Insight from the elliptic flow of open charm mesons

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Outline

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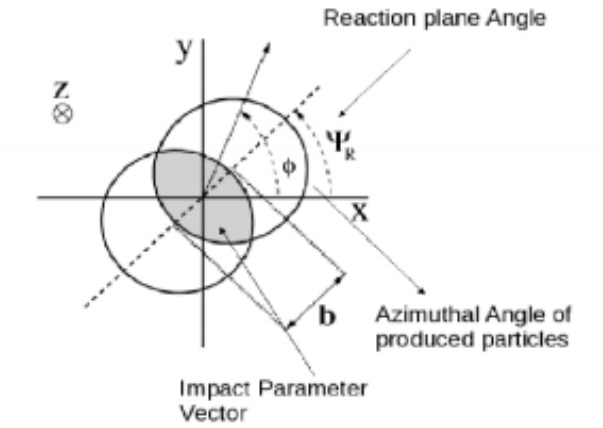
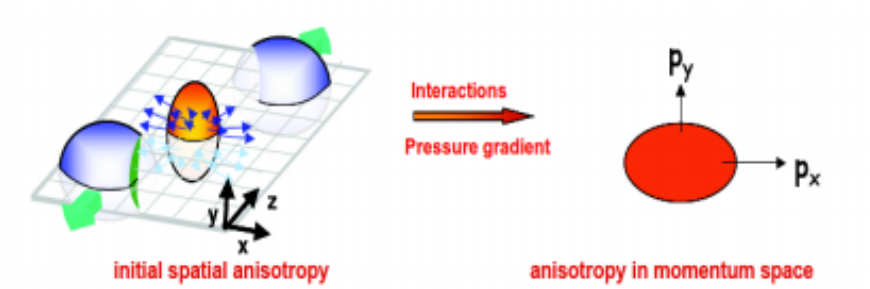
- *The Quark Coalescence Model*
- *Results*
  - *Centrality bias*
  - *Elliptic flow of D^0 and D_S at RHIC*
  - *Elliptic flow of D^0 and D_S at LHC*
  - *Effect of specific viscosity*
- *Summary*

Elliptic flow





The particle azimuthal distribution with respect to the reaction plane is given by

$$\frac{dN}{d\phi} = \frac{1}{2\pi}\left(1 + \sum_{n=1}^{\infty} 2v_n \cos\left[n\left(\phi - \Psi_R\right)\right]\right) \qquad \phi = \tan^{-1}\left(\frac{p_y}{p_x}\right)$$

Elliptic flow is given by the second harmonic : $v_2 = \left\langle \cos\left[2\left(\phi - \Psi_R\right)\right]\right\rangle$

Introduction

- *Heavy quarks – an important probe for QGP*
- *Produced in early stages of relativistic heavy ion collisions through hard partonic scattering*
- *Probability of thermal production is small at RHIC energies*

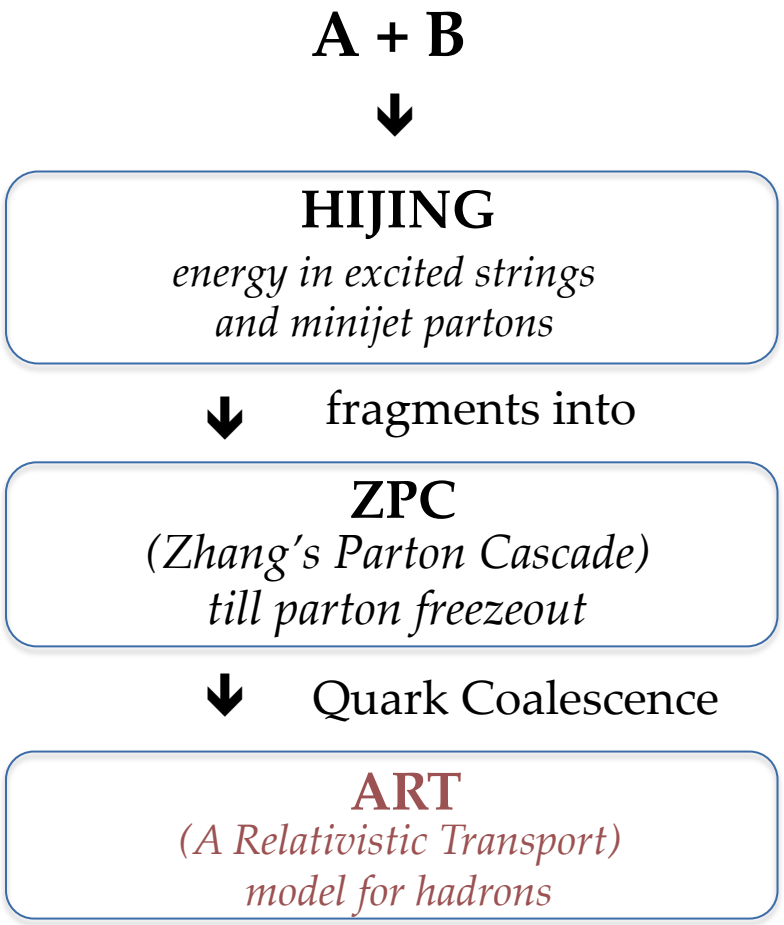
*In this talk, we will discuss what we can learn from the **elliptic flow** of **open charm mesons** using **A Multi Phase Transport model** with **quark coalescence** as the mechanism for hadronization.*

Establishing the model

A Multi Phase Transport (AMPT) model

Coalescence prescription

AMPT model

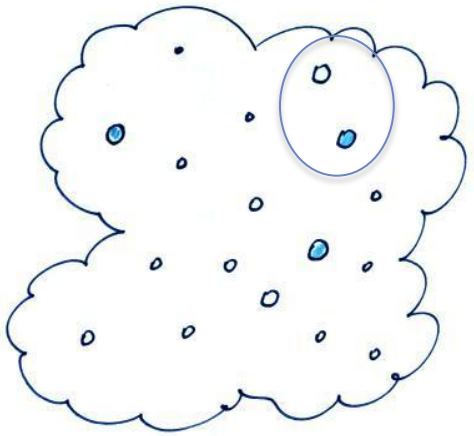


- *Hybrid transport model*
- *Work with the **String Melting** version*
- *Initial conditions from HIJING*
- *Strings are converted to soft partons*
- *Scattering among partons is modeled by ZPC*
- *Hadronization of heavy quarks is not implemented*

Phys. Rev. C 72, 064901 (2005)

Coalescence prescription

$$\rho^{w}\left(\vec{r},\vec{k}\right)=\int\psi\left(\vec{r}+\frac{\vec{R}}{2}\right)\psi^{*}\left(\vec{r}-\frac{\vec{R}}{2}\right)\exp(-i\vec{k}\cdot\vec{r})d^{3}\vec{R}$$



- *The probability of producing a hadron from the soup of partons is determined by the overlap of phase space distribution of partons at freeze out with the parton Wigner phase space function inside the hadron*

- *Assumptions :*
  - *correlation between coalescing parton is weak*
  - *Binding energy of the formed hadron can be neglected*

Phys. Rev. C 73, 044903 (2006)
Phys. Lett. B 595, 202 (2004)

Results

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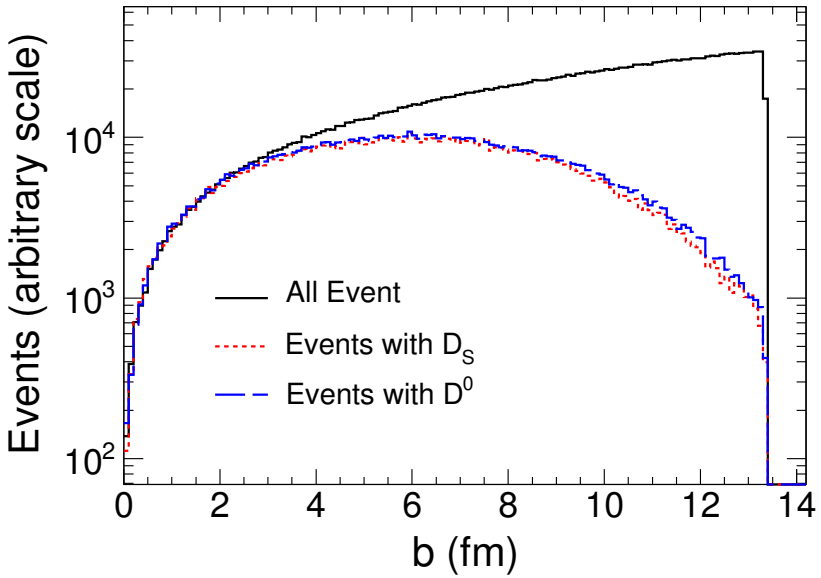
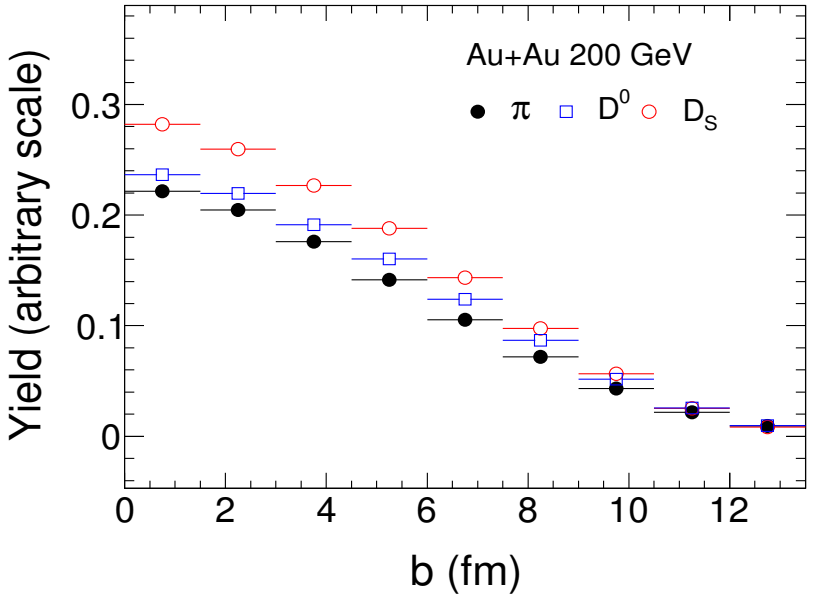
1. *Centrality bias*
2. *Elliptic flow of D^0 and D_S at RHIC*
3. *Elliptic flow of D^0 and D_S at LHC*
4. *Effect of shear viscosity*

Centrality Bias

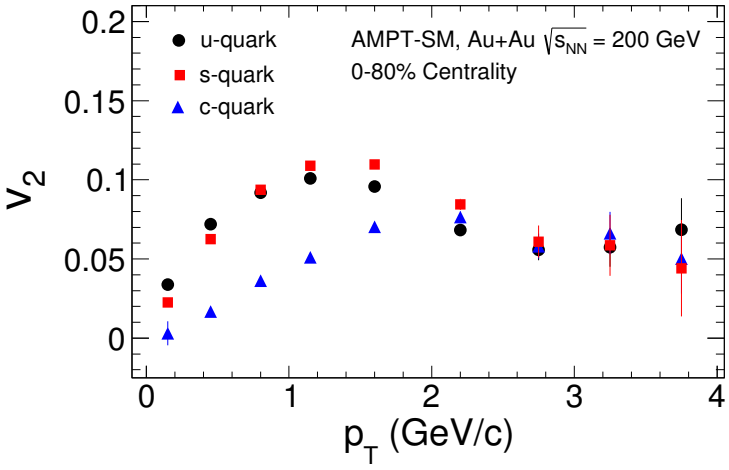


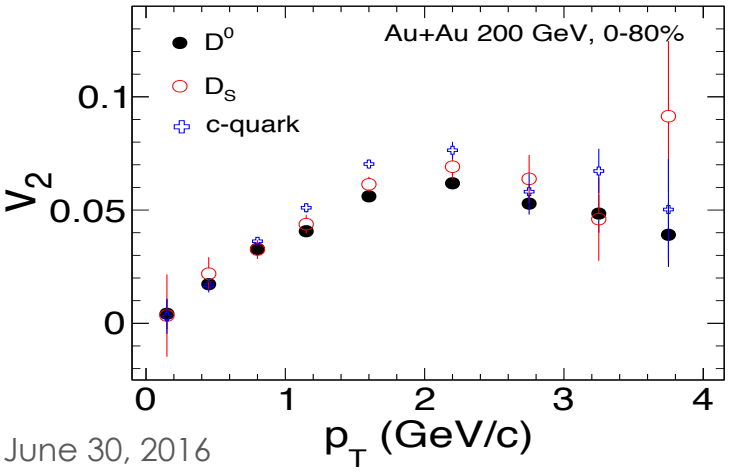


Events with at least one open charm and production of open charm is biased towards central events as compared to light hadrons

One should be careful when comparing elliptic flow of open charm mesons with charged hadrons for wide centrality range

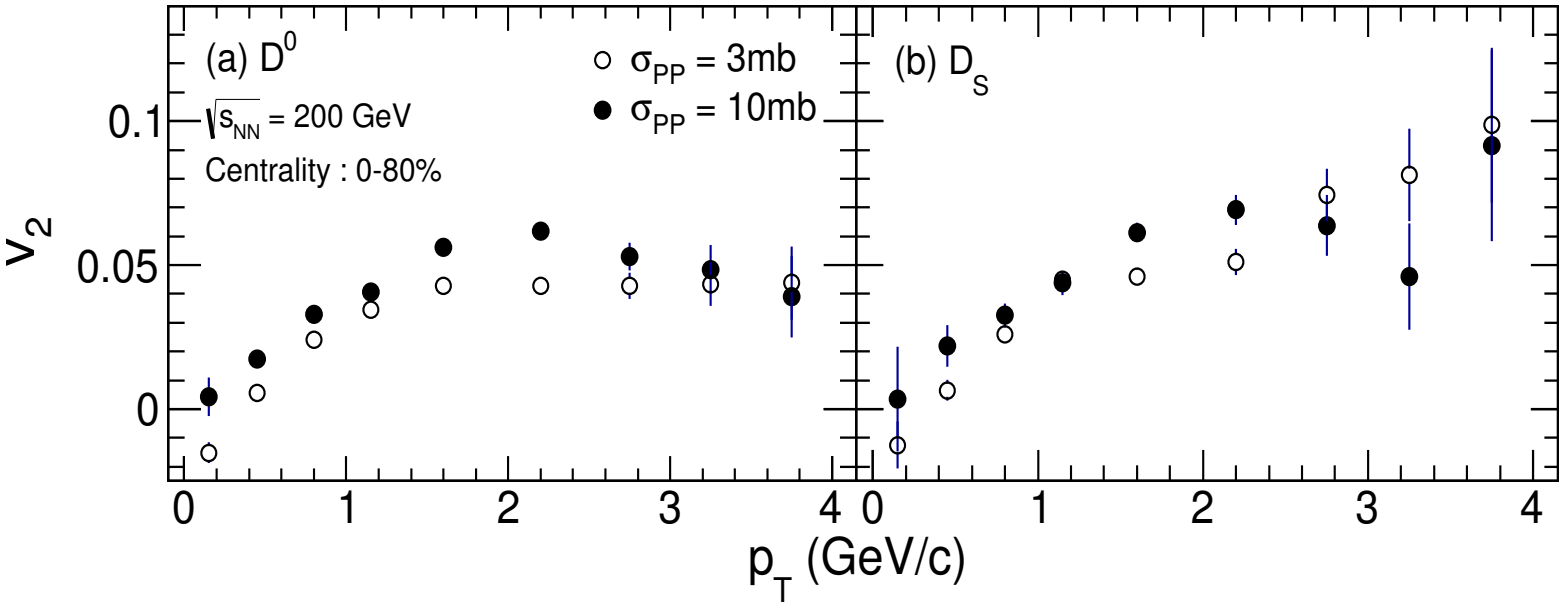
Elliptic flow at RHIC





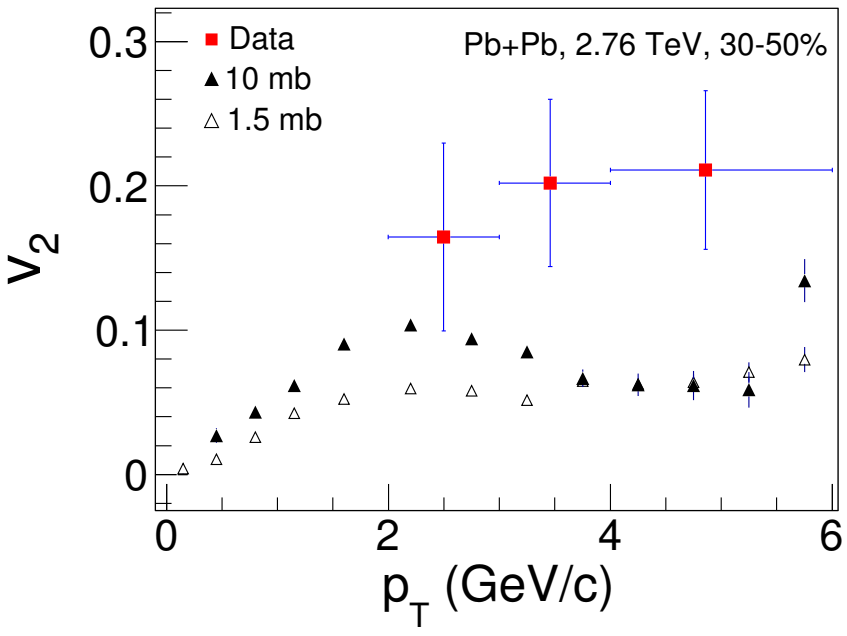
- *Interactions between partons in AMPT-SM gives rise to substantial elliptic flow*
- *Typical plots for partonic interaction cross-section of 10 mb.*
- *Elliptic flow of up (u) and strange (s) quarks is greater than charm (c) in AMPT-SM model at low transverse momentum*
- *Magnitude of elliptic flow of D mesons similar to charm quark – NCQ scaling may not hold*

Elliptic flow at RHIC



- *Elliptic flow decreases with decrease in parton parton interaction cross-section, which is similar as observed for charged hadron*

Elliptic flow at LHC



- *Elliptic flow of charged hadrons is described by partonic interaction cross-section of 1.5 mb for $p_T < 2$ GeV/c*
- *Model calculations under-predict data for D meson for $p_T > 2$ GeV/c*
- *Looking forward to results from ALICE upgrades for low p_T*

Specific viscosity

In the string melting version of AMPT, parton scattering cross-section is given by :

$$\sigma_{PP} \approx \frac{9\pi\alpha^2}{2\mu^2}$$

For a massless system of quarks and gluons at temperature T, specific viscosity is estimated to be

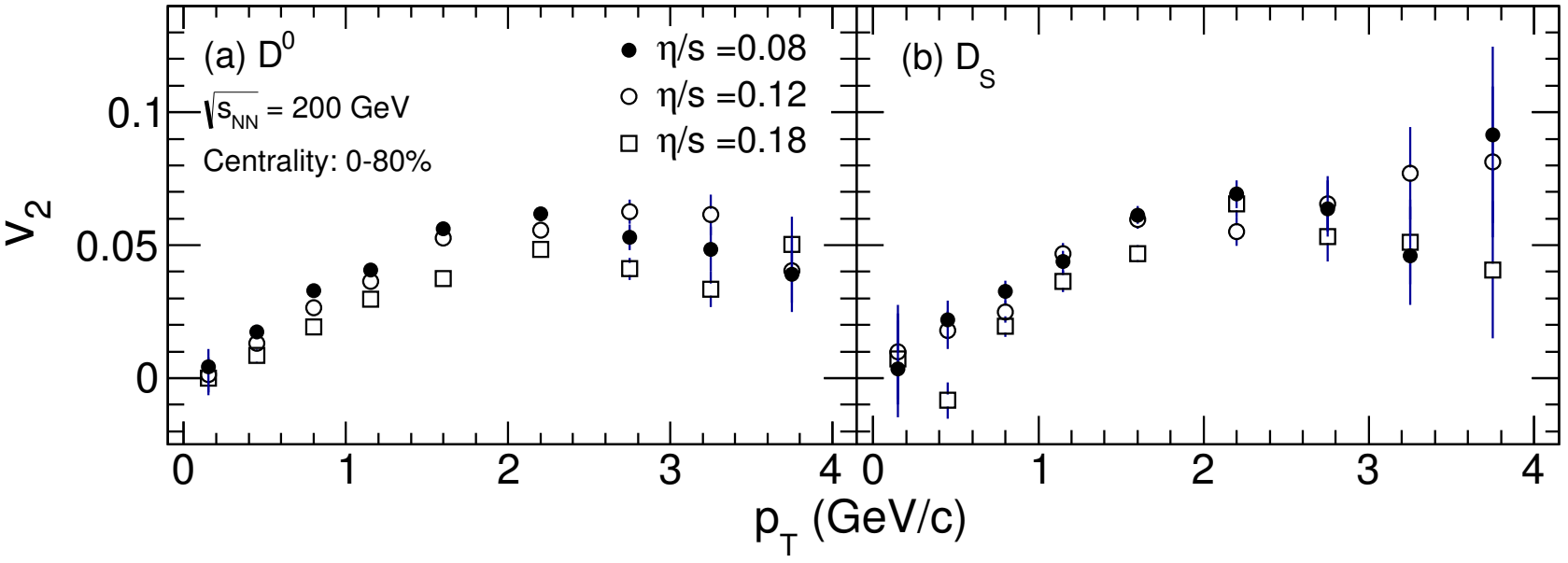
$$\frac{\eta_s}{s} \approx \frac{3\pi}{40\alpha^2} \frac{1}{\left(9+\frac{\mu^2}{T^2}\right)\log\left(\frac{18+\mu^2/T^2}{\mu^2/T^2}\right)-18}$$

Tuning α and μ, we can get different values of η_s/s for T = 378 MeV (RHIC)

η_s/s	σ_{PP} (in mb)	α	μ (in fm^{-1})	Comment
0.08	10	0.47	1.77	Default
0.12	10	0.33	1.24	Tuned
0.18	10	0.23	0.88	Tuned
0.18	3	0.47	3.22	Default

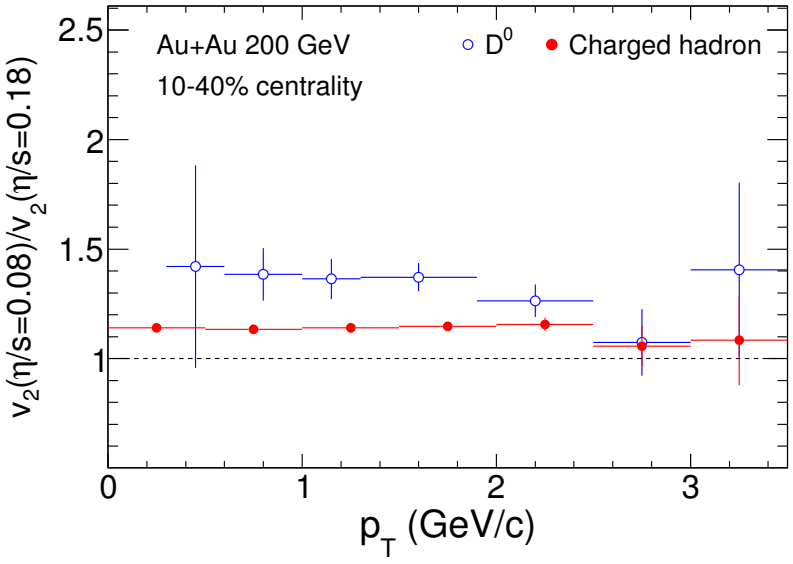
Phys. Rev. C 83, 034904 (2011)

Effect of specific viscosity



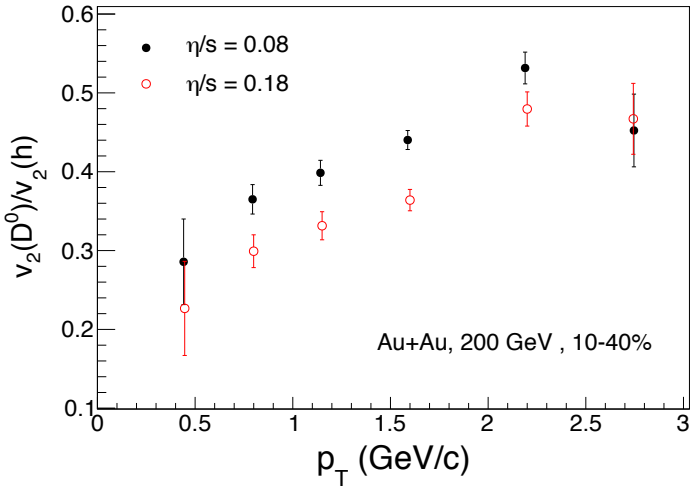
- *Magnitude of elliptic flow decrease with increase in specific viscosity*
- *Though elliptic flow is generated by partonic interactions in the AMPT-SM model, its magnitude is sensitive to specific viscosity*

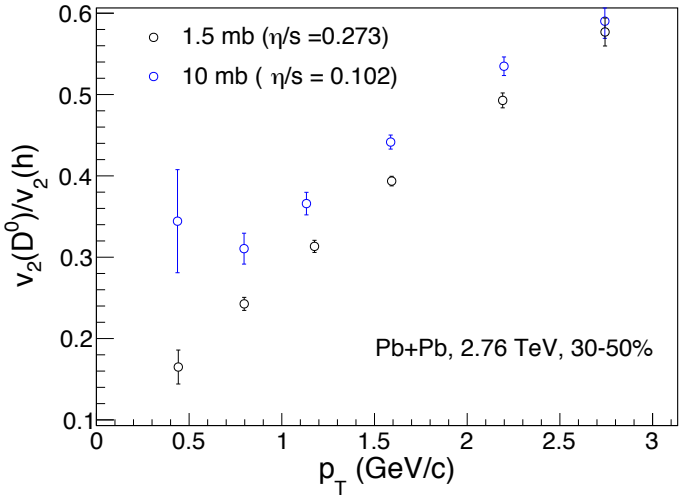
As a sensitive probe



- *Change in v_2 is ~15% for hadrons and ~35% for D^0 for $p_T < 2$ GeV/c*
- *We find the ratio to be independent of centrality and energy in our model*
- *Elliptic flow of open charm meson is more sensitive to viscous properties of QGP as compared to light hadrons*

As a sensitive probe





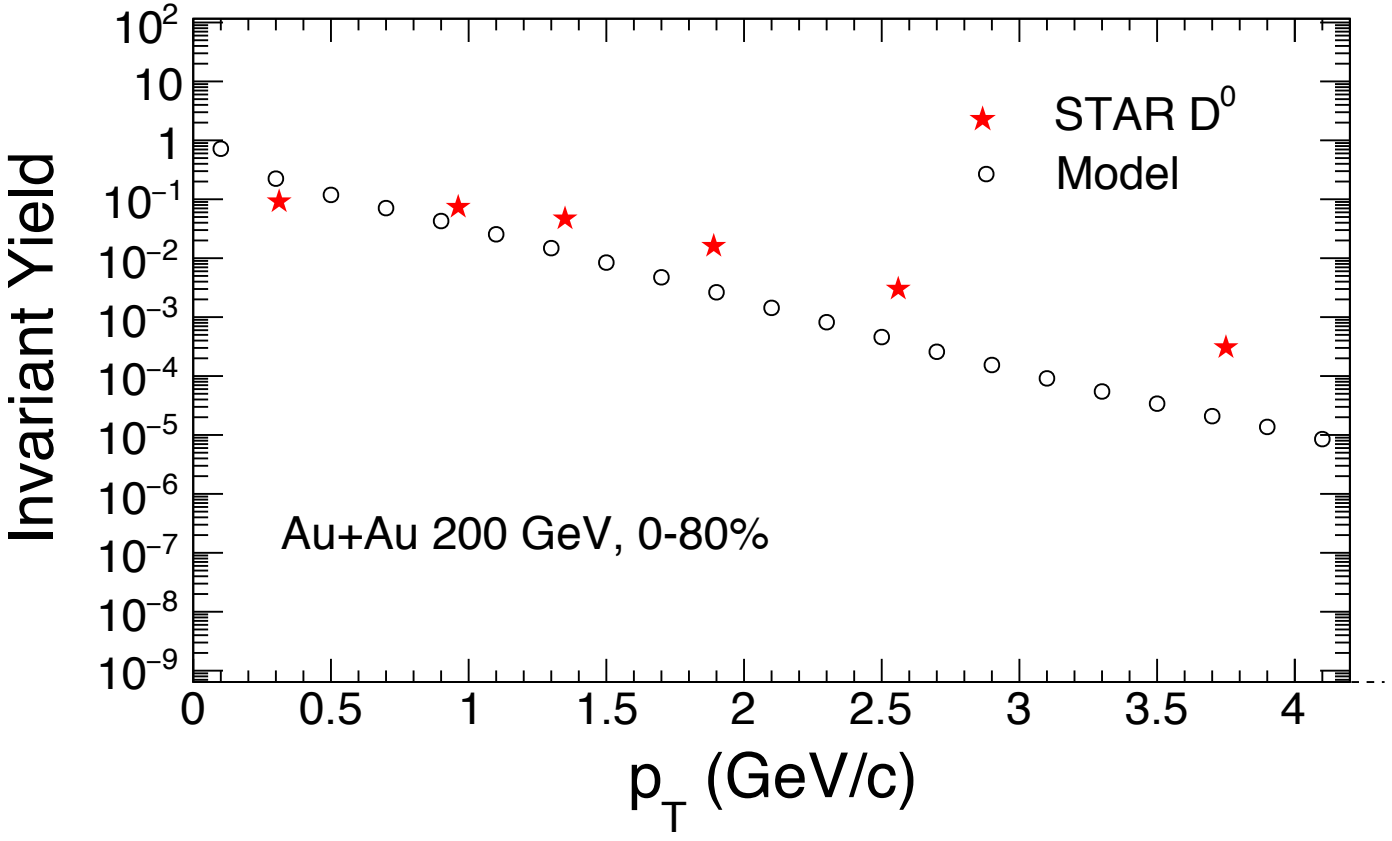
- *The ratio of v_2 of D^0 to v_2 of charged hadrons is independent of analysis technique used to obtain elliptic flow*
- *Can be calculated in data and compared to model studies to constrain specific viscosity of the medium*

Conclusion

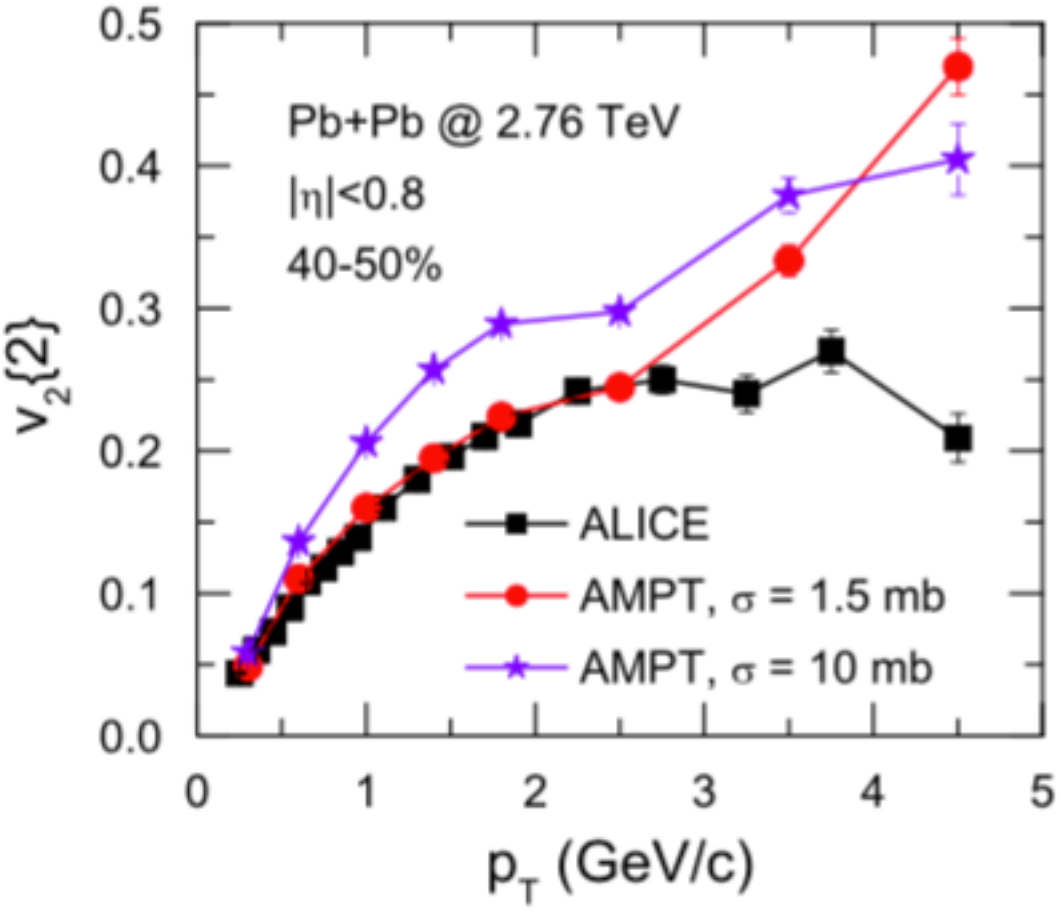
- *Estimated the elliptic flow of open charm mesons at RHIC and LHC energies using coalescence prescription within the framework of AMPT model*
- *Demonstrated that their production is heavily biased towards central collisions*
- *Presented a systematic study on the effect of specific viscosity on elliptic flow within the transport model approach*
- *Look forward to high statistics measurements at RHIC and LHC to compare our results*

Thank you !

Invariant yield



AMPT at LHC



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