^{235}U Resolved Resonance Evaluation for Benchmark Calculations in the Intermediate Energy Region*

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INTRODUCTION

The Working Party on International Nuclear Data Evaluation Co-operation (WPEC) subgroup 29 (SG 29) was established to investigate an issue with the ^{235}U capture cross-section in the energy range 0.1 to 2.25 keV.[1] The WPEC criticality calculation results indicated an overestimation of the ^{235}U capture cross-section of 10% or more. To understand and solve the problem, a recommendation was made to perform new capture cross-section measurements followed by a resonance evaluation. Hence, time-of-flight capture cross-section measurements were done at the Rensselaer Polytechnic Institute (RPI) [2] and at the Los Alamos National Laboratory (LANL).[3] These new measurements were used together with the computer code SAMMY to reevaluate the ^{235}U resonance parameters in the energy range from thermal to 2.25 keV. The impact of the new evaluation in benchmark calculations was done for the critical benchmark sensitive to the 0.1 to 2.25 keV energy range. The purpose of this work is to describe the ^{235}U SAMMY evaluation and present the critical benchmark results.

^{235}U RESONANCE EVALUATION

In the 1990s, a ^{235}U resonance evaluation was released for inclusion in the US Evaluated Nuclear Data File.[4] The evaluation was done based on high-resolution transmission and fission cross-section data. Although at the time there existed capture cross-section data, these data were not systematically included in the SAMMY evaluation due to issues such as normalization and background. In addition to experimental data included in the previous ^{235}U evaluation, new capture cross-section data recently performed at RPI and LANL were used in the ^{235}U resonance reevaluation. A few selected existing experimental data are shown in Table I, while the complete set is listed in Table 2 of Ref. [4]. Integral quantities such as fission and capture resonance integral Westcott factors were also included in the evaluation.

TABLE I. Selected Set of Experimental Data Included in the SAMMY Resonance Evaluation

Author	Energy Range (eV)	Data
De Saussure (RPI/1967) [5]	0.01–2250.0	Fission and capture at 25.2 meters
Perez (ORNL/1973) [6]	0.01–100.0	Fission and capture at 39.7 meters
Weston (ORNL/1984) [7]	14.0–2250.0	Fission at 18.9 meters
Gwin (ORNL/1984) [8]	0.01–20.0	Fission at 25.6 meters
Spencer (ORNL/1984) [9]	0.01–1.0	Transmission at 18.0 meters and sample thickness of 0.001468 atom/barns
Harvey (ORNL/1988) [10]	4.0–2250.0	Transmission at 80.0 meters and sample thickness of 0.001468 atom/barns
Harvey (ORNL/1988 [10]	4.0–2250.0	Transmission at 80.0 meters and sample thickness of 0.03269 atom/barns
Danon (RPI/2011 [2]	100.0–2250.0	Fission and capture yield at 25.56 meters
Jandel (LANL/2012) [3]	100.0–2250.0	Capture at 25.45 meters

In the present evaluation the Reich-Moore formalism was used, and resonance parameters representing the experimental data reasonably well in the energy region up to 2250 eV were derived.

Figure 1 displays a comparison of the average capture yield calculated with the ENDF/B-VII.0, the new

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evaluated resonance parameter, and the RPI experimental capture yield. Clearly, as can be seen, the overprediction of the capture cross-section has been removed with the new ^{235}U preliminary resonance parameter evaluation.

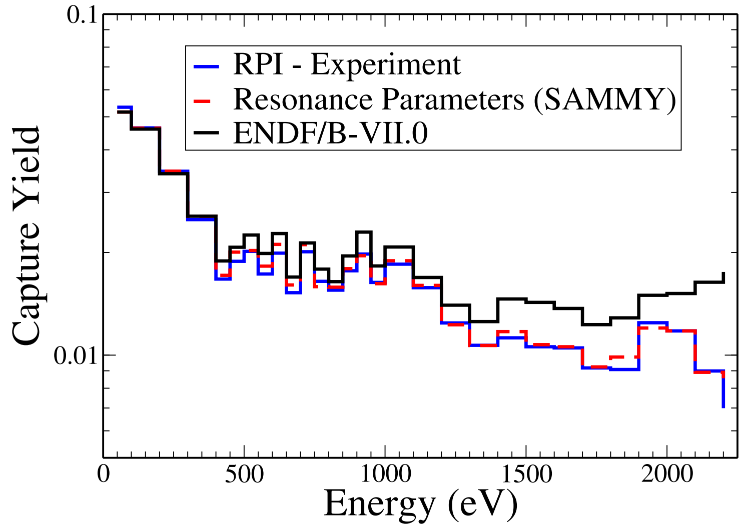

Fig. 1. Comparisons of the RPI capture yield data with calculations done with the preliminary set of ^{235}U resonance parameters. It is also shown with the calculation using the ENDF/B-VII.0 resonance parameters.

BENCHMARK RESULTS AND CONCLUSIONS

The impact of the new preliminary ^{235}U resonance evaluation in benchmark calculations was investigated using intermediate energy benchmark listed in the *International Handbook of Evaluated Criticality Safety Benchmark Experiments* (IHECSBE).[11] The experiments included in the IHECSBE and identified as HEU-MET-INTER-006 series (ZEUS benchmark) were calculated with the MCNP code. The new set of resonance parameters was converted into the ENDF/B format and included in the Japanese Evaluated Nuclear Data Library (JENDL-4), where it replaced the existing JENDL resonance parameters. The new ^{235}U library named JENDL4+ORNL was processed with the NJOY code to generate MCNP formatted cross-section. In the MCNP calculation, everything else was taken from the ENDF/B-VII.0. The MCNP calculated-to-experimental (C/E) results are shown in Table II together with results from ENDF/B-VII.0 and JENDL-4. Listed also in Table II is the energy corresponding to the average neutron lethargy causing fission (EALF). EALF indicates the portion of the neutron spectrum that has a component in the resolved resonance region of ^{235}U.

It is interesting to note that as the EALF increases, the k_{eff} bias appears to be reduced with the new preliminary ^{235}U resonance evaluation. The C/E for EALF=80.80 keV also indicates that the ^{235}U evaluation in unresolved and high-energy range need to be reviewed. In conclusion, although the new cross-section measurement done at RPI and LANL seems to indicate that the reduction on the capture cross section leads to a better calculation of k_{eff} for intermediate-energy benchmark systems, additional benchmarks sensitive to the intermediate energy region are needed.

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Table II. MCNP Benchmark Results for the ZEUS Intermediate Energy Benchmark

Case Number	EALF (keV)	Benchmark k_{eff}	C/E values for k_{eff}		
			ENDF/B-VII.0	JENDL4	JENDL4+ORNL
HEU-MET-INTER-006-1 (ZEUS1)	4.44	0.9977 ±0.0008	0.9953 ± 0.0088	1.0031 ± 0.0088	0.9987 ± 0.0088
HEU-MET-INTER-006-2 (ZEUS2)	9.45	1.0001 ±0.0008	0.9960 ±0.0088	1.0049 ± 0.0088	1.0000 ± 0.0088
HEU-MET-INTER-006-3 (ZEUS3)	22.80	1.0015 ±0.0008	0.9992 ±0.0088	1.0066 ± 0.0088	1.0006 ± 0.0088
HEU-MET-INTER-006-4 (ZEUS4)	80.80	1.0016 ±0.0008	1.0059 ± 0.0088	1.0051 ± 0.0088	1.0034 ± 0.0088

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