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Preliminary Search for Fission Induced Fission

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PRELIMINARY SEARCH FOR FISSION INDUCED FISSION

Introduction

Fission fragments constitute a source of charged nuclear high energy particles of unique character. Besides being highly excited they contain a large excess of neutrons. Having the order of 100 Mev energy they can come within several nuclear diameters of other nuclei during their slowing down process in matter. A fragment of mass 100, charge 40, and energy 86 Mev comes within four diameters of a thorium nucleus. Somewhat lighter fragments of higher energies are able to come within less than two diameters of a thorium nucleus. One might expect certain type nuclear reactions during such collisions. The large coulomb fields present, and also the large excess of neutrons available in the fission fragment, might produce a disturbance which would lead to fission of the thorium nucleus. Such a phenomenon was looked for in this experiment.

Apparatus

Fig. 1 is a diagram of the ionization chamber used in this experiment. Fission fragments produced at the uranium foil by the thermalized flux of the water boiler are collimated by 1/8 inch holes in a 1/8 inch thick aluminum plate. The fission fragments pass through a thin thorium foil on the upper side of the chamber in Fig. 1. The fragments, which produce ionization between the high voltage electrode and the center grounded electrode, are so collimated that they produce no effect on the annular ring electrode. If fission is produced in the

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thorium foil, however, some of the fragments will be emitted in such a direction as to produce ionization between the annular ring and the high voltage electrode. Such fragments are counted by amplifier #1. The other fragments from the U^{235} fission, which pass into the lower part of the chamber producing ionization between the high voltage electrode and the lower collector plate, are counted by amplifier #2. For checking background, a shutter can be rotated between the uranium and thorium foils. Fig. 2 is a photograph of the counter.

The fissionable material was placed on 0.1 mg/cm^2 aluminum leaf by the evaportation technique. The uranium foil was approximately equal to 0.06 mg/cm^2 of enriched 25. Several throium foils were used, the thicknesses of which were of the order 0.2 mg/cm^2. The foils were so mounted that the uranium surface and the thorium surface faced each other. Gilmore and Potter prepared the foils used in the experiment.

Fig. 3 shows schematically the electronics apparatus used. The outputs from the thorium side of the chamber and from the uranium side were each connected to the grid of "model 500" preamplifiers and "model 500" amplifiers. R. C. clipping gave pulses of about three microseconds duration. Each amplifier system feeds into a discriminator coincidence circuit. The counts from each channel and the number of coincidences were recorded by scalers. The width of the discriminated pulses could be varied in the coincidence circuit; 0.85 microsecond gate widths were used in this experiment. Since the pulse clipping times were so short, only electrons were collected from the ionization. The high voltage plate of the counter was held about 1000 volts negative by a well-filtered electronic voltage supply.

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Characteristics of Chamber

The gas used in the chamber was 5 percent CO_2 in argon. The pressure (14 cm of mercury) of the gas in the chamber was chosen so that the range of fragments from thorium could traverse the region between the annular ring and the high voltage plate.

The fraction of the fission fragments counted which pass through the thorium foil was determined experimentally. The center plate on the thorium side of the counter was connected to the Channel I preamplifier and the collection plate on the uranium side was connected to the Channel 2 preamplifier. With the gain of amplifier #1 set so that all fragments on the thorium side of the chamber are counted as indicated by the plateaus of the bias curve for Channel 1, one runs a curve of coincidence as function of the gain of amplifier #2, the neutron source being constant. Fig. 4 gives the results of such runs. The coincidence curve after the steep initial rise becomes quite flat over a very wide range of gain. There is a steep initial rise for the Channel 2 bias curve, corresponding to the rise of the coincidence curve, followed by a gradual rise over a wide range in gain. The gradual rise is probably due to fission fragments coming out from the foil at large angles so that end effects at the collector plate cut down the pulse height. Such fragments would not have their correspond-ing fragments so collimated as to pass through the thorium foil and should be discriminated against. The arrow in Fig. 4 indicates the gain setting chosen for this experiment. At this gain setting 9 per-cent of the counts in Channel 2 correspond to fragments passing through the thorium foil, as determined by the ratio of the ordinates of the two curves at the gain setting used.

The fraction of total thorium fragments which are counted by the annular ring was also found experimentally. The shutter was closed between the uranium foil and the thorium one, and the counter was pleced in the fast neutron flux from the cyclotron. A run was made of counts from thorium fission, as a function of gain of amplifier #1, with the annular ring connected to preamplifier #1. This data is represented by the lower curve of Fig. 5. Then the run was repeated with the central plate and the annular ring of the thorium side of the counter both connected to preamplifier #1. The results of this run are indicated by the upper curve of Fig. 5. The gain settings chosen for two series of runs are marked by arrows in Fig. 5. For the first series of runs 23 percent of the thorium fragments are counted; for the second series of runs 14 percent were counted.

Experimental Procedure

Before, and at more or less equal intervals during the run, the electronic apparatus was checked with a model 100 pulser. Voltage pulses of known height were fed simultaneously into the input grids of the two preamplifiers. The gains of the amplifiers were determined by varying the input pulses until the discriminators just tripped. The gains were found to vary only by a few precent over several hours of running. Also, the coincidence circuit and scalers were checked by allowing the pulser, with the input about 50 percent above that just necessary to trip the discriminators, to run for several minutes and

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recording the counts accumulated by the two channels and the coincidence circuit.

After the calibration, one was ready to start the run. The chamber was placed in the well thermalized neutron flux of the graphite pile of the Los Alamos water boiler. A run of about an hour was taken with shutter between the two foils open. Then the shutter was closed and another hour run was made with the counting rate the same. The apparatus was then calibrated as described above and the procedure repeated. Such pairs of runs were made with the counting rate of the Channel 2 varying from about 0.4×10^6 per hour to about 12.0×10^6 per hour. For the preliminary data given in this report, about 200 million fission fragments were counted. Since the counting rates in the two channels are about constant, independent of whether the shutter is open or closed, the background run, in which the shutter was closed, could be used not only to correct for neutron induced fission in the thorium but also to correct for the accidental coincidence.

Discussion of Results

In Table I, the data taken to date is arranged in rows, so that each row represents the total data for runs in which the counting rate was more or less constant. The accumulation of data from the first two rows suggests that there might be a positive effect. Since large angle Rutherford Scattering of the fission fragments from the throium nucleus might produce an ion which could be counted by the annular ring, one made a series of runs with a lead foil substituted for the thorium one. The data from these runs is included in the third and fourth rows.

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For these runs the coincidence rate for background and regular runs is, as indicated in row #3, somewhat larger than for previous runs with thorium foils and the same counting rate. This may be due to statistical fluctuations, or it may be that a few coincidence counts came in due to some external cause, such as motors starting, etc. Extra counts like this, providing they come in at random, have the effect of raising the statistical error of the results when one subtracts the background correction. The runs recorded in row #4 seem to be entirely consistent with the thorium runs. The data taken with the lead foils gave a higher coincidence rate for the shutter open than for it closed. When one subtracts the effect obtained with the lead foil from that obtained from the thorium foil, one gets a difference which is well inside the statistical error.

If the effect obtained with lead is real and is due to Rutherford angle scattering of fission fragments, the energy given the recoil nuclei reduces the energy of the fragment to such an extent that one should be able to bias against it and real thorium fissions. For 60° scattering a fragment of mass 100 loses about 1/2 its energy. In order to bias against such scattered fragments, therefore, a series of runs were made in which the gain of the amplifier for the thorium fragments was reduced by about 30 percent, so that the efficiency of counting thorium fragments, as indicated by Fig. 3 was 14 percent. These runs give a cross section less than the statistical error. The summary of all the runs taken to date is tabulated in Table II. The weighted mean of the average cross section from this data is 6 $\pm$ 6 barns. One can interpret this only to

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mean that the cross section is less than 6 barns with a 67 percent probability.

From the ranges of fission fragments in uranium relative to neutrons, one can say that for fission fragment induced fissions in uranium to be comparable to neutron produced fission, the cross section of fission fragment induced fission should be approximately equal to 10^4 barns. The result of the experiment then, indicates that at least in thorium, if fission fragments produce an effect at all it is less than 0.1 percent of that due to neutrons.

The author wishes to acknowledge the suggestion of Dr. John Manley which began this investigation. Thanks are also due to the personnel of Group P-2 for the use of the Los Alamos water boiler, to the electronics group, particularly to Dr. E. Titterton and Mr. E. Exter, for the coincidence circuit and other electronic equipment, and to Mr. J. Gilmore and Mr. R. Potter who made the necessary foils.

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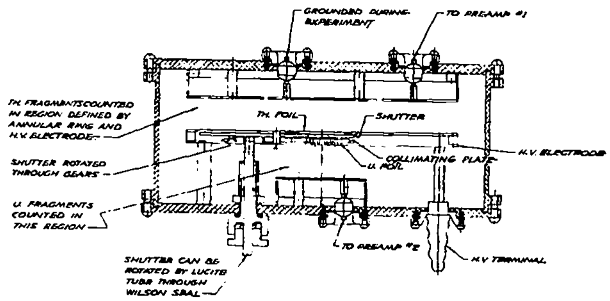
FIG 1



FISSION FRAGMENT INDUCED FISSION COUNTER

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FIG 2

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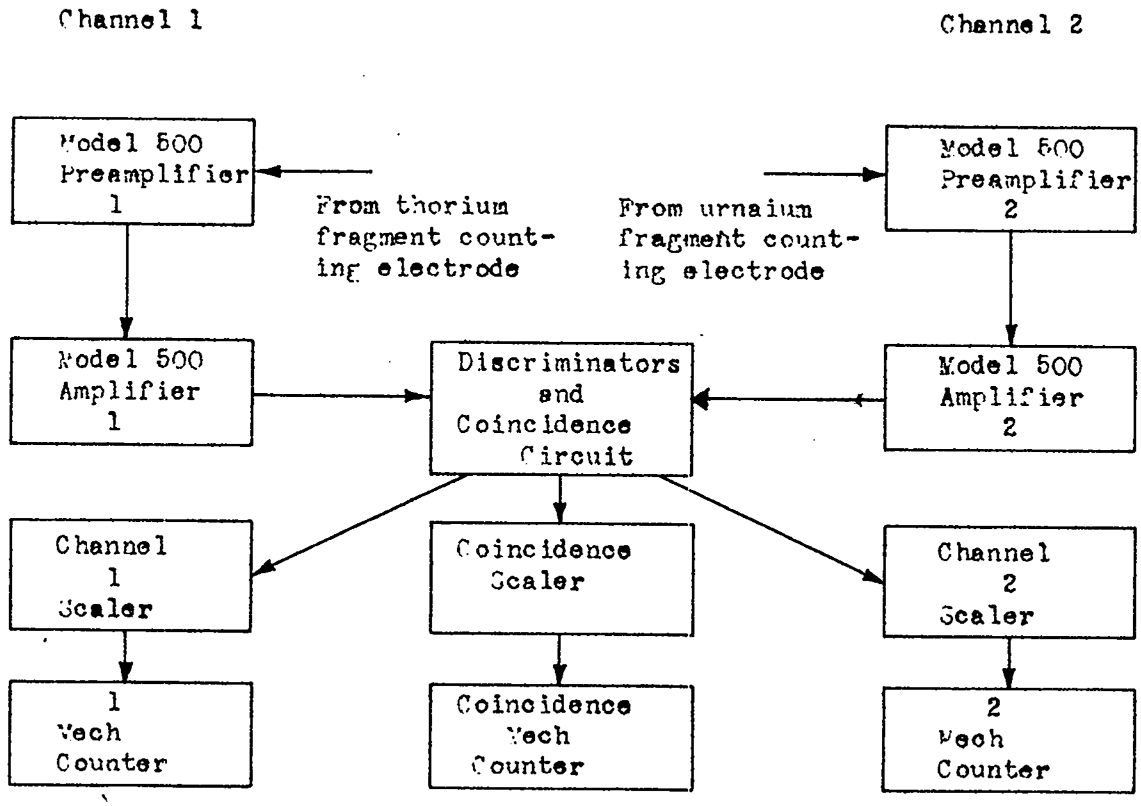
Channel 1
Channel 2
Model 500 Preamplifier 1
From thorium fragment counting electrode
From urnaium fragment counting electrode
Model 500 Preamplifier 2
Model 500 Amplifier 1
Discriminators and Coincidence Circuit
Model 500 Amplifier 2
Channel 1 Scaler
Coincidence Scaler
Channel 2 Scaler
1 Mech Counter
Coincidence Mech Counter
2 Mech Counter

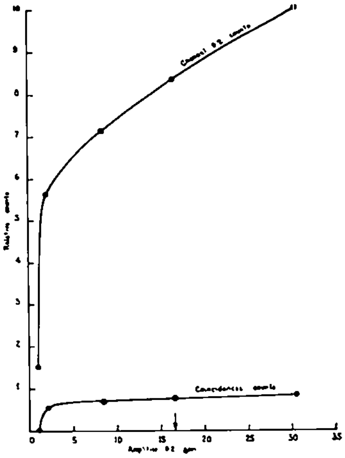
0
5
10
15
20
25
30
35
1
2
3
4
5
6
7
8
9
10

FIG 4

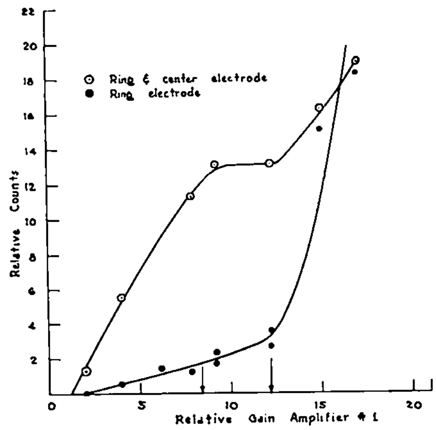
Ring & center electrode
Ring electrode
Relative Counts
Relative Gain Amplifier # 1
0
5
10
15
20
2
4
6
8
10
12
14
16
18
20
22

FIG 5

TABLE I

APPROXIMATE COUNTS

Amplifier #2 Gain	Foil	Counting Rate Channel Counts per minute	Shutter Open Channel 1	Shutter Open Channel 2	Shutter Open Coincidences	Shutter Closed Channel 1	Shutter Closed Channel 2	Shutter Closed Coincidences	
12.2	Th 0.19 mg/cm^2	7.0×10^4	1.9×10^3	26.4×10^6	4	1.7×10^3	26.3×10^6	1	
12.2	Th 0.19 mg/cm^2	18.0×10^4	2.1×10^3	32.5×10^6	6	2.0×10^3	32.1×10^6	2	11.3 ± 5.9
12.2	Pb 0.19 mg/cm^2	18.0×10^4	3.1×10^3	54.0×10^6	21	2.7×10^3	53.9×10^6	17	5.1 ± 10.0
12.2	Pb 0.19 mg/cm^2	9.0×10^4	1.2×10^3	19.6×10^6	7	1.3×10^3	24.0×10^6	7	6.2 ± 8.1
8.4	Th 0.33 mg/cm^2	15.0×10^4	4.0×10^3	64.0×10^6	15	3.9×10^3	66.0×10^6	12	4.8 ± 7.5

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TABLE II

SUMMARY OF RESULTS TO DATE

Foil for Channel 2	Amplifier 2 gain	σ barns	σ corr. barns	σ av. barns
Th 0.19 mg/cm^2	12.2	11.3 $\pm$ 5.9	5.1 $\pm$ 10.0	
Pb 0.19 mg/cm^2	12.2	6.2 $\pm$ 8.1		
Th 0.33 mg/cm^2	8.4	4.8 $\pm$ 7.5		5 $\pm$ 6

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