

Forward-backward multiplicity correlations in separated azimuth and pseudorapidity in pp collisions at LHC energies

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Introduction

Colliding heavy-ions at ultra-relativistic speeds is the only possible way to produce and study the properties of Quark-Gluon Plasma (QGP) in a laboratory setting. The space-time evolution of the created matter in the final state typically fluctuates from event to event due to the event-by-event density fluctuations in the initial state of the collision [1]. These final state fluctuations are believed to be a potential source of correlations observed in pp, pA, and AA collisions. Examining these correlations at ultra-relativistic beam energies across different collision configurations can shed light on the underlying dynamics of multi-particle production. The correlations observed among final state particles may arise from two primary sources: Short Range Correlations (SRCs) and Long Range Correlations (LRCs). SRCs are supposed to arise from various short-range final state effects such as decays of clusters, Bose-Einstein's correlations, mini-jets, etc. The correlation strength dominated by SRCs vanishes rapidly as pseudorapidity gap (η_{gap}) between forward and backward window increases. LRCs, on the other hand, originate from initial state phenomena, for example, fluctuations in pomerons, strings, mini-jets etc. [5, 6]. To better understand the origins of SRCs and LRCs, as well as to distinguish between the two, one can examine observable like the forward-backward (FB) multiplicity correlation [5]. The FB correlation strength, $b_{\text{corr}}(\text{mult.})$ can be defined in terms of the Pearson correlation coefficient, which

is extracted from a linear relation between mean multiplicity measured in the backward η -window, $\langle N_b \rangle_{N_f}$, as a function of the event multiplicity in the forward η -window, N_f .

$$b_{\text{corr}}(\text{mult.}) = \frac{\langle N_f N_b \rangle - \langle N_f \rangle \langle N_b \rangle}{\langle N_f^2 \rangle - \langle N_f \rangle^2} \quad (1)$$

The ALICE collaboration [3] measured $b_{\text{corr}}(\text{mult.})$ for pp collisions at $\sqrt{s} = 0.9, 2.76$ and 7 TeV and compared the experimental data with theoretical models like PHOJET [7] and PYTHIA6 (Perugia Tune 0 and 2011) [8]. Although these models could explain the data qualitatively, there was a disagreement between the experimental results and the model calculations. Another study performed using QGSM model [4] reported 20% underestimation of $b_{\text{corr}}(\text{mult.})$ at lower $\eta_{\text{sep}} (< 0.8)$. This discrepancy can be attributed to the lower production cross-section of resonance particles in the QGSM model. As these models fail to explain experimental data, henceforth, in the present investigation, we have attempted to study these correlations separated in azimuth and pseudorapidity at LHC energies using the PYTHIA8 [2] model by altering the multi-parton interaction (MPI)-based color reconnection (CR) ranges. CR is a non-perturbative effect that occurs during the final stages of hadronization and parton showering, where the rearrangement of color strings takes place, leading to changes in the final-state particle distributions. For the present work, MPI-based CR is utilized with three distinct values of CR ranges i.e., 1.8, 3.6, and 5.4. Three million inelastic (INEL) non-diffractive pp interactions at $\sqrt{s} = 0.9$, and 7 TeV have been simulated using PYTHIA8 version 8.311.

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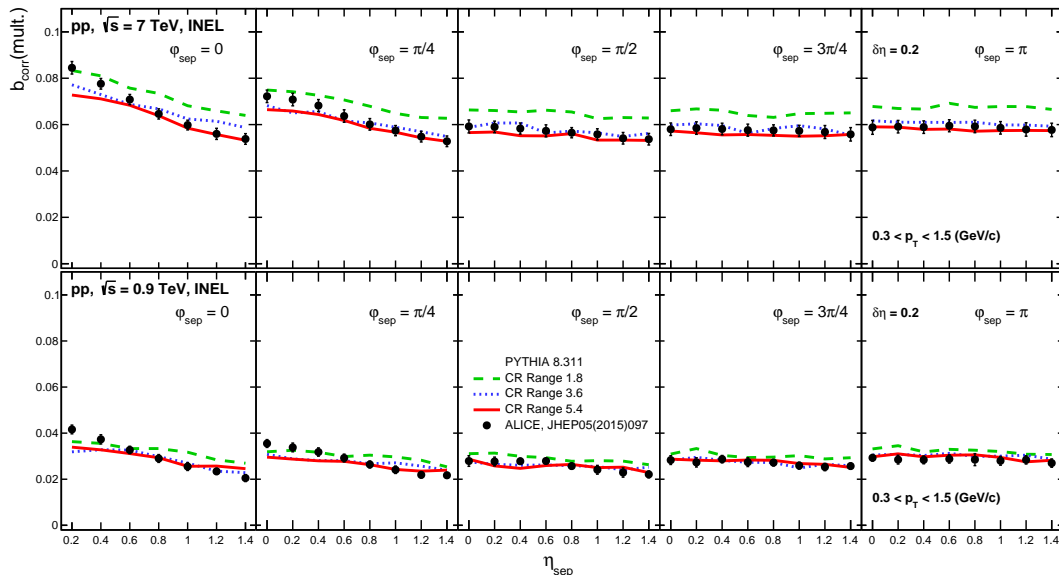


FIG. 1: Correlation strength, $b_{\text{corr}}(\text{mult.})$ in separated η - φ planes plotted as a function of η_{sep} for PYTHIA8 (version 8.311) simulated pp interactions at $\sqrt{s} = 0.9$ and 7 TeV along with ALICE results [3].

Results and discussion

$b_{\text{corr}}(\text{mult.})$ as described by Eqn.(1) is plotted in Fig.1 as a function of η_{sep} for PYTHIA8 simulated pp interactions at $\sqrt{s} = 0.9$ and 7 TeV and compared with available ALICE results [3]. This study has been carried out for five different φ_{sep} separations ($0, \pi/4, \pi/2, 3\pi/4$ and π). For both the studied energies a decrease of the $b_{\text{corr}}(\text{mult.})$ as a function of η_{sep} is observed for $\varphi_{\text{sep}} = 0$ and $\pi/4$. However, the decrease is more pronounced for $\sqrt{s} = 7$ TeV. This observation can be attributed to the dominance of SRCs among particles concentrated in the narrow phase space separated by $\varphi_{\text{sep}} \leq \pi/4$. At $\varphi_{\text{sep}} = \pi/2$ and beyond, $b_{\text{corr}}(\text{mult.})$ tends to saturate for both $\sqrt{s} = 7$ and 0.9 TeV, attaining a value of around 0.06 and 0.03 respectively. This study concludes that azimuthal sectors with $\varphi_{\text{sep}} > \pi/4$ are solely influenced by contributions from LRCs. The CR range 1.8 fails to explain ALICE results quantitatively across all azimuthal sectors. Overall, the PYTHIA8

model with CR range 5.4 offers a reasonably good description of the data at $\sqrt{s} = 7$ TeV, while both CR ranges 3.6 and 5.4 are consistent with the ALICE data at $\sqrt{s} = 0.9$ TeV.

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