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A STUDY OF HIGH-ENERGY NUCLEAR DISINTEGRATION

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A study has been carried out with the intermittency parameter of disintegration of light (C,N,O) and heavy group (Ag,Br) of photoemulsion nuclei. The result for the dependence of anomalous fractal co-dimension (d_q) with the order of the moment q as well as the variation of λ_q against q indicate that self-similar cascade mechanism is responsible for the disintegration of target nuclei. No signal of phase transition during the process has been observed.

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1. Introduction

In high-energy nuclear interactions, slow particles are expected to come out from a thermally equilibrated nuclear system. But Dalkhzhaz and others [1] got an indication of non-equilibrium processes involved in the emission of target-associated slow particles. Later, Takiabaev [2] and Ghosh [3] also observed the dominance of non-statistical fluctuations over the statistical part of the angular distribution of slow particles. The data could not be explained by the cascade-evaporation model.

A power-law behaviour of scaled factorial moment with decreasing bin size, called intermittency [4], has been observed in the study of emission of black/slow particles during target fragmentation of 1.8 GeV/c K^- and 20 GeV/c proton with light (CNO) and heavy group (AgBr) of photo emulsion nuclei [5]. Intermittency is believed to be a manifestation of the QGP phase transition. But that requires a temperature of the order of 150 – 200 MeV, which is not available in the interactions we have studied. Meanwhile, other alternative suggestions have also been proposed, which consider the process to be self-similar random-cascade, formation of jets [6] and mini-jets [7] with conventional short-range correlation [8]. The short-range correlation among emitted black particles has been observed in our data sample. In this paper, we investigate whether the observed intermittency indicate a self-similar random cascade, and whether the emitted black particles are of monofractal or multifractal type.

2. Experimental details

In our experiment, we have analysed data from the irradiation of K5 emulsion stacks by 1.8 GeV/c K^- mesons (flux $= 2 \times 10^5$ cm^{-2}) and 20 GeV/c protons (flux $\sim 2 \times 10^4$ cm^{-2}) at Brookhaven AGS accelerator. The emulsion plates were area scanned to detect the presence of disintegrating centres or stars. These stars were further scrutinized under magnification of 1500×, using oil-immersion objective with Olympus microscope to detect C, N and O, and Ag and Br interactions. The details of selection criteria for the analysis of events and tracks may be found in Ref. [9].

The number of events considered for the present study was as follows:

Type of interaction	K^- – CNO	K^- – AgBr	p – CNO	p – AgBr
No. of events	300	795	230	887

3. Methodology of analysis

Lipa [10] pointed out that the scaling property could be reinterpreted in terms of the fractal properties of the particle density fluctuation. It is possible to correlate the intermittency exponents α_q to the generalised dimensions, which is called Renye dimensions [11], by

$$\frac{\alpha_q}{q-1} = d_q = 1 - D_q \,, \tag{1}$$

where d_q is the anomalous fractal dimension or Renyi co-dimension and measures the intermittency dimension. D_q is the fractal dimension which describes fractal and multifractal in the classical system. It is important to study q dependence of d_q as it points out to the possible mechanism of multiparticle production process [11]. Also, it reflects the inner fractal structure of the fluctuations representing monofractal pattern with the unique d_q, or multifractal ones with the hierarchy $d_{q1} > d_{q2}$, $q_1 > q_2$ [12].

The signal that a phase transition is taking place (if any) is the most intriguing question in the study of high-energy interaction. Phase transition may be of thermal or of non-thermal type, depending on whether the new phase is characterized by new thermal behaviour or not. If a quark-gluon-plasma is formed in thermodynamic equilibrium during a high-energy interaction, then a possible phase transition to the final hadronic phase should follow it. If this phase transition is sufficiently close to the second order, then the final hadronic phase is expected to show intermittent behaviour. In that case, fractal co-dimension, d_q, is expected to behave independently of the order of the moment q. Otherwise, if the phase transition is of first order with short correlation length, then final hadronic phase is no longer self-similar at large scales. In that case, the fractal co-dimension should vanish. On the other hand, if self-similarity is the underlying mechanism of particle production, then fractal co-dimension d_q should depend on the order of the moment q. However, the parameters of the self-similar cascade can be chosen in such a way that fractal co-dimension will become independent of q [13]. So, the condition $d_q = \mathit{constant}$ is not sufficient to ensure that a phase transition has taken place.

The phase transition may not necessarily be of thermal type, but can instead be non-thermal. This could, for example, take place during parton shower cascade as has been formulated for a number of ultra-soft phenomena including intermittency [14]. It leads to the co-existence of different phases in analogy with different phase spin-glass system. Peschanski [15] observed that if intermitency is due to self-similar cascading, then a non-thermal phase transition might take place. Peschanski and Bialas observed that if two phases co-exist, then the function defined by

$$\lambda_q = \frac{\alpha_q + 1}{q} \tag{2}$$

should have a minimum at a certain q.

4. *Results and discussion*

The intermittency exponents, α_q, have been obtained from the slope of the linear fit to the data points in the $\ln(F_q)$ vs. $\ln(M)$ graph [5]. The results are listed in Table 1. The anomalous fractal co-dimension d_q and the function λ_q are calculated from

TABLE 1, The value of the intermittency exponents (α_q) in the 1.8 GeV/c K$^-$ and 20 GeV/c proton interaction with the light (CNO) and heavy group (AgBr) of photo-emulsion nuclei.

Type of interaction	q	Intermittence exponents (α_q)
K$^-$–CNO	2	0.625 ± 0.028
	3	1.405 ± 0.067
K$^-$–AgBr	2	0.155 ± 0.009
	3	0.651 ± 0.038
	4	1.199 ± 0.078
p–CNO	2	0.626 ± 0.022
	3	1.666 ± 0.057
p–AgBr	2	0.133 ± 0.008
	3	0.626 ± 0.018
	4	1.159 ± 0.035

the values of the intermittency exponents α_q with the help of Eqs. (1) and (2). The variation of anomalous fractal dimension d_q with that of the order of the moment q is shown in Figs. 1a – d. It is seen that d_q increases with the order of the moment q. As suggested by Bialas and Hwa [6], if self-similar cascade process is responsible for the creation of the final hadron system, then one rather expects d_q to be approximately linear in q. Also the behaviour of d_q with the order of the moment q (i.e. $d_{q1} > d_{q2}$, $q_1 > q_2$) indicates a multifractal phase space of emission of the black particles.

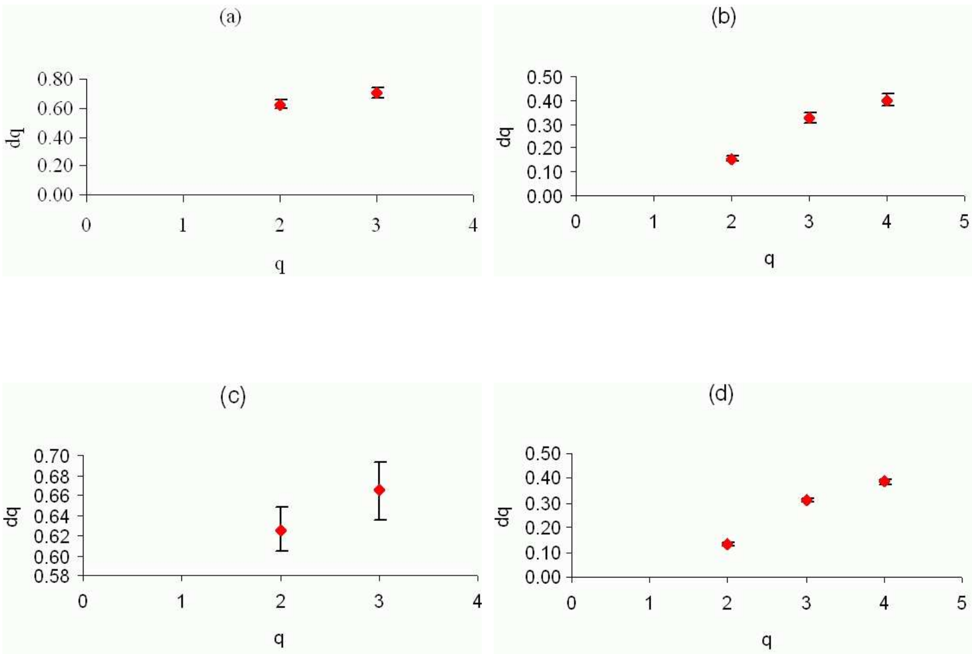

Fig. 1. Variation of the anomalous fractal dimension with the order of the moment for a) $K^- -CNO$*, b)* $K^- -AgBr$*, c)* $p-CNO$ *and d)* $p-AgBr$ *interactions.*

The variation of the function λ_q with the order of the moment q is shown in Figs. 2a – d. From the graph, the minimum value of λ_q and the corresponding value of q cannot be determined. So, as per suggestion of Peschanski and others [6,12,15], the present interaction simply reveals one-phase system with no indication of QGP phase transition to the final hadronic state. Such behaviour of λ_q with q definitely indicates intermittency, which may be attributed to the self-similar cascade, responsible for target disintegration as observed from the order dependency of anomalous fractal dimension d_q with the moment q.

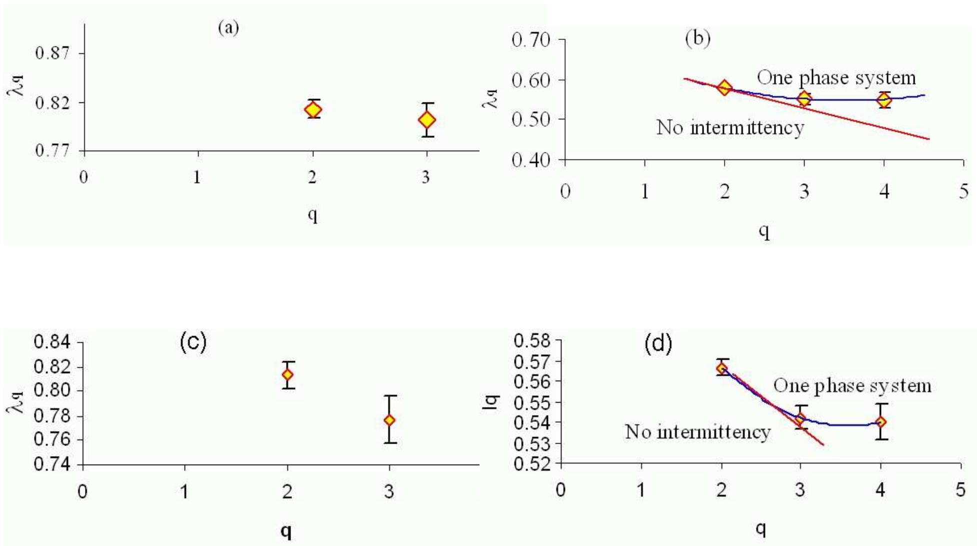

Fig. 2. Variation of λ_q against q for a) K^- –CNO, *b)* K^- –AgBr, *c)* p –CNO *and d)* p –AgBr *interactions.*

5. Conclusion

So, we arrive at the following conclusions:

1. The dependence of anomalous fractal dimension d_q with the order of the moment q obtained from the study of emission of black particles is an indication of the self-similar cascade mechanism responsible for target fragmentation.

2. The order dependence of anomalous fractal dimension d_q further indicates that the phase space of the emission angle of the black particles is of multifractal type.

3. Although the analysis of the data does not support evidence for a QGP phase transition, it does indicate a one-phase system with the presence of intermittency during black-particle emission.

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PROUČAVANJE VISOKOENERGIJSKIH NUKLEARNIH RASPADA

Proučavamo raspade grupe lakih (C, N, O) i grupe teških (Ag, Br) jezgri u fotoemulziji primjenom parametra prekidanja. Ishodi analize ovisnosti anomalne fraktalne ko-dimenzije (d) o redu momenta q, kao i promjene λ_q sa q, pokazuju da je kaskadni mehanizam samo-sličnosti odgovoran za raspad jezgri u meti. Ne opažamo znakove faznog prijelaza u tim procesima.