NRG Studies on ESFR Oxide Core Feedback Coefficients: Uncertainty Analyses

(ESFR WP3 T2.1.3)

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② Concept for uncertainty propagation:

⟹ *Total Monte Carlo (and a perturbation method for sensitivity)*

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④ Nuclear Data:

⟹ ^{238}U, $^{239,240,241,242}Pu$ *and* ^{23}Na

⑤ Results:

⟹ *Void coefficient,* k_{eff}, β_{eff} *and Doppler coefficient*

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Goals:

① Obtain uncertainties on the JRC Petten ESFR model due to nuclear data uncertainties (obtained from H. Tsige-Tamirat, November 2009)

② Systematic approach, reliable and reproducable

Solution (1): Total Monte Carlo

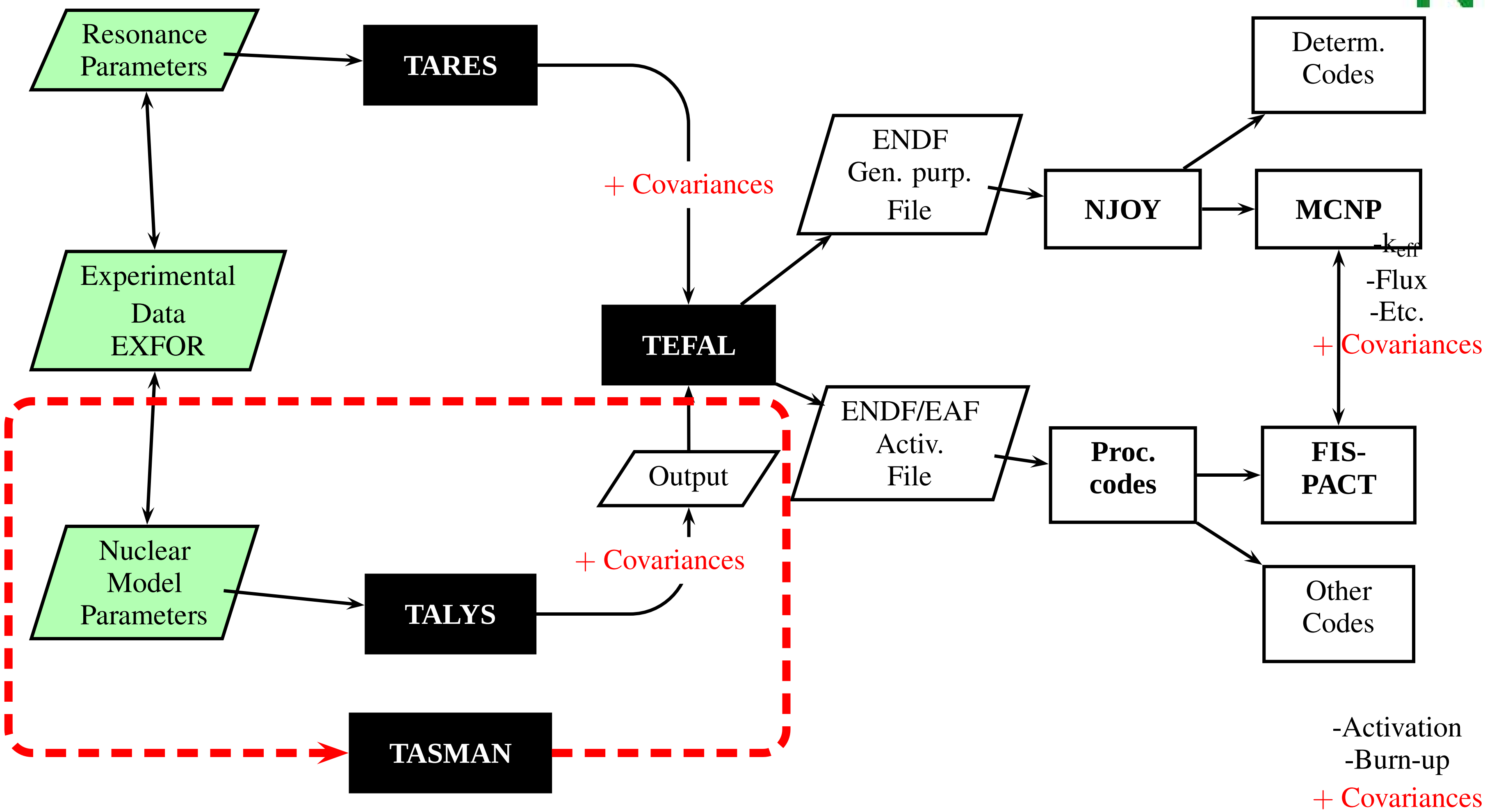
Control of nuclear data (TALYS)
+ simple processing (NJOY)
+ system simulation (MCNP/ERANOS/CASMO...)

1000 times

Solution (2): Perturbation method

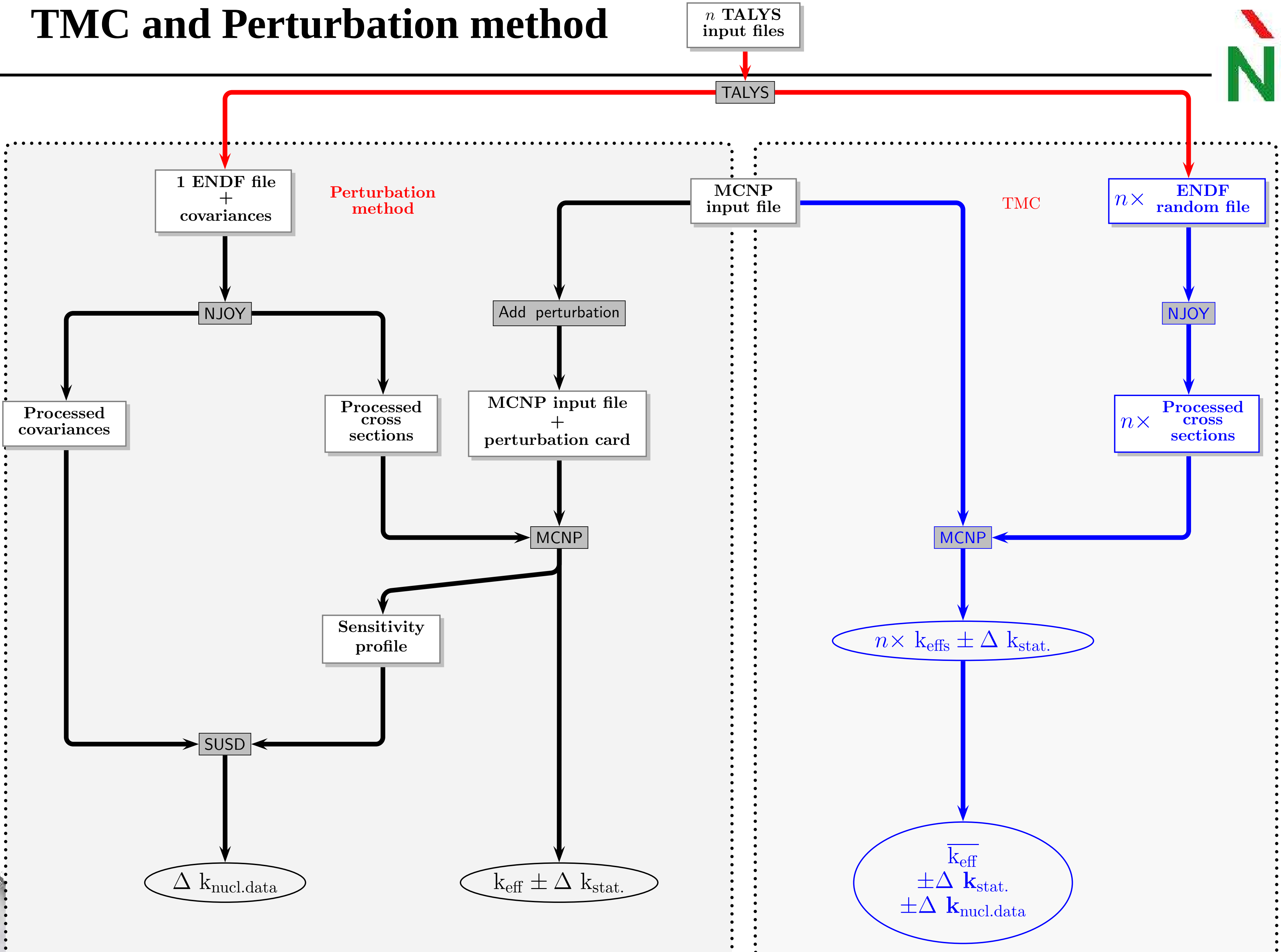
$\Longrightarrow$MCNP+ Perturbation cards

Concept: TALYS + Monte Carlo = Total Monte Carlo

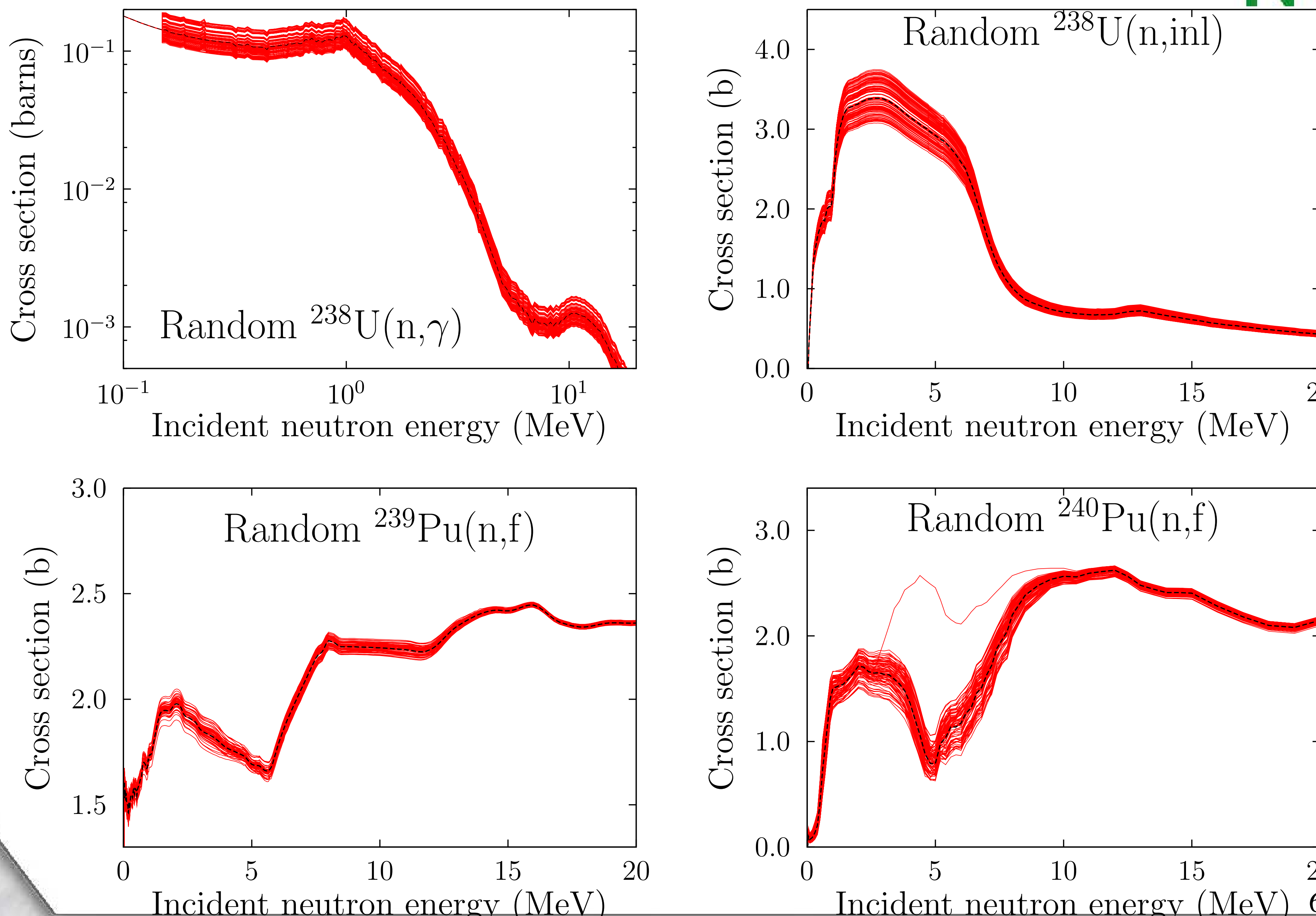


Monte Carlo: 1000 TALYS runs

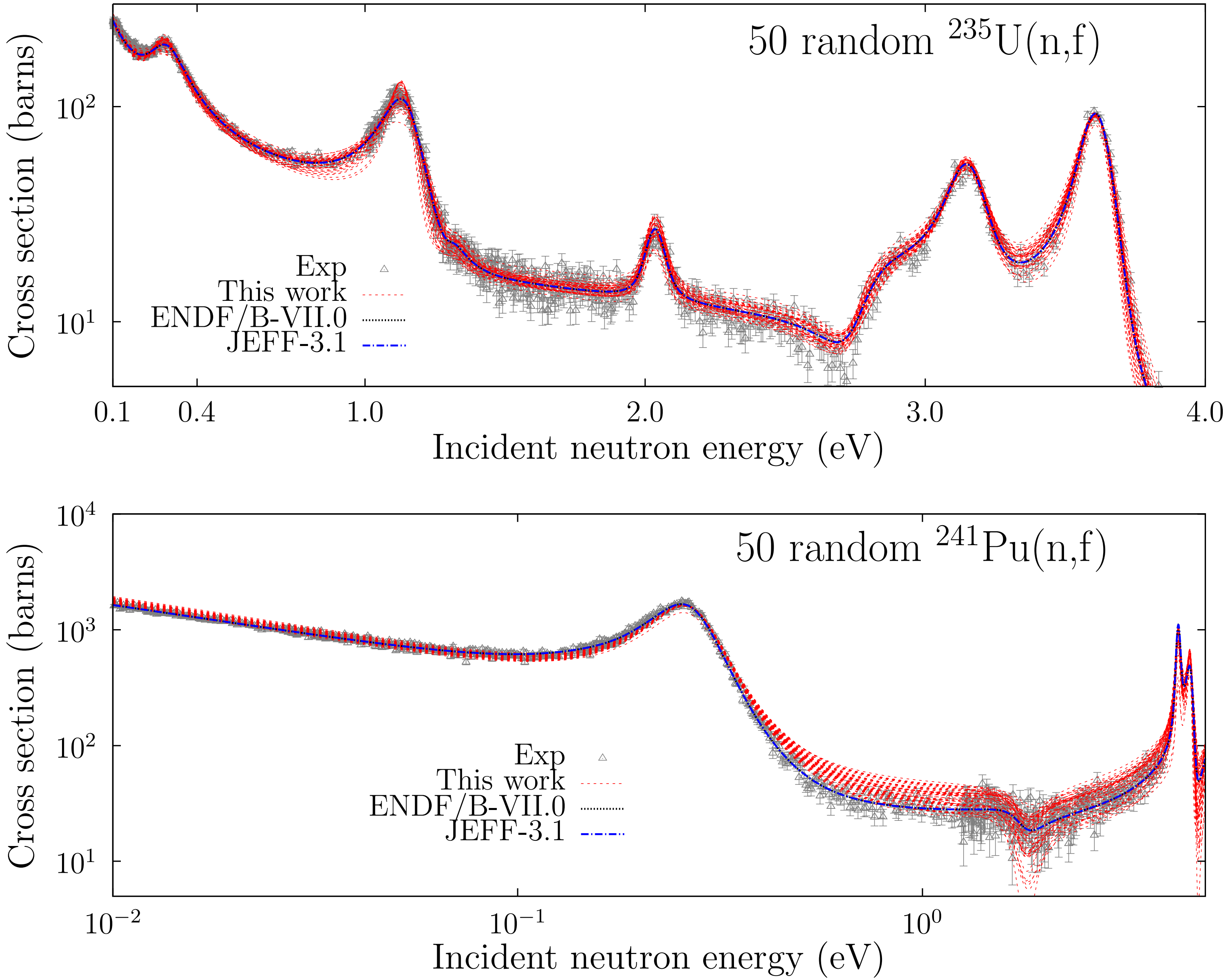
TMC and Perturbation method



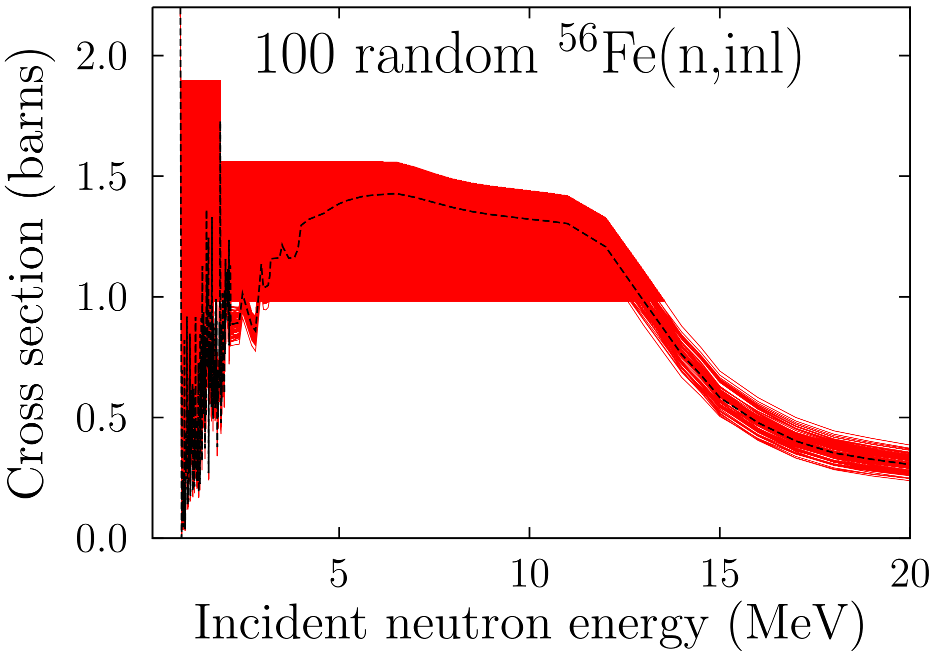
Nuclear data: ^{239}Pu and ^{238}U

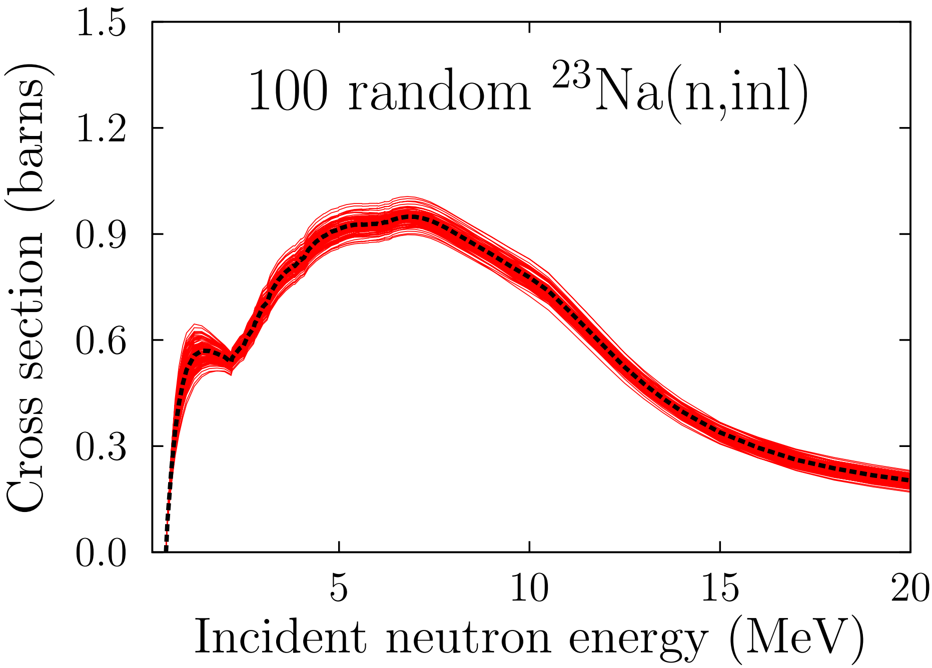


Nuclear data: examples in the resonance region



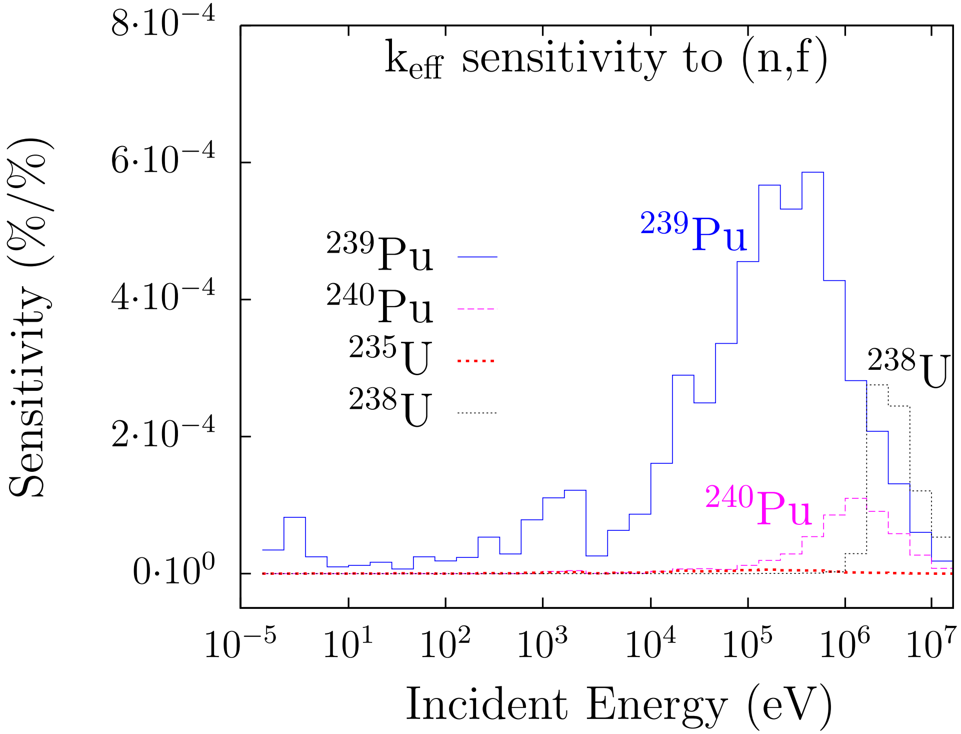
Nuclear data: ^{56}Fe and ^{23}Na

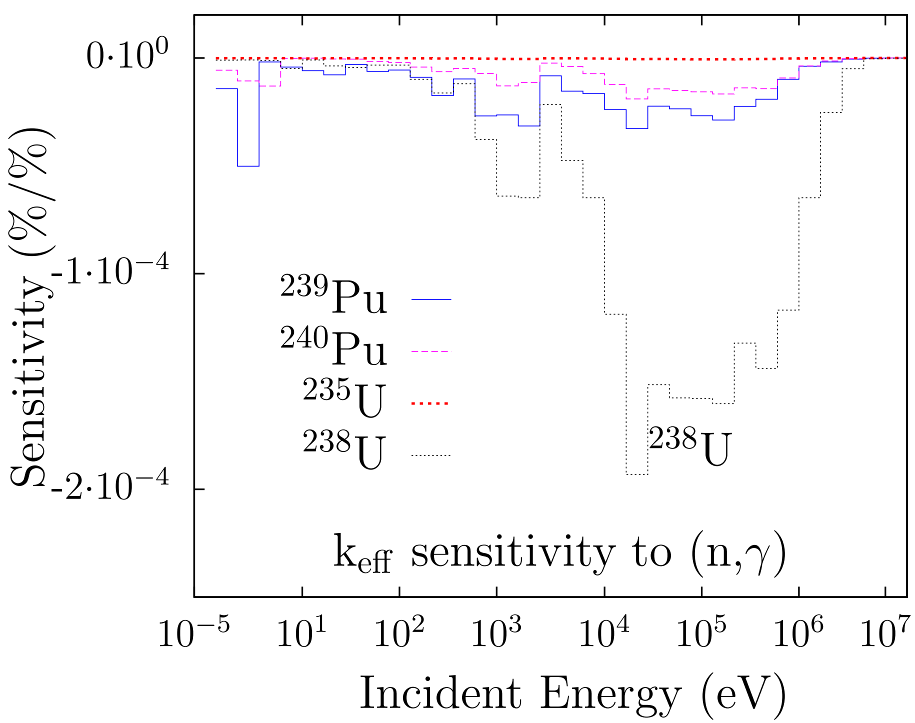




Sensitivities to k_{eff}

Main components: ^{23}Na, ^{56}Fe, Zr, ^{238}U, ^{239,240}Pu
Most sensitive reactions: ^{239}Pu(n,f) and ^{238}U(n,γ)





Results for the ESFR parameters

The sodium void reactivity (SVR) in units of dollars ($) can be obtained with the following equation :

$$\mathrm{SVR} = \frac{k_2 - k_1}{k_1 k_2}\frac{1}{\beta_{\mathrm{eff}}} \times 10^5, \tag{1}$$

where the number of delayed neutron β_{eff} (in units of pcm) and the k_{eff} values are obtained from the MCNP calculations.
k_1 corresponds to the core flooded with Na coolant, and k_2 to the same core voided of Na coolant.
In both cases the Na coolant present in the axial and radial reflectors is supposed to remain unchanged.

Results for the ESFR parameters

If we suppose that β_{eff} does not vary with different nuclear data files and that k_1 and k_2 are fully correlated, the uncertainty on the sodium void reactivity can be expressed as:

$$\Delta \text{SVR}_{\text{perturbation}} = \left| \frac{\Delta k_1}{k_1^2} - \frac{\Delta k_2}{k_2^2} \right| \frac{1}{\beta_{\text{eff}}} \times 10^5, \tag{2}$$

In the case of the TMC method, β_{eff} is also varying.
Results on the void coefficient, k_{eff} and β_{eff} are presented in the following slide.
The change in reactivity per degree of change in the temperature of nuclear fuel (or Doppler coefficient) is calculated from differences in k_{eff} obtained at three different temperatures: 1227 C (nominal temperature) $\pm$ 200 C.

Results for the ESFR parameters

Table 1: Uncertainties on the sodium void coefficient (SVR), k_{eff}, β_{eff} and Doppler coefficient due to different nuclear data uncertainties

Coefficient	value	Uncertainty due to nuclear data
SVR	5.86 $	$\simeq$ 5 %
Non Voided k_{eff}	0.98298	$\simeq$ 100 pcm
Voided k_{eff}	1.00481	$\simeq$ 15 pcm
β_{eff}	371 pcm	$<$ 1 pcm
Doppler	-0.60 pcm/C	$\simeq$ 7-13 %

The uncertainty obtained for the Doppler coefficient takes into account the statistical uncertainty coming from the various MCNP calculations, and the limited number of perturbed calculations from the TMC approach.

Conclusions and Future improvements

- The TMC method was applied to propagate nuclear data uncertainties for the ESFR model
- Main isotopes were considered ($^{239,240,241,242}Pu$, ^{238}U and ^{23}Na),
- Uncertainties have been calculated for the sodium void coefficient, k_{eff}, β_{eff} and Doppler coefficient for the ESFR model,
- Similar uncertainties were obtained for the Kalimer-600 (see publication from the same authors in the Journal of Nuclear Science and Technology, 2011)