Search for long-range correlations in Pb-Pb collisions at LHC energies

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Introduction

The forward-backward (FB) correlations are usually studied in terms of multiplicities of charged particles emitted in forward (F) and backward (B) pseudorapidity (η) windows. The strength of (FB) multiplicity correlations is characterized by the correlation coefficient, b_{corr}, which is estimated from the linear dependence of the event averaged mean multiplicity in (B) region $< N_B >$ on the event multiplicity in (F) region N_F, written as[1]:

$$< N_B > = a + b_{corr} N_F$$

Values of b_{corr} may also be calculated using the Pearson correlation coefficient:

$$b_{corr} = \frac{<N_B N_F> - <N_B><N_F>}{<N_F^2> - <N_F>^2}$$

FB correlations have two components: The short-range correlation (SRC) and the long-range correlation (LRC). Strong SRC have been observed in hadron–hadron (hh) and nucleus–nucleus (AA) collisions in a wide range of beam energies, whereas LRC have been observed at sufficiently high energies. Occurrence of (LRC) have been understood in terms of multi-parton interactions[2]. The Color glass Condensate too suggests that the correlations produced during the initial stages of collisions should spread to rather longer ranges of rapidity[2]. Furthermore, LRC are regarded as a signature of string fusion and percolation phenomena, which is one of the collectivity effects in AA collisions[3]. FB multiplicity correlations are thought to be sensitive to the collision energy and also to the phase space window width and positions. However, a relationship between the correlation strength and and the collision centrality is still obscure, which seems to be sensitive to the width as well as the center of the centrality window. An attempt is, therefore, made to examine the dependence of FB correlations on the collision centrality and centrality bin size in AA collisions at LHC energies. Contribution from LRC are also looked into by minimising the SRC contributions from the observed correlations. Monte Carlo (MC) event samples corresponding to Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 and 5.02 TeV are simulated in the framework of HYDJET++ model. The number of events in the data samples corresponding to the two energies are 2.9 and 2.7 million respectively.

Results and Discussion

The HYDJET++ model combines the description of soft process with the treatment of hard partons propagating medium[4]. Various features of heavy-ion collisions at RHIC and LHC energies, like, azimuthal anisotropy, flow, femtoscopy, etc., are nicely described by the model[4].

Centrality dependence of b_{corr} for different centrality classes, i.e., 2%, 5% and 10% for Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV are compared with ALICE published values[1] in Fig.1(left panel). The kinematical cuts applied to the MC event samples are the same as those mentioned in ref[1], i.e. η and p_t ranges as $-0.8 < \eta < 8.0$ and $0.2 < p_t < 2.0$ GeV/c respectively. The centralities of the events are estimated by following the criteria of ALICE-V0M detector, described elsewhere[3]. It is observed that for 0-10% collisions, the model overestimates the correlation strength but qualitatively reproduces the trend exhibited by the ALICE data. For smaller centrality bins, however, the model fails to predict the

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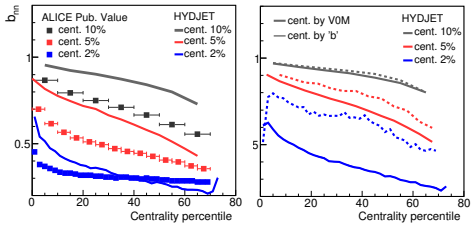

FIG. 1: Centrality dependence of b_{corr} correlations for Pb–Pb collisions at $\sqrt{s_{NN}}$ = 2.76 and 5.02 TeV.

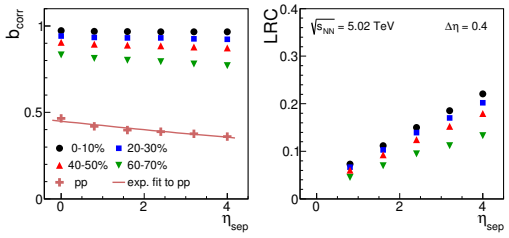

FIG. 2: b_{corr} vs η_{sep} (left) and growth of LRC for different centrality classes (right) for Pb–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV.

trends observed with the real data. Variations of b_{corr} with centrality percentile for 5.02 TeV Pb–Pb collisions are plotted in the right panel of Fig.1. Since FB multiplicity correlation strength is quite sensitive to the centrality determination method, the centrality percentile is also determined by using the ranges of impact parameter b, as has been used in input file of HYDJET ++ event simulation code. Results of this centrality selection criteria are also shown in the figure. It is interesting to note that the b_{corr} values for 10% centrality class estimated by using V0M and impact parameter methods are nearly the same. For 2% and 5% centrality classes, b_{corr} computed using the impact parameter values are higher as compared to the ones obtained through V0M criteria. These observations, thus, suggest that not only the centrality bin width but also the method of centrality selection plays important role in the study of (FB) multiplicity correlations.

LRC are usually measured for a large gap between the F and B η windows ($\eta > 2.0$) units. For such separations strength of SRC is expected to be reduced significantly and the observed correlations are due to LRC. Shown in Fig.2 are the variations of b_{corr} with η separation (for $\Delta\eta = 0.4$) for different collision centralities in 5.02 TeV Pb-Pb collisions. Variations of b_{corr} with η_{sep} for pp collisions at $\sqrt{s}$ = 5.02 TeV are also plotted in Fig.2. Plots for pp collisions are obtained by simulating 10 million events using the MC generator PYTHIA-8 (default tune). It is interesting to note that the plots corresponding to 0-10% and 20-30% centralities are nearly flat. Such a flat FB correlation strength extending to large η separations may be attributed to be raised by LRC due to multi-parton interactions as predicted by the models of multiple scattering, like dual parton model. For mid-central and peripheral collisions, b_{corr} are observed to decrease with increasing gap between the F and B windows. It may also be observed that for 60-70% central collisions the trend of decrease is similar to those exhibited by pp events except the differences in magnitudes. This suggests that if contributions from pp collisions are subtracted from those due to Pb-Pb collisions, the remaining correlation strength would be more or less free from SRC and one can observe how LRC grows with η_{sep} for various centrality classes. This is shown in the right panel of Fig.2. The contributions from pp collisions are subtracted by following the procedure described in ref[5]. The growth of LRC with η_{sep} are distinctly visible in the figure. the magnitude of correlations are also noticed to increase on moving from central to peripheral collisions.

References

[1] Igor Altsybeev (for the ALICE Collaboration),arXiv:1711.04844v1.
[2] Vladimir Kovalenko, Vladimir Vechernin, arXiv:1611.07274v1.
[3] R. He et al, Phys. Rev. C**93** (2016) 044918.
[4] P. Bozek and W. Broniowski, Phys. Rev. C**96** (2017) 014904.
[5] B.K. Srivastava et al, Int. J. Mod. Phys. E **16** (2007) 2215.