Theoretical Aspect of Quark-Hadrons Phase Transition in Quark-Gluon Plasma at RHIC

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ABSTRACT

Fermi momentum of nucleon particles always larger than QCD scale which makes the gross picture quark and gluon substructure. At some temperature, nuclear matter possesses nucleons as well as thermal radiations. At thermal equilibrium, hadron density is a function of chemical potential and Bessel function of second order. The first order phase transition in QGP is a liquid-gas type transition which is strongly to weakly coupled QGP transition. At some weakly couped limit, shear viscosity to entropy ratio is very large, it implies the strong elliptical and radial flow of quark gluon plasma

INTRODUCTION

The order of phase transition of a medium is a basic thermodynamic characteristic. The phase transition may be first order or second order depending upon the first order or second order derivative of thermodynamic potential in the thermodynamic limit. The first order phase transition is the solid-liquid transition while liquid-gas phase transition is the second order transition. The second order phase transition in nuclear matter is possible if the nuclear matter has some specific baryon density at its ground state at zero temperature [1]. The ground state values of temperature and quark potential of infinite nuclear matter is $(T,\mu)=(0,310)$ MeV [2]. The second order of phase transition occurs at terminating point when the temperature is of the order of approximately 10 MeV. The hadronic phase exist in which the matter is strongly interacting for the value of $(T,\mu)\approx(170,350)$ [3]. The transition becomes crossover for lower net-baryon densities or say smaller quark chemical potentials. This crossover does not show the real separation between hadronic phase and the QGP phase but the fluctuations occur at near critical point [2]. Study of these fluctuations might reveal some characteristic properties about the first and second order phase transitions. Finally the quark matter is colour condensate at large quark chemical potentials and at low temperatures [4].

The first order transition which is liquid to gas transition relative to nuclear matter confirmed that the baryon density has a specific value at the ground state of nuclear matter even temperature should be zero. The strongly coupled plasma occurs in hadronic phase when the magnitude of quark chemical potential is less than approximately 350 MeV and temperature approximately ranging 170-175 MeV. The second order phase occurs at temperature same as the first order transition but the magnitude of quark chemical potential is approximately 240 MeV [5,6]. Besides first and second order, the transition becomes crossover if quark chemical potential (or say lower baryon density) is low and temperature becomes large. At this transition of crossover, the line of hadronic matter and quark gluon plasma cannot be distinguished. In theoretical point of view, there occur large fluctuations near critical points or terminating points of transition and crossover. Thus the study of fluctuations at the critical points is characterized by some qualitative characteristics for order of phase transitions. When the value of quark chemical potentials μ becomes smaller than the value ranging (300-350) MeV and temperature T smaller than the QCD scale ΛQCD, nuclear matter is a gas of hadrons. At larger quark chemical potential of the gluon medium, the quark matter approaches to color condensate.

THE QUARK-HADRON PHASE TRANSITION

One important thermodynamic parameter called the Fermi momentum of particles can consider the unique part in describing second order phase transition [7]. Those particles whose momentum lies on the Fermi surface can only scatter elastically. If the Fermi momentum is larger than the QCD scale which is approximately 170 MeV, nucleons scatter themselves to make lesser the quark and gluon substructure on nuclear level. At some value of temperature, however small or large, the nuclear matter consists of nucleons as well as thermal hadrons. A system in thermodynamically equilibrium, the hadron density is an exponential function and is proportional to mass m_i, chemical potential μ_i and Bessel function of second order K_2 in modified form i.e.

$$n_i = \Upsilon e^{\mu_i/T}$$

$$= \Upsilon \frac{m_i^3 T K_2}{T}$$

$$= \Upsilon m_i^3 K_2$$

The relation shows that the density of hadron particles is proportional to the cube of the mass of nucleon particles in the gluon medium. For a hadron system in which quark chemical potential 350 MeV and the value of temperature 175 MeV, the hadron density is constant and thus the nuclear matter is a gas of hadrons.

The QGP-hadrons phase transition represents the liquid-gas type first order phase transition. RHIC experiment already shows in different ways that observed viscosity of quark-gluon plasma is very small enough. The cold atomic gas provides the way to study the crossover from weakly to strongly coupled quark gluon plasma. The asymptotic freedom implies that the quark and gluon in free gaseous state provides an equation of state. Lattice QCD calculation at initial stage of collision at RHIC shows that about 80% of free gas limit encloses by pressure and energy density of the gas which is consistent with the first order perturbation correction. It implies the strong elliptical and radial flow of QGP. In weak coupled limit, the shear viscosity to entropy ratio is inversely equal to the fourth power of coupling constant. It shows that the ratio is very large at weak coupled quark gluon plasma. A mixed phase of nucleons occurs at small temperature and lower value of ground state density.

CONCLUSION

Hadron density is directly as the cube of the mass of nuclear particles of gluon medium. At RHIC temperature of phase transition, hadron density is exponentially increases. When the value of quark chemical potentials μ becomes smaller than the value ranging (300-350) MeV and temperature T smaller than the QCD scale, nuclear matter is a gas of hadrons. At larger quark chemical potential of the gluon medium, the quark matter approaches to color condensate.

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