Initial state longitudinal asymmetry at FAIR-CBM energy

Soumya Sarkar[1,2] and Provash Mali[1] and Amitabha Mukhopadhyay[1*]
[1] *Department of Physics, University of North Bengal, Siliguri-734013, West Bengal, India*
[2] *Department of Physics, Siliguri College, Siliguri-734001, West Bengal, India*

The number of nucleons directly participating in a high-energy nucleus-nucleus (AB) collision ($N_{\rm part}$) may fluctuate from one event to another. Such fluctuations, expected even at a definite centrality of a symmetric colliding system, can create a longitudinal asymmetry that shifts the position of the participant zone, and influence the forward-backward asymmetry of the rapidity distribution of the produced particles. The shift in rapidity with respect to the nucleon-nucleon center of mass (CM) frame can be approximated as

$$y_0 \approx \frac{1}{2}\ln\frac{A}{B} \qquad (1)$$

where A and B are the contributions to

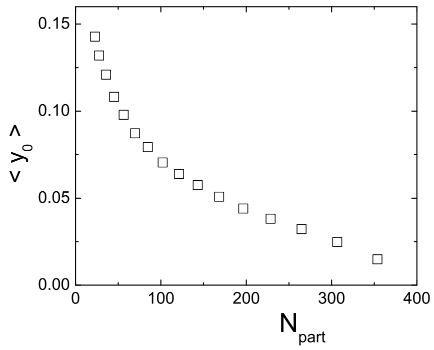

FIG. 1: $N_{\rm part}$ dependence of mean participant-zone rapidity shift $\langle y_0\rangle$.

$N_{\rm part}$ from the two colliding nuclei [1]. Recent investigations suggest that the measurement of this shift may help us understand the effects of longitudinal asymmetry on various final state observables like odd harmonics of anisotropic flow, the forward-backward correlations, source sizes etc. [2, 3]. y_0 can be expressed in terms of a participant asymmetry parameter $\alpha_{\rm part} = (A-B)/(A+B)$ as,

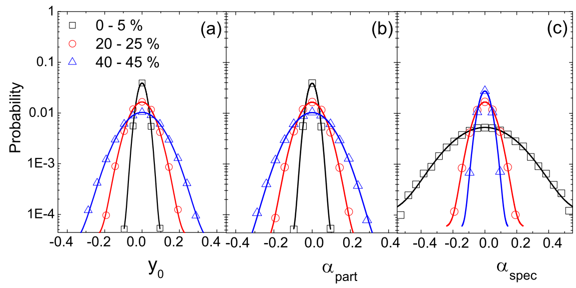

FIG. 2: (Color on line) Distributions of (a) participant-zone rapidity shift (y_0), (b) participant asymmetry ($\alpha_{\rm part}$), and (c) spectator asymmetry ($\alpha_{\rm spect}$).

$$y_0 = \frac{1}{2}\ln\frac{1+\alpha_{\rm part}}{1-\alpha_{\rm part}} \qquad (2)$$

and also in terms of a spectator asymmetry parameter $\alpha_{\rm spec} = [(N-A)-(N-B)]/[(N-A)+(N-B)]$ as,

$$y_0 = \frac{1}{2}\ln\frac{(A+B)(1+\alpha_{\rm spec}) - 2N\alpha_{\rm spec}}{(A+B)(1-\alpha_{\rm spec}) + 2N\alpha_{\rm spec}} \qquad (3)$$

In this analysis we have generated 10^6 minimum bias Au + Au events at $E_{\rm lab} = 30$A GeV using the AMPT [4] code in its string melting version. The Monte Carlo Glauber (MCG) model [5] is employed to determine the initial state. Fig.1 shows that the rapidity shift $|y_0|$ monotonically decreases with increasing $N_{\rm part}$. In Fig.2 we present the distributions of y_0, $\alpha_{\rm part}$, and $\alpha_{\rm spec}$ for different $N_{\rm part}$. The width of y_0 distribution is found to be increasing with decreasing centrality which is in agreement with our observation of Fig.1. The nature of $\alpha_{\rm part}$ distribution is almost identical to the y_0 distribution. The distribution of $\alpha_{\rm spec}$ and $\alpha_{\rm part}$ are

*Electronic address: `amphys@nbu.ac.in`

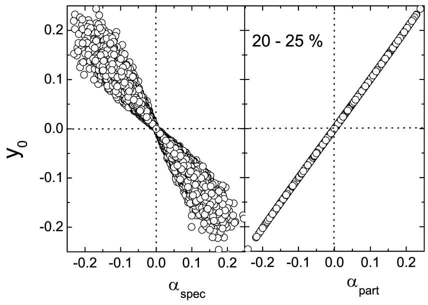

FIG. 3: Event by event participant-zone rapidity shift (y_0) as a function of (a) spectator asymmetry ($\alpha_{\rm spect}$) and (b) participant asymmetry ($\alpha_{\rm part}$) for the 20 - 25 % centrality class.

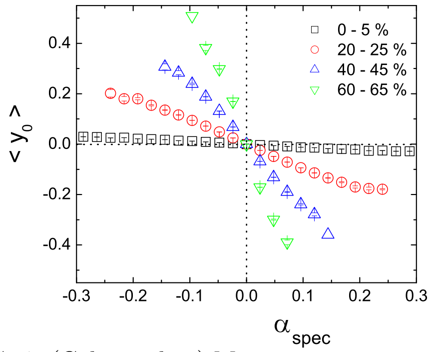

FIG. 4: (Color on line) Mean participant zone rapidity shift (y_0) as a function of spectator asymmetry ($\alpha_{\rm spect}$).

complimentary to each other. The event by event distribution of y_0 against $\alpha_{\rm spec}$ and $\alpha_{\rm part}$ for the 20 - 25 % centrality class is shown in Fig.3. This shows a correlation between y_0 and $\alpha_{\rm part}$. The dispersion in event wise y_0 value at a particular $\alpha_{\rm spec}$, is also established. Fig.4 shows the mean rapidity shift (y_0) as a function $\alpha_{\rm spect}$ for different centrality classes. We also intend to scrutinize the effects (if any) of the participant-zone rapidity shift on the final state observables. In this analysis we have separated out the events with positive asymmetry ($y_0 > 0$) and negative asymmetry ($y_0 < 0$). The respective rapidity distributions are obtained and their ratios at different centrality classes with a third order polynomial fit are plotted against rapidity in Fig.5. The fit parameters at different $<| y_0 |>$ for different centrality classes are listed in Table.I.

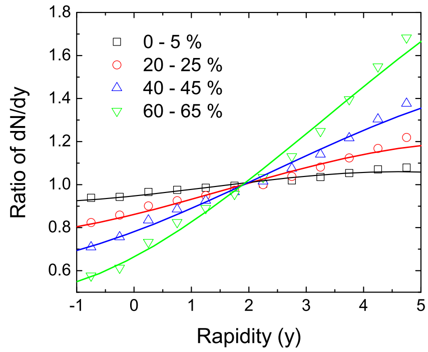

FIG. 5: (Color on line) Ratio of $dN_{\rm ch}/dy$ for events with positive shift ($y_0 > 0$) to those with negative shift ($y_0 < 0$) as a function of rapidity (y). The solid lines are fits with third order polynomial.

The c_1 parameter, characterizing the asymmetry in η-distributions, dominates over c_2 and c_3. The longitudinal asymmetry can classify the events and provide information about the initial states. The simulated results presented in this work will set a reference baseline for the upcoming CBM experiment to be held at FAIR.

$<\|y_0\|>$	c_1	c_2	c_3
0.0442	0.0504	0.0001	-0.00033
0.0706	0.0868	0.0065	-0.00078
0.0872	0.1052	0.0104	-0.00136
0.1081	0.1307	0.0130	-0.00189
0.1323	0.1505	0.0268	-0.00225

TABLE I: Fit parameters of third order polynomial corresponding to different $<| y_0 |>$.

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