Velocity of sound in a Quark-Gluon Plasma with one loop correction in mean field potential

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Introduction

It is expected that matter formation during the early stage of Universe expansion is under the condition of a phase transition of deconfined matter of free quarks and gluons to a confined matter of hadrons. Really it is estimated as a process of very complicated phenomena in the present day of heavy-ion collider experiments. This deconfined phase of free quarks and gluons is known as Quark-Gluon Plasma (QGP). So the study of quark-gluon plasma (QGP) fireball in Ultra Relativistic Heavy-Ion Collisions has become an exciting field in the present day of heavy ion collider physics [1]. In this brief paper, we focus to calculate the thermodynamic properties of the QGP evolution through the free energy expansion of the system. Then we calculate the velocity of sound of this system at finite temperature. To evaluate the free energy of the system, we use the mean-field potential with one loop correction factor to construct the density of states (DOS) of particles in the system. Thus the free energy evolution is obtained through this density of state of the constituent particles of quarks and gluons. Due to the correction factor in the mean field potential through coupling value, [2, 3] there are changes in the free energy expansion of QGP fireball, and it also impacts in the stability of droplet with the variation of dynamical quark and gluon flow parameters, which is used in the construction of DOS.

In brief, we directly calculate the thermodynamic properties and calculate the velocity of sound through these thermodynamics.

The paper is arranged as: In Sec.1 we present introduction. In Sec.2 we describe thermodynamic properties and sound velocity and in Sec.3 we give results and conclusion.

Thermodynamic properties and sound velocity .

The free energy of the system is sum of the free energy of quarks, gluons,pions and interfacial energy $F_{interface}$. The interfacial energy is considered as bag energy in the system. Therefore, we obtain the free energy of quarks and gluons as [4]

$$F_i = \mp T g_i \int dq \rho_{q,g}(q) \ln(1 \pm e^{-(\sqrt{m_i^2+q^2})/T}) \;, \tag{1}$$

where,

$$\rho_{q,g}(q) = \frac{\nu}{\pi^2}[\frac{\gamma_{q,g}^3 T^2}{2}]^3 g^6(q) A, \tag{2}$$

in which

$$A = \{1 + \frac{\alpha_s(q)a_1}{\pi}\}^2[\frac{(1+\alpha_s(q)a_1/\pi)}{q^4} + \frac{2(1+2\alpha_s(q)a_1/\pi)}{q^2(q^2+\Lambda^2)\ln(1+\frac{q^2}{\Lambda^2})}] \tag{3}$$

and other symbols are the usual standard parameters [2]. So the total free energies of the system is sum as:

$$F_{total} = \sum_i F_i \;+\; F_{interface} \;+\; F_\pi, \tag{4}$$

where F_π is the standard energy of pions. Now we calculate the entropy and specific heat of the system and further calculate sound velocity through the thermodynamic

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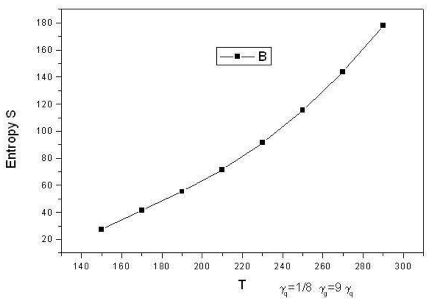

FIG. 1: Entropy vs. T.

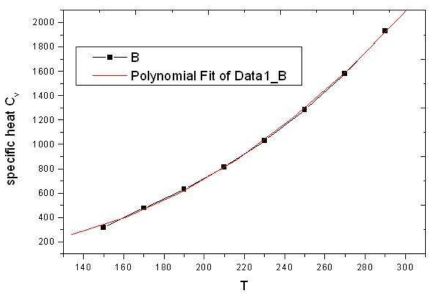

FIG. 2: Specific heat vs T.

properties. So standard thermodynamics give the following relations:

$Entropy\ S = -\frac{\delta F}{\delta T}$

$Specific\ heat\ C_v = T(\frac{\delta S}{\delta T})_V$

$Sound\ velocity\ C_s^2 = \frac{S}{C_v}$

The behaviors of the system are obtained from the thermodynamic properties and sound velocity.

Results and conclusions

The results are shown in the figures. We calculate the entropy, specific heat and velocity of sound for a particular flow parameter which

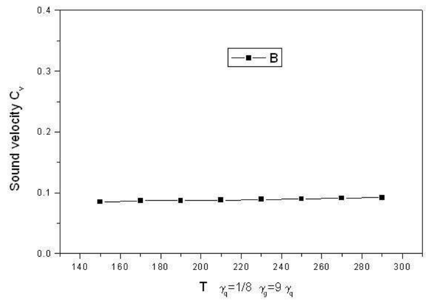

FIG. 3: Sound velocity vs T.

is used in the evolution of free energy. At this particular flow parameter, we can obtain the stability of the droplet formation. The parameter is found to be $\gamma_q = 1/8$ and $\gamma_g = 9\gamma_q$. This parameter is chosen as ad-hoc fashion to fit the evolution of QGP fireball. The calculated sound velocity through the one loop correction in the mean field potential approaches to the order 0.2 ± 0.02 times velocity of light, it is good approximation in comparison to earlier result.

Acknowledgments

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