Quark Binding Potential in QGP

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Abstract: The interquark potential of the heavy mesons like $b\bar{b}$ and $c\bar{c}$ immersed in Quark Gluon Plasma(QGP), gets screened due to the presence of the medium QGP. The dissociation energies of the heavy mesons have been studied in detail with the modified form of the screened Yukawa potential of the QGP and the Rosner interquark potential. The critical screeninig parameters have also been estimated.

1. Introduction:

It is well known that the strongly interacting matter with a very high density undergoes a transition to a state of deconfined quarks and gluons. Deconfinement takes place if the color screening dissolves the binding potential between quark and quark or quark and antiquark. The J/ψ or the Υ have much smaller radii than the radii of usual mesons and nucleons, due to which the bound state remains unaffected in QGP unless and until the temperature or the density becomes so high that the binding of bound state gets broken. The suppression of J/ψ is the one of the signals for quark deconfinement [1]. To investigate quark plasma formation experimentally, it is essential to depend on color screening and deconfinement. In QGP medium, the string tension between a charm c and a charm antiquark $\bar{c}$ disappears and quarks and gluons are deconfined. Only the Coulomb type of color interaction exists between the c and the $\bar{c}$. After the deconfinement of J/ψ, it is impossible to create it by hadronization of plasma. Hence in high energy heavy ion collisions, the suppression of J/ψ production may be considered as a symbol for the presence of quark gluon plasma [1,2-7]. Karsch et al [7] have observed the dependence of the dissociation energies, the binding radii and the masses of heavy quark resonances on the color screening length r_D of the medium and concluded that no binding exists below r_D. Liu et al [8] have studied the binding and dissolution for the $c\bar{c}$ and $b\bar{b}$ bound states using different quark potentials in a non-relativistic approximation. They have estimated the critical value of the screening length using Debey screening effect. They have also estimated the critical temperature T_c of medium. Stubbins [9] has used the generalized variational method to investigate energies for the Yukawa and Hulthen potentials.

In the present work we have investigated the effect of $q\bar{q}$ potential on QGP. The variation of dissociation energy with screening length have been estimated for different value of screening parameter. The critical screening length at which dissociation energy vanishes for heavy mesons and their excited states have been extracted.

2. Methodology:

The Hamiltonian for a $q\bar{q}$ system can be represented

$$H(r,T) = \frac{\overrightarrow{p}^2}{2m_{re}} + V_{q\bar{q}(r,T)} \tag{1}$$

where m_{re} is the reduced mass of the $q\bar{q}$ system,$V_{q\bar{q}}(r,T)$ is the interquark binding potential. The quark-antiquark potential can be represented as phenomenological Rosner potential[10] which runs as:

$$V_{qq}(r,0) = -0.712GeV + 0.801GeV\frac{(r \times 1GeV)^{\alpha} - 1}{a} \quad (2)$$

where a is the constant and is equal to 0.12 [10], and r is radius of heavy mesons. In the thermodynamic environment of quarks and gluons the interquark potential gets modified due to the color screening so that the qq potential can be represented as:

$$V_{qq}(r,T) = -\frac{Z\langle\rangle}{r}-(-0.772GeV + 0.801GeV\frac{(r \times 1GeV)^{\alpha} - 1}{a}] \quad (3)$$

where Z is a constant and is equal to 1 GeV^{-1} and λ is a temperature dependent screening parameter which is parameterized as $\lambda(T) = \lambda(0)(1 - T/T_c)^{-0.2}$ and $\lambda(0) = 0.2GeV$[7]. Considering the wave function [9]

$$\Psi_K = B_k r^k e^{-(\beta/2)} Y_{l,m}(\theta,\phi) \quad (4)$$

K = 0,1,2,..... and l = 0,1,...

here B_k is normalization constant and can be represented as:

$$B_k = \left(\frac{\beta^{2k+3}}{(2k+2)!}\right)^{1/2} \quad (5)$$

where β is variational parameter (9], the eigenvalue equation can be represented as [7]:

$$[H(r,\lambda(T)) - E_{n,l}(\lambda(T))]\Psi_K(r,\lambda(T)) = 0 \quad (6)$$

where the principal quantum number n and orbital quantum number l ? $(n-1)$ classify the eigenvalues.

The energy needed for the dissolution of bound states of heavy quarks at the critical temperature T_c is very essential quantity and at $\lambda(T)$, the dissolution energy is defined as(8]

$$E_{dis}^{n,l}(\lambda(T)) = V_{qq}(r \to \infty, \lambda(T)) + B_{nl}(\lambda(T)) \quad (7)$$

where $B_{nl}(\lambda(T))$ represents the binding energies of the mesons. At $r \to \infty$ the equation (7) reduces to:

$$E_{dis}^{n,l}(\lambda(T)) = B_{nl}(\lambda(T)) \quad (8)$$

The dissolution energy indicates the dissociation of the bound states. The value of dissolution energy is positive for bound states and is negative for continuum which leads to the condition:

$$E_{dis}^{n,l}(\lambda(T)) = 0 \quad (9)$$

Equation (9) gives the critical value of λ, beyond which for given quantum number there are no bound states. With the wave function [9] the expression for the binding energy becomes:

$$\langle H\rangle = \frac{tr/32}{2m} - 21r/33[(\text{?} + (-0.772))] \frac{}{(\beta+\lambda)^2} \quad (10)$$

We have considered first three radial excitation corresponding to J/ψ and T for n=1, l=0, ψ' and T' for n=2, l=0 and ψ'' and T'' for n=3, l=0 and X_c and X_b for n=2, l=1. We have estimated the critical screening parameter ($\lambda_c(T)$) with different values of variational parameter β and results are furnished in Table No.1.

Table 1: Estimated critical temperature dependent screening parameter ($\lambda_c(T)$) in GeV of the heavy mesons with different values of variational parameter (β) in GeV.

[illegible]	β=0.5
[illegible]	2.248
[illegible]	.4805
[illegible]	0.453
[illegible]	0.478
[illegible]	4.475
[illegible]	0.955
[illegible]	0.708
[illegible]	0.936

In the present work we have investigated in detail the variation of dissociation energies of the $b\bar{b}$ and $c\bar{c}$ heavy mesons with screening parameter which is function of temperature. We have considered the screening parameter β which lies in the range of 0.1 GeV to 0.5 GeV. Liu et al[8] has studied the quark binding potential in QGP for various value of power of potential between quark and antiquark and studied J/ψ suppression. The study of critical screening length is of utmost importance for the study of QGP. In the present work we have studied the effect of interquark Rosner potential on the screeniing of Yukawa potential of QGP, which is responsible for the dissociation of heavy mesons in QGP. In our future work we would study the problem considering various phenomenological potentials between quarks and anti quarks. For the better understanding of the J/ψ and Υ suprcssion as the signatures of QGP, our work would help to continue further studies in the domain of dissociation of heavy mesons in QGP.

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