Transverse momentum spectra and elliptic flow in ideal hydrodynamics and geometric scaling

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One of the important findings in Au+Au collsions at RHIC is that the centrality dependence of particles multiplicity can be understood in a simple geometric model. The particle pseudorapidity density in nucleus-nucleus collision can be expressed as

$$\frac{dN}{d\eta} = n_{pp}[(1 - f_{hard})\frac{N_{part}}{2} + f_{hard}N_{coll}] \quad (1)$$

Number of participant N_{part} and number of collsion N_{coll} are calculated from Glauber model. Geometric scaling of Au+Au collsion as in Eq.1 are used in hydrodynamic models to specify the initial energy density distribution over the trnsverse plane. The parametrised form of the energy density is

$$\varepsilon(\mathbf{b}, x, y) = \varepsilon_0[(1 - f_{hard})N_{part}(\mathbf{b}, x, y) + f_{hard}N_{coll}(\mathbf{b}, x, y)] \quad (2)$$

where $N_{part}(\mathbf{b}, x, y)$ and $N_{coll}(\mathbf{b}, x, y)$ are the transverse density distribution for the participant pairs and the collision number respectively. f_{hard} is the fraction of hard scattering. Parameterisation Eq.2 is generally called Glauber model initialisation. ε_0 in Eq.2 is the central energy density in $\mathbf{b} = 0$ collision. Ideal hydrodynamics with hard scattering fraction f_{hard}=0.25 and 0.13 gives a reasonable description to the experimantal data. However the glauber model initialisation with hard scattering fraction 0.25 and 0.13 underpredict the experimental elliptic flow in very central,e.g.,0-10% collision. Elliptic flow is a key observable in establishing that in $\sqrt{s} = 200GeV$ Au+Au collsion the lattice QCD predicted qurk-gluon-plasma (QGP) is produced. Finite elliptic flow in Au+Au collsion and the fact that hydrodynamic model do explain the flow are generally cited as the proof of QGP production. It is then important to understand why the Glauber model initialistion underestimate the elliptic flow in very central collision.

We have simulated $\sqrt{s} = 200GeV$ Au+Au collsion with the Glauber model initial condition at two extreme limits of the hard scattering fraction f_{hard}=0 and 1, which will help us to understand the relationship between elliptic flow in central Au+Au collision and the geometric scaling of the initial energy density as in Eq.2. Fraction of hard scattering f_{hard}=0 implies initial energy density scales with participant density N_{part} and the other limit f_{hard}=1 corresponds the energy density scaling with number of binary collision N_{coll}. An actual scenario may be in between the two limit. The space time evolution of the fluid is obtained by solving the energy-momentum conservation equation,

$$\partial_\mu T^{\mu\nu} = 0, \quad (3)$$

where $T^{\mu\nu} = (\varepsilon + p)u^\mu u^\nu - pg^{\mu\nu}$, ε, p and u being the energy density, pressure and fluid velocity respectively. Assuming boost-invariance, Eq.3 are solved in ($\tau = \sqrt{t^2 - z^2}, x, y, \eta_s = \frac{1}{2}\ln\frac{t+z}{t-z}$) coordinates, with a code "'AZHYDRO-KOLKATA"', developed at the Cyclotron Centre, Kolkata.

Eq.3 is only closed with an equation of state (EOS) which relates pressure with energy density,p=$p(\epsilon)$. We use Lattice+HRG EOS where the crossover is at T_{co}=196 MeV. For the initialisation of hydro we take initial time τ_i=0.6 fm, freezeout temperature T_f=150 Mev, zero velocity in transverse direction. The only remaining parameter ε_0 is fixed

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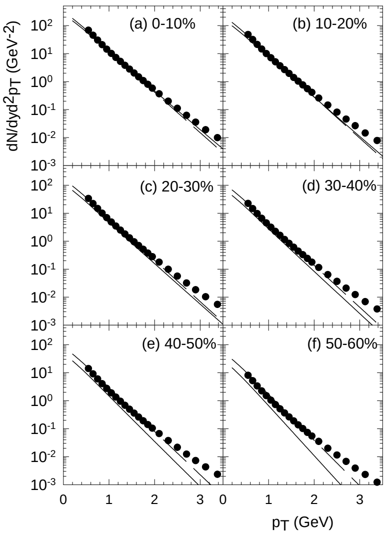

FIG. 1: Filled circles are PHENIX data for charged particles p_T spectra in 0-60% Au+Au collisions. The dashed and solid lines are hydrodynamic predctions with f_{hard}= 0 and 1 respectively.

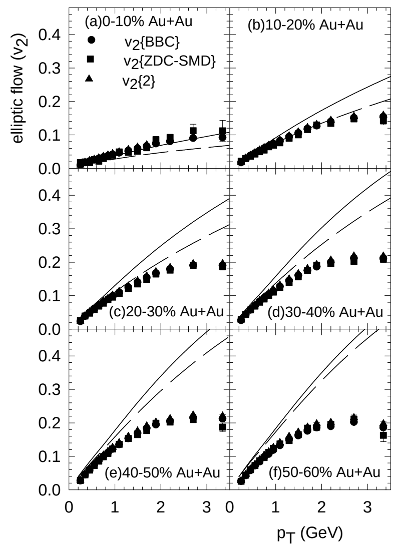

FIG. 2: same as in Fig.1 but for elliptic flow.

by fitting the experimental PHENIX data of p_T spectra in most central collision. We obtain ϵ_0= 36.1 and 48 GeV/fm^3 for f_{hard}= 0 and 1 respectively. In Fig.1 and 2, model simulations [1] for charged particles p_T spectra and elliptic flow in 0-60% Au+Au collisions are compared with PHENIX data [2]. The dashed and solid lines are respectively for f_{hard}= 0 and 1. Spectra in 0-10% collision is well explained in both the scenarios, but in peripheral collisions, data are better explained with f_{hard}=0. Simulated spectra with f_{hard}=0 underpredicts the experimental data in peripheral collisions.

Centrality dependence of elliptic flow v_2 shows significant difference between the two scenarios. Flow is more in simulations with f_{hard}=1. v_2 in 0-10% collision v_2 is better explained with f_{hard}=1 rather than with f_{hard}=0. In more peripheral collisions, data are better explained with f_{hard}=0. Viscous effects are also important in those collision centralities. If we demand that the hydrodynamic model explains charged particles p_T spectra and elliptic flow simultaneously, then one obtains an interesting result: experimental data prefer initial energy density scaling with collision number in central (0-10%) collisions and in peripheral collisions scaling with participant number. The result may have implication on the dynamics of the pre-equilibrium stage. The fluid produced in Au+Au collisions evolve through a pre-equilibrium stage to equilibration. At present, we have limited knowledge about the pre-equilibrium stage. Present results suggests that in 0-10% Au+Au collisions, pre-equilibrium stage is dominated by binary collisions, but in a less central collision, pre-equilibrium stage is dominated by the 'wounded' nucleons.

References

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