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SUMMARY OF THE RESEARCH PROGRESS MEETING

October 28, 1948

R. K. Wakerling

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SUMMARY OF THE RESEARCH PROGRESS MEETING

October 28, 1948

R. K. Wakerling

Deuteron Scattering. C. Wiegand.

A series of deuteron-proton scattering experiments has been started employing a telescope of three proportional counters in an arrangement similar to that used in the neutron-proton scattering experiments. The results of such a study are of theoretical importance. If it is discovered that the cross section for deuteron-proton scattering is small, one could conclude that the cross section of the deuteron is the same as the sum of the neutron and proton cross sections. It may be possible to combine the data with that from n-p scattering to shed light on certain aspects of nuclear structure.

The experimental arrangement employed is shown schematically in Figure 1. The deuterons leave the cyclotron chamber through a long tube. Six feet from the end of the tube they are collimated by passing through a 1 inch x 1-1/2 inch opening in a heavy copper plate. The end of the tube is closed by means of a 1/8 inch aluminum window, outside of which is placed a second collimator consisting of a copper plate with a 1" diameter hole to further define the deuteron beam. Adjacent to the second collimator is placed a thin ionization chamber through which the beam passes. This chamber serves the function of measuring the size of the beam. Each deuteron crossing this chamber is assumed to generate 500 ions. After passing through the ionization chamber the deuterons impinge upon a scatterer and are detected by a telescope of three proportional counters, after passing through a suitable thickness of aluminum absorber. In this work a low current beam was used which was essentially mono-energetic.

In the first experiments the apparatus was arranged to detect particles scattered at an angle of 6^{0}, which is the predicted angle of maximum scattering. With a deuteron current of 10^{-14} amperes and a carbon scatterer of .7 gms/sq. cm. in thickness, 10^{7}

deuterons should leave the target per second. In such an experiment one must be certain that the counter system is detecting only the deuterons. From a carbon target one can expect elastically scattered deuterons of energy approximately 200 Mev, protons and neutrons from deuteron stripping of energy approximately 100 Mev, and inelastically scattered charged particles of energy considerably less than 200 Mev. In the event a CH_2 target is used one might get in addition elastically scattered protons.

One means of adjusting the counters to detect only the deuterons is to make use of a thickness of aluminum in front of the counters sufficient to allow just the deuterons to get through. Such an absorber cuts down the proton energy to a point where these particles cannot be counted. This is particularly important in the case where the protons are scattered in nearly the same direction as the deuterons. That this is a possible situation is illustrated by the following table which shows the results of calculations for two typical cases. In the second of these it is seen that the angular difference between the deuterons and protons scattered is less than 4°. These calculations were made on the assumption of an incident deuteron energy of 180 Mev. The number of counts varies

Typical Sets of Values

	Scattering Angle	Energy	Al Range	Specific Ionization $\left(\frac{dE}{dx}\right)$, $\frac{\text{Mev}}{\text{mg/cm}^2}$
d	$7\text{-}1/2^{\circ}$	172 Mev	15.2 gm/cm^2	0.009
p	$78\text{-}1/2^{\circ}$	8	0.11	0.057
d	$7\text{-}1/2^{\circ}$	20	0.34	--
p	3°	160	22.8	0.005

as a function of voltage as shown in Fig. 2. The counters were customarily operated at 1400 volts.

When the number of counts is plotted as a function of absorber thickness, at the 6° position, one obtains a curve of the character shown in Fig. 3. The maximum occurs at an absorber thickness of 16.3 grams/cm^2, and the width at half maximum is 1 gm/cm^2, or approximately 6 Mev. The sharp decrease in the curve beyond the maximum shows that only deuterons elastically scattered by the carbon are being counted. If one adds to the 16.3 gm/cm^2 of aluminum in the absorber the aluminum equivalent of the air column, the carbon scatterer, the counter walls, the aluminum window and the Al equivalent of the residual range of the deuterons, one has a total thickness of aluminum of 18.2 gm/cm^2. This compares very well with Stephan's value of the deuteron range in aluminum of 18.7 $\pm$ 1 gm/cm^2.

When the carbon target is replaced by a .62 gm/cm^2 CH_2 target it was predicted theoretically that the scattering maximum should occur at .7 barns. It should be noted that a CH_2 target of this thickness reduces the energy of the deuterons by the same amount as the previously mentioned carbon target. A few observations were made at an absorber thickness predicted to correspond to the expected peak but the results were not complete enough to allow a positive conclusion to be drawn. It was felt quite definitely, however, that the peak is not at .7 barns.

An angular distribution curve covering the range 5°-15° was also taken by varying the angle of the counter telescope. Figure 4 summarizes the results of this measurement. The technique employed will be refined in an attempt to extend the curve to the region of very small angles. The second curve of Fig. 4 gives the variation counting rate without a target in place.

A source of error of unknown magnitude arises from the effects of nuclear reactions in the aluminum absorber. This remains to be investigated. The correction may be sufficient to change the absolute value of any cross sections found but the ratio of the results with carbon and CH_2 will not be affected. The measurements reported here are only preliminary and it is planned to continue and extend them considerably.

It has also been decided to measure the absolute stripping cross section for deuterons. For this purpose a magnetic selector will be used to sort the protons and deuterons, and the magnitude of the neutron beam will be measured with a bismuth fission ionization chamber. Such an experiment should give data that will allow a comparison to be made with the theoretical results predicted by Serber's theory of deuteron stripping.

Deuterons in the Neutron Beam. K. Brueckner.

In the cloud chamber one finds rather long tracks of highly ionizing particles when working with the neutron beam of the cyclotron. It has been felt for some time that such tracks are due to secondary particles arising in the aluminum window of the cloud chamber and in the air outside the chamber. To determine the character of the particles 200 tracks of this type were observed, and from their curvature an estimate made of the energies of the particles. Only those tracks were taken that went completely across the chamber, which has a diameter of approximately 13 inches, and whose directions were essentially that of the incident neutron beam. This allowed rather accurate measurements of the curvature to be made. Actually the tracks falling within a cone of angle 13° were taken. Figure 5 shows the distribution of the number of tracks with energy. The portion of the curve to the left of the 120 Mev point follows the theoretically predicted curve for protons rather closely. However, the portion of the curve beyond 120 Mev, which accounts for 20 per cent of the tracks, is quite unexpected if the particles are all protons, for in that event only 2 to 5 per cent of the tracks would lie beyond the 120 Mev point. A number of reasons were advanced to support the conclusion that these high energy particles must be either deuterons or tritons. In order to make the results more conclusive some experiments will be done with absorbers of various thicknesses in the chamber.

Secondary Particles from Nuclei. H. York.

The cloud chamber observations of heavy energetic particles reported above cast some doubt on the first work on secondary particles from nuclei reported in the meeting of October 7. In order to throw further light on this matter the apparatus shown in Figure 6 was devised. This employs a steering magnet outside the concrete cyclotron shielding placed in a position to deflect particles scattered from a 1/2 inch thick carbon target at an angle of 10°. The radius of curvature in this magnetic field is 68 inches. A system of collimating slits was employed to define the scattered beam, and absorbers of 1/8, 1/2, and 1 inch thickness were used to cover various energy ranges. A de-sensitized counter of the type mentioned in the earlier report was used to limit the upper energy of the particles counted.

With the three absorbers the three curves of Fig. 7 were obtained. In each case the curve is bi-modal, the first maximum corresponding to scattered protons and the second to deuterons. Although the apparatus is twice as sensitive to deuterons as protons, one cannot compare the absolute values because of the energy spread of the particles detected. An experiment has also been done with copper and lead scatterers. All that one can say at this time is that approximately 25 per cent of the particles scattered at 10^{0} are deuterons when a carbon scatterer is used. The yield is somewhat smaller with a lead scatterer. This figure undoubtedly represents a lower limit on the number of deuterons formed in the nucleus, since many of them are stripped in the target and give rise to low energy protons.

Another method was tried that seemed to offer some promise and has the advantage of giving much more favorable counting rates. It makes use of a 35 per cent difference in ionization between the protons and deuterons of the same range. The neutron beam is allowed to strike a polyethylene target and the scattered particles are detected by the same counter arrangement employed in the first experiment. As the gain or the high voltage on the counter is varied, one should get a variation of counting rate having two plateaus of the type shown in Fig. 8 if one is counting both protons and deuterons. With the counting system in use a 100 volt change on the counter corresponded to a change in gain of 1.85. With 87 Mev protons from a polyethylene scatterer the curve of variation of counting rate with high voltage is of the type illustrated in Fig. 9, curve 1. With 30 Mev protons and 40 Mev deuterons, which have the same range, the curves were predicted to be in the positions of curves 2 and 3 of Fig. 9 by virtue of the difference in ionization. It was found that the experimental points fell between these two curves so that the results are inconclusive. However, it is felt that this method holds some promise, and it is intended to explore its possibilities further.

High Energy Deuterons in Photographic Plates. H. Bradner.

The neutron beam of the 184-inch cyclotron was allowed to strike a carbon target of dimension 30 mils x 2 inches after emerging from the shielding. A stack of nuclear plates was placed in such a position as to receive particles scattered at an angle of 10^{o} with the incident beam. A 250 mil aluminum shield was placed in front of the photographic plates. A few of these plates have been examined thus far, and give evidence for the existence of deuteron tracks in the plates not arising from deuterons produced in the plates. In one plate examined a 5700 micron proton track entirely within the emulsion was discovered. This corresponds to a proton of energy 37 Mev. Close by, a 3700 micron track was found which by grain counting was concluded to be a deuteron track. The ratio of masses determined by the grain counting was 25 to 13.5, which is the correct ratio to within observational errors. This deuteron could have been formed in the aluminum shield or in the target. The results from the few tracks that have been observed thus far can be summarized in the following table. Needless to say, an insufficient number of tracks is involved to allow any conclusions of a statistical nature to be drawn.

	Probable	Highly Probable	Almost Certain
Proton	6	2	1
Deuteron	3	4	1

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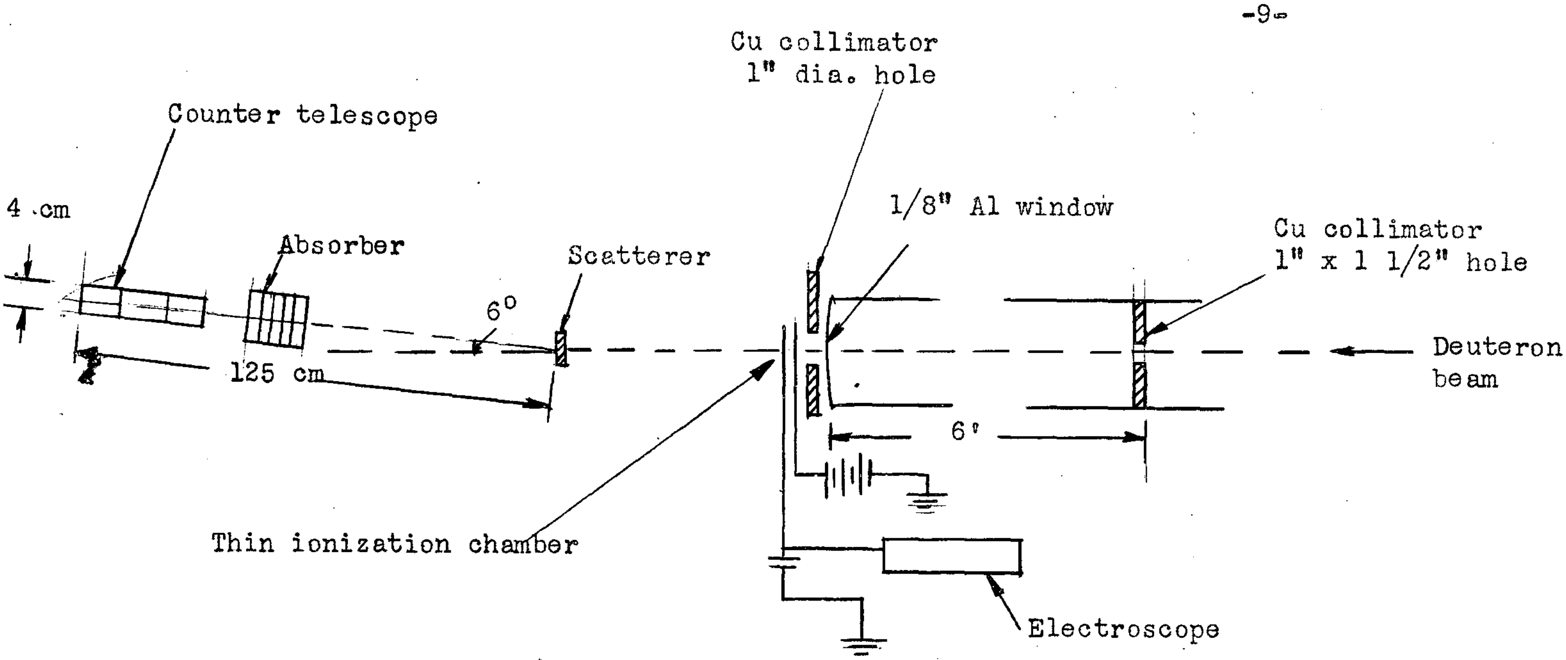
Cu collimator
1" dia. hole
Counter telescope
4 cm
1/8" Al window
Cu collimator
1" x 1 1/2" hole
Absorber
Scatterer
6°
Deuteron
beam
125 cm
6"
Thin ionization chamber
Electroscope

Fig. 1

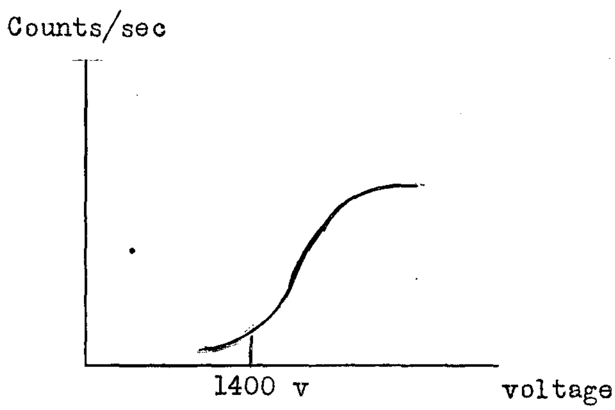
Counts/sec
1400 v
voltage

Fig. 2

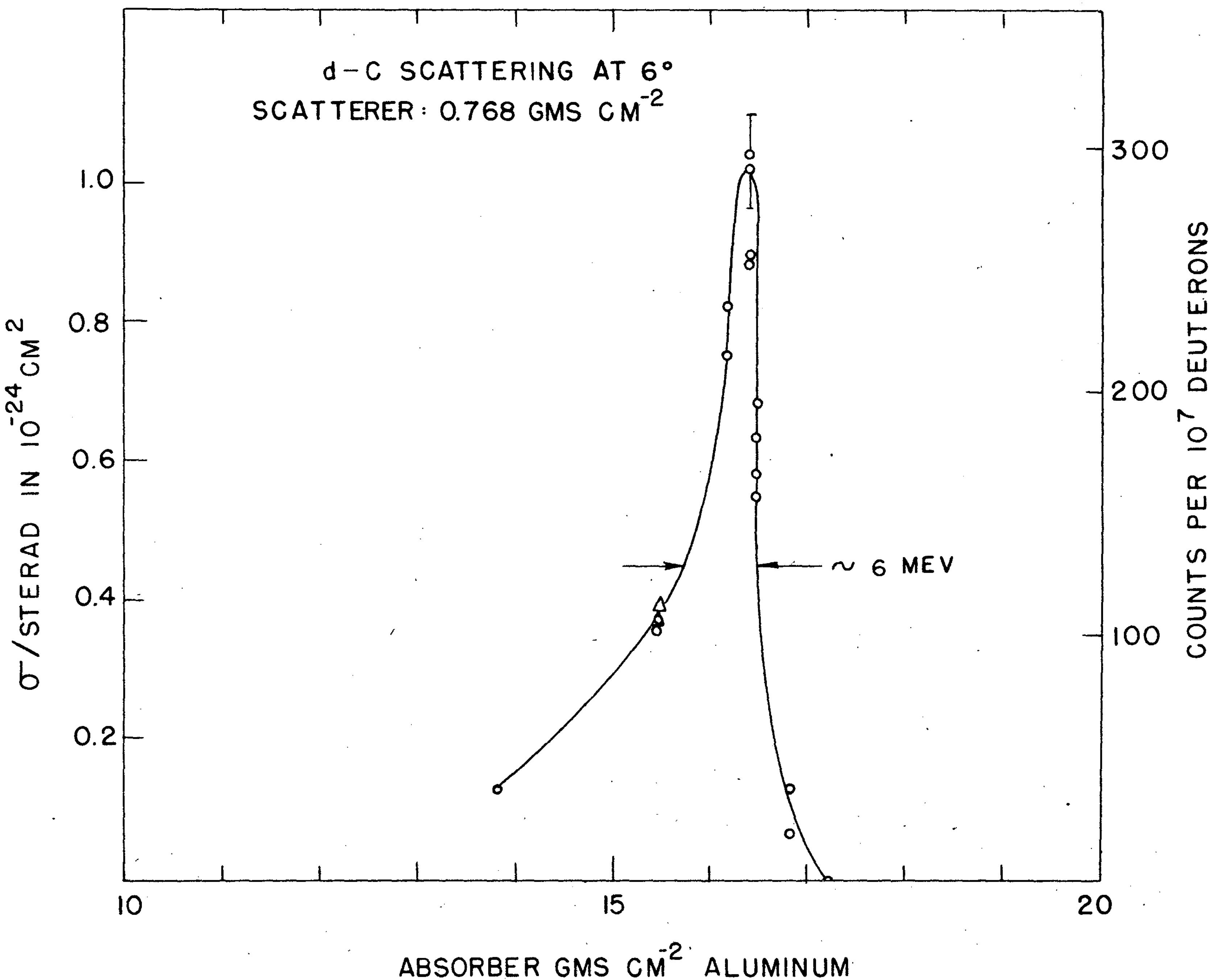
d−C SCATTERING AT 6°
SCATTERER: 0.768 GMS CM^{-2}
1.0
0.8
0.6
0.4
0.2
σ/STERAD IN 10^{-24} CM^2
300
200
100
COUNTS PER 10^7 DEUTERONS
~ 6 MEV
10
15
20
ABSORBER GMS CM^{-2} ALUMINUM

FIG. 3

13091-1

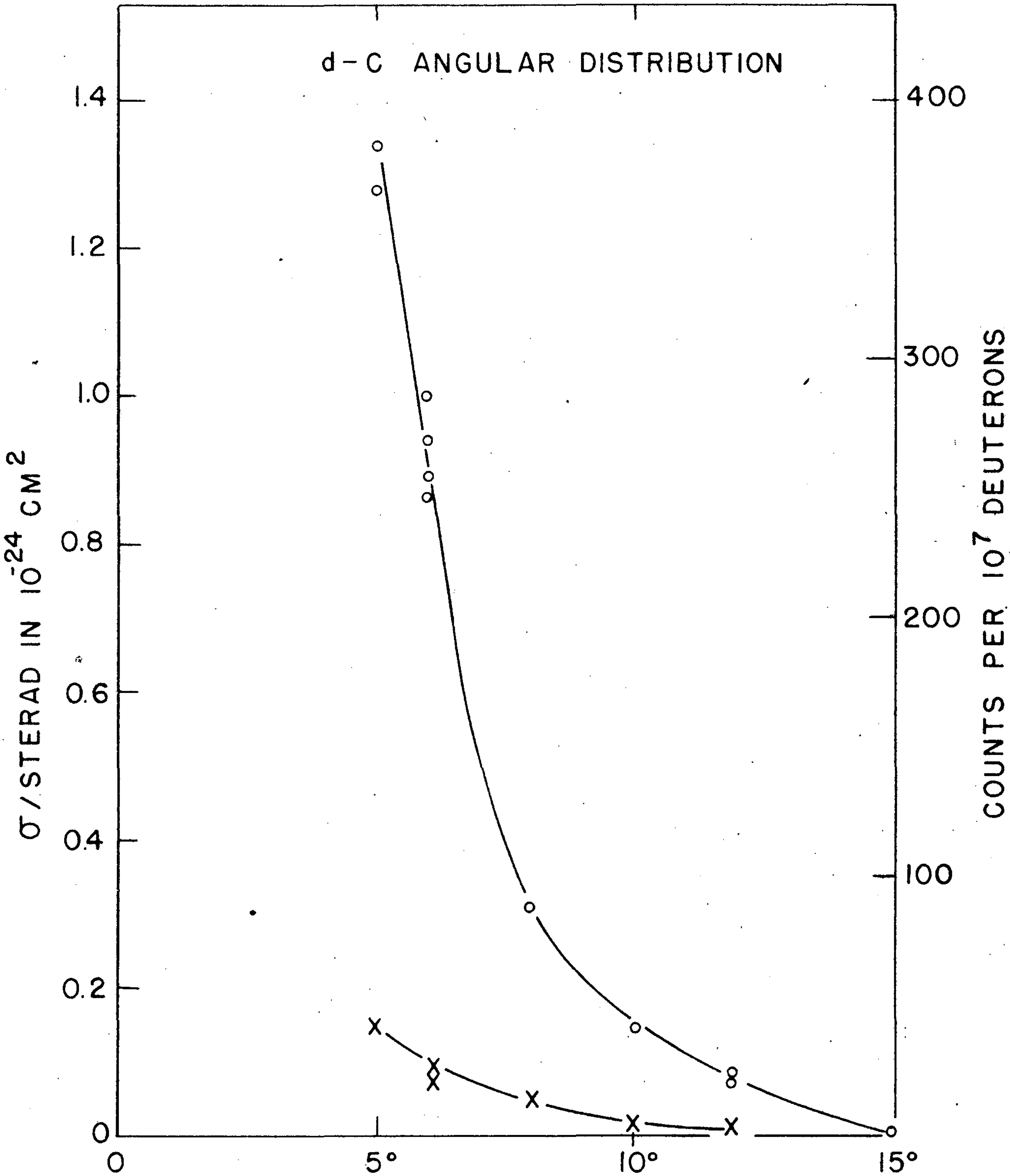
d-C ANGULAR DISTRIBUTION
σ/STERAD IN 10^{-24} CM^2
COUNTS PER 10^7 DEUTERONS
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
100
200
300
400
0
5°
10°
15°

FIG. 4

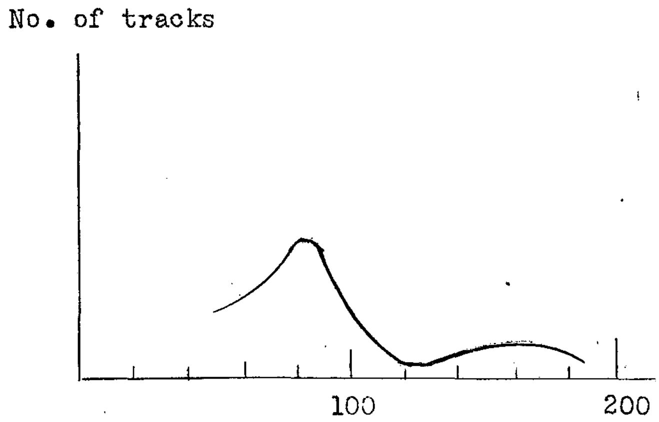
No. of tracks
100
200

Fig. 5

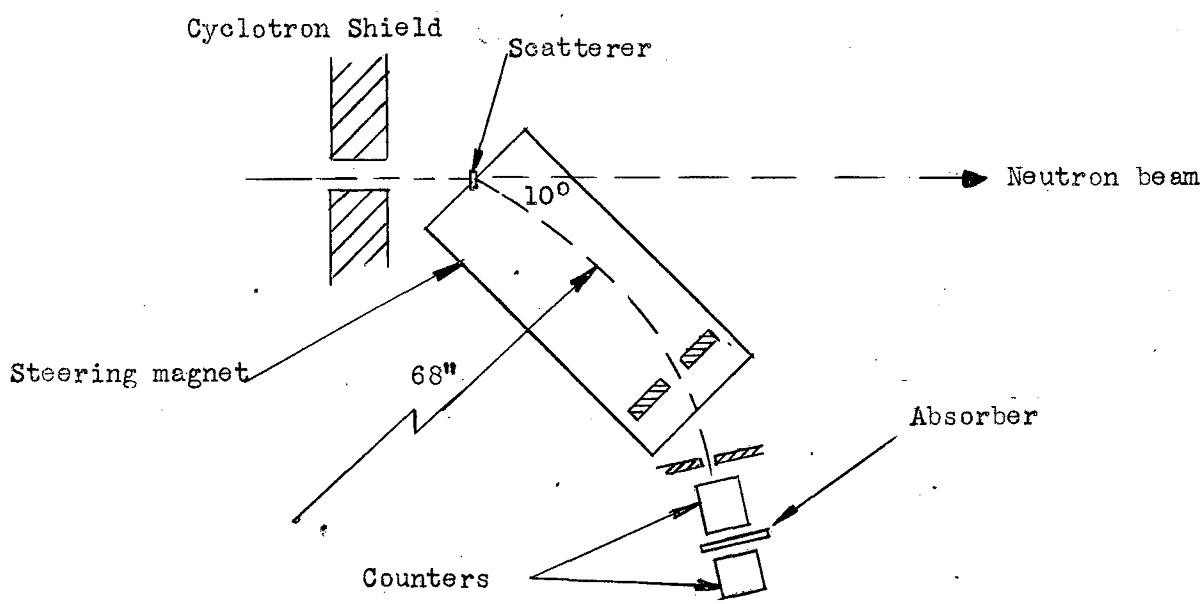
Cyclotron Shield
Scatterer
Neutron beam
10°
Steering magnet
68"
Absorber
Counters

Fig. 6

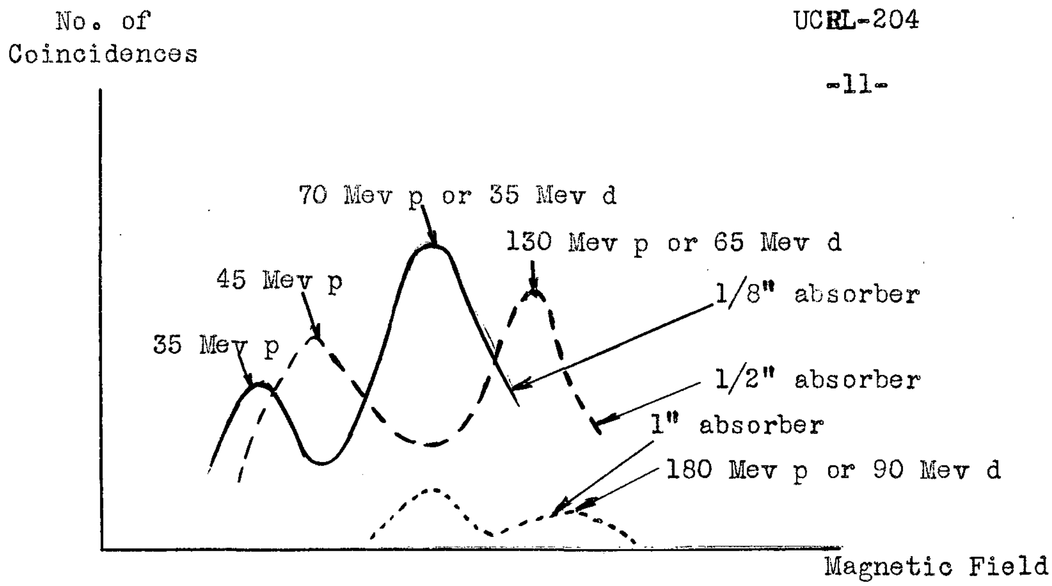

Fig. 7

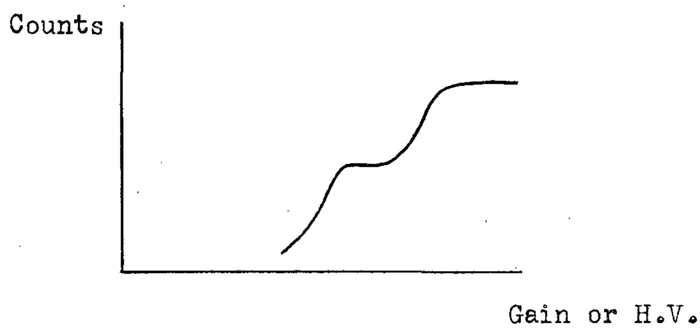

Fig. 8

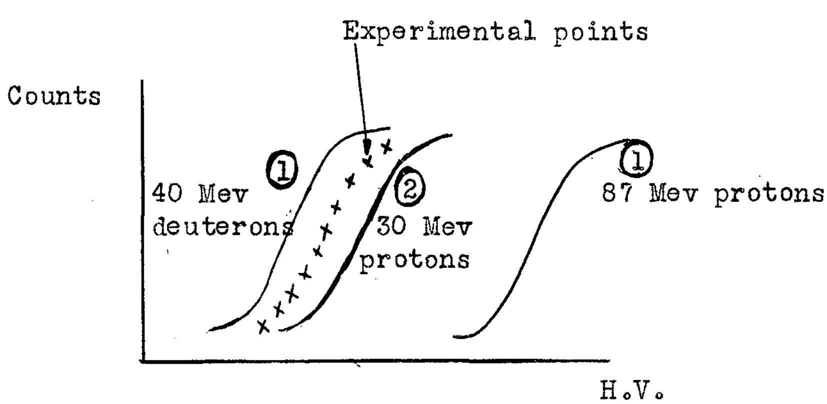

Fig. 9

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