Validation of Recent Changes in Actinide Evaluations U-235, U-233, Pu-239

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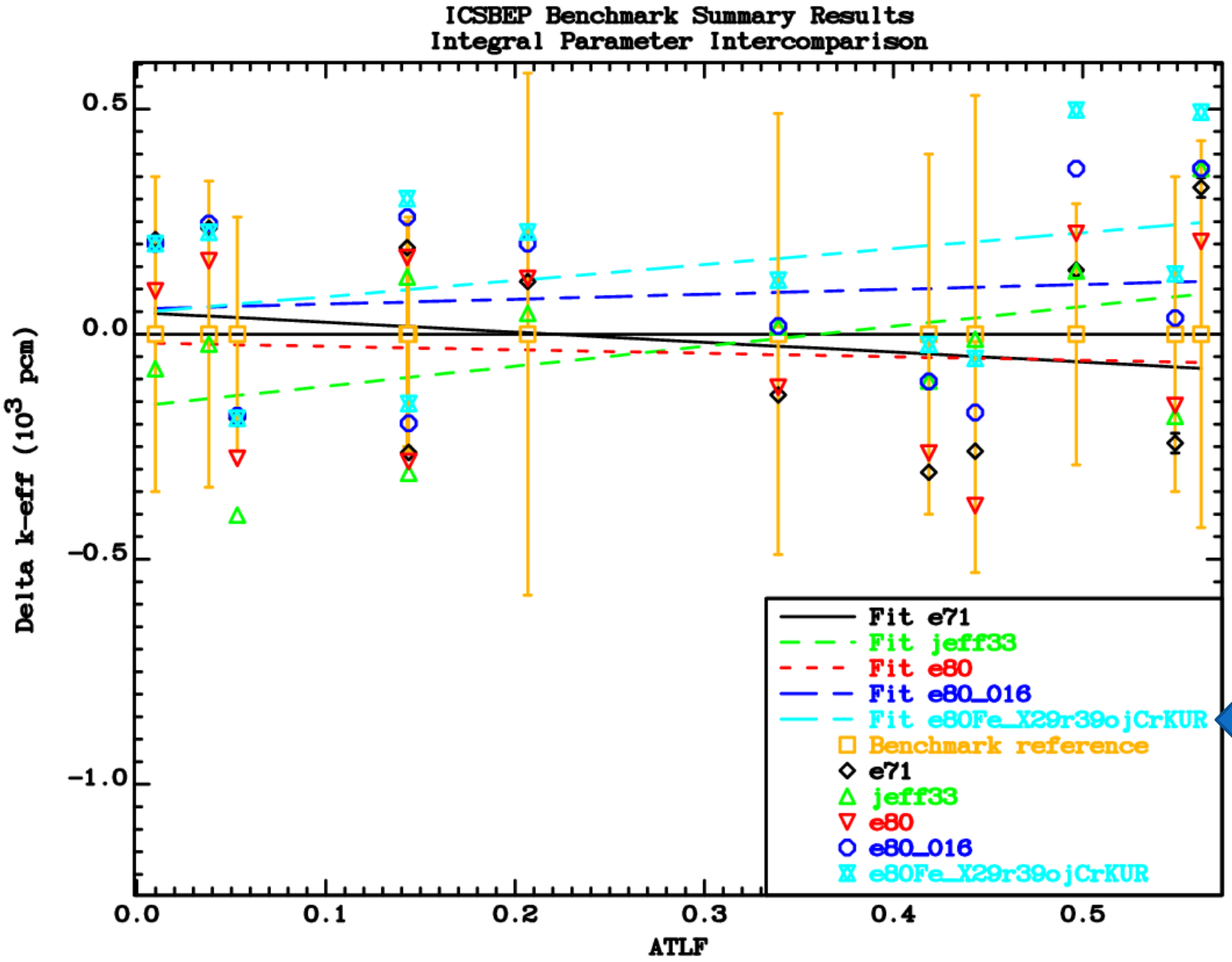
(on behalf of INDEN collaboration)

U-235 Updates Summary (ORNL/IAEA)

- Fluctuations in the fission cross section in the URR range were refined to represent measured data following Paradela *et al.* evaluation.
- Small changes to the low-energy resonances to improve the fit to measured capture data from RPI (capture reduced by 5% from 0.06-7.8 eV, by 7.7% from 7.8-11 eV) .
- Very small change to thermal nu-bar within uncertainties.
- Discrete level data are stored in MF=6 (format requirement, no impact on calculations).
- Issues leading to negative eigenvalues in cross-covariances in the RR sorted out.

Impact of U-235 changes to integral benchmarks

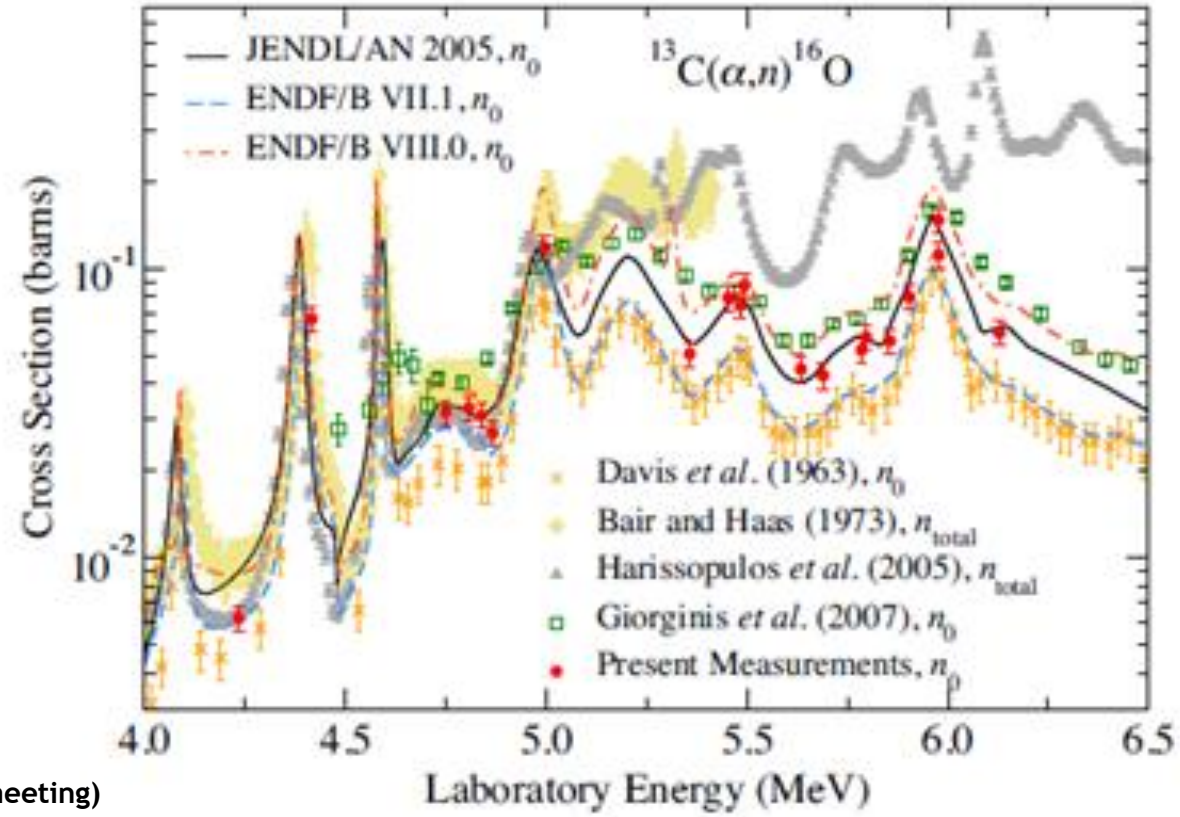
- Impact on fast assemblies is very small.
- Strong impact of **O-16 cross sections** – needs to be sorted out before the impact of U-235 can be assessed.
- Affected benchmarks are the SNL series (LCT-078, 79, 80, 96, 97), see presentation "**Nuclear Data Testing for PWR at JSI**").
- Some impact on the gradient as a function of ATLF in thermal solution benchmarks due to the reduction of capture around 1eV and reduction of absorption in O-16 (slight increase with ATLF).
- Both factors lead to increased criticality for high-leakage solutions



New INDEN files

O-16 Alternative Evaluation (differential)

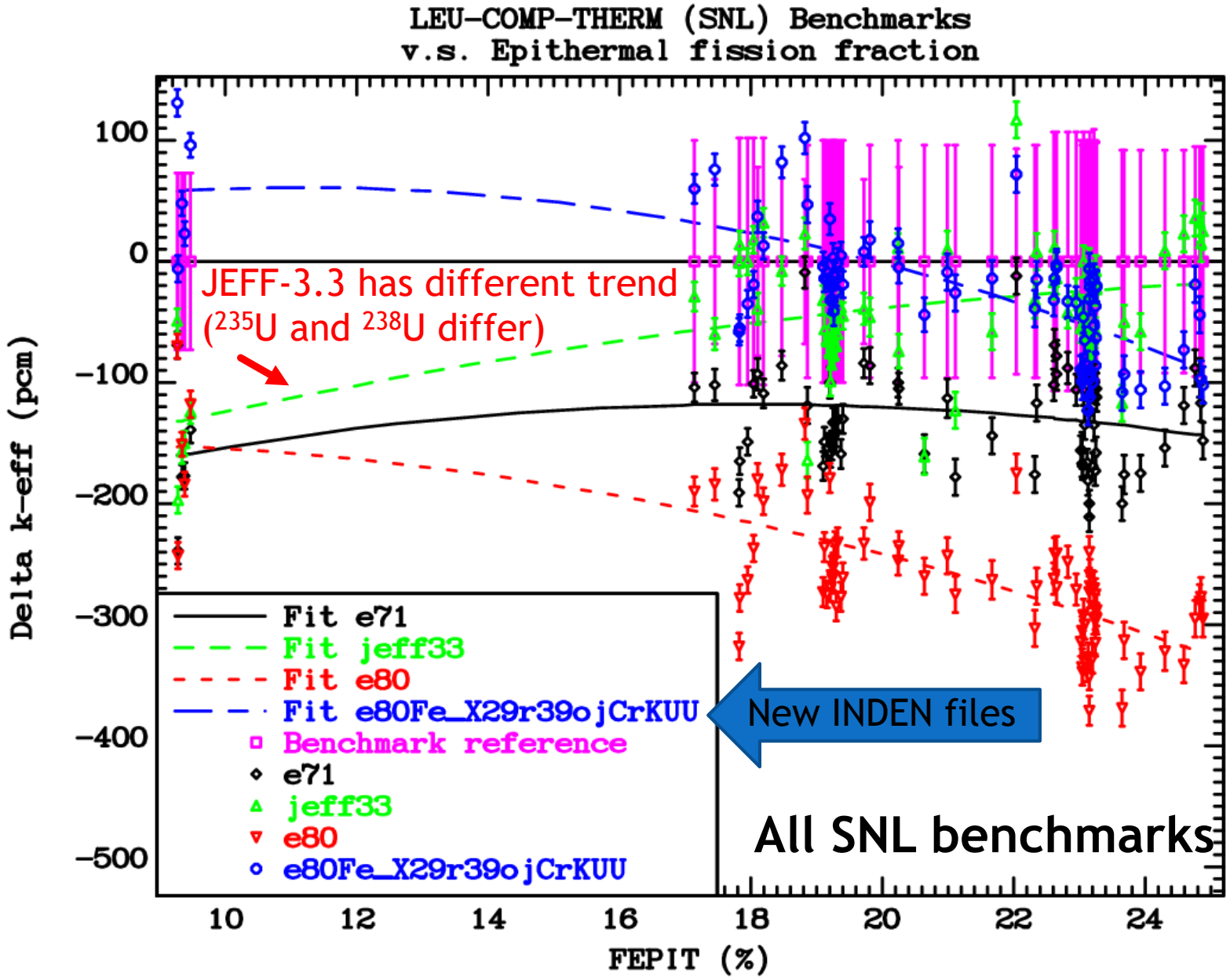
- There is still a lot of controversy regarding the O-16 evaluation, particularly the O-16(n, α) cross section
- New data by Febbraro et al, Phys. Rev. Lett **125** (2020) 062501



inverse reaction to (n,α)

JENDL/AN 2005 best !
ENDF/B-VIII.0 too high
ENDF/B-VII.1 low

JEFF-33 = ENDF/B-VII.1


LEU-COMP-THERM (SNL) Benchmarks
v.s. Epithermal fission fraction
Delta k-eff (pcm)
FEPIT (%)
JEFF-3.3 has different trend
(235U and 238U differ)
Fit e71
Fit jeff33
Fit e80
Fit e80Fe_X29r39ojCrKUU
Benchmark reference
e71
jeff33
e80
e80Fe_X29r39ojCrKUU
New INDEN files
All SNL benchmarks

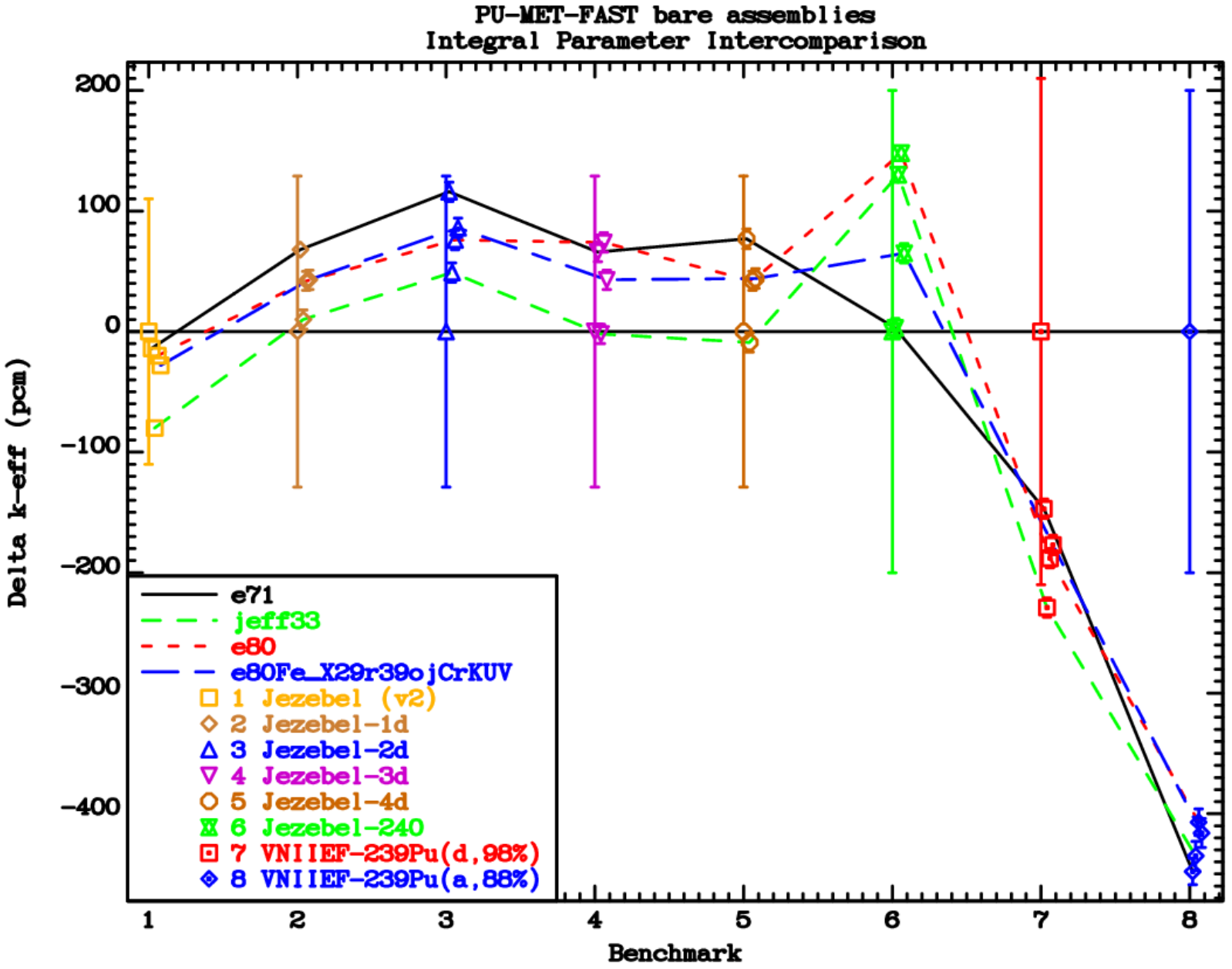
Pu-239 Updates (ORNL/IAEA)

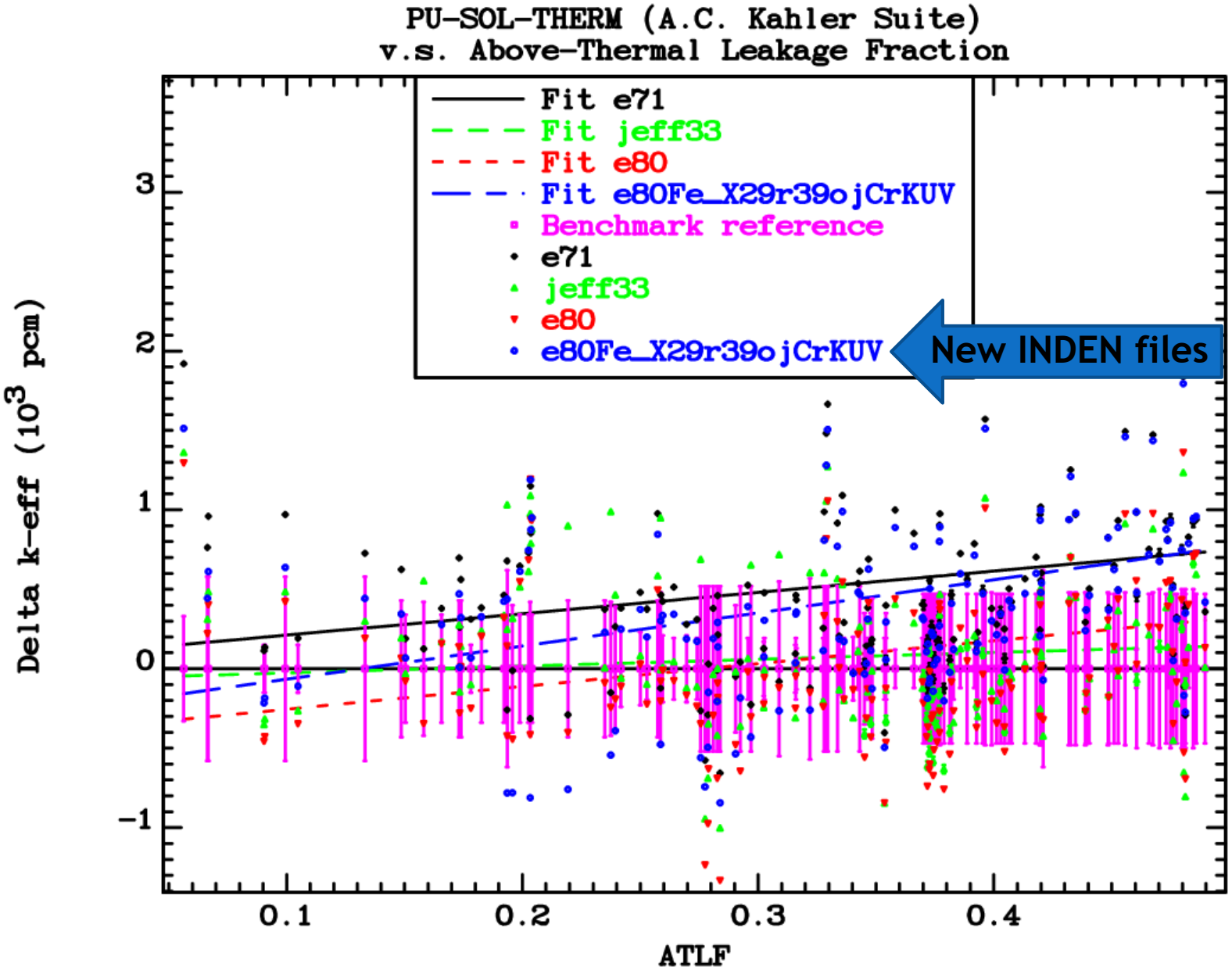
- New ORNL resonance evaluation by M. Pigni (local designation "res-stan-00e"). Increased thermal fission to agree with Neutron Standards (Thermal Neutron Constants)
- Thermal PFNS evaluated with Standards 2017, IAEA-CRP (Talou et al.) at higher energies

  → PFNS <En=th>=2.08 MeV (ENDF/B-VIII.0 =2.11 MeV), -30 keV.
- EMPIRE calculation of cross sections above the resonance range reproducing ENDF/B-VIII.0 (n,f) and (n,g). Focus on elastic/inelastic cross sections
- Small adjustment to prompt nu-bar to compensate PFNS effect in fast assemblies (about -100 pcm loss of criticality)

Impact of Pu-239 updates on benchmarks

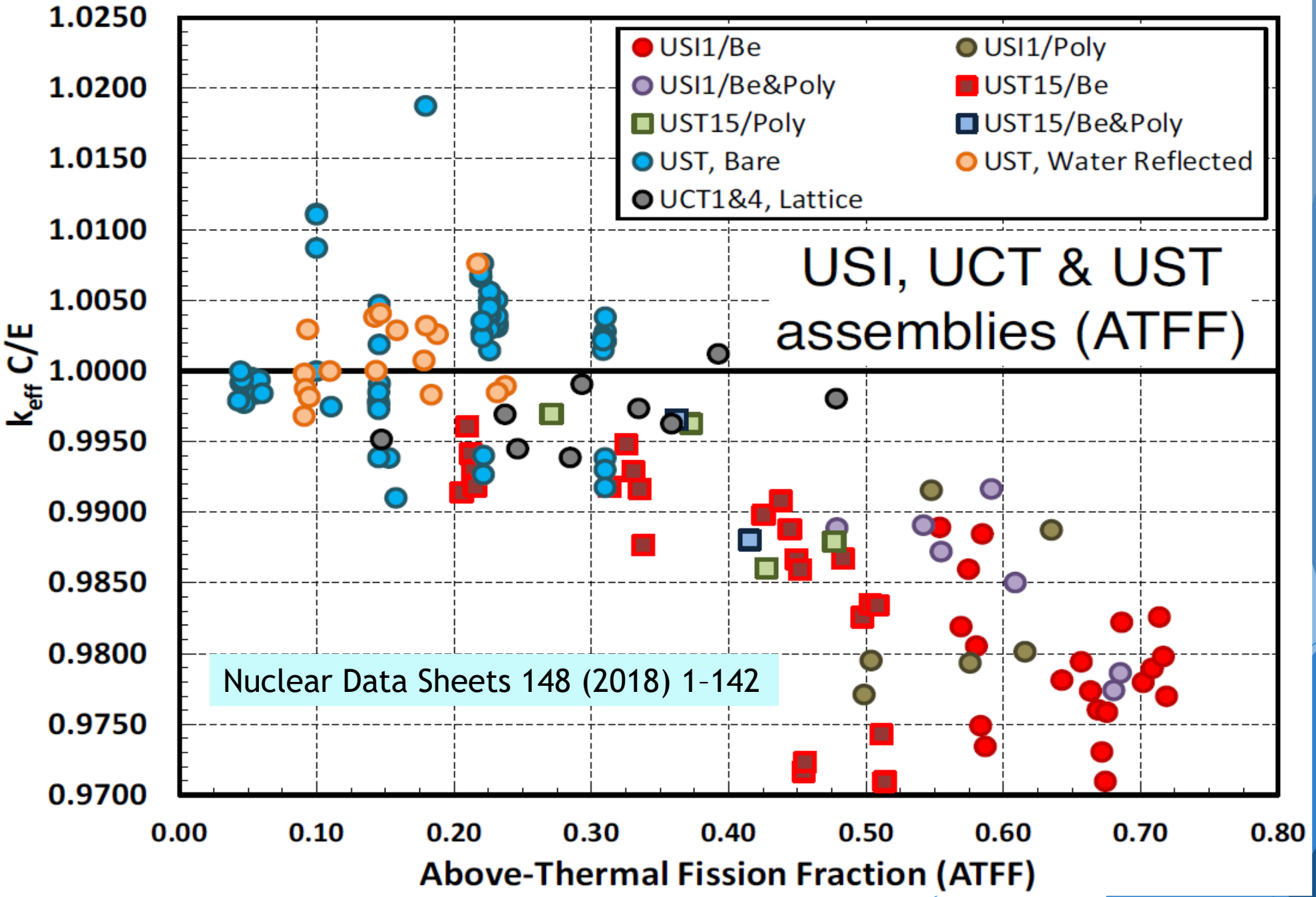
- Fast benchmarks (bare Pu assemblies) are calculated at least as good or better that ENDF/B-VIII.0
- Some reaction rate improvement observed (see Capote talk)
- The suite of thermal solution benchmarks as used by Skip Kahler shows a slightly stronger positive gradient than ENDF/B-VIII.0
- RPI quasi-differential benchmark previously discussed (RC & Kumar)
- Some reaction rates in Pu-239 assemblies improved (see RC talk)
  - More work is needed on:
    - PFNS (work in progress at LANL)
    - Resonance parameters (resonances below 2eV) and Mosby capture data
    - Fast range (improve the optical model and calculations)


PU-MET-FAST bare assemblies
Integral Parameter Intercomparison
Delta k-eff (pcm)
Benchmark
200
100
0
-100
-200
-300
-400
1
2
3
4
5
6
7
8
e71
jeff33
e80
e80Fe_X29r39ojCrKUV
1 Jezebel (v2)
2 Jezebel-1d
3 Jezebel-2d
4 Jezebel-3d
5 Jezebel-4d
6 Jezebel-240
7 VNIIEF-239Pu(d,98%)
8 VNIIEF-239Pu(a,88%)


PU-SOL-THERM (A.C. Kahler Suite)
v.s. Above-Thermal Leakage Fraction
Fit e71
Fit jeff33
Fit e80
Fit e80Fe_X29r39ojCrKUV
Benchmark reference
e71
jeff33
e80
e80Fe_X29r39ojCrKUV
New INDEN files
Delta k-eff (10^3 pcm)
ATLF
3
2
1
0
-1
0.1
0.2
0.3
0.4

U-233 Updates

- The current evaluation in ENDF/B-VIII.0 is known to have deficiencies; see ENDF/B-VIII library documentation: Nuclear Data Sheets **148** (2018) 1–142.
- Of particular concern is the large negative gradient of reactivity in thermal solution benchmarks as a function of the epithermal fission fraction (FEPIT=ATFF).
- Thermal capture does not agree with Neutron Standards (Thermal Neutron Constants)
- PFNS does not follow IAEA (non model) PFNS thermal evaluation: PFNS <En=th>=2.03 MeV (ENDF/B-VIII.0 =2.07 MeV), -40 keV.

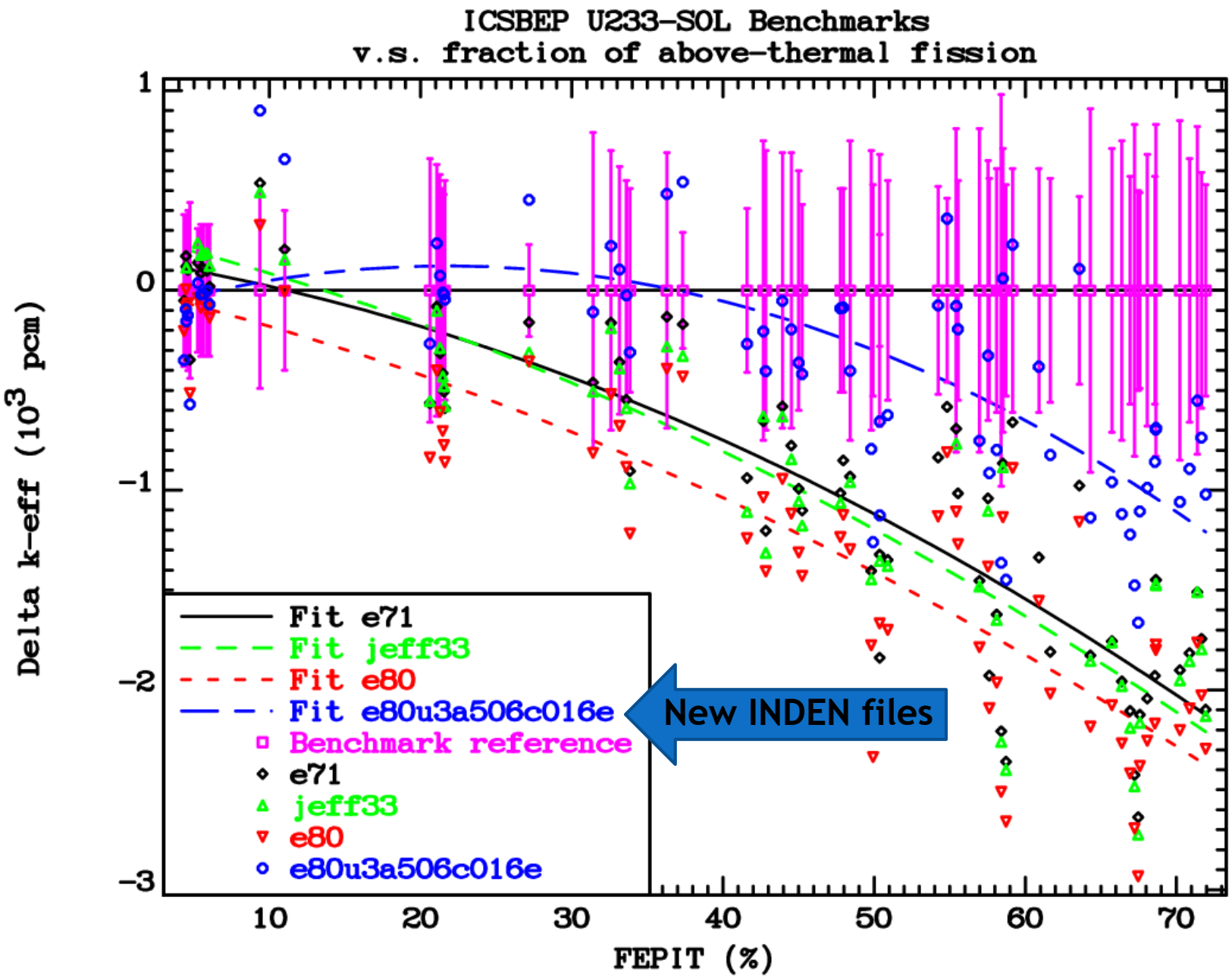

USI1/Be
USI1/Poly
USI1/Be&Poly
UST15/Be
UST15/Poly
UST15/Be&Poly
UST, Bare
UST, Water Reflected
UCT1&4, Lattice
USI, UCT & UST assemblies (ATFF)
Nuclear Data Sheets 148 (2018) 1-142
k_{eff} C/E
1.0250
1.0200
1.0150
1.0100
1.0050
1.0000
0.9950
0.9900
0.9850
0.9800
0.9750
0.9700
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
Above-Thermal Fission Fraction (ATFF)

U-233 Updates (ORNL/IAEA summary)

- PFNS for incident thermal neutrons as evaluated by the Neutron Standard group using a non-model evaluation (PFNS <En=th>=2.03 MeV)
- PFNS at higher incident energies from IAEA-CRP (Talou et al., LA model), consistent at the thermal point with non-model evaluation
- New resonance parameters from ORNL by M. Pigni (local label “06c”)
- Thermal constants were forced to agree with Standards-2017 (thermal elastic, capture, fission, nu-bar)
- Fluctuations in nu-bar(E) below 30 eV follow Reed (X4#10427002, 1973)

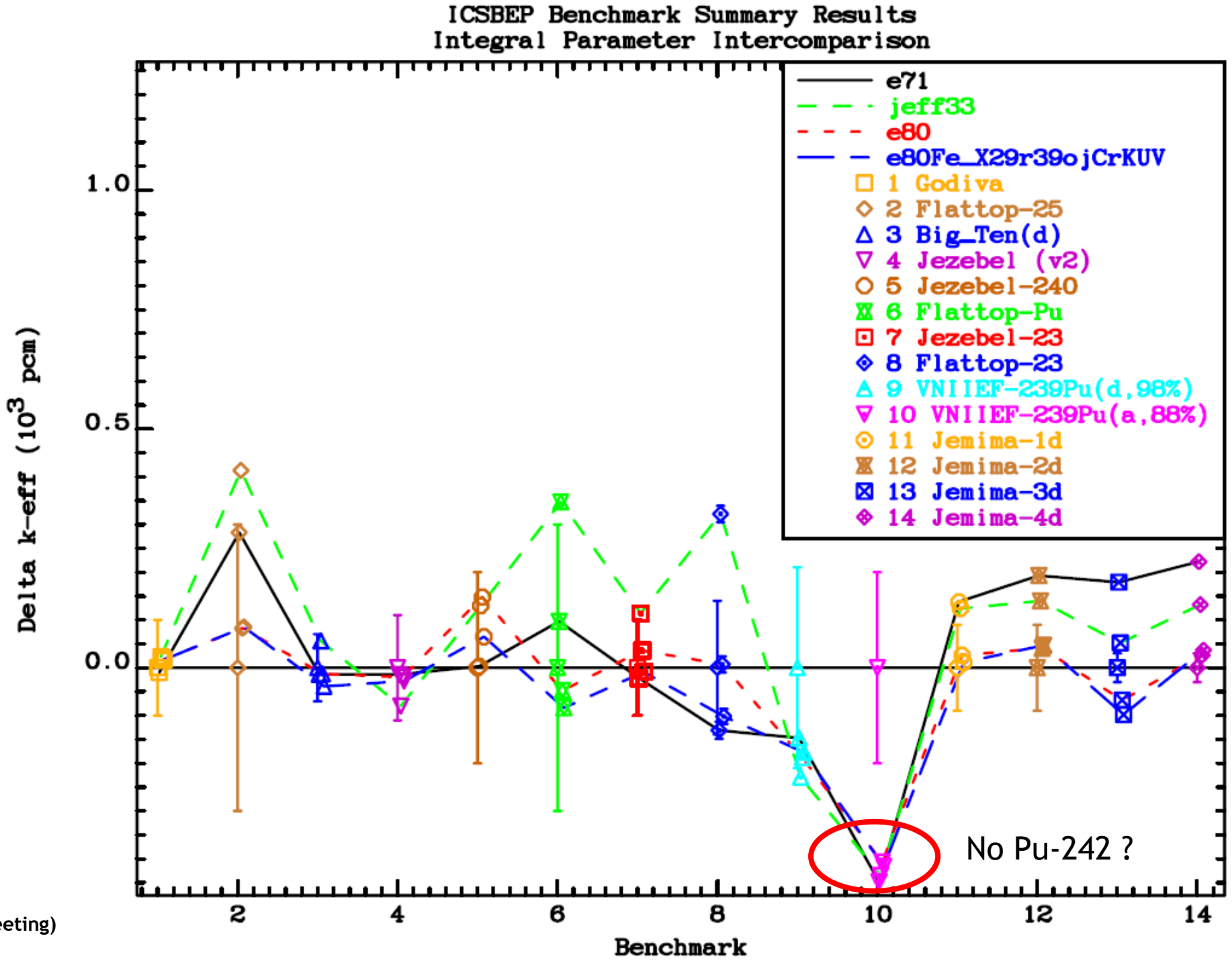
U-233 Impact on Integral Benchmarks

- Some fast reactor benchmarks are calculated at least as good or better.
- Some reaction rate improvement (see Capote talk)
- The strong negative trend as a function of the above-thermal leakage fraction is greatly diminished:
  - Mainly due to changes in PFNS and some impact of the resonance parameters.
  - Some overall increase in reactivity is due to O-16.


ICSBEP U233-SOL Benchmarks
v.s. fraction of above-thermal fission
Delta k-eff (10^3 pcm)
FEPIT (%)
1
0
-1
-2
-3
10
20
30
40
50
60
70
Fit e71
Fit jeff33
Fit e80
Fit e80u3a506c016e
Benchmark reference
e71
jeff33
e80
e80u3a506c016e
New INDEN files

Overall performance for the major actinides

No.	ICSBEP Label	Short name	Common name
1	HEU-MET-FAST-001	hmf001	Godiva
2	HEU-MET-FAST-028	hmf028	Flattop-25
3	IEU-MET-FAST-007	imf007d	Big_Ten(detailed)
4	PU-MET-FAST-001	pmf001	Jezebel
5	PU-MET-FAST-002	pmf002	Jezebel-240
6	PU-MET-FAST-006	pmf006	Flattop-Pu
7	U233-MET-FAST-001	umf001	Jezebel-U233
8	U233-MET-FAST-006	umf006	Flattop-23
9	PU-MET-FAST-022	pmf022	VNIIEF-Pu239(d98%)
10	PU-MET-FAST-029	pmf029	VNIIEF-Pu239(a88%, NoPu242?)
11	IEU-MET-FAST-001	imf001-001d	Jemima-1d
12	IEU-MET-FAST-001	imf001-002d	Jemima-2d
13	IEU-MET-FAST-001	imf001-003d	Jemima-3d
14	IEU-MET-FAST-001	imf001-004d	Jemima-4d


ICSBEP Benchmark Summary Results
Integral Parameter Intercomparison
e71
jeff33
e80
e80Fe_X29r39ojCrKUV
1 Godiva
2 Flattop-25
3 Big_Ten(d)
4 Jezebel (v2)
5 Jezebel-240
6 Flattop-Pu
7 Jezebel-23
8 Flattop-23
9 VNIIEF-239Pu(d,98%)
10 VNIIEF-239Pu(a,88%)
11 Jemima-1d
12 Jemima-2d
13 Jemima-3d
14 Jemima-4d
Delta k-eff (10^3 pcm)
1.0
0.5
0.0
2
4
6
8
10
12
14
Benchmark
No Pu-242 ?

Conclusions

Many improvements were made to evaluated nuclear data of actinides in the resonance region and above.

- Minor changes to U-235: assessment of changes depend on the finalization of the O-16 evaluation.
- U-233 improvements show significant progress in performance. Some further improvement might be needed at intermediate energies.
- Pu-239 ORNL/IAEA evaluation is promising, more work is needed.