Determining the Existence and Nature of the Quark-Gluon Plasma by Upsilon Suppression at the LHC *

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Following up on the work presented in Ref. [1], we found that expectations for Υ production in Pb+Pb collisions at the LHC are very dependent upon the nature and details of the quark-gluon plasma (QGP). We demonstrated that this dependence may allow us to determine the fundamental nature of the QGP, including: the energy density, the initial temperature, the plasma radius and the screening mass. We chose the Υ family to examine in detail because while the Υ rate is high enough for statistically significant measurements to be made, particularly at the LHC, the Υ is not strongly affected by interactions with hadronic matter. Strikingly different expectations for the p_T-dependence of the Υ'/Υ ratio, are found depending upon whether or not the QGP is formed and on the QGP properties. While our calculations of the survival probability are rather schematic, the general trend is correct.

The much higher energy of the LHC could be crucial for Υ suppression by a QGP. The high minijet density at the LHC implies that the p_T spectra of the Υ resonances are likely to be highly sensitive to details of QGP formation. In contrast, at RHIC, the minijet density will be a factor of 10 to 30 smaller, and the maximum initial temperature predicted is $T_0 \sim 0.5$ GeV. Thus no suppression is expected. Thus even a very high T_0 does not guarantee plasma suppression. Models assuming a slow equilibration result in greater suppression because of the longer time the system spends in the screening region with $T > T_D$ where T_D is the resonance dissociation temperature.

Even if suppression is absent at RHIC, it is only at RHIC that pA measurements will be possible. Despite the lower energy, these pA measurements will greatly aid in constraining and checking our understanding of nuclear effects. Thus, RHIC measurements will provide important benchmarks.

We demonstrated that statistics should be adequate to detect the differences in the Υ'/Υ ratio that would discriminate between different QGP models. Although such ratios have the advantage that systematic effects will cancel, further vital information can be extracted if the p_T spectra for the individual resonances can be measured. We have pointed to a comparison with Z production as a potentially useful benchmark. The ideal situation arises if HERA nuclear shadowing data is available for the x and Q^2 values appropriate for both Υ and Z production at the LHC so that the observed p_T spectrum for the Z could be compared to predictions using the experimentally measured nuclear parton densities. If there is agreement, then we can unfold the shadowing effects on the Υ p_T spectra.

Certain detector features will play a key role in carrying out the analysis as envisioned here. The resolution for the CMS detector is such that the Υ, Υ' and Υ'' resonances can be cleanly separated. Less certain is the extent to which the $\chi_b \to \gamma\Upsilon$ process can be separated from direct Υ production. The statistics necessary to discriminate between different QGP models is much greater if the direct 'prompt' Υ'/Υ ratio cannot be isolated. One also would lose the ability to observe the χ_b/Υ ratio. It will be important for the LHC detector groups to give further attention to both experimental issues.

[1] R. Vogt, CMS-TN/96-041.

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