Exploring the shape of QGP droplet using high-$p_\perp$ tomography

Bithika Karmakar

Incubator of Scientific Excellence - Centre for Simulations of Superdense Fluids
University of Wrocław, Poland

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Collaborators: Dusan Zigic, Jussi Auvinen, Pasi Huovinen, Marko Djordjevic and Magdalena Djordjevic

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Introduction

- Quark Gluon Plasma (QGP) is created in ultrarelativistic heavy-ion collisions.

- Consists of interacting quarks, antiquarks and gluons.

- Low-$p_\perp$($p_\perp \leq 5GeV$) observables are generally used to study the medium properties.

- High-$p_\perp$ partons propagate through the medium. Jet loses energy by interacting with the medium.

- The rare high-$p_\perp$ particles can also become excellent probe of the QCD matter.

Initial condition model

- Initial condition models (e.g., Glauber, MC-KLN, IP Glasma etc) aim to determine the initial energy or entropy deposition.

- Bayesian analysis has been used to constrain the initial conditions using T$_R$ENTo model. Nature Phys. 15, no. 11, 1113-1117 (2019)

- For a pair of projectiles A and B colliding along z axis, the participant thickness is

$$T_{A,B}(x, y) = \int dz\, \rho_{A,B}^{part}(x, y, z).$$

- The initial entropy density is $s(x, y) \propto T_R(p; T_A, T_B) = \left(\frac{T_A^p + T_B^p}{2} \right)^{1/p}$.

- $p = 0$ is found to be preferred in Bayesian analysis when initial free streaming is considered.

Probing the shape of QGP droplet

- Initial free streaming not favored by high-$p_\perp$ data.
  S. Stojku, J. Auvinen, M. Djordjevic, P. Huovinen and M. Djordjevic, Phys. Rev. C **105** (2022) 2, L021901

- Can lead to different results without free streaming.

- DREENA can be used to constrain the initial profiles with no free streaming.

- We use $p \in \{1/3, 0, -1/3, -2/3, -1\}$ to see which value the high-$p_\perp$ data prefers.

- Other parameters of the bulk evolution are tuned to agree with the low-$p_\perp$ data.
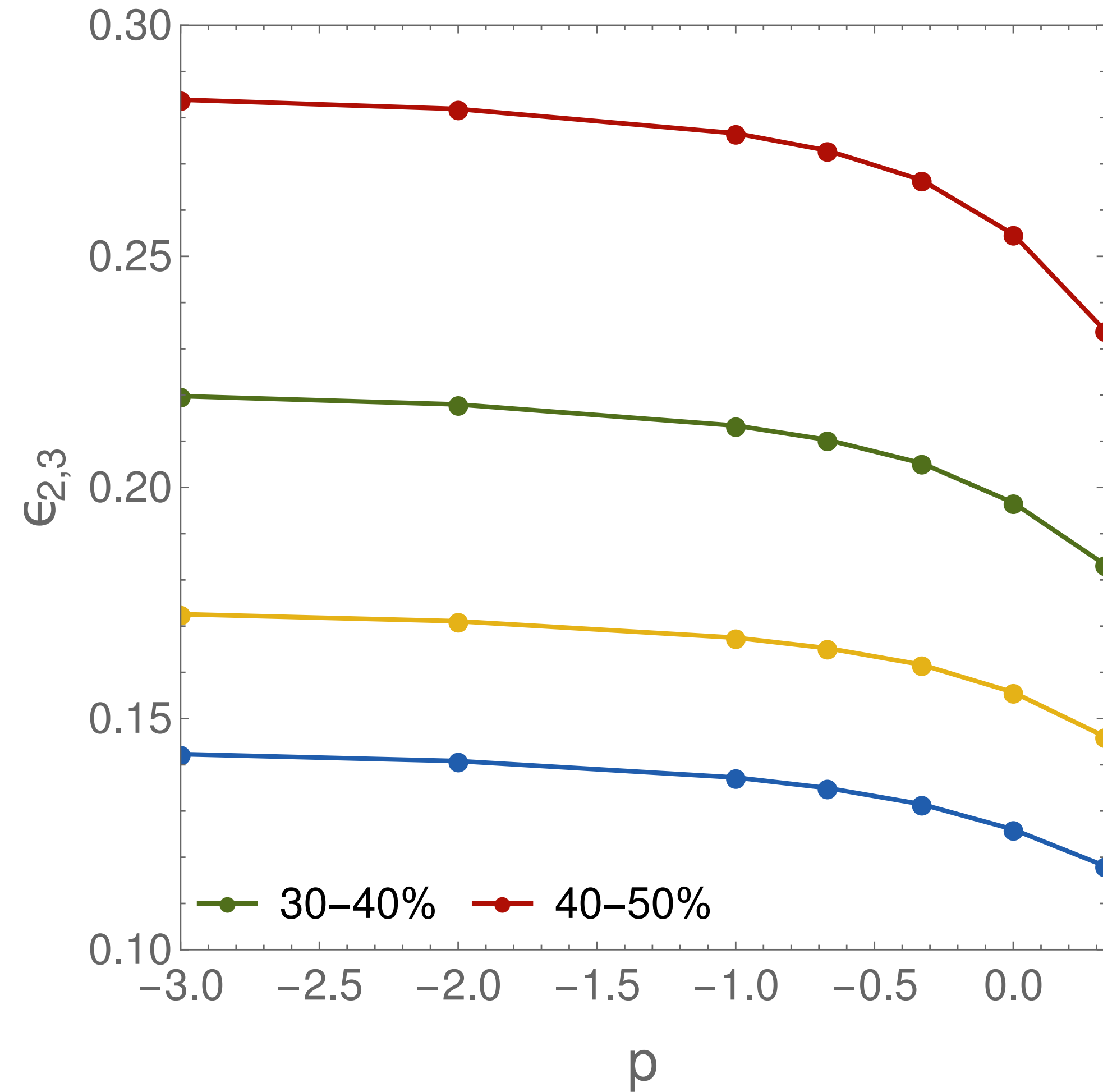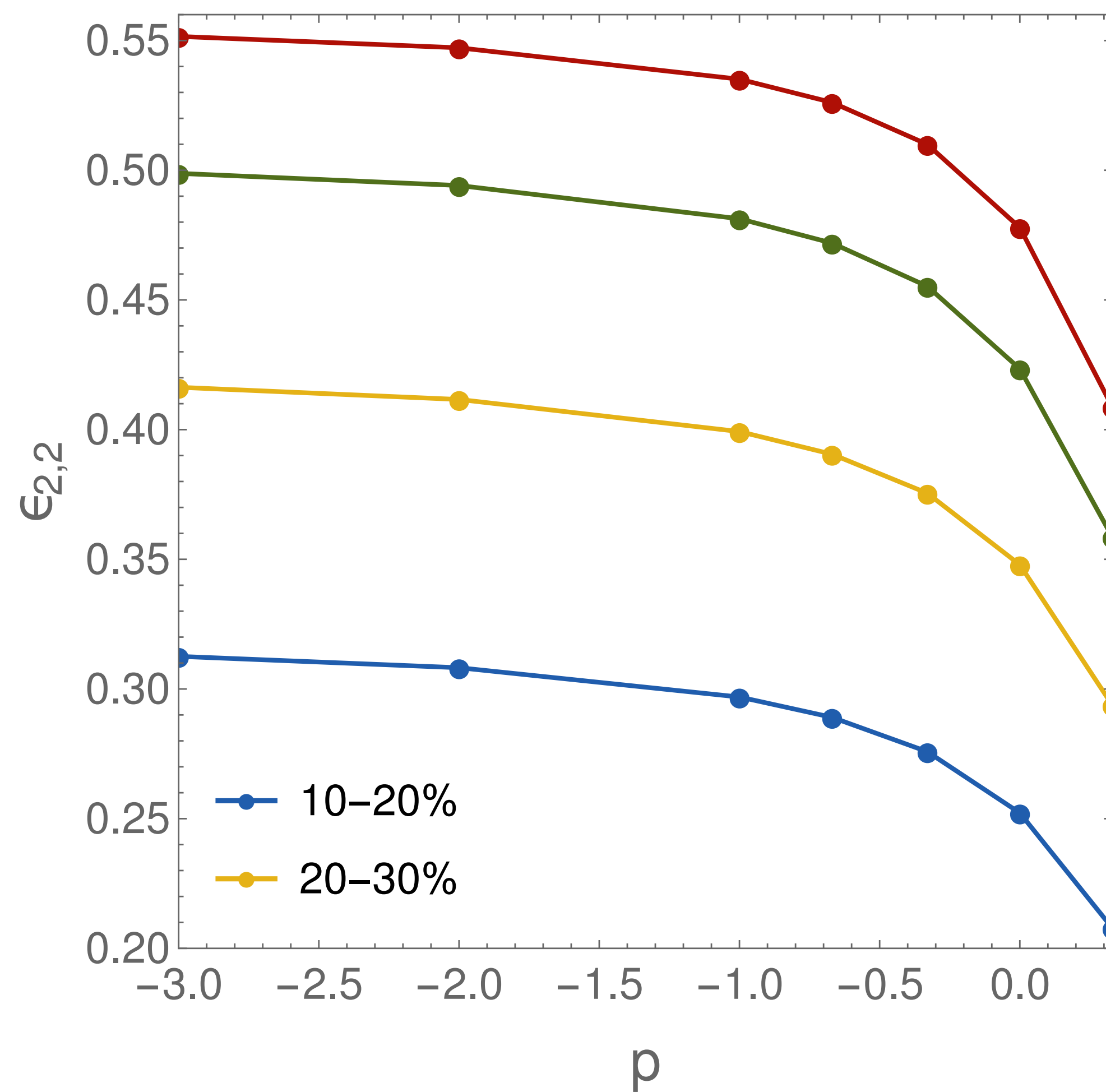
- We use constant η/s in each case.

Averaged initial temperature ($\tau = 1fm$)
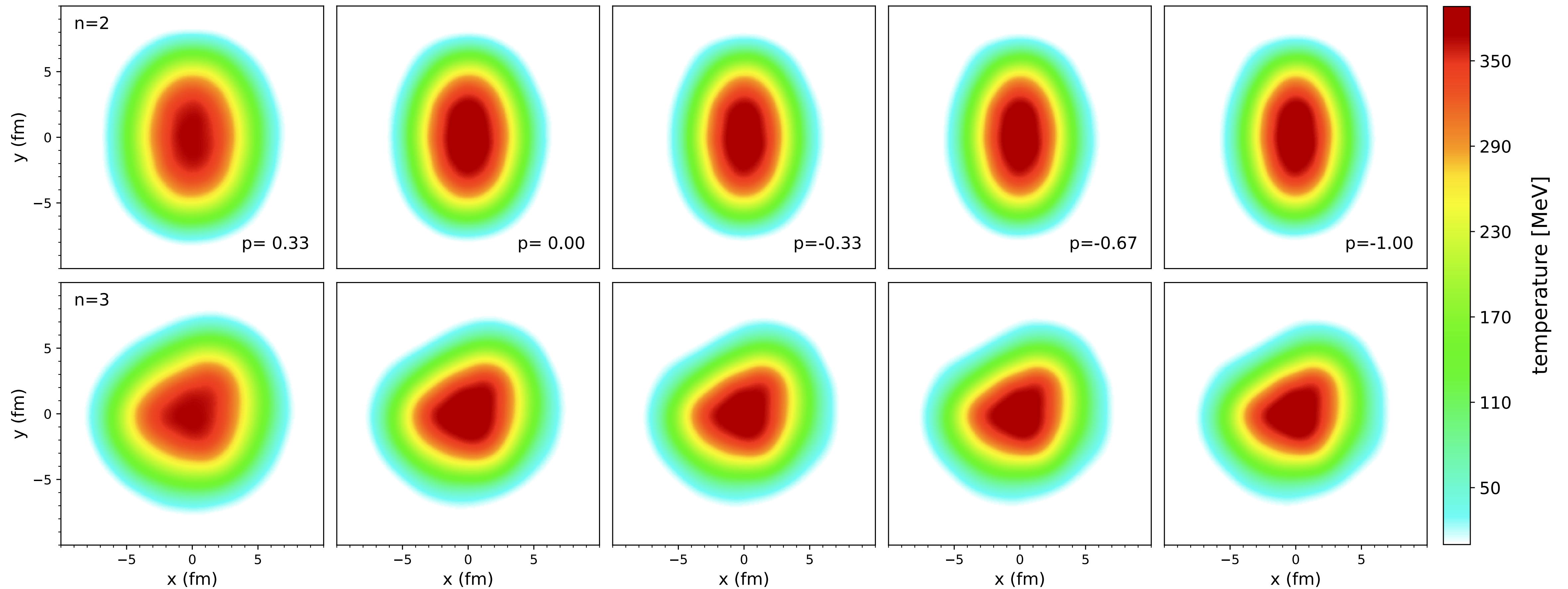
Initial state anisotropy

Generalized DREENA-A (Adaptive)

- **D**ynamical **R**adiative and **E**lastic **EN**ergy loss **A**pproach

  - Based on finite temperature field theory and generalized HTL approach

    M. Djordjevic, PRC **74**, 064907, (2006) ; PRC **80**, 064909 (2009), M. Djordjevic and U. Heinz, PRL **101**, 022302

  - Takes into account both radiative and collisional energy losses

  - No fitting parameter

- $$\frac{E_f d^3 \sigma_q(H_Q)}{dp_f^3} = \frac{E_i d^3 \sigma(Q)}{dp_i^3} \otimes P(E_i \to E_f) \otimes D(Q \to H_Q),$$

- $$\frac{E_f d^3 \sigma_u(H_Q)}{dp_f^3} = \frac{E_i d^3 \sigma(Q)}{dp_i^3} \otimes D(Q \to H_Q).$$

- Includes event-by-event fluctuating arbitrary temperature profiles.

- Agrees with R_{AA}, high-$p_\perp$ v_2, v_3. Predictions vastly underestimates high-$p_\perp$ v_4 (High-$p_\perp$ v_4 puzzle), allows to extract bulk medium properties. D. Zigic, J. Auvinen, I. Salom, M. Djordjevic and P. Huovinen, Phys. Rev. C **106** (2022) 4, 044909
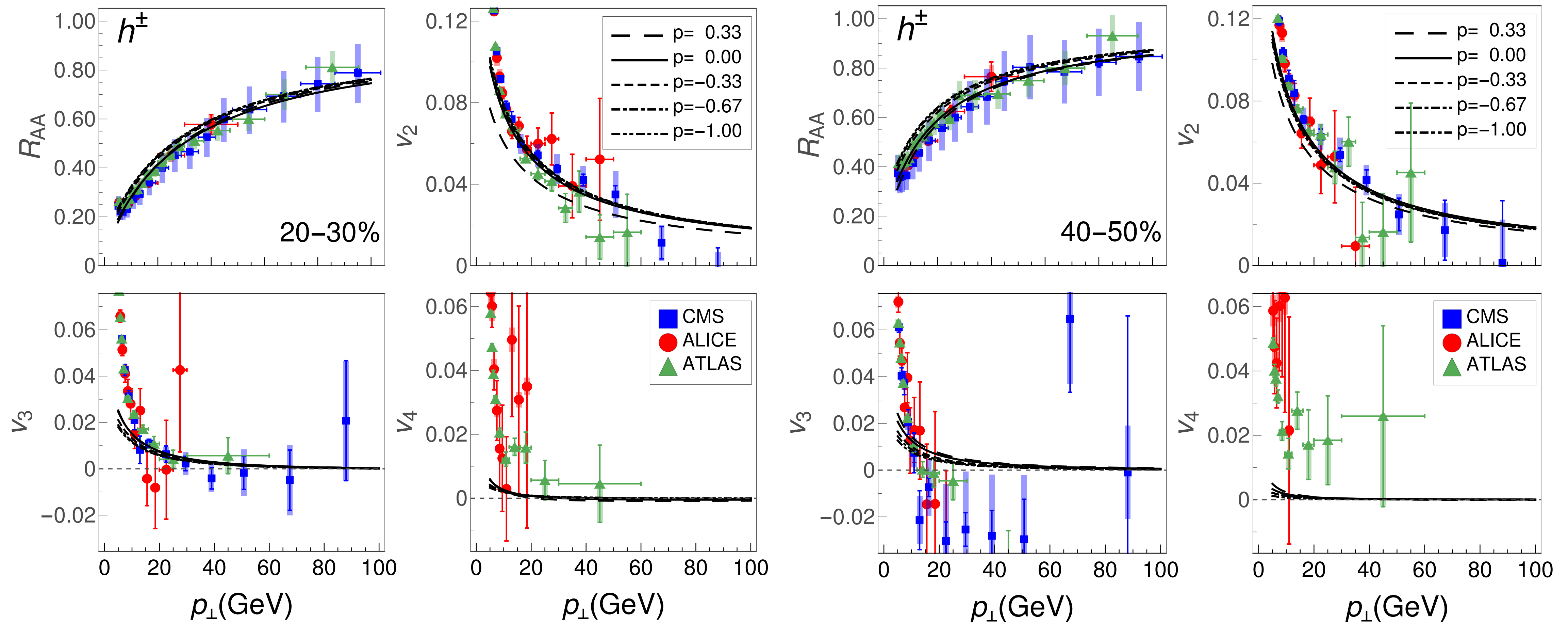
Dusan Zigic, Wed 15:00   **Bojana Illic, Fri 11:50**

# Charged hadron R_{AA} and high-$p_\perp$ v_n in Pb+Pb $\sqrt{s} = 5.02$ TeV

Study of early evolution of heavy-ion collision

- Although high-$p_\perp$ data prefer no initial free streaming and delayed onset of hydrodynamics, it may appear unrealistic.

- We try to accommodate earlier onset of hydrodynamic evolution by considering the highly anisotropic initial profiles (T_RENTo $p < 0$).

- We consider $\tau_0 = 1\, fm, 0.6\, fm$ and $0.2\, fm$.

- Readjusted η/s and T_RENTo normalization to reproduce the low-$p_\perp$ data.

Charged hadron R_{AA} and high-$p_\perp$ v_n in Pb+Pb $\sqrt{s} = 5.02$ TeV
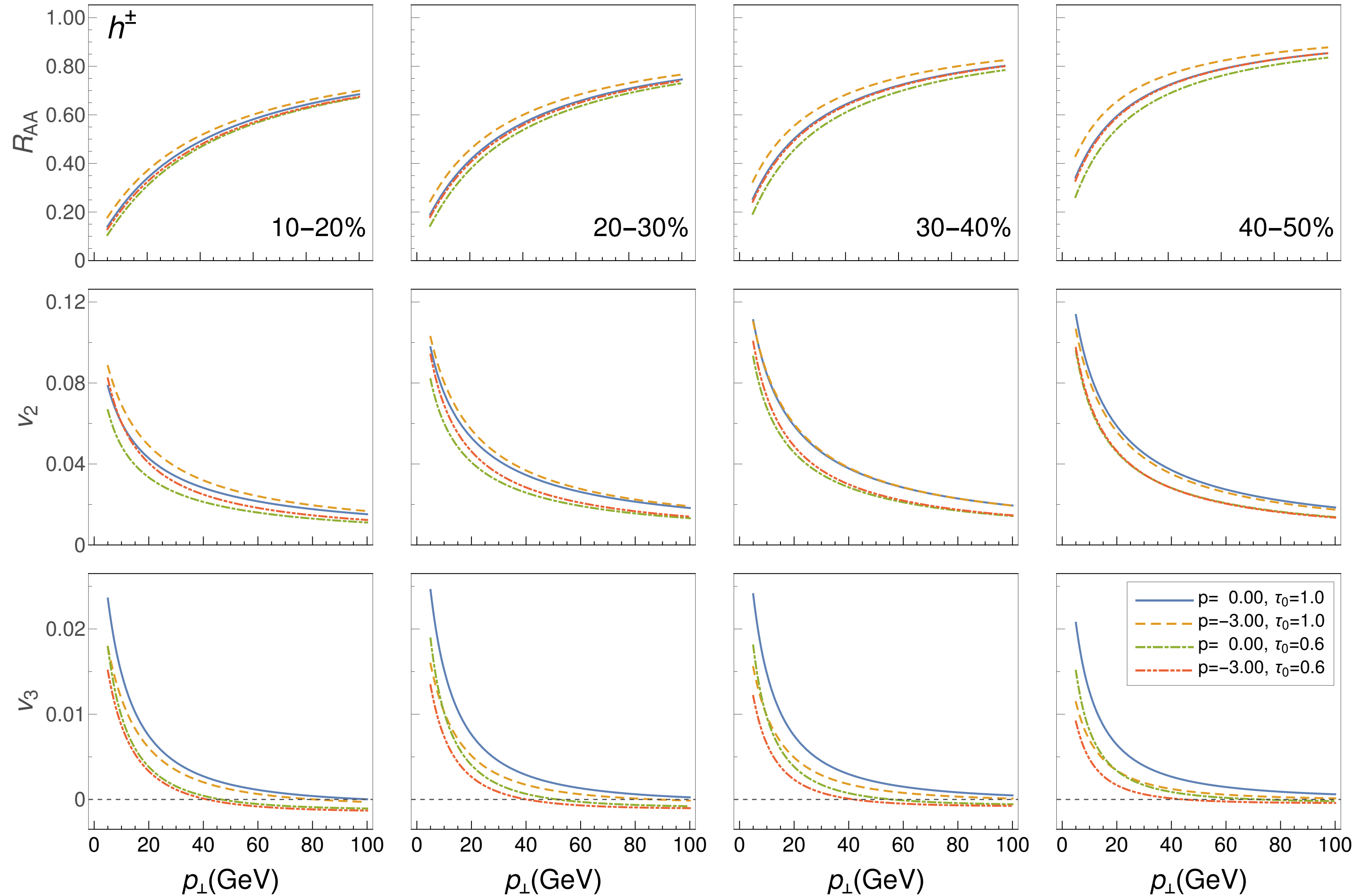
Summary

- The shape of the initial state has been modulated by varying the parameter p of T_RENTo model.

- It is found that $p \approx 0$ gives the best overall fit which is consistent with the Bayesian analysis of low-$p_\perp$ data.

- We tested if larger anisotropy of the initial profiles ($p \ll 0$) would allow an earlier onset of fluid dynamical evolution.

- Lower values of p enhance R_{AA} and high-$p_\perp$ v_2, the enhancement is insufficient for facilitating an earlier onset of transverse expansion.

Extreme QCD 2025

- **Dates:** July 2 – 4, 2025

- **Venue**: University of Wroclaw, Wroclaw, Poland

- **Student support:** fee, travel, accommodation

- **Web:** INDICO INSPIRE
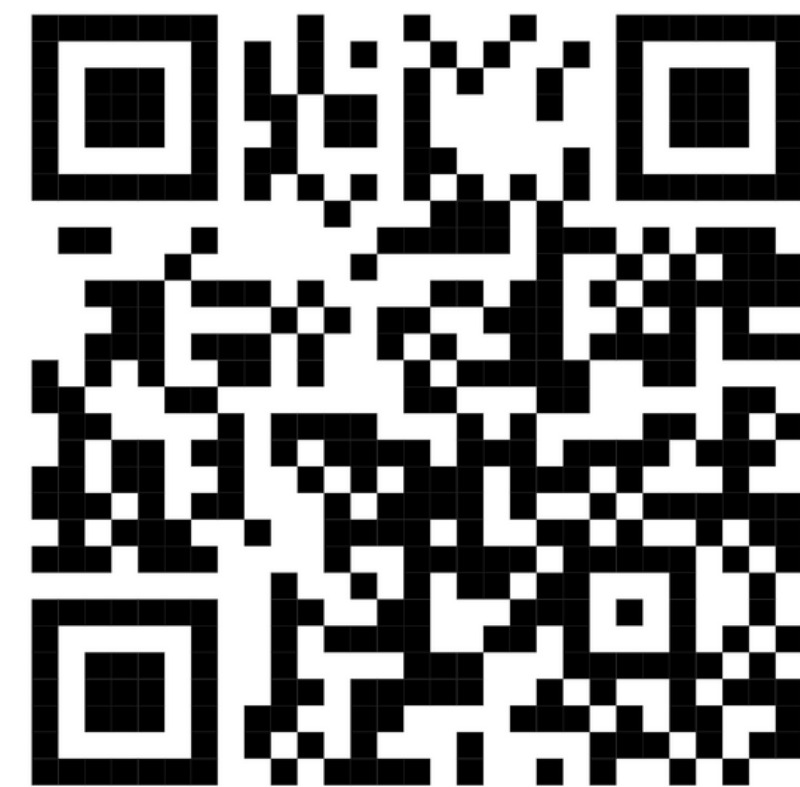
XQCD 2025

Uniwersytet Wrocławski

Thank you for your attention

$$\epsilon_{m,n} = -\frac{\int dxdy \, r^m \cos\left[n(\phi - \Psi_{m,n})\right] e(x, y)}{\int dxdy \, r^m e(x, y)}$$

$$\Psi_{m,n} = \frac{1}{n} \arctan \frac{\int dxdy \, r^m \sin(n\phi) e(x, y)}{\int dxdy \, r^m \cos(n\phi) e(x, y)} + \pi/n$$

Early evolution using DREENA-A

1. Cyan $\rightarrow \tau_q = \tau_0 = 0.2fm$

2. Orange $\rightarrow \tau_0 = 0.2fm; \tau_q = 1fm$

3. Red $\rightarrow$ FS; $\tau_0 = \tau_q = 1fm$
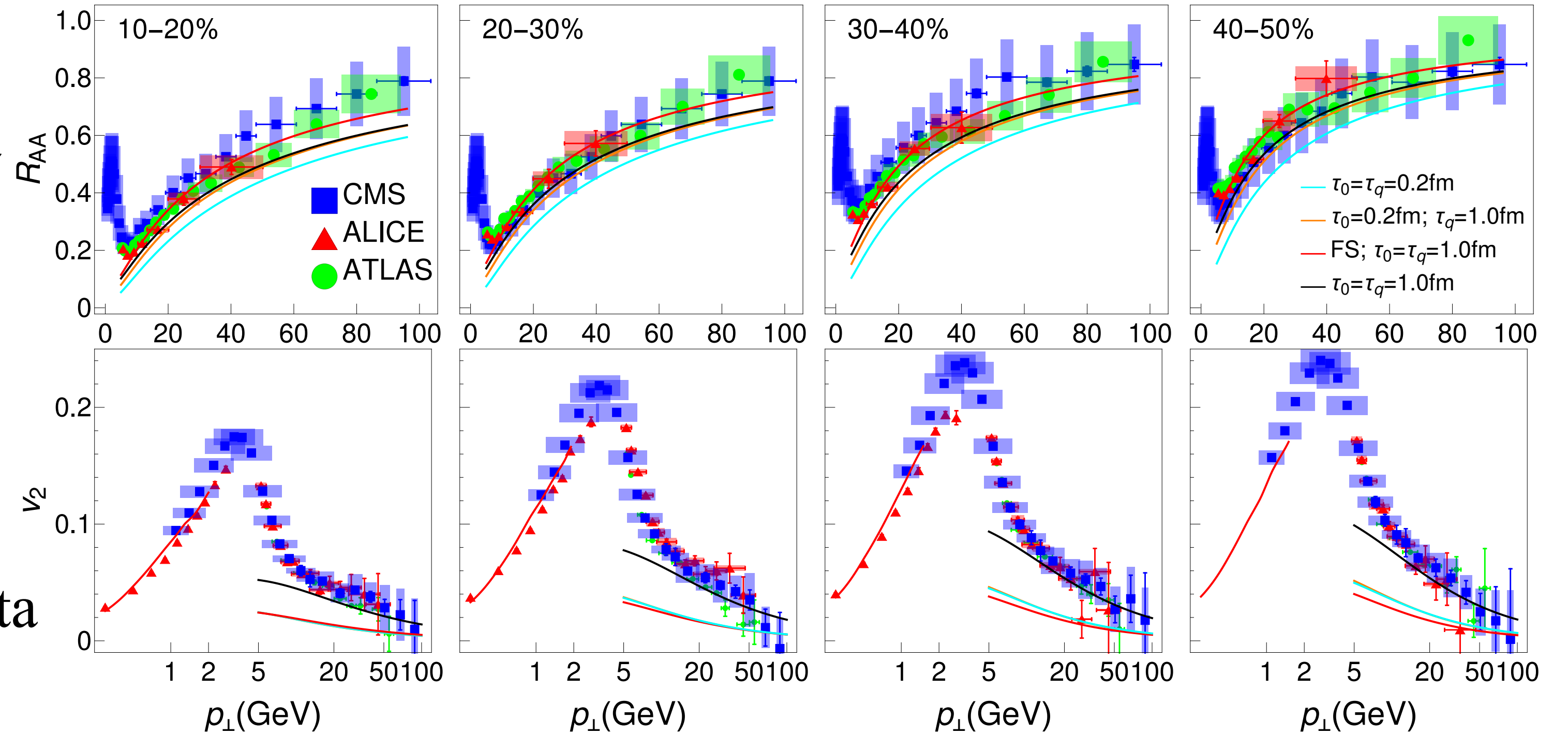
4. Black $\rightarrow \tau_0 = \tau_q = 1fm$

- Fits low-$p_\perp$ data well

- Divergent is disfavored by R_{AA} data

- Delaying τ_q hardly changes v_2

- Early FS does not fit data as well

- v_2 predictions approach data when $\tau_0 = \tau_q = 1fm$ (No early free steaming)

Pb + Pb $\sqrt{s} = 5.02$ TeV