Electromagnetic and Hard Probes of Strongly Interacting Matter

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Introduction

The thesis contains theoretical investigations associated with the extreme state of matter, called Quark-Gluon Plasma (QGP), which is believed to be created in the collisions of heavy nuclei at relativistic energies.The state of matter is also presumed to exist in extraterrestrial conditions like; few microseconds after the cosmological Big Bang, and at the core of neutron star. The search for QGP is uniquely important because it enriches our current understanding of Quantum Chromodynamics (QCD) at high temperature or high density and helps to trace back the history of evolution of universe. Various aspects of QGP have been inspected through: direct photon momentum correlation, quenching of large momentum jets and identification of jet-triggered photons from Compton backscattering in this thesis.

Thermal photon intensity interferometry as probe of equation of state

We have constructed an equation of state (EoS) of hot hadronic matter within the framework of hadron resonance gas model, which consists of discrete hadronic states of mass $(m) \leq 2$ GeV and continuous Hagedorn states in the mass range $2 < m < 12$ GeV and accounted for the finite volume of hadrons. This description is then switched over either to Bag model EoS or to lattice EoS of QGP at temperature 165 MeV. The EoS includes the Bag Model (HHB) admits a first order phase transition whereas the lattice based EoS (HHL) exhibits crossover from QGP to hadron gas (see Fig. 1). Considering ideal relativistic hydrodynamic evolution of the system, we have calculated thermal particle and photon momentum spectra for the central collisions of Au or Pb nuclei at the top RHIC (200A GeV) and LHC (5.5A TeV) energies for the two EoS.

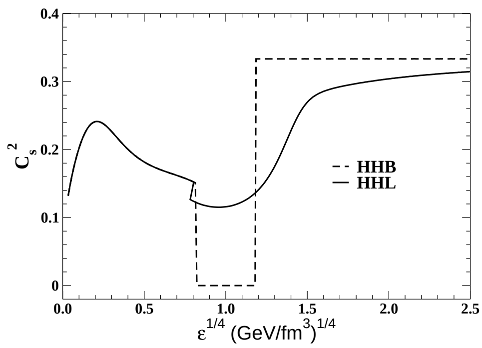

FIG. 1: Square of speed of sound of the two EoS.

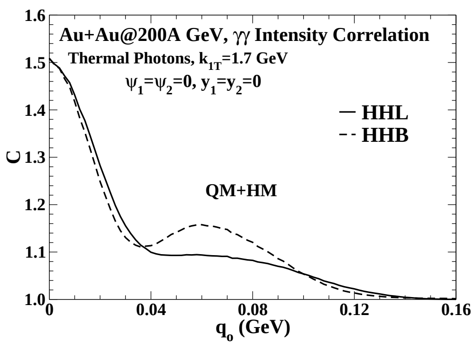

FIG. 2: Thermal phtoton outward correlation function for the two EoS at RHIC energy.

The difference between thermal particle and photon spectra for the two EoS is found to be insignificant [1]. However the momentum correlation function of thermal photons is found to be quite distinct for the two EoS at RHIC and LHC energies (See Ref. [1] for details), especially the 'outward'correlation as shown in Fig. 2 for Au + Au collisions at RHIC.

Jet-quenching at RHIC and LHC

The phenomenon of suppressed production of large momentum hadrons in nucleus-

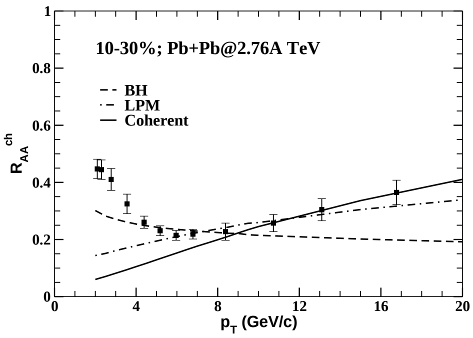

FIG. 3: Nuclear modification factor of charged hadron production calculated with three parton energy loss mechanisms at the LHC energy.

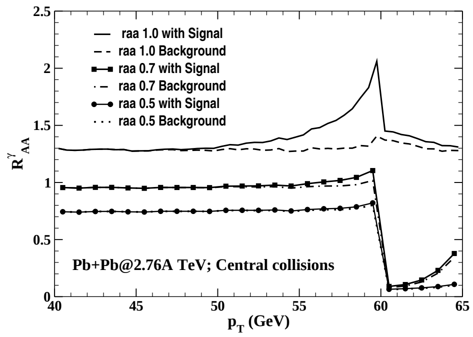

FIG. 4: Nuclear modification factor of back-scattering photons for various trigger jet energy loss scenarios at the LHC energy.

nucleus collisions to the proton-proton collisions, commonly referred as 'jet-quenching'. We have studied the system size dependence of jet-quenching by analyzing the transverse momentum spectra of hadrons produced in the collisions of Au and Cu nuclei at RHIC (200A GeV) and Pb nuclei at the LHC (2.76A TeV) energies [2]. Our model only accounts for radiative energy loss of partons and consider three different regimes namely; Bethe-Heitler (BH) regime of incoherent gluon radiation, Landau-Pomeranchuk-Midgal (LPM) regime of partial coherent gluon radiation and Complete coherent gluon radiation regime. The QGP medium is considered here as an ensemble of static scattering centers at some average temperature. Treating the energy loss per collision as only adjustable parameter; we demonstrate the change in energy loss mechanisms of parton with the transverse momenta of final hadrons for different centrality bins at RHIC and the LHC. The nuclear modification factor ($R^{\rm ch}_{\rm AA}$) of charged hadron production at LHC for the three different schemes of energy loss is shown in Fig. 3.

Jet-triggered photons in QGP

High energy photons originated from back-scattering of jets in QGP are a valuable probe of temperature of the plasma, and of the energy loss mechanism of quarks. We have for the first time calculated the correlation of these photons with away-side trigger jets at large momentum in order to quantify this source. Only the hard prompt photons are produced in coincidence with a jet, hence considered as a 'background'for this study. We have calculated the yield and nuclear modification factor ($R^{\gamma}_{\rm AA}$) of back-scattering photons in coincidence with trigger jets at the RHIC and LHC kinematic situations [3]. The back-scattered photons have caused a sharp peak in ($R^{\gamma}_{\rm AA}$) which could be considered as potential signal. However medium induced trigger jet energy loss tends to wash out this potential signal. In Fig. 4 we have shown $R^{\gamma}_{\rm AA}$ of back-scattering photons (signal) and prompt photons (background) for three trigger jet energy loss scenarios for Pb + Pb collisions at LHC (2.76A TeV) energy. Thus separation of back-scattering photons from other direct photon sources depends crucially on our ability to estimate the initial trigger jet energy. With the current jet reconstruction scenario used in experiment, this is not feasible yet.

References

[1] S. De, D. K. Srivastava, R. Chatterjee, J. Phys. G **37**, 115004 (2010).

[2] S. De, D. K. Srivastava, J. Phys. G **39**, 015001 (2012); J. Phys. G **40**, 075106 (2013).

[3] S. De, R. J. Fries, D. K. Srivastava, arXiv:1402.1568 (Phys. Rev. C; in press).