Direct photon productions from Pb+Pb collisions at 2.76 TeV LHC energy.

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Introduction

The photons and dileptons are by now recognized as promising signals of QGP which is believed to be formed in the nuclear collisions at relativistic energies [1]. The nature of the interaction of these electromagnetic particles $(\gamma, \mu^+\mu^-, e^+e^-)$ with the medium they are formed ensures them as thermometric signals. These are produced at every space time point during the evolution and escape out of the medium retaining the thermodynamic information of the sources. In this present work we have evaluated the direct photon productions from Pb+Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV for 0-40% centrality and compare the theoretical evaluations with the recently available data for LHC energy [2].

Direct photons

The observed photons can be categorized according to different sources and states of the medium as follows; (i) prompt photons-originating from the interactions of the partons of the colliding nuclei, (ii) pre-equilibrium photons- emitting before the medium gets thermalised, (iii) thermal photons- coming from the interaction of thermal partons as well as thermal hadrons, (iv) some photons are also produced the from the passage of jets through plasma and (v) the decay photons-coming from the decay of long lived hadrons ($\pi^0 \rightarrow \gamma\gamma$, $\eta \rightarrow \gamma\gamma$, *etc*). Here we analyze the photon data from LHC energy [2], where photons from the hadronic decays, have already been excluded. It is important to mention here that the contributions from pre-equilibrium sources and due to the passage of jets through the medium have not been considered.

A. Prompt photons

The important processes of hard scatterings of partons of the colliding nuclei that produces prompt photons are basically Compton ($q(\bar{q})+g \rightarrow q(\bar{q}) + \gamma$), annihilation ($q + \bar{q} \rightarrow g + \gamma$) and quark fragmentation ($q(\bar{q}) \rightarrow q(\bar{q}) + \gamma$) processes. But there higher order processes contribute the net productions significantly. The complete NLO-pQCD [$O(\alpha\alpha_s^2)$] calculation is comparable with the leading order calculation with a higher K factor. We use the leading order calculation and scale it up by the number of binary collisions and multiply by proper K factor for Pb+Pb collisions at $\sqrt{s_{NN}}$= 2.76 TeV(LHC) energy to evaluate the prompt photon p_T spectra (dN/d^2p_Tdy).

B. Thermal photons

The invariant yield of thermal photons can be expressed as,

$$\frac{d^2N_\gamma}{d^2p_Tdy} = \sum_{i=phases} \int_i \left(\frac{d^2R_\gamma}{d^2p_Tdy}\right)_i d^4x \quad (1)$$

N_γ represents the number of photons and y is the rapidity. The static rate of photon production at a temperature T from a phase i is given as $(d^2R_\gamma/d^2p_Tdy)_i$. d^4x is the four volume element. Here its evolution is taken care by relativistic ideal hydrodynamics with an particular ansatz equation of state (see [3]. The emission of photons from QGP are primarily from Compton ($q(\bar{q})g \rightarrow q(\bar{q})\gamma$) and annihilation ($q\bar{q} \rightarrow g\gamma$) processes. Apart from these the productions from the reactions, $gq \rightarrow gq\gamma$, $qq \rightarrow qq\gamma$, $qq\bar{q} \rightarrow q\gamma$ and $gq\bar{q} \rightarrow g\gamma$ contribute substantially. We have used the rate calculation for the QGP phase up to order O($\alpha\alpha_s^2$).

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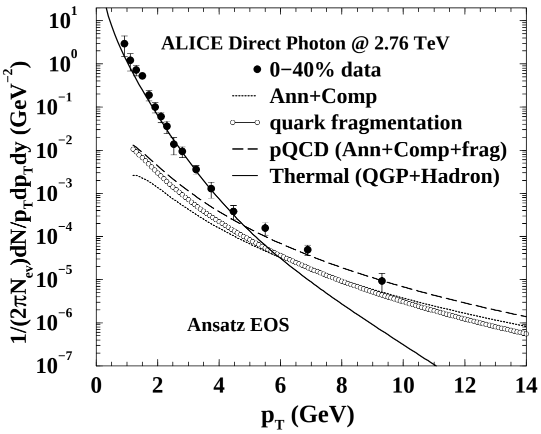

FIG. 1: The direct photon data (solid circles) from Pb+Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV LHC energy [2] and the theoretical results from different sources are shown.

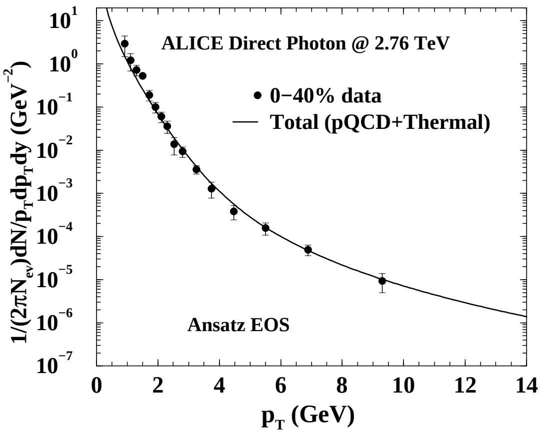

FIG. 2: The solid circles (data) represents the same as in Fig. 1. The solid line represents the theoretical evaluation for the sum of thermal and pQCD (prompt) contributions.

Similar to QGP phase, we have considered a set of hadronic interactions for the production of thermal photons from hadronic phase. These processes are ; (i) $\pi\pi \to \rho\gamma$, (ii) $\pi\rho \to \pi\gamma$, (iii)$\pi\pi \to \eta\gamma$ and (iv) $\pi\eta \to \pi\gamma$, (v) $\rho \to \pi\pi\gamma$, (vi) $\omega \to \pi\gamma$ (vii) $\pi K^* \to K\gamma$, (viii)$\pi K \to K^*\gamma$, (ix) $\rho K \to K\gamma$, (x) $KK^* \to K\gamma$.

Results

In Fig. 1 the direct photon data from Pb+Pb collisions for 0-40% centrality at $\sqrt{s_{NN}}$=2.76 TeV measured by ALICE collaboration (solid circles) [2] is shown. The dotted line represents the prompt photon productions from the pQCD calculation of annihilation and Compton processes (K_γ=3.2) using *Cteq6m* for N_{coll}=853(for 0-40%). The solid line with open circles show the contributions from quark-fragmentation (with K_{brem}=2.8) to the prompt photons.

The long-dashed line is the sum over all the hard processes. The thermal contribution evaluated from QGP and hadron gas (with T_i=546 MeV, τ_i=1.0 fm and ansatz EOS) is displayed in Fig. 1 (solid line). Fig. 1 shows that the thermal contribution dominates the invariant yield upto $p_T \sim 4$ GeV. The spectrum beyond $p_T > 4$ GeV is dominated by pQCD calculations. The solid line in Fig. 2 displays the sum of thermal and pQCD contributions explaining the data within the ambit of considered parameters. In summary, we discuss the photon productions at LHC energy from various sources and compare with the experimental data measured by ALICE collaboration. See [3] for proper references related to this work. The author acknowledges Prof. B. Sinha, Homibhabha professor for many discussions.

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