$\pi\pi$-INTERACTION DATA DERIVED FROM THE π-MESON PRODUCTION REACTION IN πp COLLISIONS. II. ρ^0-MESON PRODUCTION

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The $\pi^- + p \rightarrow \pi^- + \pi^+ + n$ reaction on free or quasi-free protons in the C_3H_8 + Xe working mixture of a 17-liter bubble chamber was studied for initial π^--meson momenta of 2.8 BeV/c. A strong $\pi\pi$ interaction has been detected in the energy region $\omega = M_{\pi\pi} \approx 0.8$ BeV and in the region $\omega \approx 1.4$ BeV. An angular distribution $\sim \cos^2\varphi_\pi^*$ in the c.m.s. of the two π mesons corresponds to the first resonance in this case. This is equivalent to the production of a vector ρ meson aligned along the initial direction. The probability of formation of a two-meson mass $0.35 \leq M_{\pi\pi} \leq 0.5$ BeV does not exceed several percent of the total cross section of the process.

In our preceding investigation [1] we studied the reaction

$$\pi^- + p \rightarrow \pi^- + \pi^0 + p \tag{1}$$

with a 2.8 BeV/c π^--meson beam and showed that the main channel of this process is the formation of a resonant state of two pions at an energy $\omega = M_{\pi\pi} \approx 750$ MeV (ρ^- meson). Events with proton energy $10 \lesssim E_p \lesssim 100$ MeV in the laboratory system (l.s.) were selected. The ρ-meson mass was determined from the energy and angle of emission of the proton in the l.s., and the proton angle varied in the range 35—55° by virtue of the two-particle kinematics of the process (1).

In the present investigation we studied the reaction

$$\pi^- + p \rightarrow \pi^- + \pi^+ + n \tag{2}$$

with the aid of a bubble chamber with a xenon-propane mixture, at an initial π^--meson momentum 2.8 ± 0.3 BeV/c. The chamber was operated without a magnetic field. From the character of the angular distributions of the π^- mesons it was deduced that a strong resonance-type interaction occurs at values of ω close to 0.8 and 1.4 BeV.

EXPERIMENTAL METHOD AND RESULTS

The photographic film was scanned by two independent observers. Two-prong events were selected in which the secondary-particle ionization differed from the ionization of the incoming pion by not more than 1.5—2 times. In other cases the particle was identified as a pion by the multiple scattering and change in ionization along the particle track. The events selected were processed on a stereo comparator. The meson emission angles and the angle $\theta_{\pi\pi}$ between two mesons were measured. In those cases when an electron-positron conversion pair from the process

$$\pi^- + p \rightarrow \pi^+ + \pi^- + m\pi^0 + n \rightarrow \pi^+ + \pi^- + 2m\gamma + n \quad (m = 1, 2, \ldots) \tag{3}$$

was directed towards the point of interaction, we measured the angles of emission and the maximum possible path length of the γ quantum in the chamber.

Altogether we found and processed 430 events of the $\pi^- + p \rightarrow \pi^- + \pi^+ + n$ type and 343 events of the $\pi^- + p \rightarrow \pi^- + \pi^+ + m\gamma + n$ type ($m = 1, 2, 3, \ldots$). Figure 1 shows the distribution of the events as a function of the angle $\theta_{\pi\pi}$ between two charged mesons in the l.s. for all the events ($m = 0, 1, 2, \ldots$). Figure 2 shows an analogous distribution for the process (2), with account of the corrections connected with the process (3), when none of the γ quanta produces an electron-positron conversion

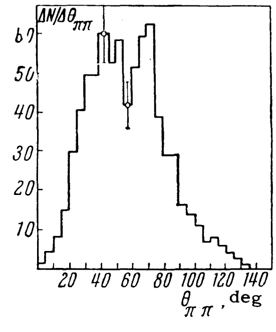

FIG. 1. Distribution of events as a function of the angle $\theta_{\pi\pi}$ between two charged mesons in the l.s. for the reaction $\pi^- + p \rightarrow \pi^- + \pi^+ + n + m\gamma$ ($m = 0, 1, 2, \ldots$). A total of 774 events was processed.

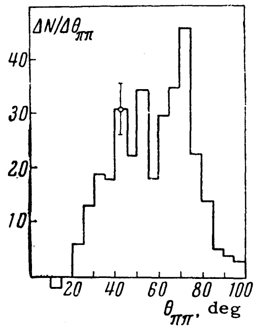

FIG. 2. Distribution of events as a function of the angle $\theta_{\pi\pi}$ between two charged mesons in the l.s. for the reaction $\pi^- + p \to \pi^- + \pi^+ + n$. A total of 321 events was processed.

pair. The high γ-quantum counting efficiency enables us to determine this correction with a high degree of accuracy[1)]; the uncertainty in the number of events of reaction (2), due to the process (3), does not exceed 5%. In addition, the distribution of Fig. 2 does not include four events when each pion had a momentum $p_\pi \leq 300$ MeV/c.

DATA REDUCTION AND DISCUSSION

If we neglect the pion-neutron interaction, the angular distribution of Fig. 2 can be transformed into the mass spectrum of a two-meson system. This gives rise to uncertainties connected with the fact that the momentum spectrum of the neutrons is not known. However, the average angle $\bar{\theta}_{\pi\pi} \cong f(M_{\pi\pi}, p_n)$ depends weakly on the neutron momentum p_n. It was assumed in the calculations that the average momentum $\bar{p}_n$ exceeds the minimum possible value for a given two-meson mass $M_{\pi\pi}$ by 200 MeV/c.

The second assumption that must be made to convert the distribution shown in Fig. 2 into a mass spectrum concerns the character of the angular distributions of the pions in the c.m.s. of two mesons (ρ-system).

Figure 3 shows the distribution with respect to the invariant ω^2, obtained by assuming a distribution $\sim \cos^2\varphi_\pi^*$ for the events in the interval $30° \lesssim \theta_{\pi\pi} \lesssim 57°$ and an isotropic distribution for the events in the interval $57° < \theta_{\pi\pi} < 80°$ (φ_π^* — angle of the π meson in the ρ system relative to the initial direction). The indicated angular intervals are converted here into two resonant-type distributions in the ranges $20\mu^2 \lesssim \omega^2 \lesssim 50\mu^2$ and $50\mu^2 \lesssim \omega^2 \lesssim 130\mu^2$, respectively, in Fig. 3 (μ — pion mass).

The second assumption can be verified by independently recalculating the distribution of Fig. 2 for given ρ-system parameters (the mass $M_{\pi\pi}$, the momentum, and the direction in the l.s.). Figure 4 shows the angular distribution obtained in the ρ-system for a group of events with $M_{\pi\pi}$

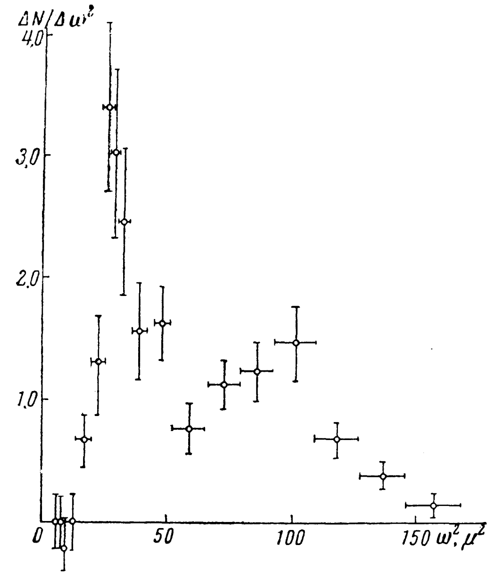

FIG. 3. Distribution of events in terms of the square of the energy (ω^2) of two pions (in relative units) for the reaction $\pi^- + p \to \pi^- + \pi^+ + n$.

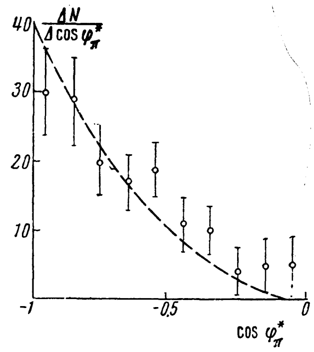

FIG. 4. Angular distribution of pions in the c.m.s. of two pions for events in the interval $30° \lesssim \theta_{\pi\pi} \lesssim 57°$. The dashed line is proportional to $\cos^2\varphi_\pi^*$.

≈ 0.8 BeV for l.s. ρ-system momenta $p = 2.3$ BeV/c, in the direction of the initial π-meson momentum. The permissible changes in the momentum p and its direction change the distribution within the indicated statistical errors. Thus, a distribution $\sim \cos^2\varphi_\pi^*$ for the first resonance is actually the result of the experimental spectrum shown in Fig. 2. For the second resonance, the distribution in the ρ system has a rather complicated character, giving approximately an equal number of events in the intervals $-1 \leq \cos\varphi_\pi^* \leq -0.5$ and $-0.5 \leq \cos\varphi_\pi^* \leq 0$, which can be approximately replaced by an isotropic distribution.

Both energy resonances obtained contain approximately an equal number of events and have a similar appearance in the $\omega = M_{\pi\pi}$ (Fig. 5). We analyzed various processes that could simulate the second resonance—elastic π^-p scattering on free or weakly-bound protons, resonant πN interaction in the final state, etc. A detailed analysis of these processes has shown that they cannot explain the obtained experimental distribution in the

[1)]The procedure is described in detail in [2].

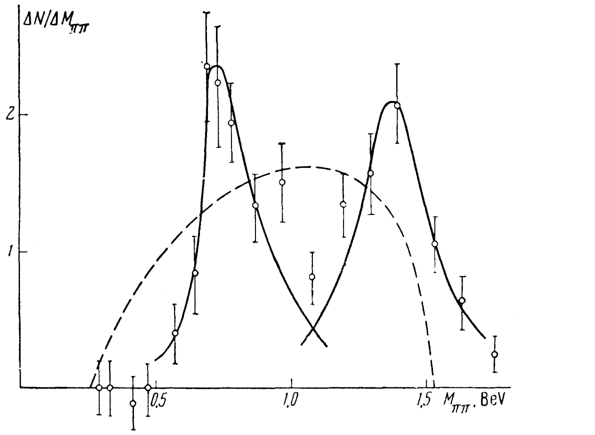

FIG. 5. Distribution of the events with respect to the bipion mass $M_{\pi\pi}$ (in relative units). Dashed line—phase-volume curve.

region of the second resonance, so that this second resonance is apparently also a characteristic of the $\pi\pi$ interaction.

An interesting result is the absence of events in the interval $\omega^2 \lesssim 15\mu^2$ ($M_{\pi\pi} \lesssim 0.5$ BeV), which is apparently a consequence of the previously indicated [1] neutralization of the pole and non-pole diagrams for the investigated reaction, and not a characteristic of the $\pi\pi$ interaction.

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

[2] Bayukov, Leksin, and Shalamov, JETP **41**, 1787 (1961), Soviet Phys. JETP **14**, 1270 (1962).

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