Role of effective quark mass on lepton pair production in the presence of magnetic field

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Introduction

In the past few years, a lot of work have been done on the effect of strong magnetic field on electromagnetic response of QCD as a theoretical probe to the dynamics of QCD, experimental heavy ion collisions and various properties of dense astrophysical and cosmological matter. In order to understand the dynamics of QCD, the possibility of the existence of such an intense magnetic field of the order $eB \sim {m_\pi}^2$ at RHIC and $eB \sim 10{m_\pi}^2$ at LHC has encouraged theoretician to study many new phenomenon such as chiral magnetic effect, chiral magnetic wave, and change in the photon and dilepton production etc. [1–6]. The off-central heavy ion collision produce large electromagnetic fields and due to this electromagnetic effect, a strong magnetic field is produced in the system [7, 8].

The two heavy-ion nuclei approaching towards each other generate two electric currents in opposite directions and eventually produce a large time dependent magnetic field perpendicular to the collision plane. Using Biot Savart formula, a naive estimation of the magnetic field can be made. In RHIC, Au + Au collisions at $\sqrt{s} = 200$ GeV has reported the magnetic field produced in the order of 10^{19} Gauss and in LHC Pb + Pb collisions at $\sqrt{s} = 2.76$ TeV the magnetic field is of the order of 10^{20} Gauss [9, 10]. Thus the experimental results reported by PHENIX at RHIC ($E \leq 200GeV$) established the fact that a transient strong magnetic field is created in heavy-ion collision. The magnitude of the magnetic field produced is found to be linearly dependent on the collision energy and it is evident from Lorentz gamma factor appearing in Biot-Savart formulae given as,

$$eB = \frac{\gamma \alpha Z}{{R_A}^2} \quad (1)$$

Dileptons production from a QGP

In heavy-ion collision, dileptons are produced from quarks (or antiquarks) through the mediation of a virtual photon. Here we consider a process where both the quark and the lepton move in the magnetic field created during the heavy-ion collision. Although there may be another possibility in which either the quark or the lepton move in the magnetic field. Earlier it is believed that both quarks and leptons move most sensitive to the prevailing magnetic field in heavy-ion collision. At RHIC and LHC, the centre-of-mass energy per nucleon is larger than the ratio of nucleon mass to the product of nuclear radius and electrical conductivity. This condition is based on a reasonable approximation that the time dependence of the magnetic field is adiabatic [11]. With the above approximations, the dilepton production rate can be written as,

$$\frac{dN_{q \to l_1 l_2}}{dt d\Omega dE} = \int n(w) \frac{dN_{\gamma \to l_1 l_2}}{dt d\Omega dE} dw \quad (2)$$

where $n(w)$ is the flux of equivalent real photon replacing virtual photon.

In this paper, we calculate the dilepton yield in quark-gluon plasma exposed to inherent magnetic field present in heavy ion collisions by considering an effective quark mass [12] using an expression given in Ref. [11]. It is ex-

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pressed as,

$$\frac{dN_{q\to l_1 l_2}}{dt d\Omega dE} = \frac{NSQ^2\alpha^2 {m_l}^2}{3\pi^5}\sum_{i=0} {Z_q}^2 \times \int_0^{\pi/2} d\beta \int_0^{Y/2} dy f(y) \times \int_E^{w_m} d\omega \ln \frac{E}{w[1+(\chi E/w)^{1/3}]}(\frac{2}{x} - \chi x^{1/2}) Ai(x)$$

Results

Magnetic field generated in heavy-ion collisions has a profound impact on dilepton production. Moreover, the QGP has a finite lifetime, and to what extent the thermalization is achieved depends on the transport property of the QGP. Therefore, strong magnetic fields give rise to an anisotropy of the momentum diffusion constant. Non-vanishing contributions to the longitudinal momentum transfer come from either the finite quark-mass correction or the contribution of the gluon scatterers. Therefore in this paper, we considered a suitably modified quark mass m^2_{eff} to calculate the dilepton yield in an inherent magnetic environment. The results are found to be very encouraging in terms of high yield of dileptons. The dilepton yield with effective quark mass [12] shows an enhanced result as compared to the recent result of Tuchin et al. [11]. Figure (1) depicts the dilepton yield with the effective quark mass at different energy with the inclusion of magnetic field. Results are also enhanced in the dilepton yield for the non-zero value of quark mass as compared to zero quark mass. Thus, effective quark mass plays an important role in the production of dilepton yield. The study helps us to gain the better understanding in the behaviour of quark gluon plasma in a strong magnetic field created in relativistic heavy ion collisions at RHIC and LHC.

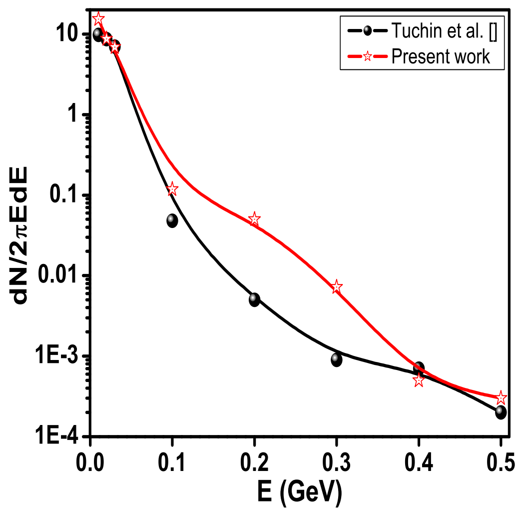

FIG. 1: Dilepton production rate $\frac{dN}{2\pi E_+ dE_+}$ are shown. The result is compared with the result of Tuchin [11]

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