Enhancement in the production of photons from hot and dense matter of quark gluon plasma

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Introduction

In relativistic heavy-ion collisions, photons has long been recognized as a useful deep probe that provide the exact information of quark-gluon plasma (QGP). These photons probe the entire space time evolution of the plasma due to electromagnetic interaction and has large mean free path [1, 2]. Researcher believe that the system is not fully transparent due to massive collision between nuclei and it has some finite value of chemical potential. In this present work, we perform the calculation of leading order processes for photon emission which consist QCD Compton Scattering, $q\bar{q}$ annihilation, Bremsstrahlung (brems), and annihilation with scattering (aws) from hot and dense matter using quark mass dependent on temperature and quark chemical potential. The results are improved with the effect of quark chemical potential as well as parametrization factor.

Photons from hot and dense matter

The photon production at finite chemical potential is studied by the several theoretical and experimental group. The various model has already been introduced to prove the existence of QGP [2, 3]. We extend our work by considering the leading order processes for photon production. The photon rate of momentum q is given by the expression [4]:

$$\frac{dN}{d^4xd^3q} = 0.004A(q)\left[ln\left(\frac{T}{m_q(T,\mu_q)}\right) + \frac{1}{2}ln\left(\frac{2E}{T}\right) + C_{tot}\left(\frac{E}{T}\right)\right] \quad (1)$$

with $E = q$. The leading-log coefficient $A(q)$ is given as:

$$A(q) = 0.029\frac{m_q^2(T,\mu_q)}{E}f_D(E) \quad (2)$$

Here, $m_q^2(T,\mu_q)$ is the leading order large momentum limit of the quark mass. we use dynamical quark mass as finite value which depends on temperature and chemical potential [5]. The mass of these particles generated due to the interaction among quarks and/or gluons. The modified quark mass is defined as [5]:

$$m_q^2(T,\mu_q) = \gamma_q\left[1 + \frac{\mu_q^2}{\pi^2T^2}\right]g^2(q)T^2. \quad (3)$$

Where $\gamma_q = 1/6$ or $1/3$ is the phenomenological parameter of quarks, T is the temperature and $g(q)$ is first order QCD running coupling constant taken by [3]. The parameter γ_q is modified as $\gamma_q[1 + \mu_q^2/\pi^2T^2]$ for the good approxiamtion of temperature [5]. The parameter γ_g is fixed as 6 times of γ_q. $f_D(E)$ is the fermi distribution function. The results of non-trivial function $C_{tot}(\frac{E}{T})$ is taken by Ref. [4].

Finally we compute the total photon spectrum of complete leading order at temperature $T = 0.57$ GeV with the various value of quark chemical potential for flavor 3 by integrating the total rate over the space-time history of the collision [3]. Therefore with the rapidity values and q_T, we study the total photon spectrum.

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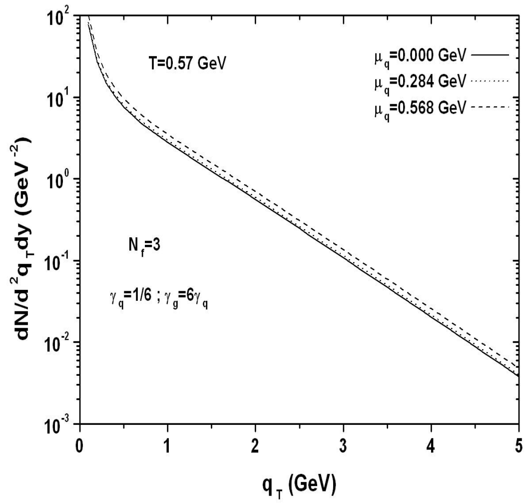

FIG. 1: The photon spectra at temperature $T = 0.57$ GeV for $N_f = 3$ with the various value of μ_q by fixing $\gamma_q = 1/6$ and $\gamma_g = 6\gamma_q$.

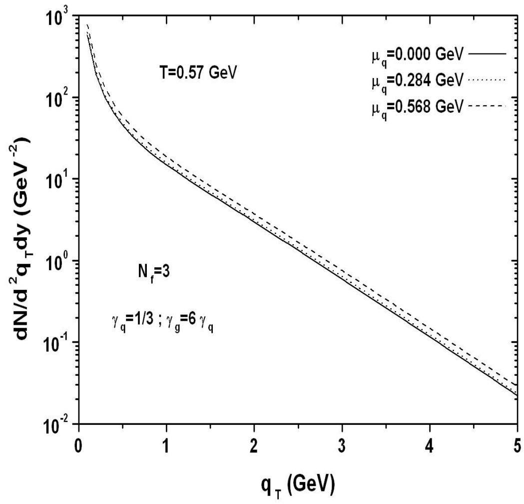

FIG. 2: The photon spectra at temperature $T = 0.57$ GeV for $N_f = 3$ with the various value of μ_q by fixing $\gamma_q = 1/3$ and $\gamma_g = 6\gamma_q$.

Results and Discussion

We performed the total photon spectrum over the space-time evolution of QGP with variation of μ_q using parametrization factor $\gamma_q = 1/6$ or $1/3$ and $\gamma_q = 6\gamma_g$ at temperature $T = 0.57$ GeV for flavor $N_f = 3$.

In Figure [1], we plot production rate of photon with transverse momentum with parametrization value $\gamma_q = 1/6$ and $\gamma_g = 6\gamma_q$ and found production rate increases with increases quark chemical potential, μ at temperature $T = 0.57$ GeV. It also shows the uniform fall in total emission rate as a function of transverse momentum q_T for all values of quark chemical potential. In figure [2], we again show the production rate with parametrization value $\gamma_q = 1/3$ and $\gamma_g = 6\gamma_q$. In this figure, emission rate is much enhanced with order of 1 as comparison to figure [1] with this parametrization factor. The increase in the emission rate is highly effected by the quark chemical potential and parametrization factor. Our model's results are suitably fitted with these sets of parameter and shows enhanced result. The total photon rate thus increases with suitable choice of phenomenological parameter by varying the quark chemical potential. Overall photons are considered as best signature of QGP in relativistic heavy-ion collisions.

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