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# NEUTRON ENERGY SPECTROMETER



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This document consists of 13 pages.
Copy 8 of 131 Series A.

Contract No. W-7405, eng 26

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Shielding Section

# NEUTRON ENERGY SPECTROMETER

B. R. Gossick,** K. Henry**

* This report is also issued as NEPA-1407-ECR-7

** NEPA personnel

Date Issued JUN 1 2 1950

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# NEUTRON ENERGY SPECTROMETER

B. R. Gossick, K. Henry

## Introduction

By employing a proportional counter of special design, it is possible to make a fast neutron spectrometer with which the energy distribution can be obtained without taking derivatives of the counting rate. To avoid differentiating the counting rate, it is necessary to know both the range and angle of the recoil within acceptable errors. By virtue of biasing a linear pulse amplifier to take advantage of the peak in the Bragg specific ionization curve, only those recoils are counted which traverse a given thickness of stopping material through a collimator and then end their path near a short anode. Thus the range is associated directly with the number of counts. It is, of course, necessary to know the direction of the incident neutrons, so that the limits of the recoil angle are defined by the collimator.

## Principles of Operation

The flux of neutrons with energy between E and E + dE striking the radiator is given by

$$\varphi(E) = \frac{P(E)}{Gt\,\sigma(E)\,dE} \qquad (1)$$

where P(E) gives the recoil counting rate produced by neutrons with energy between E and E and dE, G is a constant, t is the radiator thickness, $\sigma(E)$ represents the hydrogen scattering cross section for neutrons with energy between E and E and dE, and dE is the uncertainty in energy because of radiator thickness and discriminator bias setting. (see Figure I) It should be mentioned that the counting rate P(E) is a differential, being the difference between the rates with and without the radiator.

The proportional counter tube with a differential anode is shown in Figure II. Satisfactory results have been obtained with a gas amplification of $\sim$20, the filling mixture being 9 cm. Hg of argon and 1 cm. Hg of carbon dioxide. Following the lead of J. H. Coon, and R. A. Nobles (MDDC-96) the cathode is covered with a 10 mil liner of platinum to reduce background.

It is convenient to use a point source of monochromatic alphas to determine the active region of the tube and at the same time to obtain the correspondence between discriminator bias voltage and stopping power. Denoting the distribution function for alpha pulses with amplitude between V and V + dV as N(V), the counting rate $C(V')$ is given by

$$C(V') = \int_{V'}^{\infty} N(V)dV \quad , \qquad (2)$$

where $V'$ is the discriminator bias setting. By differentiating the counting rate $C(V')$ one obtains the distribution function $N(V')$,

$$N(V') = \frac{dC(V')}{dV'} \quad . \qquad (3)$$

Experimental curves of (2) and (3) taken from $Pu^{239}$ alpha measurements are shown in Figure III. With a calibrated point source of $Pu^{239}$ placed near the center of the window, the pulses produced by alphas falling within the cone OAB (Figure II) represent the area under the curve $N(V')$ to the right of the cross hatching. The number of pulses produced by alphas falling between cones OAB and OCD are given by the cross hatched area. Thus, the tube itself functions as a collimator. It is possible to confirm the proportionality between the stopping power of the particle traversing the active region and the bias $V'$ corresponding to $N(V')_{max.}$ by measuring $N(V')$ with different absorbers and referring to range-energy curves.[1]

Measurements made with $Li^7(p,n)Be^7$, $d(d,n)He^3$, and $H^3(d,n)He^4$ reactions using an electrostatic accelerator, and with a Po-Be source are plotted in Figures IV, V, VI and VII.

Root mean square errors are tabulated as follows:-

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1) Range-Energy Curves, W. A. Aron, B. G. Hoffman, F. C. Williams, AECU-663 (1949).

The Properties of Atomic Nuclei, II. Range-Energy Curves Alpha-Particles, Protons, and Mesons, H. A. Bethe, Brookhaven National Laboratory (1949).

| Percent r.m.s. errors in energy | $Li^7(p,n)Be^7$ | $d(d,n)He^3$ | $H^3(d,n)He^4$ |
|---|---|---|---|
| Recoil angle | 4.0 | 4.0 | 4.0 |
| Angular range error | 0.7 | 0.7 | 0.7 |
| Radiator thickness | 5.1 | 7.8 | 3.2 |
| Bias interval width | 5.7 | 1.5 | 0.2 |
| Range straggling | 1.3 | 1.1 | 0.9 |

Besides the proportional counter tube, a collection of polystyrene radiators and 2-S aluminum absorbers, the following equipment was used:-

Linear Pre-Amp, Model 205-B, Atomic Instrument Company

Linear Amplifier, Model 204-B, Atomic Instrument Company

64 Scaler, ORNL Model Q-762, Nuclear Instrument and Chemical Corporation

Precision High Voltage Supply, NEPA Controls and Instrumentation Department

## Acknowledgments

This work was done as a joint NEPA-ORNL project. The cooperation and helpful suggestions of many people are gratefully acknowledged. Among those to whom we are particularly indebted are: Dr. Clark Goodman of M.I.T., Dr. C. E. Mandeville of Bartol Research Foundation, and Mr. Richard Zedler of ORNL.

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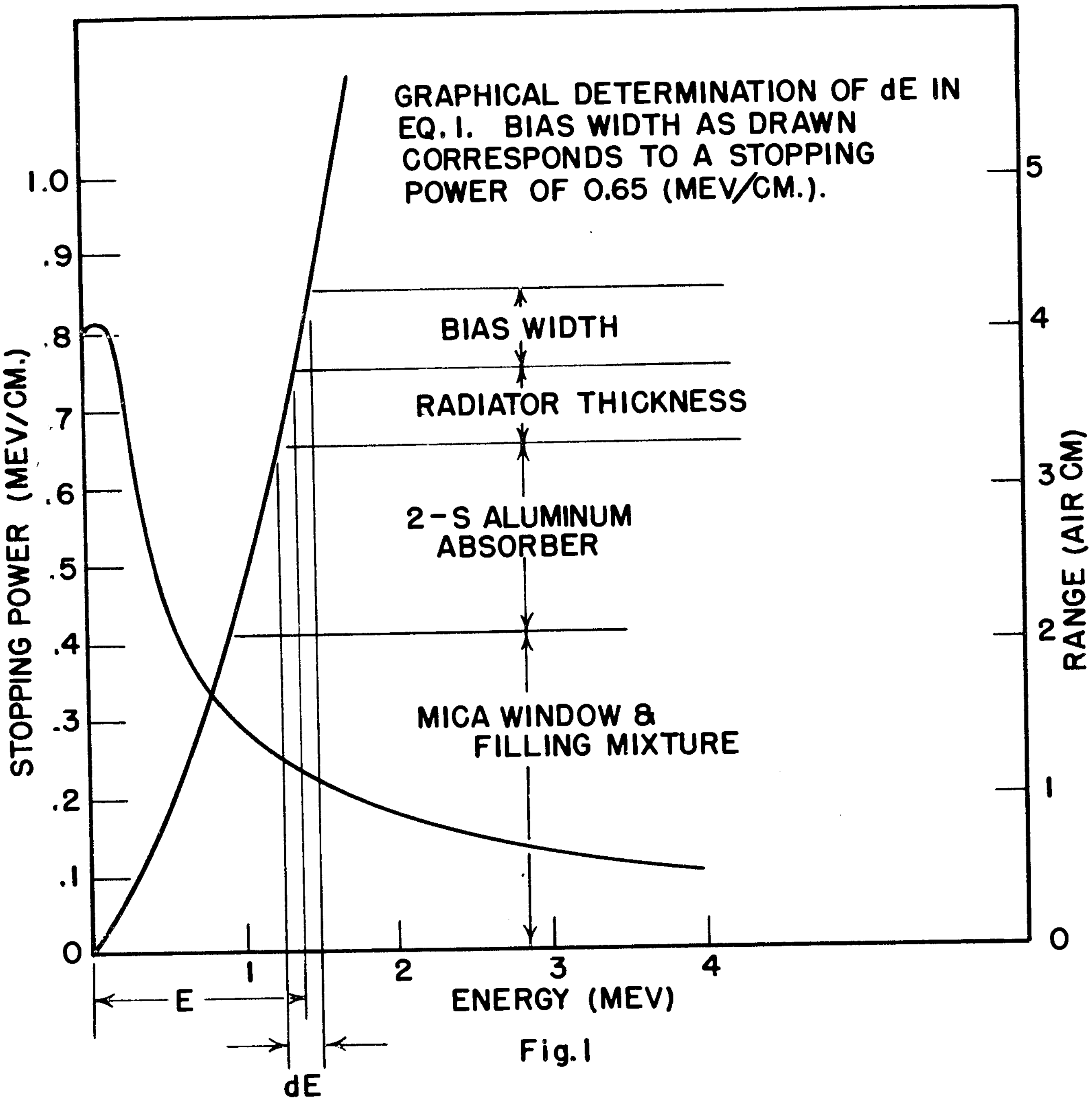


Fig. I

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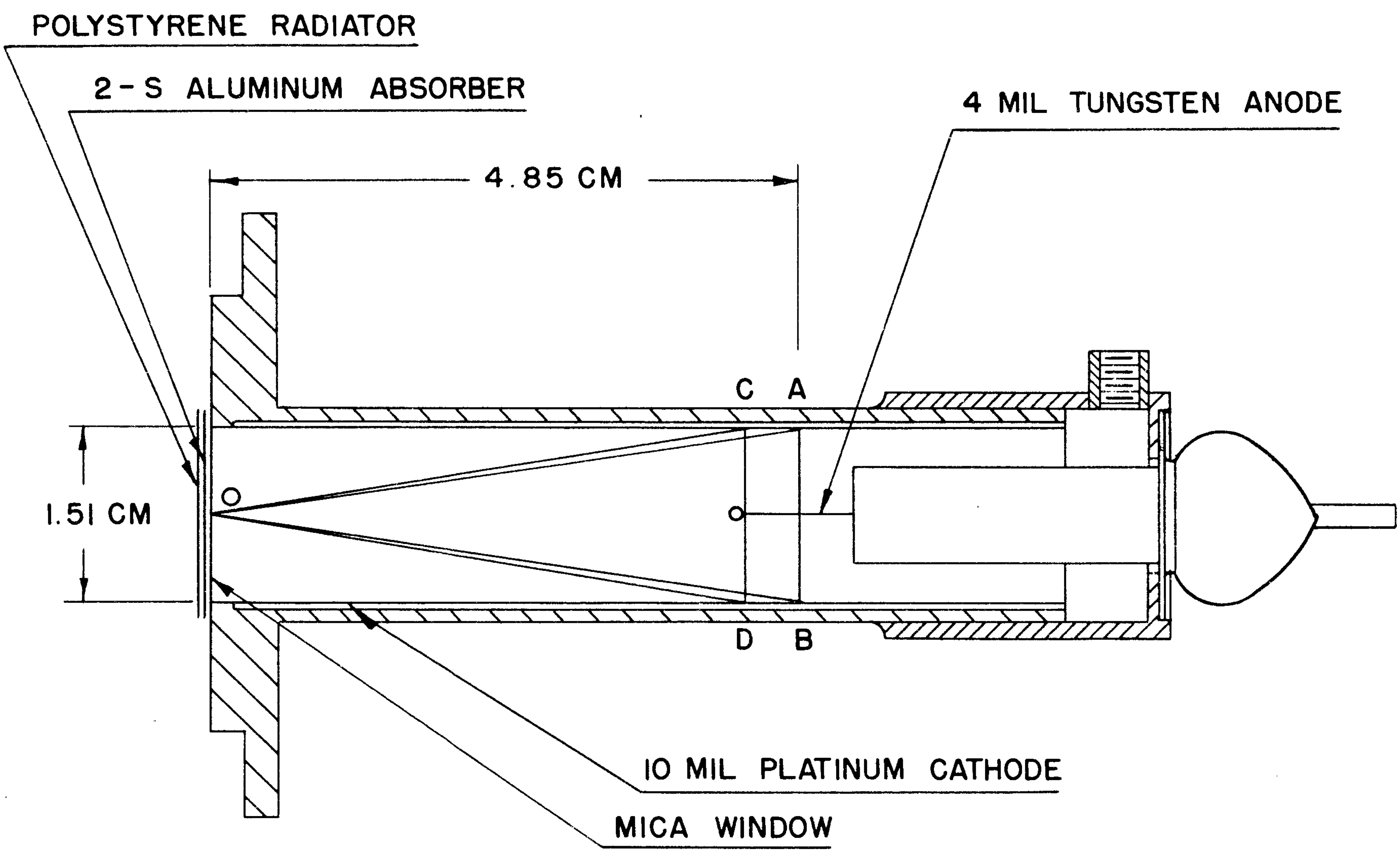


FIG. 2

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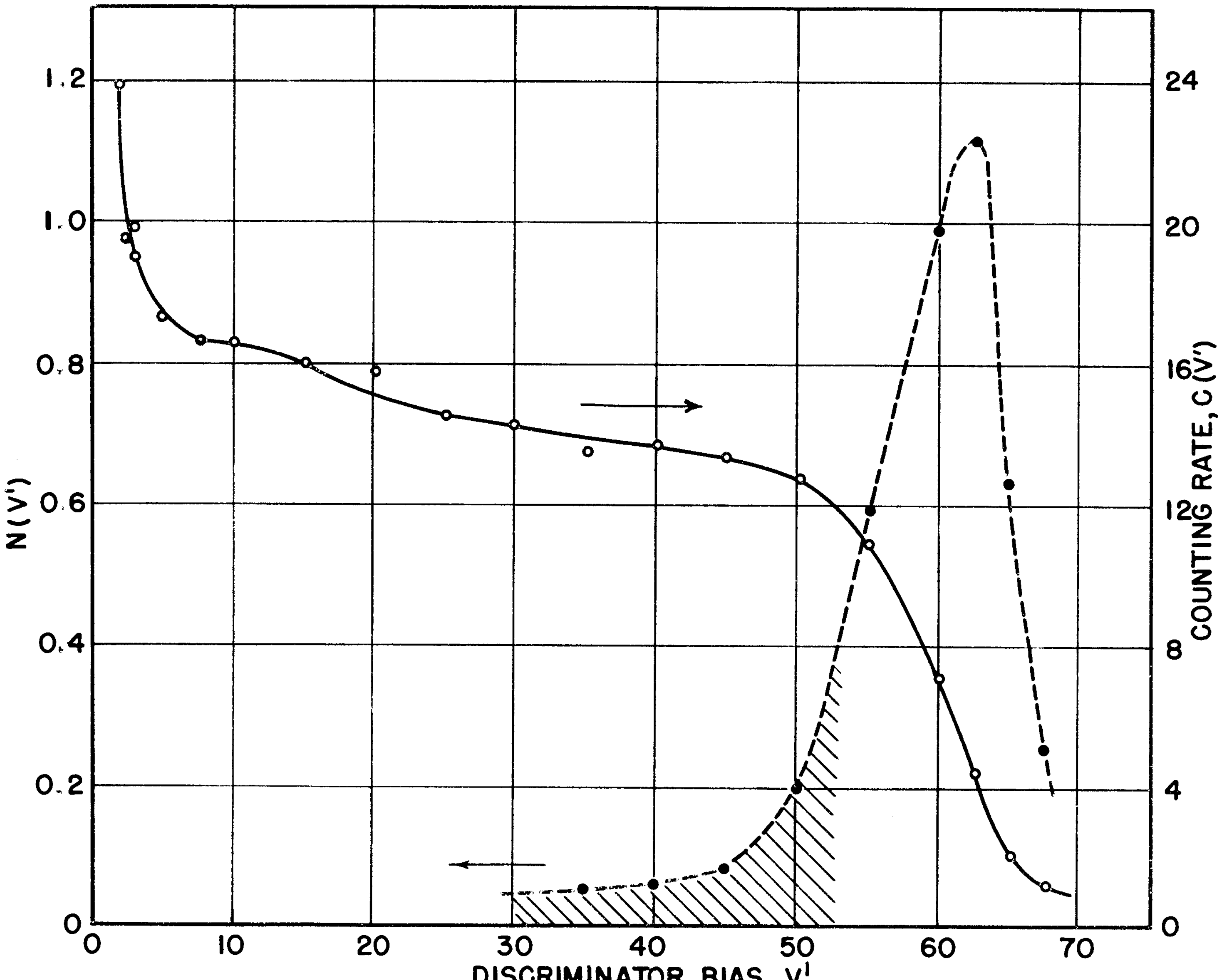


Fig 3

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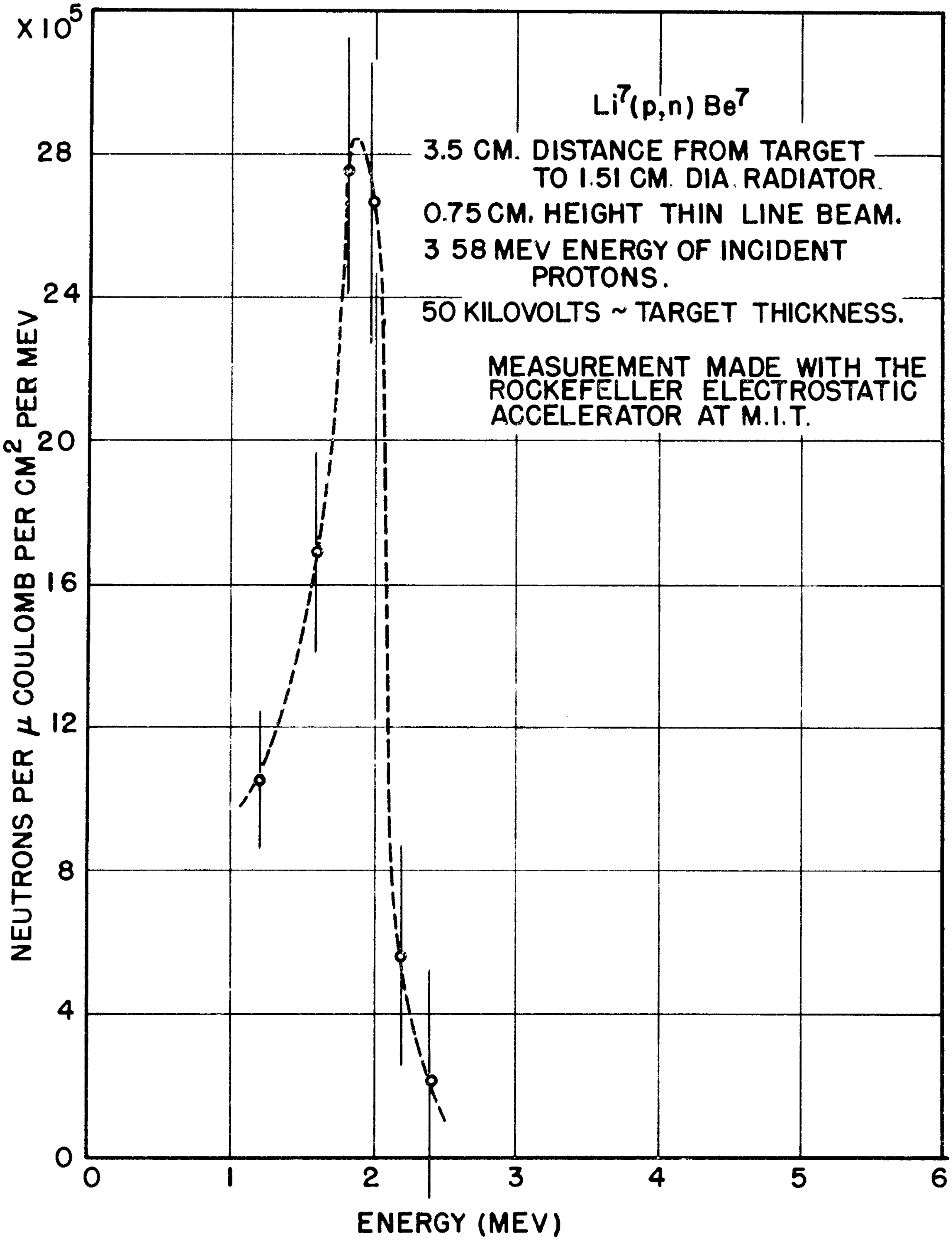


Fig. 4

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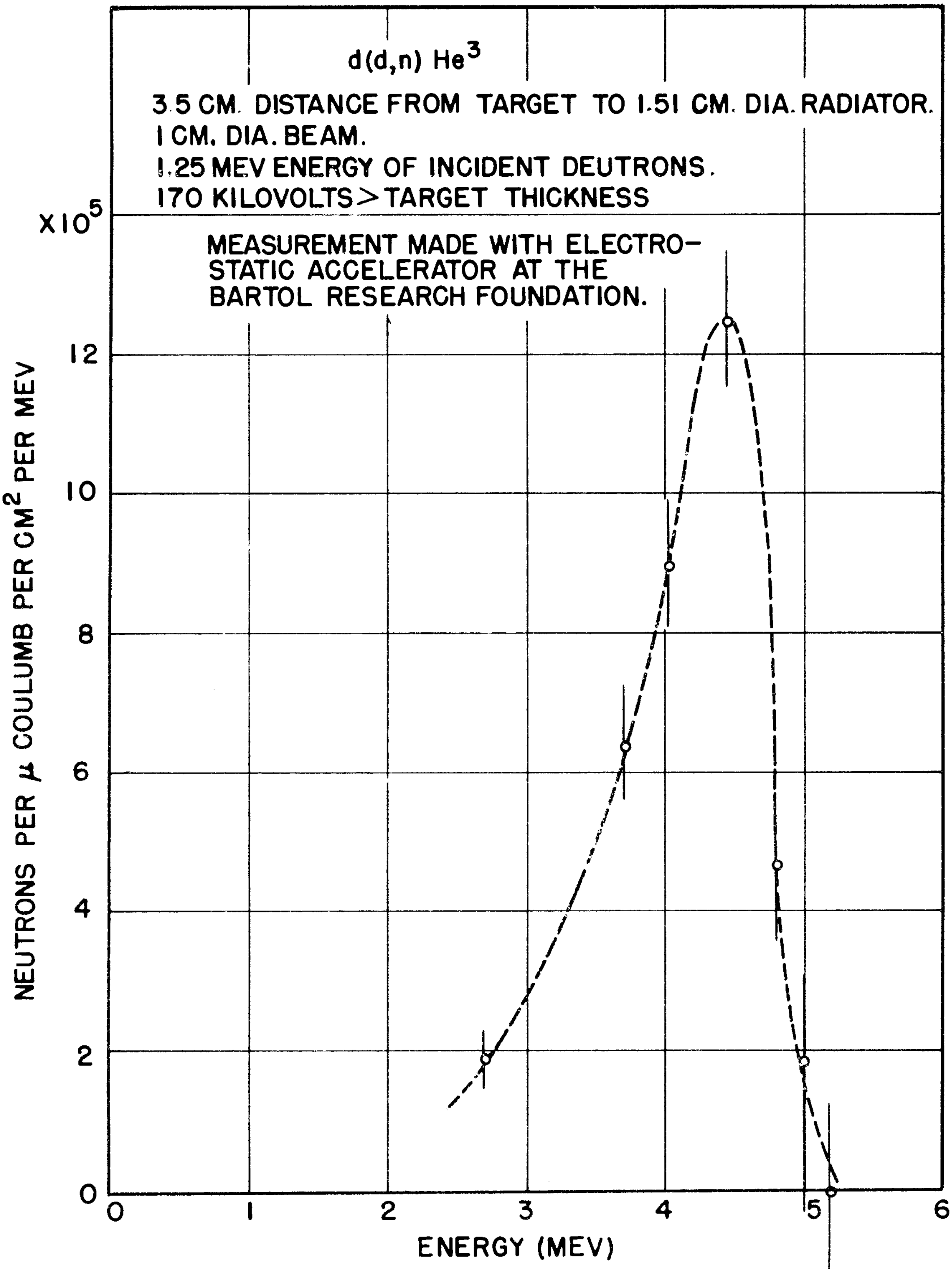


Fig. 5

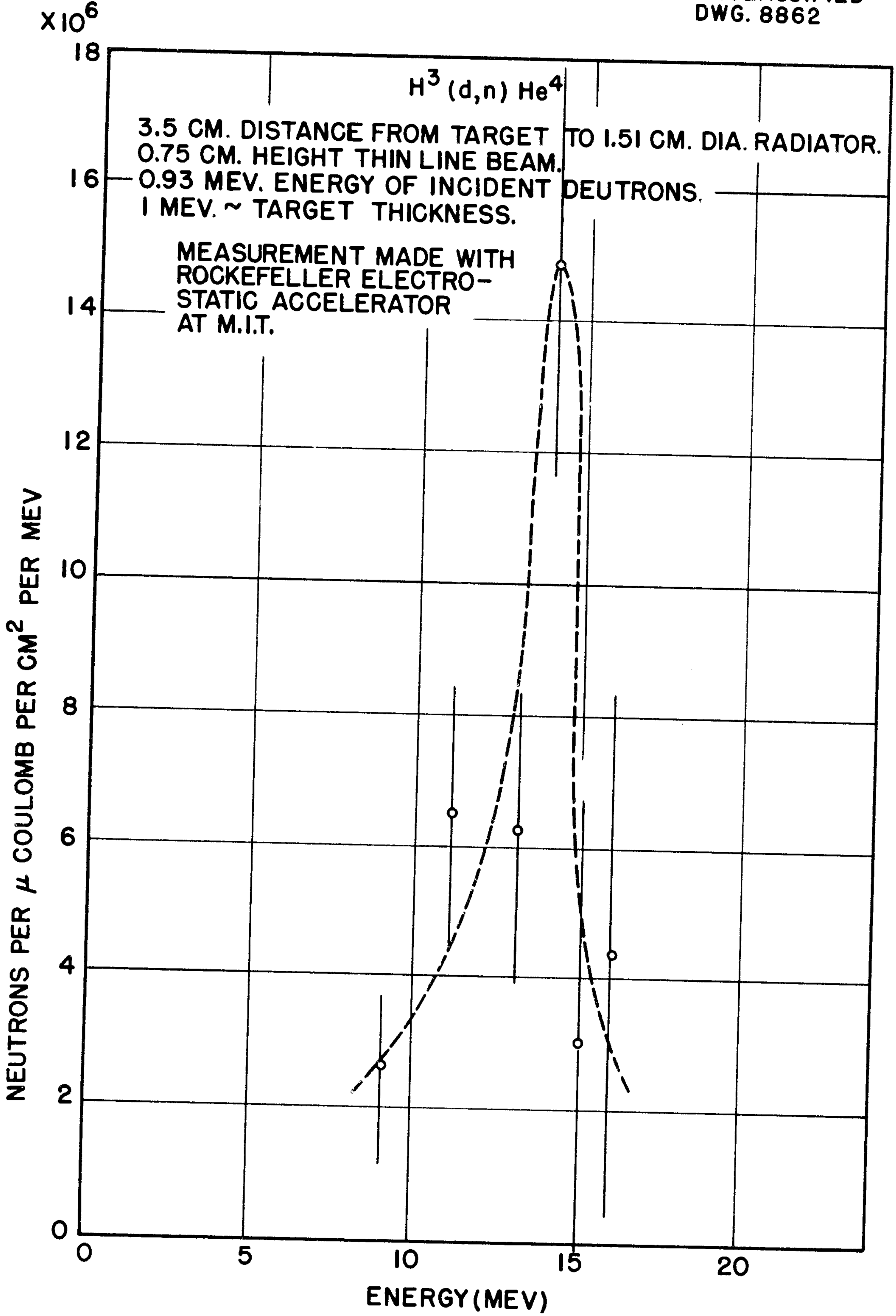
X10^6
18
16
14
12
10
8
6
4
2
0
0
5
10
15
20
H^3 (d,n) He^4
3.5 CM. DISTANCE FROM TARGET TO 1.51 CM. DIA. RADIATOR.
0.75 CM. HEIGHT THIN LINE BEAM.
0.93 MEV. ENERGY OF INCIDENT DEUTRONS.
1 MEV. ~ TARGET THICKNESS.
MEASUREMENT MADE WITH ROCKEFELLER ELECTRO-STATIC ACCELERATOR AT M.I.T.
NEUTRONS PER μ COULOMB PER CM^2 PER MEV
ENERGY (MEV)

Fig. 6

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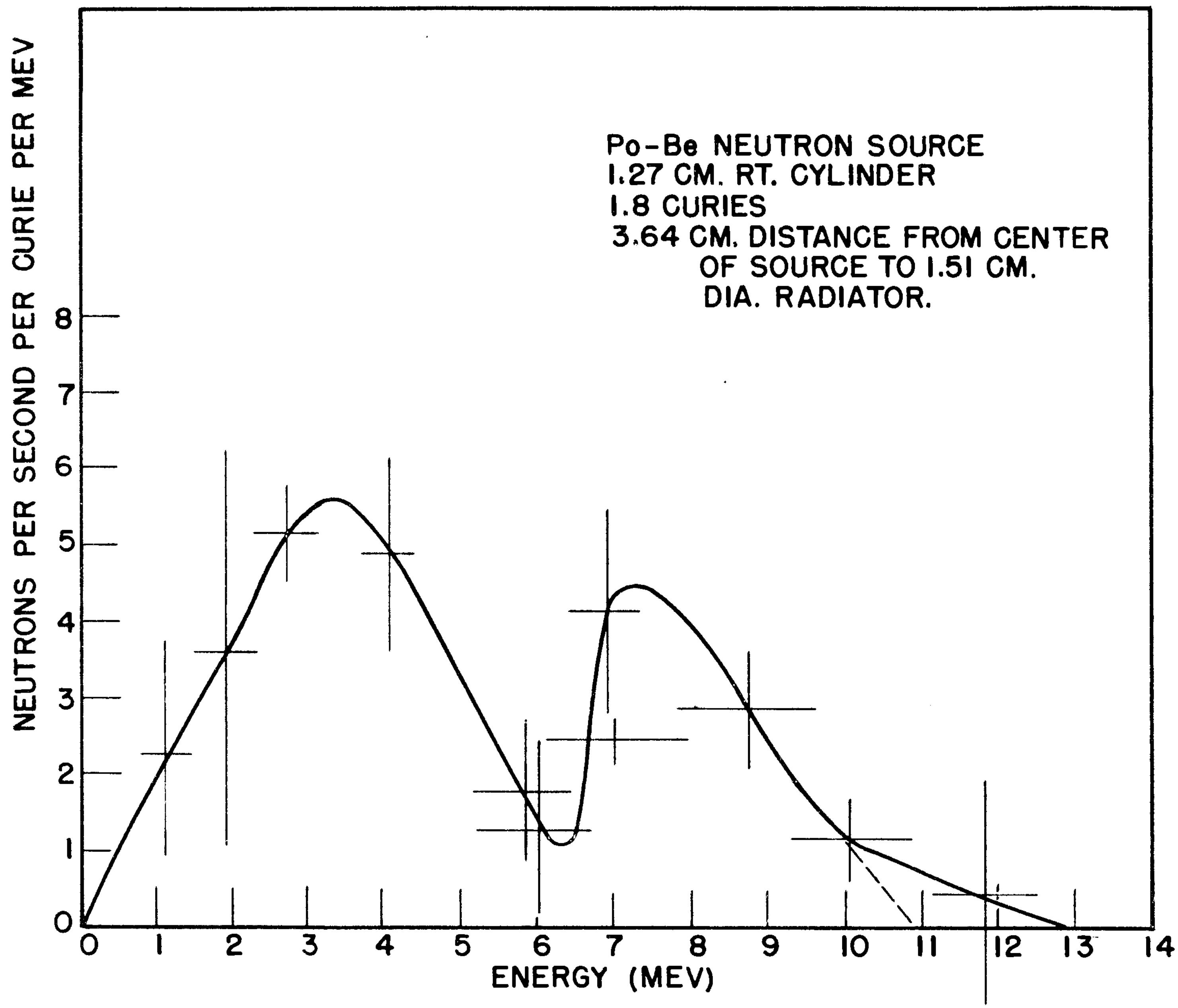


Fig. 7