Forward-Backward Multiplicity Fluctuations in Relativistic Heavy-Ion Collisions

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Studies involving multiplarticle correlations are regarded as an important tool to explore the mechanism of particle production in hadronic and heavy ion collisions. Both short-range and long-range correlations have been observed in the past decades[1] which have been interpreted via the concept of clustering[2], i.e clusters are formed in the initial stage of the interaction which finally decay isotropically in their center of mass frame to real hadrons. Various properties of clusters, e.g. their size (or multiplicity), width in the phase space, etc., may be extracted by studying the correlations amongst the nth nearest neighbors[3]. Interest in the studies of correlations emitted in the forward and backward region of phase space has grown considerably[1, 4] because of the idea that the formation of quark-gluon plasma would lead the modification of clusters relative to those in hadron-hadron(hh) collisions. A number of attempts have been made[4]$^{and\ references\ therein}$ to study the forward backward multiplicity correlations. However, most of these investigations are based on the short-range correlations and involve hh collisions data. RHIC data, however, suggest that multiparticle correlations would extend over a long range provided the hh collision energy is high enough. Furthermore, an enhanced long range correlation might be present in nucleus-nucleus(AA) collisions as compared to hh collisions at the same beam energy[3]. The observed long-range correlations in AA collisions may be a signal for multiple partonic interactions in the dense matter[4]. It has also been suggested[3] that an enhanced long range correlation might be present in hadron-nucleus and nucleus-nucleus(AA) collisions as compared to hh collisions at the same beam energy. An attempt is, therefore, made to investigate the forward-backward correlation in AA collisions by analyzing the experimental data involving the interactions of S^{32} and O^{16} with AgBr nuclei in emulsion at 200A GeV/c. The number of events in the two data samples are respectively 452 and 232. In order to compare the findings based on the experimental data with the various Monte Carlo models, equal number of Monte Carlo events corresponding to the two types of interactions are simulated and analyzed. The Monte Carlo generators (MCGs) used for this purpose are HIJING-1.35, HIJING-$B\overline{B}$-1.0 and AMPT-1.21-v2.21. Furthermore, in order to ensure that the observed fluctuations are the features of particle production phenomena, a parallel analysis of the mixed events corresponding to experimental data is also carried out.

Forward-backward charge correlations can be studied[5, 6] in terms of variable C, which measures the charge asymmetry in the forward(f-) and backward(b-) regions. Two symmetric pseudorapidity regions with centres at $\pm\eta$ and having equal width $\Delta\eta$ are considered. The numbers of charged particles lying in the f- and b- regions, i.e. $\eta + \frac{\Delta\eta}{2}$ and $\eta - \frac{\Delta\eta}{2}$ are counted event wise. These numbers are referred to as n_f and n_b respectively. The event-wise asymmetry variable, in terms of n_f and n_b, is defined as $C = (n_f - n_b)/\sqrt{(n_f + n_b)}$, while its variance is given by $\sigma_c^2 \simeq \frac{D_{ff} - D_{bb} - 2D_{fb}}{<n_f + n_b>}$, where $D_{ff} =< n_f^2 > - < n_f >^2$ and $D_{bb} =< n_b^2 > - < n_b >^2$ are respectively the variance in the f- and b- hemispheres, whereas $D_{fb} =< n_f n_b > - < n_f >< n_b >$ is referred to as the covariance; the quantities within angular brackets are event averaged values. The parameter σ_c^2 measures the dynamical fluctuation and is referred to as the effective cluster multiplicity, $K_{eff.}$ The strength of f-b correlation is given by $b = D_{fb}/D_{ff}$. Therefore, if $b = 0$, the covariance D_{fb}

vanishes and hence $\sigma_c^2 \sim K_{eff}$. It has been emphasized that K_{eff} should be regarded as the product of true cluster multiplicity times a leakage factor ξ that takes into account the limited η window[6]. In the absence of correlations among the produced particles $\sigma_c^2 = 1$.

Variations of σ_C^2 with η for the experimental, MCGs and mixed events are shown in Fig.1. Values of σ_C^2 against η are obtained by keeping the width of the η windows($\Delta\eta = 0.5$) fixed, while their positions in the f- and b- regions are varied by taking the η values from ± 0.25 to ± 2.0 in the steps of 0.25. It may be noticed in the figure that for all the three MCGs, trends of increase of σ_C^2 with η are almost identical. These values are, however, smaller than those observed with the real data. It may also be noted in the figure that for $\eta = 0.25$, $\sigma_C^2 \sim 1$ for all the data sets. This is expected[6] because of the idea that the particles resulting from the decay of clusters produced at $\eta \sim 0$ will fall in both f- and b- hemispheres, including an intrinsic long-range correlations causing a decrease in σ_C^2. In the context of QGP, reduction of σ_C^2 is expected because the production of QGP near mid-rapidity, if takes place, would break-up the cluster structure observed in hh- collisions. It may also be noted in the figure that at the largest value of η, ($\eta = 2.0$), σ_C^2 approaches to $\sim$ 1.5, a value close to $K_{eff} = 1.5$, expected from the resonance gas. The next set of results are based on the variations of σ_C^2 with $\Delta\eta$, presented in Fig.2. These values, for the various data sets, are calculated by varying the size of the window, $\Delta\eta$ such that the windows remain symmetric with respect to a fixed η centre, ($\eta = \eta_{cm}$). It is observed in the figure that $\sigma_C^2 \sim 1$ for the smallest window and thereafter increases monotonically with increasing $\Delta\eta$. This may be attributed to the idea that with increasing $\Delta\eta$, probability of finding more than one particle resulting from a single cluster in either f- or b- region will increase. It may also be noted that for a given $\Delta\eta$ value of σ_C^2 for the experimental data are larger than those due to various MCGs. This indicates the presence of a rather stronger correlation in the experimental data as compared to those

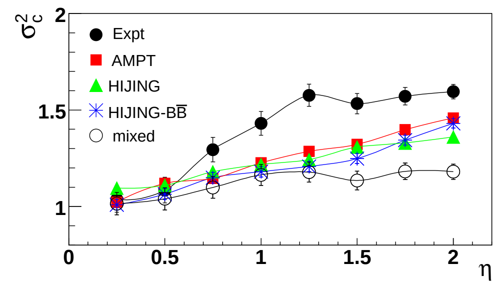

FIG. 1: Dependence of σ_C^2 on η for the real, and simulated events corresponding to 200A GeV/c S-AgBr collisions

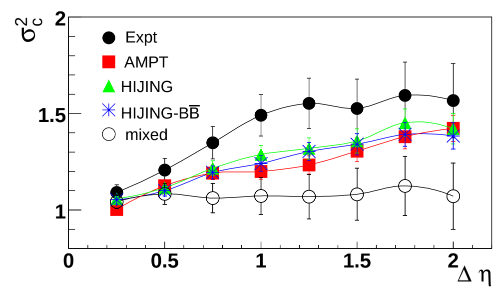

FIG. 2: Variations of σ_C^2 with $\Delta\eta$ for 200A GeV/c S-AgBr collisions

obtained from various MCGs. Furthermore, it is interesting to observe in Figs.1 and 2 that for the mixed events $\sigma_C^2 \sim 1$, irrespective of the widths of η windows. This indicates the correlations present in real event vanish after event mixing. Variations of σ_C^2 with η and $\Delta\eta$ for the events produced in 200A GeV/c O-AgBr collisions has also been studied. A comparison of the above results with these finding and also with those observed at PHOBOS will be presented.

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