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On the intermittency in peripheral He-Li interactions at 4.5 A GeV/c

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Abstract. An analysis of the intermittency in peripheral He-Li collisions at 4.5 A GeV/c is performed to search for a limit in the collision geometry to evidence anomal states in nuclear matter at different densities and temperatures. The Bialas-Peschanski formalism has been used. Scaled experimental factorial moments have been calculated. Investigation on self-similarity in particle production due to cascading nature of this production is done. The experiments have been performed at the Syncrophasotron from the JINR Dubna (Russia).

Key words: *relativistic nuclear collisions, fluctuations, intermittency and particle production mechanisms*

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Introduction

In relativistic nuclear interactions non-statistical fluctuations in particle production could be observed. The fluctuations observed are, mainly, fluctuations of the charged particle experimental multiplicity distributions from the Poisson distribution. These fluctuations could be related to the anomaly behaviours and phase transitions in nuclear matter. Some correlations in particle production mechanisms could be reflected, too. A difference between the experimental multiplicity and Poisson distribution indicates the existence of some fluctuations from this behaviour and that only high multiplicities contribute significantly to the appearance of intermittency. Bialas and Peschanski introduced this quantity [1].

In the last years the subjects about intermittency gained considerable interests, both experimental and theoretic [2-9]. It represents a law-power behaviour of the factorial moments of different distributions. The advantages of using factorial moments are that they have the property to filter statistical fluctuations of the interesting physical quantities, as particle multiplicity, indicating the presence of the dynamical fluctuations. This information could be affected by the existence of some geometrical fluctuations. Therefore, to obtain confidence results on fluctuations high statistics events and accurate determination of the collision geometry are necessary. The experiments at the relativistic heavy ion colliders could offer such conditions.

In this paper we study the factorial moments of the pseudorapidity distributions of charged particles as function of resolution, i.e. the size of pseudorapidity interval used in constructing the distributions, for peripheral He-Li collisions at 4.5 A GeV/c. The experiments have been performed at the Syncrophasotron from the JINR Dubna (Russia), using the SKM 200 Spectrometer [2]. The Bialas-Peschanski formalism has been used.

Experiments

In this paper we investigate the *He-Li* interactions performed at the JINR Dubna where a He beam at *4.5 A GeV/c* interacts with Li target inside the streamer chamber of the SKM 200 Spectrometer. The streamer chamber, having the dimensions 2m×1m×0,6m is the main detection component of the SKM 200 Spectrometer used in this experiment. It was placed in a magnetic field of 0.8 T (Fig.1). The chamber is filled with neon at normal pressure; the gas served, in some experiments, as nuclear target, too. There are two triggering systems: (i) *minimum-bias trigger* selecting all inelastic interactions of the incident nuclei (*T(0,0)*); (ii) *triggering system for central interactions*, system which is sensitive to the absence of the fast charged fragments or/and fast neutrons ($p_{frag} > 3.5$ *GeV/c*) of the projectile nucleus in different angular ranges ($T(è_{ch} >0, è_n \quad 0))$.

The main deficiency of the SKM 200 Spectrometer is that only the negative pions can be correctly identified by direct methods. Charged particles, with different ionisations, and neutral particles decaying in the streamer chamber are detected, too. Therefore, the main experimental results presented in this paper refer to the negative pions and charged particles.

Experimental data sample contains *3431* events from which we selected *3203* events for peripheral collisions with an average charged particle multiplicity of *4.09±1.39*. The pseudorapidity ç is calculated as a function of emission angle of the particle. Therefore, the uncertainty in the pseudorapidity does not exceed *0.1*. The analysis of the data sample has been performed in Δh interval of (*0.5; 3*). Here we expected to have the events with higher multiplicity, because these events have the biggest contribution to the intermittency effect.

Method presentation

The method used to analyze the intermittent behaviour of single charge particle production is the study of scaled factorial moments F_q, described in terms of pseudorapidity (h), where h is related to the spatial emission angle, q, by the following relationship:

$$h = -\ln(\tan\frac{q}{2})\,. \qquad (1)$$

The phase-space interval Δh is divided in M bins of width:

$$dh = \frac{\Delta h}{M}\,. \qquad (2)$$

The scaled factorial moments are defined as in [3], namely:

$$\langle F_q \rangle = \left\langle M^{q-1} \sum_{i=1}^{M} \frac{\langle n_i (n_i - 1)\ldots(n_i - q + 1)\rangle}{\langle n \rangle^q} \right\rangle, \qquad (3)$$

where n_i is the number of particles in the *i-th* bin, running from *1* to *M*, and $<n>$ is the average multiplicity in the whole Δh interval. For a given order q in the pseudorapidity space considered, the F_q moments are normalised over all events.

The intermittent nature in particle production mechanism gives for the scaled factorial moments a power-law dependency on the phase space width size, given by the following relationship [1-9]:

$$\langle F_q \rangle \approx dh^{-\Phi_q}\text{, as } dh \to 0\,. \qquad (4)$$

Experimental results

As we mentioned previously, experimental data obtained in peripheral *He-Li* collisions at *4.5 A GeV/c* are considered in this paper. The experimental data sample contains *3431* events from which we selected *3203* events for peripheral collisions with an average charged particle multiplicity of *4.09±1.39*. The pseudorapidity is calculated as a function of emission angle of the particle, according to the equation *(1)*. In Fig.2 the experimental pseudorapidity distribution is shown (continuous line). The uncertainty in the pseudorapidity does not exceed *0.1*.

To obtain more information on the particle production mechanism a simulation using HIJING Code has been done. The HIJING Code [10] is a Monte Carlo program for parton and particle production in high energies hadronic and nuclear collisions. The program is based on some QCD inspired models for multiple jet production. It includes different physical aspects to study jet and associated particle production in high energies proton-proton, proton-nucleus and nucleus-nucleus collisions. The Physics background consists in consideration of the multiple minijet productions, soft excitation, soft excitations, nuclear shadowing of parton distribution functions and jet interactions in dense matter. The HIJING Code can be used in a wide energy range.

Therefore, in Fig.2 the predictions of the HIJING Code for the pseudorapidity distribution for He-Li peripheral collisions at 4.5 A GeV/c are included, too (dashed line). Significant differences between experimental and simulated pseudorapidity distributions can be observed, especially in the ranges *0.0* ³ ***h*** ³ *1.5* and ***h*** ³ *3.5*.

The analysis of the experimental data sample has been performed in Δh interval of (*0.5; 3*). Here we expected to have the events with higher multiplicity, because these events have the biggest contribution to the intermittency effect. The corresponding pseudorapidity distribution is presented in the Fig.3.

Defining the multiplicity distribution in terms of the pseudorapidity, ***h***, the experimental normalised factorial moments $<F_q>$'s have been calculated for the order of moments *q=2,3* and *4*. Fig.4 indicates a linear behaviour of $ln < F_q>$ with $-ln\,dh$. The experimental dependencies are compared, for each order *q*, with the HIJING Code predictions (dashed lines). They seem to exhibit qualitative similar behaviours. The slope value obtained by linear best-fit process gives the intermittency exponents. The results are included in Table I. The only significant difference between experimental and HIJING Code simulation results is observed for moment order $q = 3$. This difference could be related to the fact that the ordinary moments of the third order describe the distribution asymmetry. From the results presented in Fig.2 we can observe the significant difference in the symmetry degree of the two curves.

Table I. Experimental and HIJING simulated intermittency exponents

for He-Li collisions at 4.5 A GeV/c

q	F_q^{exp}	$2\Phi_q / q(q-1)_{exp}$	F_q^{HIJING}	$2\Phi_q / q(q-1)_{HIJING}$
2	*0.015±0.004*	*0,015*	*0.012±0.004*	*0.012*
3	*0.070±0.010*	*0,023*	*0.035±0.008*	*0.011*
4	*0.090±0.020*	*0,015*	*0.063±0.013*	*0.010*

Different attempts have been done to find a systematic of Φ_q's [1-9,11]. Using the self-similar cascading model, a scaling rule was proposed which relates the exponents Φ_q's of different orders to second order exponents [11]; the following relationship has been obtained:

$$\frac{2\Phi_q}{q(q-1)} = \Phi_2 = const.. \qquad (5)$$

The experimental and HIJING Code simulation results are included in Table I, too. For experimental results, we observe again a significant deviation for the third order, too. The HIJING Code simulation results present a relative constant value of the intermittency coefficient of second order, obtained by equation (5). Therefore, we can suppose differences in the actual particle production mechanism and the model.

Conclusions

For peripheral *He-Li* collisions at 4.5 A GeV/c we assumed self-similarity in particle production due to a possible cascading nature of the particle production mechanism. Comparisons with HIJING Code predictions indicate some significant differences between experiment and model. These differences include the pseudorapidity distribution forms, scaled factorial moments values, intermittency coefficient values and constancy of the quantity defined by the equation (5). Therefore, Additional analyses are needed to say more about self-similarity and cascading. Comparisons with corresponding values of these quantities obtained in central collisions are necessary, too. Some connections with multi-fractal behaviour could be important, too.

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Figure Captions

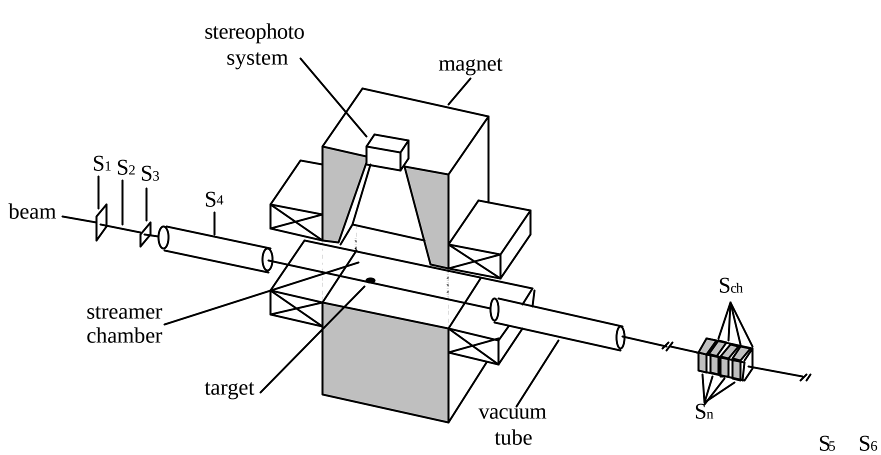

Fig.1- SKM 200 streamer chamber

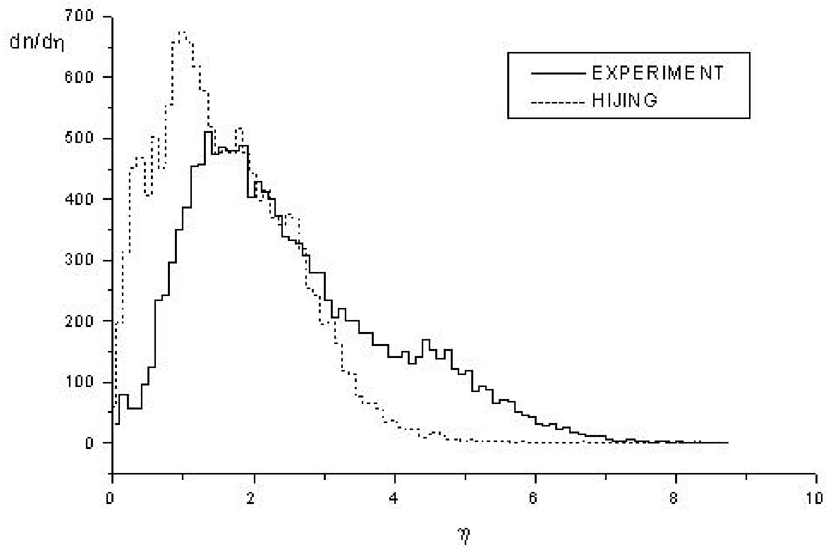

Fig.2 - The experimental pseudorapidity distribution in the full pseudorapidity interval for He-Li peripheral collisions (continuous line). Comparison with HIJING Code simulation (dashed line)

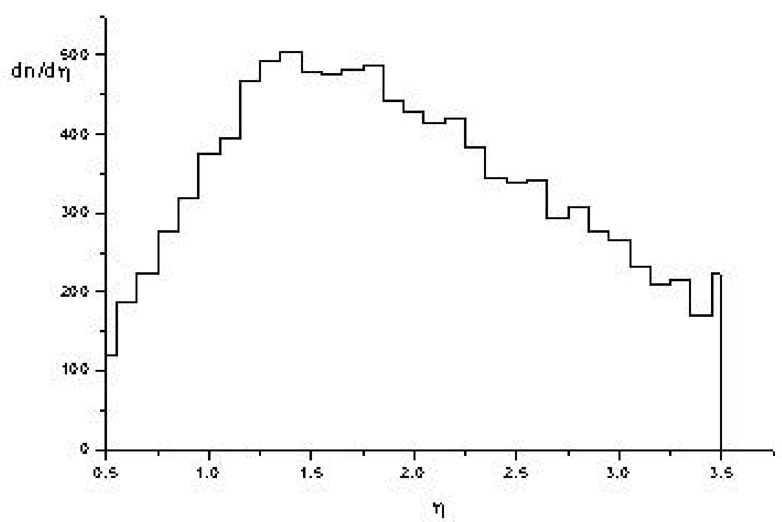

Fig.3 - The experimental pseudorapidity distribution in the selected Δh window

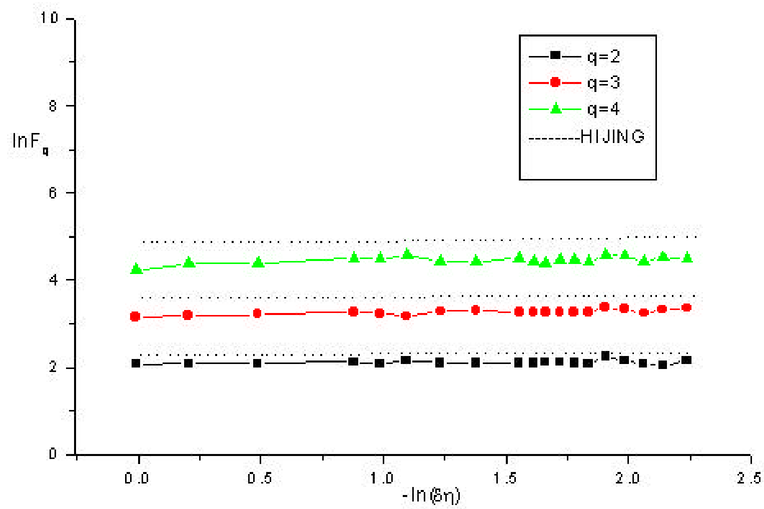

Fig.4 - The variation of *ln<Fq>* as a function of *–lndh* for 3 orders (q=2,3,4). Comparisons with HIJING Code results are include (dashed line for each order)