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Thermodynamics of the 'Little Bang' (recorded)

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Observation of the cosmic microwave background radiation (CMBR) by various satellites confirms the Big Bang evolution, inflation and provides important information regarding the early Universe and its evolution with excellent accuracy [1]. In little bangs, the produced fire-ball goes through a rapid evolution from partonic QGP phase to a hadronic phase, and finally freezes out. 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 the early Universe [2-3]. Heavy-ion experiments are predominantly sensitive to the conditions that prevail at the later stage of the collision as majority of the particles are emitted near the freeze-out. Thus, a direct and quantitative estimation of the properties of hot and dense matter in the early stages and during each stage of the evolution has not yet been possible.

In heavy-ion collisions, the mean transverse energy p_T is a proxy of the temperature and the mean number of charged particles (<N_{ch}>) is a manifestation of energy or entropy density. The major motivation of our study is to generate a map of ϵ and T, similar to the CMBR map, using fluctuation and correlation techniques.

The two-particle p_T correlations have been studied for long, and defined in terms of a dimensionless correlation function as a ratio of the differential correlator to the square of the average transverse momentum

$$P_2(\Delta\eta,\Delta\varphi) = \frac{\langle \Delta p_\mathrm{T} \Delta p_\mathrm{T}\rangle(\Delta\eta,\Delta\varphi)}{\langle p_\mathrm{T}\rangle^2} = \frac{1}{\langle p_\mathrm{T}\rangle^2}\frac{\int_{p_\mathrm{T,min}}^{p_\mathrm{T,max}} \rho_2(\mathbf{p}_1,\mathbf{p}_2)\ \Delta p_\mathrm{T,1}\Delta p_\mathrm{T,2}\ \ \Delta p_\mathrm{T,1}\Delta p_\mathrm{T,2}}{\int_{p_\mathrm{T,min}}^{p_\mathrm{T,max}} \rho_2(\mathbf{p}_1,\mathbf{p}_2)\ \ \Delta p_\mathrm{T,1}\mathrm{d}p_\mathrm{T,2}},$$

where is the inclusive average momentum of produced particles in an event ensemble. Technically, in this type of analysis, integrals of the numerator and denominator of the above expression are first evaluated in four-dimensional space as functions of . The ratio is calculated and subsequently averaged over all coordinates. But when p_T is used a proxy to system temperature, it is affected by the radial flow, and falls short to capture the true 'temperature' fluctuation.
To overcome this, we propose a 4-particle p_T and number fluctuations where the non-flow effect are suppressed. With this, we can link it to the thermodynamic response functions like specific heat, heat capacity and compressibility. With the advent of high luminosity and high statistics runs in Run3 and Run4 of CERN Large Hadron Collider (LHC), it will be possible to generator 4-particle correlations. The ALICE experiment is expected to take data in LHC Run5 with a completely new detector covering 8 units in rapidity. For these runs, the fluctuation map can be more effective to extract relevant physics towards thermodynamics of hot and dense matter.

References:

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