STEK experiment Opportunity for Validation of Fission Products Nuclear Data

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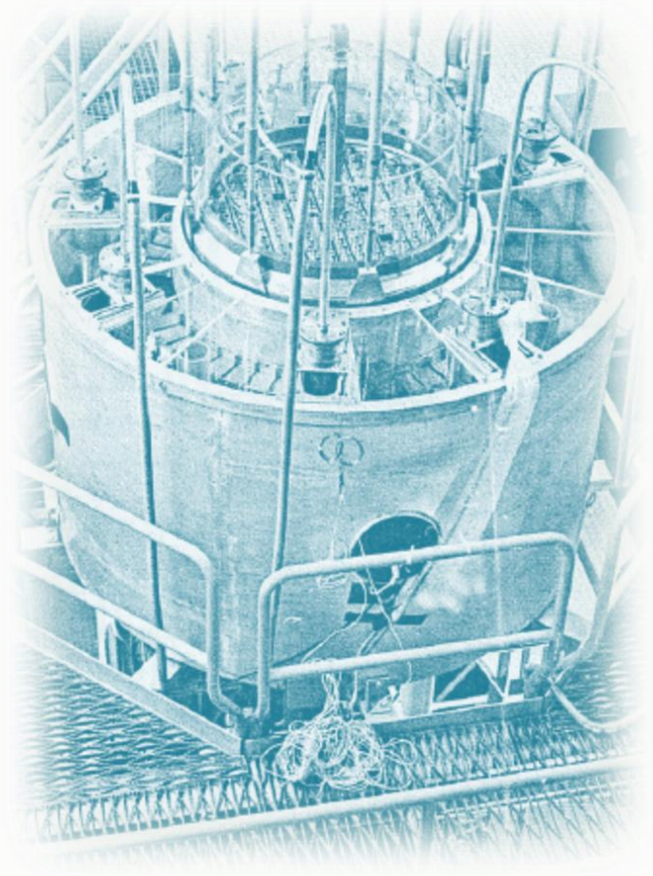
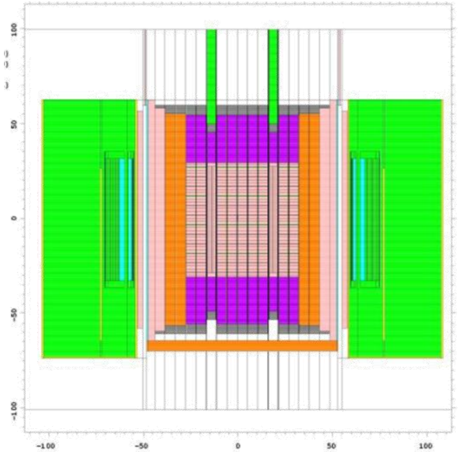


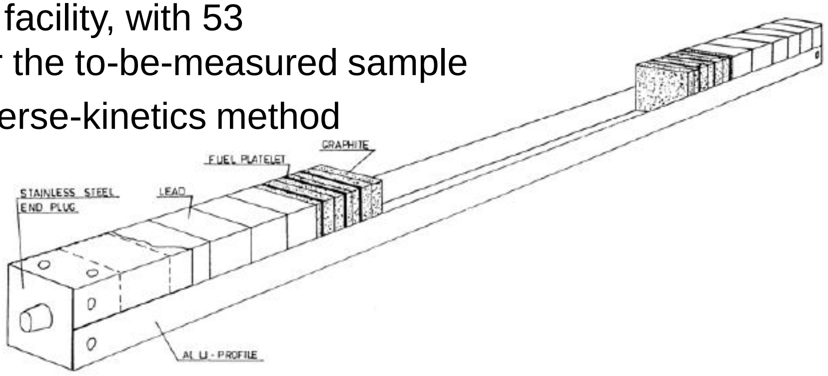
Introduction

- ✓ **<u>STEK (Fast Thermal Experiment in KRITO)</u>:**
  - Fast-thermal coupled critical facility, built by RCN (The Netherlands)
  - Operated at ECN from 1969 to 1973
  - Main goal: measure integral cross sections of fission products and validate nuclear data evaluations
  - Reactivity effect of fission products plays an important role in the development of fast reactors with extended burnup. Fission products are one of the sources of inaccuracies in the prediction of their behavior
  - Measurements of reactivity worth of most important fission products in fast neutron spectra
  - 5 different cores: STEK-500, -1000, -2000, -3000, and -4000 (decreasing order of spectrum hardness)
- ✓ **Current study has as ultimate goal the improvement of the quality of the nuclear data for the important fission products**
- ✓ **Multi-year program ongoing at NRG, Petten**

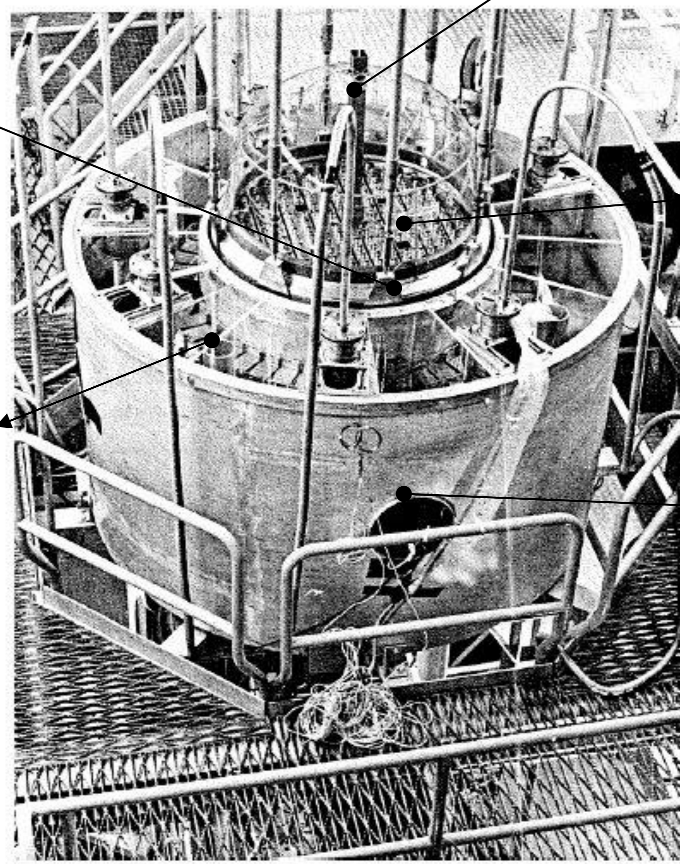


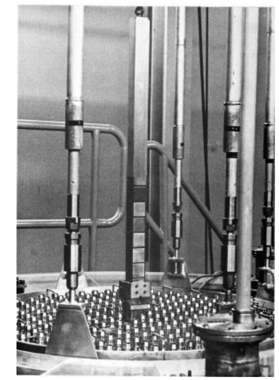
STEK facility

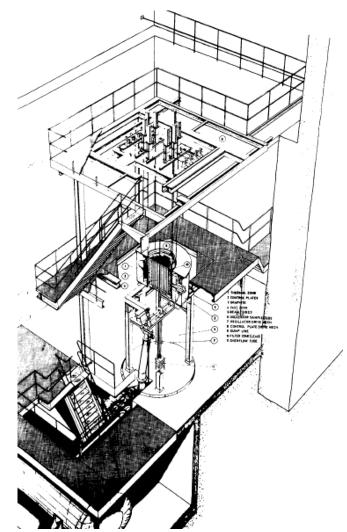
- ✓ Co-operation between the German Federal Republic, Belgium and The Netherlands on research of FBR
- ✓ Unique experiment with a comprehensive list (~ 115 samples) of fission products (and other materials) measured at 5 different core configurations
- ✓ **Central zone**: fast zone with fuel elements constituted of pile-up of graphite and enriched Uranium (90%) platelets, surrounded by lead and graphite elements
- ✓ **Outer zone**: thermal zone with MTR fuel elements submerged in water
- ✓ Centre fuel element replaced by an **oscillator element**, containing the sample to be measured
- ✓ **Reactivity control**: by 8 control plates (Al-B_4C) placed between the central and the outer zones. 4 safety rods placed in the fast zone.
- ✓ **Oscillator element**: placed at the center of the facility, with 53 compartments, either filled with core material or the to-be-measured sample
- ✓ Sample reactivity worths obtained using the inverse-kinetics method



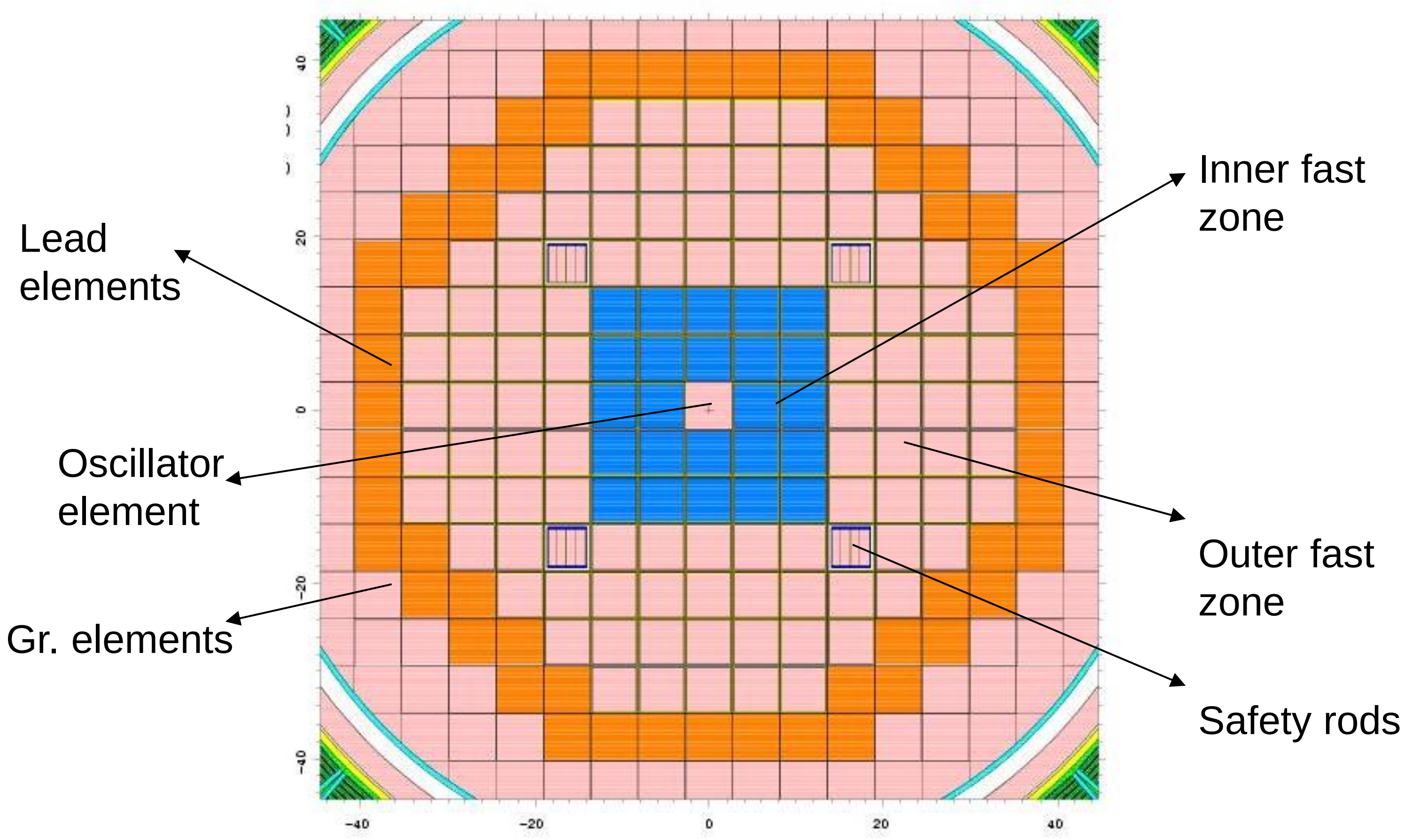
STEK facility (2)





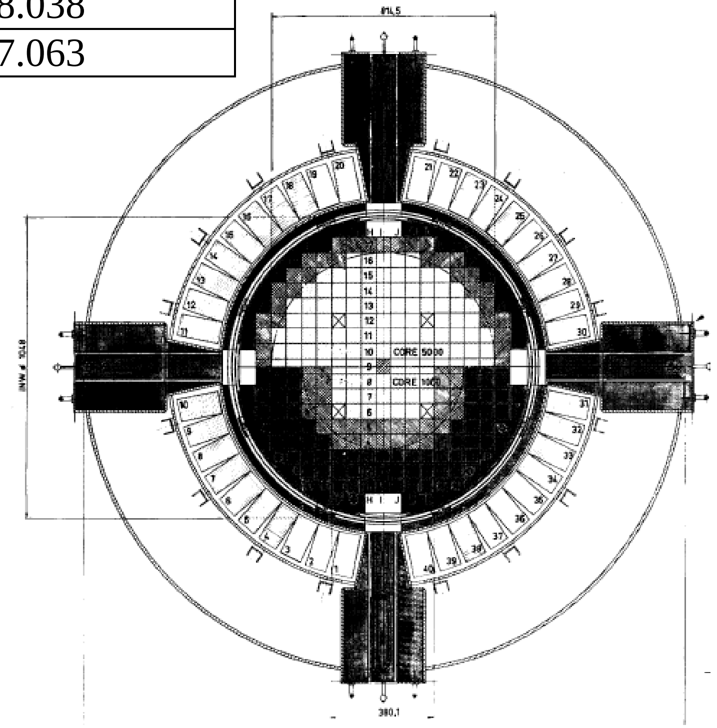


Central Fast Fuel Zone

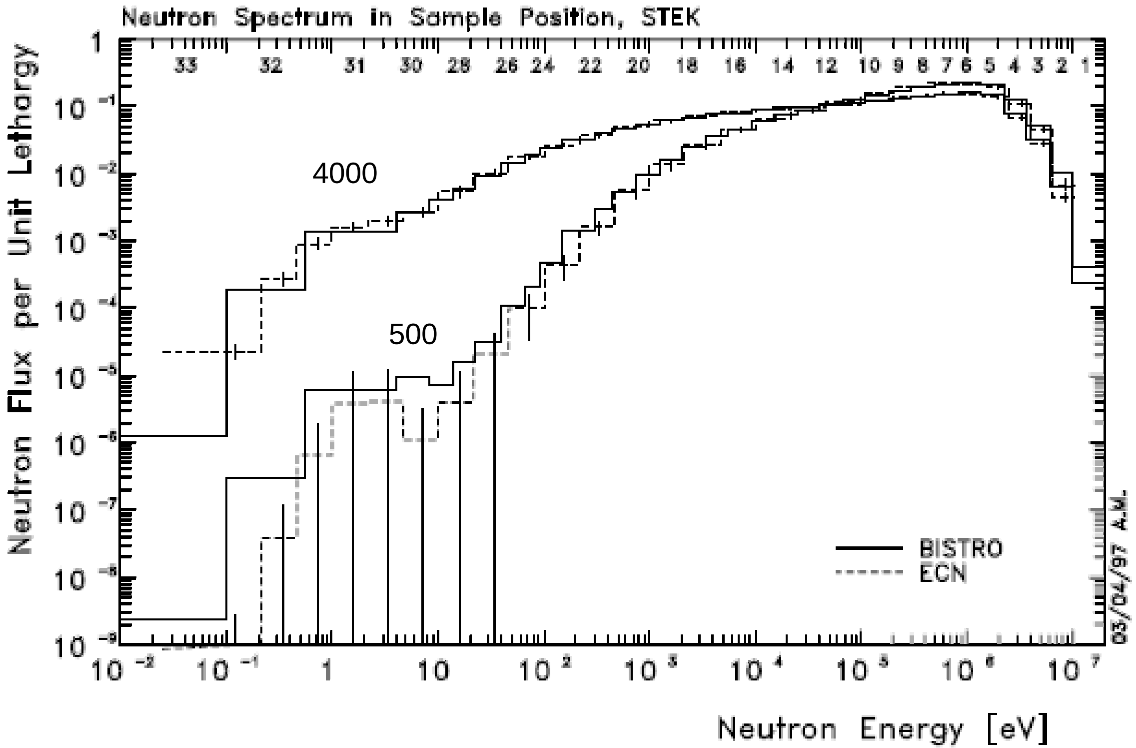


Core Configurations

Configuration	*C / ^{235}U atomic ratio*	*Mass ^{235}U –fast core [kg]*
STEK-4000	72	89.693
STEK-3000	48	95.044
STEK-2000	35	92.164
STEK-1000	23	88.038
STEK-500	11	77.063



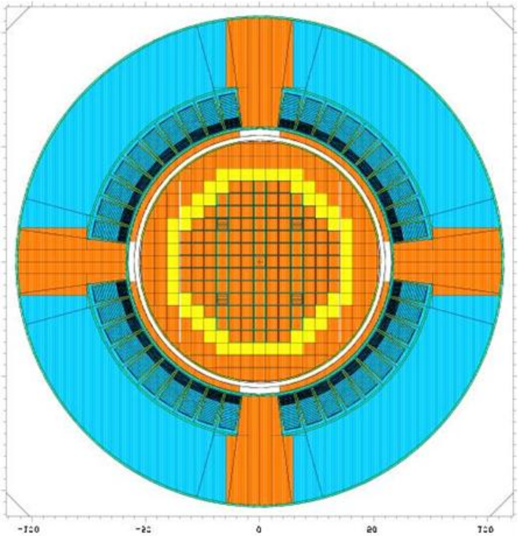
Neutron flux spectrum



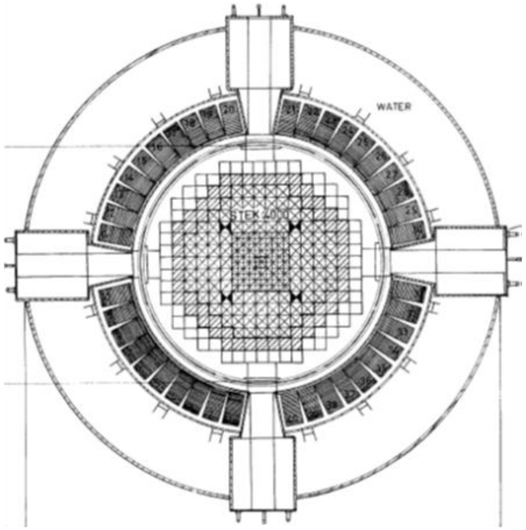
Ref: NT-97224, A. Meister and G. Rimpault

Calculation Tools and Modeling

MCNPX model

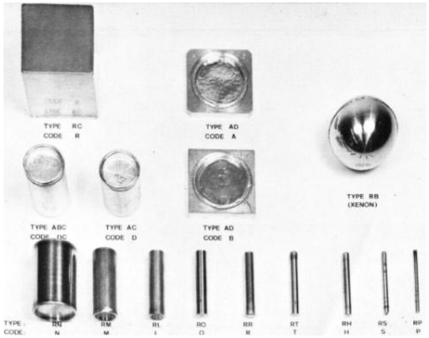


Technical Drawing



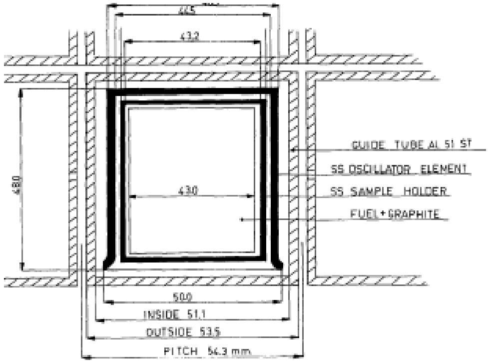
- MCNPX version 2.7 transport code, run under MPI
- Nuclear data taken from JEFF3.1 evaluation library, except for the measured samples
- Differential method used to calculate the samples reactivity worth

Results - Samples



Main isotope	*Chemical compound*	*Physical shape*	*Isotopic composition*	*Weight [g]*
C	C	platelets	natural	92.4408
In	In	plates	natural	39.7639
Eu	Eu_2O_3 Eu: 86.36 w%	powder	natural	3.0100
Tc-99	Tc	powder	100% Tc-99	1.8934
Nd-145	Nd_2O_3	powder	91.82% Nd-145	2.5292
Pr-141	Pr_6O_{11}	powder	100% Pr-141	25.8065

- ✓ Samples selected based on its high reactivity value
- ✓ Simulated using differential method, two independent calculations with and without sample



Results – Different Evaluations

	Europium			*Indium*			*Carbon*		
	TENDL	ENDF	JEFF3.1	TENDL	ENDF	JEFF3.1	TENDL	ENDF	JEFF3.1
Δρ-cal [pcm]	**-14 +/- 3**	**-14 +/- 3**	**-20 +/- 3**	**-28 +/- 3**	**-29 +/- 3**	**-21 +/- 3**	**----**	**+13 +/- 3**	**+8 +/- 3**
Δρ-exp [pcm]	-13.2 (0.1%)			-23.8 (0.1%)			+13.09 (0.6%)		
C/E	**1.1 ± 0.2**	**1.1 ± 0.2**	**1.5 ± 0.2**	**1.2 ± 0.1**	**1.2 ± 0.1**	**0.9 ± 0.2**	**-----**	**1.0 ± 0.2**	**0.6 ± 0.2**

	Technetium-99	
	TENDL-2013	JEFF3.1
Δρ-cal [pcm]	**-2.1 +/- 0.9**	**-1.8 +/- 0.5**
Δρ-exp [pcm]	–1.62 (1%)	
C/E	**1.3 ± 0.5**	**1.12 ± 0.31**

- ✓ Simulated for STEK-4000 core configuration
- ✓ Eu sample: TENDL-2011 and ENDF/B.VII.0 give better agreement with experiment
- ✓ In sample: JEFF3.1 data seems to perform better
- ✓ C sample: no data file is available in TENDL-2011, and clearly the data from ENDF/B.VII.0 gives better results
- ✓ Tc-99 sample: results in good agreement with both libraries, considering the large standard deviations

Results – Different Configurations

Europium sample

	STEK-4000	*STEK-3000*	*STEK-2000*	*STEK-1000*	*STEK-500*
Δρ-cal [pcm]	**-20 +/- 3**	**-11.0 +/- 1.4**	**-5.0 +/- 1.4**	**-4.0 +/- 1.4**	**-2.0 +/- 0.7**
Δρ-exp [pcm]	-13.2 (0.1%)	-10.0 (0.22%)	-8.2 (0.26%)	-5.9 (0.28%)	-2.9 (0.75%)
C/E	1.5 ± **0.2**	1.1 ± **0.1**	0.6 ± **0.2**	0.7 ± **0.2**	0.7 ± **0.2**

- ✓ JEFF3.1 data for Eu sample
- ✓ Decreasing reactivity worth with hardness of spectrum
- ✓ Not a good agreement between calculated and experimental values, except for STEK-3000
- ✓ These values can give important information for nuclear data evaluators to adjust the slope of the capture cross section. C/E values give indication of data quality in a specific energy range.

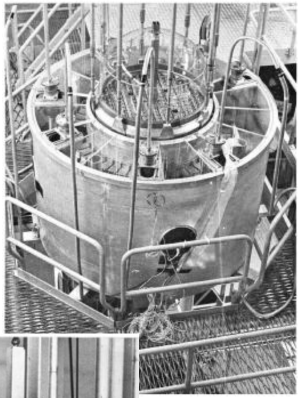
NRG

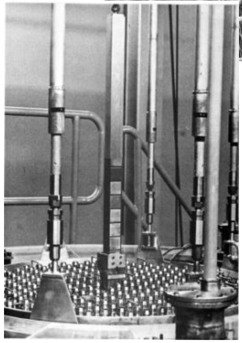
Simulation performance

- ✓ MCNPX run under MPI or independently in multiple processors
- ✓ Due to the complexity of the model the runs are long
- ✓ As a rule of thumb: 350 AMD processors (of ~ 2.2 GHz) required for a statistical uncertainty of 0.25 pcm within a running period of 6 days

Conclusions and prospects

- ✓ STEK experiment offers unique opportunity to improve nuclear data evaluation for fission products
- ✓ All five core configurations were modeled in MCNPX
- ✓ MCNPX could be run under MPI or in independently in multiprocessors, which reduced substantially the runtime
- ✓ Reactivity worth caused by Carbon, Indium, Europium and ^{99}Tc samples were simulated, using nuclear data from : TENDL-2011(3), ENDF-B.VII, and JEFF3.1. Differences were found between the evaluations
- ✓ Eu sample simulated for the 5 core configurations, using the JEFF3.1 data. C/E values vary between 0.6 and 1.5, and the best agreement is found for the STEK-3000 configuration
- ✓ Results could give important information to the evaluators to try to improve the nuclear data for this element
- ✓ Runtime remains an issue if the model is used for evaluation work of some fission products with a very low reactivity effect
- ✓ In a follow-up of this study a STEK model will be developed using the DRAGON code, and possibly in combination with DONJON





Thank you !