Santa Fe Jets and Heavy Flavor Workshop
UCLA, Jan. 28-30, 2019.

Sequential Hadronization with Charm Conservation in Heavy Ion Collisions

Jiaxing Zhao (Tsinghua University)

arXiv: 1805.10858

In collaboration with:
Shuzhe Shi, Nu Xu and Pengfei Zhuang

Outline

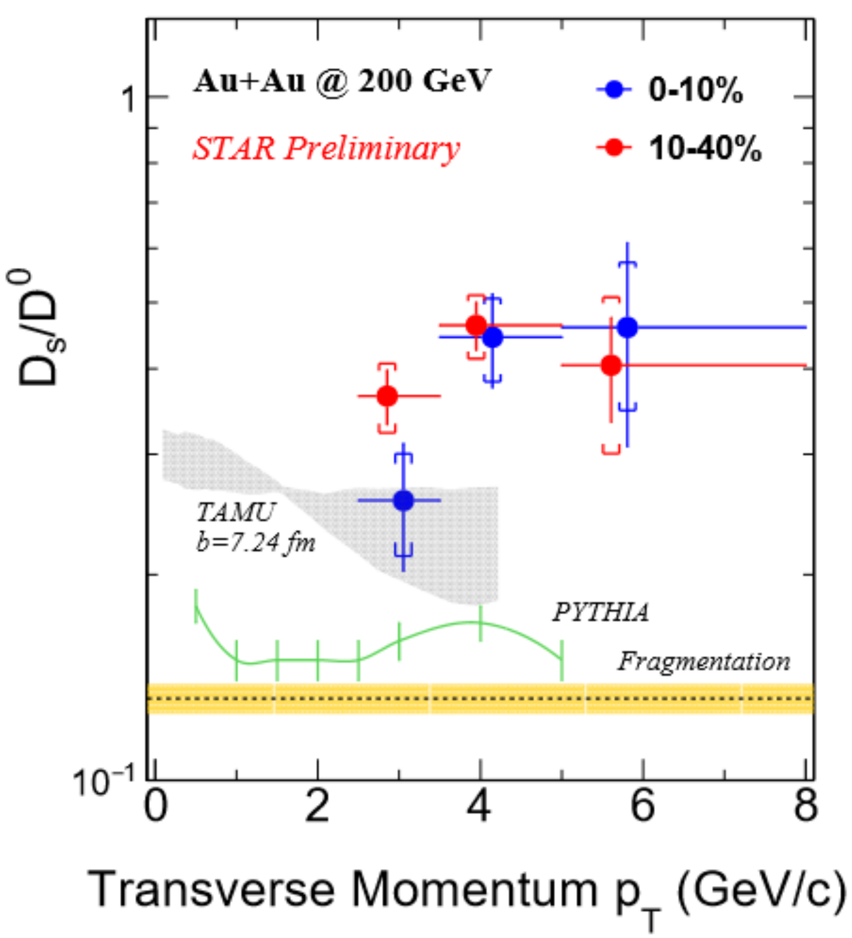
Part1. Introduction and motivation

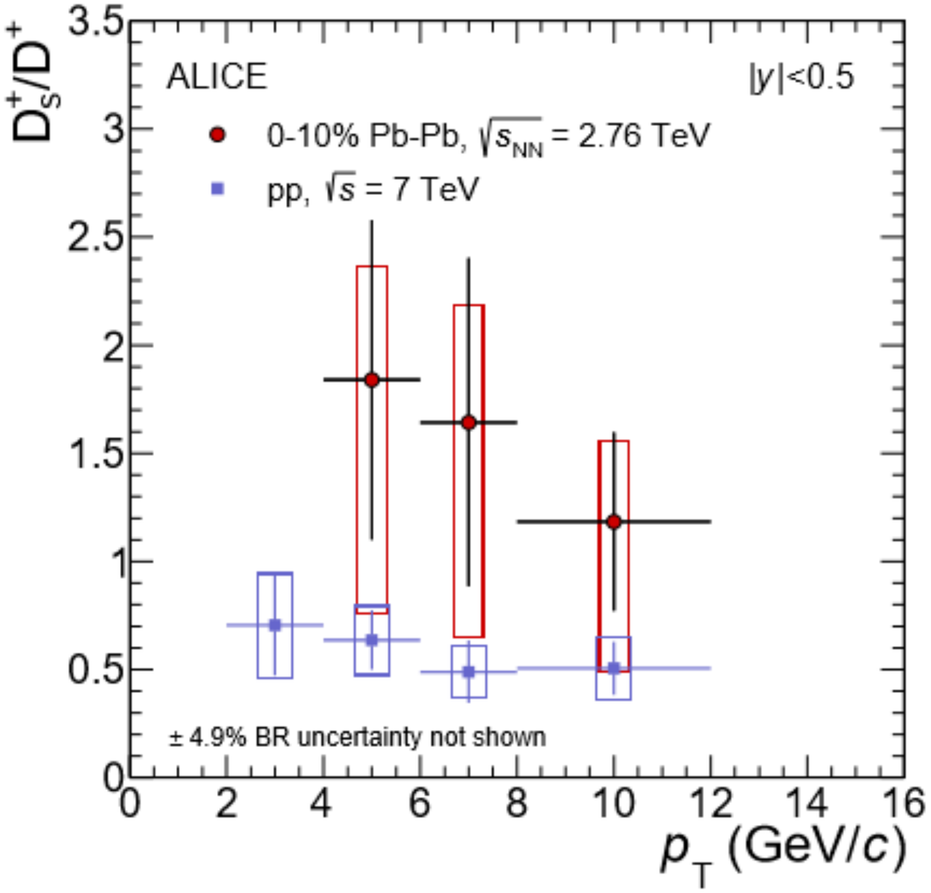
Part2. Charm Conservation and Hadronization Sequential

Part3. Results and Analysis

Part4. Summary and Outlook

Enhancement in Charm Sector in HIC



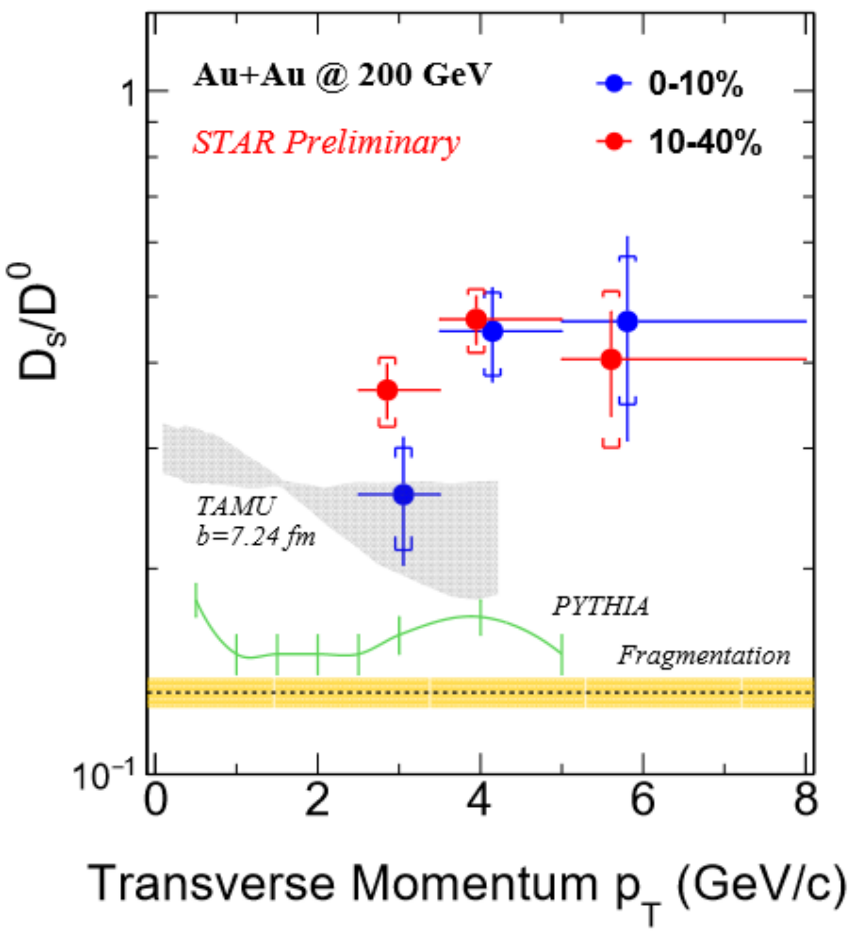


L. Zhou [STAR Collaboration] NPA967. 620(2017)

J. Adam et al. [ALICE Collaboration] JHEP. 1603. 082(2016)

Significantly enhanced in Heavy ion collisions vs. pp collisions!

Enhancement in Charm Sector in HIC



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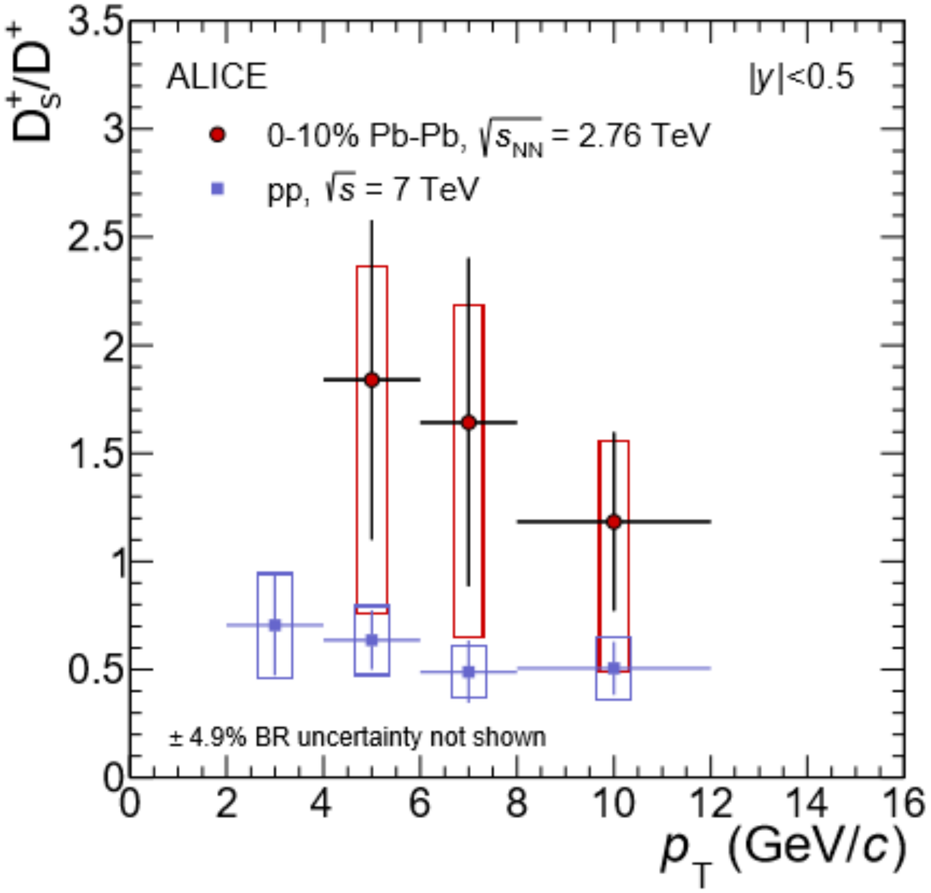


J. Adam et al. [ALICE Collaboration] JHEP. 1603. 082(2016)

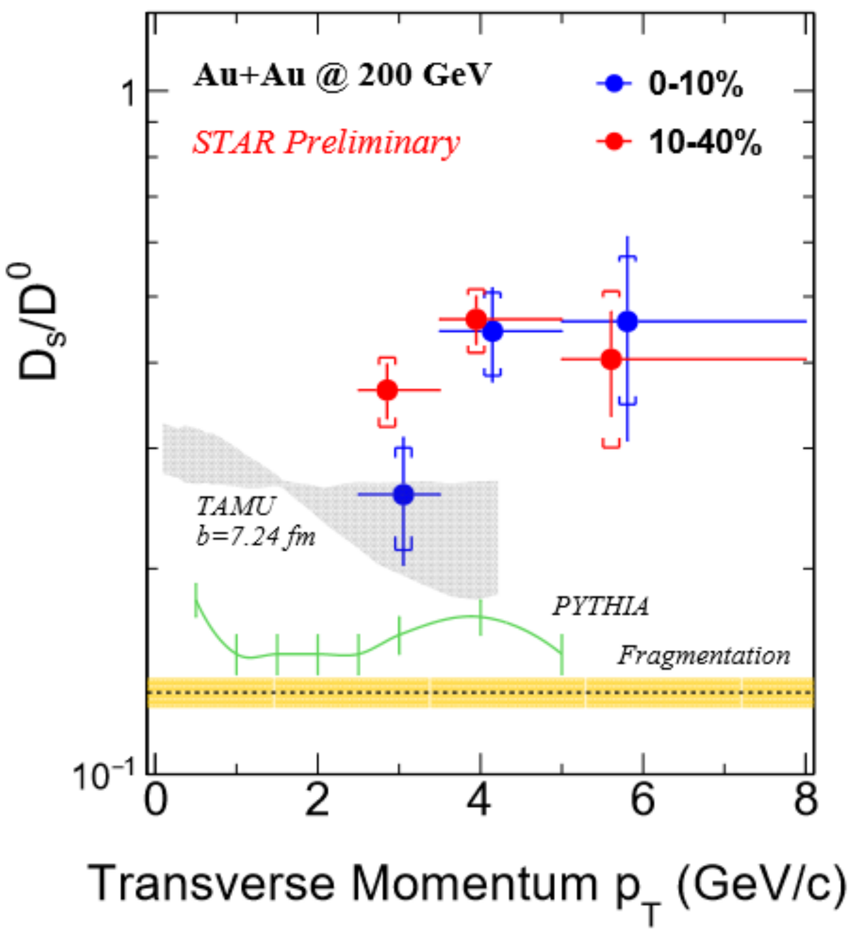
Significantly enhanced in Heavy ion collisions vs. pp collisions!

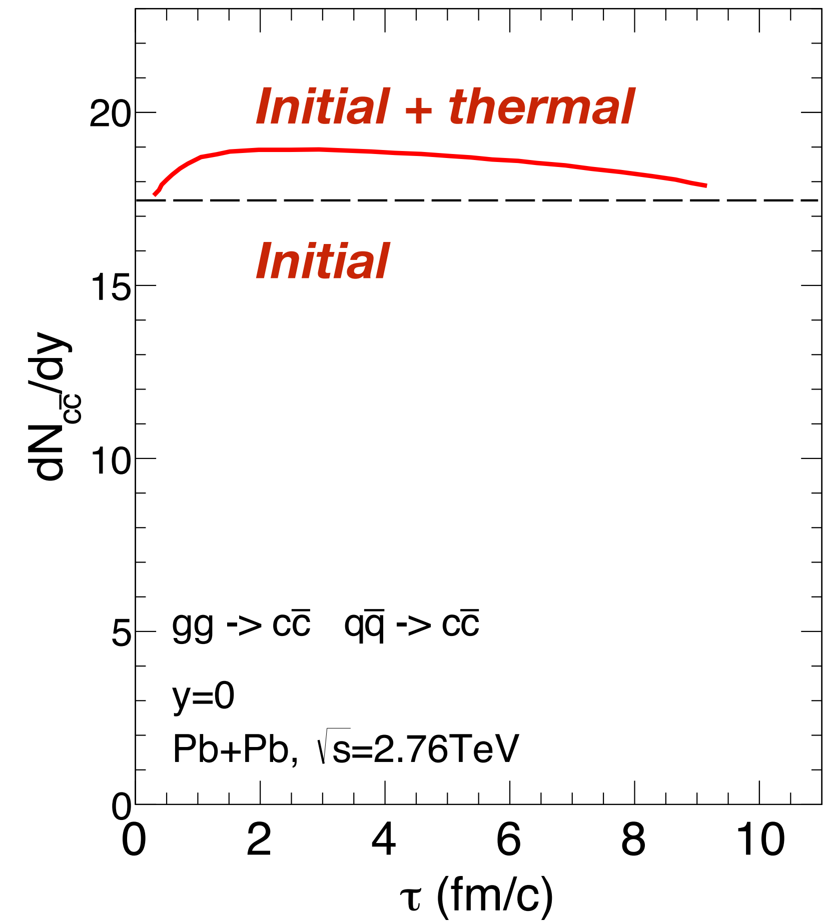
- Induced by strangeness (Ds) enhancement?

  Strange quark thermal production in QGP.
  (Ms ~100MeV, T~300MeV)

See for instance. M. He, R. Fries and R. Rapp, PRL110. 112301(2013)

Charm Quark Conservation





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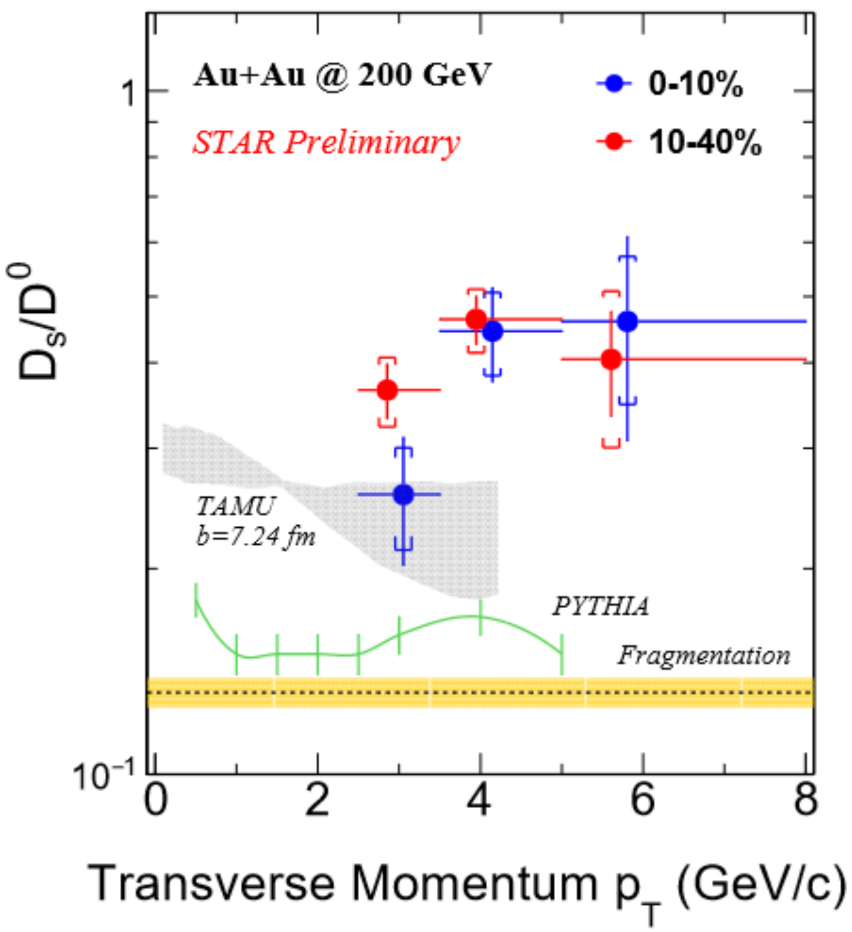
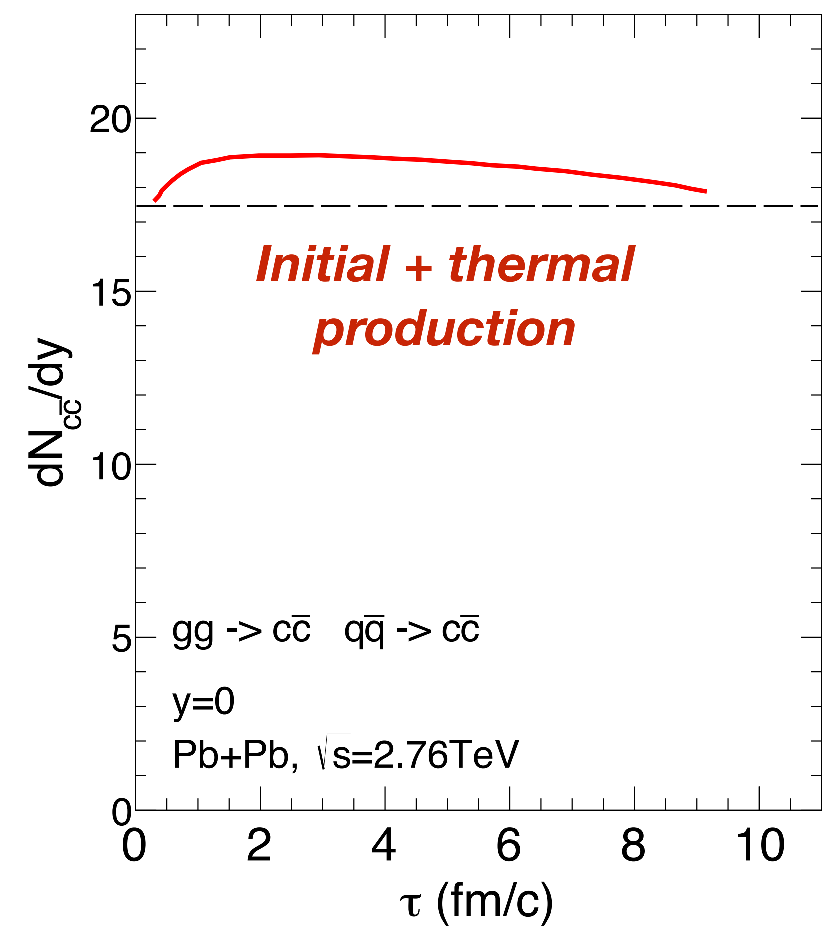
Charm Conservation play an important role!

- Ds enhancement –> D0 suppression –> extra Ds/D0 enhancement!

  (Mc ~1500MeV, T~300MeV)

Charm Quark Conservation





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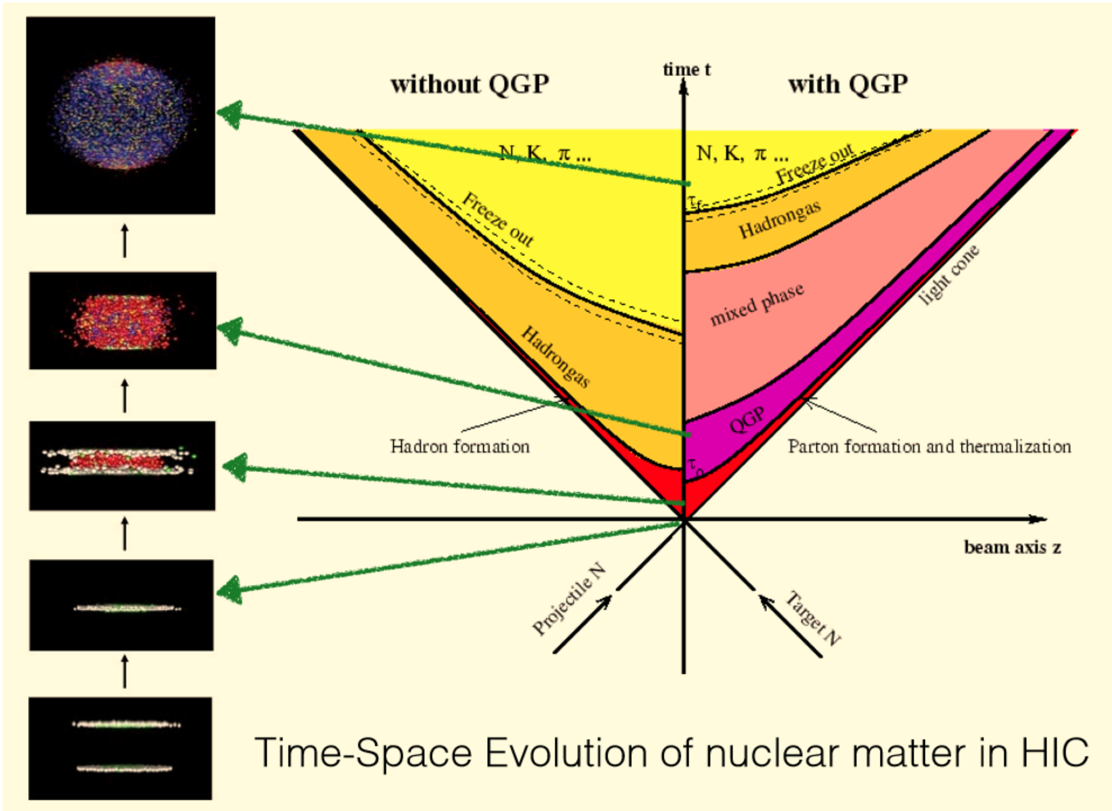
Q: How to realize the charm conservation self-consistently?

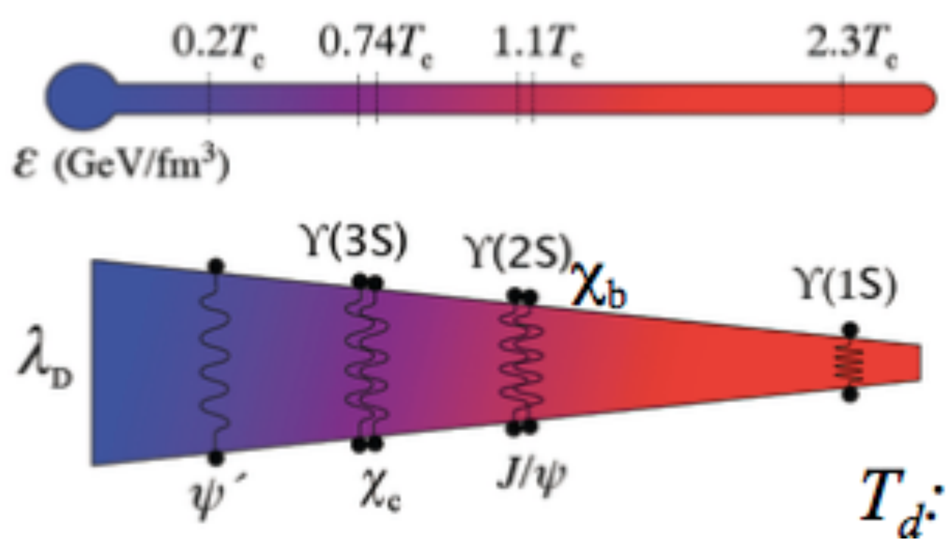
Hadronization in HIC



A hot and dense matter(QGP) produced in HIC!

Initial Produced charm hadrons would be "melt" and will be regenerated at final stage!

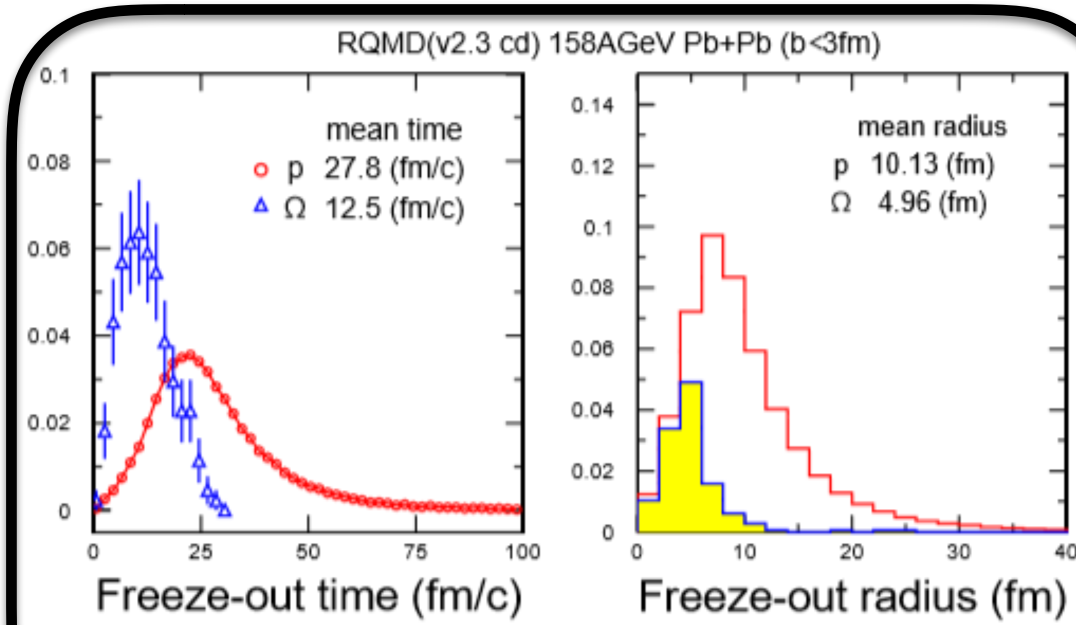
Hadronization Sequence



H. Satz. J. Phys. G32, R25(2006)

Lattice results: open charm hadrons dissolve close but higher than light hadrons!

A. Bazavov, HT. Ding, S. Mukherjee et al. Phys. Lett. B737,210(2014)



H. Hecke. H. Sorge and N. Xu. PRL 81, 5764(1998)

larger binding energy

↓

survive at higher temperature

↓

hadronization earlier.

Hadronization Sequence

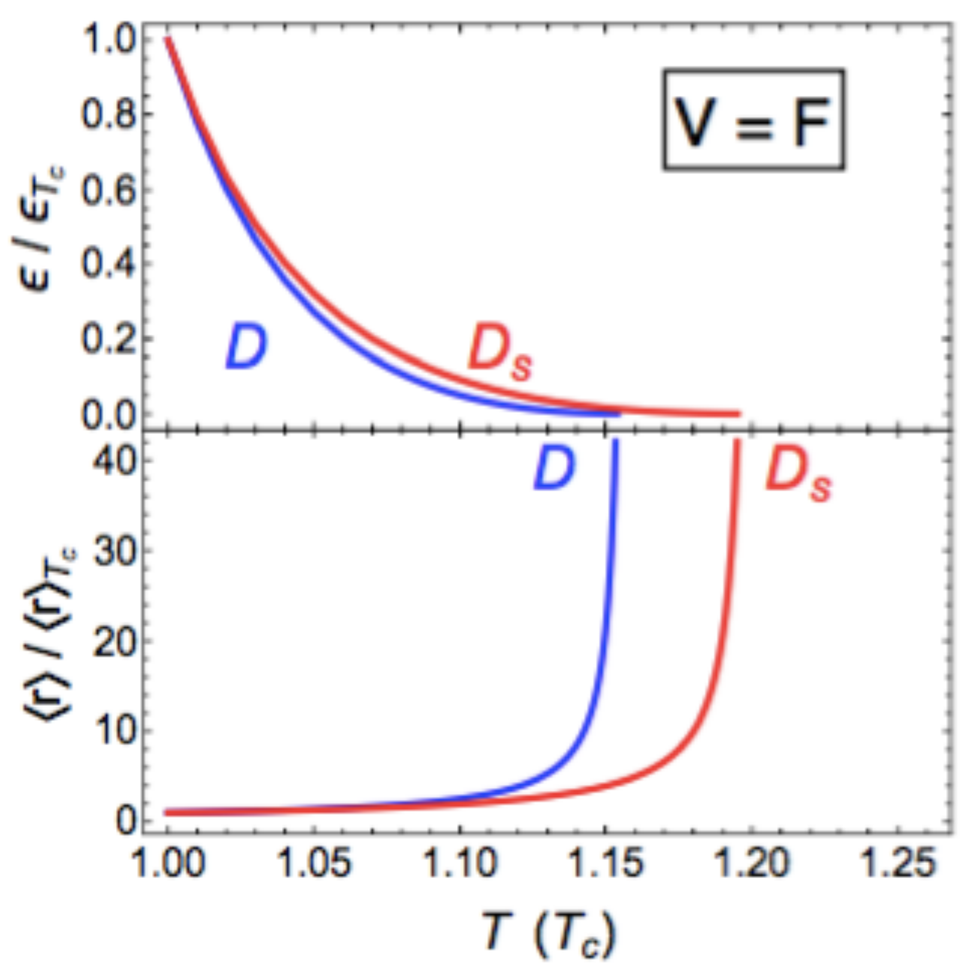
Tow-body Dirac equation is used for open charm bound states

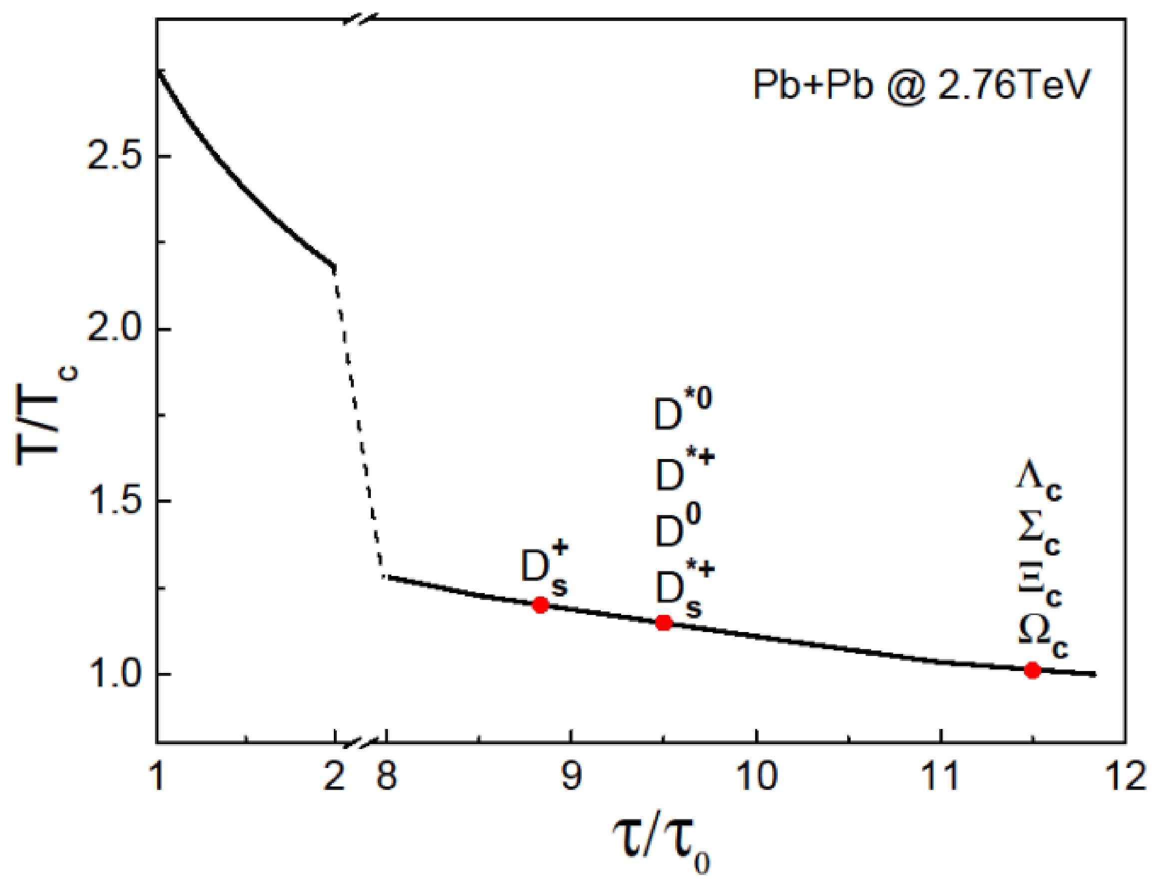
H. Crater, J. Yoo and C. Wong. PRD 79. 034011(2009)   *S. Shi, X. Guo and Pengfei Zhuang. PRD 88. 014021(2013)*

Solve 2-body Dirac equation + lattice Free energy

get the binding energy and wavefunction!

The dissociation temperature T_d: $\epsilon(T_d) = 0$





Coalescence Hadronization

Coalescence mechanism play an important role in hadrons production in heavy ion collisions.

$$\frac{dN}{d^2\mathbf{P}_T d\eta} = C \int \frac{P^\mu d\sigma_\mu(R)}{(2\pi)^3} \int \frac{d^4 r d^4 p}{(2\pi)^3} F(r_1, p_1, r_2, p_2) W(r, p)$$

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- **The hadronization hypersurface determined by hydrodynamics and dissociation temperature.**

$$\partial_\mu T^{\mu v} = 0 \quad \partial_\mu n^\mu = 0$$

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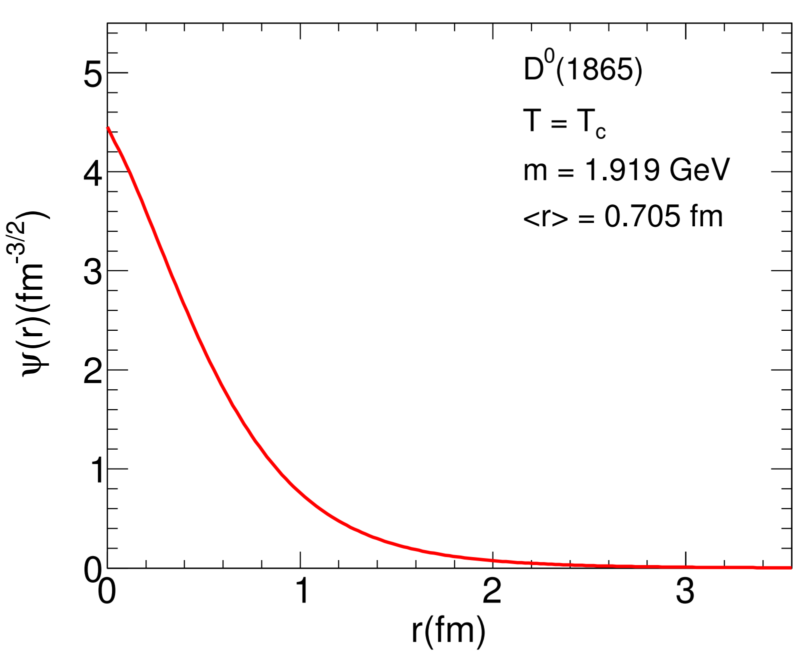
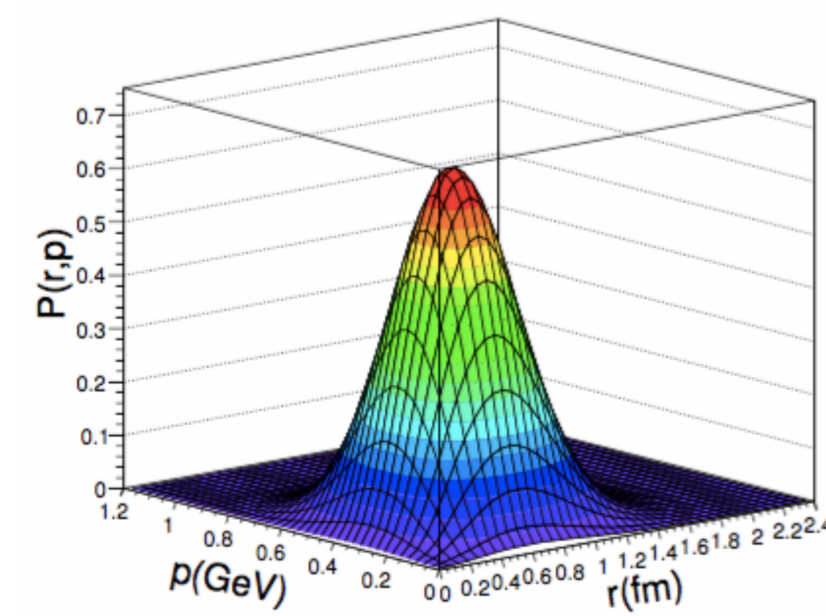
- The covariant wigner function can be constructed by wavefunction.

$$W(r,p) = \int d^4 y e^{-ipy}\psi(r+\frac{y}{2})\psi(r-\frac{y}{2})$$



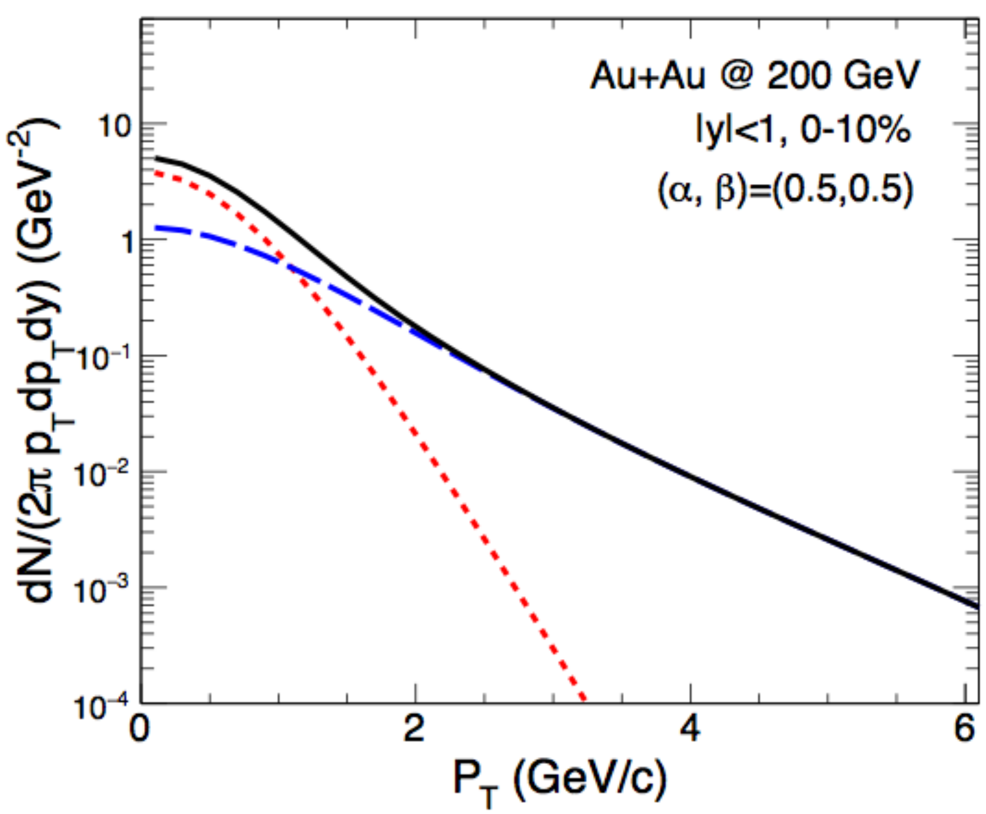


Quark Distribution Function

Light quark reach chemical equilibrium in QGP

$$f(r,p) = \frac{N_s}{e^{u^\mu(r)p_\mu/T(r)}+1}$$

Heavy quark evolution can be described by transport equation



$$f_c = \rho_c(r)[\alpha f_{th} + \beta f_{pp}]$$

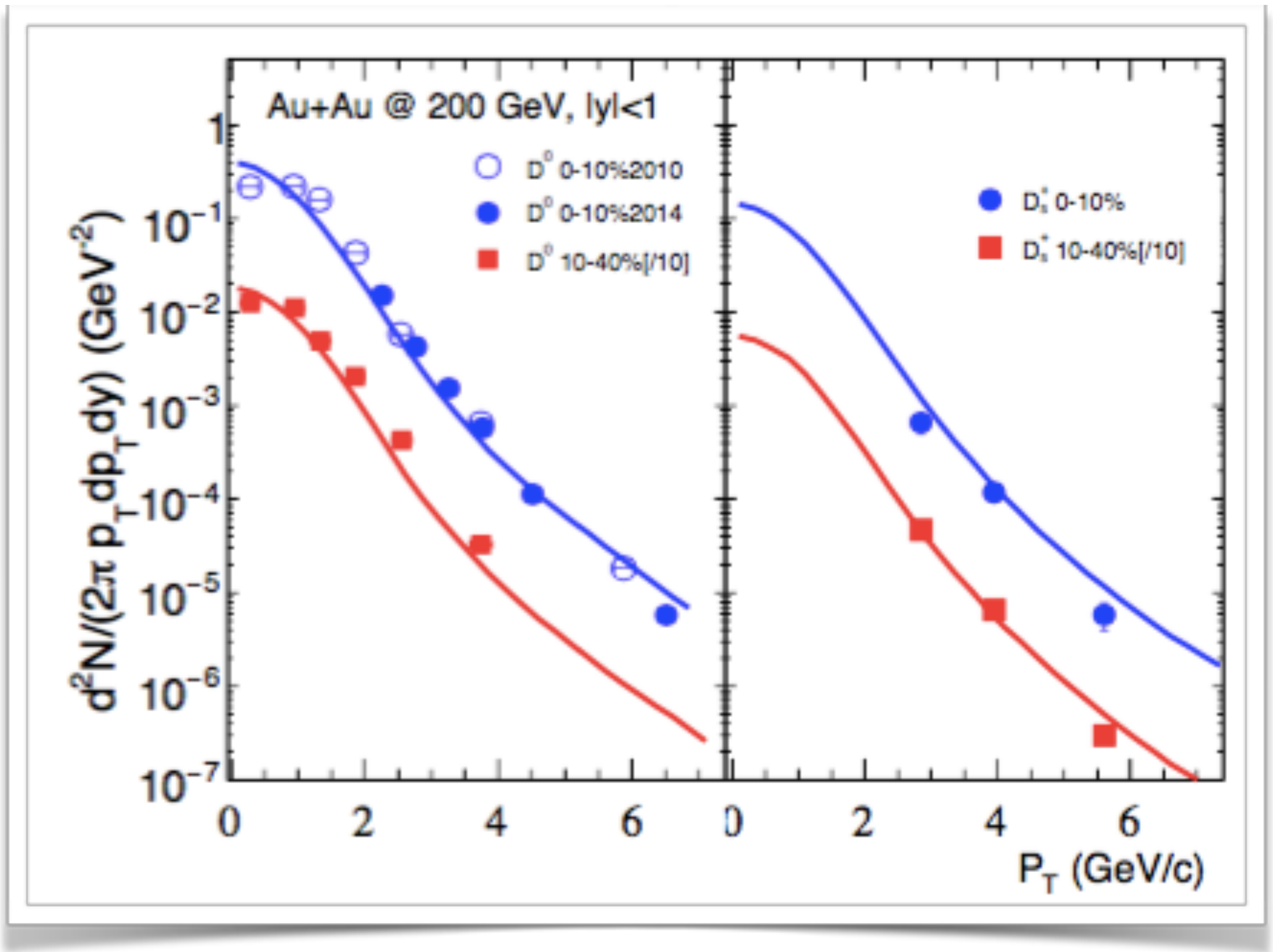
$$\rho_c(x|\mathbf{b}) = r(\tau)T_A(\mathbf{x}_T)T_B(\mathbf{x}_T-\mathbf{b})\frac{\cosh\eta}{\tau}\frac{d\sigma_{pp}^{c\bar{c}}}{d\eta}$$

Charm conservation:

$$r(\tau) = \begin{cases} 1 & \tau \le \tau_{D_s^+} \\ 1 - N_{D_s^+}/N_c & \tau_{D_s^+} < \tau \le \tau_{D^0} \\ 1 - N_D/N_c & \tau_{D^0} < \tau \end{cases}$$

Results

Transverse momentum spectrum of Ds, D0 and charm baryon



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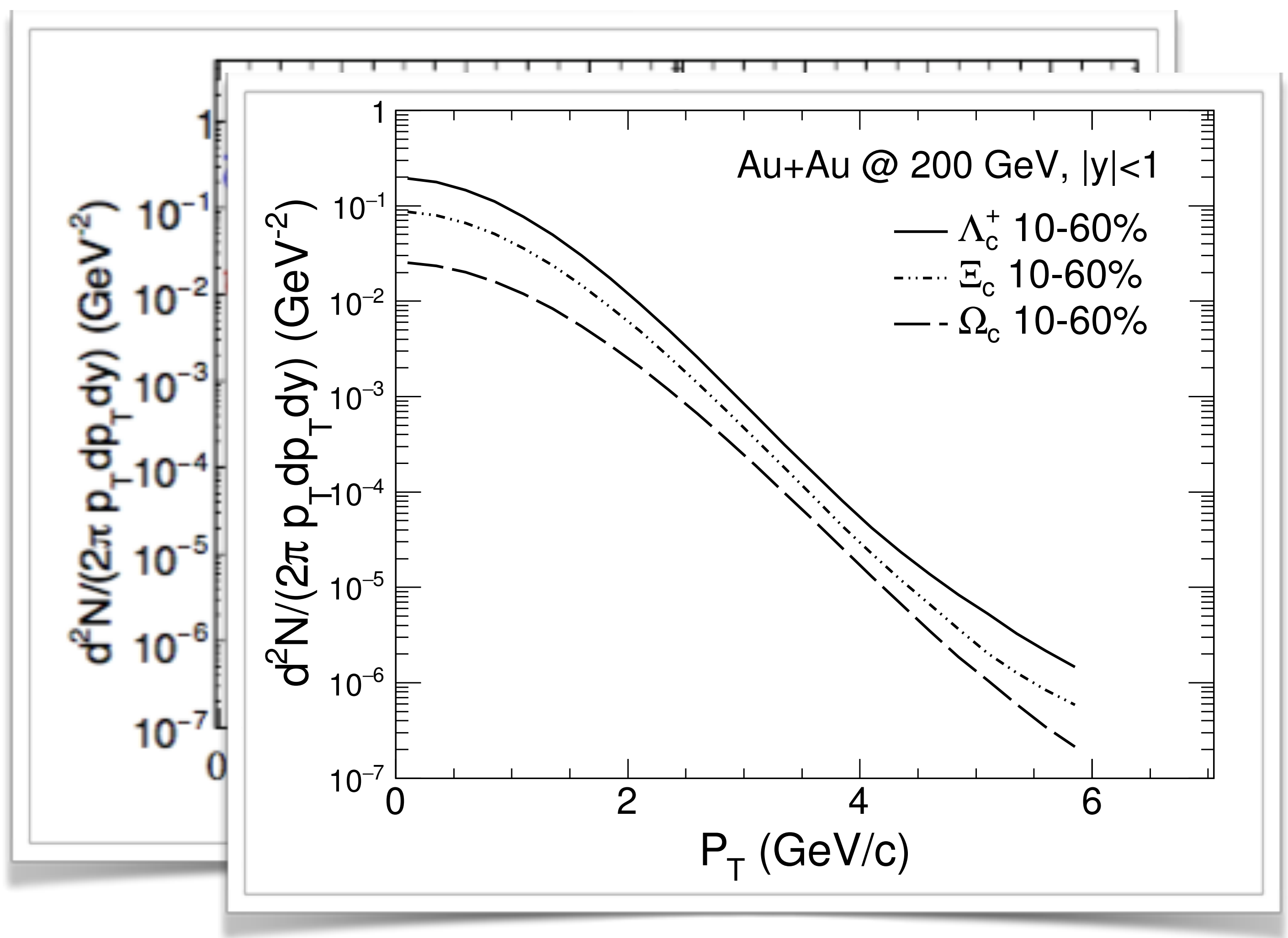

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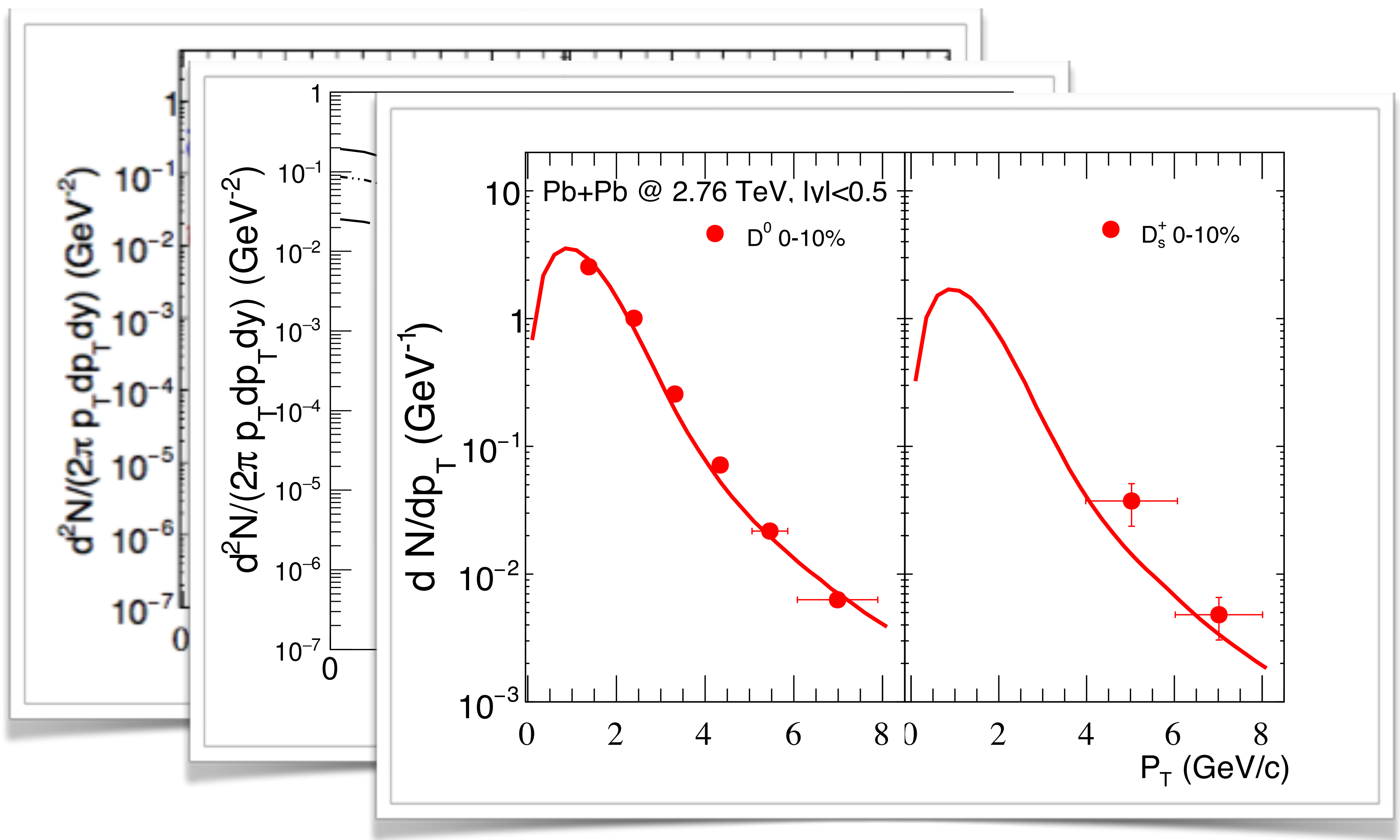

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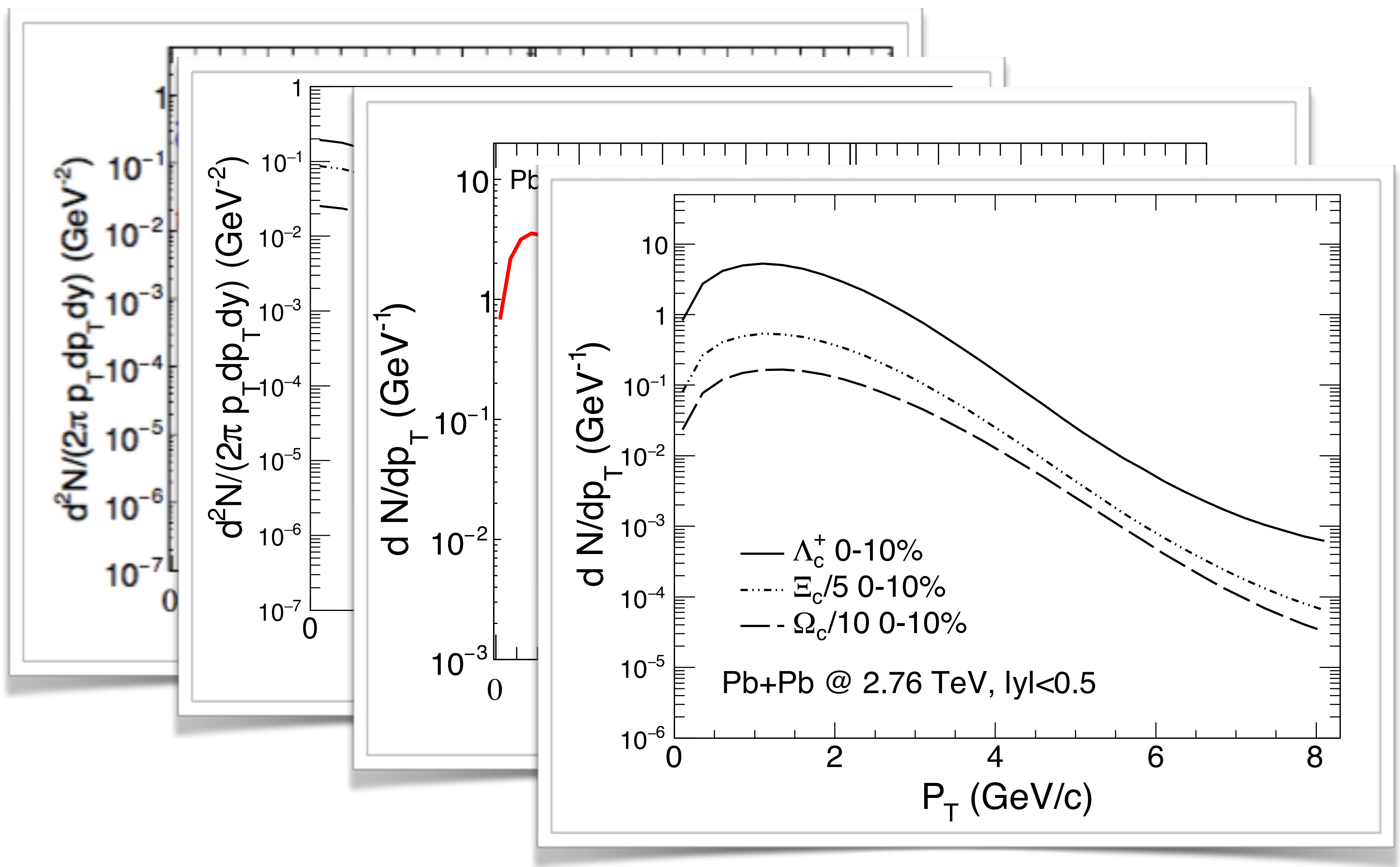
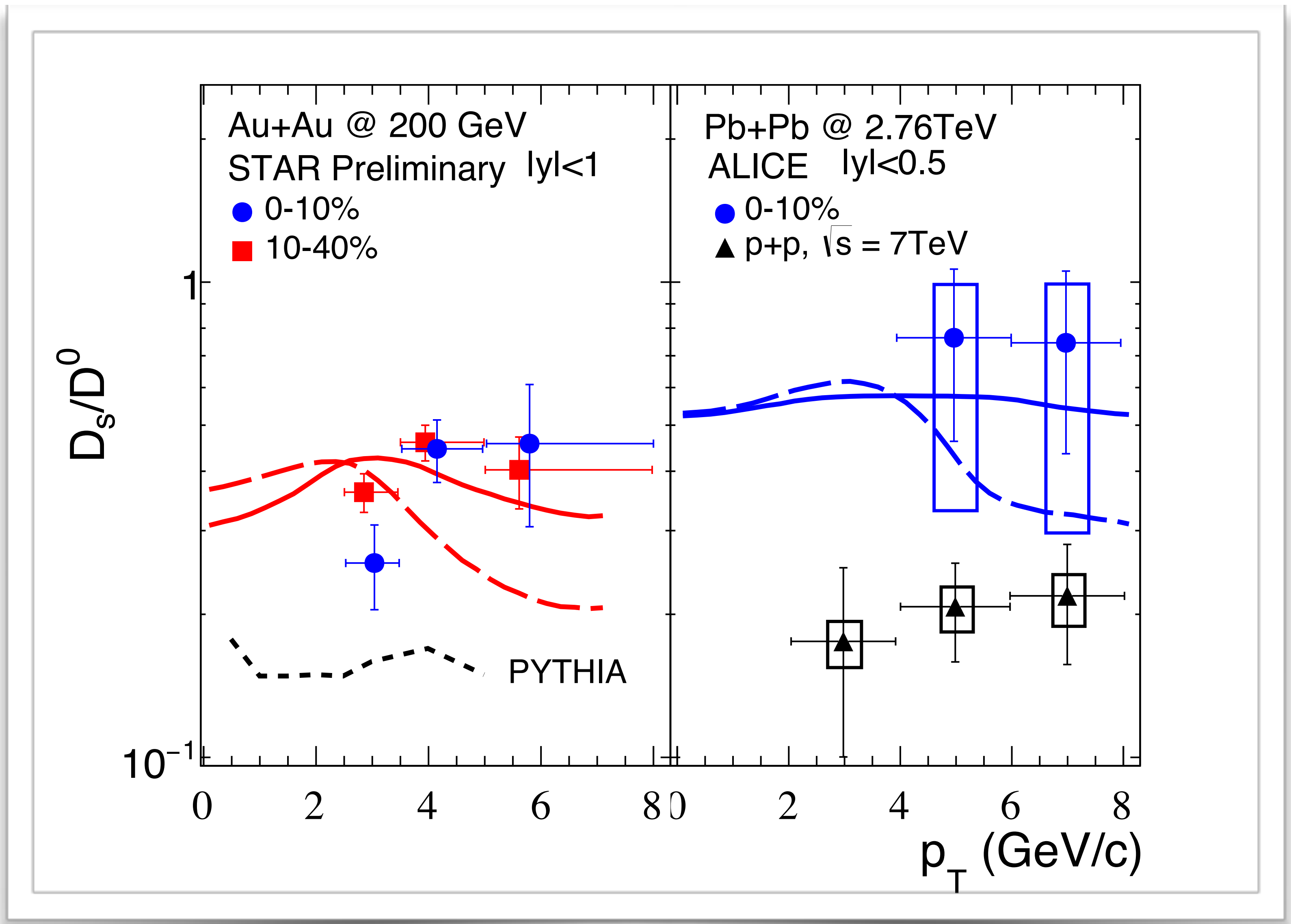


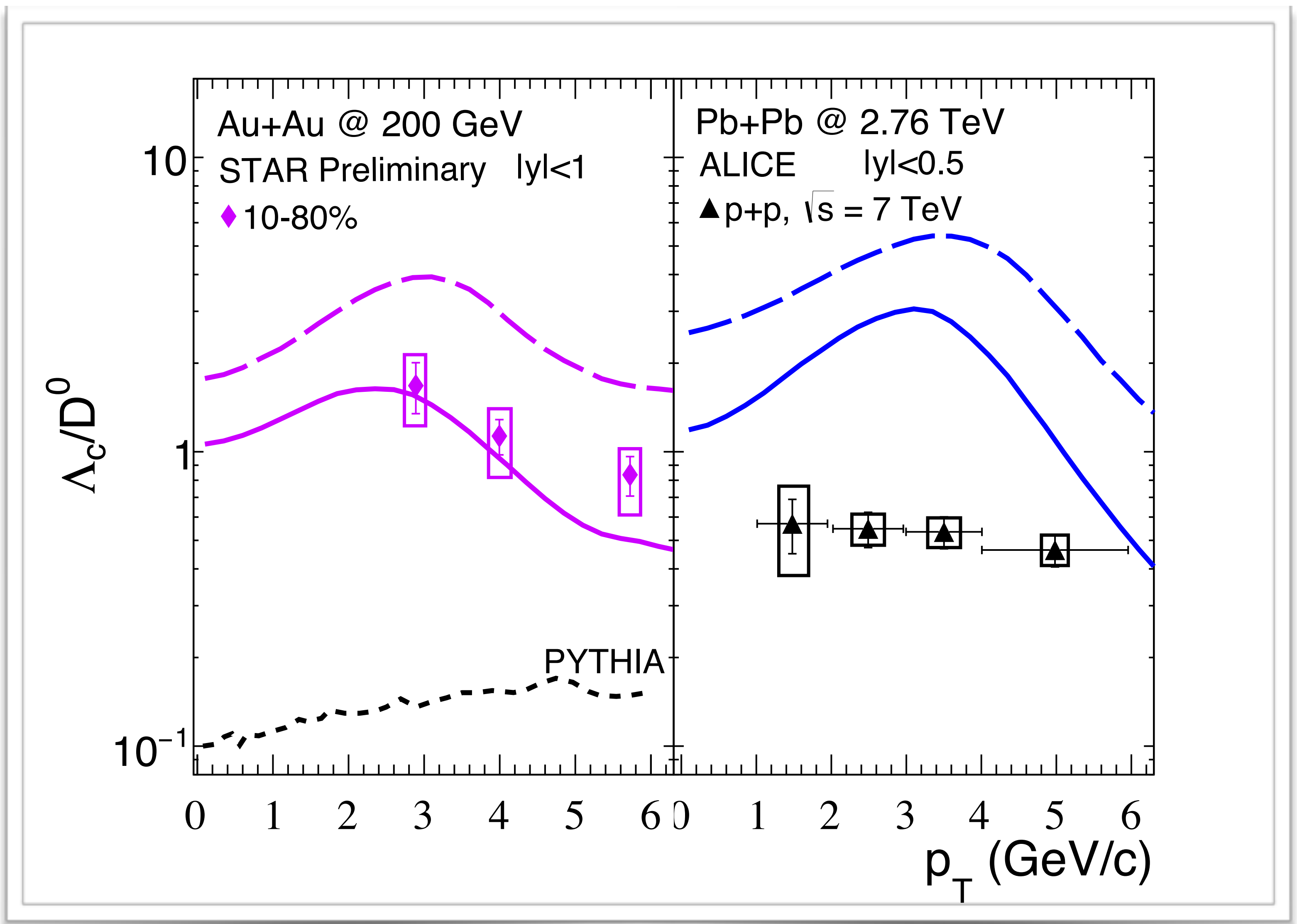
Results



Solid line: sequential coalescence + charm conservation

Dashed line: simultaneous coalescence at Tc

Results



Solid line: sequential coalescence + charm conservation

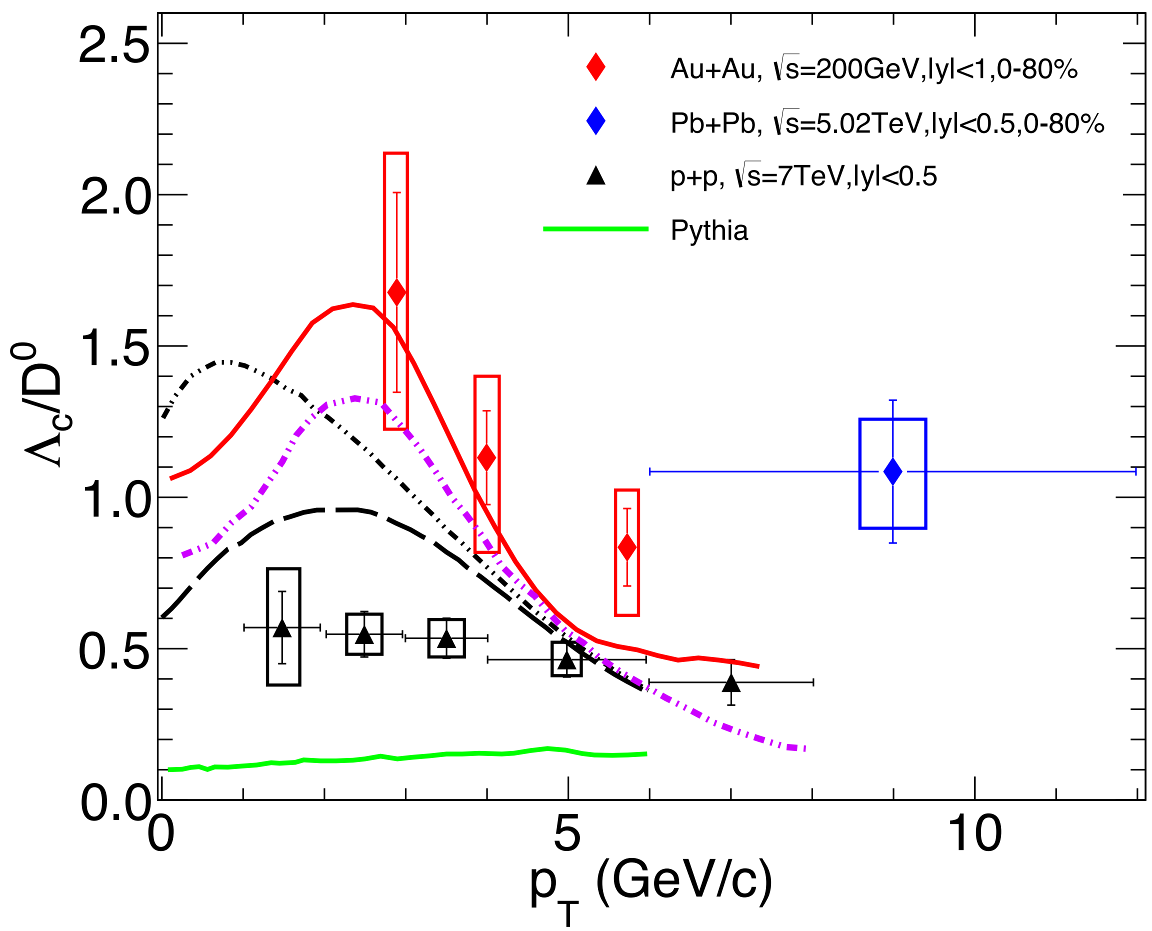
Dashed line: simultaneous coalescence at Tc

Summary

1. Hadronization sequence of open charm mesons determinate by 2-body Dirac equation.
2. Sequential hadronization is a consistent way the consider the charm conservation in HIC!
3. Reasonable agreement between sequential hadronization and experiment data.

Need more exp. data to constrain the hadronization mechanism !

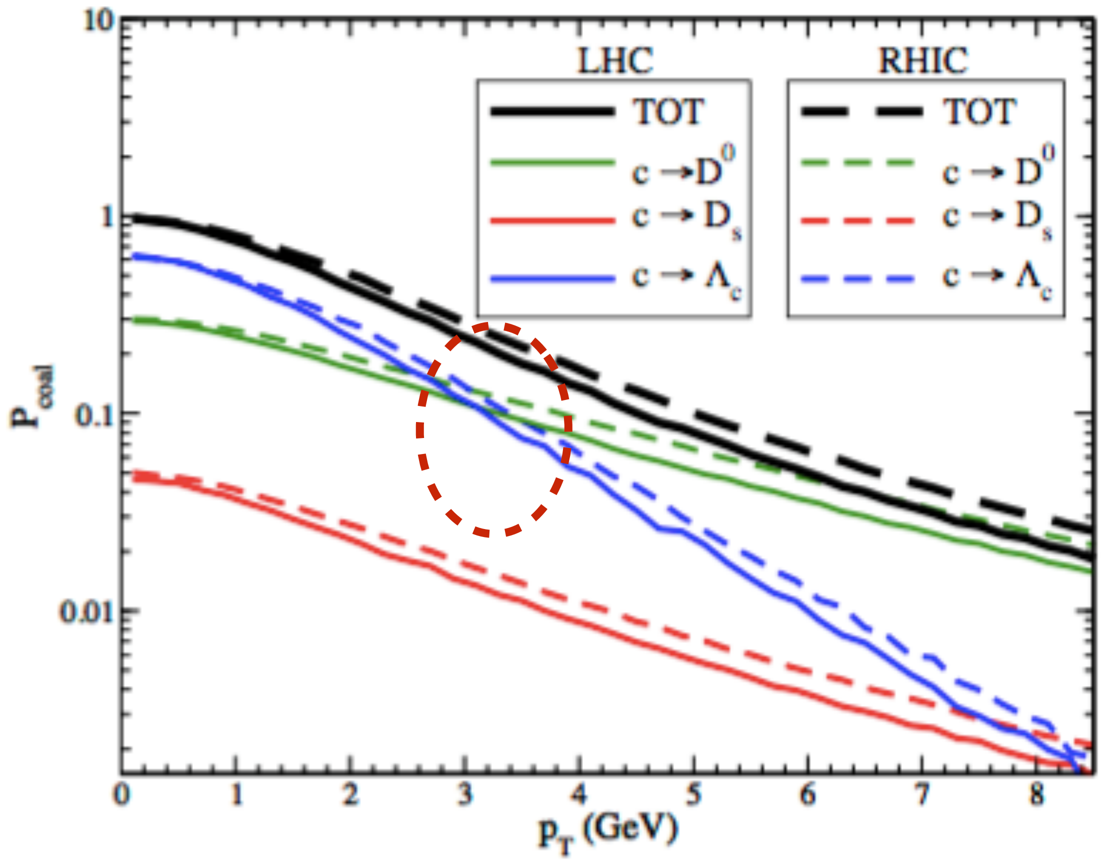
Outlook



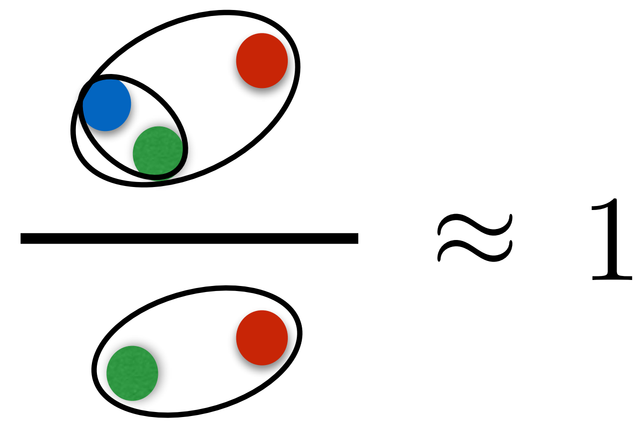
Model calculations are lower than data at higher pT.

1. Fragment to heavy flavor baryons is not well understood?

Outlook



V. Greco. Eur. Phys. J. C78(2018) no. 4, 348.



Model calculations are lower than data at higher pT.

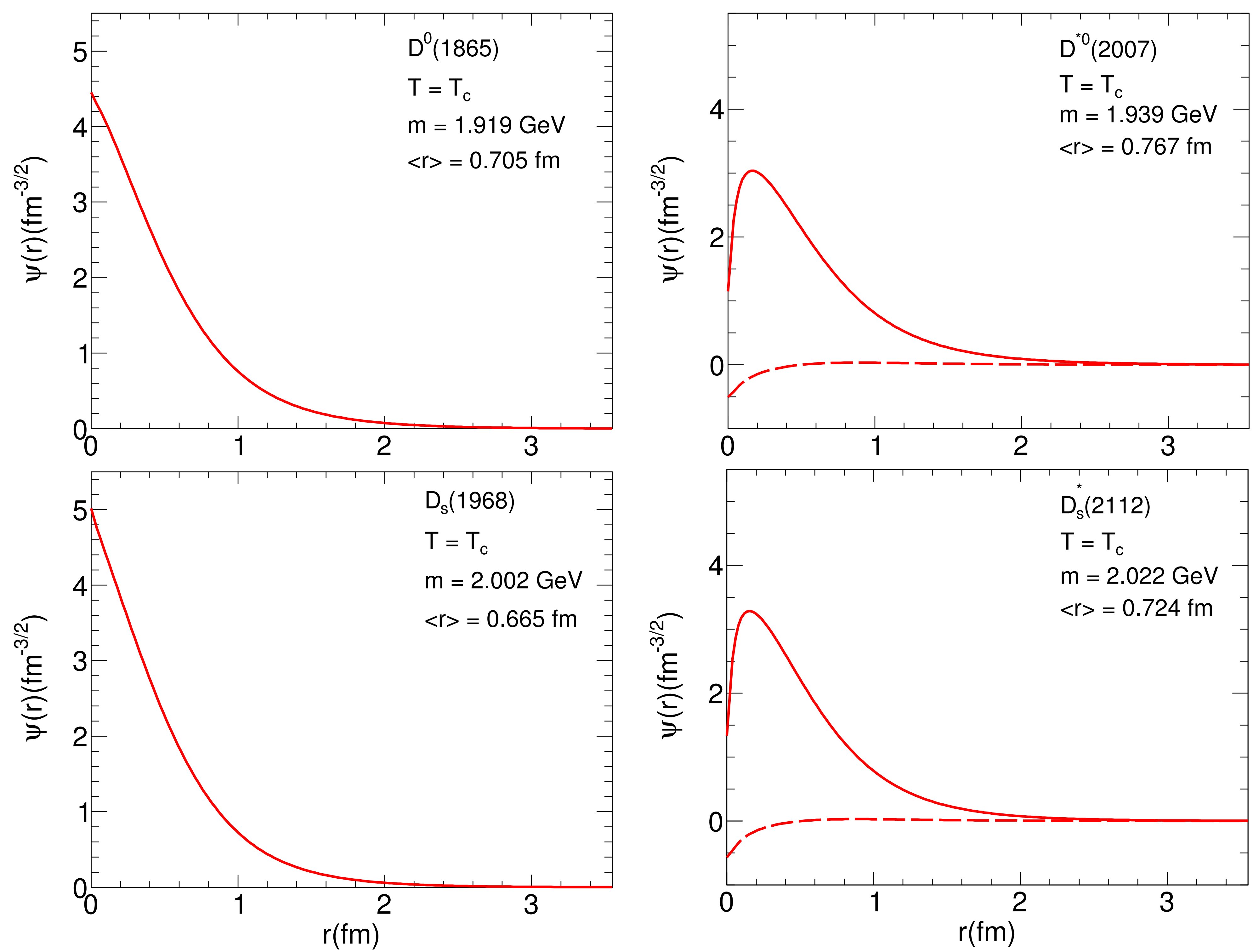
1. Fragment to heavy flavor baryons is not well understood?

2. Effect of the inner structure of lambda_c?

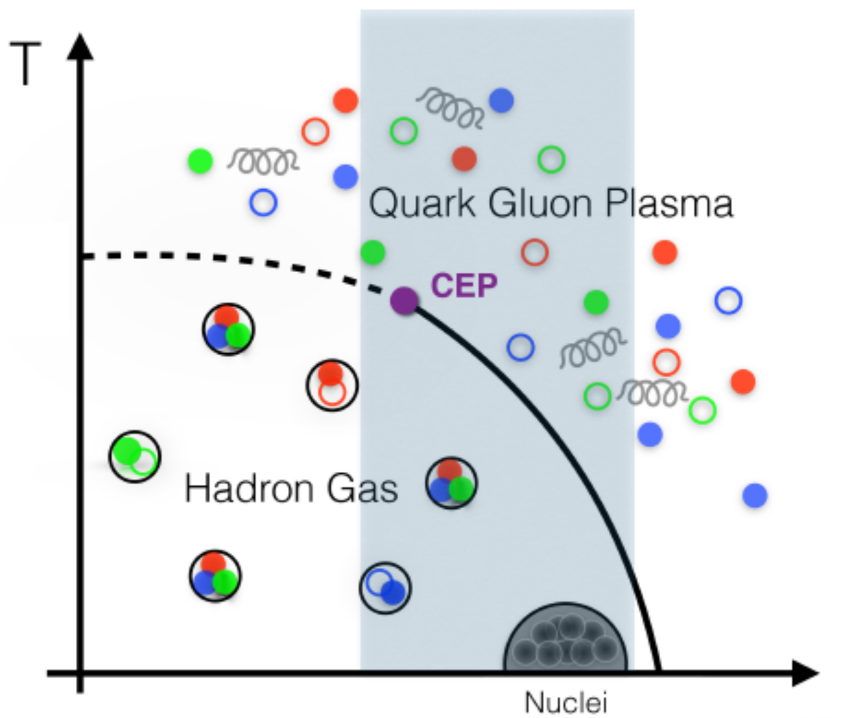
THANK YOU !

BACKUP

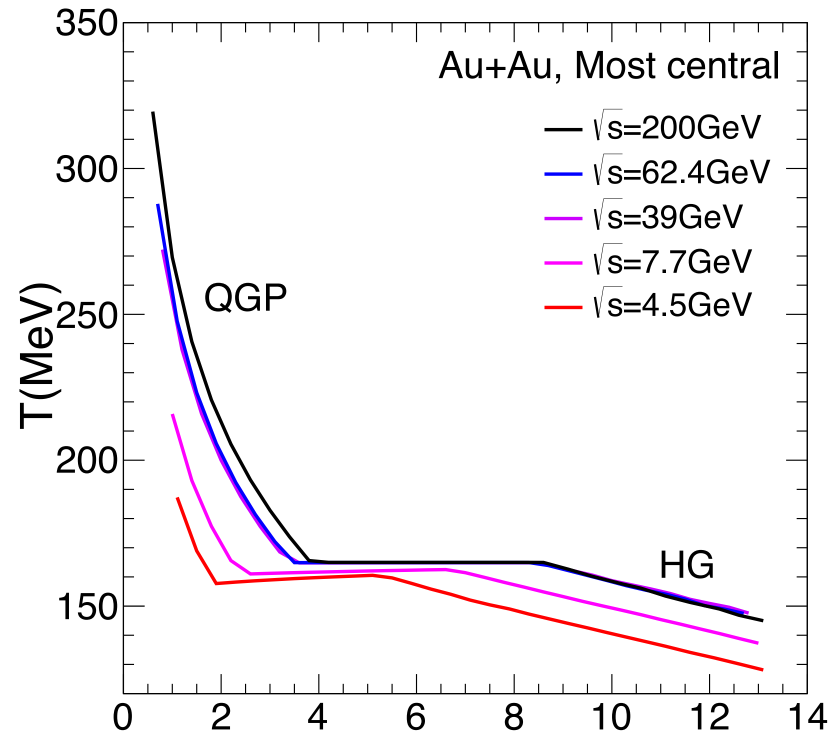
For charmed mesons we can solve Tow Body Dirac Equation to get wave function and masses!



Ds/D0 Ratio at High Baryon Density



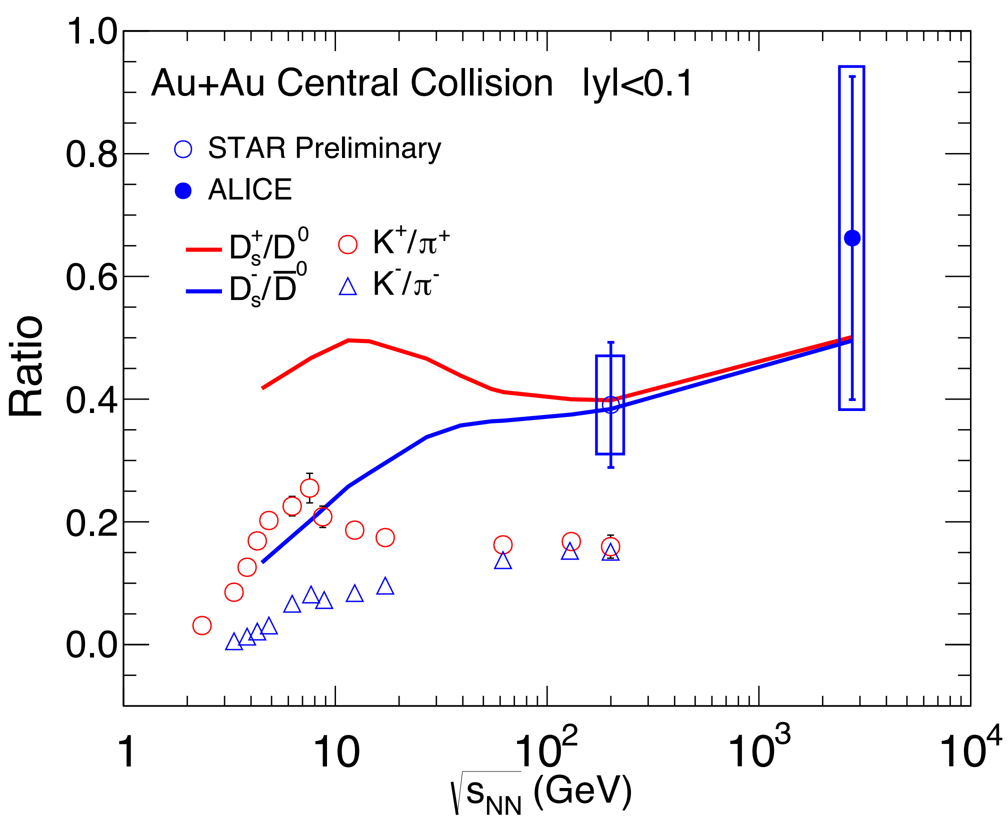
HTD, F. Karsch, S. Mukherjee, arXiv:1504.0527

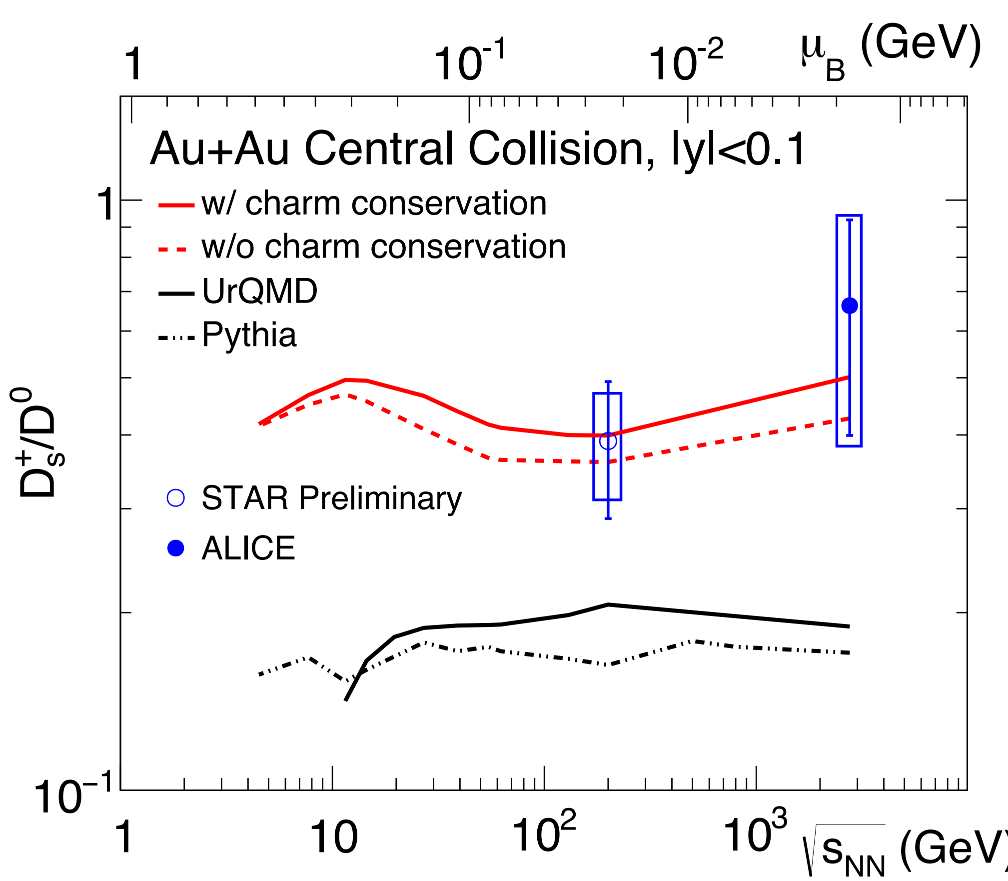


RHIC BESII

Fixed-target BESIII

CBM, NICA, HIAF





In progressing…