Study of QGP with particle production of photons in a magnetic field environment

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Introduction

The photons/dileptons contain rich information in the study of quark gluon plasma (QGP). These signals once produce can travel from starting phase of QGP to hadronic phase of a matter. This is the reason due to the which these signals are popular among other signatures of QGP in the field of high energy heavy ion collisions [1, 2].

In nucleus nucleus collisions at RHIC and LHC, it is assumed that a huge and intense magnetic field [3, 4] produces that significantly affects the properties of QGP. The generated magnetic field in heavy ion collisions at RHIC and LHC is perpendicular to the collision plane. The magnitude of such strong magnetic field assumed around 10^{19} Gauss at RHIC whereas it is around 10^{20} Gauss at LHC [5]. So, it is interesting to look at the photon spectrum in the presence of magnetic field.

Photon rate from QGP in the magnetic field environment

Extensive research is going on to establish the existence of quark-gluon plasma (QGP) in heavy-ion collision. In this work, we compute QCD quark-antiquark annihilation process in QGP towards the photon yield at three different scales; finite quark chemical potential, temperature and magnetized effective quark mass. The simplest lowest order (LO) process i.e. $(q\bar{q} \rightarrow \gamma g)$ has been used in evaluating photon yield which appear at one loop level for a given system of quarks and gluons. In general, a huge and intense magnetic field B at time $t = 0$ is given as:

$$B(t=0) = \frac{1}{4\pi\epsilon_0 c^2} \frac{qv(1-\beta^2)sin\theta}{r^2(1-\beta^2 sin\theta)^{3/2}} \ . \quad (1)$$

At $t = 0$, a heavy ion with charge Z and rapidity y travel along the z direction is at $x_\perp$. The magnetic field at $\overrightarrow{x} = (x_\perp, z)$ due to the heavy ions is taken as:

$$eB(t) = Z\alpha_{em} Sinhy \times \left[\frac{(\overrightarrow{x'}_\perp - \overrightarrow{x}_\perp)e_z}{[(\overrightarrow{x'}_\perp - \overrightarrow{x}_\perp)^2 + (tsinhy - Zcoshy)^2]^{3/2}} \right] \quad (2)$$

Some reports on photon production have done significant work by considering the temperature and chemical potential value in finite quark mass. The finite quark mass is further modified as effective quark mass $m_{eff}(T, \mu)$ [6–8].

Finally, we use the single particle energy [9, 10]:

$$E = [m^B_{eff} + k^2]^{1/2} \quad (3)$$

where k is the momentum along the direction of the existing magnetic field. Using above results, one can obtain the expression for photon emission rate through annihilation process in QGP phase:

$$E\frac{dN^{Ann}}{d^3k d^4x} = \frac{2\alpha\alpha_s}{\pi^4} e^{2\mu/T} T^2 e^{-E/T} \times \sum_f e_f^2 \left[\ln \frac{4ET}{k_c^2} - C_E - 1 \right] \quad (4)$$

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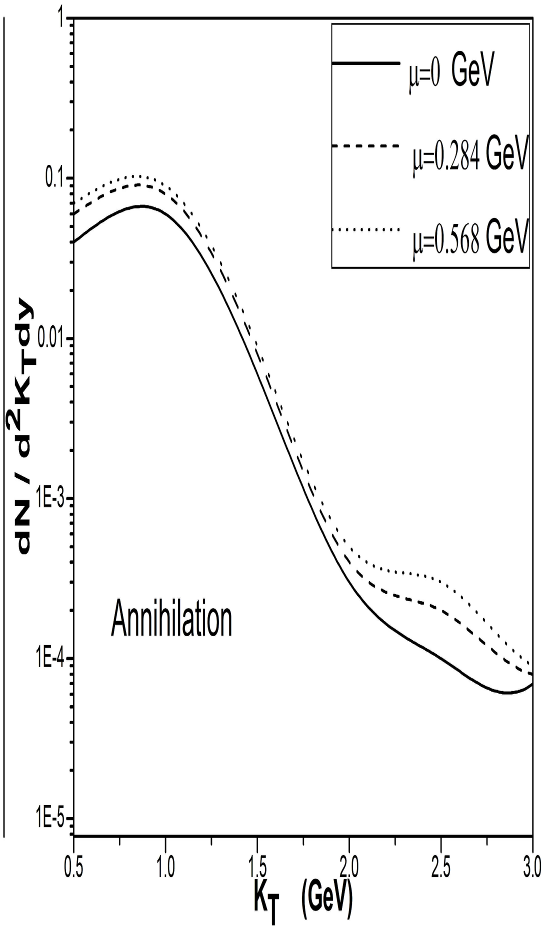

FIG. 1: The photon spectrum is shown by varying chemical potential using $q\bar{q}$ annihilation process in the magnetic field environment of QGP.

where $k_c^2 = 2m_{eff}^2$. The total photon spectrum is computed by integrating the rate over the space-time evolution of the QGP. The total yield is expressed as [11]:

$$\begin{aligned} \frac{dN}{d^2k_T dy} &= \int d^4x (E\frac{dN}{d^3kd^4x}) \\ &= Q\int_{\tau_1}^{\tau_2} \tau d\tau \int_{-y}^{+y} dy (E\frac{dN}{d^3kd^4x}) \ . \end{aligned} \quad (5)$$

Here, τ_1 and τ_2 are the initial and final time, y is the rapidity and k_T is transverse momentum. Finally, we obtain total photon spectrum for $q\bar{q}$ annihilation process in QGP.

Results and Conclusion

In this work, we revisited our earlier calculation of photon production rate [12] and modify our calculations of photon yield using quark chemical potential for N_f=3 in the presence of magnetic field.

Fig. 1 depicts the photon spectrum from the exotic state of matter through the annihilation process. The production rate is found to be increases with the increase in the quark chemical potential μ_q in the environment of magnetic field. The modified quark mass in the magnetic field environment creates a appreciable enhancement in the production rate of photon. It is also found to be large at such hot phase of temperature T = 400 MeV. We further pointed out that there are two bumps occured at $K_T \approx 1.0$ GeV and at $K_T \approx 2.5$ GeV. The reason behind these two bumps is still not clear but future work may help us to find out the exact reason behind these bumps.

In principle, the production rate of photon should have decreasing pattern with transverse momentum. The current observation of photons provides some interesting and surprising results. The findings due to magnetic field could lead to new inventions in the field of quark gluon plasma and heavy ion collisions. Therefore, the effective mass of quark in the presence of magnetic field with chemical potential plays a significant role in the production rate of photon.

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