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THE $\pi^- + p \to \pi^+ + \pi^- + n$ *REACTION AT 240 MeV AND THE* $\pi\pi$ *INTERACTION*

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The mass spectrum of the $\pi^+\pi^-$ system is investigated in the 280—350 MeV energy range. The spectrum is shifted with respect to phase-space distribution towards large mass values, but no resonance effects have been observed. Some arguments are presented in favor of the suggestion that the spectrum shift is due to the $\pi\pi$ interaction in the final state. Possible causes of the appearance of the anomaly in pion production in the $p + d \to He^3 + \pi + \pi$ reaction are discussed.

RECENT experimental studies of the $\pi N \to \pi\pi N$ reaction have made it possible to obtain important information on the pion-pion interaction. In the high-energy region, several rapidly decaying particles or $\pi\pi$ resonances have been discovered; the study of these reactions in the low-energy region has made it possible to determine some parameters of the $\pi\pi$ interaction in the s state. An important means of obtaining information on the nature of the $\pi\pi$ interaction is the study of the mass distribution of the two-pion system.

In this work, we studied with the aid of the emulsion technique the reaction

$$\pi^- + p \to \pi^+ + \pi^- + n \qquad (1)$$

for incident π^- mesons of mean energy 240 ± 15 MeV. Preliminary results of the measurements were reported in [1]. The mass spectrum of the $\pi^+\pi^-$ system in the 280—350 MeV interval was studied in detail. At present, we have recorded 255 events, corresponding to a mean cross section ~ 0.1 mb.[1] To find events corresponding to reaction (1), the emulsion was scanned for stopping π^+ mesons; the selection criteria have been described earlier.[2] In 85% of the cases, both pions stopped in the stack and their energy was determined from range measurements. In the remaining cases, the π^- meson escaped from the stack and its energy was determined from ionization measurements. The accuracy of mass determinations of the $\pi^+\pi^-$ system was 1.5—3.0 MeV.

The mass spectrum of the $\pi^+\pi^-$ system is compared in Fig. 1 with the phase-space distribution calculated with allowance for the energy spread of

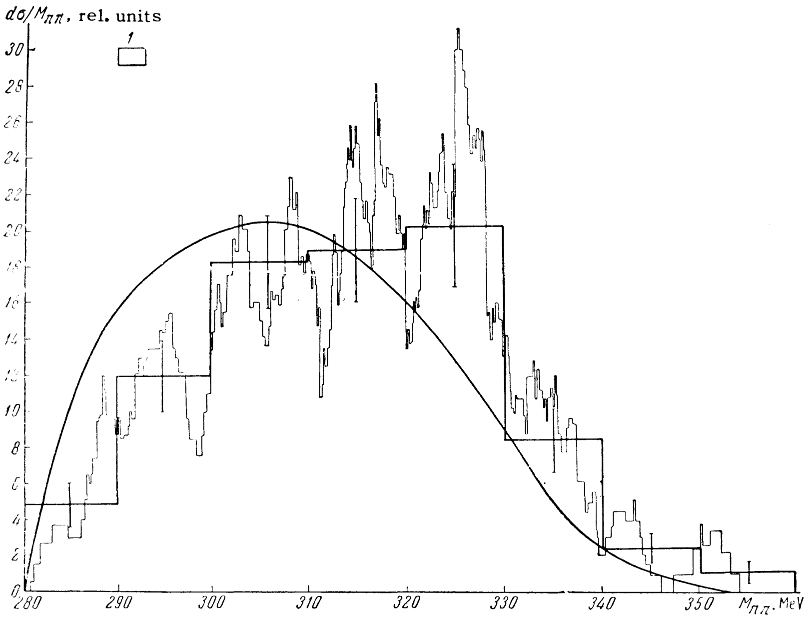

FIG. 1. Mass spectrum of $\pi^+\pi^-$ system from the reaction $\pi^- + p \to \pi^+ + \pi^- + n$ (255 events). The histogram and ideogram represent the experimental data, the smooth curve represents the phase-space distribution.

the primary π^- mesons for all events recorded in the stack. An ideogram was constructed in order to determine the choice of the interval for the histogram. The phase-space curve and the histogram were normalized to the same area. As is seen from Fig. 1, the experimental distribution is systematically displaced relative to the phase-space curve towards larger mass values.

In order to consider the dependence of the square of the matrix element for the reaction $\pi^- + p \rightarrow \pi^+ + \pi^- + n$ on the energy of the $\pi^+\pi^-$ system, the experimental data was divided by the value of the phase-space curve at the corresponding points. The results are shown in Fig. 2.

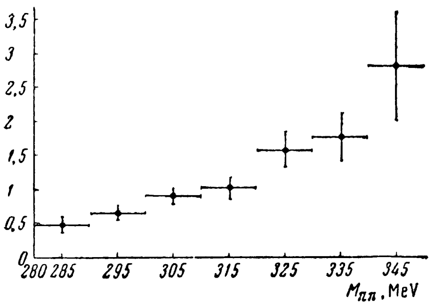

FIG. 2. Results of the division of the mass spectra of the $\pi^+\pi^-$ system from the reaction $\pi^- + p \rightarrow \pi^+ + \pi^- + n$ by the phase-volume (in relative units).

It is seen from the figure that the matrix element increases with the energy of the $\pi^+\pi^-$ system and does not coincide with the phase-space curve. (The probability of agreement was found to be less than 1% by the χ^2 criterion.) It is difficult to ascribe the deviation of the mass spectrum from the statistical distribution to the πN interaction in the final state. Thus, for example, at our energies the mass spectrum of the $\pi^+\pi^-$ system from the $\pi^- + p \rightarrow \pi^+ + \pi^- + n$ reaction calculated from the isobaric model [3] of the πN interaction does not differ from the statistical distribution. Therefore the shift in the $\pi^+\pi^-$ system spectrum towards the larger mass values is apparently caused by the final-state interaction of the pions. At low energies, two pions can be produced in states with isospin $T_{\pi\pi} = 0$ and $T_{\pi\pi} = 2$. A number of authors [4] have shown that the pions in the energy region considered by us are produced primarily in the isospin state $T_{\pi\pi} = 0$.

A detailed study of the behavior of a two-pion system in the low-energy region is of particular interest in connection with the so-called "anomaly" observed in pion production in p + d collisions [5,6] (the ABC meson). Subsequently, an ABC peak was found [7] in the mass spectrum of the $\pi^+\pi^-$ system produced in the reaction $\bar{p} + p \rightarrow 2\pi^+ + 2\pi^- + n\pi^0$. The question of the existence of the ABC meson has also arisen in connection with discussions of Regge poles. [8] On the other hand, a number of authors have not observed a new neutral meson of mass less than $\sim 3m_\pi$. In the mass spectrum of the $\pi^+\pi^-$ system studied by us, we did not observe any anomaly of a resonance character in the 280—350 MeV interval within the limits of experimental error. This, in particular, indicates that the upper limit of the total cross section for the production of the ABC meson of mass 300 ± 10 MeV in reaction (1) does not exceed 10^{-29} cm^2.

In a number of papers, [6,10–12] it has been suggested that the ABC anomaly was possibly due to a strong $\pi\pi$ interaction in the final state with isospin $T_{\pi\pi} = 0$, which can be characterized by a scattering length a_0. However, from the data on pion production in p + d collisions, it is still difficult to make any definite conclusion on the value of the scattering length for pions in the isospin state $T_{\pi\pi} = 0$, since different authors obtain different values of the parameter a_0 on the basis of the same experimental data: + (0.5—1.5), [10] + (2—2.5), [11] + (2—2.8) [6] +1.6, [12] (in units of $\hbar/m_\pi c$).

It should be noted that the anomaly discovered by Booth, Abashian, and Crowe [5,6] was observed at the end of the spectrum. A resonance peak is observed here after the phase-space distribution normalized to the part of the experimental curve lying outside the peak is subtracted from the experimental data. Such a procedure is correct if it is assumed that in the reaction there is a two-particle channel $p + d \rightarrow He^3 + \omega_{ABC}$ competing with the three-particle channel $p + d \rightarrow He^3 + \pi + \pi$. Another reason for the deviation of the experimental spectrum of He^3 from the three-particle phase-space can be the dependence of the matrix element for the $p + d \rightarrow He^3 + \pi + \pi$ reaction on the mass of the $\pi\pi$ system. In this case, the experimental data should be divided by the value of the phase-space curve normalized to the entire area under the experimental curve in order to explain qualitatively the dependence of the matrix element for the reaction on the given variable.

Figure 3 shows the results of such a division for the experimental data presented in Fig. 3 of [6]. As is seen from Fig. 3, no anomalies of a resonance character are observed in this case. This result, along with the results obtained from the mass spectrum of the $\pi^+\pi^-$ system in reaction (1), is an additional argument in favor of the suggestion that the anomaly [5] is not due to the production of a new particle or resonance. It is pos-

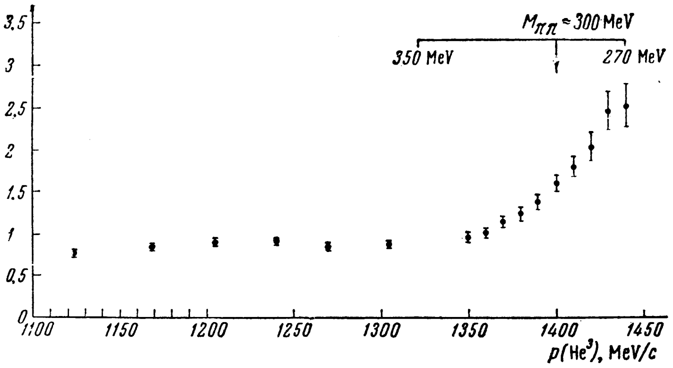

FIG. 3. Results of the division of the momentum spectrum of He^3 from the reaction $p + d \rightarrow He^3 + \pi + \pi$ at 743 MeV at 11.8° (Figure 3 of [6]) by the phase-volume (in relative units).

sible that the anomaly[5] arises as a result of a nonresonance $\pi\pi$ interaction in the final state with isospin $T_{\pi\pi} = 0$. Other factors which can lead to the occurrence of the anomaly have been considered by Booth, Abashian, and Crowe[6] and in discussions of their work.[13]

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