Intermittency in ^{28}Si-Ag/Br interaction at 14.5A GeV/c

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Introduction

The scaled factorial moment (F_q) is capable of suppressing Poisson type statistical noise arising out of finite particle multiplicity of an event. The power law type of scaling behaviour of F_q: $F_q = (\delta X)^{-\phi_q}$ with diminishing phase space interval size (δX) is known as 'intermittency', where $\phi_q(> 0)$ called the intermittency index, can indirectly measure the strength of intermittency. F_q has been extensively used to identify and characterize the dynamical component of particle density fluctuation in different high-energy interactions [1]. The power law scaling relation mentioned above indicates a self-similar (multi) fractal structure in the dynamical fluctuation, that probably has its origin in some kind of scale invariant particle production mechanism. Several speculations like BE correlation, thermal/non-thermal phase transition, internuclear cascading, collective behaviour etc., have been made to explain intermittency, but each met a limited success. In this paper we present a one dimensional ($1d$) intermittency analysis of the shower tracks (caused primarily by singly charged mesons moving at relativistic speed: $v > 0.7c$) that came out of ^{28}Si-Ag/Br interaction at 14.5A GeV/c. Nuclear emulsion technique has been utilized for data collection, which comprise of 331 events with an average shower track multiplicity $\langle n_s \rangle = 52.62 \pm 1.78$.

Results

In FIG.1 graphical plots of vertically averaged F_q against phase space partition number (M) can be seen. To make our results independent of the shape of the underlying distribution, in stead of pseudorapidity (η) and azimuthal angle (φ) the respective cumulant variables (X_η and X_φ) were used. In terms of the X variables the vertically and horizontally averaged values are same within errors. The ϕ_q values are obtained through linear fit of the data points following: $\ln \langle F_q \rangle = \phi_q \ln M + \beta_q$. For each q the first four data points have not been considered in the fit process, as this region is affected by trivial kinematic conservation rules. In the upper panel of FIG.1 the experimental results have been compared with the FRITIOF [2] prediction in η-space, whereas in the lower panel the same are plotted along with the Monte Carlo (MC) prediction in φ-space. Errors associated with the data points are purely statistical. Both plots indicate a presence of intermittency in the experimental data, but the effect is neither observed in the model code FRITIOF nor in the MC generated events. The ϕ_q values are quoted in TABLE I, and they depend on the underlying phase space variable.

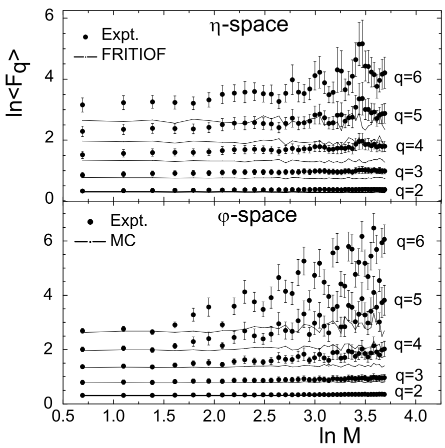

FIG. 1: $\ln < F_q >$ against $\ln M$

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TABLE I: Experimental values of ϕ_q.

q	η-space	φ-space
2	0.0112±0.0005	0.0165±0.0006
3	0.0395±0.0026	0.0649±0.0022
4	0.1120±0.0066	0.2136±0.0050
5	0.2547±0.0132	0.5899±0.0115
6	0.4769±0.0234	1.9411±0.0290

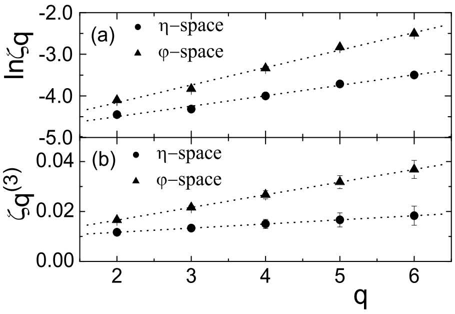

FIG. 2: Normalized exponents plotted against q.

A more direct measure of the intermittency strength, irrespective of the mechanism responsible for the phenomenon, is obtained from the $\alpha_{\text{eff}} = \sqrt{2\phi_2}$ parameter [5]. We obtained, $\alpha_{\text{eff}} = 0.15 \pm 0.01$ in the η-space and $\alpha_{\text{eff}} = 0.18 \pm 0.02$ in the φ-space. Contribution from a few particle correlation to higher order $\langle F_q \rangle$ can be determined through the normalized exponents [3]: $\zeta_q = \phi_q / \binom{q}{2}$ with $q \geq 2$, and a true three-particle correlation function can be written as: $\zeta_q^{(3)} = (q-2)\zeta_3 - (q-3)\zeta_2$. Both parameters have been schematically represented with varying q in FIG.2 only for the experimental data. In both η and φ-space ζ_q increases exponentially and $\zeta_q^{(3)}$ increases linearly with q. In φ-space the rate of increase however, is more rapid than that in the η-space. Our result therefore, supports presence of true higher order correlation. A nonthermal phase transition and/or simultaneous coexistence of two phases (e.g., spin-glass) can be investigated by studying the intermittency parameter $\lambda_q = (\phi_q + 1)/q$ [4]. A minimum in λ_q at a certain critical $q = q_c$ would represent non-thermal phase transition. The region $q < q_c$ is dominated by a large no of small fluctuations (liquid phase), and the region $q > q_c$ is dominated by a small no of large fluctuations (dust phase). FIG.3 shows hint of such minimum around $q \geq 4$, the effect being more prominent in the φ-space. Since the topological dimension of the supporting space (η or φ) is one, the (multi)fractal anomalous dimension d_q is given by: $d_q = \phi_q/(q-1)$. Following the relation $d_q/d_2 = (q-1)^{(\nu-1)}$ we have calculated the Ginzburg-Landau(GL) universal parameter ν related to a thermal phase transition: $\nu = 2.304 \pm 0.02$ in η and $\nu = 2.65 \pm 0.03$ in φ-space. Both values are far apart from the universally accepted value ($\nu = 1.304$) required for a thermal phase transition [1]. The d_q/d_2 ratio also does not support a cascade mechanism. The Lévy stable index μ in the present case ($\mu = 3.15 \pm 0.03$ and $\mu = 3.70 \pm 0.03$ respectively in η and in φ-space) was much larger than its physically allowed limit ($0 \leq \mu \leq 2$).

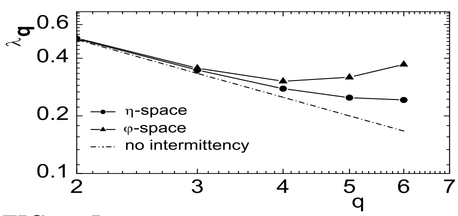

FIG. 3: Intermittency parameter against q.

Conclusion

The present analysis shows a clear signature of 1d intermittency in our ^{28}Si-Ag/Br data, that cannot simply be interpreted in terms of a few particle correlation. The analysis also hints at a non-thermal phase transition (e.g., liquid-gas) or simultaneous co-existence of two such different phases.

References

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