



Present Status of *JEFF-3.1* Qualification for *LWR*

Reactivity and Fuel Inventory Prediction

Experimental Validation Group (CEA Cadarache/Saclay)

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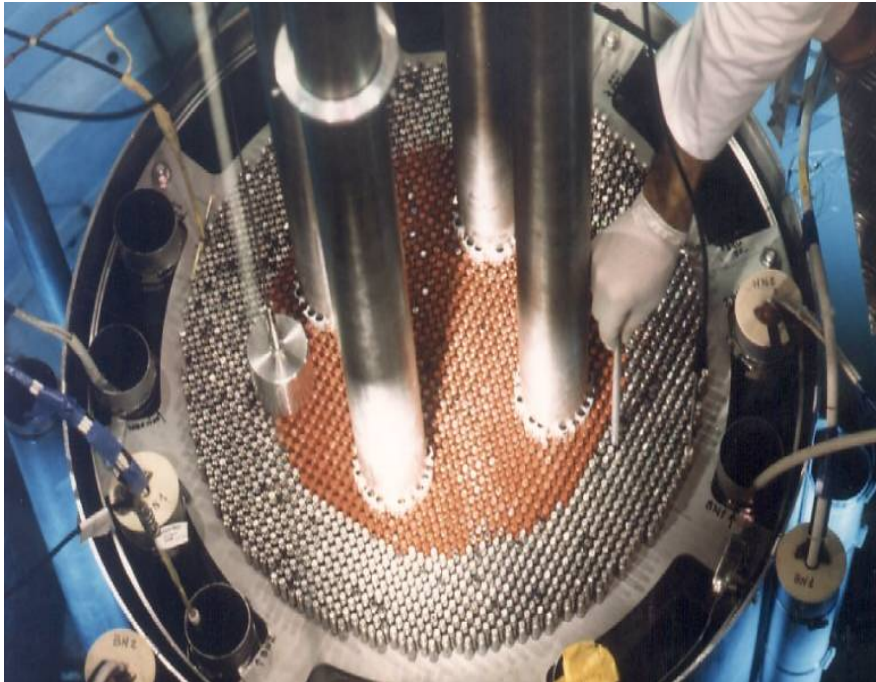
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Summary:

✘ B_m^2 and k_{eff} experimental validation for UO_2 and MOx lattices at Beginning of Cycle

✘ Fuel Inventory Prediction using JEFF-3.1



LWR mock-up in EOLE Facility
(EPICURE-MOx Lattice)

Material Buckling Experimental Validation:
Pin cell calculation

	B_m^2 (pcm)	EPICURE UH-1.2 UO _x (²³⁵ U: 3.7% (w/o)) □: 1,26cm R _m =1,2	MISTRAL-1 UO _x (²³⁵ U: 3.7% (w/o)) □: 1,32cm R _m =1,7	MISTRAL-2 MO _x (7% Pu content) □: 1,32cm R _m =1,7	MISTRAL-3 MO _x (7% Pu content) □: 1,39cm R _m =2,0
Experiment		0 ± 400	0 ± 500	0 ± 350	0 ± 350
APOLLO2	JEF-2.2	449	-222	74	308
	JEFF-3.1	2	-552	118	310

Technological and experimental uncertainties

k_{eff} Experimental Validation

(« homogeneous » core with regular lattice)

Whole Core Calculation



	k_{eff} values	EPIPURE UH-1.2 UO _x (²³⁵ U: 3.7% (w/o)) □: 1,26cm R _m =1,2	MISTRAL-1 UO _x (²³⁵ U: 3.7% (w/o)) □: 1,32cm R _m =1,7	MISTRAL-2 MO _x (7% Pu content) □: 1,32cm R _m =1,7	MISTRAL-3 MO _x (7% Pu content) □: 1,39cm R _m =2,0
Experiment		1,00055	1,00109	1,00060	1,00057
APOLLO2	JEF-2.2	1,00603	1,00522	1,00732	1,00818
	JEFF-3.1	1,00176	1,00220	1,00793	1,00809
TRIPOLI4	JEFF-3.1	1,0028 (2)	1,0026 (2)	1,0072 (2)	1,0081 (2)

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$\Delta\rho^{(JEF-2.2 \rightarrow JEFF-3.1)}$ **UOx components:**

- - 400pcm : ²³⁵U
- +200pcm : ²³⁸U
- - 100pcm : ⁹ⁱZr

~ - 300pcm

$\Delta\rho^{(JEF-2.2 \rightarrow JEFF-3.1)}$ **MOx components:**

- XS — ● +130pcm : ²³⁸U
- +110pcm : ²³⁹Pu
- +160pcm : ²⁴⁰Pu
- - 180pcm : ²⁴¹Pu
- - 330pcm : ²⁴¹Am
- - 80pcm : ⁹ⁱZr
- S(α,β) — ● +150pcm : H₂O

~ 0pcm

k_{eff} Experimental Validation

(« homogeneous » core with regular lattice)

Whole Core Calculation



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TRIPOLI4	JEFF-3.1	1,0028 (2)	1,0026 (2)	1,0072 (2)	1,0081 (2)

Reactivity of LWR-UOx cores well predicted (+100 ± 200pcm)

Reactivity of 100% MOx cores overestimated (+700 ± 300pcm)

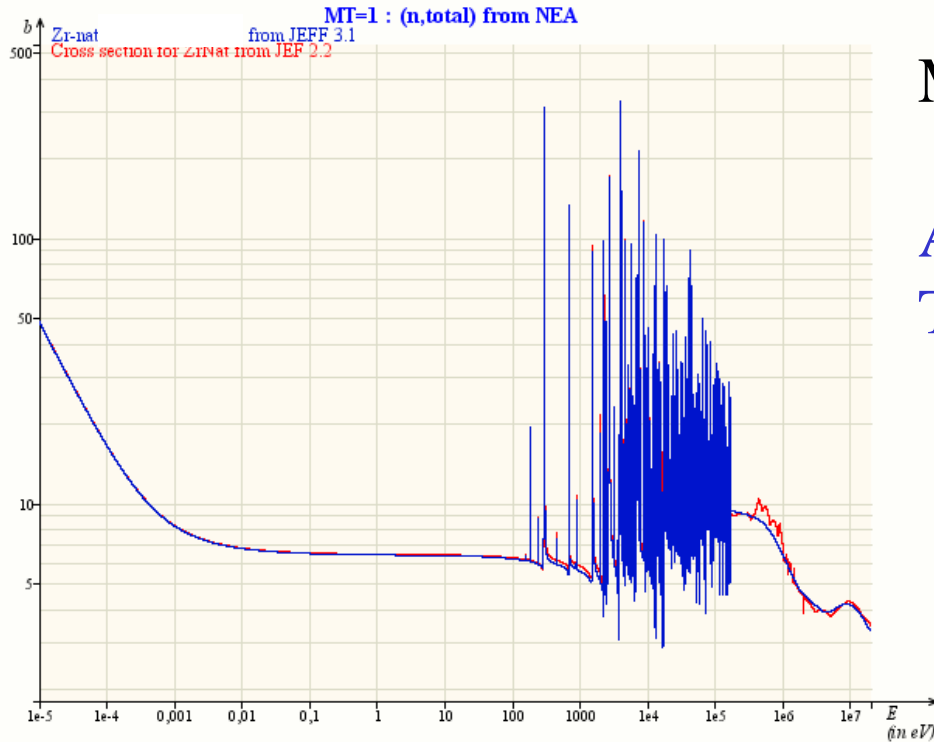
Reactivity effect of zirconium-isotopes evaluations (vs JEF-2.2 natural element evaluation)



natZr



90, 91, 92, 94, 96Zr



MISTRAL-2 (MOx):

APOLLO2: $\Delta\rho_{(nat/iso)} = - 92\text{pcm}$

TRIPOLI4: $\Delta\rho_{(nat/iso)} = - 80\text{pcm} (30)$

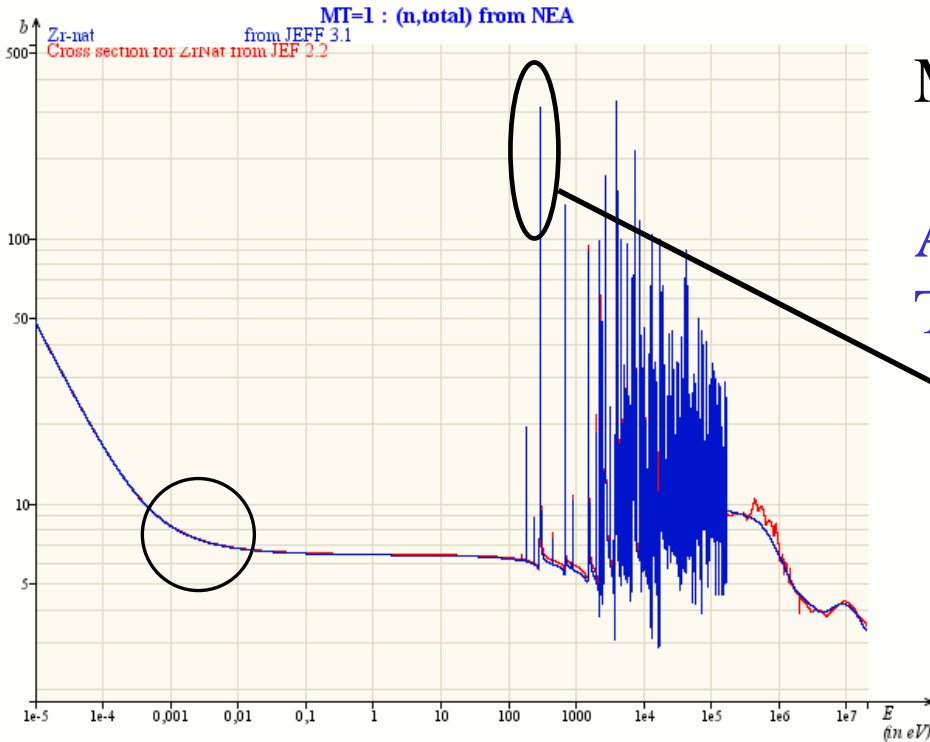
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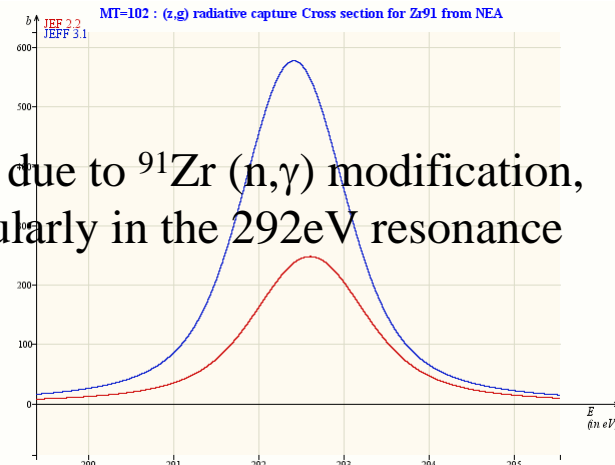


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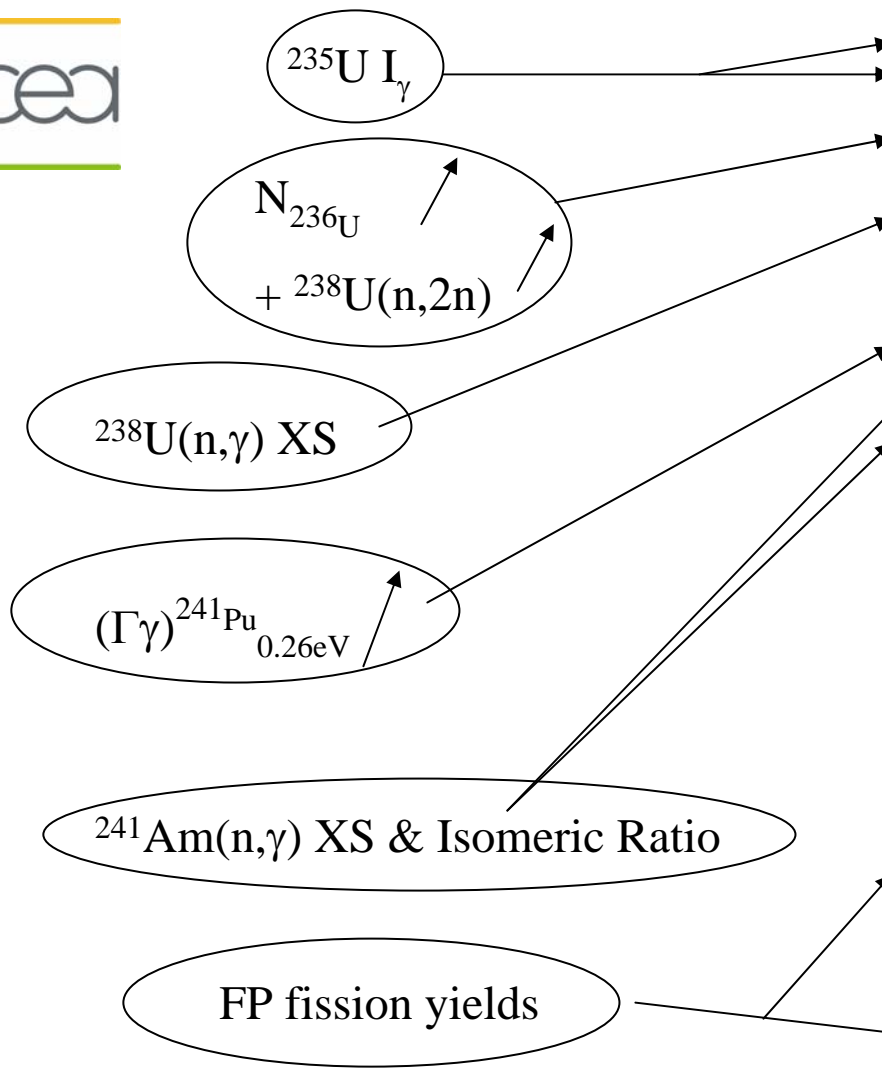
Mainly due to $^{91}\text{Zr} (n,\gamma)$ modification, particularly in the 292eV resonance





**✘ UOx Spent Fuel Inventory Experimental
Validation using JEFF-3.1:**

**Comparison between Depletion Calculations
and Spent Fuel Radio-chemical Assays**



GRAVELINES PWR 3 fuel rods ²³⁵ U 4.5% (w/o) 60GWd/t	C/E - 1 (%) JEF-2.2	C/E - 1 (%) JEFF-3.1	Experimental Uncertainties ($\delta E/E$)
²³⁴ U/ ²³⁸ U	1,8	4,3	3,0
²³⁵ U/ ²³⁸ U	4,6	2,1	3,5
²³⁶ U/ ²³⁸ U	-4,2	-0,7	0,6
²³⁷ Np/ ²³⁸ U	-6,5	-1,3	3,2
²³⁸ Pu/ ²³⁸ U	-10,2	-9,0	3,7
²³⁹ Pu/ ²³⁸ U	1,4	0,4	1,3
²⁴⁰ Pu/ ²³⁸ U	-0,7	0,4	1,1
²⁴¹ Pu/ ²³⁸ U	-2,3	-3,0	1,6
²⁴² Pu/ ²³⁸ U	-8,6	-3,1	2,8
²⁴¹ Am/ ²³⁸ U (EOI)	5,8	0,1	5,0
^{242m} Am/ ²³⁸ U	-21,6	2,3	7,1
²⁴³ Am/ ²³⁸ U	-8,7	-2,4	4,4
²⁴³ Cm/ ²³⁸ U	-19,2	-26,5	6,3
²⁴⁴ Cm/ ²³⁸ U	-16,8	-11,2	4,3
²⁴⁵ Cm/ ²³⁸ U	-17,8	-17,9	5,9
²⁴⁶ Cm/ ²³⁸ U	-29,2	-32,2	7,0
²⁴⁷ Cm/ ²³⁸ U	-16,0	-1,3	9,6
¹⁴³ Nd/ ²³⁸ U	1,4	-0,7	1,2
¹⁴⁴ Nd/ ²³⁸ U	-2,1	-0,5	3,1
¹⁴⁵ Nd/ ²³⁸ U	-0,4	-0,4	1,5
¹⁴⁶ Nd/ ²³⁸ U	0,9	1,3	2,4
¹⁴⁸ Nd/ ²³⁸ U	1,5	1,4	2,1
¹⁵⁰ Nd/ ²³⁸ U	0,7	0,7	2,3
¹³³ Cs/ ²³⁸ U	-4,4	-3,2	1,3
¹³⁴ Cs/ ²³⁸ U	-0,7	-1,9	2,4
¹³⁵ Cs/ ²³⁸ U	-3,8	-4,9	2,6
¹³⁷ Cs/ ²³⁸ U	-5,8	-6,4	2,1

Conclusion



✘ Preliminary JEFF-3.1 qualification results :

✘ k_{eff} prediction for :

✘ LWR-UO_x : $(C_{\text{JEFF-3.1}} - E) = +100 \pm 200\text{pcm}$ (JEF-2.2: +480pcm)

✘ LWR-MO_x : $(C_{\text{JEFF-3.1}} - E) = +700 \pm 300\text{pcm}$ (JEF-2.2: +710pcm)

✘ PIE prediction for UO_x fuels is improved thanks to ^{235,238}U, ²⁴¹Pu, ²⁴¹Am XS and isomeric ratios evaluations.

✘ Additional work is needed :

✘ PIE prediction for MO_x fuels

✘ Reactivity loss in depletion (UO_x and MO_x spent fuel oscillations in MINERVE Facility)

✘ Separated isotopes oscillation (2% accuracy) is in progress:

✘ OSMOSE: actinides from ²³²Th to Cm

✘ OCEAN: neutronic absorbers (Gd + Hf + Er...)