Forward-backward correlation at FAIR energy in UrQMD

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Event-by-event fluctuation and correlation in particle multiplicities are two important observables for studying multiparticle production dynamics. In high-energy nucleus-nucleus (AB) collisions the initial density fluctuations are very efficiently transferred into the collective flow correlations in the momentum space. Recently, the initial state density fluctuations are also studied in the longitudinal direction [1]. The longitudinal fluctuations are directly related to the entropy production at the very early stages of the collisions, well before the onset of any collective flow. In terms of the multiplicity of produced particles they appear as long-range correlations separated in rapidity (y) or pseudorapidity (η). On the other hand short-range correlations, localized over a relatively smaller η-range, are usually generated through low mass clusters. In hadron-hadron interaction, the short range correlation length is typically one unit in η, and in AB collisions it is even smaller. In this letter we have tried to set a reference base line regarding the forward-backward (FB) multiplicity correlation of final state charged hadrons for the upcoming Compressed Baryonic Matter (CBM) experiment to be held at the Facility for Antiproton and Ion Research (FAIR). The ultra-relativistic quantum molecular dynamics (UrQMD) model is used to simulate a million Au+Au events at $E_{\text{Lab}} = 40A$ GeV used in this analysis. We define two pseudorapidity (η) windows of width $\Delta\eta$ each, located symmetrically at distances $\pm\eta$ from the centroid (η_0) of the overall η-distribution of the charged hadrons. Let N_F and N_B be the number of particles falling respectively within the forward and backward windows. The FB asymmetry parameter $C = (N_F - N_B)/(N_F + N_B)$ is then introduced [2]. The variance in the particle multiplicity is $D^2_{xx} = \langle N_x^2 \rangle - \langle N_x \rangle^2$, where $x = F$ for the forward and $x = B$ for the backward window, and the covariance, measuring the long-range correlation, is given by $D^2_{BF} = \langle N_B N_F \rangle - \langle N_B \rangle \langle N_F \rangle$. The fluctuation in C obtained as

$$\sigma_c^2 = \frac{D^2_{FF} + D^2_{BB} - 2D^2_{FB}}{\langle N_F + N_B \rangle} \tag{1}$$

accounts for the dynamical component of fluctuations. The correlation strength is given by $b = D^2_{BF}/D^2_{FF}$ and $b = 0.5$ means that 50% of the particles are correlated [3].

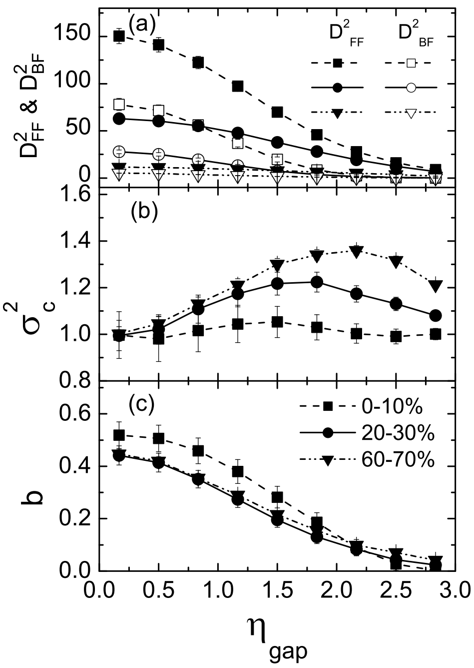

FIG. 1: Forward-backward correlation parameters are plotted against η_{gap} for charged hardons at different centralities.

The variations of D^2_{FF}, D^2_{FB}, σ_c^2 and b as functions of $\eta_{\text{gap}} = 2(\eta - \eta_0)$ are shown in

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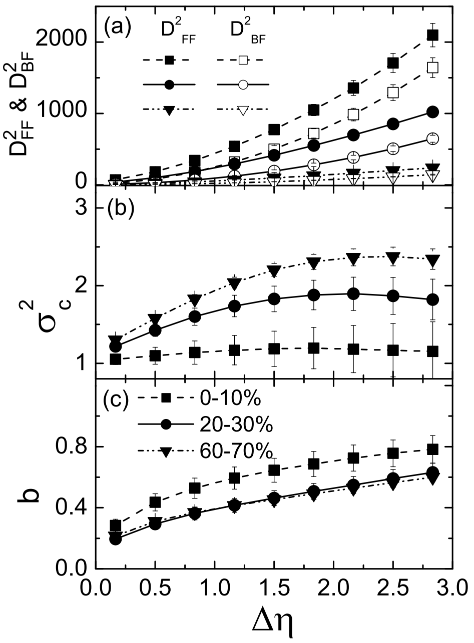

FIG. 2: Forward-backward correlation parameters are plotted against $\Delta\eta$ for charged hardons at different centralities.

Fig. 1 at some selected centrality classes. The window is fixed at $\Delta\eta = 0.5$. We find that both D^2_{FF}, D^2_{FB} monotonically decrease with increasing $\eta_{\rm gap}$ and $D^2_{FF} > D^2_{FB}$ at all centralities. Both D^2_{FF} and D^2_{FB} also decrease with increasing centrality. For the 0-10% most central events both of them are vanishingly small valued. In each centrality class the fluctuation measure σ^2_c, which is influenced by both short and long-range correlations, slowly increases with $\eta_{\rm gap}$, reaches a maximum and then drops down to some extent as $\eta_{\rm gap} \to 3.0$. In peripheral collisions (60-70% centrality) the peak value of $\sigma^2_c \approx 1.4$, slightly less than the resonance gas limit (1.5) [4]. Dominance of short range correlation leads to a reduction in σ^2_c. For the 0-10% most central collisions σ^2_c is very close to unity, which is its Poisson limit and indicates no cluster. The correlation strength decreases monotonically with increasing $\eta_{\rm gap}$, and as $\eta_{\rm gap} \to 3.0$, at all centralities $b \to 0$. Correlation strength is highest in the 0-10% most central collisions, and no significant difference in this regard is seen between 20-30% and 60-70% centrality classes. The correlation though gets weaker with increasing $\eta_{\rm gap}$, long rage correlation survives even in the framework of UrQMD.

In Fig.2 we show our results on D^2_{FF}, D^2_{FB}, σ^2_c and b plotted against $\Delta\eta$. The separation between forward and backward windows is set at $\eta_{\rm gap} = 1.5$. Both D^2_{FF} and D^2_{FB} increase like $(\Delta\eta)^\alpha : \alpha > 1$. With increasing centrality both get reduced in magnitude. D^2_{FF} is consistently greater than D^2_{FB}. The fact that $D^2_{FB} > 0$ indicates presence of long range correlation. The fluctuation measure σ^2_c increases nonlinearly with $\Delta\eta$, and at all centralities beyond $\Delta\eta = 1.5$ it saturates at different values. With increasing centrality σ^2_c becomes smaller, and for the 0-10% most central events $\sigma^2_c \approx 1.0$ which again indicates no cluster. The correlation strength b too increases slightly nonlinearly with $\Delta\eta$. For 20-30% and 60-70% centrality classes there is effectively no difference between the results. In the 0-10% most central events the strength is highest. Our results show presence of both short and long range correlation that do not warrant formation of any exotic state. The observations can be interpreted in terms of the particle production mechanism embedded into UrQMD, and they are grossly consistent with the PHOBOS measurement and corresponding UrQMD simulation [5].

Acknowledgment: This work is financially supported by the University of North Bengal.

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