Nuclear data uncertainty propagation: Total Monte Carlo vs. covariances

D. Rochman, A.J. Koning, S.C. van der Marck,

and D. van Veen

Nuclear Research and Consultancy Group,

NRG, Petten, The Netherlands

SG-33, May 2010

Contents

① Goals:

$\Longrightarrow$ *Propagate nuclear data uncertainties for the SG-33*

② Methodology for uncertainty propagation:

$\Longrightarrow$ *TMC vs. covariances (exact or with covariances ?)*

③ Models:

$\Longrightarrow$ *(1) Total Monte Carlo and (2) perturbation*

④ Tests:

$\Longrightarrow$ *Consistence between both methods*

⑤ Preliminary results:

$\Longrightarrow$ *on k_{eff} for ^{239,240}Pu, pmf1 and pmf2*

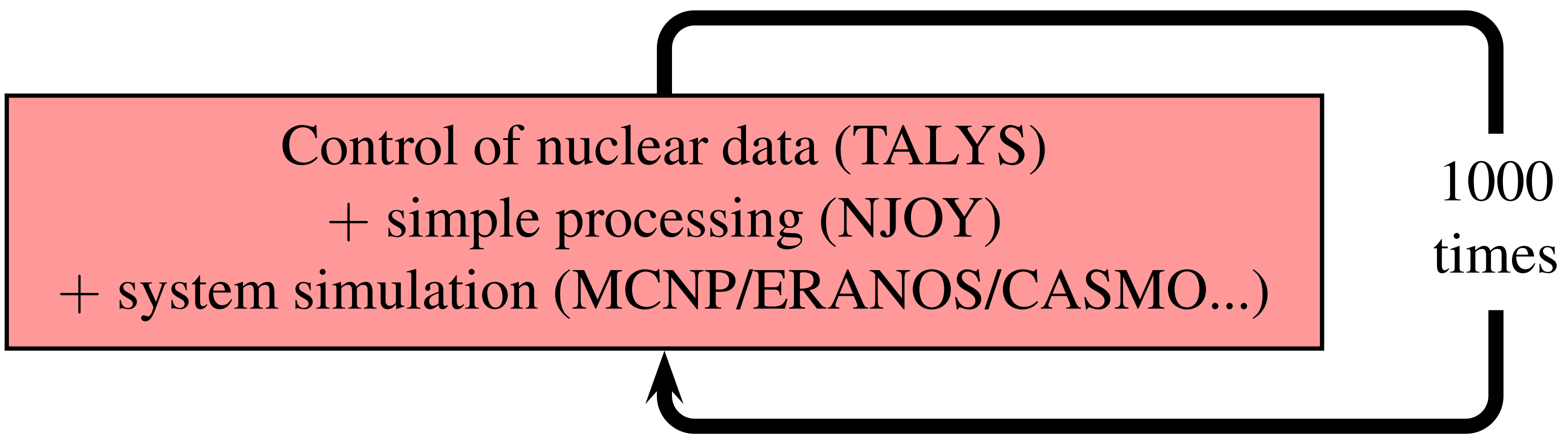
⑥ Conclusions

Goals:

① Obtain uncertainties for SG-33 due to nuclear data uncertainties

② Systematic approach, reliable and reproducable

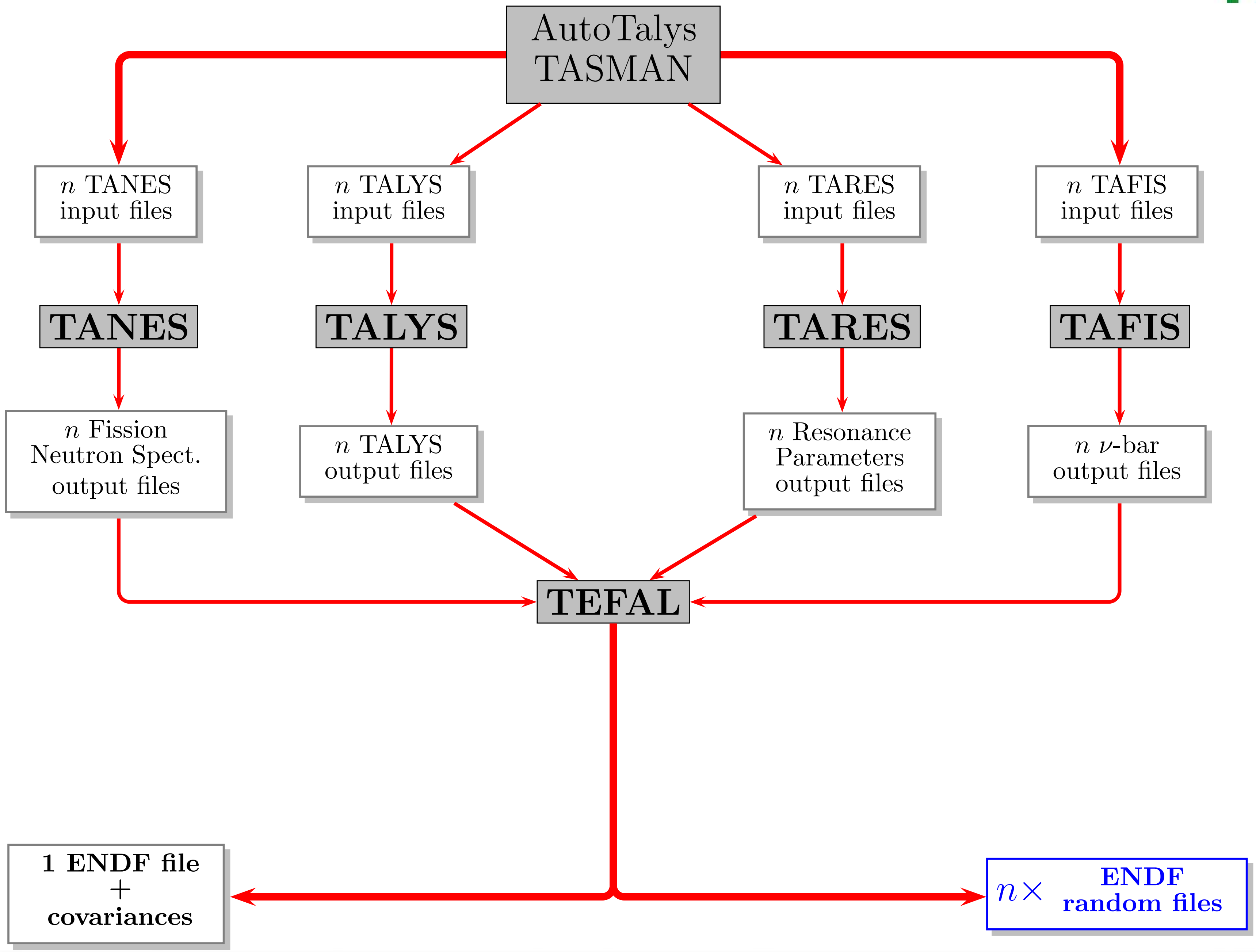
Solution (1): Total Monte Carlo



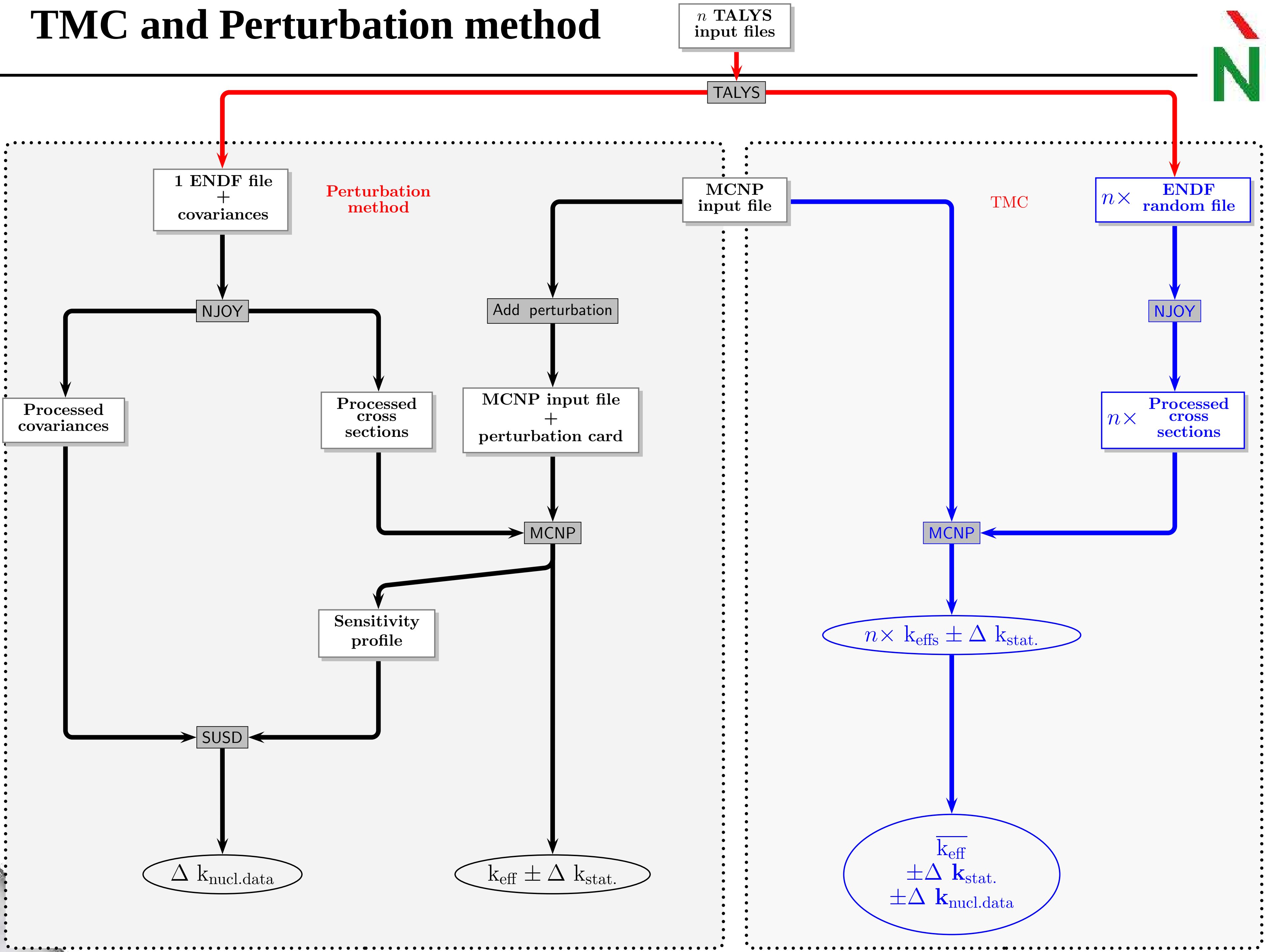
Solution (2): Perturbation method

$\Longrightarrow$MCNP+ Perturbation cards+covariance files

TMC and Perturbation method: File production



TMC and Perturbation method



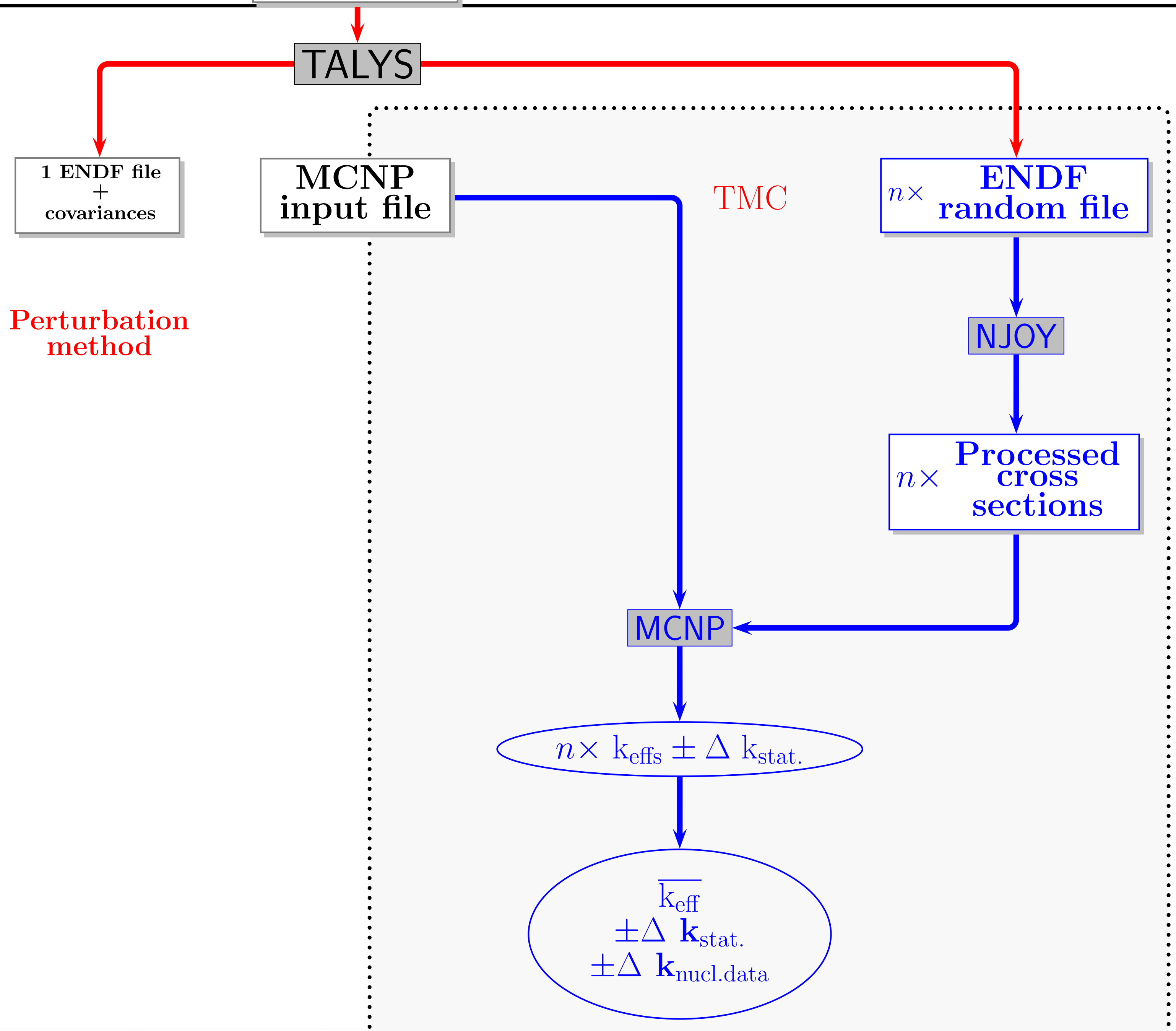
Necessary softwares

Common to TMC and Perturbation methods:
☞ TALYS
☞NJOY (ACE)
☞MCNP

For the TMC method only:
$\emptyset$

For the Perturbation method only:
☞ NJOY (ERRORR)/PUFF
☞ Add perturbation
☞ SUSD

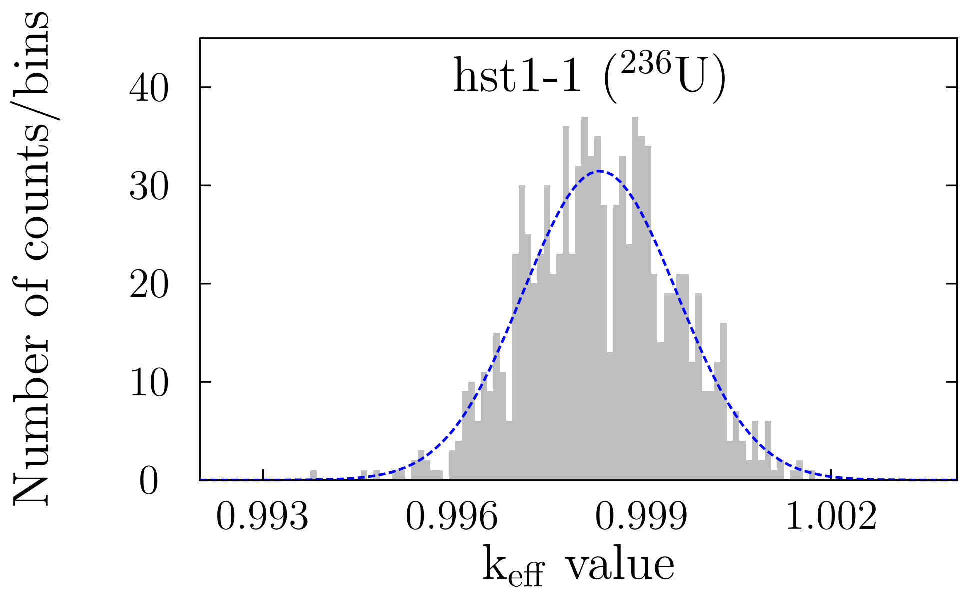
Idea: TALYS +(n TALYS input files) Monte Carlo = Total Monte Carlo



Total Monte Carlo: examples

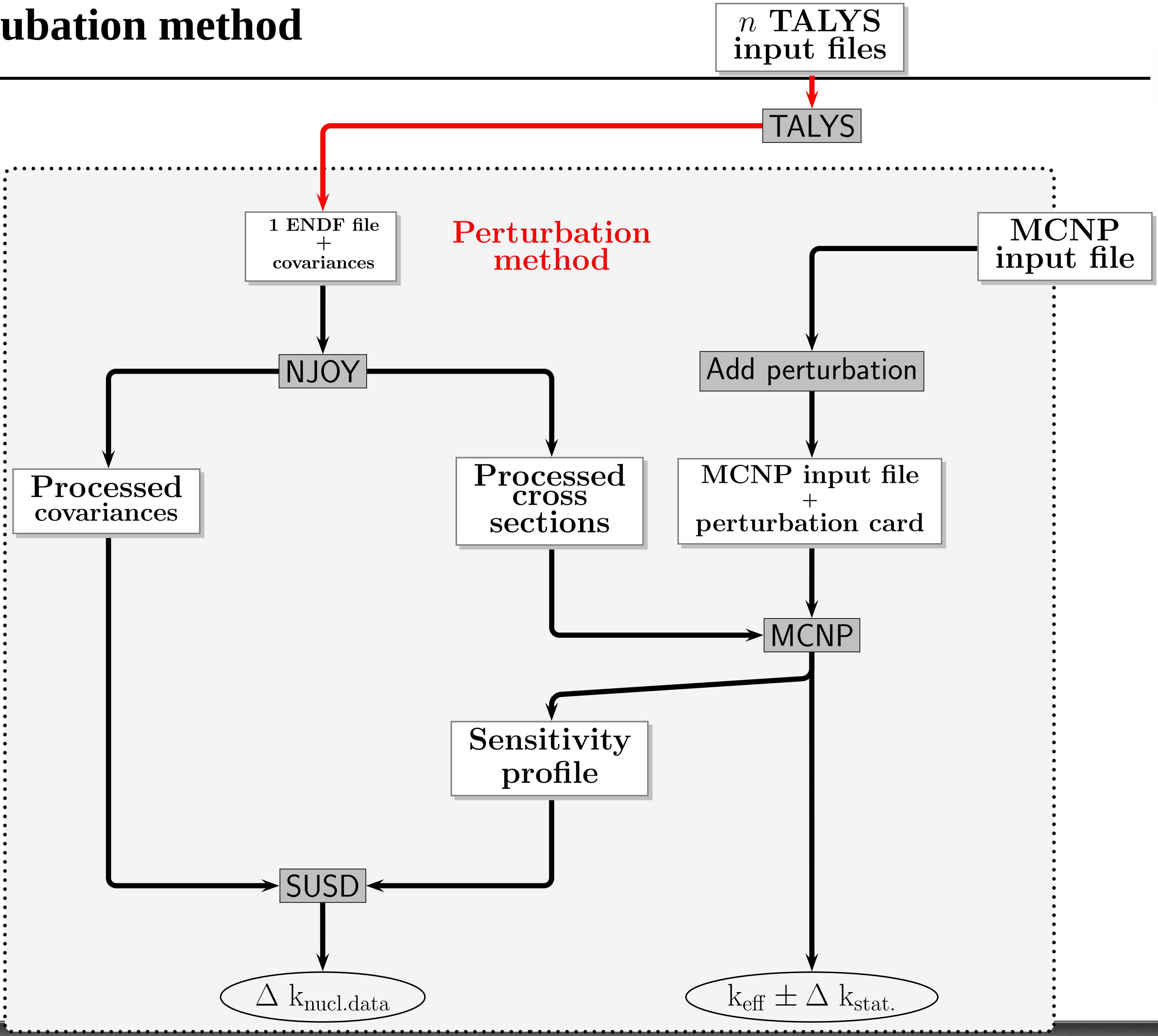
For each random ENDF file, the benchmark calculation is performed with MCNP. At the end of the *n* calculations, *n* different k_{eff} values are obtained. In the obtained probability distribution of k_{eff}, the standard deviation σ_{total} reflects two different effects:

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

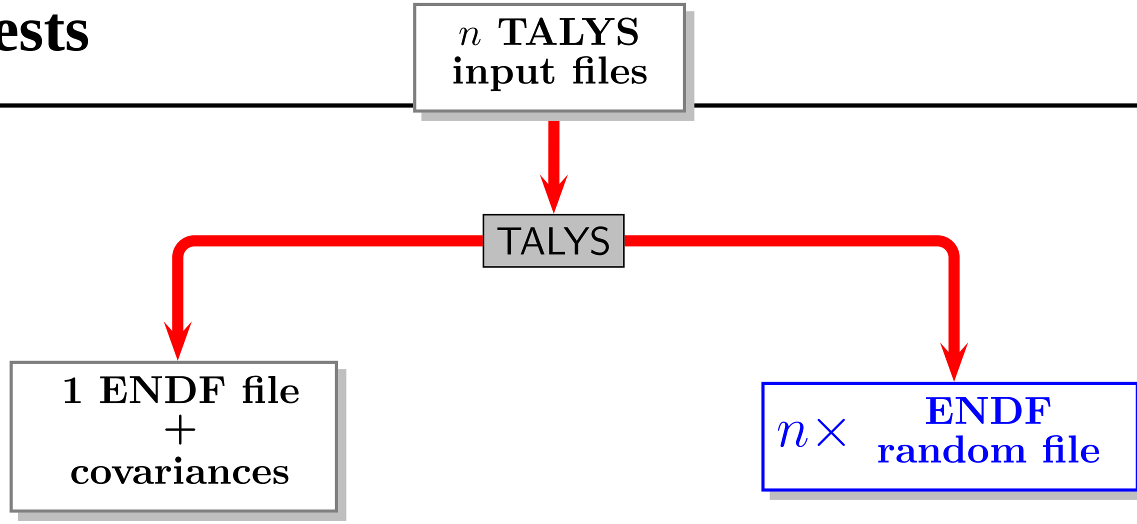


Each random file is completely different than another one: nu-bar (”*MF1*”), resonance parameters (”*MF2*”), cross sections (”*MF3*”), but also *MF4*, *MF5* and *MF6*.

Pertubation method



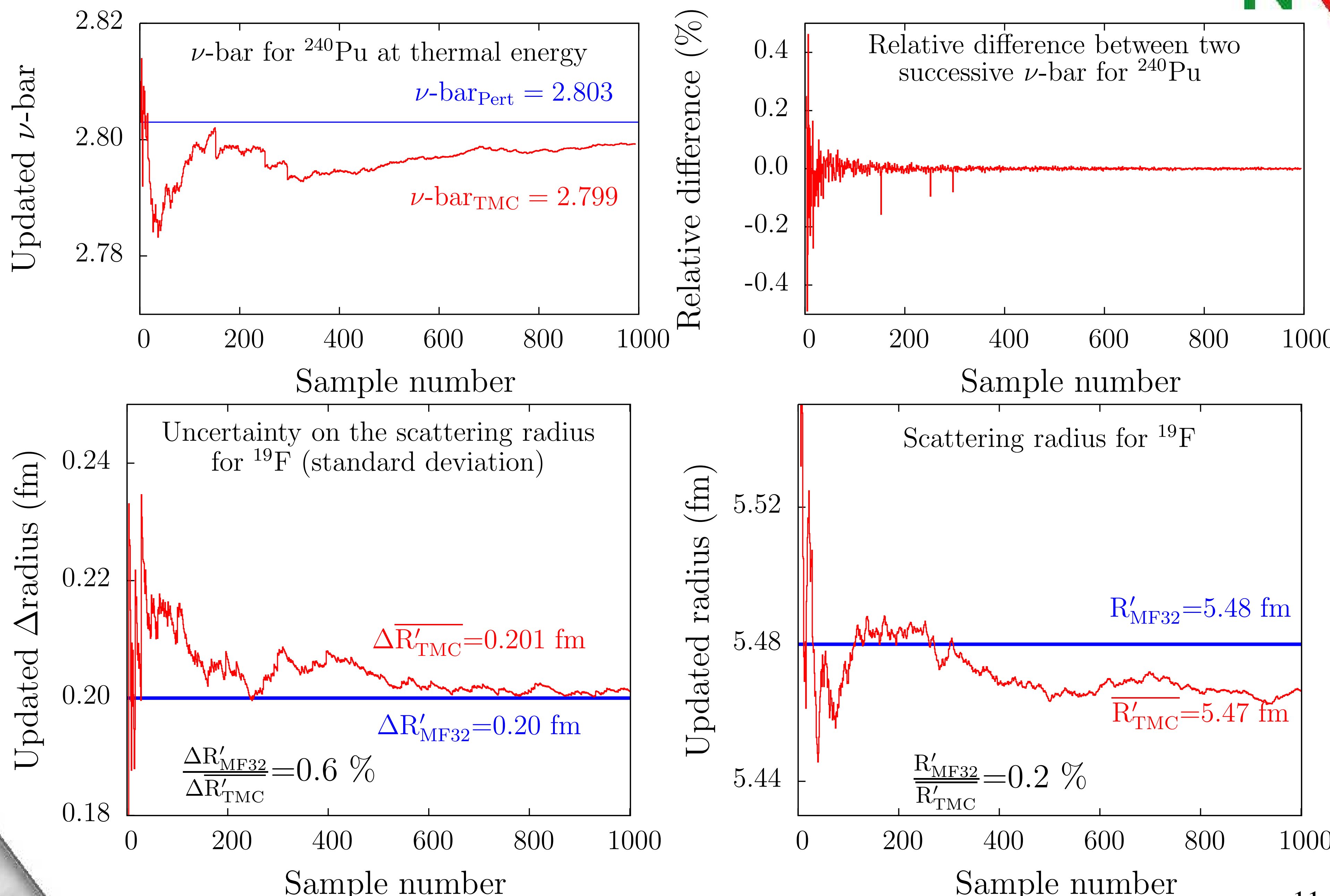
Consistency tests



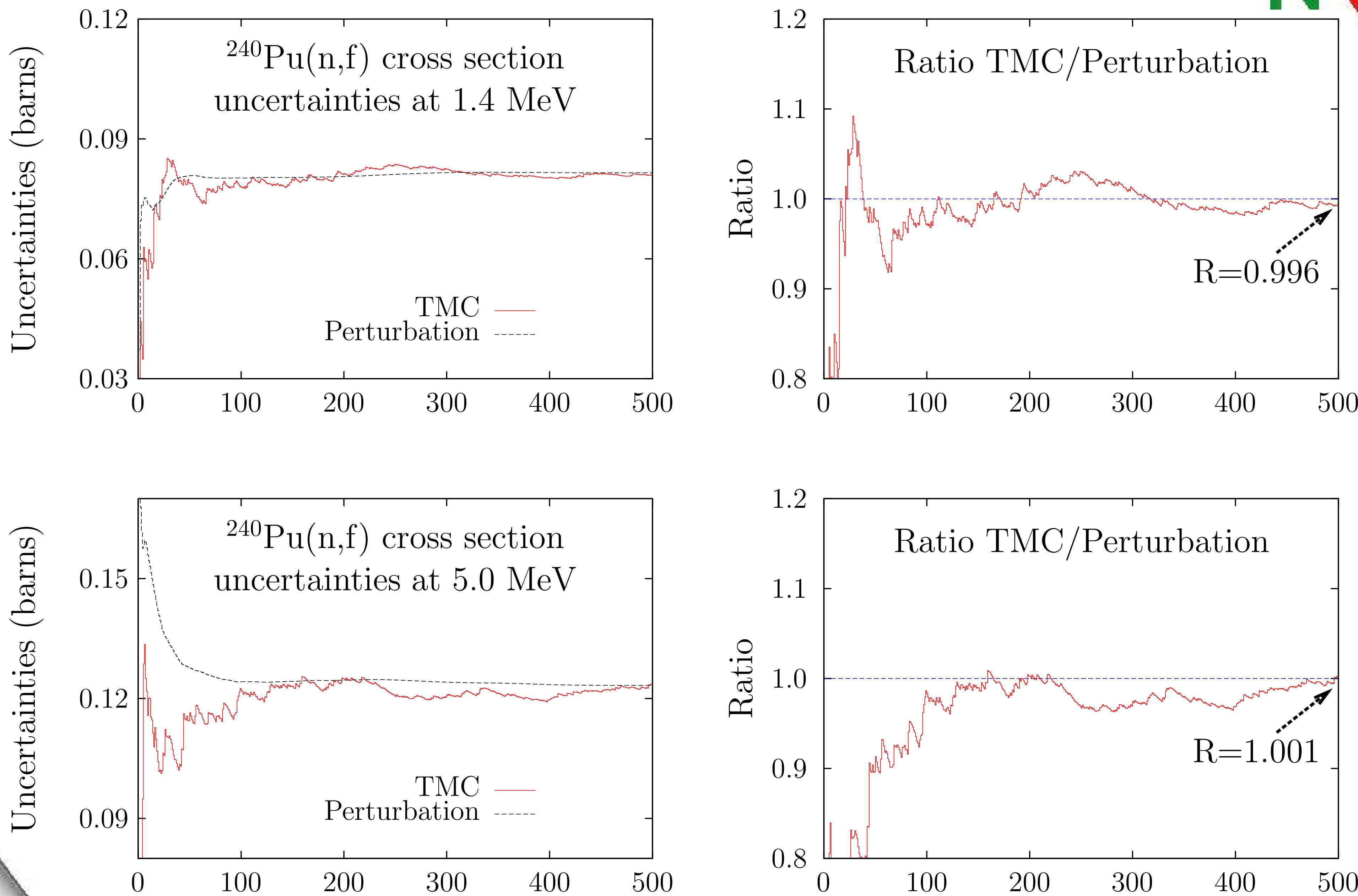
Convergence and consistency of:

- ν-bar.
- resonance parameter distributions.
- cross sections probability distributions.
- angular distribution probability distributions.
- Monte Carlo calculations.
- the perturbation method.

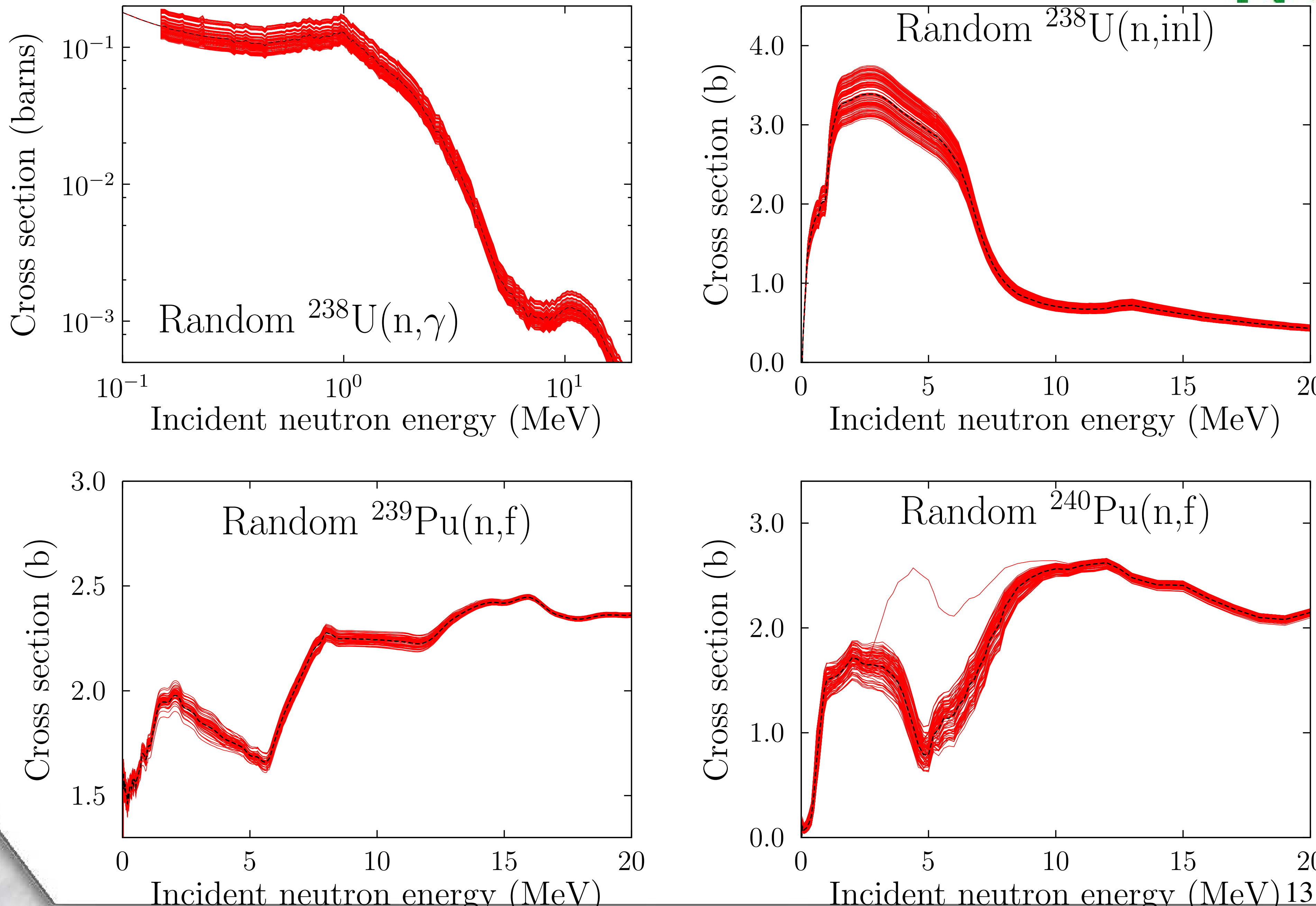
Convergence and consistency of ν-bar and resonance parameters



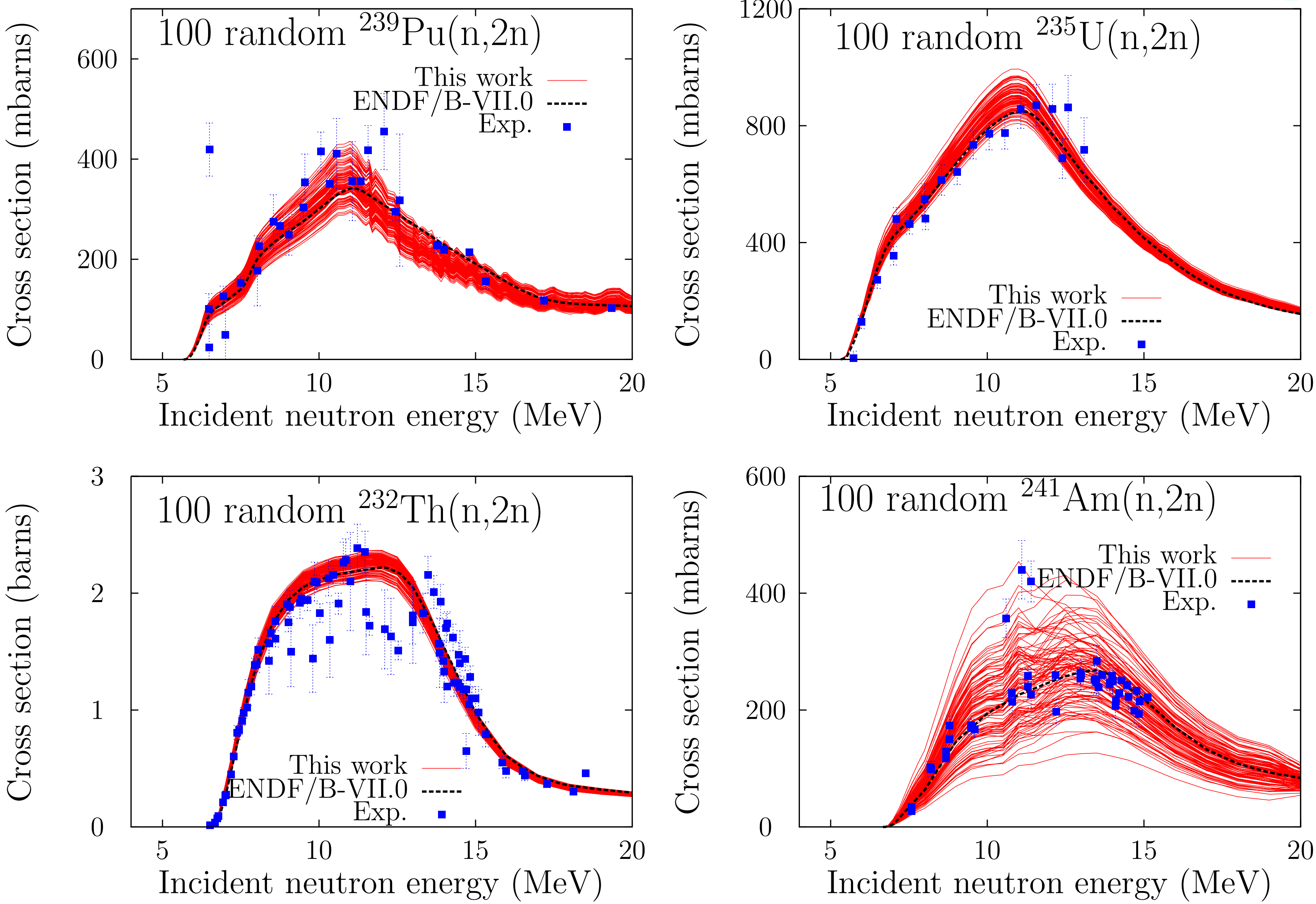
Convergence TMC/Perturbation



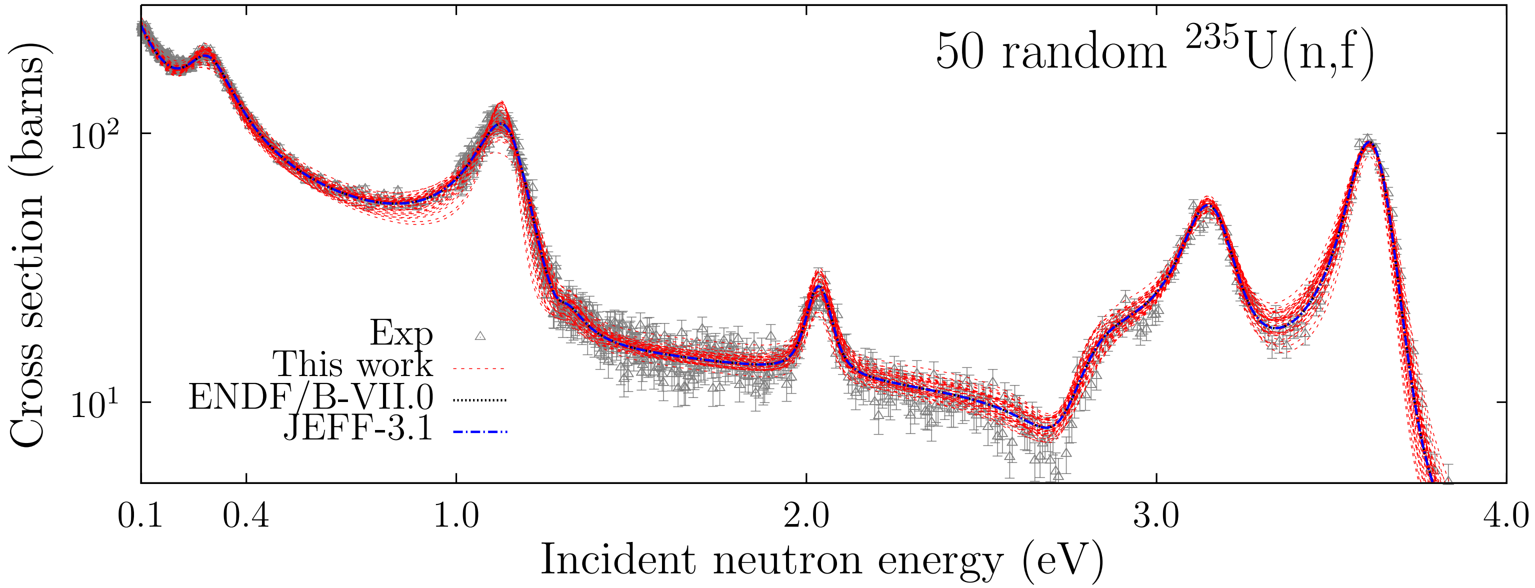
Nuclear data: ^{239}Pu and ^{238}U

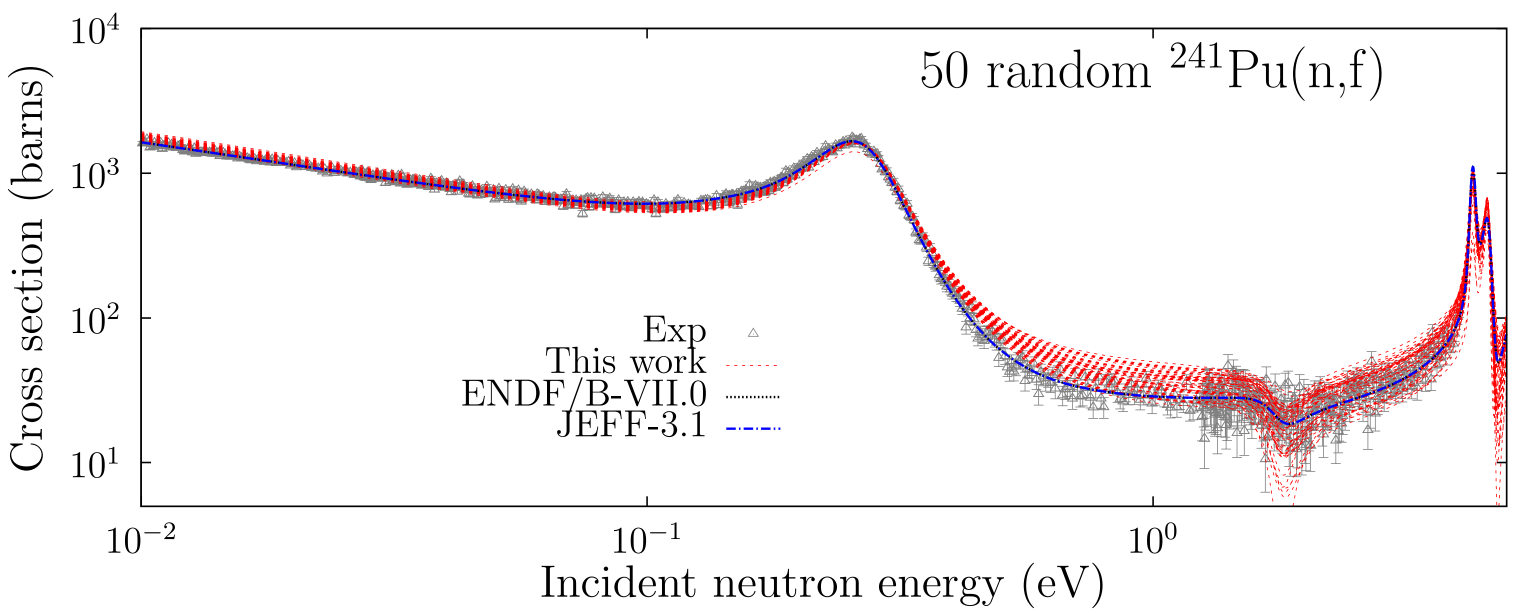


Nuclear data: examples on (n,2n) cross sections

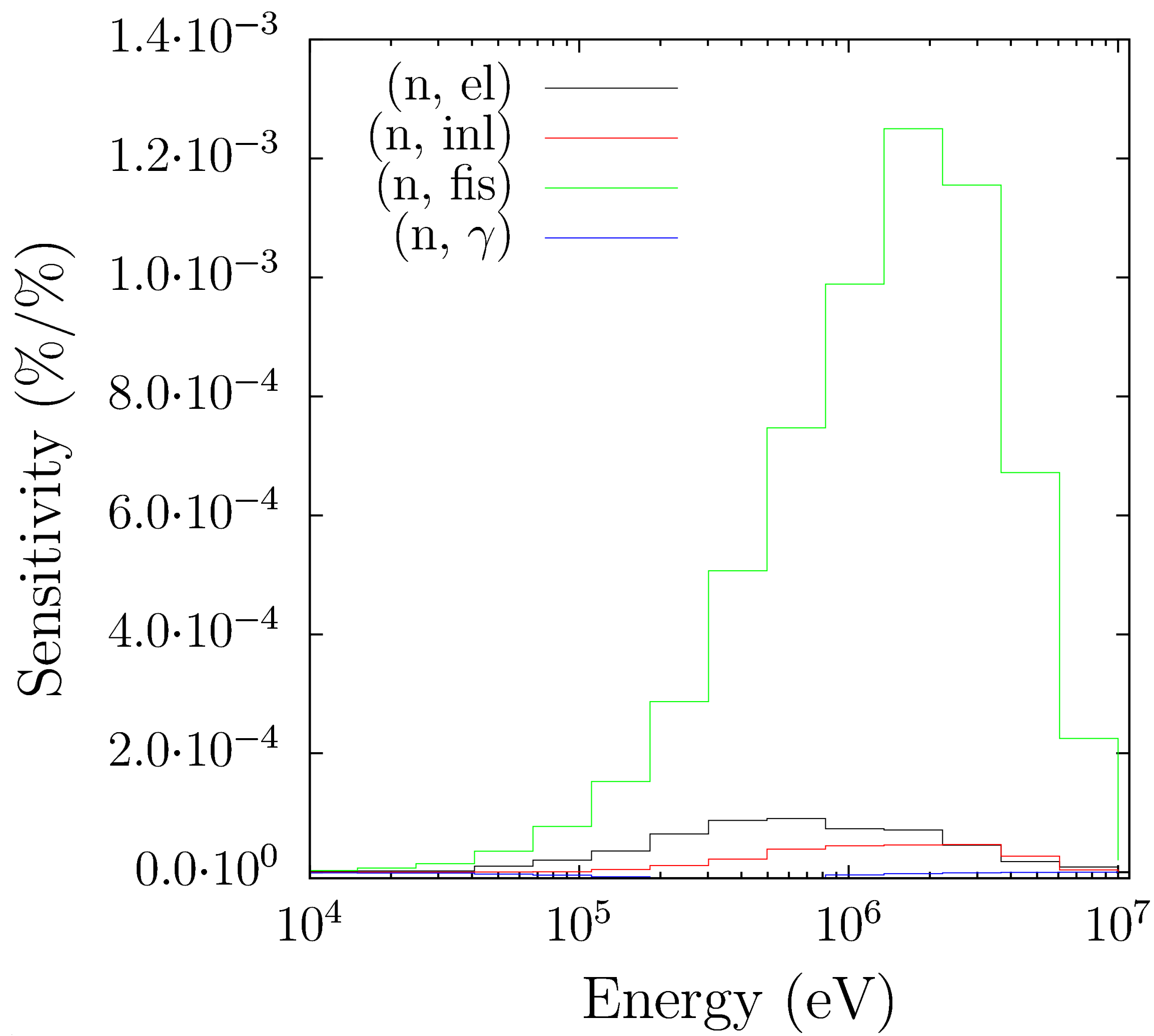


Nuclear data: examples in the resonance region





Example for sensitivity to ^{239}Pu cross section for pmf1 (Jezebel)



Results

Comparison TMC-Perturbation methods for a few k_{eff} benchmarks. The ratio in the last column is ”TMC over Perturbation”.

		Total Monte Carlo	Perturbation	Ratio
Benchmark	Isotopes	Uncertainty due to nuclear data (pcm)	Uncertainty due to nuclear data (pcm)	
pmf1	^{239}Pu	1000	860	1.16
pmf2	^{239}Pu	840	720	1.16
pmf2	^{240}Pu	790	650	1.21

Results: Details of the TMC-Perturbation methods for ^{239,240}Pu k_{eff} benchmarks

	pmf2 ^{239}Pu			pmf2 ^{240}Pu	
	Δk_{eff} (pcm)			Δk_{eff} (pcm)	
	TMC	Perturbation		TMC	Perturbation
Total	840	720		790	650
MF1	400	-		370	-
(n,inl)	170	140		70	50
(n,el)	250	240		30	40
(n,γ)	100	100		30	30
(n,f)	720	660		730	640
MF4	20	-		20	-
MF5	50	-		30	-
MF6	50	-		30	-

Conclusions

- First attempt to compare two uncertainty propagation method
- TMC: more general and exact answer, does not require special codes, more exhaustive
- but slower

- Perturbation: approximate, require special processing and codes, limited
- but faster
- TMC uncertainties $\simeq$ 15-20 % larger than from perturbation for pmf2 considering $^{239,240}Pu$