Jet conversion photons from an anisotropic quark-gluon-plasma

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Introduction

The main goal of experiments which perform ultra-relativistic heavy-ion collisions is to produce and study the properties of a deconfined plasma of quarks and gluons. This new state of matter, called quark-gluon plasma (QGP) is expected to be formed at temperature of the oder of $170 - 200$ MeV. Another most important task is to characterize different properties of this new state of matter, such as isotropization/thermalization.

The most difficult problem lies in the determination of isotropization and thermalization time scales ($\tau_{\rm iso}$ and $\tau_{\rm therm}$). Studies on elliptic flow (upto about $p_T \sim 1.5 - 2$ GeV) using ideal hydrodynamics indicate that the matter produced in such collisions becomes isotropic with $\tau_{\rm iso} \sim 0.6$ fm/c.On the contrary, perturbative estimates yield much slower thermalization of QGP [1]. However, recent hydrodynamical studies [2] have shown that due to the poor knowledge of the initial conditions, there is a sizable amount of uncertainty in the estimation of thermalization or isotropization time. Electromagnetic probes have long been considered to be one of the most promising tools to characterize the initial state of the collisions. Because of the very nature of their interactions with the constituents of the system they tend to leave the system without much change of their energy and momentum. Photons (dilepton as well) can be one such observables.

However, photons from jet plasma interaction dominates at high p_T region where the transverse expansion is negligible. Our primary concern here is to see the effect of pre-equilibrium momentum space anisotropy on the jet-photon production. The phenomenological consequences of early stage pre-equilibrium momentum space anisotropy of QGP have been studied in Ref. [3, 4] in the context of dileptons and in Ref. [5, 6] in the context of photons. In the present work, we will be investigating the p_T distribution of the jet conversion photons in the presence of pre-equilibrium momentum space anisotropy.

Photons from jet conversion mechanism are produced when a high energy jet interacts with the medium constituents via annihilation and Compton processes [7].

In absence of any precise knowledge about the dynamics at early time of the collision, one can introduce phenomenological models to describe the evolution of the pre-equilibrium phase. In this work, we will use one such model, proposed in Ref. [3].

Formalism

The anisotropic distribution function can be obtained [8] from the isotropic distribution function in the following way:

$$\begin{aligned} f_i(\mathbf{k}, \xi, p_{\rm hard}) &= f_i^{iso}(\sqrt{\mathbf{p}^2 + \xi(\mathbf{p}.\mathbf{n})^2}, \\ &\quad p_{\rm hard}(\tau, \eta)) \end{aligned} \tag{1}$$

where $\mathbf{n}$ is the direction of anisotropy and ξ is a parameter controlling the strength of the anisotropy with $\xi > -1$. The hard momentum scale $p_{\rm hard}$ is the hard momentum scale. In the case of an isotropic QGP, $p_{\rm hard}$ can be identified with the plasma temperature (T). In this work, we will concentrate jet conversion photons which arises from the electromagnetic interaction of jet-quarks, originated from the hard-scattering of colliding nuclei, with the plasma partons.

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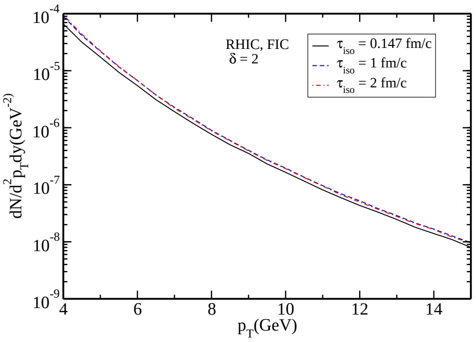

FIG. 1: (Color online) p_T distributions of jet conversion photons for FIC interpolating model at $\delta = 2$ at RHIC energy. Here $T_i = 0.446$ GeV and $\tau_{\rm iso} = 0.147$ fm/c

To convolute the jet-photon rate with the evolution of the QGP, we need to know the time dependence of the ξ and $p_{\rm hard}$. For the time dependence of ξ and $p_{\rm hard}$ we have used the phenomenological model in Ref. [3–6, 9]. This model assumes an intermediate time scale $\tau_{\rm iso}$: for $\tau < \tau_{\rm iso}$ the system is anisotropic and for $\tau > \tau_{\rm iso}$ system is isotropic.

1. Result

The simple model [4, 5], which smoothly interpolates between an initially non-equilibrium plasma to an isotropic plasma, is based on the assumption that the initial conditions are held fixed. Fixed initial condition interpolating models always result into an enhanced value of hard momentum scale as a consequence of pre-equilibrium anisotropy. As a consequence of this enhancement of $p_{\rm hard}$, pre-equilibrium anisotropy increases the density of plasma partons. Introduction of pre-equilibrium anisotropy with fixed initial condition increases the density of plasma partons moving in the transverse direction [5] and at the same time decreases the density of plasma partons moving in the forward direction. This feature of fixed initial condition pre-equilibrium momentum-space anisotropy should be reflected in the jet conversion photon p_T distribution which we will see in Fig 1.

Summary & Conclusions

To summarize, we have investigated the effects of the pre-equilibrium momentum space anisotropy of the QGP on the p_T distribution of the jet conversion photons. To describe space-time evolution of hard momentum scale, $p_{\rm hard}(\tau)$ and anisotropy parameter, $\xi(\tau)$, two phenomenological models have been used [4]. These phenomenological models assume the existence of an intermediate time scale called the isotropization time ($\tau_{\rm iso}$). The first model is based on the assumption of fixed initial condition. We observed that, for fixed initial condition, a *free streaming* interpolating model can enhance the jet conversion photon yield significantly.

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