Production of dileptons from magnetized hadronic matter

R. Mondal[a,d],* N. Chaudhuri[a,d], S. Ghosh[b], P. Roy[c,d], and S. Sarkar[a,d]
[a] Variable Energy Cyclotron Centre, 1/AF Bidhannagar, Kolkata - 700064, India
[b] Government General Degree College Kharagpur-II, Paschim Medinipur - 721149, West Bengal, India
[c] Saha Institute of Nuclear Physics, 1/AF Bidhannagar, Kolkata - 700064, India and
[d] Homi Bhabha National Institute, Training School Complex, Anushaktinagar, Mumbai - 400085, India

Introduction

One of the main objectives of relativistic heavy ion collision (HIC) at LHC and RHIC is to study the strongly interacting nuclear matter. This novel state of matter created in HIC is very short-lived ($\sim$ few fm/c) highly restricting any possibility of direct observation. Thus one has to rely on indirect observables such as electromagnetic (EM) probes (photons, dileptons). The EM probes can only participate in electromagnetic interaction. Owing to the large mean free path comparing with the typical size of the system, it can leave the system without further interaction. So EM probes can carry unaltered informations where produced. However, as the system cools down, it is expected that hadronic matter will be generated from quark-gluon-plasma (QGP) via a phase transition or crossover. This hadronic phase has also substantial contribution on the dilepton production in the low invariant mass region. It is found in recent studies that a very strong transient (decays within$\sim$ few fm/c) magnetic fields of the order $\sim 10^{18}$ Gauss or larger might be generated in non-central collision of two heavy nuclei due to the receding spectators. However, the presence of finite electrical conductivity of the medium (both QGP and hadronic) can delay the decay process of the magnetic field. There are broad discussions on dilepton production in literature from QGP medium with background magnetic field in different approaches.

In this presentation, we calculate dilepton production rate (DPR) from a magnetized hot hadronic medium in terms of the spectral function of rho meson. The spectral function is obtained from the electromagnetic current correlation function evaluated using real time formalism (RTF) in the scheme of thermal field theory (TFT).

*Electronic address: rajkumarmondal.phy@gmail.com

Formalism

The DPR per unit four momentum volume per unit space-time volume in terms of the thermo-magnetic spectral function of the ρ meson i.e. $A(q;T,B) = -\frac{1}{3}g^{\mu\nu}\mathrm{Im}\,\overline{D}_{\mu\nu}$ is given by[1]

$$\frac{dN}{d^4xd^4q} = \frac{\alpha^2}{\pi^3q^2}L(q^2)f_{\rm BE}(q_0)F_\rho^2m_\rho^2A(q;T,B). \quad (1)$$

α is fine structure constant, $f_{\rm BE}(x)$ is Bose-Einstein distribution function, m_ρ is bare mass of ρ meson, F_ρ is coupling constant between the ρ meson and photon field and $L(q^2) = \left(1+\frac{2m_l^2}{q^2}\right)\sqrt{1-\frac{4m_l^2}{q^2}}$, m_l is the leptonic mass. The spectral function contains imaginary part of thermo-magnetic complete ρ meson propagator $\mathrm{Im}\,\overline{D}_{\mu\nu}$ which is most significant component in the estimation of DPR and determines the thresholds as well as the intensity of dilepton emission. We have calculated complete ρ meson propagator $\overline{D}_{\mu\nu}$ by solving Dyson-Schwinger equation (Eq. 2) in terms of bare ρ-propagator $\overline{D}^{(0)}_{\mu\nu}$ and the analytic thermo-magnetic self-energy function $\overline{\Pi}^{\alpha\beta}$.

$$\overline{D}_{\mu\nu} = \overline{D}^{(0)}_{\mu\nu} + \overline{D}^{(0)}_{\mu\alpha}\overline{\Pi}^{\alpha\beta}\overline{D}_{\beta\nu} \quad (2)$$

The ρ-meson self-energy is obtained in thermo-magnetic background (without any

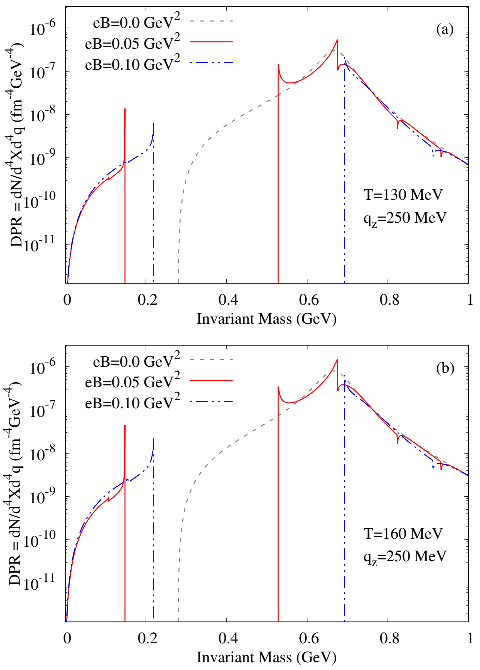

FIG. 1: Dilepton production rate (DPR) as a function of invariant mass : (a) T= 130 MeV and (b) T= 160 MeV.

approximation on the strength of magnetic field) considering the effective field theoretic Lagrangian[2]

$$\mathcal{L}_{\text{int}} = -g_{\rho\pi\pi} \left(\partial_\mu \boldsymbol{\rho}_\nu\right) \cdot \left(\partial^\mu \boldsymbol{\pi} \times \partial^\nu \boldsymbol{\pi}\right). \quad (3)$$

$g_{\rho\pi\pi}$ is the coupling constant of the interaction. We have used Schwinger method to obtain the pion propagator in magnetic field for the calculation of ρ meson self-energy. The analytic structure of self-energy in complex plane shows that there is a non-trivial contribution coming from Landau cut in addition to the usual Unitary cut in physical time-like kinematic domain owing to the fact that the charged pions occupy different Landau levels before and after scattering with the ρ meson. This is purely a magnetic field effect.

Numerical Results

The DPR from thermo-magnetic hadronic matter is shown in Fig. 1. The Fig. 1 shows dileption yield in the low invariant mass region for finite value of magnetic field due to the presence of Landau cut. The spike-like structure of dilepton production is observed over the whole range of invariant mass due to the "threshold singularities" at each Landau level present in the spectral function of ρ meson. The threshold of both Unitary and Landau cuts is independent of temperature of the medium and shifts with the magnetic field. In thermo-magnetic medium, there exists a forbidden gap in the dilepton production between the Landau and Unitary cut threshold which have a width independent of temperature. The width of the forbidden gap increases and moves towards higher value of invariant mass with the increase of magnetic field. This dependency on magnetic field for both Unitary and Landau cut can be understood from the discussion of the analytic structure of spectral function. Comparing Fig. 1 (a) and (b), the overall magnitude of DPR increases with the increase in temperature as consequence of the enhancement of the available thermal phase-space.

References

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