# Nuclear data of the future: daring selection via adjustment and Total Monte Carlo

**D. Rochman**

*Nuclear Research and Consultancy Group,*

*NRG, Petten, The Netherlands*

Workshop on Nuclear Data and Uncertainty Quantification, CCFE, UK, January 2012

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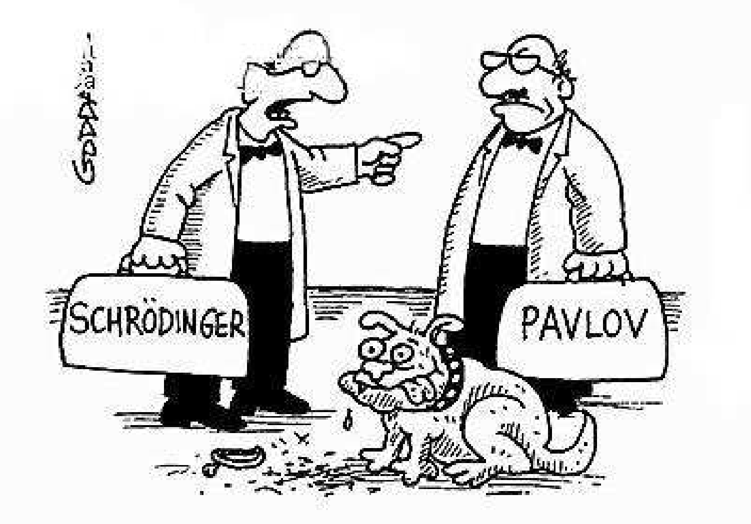
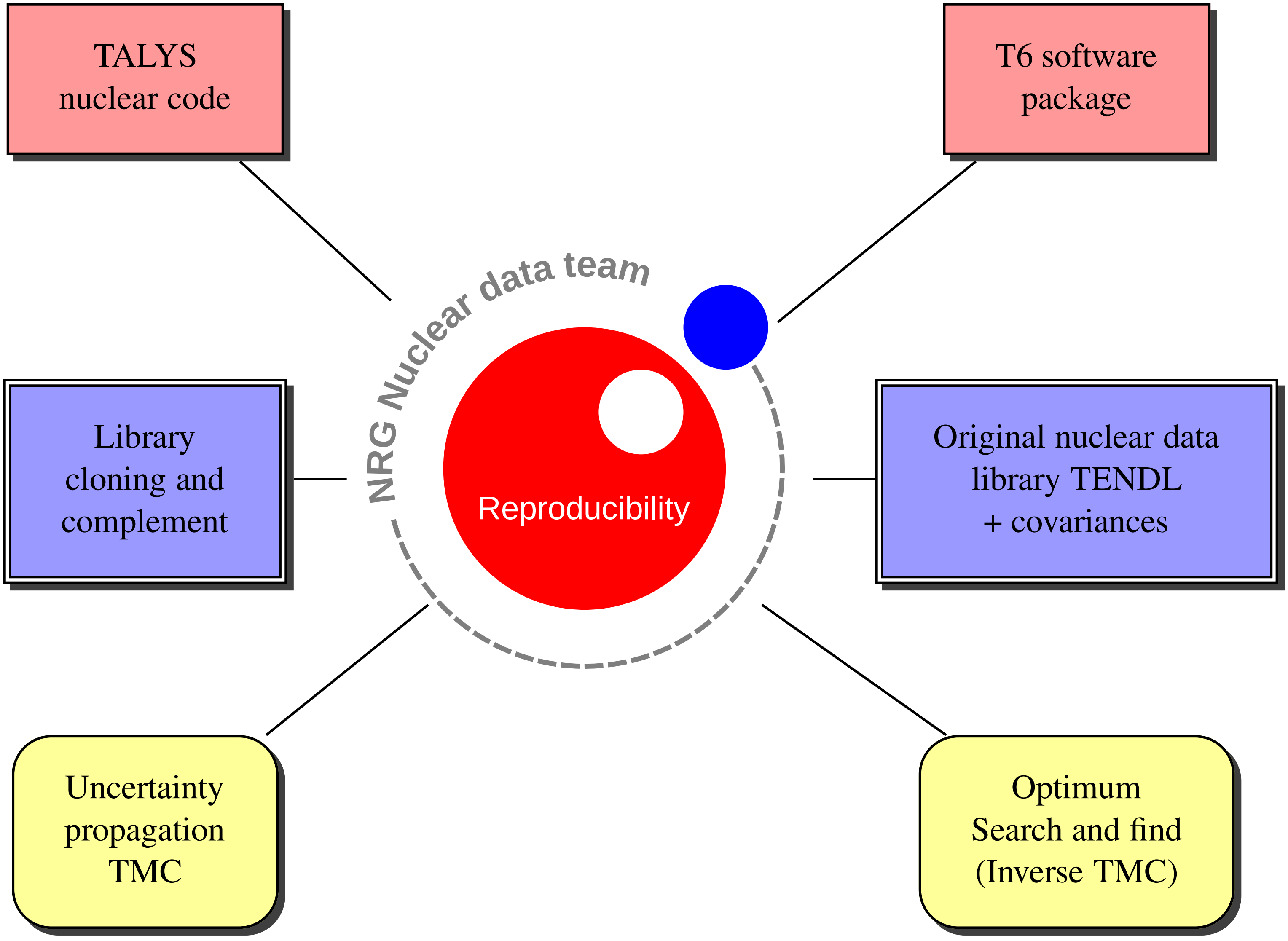



Pavlov's dog eating Schrodinger's cat
(deterministic vs. Monte carlo approach)

# Backbone of our methodology: REPRODUCIBILITY



# Optimum
# Search and find
# (Inverse TMC)

- Started in 2010
- Two publications so far (plus 2 submitted)
- Controversial (if understood at all)
- We believe this is the future of nuclear data evaluation work
- It might be the only way to sensibly improve C/E

## Inverse TMC on $^{239}$Pu

Total Monte Carlo + selection
$$\Longrightarrow \frac{1}{TMC}$$

① Use TALYS to create a single $^{239}$Pu evaluation close or equal to ENDF/B-VII.0 or JEFF-3.1.1

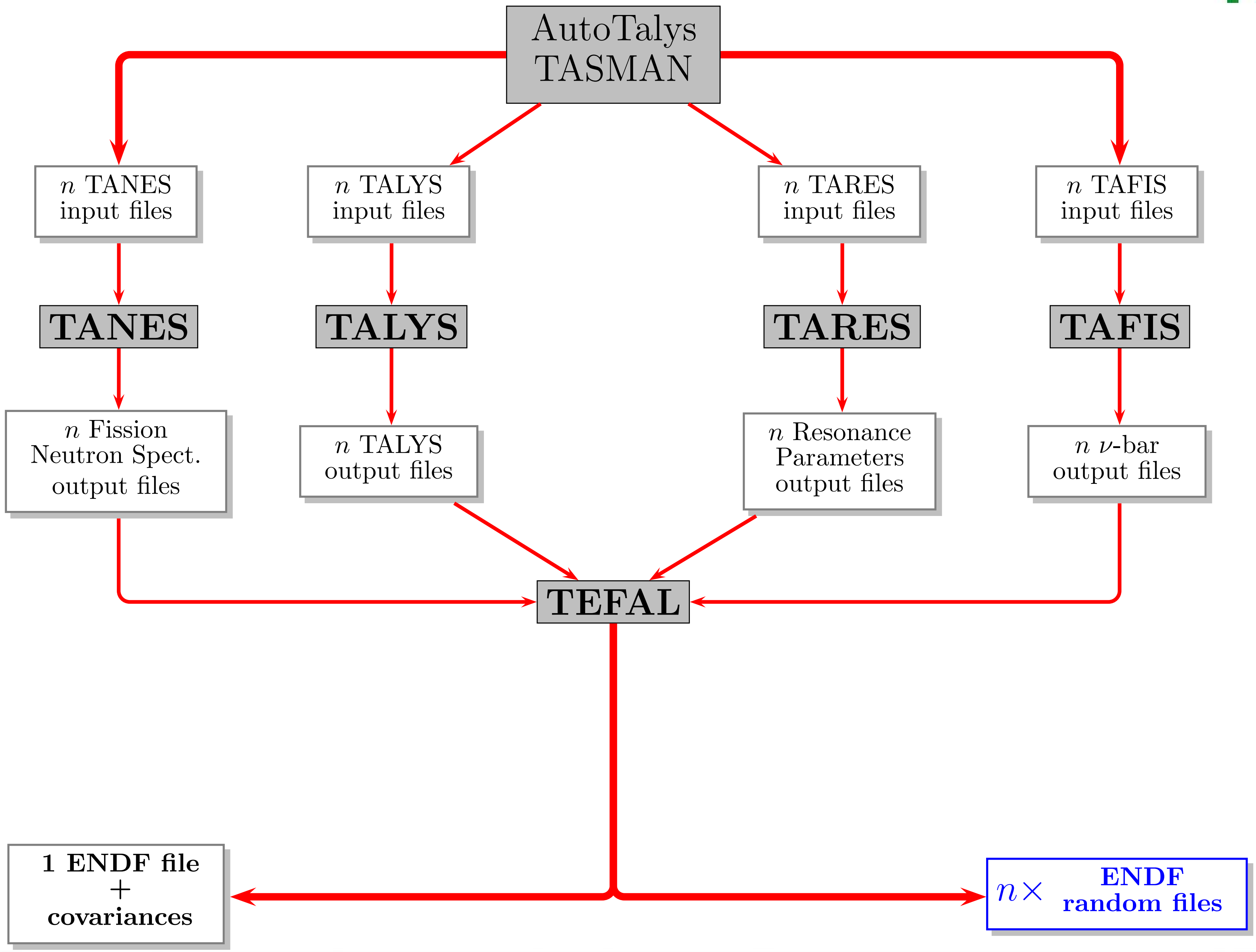
② Randomize all model parameters (resonances, nubar, fission neutron spectrum, TALYS parameters) to create 500 random $^{239}$Pu evaluations

③ Benchmarks the $n \geq 500$ files with the same set of criticality benchmarks

④ Select the best random file

Example: 100 benchmarks, 500 random files $\Longrightarrow$ 500 TALYS + NJOY and $100 \times 500 = 5 \cdot 10^4$ MCNP loops, 1.4 years on a single processor, or 5 days on 100 processors (3 GHz)

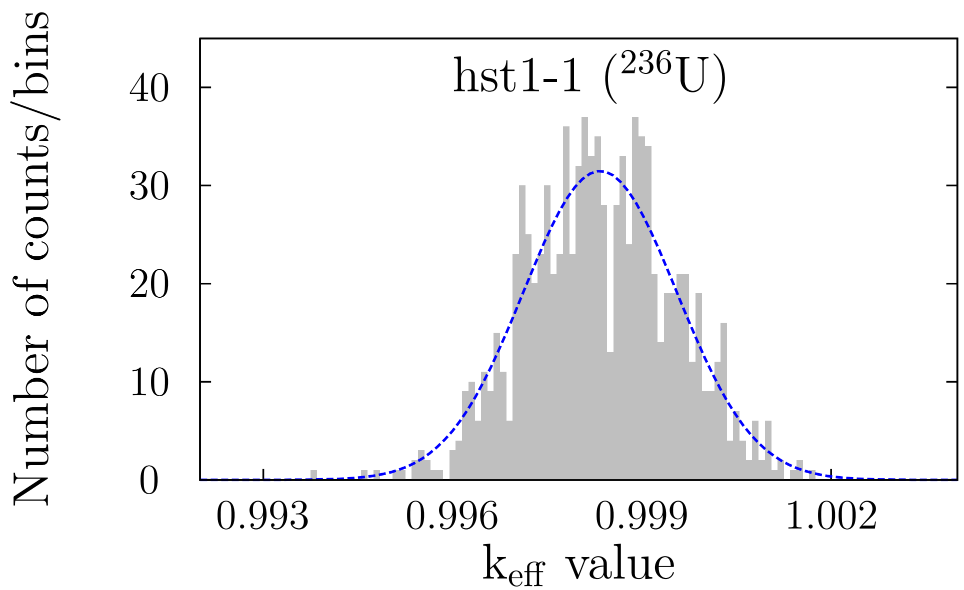
# The TALYS system



# Total Monte Carlo: examples

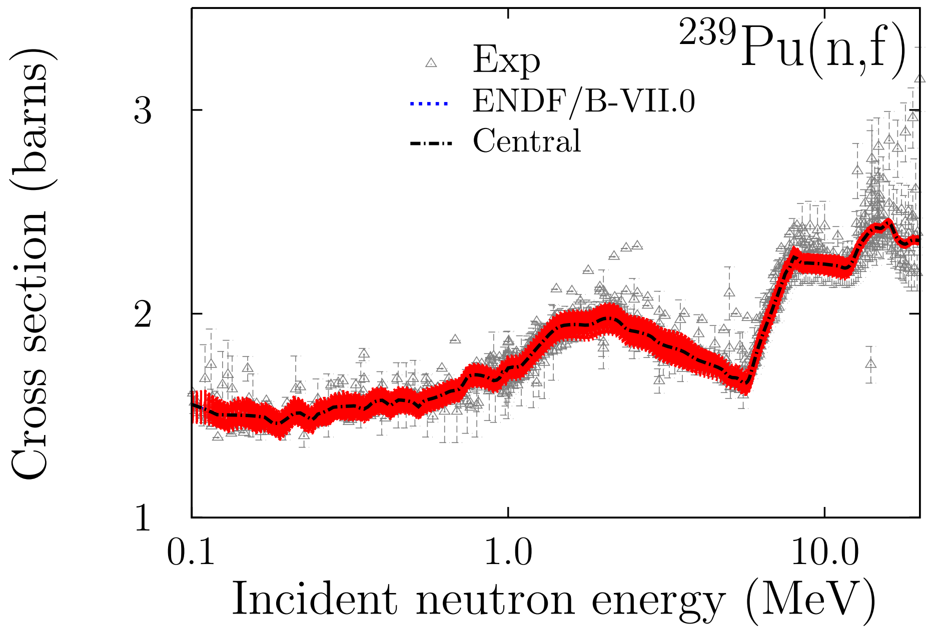
For each random ENDF file, the benchmark calculation is performed with MCNP. At the end of the *n* calculations, *n* different $k_{eff}$ values are obtained. In the obtained probability distribution of $k_{eff}$, the standard deviation $\sigma_{total}$ reflects two different effects:

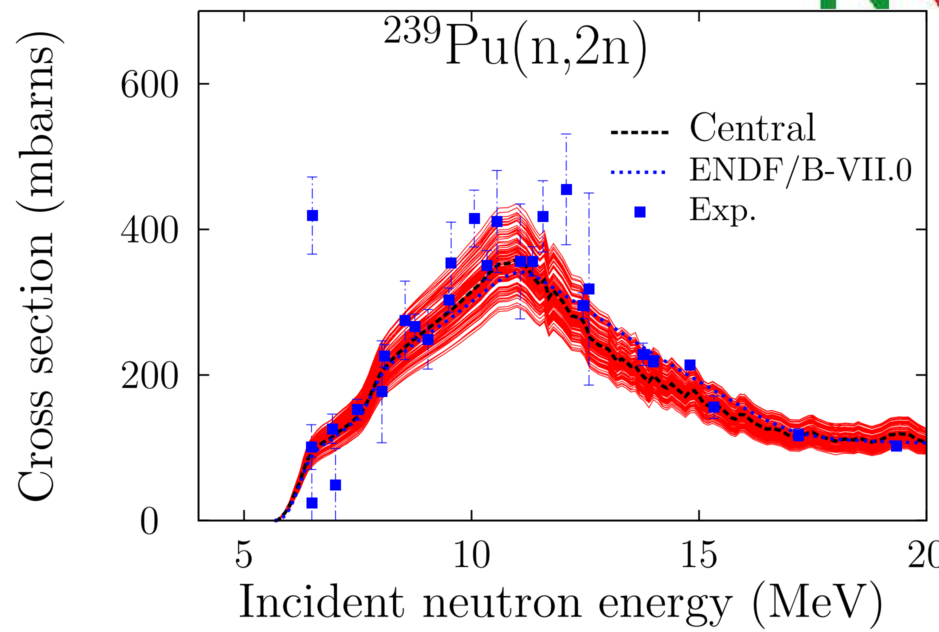
$$\sigma^2_{total} = \sigma^2_{statistics} + \sigma^2_{nuclear\ data}. \quad (1)$$

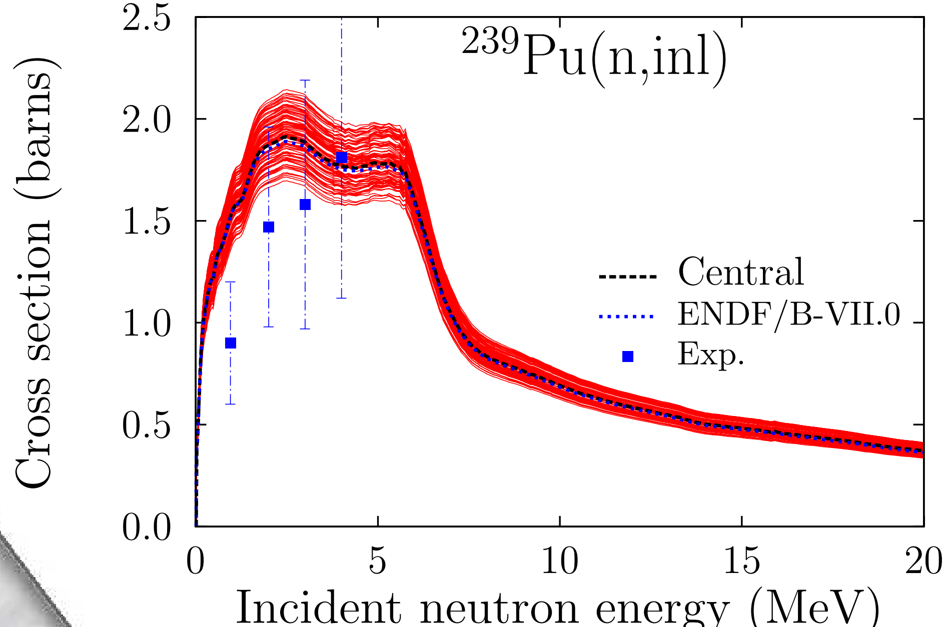



Each random file is completely different from another one: nu-bar (”*MF1*”), resonance parameters (”*MF2*”), cross sections (”*MF3*”), also *MF4*, *MF5*, *MF6*, etc.

# Nuclear data: random $^{239}$Pu in the thermal and fast range



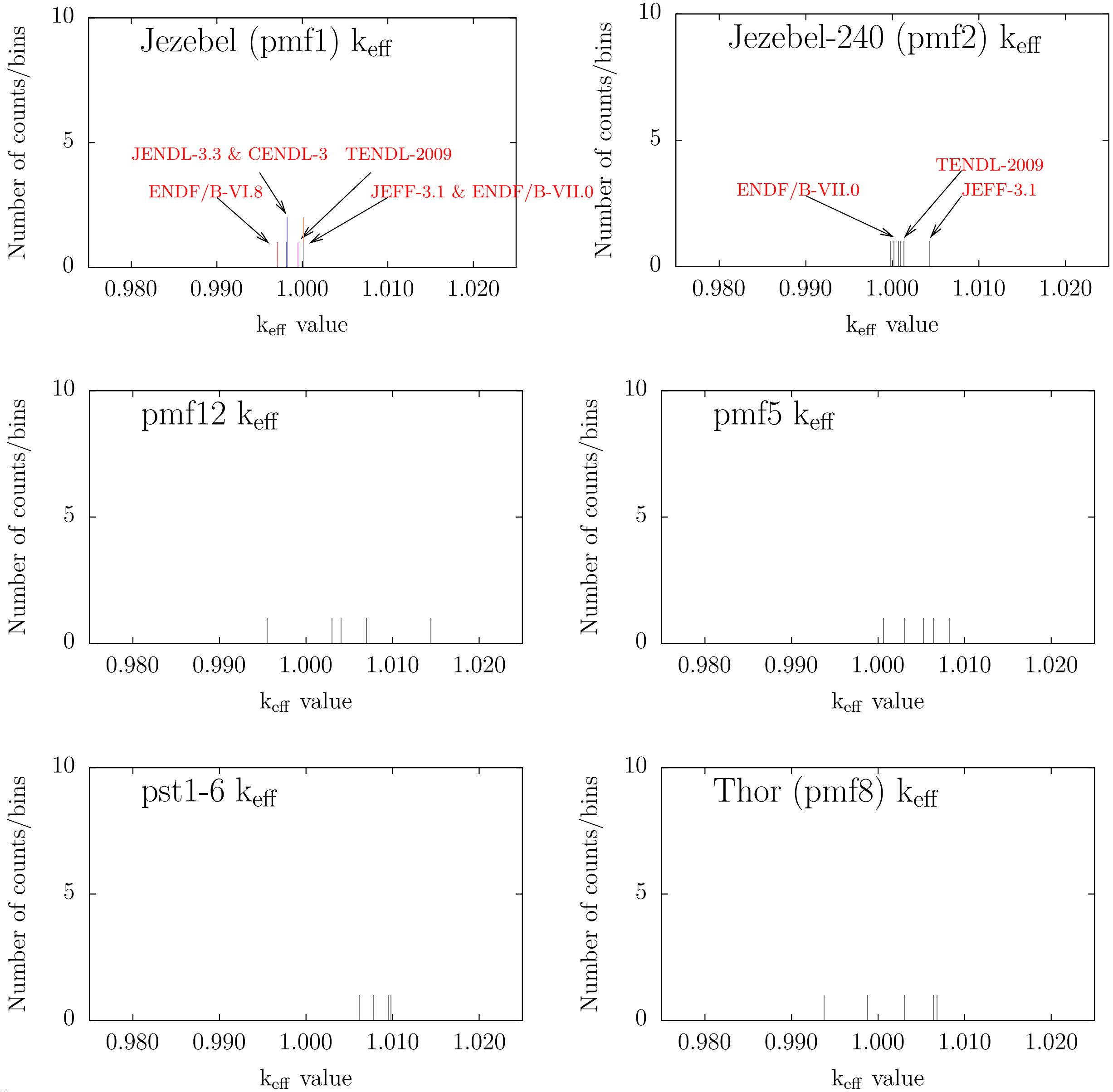




(1) Central cross sections *almost* equal to ENDF/B-VII.0 or JEFF-3.1

(2) Random cross sections obtained from random model parameters

(3) Similar results in MF1, 2, 4, 5 and 6

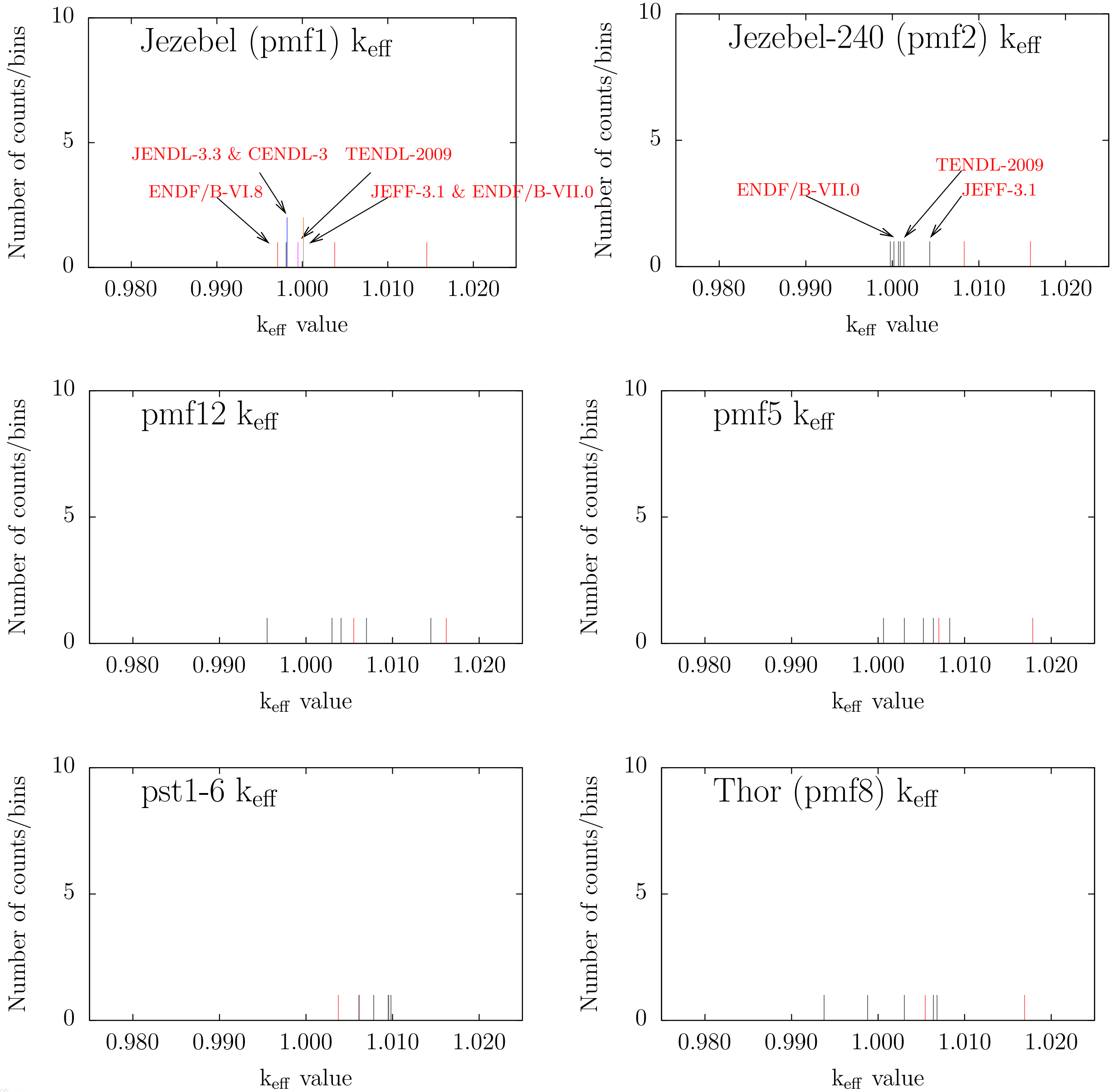
# Inverse TMC: simple example with 6 $k_{eff}$ benchmarks




| | $\alpha$ |
|---|---|
| JEFF-3.1.1: | 1.14e$^{-4}$ |
| JENDL-3.3: | 1.71e$^{-4}$ |
| TENDL-2009: | 3.66e$^{-4}$ |
| ENDF/B-VI.8: | 1.72e$^{-4}$ |
| ENDF/B-VII.0: | 1.69e$^{-4}$ |

$$\alpha = \sum_{i=0}^{n} \frac{(C_i - E_i)^2}{C_i},$$

# Inverse TMC: simple example with 6 $k_{eff}$ benchmarks




α

| | |
|---|---|
| JEFF-3.1.1: | $1.14e^{-4}$ |
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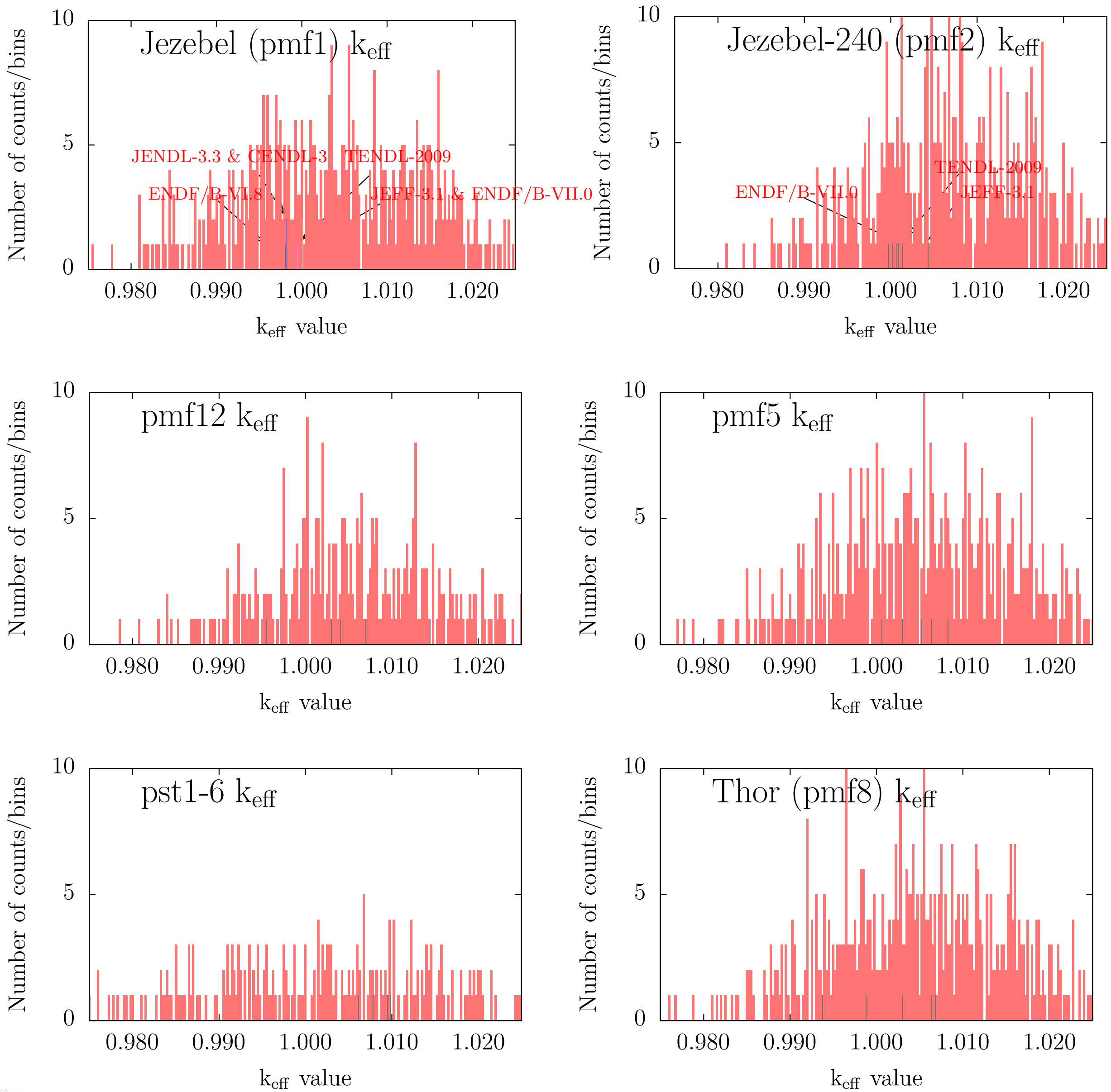
| TENDL-2009: | $3.66e^{-4}$ |
| ENDF/B-VI.8: | $1.72e^{-4}$ |
| ENDF/B-VII.0: | $1.69e^{-4}$ |
| random 0: | $2.29e^{-4}$ |
| random 1: | $13.4e^{-4}$ |

# Inverse TMC: 6 $k_{eff}$ benchmarks with random $^{239}$Pu



## Real case: 120 $^{239}$Pu benchmarks

Table 1: List of plutonium benchmarks selected for the random search.

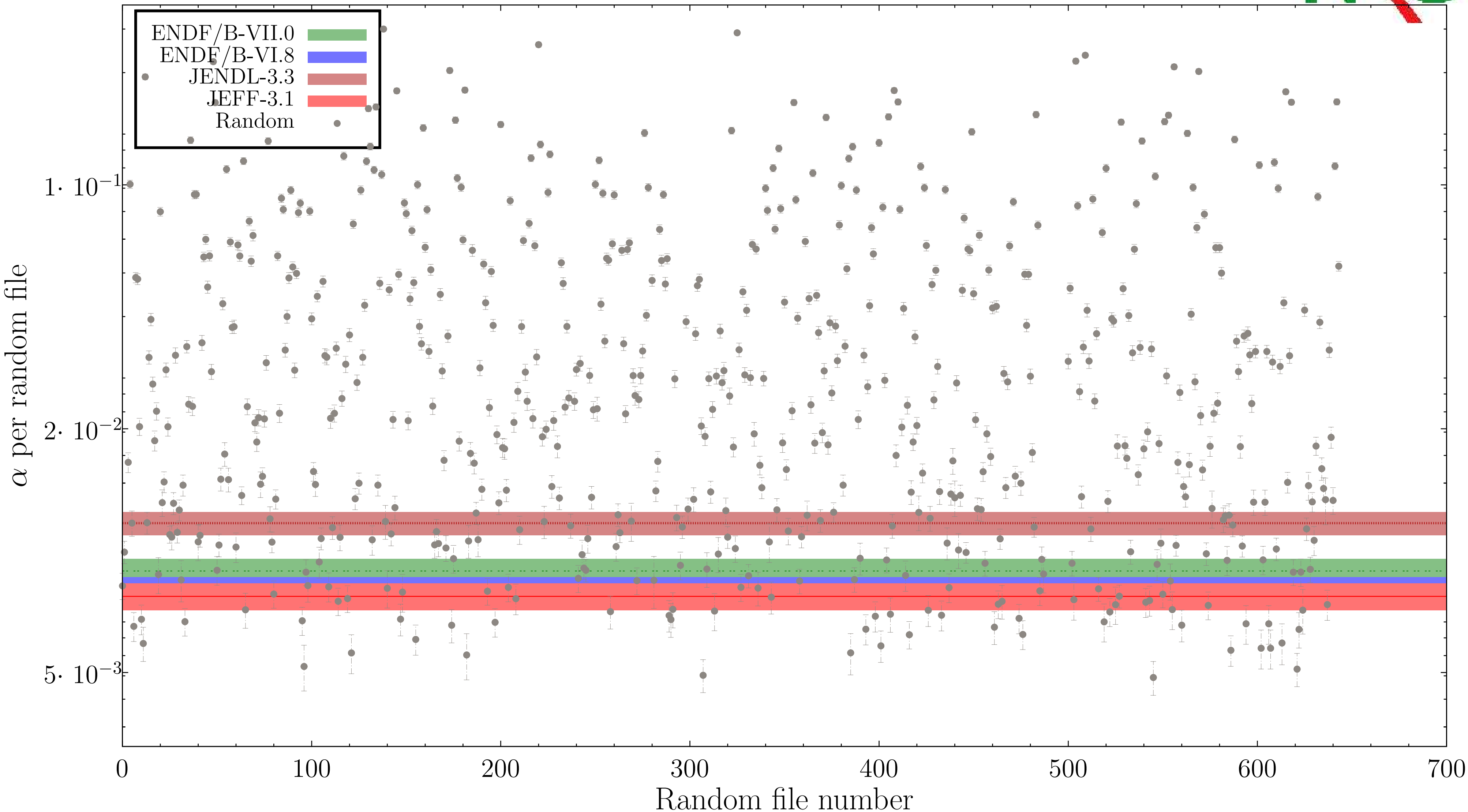
| Name | Cases | Name | Cases | Name | Cases | Name | Cases |
|---|---|---|---|---|---|---|---|
| pmf1 | 1 | pmf2 | 1 | pmf5 | 1 | pmf6 | 1 |
| pmf8 | 1 | pmf12 | 1 | pmf13 | 1 | pci1 | 1 |
| pmi2 | 1 | pst1 | 6 | pst2 | 6 | pst3 | 8 |
| pst4 | 13 | pst5 | 9 | pst6 | 3 | pst7 | 9 |
| pst8 | 29 | pst12 | 22 | pmm1 | 6 | | |

$$\alpha = \sum_{i=0}^{n} \frac{(C_i - E_i)^2}{C_i}, \tag{2}$$

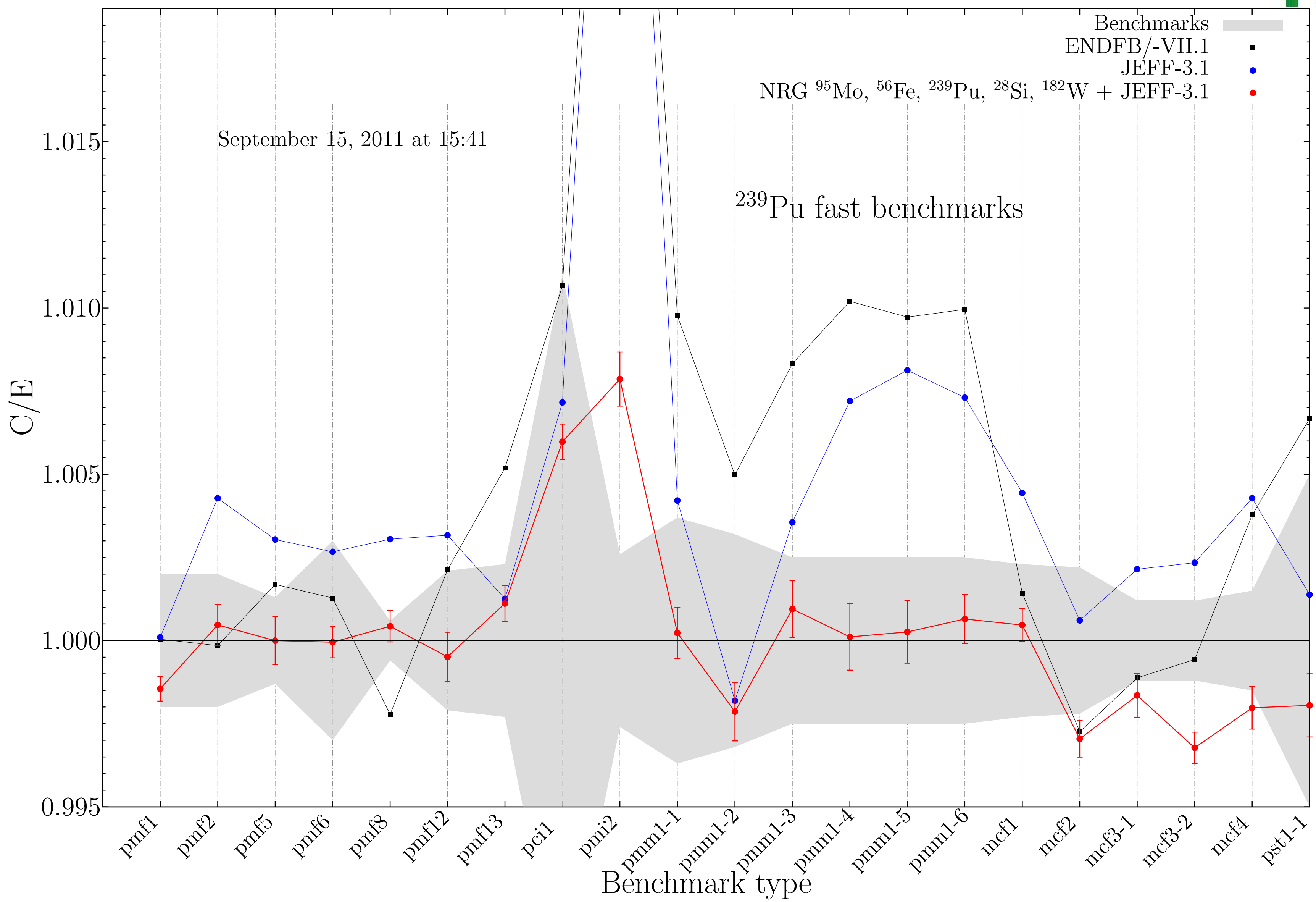
Results independent of the type of factor $\alpha$, $\chi^2$... or

$$F = 1 - 10^{\sqrt{\frac{1}{N}\sum(\log(E_i) - \log(C_i))^2}} \tag{3}$$

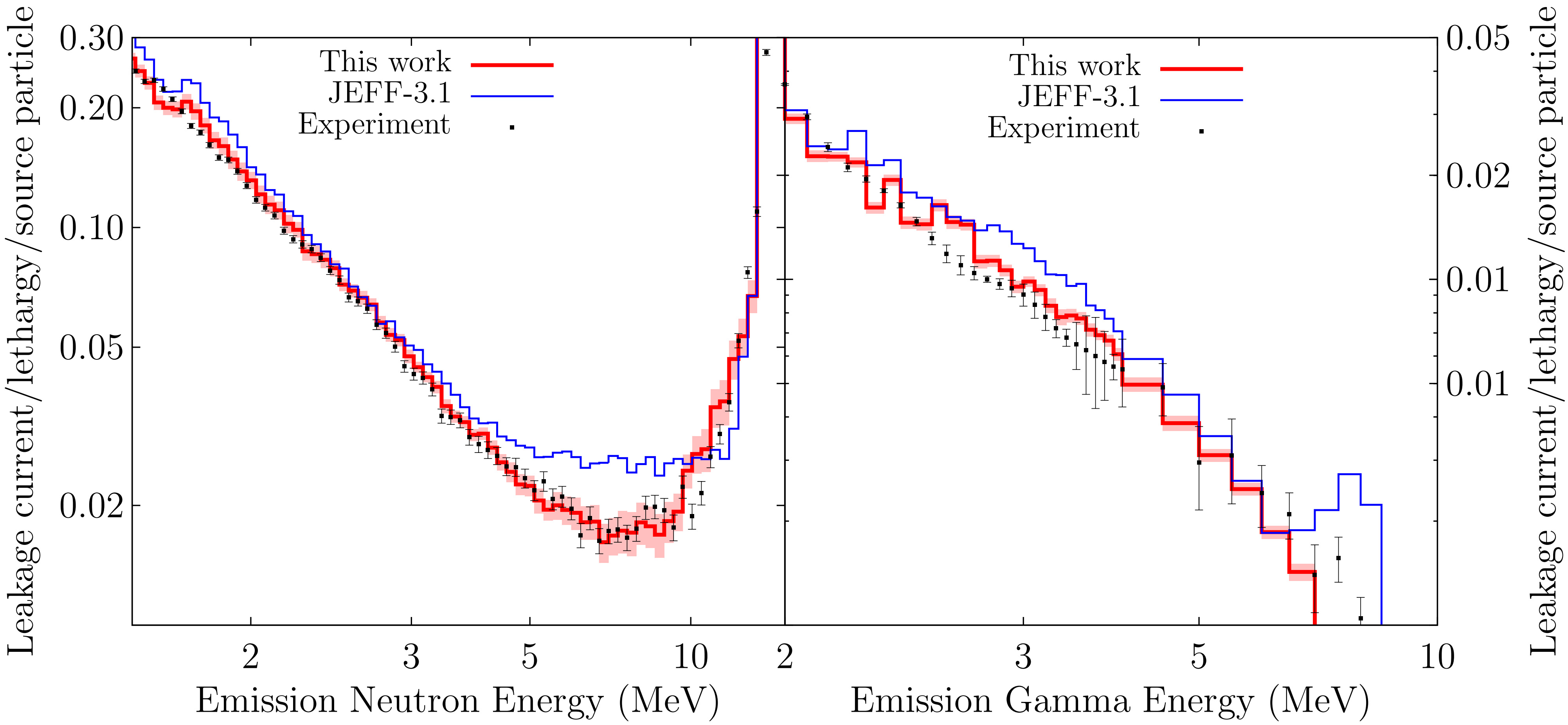
# α values for random $^{239}$Pu evaluations



# Inverse TMC: *best* $^{239}$Pu for the ANDES project



# Inverse TMC: second example on natural copper and Oktavian benchmark



# Inverse TMC: third (and last) example on thermal scattering data H in $H_2O$

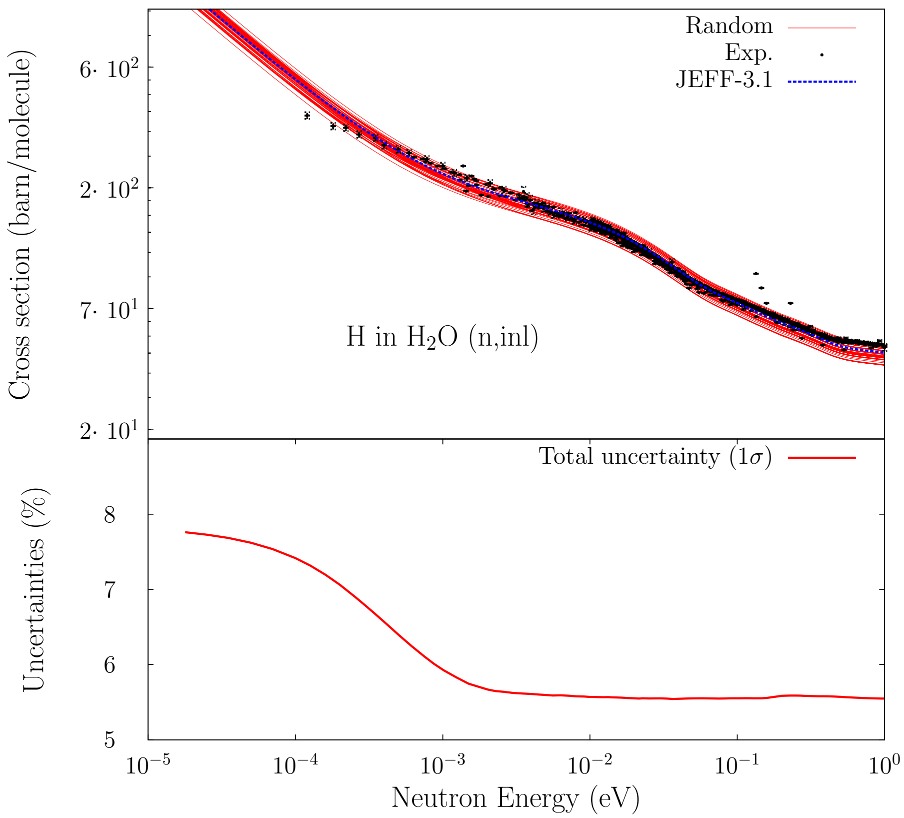
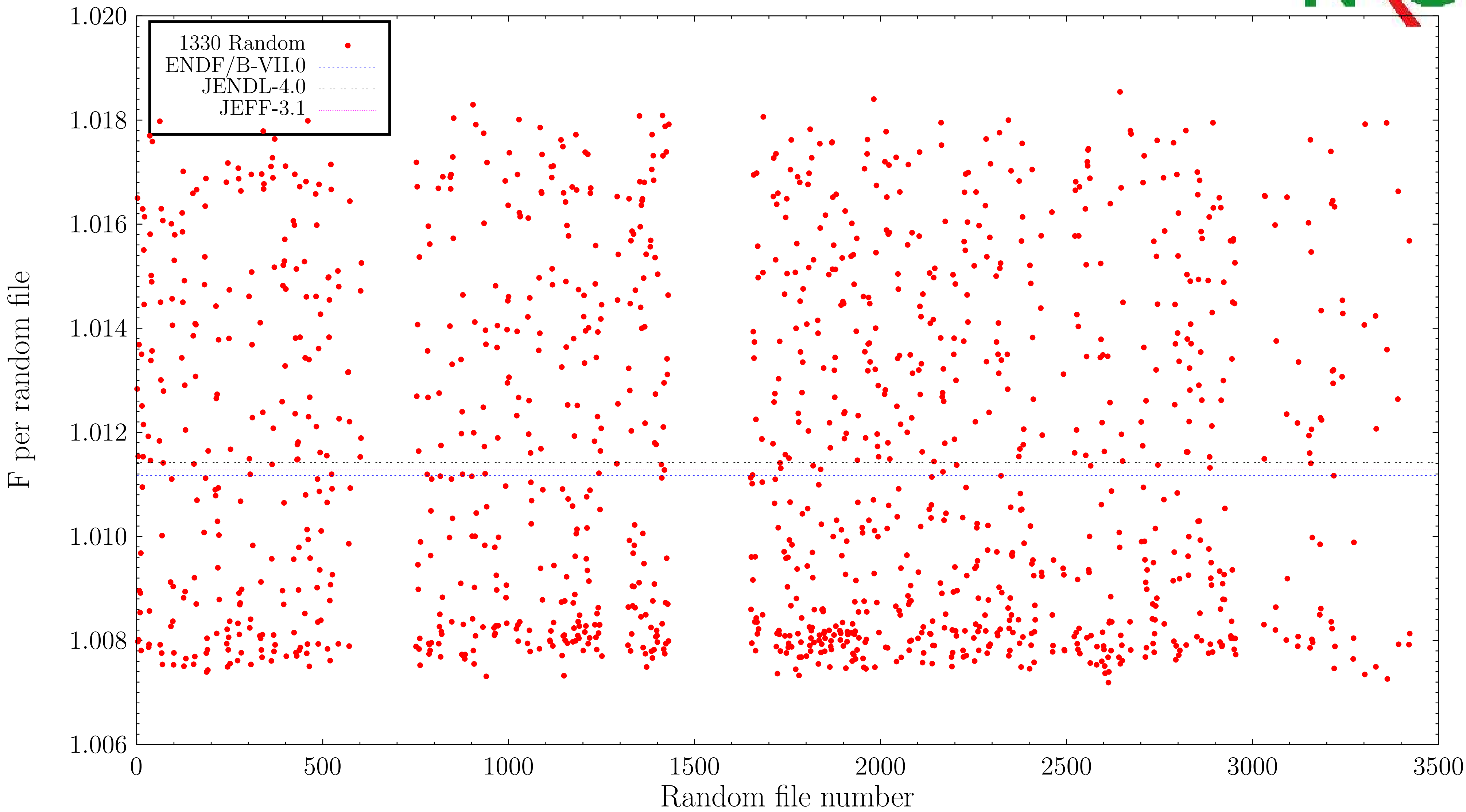



Table 2: List of thermal benchmarks selected for the random search.

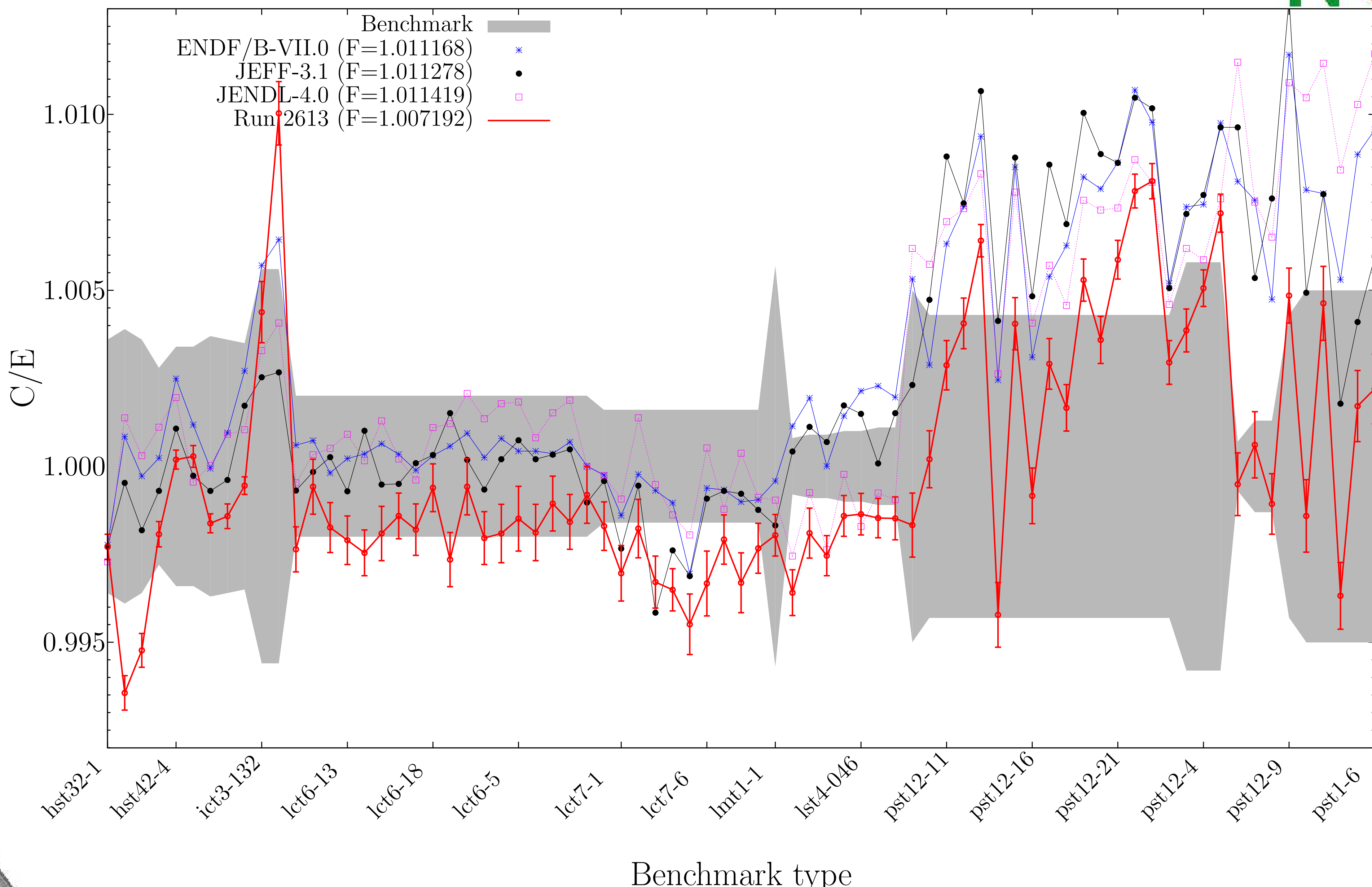
| Name | Cases | Name | Cases |
|---|---|---|---|
| pst12 | 22 | pst1 | 6 |
| lct7 | 10 | lct6 | 18 |
| lst4 | 7 | lmt1 | 1 |
| ict3 | 2 | hst32 | 1 |
| hst42 | 8 | | |

$$F = 10^{\sqrt{\frac{1}{N}\sum(\log(E_i)-\log(C_i))^2}} \quad (4)$$

# Example on thermal scattering data H in $H_2O$



# Example on thermal scattering data H in $H_2O$



## Future work

- Continue with TMC (more reactor calculations, applied to current reactors),
- Improve the quality of the TENDL library (baseline for TMC, $TMC^{-1}$),
- Apply $TMC^{-1}$ to a large number of isotope (including crit-safety, reactor, dosimetry benchmarks)
- Go where covariance methods can not be applied (TMC applied to thermo-hydraulic and transient calculations)
- Create the world best nuclear data library (NRG, CCFE, others are welcome)

☺And finally world domination (and world peace).