Thermal photon production from 39A TeV Pb+Pb collisions at the Future Circular Collider

Pingal Dasgupta,* Rupa Chatterjee, and Dinesh K. Srivastava
Variable Energy Cyclotron Centre, 1/AF, Bidhan Nagar, Kolkata-700064, India

Collisions of heavy nuclei at ultra-relativistic energies lead to the formation of Quark-Gluon Plasma (QGP), a hot and dense state of matter where quarks and gluons (together known as partons) are the effective degrees of freedom rather than hadrons. Soon after the collision the system reaches a state of local thermal equilibrium due to multiple rescatterings and production of secondaries as a result of gluon multiplications. The system or the fireball cools by expansion, hadronizes, and finally decouples and hadrons thus produced reach the detector. It is believed that, a few microseconds after the big bang our universe was in the state of Quark-Gluon Plasma.

Various experiments performed at the Super Proton Synchrotron (SPS) at CERN, the Relativistic Heavy Ion Collider (RHIC) at BNL and the Large Hadron Collider (LHC) at CERN have provided significant insight about the properties of QGP and the theory of strong interactions.

The upcoming Future Circular Collider (FCC) facility at CERN is aimed to study P+P collisions at centre of mass energy 100 TeV, which is about 7 times higher than the top LHC energy for P+P collisions. Heavy ion collision at FCC (Pb+Pb at $\sqrt{s_{NN}}$= 39 TeV) [1] is expected to produce initial states having much larger initial temperature and energy density than those produced at LHC and RHIC energies. One also expect to have a long lived QGP and larger system volume at FCC. We study evolution of the hot and dense matter produced at FCC using ideal hydrodynamic model, production of thermal photons from that and compare our results with those obtained at RHIC and at the LHC energies [2].

	N-N inelastic cross section (mb)	Initial time τ_0 (fm)	Initial central temperature (GeV)
Au+Au @ 200 GeV	42	0.20	0.52
Pb+Pb @ 2.76 TeV	64	0.10	0.87
Pb+Pb @ 39 TeV	80	0.10	1.14

TABLE I: Initial parameters at RHIC, LHC and FCC energies.

We have used longitudinally boost invariant 2+1 dimensional hydrodynamic model [3] with smooth initial density distribution to study the space-time evolution of the expanding system produced in collisions of Pb nuclei at FCC. The initial parameters for 200A GeV Au+Au at RHIC and 2.76A TeV Pb+Pb at LHC are set from the experimentally measured final charged particle multiplicities of 680 and 1600 respectively. For 39A TeV Pb+Pb collisions at FCC, the charged particle multiplicity is taken from the Ref. [1] as 3600. Table 1 shows the initial parameters for the three different energies.

We see from the constant energy density contour plots at the freezeout surface that the system produced for central Pb+Pb collisions at FCC is larger in size and also the lifetime of the system is about 20% larger at FCC than at LHC. We study time evolutions of the average energy density, average temperature and average transverse flow velocity for central heavy ion collisions at RHIC, LHC and FCC energies to get quantitative understanding of these variables at different energies.

Figure 1 shows the average temperature as

*Electronic address: pingaldg@vecc.gov.in

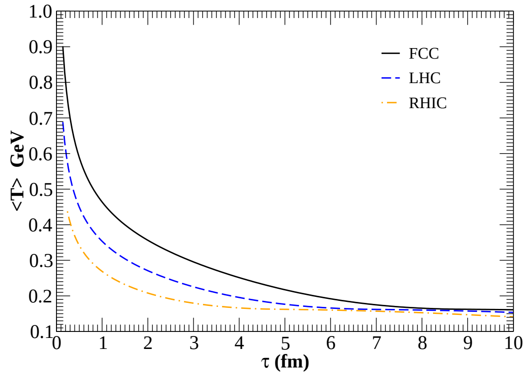

FIG. 1: Average temperature as a function of τ for most central collisions at RHIC, LHC, and FCC energies calculated using hydrodynamic model.

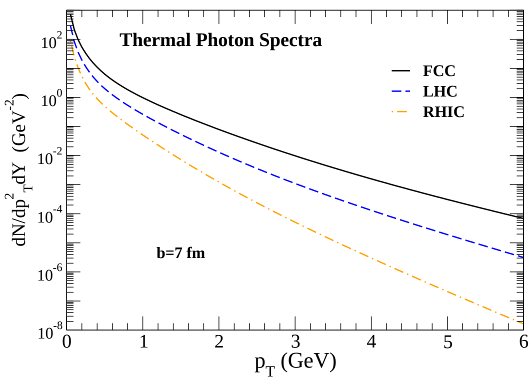

FIG. 2: Thermal photon spectra at RHIC, LHC, and FCC energies using hydrodynamic model.

a function of proper time for three different energies. We see that for central heavy ion collisions at FCC the temperature at initial time is about 900 MeV which is about 40% larger than the initial average temperature at LHC considering similar formation time. The average transverse flow velocity also found to increase significantly at FCC than at LHC. Thus, one can expect much stronger collective phenomenon at FCC and especially the anisotropic flow parameter at FCC can give potential information about the system formed and its initial state.

We calculate p_T spectra of thermal photons for heavy ions collisions at the maximum RHIC, LHC and FCC energies considering state-of-the-art photon rates (QGP rates from Ref. [4] and hadronic photon rates from Ref. [5]). Thermal photons from quark and hadronic matter phases are obtained by integrating the rates of emission over the space time history of the fireball which is of the form,

$$E\frac{dN_\gamma}{d^3p} = \int [\ (...)\ \exp(-\mathrm{p.u(x)/T(x)})\ ]\mathrm{d}^4\mathrm{x}.$$

The thermal photon spectrum is dominated by hadronic matter contribution in the low p_T ($<$ 1.0 GeV) region and quark matter radiation outshines the hadronic contribution beyond that p_T range. We see a much larger production of thermal photons at FCC compared to LHC and RHIC energies because of larger system volume and initial temperature. We also calculate elliptic flow of thermal photons for non-central collisions at FCC and see a significant increase in v_2 compared to RHIC and LHC.

Systematic study of heavy ion collisions at FCC along with RHIC and LHC expected to provide new insight about the initial state of the produced system as well as its evolution.

References

[1] N. Armesto, A. Dainese, D. dEnterria, S. Masciocchi, C. Roland, C. A . Salgado, M. van Leeuwen, U. A . Wiedemann, Nucl. Phys A **931**, 1163 (2014).

[2] P. Dasgupta, R. Chatterjee, and D. K. Srivastava [in preparation].

[3] P. Kolb and U. Heinz, [arXiv:nucl-th/0305084].

[4] P. Arnold, G. D. Moore, and L. G. Yaffe, JHEP **0112**, 009 (2001).

[5] S. Turbide, R. Rapp, and C. Gale, Phys. Rev. C **69**, 014903 (2004).