A study on Quark-Gluon plasma equation of state using thermal quark mass

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Abstract

We study the QGP equation of state (EoS) using a simple statistical model. In this, temperature dependent quark mass is used with the inclusion of curvature term. The model results provide QGP EoS which are in good agreement with the lattice QCD results.

Introduction

It is widely accepted that the ulta-relativistic heavy-ion collisions bring us information about the properties of QGP. At high temperature and/or high chemical potential, quantum chromodynamics (QCD) predicts the order of phase transition from hadronic phase to the quark-gluon plasma phase. Such phase transition form a new state of matter, called the quark-gluon plasma (QGP) [1, 2].

Model Description

So far we have calculated the free energy with effect of curvature term using dynamical quark mass [3]. we now extend the previous work using finite quark mass to calculate EoS [4]. The finite quark mass is temperature dependent and defined as [4]:

$$m_q^2(T) = \gamma_q g^2(k) T^2. \tag{1}$$

where, $g^2(k) = 4\pi\alpha_s$ and other parameters are used as Ref. [3, 4]. The parametrization factor $\gamma^2 = 2[\frac{1}{\gamma_q^2} + \frac{1}{\gamma_g^2}]$ is used with $\gamma_q = 1/6$ [4] and $\gamma_g = 0.02\gamma_q$ is used to fit into lattice QCD results.

Evolution of free energy

The free energy, F_i for quarks and gluons is modified with the inclusion of curvature term using finite quark mass using Ref. [3, 4]. It is defined as:

$$F_i = \mp T g_i \int dk \rho_i(k) \ln(1 \pm e^{-(\sqrt{m_i^2+k^2})/T}) , \tag{2}$$

where $\rho_i(k)$ is the density of states of the particular particle i (quarks and gluons), and g_i is the degeneracy factor and its value is taken from [5]. Using equation (2), we can calculate pressure and energy density using thermodynamic relation. It is given as Ref. [5]:

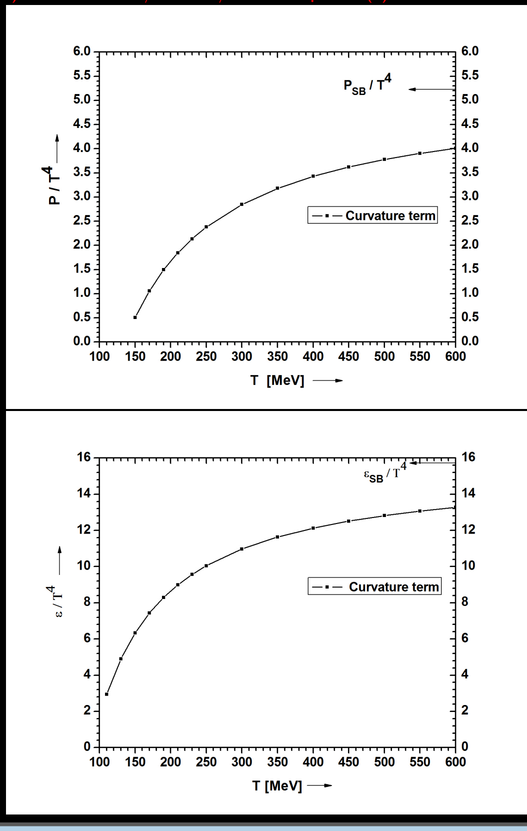
$$P_i = -\frac{d}{dv} F_i . \tag{3}$$

where, i stands for quarks, gluons and interface term. Total pressure is the sum of the pressure due to all the constituents. Further the energy density is used as [5],

$$\varepsilon = T \frac{d}{dT} P - P . \tag{4}$$

Using these relations, we calculate P/T^4 and ε/T^4. These relations are useful to study the quark gluon plasma equation of state using temperature dependent quark mass with curvature term. We can also compute entropy and speed of sound using above relation but here we are not taken into account.

(Figure): The variation of P/T^4 and ε/T^4 with temperature (T) is shown.



Results and Conclusion

In Figures [1] and [2] we show the plots of P/T^4 and ε/T^4 with temperature (T). Both the graphs are matched with lattice results especially at high temperature T∼ 600 MeV. At such high temperature, P/T^4 and ε/T^4 approach a value which is below the SB limit. Our results using temperature dependent quark mass with the effect of curvature term are almost same as Ref. [5]. It shows that the theoretical model with the thermal correction in the quark mass including curvature term does not alter the results of Gosain et al. [5] very much, in fact the change caused in the QGP EoS is negligible. Our results are compared with the results of Ref. [5]. Also the EoS prediction by other models are in conformity with lattice results [1, 2].

Overall, the present model gives a negligibly small improvement so it varifies the previous theoretical results in QGP EoS. Thus, the temperature dependent quark mass with the inclusion of curvature term shows the useful information to study QGP EoS in high energy heavy-ion collisions.

References

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