SCALED FACTORIAL MOMEMT ANALYSIS OF Au+Em INTERACTIONS

Jana VRLÁKOVÁ and Stanislav VOKÁL
Institute of Physics, Faculty of Science, University of P. J. Šafárik,
Jesenná 5, 041 54 Košice, tel. 055/62 21926,
E-mail: vrlakova@upjs.sk, vokal@upjs.sk

SUMMARY

Scaled factorial moment analysis for the relativistic particles produced in Au+Em interactions at 11.6 A GeV/c has been done. An evidence for the presence of intermittent behaviour has been shown using three methods of analysis - horizontal, vertical and mixed factorial moment methods. The fluctuations of relativistic particles have been studied on events with different degree of centrality. The results of horizontal factorial moment analysis have been compared with the values obtained for the other experimental data.

Keywords: *scaled factorial moments, fluctuations, relativistic interactions, emulsion detector*

1. INDRODUCTION

Experimental data on particle fluctuations in a small space domains has been presented for different collisions at different energies [1-3]. It has been found that the intermittency is a general property of multiparticle production at high energies [4]. The intermittent behaviour of multiparticle production can be related to the formation of mini-jets, a second order phase transition from quark gluon plasma to the normal hadronic matter or the random cascading process [5]. In this paper we present some results of the analysis of the relativistic particle fluctuations in pseudorapidity scale for ^{197}Au+Em interactions at 11.6 A GeV/c. It has been suggested to study the dependence of factorial moments F_q , where q is the order of the moment, as a function of the bin width δη [6], the pseudorapidity interval is Δη. The intermittent behaviour should lead to a power law dependence of the factorial moments on the bin size

$$F_q \propto \left(\frac{\Delta\eta}{\delta\eta}\right)^{\varphi_q}, \qquad (1)$$

and $\varphi_q > 0$.

2. EXPERIMENT

Nuclear emulsions were exposed horizontally to 11.6 A GeV/c ^{197}Au beam at BNL.The experimental details can be found in [7]. In the measured interactions all charged secondary particles were classified according to the commonly accepted emulsion experiment terminology into following groups:

s-particles (shower), fast particles with $\beta \geq 0.7$ emitted outside the fragmentation cone, these are tracks with ionization $I < 1.4\, I_0$, I_0 is the minimum ionization produced by singly charged particles; this group includes particles produced in the interactions as well as those knocked-out from the target nucleus;

g-particles (grey), charged particles with a range ≥ 3 mm in emulsion with ionization $I > 1.4\, I_0$ $(\beta < 0.7)$ mainly consisting of fast target recoil protons;

b-particles (black), singly and multi-charged fragments evaporated from the target, spectators with a range < 3 mm;

h-particles - target fragments, their numbers obey the relation $n_b+n_g=N_h$;

f-particles, projectile spectator fragments, singly and multiple charged, emitted inside fragmentation cone, usually we determine the number of alpha particles (n_α) and the number of fragments with $Z>2$, separately.

The polar (Θ) and azimuthal (ψ) emission angles of all tracks have been measured. The pseudorapidity

$$\eta = -\ln\left[\tan\tfrac{\theta}{2}\right] \qquad (2)$$

has been calculated for each shower particle.

3. METHODS OF ANALYSIS AND RESULTS

We used three methods of analysis : method of horizontal factorial moments (HFM), vertical factorial moments (VFM) and mixed moments (MFM) published in [8] . The standard horizontal factorial moments $F_e^{(H)}$ characterizing the *eth* event are defined by the following formula:

$$F_e^{(H)}(q) = M^{q-1}\sum_{m=1}^{M}\frac{F(n_{me},q)}{\left[N_e^{(H)}\right]^q}, \qquad (3)$$

where M is the number of equal bins of size δη into which the pseudorapidity interval Δη has been divided, n_{me} is the number of shower particles in the *mth* bin. Non averaging and non normalized factorial moments are given by

$$F(n_{me},q)=n_{me}(n_{me}-1)...(n_{me}-q+1) \tag{4}$$

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

$$F^{(H)}(q)=\frac{1}{E}\sum_{e=1}^{E}F_e^{(H)}(q), \tag{5}$$

where E is the total number of events. Denominator of the horizontal moment (3) is

$$N_e^{(H)}=\sum_{m=1}^{M} n_{me}. \tag{6}$$

Vertical analysis is suggested in case of rare events with sharp peaks [8]. The normalized standard vertical moments characterizing the *mth* bin are given by

$$F_m^{(V)}(q)=E^{q-1}\sum_{e=1}^{E}\frac{F(n_{me},q)}{\left[N_m^{(V)}\right]^q} \tag{7}$$

and the horizontal averaging gives the full form

$$F^{(V)}(q)=\frac{1}{M}\sum_{m=1}^{M}F_m^{(V)}(q), \tag{8}$$

where

$$N_m^{(V)}=\sum_{e=1}^{E}n_{me} \tag{9}$$

is the sum of multiplicities which appear in the *mth* bin of all events. Besides the horizontal and vertical factorial moment methods a mixed approach is applied. Mixed factorial moments are defined as

$$F^{(HV)}=M^{q-1}E^{q-1}\frac{\sum_{m=1}^{M}\sum_{e=1}^{E}F(n_{me},q)}{\left[N^{(HV)}\right]^q} \tag{10}$$

where

$$N^{(HV)}=\sum_{m=1}^{M}\sum_{e=1}^{E}n_{me} \tag{11}$$

is the total number of charged particles observed in the sample of E events.

From the total number of 1,185 measured events of ^{197}Au+Em interactions at 11.6 AGeV/c, 261 events of ^{197}Au induced collisions on Ag (Br) with $n_s > 100$ have been selected. We used for analysis the shower particles in a pseudorapidity window from 0 to 4.75. Fig.1 shows the pseudorapidity distribution of shower paricles for selected events.

For experimental data of Au+Ag(Br) interactions at 11.6 A GeV/c we used all the three

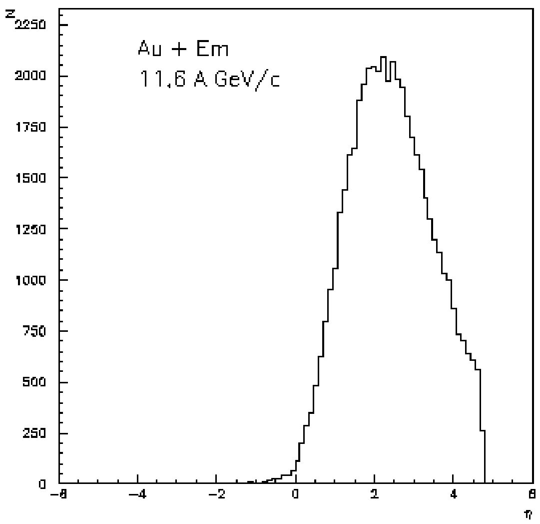

Fig. 1 Pseudorapidity distributions of shower particles for selected Au+Em interactions at 11.6 A GeV/c.

above mentioned methods of analysis - HFM, VFM and MFM methods. Fig.2 presents the $ln\langle F_q\rangle$ dependence on $ln\,M$ (M is number of bins)

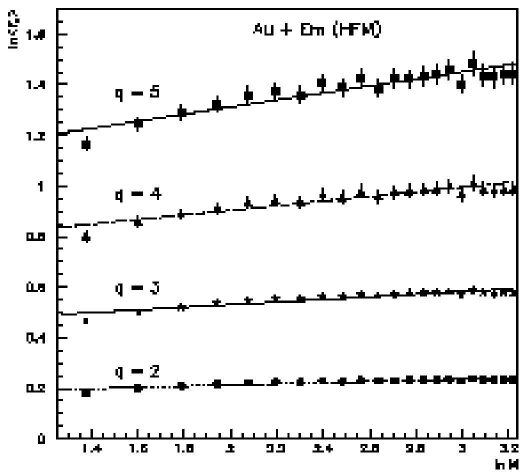

Fig. 2 $ln\langle F_q\rangle$ as a function of $ln\,M$ for Au+Em interactions at 11.6 A GeV/c.

obtained by HFM method. The dependences of $ln\langle F_q\rangle$ on $ln\,M$ were fitted for M=4 - 25. The values of slopes φ_q obtained by all these methods are given in the Table 1 for q=2-5, where q is the order of factorial moment. The errors of slopes were calculated in according to [9].

All three methods show an evidence of presence of intermittent behaviour. φ_q values are the smallest in the case of calculations by VFM. It has been shown in [10] that the values of slopes were similar using all three methods for analysis of ^{28}Si interactions at 14.6 A GeV/c.

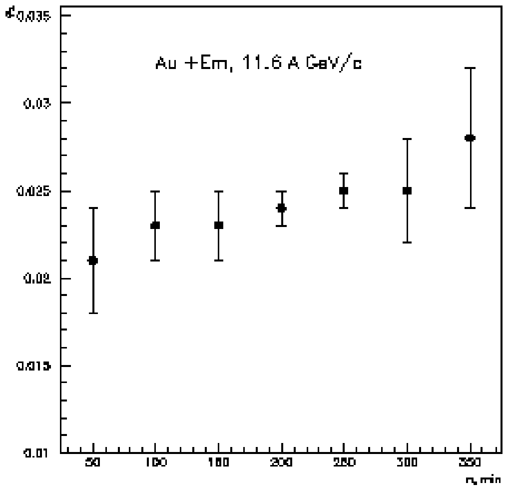

Fig.3 φ_2 dependence on degree of centrality of events.

Tab. 1 The values of slopes for 11.6 A GeV/c ^{197}Au induced interactions in η space for q=2-5 using HFM, VFM and MFM methods, M=4-25.

	HFM	VFM	MFM
φ_2	0.023 ± 0.002	0.010 ± 0.003	0.019± 0.001
φ_3	0.052 ± 0.004	0.034 ± 0.009	0.041 ± 0.003
φ_4	0.092 ± 0.011	0.067 ± 0.025	0.064 ± 0.008
φ_5	0.140 ± 0.024	0.078 ± 0.051	0.084 ± 0.016

Also we have studied the dependence of slopes values on the centrality of selected events. We used the number of shower particles as criteria of centrality of events. We calculated (using HFM method only) the values of slopes for $ln\langle F_q\rangle$ dependence on ln M for different selected events. Fig. 3 presents the φ_2 (the value of slope for q=2) dependence on n_{smin}. One can see that φ_2 increases with increasing of centrality degree of selected events.

For comparison we used different experimental data. Their characteristics - beam nucleus, momentum (P), total number of events (N_t), number of selected events (N_s) and average number of shower particles for selected events ($\langle n_s\rangle$) are given in the Table 2. The values of slopes for the different experimental data using HFM calculations are given in Table 3.

Tab.2 Characteristics of experimental data

	^{16}O	^{28}Si	^{197}Au
P[A GeV/c]	14.6	14.6	11.6
N_t	689	1093	1185
N_s	152	168	261
$\langle n_s\rangle$	48±2	76±2	189±70

The calculations were done by the HFM method, in the same pseudorapidity window $\Delta\eta$= 0 - 4.75 and for same number of bins M=4-25. The values of

Tab.3 The values of slopes of $\ln\langle F_q\rangle$ dependences on ln M for different beam nuclei

	^{16}O	^{28}Si	^{197}Au
φ_2	0.036 ± 0.005	0.029 ± 0.004	0.023 ± 0.002
φ_3	0.085 ± 0.014	0.063 ± 0.010	0.052 ± 0.004
φ_4	0.149 ± 0.026	0.100 ± 0.018	0.092 ± 0.011
φ_5	0.224 ± 0.040	0.133 ± 0.027	0.140 ± 0.024

slopes φ_q obtained for different beam nuclei at similar momenta (11.6 - 14.6 A GeV/c) are similar.

The same trend was shown in [11], where the ^{22}Ne, ^{28}Si and ^{32}S interaction with emulsion have been studied at 4.1 - 4.6 A GeV/c.

4. CONCLUSION

Non-statistical fluctuations in multiparticle production at 11.6 A GeV/c of Au+Ag(Br) interactions have been analysed using horizontal, vertical and mixed factorial moment methods.Three methods of analysis - horizontal, vertical and mixed factorial moment methods give an evidence for the presence of intermittent behaviour for ^{197}Au induced interactions at 11.6 A GeV/c. Values of slopes for $ln\langle F_q\rangle$ dependences on *ln M* (calculated by HFM only) for different beams with similar momenta (from 11.6 to 14.6 A GeV/c) are similar.

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