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Benchmark Model Validation

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Objective

From the mandate:

“provide … benchmark suites for the validation of nuclear data libraries that can meet a basic tenet of science”.

Scope

- In this presentation the focus is on the ICSBEP collection of “benchmark” experiments:
  - The total number of cases approaches 5000.
  - Very few of them meet the aforementioned criteria.
  - The user does not know in advance which benchmarks to trust without repeating much of the work by the benchmark evaluators.

Requirements

- High fidelity experiments that can be used as benchmarks.
- Validated benchmark computational models.
- Good uncertainty characterization of the benchmarks.

High Fidelity Experiments

- Traceability of quantities (who measured what and how).
- As-built dimensions, positioning tolerances, estimates of swelling, buckling due to loading, etc.
- Accurate material composition regarding impurities, build-up of burn-up products (if not fresh), etc.
- Component masses with uncertainties.
- Consistency of masses, volumes and densities.

Validated benchmark computational models

- Independently checked input models for the same transport code by different users.
- Comparison of results of different codes using the same source evaluated nuclear data library.

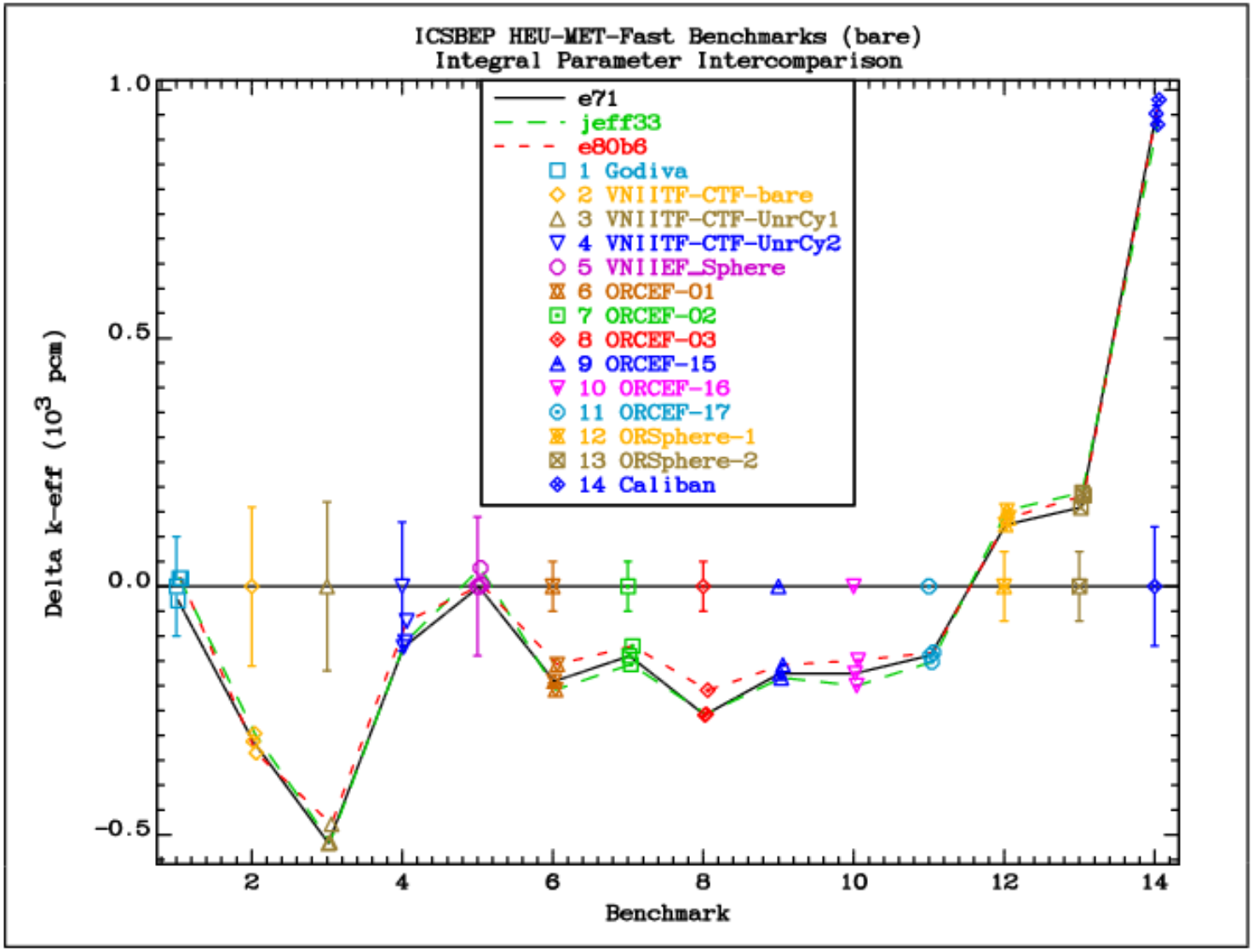
Accurate uncertainty information

- Uncertainties must reflect the uncertainties in geometry and material specifications.
- Uncertainty estimates must be given for quantities that were not reported adequately in the experiment, but might affect the measured values.
- Uncertainties need to be split into components that affect all experiments in a series and statistical components; ideally, a full covariance matrix should be given.

Bad example: HEU-MET-FAST bare

- Dependence primarily on ^{235}U.
- Sensitivities are very similar.
- Quoted uncertainties are small (**10 pcm** in some ORNL cylinders!!!)
- Spread **~1500 pcm**!!!
- Spread **~700 pcm** (excluding CALIBAN)
- CALIBAN off by **~1000 pcm** from average.
  - Inconsistent mass/volume and density by 0.5%
  - The problem has been reported before…
  - … No response ☹.

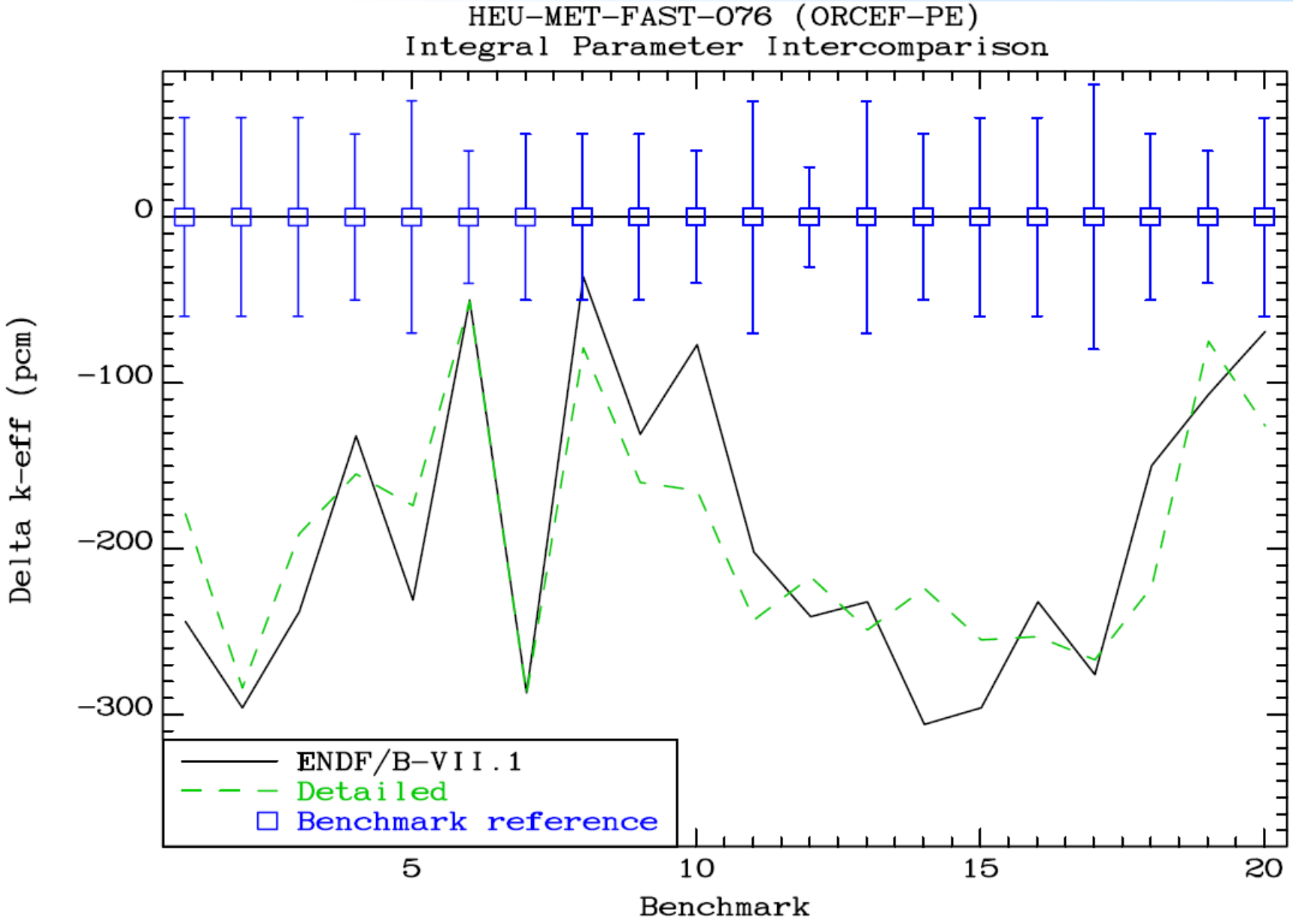
HEU-MET-FAST (bare)



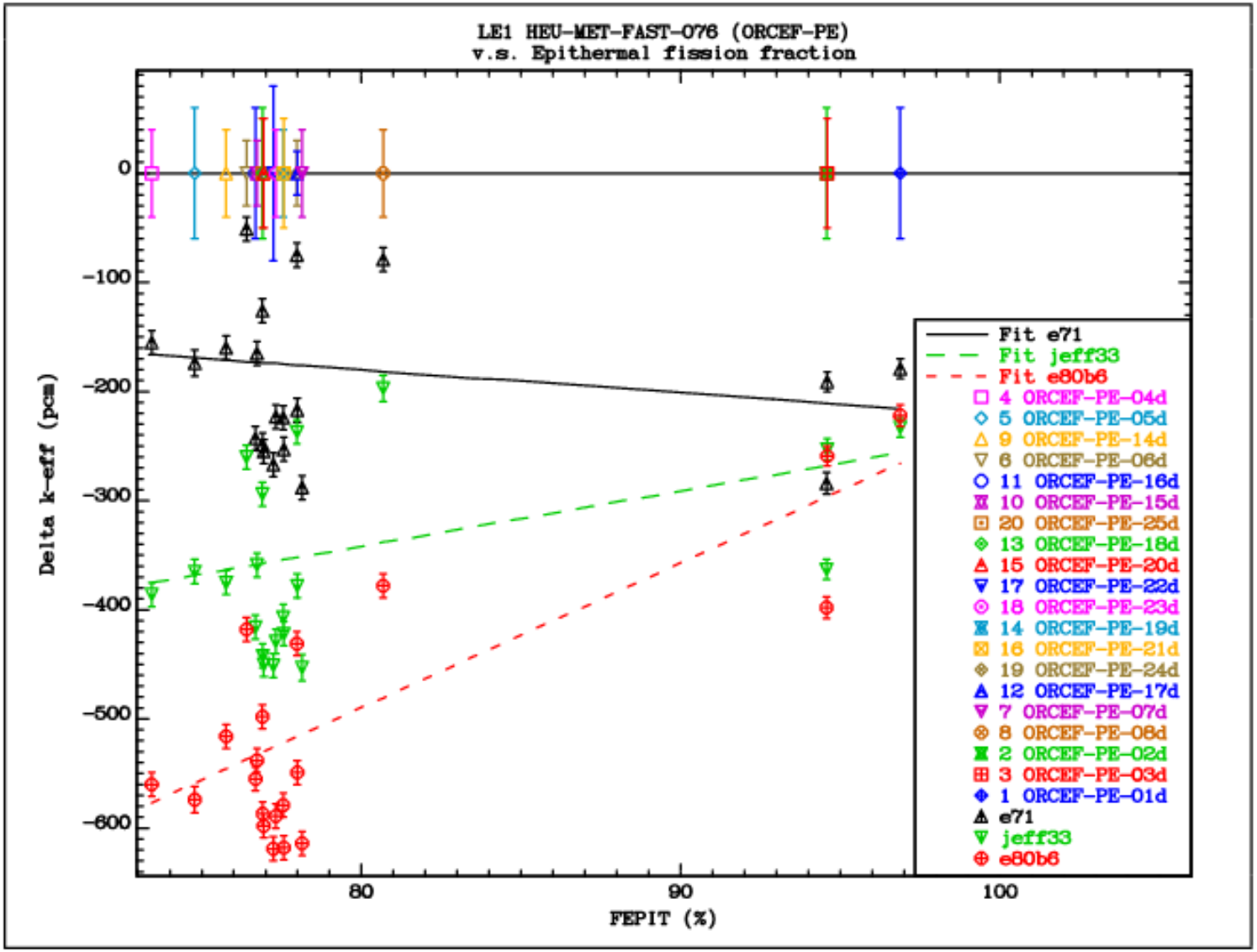
Bad example: HEU-MET-FAST-076

- Specified uncertainties as small as **30 pcm!!!**
- Difference between simplified and detailed model much greater than the specified uncertainty.
- Large scatter of data for the same spectral parameter.

HMF076 – detailed v.s. simplified model



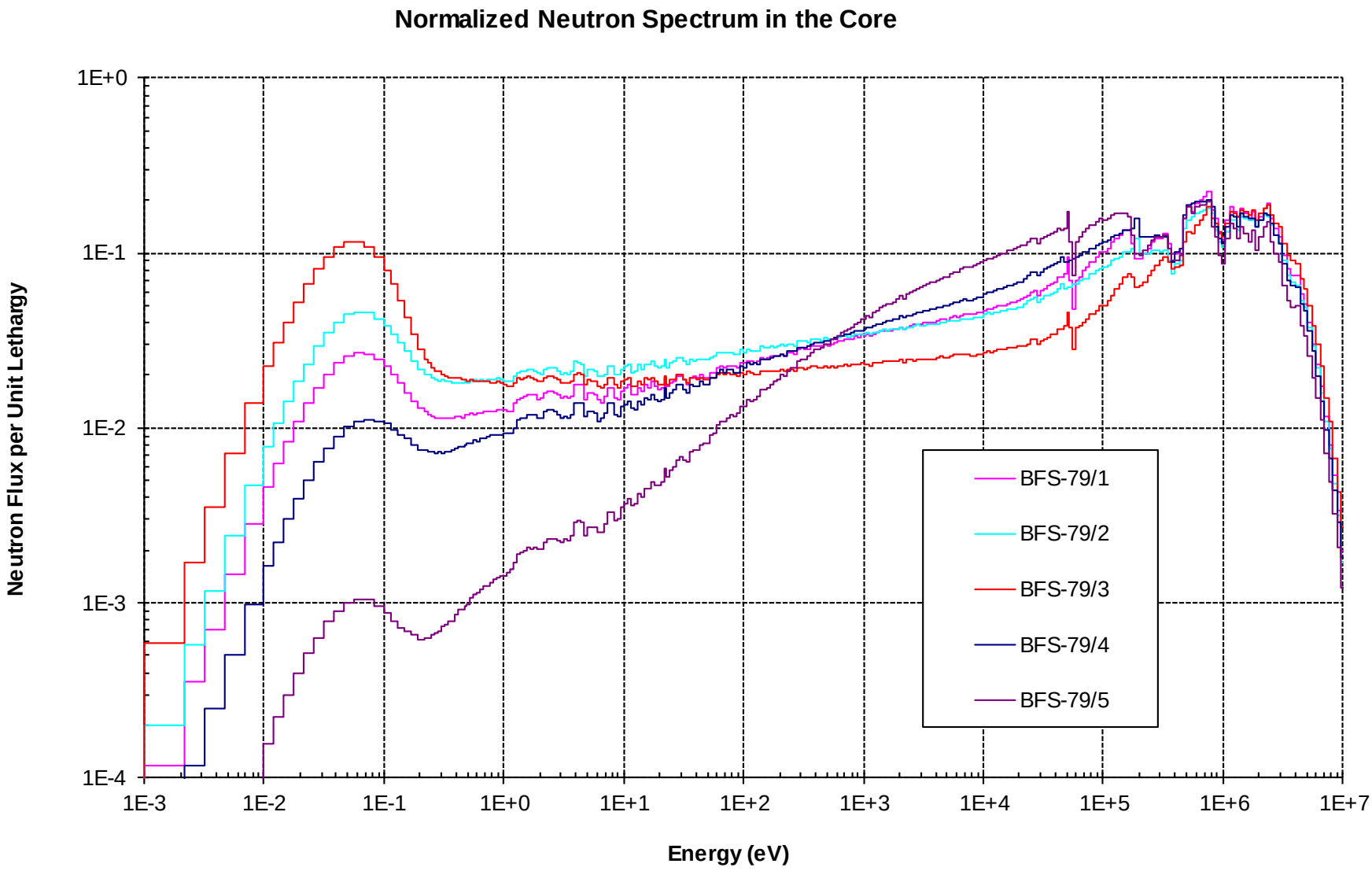
HMF076 v.s. Epithermal Fission Fraction



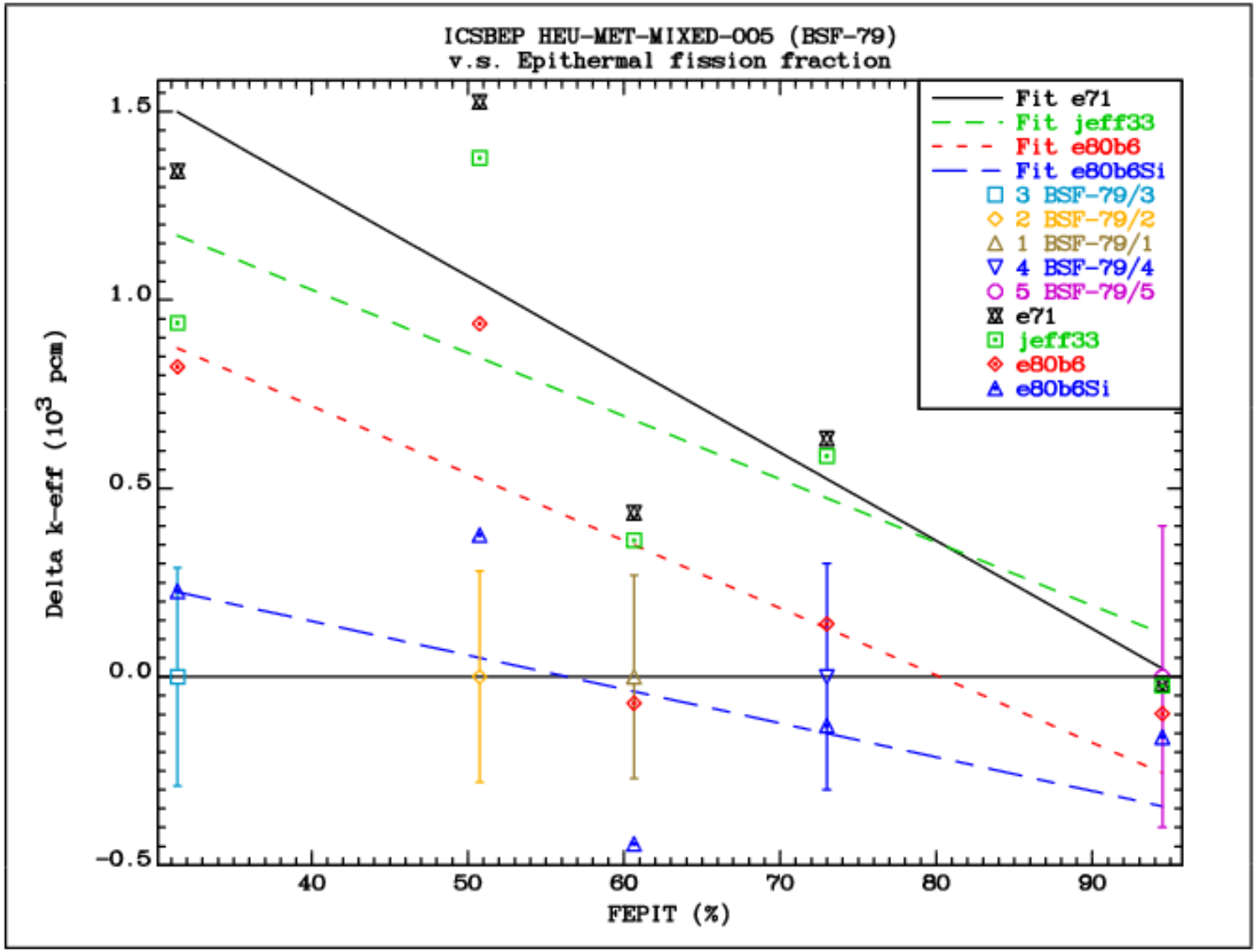
Good example:HEU-MET-MIXED-005

- In spite of being complex, there is consistency in trends with spectrum hardness.
- Spectrum information is provided.
- Uncertainties seem reasonable.
- Points to specific problems in nuclear data:
  - Main problem in the thermal energy range.
  - Silicon appears in large quantities as Si O_2
  - Increasing ^{28}Si thermal cross section helps (supported by Firestone et al. by PGAA technique)
    Not a solution but an indication where to look!

HEU-MET-MIXED-005 (spectra)



HEU-MET-MIXED-005 (Si O_2)



Conclusions

- We still have a long way to go.
- Good examples can be found, e.g. hmm005
  - Supported by the U.S. National Spent Nuclear Fuel Program (NSNFP).
  - Performed at the Institute of Physics and Power Engineering (IPPE).
  - Provides indication where to look, while solving the nuclear data riddles.
  - Implications: possibility to reduce safety margins in criticality safety analysis → justifies research in nuclear data measurements and evaluation.

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Thank you!