PAUL SCHERRER INSTITUT

Paul Scherrer Institut

Sandro Pelloni and Mathieu Hursin

Sensitivity coefficients by means of SERPENT-2

Use of sensitivity coefficients from SERPENT-2

$$\frac{\Delta\Sigma^{i,r}_{x,g}}{\Sigma^{i,r}_{x,g}} = \frac{N^{i,r}_{per}\sigma^{i,r}_{x,g,per} - N^{i,r}_{ref}\sigma^{i,r}_{x,g,ref}}{N^{i,r}_{ref}\sigma^{i,r}_{x,g,ref}}$$

$$\Delta k_i = \sum_r \sum_x \sum_g S^{complete}_{k,\Sigma^{i,r}_{x,g}} \frac{\Delta\Sigma^{i,r}_{x,g}}{\Sigma^{i,r}_{x,g}}$$

$$\Delta k_{Void} = \sum_{i \in Coolant} \Delta k_i$$

per: perturbed (voided)
N : atom number density
i : coolant nuclide
r : voided region
x : reaction
g : energy group
σ : microscopic cross-section
Σ : macroscopic cross-section
S : sensitivity coefficient

This is the SCALE methodology. We may use multiple sets instead of one set of sensitivity coefficients for evaluating the reactivity effect in cases where the effect is not linear.

Comparison ERANOS/SERPENT-2

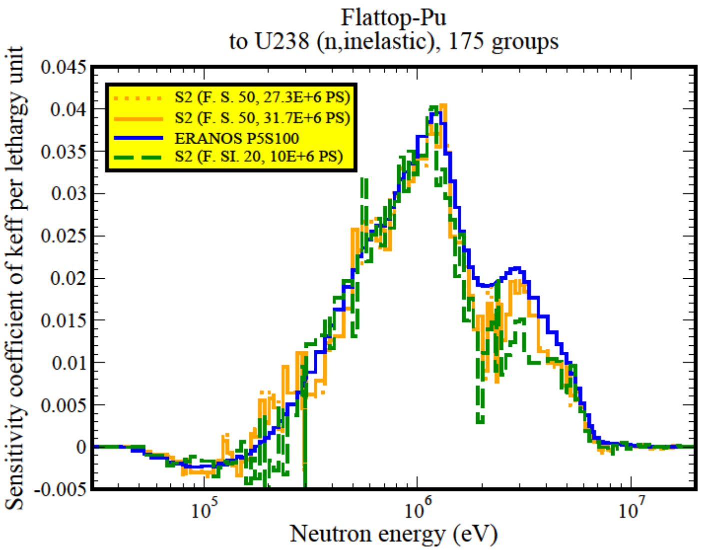
k_{eff}		
Configuration	ERANOS P_5S_{100} JEFF-3.1 (VITAMIN-J)	SERPENT-2 JEFF-3.1
Jezebel-Pu239	0.99794	0.99936±0.00013
Jezebel-Pu240	1.00199	1.00410±0.00007
Flattop-Pu	0.99923	1.00062±0.00011
ZPPR9	1.00090	0.99957±0.00008

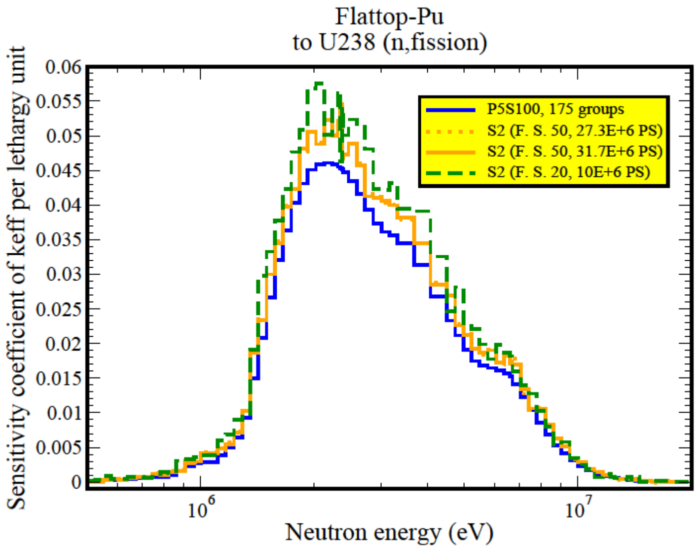
Agreement is achieved between ERANOS and Serpent.

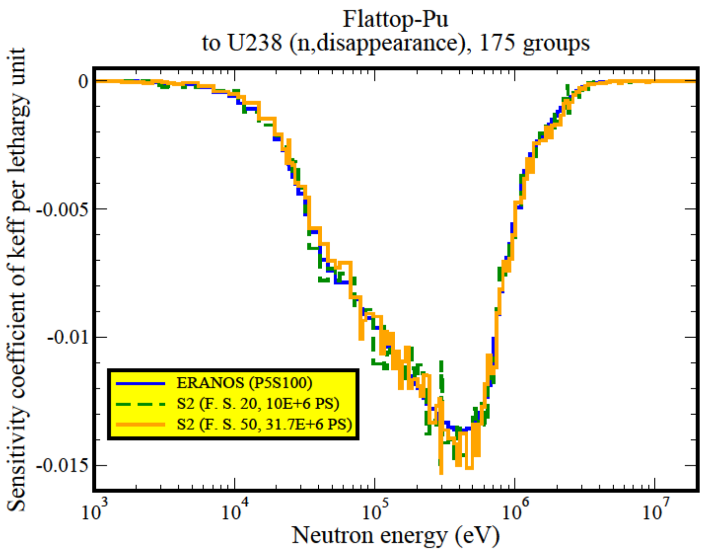
However, for leaky configurations having a large infinite multiplication factor of the fuel (bare spheres and particularly systems with thick heavy metal reflectors such as Flattop-Pu which is a 6 kg Pu sphere of radius 4.5 cm reflected by 19.6 cm natural U),

higher orders of anisotropic scattering and angular flux approximations than P_1S_{16} are required in the ERANOS deterministic approach using finite difference discrete-ordinates.
Whereas detailed resonance calculations (e.g. using collision probabilities for thin regions) and large numbers of broad groups (e.g. 175) appear unimportant for these systems.

Flattop-Pu (Statistics and SERPENT-2 options)







Fair agreement between Serpent-2 and ERANOS.
The presence of low lethargy width intervals might results in spikes in the Serpent results due to low scoring efficiency. These spikes would largely disappear when the statistical uncertainty is reduced, though leading to large calculation times resulting from more than 1 billion particles being considered.
Mostly concerned are sensitivity coefficients to scattering cross-sections.

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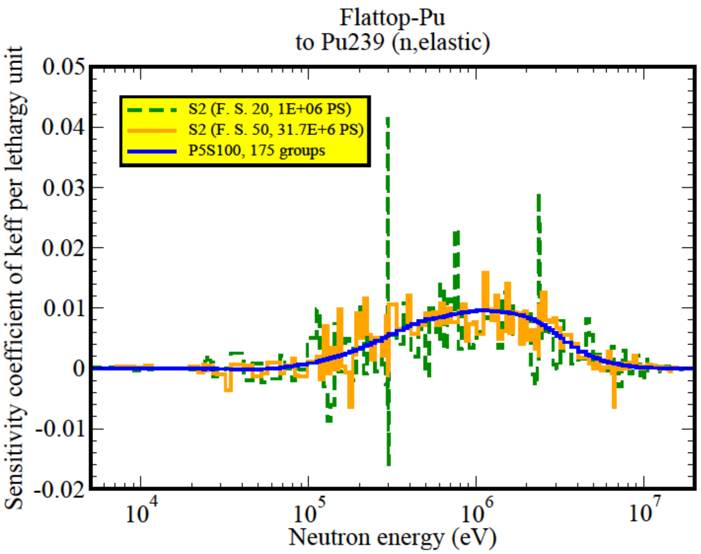
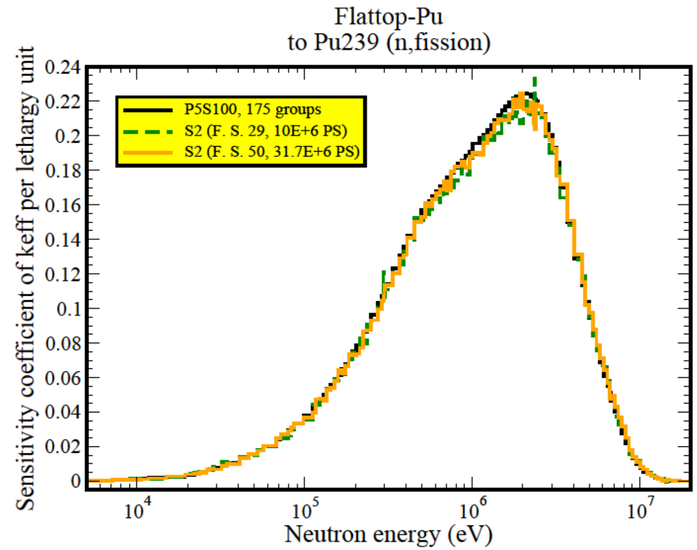
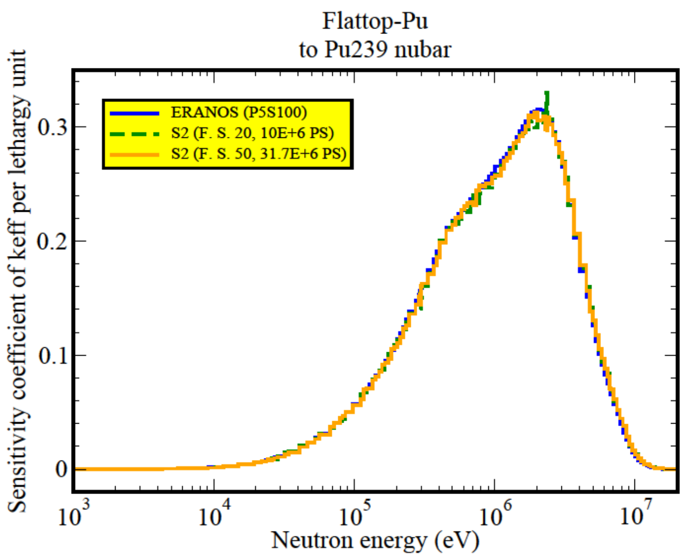
Flattop-Pu (Statistics and SERPENT-2 options)

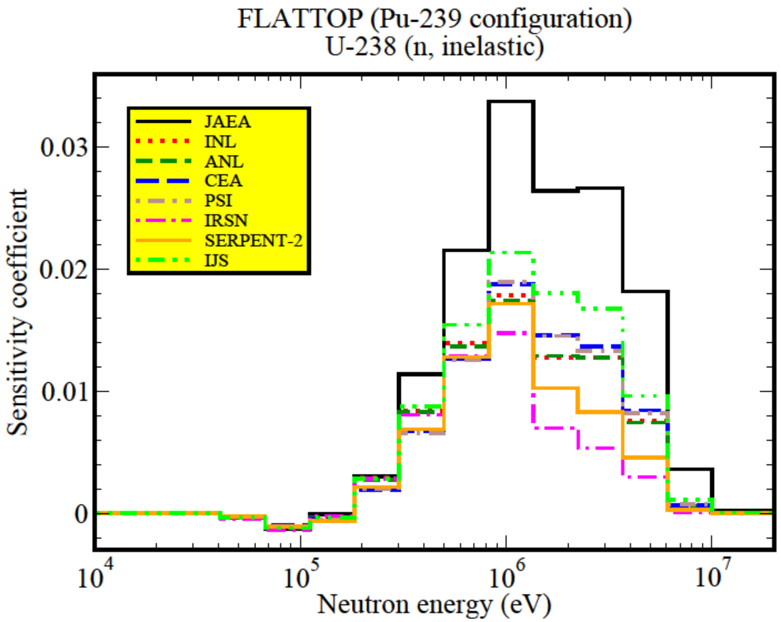


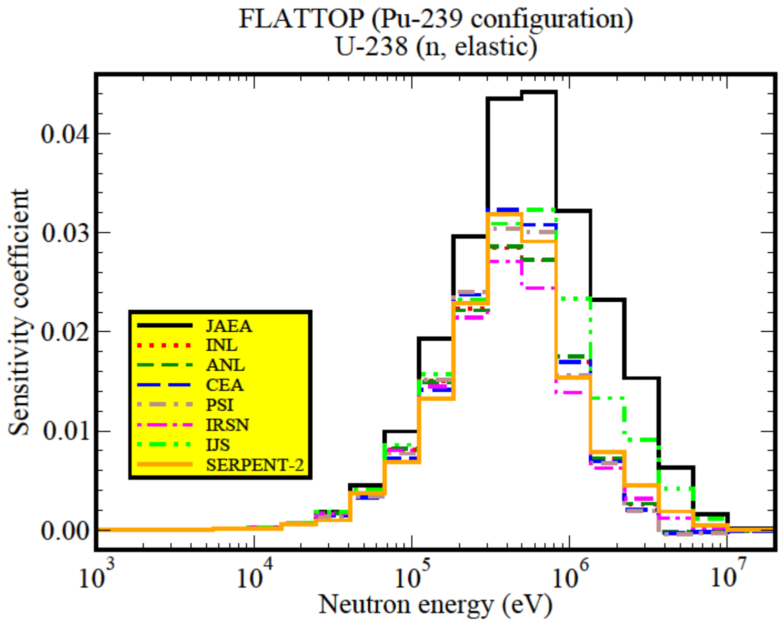




Whereas sensitivities to fission related cross-sections are by far less dependent on statistical accuracies and Serpent-2 options than are sensitivities to scattering cross-sections.

Flattop-Pu (SG33 comparison)

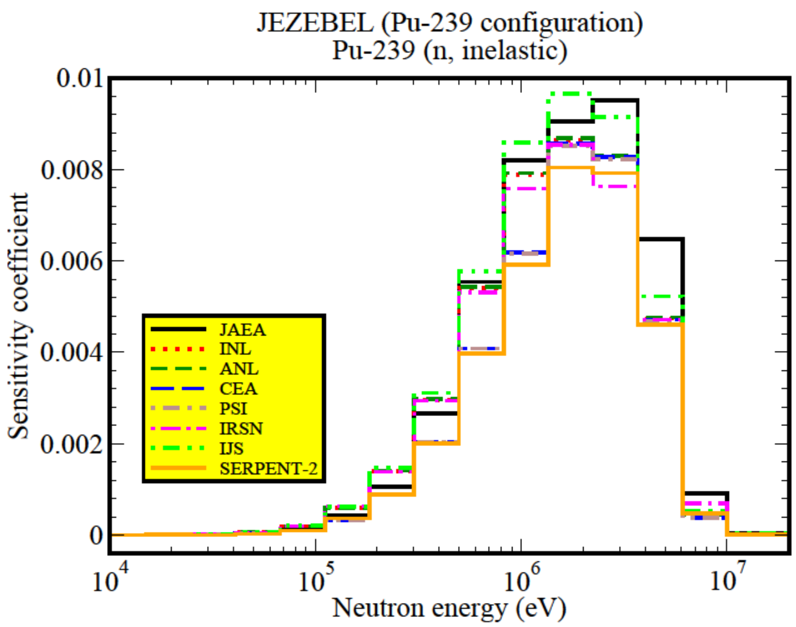


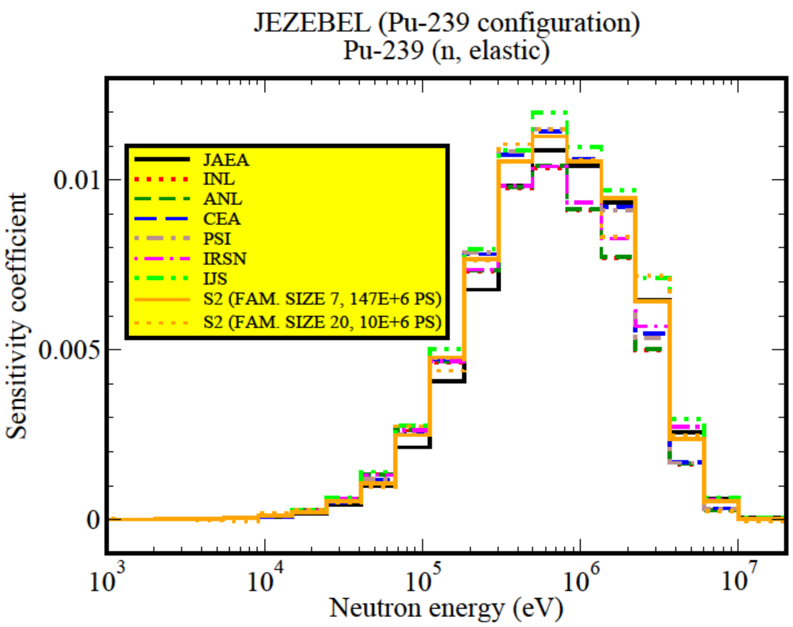


Fair agreement between Serpent-2 and TSUNAMI-3D despite the different libraries.

Agreement of the different ERANOS solutions. Disagreement with Serpent-2 in the fission source range due to the use of prescribed P_1S_4 approximations.

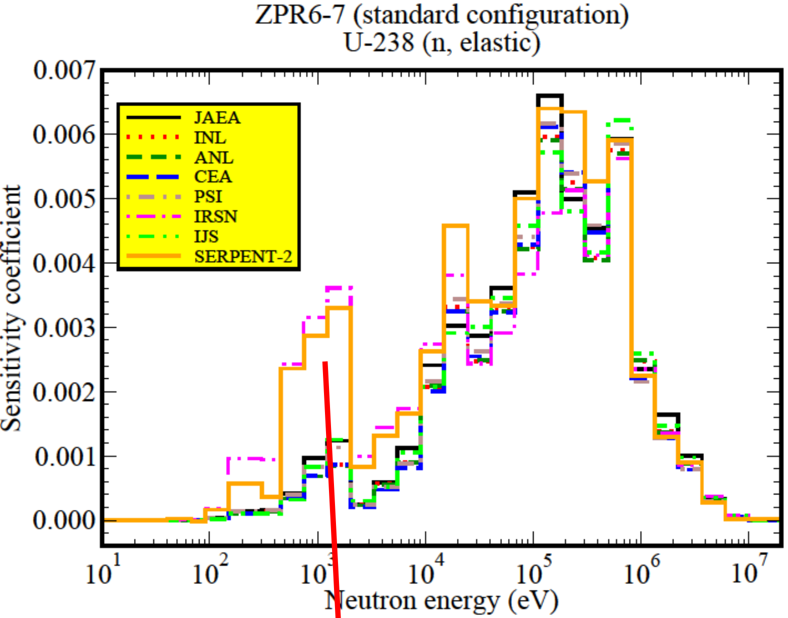
Jezebel-Pu239 (SG33 comparison)

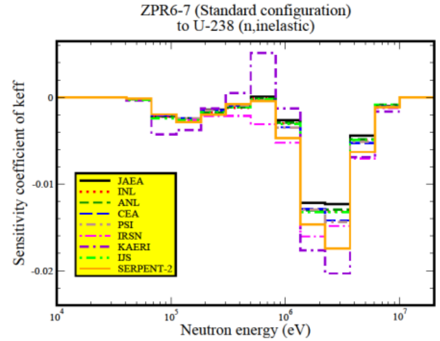


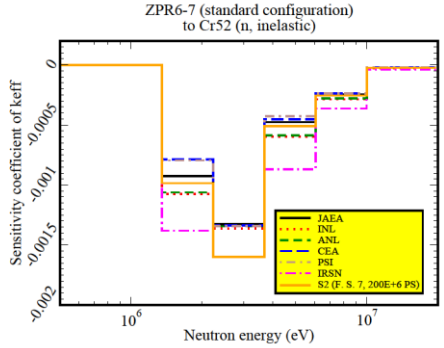


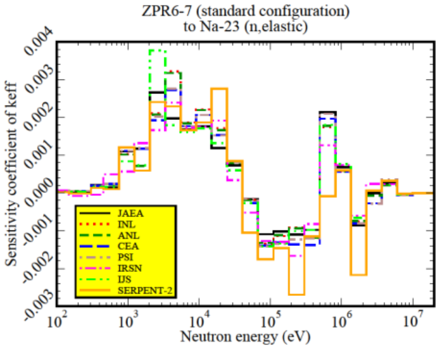
Similar findings as for Flattop-Pu. However, the differences are smaller.

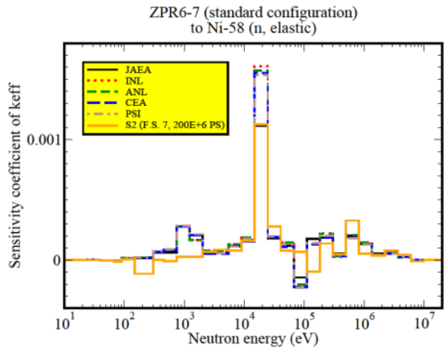
ZPR6-7 (SG33 comparison)











ZPR6-7: A large single zone sodium cooled MOX fueled core. Fair agreement between Serpent-2 and TSUNAMI-3D. There is a strong implicit effect around the sodium scattering resonances.