Forward-backward correlations between mean transverse momenta in Pb-Pb collisions at LHC energies

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Introduction

Forward-backward (FB) correlations have been commonly studied in terms of multiplicities of particles produced in F and B regions of the pseudorapidity (η) distributions. However, since multiplicity is an extensive variable, therefore, the correlations would be affected by the system's volume. To overcome this, intensive observables like transverse momenta of particles, can be considered[1, 2]. The FB correlations are usually studied in terms of correlation coefficient, b_{ptpt} which can be estimated from the linear relation $\langle \mathrm{B} \rangle$ = a + b F, where F denotes the quantity measured in the forward η window while $\langle \mathrm{B} \rangle$ the mean value of the quantity measured in the backward η window. The present study is an attempt to study the FB correlations in terms of transverse momenta of particles produce in Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ and 5.02 TeV by analysing the Monte Carlo events simulated in the framework of HYDJET++ Model. The findings are compared with the experimental results reported by ALICE collaboration and also with those predicted by other MC Models.

Results and Discussion

The HYDJET++ Model is a two component model[3], where the final state of a collision is the superposition of two independent components; the soft hydrodynamic and hard jets. It has been observed the various features of the experimental data at RHIC and LHC energies are nicely reproduced by this model. For this reason, the model is considered for the present study.

The FB correlations are examined in terms of transverse momenta (p_t) of charged particles by estimating mean values of p_t in the F and B windows, $\langle \overline{p_{tF}} \rangle$ and $\langle \overline{p_{tB}} \rangle$, where $\overline{p_{tF}}$ and $\overline{p_{tB}}$ are the event mean p_t values, while the angular brackets $\langle ... \rangle$ denote the average value over the entire sample. The correlation strength is estimated by using the relation $\langle \overline{p_{tB}} \rangle$ = a $+ b_{ptpt} \langle \overline{p_{tF}} \rangle$. If this linear relationship holds then the correlation strength can also be obtained using the formula of Pearson correlation coefficient,

$$b_{ptpt} = \frac{\langle \overline{p_{tF}} . \overline{p_{tB}} \rangle - \langle \overline{p_{tF}} \rangle \langle \overline{p_{tB}} \rangle}{\langle \overline{p_{tF}}^2 \rangle - \langle \overline{p_{tF}} \rangle^2}$$

In order to examine the dependence of b_{ptpt} on the collision centrality, the centralities of the events are determined by using the criteria of ALICE V0M detector, i.e. by counting the charged particles produced in an event within the pseudorapidity ranges, -3.7< η <-1.7 and 2.8< η <5.1. The multiplicity distribution of a given sample is then drawn and quantiled. The multiplicity limits for the desired centrality percentiles, i.e. $2\%, 5\%, 10\%$ etc. are, thus, obtained. Furthermore, in order to compare the findings with the ALICE reported results, the same kinematical cuts are applied which has been considered by ALICE collaboration, i.e. p_t and η intervals as 0.2< p_t <2.0 GeV/c and, $-0.8 < \eta < 0.8$. Values of b_{ptpt} for various centrality bins are calculated by considering the η window width and separations as $\Delta\eta$ = 0.4 and η_{sep} = 0.8 with such a separation between the η windows, would allow the short-range effect from resonance decays and (mini-) jets are expected to be reduced. The number of events analysed are 2.9 and 2.7 million at $\sqrt{s_{NN}} = 2.76$ and 5.02 TeV respectively.

Variations of b_{ptpt} with centrality percentile

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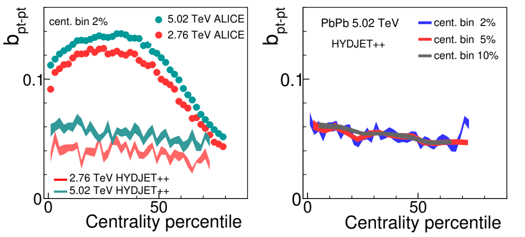

FIG. 1: Centrality dependence of b_{ptpt} correlations for Pb–Pb collisions at $\sqrt{s_{NN}}$ = 2.76 and 5.02 TeV.

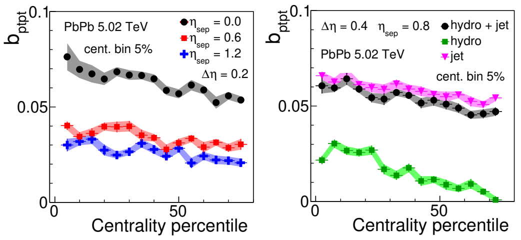

FIG. 2: Centrality dependence of b_{ptpt} in 5% centrality bins (a)for different η seprations and (b) for hard jet and soft hydro components.

for 2% centrality bins at the two energies are plotted in Fig.1 (left panel). The markers represent the values from the real data, reported by ALICE collaboration[1]. It may be noted that HYDJET++ predicted values are positive and show a regular growth from peripheral to central collisions, while the values reported by ALICE collaboration are observed to increase upto mid-central collisions and thereafter show a decreasing trend. Furthermore, the model predicted values are significantly smaller than the ones reported for ALICE data. The observed trend of centrality dependence of b_{ptpt} are observed to be nearly similar to that predicted by AMPT model with string-melting and re-scattering switched 'on'[1]. The observed non-zero values of the correlation strength can be related to the ebe fluctuations of the event-wise mean transverse momenta of the particles. Such fluctuations might be attributed to the ebe fluctuations of the initial size of the fireballs[1, 4].

Centrality dependence of b_{ptpt} for centrality bin widths 10%, 5% and 2% are shown in Fig.1 (right panel). It is interesting to note that b_{ptpt} values are independent of the centrality bin width. Since $\langle p_t \rangle$ is an intensive quantity, b_{ptpt} values are expected to be independent of the centrality bin widths, provided the bin widths are not too large.

It is speculated that the short-range correlations would be confined mostly within a region, $\Delta\eta \sim 1$ units around mid-rapidity, therefore, in order to examine the contributions from the short-range correlations, the strength of $p_t p_t$ correlations are estimated for different values of η_{sep} i.e., $\eta_{sep} = 0.0$, 0.6 and 1.2 but keeping $\Delta\eta$ fixed as 0.2 unit. The results are displayed in the left panel of Fig.2. It may be noted that the data points corresponding to $\eta_{sep} = 0.6$ and 1.2 lie close to each other, while for $\eta_{sep} = 0$, correlation strength is observed to be quite large for all centrality classes. This indicates the dominance of short-range correlations around the central η region, which might arise due to hadronic resonances of the soft component of the model[3]. Similar observations have been made by ALICE collaboration[1] for 2.76 TeV Pb–Pb collisions.

In order to examine the contributions from hard jets and soft hadronic component, b_{ptpt} values for the two components (hyro and jets) are computed separately for 5% centrality bins for Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV and plotted in the right panel of Fig.2. It is observed that the major contribution to the correlation comes from the jets, while from the soft hydrodynamic part a small contribution is noticed to be present in central collisions only.

References

[1] Igor Altsybeev (for the ALICE Collaboration),arXiv:1711.04844v1.

[2] Vladimir Kovalenko, Vladimir Vechernin, arXiv:1611.07274v1.

[3] E. E. Zabrodin et al, J. of Exp. and Theor. Phys. **130**(2020)660.

[4] P. Bozek and W. Broniowski, Phys. Rev. C**96** (2017) 014904.