Photon emission from quark-gluon plasma at finite chemical potential

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Introduction

The study of relativistic heavy-ion collision (RHIC) is to probe the exact information of the quark-gluon plasma (QGP) [1]. It is widely accepted that experiments in RHIC at BNL and LHC at CERN indicate the formation of QGP.

Photons are one of the best signals expected for a QGP [2, 3]. The high-energy photons are sensitive observables to the dynamics of the deconfined phase. The experimental challenge of obtaining spectra of only direct photons has been gone through by several expeiments; WA98 at SPS/CERN [4] and PHENIX at RHIC/BNL [5] have showed explicit data points for direct photons. Assuming the formation of a QGP already at AGS, SPS and RHIC energies, a finite quark chemical potential is considered. Several authors have studied the photon production at finite baryon chemical potential [6, 7]. In this work, we calculate photon production from QGP at finite chemical potential.

A brief description of simple model

A simple phenomenological model is used as quasiparticle in which mass is dependent on temperature and parametrization factors. Due to thermal interactions between quarks and gluons, the mass of these particle generated and shows well behaviour above and around critical temperature. The finite quark mass is defined as [8, 9]:

$$m_q^2(T, \mu_q) = \gamma'_{q,g} g^2(p) T^2. \quad (1)$$

where $\gamma'_{q,g}$ is the phenomenological parameter of quarks and gluons, p is the quarks (gluons) momentum, T is the temperature and $g(p)$ is first order QCD running coupling constant.

In this model, we use the finite value of quark chemical potential through the flow parameters of quarks. These parameters are used to take care the hydrodynamical aspect of hot QGP. The parameter γ'_q is taken by modifying the earlier value of γ_q. We replace γ_q by $\gamma_q[1+\mu_q^2/\pi^2T^2]$ and represented as γ'_q [8]. On the other hand, there is no change in the gluon parameter and we put it remain same as earlier one, i.e. γ'_g as γ_g, The value of γ_g is fixed as 1/3. We compute the thermal photon emission from quark-gluon plasma of complete leading order (LO) results at temperatures $T = 0.35$ GeV with the arbitrary value of quark chemical potential taken by [9] for flavor 2 .

Photon emission from QGP

We estimate our work of photon production at finite baryon density considering the leading order processes for photon production. Due to baryon rich density, the number of quark contents in the system is large enough to interact among themselves and other particles. The rate for photons of momentum p is given by the expression [10, 11]:

$$\frac{dN}{d^4xd^3p} = \frac{1}{(2\pi)^3} A(p) \left[ln \left(\frac{T}{m_q(T, \mu_q)} \right) + \frac{1}{2} ln \left(\frac{2E}{T} \right) + C_{tot} \left(\frac{E}{T} \right) \right] \quad (2)$$

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with $E = p$ and $m_q^2(T, \mu_q)$ is the leading order large momentum limit of the thermal quark mass. The leading-log coefficient $A(p)$ is given as,

$$A(p) = 6\alpha_e \sum_f e_f^2 \frac{m_q^2(T, \mu_q)}{E} f_D(E) \quad (3)$$

The summation is over the number of quark flavors and e_f^2 is their electric charge, α_e is the electromagnetic constant and mass of quark is taken by Ref. [8, 9]. $f_D(E)$ is the fermi distribution function. The results of $C_{tot}(\frac{E}{T})$ is taken by Ref. [10, 11]. Then we study the total photon spectrum above critical temperature by integrating the total rate over the space-time history of the collision. It is expressed as [11]:

$$\frac{dN}{d^2p_T dy} = \int d^4x (E\frac{dN}{d^3pd^4x})$$
$$= Q\int_{\tau_0}^{\tau_f} \tau d\tau \int dy (E\frac{dN}{d^3pd^4x}) \quad (4)$$

Results and discussion

In Figure [1], we show the production rate of photon with transverse momentum for arbitrary values of quark chemical potential with different set of parameters. We found that the photon production increases with increase the quark chemical potential at fix temperature $T = 0.35$ GeV and there is uniform fall in total emission rate as a function of transverse momentum for all values of quark chemical potential with $\gamma_q = 2\gamma_g$ for flavor $n_f = 2$. The increase in the emission rate is highly effected by the temperature as well as the quark chemical potential of the system with the various set of initial condition. With $\gamma_q = 2\gamma_g$, the total rate is significant large. Our results are more enhanced as comparison to the results of Ref. [11] at zero chemical potential.

Thus the modified result of photon production give the significant contribution at finite temperature and chemical potential. Overall, our model of parametrization factor gives a significant contribution and improve the calculation of photon emission in high-energy heavy-ion collisions.

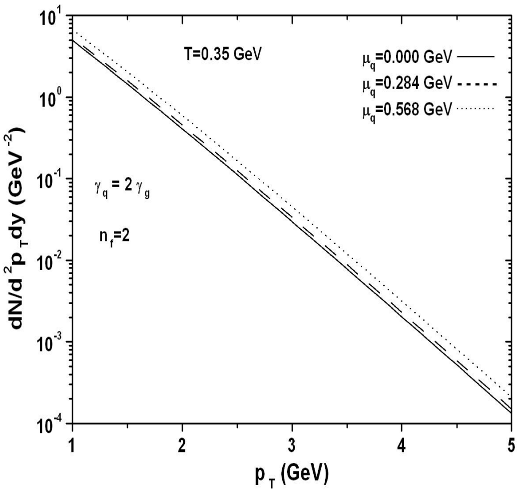

FIG. 1: The photon spectra at thermal temperature $T = 0.35$ GeV for $n_f = 2$ with the variation of quark chemical potential at $\gamma_g = 1/3$ and $\gamma_q' = 2[1 + \mu_q^2/\pi^2T^2]\gamma_g$ i.e. $\gamma_q = 2\gamma_g$.

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