

Longitudinal structure of the initial state from 3+1D Glasma simulations

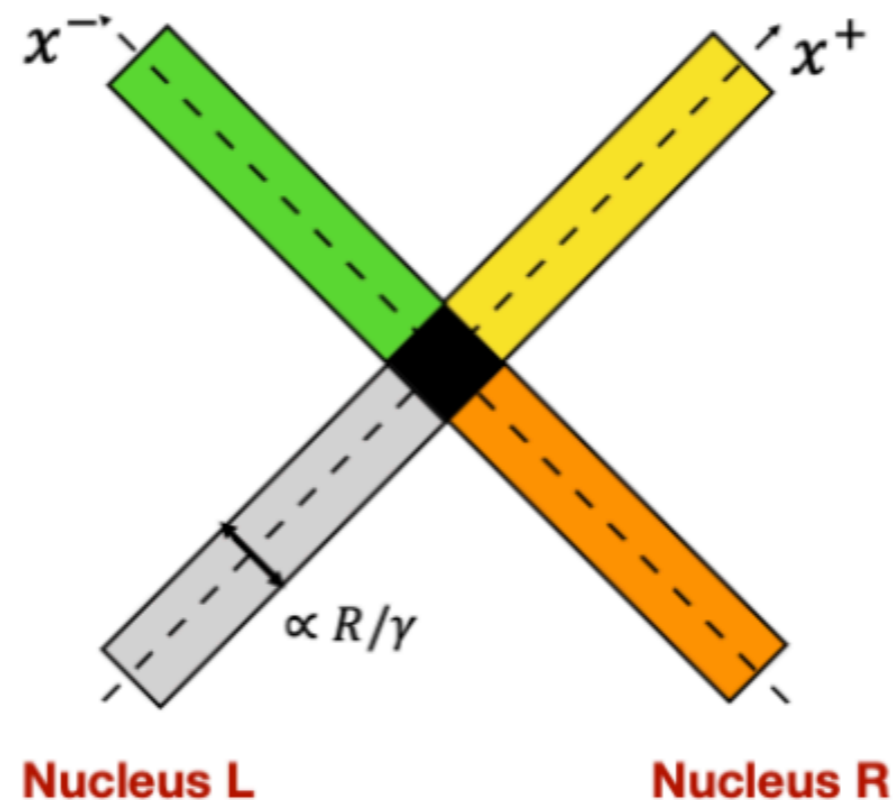
Pragya Singh*, Sören Schlichting
Universität Bielefeld

Initial Stages 2021, Virtual Conference
January 12, 2021

Based on S. Schlichting and P. Singh [Phys. Rev. D 103, 014003](#)

Motivation & Introduction

New measurements at RHIC and LHC indicates towards the presence of longitudinal dynamics [arXiv:1503.01692](https://arxiv.org/abs/1503.01692) [arXiv:1709.02301](https://arxiv.org/abs/1709.02301)



Solve 3+1D classical Yang-Mills equations & evolution equations for eikonal currents, before, during and after the collision

Collision with (semi-) realistic charge distribution

Now in practice we employ a factorized ansatz for position and momentum dependence of the color charge distribution

$$\langle \rho^a(x) \rho^b(y) \rangle = \delta^{ab} T \left(\frac{x+y}{2} \right) \Gamma(x-y)$$

We determine the momentum dependence from **TMDs** in the dilute approximation (**GBW model**)

$$\tilde{\Gamma}(k_{\perp}, k_z) = \frac{8\pi}{g^2} \frac{N_c}{N_c^2 - 1} \frac{k_{\perp}^4}{Q_s^2(x_2)} \exp \left(- \frac{k_{\perp}^2}{Q_s^2(x_2)} \right) \Bigg|_{x_2 = -\sqrt{2}k_z / \sqrt{s_{NN}}}$$

Superimpose **3D MC-Glauber profile** of spatial distribution of color charges

$$T(x, y, z) = \sum_{i=1}^A T_i(x, y, z) .$$

Effect of fluctuation at RHIC energies

Before the collision

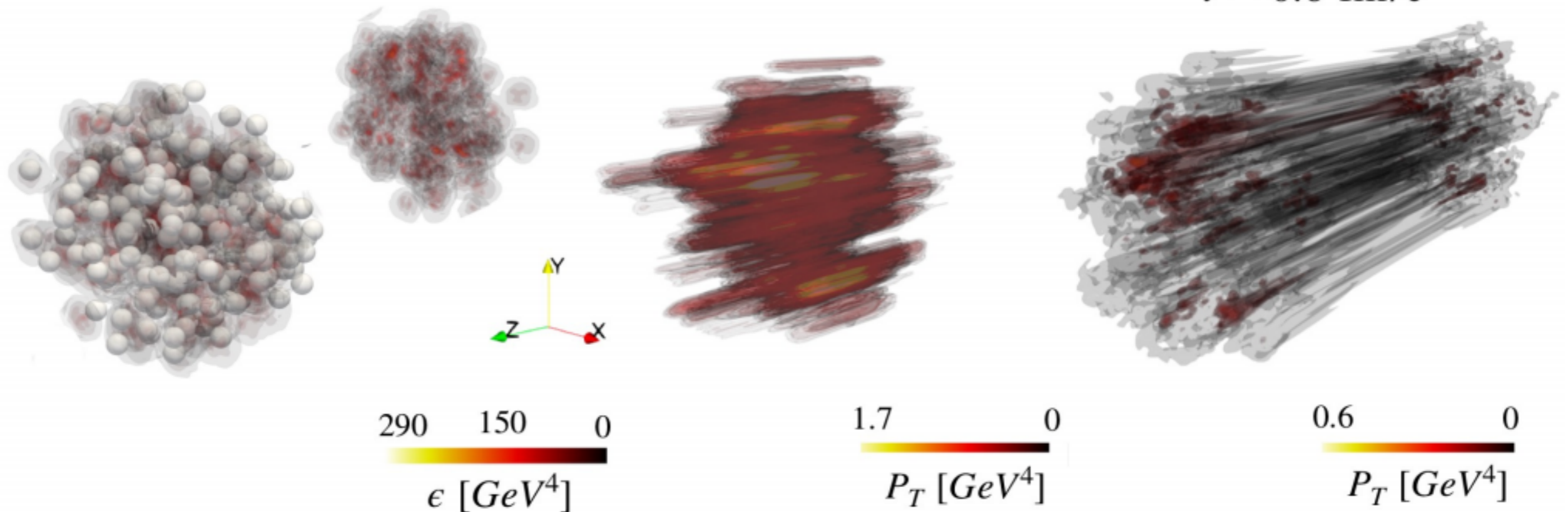
During the collision

After the collision

$t = -0.37 \text{ fm}/c$

$t = 0 \text{ fm}/c$

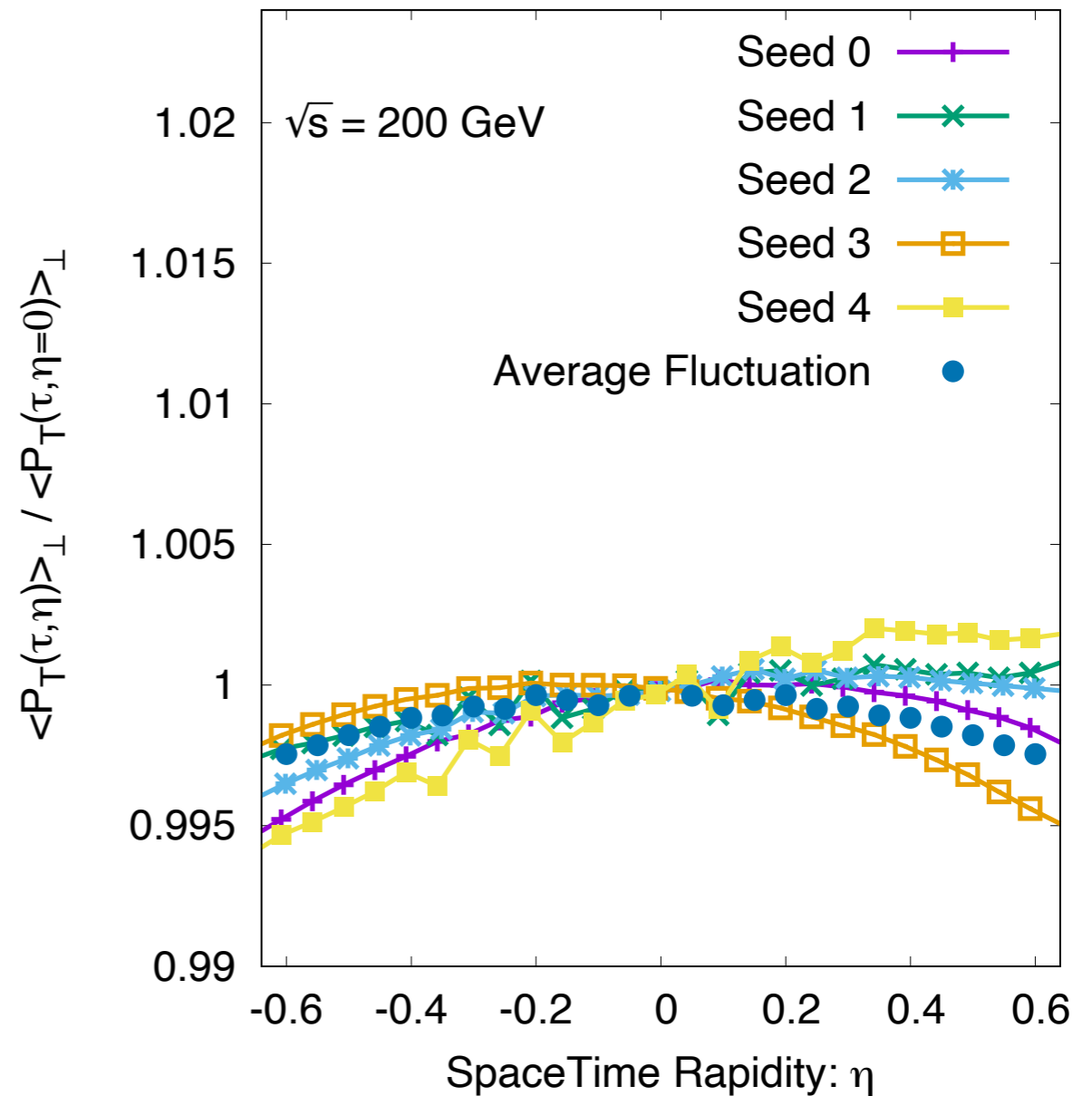
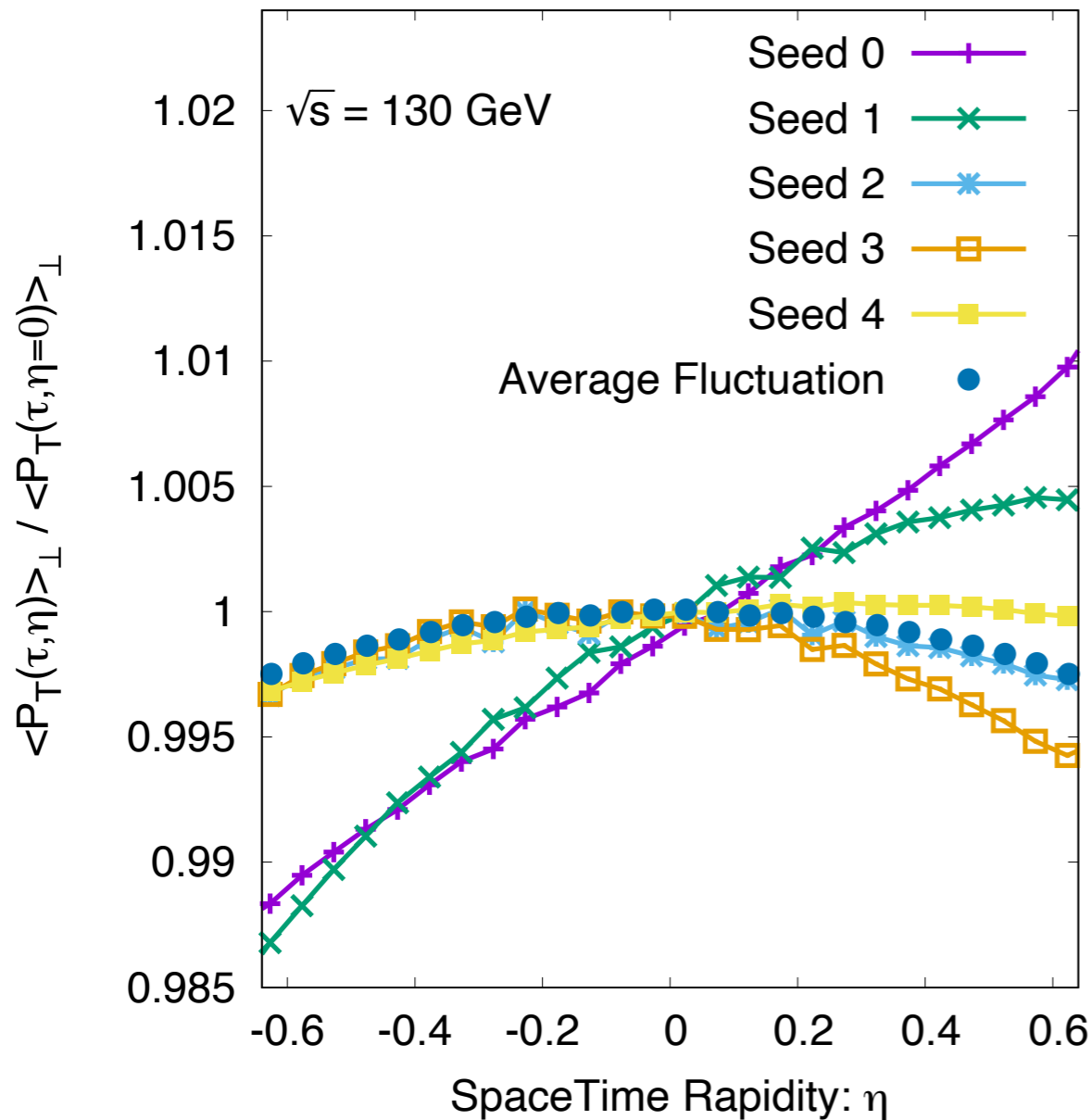
$t = 0.6 \text{ fm}/c$



Au-Au collision at $\sqrt{s} = 200 \text{ GeV}$

Inhomogeneity emerge mostly due to the fact that different nucleons control energy deposition at different space-time positions

Effect of fluctuation at RHIC energies



Fixed $\tau \simeq 0.75 \text{ fm}/c$

Fluctuation relatively small $\leq 1\%$ and decreases with increasing \sqrt{s}

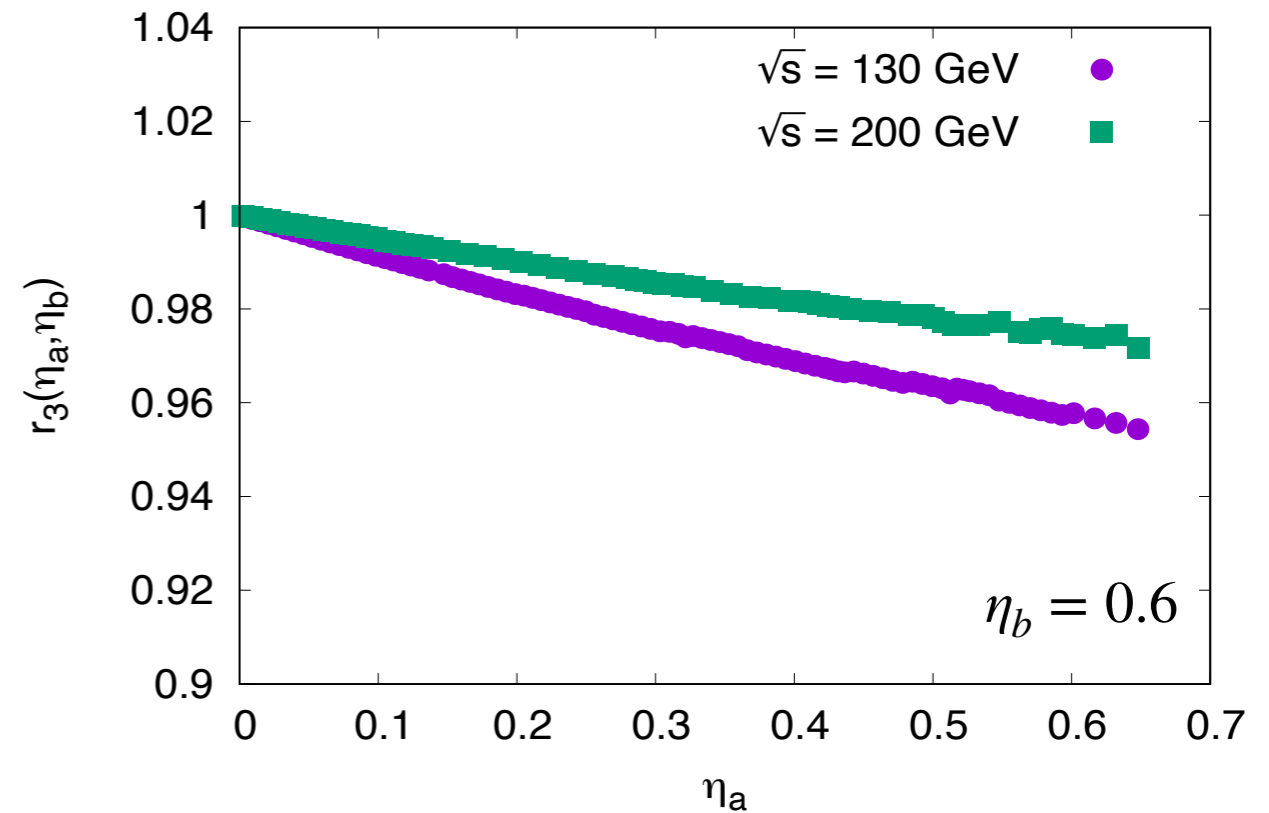
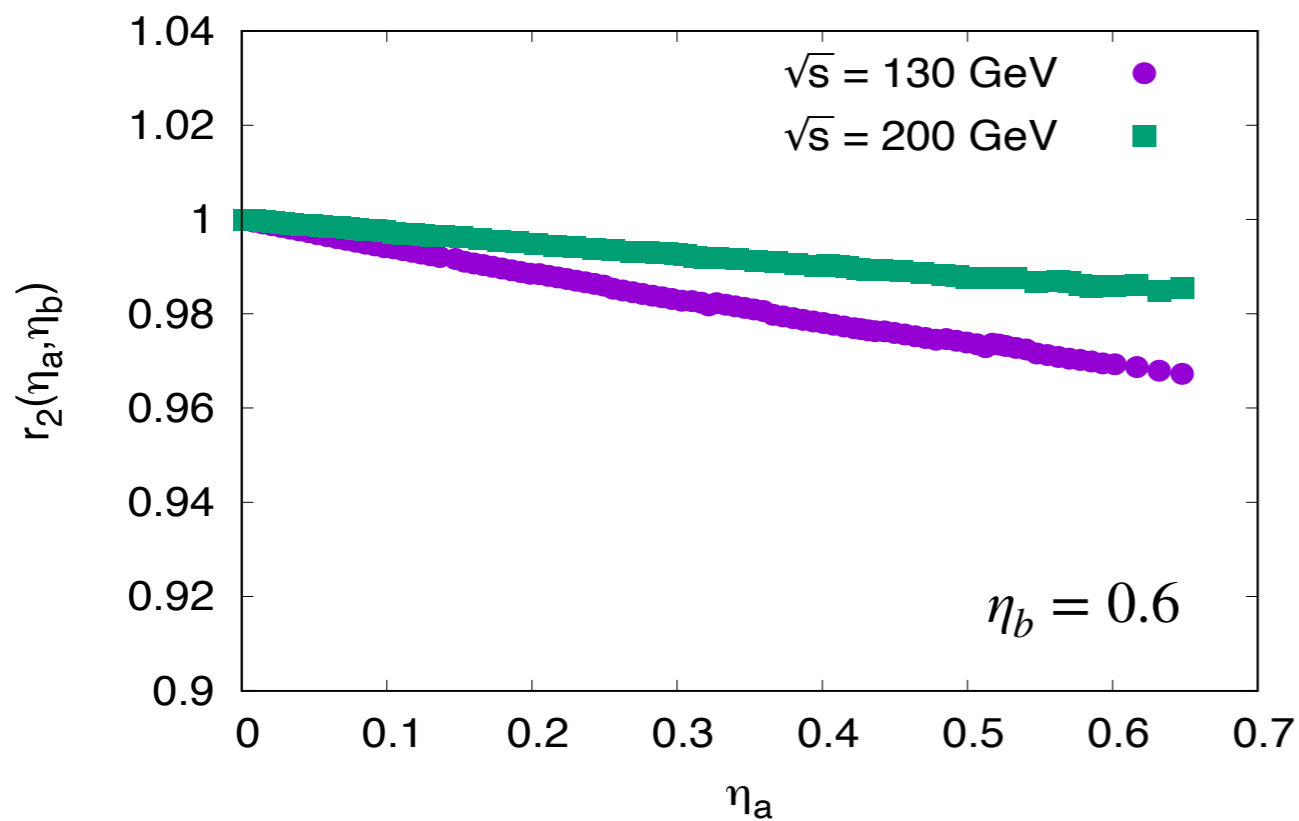
Decorrelation of n-th order anisotropic flow

Characterise overall decorrelation using forward-backward ratio

$$r_n(\eta_a, \eta_b) = \frac{\langle \text{Re}[\epsilon_n(-\eta_a) \cdot \epsilon_n^*(\eta_b)] \rangle}{\langle \text{Re}[\epsilon_n(\eta_a) \cdot \epsilon_n^*(\eta_b)] \rangle} \quad \text{Using initial state } \epsilon_n$$

CMS Collaboration PRC 92, 034911 (2015)

Simultaneous description of r_2 and r_3 for central collision



Strong decorrelation at lower energies

Conclusion & Outlook

New measurements of longitudinal fluctuations at RHIC and LHC have increased interest in longitudinal structure of initial state.

Developed a framework to describe 3D profiles of initial energy deposition using CGC.

Successful results from numerical simulations; additional analytic insights highly desirable

So far focused on longitudinal profiles of initial state energy deposition; also interesting to explore early time non-equilibrium dynamics

Thank you...

Backup: 3+1D Glasma simulations

1. Sample 3D distribution of color charges $\rho(x^\pm, x_\perp)$ in each half boxes.
2. Solve for Weizsäcker-Williams fields (WW) of the incoming nuclei.
3. Evolve gauge fields and corresponding conjugate momenta according to the discretised 3+1D YM

$$[D_\mu, F^{\mu\nu}] = J^\nu$$

4. Evolve eikonal currents according to continuity equation.

$$[D_\mu, J^\mu] = 0$$

5. Solve 3. and 4. simultaneously to simulate early time dynamics of collision in 3+1D

Rigorous derivation of initial condition that successfully conserves Gauss Law.