Investigation on degree of complexity in multi-particle production at LHC energies using Visibility Graph technique

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Introduction

Complex Network study allows to characterize various systems having many components interacting with each other. Time series can be analysed using complex network study. Visibility graph technique [1] is one of the methods of such study, which captures the geometrical structure of time series. The network, obtained from the time series by this technique, opens up non-trivial information about the series itself. It can transform periodic, random and fractal time series into regular, random and scale-free graphs respectively. This technique can be applied to a finite time series like data to quantify fractality of a time series. L. Lacasa et al.[2] have introduced Hurst exponent (H) from the knowledge of Power of the Scale-freeness in Visibility Graph (PSVG) factor, which is found to be a good indicator of phase transition for a complex system[3].

Various analyses have revealed that particle production mechanism in high energy interaction are self-similar, which signifies its fractal geometry. This contribution presents an attempt to search for the evidence of fractality in multi-particle production process in pp collision at $\sqrt{s}$ = 7 and 13 TeV, simulated by EPOS3, using this technique. We have mapped event-by-event pseudo-rapidity (η) distribution of charged particles into a scale-free network for our study.

Event Selection

We used the pQCD inspired Monte-Carlo model, EPOS3 [4] with the hydrodynamical evolution of produced particles to generate 3 million minimum-bias pp events for $\sqrt{s}$ = 7 & 13 TeV. Events are chosen with a minimum of three charged particles in the kinematic interval $p_T > 0.1$ GeV/c and $|\eta| < 2.5$ in order to include all charged particles produced in hard as well as soft processes.

Results

We applied the successive difference method for bin count: $y(\eta_i) = dn(\eta_{i+1}) - dn(\eta_i)$ and projected it onto positive (y, η) plane in order to get modified pseudorapidity distribution i.e. time series. Each data value in the time series is considered to be a node. The produced time series for each event sample are then mapped into the corresponding visibility graphs considering that two arbitrary nodes with data values (t_a, X_a) and (t_b, X_b) are visible to each other if any other point (t_c, X_c) between them satisfies the condition $X_c \leq X_b + (X_a - X_b)\frac{t_b - t_c}{t_b - t_a}$. If there are n nodes in total in a network and n_k of them have degree k, then the degree distribution $P(k) = \frac{n_k}{n}$. An overall degree distribution $P(k)$ for the entire event sample is obtained after combining the single event distributions together and Fig.1 represents its variation with degree parameter k for nine different thresholds for the charged particle transverse momentum (p_{Tmin}). It is evident from Fig. 1 that the power law rela-

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tionship [$P(k) \sim k^{-\lambda_p}$] is satisfied for all p_T thresholds. This result provides evidence in favour of the fractal nature of fluctuation patterns in multiparticle production in pp collision at $\sqrt{s}$ = 7 & 13 TeV.

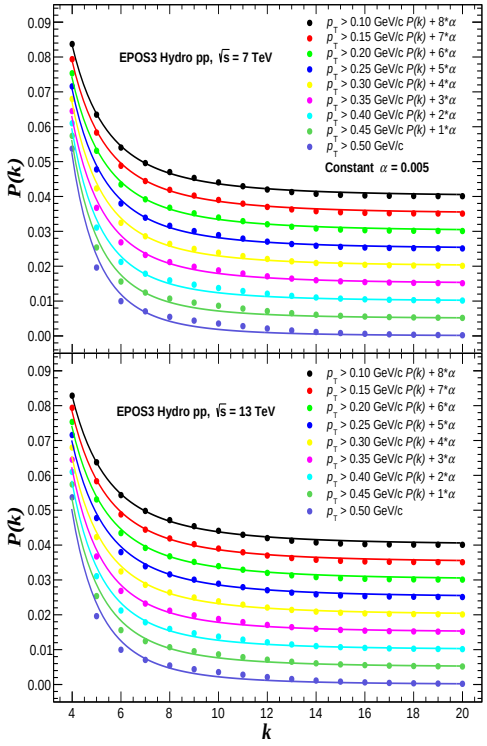

FIG. 1: $P(k)$ vs k along with fittings for different p_T thresholds.

To extract the PSVG factor λ_p, we have fitted each degree distribution with power law function. Fig. 1 also shows the fitting exercise for all the p_T thresholds. Fitting parameters (PSVG) are plotted against p_T thresholds for both the energies. Fig. 2 indicates that PSVG factor λ_p increases with the increase of p_{Tmin} in pp collisions for both the chosen centre-of-mass energies.

Summary

We have presented an in depth study on fractal property of fluctuation pattern in the

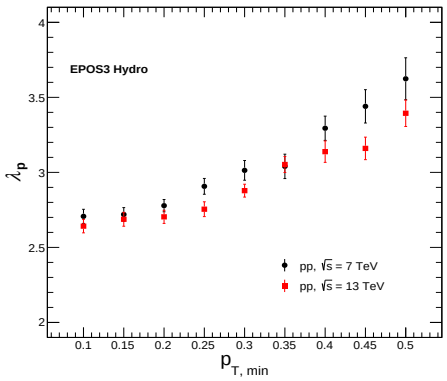

FIG. 2: Variation of PSVG factor (λ_p) with different p_T thresholds.

multi-particle production using the EPOS3 simulated pp events at LHC energies. The study reveals that with the transition from soft processes to hard processes, particle production becomes more complex in nature. Also, we find that there is a hint of energy dependence in λ_p which becomes prominent at high p_{Tmin} range.

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