Effects of hydrodynamic fluctuations on azimuthal flow in ultra-central heavy-ion collisions

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Abstract: In ultra-central heavy-ion collisions, because of lack of collision geometry, fluctuations play very important roles to generate anisotropic flow. While initial state fluctuations are actively studied, hydrodynamic fluctuations during the space-time evolution of QGP are also important. We simulate with and w/o hydrodynamic fluctuations and initial state fluctuations using Integrated Dynamical Model and analyze the effects of hydrodynamic fluctuations on anisotropic flow quantitatively.

1. Introduction

Purpose of this study
- Massive numerical simulations with & w/o fluctuations
- Evaluate the effects of hydrodynamic fluctuations on anisotropic flow
- Compare simulation results with experimental data

2. Integrated Dynamical Model and Analysis

Describe the whole process of heavy-ion collision reaction using several models for different stages of reaction

Fix impact parameter \( b = 0 \) fm
- Absence of collision geometry effects: Only fluctuation effects
- Analyze the effects of hydrodynamic fluctuations
- Initial state model
- QGP hydro model
- ON/OFF initial state fluctuations
- ON/OFF hydrodynamic fluctuations

3. Relativistic Fluctuating Hydro Model

- Conservation Law + EoS
- Constitutive eq.

\[
\tau_\alpha \Delta^{\alpha\beta} \partial_t \Delta^{\beta\gamma} + \left( \frac{1}{3} \tau_\alpha \partial_\alpha \Delta^{\beta\gamma} \right) = 2 \eta \Delta^{\alpha\beta} \partial_\beta \Delta^{\alpha\gamma} + \delta \eta \partial_\alpha
\]

\( \tau_\alpha \): Relaxation time
\( \eta \): Shear viscosity
\( \Delta^{\alpha\beta} \): Landau frame

Flow harmonics

4. Result: Flow Harmonics

<table>
<thead>
<tr>
<th>Method</th>
<th>Flow Harmonics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluctuating hydro model</td>
<td>overestimates the experimental data especially in ( v_2 )</td>
</tr>
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<td>Hydrodynamic fluctuations</td>
<td>generate anisotropic flow</td>
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<td>Anisotropic flow by hydrodynamic fluctuations</td>
<td>exhibits a similar tendency to experiment</td>
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</table>

5. Summary and Outlook

- We analyze the effects of hydrodynamic fluctuations on anisotropic flow using the results of \( b = 0 \) fixed Integrated Dynamical Model with and w/o initial state fluctuations.
- Hydrodynamic fluctuations generate anisotropic flow even without initial fluctuations, and elliptic flow \( v_2 \) and triangular flow \( v_3 \) are almost the same.
- We also compare simulation results with experimental data (0-0.2% Centrality).
- Simulation results overestimate the experimental data especially in \( v_2 \).
- In future, we plan to introduce initial fluctuating flow distributions into Integrated Dynamical Model for better description of experimental results.