Wir schaffen Wissen – heute für morgen

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PROTEUS FDWR-II (HCLWR) program summary for SG-39; Preliminary Sensitivity Coefficient for Core 7, 8 & 9

Outline

FDWR Experiments at PROTEUS

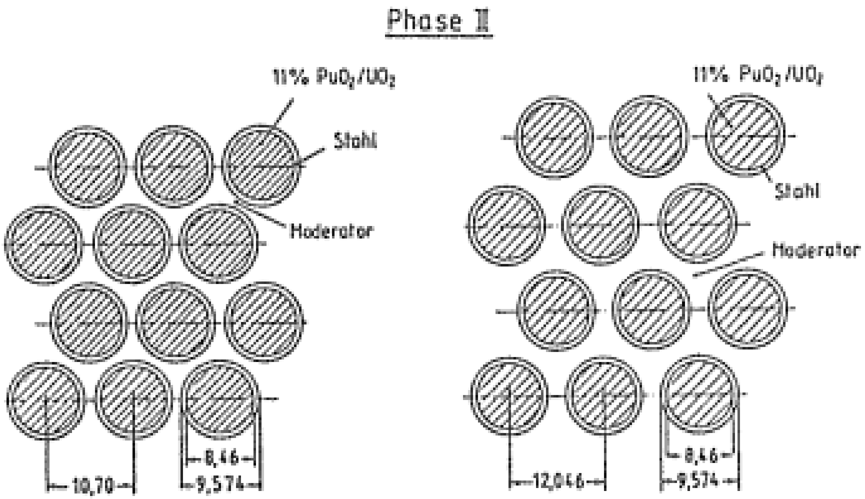
Computational Models of FDWR Experiments

- Selected C/E values for interesting configurations
- Spectrum information

Preliminary Sensitivity Results

Conclusion and where to go from here

FDWR-II – Experimental Configurations



Kern	p/d	V_M/V_F	Moderator	Eff. Moderation
7	1.12	0.48	H_2O	0.48
8	1.12	0.48	ohne	0.00
9	1.12	0.48	Dowtherm	0.28
10	1.12	0.48	Dowtherm	0.28
11	1.12	0.48	ohne	0.00
12	1.12	0.48	H_2O	0.48
13	1.26	0.95	H_2O	0.95
14	1.26	0.95	ohne	0.00
15	1.26	0.95	Dowtherm	0.55
16	1.26	0.95	H_2O	0.95
17	1.26	0.95	ohne	0.00
18	a)	2.07	H_2O	2.07
19	1.26	0.95	H_2O	0.95
20	1.26	0.95	D_2O	-

FDWR Phase II

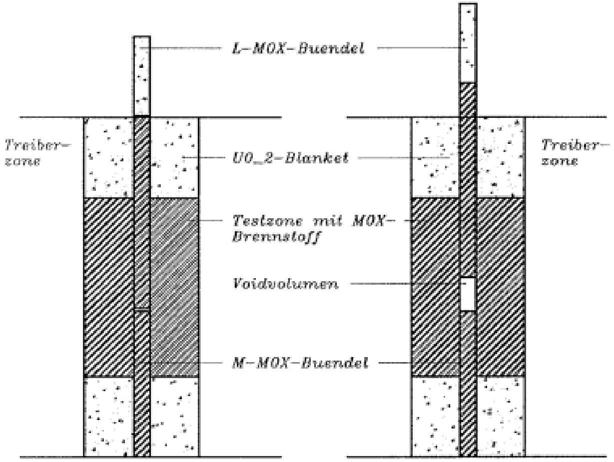
•From 1985 to 1990 in PROTEUS reactor

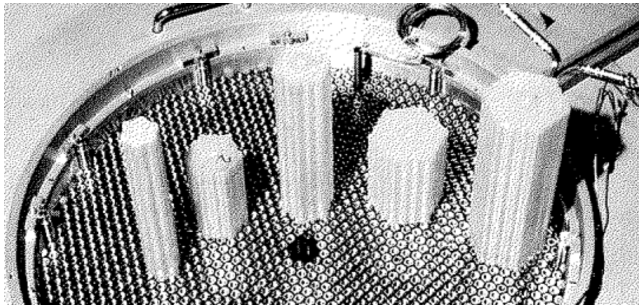
•PROTEUS is a driven system whose test zone contains the FDWR lattices

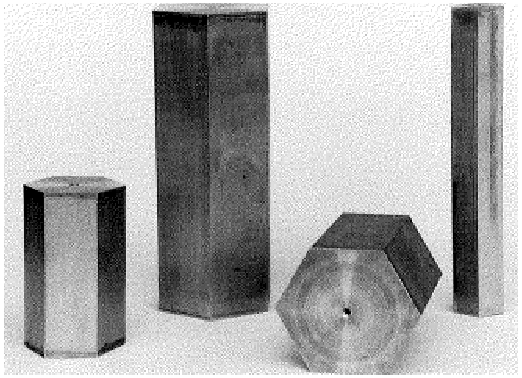
•UO_2/PuO_2 pellets with 11% PuO_2
•Pu(8/9/0/1/2): 1%, 64%, 23%, 8%, 4%
•Fuel diameter: 8.46mm
•Fuel total height: 84 cm
•2 axial blankets:
  - •Udep. 0.224w% ^{235}U
  - •28-cm high each

•Several moderation conditions
  - •Two triangular pitches
  - • Different moderators (water, downterm, air)

FDWR-II – Measurement types







$$k_\infty = 1 + B^2 \cdot M^2$$

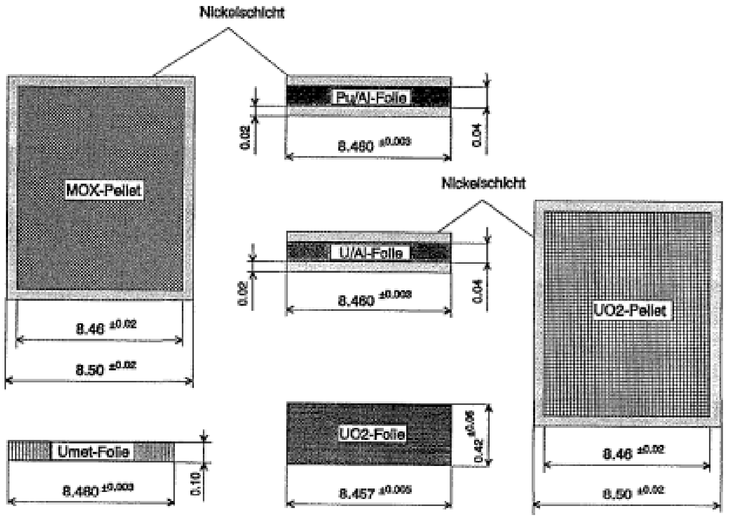
$$\frac{\rho_Z}{\rho_S}\frac{S}{R_f} = \bar{\nu}\frac{\overline{\Phi^+}^X}{\overline{\Phi^+}^S}\left(1 - \frac{1}{k^+}\right)$$

- K∞ measurements
  - Using axial and radial bucklings
  - Using compensation methods with auto-rod and a ^{252}Cf sources

- Reactivity effects of
  - Void volume
  - Moderator volume
  - Absorber rods

Absorber	Form	Durchmesser	Cladding	Bemerkung
B_4C(nat)	Pellet	7.473	ja	Referenzabsorber
B_4C(nat)	Pulver	7.430	ja	
B_4C(93%) ^{10}B	Pellet	7.430	ja	
Ag15In5Cd	Legierung	8.830	nein	
Hafnium	Metall	8.350	ja	
Gd_2O_3	Pellet	8.310	ja	
Sm_2O_3	Pellet	7.000	ja	
Tantal	Metall	8.290	ja	
Eu_2O_3	Pellet	8.243	ja	
Zircaloy-2	Legierung	8.300	nein	Strukturmaterial
Stahl	Metall	8.240	nein	Strukturmaterial

FDWR-II – Measurement types

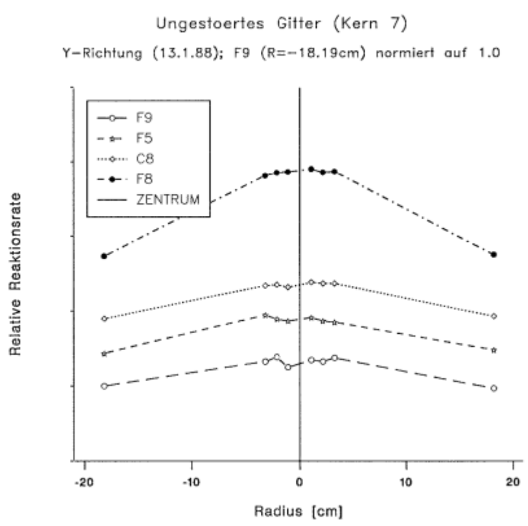


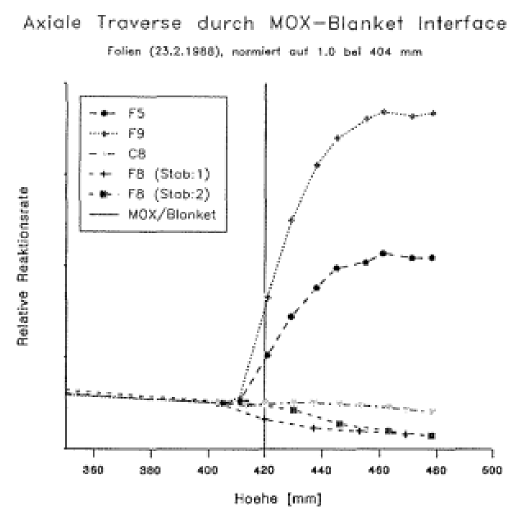
Spectral index measurements (core 7)

- F5/F9 ~0.91 F1/F9 ~ 1.68
- F8/F9 ~1.14e-2 C2/F9 ~ 1.12
- C8/F9 ~7.8e-2
- Typical uncertainties

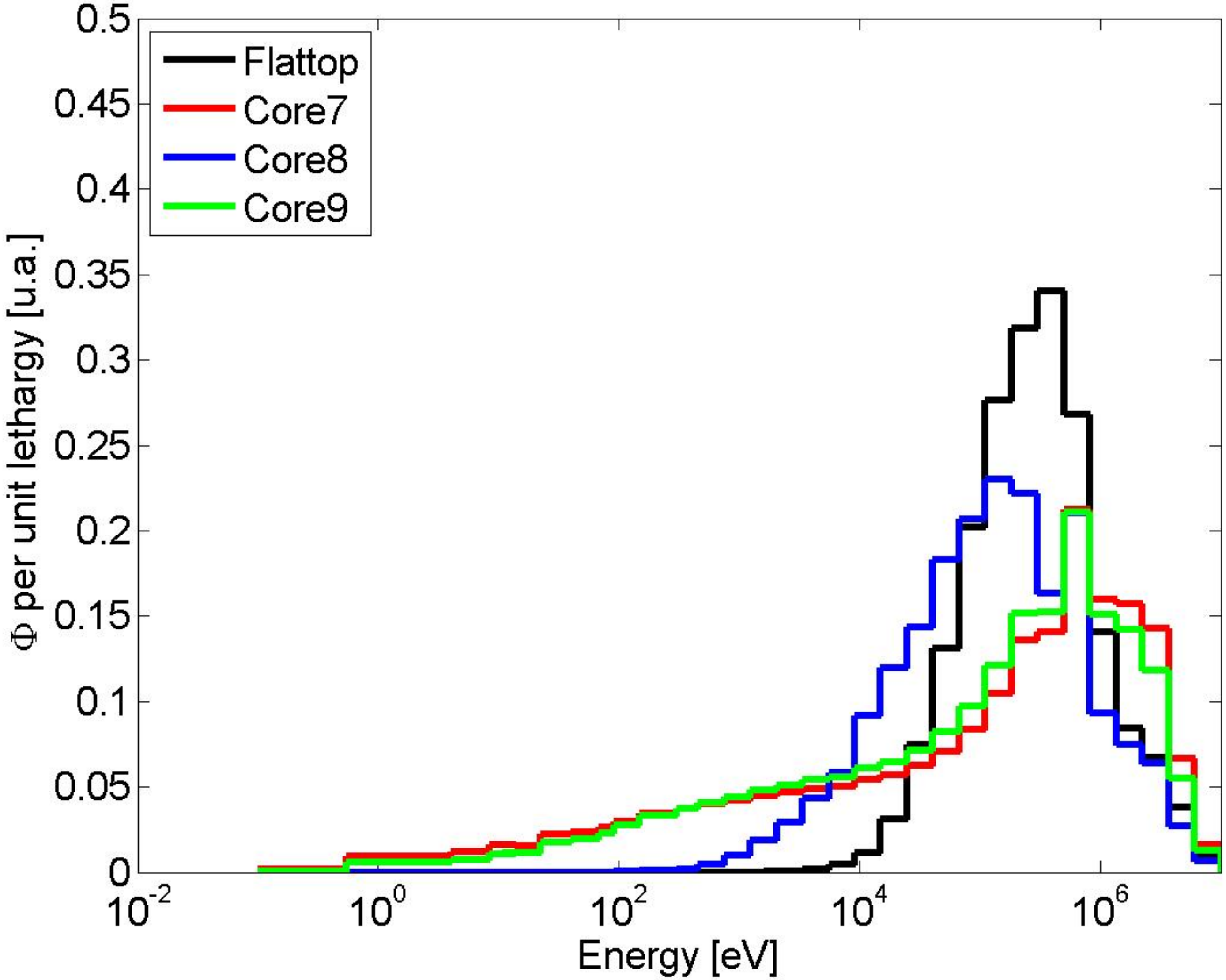
F5: 1.8%, F8: 1.9%, F9:1.5%, C8: 1.8%

Reaction rate radial and axial traverses





Spectrum Comparison



FDWR-II – Calculation tools

PSI

- In the 80's
  - Cell calculations: WIMSD4 with the WIMS-1981 data library
  - Whole reactor calculations: ONEDANT (one dimension transport)
  - Macroscopic cross-sections generation:
    - WIMSD4 (P0 transport corrected) → DSNXSL →XSLIB
- In the 2010's
  - Master student started reanalysis with MCNP6 & SERPENT-v2 (2.1.15)
    - Cell calculations for core 7,8 and 9 so far
    - Slow progress…
  - Limited effort ~ 14 days

KfK

- Cell calculations: KAPER4 with the G69P1V02 data library (69 Groups)
- Whole reactor calculations: 2D DIXY2 diffusion and TWODANT transport codes
- Macroscopic cross-sections with transport corrected P0 and P1, S4

TUBS

- XS preparation: modified WIPRO, NJOY (ENDF/B-V, JEF-1), various DATUBS-nn
- Cell calculations: SPEKTRA (various libraries)
- Whole reactor calculations: DITUBS (2D diffusion, 35 groups)

Selected C/E values for interesting configurations

Core 7, 8 and 9 are considered the most interesting

- For their "soft spectrum"

C/E

C/E	Core 7			Core 8			Core 9		
	Value	Rel. unc.	Abs. unc.	Value	Rel. unc.	Abs. unc.	Value	Rel. unc.	Abs. unc.
C8/F9	1.007	1.80%	0.018	1.021	1.60%	0.016	0.989	1.70%	0.017
F8/F9	1.024	1.90%	0.019	1.003	1.81%	0.018	1.017	1.80%	0.018
F5/F9	1.017	1.50%	0.015	1.023	1.30%	0.013	1.023	1.50%	0.015
F1/F9	0.988	3.00%	0.030	1.011	3.00%	0.030	0.987	5.00%	0.049
C2/F9	1.044	3.01%	0.031	1.132	3.00%	0.034	1.035	3.02%	0.031

No obvious bias , except maybe for Pu-242 capture in Core 8 (~ 3.8 std).

Need community feedback to understand potential interest for data assimilation

Total k-eff sensitivities

Sensitivity of k-eff

Total sensitivity (and uncertainty) for core 7, 8 and 9

SERPENT and MCNP6 return consistent results for core 7

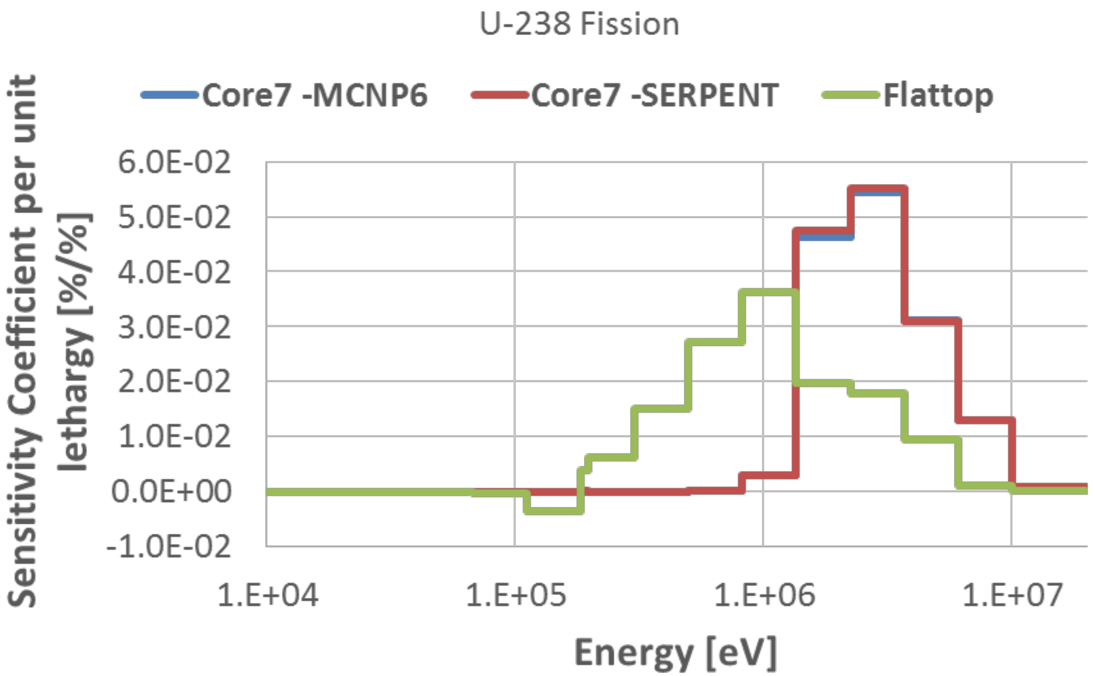
Configuration		Core 7				Core 8		Core 9	
Code		MCNP6		SERPENT		MCNP6		MCNP6	
Isotope	reaction	sensitivity	rel. unc.	sensitivity	rel. unc.	sensitivity	rel. unc.	sensitivity	rel. unc.
Pu-239	fission	0.3746	0.2%	0.3679	0.2%	0.4455	0.1%	0.3845	0.2%
Pu-239	total + sab	0.2244	0.6%	0.2178	0.6%	0.4053	0.3%	0.2588	0.6%
U-238	capture	-0.1744	0.2%	-0.1769	0.2%	-0.2654	0.2%	-0.2055	0.2%
Pu-239	capture	-0.1493	0.2%	-0.1505	0.2%	-0.0380	0.2%	-0.1268	0.3%
U-238	total + sab	-0.0885	3.3%	-0.0922	3.3%	-0.2245	1.7%	-0.1197	3.4%
Pu-241	fission	0.0801	0.4%	0.0789	0.4%	0.0713	0.3%	0.0844	0.4%
U-238	fission	0.0743	0.5%	0.0754	0.5%	0.1150	0.3%	0.0839	0.6%
Pu-240	capture	-0.0679	0.4%	-0.0674	0.4%	-0.0141	0.3%	-0.0507	0.6%
Pu-241	total + sab	0.0640	0.6%	0.0627	0.6%	0.0673	0.4%	0.0705	0.7%
Pu-240	total + sab	-0.0512	1.2%	-0.0514	1.2%	0.0184	0.7%	-0.0311	2.4%

Sensitivity per unit lethargy [1]

For selected (arbitrary) nuclide-reaction pairs of Core 7

SERPENT and MCNP6 return consistent results

- Relatively low number of neutron histories
- Default number of latent generation for MCNP6, 15 for SERPENT-v2

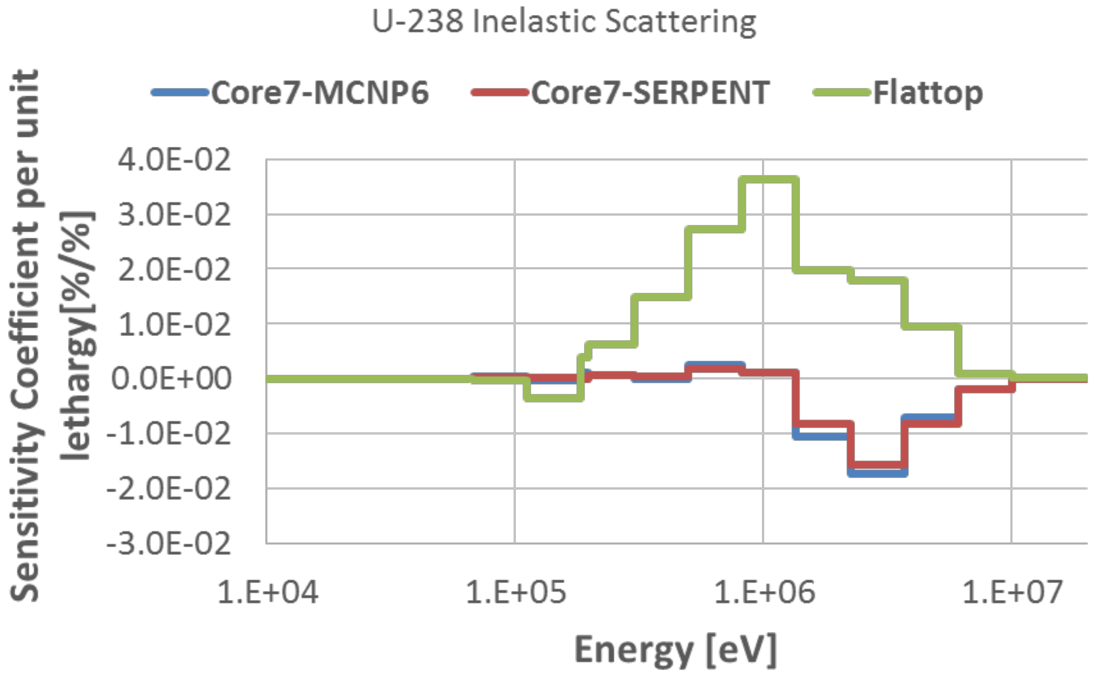


Sensitivity per unit lethargy [2]

For selected (arbitrary) nuclide-reaction pairs of Core 7

SERPENT and MCNP6 return consistent results

- Relatively low number of neutron histories
- Default number of latent generation for MCNP6, 15 for SERPENT-v2

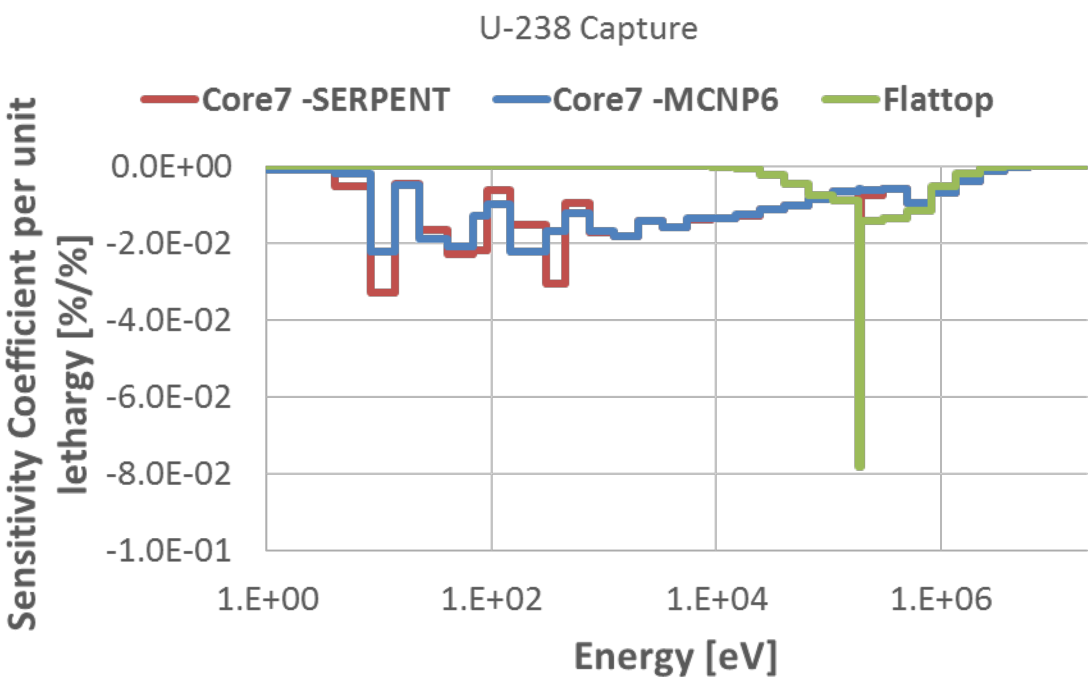


Sensitivity per unit lethargy [3]

For selected (arbitrary) nuclide-reaction pairs of Core 7

SERPENT and MCNP6 return consistent results in the fast energy range, issue at lower energies

- Relatively low number of neutron histories
- Default number of latent generation for MCNP6, 15 for SERPENT-v2



Conclusion

Re-analysis of FDWR experiments at PROTEUS with modern modelling tools has started

- Limited resources
- Cell models only
- Preliminary results were presented

For the considered core configurations, no obvious bias

Consistent sensitivity information were generated with SERPENT-2 and MCNP6

Dissemination of information is the next step

- Will not be for free
- At least the cost for in-house re-analysis should be paid for.
- The data itself may or may not go for free.