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Mocsy, A.; Petreczky, P.

Presented at the Workshop on Heavy Ion Collisions at LHC: Last Call for Predictions

CERN, Switzerland, May 14 – June 8, 2007

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Predictions for Quarkonia Dissociation

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Abstract. We predict the upper bound on the dissociation temperatures of different quarkonium states.

In a recent paper [1] we analyzed in detail the quarkonium spectral functions. This analysis has shown that spectral functions calculated using potential model for the non-relativistic Green's function combined with perturbative QCD can describe the available lattice data on quarkonium correlators both at zero and finite temperature in QCD with no light quarks [1]. Charmonia, however, were found to be dissolved at temperatures significantly lower than quoted in lattice QCD studies, and in contradiction with other claims made in recent years from different potential model studies. In [2] we extended the analysis to real QCD with one strange quark and two light quarks using new lattice QCD data on quark anti-quark free energy obtained with small quark masses [3].

Here we briefly outline the main results of the analysis of [2], in particular the estimate for the upper limit on the dissociation temperatures. There is an uncertainty in choosing the quark-antiquark potential at finite temperature. In [2] we considered two choices of the potential, both consistent with the lattice data [3]. The more extreme choice, still compatible with lattice data, leads to the largest possible binding energy. In this most binding potential some of the quarkonium states survive above deconfinement, but their strongly temperature-dependent binding energy is significantly reduced. This is shown in Fig. 1. Due to the reduced binding energy thermal activation can lead to the dissociation of quarkonia, even when the corresponding peak is present in the spectral function. Knowing the binding energy we estimate the thermal width using the analysis of [4]. The expression of the rate of thermal excitation has particularly simple form in the two limiting cases:

$$\Gamma(T) = \frac{(LT)^2}{3\pi} M e^{-E_{bin}/T}, \quad E_{bin} \gg T \quad \Gamma(T) = \frac{4}{L} \sqrt{\frac{T}{2\pi M}}, \quad E_{bin} \ll T. \quad (1)$$

Here M is the quarkonium mass, L is the size of the spatial region of the potential, given by the distance from the average quarkonium radius to the top of the potential, i.e. $L = r_{med} - \langle r^2 \rangle^{1/2}$, r_{med} being the effective range of the potential [2]. Using the above formulas we estimate the thermal width of charmonium and bottomonium states. Since

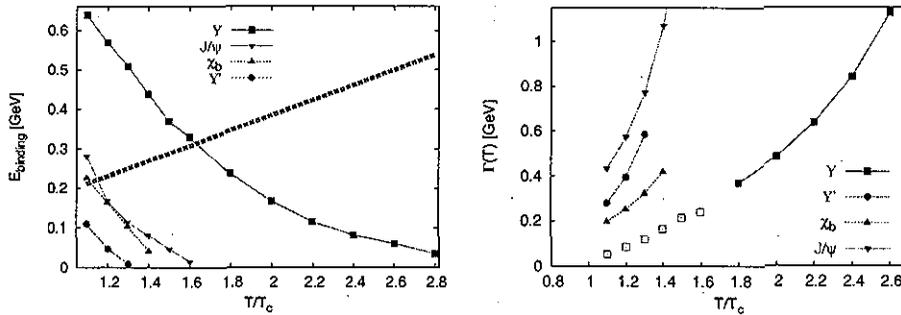


Figure 1. Upper limit of the binding energy (left) and the width (right) of quarkonium states. For better visibility, in the limit of small binding, the open squares show the width of the 1S bottomonium state multiplied by six.

in the deconfined phase $E_{bin} < T$ the 1S charmonium and 2S and 1P bottomonium states are in the regime of weak binding, and their width is large, as shown in Fig. 1. The 1S bottomonium is strongly bound for $T < 1.6T_c$ and its thermal width is smaller than 40MeV. For $T > 1.6T_c$, however, even the 1S bottomonium states is in the weak binding regime resulting in the large increase of the width, see Fig. 1. When the thermal width is significantly larger than the binding energy no peak structure will be present in the spectral functions, even though the simple potential model calculation predicts a peak. Therefore, we define a conservative dissociation temperature by the condition $\Gamma > 2E_{bin}$. The obtained dissociation temperatures are summarized in Table .

From the table it is clear that all quarkonium states, except the 1S bottomonium, will melt at temperatures considerably smaller than previous estimates, and will for certain be dissolved in the matter produced in heavy ion collision at LHC. Furthermore, it is likely that at energy densities reached at the LHC a large fraction of the 1S bottomonium states will also dissolve. It has to be seen to what extent these findings will result in large R_{AA} suppression at LHC. For this more information about initial state effects is needed. Moreover, the spectral functions are strongly enhanced over the free case even when quarkonium states are dissolved [1, 2] indicating significant correlations between the heavy quark and antiquark. Therefore, one should take into account also the possibility of quarkonium regeneration from correlated initial quark-antiquark pairs.

state	χ_c	ψ'	J/ψ	Υ'	χ_b	Υ
T_{dis}	$\leq T_c$	$\leq T_c$	$1.2T_c$	$1.2T_c$	$1.3T_c$	$2T_c$

Table 1. Upper bound on quarkonium dissociation temperatures.

- [1] Á. Mócsy and P. Petreczky, arXiv:0705.2559 [hep-ph].
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