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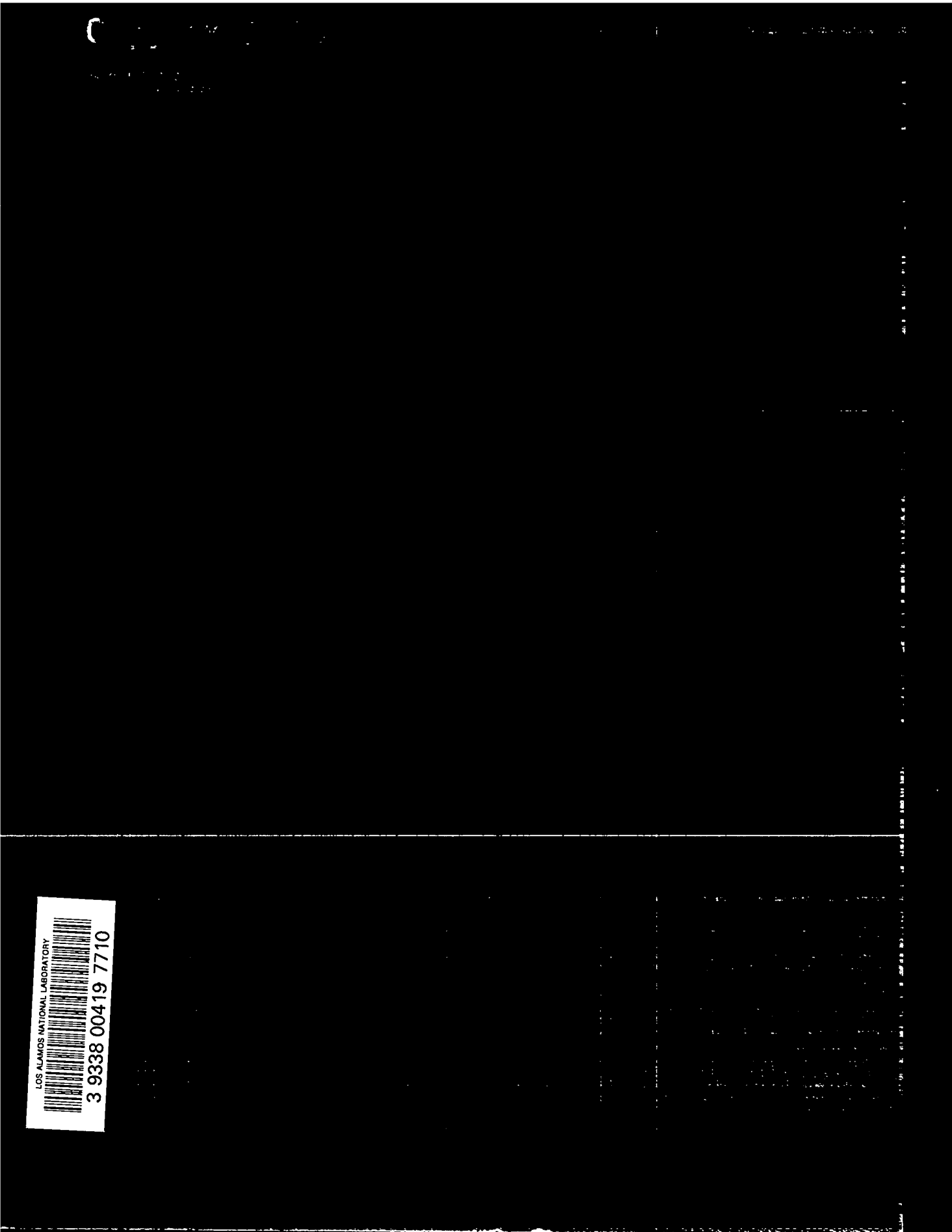

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ENERGY SPECTRUM OF SPONTANEOUS FISSION FRAGMENTS

By

Emilio Segre and Clyde Wiegand

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SUMMARY

The energy spectrum of spontaneous fission fragments of Pu^{240} is compared with the same spectrum for slow neutron fission of Pu^{239}. No significant difference was found and the interpretation of this result is discussed.

This work was done at the University of California, Berkely, is a continuation of work performed at Los Alamos Scientific Laboratory.

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ENERGY SPECTRUM OF SPONTANEOUS FISSION FRAGMENTS

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Emilio Segrè and Clyde Wiegand

The energy spectrum of fission fragments for fission induced in Pu^{239} by slow neutrons has been investigated recently by Deutsch(1) measuring the ionization produced by the fission fragments. There is also detailed information of the yield of the various chains based upon chemical evidence.

It is of considerable interest to compare the energy spectrum of spontaneous fission of Pu^{240} with that of the slow neutron induced fission of Pu^{239}. The nucleus undergoing fission is in both cases Pu^{240}, the only difference being that in the case of spontaneous fission it is in the fundamental state, whereas in the case of slow neutron induced fission it has an excitation of about 5 Mev. This excitation reduces the "half life" for fission from 1.25×10^{11} years to an estimated 10^{-15} seconds, i.e. by a factor 10^{34}. Now one could think that in the case of spontaneous fission, only a very special type of nuclear motion may be conductive to fission, and that only one or very few types of fragments would be emitted. If this were true the

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energy spectrum would contain one or very few couples of lines. (Couples because there is always one line due to the heavy fragment and one line due to the light fragment).

It can be remarked however that even if only one type of motion ends in spontaneous fission, the two fragments after having passed the potential barrier so that their future density of coming apart is fixed, may interchange nuclear matter and hence change their relative mass and energy.

It is in order to settle experimentally these problems that we have investigated the energy spectrum of spontaneous fission of Pu^{240} and compared it with that of slow neutron fission of Pu^{239}. The results of the investigation do not show any very great difference between the two spectra, which could be interpreted by assuming that several types of motion lead to spontaneous fission, or, in other words that there are several passes through which the potential barrier can be crossed by the fragments. Another possible interpretation would be a reshuffling of nuclear matter, after the crossing of the barrier as mentioned above.

It must be pointed out, however, that the experiments are not completely conclusive because the resolution of the apparatus used has turned out to be relatively poor as one can see by comparing e.g. the spectrum of the slow neutron fission fragments of Pu^{239} measured by Deutsch with ours. It does not look to us that it would be expedient to try to

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improve our technique by a large margin and we would rather suggest a chemical approach to the problem. Namely, observe the yields of the various chains in spontaneous fission. This seems feasible if one operates with about 50 grams of Pu containing about 2% Pu^{240}. Special precautions should of course be taken to prevent the multiplication effects from playing an important part in determining the rate of fission in the material. This can be obtained e.g. by working with very small batches or by using some protective substance, like boron or cadmium, in the solutions.

In our experiment the ionization produced by the spontaneous fission fragments emerging from a thin layer of Pu was measured with a linear pulse amplifier and recorded photographically. With the same apparatus and samples we recorded also the ionization produced by slow neutron fission fragments.

The chamber used is illustrated in Figure 1. In this chamber electrons were collected in purified argon gas. The screen which is placed adjacent to the collecting electrode shields this electrode from effects of ion displacement in the region between the screen and the high voltage electrode. Gas pressure and spacing of the screen and high voltage electrode were adjusted so that no ionizing particle penetrates into the region between the screen and the collecting electrode.

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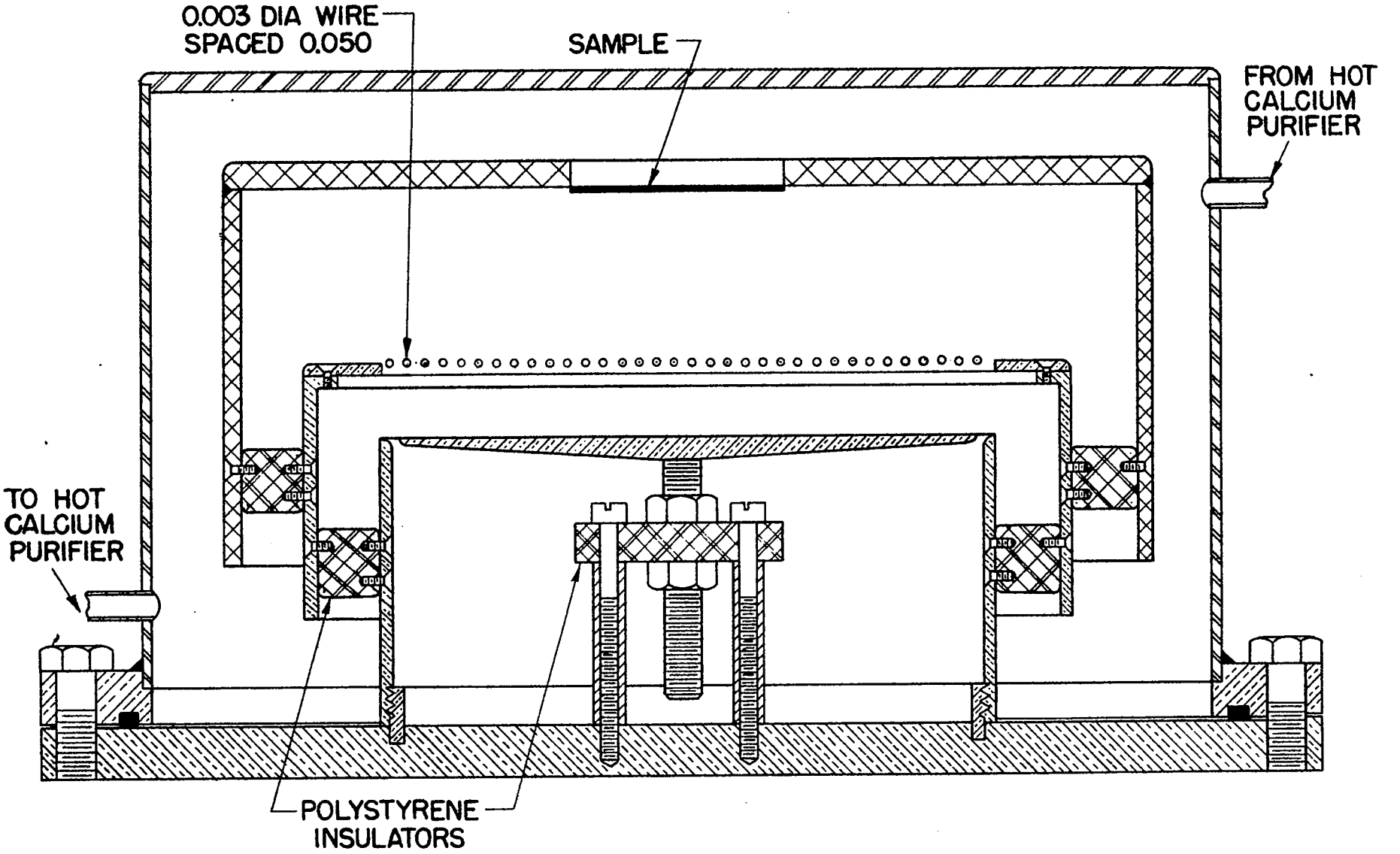

CHAMBER FOR MEASURING FISSION FRAGMENT ENERGIES

FIG. 1

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Thus for all ions formed be the ionizing particle the effective displacement as seen by the collecting electrode is the distance between the screen and the collecting electrode. This means that for equal numbers of ions, the pulse output of the chamber is the same irrespective of the direction of the track of ionization. The pulse output of a linear amplifier connected to the chamber is proportional to the energy of the ionizing particle since the number of ions is proportional to the energy, or at least we make this assumption. The collecting potentials with respect to the collecting electrode were: screen -900 volts, high voltage electrode -1700 volts. The chamber was filled with argon gas to a pressure of 1.5 atmospheres. The argon was continuously purified by passage over metallic calcium maintained at a temperature of 200 degrees Centigrade.

The data from a resolution test using the alpha particles from natural uranium is presented in Figure 2. The histogram shows the two groups resolved and their energies in the correct ratio.

The sample used in the fission fragment energy experiment was a deposit of plutonium one cm in diameter electro plated on 0.005 inch thick platinum. The sample weighed about 17×10^{-6} grams measured by counting the alpha activity (7 per cent of the Pu was Pu^{240}). The sample gave 1.91

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This energy scale is based on the known energies of uranium α particles.

RESOLUTION TEST HISTOGRAM OF URANIUM α PARTICLES

FIG. 2

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spontaneous fissions per hour. 750 spontaneous and 839 slow neutron induced fissions were used in our histograms.

The linear amplifier used had a time of rise of 0.2 microseconds. The time of collection of the electrons in the chamber was about one microsecond and the decay time of the amplifier was 5 microseconds. This resistance-capacitance decay time resulted in considerable loss of pulse height but was necessary because of the fluctuating background of the alpha particle ionization when the apparatus was adjusted to record fission pulses. However, an absolute determination of the energy of the fission fragments was not needed since a comparison was made with fragments produced by slow neutrons.

A block diagram of the experimental apparatus is shown in Figure 3. The pulse was fed from the amplifier to an intensifier circuit to which was connected a cathode ray oscillograph. The intensifier was adjusted to brighten the fission pulses on the screen of the oscillograph so that they could be recorded photographically. The camera used was a General Radio Oscillograph Recorder which used supersensitive 35 mm motion picture film. The film was driven through the recorder at the rate of one foot per hour. Figure 4 is a reproduction of a small section of the film.

In order that drifts in gain of the amplifying equipment could be detected and corrected for, a series of pulses from

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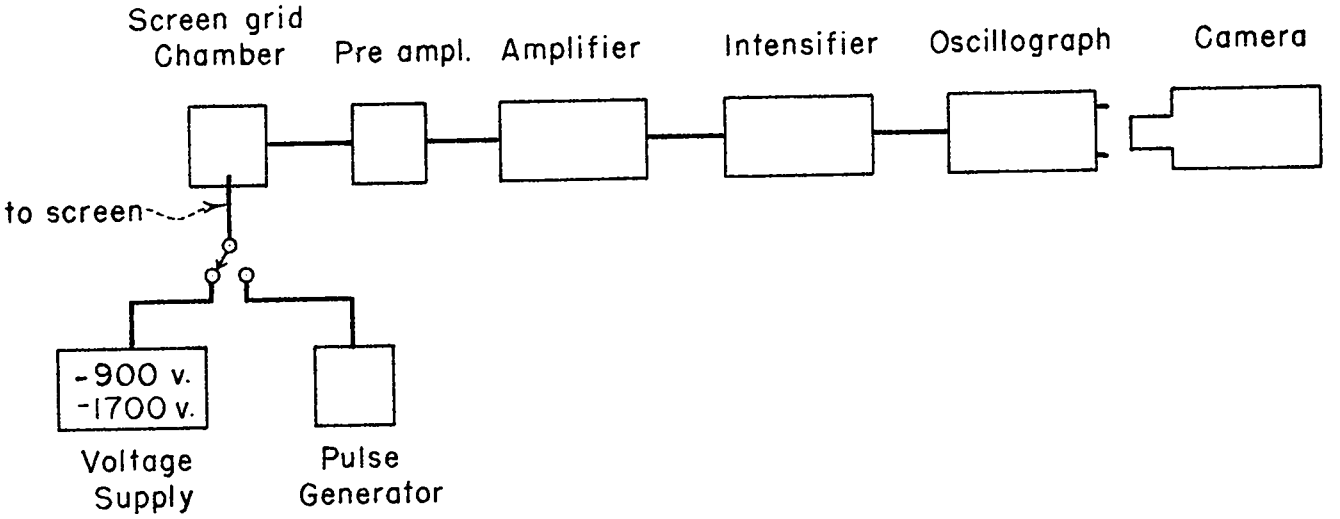

BLOCK DIAGRAM OF FISSION FRAGMENT EXPERIMENT

FIG. 3

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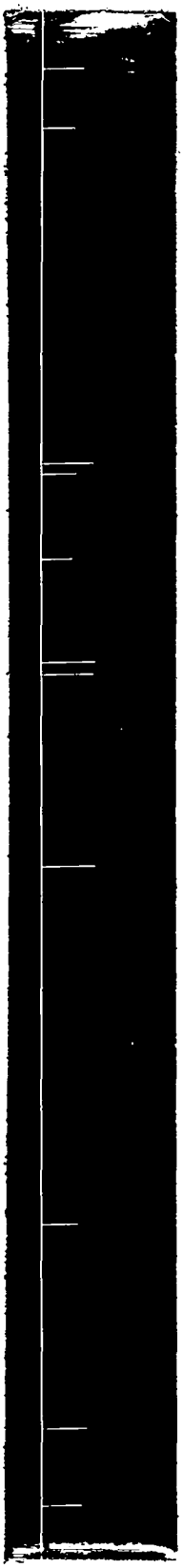

Figure 4

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a standard pulse generator was impressed on the film at the beginning and end of each run. For this calibration the pulse generator was connected directly to the screen electrode of the chamber and, by capacitance coupling to the collecting electrode, the pulse was fed through the entire apparatus.

Figure 5 presents a histogram of the spontaneous fission pulses recorded. For comparison the pulse height distribution of slow neutron induced fission is shown on the same graph. The induced fission curve was obtained with the same apparatus and sample. The slow neutrons were obtained from a radium plus beryllium source with water as the slowing down medium.

The abscissae scale is a scale of deflections of the oscilloscope, in arbitrary units. We assume that the energy of the fragment is proportional to the ionization produced. Under this assumption we have calibrated the abscissae scale in such a way that the energy corresponding to the light fragment peak is 93 Mev as measured by Deutsch (l.c.). In the ordinates we have the number of pulses giving an ionization between definite limits.

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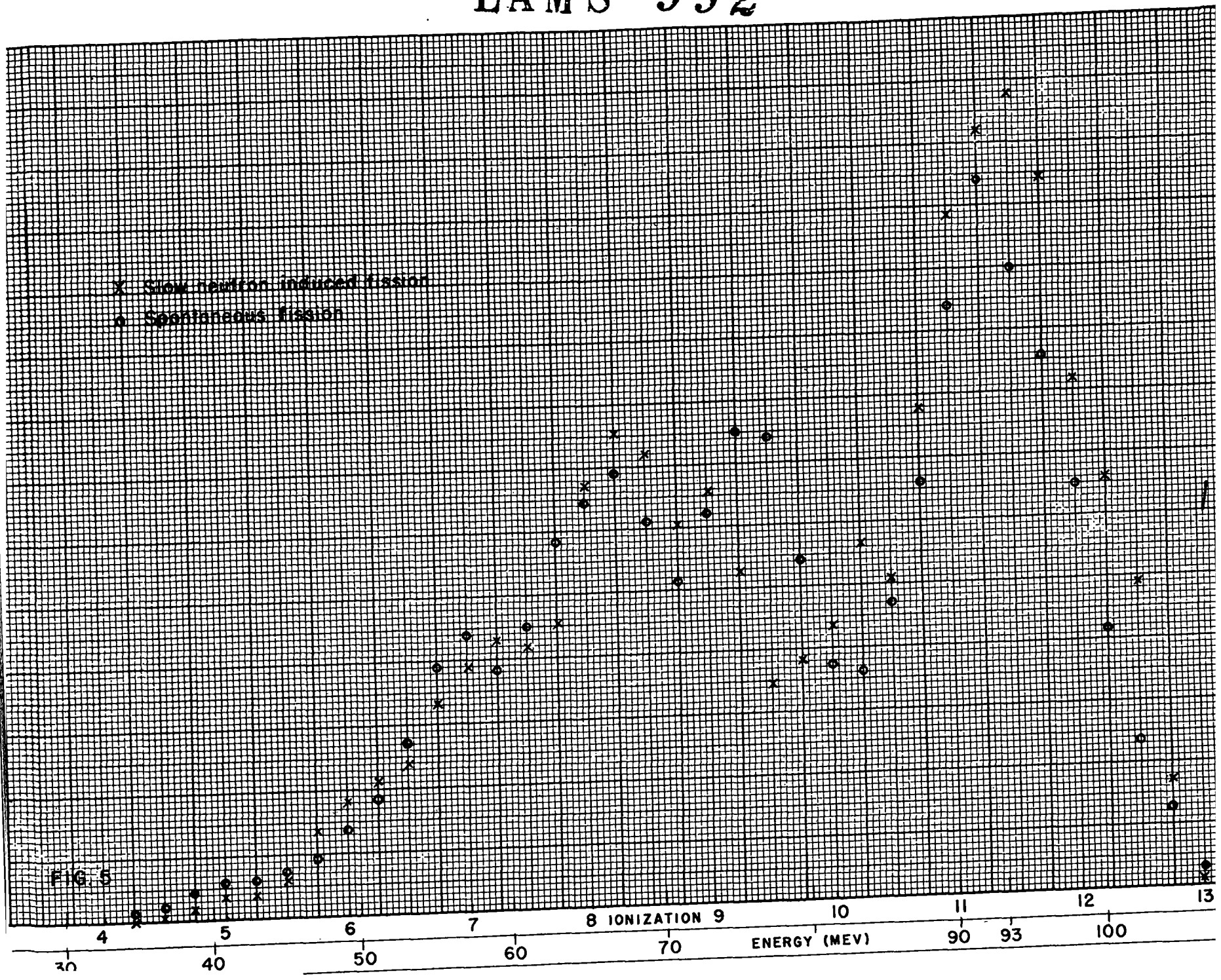

FIG. 5

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