Probing heavy-ion collisions through initial state observables

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Introduction

The initial conditions (ICs) play an important role in the dynamical evolution of the fireball created in ultra-relativistic heavy ion collisions (HICs). The ignorance of the ICs translates into the uncertainties over the extracted properties from data of the strongly interacting medium created in these collisions, e.g. values of its transport coefficients like shear viscosity to entropy density ratio η/s [1]. In the absence of the comforts of a table-top experiment where systems can be prepared in *precise and specific conditions*, a tried and tested method in HICs has been to select a measurable quantity Q and then characterize events by their Q values. The standard method uses the final state charged particle multiplicity to characterize the events into different centrality classes corresponding to different initial states like the number of wounded nucleons N_{part}, number of binary collisions N_{coll}, shape of the overlap region, say the elipticity ϵ_2 which are all correlated with the impact parameter b due to the specific shape of the nucleus. However, the geometric and quantum fluctuations in the initial state result in appreciable variation of b, N_{part}, N_{coll} and ϵ_2 etc., even within the same centrality bin. Thus the inference of the properties of the fireball from data is hindered by uncertainties in the characteristics of the initial state [2].

Here, we advocate a second binning in terms of the spectator neutrons that do not participate in the collision. Spectators are pristine messengers of the ICs, unadulterated by the fireball evolution and hence can potentially provide vital information of the ICs. Similar information as the spectators is also carried by the rapidity integrated conserved charges which can however be measured from final state observables. We will present correlations of initial state observable (ϵ_2, ϵ_3) and final state observable (v_2, v_3) in bins of spectator neutrons as well as conserved charges. The standard scaling relation between v_2/ϵ_2 and $1/SdN_{ch}/d\eta$ [3] in centrality bins alone is broken by the second binning, where S is the overlap area defined by $S = 4\pi\sigma_x\sigma_y$ and σ_x, σ_y are the respective root mean square widths of the nucleon density distributions.

Event selection method

The standard practice is to categorize events into different centrality classes according to final state charged particle multiplicity as shown in Fig. 1. Here we propose to do a second round of binning with (a) the total spectator neutron (L+R), where L and R are the left and right going spectator neutrons, respectively [4], (b) with conserved charges (net baryon ($B - \bar{B}$)), within each centrality bin as illustrated in Fig. 2.

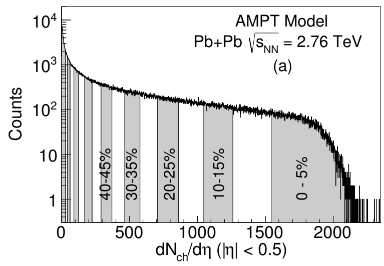

FIG. 1: The multiplicity distribution for minimum bias Pb+Pb collisions at $\sqrt{s_{NN}} = 2760$ GeV from AMPT model. Different centrality bins are also shown in alternate white and grey bands.

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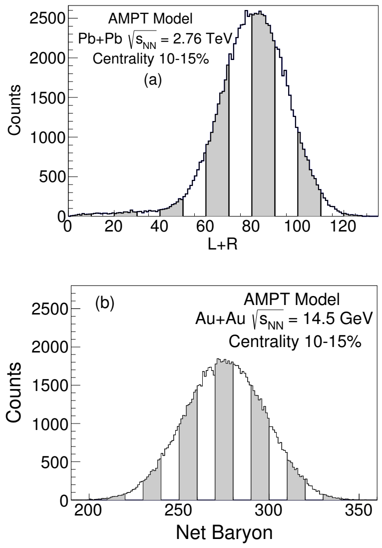

FIG. 2: (a) The total spectator neutron number L+R distribution, (b) The net baryon distribution for the (10-15)% centrality. The different L+R bins and Net Baryon bins are also shown by alternate white and grey bands.

Results and discussions

We have plotted the ratio v_2/ϵ_2 vs $(1/S)dN_{ch}/d\eta$ with centrality and L+R bins in Fig. 3 and net baryon bins in Fig. 4. The centrality averaged points exhibit the usual trend of an initial fast rise and final saturation of the ratio v_2/ϵ_2 vs $(1/S)dN_{ch}/d\eta$. However, the L+R bins (net baryon bins) in each centrality show the opposite behavior and breaks the usual scaling relation [4]. In a given centrality bin, with rise in L+R, the transverse overlap area S sharply falls while $dN_{ch}/d\eta$ is almost constant. Thus $(1/S)dN_{ch}/d\eta$ which acts like a proxy for K^{-1}(Knudsen number K) [3], increases with L+R although the hydrodynamic response v_2/ϵ_2 falls sharply. We expect more (less) hot spots and gradients in the initial energy profile of events with larger (smaller) L+R leading to more (less) viscous correction. This ultimately leads to inefficient conversion of the initial ϵ_n into the final v_n in events with larger L+R as compared to those with smaller L+R. A similar argument also holds for the net baryon bins.

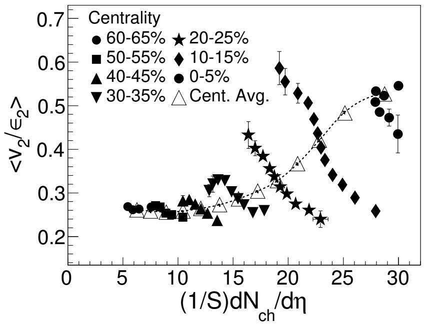

FIG. 3: v_2/ϵ_2 vs $(1/S)dN_{ch}/d\eta$ for different centrality and L+R bins in Pb+Pb collisions at $\sqrt{s_{NN}}$ = 2760 GeV.

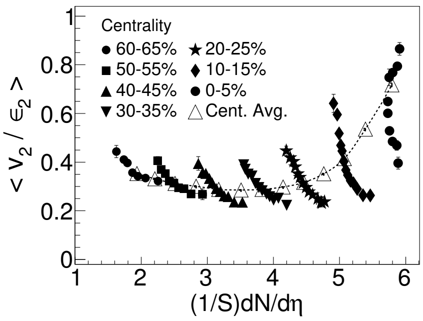

FIG. 4: v_2/ϵ_2 vs $(1/S)dN_{ch}/d\eta$ for different centrality and Net Baryon bins in Au+Au collisions at $\sqrt{s_{NN}} = 14.5$ GeV.

Acknowledgments

We acknowledges financial support by the DAE-SRC project sanction number 2010/21/15-BRNS/2026.

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