Entropy Production in ^{16}O-AgBr and ^{32}S-Gold Collisions at 200A GeV/c

Shakeel Ahmad[1], Anuj Chandra[1], and Tufail. Ahmad[2]
[1] *Department of Physics, Aligarh Muslim University, Aligarh, INDIA and*
[2] *University Polytechnic, Aligarh Muslim University, Aligarh, INDIA*

An interesting quantity that may provide visible insight into the state of matter in the early stage of nucleus-nucleus (AA) collisions is the net entropy, which is believed to be roughly conserved between initial thermalization and freeze-out[1]. After freeze-out, when particles are freely streaming, entropy remains fixed. Event coincidence probability method of measuring entropy is believed to be well suited for the analysis of the local properties in multiparticle system produced in hadronic and ion collisions[2]. Further, entropy measurements may serve as an additional tool for studying the event-by-event (ebe) fluctuations and particle correlations. An attempt is, therefore made to study the entropy production in AA collisions by analysing the experimental data on ^{16}O-AgBr and ^{32}S-Gold collisions at 200A GeV/c. All the relevant details of the data may be found elsewhere[3]. In order to compare the findings of the present work with the predictions of Monte Carlo model, AMPT, event samples corresponding to the two sets of the real data are simulated and analysed.

Entropies of particles produced may be estimated[2] from their probability distribution, using the relation, $S = -\sum_n P_n ln P_n$. Because of the invariance of entropy under an arbitrary change of multiplicity scale, one may choose sub-sample of particles, e.g. relativistic charged particles emitted in a selected pseudorapidity, η-window. Analysis of the experimental data on hadron-hadron (hh) collisions in the c.m. energy range from 22 GeV to 7 TeV indicates that entropy increases with beam energy while the entropy normalized to maximum rapidity seems to be energy independent quantity[2, 4]. In the case of AA collisions too we observe similar dependence of entropy on beam energy. These observations indicate the presence of a kind of entropy scaling in hadronic and ion collisions over a wide range of beam energy. Forward-Backward (F-B) correlations and multiplicity fluctuations have been investigated[3, 5] by comparing the multiplicities in a window width, $\Delta\eta$, placed in the F region with the multiplicities in an identical window placed in the B region; F and B window positions are so chosen that they are symmetric around η_c; η_c being the centre of symmetry of the η distribution. Findings from these investigations indicate the presence of ebe multiplicity asymmetry, which in turn suggests that the entropy values in the two regions would be different. We have, therefore, studied the entropy in F and B regions by selecting two η-windows of the same widths $\Delta\eta$(=0.5) and placing one in F and the other in B regions. The windows are placed such that all the charged particles having their η values lying in the interval, $\eta_c \leq \eta < \eta_c + \Delta\eta$ are counted to estimate the entropy in the F region, whereas those having their η values in the range, $\eta_c > \eta \geq \eta_c - \Delta\eta$ are considered to determine the entropy in the B region. The window width is then increased in step of 0.5 until the F and B regions with η_c+3 and η_c-3 respectively are covered. Dependence of entropy on η-bin width in F and B regions for the experimental and AMPT events are shown in Fig.1. It is observed that entropy increases with $\Delta\eta$ upto $\Delta\eta \simeq 1.5$ and thereafter acquire nearly a constant value and that the observed trend of variations of S with $\Delta\eta$ is nicely reproduced by the AMPT model. It is also reflected from the figure that for any given $\Delta\eta$, in F or B regions, entropy values are found to be higher for the collisions involving heavier nuclei. Furthermore, it is interesting to note that for any given data set (real or simulated), the entropy values in the F region are larger than those in the B region. Such a difference in the S values is noticed almost in the entire $\Delta\eta$ region considered. This difference might arise due to the presence of strong F-B correlations around mid rapidity.

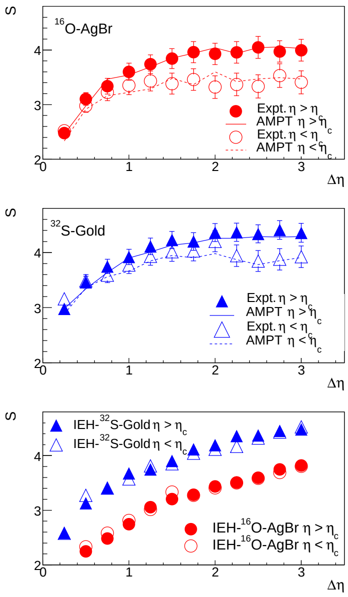

FIG. 1: Variations of S with $\Delta\eta$ in F and B regions for the real, AMPT and IEH events

In order to test whether the observed entropy difference in the two regions are the distinct feature of the data or arises simply due to fluctuations in the event multiplicities, correlation free Monte Carlo events corresponding to the two real data sets are simulated and analysed; these events are simulated in the frame work of Independent Emission Hypothesis (IEH) by adopting the criteria discussed in ref.3. Results from the analysis of these event samples are presented in the bottom panel of Fig.1. It is observed that the trend of variations of S with $\Delta\eta$ for these events are quite different from those exhibited by the experimental or AMPT data. Moreover, for IEH event samples the values of S against $\Delta\eta$ in F and B regions are nearly the same. Thus, the observed difference in the entropy values in F and B regions for the real and AMPT data (and not with the IEH events) might arise due to the strong correlations existing between the particles belonging to the adjacent F and B regions. These F-B correlations are believed to be of short range in nature, arising due to production of cluster, which finally decay isotropically to real hadrons and there is no or very small contribution from the long range correlations, particularly at lower energies[5]. In order to ensure whether there is some contribution from the long range correlations, contributions coming from short range correlations are to be excluded. For this purpose, entropy values in F and B regions are calculated after introducing certain gaps between the two η-windows, i.e., particles with $\eta \leq \eta_c + \eta_{gap/2}$ in F region and those with $\eta \geq \eta_c - \eta_{gap/2}$ in the B regions are not counted to estimate the entropy. It is observed that with increasing separation between the F and B η-windows, difference in the entropy values in the two regions become smaller and smaller and finally vanish when this gap is as large as 3η units. This fact is reflected from Fig.2, in which variations of S with $\Delta\eta$ in F and B regions, separated by 3η units are shown for ^{16}O-AgBr collisions. These observations, thus, suggest that there exists a strong F-B multiplicity correlations and are mostly of short range type. These correlations get weakened and finally vanish for large separations between F and B regions.

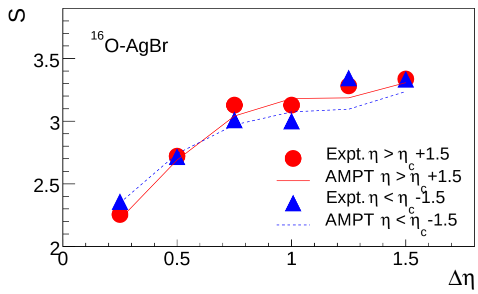

FIG. 2: S vs $\Delta\eta$; F and B regions separated by 3η units.

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