Medium effects on Relaxation times and Transport coefficients of Pion-Kaon-Nucleon system

A. Pallavi Kalikotay[1],* Nilanjan Chaudhuri[2], Snigdha Ghosh[3], and Sourav Sarkar[2]
[1] *Department of Physics, Kazi Nazrul University, Asansol - 713340, West Bengal*
[2] *Variable Energy Cyclotron Centre, Kolkata - 700064, West Bengal and*
[3] *Indian Institute of Technology Gandhinagar, Palaj, Gandhinagar - 382355, Gujarat*

Experimental studies on elliptic flow of hadrons at RHIC suggests a small but finite value of shear viscosity over entropy density ratio η/s. This has lead to the widespread interest in the study of dissipative phenomena in the dynamical evolution of matter produced in relativistic heavy ion collisions.

Transport coefficients which are the measures of dissipative processes in the system are estimated e.g. by considering the transport of momenta and heat among the constituents. Collisions among the constituents of the system are responsible for such transport and hence the collision integral that appears on the right hand side of the transport equation has the scattering cross section as the dynamical input. The production of hadronic matter in the later stages of relativistic heavy ion collision takes place during the later stages of heavy ion collisions when the matter is still at very high temperature and/or density. Hence in order to have a realistic estimate of the transport co-efficients it is important to consider the medium effects on the scattering cross-section. In this work, we have considered a multi-component system composed of pions, kaons and nucleons. Pions are the most abundantly produced species in heavy ion collisions and a few studies have been made to understand the medium effects on transport properties of pion system [[1]-[2]]. Kaons are the next most abundant species and nucleons are introduced in the system so that we can study the variation of transport coefficients as a function of baryonic density.

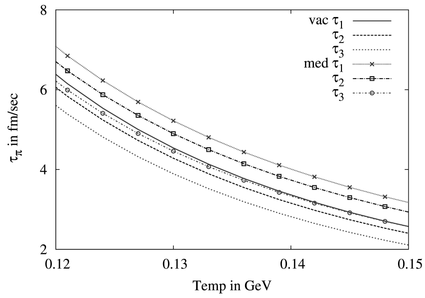

FIG. 1: Vaccum and Medium average relaxatime time of pions in pion system(τ_1), pion-kaon system (τ_2) and pion-kaon-nucleon system (τ_3).

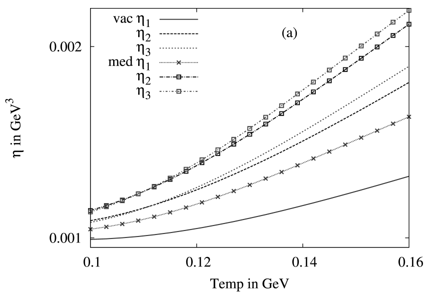

FIG. 2: Shear viscosity coefficient in vaccum and medium of pions in pion system(η_1), pion-kaon system (η_2) and pion-kaon-nucleon system (η_3).

In the Fig.[1] and all the other plots shown henceforth, suffixes 1, 2 and 3 denote pion, pion-kaon and pion-kaon-nucleon systems respectively. The reduction of relaxation time with increasing temperature can be explained classically, since it goes like $\sim 1/n\sigma$ where n is the number density and σ is the cross section. Now with the increase in temperature the density n increases and plays the dominant role

*Electronic address: orionpallavi@gmail.com

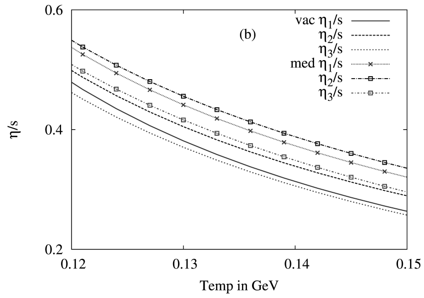

FIG. 3: Vacuum and in-medium kinematic viscosity η/s of pions in pion system(η_1/s), pion-kaon system (η_2/s) and pion-kaon-nucleon system (η_3/s)..

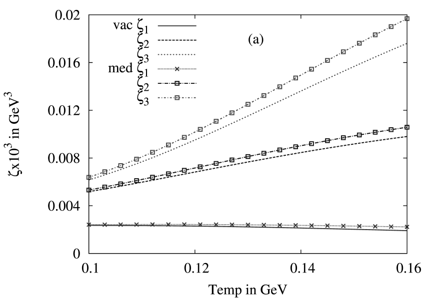

FIG. 4: Bulk viscosity coefficient in vaccum and medium of pions in pion system(ζ_1), pion-kaon system (ζ_2) and pion-kaon-nucleon system (ζ_3)..

to reduce the relaxation time. Also note that with the increase in number of components which results in an overall gain in the system density, the average relaxation time decreases. This can be understood from the fact that as the density of the system increases, it undergoes a larger number of collisions because of which the relaxation mechanism gets boosted. Furthermore, the individual relaxation time is inversely proportional to the cross section. The latter has been shown to decrease with temperature and density. This suppression of cross-section has lead to the increase in the magnitude of relaxation time. Fig. 2 shows the variation of shear viscosity for both vacuum and in-medium cross-sections as a function of temperature. The medium effects has increased the magnitude of η in all the three

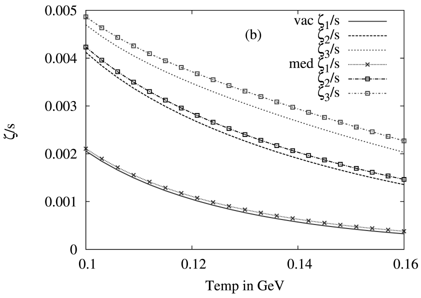

FIG. 5: Bulk viscosity over entropy (ζ/s) of pions in pion system(ζ_1), pion-kaon system (ζ_2) and pion-kaon-nucleon system (ζ_3) with and without the medium effects.

cases which is due to the increase in medium relaxation time of the constituents. Now, since entropy density(s) reduces with increase of temperature, the kinematic viscosity(η/s) will decrease monotonically with increase of temperature. This is evident from Fig.3 for all the systems under considerations. One should note that the minimum value of η/s is well above the KSS-bound. The variation of bulk viscosity(ζ) and ratio ζ/s as a function of temperature are shown in Figs.4 and 5 for pion system, pion-kaon system and pion-kaon-nulceon system respectively. The medium effects are evident in this case as well.

Thus it is seen that the medium effects modify the temperature and density dependence of the viscous coefficients to an appreciable extent. Also the addition of components to the pion gas leads to an increase in the magnitude of viscous coefficients.

References

[1] Sukanya Mitra, Sabyasachi Ghosh and Sourav Sarkar, Phys. Rev. C85, 064917(2012).

[2] Sukanya Mitra and Sourav Sarkar Phys. Rev. D87, 094026(2013)