Charged particle p_{T} spectra and elliptic flow in a 2+1D viscous hydrodynamics including shear and bulk viscosity

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Relativistic hydrodynamics is a useful tool for modeling the space-time evolution of the nuclear matter produced in high energy heavy ion collision. It is important to know about the transport properties (e.g. shear and bulk viscosity, heat conductivity) of the nuclear medium. The calculation of the transport coefficient from the first principle (Lattice QCD, Relativistic Boltzmann transport equation) is quite difficult. The lattice QCD, PQCD and string theoretical calculation predicts a nonzero values of shear and bulk viscosity. In spite of much effort by using those methods, the true value of these transport coefficients is still quite uncertain. Relativistic viscous hydrodynamics can be used to estimate the exact values of transport properties of the medium by treating them as an input to the simulation and comparing the simulated results with the experimental data.

In this work the Israel-Stewart theory of 2nd order causal dissipative theory have been used to simulate the space-time evolution of the QCD matter in 2+1 dimension by using the numerical code "AZHYDRO-KOLKATA". A realistic temperature dependent bulk viscous coefficient to entropy density ratio ζ/s was used to explain the charged particle p_{T} spectra and elliptic flow measured at RHIC Au-Au collision..

Figure 1 shows the temperature dependence of ζ/s used in the simulation. The ζ/s was constructed by parameterizing the lattice calculation and hadron resonance gas calculation for the QGP and hadronic phases respectively. The shear viscosity to entropy density ratio (η/s) was taken independent of temperature.

Assuming a near local thermal equilibrium, the numerical simulation of space time evolution of the nuclear matter produced in Au-Au collision at top RHIC energies is done for different collision centrality. The solution of the viscous hydrodynamics requires initial parameters and an equation of state (EoS), which relates pressure and energy density. To terminate the simulation, a freeze-out condition has to be specified. We used a constant temperature freeze-out and Cooper-Frey algorithm was used to calculate charged particle p_{T} spectra and elliptic flow on the freeze-out hyper surface. The initial conditions used in this simulation are given in table 1.The EoS was constructed from hadron resonance gas and recent lattice data [1].

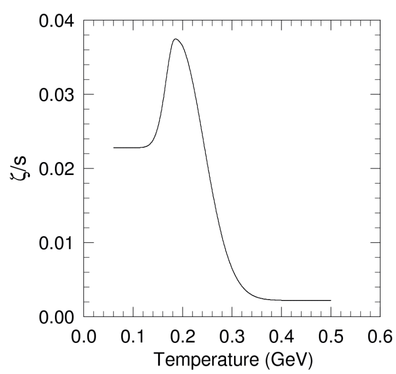

Fig 1: Temperature dependence of ζ/s.

Table 1:

Parameters	Value
Initial energy density For η/s	25.5,19.6,16.7,14.0(GeV/fm3) 0.0, 0.08, 0.12, 0.16 respectively
Thermalization time	0.6 fm/c
Initial velocity	0
Freeze-out temperature	130 MeV

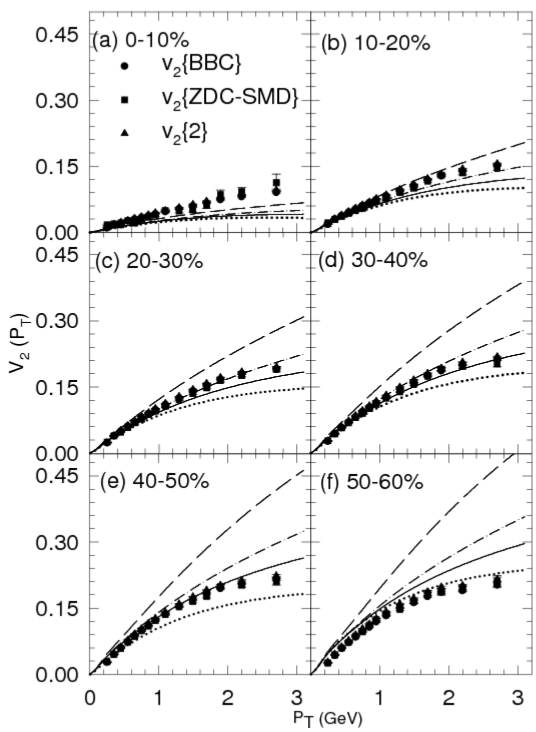

Fig. 2: The solid symbols are the measured charged particle elliptic flow for Au+Au collision at C.M. energy 200GeV for six different centrality (0-60%) by different methods [2].The dashed line is the ideal hydrodynamic simulation. The dashed dot, continuous and dotted lines are the viscous hydrodynamics simulation with constant η/s=0.08,0.12 and 0.16 respectively. The viscous hydro also includes the temperature dependent ζ/s as shown in Fig.1.

In Figure 2 the solid circle, square and triangles are experimentally measured v2 by various methods by PHENIX collaboration for the 0-60% collision centrality in Au-Au 200GeV collision. Four lines are the simulated v2 for ideal (dashed line) and viscous fluid evolution with different η/s=0.08 (dashed dot), 0.12 (solid) and 0.16 (dotted). The temperature dependence of ζ/s is considered (Fig. 1). Ideal or viscous hydrodynamics fails to explain the v2 as a function of p_T for most central collision (0-10% for our case). This is because in the current simulation event by event fluctuation of the initial conditions are not considered. We observe that the v2 data demands more shear viscosity along with the present form of temperature dependent ζ/s as one goes from central to peripheral collisions. This can be understood in the following way, the relative life time of the QGP phase compared to the hadronic phase decreases as one goes from central to peripheral collision. The viscous coefficient tends to have larger values in the hadronic phase.

References

[1] Victor Roy and A.K. Chaudhuri [arXiv:1109.1630].
[2] S. Afanasiev et al. [PHENIX Collaboration], Phys. Rev. C. 80,024909 (2009).