Energy characteristics of π^--meson interactions with nuclei at 50 GeV

V. F. Vionov, A. Sh. Gaĭtinov, I. Ya. Chasnikov, Dzh. Salomov, K. D. Tolstov, R. A. Khoshmukhamedov, G. S. Shabratova, A. El-Nagy, Z. I. Solov'eva, M. I. Adamovich, V. G. Larionova, G. I. Orlova, M. I. Tret'yakova, S. N. Kharlamov, M. M. Chernyavskiĭ, S. A. Azimov, R. A. Bondarenko, K. G. Gulamov, V. I. Petrov, T. P. Trofimova, L. P. Chernova, and G. M. Chernov

Alma-Ata–Dubna–Leningrad–Moscow–Tashkent Collaboration

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The momenta of secondary charaged particles from π^--meson interactions with nuclei at 50 GeV were measured by an emulsion method in a strong magnetic field. It is shown that the average transverse momenta and the fractions of the energy carried away by particles with opposite charges depend little on the target-nucleus dimensions. The data do not agree with the concept that the primary pion is completely passive after collision at 50 GeV.

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The recently exhibited great interest in hadron-nucleus collisions is due to the possibility of using them to study the space-time evolution of strong hadron interaction processes.[1–6] It is therefore to be hoped that a detailed study of the multiple production of particles will make a choice possible between the various models of the elementary hadron-hadron interaction act.

Pellicle stacks of fifty type BR-2 films 600 μ thick and 60 mm in diameter were placed in a strong magnetic field and bombarded by a beam of π^- mesons of momentum $p_0 = 50$ GeV/c ($\Delta p/p_0 \approx 1\%$) in the Serpukhov accelerator. The pulsed magnetic field of 180-kOe intensity was produced with the "Mamont" setup constructed at CERN and delivered to JINR. The details of the experiment will be published elsewhere.

The emulsions were scanned along the primary π^{-1}-meson tracks. Altogether 340 inelastic strong pion-nucleus interactions were observed. This number does not include events of coherent pion-nucleus interactions. In the observed events, we measured the momenta and determined the signs of the charges of almost 2000 particles. The average momentum measurement error was $\Delta p/p = 0.15$. A geometrical correction was introduced for the particle momenta measured at large angles.

To investigate the dependence of the characteristics on the target-nucleus dimensions we consider below three groups of events characterized by the number N_h of strongly-ionizing particles: events with $N_h = 0$ or 1 (the strongly ionizing particle is emitted forward in the c.m.s.), events with N_h satisfying the condition $1 < N_h \leq 6$ (including also events with one strongly ionizing particle emitted backward in the c.m.s.), and events

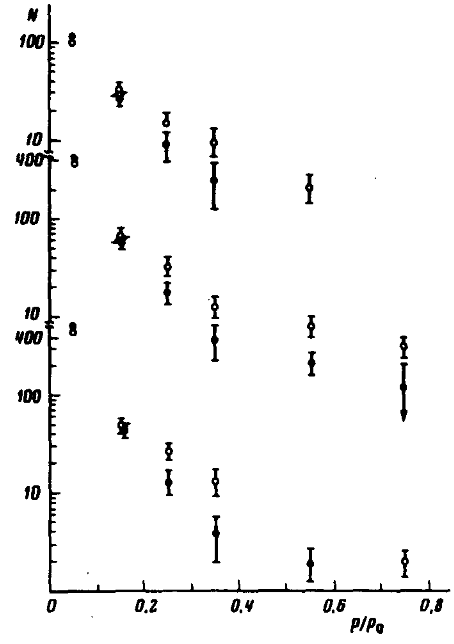

FIG. 1. Momentum distributions, in the lab, of the π^- (light circles) and π^+ (dark) in π^-N interactions (a) and π^-A interactions with $N_h \leq 6$ (b) and $N_h \geq 7$ (c) at $p_0 = 50$ GeV/c.

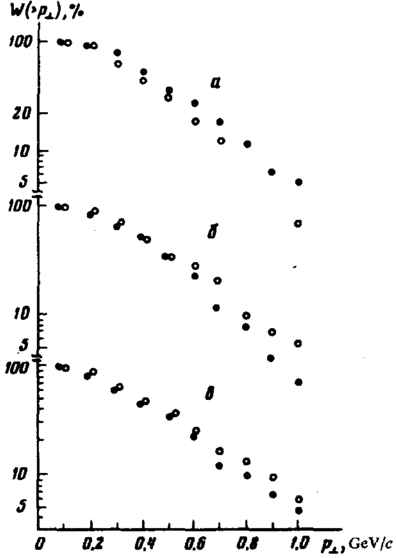

FIG. 2. Integral $p_\perp$-distributions of π^-(dark circles) and π^+ (light circles) in π^-N interactions (a) and π^-A interactions with $N \leq 6$ (b) and $N_h \geq 7$ (c) at $p_0 = 50$ GeV/c.

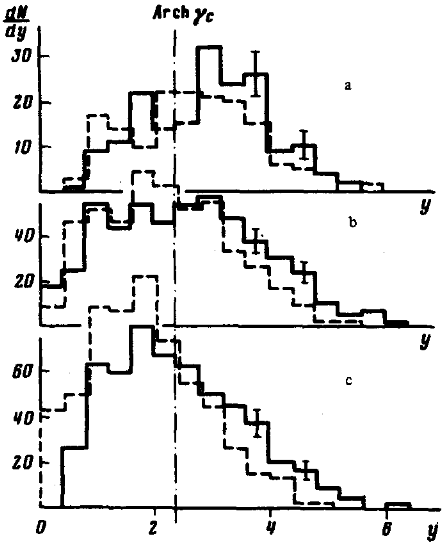

FIG. 3. Distributions with respect to the longitudinal rapidity y for π^- (solid line) and π^+ (dashed) from the π^-N interactions (a) and π^-A interactions with $N \leq 6$ (b) and $N_h \geq 7$ (c).

TABLE 1. Average number of high-energy particles per event.

Momentum	π^-			π^+		
	π^-N	$\pi^-A, N_h \leq 6$	$\pi^-A, N_h \geq 7$	π^-N	$\pi^-A, N_h \leq 6$	$\pi^-A, N_h \geq 7$
$> 0.1p_0$	1.08 ± 0.13	0.99 ± 0.08	0.79 ± 0.08	0.64 ± 0.10	0.58 ± 0.06	0.55 ± 0.06
$> 0.2p_0$	0.58 ± 0.09	0.55 ± 0.06	0.40 ± 0.06	0.21 ± 0.06	0.23 ± 0.04	0.18 ± 0.04
$> 0.3p_0$	0.35 ± 0.07	0.34 ± 0.05	0.20 ± 0.04	0.08 ± 0.03	0.12 ± 0.03	0.08 ± 0.03
$> 0.4p_0$	0.20 ± 0.05	0.26 ± 0.04	0.09 ± 0.03	0.02 ± 0.02	0.08 ± 0.02	0.05 ± 0.02
$> 0.5p_0$	0.12 ± 0.04	0.21 ± 0.04	0.08 ± 0.02	0.02 ± 0.02	0.03 ± 0.01	0.02 ± 0.01

with $N_h \geq 7$. These three groups of events, respectively, characterize in first-order approximation the collisions of the pions with free and quasifree peripheral nucleons (π^-N collisions), π^-A collisions with nuclei of the CNO group, and peripheral collisions with the AgBr nuclei, and π^-A collisions with the AgBr nuclei only. Thus, groups with different values of N_h will characterize the thickness of the nuclear matter transversed by the pion in the nucleus.

The experimental distributions with respect to the momenta, the transverse momenta, and the longitudinal rapidity are shown in Figs. 1–3. The mean values of these quantities, and also the values of $\cos\theta^*$ (θ^* is the particle emission angle in the pion-nucleon s.m.s.), the Feynman variable $x = p^*_\parallel / p^*_0$ in the same system, and the mean values of the fraction of the energy in the laboratory system of $K_\pm$ and K_0 carried away by the charged particles and neutral fast particles, are all represented in Tables 1 and 2.

The following can be concluded from the analysis of the data:

a) The momentum and rapidity spectra become softer on going to collisions with heavy nuclei at higher excitations ($N_h \geq 7$), namely, the number of slow particles increases abruptly (Figs. 1 and 3). The angular distribution in the c.m.s., on going from π^-N collisions to π^-A collisions, changes from asymmetrical forward (a known fact for π^-N collisions) to sharply asymmetrical backward (Table 2) for the group of heavy nuclei with $N_h \geq 7$. These statements pertain both to π^- and π^+ mesons (we identify all the charged particles with pions).

b) The growth of the number of particles with small p and y (Figs. 1 and 3) is much faster than the decrease of the number of particles with large p and y; thus, the shape of, say, the y-distribution, changes on going to large N_h. This circumstance follows naturallly from the intranuclear-cascade concepts[7]. Comparison with the cluster models[4–6] calls for subdivision of the h-particles into the higher energy g-particles (protons of energy ≥ 30 MeV), which represent collisions with nucleons, and slower b-particles, which are connected with the nuclear decay process.

c) The shape of the distribution with respect to the transverse momenta $p_\perp$ and the mean values $\langle p_\perp \rangle$ do not depend, within the limits of errors, on either the dimen-

TABLE 2. Mean values of the momentum and angular characteristics.

Characteristic	π^-N	π^-A	
		$N_h \leq 6$	$N_h \geq 7$
$\langle p_\perp \rangle_{\pi^-}$	0.38 ± 0.03	0.35 ± 0.02	0.33 ± 0.02
$\langle p_\perp \rangle_{\pi^+}$	0.32 ± 0.03	0.38 ± 0.02	0.38 ± 0.02
$\langle y \rangle_{\pi^-}$	2.94 ± 0.08	2.56 ± 0.07	2.12 ± 0.06
$\langle y \rangle_{\pi^+}$	2.65 ± 0.09	2.18 ± 0.06	1.87 ± 0.06
$\langle x \rangle_{\pi^-}$	0.094 ± 0.014	0.053 ± 0.013	−0.025 ± 0.011
$\langle x \rangle_{\pi^+}$	0.028 ± 0.013	−0.037 ± 0.011	−0.067 ± 0.009
$\langle \cos\theta^* \rangle_{\pi^-}$	0.33 ± 0.05	0.08 ± 0.04	−0.16 ± 0.04
$\langle \cos\theta^* \rangle_{\pi^+}$	0.18 ± 0.05	−0.12 ± 0.04	−0.30 ± 0.04
$\langle K_\pm \rangle$	0.60 ± 0.04	0.61 ± 0.02	0.56 ± 0.02
$\langle K_0 \rangle$	0.38 ± 0.04	0.38 ± 0.02	0.38 ± 0.02

sions of the target nucleus or the sign of the pions. The dependence of $\langle p_\perp \rangle$ on N_h and the absolute values of $\langle p_\perp \rangle$ contradict the calculations[7] on the cascade-evaporation model. The forms of the $p_\perp$-distributions are in poor agreement with both the linear-exponential approximation and the Boltzmann approximation. The shapes of the $p_\perp$-distributions of the π^+ and π^- mesons do not differ from each other.

d) The energy distribution among the secondary particles having opposite charges is practically independent of the dimensions of the nucleus, and comparison with data on pion-nuclear collisions at low energies[8,9] shows that there is also independence of the collision energy. The observed weak dependence of the coefficients $K_\pm$ and K_0 on the target-nucleus dimensions is customarily taken as an argument favoring cluster models of multiple production.[4-6] However, it should be noted that calculations based on the cascade-evaporation model also yield a rather weak dependence of the energy distribution on N_h.[7] Nonetheless, the quantitative comparison leads to a discrepancy with the calculations in accordance with this model with allowance for multiparticle interactions. Indeed, the calculations of[7] for pion-nucleus interaction at 50 GeV/c yield an average kinetic energy $\langle T_s \rangle = 2.8 \pm 0.2$ GeV and $\langle n_s \rangle = 7.2 \pm 0.4$. Adding the average energy of the leading particle, we obtain $\langle K_\pm \rangle \approx 0.8$, which is 1.3 times larger than in experiment (Table 2).

e) In all groups of collisions, the number of π^- mesons with large momenta is larger than the number of π^+ mesons (effect of the leading particle; Figs. 1 and 3, Table 1). The preservation of the effect of the leading particles with changing N_h excludes, in our opinion, the purely statistical approach to the dynamics of hadron-nucleon interactions. The preservation of the leading particles, however, is accompanied by a shift of these particles into the region of smaller p and y (larger θ^*) on going to larger thicknesses of nuclear matter. Consequently, the energy fractions carried away by the particles have an A-dependence, which contradicts the notion that the primary particle is fully passive after the first interaction inside the nucleus at an energy 50 GeV (the physical premises for the hypotheses of the full or partial passivity can be found in[1,6]).

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