Title
THE PHOTO-DISSOCIATION OF THE DEUTERON BY HIGH ENERGY GAMMA RAYS

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January 24, 1952

Berkeley, California

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An analysis was made on proton tracks found in the photographic emulsions exposed to the secondary particles from a high pressure deuterium gas target bombarded by the synchrotron bremsstrahlung gamma-rays of maximum energy 320 Mev*, with the object of investigating the photo-dissociation of the deuteron in the high energy region. The secondary particles were collimated by slit systems in such a manner that we could analyse the protons at the emission angles of approximately 45, 90, and 135 degrees.

The minimum energy required for the proton to penetrate through the walls of the target chamber to reach the plates was 70 Mev at 45 and 135 degrees and 60 Mev at 90 degrees. This circumstance excluded the possibility of recoil protons ejected by the photo-meson producing process from reaching the plates. The energy of the proton was computed from the thickness of the absorbing material between the end point of the proton and the target.

In the case of the photo-dissociation of the deuteron into a proton and a neutron, there is a relation $k = 2T(1-\frac{T}{M}\frac{P\cos\theta}{M})^{-1}$ between

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* The exposure had been made originally by R. S. White and others of this laboratory to investigate the photo-meson production in deuteron.[1]

1. Bull. Am. Phys. Soc. Vol. 26, No. 8, 22(1951)

the energy T and momentum P of the proton of mass M, the angle θ between the direction of the ejection and the incident beam, and the energy k of the photon which caused the dissociation.

Putting k = 320 Mev in this relation we get 93, 136, and 200 Mev for the maximum energy of protons at 45, 90, and 135 degrees respectively.

The energy spectra obtained are shown in Fig. 1. Each spectrum shows a well defined cutoff at the proton energies 95, 135, and 200 Mev, coinciding closely with the expected values. This seems to indicate that these protons are actually the photo-protons produced by the splitting of a deuteron into a proton and a neutron by the absorption of a photon.

Assuming the bremsstrahlung spectrum to be proportional to 1/E, we can compute from the results shown in Fig. 1, the differential cross section per photon for the photo-dissociation as a function of the photon energy. The result is given in Table I.* In the case of 45 degrees one can see the dependence of the cross section on photon energy in a fairly wide range. Below 150 Mev it decreases rather steeply with the increasing energy and at about 150 Mev it begins to flatten out and then starts to increase again with the increasing energy.

The angular distribution in laboratory system shows a fairly strong forward asymmetry. The same trend can be seen in the center of mass system.

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* Relatively large error in the case of 45° compared to the other cases came from the ambiguity involved in the background.

The total cross section was roughly estimated by multiplying the differential cross section at 90° by 4π. Below 150 Mev where no data for 90° was available, the cross section was assumed to be proportional to the differential cross section at 45°. Table II shows the results. The errors indicated are those referred to the relative values. Referring to the absolute value, the error might be as large as a factor of 3. Comparing with Schiff's theoretical values given in Table II, one should rather consider that the experimental values are compatible with the theoretical values below 150 Mev, which is the upper limit of the validity of the theory set by Schiff himself. Above 150 Mev the cross section does not decrease as the straight forward extrapolation of Schiff's curve does. Recently, Gilbert and Rose[2] at this Laboratory studied the photo-dissociation of the deuteron in nearly the same energy range as the present work using counter technique. They obtained the total cross section for the dissociation at the photon energies of 200 and 250 Mev in c.m. system, which are about twice as large as the present values. Due to the relatively large error involved in both experiments, results should be regarded as in agreement with each other.

The increase of the cross section for the photo-dissociation above 150 Mev may be explained by the increasing importance of the absorption of a photon with the emission and reabsorption of a virtual meson in the energy range above the meson threshold. It is hoped that

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2. W. S. Gilbert and J. W. Rose; Bull. Am. Phys. Soc. Vol. 26 (1951) No. 8,18

the experimental evidence given here may provide a more direct and a more stringent test for the different types of meson theory, than has been the case with the experiments in low energy region, where the comparison of the theory with the experiments was made more or less indirectly, as far as the meson theory is concerned.

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TABLE I

The Differential Cross Section as a Function of Photon Energy in Laboratory System

	Energy of Photon in Mev	Diff. Cross Sec. in Micro Barns		Energy of Photon in Mev	Diff. Cross Sec. in Micro Barns
45°	133	14.4 ± 1.8	90°	158	2.7 ± 0.6
	144	12.8 ± 1.9		178	2.4 ± 0.7
	152	6.6 ± 1.8		194	2.4 ± 0.7
	162	10.7 ± 3.0		211	3.4 ± 1.0
	170	6.9 ± 2.2		226	5.1 ± 1.3
	189	5.4 ± 2.1		248	5.2 ± 1.7
	205	6.5 ± 2.3		272	5.5 ± 1.3
	228	5.0 ± 2.6			
	285	8.0 ± 3.8	135°	250	0.99 ± 0.27
	304	12.3 ± 4.0		272	0.99 ± 0.35

TABLE II

The Total Cross Section as a Function of Photon Energy

Energy of Photon in Lab. System	Energy of Photon in c.m. System	Total Cross Section in $10^{-29} cm^2$	Theoretical Value (Schiff)
133	125	6.2 ± 0.5	2.3×10^{-29} cm^2
158	146	3.4 ± 0.8	1.6 "
178	163	3.0 ± 0.8	
194	176	3.0 ± 0.9	
211	191	4.3 ± 1.2	
226	202	6.4 ± 1.7	
248	220	6.6 ± 2.2	
272	239	6.9 ± 1.7	

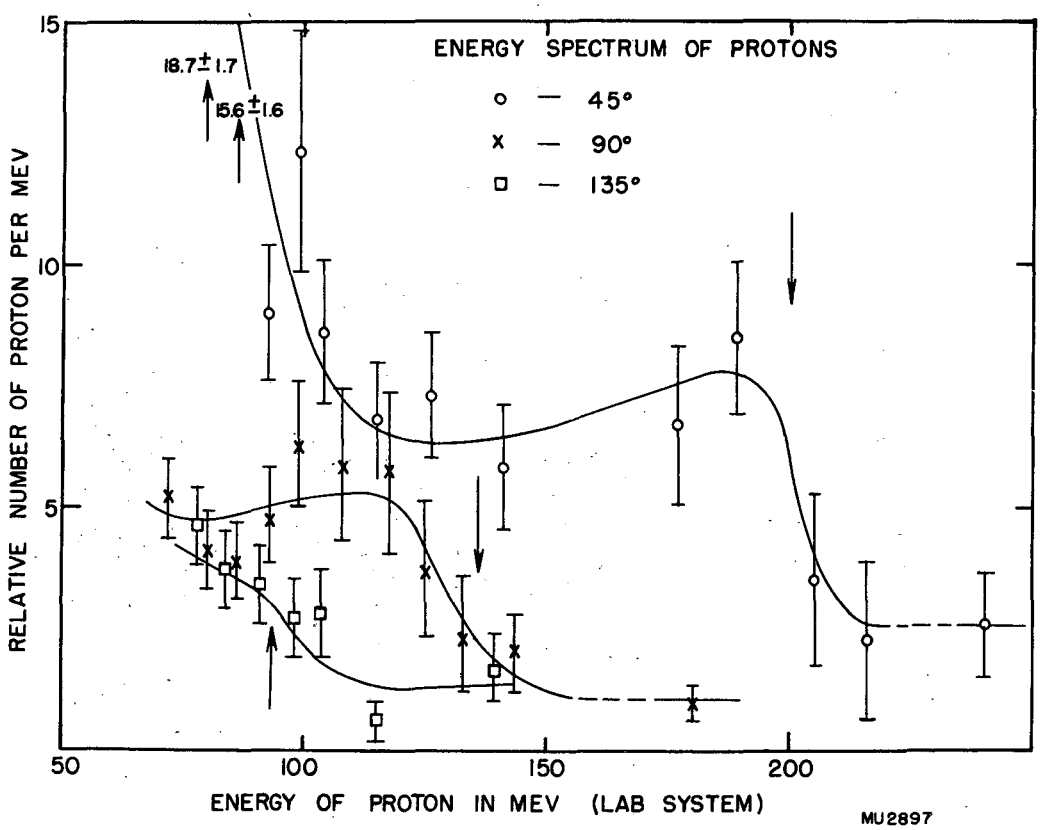
ENERGY SPECTRUM OF PROTONS
o — 45°
x — 90°
□ — 135°
18.7±1.7
15.6±1.6
RELATIVE NUMBER OF PROTON PER MEV
ENERGY OF PROTON IN MEV (LAB SYSTEM)
15
10
5
50
100
150
200
MU2897

Fig. 1