



# Work possibilities for ANDES/WP3 at NRG

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① Goals:

⇒ *Define the NRG work in the WP3 of ANDES*

② 2 main possibilities:

⇒ *uncertainties and/or Random search*

③ Uncertainties

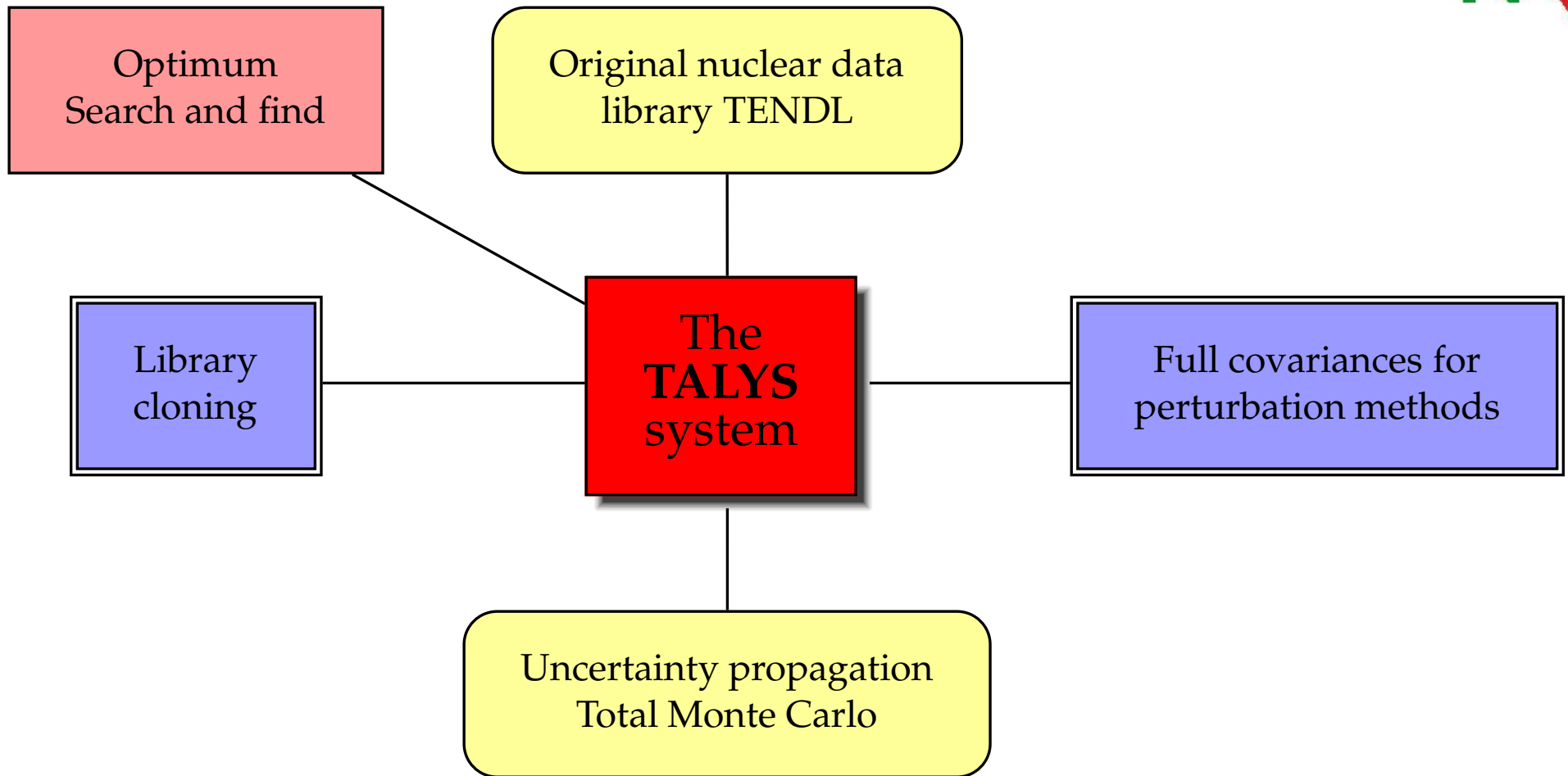
⇒ *(1) Total Monte Carlo and (2) perturbation for crit-safety benchmarks*

④ Random search:

⇒ *Find the best  $^{239}\text{Pu}$  evaluation for a given set of benchmarks*

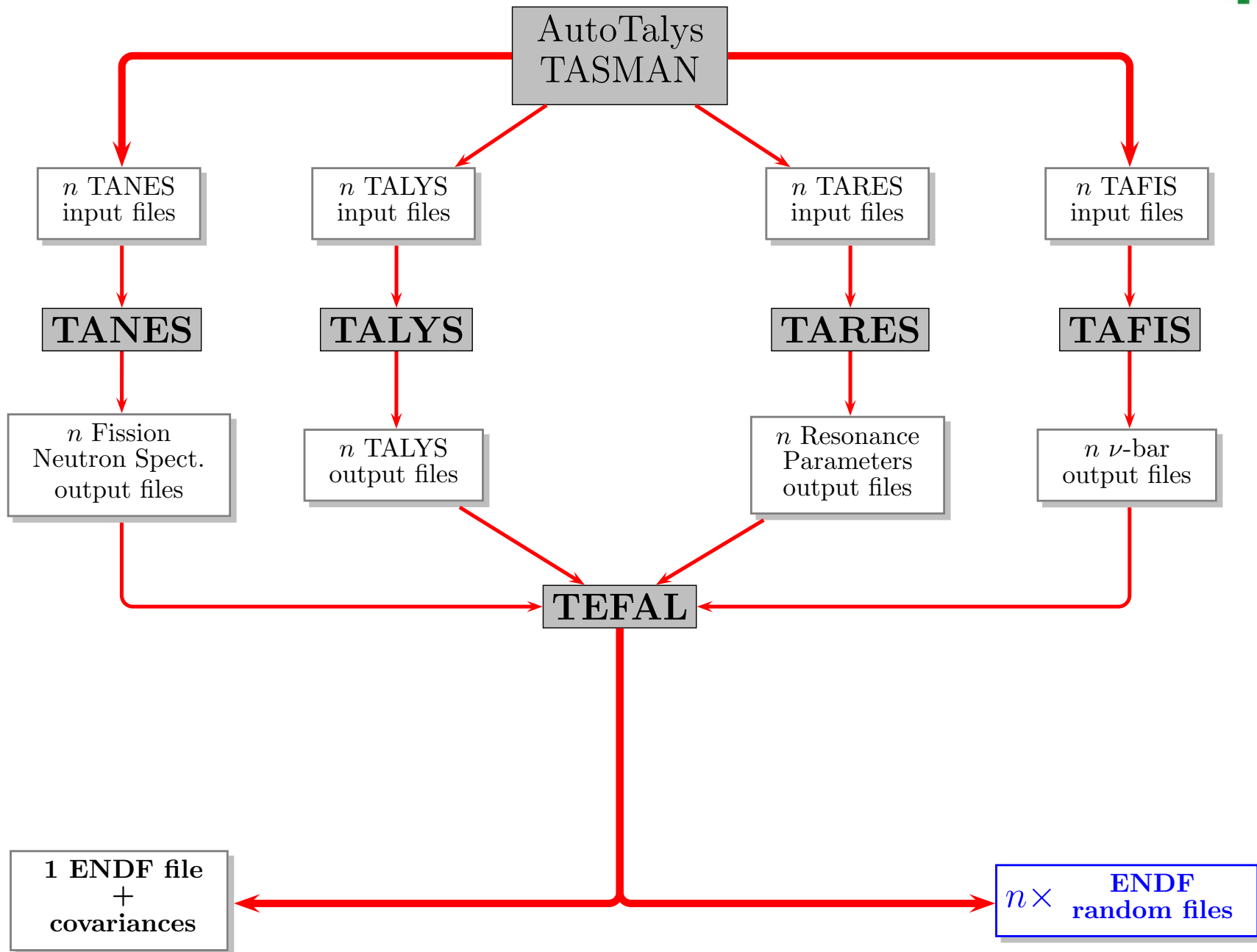
⑤ Some examples

⑥ Conclusions



Our work is based on the "TALYS system". Different outcomes are possible.

# The TALYS system

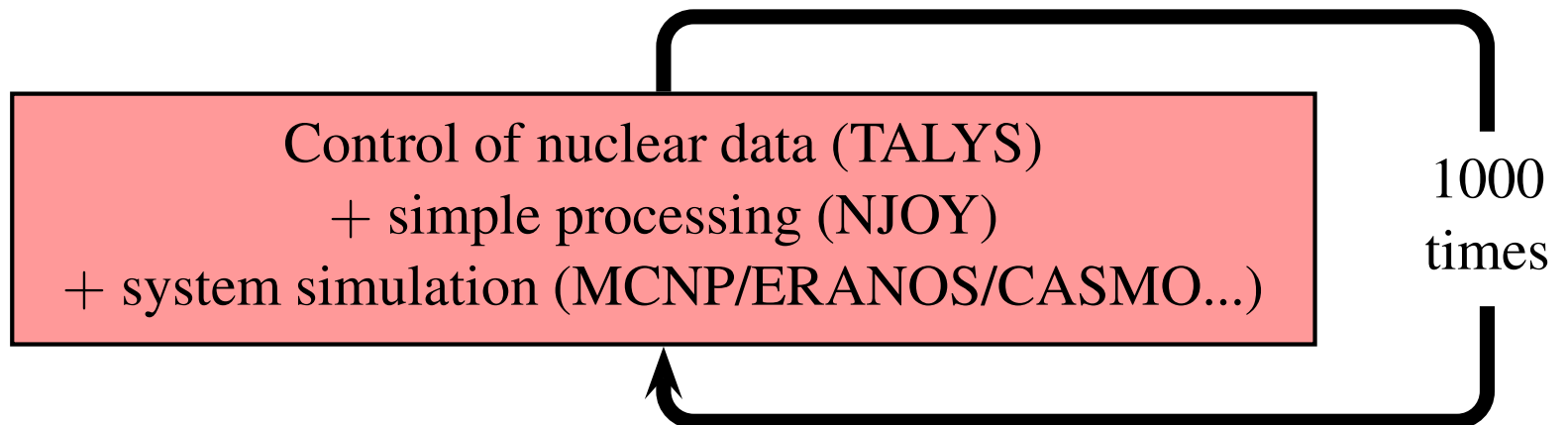


# (1) Possibilities at NRG: uncertainty propagation



- ① Obtain uncertainties for ANDES due to nuclear data uncertainties
- ② Systematic approach, reliable and reproducible

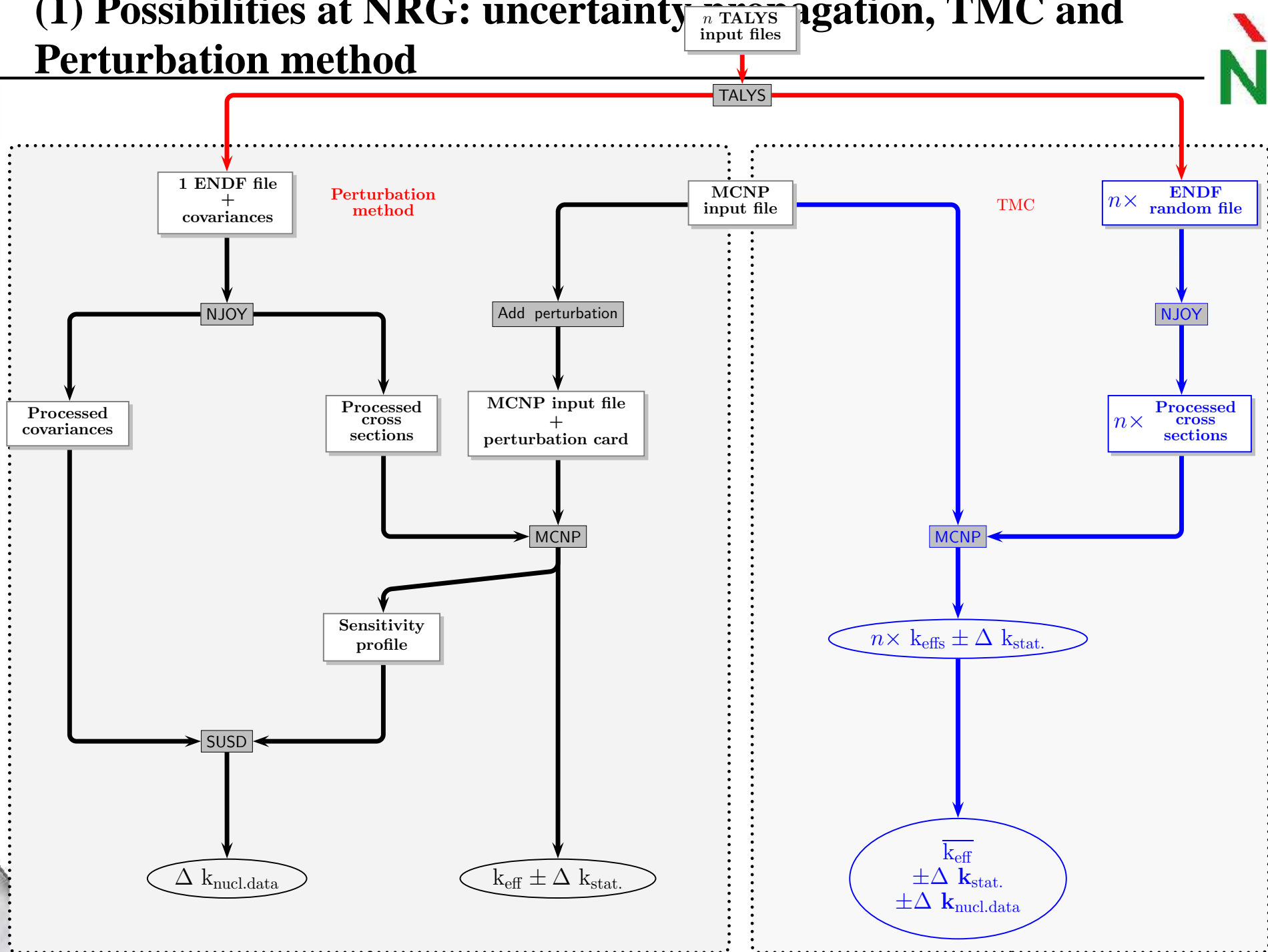
## Solution (1): Total Monte Carlo



## Solution (2): Perturbation method

⇒ MCNP + Perturbation cards + covariance files

# (1) Possibilities at NRG: uncertainty propagation, TMC and Perturbation method

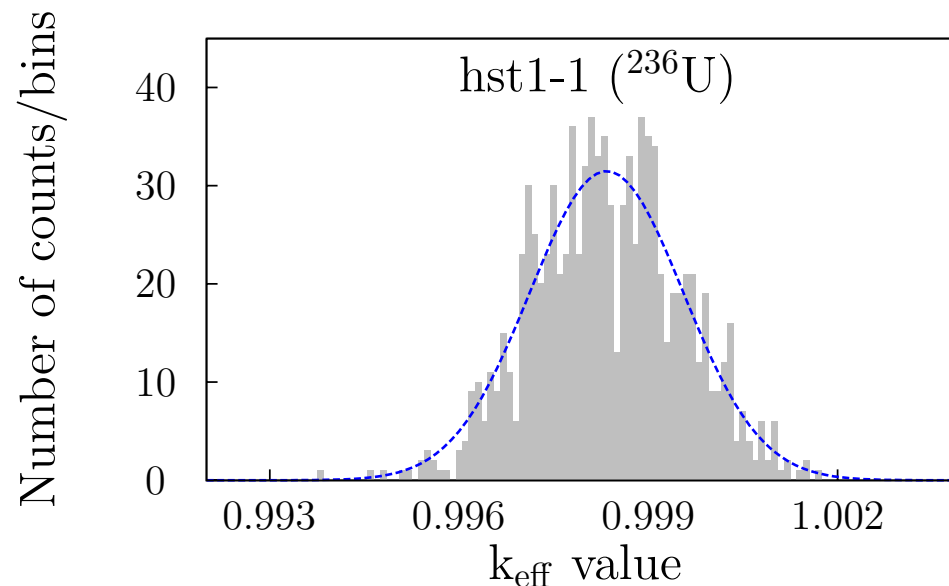


# Total Monte Carlo: examples



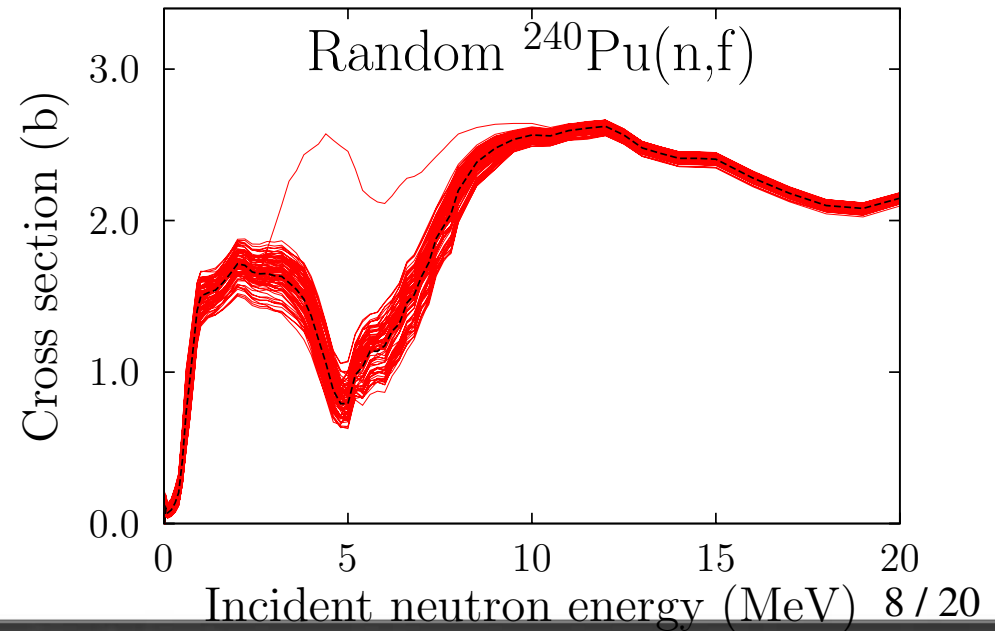
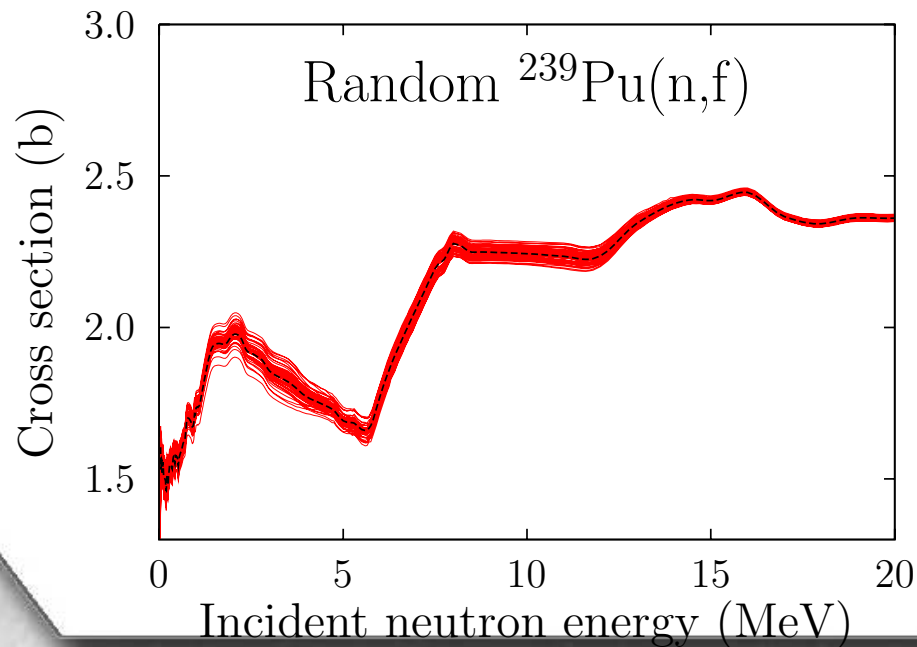
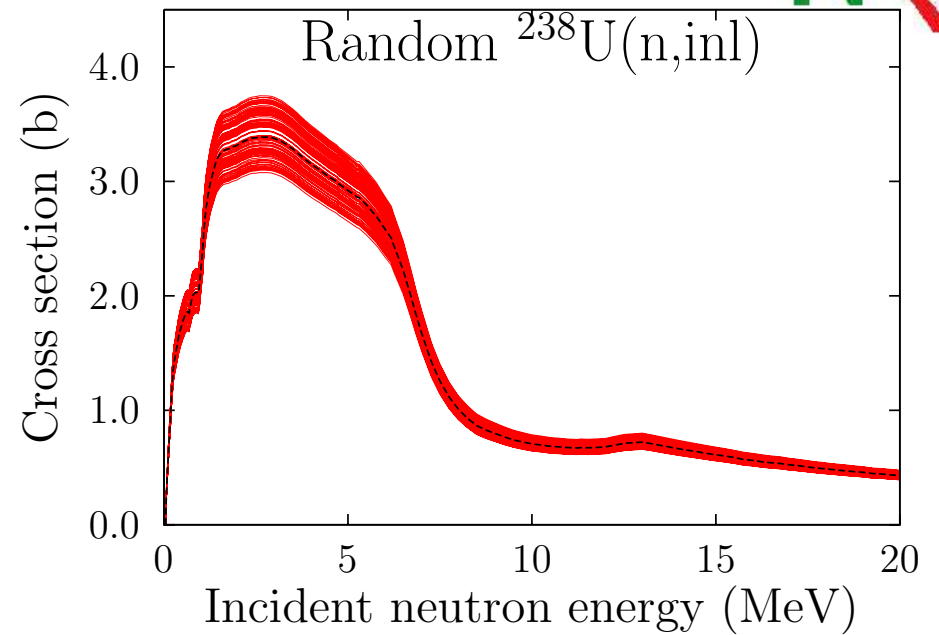
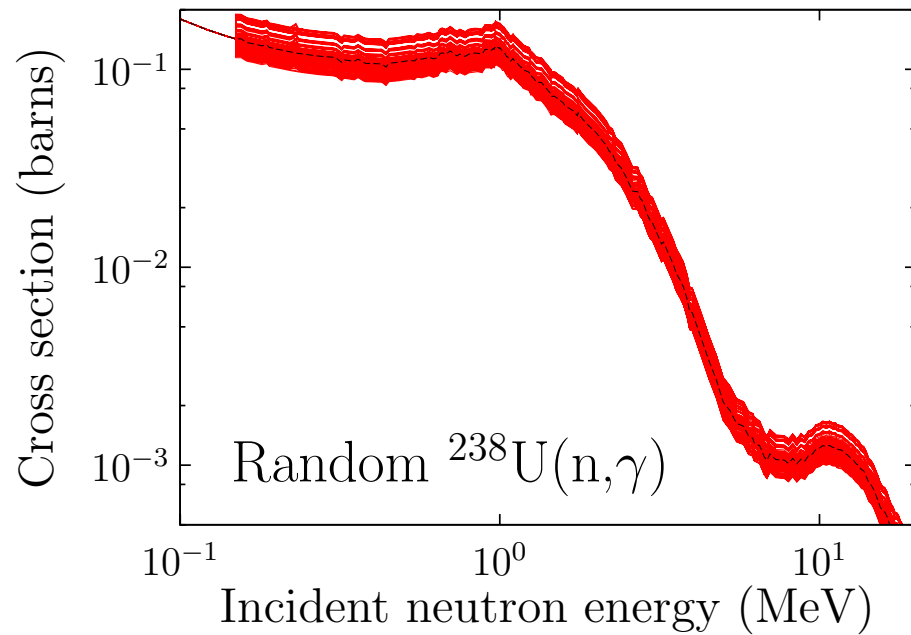
For each random ENDF file, the benchmark calculation is performed with MCNP. At the end of the  $n$  calculations,  $n$  different  $k_{\text{eff}}$  values are obtained. In the obtained probability distribution of  $k_{\text{eff}}$ , the standard deviation  $\sigma_{\text{total}}$  reflects two different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

$$\sigma_{\text{total}}^2 = \sigma_{\text{statistics}}^2 + \sigma_{\text{nuclear data}}^2 \quad (1)$$



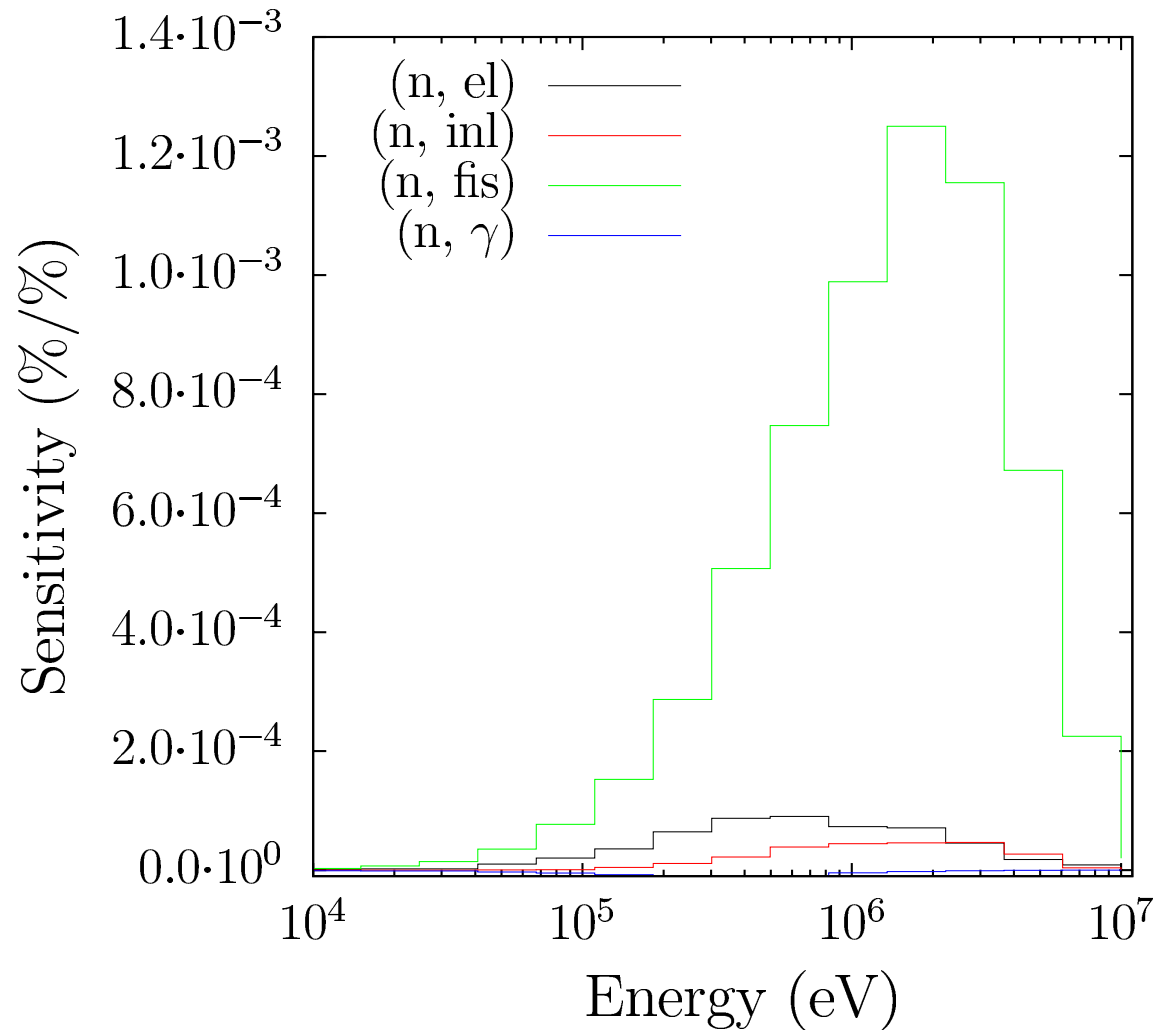
Each random file is completely different than another one: nu-bar ("*MF1*"), resonance parameters ("*MF2*"), cross sections ("*MF3*"), but also *MF4*, *MF5* and *MF6*.

# Nuclear data: $^{239}\text{Pu}$ and $^{238}\text{U}$

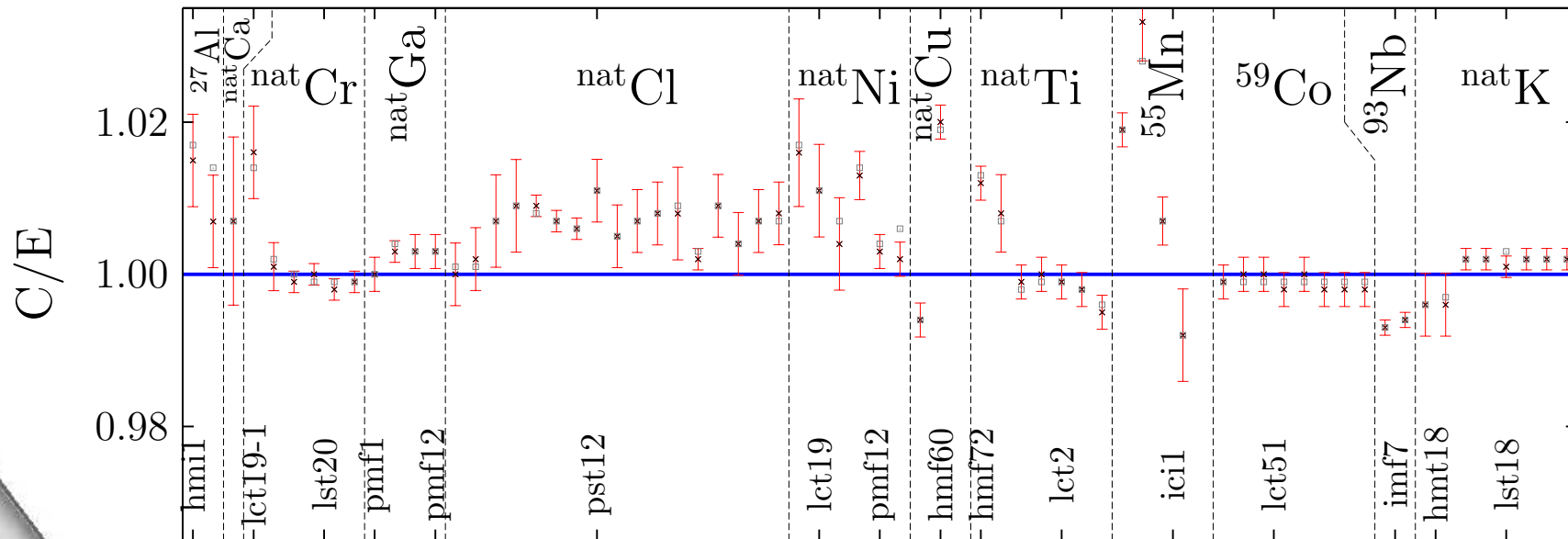
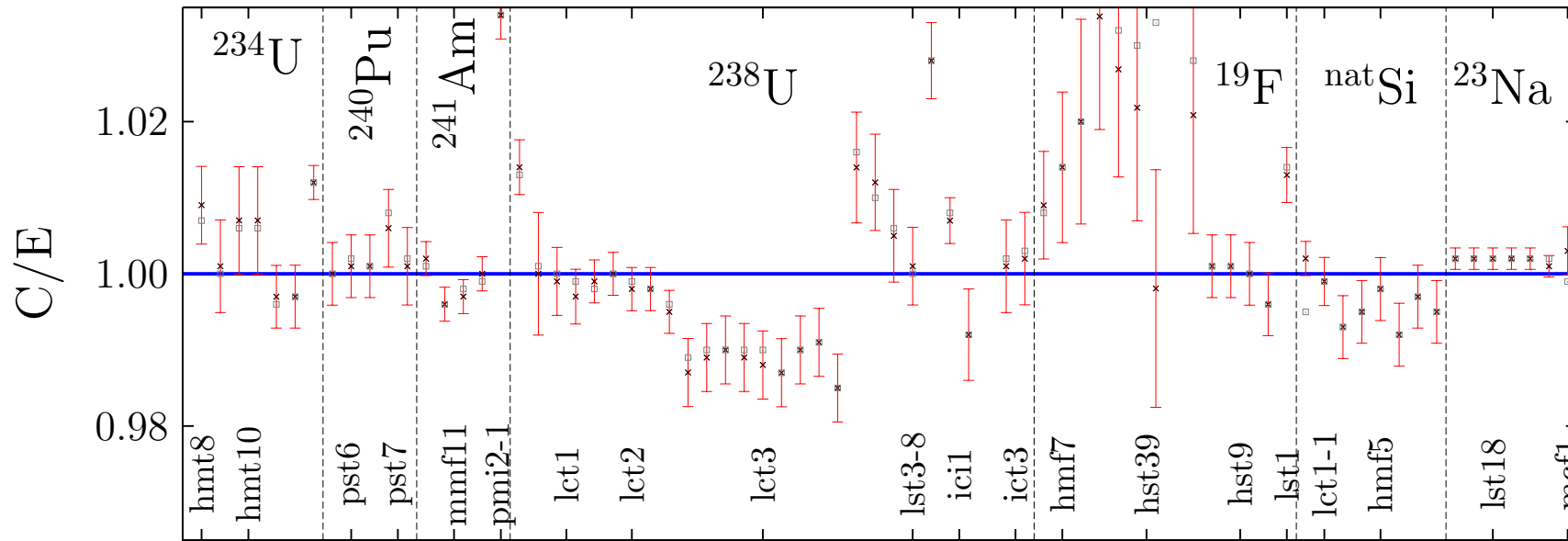




# Example for sensitivity to $^{239}\text{Pu}$ cross section for pmf1 (Jezebel)



# Examples of results for a few criticality benchmarks

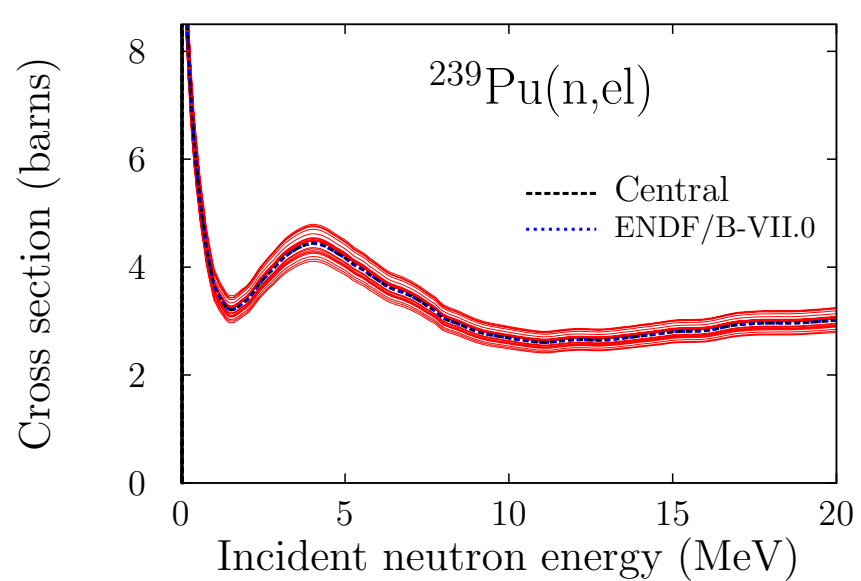
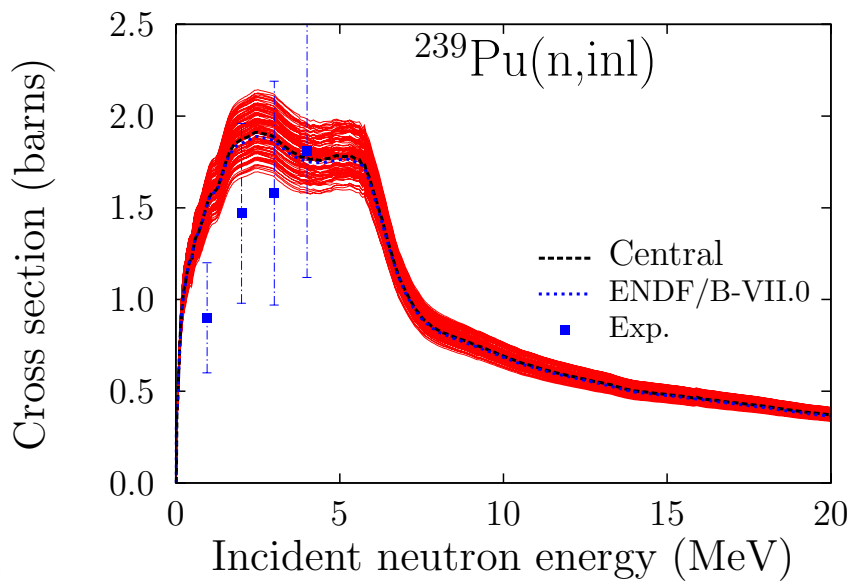
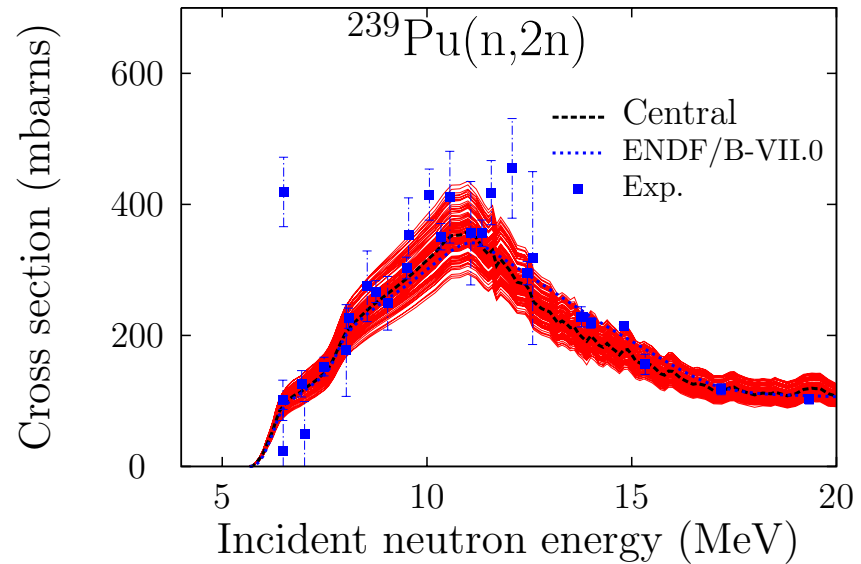
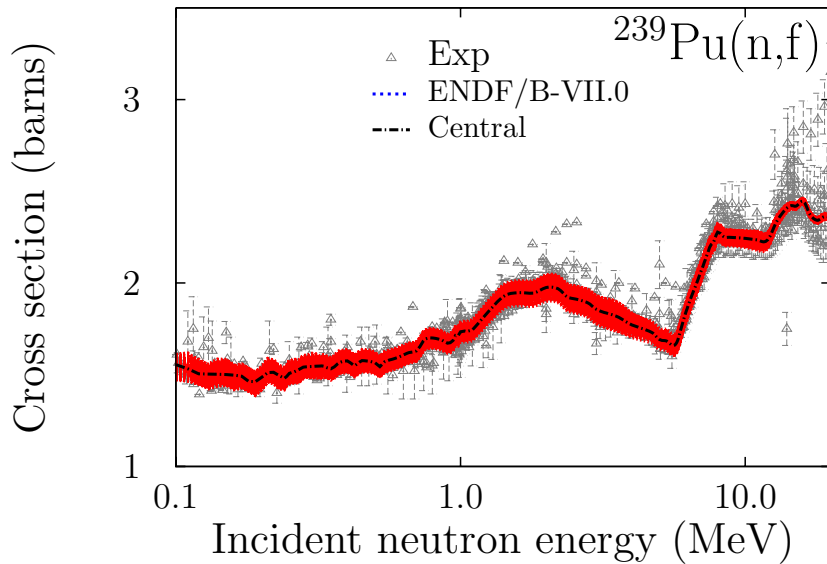


## Example of the *Random search* on $^{239}\text{Pu}$

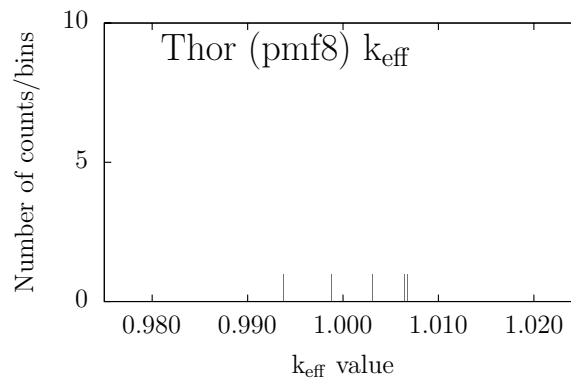
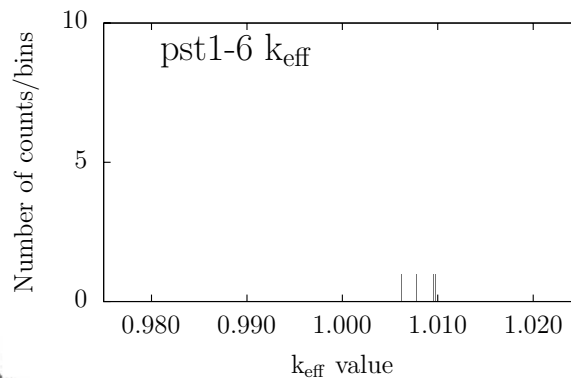
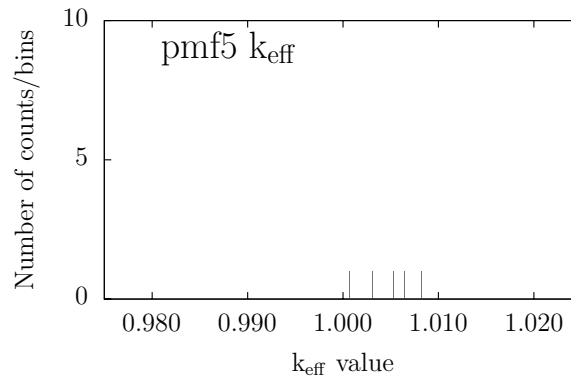
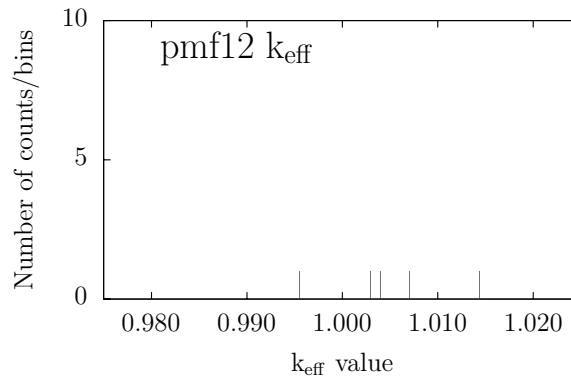
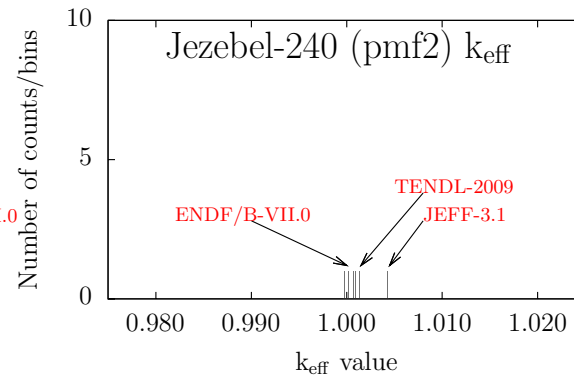
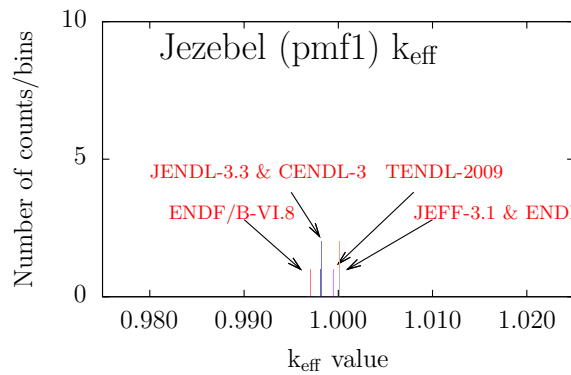


- ① Use the "TALYS system" to create a single  $^{239}\text{Pu}$  evaluation close or equal to ENDF/B-VII.0 or JEFF-3.1.1
- ② Randomize all model parameters (resonances, nubar, fission neutron spectrum, TALYS parameters) to create  $n > 500$  random  $^{239}\text{Pu}$  evaluations
- ③ Benchmarks the  $n$  files with the same set of criticality benchmarks
- ④ Select the best random file

## (2) Possibilities at NRG: Random search of the *best* $^{239}\text{Pu}$

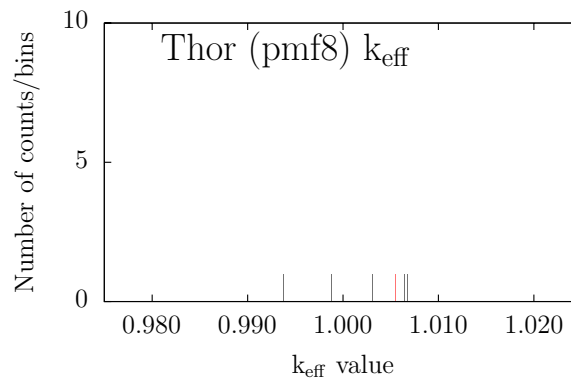
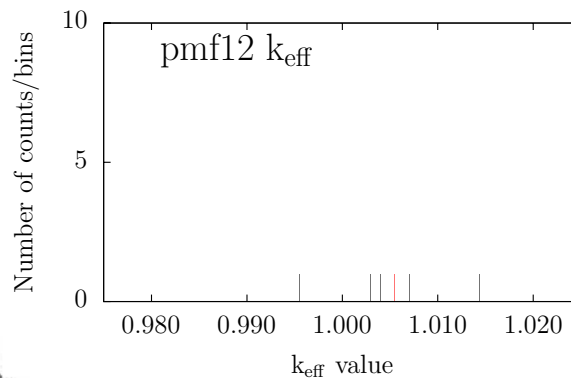
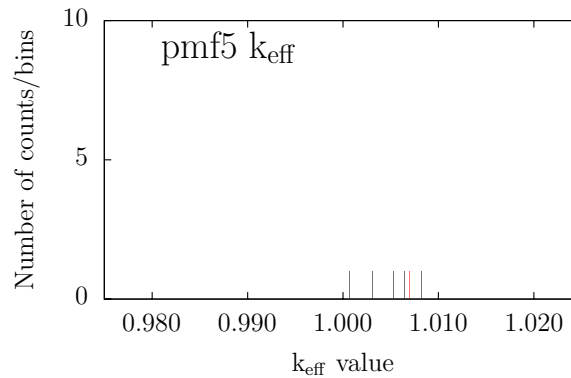
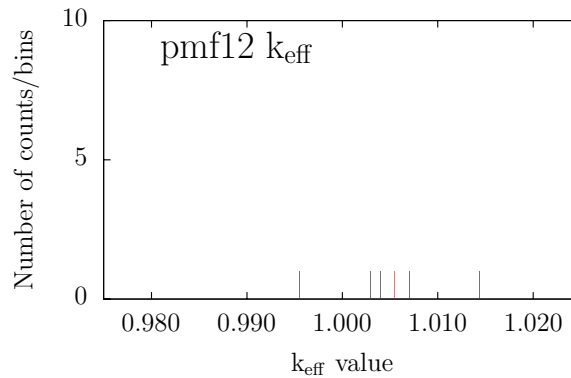
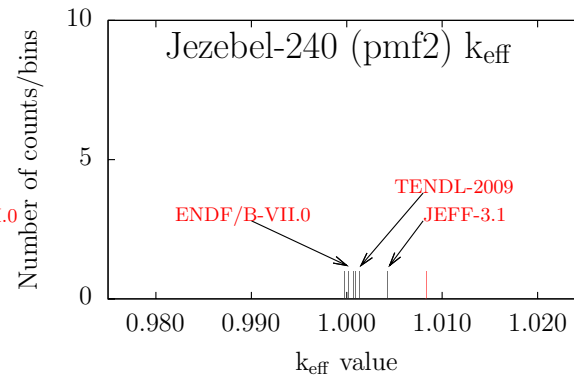
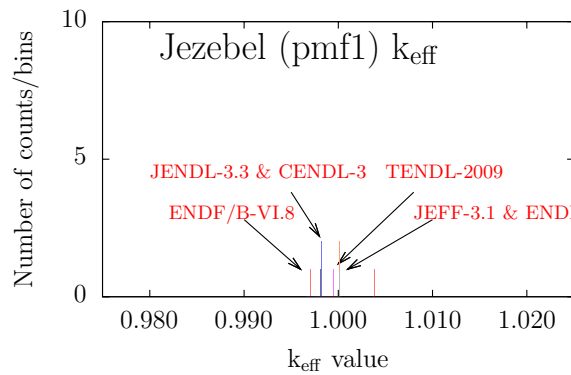
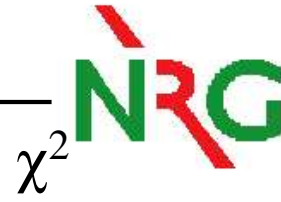


# Benchmarking: simple example with 6 $k_{\text{eff}}$ benchmarks



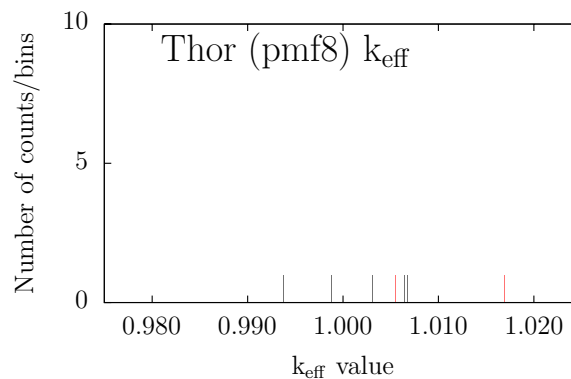
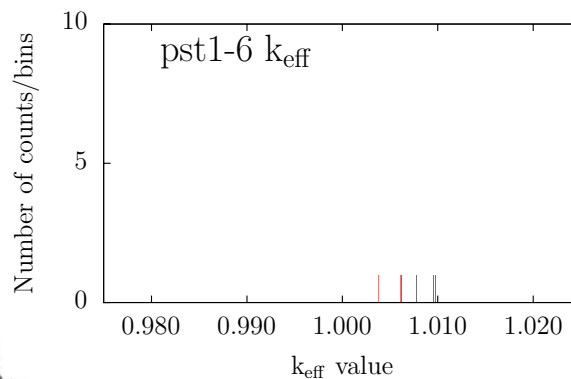
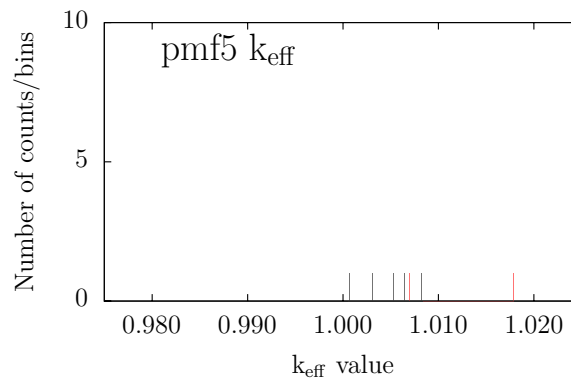
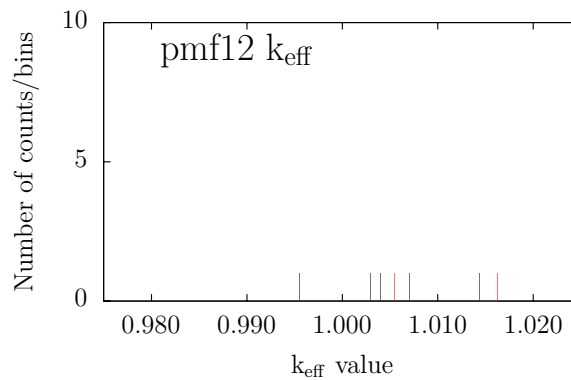
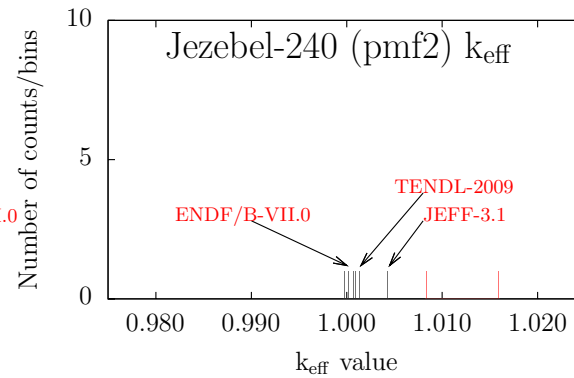
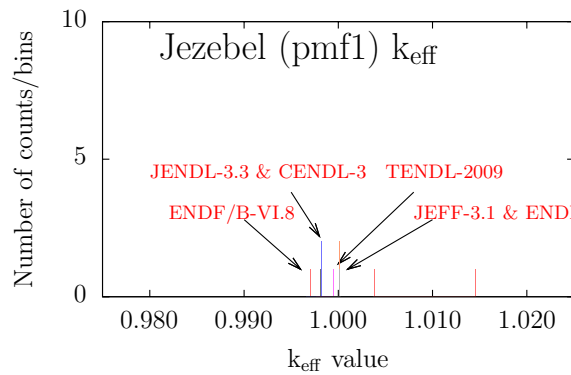
JEFF-3.1.1:	$1.14e^{-4}$
JENDL-3.3:	$1.71e^{-4}$
TENDL-2009:	$3.66e^{-4}$
ENDF/B-VI.8:	$1.72e^{-4}$
ENDF/B-VII.0:	$1.69e^{-4}$

# Benchmarking: simple example with 6 $k_{\text{eff}}$ benchmarks



JEFF-3.1.1:	$1.14e^{-4}$
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<b>random 0:</b>	<b><math>2.29e^{-4}</math></b>

# Benchmarking: simple example with 6 $k_{\text{eff}}$ benchmarks



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<b>random 0:</b>	<b><math>2.29e^{-4}</math></b>
<b>random 1:</b>	<b><math>13.4e^{-4}</math></b>

# Benchmarking: 6 $k_{\text{eff}}$ benchmarks with random $^{239}\text{Pu}$

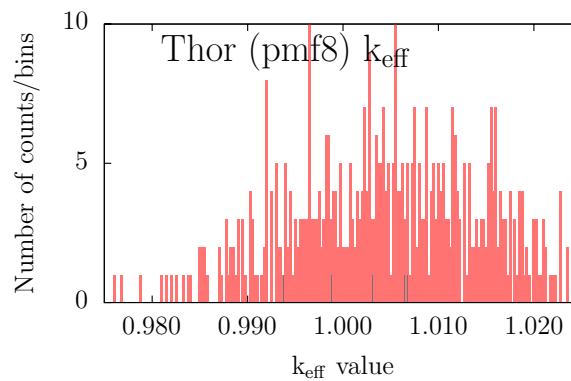
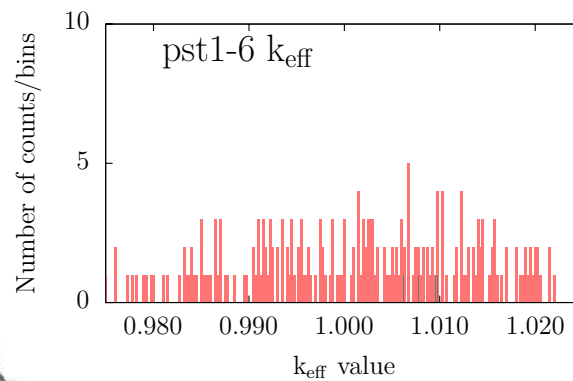
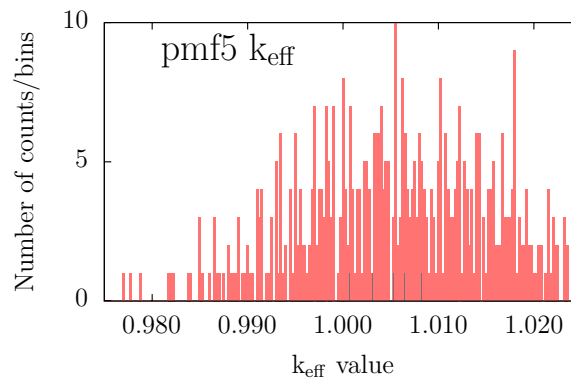
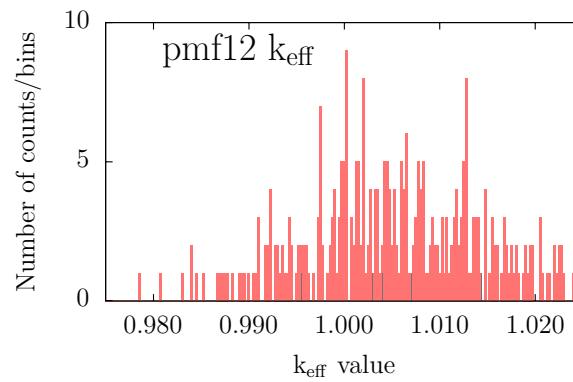
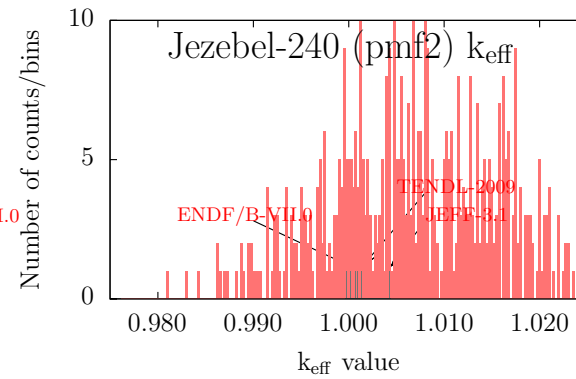
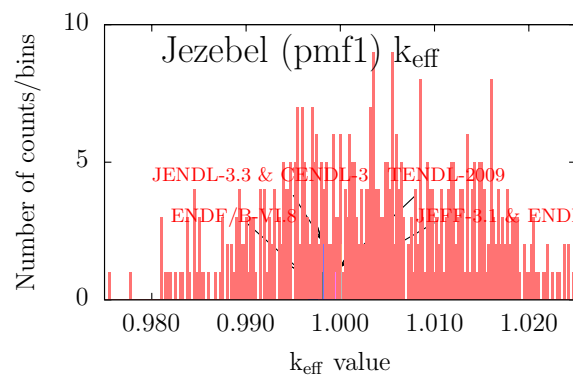


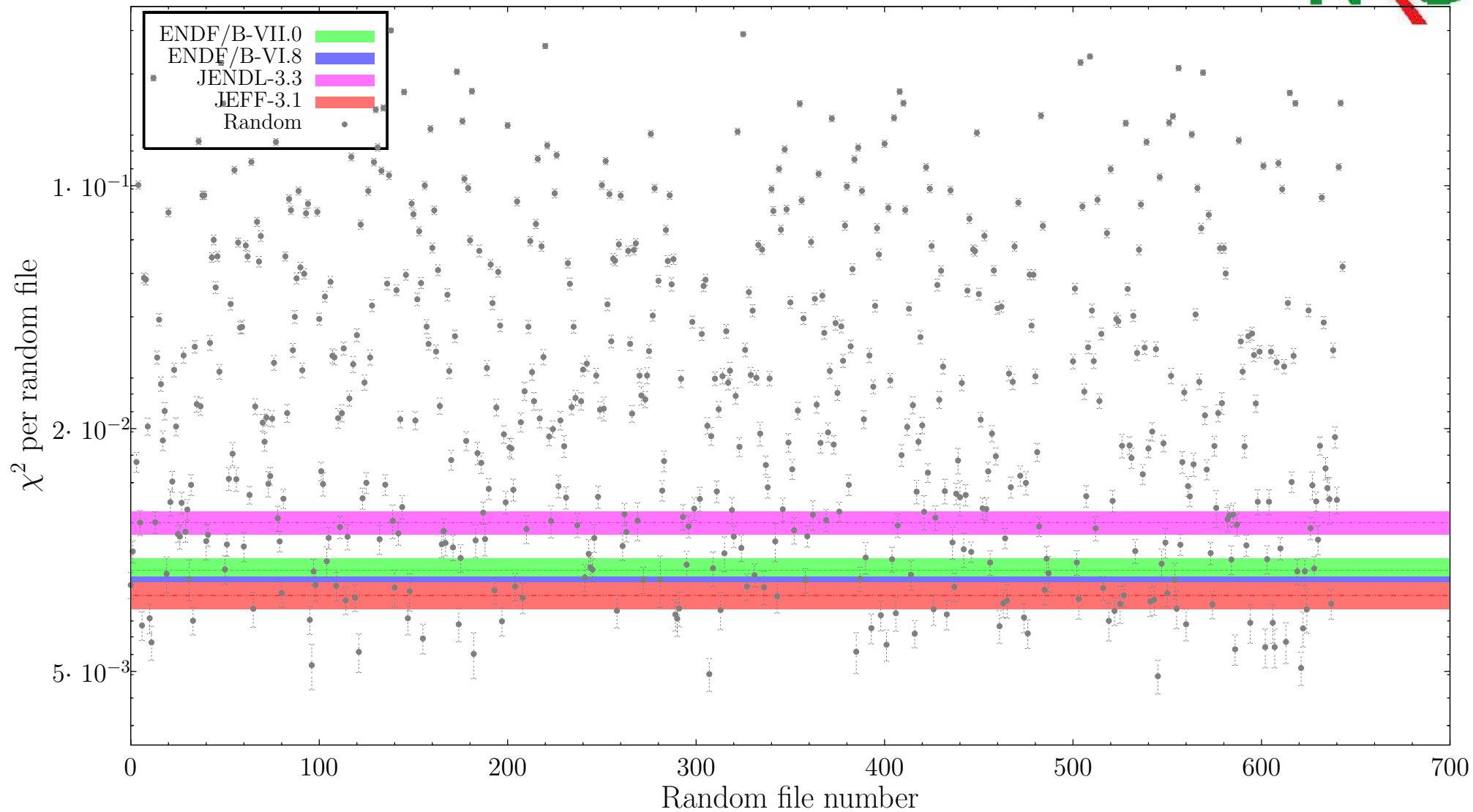


Table 1: List of plutonium benchmarks selected for the random search.

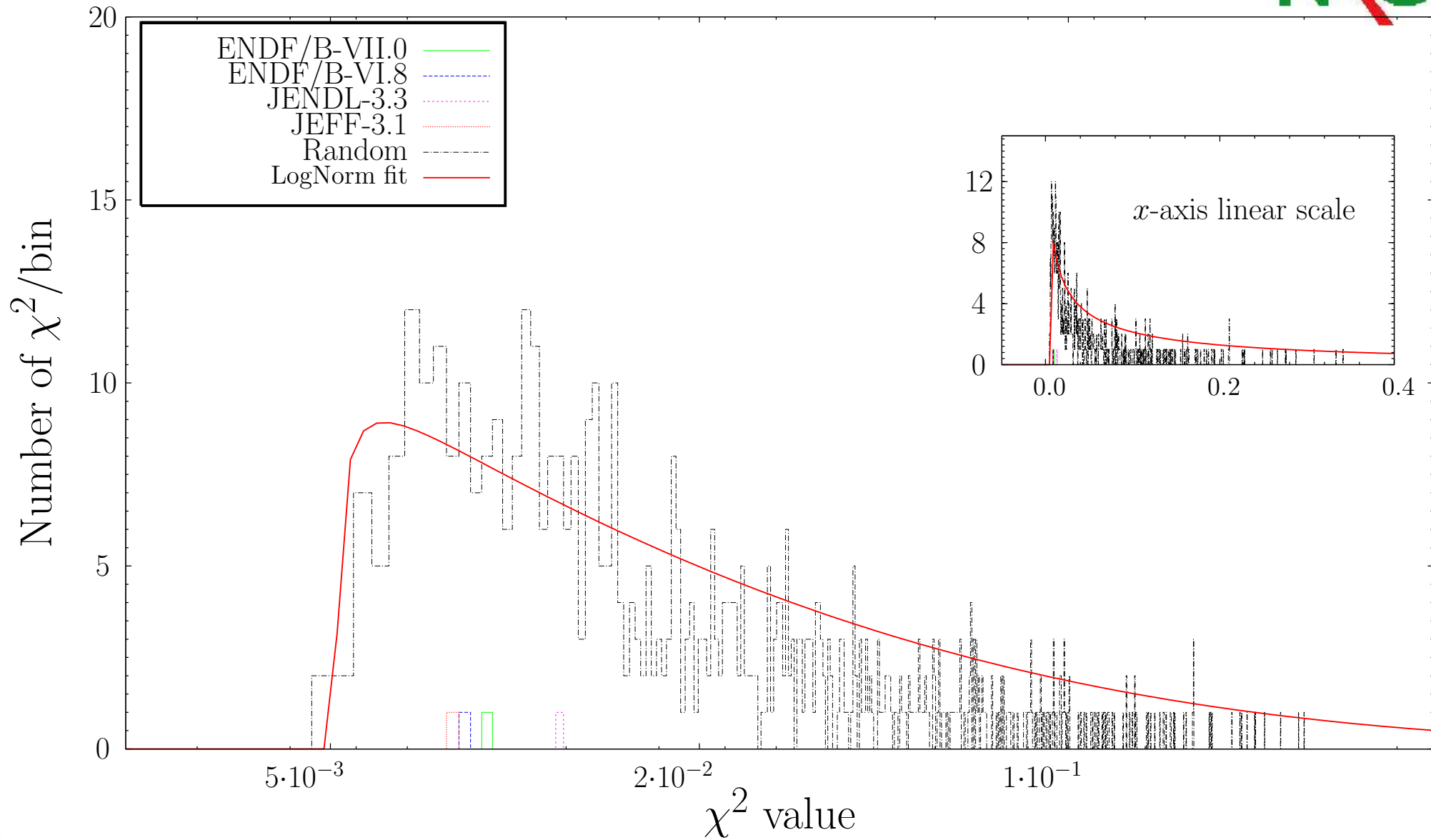
Name	Cases	Name	Cases	Name	Cases	Name	Cases
pmf1	1	pmf2	1	pmf5	1	pmf6	1
pmf8	1	pmf12	1	pmf13	1	pci1	1
pmi2	1	pst1	6	pst2	6	pst3	8
pst4	13	pst5	9	pst6	3	pst7	9
pst8	29	pst12	22	pmm1	6		

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

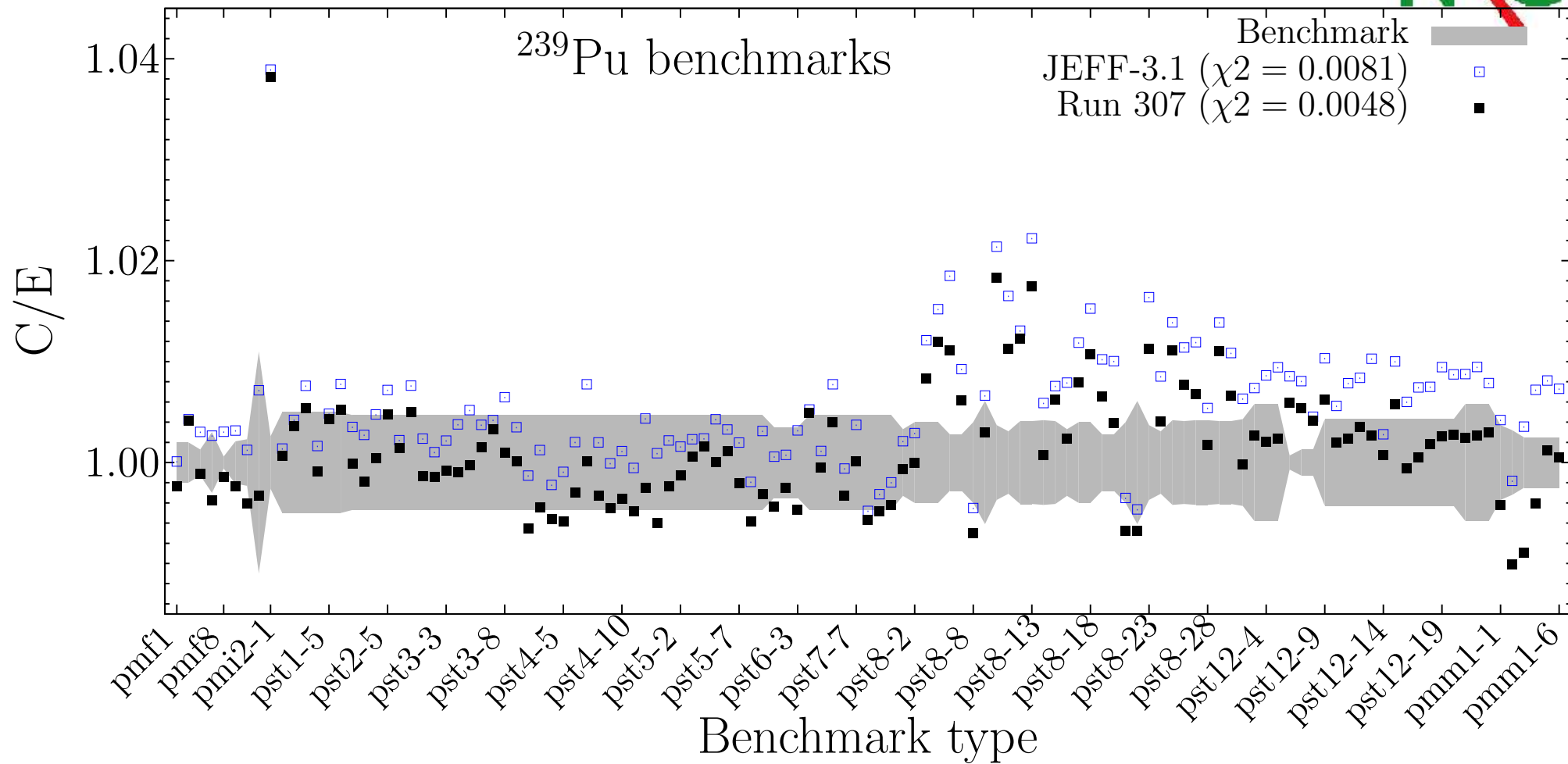
# $\chi^2$ values for random $^{239}\text{Pu}$ evaluations



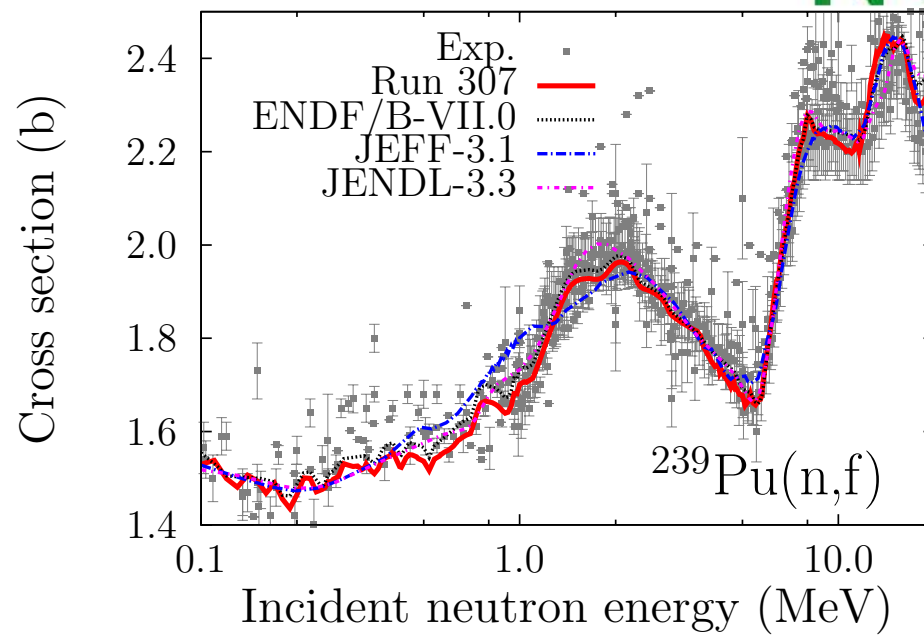
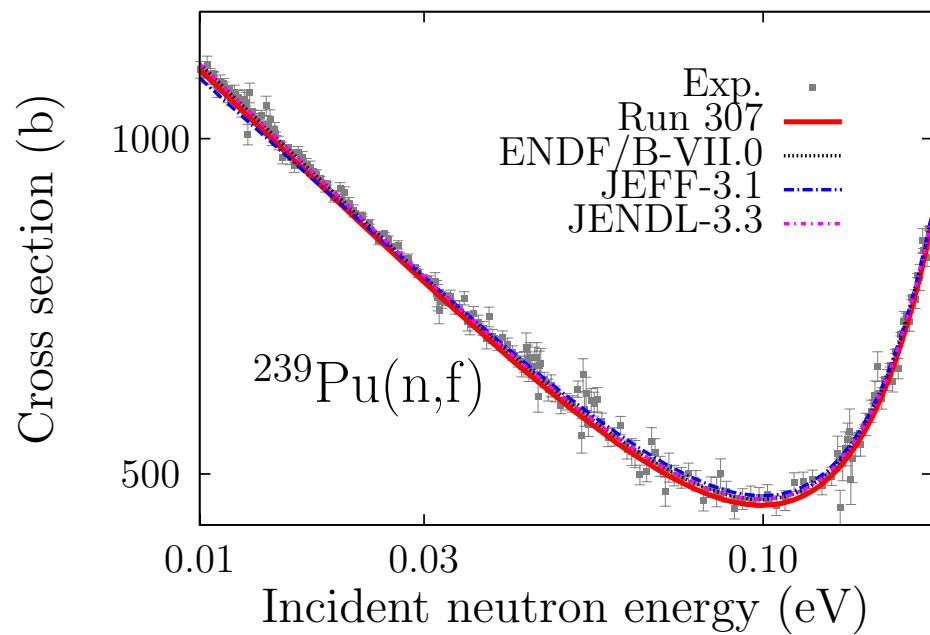
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# $\chi^2$ values for random $^{239}\text{Pu}$ evaluations



# Best $^{239}\text{Pu}$ for this set of benchmarks



- ☺ Uncertainty and sensitivity analysis on a large set of criticality benchmarks
  - Thermal and fast benchmarks
  - Monte Carlo and perturbation methods
  - Use libraries from WP2
  - Other benchmarks
  
- ☺ Random search for the best  $\chi^2$  with a given set of benchmarks
  - Define the benchmarks
  - Equal weight ?
  - Perform the search