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Fig. 1

Figure 1: Fig. 1

**Abstract****Full Text****PHYSICS****A. Kh. VINITSKY, I. G. GOLYAK, V. I. RUSKIN,**  
Academician of the Academy of Sciences of the Kazakh SSR Zh. S.  
**TAKIBAEV****INVESTIGATION OF THE CHARACTER OF  
PARTICLE PRODUCTION****IN INELASTIC PION-NUCLEON INTERAC-  
TIONS**

The present work gives the results of an experimental investigation of the production of pions, strange particles, and new rapidly decaying systems in the inelastic interaction of pions of energy 7.5 BeV with the nuclei of the nuclear-emulsion material.

Photoemulsion stacks were irradiated with the pion beam of the Dubna synchrophasotron. A total of 900 m of primary tracks of  $\pi$ -mesons were scanned, as a result of which 2100 interactions were recorded. From this number of "stars," pion-nucleon interactions were selected according to generally accepted criteria <sup>(1)</sup>. As a result of the selection, 200 events were classified as inelastic pion-nucleon interactions. To identify the secondary particles we analyzed their tracks if the dip angle of the track relative to the plane of the photoemulsion was  $\leq 8^\circ$ . Particles with larger dip angles were taken into account with the aid of the corresponding geometrical corrections.

Of all 323 identified particles, 259 proved to be pions, 19  $K$ -mesons, and 45 protons. Particles falling into the region difficult for identification (from 1.5 to 2.5 BeV), according to the work <sup>(2)</sup>, were assigned to pions. However, the number of such particles is small and they do not affect the final conclusions.

Figure 1 gives the angular distributions of secondary protons and pions in the c.m.s.

**Fig. 1.** Angular distribution of secondary protons (*a*) and pions (*b*) from all stars in the c.m.s.

Figure 2: Momentum spectra of protons and pions

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Figure 3: Angular and momentum distributions of protons

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It follows from Fig. 2 that there are two peaks in the momentum distribution of protons and  $\pi$ -mesons.

Comparison of the distributions presented in Fig. 3 leads to the conclusion that protons from pion-neutron collisions are more energetic than protons from pion-proton collisions. In other words, target nucleons that have undergone charge exchange in an inelastic collision, in general, carry away more energy and are collimated more narrowly than target nucleons that retain their charge in the inelastic-collision process.

In a detailed analysis we found a rather significant number (19) of particles identified with high probability as  $K$ -mesons. A secondary, more careful processing of the tracks of these particles confirmed

our preliminary results. It should be emphasized that the energy of these  $K$  mesons in the l.s. fluctuates within small limits, from 0.5 to 1.0 BeV (from 500 to 700 MeV, respectively, in the c.m.s.).

It is very interesting that in three cases of inelastic pion-nucleon interaction two  $K$  mesons are produced simultaneously; moreover, if one assumes that they are the result of the rapid decay of some unknown system, then its mass proved to be equal to 1 BeV in all three cases.

Fig. 2. Momentum spectrum of protons (a) and pions (b) from two- and three-prong stars in the c.m.s.

cases. We are inclined to regard this fact as an indication of the possible existence of a resonant  $K\bar{K}$  system. It is very probable that in most cases the remaining single charged  $K$  mesons are also the product of such a system, but one decaying into  $K^0$ - and  $K^\pm$ -mesons, since the observed  $K$  mesons lie in a rather narrow energy interval. Indications of the existence of a similar system consisting of  $K^0$  and  $\bar{K}^0$  are contained in Ref. (3).

Fig. 3. Angular and momentum distributions of protons in pion-proton (a) and pion-neutron (b) collisions in the l.s. (the numbers at the experimental points denote the statistical weights of the particles corresponding to these points)

We attempted to give a certain theoretical interpretation of the experimental results obtained above for two- and three-prong stars. Various possible mechanisms of the interaction were considered according to the diagrams shown in Fig. 4. Diagrams *a* and *b* were calculated under two assumptions concerning

the form of  $\sigma_{\pi\pi}$ : 1)  $\sigma_{\pi\pi}(\omega^2) = \text{const}$ , 2)  $\sigma_{\pi\pi}$  is described by the Breit-Wigner resonance formula in the state  $T = I = 1$ . Diagrams  $c, e, d$  represent

are processes of pion-nucleon interactions proceeding through the exchange of quasiparticles (resonance systems) consisting of 2 and 3 pions ( $T = I = 1$ ;  $T = 0, I = 1$ ). In calculating the cross sections of the corresponding diagrams, the integration was carried out without a cutoff in virtuality within the region allowed by the laws of conservation of energy-momentum. Taking these diagrams into account may, to some extent, provide information on the contribution of non-pole processes.

The maximum and minimum values of the proton momenta, as well as the most probable region of momentum values obtained from the various diagrams, are summarized in Table 1. The analysis shows that diagrams  $b, c$ , and  $d$  make the main contribution to the region of the high-energy peak in the proton momentum distribution at 1.4–1.6 BeV/ $c$ . The most probable value of the momenta calculated from diagram  $a$  does not coincide with the maximum in the experimentally found spectrum. Moreover, in the experimental momentum spectrum there is a second maximum in the energy region from 0.4 to 0.6 BeV, which is not explained by diagrams  $a-c$ .

**Table 1**  
**Momentum characteristics of protons**  
(BeV/ $c$ )

Type of process*	$P_{\min}^*$	$P_{\max}^*$	$P^*$
$a_{\text{I}}$	0.4	1.8	1.0–1.4
$a_{\text{II}}$	—	—	1.75
$b_{\text{I}}$	0.2	1.8	1.4–1.6
$b_{\text{II}}$	0.8	1.7	1.3
$c$	0.4	1.8	1.1–1.4
$e$	0.4	1.8	1.1–1.4
$d$	0.0	1.75	1.3–1.5

\* I —  $\sigma_{\pi\pi} = \text{const}$ , II —  $\sigma_{\pi\pi}$  is determined by the resonance formula.

It seems to us that there are two possible explanations of this maximum: 1) it is explained by non-pole processes proceeding with a large transfer of momentum to the proton, which apparently can be described by statistical theory; 2) this maximum can be explained by a pole diagram of the type of diagram  $e$ , where the internal line is a three-pion resonance system with  $I = 0$ .

**Fig. 4.** Feynman diagrams for pion-nucleon interaction proceeding through the exchange of one-, two-, and three-pion systems.

Analysis of the momentum spectra of pions and their angular correlations also indicates the important role of processes  $b, c$ . Apparently, the contribution

Fig. 4. Feynman diagrams for pion-nucleon interaction proceeding through the exchange of one-, two-, and three-pion systems

Figure 4: Fig. 4. Feynman diagrams for pion-nucleon interaction proceeding through the exchange of one-, two-, and three-pion systems

of the interaction carried out through a two- and three-pion resonance system should also be taken into account in nucleon-nucleon collisions.

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*Note: Figure translations are in progress. See original paper for figures.*

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