Nuclear data uncertainty propagation: Total Monte Carlo vs. covariances

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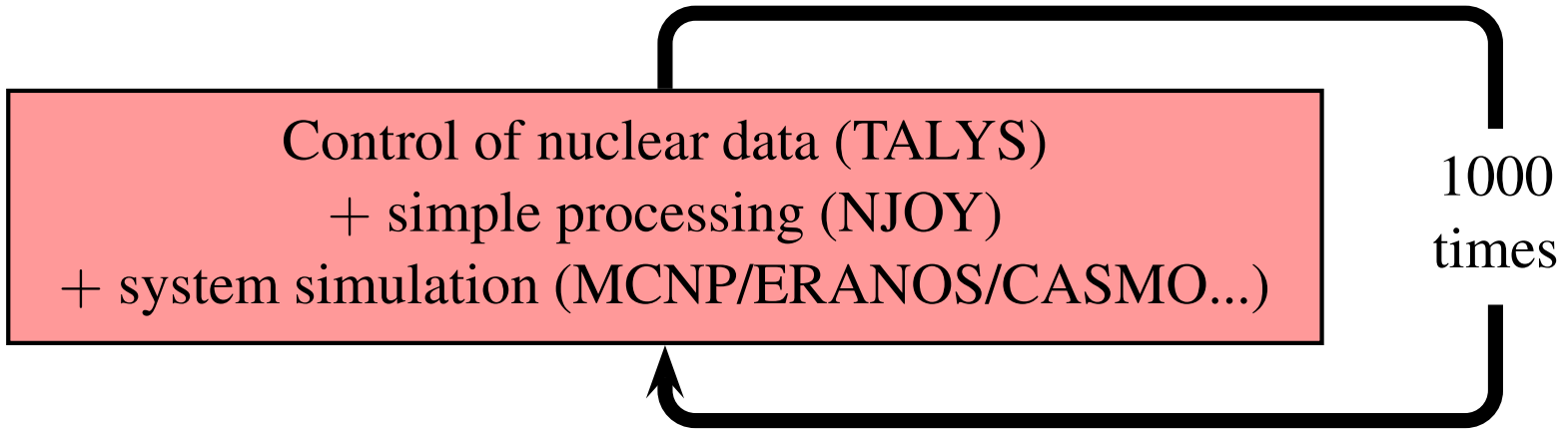
Contents

Goals:

① Obtain uncertainties on a large-scale models due to nuclear data uncertainties

② Systematic approach, reliable and reproducable

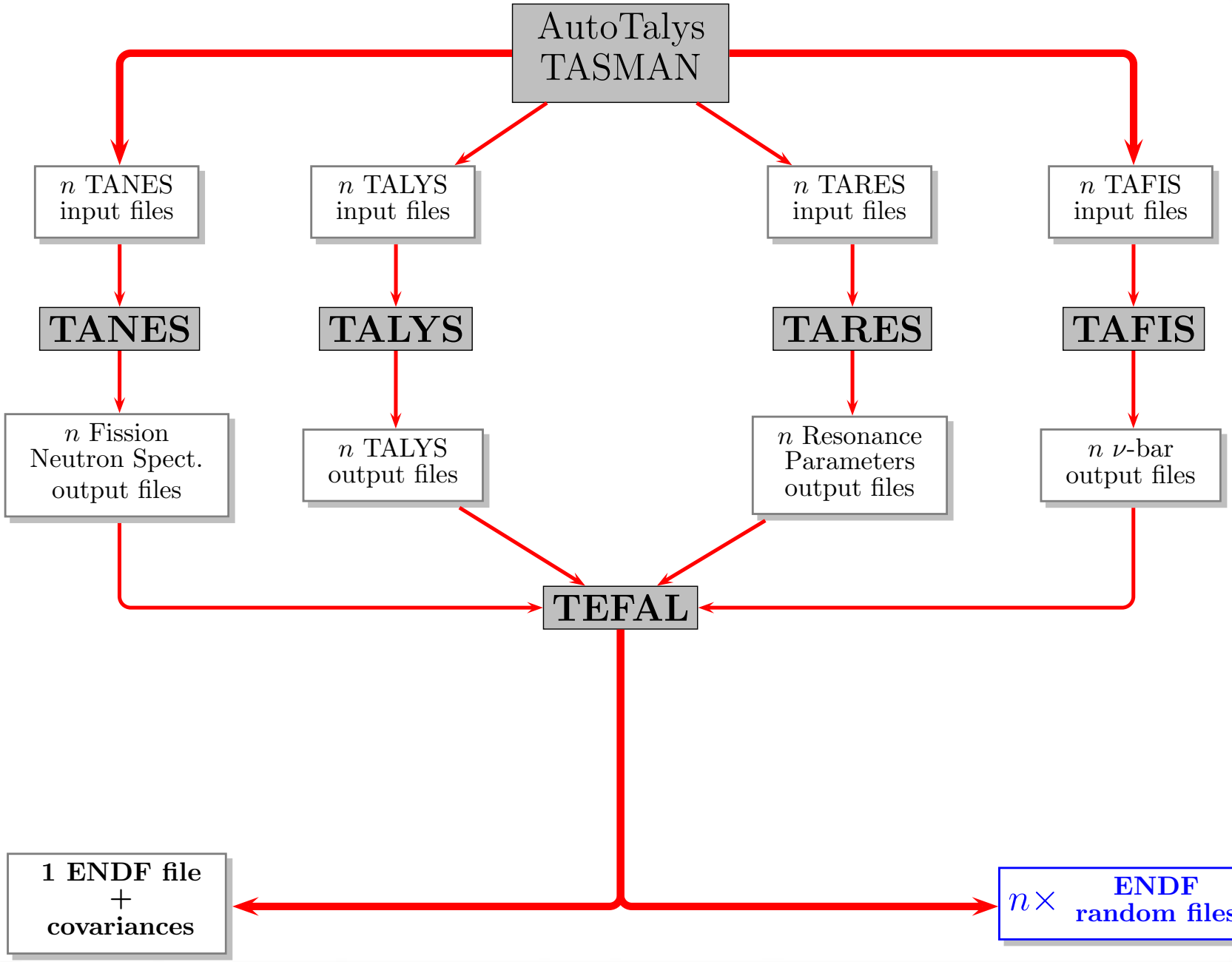
Solution (1): Total Monte Carlo



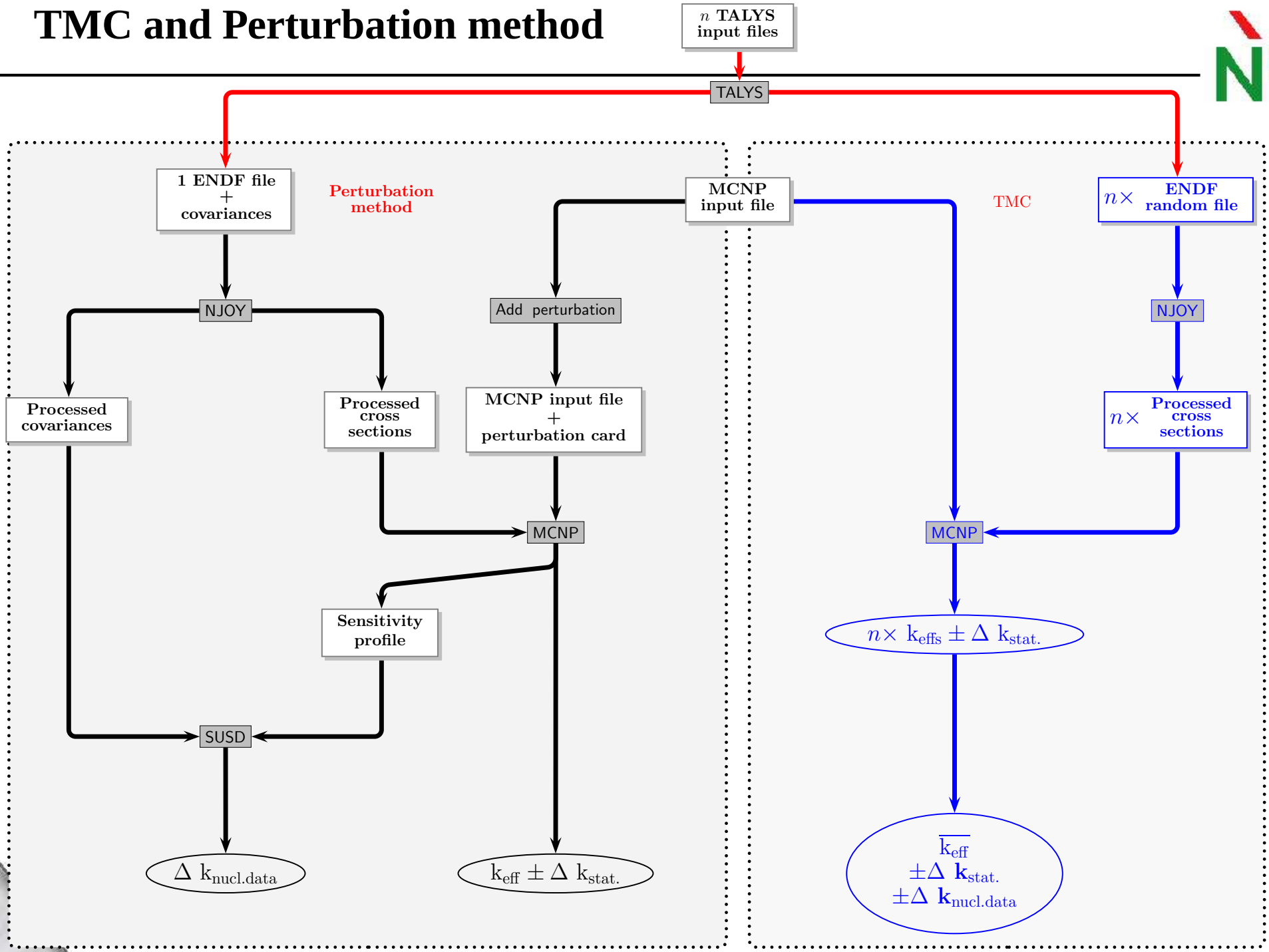
Solution (2): Perturbation method

$\Longrightarrow$MCNP+ Perturbation cards+covariance files

TMC and Perturbation method: File production



TMC and Perturbation method



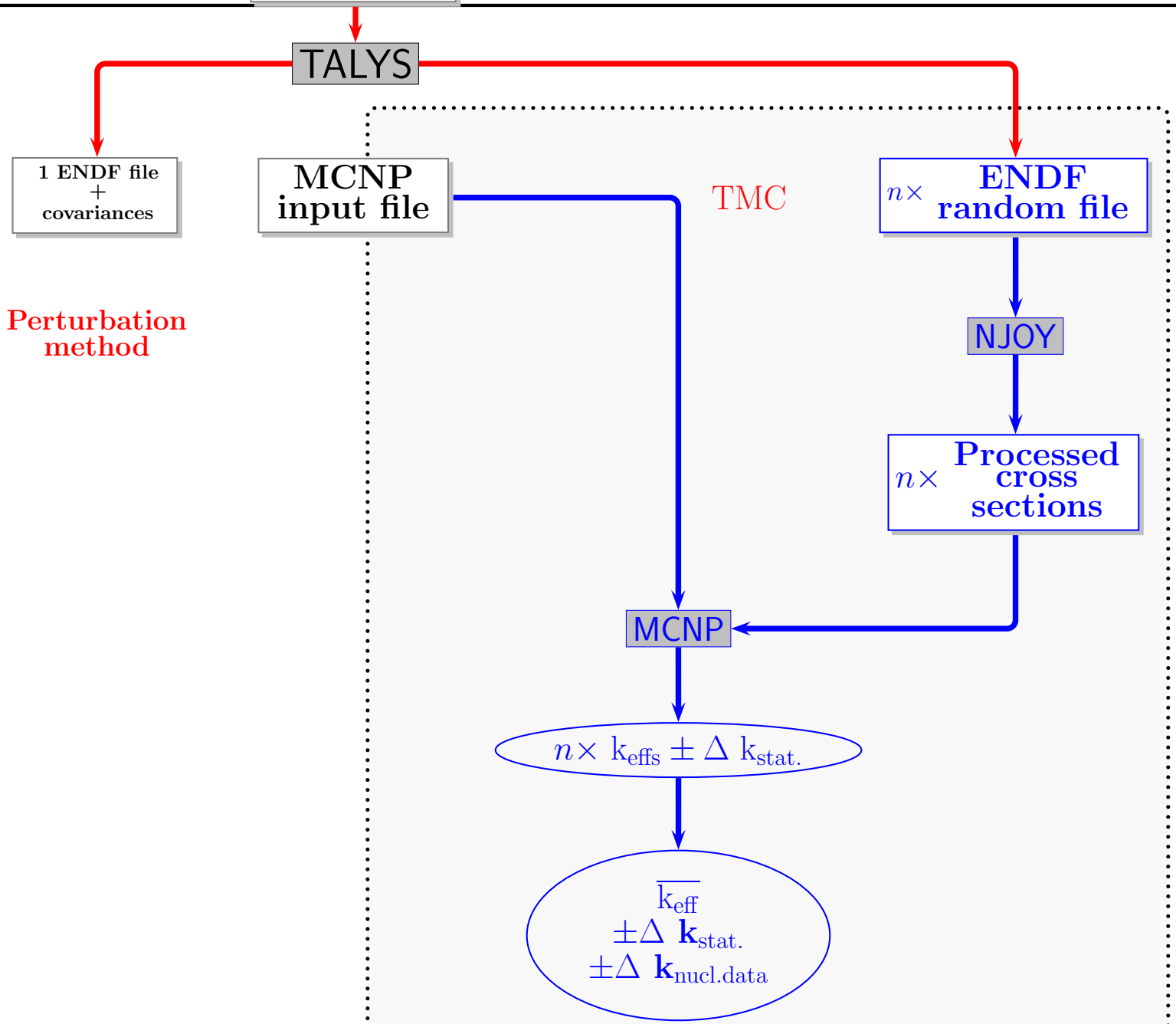
Necessary softwares

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

For the TMC method only:
- ∅

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

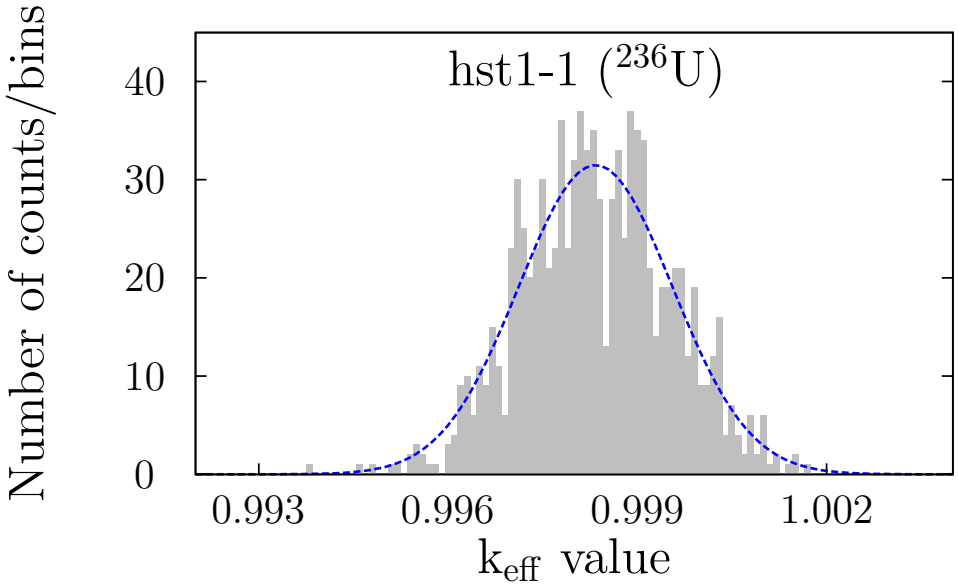
Idea: TALYS +(n TALYS input files) Monte Carlo = Total Monte Carlo



Total Monte Carlo: examples

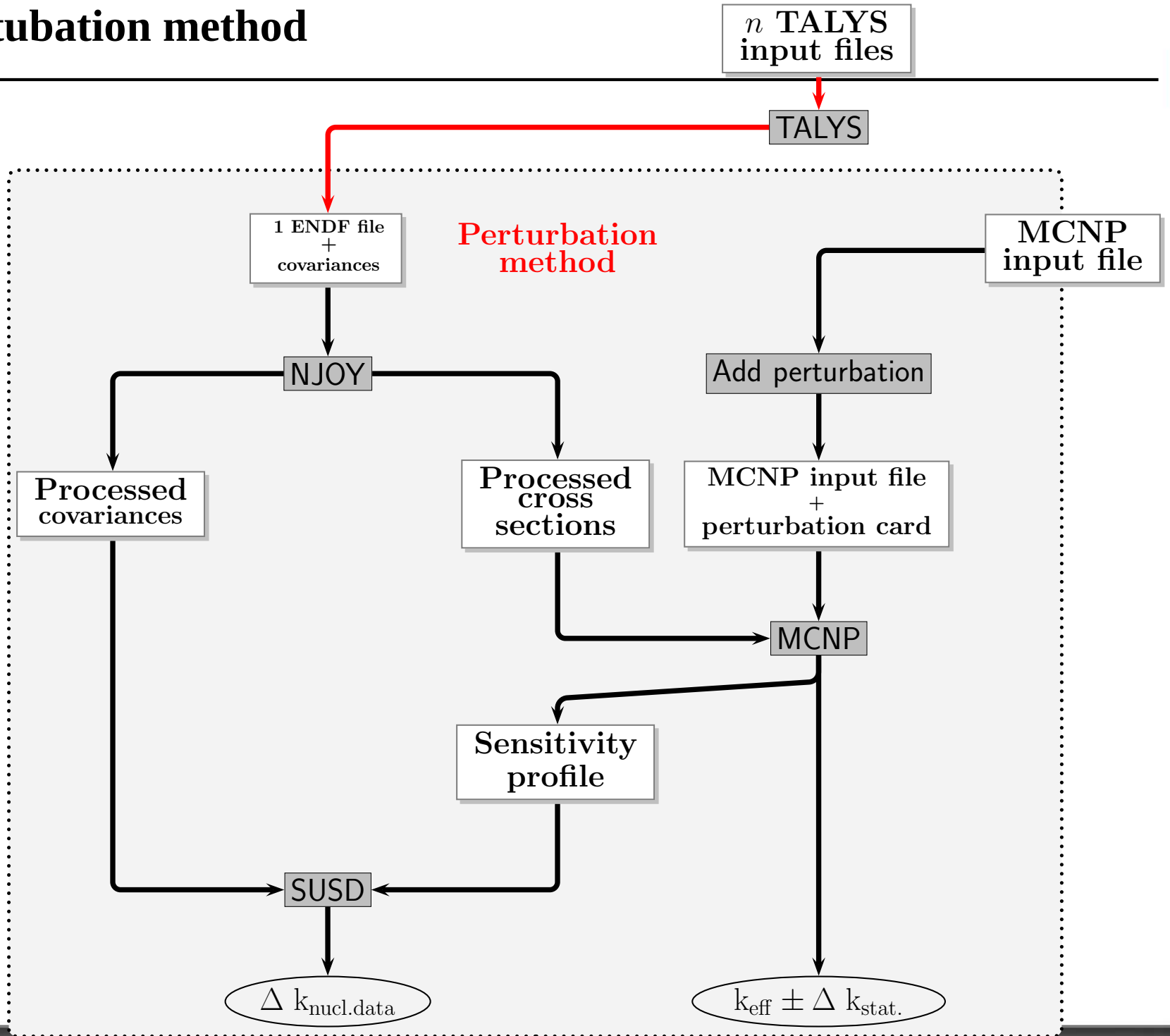
For each random ENDF file, the benchmark calculation is performed with MCNP. At the end of the *n* calculations, *n* different k_{eff} values are obtained. In the obtained probability distribution of k_{eff}, the standard deviation σ_{total} reflects two different effects:

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

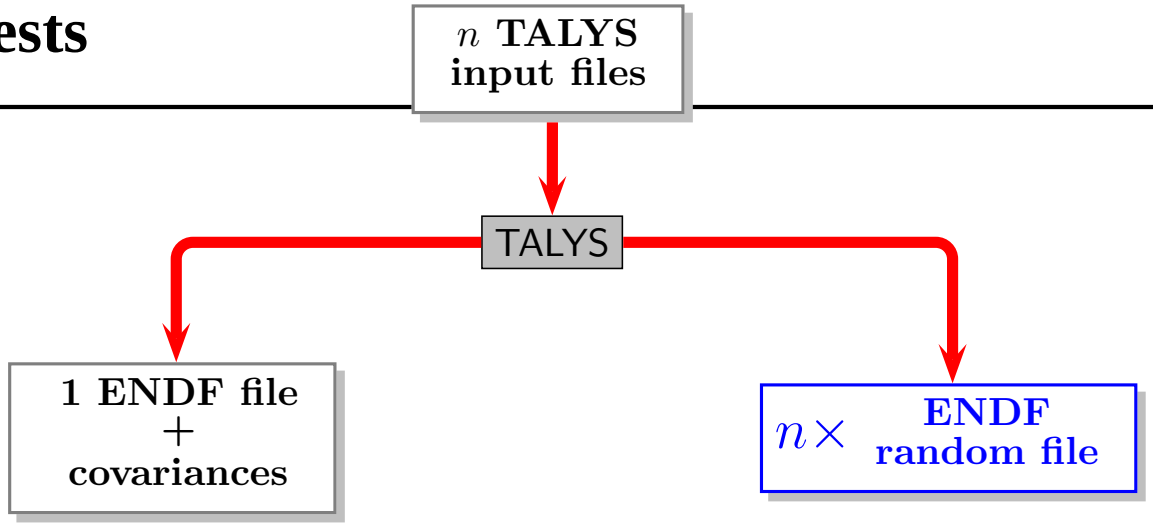


Each random file is completely different than another one: nu-bar ("*MF1*"), resonance parameters ("*MF2*"), cross sections ("*MF3*"), but also *MF4*, *MF5* and *MF6*.

Pertubation method



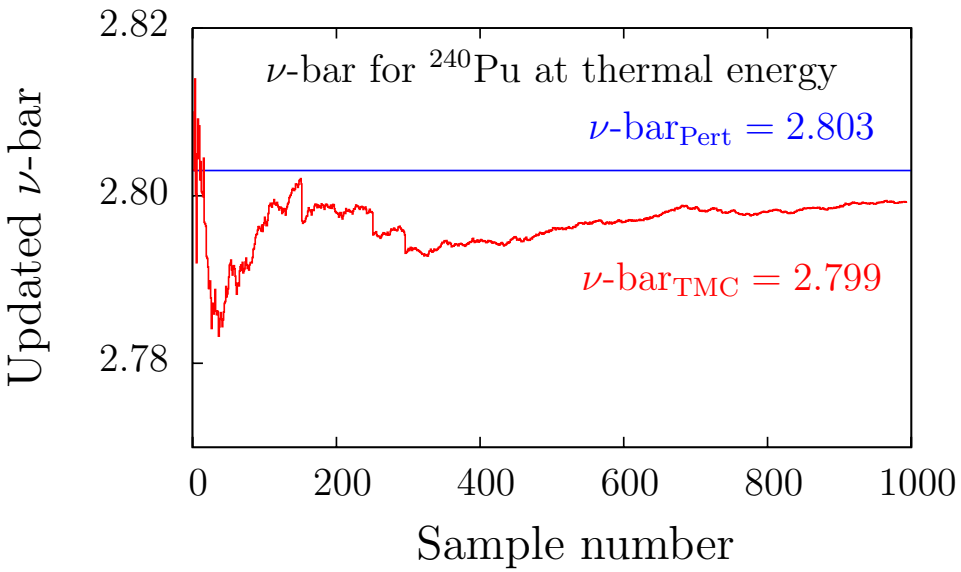
Consistency tests

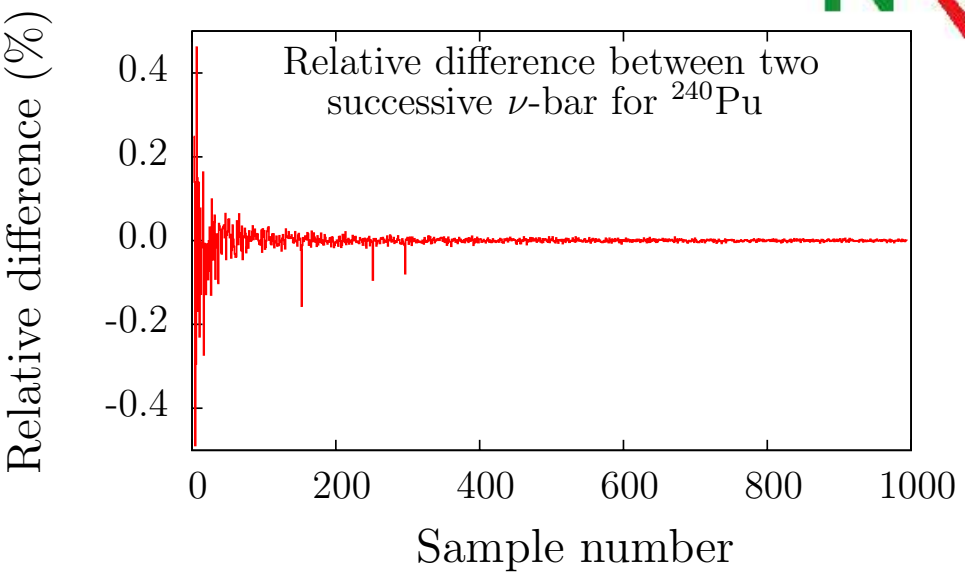


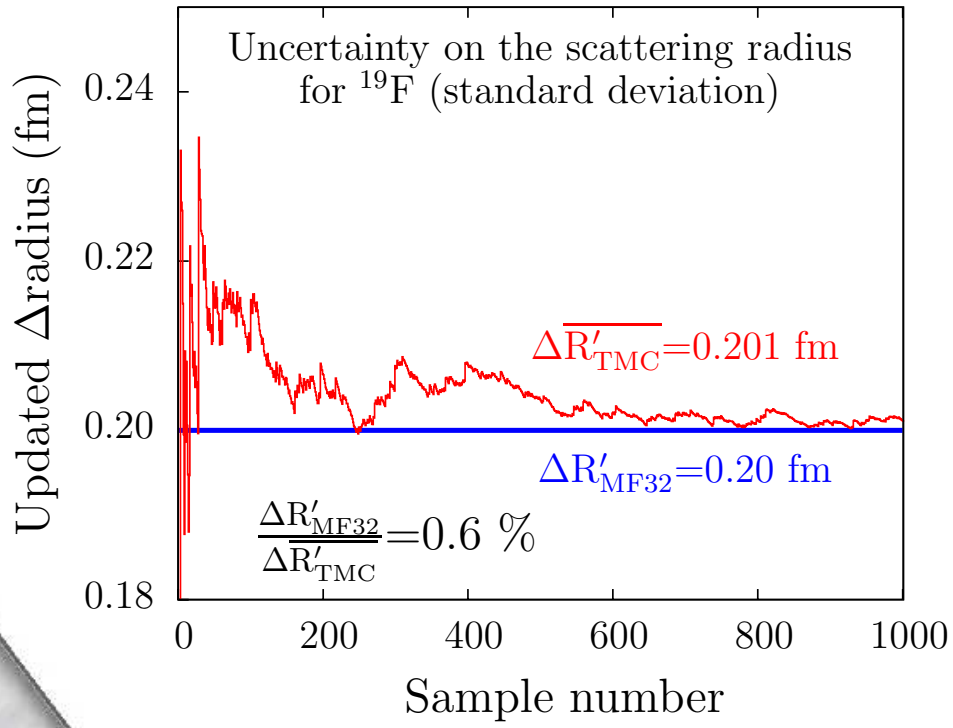
Convergence and consistency of:

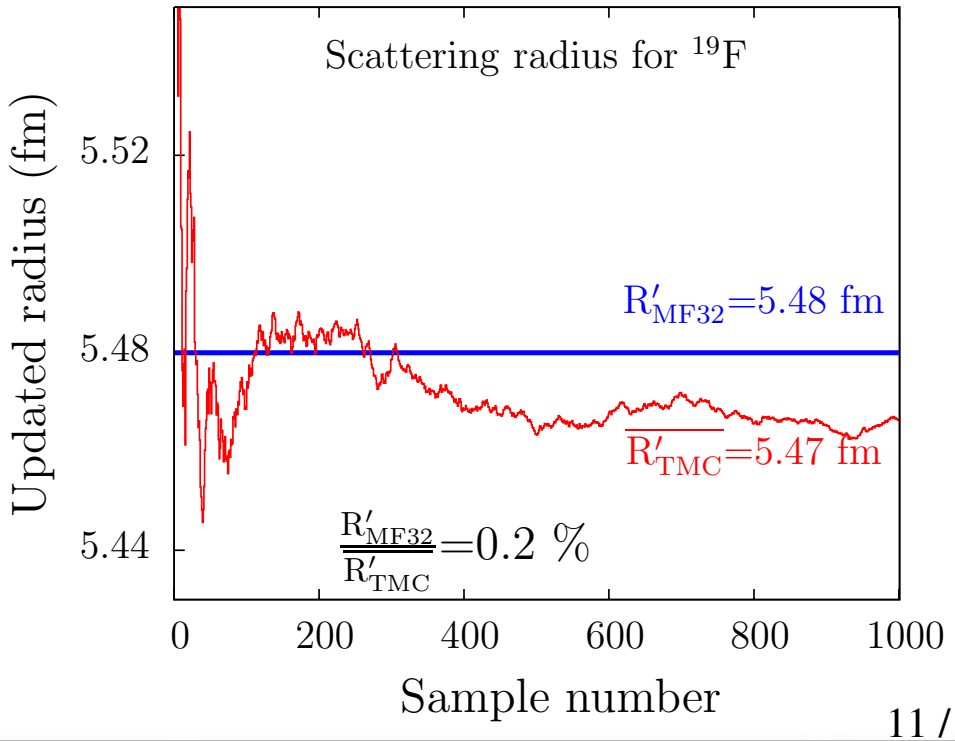
- ν-bar.
- resonance parameter distributions.
- cross sections probability distributions.
- angular distribution probability distributions.
- Monte Carlo calculations.
- the perturbation method.

Convergence and consistency of ν-bar and resonance parameters

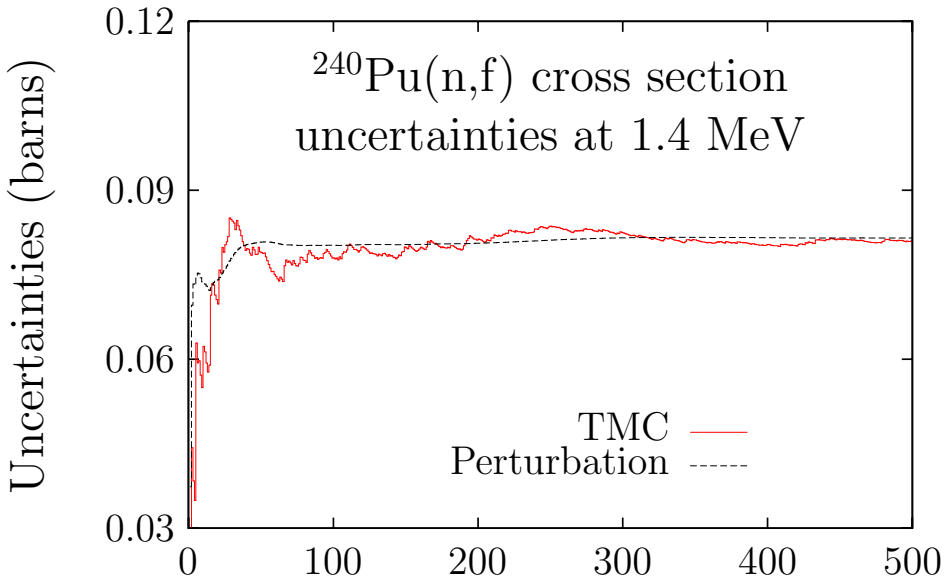


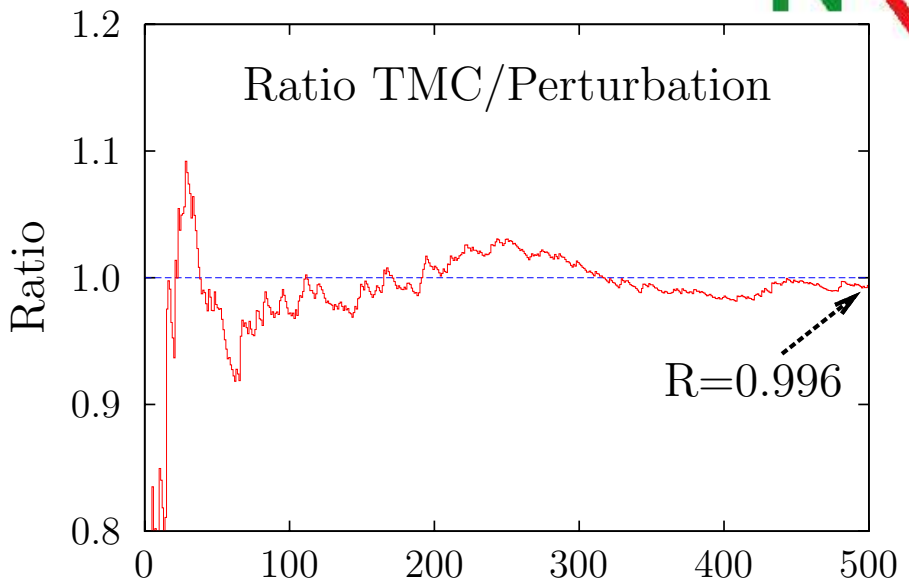


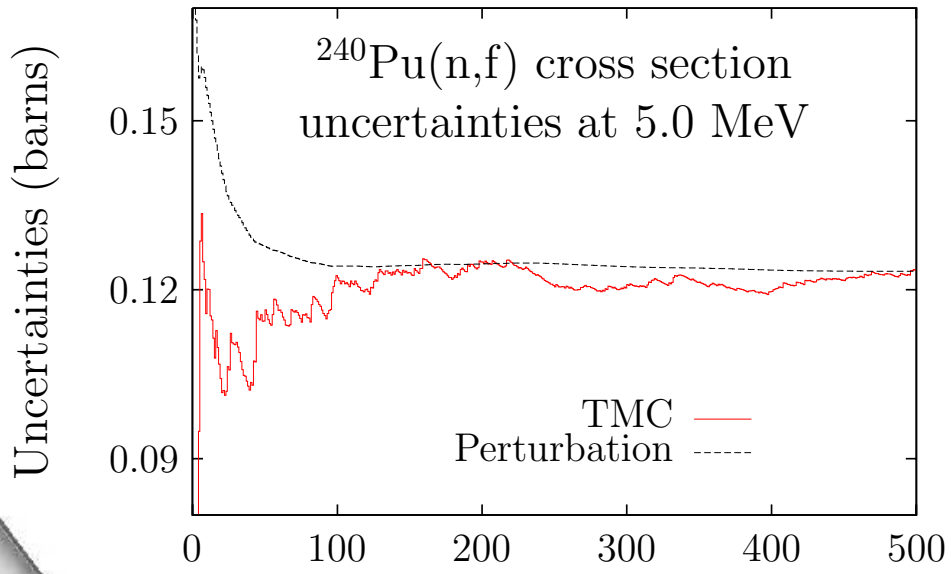


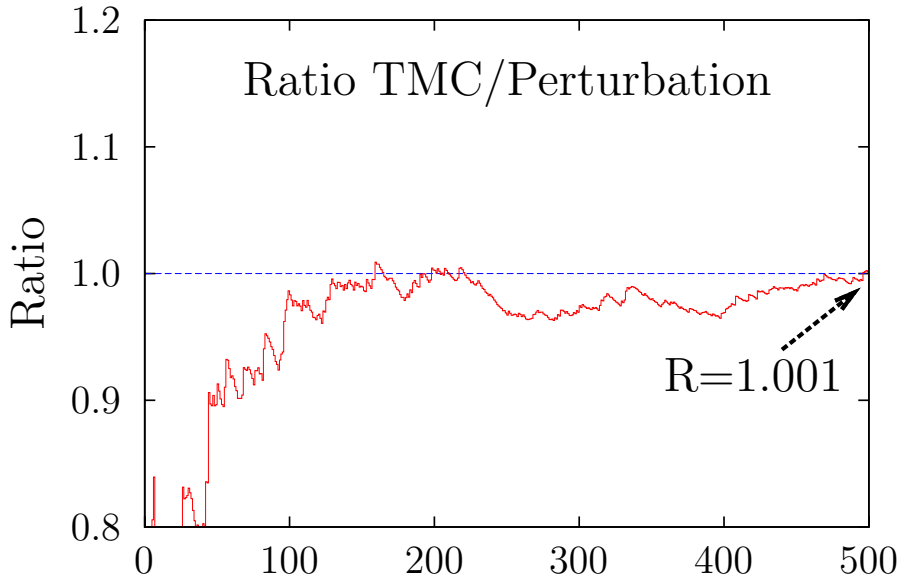


Convergence TMC/Perturbation

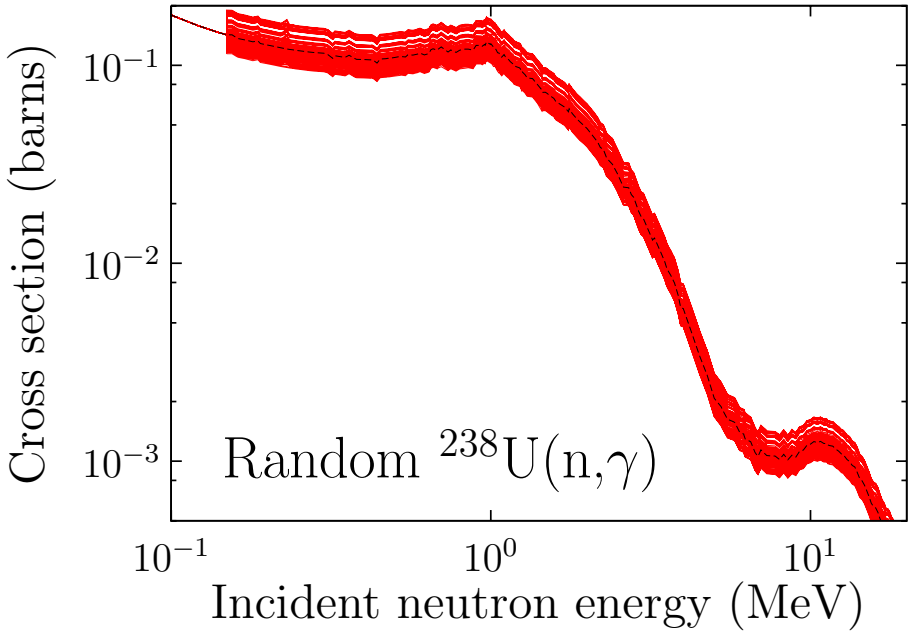


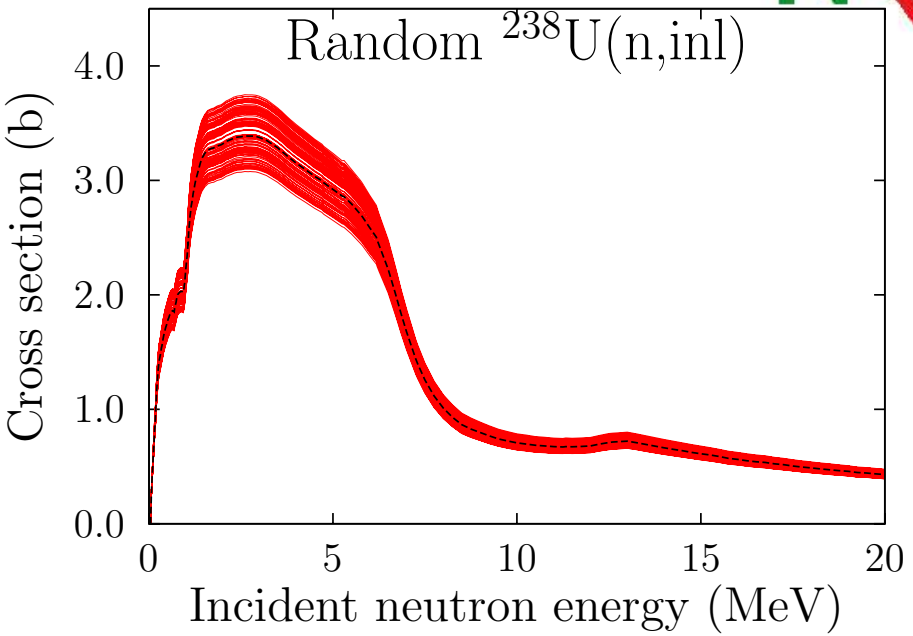


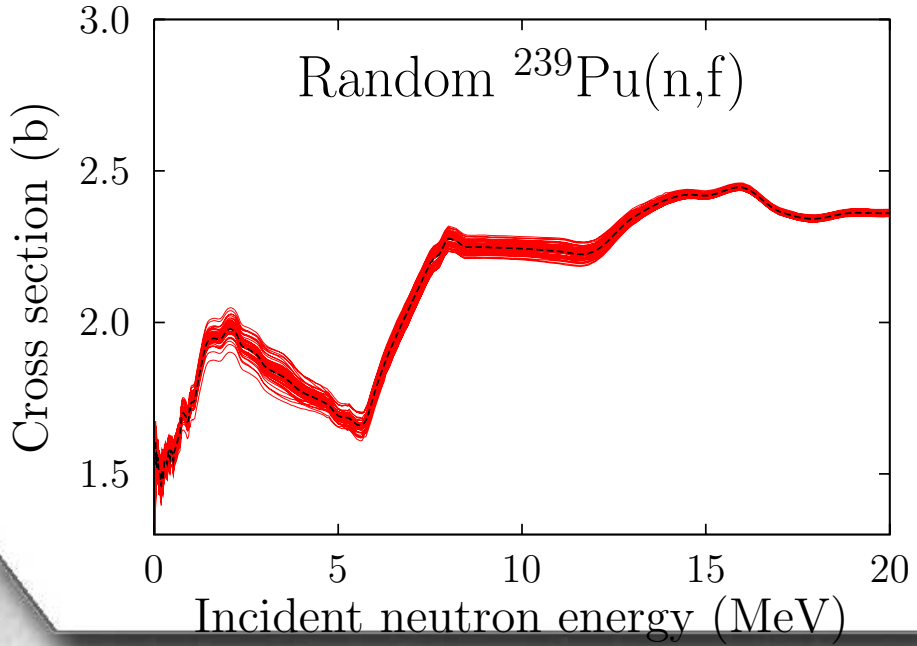


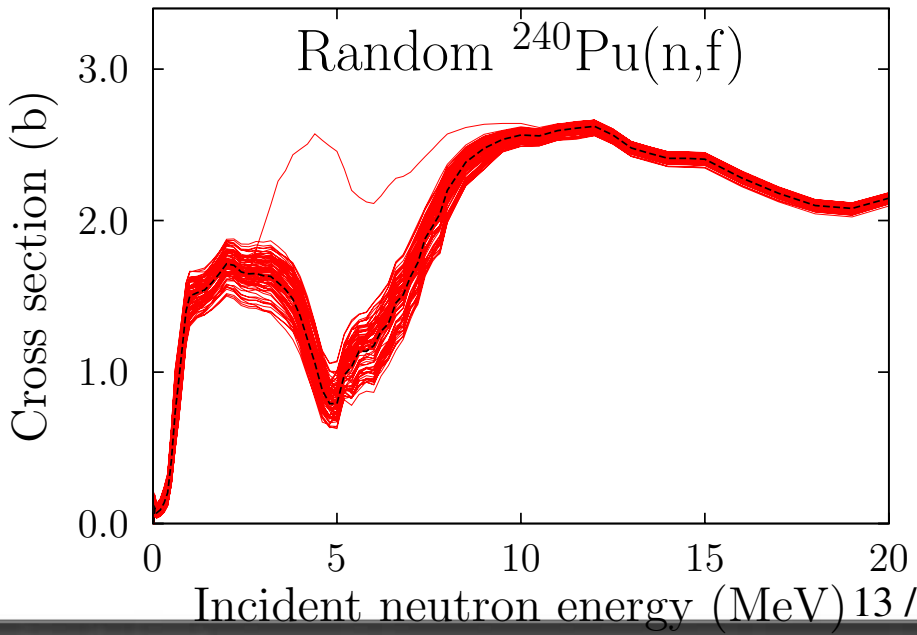


Nuclear data: ^{239}Pu and ^{238}U

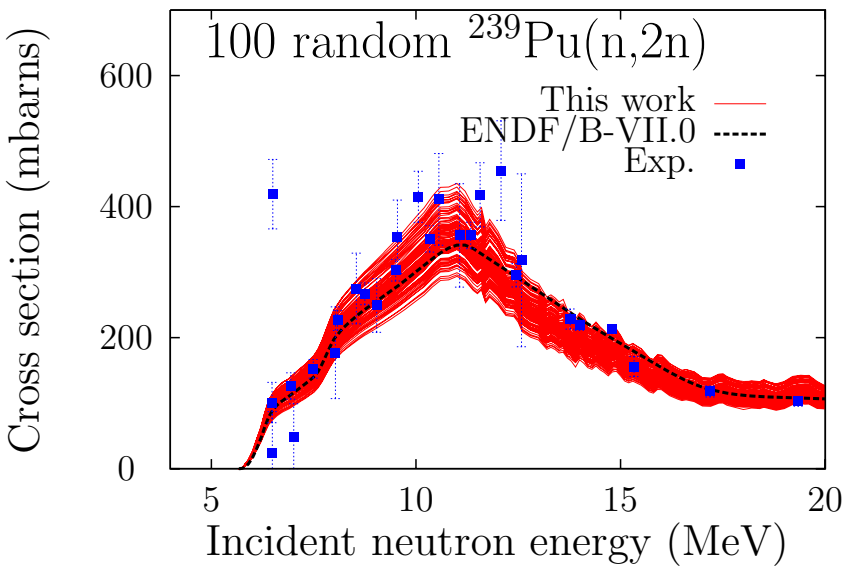


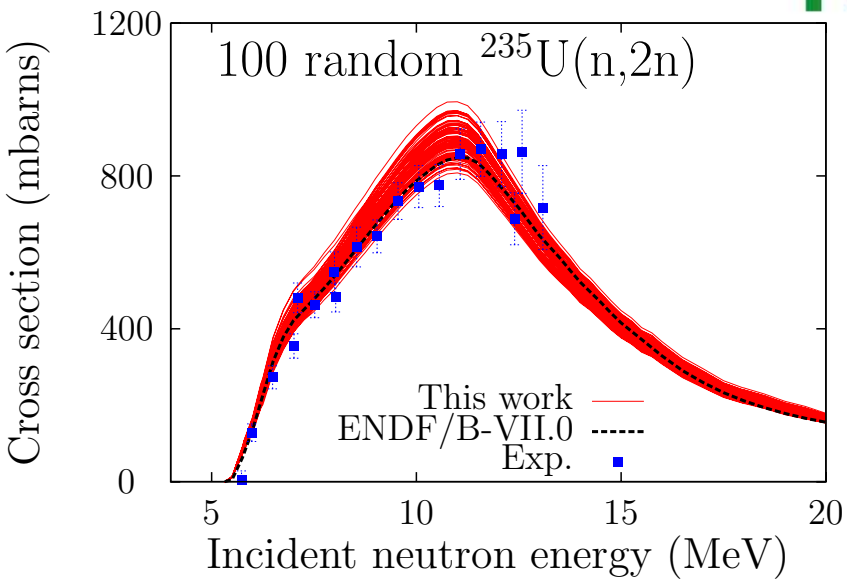


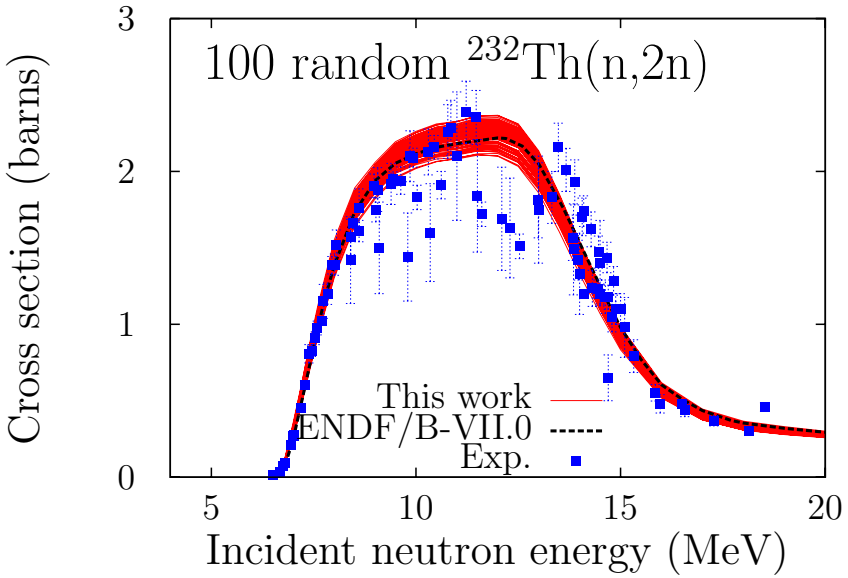


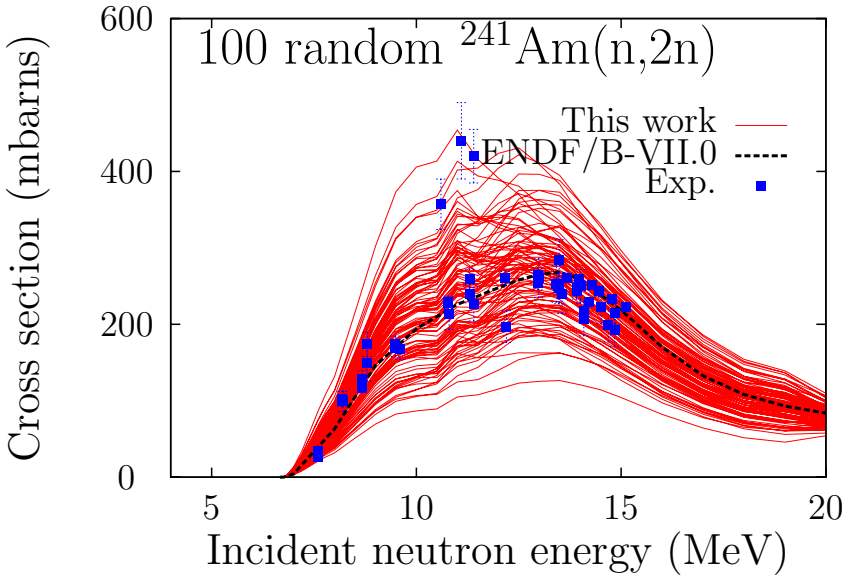


Nuclear data: examples on (n,2n) cross sections

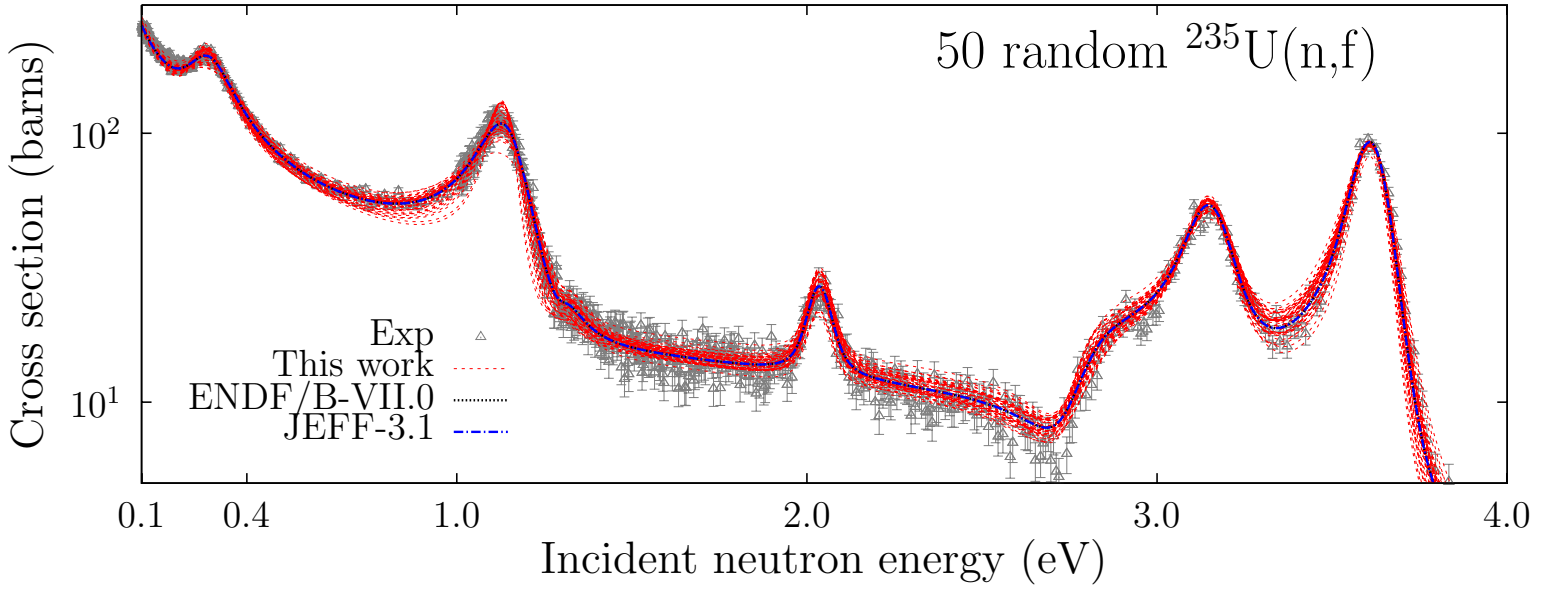


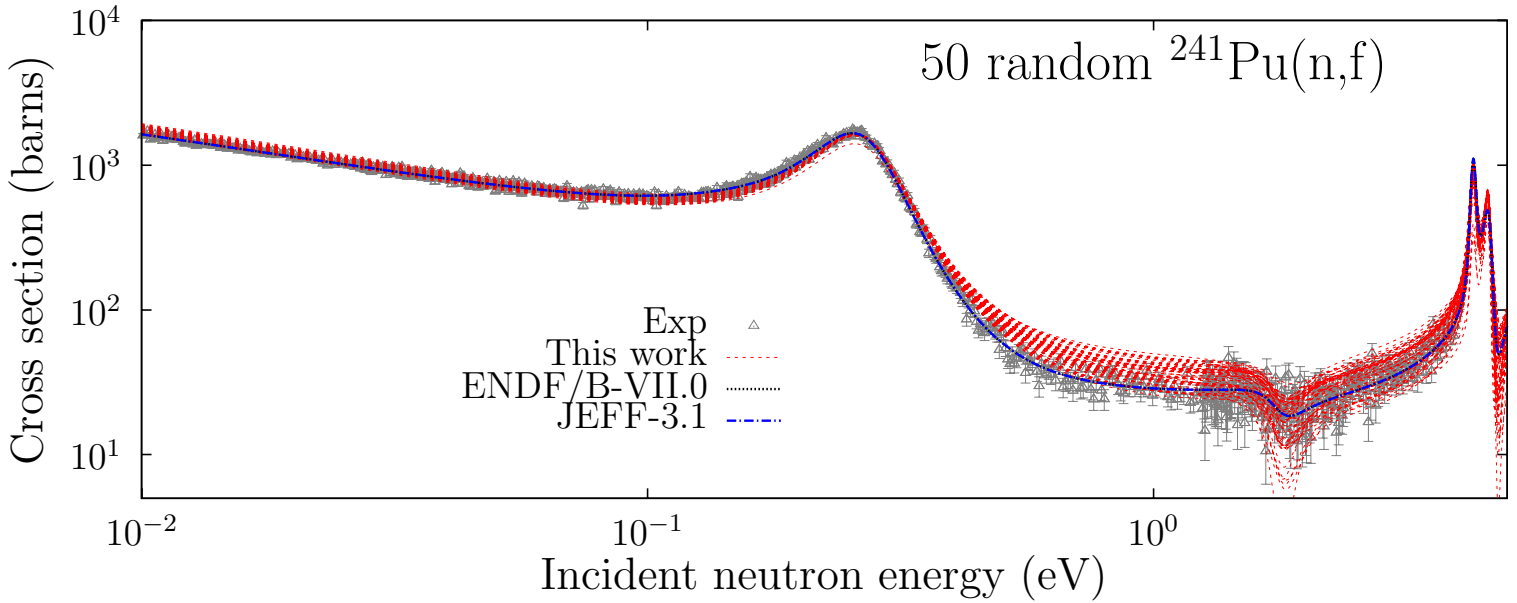






Nuclear data: examples in the resonance region





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)	
hst39-6	^{19}F	330	290	1.16
hmf7-34	^{19}F	350	290	1.21
ict3-132	^{90}Zr	190	150	1.29
hmf57-1	^{208}Pb	500	410	1.22
pmf2	^{239}Pu	840	720	1.16
pmf2	^{240}Pu	790	650	1.21

Results: Details of the TMC-Perturbation methods for ^{19}F k_{eff} benchmarks

	hst39-6 ^{19}F			hmf7-34 ^{19}F	
	Δk_{eff} (pcm)			Δk_{eff} (pcm)	
	TMC	Perturbation		TMC	Perturbation
Total	330	290		350	290
MF2	280	240		310	280
MF3	170	160		75	105
MF4	100	-		80	-
MF6	30	-		35	-

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 15 to 30 % larger than from perturbation

Perturbation approach still dominates the *market*,
but for how long ?