Gluon emission in quark-gluon plasmas

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Introduction

Lattice quantum chromo dynamics (LQCD) calculations predict a transition from confined state in hadrons to a deconfined state of quarks and gluons above a temperature of 170 MeV or an energy density above 1GeV/fm^3. In the relativistic heavy ion collisions at RHIC at BNL an energy density above 5GeV/fm^3 is attained. Experimental measurements of several observables at RHIC indicated that a transition to a deconfined state of matter is formed [1],[2]. Among these observables, jet-quenching phenomenon is an important signal for a hot dense medium formed in relativistic heavy ion collisions. This is owing to the fact that jet suppression has its origin in parton energy loss in the quark matter following gluon radiation, which distinctly differs from energy loss in hadronic matter. For example the suppression of high-p_T pions, from 3GeV to 10GeV, at RHIC at BNL experiments can be explained by assuming a deconfined state.

We calculated the gluon emission processes in QGP medium. This is the basic mechanism applied to calculate parton energy loss calculations. However, parton energy loss also has contributions arising from collisional energy loss, well discussed in literature. In photon and gluon emission, coherent radiation processes involve multiple scatterings of the partons in the QGP medium during their formation time. This leads to the interference effects known as Landau-Pomeranchuk-Migdal effect (LPM). Gluon emission is discussed widely in literature [3]-[6]. Unlike the emission of electromagnetic quanta, the emitted hard gluon feels the random colored background field. However, similar to the case of bremsstrahlung photon emission, the gluon and quark must be nearly collinear.

We follow the formalism given in [4]-[6] which implements LPM effects by resumming the ladder diagrams. The bremsstrahlung integral equations determine the gluon emission amplitude given by $\mathbf{F}_s(\mathbf{h}$,p,k) function in Eq.1. The term $\delta E(\mathbf{h}, p, k)$ in Eq.1 is the energy differential between initial and final states as in Eq.2. Accordingly, the gluon emission rates are given by Eq.3. The hard gluon emission rates from QGP are finite owing to cancellations in the infrared limit as the collision terms in Eq.1 involve only the differences. This formalism is similar to the photon emission from QGP, however, the gluon emitted can interact with other scattering centers as well as self interaction. For the case of gluon emission, we are using the iterations method developed by us earlier [7] to solve integral equation to obtain $\mathbf{F}_s(\mathbf{h}$,p,k) function. We obtained $\mathbf{F}_s(\mathbf{h}$,p,k) distributions for various values of gluon amd parton momenta (k,p) considering the mechanisms $q- > qg$, $g- > gg$, $g- > q\bar{q}$. Further, we are developing a variational approach to obtain these distributions. We present a few $\mathbf{F}_s(\mathbf{h}, p, k)$ distributions in Figs.1 for various values of gluon and parton momenta (k,p). The real part is shown in figure (a) and imaginary part in figure (b). As shown in figure, the real part of the distributions are very sharply peaked and the peak position and peak value depend on the process. In the symposium, we will present these gluon $\mathbf{h}$ distributions for these three processes.

$$\begin{aligned} 2\mathbf{h} \; = \; & i\delta E(\mathbf{h}, p, k)\mathbf{F}(\mathbf{h}) + g^2 \int \frac{d^2\mathbf{q}_\perp}{(2\pi)^2} C(\mathbf{q}_\perp) \\ & \times \{(C_s - C_A/2)\,[\mathbf{F}(\mathbf{h}) - \mathbf{F}(\mathbf{h} - k\mathbf{q}_\perp)] \\ & + (C_A/2)\,[\mathbf{F}(\mathbf{h}) - \mathbf{F}(\mathbf{h} + p\mathbf{q}_\perp)] \\ & + (C_A/2)\,[\mathbf{F}(\mathbf{h}) - \mathbf{F}(\mathbf{h} - (p-k)\mathbf{q}_\perp)]\} \quad (1) \end{aligned}$$

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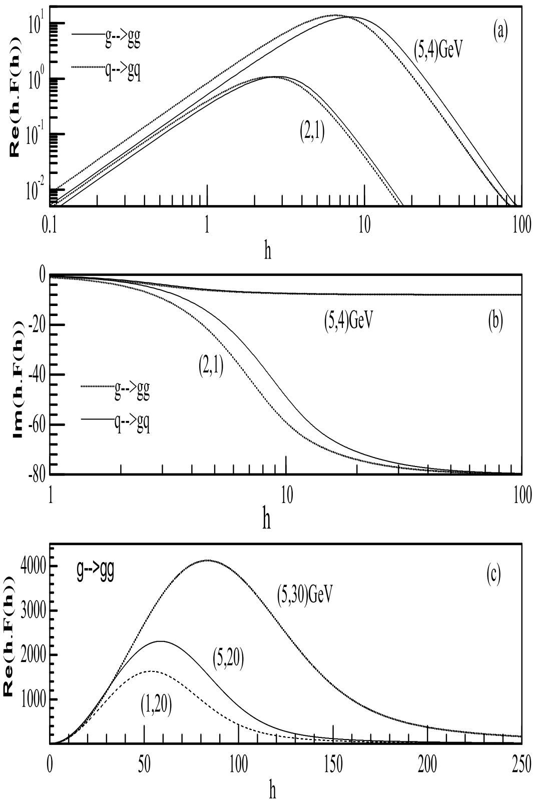

FIG. 1: (a) Shows the real part of **h** distributions of the $\mathbf{h}\cdot\Re\mathbf{F}(\mathbf{h})$ for gluons. Various curves are for various parton momenta (p) and gluon momenta (k) values as mentioned in figure labels as (p,k). The distributions are obtained using iterations method.
(b) Shows the imaginary part of **h** distributions of the $\mathbf{h}\cdot\Im\mathbf{F}(\mathbf{h})$
(c) Shows the real part of **h** distributions of the $\mathbf{h}\cdot\Re\mathbf{F}(\mathbf{h})$ for pure glue process. Various curves are for various parton momenta (p) and gluon momenta (k) values as mentioned in figure labels as (p,k).

$$\delta E(\mathbf{h},p,k) = \frac{\mathbf{h^2}}{2pk(p-k)} + \left[\frac{m_k^2}{2k}+\frac{m_{p-k}^2}{2(p-k)}-\frac{m_p^2}{2p}\right] \quad (2)$$

$$\frac{d\Gamma_g^{LPM}}{d^3\mathbf{k}} = \frac{\alpha_s}{4\pi^2k^2}\sum_s N_s d_s C_s \int_{-\infty}^{+\infty}\frac{dp}{2\pi}\int\frac{d^2\mathbf{h}}{4\pi^2} n_s(p+k)[1\mp n_s(p)][1+n_b(k)] \frac{1}{k^3}|\Gamma^s_{p\to p+k}|^2 2\mathbf{h}\cdot\Re\mathbf{F}_s(\mathbf{h};p,k) \quad (3)$$

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