SHEAR VISCOSITY OF A HADRONIC GAS MIXTURE

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We discuss in detail the shear viscosity coefficient η and the viscosity to entropy density ratio η/s of a hadronic gas of pions and nucleons. In particular, we study the effects of baryon chemical potential on η and η/s. We solve the relativistic quantum Boltzmann equations with binary collisions ($\pi\pi$, πN, and NN) for a state slightly deviated from thermal equilibrium at temperature T and baryon chemical potential μ. The use of phenomenological amplitudes in the collision terms, which are constructed to reproduce experimental data, greatly helps to extend the validity region in the T-μ plane. This is highly contrasted with the case with low energy effective field theories. The total viscosity coefficient $\eta(T,\mu) = \eta^\pi + \eta^N$ increases as a function of T and μ, indirectly reflecting energy dependences of binary cross sections. The increase in μ direction is due to enhancement of the nucleon contribution η^N while the pion contribution η^π diminishes with increasing μ. On the other hand, due to rapid growth of entropy density, the ratio η/s becomes a decreasing function of T and μ in a wide region of the T-μ plane. In the kinematical region we investigated $T < 180$ MeV, $\mu < 1$ GeV, the smallest value of η/s is about 0.3, thus it never violates the conjectured lower bound $\eta/s = 1/4\pi \sim 0.1$ as shown in the figure. (However, the results of the effective field theories violate the bound.) The smallness of η/s in the hadronic phase and its continuity at $T \simeq T_c$ (at least for crossover at small μ) implies that the ratio will be small enough in the deconfined phase $T \gtrsim T_c$. There is a nontrivial structure at low temperature and at around normal nuclear density. We examine its possible interpretation as the liquid-gas phase transition.

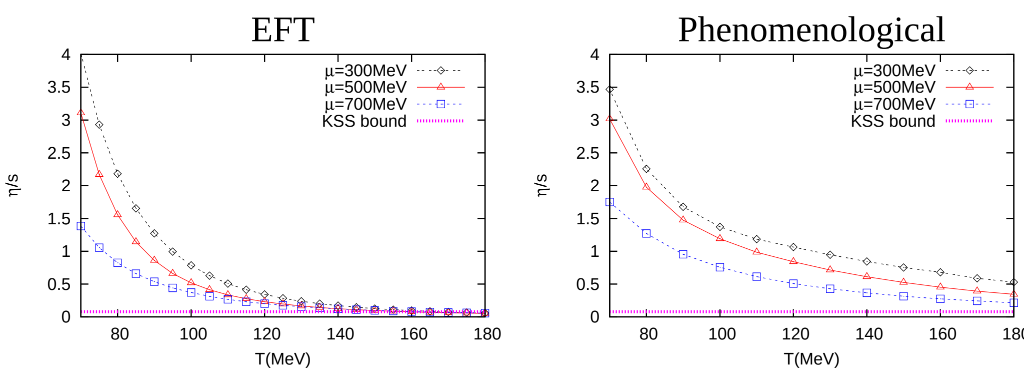

Figure 1: The ratio η/s as a function of temperature at different baryon chemical potentials $\mu = 300$, 500, 700MeV. Left panel is the results of the low energy effective field theories (EFT), and Right panel is the results of the phenomenological amplitudes.

References

[1] K. Itakura, O. Morimatsu, and H. Otomo, arXiv:0711.1034 [hep-ph].