Multiplicity dependent chaotic pionisation in p-p collisions for anisotropic phase space at LHC energy

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Introduction

Relativistic heavy-ion collisions have revealed details about the characteristics of matter in the early universe over the last few decades. It is thought that during this time the premordial state of our universe was created from hot and dence quark gluon plasma state. Now we have studied the relativistic heavy-ion collisions to find out the informations regarding the spatiotemporal evolution of charged particle multiplicities. In high energy heavy-ion collision, there is a non statistical dynamical fluctuations among the multiplicities of colliding particles. To extract the dynamical fluctuations from the relativistic heavy-ion collisions Bialas and Peschanski had proposed the intermittency dependent scale factorial moment (SFM)[1]. It shows the power law variation on decreasing phase space interval. According to Van Hove the phase space shows the anisotropic behaviour rather than isotropic behaviour[2]. Wu and Liu had also contributed that the scaling property should not similar along transverse and longitudinal directions[3]. In this paper we have studied the Ultra-Relativistic Quantum Molecular Dynamics (UrQMD) generated p-p collisions in anisotropic phase space for impact paramere b= 0.4 at LHC energy 13 TeV.

Methodology

For anisotropic two dimensional $\eta-\phi$ space the scale factorial moment is
$F_q = M^{q-1} \sum_{m=1}^{M} \frac{\langle (n_m-1)....(n_m-q+1) \rangle}{n_m^q}$
Here M denotes the total no. of bins and $M = M_\eta \times M_\phi$, where M_ϕ and M_η are the no. of bins along ϕ and η axis respectively. When $0 < H < 1$, $M_\eta = M_\phi^H$ and for $H > 1$, $M_\phi = M_\eta^{1/H}$. Here H is known as Hurst exponent and n_m is the no. of pions in m^{th} bin. For anisotropic phase space $ln < F_q >$ shows the non linear behaviour with ln M, however we have fitted the variation of $ln < F_q >$ with ln M through the polynominal equation by keeping the non linear coefficient zero and have obtained the intermittency index ϕ_q for moment order q=2,3...8 at b=0.4. ϕ_q denotes the strength of intermittency. According to Bialas and Peschanski $< F_q > \propto$ M$^{\phi_q}$ or, $ln < F_q >= \phi_q\ lnM + C$ [4].
According to α- model we have calculated the fractal strength α_q as [5]

$$\alpha_q = \sqrt{\frac{6ln2(D - D_q)}{q}} \quad (1)$$

Where D=2 for two dimensional analysis and D_q is the general fractal dimension

$$D_q = D - \frac{\phi_q}{(q-1)} \quad (2)$$

Result and Discussions

Here we have used the scale factorial moment method to analyse the intermittency strength and strength of fractality among the charge particle multiplicities of p-p collisions at b=0.4. In Fig. 1 we have presented the variation of $ln < F_2 >$ for moment order q=2 with ln M, keeping the no. bins M=4,5,6...40 for H=0.3 & 1.3. For anisotropic phase space $ln < F_q >$ shows the non linear behaviour with ln M. Since we have fitted this non linear behaviour of $ln < F_2 >$ with ln M through

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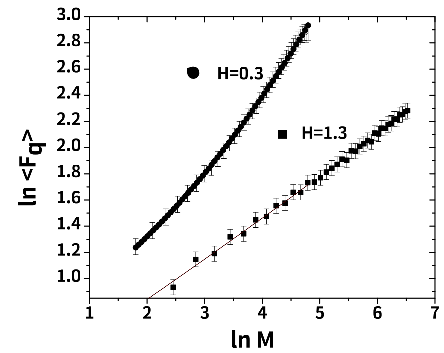

FIG. 1: **Variations of $ln < F_q >$ with ln M for H=0.3 & 1.3**

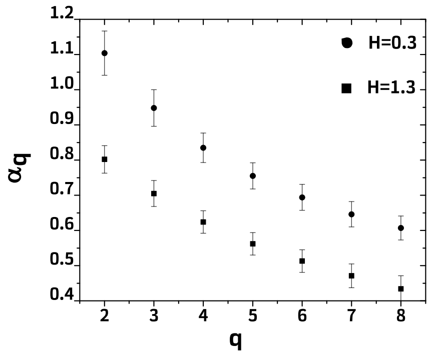

FIG. 2: **Variations of α_q with respect to q for H=0.3 & 1.3.**

the quadratic equation $y = ax^2 + bx + c$. Where 'a' is the non linear co-efficient, measures the non linearity of SFM. We have observed comparatively large discontinuity in the variation of second order SFM for H=1.3 i.e. for $H > 1$ region. The statistical errors which are obtained using standard deviation method are added with all plots through the error bars.

In Table 1 we have shown the values of ϕ_q including the Pearson coefficient R^2 and α_q for H=0.3 & 1.3. From Table 1 we have observed that the values of ϕ_q are decreasing with increasing the moment order and it has greater value for $H < 1$ region compare to the $H > 1$ region. Hence in $H < 1$ region strong intermittency is observed.

TABLE I: Value of the observables obtained from scale factorial moment method

H	q	ϕ_q	R^2	α_q
0.3	2	0.580±0.007	0.994	1.098±0.059
	3	1.282±0.012	0.997	0.943±0.045
	4	1.976±0.016	0.998	0.828±0.035
	5	2.669±0.020	0.998	0.745±0.032
	6	3.363±0.024	0.998	0.683±0.029
	7	4.057±0.028	0.998	0.634±0.027
	8	4.751±0.032	0.998	0.594±0.025
1.3	2	0.309±0.003	0.997	0.802±0.039
	3	0.718±0.007	0.997	0.705±0.037
	4	1.126±0.012	0.996	0.624±0.032
	5	1.521±0.018	0.995	0.562±0.032
	6	2.896±0.029	0.992	0.513±0.032
	7	2.242±0.047	0.985	0.471±0.034
	8	2.544±0.075	0.971	0.434±0.037

In Fig. 2 we have shown the variation of α_q with order q for H=0.3 & 1.3. From these variations we have observed that fractal strength is decreasing with increasing order q for both H=0.3 & 1.3. From this Fig. 2 it is also observed that the stronger fractal strength is present in $H < 1$ region compare to the $H > 1$ region.

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References

[1] Bialas, A., Peschanski, R., *Nucl. Phys. Sect. B*, **273** 703–718 (1986).
[2] L Van Hove, *Phys. Lett.*, **B28** 429 (1969).
[3] Wu Yuanfang, Liu Lianshou, *Phys. Rev. Lett.*, **70** 3197 (1993).
[4] M.K. Ghosh *et al.*, *Can. J. Phys.*, **88** 8 (2010).
[5] Prabir Kr. Haldar *et al.*, *Astroparticle Physics*, **42** 76-85 (2013).