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CENTRAL COLLISIONS OF ^{208}Pb WITH Ag(Br) NUCLEI AT 158 A GeV/c[1]

J. Vrláková[2,*], S. Vokál[3,*,‡], A. Dirner[4,*]

[*] *Institute of Physics, Faculty of Sci., P.J. Šafárik University, Jesenná 5, 041 01 Košice, Slovakia*

[‡] *Joint Institute for Nuclear Research, 141980, Dubna, Moscow Region, Russia*

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Nonstatistical fluctuations of particle production in relativistic collisions have been studied using the method of scaled factorial moments. Such fluctuations may be used to signal the formation of a quark-gluon plasma in the early stage of heavy ion interactions at high energies. The experimental data of ^{208}Pb nuclei at 158 A GeV/c taken with nuclear emulsion have been analysed. The dependences of intermittency parameter λ_q on the order of factorial moment q have been studied for ^{16}O and ^{208}Pb induced interactions.

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1 Introduction

Quantum chromodynamics predicts the existence of quark-gluon plasma (QGP) - a new phase of strongly interacting systems at high energy density or temperature [1]. Relativistic heavy ion collisions have provided the opportunity to search for the signal of QGP in the laboratory. Large fluctuations of particle production are expected in the transition from QGP to hadron phase [2]. Experimental data on particle fluctuations in a small space domains have been presented for different collisions at different energies [3–6]. In this paper some results of the search for nonstatistical fluctuations of relativistic particles produced in ^{208}Pb+Ag(Br) interactions at 158 A GeV/c have been presented.

2 Analysis and results

The fluctuations of particle distributions also includes statistical fluctuations in addition to dynamical fluctuations. A. Bialas and R. Peschanski [7,8] proposed a method to investigate density fluctuations and showed how dynamical fluctuations could be separated from the statistical noise. They suggested to study the dependence of factorial moment F_q, where q is the order of the moment, as a function of the bin width $\delta\eta$. The intermittent behaviour should lead to a power law

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[2] E-mail address: vrlakova@upjs.sk

[3] E-mail address: vokal@sunhe.jinr.ru

[4] E-mail address: dirner@upjs.sk

dependence $F_q \propto (\Delta\eta/\delta\eta)^{\varphi_q}$, $\varphi_q > 0$, $\Delta\eta$ is the pseudorapidity interval of produced relativistic particles [7, 8]. In our analysis the method of horizontal scaled factorial moments [9] has been used. The standard horizontal factorial moment $F_e^{(H)}(q)$ characterizing the eth event is defined by the following formula

$$F_e^{(H)}(q) = M^{q-1} \sum_{m=1}^{M} \frac{F(n_{me}; q)}{[N_e^{(H)}]^q}, \tag{1}$$

where M is the number of equal bins of size $\delta\eta$ into which the pseudorapidity interval $\Delta\eta$ has been divided, n_{me} is the number of relativistic particles in the mth bin. The non-averaging and non-normalized factorial moment is given by

$$F(n_{me}; q) = n_{me}(n_{me} - 1)...(n_{me} - q + 1). \tag{2}$$

Vertical averaging of $F_e^{(H)}$ gives the full form

$$F^{(H)}(q) = \frac{1}{E} \sum_{e=1}^{E} F_e^{(H)}(q), \tag{3}$$

where E is the total number of events. The denominator of the horizontal moment (1) is given as

$$N_e^{(H)} = \sum_{m=1}^{M} n_{me}. \tag{4}$$

Nuclear emulsions were irradiated horizontally by 158 A GeV/c ^{208}Pb beam at the CERN SPS (experiment EMU12). Experimental details can be found in [10]. In the measured interactions all charged secondary particles were classified according to the commonly accepted emulsion experiment terminology. The relativistic (shower) particles were those with $\beta \geq 0.7$ emitted outside the fragmentation cone. This group includes particles produced in the interactions as well as those knocked-out from the target nucleus. The polar (θ) and azimuthal (ψ) emission angles of all tracks were measured. The pseudorapidity ($\eta = -\ln[\tan\frac{\theta}{2}]$) was calculated for each relativistic particle.

From the total number of 628 measured events of ^{208}Pb + Em interactions at 158 A GeV/c, 64 collisions with the number of relativistic particles $n_s > 350$ have been selected. The interactions with $n_s > 350$ are those of lead nuclei with the heavy emulsion targets Ag and Br [11]. The interactions with $n_s > 700, 1000$, i.e. interactions with increasing number of shower particles or degree of centrality, respectively, have been analysed also. The group with $n_s > 1000$ comprises the central Pb+Ag(Br) interactions [11].

Fig. 1 presents the $\ln < F_q >$ dependence on $\ln M$ (M is number of bins) obtained by horizontal factorial moment method for interactions with $n_s > 350$. The dependences for interactions with $n_s > 700, 1000$ are similar. In Fig. 2 the increasing dependences of values of slopes φ_q ($\ln < F_q >= \alpha_q + \varphi_q . \ln M$) on the order of factorial moment q are shown for all groups of interactions ($n_s > 350, 700, 1000$). The steepest dependence was found for interactions with $n_s > 1000$. The slope values ($\varphi_q > 0$) for Pb+Ag,Br interactions show an evidence for the presence of intermittent behaviour or nonstatistical fluctuations.

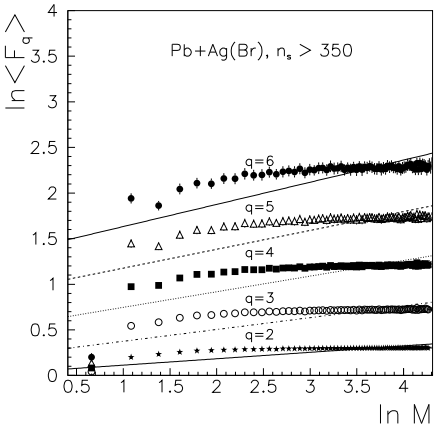

Fig. 1. The dependence of $\ln < F_q >$ on $\ln M$ for Pb+Ag(Br) interactions at 158 A GeV/c, $q = 2-6$, $n_s > 350$.

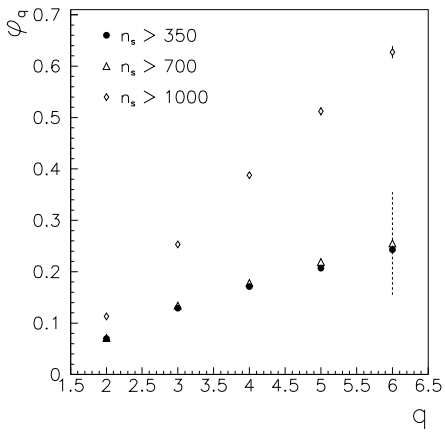

Fig. 2. The dependence of slopes (φ_q) on q for Pb+Ag(Br) interactions with $n_s > 350, 700, 1000$, $q = 2-6$.

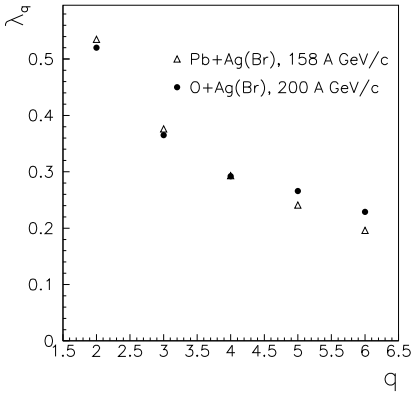

Fig. 3. The dependence of the intermittency parameter (λ_q) on q for ^{208}Pb+Ag(Br) at 158 A GeV/c and ^{16}O+Ag(Br) at 200 A GeV/c .

The dependences of intermittency parameter (λ_q) on the order of factorial moment q for ^{208}Pb at 158 A GeV/c and ^{16}O at 200 A GeV/c induced interactions have been studied. If the function

$$\lambda_q = \frac{\varphi_q + 1}{q} \tag{5}$$

had a minimum at a certain $q = q_c$, there would be a possibility of observing a non-thermal phase transition [12]. There are some hints for the existence of minima at $q_c = 4$ [13] and $q_c = 4 - 5$ [14]. In Fig. 3 the dependences of λ_q on q for both experimental data samples are

presented, but no minimum has been found. The search for minimum was limited for the values of $q < 6$ because of the small numbers of particles emitted in the bins with large value of M.

3 Conclusion

Nonstatistical fluctuations in ^{208}Pb induced interactions in emulsion detector at 158 A GeV/c have been studied. An evidence for the presence of intermittent behaviour has been shown using horizontal factorial moment method. The dependences of intermittency parameter λ_q on q have been studied for ^{16}O at 200 A GeV/c and ^{208}Pb at 158 A GeV/c induced interactions, but no clear minimum has been found.

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