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Chaotic behaviour of multiparticle production in relativistic heavy ion collisions

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Abstract: An attempt has been made to understand the chaotic behaviour of multiparticle production in relativistic heavy ion collisions. For this goal first we have measured the distributions of Scaled Factorial Moments (SFMs) and found a scaling behaviour, which supported to chaoticity or spatial fluctuations in relativistic heavy-ion collisions at high energies. Finally, the values of entropy indices, μ_q are calculated which indicate the chaotic nature of multiparticle production system with a specific self-similar structure.

Keywords: Fractality and Chaoticity, Nuclear emulsions experiment and Global features in relativistic heavy ion collisions.

Introduction

The ultimate aim of relativistic heavy ion experiments at AGS, CERN SPS and relativistic heavy ion collider, RHIC, at Brookhaven National Laboratory is to provide an opportunity to investigate strongly interacting matter at energy densities unprecedented in a laboratory, which ultimately gives an evidence for the quark-gluon plasma (QGP) formation. The QGP is a state of matter in which quarks and gluons are no longer confined to volumes of hadronic dimensions. In deep inelastic scattering experiments, it has already been revealed that quarks at very short distances move freely, which is referred to as the asymptotic freedom. Quantum Chromodynamics (QCD) describes the strong interactions of quarks and gluons. A Variety of possible signatures for the existence of a deconfined state of matter in nucleus-nucleus (A-A) collision have been proposed theoretically and also studied experimentally by various workers [1], [2]. The experimental observation of large rapidity fluctuations [3] has provided interest and excitement about their nature and origin. Bialas and Peschanski [4] have suggested that a power law scaling behaviour of normalized SFMs $(<F_q> \propto M^{\alpha_q})$ on the bin size and described the phenomenon as "intermittency", a term coined from hydrodynamic turbulence [5]. The SFMs method cannot only predicts the existence of large non-statistical fluctuations but it could also investigate the pattern of fluctuations and their origin.

It is generally believed that through the heavy ion collisions at ultra-relativistic energies big systems with very high energy density [6] might be produced. In these systems novel phenomena, such as colour deconfinement [7], chiral-symmetry restoration [8], discrete-symmetry spontaneous-breaking [9], etc., are expected to be present and different events might be governed by different dynamics. With this goal in mind, the event-by-event (E-by-E) study of high-energy collisions has attracted more and more attention [10]. As it is already stated before that, the power law dependence of SFMs referred to as the intermittency [4], [5] has been extensively used to investigate fluctuations and chaos in multiparticle production in high-energy hadronic and heavy-ion nucleus-nucleus collisions [11], [12]. On the basis of E-by-E the values of scaled factorial moments, F_q^e, are envisaged to help disentangle some interesting and very much useful informations about the chaotic behaviour of multiparticle production. A few moments of F_q^e distribution, for example, the normalized moments $C_{p,q}$ are likely to serve the purpose. If $C_{p,q}$ shows a power law behaviour then such behaviour is referred to as erraticity [13], [14]. It may be stressed that erraticity analysis would like into account simultaneously the spatial as well as the E-by-E fluctuations beyond the intermittency. Studies involving erratic fluctuations in hadronic and heavy-ion collisions, carried out so far [15], [16] are not conclusive. It was, therefore, considered worthwhile to examine erraticity behaviour in relativistic nucleus-nucleus collisions. Attention is focused on the behaviour of erraticity exponents and erraticity spectrum, which are likely to provide maximum informations on self-similar fluctuations [13], [14]. Hence in the present work an exercise has been made to perform the study of (E-by-E) spatial fluctuations of relativistic shower particles produced in the collisions of ^{28}Si+Em at energy14.6A GeV in 1-D and 2-D phase spaces of X-variable. The findings are compared with the predictions of Ultra-relativistic Quantum Molecular Dynamics (UrQMD) model [17], [18].