Benchmark Results with the IAEA-CIELO Evaluated Data Files

A. Trkov
(on behalf of CIELO collaboration)
International Atomic Energy Agency
Vienna, Austria

IAEA
International Atomic Energy Agency

CIELO Project

- CIELO Objective:
  - Obtain “best” evaluated nuclear data files through broad international collaboration
- Scope
  - ^{239}Pu, ^{238}U, ^{235}U, ^{56}Fe, ^{16}O, ^{1}H
- Follow-up activity is foreseen to address other nuclides

Activities at the IAEA

- Evaluation work related to several IAEA projects
  - PFNS of actinides
  - Neutron Standards
  - RIPL
  - IRDFF
- Evaluations with direct IAEA participation
  - ^{238}U (fast) + IRMM (RRR)
  - ^{235}U (fast, in collaboration with ORNL for RRR)
  - ^{56}Fe (in collaboration with NNDC-BNL)
- See “https://www-nds.iaea.org/CIELO/”

^{238}U – New Features

- Corrections to resonance bound states (further refinements of RRR expected from IRMM)
- Take into account new capture measurements at GELINA
- Make capture and fission consistent with Standards fit 2006
- PFNS by Rising-Talou
- Take into account new measurements of (n,2n) at TUNL
- Use new dispersive optical model with 20 coupled states
- Empire calculation using 2H fission barrier with absorption (optical model for fission)
- (n,2n) validated using SACS ratio systematics
- More details on "https://www-nds.iaea.org/CIELO/Capote-miniCSWEG2016-u238.pdf"

^{235}U – New Features

- Thermal cross sections from a new GMA fit using microscopic data only (proposed for Standards-2006)
- Refinements to RRP (<20 eV, work in progress).
- (n,f) from Standards 2006
- (n,g) adopted from ENDF/B-VII.1 (to be updated by new data)
- Thermal PFNS from IAEA CRP, Rising-Talou E_n< 5 MeV, ENDF/B-VII.1 above
- Dispersive optical model with 10 coupled states
- Empire calculation with 3H fission barrier with absorption (optical model for fission)
- More details on "https://www-nds.iaea.org/CIELO/Capote-miniCSWEG2016-u235.pdf"

^{56}Fe Features (work in progress)

- Trials with IRSN.v2 RRP were not successful
- RRR+elastic angular distributions: JENDL-4.0 (with some tweaking of capture 10-25 keV, reduction of orig. bgnd.)
- (n,tot): E>850 keV: JEFF-3.2 (← Berthold data)
- (n,n'): Dupont (local shape) normalised to Negret data
- (n,el) angular distrib.>850 keV: JEFF-3.2 (← Kinney data)
- Some tweaking of P_2, P_4 Legendre coefficients informed by quasi-differential data from RPI and reflector benchmark results
- Dispersive soft-rotator OMP above 4 MeV (6 CC)
- Consistent modelling up to 150 MeV

IAEA-CIELO library proposal (24/04/2016)

^{239}Pu – LANL c23 with nu-bar from ENDF/B-VII.1

^{238}U – IAEA/IRMM evaluation “ib46rjFs”

^{235}U – IAEA/ORNL evaluation “u235ib06ao17g6cnu5cf2”

– RRR is preliminary, on-going work on 20-2250 eV

^{56}Fe – IAEA/BNL evaluation “fe56ib15s”, further improvements are on-going

^{54,57,58}Fe – BNL evaluations

^{16}O – LANL Hale evaluation “o16_haleadx”

^{1}H – CAB thermal scattering law

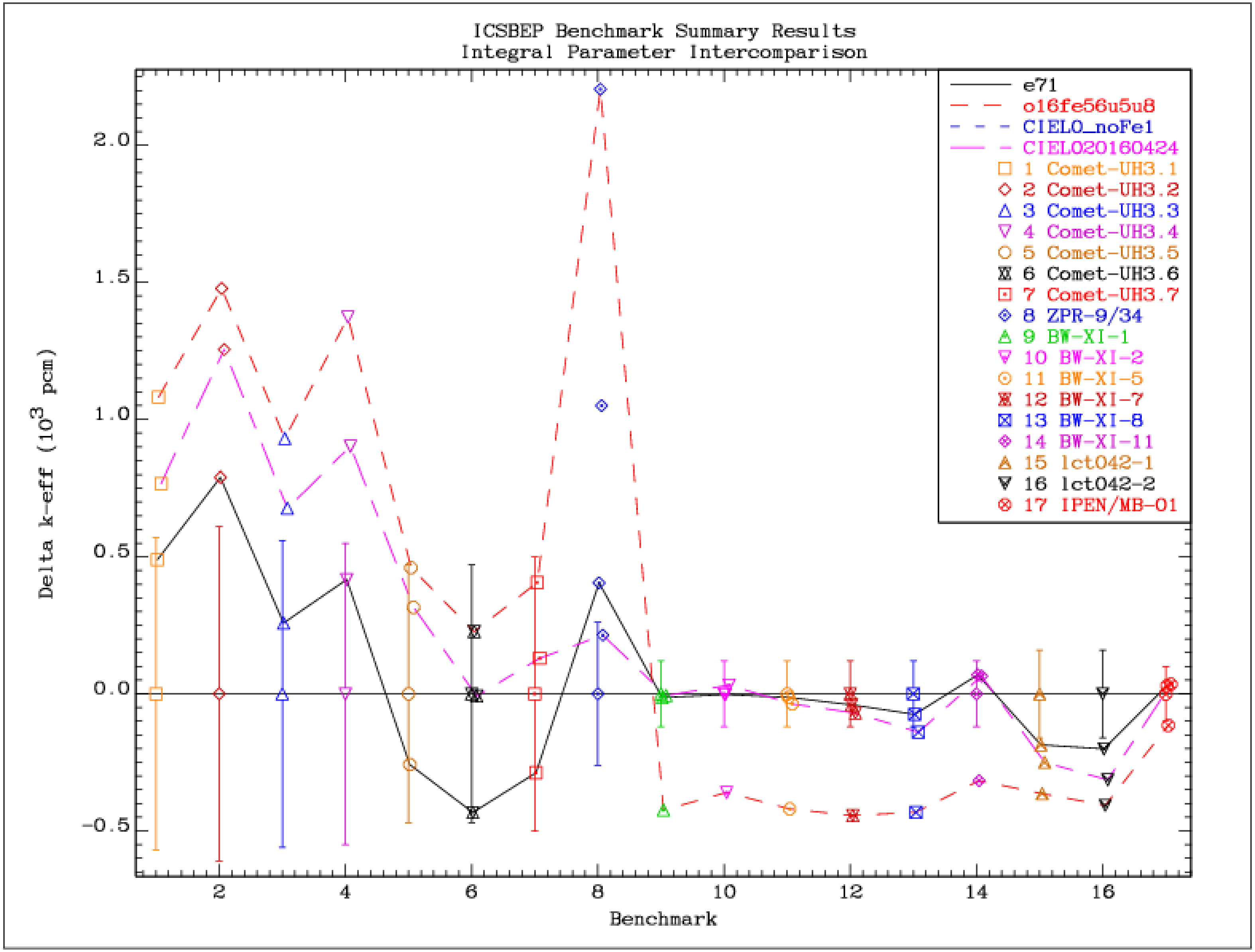
All IAEA files are available on **https://www-nds.iaea.org/CIELO/**

Benchmarking Status – November 2015

- Many ICSBEP benchmarks were analysed
- A few cases were identified where performance was worse than with ENDF/B-VII.1
- Since then (label "o16fe56u5u8"), considerable improvement was made (label "CIELO20160424")
- Beware of compensating effects (e.g., ZPR-9/34)
  - New ^{235}U more reactive (due to decreased capture)
  - Compensated by increased capture in ^{56}Fe and minor isotopes
  - Old ^{56}Fe is **incompatible** with the new evaluations

Benchmark naming convention

ICSBEP label	Short name	Common name	Comment
HEU-COMP-INTER-003	hci003-1	COMET-UH3-1	Refl. D38/D38 (outer/inner)
HEU-COMP-INTER-003	hci003-2	COMET-UH3-2	Refl. D38/Be
HEU-COMP-INTER-003	hci003-3	COMET-UH3-3	Refl. D38/Be
HEU-COMP-INTER-003	hci003-4	COMET-UH3-4	Refl. D38/Fe
HEU-COMP-INTER-003	hci003-5	COMET-UH3-5	Refl. none/Be
HEU-COMP-INTER-003	hci003-6	COMET-UH3-6	Refl. none/D38
HEU-COMP-INTER-003	hci003-7	COMET-UH3-7	Refl. none/D38
HEU-MET-INTER-001	hmi001	ZPR-9/34	
LEU-COMP-THERM-008	lct008-01	BW-XI-1	1511 ppm B
LEU-COMP-THERM-008	lct008-02	BW-XI-2	1223 ppm B,153 H2O
LEU-COMP-THERM-008	lct008-05	BW-XI-5	1181 ppm B,117 H2O, 36 BPR
LEU-COMP-THERM-008	lct008-07	BW-XI-7	1031 ppm B, 81 H2O, 72 BPR
LEU-COMP-THERM-008	lct008-08	BW-XI-8	779 ppm B, 9 H2O, 144 BPR
LEU-COMP-THERM-008	lct008-11	BW-XI-11	1384 ppm B, 9 H2O, 144 Al2O3
LEU-COMP-THERM-042	lct042-1	lct042-1	
LEU-COMP-THERM-042	lct042-2	lct042-2	
LEU-COMP-THERM-043	lct043-2	IPEN/MB-01	

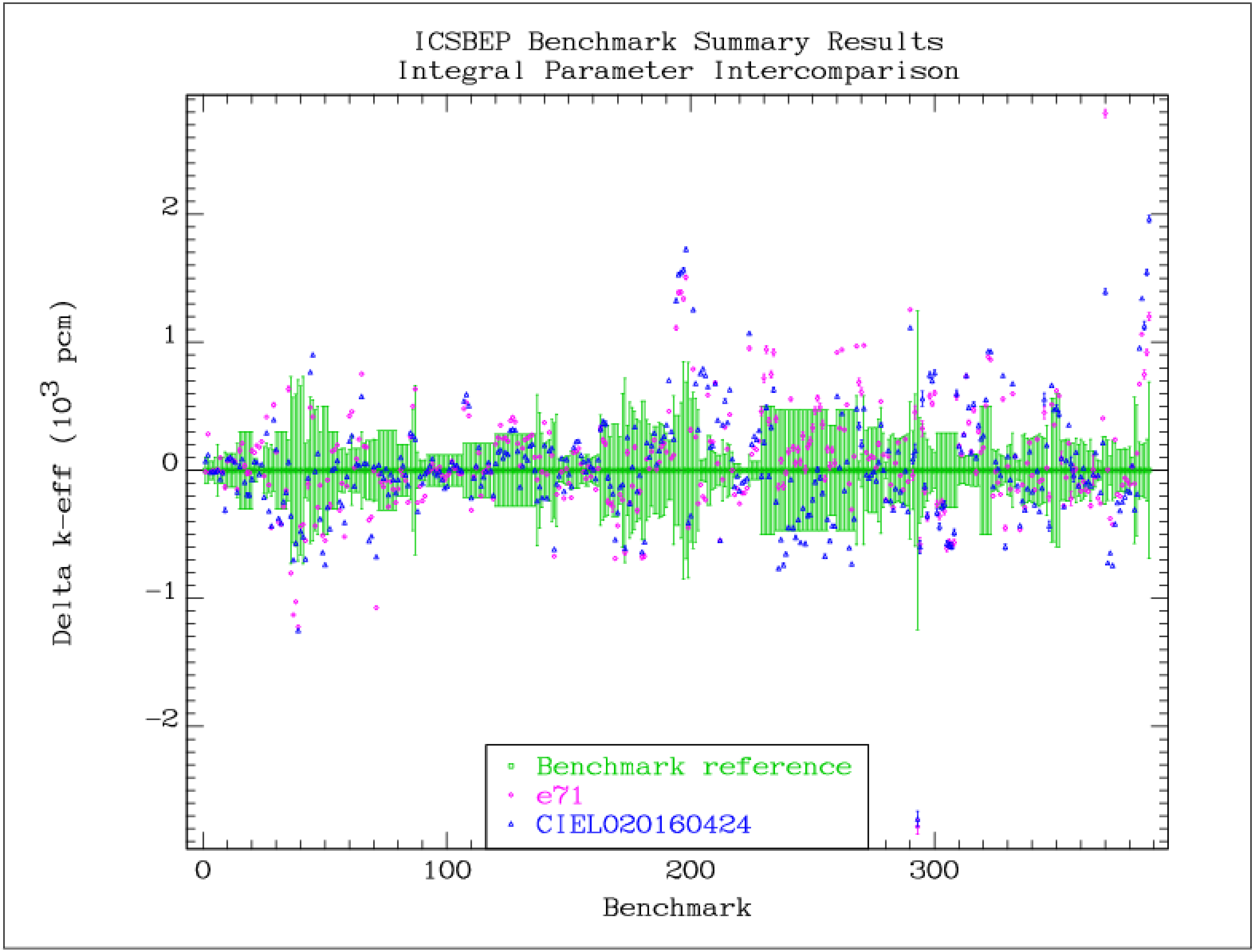


ICSBEP Benchmark Summary Results
Integral Parameter Intercomparison
Delta k-eff (10^3 pcm)
Benchmark
e71
o16fe56u5u8
CIELO_noFe1
CIELO20160424
1 Comet-UH3.1
2 Comet-UH3.2
3 Comet-UH3.3
4 Comet-UH3.4
5 Comet-UH3.5
6 Comet-UH3.6
7 Comet-UH3.7
8 ZPR-9/34
9 BW-XI-1
10 BW-XI-2
11 BW-XI-5
12 BW-XI-7
13 BW-XI-8
14 BW-XI-11
15 lct042-1
16 lct042-2
17 IPEN/MB-01

Benchmarking

- 388 cases from the ICSBEP collection
- MCNP-6.1 with ENDF/B-VII.1 base library
- Input models mostly from ICSBEP (with tighter convergence tolerance), but also by contribution from other data testers

	ENDF/B-VII.1	CIELO201624	ENDF/B-VIII.b1
Chi^2/DoF	116		


ICSBEP Benchmark Summary Results
Integral Parameter Intercomparison
Delta k-eff (10^3 pcm)
2
1
0
−1
−2
0
100
200
300
Benchmark
Benchmark reference
e71
CIELO20160424

Validation strategy

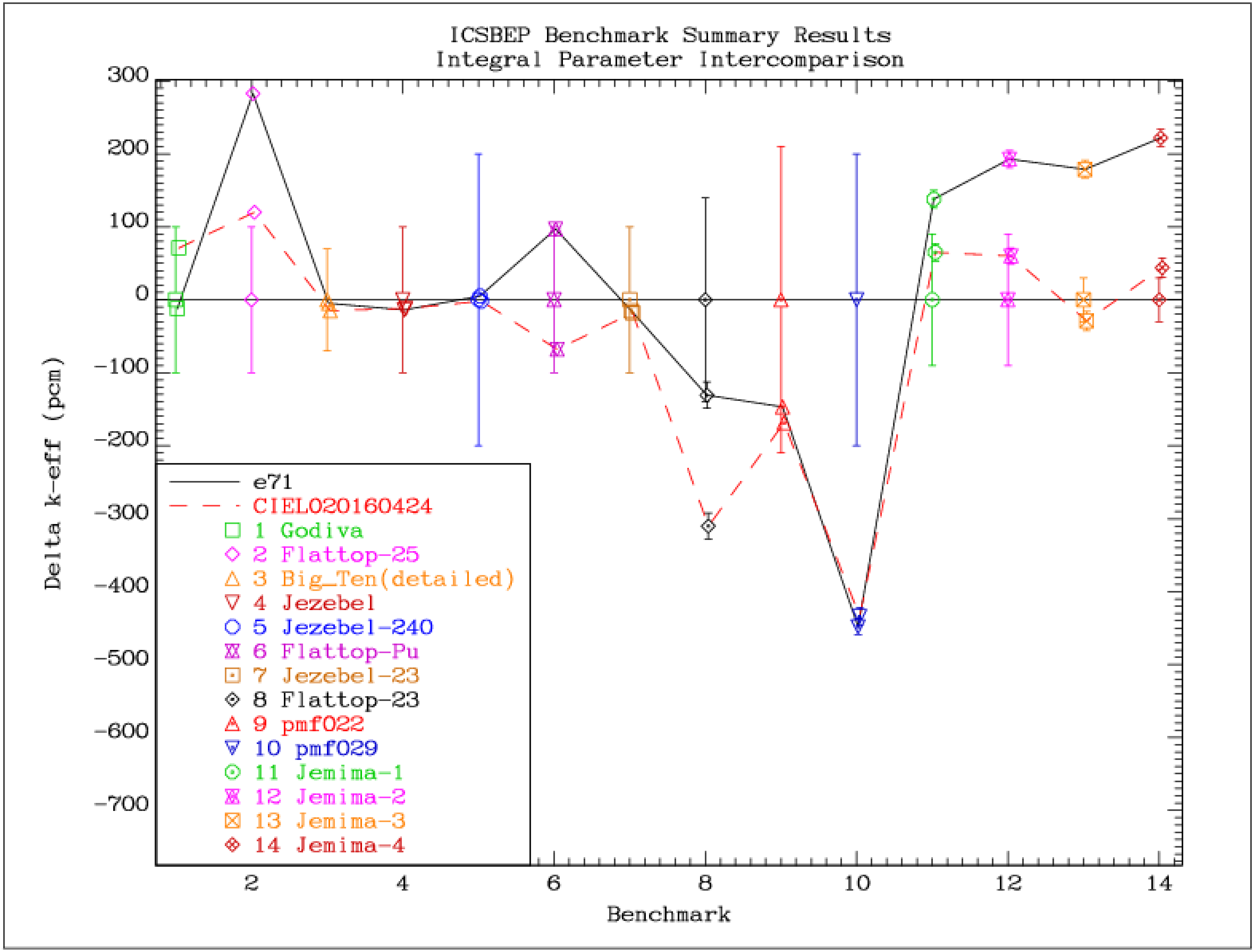
- Check ^{235}U bare assemblies to test ^{235}U cross sections in the fast energy range (neutron source for all other assemblies)
- Check ^{239}Pu bare assemblies (as above)
- Check highly-enriched ^{235}U solutions (slowing-down properties of ^{1}H, ^{16}O, TSL, PFNS and thermal constants)
- Check ^{238}U-reflected assemblies (cross sections and angular distributions of ^{238}U)
- Check assemblies containing Fe

Major fast benchmarks (short list)

- 14 cases from the ICSBEP, short list of important high- and intermediate-enriched fast spectrum benchmarks
- Major improvement relative to ENDF/B-VII.1

Chi^2/DoF	ENDF/B-VII.1	CIELO201624	ENDF/B-VIII.b0
	8.05	1.20	

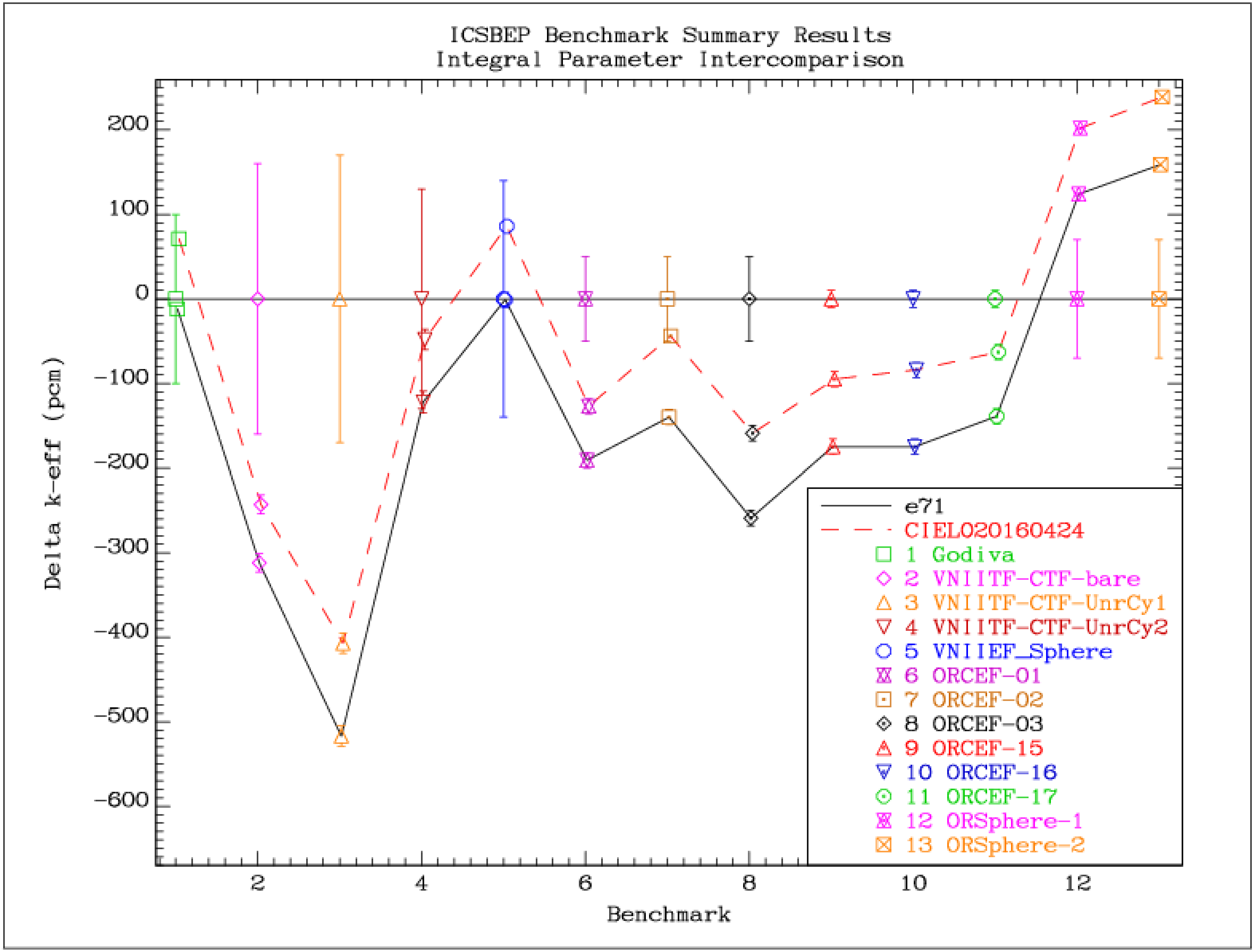
IAEA



ICSBEP Benchmark Summary Results
Integral Parameter Intercomparison
Delta k-eff (pcm)
300
200
100
0
−100
−200
−300
−400
−500
−600
−700
2
4
6
8
10
12
14
Benchmark
e71
CIELO20160424
1 Godiva
2 Flattop-25
3 Big_Ten(detailed)
4 Jezebel
5 Jezebel-240
6 Flattop-Pu
7 Jezebel-23
8 Flattop-23
9 pmf022
10 pmf029
11 Jemima-1
12 Jemima-2
13 Jemima-3
14 Jemima-4

^{235}U Bare

- The performance is comparable or better than ENDF/B-VII.1
- Slight positive bias in reactivity for Godiva
- Experimental benchmark uncertainties are probably underestimated

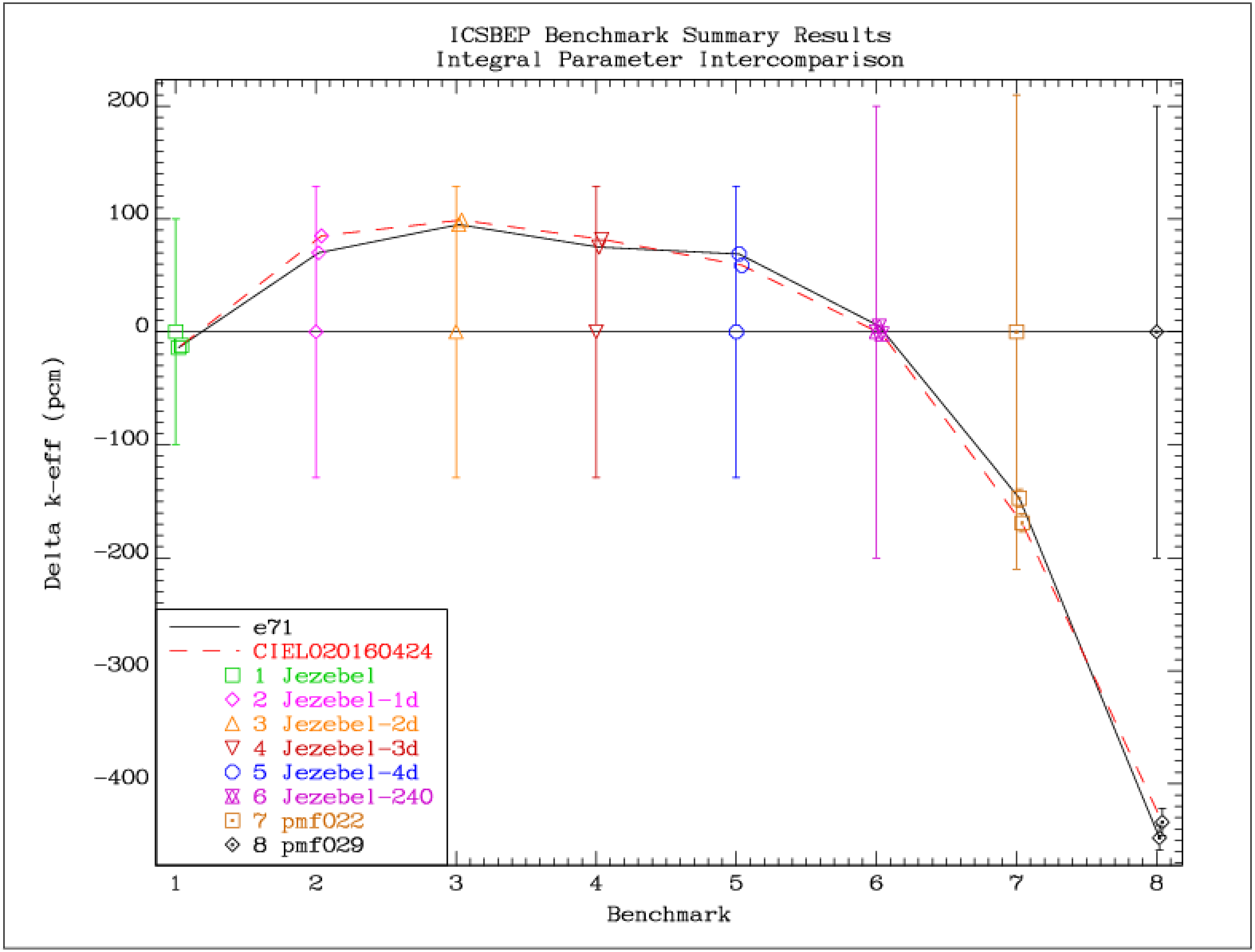


ICSBEP Benchmark Summary Results
Integral Parameter Intercomparison
200
100
0
−100
−200
−300
−400
−500
−600
Delta k-eff (pcm)
2
4
6
8
10
12
Benchmark
e71
CIEL020160424
1 Godiva
2 VNIITF-CTF-bare
3 VNIITF-CTF-UnrCy1
4 VNIITF-CTF-UnrCy2
5 VNIIEF_Sphere
6 ORCEF-01
7 ORCEF-02
8 ORCEF-03
9 ORCEF-15
10 ORCEF-16
11 ORCEF-17
12 ORSphere-1
13 ORSphere-2

Pu-bare

- Very few benchmarks are available
- Jezebel “average” and 4 detailed
- “dirty” Jezebel
- Two Russian (98% delta, 88% alpha)

The last one is strongly underestimated



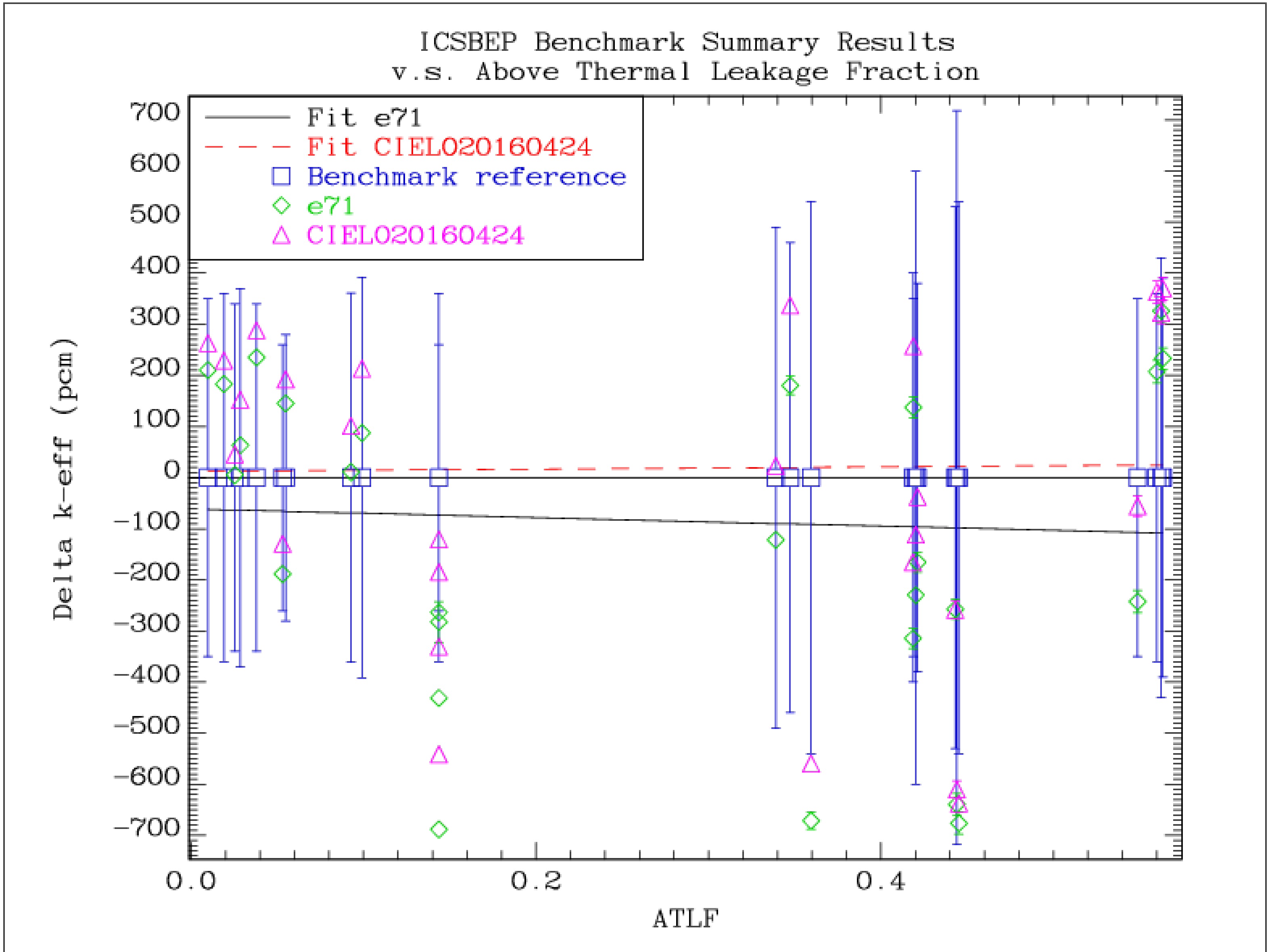
ICSBEP Benchmark Summary Results
Integral Parameter Intercomparison
Delta k-eff (pcm)
200
100
0
−100
−200
−300
−400
1
2
3
4
5
6
7
8
Benchmark
e71
CIEL020160424
1 Jezebel
2 Jezebel-1d
3 Jezebel-2d
4 Jezebel-3d
5 Jezebel-4d
6 Jezebel-240
7 pmf022
8 pmf029

^{235}U Thermal solutions

- All thermal solution benchmarks considered, except HEU-SOL-THERM-050 due to their large scatter, but including all HEU-SOL-THERM-013 (borated)

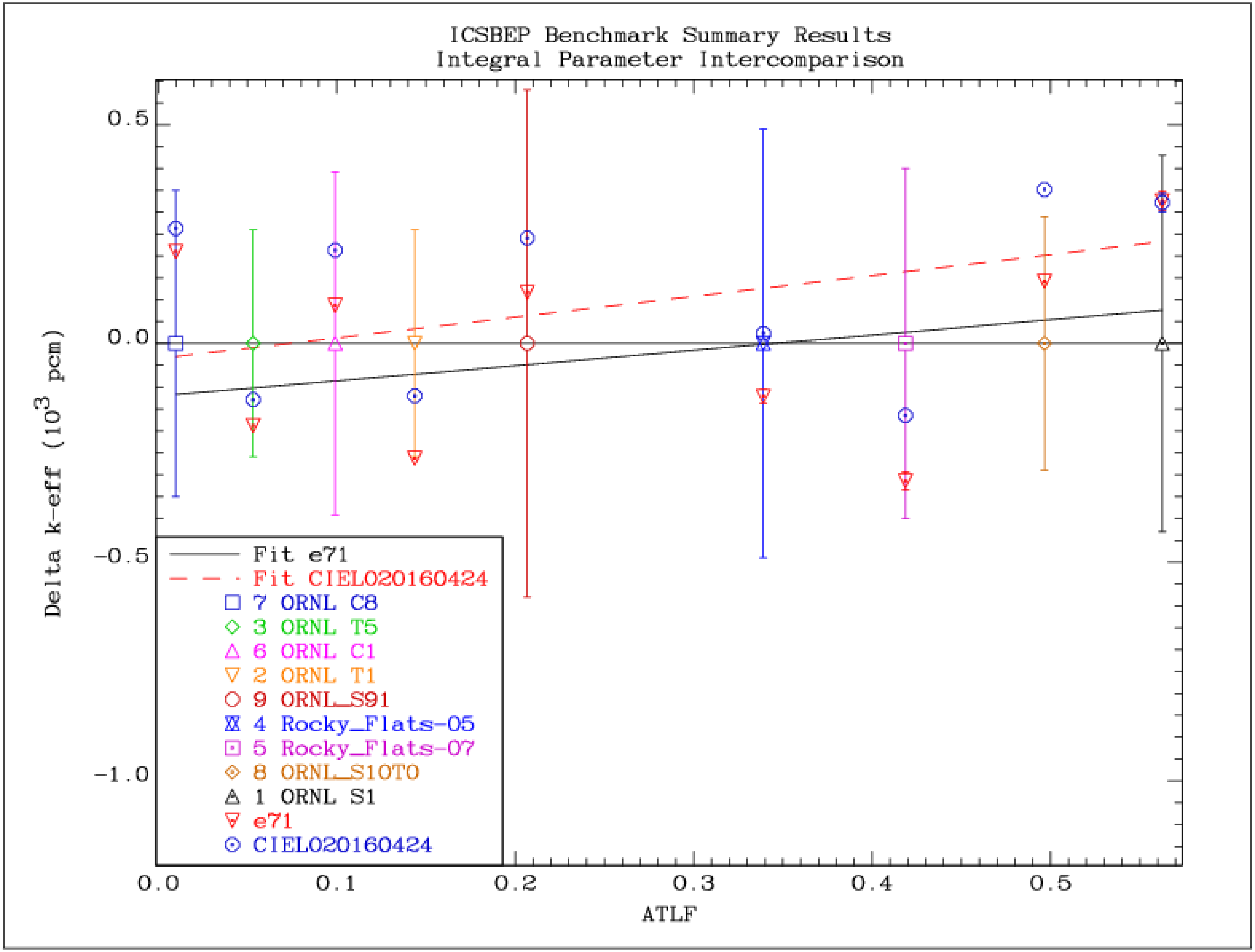
	ENDF/B-VII.1	CIELO201624	ENDF/B-VIII.b0
Chi^2/DoF	0.59	0.51	

IAEA

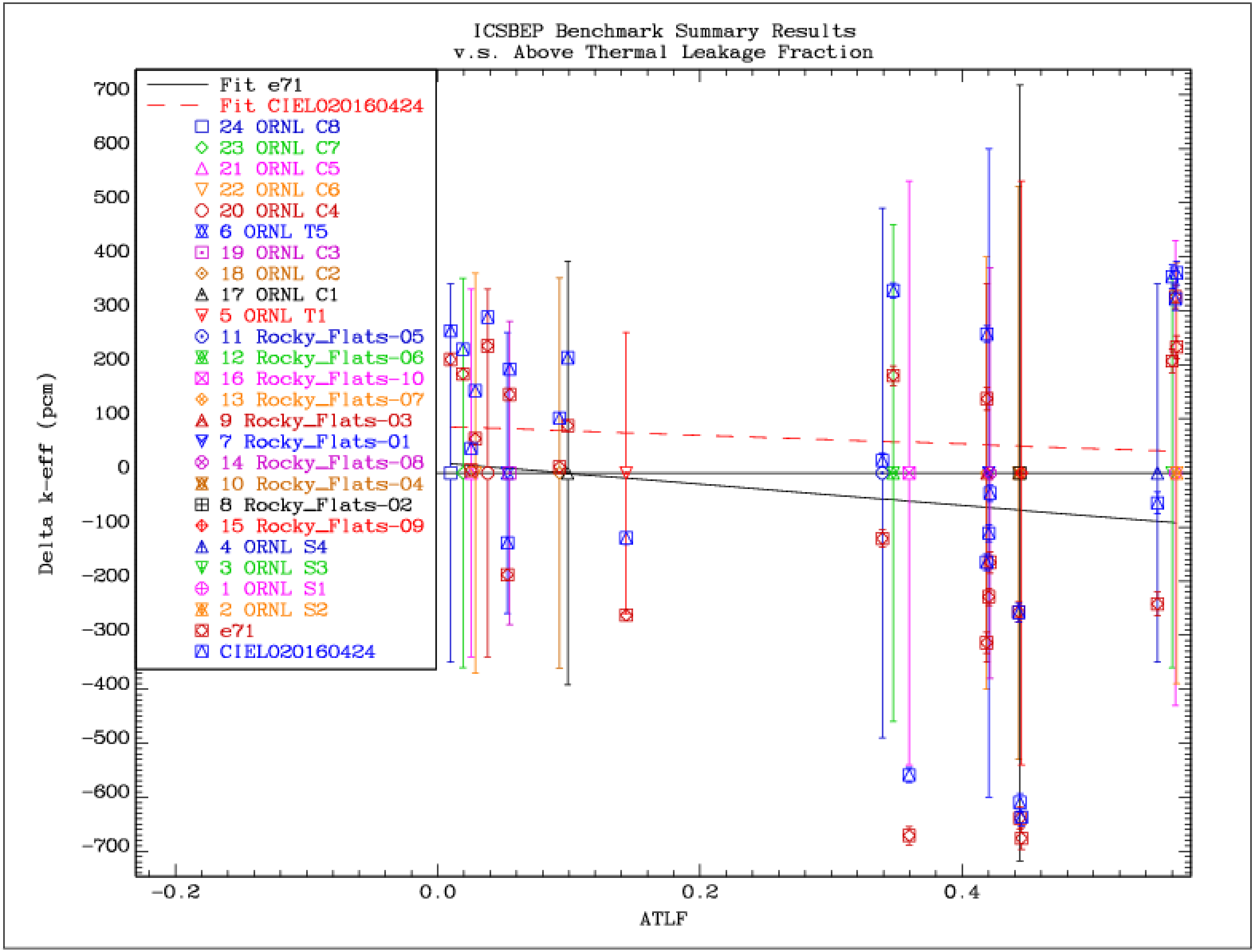

ICSBEP Benchmark Summary Results
v.s. Above Thermal Leakage Fraction
Fit e71
Fit CIELO20160424
Benchmark reference
e71
CIELO20160424
700
600
500
400
300
200
100
0
−100
−200
−300
−400
−500
−600
−700
Delta k-eff (pcm)
0.0
0.2
0.4
ATLF

^{235}U Thermal solutions (cont.)

- A short list of benchmarks is reasonably representative of the full list (within uncertainties)
- The performance is comparable to ENDF/B-VII.1 (negligible trend with ATLF compared to measured uncertainties)
- Exclusion of borated assemblies changes slightly the results, but well within the experimental uncertainties

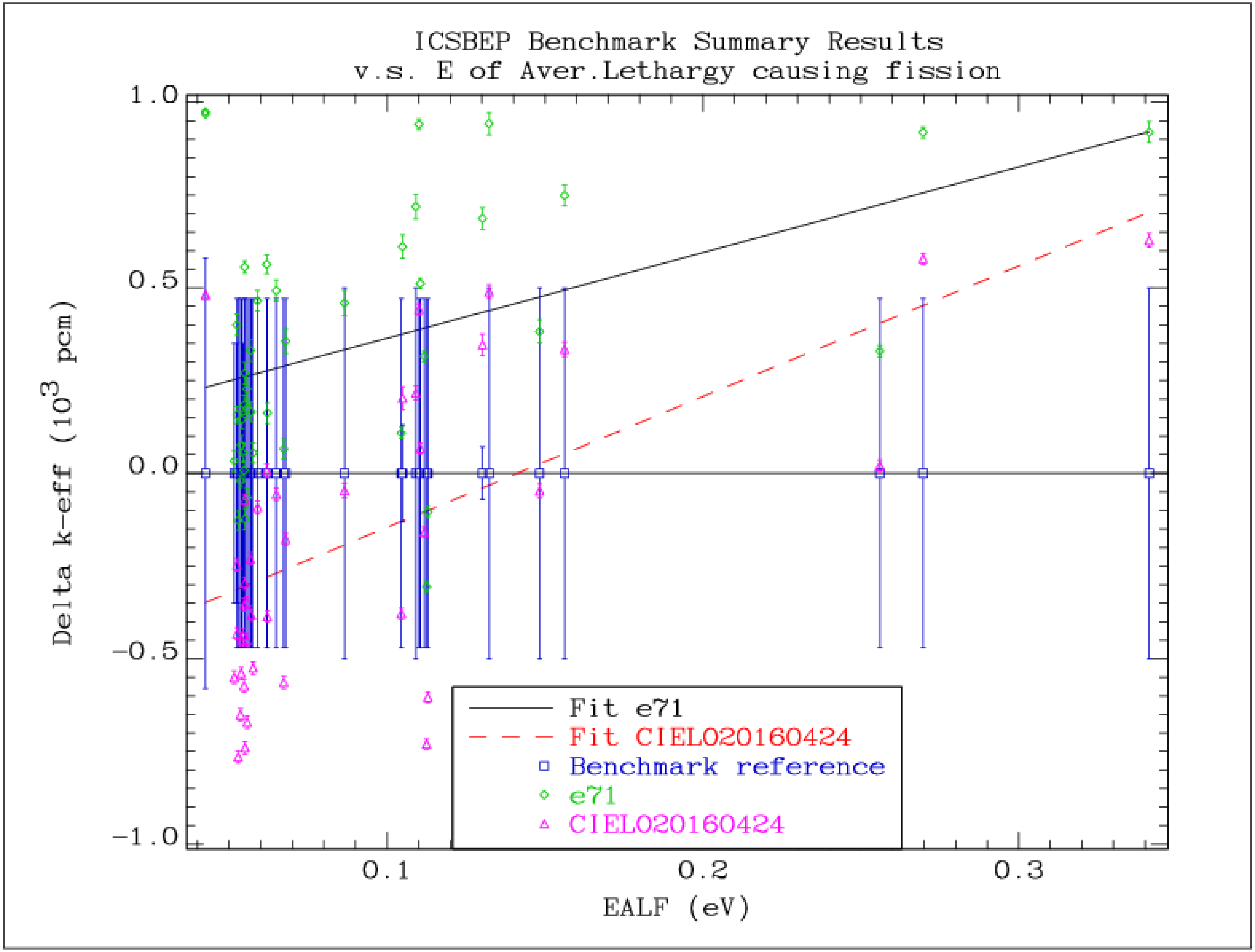


ICSBEP Benchmark Summary Results
Integral Parameter Intercomparison
Delta k-eff (10^3 pcm)
ATLF
0.5
0.0
-0.5
-1.0
0.0
0.1
0.2
0.3
0.4
0.5
Fit e71
Fit CIEL020160424
7 ORNL C8
3 ORNL T5
6 ORNL C1
2 ORNL T1
9 ORNL_S91
4 Rocky_Flats-05
5 Rocky_Flats-07
8 ORNL_S10TO
1 ORNL S1
e71
CIEL020160424


ICSBEP Benchmark Summary Results
v.s. Above Thermal Leakage Fraction
Fit e71
Fit CIELO20160424
24 ORNL C8
23 ORNL C7
21 ORNL C5
22 ORNL C6
20 ORNL C4
6 ORNL T5
19 ORNL C3
18 ORNL C2
17 ORNL C1
5 ORNL T1
11 Rocky_Flats-05
12 Rocky_Flats-06
16 Rocky_Flats-10
13 Rocky_Flats-07
9 Rocky_Flats-03
7 Rocky_Flats-01
14 Rocky_Flats-08
10 Rocky_Flats-04
8 Rocky_Flats-02
15 Rocky_Flats-09
4 ORNL S4
3 ORNL S3
1 ORNL S1
2 ORNL S2
e71
CIELO20160424
Delta k-eff (pcm)
700
600
500
400
300
200
100
0
-100
-200
-300
-400
-500
-600
-700
-0.2
0.0
0.2
0.4
ATLF

Pu thermal solutions

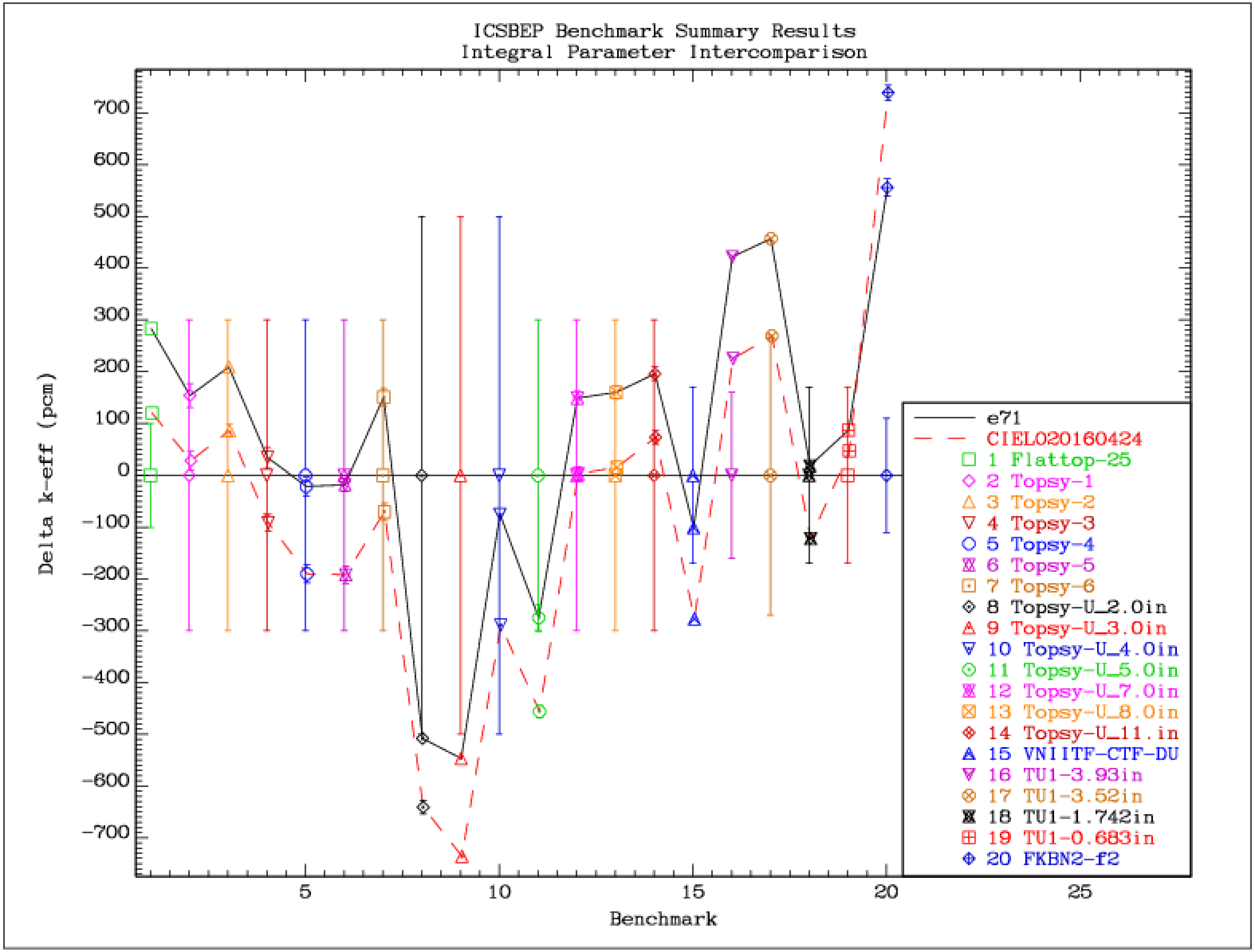
- 43 cases from ICSBEP considered
- No ATLF available, plotted against EALF
- PNL-11 assemblies are particularly low
- Results are <u>very</u> preliminary
  - Only 4 Valduc benchmarks are included
  - Trendline fit unweighted (some benchmarks over narrow EALF range have small uncertainties)


ICSBEP Benchmark Summary Results
v.s. E of Aver.Lethargy causing fission
1.0
0.5
0.0
−0.5
−1.0
Delta k-eff (10^3 pcm)
0.1
0.2
0.3
EALF (eV)
Fit e71
Fit CIELO20160424
Benchmark reference
e71
CIELO20160424

HEU ^{238}U-reflected assemblies

- 20 benchmarks from ICSBEP were included
- The performance is marginally worse than ENDF/B-VII.1

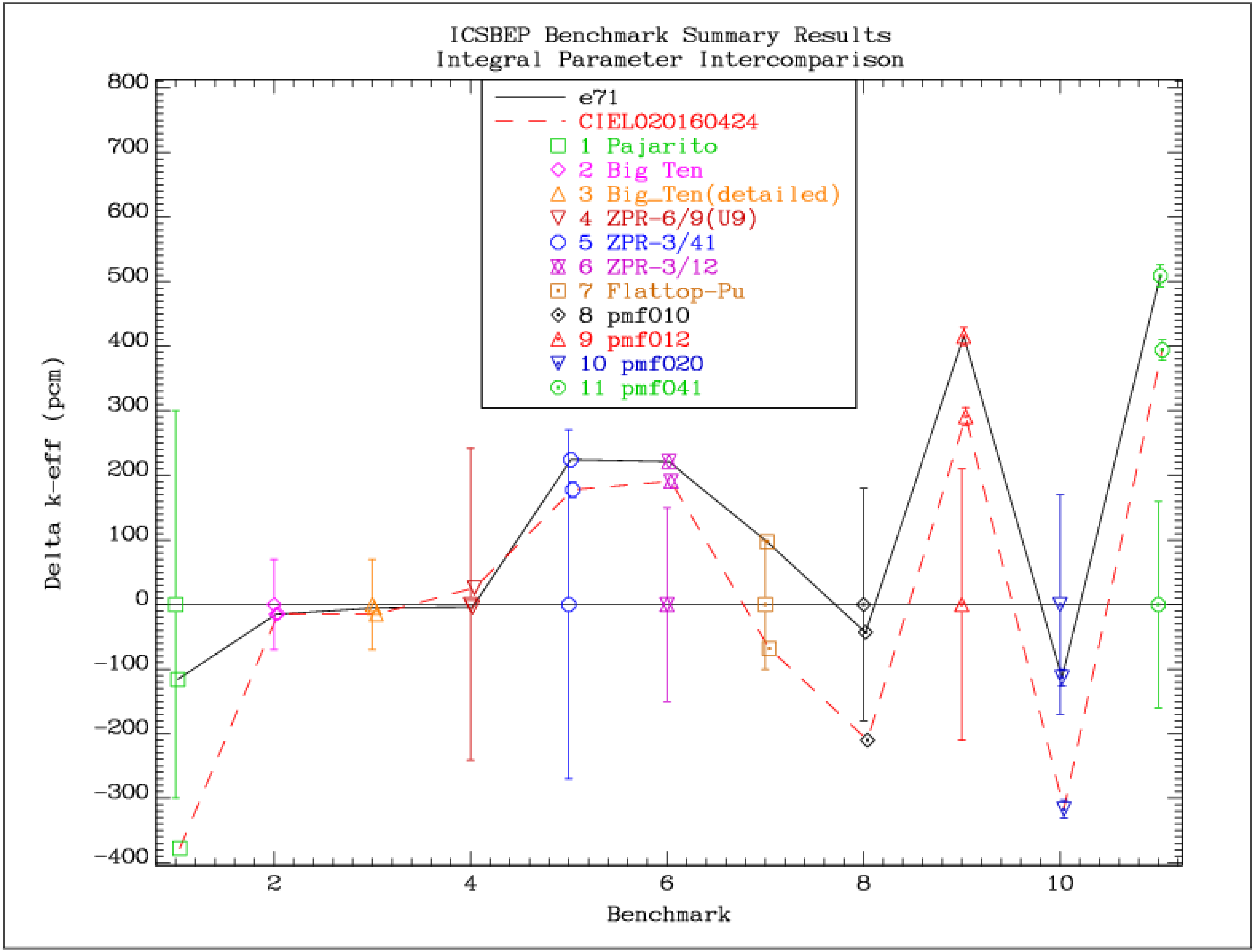
	ENDF/B-VII.1	CIELO201624	ENDF/B-VIII.b0
Chi^2/DoF Outliers	2.45 5	3.01 6	


ICSBEP Benchmark Summary Results
Integral Parameter Intercomparison
Delta k-eff (pcm)
Benchmark
e71
CIELO20160424
1 Flattop-25
2 Topsy-1
3 Topsy-2
4 Topsy-3
5 Topsy-4
6 Topsy-5
7 Topsy-6
8 Topsy-U_2.0in
9 Topsy-U_3.0in
10 Topsy-U_4.0in
11 Topsy-U_5.0in
12 Topsy-U_7.0in
13 Topsy-U_8.0in
14 Topsy-U_11.in
15 VNIITF-CTF-DU
16 TU1-3.93in
17 TU1-3.52in
18 TU1-1.742in
19 TU1-0.683in
20 FKBN2-f2

IEU and Pu ^{238}U-reflected assemblies

- 11 benchmarks from ICSBEP were included
- The performance is very similar to ENDF/B-VII.1

	ENDF/B-VII.1	CIELO201624	ENDF/B-VIII.b0
Chi^2/DoF	1.68	1.55	



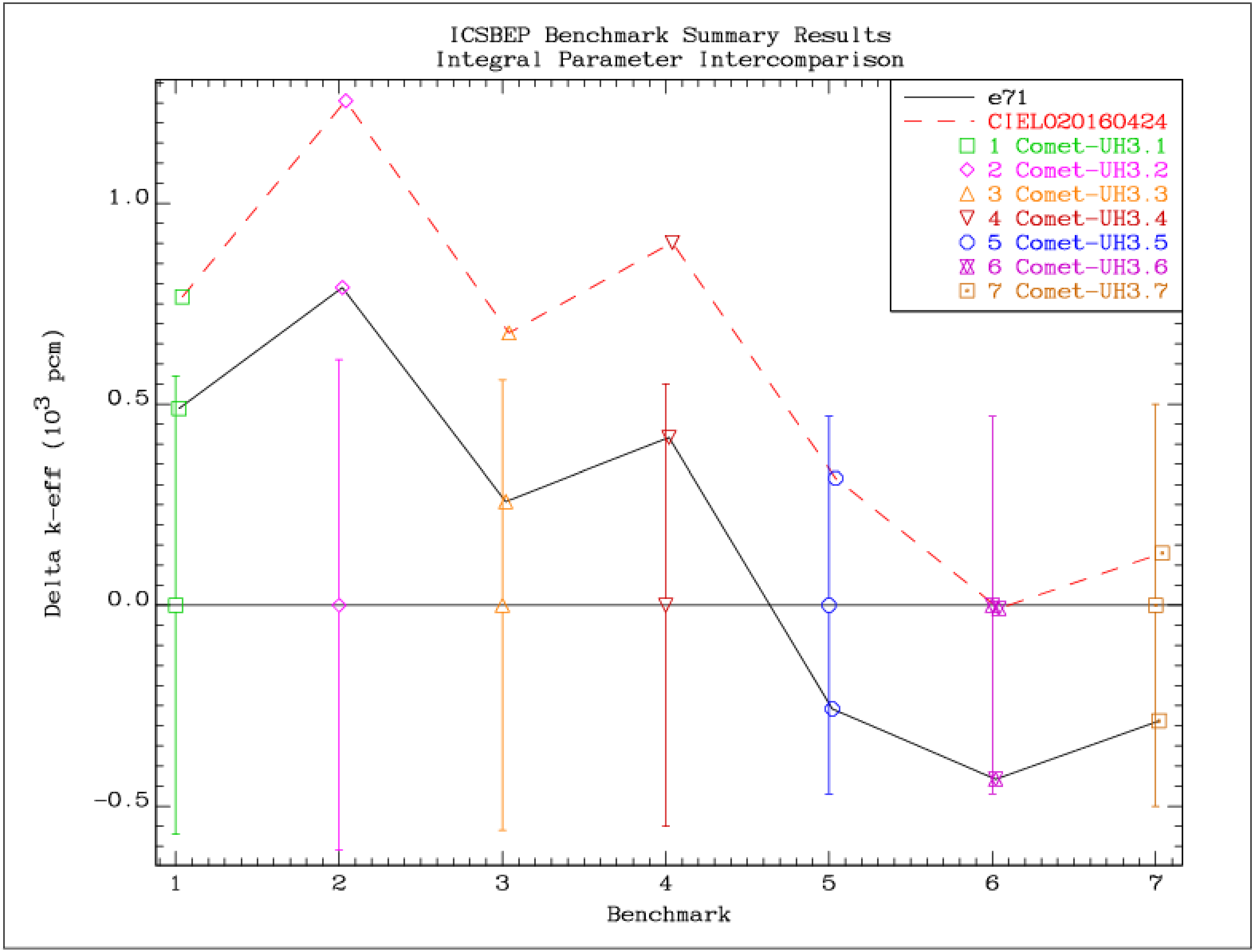
ICSBEP Benchmark Summary Results
Integral Parameter Intercomparison
e71
CIEL020160424
1 Pajarito
2 Big Ten
3 Big_Ten(detailed)
4 ZPR-6/9(U9)
5 ZPR-3/41
6 ZPR-3/12
7 Flattop-Pu
8 pmf010
9 pmf012
10 pmf020
11 pmf041
Delta k-eff (pcm)
800
700
600
500
400
300
200
100
0
−100
−200
−300
−400
2
4
6
8
10
Benchmark

Comet UH3 (HEU-COMP-INTER-003)

- Performance worse than ENDF/B-VII.1 (on-going work in RR above 20eV)
- Cases 1-4 have thick DU reflector – they are calculated high with CIELO data
- No trend with EALF (not shown)

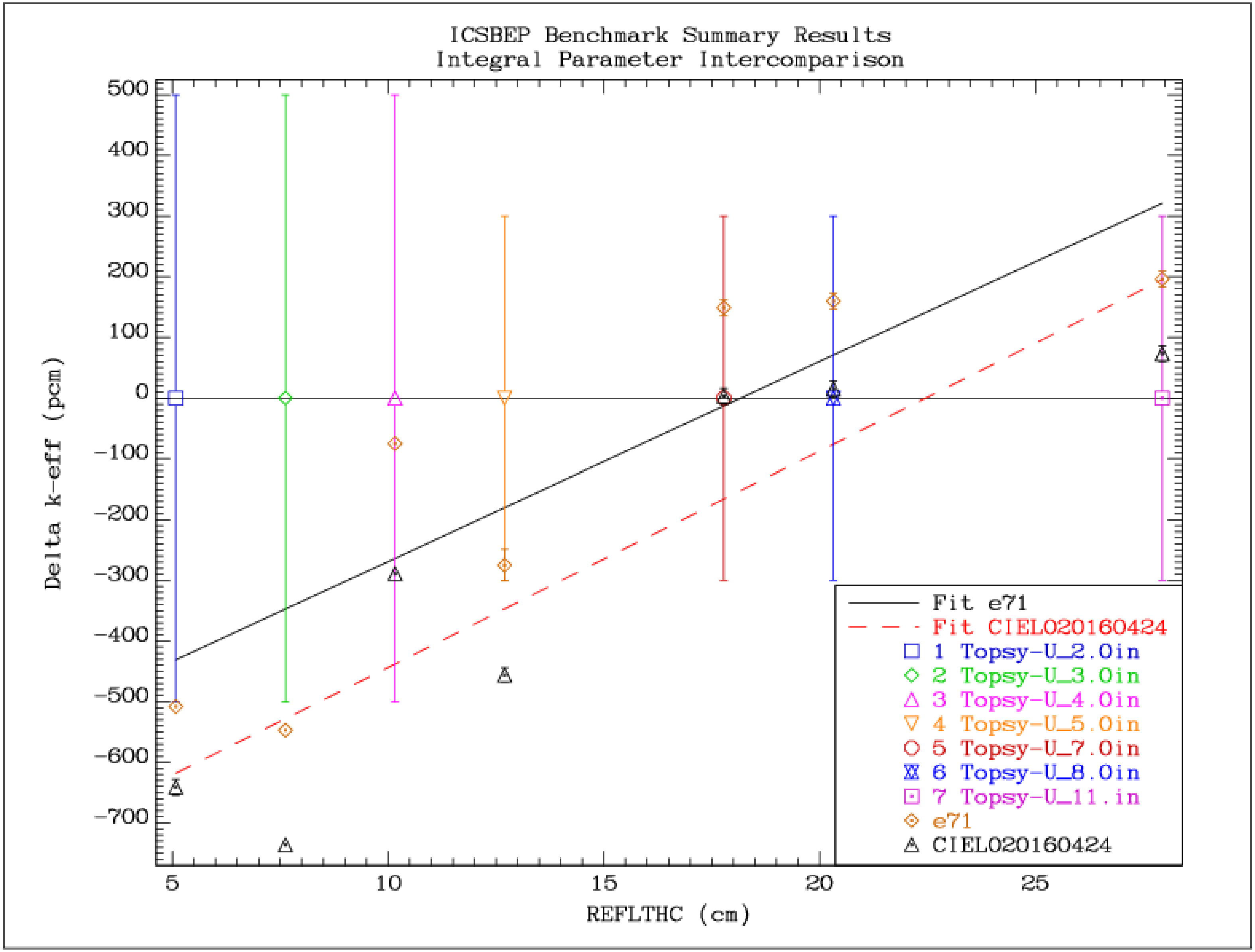
To be checked:

- Cross sections in the middle of RRR of ^{235}U
- Angular distributions of ^{238}U
- Fission neutron anisotropy (not treated in any of the commonly used MC codes)


ICSBEP Benchmark Summary Results
Integral Parameter Intercomparison
e71
CIELO20160424
1 Comet-UH3.1
2 Comet-UH3.2
3 Comet-UH3.3
4 Comet-UH3.4
5 Comet-UH3.5
6 Comet-UH3.6
7 Comet-UH3.7
Delta k-eff (10^3 pcm)
1.0
0.5
0.0
-0.5
1
2
3
4
5
6
7
Benchmark

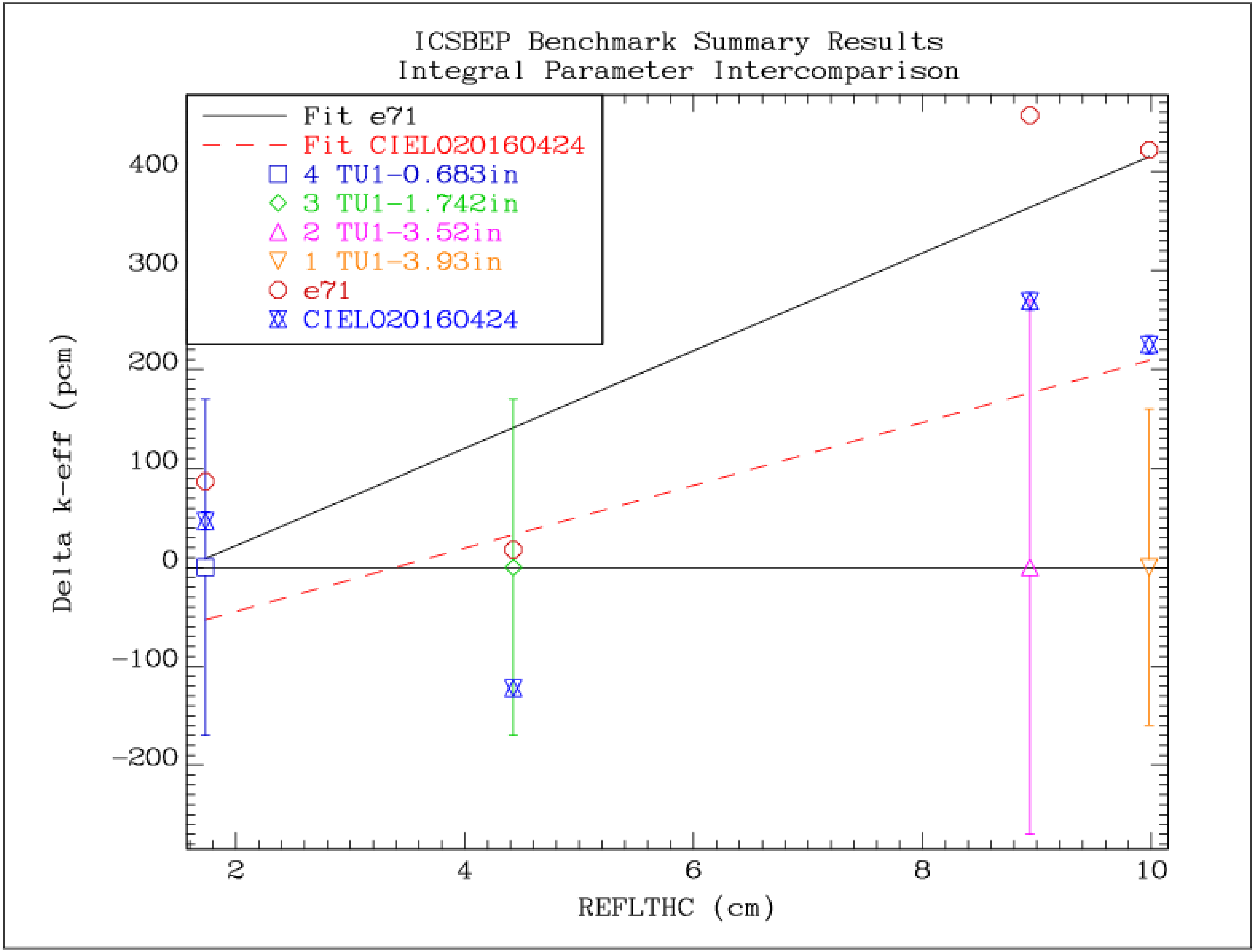
Topsy refl. ^{238}U (HEU-MET-FAST-003)

- ^{238}U reflector (2 – 11 inch)
- Clear trend with reflector thickness ~35 pcm/cm)


ICSBEP Benchmark Summary Results
Integral Parameter Intercomparison
Delta k-eff (pcm)
500
400
300
200
100
0
−100
−200
−300
−400
−500
−600
−700
5
10
15
20
25
REFLTHC (cm)
Fit e71
Fit CIEL020160424
1 Topsy-U_2.0in
2 Topsy-U_3.0in
3 Topsy-U_4.0in
4 Topsy-U_5.0in
5 Topsy-U_7.0in
6 Topsy-U_8.0in
7 Topsy-U_11.in
e71
CIEL020160424

Comet TU (HEU-MET-FAST-032)

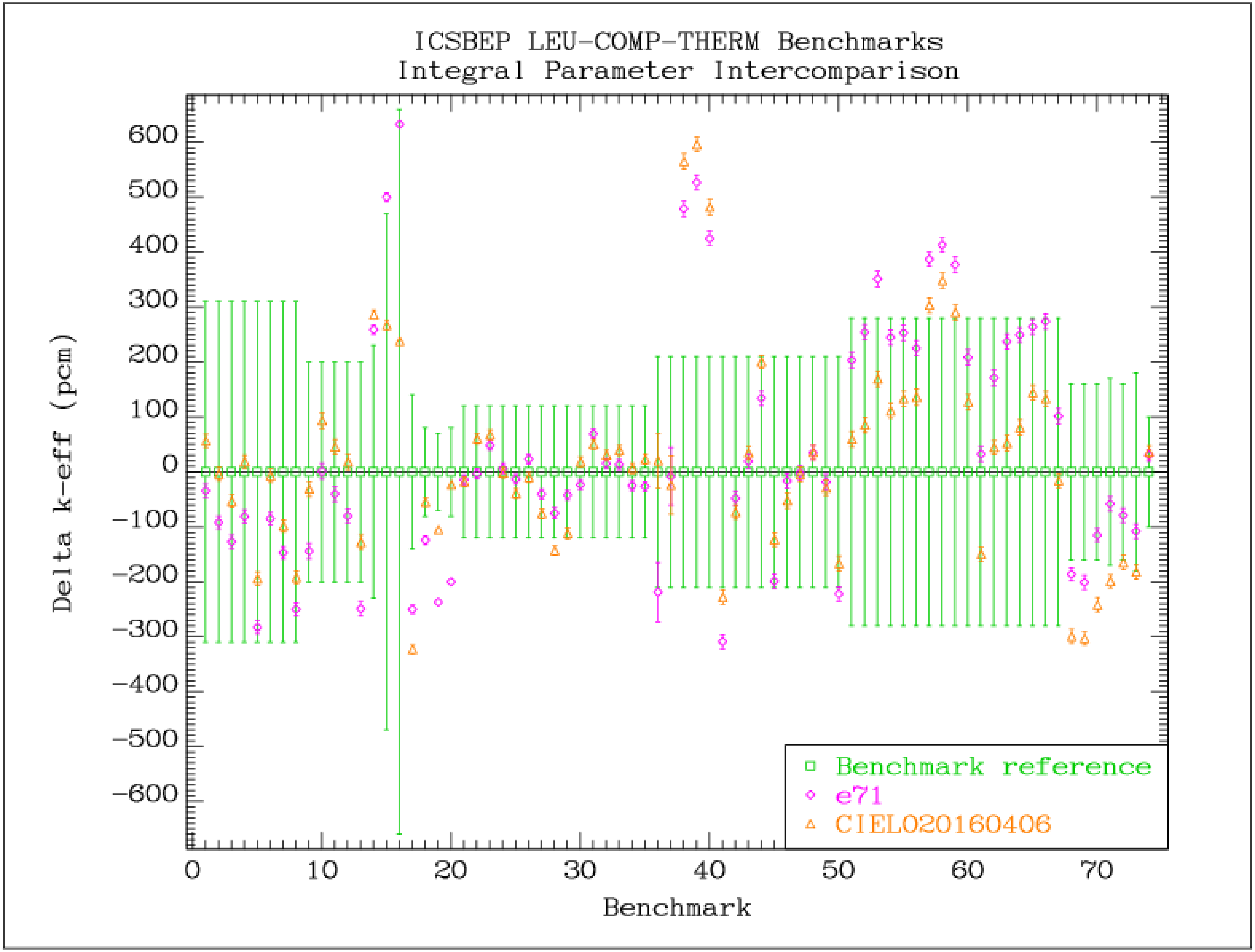
- Smaller variation of ^{238}U reflector thickness
- Similar trend


ICSBEP Benchmark Summary Results
Integral Parameter Intercomparison
Fit e71
Fit CIEL020160424
4 TU1-0.683in
3 TU1-1.742in
2 TU1-3.52in
1 TU1-3.93in
e71
CIEL020160424
Delta k-eff (pcm)
400
300
200
100
0
−100
−200
2
4
6
8
10
REFLTHC (cm)

LEU-COMP-THERM

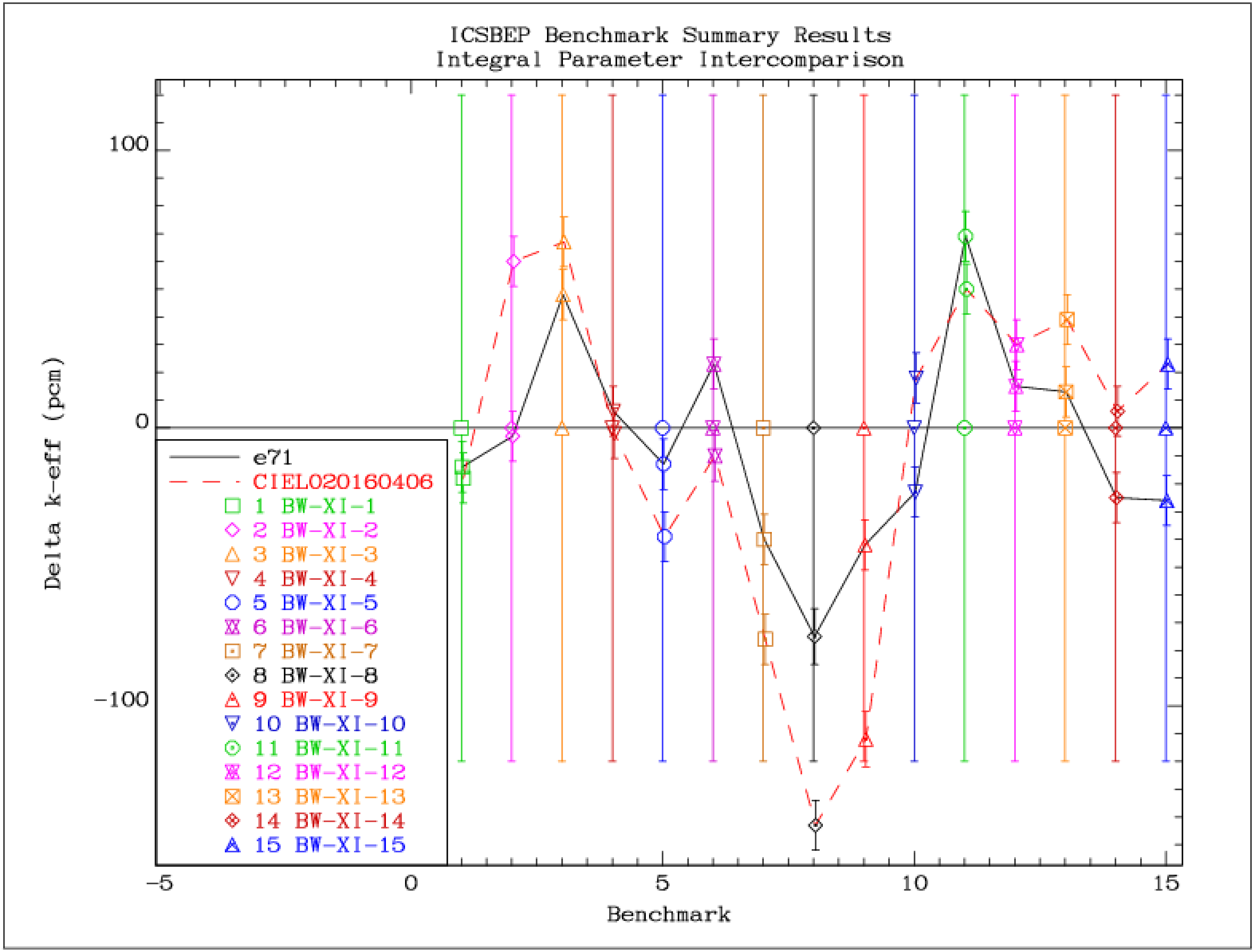
- 74 benchmarks from ICSBEP were included
- Improved performance is observed compared to ENDF/B-VII.1
- Distinct outliers are Pb-reflected systems LCT010 (Cases 1-4 and 20-23)
- Only some LCT042 cases are worse (borated)

	ENDF/B-VII.1	CIELO201624	ENDF/B-VIII.b0
Chi^2/DoF	0.99	0.78	


ICSBEP LEU-COMP-THERM Benchmarks
Integral Parameter Intercomparison
Delta k-eff (pcm)
600
500
400
300
200
100
0
−100
−200
−300
−400
−500
−600
0
10
20
30
40
50
60
70
Benchmark
Benchmark reference
e71
CIEL020160406

BW-XI (LEU-COMP-THERM-008)

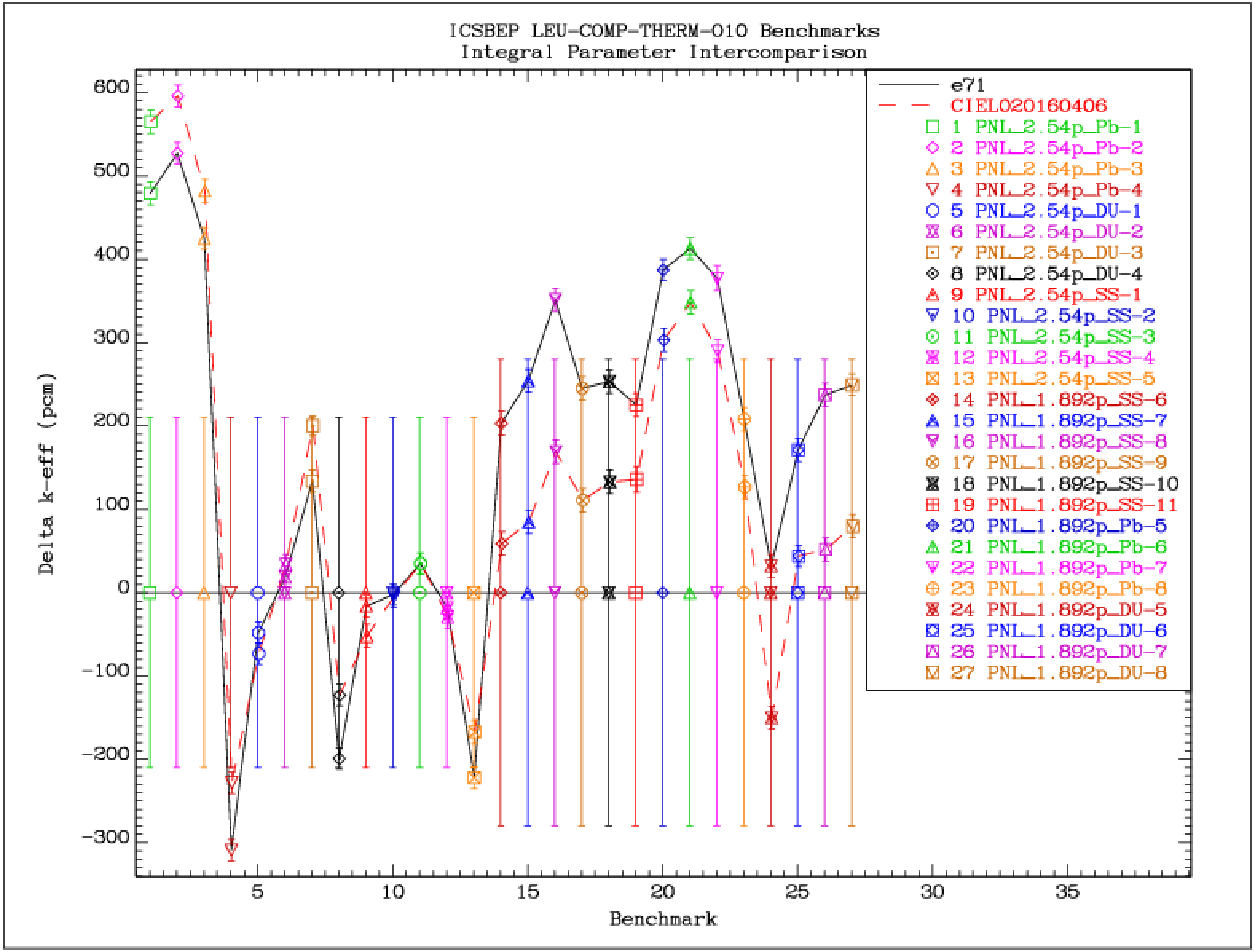
- Borated lattices with different inserts
- EALF range is rather narrow
- Cases 8 and 9 are heavily loaded with BPR and are predicted low with CIELO data



ICSBEP Benchmark Summary Results
Integral Parameter Intercomparison
Delta k-eff (pcm)
100
0
-100
-5
0
5
10
15
Benchmark
e71
CIEL020160406
1 BW-XI-1
2 BW-XI-2
3 BW-XI-3
4 BW-XI-4
5 BW-XI-5
6 BW-XI-6
7 BW-XI-7
8 BW-XI-8
9 BW-XI-9
10 BW-XI-10
11 BW-XI-11
12 BW-XI-12
13 BW-XI-13
14 BW-XI-14
15 BW-XI-15

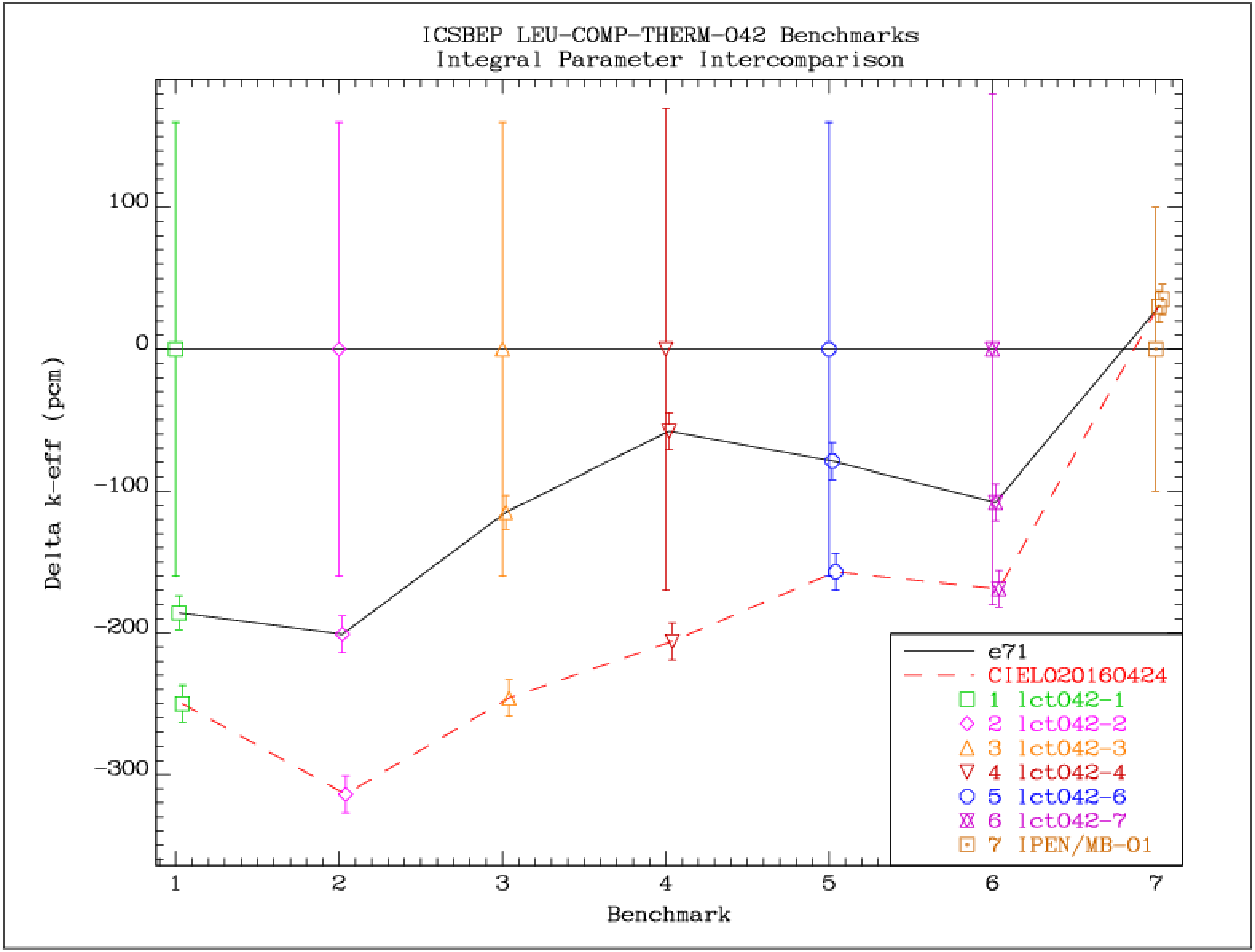
PNL-lattices (LEU-COMP-THERM-010)

- Lattices with two different pitches and different reflectors
- Only the Pb-reflected cases (1-4 and 20-24) remain discrepant


ICSBEP LEU-COMP-THERM-010 Benchmarks
Integral Parameter Intercomparison
Delta k-eff (pcm)
Benchmark
600
500
400
300
200
100
0
−100
−200
−300
5
10
15
20
25
30
35
e71
CIEL020160406
1 PNL_2.54p_Pb-1
2 PNL_2.54p_Pb-2
3 PNL_2.54p_Pb-3
4 PNL_2.54p_Pb-4
5 PNL_2.54p_DU-1
6 PNL_2.54p_DU-2
7 PNL_2.54p_DU-3
8 PNL_2.54p_DU-4
9 PNL_2.54p_SS-1
10 PNL_2.54p_SS-2
11 PNL_2.54p_SS-3
12 PNL_2.54p_SS-4
13 PNL_2.54p_SS-5
14 PNL_1.892p_SS-6
15 PNL_1.892p_SS-7
16 PNL_1.892p_SS-8
17 PNL_1.892p_SS-9
18 PNL_1.892p_SS-10
19 PNL_1.892p_SS-11
20 PNL_1.892p_Pb-5
21 PNL_1.892p_Pb-6
22 PNL_1.892p_Pb-7
23 PNL_1.892p_Pb-8
24 PNL_1.892p_DU-5
25 PNL_1.892p_DU-6
26 PNL_1.892p_DU-7
27 PNL_1.892p_DU-8

LEU-COMP-THERM-042

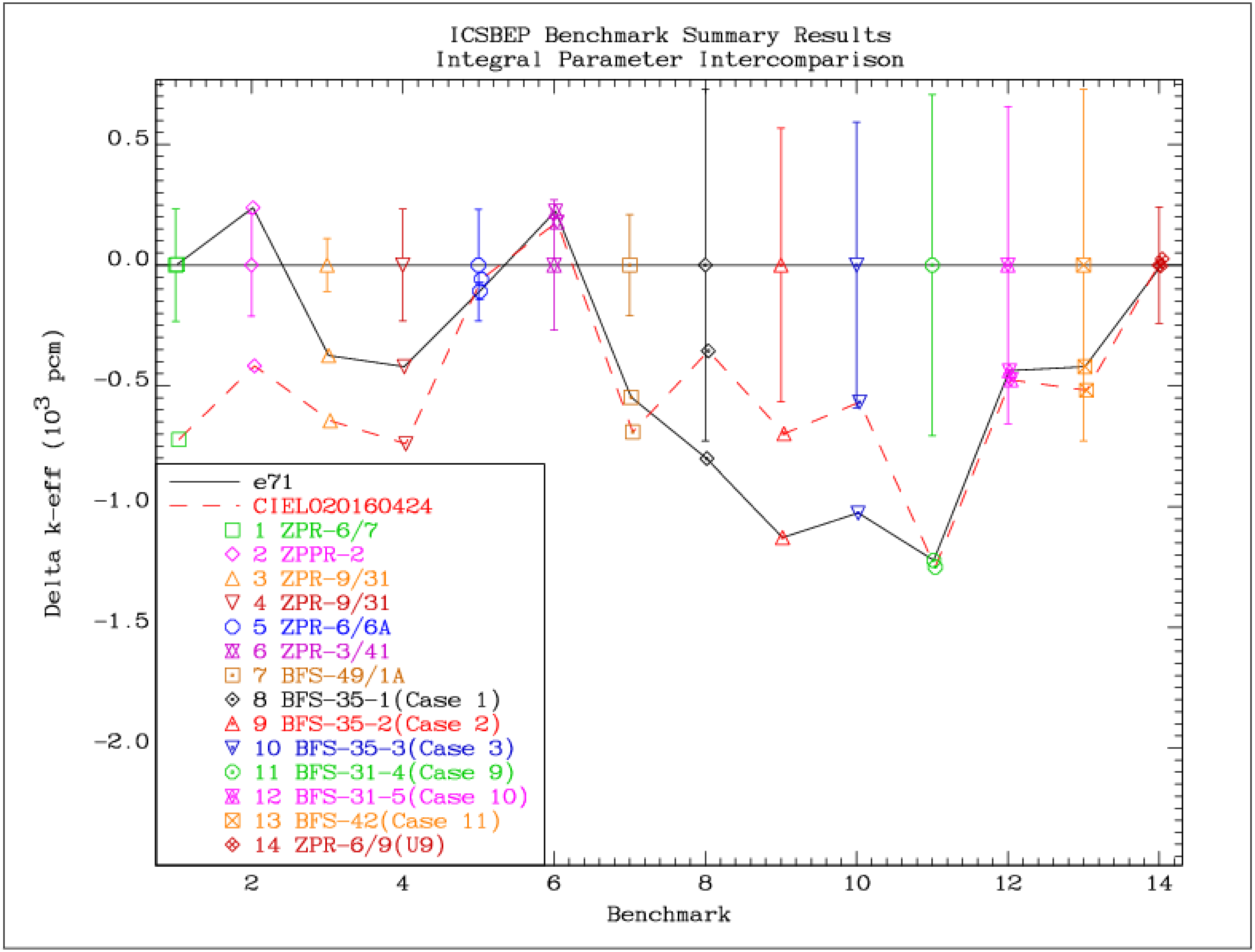
- Fuel clusters reflected on side by SS and separated by different plates
- Case 5 with Cd plate excluded (large discrepancy)
- All cases with SS, borated SS, Boral, Boroflex, Copper, Copper-Cadmium plates are predicted lower than ENDF/B-VII.1



ICSBEP LEU-COMP-THERM-042 Benchmarks
Integral Parameter Intercomparison
Delta k-eff (pcm)
100
0
-100
-200
-300
1
2
3
4
5
6
7
Benchmark
e71
CIELO20160424
1 lct042-1
2 lct042-2
3 lct042-3
4 lct042-4
5 lct042-6
6 lct042-7
7 IPEN/MB-01

Benchmarks sensitive to Fe (Part-A)

- Some ZPR cases are worse
- Some BSF cases are better



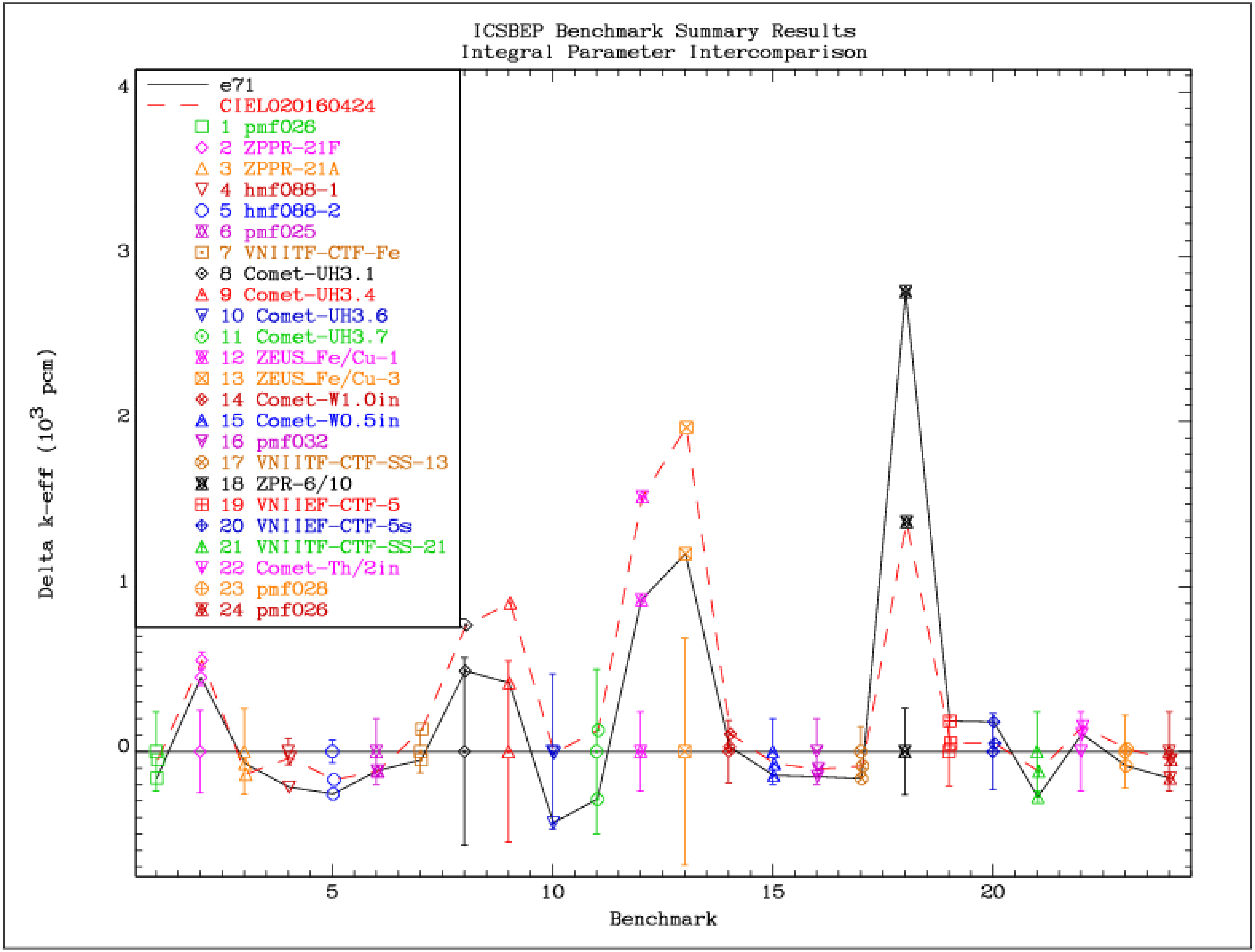
ICSBEP Benchmark Summary Results
Integral Parameter Intercomparison
Delta k-eff (10^3 pcm)
0.5
0.0
-0.5
-1.0
-1.5
-2.0
2
4
6
8
10
12
14
Benchmark
e71
CIEL020160424
1 ZPR-6/7
2 ZPPR-2
3 ZPR-9/31
4 ZPR-9/31
5 ZPR-6/6A
6 ZPR-3/41
7 BFS-49/1A
8 BFS-35-1(Case 1)
9 BFS-35-2(Case 2)
10 BFS-35-3(Case 3)
11 BFS-31-4(Case 9)
12 BFS-31-5(Case 10)
13 BFS-42(Case 11)
14 ZPR-6/9(U9)

Benchmarks sensitive to Fe (Part-B)

Performance equally good or better than ENDF/B-VII.1, except

- UH3 benchmarks (DU reflected, already discussed, work in progress on ^{235}U)
- Zeus benchmarks – sensitive to Cu
- Big improvement in ZPR-6/10 but still discrepant

More detailed analysis of the outliers is needed


ICSBEP Benchmark Summary Results
Integral Parameter Intercomparison
e71
CIEL020160424
1 pmf026
2 ZPPR-21F
3 ZPPR-21A
4 hmf088-1
5 hmf088-2
6 pmf025
7 VNIITF-CTF-Fe
8 Comet-UH3.1
9 Comet-UH3.4
10 Comet-UH3.6
11 Comet-UH3.7
12 ZEUS_Fe/Cu-1
13 ZEUS_Fe/Cu-3
14 Comet-W1.0in
15 Comet-W0.5in
16 pmf032
17 VNIITF-CTF-SS-13
18 ZPR-6/10
19 VNIIEF-CTF-5
20 VNIIEF-CTF-5s
21 VNIITF-CTF-SS-21
22 Comet-Th/2in
23 pmf028
24 pmf026
Delta k-eff (10^3 pcm)
Benchmark
0
1
2
3
4
5
10
15
20

Iron Shielding benchmark EURACOS

Work at JSI and IRMM: Reference:

- Annals of Nuclear Energy 77 (2015) 318–325

Source/Geometry

- Fission plate behind thermal column
- Bulk iron

Data:

- CIELO refers to fe56ib15k
- Ib15s same file, tweaked P_2 and P_4 Legendre coefficients of elastic angular distributions

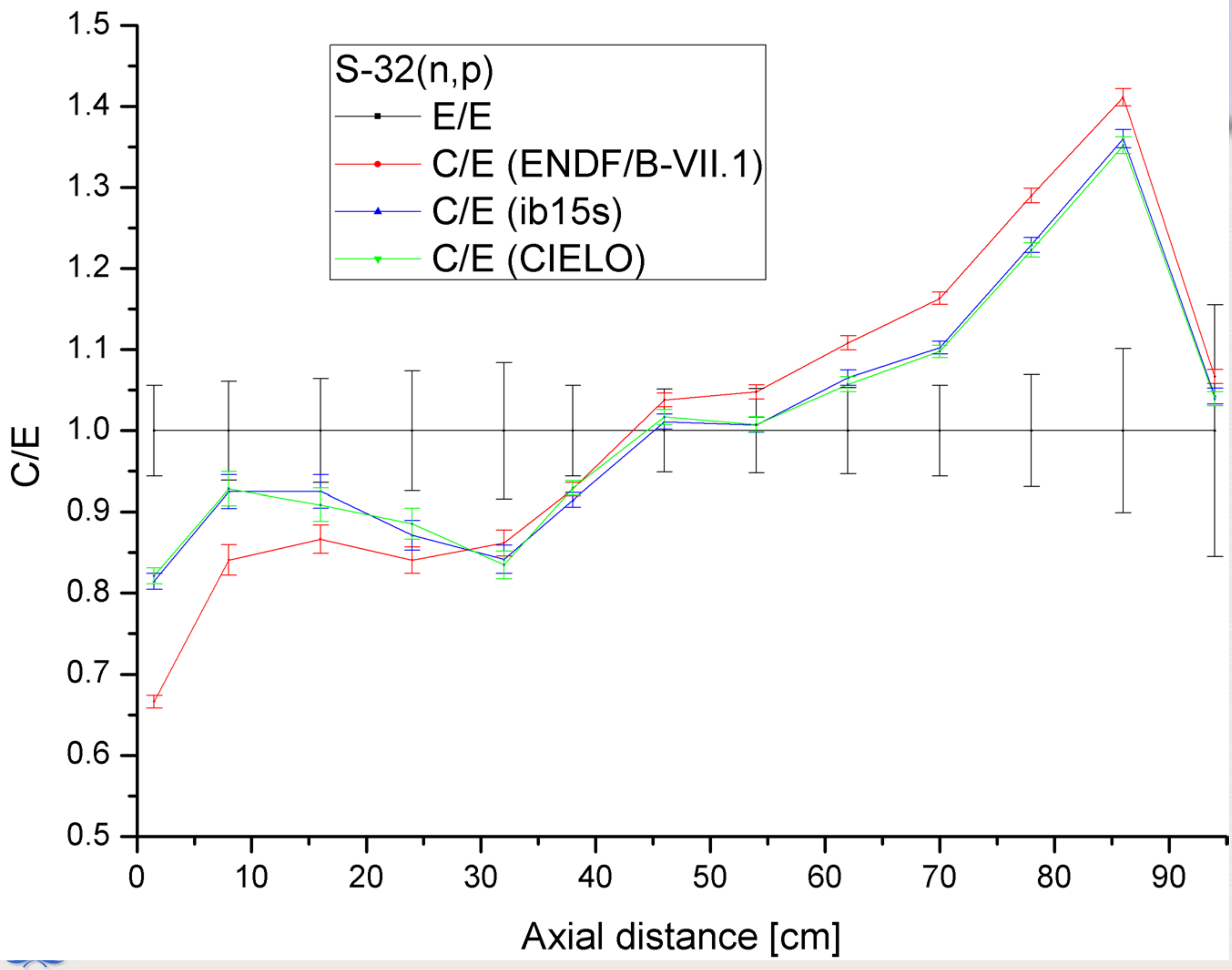
EURACOS (Cont.)

Monitor median energies in ^{252}Cf spectrum

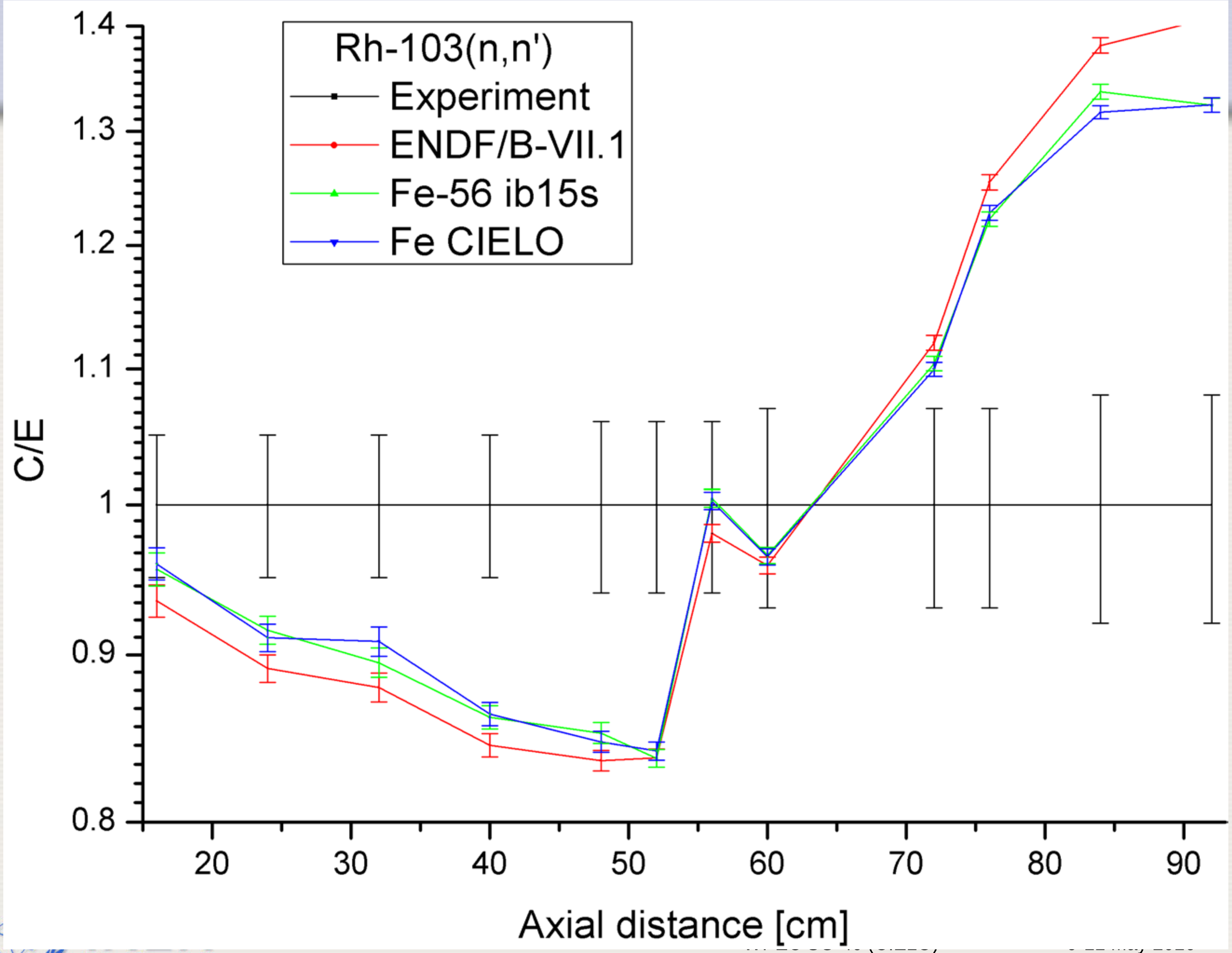
- 4.07 MeV $^{32}S(n,p)$
- 2.67 MeV $^{115}In(n,n')$
- 2.38 MeV $^{103}Rh(n,n')$

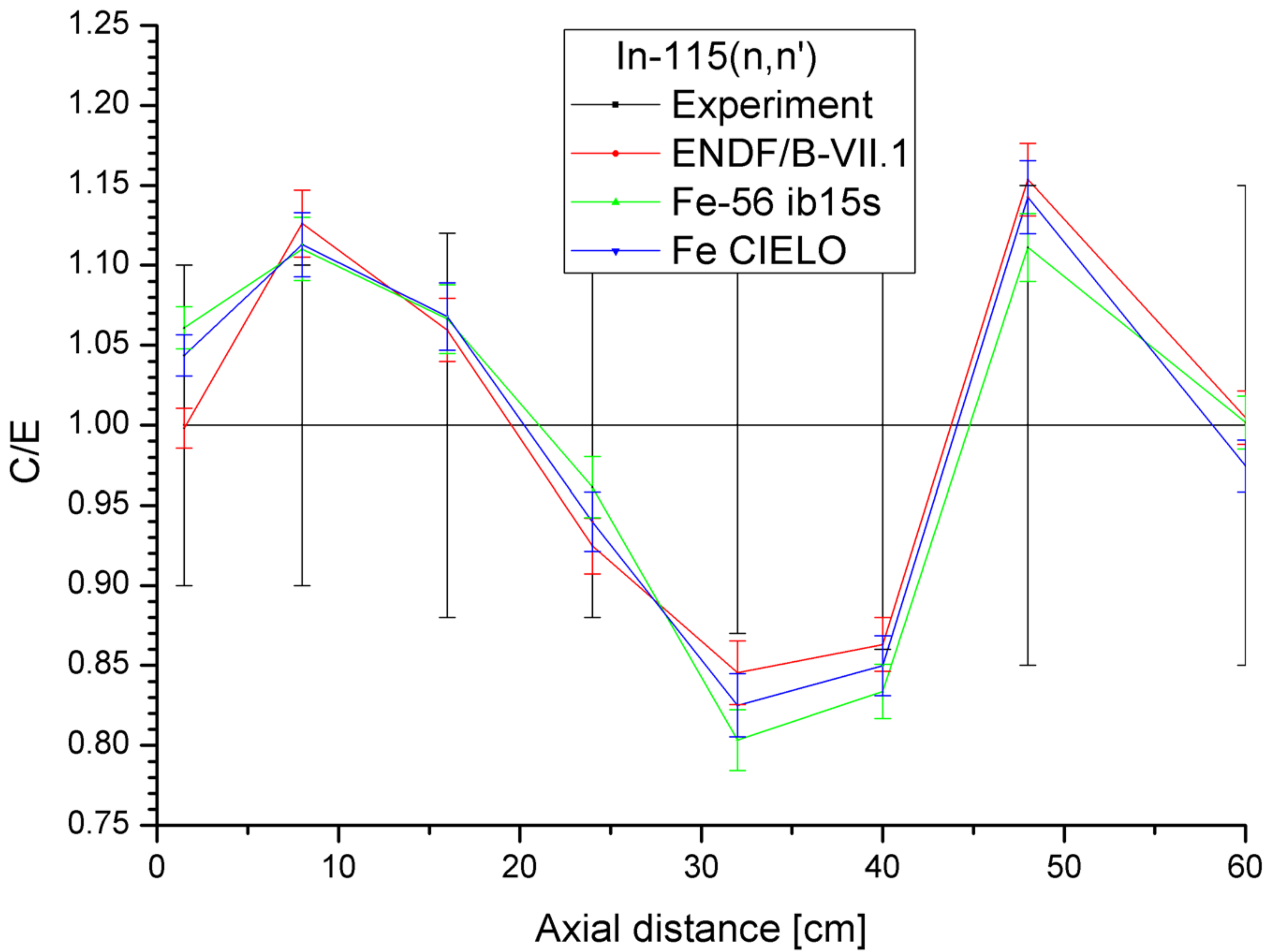
Au monitor median energy in 1/E spectrum

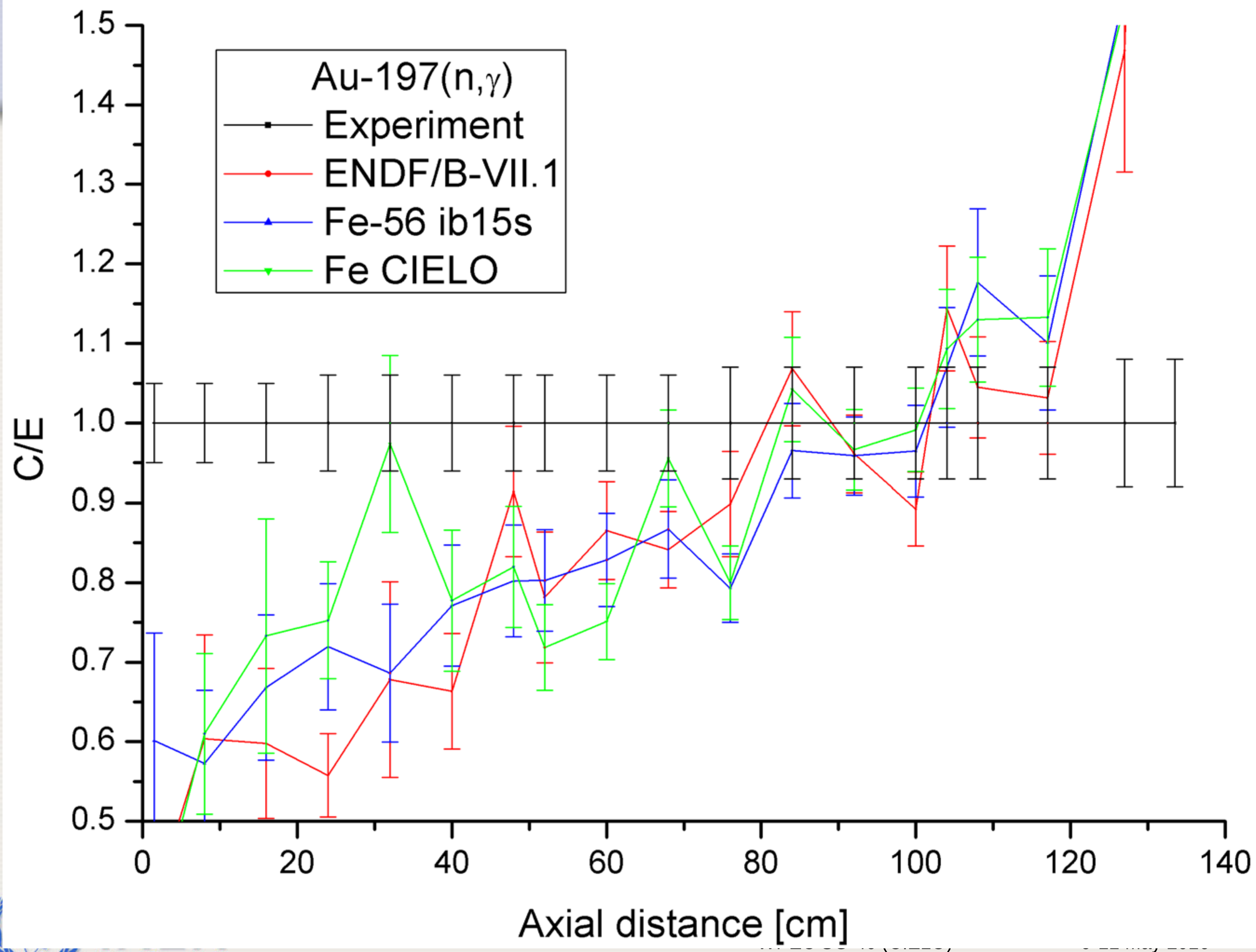
- 4.88 eV



S-32(n,p)
E/E
C/E (ENDF/B-VII.1)
C/E (ib15s)
C/E (CIELO)
C/E
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0
10
20
30
40
50
60
70
80
90
Axial distance [cm]


Rh-103(n,n')
Experiment
ENDF/B-VII.1
Fe-56 ib15s
Fe CIELO
C/E
1.4
1.3
1.2
1.1
1
0.9
0.8
20
30
40
50
60
70
80
90
Axial distance [cm]


In-115(n,n')
Experiment
ENDF/B-VII.1
Fe-56 ib15s
Fe CIELO
C/E
1.25
1.20
1.15
1.10
1.05
1.00
0.95
0.90
0.85
0.80
0.75
0
10
20
30
40
50
60
Axial distance [cm]


Au-197(n,γ)
Experiment
ENDF/B-VII.1
Fe-56 ib15s
Fe CIELO
C/E
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0
20
40
60
80
100
120
140
Axial distance [cm]

Conclusions on ^{235}U

- Fast energy range OK
- Thermal energy range OK
- More work is needed in RRR (>20 eV)

Conclusions on ^{238}U

- Works well in intermediate-enriched systems
- Strong trend with reflector thickness (~35 pcm/cm)
- Needs checking:
  - Capture in the RRR
  - Angular distributions
  - Anisotropy of fission neutrons (wild guess)

Conclusions on ^{239}Pu

- Very few bare assembly benchmarks are available
- Seems to work reasonably in reflected systems
- More checking is needed for thermal solutions

Conclusions on Fe

- Validation is difficult due to interferences with other nuclides
- No real improvement in RRR at low Energies since Froehner
- Measurement of capture 10-25 keV is badly needed
- Situation at higher energies seems better (waiting the release of RPI data and improved evaluation from IRSN)
- EURACOS shielding benchmark inconclusive (uncertainties about source, see ANE77(2015)318-325)
- Analysis of other shielding benchmarks in progress
- Re-evaluation must include minor isotopes due to interference (and possibly Cr, Mn, Ni…)