Study of Forward Backward Correlations in Small Collision Systems at the LHC Energies Using a Strongly Intensive Observable

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Introduction

Forward-backward (FB) correlation are considered to be powerful tool to study correlations and fluctuations between produced particles in high energy nuclear collisions carrying important information regarding the basics of particle production mechanism. Most challenging part of FB correlation study is to avoid volume fluctuations, i.e., event-by-event fluctuations of the number of the participating nucleons [1]. Though considering intensive observable like the sum of the absolute transverse momentum of particles within the observation windows reduces such contribution of volume fluctuations [2], our multiplicity-dependent summed-p_T correlation study [3] manifested that FB momentum correlation coefficient depends on the total number of charged particle produced in a pseudorapidity (η) bin. In our present work, hence, we have explored more sophisticated correlation observable Σ [4] to suppress the contribution of volume fluctuations. It has been confirmed [5] that the strongly intensive observable Σ does not depend on system volume nor system volume fluctuations and carries more clear information on the early dynamics of the high energy hadronic interactions compared to FB multiplicity and momentum correlations. The so-called strongly intensive quantity $\Sigma[N_f, N_b]$ based on the charged-particle multiplicities in forward (N_f) and backward (N_b) η windows is defined by the following formula:

$$\Sigma[N_f, N_b] = \frac{W_b\langle N_f\rangle + W_f\langle N_b\rangle - 2(\langle N_f N_b\rangle - \langle N_f\rangle\langle N_b\rangle)}{\langle N_f\rangle + \langle N_b\rangle}$$

Here, Forward (backward) scaled variance $W_{f(b)}$ is defined as:

$$W_{f(b)} = \frac{\langle {N_{f(b)}}^2\rangle - \langle N_{f(b)}\rangle^2}{\langle N_{f(b)}\rangle}$$

We have studied the behaviour of $\Sigma[N_f, N_b]$ as a function multiplicity bin width and distance between F and B window centers (η_{sep}) using EPOS3 [6] simulated pp events at $\sqrt{s} = 13$ TeV and pPb events at $\sqrt{s_{\rm NN}} = 5.02$ TeV with hydrodynamical evolution of particles.

Results and Discussions

Fig. 1 represents $\Sigma[N_f, N_b]$ variable as a function of multiplicity bin width i.e. Δ multiplicity for EPOS3 simulated pp events at $\sqrt{s} = 13$ TeV and pPb events at $\sqrt{s_{\rm NN}} = 5.02$ TeV. Identifying sharp multiplicity cuts we have converted pp and pPb events multiplicity distributions into percentile classes following ALICE centrality class determination method. We focused mainly on most central collisions i.e. high multiplicity events (0-10%). We increased multiplicity bin width from 2% to 10% around 5% for both pp and pPb event multiplicity classes. It is clear from the figure that with the increase of multiplicity bin width, $\Sigma[N_f, N_b]$ values remain almost unaffected for both pp and pPb events though the values of Σ are higher in case of pp events.
Fig. 2 exhibits the variation of $\Sigma[N_f, N_b]$ with η_{sep} for EPOS3 simulated pp events at $\sqrt{s} = 13$ TeV and pPb events at $\sqrt{s_{\rm NN}} = 5.02$ TeV. It is clearly visible that $\Sigma[N_f, N_b]$ values increase with the increase of η_{sep} for both pp

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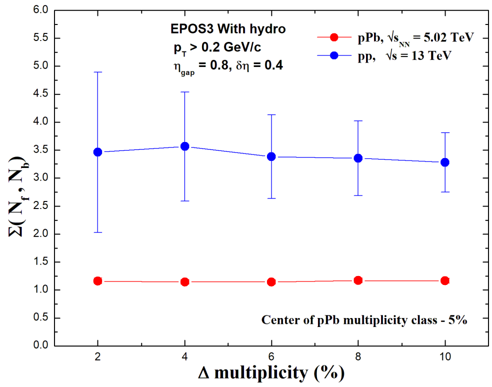

FIG. 1: $\Sigma[N_f, N_b]$ as a function of multiplicity bin width in EPOS3 simulated pp events at $\sqrt{s} = 13$ TeV and pPb events at $\sqrt{s_{\rm NN}} = 5.02$ TeV.

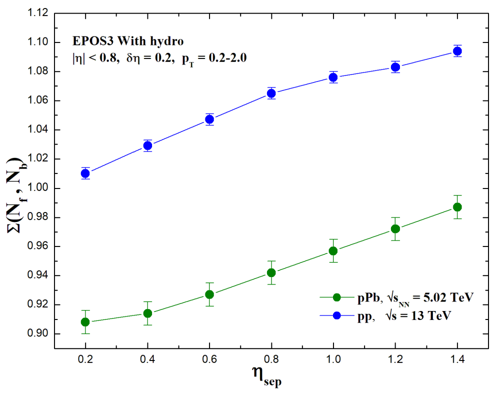

FIG. 2: $\Sigma[N_f, N_b]$ as a function of η_{sep} in EPOS3 simulated pp events at $\sqrt{s} = 13$ TeV and pPb events at $\sqrt{s_{\rm NN}} = 5.02$ TeV.

and pPb events and also $\Sigma[N_f, N_b]$ values are higher for pp events than pPb events. This behaviour of $\Sigma[N_f, N_b]$ observable as a function of η_{sep} is well explained in the framework of quark gluon string model with independent identical strings [7].

Conclusions

We have presented the behavior of a strongly intensive FB correlation observable, Σ based on the charged particle multiplicities using EPOS3 simulated pp events at $\sqrt{s} = 13$ TeV and pPb events at $\sqrt{s_{\rm NN}} = 5.02$ TeV. Our study reveals that with the increase of multiplicity bin width the values of $\Sigma[N_f, N_b]$ variable remains almost unchanged and with the increase of η_{sep}, $\Sigma[N_f, N_b]$ values increase for both pp and pPb events. The property of independence of Σ variable with multiplicity bin width indeed confirms that Σ is insensitive to volume fluctuations of the system and also emphasizes on the robustness of Σ observable as a strongly intensive quantity. In addition we have noticed that the values of $\Sigma[N_f, N_b]$ are higher for pp events than pPb events. It has also been observed that at larger distance between F & B window centres, $\eta_{sep} \sim 1$, $\Sigma[N_f, N_b]$ increases slowly for pp events which may indicate smaller contribution of long range components compared to short range components in the FB multiplicity correlations.

Acknowledgments

We gratefully acknowledge the technical support from grid peer team of VECC, Kolkata and the financial help from the DST-GOI under the scheme 'Mega facilities for Basic Research'.

References

[1] A. Bzdak, Phys. Rev. C **80**, 024906 (2009).
[2] M. A. Braun, et al., Phys. Rev. Lett. **85**, 4864 (2000).
[3] M. Mondal, et al., Phys. Rev. D **102**, 014033 (2020).
[4] M. I. Gorenstei, Phys. Rev. C **84**, 014904 (2011).
[5] I. Sputowska, (ALICE collaboration) MDPI Proceedings 2019, 10, 14.
[6] K. Werner, et al., Phys. Rev. C **89**, 064903 (2013).
[7] V. Vechernin, (2018) Eur. Phys. J: Web of Conf. 191 04011.