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FISSION CROSS SECTION OF U^{238} IN THE NEIGHBORHOOD OF 7 MEV

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Fission Physics

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Abstract

By use of the reaction $D(d,n)He^3$ where the bombarding deuterons were accelerated by the Los Alamos cyclotron, monoenergetic neutrons are obtained with which the fission cross section of $Uranium^{238}$ in the region of seven Mev has been studied. Fissions due to background neutrons are eliminated by only counting fission fragments in coincidence with the He^3 particles. Apparatus for carrying out this experiment has been described in the literature.[1] This measurement with 7.2 Mev neutrons gives the value for the fission cross section of U^{238} as 0.81 ± 0.08 barns. This determination together with previous determinations[2] allows one to draw a curve of the U^{238} cross section from one to nine Mev. The data suggests a step rise in the cross section between seven and nine Mev, although the statistics are such that a smooth curve is not definitely excluded. Theoretically this is particularly interesting in view of the fact that the energy required to produce fission (by γ ray excitation for example) is in this neighborhood.

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[1] Curtis, Fowler, and Rosen, Rev. Sci. Inst. 20, 388 (1949).

[2] Curtis, Fowler, and Rosen, LA-710 (1948).

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FISSION CROSS SECTION OF U^{238} IN THE NEIGHBORHHOD OF 7 MEV

Introduction

Since the energy required to produce fission in 238 is in the neighborhhod of seven Mev it is desirable for theoretical reasons to study the cross section for fission with neutrons of this energy. For this reason the cross section has been measured for neutron energy of 7.2 Mev by the method described in LA-710.[2] The source of neutrons is the $D(d,n)He^3$ reaction. The bombarding deuterons are accelerated by the Los Alamos cyclotron to an average energy of 10.7 Mev. The neutron flux is known by the number of He^3 particles produced which are counted by a proportional counter. In order to reduce the fission counts produced by the neutron background only those fissions in coincidence with the He^3 particles are counted. By this method the U^{238} cross section has been determined previously for neutron energies of 8.8 Mev, 5.8 Mev, and 8.9 Mev. The results of these earlier measurements are given in LA-710.

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I. APPARATUS AND EXPERIMENT

With the exception of a few minor changes the apparatus which was used for this experiment is the same as that used previously.[1] A different gas target was designed for this experiment (Fig. 1). The side port for He^3 particles has been extended so that the window of this port is directly in front of the proportional counter. The first He^3 defining slit is installed in the side port near the center of the target as shown. In the extension to the side port there is an anti-scattering diaphragm about 4 in. from the center of the target. This design of target reduces the loss of the He^3 particles due to the scattering by the window since the window is placed directly in front of the counter. The additional deuterium gas in the path of the He^3 particles made this design impracticable for the earlier experiments where the energy of the He^3 particles was lower. As in the case of one run in the previous experiment, tantalum was used in the exit port of this target for the purpose of reducing the neutron background. Table I gives the pertinent data with regard to the dimensions of the diaphragm defining the He^3 particles.

The proportional counter has been redesigned for this experiment so that the five mil collecting wire was offset 1/4 in. from the center of the counter. Also, a selsyn controlled foil system mounted in the reaction chamber lid has been installed so that 100 combinations of foil thicknesses were available for slowing down the He^3 particles so that the ends of their paths lie in the counter. These last two improvements allow much better resolution of the He^3 peak than was possible with the former

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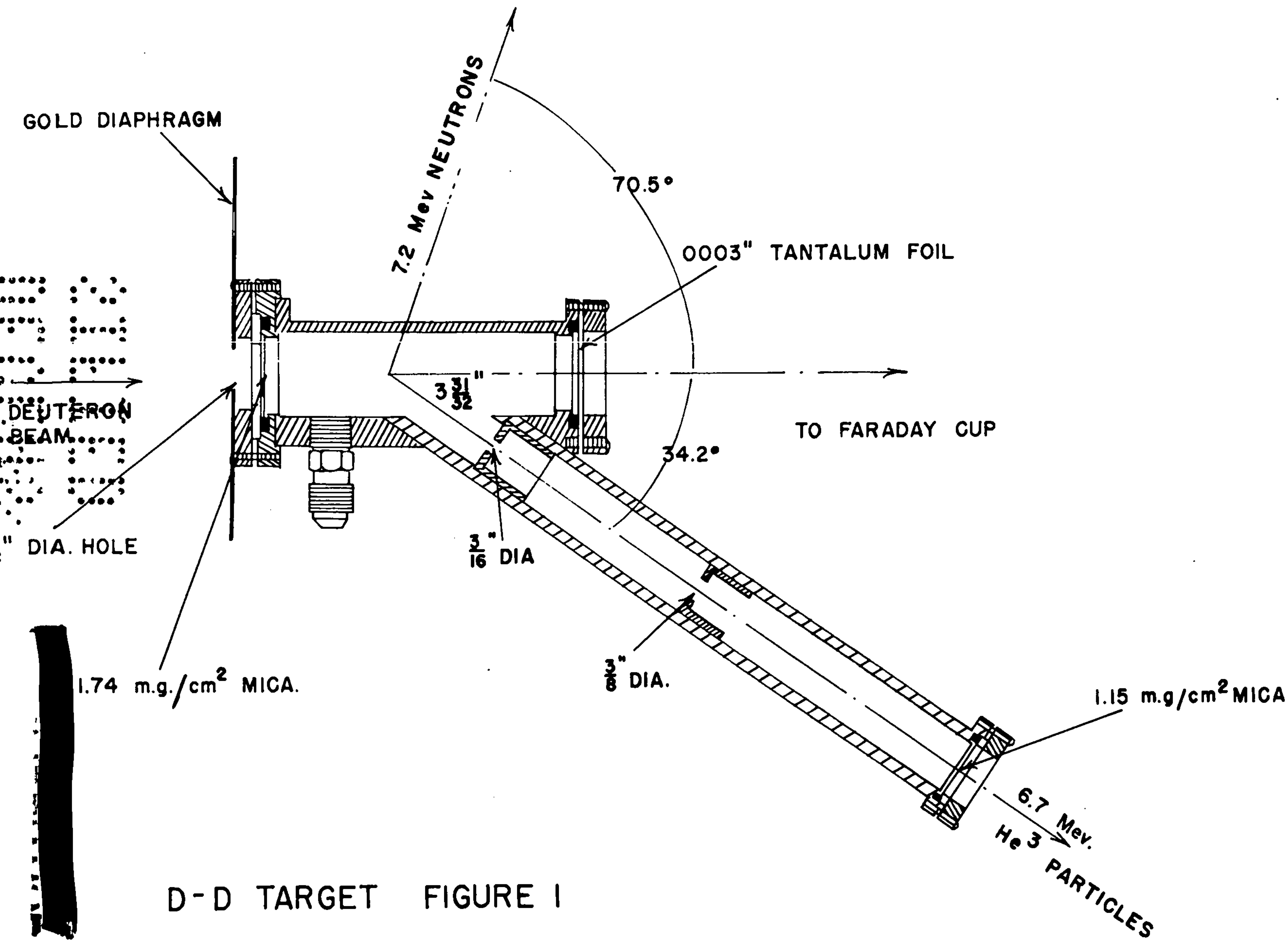

D-D TARGET FIGURE I

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TABLE I

ϕHe^3	34.2°
Diaphragms for He^3 Particles	
Target	3/16" x 9/32"
Proportional Counter	9/64" x 9/32"
Thickness of Windows in Target	
Entrance	1.74 mg/cm^2 mica
Exit	0.0003 mil tantalum
He^3 Port	1.15 mg/cm^2 mica
Energy of Deuteron Beam	10.7 Mev
Horizontal Spread He^3 Beam $\Delta\phi He^3$ . . .	$\pm 2.2^{\circ}$
Vertical Spread He^3 Beam $\Delta\alpha He^3$ . . .	$\pm 3.2^{\circ}$
Center of Neutron Beam ϕn	70.5°
Horizontal Spread Neutron Beam $\Delta\phi n$.	$\pm 5.2^{\circ}$
Vertical Spread Neutron Beam $\Delta\alpha n$.	$\pm 5.3^{\circ}$
Neutron Energy	7.2 ± 0.5 Mev

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apparatus.[3]

The peak due to He^3 particles emitted at 34.2 degrees from the target shown in Fig. 1 is given in Fig. 2. The crosses represent the background obtained by placing 5.6 cm of absorber between the counter and the target so as to cut out the He^3 peak. The bias was set to count pulses in channel four and above. For the data obtained here there was a 1.7 percent correction to the number of He^3 counts due to background and the He^3 peak as indicated by the crosses in Fig. 2.

The fission counter was identical to the one discussed in Section V of LA-710. The same Uranium foils were used in this experiment as in the former experiment. There were 12 foils of average thickness 0.641 mg/cm^2 of Uranium. The method of determining this thickness of Uranium, as well as the checks made for uniformity of the foils, have been discussed previously (Section V, LA-710). The energy distribution of the fission fragments of U^{238}, determined in this counter using a pulse height analyzer, was similar to that given in Fig. 15 of LA-710. However, the bias setting for the discriminator was slightly higher than in the previous experiment. In this experiment the correction due to this bias setting (that is, the number of counts between this bias setting and zero) was about 4.4 percent as compared to two percent for the former experiment.

The electronic apparatus was the same as that used in the

3 K. W. Erickson, J. L. Fowler, and E. J. Stovall, Jr., Phys. Rev. 75, (1949)

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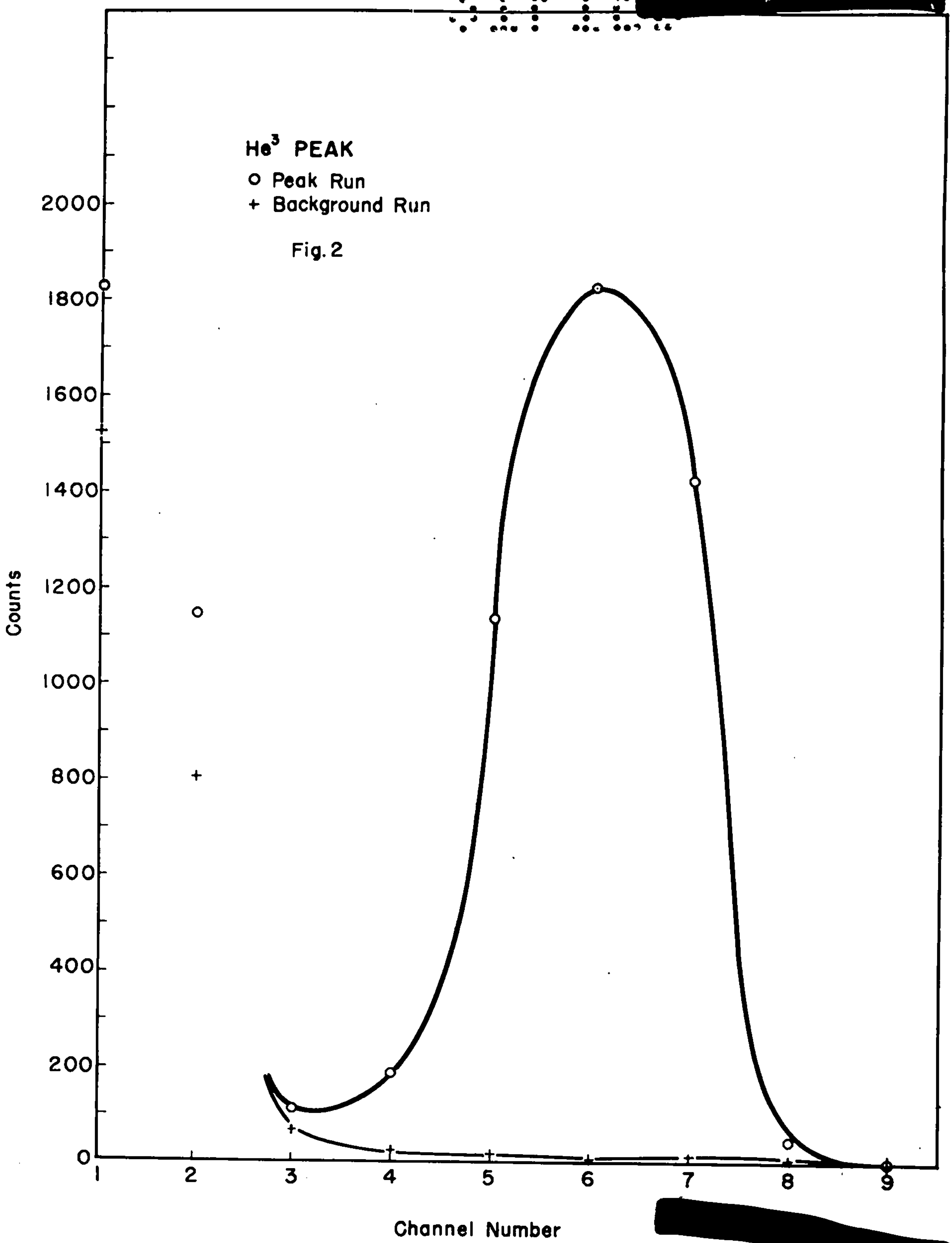

Fig. 2

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experiment of LA-710. The experimental procedure used was the same as that discussed in Section VIII of the former experiment; that is, the number of He^3 particles, the number of fissions, and the number of coincidences between them are determined from 1/2 hour runs. The number of accidental coincidences is obtained from the resolving time of the apparatus which is experimentally determined by runs in which the fission counter is rotated to such an angle that there can be no real coincidences. In this experiment the beam current was recorded on a tape by a GE recording micro-ammeter which was in series with a current integrator.

Frequently during the experiment the energy of the deuteron beam was measured by magnetic deflection.[1] Table II gives the results of these energy measurements. The last column gives the energy of the deuteron beam at the point in the target where the He^3 particles are produced.

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TABLE II

DATE	ENERGY
6-22-49	10.70 Mev
6-28-49	10.70 Mev
6-30-49	10.80 Mev
7-7-49	10.60 Mev
Average Energy =	10.70 Mev

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II. RESULTS

The results of 41 one-half hour runs are given in Table III. The last column which gives the number of real coincidences divided by the number of He^3 particles has been corrected for as explained in Section VIII of LA-710. The values of the real coincidences per He^3 particle have been plotted in Fig. 3 in the order in which the data were taken. The points lie about their mean in the manner expected from the theory of probability. In Table IV the data has been summarized. Column 1 gives the neutron energy, column 2 gives the experimental resolving time in seconds, column 3 gives the average value of the coincidences per He^3 particle taken from the data in Table III. In column 4 this data is corrected for the neutron absorption as explained in Section VII of LA-710. In column 5 the data has been corrected for the fission counter bias. Column 6 gives the cross section of U^{238} as calculated from this data together with its standard error. In Fig. 4 all the measurements of the cross section of U^{238} have been plotted. Below three Mev the curve is taken from LA-520.[4] The points indicated by squares are those determined by use of the long electrostatic generator in which deuterons on deuterons gave neutrons up to an energy of 5.85 Mev.[4] The three points recorded in LA-710 have been plotted as circles together with the spread in cross section and the spread in energy. The point at 14 Mev is a re-measurement of the U^{238} cross

[4] J. H. Williams, LA-520 (1946).

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TABLE III

Run No.	Δt Sec.	N_f Counts	N_p Counts	C Coincidences	$\frac{Cr}{N_p\ Corr.}$
1	1.59×10^3	2.20×10^4	0.857×10^6	34	$14.3 \pm 9.4 \times 10^{-6}$
2	1.80	1.79	0.861	25	10.8 ± 7.8
3	1.26	1.10	0.544	11	4.1 ± 8.4
4	0.90	0.72	0.346	8	8.2 ± 10.3
5	1.80	1.53	0.688	20	13.6 ± 8.5
6	1.80	1.27	0.588	26	32.3 ± 10.1
7	1.80	1.88	0.629	19	11.2 ± 9.3
8	1.80	1.30	0.612	10	3.0 ± 7.3
9	1.80	1.45	0.707	23	18.0 ± 8.4
10	1.80	1.89	0.878	25	3.9 ± 8.1
11	1.80	1.39	0.695	29	24.2 ± 9.5
12	1.80	1.38	0.644	21	14.9 ± 9.2
13	1.80	1.28	0.605	23	21.7 ± 9.8
14	1.80	1.88	0.584	16	3.2 ± 9.8
15	1.31	0.82	0.396	15	23.6 ± 11.8
16	1.32	0.87	0.397	13	17.6 ± 11.3
17	1.80	1.34	0.644	27	25.0 ± 9.8
18	1.80	1.40	0.672	13	1.2 ± 7.7
19	1.80	1.72	0.818	28	12.0 ± 8.6
20	1.80	1.41	0.691	26	19.6 ± 9.3
21	1.80	1.45	0.717	20	9.3 ± 8.3
22	1.80	1.60	0.793	26	12.0 ± 8.4

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TABLE III (contd)

Run No.	Δt Sec.	N_f Counts	N_p Counts	C Coincidences	$\frac{Cr}{N_p}$ Corr.
23	1.80×10^3	1.92×10^4	0.906×10^6	31	$9.5 \pm 8.4 \times 10^{-6}$
24	1.80	1.65	0.780	36	25.1 ± 9.5
25	1.05	0.94	0.449	12	1.1 ± 11.1
26	1.80	2.12	1.003	38	10.6 ± 8.4
27	1.80	1.66	0.793	24	8.9 ± 8.3
28	1.80	1.77	0.776	35	22.4 ± 9.7
29	1.80	1.46	0.702	25	16.8 ± 9.1
30	1.80	2.14	0.938	44	19.5 ± 9.3
31	1.02	1.02	0.516	18	11.6 ± 11.1
32	1.80	1.61	0.734	24	13.1 ± 8.9
33	1.80	1.51	0.718	21	10.9 ± 8.4
34	1.80	1.86	0.863	40	23.9 ± 9.5
35	1.80	1.17	0.566	20	21.4 ± 9.7
36	1.80	1.14	0.576	13	8.9 ± 8.3
37	1.80	1.24	0.582	19	17.8 ± 9.5
38	1.80	1.76	0.705	24	12.8 ± 9.4
39	1.80	1.125	0.551	23	28.4 ± 10.3
40	1.80	1.02	0.555	10	5.7 ± 7.7
41	1.92	0.88	0.386	8	10.8 ± 9.3

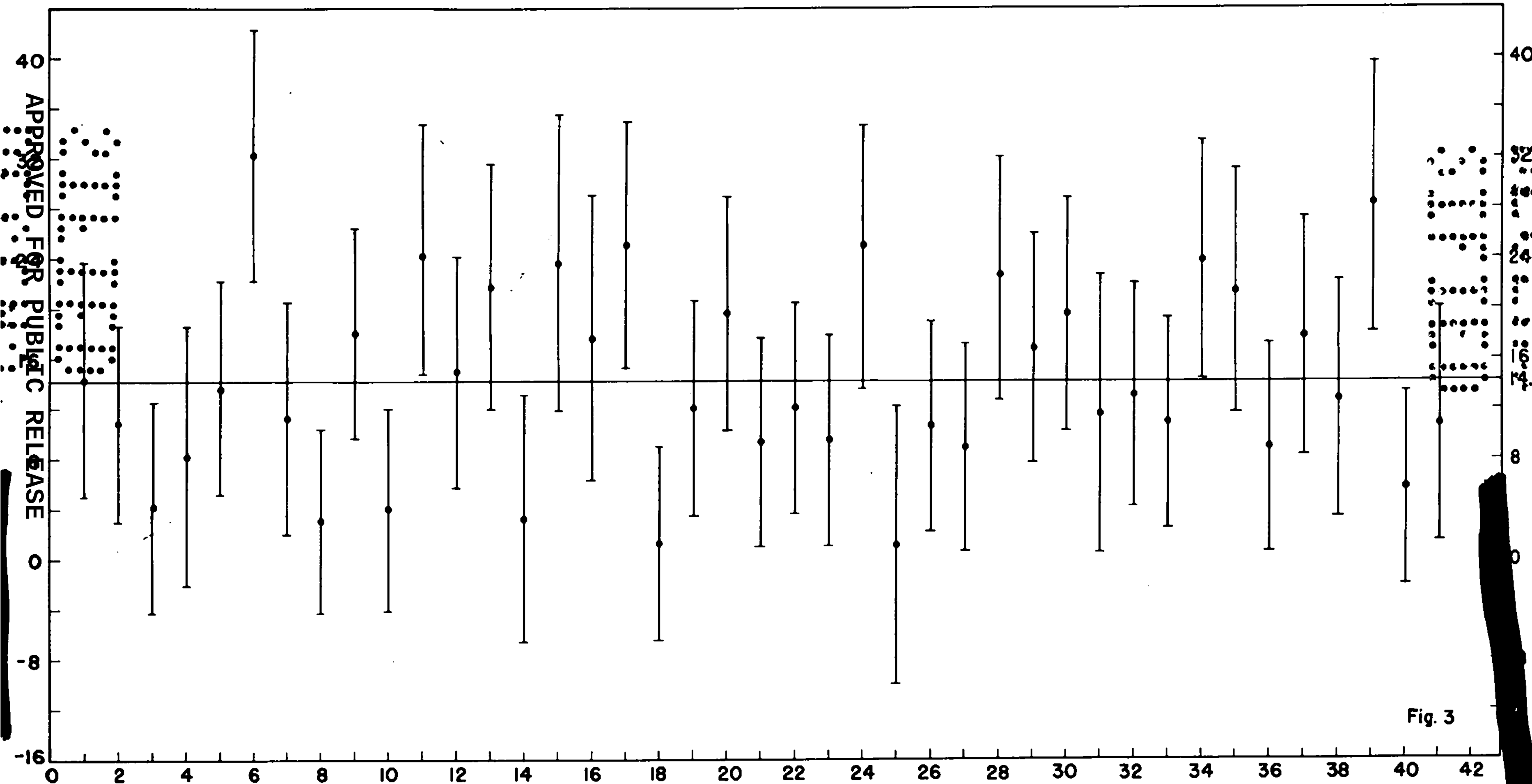

Fig. 3

Run II.

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TABLE IV

Neutron Energy	7.2 ± 0.5
τ Experimental Resolving Time (sec)	$2.18 \pm 0.11 \times 10^{-6}$
C_r/N_p	
Average	$14.2 \pm 1.4 \times 10^{-6}$
Corrected for Neutron Absorption	$15.1 \pm 1.5 \times 10^{-6}$
Corrected for Fission Counter Bias	$15.8 \pm 1.6 \times 10^{-6}$
σ_{28} Barns	0.81 ± 0.08

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section as determined by Warren Nyer.[5] The new value of the cross section at 7.2 Mev (0.81 ± 0.08 barns) is plotted as a circle with a cross. The most probable curve through the set of points is a step curve similar to the one shown as a solid line. However, the uncertainty of the measurement is such that a continuous curve as shown by the dashed line is not excluded. If one calculates the relative probability of the solid curve and the dashed curve on the basis of the distance of the points away from the two curves in terms of the standard errors of the measurements, then one finds the step curve (the solid curve) is about four times more probable than the dashed curve. The step in the cross section curve, seen in Fig. 4, occurs at about seven Mev, which is about the threshold for γ ray fission for U^{238}. A possible explanation of this step may be that for neutrons above seven Mev there is, besides the capture process which leads to fission in the lower energy region, the possibility of an inelastic scattering of the neutrons which also leads to fission. Of course, more accurate data is needed to firmly establish this point. If this latter process is true, however, one might expect the number of neutrons produced per fission to be higher for higher energy neutrons (say in the region of 14 Mev) due to this inelastic scattering process. It may even be expected that the fission process itself may be different for fission produced by inelastic scattering. This may show up as a difference in distribution of the fission fragments.

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[5] Warren Myer, LA-719(1948)

Neutron Energy in Mev

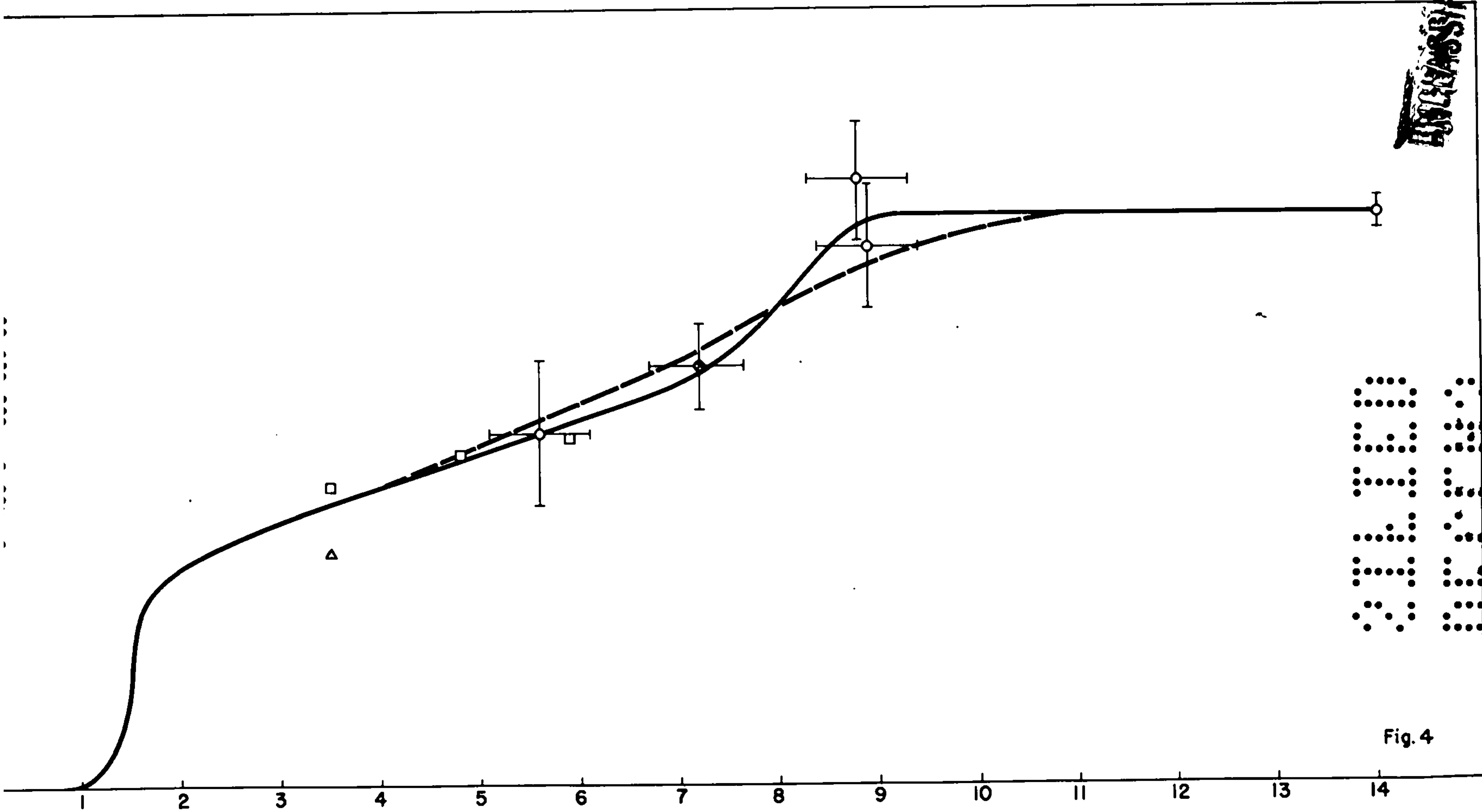

Fig. 4

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