Heavy-flavor dynamics in p-Pb collisions

Yingru Xu, Shanshan Cao, Weiyao Ke, Guang-You Qin,
Marlene Nahrgang, Jussi Auvinen, Steffen A. Bass

yx59@phy.duke.edu

Introduction

heavy-flavor (charm and bottom)

- predominantly produced in the early stage
- probe the full evolution of the QGP medium
- incomplete thermalization

p-Pb collisions

- a baseline for AA collisions
- disentangle the cold nuclear matter (CNM) effects and the hot nuclear matter (HNM) effects

Initial Condition of Asymmetric Systems

1. Parton participant model (position space)

- assign each parton a fluctuated thickness function
- a CGC inspired formula with rapidity dependence for particle production:

$$\frac{ds}{dydx_{\perp}^2} \propto Q_{min}^2 \left(\ln \left(\frac{Q_{max}^2}{Q_{min}^2} \right) + 2 \right) \qquad (1)$$

where s is the entropy density, $Q_A^2 = Q_0^2 T_A e^{\lambda y}$, $Q_B^2 = Q_0^2 T_B e^{-\lambda y}$

- overlaping geometry sampling for heavy quarks:

$$T_{AA} = \int_{S_{\perp}} d\vec{x_{\perp}}^2 T_A(\vec{x_{\perp}}) T_B(\vec{x_{\perp}}) \qquad (2)$$

pQCD calculation (momentum space)

- the CTEQ6 and EPS09 parameterizations are adopted

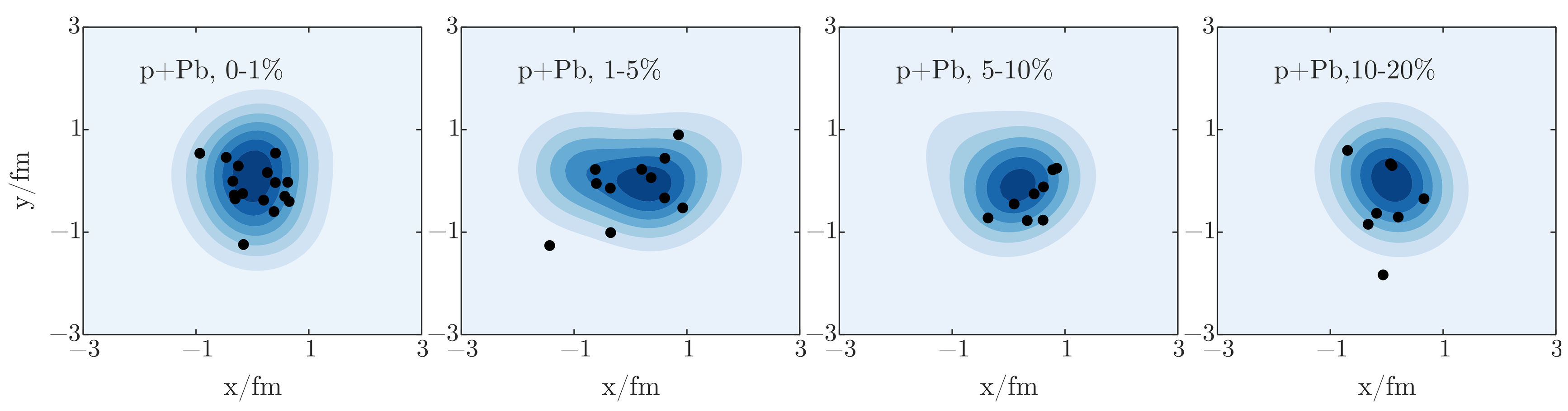

Figure 1: An example of the fluctuating initial entropy density profile with heavy quarks at mid-rapidity (p-Pb collisions at $\sqrt{S_{NN}}$= 5.02 TeV). The profile is obtained with 3 parton constituents and $R_{\perp}$= 0.6 fm Gaussian smearing width.

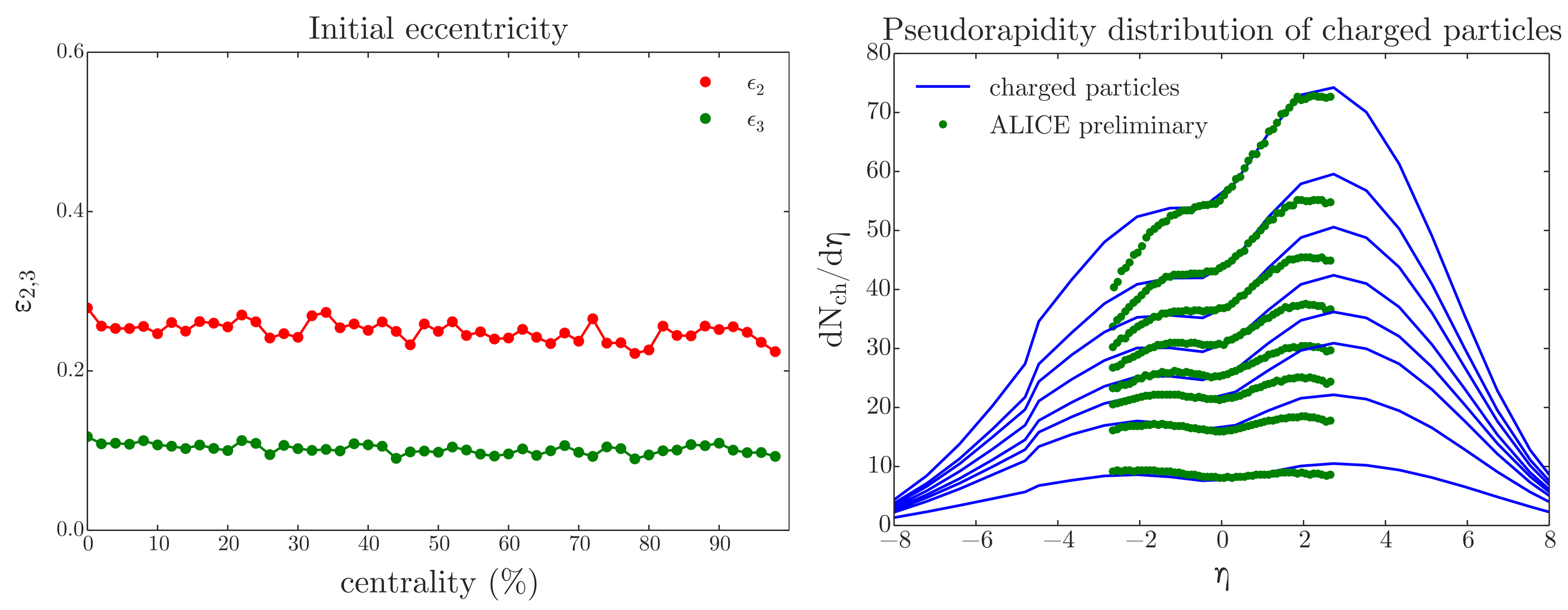

Figure 2: The event-by-event averaged initial eccentricity ϵ_2 and ϵ_3 for p-Pb collisions at $\sqrt{S_{NN}}$= 5.02 TeV(left); pseudo-rapidity distributions of charged hadrons in p-Pb collisions at $\sqrt{S_{NN}}$= 5.02 TeV (right). For the (3+1)D viscous hydrodynamics model, η/s is chosen as 0.08.

HQ Dynamics in the QCD Medium

2. In-medium propagation: an improved Langevin approach:

$$\frac{dN_g}{dxdk_{\perp}^2 dt} = -\eta_D(p)\vec{p} + \vec{\epsilon} + \vec{f_g} \qquad (3)$$

- the first two items are the drag and thermal random forces $\eta_D(p) = \frac{\kappa}{2TE}$, $< \epsilon^i(t)\epsilon^j(t') >= \kappa\delta^{ij}\delta(t-t')$
- third item $\vec{f_g} = -\frac{d\vec{p_g}}{dt}$ is the gluon emission induced recoil force, a higher-twist calculation used for gluon distribution:

$$\frac{dN_g}{dxdk_{\perp}^2 dt} = \frac{2\alpha_s(k_{\perp})}{\pi} P(x) \frac{\hat{q}}{k_{\perp}^4} \sin^2\left(\frac{(t-t_i)}{2\tau_f}\right) \left(\frac{k_{\perp}^2}{k_{\perp}^2 + x^2 M^2}\right)^4 \qquad (4)$$

Transport coefficients: $D = \frac{T}{M\eta_D(0)} = \frac{2T^2}{\kappa}$, $\hat{q} = 2\kappa \frac{C_A}{C_F}$

Note: In this Langevin framework, it is not easy to reproduce both R_{AA} and v_2 comparable to experimental results. In Pb-Pb collision at $\sqrt{S_{NN}}$ = 2.76 TeV, the best fit for R_{AA} is $D(2\pi T)$ = 5.0 while the best fit for v_2 is 0.5. Thus we adopted two diffusion coefficients in the p-Pb collisions calculation.

3. Hadronization: hybrid model of fragmentation and recombination

Results

1. Nuclear modification factor R_{pPb}

- shadowing due to the CNM effects is small at high p_T and substantial at low p_T
- in-medium evolution raises R_{pPb} at low p_T and suppresses it at intermediate p_T

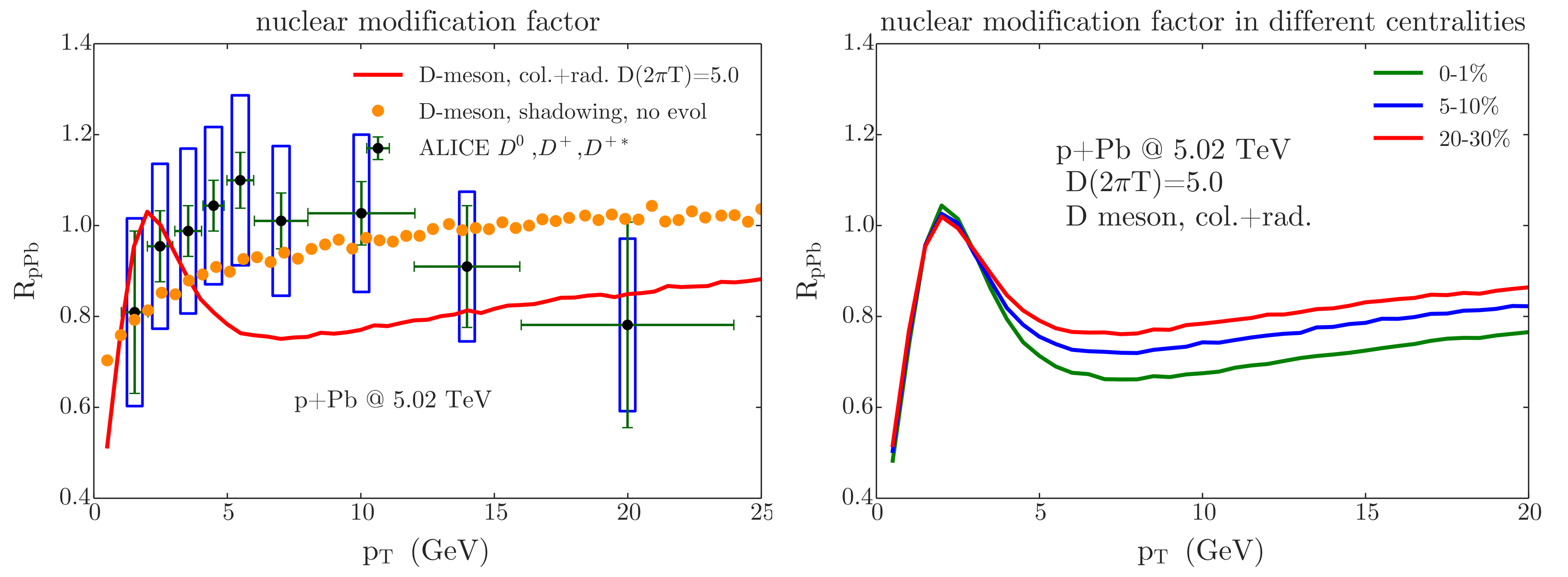

Figure 3: R_{pPb} for D mesons under minimum bias situation, diffusion coefficient is chosen as $D(2\pi T)$= 5.0 (left); R_{pPb} in different centrality classes(right)

2. Elliptic flow v_2

- D(2πT)=5.0, integrated D meson v_2 significantly below that of charged particles ⇒ incomplete coupling between charm quarks and the medium
- D(2πT)=0.5, v_2 of D mesons, charged particles and charm quarks are comparable ⇒ the flow of D meson is produced mostly from the coupling to the medium

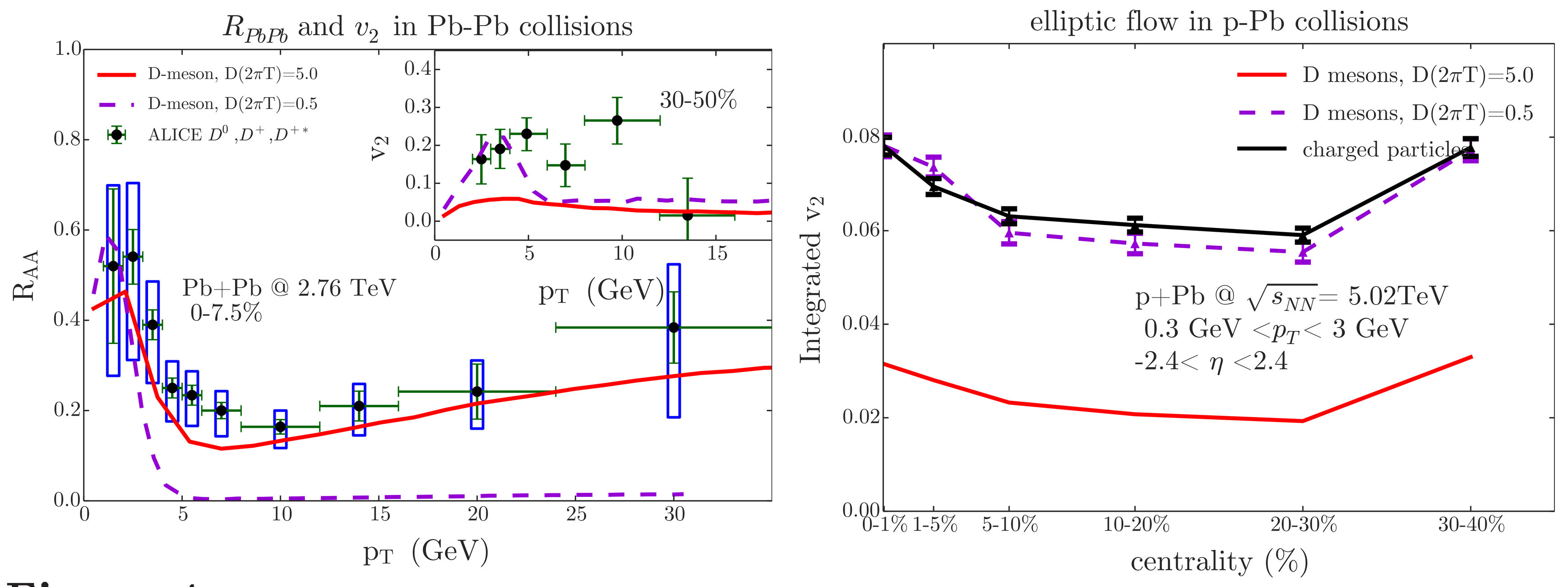

Figure 4: R_{PbPb} and v_2 in PbPb collisions for different diffusion coefficients(left); p_T integrated elliptic flow v_2 of D mesons and charged particles as a function of centrality(right)

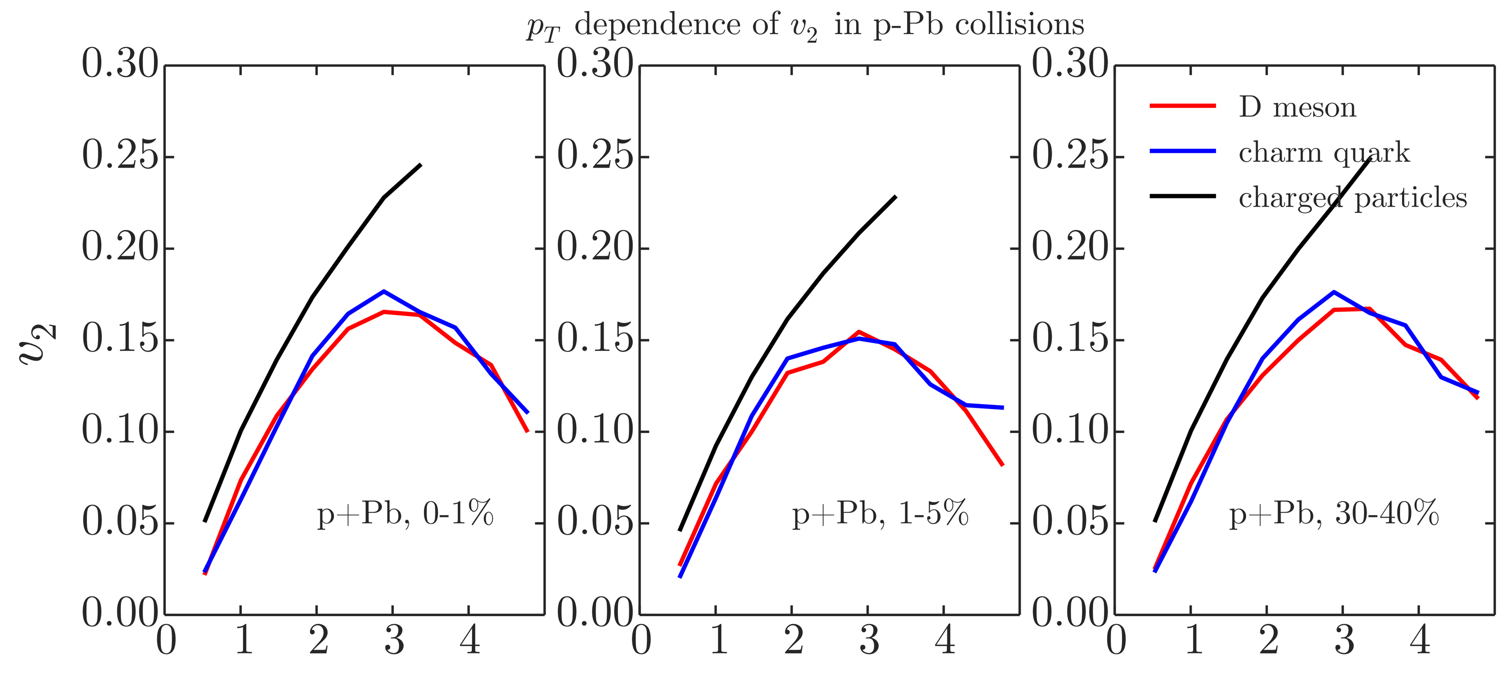

Figure 5: p_t differential elliptical flow in different centralities

Conclusion

1. comprehensive framework of heavy flavor and bulk dynamics in p-Pb collisions
2. centrality dependence of R_{pPb} in p-Pb collisions
3. a transferring from the initial eccentricity to the medium flow and an incomplete coupling between charm quarks and the medium

References

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