

LAMS-2642

CIC-14 REPORT COLLECTION

REPRODUCTION

COPY

**LOS ALAMOS SCIENTIFIC LABORATORY**  
**OF THE UNIVERSITY OF CALIFORNIA ○ LOS ALAMOS NEW MEXICO**

**ENERGY AND TIME DEPENDENCE OF  
DELAYED GAMMAS FROM FISSION**

LOS ALAMOS NATIONAL LABORATORY



3 9338 00209 9991

## LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

Printed in USA Price \$ 1.00. Available from the  
Office of Technical Services  
U. S. Department of Commerce  
Washington 25, D. C.

LAMS-2642  
PHYSICS  
(TID-4500, 17th Ed.)

**LOS ALAMOS SCIENTIFIC LABORATORY**  
**OF THE UNIVERSITY OF CALIFORNIA LOS ALAMOS NEW MEXICO**

**REPORT WRITTEN:** January 1962

**REPORT DISTRIBUTED:** July 6, 1962

ENERGY AND TIME DEPENDENCE OF  
DELAYED GAMMAS FROM FISSION

Work done by:

Members of Group N-2  
P. C. Fisher (now with Lockheed  
Missiles and Space Division)  
L. B. Engle  
M. P. Kellogg

Report written by:

L. B. Engle  
P. C. Fisher



Contract W-7405-ENG. 36 with the U. S. Atomic Energy Commission

All LAMS reports are informal documents, usually prepared for a special purpose and primarily prepared for use within the Laboratory rather than for general distribution. This report has not been edited, reviewed, or verified for accuracy. All LAMS reports express the views of the authors as of the time they were written and do not necessarily reflect the opinions of the Los Alamos Scientific Laboratory or the final opinion of the authors on the subject.



## ABSTRACT

This report contains some results of an experiment designed to measure the energy and time dependence of the gammas emitted after effectively instantaneous neutron-induced fission of  $\text{Th}^{232}$ ,  $\text{U}^{233}$ ,  $\text{U}^{235}$ ,  $\text{U}^{238}$ , and  $\text{Pu}^{239}$ . Seventeen-bin distributions of the absolute number of photons/fission-sec-Mev and intercomparisons and integrations over energy and time of these distributions are given. Gammas having energies between 0.12 and 6.5 Mev were detected during five short time intervals between 0.2 sec and 45 sec after fission occurred.



## TABLE OF CONTENTS

	Page
ABSTRACT . . . . .	3
INTRODUCTION . . . . .	9
REFERENCES . . . . .	12

### TABLES

1.	Bin Widths and Midpoints in Mev for Photon Spectra . . . . .	13
2.	Distribution of Photons/Fission-sec-Mev for the Different Time Intervals Following $\text{Th}^{232}$ Fission . . . . .	15
3.	Distribution of Photons/Fission-sec-Mev for the Different Time Intervals Following $\text{U}^{233}$ Fission . . . . .	19
4.	Distribution of Photons/Fission-sec-Mev for the Different Time Intervals Following $\text{U}^{235}$ Fission . . . . .	23
5.	Distribution of Photons/Fission-sec-Mev for the Different Time Intervals Following $\text{U}^{238}$ Fission . . . . .	27

TABLES (Continued)

	Page
6. Distribution of Photons/Fission-sec-Mev for the Different Time Intervals Following Pu <sup>239</sup> Fission . . . . .	31
7. Results of Delayed Gamma Spectra Integrated over Energy for Different Time Intervals after Fission . . . . .	39
8. Results of Delayed Gamma Spectra Integrated over Energy and Time from 0.20 to 45.0 sec after Fission . . . . .	41

FIGURES

1. Pulse height distribution of gammas for different time intervals following Th <sup>232</sup> fission . . . . .	14
2. Photon spectra of gammas for different time intervals following Th <sup>232</sup> fission . . . . .	16
3. Ratios of Th <sup>232</sup> photon spectra at all time intervals . . . . .	17
4. Pulse height distribution of gammas for different time intervals following U <sup>233</sup> fission . . . . .	18
5. Photon spectra of gammas for different time intervals following U <sup>233</sup> fission . . . . .	20



FIGURES (Continued)

	Page
6. Ratios of $U^{233}$ photon spectra at all time intervals . . . . .	21
7. Pulse height distribution of gammas for different time intervals following $U^{235}$ fission . . . . .	22
8. Photon spectra of gammas for different time intervals following $U^{235}$ fission . . . . .	24
9. Ratios of $U^{235}$ photon spectra at all time intervals . . . . .	25
10. Pulse height distribution of gammas for different time intervals following $U^{238}$ fission . . . . .	26
11. Photon spectra of gammas for different time intervals following $U^{238}$ fission . . . . .	28
12. Ratios of $U^{238}$ photon spectra at all time intervals . . . . .	29
13. Pulse height distribution of gammas for different time intervals following $Pu^{239}$ fission . . . . .	30
14. Photon spectra of gammas for different time intervals following $Pu^{239}$ fission . . . . .	32
15. Ratios of $Pu^{239}$ photon spectra at all time intervals . . . . .	33
16. Ratios of photon spectra for all isotopes at 0.2 to 0.5 sec interval . . . . .	34

FIGURES (Continued)

	Page
17. Ratios of photon spectra for all isotopes at 1.0 to 2.0 sec interval . . . . .	35
18. Ratios of photon spectra for all isotopes at 4.0 to 5.5 sec interval . . . . .	36
19. Ratios of photon spectra for all isotopes at 10.0 to 13.0 sec interval . . . . .	37
20. Ratios of photon spectra for all isotopes at 35.0 to 45.0 sec interval . . . . .	38
21. Comparison of photon spectra integrated over energy for the different time intervals after fission . . . . .	40

## INTRODUCTION

The purpose of this report is to make available information derived from delayed gamma measurements. Results are presented as the energy dependence of gammas in several time intervals following the fission of various isotopes. The comments and explanations pertaining to experimental procedures and to analysis of data, from which these results were obtained, will appear later in several detailed articles. Integrated results will be extended to about 250 seconds after fission, representing 200 sec of data which do not appear in this report.

In the experiment, a sample of material was placed near the center of the Godiva II critical assembly. Following irradiation by a less than 0.05-sec-long burst of fission spectrum neutrons, the sample was pneumatically transferred to a counting geometry containing a 4 in. x 4 in. NaI crystal. The pulses from the crystal were recorded in a 100-channel analyzer for time intervals of 0.2 to 0.5, 1 to 2, 4 to 5.5, 10 to 13, and 35 to 45 sec after fission. Overlapping sets of pulse-height-analyzer data were used to suitably cover the large range of

counting rates present in a given photon spectrum. In addition to these energy spectra, the time decay of gammas above several fixed pulse-height biases was followed from 0.3 sec to 300 sec after fission. However, no time decay data are given in this report.

Normalization of the 100-channel data was accomplished by radiochemical determination of the absolute number of fissions responsible for a measured number of counts in a given pulse-height interval during a given time interval after fission. A seventeen-bin NaI crystal response function was constructed from the results of gamma measurements made from radioactive sources of known strength and from several  $(p,\alpha\gamma)$  reactions. Photon spectra were derived by applying this crystal-response function to the pulse-height data.

The figures and tables grouped together at the end of this report consist of data related to the various photon spectra measured. Table 1 lists the parameters for the seventeen-bin photon intervals. The original pulse height distributions for the isotopes  $\text{Th}^{232}$ ,  $\text{U}^{233}$ ,  $\text{U}^{235}$ ,  $\text{U}^{238}$ , and  $\text{Pu}^{239}$  are given in Figures 1, 4, 7, 10, and 13, respectively. Tabular and graphical results for the distribution of photons/fission-sec-Mev with time are given in Tables 2 through 6 and Figures 2, 5, 8, 11, and 14. The relative

hardness of a given isotope's spectra at different times is shown in Figures 3, 6, 9, 12, and 15. These ratios were obtained by dividing the spectrum for a given time interval by the spectrum for the 0.2 to 0.5 sec interval.

Comparison of the spectra for different isotopes at a given time interval after fission appear in Figures 16, 17, 18, 19, and 20. The results for spectra integrated over energy appear in Table 7. Table 8 lists both the total delayed-gamma energy per fission and the total number of delayed gammas per fission emitted by the different isotopes. As mentioned earlier, only photons having energies greater than 0.12 Mev were measured. Sufficient time decay data exist to allow calculation of the total number of photons emitted between 0.2 sec and about 250 sec after fission. However, the results in Table 8 apply only to those photons emitted between 0.2 sec and 45 sec after fission.

Only qualitative estimates for the experimental error have been computed. These estimates indicate a maximum standard deviation of  $\pm 15\%$  for all but the  $\text{Pu}^{239}$  numbers, to which a value of  $\pm 25\%$  applies.

A few further details concerning this experiment can be obtained by consulting the references.

## REFERENCES

- R. B. Leachman, Neutrons and Radiations from Fission, describing the work of Fisher and Koontz in Proceedings of the Second United Nations International Conference on the Peaceful Uses of Atomic Energy, Geneva 1958, P/665, Vol, 15, pp 331, United Nations, New York (1958).
- P. C. Fisher, M. P. Kellogg, P. G. Koontz, L. B. Engle, Delayed Gammas from Fission of  $\text{Th}^{232}$ ,  $\text{U}^{235}$ ,  $\text{U}^{238}$ , and  $\text{Pu}^{239}$ , Bull. Am. Phys. Soc. Ser. II, 4, 31, 1959.
- P. C. Fisher, L. B. Engle, Delayed Gammas from Fission I, Bull. Am. Phys. Soc. Ser. II, 6, 307, 1961.
- L. B. Engle, P. C. Fisher, Delayed Gammas from Fission II, Bull. Am. Phys. Soc. Ser. II, 6, 308, 1961.

Table 1

Bin Widths and Midpoints in Mev for Photon Spectra

<u>Bin</u>	<u><math>\Delta E</math> (Mev)</u>	<u>Midpoint (Mev)</u>
1	0.137 - 0.213	0.175
2	0.213 - 0.309	0.261
3	0.309 - 0.428	0.369
4	0.428 - 0.575	0.502
5	0.575 - 0.749	0.662
6	0.749 - 0.954	0.852
7	0.954 - 1.195	1.075
8	1.195 - 1.478	1.337
9	1.478 - 1.808	1.643
10	1.808 - 2.189	1.998
11	2.189 - 2.620	2.405
12	2.620 - 3.110	2.865
13	3.110 - 3.655	3.383
14	3.655 - 4.257	3.956
15	4.257 - 4.918	4.587
16	4.918 - 5.636	5.277
17	5.636 - 6.419	6.028

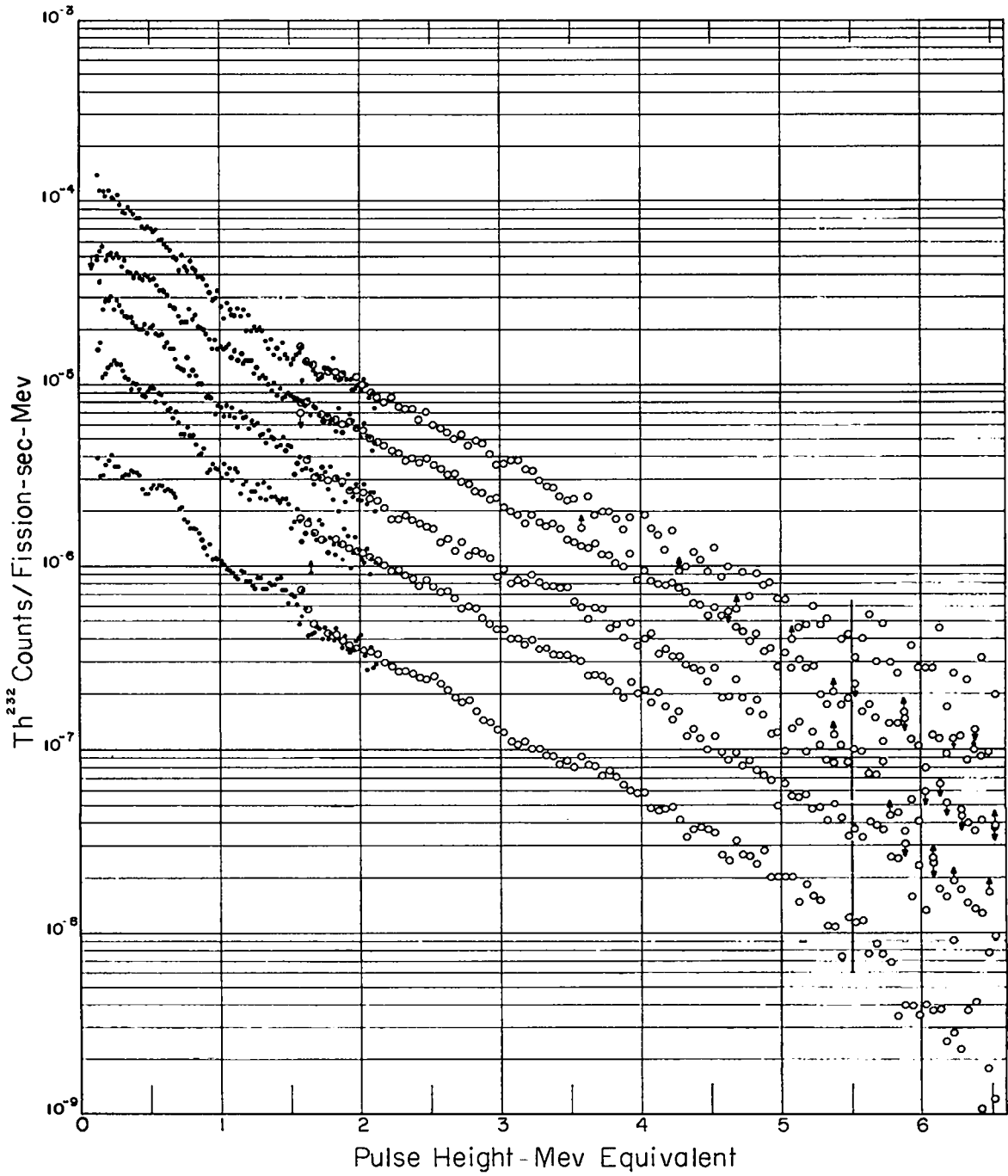


Figure 1. Pulse height distribution of gammas for different time intervals following  $\text{Th}^{232}$  fission



Table 2

Distribution of Photons/Fission-sec-Mev for the  
Different Time Intervals Following  $\text{Th}^{232}$  Fission

Interval Midpoint (Mev)	0.2 - 0.5 sec	1.0 - 2.0 sec	4.0 - 5.5 sec	10.0 - 13.0 sec	35.0 - 45.0 sec
0.175	$2.32 \times 10^0$	$9.79 \times 10^{-1}$	$6.52 \times 10^{-1}$	$2.54 \times 10^{-1}$	$5.53 \times 10^{-2}$
0.261	$1.19 \times 10^0$	$5.49 \times 10^{-1}$	$3.20 \times 10^{-1}$	$1.51 \times 10^{-1}$	$3.77 \times 10^{-2}$
0.369	$8.05 \times 10^{-1}$	$3.59 \times 10^{-1}$	$2.20 \times 10^{-1}$	$9.15 \times 10^{-2}$	$2.80 \times 10^{-2}$
0.502	$6.51 \times 10^{-1}$	$3.40 \times 10^{-1}$	$1.88 \times 10^{-1}$	$8.39 \times 10^{-2}$	$2.35 \times 10^{-2}$
0.662	$5.04 \times 10^{-1}$	$2.49 \times 10^{-1}$	$1.52 \times 10^{-1}$	$7.19 \times 10^{-2}$	$2.63 \times 10^{-2}$
0.852	$4.19 \times 10^{-1}$	$2.11 \times 10^{-1}$	$1.05 \times 10^{-1}$	$4.43 \times 10^{-2}$	$1.49 \times 10^{-2}$
1.075	$2.85 \times 10^{-1}$	$1.66 \times 10^{-1}$	$7.31 \times 10^{-2}$	$3.35 \times 10^{-2}$	$9.66 \times 10^{-3}$
1.337	$1.90 \times 10^{-1}$	$1.15 \times 10^{-1}$	$5.95 \times 10^{-2}$	$2.82 \times 10^{-2}$	$9.14 \times 10^{-3}$
1.643	$1.30 \times 10^{-1}$	$7.88 \times 10^{-2}$	$4.12 \times 10^{-2}$	$1.67 \times 10^{-2}$	$5.95 \times 10^{-3}$
1.998	$1.06 \times 10^{-1}$	$5.91 \times 10^{-2}$	$2.74 \times 10^{-2}$	$1.26 \times 10^{-2}$	$3.72 \times 10^{-3}$
2.405	$7.82 \times 10^{-2}$	$4.23 \times 10^{-2}$	$1.90 \times 10^{-2}$	$9.57 \times 10^{-3}$	$3.03 \times 10^{-3}$
2.865	$5.36 \times 10^{-2}$	$3.07 \times 10^{-2}$	$1.24 \times 10^{-2}$	$6.34 \times 10^{-3}$	$1.88 \times 10^{-3}$
3.383	$3.13 \times 10^{-2}$	$1.82 \times 10^{-2}$	$8.83 \times 10^{-3}$	$3.84 \times 10^{-3}$	$1.03 \times 10^{-3}$
3.956	$1.91 \times 10^{-2}$	$1.17 \times 10^{-2}$	$5.31 \times 10^{-3}$	$2.66 \times 10^{-3}$	$7.59 \times 10^{-4}$
4.587	$1.35 \times 10^{-2}$	$7.78 \times 10^{-3}$	$3.21 \times 10^{-3}$	$1.43 \times 10^{-3}$	$4.23 \times 10^{-4}$
5.277	$4.24 \times 10^{-3}$	$2.70 \times 10^{-3}$	$1.23 \times 10^{-3}$	$5.71 \times 10^{-4}$	$2.18 \times 10^{-4}$
6.028	$5.88 \times 10^{-3}$	$2.41 \times 10^{-3}$	$1.03 \times 10^{-3}$	$4.61 \times 10^{-4}$	$9.18 \times 10^{-5}$

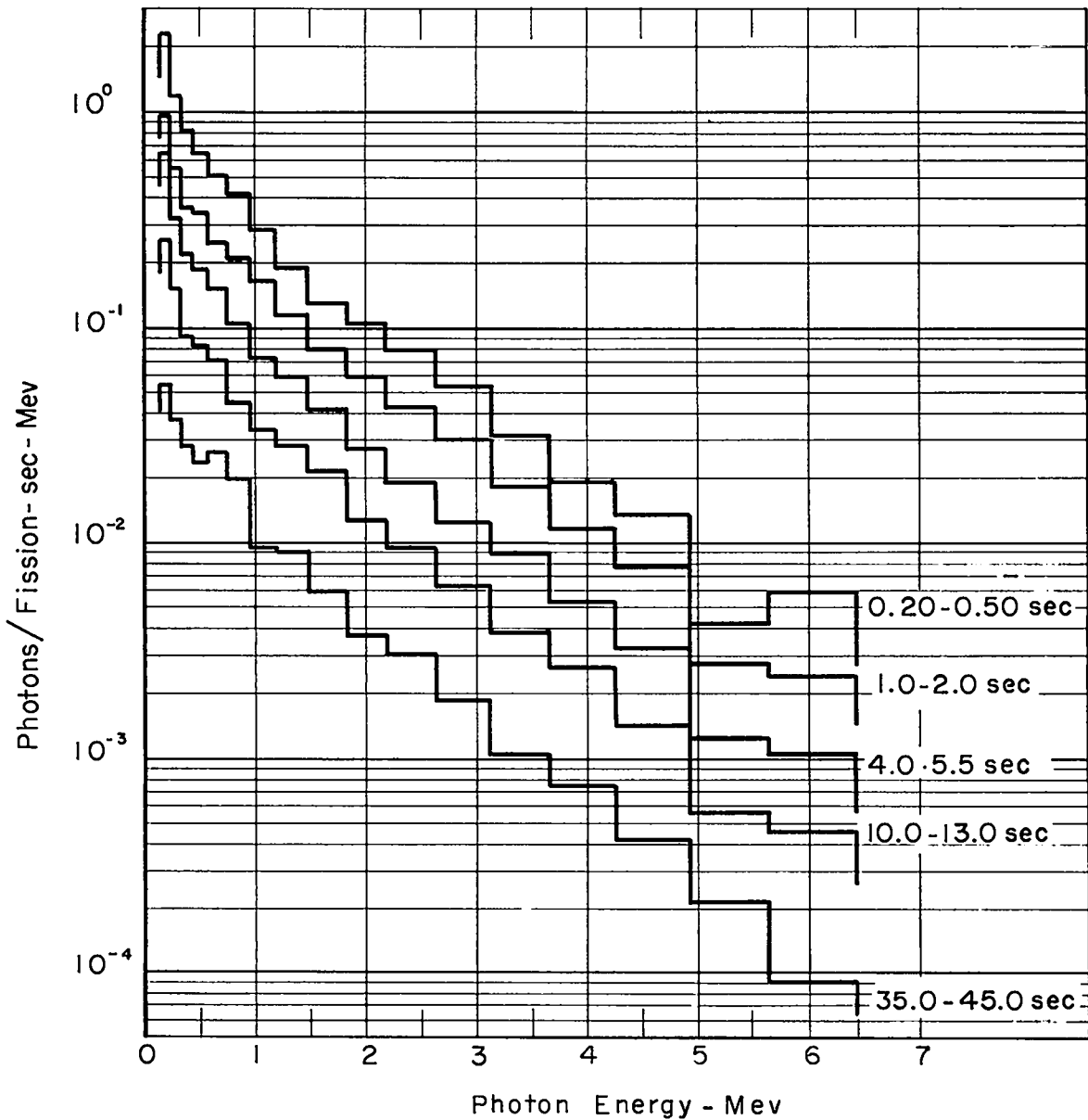


Figure 2. Photon spectra of gammas for different time intervals following  $\text{Th}^{232}$  fission

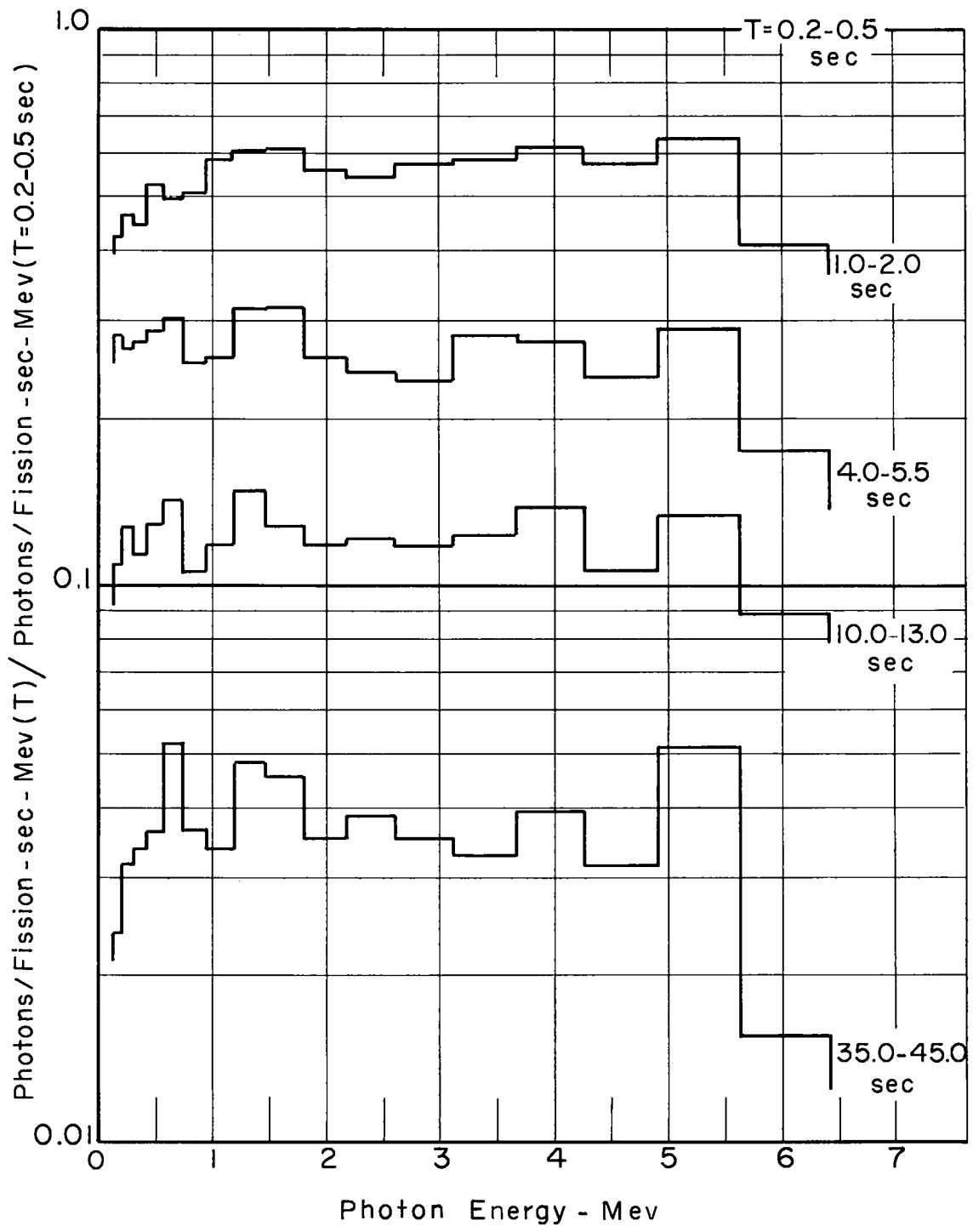


Figure 3. Ratios of  $\text{Th}^{232}$  photon spectra at all time intervals

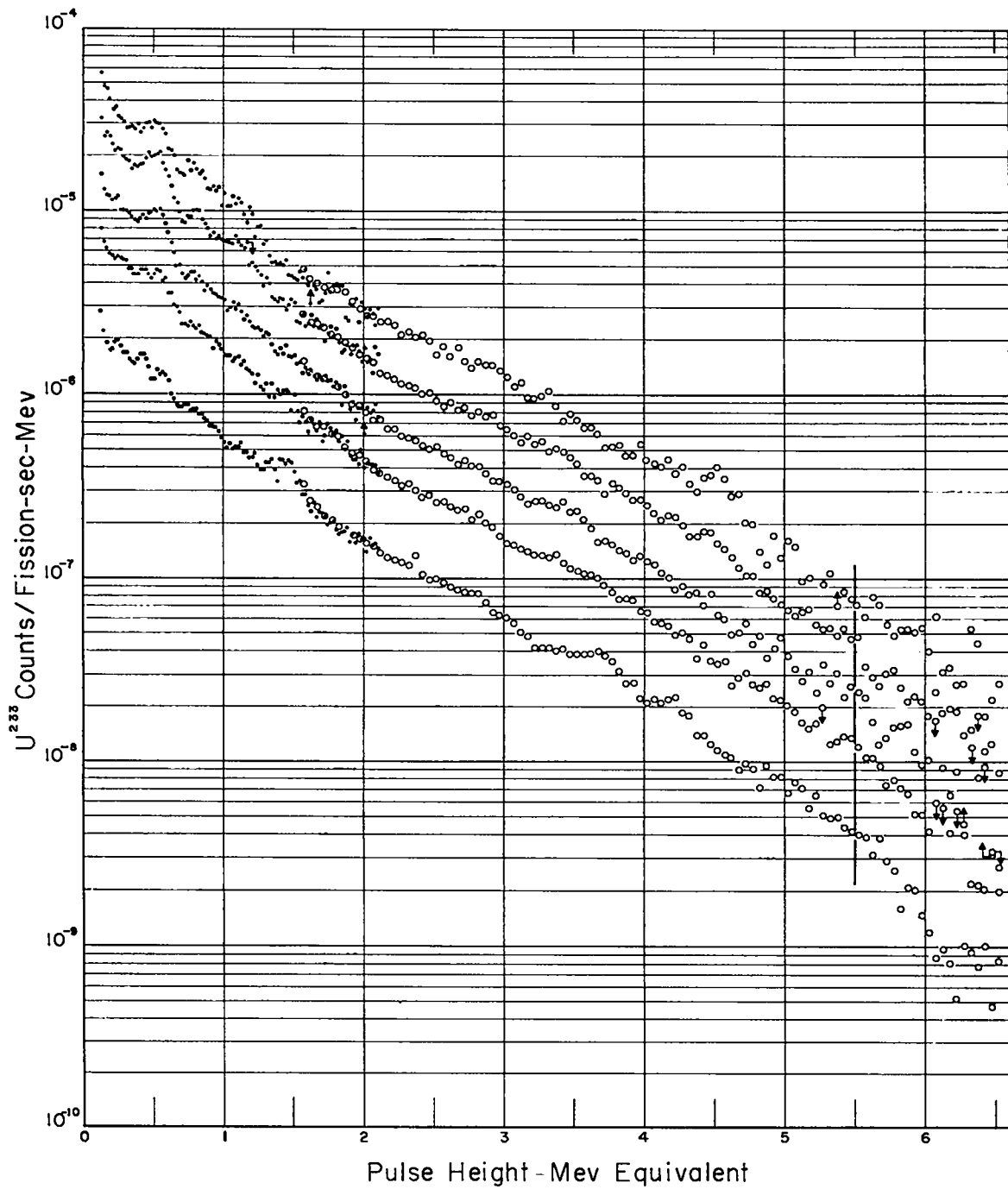


Figure 4. Pulse height distribution of gammas for different time intervals following  $U^{233}$  fission

Table 3

Distribution of Photons/Fission-sec-Mev for the  
Different Time Intervals Following U<sup>233</sup> Fission

Interval Midpoint (Mev)	0.2 - 0.5 sec	1.0 - 2.0 sec	4.0 - 5.5 sec	10.0 - 13.0 sec	35.0 - 45.0 sec
0.175	$6.20 \times 10^{-1}$	$3.37 \times 10^{-1}$	$1.77 \times 10^{-1}$	$8.86 \times 10^{-2}$	$2.67 \times 10^{-2}$
0.261	$2.77 \times 10^{-1}$	$1.81 \times 10^{-1}$	$9.96 \times 10^{-2}$	$5.17 \times 10^{-2}$	$1.75 \times 10^{-2}$
0.369	$2.03 \times 10^{-1}$	$1.27 \times 10^{-1}$	$7.14 \times 10^{-2}$	$3.77 \times 10^{-2}$	$1.28 \times 10^{-2}$
0.502	$2.78 \times 10^{-1}$	$1.99 \times 10^{-1}$	$1.01 \times 10^{-2}$	$4.37 \times 10^{-2}$	$1.19 \times 10^{-2}$
0.662	$1.73 \times 10^{-1}$	$1.09 \times 10^{-1}$	$5.72 \times 10^{-2}$	$2.92 \times 10^{-2}$	$8.73 \times 10^{-3}$
0.852	$1.62 \times 10^{-1}$	$8.91 \times 10^{-2}$	$3.90 \times 10^{-2}$	$2.16 \times 10^{-2}$	$7.45 \times 10^{-3}$
1.075	$1.35 \times 10^{-1}$	$8.12 \times 10^{-2}$	$3.38 \times 10^{-2}$	$1.77 \times 10^{-2}$	$5.49 \times 10^{-3}$
1.337	$7.22 \times 10^{-2}$	$4.47 \times 10^{-2}$	$2.25 \times 10^{-2}$	$1.26 \times 10^{-2}$	$5.06 \times 10^{-3}$
1.643	$4.20 \times 10^{-2}$	$2.72 \times 10^{-2}$	$1.53 \times 10^{-2}$	$8.24 \times 10^{-3}$	$3.23 \times 10^{-3}$
1.998	$3.18 \times 10^{-2}$	$1.82 \times 10^{-2}$	$9.41 \times 10^{-3}$	$5.02 \times 10^{-3}$	$1.72 \times 10^{-3}$
2.405	$2.09 \times 10^{-2}$	$1.10 \times 10^{-2}$	$6.01 \times 10^{-3}$	$3.24 \times 10^{-3}$	$1.18 \times 10^{-3}$
2.865	$1.72 \times 10^{-2}$	$8.62 \times 10^{-3}$	$4.30 \times 10^{-3}$	$2.34 \times 10^{-3}$	$9.38 \times 10^{-4}$
3.383	$1.08 \times 10^{-2}$	$5.99 \times 10^{-3}$	$3.01 \times 10^{-3}$	$1.49 \times 10^{-3}$	$4.42 \times 10^{-4}$
3.956	$5.13 \times 10^{-3}$	$3.30 \times 10^{-3}$	$1.68 \times 10^{-3}$	$9.40 \times 10^{-4}$	$3.84 \times 10^{-4}$
4.587	$4.54 \times 10^{-3}$	$2.06 \times 10^{-3}$	$8.53 \times 10^{-4}$	$4.65 \times 10^{-4}$	$1.52 \times 10^{-4}$
5.277	$1.16 \times 10^{-3}$	$7.27 \times 10^{-4}$	$3.88 \times 10^{-4}$	$2.18 \times 10^{-4}$	$8.63 \times 10^{-5}$
6.028	$9.91 \times 10^{-4}$	$4.57 \times 10^{-4}$	$2.43 \times 10^{-4}$	$1.17 \times 10^{-4}$	$3.36 \times 10^{-5}$

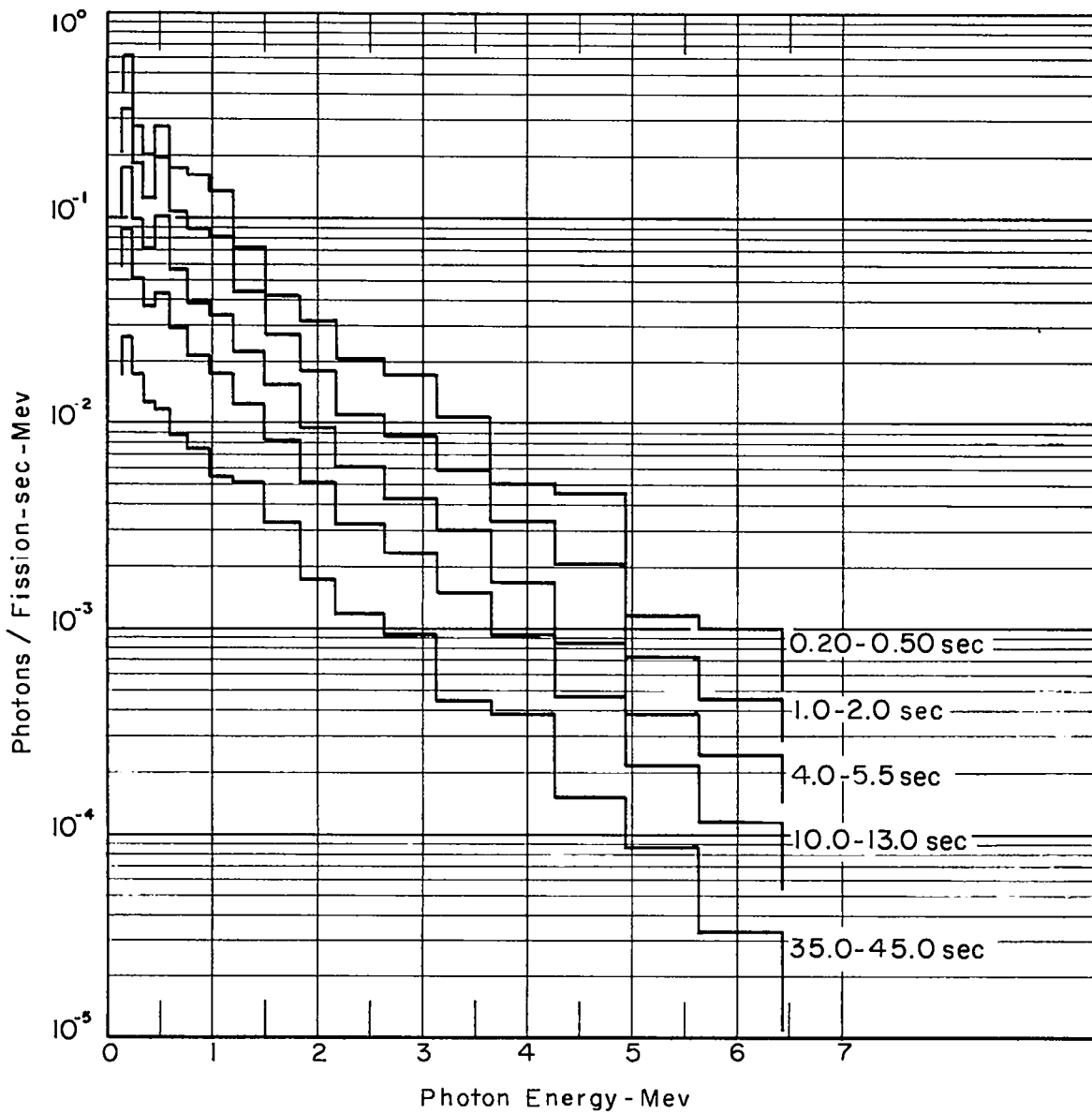


Figure 5. Photon spectra of gammas for different time intervals following  $U^{233}$  fission

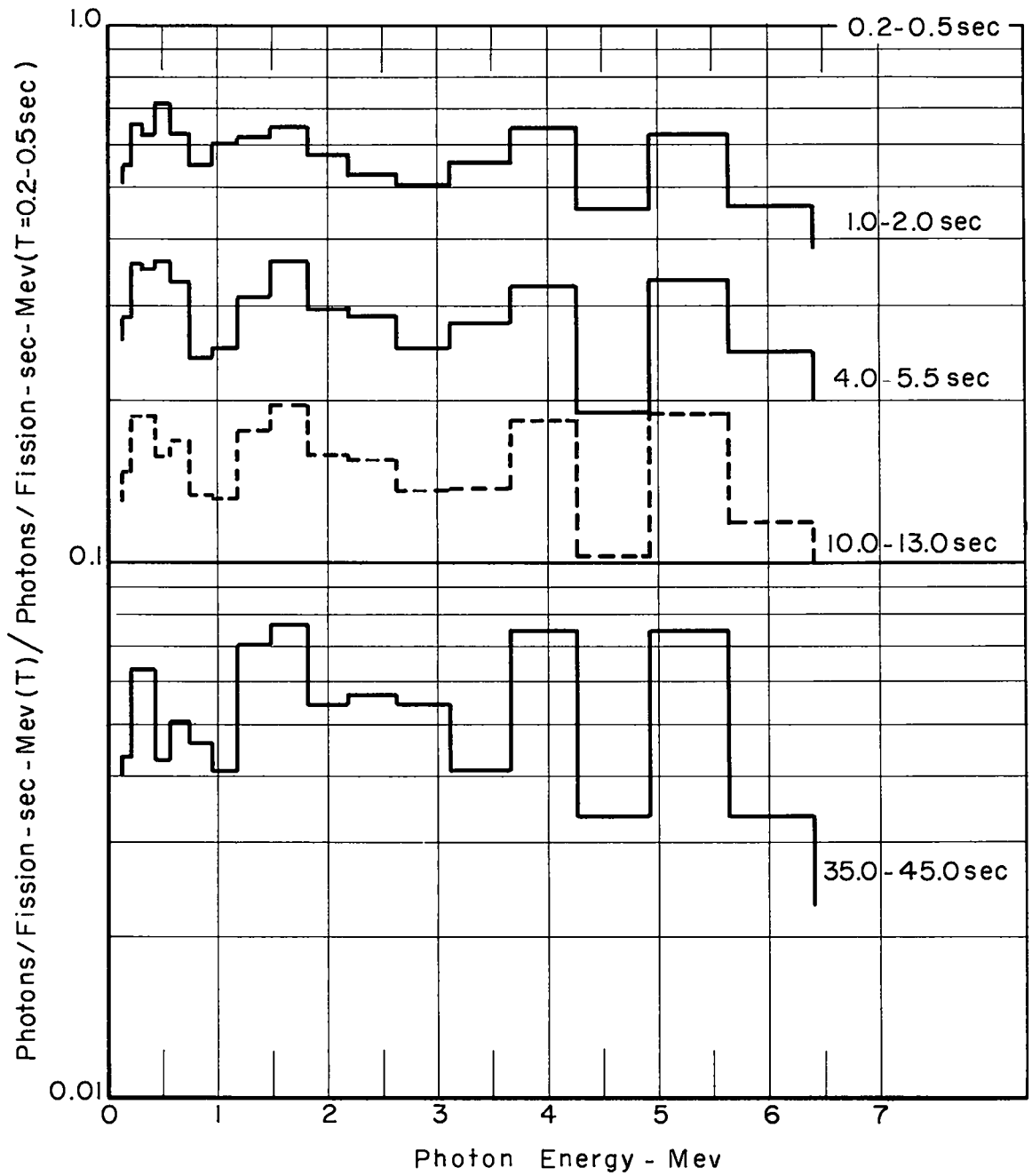


Figure 6. Ratios of  $U^{233}$  photon spectra at all time intervals

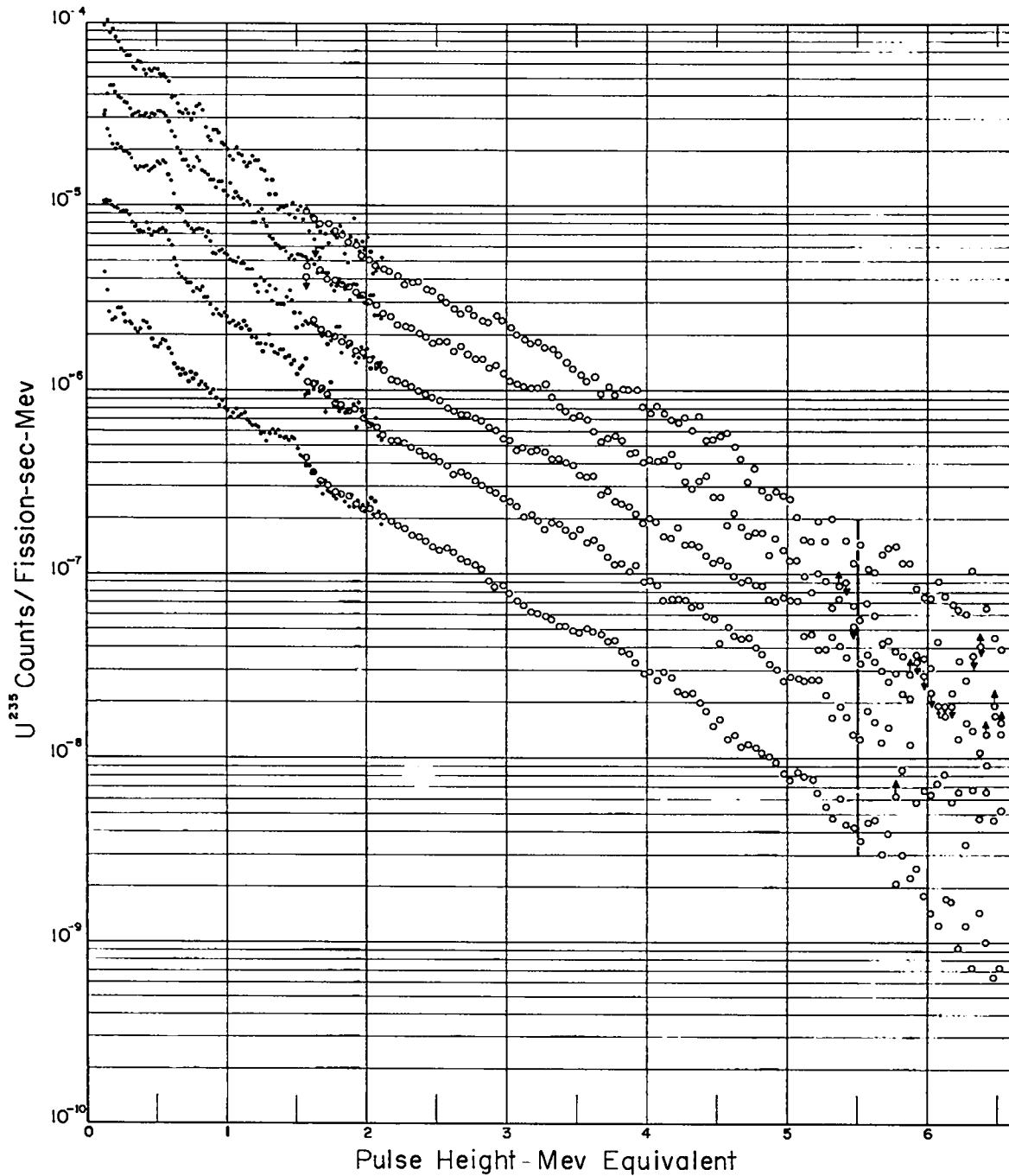


Figure 7. Pulse height distribution of gammas for different time intervals following  $U^{235}$  fission



Table 4

Distribution of Photons/Fission-sec-Mev for the  
Different Time Intervals Following U<sup>235</sup> Fission

Interval Midpoint (Mev)	0.2 - 0.5 sec	1.0 - 2.0 sec	4.0 - 5.5 sec	10 - 13 sec	35 - 45 sec
0.175	$1.33 \times 10^0$	$5.37 \times 10^{-1}$	$3.20 \times 10^{-1}$	$1.45 \times 10^{-1}$	$3.85 \times 10^{-2}$
0.261	$6.87 \times 10^{-1}$	$3.37 \times 10^{-1}$	$1.95 \times 10^{-1}$	$9.30 \times 10^{-2}$	$2.48 \times 10^{-2}$
0.369	$4.60 \times 10^{-1}$	$2.35 \times 10^{-1}$	$1.31 \times 10^{-1}$	$6.17 \times 10^{-2}$	$1.86 \times 10^{-2}$
0.502	$4.92 \times 10^{-1}$	$2.98 \times 10^{-1}$	$1.65 \times 10^{-1}$	$7.19 \times 10^{-2}$	$1.67 \times 10^{-2}$
0.662	$3.28 \times 10^{-1}$	$1.94 \times 10^{-1}$	$1.03 \times 10^{-1}$	$4.66 \times 10^{-2}$	$1.19 \times 10^{-2}$
0.852	$3.00 \times 10^{-1}$	$1.53 \times 10^{-1}$	$6.50 \times 10^{-2}$	$3.10 \times 10^{-2}$	$1.03 \times 10^{-2}$
1.075	$2.18 \times 10^{-1}$	$1.33 \times 10^{-1}$	$5.62 \times 10^{-2}$	$2.55 \times 10^{-2}$	$7.91 \times 10^{-3}$
1.337	$1.45 \times 10^{-1}$	$7.72 \times 10^{-2}$	$3.73 \times 10^{-2}$	$1.95 \times 10^{-2}$	$6.84 \times 10^{-3}$
1.643	$8.68 \times 10^{-2}$	$5.06 \times 10^{-2}$	$2.66 \times 10^{-2}$	$1.20 \times 10^{-2}$	$4.06 \times 10^{-3}$
1.998	$6.17 \times 10^{-2}$	$3.46 \times 10^{-2}$	$1.69 \times 10^{-2}$	$7.56 \times 10^{-3}$	$2.47 \times 10^{-3}$
2.405	$3.86 \times 10^{-2}$	$2.17 \times 10^{-2}$	$1.09 \times 10^{-2}$	$5.12 \times 10^{-3}$	$1.78 \times 10^{-3}$
2.865	$2.87 \times 10^{-2}$	$1.62 \times 10^{-2}$	$7.12 \times 10^{-3}$	$3.51 \times 10^{-3}$	$1.26 \times 10^{-3}$
3.383	$1.85 \times 10^{-2}$	$1.07 \times 10^{-2}$	$5.29 \times 10^{-3}$	$2.19 \times 10^{-3}$	$6.10 \times 10^{-4}$
3.956	$9.71 \times 10^{-3}$	$5.74 \times 10^{-3}$	$2.64 \times 10^{-3}$	$1.24 \times 10^{-3}$	$4.60 \times 10^{-4}$
4.587	$7.96 \times 10^{-3}$	$3.37 \times 10^{-3}$	$1.55 \times 10^{-3}$	$7.12 \times 10^{-4}$	$2.12 \times 10^{-4}$
5.277	$1.67 \times 10^{-3}$	$1.21 \times 10^{-3}$	$5.86 \times 10^{-4}$	$2.94 \times 10^{-4}$	$8.95 \times 10^{-5}$
6.028	$1.94 \times 10^{-3}$	$7.20 \times 10^{-4}$	$4.54 \times 10^{-4}$	$1.65 \times 10^{-4}$	$4.16 \times 10^{-5}$

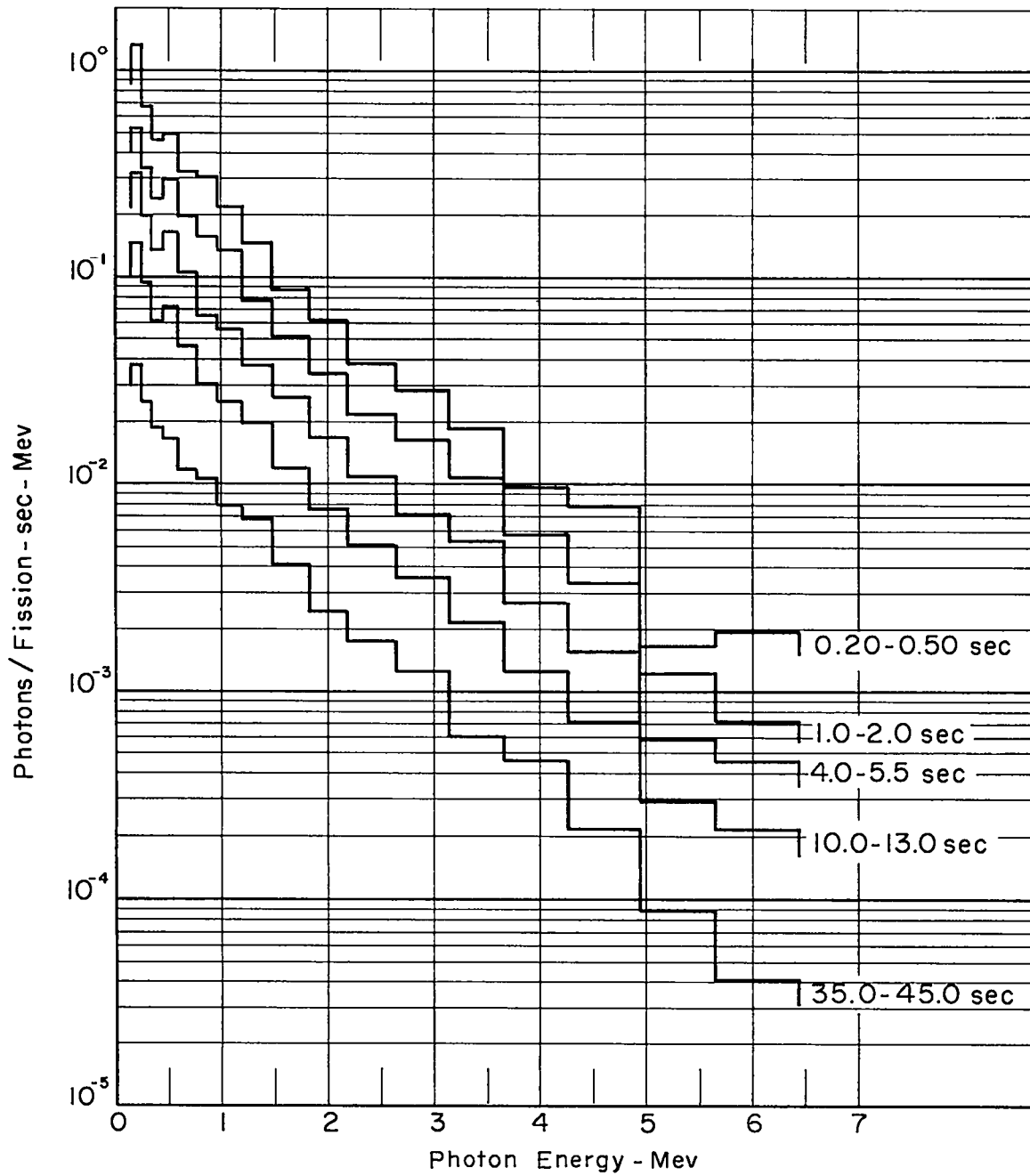


Figure 8. Photon spectra of gammas for different time intervals following  $U^{235}$  fission

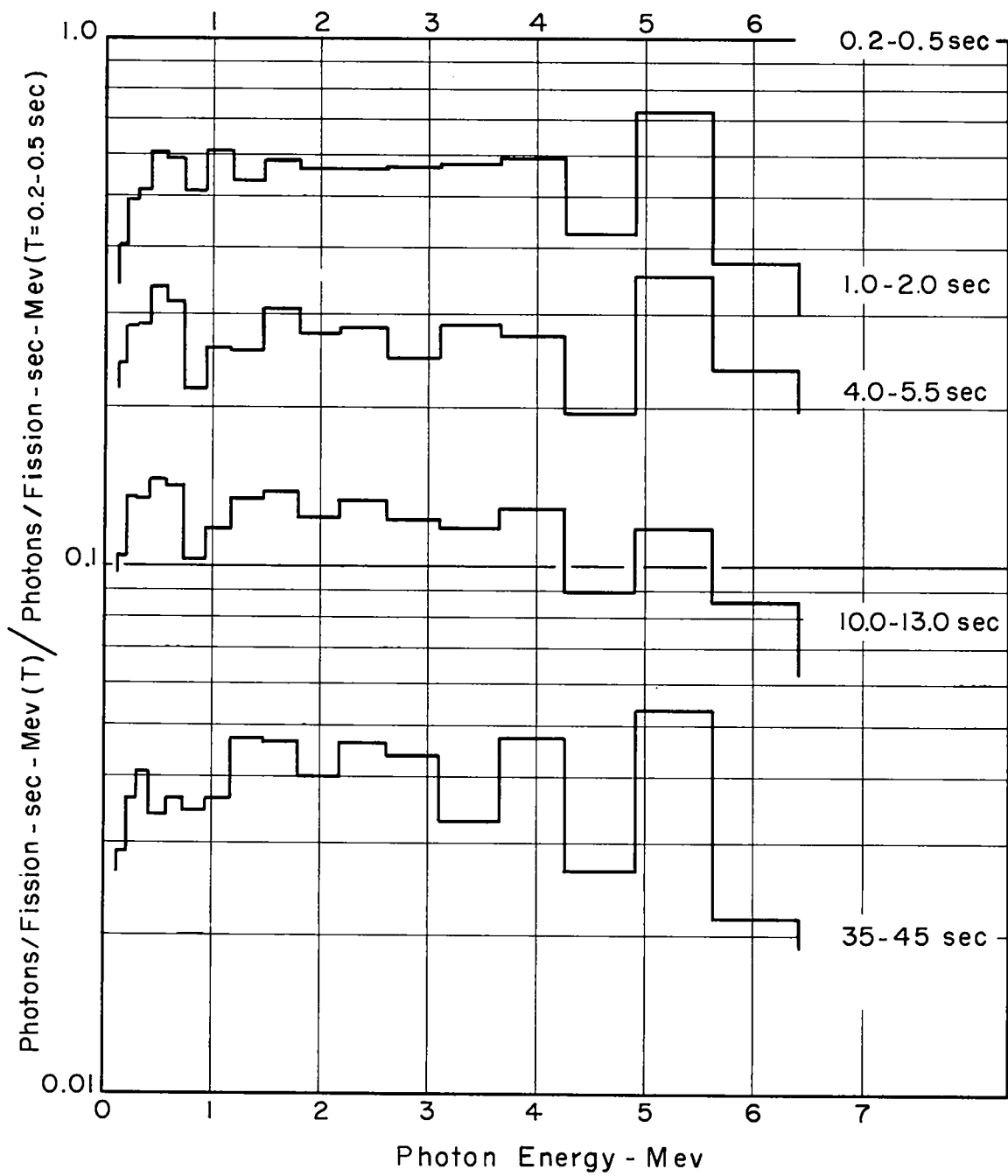


Figure 9. Ratios of U<sup>235</sup> photon spectra at all time intervals

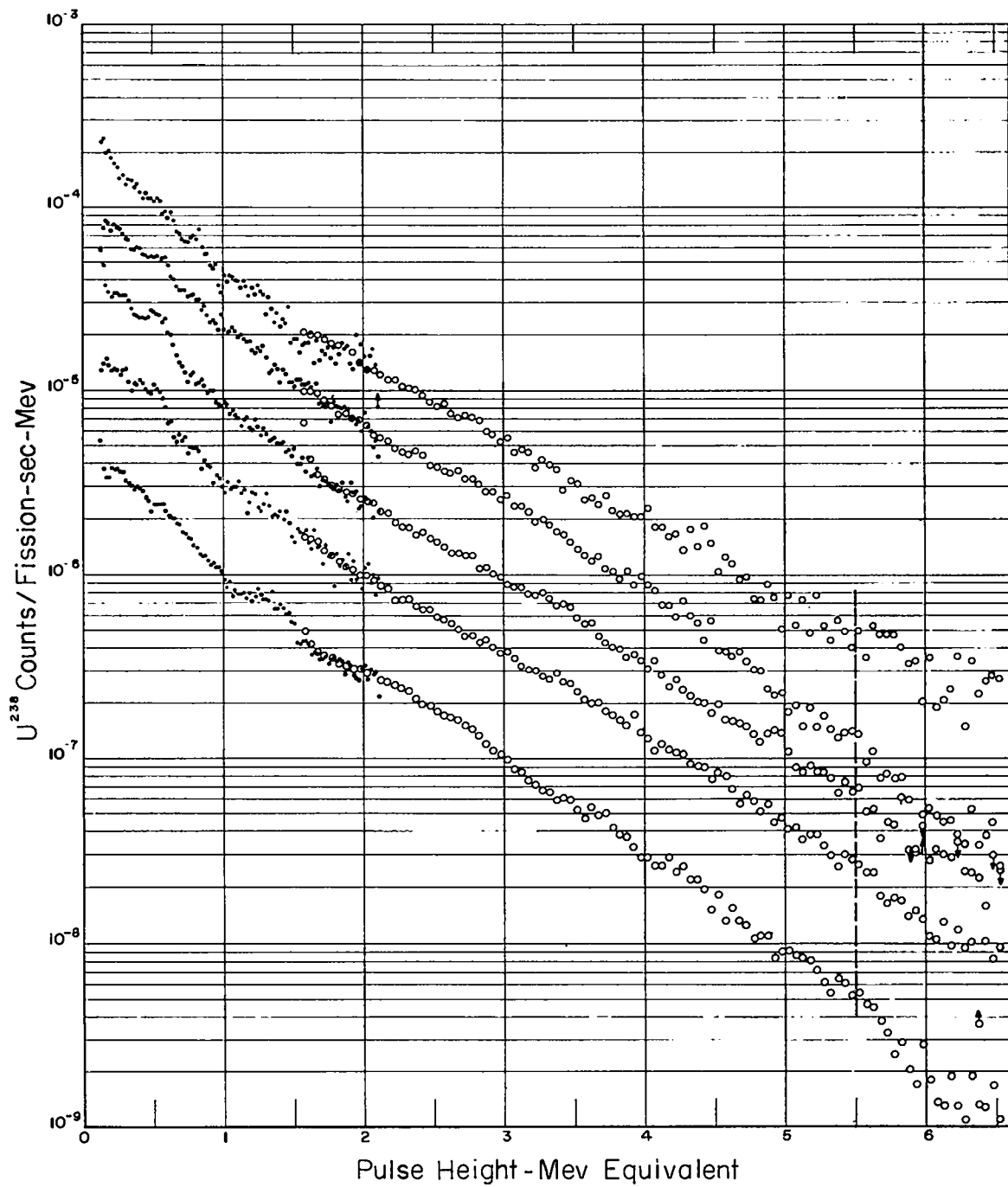


Figure 10. Pulse height distribution of gammas for different time intervals following  $U^{238}$  fission

Table 5

Distribution of Photons/Fission-sec-Mev for the  
Different Time Intervals Following U<sup>238</sup> Fission

Interval Midpoint (Mev)	0.2 - 0.5 sec	1 - 2 sec	4.0 - 5.5 sec	10.0 - 13.0 sec	35.0 - 45.0 sec
0.175	$3.45 \times 10^0$	$1.08 \times 10^0$	$6.66 \times 10^{-1}$	$2.18 \times 10^{-1}$	$5.28 \times 10^{-2}$
0.261	$1.61 \times 10^0$	$7.62 \times 10^{-1}$	$3.52 \times 10^{-1}$	$1.33 \times 10^{-1}$	$3.86 \times 10^{-2}$
0.369	$1.14 \times 10^0$	$4.93 \times 10^{-1}$	$2.35 \times 10^{-1}$	$9.93 \times 10^{-2}$	$2.65 \times 10^{-2}$
0.502	$9.86 \times 10^{-1}$	$4.77 \times 10^{-1}$	$2.59 \times 10^{-1}$	$1.04 \times 10^{-1}$	$2.21 \times 10^{-2}$
0.662	$7.39 \times 10^{-1}$	$3.80 \times 10^{-1}$	$1.75 \times 10^{-1}$	$5.91 \times 10^{-2}$	$1.90 \times 10^{-2}$
0.852	$6.27 \times 10^{-1}$	$2.83 \times 10^{-1}$	$1.08 \times 10^{-1}$	$4.18 \times 10^{-2}$	$1.33 \times 10^{-2}$
1.075	$4.26 \times 10^{-1}$	$2.33 \times 10^{-1}$	$8.10 \times 10^{-2}$	$3.00 \times 10^{-2}$	$9.05 \times 10^{-3}$
1.337	$3.32 \times 10^{-1}$	$1.59 \times 10^{-1}$	$6.26 \times 10^{-2}$	$2.65 \times 10^{-2}$	$8.71 \times 10^{-3}$
1.643	$1.80 \times 10^{-1}$	$1.09 \times 10^{-1}$	$4.41 \times 10^{-2}$	$1.62 \times 10^{-2}$	$4.40 \times 10^{-3}$
1.998	$1.59 \times 10^{-1}$	$7.16 \times 10^{-2}$	$2.82 \times 10^{-2}$	$1.12 \times 10^{-2}$	$3.11 \times 10^{-3}$
2.405	$1.08 \times 10^{-1}$	$4.60 \times 10^{-2}$	$1.86 \times 10^{-2}$	$7.43 \times 10^{-3}$	$2.47 \times 10^{-3}$
2.865	$7.76 \times 10^{-2}$	$3.70 \times 10^{-2}$	$1.24 \times 10^{-2}$	$5.07 \times 10^{-3}$	$1.69 \times 10^{-3}$
3.383	$4.33 \times 10^{-2}$	$2.15 \times 10^{-2}$	$8.98 \times 10^{-3}$	$3.29 \times 10^{-3}$	$7.70 \times 10^{-4}$
3.956	$2.30 \times 10^{-2}$	$1.19 \times 10^{-2}$	$4.52 \times 10^{-3}$	$1.83 \times 10^{-3}$	$4.58 \times 10^{-4}$
4.587	$1.76 \times 10^{-2}$	$6.32 \times 10^{-3}$	$2.35 \times 10^{-3}$	$1.03 \times 10^{-3}$	$2.21 \times 10^{-4}$
5.277	$4.98 \times 10^{-3}$	$2.20 \times 10^{-3}$	$1.04 \times 10^{-3}$	$4.50 \times 10^{-4}$	$1.02 \times 10^{-4}$
6.028	$6.79 \times 10^{-3}$	$1.16 \times 10^{-3}$	$7.59 \times 10^{-4}$	$2.73 \times 10^{-4}$	$4.44 \times 10^{-5}$

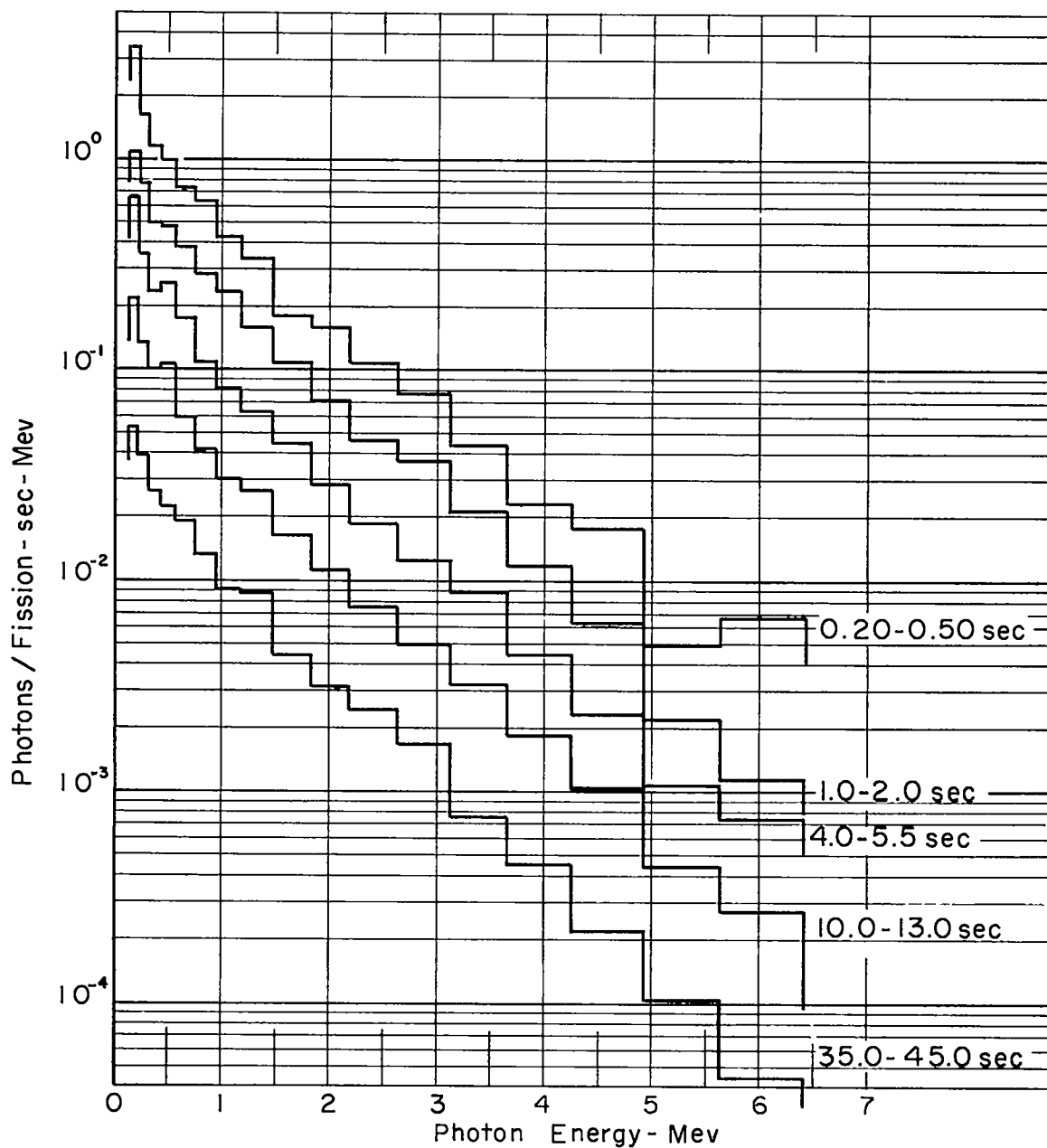


Figure 11. Photon spectra of gammas for different time intervals following  $U^{238}$  fission

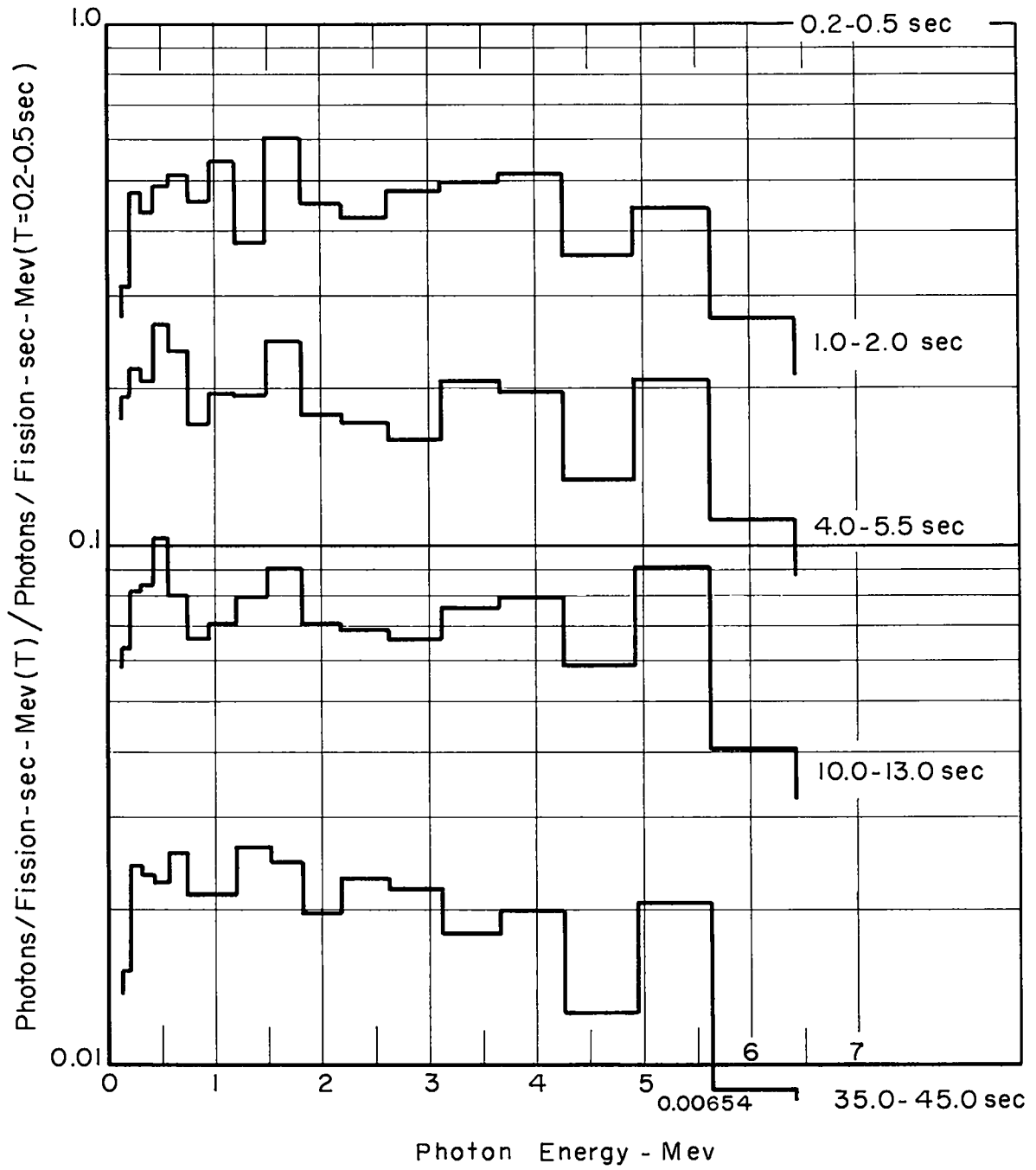


Figure 12. Ratios of  $^{238}\text{U}$  photon spectra at all time intervals

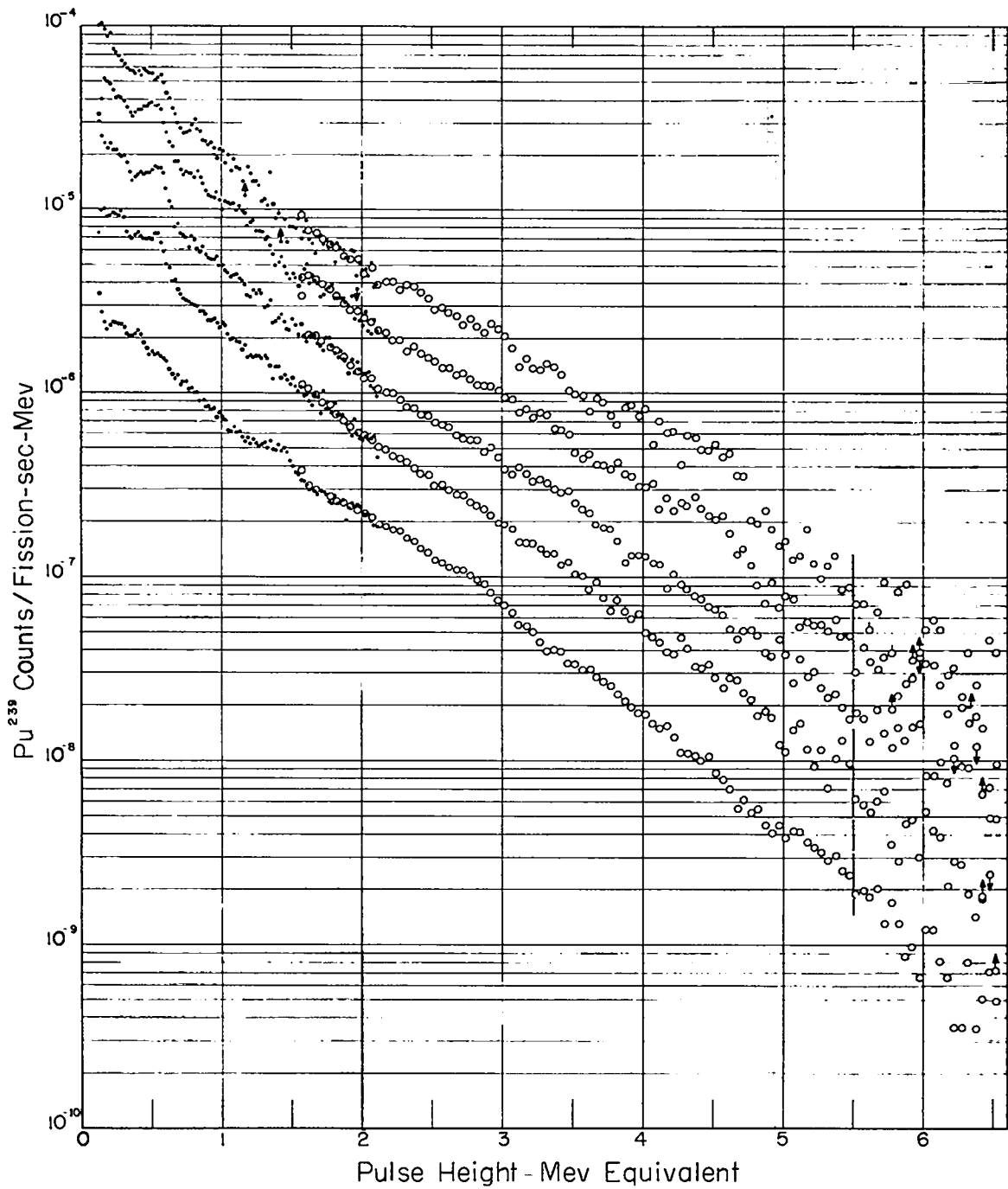


Figure 13. Pulse height distribution of gammas for different time intervals following  $\text{Pu}^{239}$  fission



Table 6

Distribution of Photons/Fission-sec-Mev for the  
Different Time Intervals Following Pu<sup>239</sup> Fission

Interval Midpoint (Mev)	0.2 - 0.5 sec	1.0 - 2.0 sec	4.0 - 5.5 sec	10.0 - 13.0 sec	35.0 - 45.0 sec
0.175	$1.43 \times 10^0$	$6.02 \times 10^{-1}$	$3.45 \times 10^{-1}$	$1.43 \times 10^{-1}$	$3.56 \times 10^{-2}$
0.261	$6.84 \times 10^{-1}$	$3.97 \times 10^{-1}$	$2.10 \times 10^{-1}$	$1.05 \times 10^{-1}$	$2.38 \times 10^{-2}$
0.369	$4.60 \times 10^{-1}$	$2.72 \times 10^{-1}$	$1.33 \times 10^{-1}$	$6.50 \times 10^{-2}$	$1.87 \times 10^{-2}$
0.502	$5.35 \times 10^{-1}$	$3.91 \times 10^{-1}$	$1.75 \times 10^{-1}$	$7.38 \times 10^{-2}$	$1.54 \times 10^{-2}$
0.662	$3.42 \times 10^{-1}$	$2.10 \times 10^{-1}$	$1.07 \times 10^{-1}$	$4.28 \times 10^{-2}$	$1.20 \times 10^{-2}$
0.852	$2.75 \times 10^{-1}$	$1.45 \times 10^{-1}$	$6.17 \times 10^{-2}$	$2.83 \times 10^{-2}$	$9.30 \times 10^{-3}$
1.075	$2.12 \times 10^{-1}$	$1.27 \times 10^{-1}$	$5.11 \times 10^{-2}$	$2.30 \times 10^{-2}$	$6.79 \times 10^{-3}$
1.337	$1.23 \times 10^{-1}$	$7.71 \times 10^{-2}$	$3.28 \times 10^{-2}$	$1.64 \times 10^{-2}$	$6.03 \times 10^{-3}$
1.643	$8.13 \times 10^{-2}$	$4.60 \times 10^{-2}$	$2.56 \times 10^{-2}$	$1.15 \times 10^{-2}$	$3.50 \times 10^{-3}$
1.998	$5.28 \times 10^{-2}$	$3.10 \times 10^{-2}$	$1.53 \times 10^{-2}$	$7.02 \times 10^{-3}$	$2.47 \times 10^{-3}$
2.405	$3.89 \times 10^{-2}$	$1.87 \times 10^{-2}$	$9.28 \times 10^{-3}$	$4.46 \times 10^{-3}$	$1.74 \times 10^{-3}$
2.865	$2.97 \times 10^{-2}$	$1.37 \times 10^{-2}$	$5.93 \times 10^{-3}$	$2.96 \times 10^{-3}$	$1.25 \times 10^{-3}$
3.383	$1.46 \times 10^{-2}$	$8.40 \times 10^{-3}$	$4.10 \times 10^{-3}$	$1.69 \times 10^{-3}$	$5.28 \times 10^{-4}$
3.956	$8.37 \times 10^{-3}$	$3.79 \times 10^{-3}$	$1.81 \times 10^{-3}$	$7.60 \times 10^{-4}$	$2.85 \times 10^{-4}$
4.587	$6.77 \times 10^{-3}$	$2.95 \times 10^{-3}$	$9.10 \times 10^{-4}$	$4.30 \times 10^{-4}$	$1.14 \times 10^{-4}$
5.277	$1.42 \times 10^{-3}$	$6.54 \times 10^{-4}$	$3.14 \times 10^{-4}$	$1.47 \times 10^{-4}$	$4.62 \times 10^{-5}$
6.028	$1.04 \times 10^{-3}$	$5.36 \times 10^{-4}$	$2.47 \times 10^{-4}$	$7.88 \times 10^{-5}$	$2.07 \times 10^{-5}$

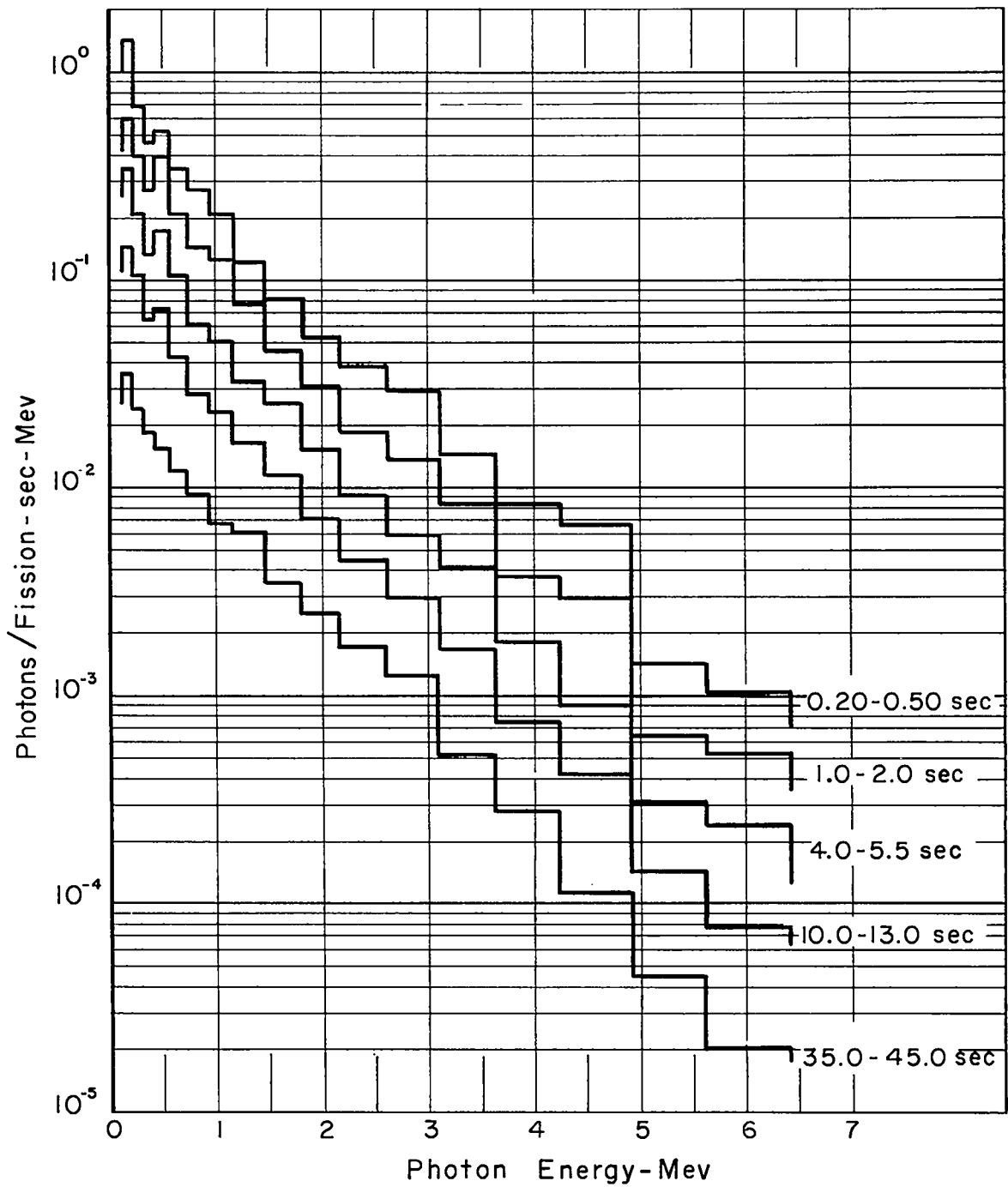


Figure 14. Photon spectra of gammas for different time intervals following  $\text{Pu}^{239}$  fission

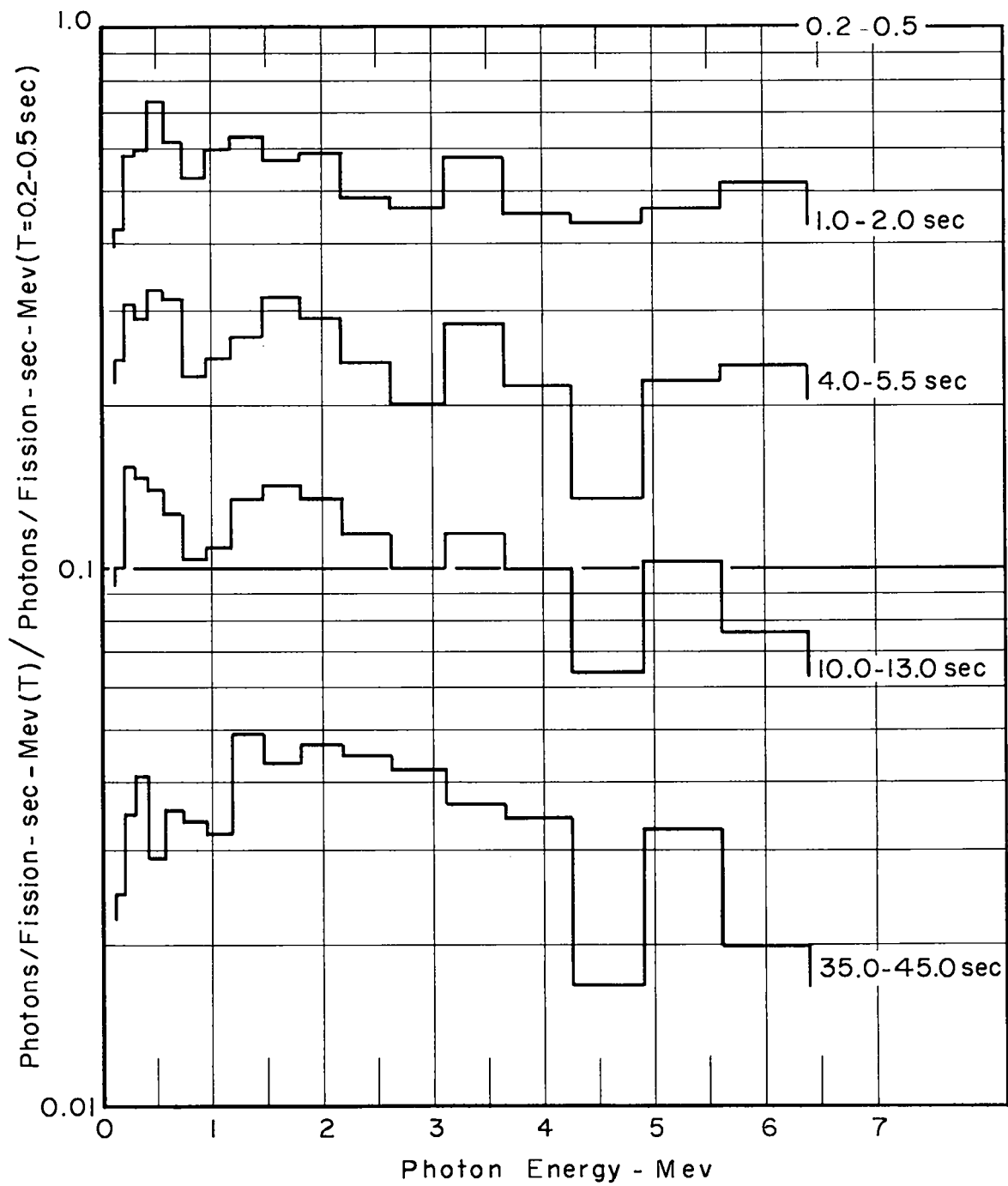


Figure 15. Ratios of  $\text{Pu}^{239}$  photon spectra at all time intervals

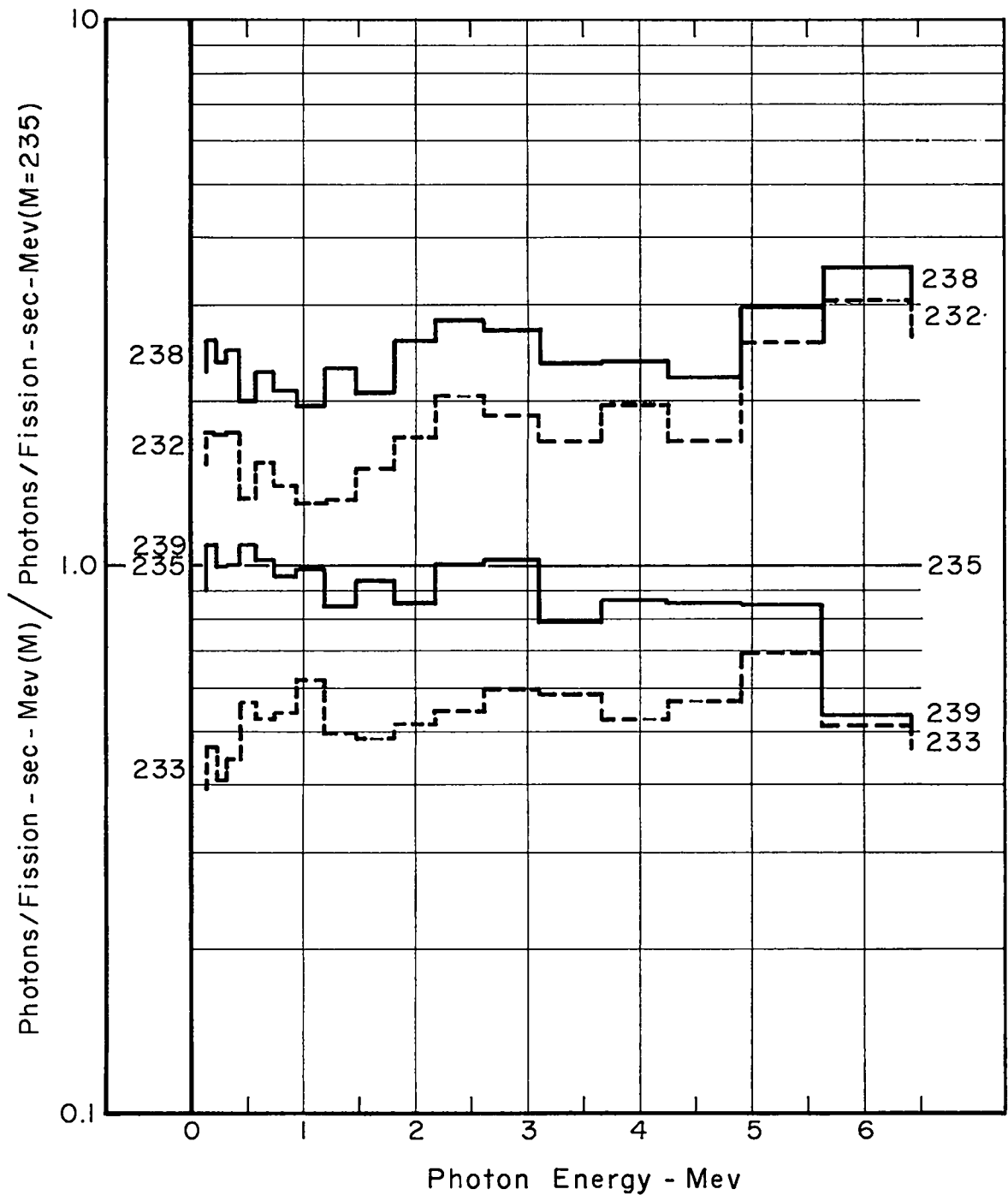


Figure 16. Ratios of photon spectra for all isotopes at 0.2 to 0.5 sec interval

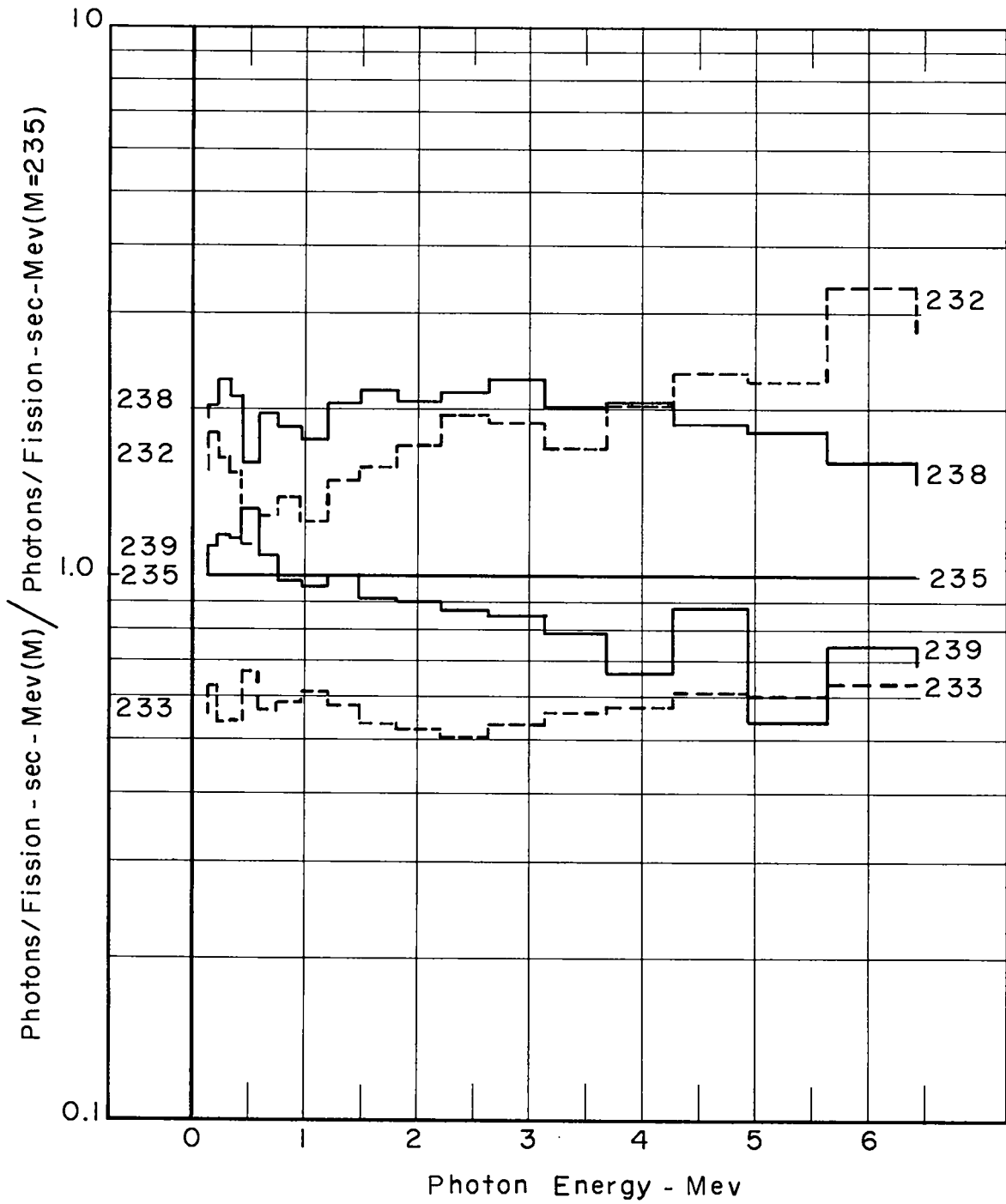


Figure 17. Ratios of photon spectra for all isotopes at 1.0 to 2.0 sec interval

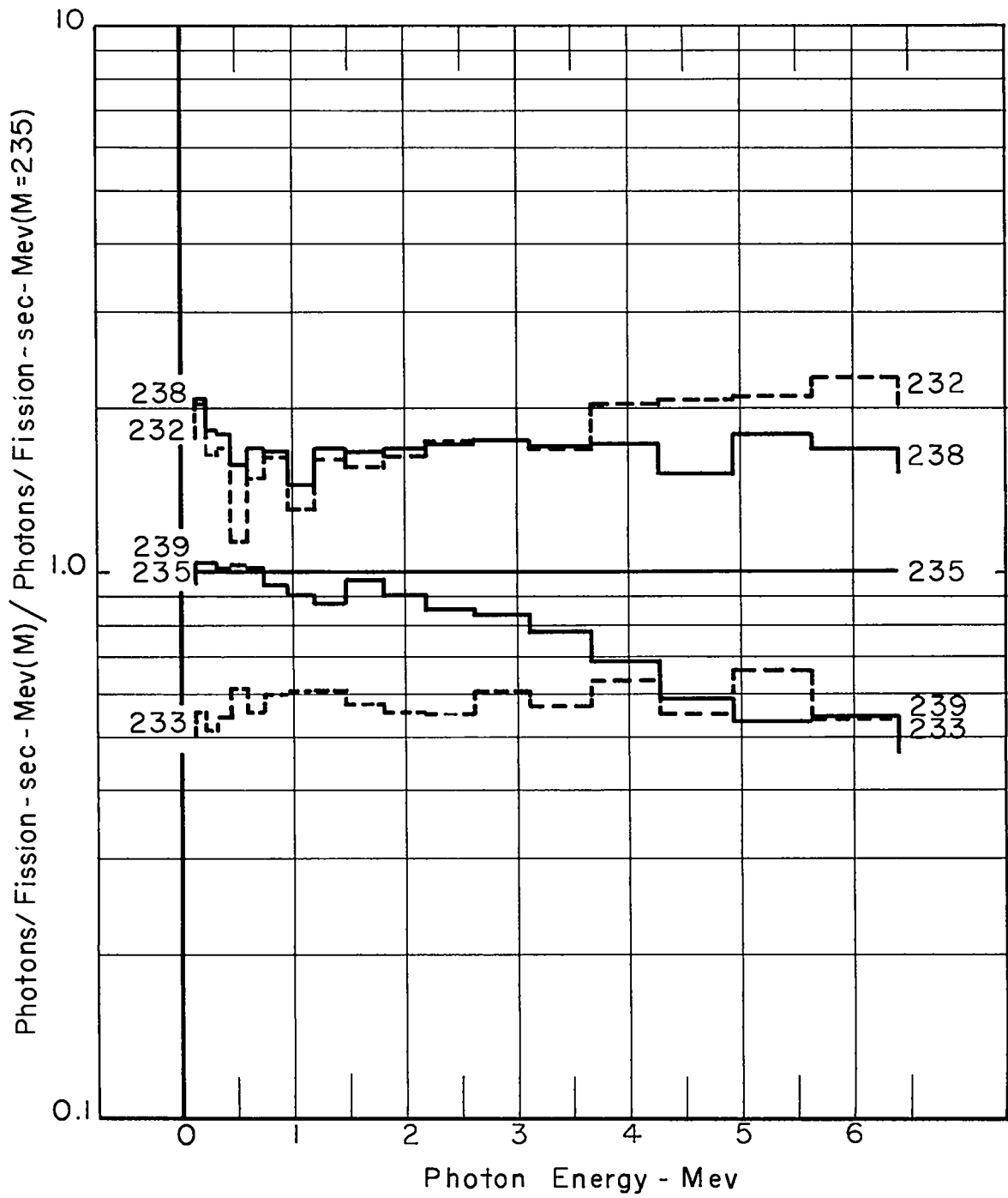


Figure 18. Ratios of photon spectra for all isotopes at 4.0 to 5.5 sec interval

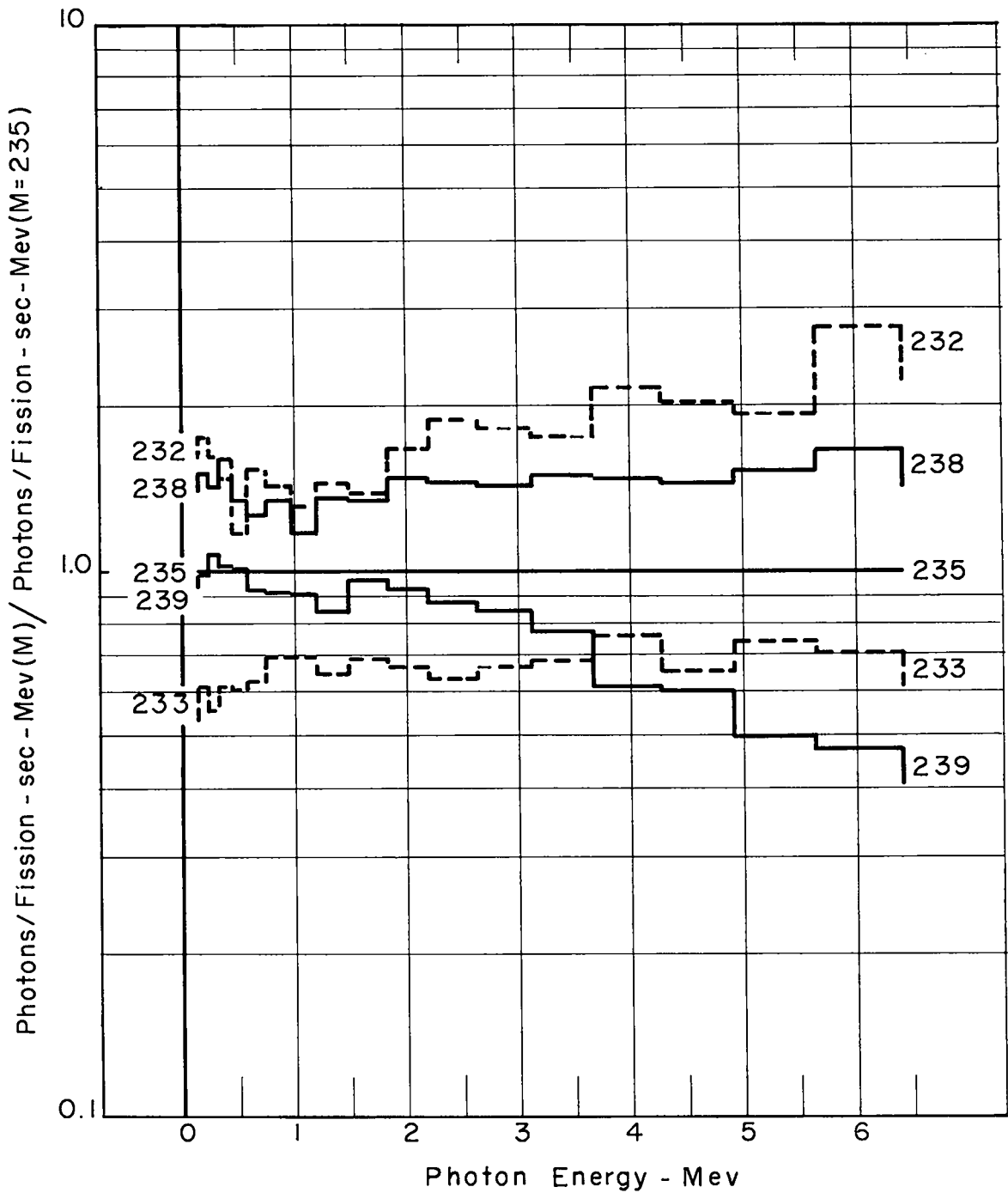


Figure 19. Ratios of photon spectra for all isotopes at 10.0 to 13.0 sec interval

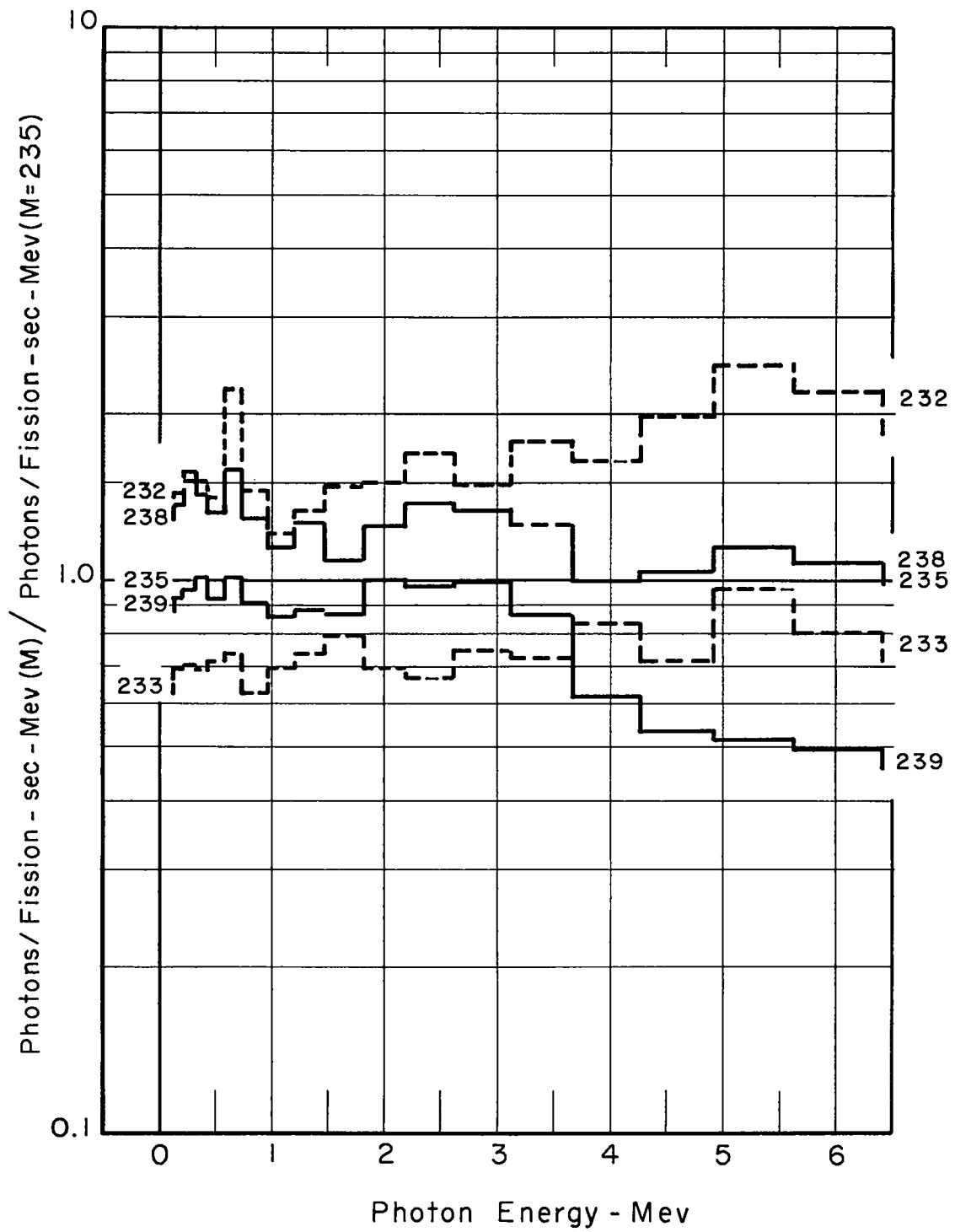


Figure 20. Ratios of photon spectra for all isotopes at 35.0 to 45.0 sec interval



Table 7

Results of Delayed Gamma Spectra Integrated  
over Energy for Different Time Intervals  
after Fission

<u>Isotope</u>	<u>Time Interval</u>	<u>Photons/ Fission-Sec</u>	<u>Mev/ Fission-Sec</u>	<u>Mev/ Photon</u>
232	0.2-0.5 sec	0.966	0.916	0.948
	1.0-2.0 sec	0.487	0.501	1.029
	4.0-5.5 sec	0.267	0.246	0.921
	10.0-13.0 sec	0.118	0.112	0.949
	35.0-45.0 sec	0.0343	0.0343	1.000
233	0.2-0.5 sec	0.312	0.303	0.971
	1.0-2.0 sec	0.189	0.177	0.937
	4.0-5.5 sec	0.0958	0.0885	0.924
	10.0-13.0 sec	0.0490	0.0465	0.949
	35.0-45.0 sec	0.0161	0.0161	1.000
235	0.2-0.5 sec	0.613	0.564	0.920
	1.0-2.0 sec	0.324	0.311	0.960
	4.0-5.5 sec	0.169	0.153	0.905
	10.0-13.0 sec	0.0775	0.0706	0.911
	35.0-45.0 sec	0.0225	0.0221	0.982
238	0.2-0.5 sec	1.42	1.32	0.930
	1.0-2.0 sec	0.636	0.618	0.972
	4.0-5.5 sec	0.289	0.255	0.882
	10.0-13.0 sec	0.110	0.0988	0.898
	35.0-45.0 sec	0.0303	0.0281	0.927
239	0.2-0.5 sec	0.608	0.529	0.870
	1.0-2.0 sec	0.344	0.296	0.860
	4.0-5.5 sec	0.166	0.138	0.831
	10.0-13.0 sec	0.0746	0.0624	0.836
	35.0-45.0 sec	0.0209	0.0197	0.943

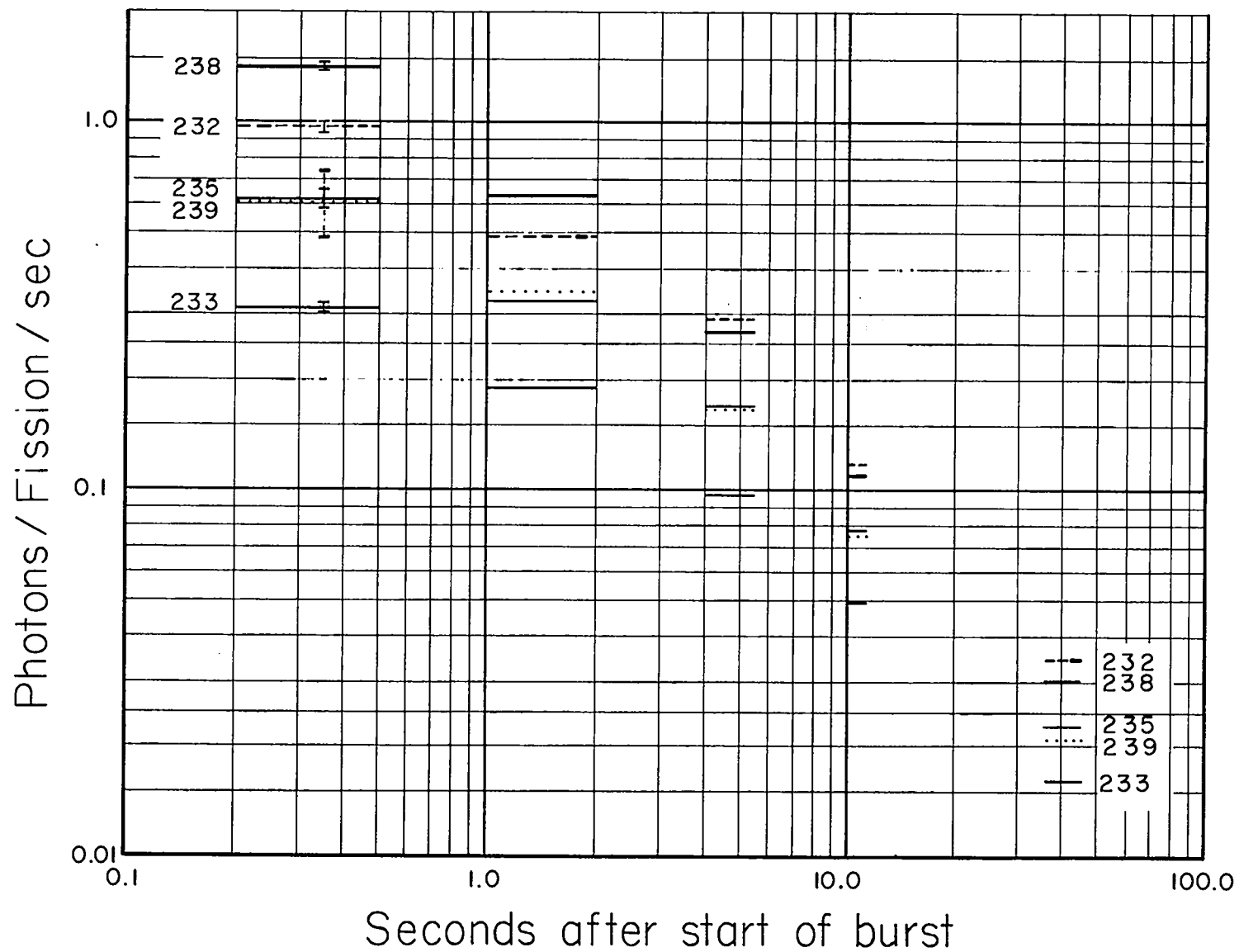


Figure 21. Comparison of photon spectra integrated over energy for the different time intervals after fission

Table 8

Results of Delayed Gamma Spectra Integrated over  
Energy and Time from 0.20 to 45.0 sec after Fission

<u>Isotope</u>	<u>Photons/Fission</u>	<u>Mev/Fission</u>	<u>Mev/Photon</u>
232	5.07	5.04	0.994
233	2.02	1.97	0.975
235	3.31	3.18	0.961
238	5.50	5.08	0.924
239	3.26	2.86	0.877