Studies on the multiplicity dependence of beauty and non-prompt charm hadron production in pp collisions at 13 TeV with AMPT

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The 16th Workshop on QCD Phase Transition and Relativistic Heavy-Ion Physics
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Heavy flavor study from charm to beauty

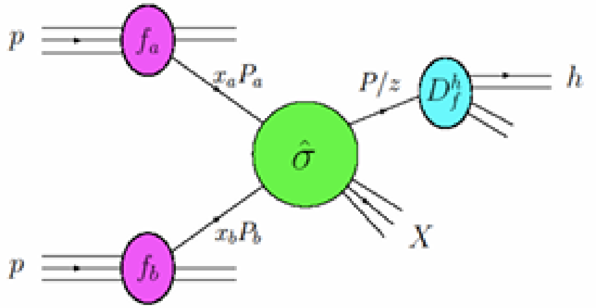
- $m_Q >> \Lambda_{QCD}$, can be calculated in pQCD factorization over a wide p_T

$$\frac{d\sigma^{D}}{dp_{T}^{D}}(p_T;\mu_F;\mu_R) = PDF(x_a,\mu_F)PDF(x_b,\mu_F) \otimes \frac{d\sigma^{c}}{dp_{T}^{c}}(x_a,x_b,\mu_R,\mu_F) \otimes D_{c\to D}(z=p_D/p_c,\mu_F)$$

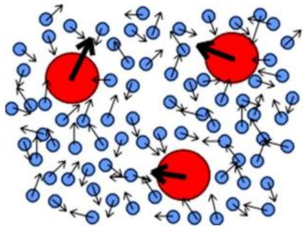
parton distribution function (PDF) (non-perturbative)

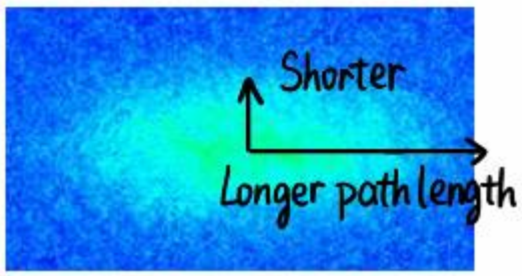
partonic cross section (perturbative)

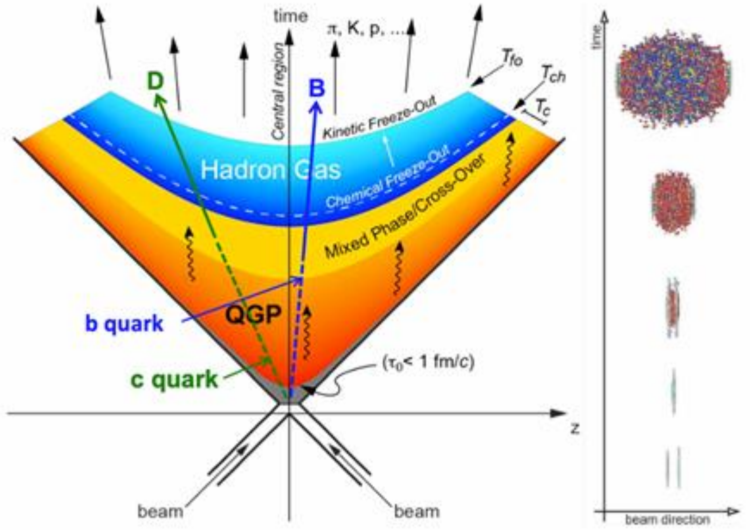
hadronisation by fragmentation (non-perturbative)



- $\tau \sim 1/m_Q$, produced early. Unique access to high temperature stage.
- $m_Q >> T_{QGP}$, keep identity in HI collisions. Experience the entire evolution of the medium, unique probes for QGP tomography.





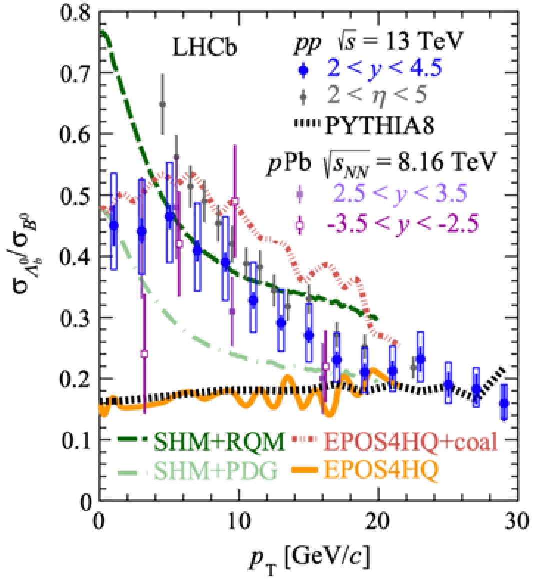


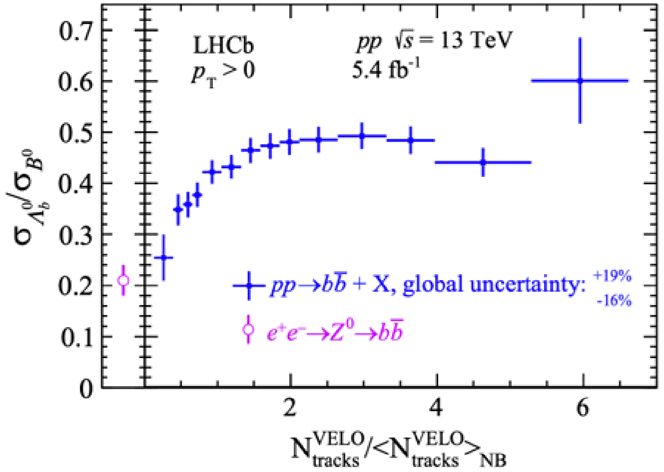
Non-universal HF fragmentation

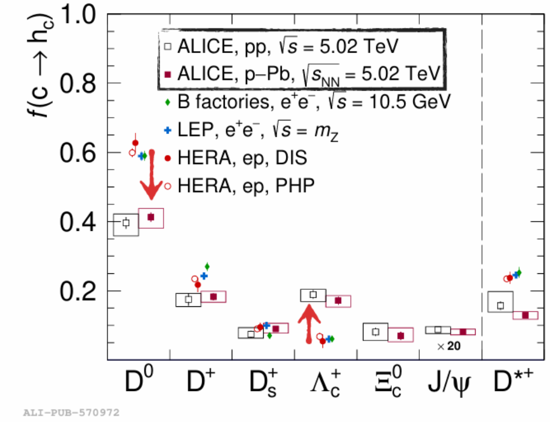
- Enhanced charm baryons in pp and pA
- Multiplicity dependent beauty hadro-chemistry
- Momentum redistribution not captured in traditional string fragmentation model

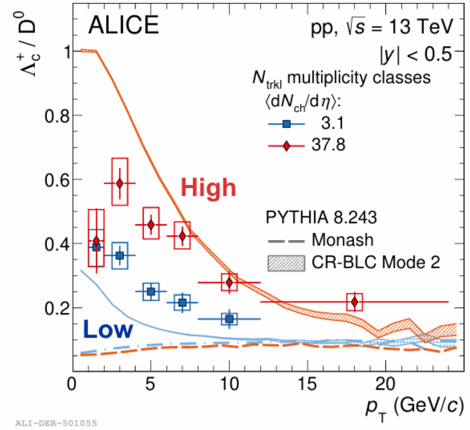
HF fragmentation fraction universality is challenged!

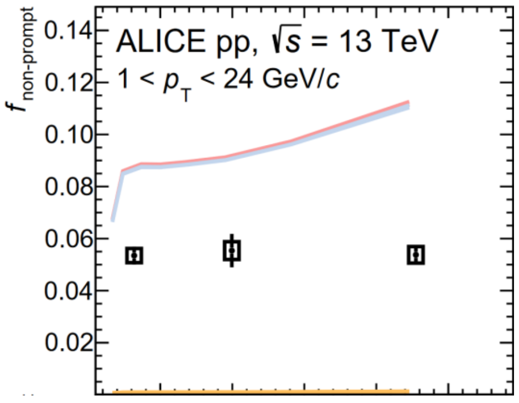
LHCb, PRL 132 (2024) 081901







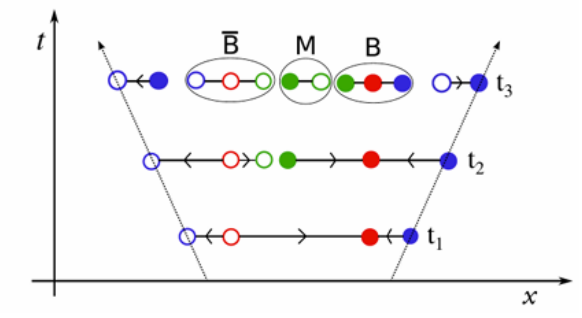




JHEP 10 (2023) 092

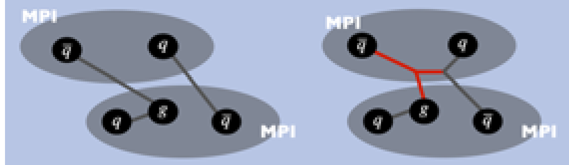
HF hadronization model

Fragmentation

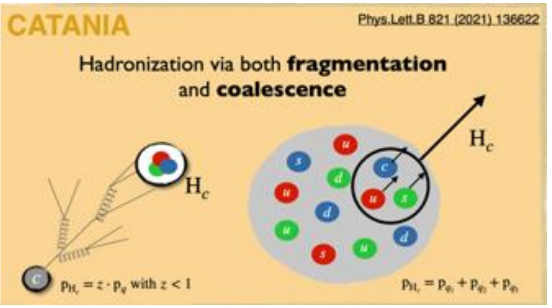


PYTHIA 8

JHEP 08 (2015) 003
Eur.Phys.J. C 74 (2014) 3024



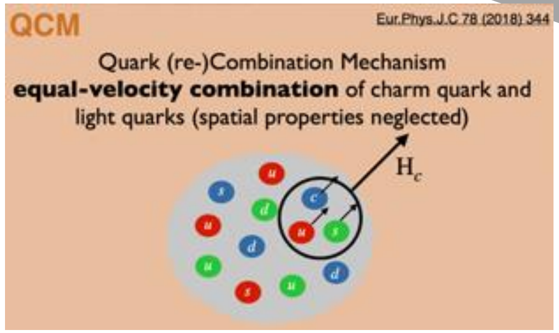
String fragmentation and reconnection between different MPI



EPOS4HQ

Phys Rev D 109 (2024) 054011
Phys Rev C 110 (2024) 024909

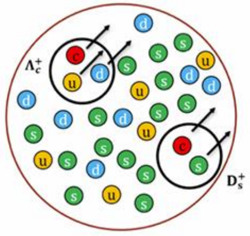
Core and corona approach with hybrid hadronization and hadronic afterburner



SHM + RQM

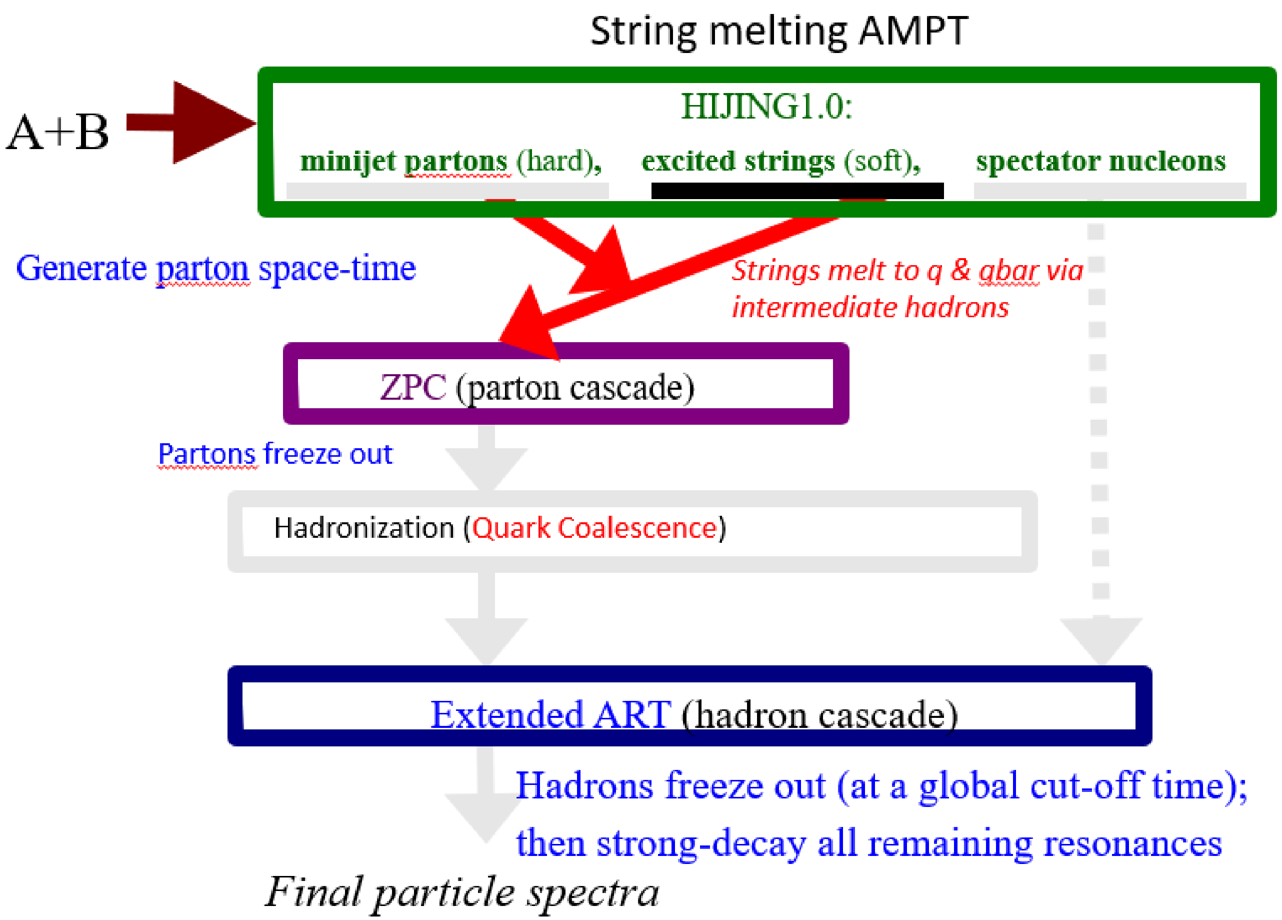
Phys Lett B 795 (2019) 117
Phys Rev Lett 124 (2020) 042301
Phys Lett B 815 (2021) 136144
Phys Rev C 110 (2024) 034905

- Statistical hadronization weights
- Augmented set of heavy flavor baryon state in RQM



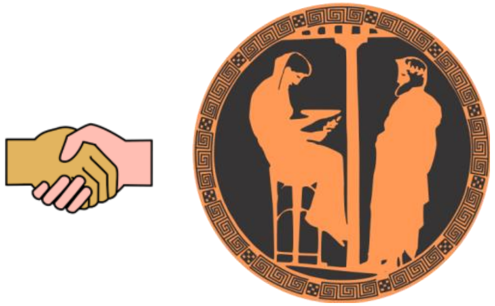
Coalescence

AMPT × PYTHIA8

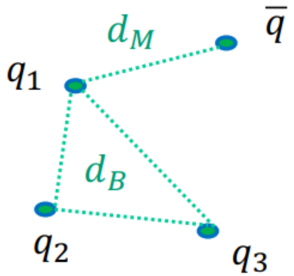


PRC 72 (2005) 064901
NST 32 (2021) 113

EPJC 81 (2021) 755
EPJC 84 (2024) 1029



$\frac{d_B}{d_M} < r_{BM}$, q_1 *coalesce to baryon*



PRC 96 (2017) 014910
PRC 101 (2020) 034905
NST 36 (2025) 134

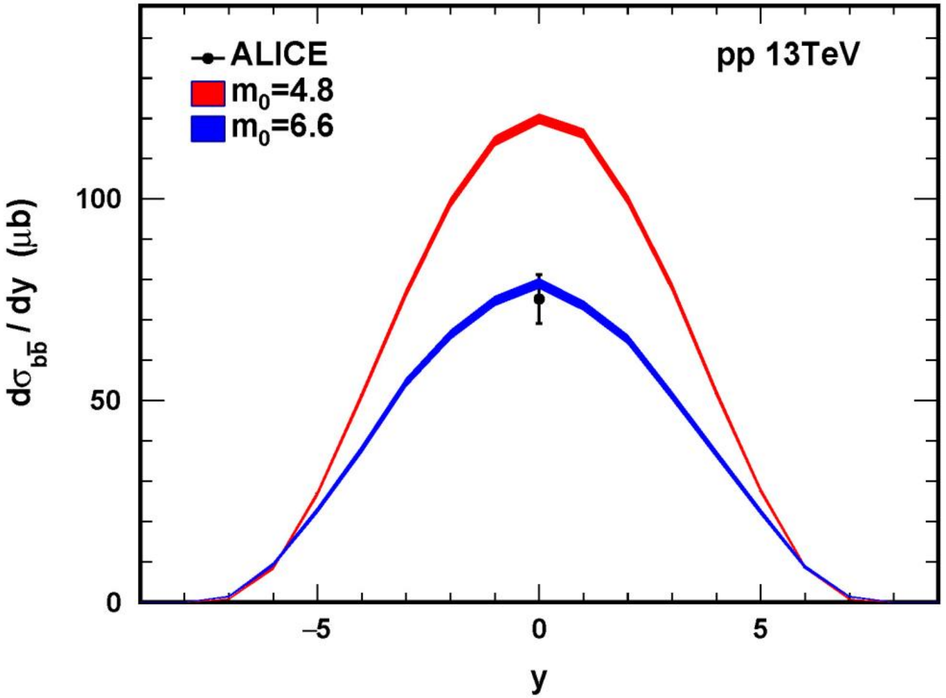
$$r_{BM}^{c} = 1.4, r_{BM}^{b} = 1.2$$

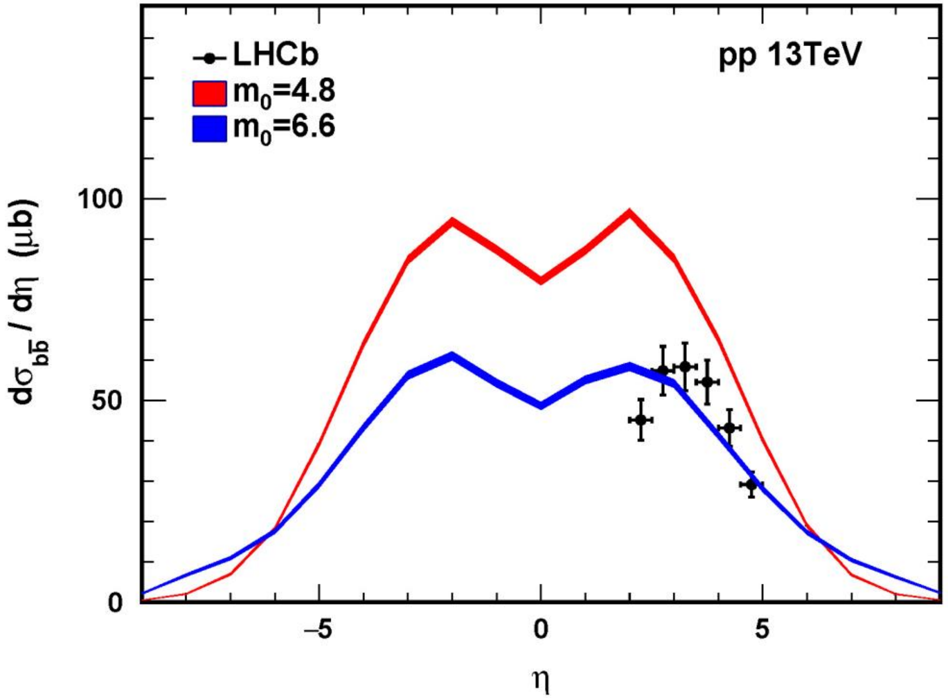
- Include PYTHIA8 initial conditions
- Possible to extend to various system sizes
- Spatial coalescence parameter
- Simultaneously inclusion of light bulk evolution and the HF probes

Beauty quark production in initial conditions

- In the default PYTHIA8 initial conditions, the $b\bar{b}$ cross-section is higher than the data.
- Increase beauty mass at production stage to fit the data.

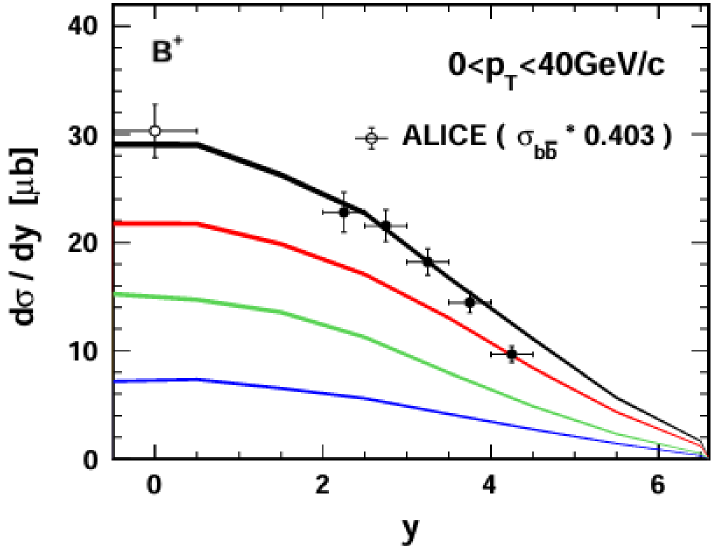
The default m_0 is 4.8 GeV/c^2.

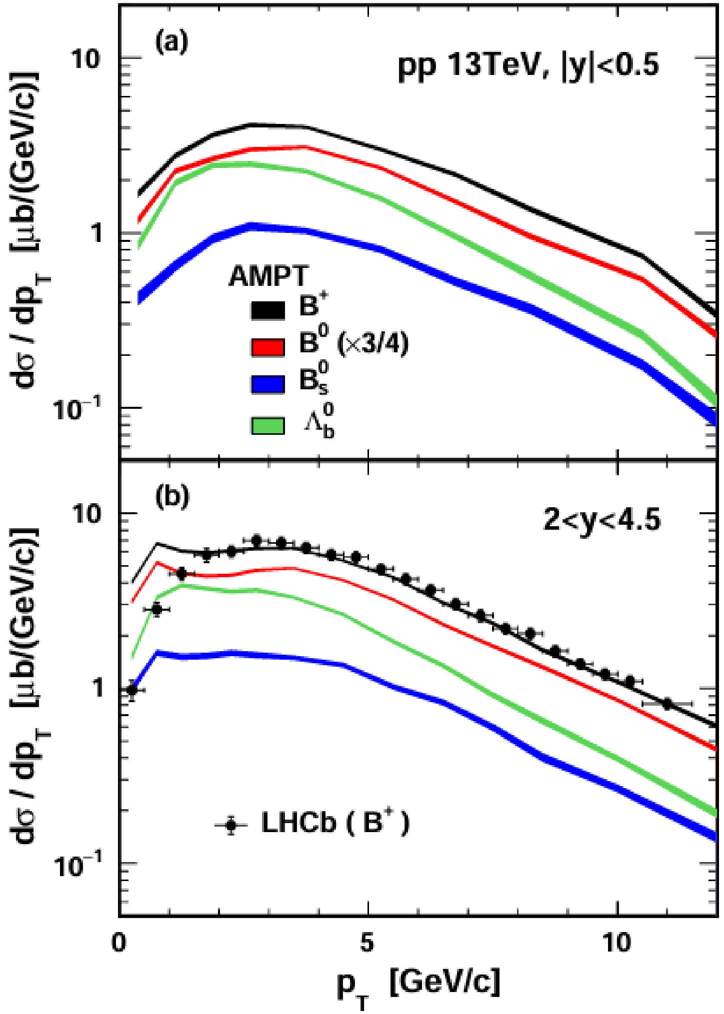




Beauty hadron production

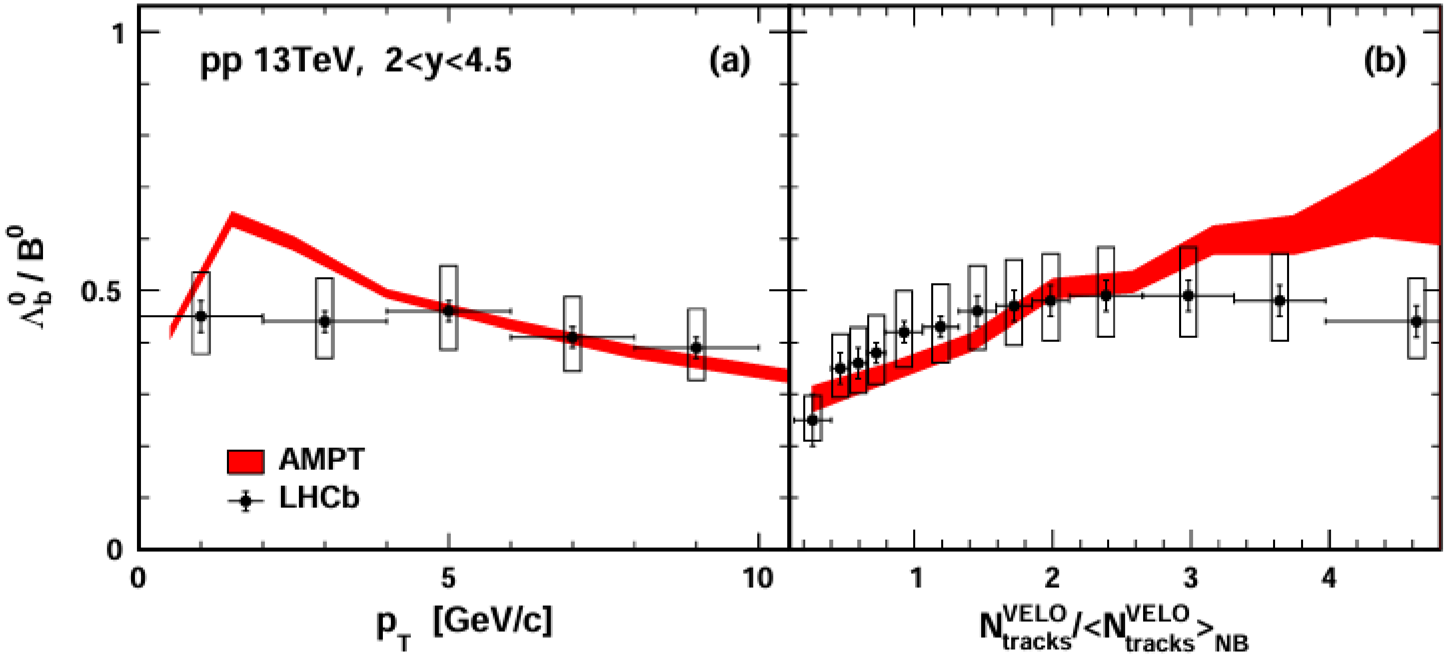
- Beauty hadron production consistent with the LHCb and ALICE converted B^+ data
- Possible to predict different beauty hadron species yield
- Threshold effect at very low p_T region in forward rapidity region.





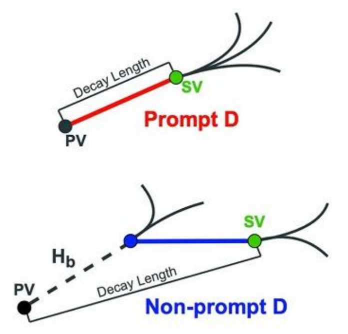
Beauty baryon to meson ratios

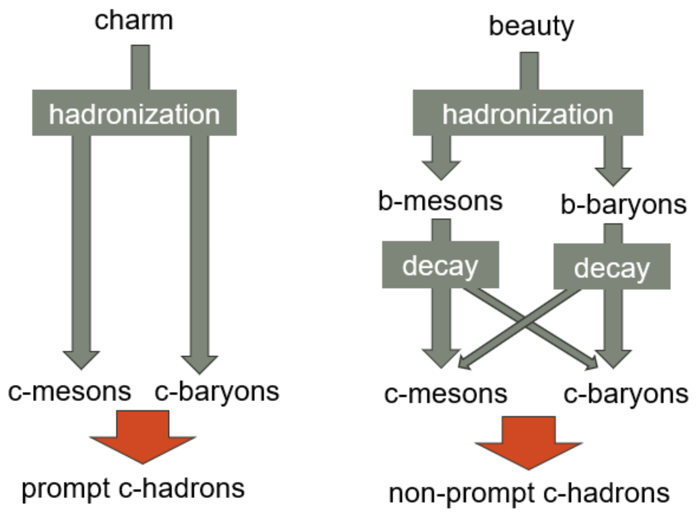
- LHCb beauty baryon to meson ratio data reasonably described.
- Coalescence induced bump like structure at intermediate p_T.
- Increasing trend dependent on multiplicity.

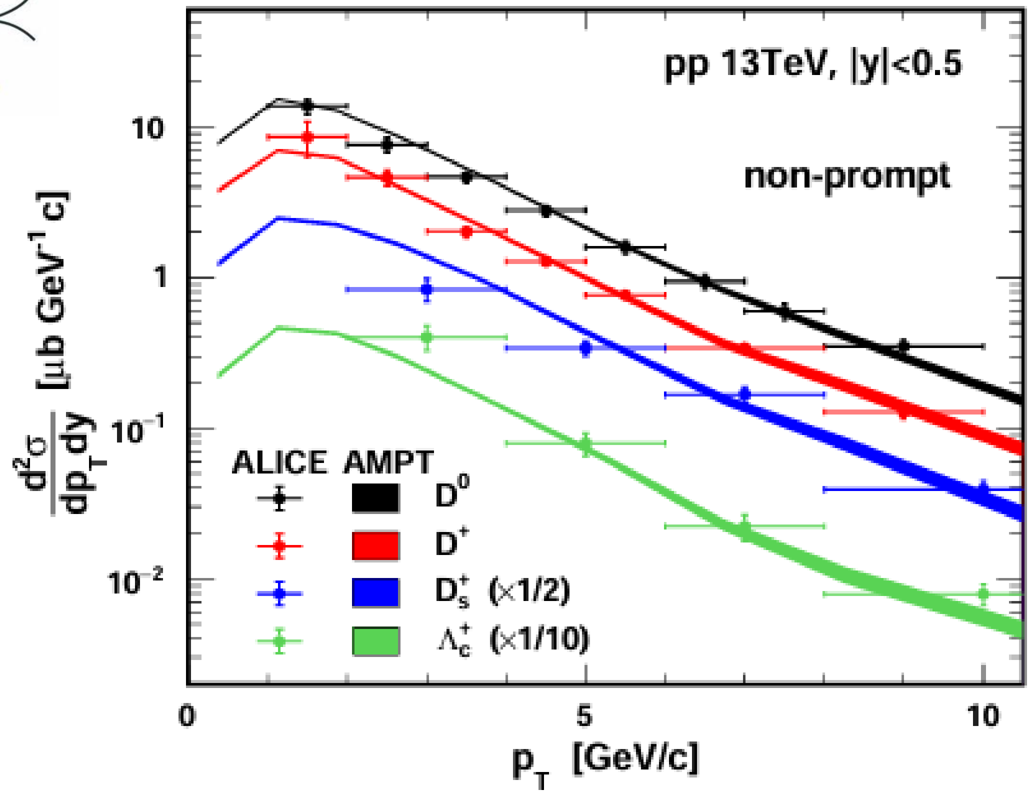


Non-prompt charm hadron production

- Non-prompt charm as proxy to beauty.
- Experimental advantage to reconstruct especially at low p_T.
- Different sources of beauty decay to non-prompt charm hadron.
- Forward beauty tuned AMPT reasonably describe the non-prompt charm spectra at mid-rapidity.

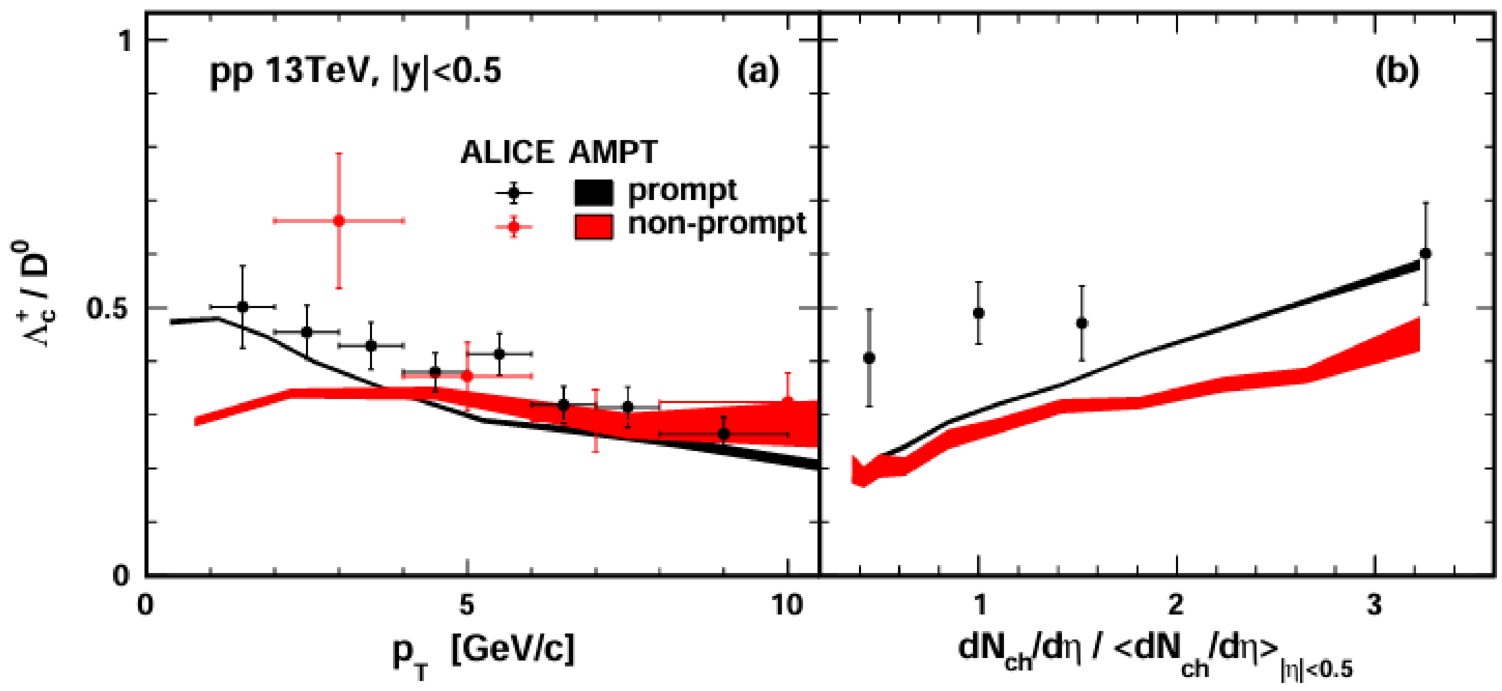






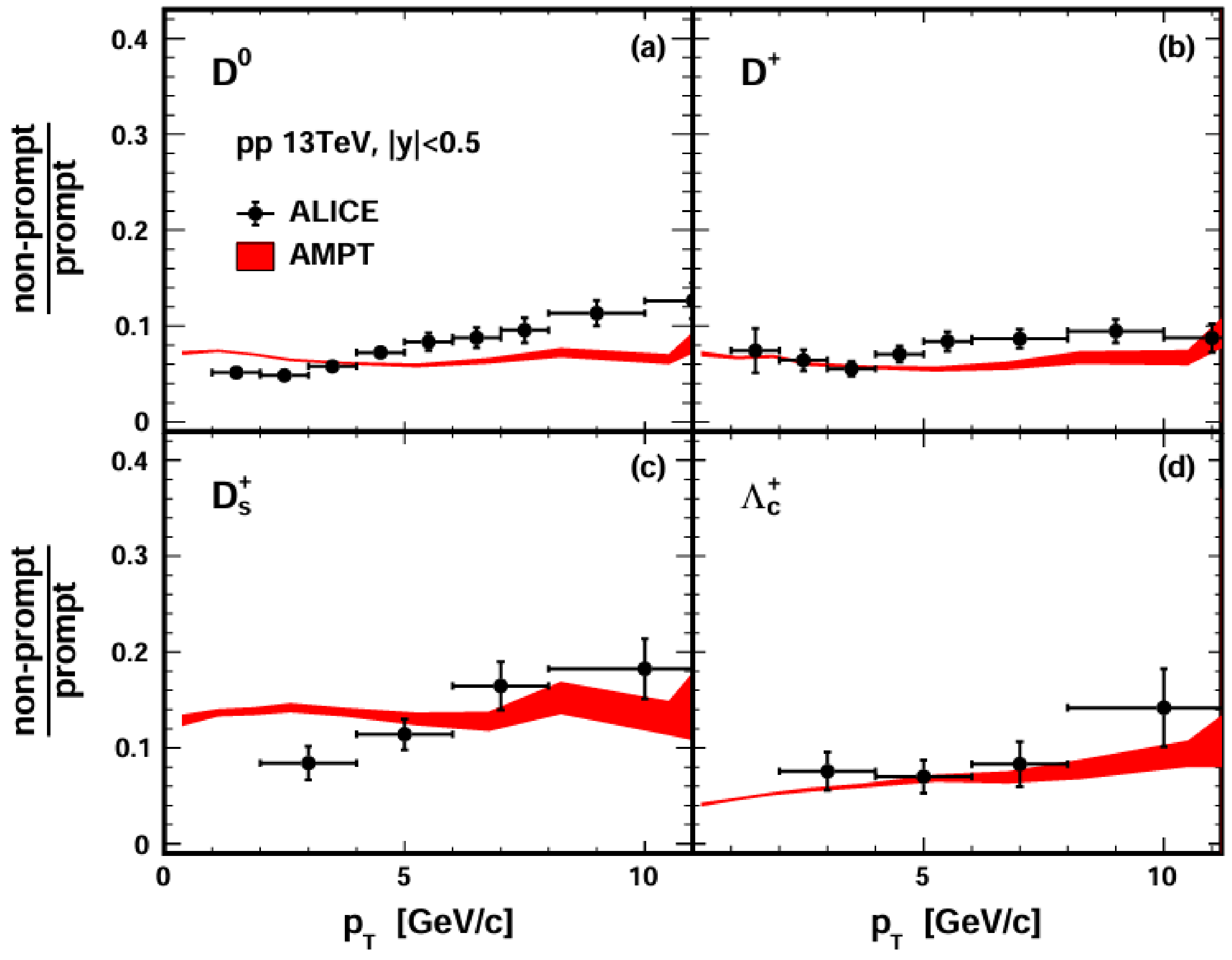
Non-prompt charm baryon to meson ratio

- Non-prompt baryon to meson ratio consistent with data except at very low p_T
- Slower increase with multiplicity compared to prompt charm sector



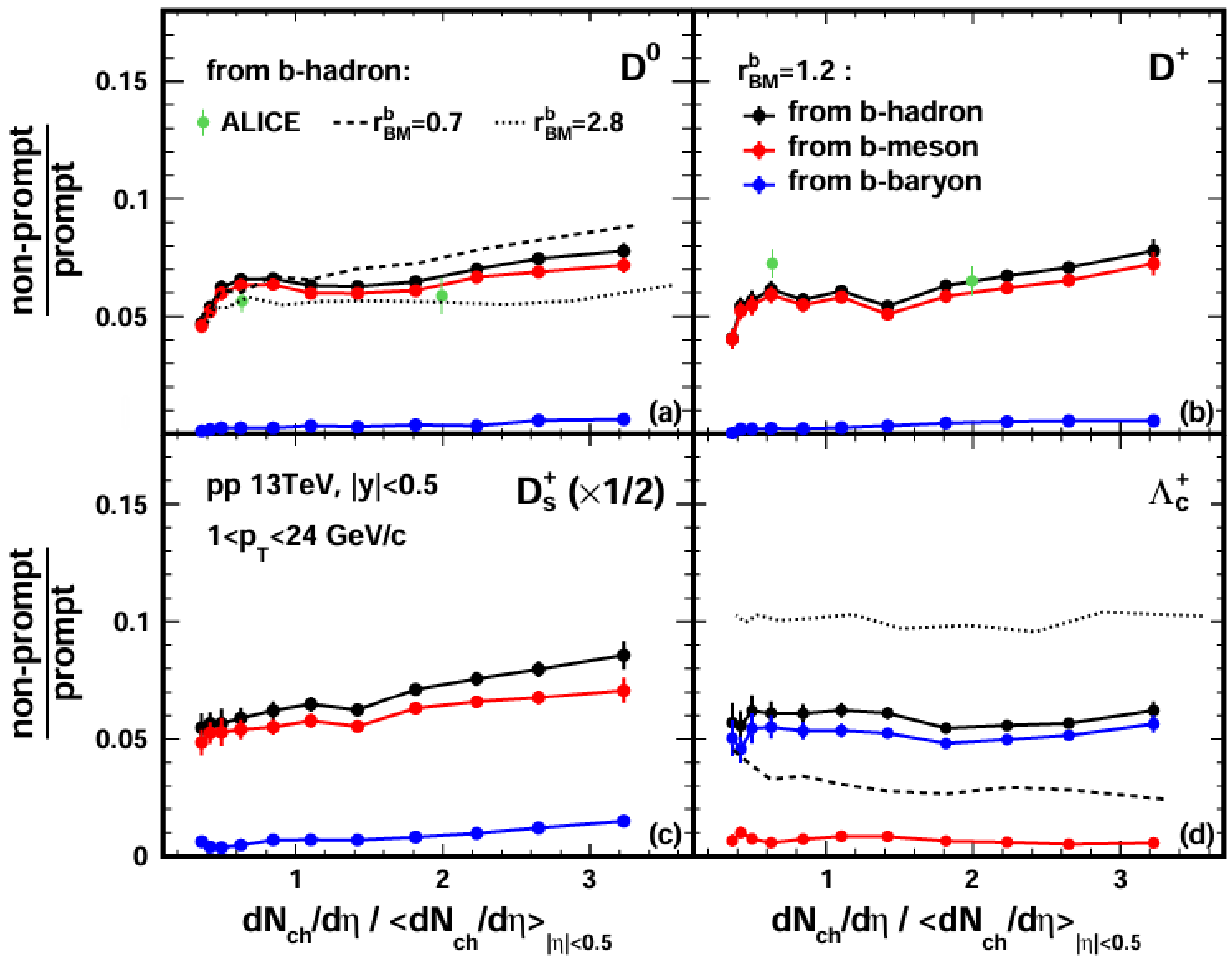
Non-prompt to prompt ratio

- Non-prompt to prompt ratio compares the beauty and charm quark p_T spectra.
- Overall NP/P ratio consistent with data for different charm hadron species.
- Agreement to the overall ratio due to the variation of the beauty quark mass.



Multiplicity dependence of NP/P ratio

- Non-prompt to prompt D^0 and D^+ data described by AMPT
- Non-prompt to prompt charm meson (baryon) sensitive to beauty meson (baryon) source
- Multiplicity dependences of charm meson and baryon are related to the difference between beauty and charm coalescence behavior



Summary

- The AMPT model with modifications to the b quark mass and coalescence parameter, provides an improved description of beauty and non-prompt charm hadron production.
- The study highlights that the multiplicity dependence of non-prompt to prompt ratios is a sensitive probe of the underlying beauty quark coalescence dynamics.
- This framework paves the way for future studies of heavy quark collectivity and evolution in the dense environment of high multiplicity pp collisions.

Workshop on Transport Approaches for Extreme Nuclear Matter at RHIC-BES and Beyond

Dec 19 – 22, 2025

Enter your search term

The **Workshop on Transport Approaches for Extreme Nuclear Matter at RHIC-BES and Beyond** will be held in Wuhan, Hubei, on December 19–22, 2025. The workshop is jointly organized by Central China Normal University, Wuhan University of Technology, China University of Geosciences (Wuhan) and Wuhan Textile University, with Central China Normal University serving as the local host.

This workshop is dedicated to advancing the development, application, and critical assessment of **transport models** in the study of nuclear matter under extreme conditions, particularly in the context of relativistic heavy-ion collisions at RHIC-BES and future experimental programs. Transport approaches play a vital role in describing the dynamical evolution of these collisions across a broad energy range, especially where nonequilibrium effects and complex microscopic interactions dominate.

The workshop will bring together a diverse community of theorists and experimentalists to exchange ideas on the current state of transport modeling, including hadronic and partonic transport, hybrid frameworks, and the treatment of rare probes and fluctuations. Through focused discussions and collaborative sessions, the workshop aims to foster cross-model comparisons, highlight areas for improvement, and identify key observables and strategies that can guide future model development and experimental analyses. The ultimate goal is to strengthen the theoretical foundations and predictive power of transport models in support of current and next-generation heavy-ion collision programs.

Date:

- December 19: Registration and free discussion
- December 20–21: Workshop on Transport Approaches for Extreme Nuclear Matter at RHIC-BES and Beyond
- December 22: Free discussion and departure

Venue: Room 9409 (on 4th floor) of Bldg. 9 at CCNU

Accommodation: Accommodation at Guiyuan Hotel can be booked at the registration page.

Website: https://indico.ihep.ac.cn/event/26058/

Registration Fee: 1500 RMB （教师/博后），1000RMB（学生）(collected at the registration)

Registration Period: September 4 – December 15, 2025

Abstract Submission Deadline: September 4 – December 15, 2025

Conference registration and abstract submission are now open. We warmly welcome you to register and submit your presentation title.

Contact

chaoz@whut.edu.cn

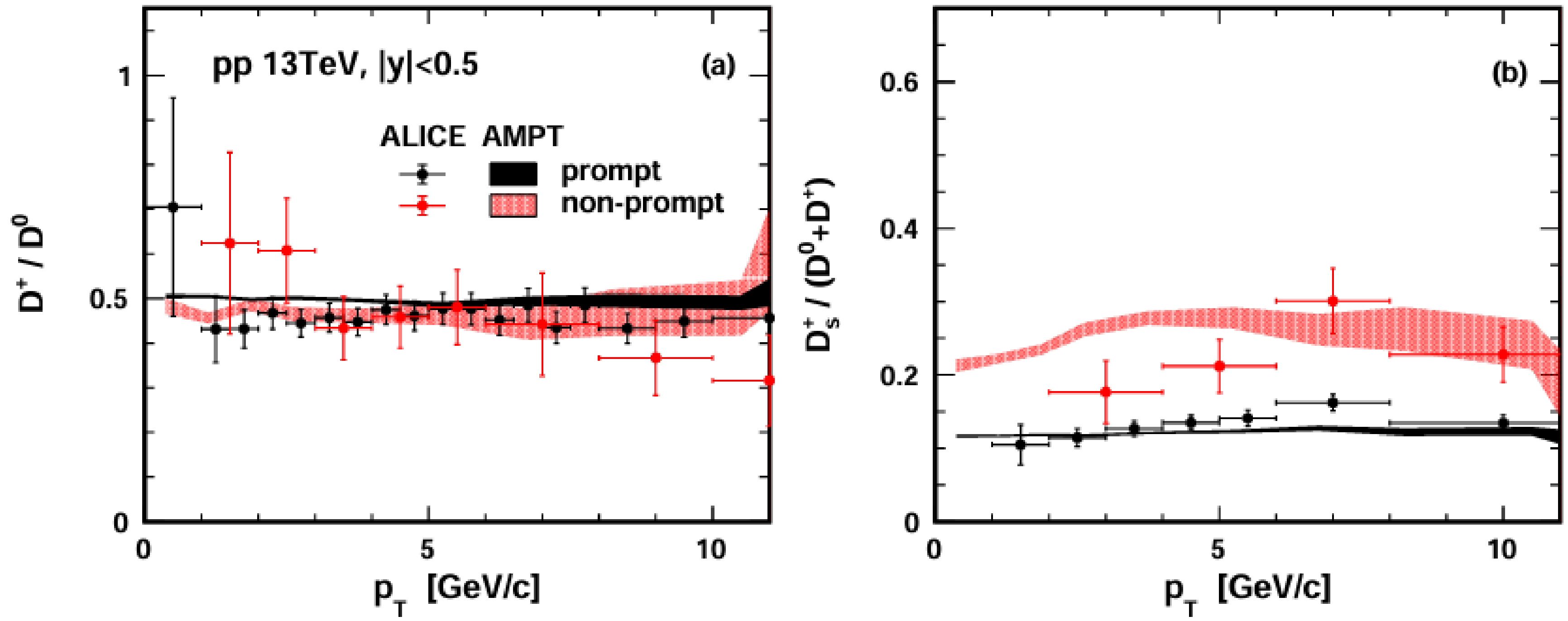
shiss@ccnu.edu.cn

18064036284

Backup

Non-prompt charm meson ratio

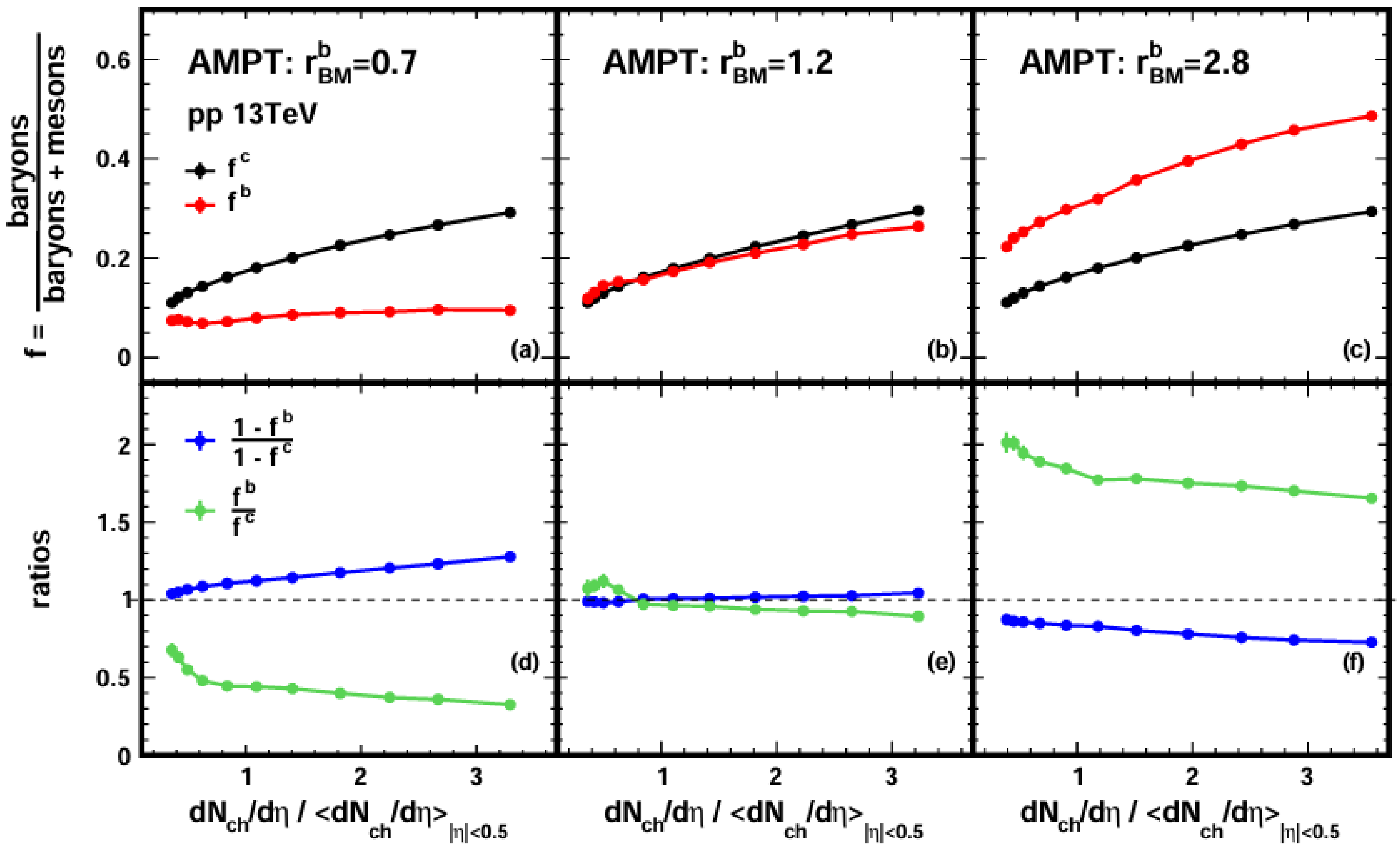
- Beauty hadron constituent quark composition ratio consistent with data



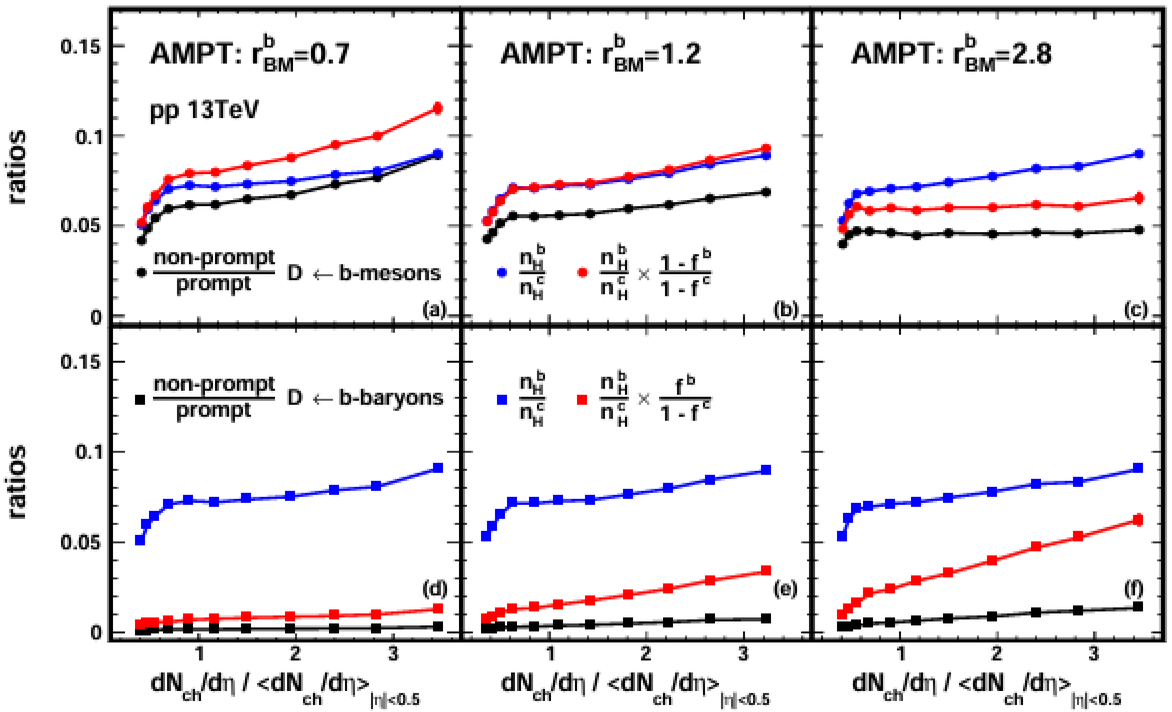
Sources to the NP/P multiplicity dependence

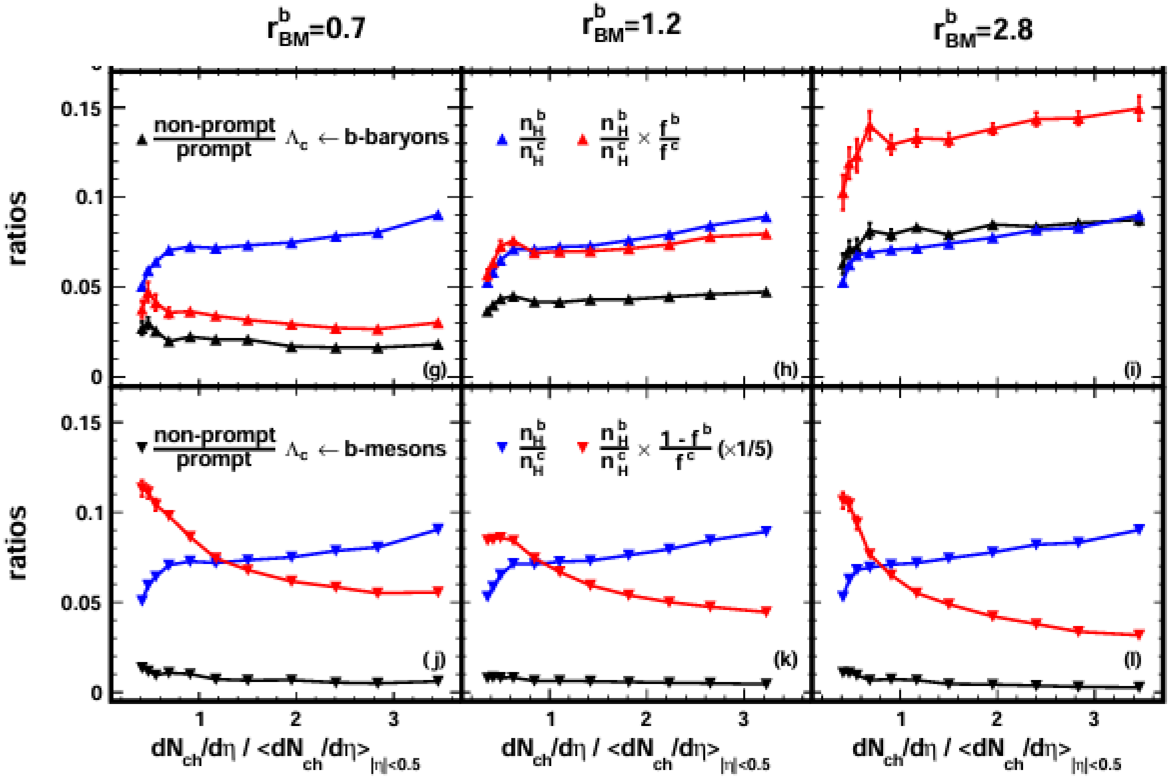
$$\frac{NP}{P}(M^c) = \frac{n_H^b}{n_H^c} \times \frac{1-f^b}{1-f^c} \times BR(M^b \to M^c) + \frac{n_H^b}{n_H^c} \times \frac{f^b}{1-f^c} \times BR(B^b \to M^c),$$

$$\frac{NP}{P}(B^c) = \frac{n_H^b}{n_H^c} \times \frac{f^b}{f^c} \times BR(B^b \to B^c) + \frac{n_H^b}{n_H^c} \times \frac{1-f^b}{f^c} \times BR(M^b \to B^c)$$



Sources to the NP/P multiplicity dependence



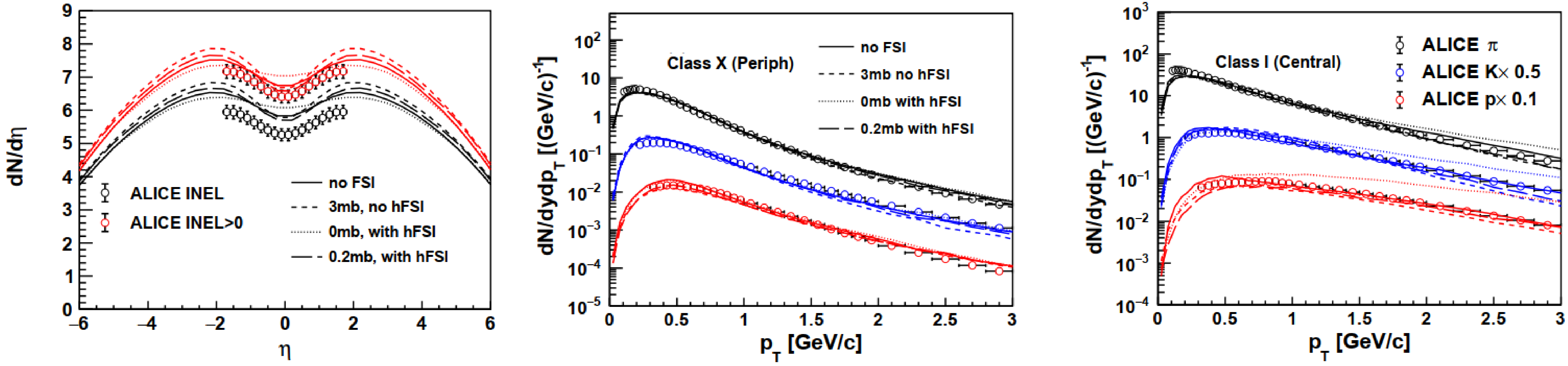


Final state interaction(FSI) in pp collisions

- Final state interaction effects weak in charge density
- Stronger FSI in high multiplicity events
- Radial flow like contribution from final state hadron interaction

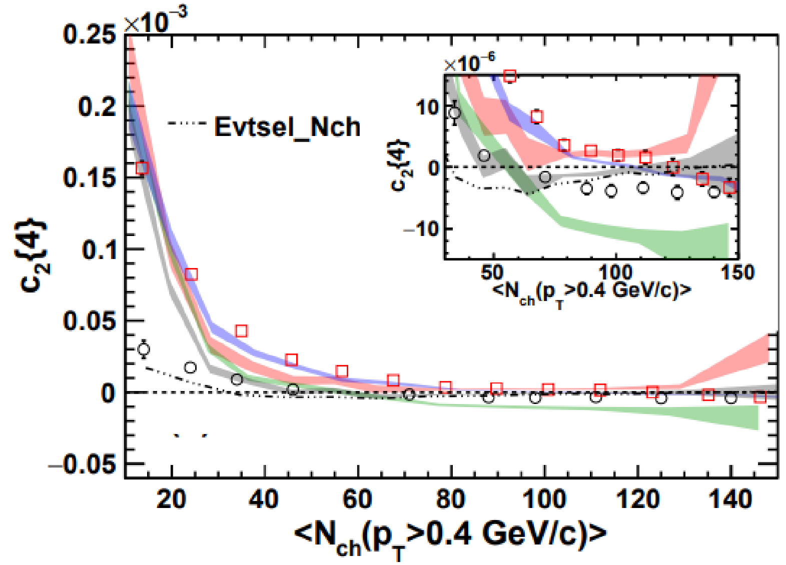
pp 13 TeV, hadron level

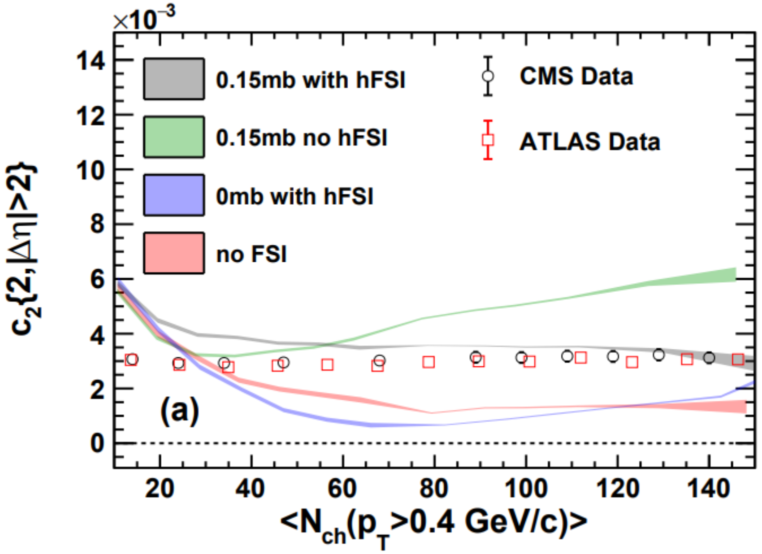
Eur.Phys.J. C81 (2021) 755

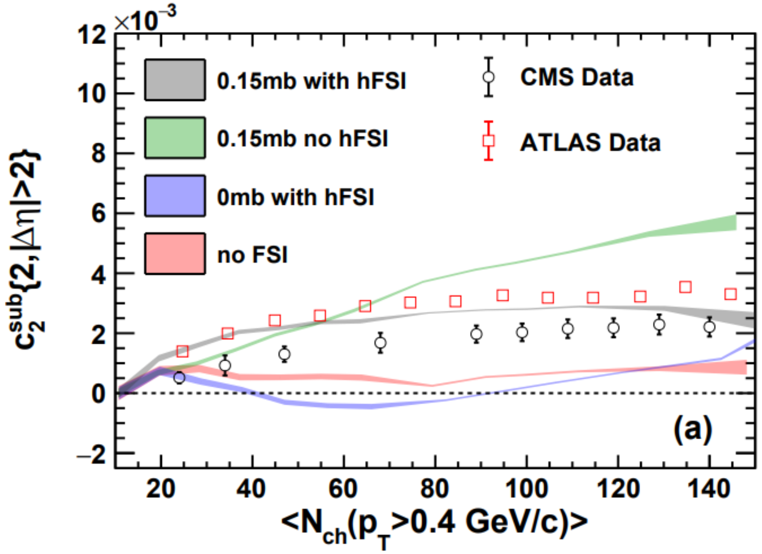


Reasonable collective flow description

- Reasonable description to multiplicity dependence of elliptic flow in two and multiparticle correlations
- Partonic stage evolution important to understand the data behavior







Eur.Phys.J. C84 (2024) 1029

Compared to FONLL calculations

- Consistent to FONLL results within uncertainties at lower p_T
- Mass tuning impacts mainly at low p_T
- Low pT bump due to the threshold effects
- Missing sophisticated higher order corrections to have better slope