A quasi-particle approach to electromagnetic radiation

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Introduction

The work on electromagnetic emission from quark-gluon plasma (QGP) has received significant attention in recent years. These radiation are interesting probe in the context that it allows the investigation of the full time evolution and dynamics of the produced matter. These probes (photons and dileptons) once produced leave the reaction zone essentially undistorted and carry direct information from the hot and dense medium to the detectors [1]. Unfortunately, the Lattice data due to its limitations also could not shed any light on the low mass dileptons.

Experimentalists at RHIC and LHC noticed that the formation of QGP is not completely transparent during collisions of massive nuclei [2]. They found a sizable amount of baryon chemical potential at the central collision zone. This baryon chemical potential μ is taken to be at energies around $\sqrt{s} \leq 200$ AGeV. Further the microscopic models [3] also reported that the colliding heavy ions may not be fully transparent. Thus, many theoretical and experimental results [4, 5] have been produced in the presence of non-zero chemical potential. Similarly, these types of works are further studied by Strickland and co-worker with the modification of the distribution function. They introduced quark and gluon fugacities in Jüttner distribution function [6]. Majumder *et al.* have also discussed dileptons from QGP produced at the RHIC energies in the limit of finite baryon density. Therefore the study of electromagnetic probes of QGP such as dilepton is important [7, 8].

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A Quasi-particle approach to dilepton production

In this paper we study the dilepton production rate in heavy-ion collision with the effective quark mass and it is suitably defined in Ref. [9, 10],

$$m_{eff}^2 = {m_c}^2 + \sqrt{2} m_c m_q + {m_q}^2 \qquad (1)$$

where m_c is the current mass of the quark and m_q is the thermal mass of the quark [11]. The chemical potential is considered as $\mu = 1.574, 2.515$ and 3.583 GeV, which is good approximation as assumed in the scale of Lattice data of having chemical potential in the centrality zone. Here we exclusively consider $q\bar{q} \rightarrow l^+ l^-$ reaction as our choice because of the higher production of lepton pair in the intermediate mass region. The Fermi-Dirac distribution function for quarks and antiquarks is used as;

$$f_{q,\bar{q}}(p_1, T, \mu) = \frac{\lambda_{q(\bar{q})}}{\exp^{\frac{(p_1 \mp \mu)}{T}} + \lambda_{q(\bar{q})}} \qquad (2)$$

The function is slightly modified due to the approximation from Jüttner distributions of a chemically non-equilibrated system with its parton fugacity $\lambda_{q(\bar{q})}$. For gluon distribution, it is also approximated Bose-Einstein and it is defined as:

$$f_g(p_g, T, \mu) = \frac{\lambda_g}{\exp^{\frac{p_g}{T}} - \lambda_g} \qquad (3)$$

We obtain the production rate using the dilepton emission rate $\frac{dN}{dM^2 d^4x}$ (i.e. the number of dilepton emitted per space time volume per invariant lepton pair mass) given by [12]:

$$\frac{dN}{dM^2 d^4x} = \frac{5\alpha^2 TM}{18\pi^3} \lambda_q^2 \left[1 + \frac{2m_{eff}^2}{M^2}\right] K_1(\frac{M}{T}) (4)$$

Here $K_1(M/T)$ is the modified Bessel's function which is taken as $K_1(M/T) = G(z)$, λ_q is quark fugacity dependent on the chemical potential and volume element is taken as $d^4x = d^2x_T dy \tau d\tau$.

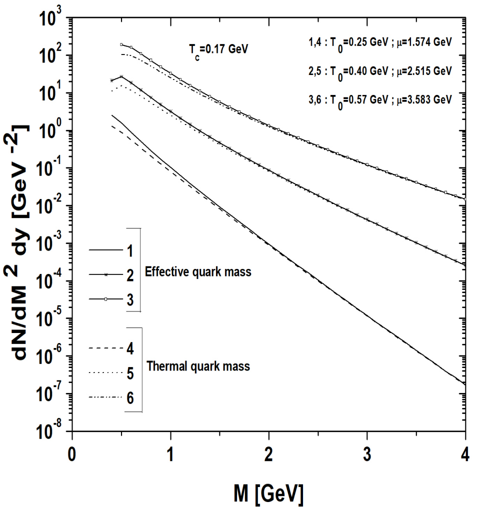

FIG. 1:

Results

The given figure elucidates the dilepton emission rate with respect to lepton invariant mass for different values of chemical potential $\mu = 1.574, 2.515$ and 3.583 GeV at temperatures ranging from $T_0 = 0.25$ GeV to $T_0 = 0.57$ GeV and at critical temperature $T_c = 0.17$ GeV. In this, we found that there is a visible increment in the production rate. Figure clearly shows a enhancement in the dilepton production with effective quark mass as compared to the thermal quark mass. The increment in the production rate with chemical potential and temperature dependent quark mass is prominent in the relevant range of invariant mass region. Therefore, our model results are interesting which gives a significant output with effective quark mass in QGP phase. In the high mass region, it shows a very much similar behaviour with the thermal quark mass and effective mass of quark. The results are compared with the earlier work [13].

Discussion

We conclude that the quasi-particle model gives an improved results over those of massless quark and thermal quark mass in the production of dileptons. Results also enhance in the relavant range of invariant mass with effective quark mass. This improved result is specially contributed by the effective mass of the quark which is dependent on temperature and chemical potential. QGP is described by the system of massive non-interacting quasi-particles where these quasi-particles acquire mass due to the interaction of quarks and gluons with the surrounding matter in the medium. Therefore, we finally conclude that the results on dilepton production are found to be good and it is lying almost in the spectrum of most recent theoretical calculations.

References

[1] J. Alam, S. Raha and B. Sinha, Phys. Rep. **273**, 243 (1996).
[2] S. Nagamiya, Nucl. Phys. A **544**, 5c (1992).
[3] H. J. Mohring and J. Ranft, Z. Phys. C **52**, 643 (1991).
[4] N. Hammon *et al.* , Phys. Rev. C **61**, 014901 (1999).
[5] A. Dumitru *et al.* , Phys. Rev. Lett. **70**, 2860 (1993).
[6] M. Strickland, Phys. Lett. B **331**, 245 (1994).
[7] P. B. Arnold, G. D. Moore, and L. G. Yaffe, JHEP **0206**, 030 (2002).
[8] R. Rapp, Adv. High Energy Phys. **2013**, 148253 (2013).
[9] P. K. Srivastava, S. K. Tiwari, and C. P. Singh, Phys. Rev. D **82**, 014023 (2010).
[10] Y. Kumar, EPJ Web of Conf. **182**, 02070 (2018).
[11] Y. Kumar and P. Jain, IJMPA **30**, 1550196 (2015).
[12] A. Bialas and W. Czyz, Phys. Rev. D **30**, (1984) 2371.
[13] S. S. Singh and Y. Kumar, Can. J. Phys. **92**, 31 (2014).