A Comparative Study of Heavy Quark Potential with KMS Model in a Hot QCD medium within a Quasi Particle Model

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Introduction

Following is a recent work on the comparative study of heavy quark potential with KMS model on the effective description of the equations of state for hot QCD medium in terms of the quasi-gluons and quasi-quark/antiquarks with respective effective fugacities. Since the velocity of the quarks in the bound state is small, $v \ll 1$, so quarkonium can be understood in terms of non-relativistic potential models [1] using the Cornell potential [2].The potential model descriptions have also been applied to understand quarkonium properties at finite temperature. The pioneering paper of Matsui and Satz [3] was followed by the work of Karsch, Mehr and Satz (KMS) [5], which presented the first quantitative calculation. Here, we shall consider an isotropic QGP medium which is descibed in terms of quasi-particle degrees of freedom based on a recently proposed quasi-particle model for hot QCD equations of state [4]. We first obtain the medium modified form of the heavy quark potential by correcting the full Cornell potential and then determined the dissociation temperatures for pure, 2-, 3-flavor in hot QCD medium using quasi particle debye mass.After then the comparative study of heavy quark potential with KMS model and corrected quark mass KMS model have been performed with the assumption of an isotropic medium.

1. Formalism

For the description heavy-quark potential at finite temperature in an isotropic plasma we consider the r-dependence of the medium modified potential [6, 7] having form:

$$\mathbf{V}(r,T) = \left(\frac{2\sigma}{m_D^2} - \alpha\right)\frac{\exp(-m_D r)}{r} - \frac{2\sigma}{m_D^2 r} + \frac{2\sigma}{m_D} - \alpha m_D \quad (1)$$

Here,α is an effective Coulomb coupling at (moderately) short distances, σ is the string tension and $m_D(T)$ [8] is the Debye screening mass which has the form in the pure gluonic case:

$$m_D^2 = g^2(T)T^2\left(\frac{N_c}{3} \times \frac{6PolyLog[2,z_g]}{\pi^2}\right) \quad (2)$$

and full QCD:

$$m_D^2 = g^2(T)T^2\left[\left(\frac{N_c}{3} \times \frac{6PolyLog[2,z_g]}{\pi^2}\right) + \left(\frac{N_f}{6} \times \frac{-12PolyLog[2,-z_q]}{\pi^2}\right)\right] \quad (3)$$

Here, $g(T)$ is the QCD running coupling constant, $N_c = 3$ $(SU(3))$ and N_f is the number of flavor, the function $PolyLog[2,z]$ having form, $PolyLog[2,z] = \sum_{k=1}^{\infty}\frac{z^k}{k^2}$ and z_g is the quasi-gluon effective fugacity and z_q is quasi-quark/antiquark effective fugacity. Both z_g and z_q have a very complicated temperature dependence and asymptotically reach to the ideal value unity [4]. Now,the KMS model [5] assumes the above form of the heavy-quark potential at finite temperature in an isotropic plasma with $\xi = 0$. This potential represents an interpolation from the well-known Cornell potential at short distance to an exponentially Debye-screened string attraction at large r. Since finite quark mass can also be accounted so corrections to KMS potential has to be done by adding a temperature and spin-independent correction proportional

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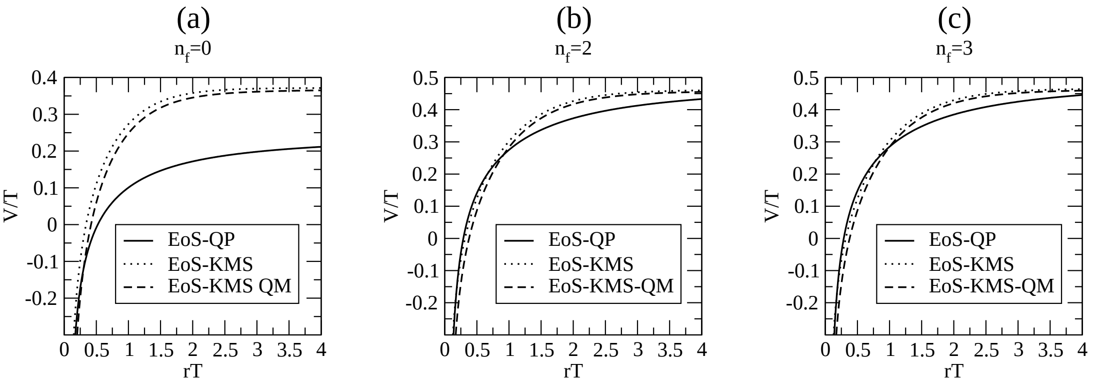

FIG. 1: The comparison of $V(r,T)/T$ of Quasi Particle EoS as a function of rT with KMS EoS and corrected KMS Quark Mass potential.

TABLE I: Lower(upper) bound on the dissociation temperature(T_D) for the quarkonia states (in units of T_c) using fugacity parameters

State	Pure QCD	$N_f = 2$	$N_f = 3$
J/ψ	1.6(1.9)	1.6(2.1)	1.5(2.0)
ψ'	1.3(1.5)	1.2(1.6)	1.2(1.5)
Υ	1.9(2.4)	2.1(2.6)	2.0(2.5)
Υ'	1.5(1.8)	1.6(1.9)	1.5(1.8)

to $\sigma/(m_Q^2\, r)$ [9].Thus the accuracy of the wave functions of quarkonium states has improved, which is obtained from the solution of the Schrödinger equation.

2. Results and Discussion

We have plotted the heavy quark potential of rT for fixed T/T_c for pure gluonic, $N_f = 2$ and $N_f = 3$ cases and compared it with the KMS model and corrected Quark Mass KMS model [10]. We have incorporated the Debye mass of quasi particle for pure gluonic and full QCD cases. We see that in Fig.1 heavy quark potential is close to KMS model and corrected Quark mass KMS potential.For pure gluonic case, heavy quark potential does not overshoot the KMS and corrected Quark mass KMS potential model. On the other hand, it shows that at higher number of flavor i.e. for $N_f = 2$ and $N_f = 3$ cases heavy quark potential overshoots the KMS and corrected Quark mass KMS potential model. After then we subsequently determined the dissociation temperature of heavy Quarkonium listed in Table 1 in hot QCD medium by employing the medium modification to a heavy quark potential and explore how the pattern changes for gluonic case and full QCD.

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