Dissociation of heavy quarkonia in an anisotropic medium

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I. INTRODUCTION

Following our recent work on dissociation of heavy quarkonia, within quasi-particle approach, for the isotropic medium in Ref. [1], the present analysis accommodate the presence of local momentum anisotropy to estimate the dissociation temperature of heavy quarkonia. While considering the momentum anisotropy, both the oblate and the prolate situation have been taken into account and compared with the isotropic one. The motivation to incorporate the anisotropy in the study of quarkonia suppression comes from the fact that, the QGP produced in heavy ion (off-central) collisions does not possess isotropy. Instead, the momentum anisotropy is present in all the stages of the heavy-ion collisions, and hence, the inclusion of the anisotropy is inevitable.

The dissociation temperatures have been calculated by exploiting the criterion [2–5], that says, at the dissociation temperature, the thermal width equals twice the (real part of) binding energy. The effects of anisotropy will modify the in-medium potential and, in turn, significantly revise the values of dissociation temperature. In the oblate case the dissociation temperature has observed to be higher than the isotropic case. While in the prolate case, it is observed to be the least among the three cases. The tightly bound ground state has higher binding energies and is expected to melt later than the excited state and hence, they must have a sequential suppression pattern with temperature. The order observed in the present analysis supports the above fact as, $\Upsilon^{'}$ ($2s$-state of $b\bar{b}$), has been suppressed at smaller temperature than the Υ ($1s$-state of $b\bar{b}$), for all considered EoSs.

II. EFFECTIVE FUGACITY QUASI-PARTICLE MODEL(EQPM)

EQPM, maps the hot QCD medium effects with the effective equilibrium distribution function, $f_{g,q}(p)$, of quasi-partons [6, 7], that describes the strong interaction effects in terms of effective fugacities, $z_{g,q}$.

The Debye mass, m_D can be obtained using the distribution functions given as,

$$m_D^2 = -4\pi\alpha_s(T)\bigg(2N_c\int\frac{d^3p}{(2\pi)^3}\partial_p f_g(\mathbf{p}) + 2N_f\int\frac{d^3p}{(2\pi)^3}\partial_p f_q(\mathbf{p})\bigg), \tag{1}$$

Applying quasi-parton equilibrium distribution function we have,

$$m_D^{2\,(EoS(i))} = 4\pi\alpha_s(T)T^2\bigg(\frac{2N_c}{\pi^2}PolyLog[2,z_g^i] - \frac{2N_f}{\pi^2}PolyLog[2,-z_q^i]\bigg). \tag{2}$$

Where the index-i, denotes the different EoSs, incorporating the QCD interactions modeled from improved perturbative 3-loop HTL QCD computations by N. Haque *et, al.* [8, 9] and recent $(2+1)$-flavor lattice QCD simulations [10, 11].

In the limit, $z_{g,q}\to 1$ the m_D, reduces to the leading order (LO) or ideal case given as,

$$m_D^{2\,(LO)} = 4\pi\alpha_s(T)\;T^2(\frac{N_c}{3}+\frac{N_f}{6}). \tag{3}$$

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A. Binding energy(E_b) and thermal width (Γ)

The imaginary part of the potential is a perturbation to the vacuum potential, provides an estimate for the thermal width for a particular resonance state which is given by the following equation,

$$\Gamma(T) = -\int d^3\mathbf{r}\;|\Psi(r)|^2\,\mathrm{Im}\;V(\mathbf{r}) \tag{4}$$

Ultimately, the thermal width for the leading logarithmic order for $1s$-state is given as,

$$\Gamma_{1s}(T) = T\left(\frac{4}{\alpha m_Q^2}+\frac{12\sigma}{\alpha^4 m_Q^4}\right)\left(1-\frac{\xi}{6}\right)m_D^2\log\left(\frac{\alpha m_Q}{2m_D}\right). \tag{5}$$

Similarly, the thermal width for the leading logarithmic order for $2s$-state is given as,

$$\Gamma_{2s}(T) = a_0^2\;m_D^2\left(\frac{\xi}{3}-2\right)T\log\left(\frac{1}{a_0 m_D}\right)\left(7\alpha+48\sigma\;a_0^2\right). \tag{6}$$

Now, exploiting the criteria discussed earlier, we can plot twice the binding energy along with the thermal width and obtain the dissociation temperature as a point of their intersection.

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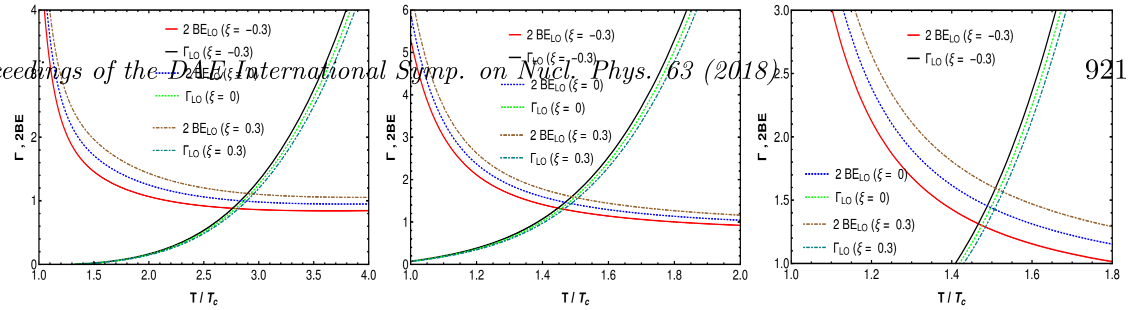

FIG. 1. Γ, 2BE(E_b) vs T/T_c for Υ (left panel), $\Upsilon^{'}$ (middle panel) and J/ψ (right panel), at $T_c = 0.17GeV$ with different ξ for the leading order (non-interacting) results .

III. RESULTS AND DISCUSSION

In present analysis, the various quantities has been obtained and the results are plotted, while considering the week anisotropy in the hot QCD plasma with the fixed critical temperature, $T_c = 0.17$ GeV. For prolate, $\xi = -0.3$ and for oblate, $\xi = 0.3$ has been considered whereas for the isotropic one we have, $\xi = 0$.

TABLE I. Ideal (non-interacting EoS) results for all three prolate, isotropic and oblate cases

LO results			
Temperatures are in the unit of T_c			
States ↓	$\xi = -0.3$	$\xi = 0.0$	$\xi = 0.3$
Υ	2.861	2.964	3.062
Υ′	1.447	1.478	1.508
J/ψ	1.487	1.520	1.551

In Fig. 1, the thermal width of Υ (left panel), $\Upsilon^{'}$ (middle panel) and J/ψ (right panel) have been plotted, along with twice the real part of their corresponding BE. In all the plots, for oblate cases, $\xi = 0.3$, the intersection points are found to be the larger as compared to the isotropic cases, $\xi = 0$. The numbers for prolate cases, $\xi = -0.3$, observed to be the least among them. In the LO case, one can observe that the dissociation temperature is higher for Υ (1s- state), as compared to J/ψ (1s- state), while the excited states, $\Upsilon^{'}$ (2s- state) has lowest dissociation temperature. This hierarchy has been observed in all the three oblate, prolate and the isotropic cases.

A similar pattern is observed while taking the hot QCD medium effects into consideration, either through HTL perturbative results or lattice simulation results.

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[1] V. K. Agotiya, V. Chandra, M. Y. Jamal and I. Nilima, Phys. Rev. D **94**, 094006 (2016).
[2] A. Mocsy and P. Petreczky, Phys. Rev. Lett. **99**, 211602 (2007).
[3] Y. Burnier, M. Laine, and M. Vepsalainen, JHEP. **01**, 043 (2008).
[4] M. A. Escobedo, J. Soto Phys. Rev. A **78**, 032520 (2008).
[5] M. Laine, Nucl. Phys. A **820**, 25C (2009).
[6] V. Chandra, R. Kumar, V. Ravishankar, Phys. Rev. C **76**, 054909 (2007); [Erratum: Phys. Rev. C **76**, 069904 (2007)]; V. Chandra, A. Ranjan, V. Ravishankar, Eur. Phys. J. A **40**, 109-117 (2009).
[7] V. Chandra, V. Ravishankar, Phys. Rev. D **84**, 074013 (2011).
[8] N. Haque, A. Bandyopadhyay, J. O. Andersen, Munshi G. Mustafa, M. Strickland and Nan Su, JHEP **1405**, 027 (2014).
[9] J. O. Andersen, N. Haque, M. G. Mustafa and M. Strickland, Phys. Rev. D **93**, 054045 (2016).
[10] A. Bazabov *et, al.*, Phys. Rev D **90**, 094503 (2014).
[11] S. Borsanyi, Z. Fodor, C. Hoelbling, S. D. Katz, S. Krieg, Kalman K. Szabo, Phys. Lett. B **370**, 99-104 (2014).