Study of Thermodynamic and Transport Properties of Strongly Interacting matter in a Color String Percolation Model at RHIC

Pragati Sahoo[1],* Swatantra Kumar Tiwari[1], Sudipan De[1], and Raghunath Sahoo[1]
[1] *Discipline of Physics, School of Basic Sciences,*
Indian Institute of Technology Indore, Indore- 453552, INDIA

INTRODUCTION

The main perspectives of Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory are to study the properties of the strongly interacting matter and to explore the conjectured Quantum Chromodynamics (QCD) phase diagram. Lattice QCD (lQCD) predicts a smooth crossover at vanishing baryon chemical potential (μ_B) and other QCD based theoretical models predicts first order phase transition at large μ_B. Searching of the Critical Point in the QCD phase diagram, finding the evidence and nature of phase transition, studying the properties of the matter formed in nuclear collisions as a function of $\sqrt{s_{NN}}$ are the main goals of RHIC. To investigate the nature of the matter produced at heavy-ion collisions, the thermodynamical and transport quantities like: energy density, shear viscosity etc. are studied. It is expected that the ratio of shear viscosity (η) to entropy density (s) would exhibit a minimum value near the QCD critical point.

The Color String Percolation Model (CSPM) is a QCD inspired model, according to which the color flux tubes or color strings are stretched between the colliding partons in terms of gluon color field [1]. It is observed that, CSPM can be successfully used to describe the initial stages in high energy heavy-ion collisions and are successfully compared with lQCD predictions [2].

*Electronic address: `pragati.sahoo@cern.ch`

THERMODYNAMIC AND TRANSPORT PROPERTIES

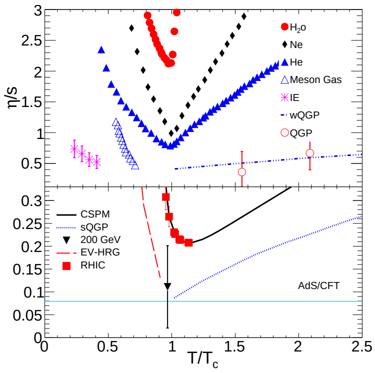

FIG. 1: (Color online) η/s as a function of T/T_c.

In CSPM, as the interactions of strings increase the hadron multiplicity (μ) reduces and the average squared transverse momentum, $\langle p_T^2 \rangle$ of these hadrons increases, to conserve the total transverse momentum. As the number of strings, n increases the macroscopic cluster suddenly spans the area. Now, the quantity which puts limit in the sudden expansion in 2D percolation theory is the dimensionless percolation density parameter given by,

$$\xi = \frac{N_S S_1}{S_n}. \tag{1}$$

where, N_S is the number of strings formed in the collisions, S_1 is transverse area of the a single string and S_N is the transverse nuclear overlap area. We evaluate the initial value of ξ by fitting the experimental data of p_T spectra in pp collisions at $\sqrt{s} = 200\ GeV$. Then in order to evaluate the interactions of strings in A+A collisions, we use the parameterisation by fitting the p_T spectra with the following function:

$$\frac{dN_c}{dp_T^2} = \frac{a}{(p_0\sqrt{F(\xi_{pp})/F(\xi)} + p_T)^\alpha}. \quad (2)$$

where, $F(\xi)$ is the color suppression factor. The initial temperature of the percolation cluster, $T(\xi)$ can be represented in terms of F(ξ) as [1]:

$$T(\xi) = \sqrt{\frac{\langle p_T^2 \rangle_1}{2F(\xi)}}. \quad (3)$$

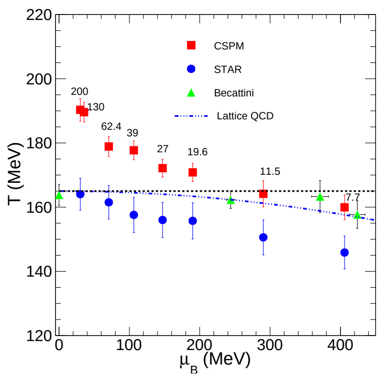

FIG. 2: (Color online) The graph between temperature and baryon chemical potential (μ_B) estimated in different calculations at various center-of-mass energies.

An attempt is made to formulate thermodynamic and transport properties of the strongly interacting matter produced in central Au+Au collisions at various RHIC energies using CSPM model. Combining boost invariant Bjorken hydrodynamics with CSPM we express energy density as follows,

$$\varepsilon = \frac{3}{2}\frac{\frac{dN_c}{dy}\langle m_T \rangle}{S_n \tau_{pro}}. \quad (4)$$

It is found that ε is proportional to ξ. The parameterisation of the CSPM results gives, $\varepsilon = 0.786\ \xi$ (GeV/fm^3) [3]. Using this parameterisation we calculate various thermodynamical and transport properties like energy density, shear viscosity etc. The detailed calculations can be found in Ref. [3]. Figure 1 shows the shear viscosity to entropy density ratio as a function of T/T_c. The η/s which is the measure of the fluidity is used as one of the important observables to understand the QCD matter and as evidenced by various measurements, it shows minimum at the critical point for various substances like: helium, nitrogen and water.

The initial temperatures at RHIC energies are estimated using Eq. 3 and presented with different model predictions of chemical freeze-out temperature (T), and baryon chemical potential (μ_B) in figure 2. The difference between the initial temperature and the chemical freeze-out temperature increases, as the collision energy increases, which suggests the creation of higher temperature and energy density at higher centre-of-mass energies. The CSPM is a new paradigm which has been successful in explaining the thermalisation both in nuclear and hadronic collisions.

In this work, we presented an intact study of thermodynamical and transport properties of the QCD matter created at RHIC energies using CSPM and the results are in excellent agreement with the lattice QCD results [3]. In summary (i) all the observables at various RHIC energies shows similar trend as results obtained in lQCD, (ii) The CSPM based analysis of RHIC data from STAR show that the transition from deconfined to confined phase takes place possibly between 15 and 19 GeV of collision energy.

References

[1] M.A. Braun *et al.*, Phys. Reports. **509**, 1 (2015).
[2] A. Bazavov *et al.*, Phys. Rev. D **80**, 014504 (2009).
[3] P. Sahoo, S. K. Tiwari, S. De, R. Sahoo, R. P. Scharenberg and B. K. Srivastava, arXiv:1708.06689 [hep-ph].