Multiplicity distribution of secondary particles for hadron interactions with nuclei at 7 GeV/*c*

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Institute of Theoretical and Experimental Physics
(Submitted July 11, 1977)
Pis'ma Zh. Eksp. Teor. Fiz. **26**, No. 5, 415–419 (5 September 1977)

Multiple production of particles was investigated in inelastic proton-nuclear and pion-nuclear interactions at a momentum $P = 7$ GeV/*c* for the nuclei Be, C, Al, Cu, Cd, Pb, and U. It was found that the distribution in the total multiplicity of the charged particles is described by the same universal function $\Psi(z)$ as for the *pp* interactions.

PACS numbers: 13.75.—n

Multiple production in pA (Be, C, Al, Cu, Cd, Pb) and $\pi^- A$ (Be, C, Al, Cu, Cd, Pb, U) interactions was investigated at 7 GeV/*c*. The TISS-2 (high-aperture tracking spark spectrometer) was used for the measurements and registered events of inelastic hA interactions with scattering of the primary

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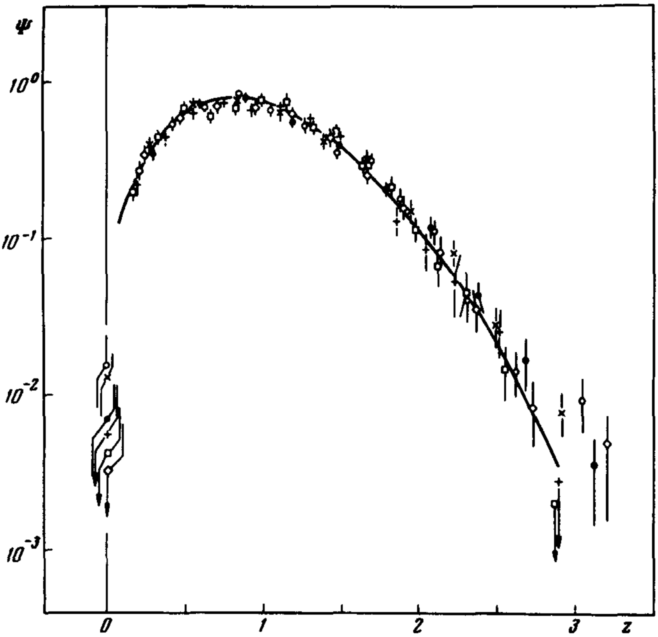

FIG. 1. The function $\Psi(z)$ for pA interactions at 7 GeV/c: ●—Be, ×—C, ◇—Al, ○—Cd, +—Cu, □—Pb.

particles through an angle more than 40 mrad. The experimental setup is described in greater detail in[1].

The spectrometer efficiency was high enough to register several particles[2] and depended on the emission angle and on the momentum of the secondary particles. We registered effectively charged particles with $\theta_{lab} < 60°$ and $\theta_{lab} > 120°$ at momenta $p > 0.2$ GeV/c for protons and $p > 0.05$ GeV/c for pions. To obtain identical slow-proton registration thresholds, the thicknesses of the targets with the different nuclei were chosen to range from 1 to 3 g/cm^2.

The photographs of the inelastic interactions were scanned twice on scanning stages. We reduced altogether about 1200 events of pA interactions and 1000 events of $\pi^- A$ interactions for each nucleus.

The distribution in the multiplicity of the secondary particles is customarily represented in the form of the function

$$\Psi(z) = \langle n \rangle \frac{\sigma_n}{\sigma_{in}},$$

where $z = n/\langle n \rangle$, σ_n is the topological cross section for the production of n particles, and σ_{in} is the total inelastic cross section.

Koba, Nielsen, and Olsen (KNO) have predicted[3] that $\Psi(z)$ is asymptotically independent of the initial energy (KNO scaling). The absence of an energy dependence of $\Psi(z)$ at $E_0 > 50$ GeV was initially observed for pp interactions,[4] and later for interactions of other hadrons $(\pi^{\pm}p, K^{\pm}p)$.[5] In all these cases,

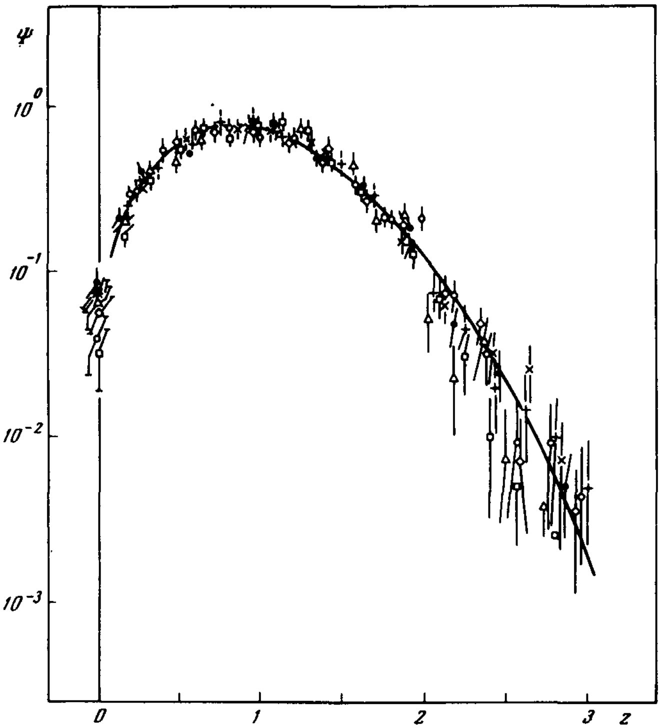

FIG. 2. The function $\Psi(z)$ for $\pi^- A$ interactions at 7 GeV/c: ●—Be, ×—C, ◇—Al, ○—Cu, +—Cd, □—Pb, Δ—U.

$\Psi(z)$ is universal. The same function $\Psi(z)$ describes the multiplicity distribution of the pions in π^-C and π^-Ne interactions at initial momenta 4, 5, 7.5, 40 and 10.5, 200 GeV/c, respectively.[6,7]

Figures 1 and 2 show the behavior of $\Psi(z)$, which describes the distribution in multiplicity of all the registered particles (these are principally protons and pions) in pA and $\pi^- A$ interactions at 7 GeV/c. The solid curves correspond to the approximation used for $\Psi(z)$ in pp interactions.[4]

It can be deduced from Fig. 1 and Fig. 2 that the universal function $\Psi(z)$ is suitable also for the description of the multiplicity distributions of all the particles in pA and $\pi^- A$ interactions. The values of χ^2 obtained in this case in the region $0 < z < 2.7$ are listed in Table I. The observed agreement seems unexpected if it is recognized that when $\Psi(z)$ is constructed the number of secondary particles includes protons which are not the production of the quasi-free interaction. The fraction of the protons for different nuclei ranges from 0.2 to 0.65 of the total number of charged particles. Moreover the multiplicity distributions taken separately for the slow ($p < 1$ GeV/c) positive particles or π^- mesons emitted forward are not described by a universal function.[4] On the other hand, the multiplicity distributions in all these cases depend little on the atomic number of the target nucleus. An exception is the multiplicity distribu-

TABLE I.

Interactions	Target	χ^2/N	N
pA	Be	1.006	9
pA	C	0.936	9
pA	Al	0.736	10
pA	Cu	0.929	12
pA	Cd	1.250	13
pA	Pb	1.816	15
π^-A	Be	2.549	9
π^-A	C	1.388	10
π^-A	Al	1.350	11
π^-A	Cu	0.963	13
π^-A	Cd	0.922	14
π^-A	Pb	2.973	16
π^-A	U	2.886	16
pA	all nuclei	1.169	68
π^-A	all nuclei	1.920	89

tion of the π^- mesons emitted forward in the interaction of the π^- with the nuclei, Be, C and Al, which can be described by the function.[4]

Notice should be taken of the possible influence of the efficiency of the spectrometer on the distribution $\Psi(z)$, but this influence is expected to be weak because of the normalization $n/\langle n\rangle$.

The universality of the function $\Psi(z)$ used both for the description of the multiplicity distributions in hadron-hadron interactions and in hadron-nuclear interactions when the secondary particles include the protons emitted by the nuclei can be attributed to one of the following possibilities: 1) The $\Psi(z)$ distribution is not sensitive (within the limits of experimental accuracy) to the mechanism of the multiple production of the particles; 2) there is a deep analogy between the production of particles in hadron-hadron and hadron-nuclear interactions, and this analogy can in turn be the consequence of the quasistatistical nature of multiparticle reactions in the case when the multiplicity of the secondary particles is sufficient.

In either case, the observed universality of $\Psi(z)$ at different energies, for interactions of different elementary particles, seems natural.[4,5]

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[1] A. V. Arefyev *et al.*, Preprint, ITEP-56, 1977.
[2] A. V. Aref'ev *et al.*, Preprint, ITEP-794, 1970.
[3] Z. Koba *et al.*, Phys. Lett. **38B**, 25 (1972).
[4] P. Slattery, Phys. Rev. Lett. **29**, 1624 (1972).
[5] D. Fong *et al.*, Nucl. Phys. B **102**, 386 (1976); W. M. Morse *et al.*, Phys. Rev. D **15**, 66 (1977).
[6] S. A. Azimov *et al.*, Nucl. Phys. B **107**, 45 (1976).
[7] J. R. Elliott *et al.*, Phys. Rev. Lett. **34**, 607 (1975).