Quantifying deviations from local equilibration in a coarse-grained transport approach

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Abstract

Many hybrid models of heavy ion collisions construct the initial state for hydrodynamics from transport models. Hydrodynamics requires that the energy-momentum tensor $\mathbf{T}^{\mu\nu}$ and four-currents $\mathbf{j}^{\mu}$ do not deviate considerably from the equilibrium ideal-fluid form, but the ones constructed from transport do not necessarily possess this property. In this work we investigate the space-time picture of $T^{\mu\nu}$ deviations from equilibrium in Au+Au collisions using a coarse-grained transport approach. The collision energy is varied in the range $E_{CN}=5-16A$ GeV. The sensitivity of $T^{\mu\nu}$ deviations from equilibrium to collision centrality, and other parameters such as the switching criterion, the amount of statistics used to construct the initial state, and the smearing parameter $\sigma$ is investigated. For low statistics deviations of $T^{\mu\nu}$ from equilibrium are large and dominated by the effect of finite sampling. For large statistics the pressure anisotropy drops the most significant role, while the off-diagonal components of $T^{\mu\nu}$ are small in a large volume during the whole evolution. For all considered energies and centralities the pressure anisotropy exhibits a similar feature: there is a narrow interval of time, when it rapidly drops in a considerable volume. This allows us to introduce an "isotropization time", which is found to decrease with energy and slightly increase with centrality. The isotropization times are larger than times typically used for initializing hydrodynamics.

Methodology


2) Create a 2D grid in the event plane and compute energy-momentum tensor $T^{\mu\nu}$ at each point of this grid

3) Transform $T^{\mu\nu}$ to the local Landau rest frame in each grid cell

4) Quantify deviation from ideal fluid using three quantities

Pressure anisotropy:

$$\frac{|T_{xx} - T_{yy}|}{T_{xx} + T_{yy}}$$

Off-diagonality:

$$\frac{|T_{xy}|}{T_{xx} + T_{yy}}$$

Relative velocity between Landau and Eckart frames:

$$v_{LE} = \sqrt{\frac{1}{2}(T_{xx} + T_{yy} - T_{xy})}$$

5) Vary collision energy and centrality

Pressure anisotropy evolution at several space points of $E = 50A$ GeV Au+Au collision, $0 < X < 2$ is always true, for ideal hydrodynamics $X = 0$. Further results on the pressure anisotropy are in the center.

Smearing kernel

$$K(r) = (2\pi m)^{-3/2} \exp\left(-\frac{r^2}{2\sigma^2}\right)$$

Sensitivity to the smearing $\sigma$

Summary

- Deviation of the energy-momentum tensor $T^{\mu\nu}$ from ideal fluid in the coarse-grained molecular dynamics Au+Au simulations was studied
- For large enough statistics off-diagonality is small
- Local pressure anisotropy rapidly increases over the whole volume at some time, which we call isotropization time
- The isotropization time decreases with collision energy, the trend is similar to that of the geometrical overlap time
- All results are sensitive to the smearing parameter

Effect of cuts

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