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PFNS uncertainties – the constrained sensitivity methodology

- **Ivo Kodeli**

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WPEC SG26: Uncertainty and Target Accuracy Assessment for Innovative Systems Using Recent Covariance Data Evaluations Co-ordinator: M. Salvatores

- NEA/WPEC-26, International Evaluation Co-operation Volume 26, Appendix C: Evaluation of Fission Spectra Uncertainty and their Propagation, I. Kodeli, M. Ishikawa, G. Aliberti, OECD 2008.
- I. Kodeli, A. Trkov, R. Capote, Y. Nagaya, V. Maslov, Evaluation and Use of the Prompt Fission Neutron Spectrum and Spectra Covariance Matrices in Criticality and Shielding, Nuclear Instruments and Methods in Physics Research A 610 (2009) 540-552, (doi :10.1016/j.nima.2009.08.076).
- Y. Nagaya, I. Kodeli, G. Chiba, M. Ishikawa, Evaluation of sensitivity coefficients of effective multiplication factor with respect to prompt fission neutron spectrum, Nuclear Inst. and Methods in Physics Research, A 603 (2009) 485-490.
- I. Kodeli, On the Equivalence between the SAGEP Sensitivity Method and the ENDF-102 Formalism for the ‘Correction’ of Fission Spectra Covariance Matrix (NEA DB Note, Nov. 2007)

Data Formats for Cross Section Covariances in Evaluated Data Files

- ***MF*=31:** covariance of average number of neutrons per fission (ν - MT=452, 455, 456)
- ***MF*=32:** Shape and area of individual resonances
- ***MF*=33:** covariance of neutron cross section
- ***MF*=34:** covariance of angular distribution of secondary neutron (currently MT=2/P_1 only)
- ***MF*=35:** covariance of energy distribution of secondary particles (currently MT=18 only)

No processing available:

- ***MF*=30**: Covariances obtained from parameter covariances and sensitivities
- ***MF*=40**: Covariances for production of radioactive nuclei

Processing available (NJOY-ERROR, PUFF, Frendy)

Prompt fission neutron spectrum properties

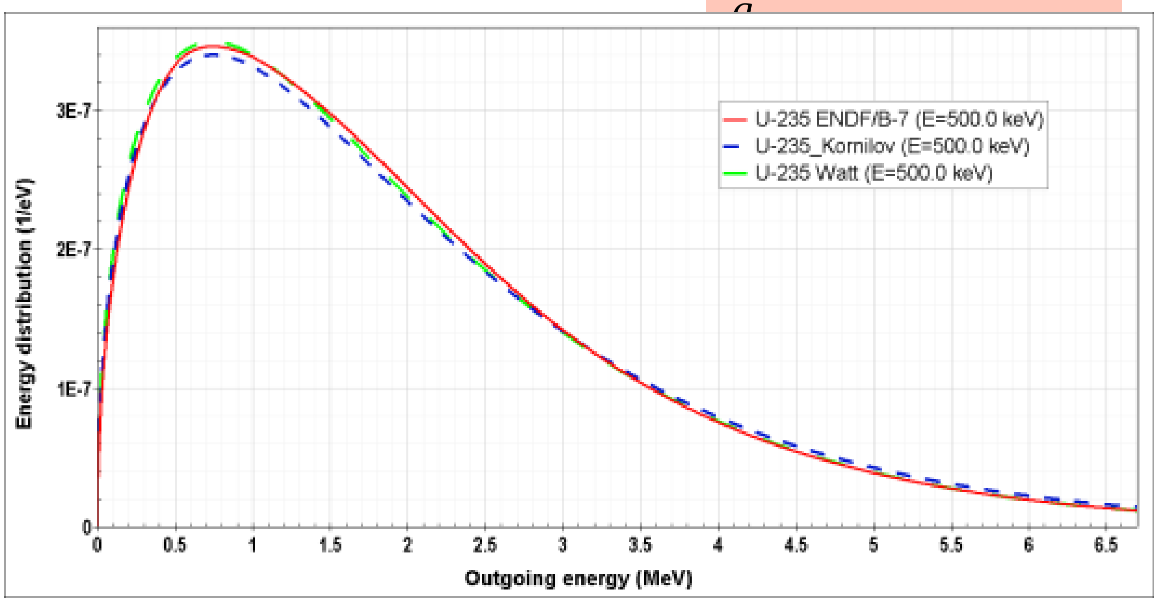
- Fission spectrum is normalised to 1
  sum of bin probabilities equals 1:

$$\sum_g \chi_g = 1$$

- To assure that the perturbed spectrum remains normalised the covariance matrix should comply with the «zero sum» rule: sum of abolute matrix elements in each line and column must be zero:

$$\sum_g \overline{\delta\chi_g \delta\chi_{g'}} = 0$$

- Covariances are given the bin probabilities (not distributions)



Normalisation applied to sensitivity coefficients

- If the matrix does not sattisfy the "zero sum" rule, the ENDF-6 manual suggests the correction formula:

$$\tilde{V}_{i,j} = V_{i,j} - \chi_i \sum_k V_{k,j} - \chi_j \sum_k V_{k,i} + \chi_i \chi_j \sum_{k,k'} V_{k,k'}$$

or in matrix notation: $\tilde{V} = S_\chi^t \cdot V \cdot S_\chi$ $\quad S_{g,g'}^{\chi} = \delta_{g,g'} - \chi_{g'}$

- Instead of "correcting" the matrices, we can apply the «correction» to the sensitivities :

$$(\Delta R)^2 = S_R^t \cdot \tilde{V} \cdot S_R = S_R^t \cdot \left(S_\chi^t \cdot V \cdot S_\chi\right) \cdot S_R$$

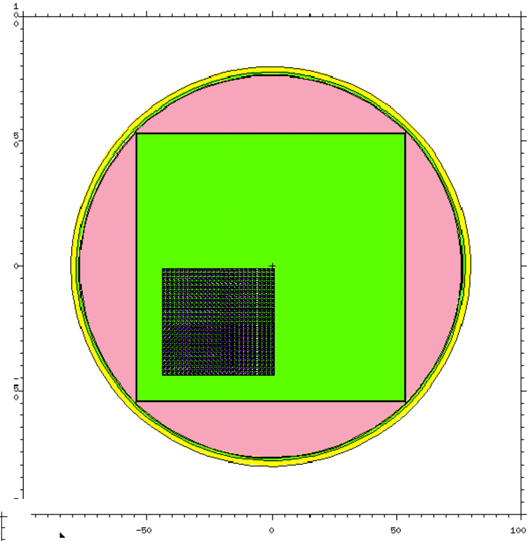
$$= \left(S_\chi \cdot S_R\right)^t \cdot V \cdot S_\chi \cdot S_R = S_{RN}^t \cdot V \cdot S_{RN}$$

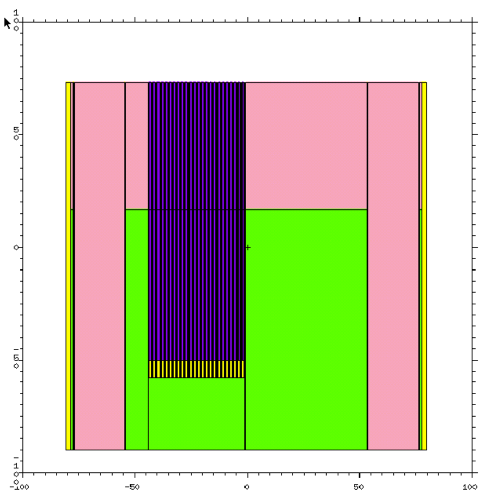
Constrained sensitivities

SAGEP, SUSD3D

IRPhE-International Reactor Physics Experiments Database (OCDE/AEN)

KRITZ-2 – expériences thermiques
6 configurations critiques avec combustibles UO2 et MOX.





SNEAK-7 – expériences rapides
2 configurations MOX

SNEAK-LMFR-EXP-001
CRIT-SPEC-COEF-KIN-RRATE-MISC

SNEAK 7A AND 7B
PU-FUELLED FAST CRITICAL ASSEMBLIES IN THE KARLSRUHE FAST CRITICAL FACILITY

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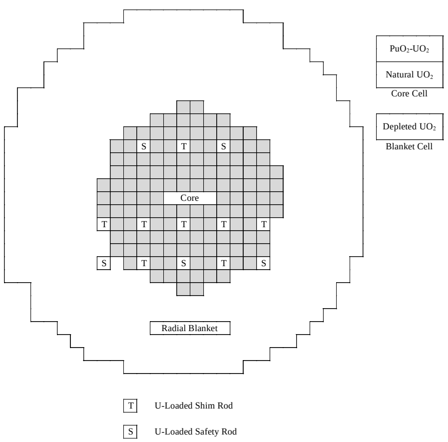
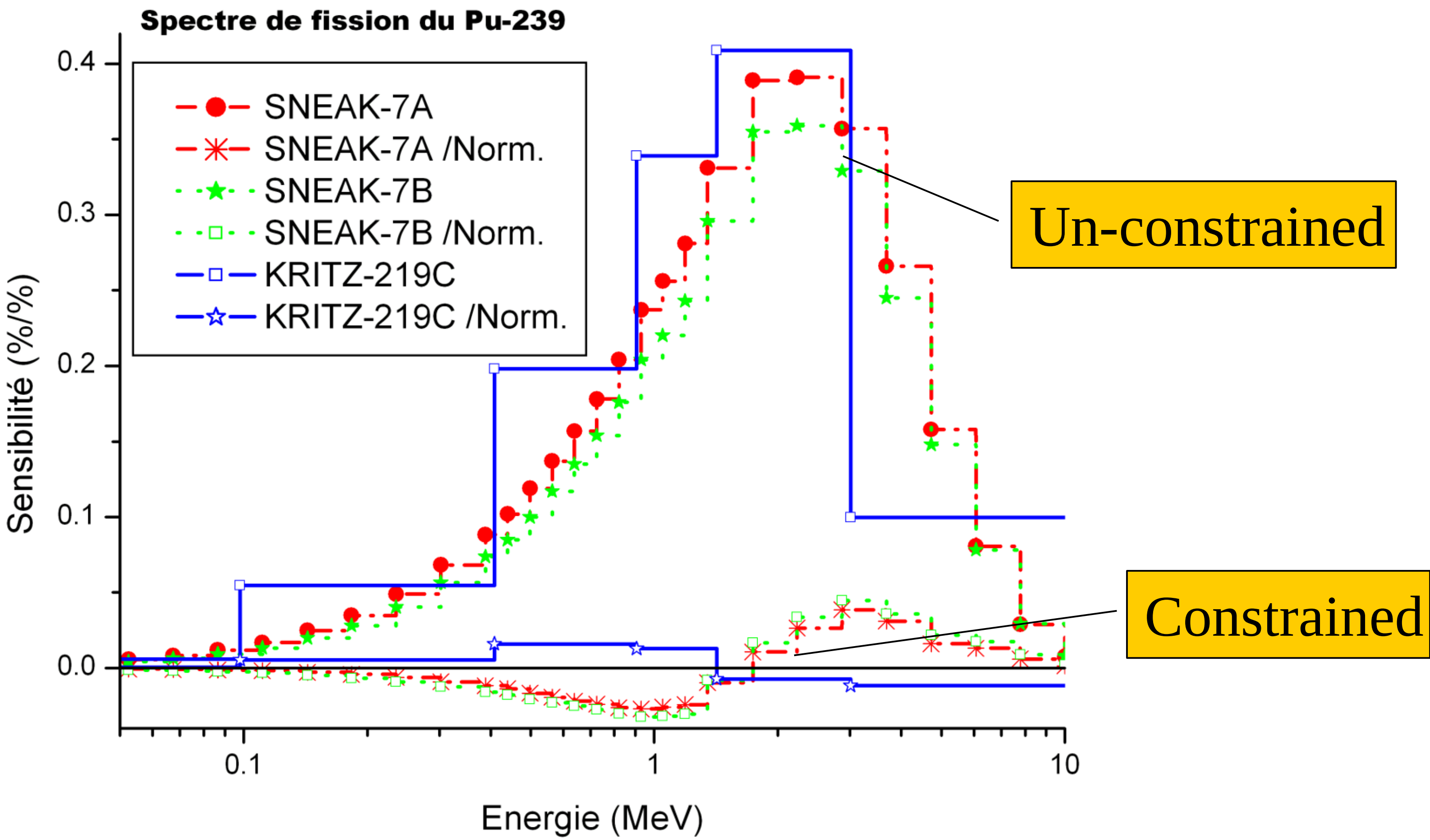


Études basées sur les calculs de transport déterministes (TWODANT, THREEDANT) et de sensibilité & d’incertitude (SUSD3D)

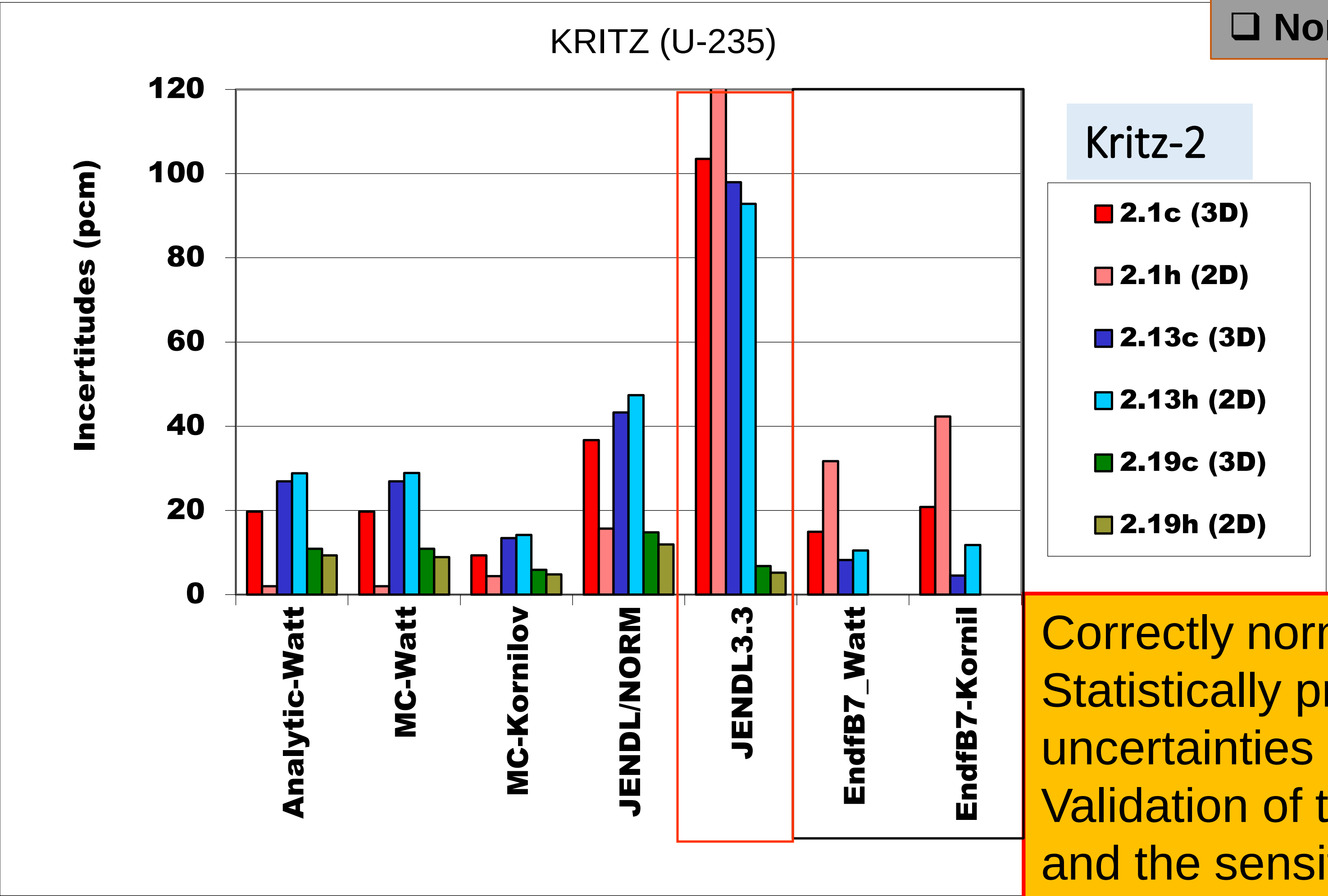
Constrained and un-constrained sensitivities



Uncertainty in *k-eff* (pcm) due to U-235 fission spectra uncertainty (KRITZ)

Covariance matrices
- ❑ ***Analytic-Watt***
- ❑ ***MC-Watt***
- ❑ ***MC-Kornilov***
- ❑ ***JENDL3.3***

Sensitivities
- ❑ **Normalised**
- ❑ **Non-normalised**



Correctly normalised matrices; Statistically probable uncertainties ; Validation of the MC method and the sensitivity method.

Conclusions & recommendation

- **“Constrained” sensitivity method** was recommended in the scope of WPEC-SG26. **Constrained sensitivity method has the merit to provide correct results even for incorrectly normalized SED covariance matrices.** Incorrectly normalised matrices can be detected comparing the uncertainties based on “normalised” and “un-normalised” sensitivities.
- **However:** PFNS are needed to calculate the constrained sensitivity vector therefore these sensitivities are only valid for the selected PFNS evaluation. Renormalisation of the sensitivities to different PFNS would require in addition the information on the PFNS used as a constraint;
- **Recommendation: unconstrained PFNS sensitivities, which are PFNS independent, should be stored in the international sensitivity profile databases, rather than constrained one. Users of the data should constraint the sensitivity using his own PFNS.**