3D Dynamical Simulations for Relativistic Heavy-ion Collisions

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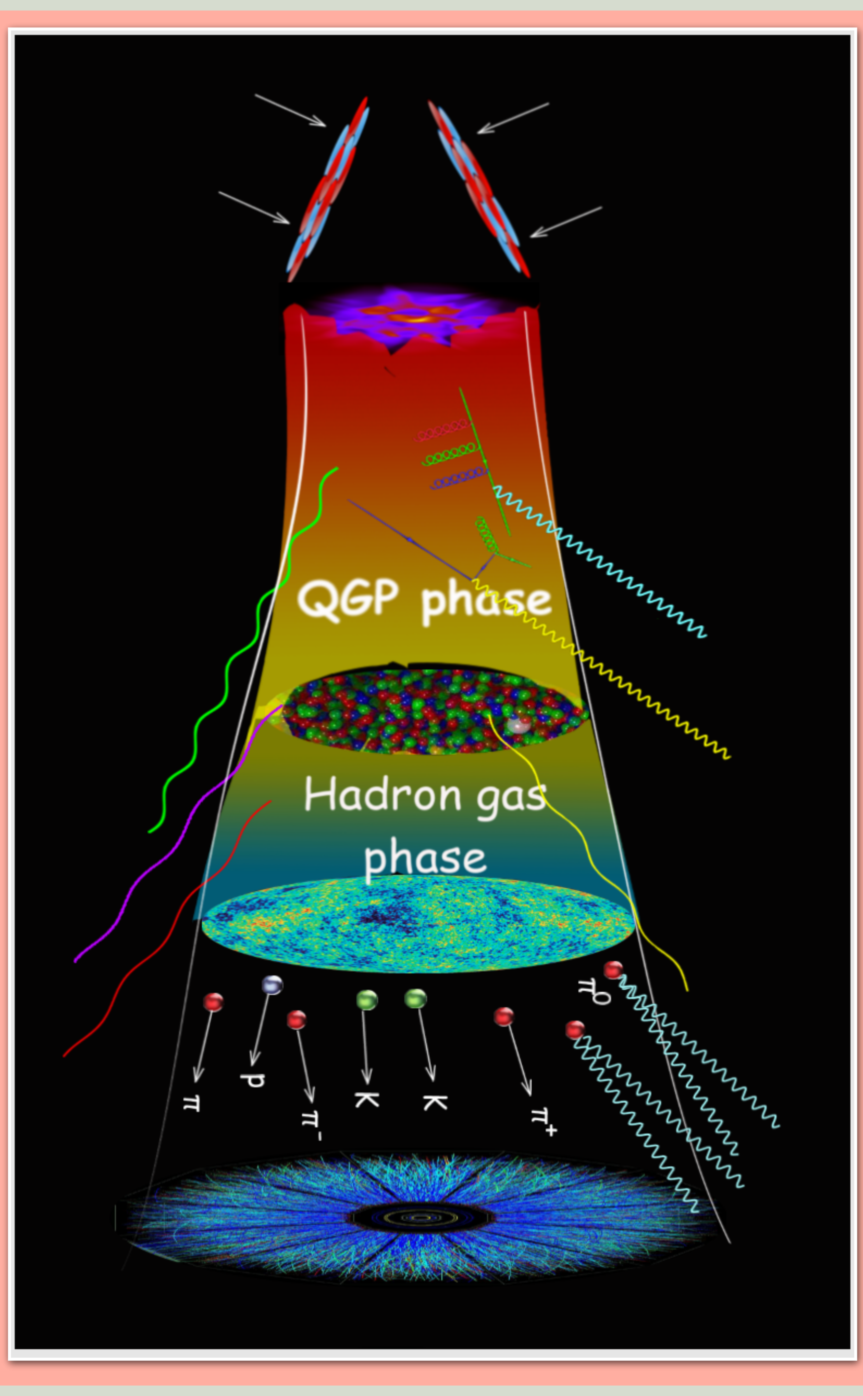
Abstract

This work focuses on developing a novel theoretical tool to study the 3D dynamics of relativistic heavy-ion collisions in the Beam Energy Scan (BES) program at the Relativistic Heavy-Ion Collider (RHIC). We propose a way to construct 3D initial conditions with minimum model parameters based on the information from the Glauber collision geometry and conservation of energy and momentum. We studied the rapidity dependence of the flow observable and demonstrated that the elliptic flow measurements at the beam energy scan can set strong constraints on $\eta/s(T, \mu_B)$

Introduction

- Heavy-ion collisions have complex dynamics and go through a multi-stage evolution
- Fluid dynamics can successfully describe the macroscopic expansion of the system
- A quantitative 3d dynamic modeling can help us understand a variety of the bulk flow measurements



Implementation of Energy Momentum Conservation

- Energy-momentum conservation are imposed to constrain the model parametrization.
- Determine the local collision energy and net longitudinal momentum at any point in the transverse plane (x,y).
- The hydrodynamic fields initialized with these initial conditions.

$$E(x,y) = [T_A(x,y) + T_B(x,y)] m_N \cosh(y_{\rm beam}) \equiv M(x,y)\cosh(y_{\rm CM}(x,y))$$

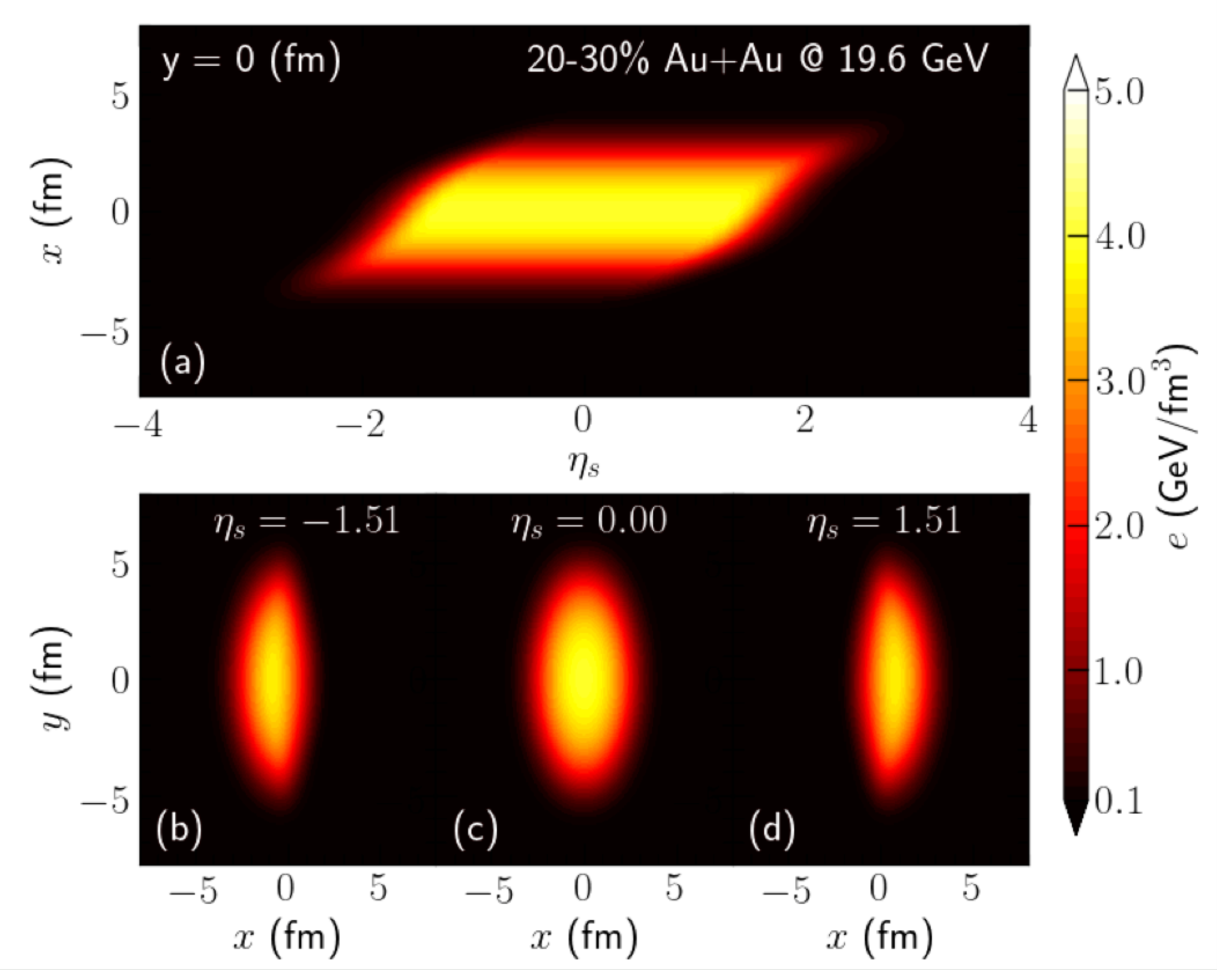
$$E(x,y) = \int d^3\Sigma_\mu T^{\mu t}(x,y,\eta_s)$$

$$P_z(x,y) = [T_A(x,y) - T_B(x,y)] m_N \sinh(y_{\rm beam}) \equiv M(x,y)\sinh(y_{\rm CM}(x,y)) .$$

$$P_z(x,y) = \int d^3\Sigma_\mu T^{\mu z}(x,y,\eta_s) \qquad M(x,y) \propto \sqrt{T_A T_B}$$

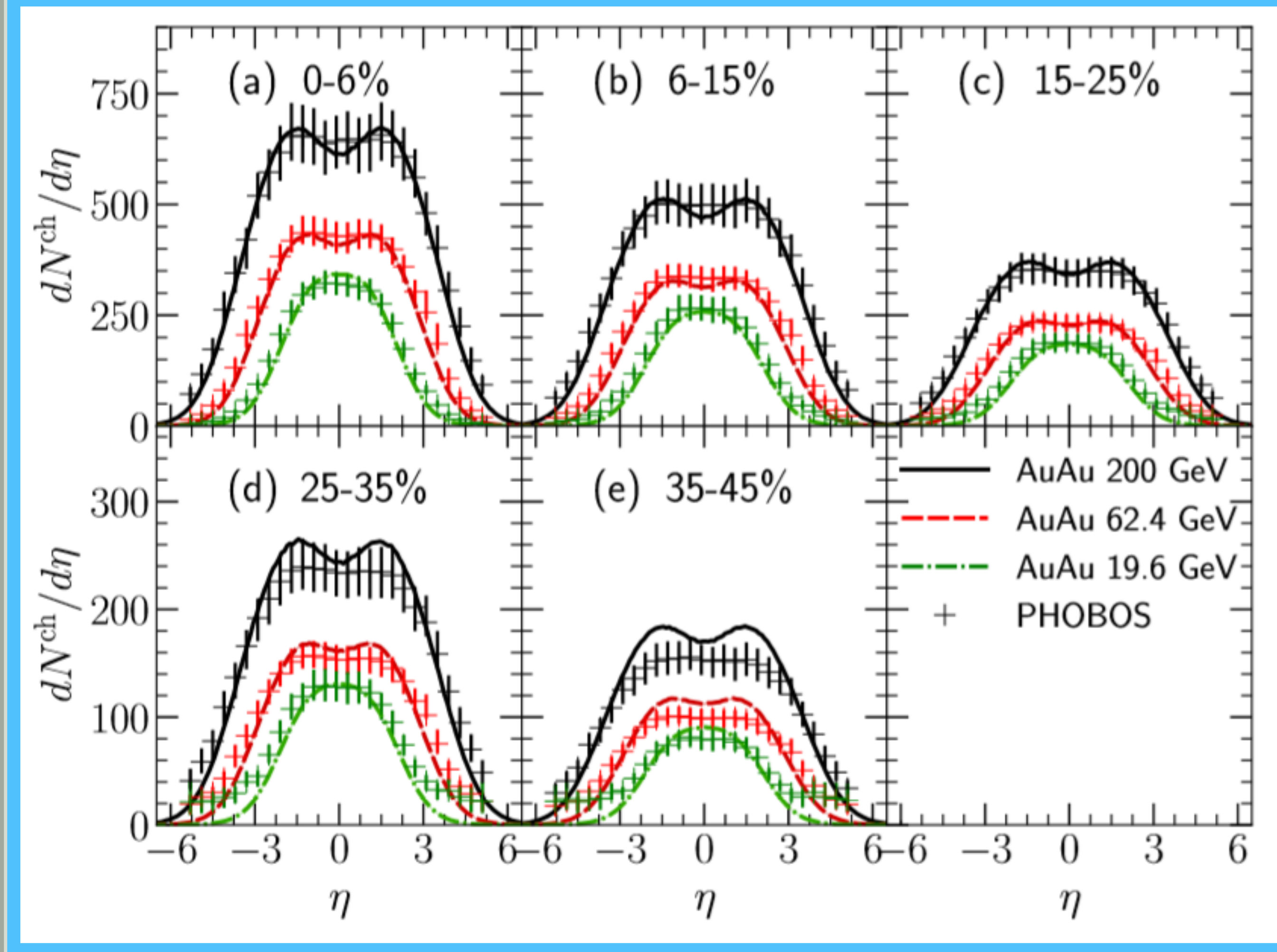
T_A&T_B are the nucleus thickness function

3D Initial Energy Density Distribution



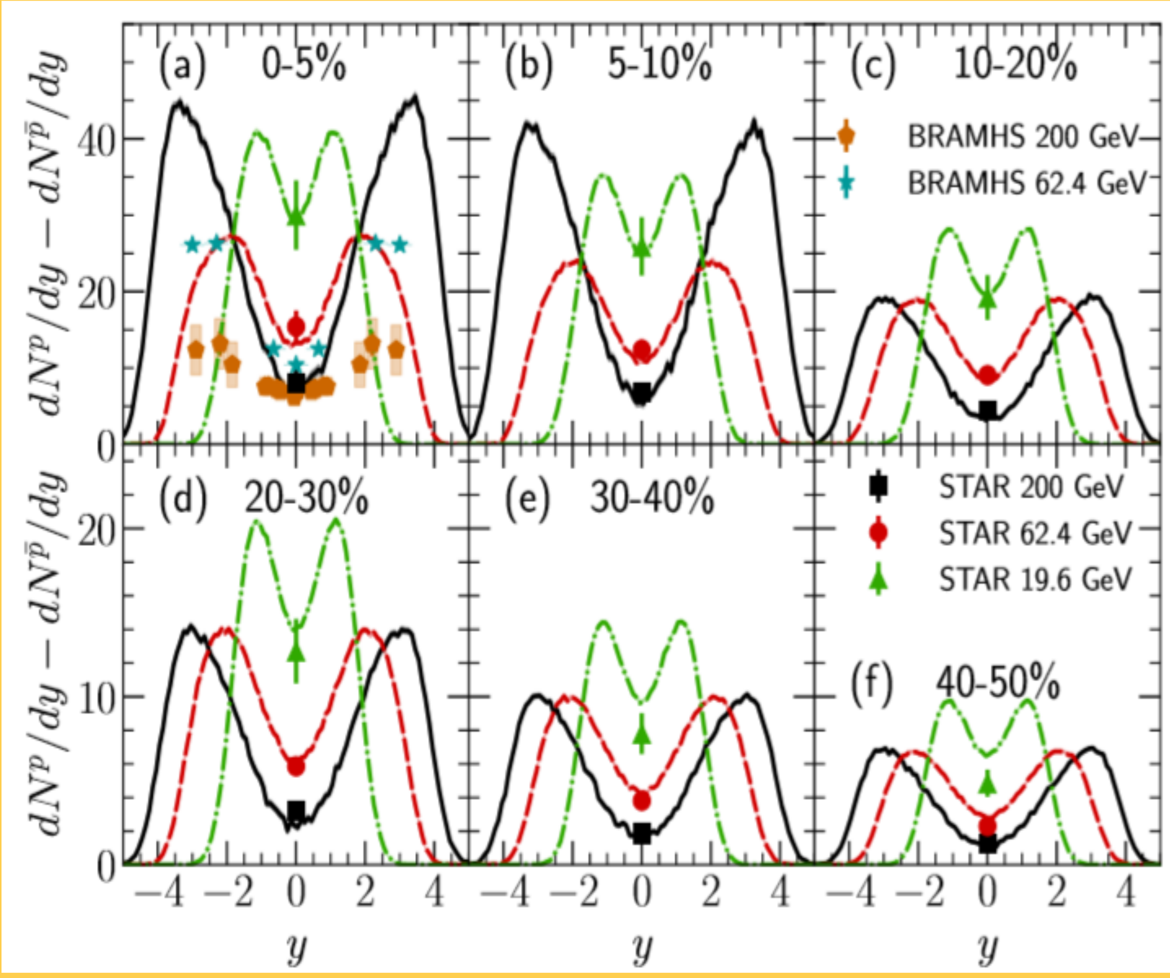
- Longitudinal momentum shifts energy plateau to forward and backward rapidities; The shape of energy density become more eccentric

Charge Hadron Production



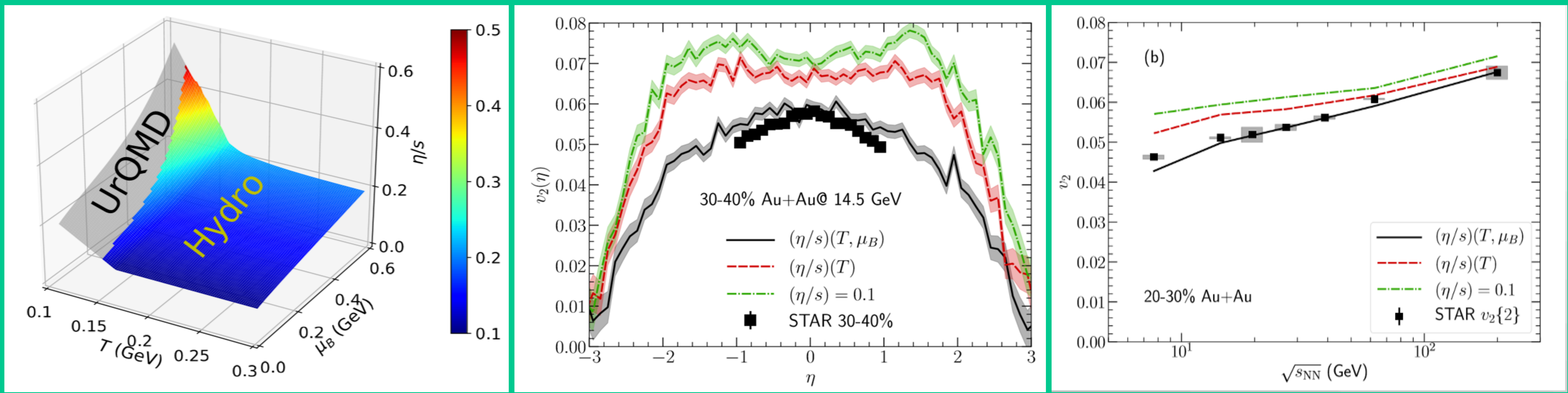
- Model calibrated in central collision [panel (a)]; Good prediction in semi-peripheral centralities [(b)-(e)]

Baryon Stopping Dynamics



- The net proton rapidity distributions are reasonably reproduced

Constraining of $\eta/s(T, \mu_B)$ with elliptic flow



- Elliptic flow measurements as a function of η as well as $\sqrt{s}$ set strong constraints on the QGP η/s as a function of (T, μ_B)

Conclusion and outlook

- Energy and momentum conservation play an crucial role in constructing 3D initial conditions for heavy-ion collisions $e \propto \sqrt{T_A T_B}$
- Elliptic flow measurements at beam energy scan can set strong constraints on $\eta/s(T, \mu_B)$

➡ Model fluctuations from initial-state and critical point

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