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ABSTRACT

The experimental data on multiplicities of charged secondaries produced in pion-núcleus interactions in an emulsion at 200 Gev/c and correlations between them are presented and discussed. Parameters of multiplicity distributions are compared with the relevant ones at lower energies and with data from pA-interactions at 200 Gev/c. The multiplicity of heavily ionzing particles in π^-A-interactions weakly depend on the incident energy. The KNO scaling is observed being the same for incident protons and pions.

INTRODUCTION

There is the increasing interest in the study of inelastic hadron-nucleus interactions /1/. This interest is evoked by the hope that a study of hadron-nucleus collisions can throw light upon the mechanism of multiple production, that gives the dominant contribution to inelastic cross-sections at high energies.

We report here the experimental results on multiplicity of charged secondary particles in inelastic collisions of 200 Gev/c π^--mesons with emulsion nuclei.

EXPERIMENTAL MATERIAL

The stacks of 600 mkm layers of GOSNIIHIMFOTOPROEKT BR-2 nuclear emulsions were exposed to 200 Gev/c π^--meson beam at the Fermilab accelerator. By along the track scanning 5255 events have been recorded on the effective length of primary track equal to 2314.6 m. Inthese events all the charged particles were classified according to their ionization and range into shower ($I < 1.4I_o$, I_o is the ionization of primary tracks), gray ($I \geqslant 1.4I_o$, the kinetic energy of protons $T_p > 30$ Mev) and black ($T_p \leqslant 30$ Mev) prongs, and the emission angles of shower particles were measured.

After the exclusion of the elastic scatterings (39 events), the coherent reactions (221 events), an analysis of which will be published elsewhere and interactions on the hydrogen nuclei (p-free-p interactions, 185 events) our sample of inelastic pion-nucleus collisions analyzed in this paper consists of 4810 events with the measured n_b, n_g and n_s and the emission angles of shower secondaries.

MULTIPLICITY OF HEAVILY IONIZING PARTICLES;

In the Fig.1 we have plotted multiplicity distributions of heavily ionizing b-,g- and h-particles ($n_h = n_b + n_g$) in inelastic interactions of 200 Gev/c pions in emulsion, and the Table1. presents the mean values of multiplicities of different kinds of charged secondaries in comparision the available data/2 - 5/.

One can see from Table 1. that the mean multiplicities of heavy tracks practically do not depend on the energy supporting the assumption that the energy transferred by projectile to the target nucleus is independent (or very weakly depends) on the incident energy. From the comparision of π^-A and pA data at the same energy we see also that the mean multiplicities of heavy prongs are systematically smaller in pA interactions. In the classical picture of consecutive infranuclear collisions of projectile (see,e.g./12/) the mean multiplicities of nuclear fragments are the monotonuosly growing functions of the number of intranuclear collisions ν . The mean values of ν ,in turn, are conditioned by the size of nucleus and by inelastic hadron-nucleon cross section. Therefore in such a picture it is easy to understand the difference between multiplicities of heavy prongs in π^-A and pA interactions if we take inte account the fact that $\sigma_{inel}(\pi N) < \sigma_{inel}(pN)$.

Moreover, comparing the data of Fig.1. with the relevant distributions at lower energies /3,6/ one can conclude that multiplicity distributions of heavy tracks weakly depends on the incoming energy as well. For instance, the quantity $\langle n_h \rangle / \sqrt{D}$ ($D = \langle n^2 \rangle - \langle n \rangle^2$) in π^-A interactions in emulsion at 7.5; 17; 60 and 200 Gev equals to 1.07 ± 0.04; 1.05 ± 0.02; 1.0 ± 0.03; 0.95 ± 0.02, and the integral correlation parameter

$$f_2 = \langle n(n-1) \rangle - \langle n \rangle^2$$

for h-particles equals to 32.4 ± 2.2; 39.0 ± 1.4; 45.1 ± 2.4, and 46.64 ± 154, respectively. It should be noted, however, that due to composite nature of emulsion the distinction of $f_2(h)$ from the zero could not be considered as an indication of two-partiále correlations between the nuclear fragments.

Such limiting behaviour of multiplicity of the target fragmentation products contradicts obviously the classical intranuclear cascading /7/ and consistent with the models /8,11,12/ which take into account the details of the spase-time structure of multiple production.

MULTIPLICITY OF SHOWER PARTICLES.

Fig.2a. presents the available data on the mean multiplicity of relativistic particles $\langle n_s \rangle$ in π^-Em interactions /2,3,4,6/ in comparision with the energy dependence of $\langle n_{ch} \rangle$ from π^-p-collisions /9/. It is seen that the energy dependence of $\langle n_s \rangle$ is similar to that in π^-p-interactions and could be described satisfactorily by a logarithmic law (the straight lines in Fig.2a.). In Fig2b, the data, characterizing the energy dependence of the popular ratio $R = \langle n_s \rangle_{\pi A} / \langle n_{ch} \rangle_{\pi p}$, that is the measure of nuclear multiplication of produced particles are plotted. We see that the ratio R for $\pi^- A$-interactions increases in the range 17 - 200 Gev/c. Although the energy dependences of R are similar in $\pi^- A$- and pA-interactions (the curve 4 in the Fig.2b. approximates the energy dependence of R in pA-collisions[5,10], the absolute values of $R_{\pi^- A}$ are smaller noticeably than R_{pA}. This distinction is the consequence of the fact that $\langle n_s(\pi^- A) \rangle < \langle n_s(pA) \rangle$ and $\langle n_{ch}(\pi^- p) \rangle > \langle n_{ch}(pp) \rangle$ at the same energy of projectile hadron. In models of type[11,12] where the incoming hadron interacts consecutively with the intranuclear nucleons, the observed difference in mean multiplicities of shower particles in pA- and $\pi^- A$-collisions, in turn, could be connected with the well known distinction between inelastic proton-nucleon and pion-nucleon cross sections.

It is interesting to define the A-dependence of the mean multiplicity of shower particles. This dependence obviously is conditioned by the parametrization accepted for $\langle n_s \rangle$. If we assume that $\langle n_s \rangle_{\pi^- A} = \langle n_{ch} \rangle_{\pi p} A^{\alpha}$, then the parameter α can be defined easily by using the well known relation

$$R = \sum_i N_i \sigma_i A_i^{\alpha} / \sum_i N_i \sigma_i , \qquad (2)$$

where N_i is the density of nuclei of i-th type in emulsion and σ_i is the inelastic cross section. Taking the value

$R = 1.52 \pm 0.02$ for π^-A-interactions at 200 Gev/c obtained in the present work, we have

$$\alpha = 0.092 \pm 0.005 ,$$

i.e. very weak dependence on the size of target nucleus. We point out that this value is smaller considerably than $\alpha = 0.15$, defined earlier for pA-interactions at the same energy/5/.

Fig.3. shows the multiplicity distribution of shower particles and in Fig.4 this distribution is plotted in the scaling variables $z = n_s / \langle n_s \rangle$. Curves in Fig.3. represent theoretical distributions, coming from the Gottfried's/11/ (the curve 2) and Fishbane-Trefil/12/ (the curve 1) models, which have been calculated by a way described in details in/5/. As it is well known, these models predict, that in hadron-nucleus interactions

$$\langle n_s(hA) \rangle = (a + b \langle \nu \rangle) \cdot \langle n_{ch}(hN) \rangle , \qquad (3)$$

where $a = b = 0.5$ in the two-phase model of hadronic matter/12/ and the energy flux cascade model/11/ predicts $a = 2/3$, $b = 1/3$. We see from the Fig.3., that the curve 1 gives the more preferable description of experimental data. It should be stressed, however, that in general the parameters a and b in eq.(3) may depend on the mass number of nucleons and incident energy. Such results has been predicted, for instance, in the framework of the parton model/8/.

The curve shown in Fig.4. represent the KNO scaling function

$$\psi(z) = (3.0z + 26\,z^3 + 4.6\,z^5 + 0.18\,z^7)\exp(-4.0\,z), \quad (4)$$

that has been defined in the reference /5/ by fitting experimental data on pA-interactions. Itis seen, that the multiplicity of shower particles in π^-A-interactions at 200 Gev/c is consistent with the KNO scaling hypothesis and the KNO function in the first approximation does not depend on the projectile (proton or pions).

There are the well known regularities for multiplicity moments in pp- and $\pi^{\pm}$p-interactions at high energies. Although the reliable data on multiplicity in π^-A-interactions are not so rich as in π^-p-interactions, we can note, that the ratio $\langle n_s \rangle / D$, that equals to 1.73 ± 0.03 for our data, concides with the value 1.78 ± 0.07 obtained in /6/ for π^-A-interactions at 60 Gev/c. Howwever the normalized moments of n_s-distribution C_2, C_3 $(C_k = \langle n_s^k \rangle / \langle n_s \rangle^k)$ $(1.33 \pm 0.03$ and 2.22 ± 0.09, respectively) in 200 Gev/c π^-A-interactions concide with the values asymptotic for hadron-nucleon collisions /13/.

CORRELATIONS BETWEEN MULTIPLICITIES OF CHARGED SECONDARIES.

We present our results on correlation dependences of the type $\langle n_i(n_j) \rangle$ $(n_i, n_j = n_s, n_g, n_b, n_h)$ in π^-A-interactions in Fig.5. As follows from this Figure all these dependences could be fitted satisfactorily by the linear functions with positive slopes

$$< n_i > = a_{ij} n_j + b_{ij} \quad (a_{ij} \sim 0) \qquad (5)$$

in the whole range of n_j variation (except the dependences on n_g, which reach a plateau at $n_g \gtrsim 8 - 10$). The straight lines plotted in Fig.5 represent the fits to experimental data and parameters a_{ij}, b_{ij} are listed in Table 2. The dependence $< n_s (n_g) >$ is the most strong one, just as in pA-interactions, so n_g is the most acceptable measure of the number of intranuclear collisions of the projectile (or leading cluster).

From the comparision of the character of multiplicity correlations in πA and pA[5]-interactions at 200 Gev/c it is easy to observe that: 1) correlations between slow secondaries do not depend on the nature of projectile (the amount of g and b-particles in the heavy component is the same both in pA and in πA-collisions), 2) the mean multiplicity of shower particles at fixed n_h or n_g is larger for pA-interactions, 3) there is the indication that the "saturation" of $< n_s(n_g) >$ -dependence is reached earlier in πA-interactions.

All these features can be qualitatively reproduced by models of hadron- nucleus interactions, where the production results in consecutive collisions of leading particle (or leading cluster) with intranuclear nucleons.

CONCLUDING REMARKS.

The experimental data show that:

1.Multiplicity of heavily ionizing particles in πA-interactions (as well as in pA-collisions) weaklydepends on the incident energy.

2. Parameters characterizing multiplicity of shower particles are similar to that in π^-N-interactions. The KNO scaling is observed, and KNO function,depending on A, is the same for incident protons and pions.

3. It is probably that multiplicity of all charged secondaries in π^-A (and generally in hadron- nucleus) interactions is conditioned by the unique "nuclear" parameter ν - the number of collisions of the incident particle with intranuclear nucleons ($\langle\nu\rangle = A \cdot \sigma_{hN} / \sigma_{hA}$).

In conclusion we are glad to thank the management of FNAL for exposition of emulsion chambers.The help of Profs. L.Voyvodic and I.V.Chuvilo is greatly acknowledged.

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TABLE 1. The average multiplicities of charged particles in π^- Em interactions.

	π^-A 17 Gev/c /2,3/*	π^-A 50 Gev/c /4/	π^-A 60 Gev/c /2,3/*	π^-A 200 Gev/c this work	pA 200 Gev/c /5/
$\langle n_h \rangle$	6.5 ± 0.4 7.27±0.04		7.3 ± 0.3 7.02±0.05	6.98±0.10	7.54 ± 0.20
$\langle n_b \rangle$	5.0 ± 0.4		4.7 ± 0.2	4.58± 0.07	4.97 ± 0.13
$\langle n_g \rangle$	1.5 ± 0.2	2.20±0.2	2.6 ± 0.2	2.42±0.05	2.57±0.08
$\langle n_s \rangle$	5.3 ± 0.3 5.24±0.04	7.6 ± 0.4	8.6 ± 0.2 9.23±0.07	12.23±0.1	14.0 ± 0.2

* The first value corresponds to the data from /2/.

TABLE 2. Results of the fits of experimental data on multiplicity correlations by the linear dependences $\langle n_i \rangle = a\, n_j + b$

	n_h	n_b	n_g	n_s
$\langle n_h \rangle$		$1.44n_b+0.34$	$2.25n_g+1.42$	$0.50n_s+0.83$
$\langle n_b \rangle$	$0.66n_h+0.01$		$1.25n_g+1.42$	$0.32n_s+0.67$
$\langle n_g \rangle$	$0.34n_h+0.01$	$0.44n_b+0.36$		$0.18n_s+0.14$
$\langle n_s \rangle$	$0.54n_h+8.51$	$0.74n_b+8.80$	$1.17n_g+9.37$	

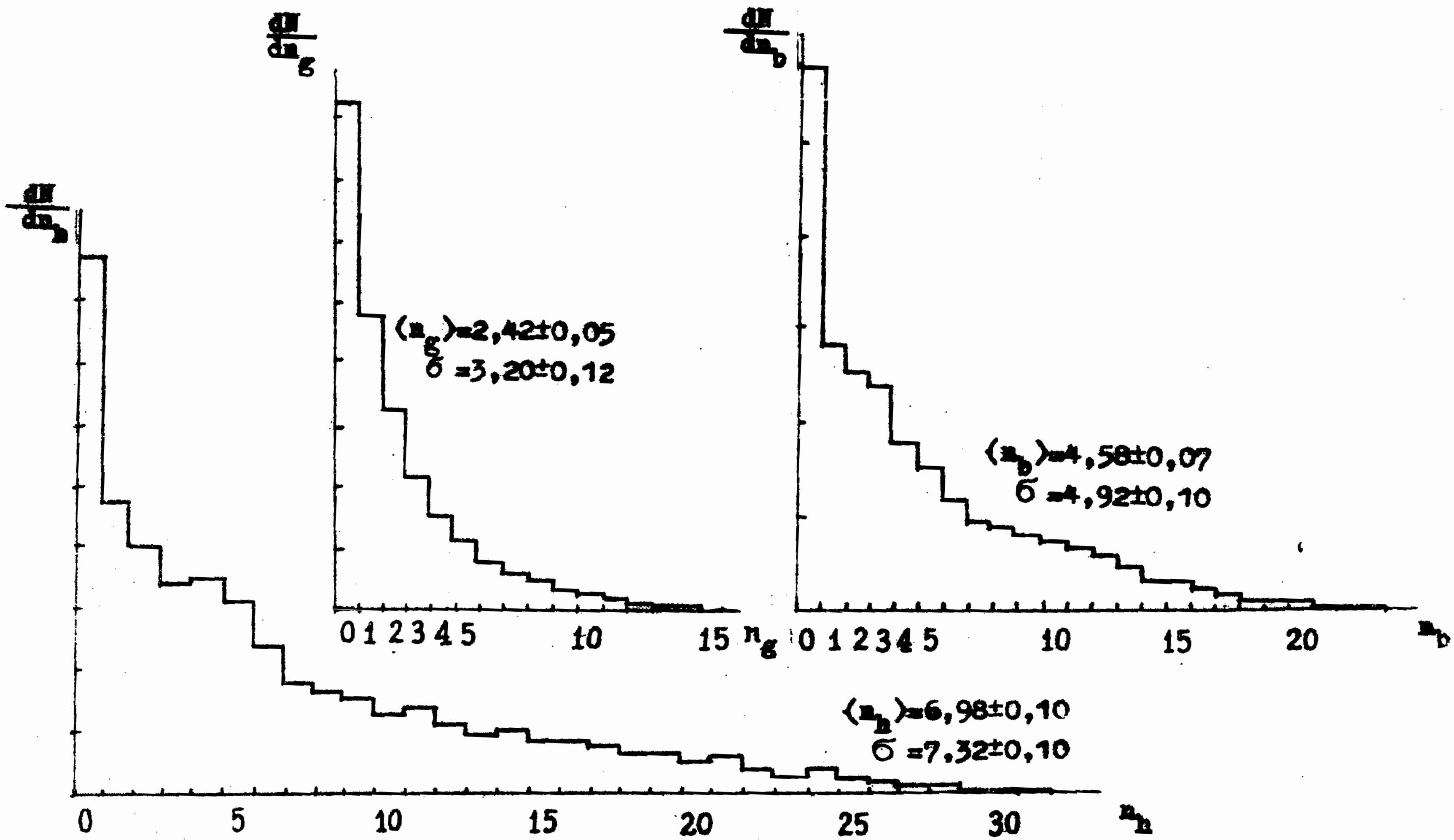

Fig 1. Multiplicity distributions of "gray","black" and heavily ionizing particles in π^-A-collisions in emulsion at 200 Gev/c.

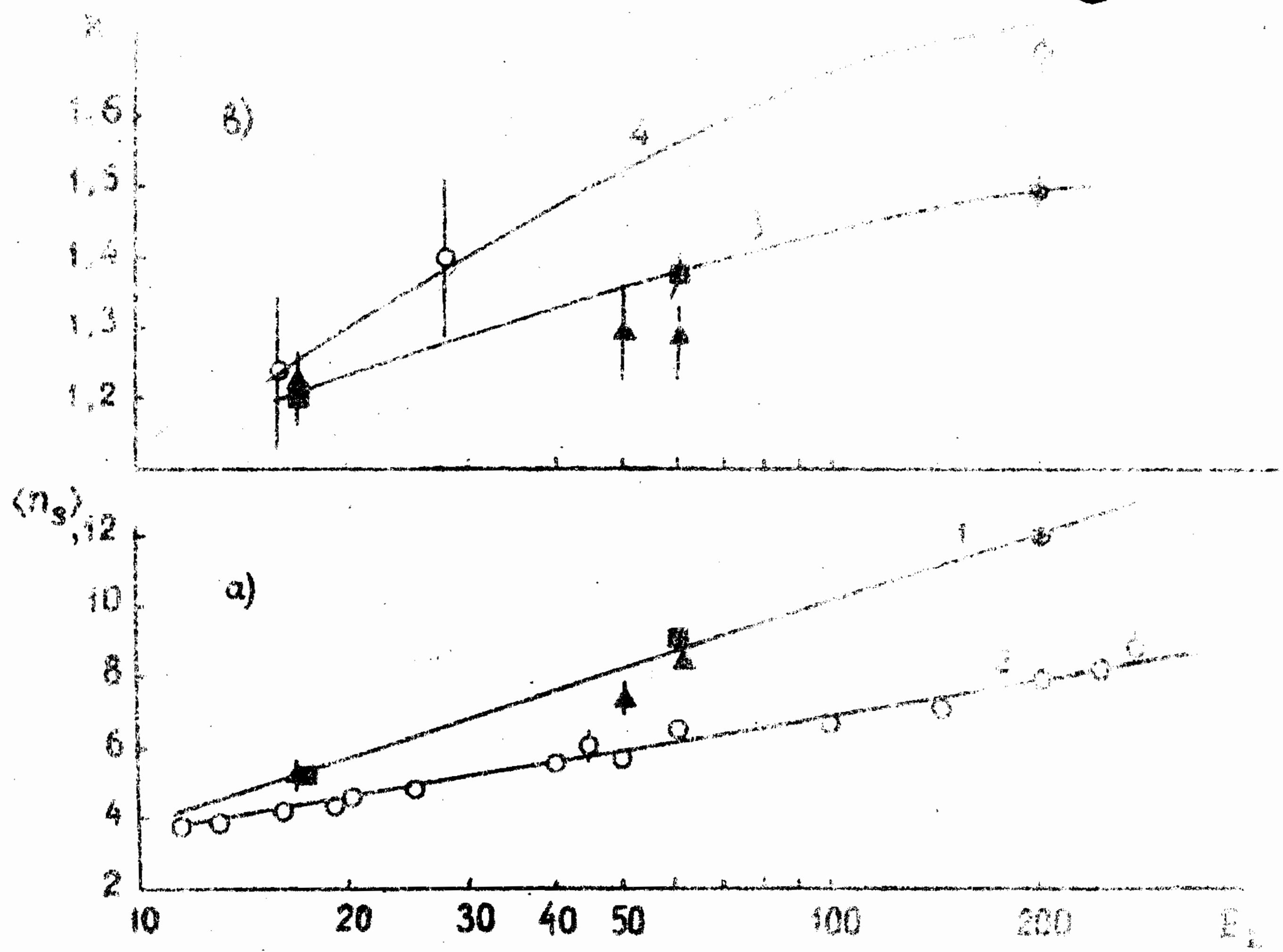

Fig 2. a) Energy dependence of the average multiplicity of relativistic particles $\langle n_s \rangle$ in $\pi^- A$-interactions[2,3,4,6] in emulsion (black figures) and in $\pi^- p$-collisions[9] (white figures). The straight lines 1 and 2 are logarithmic laws of energy dependences of $\langle n_s \rangle$ in $\pi^- A$ and $\pi^- p$-interactions.

b) Energy dependence of $R = \langle n_s \rangle / \langle n_{ch} \rangle$ in $\pi^- A$ (black figures) and pA-collisions (white figures). Curves approximate energy dependences of R in $\pi^- A$ (curve 3) and in pA-interactions (curve 4). (See[5,10]).

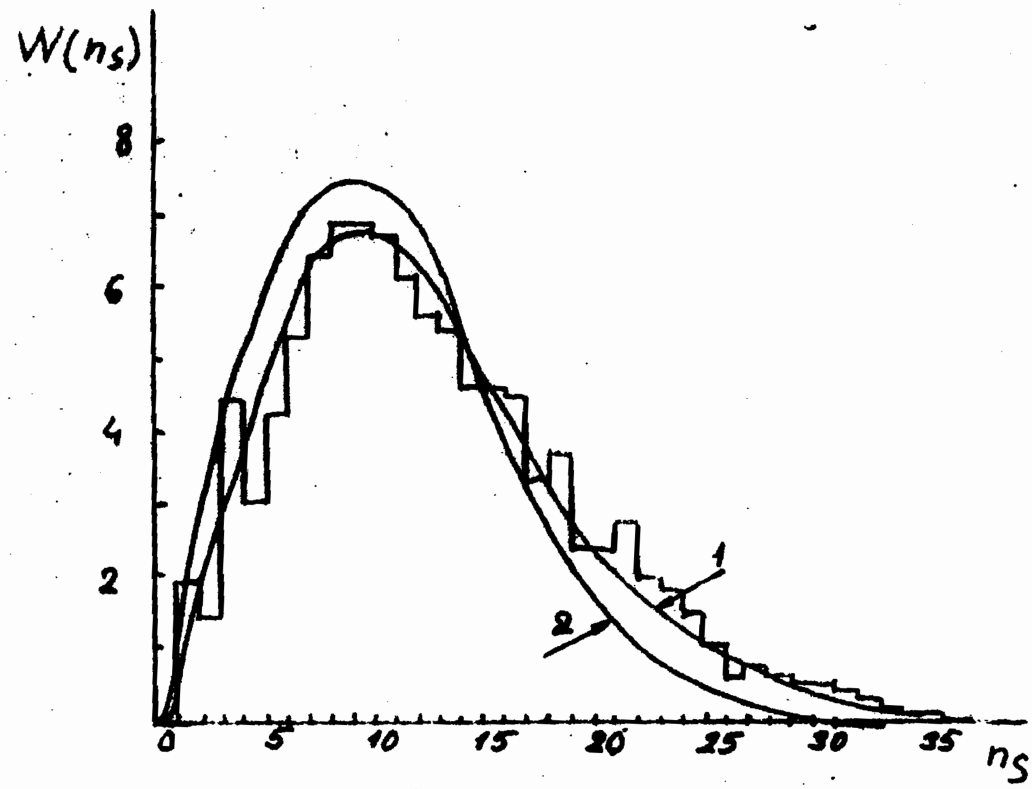

Fig 3. Multiplicity distribution of shower particles. Curve 1 represents theoretical distribution coming from Fishbane-Trefil model[12], and curve 2- model of Gottfried[11].

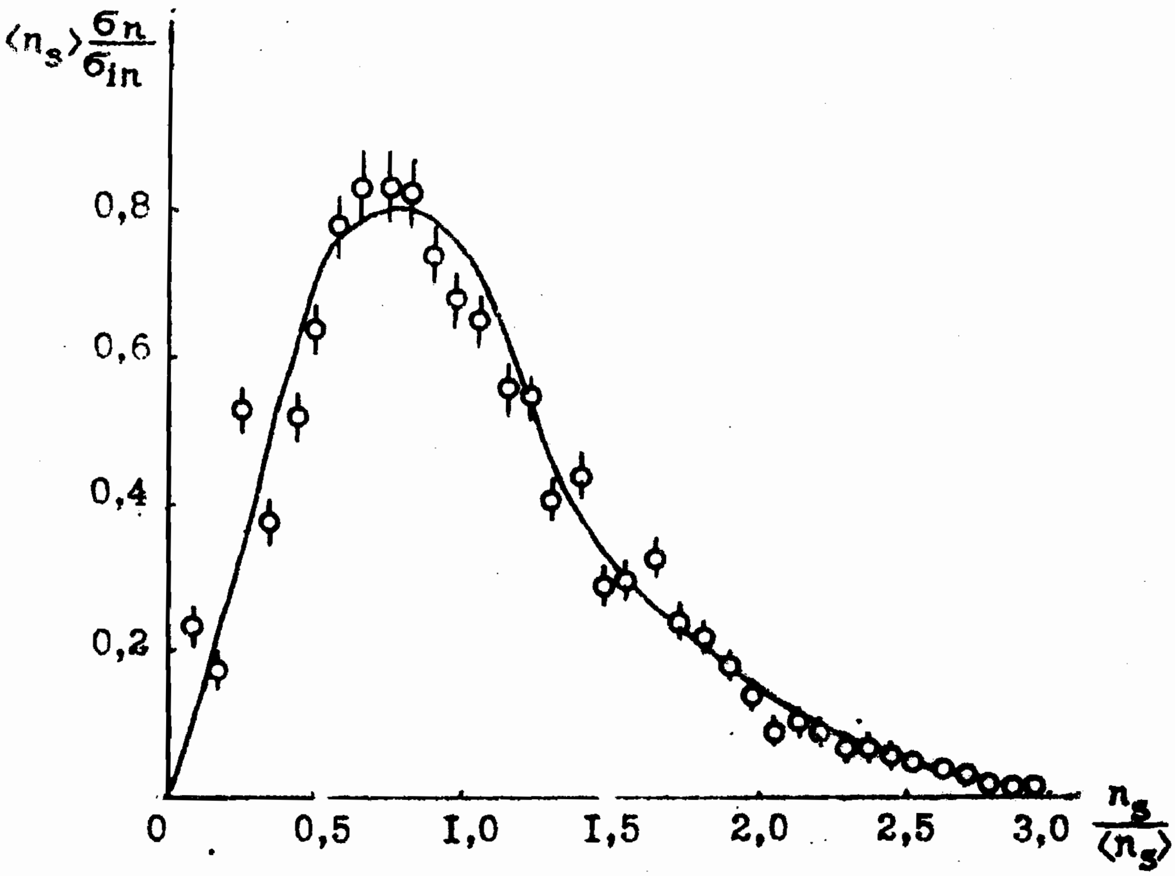

Fig 4. Multiplicity distribution of shower particles plotted in the scaling variables $z=n_s/\langle n_s \rangle$. The curve represent[5] the KNO scaling function (4) fitting experimental data on pA-interactions.

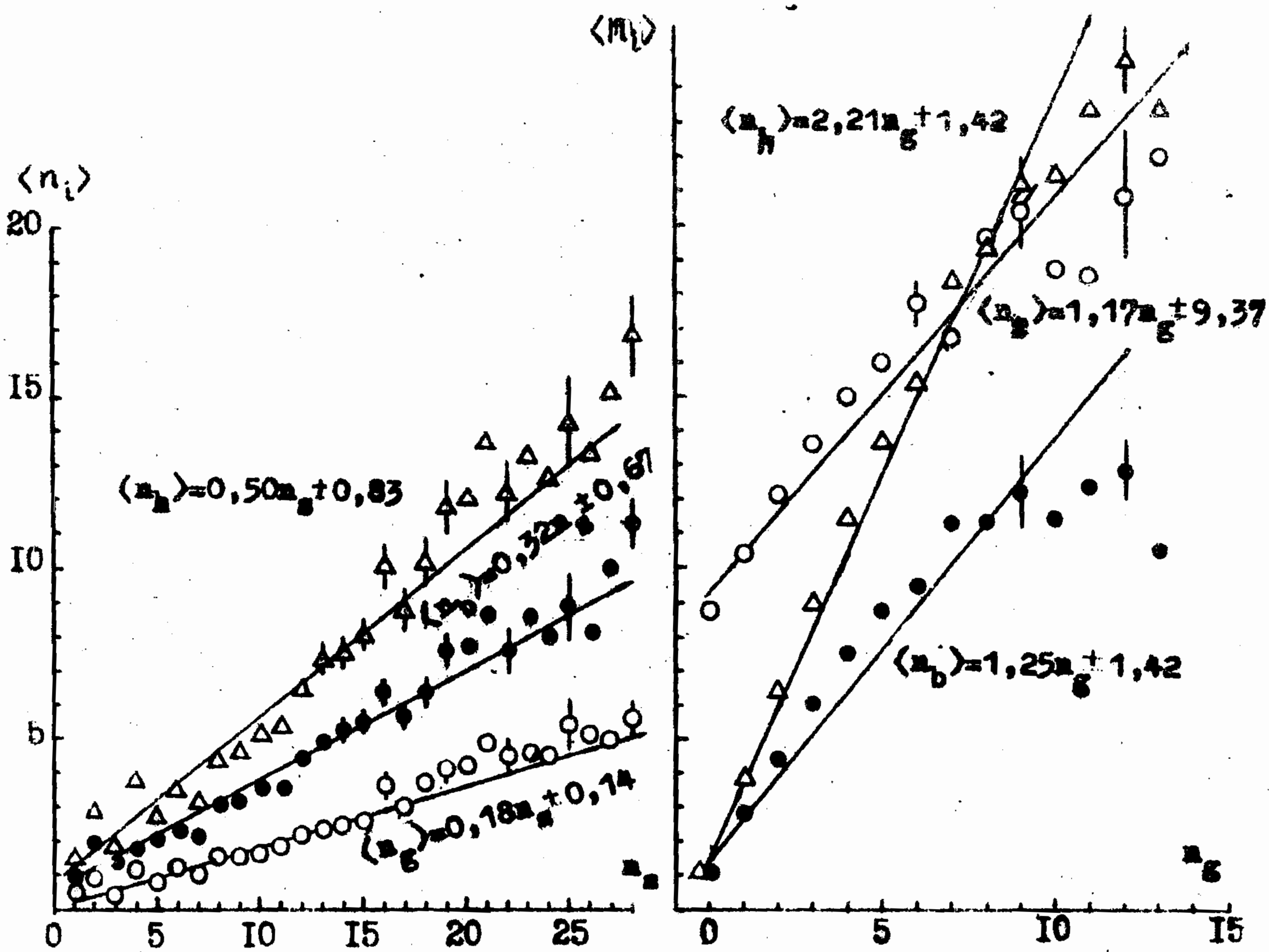

Fig 5a. Correlations of multiplicities of secondary particles $n_i(n_j)$; (n_i, n_j (i=j): n_s, n_g, n_b, n_h) in π^-A-interactions in emulsion.

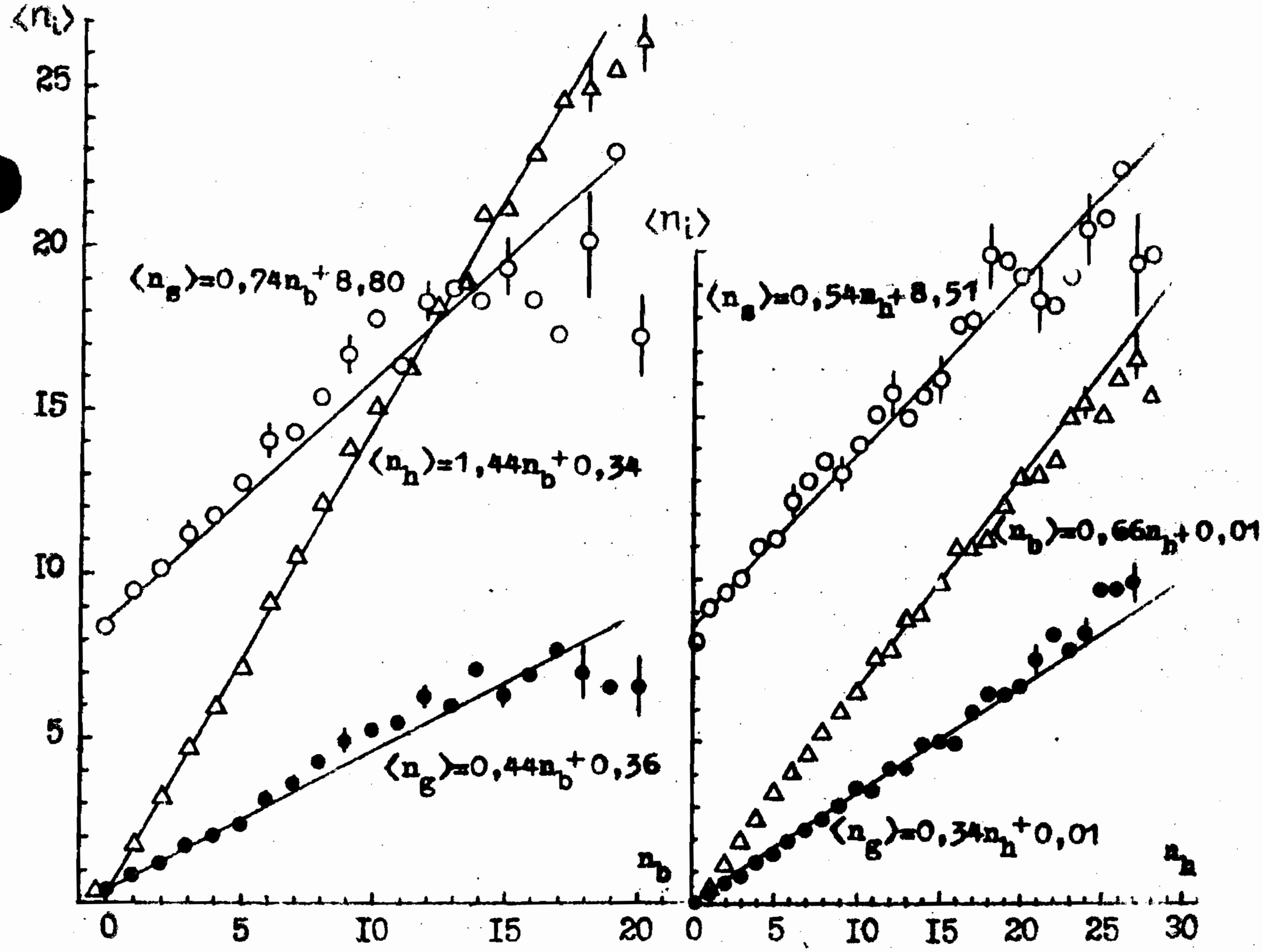

Fig 5b. Correlations of multiplicities of secondary particles $n_i(n_j)$; $(n_i, n_j (i=j): n_s, n_g, n_b, n_h)$ in π^-A-interactions in emulsion.