

Subgroup 9 Status Report: Fission Neutron Spectra

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Subgroup 9 has been charged with determining a physically correct prompt fission neutron spectrum matrix for the $n + {}^{235}\text{U}$ system. The following work has been done:

1. Measurements of the differential spectrum, together with uncertainties, have been collected for 12 experiments by N. Kornilov and P. Staples. The experiments span an incident neutron energy range of thermal to 5.0 MeV, which means that no experimental determinations of the spectra that we have used to determine the matrix include the physical effects of second- and third-chance fission.
2. A set of 30 integral cross section measurements in the $n(\text{thermal}) + {}^{235}\text{U}$ system have been compiled by W. Mannhart following a careful analysis and evaluation of the existing experimental database. These provide integral tests of the prompt fission neutron spectrum for thermal neutron induced fission under the assumption that the corresponding cross sections for the specific reactions are known exactly.
3. The Los Alamos model has been used to calculate a new prompt fission neutron spectrum matrix for the $n + {}^{235}\text{U}$ system. Energy-dependent compound-nucleus formation cross sections for the inverse process were used throughout. The matrix includes first-, second-, and third-chance fission components and also includes the neutrons evaporated prior to fission in second- and third-chance fission. It has been calculated for 19 incident neutron energies ranging from 0.0 to 15.0 MeV. The nuclear level-density parameters used in the calculations were determined in least-squares adjustments to the measured differential spectra assembled by N. Kornilov and P. Staples.
4. Following the calculation of the new matrix, N. Kornilov provided an additional experimental measurement of the spectrum at 14.7 MeV by G. S. Boykov et al. in 1991, together with pertinent detail about the measurement. At 14.7 MeV the total spectrum is made up of five components: three multiple-chance fission spectra (0,1,2) and two evaporation spectra (1,2). A comparison of this experiment with the 14 and 15 MeV vectors of the new matrix is a test of its predictive power and the result gives very good agreement.
5. The new fission spectrum matrix for the $n + {}^{235}\text{U}$ system is now considered complete, and ready for close scrutiny by all members of Subgroup 9, except for two remaining points:

- (a) The measurements of the thermal-neutron-induced spectrum are not in agreement. This means that the calculated thermal spectrum depends upon which measurement, or measurements, is used to determine the nuclear level-density parameter for this case. Four candidate thermal spectra have therefore been calculated for testing against the set of 30 integral cross section measurements. The candidate spectra have been forwarded to W. Mannhart who has calculated the 30 integral cross sections using each of the candidate spectra. His results have been studied and yield the following (preliminary) conclusions:
- i. The thermal spectrum determined by least-squares adjustment to the differential measurement of Starostov et al. (1984) reproduces the integral cross section measurements to within 10% ($C/E = 1.0 \pm 0.1$) out to approximately 8 MeV and fails beyond, falling to C/E values near 0.6.
 - ii. The thermal spectrum determined by least-squares adjustment to the differential measurement of Wang et al. (1989) reproduces the integral cross section measurements to within 10% out to approximately 11 MeV and fails beyond, falling to C/E values just under 0.8
 - iii. The ENDF/B-VI thermal spectrum, calculated using the Los Alamos model, reproduces the integral cross sections to within 10% out to approximately 13 MeV and fails beyond, falling to C/E values near 0.85.
 - iv. Increasing the average nuclear level density parameter used to calculate the ENDF/B-VI thermal spectrum by 1.8% results in a thermal spectrum that reproduces the integral cross section measurements to within 10% over their entire range. This spectrum, however, is too hard in the tail region in comparison to both the Starostov et al. and Wang et al. differential experimental thermal spectra.

A possible resolution of the thermal spectrum question would be to use the ENDF/B-VI thermal spectrum, calculated previously with the Los Alamos model, as a temporary thermal spectrum representing a reasonable compromise between the differential measurements, on the one hand, and the integral measurements, on the other. Before proposing such a temporary solution, however, Madland is investigating other methods of calculating the compound elastic scattering cross sections for the inverse process, which enter into the Los Alamos theoretical model of the spectrum in a crucial manner.

- (b) The question of the influence of possible scission neutrons on the prompt fission neutron spectrum has been studied by N. Kornilov and F.J. Hamsch for the spontaneous fission of ^{252}Cf . They are examining their results for possible application to the fission spectrum matrix for the $n + ^{235}\text{U}$ system.

It is worth noting here that the prompt fission neutron spectrum matrix for the $n + ^{235}\text{U}$ system in ENDF/B-VI, calculated using the Los Alamos model, was based upon only one measurement of the differential spectrum, that of Johansson and Holmqvist (1977) at 0.53 MeV, together with the existing experimental data base of "nu-bar" values.