LA-UR- 98-2943

Approved for public release;
distribution is unlimited.

Title: IMPACT OF MCNP UNRESOLVED RESONANCE PROBABILITY-TABLE TREATMENT ON URANIUM AND PLUTONIUM BENCHMARKS

CONF-981106--

Author(s): Russell D. Mosteller, NIS-6, J562
Robert C. Little, X-CI, F663

Submitted to: PRESENTATION AT THE WINTER 1998 MEETING OF THE AMERICAN NUCLEAR SOCIETY
WASHINGTON, DC NOVEMBER 15-19, 1998

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Los Alamos
NATIONAL LABORATORY

Form 836 (10/96)

DISCLAIMER

Impact of MCNP Unresolved Resonance Probability-Table Treatment on Uranium and Plutonium Benchmarks

Russell D. Mosteller
Advanced Nuclear Technology Group (NIS-6)
Nonproliferation and International Security Division
Los Alamos National Laboratory

Robert C. Little
Code Integration Group (X-CI)
Applied Theoretical and Computational Physics Division
Los Alamos National Laboratory

To Be Submitted for Presentation at the
Winter 1998 Meeting of the American Nuclear Society
Washington, DC November 15-19, 1998

Versions of MCNP[1] up through and including 4B have not accurately modeled neutron self-shielding effects in the unresolved resonance energy region. Recently, a probability-table treatment has been incorporated into a developmental version of MCNP.[2] This paper presents MCNP results for a variety of uranium and plutonium critical benchmarks, calculated with and without the probability-table treatment.

The probability-table method[3,4] relies on the statistical nature of neutron resonances in the unresolved region. Average unresolved resonance parameters from nuclear-data evaluations may be utilized by a processing code (in this case, NJOY[5]) to generate ladders of representative resonances. Cross sections from these ladders are then used to form cross-section probability distribution functions, from which NJOY prepares a table of cross sections (total, elastic, fission, radiative capture, and heating) as a function of probability. Such tables are a function of incident neutron energy. When transporting neutrons in the unresolved energy range of a particular nuclide, the developmental version of MCNP samples the total and reaction cross sections rather than simply using single average values as the code has done in the past. By virtue of randomly sampling large, intermediate, and small cross sections from the probability tables, this version of MCNP models the effects of neutron self-shielding in the unresolved resonance energy region.

Several uranium and plutonium benchmarks were selected to assess the reactivity impact of the probability-table method. The benchmarks, which are summarized in Table 1, include highly enriched uranium (HEU), intermediate-enriched uranium (IEU), low-enriched uranium (LEU) and plutonium cores that produce a range of neutron spectra. Most of these benchmarks are based on specifications provided by the Cross Section Evaluation Working Group[6] (CSEWG) or the Working Group for the International Criticality Safety Benchmark Evaluation Program[7] (ICSBEP).

The MCNP calculations were performed with a version of the code intermediate between 4B and 4C. Each calculation used at least 1 million active histories, and those for GODIVA and both JEZEBEL assemblies were extended to 3.7 million active histories. ENDF/B-VI cross-section libraries were employed exclusively. The probability-table data are from a pre-release

MCNP library and are based on ENDF/B-VI release 0 for ^{242}Pu, release 2 for ^{235}U, ^{238}U, ^{239}Pu, and ^{240}Pu, and release 3 for ^{241}Pu. The ENDF/B-VI unresolved resonance range extends from 2.25 to 25 keV for ^{235}U, from 10 to 300 keV for ^{238}U, from 2.5 to 30 keV for ^{239}Pu, from 5.7 to 40 keV for ^{240}Pu, from 0.3 to 40.2 keV for ^{241}Pu, and from 0.986 to 10 keV for ^{242}Pu. Cross sections for other isotopes in the benchmarks were from the distributed ENDF60 library,[8] and did not include probability tables.

The results from these calculations are presented in Table 2. Four conclusions can be drawn from these results. First, not surprisingly, the only benchmarks that are substantially affected are those that have a significant fraction of their interactions within the unresolved resonance region of the principal uranium and plutonium isotopes that are present. For example, the graphite-reflected IEU sphere, whose spectrum peaks at approximately 600 KeV, is essentially unaffected, while the reactivity difference for the other IEU benchmarks, whose spectra peak at 300 KeV or lower, is significant. Second, the reactivity impact of the improvement is essentially negligible for ^{235}U in these systems. The spectral peaks for all of the HEU benchmarks except GODIVA occur within the unresolved resonance region, but the probability-table treatment does not produce a statistically significant change in reactivity for any of them. Third, the probability-table method can produce substantial increases in reactivity for those benchmarks that include proportionately large amounts of ^{238}U and have high fluxes within the unresolved resonance region. Finally, the probability-table method also can produce significant reactivity changes for plutonium benchmarks whose spectra peak in or near the unresolved resonance region.

References

1. Judith F. Briesmeister, ed., "MCNP — A General Monte Carlo N-Particle Transport Code, Version 4B," LA-12625-M, Version 4B, Los Alamos National Laboratory (March 1997).

2. Lee L. Carter, Robert C. Little, John S. Hendricks, and Robert E. MacFarlane, "New Probability Table Treatment in MCNP for Unresolved Resonances," *Proceedings of the*

ANS Radiation Protection and Shielding Division Topical Conference on Technologies for the New Century (April 19-23, 1998, Nashville, Tennessee).

3. J. M. Otter, R. C. Lewis, and L. B. Levitt, "UBR, A Code to Calculate Unresolved Resonance Cross Section Probability Tables," AI-AEC-13024, Atomics International (November 1973).

4. R. N. Blomquist, R. M. Lell, and E. M. Gelbard, "VIM — A Continuous Energy Monte Carlo Code at ANL," pp. 31-46, *A Review of the Theory and Application of Monte Carlo Methods, Proceedings of a Seminar-Workshop,* D. K. Trubey and B. L. McGill, Eds., ORNL/RSIC-44, Oak Ridge National Laboratory (April 21-23, 1980, Oak Ridge, Tennessee).

5. R. E. MacFarlane and D. W. Muir, "The NJOY Nuclear Data Processing System Version 91," LA-12740-M, Los Alamos National Laboratory (October 1994).

6. "Cross Section Evaluation Working Group Benchmark Specifications," BNL-19302 (ENDF-202), Brookhaven National Laboratory (November 1974).

7. "International Handbook of Evaluated Criticality Safety Benchmark Experiments," NEA/NSC/DOC(95)03 (Rev), OECD Nuclear Energy Agency (September 1997).

8. John S. Hendricks, Stephanie C. Frankle, and John D. Court, "ENDF/B-VI Data for MCNP," LA-12891, Los Alamos National Laboratory (December 1994).

Table 1. Summary of Benchmarks

Benchmark Name	Identifier	Principal Core Material(s)	Principal Reflector Material(s)	Shape
GODIVA	CSEWG FRB 5	HEU (93 wt.%)	None	Sphere
ZPR-9-34	ICSBEP HEU-MET-FAST-035	HEU (93 wt.%), Steel	Steel	Cylinder
VERA-1B	CSEWG FRB 6	HEU (93 wt.%), Graphite	Normal U, Steel	Sphere
ZEUS	*	HEU (93 wt.%), Graphite	Copper	Cylinder
HISS/HUG	CSEWG TRB-**	HEU (92 wt.%), Graphite	——	Infinite
ZPR-III-2	CSEWG FRB 7	IEU (46 wt.%), Steel	Normal U, Steel	Cylinder
ZPR-III-6F	CSEWG FRB 7	IEU (46 wt.%), Steel	Normal U, Steel	Cylinder
Graphite-Reflected IEU Sphere	ICSBEP IEU-MET-FAST-004	IEU (36 wt.%)	Graphite	Sphere
ZPR-III-12	CSEWG FRB 9	IEU (21 wt.%), Graphite	Depleted U, Steel	Cylinder
ZEBRA-2	CSEWG FRB 10	IEW (13.7 wt.%), Graphite	Normal U	Cylinder
ZPR-III-11	CSEWG FRB 8	IEU (12 wt.%), Steel	Normal U, Steel	Cylinder
BIG TEN	CSEWG FRB 20	IEU (10 wt.%)	Depleted U	Sphere
ZEBRA-8H	ICSBEP MIX-MET-FAST-008	IEU (37.5 wt.%), Normal U (6 wt.% Average)	Steel	Infinite Lattice of Square Cylinders
SHEBA-II	ICSBEP LEU-SOL-THERM-001	LEU (5 wt.%)Uranyl Nitrate, Water	None	Cylinder
JEZEBEL	CSEWG FRB 1	Pu (4.5 at.% ^{24}0Pu)	None	Sphere
JEZEBEL-240	CSEWG FRB 21	Pu (20.1 at.% ^{240}Pu)	None	Sphere
VERA-11A	CSEWG FRB 2	Pu (4.9 at.% ^{240}Pu)	Normal U, Steel	Cylinder

* Preliminary specifications

** Identifier not yet assigned

Table 2. Reactivity Impact of Probability-Table Treatment

Benchmark Name	k_{eff} or k_{∞}		Δk
	with Probability Tables	without Probability Tables	
GODIVA	0.9968 ± 0.0003	0.9970 ± 0.0003	-0.0002 ± 0.0004
ZPR-9-34	1.0126 ± 0.0007	1.0134 ± 0.0006	-0.0008 ± 0.0009
VERA-1B	1.0024 ± 0.0007	1.0018 ± 0.0007	0.0006 ± 0.0010
ZEUS	1.0180 ± 0.0007	1.0172 ± 0.0008	0.0008 ± 0.0011
HISS/HUG	1.0317 ± 0.0004	1.0318 ± 0.0005	-0.0001 ± 0.0006
ZPR-III-2	1.0040 ± 0.0006	1.0011 ± 0.0006	0.0029 ± 0.0008
ZPR-III-6F	1.0067 ± 0.0006	1.0022 ± 0.0006	0.0045 ± 0.0008
Graphite-Reflected IEU Sphere	1.0047 ± 0.0006	1.0051 ± 0.0006	-0.0004 ± 0.0008
ZPR-III-12	1.0073 ± 0.0006	1.0049 ± 0.0006	0.0024 ± 0.0008
ZEBRA-2	1.0032 ± 0.0006	0.9954 ± 0.0005	0.0078 ± 0.0008
ZPR-III-11	1.0166 ± 0.0005	1.0142 ± 0.0004	0.0024 ± 0.0006
BIG TEN	1.0112 ± 0.0005	1.0069 ± 0.0005	0.0043 ± 0.0007
ZEBRA-8H	1.0443 ± 0.0004	1.0299 ± 0.0004	0.0144 ± 0.0006
SHEBA-II	1.0061 ± 0.0008	1.0074 ± 0.0008	-0.0013 ± 0.0011
JEZEBEL	0.9978 ± 0.0003	0.9971 ± 0.0003	0.0007 ± 0.0004
JEZEBEL-240	0.9984 ± 0.0003	0.9983 ± 0.0003	0.0001 ± 0.0004
VERA-11A	0.9919 ± 0.0007	0.9897 ± 0.0007	0.0022 ± 0.0010