Ongoing work and goals of the nuclear data team

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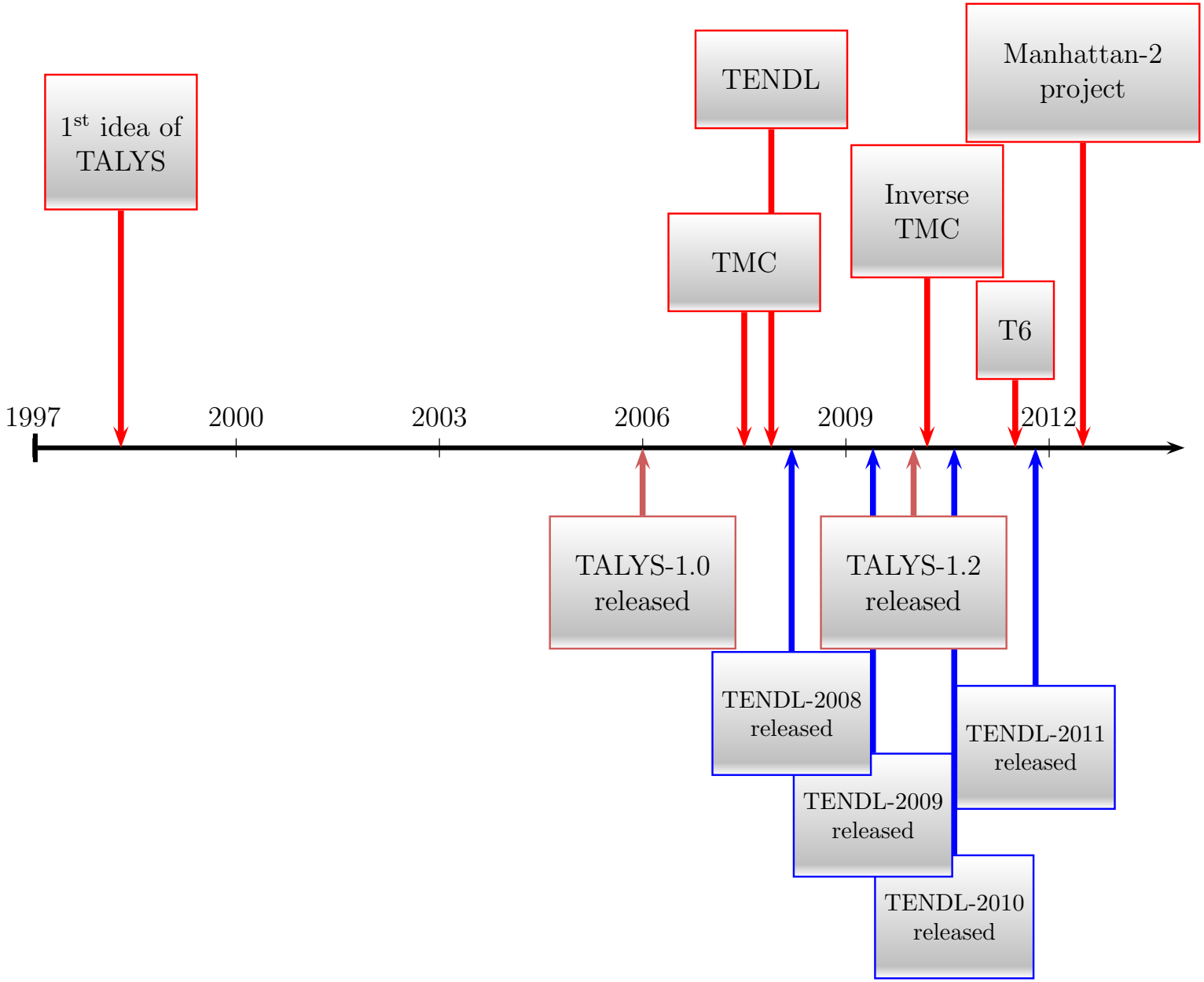
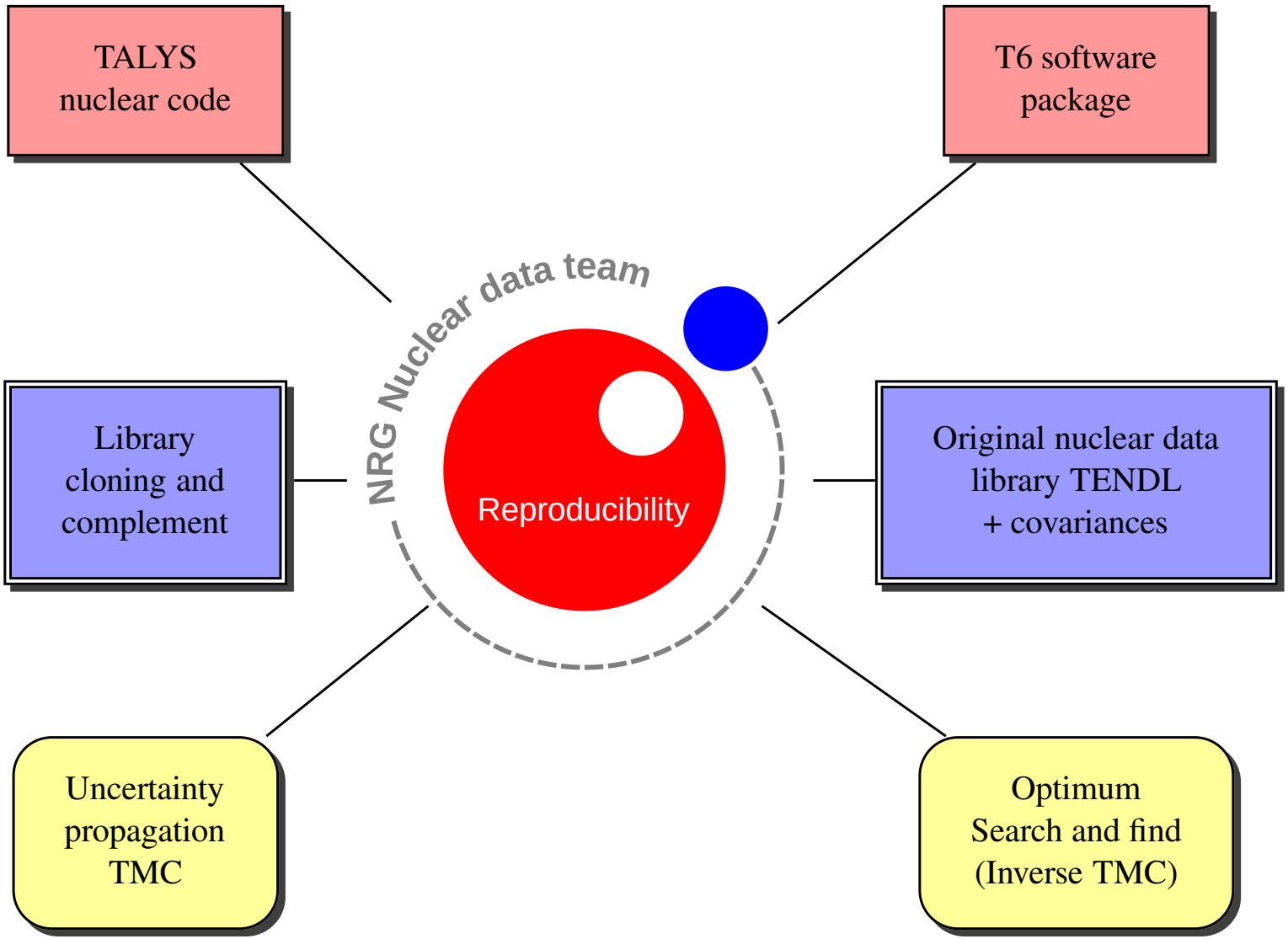
Contents

A (very) brief and recent history of nuclear data in NRG



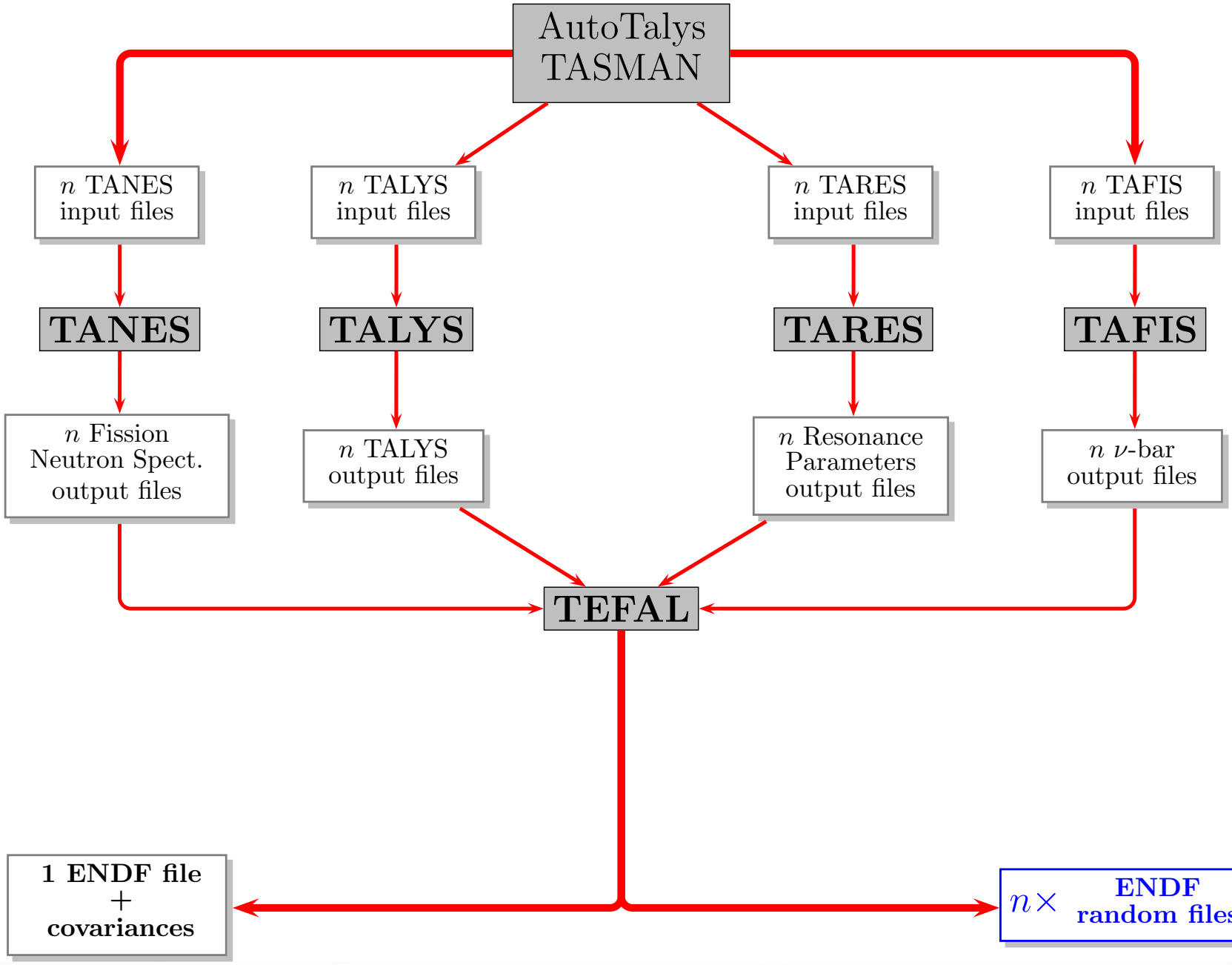
Backbone of our methodology: REPRODUCIBILITY



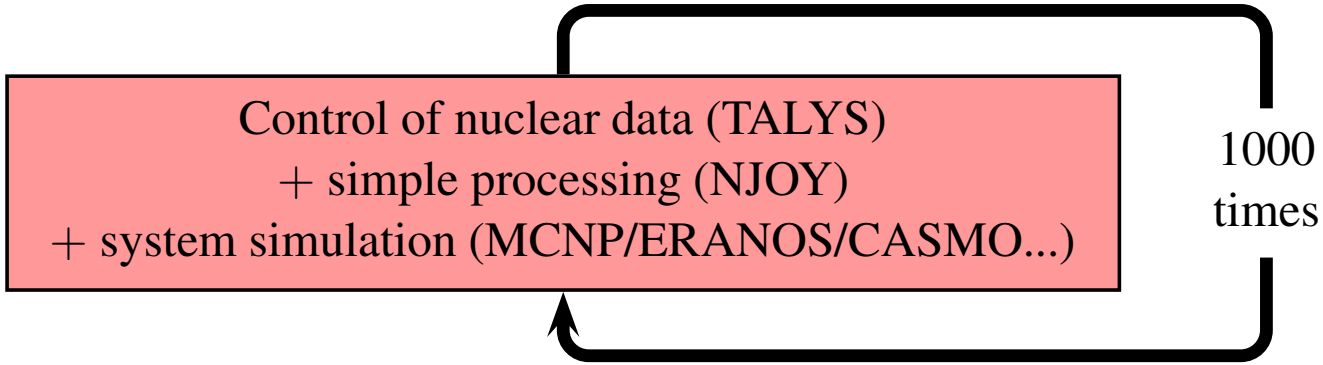
Uncertainty propagation TMC

- Started in 2008
- Many publications
- Applied to crit-saf and shielding benchmarks, reactor (k_{eff}, β_{eff}, void, Doppler), burn-up inventory, radiotoxicity
- Still a controversial method

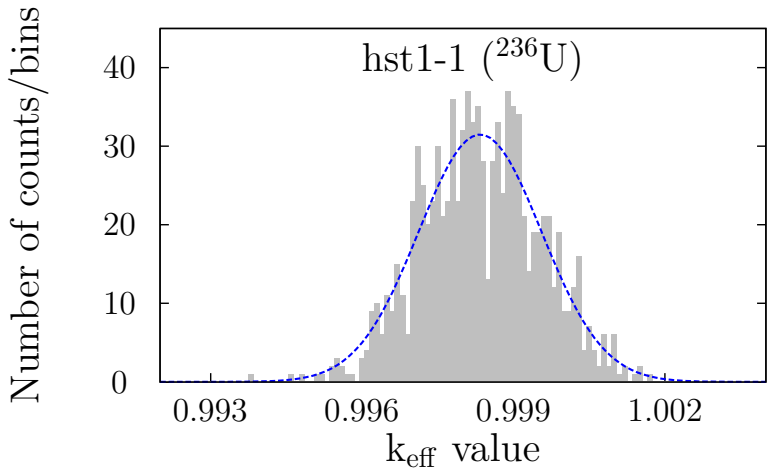
TMC: procedure for the random file production



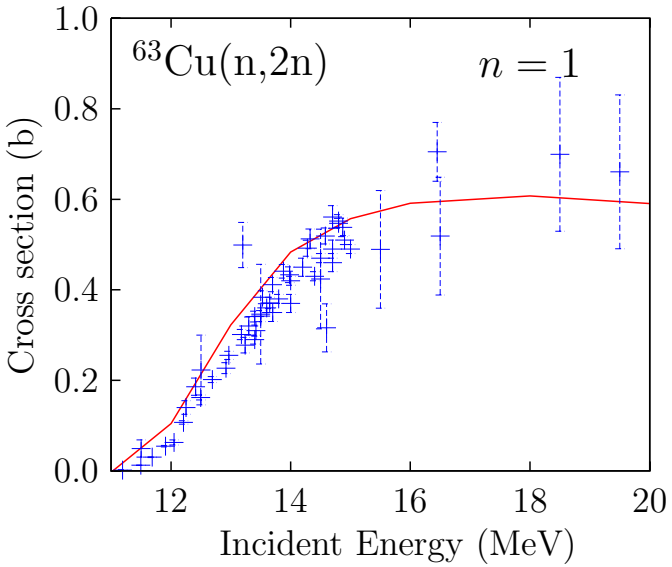
TMC: Total Monte Carlo

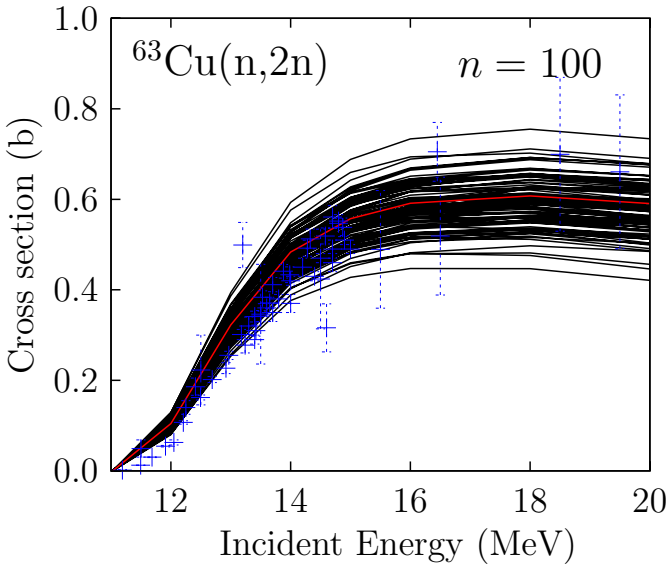


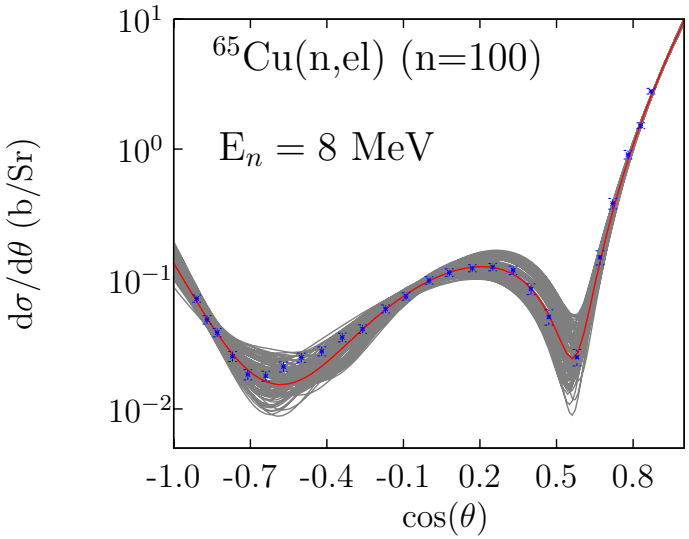
For each random ENDF file, the benchmark calculation is performed with MCNP. At the end of the *n* calculations, *n* different k_{eff} values are obtained. In the obtained probability distribution of k_{eff}, the standard deviation σ_{total} reflects two different effects: $\sigma^2_{total} = \sigma^2_{statistics} + \sigma^2_{nuclear\ data}$.

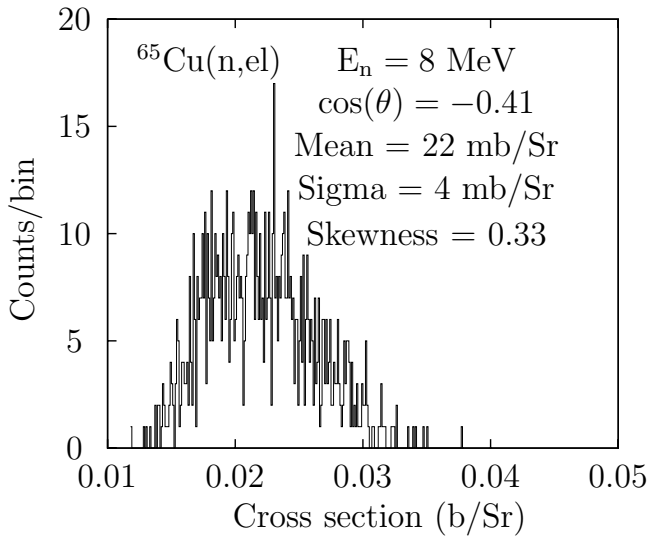


Examples with ^{63}Cu(n,2n) and ^{65}Cu(n,el)

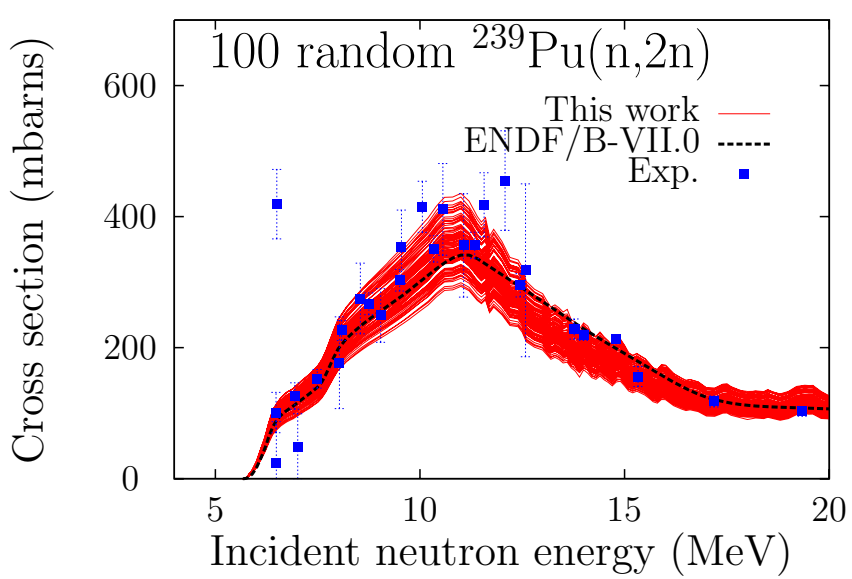


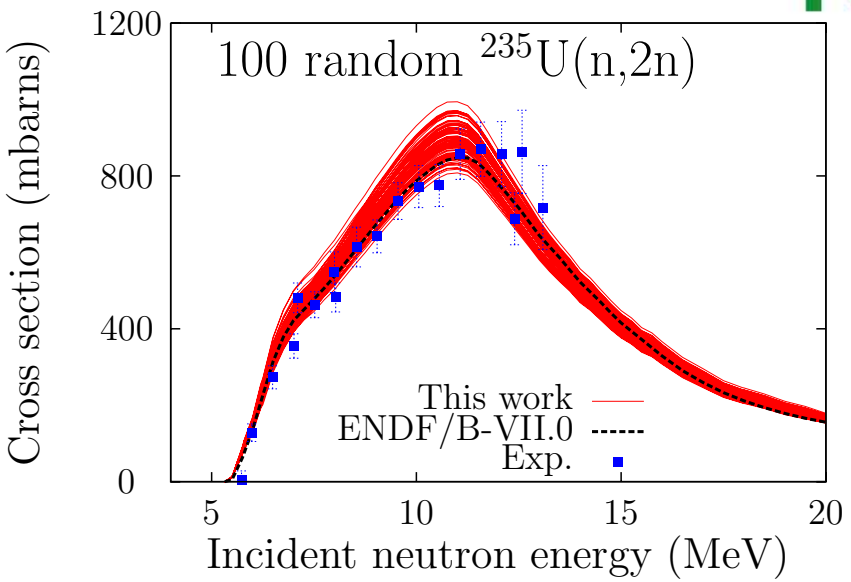


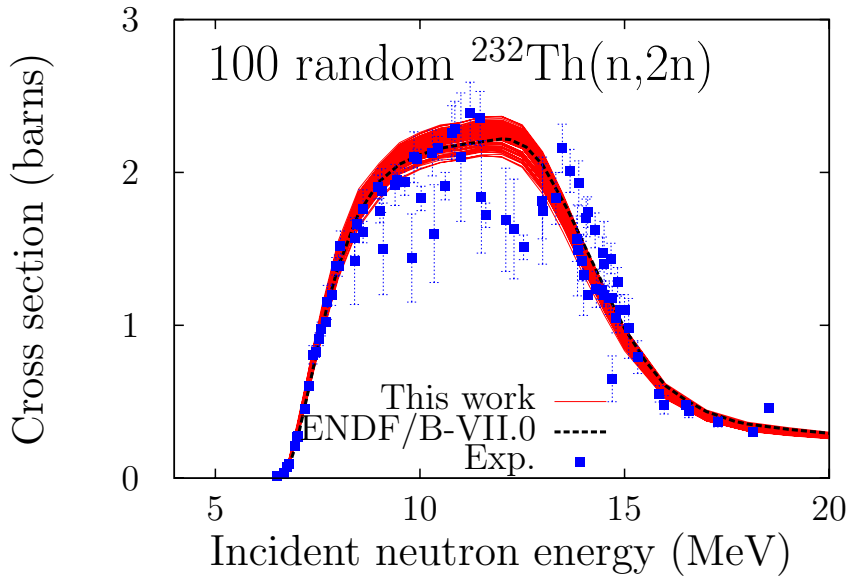


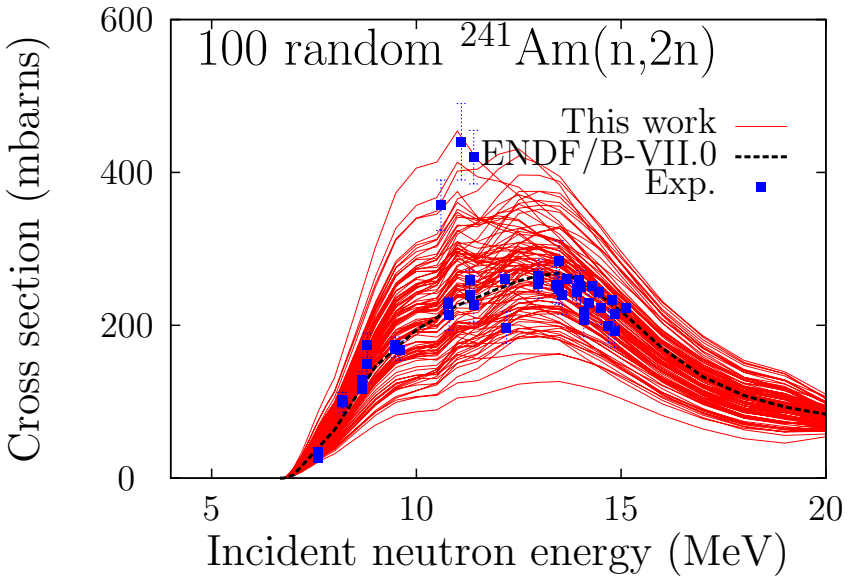


Nuclear data: examples on (n,2n) cross sections

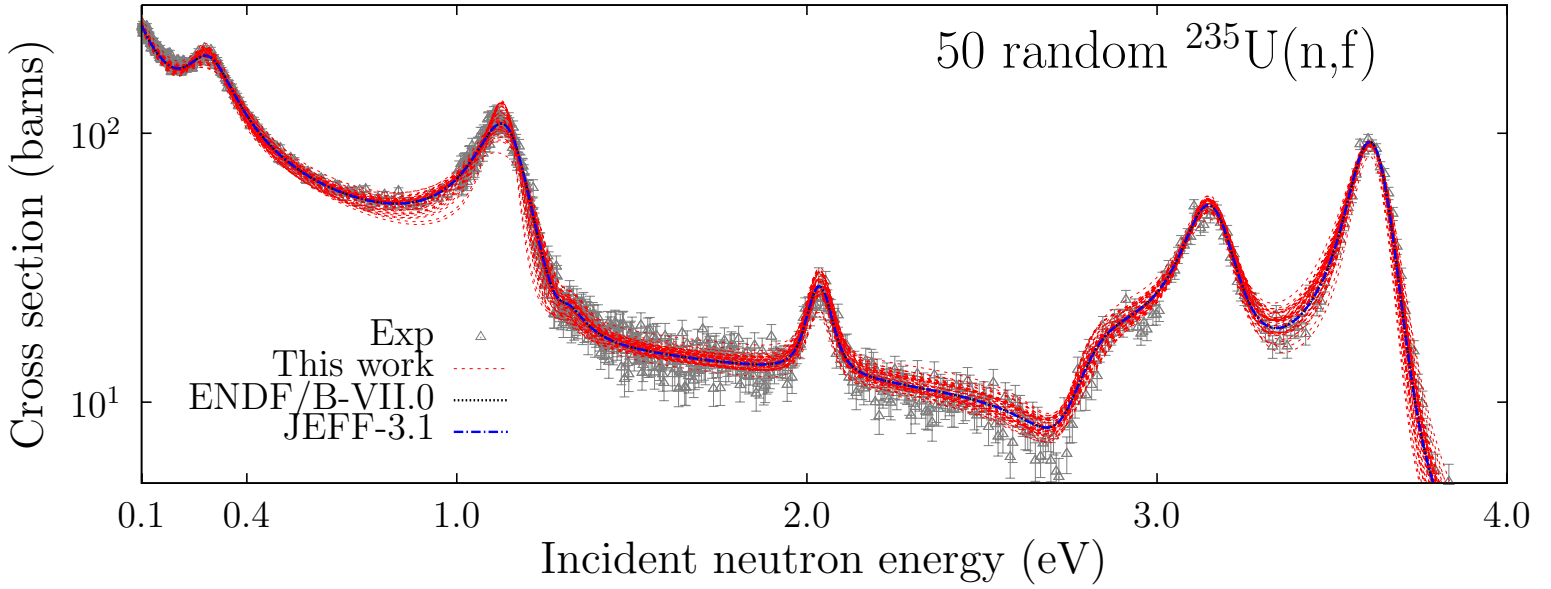


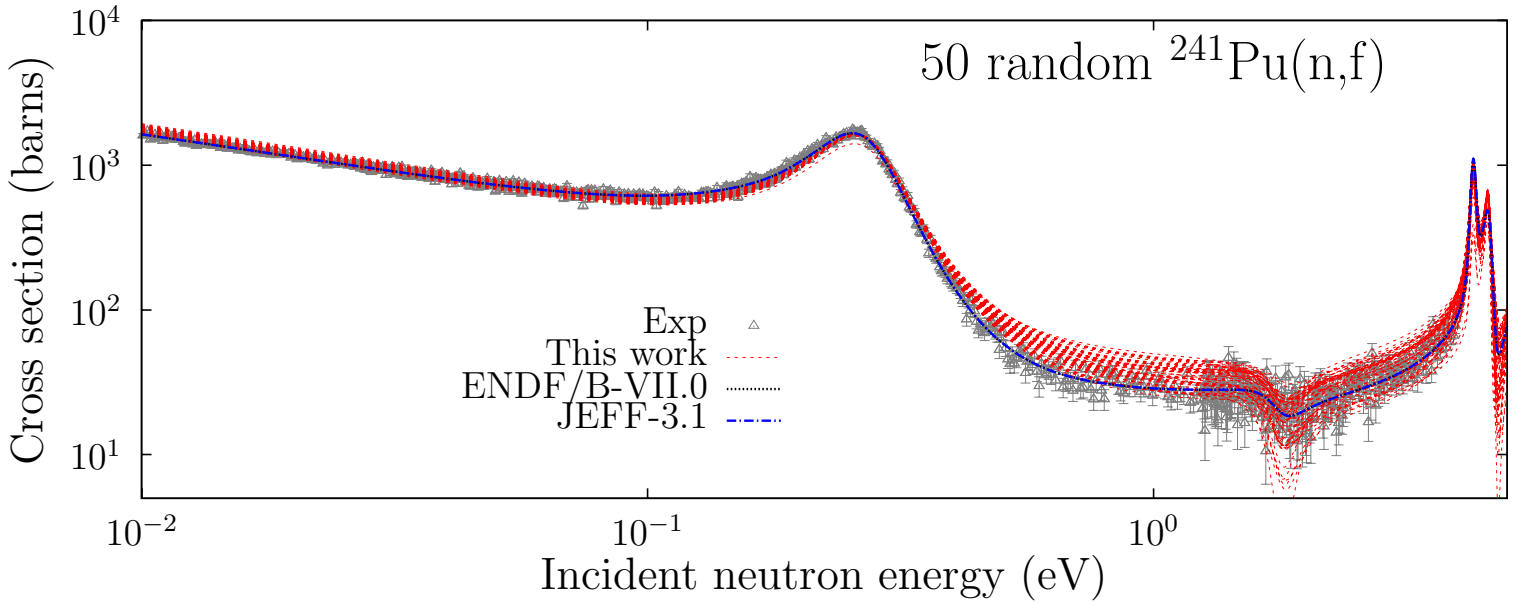




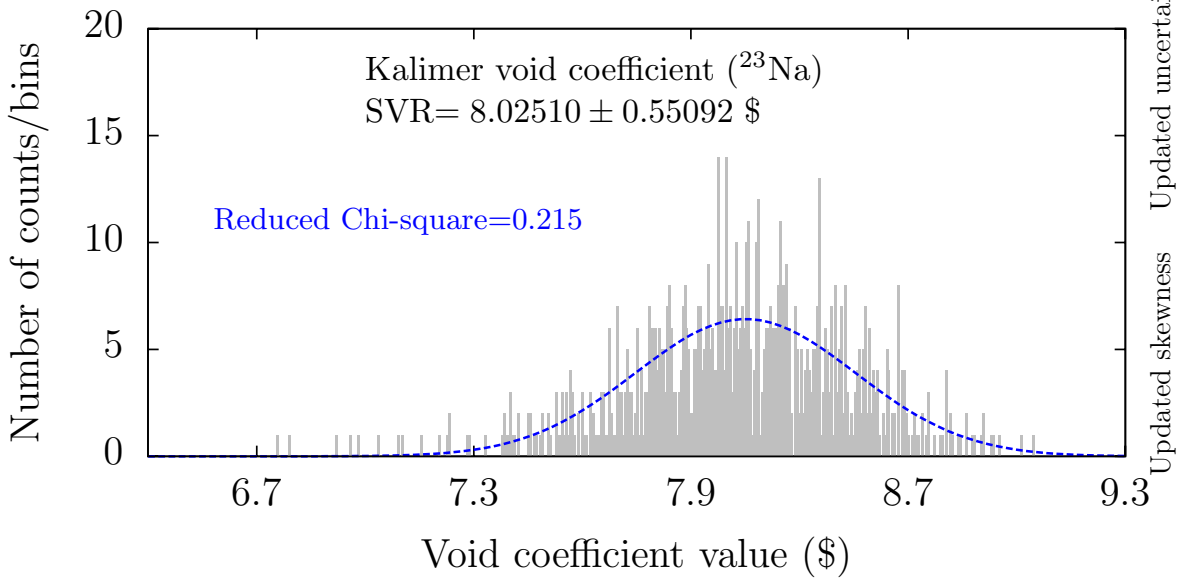


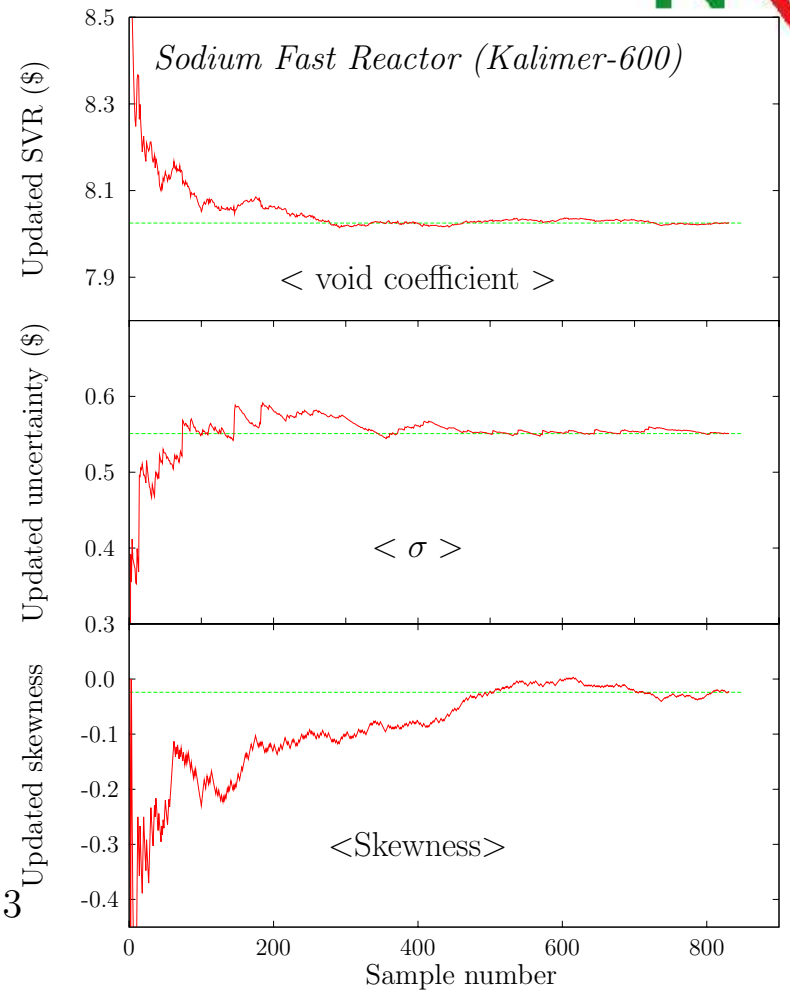
Nuclear data: examples in the resonance region



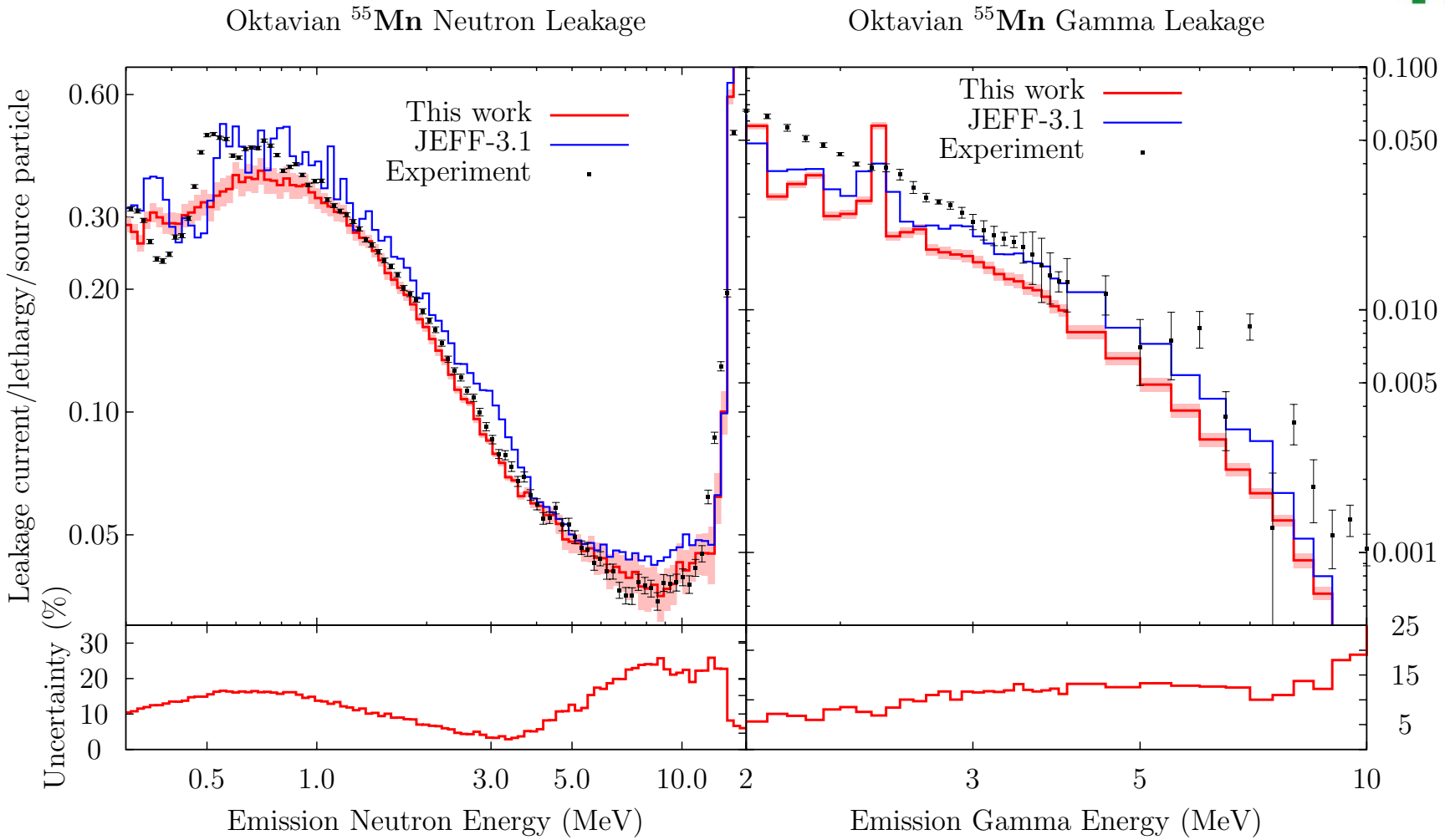


TMC applied to a SFR void coefficient



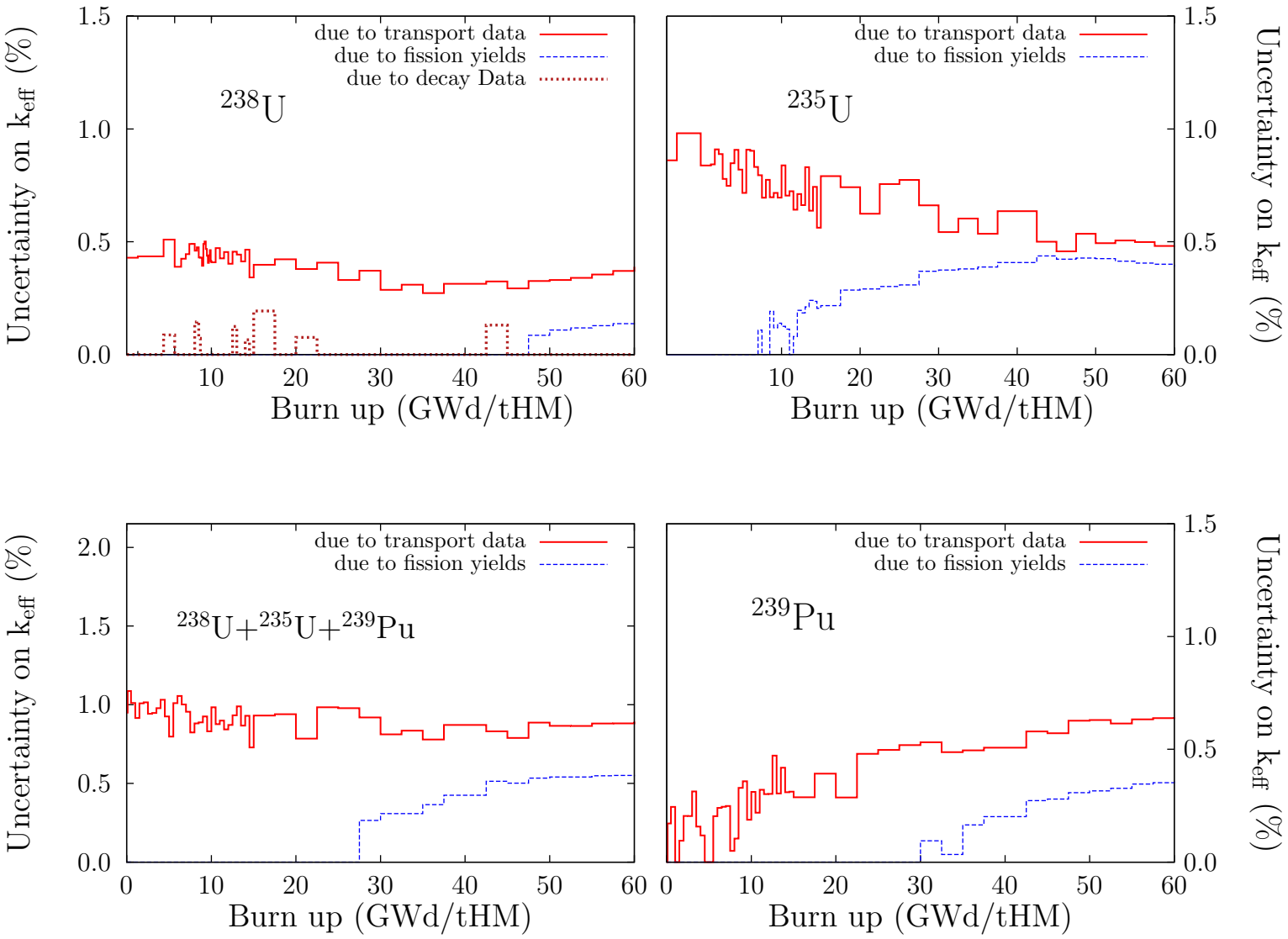


TMC applied to shielding benchmark (Mn Oktavian benchmark)

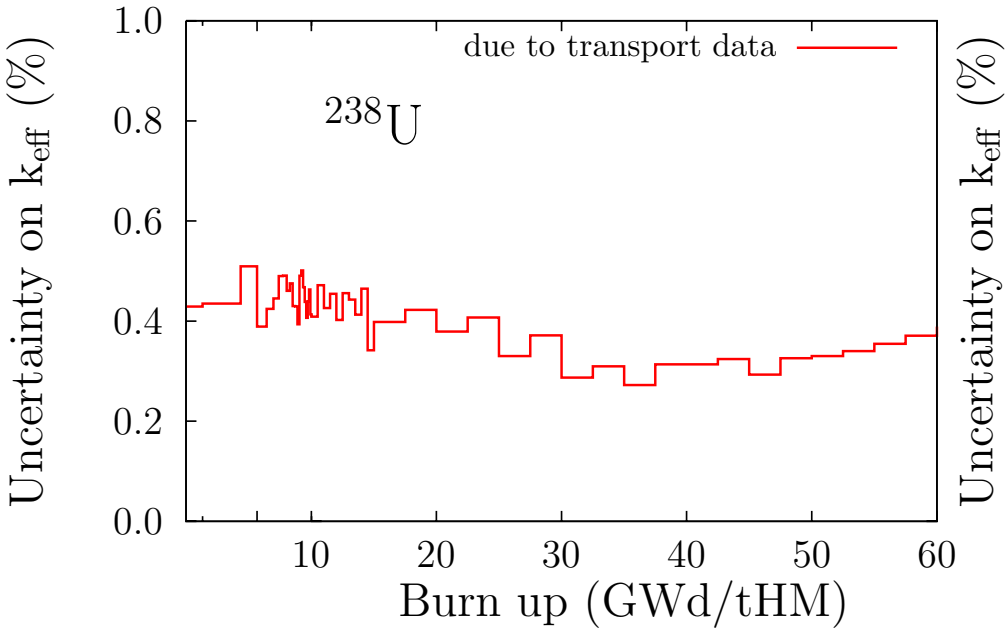


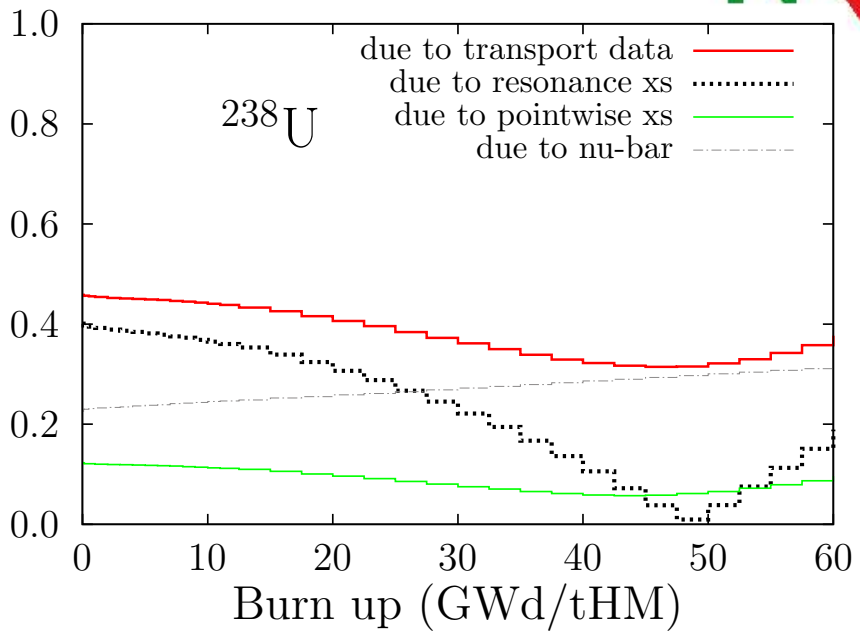
TMC applied to burn-up calculations with SERPENT

PWR fuel element based on a Westinghouse 3-loop PWR design (array of 17x17), 4 m in length, 21.5 cm in width, 400-500 kg of enriched uranium (4.8 % in ^{235}U)



TMC applied to burn-up calculations with DRAGON





SERPENT (Monte Carlo)

DRAGON (deterministic)

TENDL: nuclear data production

Library cloning and complement	Original nuclear data library TENDL + covariances

- Started in 2008
- TENDL libraries released every year
- First of its kind by the method of production
- First of its kind by separating evaluation work and library production
- $\simeq$ 80 isotopes from TENDL to JEFF-3.2β, to FENDL

TENDL: Motivations

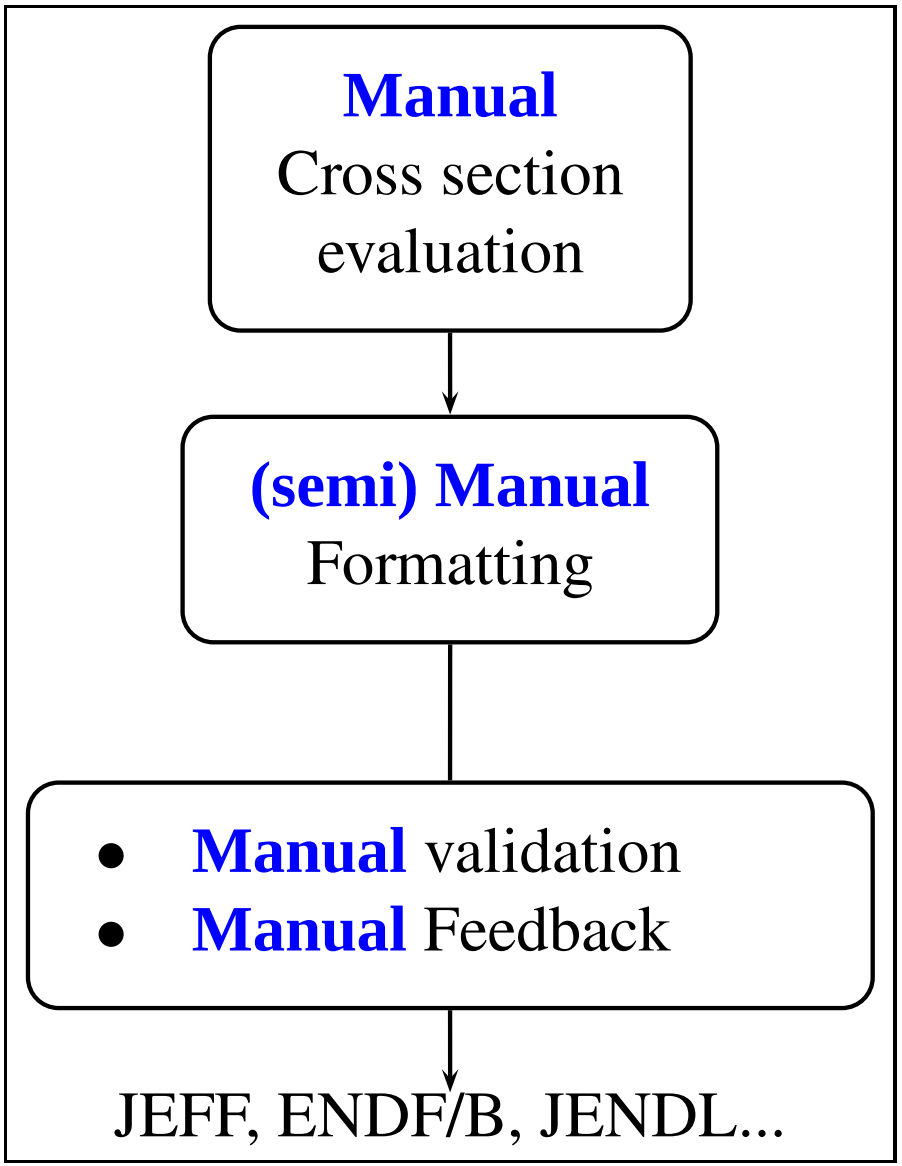
We need a consistent and complete nuclear data library to be integrated in reactor calculations, including realistic covariance data.

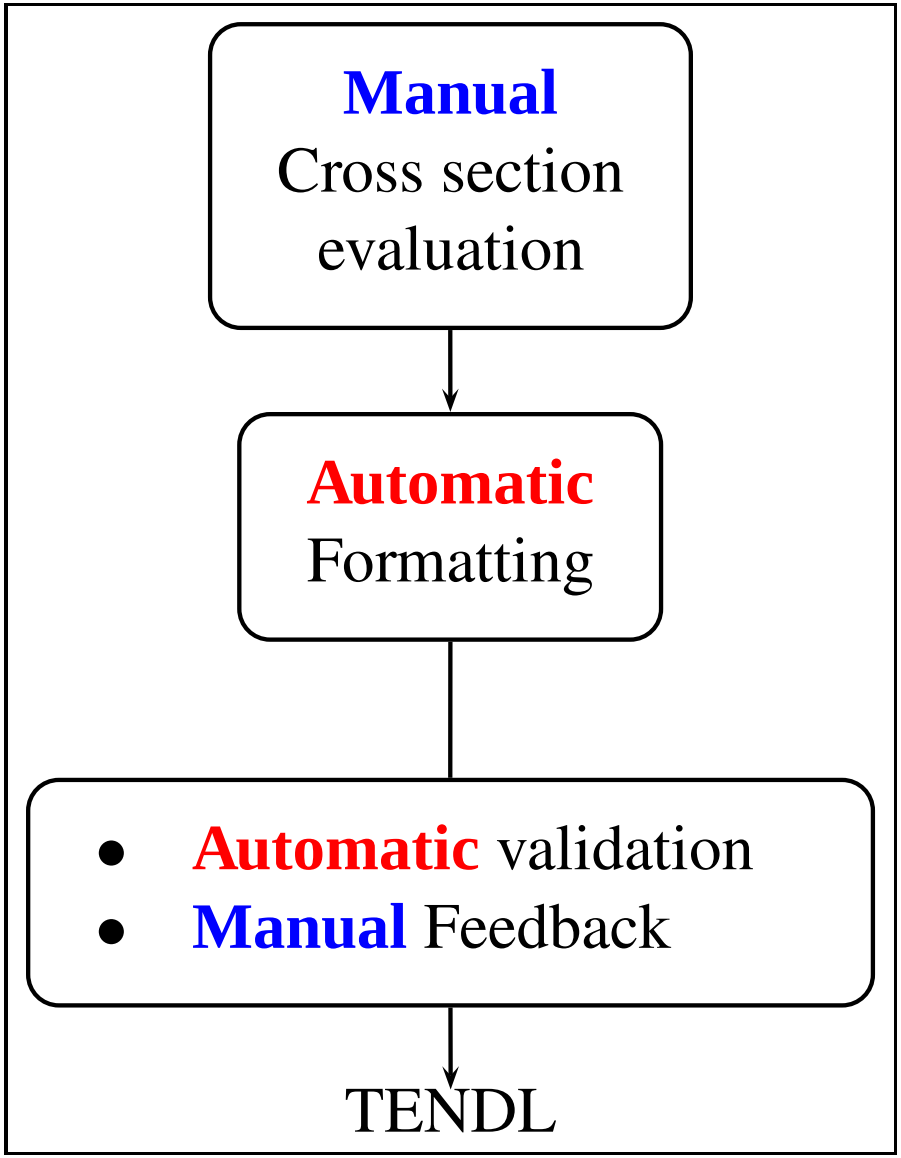
(*None of the existing libraries fulfill these requirements.*)

- Use global, robust TALYS method for the bulk of nuclides,
- Use in-depth evaluation, adjustment... for important nuclides (e.g. ^{56}Fe, ^{239}Pu),
- Reproducible library,
- ENDF, PENDF, ACE, EAF and text format,
- Available at www.talys.eu/tendl-2008 (2009, 2010 and 2011).

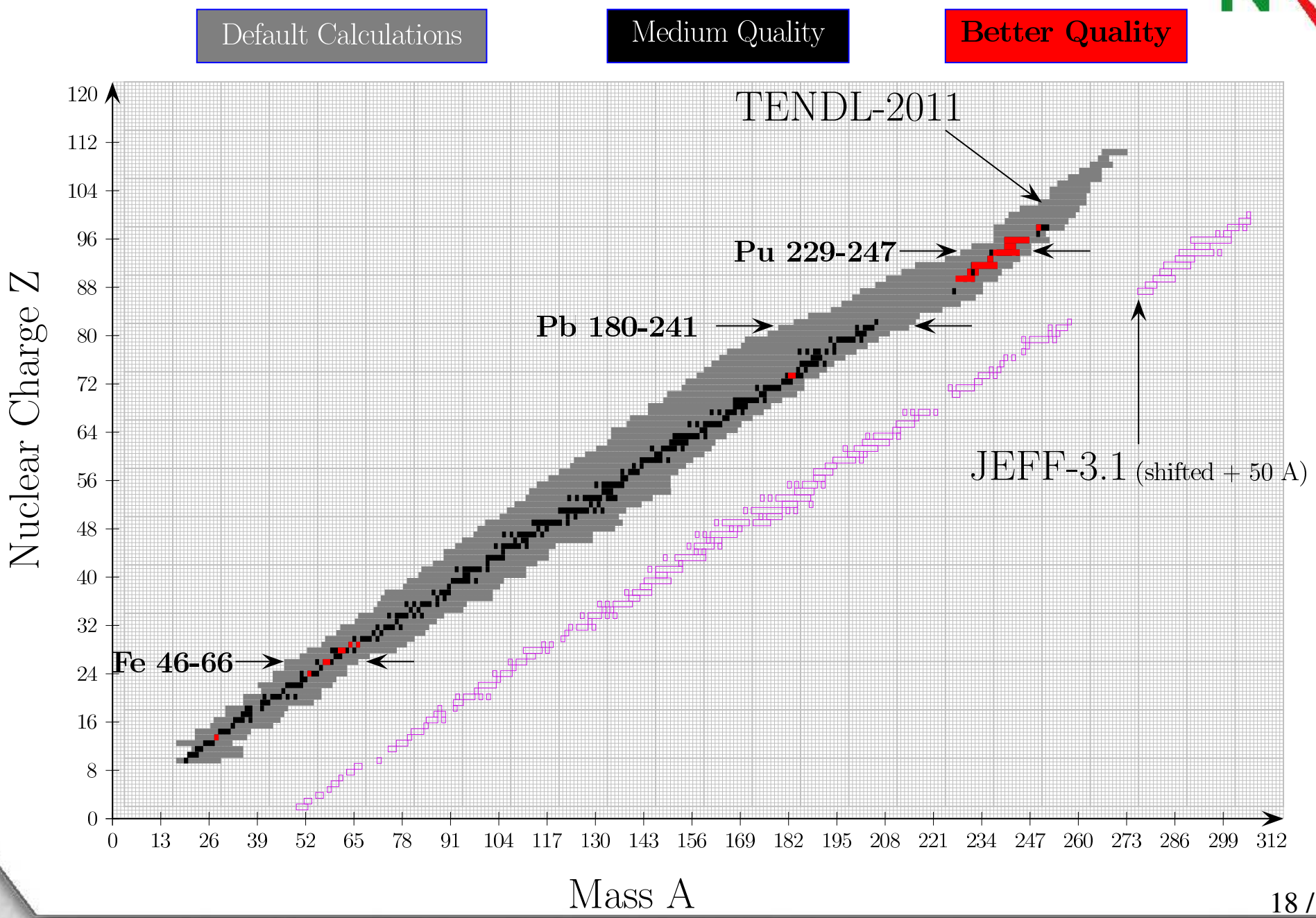
Produce TENDL-2008, -2009, -2010 ... with an increasing quality with regard to: differential data, model development, integral validation, completeness and covariance data

TENDL: Standard and modern approaches



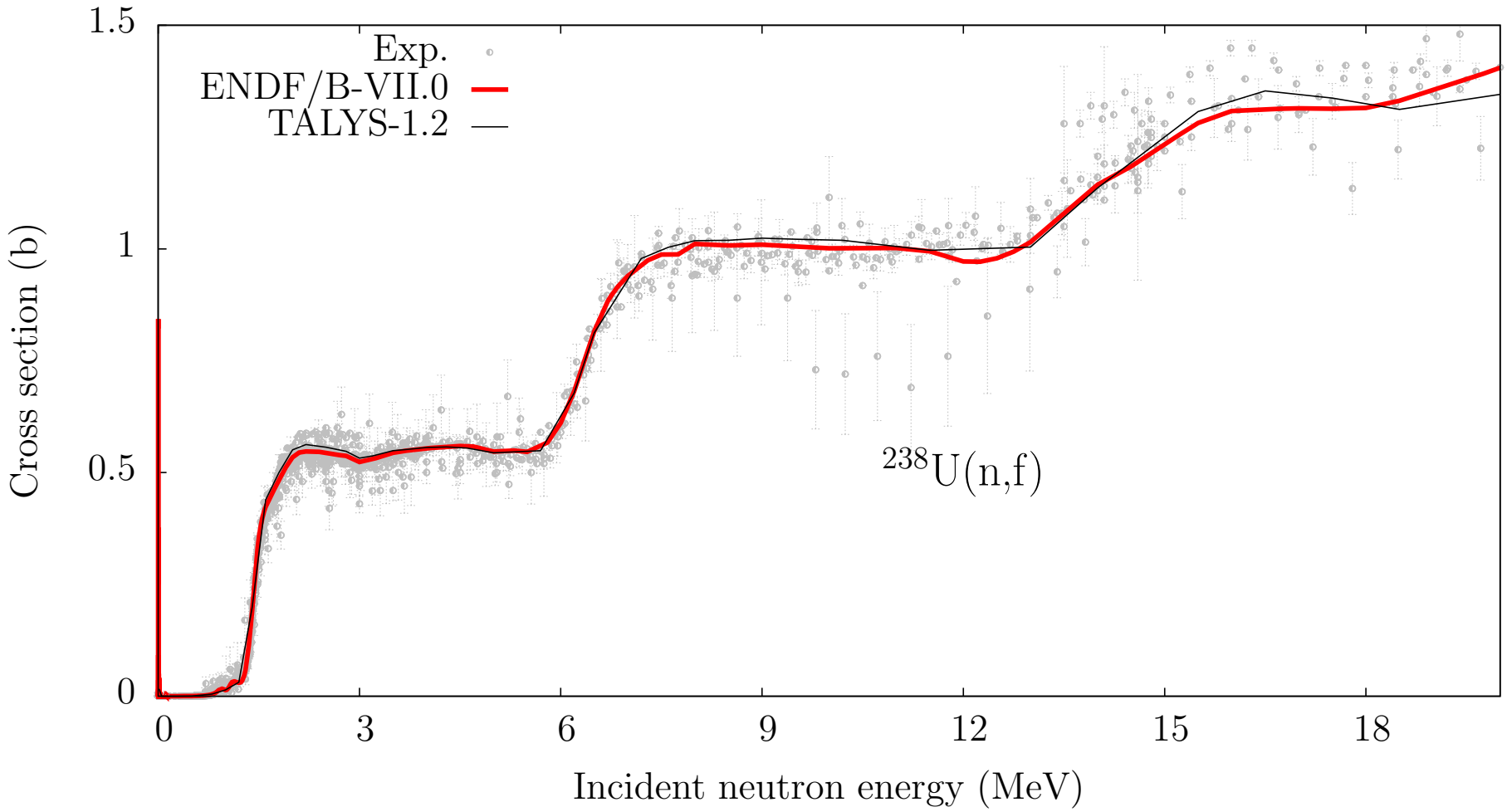


TENDL-2011: $t_{1/2} > 1$ sec, 200 MeV (n, p, d, t, a, γ reactions)



TENDL cloning of other library

When TALYS can not reproduce experimental cross sections, normalization is applied



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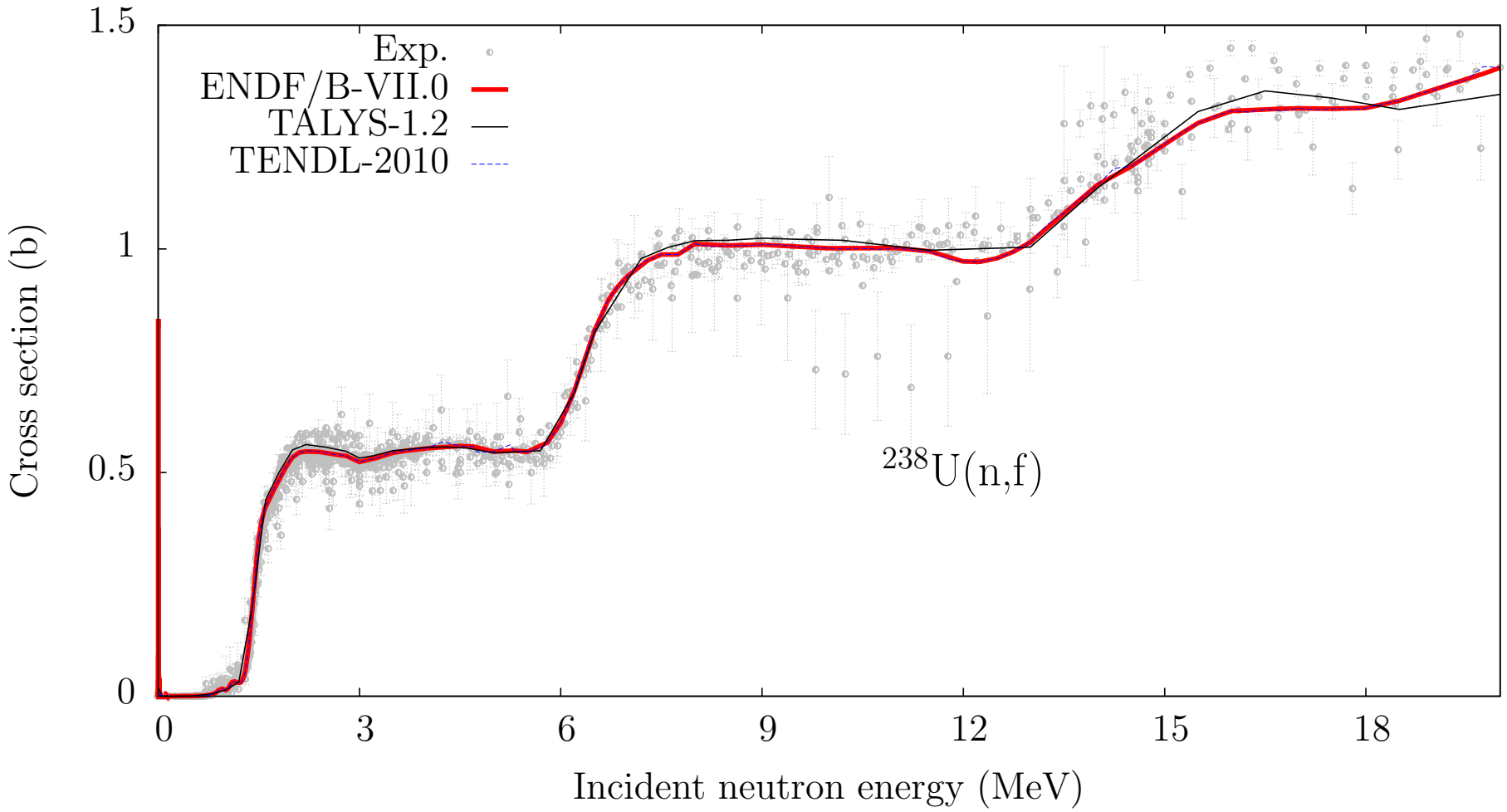


Optimum Search and find (Inverse TMC)

- Started in 2010
- Two publications so far
- 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

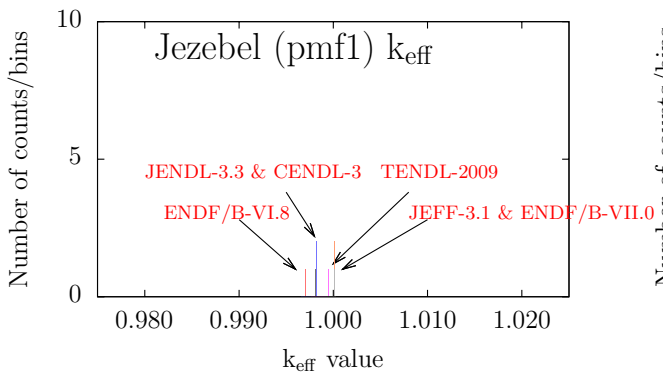
② Randomize all model parameters (resonances, nubar, fission neutron spectrum, TALYS parameters) to create 500 random ^{239}Pu evaluations

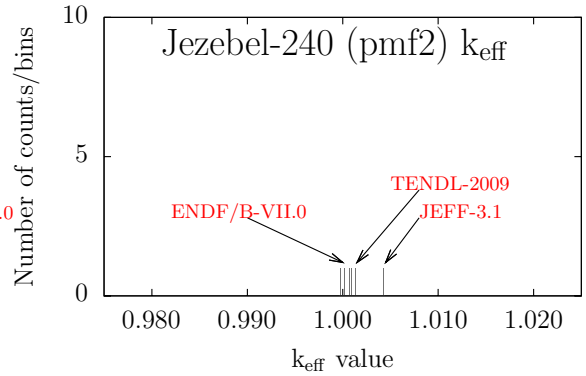
③ Benchmarks the $n \geq 500$ files with the same set of criticality benchmarks

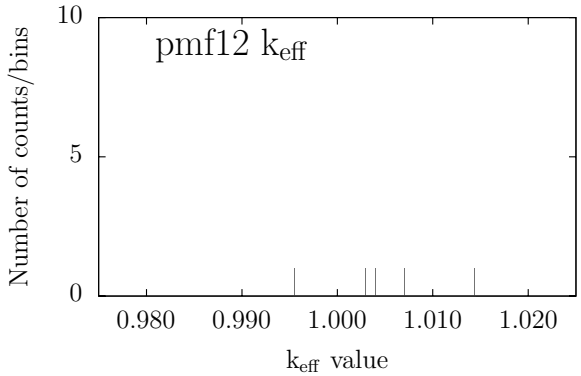
④ Select the best random file

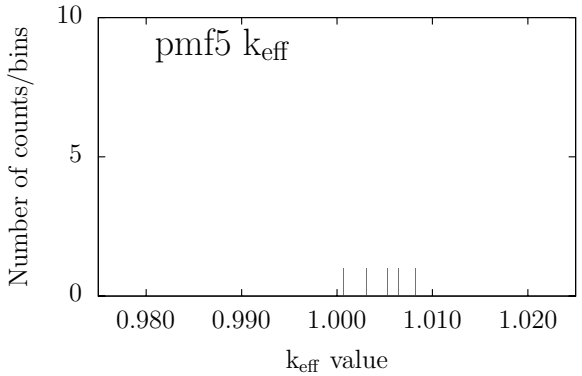
Example: 100 benchmarks, 500 random files $\Longrightarrow$ 500 TALYS + NJOY and $100 \times 500 = 5 \cdot 10^4$ MCNP loops, 1.4 years on a single processor, or 5 days on 100 processors (3 GHz)

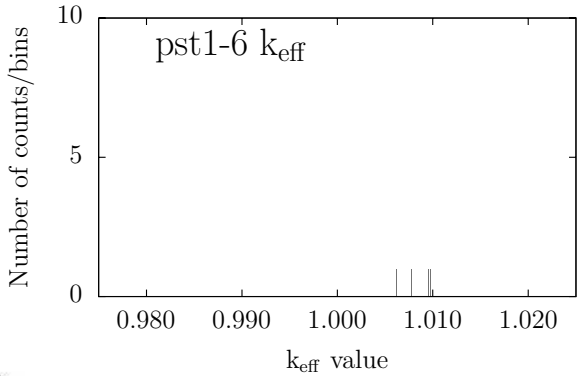
Inverse TMC: simple example with 6 k_{eff} benchmarks

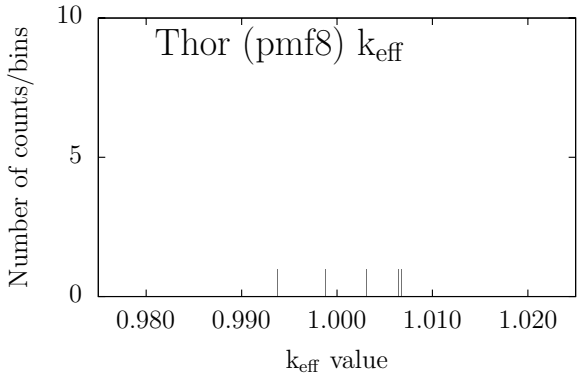








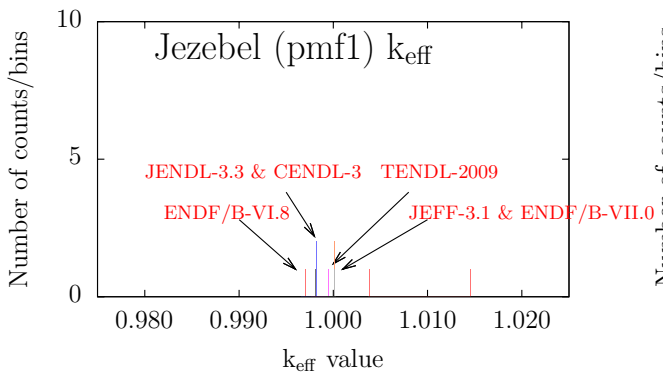


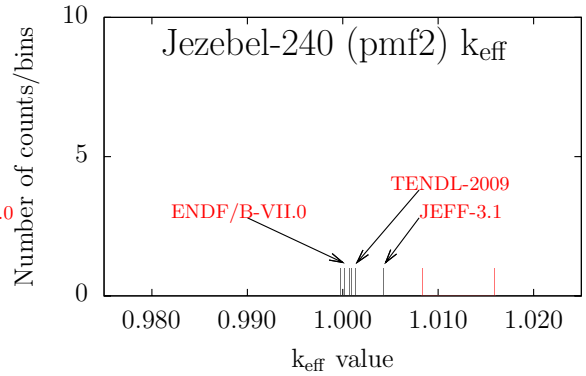


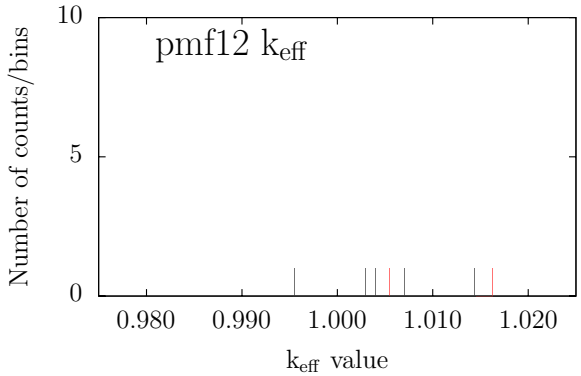
	α
JEFF-3.1.1:	$1.14e^{-4}$
JENDL-3.3:	$1.71e^{-4}$
TENDL-2009:	$3.66e^{-4}$
ENDF/B-VI.8:	$1.72e^{-4}$
ENDF/B-VII.0:	$1.69e^{-4}$

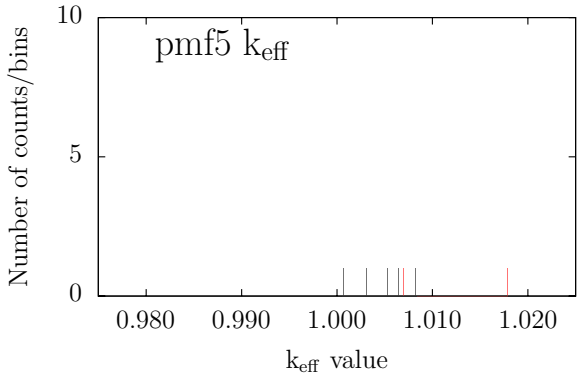
$$\alpha = \sum_{i=0}^{n} \frac{(C_i - E_i)^2}{C_i},$$

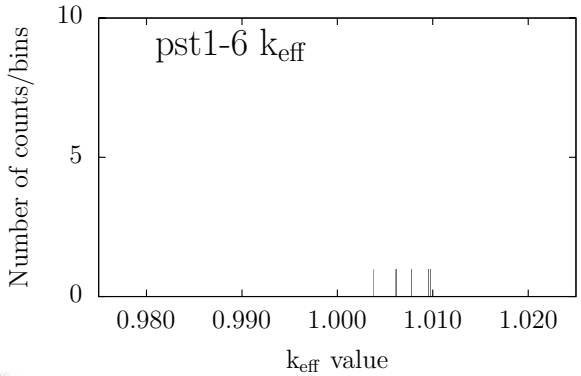
Inverse TMC: simple example with 6 k_{eff} benchmarks

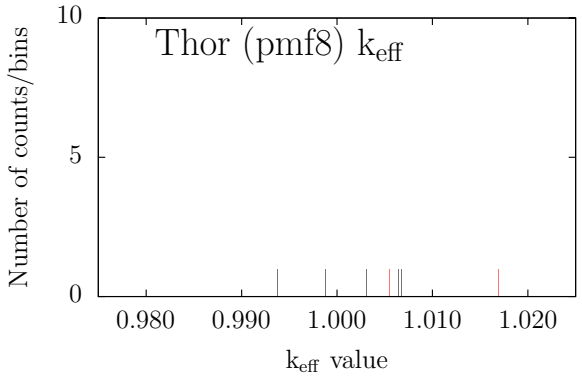












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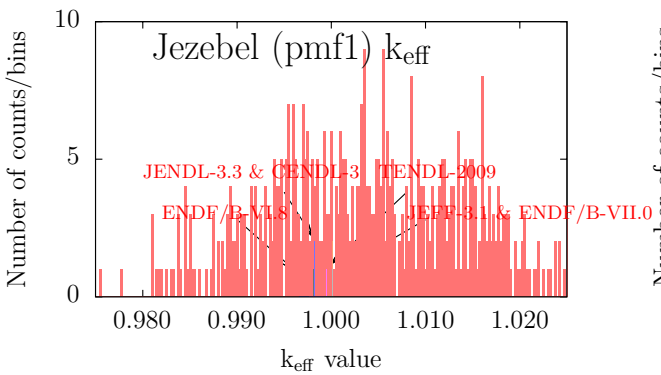
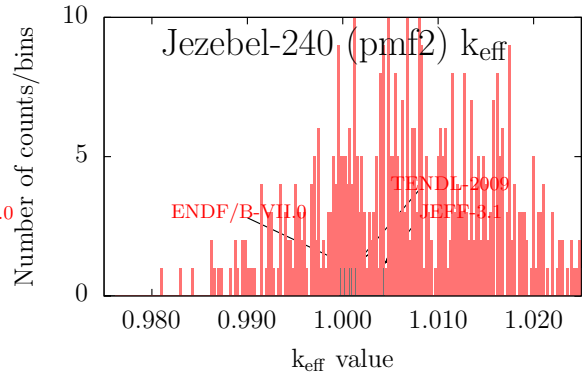
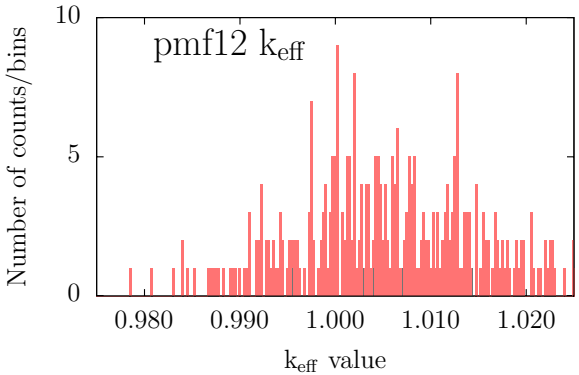
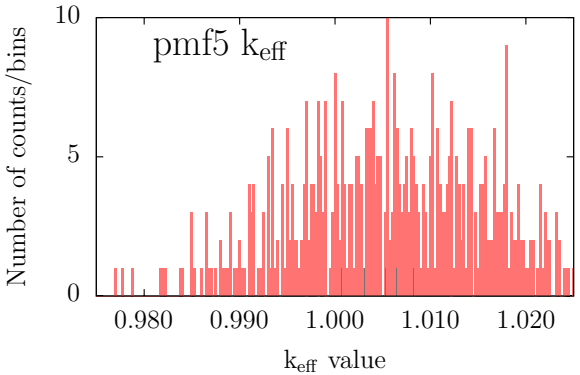
TENDL-2009:	$3.66e^{-4}$
ENDF/B-VI.8:	$1.72e^{-4}$
ENDF/B-VII.0:	$1.69e^{-4}$
random 0:	$2.29e^{-4}$
random 1:	$13.4e^{-4}$

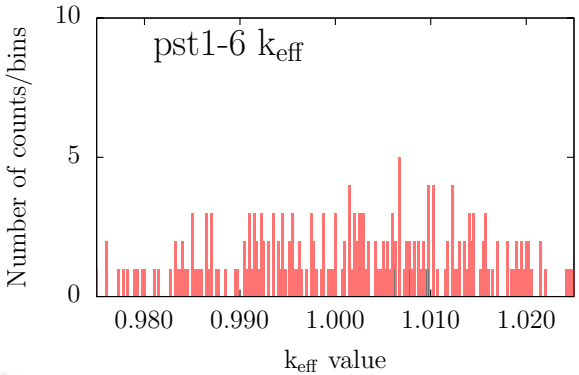
Inverse TMC: 6 k_{eff} benchmarks with random ^{239}Pu

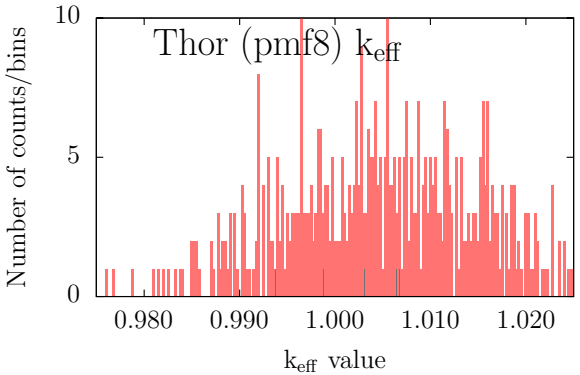












Real case: 120 ^{239}Pu benchmarks

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

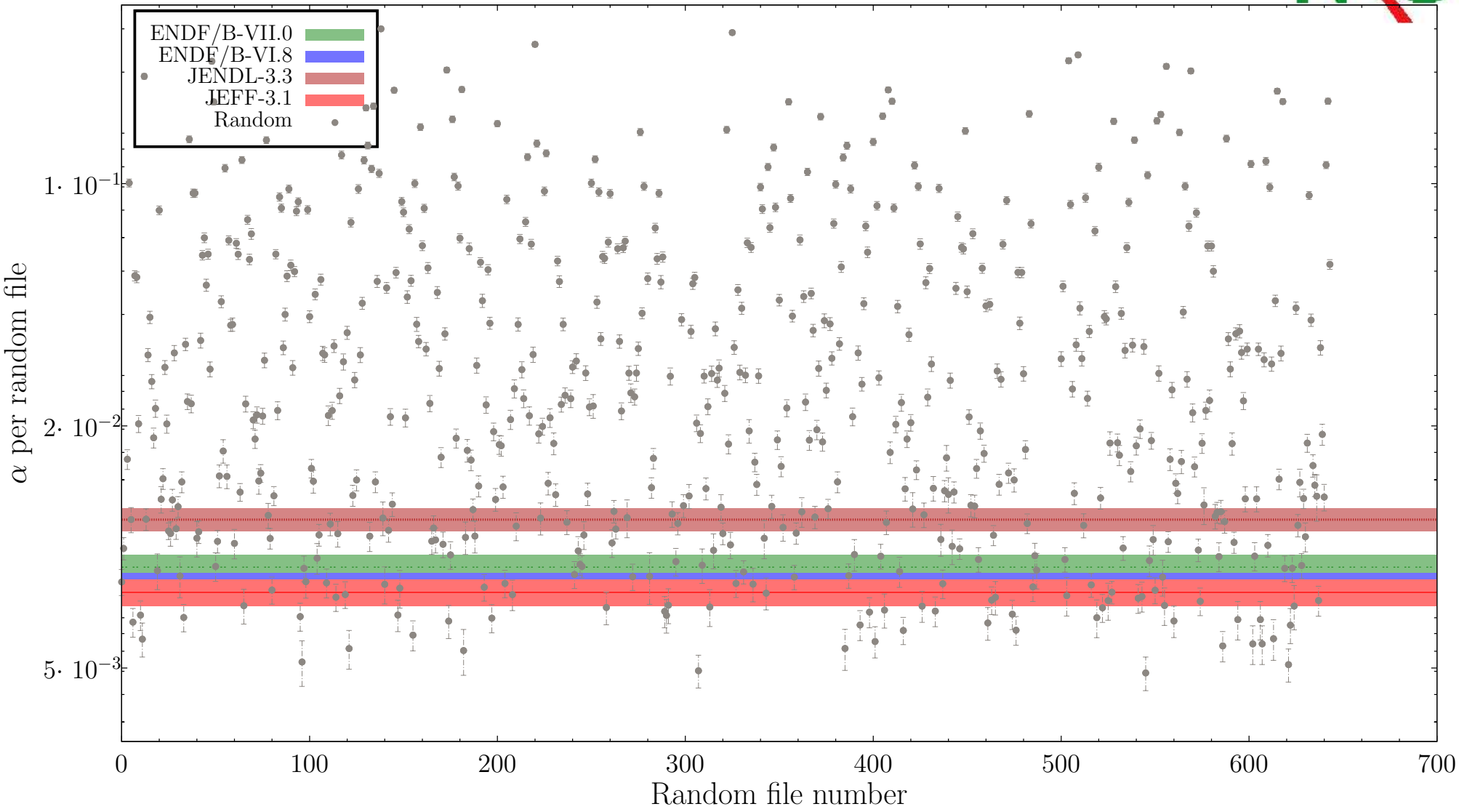
Name	Cases	Name	Cases	Name	Cases	Name	Cases
pmf1	1	pmf2	1	pmf5	1	pmf6	1
pmf8	1	pmf12	1	pmf13	1	pci1	1
pmi2	1	pst1	6	pst2	6	pst3	8
pst4	13	pst5	9	pst6	3	pst7	9
pst8	29	pst12	22	pmm1	6		

$$\alpha = \sum_{i=0}^{n} \frac{(C_i - E_i)^2}{C_i}, \tag{1}$$

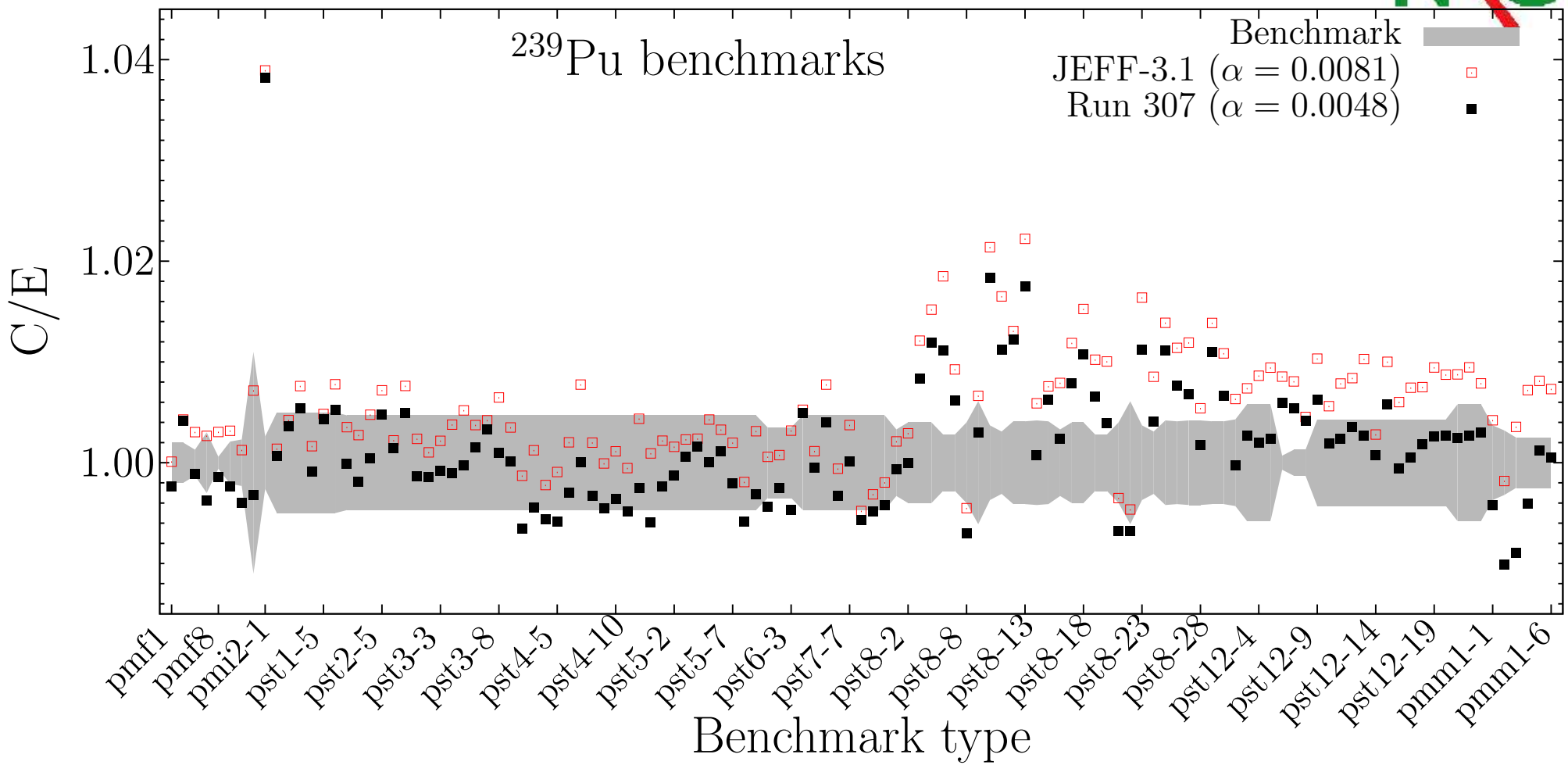
Results independent of the type of factor α, χ^2... or

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

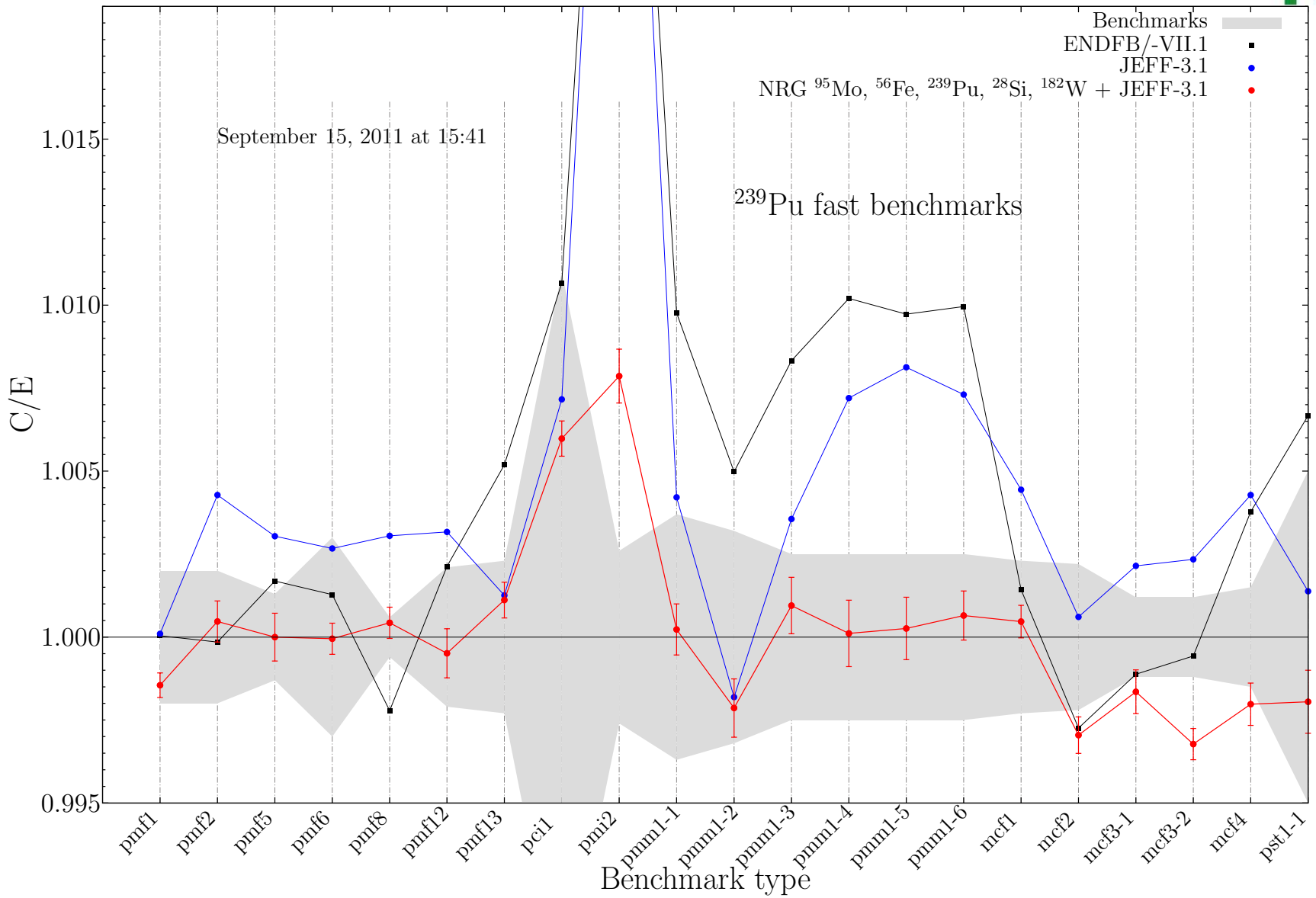
α values for random ^{239}Pu evaluations



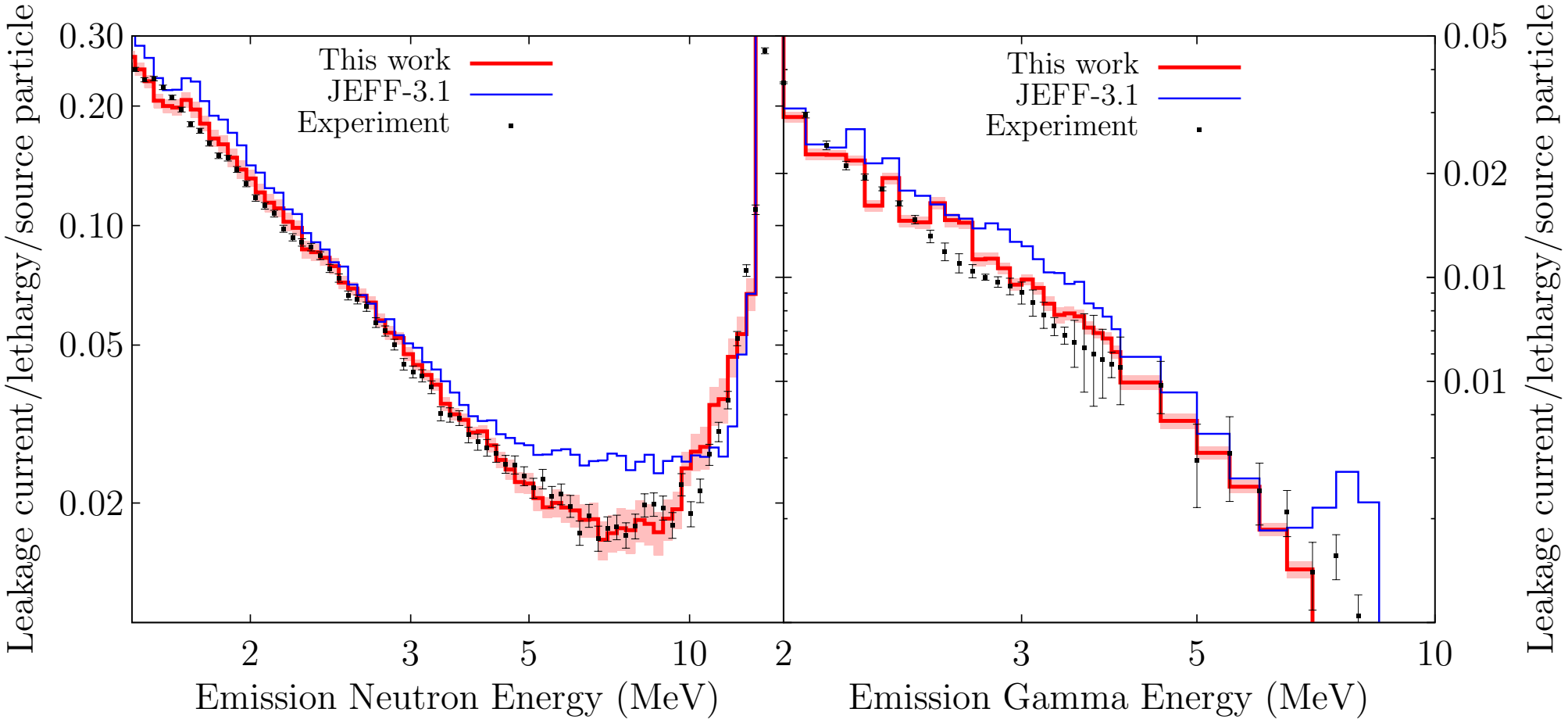
C/E values for the *best* ^{239}Pu (run 307)



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



Inverse TMC: second example on natural copper and Oktavian benchmark

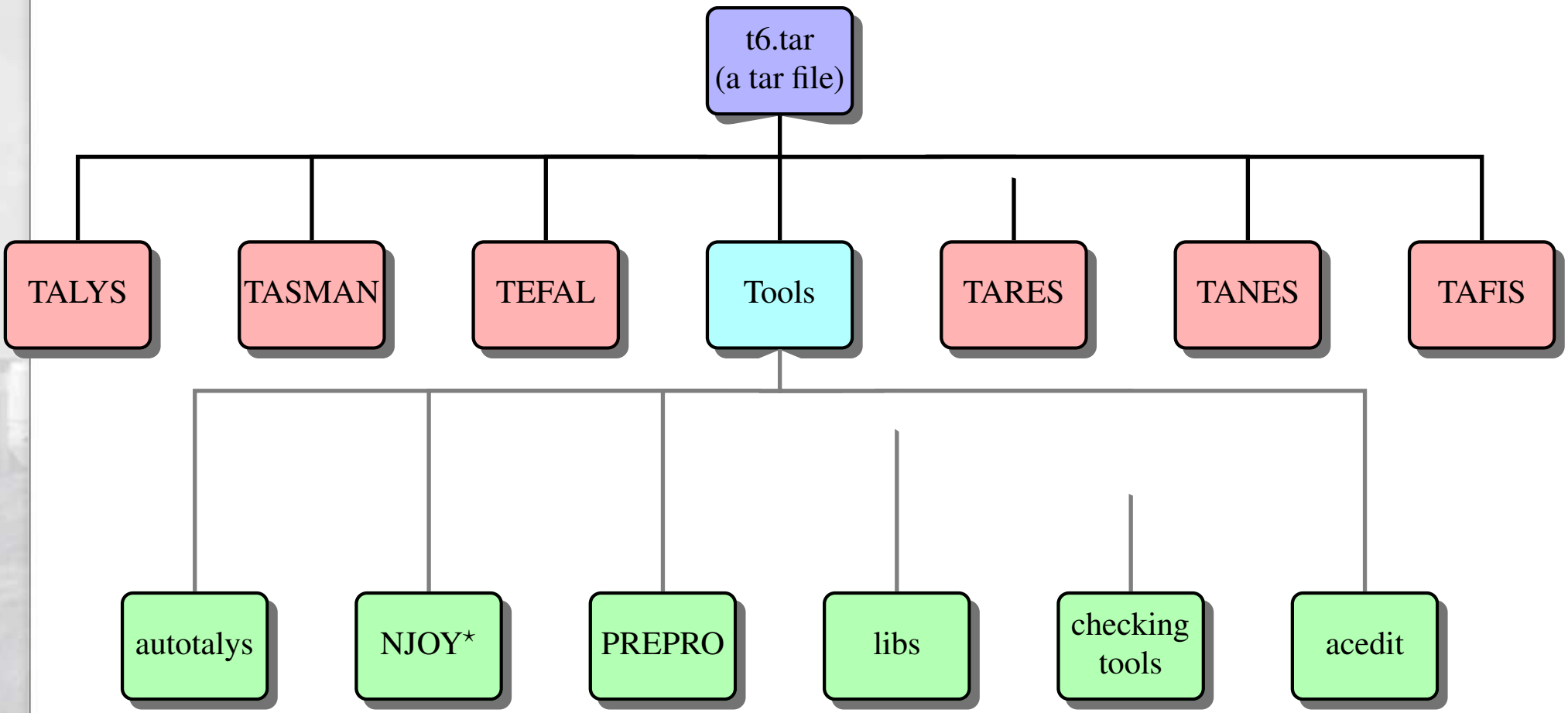


Software release: TALYS and T6

TALYS nuclear code	T6 software package

- TALYS: latest release in December 2012,
- T6: started 2011,
- T6: ”(almost) all our knowledge in a tar file”
- with T6, anyone can produce ENDF evaluations, ACE files, random files, TENDLs...

Software release: T6



t6 tested on many systems (Linux RedHat, Ubuntu, FreeBSD),
with many compilers (g95, gfortran, ifort, lf95, g++, Intel C++)
from Li to Cf, from 0 to 200 MeV
⋆: if authorized

Future work

- Continue with TMC (more reactor calculations, applied to current reactors),
- Improve the quality of the TENDL library,
  1. in format (new needs or existing problems)
  2. in cross sections (better fit to differential and integral data)
- Apply TMC^{-1} to a large number of isotope (including crit-safety, reactor, dosimetry benchmarks)
- Release T6 (or part of it) ?
- ☺ And finally world domination (and world peace).