Upsilon Suppression in Pb+Pb Collisions at the LHC? *

R. Vogt

One of the proposed signatures of the QCD phase transition is the suppression of quarkonium production, particularly of the J/ψ [1]. In a quark-gluon plasma, the suppression occurs due to the shielding of the $c\overline{c}$ binding potential by color screening, leading to the breakup of the resonance. Because the Υ is much smaller than the $c\overline{c}$ and other $b\overline{b}$ resonances, a much higher initial temperature, T_i, than expected from past estimates is needed to dissociate the Υ [1]. Therefore it was previously assumed that the Υ would not be suppressed by QGP production. However, in view of the high T_i of a gluon plasma [2], $T_i \sim 1$ GeV, a reexamination of this assumption is in order. The relative suppression of the members of the Υ family should be testable at the LHC.

The potential for nonrelativistically bound quarkonium at finite temperature is [2]

$$V(r,T) = \frac{\sigma}{\mu(T)}(1 - e^{-\mu(T)r}) - \frac{\alpha}{r}e^{-\mu(T)r} \ , \quad (1)$$

where r is the separation between the Q and $\overline{Q}$ and $\mu(T)$ is the screening mass. The parameters are $\sigma = 0.192$ GeV ^{2}, $\alpha = 0.471$, $m_c = 1.32$ GeV and $m_b = 4.746$ GeV. Minimizing the quarkonium energy gives the radius of the bound state at each T. Where there is no longer a minimum and $\mu(T = T_D) = \mu_D$ the resonance no longer forms in the plasma.

We concentrate on the Υ states since they can be cleanly measured by CMS. It is necessary to know the dependence of the screening mass on temperature before T_D can be determined. Since the behavior of $\mu(T)$ is unknown for $T \gg T_c$, we show two rather extreme scenarios which may be expected to bracket the realistic situation. The first is a parameterization based on SU(N) lattice simulations,

$$\frac{\mu(T)}{T_c} \simeq 4\frac{T}{T_c} \quad (2)$$

which results in the lowest values of T_D. Athough $\mu(T)$ is independent of T_c, since we present our results as a function of the ratio T/T_c, for definiteness we take $T_c = 260$ MeV, consistent with SU(3) lattice calculations. For this value of T_c, the Υ breaks up at $T_D/T_c \approx 1.5$. In [2], this parameterization was used with $T_c = 150$ MeV, leading to the estimate $T_D/T_c \sim 2.6$ for the Υ. With initial temperatures of 260 MeV predicted for the LHC, Υ suppression appeared unlikely. The second is a perturbative estimate,

$$\frac{\mu(T)}{T_c} = \sqrt{1 + \frac{n_f}{6}} g\left(\frac{T}{T_c}\right)\frac{T}{T_c} \ , \quad (3)$$

with a temperature-dependent running coupling constant. In this case, T_D can be quite high and depends strongly on n_f and T_c. We present results use $n_f = 3$ and $T_c = 150$ MeV.

When the parameterization of eq. (3) is used, the Υ can easily be suppressed in the minijet gluon plasma. However, the perturbative estimate leads to much higher breakup temperatures, indicating that while the Υ' and χ_b resonances may break up, directly produced Υ's will probably not. The initial energy density and temperature have been shown to be much larger at the LHC than previously predicted. One advantage of these higher densities is that Υ production may be suppressed, depending on the temperature dependence of the screening mass. The rates for bottomonium production are large enough for such effects to be observable in the dilepton spectra.

[1] T. Matsui and H. Satz, Phys. Lett. **B178** (1986) 416; F. Karsch, M.T. Mehr, and H. Satz, Z. Phys. **C37** (1988) 617.

[2] K.J. Eskola, K. Kajantie and P.V. Ruuskanen, Phys. Lett. **B332** (1994) 191; K.J. Eskola, Nucl. Phys. **A590** (1995) 383c.

*CMS TN/96-041