Photodisintegration of the Deuteron by 180-Mev and 260-Mev Gamma Rays*

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The photodisintegration of the deuteron is observed at gamma-ray energies of 180 Mev and 260 Mev. Both a low-temperature compressed-gas target and a D_2O-H_2O subtraction method are used. The photoprotons are detected in a crystal counter telescope. Their angular distribution shows a fairly marked forward asymmetry. The total cross sections at 165 and 230 Mev (c.m.) are 54 and 66 μb, respectively, with an estimated error of 10 percent on the absolute scale.

STUDIES of deuteron photodisintegration at energies above the meson threshold have been carried out by several groups[1–4] with results which have so far shown some inconsistencies. We have made repeat measurements of the process, using both a low temperature compressed-gas target and a D_2O-H_2O subtraction method. Results obtained by these two methods are in good agreement.

METHOD

Bremsstrahlung from the Cornell electron synchrotron was allowed to strike targets containing deuterium. In the case of the measurements at 260 Mev, the upper limit of the bremsstrahlung spectrum was 310 Mev; for the 180-Mev points, the limit was lowered to 225 Mev in order to reduce the background counting rates.

The bremsstrahlung flux was monitored with a thick copper ionization chamber placed behind the deuterium targets; this chamber has been calibrated in absolute value by comparison with a pair spectrometer and with shower curve measurements,[5] with an estimated error of 5 percent.

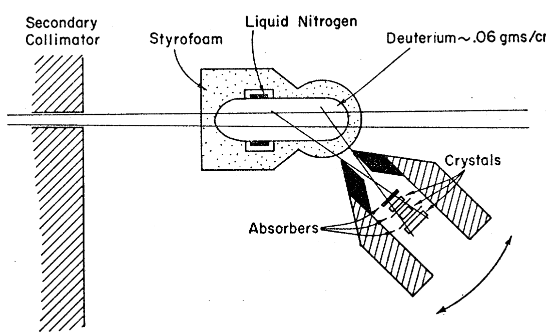

FIG. 1. Diagrammatic view of apparatus with compressed gas target.

Two different types of target were used. The first, a low-temperature compressed-gas target, consisted of a steel chamber 2 in. in diameter, 8 in. long, with 0.025-in. walls, cooled by liquid nitrogen and surrounded by styrofoam for thermal insulation. This target is shown in the diagram of Fig. 1. Deuterium gas was held in it at 1600 psi at a temperature between 77 and 82°K. The second target material was D_2O, with equivalent H_2O targets used to subtract out the photoproton counts due to the oxygen. Since hydrogen cannot give rise to photoprotons in the range of energies selected,

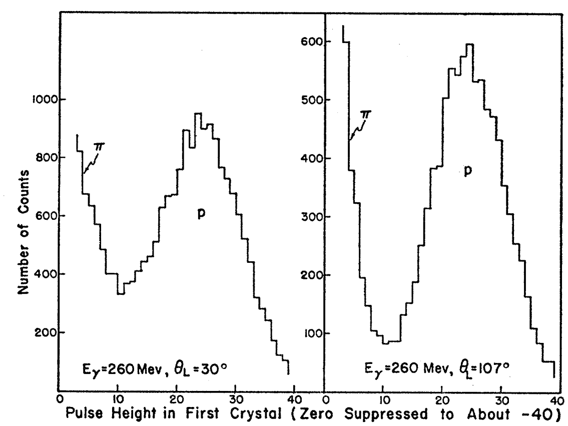

FIG. 2. Differential pulse-height spectra in first crystal for particles of defined residual range. The resolution shown for 107° is typical of that obtained at all other lab. angles except 30°.

the D_2O-H_2O counting rate is due entirely to the photoprotons from deuterium. Different target thicknesses were used in the forward and backward directions, so that the mean energy loss of protons in the target was always comparable to the energy interval accepted by the telescope. Both target thicknesses were used at 90° (c.m.) to obtain a check overlap point.

A three-crystal stilbene telescope was used to identify the photoprotons and define their energy and angle. A coincidence between the first two crystals, in anticoincidence with the third, was required. The resolving time was 0.4 μsec. Charged particles, to be accepted, have to come to rest somewhere between the second and third crystals. With the range interval thus defined, the pulse height in the first crystal serves to identify

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5 Details of the calibration of the Cornell bremsstrahlung beam are to be published shortly.

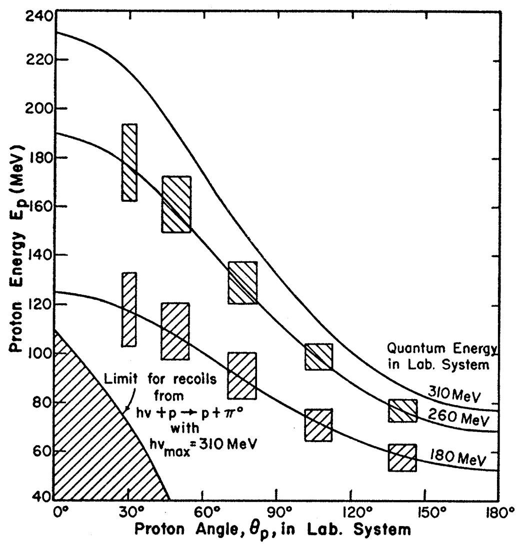

FIG. 3. Kinematics of deuteron photodisintegration, showing ranges of proton energy and angle selected.

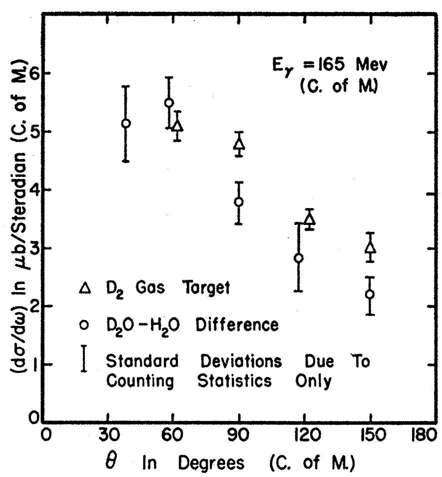

FIG. 4. Differential cross section for photodisintegration at 165 Mev (c.m.).

their masses. Figure 2 shows differential pulse-height spectra obtained from the first crystal, using a 40-channel mechanical kicksorter. The poorest resolution obtained was at 30°. At all other angles the resolution was better, as typified by the spectrum obtained at 107°.

The energy and angle of the photoproton are sufficient to determine the complete kinematics. The proton energies accepted could be varied by placing suitable copper absorbers between the crystals. Figure 3 shows the range of values selected.

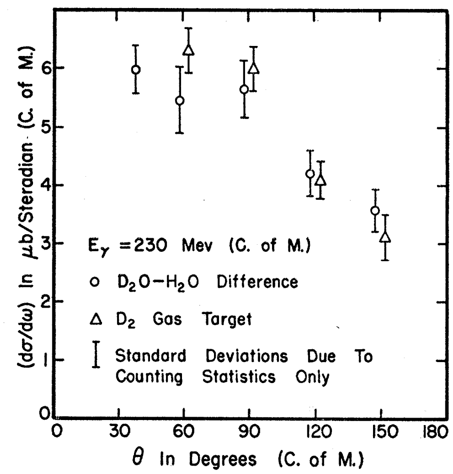

FIG. 5. Differential cross section for photodisintegration at 230 Mev (c.m.).

In the case of the gas target, defining slits of uranium and tungsten served to exclude particles produced from the end caps of the chamber. An optical model was used to compute the effective target volume and solid angle of detection at each angle.

RESULTS

Figures 4 and 5 show the differential cross sections obtained by the two methods, with fair agreement within the statistical errors. Correction for the nuclear absorption of protons in the absorbers, target walls, and crystals has been made, assuming geometrical cross sections. This correction factor generally ranged from 1.03 to 1.10, but reached the value 1.25 for the 260-Mev point at 30°. The total cross sections obtained are 54 and 66 μb at E_γ(c.m.)$=$165 and 230 Mev, respectively. The estimated error on an absolute scale is ± 10 percent.

The results are in general agreement with those of references 1 and 2, and with recent (unpublished) work[6] from the Illinois betatron group. The forward asymmetry of the angular distributions bears out the Berkeley results,[3,4] and is more marked than appeared likely from our earlier measurements.[2] However, comparison of absolute cross sections with those obtained at Berkeley would appear to be meaningless at present in view of the uncertainty of the Berkeley beam calibrations.[7]

[6] A. O. Hanson (private communication).
[7] N. Jarmie, University of California Radiation Laboratory Report UCRL-2185, April, 1953 (unpublished).