

*Benchmark Analysis of  
MCNP<sup>TM</sup> ENDF/B-VI Iron*

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# BENCHMARK ANALYSIS OF MCNP<sup>TM</sup> ENDF/B-VI IRON

by

John D. Court and John S. Hendricks

## ABSTRACT

The MCNP ENDF/B-VI iron cross-section data was subjected to four benchmark studies as part of the Hiroshima/Nagasaki dose re-evaluation for the National Academy of Science and the Defense Nuclear Agency. The four benchmark studies were:

- the iron sphere benchmarks from the Lawrence Livermore Pulsed Spheres
- the Oak Ridge National Laboratory Fusion Reactor Shielding Benchmark
- a 76-cm diameter iron sphere benchmark done at the University of Illinois
- the Oak Ridge National Laboratory Benchmark for Neutron Transport through Iron

MCNP4A was used to model each benchmark and computational results from the ENDF/B-VI iron evaluations were compared to ENDF/B-IV, ENDF/B-V, the MCNP Recommended Data Set (which includes Los Alamos National Laboratory Group T-2 evaluations), and experimental data. The results show that the ENDF/B-VI iron evaluations are as good as, or better than, previous data sets.

## I. INTRODUCTION

The discrepancy between the calculated and in situ measurements of the thermal neutron activation doses at both Hiroshima and Nagasaki have been recognized since the final report describing the 1986 Dose System, DS-86.<sup>1</sup> With the release of the new MCNP4A<sup>2</sup> ENDF/B-VI<sup>3,4</sup> evaluation for iron, it is hoped that this new data will provide better calculational matches to the integral experiments, warranting a new evaluation of the Hiroshima source spectrum.<sup>5</sup>

In this report, we compare four iron neutron data libraries: ENDF/B-V, ENDF/B-VI, the MCNP Recommended Library containing T-2 evaluations, and in some cases, ENDF/B-IV. In general, the MCNP Recommended Library appears best, but the difference between the results from the different libraries is, on the most part, small. The MCNP Recommended iron cross section, also referred to as the T-2 iron evaluation, has MCNP ZAID identification 26000.55c and is a special iron evaluation developed for the Fusion Materials Irradiation Facility (FMIT) in Hanford, Washington.<sup>6</sup> A major improvement to the iron cross-section data set in ENDF/B-VI is the addition of isotopic cross sections. Whereas ENDF/B-IV, ENDF/B-V, and the MCNP Recommended Libraries have an elemental iron cross-section data file, ENDF/B-VI contains the four naturally occurring isotopes of iron. Table I shows the different iron compositions of the four data sets.

MCNP, a general-purpose Monte Carlo N-Particle code, can be used for neutron, photon, electron, or coupled neutron/photon/electron transport and includes the ability to calculate eigenvalues for critical systems. The neutron cross-section data are pointwise continuous, and all reactions given in a particular cross-section evaluation are accounted for. Thermal neutrons are described by both the free gas and  $S(\alpha, \beta)$  models. MCNP4A is the most recent version which includes ENDF/B-VI physics, among other new features. An assortment of variance reduction techniques enables MCNP4A to tackle deep penetration and streaming problems with reduced computational loads. Of particular importance to this study, the ENDF/B-VI iron evaluation includes the new Kalbach-87 formalism (File 6-Law 1-Lang 2), which has coupled energy-angle scattering.

TABLE I. Iron Data Set Comparisons.

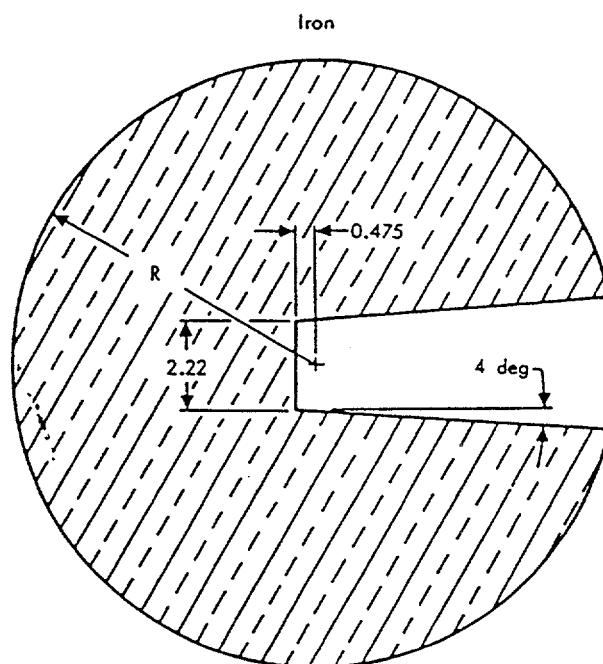
| ENDF/B-IV |      | ENDF/B-V  |      | MCNP Rec. |      | ENDF/B-VI |       |
|-----------|------|-----------|------|-----------|------|-----------|-------|
| Zaid      | At % | Zaid      | At % | Zaid      | At % | Zaid      | At %  |
| 26000.11c | 100  | 26000.50c | 100  | 26000.55c | 100  | 26054.60c | 5.90  |
|           |      |           |      |           |      | 26056.60c | 91.72 |
|           |      |           |      |           |      | 26057.60c | 2.10  |
|           |      |           |      |           |      | 26058.60c | 0.28  |

The four benchmark experiments chosen for this study consisted of an assortment of geometries composed of iron or high-carbon steel. Several source spectra were also used to adequately cover the full neutron energy range. The Lawrence Livermore Pulsed Sphere experiments<sup>7</sup> included two iron spheres of 0.9 and 4.8 mean free paths, containing a 14-MeV pulsed D-T neutron source in the center. The second benchmark calculation was the Oak Ridge National Laboratory Fusion Shielding Benchmark,<sup>8,9</sup> consisting of a monodirectional 14 MeV D-T neutron source incident on various laminated slab shields composed of SS-304 and borated polyethylene. The third benchmark model was a 76-cm diameter iron sphere<sup>10,11</sup> containing a 15.3-cm diameter void with D-T and <sup>252</sup>Cf spectra for separate neutron source calculations. We were unable to locate experimental data for this benchmark, but all four iron libraries were compared. The last benchmark was an Oak Ridge fission benchmark through iron and steel.<sup>12</sup> A beam of neutrons from a reactor was incident on four iron slabs of increasing thickness, and three different Bonner Ball measurements were taken at three different angles. Although experimental data for this benchmark was available, our interpretation of the problem specification is apparently inadequate, so only the comparisons between the four libraries are meaningful.

## II. LAWRENCE LIVERMORE PULSED SPHERES

### A. Experimental Setup

In the 1960's, the Lawrence Livermore Laboratory instituted an extensive pulsed sphere program to measure, with relatively good resolution, the neutron spectra from spherical targets bombarded with 14 MeV neutrons in order to provide benchmark data for neutron transport codes and nuclear cross sections.<sup>13</sup> Two of the three iron spheres were modeled using MCNP. Figure 1 shows the geometry of the iron spheres.<sup>13</sup> The opening into the sphere is to accommodate a low mass target assembly containing a thin tritiated titanium disk, which utilized the  $T(d,n)^4\text{He}$  reaction when bombarded with a 400 keV  $D^+$  ion beam. The result was a nearly isotropic source of 14 MeV neutrons.



| $\lambda$ | R     |
|-----------|-------|
| 0.9       | 4.46  |
| 4.8       | 22.40 |

All dimensions in centimeters

Fig. 1. Geometry of the spherical iron targets.

The 0.9 mfp sphere was fabricated from Armco Ingot Iron. The 4.8 mfp sphere was fabricated from ASTM-A7 iron. The elemental composition of the MCNP model is shown in Table II. Further details of the problem setup can be found in the MCNP input deck found in Table A.1 in the appendix.

## B. Results and Discussion

The time of flight spectrum of the neutrons leaving each sphere was measured. The results were integrated in two different time bins. The time bins were chosen to correspond roughly to the amount of time that a particle of the given energy would take to travel from the center of the sphere to the detector without collision. The neutron detectors were not located at the same distance from the center of the sphere for each experiment. The comparisons between ENDF/B-V, MCNP Recommended, and ENDF/B-VI are contained in Table III. Figures 2 through 5 show the measured spectra plotted against the calculated spectra for the 0.9 mfp iron sphere. Figures 6 through 9 are the spectra for the 4.8 mfp iron sphere.

In all cases, ENDF/B-VI appears somewhat better than ENDF/B-V, but not quite as good as the MCNP Recommended Library, which is a modified ENDF/B-V set with a LANL group T-2 evaluation, 26000.55c.

TABLE II. Elemental Composition of the Iron Spheres.

| Element | Atom %                 |
|---------|------------------------|
| Fe      | 97.0                   |
| C       | 1.2                    |
| Mn      | 1.0                    |
| P       | 0.7                    |
| S       | 0.1                    |
| $\rho$  | 7.85 g/cm <sup>3</sup> |

TABLE III. Ratio of Calculated to Experimental Values for the Livermore Pulsed Spheres.

| Radius (mfp) | Data Set  | 12-16 MeV | 2-16 MeV |
|--------------|-----------|-----------|----------|
| 0.9          | ENDF/B-V  | 0.989     | 0.984    |
|              | MCNP Rec. | 1.001     | 1.007    |
|              | ENDF/B-VI | 0.999     | 1.006    |
| 4.8          | ENDF/B-V  | 0.866     | 0.834    |
|              | MCNP Rec. | 0.934     | 0.946    |
|              | ENDF/B-VI | 0.903     | 0.952    |

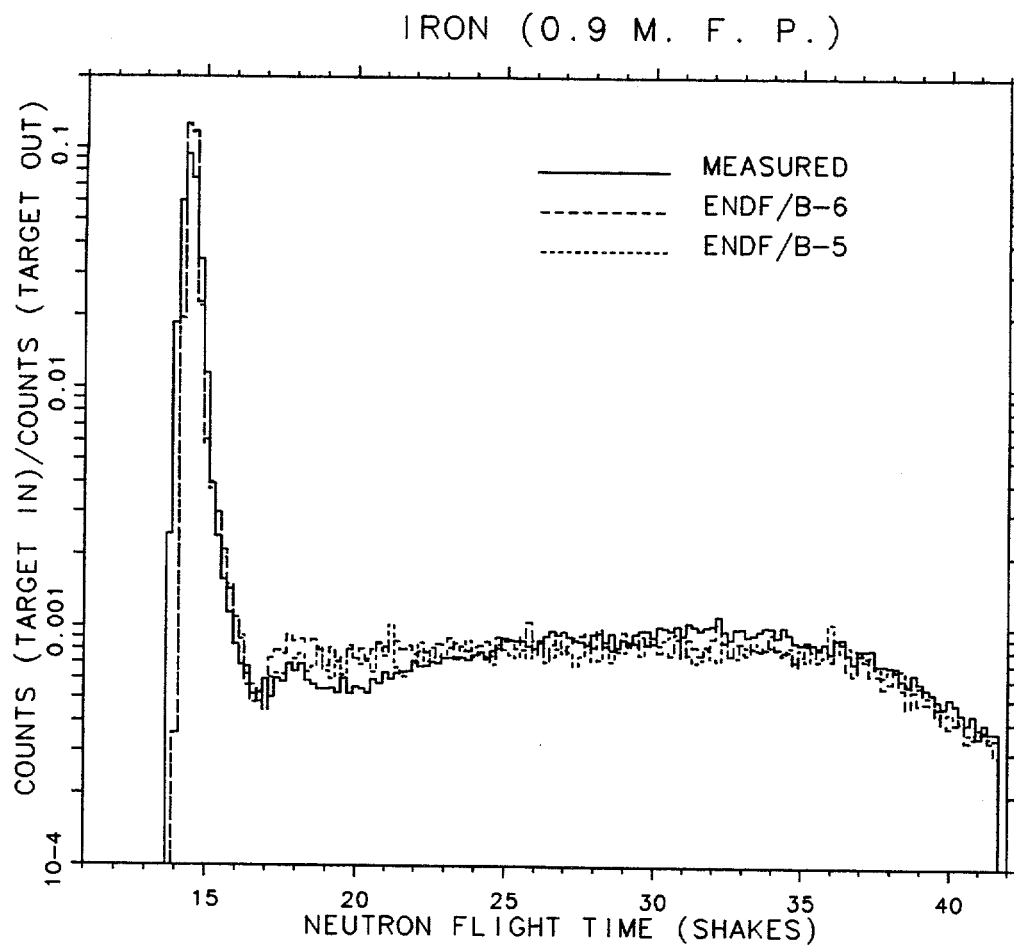


Fig. 2. Plot of experimental and calculated count rates as a function of time for an iron sphere with 0.9 mean free path radius. The detector was located 766.0 cm from the center of the sphere at 30 degrees with respect to the deuteron beam. (1 shake = 10 ns)

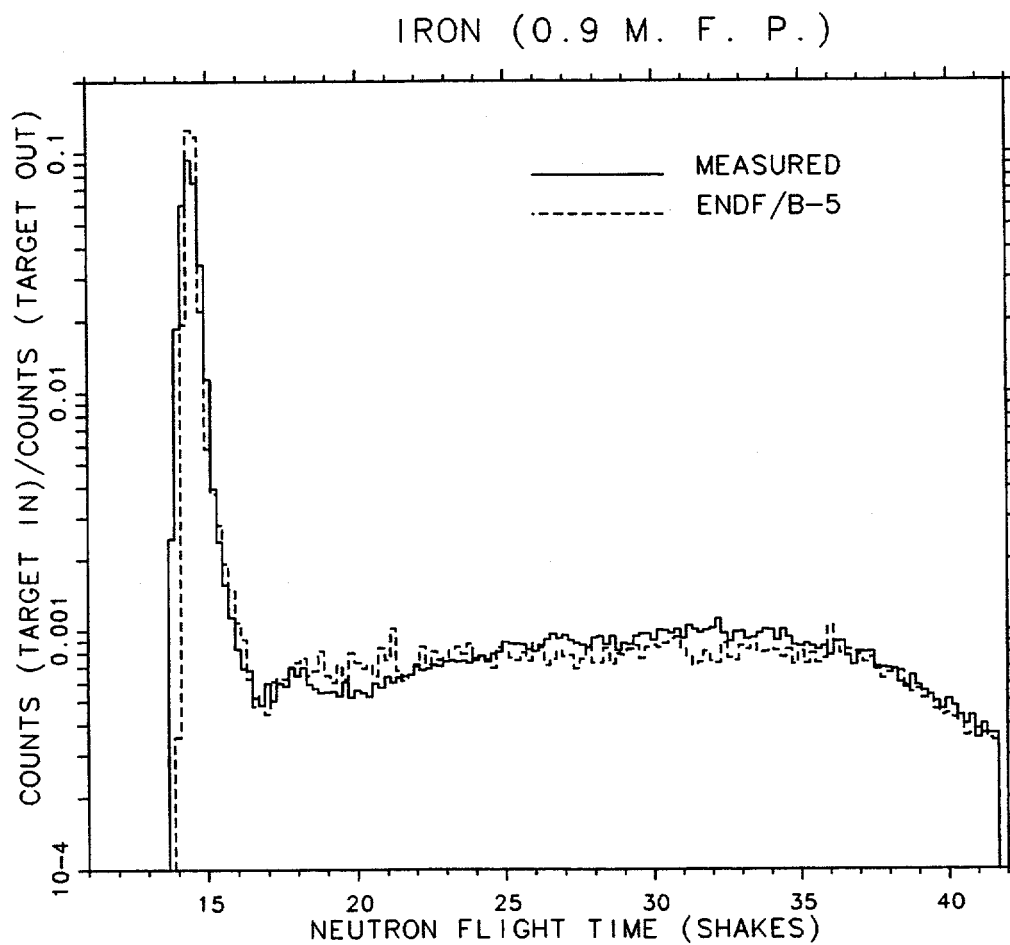


Fig. 3. Plot of experimental and ENDF/B-V calculated count rates for the iron sphere of 0.9 mean free path radius.

IRON (0.9 M. F. P.)

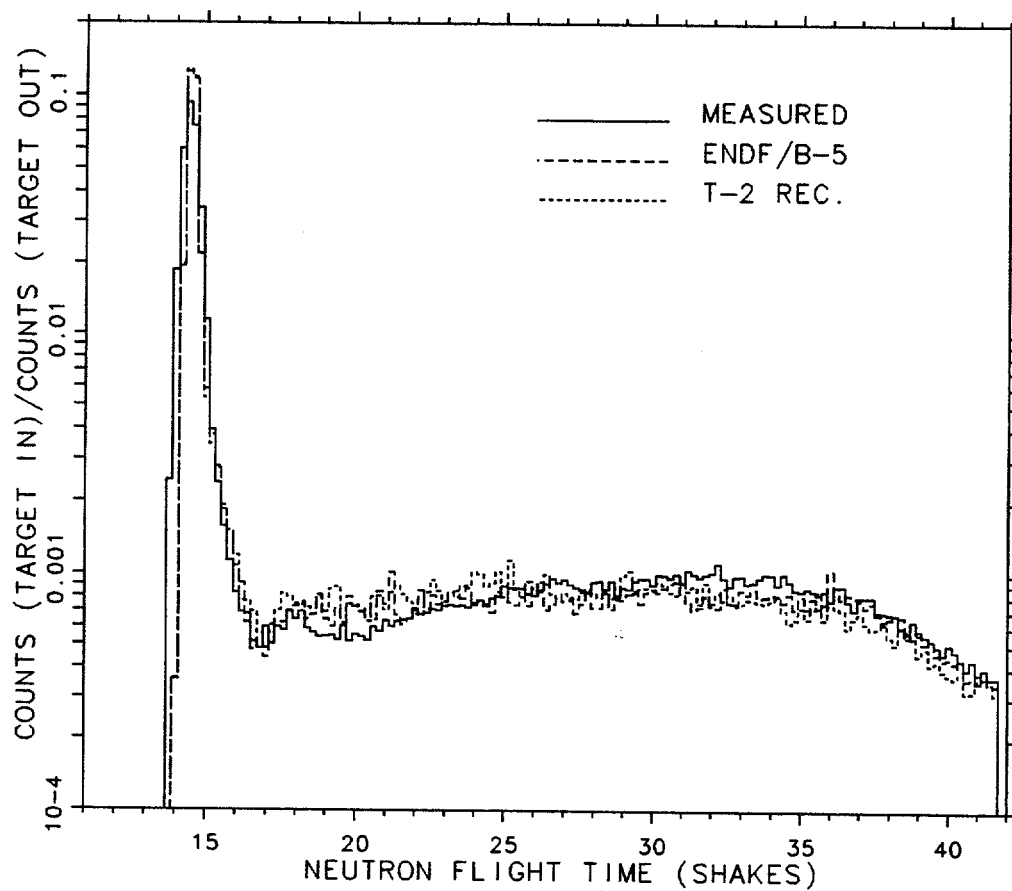


Fig. 4. Plot of experimental, ENDF/B-V, and MCNP Recommended calculated rates for the iron sphere with 0.9 mean free path radius.

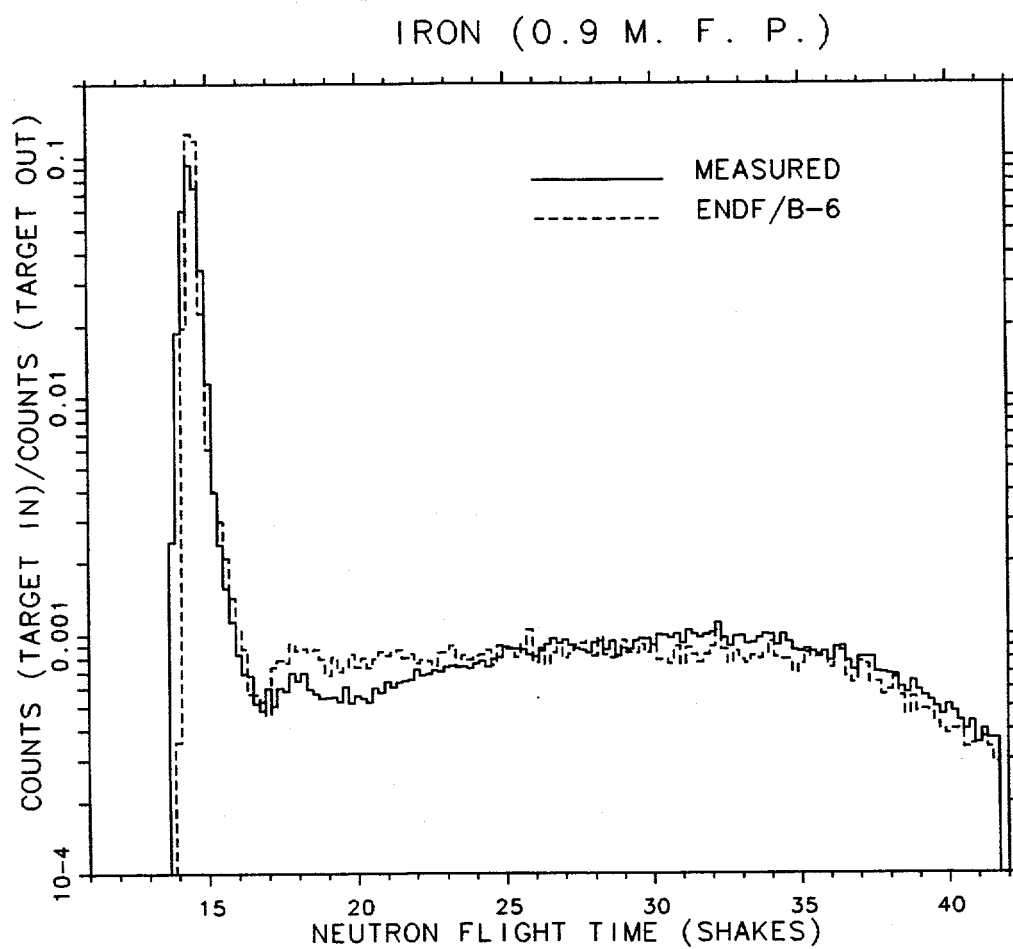


Fig. 5. Plot of experimental and ENDF/B-VI calculated count rates for the iron sphere of 0.9 mean free path radius.

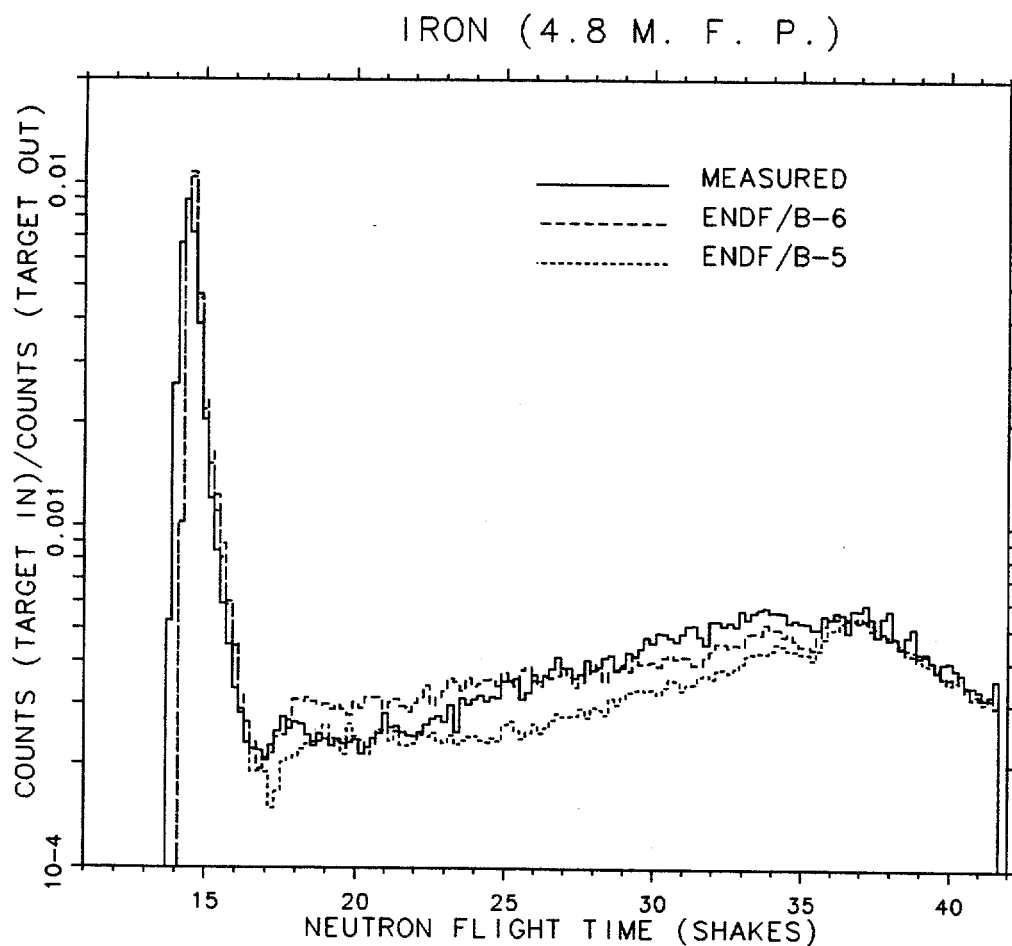


Fig. 6. Plot of experimental and calculated count rates as a function of time for an iron sphere with 4.8 mean free path radius. The detector was located 766.0 cm from the center of the sphere at 30 degrees with respect to the deuteron beam. (1 shake = 10 ns)

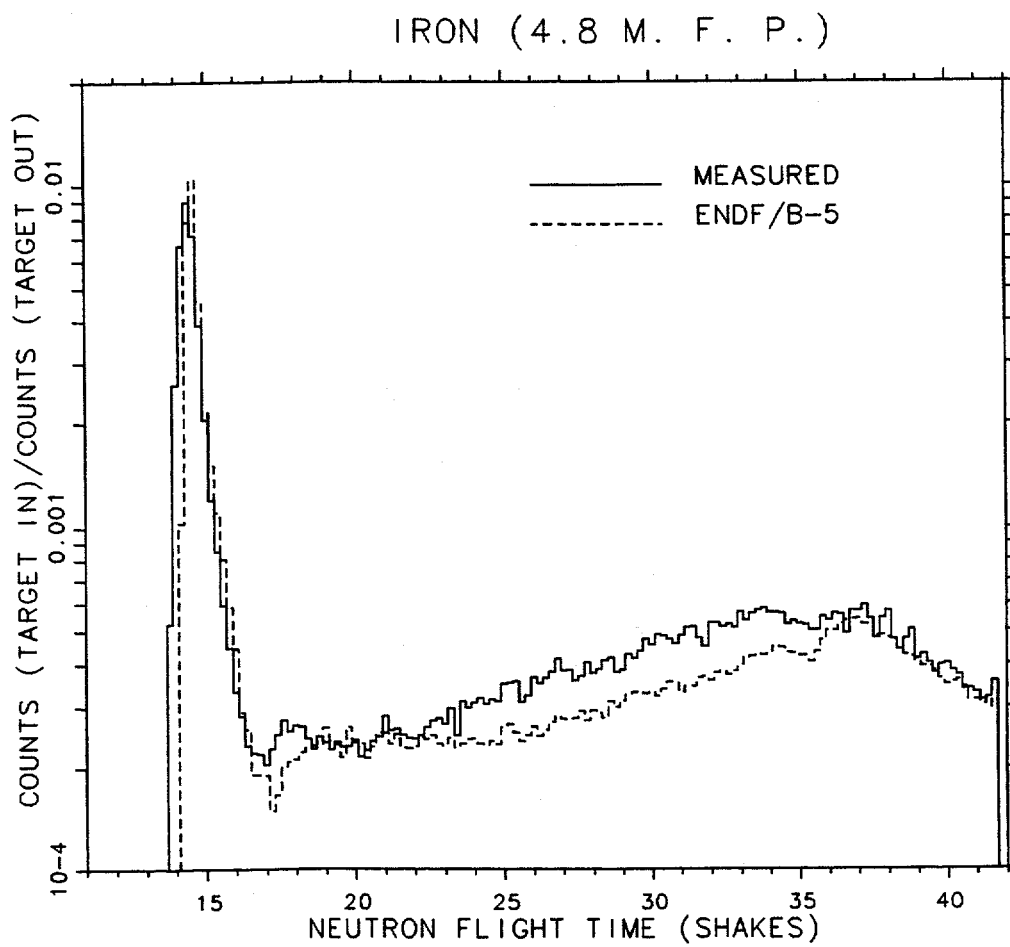


Fig. 7. Plot of experimental and ENDF/B-V calculated count rates for the iron sphere of 4.8 mean free path radius.

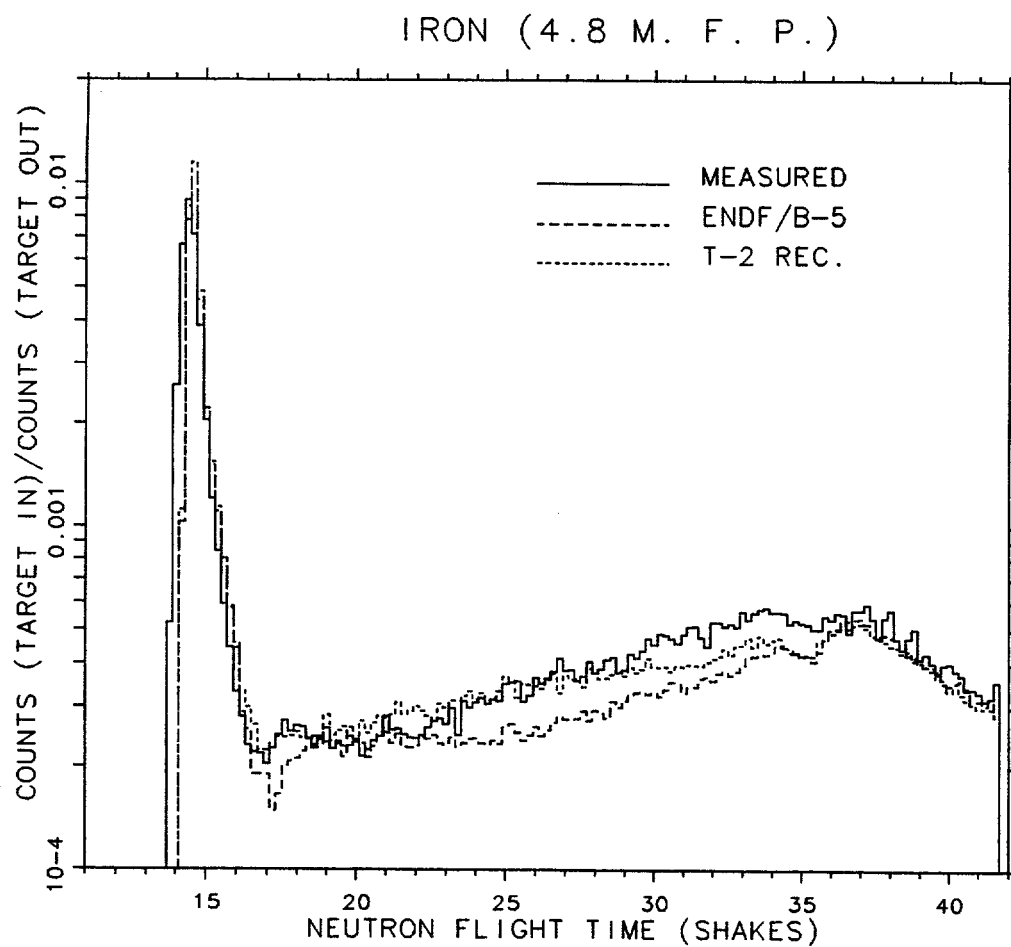


Fig. 8. Plot of experimental, ENDF/B-V, and MCNP Recommended calculated rates for the iron sphere with 4.8 mean free path radius.

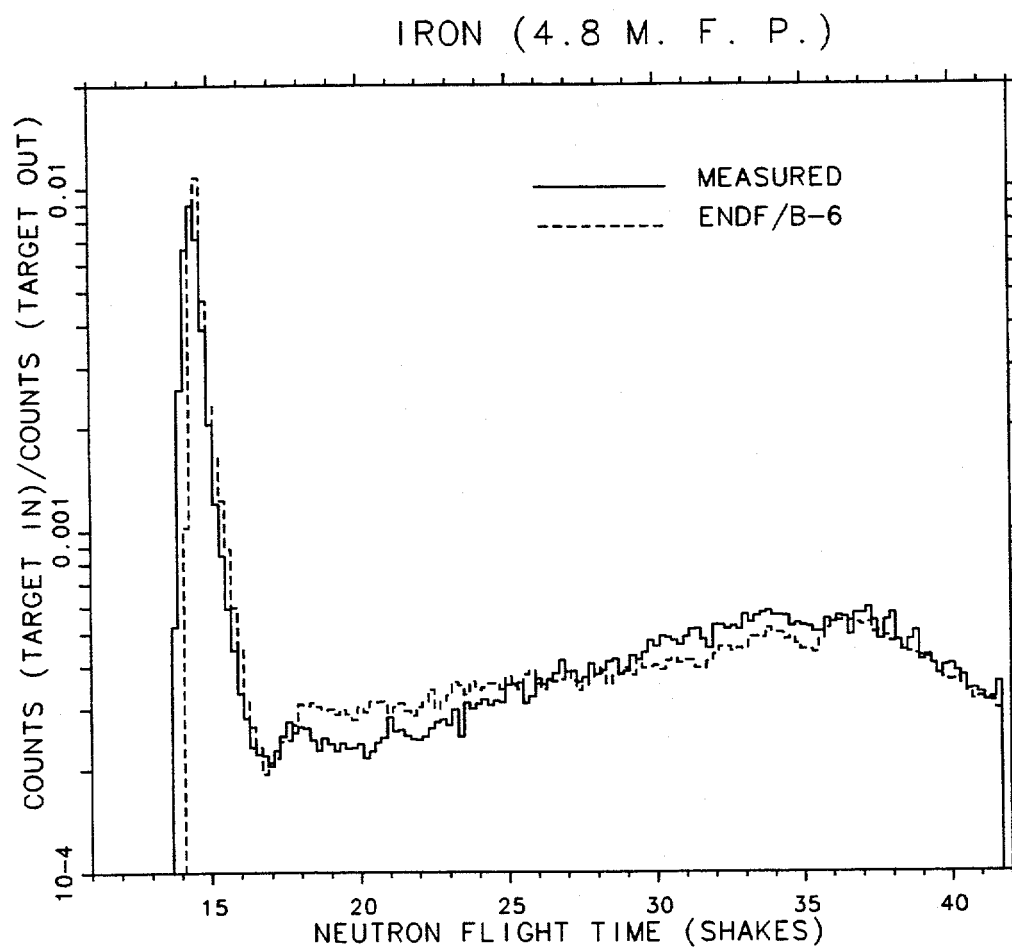


Fig. 9. Plot of experimental and ENDF/B-VI calculated count rates for the iron sphere of 4.8 mean free path radius.

### III. FUSION REACTOR SHIELDING BENCHMARK

#### A. Experimental Setup

A benchmark experiment was conducted at Oak Ridge National Laboratory in 1980 in order to simulate the radiation exposure that would be present at the first wall of a fusion reactor. Again, the  $T(d,n)^4\text{He}$  reaction was utilized by bombarding a tritiated target with a deuteron beam, resulting in a nearly-isotropic source of 14 MeV neutrons. The tritiated titanium target was imbedded inside an iron cavity liner which served as a spectrum modifier and made the neutron spectrum incident on the experimental shield configuration similar to the spectrum incident on the first wall of a fusion reactor. Figure 10 is a sketch of the experimental layout.<sup>8</sup>

The 14 MeV neutrons passed through several different configurations of laminated slabs composed of SS-304 and borated polyethylene. Table IV shows the shielding configuration compositions. The composition of the materials used in the benchmark is shown in Table V. The neutron and photon energy spectra were measured by detectors placed both on- and off-axis beyond the laminated shielding. An example MCNP input deck for this problem can be found in Table A.2 in the appendix.

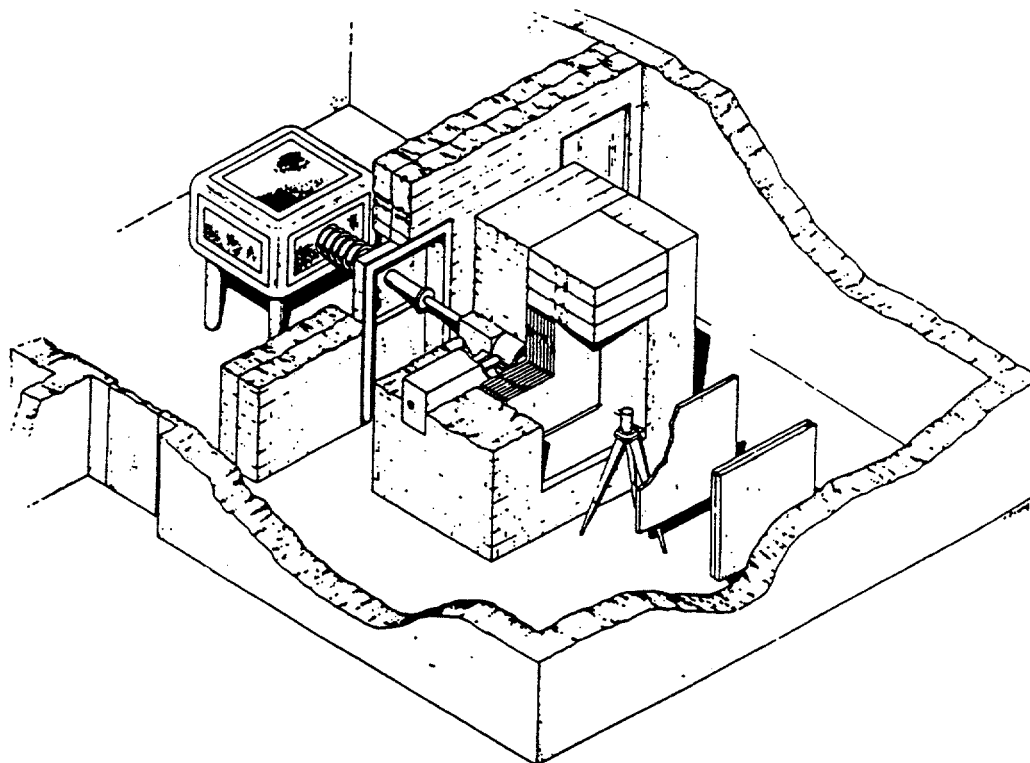


Fig. 10. Fusion Shielding Benchmark Experimental Layout.

TABLE IV. Composition and Thickness of SS-304 and Borated Polyethylene Slabs

| Configuration                         | Composition         |        |                 |                                   |      |        | Total Slab Thickness (cm) |
|---------------------------------------|---------------------|--------|-----------------|-----------------------------------|------|--------|---------------------------|
|                                       | SS-304 <sup>a</sup> | SS-304 | BP <sup>b</sup> | SS-304                            | BP   | SS-304 |                           |
|                                       | Slab Thickness (cm) |        |                 |                                   |      |        |                           |
| 1                                     | 0                   |        |                 |                                   |      |        | 0                         |
| 2                                     | 15.24               |        |                 |                                   |      |        | 15.24                     |
| 3                                     | 30.48               |        |                 |                                   |      |        | 30.48                     |
| 4                                     | 30.48               | 5.08   | 5.08            |                                   |      |        | 40.64                     |
| 5                                     | 30.48               | 5.08   | 5.08            | 5.08                              |      |        | 45.72                     |
| 6                                     | 30.48               | 5.08   | 5.08            | 5.08                              | 5.08 |        | 50.80                     |
| 7                                     | 30.49               | 5.08   | 5.08            | 5.08                              | 5.08 | 5.08   | 55.88                     |
| <sup>a</sup> Stainless Steel Type 304 |                     |        |                 | <sup>b</sup> Borated Polyethylene |      |        |                           |

TABLE V. Fusion Shielding Benchmark Material Composition.

| Number Density (atom/cm Barn)     |                       |                       |                       |                                 |                       |                        |
|-----------------------------------|-----------------------|-----------------------|-----------------------|---------------------------------|-----------------------|------------------------|
| Element                           | Concrete              | Air                   | Iron                  | SS-304                          | BP <sup>a</sup>       | LP <sup>b</sup>        |
| <sup>1</sup> H                    | 7.86x10 <sup>-3</sup> |                       |                       |                                 | 7.13x10 <sup>-2</sup> | 5.926x10 <sup>-2</sup> |
| <sup>10</sup> B                   |                       |                       |                       |                                 | 4.87x10 <sup>-4</sup> |                        |
| <sup>11</sup> B                   |                       |                       |                       |                                 | 1.97x10 <sup>-3</sup> |                        |
| C                                 |                       |                       |                       |                                 | 3.41x10 <sup>-2</sup> | 3.338x10 <sup>-2</sup> |
| <sup>14</sup> N                   |                       | 3.64x10 <sup>-5</sup> |                       |                                 |                       |                        |
| <sup>16</sup> O                   | 4.39x10 <sup>-2</sup> | 9.74x10 <sup>-6</sup> |                       |                                 | 3.64x10 <sup>-3</sup> | 1.125x10 <sup>-2</sup> |
| <sup>23</sup> Na                  | 1.05x10 <sup>-3</sup> |                       |                       |                                 |                       |                        |
| Mg                                | 1.40x10 <sup>-4</sup> |                       |                       |                                 |                       |                        |
| <sup>27</sup> Al                  | 2.39x10 <sup>-3</sup> |                       |                       |                                 |                       |                        |
| Si                                | 1.58x10 <sup>-2</sup> |                       |                       |                                 |                       |                        |
| K                                 | 6.90x10 <sup>-4</sup> |                       |                       |                                 |                       |                        |
| Ca                                | 2.92x10 <sup>-3</sup> |                       |                       |                                 |                       |                        |
| Cr                                |                       |                       |                       | 1.77x10 <sup>-2</sup>           |                       |                        |
| <sup>55</sup> Mn                  |                       |                       |                       | 1.77x10 <sup>-3</sup>           |                       |                        |
| Fe                                | 3.10x10 <sup>-4</sup> |                       | 8.48x10 <sup>-2</sup> | 6.02x10 <sup>-2</sup>           |                       |                        |
| Ni                                |                       |                       |                       | 7.83x10 <sup>-3</sup>           |                       |                        |
| <sup>6</sup> Li                   |                       |                       |                       |                                 |                       | 5.565x10 <sup>-4</sup> |
| <sup>7</sup> Li                   |                       |                       |                       |                                 |                       | 6.944x10 <sup>-3</sup> |
| <sup>a</sup> Borated Polyethylene |                       |                       |                       | <sup>b</sup> Lithiated Paraffin |                       |                        |

## B. Results and Discussion

Four configurations were modeled in MCNP, configurations 1, 2, 3, and 7. Table VI gives the positions of the detectors relative to the neutron source in the MCNP reference coordinate system for the four configurations.<sup>14</sup> The detector coordinates in the MCNP input files are relative to the reference coordinate system. Only neutron flux tallies have been reported in this publication.

The calculated results were integrated over five different energy ranges and compared to the experimental confidence levels. These results, presented in Table VII, indicate that the integration is above the upper limit with a value greater than one, below the lower limit by a value less than one, and within the experimental limits by a value equal to one.

In these integral results, the recommended MCNP data library and ENDF/B-VI returned much the same results, which are better than the ENDF/B-V results.

Experimental data was taken in the form of experimental upper and experimental lower bounds. Each configuration and detector position was modeled in MCNP and plotted against the experimental upper and lower bounds in Figures 11 through 34.

Again, ENDF/B-VI and the MCNP Recommended Library results appear better than the ENDF/B-V results, especially for Configuration 7.

TABLE VI. MCNP Detector Tally Positions

| Shielding Configuration | Coordinates (cm)                                     |
|-------------------------|------------------------------------------------------|
| 1                       | on axis: (0, 154.5, 0)                               |
| 2                       | on axis: (0, 154.5, 0)                               |
| 3                       | on axis: (0, 154.5, 0)<br>off axis: (-100, 159.2, 0) |
| 7                       | on axis: (0, 154.5, 0)<br>off axis: (46, 154.5, 0)   |

TABLE VII. Fusion Reactor Shielding Integrated Energy Group Comparisons

| Configuration | Detector Position | Energy Group (MeV) | ENDF/B-V | T-2 Rec. | ENDF/B-VI |
|---------------|-------------------|--------------------|----------|----------|-----------|
| 1             | On                | 0-2                | 1.249    | 1.157    | 1.164     |
|               |                   | 2-5                | 1.140    | 1.143    | 1.140     |
|               |                   | 5-10               | 1.000    | 1.000    | 1.000     |
|               |                   | 10-13              | 0.934    | 0.955    | 1.109     |
|               |                   | > 13               | 1.116    | 1.100    | 0.949     |
| 2             | On                | 0-2                | 1.003    | 0.997    | 0.982     |
|               |                   | 2-5                | 0.981    | 1.000    | 1.012     |
|               |                   | 5-10               | 0.865    | 1.000    | 1.000     |
|               |                   | 10-13              | 1.000    | 1.056    | 1.054     |
|               |                   | > 13               | 1.035    | 1.085    | 1.043     |
| 3             | On                | 0-2                | 0.979    | 1.000    | 0.970     |
|               |                   | 2-5                | 0.875    | 0.999    | 1.000     |
|               |                   | 5-10               | 0.770    | 0.970    | 1.000     |
|               |                   | 10-13              | 0.949    | 1.000    | 1.000     |
|               |                   | > 13               | 0.953    | 1.039    | 0.972     |
|               | Off               | 0-2                | 1.258    | 1.301    | 1.255     |
|               |                   | 2-5                | 1.000    | 1.145    | 1.127     |
|               |                   | 5-10               | 0.869    | 1.000    | 1.018     |
|               |                   | 10-13              | 0.910    | 1.000    | 1.000     |
|               |                   | > 13               | 1.170    | 1.356    | 1.217     |
| 7             | On                | 0-2                | 0.798    | 0.901    | 0.842     |
|               |                   | 2-5                | 0.823    | 0.997    | 0.961     |
|               |                   | 5-10               | 0.848    | 1.000    | 1.000     |
|               |                   | 10-13              | 0.910    | 1.000    | 1.000     |
|               |                   | > 13               | 1.000    | 1.097    | 1.038     |
|               | Off               | 0-2                | 0.736    | 0.822    | 0.793     |
|               |                   | 2-5                | 0.757    | 0.948    | 0.921     |
|               |                   | 5-10               | 0.765    | 0.951    | 1.000     |
|               |                   | 10-13              | 0.870    | 1.000    | 1.000     |
|               |                   | > 13               | 0.907    | 1.016    | 0.977     |

CONFIGURATION 1 - ON AXIS  
ENDF/B-5

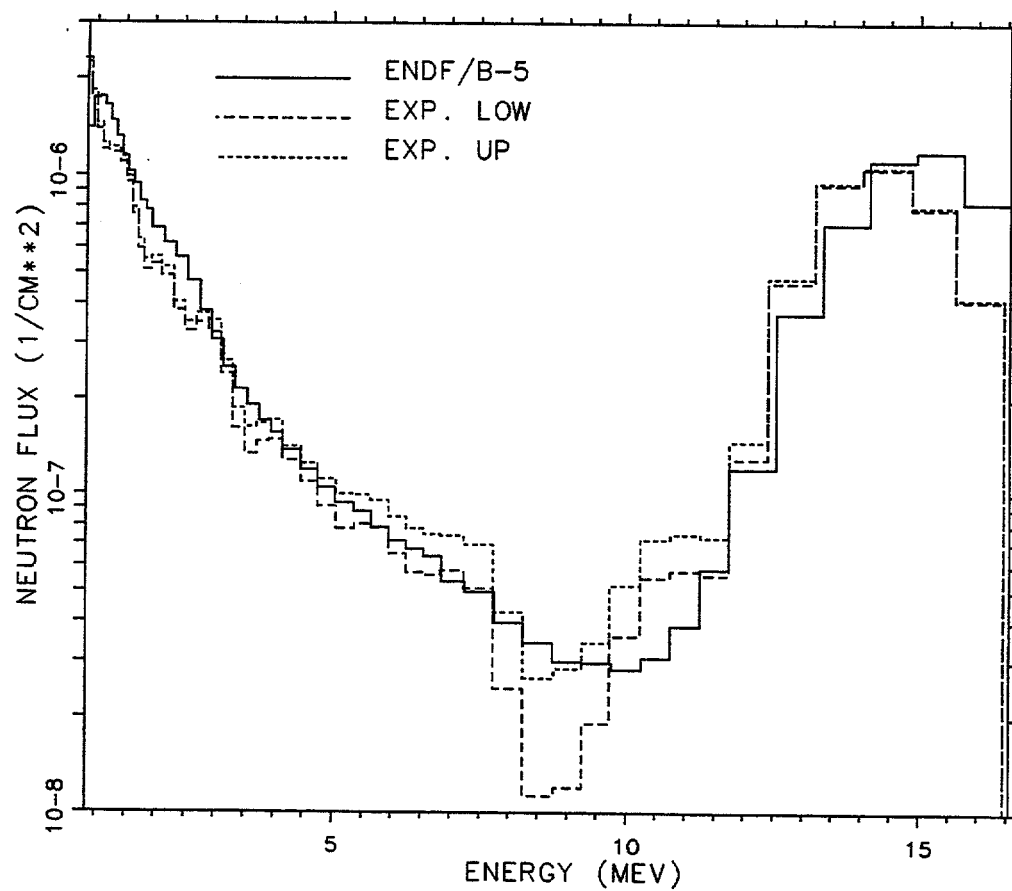


Fig. 11. Plot of ENDF/B-V calculated and experimental upper and lower confidence levels for configuration 1 with the detector on axis.

CONFIGURATION 1 - ON AXIS  
T-2 REC.

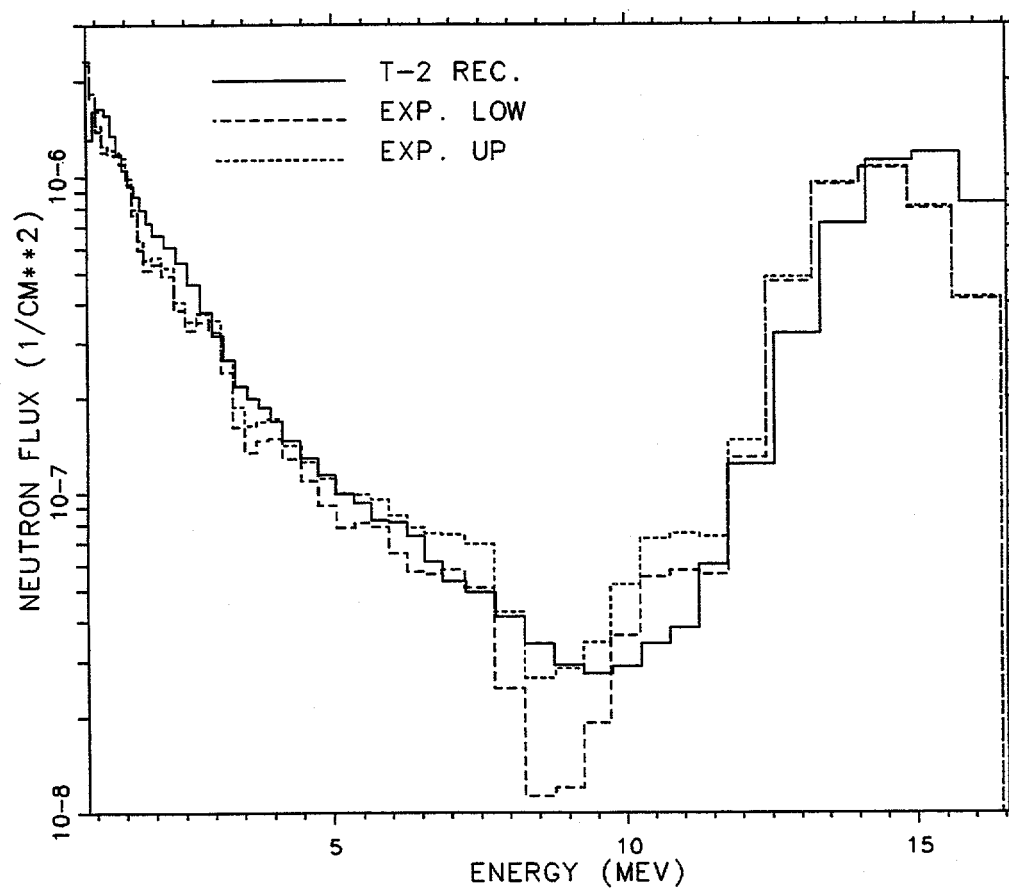


Fig. 12. Plot of MCNP Recommended calculated and experimental upper and lower confidence levels for configuration 1 with the detector on axis.

CONFIGURATION 1 - ON AXIS  
ENDF/B-6

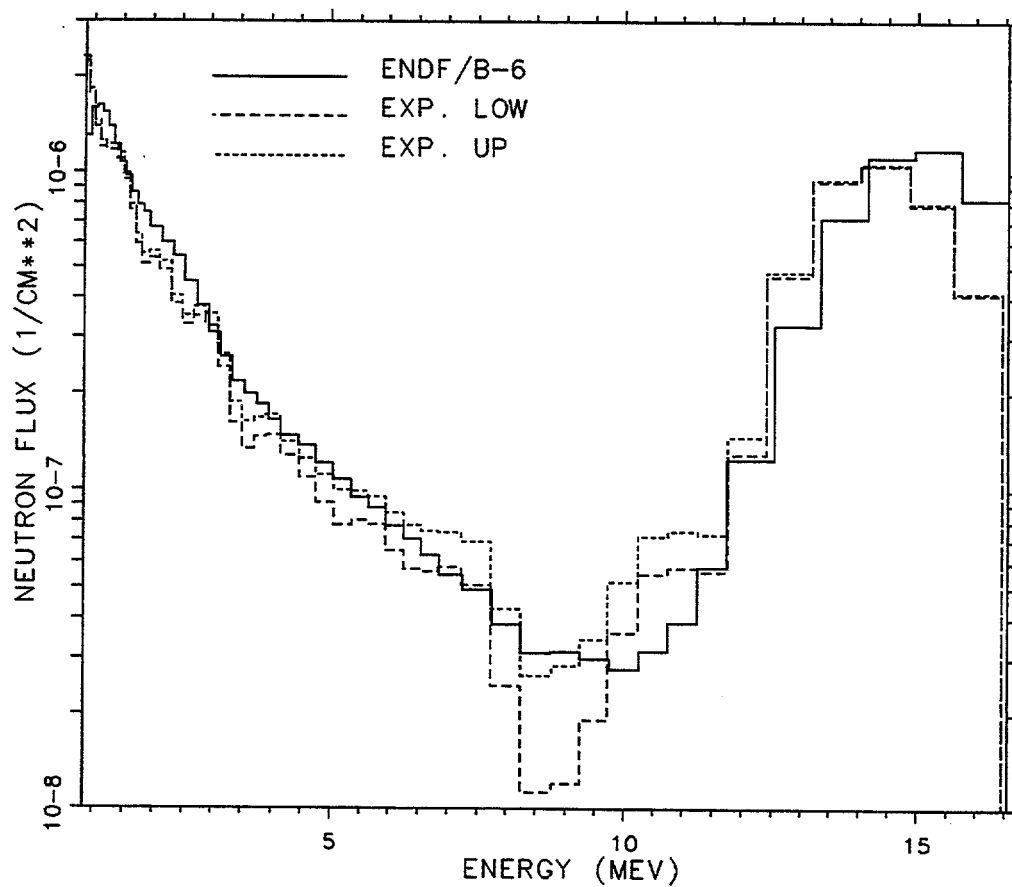


Fig. 13. Plot of ENDF/B-VI calculated and experimental upper and lower confidence levels for configuration 1 with the detector on axis.

CONFIGURATION 1 - ON AXIS  
T-2 REC. - ENDF/B-6

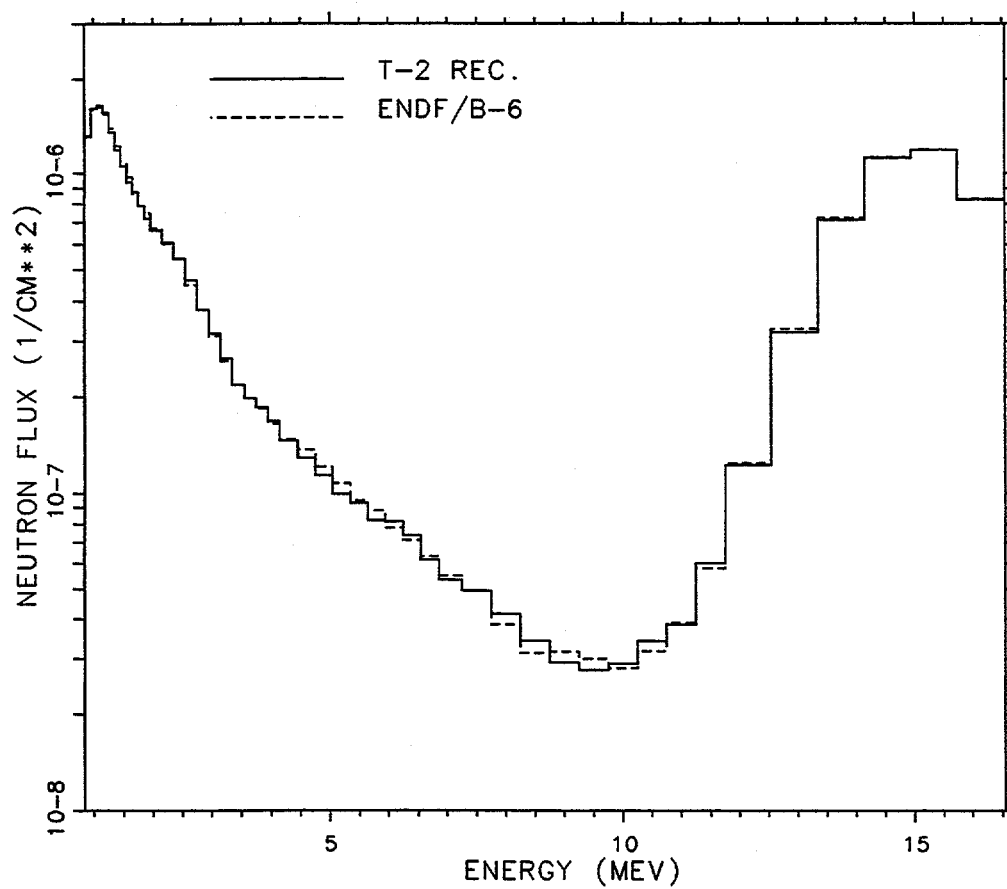


Fig. 14. Plot of MCNP Recommended and ENDF/B-VI calculated for configuration 1 with the detector on axis.

CONFIGURATION 2 - ON AXIS  
ENDF/B-5

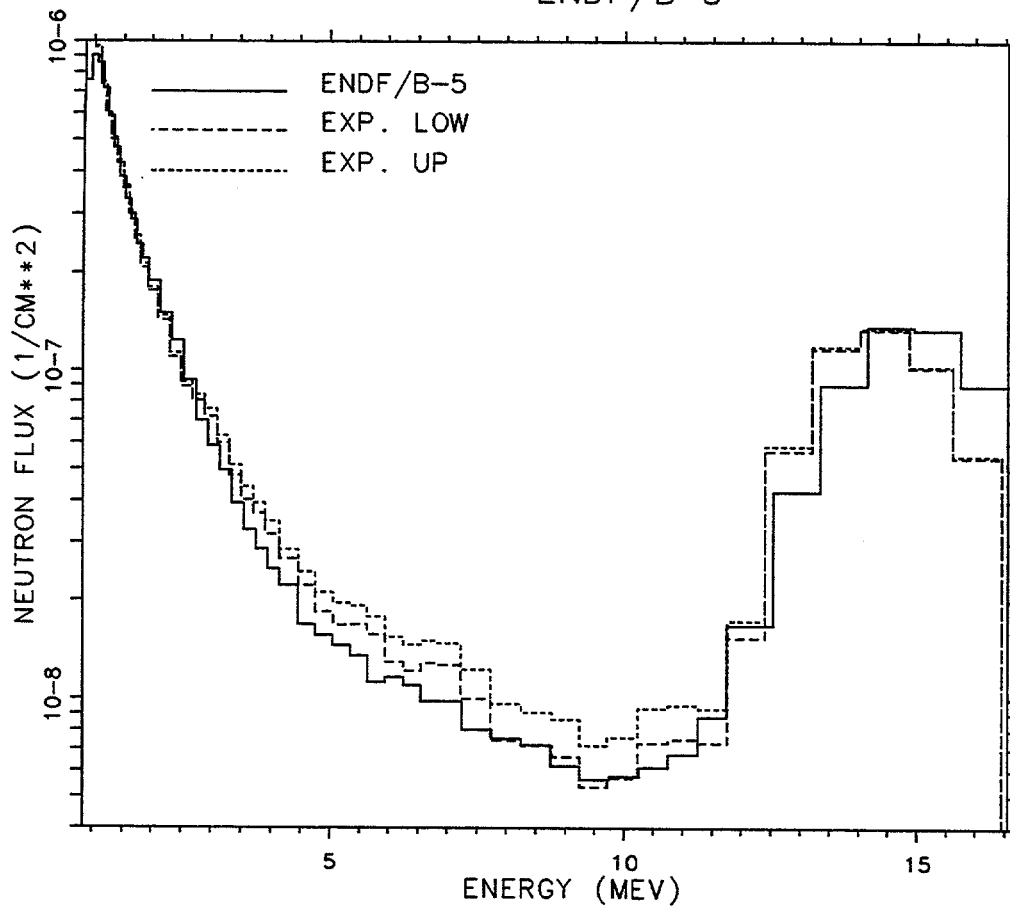


Fig. 15. Plot of ENDF/B-V calculated and experimental upper and lower confidence levels for configuration 2 with the detector on axis.

CONFIGURATION 2 - ON AXIS  
T-2 REC.

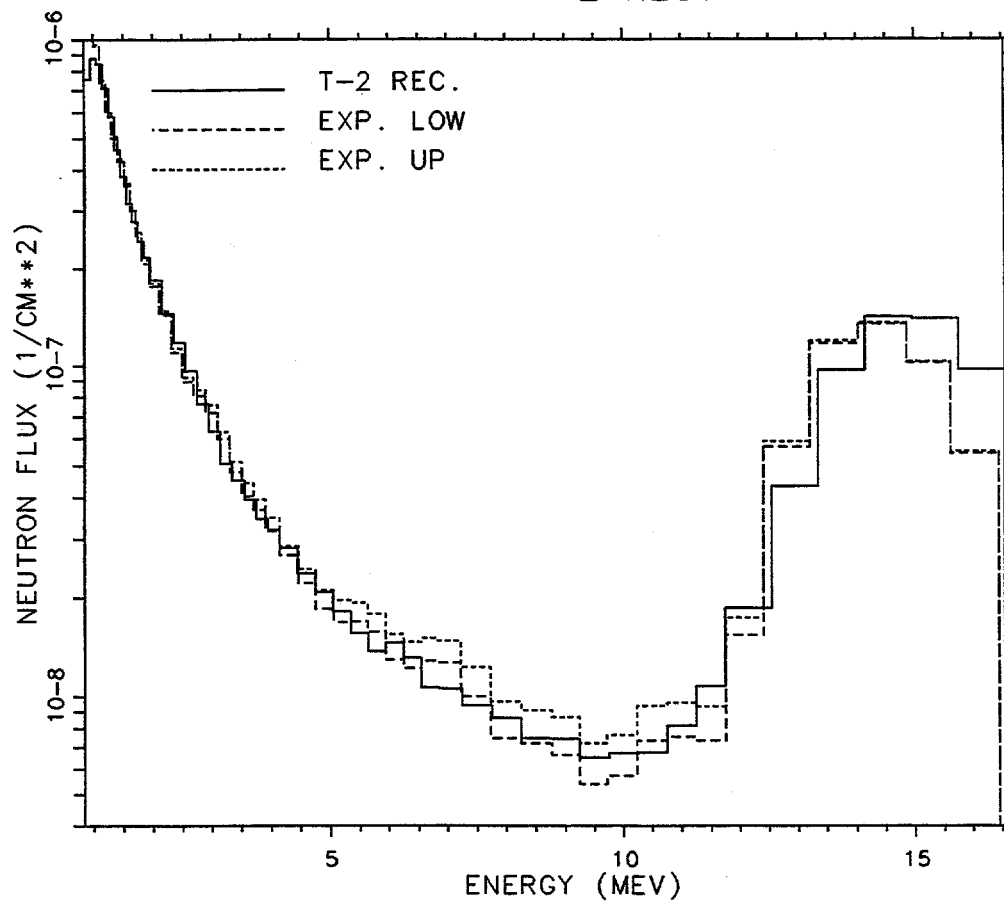


Fig. 16. Plot of MCNP Recommended calculated and experimental upper and lower confidence levels for configuration 2 with the detector on axis.

CONFIGURATION 2 - ON AXIS  
ENDF/B-6

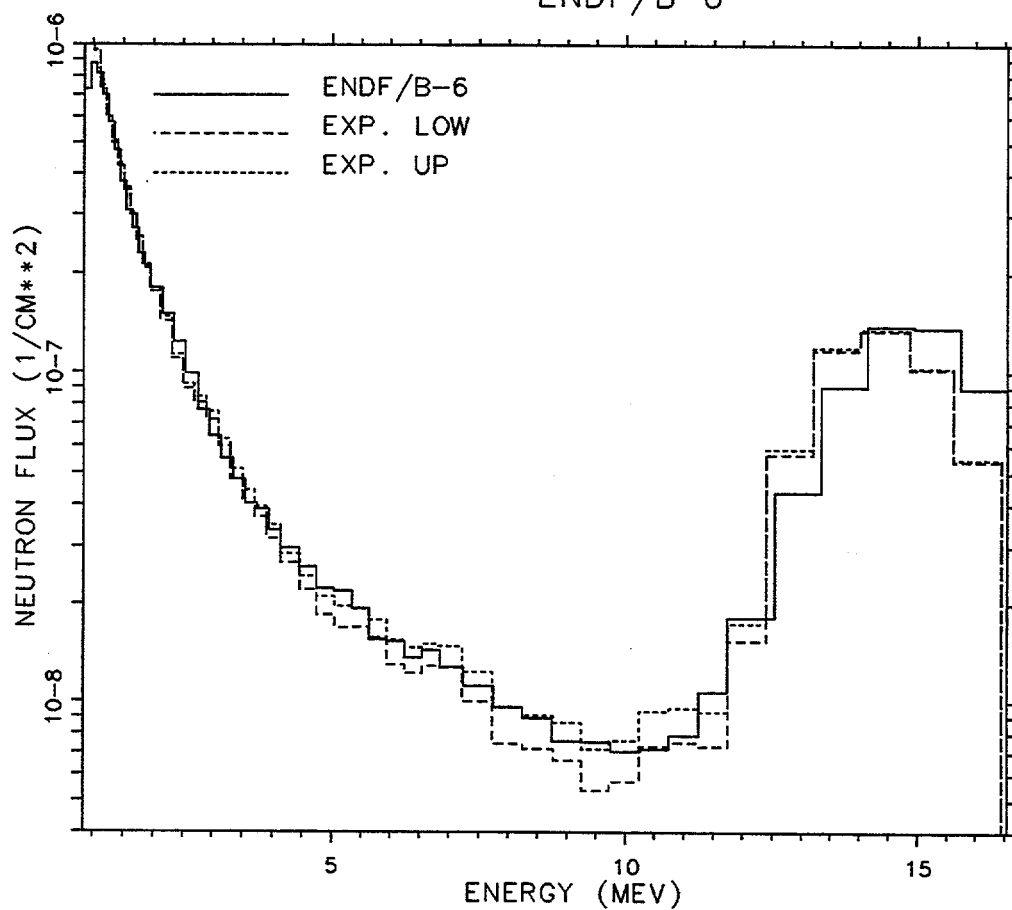


Fig. 17. Plot of ENDF/B-VI calculated and experimental upper and lower confidence levels for configuration 2 with the detector on axis.

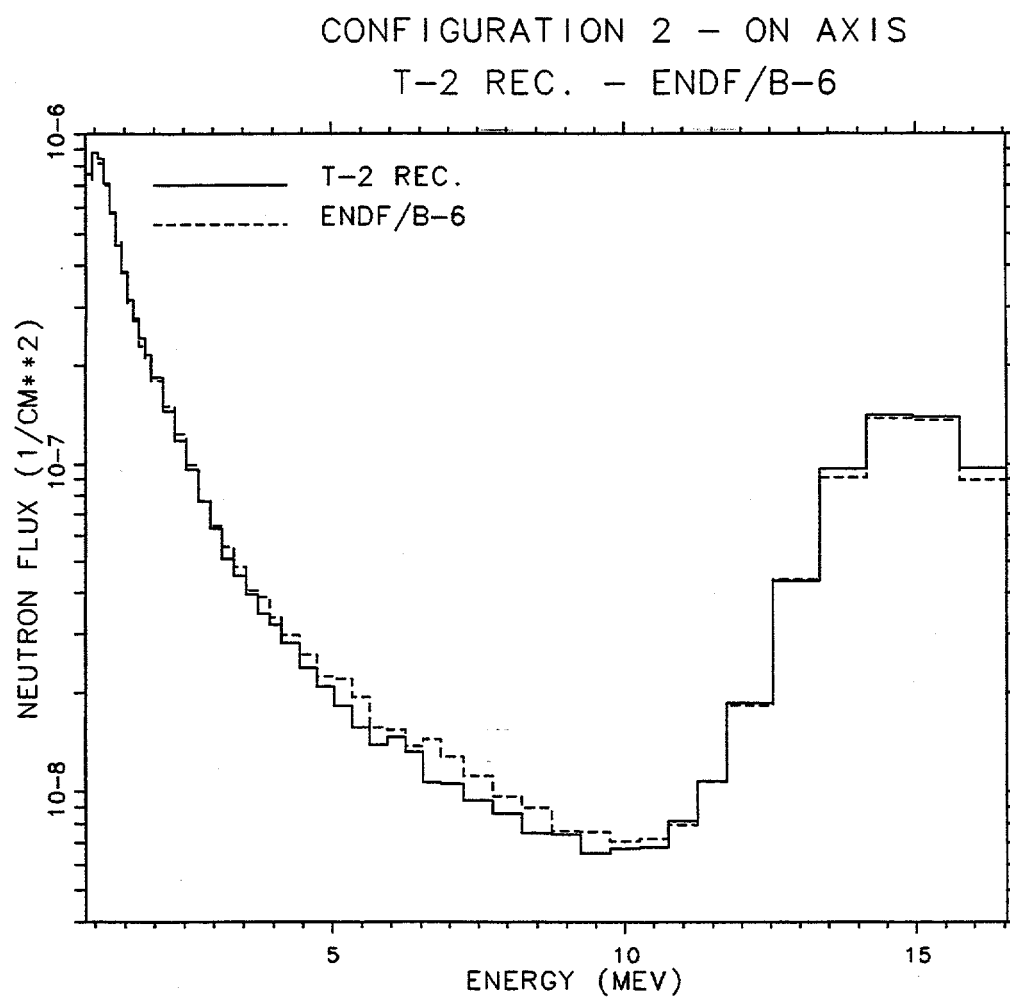


Fig. 18. Plot of MCNP Recommended and ENDF/B-VI calculated for configuration 2 with the detector on axis.

CONFIGURATION 3 - ON AXIS  
ENDF/B-5

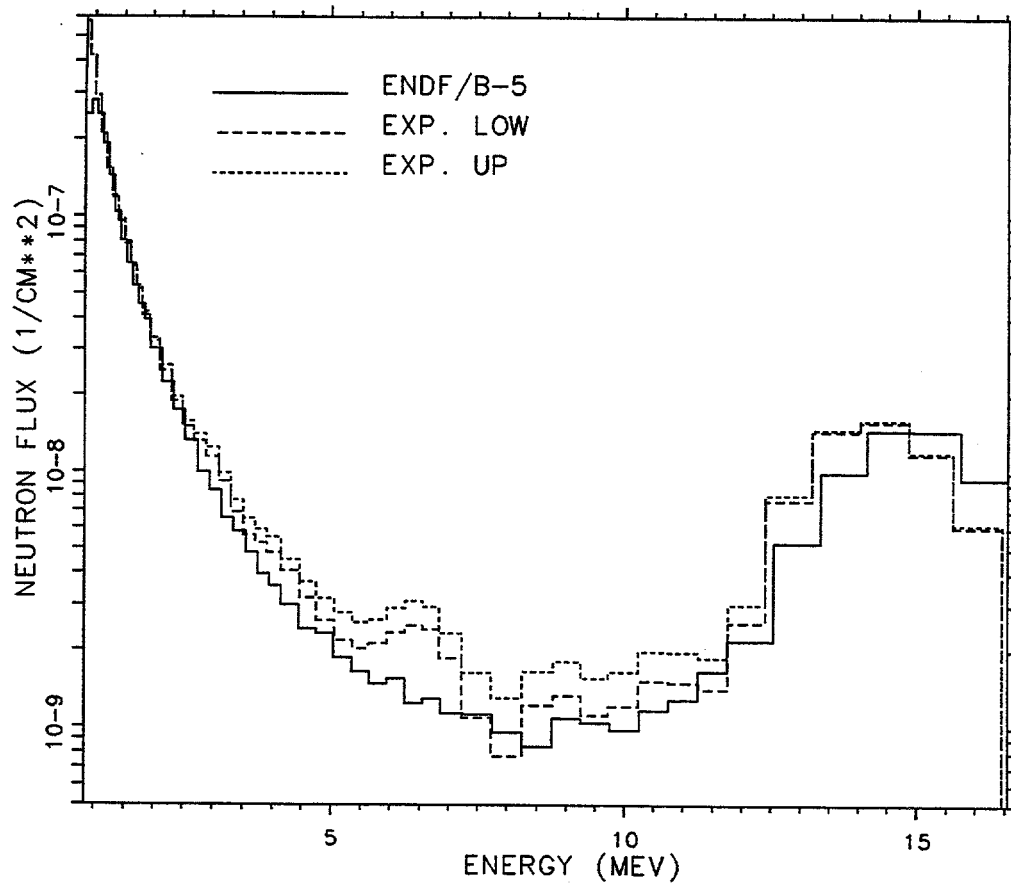


Fig. 19. Plot of ENDF/B-V calculated and experimental upper and lower confidence levels for configuration 3 with the detector on axis.

CONFIGURATION 3 - ON AXIS  
T-2 REC.

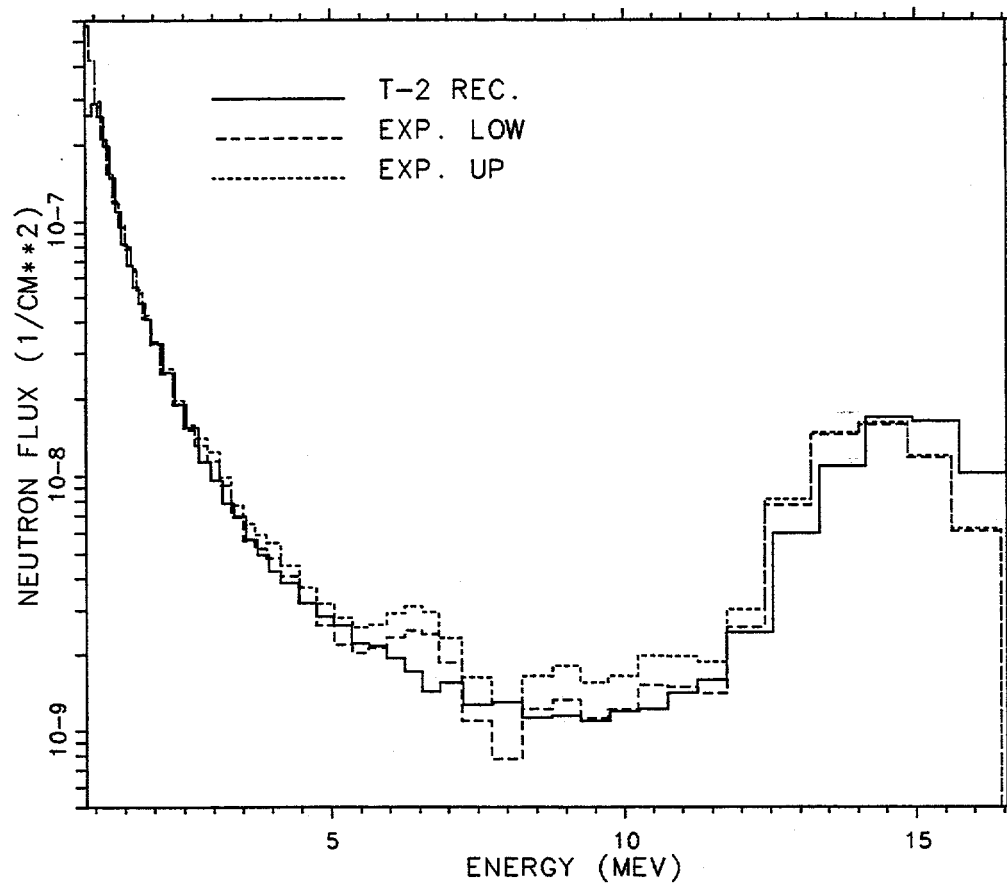


Fig. 20. Plot of MCNP Recommended calculated and experimental upper and lower confidence levels for configuration 3 with the detector on axis.

CONFIGURATION 3 - ON AXIS  
ENDF/B-6

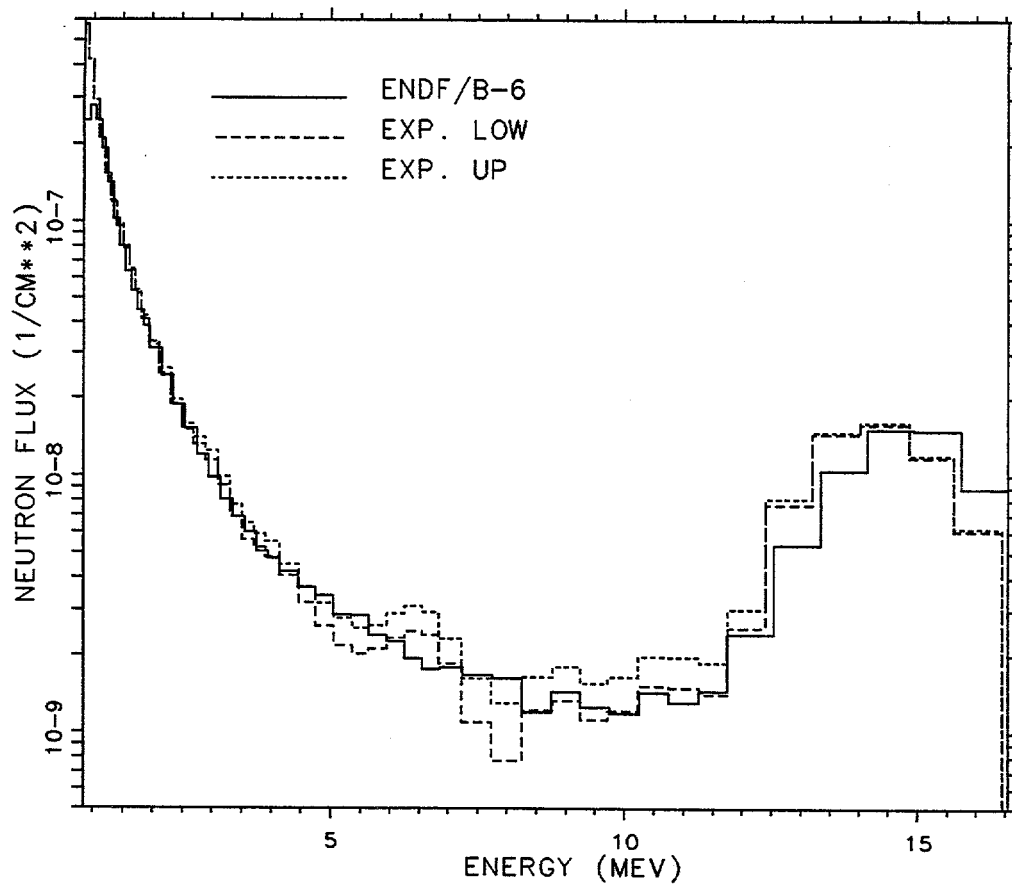


Fig. 21. Plot of ENDF/B-VI calculated and experimental upper and lower confidence levels for configuration 3 with the detector on axis.

CONFIGURATION 3 - ON AXIS  
T-2 REC. - ENDF/B-6

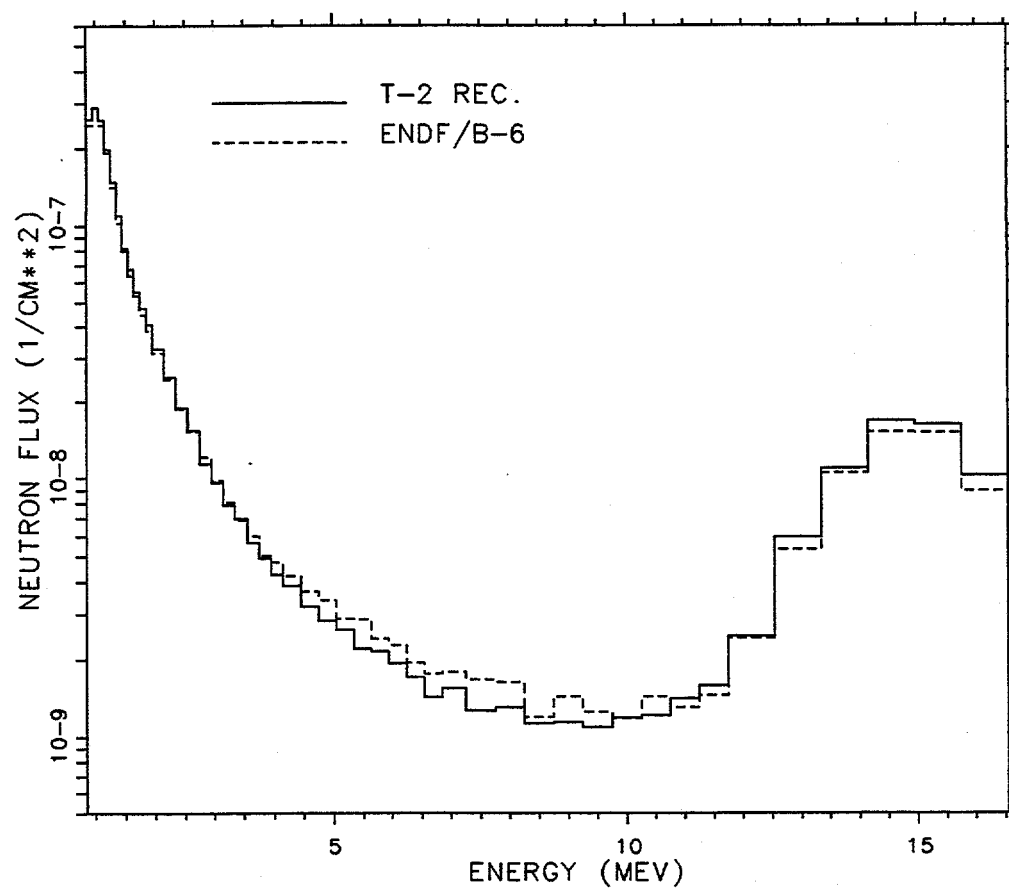


Fig. 22. Plot of MCNP Recommended and ENDF/B-VI calculated for configuration 3 with the detector on axis.

CONFIGURATION 3 - OFF AXIS  
ENDF/B-5

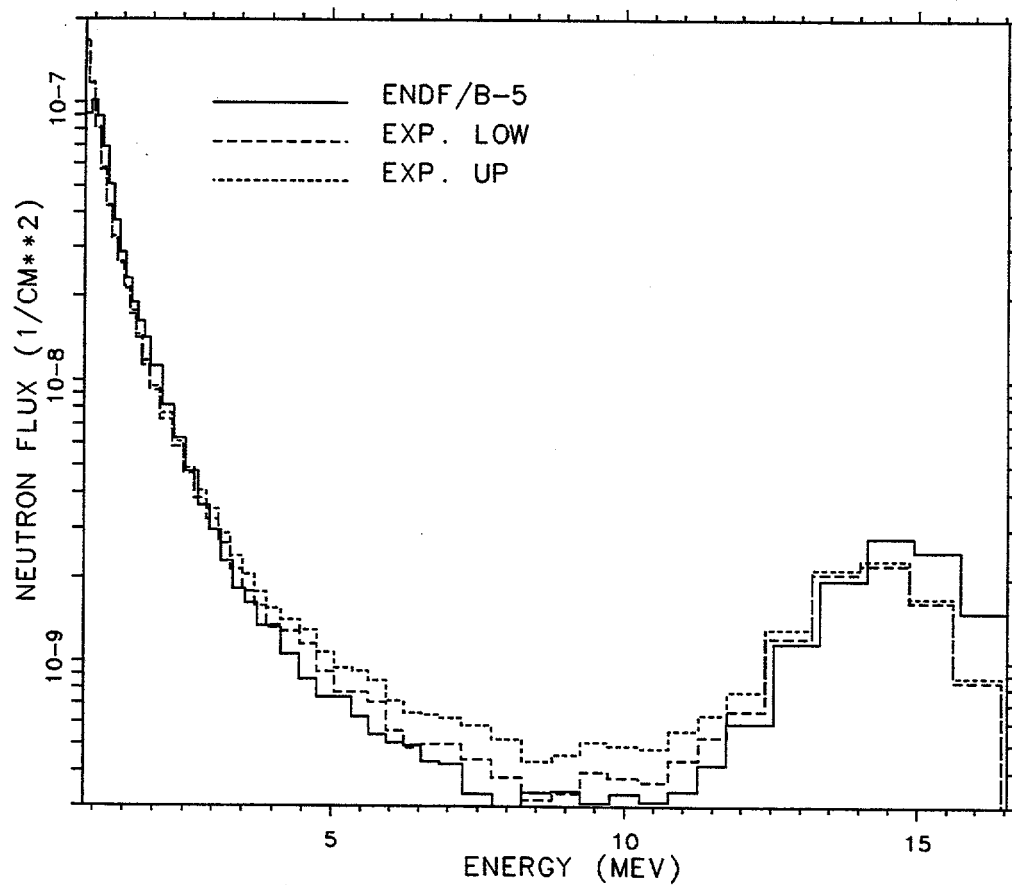


Fig. 23. Plot of ENDF/B-V calculated and experimental upper and lower confidence levels for configuration 3 with the detector off axis.

CONFIGURATION 3 - OFF AXIS  
T-2 REC.

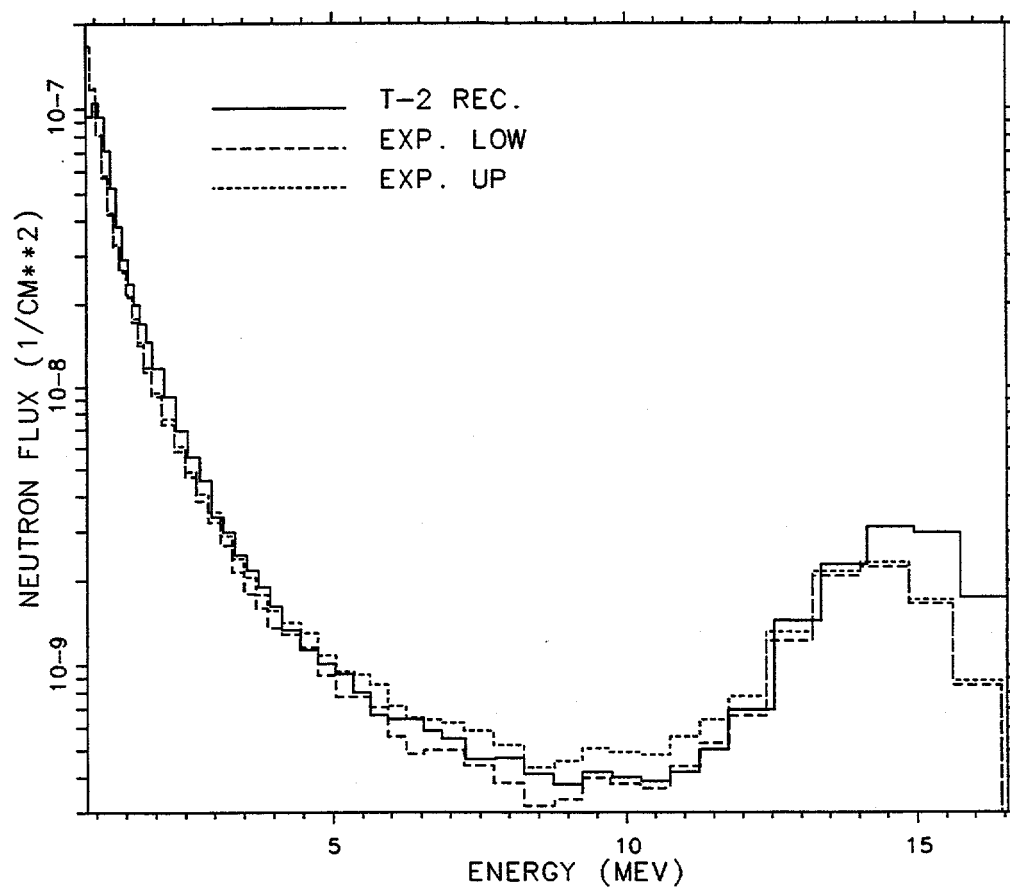


Fig. 24. Plot of MCNP Recommended calculated and experimental upper and lower confidence levels for configuration 3 with the detector off axis.

CONFIGURATION 3 - OFF AXIS  
ENDF/B-6

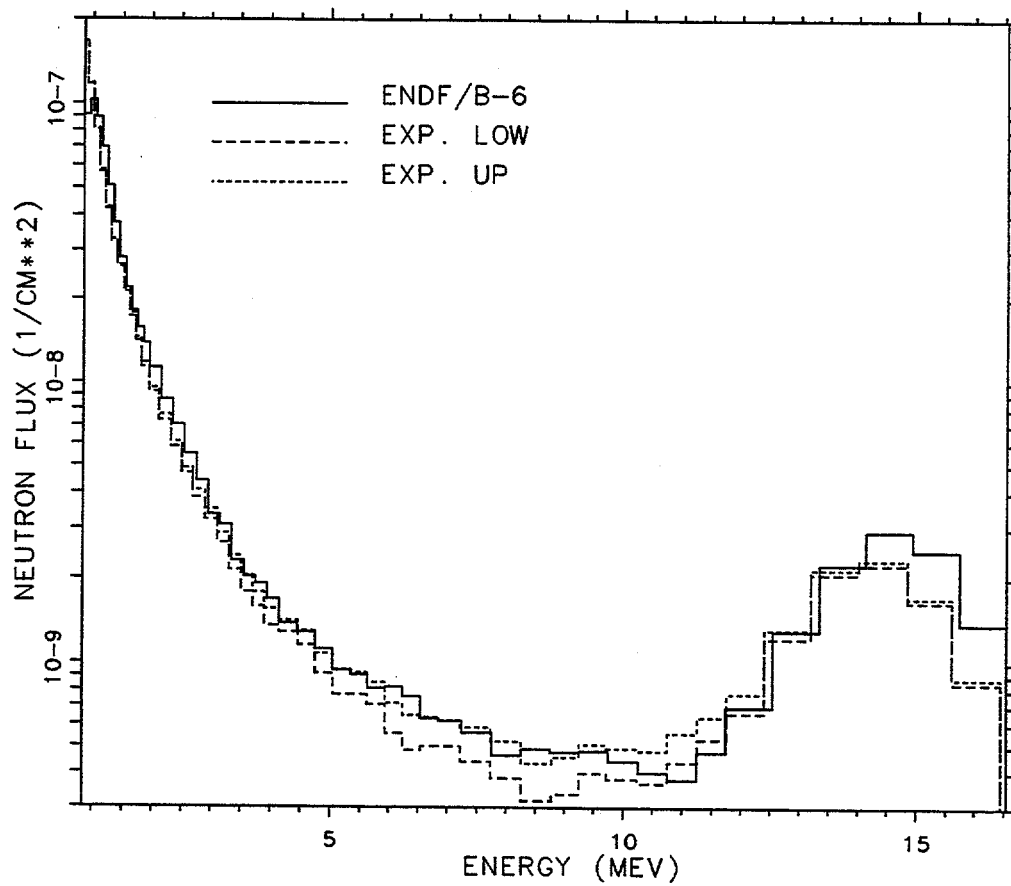


Fig. 25. Plot of ENDF/B-VI calculated and experimental upper and lower confidence levels for configuration 3 with the detector off axis.

CONFIGURATION 3 - OFF AXIS  
T-2 REC. - ENDF/B-6

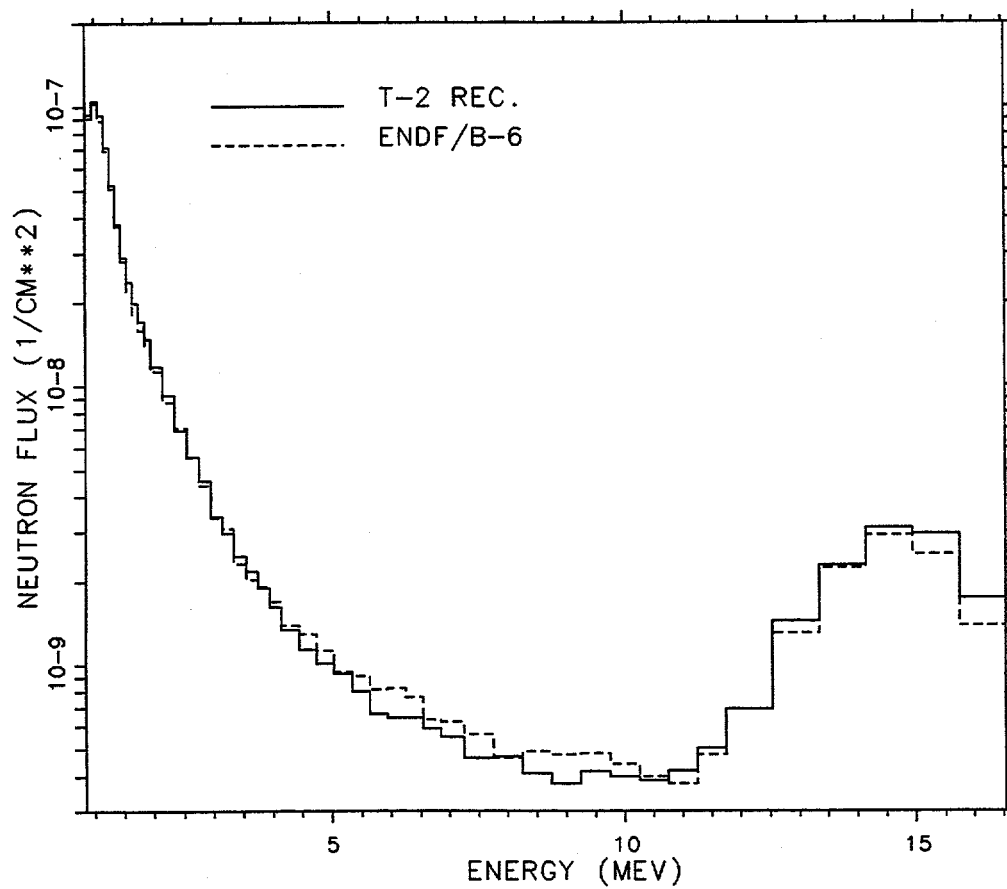


Fig. 26. Plot of MCNP Recommended and ENDF/B-VI calculated for configuration 3 with the detector off axis.

CONFIGURATION 7 - ON AXIS  
ENDF/B-5

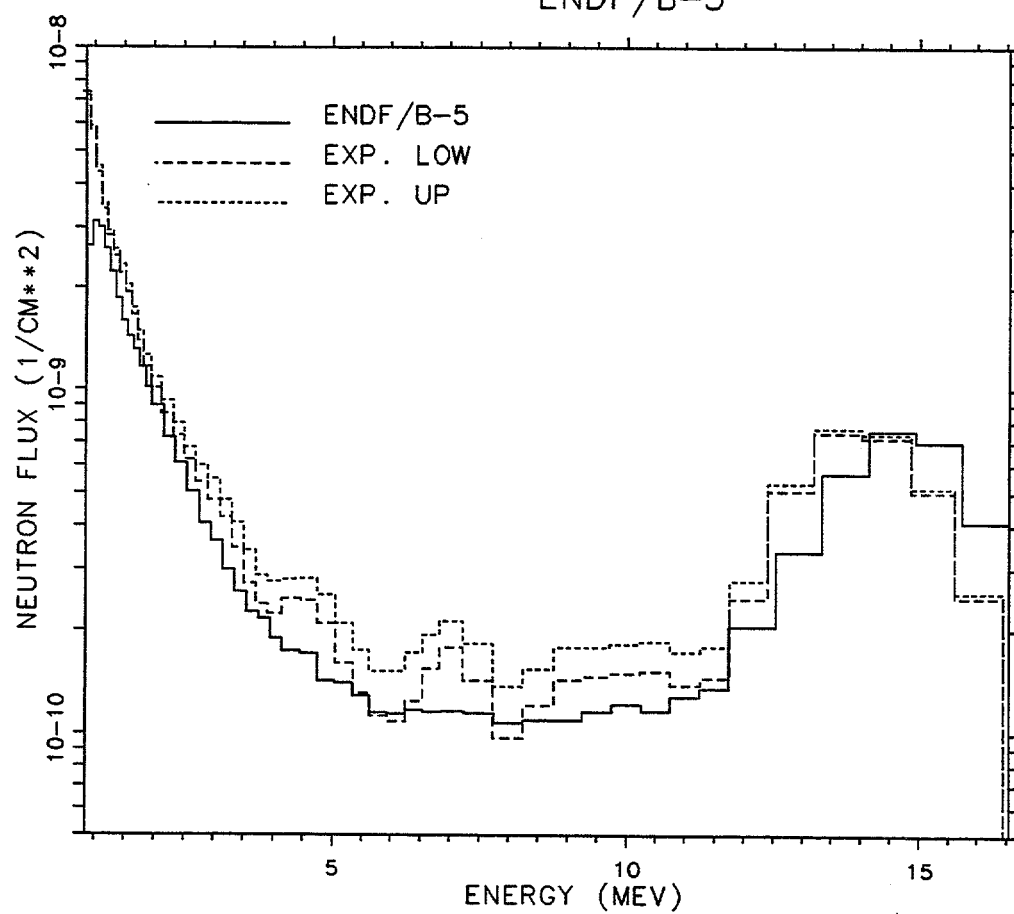


Fig. 27. Plot of ENDF/B-V calculated and experimental upper and lower confidence levels for configuration 7 with the detector on axis.

CONFIGURATION 7 - ON AXIS  
T-2 REC.

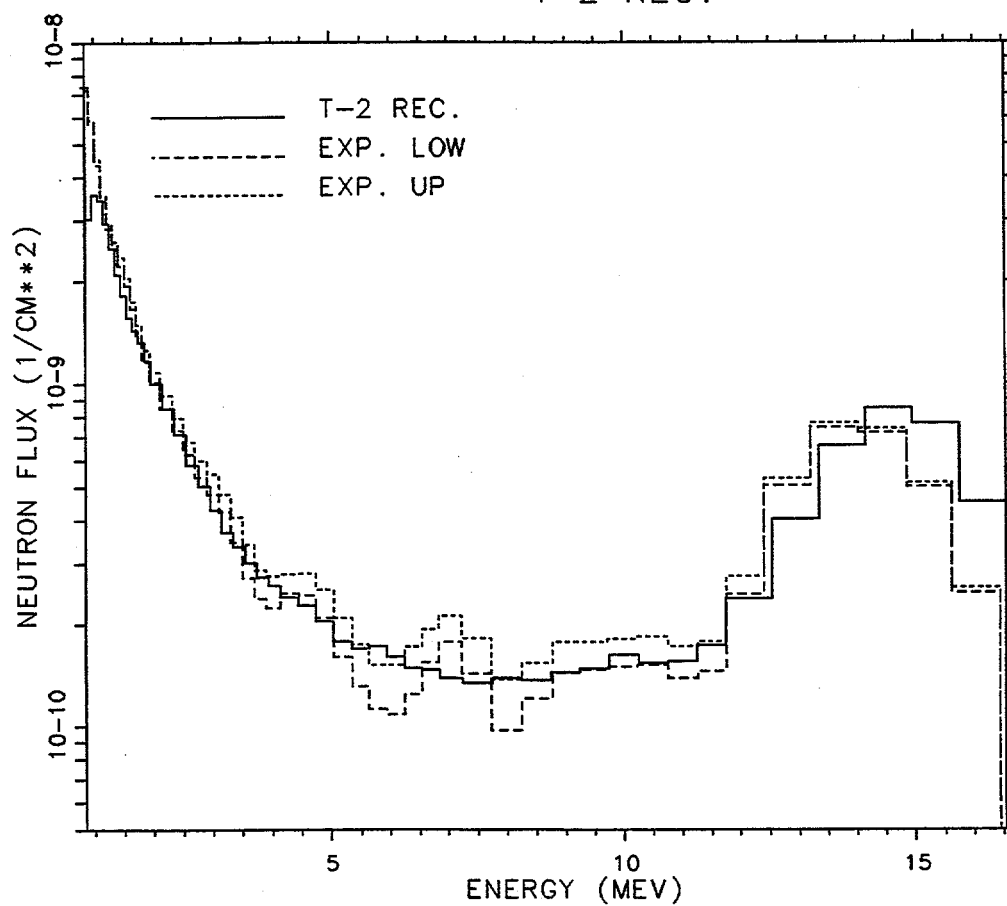


Fig. 28. Plot of MCNP Recommended calculated and experimental upper and lower confidence levels for configuration 7 with the detector on axis.

CONFIGURATION 7 - ON AXIS  
ENDF/B-6

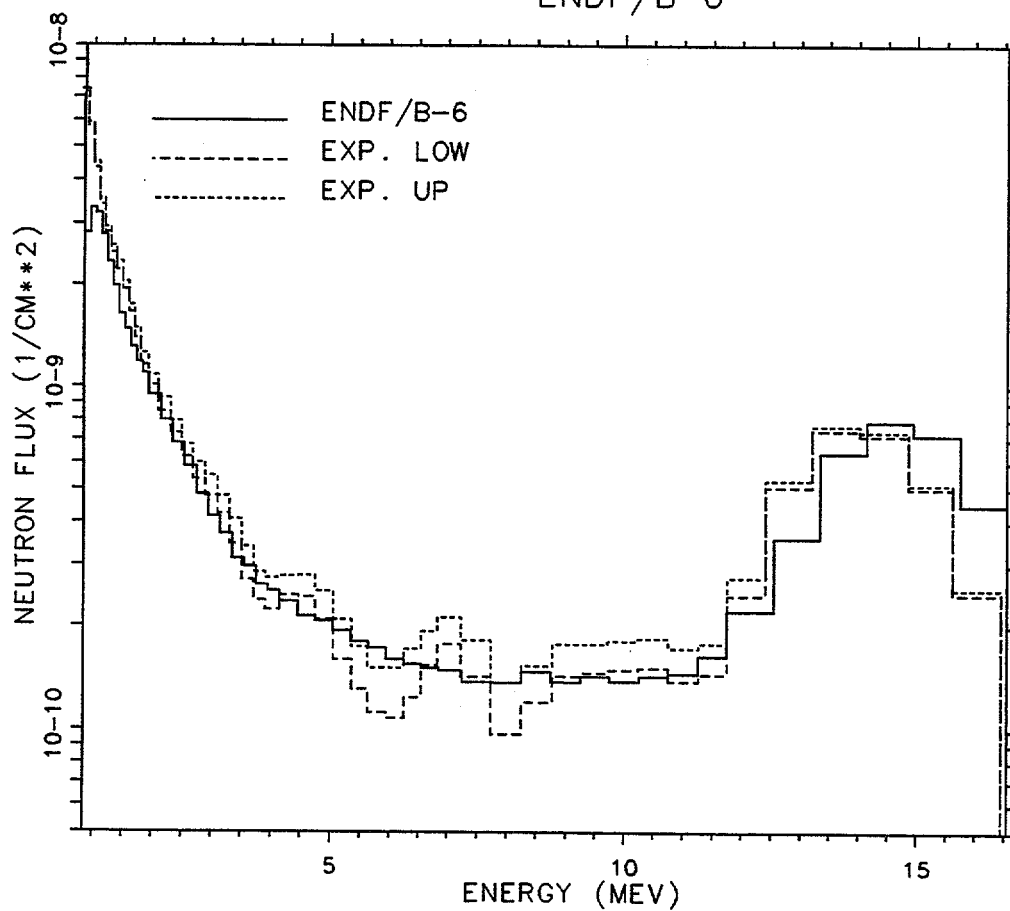


Fig. 29. Plot of ENDF/B-VI calculated and experimental upper and lower confidence levels for configuration 7 with the detector on axis.

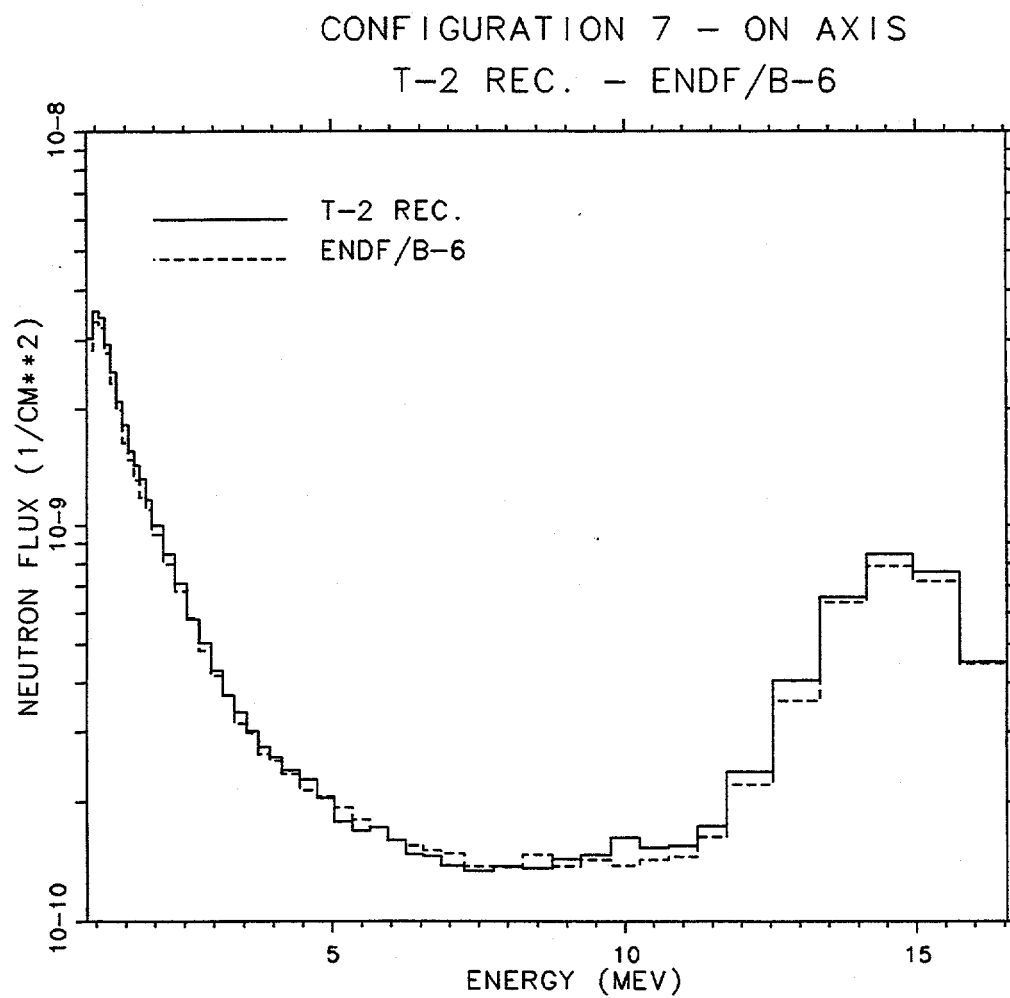


Fig. 30. Plot of MCNP Recommended and ENDF/B-VI calculated for configuration 7 with the detector on axis.

CONFIGURATION 7 - OFF AXIS  
ENDF/B-5

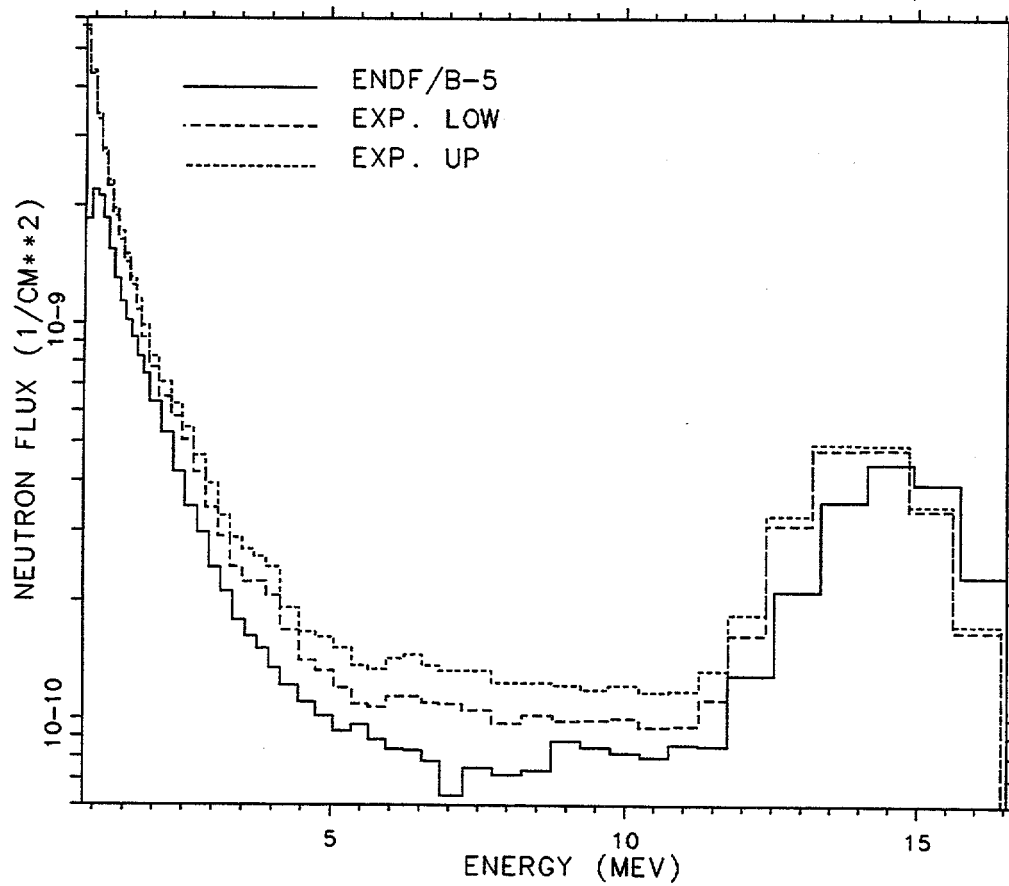


Fig. 31. Plot of ENDF/B-V calculated and experimental upper and lower confidence levels for configuration 7 with the detector off axis.

CONFIGURATION 7 - OFF AXIS  
T-2 REC.

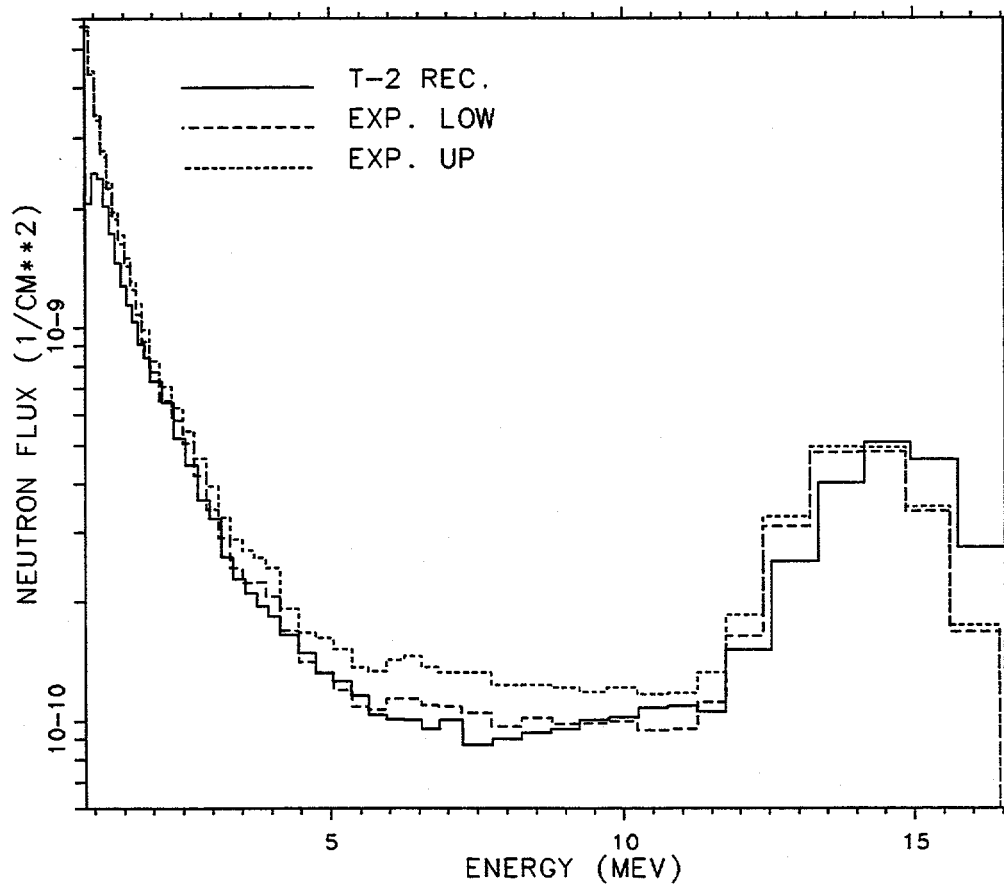


Fig. 32. Plot of MCNP Recommended calculated and experimental upper and lower confidence levels for configuration 7 with the detector off axis.

CONFIGURATION 7 - OFF AXIS  
ENDF/B-6

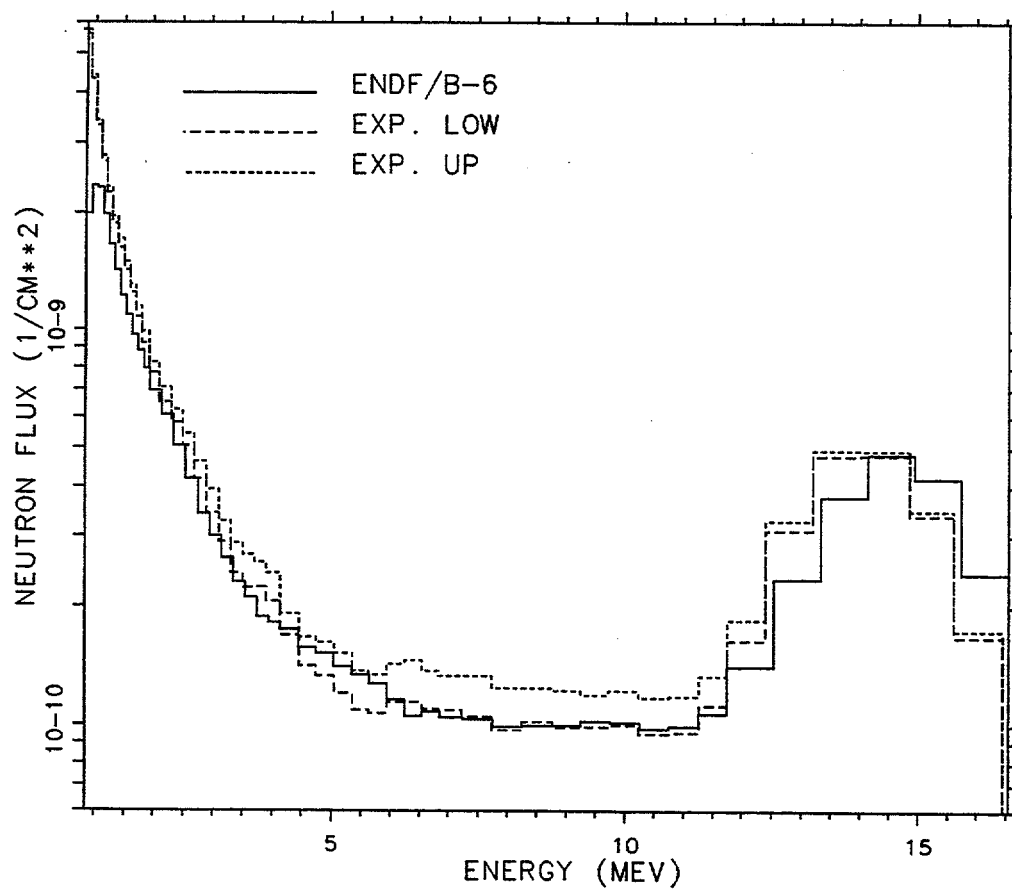


Fig. 33. Plot of ENDF/B-VI calculated and experimental upper and lower confidence levels for configuration 7 with the detector off axis.

CONFIGURATION 7 - OFF AXIS  
T-2 REC. - ENDF/B-6

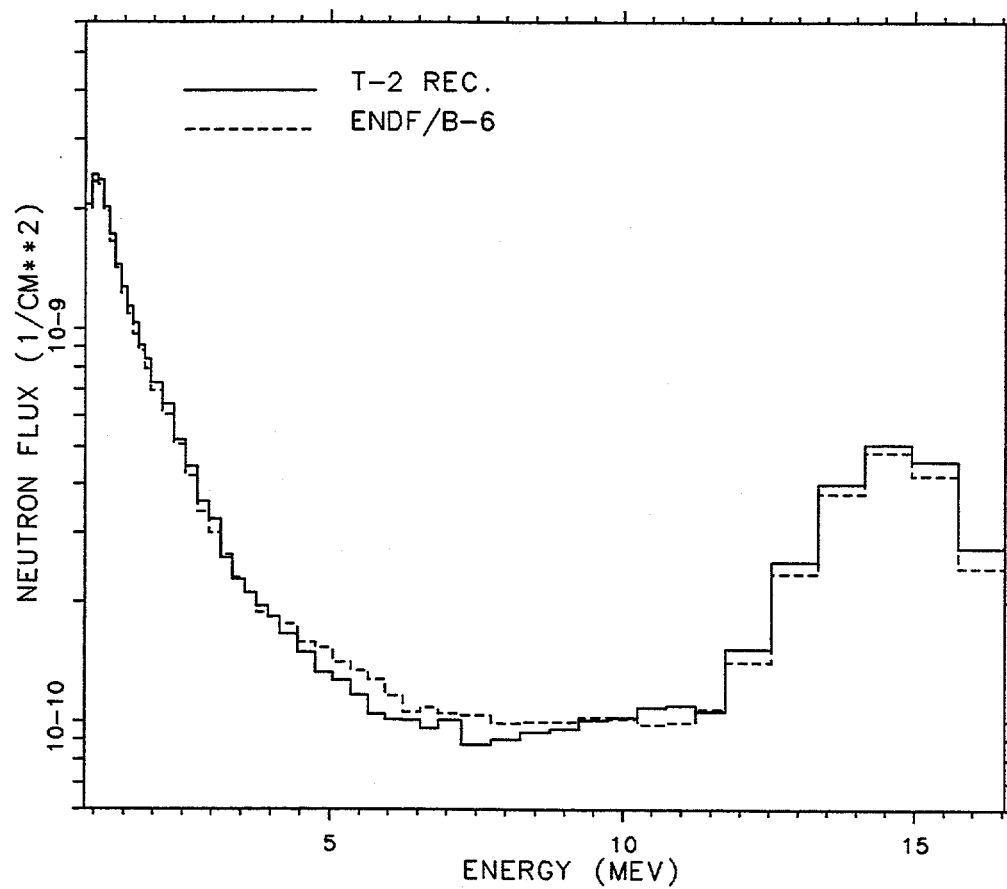


Fig. 34. Plot of MCNP Recommended and ENDF/B-VI calculated for configuration 7 with the detector off axis.

## IV. 76 CM. DIAMETER IRON SPHERE BENCHMARK

### A. Experimental Setup

In the early 1970's at the University of Illinois, neutron leakage measurements were made with a NE-213 spectrometry system on a 76-cm. diameter iron sphere. The sphere contained a central void of 15-cm. diameter and a re-entrant hole of 9.5-cm. diameter for the neutron generator beam tube. Two different neutron sources were used in the measurements. A neutron generator was used as a source of 14 MeV neutrons from the  $T(d,n)^4\text{He}$  reaction,<sup>11</sup> and a  $^{252}\text{Cf}$  source was used for another set of measurements.<sup>10</sup> The neutron detector was placed 2 m. from the center of the sphere at an angle of 90 degrees from the deuteron beam tube. The assumption was made that the detector was in the same position for the  $^{252}\text{Cf}$  source spectrum. The source spectrum for the MCNP modeling was a Maxwellian fission source with a temperature of 1.425 MeV.<sup>15</sup>

### B. Results and Discussion

In the absence of experimental data, calculations were done for the ENDF/B-IV, ENDF/B-V, the MCNP Recommended (a group T-2 evaluation), and ENDF/B-VI data sets. Both pure iron and a high carbon steel were used in separate calculations. ENDF/B-IV was not used in the high carbon steel calculations due to the absence of data for  $^{31}\text{P}$ ,  $^{32}\text{S}$ , and  $^{55}\text{Mn}$ . The composition of the high carbon steel is identical to the composition of the Lawrence Livermore pulsed iron sphere and can be found in Table II. Further details of the problem setup can be found in Table A.3 in the appendix.

ENDF/B-VI was compared to each of the previous data sets and the percentage difference computed. These differences are shown in Table VIII. ENDF/B-VI and the MCNP Recommended Library are generally in good agreement, while the ENDF/B-V and ENDF/B-IV libraries allow significantly lower transmission and tend to agree with each other.

Figures 35 and 36 show the complete spectrum for the iron sphere with a  $^{252}\text{Cf}$  source, with Figures 37 through 41 showing the spectra for the different energy groups of Table VIII. Figures 42 and 43 show the complete spectrum for iron with a D-T source, with the energy groups shown in Figures 44 through 48. The high carbon steel results are given in Figures 49 through 62. In some cases, particularly Figures 41, 54, and 55, statistics are poor, and the plotted results are unreliable.

Generally, ENDF/B-VI and the MCNP Recommended Library are in fairly close agreement, and the ENDF/B-V and ENDF/B-IV libraries give somewhat lower transmissions.

TABLE VIII. 76 cm. Iron Sphere Results: ENDF/B-VI Data Set Differences

| Composition                                   | Source                     | Energy Group<br>(MeV) | % Difference<br>$(\frac{ENDF/B-VI-ENDF/B-x}{ENDF/B-x}) \times 100$ |          |          |
|-----------------------------------------------|----------------------------|-----------------------|--------------------------------------------------------------------|----------|----------|
|                                               |                            |                       | ENDF/B-IV                                                          | ENDF/B-V | T-2 Rec. |
| Pure Iron                                     | $^{252}\text{Cf}$          | 0.5-2                 | +4.54                                                              | +0.342   | -2.02    |
|                                               |                            | 2-5                   | +17.48                                                             | +14.11   | +1.739   |
|                                               |                            | 5-10                  | +21.0                                                              | +22.8    | +10.48   |
|                                               |                            | 10-13                 | +82.2                                                              | +128.2   | +16.5    |
|                                               |                            | > 13                  | +41.6                                                              | -56.8    | -21.6    |
|                                               | $\text{T(d,n)}^4\text{He}$ | 0.5-2                 | +0.819                                                             | +1.017   | -2.76    |
|                                               |                            | 2-5                   | +20.8                                                              | +19.22   | -1.580   |
|                                               |                            | 5-10                  | +36.9                                                              | +39.2    | +14.44   |
|                                               |                            | 10-13                 | +12.62                                                             | +11.93   | -0.769   |
|                                               |                            | > 13                  | +2.33                                                              | +3.32    | -10.81   |
| High Carbon Steel                             | $^{252}\text{Cf}$          | 0.5-2                 | *                                                                  | +3.21    | -0.723   |
|                                               |                            | 2-5                   | *                                                                  | +11.11   | +2.91    |
|                                               |                            | 5-10                  | *                                                                  | +18.22   | +19.48   |
|                                               |                            | 10-13                 | *                                                                  | -17.72   | -31.9    |
|                                               |                            | > 13                  | *                                                                  | -16.95   | -1.211   |
|                                               | $\text{T(d,n)}^4\text{He}$ | 0.5-2                 | *                                                                  | +2.53    | -0.802   |
|                                               |                            | 2-5                   | *                                                                  | +21.8    | +1.913   |
|                                               |                            | 5-10                  | *                                                                  | +43.3    | +15.05   |
|                                               |                            | 10-13                 | *                                                                  | +19.07   | +2.86    |
|                                               |                            | > 13                  | *                                                                  | +5.22    | -8.22    |
| *Contains isotopes not available in ENDF/B-IV |                            |                       |                                                                    |          |          |

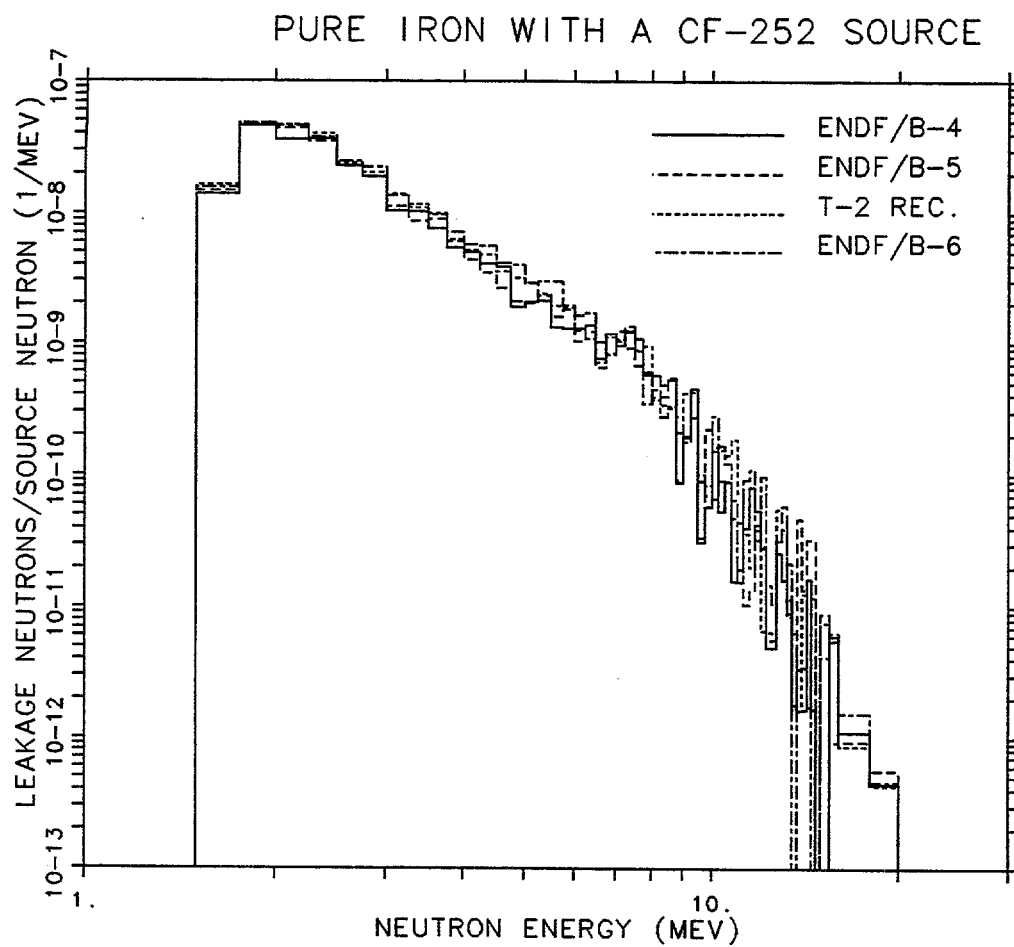


Fig. 35. Plot of ENDF/B-IV, ENDF/B-V, MCNP Recommended, and ENDF/B-VI calculated for pure iron with a  $^{252}\text{Cf}$  source.

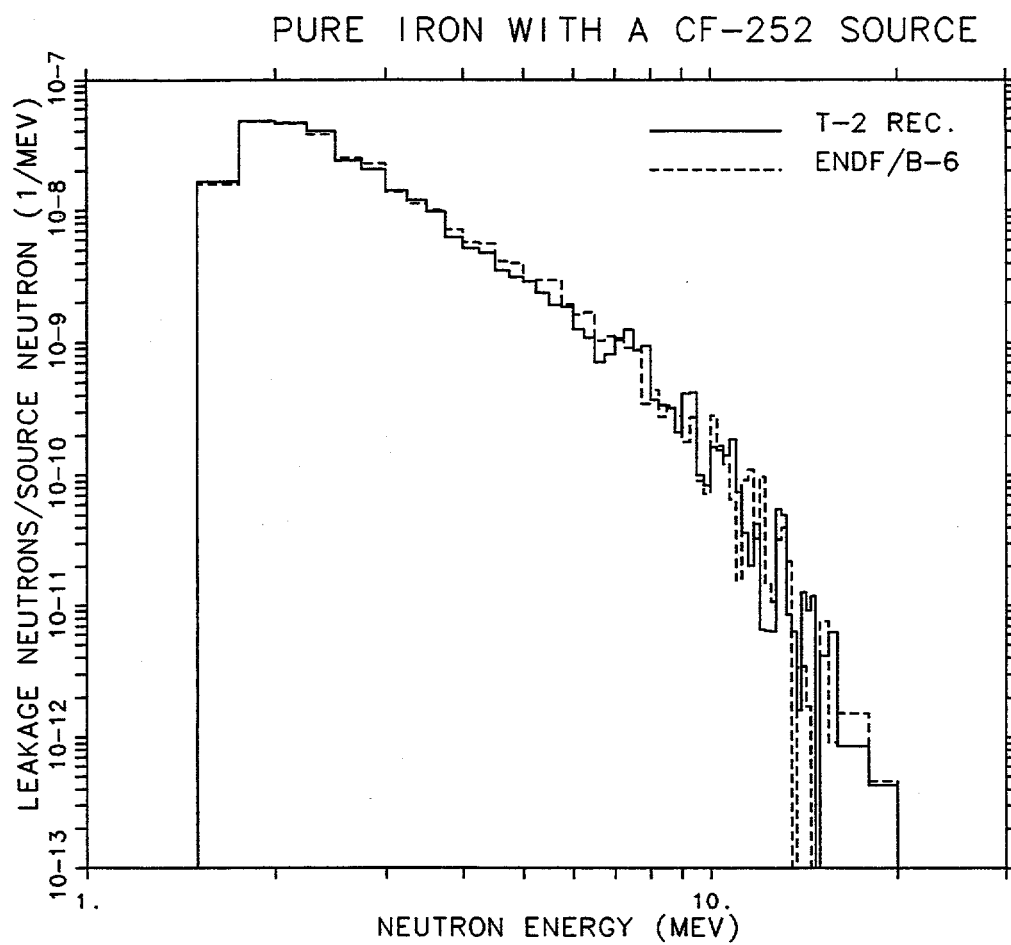


Fig. 36. Plot of MCNP Recommended and ENDF/B-VI calculated for pure iron with a  $^{252}\text{Cf}$  source.

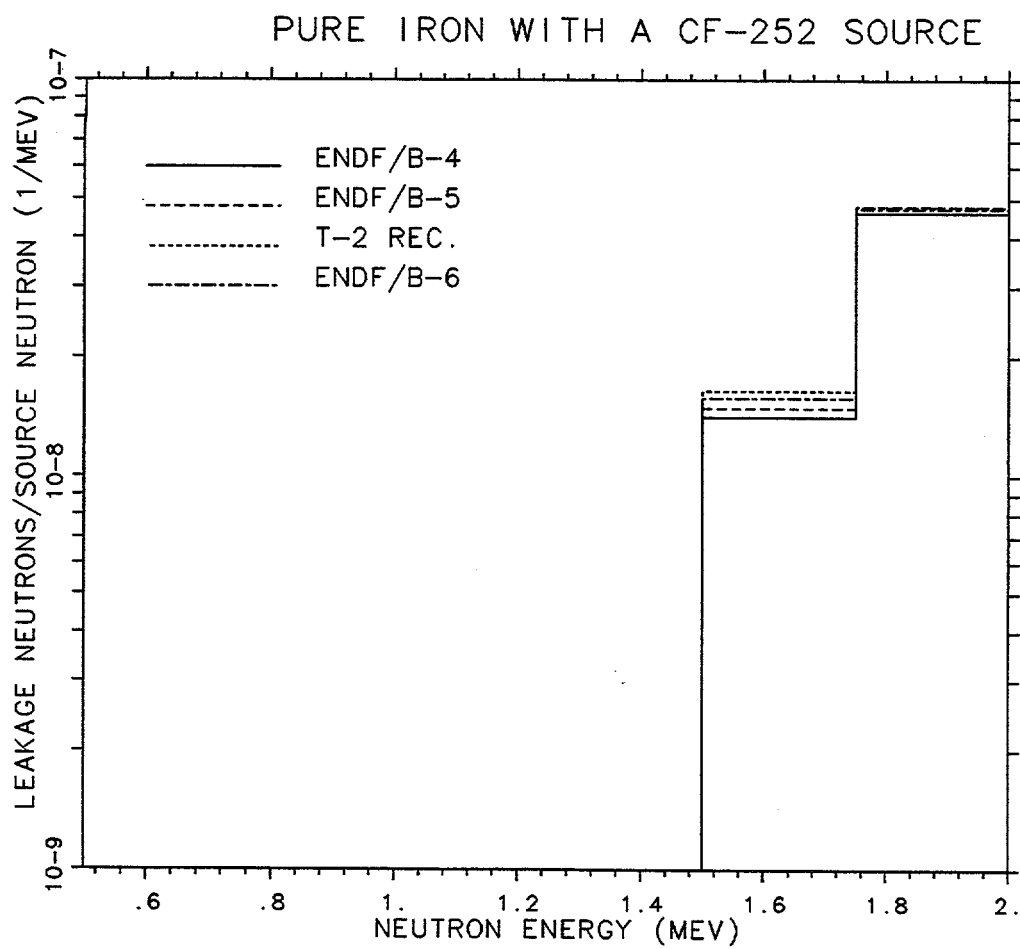


Fig. 37. Plot of pure iron with a  $^{252}\text{Cf}$  source for the energy group 1.5–2 MeV.

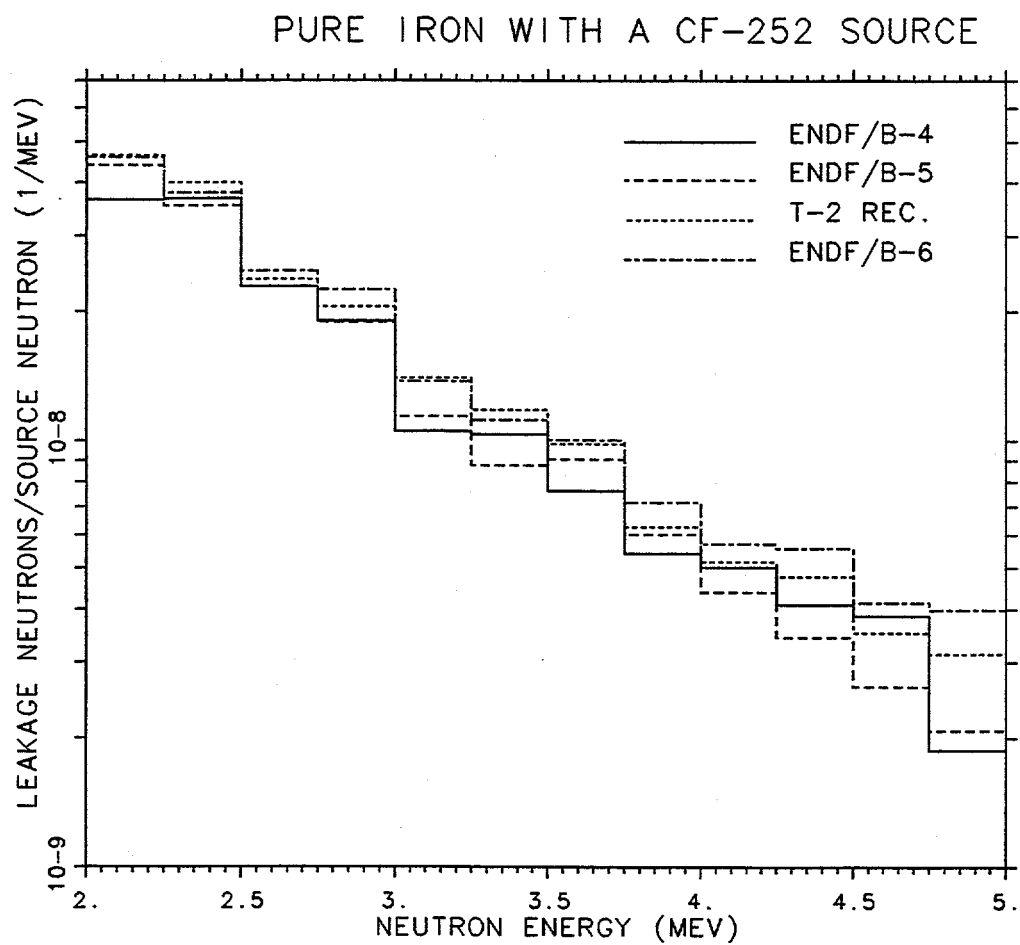


Fig. 38. Plot of pure iron with a  $^{252}\text{Cf}$  source for the energy group 2-5 MeV.

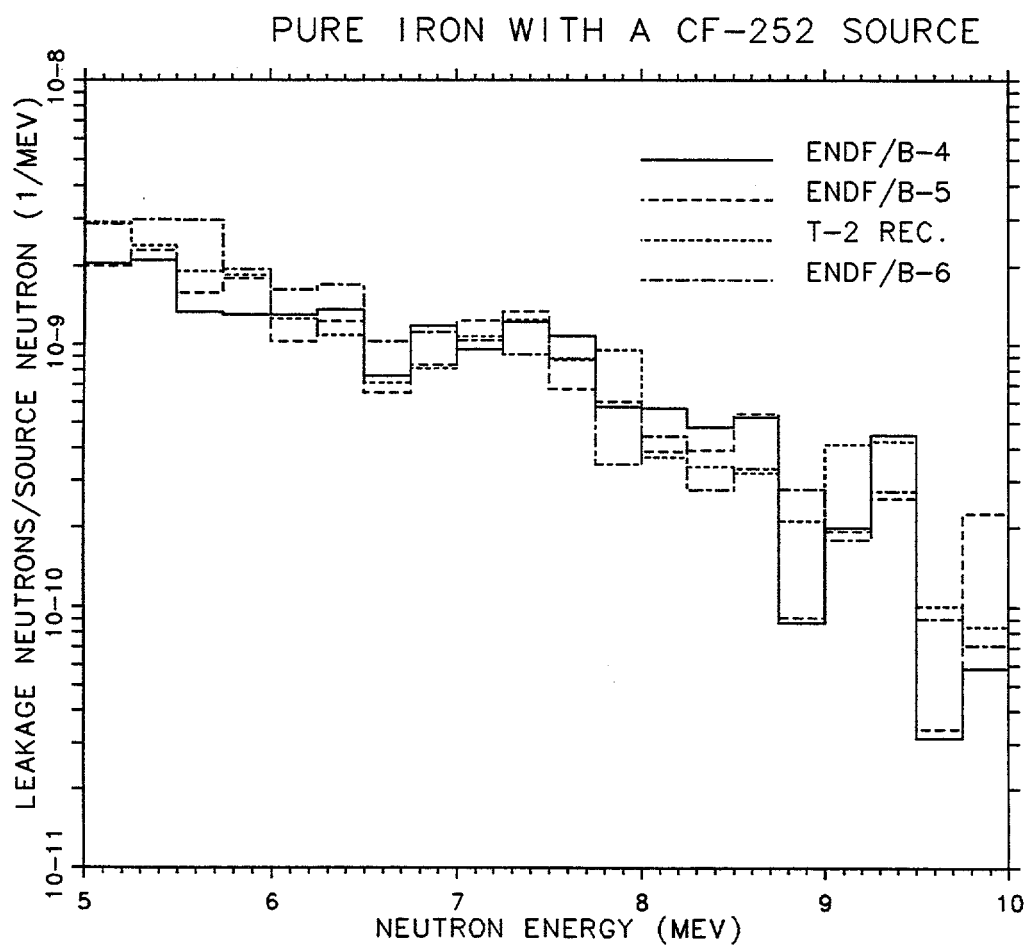


Fig. 39. Plot of pure iron with a  $^{252}\text{Cf}$  source for the energy group 5-10 MeV.

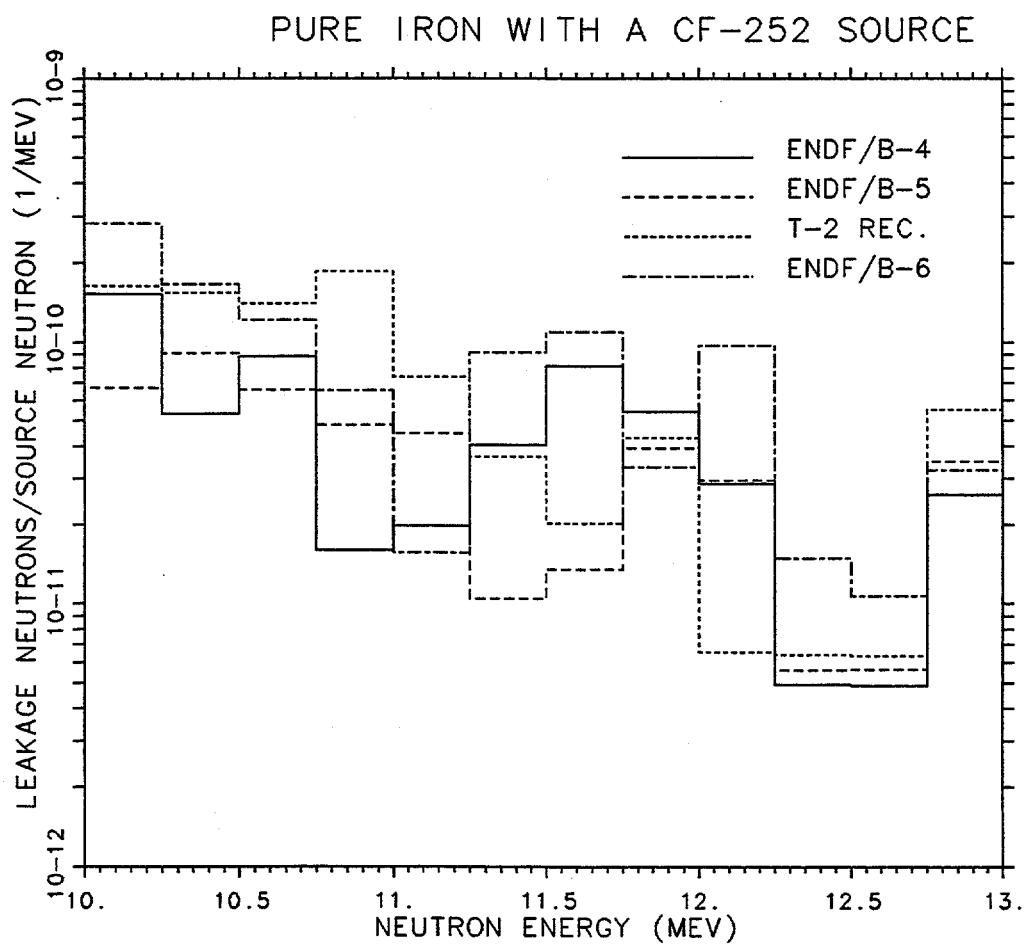


Fig. 40. Plot of pure iron with a  $^{252}\text{Cf}$  source for the energy group 10–13 MeV.

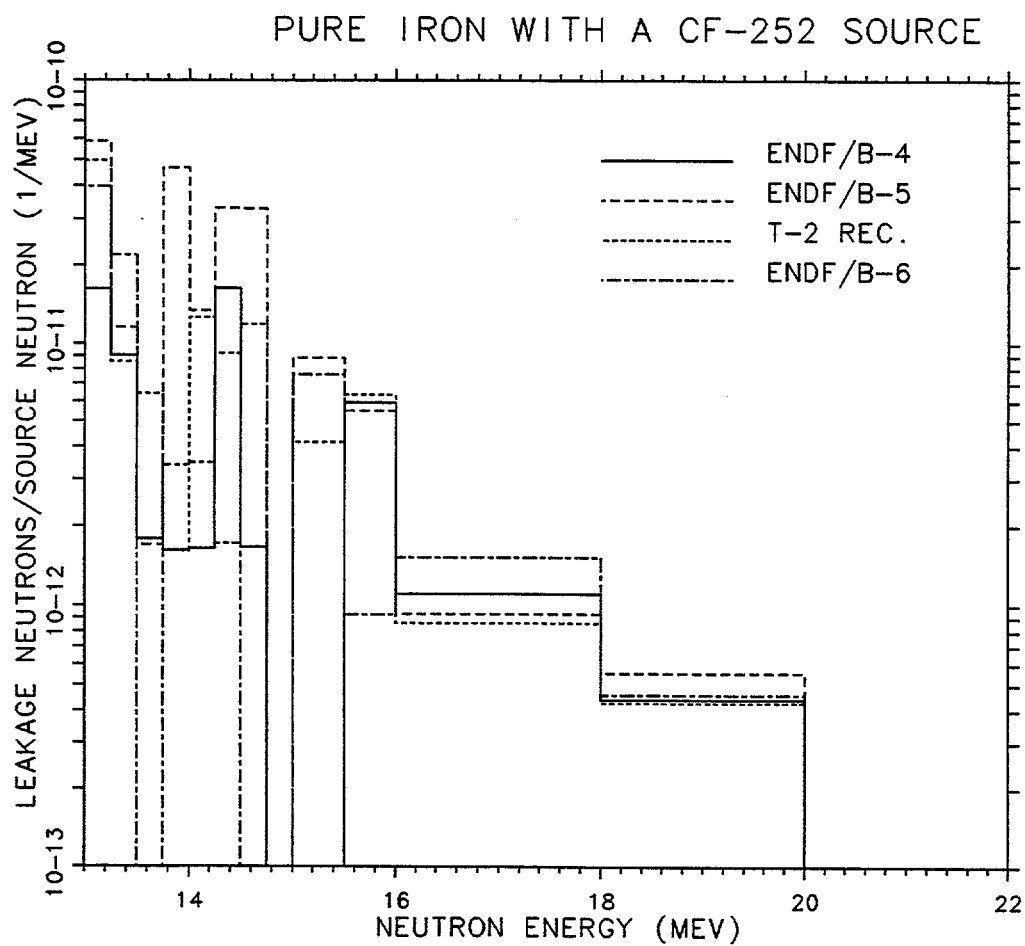


Fig. 41. Plot of pure iron with a  $^{252}\text{Cf}$  source for the energy group  $> 13$  MeV. The results are affected by a lack of good statistics.

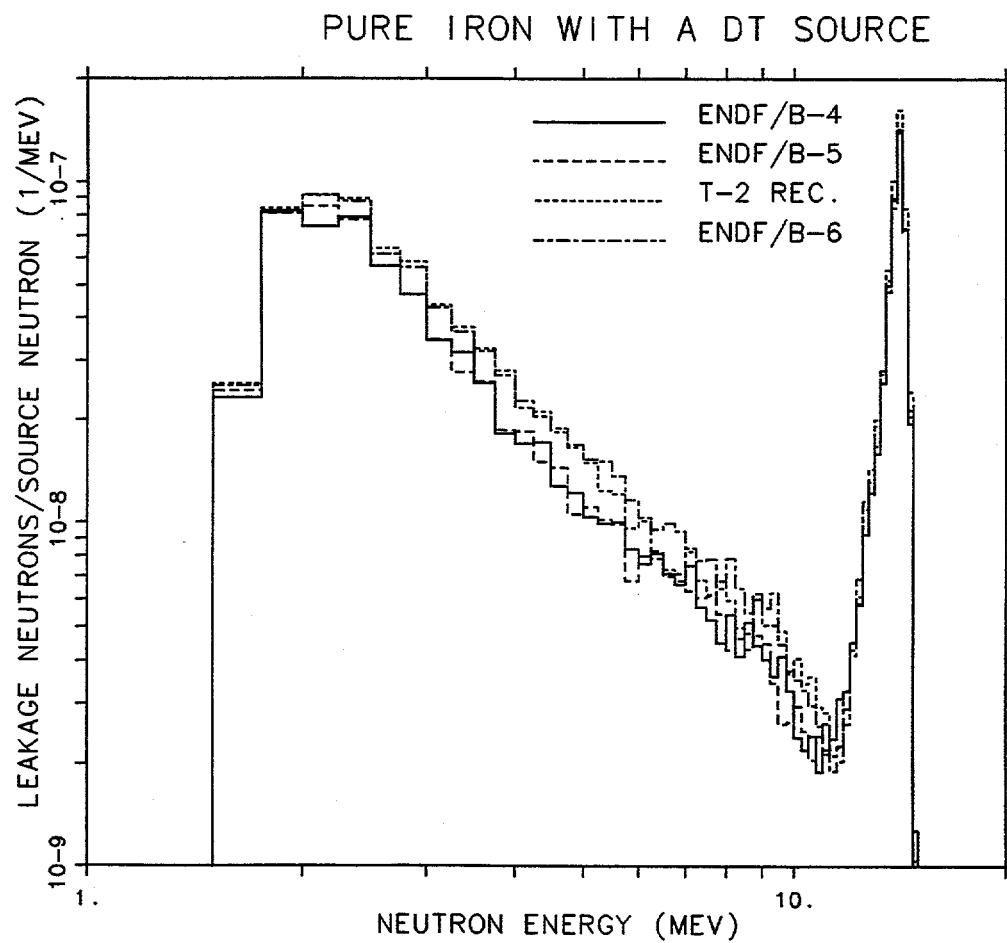


Fig. 42. Plot of ENDF/B-IV, ENDF/B-V, MCNP Recommended, and ENDF/B-VI calculated for pure iron with a  $T(d,n)^4\text{He}$  source.

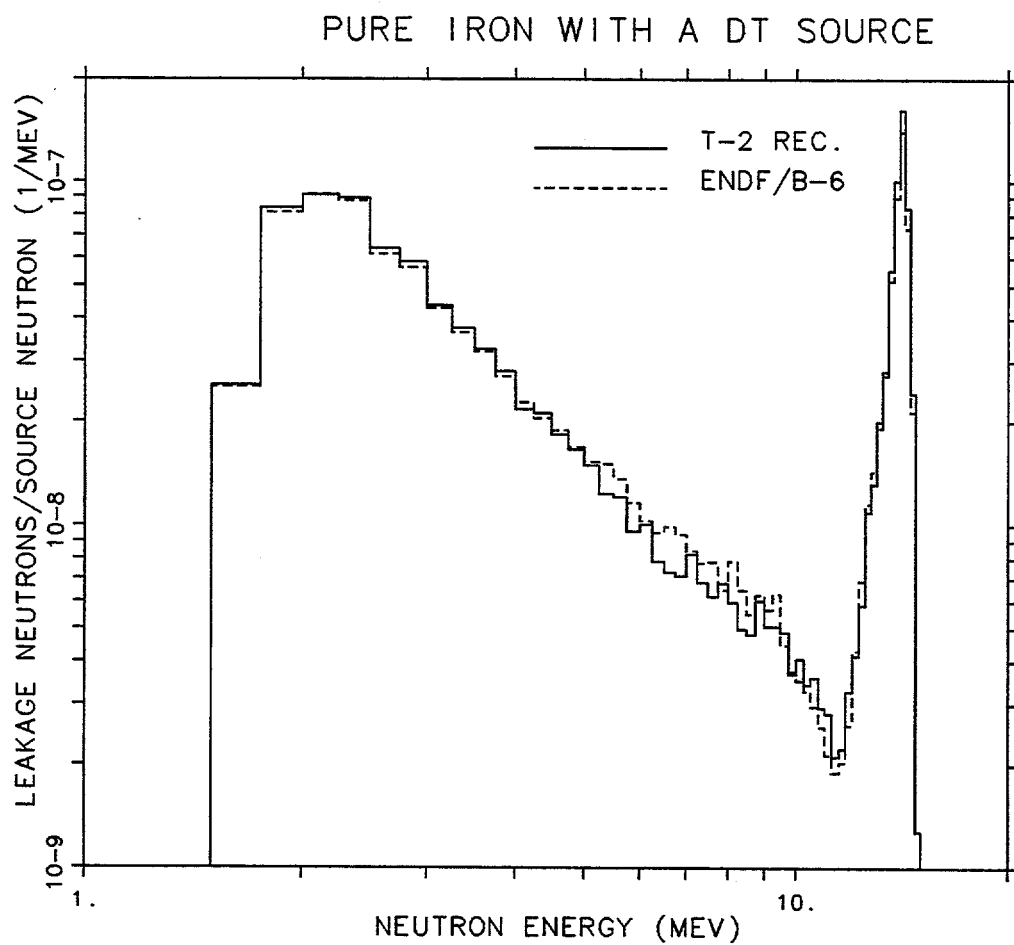


Fig. 43. Plot of MCNP Recommended and ENDF/B-VI calculated for pure iron with a  $T(d,n)^4\text{He}$  source.

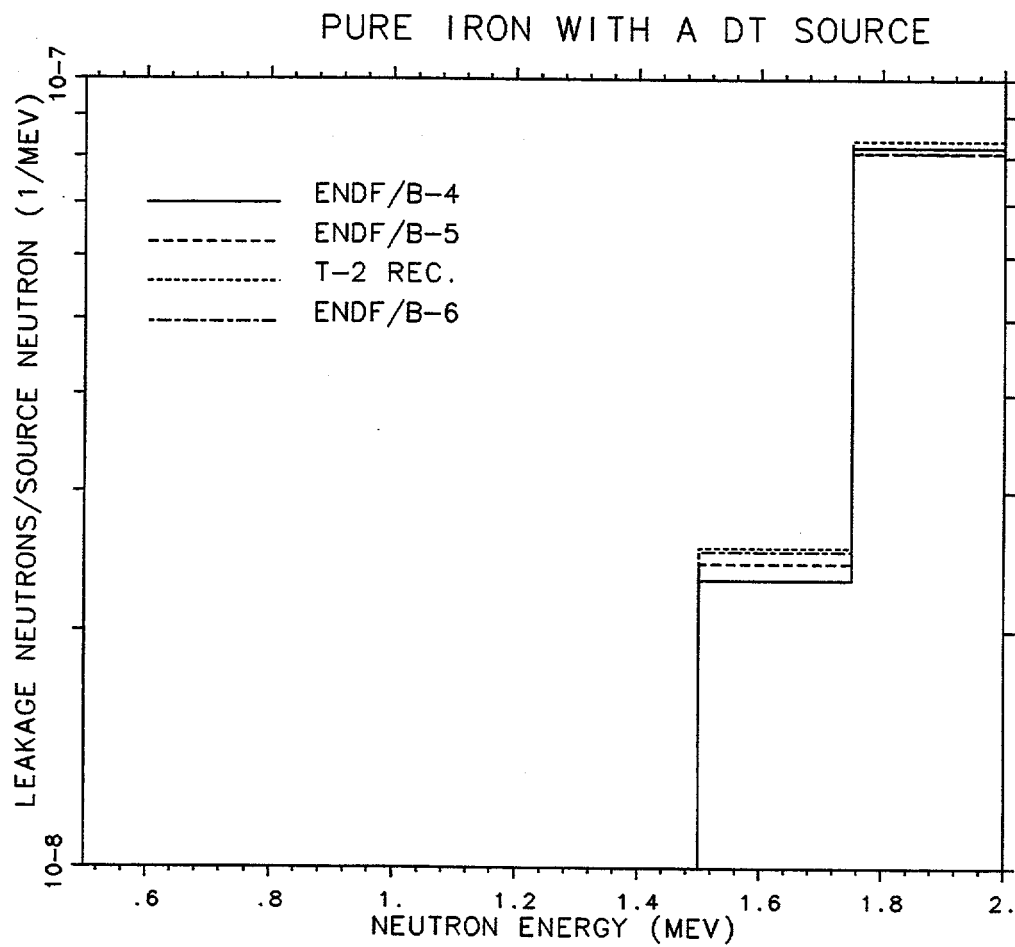


Fig. 44. Plot of pure iron with a  $T(d,n)^4\text{He}$  source for the energy group 0.5-2 MeV.

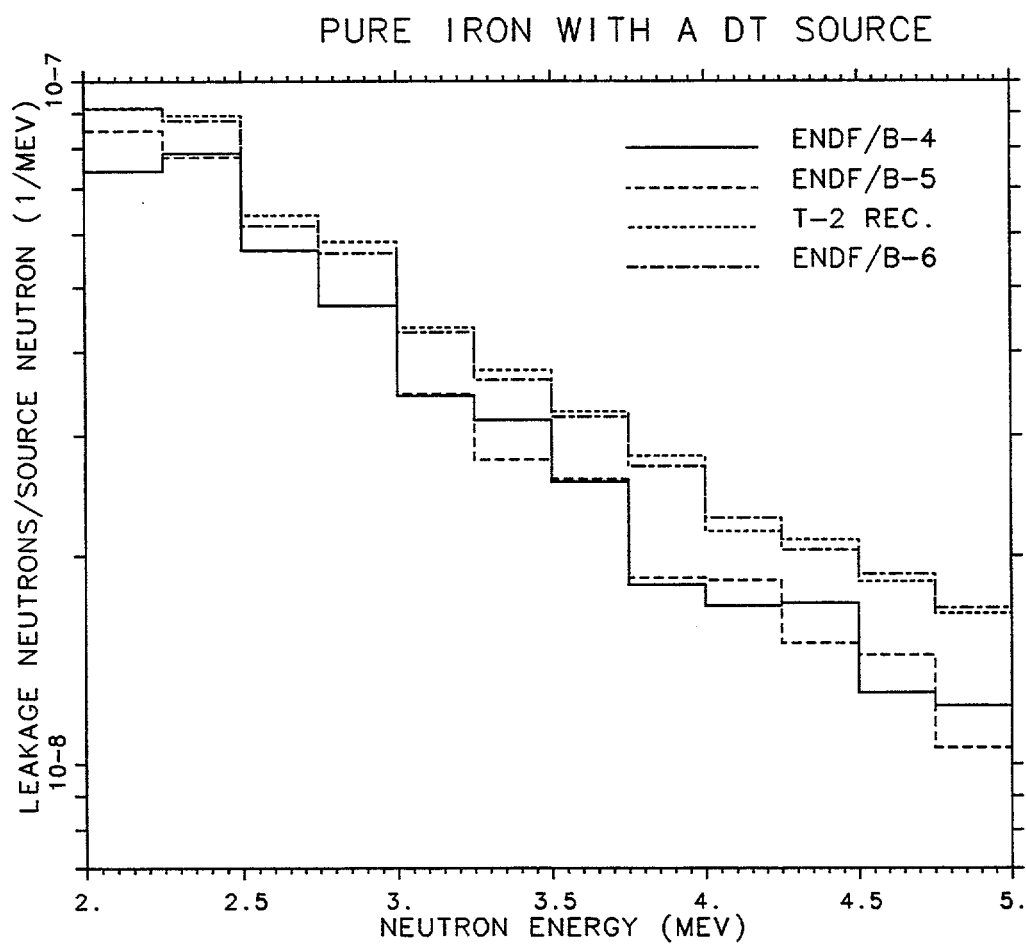


Fig. 45. Plot of pure iron with a  $T(d,n)^4\text{He}$  source for the energy group 2-5 MeV.

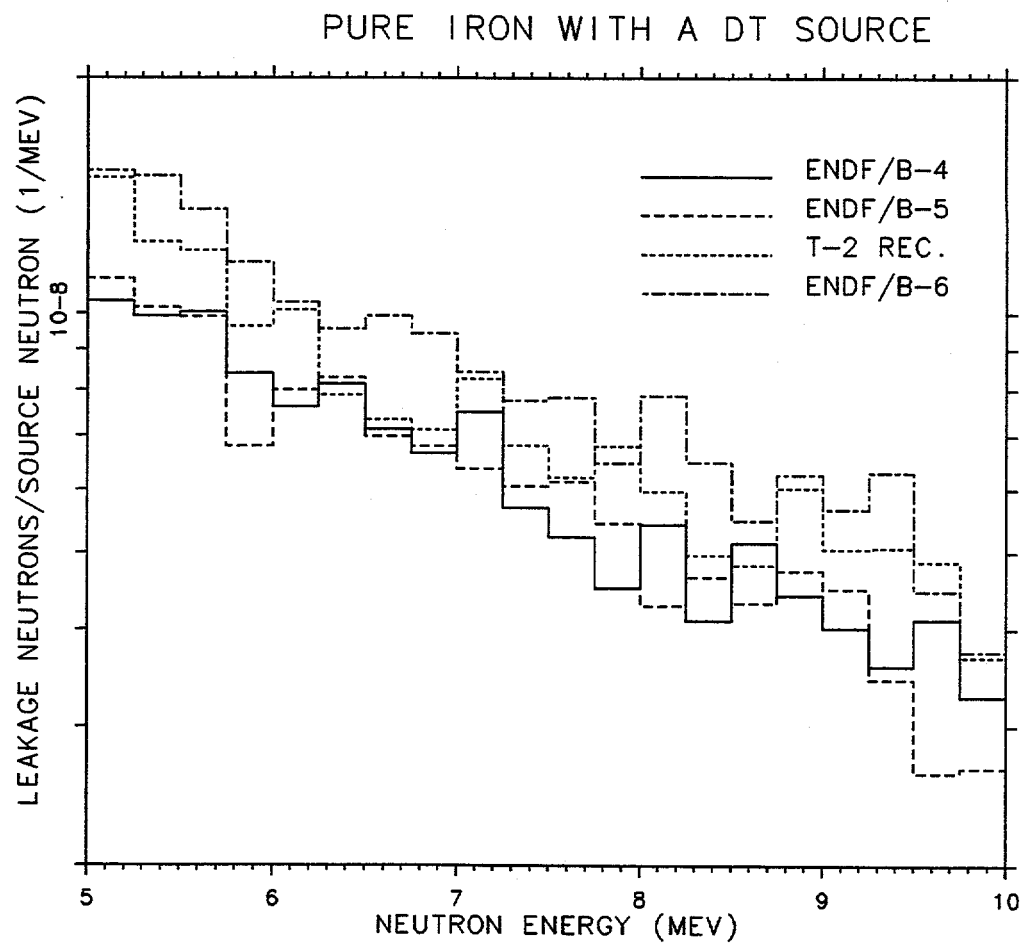


Fig. 46. Plot of pure iron with a  $T(d,n)^4\text{He}$  source for the energy group 5–10 MeV.

# PURE IRON WITH A DT SOURCE

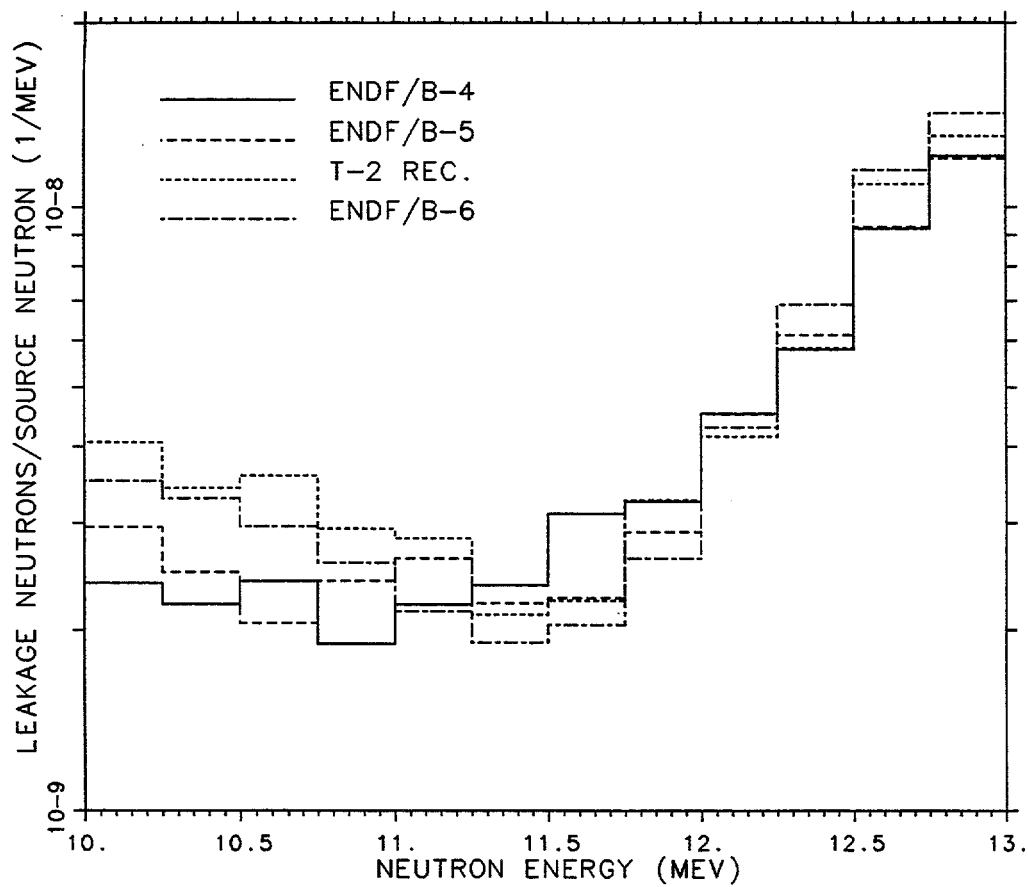


Fig. 47. Plot of pure iron with a  $T(d,n)^4\text{He}$  source for the energy group 10-13 MeV.

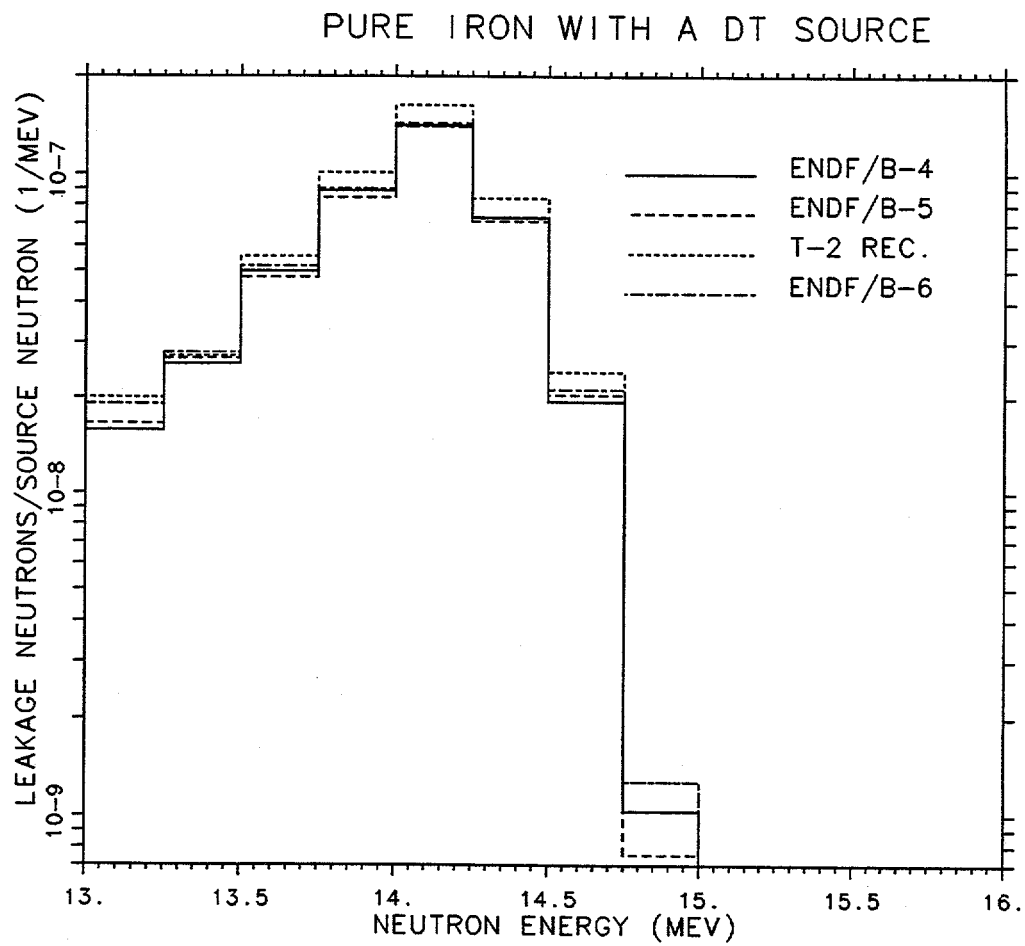


Fig. 48. Plot of pure iron with a  $T(d,n)^4\text{He}$  source for the energy group  $> 13$  MeV.

# HIGH CARBON STEEL WITH A CF-252 SOURCE

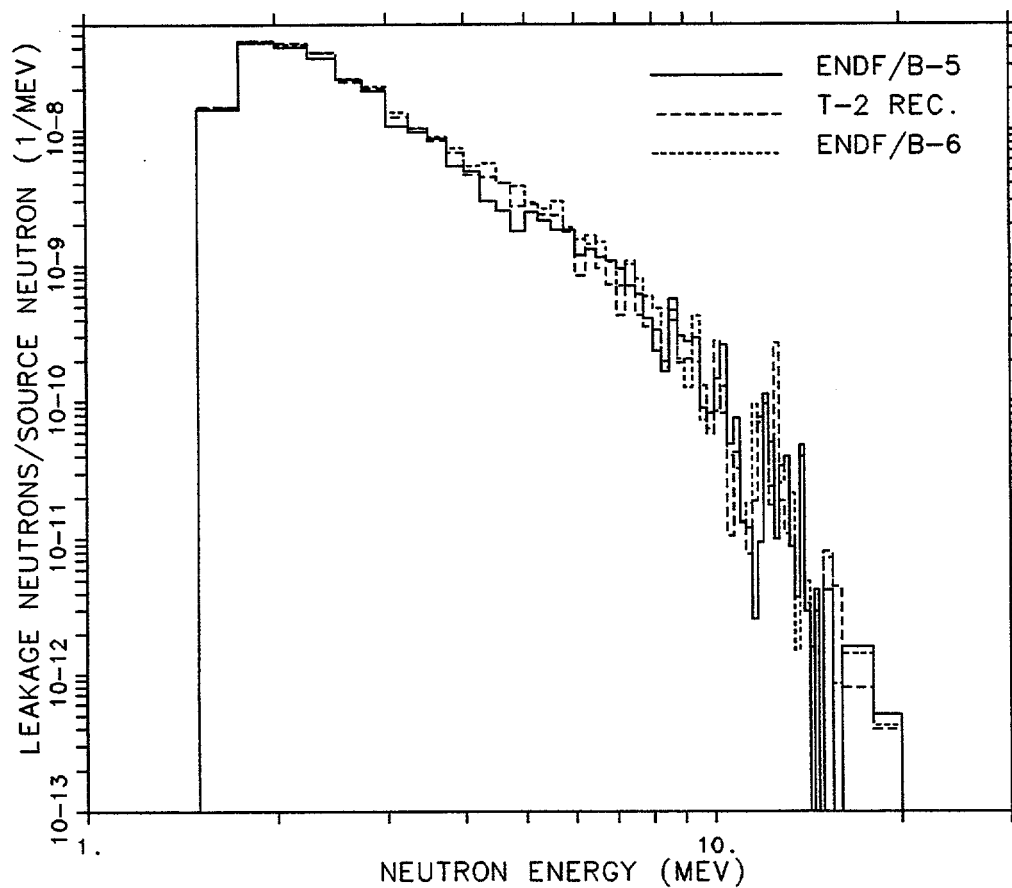


Fig. 49. Plot of ENDF/B-V, MCNP Recommended, and ENDF/B-VI calculated for high carbon steel with a  $^{252}\text{Cf}$  source.

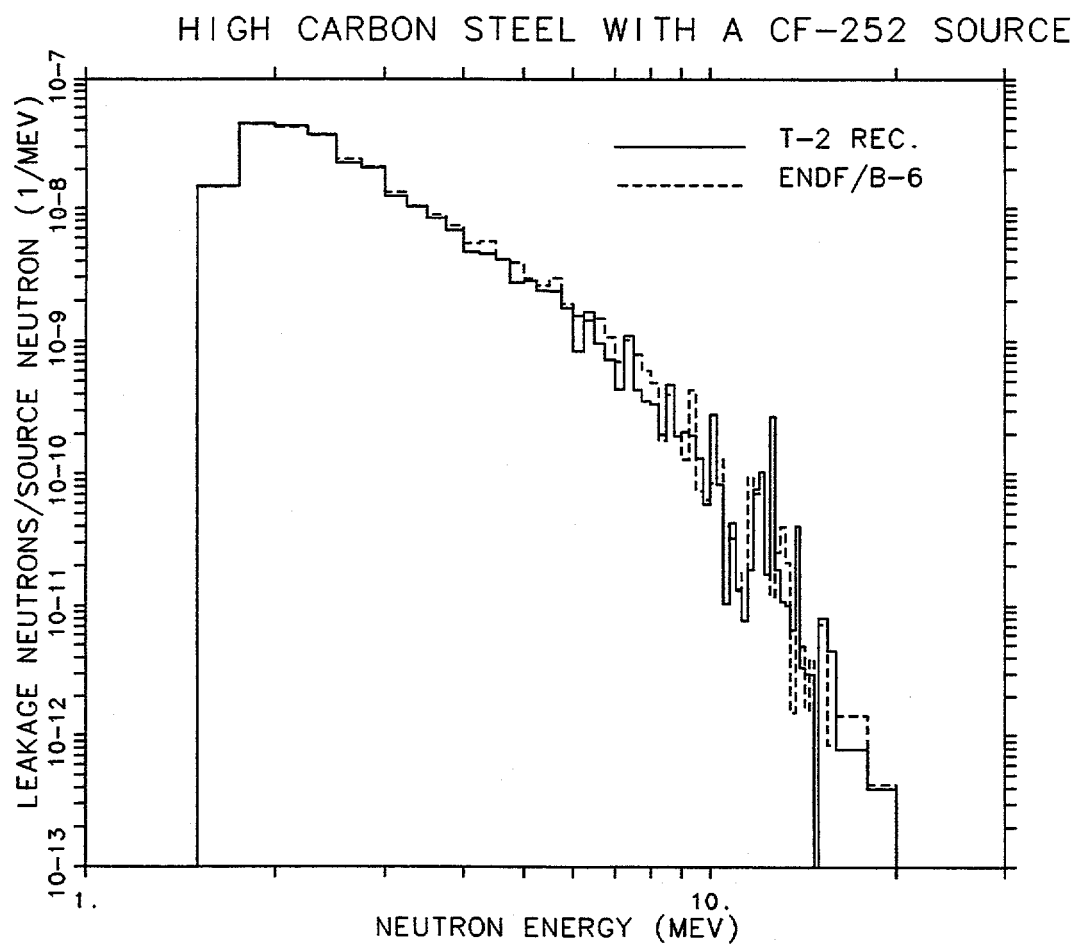


Fig. 50. Plot of MCNP Recommended and ENDF/B-VI calculated for high carbon steel with a  $^{252}\text{Cf}$  source.

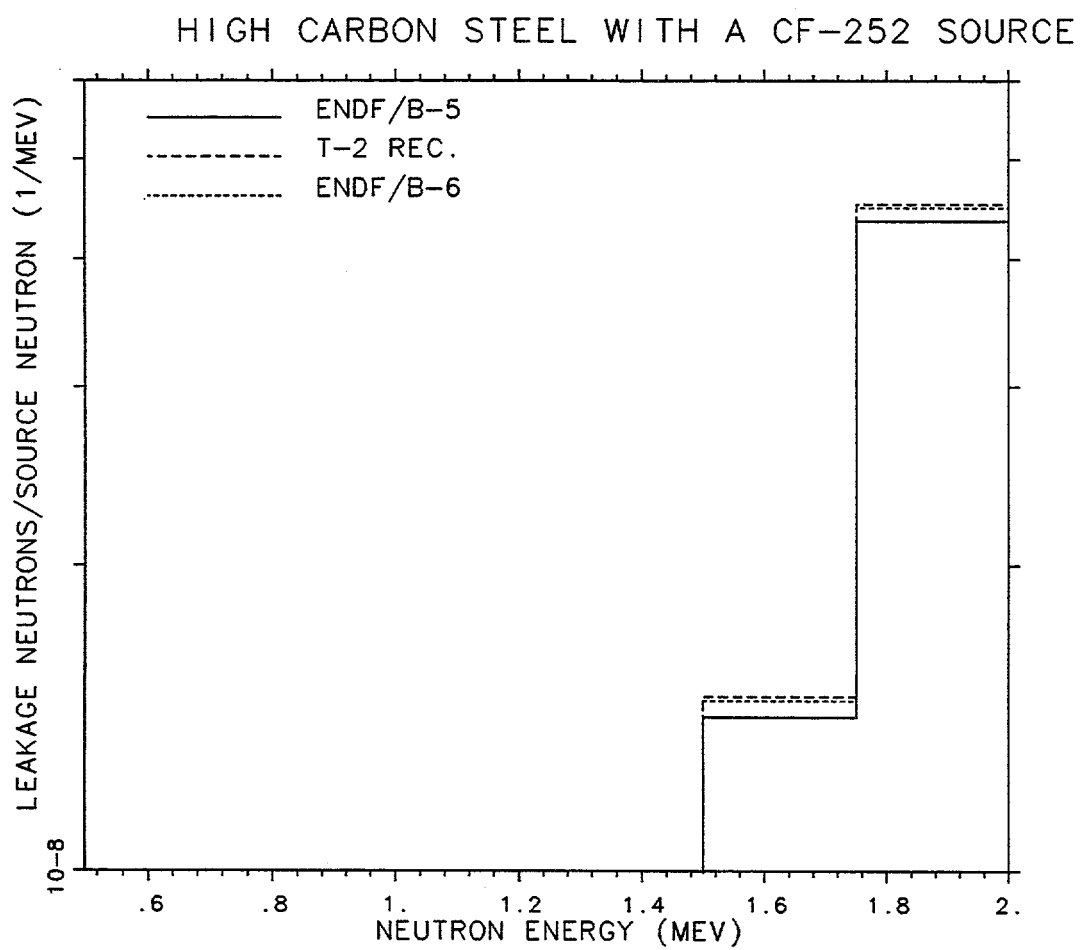


Fig. 51. Plot of high carbon steel with a  $^{252}\text{Cf}$  source for the energy group 0.5-2 MeV.

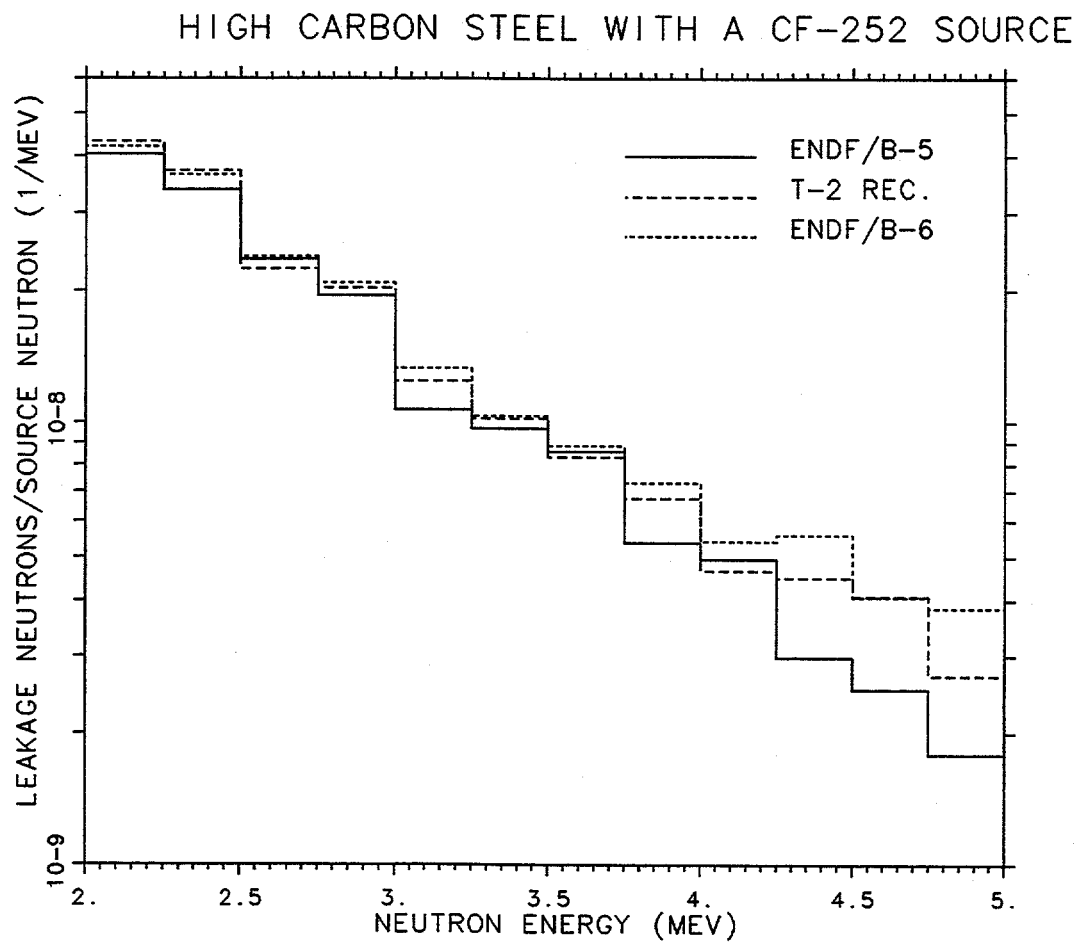


Fig. 52. Plot of high carbon steel with a  $^{252}\text{Cf}$  source for the energy group 2-5 MeV.

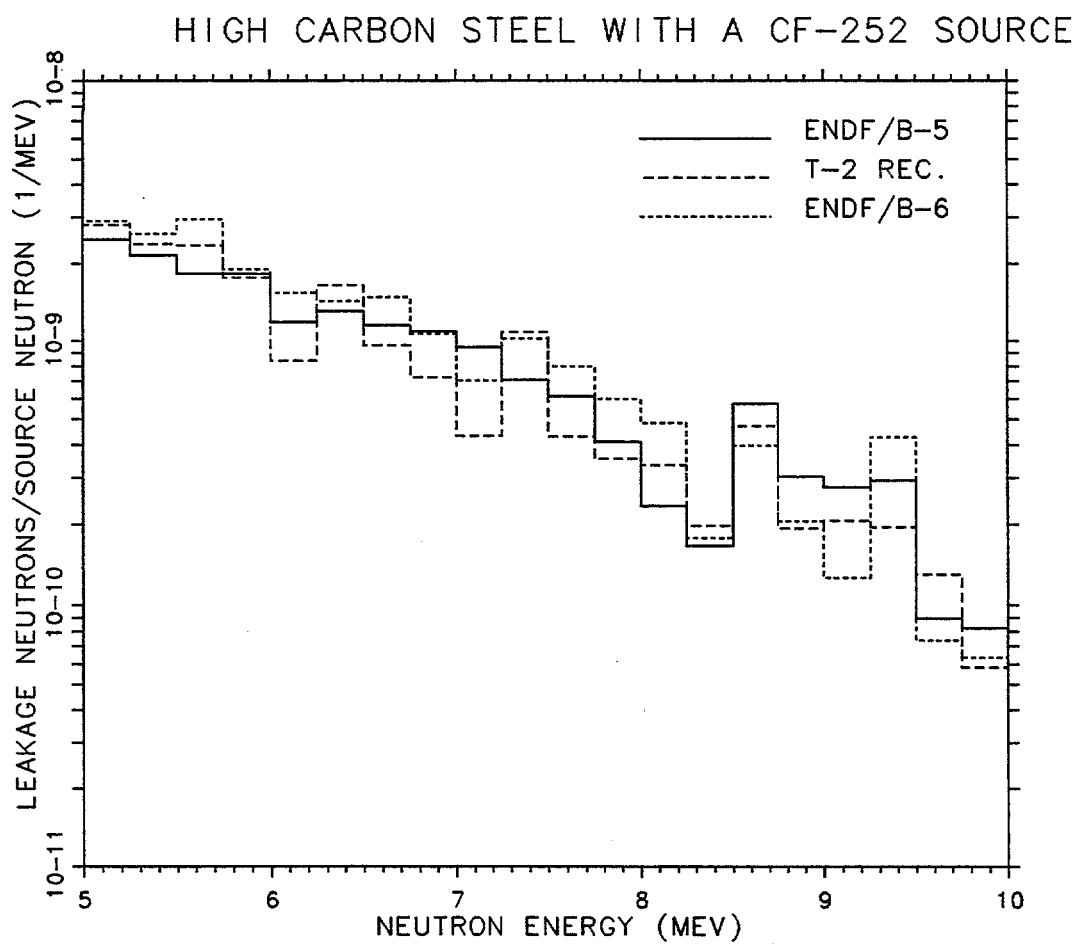


Fig. 53. Plot of high carbon steel with a  $^{252}\text{Cf}$  source for the energy group 5-10 MeV.

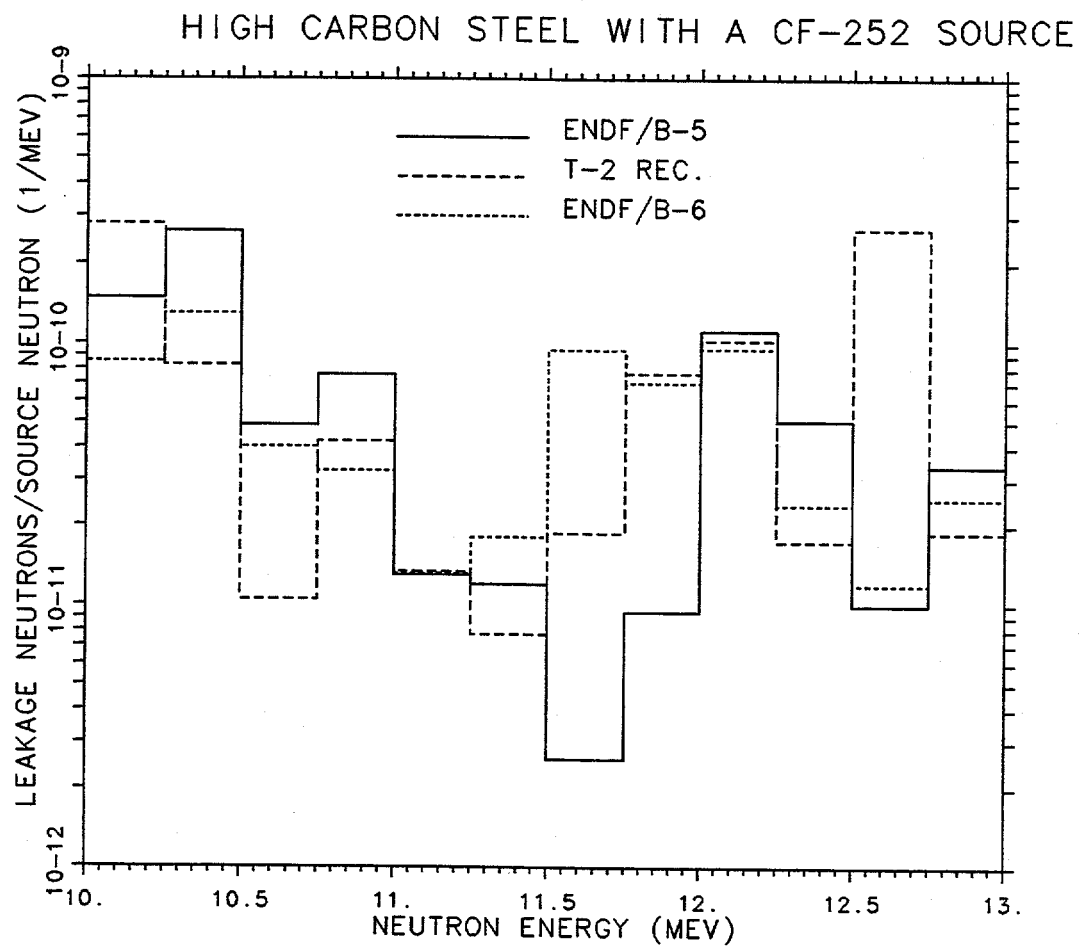


Fig. 54. Plot of high carbon steel with a  $^{252}\text{Cf}$  source for the energy group 10-13 MeV.

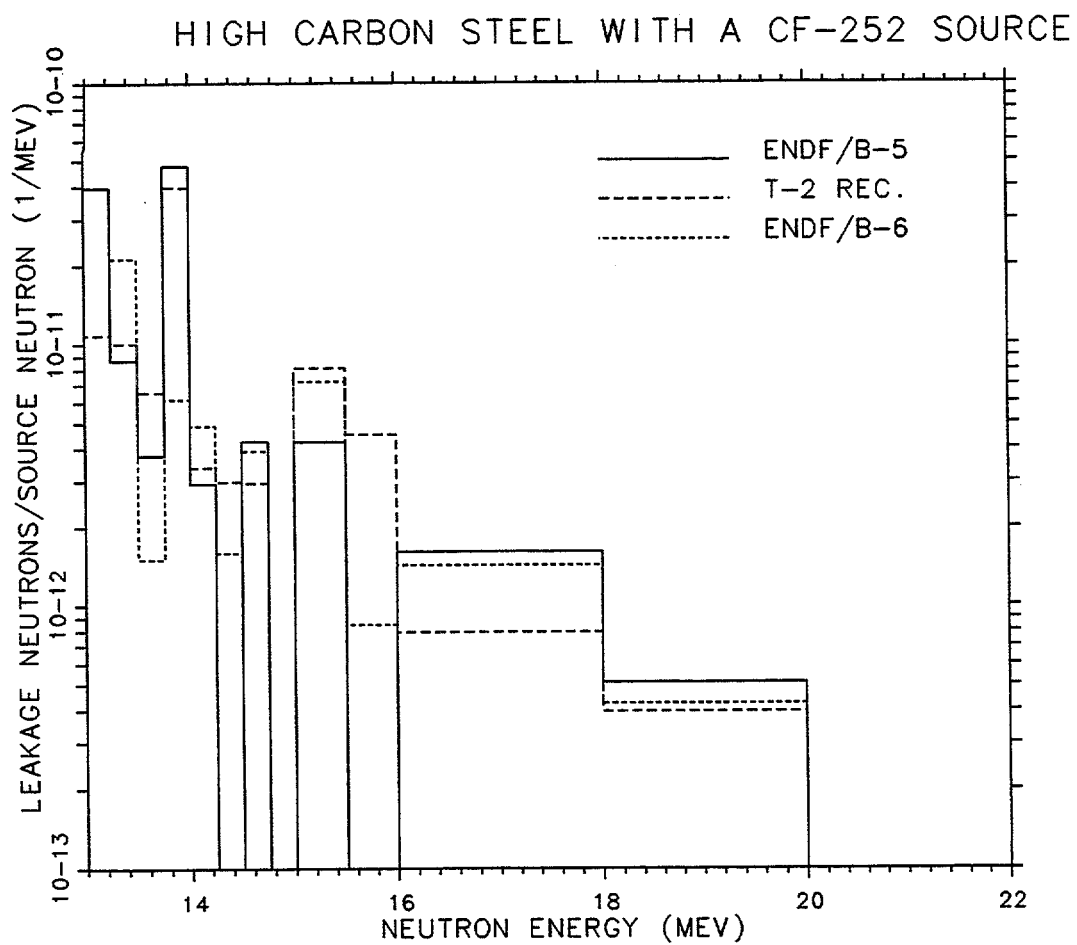


Fig. 55. Plot of high carbon steel with a  $^{252}\text{Cf}$  source for the energy group  $> 13$  MeV.

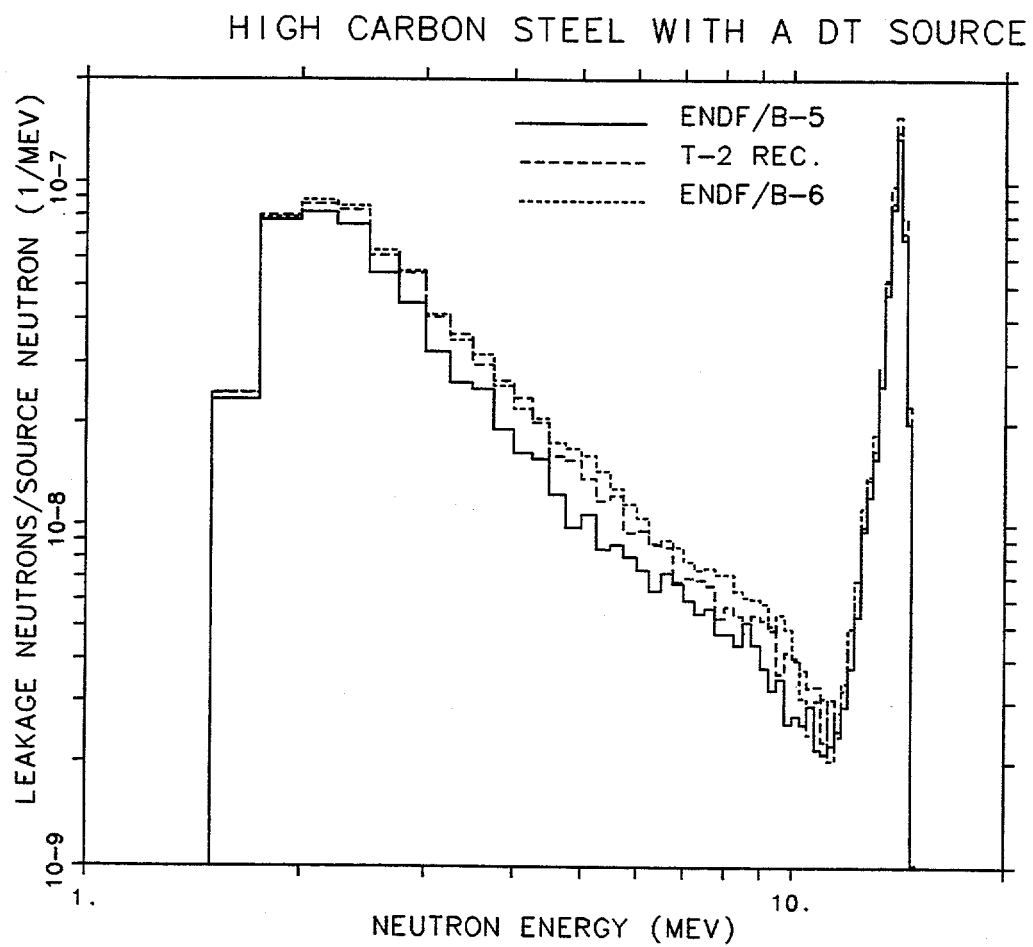


Fig. 56. Plot of ENDF/B-V, MCNP Recommended, and ENDF/B-VI calculated for high carbon steel with a  $T(d,n)^4\text{He}$  source.

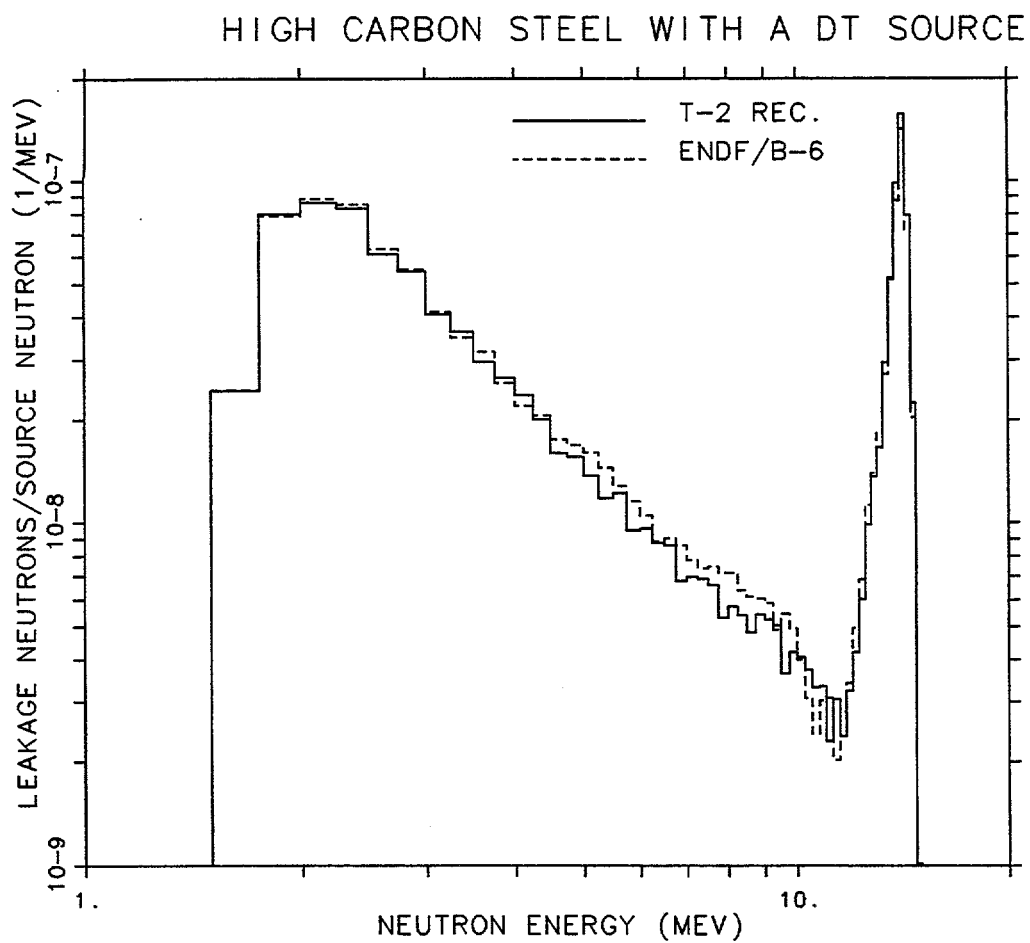


Fig. 57. Plot of MCNP Recommended and ENDF/B-VI calculated for high carbon steel with a  $T(d,n)^4\text{He}$  source.

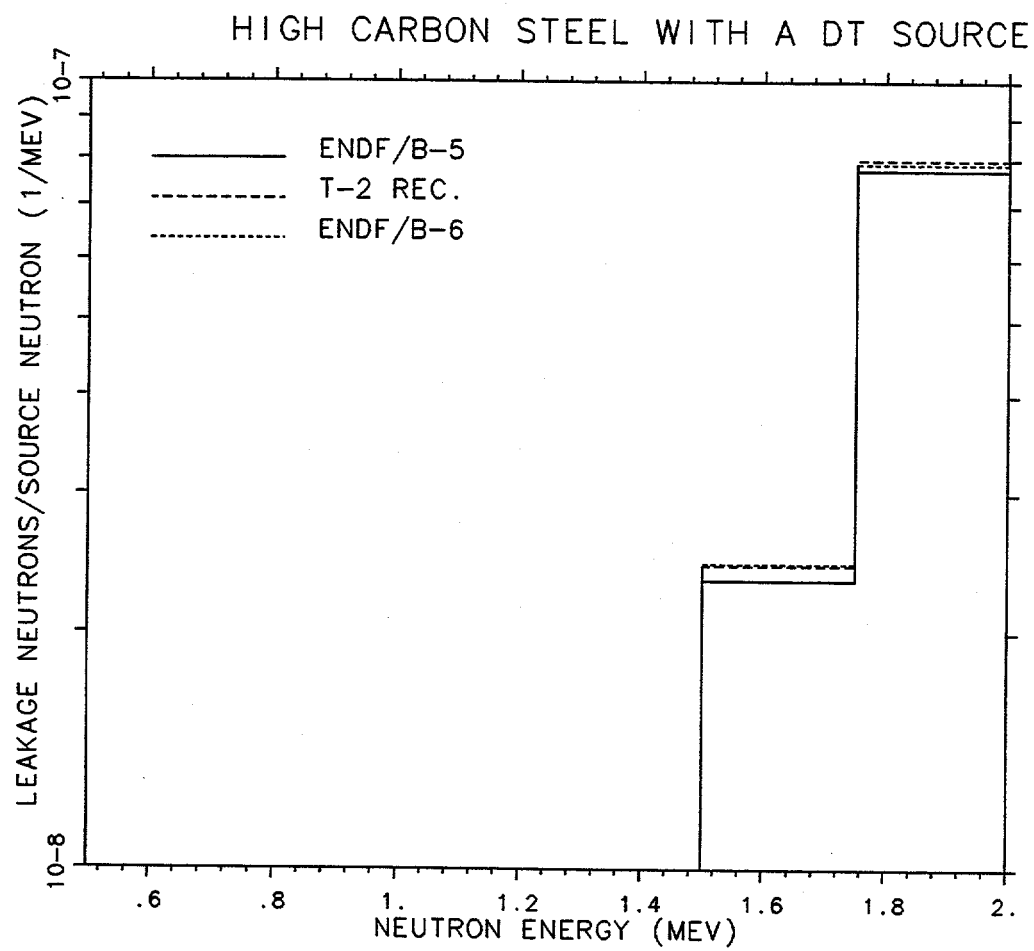


Fig. 58. Plot of high carbon steel with a  $T(d,n)^4\text{He}$  source for the energy group 0.5–2 MeV.

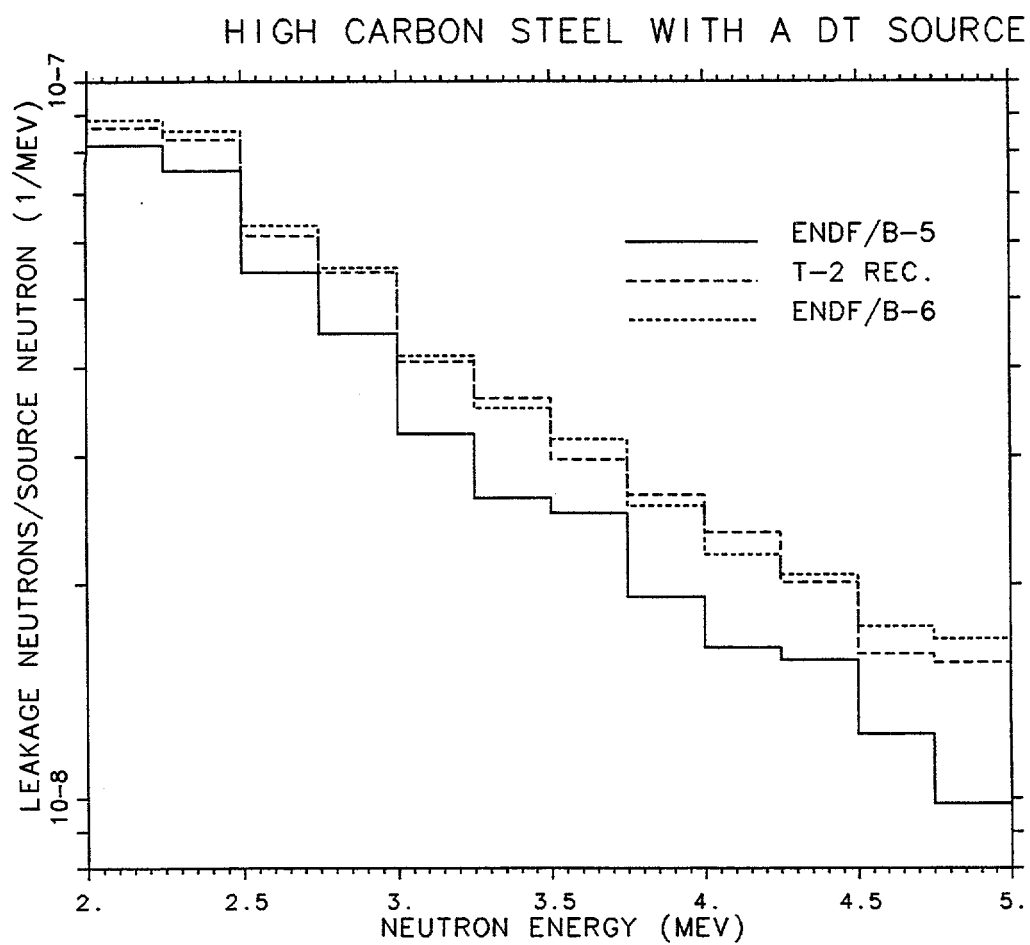


Fig. 59. Plot of high carbon steel with a  $T(d,n)^4\text{He}$  source for the energy group 2-5 MeV.

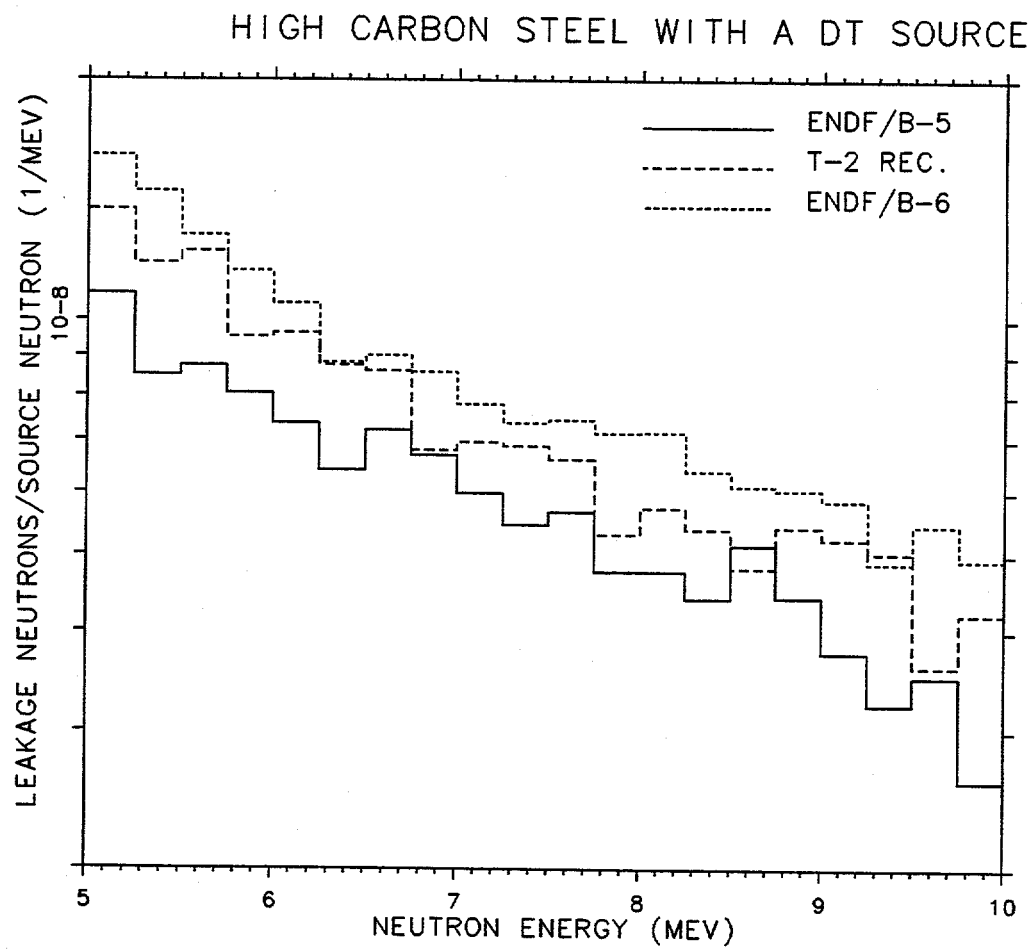


Fig. 60. Plot of high carbon steel with a  $T(d,n)^4\text{He}$  source for the energy group 5-10 MeV.

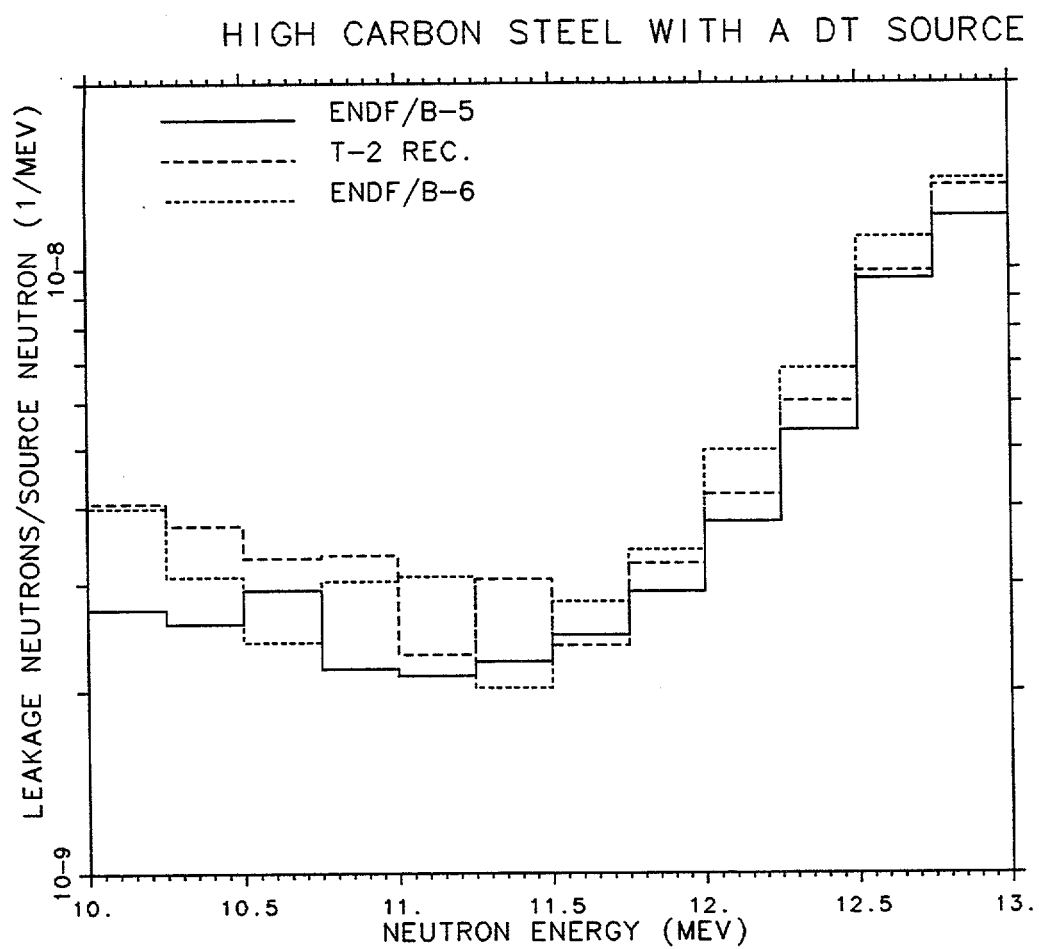


Fig. 61. Plot of high carbon steel with a  $T(d,n)^4\text{He}$  source for the energy group 10–13 MeV.

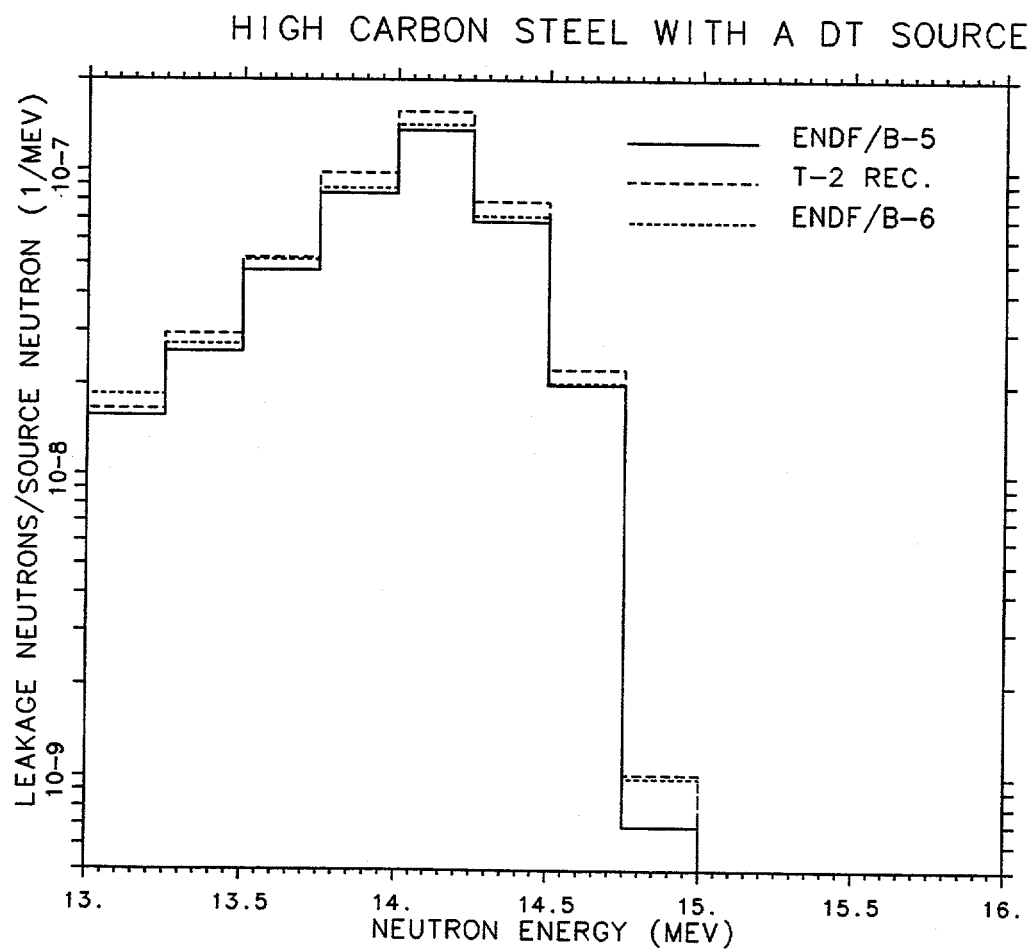


Fig. 62. Plot of high carbon steel with a  $T(d,n)^4\text{He}$  source for the energy group  $> 13$  MeV.

## V. BENCHMARK FOR NEUTRON TRANSPORT THROUGH IRON

### A. Experimental Setup

In the early 70's, measurements were undertaken at the Oak Ridge National Laboratory's Tower Shielding Facility to determine the neutron fluence and neutron spectra behind slabs of iron up to 3 feet thick. Using a collimated beam of reactor neutrons as a source, measurements of neutrons above thermal energy through various thicknesses of iron slabs were made with the use of spherical  $\text{BF}_3$  detectors surrounded by various thicknesses of polyethylene and an outside shell of cadmium. These Bonner Ball detectors provided measurements of weighted integral flux. Figure 63 shows a schematic of the experimental setup.<sup>16</sup>

Four different thicknesses of iron slab were exposed to the neutron beam, and measurements were made at three different points behind the slab with three different size Bonner Ball detectors, giving nine measurements for each iron slab thickness. The density of the iron slabs averaged  $7.79 \text{ grams/cm}^3$ . The average composition of the iron slab is shown in Table IX, where it is to be noted that the iron slabs were actually carbon steel. Table X shows the position of the Bonner Ball detectors with respect to the MCNP source, which is located at the origin of the coordinate system.

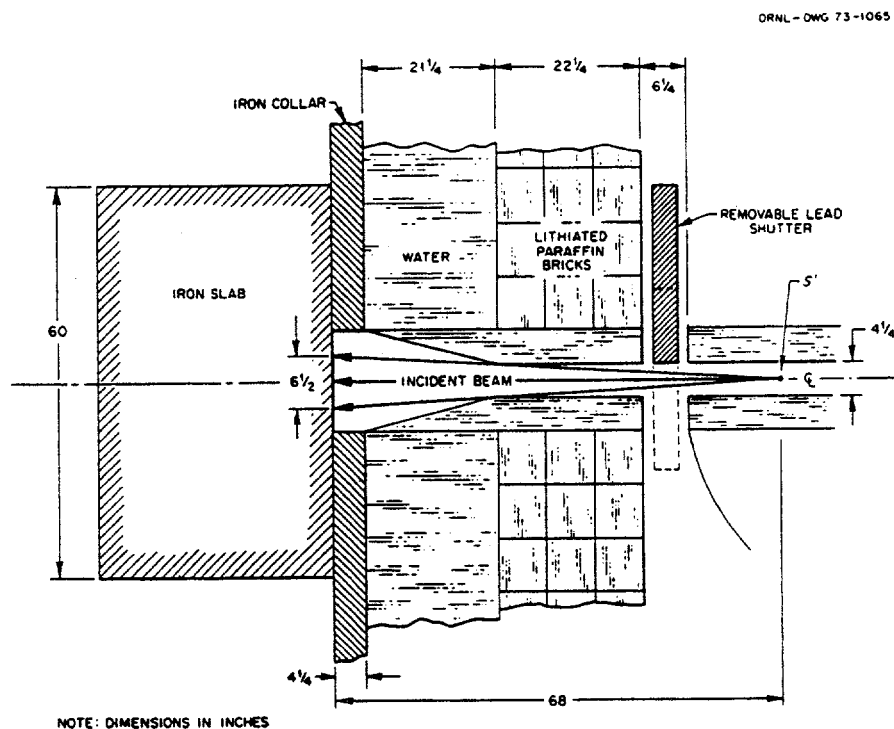


Fig. 63. Oak Ridge Iron Transport Benchmark Layout.

TABLE IX. Composition of the Iron Slabs in atom/cm Barns.

| Element   | Composition            |
|-----------|------------------------|
| Carbon    | $9.815 \times 10^{-4}$ |
| Manganese | $5.55 \times 10^{-4}$  |
| Iron      | $8.372 \times 10^{-2}$ |

TABLE X. Experimental Configuration for the Iron Transmission Measurements.

| Detector Locations                                                                                                                                                                                                                             |                                                                     |                      |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------|----------------------|
| Iron Slab Thickness (cm)                                                                                                                                                                                                                       | Observation Angle <sup>a</sup> With Respect to Centerline (degrees) | Coordinate Position  |
| 3.937                                                                                                                                                                                                                                          | 0                                                                   | (-562.74, 0, 0)      |
|                                                                                                                                                                                                                                                | 15                                                                  | (-547.50, 99.06, 0)  |
|                                                                                                                                                                                                                                                | 45                                                                  | (-448.44, 271.78, 0) |
| 30.810                                                                                                                                                                                                                                         | 0                                                                   | (-561.67, 0, 0)      |
|                                                                                                                                                                                                                                                | 15                                                                  | (-548.97, 92.71, 0)  |
|                                                                                                                                                                                                                                                | 45                                                                  | (-457.53, 254.00, 0) |
| 62.001                                                                                                                                                                                                                                         | 0                                                                   | (-559.84, 0, 0)      |
|                                                                                                                                                                                                                                                | 15                                                                  | (-549.68, 83.82, 0)  |
|                                                                                                                                                                                                                                                | 45                                                                  | (-464.59, 229.87, 0) |
| 92.862                                                                                                                                                                                                                                         | 0                                                                   | (-548.68, 0, 0)      |
|                                                                                                                                                                                                                                                | 15                                                                  | (-538.52, 76.20, 0)  |
|                                                                                                                                                                                                                                                | 45                                                                  | (-463.59, 207.01, 0) |
| <sup>a</sup> The observation angle is defined as the angle between the centerline and a line connecting the detector and the midpoint of the emergent face of the slab. The vertex of this angle is the pivot point for the angular traverses. |                                                                     |                      |

## B. Results and Discussion

The MCNP calculations were done for each iron slab thickness using the four data sets of interest:

- ENDF/B-IV
- ENDF/B-V
- T-2 Recommended MCNP Library
- ENDF/B-VI

An attempt to duplicate previous results<sup>17</sup> produced results that grew progressively worse as the slabs got thicker. It is unfortunate that the problem setup for the earlier analysis of this experiment is not available and the present model inadequately models the experiment. The disagreement with experimental results indicates that there is a fundamental problem in the manner in which the problem is set up. The comparisons to experimental results are given in Tables XI through XIV and, if anything, ENDF/B-VI appears to give the worst results. Fortunately, the results can be compared between data sets, which is the focus of this work. Each Bonner Ball detector calculation was normalized to the ENDF/B-V results for the detector type and position. These normalized results are shown with the resultant spectra in Figures 64 through 99. In these comparisons, ENDF/B-VI proves to be about the same as the other data libraries.

TABLE XI. Comparison to Experiment for the 3.94 cm Iron Slab.

| Data Set  | Observation<br>Angle (deg) | % Deviation from Experiment |           |           |
|-----------|----------------------------|-----------------------------|-----------|-----------|
|           |                            | 3.09 inch                   | 5.88 inch | 9.86 inch |
| ENDF/B-IV | 0                          | 2.0                         | -3.3      | 0.1       |
|           | 15                         | 10.3                        | 0.9       | -0.3      |
|           | 45                         | 10.9                        | 8.0       | 7.5       |
| ENDF/B-V  | 0                          | 1.7                         | -4.4      | -0.7      |
|           | 15                         | 10.1                        | 1.1       | 0.3       |
|           | 45                         | 9.7                         | 7.6       | 8.0       |
| T-2 Rec.  | 0                          | 2.4                         | -3.2      | 0.1       |
|           | 15                         | 9.5                         | 0.8       | 1.1       |
|           | 45                         | 8.9                         | 6.6       | 8.0       |
| ENDF/B-VI | 0                          | 2.4                         | -2.5      | 0.6       |
|           | 15                         | 10.7                        | 0.8       | 1.6       |
|           | 45                         | 10.4                        | 6.3       | 7.9       |

TABLE XII. Comparison to Experiment for the 30.81 cm Iron Slab.

| Data Set  | Observation<br>Angle (deg) | % Deviation from Experiment |           |           |
|-----------|----------------------------|-----------------------------|-----------|-----------|
|           |                            | 3.09 inch                   | 5.88 inch | 9.86 inch |
| ENDF/B-IV | 0                          | -4.7                        | -16.7     | -18.5     |
|           | 15                         | 11.3                        | 6.4       | 4.3       |
|           | 45                         | 12.1                        | 10.4      | 7.5       |
| ENDF/B-V  | 0                          | -6.1                        | -23.5     | -28.9     |
|           | 15                         | 11.0                        | 4.6       | 0.1       |
|           | 45                         | 11.4                        | 8.0       | 2.3       |
| T-2 Rec.  | 0                          | -4.6                        | -17.2     | -19.3     |
|           | 15                         | 9.8                         | 5.6       | 3.6       |
|           | 45                         | 10.5                        | 9.3       | 6.4       |
| ENDF/B-VI | 0                          | 1.5                         | -3.1      | -3.1      |
|           | 15                         | 10.2                        | 5.7       | 5.3       |
|           | 45                         | 10.6                        | 9.9       | 9.2       |

TABLE XIII. Comparison to Experiment for the 62.00 cm Iron Slab.

| Data Set  | Observation<br>Angle (deg) | % Deviation from Experiment |           |           |
|-----------|----------------------------|-----------------------------|-----------|-----------|
|           |                            | 3.09 inch                   | 5.88 inch | 9.86 inch |
| ENDF/B-IV | 0                          | 6.7                         | -9.3      | -18.3     |
|           | 15                         | 17.8                        | 9.9       | -0.1      |
|           | 45                         | 40.0                        | 27.6      | 10.6      |
| ENDF/B-V  | 0                          | 13.6                        | -6.2      | -21.7     |
|           | 15                         | 20.3                        | 9.4       | -5.4      |
|           | 45                         | 42.9                        | 27.3      | 5.7       |
| T-2 Rec.  | 0                          | 10.0                        | -6.1      | -16.4     |
|           | 15                         | 18.0                        | 9.2       | -2.3      |
|           | 45                         | 38.1                        | 26.1      | 7.9       |
| ENDF/B-VI | 0                          | 16.6                        | 15.4      | 15.8      |
|           | 15                         | 12.1                        | 9.6       | 4.3       |
|           | 45                         | 32.0                        | 26.9      | 16.1      |

TABLE XIV. Comparison to Experiment for the 92.86 cm Iron Slab.

| Data Set  | Observation<br>Angle (deg) | % Deviation from Experiment |           |           |
|-----------|----------------------------|-----------------------------|-----------|-----------|
|           |                            | 3.09 inch                   | 5.88 inch | 9.86 inch |
| ENDF/B-IV | 0                          | 18.5                        | 5.2       | -7.7      |
|           | 15                         | 34.2                        | 26.4      | 8.4       |
|           | 45                         | 77.4                        | 70.6      | 47.3      |
| ENDF/B-V  | 0                          | 31.0                        | 17.9      | 0.1       |
|           | 15                         | 40.3                        | 30.7      | 8.4       |
|           | 45                         | 81.7                        | 73.5      | 45.7      |
| T-2 Rec.  | 0                          | 23.8                        | 11.8      | -2.4      |
|           | 15                         | 35.4                        | 27.3      | 7.5       |
|           | 45                         | 77.2                        | 69.4      | 43.8      |
| ENDF/B-VI | 0                          | 28.0                        | 36.9      | 40.6      |
|           | 15                         | 29.3                        | 31.0      | 20.9      |
|           | 45                         | 81.6                        | 86.1      | 69.8      |

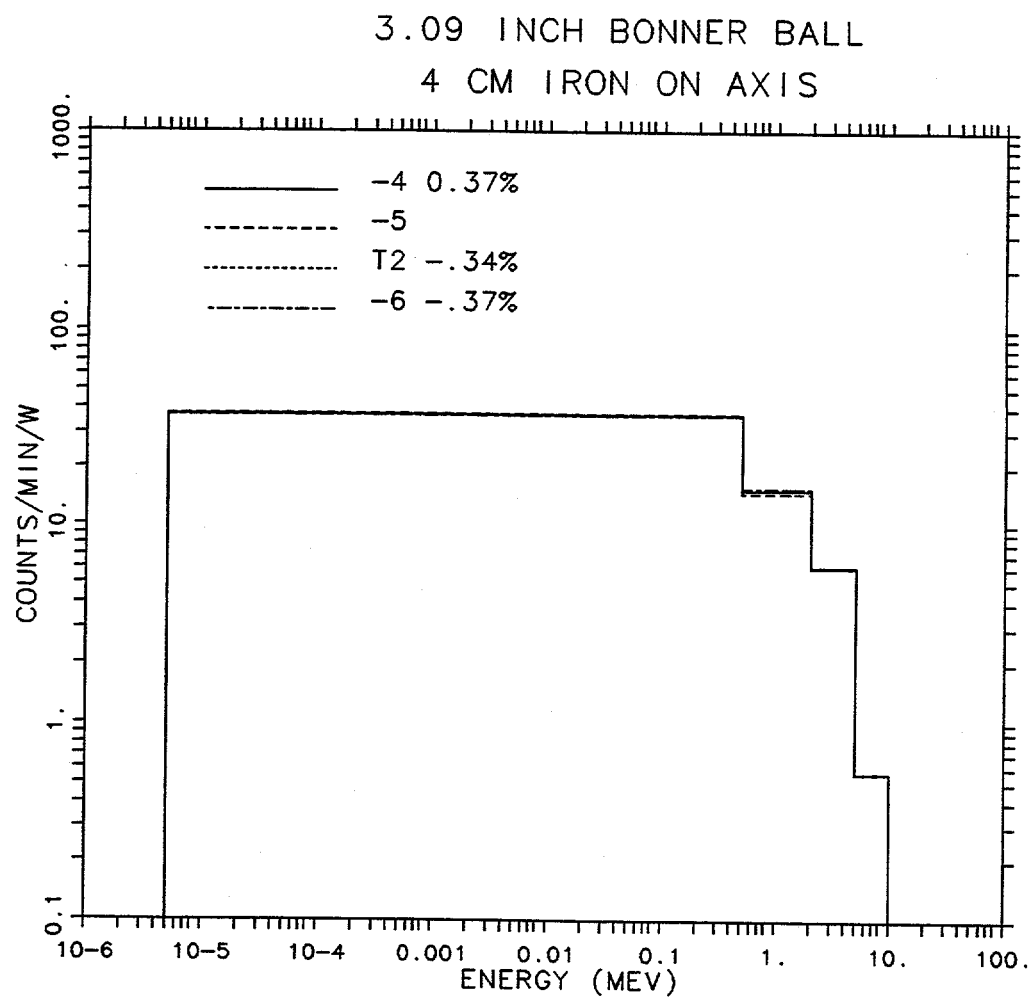


Fig. 64. Data set comparisons for the 4 cm iron slab, with the 3.09 in Bonner Ball on axis.  
(Normalized to ENDF/B-V)

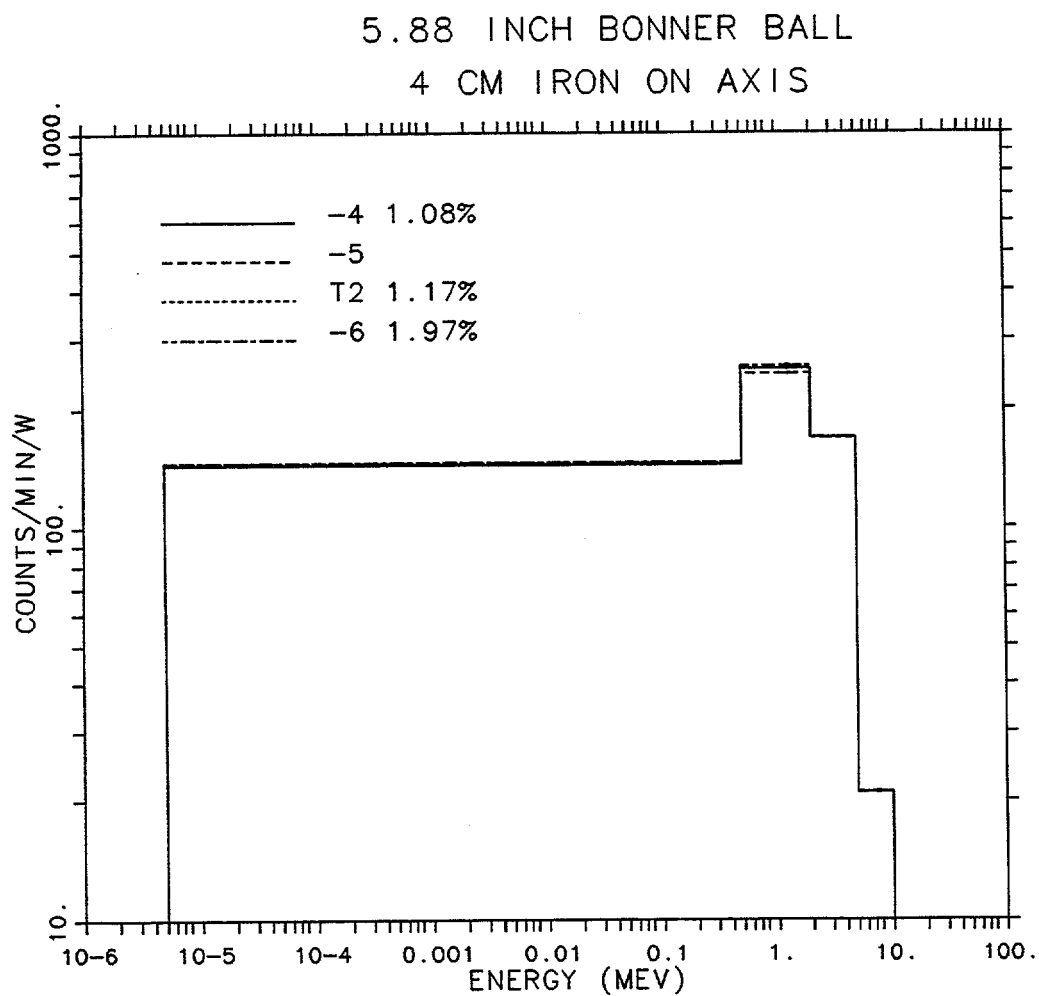


Fig. 65. Data set comparisons for the 4 cm iron slab, with the 5.88 in Bonner Ball on axis.  
(Normalized to ENDF/B-V)

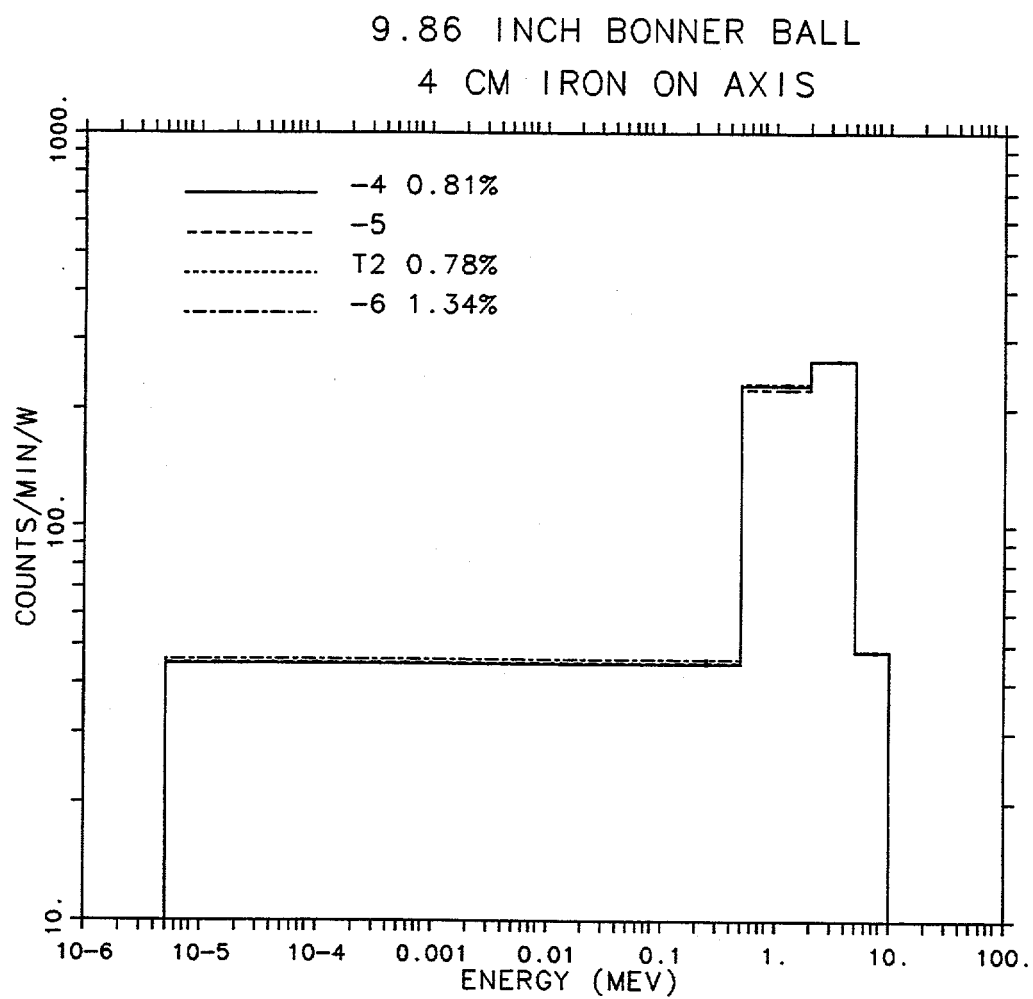


Fig. 66. Data set comparisons for the 4 cm iron slab, with the 9.86 in Bonner Ball on axis.  
(Normalized to ENDF/B-V)

3.09 INCH BONNER BALL  
4 CM IRON 15 DEG.

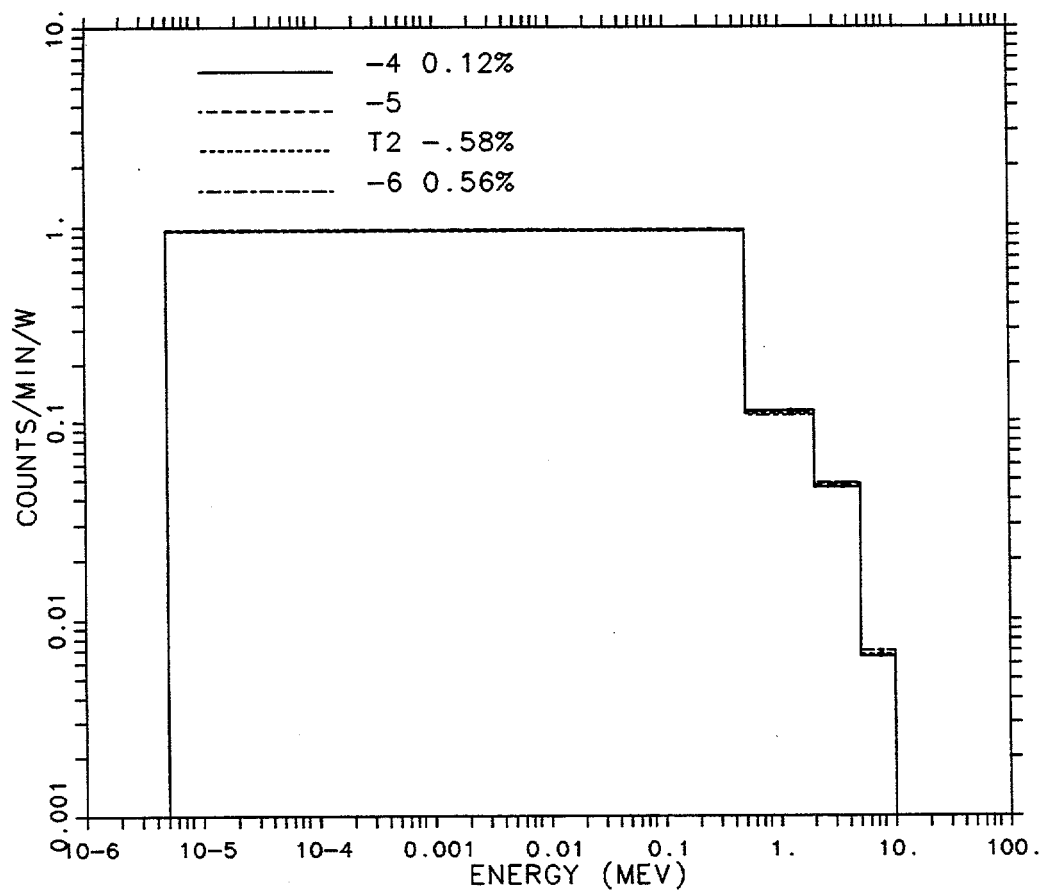


Fig. 67. Data set comparisons for the 4 cm iron slab, with the 3.09 in Bonner Ball at the 15 degree observation angle. (Normalized to ENDF/B-V)

5.88 INCH BONNER BALL  
4 CM IRON 15 DEG.

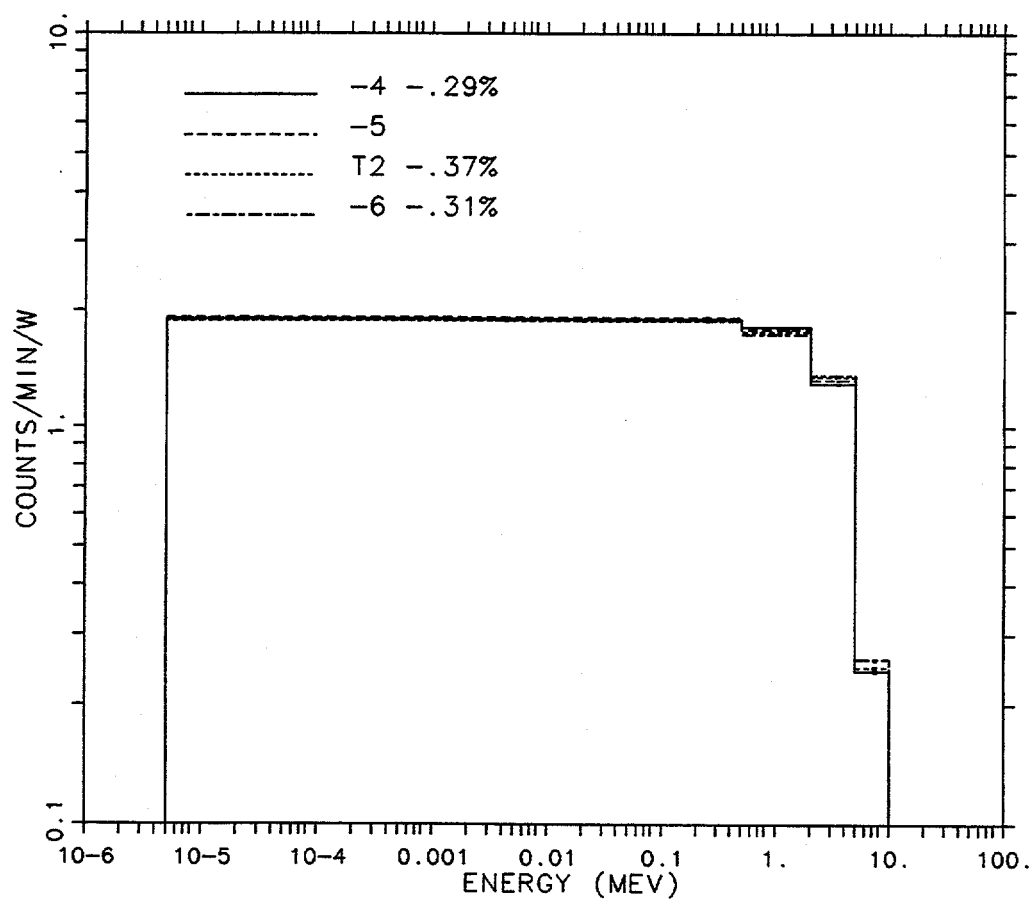


Fig. 68. Data set comparisons for the 4 cm iron slab, with the 5.88 in Bonner Ball at the 15 degree observation angle. (Normalized to ENDF/B-V)

9.86 INCH BONNER BALL  
4 CM IRON 15 DEG.

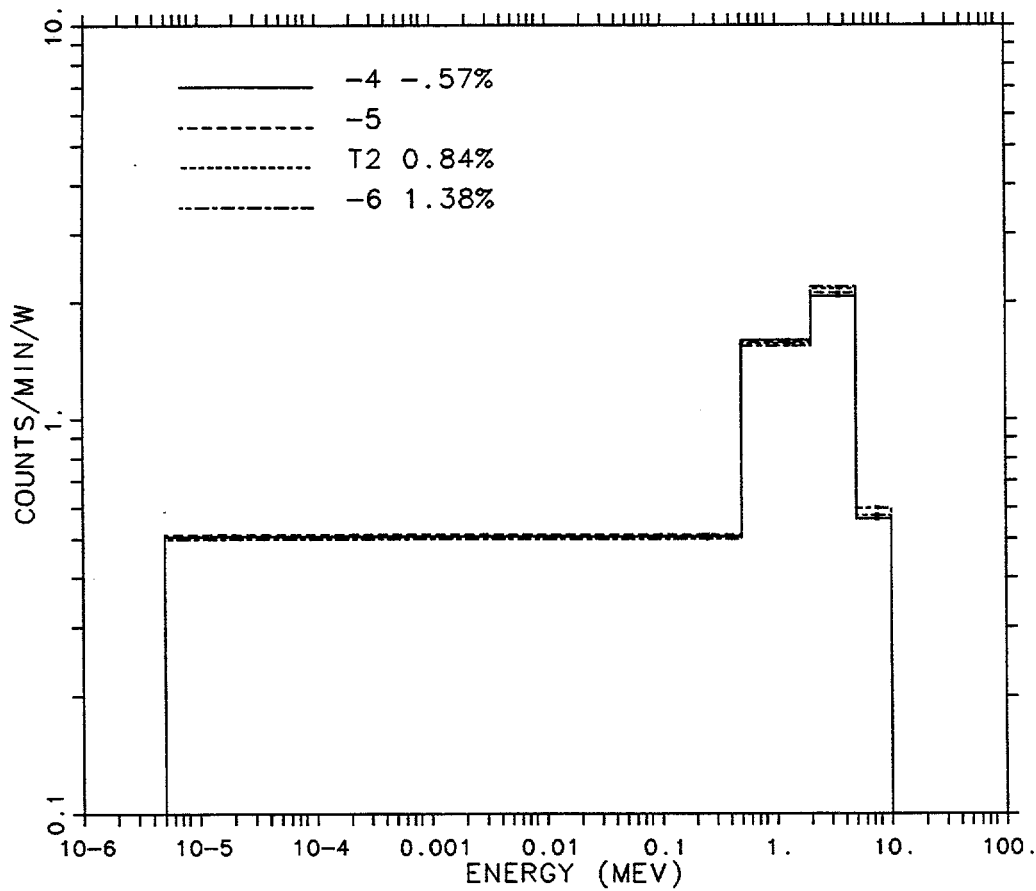


Fig. 69. Data set comparisons for the 4 cm iron slab, with the 9.86 in Bonner Ball at the 15 degree observation angle. (Normalized to ENDF/B-V)

3.09 INCH BONNER BALL  
4 CM IRON 45 DEG.

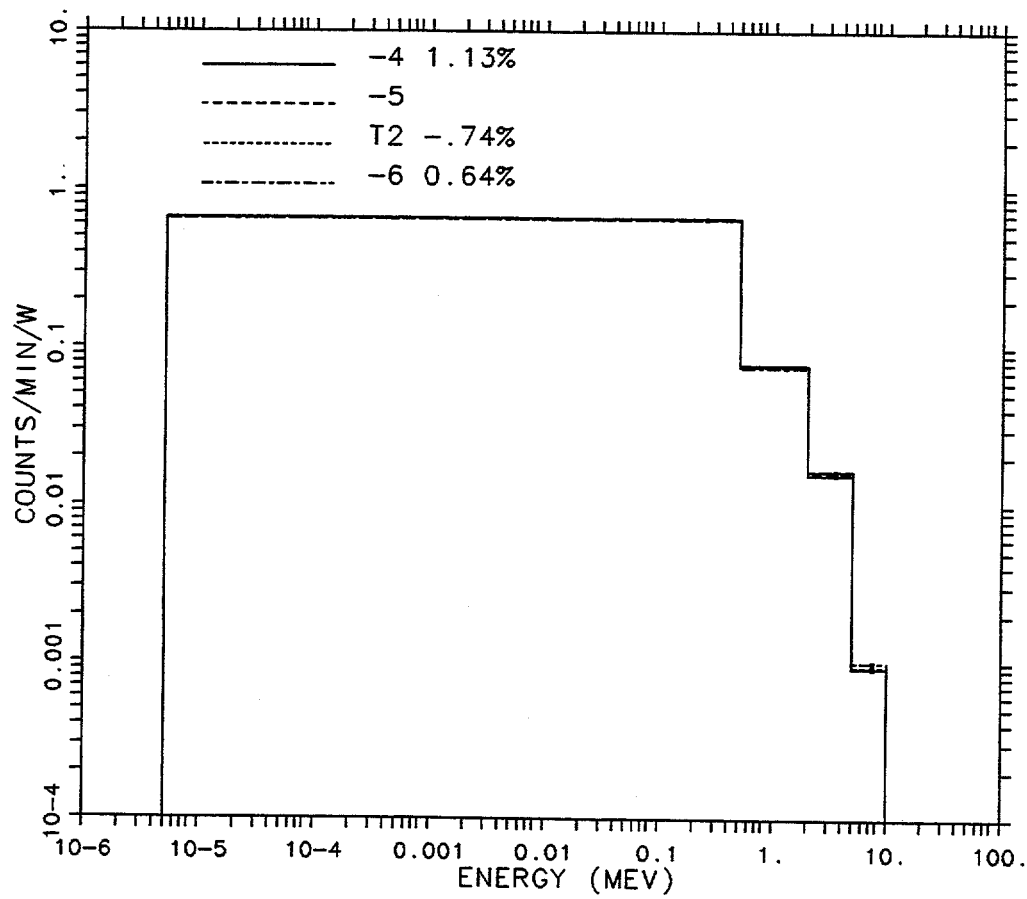


Fig. 70. Data set comparisons for the 4 cm iron slab, with the 3.09 in Bonner Ball at the 45 degree observation angle. (Normalized to ENDF/B-V)

5.88 INCH BONNER BALL  
4 CM IRON 45 DEG.

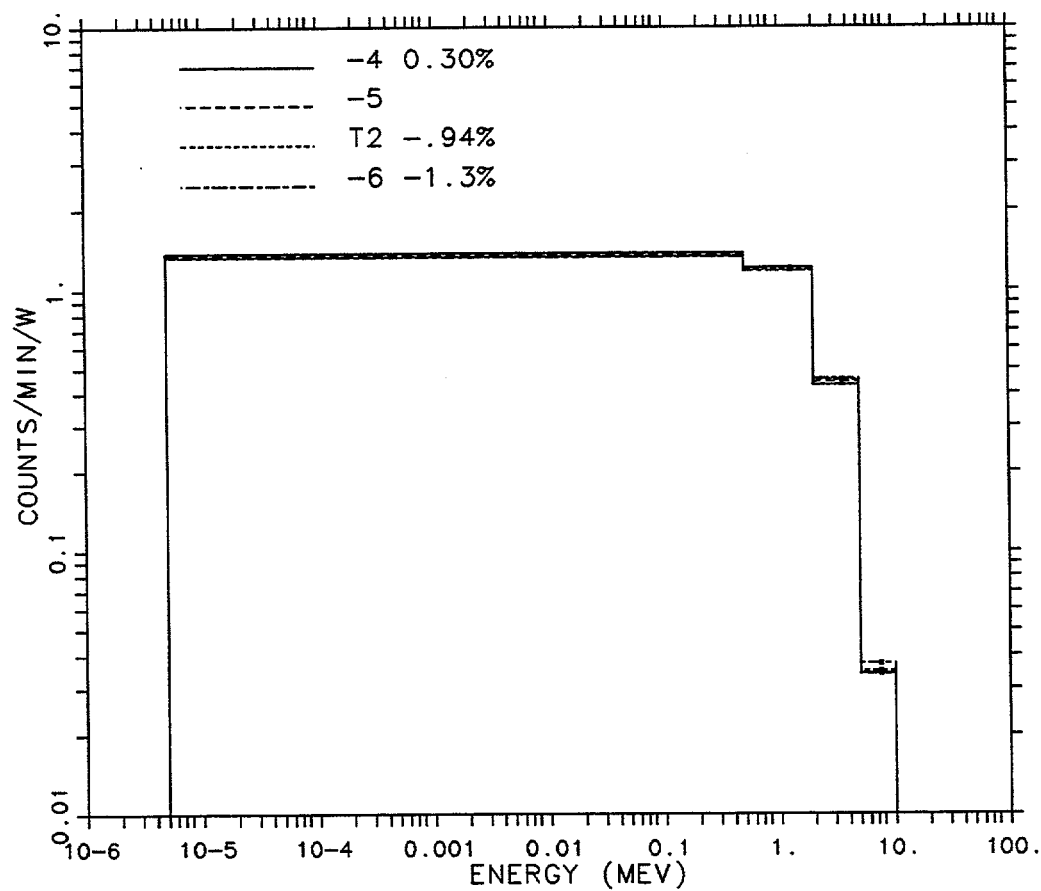


Fig. 71. Data set comparisons for the 4 cm iron slab, with the 5.88 in Bonner Ball at the 45 degree observation angle. (Normalized to ENDF/B-V)

9.86 INCH BONNER BALL  
4 CM IRON 45 DEG.

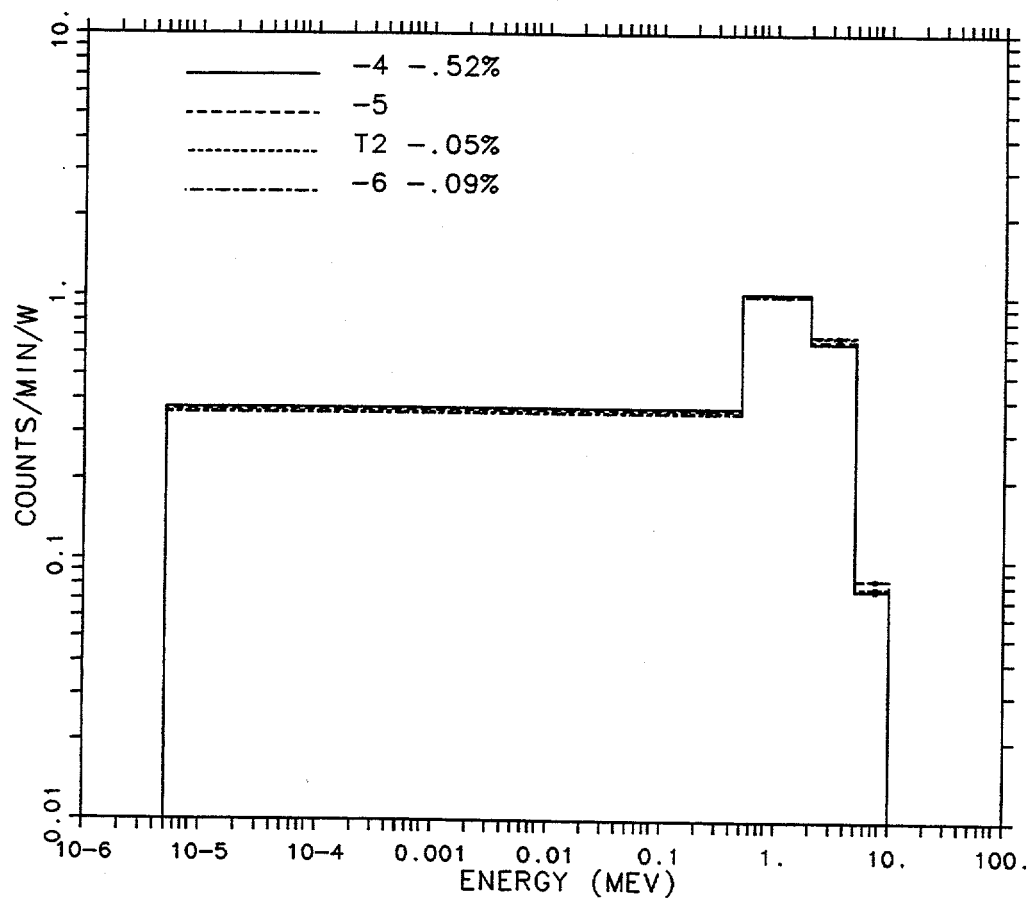


Fig. 72. Data set comparisons for the 4 cm iron slab, with the 9.86 in Bonner Ball at the 45 degree observation angle. (Normalized to ENDF/B-V)

3.09 INCH BONNER BALL  
31 CM IRON ON AXIS

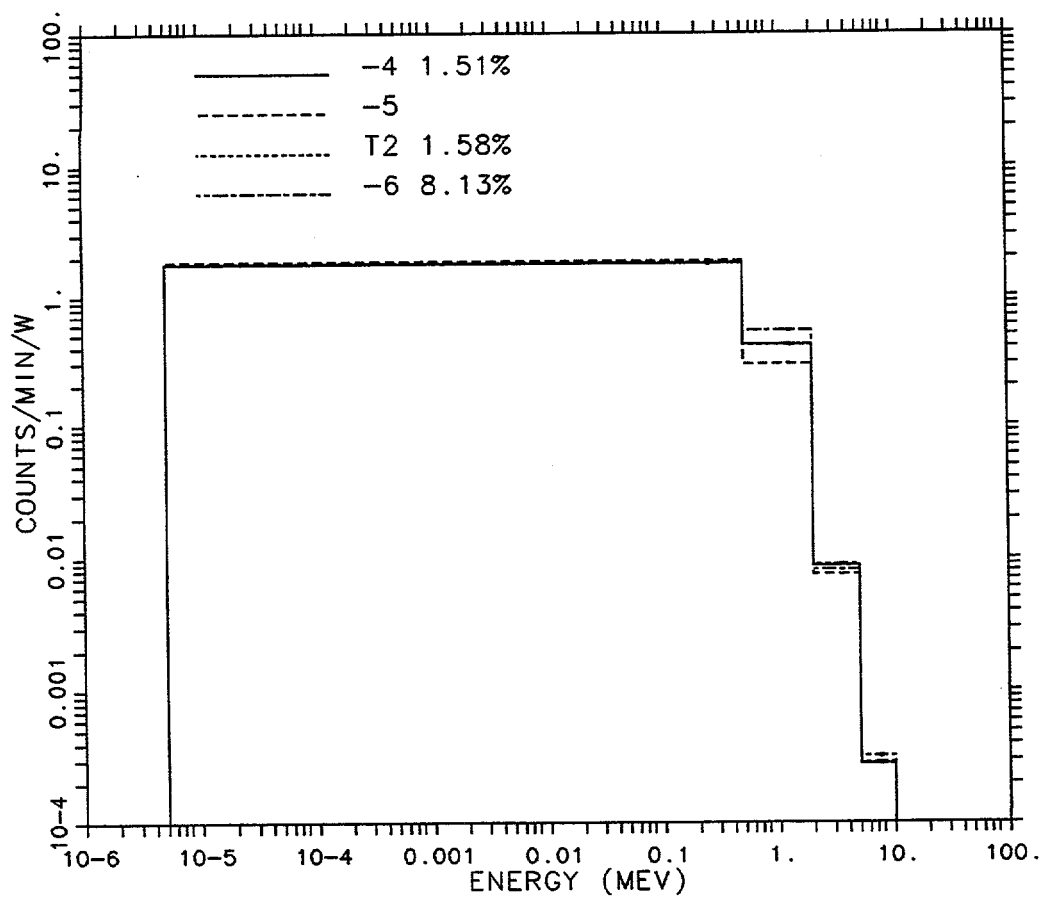


Fig. 73. Data set comparisons for the 31 cm iron slab, with the 3.09 in Bonner Ball on axis.  
(Normalized to ENDF/B-V)

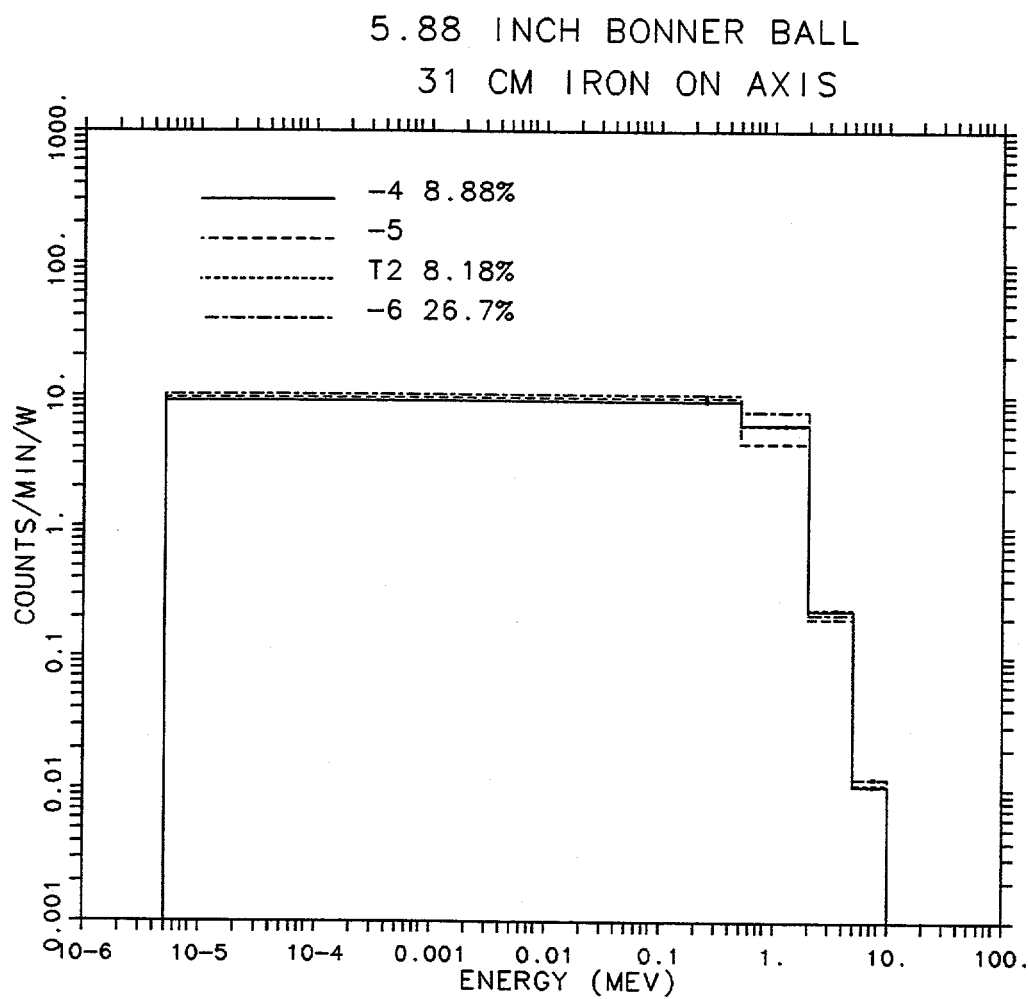


Fig. 74. Data set comparisons for the 31 cm iron slab, with the 5.88 in Bonner Ball on axis.  
(Normalized to ENDF/B-V)

9.86 INCH BONNER BALL  
31 CM IRON ON AXIS

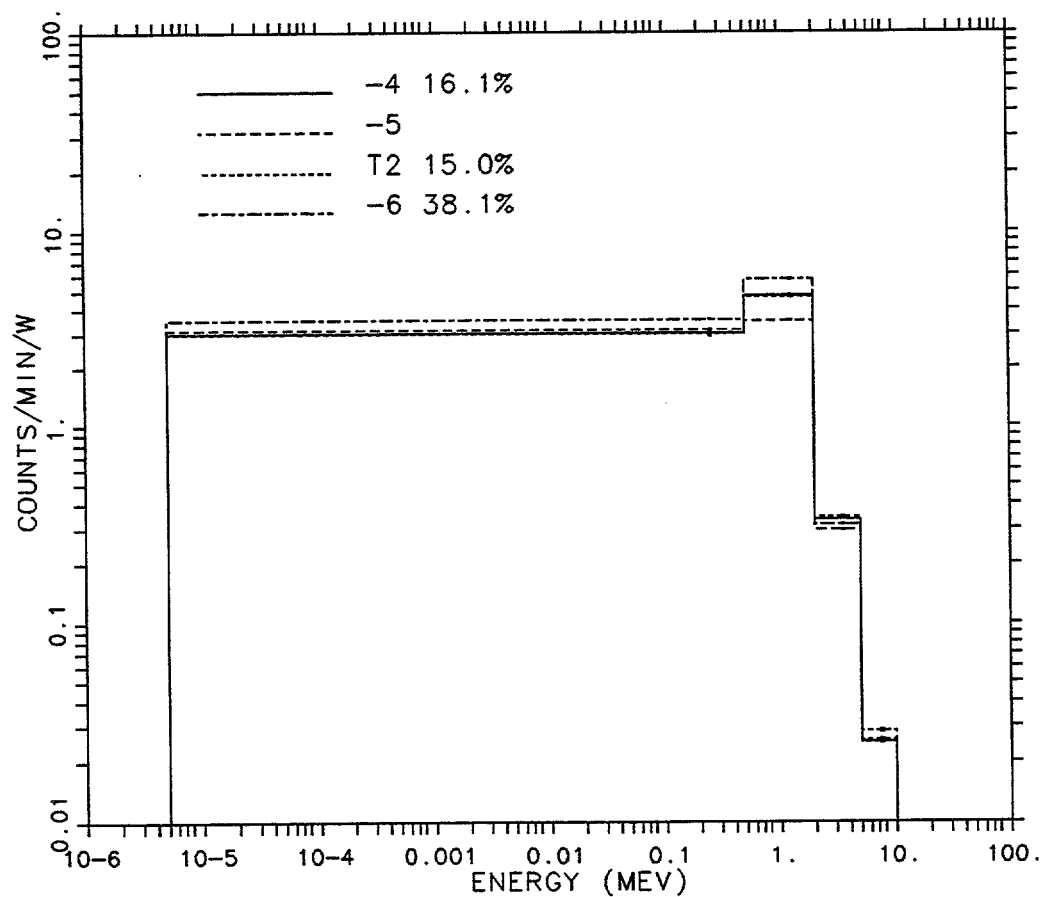


Fig. 75. Data set comparisons for the 31 cm iron slab, with the 9.86 in Bonner Ball on axis.  
(Normalized to ENDF/B-V)

3.09 INCH BONNER BALL  
31 CM IRON 15 DEG.

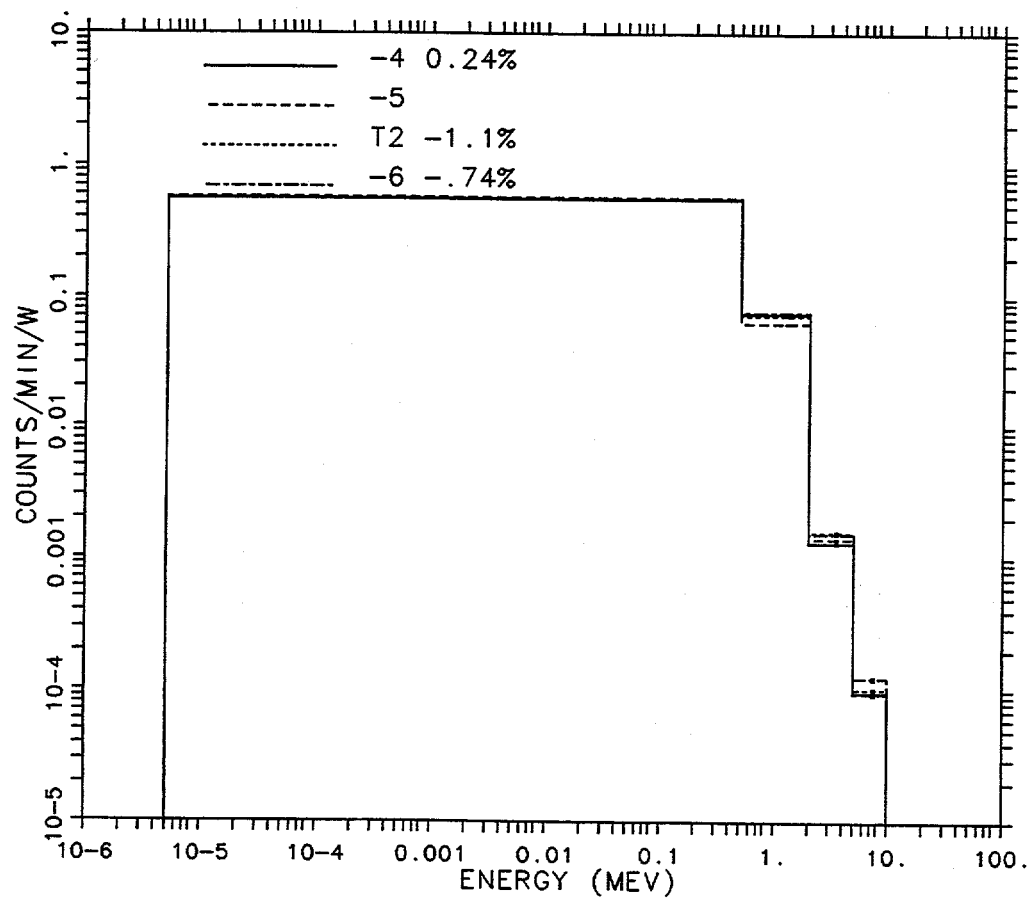


Fig. 76. Data set comparisons for the 31 cm iron slab, with the 3.09 in Bonner Ball at the 15 degree observation angle. (Normalized to ENDF/B-V)

5.88 INCH BONNER BALL  
31 CM IRON 15 DEG.

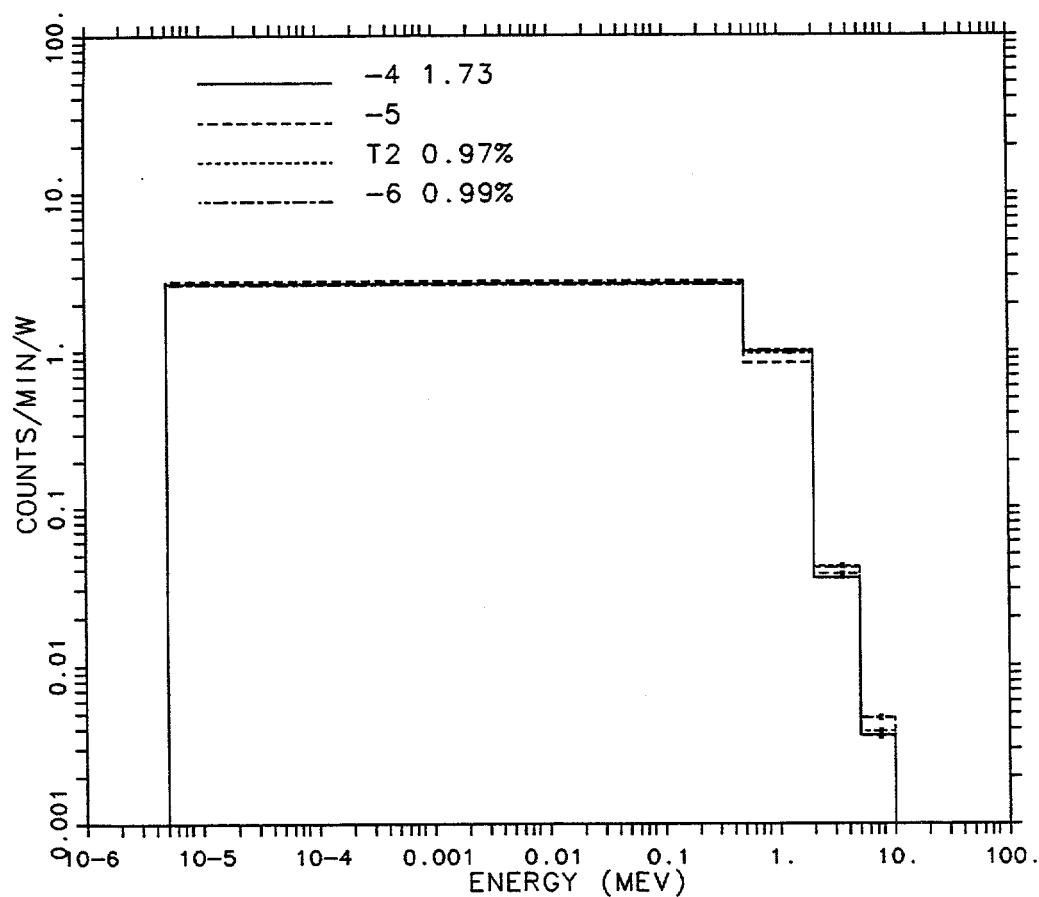


Fig. 77. Data set comparisons for the 31 cm iron slab, with the 5.88 in Bonner Ball at the 15 degree observation angle. (Normalized to ENDF/B-V)

9.86 INCH BONNER BALL  
31 CM IRON 15 DEG.

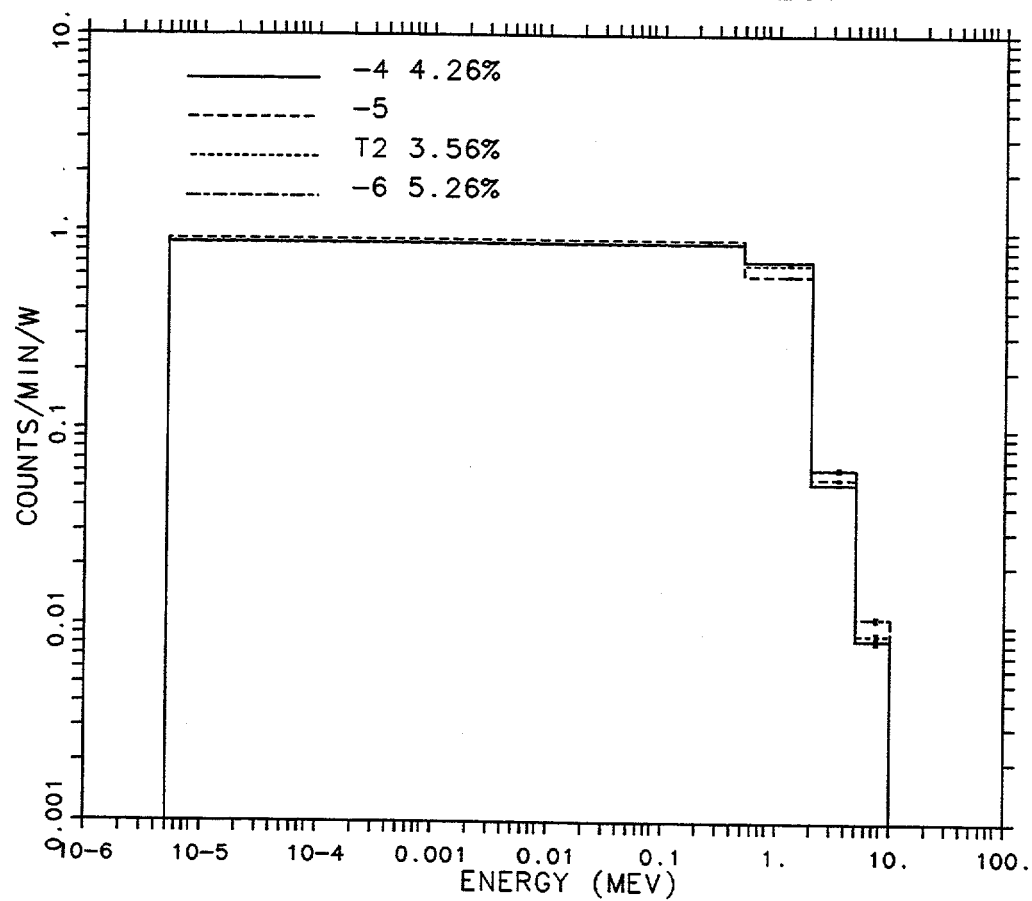


Fig. 78. Data set comparisons for the 31 cm iron slab, with the 9.86 in Bonner Ball at the 15 degree observation angle. (Normalized to ENDF/B-V)

3.09 INCH BONNER BALL  
31 CM IRON 45 DEG.

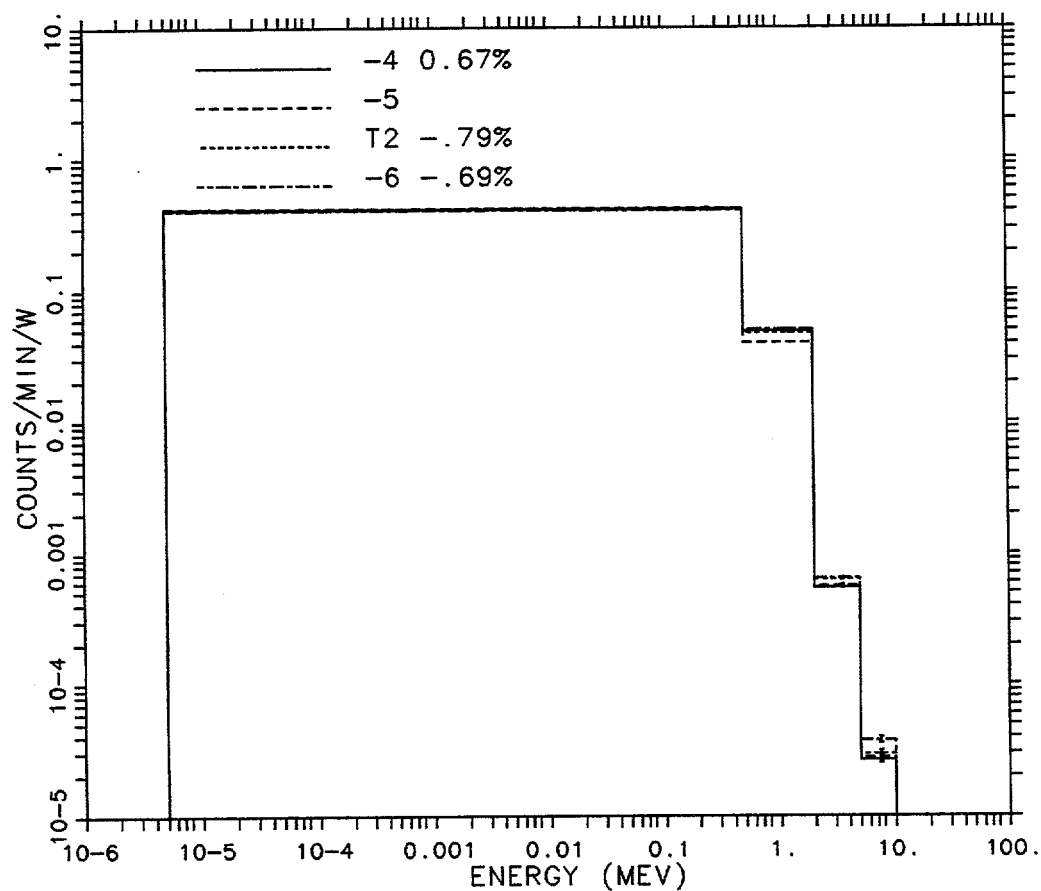


Fig. 79. Data set comparisons for the 31 cm iron slab, with the 3.09 in Bonner Ball at the 45 degree observation angle. (Normalized to ENDF/B-V)

5.88 INCH BONNER BALL  
31 CM IRON 45 DEG.

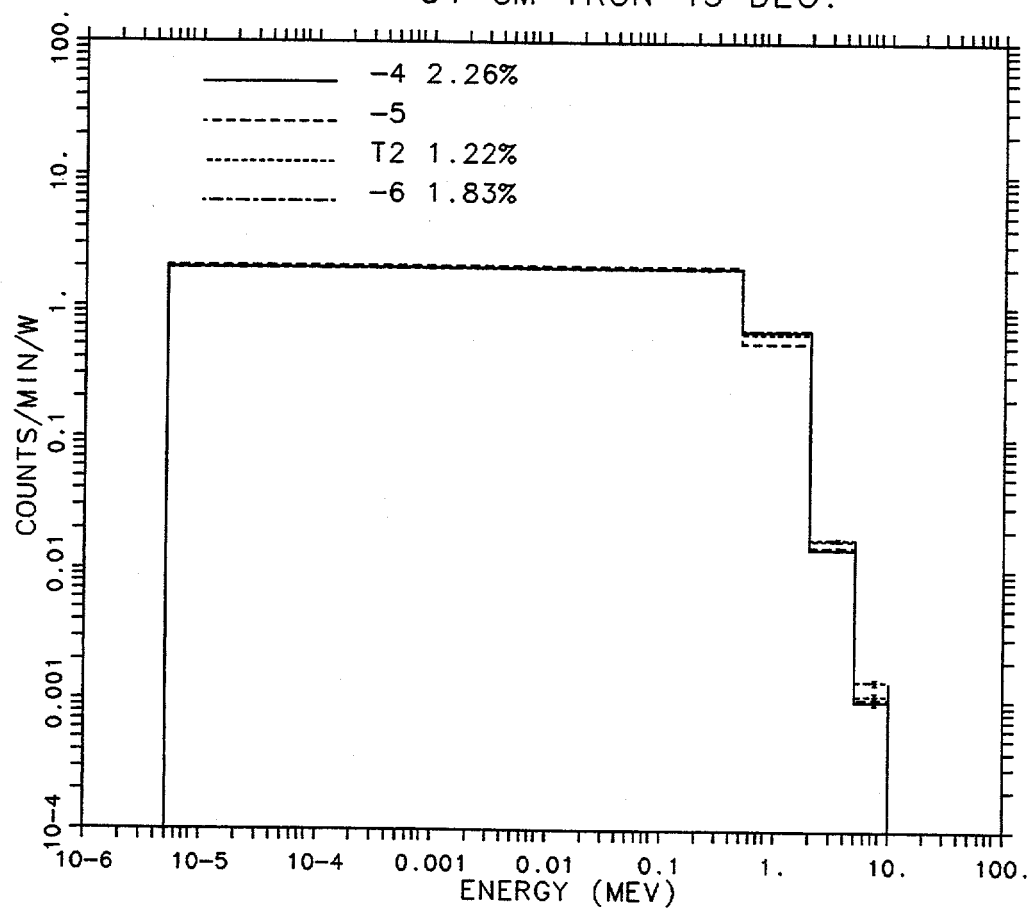


Fig. 80. Data set comparisons for the 31 cm iron slab, with the 5.88 in Bonner Ball at the 45 degree observation angle. (Normalized to ENDF/B-V)

9.86 INCH BONNER BALL  
31 CM IRON 45 DEG.

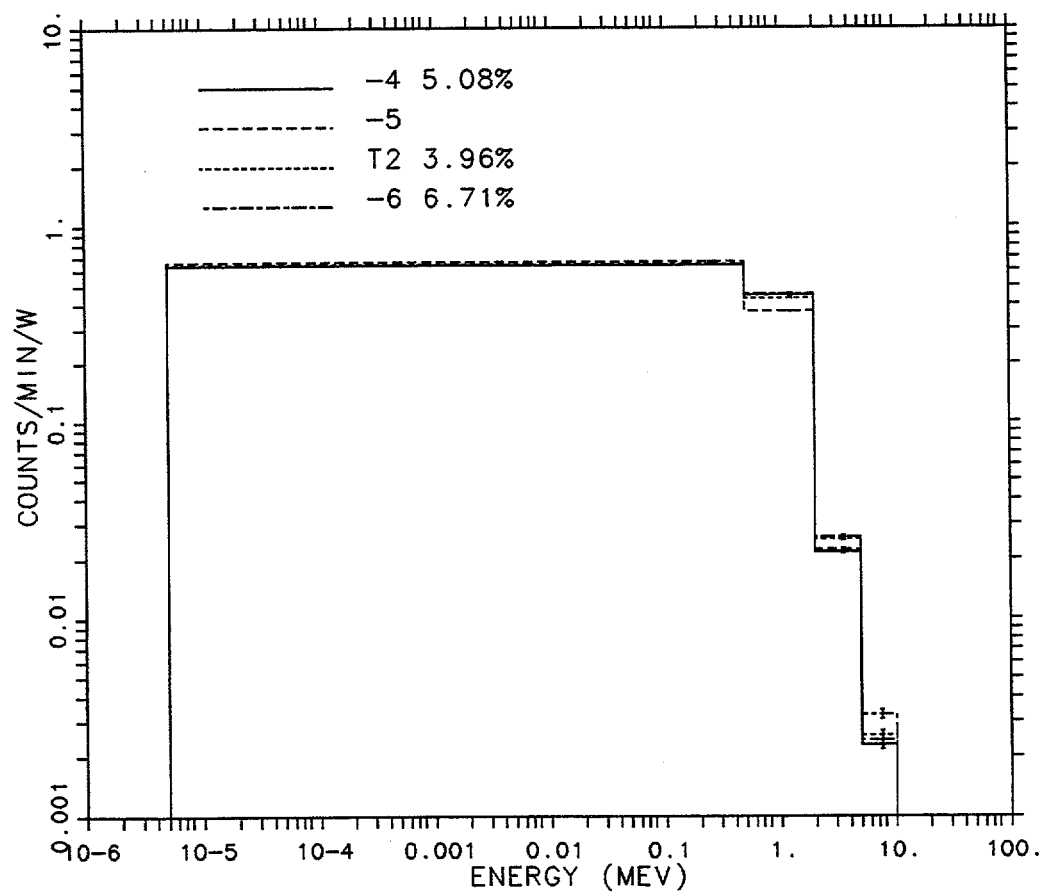


Fig. 81. Data set comparisons for the 31 cm iron slab, with the 9.86 in Bonner Ball at the 45 degree observation angle. (Normalized to ENDF/B-V)

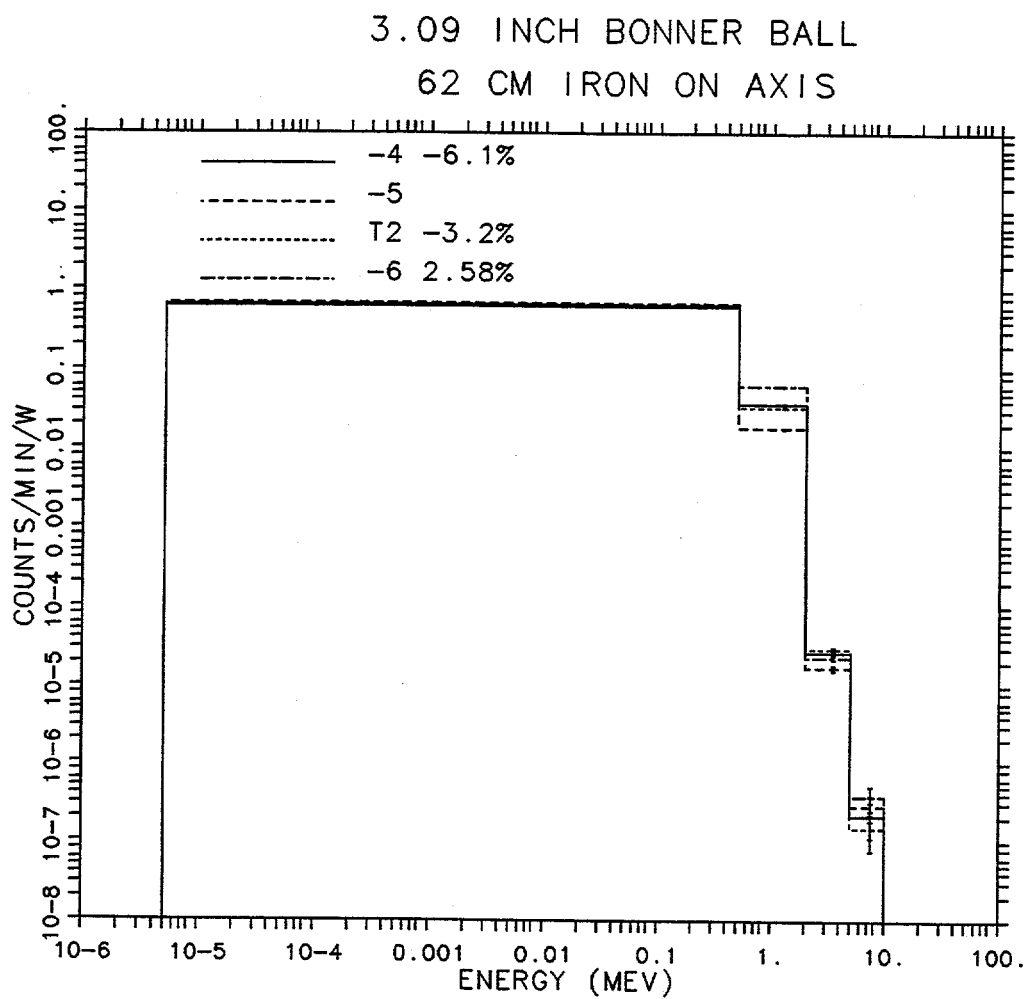


Fig. 82. Data set comparisons for the 62 cm iron slab, with the 3.09 in Bonner Ball on axis. (Normalized to ENDF/B-V)

5.88 INCH BONNER BALL  
62 CM IRON ON AXIS

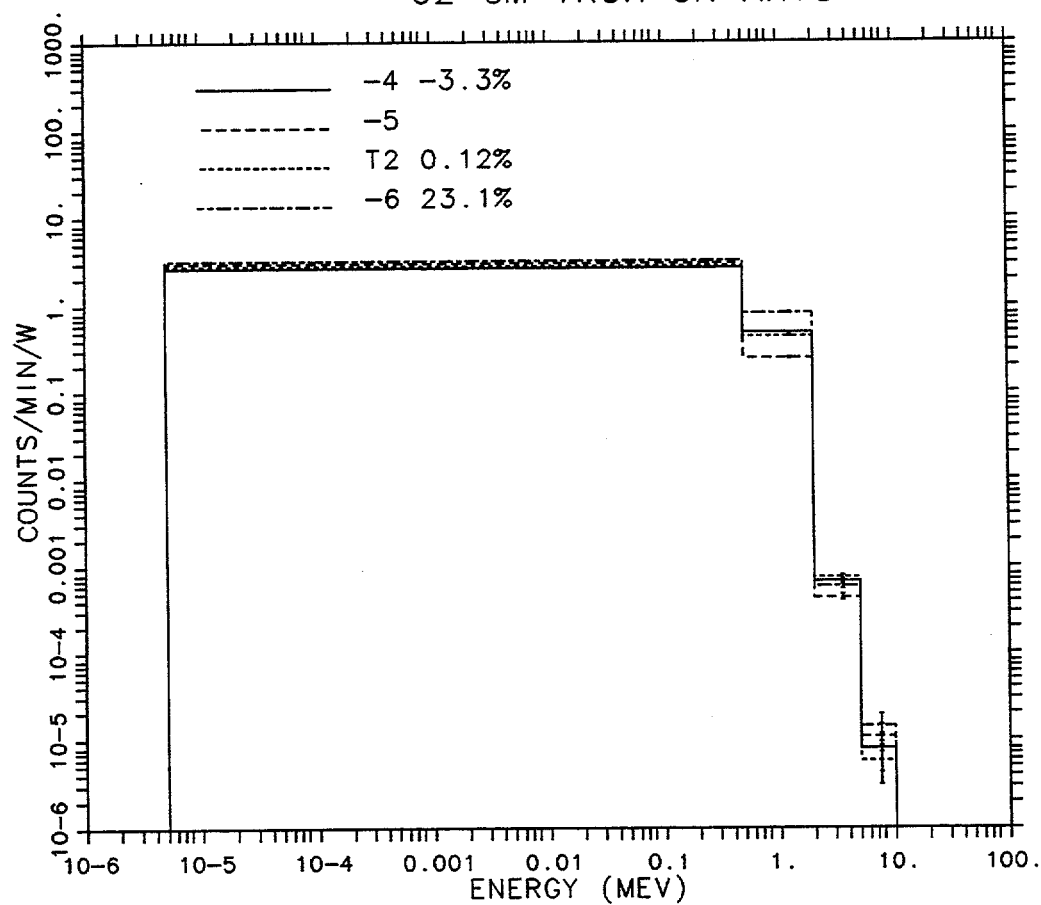


Fig. 83. Data set comparisons for the 62 cm iron slab, with the 5.88 in Bonner Ball on axis.  
(Normalized to ENDF/B-V)

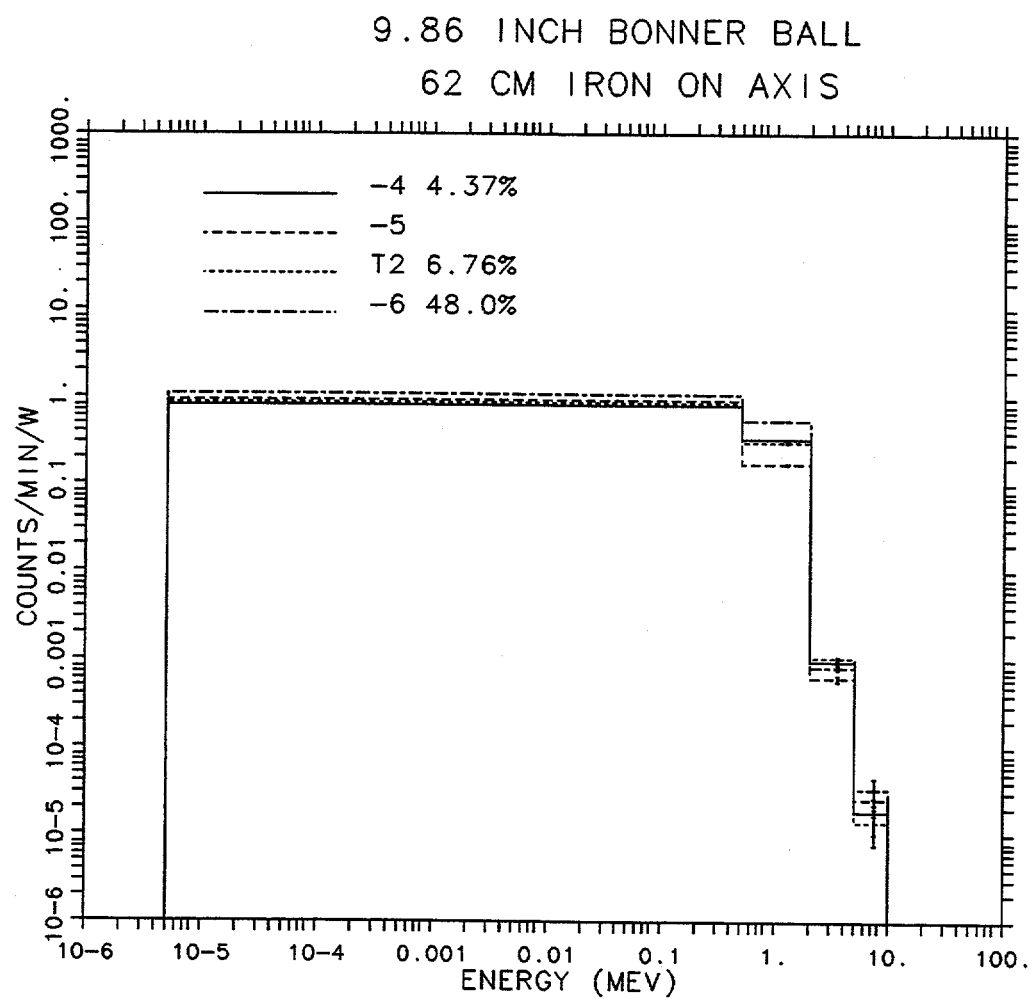


Fig. 84. Data set comparisons for the 62 cm iron slab, with the 9.86 in Bonner Ball on axis. (Normalized to ENDF/B-V)

3.09 INCH BONNER BALL  
62 CM IRON 15 DEG.

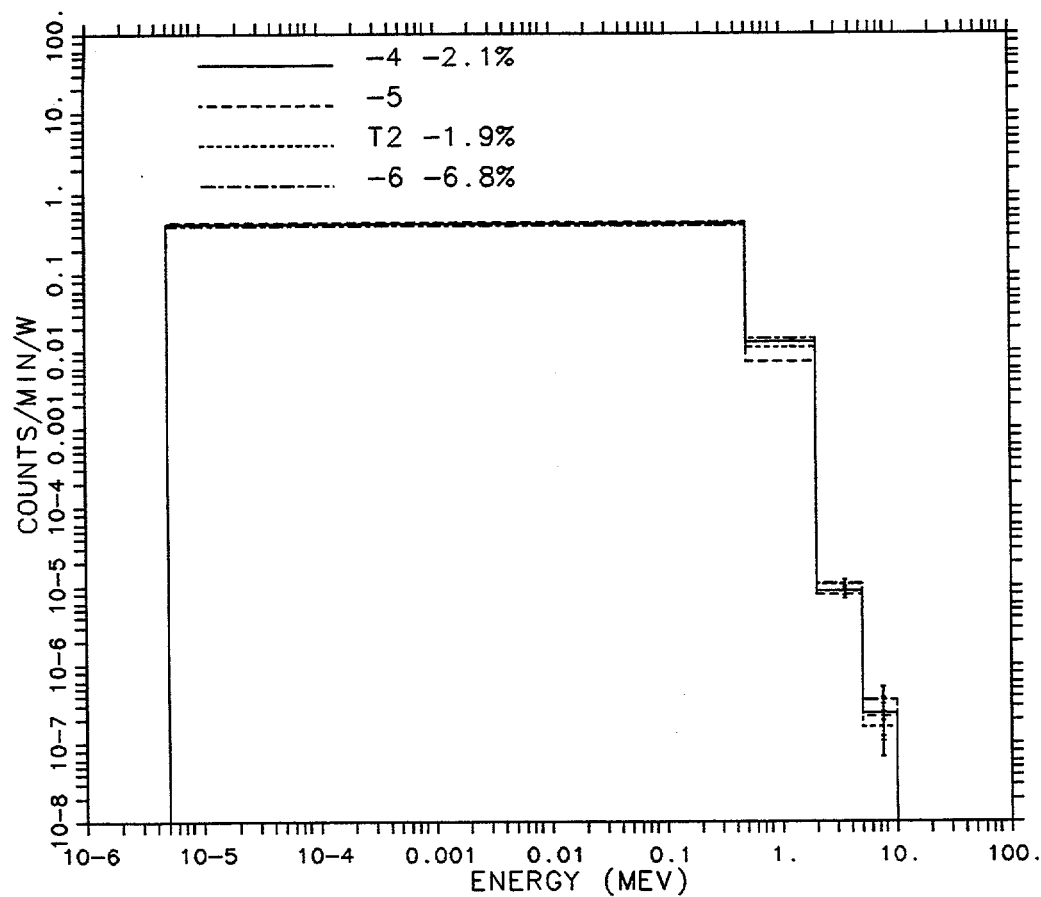


Fig. 85. Data set comparisons for the 62 cm iron slab, with the 3.09 in Bonner Ball at the 15 degree observation angle. (Normalized to ENDF/B-V)

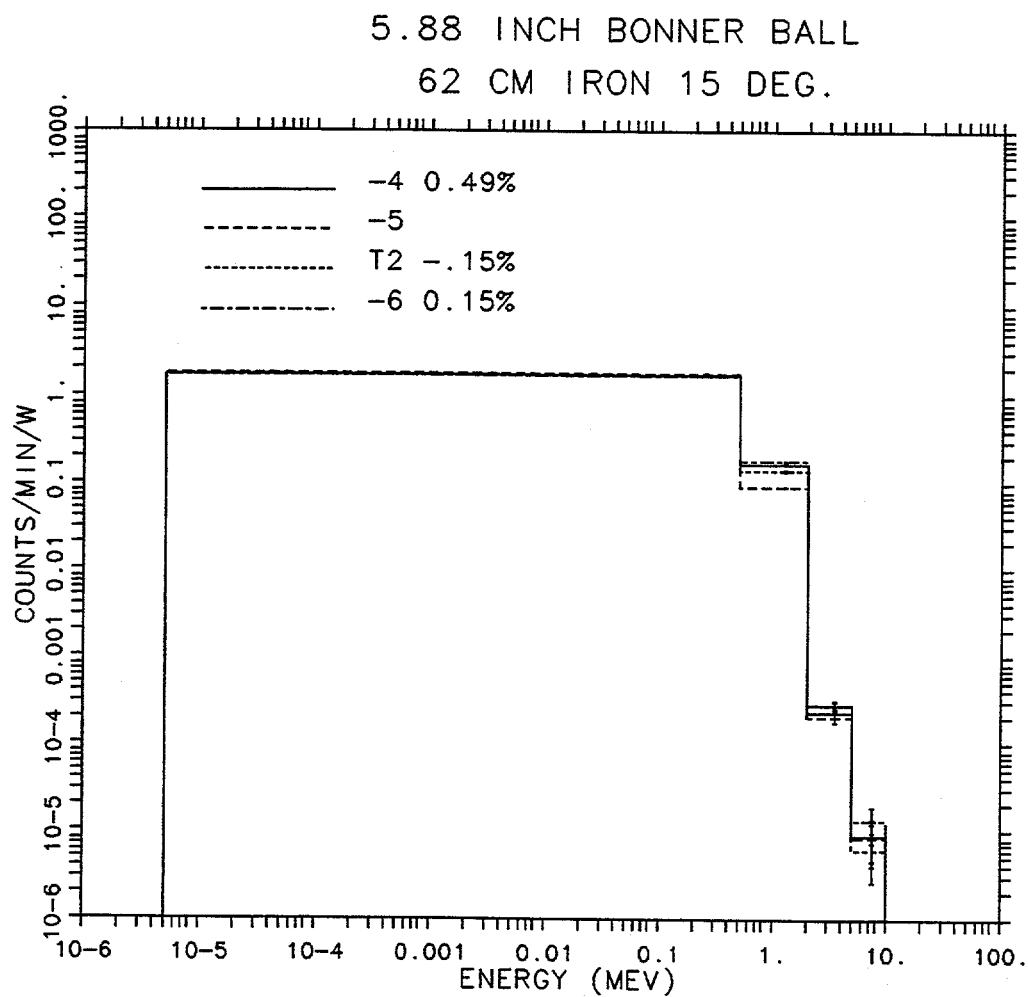


Fig. 86. Data set comparisons for the 62 cm iron slab, with the 5.88 in Bonner Ball at the 15 degree observation angle. (Normalized to ENDF/B-V)

9.86 INCH BONNER BALL  
62 CM IRON 15 DEG.

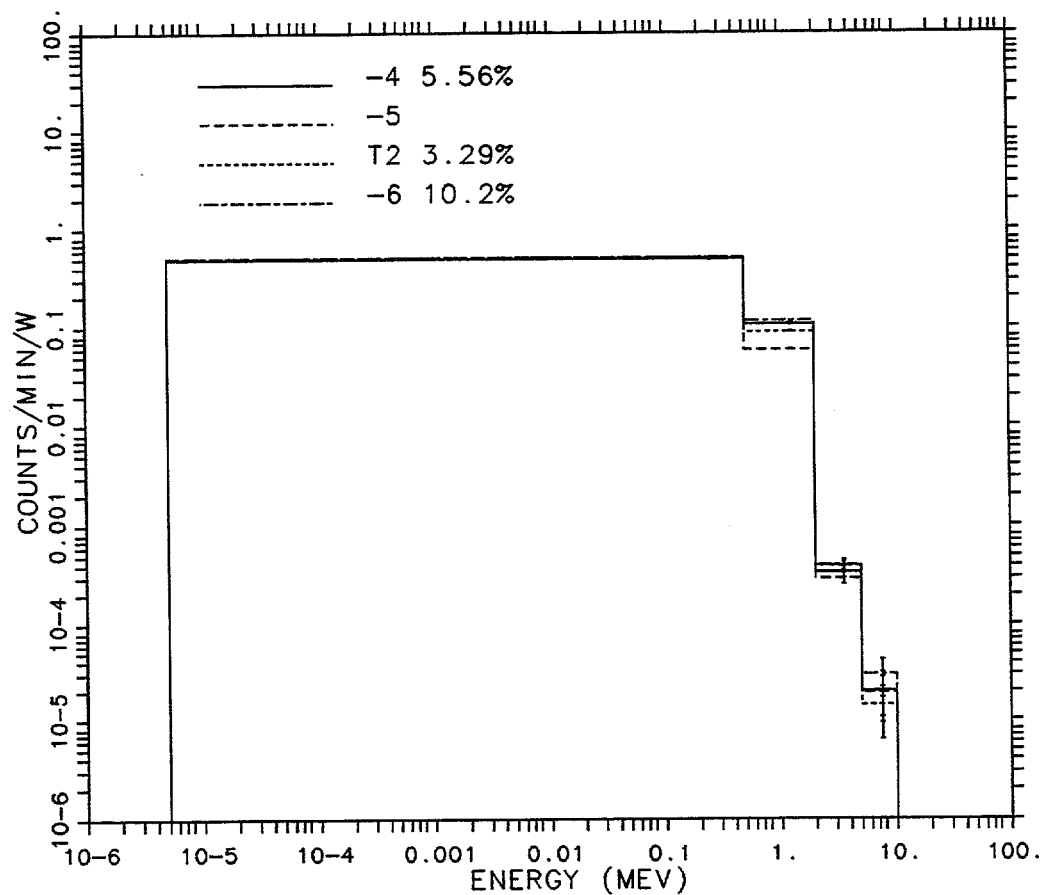


Fig. 87. Data set comparisons for the 62 cm iron slab, with the 9.86 in Bonner Ball at the 15 degree observation angle. (Normalized to ENDF/B-V)

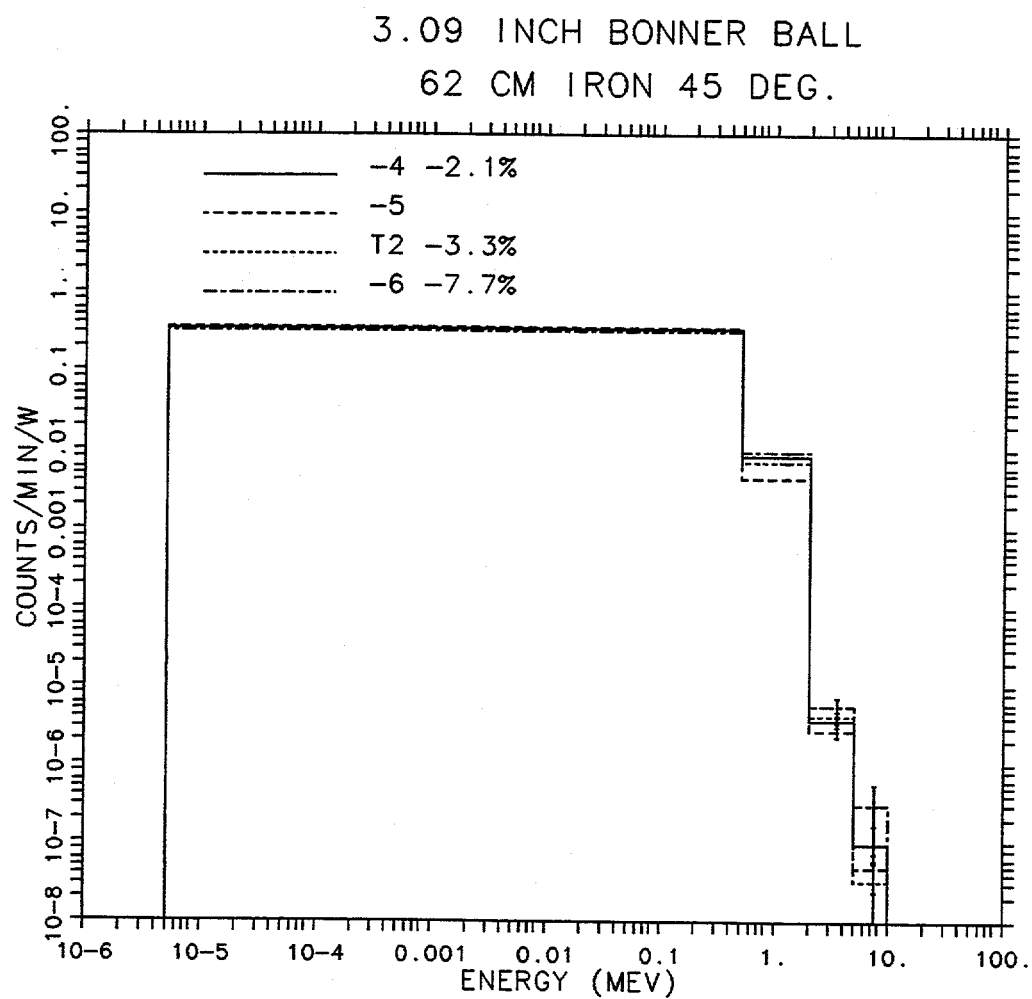


Fig. 88. Data set comparisons for the 62 cm iron slab, with the 3.09 in Bonner Ball at the 45 degree observation angle. (Normalized to ENDF/B-V)

5.88 INCH BONNER BALL  
62 CM IRON 45 DEG.

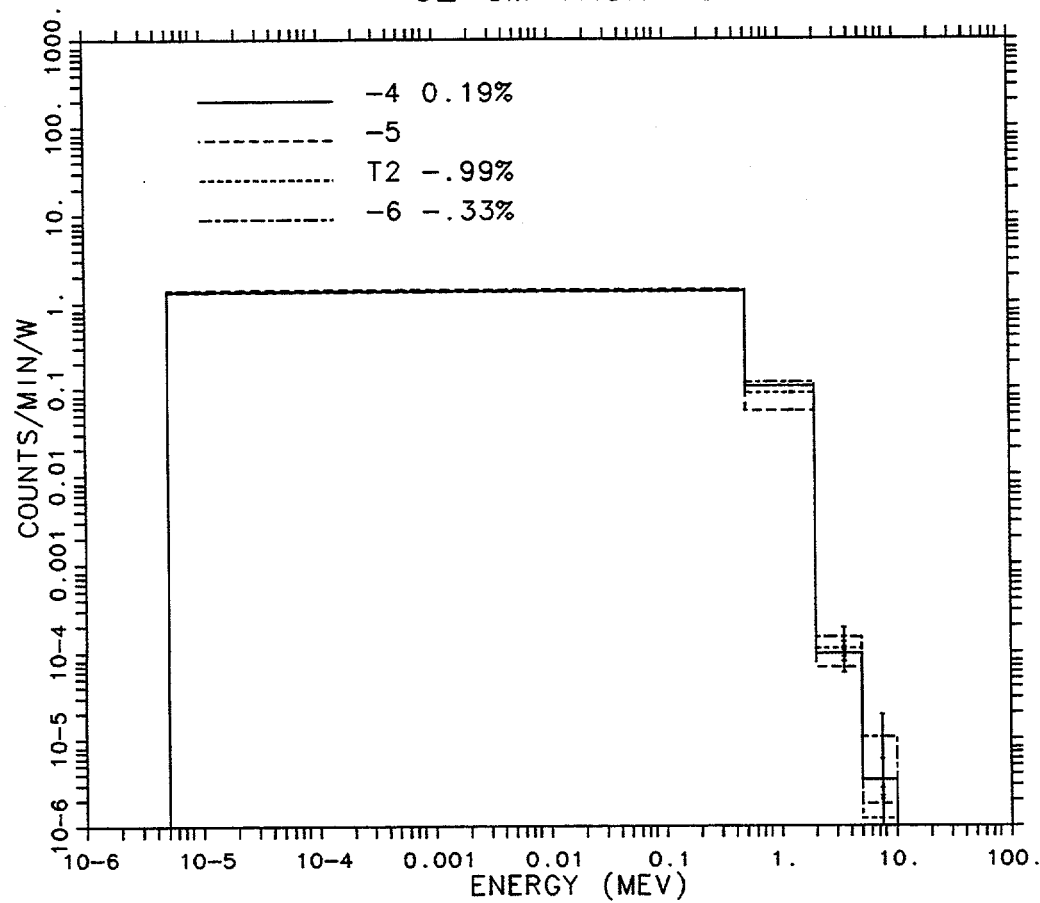


Fig. 89. Data set comparisons for the 62 cm iron slab, with the 5.88 in Bonner Ball at the 45 degree observation angle. (Normalized to ENDF/B-V)

9.86 INCH BONNER BALL  
62 CM IRON 45 DEG.

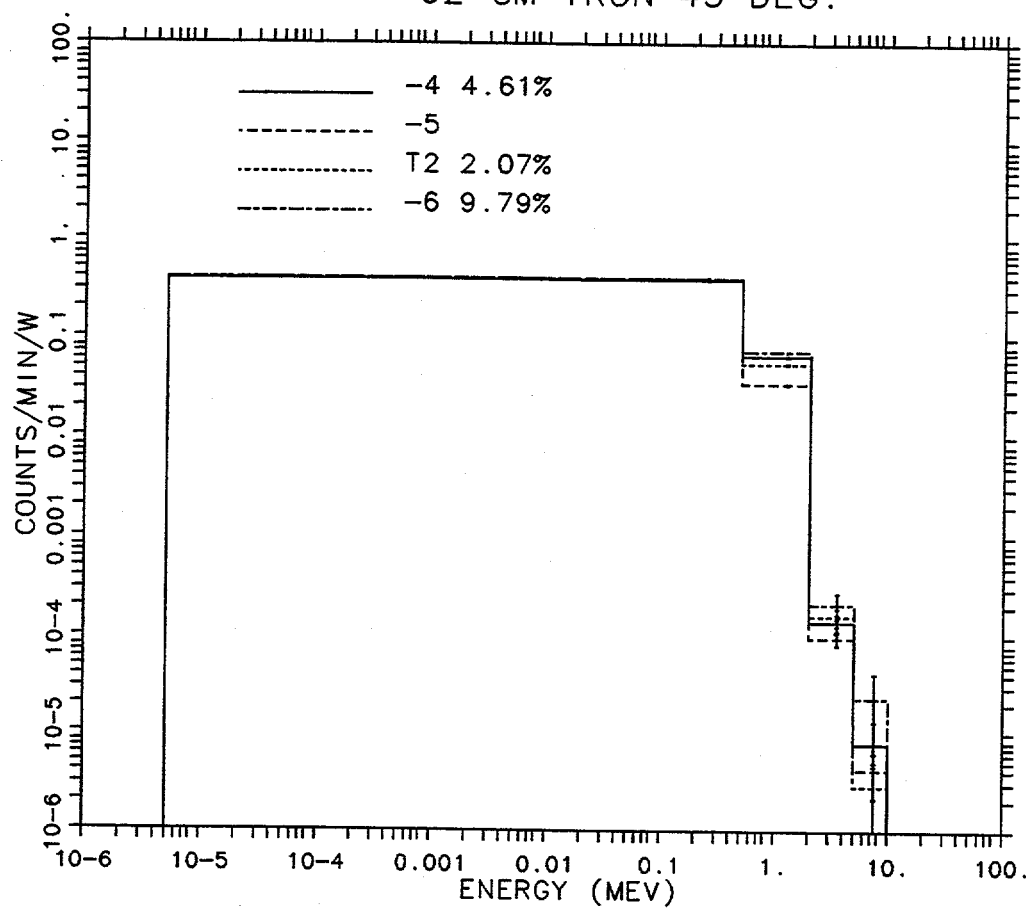


Fig. 90. Data set comparisons for the 62 cm iron slab, with the 9.86 in Bonner Ball at the 45 degree observation angle. (Normalized to ENDF/B-V)

3.09 INCH BONNER BALL  
93 CM IRON ON AXIS

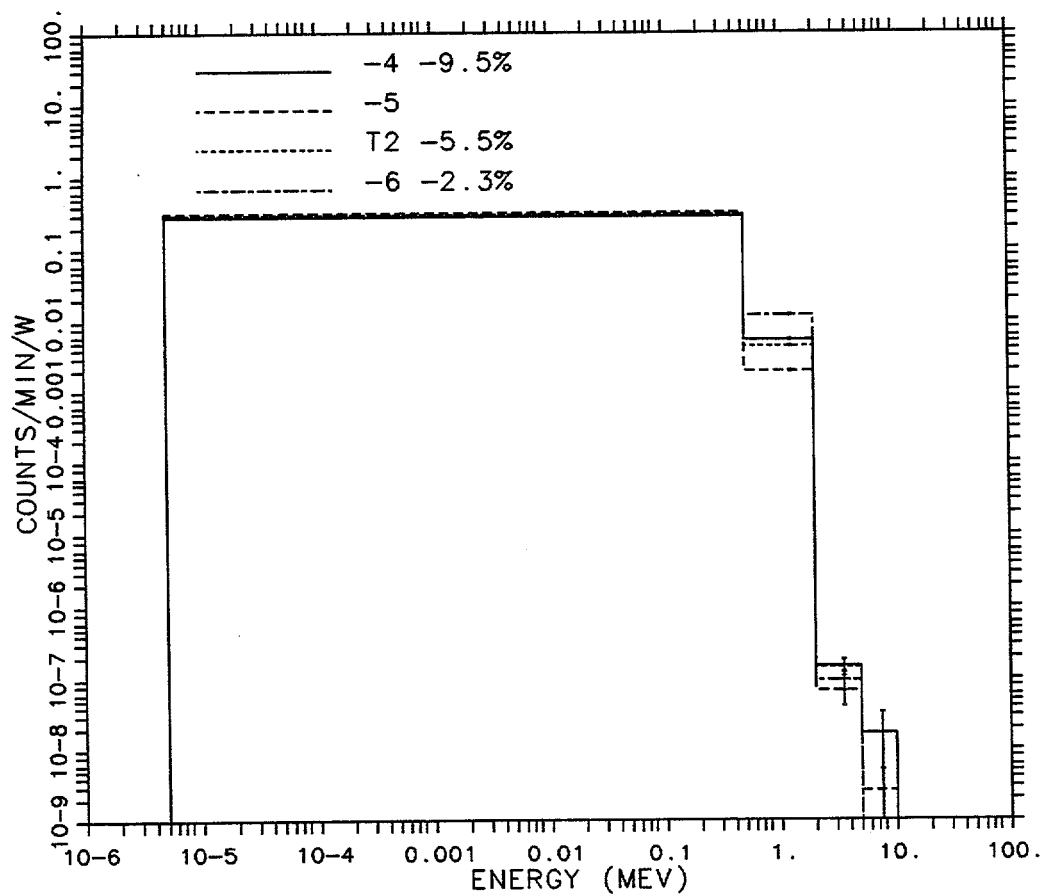


Fig. 91. Data set comparisons for the 93 cm iron slab, with the 3.09 in Bonner Ball on axis.  
(Normalized to ENDF/B-V)

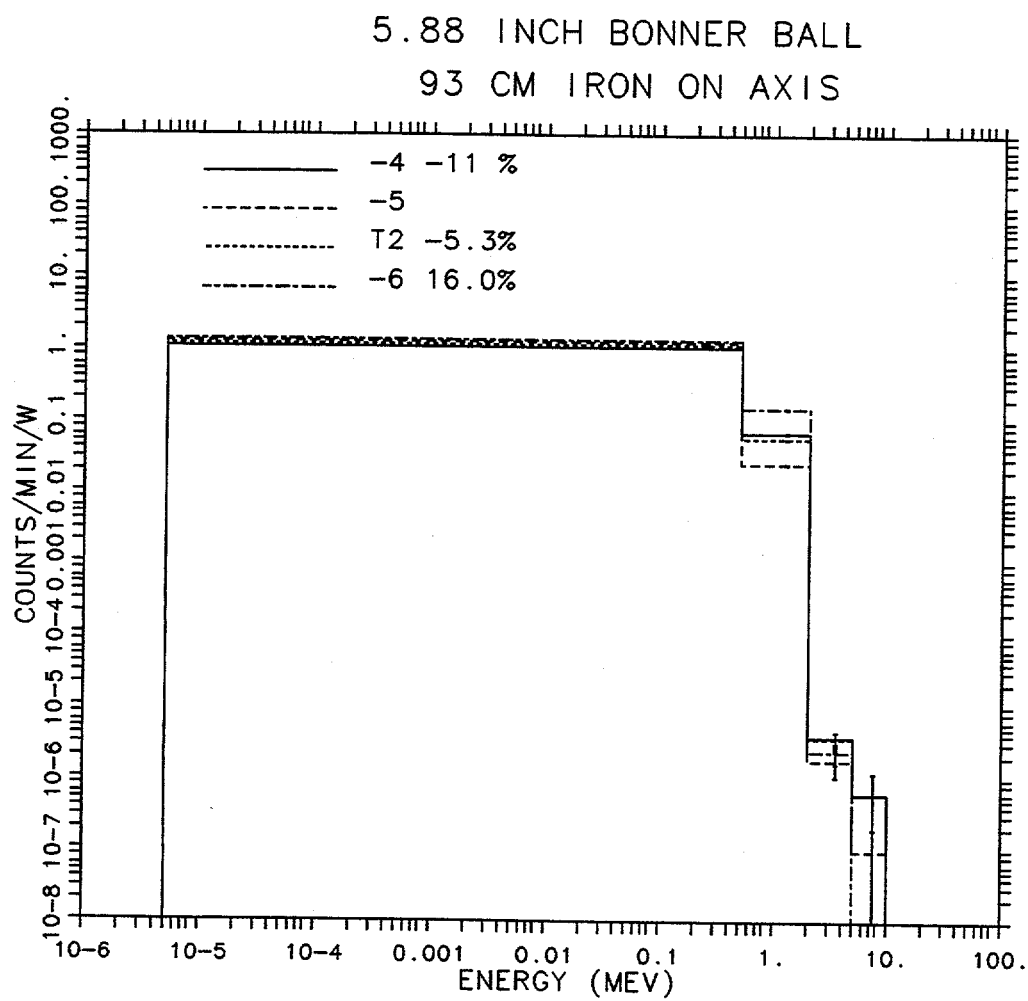


Fig. 92. Data set comparisons for the 93 cm iron slab, with the 5.88 in Bonner Ball on axis. (Normalized to ENDF/B-V)

9.86 INCH BONNER BALL  
93 CM IRON ON AXIS

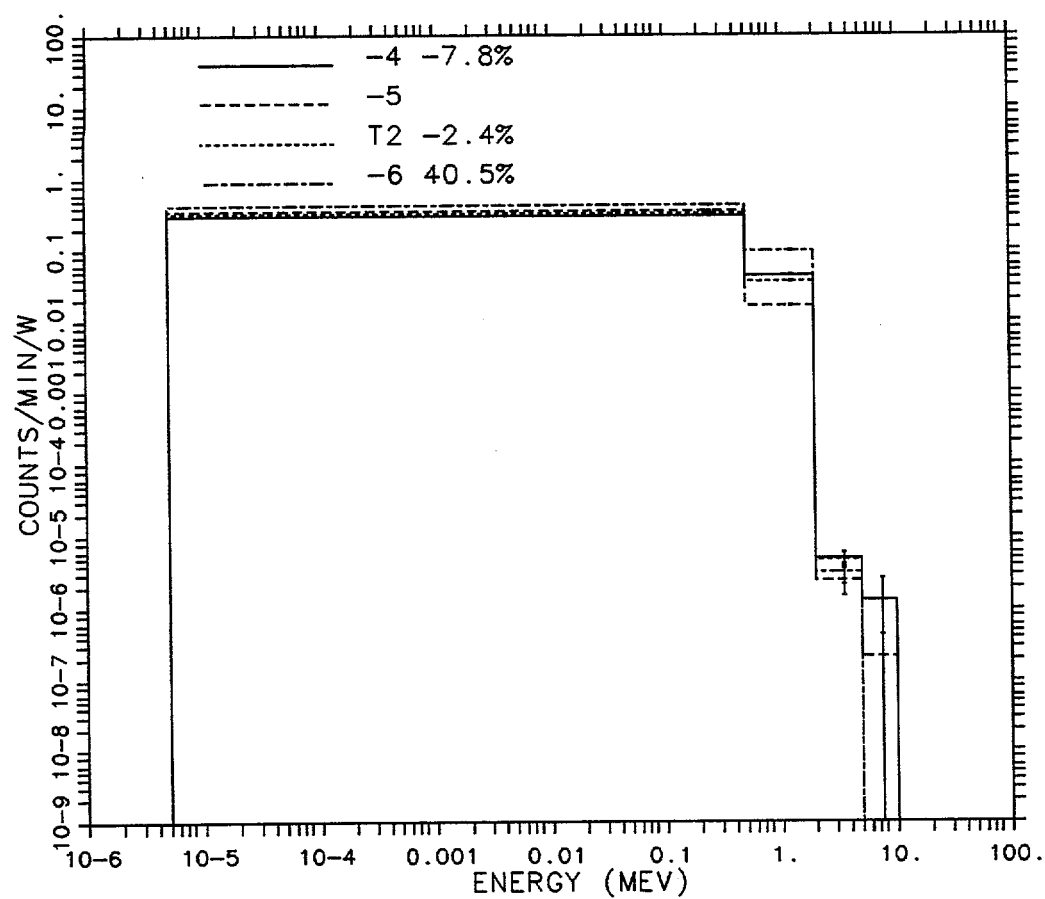


Fig. 93. Data set comparisons for the 93 cm iron slab, with the 9.86 in Bonner Ball on axis.  
(Normalized to ENDF/B-V)

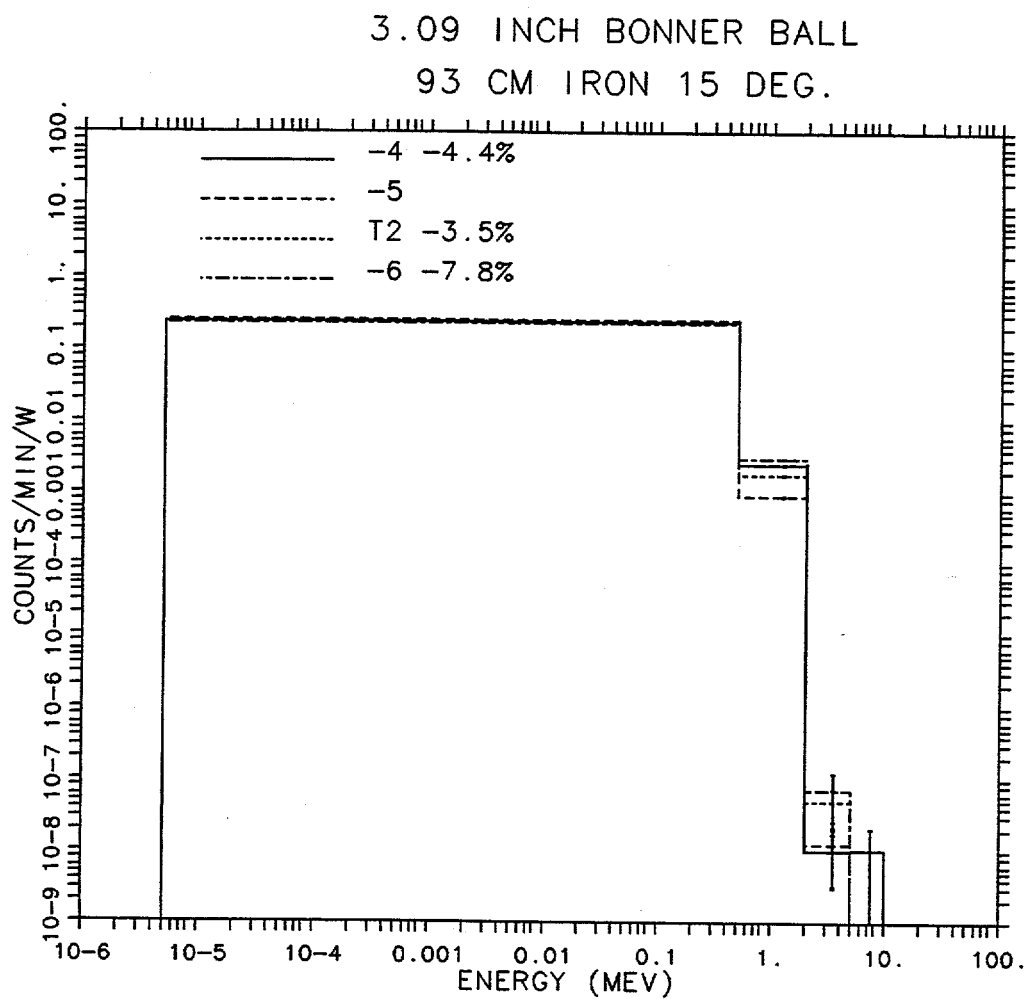


Fig. 94. Data set comparisons for the 93 cm iron slab, with the 3.09 in Bonner Ball at the 15 degree observation angle. (Normalized to ENDF/B-V)

5.88 INCH BONNER BALL  
93 CM IRON 15 DEG.

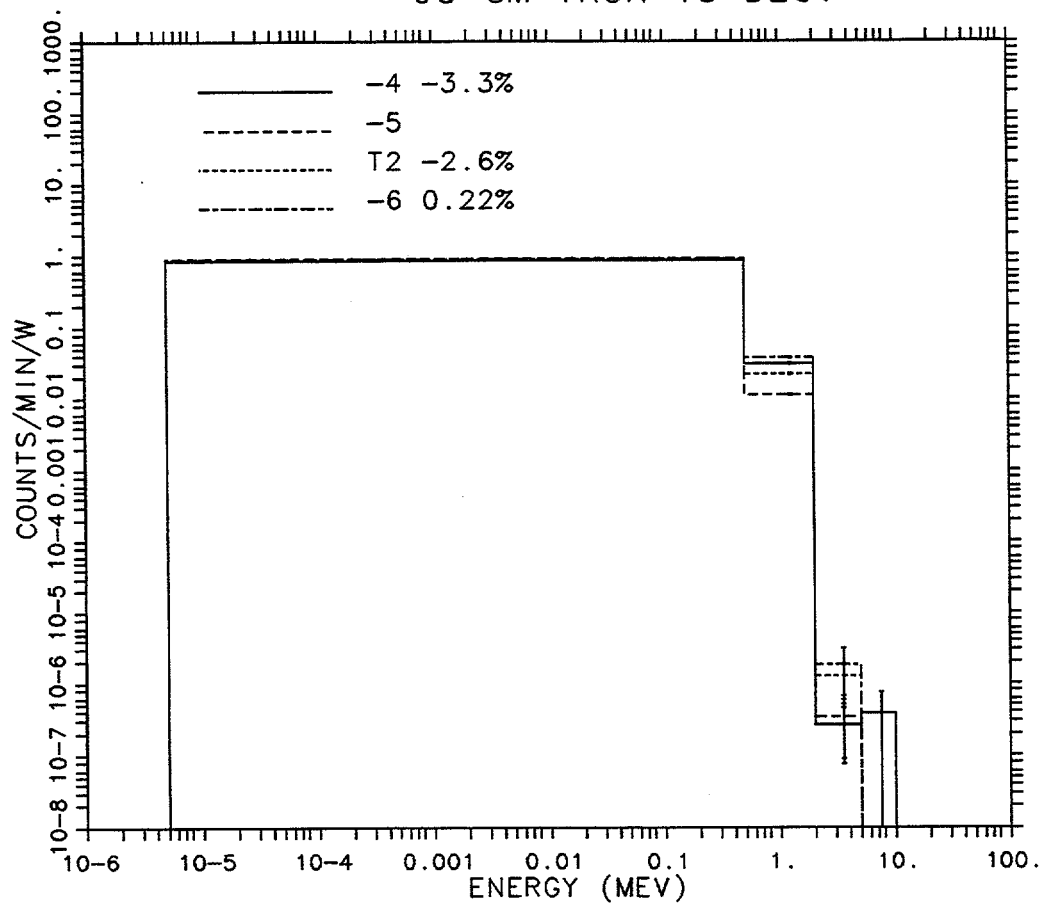


Fig. 95. Data set comparisons for the 93 cm iron slab, with the 5.88 in Bonner Ball at the 15 degree observation angle. (Normalized to ENDF/B-V)

9.86 INCH BONNER BALL  
93 CM IRON 15 DEG.

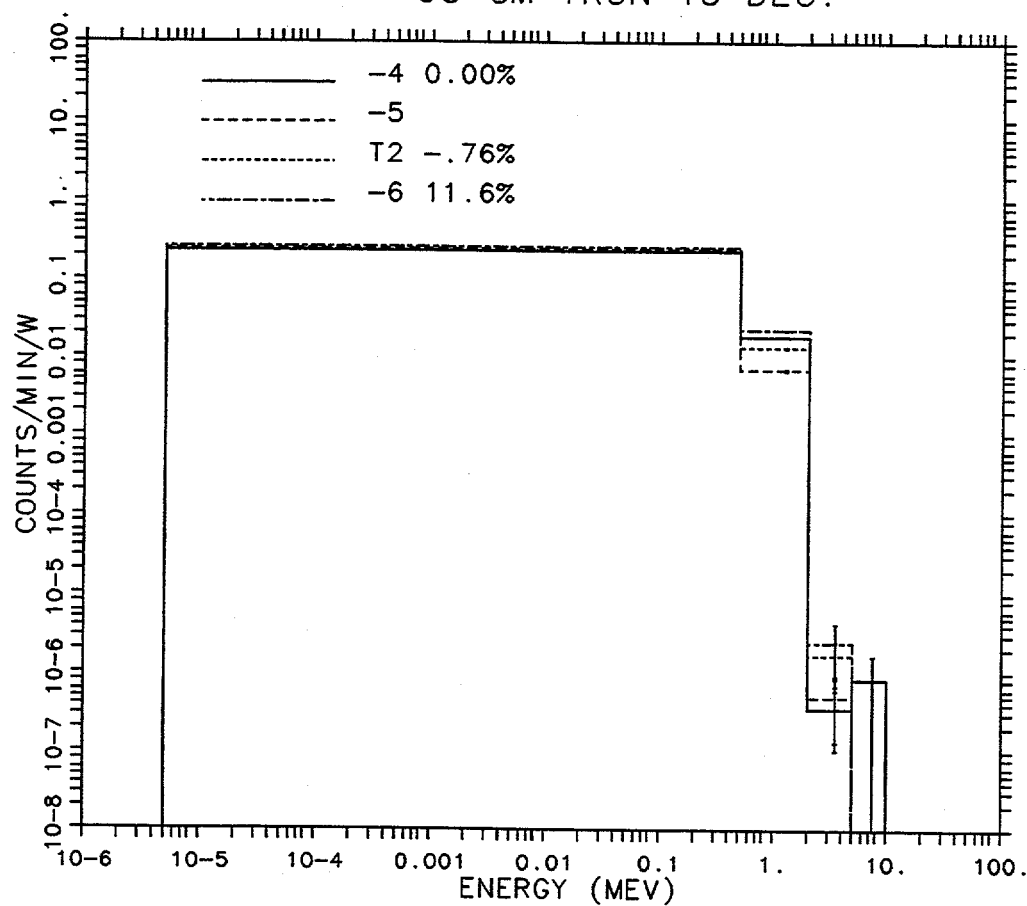


Fig. 96. Data set comparisons for the 93 cm iron slab, with the 9.86 in Bonner Ball at the 15 degree observation angle. (Normalized to ENDF/B-V)

3.09 INCH BONNER BALL  
93 CM IRON 45 DEG.

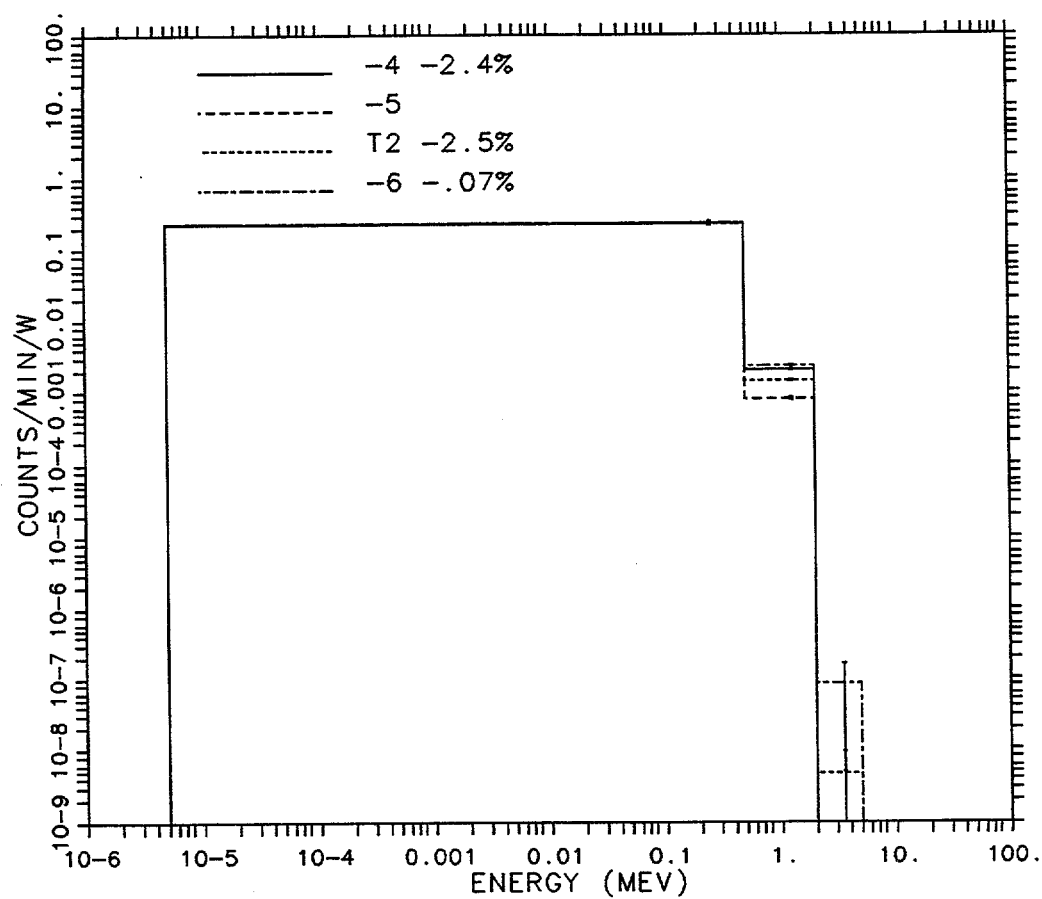


Fig. 97. Data set comparisons for the 93 cm iron slab, with the 3.09 in Bonner Ball at the 45 degree observation angle. (Normalized to ENDF/B-V)

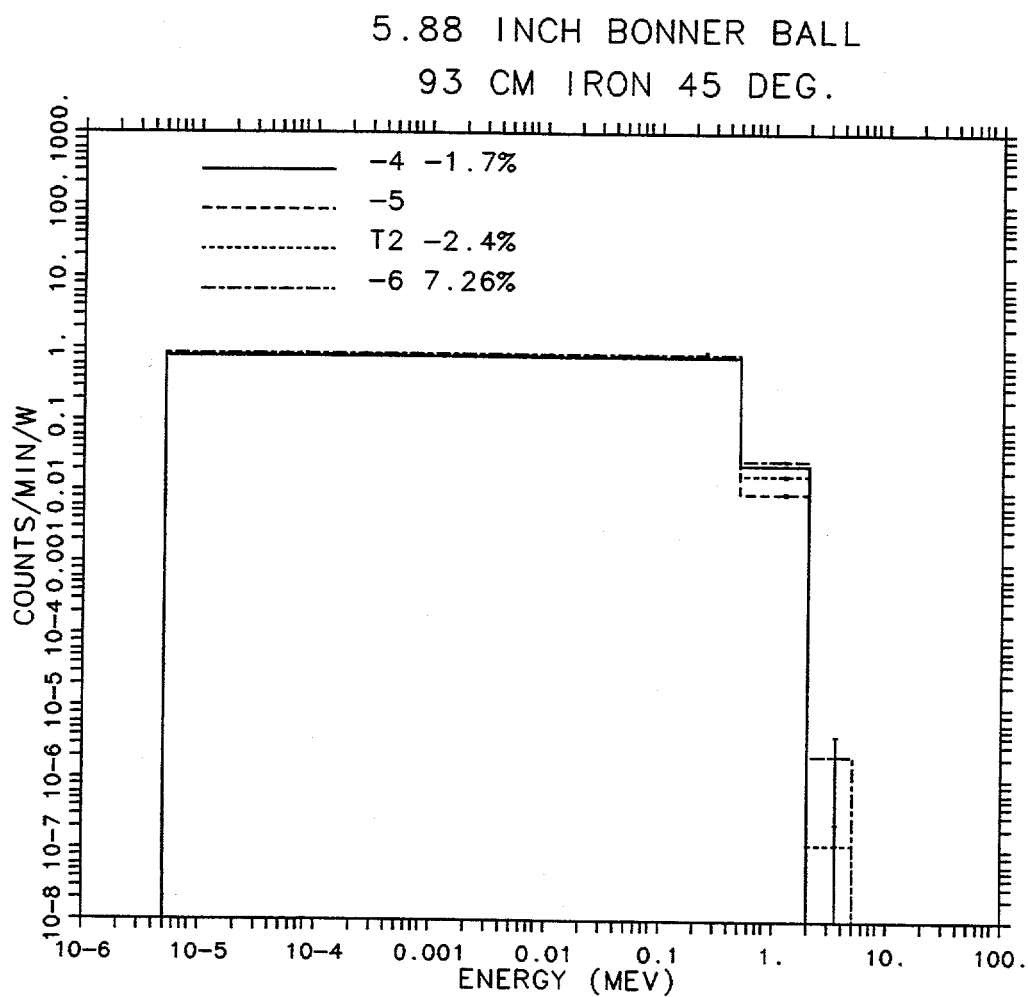


Fig. 98. Data set comparisons for the 93 cm iron slab, with the 5.88 in Bonner Ball at the 45 degree observation angle. (Normalized to ENDF/B-V)

9.86 INCH BONNER BALL  
93 CM IRON 45 DEG.

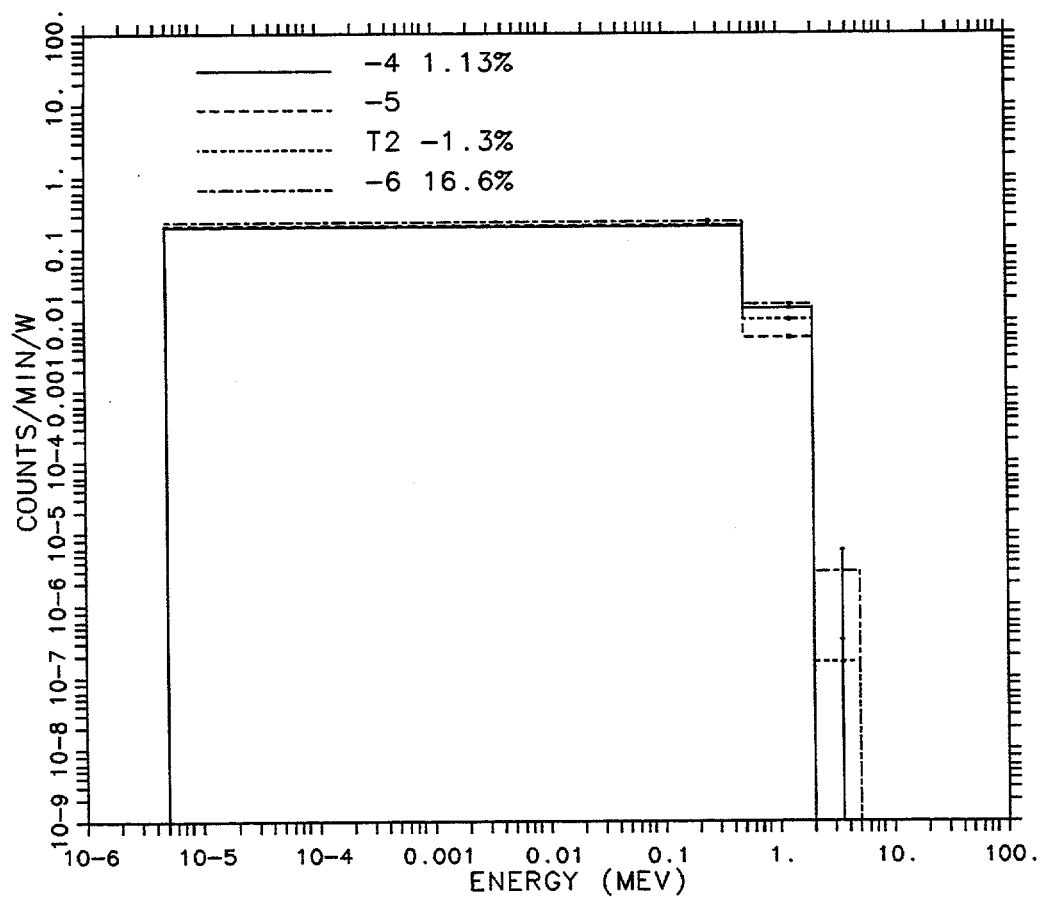


Fig. 99. Data set comparisons for the 93 cm iron slab, with the 9.86 in Bonner Ball at the 45 degree observation angle. (Normalized to ENDF/B-V)

## VI. CONCLUSIONS

In general, when experimental data is available (Benchmarks 1 and 2), the MCNP Recommended Library for iron is the best, followed by ENDF/B-VI, ENDF/B-V, and ENDF/B-IV. For Benchmark 3, where experimental data was not available, and Benchmark 4, where the problem description was evidently faulty, ENDF/B-VI and the MCNP Recommended Iron Libraries tended to agree, while the ENDF/B-V and ENDF/B-IV libraries gave lower transmissions.

Therefore, we believe that the new ENDF/B-VI libraries do not provide significantly better results than the MCNP Recommended Evaluations. However, both the new ENDF/B-VI library and the MCNP Recommended Library appear better than the ENDF/B-V and ENDF/B-IV libraries. We recommend a re-evaluation of any calculations that used ENDF/B-V or ENDF/B-IV libraries with the MCNP Recommended or ENDF/B-VI libraries.

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# **Appendix:**

## **MCNP Input Decks**

Table A.1 Input file for the ENDF/B-VI 4.8 mfp iron sphere for the Lawrence Livermore Pulsed Sphere Benchmark.

```

Fe Sphere with 4.8 M.F.P.  ENDF/B-VI
1  1 -7.85 -1 -3
2  1 -7.85 1 2 -3
3  2 -.001288 1 -2 -3
4  1 -7.85 -1 3 -4
5  1 -7.85 1 2 3 -4
6  2 -.001288 1 -2 3 -4
7  1 -7.85 -1 4 -5
8  1 -7.85 1 2 4 -5
9  2 -.001288 1 -2 4 -5
10 1 -7.85 -1 5 -6
11 1 -7.85 1 2 5 -6
12 2 -.001288 1 -2 5 -6
13 2 -.001288 6 -7
14 0 7

1  px -.475
2  x 0.0 1.11 22.3 2.67
3  so 6
4  so 12
5  so 18
6  so 22.3
7  so 1000
100 px 0.0

imp:n 1 1 1 2 2 2 4 4 4 8 8 8 8 0
sdef pos=0 0 0 dir=d1 erg=fdir=d2 rad=d3 vec=-1 0 0
sur=100 tme=d4
si1 a -1.0000 -.99619 -.98481 -.96593 -.93969
      -.90631 -.86603 -.81915 -.76604 -.70711
      -.64279 -.57358 -.50000 -.42262 -.34202
      -.25882 -.17365 -.08716 .00000 .08716
      .17365 .25882 .34202 .42262 .50000
      .57358 .64279 .70711 .76604 .81915
      .86603 .90631 .93969 .96593 .98481
      .99619 1.0000
sp1 .874 .874 .875 .876 .877
     .879 .882 .884 .888 .891
     .895 .899 .904 .909 .914
     .919 .924 .930 .935 .941
     .946 .952 .957 .962 .967
     .972 .976 .981 .985 .988
     .991 .994 .996 .998 .999
     1.0 1.0
ds2 q -.99619 180 -.98481 175 -.96593 170 -.93962 165 -.90631 160
      -.86603 155 -.81915 150 -.76604 145 -.70711 140 -.64279 135
      -.57358 130 -.50000 125 -.42262 120 -.34202 115 -.25882 110
      -.17365 105 -.08716 100 0.0000 95 .08716 90 .17365 85
      .25882 80 .34202 75 .42262 70 .50000 65 .57358 60
      .64279 55 .70711 50 .76604 45 .81915 40 .86603 35

```

Table A.1 (cont.)

|       | .90631 30       | .93969 25 | .96593 20 | .98481 15 | .99619 10 |
|-------|-----------------|-----------|-----------|-----------|-----------|
|       | 1.0000 5        |           |           |           |           |
| si3   | h 0 .6          |           |           |           |           |
| sp3   | d -21 1         |           |           |           |           |
| sp4   | -41 .3 0        |           |           |           |           |
| si5   | h 15.106 15.110 |           |           |           |           |
| sp5   | d 0 1           |           |           |           |           |
| si10  | h 15.095 15.106 |           |           |           |           |
| sp10  | d 0 1           |           |           |           |           |
| si15  | h 15.075 15.095 |           |           |           |           |
| sp15  | d 0 1           |           |           |           |           |
| si20  | h 15.049 15.075 |           |           |           |           |
| sp20  | d 0 1           |           |           |           |           |
| si25  | h 15.015 15.049 |           |           |           |           |
| sp25  | d 0 1           |           |           |           |           |
| si30  | h 14.974 15.015 |           |           |           |           |
| sp30  | d 0 1           |           |           |           |           |
| si35  | h 14.927 14.974 |           |           |           |           |
| sp35  | d 0 1           |           |           |           |           |
| si40  | h 14.873 14.927 |           |           |           |           |
| sp40  | d 0 1           |           |           |           |           |
| si45  | h 14.814 14.873 |           |           |           |           |
| sp45  | d 0 1           |           |           |           |           |
| si50  | h 14.750 14.814 |           |           |           |           |
| sp50  | d 0 1           |           |           |           |           |
| si55  | h 14.681 14.750 |           |           |           |           |
| sp55  | d 0 1           |           |           |           |           |
| si60  | h 14.608 14.681 |           |           |           |           |
| sp60  | d 0 1           |           |           |           |           |
| si65  | h 14.532 14.608 |           |           |           |           |
| sp65  | d 0 1           |           |           |           |           |
| si70  | h 14.453 14.532 |           |           |           |           |
| sp70  | d 0 1           |           |           |           |           |
| si75  | h 14.372 14.453 |           |           |           |           |
| sp75  | d 0 1           |           |           |           |           |
| si80  | h 14.289 14.372 |           |           |           |           |
| sp80  | d 0 1           |           |           |           |           |
| si85  | h 14.206 14.289 |           |           |           |           |
| sp85  | d 0 1           |           |           |           |           |
| si90  | h 14.123 14.206 |           |           |           |           |
| sp90  | d 0 1           |           |           |           |           |
| si95  | h 14.040 14.123 |           |           |           |           |
| sp95  | d 0 1           |           |           |           |           |
| si100 | h 13.958 14.040 |           |           |           |           |
| sp100 | d 0 1           |           |           |           |           |
| si105 | h 13.878 13.958 |           |           |           |           |
| sp105 | d 0 1           |           |           |           |           |
| si110 | h 13.800 13.878 |           |           |           |           |
| sp110 | d 0 1           |           |           |           |           |
| si115 | h 13.725 13.800 |           |           |           |           |

Table A.1 (cont.)

```

sp115 d 0 1
si120 h 13.654 13.725
sp120 d 0 1
si125 h 13.586 13.654
sp125 d 0 1
si130 h 13.522 13.586
sp130 d 0 1
si135 h 13.464 13.522
sp135 d 0 1
si140 h 13.410 13.464
sp140 d 0 1
si145 h 13.362 13.410
sp145 d 0 1
si150 h 13.320 13.362
sp150 d 0 1
si155 h 13.284 13.320
sp155 d 0 1
si160 h 13.254 13.284
sp160 d 0 1
si165 h 13.230 13.254
sp165 d 0 1
si170 h 13.214 13.230
sp170 d 0 1
si175 h 13.203 13.214
sp175 d 0 1
si180 h 13.200 13.203
sp180 d 0 1
fc5 WE213 detector response function, 766.0 cm flightpath, 30 degrees.
f5x:n -663.4 383 0
t5  1.37E+01  1.39000E+01  1.41000E+01  1.43000E+01  1.45000E+01  1.47000E+01
    1.49E+01  1.51000E+01  1.53000E+01  1.55000E+01  1.57000E+01  1.59000E+01
    1.61E+01  1.63000E+01  1.65000E+01  1.67000E+01  1.69000E+01  1.71000E+01
    1.73E+01  1.75000E+01  1.77000E+01  1.79000E+01  1.81000E+01  1.83000E+01
    1.85E+01  1.87000E+01  1.89000E+01  1.91000E+01  1.93000E+01  1.95000E+01
    1.97E+01  1.99000E+01  2.01000E+01  2.03000E+01  2.05000E+01  2.07000E+01
    2.09E+01  2.11000E+01  2.13000E+01  2.15000E+01  2.17000E+01  2.19000E+01
    2.21E+01  2.23000E+01  2.25000E+01  2.27000E+01  2.29000E+01  2.31000E+01
    2.33E+01  2.35000E+01  2.37000E+01  2.39000E+01  2.41000E+01  2.43000E+01
    2.45E+01  2.47000E+01  2.49000E+01  2.51000E+01  2.53000E+01  2.55000E+01
    2.57E+01  2.59000E+01  2.61000E+01  2.63000E+01  2.65000E+01  2.67000E+01
    2.69E+01  2.71000E+01  2.73000E+01  2.75000E+01  2.77000E+01  2.79000E+01
    2.81E+01  2.83000E+01  2.85000E+01  2.87000E+01  2.89000E+01  2.91000E+01
    2.93E+01  2.95000E+01  2.97000E+01  2.99000E+01  3.01000E+01  3.03000E+01
    3.05E+01  3.07000E+01  3.09000E+01  3.11000E+01  3.13000E+01  3.15000E+01
    3.17E+01  3.19000E+01  3.21000E+01  3.23000E+01  3.25000E+01  3.27000E+01
    3.29E+01  3.31000E+01  3.33000E+01  3.35000E+01  3.37000E+01  3.39000E+01
    3.41E+01  3.43000E+01  3.45000E+01  3.47000E+01  3.49000E+01  3.51000E+01
    3.53E+01  3.55000E+01  3.57000E+01  3.59000E+01  3.61000E+01  3.63000E+01
    3.65E+01  3.67000E+01  3.69000E+01  3.71000E+01  3.73000E+01  3.75000E+01
    3.77E+01  3.79000E+01  3.81000E+01  3.83000E+01  3.85000E+01  3.87000E+01

```

Table A.1 (cont.)

```

3.89E+01 3.91000E+01 3.93000E+01 3.95000E+01 3.97000E+01 3.99000E+01
4.01E+01 4.03000E+01 4.05000E+01 4.07000E+01 4.09000E+01 4.11000E+01
4.13E+01 4.15000E+01 4.17000E+01
c NE213 low bias response function
de5 lin 1.6 1.8 1.9 2.0 2.1 2.2 2.3 2.4 2.5 2.75
3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.4 6.6 6.8 7.0
7.5 8.1 8.5 9.0 10.0 11.0 12.0 12.5 13.0
13.5 14.0 15.0 16.0
df5 lin 0.00 1.46 1.86 2.26 2.58 3.00 3.29 3.42
3.63 3.95 4.10 4.25 4.33 4.39 4.40 4.37 4.28
4.15 4.20 4.18 4.12 3.97 3.80 3.77 3.65 3.44
3.24 3.06 3.01 2.98 2.98 3.01 3.08 3.25
fc15 NE213 detector, low bias, 766.0 cm flightpath, 30 degrees.
f15x:n -663.4 383 0
t15 15.5 17.5 24.9 39.1
c NE213 low bias response function
de15 lin 1.6 1.8 1.9 2.0 2.1 2.2 2.3 2.4 2.5 2.75
3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.4 6.6 6.8 7.0
7.5 8.1 8.5 9.0 10.0 11.0 12.0 12.5 13.0
13.5 14.0 15.0 16.0
df15 lin 0.00 1.46 1.86 2.26 2.58 3.00 3.29 3.42
3.63 3.95 4.10 4.25 4.33 4.39 4.40 4.37 4.28
4.15 4.20 4.18 4.12 3.97 3.80 3.77 3.65 3.44
3.24 3.06 3.01 2.98 2.98 3.01 3.08 3.25
c
c ENDF/B-VI
m1 26054.60c .0562600
26056.60c .8896840
26057.60c .0213400
26058.60c .0027160
6000.60c .012
25055.60c .010
15031.60c .007
16032.60c .001
m2 7014.60c -.7885
8016.60c -.2115
cut:n 39.1 1.6
print
prdmp 2j -1
nps 400000

```

Table A.2 Input file for the ENDF/B-VI Fusion Reactor Shielding Benchmark for Configuration 7, On Axis.

```

1- Fusion Spectra Problem ENDF/B-VI
2- 1 1 7.506e-2 1 -2 10 -21 -22 29 $ floor cell $
3- 2 1 7.506e-2 7 -8 10 -21 -22 29 $ ceiling cell $
4- 3 1 7.506e-2 2 -7 10 -21 -22 23 $ left wall cell $
5- 4 1 7.506e-2 2 -7 10 -21 -28 29 $ right wall cell $
6- 5 1 7.506e-2 2 -7 20 -21 -23 28 $ front wall cell $
7- 6 2 4.614e-5 2 -4 10 -11 -23 32 $ left door cell $
8- 7 2 4.614e-5 2 -4 10 -11 -33 34 $ middle door cell $
9- 8 2 4.614e-5 2 -4 10 -11 -35 28 $ right door cell $
10- 9 1 7.506e-2 4 -7 10 -11 -23 32 $ concrete above left door $
11- 10 1 7.506e-2 4 -7 10 -11 -33 34 $ concrete above middle door
12- 11 1 7.506e-2 4 -7 10 -11 -35 28 $ concrete above right door
13- 12 1 7.506e-2 2 -4 10 -11 -32 33 $ concrete cell betwn l/m doors
14- 13 1 7.506e-2 2 -4 10 -11 -34 35 $ concrete cell betwn m/r doors
15- 14 1 7.506e-2 4 -7 10 -11 -32 33 $ wall concrete above cell 12
16- 15 1 7.506e-2 4 -7 10 -11 -34 35 $ wall concrete above cell 13
17- 16 2 4.614e-5 2 -4 11 -12 -23 32 $ air cell betwn left door & block back
18- 17 2 4.614e-5 2 -4 11 -12 -33 34 $ air cell betwn middle door & block back
19- 18 2 4.614e-5 2 -4 11 -12 -35 28 $ air cell betwn right door & block back
20- 19 2 4.614e-5 2 -4 11 -12 -32 33 $ air cell betwn cell12 door & block back
21- 20 2 4.614e-5 2 -4 11 -12 -34 35 $ air cell betwn cell13 door & block back
22- 21 2 4.614e-5 4 -7 11 -12 -23 32 $ air cell betwn cell 9 door & block back
23- 22 2 4.614e-5 4 -7 11 -12 -33 34 $ air cell betwn cell10 door & block back
24- 23 2 4.614e-5 4 -7 11 -12 -35 28 $ air cell betwn cell11 door & block back
25- 24 2 4.614e-5 4 -7 11 -12 -32 33 $ air cell betwn cell14 door & block back
26- 25 2 4.614e-5 4 -7 11 -12 -34 35 $ air cell betwn cell15 door & block back
27- 26 2 4.614e-5 6 -7 12 -15 -23 32 $ cells 26-35: air cells abv the block
28- 27 2 4.614e-5 6 -7 12 -15 -32 33
29- 28 2 4.614e-5 6 -7 12 -15 -33 34
30- 29 2 4.614e-5 6 -7 12 -15 -34 35
31- 30 2 4.614e-5 6 -7 12 -15 -35 28
32- 31 2 4.614e-5 6 -7 15 -17 -23 32
33- 32 2 4.614e-5 6 -7 15 -17 -32 33
34- 33 2 4.614e-5 6 -7 15 -17 -33 34
35- 34 2 4.614e-5 6 -7 15 -17 -34 35
36- 35 2 4.614e-5 6 -7 15 -17 -35 28
37- 36 2 4.614e-5 2 -3 12 -15 -23 32 $ cells 36-47: air cells left of block
38- 37 2 4.614e-5 2 -3 12 -15 -32 24
39- 38 2 4.614e-5 2 -3 15 -17 -23 32
40- 39 2 4.614e-5 2 -3 15 -17 -32 24
41- 40 2 4.614e-5 3 -4 12 -15 -23 32
42- 41 2 4.614e-5 3 -4 12 -15 -32 24
43- 42 2 4.614e-5 3 -4 15 -17 -23 32
44- 43 2 4.614e-5 3 -4 15 -17 -32 24
45- 44 2 4.614e-5 4 -6 12 -15 -23 32
46- 45 2 4.614e-5 4 -6 12 -15 -32 24
47- 46 2 4.614e-5 4 -6 15 -17 -23 32
48- 47 2 4.614e-5 4 -6 15 -17 -32 24
49- 48 2 4.614e-5 2 -3 12 -15 -27 35 $ cells 48-59: air cells right of block
50- 49 2 4.614e-5 2 -3 12 -15 -35 28

```

Table A.2 (cont.)

|      |    |   |          |   |    |     |     |     |     |                                               |
|------|----|---|----------|---|----|-----|-----|-----|-----|-----------------------------------------------|
| 51-  | 50 | 2 | 4.614e-5 | 2 | -3 | 15  | -17 | -27 | 35  |                                               |
| 52-  | 51 | 2 | 4.614e-5 | 2 | -3 | 15  | -17 | -35 | 28  |                                               |
| 53-  | 52 | 2 | 4.614e-5 | 3 | -4 | 12  | -15 | -27 | 35  |                                               |
| 54-  | 53 | 2 | 4.614e-5 | 3 | -4 | 12  | -15 | -35 | 28  |                                               |
| 55-  | 54 | 2 | 4.614e-5 | 3 | -4 | 15  | -17 | -27 | 35  |                                               |
| 56-  | 55 | 2 | 4.614e-5 | 3 | -4 | 15  | -17 | -35 | 28  |                                               |
| 57-  | 56 | 2 | 4.614e-5 | 4 | -6 | 12  | -15 | -27 | 35  |                                               |
| 58-  | 57 | 2 | 4.614e-5 | 4 | -6 | 12  | -15 | -35 | 28  |                                               |
| 59-  | 58 | 2 | 4.614e-5 | 4 | -6 | 15  | -17 | -27 | 35  |                                               |
| 60-  | 59 | 2 | 4.614e-5 | 4 | -6 | 15  | -17 | -35 | 28  |                                               |
| 61-  | 60 | 2 | 4.614e-5 | 6 | -7 | 17  | -40 | -23 | 32  | \$ cells 60-69: air cells abv thermal shield  |
| 62-  | 61 | 2 | 4.614e-5 | 6 | -7 | 17  | -40 | -32 | 33  |                                               |
| 63-  | 62 | 2 | 4.614e-5 | 6 | -7 | 17  | -40 | -33 | 34  |                                               |
| 64-  | 63 | 2 | 4.614e-5 | 6 | -7 | 17  | -40 | -34 | 35  |                                               |
| 65-  | 64 | 2 | 4.614e-5 | 6 | -7 | 17  | -40 | -35 | 28  |                                               |
| 66-  | 65 | 2 | 4.614e-5 | 6 | -7 | 40  | -20 | -23 | 32  |                                               |
| 67-  | 66 | 2 | 4.614e-5 | 6 | -7 | 40  | -20 | -32 | 33  |                                               |
| 68-  | 67 | 2 | 4.614e-5 | 6 | -7 | 40  | -20 | -33 | 34  |                                               |
| 69-  | 68 | 2 | 4.614e-5 | 6 | -7 | 40  | -20 | -34 | 35  |                                               |
| 70-  | 69 | 2 | 4.614e-5 | 6 | -7 | 40  | -20 | -35 | 28  |                                               |
| 71-  | 70 | 2 | 4.614e-5 | 2 | -3 | 17  | -40 | -23 | 32  | \$ cells 70-81: air cells left of thermal shi |
| 72-  | 71 | 2 | 4.614e-5 | 2 | -3 | 17  | -40 | -32 | 24  |                                               |
| 73-  | 72 | 2 | 4.614e-5 | 2 | -3 | 40  | -20 | -23 | 32  |                                               |
| 74-  | 73 | 2 | 4.614e-5 | 2 | -3 | 40  | -20 | -32 | 24  |                                               |
| 75-  | 74 | 2 | 4.614e-5 | 3 | -4 | 17  | -40 | -23 | 32  |                                               |
| 76-  | 75 | 2 | 4.614e-5 | 3 | -4 | 17  | -40 | -32 | 24  |                                               |
| 77-  | 76 | 2 | 4.614e-5 | 3 | -4 | 40  | -20 | -23 | 32  |                                               |
| 78-  | 77 | 2 | 4.614e-5 | 3 | -4 | 40  | -20 | -32 | 24  |                                               |
| 79-  | 78 | 2 | 4.614e-5 | 4 | -6 | 17  | -40 | -23 | 32  |                                               |
| 80-  | 79 | 2 | 4.614e-5 | 4 | -6 | 17  | -40 | -32 | 24  |                                               |
| 81-  | 80 | 2 | 4.614e-5 | 4 | -6 | 40  | -20 | -23 | 32  |                                               |
| 82-  | 81 | 2 | 4.614e-5 | 4 | -6 | 40  | -20 | -32 | 24  |                                               |
| 83-  | 82 | 2 | 4.614e-5 | 2 | -3 | 17  | -40 | -27 | 35  | \$ cells 82-93: air cells right of thermal sh |
| 84-  | 83 | 2 | 4.614e-5 | 2 | -3 | 17  | -40 | -35 | 28  |                                               |
| 85-  | 84 | 2 | 4.614e-5 | 2 | -3 | 40  | -20 | -27 | 35  |                                               |
| 86-  | 85 | 2 | 4.614e-5 | 2 | -3 | 40  | -20 | -35 | 28  |                                               |
| 87-  | 86 | 2 | 4.614e-5 | 3 | -4 | 17  | -40 | -27 | 35  |                                               |
| 88-  | 87 | 2 | 4.614e-5 | 3 | -4 | 17  | -40 | -35 | 28  |                                               |
| 89-  | 88 | 2 | 4.614e-5 | 3 | -4 | 40  | -20 | -27 | 35  |                                               |
| 90-  | 89 | 2 | 4.614e-5 | 3 | -4 | 40  | -20 | -35 | 28  |                                               |
| 91-  | 90 | 2 | 4.614e-5 | 4 | -6 | 17  | -40 | -27 | 35  |                                               |
| 92-  | 91 | 2 | 4.614e-5 | 4 | -6 | 17  | -40 | -35 | 28  |                                               |
| 93-  | 92 | 2 | 4.614e-5 | 4 | -6 | 40  | -20 | -27 | 35  |                                               |
| 94-  | 93 | 2 | 4.614e-5 | 4 | -6 | 40  | -20 | -35 | 28  |                                               |
| 95-  | 94 | 4 | 8.75e-2  | 3 | -5 | -25 | 26  | 15  | -41 | \$ cells 94-103: air and shield cells inside  |
| 96-  | 95 | 4 | 8.75e-2  | 3 | -5 | -25 | 26  | 41  | -42 | \$ the concrete box                           |
| 97-  | 96 | 4 | 8.75e-2  | 3 | -5 | -25 | 26  | 42  | -43 |                                               |
| 98-  | 97 | 4 | 8.75e-2  | 3 | -5 | -25 | 26  | 43  | -44 |                                               |
| 99-  | 98 | 6 | .11150   | 3 | -5 | -25 | 26  | 44  | -45 |                                               |
| 100- | 99 | 4 | 8.75e-2  | 3 | -5 | -25 | 26  | 45  | -46 |                                               |

Table A.2 (cont.)

|      |                                                                                  |
|------|----------------------------------------------------------------------------------|
| 101- | 100 6 .11150 3 -5 -25 26 46 -47                                                  |
| 102- | 101 4 8.75e-2 3 -5 -25 26 47 -48                                                 |
| 103- | 1021 2 4.614e-5 3 -5 -25 26 461 -462                                             |
| 104- | 1022 2 4.614e-5 3 -5 -25 26 462 -463                                             |
| 105- | 1023 2 4.614e-5 3 -5 -25 26 463 -49                                              |
| 106- | 102 2 4.614e-5 3 -5 -25 26 48 -461                                               |
| 107- | 103 2 4.614e-5 3 -5 -25 26 49 -17                                                |
| 108- | 104 2 4.614e-5 3 -9 -25 26 17 -18 \$ air cell betwn inner box and thermal shield |
| 109- | 105 2 4.614e-5 3 -9 -30 31 19 -40 \$ cells 105-106: air cells fitting between    |
| 110- | 106 2 4.614e-5 3 -9 -30 31 40 -20 \$ the thermal shield and the front wall       |
| 111- | 107 2 4.614e-5 9 -6 -24 27 17 -18 \$ cells 107-109: air cells between the upper  |
| 112- | 108 2 4.614e-5 9 -6 -24 27 18 -40 \$ horizontal edge of the concrete block       |
| 113- | 109 2 4.614e-5 9 -6 -24 27 40 -20 \$ and the front wall                          |
| 114- | 110 2 4.614e-5 2 -3 -24 27 17 -18 \$ cells 110-112: air cells between the        |
| 115- | 111 2 4.614e-5 2 -3 -24 27 18 -40 \$ lower horizontal edge of the concrete       |
| 116- | 112 2 4.614e-5 2 -3 -24 27 40 -20 \$ box and the front wall                      |
| 117- | 113 2 4.614e-5 3 -9 -24 25 17 -18 \$ cells 113-118: air cells between the        |
| 118- | 114 2 4.614e-5 3 -9 -24 25 18 -40 \$ right and left vertical concrete box        |
| 119- | 115 2 4.614e-5 3 -9 -24 25 40 -20 \$ walls and the front wall                    |
| 120- | 116 2 4.614e-5 3 -9 -26 27 17 -18                                                |
| 121- | 117 2 4.614e-5 3 -9 -26 27 18 -40                                                |
| 122- | 118 2 4.614e-5 3 -9 -26 27 40 -20                                                |
| 123- | 119 0 -36 12 -13 \$ vacuum inside beamline                                       |
| 124- | 120 0 -36 13 -14 \$ vacuum inside iron can                                       |
| 125- | 121 0 14 -15 -38 \$ vacuum inside iron pipe                                      |
| 126- | 122 3 8.48e-2 36 -37 12 -13 \$ beamline                                          |
| 127- | 123 3 8.48e-2 36 -39 13 -14 \$ iron can                                          |
| 128- | 124 3 8.48e-2 38 -39 14 -15 \$ iron pipe                                         |
| 129- | 125 5 1.1139e-1 37 -39 12 -13                                                    |
| 130- | 126 1 7.506e-2 5 -6 12 -15 -24 33 \$ cells 126-134: concrete box top cells       |
| 131- | 127 1 7.506e-2 5 -6 12 -15 -33 34                                                |
| 132- | 128 1 7.506e-2 5 -6 12 -15 -34 27                                                |
| 133- | 129 1 7.506e-2 5 -6 15 -45 -24 33                                                |
| 134- | 130 1 7.506e-2 5 -6 15 -45 -33 34                                                |
| 135- | 131 1 7.506e-2 5 -6 15 -45 -34 27                                                |
| 136- | 132 1 7.506e-2 5 -6 45 -17 -24 33                                                |
| 137- | 133 1 7.506e-2 5 -6 45 -17 -33 34                                                |
| 138- | 134 1 7.506e-2 5 -6 45 -17 -34 27                                                |
| 139- | 135 1 7.506e-2 2 -3 12 -15 -24 33 \$ cells 135-143: cnrc box bottom cells        |
| 140- | 136 1 7.506e-2 2 -3 12 -15 -33 34                                                |
| 141- | 137 1 7.506e-2 2 -3 12 -15 -34 27                                                |
| 142- | 138 1 7.506e-2 2 -3 15 -45 -24 33                                                |
| 143- | 139 1 7.506e-2 2 -3 15 -45 -33 34                                                |
| 144- | 140 1 7.506e-2 2 -3 15 -45 -34 27                                                |
| 145- | 141 1 7.506e-2 2 -3 45 -17 -24 33                                                |
| 146- | 142 1 7.506e-2 2 -3 45 -17 -33 34                                                |
| 147- | 143 1 7.506e-2 2 -3 45 -17 -34 27                                                |
| 148- | 144 1 7.506e-2 -24 25 3 -50 12 -15 \$ cells 144-149: concrete box left           |
| 149- | 145 1 7.506e-2 -24 25 3 -50 15 -45 \$ vertical wall cells                        |
| 150- | 146 1 7.506e-2 -24 25 3 -50 45 -17                                               |

Table A.2 (cont.)

|      |     |     |          |          |     |     |     |     |     |                                                |
|------|-----|-----|----------|----------|-----|-----|-----|-----|-----|------------------------------------------------|
| 151- | 147 | 1   | 7.506e-2 | -24      | 25  | 50  | -5  | 12  | -15 |                                                |
| 152- | 148 | 1   | 7.506e-2 | -24      | 25  | 50  | -5  | 15  | -45 |                                                |
| 153- | 149 | 1   | 7.506e-2 | -24      | 25  | 50  | -5  | 45  | -17 |                                                |
| 154- | 150 | 1   | 7.506e-2 | -26      | 27  | 3   | -50 | 12  | -15 | \$ cells 150-155: concrete box right           |
| 155- | 151 | 1   | 7.506e-2 | -26      | 27  | 3   | -50 | 15  | -45 | \$ vertical wall cells                         |
| 156- | 152 | 1   | 7.506e-2 | -26      | 27  | 3   | -50 | 45  | -17 |                                                |
| 157- | 153 | 1   | 7.506e-2 | -26      | 27  | 50  | -5  | 12  | -15 |                                                |
| 158- | 154 | 1   | 7.506e-2 | -26      | 27  | 50  | -5  | 15  | -45 |                                                |
| 159- | 155 | 1   | 7.506e-2 | -26      | 27  | 50  | -5  | 45  | -17 |                                                |
| 160- | 156 | 1   | 7.506e-2 | 3        | -5  | -25 | 26  | 39  | 12  | -51 \$ cells 156-164: inner concrete box cells |
| 161- | 157 | 1   | 7.506e-2 | 3        | -5  | -25 | 26  | 39  | 51  | -52                                            |
| 162- | 158 | 1   | 7.506e-2 | 3        | -5  | -25 | 26  | 39  | 52  | -53                                            |
| 163- | 159 | 1   | 7.506e-2 | 3        | -5  | -25 | 26  | 39  | 53  | -54                                            |
| 164- | 160 | 1   | 7.506e-2 | 3        | -5  | -25 | 26  | 39  | 54  | -55                                            |
| 165- | 161 | 1   | 7.506e-2 | 3        | -5  | -25 | 26  | 39  | 55  | -56                                            |
| 166- | 162 | 1   | 7.506e-2 | 3        | -5  | -25 | 26  | 39  | 56  | -57                                            |
| 167- | 163 | 1   | 7.506e-2 | 3        | -5  | -25 | 26  | 39  | 57  | -58                                            |
| 168- | 164 | 1   | 7.506e-2 | 3        | -5  | -25 | 26  | 39  | 58  | -15                                            |
| 169- | c   | 165 | 2        | 4.614e-5 | 9   | -5  | -25 | 26  | 18  | -40 \$ cells 165-170: air cells centered       |
| 170- | c   | 166 | 2        | 4.614e-5 | 9   | -5  | -25 | 26  | 40  | -20 \$ around the thermal shield               |
| 171- | 167 | 2   | 4.614e-5 | -25      | 30  | 3   | -9  | 18  | -40 |                                                |
| 172- | 168 | 2   | 4.614e-5 | -25      | 30  | 3   | -9  | 40  | -20 |                                                |
| 173- | 169 | 2   | 4.614e-5 | -31      | 26  | 3   | -9  | 18  | -40 |                                                |
| 174- | 170 | 2   | 4.614e-5 | -31      | 26  | 3   | -9  | 40  | -20 |                                                |
| 175- | 171 | 4   | 8.75e-2  | 18       | -19 | 3   | -9  | -30 | 31  | \$ thermal shield                              |
| 176- | 172 | 0   | -1       |          |     |     |     |     |     | \$ void cell below the concrete room           |
| 177- | 173 | 0   | 8        |          |     |     |     |     |     | \$ void cell above the concrete room           |
| 178- | 174 | 0   | 1        | -8       | -22 | 29  | -10 |     |     | \$ void cell behind the rear wall              |
| 179- | 175 | 0   | 1        | -8       | -22 | 29  | 21  |     |     | \$ void cell in front of the front wall        |
| 180- | 176 | 0   | 1        | -8       | 22  |     |     |     |     | \$ void cell left of the room                  |
| 181- | 177 | 0   | 1        | -8       | -29 |     |     |     |     | \$ void cell right of the room                 |
| 182- |     |     |          |          |     |     |     |     |     |                                                |
| 183- |     | 1   | pz       | -91.44   |     |     |     |     |     |                                                |
| 184- |     | 2   | pz       | 0        |     |     |     |     |     | \$ upper floor plane                           |
| 185- |     | 3   | pz       | 81.2     |     |     |     |     |     | \$ inner box bottom/lower thermal shield edge  |
| 186- |     | 4   | pz       | 218.4    |     |     |     |     |     | \$ door upper edge                             |
| 187- |     | 5   | pz       | 253.92   |     |     |     |     |     | \$ inner box top                               |
| 188- |     | 6   | pz       | 317.50   |     |     |     |     |     | \$ concrete box top                            |
| 189- |     | 7   | pz       | 495.30   |     |     |     |     |     | \$ ceiling plane (lower)                       |
| 190- |     | 8   | pz       | 586.74   |     |     |     |     |     | \$ ceiling plane (upper)                       |
| 191- |     | 9   | pz       | 233.60   |     |     |     |     |     | \$ upper thermal shield edge                   |
| 192- |     | 10  | py       | -29.21   |     |     |     |     |     | \$ rear wall plane (rear)                      |
| 193- |     | 11  | py       | 0        |     |     |     |     |     | \$ rear wall plane (front)                     |
| 194- |     | 12  | py       | 160.02   |     |     |     |     |     | \$ rear of concrete box                        |
| 195- |     | 13  | py       | 208.28   |     |     |     |     |     | \$ end of paraffin                             |
| 196- |     | 14  | py       | 225.56   |     |     |     |     |     | \$ rear edge of iron can                       |
| 197- |     | 15  | py       | 253.06   |     |     |     |     |     | \$ end of iron pipe/rear of inner box          |
| 198- |     | 16  | py       | 232.02   |     |     |     |     |     | \$ plane of target                             |
| 199- |     | 17  | py       | 353.06   |     |     |     |     |     | \$ front of concrete box                       |
| 200- |     | 18  | py       | 436.52   |     |     |     |     |     | \$ front of thermal shield                     |

Table A.2 (cont.)

|      |                                                               |
|------|---------------------------------------------------------------|
| 201- | 19 py 441.60 \$ rear of thermal shield                        |
| 202- | 20 py 570.20 \$ front wall plane (inside)                     |
| 203- | 21 py 661.64 \$ front wall plane (outside)                    |
| 204- | 22 px 91.44 \$ left wall plane (outside)                      |
| 205- | 23 px 0 \$ left wall plane (inside)                           |
| 206- | 24 px -200.66 \$ left side of concrete box                    |
| 207- | 25 px -278.76 \$ left side of inner box                       |
| 208- | 26 px -434.97 \$ right side of inner box                      |
| 209- | 27 px -513.08 \$ right side of concrete box                   |
| 210- | 28 px -716.28 \$ right wall plane (inside)                    |
| 211- | 29 px -807.72 \$ right wall plane (outside)                   |
| 212- | 30 px -280.66 \$ left edge of thermal shield                  |
| 213- | 31 px -433.06 \$ right edge of thermal shield                 |
| 214- | 32 px -114.3 \$ right edge of left door                       |
| 215- | 33 px -300.99 \$ left edge of middle door                     |
| 216- | 34 px -415.29 \$ right edge of middle door                    |
| 217- | 35 px -601.98 \$ left edge of right door                      |
| 218- | 36 c/y -356.87 157.4 4.5 \$ beamline inner surface            |
| 219- | 37 c/y -356.87 157.4 5.0 \$ beamline outer surface            |
| 220- | 38 c/y -356.87 157.4 8.87 \$ iron pipe inner surface          |
| 221- | 39 c/y -356.87 157.4 16.37 \$ iron pipe outer surface         |
| 222- | 40 py 470                                                     |
| 223- | 41 py 263.06                                                  |
| 224- | 42 py 273.06                                                  |
| 225- | 43 py 283.54                                                  |
| 226- | 44 py 288.62                                                  |
| 227- | 45 py 293.70                                                  |
| 228- | 46 py 298.78                                                  |
| 229- | 47 py 303.86                                                  |
| 230- | 48 py 308.94                                                  |
| 231- | 461 py 313.06                                                 |
| 232- | 462 py 323.06                                                 |
| 233- | 463 py 333.06                                                 |
| 234- | 49 py 343.06                                                  |
| 235- | 50 pz 160                                                     |
| 236- | 51 py 170                                                     |
| 237- | 52 py 180                                                     |
| 238- | 53 py 190                                                     |
| 239- | 54 py 200                                                     |
| 240- | 55 py 210                                                     |
| 241- | 56 py 220                                                     |
| 242- | 57 py 230                                                     |
| 243- | 58 py 240                                                     |
| 244- |                                                               |
| 245- | mode n                                                        |
| 246- | wwp:n 4 3 2                                                   |
| 247- | wwc:n 1.0000E+02                                              |
| 248- | wwn1:n 2.8502E-03 2.4082E-02 2.0065E-02 2.7644E-03 5.0534E-03 |
| 249- | 1.0000E+00 2.3250E-01 1.0000E+00 9.3745E-02 1.1525E-01        |
| 250- | 3.4394E-01 1.1440E-01 2.9391E-01 3.2889E-01 2.5248E-03        |

Table A.2 (cont.)

|      |                                                                   |             |             |             |             |
|------|-------------------------------------------------------------------|-------------|-------------|-------------|-------------|
| 251- | 2.4081E-02                                                        | 3.3935E-02  | 2.6292E-02  | 9.5316E-02  | 9.7181E-02  |
| 252- | 2.3367E-02                                                        | 9.5228E-03  | 2.2842E-02  | 4.3222E-02  | 5.2033E-03  |
| 253- | 2.0471E-02                                                        | 2.0693E-02  | 2.6450E-02  | 2.3806E-02  | 2.4143E-02  |
| 254- | 8.7829E-03                                                        | 1.9774E-02  | 3.6164E-02  | 2.5231E-02  | 7.0119E-02  |
| 255- | 3.2090E-02                                                        | 1.3674E-01  | 7.2456E-03  | 8.3109E-03  | 1.0087E-02  |
| 256- | 2.4852E-02                                                        | 2.9118E-02  | 2.4378E-02  | 1.6170E-02  | 1.5929E-02  |
| 257- | 3.4177E-02                                                        | 1.7330E-02  | 4.9869E-02  | 1.6065E-02  | 1.5939E-04  |
| 258- | 2.1902E-04                                                        | 2.6421E-02  | 1.4780E-03  | 1.3265E-02  | 1.0118E-03  |
| 259- | 4.9465E-04                                                        | 5.9927E-04  | 1.4786E-02  | 7.8238E-03  | 1.1610E-02  |
| 260- | 1.7742E-02                                                        | 1.3117E-02  | 2.3405E-02  | 1.1717E-02  | 8.1729E-03  |
| 261- | 2.6723E-02                                                        | 7.4441E-03  | 5.7407E-03  | 2.2380E-02  | 1.5195E-02  |
| 262- | 1.0032E-02                                                        | 1.9793E-02  | 4.2505E-02  | 3.8536E-03  | 1.7791E-03  |
| 263- | 6.7549E-03                                                        | 1.9018E-03  | 2.8012E-03  | 1.2275E-02  | 2.8012E-03  |
| 264- | 9.7178E-04                                                        | 1.0291E-04  | 1.7744E-03  | 3.4768E-03  | 1.5151E-03  |
| 265- | 4.3000E-03                                                        | 5.1276E-03  | 1.2074E-02  | 1.8351E-03  | 6.7915E-03  |
| 266- | 8.7327E-03                                                        | 1.0296E-02  | 7.7935E-03  | 3.8375E-01  | 1.2152E-01  |
| 267- | 4.0273E-02                                                        | 7.9402E-03  | 6.5206E-03  | 2.3107E-03  | 1.2793E-03  |
| 268- | 3.9490E-04                                                        | 1.3827E-03  | 1.1491E-03  | 1.3867E-03  | 1.3467E-03  |
| 269- | 1.4074E-03                                                        | 5.0348E-04  | 2.4496E-03  | 5.0509E-03  | 2.5998E-03  |
| 270- | 4.2980E-03                                                        | 4.9403E-03  | 1.6865E-04  | 3.4768E-03  | 4.0966E-03  |
| 271- | 3.0563E-03                                                        | 2.5247E-03  | 3.4007E-03  | 2.1128E-04  | 1.3136E-02  |
| 272- | 3.9994E-03                                                        | 1.7030E+00  | 5.8084E+00  | 4.9798E-01  | 1.9183E+00  |
| 273- | 1.0000E+01                                                        | 1.0826E+00  | 3.6946E+00  | 5.0967E-01  | 3.2130E-01  |
| 274- | 9.7112E-02                                                        | 1.0000E+00  | 1.0000E+01  | 9.0891E-02  | 1.1782E-03  |
| 275- | 9.0442E-04                                                        | 6.3920E-04  | 1.0000E+01  | 1.0811E+01  | 1.0000E+00  |
| 276- | 7.4808E-01                                                        | 1.3395E+00  | 8.8688E-01  | 3.6126E-03  | 1.3345E-03  |
| 277- | 1.9702E-04                                                        | 4.3322E+00  | 1.0784E+00  | 2.0723E-03  | 5.6555E-01  |
| 278- | 2.5977E-01                                                        | 1.3386E-03  | 1.1988E-01  | 2.3554E-02  | 1.2882E-03  |
| 279- | 5.0000E+00                                                        | 2.2009E-01  | 8.6605E-04  | 1.3988E-01  | 3.0066E-01  |
| 280- | 3.8736E+00                                                        | 5.0000E+00  | 1.0000E+01  | 1.0000E+01  | 1.0000E+01  |
| 281- | 5.1133E+00                                                        | 2.2167E+00  | 3.2309E-03  | 3.4007E-03  | 8.6336E-03  |
| 282- | 3.3759E-03                                                        | 9.6020E-04  | -1.0000E+00 | -1.0000E+00 | -1.0000E+00 |
| 283- | -1.0000E+00                                                       | -1.0000E+00 | -1.0000E+00 |             |             |
| 284- | sdef pos=-356.87 232.02 157.4 dir=d1 erg=fdir=d2 rad=d3 vec=0 1 0 |             |             |             |             |
| 285- | sur=16                                                            |             |             |             |             |
| 286- | sil                                                               | a           | -1.0000     | -.99619     | -.98481     |
| 287- |                                                                   |             | -.90631     | -.86603     | -.81915     |
| 288- |                                                                   |             | -.64279     | -.57358     | -.50000     |
| 289- |                                                                   |             | -.25882     | -.17365     | -.08716     |
| 290- |                                                                   |             | .17365      | .25882      | .34202      |
| 291- |                                                                   |             | .57358      | .64279      | .70711      |
| 292- |                                                                   |             | .86603      | .90631      | .93969      |
| 293- |                                                                   |             | .99619      | 1.0000      |             |
| 294- | sp1                                                               |             | .874        | .874        | .875        |
| 295- |                                                                   |             | .879        | .882        | .884        |
| 296- |                                                                   |             | .895        | .899        | .904        |
| 297- |                                                                   |             | .919        | .924        | .930        |
| 298- |                                                                   |             | .946        | .952        | .957        |
| 299- |                                                                   |             | .972        | .976        | .981        |
| 300- |                                                                   |             | .991        | .994        | .996        |

Table A.2 (cont.)

```

301-          1.0 1.0
302-   ds2   q  -.99619 180 -.98481 175 -.96593 170 -.93962 165 -.90631 160
303-          -.86603 155 -.81915 150 -.76604 145 -.70711 140 -.64279 135
304-          -.57358 130 -.50000 125 -.42262 120 -.34202 115 -.25882 110
305-          -.17365 105 -.08716 100  0.0000  95  .08716  90  .17365  85
306-          .25882  80  .34202  75  .42262  70  .50000  65  .57358  60
307-          .64279  55  .70711  50  .76604  45  .81915  40  .86603  35
308-          .90631  30  .93969  25  .96593  20  .98481  15  .99619  10
309-          1.0000  5
310-   si3   h  0 .64
311-   sp3   d -21 1
312-   si5   h 15.106 15.110
313-   sp5   d  0 1
314-   si10  h 15.095 15.106
315-   sp10  d  0 1
316-   si15  h 15.075 15.095
317-   sp15  d  0 1
318-   si20  h 15.049 15.075
319-   sp20  d  0 1
320-   si25  h 15.015 15.049
321-   sp25  d  0 1
322-   si30  h 14.974 15.015
323-   sp30  d  0 1
324-   si35  h 14.927 14.974
325-   sp35  d  0 1
326-   si40  h 14.873 14.927
327-   sp40  d  0 1
328-   si45  h 14.814 14.873
329-   sp45  d  0 1
330-   si50  h 14.750 14.814
331-   sp50  d  0 1
332-   si55  h 14.681 14.750
333-   sp55  d  0 1
334-   si60  h 14.608 14.681
335-   sp60  d  0 1
336-   si65  h 14.532 14.608
337-   sp65  d  0 1
338-   si70  h 14.453 14.532
339-   sp70  d  0 1
340-   si75  h 14.372 14.453
341-   sp75  d  0 1
342-   si80  h 14.289 14.372
343-   sp80  d  0 1
344-   si85  h 14.206 14.289
345-   sp85  d  0 1
346-   si90  h 14.123 14.206
347-   sp90  d  0 1
348-   si95  h 14.040 14.123
349-   sp95  d  0 1
350-   si100 h 13.958 14.040

```

Table A.2 (cont.)

```

351-    sp100 d 0 1
352-    si105 h 13.878 13.958
353-    sp105 d 0 1
354-    si110 h 13.800 13.878
355-    sp110 d 0 1
356-    si115 h 13.725 13.800
357-    sp115 d 0 1
358-    si120 h 13.654 13.725
359-    sp120 d 0 1
360-    si125 h 13.586 13.654
361-    sp125 d 0 1
362-    si130 h 13.522 13.586
363-    sp130 d 0 1
364-    si135 h 13.464 13.522
365-    sp135 d 0 1
366-    si140 h 13.410 13.464
367-    sp140 d 0 1
368-    si145 h 13.362 13.410
369-    sp145 d 0 1
370-    si150 h 13.320 13.362
371-    sp150 d 0 1
372-    si155 h 13.284 13.320
373-    sp155 d 0 1
374-    si160 h 13.254 13.284
375-    sp160 d 0 1
376-    si165 h 13.230 13.254
377-    sp165 d 0 1
378-    si170 h 13.214 13.230
379-    sp170 d 0 1
380-    si175 h 13.203 13.214
381-    sp175 d 0 1
382-    si180 h 13.200 13.203
383-    sp180 d 0 1
384-    f5:n -356.87 386.52 157.4 1
385-    e5      .85 .95 1.05 1.15 1.25 1.35 1.45 1.55 1.65 1.75 1.85 1.95
386-          2.15 2.35 2.55 2.75 2.95 3.15 3.35 3.55 3.75 3.95 4.15 4.45
387-          4.75 5.05 5.35 5.65 5.95 6.25 6.55 6.85 7.25 7.75 8.25 8.75
388-          9.25 9.75 10.25 10.75 11.25 11.75 12.55 13.35 14.15 14.95
389-          15.75 16.55
390-    em5      1 10 10r 5 10r 3.33 8r 2.5 2 8r 1.25 5r
391-    fq5      e d
392-    c      ft5 geb .03 .08          $ mcnp4 patch format
393-    ft5 geb 0 .282842713 .375      $ mcnp4a format
394-    prdmp 2j 1
395-    c      f15:p -356.87 386.52 157.4 1
396-    c      e15      .72 .76 .80 .84 .88 .92 .96 1.0 1.04 1.08 1.15 1.2 1.25
397-    c      1.3 1.35 1.4 1.45 1.5 1.55 1.6 1.65 1.72 1.8 1.88 1.96
398-    c      2.04 2.12 2.2 2.28 2.36 2.45 2.55 2.65 2.75 2.85 2.95 3.05
399-    c      3.15 3.25 3.35 3.45 3.55 3.66 3.79 3.93 4.06 4.19 4.32
400-    c      4.45 4.58 4.71 4.84 4.97 5.1 5.23 5.4 5.57 5.74 5.91 6.08

```

Table A.2 (cont.)

```

401-      c      6.25 6.42 6.6 6.8 7.0 7.2 7.4 7.6 7.8 8.0 8.2 8.4 8.6 8.8 9.0
402-      c      9.2 9.4 9.6 9.8 10
403-      c      em15 1 25 8r 14.286 20 9r 14.286 12.5 7r 11.111 10 10r 9.0909 7.6923
404-      c      7.1429 7.6923 9r 5.8824 6r 5.5556 5 16r
405-      cut:n 1e33 .850 $ ignore neutrons below the detector response
406-      wwg 5 121 0 -356.87 386.52 157.4
407-      m1      1001.60c 7.86e-3
408-            8016.60c 4.39e-2
409-            11023.60c 1.05e-3
410-            12000.60c 1.40e-4
411-            13027.60c 2.39e-3
412-            14000.60c 1.58e-2
413-            19000.60c 6.90e-4
414-            20000.60c 2.92e-3
415-            26054.60c 1.798e-5
416-            26056.60c 2.843e-4
417-            26057.60c 6.82e-6
418-            26058.60c 8.68e-7
419-      m3      26054.60c 4.918e-3
420-            26056.60c 7.778e-2
421-            26057.60c 1.866e-3
422-            26058.60c 2.374e-4
423-      m4      24050.60c 7.699e-4
424-            24052.60c 1.483e-2
425-            24053.60c 1.681e-3
426-            24054.60c 4.177e-4
427-            25055.60c 1.77e-3
428-            26054.60c 3.492e-3
429-            26056.60c 5.522e-2
430-            26057.60c 1.324e-3
431-            26058.60c 1.686e-4
432-            28058.60c 5.346e-3
433-            28060.60c 2.044e-3
434-            28061.60c 8.848e-5
435-            28062.60c 2.811e-4
436-            28064.60c 7.125e-5
437-      m2      7014.60c 3.64e-5
438-            8016.60c 9.74e-6
439-      m5      1001.60c 5.926e-2
440-            6000.60c 3.338e-2
441-            8016.60c 1.125e-2
442-            3006.60c 5.565e-4
443-            3007.60c 6.944e-3
444-      m6      1001.60c 7.13e-2
445-            6000.60c 3.41e-2
446-            5010.60c 4.87e-4
447-            5011.60c 1.97e-3
448-            8016.60c 3.64e-3
449-      print
450-      nps 1000000

```

Table A.3 Input file for the ENDF/B-VI 76 cm diameter iron sphere with a  $^{252}\text{Cf}$  source.

```

1-   Fe Sphere with 76 cm dia  ENDF/B-VI
2-   1   2 -.001288 -3
3-   2   1 -7.85 -1 3 -4
4-   3   1 -7.85 1 2 3 -4
5-   4   2 -.001288 1 -2 3 -4
6-   5   1 -7.85 -1 4 -5
7-   6   1 -7.85 1 2 4 -5
8-   7   2 -.001288 1 -2 4 -5
9-   8   1 -7.85 -1 5 -6
10-  9   1 -7.85 1 2 5 -6
11- 10   2 -.001288 1 -2 5 -6
12- 11   2 -.001288 6 -7
13- 12   0 7
14-
15-   1   px .1
16-   2   cx 4.75
17-   3   so 7.5
18-   4   so 19
19-   5   so 28.5
20-   6   so 38
21-   7   so 1000
22-
23-   imp:n 2 2 2 2 3 3 3 6 6 6 6 0
24-   sdef pos=0 0 0 erg=d2
25-   sp2 -2 1.42
26-   fc5  NE213 detector response function, 200.0 cm flightpath, 90 degrees.
27-   fx5:n 0 200 0
28-   e5      0.75  1.0   1.25  1.50  1.75  2.00  2.25
29-          2.50  2.75  3.00  3.25  3.50  3.75  4.00  4.25
30-          4.50  4.75  5.00  5.25  5.50  5.75  6.00  6.25
31-          6.50  6.75  7.00  7.25  7.50  7.75  8.00  8.25
32-          8.50  8.75  9.00  9.25  9.50  9.75 10.00 10.25
33-          10.50 10.75 11.00 11.25 11.50 11.75 12.00 12.25
34-          12.50 12.75 13.00 13.25 13.50 13.75 14.00 14.25
35-          14.50 14.75 15.00 15.5  16   18   20
36-   c  NE213 low bias response function
37-   de0  lin 1.6 1.8 1.9 2.0 2.1 2.2 2.3 2.4 2.5 2.75
38-          3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.4 6.6 6.8 7.0
39-          7.5 8.1 8.5 9.0 10.0 11.0 12.0 12.5 13.0
40-          13.5 14.0 15.0 16.0
41-   df0  lin 0.00 1.46 1.86 2.26 2.58 3.00 3.29 3.42
42-          3.63 3.95 4.10 4.25 4.33 4.39 4.40 4.37 4.28
43-          4.15 4.20 4.18 4.12 3.97 3.80 3.77 3.65 3.44
44-          3.24 3.06 3.01 2.98 2.98 3.01 3.08 3.25
45-   fc15  NE213 detector, low bias, 200.0 cm flightpath, 90 degrees.
46-   f15x:n 0 200 0
47-   e15   2 5 10 13 20
48-   c
49-   c  ENDF/B-VI
50-   m1  26054.60c .0562600

```

Table A.3 (cont.)

|     |             |          |
|-----|-------------|----------|
| 51- | 26056.60c   | .8896840 |
| 52- | 26057.60c   | .0213400 |
| 53- | 26058.60c   | .0027160 |
| 54- | 6000.60c    | .012     |
| 55- | 25055.60c   | .010     |
| 56- | 15031.60c   | .007     |
| 57- | 16032.60c   | .001     |
| 58- | m2 7014.60c | -.7885   |
| 59- | 8016.60c    | -.2115   |
| 60- | cut:n j     | .5       |
| 61- | print       |          |
| 62- | pramp 2j    | 1        |
| 63- | nps         | 400000   |
| 64- | f2:n        | 6        |

Table A.4 Input file for the ENDF/B-VI 93 cm iron slab of the Oak Ridge National Laboratory Benchmark For Neutron Transport through Iron.

```

1-      ORNL Iron Benchmark 93 cm slab ENDF/B-VI
2-      1 0 -1 3 -4 5 -6
3-      2 0 2 3 -4 5 -6
4-      3 0 -3
5-      4 0 4
6-      5 0 -5
7-      6 0 6
8-      7 2 4.614e-5 1 -7 9 -10 19 -20
9-      8 2 4.614e-5 1 -8 9 -10 13 -19
10-     9 2 4.614e-5 1 -8 9 -10 20 -14
11-    10 2 4.614e-5 1 -8 11 -9 13 -14
12-    11 2 4.614e-5 1 -8 10 -12 13 -14
13-    12 2 4.614e-5 1 -2 3 -11 5 -6
14-    13 2 4.614e-5 1 -2 12 -4 5 -6
15-    14 2 4.614e-5 1 -2 11 -12 5 -13
16-    15 2 4.614e-5 1 -2 11 -12 14 -6
17-    16 1 -7.79 -8 -24
18-    17 1 -7.79 8 -15 11 -12 13 -14 16
19-    18 2 4.614e-5 8 -15 -16
20-    19 3 -1.0 15 -17 11 -12 13 -14 16
21-    20 3 -1.0 15 -17 18 -16
22-    21 2 4.614e-5 15 -17 -18
23-    22 4 0.11139 17 -21 11 -12 13 -14 16
24-    23 3 -1.0 17 -21 22 -16
25-    24 2 4.614e-5 17 -2 -22
26-    25 2 4.614e-5 21 -23 11 -12 13 -14 22
27-    26 3 -1.0 23 -2 22 -16
28-    27 2 4.614e-5 23 -2 11 -12 13 -14 16
29-    28 1 -7.79 -8 24 -25
30-    29 1 -7.79 -8 25 -26
31-    30 1 -7.79 -8 26 -27
32-    31 1 -7.79 -8 27 -28
33-    32 1 -7.79 -8 28 -29
34-    33 1 -7.79 -8 29 -30
35-    34 1 -7.79 -8 30 -31
36-    35 1 -7.79 -8 31 -32 9 -10 19 -20
37-    36 1 -7.79 -8 32 -33 9 -10 19 -20
38-    37 1 -7.79 -8 33 -34 9 -10 19 -20
39-    38 1 -7.79 -8 34 -35 9 -10 19 -20
40-    39 1 -7.79 -8 35 -36 9 -10 19 -20
41-    40 1 -7.79 -8 36 -37 9 -10 19 -20
42-    41 1 -7.79 -8 37 -38 9 -10 19 -20
43-    42 1 -7.79 -8 38 -39 9 -10 19 -20
44-    43 1 -7.79 -8 39 -40 9 -10 19 -20
45-    44 1 -7.79 -8 40 -41 9 -10 19 -20
46-    45 1 -7.79 -8 41 -42 9 -10 19 -20
47-    46 1 -7.79 -8 42 -43 9 -10 19 -20
48-    47 1 -7.79 -8 43 -44 9 -10 19 -20
49-    48 1 -7.79 -8 44 -45 9 -10 19 -20
50-    49 1 -7.79 -8 45 -46 9 -10 19 -20

```

Table A.4 (cont.)

|      |    |    |           |      |         |          |     |     |     |     |     |
|------|----|----|-----------|------|---------|----------|-----|-----|-----|-----|-----|
| 51-  | 50 | 1  | -7.79     | 7    | -8      | 46       | -47 | 9   | -10 | 19  | -20 |
| 52-  | 51 | 1  | -7.79     | 7    | -8      | 47       | 9   | -10 | 19  | -20 |     |
| 53-  |    |    |           |      |         |          |     |     |     |     |     |
| 54-  | 1  | px | -750      |      |         |          |     |     |     |     |     |
| 55-  | 2  | px | 200       |      |         |          |     |     |     |     |     |
| 56-  | 3  | py | -500      |      |         |          |     |     |     |     |     |
| 57-  | 4  | py | 500       |      |         |          |     |     |     |     |     |
| 58-  | 5  | pz | -500      |      |         |          |     |     |     |     |     |
| 59-  | 6  | pz | 500       |      |         |          |     |     |     |     |     |
| 60-  | 7  | px | -265.58   |      |         |          |     |     |     |     |     |
| 61-  | 8  | px | -172.72   |      |         |          |     |     |     |     |     |
| 62-  | 9  | py | -76.2     |      |         |          |     |     |     |     |     |
| 63-  | 10 | py | 76.2      |      |         |          |     |     |     |     |     |
| 64-  | 11 | py | -200      |      |         |          |     |     |     |     |     |
| 65-  | 12 | py | 200       |      |         |          |     |     |     |     |     |
| 66-  | 13 | pz | -200      |      |         |          |     |     |     |     |     |
| 67-  | 14 | pz | 200       |      |         |          |     |     |     |     |     |
| 68-  | 15 | px | -161.93   |      |         |          |     |     |     |     |     |
| 69-  | 16 | cx | 18.9      |      |         |          |     |     |     |     |     |
| 70-  | 17 | px | -107.95   |      |         |          |     |     |     |     |     |
| 71-  | 18 | x  | -161.93   | 18.9 | -107.95 | 5.3975   |     |     |     |     |     |
| 72-  | 19 | pz | -76.2     |      |         |          |     |     |     |     |     |
| 73-  | 20 | pz | 76.2      |      |         |          |     |     |     |     |     |
| 74-  | 21 | px | -51.435   |      |         |          |     |     |     |     |     |
| 75-  | 22 | cx | 5.3975    |      |         |          |     |     |     |     |     |
| 76-  | 23 | px | -35.56    |      |         |          |     |     |     |     |     |
| 77-  | 24 | sx | -170.22   |      |         | 6.5      |     |     |     |     |     |
| 78-  | 25 | sx | -166.1575 |      |         | 14.5625  |     |     |     |     |     |
| 79-  | 26 | sx | -160.345  |      |         | 24.375   |     |     |     |     |     |
| 80-  | 27 | sx | -152.595  |      |         | 36.125   |     |     |     |     |     |
| 81-  | 28 | sx | -142.72   |      |         | 50       |     |     |     |     |     |
| 82-  | 29 | sx | -130.5325 |      |         | 66.1875  |     |     |     |     |     |
| 83-  | 30 | sx | -115.845  |      |         | 84.875   |     |     |     |     |     |
| 84-  | 31 | sx | -98.47    |      |         | 106.25   |     |     |     |     |     |
| 85-  | 32 | sx | -78.22    |      |         | 130.5    |     |     |     |     |     |
| 86-  | 33 | sx | -54.9075  |      |         | 157.8125 |     |     |     |     |     |
| 87-  | 34 | sx | -28.345   |      |         | 188.375  |     |     |     |     |     |
| 88-  | 35 | sx | 1.655     |      |         | 222.375  |     |     |     |     |     |
| 89-  | 36 | sx | 35.28     |      |         | 260      |     |     |     |     |     |
| 90-  | 37 | sx | 72.7175   |      |         | 301.4375 |     |     |     |     |     |
| 91-  | 38 | sx | 114.155   |      |         | 346.875  |     |     |     |     |     |
| 92-  | 39 | sx | 159.78    |      |         | 396.5    |     |     |     |     |     |
| 93-  | 40 | sx | 209.78    |      |         | 450.5    |     |     |     |     |     |
| 94-  | 41 | sx | 264.3425  |      |         | 509.0625 |     |     |     |     |     |
| 95-  | 42 | sx | 323.655   |      |         | 572.375  |     |     |     |     |     |
| 96-  | 43 | sx | 387.905   |      |         | 640.625  |     |     |     |     |     |
| 97-  | 44 | sx | 457.28    |      |         | 714      |     |     |     |     |     |
| 98-  | 45 | sx | 531.9675  |      |         | 792.6875 |     |     |     |     |     |
| 99-  | 46 | sx | 612.155   |      |         | 876.875  |     |     |     |     |     |
| 100- | 47 | sx | 698.03    |      |         | 966.75   |     |     |     |     |     |

Table A.4 (cont.)

```

101-
102- mode n
103- wwp:n 5 3 5
104- wwe:n 1.0000E+02
105- wwni:n -1.0000E+00 -1.0000E+00 -1.0000E+00 -1.0000E+00 -1.0000E+00
106- -1.0000E+00 0 0 0 0
107- 0 0 0 0 0
108- 2.5178E+06 2.6000E+06 0 1.7736E+07 3.5959E+07
109- 0 1.2338E+07 2.7810E+07 0 0
110- 0.0000E+00 0 2.2719E+06 1.4306E+06 1.2553E+06
111- 1.0407E+06 8.9104E+05 7.8092E+05 6.9713E+05 6.0664E+05
112- 5.6081E+05 5.2478E+05 4.7667E+05 4.3861E+05 4.1295E+05
113- 3.8066E+05 3.5304E+05 3.2650E+05 2.9641E+05 2.6759E+05
114- 2.2474E+05 2.1117E+05 1.7605E+05 1.2906E+05 1.5248E+05
115- 1.6280E+05
116- sdef dir=d1 vec=-1 0 0 erg=d2 wgt=6.821e6 pos=0 0 0 cel=24
117- c Calculation for the source weight.
118- c The tabulated value for total intensity for the source from
119- c ORNL-4892, Table III. is 3.186e4 neutrons/cm^2/min/W/Group.
120- c The values in Table III. are taken from
121- c a circular surface area with diameter of 6.5 inches, giving an
122- c area of 2.141e2 cm^2. Normalizing to 1 Watt and multiplying by
123- c this area gives 6.821e6 neutrons/min/Group.
124- si1 0.99886 1
125- sp1 0 1
126- si2 0 1.45e-7 5.24e-7 1.89e-6 6.79e-6 2.44e-5 8.8e-5
127- 3.167e-4 1.14e-3 1.16e-3 3.7e-3 4.3e-3 5.8e-3 6.7e-3
128- 8.2e-3 8.8e-3 1.0e-2 1.5e-2 1.9e-2 2.2e-2 2.325e-2
129- 2.375e-2 2.45e-2 2.52e-2 2.57e-2 2.7e-2 3.1e-2 3.8e-2
130- 6.2e-2 6.8e-2 7.2e-2 7.7e-2 8.0e-2 8.14e-2 8.24e-2
131- 8.27e-2 8.3e-2 8.7e-2 1.1e-1 1.275e-1 1.292e-1 1.3e-1
132- 1.34e-1 1.362e-1 1.383e-1 1.395e-1 1.44e-1 1.55e-1 1.64e-1
133- 1.675e-1 1.685e-1 1.75e-1 1.82e-1 1.852e-1 2.e-1 2.08e-1
134- 2.186e-1 2.198e-1 2.32e-1 2.432e-1 2.44e-1 2.448e-1 2.62e-1
135- 2.67e-1 2.71e-1 2.75e-1 3.00e-1 3.095e-1 3.14e-1 3.307e-1
136- 3.314e-1 3.482e-1 3.505e-1 3.545e-1 3.573e-1 3.578e-1 3.588e-1
137- 3.593e-1 3.735e-1 3.75e-1 3.772e-1 3.78e-1 4.33e-1 4.365e-1
138- 4.377e-1 4.64e-1 4.675e-1 4.691e-1 4.93e-1 4.98e-1 5.03e-1
139- 5.105e-1 5.15e-1 5.34e-1 5.36e-1 5.40e-1 5.43e-1 5.465e-1
140- 5.525e-1 5.575e-1 5.59e-1 5.605e-1 5.695e-1 5.76e-1 5.80e-1
141- 5.905e-1 6.075e-1 6.125e-1 6.165e-1 6.20e-1 6.38e-1 6.44e-1
142- 6.48e-1 6.525e-1 6.59e-1 6.63e-1 6.91e-1 6.93e-1 6.97e-1
143- 7.00e-1 7.10e-1 7.32e-1 7.39e-1 7.41e-1 7.51e-1 7.525e-1
144- 7.67e-1 7.69e-1 8.20e-1 8.25e-1 8.30e-1 8.34e-1 8.36e-1
145- 8.39e-1 8.465e-1 8.525e-1 8.555e-1 8.78e-1 8.82e-1 8.91e-1
146- 8.985e-1 9.17e-1 9.19e-1 9.27e-1 9.32e-1 9.36e-1 9.395e-1
147- 9.415e-1 9.44e-1 9.46e-1 9.51e-1 9.57e-1 9.60e-1 9.74e-1
148- 9.82e-1 9.92e-1 9.98e-1 1.013 1.020 1.023 1.029
149- 1.084 1.090 1.098 1.107 1.1135 1.1165 1.1195
150- 1.130 1.136 1.155 1.169 1.192 1.197 1.205

```

Table A.4 (cont.)

|      |                                                                  |          |          |          |          |          |          |
|------|------------------------------------------------------------------|----------|----------|----------|----------|----------|----------|
| 151- | 1.211                                                            | 1.217    | 1.221    | 1.244    | 1.251    | 1.285    | 1.291    |
| 152- | 1.306                                                            | 1.313    | 1.339    | 1.363    | 1.382    | 1.392    | 1.401    |
| 153- | 1.405                                                            | 1.411    | 1.442    | 1.472    | 1.497    | 1.506    | 1.522    |
| 154- | 1.567                                                            | 1.587    | 1.638    | 1.6465   | 1.680    | 1.686    | 1.722    |
| 155- | 1.747                                                            | 1.783    | 1.81     | 1.82     | 1.889    | 1.90     | 1.943    |
| 156- | 2.232                                                            | 2.262    | 2.35     | 2.38     | 2.59     | 3.00     | 4.00     |
| 157- | 5.00                                                             | 6.00     | 8.00     | 1.00e1   |          |          |          |
| 158- | c No-norm probability distribution (multiplied by bin width)     |          |          |          |          |          |          |
| 159- | c sp2 0                                                          | 9.541e-4 | 5.844e-4 | 7.868e-4 | 2.72e-3  | 9.756e-3 | 3.302e-2 |
| 160- | c                                                                | 1.292e-1 | 5.072e-1 | 1.796e-4 | 1.626    | 5.196e-2 | 2.61e-1  |
| 161- | c                                                                | 1.89e-1  | 2.658e-2 | 9.756e-2 | 1.32     | 6.32e-1  | 3.0e-1   |
| 162- | c                                                                | 7.4e-3   | 1.613e-2 | 1.393e-2 | 6.85e-3  | 4.459e-2 | 3.896e-1 |
| 163- | c                                                                | 8.496    | 4.344e-1 | 1.764e-1 | 2.55e-1  | 8.76e-2  | 1.862e-2 |
| 164- | c                                                                | 8.55e-4  | 8.55e-4  | 1.484e-1 | 4.439    | 2.223    | 1.921e-2 |
| 165- | c                                                                | 1.044e-1 | 3.08e-2  | 2.793e-2 | 8.94e-3  | 1.233e-1 | 7.029e-1 |
| 166- | c                                                                | 6.615e-2 | 5.38e-3  | 2.243e-1 | 2.548e-1 | 5.376e-2 | 1.157    |
| 167- | c                                                                | 5.936e-1 | 7.608e-3 | 7.991e-1 | 6.922e-1 | 3.528e-3 | 3.528e-3 |
| 168- | c                                                                | 1.375e-1 | 8.76e-2  | 8.76e-2  | 3.375    | 4.769e-1 | 1.067e-1 |
| 169- | c                                                                | 2.562e-3 | 1.435    | 2.645e-2 | 8.04e-2  | 3.864e-2 | 7.17e-4  |
| 170- | c                                                                | 1.21e-3  | 9.699e-1 | 1.047e-2 | 2.244e-2 | 2.984e-3 | 1.26e1   |
| 171- | c                                                                | 5.424e-3 | 2.609    | 4.62e-2  | 9.584e-3 | 2.165    | 9.5e-2   |
| 172- | c                                                                | 2.22e-1  | 8.1e-2   | 1.465    | 1.624e-2 | 6.56e-2  | 3.81e-2  |
| 173- | c                                                                | 1.488e-1 | 1.055e-1 | 9.51e-3  | 9.51e-3  | 3.42e-1  | 1.788e-1 |
| 174- | c                                                                | 4.82e-1  | 1.284    | 1.11e-1  | 7.2e-2   | 5.53e-2  | 1.492    |
| 175- | c                                                                | 7.4e-2   | 9.495e-2 | 1.989e-1 | 7.6e-2   | 3.752    | 1.898e-2 |
| 176- | c                                                                | 4.44e-2  | 4.86e-1  | 2.354    | 2.366e-1 | 1.898e-2 | 4.75e-1  |
| 177- | c                                                                | 9.802e-1 | 1.796e-2 | 1.102e1  | 1.03e-1  | 1.005e-1 | 6.32e-2  |
| 178- | c                                                                | 3.63e-2  | 2.22e-1  | 1.392e-1 | 3.48e-2  | 1.924    | 5.92e-2  |
| 179- | c                                                                | 2.063e-1 | 1.212    | 1.478e-2 | 2.24e-1  | 8.7e-2   | 5.48e-2  |
| 180- | c                                                                | 1.37e-2  | 2.11e-2  | 1.37e-2  | 8.45e-2  | 1.206e-1 | 3.0e-2   |
| 181- | c                                                                | 2.112e-1 | 3.28e-1  | 1.17e-1  | 7.44e-1  | 1.666e-1 | 3.0e-2   |
| 182- | c                                                                | 9.735    | 1.206e-1 | 2.08e-1  | 2.664e-1 | 1.547e-1 | 3.0e-2   |
| 183- | c                                                                | 3.602e-1 | 1.206e-1 | 1.235    | 6.804e-1 | 1.822    | 8.85e-2  |
| 184- | c                                                                | 1.272e-1 | 1.278e-1 | 5.68e-2  | 1.944    | 1.813e-1 | 4.25     |
| 185- | c                                                                | 8.52e-1  | 1.813e-1 | 2.553    | 2.244    | 1.416    | 4.01e-1  |
| 186- | c                                                                | 6.64e-2  | 1.428e-1 | 3.844    | 3.75     | 2.6      | 3.42e-1  |
| 187- | c                                                                | 8.55     | 1.7      | 1.117e1  | 3.324e-1 | 4.791    | 1.554e-1 |
| 188- | c                                                                | 2.725    | 5.508    | 3.186    | 4.38e-1  | 2.077e1  | 5.225e-1 |
| 189- | c                                                                | 3.662e2  | 3.9      | 3.379e1  | 3.9      | 1.863e2  | 6.064e2  |
| 190- | c                                                                | 1.426e3  | 8.4e2    | 1.33e3   | 3.8e2    |          |          |
| 191- | c Source energy probabilities directly from Table III, ORNL-4892 |          |          |          |          |          |          |
| 192- | sp2 0                                                            | 6580     | 1542     | 576      | 555      | 554      | 554      |
| 193- |                                                                  | 8.98     | 640      | 86.6     | 174      | 87.6     | 126      |
| 194- |                                                                  | 158      | 100      | 38.3     | 14.8     | 21.5     | 19.9     |
| 195- |                                                                  | 143      | 354      | 72.4     | 44.1     | 51.0     | 29.2     |
| 196- |                                                                  | 2.85     | 37.1     | 193      | 127      | 11.3     | 5.29     |
| 197- |                                                                  | 7.45     | 27.4     | 63.9     | 49.6     | 18.9     | 5.38     |
| 198- |                                                                  | 78.2     | 42.2     | 56.0     | 6.34     | 65.5     | 61.8     |
| 199- |                                                                  | 27.5     | 21.9     | 21.9     | 135      | 50.2     | 23.7     |
| 200- |                                                                  | 11.5     | 20.1     | 13.8     | 2.39     | 4.81     | 2.42     |

Table A.4 (cont.)

|      |                                                                 |      |      |      |      |      |      |      |      |
|------|-----------------------------------------------------------------|------|------|------|------|------|------|------|------|
| 201- | 3.73                                                            | 229  | 13.5 | 4.52 | 99.2 | 13.2 | 5.99 | 90.6 | 19.0 |
| 202- | 19.5                                                            | 29.6 | 18.0 | 77.1 | 8.12 | 16.4 | 12.7 | 14.2 | 24.8 |
| 203- | 21.1                                                            | 6.34 | 6.34 | 38.0 | 27.5 | 16.9 | 45.9 | 75.5 | 22.2 |
| 204- | 18.0                                                            | 15.8 | 82.9 | 28.0 | 18.5 | 21.1 | 30.6 | 19.0 | 134  |
| 205- | 9.49                                                            | 19.5 | 14.8 | 48.6 | 107  | 33.8 | 9.49 | 47.5 | 6.85 |
| 206- | 67.6                                                            | 8.98 | 216  | 20.6 | 20.1 | 15.8 | 7.93 | 12.1 | 29.6 |
| 207- | 23.2                                                            | 11.6 | 85.5 | 14.8 | 33.3 | 27.5 | 65.5 | 7.39 | 28.0 |
| 208- | 17.4                                                            | 13.7 | 12.1 | 6.85 | 8.44 | 6.85 | 16.9 | 20.1 | 10.0 |
| 209- | 46.5                                                            | 26.4 | 32.8 | 19.5 | 49.6 | 23.8 | 10.0 | 20.1 | 177  |
| 210- | 20.1                                                            | 26.0 | 29.6 | 23.8 | 10.0 | 10.0 | 34.3 | 20.1 | 65.0 |
| 211- | 48.6                                                            | 79.2 | 17.7 | 28.4 | 21.2 | 21.3 | 14.2 | 84.5 | 25.9 |
| 212- | 125                                                             | 22.5 | 56.8 | 25.9 | 98.2 | 93.5 | 74.5 | 40.1 | 35.4 |
| 213- | 16.6                                                            | 23.8 | 124  | 125  | 104  | 38.0 | 67.6 | 190  | 85.0 |
| 214- | 219                                                             | 39.1 | 143  | 25.9 | 153  | 109  | 153  | 118  | 43.8 |
| 215- | 301                                                             | 47.5 | 190  | 1267 | 130  | 384  | 130  | 887  | 1479 |
| 216- | 2186                                                            | 1426 | 840  | 665  | 190  |      |      |      |      |
| 217- | f5:n -548.68 0 0 0                                              |      |      |      |      |      |      |      |      |
| 218- | f15:n -548.68 0 0 0                                             |      |      |      |      |      |      |      |      |
| 219- | f25:n -548.68 0 0 0                                             |      |      |      |      |      |      |      |      |
| 220- | f35:n -538.52 76.2 0 0                                          |      |      |      |      |      |      |      |      |
| 221- | f45:n -538.52 76.2 0 0                                          |      |      |      |      |      |      |      |      |
| 222- | f55:n -538.52 76.2 0 0                                          |      |      |      |      |      |      |      |      |
| 223- | f65:n -463.59 207.01 0 0                                        |      |      |      |      |      |      |      |      |
| 224- | f75:n -463.59 207.01 0 0                                        |      |      |      |      |      |      |      |      |
| 225- | f85:n -463.59 207.01 0 0                                        |      |      |      |      |      |      |      |      |
| 226- | pd0 1 17r 0.1 0.1 1 1 0.1 1 27r                                 |      |      |      |      |      |      |      |      |
| 227- | e0 0.5 2 5 10 13 20                                             |      |      |      |      |      |      |      |      |
| 228- | de0 lin 3.839e-7 4.73e-7 6.07e-7 7.79e-7 1.e-6 1.285e-6 1.65e-6 |      |      |      |      |      |      |      |      |
| 229- | 2.12e-6 2.72e-6 3.49e-6 4.49e-6 5.76e-6 7.40e-6 9.50e-6         |      |      |      |      |      |      |      |      |
| 230- | 1.219e-5 1.566e-5 2.01e-5 2.58e-5 3.31e-5 4.26e-5 5.46e-5       |      |      |      |      |      |      |      |      |
| 231- | 7.02e-5 9.01e-5 1.157e-4 1.485e-4 1.907e-4 2.45e-4 3.14e-4      |      |      |      |      |      |      |      |      |
| 232- | 4.04e-4 5.18e-4 6.66e-4 8.55e-4 1.098e-3 1.409e-3 1.810e-3      |      |      |      |      |      |      |      |      |
| 233- | 2.32e-3 2.98e-3 3.83e-3 4.92e-3 6.32e-3 8.11e-3 1.041e-2        |      |      |      |      |      |      |      |      |
| 234- | 1.337e-2 1.717e-2 2.20e-2 2.83e-2 3.63e-2 4.67e-2 5.99e-2       |      |      |      |      |      |      |      |      |
| 235- | 7.69e-2 9.88e-2 1.169e-1 1.292e-1 1.428e-1 1.578e-1 1.744e-1    |      |      |      |      |      |      |      |      |
| 236- | 1.928e-1 2.13e-1 2.35e-1 2.60e-1 2.88e-1 3.18e-1 3.51e-1        |      |      |      |      |      |      |      |      |
| 237- | 3.88e-1 4.29e-1 4.74e-1 5.24e-1 5.79e-1 6.40e-1 7.07e-1         |      |      |      |      |      |      |      |      |
| 238- | 7.82e-1 8.64e-1 9.54e-1 1.055 1.166 1.289 1.425                 |      |      |      |      |      |      |      |      |
| 239- | 1.574 1.740 1.923 2.13 2.35 2.60 2.87                           |      |      |      |      |      |      |      |      |
| 240- | 3.17 3.50 3.87 4.28 4.73 5.23 5.78                              |      |      |      |      |      |      |      |      |
| 241- | 6.38 7.06 7.80 8.62 9.52 1.053e1 1.163e1                        |      |      |      |      |      |      |      |      |
| 242- | 1.286e1 1.421e1                                                 |      |      |      |      |      |      |      |      |
| 243- | df5 lin 0 6.01e-1 1.004 1.244 1.391 1.464 1.491                 |      |      |      |      |      |      |      |      |
| 244- | 1.492 1.479 1.452 1.423 1.390 1.355 1.316                       |      |      |      |      |      |      |      |      |
| 245- | 1.277 1.237 1.193 1.092 1.109 1.072 1.031                       |      |      |      |      |      |      |      |      |
| 246- | 9.65e-1 8.47e-1 8.35e-1 8.69e-1 8.41e-1 8.02e-1 7.72e-1         |      |      |      |      |      |      |      |      |
| 247- | 7.43e-1 7.01e-1 6.82e-1 6.54e-1 6.26e-1 6.00e-1 5.73e-1         |      |      |      |      |      |      |      |      |
| 248- | 5.48e-1 5.25e-1 5.02e-1 4.81e-1 4.61e-1 4.41e-1 4.22e-1         |      |      |      |      |      |      |      |      |
| 249- | 4.02e-1 3.84e-1 3.66e-1 3.48e-1 3.30e-1 3.12e-1 2.94e-1         |      |      |      |      |      |      |      |      |
| 250- | 2.76e-1 2.57e-1 2.44e-1 2.36e-1 2.28e-1 2.20e-1 2.11e-1         |      |      |      |      |      |      |      |      |

Table A.4 (cont.)

|      |            |          |          |          |          |          |          |          |
|------|------------|----------|----------|----------|----------|----------|----------|----------|
| 251- |            | 2.03e-1  | 1.947e-1 | 1.863e-1 | 1.778e-1 | 1.694e-1 | 1.609e-1 | 1.525e-1 |
| 252- |            | 1.443e-1 | 1.359e-1 | 1.278e-1 | 1.198e-1 | 1.120e-1 | 1.044e-1 | 9.71e-2  |
| 253- |            | 9.01e-2  | 8.34e-2  | 7.69e-2  | 7.08e-2  | 6.50e-2  | 5.95e-2  | 5.44e-2  |
| 254- |            | 4.96e-2  | 4.51e-2  | 4.09e-2  | 3.71e-2  | 3.35e-2  | 3.01e-2  | 2.71e-2  |
| 255- |            | 2.43e-2  | 2.18e-2  | 1.951e-2 | 1.732e-2 | 1.534e-2 | 1.476e-2 | 1.340e-2 |
| 256- |            | 1.193e-2 | 9.83e-3  | 9.03e-3  | 7.95e-3  | 7.12e-3  | 6.35e-3  | 5.57e-3  |
| 257- |            | 4.98e-3  | 4.40e-3  |          |          |          |          |          |
| 258- | df15 lin 0 | 1.892e-1 | 3.38e-1  | 4.45e-1  | 5.28e-1  | 5.89e-1  | 6.36e-1  |          |
| 259- |            | 6.75e-1  | 7.09e-1  | 7.39e-1  | 7.67e-1  | 7.92e-1  | 8.17e-1  | 8.39e-1  |
| 260- |            | 8.61e-1  | 8.81e-1  | 8.98e-1  | 8.69e-1  | 9.31e-1  | 9.49e-1  | 9.63e-1  |
| 261- |            | 9.51e-1  | 8.81e-1  | 9.12e-1  | 9.99e-1  | 1.018    | 1.020    | 1.034    |
| 262- |            | 1.045    | 1.036    | 1.060    | 1.068    | 1.073    | 1.079    | 1.082    |
| 263- |            | 1.086    | 1.089    | 1.092    | 1.096    | 1.102    | 1.107    | 1.111    |
| 264- |            | 1.115    | 1.123    | 1.131    | 1.140    | 1.151    | 1.164    | 1.180    |
| 265- |            | 1.199    | 1.219    | 1.233    | 1.243    | 1.252    | 1.260    | 1.269    |
| 266- |            | 1.277    | 1.285    | 1.292    | 1.298    | 1.304    | 1.307    | 1.307    |
| 267- |            | 1.311    | 1.308    | 1.304    | 1.299    | 1.289    | 1.278    | 1.264    |
| 268- |            | 1.246    | 1.227    | 1.203    | 1.176    | 1.146    | 1.114    | 1.078    |
| 269- |            | 1.040    | 9.99e-1  | 9.56e-1  | 9.06e-1  | 8.65e-1  | 8.14e-1  | 7.55e-1  |
| 270- |            | 7.17e-1  | 6.57e-1  | 6.20e-1  | 5.84e-1  | 5.39e-1  | 5.09e-1  | 4.81e-1  |
| 271- |            | 4.52e-1  | 3.96e-1  | 3.69e-1  | 3.28e-1  | 2.94e-1  | 2.62e-1  | 2.28e-1  |
| 272- |            | 2.02e-1  | 1.795e-1 |          |          |          |          |          |
| 273- | df25 lin 0 | 2.43e-2  | 4.36e-2  | 5.76e-2  | 6.85e-2  | 7.66e-2  | 8.28e-2  |          |
| 274- |            | 8.81e-2  | 9.29e-2  | 9.72e-2  | 1.013e-1 | 1.052e-1 | 1.091e-1 | 1.127e-1 |
| 275- |            | 1.165e-1 | 1.201e-1 | 1.233e-1 | 1.201e-1 | 1.299e-1 | 1.338e-1 | 1.371e-1 |
| 276- |            | 1.367e-1 | 1.278e-1 | 1.339e-1 | 1.486e-1 | 1.534e-1 | 1.557e-1 | 1.598e-1 |
| 277- |            | 1.639e-1 | 1.647e-1 | 1.711e-1 | 1.751e-1 | 1.786e-1 | 1.826e-1 | 1.862e-1 |
| 278- |            | 1.900e-1 | 1.937e-1 | 1.978e-1 | 2.02e-1  | 2.07e-1  | 2.12e-1  | 2.18e-1  |
| 279- |            | 2.23e-1  | 2.30e-1  | 2.38e-1  | 2.47e-1  | 2.57e-1  | 2.69e-1  | 2.84e-1  |
| 280- |            | 3.03e-1  | 3.26e-1  | 3.44e-1  | 3.57e-1  | 3.71e-1  | 3.86e-1  | 4.02e-1  |
| 281- |            | 4.20e-1  | 4.39e-1  | 4.61e-1  | 4.84e-1  | 5.10e-1  | 5.35e-1  | 5.63e-1  |
| 282- |            | 5.97e-1  | 6.29e-1  | 6.65e-1  | 7.03e-1  | 7.42e-1  | 7.82e-1  | 8.25e-1  |
| 283- |            | 8.68e-1  | 9.12e-1  | 9.56e-1  | 9.98e-1  | 1.040    | 1.080    | 1.117    |
| 284- |            | 1.150    | 1.179    | 1.201    | 1.198    | 1.224    | 1.215    | 1.161    |
| 285- |            | 1.185    | 1.105    | 1.111    | 1.139    | 1.120    | 1.095    | 1.064    |
| 286- |            | 1.027    | 9.81e-1  | 9.13e-1  | 8.74e-1  | 8.05e-1  | 7.40e-1  | 6.61e-1  |
| 287- |            | 6.05e-1  | 5.52e-1  |          |          |          |          |          |
| 288- | df35 lin 0 | 6.01e-1  | 1.004    | 1.244    | 1.391    | 1.464    | 1.491    |          |
| 289- |            | 1.492    | 1.479    | 1.452    | 1.423    | 1.390    | 1.355    | 1.316    |
| 290- |            | 1.277    | 1.237    | 1.193    | 1.092    | 1.109    | 1.072    | 1.031    |
| 291- |            | 9.65e-1  | 8.47e-1  | 8.35e-1  | 8.69e-1  | 8.41e-1  | 8.02e-1  | 7.72e-1  |
| 292- |            | 7.43e-1  | 7.01e-1  | 6.82e-1  | 6.54e-1  | 6.26e-1  | 6.00e-1  | 5.73e-1  |
| 293- |            | 5.48e-1  | 5.25e-1  | 5.02e-1  | 4.81e-1  | 4.61e-1  | 4.41e-1  | 4.22e-1  |
| 294- |            | 4.02e-1  | 3.84e-1  | 3.66e-1  | 3.48e-1  | 3.30e-1  | 3.12e-1  | 2.94e-1  |
| 295- |            | 2.76e-1  | 2.57e-1  | 2.44e-1  | 2.36e-1  | 2.28e-1  | 2.20e-1  | 2.11e-1  |
| 296- |            | 2.03e-1  | 1.947e-1 | 1.863e-1 | 1.778e-1 | 1.694e-1 | 1.609e-1 | 1.525e-1 |
| 297- |            | 1.443e-1 | 1.359e-1 | 1.278e-1 | 1.198e-1 | 1.120e-1 | 1.044e-1 | 9.71e-2  |
| 298- |            | 9.01e-2  | 8.34e-2  | 7.69e-2  | 7.08e-2  | 6.50e-2  | 5.95e-2  | 5.44e-2  |
| 299- |            | 4.96e-2  | 4.51e-2  | 4.09e-2  | 3.71e-2  | 3.35e-2  | 3.01e-2  | 2.71e-2  |
| 300- |            | 2.43e-2  | 2.18e-2  | 1.951e-2 | 1.732e-2 | 1.534e-2 | 1.476e-2 | 1.340e-2 |

Table A.4 (cont.)

|      |            |          |          |          |          |          |          |          |
|------|------------|----------|----------|----------|----------|----------|----------|----------|
| 301- |            | 1.193e-2 | 9.83e-3  | 9.03e-3  | 7.95e-3  | 7.12e-3  | 6.35e-3  | 5.57e-3  |
| 302- |            | 4.98e-3  | 4.40e-3  |          |          |          |          |          |
| 303- | df45 lin 0 | 1.892e-1 | 3.38e-1  | 4.45e-1  | 5.28e-1  | 5.89e-1  | 6.36e-1  |          |
| 304- |            | 6.75e-1  | 7.09e-1  | 7.39e-1  | 7.67e-1  | 7.92e-1  | 8.17e-1  | 8.39e-1  |
| 305- |            | 8.61e-1  | 8.81e-1  | 8.98e-1  | 8.69e-1  | 9.31e-1  | 9.49e-1  | 9.63e-1  |
| 306- |            | 9.51e-1  | 8.81e-1  | 9.12e-1  | 9.99e-1  | 1.018    | 1.020    | 1.034    |
| 307- |            | 1.045    | 1.036    | 1.060    | 1.068    | 1.073    | 1.079    | 1.082    |
| 308- |            | 1.086    | 1.089    | 1.092    | 1.096    | 1.102    | 1.107    | 1.111    |
| 309- |            | 1.115    | 1.123    | 1.131    | 1.140    | 1.151    | 1.164    | 1.180    |
| 310- |            | 1.199    | 1.219    | 1.233    | 1.243    | 1.252    | 1.260    | 1.269    |
| 311- |            | 1.277    | 1.285    | 1.292    | 1.298    | 1.304    | 1.307    | 1.307    |
| 312- |            | 1.311    | 1.308    | 1.304    | 1.299    | 1.289    | 1.278    | 1.264    |
| 313- |            | 1.246    | 1.227    | 1.203    | 1.176    | 1.146    | 1.114    | 1.078    |
| 314- |            | 1.040    | 9.99e-1  | 9.56e-1  | 9.06e-1  | 8.65e-1  | 8.14e-1  | 7.55e-1  |
| 315- |            | 7.17e-1  | 6.57e-1  | 6.20e-1  | 5.84e-1  | 5.39e-1  | 5.09e-1  | 4.81e-1  |
| 316- |            | 4.52e-1  | 3.96e-1  | 3.69e-1  | 3.28e-1  | 2.94e-1  | 2.62e-1  | 2.28e-1  |
| 317- |            | 2.02e-1  | 1.795e-1 |          |          |          |          |          |
| 318- | df55 lin 0 | 2.43e-2  | 4.36e-2  | 5.76e-2  | 6.85e-2  | 7.66e-2  | 8.28e-2  |          |
| 319- |            | 8.81e-2  | 9.29e-2  | 9.72e-2  | 1.013e-1 | 1.052e-1 | 1.091e-1 | 1.127e-1 |
| 320- |            | 1.165e-1 | 1.201e-1 | 1.233e-1 | 1.201e-1 | 1.299e-1 | 1.338e-1 | 1.371e-1 |
| 321- |            | 1.367e-1 | 1.278e-1 | 1.339e-1 | 1.486e-1 | 1.534e-1 | 1.557e-1 | 1.598e-1 |
| 322- |            | 1.639e-1 | 1.647e-1 | 1.711e-1 | 1.751e-1 | 1.786e-1 | 1.826e-1 | 1.862e-1 |
| 323- |            | 1.900e-1 | 1.937e-1 | 1.978e-1 | 2.02e-1  | 2.07e-1  | 2.12e-1  | 2.18e-1  |
| 324- |            | 2.23e-1  | 2.30e-1  | 2.38e-1  | 2.47e-1  | 2.57e-1  | 2.69e-1  | 2.84e-1  |
| 325- |            | 3.03e-1  | 3.26e-1  | 3.44e-1  | 3.57e-1  | 3.71e-1  | 3.86e-1  | 4.02e-1  |
| 326- |            | 4.20e-1  | 4.39e-1  | 4.61e-1  | 4.84e-1  | 5.10e-1  | 5.35e-1  | 5.63e-1  |
| 327- |            | 5.97e-1  | 6.29e-1  | 6.65e-1  | 7.03e-1  | 7.42e-1  | 7.82e-1  | 8.25e-1  |
| 328- |            | 8.68e-1  | 9.12e-1  | 9.56e-1  | 9.98e-1  | 1.040    | 1.080    | 1.117    |
| 329- |            | 1.150    | 1.179    | 1.201    | 1.198    | 1.224    | 1.215    | 1.161    |
| 330- |            | 1.185    | 1.105    | 1.111    | 1.139    | 1.120    | 1.095    | 1.064    |
| 331- |            | 1.027    | 9.81e-1  | 9.13e-1  | 8.74e-1  | 8.05e-1  | 7.40e-1  | 6.61e-1  |
| 332- |            | 6.05e-1  | 5.52e-1  |          |          |          |          |          |
| 333- | df65 lin 0 | 6.01e-1  | 1.004    | 1.244    | 1.391    | 1.464    | 1.491    |          |
| 334- |            | 1.492    | 1.479    | 1.452    | 1.423    | 1.390    | 1.355    | 1.316    |
| 335- |            | 1.277    | 1.237    | 1.193    | 1.092    | 1.109    | 1.072    | 1.031    |
| 336- |            | 9.65e-1  | 8.47e-1  | 8.35e-1  | 8.69e-1  | 8.41e-1  | 8.02e-1  | 7.72e-1  |
| 337- |            | 7.43e-1  | 7.01e-1  | 6.82e-1  | 6.54e-1  | 6.26e-1  | 6.00e-1  | 5.73e-1  |
| 338- |            | 5.48e-1  | 5.25e-1  | 5.02e-1  | 4.81e-1  | 4.61e-1  | 4.41e-1  | 4.22e-1  |
| 339- |            | 4.02e-1  | 3.84e-1  | 3.66e-1  | 3.48e-1  | 3.30e-1  | 3.12e-1  | 2.94e-1  |
| 340- |            | 2.76e-1  | 2.57e-1  | 2.44e-1  | 2.36e-1  | 2.28e-1  | 2.20e-1  | 2.11e-1  |
| 341- |            | 2.03e-1  | 1.947e-1 | 1.863e-1 | 1.778e-1 | 1.694e-1 | 1.609e-1 | 1.525e-1 |
| 342- |            | 1.443e-1 | 1.359e-1 | 1.278e-1 | 1.198e-1 | 1.120e-1 | 1.044e-1 | 9.71e-2  |
| 343- |            | 9.01e-2  | 8.34e-2  | 7.69e-2  | 7.08e-2  | 6.50e-2  | 5.95e-2  | 5.44e-2  |
| 344- |            | 4.96e-2  | 4.51e-2  | 4.09e-2  | 3.71e-2  | 3.35e-2  | 3.01e-2  | 2.71e-2  |
| 345- |            | 2.43e-2  | 2.18e-2  | 1.951e-2 | 1.732e-2 | 1.534e-2 | 1.476e-2 | 1.340e-2 |
| 346- |            | 1.193e-2 | 9.83e-3  | 9.03e-3  | 7.95e-3  | 7.12e-3  | 6.35e-3  | 5.57e-3  |
| 347- |            | 4.98e-3  | 4.40e-3  |          |          |          |          |          |
| 348- | df75 lin 0 | 1.892e-1 | 3.38e-1  | 4.45e-1  | 5.28e-1  | 5.89e-1  | 6.36e-1  |          |
| 349- |            | 6.75e-1  | 7.09e-1  | 7.39e-1  | 7.67e-1  | 7.92e-1  | 8.17e-1  | 8.39e-1  |
| 350- |            | 8.61e-1  | 8.81e-1  | 8.98e-1  | 8.69e-1  | 9.31e-1  | 9.49e-1  | 9.63e-1  |

Table A.4 (cont.)

|      |              |           |          |          |          |          |          |          |
|------|--------------|-----------|----------|----------|----------|----------|----------|----------|
| 351- |              | 9.51e-1   | 8.81e-1  | 9.12e-1  | 9.99e-1  | 1.018    | 1.020    | 1.034    |
| 352- |              | 1.045     | 1.036    | 1.060    | 1.068    | 1.073    | 1.079    | 1.082    |
| 353- |              | 1.086     | 1.089    | 1.092    | 1.096    | 1.102    | 1.107    | 1.111    |
| 354- |              | 1.115     | 1.123    | 1.131    | 1.140    | 1.151    | 1.164    | 1.180    |
| 355- |              | 1.199     | 1.219    | 1.233    | 1.243    | 1.252    | 1.260    | 1.269    |
| 356- |              | 1.277     | 1.285    | 1.292    | 1.298    | 1.304    | 1.307    | 1.307    |
| 357- |              | 1.311     | 1.308    | 1.304    | 1.299    | 1.289    | 1.278    | 1.264    |
| 358- |              | 1.246     | 1.227    | 1.203    | 1.176    | 1.146    | 1.114    | 1.078    |
| 359- |              | 1.040     | 9.99e-1  | 9.56e-1  | 9.06e-1  | 8.65e-1  | 8.14e-1  | 7.55e-1  |
| 360- |              | 7.17e-1   | 6.57e-1  | 6.20e-1  | 5.84e-1  | 5.39e-1  | 5.09e-1  | 4.81e-1  |
| 361- |              | 4.52e-1   | 3.96e-1  | 3.69e-1  | 3.28e-1  | 2.94e-1  | 2.62e-1  | 2.28e-1  |
| 362- |              | 2.02e-1   | 1.795e-1 |          |          |          |          |          |
| 363- | df85 lin 0   |           | 2.43e-2  | 4.36e-2  | 5.76e-2  | 6.85e-2  | 7.66e-2  | 8.28e-2  |
| 364- |              | 8.81e-2   | 9.29e-2  | 9.72e-2  | 1.013e-1 | 1.052e-1 | 1.091e-1 | 1.127e-1 |
| 365- |              | 1.165e-1  | 1.201e-1 | 1.233e-1 | 1.201e-1 | 1.299e-1 | 1.338e-1 | 1.371e-1 |
| 366- |              | 1.367e-1  | 1.278e-1 | 1.339e-1 | 1.486e-1 | 1.534e-1 | 1.557e-1 | 1.598e-1 |
| 367- |              | 1.639e-1  | 1.647e-1 | 1.711e-1 | 1.751e-1 | 1.786e-1 | 1.826e-1 | 1.862e-1 |
| 368- |              | 1.900e-1  | 1.937e-1 | 1.978e-1 | 2.02e-1  | 2.07e-1  | 2.12e-1  | 2.18e-1  |
| 369- |              | 2.23e-1   | 2.30e-1  | 2.38e-1  | 2.47e-1  | 2.57e-1  | 2.69e-1  | 2.84e-1  |
| 370- |              | 3.03e-1   | 3.26e-1  | 3.44e-1  | 3.57e-1  | 3.71e-1  | 3.86e-1  | 4.02e-1  |
| 371- |              | 4.20e-1   | 4.39e-1  | 4.61e-1  | 4.84e-1  | 5.10e-1  | 5.35e-1  | 5.63e-1  |
| 372- |              | 5.97e-1   | 6.29e-1  | 6.65e-1  | 7.03e-1  | 7.42e-1  | 7.82e-1  | 8.25e-1  |
| 373- |              | 8.68e-1   | 9.12e-1  | 9.56e-1  | 9.98e-1  | 1.040    | 1.080    | 1.117    |
| 374- |              | 1.150     | 1.179    | 1.201    | 1.198    | 1.224    | 1.215    | 1.161    |
| 375- |              | 1.185     | 1.105    | 1.111    | 1.139    | 1.120    | 1.095    | 1.064    |
| 376- |              | 1.027     | 9.81e-1  | 9.13e-1  | 8.74e-1  | 8.05e-1  | 7.40e-1  | 6.61e-1  |
| 377- |              | 6.05e-1   | 5.52e-1  |          |          |          |          |          |
| 378- | prdump 2j 1  |           |          |          |          |          |          |          |
| 379- | m1           | 6000.60c  | 9.815e-4 |          |          |          |          |          |
| 380- |              | 25055.60c | 5.150e-4 |          |          |          |          |          |
| 381- |              | 26054.60c | 4.939e-3 |          |          |          |          |          |
| 382- |              | 26056.60c | 7.679e-2 |          |          |          |          |          |
| 383- |              | 26057.60c | 1.758e-3 |          |          |          |          |          |
| 384- |              | 26058.60c | 2.344e-4 |          |          |          |          |          |
| 385- | m2           | 7014.60c  | 3.640e-5 |          |          |          |          |          |
| 386- |              | 8016.60c  | 9.740e-6 |          |          |          |          |          |
| 387- | m3           | 1001.60c  | .667     |          |          |          |          |          |
| 388- |              | 8016.60c  | .333     |          |          |          |          |          |
| 389- | m4           | 1001.60c  | 5.926e-2 |          |          |          |          |          |
| 390- |              | 6000.60c  | 3.338e-2 |          |          |          |          |          |
| 391- |              | 8016.60c  | 1.125e-2 |          |          |          |          |          |
| 392- |              | 3006.60c  | 5.565e-4 |          |          |          |          |          |
| 393- |              | 3007.60c  | 6.944e-3 |          |          |          |          |          |
| 394- | print        |           |          |          |          |          |          |          |
| 395- | wwg 65 24 0  | -463.59   | 207.01   | 0        |          |          |          |          |
| 396- | cut:n j      | 3.839e-7  | -1.e-6   | -1.e-7   |          |          |          |          |
| 397- | mt3 lwtr.01t |           |          |          |          |          |          |          |
| 398- | mt4 poly.01t |           |          |          |          |          |          |          |
| 399- | nps 500000   |           |          |          |          |          |          |          |