Method for the study of forward-backward multiplicity correlations in heavy-ion collisions

S. De[1],* B. K. Srivastava[2], and T. K. Nayak[1]
[1] *Variable Energy Cyclotron Center, Kolkata, India and*
[2] *Department of Physics, Purdue University, USA*

Introduction

The major goals of colliding heavy-ions at relativistic energies are to create a new form of matter, called quark-gluon plasma (QGP), and to study its properties in detail. The QGP matter is formed very early in the reaction and it is a major challenge to experimentally probe this stage as majority of the detected particles are emitted at freeze-out. Correlations, that are produced across a wide range in rapidity are thought to reflect the earliest stages of the heavy-ions collisions, free from final state effects [1]. The study of correlations among particles produced in different rapidity regions may provide an understanding of the elementary (partonic) interactions which lead to the hadronization.

Forward-backward (FB) multiplicity correlation strength has been studied in the framework of wounded nucleon model [2]. The results are compared to the STAR data [3] in Au-Au collisions at $\sqrt{s_{NN}} = 200$ GeV. It has been concluded that FB correlation strength for central collisions are due to the fluctuations of wounded nucleons at a given centrality bin. Thus it is essential to control the centrality of the collisions while performing the FB correlations analysis in the heavy-ion collisions.

The correlation strength can be expressed as:

$$b_{\rm corr.} = \frac{\langle N_f N_b \rangle - \langle N_f \rangle \langle N_b \rangle}{< N_f^2 > - < N_f >^2} = \frac{D^2_{\rm bf}}{D^2_{\rm ff}}, \quad (1)$$

where N_f and N_b are the multiplicity measured in forward and backward hemisphere. $D^2_{\rm ff}$ and $D^2_{\rm bf}$ are the forward-forward and backward-forward dispersions.

In this work two different methods have been studied to extract the correlation strength (b_{corr}) and the results from these two method will be discussed.

Analysis Method

In a center-of-mass coordinate system, the forward and backward hemispheres have been conventionally defined to be opposite to each other. In this analysis the width of the pseudorapidity window i.e. the value of $\delta\eta = 0.2$ has been taken. The windows have been chosen symmetrically around $\eta = 0$ and the distance between the two windows are denoted as η gap ($\Delta\eta$) .

Results have been presented for the Au-Au 200 GeV and Pb-Pb 2.76 TeV using the simulated data from the HIJING event generator.

To calculate the correlation strength as a function of η *gap* ($\Delta\eta$) for different centrality bins two different method have been discussed. In the first method, the quantities such as, $\langle N_f \rangle$, $\langle N_b \rangle$, $\langle N_f^2 \rangle$ and $\langle N_f N_b \rangle$, can be obtained by averaging over the events within a centrality bin, and thereby calculating the dispersions, $D^2_{\rm ff}$ and $D^2_{\rm bf}$. This method of event averaging does not take the fluctuation within a centrality window into account. This method is called as $FB_{average}$ method. In order to eliminate or reduce the effect of the impact parameter (centrality) fluctuations on the measurement the second method has been introduced. In this method the above quantities have been plotted as a function of each of the reference multiplicity, $N_{\rm ref}$. Linear fits to $\langle N_f \rangle$, $\langle N_b \rangle$ and second order polynomial fits to $\langle N_f^2 \rangle$ and $\langle N_f N_b \rangle$, were used to extract the $D^2_{\rm ff}$ and $D^2_{\rm bf}$, binned by centrality, and normalized by the total number of events in each bin. This

*Electronic address: `sudipan86@gmail.com`

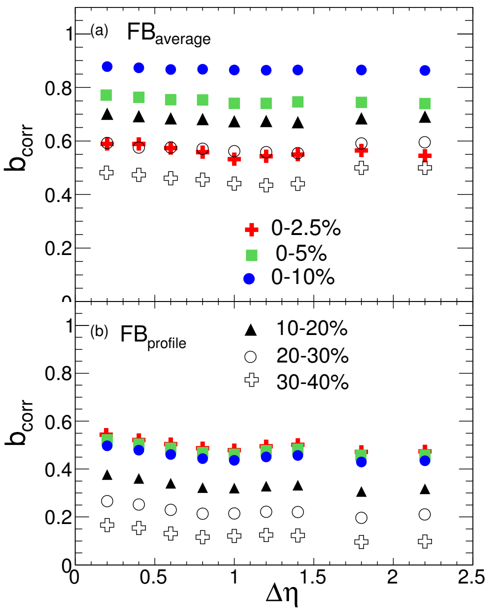

FIG. 1: Correlation strength $b_{\rm corr}$ as a function of $\Delta\eta$ for 5 centrality bins using (a) from $FB_{\rm profile}$ and (b) from $FB_{\rm average}$ for Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV.

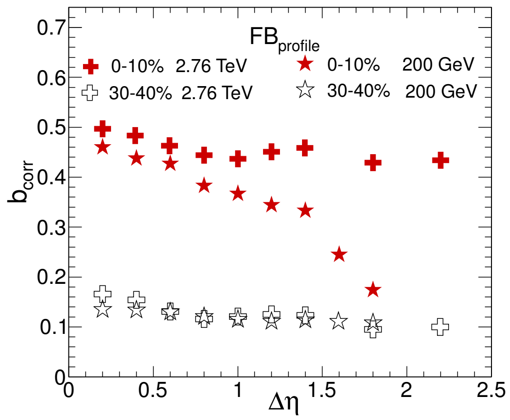

FIG. 2: Correlation length as a function of $\Delta\eta$ for 0-10% and 30-40% centralities in case of Au-Au collisions at $\sqrt{s_{NN}}$ = 200 GeV (star symbol) and Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV (cross symbol).

is called as $FB_{profile}$ method. This method removes the dependence of the FB correlation strength on the width of the centrality bin.

Results and Discussions

Results from both the methods at $\sqrt{s_{NN}}$ = 2.76 TeV are presented in Fig. 1, where the upper panel shows the values of b_{corr} using $FB_{average}$ method and the lower panel gives the results for $FB_{profile}$ method. It is observed that b_{corr} for $FB_{average}$ method does not follow any regular pattern in terms of centrality selection. For example, the b_{corr} is seen to be higher for the 0-10% centrality bin compared to 0-2.5% and 0-5% centrality bin, which is counter intuitive to our expectation. This shows that the impact parameter fluctuations are not completely removed when $FB_{average}$ method is used. On the other hand, it can be seen that using the $FB_{profile}$ method, the values of b_{corr}, has an increasing trend with the increase of centrality of the collisions. The correlation strength is highest for 0-2.5% centrality, as expected.

A comparison of the correlation strengths have been made for Au-Au collisions at $\sqrt{s_{NN}}$ = 200 GeV and Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV using the results from HIJING event generator, and following the $FB_{profile}$ method. The results are presented for two centrality windows (0-10% and 30-40%) in Fig. 2. It is observed that, for the non-central collisions of 30-40% cross section, the correlation strengths are very similar. For central collisions, a decreasing trend is observed for Au-Au collision at $\sqrt{s_{NN}}$ = 200 GeV, whereas for Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV, a flatter distribution is observed. This implies a much stronger correlation over a broad range in pseudorapidity at the LHC energy compared to those at RHIC.

References

[1] Y.V. Kovchegov, E. Levin, and L. McLerran, Phys. Rev. C 63, 024903 (2001).
[2] A. Bzdak, Phys. Rev. C80 024906 (2009).
[3] B.I. Abelev (STAR Collaboration). Phys. Rev. Lett. **103** (2009) 172301.