Anisotropic flow decorrelation in heavy-ion collisions at RHIC-BES energies with 3D event-by-event viscous hydrodynamics
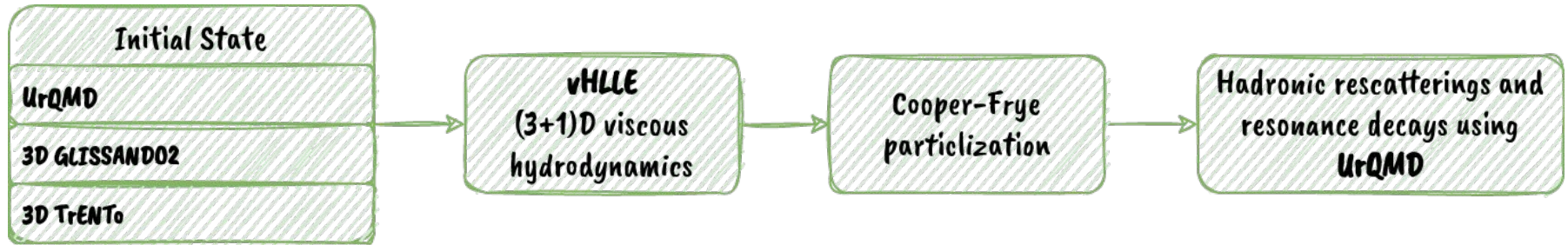
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Motivation & Model

- Longitudinal structure of anisotropic flows brings additional constraints on the initial state and/or transport coefficients of the QGP

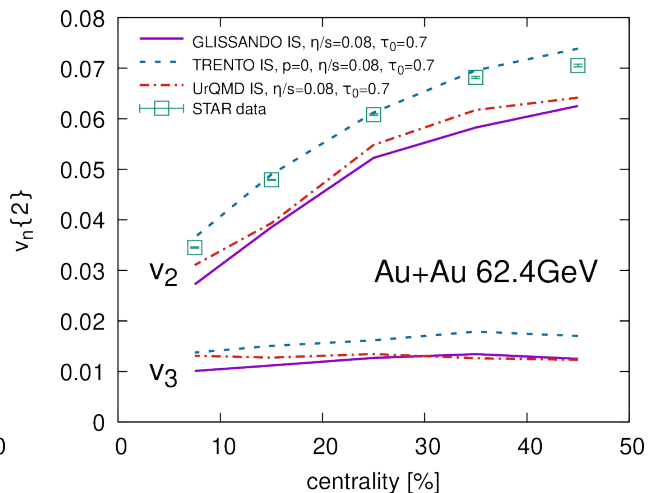- At RHIC-BES energies, flow decorrelation is just starting to be researched
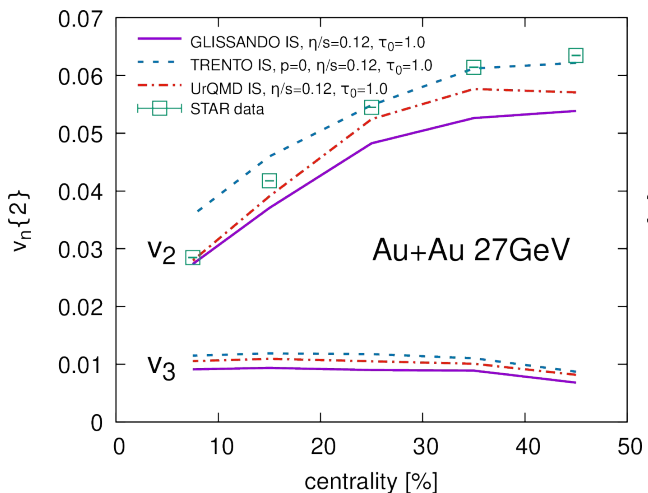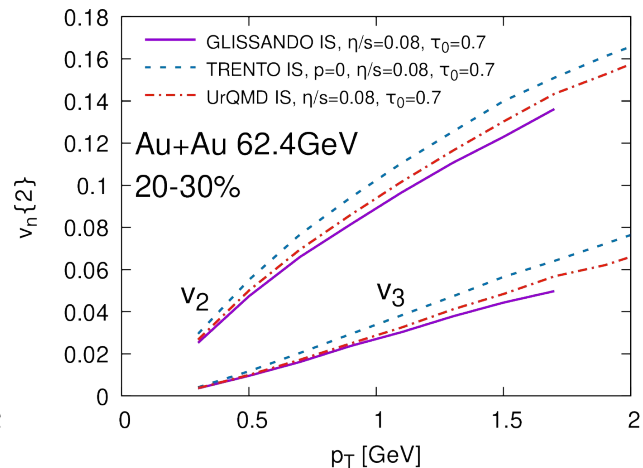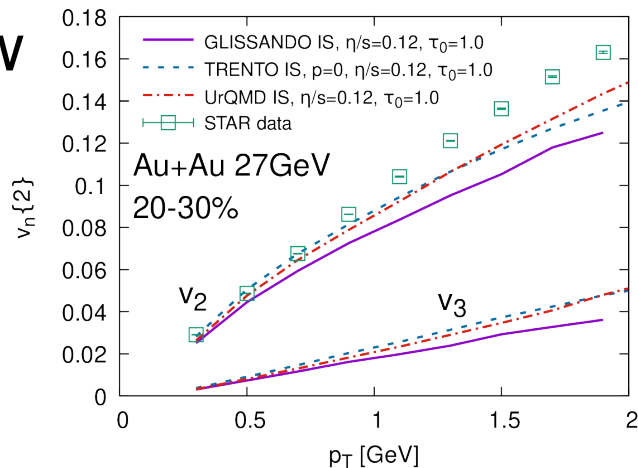

- There is a finite baryon and electric charge densities at all stages

- GLISSANDO2 and TrENTo are extended to longitudinal direction following work of Bozek [Phys. Rev. C 85, 044910 (2012)]

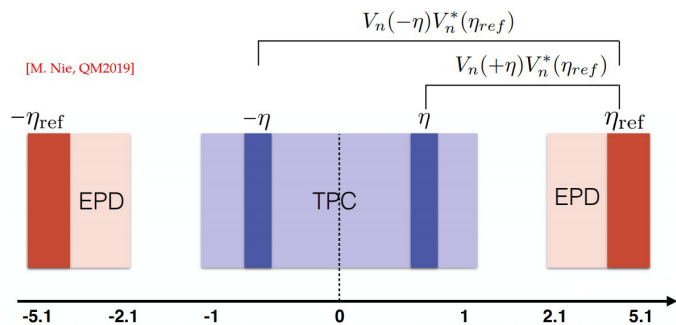- Total energy conservation is imposed in the initial state

Anisotropic Flow

- Flow coefficients can be computed from

$$v_n = \frac{\int \mathrm{d}\phi \cos(n(\phi - \Psi_n)) \frac{\mathrm{d}^3 N}{p_T \mathrm{d}p_T \mathrm{d}y \mathrm{d}\phi}}{\int \mathrm{d}\phi \frac{\mathrm{d}^3 N}{p_T \mathrm{d}p_T \mathrm{d}y \mathrm{d}\phi}}$$

- To calculate flow coefficients we used 2-particle cumulant method [Phys. Rev. C 83, 044913 (2011)]

- Models with Glissando and UrQMD IC underestimate the p_T-integrated elliptic flow

Decorrelation

[M. Nie, QM2019]

$$V_n(-\eta)V_n^*(\eta_{ref})$$

$$V_n(+\eta)V_n^*(\eta_{ref})$$

$-\eta_{ref}$ $-\eta$ η η_{ref}

EPD   TPC   EPD

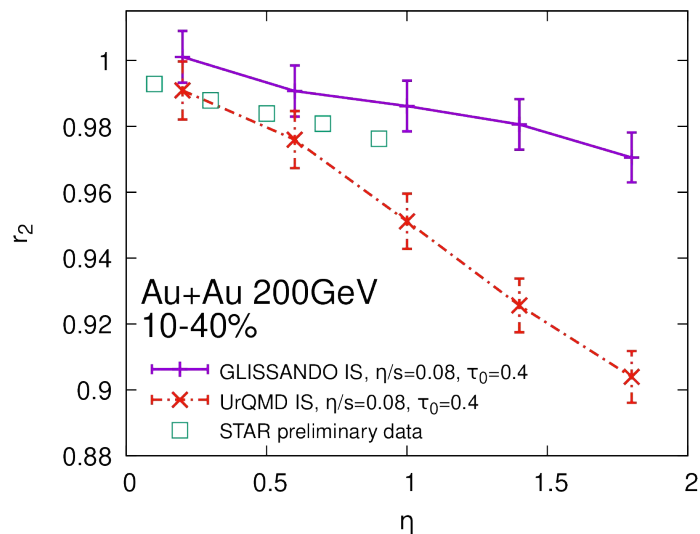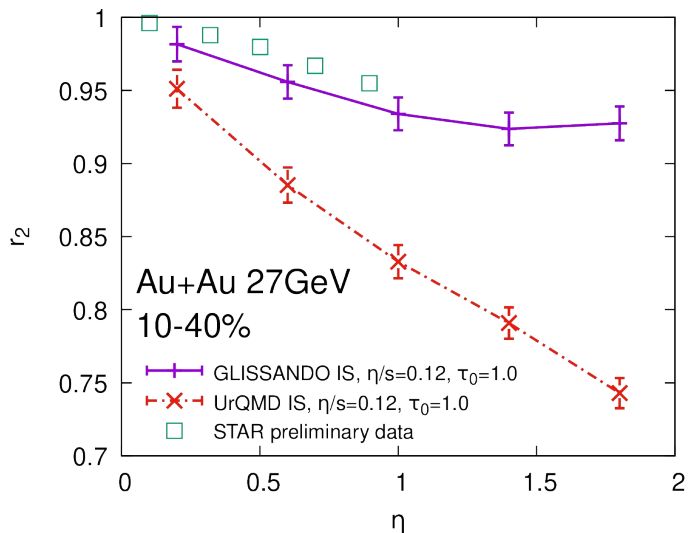-5.1 -2.1 -1 0 1 2.1 5.1

- Longitudinal fluctuations can lead to decorrelations of anisotropic flows along the pseudorapidity direction

- The factorisation ratio is defined as

$$r_n(\eta, \eta_{ref}) = \frac{\langle \mathbf{V}_n(-\eta)\mathbf{V}_n^*(\eta_{ref})\rangle}{\langle \mathbf{V}_n(+\eta)\mathbf{V}_n^*(\eta_{ref})\rangle} = \frac{\langle v_n(-\eta)v_n(\eta_{ref})\cos n(\Psi_n(-\eta) - \Psi_n(\eta_{ref}))\rangle}{\langle v_n(+\eta)v_n(\eta_{ref})\cos n(\Psi_n(+\eta) - \Psi_n(\eta_{ref}))\rangle}$$
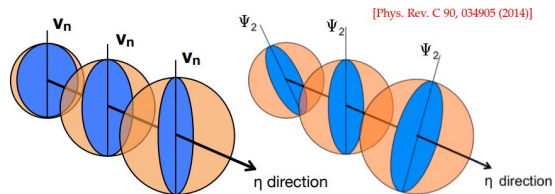
- $r_n(\eta) = 1 \Rightarrow$ no decorrelation $r_n(\eta) < 1 \Rightarrow$ decorrelation

Au+Au 27GeV
10-40%

GLISSANDO IS, η/s=0.12, τ_0=1.0
UrQMD IS, η/s=0.12, τ_0=1.0
STAR preliminary data

Au+Au 200GeV
10-40%

GLISSANDO IS, η/s=0.08, τ_0=0.4
UrQMD IS, η/s=0.08, τ_0=0.4
STAR preliminary data

UrQMD IS results in significantly stronger decorrelation

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Source of the Decorrelation

Magnitude and angle

[Phys. Rev. C 90, 034905 (2014)]
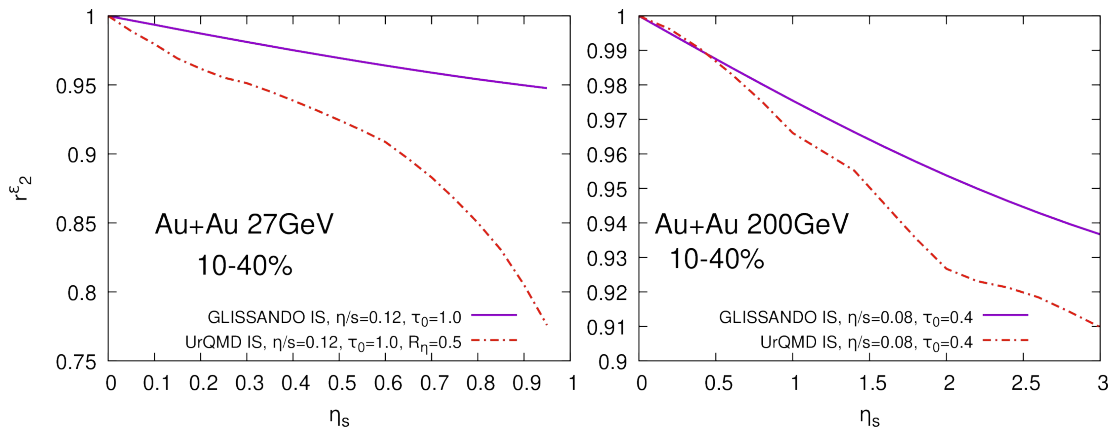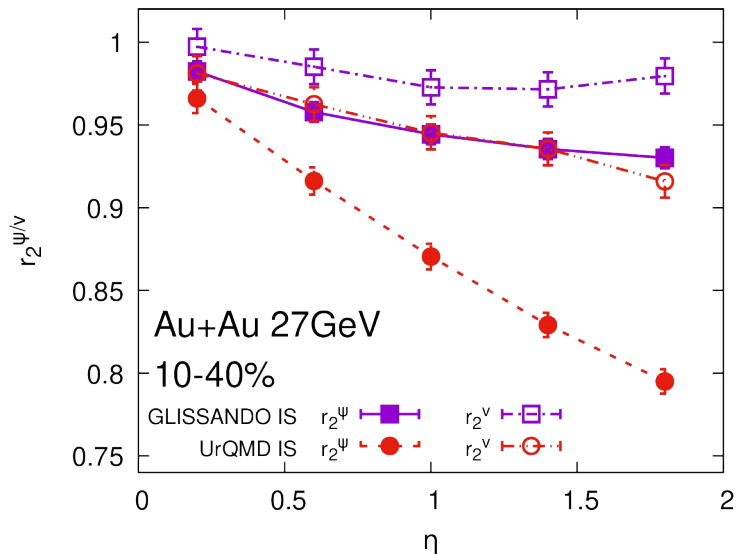

Initial state

- Analogously, we can define decorrelation of initial state spatial eccentricity

$$r_n^\epsilon(\eta_s) = \frac{\langle \epsilon_n(-\eta_s)\epsilon_n(\eta_{s,\mathrm{ref}})\cos[n(\Psi_n(-\eta_s)-\Psi_n(\eta_{s,\mathrm{ref}}))]\rangle}{\langle \epsilon_n(\eta_s)\epsilon_n(\eta_{s,\mathrm{ref}})\cos[n(\Psi_n(\eta_s)-\Psi_n(\eta_{s,\mathrm{ref}}))]\rangle}$$

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Summary

- We presented the elliptic flow and flow decorrelation in Au-Au collisions at $\sqrt{s_{NN}} = 27$, 62.4 and 200 GeV in 3-dimensional viscous hydrodynamic model with UrQMD, 3D GLISSANDO and 3D TRENTo initial states

- Flow decorrelation at $\sqrt{s_{NN}} = 27$ GeV is a first calculation of a kind in a hydrodynamic model

- At midrapidity, model with TrENTo IS ($p = 0$) best describes the elliptic flow

- We observe that the flow decorrelation is mainly caused by flow angle decorrelation, which is in agreement with other studies [Phys. Rev. C 98, 024913 (2018), Phys. Rev. C 97, 034913 (2018)]

- The model with UrQMD IS overestimates the decorrelation, which is rooted in much stronger decorrelation of initial state eccentricity

- References: Phys. Rev. C 103, 034902 (2021) and Phys. Rev. C 104, 014904 (2021)