System size and collision energy dependence of longitudinal asymmetry

Sanchari Thakur [1], Sumit Kumar Saha [1], Sk Noor Alam [2], Rupa Chatterjee [1] and Subhasis Chattopadhyay [1]

[1] Variable Energy Cyclotron Centre, Homi Bhabha National Institute, Kolkata 700064
[2]Aligarh Muslim University,Aligarh, Uttar Pradesh 202001

Introduction

In a heavy ion collision of identical nuclei, due to the fluctuations in the positions of the nucleons around the mean nuclear density profile, the number of participants fluctuates event-by-event in each colliding nucleus. This inequality in the participant number results in a non-zero net momentum in the nucleon-nucleon centre of mass frame. As a result, there is a shift of rapidity of the participant zone with respect to the nucleon-nucleon centre of mass rapidity. This is known as longitudinal asymmetry where the rapidity shift y_0 represents the magnitude of the longitudinal asymmetry. If A and B are the number of participants from two nuclei, the longitudinal asymmetry is defined as $\alpha_{part} = (A-B)/(A+B)$

The rapidity shift caused by the net momentum of the participant zone can be approximated as,

$$y_0 \approx \frac{1}{2} ln \frac{A}{B} = \frac{1}{2} ln \frac{1+\alpha_{part}}{1-\alpha_{part}}$$

For small α_{part}, $y_0 \approx \alpha_{part}$

The longitudinal asymmetry in spectator is defined as,

$$\alpha_{spec} = \frac{(N-A)-(N-B)}{(N-A)+(N-B)} = \frac{B-A}{2N-(A+B)}$$

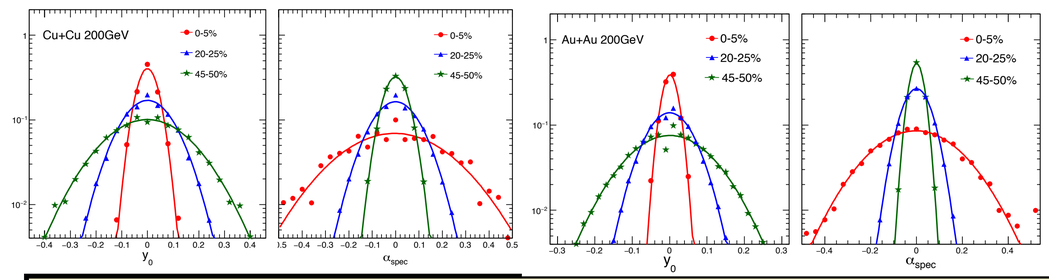
The spectator asymmetry is related to the rapidity shift as,

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

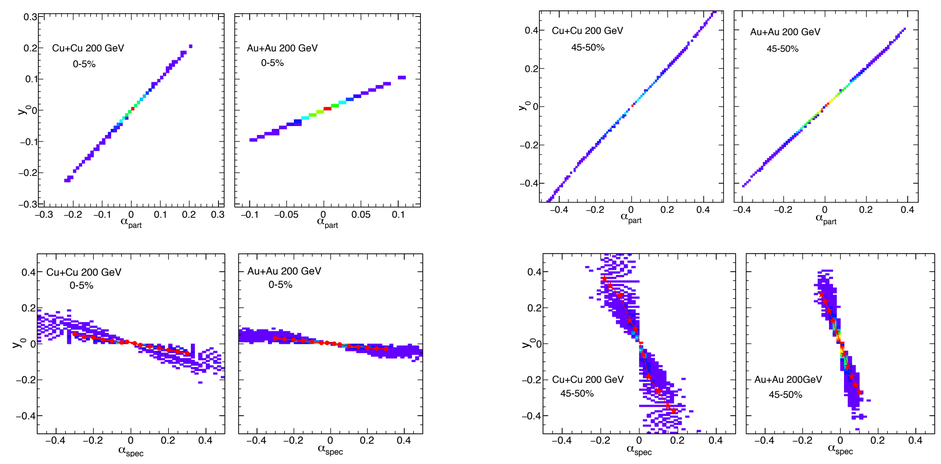
The longitudinal asymmetry affects the charged particle rapidity distribution. the effect of this rapidity shift on the charged particle multiplicity distribution is found to be quite significant even for collisions of identical nuclei. The effect of initial state fluctuations is expected to be more pronounced for peripheral collisions and also for smaller systems. Thus, the longitudinal asymmetry and rapidity shifts are also expected to be larger in smaller systems and in lower collision energies.

we have used AMPT with string melting to investigate the system size and beam energy dependence of the effect of the longitudinal asymmetry on the charged particle rapidity distributions in Cu+Cu and Au+Au systems at 200 GeV and 62.4 GeV

Longitudinal asymmetry and rapidity shift

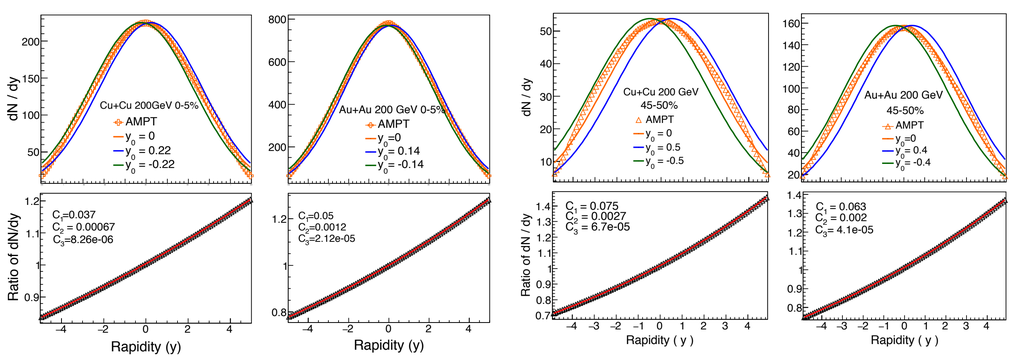


The width of the y_0 distribution increases from central to peripheral collision. The relative fluctuation increase for larger impact parameters as the number of participants is relatively smaller for those collisions. Whereas, the width decreases for α_{spec}. It shows that the relative fluctuation decreases for central collisions as the number of spectators decreases. Also, the widths of the distributions are found to be more for Cu+Cu collisons than for Au+Au collisions for a particular centrality bin. It indicates that the relative fluctuation increases with the decrease in system size as expected

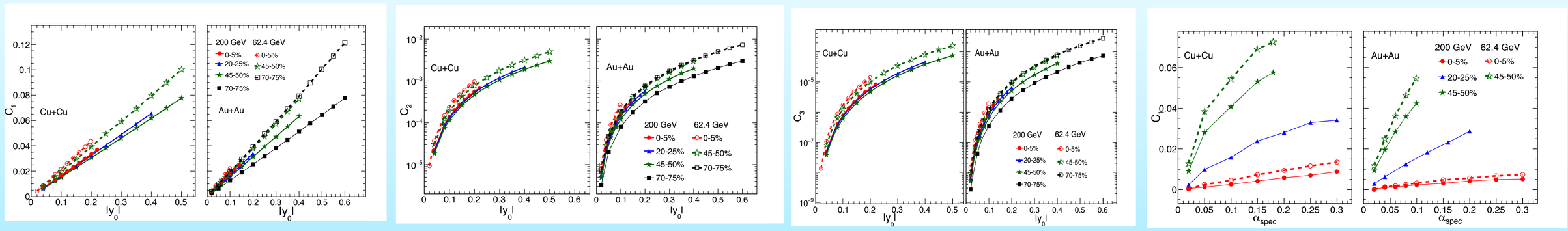


Y_0 and α_{part} are almost linearly correlated. However, no such strong linear correlation in the distribution of α_{spec} and y_0 due to the presence of the (A+B) term. The spread in y_0 increases for more peripheral collisions and also it is more for Cu+Cu collisions compared to Au+Au collisions.

Effect of rapidity shift on the multiplicity distribution



One can see a marginal change in the rapidity distribution due to y_0 shift for the most central collisions. In addition the effect of rapidity shift is slightly more for Cu+Cu collisions than for the Au+Au collisions. However, for peripheral collisions the distribution is significantly affected by the rapidity shift. The ratio of the unshifted to shifted distributions are plotted in the bottom panels of the same figures. The dominant term in the expansion is the linear term which signifies the magnitude of asymmetry. The coefficients are extracted by fitting the ratio to a third-order polynomial. The same calculation is repeated for different values of y_0 to get the variation of the coefficients with y_0.



The parameter C_1 shows a linear dependence on y_0 for each centrality. The different slopes indicates the sensitivity of the longitudinal asymmetry to the shape of rapidity distribution. C_1 is related to the rapidity shift by $C_1 = \frac{y_0}{\sigma^2}$

i.e. with increasing centrality, the width of the distribution decreases, so the slope of C_1 increases.

The coefficients are larger for Cu+Cu system. C_2 and C_3 in the polynomial fitting of the ratio are much smaller than C_1. Hence, the linear term primarily determines the effect of asymmetry. The figures indicate that the initial longitudinal asymmetry survives in the final state particle productions.

The centrality dependence of the coefficients with rapidity shift is not as much distinguishable as that with the α_{spec}, as there is no unique correspondence between α_{spec} and y_0.

An energy dependence has been clearly observed. The values of the coefficients are higher for 62.4 GeV which indicates an increase in fluctuation with decrease in the collision energy and the difference increases for peripheral collisions.

ISMD2021 50th International Symposium on Multiparticle Dynamics (ISMD2021)