Sensitivity of direct photon production to isolation cut criteria in relativistic nuclear collisions

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Introduction

Direct photons are one of the most versatile and clean tools to study relativistic nuclear collisions. These include all photons except the ones from hadron decays. The direct photon spectrum produced in relativistic heavy ion collisions is dominated by prompt photons in the larger transverse momenta ($p_{\rm T} >$ 3 GeV/c) region; and thermal photons from the quark gluon plasma (QGP) and hadron gas phase are the dominant contribution at relatively lower $p_{\rm T}$. A precise estimation of this prompt contribution in heavy-ion collisions is highly desirable for studying both the direct photon spectrum and the thermal component [1]. Direct photons are mostly produced via 2→2 processes, namely quark–gluon Compton scattering and quark–antiquark annihilation. These together with the fragmentation photons produced during fragmentation of partons into hadrons are referred to as the prompt photons. The photons produced directly from parton–parton hard scatterings can be used to constrain the parton distribution functions (PDFs) and also act as a valuable tool to test the pQCD predictions. Direct photons are produced during the entire space-time evolution of the strongly interacting QGP medium. Being electromagnetic in nature, they escape without interacting strongly with the QGP, i.e. they are penetrating probes. This makes them rich in information about the temperature of the medium (via thermal photons), but making a clean separation between the different types of direct photons is difficult. Additionally, measurements of direct photons are complicated due to the presence of a large decay background, especially from 2-γ decay of π^0 and η mesons. A selection called 'isolation criterion', which is based on a threshold on the contributions of transverse energy/momentum from particles inside a cone around the candidate photon, is applied to suppress the decay and fragmentation photons. This has led to the prescription of 'isolated photons' [2].

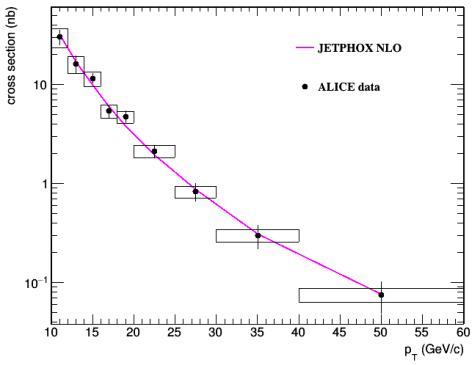

FIG. 1: Isolated photon cross section in pp collisions at $\sqrt{s} = 7$ TeV.

JETPHOX

The rate of production of prompt photons including both direct and fragmentation parts can be calculated from next-to-leading order (NLO) pQCD calculations. The production of direct and fragmentation photons at LO and NLO accuracies in hadronic collisions at relativistic energies can be studied using JETPHOX which is a well known parton level generator [3]. The 'isolation criterion' is implemented in JETPHOX calculations and can be varied to investigate the dependence of the

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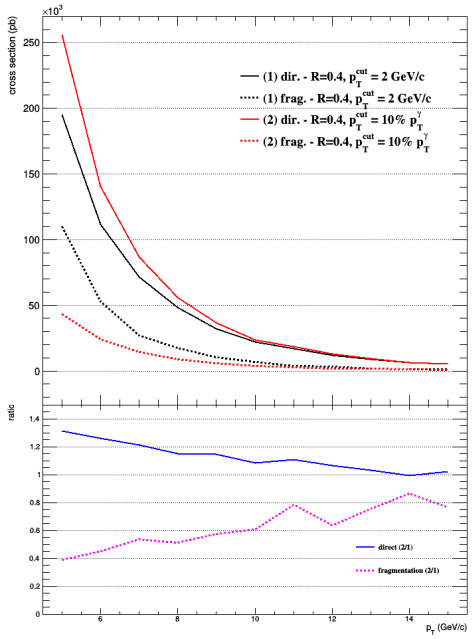

FIG. 2: Comparison between direct and fragmentation components of isolated photons in Pb–Pb collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV.

isolated photon spectra on different isolation cuts. Such a criterion is implemented by defining a cone centered around the photon direction in the η–φ plane with a fixed radius, R, then summing the transverse momenta of all the particles inside the isolation cone and limiting it to a threshold value ($p_{\rm T}^{\rm cut}$).

As a first check, we have matched NLO pQCD JETPHOX calculations with isolated photon measurements in ALICE [2] as shown in Figure 1. The PDF used is CT10, and the fragmentation function is BFG II. The values of the calculations were obtained by choosing factorisation, normalisation and fragmentation scales equal to the photon transverse momentum ($\mu_f = \mu_R = \mu_F = p_{\rm T}^{\gamma}$). An isolation threshold of $p_{\rm T}^{\rm cut} = 2$GeV/c within $R = 0.4$ around the photon was used.

Results and Discussions

In order to study the dependence of the isolated photon cross section on the isolation criteria, we have generated 4M events of Pb–Pb collisions at 5.02A TeV in the central rapidity region $|\eta| < 0.5$ using JETPHOX. For both direct and fragmentation components, two different cut offs ($p_{\rm T}^{\rm cut}$) are chosen for the isolation criteria, keeping the isolation cone radius fixed at R=0.4. For the first case, a fixed threshold of $p_{\rm T}^{\rm cut} = 2$GeV/c has been used whereas for the second case, a variable threshold dependent on the candidate photon momentum ($p_{\rm T}^{\rm cut} = 10\%\ p_{\rm T}^{\gamma}$) has been used. The direct and fragmentation parts of the isolated photons contribution are estimated separately for Pb–Pb collisions as shown in Figure 2. The isolation cut used in the calculation has been found to play a crucial role in the estimation of the two separate prompt contributions especially in the p_T region 4–10 GeV. The different isolation cuts are found to modify the fragmentation contribution by about 20–50% depending on the p_T range. On the other hand, the direct part has been found to be relatively less sensitive to the value of the isolation cut.

The prompt fragmentation photons are expected to produce small positive elliptic flow in the low and intermediate p_T regions as reported earlier [4]. The direct part of the prompt contribution does not contribute to the anisotropic flow. As a result, change in the fragmentation contribution depending on the isolation cut can also affect the photon anisotropic flow parameter. Thus, a detailed study on the sensitivity of prompt photons on the isolation cut would be valuable.

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