Benchmark Results with the IAEA-CIELO Evaluated Data Files

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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/"

^{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>850keV 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

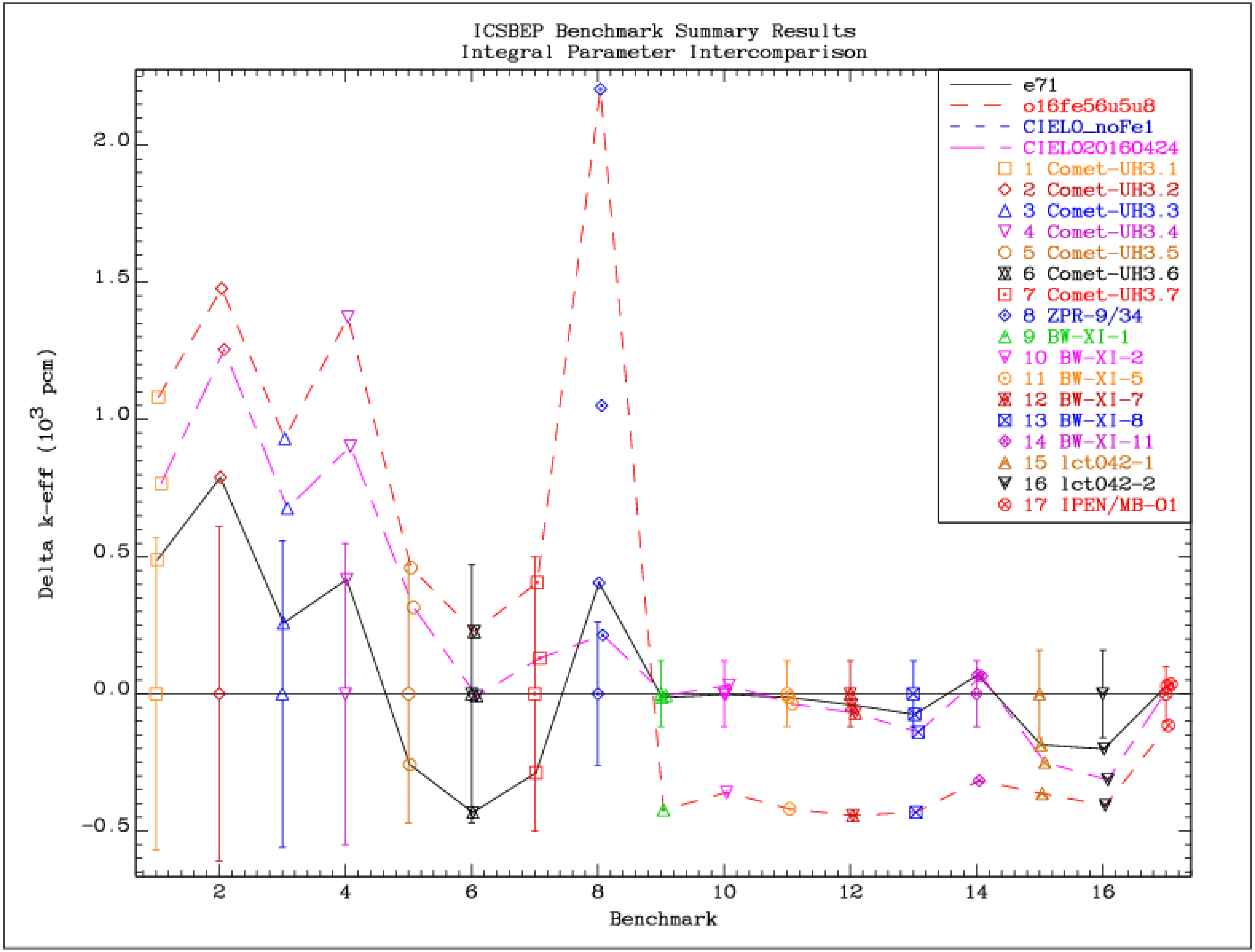
All IAEA files are available on **https://www-nds.iaea.org/CIELO/**

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	

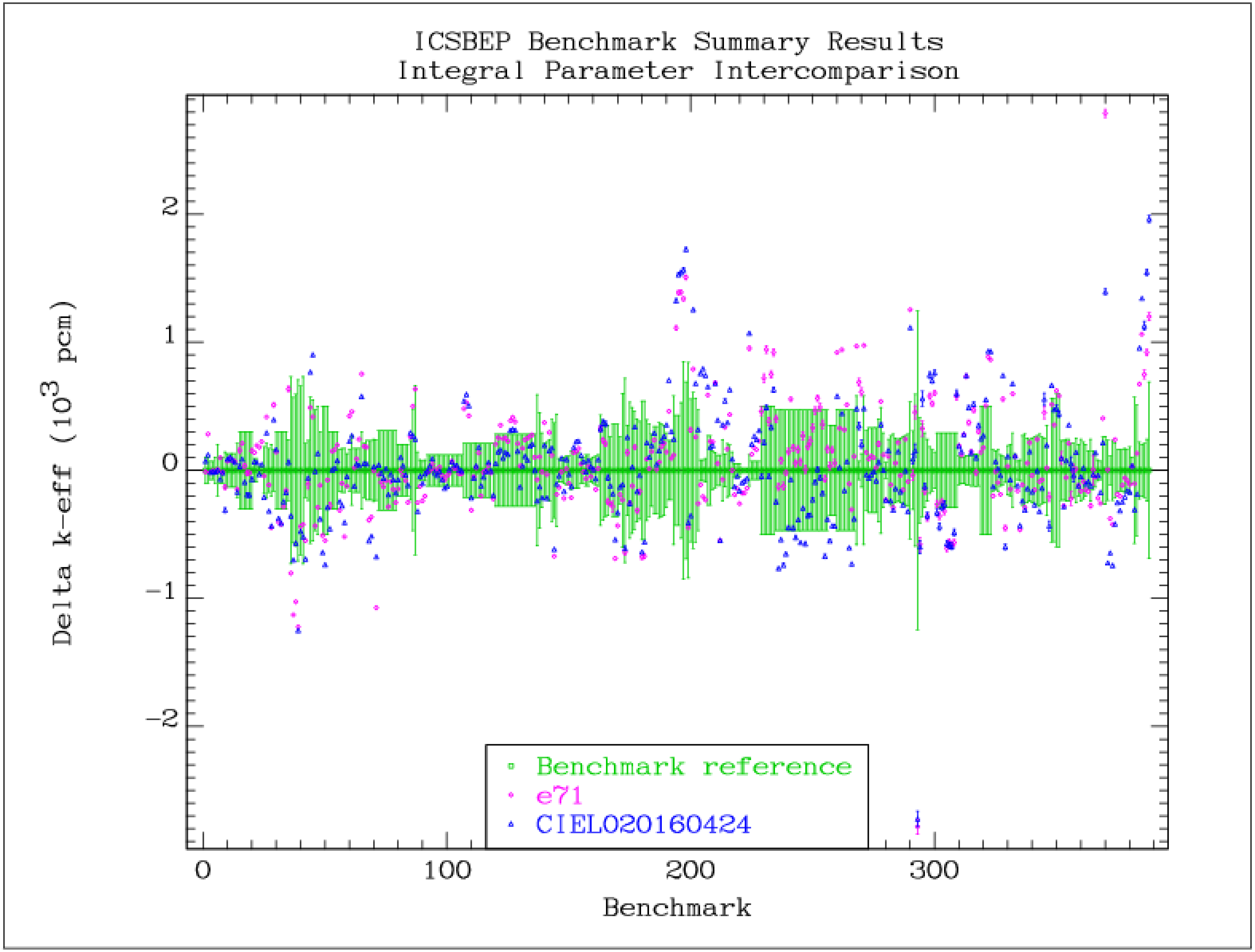


ICSBEP Benchmark Summary Results
Integral Parameter Intercomparison
Delta k-eff (10^3 pcm)
Benchmark
e71
o16fe56u5u8
CIELO_noFe1
CIELO20160424
1 Comet-UH3.1
2 Comet-UH3.2
3 Comet-UH3.3
4 Comet-UH3.4
5 Comet-UH3.5
6 Comet-UH3.6
7 Comet-UH3.7
8 ZPR-9/34
9 BW-XI-1
10 BW-XI-2
11 BW-XI-5
12 BW-XI-7
13 BW-XI-8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

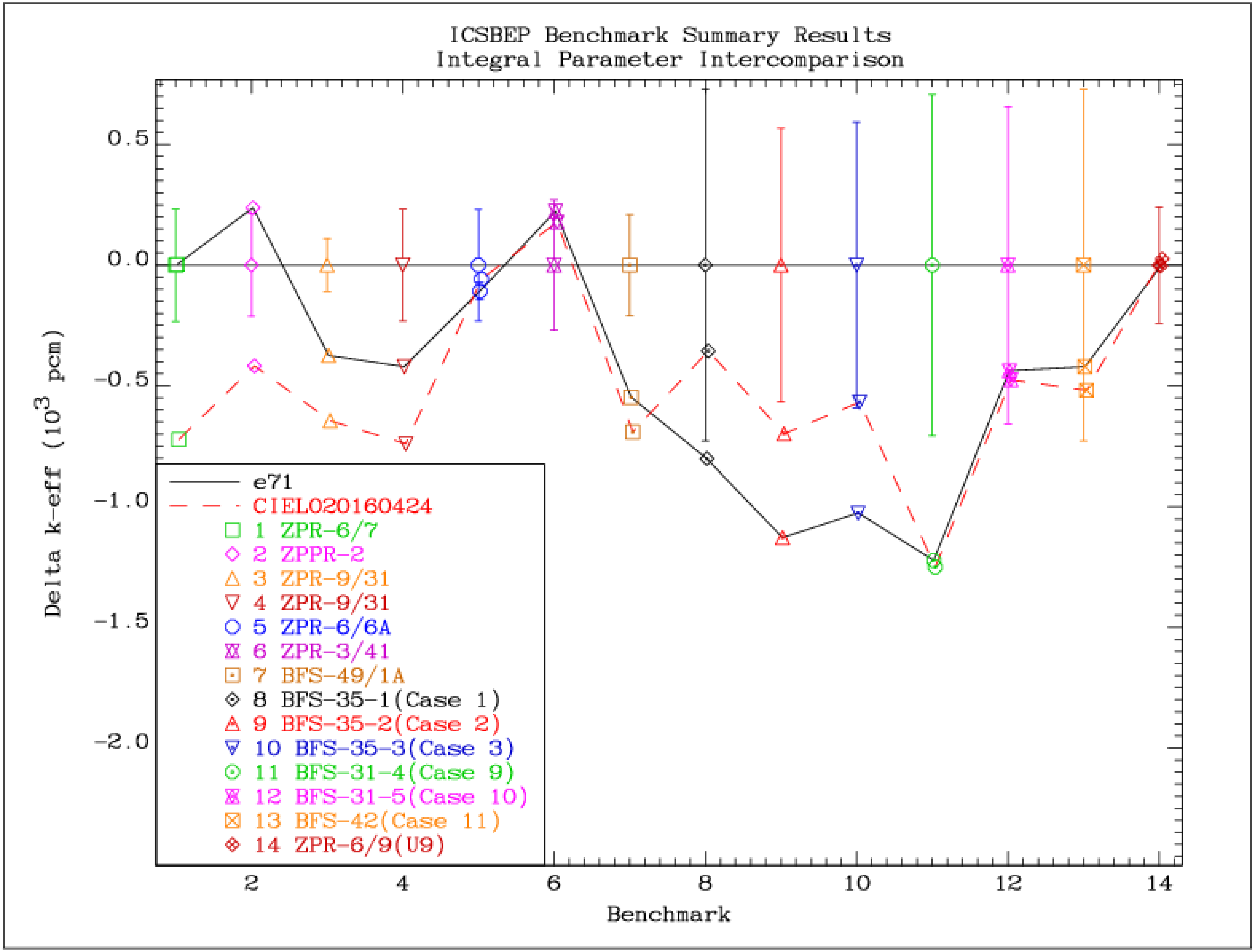

ICSBEP Benchmark Summary Results
Integral Parameter Intercomparison
Delta k-eff (10^3 pcm)
2
1
0
−1
−2
0
100
200
300
Benchmark
Benchmark reference
e71
CIELO20160424

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

Benchmarks sensitive to Fe (Part-A)

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



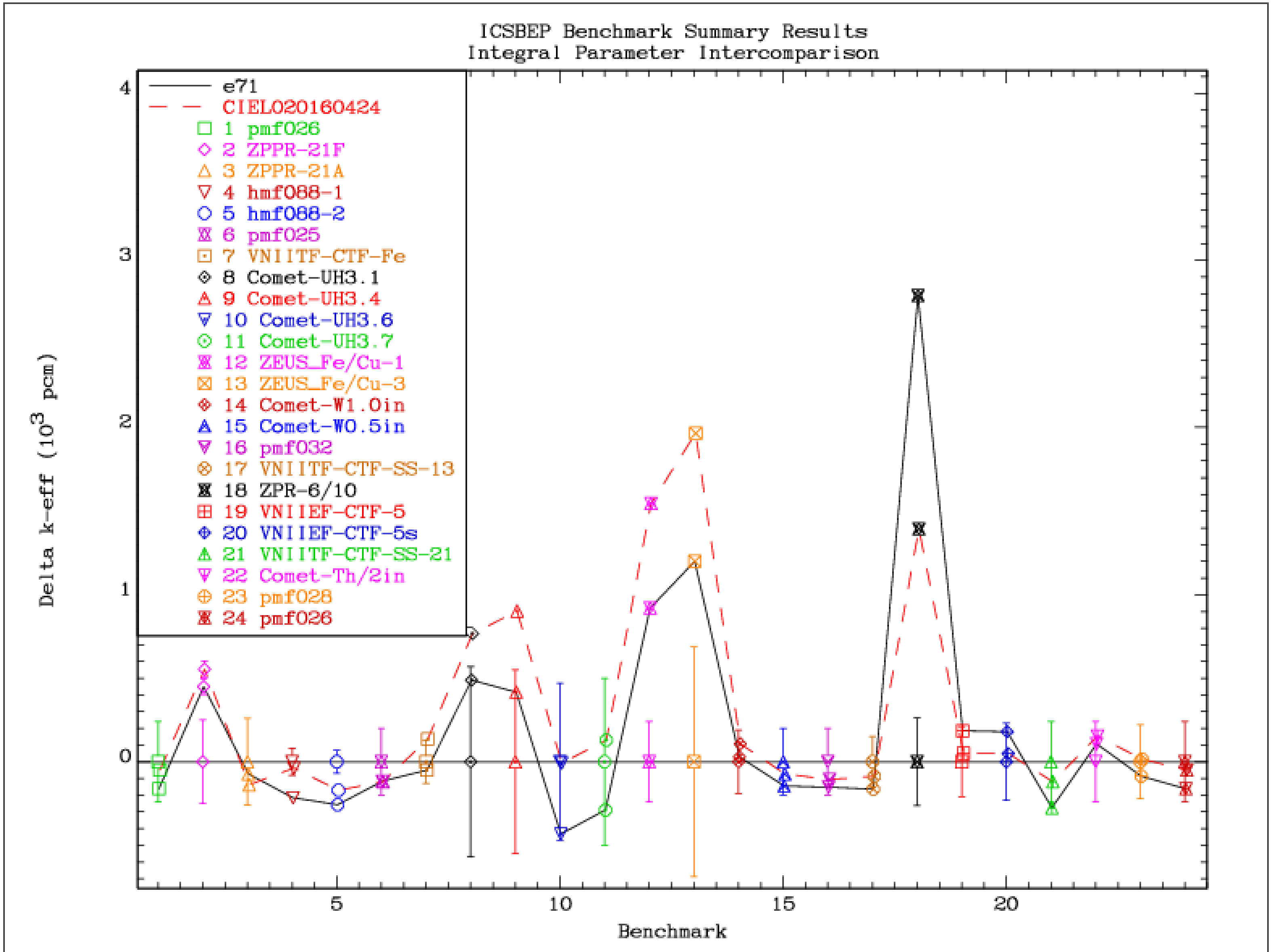
ICSBEP Benchmark Summary Results
Integral Parameter Intercomparison
Delta k-eff (10^3 pcm)
0.5
0.0
-0.5
-1.0
-1.5
-2.0
2
4
6
8
10
12
14
Benchmark
e71
CIEL020160424
1 ZPR-6/7
2 ZPPR-2
3 ZPR-9/31
4 ZPR-9/31
5 ZPR-6/6A
6 ZPR-3/41
7 BFS-49/1A
8 BFS-35-1(Case 1)
9 BFS-35-2(Case 2)
10 BFS-35-3(Case 3)
11 BFS-31-4(Case 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
CIELO20160424
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

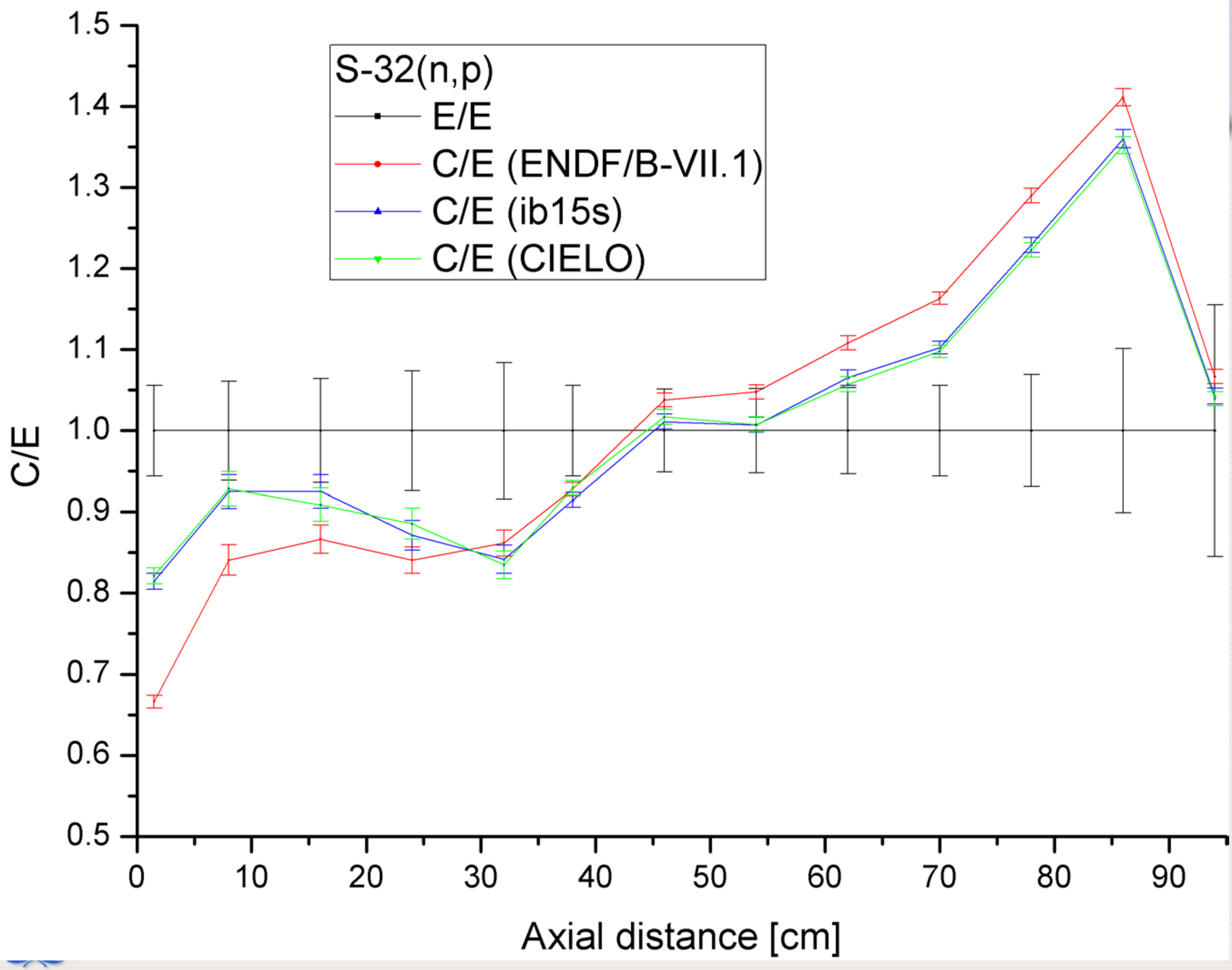
EURACOS (Cont.)

Monitor median energies in ^{252}Cf spectrum

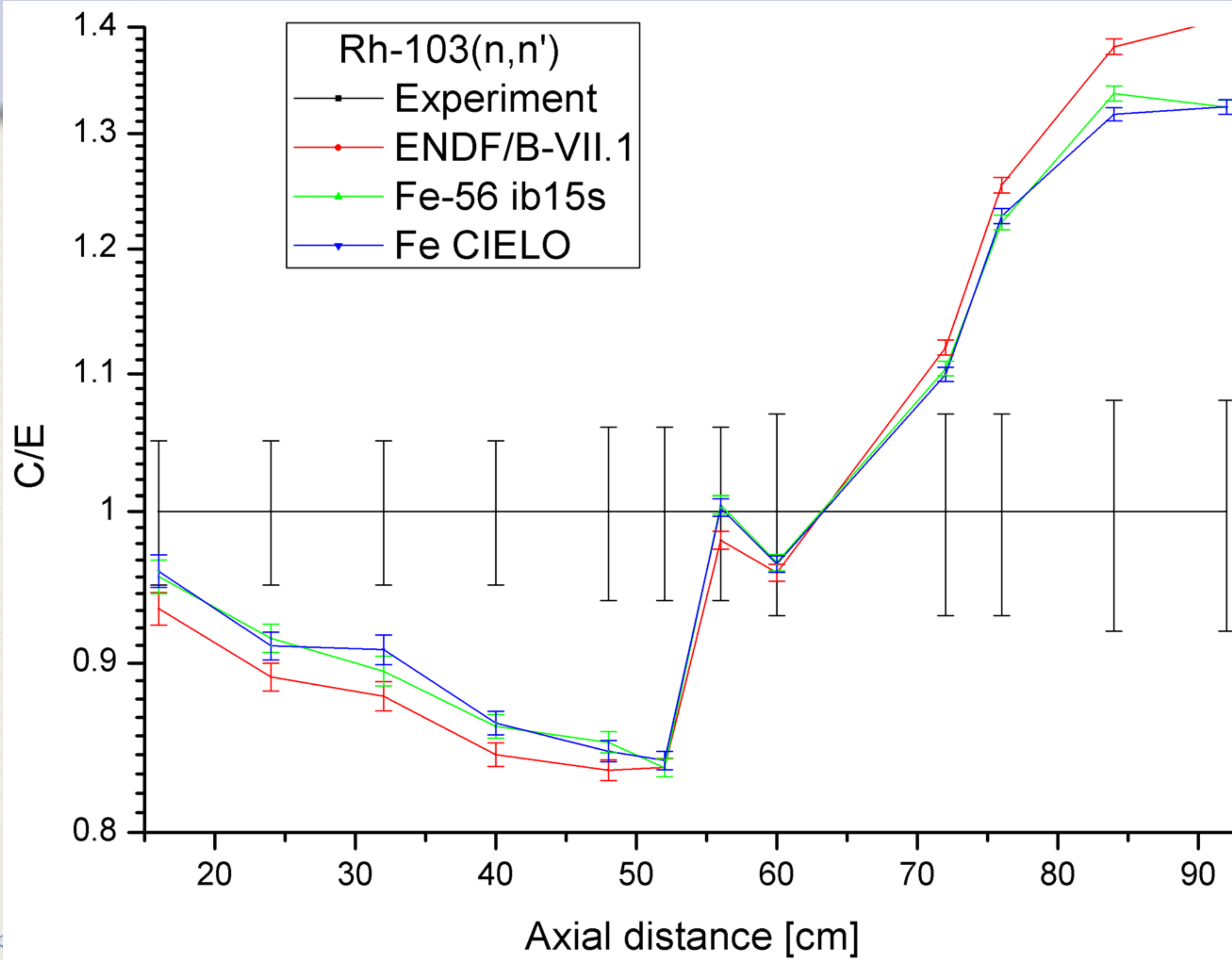
- 4.07 MeV ^{32}S(n,p)
- 2.67 MeV ^{115}In(n,n’)
- 2.38 MeV ^{103}Rh(n,n’)

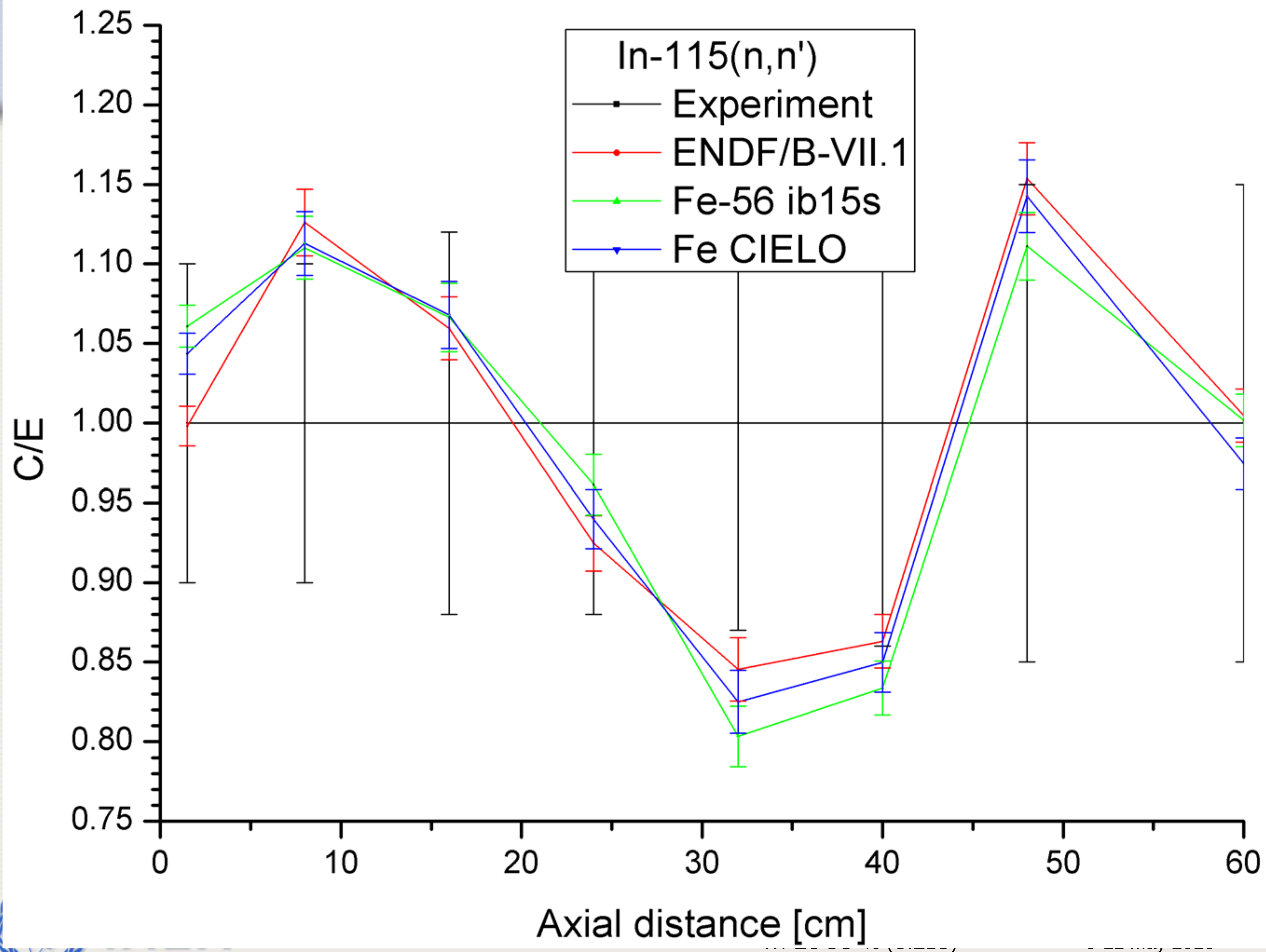
Au monitor median energy in 1/E spectrum

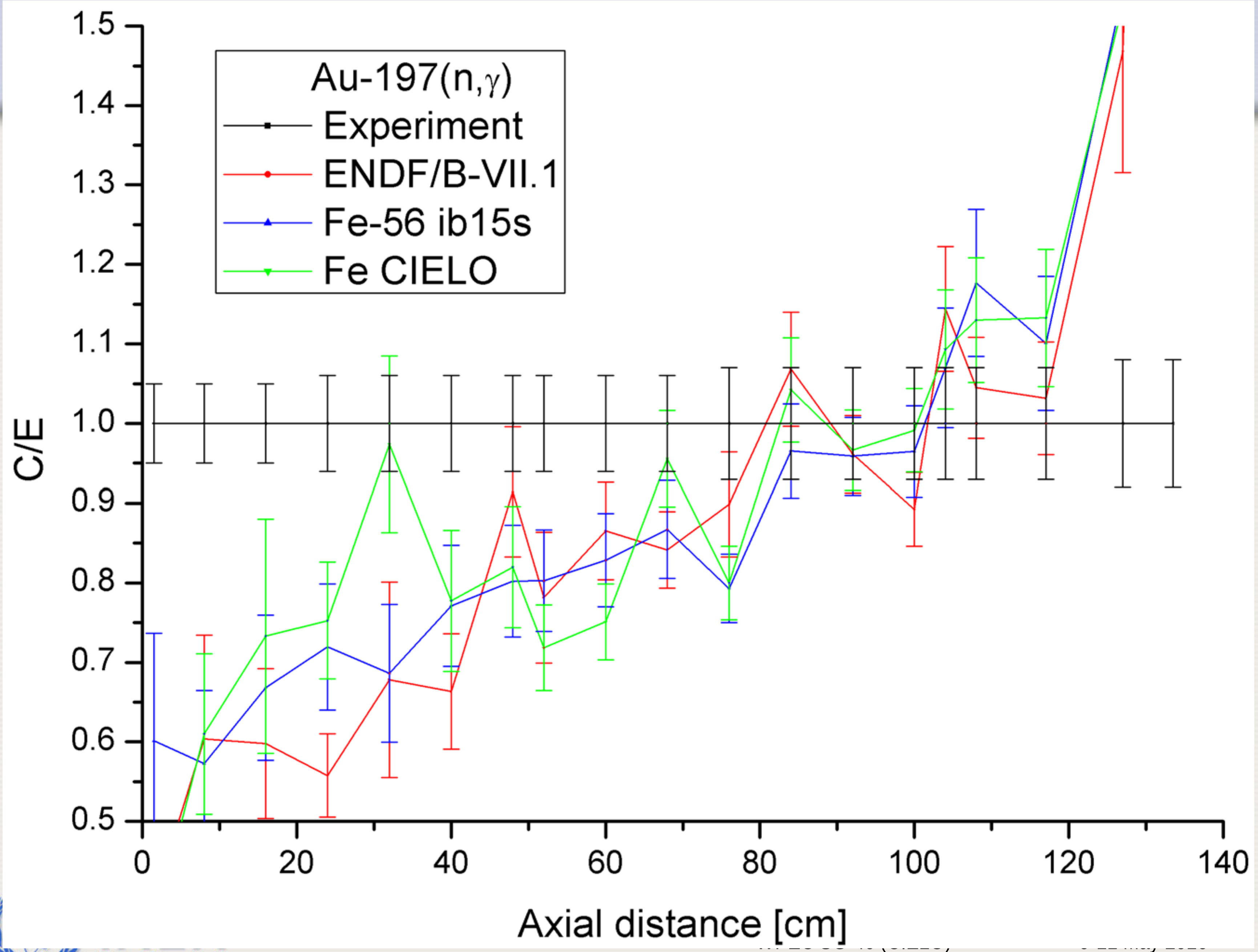
- 4.88 eV



S-32(n,p)
E/E
C/E (ENDF/B-VII.1)
C/E (ib15s)
C/E (CIELO)
C/E
Axial distance [cm]
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


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


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 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…)