Bottomonium Production at RHIC and LHC

L. Grandchamp, S. Lumpkins, D. Sun, H. van Hees, and R. Rapp

A prime goal of ultrarelativistic heavy-ion collisions (URHICs) is the production and investigation of the quark-gluon plasma (QGP), a state of matter with quarks and gluons as the relevant degrees of freedom. The suppression of heavy-quarkonium production in URHICs, relative to proton-proton (p-p) reactions, has long been considered as a signature of QGP formation [1]. However, more recent observations at the Relativistic Heavy-Ion Collider (RHIC) suggest that the created matter is a strongly interacting QGP (sQGP), which allows for the existence of heavy-quark bound states as suggested by lattice QCD [2]. Thus, with copious production of charmquarks at RHIC, secondary formation of charmonia via *c-cbar* coalescence might dominate their yield in central Au-Au collisions [3,4], contrary to the situation in Pb-Pb collisions at the CERN Super Proton Synchrotron (SPS), where *J/ψ* suppression is the main effect.

In the present work [5], we study consequences of this picture for bottomonium (*Y*) production at RHIC and the Large Hadron Collider (LHC). We assess the time evolution of *Y* states in A-A collisions via a kinetic rate equation,

$$\frac{dN_Y}{dt} = -\Gamma_Y (N_Y - N_Y^{eq})$$

(N_Y: number of Y, Γ_Y: *Y*-dissociation rate, N_Y^{eq}: *Y*-equilibrium number), which is valid if *b*-quarks (open-bottom states) are in thermal equilibrium with the surrounding QGP [6].

The dissociation rates for the various *Y* states are evaluated using dissociation cross sections with thermal quarks and gluons. Since the commonly employed gluo-dissociation process [7], *g+Y→b+bbar*, becomes inefficient for small *Y* binding energies, we use the quasi-free breakup mechanism, *g(q)+Y-> b+bbar+g(q)*, as suggested for charmonia [4]. The in-medium *Y* binding energies are taken from solutions of a Schrödinger equation with a color-screened Cornell potential [8]. We furthermore assume that the quarkonium masses are temperature independent, which implies that the *b*-quark mass also decreases with temperature (as indicated by lattice QCD as well).

Due to their large mass, *b*-quarks are not expected to kinetically equilibrate in A-A collisions. We account for this by multiplying the gain term of the rate equation with a schematic correction factor, $R = 1 - \exp(-\int d\tau / \tau_{eq})$, with τ_{eq} denoting the thermal relaxation time for *b*-quarks which we take from a recent resonance-scattering model [9].

The total number of *b-bbar* pairs in the system (which determines the *Y*-equilibrium number) is obtained from binary collision scaling (secondary production is expected to be negligible [10]) according to

$$N_{b\bar{b}} = \frac{\sigma_{pp \to b\bar{b}}}{\sigma_{pp}^{inelastic}} N_{coll}(b) R_y ,$$

with $\sigma_{pp}^{inelastic}$=42(78) mb: total inelastic p-p cross section at RHIC (LHC) [11], $N_{coll}(b)$: number of primordial N-N collisions at impact parameter *b*, $\sigma_{pp\to b\bar{b}}$=2(160)μb at RHIC (LHC) [12]. R_y=0.52(0.29) for RHIC (LHC) denotes the fraction of *b-bbar* pairs in the considered rapidity range [13]. The primordial numbers of bottomonia are taken to be proportional to the *b-bbar* number with a p-p production cross section of 3.5(152)nb at RHIC (LHC, including shadowing corrections) [14]. The initial bottomonium number in the rate equation, $N_Y(0)$, also incorporates (pre-equilibrium) nuclear absorption effects with a dissociation cross section of 3.1(4.6)mb at RHIC (LHC).

With the above ingredients we solve the rate equation for different impact parameters for A-A collisions at RHIC and LHC energies; the pertinent centrality dependencies for *Y(1S)* production are summarized in Fig. 1, including feeddown from excited bottomonia. A rather strong suppression turns out to be the main effect at both RHIC and LHC, mostly driven by the reduction in binding energies due to color-screening. This is in contrast with the findings of similar studies for charmonia [14], where J/ψ suppression is the prevalent effect at SPS, while regeneration takes over and becomes the dominant source at RHIC energies and above. Thus, the simultaneous observation of appreciable *Y(1S)* suppression and the absence of J/ψ suppression emerges as a promising signature of the sQGP at collider energies.

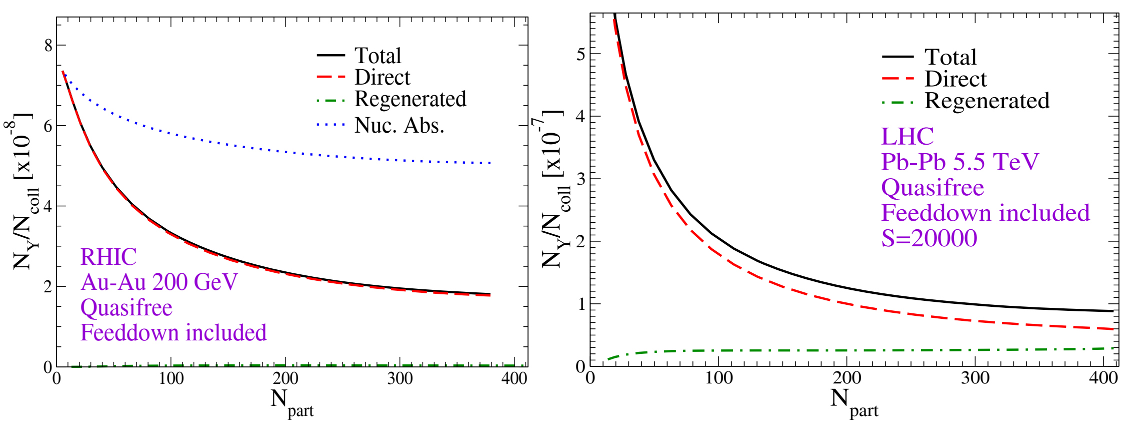

Figure 1. Centrality dependence of N_Y / N_{coll} at RHIC (200 *A*GeV Au-Au collisions, left panel) and LHC (5.5 *A*TeV Pb-Pb collisions, right panel) using the quasi-free *Y*-dissociation cross sections with color Debye-screening.

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