The Impact of the "u235g6" Family of Evaluated Data Files

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Background

The Working Party on Evaluation Cooperation of the OECD set up a subgroup WPEC-SG40 (alias CIELO) to focus on the evaluated nuclear data of the major nuclides in reactor technology, namely ^{1}H, ^{16}O, ^{56}Fe, ^{235}U, ^{238}U and ^{239}Pu. Different research groups in various parts of the world are working on improved evaluated nuclear data and their uncertainties for these nuclides; the ultimate test of improvement is the performance of the data in simulating integral experiments.

A Coordinated Research Project (CRP) is in progress at the Nuclear Data Section (NDS) of the International Atomic Energy Agency with the objective to investigate the differential and integral experimental data on the prompt fission neutron spectra (PFNS) of actinides. Additionally, in the on-going neutron standard project it is planned to include 235U PFNS induced by thermal neutrons as a reference spectrum.

The "u235g6" family of evaluated data files represents a series of files based on the ^{235}U evaluation from ENDF/B-VII.1 in which parts of the evaluated data were replaced. The aim of the present report is to describe the impact of these changes on integral benchmarks, particularly the high-leakage highly-enriched solution assemblies, which are strongly sensitive to the PFNS and the scattering properties of the materials in the assembly.

File description

The ^{235}U evaluation from ENDF/B-VII.1 is taken as the main reference. The secondary reference is the JENDL-4.0u2 evaluation of the same nuclide; this evaluation is fairly recent and was carried out with the support of the state-of-the art model calculations. The PFNS is adopted from the recent work performed within the IAEA CRP in Cross Section Standards. It is based on a preliminary fit of selected experimental data [1] with the GANDR system for the PFNS induced by thermal neutrons and by neutrons with energy between 500 eV and 2 MeV. The impact of the preliminary resonance analysis from the Oak Ridge National Laboratory by L. Leal to the CIELO collaboration was included in the study.

The following files have been generated:

e71	Original 235U evaluation from ENDF/B-VII.1.
u235g6	"e71" evaluation with the PFNS replaced by the GANDR fit to the spectra below 2 MeV.
u235g6nj4	"u235g6" evaluation with all inelastic scattering data (cross sections and angular distributions) taken from the JENDL-4.0u2 evaluation. The comparison of the cross sections is shown in Figure 1.
u235g6neaxj4	"u235g6n" evaluation with all elastic (above the resonance range) and inelastic scattering data taken from the JENDL-4.0u2 evaluation.
u235g6neaxcj4	"u235g6n" evaluation with all capture (above the resonance range), elastic (above the resonance range) and inelastic scattering data taken from the JENDL-4.0u2 evaluation.
u235g6neaxcj4r	"u235g6neaxcj4" evaluation with the resonance data replaced by the new preliminary evaluation from ORNL.

Results

The evaluated data files described above were processed with NJOY2012 to prepare ACE libraries with which the selected benchmark assemblies wire modelled. The list of benchmarks that were included in the analysis is given in Table 1. The results are shown in Figure 2.

Table 1: List of benchmarks considered in the analysis

ICSBEP name	Short name	Common name
HEU-SOL-THERM-009	hst009-1	ORNL_S1
HEU-SOL-THERM-009	hst009-2	ORNL_S2
HEU-SOL-THERM-009	hst009-3	ORNL_S3
HEU-SOL-THERM-009	hst009-4	ORNL_S4
HEU-SOL-THERM-013	hst013-1	ORNL_T1
HEU-SOL-THERM-013	hst013-2	ORNL_T2
HEU-SOL-THERM-013	hst013-3	ORNL_T3
HEU-SOL-THERM-013	hst013-4	ORNL_T4
HEU-SOL-THERM-001	hst001-01	Rockwell-01
HEU-SOL-THERM-001	hst001-02	Rockwell-02
HEU-SOL-THERM-001	hst001-03	Rockwell-03
HEU-SOL-THERM-001	hst001-04	Rockwell-04
HEU-SOL-THERM-001	hst001-05	Rockwell-05
HEU-SOL-THERM-001	hst001-06	Rockwell-06
HEU-SOL-THERM-001	hst001-07	Rockwell-07
HEU-SOL-THERM-001	hst001-08	Rockwell-08
HEU-SOL-THERM-001	hst001-09	Rockwell-09
HEU-SOL-THERM-001	hst001-10	Rockwell-10

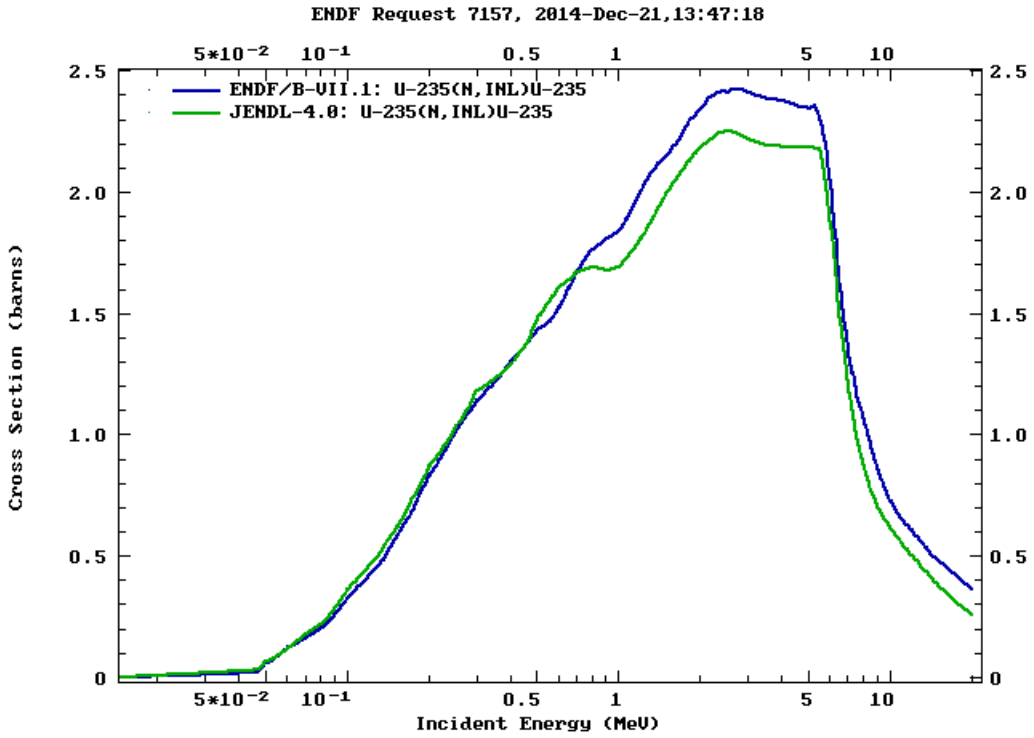

Figure 1: Comparison of the inelastic cross sections of 235U from the ENDF/B-VII.1 and the JENDL-4.0u2 evaluations.

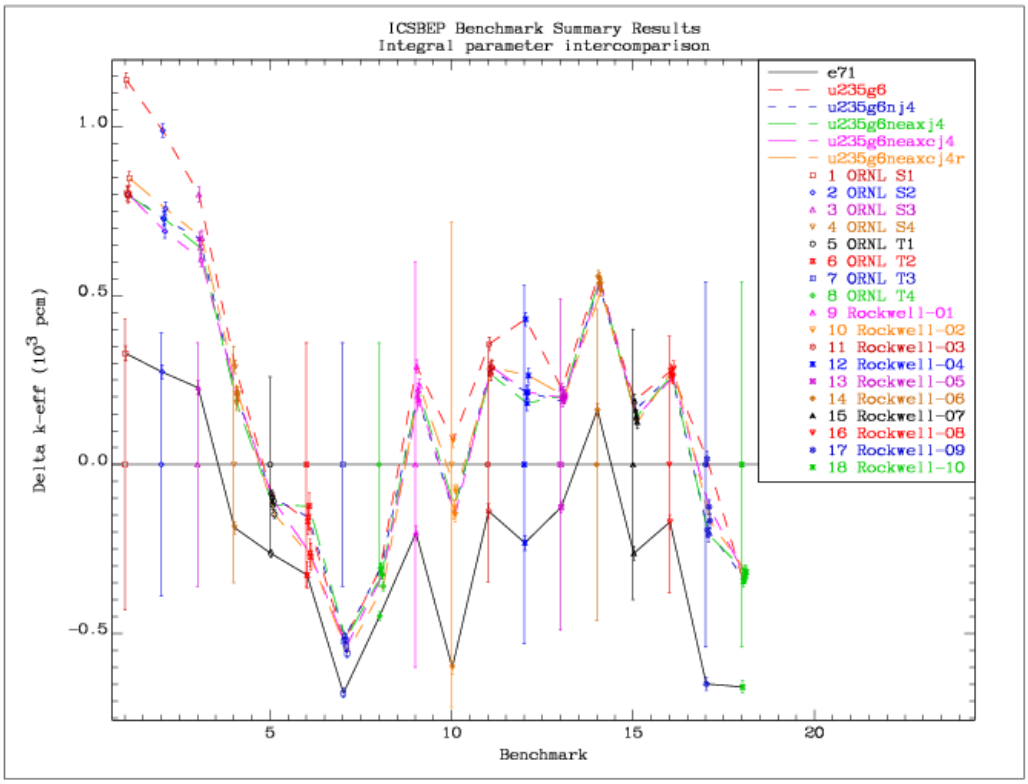

Figure 1: Results of the sensitivity study on the impact of ^{235}U data on the k_{eff} of the high-leakage, highly-enriched solution benchmark assemblies.

Conclusions

The GANDR fit of the PFNS results in a softer spectrum with an average energy of 2.008 MeV, compared to the original ENDF/B-VII.1 PFNS with an average energy of 2.03 MeV. The spectrum greatly increases the reactivity of the high-leakage highly-enriched solution assemblies. If such a spectrum is to be supported in evaluated nuclear data files, the compensating effects must be identified. An obvious one is the average number of neutrons per fission, but this has very strong implications on other critical systems, so additional options were explored.

The results presented in Figure 1 indicate that the elastic and capture cross sections have a rather small effect on reactivity of the systems under consideration. The biggest effect is due to the PFNS. This can be partly compensated by the smaller inelastic cross section, such as the one in the JENDL-4.0u2 evaluation.

It is known from a separate analysis that the LANL evaluation of ^{16}O by G. Hale also has the tendency to reduce the reactivity of these systems to a smaller extent.

The overall conclusion is that individual materials and reaction data within a material evaluation must not be considered independently due to compensating effects. By a delicate balance of PFNS and inelastic scattering in ^{235}U and considering improved evaluation for ^{16}O it seems possible to restore good performance of the ^{235}U evaluation without adverse effects on other critical systems.

The “u235g6” evaluated data files should not be considered “an evaluation”. They are merely parametric studies to indicate in which direction the evaluation rffort should be focused.

References

[1] A. Trkov: On the Selection of the Differential 235U PFNS Data, International Atomic Energy Agency, Vienna, Austria, December 2014 (unpublished).