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Analysis of the proposed ENDF/B-VII.1(β4) Nuclear Data Library

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Cross Section Evaluation Working Group Meeting
Nov. 15 - 17, 2011
Brookhaven National Laboratory

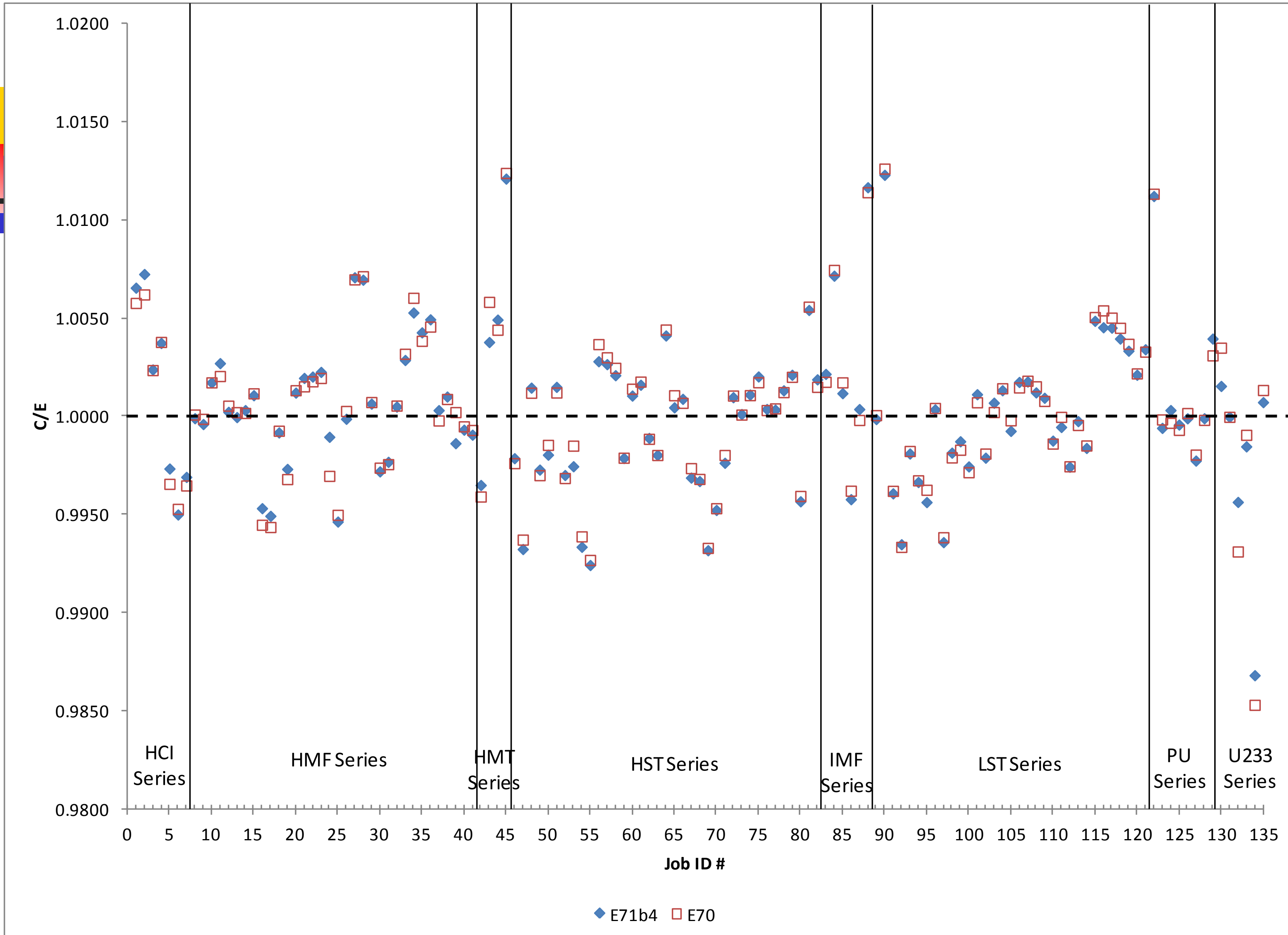
Outline of Analyses

- Suite of 135 ICSBEP Models run using 2 libraries:
  - ENDF/B-VII.0 and ENDF/B-VII.1(β4).
  - Population-average eigenvalues and standard deviations, Goodness-of-Fit parameters.
  - Trend analysis using ATLF & ATFF, for HST and LST series.
- ICT-003 "Triga" Model
  - Comparison of various zirconium evaluations and effects on k-eff.
- All calculations performed with MC21.

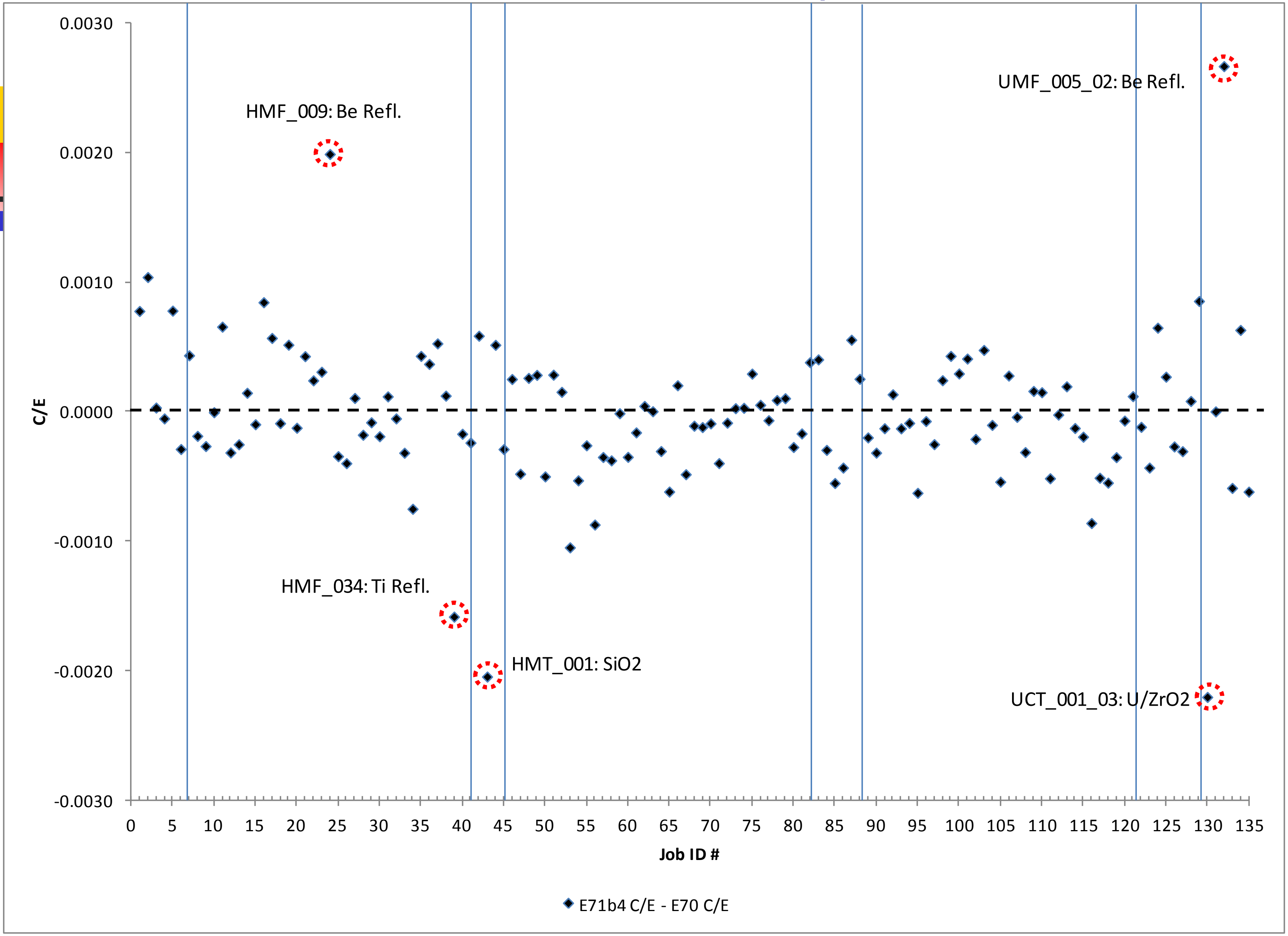
ICSBEP Suite Models

Model #	Benchmark Name	Model k-eff (ICSBEP)	Exp. Unc. (ICSBEP)	Model #	Benchmark Name	Model k-eff (ICSBEP)	Exp. Unc. (ICSBEP)	Model #	Benchmark Name	Model k-eff (ICSBEP)	Exp. Unc. (ICSBEP)	Model #	Benchmark Name	Model k-eff (ICSBEP)	Exp. Unc. (ICSBEP)
1	HCI_003_01	1.00000	0.00570	35	HMF_032_01	1.00000	0.00160	69	hst_013_03	1.00090	0.00360	103	lst_004_01	0.99940	0.00080
2	HCI_003_02	1.00000	0.00610	36	HMF_032_02	1.00000	0.00270	70	hst_013_04	1.00030	0.00360	104	lst_004_29	0.99990	0.00090
3	HCI_003_03	1.00000	0.00560	37	HMF_032_03	1.00000	0.00170	71	hst_032_01	1.00150	0.00260	105	lst_004_33	0.99990	0.00090
4	HCI_003_04	1.00000	0.00550	38	HMF_032_04	1.00000	0.00170	72	hst_042_01	0.99570	0.00390	106	lst_004_34	0.99990	0.00100
5	HCI_003_05	1.00000	0.00470	39	HMF_034_01	0.99900	0.00120	73	hst_042_02	0.99650	0.00360	107	lst_004_46	0.99990	0.00100
6	HCI_003_06	1.00000	0.00470	40	HMF_034_02	0.99900	0.00120	74	hst_042_03	0.99940	0.00280	108	lst_004_51	0.99940	0.00110
7	HCI_003_07	1.00000	0.00500	41	HMF_034_03	0.99900	0.00120	75	hst_042_04	1.00000	0.00340	109	lst_004_54	0.99960	0.00110
8	HMF_001_01A	1.00000	0.00100	42	HMI_006_02	1.00010	0.00080	76	hst_042_05	1.00000	0.00340	110	lst_007_14	0.99610	0.00090
9	HMF_001_01B	1.00000	0.00100	43	HMT_001_01	1.00100	0.00600	77	hst_042_06	1.00000	0.00370	111	lst_007_30	0.99730	0.00090
10	HMF_002_01	1.00000	0.00300	44	HMT_001_01D	1.00100	0.00600	78	hst_042_07	1.00000	0.00360	112	lst_007_32	0.99850	0.00100
11	HMF_002_02	1.00000	0.00300	45	HMT_014_01	0.99390	0.00150	79	hst_042_08	1.00000	0.00350	113	lst_007_36	0.99880	0.00110
12	HMF_002_03	1.00000	0.00300	46	hst_001_01	1.00040	0.00600	80	hst_043_01	0.99860	0.00310	114	lst_007_49	0.99830	0.00110
13	HMF_002_04	1.00000	0.00300	47	hst_001_02	1.00210	0.00720	81	hst_043_02	0.99950	0.00260	115	lst_016_105	0.99960	0.00130
14	HMF_002_05	1.00000	0.00300	48	hst_001_03	1.00030	0.00350	82	hst_043_03	0.99900	0.00250	116	lst_016_113	0.99990	0.00130
15	HMF_002_06	1.00000	0.00300	49	hst_001_04	1.00080	0.00530	83	IMF_003	1.00000	0.00170	117	lst_016_125	0.99940	0.00140
16	HMF_003_01	1.00000	0.00500	50	hst_001_05	1.00010	0.00490	84	IMF_004	1.00000	0.00300	118	lst_016_129	0.99960	0.00140
17	HMF_003_02	1.00000	0.00500	51	hst_001_06	1.00020	0.00460	85	IMF_005	1.00000	0.00210	119	lst_016_131	0.99950	0.00140
18	HMF_003_03	1.00000	0.00500	52	hst_001_07	1.00080	0.00400	86	IMF_006	1.00000	0.00230	120	lst_016_140	0.99920	0.00150
19	HMF_003_04	1.00000	0.00300	53	hst_001_08	0.99980	0.00380	87	IMF_007	0.99480	0.00130	121	lst_016_196	0.99940	0.00150
20	HMF_003_05	1.00000	0.00300	54	hst_001_09	1.00080	0.00540	88	IMF_009	1.00000	0.00530	122	PCI_001	1.00000	0.01100
21	HMF_003_06	1.00000	0.00300	55	hst_001_10	0.99930	0.00540	89	LCT_008_02	1.00070	0.00120	123	PMF_001	1.00000	0.00200
22	HMF_003_07	1.00000	0.00300	56	hst_009_01	0.99900	0.00430	90	lst_001_01	0.99910	0.00290	124	PMF_002	1.00000	0.00200
23	HMF_004_01	1.00200	0.00010	57	hst_009_02	1.00000	0.00390	91	lst_002_01	1.00380	0.00400	125	PMF_003_103	1.00000	0.00300
24	HMF_009_01	0.99920	0.00150	58	hst_009_03	1.00000	0.00360	92	lst_002_02	1.00240	0.00370	126	PMF_006	1.00000	0.00300
25	HMF_015_01	0.99960	0.00170	59	hst_009_04	0.99860	0.00350	93	lst_002_03	1.00240	0.00440	127	PMF_008	1.00000	0.00060
26	HMF_018_01	1.00000	0.00140	60	hst_010_01	1.00000	0.00290	94	lst_003_01	0.99970	0.00390	128	PMF_011	1.00000	0.00100
27	HMF_019_01	1.00000	0.00280	61	hst_010_02	1.00000	0.00290	95	lst_003_02	0.99930	0.00420	129	PST_021_03	1.00000	0.00650
28	HMF_019_02	1.00000	0.00280	62	hst_010_03	1.00000	0.00290	96	lst_003_03	0.99950	0.00420	130	UCT_001_03	1.00070	0.00250
29	HMF_020_01	1.00000	0.00280	63	hst_010_04	0.99920	0.00290	97	lst_003_04	0.99950	0.00420	131	UMF_001	1.00000	0.00100
30	HMF_021_01	1.00000	0.00240	64	hst_011_01	1.00000	0.00230	98	lst_003_05	0.99970	0.00480	132	UMF_005_02	1.00000	0.00300
31	HMF_022_01	1.00000	0.00190	65	hst_011_02	1.00000	0.00230	99	lst_003_06	0.99990	0.00490	133	UMF_006	1.00000	0.00140
32	HMF_027_01	1.00000	0.00250	66	hst_012_01	0.99990	0.00580	100	lst_003_07	0.99940	0.00490	134	USI_001_01	1.00000	0.00830
33	HMF_028_01	1.00000	0.00300	67	hst_013_01	1.00120	0.00260	101	lst_003_08	0.99930	0.00520	135	UST_008	1.00060	0.00290
34	HMF_029_01	1.00000	0.00200	68	hst_013_02	1.00070	0.00360	102	lst_003_09	0.99960	0.00520				

C/E Plots: ENDF/B-VII.1(β4) and ENDF/B-VII.0



C/E Difference Plots: ENDF/B-VII.1(β4) – ENDF/B-VII.0



ENDF/B-VII.1(β4) vs. ENDF/B-VII.0

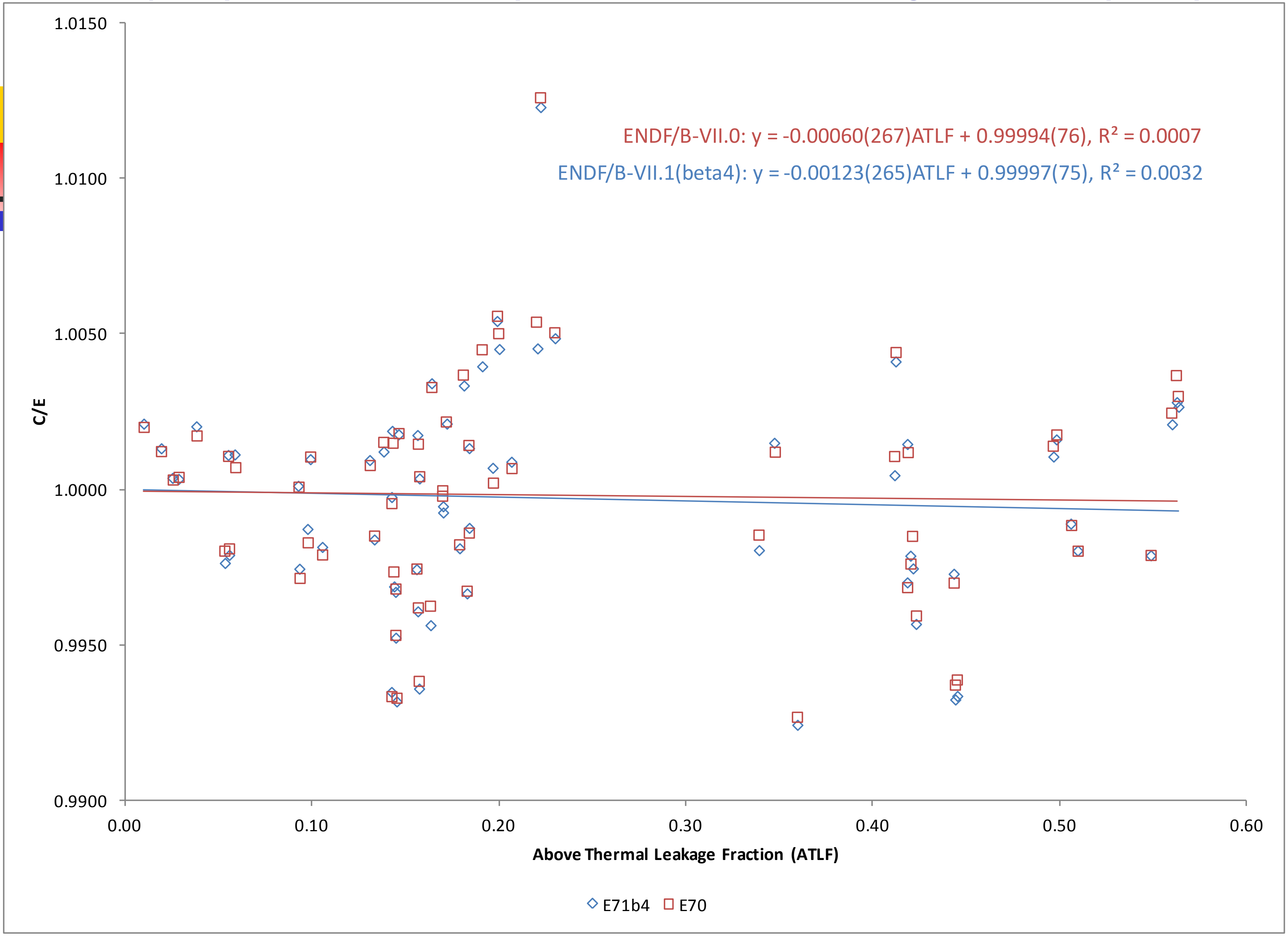
Population:

Library	Average	Std. Dev.	χ^2
ENDF/B-VII.0	1.00030	0.00399	0.0051
ENDF/B-VII.1(b4)	1.00027	0.00390	0.0048

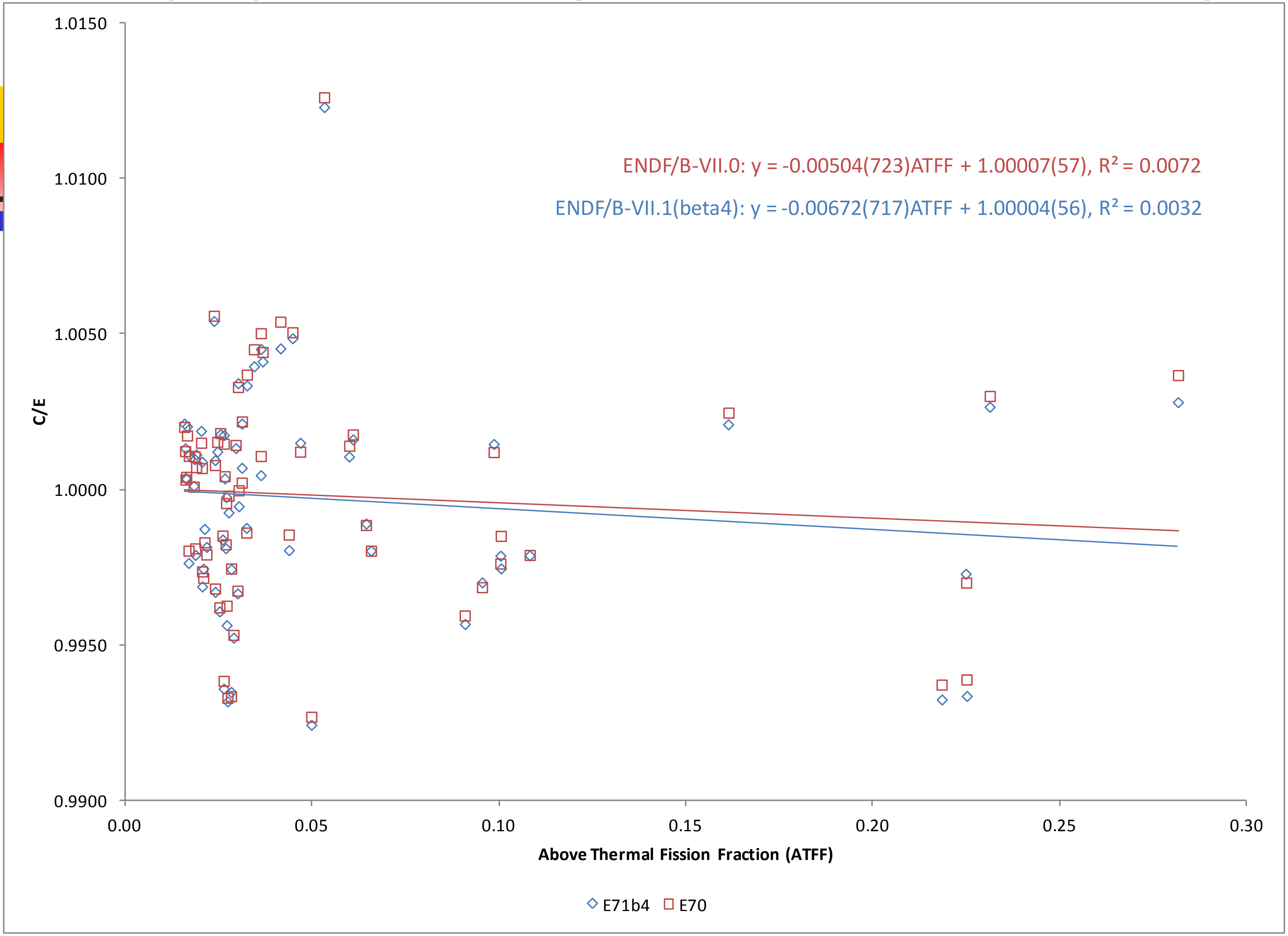
Some Notable Changes:

Benchmark	C/E E7.1b4	C/E E7.0	Difference
HMF_009	0.99895(40)	0.99696(40)	0.00199(58)
HMF_034_01	0.99863(51)	1.00021(50)	-0.00158(71)
HMT_001_01	1.00378(60)	1.00583(52)	-0.00205(80)
UCT_001_03	1.00135(40)	1.00426(42)	-0.00220(58)
UMF_005_02	0.99597(27)	0.99330(26)	0.00267(37)

Trend Analysis (HST & LST Series): Above Thermal Leakage Fraction (ATLF)



Trend Analysis (HST & LST Series): Above Thermal Fission Fraction (ATFF)



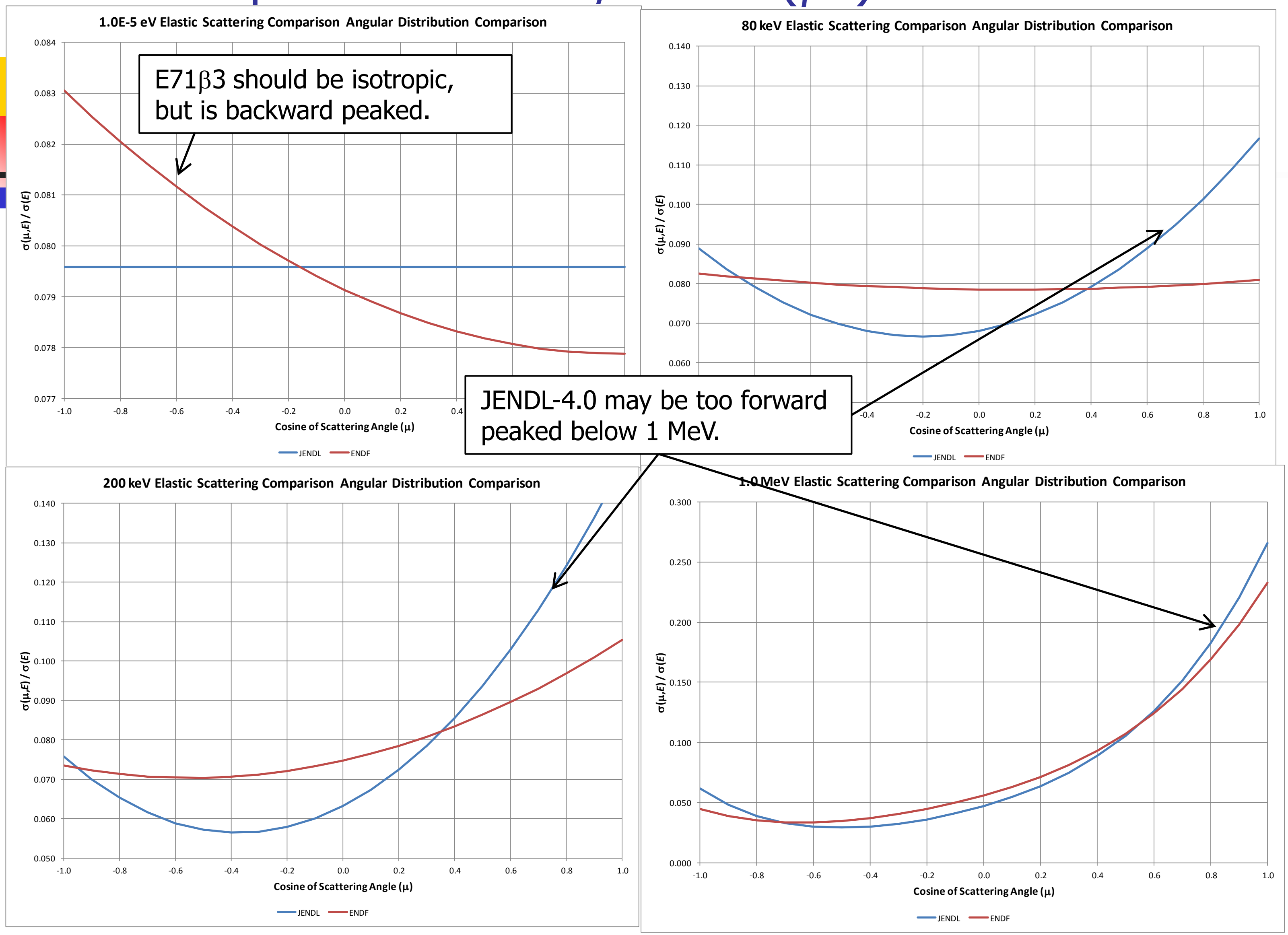
Summary of ICSBEP Suite Analysis

- The ENDF/B-VII.1(β4) data performed well in the models tested:
  - Average C/E's and standard deviations, goodness-of-fit parameters are all very similar compared to ENDF/B-VII.0.
- Notable changes in some of the models containing Be, ^{233}U, Zr, C, Ti.
  - Mostly to improve C/E values.
- No statistically significant reactivity trends introduced in the HST/LST series.
  - Slightly more negative trend in ATLF, ATFF may be a result of higher leakage & less reflector savings in HST009,010,011 series.

Zirconium

- Effects on TRIGA benchmark using different Zr evaluations has been shown to be significant.
  - ENDF/VII.0 Zr isotopes increase reactivity, JENDL-4.0 Zr isotopes reduce reactivity.
- Latest efforts have been to examine the elastic scattering angular distributions (ESADs) and their effect.
  - ENDF/B-VII.0 ESADs used in ENDF/B-VII.1(β1-β2)
    - New distributions provided in β3.
  - JENDL-4.0 ESADs adopted for the ENDF/B-VII.1(β4) zirconium isotopes.
    - Testing has shown favorable behavior in ICSBEP benchmarks.

ESAD Comparisons: ENDF/B-VII.1(β3) and JENDL-4.0



Zirconium Substitution Analysis using ICT-003 “TRIGA”

Description	K-eff (95% CI)
ENDF/B-VI.8 for all	1.00012(79)
ENDF/B-VII.0 for all	1.00352(53)
ENDF/B-VII.0 + JENDL-4.0 Zr isos.	1.00120(17)
ENDF/B-VII.1(b2) for all	1.00385(54)
ENDF/B-VII.1(b2) + VII.1(b4) Zr isos.	1.00128(17)
ENDF/B-VII.1(b4) for all	1.00086(34)

- The use of JENDL-4.0 Zr isotopes brings calculated k-eff ~220 pcm lower.
- ENDF/B-VII.1(β2) library causes k-eff to creep back up ~30 pcm higher than ENDF/B-VII.0.
- However, substituting ENDF/B-VII.1(β4) for Zr isotopes drops , k-eff ~260 pcm.
- ENDF/B-VII.1(β4) library results in a k-eff statistically in agreement with ENDF/B-VI.8.

Summary of Zirconium Analysis

- The proposed β4 zirconium greatly improves the calculated k-eff for TRIGA, relative to ENDF/B-VII.0 and previous VII.1(β) releases.
  - Adoption of JENDL-4.0 ESADs is largely responsible.
    - JENDL-4.0 ESADs tabulated for many more incident energies between 1.0E-5 eV and 1.0 MeV.
- There is still room for improvement
  - NNPP benchmark models suggest that JENDL-4.0, and now ENDF/B-VII.1(β4), ESADs may be too forward peaked.

Conclusions

- Based on the analysis performed on the ICSBEP Benchmark Suite:
  - On average, ENDF/B-VII.1(β4) performs comparable to ENDF/B-VII.0.
  - Noticeable improvements for some models with Be, Zr, U233, C.
  - No statistically significant reactivity trends introduced in ATLF or ATFF plots.
- ENDF/B-VII.1(β4) lowers the calculated k-eff in the TRIGA model to approximately the ENDF/B-VI.8 value.
  - Impact is largely due to adopting the JENDL-4.0 Zr isotope ESADs
- Analysis of Zr Isotope ESADs:
  - Some evidence in NNPP benchmark analysis to suggest JENDL-4.0 ESADs are too forward peaked below 1.0 MeV.