# Effect of color reconnection on event-by-event mean transverse momentum fluctuations in pp collisions at LHC energies

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## Introduction

Analyzing fluctuations is a crucial approach for understanding and characterizing a physical system. Investigating event-by-event fluctuations offers valuable insights into the formation of hot and dense matter created in high-energy heavy-ion collisions [1]. Fluctuations fall into two main categories: dynamical and statistical. The dynamical fluctuations reflect the dynamics and response of the system which essentially helps to identify the onset of phase transition [1]. Volume fluctuations resulting from impact parameter fluctuation in heavy-ion collision may affect measurements of fluctuation of extensive quantities such as particle multiplicity and energy. These fluctuations have the potential to distort the dynamical fluctuations that convey crucial system information [1]. The mean transverse momentum, $\langle p_{\rm T}\rangle$, is expressed as the ratio of two extensive quantities: the total transverse momenta of charged particles and the total number of charged particles. Consequently, $\langle p_{\rm T}\rangle$ is an intensive quantity suitable for event-by-event analysis, as it remains independent of the volume of the system. Investigating the dynamical fluctuations of mean transverse momentum, $\langle p_{\rm T}\rangle$, on an event-by-event basis is crucial for identifying phase transition signals, potentially linked to the critical fluctuations in thermodynamic parameters such as temperature [2].

The high-multiplicity pp collision at LHC energy reveals some remarkable heavy-ion-like features such as ridge-like structure in the two-particle azimuthal correlation as well as strangeness enhancement [3, 4]. Investigating $\langle p_{\rm T}\rangle$ fluctuations in pp collisions, one can establish a baseline and then identify non-trivial fluctuations in A-A collisions, which would manifest as deviations from the fluctuation pattern observed in the pp reference [2].

## Two-particle correlator

Two-particle transverse momentum correlator $\langle \Delta p_{\rm T_i} \Delta p_{\rm T_j}\rangle$ provides an estimate of the dynamical fluctuations of mean transverse momentum is given by [5],

$$\langle \Delta p_{\rm T_i} \Delta p_{\rm T_j}\rangle = \left\langle \frac{\Sigma_{i,j\neq i}(p_{\rm T_i}-\langle\langle p_{\rm T}\rangle\rangle)(p_{\rm T_j}-\langle\langle p_{\rm T}\rangle\rangle)}{0.5N_{ch}(N_{ch}-1)} \right\rangle \quad (1)$$

where $p_{\rm T_i}$ and $p_{\rm T_j}$ are the transverse momenta of the $i^{th}$ and $j^{th}$ particle belonging to a particular event and $0.5N_{ch}(N_{ch}-1)$ denotes the number of particle pairs in that particular event. The angular bracket in Eqn.(1) denotes the average over all the events belonging to a particular multiplicity class. The relative dynamical fluctuation is estimated by a dimensionless quantity defined as,

$$\langle \Delta p_{Ti} \Delta p_{Tj}\rangle_{final} = \frac{\sqrt{\langle \Delta p_{Ti} \Delta p_{Tj}\rangle}}{\langle\langle p_T\rangle\rangle} \quad (2)$$

## Result and discussion

Ten million inelastic non-diffractive pp collisions at the center-of-mass energies 0.9, 2.76 and 7 TeV are generated using `PYTHIA8` (version 8.311) model. Multi-parton interactions (MPI)-based CR mechanism with different values of color reconnection range, specifically 1.8 (default), 3.6 and also no-CR scenario

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are considered in this study. The dynamical mean transverse momentum fluctuations, $\sqrt{\langle \Delta p_{\mathrm{T_i}} \Delta p_{\mathrm{T_j}} \rangle} / \langle \langle p_{\mathrm{T}} \rangle \rangle$, estimated with different settings of PYTHIA8 model are compared with the results from the ALICE experiment [2].

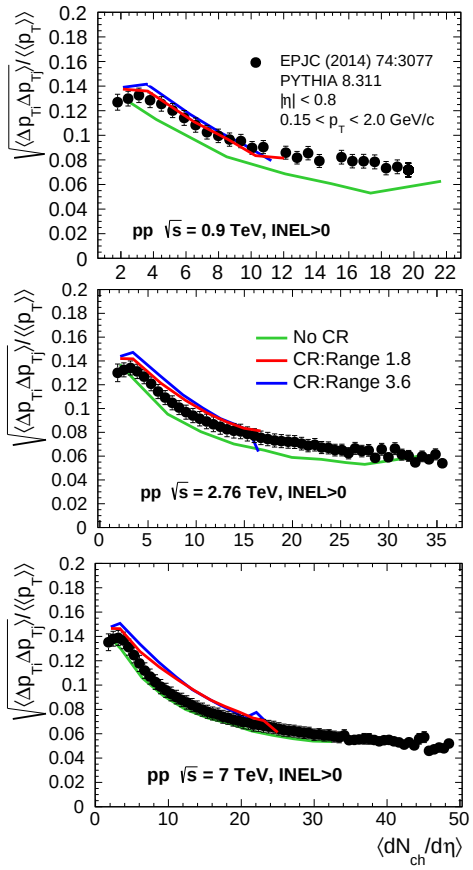


FIG. 1: Event-by-event fluctuations of mean transverse momentum as a function of average charged particle multiplicity at mid-rapidity for color reconnection ranges 1.8 (default), 3.6 and no-CR scenario at $\sqrt{s} = 0.9$, 2.76 and 7 TeV.

In this study, multiplicity classes were estimated by considering the acceptance of the forward V0 detector of ALICE experiment. V0M multiplicity is estimated based on the total number of charged particles accepted in the forward (V0A) with pseudorapidity range ($2.8 < \eta < 5.1$) and backward (V0C) having pseudorapidity coverage ($-3.7 < \eta < -1.7$). The entire analysis is being conducted where we limit the acceptance to $|\eta| < 0.8$ in line with the mid-rapidity detector of the ALICE experiment. We also limit the examination to the field of soft physics ($p_{\mathrm{T}} < 2.0$ GeV/c).

Figure 1 shows the variation of event-by-event fluctuation of mean transverse momentum evaluated by the two-particle correlator $\langle \Delta p_{\mathrm{T_i}} \Delta p_{\mathrm{T_j}} \rangle_{final}$ as a function of average charged particle multiplicity $\langle \frac{\mathrm{d}N_{ch}}{\mathrm{d}\eta} \rangle$ for two distinct color reconnection ranges 1.8 (default), 3.6 and the no-CR scenario at $\sqrt{s} =$ 0.9, 2.76 and 7 TeV. It is seen from this figure that, the strength of the two-particle correlator falls as the average charged particle multiplicity increases. In PYTHIA8 model, high multiplicity pp collision events are primarily driven by the multi-parton interaction (MPI) mechanism [2]. The independent superposition of these multi-parton interactions is thought to be the key factor contributing to the reduction in fluctuations with charged particle multiplicity. It is also evident from the figure that the PYTHIA8 model with the CR mechanism slightly overestimates the experimental data at lower multiplicity. In contrast, the no-CR scenario in PYTHIA8 fails to account for the experimental data on mean-$p_{\mathrm{T}}$ fluctuation. This study concludes that with the incorporation of CR mechanism, particle production becomes more correlated, leading to larger dynamical mean-$p_{\mathrm{T}}$ fluctuation.

## References


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