# Photodisintegration of $^4$He in the $\Delta$ region

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Photoemission of protons from $^4$He is measured at $\theta_p=30°$, 60°, 90°, and 105° in the photon energy range between 187 and 427 MeV. From the analysis of the momentum spectrum of protons, the differential cross sections for the photodisintegration of quasifree two-nucleon systems in the $^4$He nucleus are deduced as a function of the proton angle and the incident photon energy. The obtained cross sections for $^4$He are larger than those for the deuteron photodisintegration by a factor of about 4.5 in the energy region of the present experiment.

As a part of a systematic study[1–5] of the photodisintegration of light nuclei, we report here the results of a measurement of the reaction $^4$He($\gamma$,p) in the energy region of the $\Delta$ resonance.

The experiment was performed using a tagged photon beam from the 1.3 GeV electron synchrotron at the Institute for Nuclear Study, University of Tokyo. The photon energy range covered in the present experiment was from 187 to 427 MeV with an energy bin width of 10 MeV. A liquid helium target of 11.0 cm thickness was used. The momentum spectra of protons from the $^4$He($\gamma$,p) reaction were measured at proton emission angles 30°, 60°, 90°, and 105° with a magnetic spectrometer. In order to detect the protons or neutrons accompanied by the spectrometer protons, 64 plastic scintillation counters located on the opposite side of the beam from the spectrometer were used.[5]

Typical examples of proton momentum spectra measured at $E_\gamma=337\pm10$ MeV are shown in Fig. 1. As seen most clearly in the figure for $\theta_p=30°$, the spectrum consists of two components. From kinematical considerations,[2] it was concluded that the peak in the lower momentum region is due to pion photoproduction from the quasifree nucleons in the nucleus,

$$\gamma+\text{"N"}\rightarrow\pi+\text{p}\ , \tag{1}$$

and the peak in the higher momentum region is due to photodisintegration of a quasifree two-nucleon system in the nucleus,

$$\gamma+\text{"pN"}\rightarrow\text{p}+\text{N}\ , \tag{2}$$

where "N" and "pN" denote a quasifree nucleon and a quasifree two-nucleon system in the nucleus, respectively. The cross section for reaction (2) is obtained by fitting the peak at higher momentum with a Gaussian, where protons due to reaction (1) are regarded as a background. At 30°, the momentum spectrum is well represented by two Gaussians corresponding to the above reactions. At the other angles, since the background peak due to reaction (1) almost disappears from the spectra, neither the peak position nor the width can be determined. So, in the analyses the background shape is determined at all angles by a Monte Carlo calculation of reaction (1) including successive final-state interactions. In this analysis, the amplitude of the background is treated as a free parameter. The solid curves in Fig. 1 represent the results of the fitting procedure.

The photon energy dependence of the cross section for reaction (2) is shown in Fig. 2. It has a maximum at around $E_\gamma=290$ MeV, which suggests that $\Delta(1232)$ formation dominates in this reaction. The dashed curves in

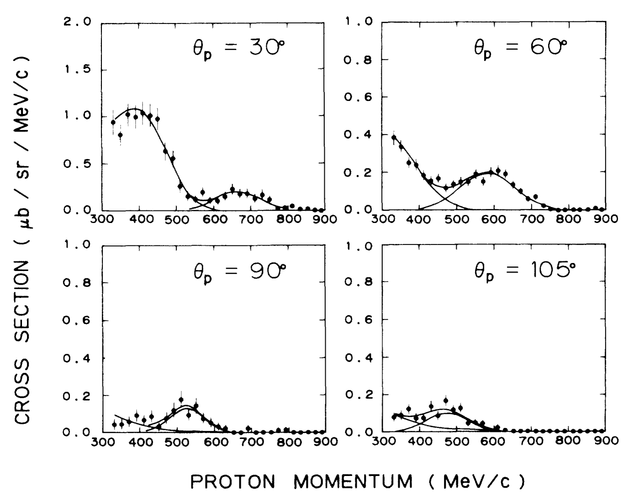


FIG. 1. Typical examples of the proton momentum spectra at $E_\gamma=337$ MeV. The solid curves in the figure show the results of fitting.

 

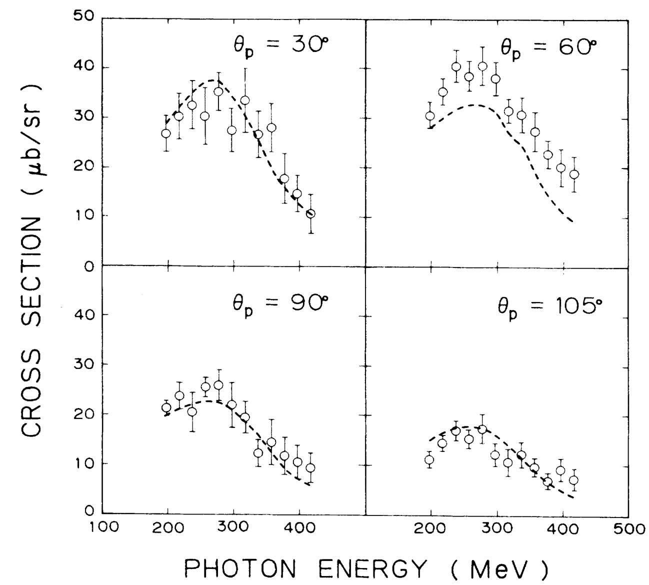


FIG. 2. Photon energy dependences of the cross section for the photodisintegration reaction of a quasifree two-nucleon system in the $^4$He nucleus. The dashed curves show the deuteron photodisintegration cross section (Ref. 6) multiplied by 4.5.

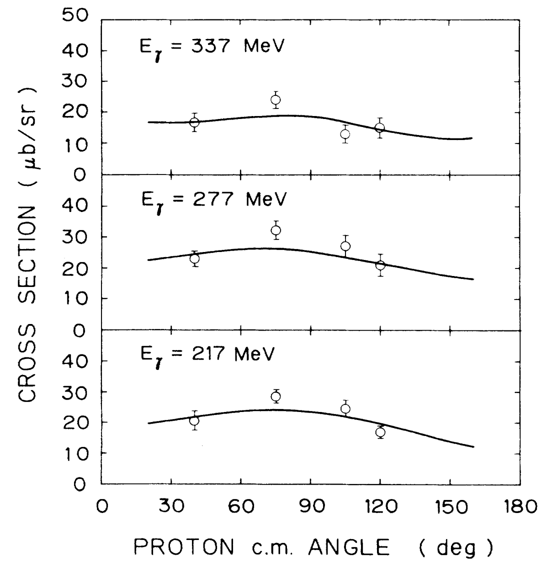


FIG. 3. Angular dependences of the cross section of the photodisintegration reaction of a quasifree two-nucleon system in the $^4$He nucleus. The solid curves show the deuteron photodisintegration cross section (Ref. 6) multiplied by 4.5.

Fig. 2 represent the photon energy dependence of the deuteron photodisintegration cross section[6] multiplied by a factor of 4.5. Though the cross sections for $^4$He are slightly larger than those for the deuteron at $\theta_p = 60°$, the gross features of the photon energy dependence for helium are well reproduced by multiplying the deuteron results by this constant factor.

Angular distributions of the cross section are shown in Fig. 3 in the c.m. system of the quasifree "pN" pair and a photon in reaction (2). Differential cross sections for the deuteron photodisintegration reaction[6] multiplied by a factor of 4.5 are shown as solid lines. Although there is a slight enhancement of the $^4$He cross sections around $\theta_{\mathrm{c.m.}} = 75°$, the angular dependence for $^4$He is roughly reproduced by that for the deuteron with the multiplying factor of 4.5. A precise determination of the ratio of quasideuteron to deuteron photodisintegration cross sections,

$$R = \frac{d\sigma/d\Omega(\gamma + \text{"pn"} \to \mathrm{p} + \mathrm{n})}{d\sigma/d\Omega(\gamma + \mathrm{d} \to \mathrm{p} + \mathrm{n})} ,$$

may give us information on the short-range part of the wave function. To obtain the true value of the cross section for reaction (2), two corrections must be made to the measured value of 4.5; one is a contribution from the p-p pair and the other is an effect of final-state interactions. From the coincidence experiment of two outgoing nucleons from reaction (2), the contribution of the p-p pair was measured to be about 10% of that of the p-n pair. Subtracting this contribution, a cross section ratio $R$ of 4.1 is obtained. Due to the final state interaction, the yield of protons is decreased and the measured cross section becomes smaller than the true cross section. This attenuation factor is calculated to be about 0.75 on average, varying from 0.7 to 0.8 in the measured momentum region of the present experiment under the assumption that the mass distribution of the helium nucleus is a uniform sphere. After this correction is made, a cross section ratio $R$ of 5.3 is obtained. This value is much larger than two, the effective number of quasideuterons in $^4$He. In this respect, it should be noted that the angular dependence of the cross section for disintegration of the two-nucleon system in the helium nucleus by pions is quite similar to that for disintegration of the deuteron by pions with a multiplication factor of 3.0 at $T_\pi = 160$ MeV,[7] without any corrections due to final and initial state interactions. If we make a 30% correction to account for the initial state interaction of the incident pions, which is expected from the pion absorption cross section, the ratio becomes about 4. This is very close to the value of 4.5 obtained in the photon induced reaction.

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[1]S. Homma, M. Kanazawa, K. Maruyama, Y. Murata, H. Okuno, A. Sasaki, and T. Taniguchi, Phys. Rev. Lett. **45**, 706 (1980).

[2]S. Homma, M. Kanazawa, K. Maruyama, Y. Murata, H. Okuno, A. Sasaki, and T. Taniguchi, Phys. Rev. C **27**, 31 (1983).

[3]S. Homma, M. Kanazawa, M. Koike, Y. Murata, H. Okuno, F. Soga, N. Yoshikawa, and A. Sasaki, Phys. Rev. Lett. **52**, 2026 (1984).

[4]S. Homma, M. Kanazawa, M. Koike, Y. Murata, H. Okuno, F. Soga, M. Sudo, M. Torikoshi, N. Yoshikawa, A. Sasaki, and Y. Fujii, Phys. Rev. Lett. **53**, 2536 (1984).

[5]M. Kanazawa, S. Homma, M. Koike, Y. Murata, H. Okuno, F. Soga, N. Yoshikawa, and A. Sasaki, Phys. Rev. C **35**, 1828 (1987).

[6]J. Arends, H. J. Gassen, A. Hegerath, B. Mecking, G. Noldeke, P. Prenzel, T. Reichelt, A. Voswinkel, and W. W. Sapp, Nucl. Phys. **A412**, 509 (1984).

[7]R. D. McKeown, S. J. Sanders, J. P. Schiffer, H. E. Jackson, M. Paul, J. R. Specht, E. J. Stephenson, R. P. Redwine, and R. E. Segel, Phys. Rev. C **24**, 211 (1981).