Testing of ^{239}Pu

Nuclear Physics Working Group Meeting

November 17-18, 2011

Brookhaven National Laboratory

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Overview

- Performance of new evaluated files are continually being tested and reported, particularly, with each major release of national libraries such as ENDF, JEFF, JENDL, CENDL, ROSFOND, ….
- Typically, the performance of the principal nuclides (e.g., "Big Three + Two", moderators, structurals, etc.
- Specifically, the performance of ^{239}Pu as evaluated in the major libraries is well documented.
  - For example, see the "Big Paper":
    M. B. Chadwick *et al*, "ENDF/B-VII.0: Next Generation Evaluated Nuclear Data Library for Nuclear Science and Technology," Nuclear Data Sheets, **107** (2006) 2931–3060.
  - Or, the "Big Paper, Redux":
    M. B. Chadwick *et al*, "ENDF/B-VII.1 Nuclear Data for Science and Technology: Cross Sections, Covariances, Fission Product Yields and Decay Data," to be published, Nuclear Data Sheets, **112** (2011) .
  - Or, the "Companion to the Big Paper":
    S. C. van der Marck, "Benchmarking ENDF/B-VII.0," Nuclear Data Sheets, **107**, 3061 (2006).

Overview

- Beta version of new ^{239}Pu evaluation tested and discussed at Cross Section Evaluation Working Group Meeting, November 1-3, 2010, Santa Fe, NM

- Conclusion: Little change in performance of ^{239}Pu in FAST, INTER, and THERM systems

- Led to formation of WPEC Subgroup 34: "Coordinated Evaluation of ^{239}Pu in the Resonance Region," (Coordinator: Leal; Monitor: McKnight)

Testing new ^{239}Pu Evaluation with THERM Benchmarks

ICSBEP Benchmark	Case Number	ENDF/B-VII.0 k-eff	±	σ	ENDF/A ^{239}Pu k-eff	±	σ	Benchmark or As-Built k-eff	±	σ	Δk-eff Old - New	±	σ
PST-001-1	1	1.00551	±	0.00029	1.00549	±	0.00028	1.00000	±	0.00500	-0.00002	±	0.00040
PST-001-2	2	1.00781	±	0.00029	1.00743	±	0.00030	1.00000	±	0.00500	-0.00038	±	0.00042
PST-001-3	3	1.01070	±	0.00029	1.01033	±	0.00029	1.00000	±	0.00500	-0.00037	±	0.00041
PST-001-4	4	1.00479	±	0.00029	1.00449	±	0.00028	1.00000	±	0.00500	-0.00030	±	0.00040
PST-001-5	5	1.00852	±	0.00029	1.00850	±	0.00028	1.00000	±	0.00500	-0.00002	±	0.00040
PST-001-6	6	1.00966	±	0.00030	1.00965	±	0.00029	1.00000	±	0.00500	-0.00001	±	0.00042
PST-002-1	1	1.00428	±	0.00027	1.00422	±	0.00028	1.00000	±	0.00470	-0.00006	±	0.00039
PST-002-3	3	1.00414	±	0.00027	1.00357	±	0.00027	1.00000	±	0.00470	-0.00057	±	0.00038
PST-002-5	5	1.00893	±	0.00028	1.00997	±	0.00028	1.00000	±	0.00470	0.00104	±	0.00040
PST-002-6	6	1.00525	±	0.00028	1.00557	±	0.00029	1.00000	±	0.00470	0.00032	±	0.00040
PST-002-7	7	1.00791	±	0.00028	1.00781	±	0.00028	1.00000	±	0.00470	-0.00010	±	0.00040
PST-003-1	1	1.00272	±	0.00025	1.00262	±	0.00025	1.00000	±	0.00470	-0.00010	±	0.00035
PST-003-4	4	1.00444	±	0.00025	1.00485	±	0.00026	1.00000	±	0.00470	0.00041	±	0.00036
PST-003-6	6	1.00613	±	0.00026	1.00589	±	0.00027	1.00000	±	0.00470	-0.00024	±	0.00037
PST-004-1	1	1.00392	±	0.00025	1.00410	±	0.00024	1.00000	±	0.00470	0.00018	±	0.00035
PST-004-6	6	1.00148	±	0.00025	1.00139	±	0.00026	1.00000	±	0.00470	-0.00009	±	0.00036
PST-004-9	9	1.00019	±	0.00026	1.00050	±	0.00026	1.00000	±	0.00470	0.00031	±	0.00037
PST-004-10	10	1.00157	±	0.00026	1.00194	±	0.00025	1.00000	±	0.00470	0.00037	±	0.00036
PST-004-11	11	1.00050	±	0.00026	1.00118	±	0.00026	1.00000	±	0.00470	0.00068	±	0.00037
PST-006-1	1	1.00031	±	0.00023	1.00026	±	0.00024	1.00000	±	0.00350	-0.00005	±	0.00033
PST-007-2	2	1.00933	±	0.00030	1.00926	±	0.00028	1.00000	±	0.00470	-0.00007	±	0.00041
PST-007-3	3	1.00315	±	0.00029	1.00362	±	0.00030	1.00000	±	0.00470	0.00047	±	0.00042
PST-007-7	7	1.00543	±	0.00030	1.00517	±	0.00028	1.00000	±	0.00470	-0.00026	±	0.00041
PST-007-10	10	1.00012	±	0.00029	1.00064	±	0.00028	1.00000	±	0.00470	0.00052	±	0.00040
PST-009-3	3	1.01902	±	0.00012	1.01911	±	0.00012	1.00000	±	0.00330	0.00009	±	0.00017
PST-011-16	16	1.01692	±	0.00029	1.01672	±	0.00029	1.00000	±	0.00520	-0.00020	±	0.00041
PST-011-18	18	0.99951	±	0.00026	0.99950	±	0.00026	1.00000	±	0.00520	-0.00001	±	0.00037

Testing new ^{239}Pu Evaluation with INTER & FAST Benchmarks

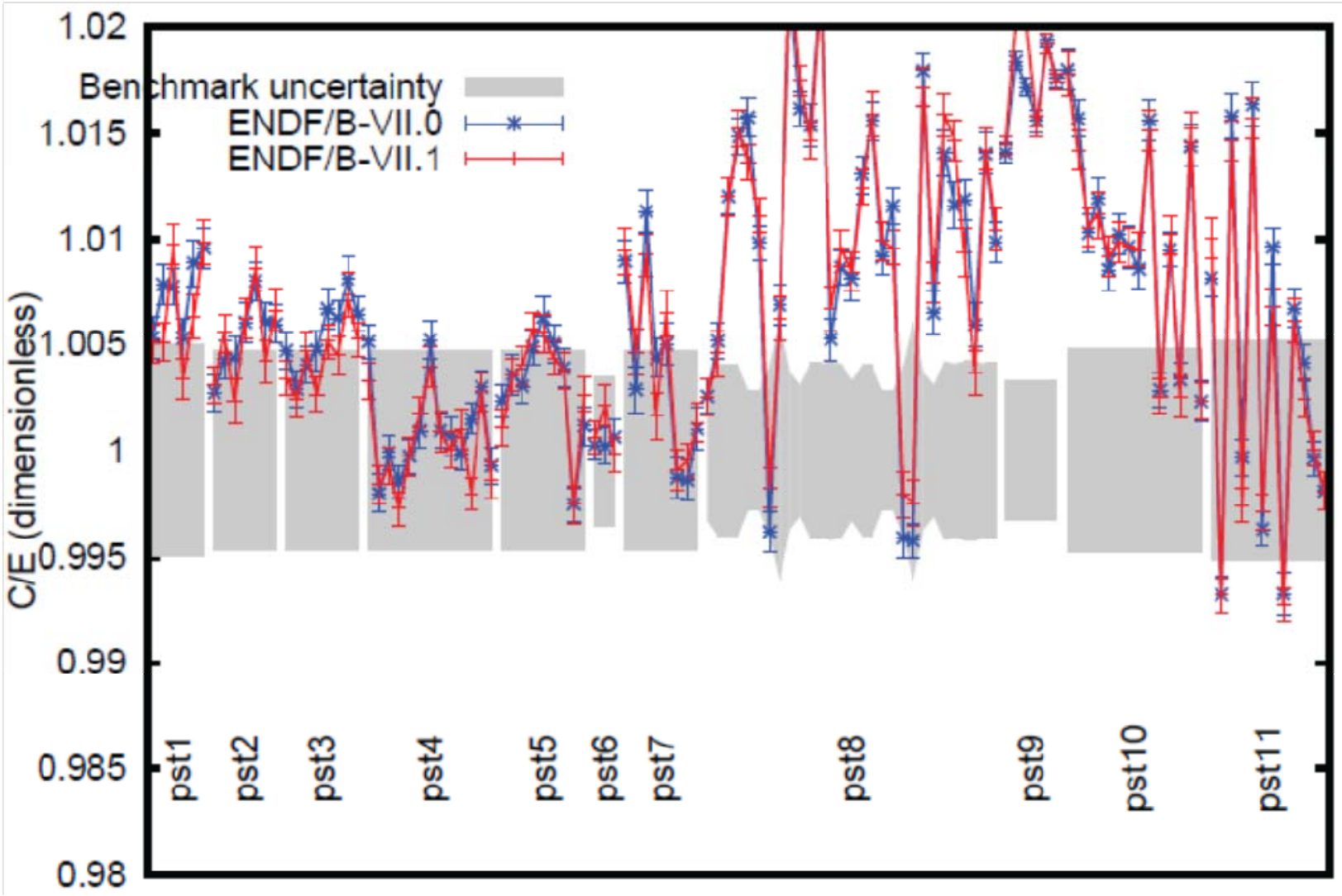
ICSBEP Benchmark	Case Number	ENDF/B-VII.0 k-eff	±	σ	ENDF/A ^{239}Pu k-eff	±	σ	Benchmark or As-Built k-eff	±	σ	Δk-eff Old - New	±	σ
PCI-001		1.01153	±	0.00017	1.01189	±	0.00017	1.00000	±	0.01100	0.00036	±	0.00024
PMI-002		1.02693	±	0.00024	1.02711	±	0.00024	0.98690	±	0.00260	0.00018	±	0.00034
MMF-001		0.99965	±	0.00018	0.99934	±	0.00019	1.00000	±	0.00160	-0.00031	±	0.00026
MMF-002-1	1	1.00544	±	0.00022	1.00484	±	0.00021	1.00000	±	0.00420	-0.00060	±	0.00030
MMF-002-2	2	1.00547	±	0.00021	1.00542	±	0.00022	1.00000	±	0.00440	-0.00005	±	0.00030
MMF-002-3	3	1.00586	±	0.00022	1.00555	±	0.00021	1.00000	±	0.00480	-0.00031	±	0.00030
PMF-001		0.99981	±	0.00018	1.00015	±	0.00019	1.00000	±	0.00200	0.00034	±	0.00026
PMF-005		1.00954	±	0.00020	1.00948	±	0.00020	1.00000	±	0.00130	-0.00006	±	0.00028
PMF-006		1.00076	±	0.00022	1.00099	±	0.00022	1.00000	±	0.00300	0.00023	±	0.00031
PMF-009		1.00469	±	0.00020	1.00464	±	0.00020	1.00000	±	0.00270	-0.00005	±	0.00028
PMF-010		0.99948	±	0.00020	0.99957	±	0.00020	1.00000	±	0.00180	0.00009	±	0.00028
PMF-011		1.00008	±	0.00023	1.00039	±	0.00024	1.00000	±	0.00100	0.00031	±	0.00033
PMF-018		0.99620	±	0.00021	0.99645	±	0.00020	1.00000	±	0.00300	0.00025	±	0.00029
PMF-022		0.99839	±	0.00019	0.99837	±	0.00019	1.00000	±	0.00140	-0.00002	±	0.00027
PMF-023		0.99976	±	0.00019	0.99978	±	0.00019	1.00000	±	0.00200	0.00002	±	0.00027
PMF-024		1.00159	±	0.00021	1.00155	±	0.00020	1.00000	±	0.00200	-0.00004	±	0.00029
PMF-025		0.99904	±	0.00020	0.99910	±	0.00019	1.00000	±	0.00200	0.00006	±	0.00028
PMF026		0.99841	±	0.00020	0.99857	±	0.00020	1.00000	±	0.00240	0.00016	±	0.00028
PMF-027		1.00307	±	0.00025	1.00282	±	0.00024	1.00000	±	0.00220	-0.00025	±	0.00035
PMF-028		0.99919	±	0.00021	0.99924	±	0.00020	1.00000	±	0.00220	0.00005	±	0.00029
PMF-029		0.99528	±	0.00018	0.99502	±	0.00019	1.00000	±	0.00200	-0.00026	±	0.00026
PMF-030		1.00265	±	0.00020	1.00312	±	0.00019	1.00000	±	0.00210	0.00047	±	0.00028
PMF-031		1.00434	±	0.00023	1.00446	±	0.00024	1.00000	±	0.00210	0.00012	±	0.00033
PMF-032		0.99850	±	0.00019	0.99891	±	0.00019	1.00000	±	0.00200	0.00041	±	0.00027

Performance of ENDF/B-VII.1

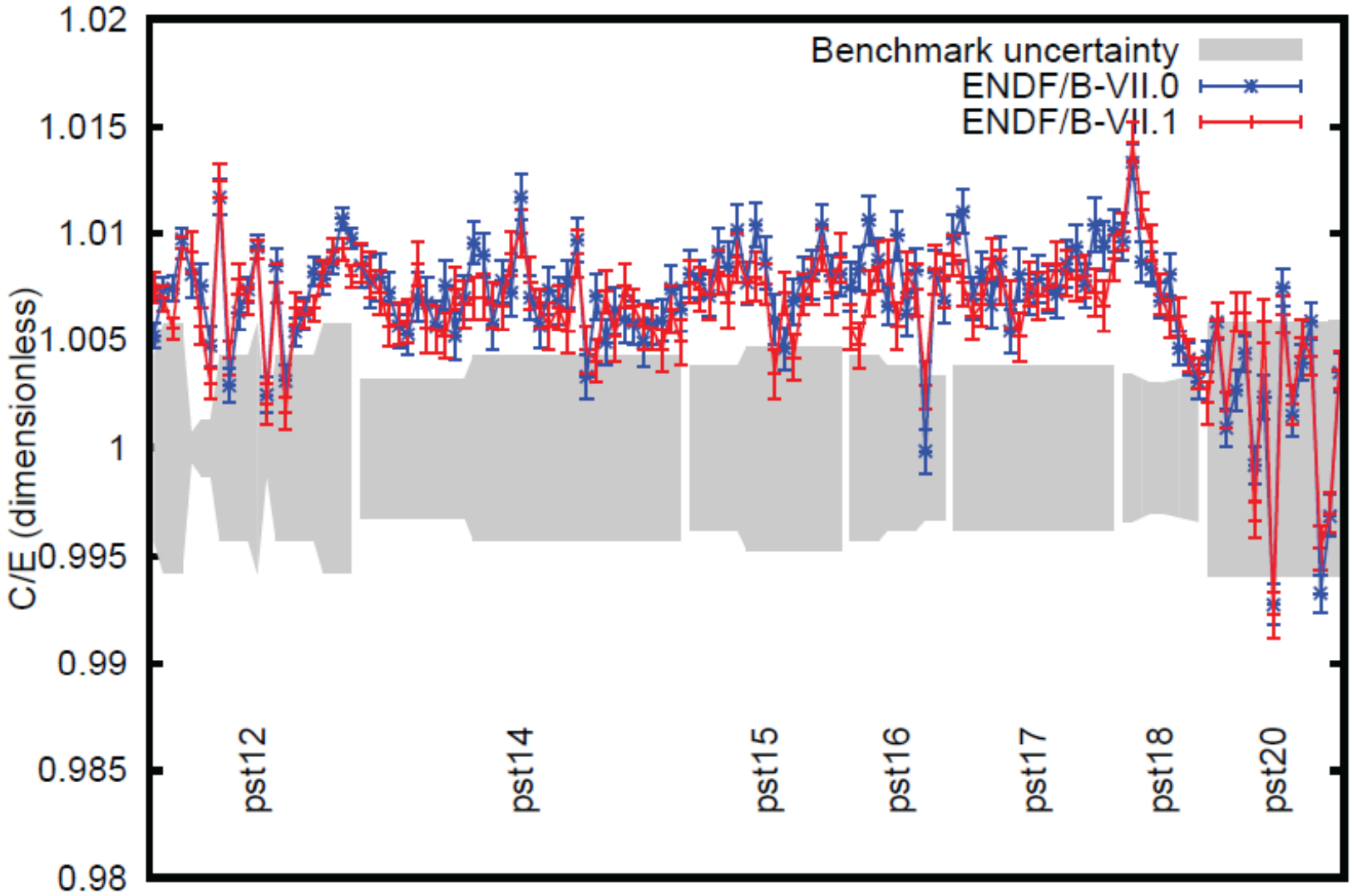
- The following results are extracted from the soon-to-be-released ENDF/B-VII.1 “Big Paper”

- In particular, the following 6 plots summarize the results for Pu-fuelled systems contributed by S. C. van der Marck

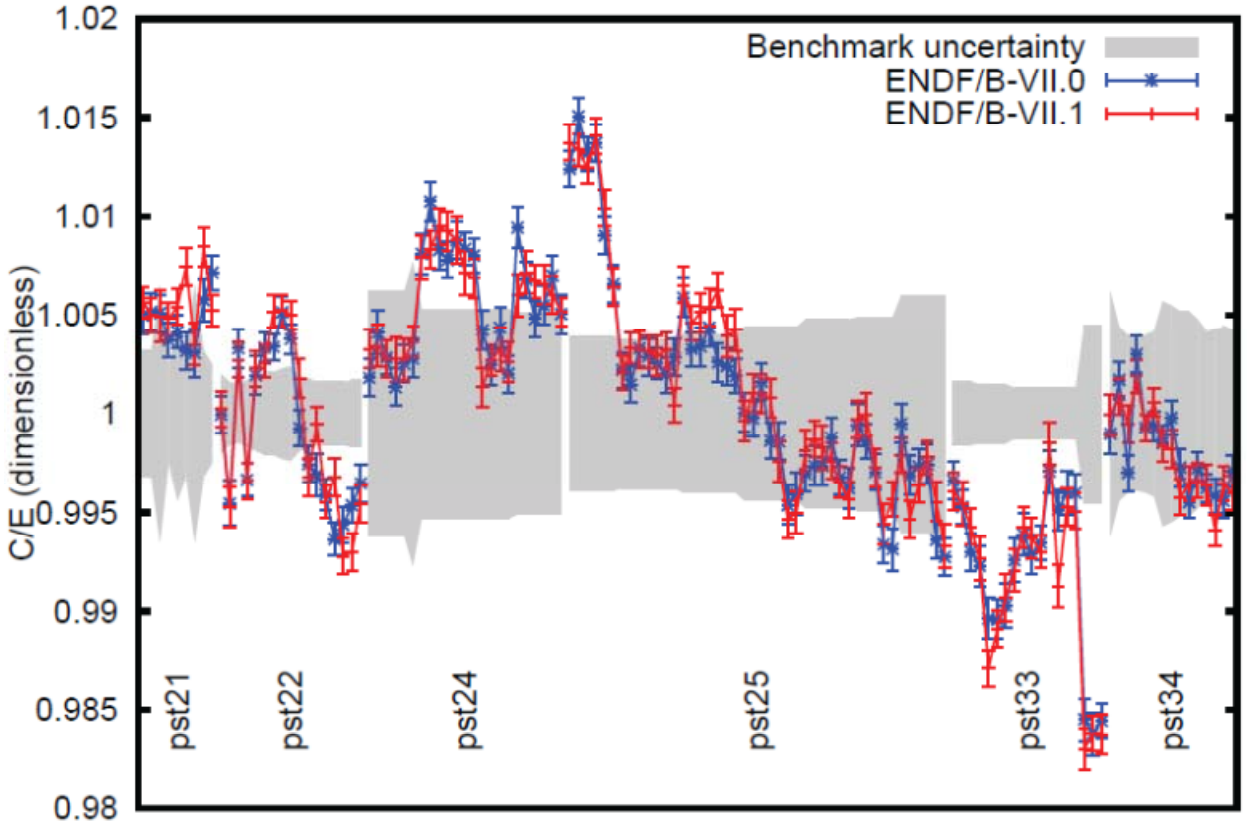
MCNP Calculations for ICSBEP PU-SOL-THERM 1/3



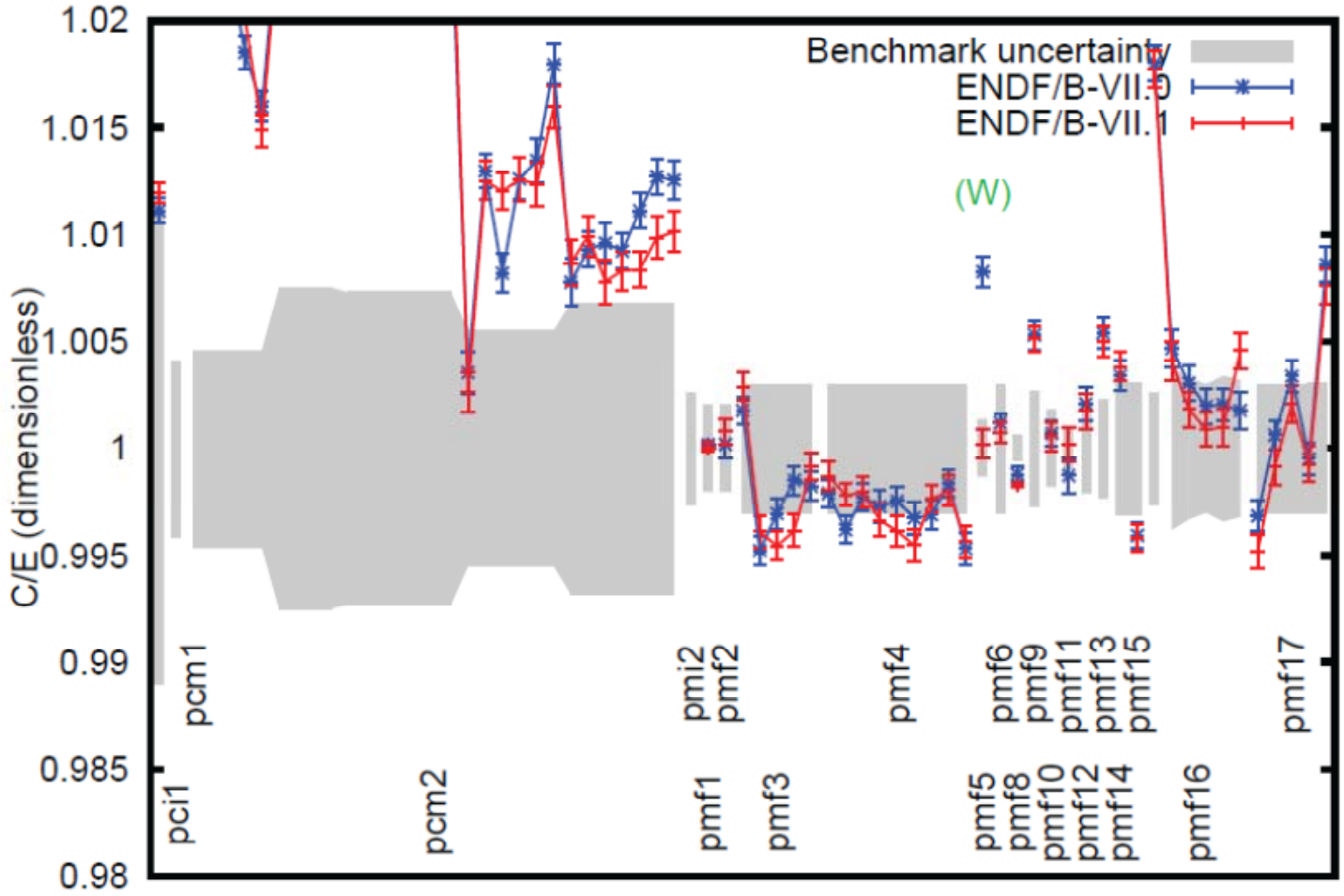
MCNP Calculations for ICSBEP PU-SOL-THERM 2/3



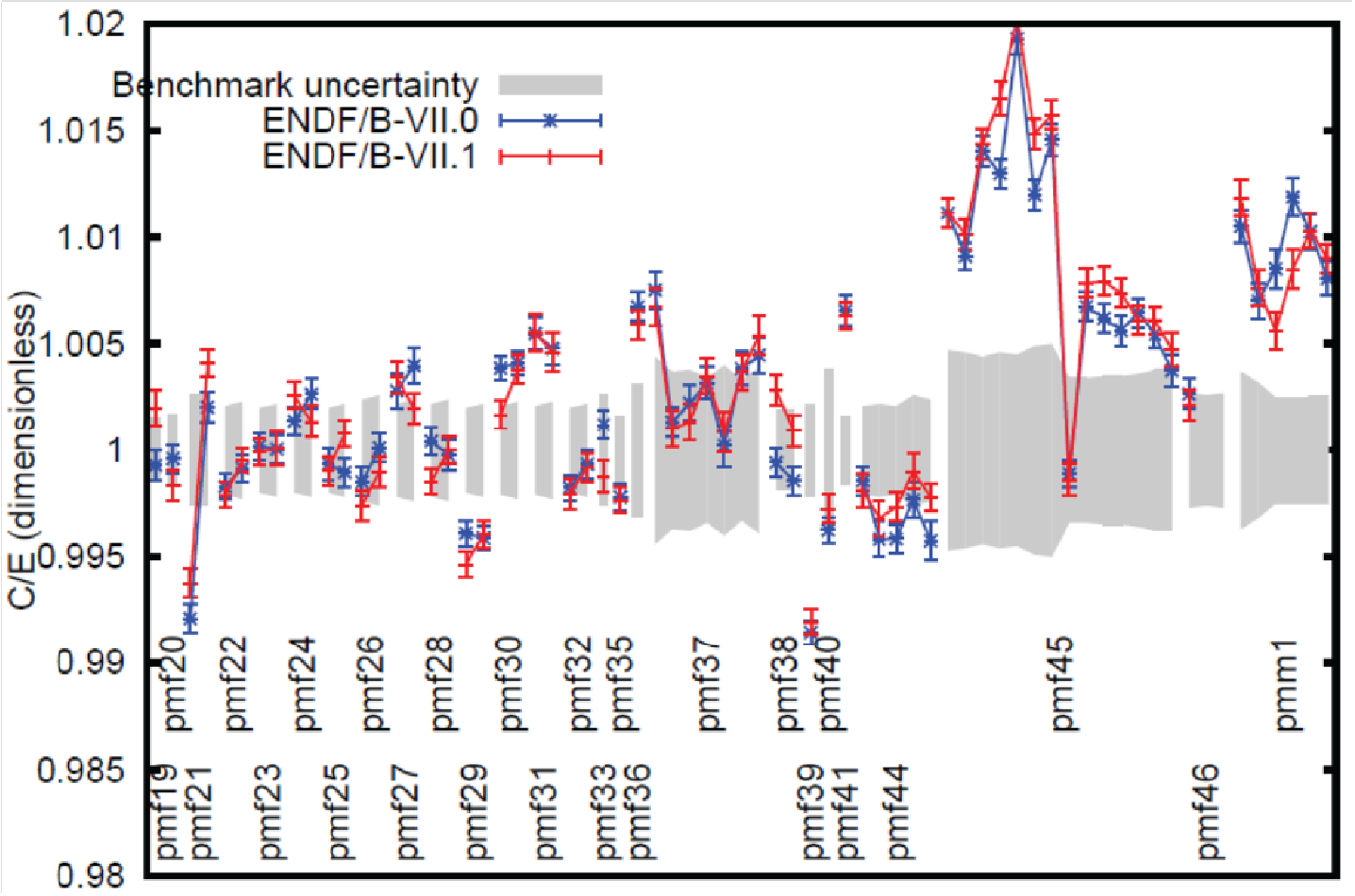
MCNP5 Calculations for ICSBEP PU-SOL-THERM 3/3



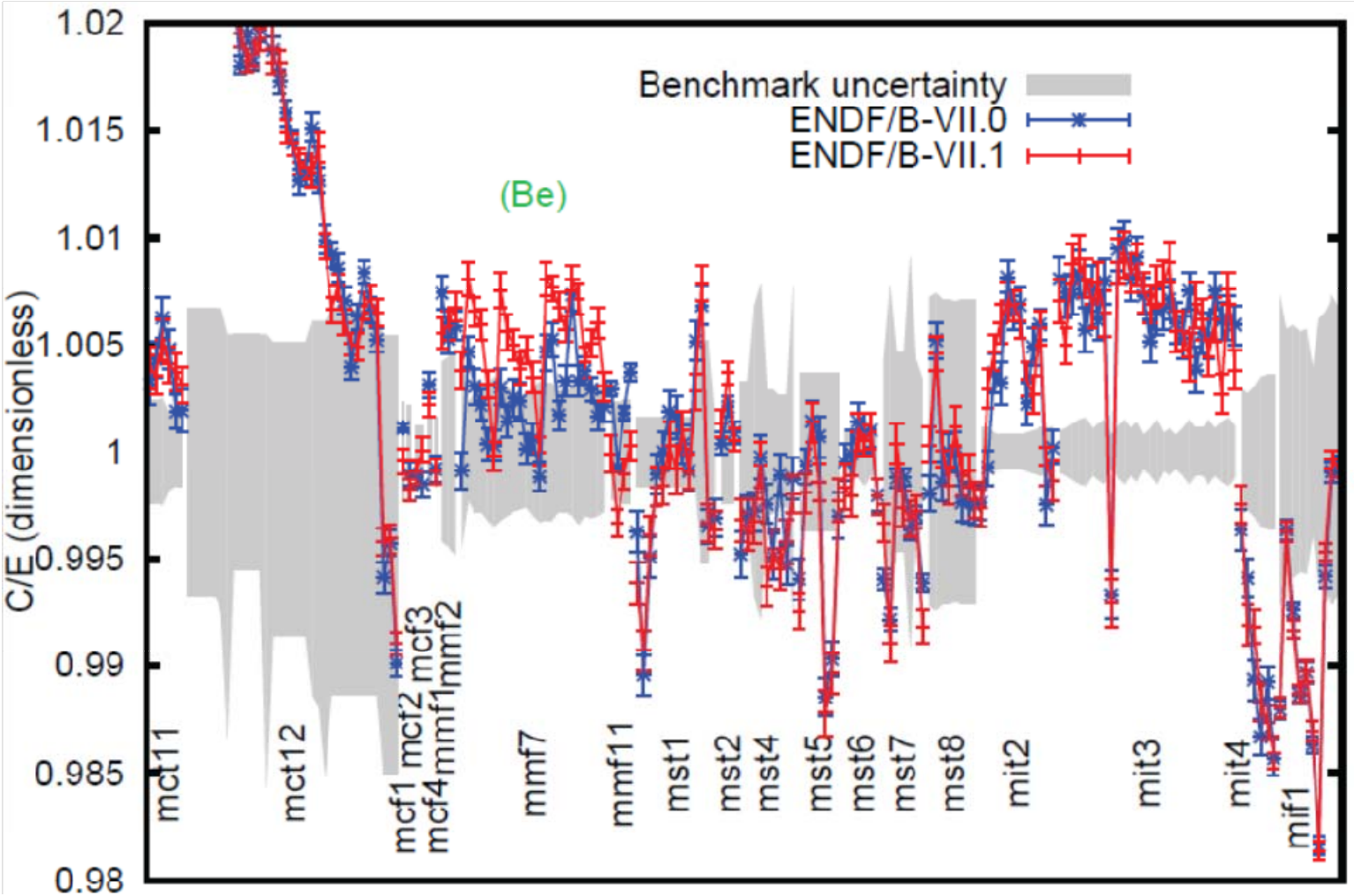
MCNP5 Calculations for ICSBEP PU-COMP-INTER, PU-COMP-MIXED, PU-MET-INTER, PU-COMP-FAST



MCNP5 Calculations for ICSBEP PU-MET-FAST, PU-MET-MIXED



MCNP5 Calculations for ICSBEP PU-MET-FAST, PU-MET-MIXED

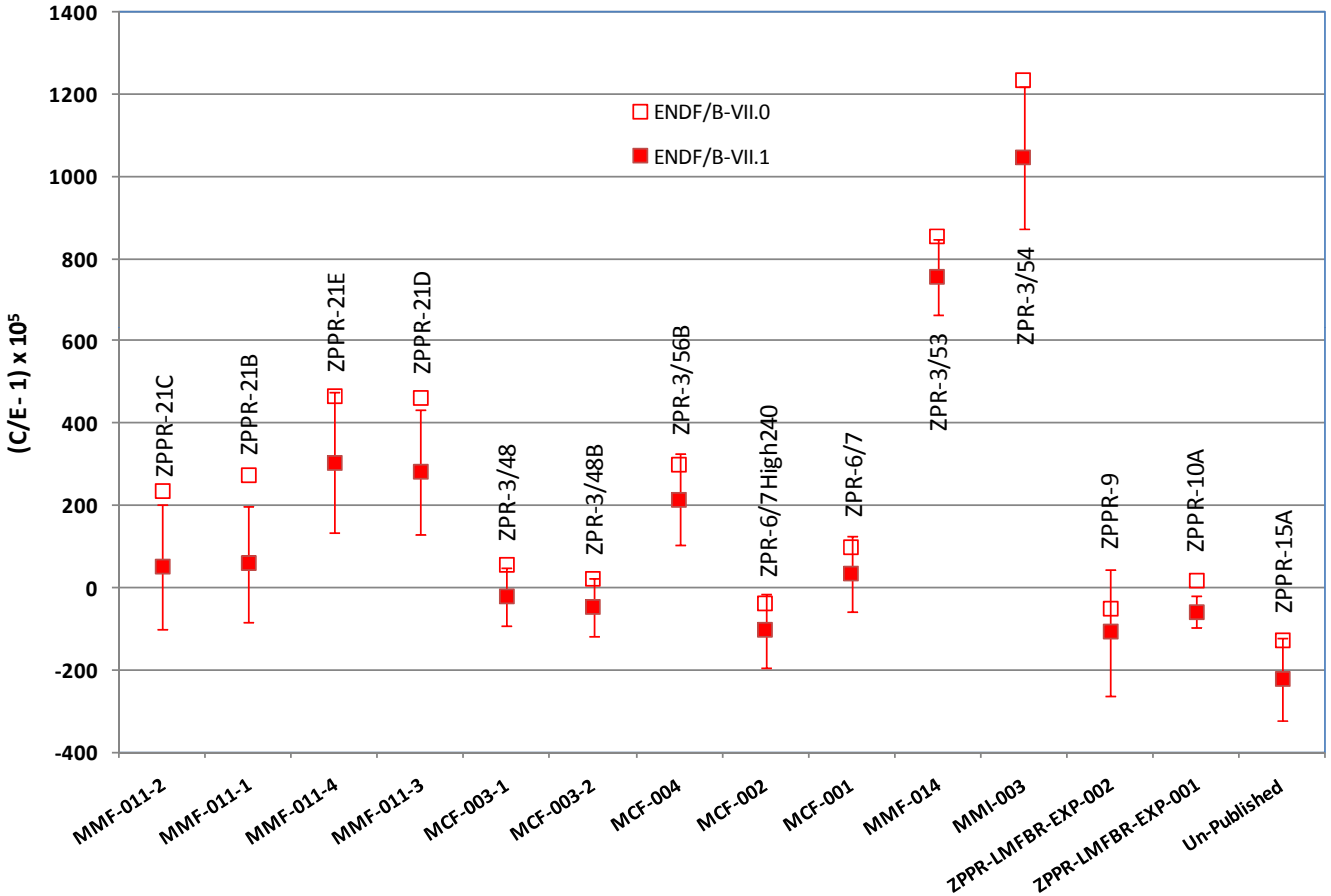


Summary of VII.1 Performance for Criticality

- Virtually no change (in an average sense) between –VII.1 and –VII.0 data
- The GOOD, BAD and the UGLY:
  the FAST, the THERMAL, and the INTER/MIXED

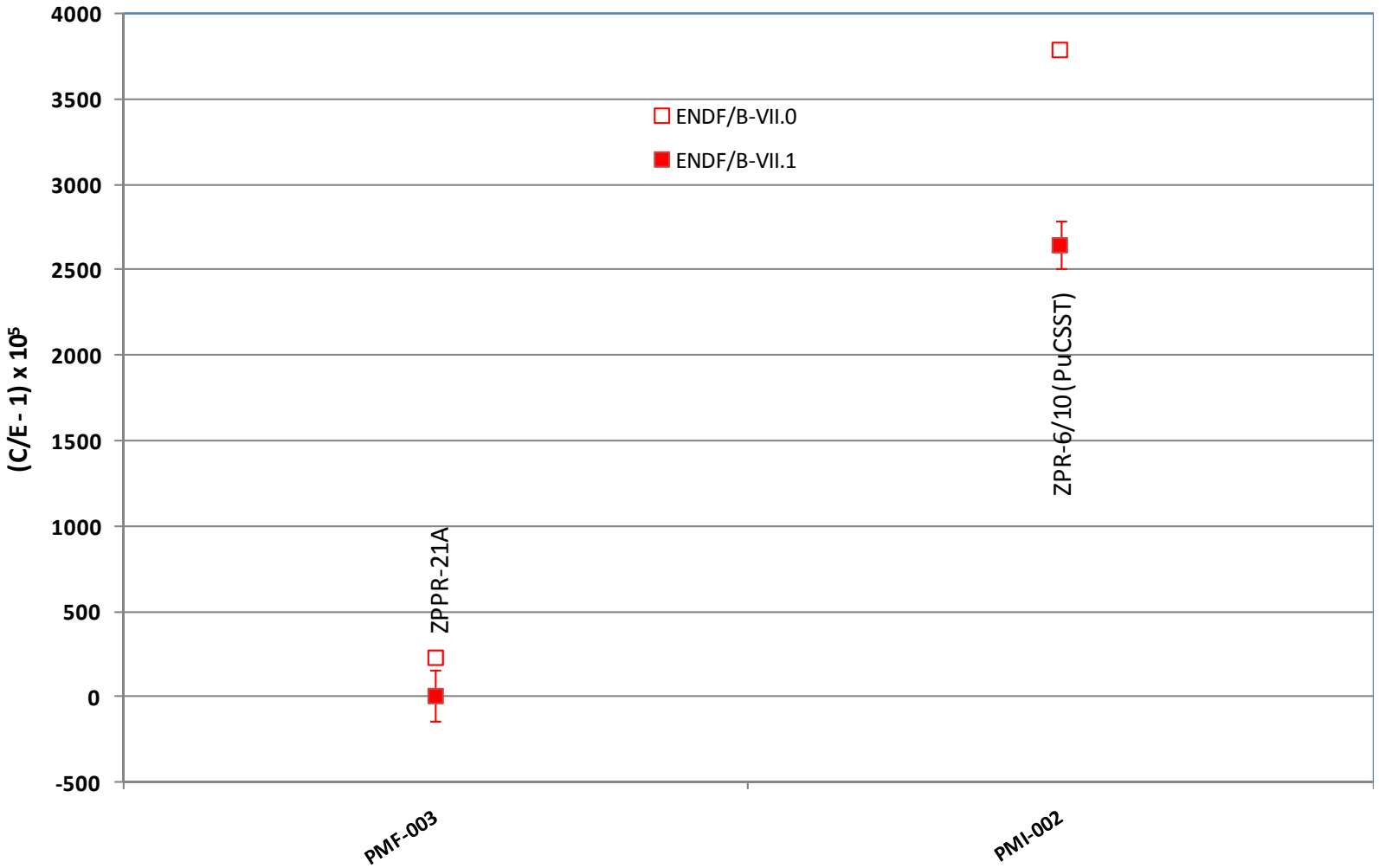
	PCI	PCM	PMI	PMF	PMM	PST
VII.1	1195	1945±921	3763	173±532	880±197	442±608
VII.0	1111	1961±872	4626	168±512	937±167	451±610
	MCT	**MCF**	**MMF**	**MST**		
VII.1	401±1640	-17±135	426±309	-213±368		
VII.0	427±1609	12±176	258±224	-182±356		

MCNP5 Calculations with "As-built" Models for MIXED (Pu,U) FAST and INTER ZPR/ZPPR Assemblies



For the mixed-(Pu,U) assemblies, 14 calculated k_{eff}'s were reduced with the ENDF/B-VII.1 data by approximately 60-215 pcm. The average bias for the 14 assemblies with ENDF/B-VII.0 data is 271 pcm; the average bias with ENDF/B-VII.1 data is 156 pcm. The biases for ZPR-3/53 and ZPR-3/54 with ENDF/B-VII.0 data are 855 and 1233 pcm, respectively; and with ENDF/B-VII.1 data are 755 and 1047 pcm, respectively. The average bias for the other 12 assemblies with ENDF/B-VII.0 data is 142 pcm; the average bias with ENDF/B-VII.1 data is 31 pcm.

MCNP5 Calculations with "As-built" Models for Pu Metal FAST and INTER ZPR/ZPPR Assemblies



Average Values of C/E - 1 (in pcm) for ENDF/B-VII.1 according to Fuel Type in ZPR/ZPPR Assemblies

Fuel Type	# of Expts	ENDF/B-VII.0 mean values, pcm	ENDF/B-VII.1 mean values, pcm	Δk Difference (VII.1 - VII.0)
		C/E-1 ± σ	C/E-1 ± σ	Δk ± σ
Pu-Metal [a]	2	2005 ± 143	1327 ± 143	-679 ± 10
Mixed (Pu,U)	14	271 ± 114	156 ± 114	-120 ± 9
HEU	13	1042 ± 201	463 ± 201	-576 ± 9
IEU	9	270 ± 115	134 ± 115	-151 ± 7

[a] Mean values are perhaps not meaningful for these assemblies because there were only 2 experiments with distinctly different energy spectra and performance

Most discrepant benchmark analysis with ENDF/B-VII.0 ZPR-6/10 (A clean Pu/C/SST assembly)

PU-MET-INTER-002	Pu/C/Steel core – Steel reflector, Iron radial reflector – 6.25 v/o Pu / 37.5 v/o C / 56.25 v/o steel unit cell

	k_{eff}	C – E (in % Δk)
Experiment	1.0016 ± 0.0013	
ENDF/B-V	1.0009 ± 0.0007	-0.07 ± 0.15
ENDF/B-VI	1.0380 ± 0.0005	3.64 ± 0.14
ENDF/B-VII.0	1.0392 ± 0.0003	3.76 ± 0.13

- Note that there was NO bias with ENDF/B-V data.
- Using ENDF/B-VII.0 data with ENDF/B-V data for ^{239}Pu : reduces C/E by 1.1% Δk
- Using ENDF/B-VII.0 data with ENDF/B-V data for Cr : reduces C/E by 1.7% Δk
- Using ENDF/B-VII.0 data with ENDF/B-V data for Mn : reduces C/E by 0.6% Δk
- Using ENDF/B-VII.0 data with new ORNL data for Mn : reduces C/E by 0.6% Δk