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THE NEUTRON SPECTRUM OF BORON BOMBARDED BY POLONIUM-ALPHAS

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ABSTRACT [redacted]

The neutron spectrum from a boron-polonium source is measured by use of methods and apparatus previously used for measurement of the fission spectrum. The neutrons have energies considerably too high to be used as a mock source to represent the fission spectrum as measured by Bloch and Staub.

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THE NEUTRON SPECTRUM OF BORON BOMBARDED BY POLONIUM-ALPHAS

INTRODUCTION

An investigation of the neutron spectrum of the reaction

$$_5B^{10} + {_2He^4} \rightarrow {_0n^1} + {_7N^{13}}$$

and

$$_5B^{11} + {_2He^4} \rightarrow {_0n^1} + {_7N^{14}}$$

was carried out using the α-particles of polonium in order to determine whether such a natural source could be used in integral experiments to represent approximately the neutron spectrum arising from the fission process of 25. Previously only scant knowledge of this spectrum was available. From the known mass values one would expect the upper limit of the neutron spectrum to be 6.2 MV for B^{10} and 5.3 MV for B^{11}. Since it has been shown[1] that most of the neutrons arise from B^{11} one would expect the neutron spectrum to break off at about 5.3 MV. Furthermore, if uncollimated neutrons are used, one would expect a more or less continuous spectrum since the energy spread of the neutrons due to the angular spread of the α's from o to π would spread the neutrons (in the case of $_7N^{14}$ in the ground state) from 5.3 to 2.8 MV. For a thick B target an additional spread will be caused and since several excited states of $_7N^{14}$ are known to exist the neutron spectrum of the reaction may be expected to be quite continuous up to 5.3 MV. Previous experiments of Chadwick[2] and Curie-Joliot[3] have shown that the

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

2) Chadwick, J., Proc. Roy. Soc. A 142, 1 (1933)

3) Curie, I. and Joliot, F., Nature, 133, 721 (1934)

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number of neutrons drop off very markedly at 3.3 MV, indicating that a large fraction of the neutrons arises from a reaction leading to an excited $_7N^{14}$. Cloud-chamber data taken by Bonner and Mott-Smith[1] however showed that there are a number of neutrons with energies up to 4.2 MV energy. These data do not give any accurate information on the shape of the spectrum since the number of tracks observed is quite small and no correction for geometry and cross-section has been applied.

METHOD OF MEASUREMENT

The method for determining the Po-B spectrum used in the present investigation is the same as was used for the fission spectrum at Stanford.[4] The neutron source consisted of 8 Pt foils 3x3 cm, covered with a total of about 200 millicuries of polonium, 1/32" plates of boron carbide being inserted between the foils. The whole system was placed in an evacuated brass box. The source was placed at 5 cm distance in front of the lighter of the pressure vessels previously used at Stanford, containing a multiple electrode ionization chamber and filled with 12.0 Atm. of H_2 and 3.13 Atm. of Argon. This mixture has a stopping power equal to that used in the second and third measurement of the fission spectrum at Stanford, so that the same values for wall corrections could be applied. No appreciable amount of material of any kind was closer to the chamber than 3 ft. A field of 7200 V/cm was used to collect the ions of both signs. From the observed distribution of number of recoil pulses versus their size the neutron spectrum was obtained in the manner described in report L A 17. The same preamplifier and

4) L A Report - 17

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linear amplifier as in the Stanford work was used and also the same differential selector for the determination of pulse size. The only change was that the time constants of the amplifier had been decreased slightly, and thus a new calibration with D-D neutrons had to be made.

Two separate measurements were taken, with a three-day interval between the two. In every run the number of pulses of the differential selector at various biases was recorded for 5 to 10 minutes with the source in front of the chamber and with the source removed. At the same time the readings of an integral counter were recorded. The average integral counter rate of the first run was 115.3 ± .7, of the second 113.1 ± .6. The difference of (1.9 ± .8%) is consistent with the change expected from the decay of the polonium which should be 1.5%. The total number of differential counts (sum of all counts at all biases) however differed in the two runs by 8.6%. Since between the two runs the width of the interval had been changed and reset it was believed that the setting was not reproduced exactly and since the two measurements agreed except for this constant factor, the numbers of the second run were simply increased by 9% and then the two measurements were combined. This combined result is given in Fig. 1. The errors indicated are the true statistical probable errors since during the measurements no fluctuations beyond the statistical ones were observed.

INTERPRETATION OF MEASUREMENTS

A most probable "smooth" curve was drawn through the measured points as shown in the figure and the derivative of this curve taken off the various points. The conversion from bias units to energy was done in the same

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way as in report L A - 17. For this purpose a new calibration with the neutrons of the D-D reaction was made in the Z laboratory. The procedure was to take the readings of the differential selector at various biases together with the reading of the integral recorder kept at a fixed bias. The ratio of the two numbers at different biases gives the relative number of recoils at the various energies and the result is plotted in Fig. 2. Again a smooth curve was drawn through the observed points. Beyond the knee a straight line is compatible with the observed points. However as discussed in report L A-17 the slope was bigger than one would expect for strictly monochromatic neutrons. We therefore obtained again in the neutron spectrum a continuous tail of slow neutrons, their total number being about 10% of the total number in the line. From the derivatives obtained from the curve the shape of the neutron spectrum was calculated in the manner described in L A-17, using for α and κ (the wall correction functions) the values calculated by Hameresh and Weinstock for the stopping power which we used. The bias-energy relation was fixed so that the maximum of the neutron distribution corresponded to 2.5 MV. It was furthermore ascertained that the amplifier was linear over the whole bias region used, and frequent checks of the amplification were made. No variation beyond about 1% was noticed. The neutron spectrum thus calculated from the recoil spectrum of the D-D neutrons is also represented in Fig. 2.

With this energy calibration the analysis of the Po-B recoil spectrum was performed in the same manner. The result is given in Fig. 1, together with the recoil distribution. The neutron scale is discussed below.

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CONCLUSIONS CONCERNING MOCK SPECTRUM

From Fig. 1 it is evident that the neutron spectrum of the polonium-boron reaction is not suitable for a fission spectrum substitute since it contains far too many high-energy neutrons. The maximum of the distribution occurs at 3 MV instead of being close to 1 MV as in the case of the fission spectrum. The average neutron energy is 2.3 MV if the spectrum is extrapolated to higher and lower energies in the manner indicated in the figure by the dotted lines, whereas the average energy of the Stanford fission spectrum is 1.5 MV. It may be noted that our result shows quite distinctly a rather sharp fall of the neutron intensity at about 3.5 MV, in good agreement with the previous results of Chadwick[2)] and Joliot-Curie[3)] but it also indicates a small number of neutrons above 4 MV in agreement with the findings of Bonner and Mott-Smith[1)].

INTENSITY OF SOURCE

Our measurements also enable us to compute the total number of neutrons emitted by the boron-polonium source used in this experiment. In order to do that one has first to determine the width of the differential selector interval. This was done in two ways. First by direct measurement of the distribution of artificial pulses. This gave a value of .225 MV. Another more accurate way is the following. It was determined with artificial pulses that the integral monitor counted all pulses above the bias setting of the differential selector corresponding to 1.45 MV. By comparing the counting rate of the integral monitor (115.3 counts per minute) with the integral of the recoil distribution curve above 1.45 MV the accurate value for the width W was found to be .196 MV. The total

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number of neutrons emitted by the source is found in the following way. The neutron scale shown on the right-hand side of Fig. 1 is determined by the use of the formula for the relative number of neutrons

$$-E\ (dR/dE)/\sigma(E)$$

which must be modified by wall corrections as discussed in L A-17. (Here the factor E arises from the angular distribution of recoils, and σ is measured in barns). This scale does not yet take into account the energy-independent factors describing the properties of the chamber and the selector interval W. If R is the integral value of the computed neutron spectrum on this scale (extrapolated to high and low energies as indicated) the number of neutrons is:

$$N = R/(w\Omega nd)$$

where Ω is the fraction of the total solid angle 4π subtended by the chamber, n the number of hydrogen nuclei per cc, and d the depth of the ionization chamber. Thus one obtains:

$$N = 3.66\cdot 10^4 \text{ neutrons/sec.}$$

According to the Segre group who prepared the polonium source its strength was estimated to be about 180 MC on September 17th. Within the two months elapsed until the present measurements were taken the source decayed by a factor $e^{-60/196} = .736$. The neutron production rate of polonium-boron is 20 neutrons per $10^6\ \alpha$'s. Since the targets in our case consisted of boron carbide this would be reduced to $4/5 \times 20 = 16$ neutrons per $10^6\ \alpha$'s.

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It has to be kept in mind furthermore that only half of the α's are active for neutron production. Thus the number of neutrons to be expected would be:

$$N = \tfrac{1}{2} \times 0.18 \times 0.736 \times 3.5 \times 10^{10} \times 16/10^{6} = \underline{3.7 \times 10^{4} n/sec}.$$

in good agreement with the above number.

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FIG. I
BORON-POLONIUM SPECTRUM

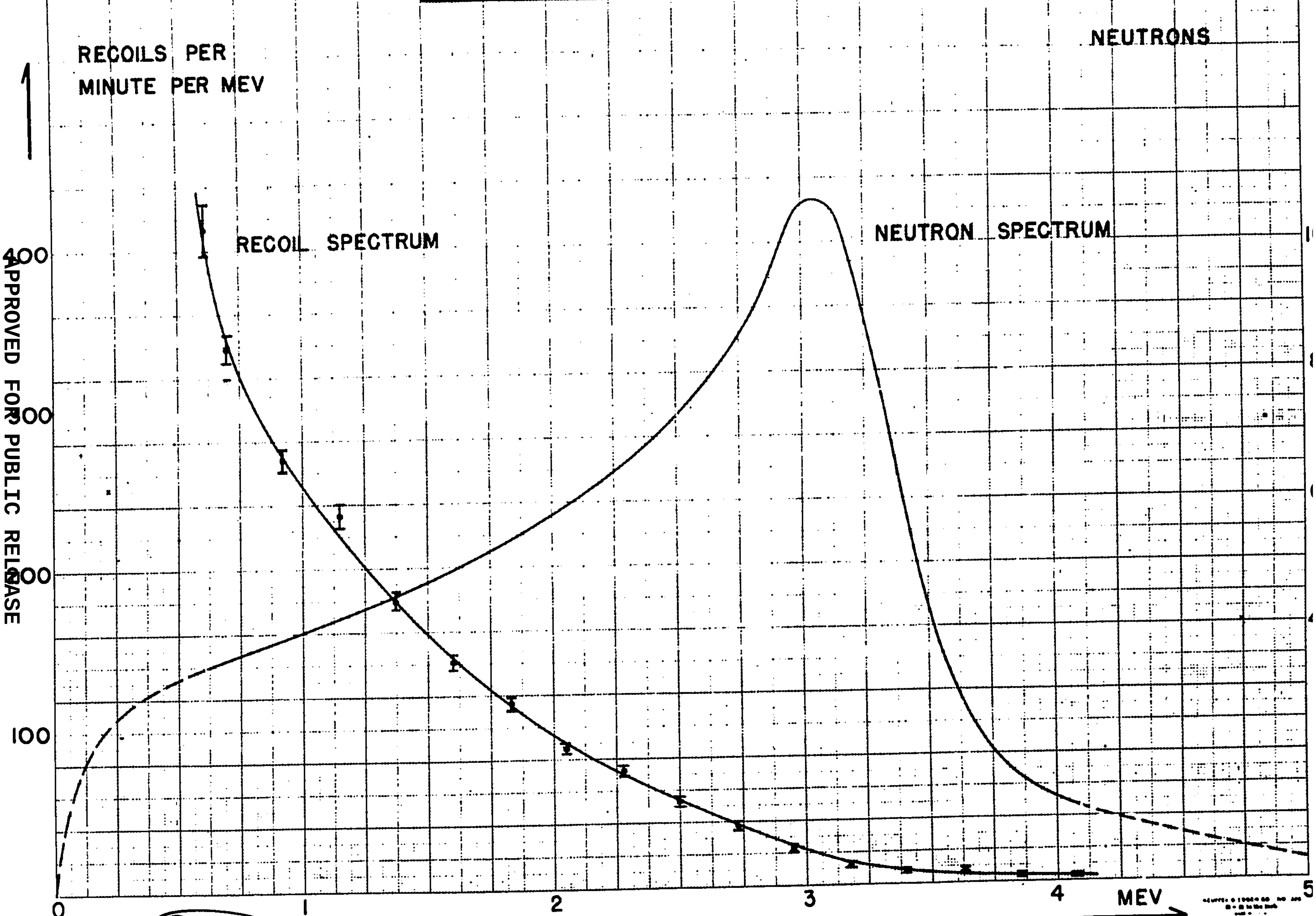

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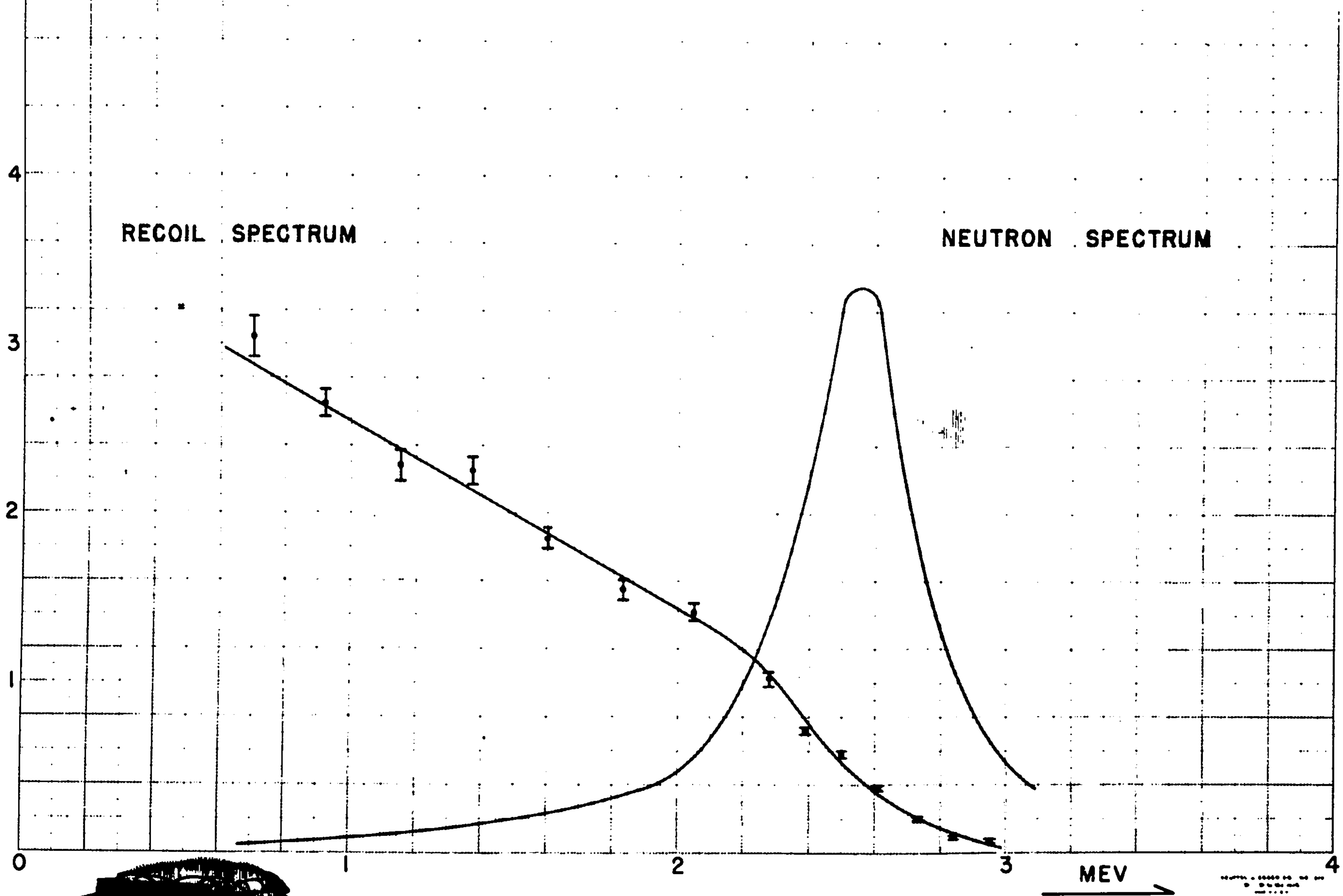
FIG. 2

D—D CALIBRATION



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