Color Screening and the lowest bound state radii of Quakonia in QGP Medium

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Introduction

In heavy-ion collision programs, the theoretical and experimental developments, aim to identify and characterize the properties of strongly interacting matter at high temperature with high density. At high temperture the hadronic matter is expected to undergo phase-transition to QGP. Quarkonium production is rather well understood in hadron-hadron collisions[1]. Behavior of the bound states of heavy quarks in a strongly interacting medium close to the deconfinement temperature T_c is of interest in the physics of quarkonium.

Formalism

For the description of the heavy quark bound states, we consider the non-relativistic Hamiltonian as

$$H = M + \frac{p^2}{2M_1} + V(r,T), \quad (1)$$

Where, M=m_1+m_2 and M_1=$\frac{m_1.m_2}{m_1+m_2}$ and m_c=1.320GeV, m_b=4.746GeV, α=0.471, σ=0.192$GeV^{\nu+1}$ and μ=1/r_D the inverse of screening length [2]. The interaction potential between quark-antiquark pair in a QGP medium is given by[3]

$$V(r,\mu) = \frac{-\alpha}{r} e^{-\mu(T)r} + \frac{\sigma}{\mu(T)}(1 - e^{-\mu(T)r^{\nu}}),$$

$$E(r,\mu(T)) = M + \frac{p^2}{2M_1} + V(r,\mu(T)) \quad (2)$$

Now, considering $<p^2><r^2>$=c, the uncertainty relation makes c of the order of unity and its precise value will depend on the choices of wave function. Minimizing eqn.(2) by neglecting medium effects i.e. $\mu \to 0$ we have obtain the lowest bound radii r_0 equals to 0.378fm and 0.169fm and the constant, c as 1.487 and 1.181 respectively for charmonium and bottomonium for the case of ν=1.

TABLE I: Different parameters of charmonia($c\bar{c}$) with potential exponent

ν	μ_c(GeV)	r_0(fm)	r_D(fm)
0.3	1.733	17.64	0.114
0.5	0.957	3.45	0.206
0.7	0.659	1.49	0.299
0.9	0.533	0.81	0.370
1.0	0.496	0.69	0.397
1.1	0.467	0.61	0.423
1.3	0.422	0.51	0.467
1.5	0.387	0.45	0.509
1.7	0.360	0.41	0.548
1.9	0.338	0.37	0.584
2.1	0.320	0.36	0.616
2.3	0.305	0.34	0.647
2.5	0.292	0.32	0.676
2.7	0.282	0.29	0.699
3.0	0.268	0.27	0.736

Bound States of Quarkonium with Medium Effects

Here we consider the stability effects due to the medium (through $\mu \neq$0) on the bound state of quarkonium (charmonia and bottomonia) states. We define an effective binding energy as [2]

$$E_{eff}(r,\mu) = E(r,\mu) - 2m - \sigma/\mu, \quad (3)$$

For different values of μ, the radius for which E_{eff}(r,μ) has a minimum is determined. With increase in the value of μ the radii for the bound state decreases and at cer-

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TABLE II: Different parameters of bottomonia ($b\bar{b}$) with potential exponent

ν	μ_c(GeV)	r_0(fm)	r_D(fm)
0.3	2.10	8.35	0.094
0.5	1.29	1.85	0.152
0.7	1.05	0.34	0.186
0.9	1.02	0.27	0.192
1.0	1.01	0.26	0.194
1.1	1.00	0.26	0.195
1.3	0.998	0.23	0.198
1.5	0.991	0.22	0.199
1.7	0.98	0.22	0.199
1.9	0.98	0.20	0.199
2.1	0.98	0.20	0.199
2.3	0.98	0.20	0.199
2.5	0.98	0.18	0.199
2.7	0.98	0.18	0.199
3.0	0.99	0.18	0.198

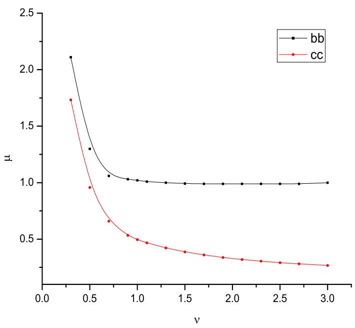

FIG. 1: Dependence of colour screening parameter (μ_c) of $c\bar{c}$ and $b\bar{b}$ with power exponent ν

tain value of μ, we find no bound state as E_{eff} becomes zero. At this critical point, the screening parameter μ=μ_c and above μ_c no bound state will be possible. This screening parameter μ_c, the colour screening length r_D=$1/\mu_c$ and the lowest bound state radii r_0, are obtained for quarkonia and bottomonia and are listed in TABLE I and II.

Results and Conclusion

We conclude that when μ reaches to $\sim$0.5GeV (and $\sim$1.0GeV), the binding be-

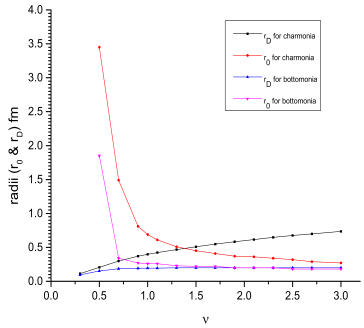

FIG. 2: Dependence of color screening radii (r_D) and lowest bound radii (r_0) of $c\bar{c}$ and $b\bar{b}$ with power exponent ν

comes impossible for $c\bar{c}$ (and $b\bar{b}$). The bound state radii for $c\bar{c}$ and $b\bar{b}$ at the last binding point increased to two to three times more than it was for the case at μ=0. The charmonia (and bottomonia) binding potential is effectively screened upto the inter quark separation of 0.4fm (0.166fm) while the size of the last bound states of charmonia (and bottomonia) is around 0.67fm (0.257fm).

Here, FIG.(1) shows a sharp decrease in μ_c with ν upto 1.0 for both charmonia and bottomonia and then it becomes almost constant. FIG.(2) shows that there is a small variation in color screening parameter for charmonia. It decreases sharply upto ν=0.5 then decreases slowly with increase in ν and in bottomonia upto ν=0.5 and further it becomes almost constant with respect to ν. While for lowest bound state there is a sharp decrease in r_0 till ν=1.0 and moving further (i.e. ν >1.0) it remains constant.

References

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