Heavy Quarkonia in a Magnetic Field
Binoy Krishna Patra1 and Mujeeb Hasan2
Department of Physics, Indian Institute of Technology Roorkee, Roorkee-247 667, India
1binoy@ph.iitr.ac.in, 2mhasan@ph.iitr.ac.in

Abstract
It is predicted that for the noncentral events in ultrarelativistic heavy-ion collisions (UrHICs), a strong magnetic field is generated at the very early stages of the collision. However, as we know the quarkonia, the physical resonances of QQ states, are formed in the plasma frame at a time, \( t \approx 1/f_p \), which is order of 1-2 fm, depending on the resonance and their momenta, \( p_f \). By the time elapsed, the magnetic field may become weak. This motivates us to explore the effects of both the weak magnetic field (\( B \ll 2\pi E_0/|e| \)) and strong magnetic field (\( B \gg 2\pi E_0/|e| \)) on the properties of heavy quarkonia immersed in a thermal medium of quarks and gluons and then studied how the magnetic field affects the quark free dissociation in the absolu-
tude medium.

Methodology
1. First we have revisited the structure of gluon self-energy tensor in the presence of both weak and strong magnetic fields in thermal QCD and obtained the relevant form factors, that in turn computes the real and imaginary parts of the resummed gluon propagator.
2. Then the linear response theory yields the real and imaginary parts of the dielectric permittivity from the respective resummed propagators.
3. Finally, the inverse Fourier transform of the permittivities of the above propagators in the static limit obtains the complex heavy quark potential.
4. Further, the real-part of the potential is used in the Schrödinger equation to obtain the binding energy, whereas the imaginary part is used to calculate the thermal-decay width of heavy quarkonia.
5. Finally we have studied the quasi free dissociation of quarkonia and obtained the dissociation temperatures of heavy quarkonia.

Heavy Quark Potential
The mass of heavy quark (mQ) is very large, so the requirements - \( m_Q \gg T \approx \hbar /\lambda_Q \) and \( m_Q \gg \sqrt{4\pi} T \) are satisfied for the description of the interactions between a pair of heavy quark and anti-quark at finite temperature in a magnetic field in terms of quantum mechanical potential, that leads to the validity of taking the static heavy quark potential
\[ V(r, T, B) = \int \frac{d^3l}{(2\pi)^3} \left( \frac{k^4}{l^4} - 1 \right) \left( \frac{1}{l} \right) \]
\[ \Rightarrow \text{Dielectric permittivity} \]
\[ \int \frac{d^3l}{(2\pi)^3} k^3 \left( \frac{k^2}{l^4} - 1 \right) \frac{1}{l} \]
\[ \Rightarrow \text{Fouier transform of the Cornell potential} V(\omega) = \frac{a}{\omega + i \sigma} \]

Resummed Gluon Propagator
Real and imaginary parts of the resummed gluon propagator
\[ \text{In strong magnetic field} \]
\[ \text{Re}[D^0(k_0 = 0, k)] = \frac{1}{k^2 + m_Q^2} \frac{1}{k^2 + M_B^2 \left(k^2 + M_B^2 \right)} \]
\[ \text{Im}[D^0(k_0 = 0, k)] = \frac{m_Q^2}{k^2 + M_B^2} \frac{1}{k^2 + M_B^2} \]
\[ \Rightarrow \text{Debye mass} \]
\[ M_B^2 = g T^2 \frac{1}{4\pi} \sum_{l=1}^{\infty} \epsilon_l B^2 \frac{2}{l \pi} \int \frac{d^3l}{(2\pi)^3} \frac{1}{l} \left( \frac{l^2}{k^4} + 1 \right) \frac{1}{l^2} \]

\[ \text{In presence of strong magnetic field} \]
\[ \text{Re}[V(r, T, B)] = \frac{1}{r^3} e^{-r/M_Q} \left[ 1 + \frac{\sigma}{M_Q} \left( 1 - e^{-r/M_Q} \right) \right] \]
\[ \text{Im}[V(r, T, B)] = \frac{\sigma}{M_Q} \left[ 1 - e^{-r/M_Q} \right] \]

Conclusions

References

10th International Conference on Hard and Electromagnetic Probes of High-Energy Nuclear Collisions