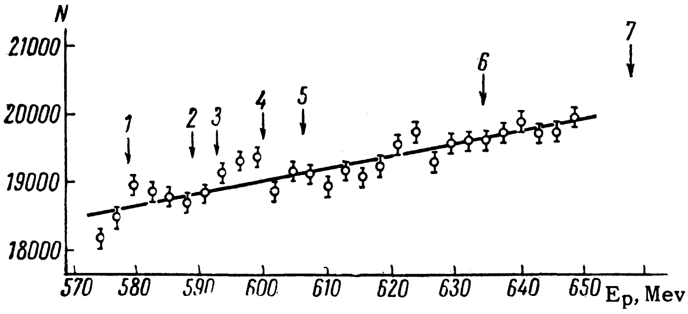

Energy dependence of the differential cross section of the reaction $p + p \to d + \pi^+$ for the angle 5.8° in the l.s. The straight line drawn in the diagram was obtained by the method of least squares. The arrows 1, 2, 3, 4, 5 show the positions of the thresholds of the reactions (2); the arrows 6 and 7 show the positions of the thresholds of reaction (3) for masses 295 and 305 Mev for the ω particle.

made it possible to distinguish deuterons reliably against the background of photons coming from the target.

The energy of the proton beam was varied by means of polyethylene blocks placed in front of the magnetic quadrupole lenses. The proton energy was determined within an interval of 2.8 Mev, which was approximately the energy dispersion of the proton beam.[5]

The kinematics of the reaction (1) are such that for an angle of 5.8° in the l.s. the momentum of the deuterons of the low-energy branch varies by only 3 percent as the proton energy is decreased from 650 to 570 Mev. This decidedly simplifies the measurements and makes it possible to determine the energy dependence of the differential cross section for the reaction (1) by measuring the deuteron yield at the maximum of the resolution curve, instead of finding the area under the resolution curve at each proton energy. At each proton energy a determination was made of the value of the current in the deflecting magnet that corresponded to the position of the peak of the deuterons from the reaction (1); this was calculated from calibration curves of the resolving power, with half-width about 2 percent, measured at three energies: 574, 607, and 657 Mev. With this procedure the inaccuracy in supplying the required current through the deflecting magnet could not cause an error of more than 0.3 percent in the results.

The averaged results of two series of measurements, without subtraction of the background of deuterons from the carbon target, which was about 15 percent, are shown in the diagram. The data were approximated by a straight line, constructed by the method of least squares. If we take into account only the statistical errors of the measurements, amounting to 0.7 percent, the χ^2 test indicates that the experimental data are not consistent with this straight line. If, however, we suppose that besides the statistical errors there is an additional dispersion in the measurements which amounts to 0.5 percent, the χ^2 test gives a 10-percent probability for the fit of the linear dependence to the experimental data. Since the results of a comparison of the separate series of measurements do not allow us to exclude such an amount of instability of the apparatus, the spread of the experimental points which is seen in the diagram cannot be ascribed to real anomalies in the energy dependence of the differential cross section for the reaction (1).

It follows from the results of this work that if the near-threshold anomalies predicted by the theory do exist in the reaction (1), their magnitude does not exceed 2 percent of the average differential cross section of reaction (1) over the proton-energy range 574 — 648 Mev.

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SEARCH FOR ANOMALIES IN THE SPECTRUM OF THE H^3 *NUCLEI EMITTED IN THE REACTION* $p + d \to H^3 + \pi^+ + \pi^0$ *AT A PROTON ENERGY OF 670 Mev*

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THERE has recently been much discussion of the problem of the resonance interaction of two π mesons with the isotopic spin $T_{\pi\pi} = 1$. The only experimental indication of the possibility of such a resonance are the preliminary results of Abashian, Booth, and Crowe,[1] who studied the momentum spectrum of the He^3 and H^3 nuclei produced in the reactions

$$p + d \to \begin{cases} He^3 + \pi^0, & (1a) \\ He^3 + \pi^0 + \pi^0, & (1b) \\ He^3 + \pi^+ + \pi^-, & (1c) \end{cases}$$

$$p + d \to \begin{cases} H^3 + \pi^+, & (2a) \\ H^3 + \pi^+ + \pi^0, & (2b) \end{cases}$$

and observed peaks in these spectra which can be interpreted as manifestations of a π-π resonance with $T_{\pi\pi} = 1$ or of the formation of a new particle with mass 310 Mev and isotopic spin T = 1. The schemes for the formation of the new particle are

$$p + d \to He^3 + \omega^0, \qquad (1d)$$

$$p + d \to H^3 + \omega^+. \qquad (2c)$$

In view of the large discrepancy between the observed resonance energy and the theoretically predicted value,[2] and also of the importance of the question of the isotopic spin of the π-π resonance, it is of great interest to get more precise momentum spectra of the H^3 nuclei produced in the reactions (2b) and (2c). For this purpose we have measured the region of the momentum spectrum of the H^3 nuclei that belongs to the low-energy branch of reaction (2a), at proton energy 670 Mev. The identification of the charged particles produced in gaseous deuterium and hydrogen targets was made from the momentum, specific ionization, range, and time of flight. The results of the measurements are shown in the diagram, where the abscissa is the current in the deflecting magnet, which is proportional to the momentum of the H^3 nuclei, and the ordinate is the difference between the counts from the gas target filled with deuterium and with hydrogen. Arrow 1 indicates the value of the current that corresponds to the lower limit of the spectrum of H^3 nuclei from the reaction (2b). Arrow 2 indicates the value of the current that corresponds to the total energy of two π mesons in their c.m.s., which is 320 Mev, and a momentum of 875 Mev for the H^3 nucleus.

A statistical treatment of the results of the measurements shows that with probability 90 percent, the yield of H^3 nuclei of momentum 875 Mev at angle 5.8° in the l.s. does not exceed 6 percent of the yield of H^3 nuclei at the same angle in reaction (2a). The cross section for the reaction (2a) was measured by a comparison with the cross section for the reaction $p + p \to d + \pi^+$.[3] The cross section for reaction (2a) calculated in the c.m.s. and referred to the angle of emergence of the π^+ meson was found to be

$$\frac{d\sigma}{d\Omega}(\theta_\pi = 12°) = (9.1 \pm 0.5) \cdot 10^{-30} \ \ cm^2/sr$$

The cross section for reactions (2b), (2c), referred to the angle between the velocity vector of the motion of the center of mass of the mesons and the axis of the beam, or to the angle of emergence of the ω particle, has the upper limit, in the c.m.s.,

$$\frac{d\sigma}{d\Omega}(\theta_\omega = 20°) \leqslant 0.2 \cdot 10^{-30} \ \ cm^2/sr$$

with probability 90 percent.

The cross section for the high-energy branch of reaction (1a) was also measured. The differential cross section in the c.m.s., referred to the angle of emergence of the π^0 meson, is

$$\frac{d\sigma}{d\Omega}(\theta_{\pi^0} = 154°) = (0.295 \pm 0.032) \cdot 10^{-30} \ \ cm^2/sr$$

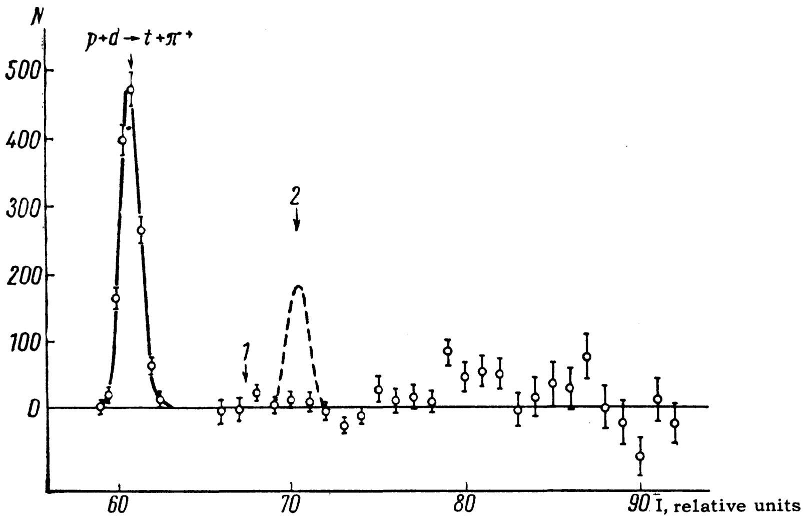

Fig. 1

Besides this, the yield of He^3 nuclei from reactions (1b), (1c), which was measured for three momenta, shows that the cross section for these reactions is comparable with that for (2a).

For a quantitative comparison of the data with the results of reference 1, a calculation of the angular distributions of reactions (2a) and (2c) was made in the impulse approximation.[4,5] The angular distribution found for reaction (2a) agrees qualitatively with a large forward-backward asymmetry.[6,7] The calculation for reactions (2b), (2c) was made on the assumption that first there is production of two π mesons or of an ω particle in the reactions

$$p + p \rightarrow d + \pi^+ + \pi^0, \qquad p + p \rightarrow d + \omega^+, \tag{3}$$

and then the neutron and deuteron combine into a tritium nucleus. The angular distributions of reactions (2b), (2c) calculated on the two extreme assumptions about the angular distribution of the deuterons in the reactions (3), an isotropic distribution and a $\cos^2\theta$ distribution, differ only slightly at angles close to 0° or 180° in the c.m.s. This fact allows us to compare the data[1] relating to the high-energy branch of the reactions (2b), (2c) with our values of the differential cross sections for the low-energy branch. The yield of H^3 nuclei measured in reference 1 and recalculated in this way is shown in the diagram by a dashed line. It exceeds the upper limit found in this work for the cross section of reactions (2b) and (2c) by about an order of magnitude.

Thus the results obtained here do not confirm the existence of a resonance of two π mesons in a state with isotopic spin $T_{\pi\pi} = 1$ and total energy from 275 to 420 Mev in their c.m.s., and also allow us to exclude the existence of an ω particle with isotopic spin $T = 1$ and mass ~ 310 Mev. Since there are now definite indications of the nonexistence of a vector meson with $T = 0$[8] and mass in the range from 300 to 400 Mev, the explanation of the anomaly found in reference 1 in terms of the existence of such a meson also seems improbable.

We must seek a possible cause of the anomaly in the spectrum of the He^3 nuclei produced in reactions (1b) and (1c) in threshold effects[9,10] associated with the endothermal process $\pi^0 + \pi^0 \rightarrow \pi^+ + \pi^-$.* As is shown by an analysis of the threshold effects made by means of dispersion relations,[11] departures from monotonic energy dependence in reactions with three particles in the final state can spread rather far from the threshold of the corresponding endothermal process.

Another conclusion from this work is that the cross section for production of two π mesons in the state with isotopic spin $T_{\pi\pi} = 0$ is about an order of magnitude larger than the upper limit on the cross section for the production of two π mesons in the state with $T_{\pi\pi} = 1$, right up to a total energy of the two π mesons in their c.m.s. of about 400 Mev. This relation between the cross sections evidently changes at higher energies, as is indicated by the data on processes $\pi N \rightarrow \pi\pi N$ obtained at energies ~ 500 Mev.[12]

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*L. I. Lapidus pointed out the possibility of this interpretation.

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