PION-NUCLEUS INTERACTIONS IN EMULSION AT 300 GeV*

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We present general characteristics of inelastic interactions of negative pions with emulsion nuclei at the energy 300 GeV. The multiplicity distributions of disintegration products of the target nucleus as well as produced particles are presented and compared with the data obtained from π^- interactions in emulsion at 60 GeV and 200 GeV. The pseudorapidity distribution of shower particles exhibits a plateau at the central region. No evidence of the bimodal structure of pseudorapidity distribution is observed.

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1. *Introduction*

In recent years many papers dealing with hadron-nucleus interactions were published, yet the accumulated experimental material is still not sufficient to create a consistent picture of hadron-nucleus interaction and to discriminate between different theoretical descriptions. Since only a few high energy pion-nucleus experiments were performed, some basic problems still remain an open question. For instance, it was claimed in [1] that in pion-emulsion interactions at 200 GeV a bimodal structure in pseudorapidity distribution of produced particles appears. Thus it was desirable to investigate whether this effect persists at higher energies of primary pions.

We compare our results obtained for π^--emulsion interactions at 300 GeV with those published by us earlier [2] which refer to π^--emulsion interactions at 60 GeV and 200 GeV. The important feature of this comparison is that all three samples were obtained in one laboratory under the same experimental conditions, e.g. scanning, measurements, selection criteria of elastic and coherent events.

The paper is organized as follows: In Sec. 2 we describe the experimental material. Sec. 3 deals with charged target fragments. In Sec. 4 we present the multiplicity and pseudorapidity distributions of shower particles. Sec. 5 contains concluding remarks.

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2. *Experimental material*

Stacks composed of Ilford G5 nuclear emulsion pellicles, 600 μm thick were exposed to 300 GeV negative pion beam at Fermilab (Fermilab exp. E574). During the exposure pellicles were oriented parallel to the beam and the pion density was 2×10^4 particles/cm^2. Interactions of beam particles were found by along the track scanning. Elastic, coherent and electromagnetic events were rejected from the total sample of events found. We consider the remaining events as an unbiased sample of inelastic pion interactions with hydrogen (~3% of the events), CNO (~23%) and AgBr (~74%) nuclei. Altogether we collected 2115 inelastic 300 GeV π^--emulsion interactions.

In each event the number of slow ($\beta \leqslant 0.7$) particles N_h being the products of disintegration of emulsion nucleus and the number of relativistic ($\beta > 0.7$) shower particles n_s were carefully counted. The emission angle of each shower particle was measured with respect to the direction of the primary particle. The heavy ionizing (slow) particles were divided into two categories: black and grey so that $N_h = N_b + N_g$. Black tracks are mainly tracks of evaporation products of the struck nucleus. Their range in emulsion is smaller than 3000 μm. Grey tracks are chiefly due to recoil protons. Their range in emulsion is greater than 3000 μm and ionization greater than $1.4\, I_0$, where I_0 stands for ionization of singly charged relativistic particle.

3. *Charged target fragments*

In Fig. 1a, b we present the distributions of grey and black tracks emitted from π^--emulsion interactions at 300 GeV, 200 GeV and 60 GeV primary pion energy. In Table I the average multiplicities $\langle N_g \rangle$, $\langle N_b \rangle$ and $\langle N_h \rangle$ are given. It is seen that the distributions of grey and black tracks do not depend on the energy of the primary pion in the energy range considered, similarly as it was observed in proton-nucleus interactions.

It was shown by Hegab and Hufner [3] and Suzuki [4], who investigated low energy intranuclear cascade initiated by nucleons recoiled by the primary particle, that this cascade is responsible for the origin of grey tracks. In [3] the relation was found between the number N_g of grey particles and the number ν of collisions of the projectile particle inside the nucleus. This relation agrees well with those found previously using phenomenological approach [5–9].

As it was shown above, the distributions of N_g and N_b do not depend on the primary pion energy, thus we can investigate the dependence of the mean number of black tracks

TABLE I

Number of events	E_0 (GeV)	$\langle N_g \rangle$	$\langle N_b \rangle$	$\langle N_h \rangle$	$\langle n_s \rangle$	D
788	60	1.73 ± 0.08	5.38 ± 0.20	7.11 ± 0.26	8.59 ± 0.18	4.93 ± 0.12
973	200	2.13 ± 0.09	4.61 ± 0.15	6.73 ± 0.22	11.94 ± 0.23	7.09 ± 0.16
2115	300	2.08 ± 0.06	4.89 ± 0.11	6.96 ± 0.16	14.23 ± 0.18	8.32 ± 0.12

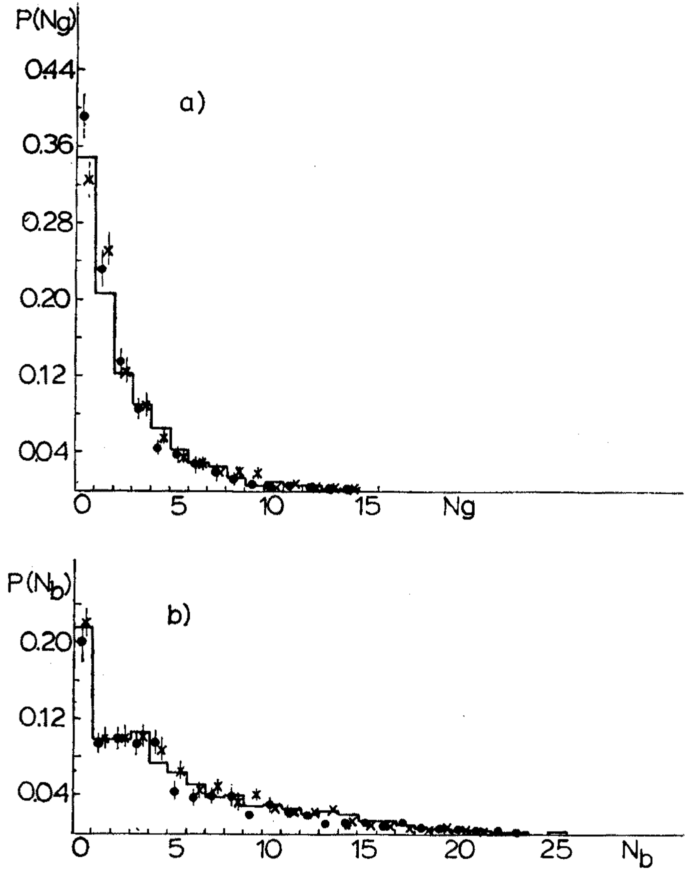

Fig. 1

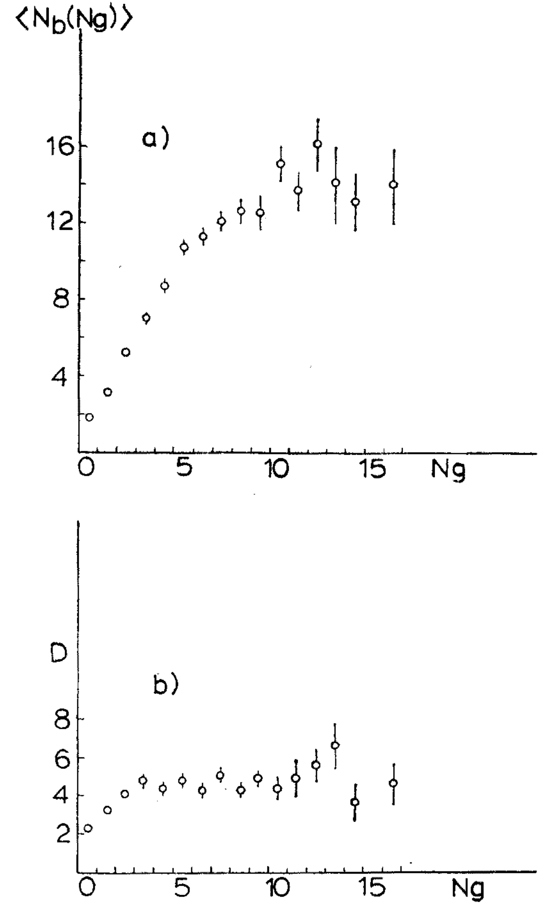

Fig. 2

Fig. 1. The distribution of a) grey and b) black tracks in π^--emulsion interactions at ● — 60 GeV, × — 200 GeV, histogram — 300 GeV. The statistical errors for 300 GeV distribution are omitted for clarity. They are 1.5 times less than those at lower energies

Fig. 2. a) The average number of black tracks $\langle N_b \rangle$ emitted in π^--emulsion interactions characterized by a given number of grey tracks N_g. b) Dispersion $D = (\langle N_b^2(N_g) \rangle - \langle N_b(N_g) \rangle^2)^{1/2}$ of $N_b(N_g)$ distribution vs N_g

$\langle N_b(N_g)\rangle$ in function of the number of grey tracks N_g using the pooled 60 GeV, 200 GeV and 300 GeV data. This dependence is depicted in Fig. 2a. Strong correlation is observed. For not very high values of N_g the dependence of $\langle N_b\rangle$ on N_g is linear: $\langle N_b\rangle = (1.79 \pm 0.06) + (1.66 \pm 0.04)N_g$ and levels off at $N_g \simeq 7$. The dispersion of the N_b distribution for a given N_g is presented in Fig. 2b.

Strong, energy independent correlation of $\langle N_g\rangle$ on N_b suggests that the degree of excitation of the hit nucleus increases with the number of recoil nucleons. Thus the number of black tracks N_b as well as the sum $N_h = N_b + N_g$ can be used as a measure of a number ν of the primary particle collisions inside the nucleus. The relations of $\langle\nu\rangle$ on N_b and $\langle\nu\rangle$ on N_h are given in [6, 9].

4. *Multiplicity and pseudorapidity distributions of shower particles*

In Table I we present the mean multiplicity and the dispersion of the multiplicity distribution of shower particles in π^--emulsion interactions. The multiplicity distribution for 300 GeV π^--emulsion interactions is depicted in Fig. 3. In Fig. 4 we present the multi-

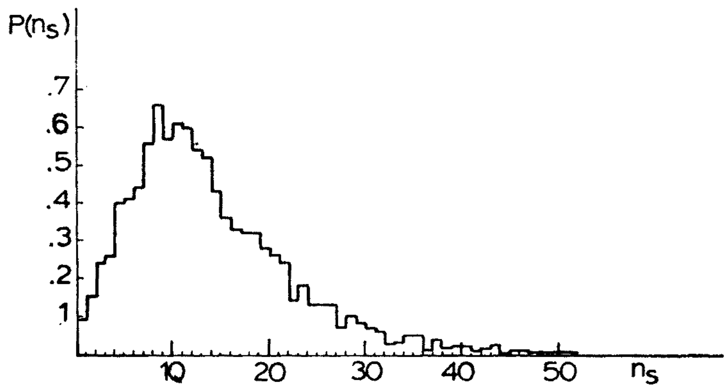

Fig. 3. Multiplicity distribution of shower particles for 300 GeV π^--emulsion interactions

plicity distribution function $\psi = \langle n_s\rangle\sigma_n/\sigma_{\rm inel}$ of shower particles produced in π^--emulsion interactions at three different energies using the KNO scaling variable $z = n_s/\langle n_s\rangle$. Our fit to the experimental data is

$$\psi(z) = (2z + 29z^3 - 1.5z^5 + 0.3z^7)\exp(-3.8z)$$

with $\chi^2/\mathrm{DF} = 0.91$.

We present the angular distribution of shower particles using the pseudorapidity variable $\eta = -\ln\tan\theta/2$ which is a good approximation of rapidity for pions. In Fig. 5 the inclusive pseudorapidity distribution of shower particles at 300 GeV π^--emulsion interactions is given. The distribution has a pronounced plateau in the central region extending for about two units of pseudorapidity. No bimodal structure of pseudorapidity distribution is observed.

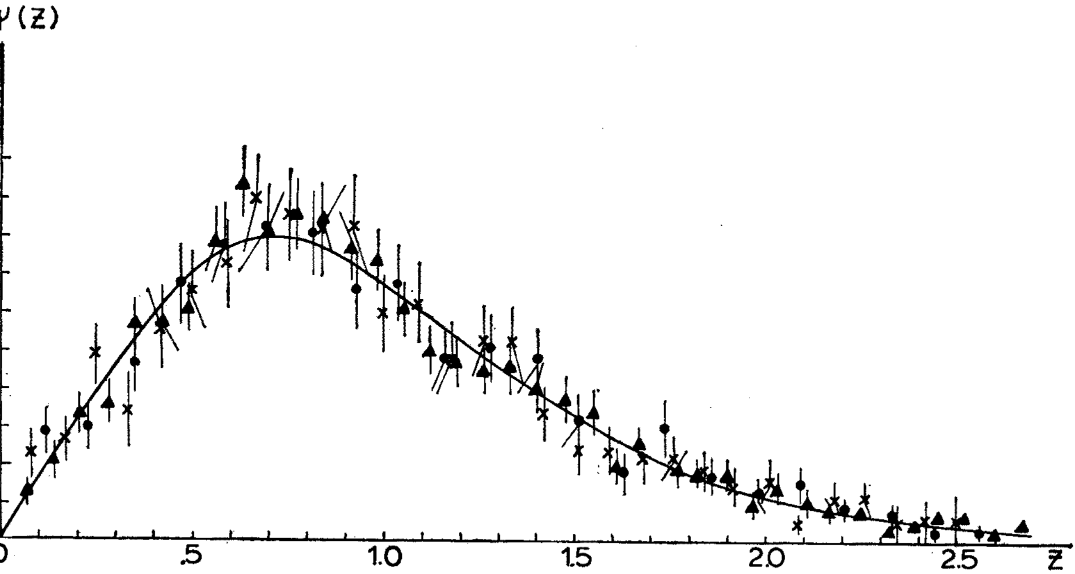

Fig. 4. KNO scaling for π^--emulsion interactions at: ● — 60 GeV, × 200 GeV and ▲ — 300 GeV

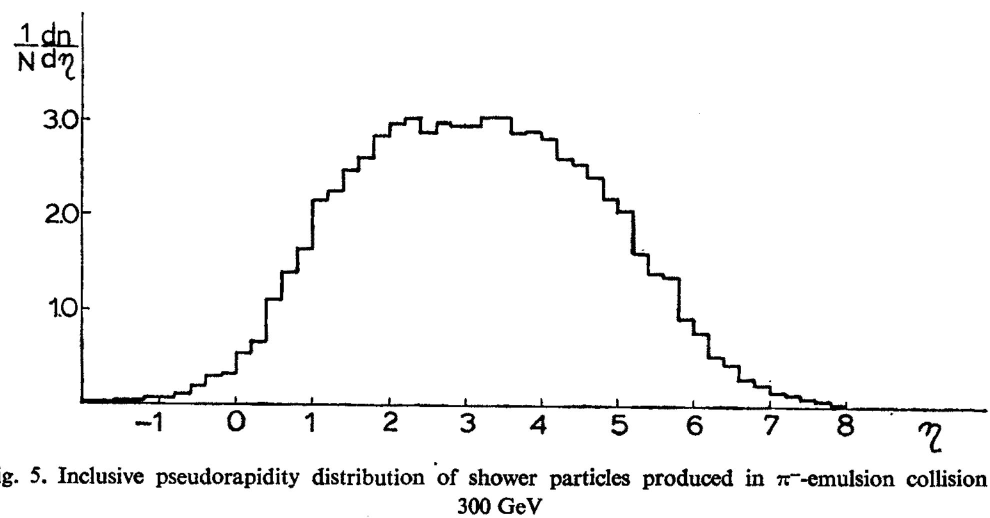

Fig. 5. Inclusive pseudorapidity distribution of shower particles produced in π^--emulsion collision at 300 GeV

5. *Conclusions*

On the basis of 3876 π^--emulsion interactions at 60 GeV, 200 GeV and 300 GeV primary pion energy the following conclusions can be drawn:

— The multiplicity distributions of disintegration products of the struck nucleus i.e. multiplicities of black tracks N_b and grey tracks N_g, the first ones attributed to the evaporation process of the excited nucleus and the second to recoil protons, do not depend on primary energy.

— For $N_g \lesssim 7$ (more than 95% of events fulfill this criterion) linear relation between $\langle N_b(N_g)\rangle$ and N_g is observed which suggests that the excitation of the nucleus is a measure of the number of recoil protons and thus on the number of projectile-nucleon collisions inside the target nucleus.
— Both N_g and N_b parameters can be used as a measure of the number $\langle \nu \rangle$ of collisions of the projectile inside the nucleus.
— The KNO scaling holds for shower particles produced in π^--emulsion interactions in the energy range (60÷300) GeV.
— The pseudorapidity distribution of shower particles produced at 300 GeV π^--emulsion interactions exhibits a plateau about two units of pseudorapidity wide. No structure (e.g. bimodality) is observed.

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