Heavy Flavor Hadrons in Quark - Gluon Plasma

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Introduction

Study of quark - gluon plasma (QGP) is very important to understand the early universe and strong nuclear interaction [1]. Conditions for such systems are easily realised at RHIC and LHC. Since heavy quarks are produced in inital stage of high energy heavy ion collisions. Therefore, heavy quarks in deconfined matter has always been topic of interest to high energy physicists. With increased energy limits at RHIC and LHC heavy quark hadrons (containing bottom quarks) in deconfined matter have also been observed [2, 3]. Therefore, alongwith charmonium suppression bottom quark hadrons have also emerged as promising signals of quark - gluon plasma.

Installation of Forward Silicon Vertex Tracker (FVTX) in PHENIX is a landmark in the measurement of distance of closest approach. This measurement helps us to identify the heavy quark yields [4]. Such experimental developments have also encouraged the theoretical development in heavy flavor physics at RHIC and LHC [5, 6]. In this work we shall try to understand the production of heavy flavor quarks at RHIC and LHC.

Heavy Quark Production

The production cross section of quarkonia can be expressed in terms of their decay widths. The expressions of different quarkonia decay widths can be written as [7]

$$\Gamma(\psi \to ggg) = 40(\pi^2 - 9)\alpha_s^3 |R_S(0)|^2/(81\pi m_\psi^2), \quad (1)$$

$$\Gamma(\psi \to q\bar{q}) = 12\alpha^2 e_Q^2 e_q^2 |R_S(0)|^2/(m_\psi^2) \quad (2)$$

where $R_S(0)$ is the $S-$wave quarkonium radial wavefunction, e_Q and e_q are quarks' electric charges, α_s is the strong coupling constant, and α is the QED coupling constant. Therefore, the production ratio of $\Upsilon(2S)/\Upsilon(1S)$ can be written as :

$$\frac{Y(\Upsilon(2S))}{Y(\Upsilon(1S))} = \frac{a_1\Gamma(\Upsilon(2S) \rightarrow ggg) + a_2\Gamma(\Upsilon(2S) \rightarrow q\bar{q})}{a_3\Gamma(\Upsilon(1S) \rightarrow ggg) + a_4\Gamma(\Upsilon(1S) \rightarrow q\bar{q})} \tag{3}$$

where a_1, a_2, a_3, and a_4 are proportionality constants emerged after averaging over color and spin. Therefore, the production ratio will be a function of α_s which is itself a function of temperature of the medium [8]. Since the fraction of heavy quarks will be small compared to light quarks hence we can take three flavor approximation for estimation of the running coupling constant. Recent experimental data from RHIC and LHC have shown that Υ states exhibit sequential suppession [2–4]. CMS data [9] also predicts that the yield ratio $\Upsilon(2S)/\Upsilon(1S)$ gradually decreases with increase in track multiplicity. This behavior can be easily understood from eqn(3) where $\Upsilon(2S)/\Upsilon(1S)$ decreases with increase in temperature and mass of the particle. It is interesting to note that the ratio increases for Pb-Pb collisions. The number of yields increases because of the increase in deconfined medium volume. The increase in ratio of yields may need some analysis with deconfined medium screening.

Conclusions

From the above discussion it is clear that the behavior of yield ratio of bottomonium states can be easily explained with temperature dependence of α_s and mass of bottomonium states. For Pb-Pb collisions the high yield ratio may need some addtional analysis.

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