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Some Features of Statistical Quantum Chromo-dynamics in Relativistic Heavy Ion Collisions

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Abstract: ***An attempt has been made to discuss the classical topic of statistical physics so called the microscopic dynamics and derive the equilibrium thermodynamics which describes a macroscopic system. Here, we try to explain the microscopic theory is the term of quantum chromo-dynamics (QCD), and we want to obtain the thermodynamics of strongly interacting matter. Finally, at this point we notice that two basic features of what we're about to study - the equilibrium condition and the arbitrarily large volume of the systems in question - may restrict the applicability of the results to nuclear collisions.***

Keywords: relativistic heavy ion collisions, deconfinement state of matter, quark gluon plasma (QGP).

1. Introduction

The primary goal of high-energy heavy ion collisions is to discover the fundamental forces, symmetries and the elementary particles in Nature. On the other hand, Particle physics is the science of the fundamental structure of matter, which leads to the study of the properties of subatomic particles and mechanism of their interactions. Its ultimate aim is to find a complete description of the elementary constituents of matter and of the forces acting between them. The final structure of elementary particle is found to consist of quarks for which no structure has been observed for them, so they are regarded as the point like particles. These results have been obtained by scattering experiments at higher and higher energies, as required to achieve information on smaller and smaller objects. Any isolated single free quarks have never been observed experimentally, and therefore it is conjectured that quarks are confined together with other quarks to form hadrons. The strong (color) force field between the quarks is intermediated by gluons, and inside the hadrons quark-antiquark pairs are formed as quantum fluctuations.

The interest in the study of high-energy nuclear matter has increased many folds due to the possibility of studying unstable states of nuclear matter under extreme condition of high energy density and high temperature. Physicists are very keen to see its outcomes as they expect that it would throw its flashes towards the evolution of the universe and deconfined state of freely interacting quarks and gluons known as quark-gluon plasma (QGP) [1-5], which is believed to have existed in the form of QGP for few microseconds after the Big Bang. It is also interesting to study about the strong forces present between the quarks and gluons in the hadronic matters. It is believed that shortly after the creation of the Big Bang all matters were in a state called the QGP. Due to rapid expansion of the universe, this plasma went through a phase transition to form large number of hadrons like pions, protons and neutrons etc. Such a new phase of matter might be produced experimentally in heavy ion collisions at ultra-relativistic energies.

2. Mathematical Descriptions

The Quantum Chromo-Dynamics (QCD) [6-8] theory describes the strong interaction between the hadronic matter which predicts a novel phase transition from a confined state of quark and gluon to deconfined state, where quarks and gluons would be free to move and freely interacting in the hadronic matter, which would be at higher energy density.

The main emphasis of the present research work is to consider the classical topic of statistical physics, which give the microscopic dynamics, and also originate the thermo-dynamical equilibrium which defines a macroscopic system. Here in this case the microscopic theory is known as QCD, and we want to acquire the thermo-dynamical system of the strongly interacting matter. For this task we noted that there are two basic features of what we were studied; the equilibrium conditions and the arbitrarily large volume of the systems that might be restrict the applicability of the results to nuclear collisions.

The QCD theory assumed that the collisions between the colored quark and gluons [9] can be treated by the following Lagrangian density equation:

$$\mathcal{L}\left(\Psi,\overline{\Psi},A\right) = -\frac{1}{4}\left(\partial_\mu A_\nu^a - \partial_\nu A_\mu^a - g f_{b\,c}^{a} A_\mu^b A_\nu^c\right)^2 + \overline{\Psi}_f^a\left(i\partial - g\lambda_a\lambda_{\alpha\beta}^a\right)\Psi_f^\beta \quad (1)$$

where; ψ and A represent to the quark and gluon fields, with equivalent color indices α, β, ….. and a, b,…… and "f" indicates the flavor of quarks (i.e. u, d, s…) and the "g" is the dimensionless coupling factor of the theory. The first term on the right hand side (R.H.S.) of Equation (1) explains the interaction of gluons; this interaction is possible - in contrastto the quantum electrodynamics (QED), where the photons do not interact directly - because the gluons also carrya color charge. The second term of Equation (1) is for the interactions of quarks and gluons, and this is basically the same structure as its electromagnetic counterpart. The specificfeature of QCD is thus the interaction between gauge fields, and one may studypure gauge field thermodynamics as a meaningful model of statistical QCD.