Dilepton rate from a hot and dense QCD medium magnetised with arbitrary strength of magnetic field

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Introduction

We have calculated the photon self-energy in presence of an arbitrary magnetic field (eB). It is known that the spectral function (SF) can be obtained from the current-current correlation function (CF) which in turn is related to the self-energy. Using that SF we have estimated the very important quantity of lepton pair production rate from a hot and dense QCD medium that is exposed to an arbitrary strength of eB [1].

This quantity has been estimated, previously, using Ritus eigenfunction method in imaginary time formalism with zero parallel component of the momentum (p_z; p_3 in their notation) [2] and using Schwinger method in real time formalism with zero perpendicular component of the momentum ($p_\perp$) [3]. As a novelty of our calculation we have estimated the dilepton rate (DR) for simultaneous non-zero values of both parallel and perpendicular components of external momentum. For our purpose we have used the Schwinger method in imaginary time formalism.

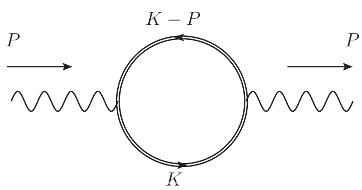

FIG. 1: Diagram for photon polarisation tensor.

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Methodology and formalism

We have considered an external anisotropic magnetic field in the direction of z axis ($\vec{B} = B\hat{z}$). The fermion propagator in this scenario was first deduced by Schwinger [4] and in the momentum space ($S_f^{(B)}(K)$) is given by Eq.1 in Ref. [1]. With this propagator at our disposal we can evaluate the photon self energy in Fig. 1 in presence of eB.

Using this self-energy we can evaluate the SF (ρ_V) which is further related to the DR as,

$$\frac{dN}{d^4X d^4P} = \frac{5\alpha_{\mathsf{EM}}^2}{27\pi^2}\frac{1}{P^2}\frac{1}{\exp\left(\frac{p_0}{T}\right)-1}\rho_V(P), \quad (1)$$

where α_{EM} is the fine structure constant. This is our master equation which we use to evaluate the DR.

Result

We notice a considerable enhancement of DR in presence of eB as compared to the Born rate (rate at $eB = 0$) in Fig. 2, which in our opinion is encouraging in the perspective of heavy-ion collision (HIC). We have given the plot for $eB = 5\,m_\pi^2$, but the enhancement is there for any value of eB lower or higher than that. The enhancement persists for the entire range of the invariant mass (M) that we studied.

In Fig. 3 the DR for non-zero values of $p_\perp$ is calculated. This is a novelty of our calculation in an arbitrary eB scenario, as previously the

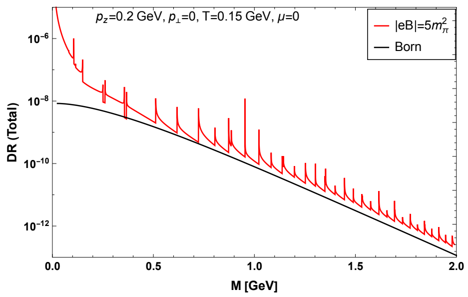

FIG. 2: DR as a function of invariant mass for $eB = 5\,m_\pi^2$ with p_T being zero.

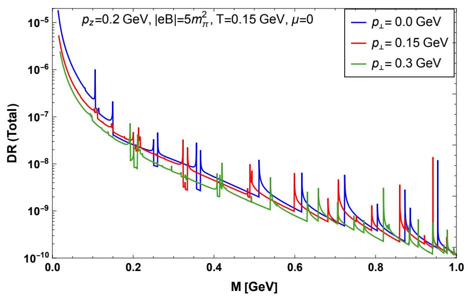

FIG. 3: DR for different values of p_T.

calculations were done for either $p_z = 0$ [2] or $p_\perp = 0$ [3]. We notice that increasing $p_\perp$ decreases the DR for a given value of M.

As an outcome of our transparent calculation we could decompose the total rate into different physical processes of annihilation and decays. This in turn helps us to break down the shares of different processes in DR, which is shown in Fig. 4 for non-zero value of chemical potential.

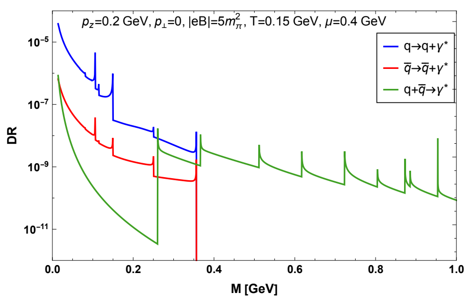

FIG. 4: Decomposition of DR for non-zero μ.

With zero magnetic field the Born rate or the rate in the lowest Landau level (LLL) approximation in presence of a strong eB gets contribution only from the quark (q)-antiquark ($\bar{q}$) annihilation process. Here we observe that in presence of an arbitrary value of eB both q and $\bar{q}$ decay processes contribute along with the annihilation process. The decay processes dominate in the low M region, whereas the higher M region is dominated by the contribution from the annihilation process. For non-zero value of μ, understandably, the contribution from the q decay is larger than that from $\bar{q}$. All these observations are depicted via Fig. 4.

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