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Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36

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SUBMITTED TO The American Nuclear Society Meeting in Pasco, Washington, April 26-30, 1992

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KEY CHANGES IN NUCLEAR DATA IN THE TRANSITION FROM ENDF/B-V TO ENDF/B-VI

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Major changes were made in the evaluated nuclear data base in going from ENDF/B-V to ENDF/B-VI. A complete revision of all the cross sections standards was implemented using results from a simultaneous analysis of all standard reactions; energy-angle correlated secondary distributions for emitted particles and gamma rays were introduced; many natural element evaluations were replaced by isotopic data; vastly expanded fission-product yield and decay data files were included; and altogether some 74 general purpose data evaluations were either completely replaced or significantly revised.[1] Applications that will utilize nuclear data from the recently issued ENDF/B-VI library are varied in scope, and a number of the improvements and changes that have occurred relative to the previous library are significant for certain of the application areas. The purpose of this paper is to examined the changes in data that have occurred in a selection of nuclear reactions important for applications, emphasizing several that influence results in key data testing calculations. In particular, the paper highlights revisions in neutron-induced reactions from ^{14}N and ^{16}O that are important in calculating neutron transport and/or reflection in air, and some of the changes in data for ^{235}U, ^{238}U, and ^{239}Pu that are significant in fast reactor applications.

The ENDF/B-VI evaluations for both ^{14}N and ^{16}O incorporate coupled-channel R-matrix analyses of neutron total, elastic scattering, and (n,x) data at neutron energies below the threshold for inelastic scattering.[2] At higher energies, both evaluations rely more upon the experimental data base, supplemented by statistical/preequilibrium nuclear theory calculations. New measurements of neutron elastic and inelastic scattering differential cross sections, as well as gamma-ray production cross sections, led to an extensive revision in the neutron emission spectra that results from 14-MeV neutron interactions with ^{14}N. The integrated elastic scattering cross section alone increased by some 9% at that energy. A comparison between the neutron emission spectra at E_n = 14.8 MeV, θ_L = 30° from ENDF/B-VI and ENDF/B-V is given in Fig. 1, together with the experimental data of Takahashi.[3] The rather large changes indicated in the figure partially account for a rather appreciable improvement in integral calculations of neutron leakage spectra from ^{14}N spheres pulsed with 14-MeV neutrons.[4]

New measurements of the neutron total cross section for ^{16}O, combined by means of a careful R-matrix analysis with the large existing elastic scattering differential data base, led to significant improvement in the ENDF/B-VI evaluation below 6 MeV. Similar improvement occurred at higher energies due mainly to new experimental data. Of particular importance at lower energies is the new total cross section measurement of Larson,[5] which shifted the energy of the first resonance in ^{16}O downward by some 10 keV, as well as the improved description of elastic angular distributions that comes from the R-matrix analysis. As a result of the new evaluation, significant improvement has been observed in the calculated k_{eff} for high leakage ^{235}U homogeneous aqueous criticals.[6]

Significant improvements occurred in the ENDF/B-VI evaluated nuclear data for the major actinides ^{235}U, ^{238}U, and ^{239}Pu, mainly as a result of the careful simultaneous analysis of the Version VI standard cross sections,[7] but also because of better determination of other quantities. Because of the inclusion of interconnecting cross section ratio measurements, the standards analysis resulted in a very consistent set of fission cross sections for ^{235}U, ^{238}U, and ^{239}Pu, as well as for the $^{238}U(n,\gamma)^{239}U$ reaction. In the cases of ^{235}U and ^{239}Pu, the accurate $\sigma_f(E_n)$ results were combined with new covariance analyses of the prompt neutron multiplicity from fission, $\bar{\nu}_p(E_n)$,[8] and with new theoretical analyses of (n,n'), (n,2n), and (n,3n) cross sections and secondary emission data.[9]

Using the product of $\bar{\nu}_p(E_n)$ and $\sigma_f(E_n)$ as a crude figure of merit, the changes in this product for ^{235}U and ^{239}Pu in going from ENDF/B-V to ENDF/B-VI are illustrated by ratio plots in Fig. 2. In the case of ^{235}U, there is a consistent decrease of order 1-2% in the $\bar{\nu}_p(E_n)\cdot\sigma_f(E_n)$ product over the energy range corresponding to fission neutrons. This is quite a large change, of course, and in the absence of other modifications to the ^{235}U data, would have resulted in a serious underprediction of k_{eff} for fast criticals such as GODIVA. Fortunately, other revisions to the ^{235}U data compensated in a natural way for the decrease in $\bar{\nu}_p(E_n)\cdot\sigma_f(E_n)$, especially the changes that occurred due to the improved theoretical analysis of (n,n') and (n,xn) cross sections, energy and angular distributions. The Version V $\rightarrow$ VI change in $\bar{\nu}_p(E_n)\cdot\sigma_f(E_n)$ for ^{239}Pu in Fig. 2 is not as pronounced as for ^{235}U, at least over the main part of the fission spectrum energy range. This observation is consistent with the fact that the changes in the evaluated $^{239}Pu(n,n')$ data for ENDF/B-VI were not nearly as large as for $^{235}U(n,n')$. For both ^{235}U and ^{239}Pu, preliminary calculations of fast critical measurements with the ENDF/B-VI evaluations indicate satisfactory agreement and show signs of greater consistency with the body of data.[6,8]

In conclusion, the ENDF/B-VI data for ^{14}N, ^{16}O, ^{235}U, ^{238}U, and ^{239}Pu are clearly improved relative to ENDF/B-V, both from the point of view of incorporating more comprehensive and accurate differential data and because improved evaluation methodology and theoretical calculations were utilized. Preliminary data testing results indicate that the new evaluations also lead to improved predictions of integral measurements. The reactions accounting for the improved integral calculations will be investigated in this paper.

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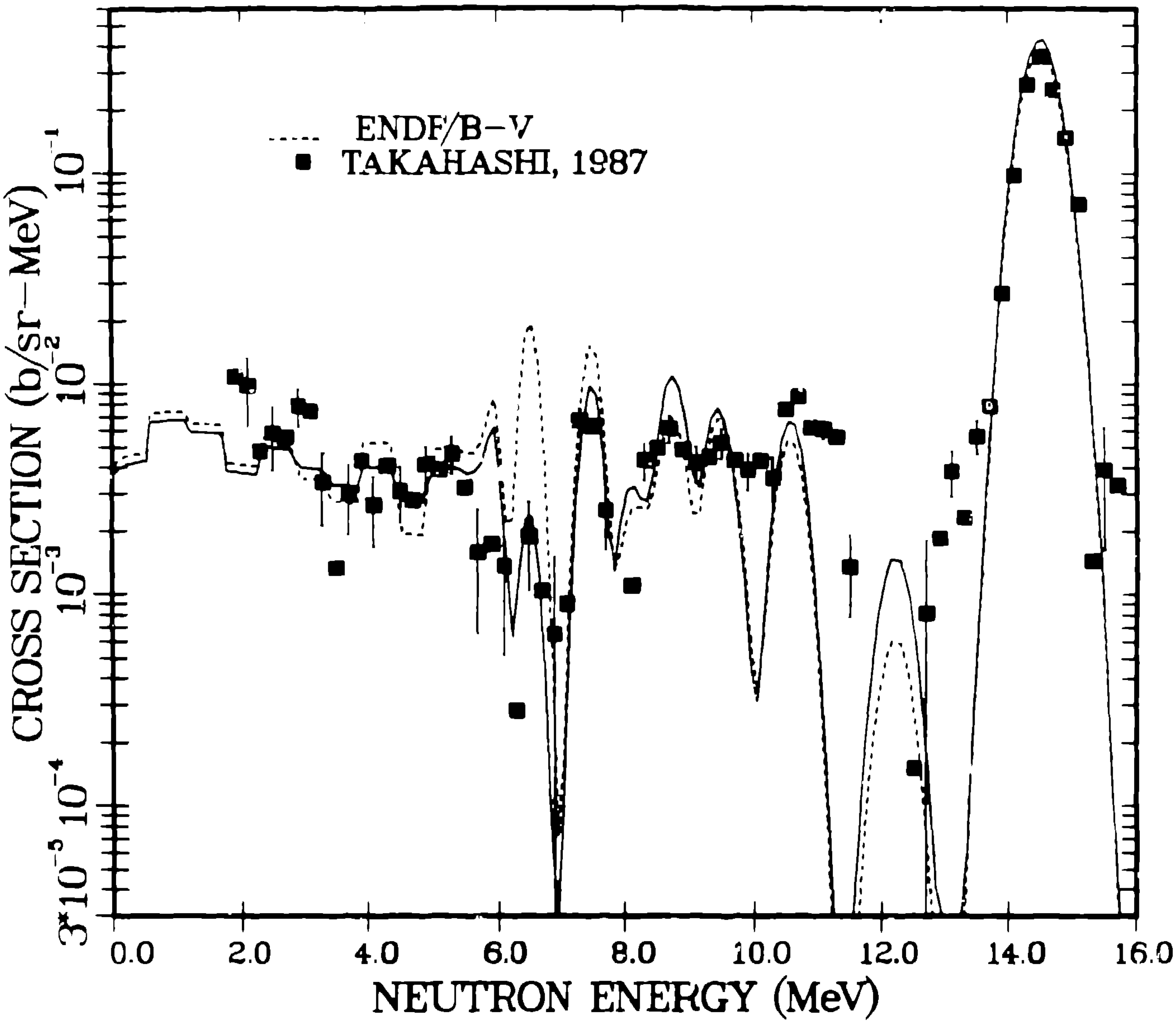

Fig. 1. Comparison of the neutron emission spectrum at E_n = 14.6 MeV and θ = 30° calculated from the ENDF/B-VI evaluation of n + ^{14}N reactions with the previous ENDF/B-V.2 evaluation and with the experimental data of Takahashi.[3] The solid curve is obtained from the ENDF/B-VI evaluation.

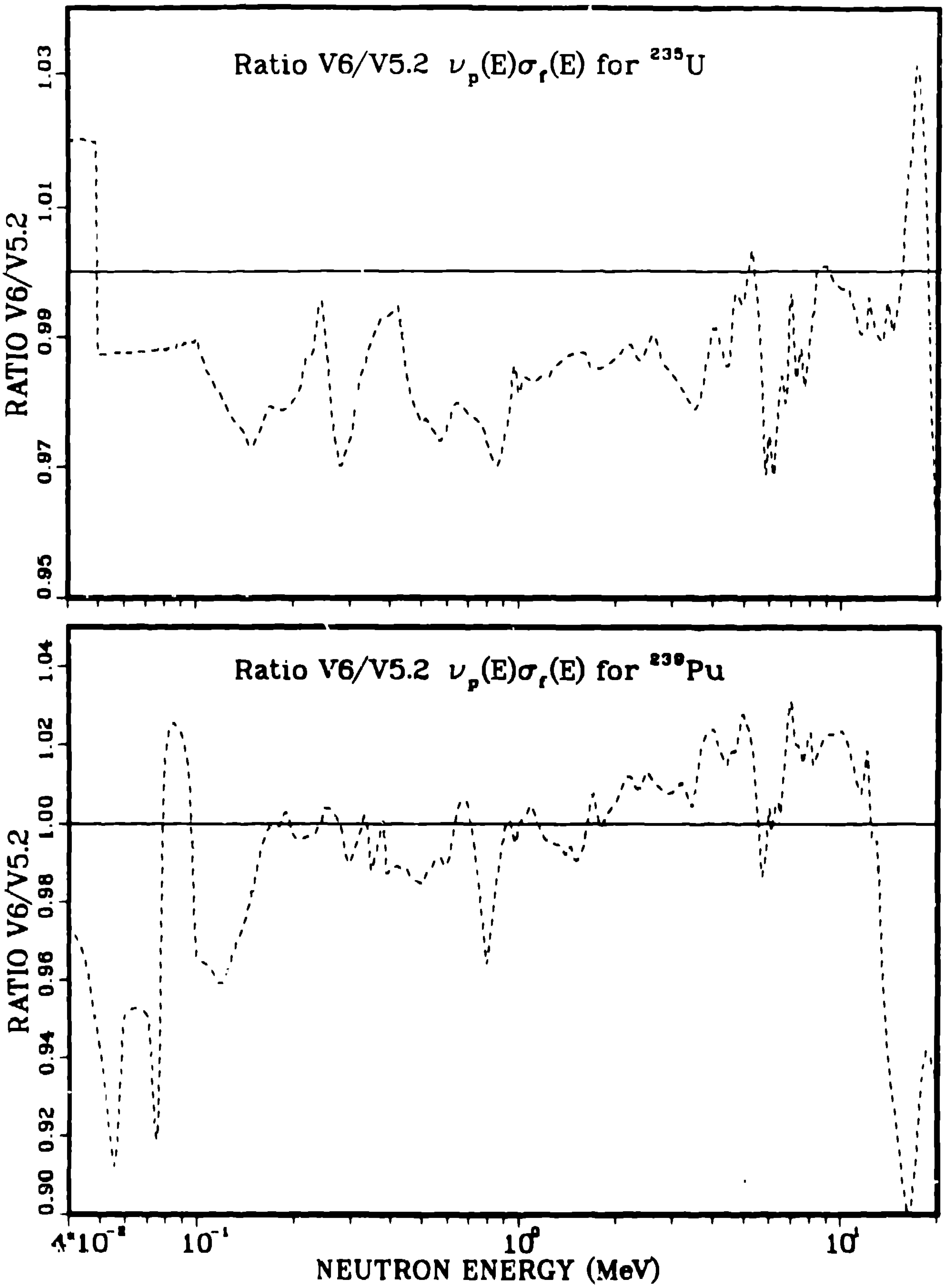

Fig. 2. Ratios of the product $\bar{\nu}_p(E_n)\cdot\sigma_f(E_n)$ for the ENDF/B/VI evaluation relative to ENDF/B-V.2 for ^{235}U and ^{239}Pu.