NRG Petten Benchmark Calculations with ENDF/B-VII.0

-- a summary for the Nov 2006 CSEWG meeting

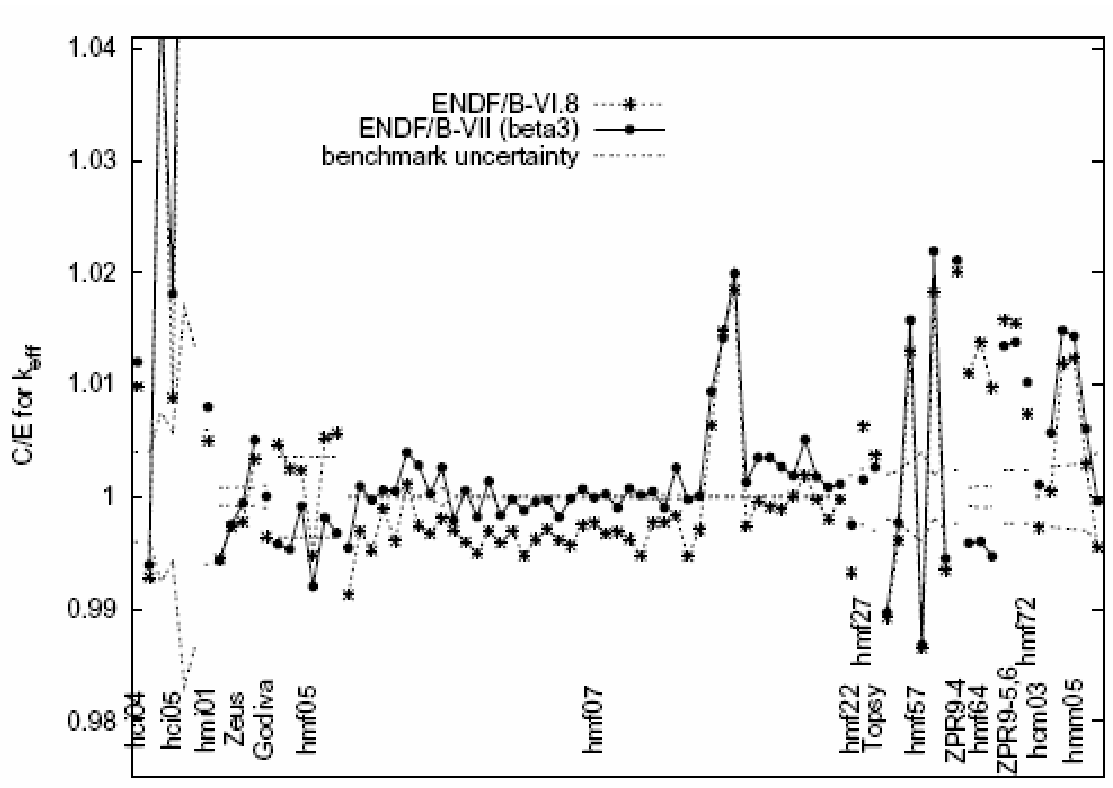
All numbers and figures in this summary are based on the work of Steven C. van der Marck.

His work is to be published in Nuclear Data Sheets.

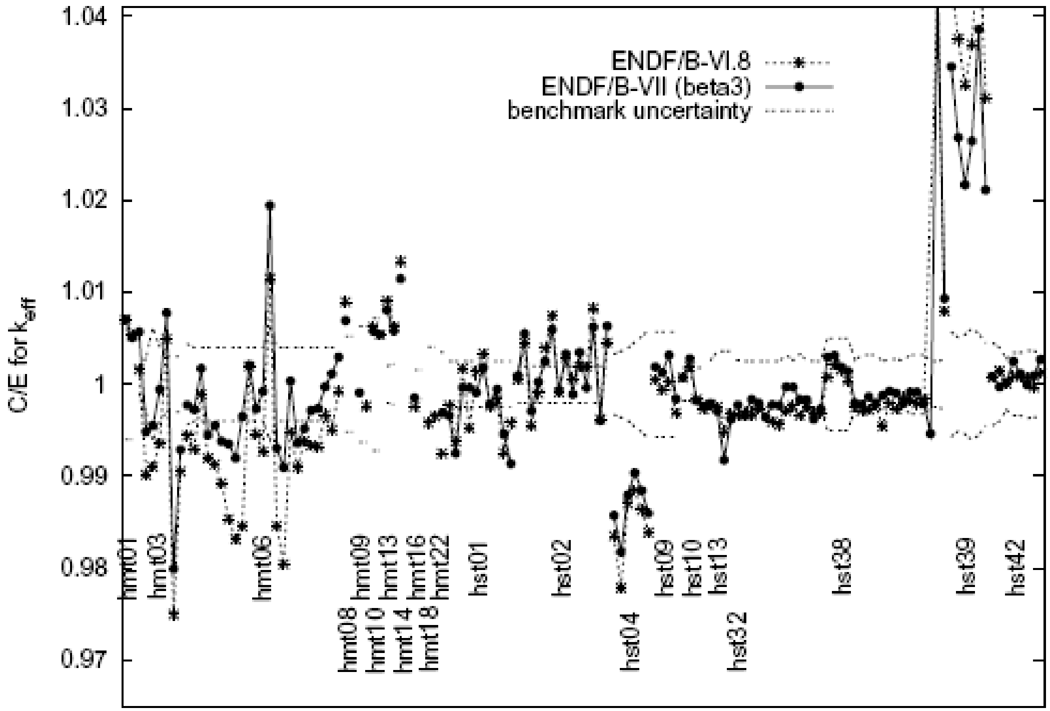
NRG Petten Benchmark Calculations with ENDF/B-VII.0

- **Analysis of ~730 ICSBEP benchmarks, shielding analyses, and β_{eff} calculations.**
- **The Petten work represents the largest single contribution to the ENDF validation effort.**
- **Provided full set of results (632 crits) based on the β1 libraries.**
  - **Valuable early feedback including a list of evaluations with processing problems.**
  - **Valuable early confirmation of extensive LANL results.**
- **Provided even more extensive sets of results (730 crits) based on β3 libraries.**

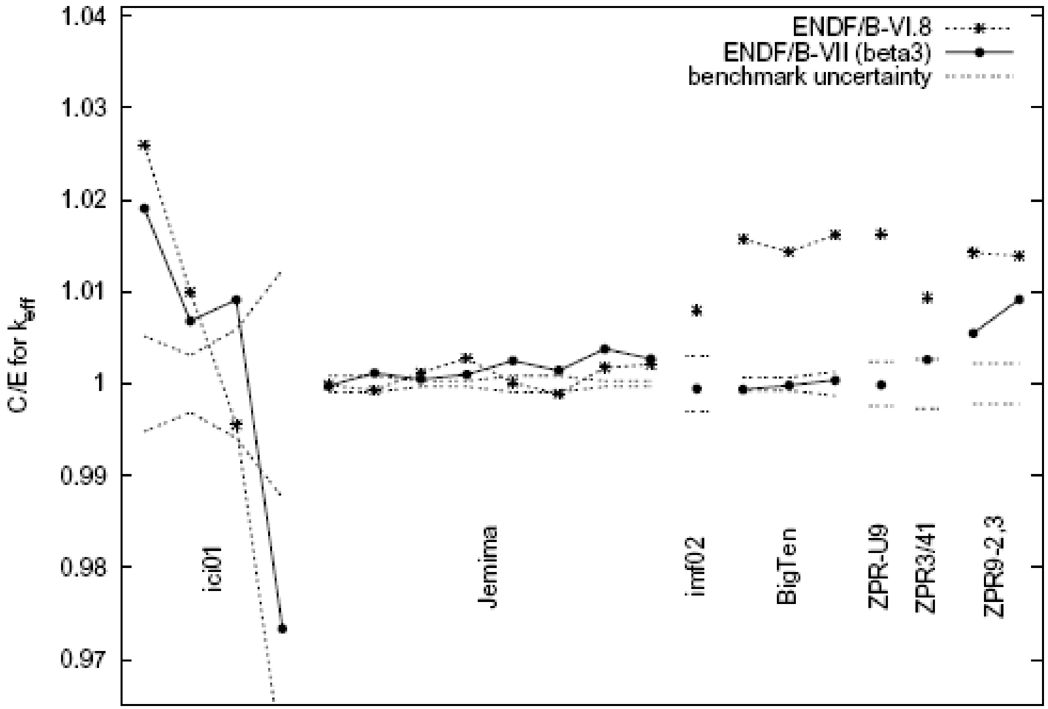
Results for the HEU benchmarks with a fast or intermediate spectrum



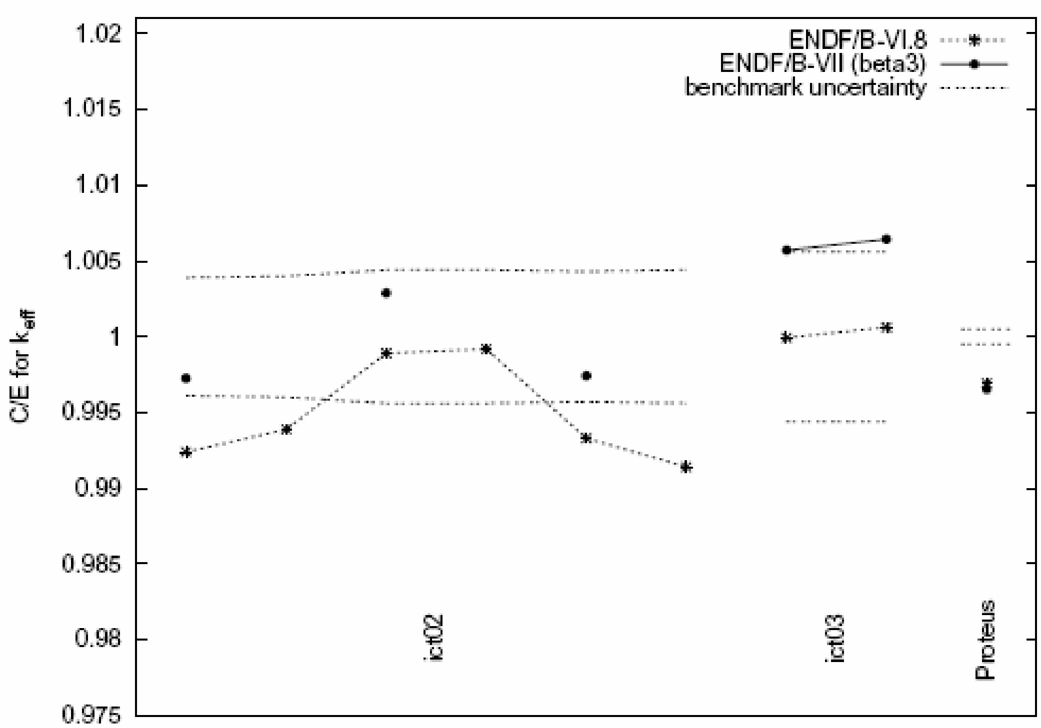
Results for the HEU benchmarks with a thermal spectrum



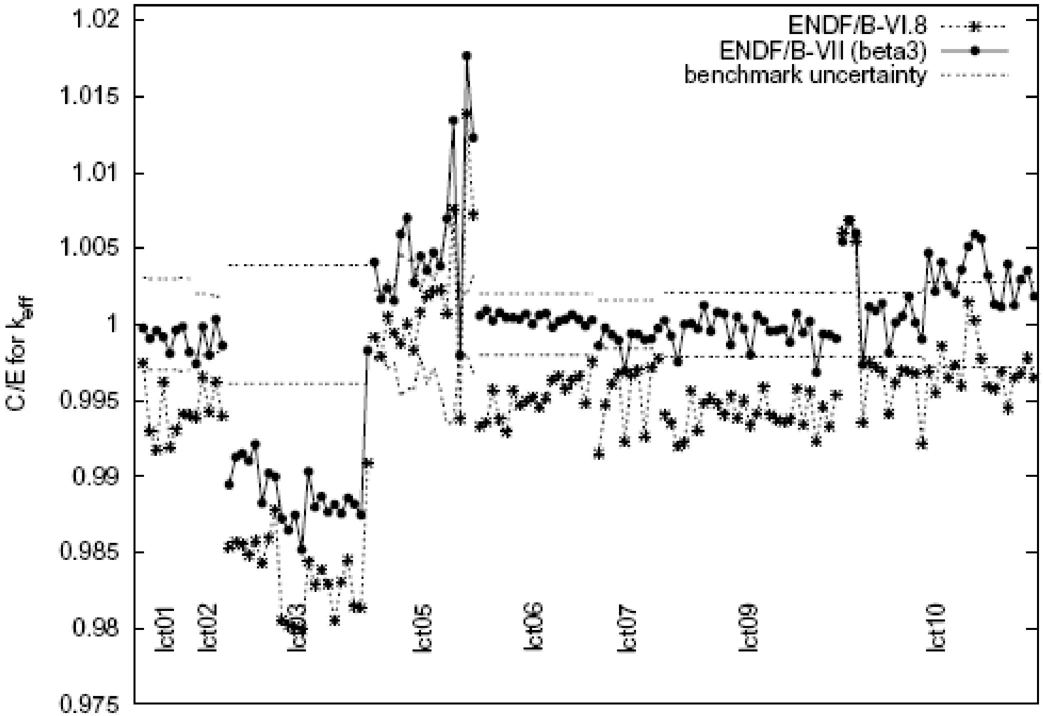
Results for the IEU benchmarks with a fast or intermediate spectrum



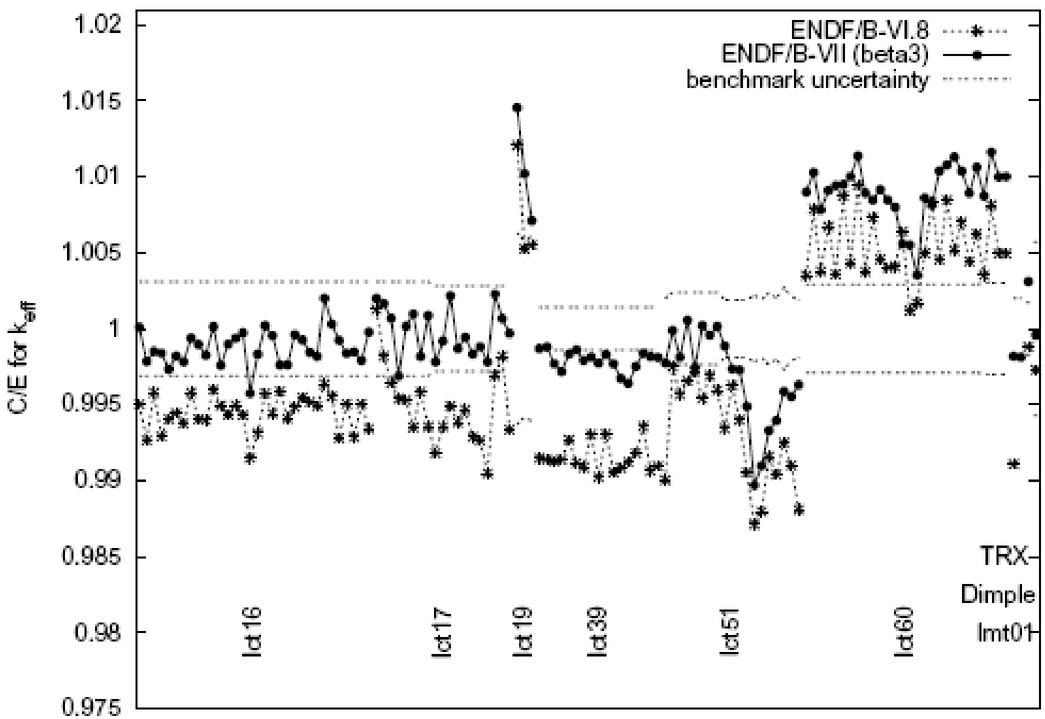
Results for the IEU benchmarks with a thermal spectrum



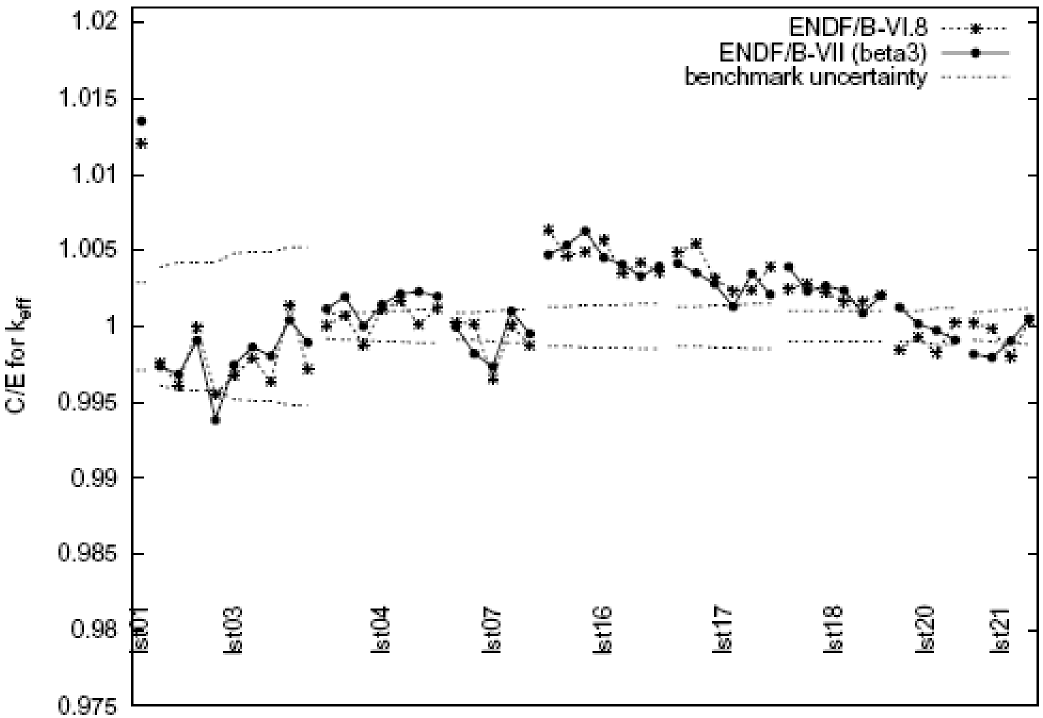
Results for the LEU benchmarks with a thermal spectrum



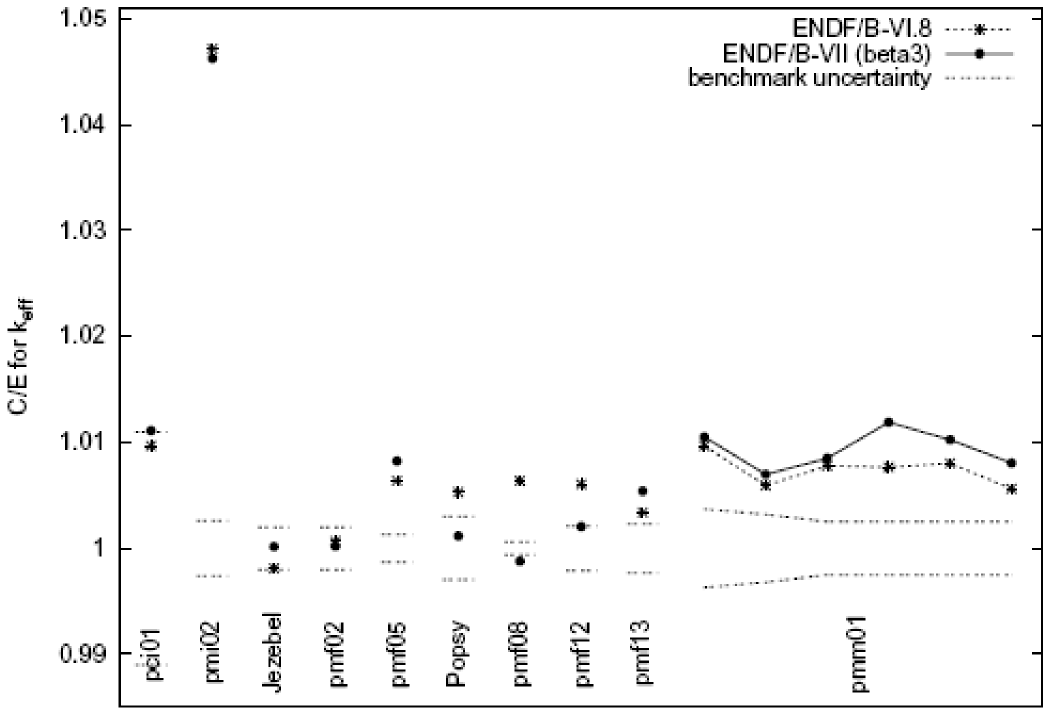
Results for the LEU benchmarks with a thermal spectrum (continued)



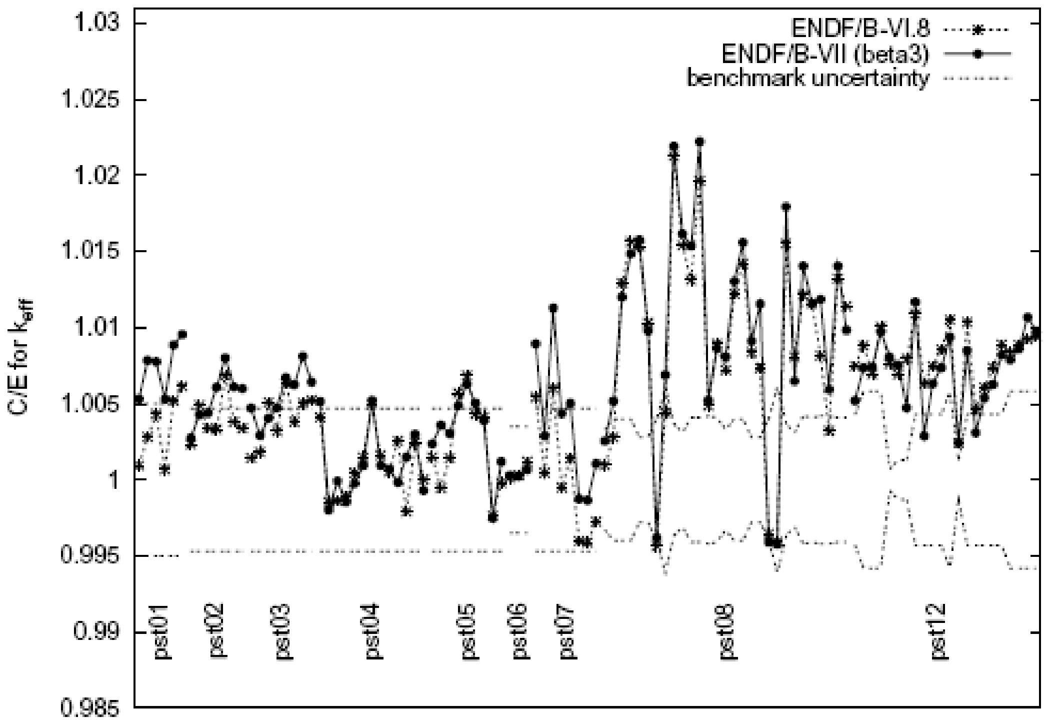
Results for the LEU benchmarks with a thermal spectrum (continued)



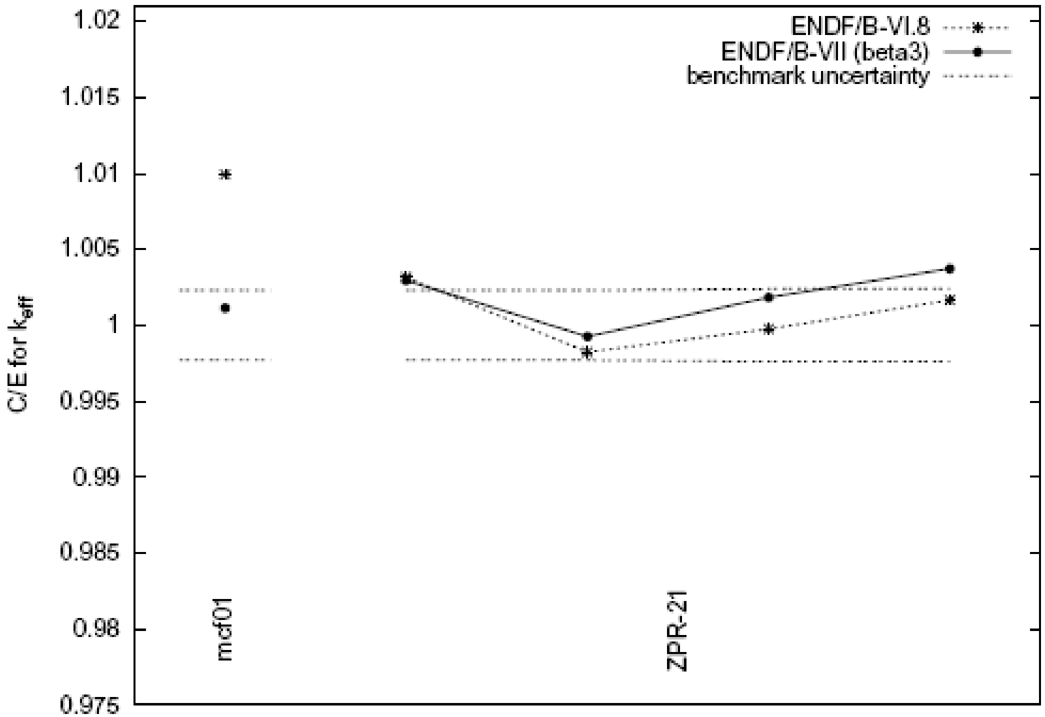
Results for the PU benchmarks with a fast, intermediate, or mixed spectrum



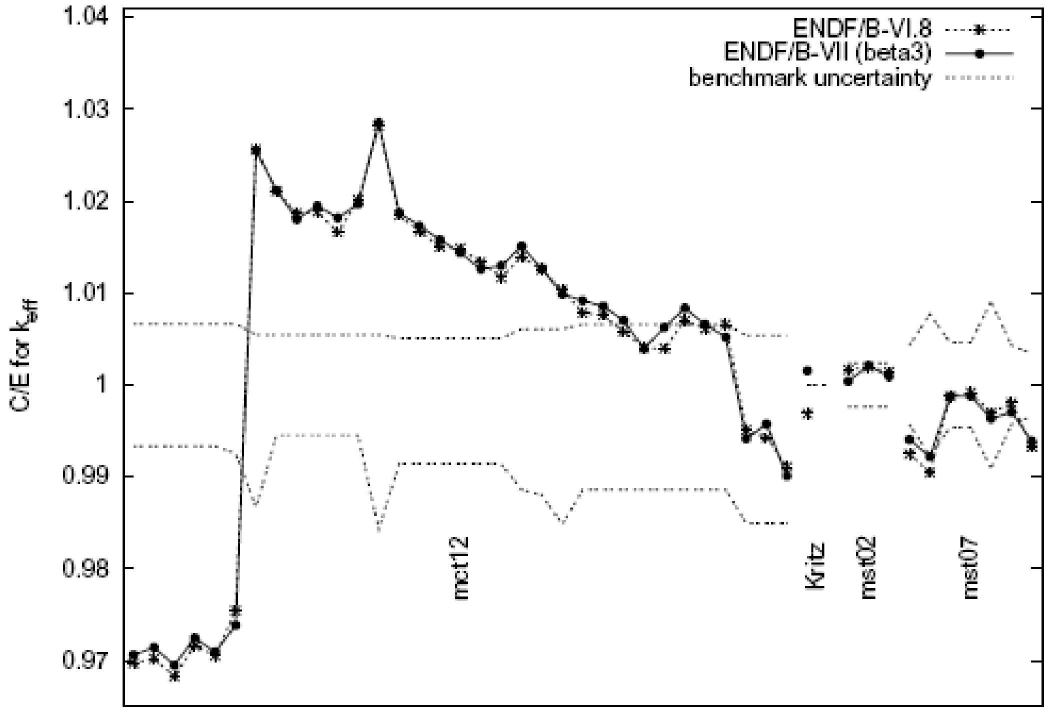
Results for the PU benchmarks with a thermal spectrum



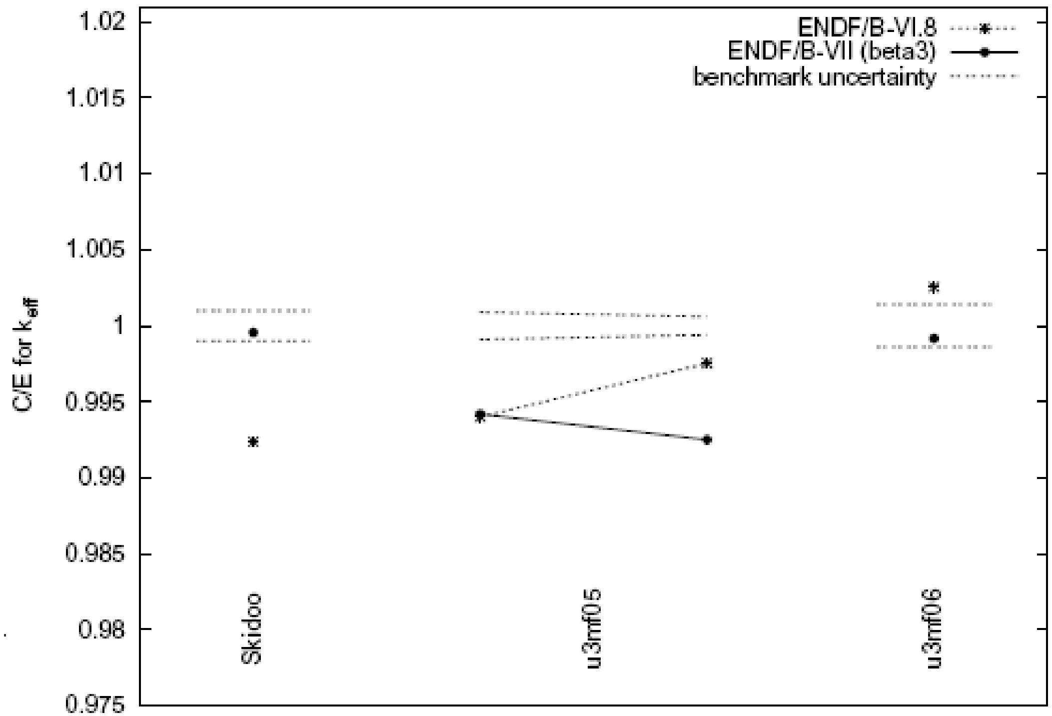
Results for the MIX benchmarks with a fast spectrum



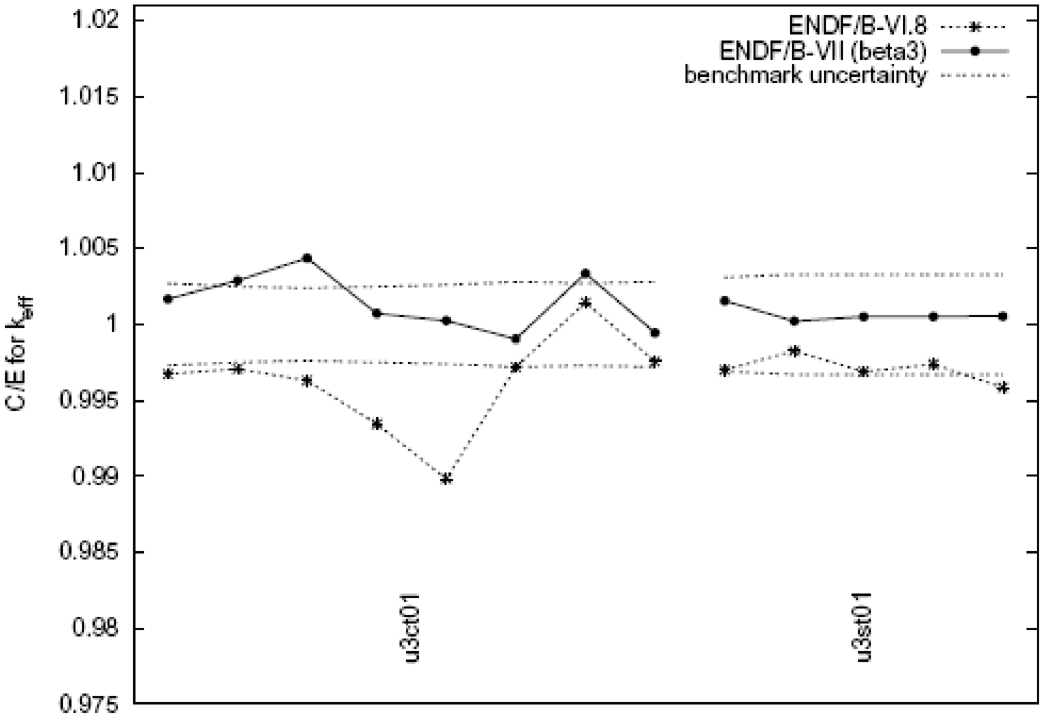
Results for the MIX benchmarks with a thermal spectrum



Results for the U233 benchmarks with a fast spectrum



Results for the U233 benchmarks with a thermal spectrum



The number of benchmarks per main ICSBEP category for thermal/intermediate/fast/mixed neutron spectrum

	COMP				MET				SOL	total
	therm	inter	fast	mixed	therm	inter	fast	mixed	therm	
LEU	257				1				49	307
IEU	6	4					16			26
HEU		6		1	41	5	66	5	87	211
MIX	34		1				4		10	49
PU		1				1	7	6	105	120
U233	8						4		5	17
total	305	11	1	1	42	6	97	11	256	730

The average values for C/E –1 (in pcm) for ENDF/B-VI.8 per main ICSBEP benchmark category

	COMP				MET				SOL
	therm	inter	fast	mixed	therm	inter	fast	mixed	therm
LEU	−452				−270				107
IEU	−299	−238					712		
HEU		1442		−273	−411	−42	186	462	142
MIX	377		978				69		−257
PU		967				4654	375	745	531
U233	−380						−338		−292

The average values for C/E –1 (in pcm) for ENDF/B-VII.0 (beta3) per main ICSBEP benchmark category

	COMP				MET				SOL
	therm	inter	fast	mixed	therm	inter	fast	mixed	therm
LEU	17				−41				123
IEU	103	219					182		
HEU		1744		104	−51	88	147	812	108
MIX	428		110				193		−254
PU		1110				4565	229	936	620
U233	146						−364		66

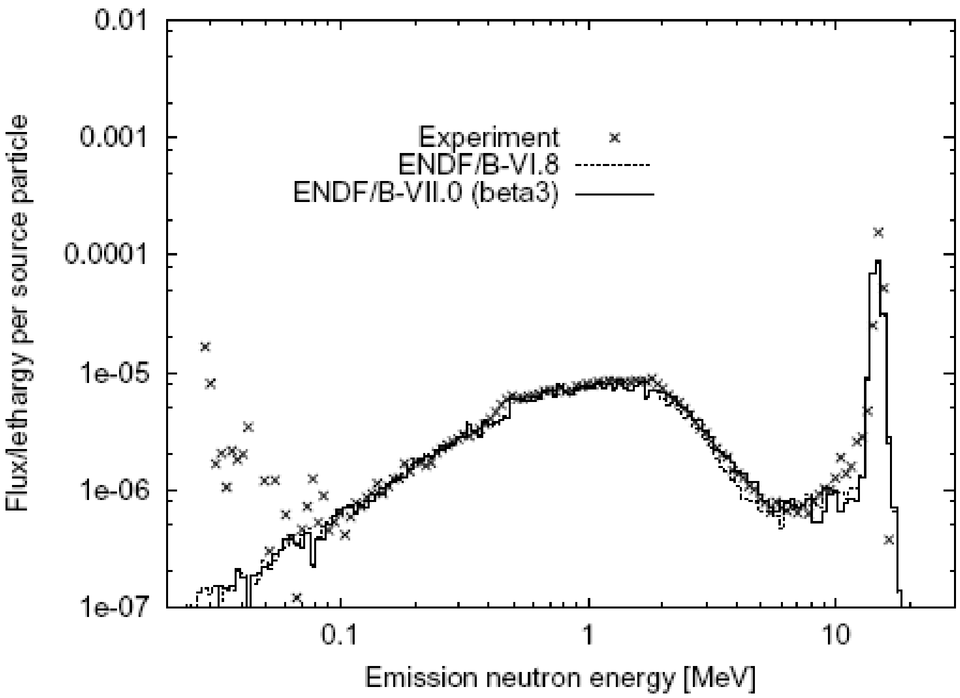
The shift in the average values for C/E –1 (in pcm) going from ENDF/B-VI.8 to ENDF/B-VII.0 (beta3) per main ICSBEP benchmark category

	COMP				MET				SOL
	therm	inter	fast	mixed	therm	inter	fast	mixed	therm
LEU	469				229				16
IEU	402	457					−530		
HEU		302		377	360	130	−39	350	−34
MIX	51		−868				124		3
PU		143				−89	−146	191	89
U233	526						−26		358

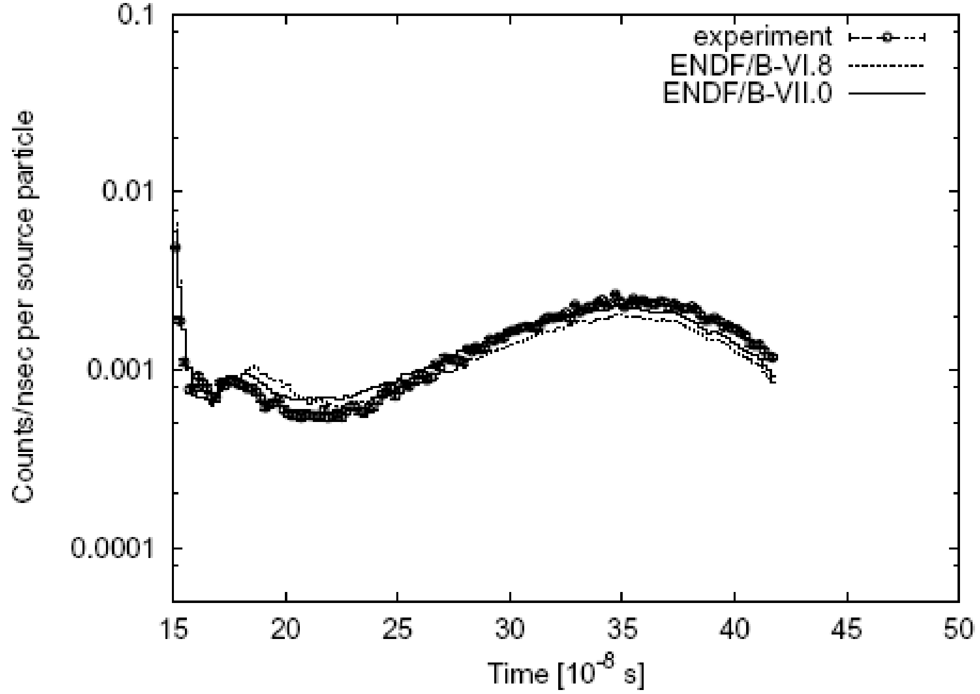
Shielding Benchmarks

- **Oktavian**
  - **Measured leakage current spectrum from D-T source through spherical piles of Al, Co, Cr, Cu, LiF, Mo, Mn, Si, Ti, W, Zr**
- **Fusion Neurtonics Source (FNS)**
  - **Measured leakage current spectrum from D-T source through slabs of Be, C, N, O, Fe, Pb**
- **LLNL Pulsed Spheres**
  - **Measured leakage current spectrum from D-T source through spheres of ^{6}Li, ^{7}Li, Be, C, N, O, Mg, Al, Ti, Fe, Pb, D_2O, H_2O, Concrete, Polyethylene, Teflon**
- **NIST Water Spheres**
  - **Cf source at center of H_2O sphere**

Neutron spectrum for the FNS, Pb, d=20cm benchmark at 12.2° angle



Neutron spectrum for the LLNL Pulsed Sphere, Pb (1.4 mfp) benchmark, angle=39°

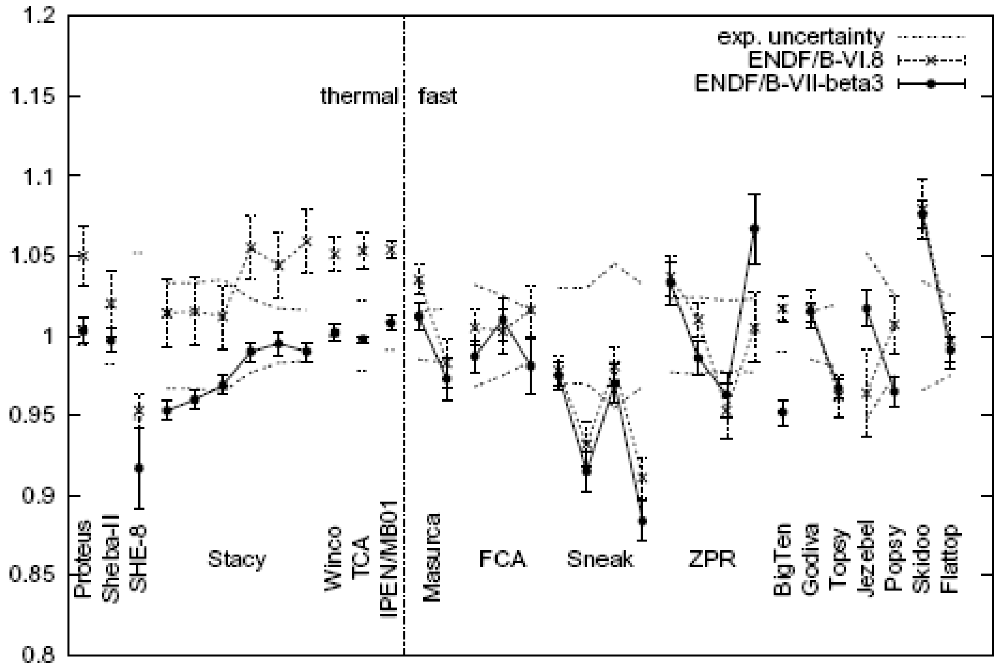


Shielding Results Summary

- **Generally changes are small between VI.8 and VII.0 data.**

- **Significant changes for:**
  - **Mg (worse)**
  - **Zr (much better)**
  - **Mo (better)**
  - **Ti (slightly better above 1 MeV; slightly worse below 1 MeV)**
  - **Pb (small improvements)**

C/E for β_{eff} for many benchmark systems. The systems are roughly ordered with respect to the average energy at which fission takes place, from low energy (left) to high (right)



The experimental and calculated β_{eff} (in pcm). The uncertainty for C/E includes only the statistical uncertainty of the calculation.

	Experiment	Calculation		C/E
		ENDF/B-VI.8	ENDF/B-VII.0	ENDF/B-VII.0
TCA	771±17	812±9	769.2±1.3	0.998±0.002
IPEN	742±7	782±4	747.6±4.0	1.008±0.005
Masurca_R2	721±11	746±7	729.3±6.9	1.012±0.009
Masurca_Z2	349±6	343±5	339.5±4.5	0.973±0.013
FCA-XIX-1	742±24	746±8	732.4±7.5	0.987±0.010
FCA-XIX-2	364±9	365±5	367.6±4.8	1.010±0.013
FCA-XIX-3	251±4	255±4	246.2±4.1	0.981±0.017
Sneak-9C1	758±24	741±7	739.2±7.0	0.975±0.009
Sneak-7A	395±12	368±5	361.6±4.7	0.915±0.013
Sneak-7B	429±13	421±5	416.0±4.9	0.970±0.012
Sneak-9C2	426±19	388±5	376.4±4.8	0.884±0.013
Zpr-Heu	667±15	692±9	689.3±8.9	1.033±0.013
Zpr-U9	725±17	732±8	714.9±8.0	0.986±0.011
Zpr-Mox	381±9	363±6	367.0±5.1	0.963±0.014
Zpr-Pu	222±5	223±5	236.9±5.2	1.067±0.022
Godiva	659±10	670±8	668.7±4.0	1.015±0.006
Topsy	665±13	640±8	643.2±3.8	0.967±0.006
Jezebel	194±10	187±5	197.3±2.1	1.017±0.011
Popsy	276±7	278±5	266.4±2.4	0.965±0.009
Skidoo	290±10	313±6	312.1±2.7	1.076±0.009
Flattop-23	360±9	359±6	356.9±2.8	0.991±0.008

The experimental and calculated α (in s⁻1). The uncertainty for C/E includes only the statistical uncertainty of the calculation.

	Experiment	Calculation		C/E
		ENDF/B-VI.8	ENDF/B-VII.0	ENDF/B-VII.0
Proteus	3.60±0.02	3.78±0.07	3.61±0.03	1.003±0.008
SHE-8	6.53±0.34	6.22±0.07	5.99±0.15	0.917±0.025
Sheba-II	200.3±3.6	204.3±4.3	199.73±1.39	0.997±0.007
Stacy-029	122.7±4.1	124.4±2.6	116.88±0.75	0.953±0.006
Stacy-033	116.7±3.9	118.5±2.5	111.99±0.71	0.960±0.006
Stacy-046	106.2±3.7	107.5±2.2	102.87±0.64	0.969±0.006
Stacy-030	126.8±2.9	133.8±2.7	125.47±0.81	0.990±0.006
Stacy-125	152.8±2.6	159.5±3.3	152.06±0.99	0.995±0.007
Stacy-215	109.2±1.8	115.6±2.3	108.11±0.68	0.990±0.006
Winco	1109.3±0.3	1166.±13.	1111.24±5.54	1.002±0.005
BigTen	$(1.17\pm0.01)\times10^5$	$(1.19\pm0.01)\times10^5$	$(1.11\pm0.01)\times10^5$	0.952±0.008

β_{eff} Results Summary

- **Very nice improvement for the 2 low-enriched thermal values versus VI.8**

- **Generally small changes for the fast U, Pu and mixed assemblies versus VI.8 with some small improvements and some slightly worse agreement**

- **Very little change for the U-233 systems**

A Few Summary Comments

- **We have utilized the "agreement" of many benchmark calculations to define the "quality" of our evaluations; now is the time to go back and drill down on the "discrepant" values and try to determine sources of the biases.**

- **It would be ideal to analyze a rather complete and diverse set of benchmarks using sensitivity/uncertainty methods. This would help identify "discrepant" *differential* and *integral data.* This is becoming more realizable (new covariance data, new computer capabilities, new incentives, …)**

- **We have benefited greatly from the Petten (van der Marck) contribution to ENDF; we will also benefit (ourselves and others) by running our "validation suites" with new versions of JEFF, JENDL, … as they become available.**