Photon rapidity density from an anisotropic quark matter

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Introduction

Relativistic heavy ion collider, (RHIC) at BNL and upcoming Large Hadron Collider (LHC) at CERN, are designed to produce and study the strongly interacting matter at high temperature and/or density. Experiments at the RHIC have already demonstrated that high p_T hadrons in central $A+A$ collisions are significantly suppressed in comparison with the binary scaled $p+p$ collisions [1]. This observation known as *jet-quenching*, clearly indicates towards the formation of *Quark Gluon Plasma* (QGP) at the RHIC experiments. Another most important task is to characterize different properties of this new state of matter, such as isotropization/thermalization.

Detection of the isotropization and thermalization time scales ($\tau_{\rm iso}$ and $\tau_{\rm therm}$) is one of the most difficult problems. Perturbative estimates [3] lead to much slower thermalization which are not in agreement to the findings using elliptic flow (upto about $p_T \sim 1.5-2$ GeV)[2]. Due to the poor knowledge of the initial conditions, there is a sizable amount of uncertainty in the estimation of thermalization or isotropization time [4]. Electromagnetic probes have long been considered to be one of the most promising tools to characterize the initial state of the collisions [5] as they escape from the system without much interactions. Photons can be used to determine the initial temperature, or equivalently the equilibration time. 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. [6], for the time dependence of the anisotropy parameter, $\xi(\tau)$, and hard momentum scale, $p_{\rm hard}(\tau)$. The phenomenological model in Ref. [6–10] assumes rapidity independent parton distribution functions. However, the experimental data are expected to be better described by rapidity dependent parton distribution functions. Therefore, in this work, we have used rapidity dependent quark and anti-quark distribution functions. The rapidity dependence of the distribution functions arises from the rapidity dependence of the initial temperature, $T_{\rm i}(\eta)$ [11].

Formalism

The anisotropic distribution function can be obtained [12] from the isotropic distribution function in the following way:

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

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 on the photon rapidity density:

$$\frac{dN}{dy} = \int d^2p_T \int d^4x \, \frac{dN}{dyd^2p_T}, \quad (2)$$

where dN/dyd^2p_T is the differential photon rate. To convolute the 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

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used the phenomenological model in Ref. [6–10]. 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.

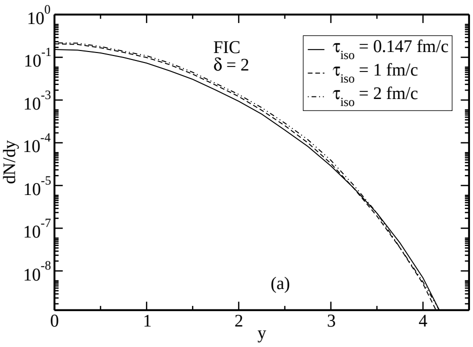

FIG. 1: Photon rapidity distribution for FIC, for $p_T = 2$ GeV for (a) $\delta = 2$

The significant impact of $\tau_{\rm iso}$ on the photon rapidity density is shown in Fig 1 where we have plotted the photon yield as a function of photon rapidity for $\tau_{\rm iso} = \tau_i$, 1 and 2 fm/c respectively. Photon yield enhanced with increasing $\tau_{\rm iso}$ for low rapidity region, however, suppressed in the high rapidity region.

Summary and Conclusion

In this work, we have investigated the effects of the pre-equilibrium momentum space anisotropy of the QGP on the rapidity density of medium 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 [7]. We observed that, for fixed initial condition, a *free streaming* interpolating model can enhance the photon yield significantly for rapidities upto $y \sim 3$.

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