Direct photon production in Pb+Pb collisions from $\sqrt{s_{NN}}$= 2.76 TeV to 39 TeV

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One of the most important goals of high energy heavy ion physics is to study the properties of Quark-Gluon Plasma (QGP) produced in collisions of heavy nuclei at the relativistic energies [1]. The observation of large anisotropic flow of charged particles as well as energy loss of high energy partons both in Au+Au collisions at the BNL Relativistic Heavy Ion collider (RHIC) and in Pb+Pb collisions at the CERN Large Hadron collider (LHC) have provided strong evidence of the formation of QGP.

The small size and transient existence (∼ few fm) of QGP phase make it quite challenging to extract information about the dynamics and properties of this hot and dense matter produced in heavy ion collisions at the relativistic energies. Electromagnetic radiations are considered as one of the potential probes to study the properties of QGP. Photons (both real as well as virtual) are emitted throughout the evolution of the produced system and their momentum spectra are sensitive to the temperature of the ambient system [2]. We have seen that the direct photon spectra from 2.76A TeV Pb+Pb collisions at LHC [3] are explained well in the region $p_T \geq 2$ GeV by most of the theory calculations [4] where prompt photons are estimated using the next-to-leading order perturbative QCD calculation and the thermal photons are calculated considering hydrodynamical evolution of the system and state of the art photon rates [5, 6].

In the present work we study thermal and prompt photon production from Pb+Pb collisions at 5.02A TeV at LHC and also at 39A TeV at the upcoming Future Circular Facility (FCC) and compare with the results obtained at 2.76A TeV at LHC [7]. In addition, we calculate the elliptic flow of thermal photons at the LHC and FCC energies. Heavy ion collision at FCC energy is expected to produce QGP phase with much larger initial temperature and energy density than at LHC energies [8, 9] and thus, a comparison of photon production as well as anisotropic flow of photons at theses energies would provide valuable information about the initial state produced in these collisions and its evolution.

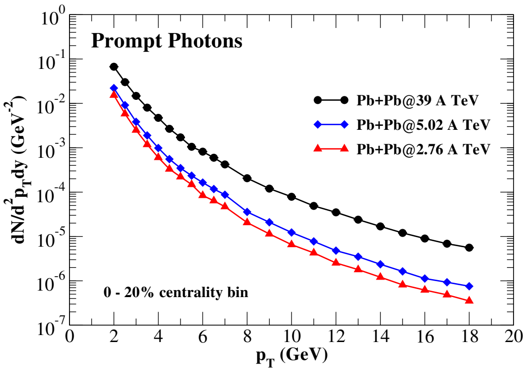

FIG. 1: Prompt photon production from Pb+Pb collisions at 2.76A TeV and 5.02A TeV at LHC and at 39A TeV at FCC for 0–20% centrality bin.

We use a (2+1) dimensional longitudinally boost invariant ideal hydrodynamic framework to study the evolution of the hot and dense QGP produced in collisions of Pb nuclei at LHC and FCC energies. The initial parameters for hydrodynamic model calculation are set by reproducing the experimental data for final charges particle multiplicities ($dN_{\rm ch}/d\eta \sim 1600$ and 2000 for 2.76A TeV

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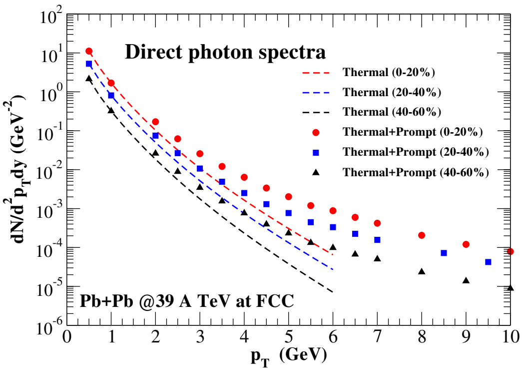

FIG. 2: Direct photon spectra from Pb+Pb collisions at 39A TeV at the upcoming FCC facility for three different centrality bins.

and 5.02A TeV respectively) at the two LHC energies. We consider value of charged multiplicity as 3600 [8] for 39A TeV Pb+Pb collisions at FCC. The initial formation time of the plasma for 2.76A TeV is taken as 0.14 fm and we keep this value fixed for 5.02A TeV and 39A TeV. The standard rates of thermal photon production from [5, 6] are used to calculate the spectra and elliptic flow. A lattice based equation of state is used and a constant temperature (160 MeV) freeze-out is considered for our calculation which reproduces the experimental data for pion spectra well.

We calculate prompt photon production using a numerical program which evaluates up to next-to-leading order in perturbative QCD [10]. The CTEQ6.6 parton distribution functions and BFG-II photon fragmentation functions are used to estimate the photons production from initial hard scatterings of Pb+Pb at the LHC and FCC energies. The factorisation, renormalization and fragmentation scales are considered as same and equal to p_T of photons.

In Fig. 1 we show the prompt photon p_T spectra from Pb+Pb collisions at energies 2.76A TeV, 5.02A TeV and for 39A TeV. The results are shown for a centrality bin 0–20%. We see an enhancement (about a factor of 2) in the production of prompt photons for collisions at 5.02A TeV compared to 2.76A TeV in the larger p_T regions at LHC energy. The production of prompt photons increases significantly ($\sim$ 8–10 times) at FCC energy in comparison to LHC energies.

The direct photon (thermal + prompt) spectra from Pb+Pb collisions at 39A TeV Pb+Pb collisions for three different centrality bins are shown in Fig. 2. The thermal contributions are also shown separately in the smae figure for a comparison. We see that at FCC energy the thermal contribution plays significant role and dominate the direct photon spectra up to a p_T value 3–4 GeV. The significantly larger lifetime as well as initial tempretaure of the produced system at FCC compared to LHC result in larger production of thermal photons. We also calculate the elliptic flow of thermal photons (not shown here) for the three different collision energies however, the flow results are found not to increase much for larger collision energies.

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References

[1] U. Heinz, arXiv:0407360 [hep-ph].
[2] F. Arleo *et. al.*, arXiv:0311131 [hep-ph].
[3] J. Adam *et. al.*, Phys. Lett. B **754**, 235 (2016)
[4] R. Chatterjee *et. al.*, Phys. Rev. C **88**, 034901 (2013); J.-F Paquet *et. al.*, Phys. Rev. C **93**, 044906 (2016).
[5] P. Arnold, G. D. Moore, and L. G. Yaffe, JHEP **0112**, 009 (2001).
[6] S. Turbide, R. Rapp, and C. Gale, Phys. Rev. C **69**, 014903 (2004).
[7] P. Dasgupta, S. De, R. Chatterjee, and D. K. Srivastava [in preparation].
[8] N. Armesto *et al.,* Nucl. Phys **A 931**, 1163 (2014); A. Dainese *et al.*,, arXiv:1605.01389.
[9] P. Dasgupta, R. Chatterjee, and D. K. Srivastava Proceedings of DAE NP 2015.
[10] P. Aurenche *et al.*, Eur. Phys. J. C **9**, 107 (1999).