Temperature Fluctuations in Little Bang : Hydro dynamical Approach

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Introduction

The physics of heavy-ion collisions at ultra-relativistic energies, popularly known as little bangs, has often been compared to the Big Bang phenomenon of early Universe. The matter produced at extreme conditions of energy density (ε) and temperature (T) in heavy-ion collisions is a Big Bang replica in a tiny scale. In little bangs, the produced fireball goes through a rapid evolution from an early state of partonic quark-gluon plasma (QGP) to a hadronic phase, and finally freezes out within a few tens of fm[1,2].

Event-by Event 2+1D Hydro

Recent experimental data from the Relativistic Heavy Ion Collider (RHIC) and the Large Hadron Collider (LHC) have confirmed the formation of a strongly coupled QGP. Hydrodynamics has been used extensively and to a large extent successfully to explain majority of these experimental results. A (2+1)-dimensional event-by-event ideal hydrodynamical framework is used in the present work to model the space-time evolution of the System produced in most central (0-5% of the total cross section) collisions of lead nuclei at $\sqrt{S_{NN}}$ = 2.76 TeV at LHC.

Fig.1 Shows the time evolution of energy density (ε) [a,b,c and d] and temperature (T) [(e),(f),(g) and (h)] at time (τ)=0.14fm, 3fm, 6fm and 12fm respectively. The Simulation is done in 2+1D Event-by-event Hydro dynamical model for LHC energy, which is successfully, describes the spectra and flow for that energy.

A lattice-based equation of state is used in this model and 170 MeV is considered as the transition temperature from the QGP

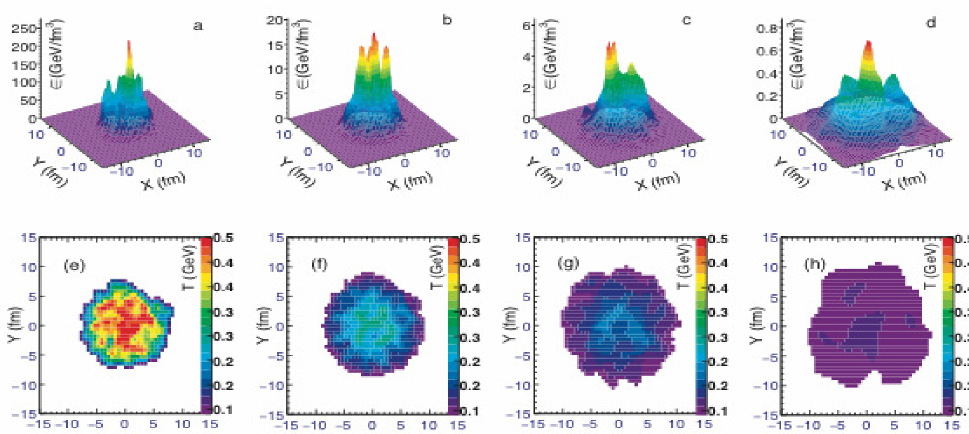

Figure 1: Distributions of energy density (upper panels) and temperature (lower panels) in the transverse (X-Y) plane at four proper times (τ), obtained from hydrodynamic calculations for one central Pb-Pb event at $\sqrt{S_{NN}}$ = 2.76 TeV

to a hadronic phase. This model has been successfully used to explain the spectra and elliptic flow of hadrons at RHIC and LHC energies. In this Monte Carlo Glauber model, the standard two-parameter Woods-Saxon nuclear density profile is used to distribute the nucleons randomly into the colliding nucleons. A wounded nucleon (WN) profile is considered where the initial entropy density is distributed around the WN using a 2-dimensional Gaussian distribution function.

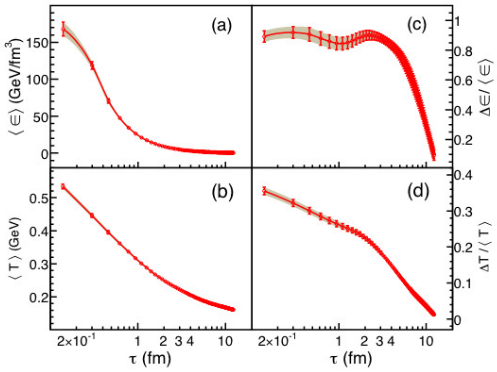

Figure 2: Temporal evolution of (a) average energy density, (b) average temperature, (c) fluctuations in energy density, and (d) fluctuations in temperature, for central Pb-Pb collisions at $\sqrt{S_{NN}}$ =2.76 TeV, obtained from hydrodynamic calculations. The shaded region represents the extent of the event-by-event variations.

Observations from Fig. 1 can be quantified by studying the mean energy density ε, mean temperature <T> over all the bins, and the bin-to-bin fluctuations ε of T at each τ. Figure 2 presents the time evolution of ε and <T>, and their fluctuations. The x-axes are plotted in logarithmic scale for zooming in on the early times. The event-by-event variations of these quantities are represented by the shaded regions, taken from about 5000 events. The <ε> and <T> decrease as time elapses. 0.2. The value of <ε> falls sharply from 168 GeV/fm^{3}at τ =0.14fm to a value of 20GeV/fm^3 at τ =1fm, and then falls slowly till freeze-out. The initial energy density values are close to the results from the ALICE collaboration, ε.τ =16 GeV/fm^2. On the other hand, the fall of <T> with τ is smooth, which goes down from 530MeV at τ =0.14fm to 300MeV at τ =1fm. At the freeze-out, <T> is close to 160 MeV.

Results & Discussion

The Event-by-Event temperature fluctuations related to the specific heat of the system produced at the time of collisions.

The free-streamer mode of hydrodynamic calculations may revel that after the collision system passes through a quasi – equilibrium stage of each point of time. And the specific heat could be achieved by the calculation of the fluctuation of the temperature at the chemical or kinetic freeze-out.

Thus this provide a important message for the experimentally achieved spectra from LHC to RHIC and finding out the thermodynamic quantities like specific heat, heat capacity and equation of state.

References

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