DATA ON THE THREE-PION INTERACTION

Ya. Ya. SHALAMOV and A. F. GRASHIN

Institute of Theoretical and Experimental Physics

Submitted to JETP editor July 12, 1962

J. Exptl. Theoret. Phys. (U.S.S.R.) **44**, 65-67 (January, 1963)

The reaction $\pi^- + n \rightarrow \pi^- + \pi^- + \pi^0 + p$ is studied with the help of a 17-liter bubble chamber filled with a freon mixture for an initial π^- meson momentum of 2.8 BeV/c. Indications are obtained that three-pion resonances for isospin I = 2 may exist for masses $M_\pi \approx 0.45$, 0.63, 0.87, and 1.05 BeV.

THE reaction

$$\pi^- + n \rightarrow \pi^- + \pi^- + \pi^0 + p \quad (1)$$

was studied in a manner similar to that of prior investigations [1,2] for π^- mesons with initial momentum $p_0 = 2.8$ BeV/c incident on quasi-free neutrons in a freon mixture. Upon examination of the photographs, events of the type

$$\pi^- + n \rightarrow \pi^- + \pi^- + p + m\gamma; \quad m = 1, 2, \ldots, \quad (2)$$

were selected when the proton came to rest in the working substance of the chamber, and also, by virtue of special features of the method, events were selected with the path length of the recoil proton in the interval $3 \lesssim l_p \lesssim 300$ mm (proton energy in the interval $10 \lesssim E_p \lesssim 200$ MeV). Analysis of the detected events was carried out with the help of a stereocomparator which reconstructed the three-dimensional picture in full size, and also a periodic check on the accuracy of spatial location was carried out with the help of markings drawn on the back and front windows of the chamber. The actual accuracy with which the angles and particle path lengths were reconstructed ranged from 1 to 3% for different regions of the chamber. For events of type (2) which were detected, the angles of emission of the secondary particles with respect to the incident π^- meson, the proton path length, and the maximum possible path length of the electron-positron pair were measured. Since a reliable identification of the protons which come to rest is possible only with account of ionization, events were considered for which the angle of inclination between the proton track and the plane of the photograph was $\varphi \leq 50$ to 60°.

For events of type (2) with m = 1 or 2, the mass distribution of the system of particles which accompany the recoil proton was plotted (see Fig. 1) according to the formula

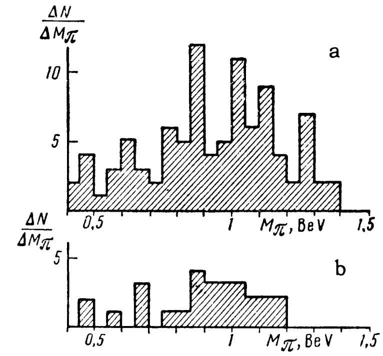

FIG. 1. Mass spectrum of a system of pions: (a) For 94 events of type (2) with m = 1, (b) For 27 events of type (2) with m = 2.

$$M_\pi = [2p_0 p_p \cos\theta_p - (\omega_0 + m) E_p + \mu^2]^{1/2},$$

where p_0 and ω_0 are the momentum and energy of the incident π meson; m, p_p, E_p, and θ_p are the mass, momentum, kinetic energy and angle of emission of the recoil proton. The extremely weak dependence of M_π on the proton path length is evident from the formula: $M_\pi \sim (l_p)^{1/4}$. Inaccuracies in the measured values of p_p and θ_p introduce small errors: $\Delta M_\pi \lesssim 20$ MeV. More substantial errors are introduced by the uncertainty in the initial momentum of the π^- meson ($\Delta p_0/p_0 \approx 10\%$) and the effect of motion of the target nucleon inside the nucleus, which would broaden possible lines in the mass spectrum M_π to a width of 100 to 300 MeV. As previously noted, [2] the actually observed lines are several times smaller in width. A possible explanation of this is the formation inside the nucleus of a nucleon isobar with an energy of about 2.5 BeV (isospin I = 3/2) which decays outside the nucleus into a nucleon plus π mesons. In this case, definite initial momenta p_0 and target nucleon momenta would be picked out, which would lead to a decrease in the broadening of the lines.

Assuming that all γ quanta in processes (2) are the result of the decay of π^0 mesons, and taking into account the fact that the efficiency of their detection by electron-positron conversion in the freon mixture amounts to about 0.34, one can satisfy oneself that reaction (1) gives a contribution of about 85% to the spectrum shown in Fig. 1(a). About 15% of the events pertaining to the spectrum of Fig. 1(a) are a contribution from the reaction

$$\pi^- + n \to \pi^- + \pi^- + \pi^0 + \pi^0 + p. \qquad (3)$$

In the spectrum shown in Fig. 1(b) [reaction (2) with m = 2], the mass distribution of the three-pion system for reaction (1) and the mass distribution of the four-pion system for reaction (3) give approximately equal contributions.

Peaks are observed in the spectrum of Fig. 1(a) at average mass values $M_\pi \approx 0.87$ and 1.03 BeV; it is possible that these are the result of isospin I = 2 resonances. Furthermore, in the region $M_\pi \approx 0.4$ to 0.5 BeV, which is strongly discriminated against by our method of analyzing events, there are six events indicating the possibility of a strong three-pion interaction near threshold.

In Fig. 2(a) the mass distribution of the three-pion system is presented for events of the type

$$\pi^- + p \to \pi^- + \pi^- + \pi^+ + p \qquad (4)$$

on free and quasi-free protons of a xenon-propane mixture, the energy intervals being smaller than in previously published work. [1]

In the spectrum shown in Fig. 2(a) there is some admixture (about 10%) of events from the formation of four mesons according to the reaction

$$\pi^- + p \to \pi^- + \pi^- + \pi^+ + \pi^0 + p, \qquad (5)$$

which in turn gives the main contribution to the spectrum of Fig. 2(b) for type (4) events with, in addition, the observed electron-positron conversion pairs. As in Fig. 1(a) (the doubly-charged three-pion system), peaks at $M_\pi \approx 0.45$ and $M_\pi \approx 1.05$ BeV are observed in the spectrum of Fig. 2(a) for the singly-charged three-pion system.

An overall histogram for reactions (1) and (4) is given in Fig. 3 at 25-MeV mass intervals; peaks are evident in this figure at $M_\pi \approx 0.45$, 0.63, 0.87, and 1.05 BeV;[1)] it is possible that these correspond

[1)]The positions of the maxima on the corresponding ideogram are indicated.

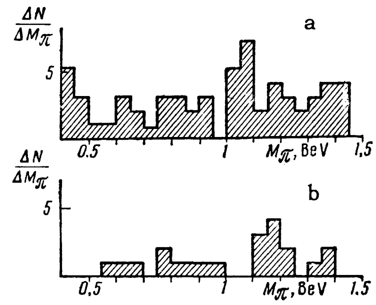

FIG. 2. Mass spectrum of a system of pions: (a) For 61 events conforming to reaction (4); (b) For 21 events conforming to reaction (5).

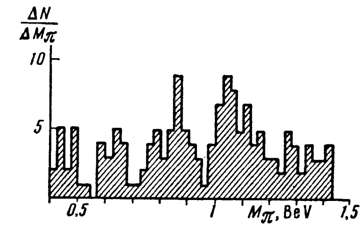

FIG. 3. Overall mass distribution of a three-pion system for reactions (1) and (4) (155 events, 25-MeV mass intervals).

to three-pion resonances for isospin I = 2. A resonance peak at $M_\pi \approx 0.65$ BeV in the neutral and singly-charged three-pion systems was observed by Pickup et al,[3] and in the singly-charged system by Zorn.[4] Resonance peaks of doubly-charged three-pion systems at $M_\pi \approx 0.85$, $M_\pi \approx 1$ BeV were observed by Aĭnutdinov et al.[5]

The authors sincerely thank A. I. Alikhanov for his constant interest and valuable remarks during the course of this work, and also thank M. S. Aĭnutdinov, S. M. Zombkovskiĭ, S. Ya. Nikitin, Ya. M. Selektor, and V. N. Shulyachenko for showing us their experimental data prior to publication.[5]

[1] Ya. Ya. Shalamov and A. F. Grashin, JETP **42**, 1115 (1962), Soviet Phys. JETP **15**, 770 (1962).

[2] Ya. Ya. Shalamov and A. F. Grashin, JETP **43**, 726 (1962), Soviet Phys. JETP **16**, 515 (1963); Preprint No. 87, Institute of Theoretical and Experimental Physics, 1962.

[3] Pickup, Robinson, and Salant, Phys. Rev. Letters **8**, 329 (1962).

[4] B. Sechi Zorn, Phys. Rev. Letters **8**, 282 (1962).

[5] Aĭnutdinov, Zombkovskiĭ, Nikitin, Selektor, and Shulyachenko, JETP **43**, 1543 (1962), Soviet Phys. JETP **16**, 1089 (1963).

Translated by H. H. Nickle
13