Radiative energy loss in gluon gas

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One of the most spectacular prediction of QCD is that the hadronic matter undergoes a phase transition to Quark Gluon Plasma(QGP) at high temperature and density. The study of QGP offers the possibility to address several fundamental question about the state of matter at high temperature and density.The naive picture of the quark-gluon plasma belongs to a natural consequence of the QCD asymptotic freedom, where the quarks and gluons are weekly interacting. However, the data that have been collected over the last decade at RHIC suggest, the QGP produced tends to be a strongly interacting fluid instead of weekly interacting gas. In the recent past many pQCD approach has been made to explane this strongly interacting fluid. The energy dissipation in QCD matter is considered as one of the most promising probes for the QGP diagnostics. The two most important mechanisms for the energy loss are radiative and collisional processes. Therefore, it is very important to understand and theoretically improve the calculations of partonic energy loss in thermal medium.

Generically the radiative energy loss can be written as $2 \to 2 + g$ process. In this work we consider the process $gg \to gg + g$, and the results for other process can be obtained from it in a straight forward way. Following previous work [1](henceforth denoted by the subscript as DA), when momentum k_5 of the radiative gluon is taken to be a soft radiation around zero rapidity in the centre of momentum frame, then the soft gluon multiplicity distribution at fixed $q_\perp$ is given by [1]:

$$\left[\frac{dn_g}{d\eta dk_\perp^2}\right]_{DA} = \frac{C_A\alpha_s}{\pi^2}\left(\frac{q_\perp^2}{k_\perp^2[(k_\perp - q_\perp)^2 + m_D^2]}\right) + \frac{C_A\alpha_s}{\pi^2}\left(\frac{q_\perp^2(q_\perp^2+m_D^2)^2}{s^2k_\perp^2[(k_\perp - q_\perp)^2 + m_D^2]}\right) \quad (1)$$

where $k_\perp$ and $q_\perp$ are the perpendicular component of k_5 and that of the momentum transfer in the centre of momentum frame respectively, m_D is the Debye mass, N_c is the number of colour degrees of freedom.

In Eq. 1, if we neglect the second term, then it reproduce the the widely used Gunion-Bertsch(GB) formula [1] for the soft gluon multiplicity distribution. Eq. 1 can be written as:

$$\left[\frac{dn_g}{d\eta dk_\perp^2}\right]_{DA} = \left[\frac{dn_g}{d\eta dk_\perp^2}\right]_{GB}\left(1 + \frac{(q_\perp^2+m_D^2)^2}{s^2}\right) \quad (2)$$

where

$$\left[\frac{dn_g}{d\eta dk_\perp^2}\right]_{GB} = \frac{C_A\alpha_s}{\pi^2}\frac{q_\perp^2}{k_\perp^2[(k_\perp - q_\perp)^2 + m_D^2]} \quad (3)$$

To estimate the contributions from the correction term we consider the ratio, R_c given by

$$R_c = \frac{\left[\frac{dn_g}{d\eta dk_\perp^2}\right]_{DA}}{\left[\frac{dn_g}{d\eta dk_\perp^2}\right]_{GB}} = 1 + \frac{(q_\perp^2+m_D^2)^2}{s^2} \quad (4)$$

We evaluate R_c by substituting $s =< s >\sim 18T^2$, $m_D = \sqrt{4\pi\alpha_s(T)}\,T$ and $q_\perp^2 =< q_\perp^2 >$ which is calculated by using the following relation:

$$< q_\perp^2 >= \frac{\int dt\, t\,(d\sigma/dt)}{\int dt\,(d\sigma/dt)} \quad (5)$$

The lower and upper limits of the above integration are $= m_D^2$ and $s/4$ respectively.

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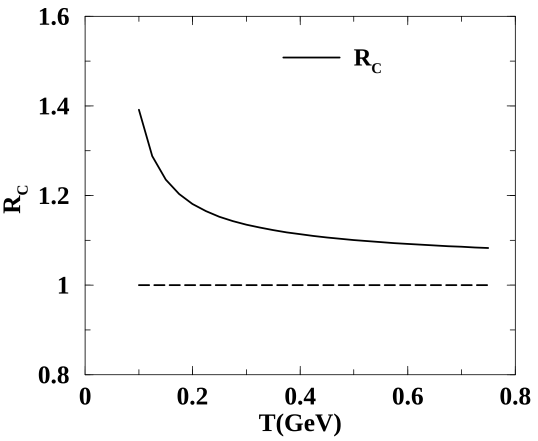

FIG. 1: The variation of R_c (see Eq. 4) with temperature.

The variation of R_c with T is depicted in Fig. 1. The temperature dependence of the strong coupling α_s is used [4]. It is observed that the correction to the gluon spectrum is appreciable for low temperature domain.

Since the correction term is appreciably large at low temperature domain, it encourage us to see the effect of this correction term in the energy loss mechanism which is manifested as the nuclear suppression factor in heavy ion collision experiment. To evaluate the radiative energy loss we closely follow the procedure given in [3], for the gluon using both DA and GB approximation . The LPM effect has been also taken into account.

In Figs. 2 the variation of radiative energy loss with T has been depicted for the process gg → ggg . The solid line represent the energy loss when DA gluon multiplicity distribution has been taken into account and the dotted line for the GB gluon multiplicity distribution. To highlight the difference beetween the energy loss due to the correction term we have define the ratio,

$$R_{EL} = \frac{DA_{EL}}{GB_{EL}} \tag{6}$$

where the numerator represent the energy loss due to DA gluon multiplicity distribution and the denominator represent the energy loss due to GB gluon multiplicity distribution. It is observed that the correction to the gluon spectrum, which leads to the energy loss is appreciable for low temperature domain. Since the low p_T particle are originated from the low temperature domain in heavy ion collision, so the correction term may significantly affect the R_{AA} and v_2 at the low p_T domain. The effect of the correction term on the transport coefficients will be presented in the symposium.

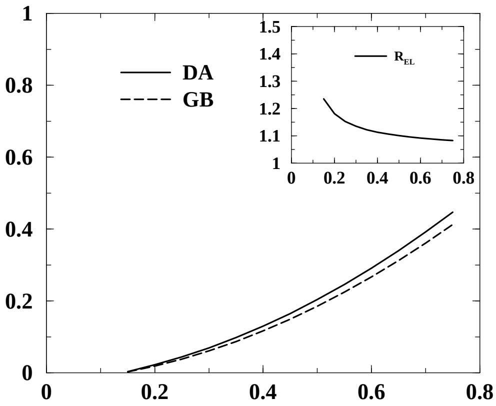

FIG. 2: The variation of energy loss with temperature. Inset: The Variation of R_{EL} with temperature.

References

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