EXCITATION OF THE He^4 *NUCLEUS BY 150 Mev PIONS*

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An upper limit of 3.8×10^{-27} cm^2 has been obtained for the He^4 excitation cross section in reactions (1) and (2) by investigating the interaction between 150-Mev π^- mesons and helium in a diffusion cloud chamber. The total cross section and the cross section for inelastic π^--He interaction and also the cross sections for reactions (1) and (2) are presented.

MANY experimental data (see, e.g. Ref. 1) indicate the possible existence of a virtual state of the He^4 nucleus at an excitation energy of ~ 22 Mev. The analysis of Baz' and Smorodinskii[2] has shown that one can fit the experimental data to the following level parameters: spin and parity 2^-, isospin T = 0. Since the energy of the level is higher than both the proton (19.8 Mev) and the neutron (20.6 Mev) binding energy, the lifetime of the level is very short (level width ~ 2 Mev) and it is rather difficult to observe the level.

In the present paper we tried to estimate the probability of exciting the He^4 nucleus in the reactions

$$\pi^- + He^4 \to \pi^- + He^3 + n, \quad (1)$$

$$\pi^- + He^4 \to \pi^- + T + p \quad (2)$$

for an energy of the incoming meson of around 150 Mev.

The reactions (1) and (2) were investigated by means of a diffusion chamber[3] filled with helium at a pressure of 18 atm and placed in a magnetic field of 12 000 oe. The chamber was exposed to the π^- beam of the proton synchrotron of the Joint Institute for Nuclear Research. About 30 000 stereoscopic pictures were taken. They were scanned twice and 1802 events of π^--He^4 interaction were found. The kinematics of these events were determined by reprojection and 304 events of reaction (1) and 87 events of reaction (2) were identified.

The total π^--He^4 interaction cross section, i.e., the sum of the inelastic π^--He^4 cross section and of the cross sections for reactions (1) and (2) was found by measuring the total π^- track length in the chamber. The following values were obtained: $\sigma_t = (254 \pm 16)$; $\sigma_{nuc} = (171 \pm 12)$, $\sigma_1 = (53 \pm 6)$ and $\sigma_2 = (11.3 \pm 2.3) \times 10^{-27}$ cm^2.

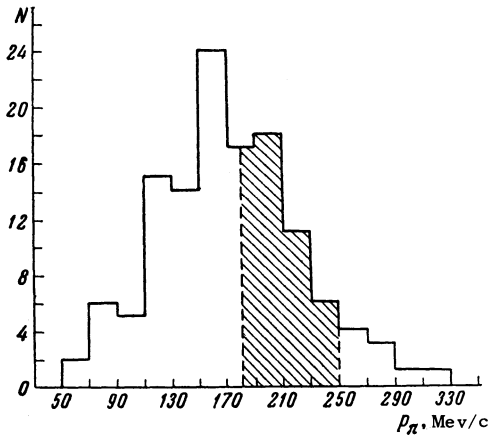

FIG. 1. Momentum distribution of π^- mesons from reaction (1) in the center-of-mass system.

If one assumes that the reactions that go through the excited state of He^4, namely

$$\pi^- + He^4 \to \pi^- + He^{4*} \to \pi^- + He^3 + n, \quad (3)$$

$$\pi^- + He^4 \to \pi^- + He^{4*} \to \pi^- + H^3 + p \quad (4)$$

happen with an appreciable probability, then one should observe in the center of mass system (c.m.s.) a peak at a momentum p = 215 Mev/c. It should have a width given by the energy uncertainty of the primary π meson beam and by the width of the level. It should be superimposed on the wide distribution originating from reactions (1) and (2).

The experimentally observed distribution of c.m.s. momenta of π^- mesons from reaction (1) is shown in Fig. 1. Only those events which allowed a determination of the π^- momentum to at least 10% by measurement of the radius of curvature (track length of the scattered π^- meson > 4 cm) were used. There were 127 such events. The analogous distributions from reaction (2) are plotted in Fig. 2: histogram (a) has been determined by

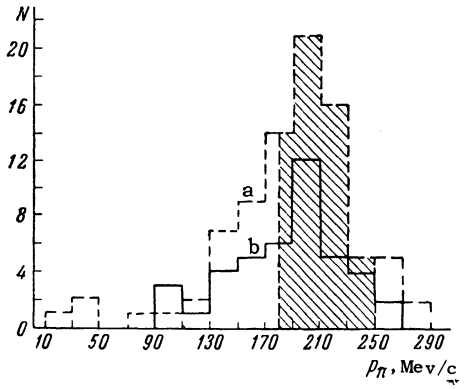

FIG. 2. Momentum distribution of π^- mesons from reaction (2) in the center-of-mass system.

measuring the angles of the outgoing particles and the momentum of the incoming π^- meson and contains 86 cases; histogram (b) contains 42 cases which allowed a determination of the momenta to at least 10% by measurement of the radius of curvature.

In order to estimate the cross section for excitation of a level at 22 Mev all events which had a π meson momentum in the interval 180 Mev/c $< p_\pi <$ 250 Mev/c (cross-hatched region in Figs. 1 and 2) were further analyzed. They were checked for kinematical consistency with reactions (3) and (4). These are: (i) The vectors of the momenta of He^{4*}, H^3, p, have to be coplanar. (ii) The emission angles of He^3, H^3 or p should not exceed the largest emission angle they could have in the laboratory system consistent with the supposed momentum of the He^{4*} particle if they would originate in the decay $He^{4*} \rightarrow He^3 + n$ or $He^{4*} \rightarrow H^3 + p$. (iii) The energy of the particles He^3, H^3 and p in the rest system of He^{4*} should lie in the interval consistent with the decay of He^{4*} with an excitation energy of 22 ± 1 Mev.

The above kinematical conditions were fulfilled within the accuracy of the measurements by 7 events of reaction (1) and by 7 events of reaction (2). This corresponds to an upper limit for the cross section for excitation of He^4 of 3.8×10^{-27} cm^2. Such a small contribution of reactions (3) and (4) to the total inelastic π^--He interaction (< 2.2%) is consistent with the experiments of Hofstadter et al.,[4] Tyren et al.,[5] and Selove and Teem.[6] There it was observed that the influence of the excited state in helium is very small indeed on the scattering of electrons of energy 400 Mev and of protons of 185 and 95 Mev.

The results of the present work also allow to conclude that the angular correlation observed by Kozodaev et al.[7] in the reaction $\pi^\pm + He^4 \rightarrow \pi^\pm + H^3 + p$ at an energy of 300 Mev can not be explained by an excited state of He^{4*}.

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