Transport properties of the matter formed in heavy-ion collisions at the Large Hadron Collider

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Recent remarkable discoveries at the Relativistic Heavy Ion Collider (RHIC) experiment at BNL provide evidence for an almost perfect fluid like behavior of the QCD matter created in a heavy ion collision. It is then important to extract the value of shear viscous coefficient of the QCD medium from theoretical calculation. The ongoing experiment at Large Hadron Collider (LHC) at a higher centre of mass energy provides a great opportunity to test our previous theoretical understanding of the fluid viscosity.

We are using causal relativistic viscous hydrodynamics in 2+1 dimension with different temperature independent shear viscosity to entropy density ratio (η/s) to extract the shear viscosity from experimental data [1]. With the assumption of a near equilibrium, the quark gluon plasma state at high temperature evolves into a hadron resonance gas at crossover temperature (T_c=175 MeV). The equation of state is taken from a combination of available lattice QCD data and hadron gas model. Particle's transverse momentum (p_T) spectra are then calculated on a constant temperature freeze-out surface with the distribution function modified to account for the viscous correction. The kinetic freeze-out temperature is taken as 130 MeV in the current work.

In this work we have analyzed the first heavy-ion collision data from the large hadron collider experiments. Specifically we have compared the centrality dependence of charged particles multiplicity, p_T integrated elliptic flow (v_2), and p_T spectra in 0-5% centrality collision for Pb+Pb collision at LHC energy ($\sqrt{s_{NN}}$=2.76 TeV) to ideal and viscous hydrodynamic simulations to extract the transport property of the system like the η/s.

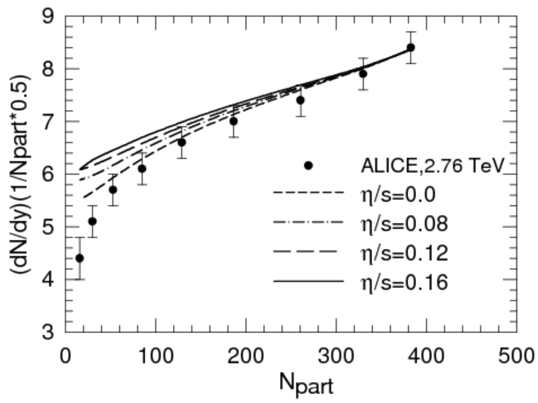

Fig.1. Solid circles are experimental charged hadrons multiplicity per participating nucleon pair at mid rapidity produced at Pb-Pb collision at ($\sqrt{s_{NN}}$=2.76 TeV) [2]. Lines are simulated results from ideal and viscous hydrodynamics.

Figure 1 shows the centrality dependence of charged hadrons pseudo-rapidity density at mid rapidity, the symbols are ALICE measurement and solid, long dashed, dashed dotted and small dashed lines is the viscous and ideal hydrodynamics simulation with η/s=0.16,0.12,0.08 and ideal fluid evolution respectively. As expected the charged particle multiplicity increases as we go from peripheral (small N_{part}) to central collisions (large N_{part}). We observe from our simulated results that the ideal fluid evolution best describe the experimental charged particle multiplicity. We expect that more differential measurements like p_T spectra and v_2 would be sensitive to small viscous effects present in the system.

In Fig.2 ALICE measurement of charged hadron p_T spectra is shown (solid circles) as a function p_T produced in central Pb-Pb collision. Small dashed (ideal fluid), dashed dotted (η/s=0.08), long dashed (η/s=0.12) and solid (η/s=0.16) lines are the results obtained for ideal and viscous simulation. The effect of resonance contribution to pion yields are taken into account. The viscous effect inclusions in the simulations are at both the evolution and distribution function level. We find addition of viscous effect makes the p_T distribution more flatter compared to ideal case.

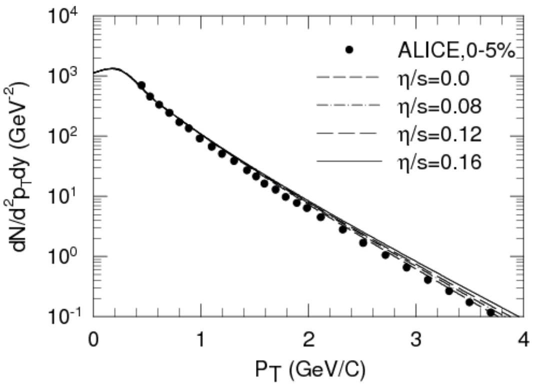

Fig.2. Solid circles are experimentally measured charged hadrons p_T spectra for 0-5% centrality Pb-Pb collision [2]. Lines are the ideal and viscous hydrodynamics simulated results.

The centrality dependence of p_T integrated elliptic flow $\langle v_2 \rangle$ measured by ALICE collaboration [2] in Pb-Pb collision is shown as solid triangles in fig.3. The v_2 is observed to be larger in peripheral collisions compared to central collisions. The data are compared to ideal and viscous hydrodynamics simulation which is shown as lines. At the LHC energy, the v_2 data seems to support a η/s value between 0 – 0.12. This conclusion is very similar to that obtained from RHIC data.

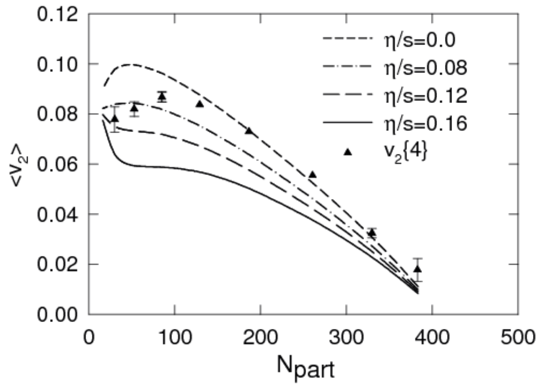

Fig.3. The triangles are experimentally measured values of p_T integrated elliptic flow as a function of number of participating nucleon pair [2]. The lines are the hydrodynamics simulation results for ideal and viscous evolution.

All the results shown here are for a temperature independent η/s. The constant η/s can be taken as the space time averaged values of the real temperature dependent η/s. However it is generally expected that η/s should be temperature dependent in both the QGP and Hadronic phases. We will also show results from our simulation using a temperature dependent η/s obtained from the available lattice QCD data and hadron gas models. The simulated results with and without a temperature dependent η/s will be compared and its implications towards understanding the transport properties of the system formed in heavy-ion collisions at the LHC energies will be discussed.

References

[1] Victor Roy and A.K. Chaudhuri, Phys. Lett. B. 703,313-317 (2011).

[2] K. Aamodt et al. [ALICE Collaboration], Phys. Rev. Lett. 105,252302 (2010) ; Phys. Rev. Lett. 106,032301 (2011)