Medium effects on $c\bar{c}$ states through colour screening

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Introduction

The heavy-ion collision programs of current and past experiments taking place at CERN, aim to identify and characterize the properties of strongly interacting matter at high temperature with high density. One of their goals is to produce deconfined quark matter. Energetic partons (jets), EM signals, suppression of heavy flavour, etc are the experimental signatures of the deconfined state.The deconfinement occurs when colour screening shields a quark from binding potential of any other quark or antiquark. Though there exist Effective Field Theory methods and lattice simulations to study the deconfinement mechanisms study based on phenomelogical model is very simple and an important tool to understand the screening effects on the binding energy of quarkonia states [1].

Formalism

In this paper, we present the deconfinement of heavy quark states in a medium through screening parameter (μ) with in a non-relativistic frame work for charmonia. The Hamiltonian for such a system is given by

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

Where, M=m_1+m_2 and M_1=$\frac{m_1.m_2}{m_1+m_2}$. The interquark interaction is described through a phenomenological potential with screening effect as given by [2]

$$V(r, \mu) = \frac{-\alpha}{r} e^{-\mu r} + \frac{\sigma}{\mu}(1 - e^{-\mu r^{\nu}}), \qquad (2)$$

with m_c=1.320GeV, α=0.471, and μ=$1/r_D$ the inverse of screening length [3]. The potential strength σ is fixed for each choices of ν, to yield the spin average ground state mass of charmonium without the medium effects (μ=0). The radial soutions are employed to compute the mean square states. The Schrödinger eqn. is solved numerically using mathematica notebook [4] for each choices of ν from 0.1 to 2.0 to obtain $E_{n,l}$. The vanishing of the bound state of quarkonia has been observed through dissociation energy defined as [3]

$$E^{n,l}_{eff}(\mu) \equiv 2m + \frac{\sigma}{\mu} - E_{n,l}(\mu), \qquad (3)$$

TABLE I: Screening parameters of $c\bar{c}$ 1s-state at μ=μ_c for different choices of σ

ν	σ	μ_c	r_{rms}	$M(\mu_c)$	r_D
	$GeV^{\nu+1}$	GeV	fm	GeV	fm
0.1	0.441	1.01547	0.67704	3.07428	0.19433
0.3	0.355	0.90442	0.72658	3.03252	0.21819
0.5	0.294	0.80337	0.77376	3.00595	0.24564
0.7	0.246	0.71047	0.81914	2.98624	0.27776
0.9	0.207	0.62863	0.86436	2.96929	0.31392
1.0	0.192	0.59417	0.88668	2.96314	0.33213
1.1	0.176	0.5612	0.9136	2.95361	0.35164
1.3	0.149	0.50597	0.97351	2.93448	0.39002
1.5	0.127	0.46265	1.04001	2.9145	0.42654
1.7	0.108	0.42787	1.1094	2.89241	0.46122
2.0	0.085	0.3889	1.20957	2.85856	0.50743

where, n is principal quantum number and l≤(n-1)orbital quantum number. Here, we restrict ourself to few low lying $c\bar{c}$ (1s, 1p, 2s) states. We study the screening effects of $c\bar{c}$ for each choices of the potential exponent, ν from 0.1 to 2.0. Eqn.(3) is positive for the bound state and get negative for the continuum. Hence, $E^{n,l}_{eff}(\mu_c)$=0 defines a critical value for the screening mass and beyond which

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no more binding is possible and hence the bound state will not exist.

TABLE II: Screening parameters of $c\bar{c}$ 2s-state at μ=μ_c for different choices of σ

ν	σ	μ_c	r_{rms}	$M(\mu_c)$	r_D
	$GeV^{\nu+1}$	GeV	fm	GeV	fm
0.1	0.833	0.83193	0.96962	3.64128	0.2142
0.3	0.570	0.70145	1.14599	3.45259	0.2565
0.5	0.406	0.58339	1.35904	3.33593	0.3116
0.7	0.295	0.47153	1.60487	3.26562	0.3894
0.9	0.217	0.36723	1.86448	3.23091	0.4628
1.0	0.192	0.32305	1.98204	3.23433	0.5774
1.1	0.160	0.27809	2.14255	3.21535	0.6484
1.3	0.119	0.21129	2.50665	3.2032	0.7643
1.5	0.088	0.16417	3.04708	3.17603	1.0462
1.7	0.066	0.1342	3.69515	3.1318	1.3025
2.0	0.043	0.11535	4.34165	3.05612	1.7621

TABLE III: Screening parameters of $c\bar{c}$ 1p-state at μ=μ_c for different choices of σ

ν	σ	μ_c	r_{rms}	$M(\mu_c)$	r_D
	$GeV^{\nu+1}$	GeV	fm	GeV	fm
0.1	0.728	0.92101	0.90081	3.43043	0.21426
0.3	0.517	0.76931	1.03515	3.31203	0.25652
0.5	0.385	0.63324	1.18696	3.24798	0.31164
0.7	0.293	0.50668	1.35569	3.21827	0.38948
0.9	0.227	0.42629	1.40402	3.32733	0.46292
1.0	0.192	0.34172	1.58942	3.20186	0.57749
1.1	0.177	0.30429	1.62205	3.22168	0.64854
1.3	0.139	0.25813	1.61366	3.3257	0.76449
1.5	0.11	0.18859	1.92708	3.22327	1.04639
1.7	0.087	0.15148	2.24087	3.21433	1.30274
2.0	0.062	0.11197	3.02153	3.19371	1.76243

Results and Conclusion

The fig.1 show the computed $E_{eff}(\mu)$ $c\bar{c}$ 1s, 1p and 2s-states respectively for the potential exponent 0.7$\leq$ ν $\leq$1.3. The computed results of different screening parameter are listed in table I, II and III. We observe a systematic decrease in μ with increase in the choices of ν. In all the cases we find the effective screening length (r_D) is much smaller than the rms radii of the respective states at μ=μ_c. We also observed that mass of $c\bar{c}$ states at μ=μ_c, $M_{n,l}(\mu_c) < M_{n,l}(\mu$=0). These observation indicate the dissociation of $c\bar{c}$ states at μ=μ_c.

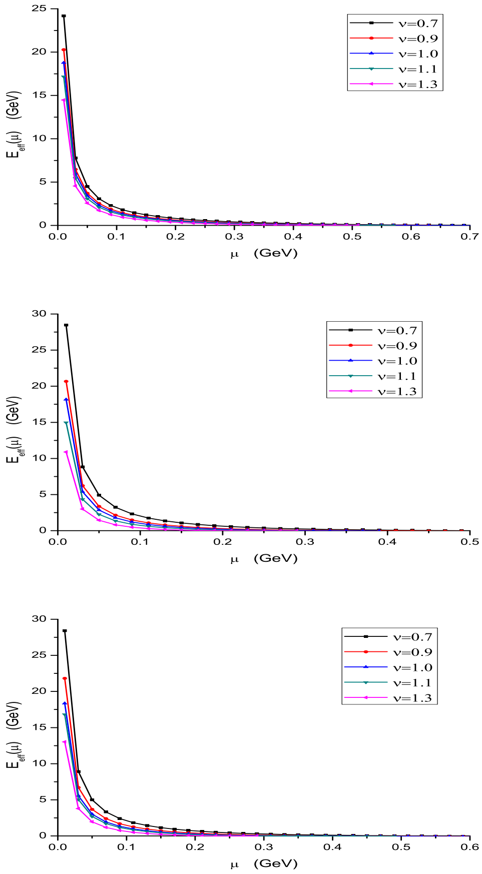

FIG. 1: Dissociation energies for $c\bar{c}$ 1s, 2s, 1p-state respectively for different choices of ν

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