Entropy Analysis in Relativistic Ion-Ion Collisions

Shakeel Ahmad[1], A. Khatun[1], Shaista Khan[1], T. Ahmad[2], and A. Ahmad[3]
[1]*Department of Physics, Aligarh Muslim University, Aligarh, INDIA*
[2] *University Polytechnic, Aligarh Muslim University, Aligarh, INDIA and*
[3]*Department of Applied Physics, Aligarh Muslim University, Aligarh, INDIA*

Processes in which particles are produced may be regarded as the so called dynamical systems[1–3]. Investigations involving the local entropy produced in relativistic nucleus-nucleus (AA) collisions are expected to provide direct information about the internal degrees of freedom of the QGP medium and its evolution[1, 4]. It has been suggested[4] that event coincidence probability method of measuring entropy as proposed by Ma[5] is well suited for the analysis of local properties in multiparticle system produced in high energy collisions. This method is applicable to both hadron-hadron and nucleus-nucleus collisions. In AA collisions, entropy measurement can be used not only to search for QGP formation but it may also serve as an additional tool to study the correlations and event-by-event(ebe) fluctuations[3, 4].

Rényi entropies of particles produced may be estimated[4] from their probability distribution, using the relation, $H_k = \sum_n (p_n)^k$, where p_n is probability of production of n relativistic charged particles in an interaction. The invariance of entropy under an arbitrary change of multiplicity scale allows to choose a subsample of particles, like charged particle in limited η-windows. It has been observed[1, 2] that entropy in a given η window increases with increasing beam energy while the entropy normalized to maximum rapidity becomes energy independent quantity, indicating a kind of entropy scaling in hadronic and ion-ion collisions. The study of entropy dependence on the charged particle multiplicity in limited η window is expected to provide interesting information in the context of multiparticle production process. It was, therefore, considered worthwhile to study the dependence of Rényi entropy, on charged particle multiplicity by analysing the experimental data on ^{16}O-AgBr collisions at incident energies 14.5A, 60A and 200A GeV/c. All the relevant details of the data may be found elsewhere[1, 2]. Findings based on the experimental data are compared with the predictions of Monte Corlo model HIJING. For this purpose data samples corresponding to experimental event samples are simulated, using the code HIJING -1.35, and analysed.

Probability $P_n\,(\Delta n)$, of producing n relativistic charged particles in a pseudorapidity window of fixed width is calculated by slecting a window of fixed width $\Delta\eta = 0.5$. This window is chosen so that its mid position coincides with the centre of symmetry of η distribution, η_c. Thus, all the charged particles having η values lying in the interval ($\eta_c - \Delta\eta/2 \leq \eta \leq \eta_c + \Delta\eta/2$) are counted to evaluate P_n. The window width is then increased in step of 0.5 untill a region $\eta_c \pm 3.0$ is covered. Variations of Rényi entropy, H_2 with $\Delta\eta$ for the real and HIJING events are plotted in Fig.1. It is observed that with widening of η windows entropy first increases upto $\Delta\eta$ ∼2.5 and thereafter tends to acquire a constant value. Furthermore for a given $\Delta\eta$, H_2 values are noted to increase with increasing beam energy. It is interesting too to note from the figure that the trends of increase of H_2 with $\Delta\eta$, exhibited by the real data are nicely reproduced by HIJING predictions. In Fig.2. variations of H_2 with mean charged particle multiplicity in the limited η-window, $< n_s >$ are displayed. It may be observed from the figure that the value of H_2 corresponding to three different incident energies overlap to form a single curve indicating a kind of entropy scaling in AA collisions. Results from HIJING data, shown in the figure also reveal that the entropy scaling observed with the real data is supported reasonably well by the HIJING model. The solid lines in figure are obtained from the best fit to the data using the relation $H_2 = a + b\, ln < n_s >$, where a and b are constants. The values of b obtained from the best fit to the data are listed in Table 1. It may be noted from the table that the values of constant b for the real data are close to those obtained for the HIJING event samples.

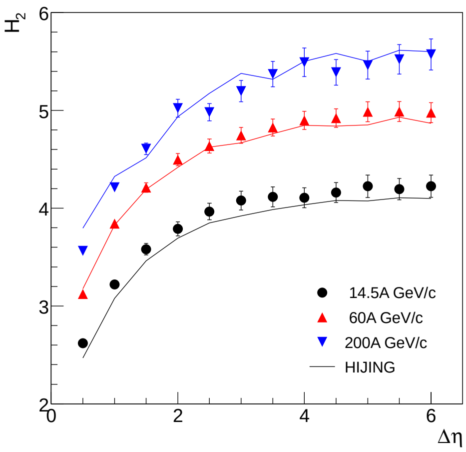

FIG. 1: Variations of H_2 with $\Delta\eta$ for the real and HIJING events.

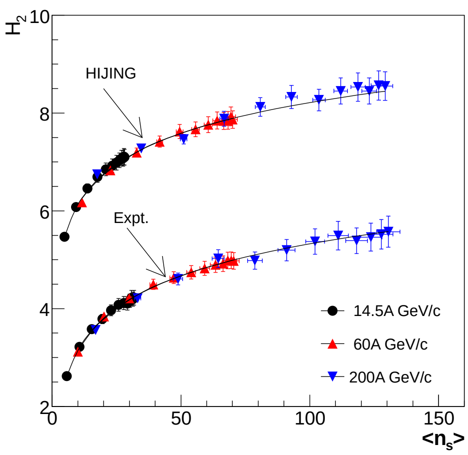

FIG. 2: Dependence of H_2 on $< n_s >$ for the real and HIJING event samples. For clarity sake, HIJING simulated values of H_2 are increamented by 3 units.

Forward-Backward(FB) multiplicity correlations have been investigated[2] by compairing the multiplicities in a window of width $\Delta\eta$ placed in forward(F) region with the multiplicities in an identical window placed in the backward(B) region. The windows are so selected that they are symmetric around η_c. Findings from these investigations indicate the presence of event-by-event(ebe) multiplicity asymmetry which, in turn, suggest that entropy values in F and B regions would be different. It has been observed[1, 2] that the entropy values in a window of width $\Delta\eta$ placed in F regions is more than that in an identical window placed in the B regions. We, therefore, attempt to study the dependence of H_2 on mean charged particle multiplicies in the η-window of limited width placed in F and B regions by plotting H_2 against $< n_s >^F$ and $< n_s >^B$ (not shown); $< n_s >^F$ and $< n_s >^B$ being the mean multiplicities of relativistic charged particles in F and B regions respectively. It is observed that the data at the three incident energies overlap suggesting the similar kind of entropy scaling, as observed in the combined F-B region (Fig.2). The fitted values of the constant b are listed in Table 1. It is interesting to note in Table 1 that the values of constant, 'b' which represent the slope of logH_2 vs $< n_s >$ plot acquire almost similar values for various data sets(real and HIJING) corresponding to F, B and combined F-B regions, indicating a kind of universality in the entropy scaling. These results will be presented in detail.

Table 1: Values of parameter b for various data sets

	b	
	Expt.	HIJING
F-B region	0.95 ± 0.01	0.91 ± 0.01
F-region	0.96 ± 0.01	0.93 ± 0.01
B-region	0.94 ± 0.01	0.90 ± 0.01

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