Comprehensive Study of Bottomonium Suppression under Unified Model of Quarkonia Suppression

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Introduction

High-energy collisions between heavy nuclei has provided multiple indications of deconfined phase of matter, called quark-gluon plasma (QGP). It is formed at phenomenally high temperatures and/or baryon density. Experiments at RHIC and LHC consolidate medium existence and allow us to characterize its properties. The quarkonia suppression is one of the key signatures in identifying the QGP existence in ultra-relativistic heavy-ion collisions (uHIC). In QGP medium, quarkonium states formed in the early prethermal stages of the collision can be suppressed because of color screening, gluonic dissociation, collisional damping and cold nuclear matter (CNM) effects. The regeneration of quarkonia is also possible due to presence of significant number of $q\bar{q}$ pair formation at LHC energy. Here we study the survival of Υ(1S) and Υ(2S) as a function of transverse momentum (p_T) of quarkonia and centrality (b/or N_{Part}) of the collision. Finally, we compare our results with the corresponding nuclear modification factor, R_{AA} at mid rapidity, obtained from the Pb+Pb collision at LHC energy, $\sqrt{s_{NN}} = 2.76$ TeV [1, 2].

Description: UMQS

In this unified model of quarkonia suppression (UMQS), we incorporate suppression mechanisms along with regeneration due to correlated $b\bar{b}$ pair. Using available production cross sections for $b\bar{b}$ and Υ, we have calculated the number of $b\bar{b}$ pairs and Υ produced in heavy ion collisions at LHC energy, $\sqrt{s_{NN}} = 2.76$ TeV. Because of the recombination, the overall suppression of bottomonium will be reduced. We used here a framework of coupled rate equations [3] and its solution gives net production of bottomonia, $N_\Upsilon(\tau_f, b)$ in uHIC;

$$N^f_\Upsilon(p_T, b) = \epsilon(\tau_f, p_T, b)\Big[N^i_\Upsilon(\tau_0, b) + N^2_{b\bar{b}}\int_{\tau_0}^{\tau_f} \Gamma_{F,nl}(\tau, p_T, b)[V(\tau, b)\epsilon(\tau, p_T, b)]^{-1} d\tau\Big]. \quad (1)$$

Here, $N^i_\Upsilon(\tau_0, b) = N_\Upsilon(\tau_0, b) \times S_{sh}$ is initially suppressed production due to shadowing effect, S_{sh} [4]. The term τ_0 is initial thermalization time of QGP and τ_f is the life time of the QGP. $\epsilon(\tau_f)$ and $\epsilon(\tau)$ are the suppression factors. Variables used in the Eq.(1), have been discussed in details in refered article [3]. We have also introduced the effective temperature approach (discussed in ref. [8]) in our UMQS model calculation. Finally, we have calculated the net survival probability S_P, given by;

$$S^\Upsilon_p(p_T, b) = \frac{N^f_\Upsilon(p_T, b)}{N_\Upsilon(\tau_0, b)} \times S^\Upsilon_c(p_T, b). \quad (2)$$

Here, $S^\Upsilon_c(p_T, b)$ [6] is the survival probability due to color screening. In UMQS, we assumed that color screening mechanism is independent to the other suppression mechanisms.

Inputs for UMQS We have calculated initially produced $N_\Upsilon(\tau_0, b)$ using the σ^Υ_{NN} given in Table I. For calculating the $N_{b\bar{b}}$, we have used the $b\bar{b}$ production cross section $\sigma^{b\bar{b}}_{NN} = 43\ \mu b$ [7].

TABLE I: Mass M_Υ, initial production section σ^Υ_{NN}, dissociation temperature T_D and formation time τ^Υ_f for the bottomonium states are given.

	M_Υ(GeV)	σ^Υ_{NN}(nb)	T_D(MeV)	τ^Υ_f(fm)
$\Upsilon(1S)$	9.46	188 [7]	668 [5]	0.76
$\Upsilon(2S)$	10.02	$0.30^*\sigma^{\Upsilon(1S)}_{NN}$	220	1.9

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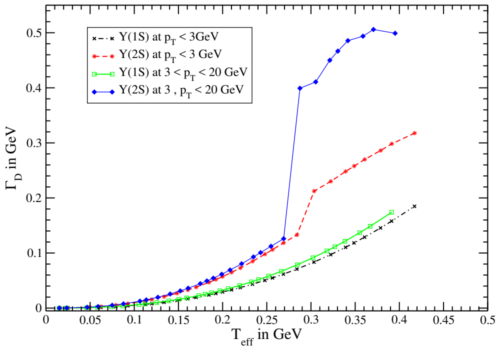

FIG. 1: (Color online) Variation of dissociation factor, Γ_D with effective temperature, T_{eff} for Υ(1S) and Υ(2S) at low and high p_T.

Results and Discussions

Dissociation factor Γ_D, plotted in Fig. 1, is the sum of gluonic dissociation and collisional damping factors [8]. Fig. 1 shows that Γ_D for Υ(2S) is more compared to Υ(1S) at low and high p_T. It changes abruptly for Υ(2S) near $T_{eff} = 230MeV$ while variation for Υ(1S) is slowly varying function of p_T. In Figs. 2 and 3, model calculations for the bottomonium states are compared with experimental results, R_{AA} as a function of N_{Part} and p_T, respectively. Our UMQS results for Υ(1S) explain the experimental data reasonably well. UMQS results for Υ(2S) also explain the experimental data qualitatively. It also explains that $\Upsilon(1S)$ is suppressed in QGP because of gluonic dissociation and collisional damping. Dissociation of Υ(1S) due to color screening is found insignificant in our calculation due to its high dissociation temperature (T_D). Shadowing effect as a function of N_{Part} is included for both the bottomonium states shown in Fig. 2. While p_T dependence plotted in Fig. 3 does not include shadowing effect in our present calculation.

Acknowledgments

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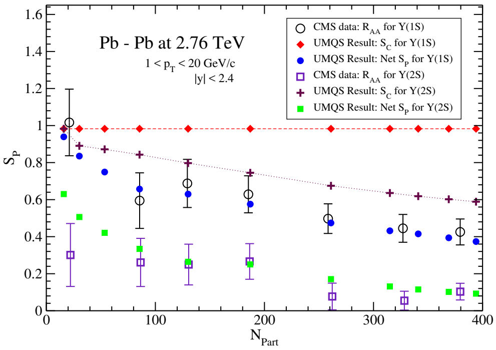

FIG. 2: (Color online) Net survival probability, S_P, along with S_C for Υ(1S) & Υ(2S) is plotted against N_{Part}.

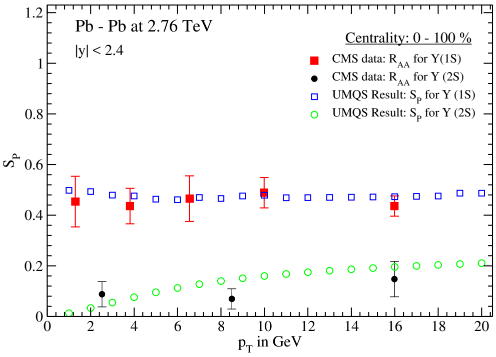

FIG. 3: (Color online) Net survival probability, S_P, for Υ(1S) and Υ(2S) is plotted p_T.

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