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(Nota interna: n. 326)

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INTRODUCTION. -

Lithium six is the first of the light nuclei in which there is some evidence of the existence of nuclear substructures. In fact many experiments at low energy can be interpreted assuming a Lithium nucleus composed of a deuteron lightly bound to an alpha particle. For this reason we decided to study the photodisintegration of lithium six at high energy selecting the particular final state with an outgoing deuteron. The deuteron was the only particle detected. To gather information on the incoming gamma ray energy we have measured a yield curve as a function of the primary electron energy integrating our cross section over the Bremsstrahlung spectrum. Our results seem consistent with a crude model taking into account only the coherent photoproduction of π^0 on virtual deuterons. The rescattering of the neutral pion on the other nucleons does not seem very important.

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EXPERIMENTAL APPARATUS. -

Electron beam.

The electron beam was momentum, analyzed by the three magnets deflecting system of the 1 GeV station described in ref. (1). The setting of the analyzing magnets was determined by means of a proton magnetic resonance probe placed in the magnet's gap and by a precision shunt in series with the magnet coils.

The energy defining slits were set to select a momentum interval of ± 0. 5% around the chosen value. After having been focused by a quadrupole doublet the beam entered the experimental area. The target, on the axis of rotation of a magnetic spectrometer, was directly connected to the vacuum system of the accelerator. After traversing the target the beam left the vacuum system and traversed three secondary emission electron monitors (SEM).

Their outputs were connected to three integrators(2) and continuously monitored during the runs. The secondary electron monitors were calibrated against the Faraday cup before and after each point. For two of them, the relative stability was found to be better than 1%. The stability of the third monitor was not better than some percent and was not used to normalize the data.

The target was mounted on a remotely controlled translating slide. The slide supported the lithium target, a fluorescent screen and an empty position. In this way it was possible to control the position of the electron beam at the target, and calibrate the Secondary Emission Monitors versus the Faraday cup for each value of the primary electron energy.

Target. -

The target was made out of enriched Lithium six. The isotopic composition was: 1. 3% Li^7; 98. 7% Li^6. The thickness was measured to be 0. 166 gr/cm^2.

Detection apparatus. -

The deuterons emitted from the target were momentum analysed using the double focusing zero dispersion magnetic spectrometer described in ref. (3). The energy defining slits of the spectrometer were set to accept a momentum interval of ± 1%. The deuterons transmitted by the magnet were detected by two scintillation counters in coincidence. Discrimination of deuterons against the larger background of ligher particles, mostly protons, was done on the basis of the pulse heights in the two counters and with a lucite Cerenkov counter in anticoincidence. Pulse height discrimination was performed with 100 Mc discriminators. The output pulses from the counters were sent also to a gated stretcher and were continuously monitored with a multichannel pulse height analyser. In this way it was possible to make sure that the contamination from protons and positive pions was very small. We also found no appreciable evidence of contamination from heavier particles (t, He^3, He^4). The electronics consisted of 100 Mc. digital logic. Random coincidences were monitored by the delayed coincidence method during all our data-taking runs.

EXPERIMENTAL RESULTS. -

The measurements were performed at a constant angle and momentum for the outgoing deuteron, varying the primary electron energy. Deuterons were detected at 35° in the laboratory system with a momentum of 498 MeV/c.

We were looking for the reaction:

$$e + Li^6 \rightarrow e' + d + \alpha^x$$

where α^x indicates the final state of four nucleons and pions which was not detected by our apparatus. The total energy in its own center of mass of this system was a function of the energy of the photon exchanged between the electron and the hadron current. The final electron also was not detected. For this reason the double differential electroproduction cross section had to be integrated over all possible energies and directions of the final electron. This amounts to measuring the photoproduction cross section where the real photons are substituted by a virtual photon spectrum very similar in shape to the Bremsstrahlung spectrum. The absolute intensity of this spectrum can be estimated to be equivalent to the intensity produced by a radiator of 0.02 radiation lenght[(4)]. The real radiator contributed by the finite lenght of the target was a correction of the order of 8%.

The result of the experiment is indicated in Fig. 1. The abscissae indicate the primary electron energy and the corresponding exitation energy of the four nucleon system. The ordinates indicate the exitation function defined by:

$$Y(E) = \int_0^E \frac{d^2\sigma(k)}{d\Omega_d \, dT_d} \, \frac{f(E,k)}{k} \, d_k$$

in units of microbarn/steradian MeV. E indicates the primary electron energy, k the energy of the exchanged gamma ray, and f(E, k) is the energy spectrum of the Bremsstrahlung beam.

The absolute value of the cross section has been estimated by a first order calculation of the optical properties of the magnet. It seems reasonable to assign to this calculation an error of ± 20%.

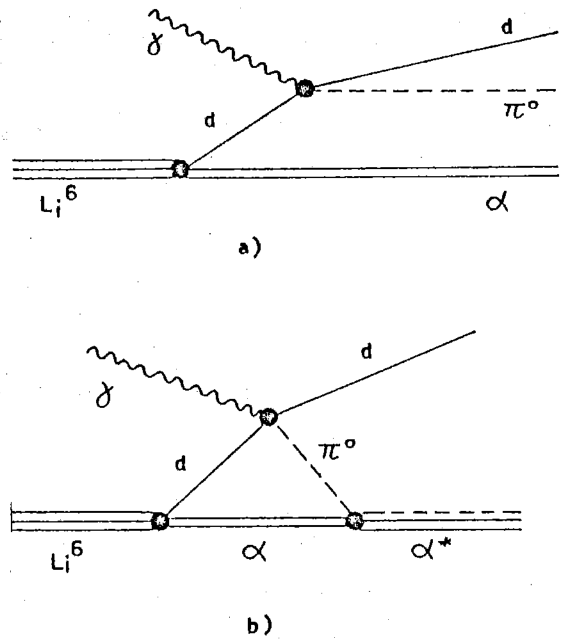

FIG. 1 - Indicates the Feynman graphs which we have taken into account. In a) there is no final state interaction of the pion with the four nucleons system. In b) the final state interaction is shown.

DISCUSSION. -

The photodisintegration of Li^6 has been studied my many authors (5÷9) in the energy region below the threshold for pion photoproduction. In this energy region many experiments can be interpreted in terms of a cluster model for the Lithium 6 nucleus. A study of the reactions (p, pd) and (p, pα) in Li^6 (10) indicates that the clustering of the six nucleons in a deuteron and an alpha particle have a probability of approximately 25%.

Our measurement was performed with a large momentum transfer to the final deuteron. The presence in the Lithium nucleus of virtual deuterons with momentum this large is highly improbable. Therefore in a model based on the impulse approximation we can neglect all diagrams were the deuteron is a spectator.

The crude model we have calculated takes into account only the contribution from the graph indicated in Fig. 1a).

For the upper vertex we have taken the measured values of the total cross section for the coherent photoproduction of neutral pions in deuterium[11 ÷ 13]. For the Li^6 - d - α vertex we have taken a constant form factor with a cut-off. Similar processes[14] have been shown to be quite independent of the choice of this particular form factor.

The impulse approximation contributes a geometrical efficiency factor due to the restriction imposed by the conservation of energy and momentum on the phase space available to the initial virtual deuteron. We have calculated this simple model with and without cut-off for the Li - d - α vertex. The geometrical efficiency factors are indicated in Fig. 2. The two results have been independently normalized to obtain a good fit to our data.

They are indicated by the two curves in Fig. 3. We can account for the final state interaction of the photoproduced pion with the spectator nucleons by multuplying these results by a factor proportional to the total pion-alpha cross section. This cross section has a maximum corresponding to the first pion nucleon isobar for Q_{α^*} = 300 MeV. Due to the particular choice of our kinematical conditions the final state accounted for in this way would produce a steeper rise of our yield curve. This seems in contradiction with our data.

It is interesting to note the steep rise at a gamma ray energy of 700 MeV

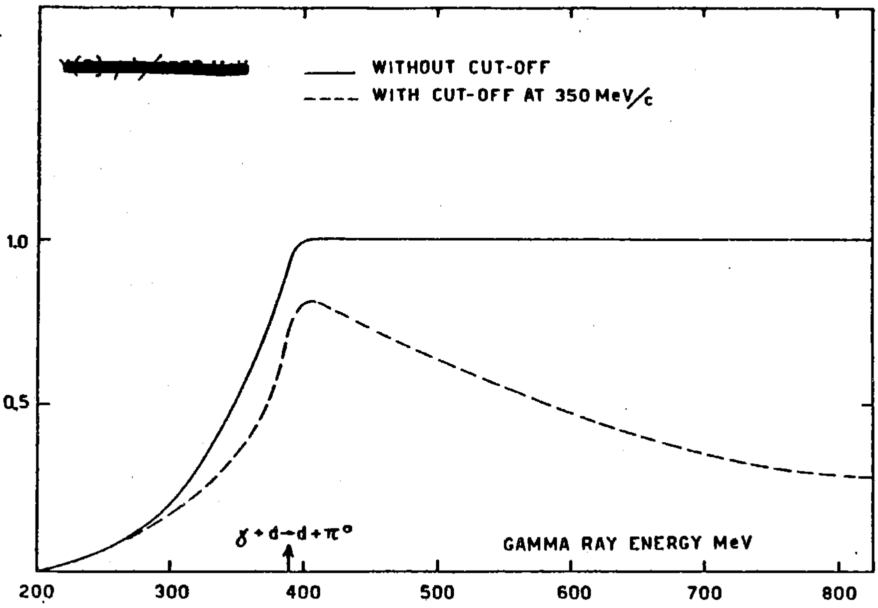

FIG. 2 - shows the result of our aestimate of the geometrical efficiency factor calculated without introducing a cut-off value for the momentum of the virtual deuteron (solid line) and introducing a cut-off value of 350 MeV/c (broken line). The arrow indicate the threshold for the reaction $\gamma + d \rightarrow d + \pi^0$ on a free deuteron.

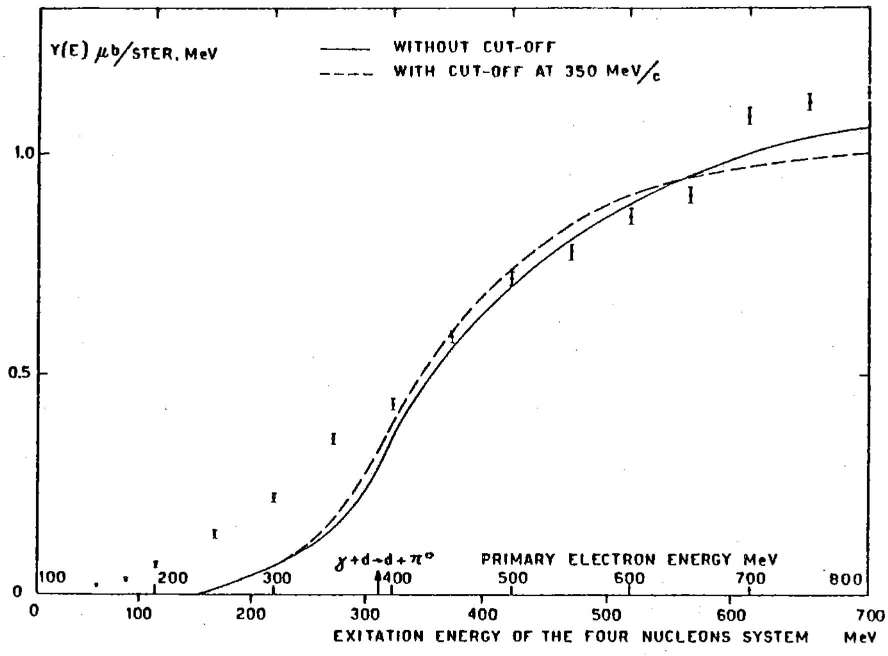

FIG. 3 - shows the yield curve measured in our experiment. Error bars indicate statistical fluctuations only. The solid line shows the result of our very crude model when no cut-off is introduced in the Li-d-α vertex. The broken line shows the result of the same calculations with a cut-off at 350 MeV/c. The two calculations have been indipendently normalized to compare with our experimental results. The arrow indicate the threshold for the reaction $\gamma + d \rightarrow$ $\rightarrow d + \pi^0$ on a free deuteron.

corresponding to a Q_{α^*} of approximately 620 MeV. In our model this could be interpreted as a sharp resonance in the system of the four nucleon and pions. This resonance should appear at an exitation energy between 570 and 620 MeV and should have a width (FWHM) of less then 40 MeV. No evidence of such a state has been reported up to now. However a recent experiment(15) on the photodisintegration of He^4 at high energy shows a sharp peak at the sa me value of the exitation energy.

This second experiment unfortunately is not in a position to yield any information on the isospin of this state. From our experiment we are inclined to advance the hypothesis that the state might be a T = 1. This hypothesis, however, depends completely on the particular model that we have made to explain our data. Due to the limited statistical evidence of both experiments it seems higly appropriate to try to gather more information on the possible existence of this state. In particular a measurement of the total cross section for $\pi - \alpha$ scattering should allow the determination of the isospin of this state.

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