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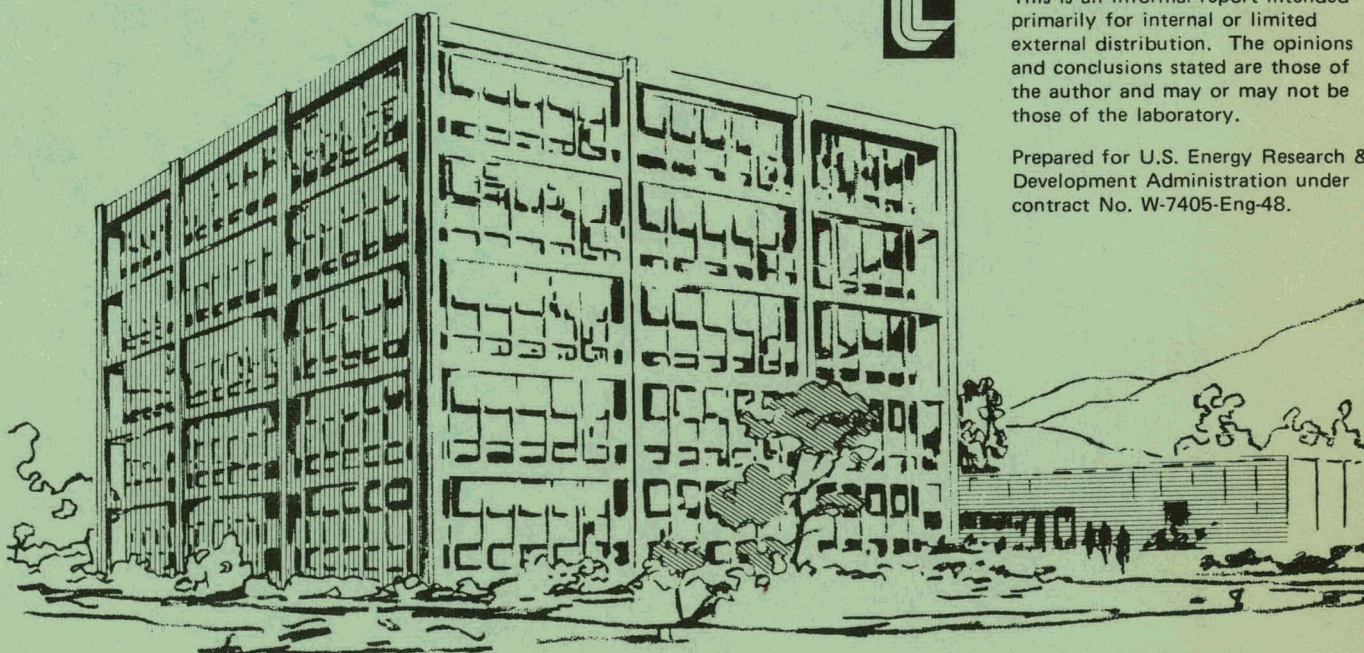
Measurement of the Neutron-Induced Fission Cross Section
of ^{232}Th Relative to ^{235}U from 0.7 to 30 MeV

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MEASUREMENT OF THE NEUTRON-INDUCED FISSION CROSS SECTION
OF ^{232}Th RELATIVE TO ^{235}U FROM 0.7 TO 30 MeV

ABSTRACT

Continuing our fission cross-section ratio studies at Lawrence Livermore Laboratory, we have measured the $^{232}\text{Th}/^{235}\text{U}$ fission cross-section ratio from 0.7 to 30 MeV. Using the threshold method, we obtained a value of 0.1081 ± 0.0022 for the average cross-section ratio in the interval from 1.75 to 4.00 MeV.

PRELIMINARY RESULTS

We measured the fission cross section of ^{232}Th relative to that of ^{235}U , using ionization fission chambers at Lawrence Livermore Laboratory's 100-MeV electron linear accelerator. The time-of-flight technique was used to measure the cross-section ratio as a function of neutron energy over the energy range from 1 keV to 30 MeV. Using the threshold method,¹⁻³ we obtained a value of 0.1081 ± 0.0022 for the average cross-section ratio in the interval from 1.75 to 4.00 MeV. We conducted the measurement at the 15.7-m time-of-flight station.

Figures 1-3 show and Table 1 lists our preliminary data for the $^{232}\text{Th}/^{235}\text{U}$ ratio from 0.7 to 30 MeV. The lines shown in Figs. 1 and 2 were obtained by using files of evaluated fission cross sections.⁴

Figure 3 shows the fission cross-section ratio in the energy range 0.6 to 1.5 MeV. Below 0.7 MeV the cross-section ratio drops rapidly and the sensitivity of the present measurement limits us to the energy range above 0.7 MeV. Gross structure resonances are observed near 750 keV and 950 keV. Verification that these structures are from the $^{232}\text{Th}(n,f)$ cross section awaits further data analysis and a detailed isotopic analysis of the thorium sample. If the gross structures remain after these analyses are completed, a publication is planned.

The Cross Section Evaluation Working Group (CSEWG), responsible for the upcoming ENDF/B-V evaluations, requested this brief report. We plan a more complete and formal presentation of this measurement.

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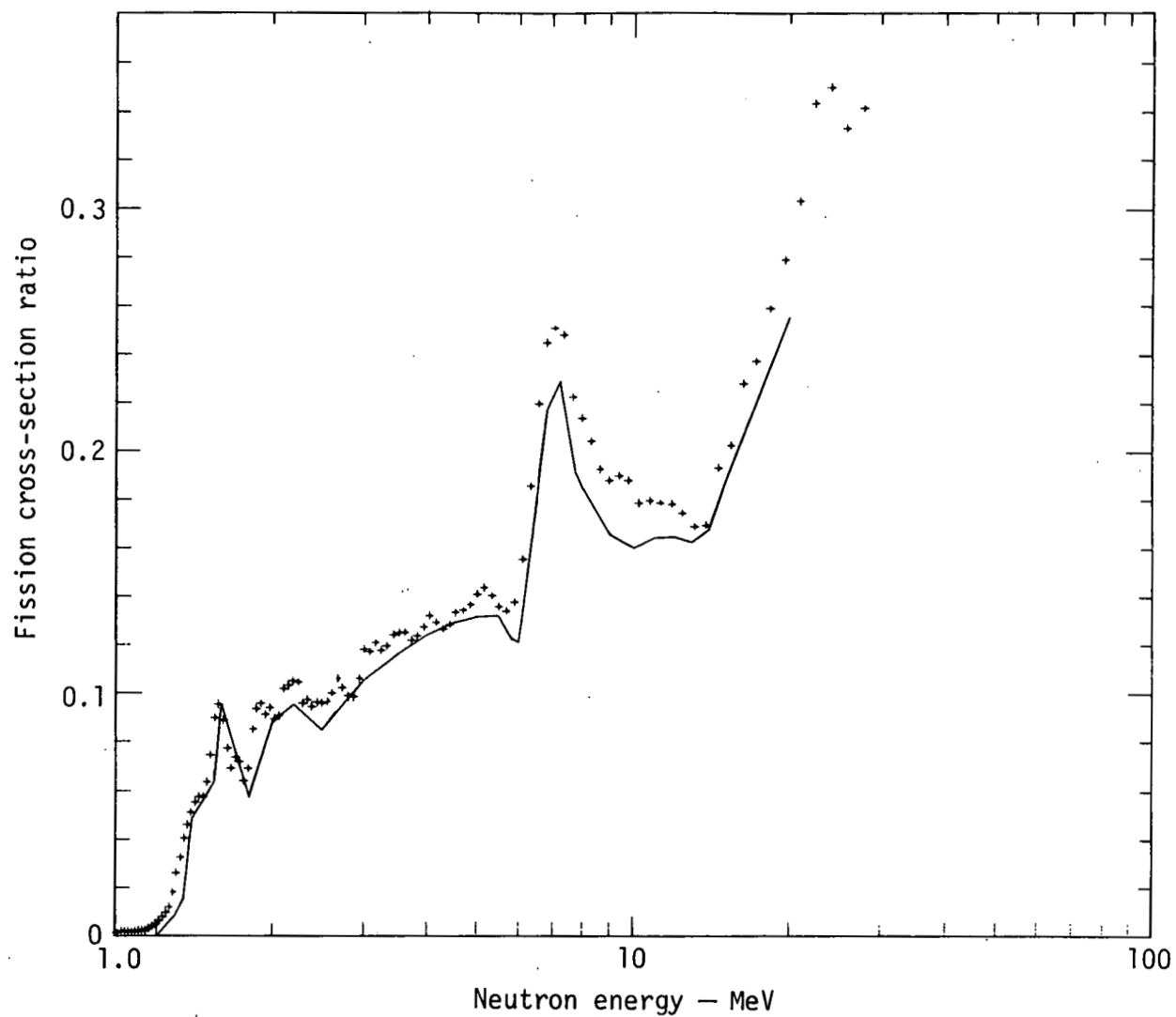


Fig. 1. Ratio of ^{232}Th to ^{235}U fission cross sections in the energy range 1 to 30 MeV. The line denotes the $^{232}\text{Th}/^{235}\text{U}$ ratio obtained by using the ENDF/B-IV evaluated fission cross-section files.

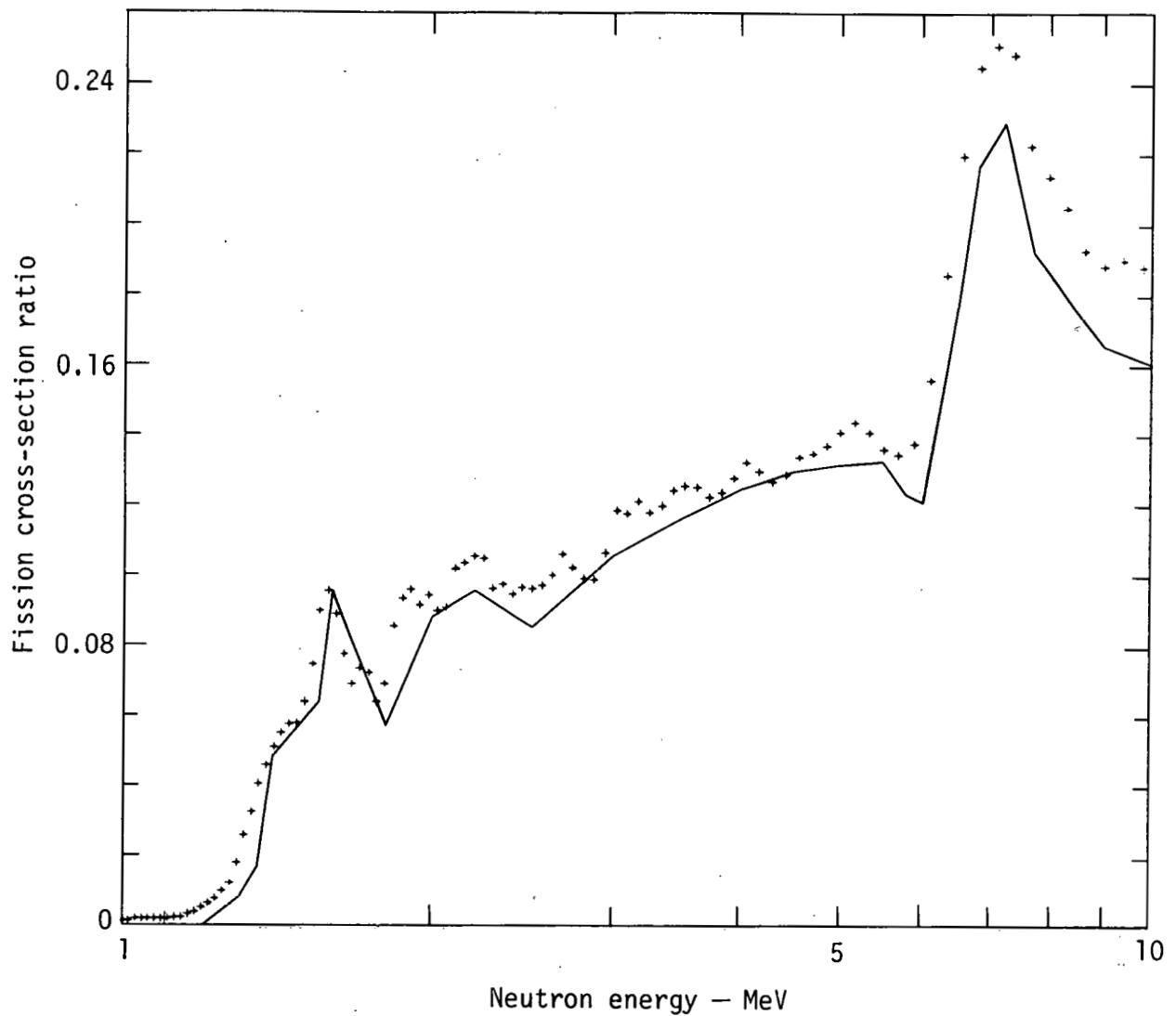


Fig. 2. Ratio of ^{232}Th to ^{235}U fission cross sections in the energy range 1 to 10 MeV. The line denotes the $^{232}\text{Th}/^{235}\text{U}$ ratio obtained by using the ENDF/B-IV evaluated fission cross-section files.

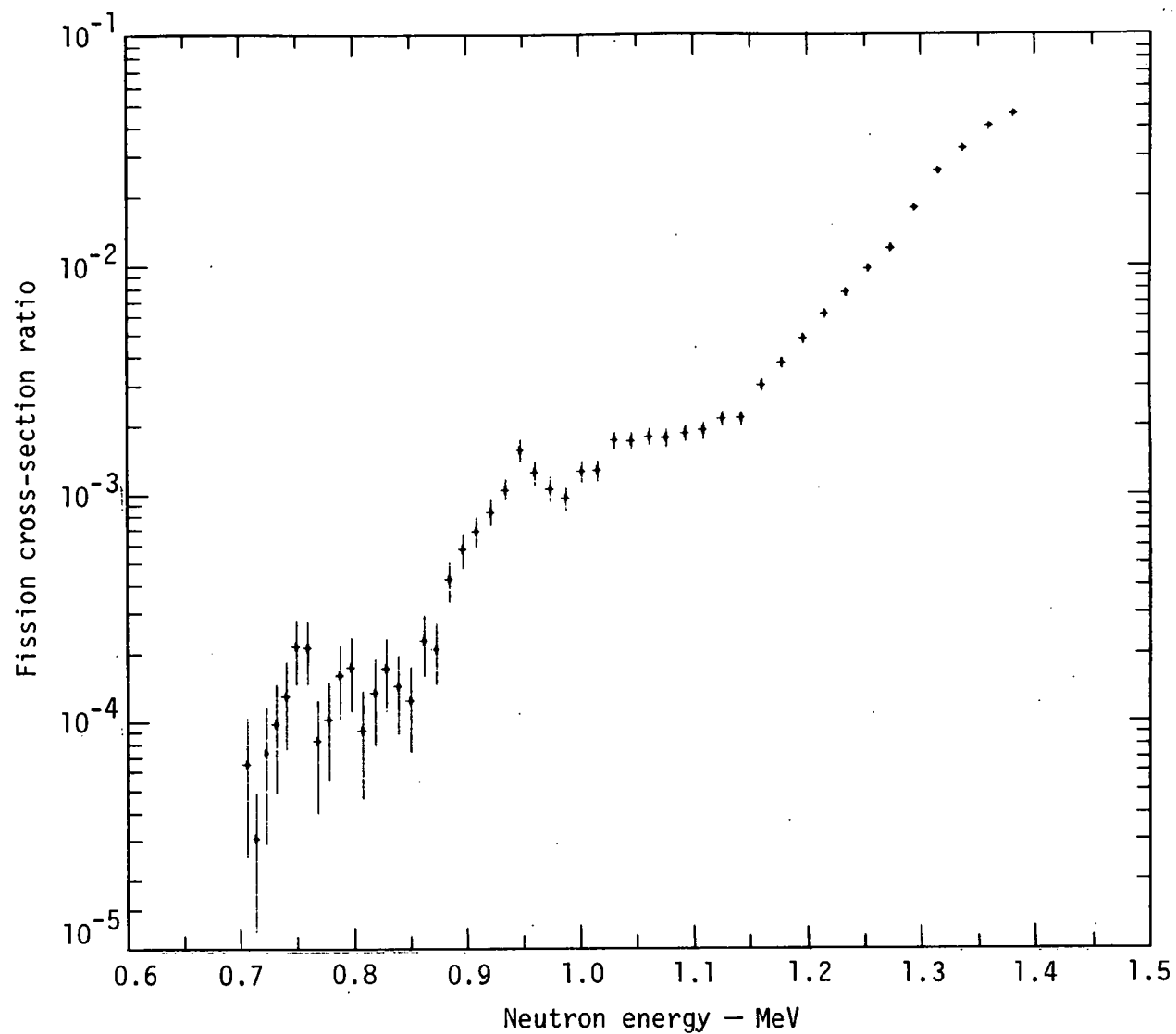


Fig. 3. Ratio of ^{232}Th to ^{235}U fission cross sections in the energy range 0.7 to 1.4 MeV. The statistical error bars, representing one standard deviation, are shown for each point.

Table 1. Fission cross-section ratio of ^{232}Th to ^{235}U .

| Neutron energy (MeV) | Ratio | Statistical uncertainty ^a (%) | Neutron energy (MeV) | Ratio | Statistical uncertainty ^a (%) |
|----------------------------|---------|--|----------------------------|---------|--|
| 0.6970 | 0 | | 1.294 | 0.01769 | 3.0 |
| 0.7053 | 0.00007 | 61.7 | 1.315 | 0.02562 | 2.5 |
| 0.7137 | 0.00003 | 61.6 | 1.336 | 0.03231 | 2.2 |
| 0.7224 | 0.00007 | 61.0 | 1.359 | 0.04035 | 2.0 |
| 0.7311 | 0.00010 | 51.1 | 1.381 | 0.04575 | 1.9 |
| 0.7401 | 0.00013 | 42.1 | 1.405 | 0.05073 | 1.8 |
| 0.7492 | 0.00021 | 31.9 | 1.428 | 0.05498 | 1.7 |
| 0.7584 | 0.00021 | 31.7 | 1.453 | 0.05736 | 1.7 |
| 0.7679 | 0.00008 | 52.1 | 1.478 | 0.05761 | 1.7 |
| 0.7775 | 0.00010 | 46.1 | 1.504 | 0.06358 | 1.6 |
| 0.7873 | 0.00016 | 36.0 | 1.530 | 0.07470 | 1.5 |
| 0.7973 | 0.00017 | 31.8 | 1.557 | 0.08975 | 1.4 |
| 0.8074 | 0.00009 | 60.2 | 1.585 | 0.09546 | 1.3 |
| 0.8178 | 0.00013 | 41.9 | 1.614 | 0.08895 | 1.4 |
| 0.8284 | 0.00017 | 36.0 | 1.643 | 0.07749 | 1.5 |
| 0.8392 | 0.00014 | 38.5 | 1.674 | 0.06888 | 1.7 |
| 0.8501 | 0.00012 | 41.6 | 1.705 | 0.07341 | 1.6 |
| 0.8614 | 0.00023 | 30.3 | 1.737 | 0.07201 | 1.7 |
| 0.8728 | 0.00021 | 30.3 | 1.770 | 0.06374 | 1.7 |
| 0.8845 | 0.00042 | 20.9 | 1.804 | 0.06894 | 1.6 |
| 0.8963 | 0.00057 | 17.6 | 1.838 | 0.08521 | 1.5 |
| 0.9085 | 0.00069 | 15.7 | 1.874 | 0.09340 | 1.5 |
| 0.9209 | 0.00083 | 14.0 | 1.911 | 0.09579 | 1.5 |
| 0.9335 | 0.00104 | 12.8 | 1.949 | 0.09136 | 1.5 |
| 0.9464 | 0.00156 | 11.5 | 1.988 | 0.09417 | 1.5 |
| 0.9596 | 0.00124 | 12.1 | 2.029 | 0.08966 | 1.5 |
| 0.9730 | 0.00105 | 12.9 | 2.070 | 0.09090 | 1.5 |
| 0.9868 | 0.00096 | 13.5 | 2.113 | 0.1018 | 1.5 |
| 1.001 | 0.00126 | 11.8 | 2.157 | 0.1035 | 1.5 |
| 1.015 | 0.00127 | 11.7 | 2.203 | 0.1054 | 1.5 |
| 1.030 | 0.00174 | 9.8 | 2.250 | 0.1047 | 1.5 |
| 1.045 | 0.00171 | 9.8 | 2.299 | 0.09605 | 1.7 |
| 1.060 | 0.00179 | 9.5 | 2.349 | 0.09743 | 1.7 |
| 1.076 | 0.00176 | 9.4 | 2.401 | 0.09455 | 1.7 |
| 1.092 | 0.00185 | 9.1 | 2.454 | 0.09642 | 1.7 |
| 1.108 | 0.00190 | 9.1 | 2.510 | 0.09608 | 1.7 |
| 1.125 | 0.00214 | 8.7 | 2.567 | 0.09699 | 1.8 |
| 1.142 | 0.00215 | 8.6 | 2.626 | 0.09996 | 1.8 |
| 1.159 | 0.00299 | 7.3 | 2.688 | 0.1061 | 1.8 |
| 1.177 | 0.00374 | 6.4 | 2.751 | 0.1023 | 1.8 |
| 1.195 | 0.00478 | 5.6 | 2.817 | 0.09916 | 1.8 |
| 1.214 | 0.00612 | 5.1 | 2.886 | 0.09861 | 1.9 |
| 1.233 | 0.00758 | 4.5 | 2.956 | 0.1062 | 1.8 |
| 1.253 | 0.00969 | 4.0 | 3.030 | 0.1184 | 1.8 |
| 1.273 | 0.01189 | 3.6 | 3.106 | 0.1174 | 1.8 |

Table 1. (Continued).

| Neutron energy (MeV) | Ratio | Statistical uncertainty ^a (%) | Neutron energy (MeV) | Ratio | Statistical uncertainty ^a (%) |
|----------------------------|--------|--|----------------------------|--------|--|
| 3.185 | 0.1210 | 1.8 | 8.295 | 0.2044 | 1.2 |
| 3.267 | 0.1177 | 1.8 | 8.647 | 0.1925 | 1.3 |
| 3.353 | 0.1197 | 1.9 | 9.021 | 0.1878 | 1.4 |
| 3.442 | 0.1242 | 1.8 | 9.420 | 0.1897 | 1.4 |
| 3.534 | 0.1254 | 1.8 | 9.846 | 0.1878 | 1.5 |
| 3.630 | 0.1250 | 1.8 | 10.30 | 0.1786 | 1.7 |
| 3.730 | 0.1222 | 1.9 | 10.79 | 0.1796 | 1.7 |
| 3.835 | 0.1236 | 1.9 | 11.31 | 0.1784 | 1.8 |
| 3.944 | 0.1276 | 1.8 | 11.88 | 0.1780 | 1.9 |
| 4.057 | 0.1320 | 1.8 | 12.49 | 0.1745 | 2.0 |
| 4.176 | 0.1295 | 1.8 | 13.14 | 0.1688 | 2.0 |
| 4.300 | 0.1267 | 1.9 | 13.85 | 0.1693 | 2.0 |
| 4.429 | 0.1285 | 1.8 | 14.62 | 0.1929 | 2.0 |
| 4.564 | 0.1337 | 1.8 | 15.45 | 0.2025 | 2.1 |
| 4.706 | 0.1346 | 1.8 | 16.36 | 0.2278 | 2.1 |
| 4.855 | 0.1368 | 1.8 | 17.35 | 0.2374 | 2.2 |
| 5.010 | 0.1408 | 1.8 | 18.44 | 0.2590 | 2.3 |
| 5.173 | 0.1436 | 1.8 | 19.63 | 0.2790 | 2.4 |
| 5.345 | 0.1407 | 1.8 | 20.94 | 0.3031 | 2.4 |
| 5.525 | 0.1359 | 1.7 | 22.39 | 0.3431 | 2.4 |
| 5.714 | 0.1342 | 1.7 | 24.00 | 0.3498 | 2.6 |
| 5.913 | 0.1376 | 1.6 | 25.79 | 0.3330 | 2.8 |
| 6.123 | 0.1555 | 1.5 | 27.80 | 0.3412 | 2.9 |
| 6.344 | 0.1856 | 1.3 | 30.05 | 0.3636 | 3.0 |
| 6.578 | 0.2195 | 1.2 | 32.58 | 0.4188 | 3.1 |
| 6.825 | 0.2447 | 1.1 | | | |
| 7.086 | 0.2508 | 1.1 | | | |
| 7.362 | 0.2479 | 1.1 | | | |
| 7.655 | 0.2223 | 1.1 | | | |
| 7.965 | 0.2134 | 1.2 | | | |

^aThis indicates a counting error expressed as one standard deviation. Total errors may be estimated by combining the normalization error of 2.0% and the estimated overall systematic error of 1% with the counting errors in the table.

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4. Evaluated Nuclear Data File/Format B -- Version IV. This evaluation (ENDF/B-IV) originates at the Brookhaven National Laboratory, Upton, N.Y.

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