Pulses resulting from electron collection were amplified and used to trigger the sweep of a fast synchroscope. They were also applied to the vertical deflection plates through a length of coaxial cable serving as a 0.2-microsecond delay line. The combined rise time of the preamplifier, amplifier, and vertical amplifier of the synchroscope is 0.02 microsecond. This is short compared with the pulse rise times observed, which were between 0.2 and 0.4 microsecond. Using a Kodak Retina camera (1 sec at f:3.5), photographs of the resulting traces at different counter voltages were taken. A straight line parallel to the average slope of the trace was drawn on the print. This line was extended from zero to maximum amplitude, and the projection of this line onto the time base line corresponded to the rise time. The sweep speed was approximately 6 inches per microsecond. In determining the rise time, corrections were made for the slight nonlinearity of the sweep.

To correct for the penetration of the alpha-particles into the chamber, the center of gravity of the resulting electron cloud was calculated. The center of gravity of the electrons produced by the 8.78-Mev alpha-particle of ThC′ is 0.038 mm from the source plane. The drift space is the distance from the center of gravity to the collecting electrode. From these data the drift velocity and the mobility were computed.

In Fig. 1, the mobility U *versus* the field is plotted for two plate separations (0.185 and 0.107 cm). The dotted curve is

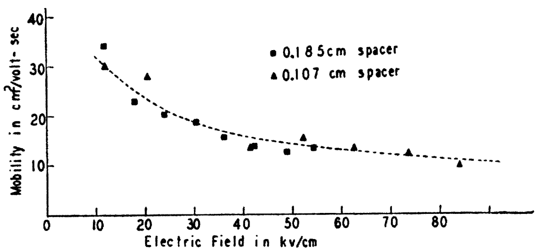

FIG. 1. Electron mobility U *vs* electric field E in liquid argon. The dashed curve is calculated for U proportional to $E^{-\frac{1}{2}}$ and fitted at one point.

calculated, assuming the mobility to be proportional to $E^{-1/2}$, where E is the field strength. The agreement here is well within the experimental accuracy, estimated to be about 15 percent.

Based on kinetic theory considerations, the formula for the mobility is

$$U=c^{3/4}(mM)^{-1/4}(e\lambda)^{1/2}E^{-1/2},$$

where m is the electron mass, M the mass of the argon atom, e the electronic charge, λ the mean free path. The constant c, which various corrections make uncertain, lies between $\frac{1}{2}$ and $\frac{2}{3}$. The value of λ may be calculated from this formula. The collision cross section q may be calculated from the general relation:

$$Nq\lambda=1,$$

where N is the number of argon atoms per cc. According to the reasoning which leads to the mobility formula above, the mean energy of the electrons is about 10 ev. The collision cross section obtained in this manner for electrons of 10 volts mean energy is about 100 times smaller than the published values[4] for the gas.

Preliminary results in solid argon indicate an electron multiplication by a factor greater than 10, in agreement with Hutchinson's work. The mobility in the solid is much greater than that in the liquid. Conductivity pulses have also been observed in liquid helium, and measurements are being continued in solid argon and liquid and solid helium.

We wish to thank Professor H. Margenau for numerous discussions concerning the theoretical aspects of the problem.

* Assisted by the joint program of the ONR and AEC.

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The Angular Distribution in the Photodisintegration of the Deuteron at Low Energies

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(Received July 9, 1951)

THE angular distribution of the protons and neutrons produced in the photodisintegration of the deuteron has been determined by a number of authors[1-3] and for several γ-ray energies. So far the precisions of these measurements do not permit the establishment of agreement or disagreement between theory and experiment. The main difficulty arises from the low intensity obtained in experiments where sufficient angular definition of the photonucleons was provided.

We have made measurements with a new method, giving higher intensities. In this method one makes use of the fact that the energy of the photonucleons depends on the angle relative to the disintegrating γ-ray at which they are ejected (conservation of the linear momentum of the γ-ray). The energy of a photoproton in laboratory coordinates is:

$$E_p=\tfrac{1}{2}(E_\gamma-E_T)+\frac{E_\gamma^2}{8Mc^2}+\frac{E_\gamma}{2}\left(\frac{E_\gamma-E_T}{Mc^2}\right)^{\frac{1}{2}}\cos\theta.$$

The number of photoprotons ejected into unit solid angle at angle θ is:

$$I_\theta=(a+b\sin^2\theta),$$
$$a=\sigma_m,\quad b=\tfrac{3}{2}\sigma_e,$$

where θ is the angle between the photoproton and the incident quantum in center-of-mass coordinates. Combining these two equations we obtain the relation for Y_x, the number of protons per unit energy interval at energy x,

$$Y_x=A\{a+b-(b/\alpha^2)(x-d)^2\},$$

where $\alpha=\frac{1}{2}E_\gamma[(E_\gamma-E_T)/Mc^2]^{\frac{1}{2}}$, $d=\frac{1}{2}(E_\gamma-E_T)$, and A is a factor depending on the γ-ray flux, the number of deuterium nuclei per unit volume, and the wall effect. Table I shows the expected energy spread for the three γ-ray sources used in our measurements.

Originally this effect was established qualitatively with a deuterium-filled ionization chamber.[4] For the present measurement we used a proportional counter, to eliminate the positive ion effects, and to reduce the amplifier noise to negligible proportions.

The counters consisted of a long cylinder of copper or aluminium closed at each end by caps carrying Kovar-glass seals. The center wire was passed through these seals and connected to the first valve of an amplifier. Great care was taken to insure that the wires were central. X-ray radiographs showed that the wires were axial to within 1/10 mm. The sensitive volume of the counter was defined by thickening the center wire in the usual way. The end effects were reduced to 1 percent by using a long counter 30 cm in length, of diameter 2.54 cm, and placing the source at the middle.

The pressure of deuterium in the counter had to be adjusted for each γ-ray energy so as to avoid too high a γ-ray background on the one hand and too large a wall effect on the other.

The output pulses were examined with a kicksorter of the Wilkinson type. Distributions from each counter under various conditions of pressure and relative γ-background were in excellent agreement. Pulse heights were expressed relative to a standard pulse; the energy calibration in kev was established using the fact that the peak of the distribution occurs at the average photoproton energy [Eq. (1)]. Agreement to 0.5 percent was obtained

TABLE I. Expected energy spread for the gamma-ray sources used.

Source	Energy of protons	Spread of energy
Na^{24}	$E_p=(265.5\pm32.9\cos\theta)$ kev	±12.4%
ThC″	$E_p=(194\pm26.6\cos\theta)$ kev	±13.7%
Ga^{72}	$E_p=(138.5\pm21.6\cos\theta)$ kev	±15.6%

for the ratios of average pulse height to the expected ratio of average photoproton energy. For sources of about 10 mC, distributions were recorded with counting rates at the peak of about 60/min. A least squares fit parabola was calculated for each distribution; a dozen distributions were investigated for each γ-ray energy.

Corrections are made for the finite channel width of the kicksorter, and for the spread in pulse height caused by the statistical nature of the multiplication process.[5] A correction for noncentrality of the wire was investigated by calculating the change in field strength it produces and using measured curves of multiplication *versus* high voltage. The correction never amounted to more than 0.05 percent of the average pulse height. The most serious correction is that made for the statistics of the multiplication process. This increases the final value of σ_m/σ_e for Na^{24} by 10 percent, for ThC'' by 8 percent and for Ga^{72} by 6 percent. The errors calculated for curve fitting are ± 3 percent each for Na^{24} and Ga^{72}, and ± 2 percent for RdTh.

Final answers (assuming validity of the above-mentioned correction for statistical spread) are listed in Table II.[6-8]

TABLE II. Ratio of photomagnetic cross section to photoelectric cross section.

Source	σ_m/σ_e Present work	Previous experiments	Meson theories[a]	Effective range theory[b,c]
Na^{24}	0.247 ±0.007	0.30 ±0.02[d]	0.234	0.254
ThC''	0.360 ±0.008	0.39 ±0.12	0.369	0.395
Ga^{72}	0.600 ±0.02	0.61 ±0.04	0.585	0.67

[a] See reference 6.
[b] See reference 7.
[c] See reference 8.
[d] Average of references 1.

We wish to thank Lord Cherwell for all the encouragement given to us. This work was made possible by a grant from the Paul Foundation Fund of the Royal Society.

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The Angular Distribution of V^0-Particle Decay Products*

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IN a series of 20,000 cloud-chamber photographs taken at sea level approximately 800 penetrating showers were seen in 16 months and in these there were 37 V^0-particles and 8 $V^{\pm}$-particles. The arrangement of lead in the cloud chamber was changed from time to time in the hope of making the detection of V-particles more probable. In a multi-plate chamber it is essential to have the plates widely spaced since the particles are observed to decay in the gas. It is also important to have a triggering arrangement that trips on low energy penetrating showers as well as high energy events. The high energy events are usually so complicated as to make the observation of V-particles very difficult.

The cloud chamber has seven ½-inch lead plates spaced 2½ inches apart, illuminated depth 5 inches and useful width 16 inches. The counter arrangement required that one (and only one) counter be tripped in the top tray of 5 one-inch counters and the two lower 2-inch counters side by side simultaneously be tripped. Many electron showers are eliminated by the anticoincidence.

A study has been made of 26 V^0 events in which the plane of the V^0 appeared to contain the point where the original event occurred. In many cases the ionization and scattering of the particles, together with the angles made with the line of the V^0 indicated that the decay particles must have had quite different masses. The events were then analyzed on a simple assumption, namely, $V^0 \rightarrow p+\pi^-$. Curves were drawn giving the angular distribution of the proton and meson in the laboratory system for various values of the velocity β_0 of the V^0 and for various angles φ^* of emission of the particles in the moving system. Two mass values of the V^0 were chosen: $2170m_e$ and $2390m_e$, and separate sets of curves were drawn for each assumed mass value.

The procedure was then to take the measured values of angles in the laboratory system and try to find a single set of values of β_0 and φ^* for each observed pair of angles. It turned out that in all cases except one it was possible to determine the identity of the particles just by knowing the angles; the proton almost always makes the smaller angle. Thus for a given choice of the mass of the V^0 a set of values of β_0 and φ^* was obtained. It was immediately clear that something was wrong since only three out of 26 values of φ^* were less than 90°. Thus under these assumptions the protons had to come out predominantly in the backward direction in the moving system, and changing the mass of the V^0 to $2390m_e$ had no effect on the situation (although the β_0 values had to change). The difficulty is that the measured angles are more nearly equal to each other than is to be expected when the masses of the particles differ as much as do those of a proton and meson.

The possibility arises that some of the processes are $V^0 \rightarrow \pi^+ + \pi^-$ and that this distorts the angular distribution. Another possibility is that the process is a three-body decay and, as Leighton, Wanlass, and Alford[1] have pointed out, the coplanarity is coincidental. As pointed out by T. D. Lee, a possible three-particle decay is $V^0 \rightarrow p+\mu+\nu$. With an excitation energy of about 140 Mev and a lifetime of 10^{-10} sec, the coupling constant turns out to be 2×10^{-48} erg cm³. It is somewhat remarkable that this coupling constant is of the same order of magnitude as that used in the β-decay of the nucleons and the μ-mesons and the interaction of the nucleons with the μ-mesons.[2,3] It can also be shown that the neutrino and the meson tend to come out in the same direction because of phase space limitations. This would have the effect of reducing the momentum of the meson in the moving system and thus removing the difficulty with the angular distribution.

A trial calculation has been made to check this, using the simplifying assumption that the neutrino and meson go off in the same direction and share the momentum equally. The angular distribution inferred under these assumptions is spherically symmetrical in the moving system.

I am indebted to Dr. Tsung Dao Lee for stimulating discussions and for communicating some results of his calculations on the theoretical aspects of this problem.

* Assisted by the joint program of the ONR and AEC.
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Erratum: Magneto-Optics of an Electron Gas with Guided Microwaves

[Phys. Rev. **82**, 956 (1951)]

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PARTS of the caption to Fig. 1 should read as follows: Gas: Ne+1 percent A at 1 mm Hg. Signal pulse 50 μsec after 5 μsec dc discharge pulse.