Observing Quarkonia Suppression as a prob to detect magnetic field produced in Relativistic Heavy Ion Collisions.

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Introduction

In Relativistic Heavy Ion Collision Experiments (RHICE) there are certain possibilities of production of huge magnetic field for non-central collision. The magnetic field will last for only few fm/c time, making the direct detection of this magnetic field impossible. Indirect detection method is needed to confirm the existence of magnetic field. The bound states of heavy quarks (charm, bottom) and its antiquarks are known as quarkonia. Intensive research work is going on in the field of quarkonia suppression in RHICE. Matsui and Satz [1] first proposed J/ψ (ground state of charm and anti-charm quark) suppression as a signal for QGP formation. In this paper quarkonia suppression has been utilized as a probe to detect the magnetic field produced in RHICE.

In QGP because of high temperature, the potential between quark (Q) and anti-quark ($\bar{Q}$) becomes Debye screened. If the screening is sufficient then the potential will be too weak to hold $Q\bar{Q}$ together as a bound state, leading to melting of quarkonia. The magnetic field has same effect on the potential between quark (Q) and anti-quark ($\bar{Q}$). Though the field may not remain strong enough for long time to dis-integrate the bound state as it decays very fast. But here we have shown that the time varying magnetic field leads to non adiabatic evolution of quarkonia bound states and the states melts due to transition to scattering or unbound states.

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Quarkonia in Medium

The in medium Debye screened potential between quark (Q) and anti-quark ($\bar{Q}$) [2] can be written as

$$V(r) = -\frac{\alpha}{r}exp(-m_D r)+\frac{\sigma}{m_D}(1-exp(-m_D r)) \quad (1)$$

where $\alpha = \frac{4}{3}\alpha_s$, α_s is the strong coupling constant, σ is the string tension and m_D is the Debye mass [3], which is nothing but the static limit ($|\vec{p}| = 0, p_0 \to 0$) of the longitudinal part of the gluon self energy $\pi_{\mu\nu}$. If there is no magnetic field in medium then m_D can be written for three flavor case as $m_D = gT\sqrt{1 + N_f/6}$ [4].

To calculate the quarkonia potential in presence of magnetic field, one needs to calculate the Debye mass m_D in presence of magnetic field which is calculated by taking the static limit ($|\vec{p}| = 0, p_0 \to 0$) of the longitudinal part of the gluon self energy $\pi_{\mu\nu}$ and the Debye mass is then obtained as [5]

$$m_D^2 = \frac{g^2}{4\pi}\sum_f \frac{|q_f B|}{\pi} \quad (2)$$

1. Result

Initially the magnetic field can be of the order of m_π^2. As time evolves the intensity de-

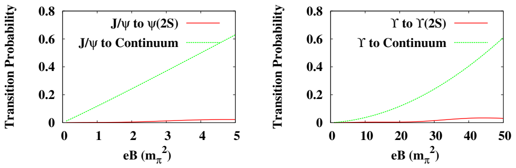

FIG. 1: Magnetic field vs transition probability for charmonia (left) and bottomonia (right).

creases so as Debye mass. Hence potential between $Q\bar{Q}$ or Hamiltonian also becomes time dependent. The decay of magnetic field with time is not well known. Tuchin discusses some possible way of decay of magnetic field [6], but there is no analytical form for the decay. Interestingly the simplest power law decay

$$B = B_0 \frac{1}{1+at} \tag{3}$$

reasonably matches with that numerical calculation by Tuchin for $a = 1$. Here B_0 is initial intensity of magnetic field. In this work we consider this simple power law decay to show the non-adiabatic evolution of quarkonia. Initially we vary B_0 keeping a fixed as unity and see the evolution up to $10 fm/c$ time. Then we vary a to see the effect of the slope of decay.

We have used first order perturbation theory to calculate the transition amplitude for transition from ground state of quarkonia to other excited states. Also we have calculated the transition probability for transition from ground states to continuum states having all possible momentum. Transition to continuum or unbound states directly gives us the dissociation probability of quarkonia. From Fig.1 (left) one can see that the dissociation probability of J/ψ becomes about 60% when the initial magnetic field intensity was $5m_\pi^2$ and transition to other excited states remains negligible compare to dissociation probability. The probability decreases with initial intensity of magnetic field. Fig.1 (right) shows that the bottomonia survives more than the charmonia. The dissociation probability remains less than 10% when the initial intensity of magnetic field is taken as $10m_\pi^2$ though its increases as we increase intensity of the field.

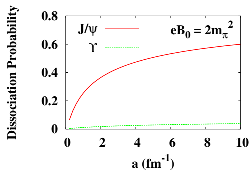

FIG. 2: "a" vs dissociation probability

Fig.2 shows how the dissociation probability varies with the parameter "a" in the expression used in power law decay. As "a" increases the slope increases as well as Hamiltonian changes more rapidly. As a result the adiabaticity violets more and more and the dissociation probability also increases.

2. Conclusion

In conclusion we want to point out that according to LHC result the produced magnetic field intensity can be at most $50m_\pi^2$. The J/ψ and Υ remains bound in that magnetic field if we ignore the non adiabatic evolution. Consideration of non adiabaticity in presence of transient magnetic field the dissociation probability becomes non-vanishing for lower intensity also. For better theoretical development in the field of quarkonia suppression one needs to incorporate the non adiabatic evolution of quarkonia, as medium evolves rapidly.

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