Progress on Fission Product Cross-Sections Improvement of LWR Cycle Length Prediction

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JEFF-3.1 Nuclear Data Integral Trends based on:

- Separated Fission Product Oscillations in MINERVE (Burn-up Credit Program) :
  - Improvement of Sm149, Rh103, Nd143, Cs133 : new evaluations already introduced in JEFF-3.1
  - overestimation of JEFF-3.1 $^{99}Tc(n,\gamma)$
- PWR Spent Fuel Radiochemical Analysis: PIEs confirm the Actinide prediction. Improvements on Nd143, Nd148, Eu154, Eu155-Gd155 build-up is demonstrated using JEFF-3.1.
- Spent fuel Oscillations in MINERVE: $[C/E-1]_{\Delta\rho_{cycle}} = +1\% \pm 1.3\%$
- K_{eff}^{BOC} underprediction and over-estimation of the PWR reactivity loss per cycle by about 200 pcm (cycle follow-up by AREVA-NP)

AND

New cross-section evaluations are now available through OECD/NEA/WPEC/SG23:
« Review of 164 Fission Product Evaluations »,
V.G. Pronyaev, IPPE Obninsk, Russia, July 2005.

Then, new evaluated neutron data files are proposed to JEFF-3.2β:

^{103}Ru

^{99}Tc

^{148g}Pm

^{93}Zr

^{147}Pm

^{154}Eu

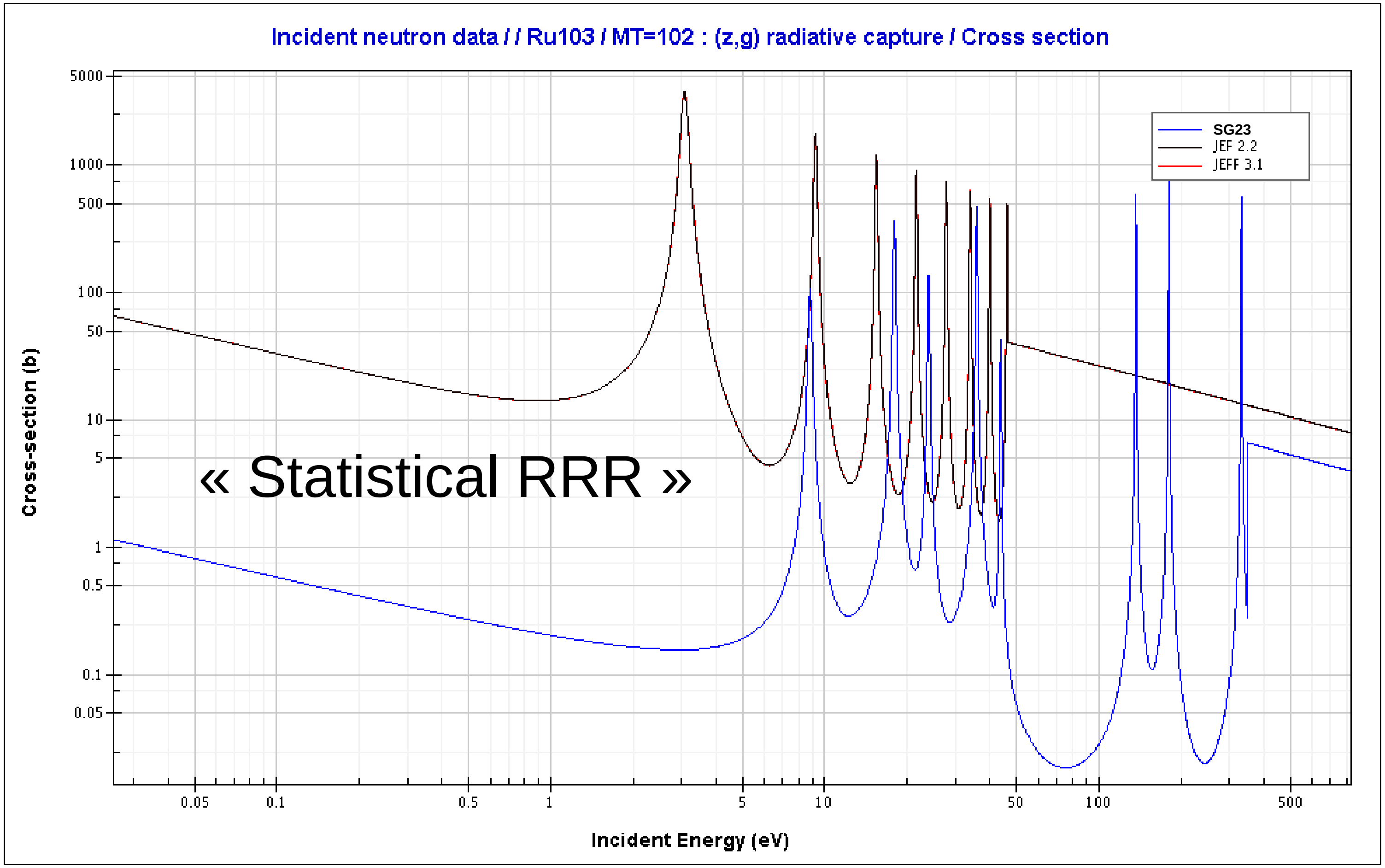
^{135}Cs

^{103}Ru neutron radiative capture

^{103}Ru	JEF-2.2		JEFF-3.1		WPEC/SG23		BNL 2006		$-\rho$(20GWj/t) pcm	$-\rho$(60GWj/t) pcm
	$\sigma_{\gamma 0}$	I_γ	$\sigma_{\gamma 0}$	I_γ	$\sigma_{\gamma 0}$	I_γ	$\sigma_{\gamma 0}$	I^c_γ		
	66.83	593.76	66.83	593.7	1.17	46.74	1.2	5	73	90

JEFF-3.2β

T = 39 d

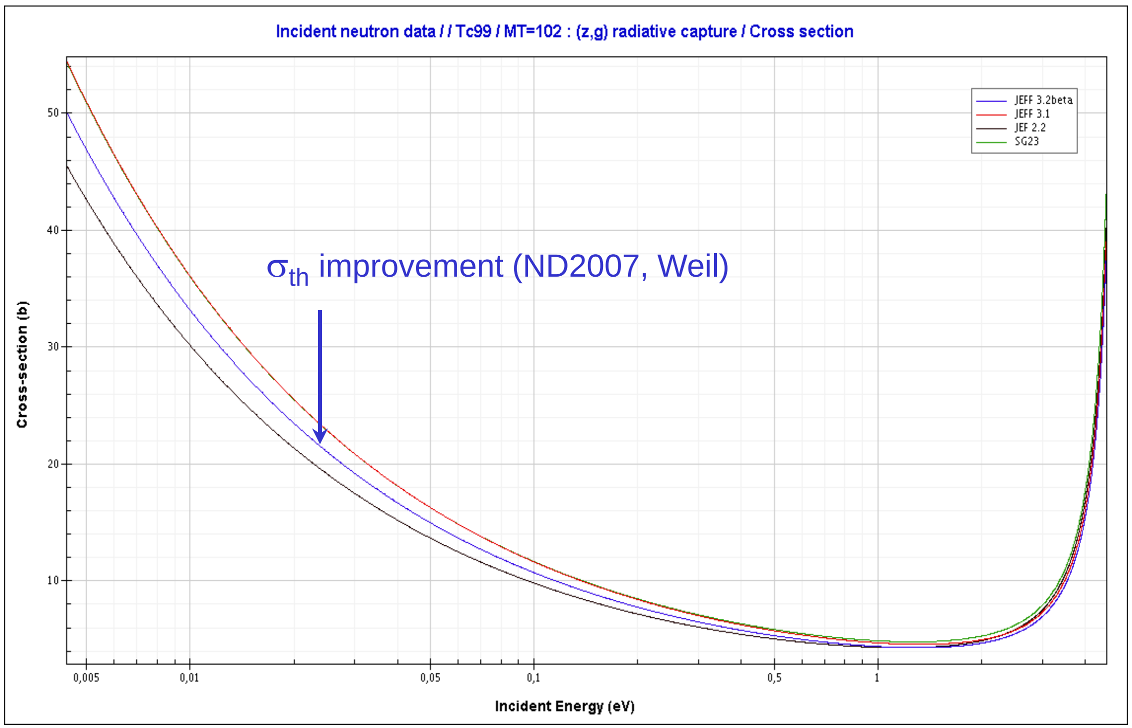


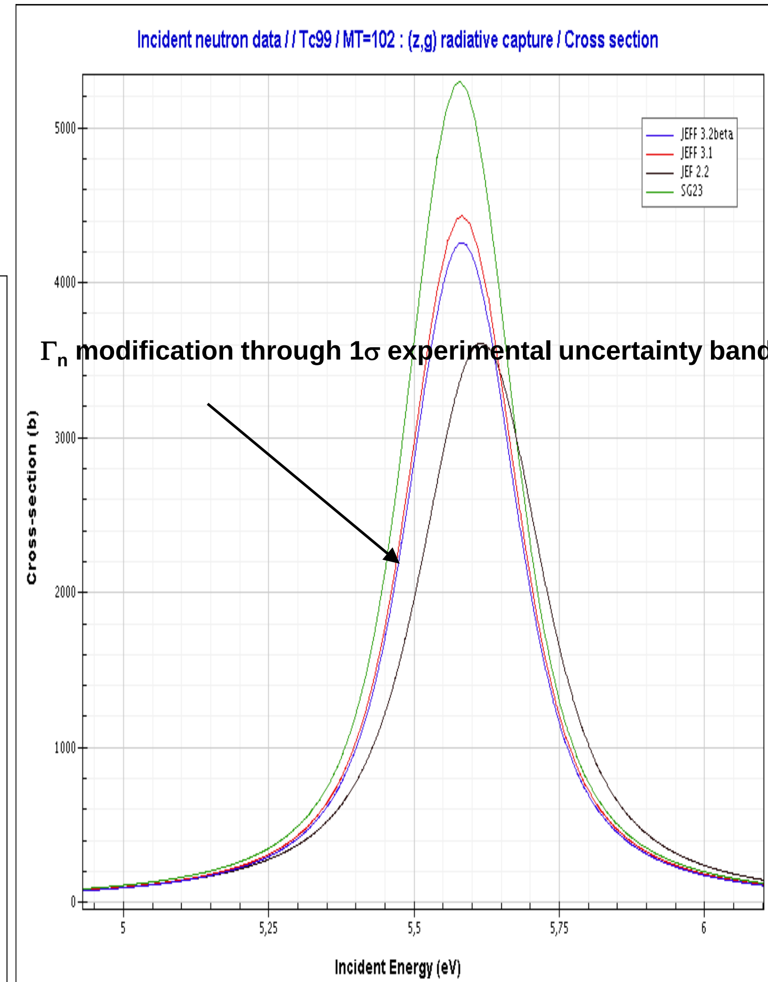
^{99}Tc neutron radiative capture

^{99}Tc	JEF-2.2		JEFF-3.1		WPEC/SG23		JEFF-3.2β		BNL 2006		−ρ(20GWj/t) pcm	−ρ(60GWj/t) pcm
	$\sigma_{\gamma 0}$	I_γ	$\sigma_{\gamma 0}$	I_γ	$\sigma_{\gamma 0}$	I_γ	$\sigma_{\gamma 0}$	I_γ	$\sigma_{\gamma 0}$	I_γ		
	19.11	304.3	**22.82**	322.9	22.80	362.0	**21.0**	**313.1**	22.8 (1.3)	358 (20)	401	780

JEFF-3.2β

$T = 2.1^{E}5$ y

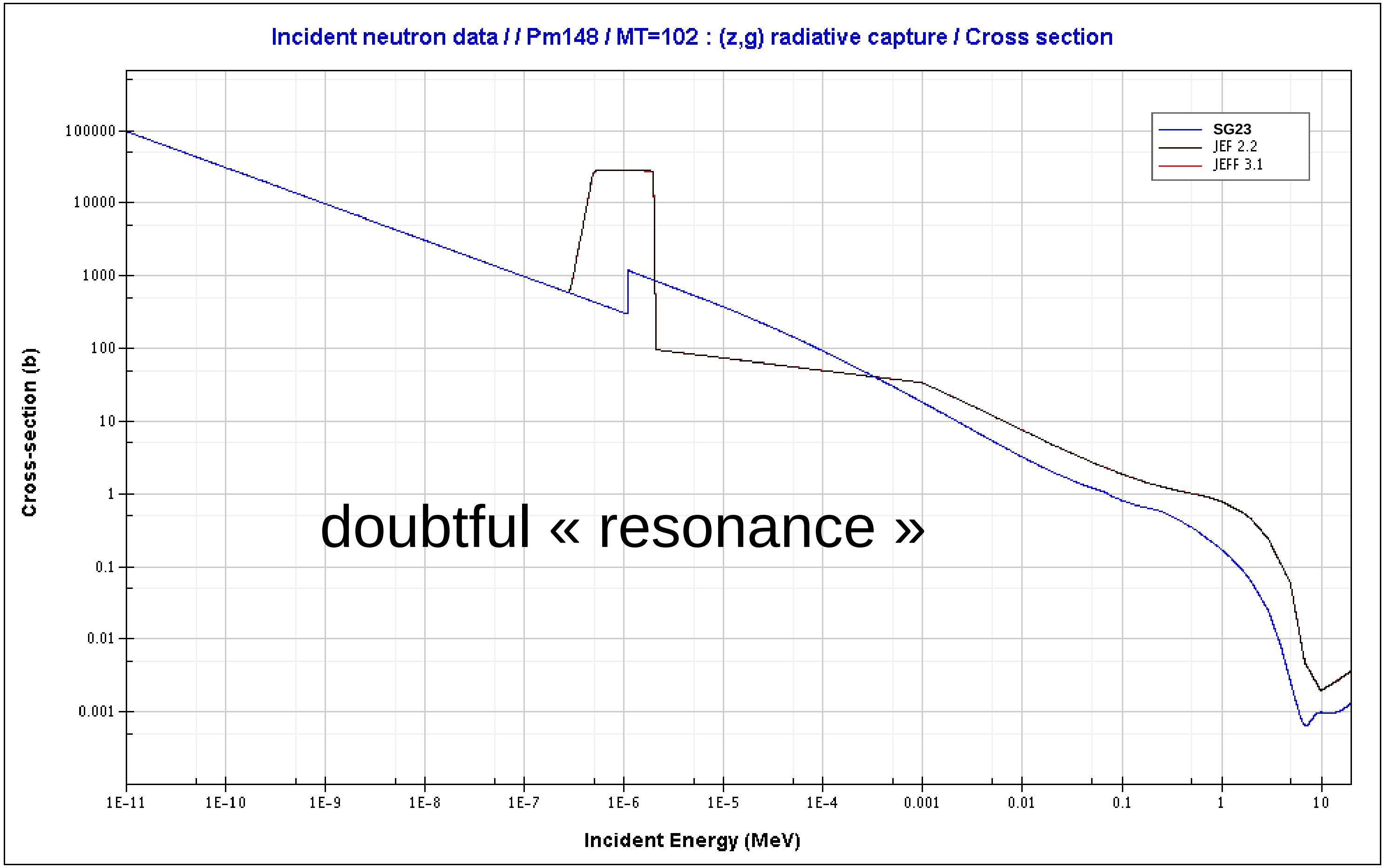




^{148g}Pm neutron radiative capture

^{148g}Pm	JEF-2.2		JEFF-3.1		WPEC/SG23 (JEFF-3.2β)		BNL 2006		−ρ(20GWj/t) pcm	−ρ(60GWj/t) pcm
	$\sigma_{\gamma 0}$	I_γ	$\sigma_{\gamma 0}$	I_γ	$\sigma_{\gamma 0}$	I_γ	$\sigma_{\gamma 0}$	I_γ		
	2000	39864	2001	39846	2001	2518	2000 (1000)	•	57	78

T = 5 d

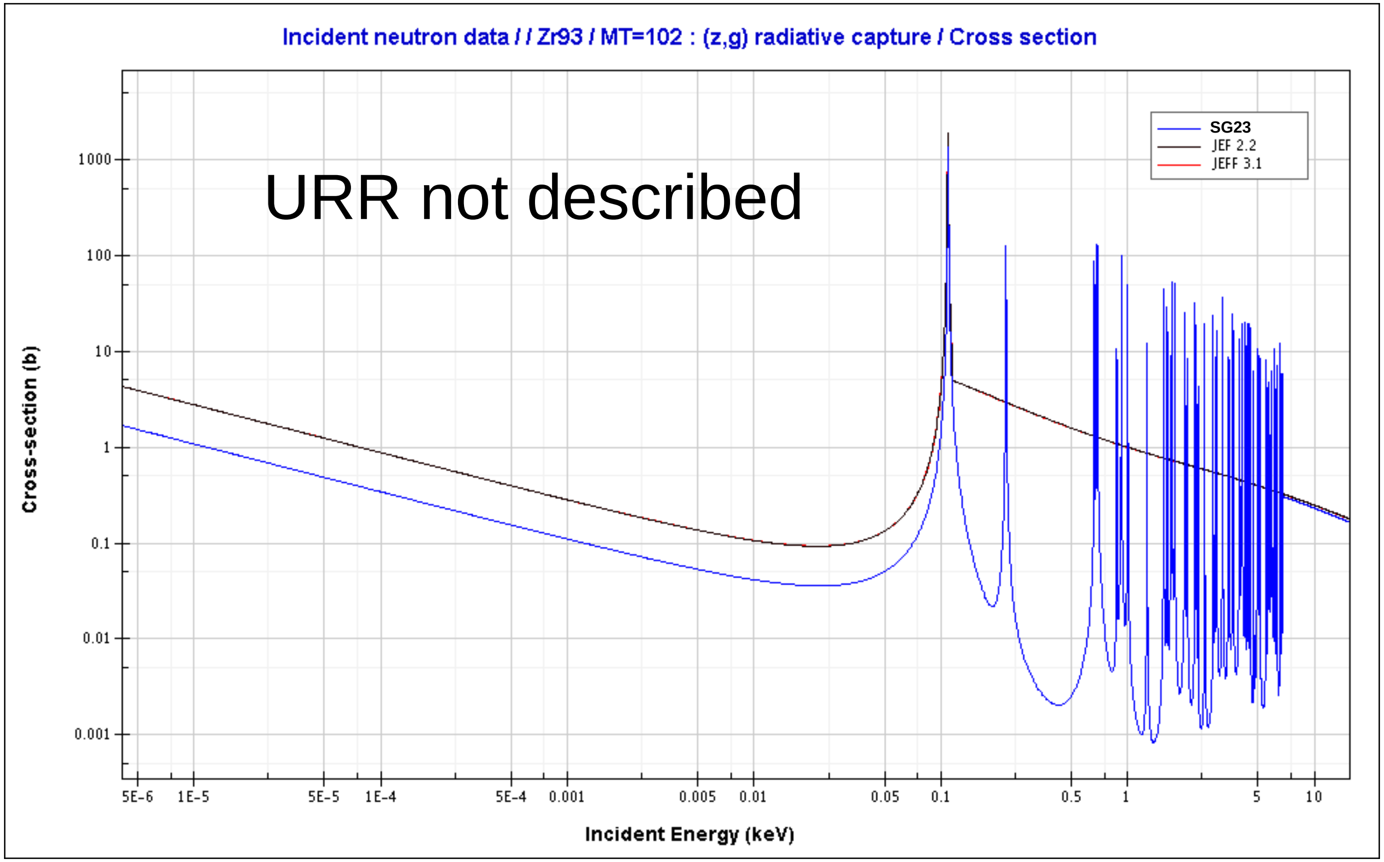


^{93}Zr neutron radiative capture

^{93}Zr	JEF-2.2		JEFF-3.1		WPEC/SG23		BNL 2006		$-\rho$(20GWj/t) pcm	$-\rho$(60GWj/t) pcm
	$\sigma_{\gamma 0}$	I_γ	$\sigma_{\gamma 0}$	I_γ	$\sigma_{\gamma 0}$	I_γ	$\sigma_{\gamma 0}$	I_γ		
	1.78	33.0	1.78	33.0	0.69	17.76	<4	17.5	54	125

JEFF-3.2β

T=1.5^{E}6 y

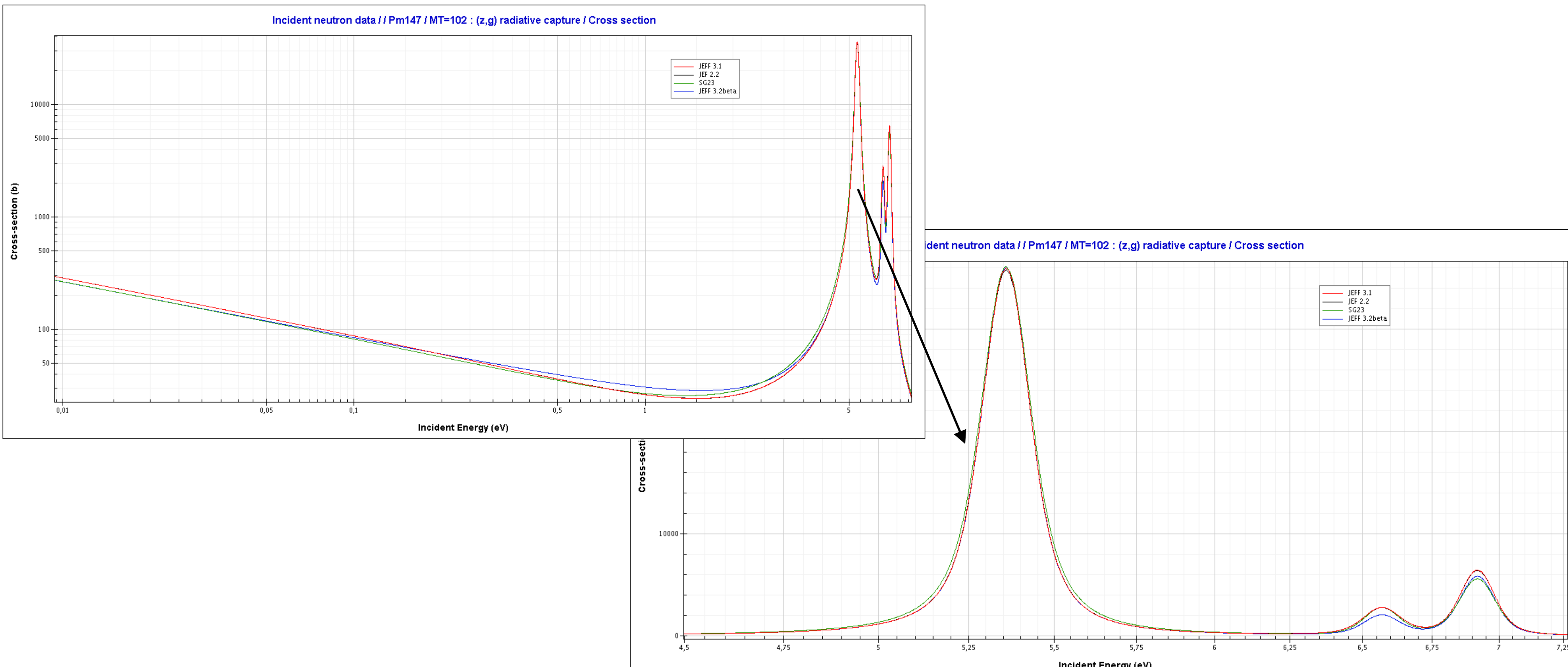


^{147}Pm neutron radiative capture

^{147}Pm	JEF-2.2		JEFF-3.1		WPEC/SG23		JEFF-3.2β		BNL 2006		$-\rho$(20GWj/t) pcm	$-\rho$(60GWj/t) pcm
	$\sigma_{\gamma 0}$	I_γ	$\sigma_{\gamma 0}$	I_γ	$\sigma_{\gamma 0}$	I_γ	$\sigma_{\gamma 0}$	I_γ	$\sigma_{\gamma 0}$	I^c_γ		
	180.6	2144	**180.6**	2143	167.7	2205	**168.4**	**2109**	168.4 (3.5)	2064 (100)	536	500

JEFF-3.2β

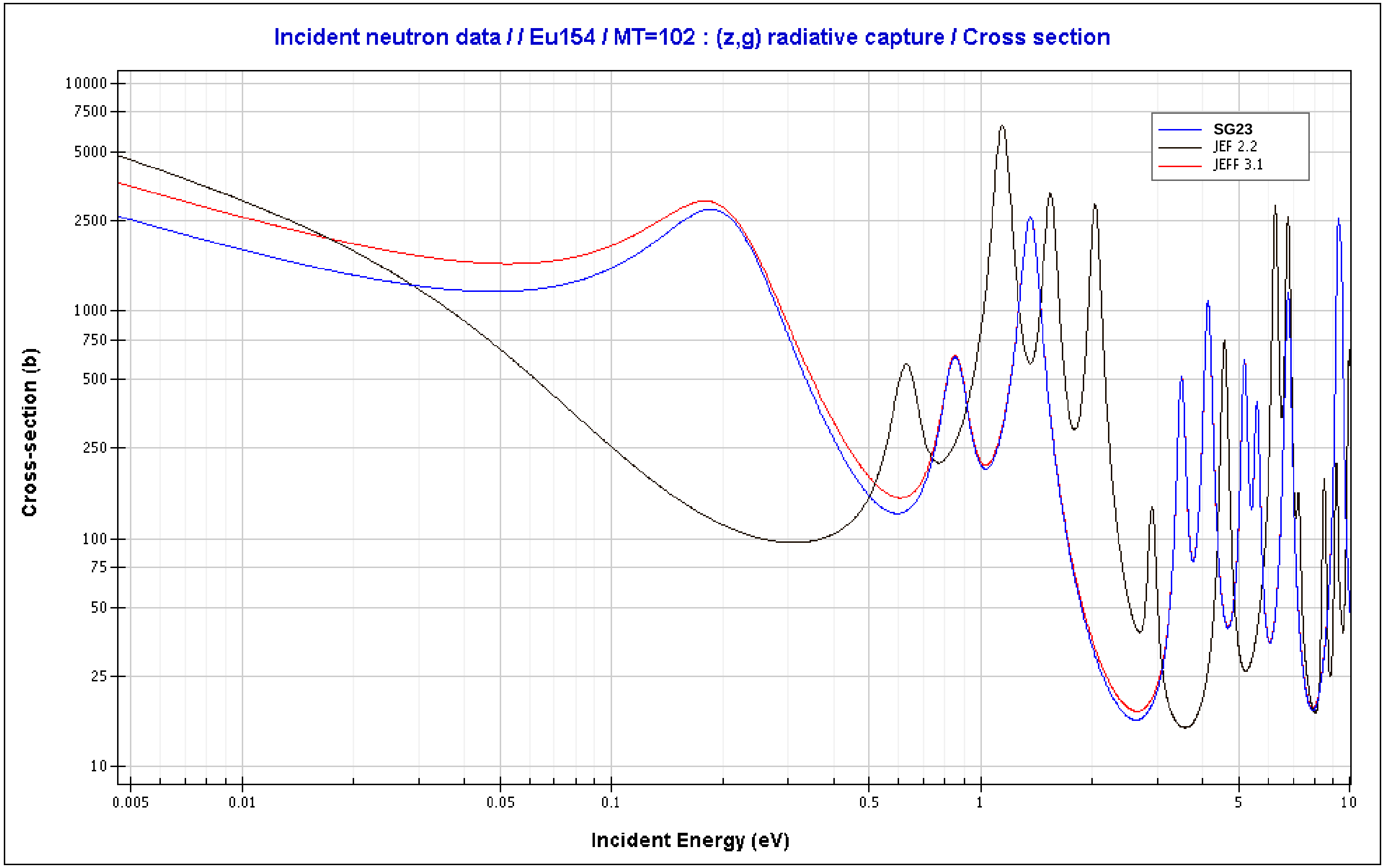
T=2.6y



^{154}Eu neutron radiative capture

^{154}Eu	JEF-2.2		JEFF-3.1		WPEC/SG23 JEFF-3.2β		BNL 2006		$-\rho$(20GWj/t) pcm	$-\rho$(60GWj/t) pcm
	$\sigma_{\gamma 0}$	I_γ	$\sigma_{\gamma 0}$	I_γ	$\sigma_{\gamma 0}$	I_γ	$\sigma_{\gamma 0}$	I^c_γ		
	1500	2558	**1845**	1358	**1352**	**1299**	1340 (130)	802	143	666

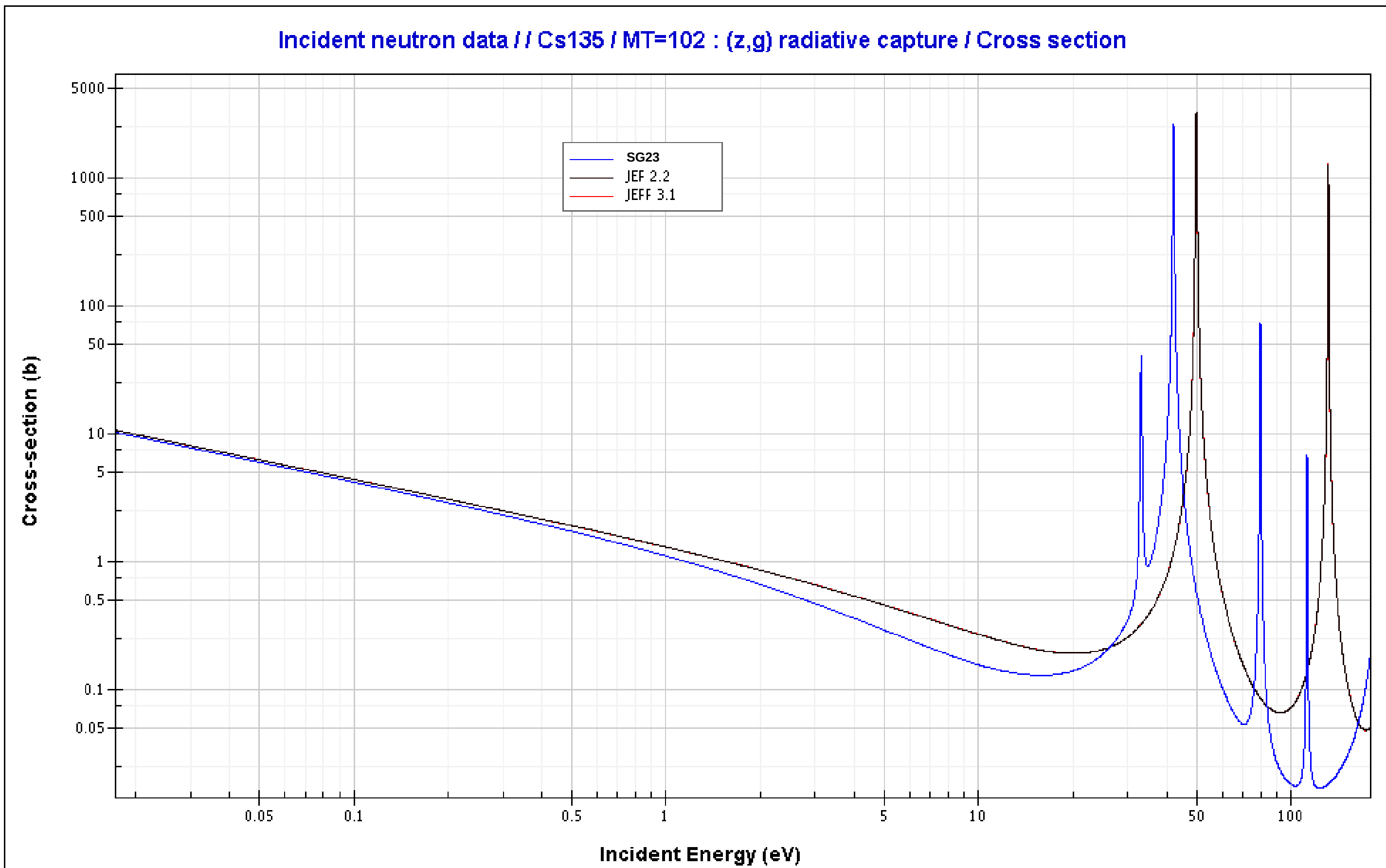
T = 8.6 y



^{135}Cs neutron radiative capture

^{135}Cs	JEF-2.2		JEFF-3.1		WPEC/SG23 JEFF-3.2β		BNL 2006		$-\rho$(20GWj/t) pcm	$-\rho$(60GWj/t) pcm
	$\sigma_{\gamma 0}$	I_γ	$\sigma_{\gamma 0}$	I_γ	$\sigma_{\gamma 0}$	I_γ	$\sigma_{\gamma 0}$	I_γ		
	9.01	61.06	9.01	**61.05**	**8.66**	**50.65**	8.3 (0.3)	37.9 (2.7)	50	113

T=2.3E6 y



Improvements on integral experiments due to these JEFF3.2β evaluations

LWR:	δk_{eff} BOC	$\delta\Delta\rho_{cycle}$
- ^{103}Ru:	15 pcm	15 pcm
- ^{99}Tc:	6 pcm	3 pcm
- ^{148g}Pm:	90 pcm	85 pcm
- ^{93}Zr:	21 pcm	11 pcm
- ^{147}Pm:	4 pcm	2 pcm
- ^{154}Eu:	18 pcm	11 pcm
- ^{135}Cs:	6 pcm	3 pcm
Total :	+160 pcm	+130 pcm

⇒ Cancellation of the K_{eff} and L_{cycle} under-estimations

Oscillation of Tc99 sample in MINERVE :

	^{99}Tc: (C/E-1)±δE/E
JEFF-3.1	**(+9±4)%**
JEFF-3.2β	**(+3±4)%**

(confirmed by DIMPLE worth measurements: C.Dean, P. Smith, R. Perry from SERCO)

Conclusions

Proposed JEFF-3.2β FP cross section evaluations (Cad+ WPEC/SG23) improve LWR calculations:

✓ satisfactory $(\text{Keff})_{BOC}$

✓ accurate loss of reactivity with burn-up and L_{cycle}.

The associated APOLLO2.8 multigroup library (CEA2005.V4) including JEFF-3.1 evaluations except:

^{237}Np (JEFF-3.0), ^{239}Pu (JEFF-3.2β) (see JEF/DOC-1144/1158/1174)
^{16}O, ^{91,96}Zr (JEFF-3.2β) (see JEF/DOC-1207/1208/1226)
^{103}Ru, ^{99}Tc, ^{148g}Pm, ^{93}Zr, ^{147}Pm, ^{154}Eu, ^{135}Cs (JEFF-3.2β) (see JEF/DOC-1238)

is recommended by CEA for LWR applications.