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Single and Double Pion Photoproduction on ^{3}He.

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In this paper we report the preliminary results of an experiment of photoproduction on ^{3}He, performed in order to obtain general information about the dynamic behaviour of this nucleus up to an energy of 800 MeV of the incoming photon.

The interest of an investigation on ^{3}He has been stressed by many authors ([1-5]), due to its peculiar static properties ([6]) ascribed to a possible relevant contribution of mesonic exchange currents to its structure ([7,8]).

This approach implies that even the dinamic properties of ^{3}He could be affected.

The experimental situation shows so far an almost complete lack of information beyond the π photoproduction threshold ([9,10]), while at lower energies several data are available on the two- and three-body photodisintegration reactions ([11-16]).

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The present experiment was performed by the diffusion cloud chamber technique. The chamber, operating with an admixture of H_2 and ^3He and inserted in a 10 kG analising magnet, was described in a previous paper ([17]) together with the general experimental layout.

The bremsstrahlung beam of the Frascati electronsynchrotron was hardened by 2.9 LiH radiation lenghts and the resulting shape of the spectrum taken from a paper by HART and WHITE ([18]). An experimental check of the assumed spectrum, obtained from a sample of 1500 e^+e^- pairs, shows a very good agreement for γ-ray energies greater than 100 MeV, while for the lower energies the possible existence of a measuring bias makes the comparison no longer feasible. A total number of 105000 pictures was taken and the total photon flux was estimated by counting the number of e^+e^- pairs in each picture containing at least one interesting event and by averaging with LIN method ([19]). The resulting average pair number is 3.57 per picture.

The whole film was scanned twice in two different laboratories and the resulting scanning efficiency is estimated to be 98%.

All the events found in the fiducial zone of the chamber were measured and the geometrical reconstruction was performed by means of a computer program. A subsequent program chain allowed to complete kinematical reconstruction for all the two-prong events with overdetermined kinematics.

The reaction assignment was tried for all the available events on the basis of ionization, angular distribution and kinematical limitations, regardless of their kinematical fit. No ambiguity was possible between H and ^3He events.

For a limited number of events the reaction assignment was not possible; a further analysis made possible the evaluation of uncertainty intervals for the actual data. The kinematical-fit assignments confirm independently the validity of the adopted criteria.

In this paper we limit ourselves to consider the results concerning the cross-sections per equivalent quantum (σ_{EQ}) for the various reactions (Table I) up to the maximum photon energy.

In Table I the numbers of events and σ_{EQ} are given for reactions or group of reactions; statistical errors and uncertainties are quoted. In our notation the square brackets indicate that only the inelastic channel is considered.

TABLE I.

Reaction	Number of events	σ_{EQ} (μb)	Uncertainty U
$\gamma + {}^3He \to pD$	911	—	0.04
$\to \pi^+ T(\pi^0) + \pi^+ [T](\pi^0)$	386	512 ± 29	0
$\to$ all other two-prong events	1830	—	0.04
$\to \pi^- 3p(\pi^0)$	55	74 ± 11	0.30
$\to \pi^+\pi^- [{}^3He]$	123	236 ± 21	0.11
$\to$ three-prong events	111	—	0.11

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We proceed now to examine briefly the forementioned results.

1) *Photodisintegration reactions.* The total number of two-body events and the preliminary results on the energy dependence of the total cross-section, not reported in this paper, are in good agreement with other experimental data ([15]).

The number of the three-body events is in agreement, within the errors, with the known cross-sections ([15]), considering that it has a relevant contribution from the inelastic photoproduction channel.

2) *Photoproduction reactions.* For the photoproduction reactions we assume

$$\frac{\sigma_{\mathrm{EQ}}^{\mathrm{He}}}{n} = \eta \sigma_{\mathrm{EQ}}^{\mathrm{fn}} ,$$

where n is the number of ^{3}He nucleons giving rise to the considered reaction and $\sigma_{\mathrm{EQ}}^{\mathrm{fn}}$ is the corresponding cross-section per equivalent quantum on free nucleon. η is an overall efficiency containing the dependence from the properties of the interaction and a reduction factor, due to the Pauli exclusion principle.

For single and double charged photoproduction we calculated, by means of the Monte Carlo method, the Pauli reduction factor, using the ^{3}He charge distribution ([20]) and the well-known experimental nucleon recoil momentum distribution for the free nucleon. The impulse approximation has been used throughout as a general approach to the calculations and the analysis.

a) π^+ *photoproduction.* To obtain the total σ_{EQ}, elastic plus inelast c, for the π^+ photoproduction we have to evaluate the $\pi^+\pi^0$ contribution. Assuming $\sigma_{\pi^+\pi^-}^{\mathrm{fn}} = \sigma_{\pi^+\pi^0}^{\mathrm{fn}}$, as suggested by some experimental data ([21]), with a calculated Pauli factor of 0.7 for $\pi^+\pi^0$ production, we obtain

$$\sigma_{\mathrm{EQ}}(\mathrm{T}\pi^+ + [\mathrm{T}]\pi^+) = (465 \pm 29)\ \mu\mathrm{b}$$

and

$$\eta_{\pi^+} = 0.92 \pm 0.06 , \qquad U \simeq 0 ,$$

where only the final states are indicated.

A recent theoretical calculation ([22]), based on the impulse approximation method, gives

$$\sigma_{\mathrm{EQ}}(\mathrm{T}\pi^+) = 62.1\ \mu\mathrm{b}$$

in agreement with the number of our fitted events (53). From these data the elasticity ratio results

$$\varepsilon_{\pi^+} = 0.13 \pm 0.01 .$$

b) π^0 *photoproduction.* With the same approach previously used we can give a rough estimation of the π^0 photoproduction efficiency. By means of a subtraction, on the basis of the known cross-section for three-body photodisintegration ([15]), we

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obtain

$$\eta_{\pi^0} = 1.40 \pm 0.36 , \qquad U = 0.26 .$$

c) π^- *photoproduction.* For the π^- photoproduction we obtain, after subtraction of the $\pi^-\pi^0$ contribution, with the same hypothesis used for the $\pi^+\pi^0$ subtraction,

$$\sigma_{EQ}(\pi^- 3p) = (64 \pm 11) \mu b .$$

The large difference between $\sigma_{EQ}(\pi^-)$ and $\sigma_{EQ}(\pi^+)$ can be understood as a consequence of the Pauli principle, completely forbidding the S-state for the nuclear-system recoil in the π^- photoproduction reaction.

The Monte Carlo result for the π^- reduction factor is 0.27, in very good agreement with the experimental value

$$\eta_{\pi^-} = 0.25 \pm 0.04 , \qquad U = 0.3 .$$

d) $\pi^+\pi^-$ *photoproduction.* For the $\pi^+\pi^-$ double photoproduction we obtain

$$\sigma_{EQ}(\pi^+\pi^- {}^3\mathrm{He} + \pi^+\pi^- [{}^3\mathrm{He}]) = (249 \pm 31) \mu b$$

and

$$\eta_{\pi^+\pi^-} = 1.57 \pm 0.2 , \qquad U = 0.11 .$$

In our opinion the large value of $\eta_{\pi^+\pi^-}$, if confirmed by further analysis, is the most relevant result of the present investigation. It can be probably interpreted in terms of large interference contributions from the double-photoproduction amplitudes on nucleon.

We remark that, if one used the result to evaluate the $\pi^+\pi^0$ and $\pi^-\pi^0$ contributions, slightly different numbers are obtained for π^+ and π^- reactions:

$$\sigma_{EQ}(\mathrm{T}\pi^+ + [\mathrm{T}]\pi^+) = (441 \pm 29) \mu b , \qquad \sigma_{EQ}(\pi^- 3p) = (60 \pm 11) \mu b ,$$

$$\eta_{\pi^+} = 0.87 \pm 0.06 , \qquad \eta_{\pi^-} = 0.24 \pm 0.04 .$$

In any case positive interference contributions seem to play a significant role also in the π^+ photoproduction reaction.

Further work, concerning in particular the double-photoproduction reactions, is in progress both as theoretical calculations and as experimental analysis.

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