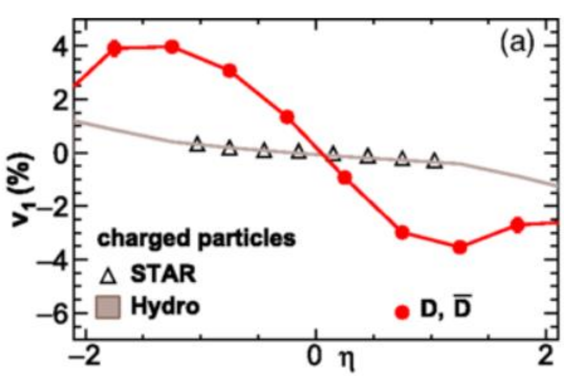
- Open heavy flavor production
- Improvements in AMPT to describe HF production
- Results
  - Open charm production in pp
  - Open charm production in AA

# Why heavy flavor

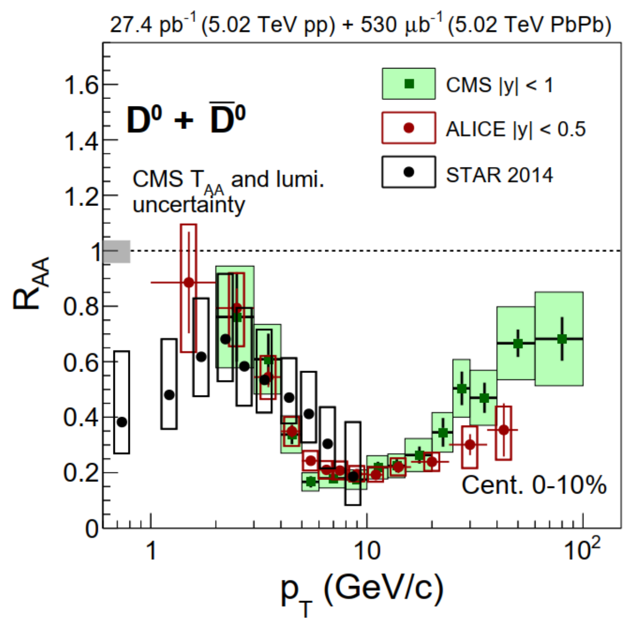
- Heavy mass
  - $m_Q >> \Lambda_{QCD}$ , applicable in pQCD framework for a wide $p_T$ range
  - $m_Q >> T_{QGP}$ , short formation time, thermalization time comparable to the fireball life time
- Unique probe to the QGP medium
  - Low $p_T$ region, Langevin process characterization
  - High $p_T$ region, heavy quark energy loss

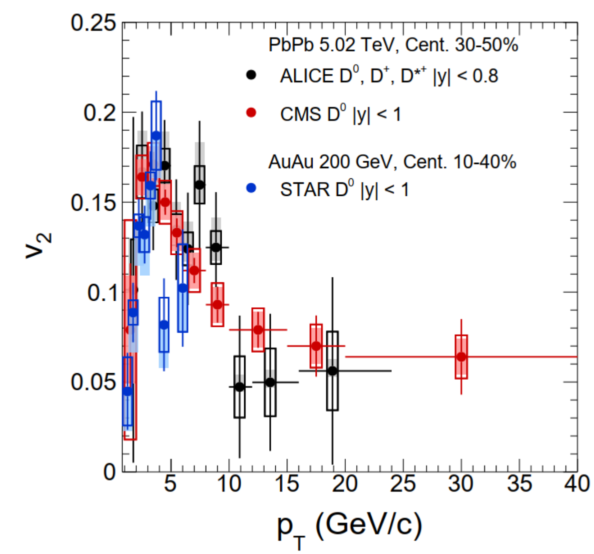
# Extracting the medium information with HF probes

- Directed charm flow
- Nuclear modification factor RAA
- Anisotropic flow coefficient




S. Chatterjee, P. Bozek, PRL, 120 (2018) 192301




X. Dong, Y. J. Lee, R. Rapp arXiv: 1903.07709

# Studying HF production in AMPT

- Unified framework to explore the QGP evolution
  - Transport properties solved in the parton/hadron cascades
  - Different flavor components included with e-by-e fluctuations
- HF production channels
  - Pair production $q+\bar{q}\to Q+\bar{Q}$, $g+g\to Q+\bar{Q}$
  - Gluon splitting $g\to Q+\bar{Q}$
  - Flavor excitation $q+Q\to q+Q$ $g+Q\to g+Q$

$$\frac{d\sigma^{Q\bar{Q}}}{dp_T^2 dy_1 dy_2}=K\sum_{a,b} x_1 f_a(x_1,\mu_F^2) x_2 f_b(x_2,\mu_F^2)\frac{d\sigma^{ab\to Q\bar{Q}}}{d\hat{t}}$$

# Improvement for HF quark production in AMPT

- Modern nucleon and nuclear PDF
- Treatment to the transverse momentum cut in two component model for HF channels

$$\frac{d\sigma_{\text{jet}}}{dp_{\text{T}}^2 dy_1 dy_2} = K \sum_{a,b} x_1 f_a(x_1, \mu_F^2) x_2 f_b(x_2, \mu_F^2) \frac{d\sigma^{ab}}{d\hat{t}}$$

$$\sigma_{\text{jet}}(s) = \frac{1}{2} \int_{p_0^2}^{s/4} dp_{\text{T}}^2 dy_1 dy_2 \frac{d\sigma_{\text{jet}}^{\text{light}}}{dp_{\text{T}}^2 dy_1 dy_2} + \frac{1}{2} \int_0^{s/4} dp_{\text{T}}^2 dy_1 dy_2 \frac{d\sigma_{\text{jet}}^{\text{heavy}}}{dp_{\text{T}}^2 dy_1 dy_2}$$

$$p_0^{pp}(s) = -1.71 + 1.63\ ln(\sqrt{s}) - 0.256\ ln^2(\sqrt{s}) + 0.0167\ ln^3(\sqrt{s})$$

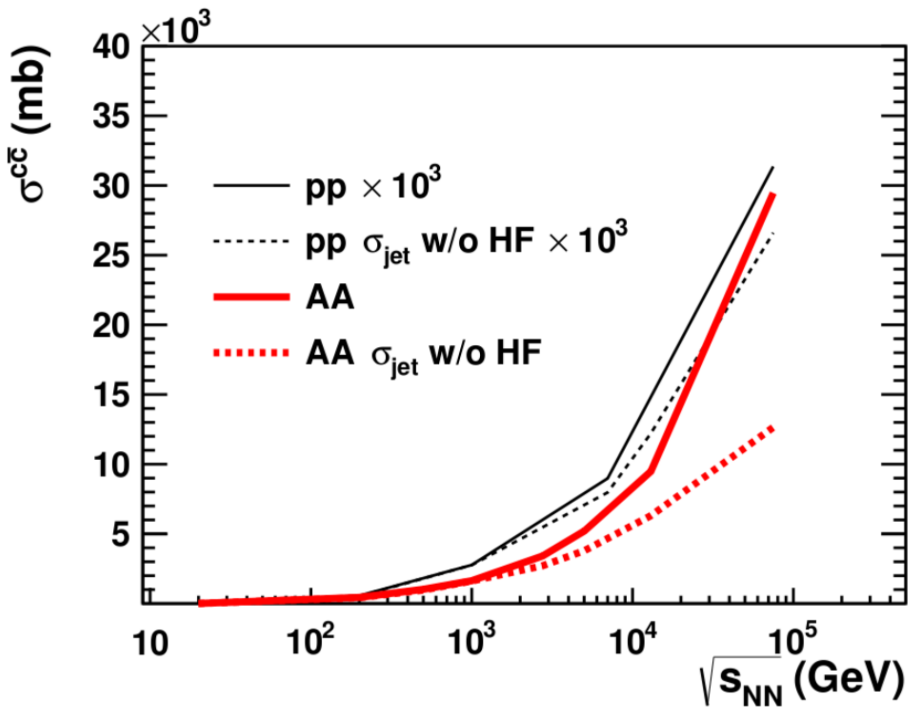
$$p_0^{AA} = p_0^{pp} A^{q(s)}$$

q(s) 0 to 0.16, starting at √s=200 GeV

Applicable in central AA collisions principally

# Improvement for HF quark production in AMPT

- Including HF sector to the $\sigma_{jet}$ estimation in two component model



# Improvement for HF hadron production in AMPT

- Coalescence procedure for charm/bottom hadron

$D,\ D^*,\ D_s,\ D_s^*,\ \Lambda_c,\ \Sigma_c,\ \Xi_c,\ \Xi_c',\ \Xi_{cc},\ \Omega_c,\ \Omega_{cc},\ \Omega_{ccc}$

$B,\ B^*,\ B_s,\ B_s^*,\ B_c,\ B_c^*,\Lambda_b,\ \Sigma_b,\ \Xi_b,\ \Xi_b',\ \Xi_{bc},\ \Xi_{bc}',\ \Xi_{bb},\ \Omega_b,\ \Omega_{bc},\ \Omega_{bc}',\ \Omega_{bb},\ \Omega_{bbc},\ \Omega_{bbb}$

- Vector to pseudo-vector meson ratio

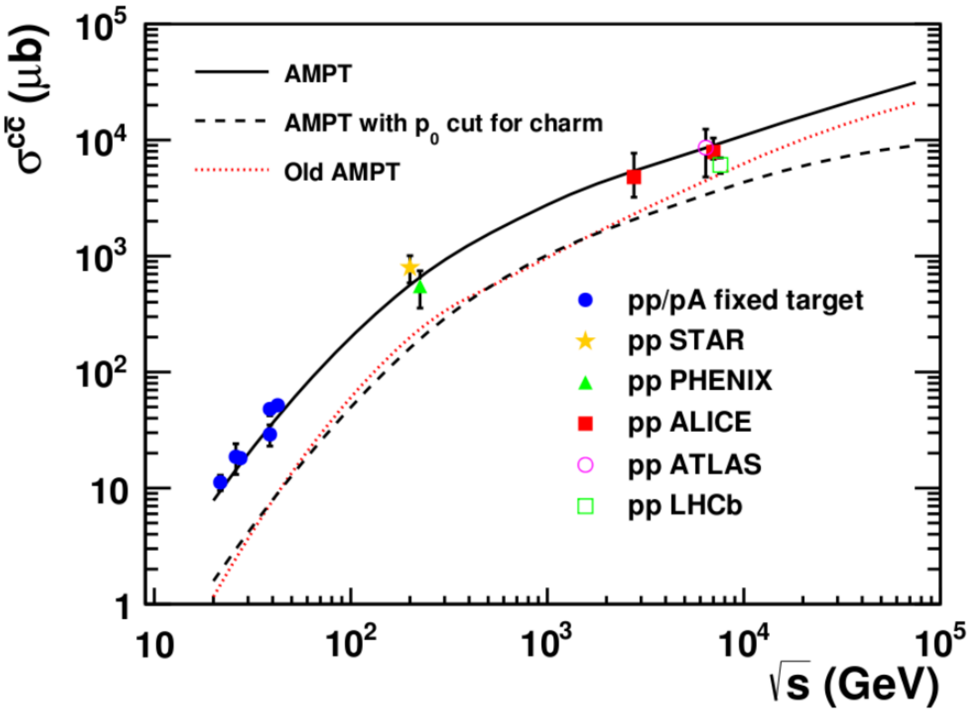
$\rho/\pi$ =0.3 $K^*/K$ =0.5 $D^*/D$ or $B^*/B$ =2.0

- Charm baryon to meson formation probability tuning in coalescence

$r_{BM}\ (u/d/s)$ =0.53 $r_{BM}$ (c/b/t)=1.00

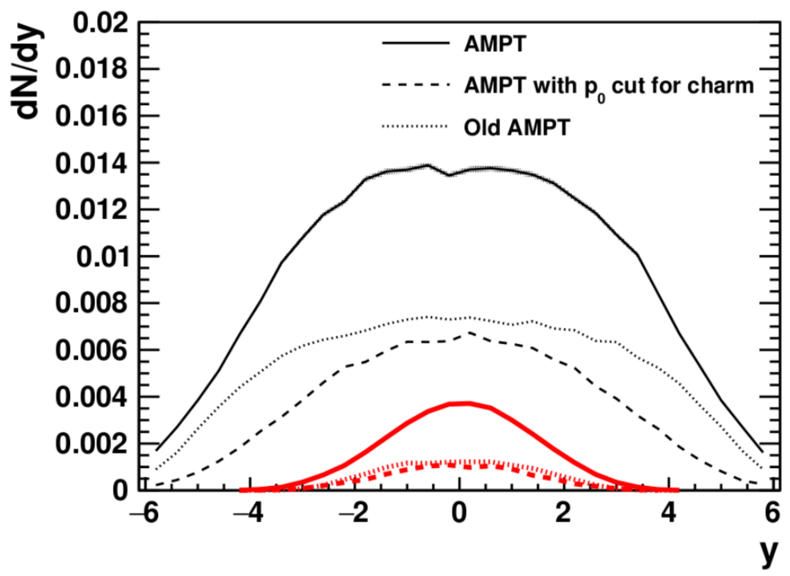
# Charm quark production in pp

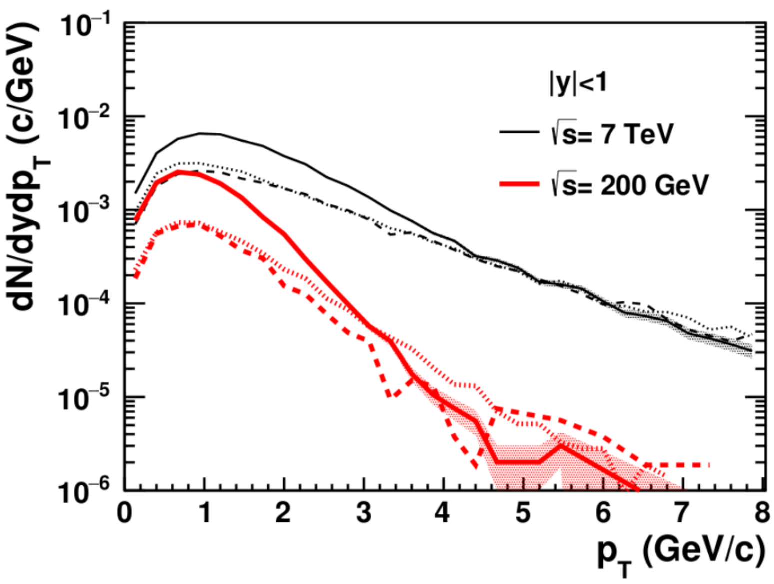
- Old AMPT produces similar cross section to the case with $p_0$ cut
- Removal of $p_0$ enhances the total cross section significantly



# Charm quark production in pp

- Changes without $p_0$ generates a wider rapidity width compared to the old AMPT results
- $p_0$ change dominates in the region of mid-rapidity and low $p_T$

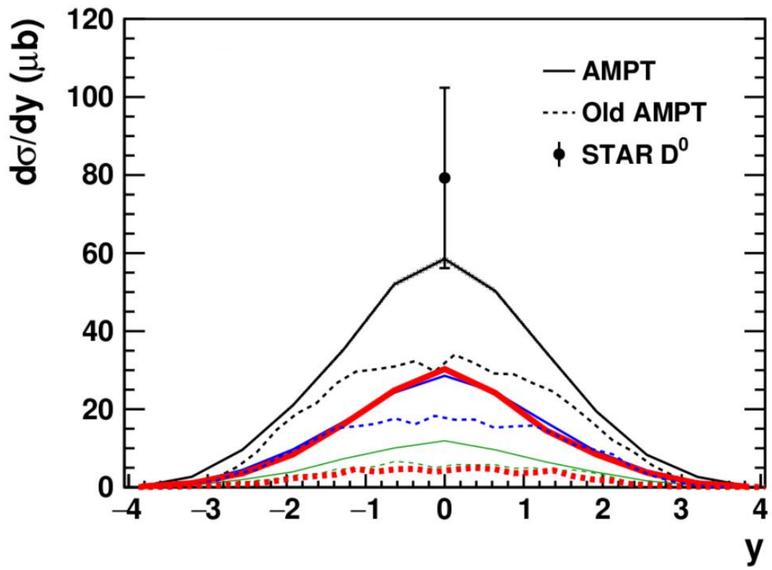


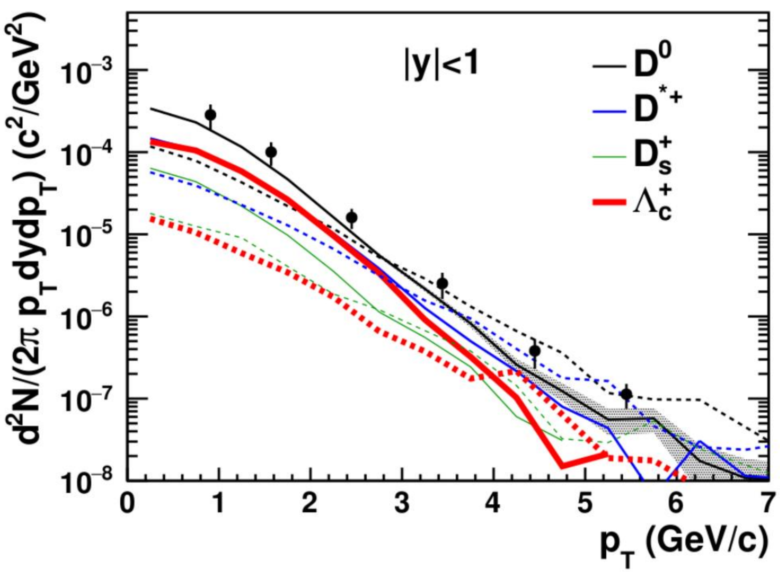



# Charm hadron yield in pp

- $D^0$ hadron yield in the new model setup is slightly below STAR data with a reasonable $p_T$ spectra
- Hadron specie ratio very different in the new and old model

**pp 200 GeV**

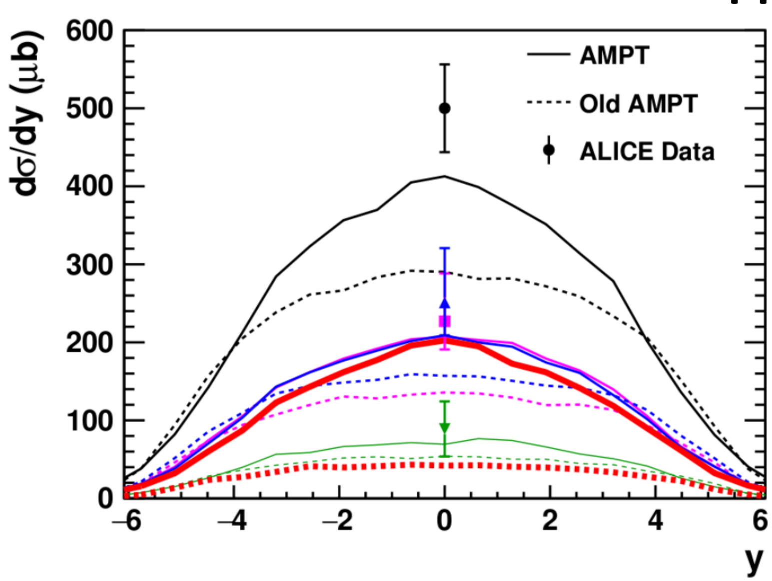


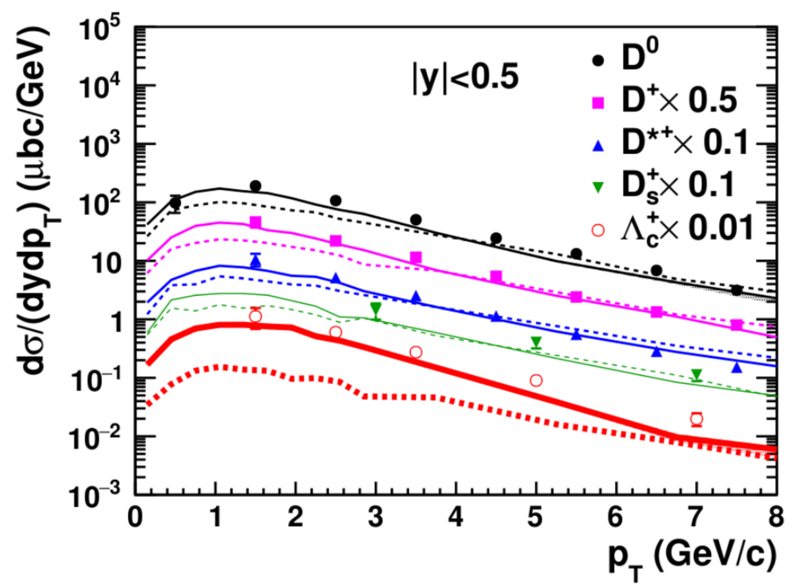



# Charm hadron yield in pp

- Agreement roughly with the data in a wide range of hadron species for charm particles
- $D^*$ similar in both versions while $D^0$ and $D^+$ much higher than the old AMPT results
- $D^*$ is still underestimated especially in low $p_T$, $\Lambda_c$ agrees after our $r_{BM}$ tuning

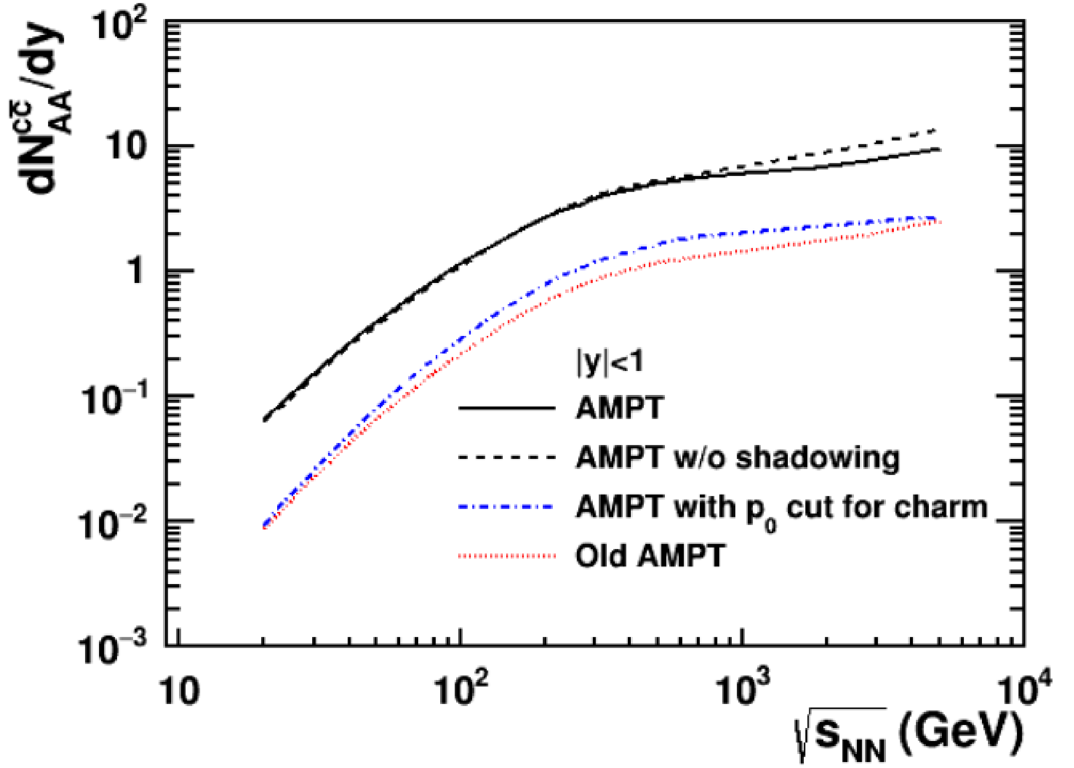
**pp 7 TeV**



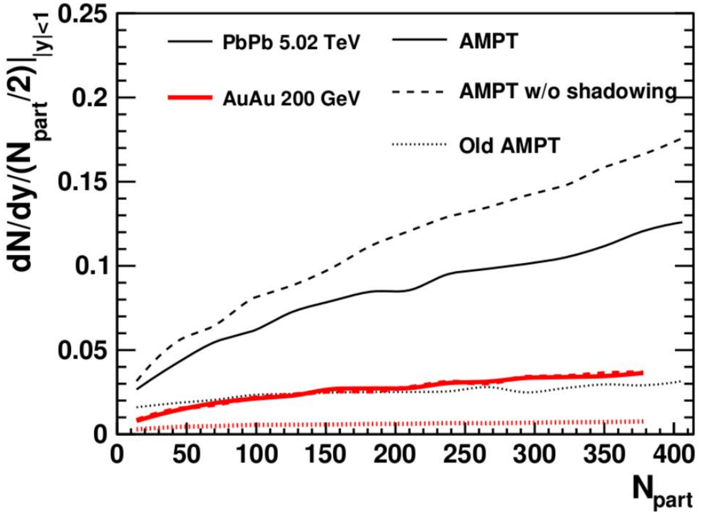
# Charm quark production in AA

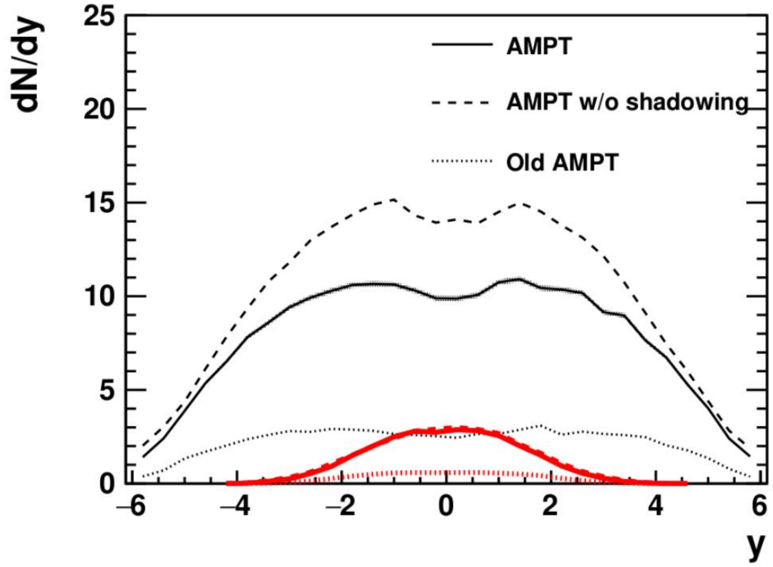
- $p_0$ cut impact is similar in AA and pp
- Shadowing starts to become important in very high energy

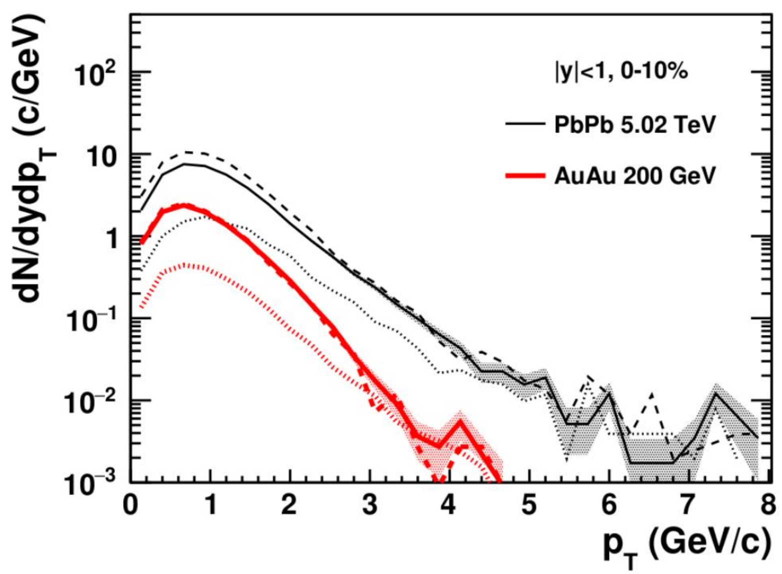


# Charm quark production in AA

- Impact parameter shadowing matters for the charm yield at LHC energies
- Significant increase compared to the old AMPT results
- Enhancement originates from low $p_T$ region



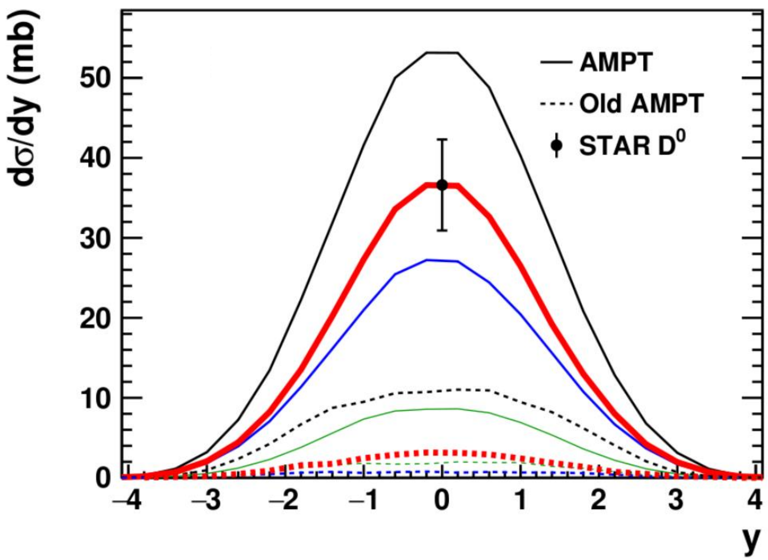



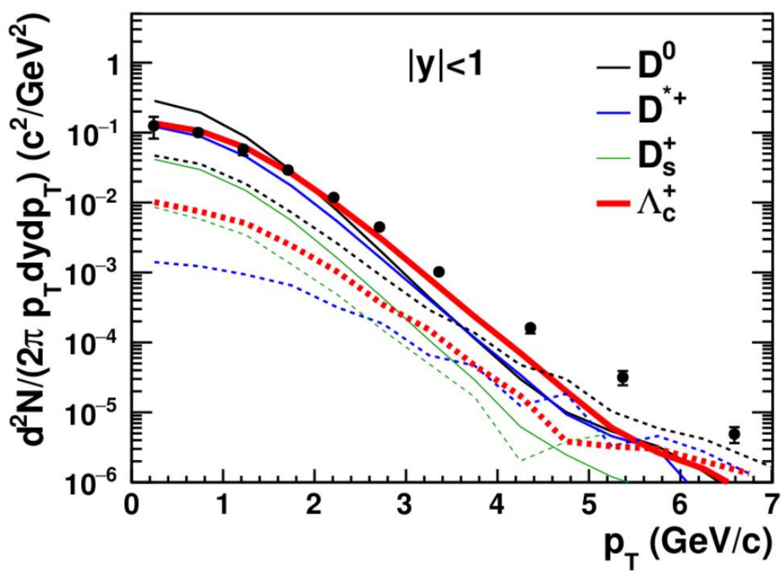



# Charm hadron production in AA

- $D^0$ production a bit higher than the STAR data
- Different slope compared to the data trend
- Charm hadron shows mass dependence in the $p_T$ distribution

**AuAu 200 GeV**

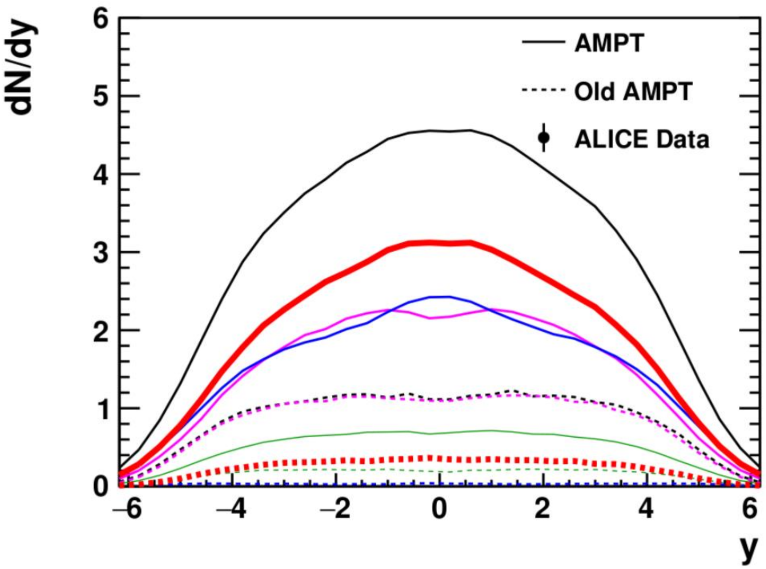


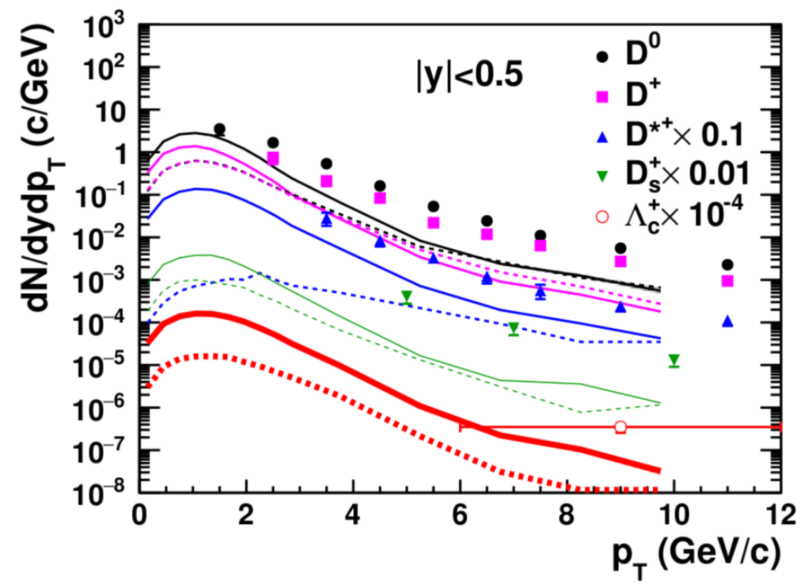



# Charm hadron production in AA

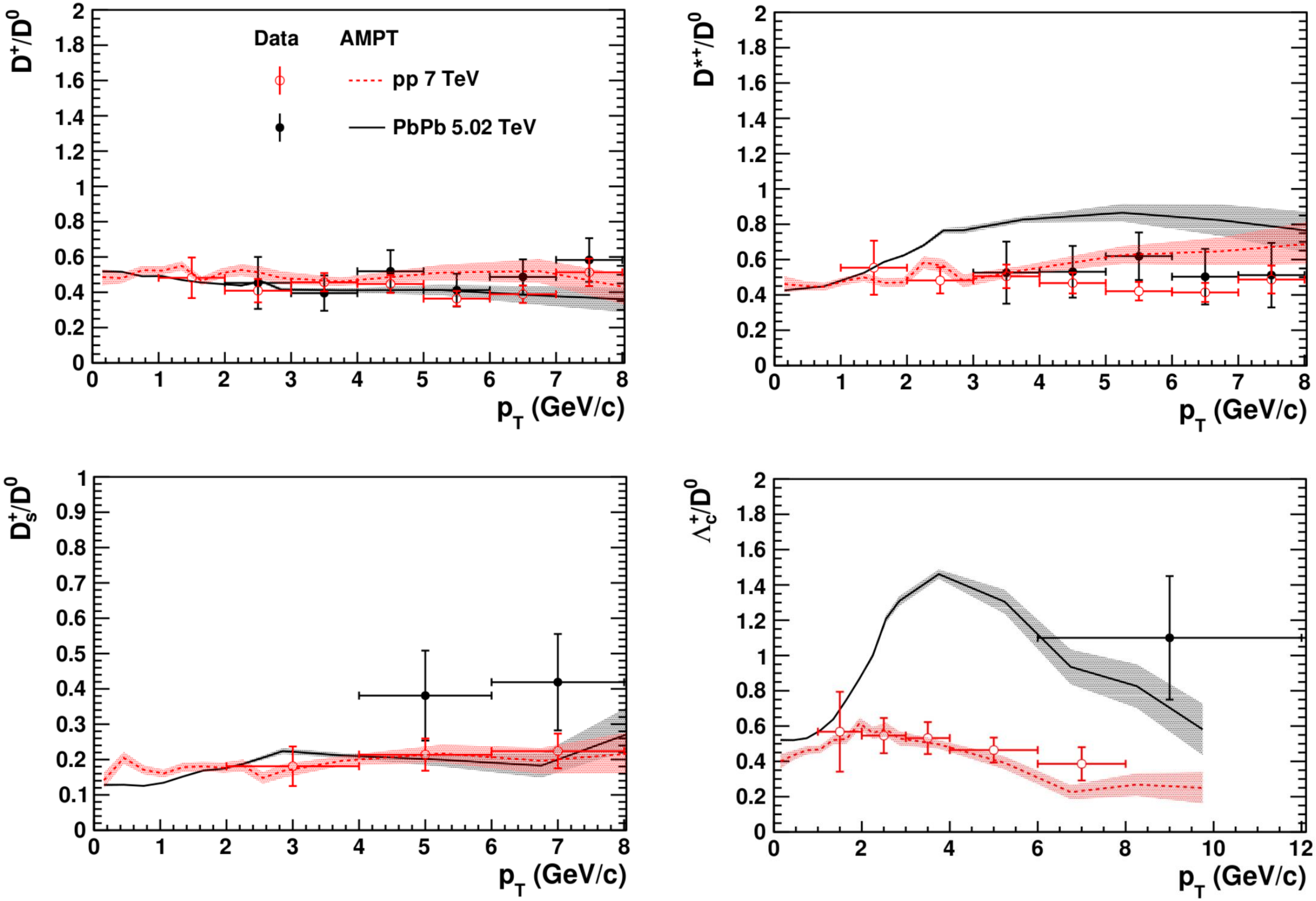
- Updated AMPT results underestimate the LHC data for all hadron species especially in the high $p_T$ region
- Possible improvement may come from the final state parton scattering strength tuning
- Missing flavor excitation could be another source

**PbPb 5.02 TeV**



# Charm hadron production in AA



# Summary

- AMPT model provides a well established framework to study the heavy quark transport effects
- Treatment to the $p_0$ cut in the heavy quark production is important to get reasonable charm productions
- With well tuned parameters we are capable of describing the charm hadron production data
- A foundation for the future heavy flavor studies in the AMPT framework