Shear and bulk viscosities of strongly interacting parton-hadron matter*

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Introduction

We study the shear and bulk viscosities of "infinite" partonic and hadronic matter as functions of temperature T within the parton-hadron-string dynamics (PHSD) off-shell transport approach [1]. The PHSD transport model, which is based on a lattice QCD (lQCD) equation of state [2] and accordingly well describes the entropy density $s(T)$, the energy density $\varepsilon(T)$ as well as the pressure $p(T)$ in comparison to lQCD results.

The "infinite" matter is simulated within a cubic box with periodic boundary conditions initialized at various values for baryon density (or chemical potential) and energy density. The size of box is fixed to 9^3 fm^3. The initialization is done by populating the box with light (u, d) and strange (s) quarks, antiquarks and gluons with random space positions. If the energy density in the system is below the critical energy density ($\varepsilon_c \approx 0.5$GeV/fm^3), the evolution proceeds through the dynamical phase transition and ends up in an ensemble of hadrons. The system initially is close to the thermal equilibrium with thermal distribution for the momenta of partons and far out from the chemical equilibrium due to the strangeness suppression by factor of 3 in comparison to the light quarks and antiquarks. The system approaches kinetic and chemical equilibrium at all energies densities during it's evolution within PHSD. After equilibration, the properties of the system at given temperature can be studied. For more details we refer thre reader to Ref. [3], where the particle abundances, spectra, fluctuations and spectral functions were studied.

Shear and bulk viscosities

The ratio of the shear viscosity to entropy density $\eta(T)/s(T)$ extracted from the PHSD simulations in the box, which is presented in Fig. 1, shows a minimum (with a value of about 0.1) close to the critical temperature T_c, while it approaches the perturbative QCD (pQCD) limit at higher temperatures. For $T < T_c$, i.e. in the hadronic phase, the ratio η/s rises fast with decreasing temperature due to a lower interaction rate of the hadronic system and a significantly smaller number of degrees of freedom. We obtain practically the same results in the Kubo formalism and in the relaxation time approximation. Our results are also in almost quantitative agreement with the ratio $\eta(T)/s(T)$ from the virial expansion approach as well as with lQCD data for the pure gauge sector.

The bulk viscosity $\zeta(T)$ evaluated in the relaxation time

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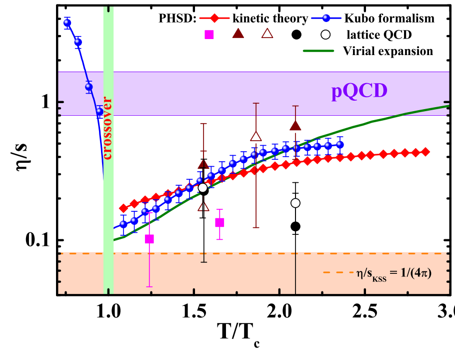

Figure 1: The specific shear viscosity η/s as a function of T/T_c extracted from PHSD simulations in the box.

approach, which is shown in Fig. 2, is found to strongly depend on the effects of mean fields (or potentials) in the partonic phase. We find a significant rise of the ratio $\zeta(T)/s(T)$ in the vicinity of the critical temperature T_c, when consistently including the scalar mean-field from PHSD, which is also in agreement with that from lQCD calculations.

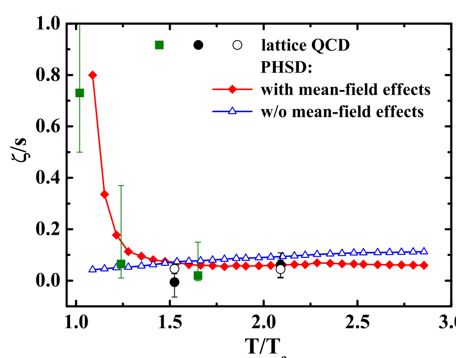

Figure 2: The specific bulk viscosity ζ/s as a function of T/T_c extracted from PHSD simulations in the box.

References

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