

Mean transverse momentum fluctuations in pp collisions at $\sqrt{s} = 13$ TeV using ALICE detector at LHC

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An analysis of the high-multiplicity triggered pp data at $\sqrt{s} = 13$ TeV, obtained with the ALICE detector, is carried out to study the event-by-event fluctuations of mean transverse momentum ($\langle p_T \rangle$) using a two-particle p_T correlator. The driving force behind these studies is the search for dynamical fluctuations that may be associated with the formation of Quark-Gluon Plasma (QGP) droplets in small collision systems, such as pp, for which traces have been observed in previous studies. The values of the correlator are observed to decrease with increasing charged particle density and exhibit power-law behavior similar to the one observed for pp and Pb–Pb collisions at lower energies. The findings also reveal that Monte Carlo model PYTHIA reproduces the observed dependence of the correlator on charged particle density.

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1. Introduction

Event-by-event mean transverse momentum fluctuations of charged particle produced in nucleus-nucleus (AA) collisions are regarded as a signal for a phase transition from a quark gluon plasma (QGP) to hadron gas [1, 2]. Fluctuations of mean p_T have been observed to decrease with collision centrality. The observed trend of decrease, however, shows a deviation from what is expected from a simple superposition scenario. This has been attributed to the onset of thermalization and hadronization, but no strong connection to the critical behavior could be made. It has, however, been suggested that the p_T correlations and their centrality dependence might be affected by the initial state density fluctuations [1, 3].

Fluctuations in $\langle p_T \rangle$ might arise due to several kind of correlations among the p_T of the produced particles like resonance decay, quantum correlations and jets. To account for these correlations from conventional mechanisms, similar studies can be carried out for pp collisions where such correlations are also present [1]. The results from pp collisions can be used to construct a model independent baseline to search for the non trivial fluctuations in AA collisions. Furthermore, the evidence of deconfinement [4], strangeness enhancement [5] and observation of collectivity in high-multiplicity pp collision events [6] has increased the interest in pp collision at LHC energies. An attempt is, therefore, made to study the mean p_T fluctuations in high-multiplicity events in pp collisions at $\sqrt{s} = 13$ TeV using the two-particle correlator, C_m , which is regarded as a measure of dynamical component of mean p_T fluctuations. The study is based on the analysis of 2 billion minimum-bias and 0.8 billion high-multiplicity events recorded by ALICE detector.

In a multiplicity class m , C_m , is defined as [1]

$$C_m = \frac{1}{\sum_k^{n_{ev,m}} N_k^{pairs}} \sum_{k=1}^{n_{ev,m}} \sum_{i=1}^{N_{acc,k}} \sum_{j=i+1}^{N_{acc,k}} ((p_{T,i} - M(p_T)_m) \cdot (p_{T,j} - M(p_T)_m)) \quad (1)$$

where, N_k^{pairs} is the number of pairs in an event, n_{ev} is the number of events in class m and $M(p_T)_m$ is the mean p_T of all particles in all events of that multiplicity class and is given as

$$M(p_T)_m = \frac{1}{\sum_{k=1}^{n_{ev,m}} N_{acc,k}} \sum_{k=1}^{n_{ev,m}} \sum_{i=1}^{N_{acc,k}} p_{T,i} \quad (2)$$

where, $N_{acc,k}$ is the measured multiplicity of an event k .

2. Results and Discussion

Variations of the normalized correlator, $\sqrt{C_m}/M(p_T)_m$ on the true multiplicity for minimum bias (MB) and high-multiplicity (HM) triggered events for 13 TeV pp collisions are shown in left panel of Fig. 1. The measurement has been performed in intervals of one unit of N_{ch} up to $N_{ch} = 54$ and beyond this value, in intervals of four units to minimize statistical fluctuations in the high-multiplicity tail. It is interesting to note that the MB and HM data points tend to form a continuous curve and give a common trend of decrease of correlator with increasing multiplicity. The non-zero values of the correlator is an indication of presence of significant dynamical fluctuations in the data. The observed dependence of $\sqrt{C_m}/M(p_T)_m$ on the mean charged particle density, $dN_{ch}/d\eta$ is compared with those reported at lower energies [2]. The results are shown in the right panel of Fig. 1. The figure shows that the correlator acquires nearly energy independent values except in the region of low multiplicity ($\langle dN_{ch}/d\eta \rangle \leq 8$), where the difference is $\sim 10\%$, whereas for $\langle dN_{ch}/d\eta \rangle \geq 10$ the difference may be noted to be $\sim 2\%$ only.

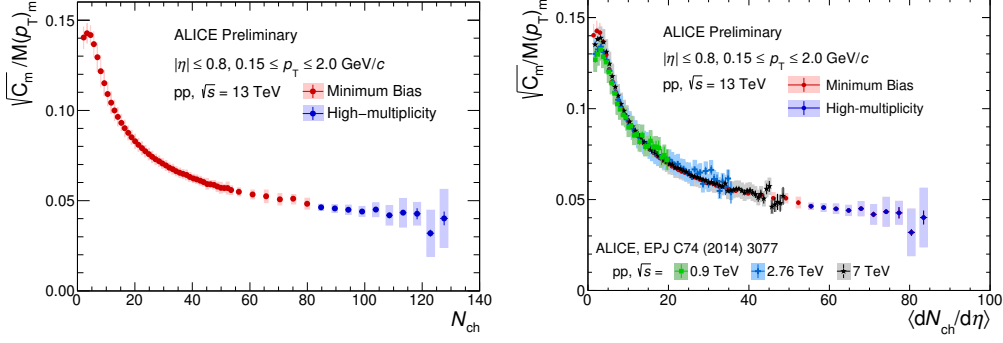


Figure 1: Variations of correlator with multiplicity for pp collisions at $\sqrt{s} = 13$ TeV (left). A comparison of correlator values for pp collisions at various energies. The statistical errors are represented by lines and systematic errors by shaded boxes.

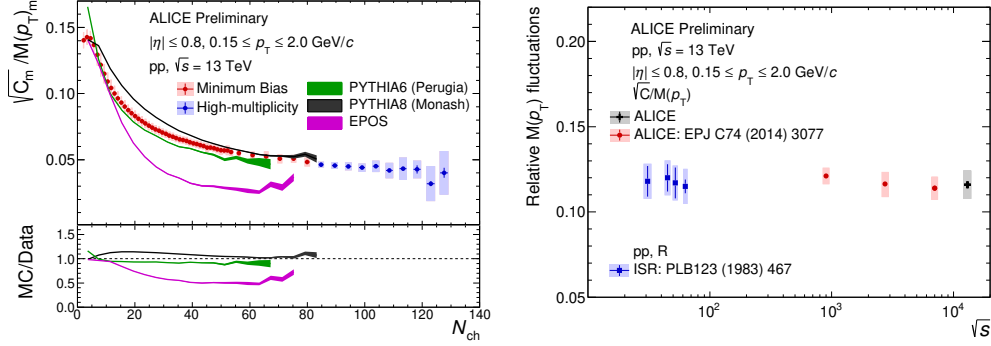


Figure 2: Models predictions compared with the experimental findings (left). Inclusive correlator values from ISR to LHC energies (right). The statistical errors are represented by lines and systematic errors by shaded boxes.

Shown in Fig. 2 (left) is the comparison of the present findings with the predictions of Monte Carlo (MC) models PYTHIA (Monash and Perugia tunes) and EPOS. It is observed that for $N_{ch} \leq 15$, EPOS satisfactorily reproduces the data but predicts quite small values for $N_{ch} > 18$ and beyond. On the other hand, PYTHIA8 describes the data qualitatively while PYTHIA6 predictions agree both qualitatively and quantitatively. Inclusive values of the correlator are also computed and compared to those reported for lower energies. This is displayed in right panel of Fig. 2. The blue markers in the figures are the values of relative fluctuation measure, R reported at ISR energies [7]; it has been shown [1] that fluctuations estimated using R and $\sqrt{C_m}/M(p_T)_m$ agree with each other within 10 – 15%. It is evidently clear from the figure that the correlator acquire almost energy independent values from ISR to LHC energies.

References

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