Hydro-like features in high-multiplicity *pp* events at the LHC energies contrasted with EPOS3 hydrodynamic model

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Introduction

The study of mutiparticle production in relativistic proton-proton collisions aims at understanding the QCD physics in the perturbative domain. These collisions, considered as elementary ones, also make the reference line for extracting exotic phenomenon, the formation of thermalised partonic medium - Quark Gluon Plasma (QGP) - in relativistic heavy ion collisions. However, the highest accelerator energies available, so far, at the Large Hadron Collider (LHC) surprise [1, 2, 3] us with certain features in multi-particle production in pp collisions which are known as the characteristics properties of particle production through formation of thermalised fluid-like medium in relativistic heavy-ion collisions. These unexpected features in pp collision indicate that we are still far from clear understanding of particle production mechanism in the so-called elementary collisions.

While the fact that the high-multiplicity *pp* events do not really corroborate [4] with conventional particle production models, like PYTHIA, the origin for the hydro-like behaviour is also not yet identified . In this article, we attempt to describe the unexpected features of high-multiplicity *pp* events with EPOS3, a hydrodynamic model. We have generated 20 millions events for each of the centre-of-mass energies, 7 and 13 TeV with two different options: with-hydro and without-hydro. With the generated events, we compare two significant hydro-like features as observed in the LHC *pp* data: the increasing trend of $< p_T >$ as a function of N_{ch} and the long-range two particle angular correlations in high-multiplicity *pp* events.

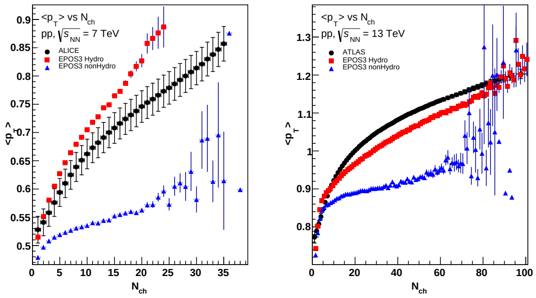

FIG. 1: $< p_T >$ as a function of N_{ch} for pp $\sqrt{s} = 7$ TeV (left panel) and $\sqrt{s} = 13$ TeV(right panel), as measured by ALICE and ATLAS respectively are compared with the simulated events of EPOS3.

Analysis and Results

The N_{ch} dependence $< p_T >$, that is indicative to the collective hadronization, has been calculated for the simulated events and compared with experimental measurement in Figure 1. For $\sqrt{s} = 7$ TeV, a comparison of the simulated events has been done with the ALICE data [5] upto p_T 10 GeV/c over pseudorapidity range $|\eta| < 0.3$, while for $\sqrt{s} = 13$ TeV, the comparison has been made with ATLAS data over all p_T range and $|\eta| < 2.5$. From the Figure 1, it is clear that though EPOS3 data shows an increasing trend of $< p_T >$ vs N_{ch} distribution, it can not explain the experimental data. .

The two particle azimuthal correlation function is defined by the per-trigger associated

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yield of charged particles:

$$\frac{1}{N_{trigg}}\frac{d^2N^{assoc}}{d\Delta\eta d\Delta\phi} = B(0,0)\times\frac{S(\Delta\eta,\Delta\phi)}{B(\Delta\eta,\Delta\phi)} \quad (1)$$

where, N_{trigg} is the number of trigger particles in a given $p_T^{trigger}$ range. The function $S(\Delta\eta, \Delta\phi)$ is the differential measure of per-trigger distribution of associated hadrons in the same-event, i.e,

$$S(\Delta\eta,\Delta\phi) = \frac{1}{N_{trigg}}\frac{d^2N^{assoc}_{same}}{d\Delta\eta d\Delta\phi} \quad (2)$$

The same-event distribution functions are corrected for the random combinatorial background and effects due to the limited acceptance by dividing the raw same-event distribution function by the mixed-event background distribution, where trigger and associated particles are paired from two different events of similar multiplicity. The background distribution function $B(\Delta\eta, \Delta\phi)$ is defined as:

$$B(\Delta\eta,\Delta\phi) = \frac{d^2N^{assoc}_{mixed}}{d\Delta\eta d\Delta\phi} \quad (3)$$

The factor B(0,0) in Eq. (1) is used to normalize the mixed-event correlation function such that it is unity at $(\Delta\eta, \Delta\phi) = (0, 0)$.

The generated events have been classified into several multiplicity windows, following the criteria adopted in the data analysis [2]. The associated yield from CMS data within $2 < |\Delta\eta| < 4$ has been compared with EPOS3 with p_T^{trigg} and p_T^{assoc} being 1-2 GeV/c. The results have been shown in the Figure 2, for multiplicity windows in the high-multiplicity region: $N_{ch} \sim$ 90-110 for 7 TeV data and 80-105 for 13 TeV data. The hydro-version of the EPOS3 indeed results a ridge-like structure for both the energies, 7 TeV and 13 TeV, as expected. However, it is clear from the Figure 2, EPOS3 calculations are far from the measured two-particle angular correlations of the data.

Discussions

EPOS3 model works on "Parton-based Gribovv-Regge theory". The initial conditions are given by the distribution of pomerons which correspond to colour flux tubes. The flux tubes expand and at some stage get fragmented into string segments of quark-antiquark pairs. In high energy high-multiplicity pp events, many elementary parton-parton scattering produce a large number of flux tubes and eventually high local string-segment density. The high energy of string segments and / or high local string-segment density (above a critical value) constitute the bulk matter, forming a medium [6]. The miss-match in the magnitude of the hydro-like behaviours between the data and the EPOS3 indicates that mechanisms, as adopted in EPOS3, for the creation of the bulk matter, could be different from the actual mechanism that is reflected in the data.

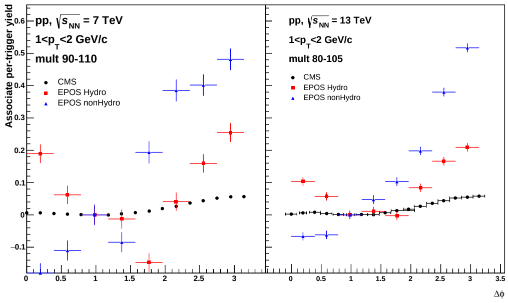

FIG. 2: One-dimensional $\Delta\phi$ projection of the associated charged particle yield for the region of ridge-like correlations from the CMS data and the EPOS3 event generator.

References

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