Parton-hadron matter in- and out-off equilibrium

O.Linnyk for the PHSD group

Institut für Theoretische Physik, Universität Giessen, 35392 Giessen, Germany

Contact email: *Olena.Linnyk@theo.physik.uni-giessen.de*

We study the equilibrium properties of strongly-interacting infinite parton-hadron matter and the non-equilibrium dynamics of heavy-ion collisions within the Parton-Hadron-String Dynamics (PHSD) transport approach, which incorporates explicit partonic degrees of freedom in terms of strongly interacting quasiparticles (quarks and gluons) in line with an equation of state from lattice QCD as well as the dynamical hadronization and hadronic collision dynamics in the final reaction phase.

We present the equilibration of observables and their fluctuations in the QGP and also transport coefficients, such as shear and bulk viscosity [1], as well as out-off equilibrium phenomena seen in azimuthal angular distribution in higher harmonics (v1,v2,v3,v4) in heavy-ion collisions at ultrarelativistic energies [2].

We find that the ratio of the shear viscosity to entropy density $\eta(T)/s(T)$ from PHSD 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 in line with lattice QCD results. Within statistics, we obtain practically the same results in the Kubo formalism and in the relaxation time approximation. The bulk viscosity $\zeta(T)$ – evaluated in the relaxation time approach – is found to depend strongly 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.

In non-equlibrium case of heavy-ion collisions the experimentally observed increase of the elliptic flow v_2 of charged hadrons with collision energy is successfully described in terms of the PHSD approach. The PHSD scaling properties of various collective observables are confronted with experimental data as well as with hydrodynamic predictions. The analysis of higher-order harmonics v_3 and v_4 in the azimuthal angular distribution shows a similar tendency of growing deviations between partonic and purely hadronic models with increasing collision energy. This demonstrates that the excitation functions of azimuthal anisotropies reflect the increasing role of quark-gluon degrees of freedom in the early phase of relativistic heavy-ion collisions. Furthermore, the specific variation of the ratio $v_4/(v_2)^2$ with respect to bombarding energy, centrality and transverse momentum is found to provide valuable information on the underlying dynamics.

[1] V. Ozvenchuk, O. Linnyk, M. I. Gorenstein, E. L. Bratkovskaya and W. Cassing, arXiv:1212.5393 [hep-ph]; arXiv:1203.4734 [nucl-th].

[2] V. P. Konchakovski, E. L. Bratkovskaya, W. Cassing, V. D. Toneev, S. A. Voloshin and V. Voronyuk, Phys. Rev. C **85** (2012) 044922 [arXiv:1201.3320 [nucl-th]].