Dynamical fluctuations in multiplicity distribution of particles produced in relativistic nuclear collisions

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Introduction

Non-statistical fluctuations in high multiplicity events produced in relativistic particle-nucleus and nucleus-nucleus collisions have been extensively investigated by Takagi [1]. Miyamura and Tabuki [2] have also studied multiplicity distributions in different rapidity bins using scaled factorial moments, F_q, approach [3]. The bin size dependence of normalized factorial moments of the JACEE event [4] was analyzed by Bialas and Peschanski [5]. However, approaches, which are based on the concept of multi-fractals, appear to be the most promising as they are believed to be related to self-similar cascading, chaos, phase transitions, etc; [6]. Some interesting results on intermittency and multifractality have already been reported earlier [7]. But it always turned out that the experimental data do not show the expected linear behavior in $\ln<n_q>$ versus $\ln<n>$ plots. However, the trend may be explained successfully by Takagi's method.

In the present study, nature of dynamical fluctuations is investigated by analyzing experimental data on 200A GeV/c ^{16}O-nucleus collisions.

Mathematical Formalism

To investigate multifractality behaviour, we have adopted the formalism developed by Takagi. In this approach Takagi divided the full rapidity interval into 'm' bins of equal size, $\delta\eta=\Delta\eta\ /\ m$. In a single bin multiplicity distribution, $P_n(\delta\eta)$, for n=0,1,2,3 …, the inclusive rapidity distribution, $dn/d\eta$, is envisaged to be flat and $P_n(\delta\eta)$ is visualized to be independent of the location of the bin. Let n_{ij} be the number of charged particles in j^{th} bin of i^{th} event and N the total number of events. The particle density, P_{ij}, is related to $T_q(\delta\eta)$ in the following fashion:

$$T_q(\delta\eta)=\ln \sum_{j=1}^{M}\sum_{i=1}^{m} P_{ij}^{q} \qquad \text{for } q>0 \qquad (1)$$

where q is order of the moment. This is similar to linear logarithmic function of resolution, $R(\delta\eta)$, having the form:

$$T_q(\delta\eta)=A_q + B_q \ln R(\delta\eta) \qquad (2)$$

where A_q and B_q are independent of $\delta\eta$ and for a given range of $R(\delta\eta)$. The generalized dimensions, D_q, are calculated from:

$$D_q = B_q /(q-1) \qquad (3)$$

In order to measure the fluctuations, Takagi has modified Eq. (2) to have the following form:

$$\ln<n^q>=A_q + (B_q + 1)\ln<n> \qquad (4)$$

where q is a positive real number.

The values of generalized dimensions, D_q, are obtained by obtaining the values of the slopes using Eq. (3) for q=2, 3, 4 and 5.

For investigating intermittency behavior we divide the rapidity into M smaller rapidity bins. The intermittency is given as:

$$F_q(\delta\eta)=\frac{1}{N_{evt}}\sum_{N_{evt}}\sum_{m=1}^{M}\frac{<n(n-1)........(n-q+1)>}{<N>^{q}} \qquad (5)$$

M, determined by the above equation, is a positive integer. The intermittent behavior of the multiplicity distribution manifests itself as a power law dependence of factorial moment on the cell size for cell size≥ 0.

$$<F_q> \propto M^{\alpha_q} \qquad (6)$$

The exponent α_q is the slope characterizing the linear rise of $\ln<F_q>$ with lnM and is obtained as the slope. By obtaining the values of α_q, D_q values are determined using the relation:

$$D_q=\alpha_q/(q-1) \qquad (7)$$

D_q and d_q are related as

$$D_q=1-d_q \qquad (8)$$

Experimental details

An emulsion stack, exposed to a beam of 200A GeV/c Oxygen nuclei from AGS, BNL is used in the present study. The events were scanned along the track method and space angles of the produced charged particle, were measured using the coordinate method. The other details of the experiment may be found in Reference [7]. A random sample comprising of 1165 interactions having $n_h \geq 0$ produced in 200A GeV/c ^{16}O-nucleus interaction are analyzed; where n_h represents the number of charged particles produced in an interaction with relative velocities, $\beta(= v/c)<0.7$, where c represents speed of light in vacuum.

Results and Discussions

The values of T_q are plotted against q for different pseudorapidity intervals for our experimental data. It is seen from Fig.1 that variation of T_q with q is a linear one.

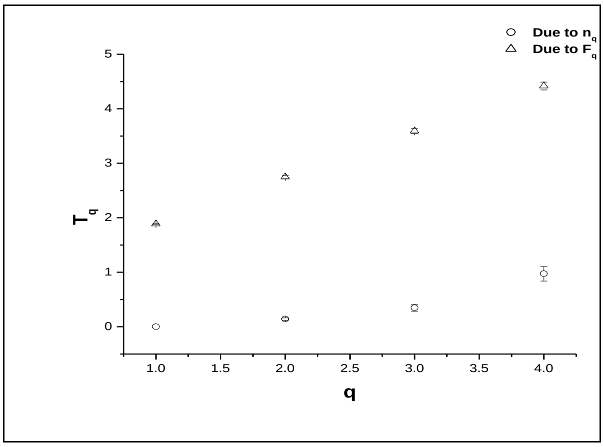

Fig. 1 Variation of T_q with q

The values of generalized dimensions, D_q, may be calculated from the slopes of the linear fits using Eqs. (4) and (7).

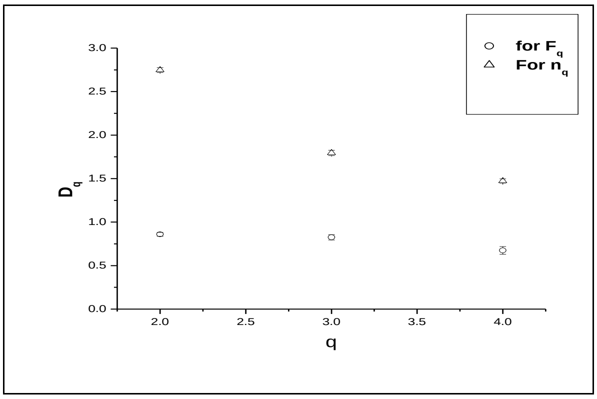

Fig. 2 Variation of D_q with q

The values of D_q are listed in the Table 1.

Table: 1

q	D_q	
	F_q	n_q
2	0.8590 2.7479	±0.0222 ±0.0281
3	0.8254 1.7955	± 0.0305 ±0.0296
4	0.6752 1.4727	± 0.0444 ±0.0241

Conclusion:

Strong dependence of T_q on the value of q for multifractal and intermittency approaches are observed. Finally, the values of D_q reveal the presence of multifractal geometry in the data.

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