Electrical Conductivity and Shear Viscosity of Quark Gluon Plasma in a Quasiparticle Model

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Introduction

Relativistic heavy-ion collisions (HIC) have reported the formation of a strongly coupled quark gluon plasma (sQGP) [1]. To study the properties of this sQGP is the main focus nowadays. Among these the shear viscosity (η) and electrical conductivity (σ_{el}) could reflect the transport properties of the medium. By studying the shear viscosity or more specifically shear viscosity to entropy density ratio (η/s), one can understand the nature of interactions among the constituents of the produced medium, it gives a measure of the fluidity. Electrical conductivity represents the linear response of the system to an applied external electric field. The basic question one could ask is that whether the matter created at heavy ion collision experiment is an electrical conductor or an insulator. Recent lattice QCD as well as phenomenological studies have shown that these transport quantities show some kind of minimum in its variation with respect to temperature near the temperature corresponding to the transition from hadronic phase to quark-gluon phase.

Very recently it has been shown that the ratio $(\eta/s)/(\sigma_{el}/T)$ is independent of the uncertanities due to the running coupling $g(T)$ [2]. Therefore the dimensionless ratio $(\eta/s)/(\sigma_{el}/T)$ can provide information of the properties of the strongly interacting matter with controlled model uncertainties [2]. This ratio is also calculated with a quasiparticle model and presented here. In next section we will present the method to calculate the shear viscosity and electrical conductivity in a quasiparticle model [3, 4] which is followed by the results.

Model Calculations

The details of quasiparticle model can be found in Ref. [3, 4]. The expression to calculate the shear viscosity can be written as follows :

$$\eta = \frac{1}{15T}\int \frac{d^3k}{(2\pi)^3}\frac{k^4}{E^2}\, g\, \tau_{q/g} \times \left[f_0(1\pm f_0)+\bar{f}_0(1\pm \bar{f}_0)\right], \quad (1)$$

and that corresponding to the electrical conductivity as :

$$\sigma_{el} = \frac{e^2}{3T}\int \frac{d^3k}{(2\pi)^3}\frac{k^2}{E^2}\, g\, \tau_{q} \times \left[f_0(1- f_0)+\bar{f}_0(1- \bar{f}_0)\right], \quad (2)$$

where k is the momentum and $E=\sqrt{k^2+M^2}$ is the energy with M being the thermal mass for quark or gluon, $\pm$ for fermion and boson (i.e., quark and gluon), respectively and f_0 ($\bar{f}_0$) stands for equilibrium distribution function for particle and anti-particle, respectively. In Eqs. (1) and (2), τ is the collision time. To calculate the collision time for quarks, antiquarks and gluons in QGP we use the expressions as derived in Ref [5]. We get the final expression for shear viscosity and electrical conductivity by adding the contributions of all types of particles in Eqs. (1) and (2), respectively.

Results

In Fig. 1, we have presented the variation of η/s with respect to T/T_C at zero chemical potential by the magenta band where T_C corresponds to the quark-hadron transition temperature. Band arises due to the uncertanity in the QCD scale parameter (Λ). We have

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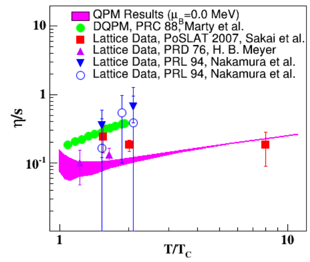

FIG. 1: (colour online) Variation of shear viscosity to entropy density ratio (η/s) with respect to T/T_C at zero chemical potential.

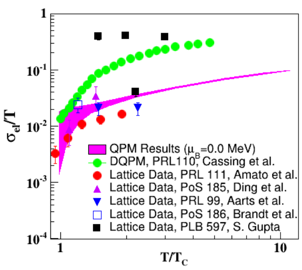

FIG. 2: (colour online) Variation of DC electrical conductivity to temperature ratio (σ_{el}/T) with respect to T/T_C at zero chemical potential.

compared our model results to the corresponding results obtained in various lattice calculations. Further we have also compared our results with the results obtained in dynamic quasiparticle model (DQPM). We find that

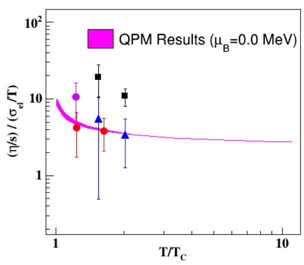

FIG. 3: (colour online) Variation of $(\eta/s)/(\sigma_{el}/T)$ with respect to T/T_C at zero chemical potential. Interpolated lattice results are taken from Ref. [2].

the η/s increases with increase in temperature for the QGP phase. Our results are in accordance with some of the lattice calculations (which currently has large uncertainties).

Fig. 2, shows the variation of σ_{el}/T with respect to T/T_C at zero chemical potential. We have compared our model results to the corresponding results obtained in various lattice calculations and the results obtained in dynamic quasiparticle model (DQPM). We find that the σ_{el}/T increases monotonically with increase in temperature of the QGP system.

Fig. 3, demonstrates the variation of $(\eta/s)/(\sigma_{el}/T)$ with respect to T/T_C at zero chemical potential. We have compared our model results to the corresponding results obtained in Ref. [2] by interpolating the results of various lattice calculations. We find that the ratio start from a large value near the $T/T_C = 1$ and then it decreases with increase in temperature.

In conclusion, we have calculated the two important transport properties of QGP in the framework of a quasiparticle model. These have been compared to available lattice QCD calculations (at few temperature values with large uncertainties). The agreement with lattice QCD calculations are found to be reasonable. Both the η/s and σ_{el}/T are observed to increase with temperature in our model.

Acknowledgments

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References

[1] P. Romatschke and U. Romatschke, Phys. Rev. Lett. 99, 172301 (2007); B. Schenke, S. Jeon and C. Gale, Phys. Rev. C 82, 014903 (2010).
[2] A. Puglisi, S. Plumari and V. Greco, arXiv:1407.2259v1[hep-ph].
[3] P. K. Srivastava, S. K. Tiwari, C. P. Singh, Phys. Rev. D 82, 014023 (2010).
[4] P. K. Srivastava, C. P. Singh, Phys. Rev. D 85, 114016 (2012).
[5] A. Hosoya and K. Kajantie, Nucl. Phys. B 250, 666 (1985).