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THE ENERGIES OF THE NEUTRONS FROM POLONIUM ALPHAS ON BORON

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ABSTRACT

The energy spectrum of the neutrons emitted when a thick boron target is bombarded by polonium alpha particles has been studied by the photographic emulsion method. From 355 recoil proton tracks a neutron distribution is inferred which shows a broad maximum at about 2.5 Mev and extrapolates to zero at about 6 Mev on the high-energy end. A suggestion is made for producing a mock fission-neutron source, and a brief discussion is included of the photographic vs. ionization-chamber techniques of measuring neutron energies.

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THE ENERGIES OF THE NEUTRONS FROM POLONIUM ALPHAS ON BORON

Introduction

The energy spectrum of the neutrons from natural alpha source on boron was studied by several workers shortly after the neutron was first discovered 1,2,3). These early measurements (made by measuring the range of protons knocked out of paraffin or by proton recoils in a cloud chamber) gave insufficient and discordant data. Neutron energy measuring techniques were not well developed at that time and the natural alpha sources were often so weak that satisfactory statistics were seldom obtained.

Recently 180 millicuries of Po on eight 3 x 3 cm Pt foils4) were available for experimental use. A neutron source was made by interleaving the Po foils between sintered B_4C slabs5), the whole Po-B assembly being placed in the brass box of Fig. 1, evacuated, and sealed off by means of a Kovar to glass seal. This source was later used by Staub and Nicodemus for the measurements recently reported in L A Report 48.

Exposure Arrangement

For the present experiment the above neutron source was suspended in the center of the room and Ilford Halftone Plates (100μ thick) were placed 14 cm from one of the faces of the box (see Fig. 2).

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1) Chadwick, Proc. Roy. Soc., 142, 1, (1933)

2) Curie and Joliot, J. de Phys. et Rad., 4 278, (1933)

3) Bonner, T. W. and Mott-Smith, L., Phys. Rev., 46, 258, (1934)

4) Prepared by R. J. Prestwood

5) Prepared by the Metallurgical Group

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A fourteen-day exposure gave a sufficient number of tracks per field of view. Background plates (with the source removed) were later left in the room an equal length of time. Examination of these plates indicated that there was no appreciable background.

The processing and measuring techniques are those described in earlier reports (6,7). The actual track measurements were made by I. H. Perlman.

Results

355 recoil proton tracks have been measured and plotted in energy intervals. (The stopping power of the emulsion had previously been carefully calibrated 6).) Each energy interval was decreased by $1/2\ E\theta^2$ because recoils out to $\theta = 17^\circ$ were measured. The results given in Fig. 3 have also been corrected for n-p scattering cross section and for a geometry correction arising from the fact that long tracks are more likely to leave the emulsion 7). Also for comparison Staub's ionization chamber measurements with the identical Po-B source are included on Fig. 4. The ionization-chamber data have been normalized to the same area as the photographic data.

Discussion

If one uses the latest mass values 8), one calculates $Q = 1.18 \pm 0.1$ Mev for $B^{10}\ (\alpha,n)N^{13}$ and $Q = +0.28 \pm .09$ Mev for $B^{11}\ (\alpha,n)N^{14}$. Hence for Po-α, the maximum neutron energies would be 6.13 Mev and 5.19 Mev respectively. Since the present spectrum extrapolates to zero at about 6 Mev, this is a

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6) H. T. Richards, L A Report 60

7) H. T. Richards, Phys. Rev., 59, 796 (1941) [redacted]

8) Chicago Handbook, CL-697, Chap. III, Part A

satisfactory check of the mass values, particularly since only a small fraction of the neutrons are supposed to be from the B^{10} isotope 9). Neutrons of 4.2 Mev 3) were the highest observed by any of the early workers.

Synthesis of a Mock Fission-Neutron Source

One of the principal reasons for the present neutron energy study was to determine whether the Po-B neutrons could be used as a mock fission-neutron source. In agreement with the results of Staub 10), we find that the Po-B neutrons have a significantly higher average energy than the fission neutron spectrum measured by the same technique 6) (see Fig. 3). However, it may be possible by making use of other (α ,n) reactions to "doctor" this source to resemble satisfactorily the fission neutron spectrum. Those reactions most promising from the point of view of intensity and estimated neutron energies are $F^{19}(\alpha\, n)Na^{22}$, $Na^{23}(\alpha\, n)Al^{26}$, and $Al^{27}(\alpha\, n)Po^{30}$.

The relative yields with Po alphas (Robert's measurements) 11), the calculated Q values 12), and resultant maximum neutron energies expected with Po-αs are given in Table I for some of the relevant (α n) reactions.

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9) Livingston and Bethe, Rev. Mod. Phys., 9, 306 (1937)

10) H. Staub, L A Report 48

11) Roberts, Cf-864 and CN-1190 [redacted]

12) Computed from the masses in the Chicago Handbook, CL-697

Table I

Target	Q (Mev)	E_n max for Po-α	Yield (neuts/10^6 Poα)
Li^6	-3.97		2.7
Li^7	-3.33	0.38 Mev	
B^{10}	+1.18	6.13 Mev	22
B^{11}	+0.28	5.19 Mev	
F^{19}	-0.40	4.6 Mev	12
Na^{23}	-1.63	3.4 Mev	1.5
Al^{27}	-2.23	1.67 Mev	0.7

The fluorine reaction appears to be the most promising method of weighting the low-energy part of the neutron distribution, particularly since the results of Bonner and Mott-Smith3) indicate that most of the neutrons are of much lower energy than the maximum; in fact, most of the neutrons observed were of energy less than 2.0 Mev.

A suitable experimental arrangement might be to have the Po deposited on aluminum foils. The aluminum foils are then mounted in a gas-tight holder which is filled with BF_3 gas at such pressure that the BF_3 would completely stop the Po alphas. In such an arrangement the neutron yield from the fluorine reaction would be about 1.6 times that of the boron and the neutron yield from the aluminum reaction would be about 0.13 that of the boron reaction. These reactions should decrease the average energy quite appreciably while the neutron yield from a given amount of Po would still be 0.86 times that of the arrangement used in the present experiment. If the average energy of such a source were too low, the aluminum foils could be replaced by platinum and the yield cut only 7 per cent further.

Comparison of Photographic vs. Ionization Chamber Method for Measuring Neutron Energies

The second reason why the present neutron studies were undertaken was to provide a comparison of the photographic-emulsion technique and ionization-chamber method of measuring neutron energies. The two techniques had given somewhat different results for the fission neutron spectrum$^{6,13)}$, and hence it was desired to test the two methods on other neutron sources.

The agreement on the Po-B neutron spectrum is better than on the fission spectrum (see Fig. 4 and L A Report 60). As was the case on the fission spectrum, the emulsion method appears to be capable of extending the spectrum to higher energies than that covered by the ionization shamber. The only significant disagreement between the two techniques is on the two low-energy points and the region around 3.0 Mev. In the former region the ionization-chamber data ar higher, which result is similar to the fission data. Because of the shortness of the tracks in the emulsion, this region is the least reliable part of the range covered by the emulsion technique. However, from the calibration studies reported in L A Report 60, one would expect that the emulsion method would give <u>too many</u> low energy tracks because of the asymmetric appearance of the calibration groups at low energies. The disagreement at 3.00 Mev is also quite striking. Staub and Nicodemus report a rather sharp peak in this

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13) Bloch and Staub, L A Report 17 and L A Report 17-A

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region which does not appear at all on the emulsion data. From the resolution which the emulsion method shows on d-d neutrons in this energy region (L A Report 60), it is difficult to understand how a peak as sharp as that reported in L A Report 48 could be missed in the present study. A possible explanation might be that the differentiation of the integral recoil ionization data has unduly sharpened the maximum of the ionization-chamber data (see Fig. 1 of L A Report 48). This possibility, perhaps combined with very slight uncertainties in both energy calibrations, makes it seem likely that the two sets of data are in essential agreement.

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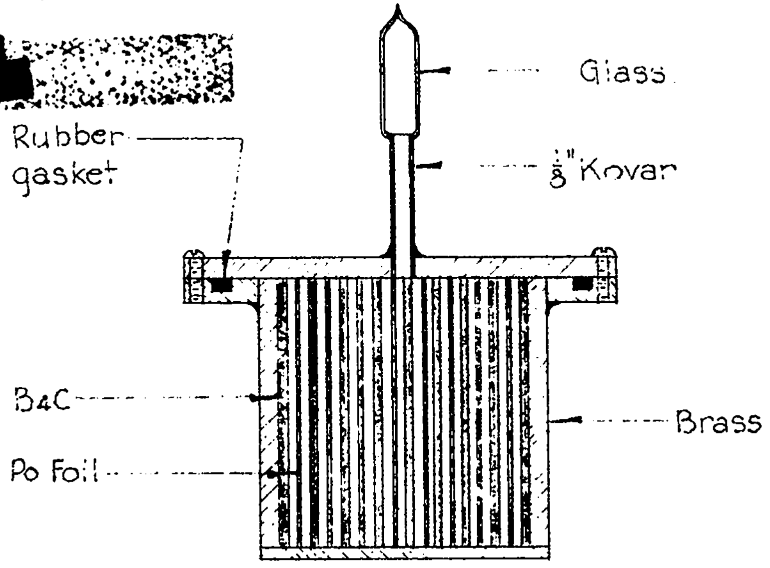

FIG. 1
Detail of Po-B Source

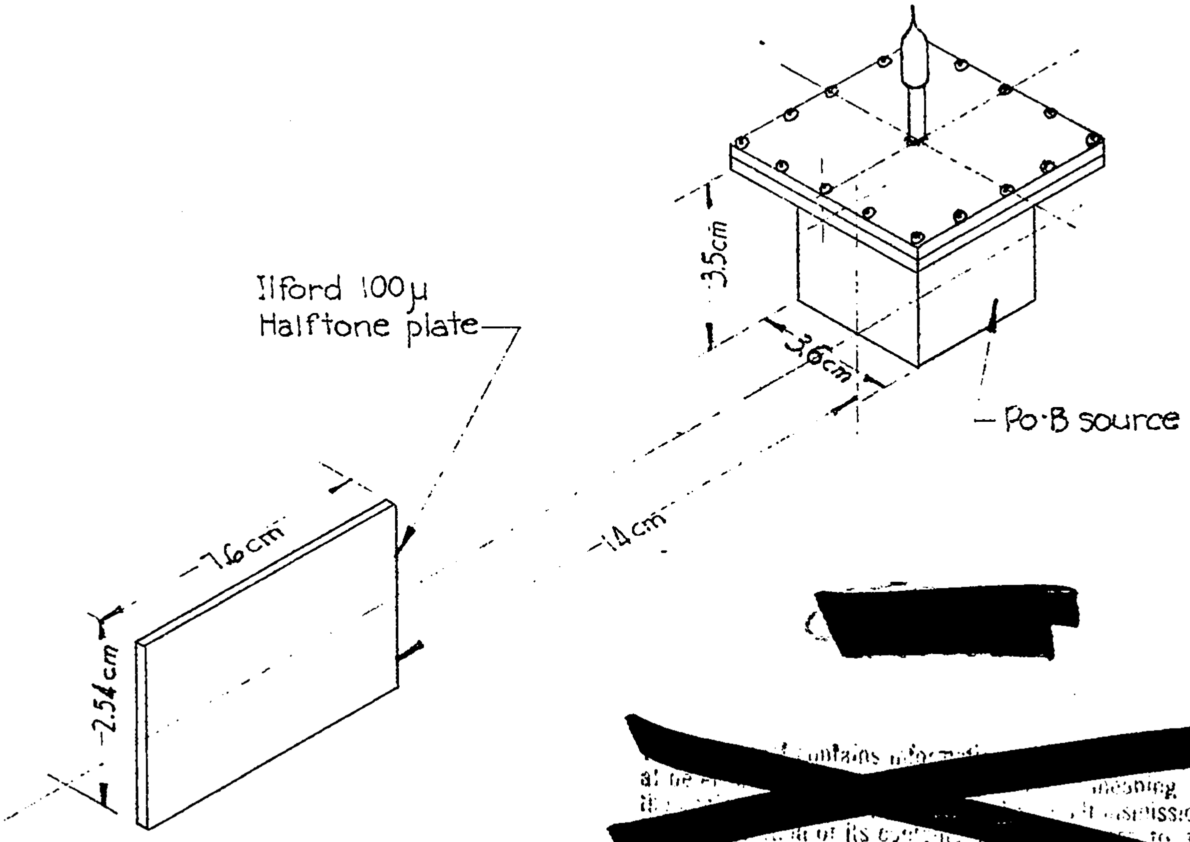

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FIG. 2
Exposure Arrangement

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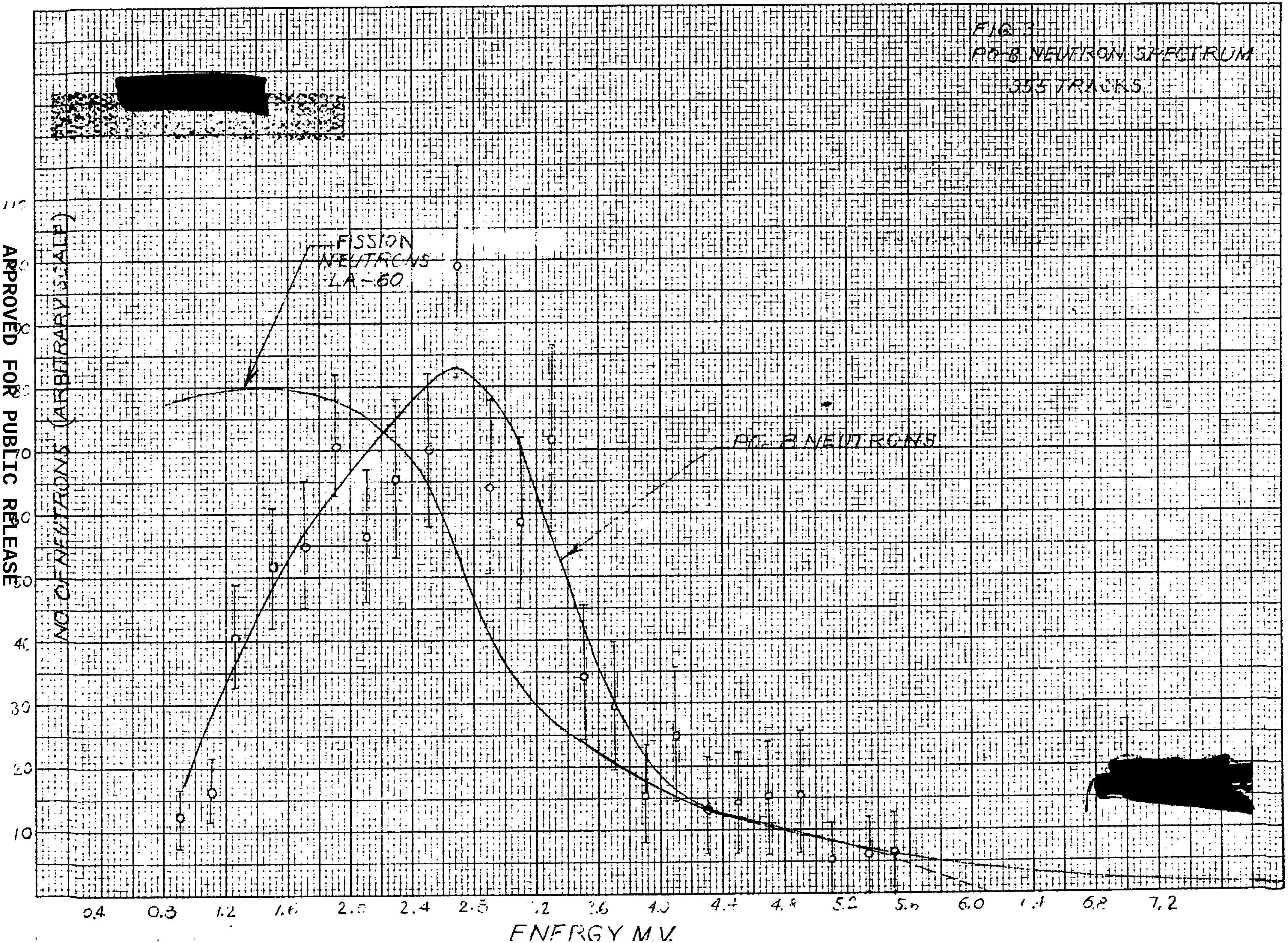
FIG. 3
PO-B NEUTRON SPECTRUM
355 TRACKS



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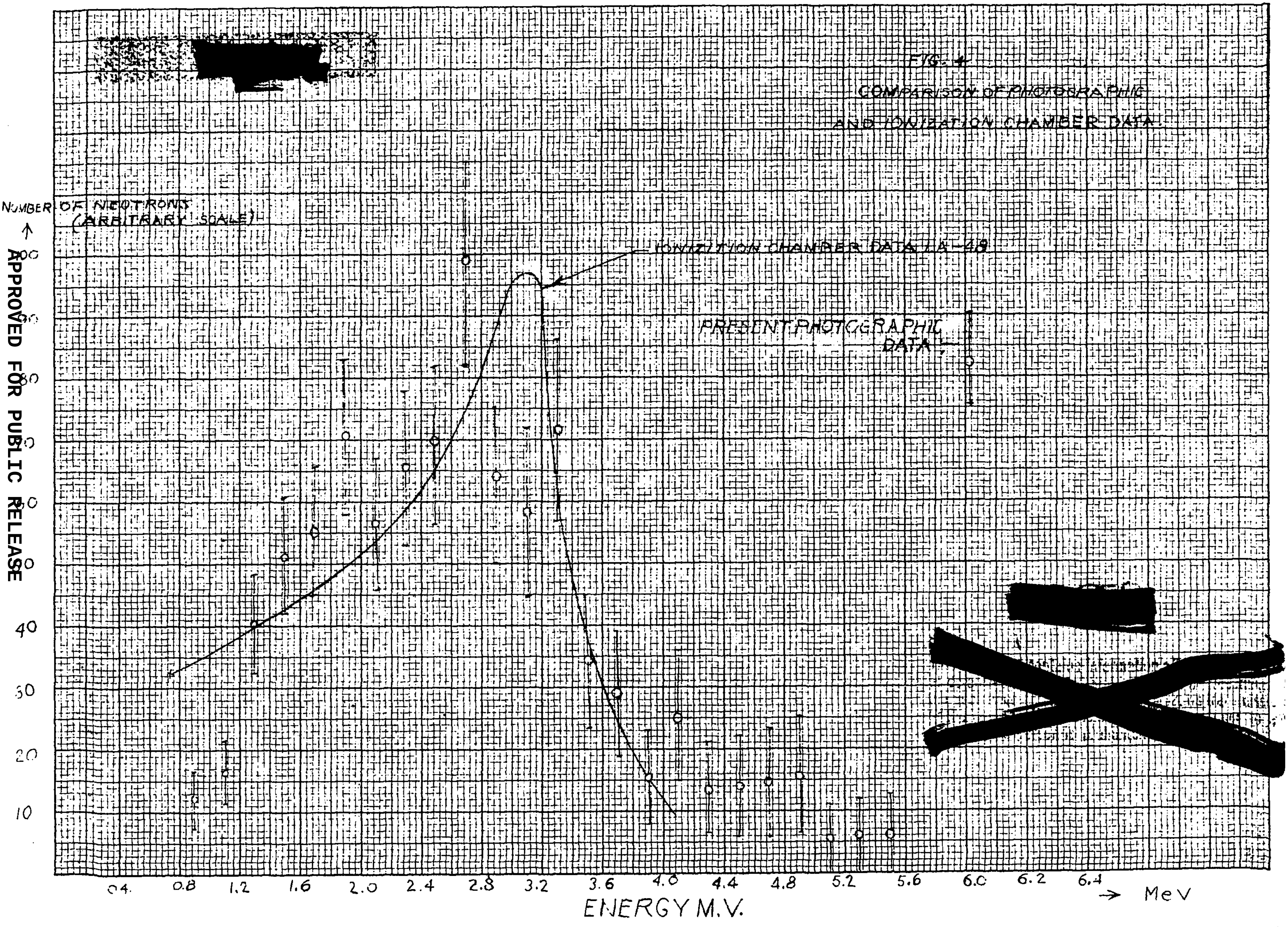

FIG. 4

COMPARISON OF PHOTOGRAPHIC AND IONIZATION CHAMBER DATA.

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