Bottomonium Suppression based on Quasi-Particle Model In Isotropic hot QCD Medium

Vineet Kumar agotiya[1*] and Indrani Nilima[1]
[1]*Department of Physics,Central University of Jharkhand,brambe, Ranchi-835205 INDIA*

Introduction

In the early days most of the interests were focused on the suppression of charmonium states [1, 2] of collider experiments at SPS and RHIC, but several observations are yet to be understood *namely* the suppression of ψ (1S) does not increase from SPS to RHIC, even though the centre-of-mass energy is increased by fifteen times. The heavy-ion program at the LHC may resolve those puzzles because the beam energy and luminosity are increased by ten times of that of the RHIC. Moreover the CMS detector has excellent capabilities for muon detection and provides measurements of ψ(2S) and the Υ family, which enables the quantitative analysis of quarkonia. That is why the interest may be shifted to the bottomonium states at the LHC energy.

In the present article, we shall employ quasi-particle model for hot QCD equations of state [3] to extract the debye mas which is obtained in terms of quasi-particle degrees of freedom.

1. Heavy quark potential and debye mass in isotropic medium

A potential model for the phenomenological descriptions of heavy quarkonium suppression would be quite useful inspite of the progress of direct lattice QCD based determinations of the potential. We can obtain the medium-modification to the vacuum potential by correcting its both Coulombic and string part with a dielectric function $\epsilon(p)$ encoding the effect of deconfinement [4]. Now the imaginary part of the potential in the QGP medium has been considered, which reads [5, 6].Here we had used the temperature dependence of the quasi-particle Debye mass, m_D^{QP} in full QCD with $N_f = 3$ to determine bottomonium suppression.

2. Binding energy and Survival of bottomonium state

The solution of the Schrödinger equation gives the eigenvalues for the ground states and the first excited states in bottomonium (Υ, Υ' etc.) spectra :

$$\mathrm{Re}\ \mathrm{E}^{\mathrm{iso}}_{\mathrm{bin}} \overset{\hat{s}\gtrsim 1}{=} \left(\frac{\mathrm{m_Q}\sigma^2}{\mathrm{m_D^4 n^2}} + \alpha \mathrm{m_D}\right);\ \mathrm{n} = 1, 2 \cdots (1)$$

where m_Q is the mass of the heavy quark.

In our analysis, we have fixed the critical temperature ($T_c = 0.197GeV$) and have taken the quark masses m_Q, as m_Υ = 4.5 GeV, $m_{\Upsilon'} = 5.01$ GeV and $m_{\chi_b} = 5.18$GeV, as calculated in [9] and the string tension (σ) is taken as $0.184GeV^2$.

As we know, dissociation of a quarkonia bound state in a thermal QGP medium will occur whenever the binding energy, E_B of the said state will fall below the mean thermal energy of a quasi-parton. In such situations the thermal effect can dissociate the quakonia bound state. To obtain the lower bound of the dissociation temperatures of the various quarkonia states, the (relativistic) thermal energy of the partons will 3 T. The dissociation is suppose occur whenever,

$$\mathrm{Re}\ \mathrm{E}^{\mathrm{iso}}_{\mathrm{bin}} \overset{\hat{s}\gtrsim 1}{=} \mathrm{E_B(T_D)} = 3\mathrm{T_D}. \qquad (2)$$

The T_D's for the $b\bar{b}$ sates Υ, Υ' and χ_b with the dissociation temperature are listed in Table I for EoS. We observe that (on the basis of temperature dependence of binding energy) ψ' dissociates at lower temperatures as compared to J/ψ and χ_c for the equations of state.

*Electronic address: agotiya81@gmail.com

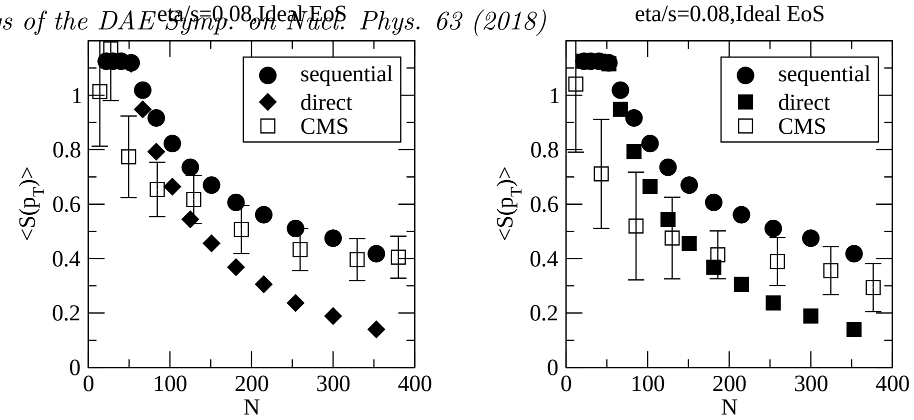

FIG. 1: The variation of integrated survival probability versus N for Υ at $\sqrt{S_{NN}}$=5.02 TeV with preliminary CMS data [8] and 2.76 TeV with preliminary CMS data [7].The experimental data are shown by the squares with error bars whereas circles and diamond represent with () without () sequential melting using the value of T_D's and related parameters from Table I for equation of state.

TABLE I: Dissociation temperatureT_D (for a 3-flavor QGP), using quasi-particle debye mass for bottomonium states, for EoS2.

State	τ_F	T_D	c_s^2(SIQGP)	ϵ_s(SIQGP)	ϵ_s(Id)
Υ	0.76	2.04	0.335	27.05	27.09
Υ'	1.90	1.58	0.328	9.35	9.44
χ_b	2.60	1.65	0.331	11.21	11.34

The -integrated inclusive survival probability of Υ in the QGP becomes [10].

$$\langle S^{\text{incl}} \rangle = 0.6_{\Upsilon} + 0.3_{\chi_b} + 0.1_{\Upsilon'} \qquad (3)$$

3. Results and Conclusions

Here we are using the values as inputs listed in Table I to calculate for EOS.The experimental data (the nuclear-modification factor R_{AA}) are shown by the squares with error bars whereas circles represent sequential suppression. We had compared our results with the experimental results for the case of $\eta/s = 0.08$ and found good agreement. We observe from the fig 1 that for both the directly and sequentially produced Upsilon (Υ) are quite high with the higher values of T_D's for deal equation of states. We find that the survival probability of sequentially produced Υ is slightly higher compared to the directly produced Υ and is closer to the experimental results. We have studied the sequential suppression for bottomonium states at the LHC energy by using quasi particle debye mass. We have found a good agreement with the experimental data from LHC 2.76 TeV/nucleon Pb-Pb, and LHC 5.02 TeV/nucleon Pb-Pb collisions [11, 12].

References

[1] T. Matsui and H. Satz, Phys. Lett. B **178**, 416 (1986).

[2] F. Karsch, M.T. Mehr, H. Satz, Z. Phys. C **37**, 617 (1988).; F. Karsch, H. Satz, Z. Phys.C **51**, 209 (1991).

[3] Vinod Chandra, A. Ranjan, V. Ravishankar, Euro. Phys. J C **40**, 109 (2009);Phys.Rev.C **76**, 054909 (2007).

[4] V. Agotiya, V. Chandra and B. K. Patra, Phys. Rev. C **80**, 025210 (2009).

[5] V.K.Agotiya, V.Chandra, M.Y. Jamal , I. Nilima, Phys. Rev. D **94**, 094006 (2016);Pepan Letters **15**, 2 (2018).

[6] L.Thakur, U.Kakade and B. K. Patra,Phys. Rev.D 89,094020 (2014).

[7] CMS Collaboration Twiki, CMS-PAS-HIN-10-006,2015.

[8] Chad Flores (ALICE Collaboration), Quark matter 2017, https://goo.gl/imTtmM, 2017.

[9] V.M.Aulchenko *et al.* [KEDR Collaboration], Phys. Lett. B **573**, 63 (2003).

[10] H. Satz, Nucl. Phys. **A783**, 249 (2007).

[11] B.Krouppa, R.Ryblewski,M.Strickland, Nucl. Phys. A **00**, 1-4 (2017).

[12] B.Krouppa, R. Ryblewski,M.Strickland, Phys. Rev. C **92**, 061901 (2015).