STEK and SEG expriments: Analysis available in several documents, in particular at CEA-Cadarache and at former JNC

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Integral Test of Neutron Data and Comparison of Codes by Re-analysis of the SEG and STEK Experiments

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Integral Test of JENDL-3.2 Data by Re-analysis of Sample Reactivity Measurements at Fast Critical Facilities

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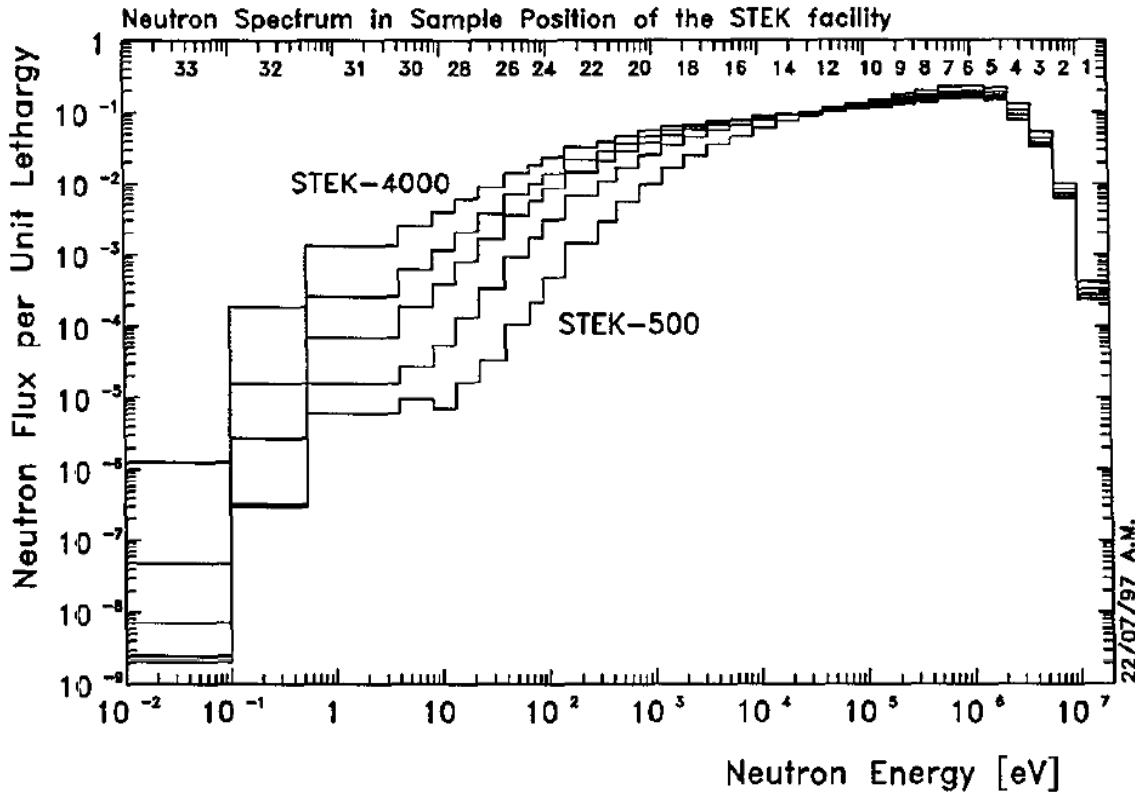
The STEK experiments

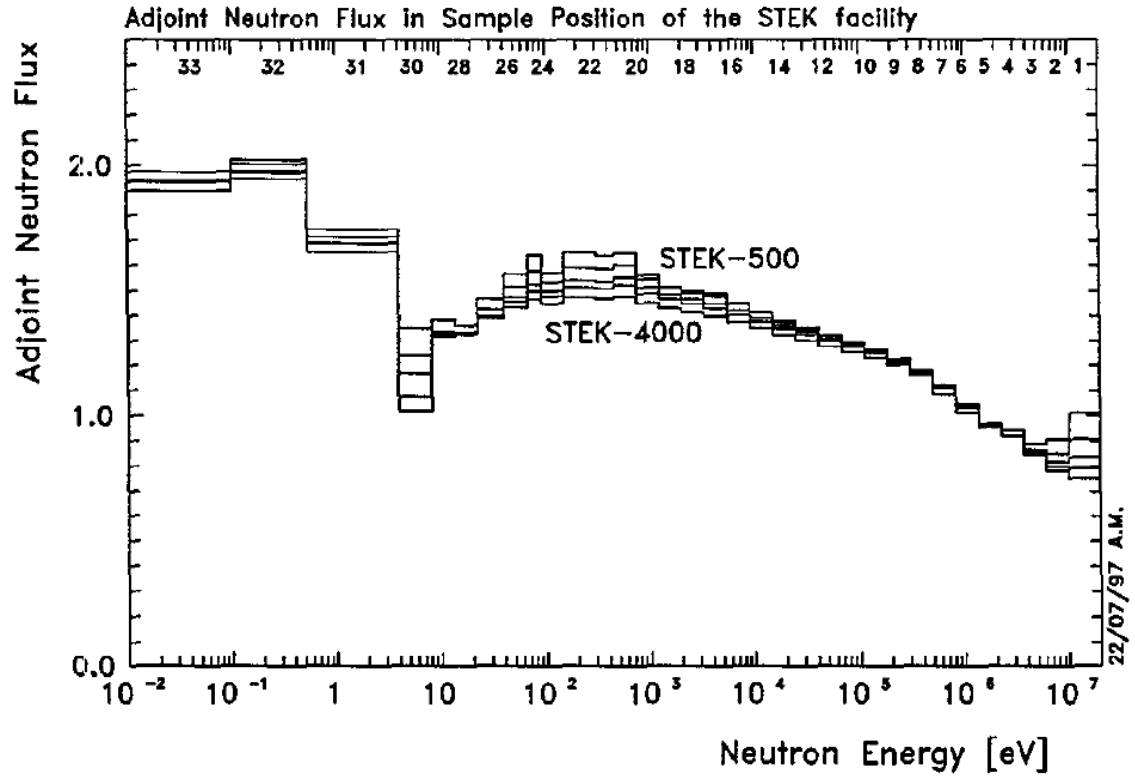
The STEK-experiments have been performed to check neutron data of the most important reactor materials, especially of fission product nuclides, fuel isotopes and structural materials. The measured central reactivity worths (CRW) of small samples were compared with calculated values. These C/E-ratios have been used then for data corrections or in adjustment procedures.

The reactors STEK (ECN Petten/ Netherlands) was a fast-thermal coupled facility of zero power. The annular thermal drivers were filled by fuel assemblies and moderated by water. The inner insertion lattices were loaded with pellets of fuel and other materials producing the fast neutron flux. The characteristics of the neutron and adjoint spectra were obtained by special arrangements of these pellets in unit cells. In this way, a hard or soft neutron spectrum or a special energy behavior of the adjoint function could be reached. The samples were moved by means of tubes to the central position (pile-oscillation technique). The original information about the facility and measurements is compiled in RCN-209, ECN-10

The 5 STEK configurations cover a broad energy range due to their increasing softness. The experiments are very valuable because of the extensive program of sample reactivity measurements with many fission product nuclides important in reactor burn-up calculations.

At first, analyses of the experiments have been performed in Petten. Newer analyses were done later in Cadarache / CEA France using the European scheme for reactor calculation JEF-2.2 / ECCO / ERANOS (see Note Techniques and JEF/DOC-746). Furthermore, re-analyses were performed in O-arai / JNC Japan with the JNC standard route JENDL-3.2 / SLAROM / CITATION / PERKY. Results obtained with both code systems and different data evaluations (JEF-2.2 and JENDL-3.2) are compared in JEF/DOC-861.


Neutron Spectrum in Sample Position of the STEK facility
Neutron Flux per Unit Lethargy
Neutron Energy [eV]
STEK-4000
STEK-500
22/07/97 A.M.


Adjoint Neutron Flux in Sample Position of the STEK facility
Adjoint Neutron Flux
Neutron Energy [eV]
STEK-500
STEK-4000
22/07/97 A.M.

Softest spectrum

Hardest spectrum

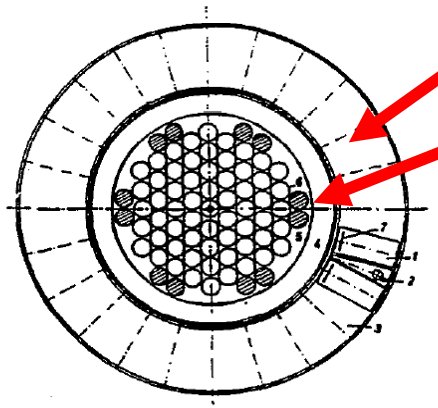
Table 6:
C/E-values of infinitely dilute sample reactivities in STEK, normalized to the C/E-value of boron-10, obtained with the JNC standard route in 70 energy groups

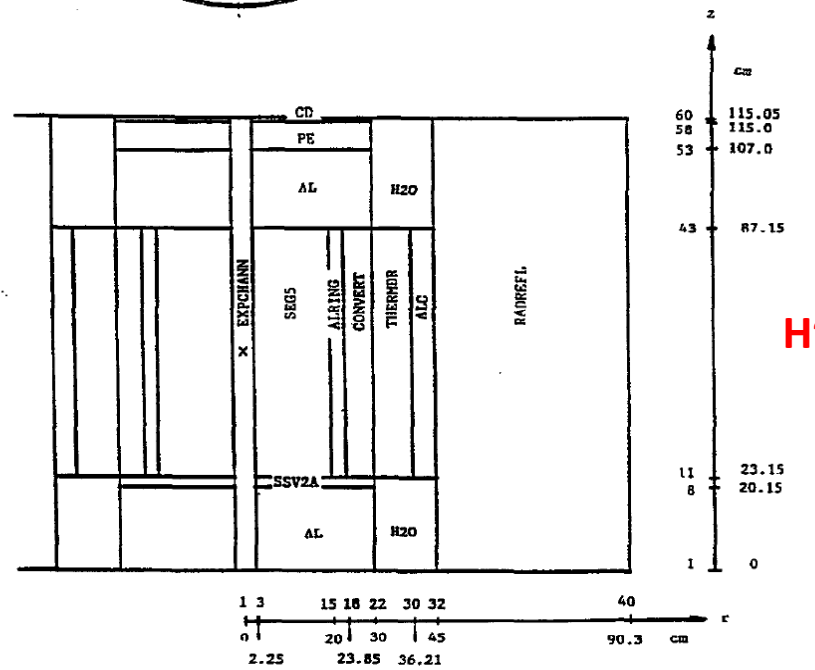
MAT	ID	STEK-4000	STEK-3000	STEK-2000	STEK-1000	STEK-500	Comment
B-10	105	1.00 ± 4%	1.00 ± 5%	1.00 ± 4%	1.00 ± 4%	1.00 ± 4%	Normalization
H	1	1.01 ± 7%	0.96 ± 6%	0.97 ± 6%	1.00 ± 5%	0.98 ± 6%	Standard
C	6	1.03 ± 5%	0.93 ± 6%	0.94 ± 8%	0.96 ± 6%	0.94 ± 6%	Standard
O	8	0.91 ±20%	0.96 ± 7%	0.93 ± 6%	0.96 ± 5%	1.01 ± 6%	
Al	13	1.05 ± 6%	0.97 ± 8%	0.99 ± 8%	1.06 ± 5%	1.07 ± 7%	
Si	**14**	**0.87 ± 6%**	**0.77 ±13%**	**0.78 ±12%**	**0.84 ± 6%**	-	**!**
Cl	17	1.09 ± 9%	1.13 ± 9%	1.32 ±12%	1.53 ±13%	1.11 ±14%	
V	**23**	x	**0.54 ± 8%**	**0.59 ± 8%**	**0.73 ± 8%**	-	**Small effect, !**
Cr	**24**	x	**0.41 ± 7%**	**0.47 ± 9%**	**0.56 ± 8%**	-	**Small effect, !**
Fe	**26**	x	**0.38 ±10%**	**0.50 ± 8%**	**0.70 ± 7%**	**0.86 ± 6%**	**Small effect, !**
Pb	**82**	**1.67 ± 7%**	**1.98 ± 9%**	**1.53 ±13%**	**1.55 ± 7%**	**1.72 ± 6%**	**Small effect, !**
Th-232	**902**	**1.64 ± 7%**	-	-	**1.32 ±10%**	-	**!**
U-235	925	1.09 ± 6%	0.98 ± 7%	0.96 ± 6%	1.00 ± 5%	1.01 ± 5%	Standard
U-236	926	1.27 ±12%	-	-	0.81 ±29%	-	
U-238	928	0.87 ±15%	0.90 ±20%	1.11 ±22%	1.41 ±24%	x	
Pu-239	949	1.13 ± 8%	0.94 ± 8%	0.96 ± 7%	1.01 ± 8%	1.03 ± 7%	
Pu-240	**940**	**1.62 ±20%**	**1.65 ±45%**	**1.28 ±53%**	x	-	**Large err., ?**

The ROSSENDORF experiments include sample reactivity measurements at the central position of the fast-thermal coupled system RRR/SEG, well described and documented now in /2/. The measurements are based on the pile-oscillator method developed to a high perfection.

Driver

Converter





H~60 cm

The general behaviour of the energy-dependent adjoint flux (neutron importance function) in fast systems is characterized by a depression in the energy region of about 10 keV and a more or less rapid increase to lower and higher energies, which in a rough approximation is due to the greater number of fission neutrons produced per neutron absorbed.

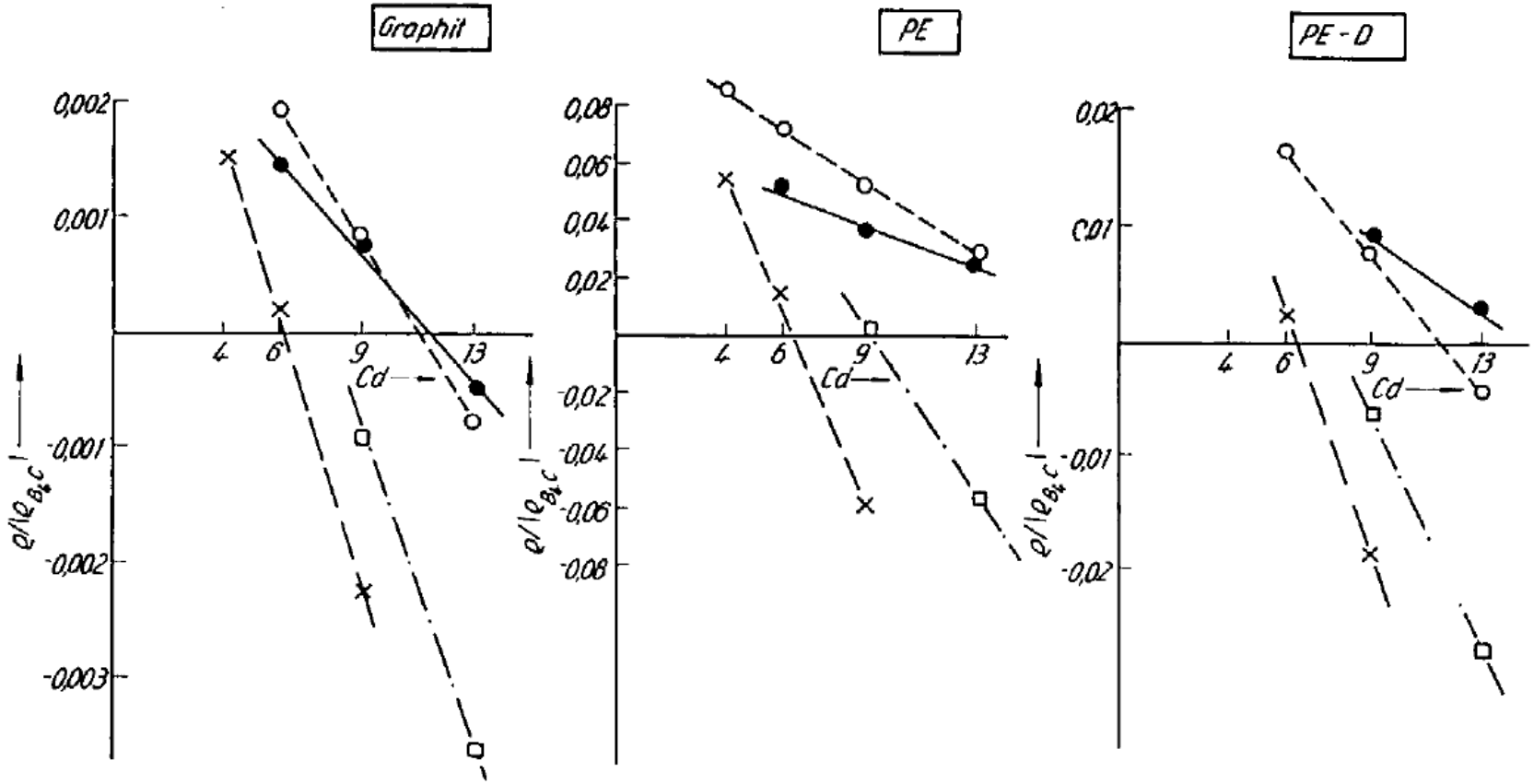
To lower the importance in the fast energy range the content of 238U in the system should be as low as possible.

Moreover, the neutron spectrum, which is a weight-function in the moderation term for the reactivity, is shifted to lower energies by a scattering material introduced into the system (in SEG: essentially graphite).

The growing increase of the neutron importance to lower energies is best compensated by poisoning the system with 1/v-absorber material (in SEG: Cd or B4C).

In the special case of a fast-thermal coupled system the choice of the buffer between the fast substituted lattice and the annular thermal driver zone is essential too. The best option is to replace natural uranium, which in general contributes to a better establishment of the equilibrium spectrum in the fast lattice, by a graphite buffer. In fact, such a converter will increase the importance of high energy neutrons.

Important information about the adjoint spectrum could be derived from the reactivity worth of graphite (G), polyethylene (PE), deuterized polyethylene (PED) and deuterized polystyrene (PSD), measured by means of the pile oscillator. In particular, the Cd amount can be optimized, in order to produce near zero reactivity of pure scatterer materials:



–●– Experiment; – – ○ – – KEDAK-3, FEDGROUP; – · – □ – · – ABBN-78; – · · – × – – *Bachmann* [9]

On the contrary to increase the slope of the adjoint flux e.g. at high energy, one should let fission neutrons in the system, avoiding any moderation process.
In order to get a high sensitivity of the reactivity measurements, the system has to contain a large amount of fissionable material.
Moreover, the importance of high energy neutrons is increased if ^{238}U with its fast fission behaviour is brought into the system.
Finally, low energy neutrons are avoided if a strong absorption material with 1/v-behaviour of its absorption cross-section is arranged in the vicinity of the measuring position.

The configuration SEG-6 represented an optimization of this different system components.
As shown in the figure, the matrix has in the center a homogenous cylinder containing an absorbing material. This separate component of the system is surrounded by 4 rings of channels. Each ring has 12 channels for the insertion of material pellets.
Whereas the inner ring is filled with uranium pellets (36% enriched in ^{235}U) the next 2 rings contain natural uranium.
Only the outer channels are occupied with aluminum pellets

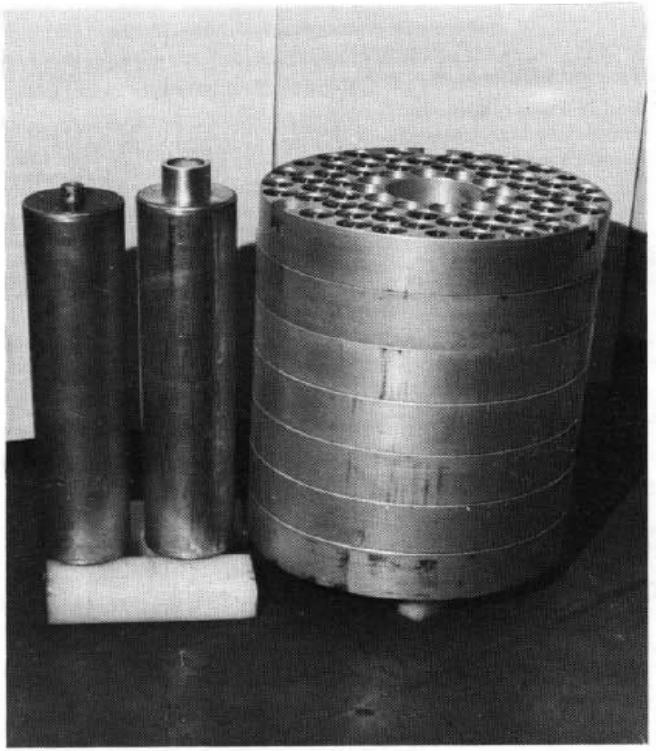


Fig. 1. The new aluminium matrix for the SEG-6 assembly in the RRR zero power reactor at the CINR

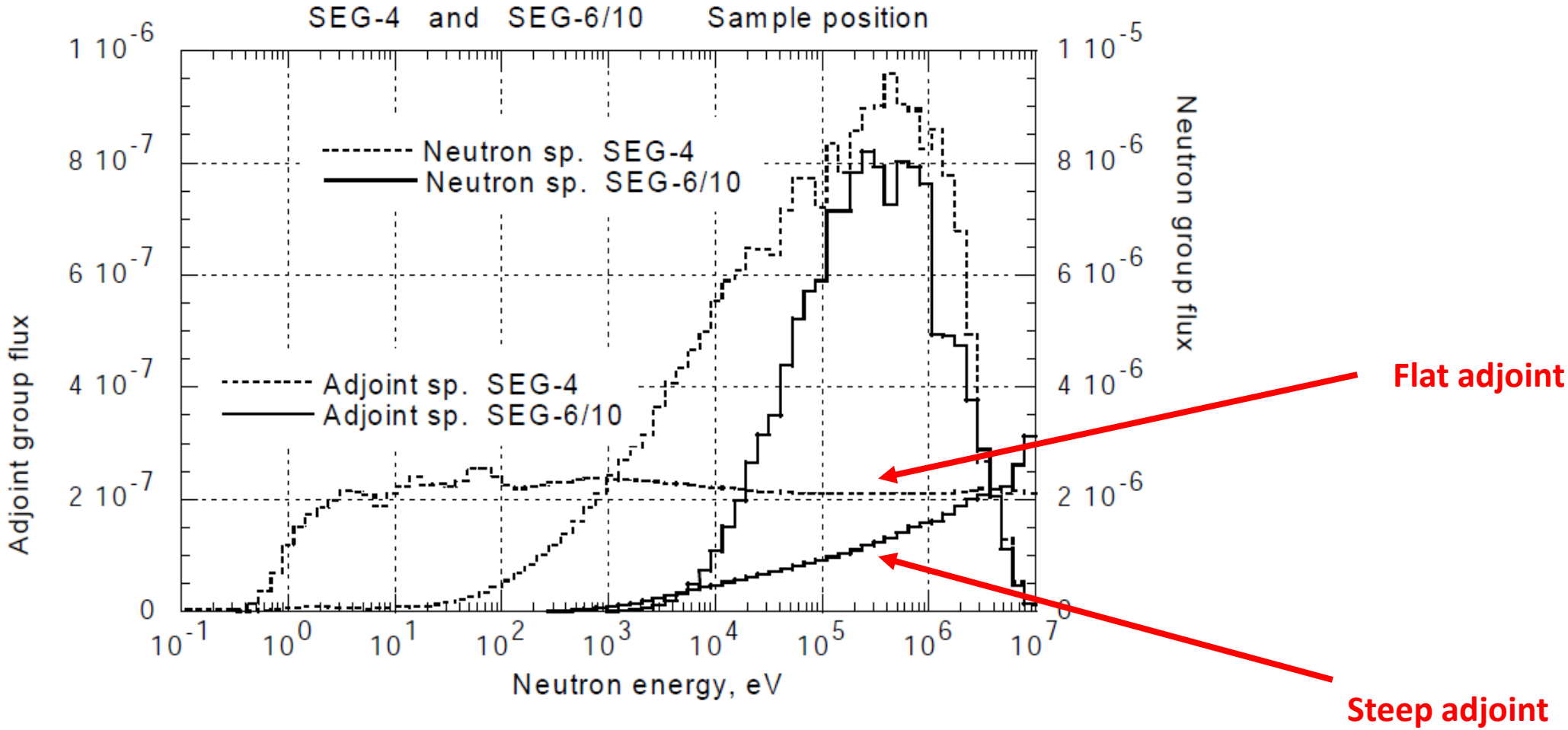

SEG-4 and SEG-6/10 Sample position
Neutron sp. SEG-4
Neutron sp. SEG-6/10
Adjoint sp. SEG-4
Adjoint sp. SEG-6/10
Adjoint group flux
Neutron group flux
Neutron energy, eV
1 10-6
8 10-7
6 10-7
4 10-7
2 10-7
0
1 10-5
8 10-6
6 10-6
4 10-6
2 10-6
0
10-1
100
101
102
103
104
105
106
107
Flat adjoint
Steep adjoint

Table 9:
C/E-values of infinitely dilute sample reactivities in SEG-6/45, normalized to the C/E-value of hydrogen (European scheme: graphite), obtained with the JNC standard route, the European scheme, and a cross-wise use of JEF-2.2 with JNC codes

Sample Material	ID-No.	C/E-values 70g JNC route JENDL/JNC codes	C/E-values 70g Cross-wise JEF/JNC codes	C/E-values 33g European scheme JEF/ECCO/ERANOS	Error (%)
H	1	1.000	1.000	1.071	5
C	6	0.918	0.959	1.000	8
B-10	105	**0.823**	**0.821**	0.896	12
Mo	42	0.935	0.898	0.913	7
Fe	26	**0.925**	0.952	**0.916**	7
U-235	925	0.898	0.907	0.978	7
U-238	928	0.906	0.881	0.923	12
Th	902	**0.858**	**0.832**	**0.865**	9

Both STEK and SEG experiments are very interesting from the physics point of view:

- **Systematically variable neutron spectrum hardness (STEK)**
- **Ad-hoc tailored adjoint flux shapes to reduce/amplify reactivity effects due to scattering (SEG)**

Mostly devoted to FP isotope data

Experiments not easy to analyse:

- **Thermal-fast coupled experiments**
- **Self-shielding effects**
- **Etc**

Experimental uncertainties sometimes significant:

- **Statistical**
- **Normalisation (usually a hard point)**

Results available could incite to revisit to some extent the analysis (any suggestions from the groups involved in previous analysis?): Oxygen, U-238