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EFFECT OF EVOLUTION OF DIRECT PHOTONS ON THE VISCOSITY OF QUARK GLUON PLASMA

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ABSTRACT
The quark-gluon plasma at the stage of thermodynamic equilibrium is reviewed. The quark hadron phase transition and the color superconducting phases of quark-gluon matter with the help of phase diagram are discussed. The lattice QCD results on the order of the phase transition of QGP. We discuss some aspects of atomic Fermi gas in the unitary limit in the first order transition. We consider the equation of state and the critical temperature for pair condensation. The strongly interacting phase transition (Quark-Hadron phase transition) also discussed.

KEYWORDS: Quark Gluon Plasma, Hadrons Suppression, Transport parameter, chemical potential, Baryon density, Lattice QCD, Equation of state.

INTRODUCTION
The RHIC experiment data confirmed that the noble state of matter called quark gluon plasma can be observed in nucleus-nucleus collisions at very high temperature and energy density. The hadrons emitted with large transverse momentum during central collisions and are strongly suppressed [1]. This suppression of hadrons is characterized by jet quenching and these suppressions results in the production of gluon by multiple collisions [2]. The collective flow of a medium is described by relativistic hydrodynamics [3]. The whole phenomenon is governed by transport parameter $\hat{q}$ which is defined as the squared average transverse momentum exchange between the gluon medium and the fast parton per unit path length [4].

We would like to consider the strongly coupled classical plasma to study its qualitative features and photons production during nucleus collisions. The perturbative expansion can be explained by the interaction between hard jets and strongly interacting matter [5]. The parton gets excited in QCD coupling which makes weak coupling of QCD. This weak coupling of QCD referred to the partonic quasi particle picture. But, strong coupling vanishes this parton quasi particle picture. There exist a general relation between jet parameter $\hat{q}$ and the coefficient of viscosity η which indicate the weakly coupled plasma and responsible for the generation of viscosity of gluon medium.

The interaction between quarks and gluons at some temperature T radiate photons. The production of photons confirms the strongly interacting nature of quark gluon plasma at RHIC. When the transverse momentum p_T is lower than the plasma temperature, photons decays from π^0. At large transverse momenta, the spectra for thermal photons fall rapidly. When p_T is lower than 3 GeV, direct photons dominates. But the identification of these direct photons at this momenta range are much very difficult from the hadronic decay of π^0. But when transverse momenta are greater than 3 GeV, direct photons can be identify and can measure the spectra. These high energy direct photons also generate virtual photons which soon convert into e^+e^- pairs.

METHOD AND FORMULATION

Consider a model in which the plasma matter is divided into small volumes. Assuming all volumes is thermally equilibrium at that given temperature T_0 and the plasma density ρ. Now the specific entropy of fluid plasma is a function of fluid density and fluid temperature ie. $s = s(\rho, T_0)$. The entropy of overall plasma flow is then,

$$S = \int [\rho(r), T_0(r)]\, dr \tag{1}$$

Thus the difference in entropy in any two cases is due to the difference of thermodynamic quantities upon which the entropy depends on both cases.

The entropy of the whole system of quark gluon plasma is derived by S for the Gibbs ensemble for N equivalent photon particles. But the mean entropy of the system is independent of total N, therefore

$$S_{ensembles} = k\{\textstyle\sum_i n_i \ln N - \sum_i n_i \ln n_i\}$$

$$= -k \sum_i n_i ln\left(\frac{n_i}{N}\right) \tag{2}$$

Thus to identify isolated photon in one N^{th} state is,

$$S = -k \sum_i \left(\frac{n_i}{N}\right) ln\left(\frac{n_i}{N}\right) \tag{3}$$

where n_i/N is the probability term for photon being found in i^{th} state. When generated photon particles or bosons travel through quark gluon plasma, the dynamic viscosity of the plasma as suggested by modified form of Stoke's law is,

$$\eta = \frac{2(\Delta\rho)gr_i^2}{9v_i} \tag{4}$$

where $\Delta\rho$ is the difference in densities between the fluid and the i^{th}photon particle, g is acceleration due to gravity, r implies the radius of photon particle and v is velocity of photon particle. During evaluation of photon, transition of phases takes place so that the energy density of plasma becomes $\epsilon \sim \frac{\pi^2}{30} NT^4$ where N is the degrees of freedom and T is the absolute temperature. Therefore the viscosity of the medium becomes,

$$\eta = \frac{2\left[\frac{\pi^2}{30}NT^4\right]gr_i^2}{9v_i} \tag{5}$$

As all quantities in the expression is constant except temperature T and velocity of photon particle. Thus we have,

$$\text{Or, } \eta = \Omega\ \frac{T^4}{V} \tag{6}$$

i.e. the viscosity is inversely proportional to the velocity of particle evaluated during high energy collision but directly proportional to the four times of temperature. The well known result of the shear viscosity of gluon medium [6] is

$$\eta_G = 4.51 \frac{T^3\rho}{\hat{q}} \tag{7}$$

where $\hat{q}$ is the transport coefficient. Comparing equations (6) and (7) we have,

$$\frac{\rho}{\hat{q}} = \frac{1}{4.51}\frac{\Omega T}{v}$$

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Or,

$$\hat{q} = (4.51)\rho \frac{v}{\Omega T} \tag{8}$$

which shows that the transport coefficient of the gluon medium or the jet quenching is directly as the density of the medium and velocity of the medium.

RESULT AND CONCLUSION

The ratio of viscosity to entropy parameters of a strongly interacting matter is consistent with $\eta/s \geq 1/4\pi$ [7]. A large number of identified photon particles, its spectra, its elliptical flow etc can be explained in hydrodynamic model with time scale $\tau_i = 0.6\ fm$ and initial temperature $T_0 = 350\ MeV$. The evaluation of photon increases at large transverse momentum p_T . When the transverse momenta of photon p_T is large than 4 GeV, then the direct photons dominates the inclusive photon spectra in heavy ion collision. Photons evaluated during the collision do not flow with the system but their evolution may decrease the fluid viscosity and thereby increasing its transverse momentum p_T.

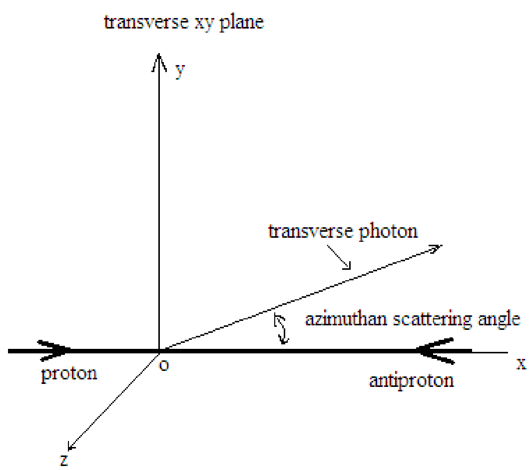

Fig. 1.Transverse momentum $p_T = p\ sin\theta$ of evaluated photon

At low $p_T \leq 0.5\ GeV$, the hydrodynamic model is not favorable for the fluid viscosity. At $p_T \geq 0.5\ GeV$, viscous flow increases elliptically with the value of p_T. For viscosity to entropy ratio $\eta/s = 0.8$, direct photons yield up to $p_T \leq 1.3\ GeV$, the viscosity to entropy ratio becomes $\eta/s = 0.2$ as in our theoretical calculation at central temperature $T_0 = 350GeV$ compared to data obtained, which theoretical confirms the direct photons for $p_T \sim 3GeV$ in $Au + Au$ collision at RHIC [8].

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