Correction Factors derived from the recent JEFF3.1.1 Library for PWR-UOx BUC applications

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BUC Methodology

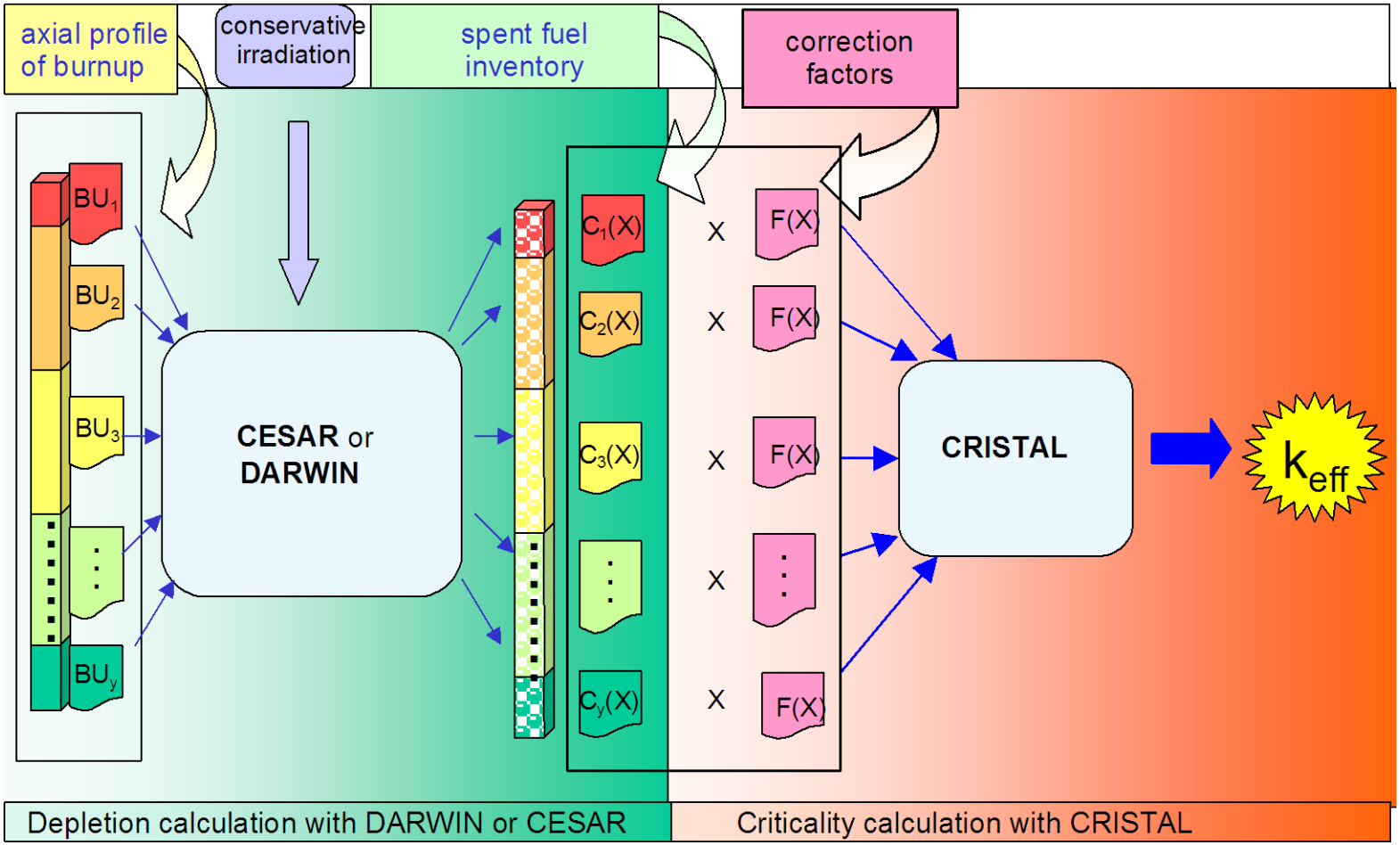
The recent BUC methodology developed by CEA in collaboration with AREVA-NC is accounting for:

- Actinides + 15 Fission Products (stable and non-gazeous)
- Conservative hypothesis for the depletion calculation
- Qualification Reports for spent fuel inventory calculation and reactivity worth of BUC nuclides : Isotopic Correction Factors
- Bounding axial burnup profile of spent fuel assemblies

  (Session III, 3.3)

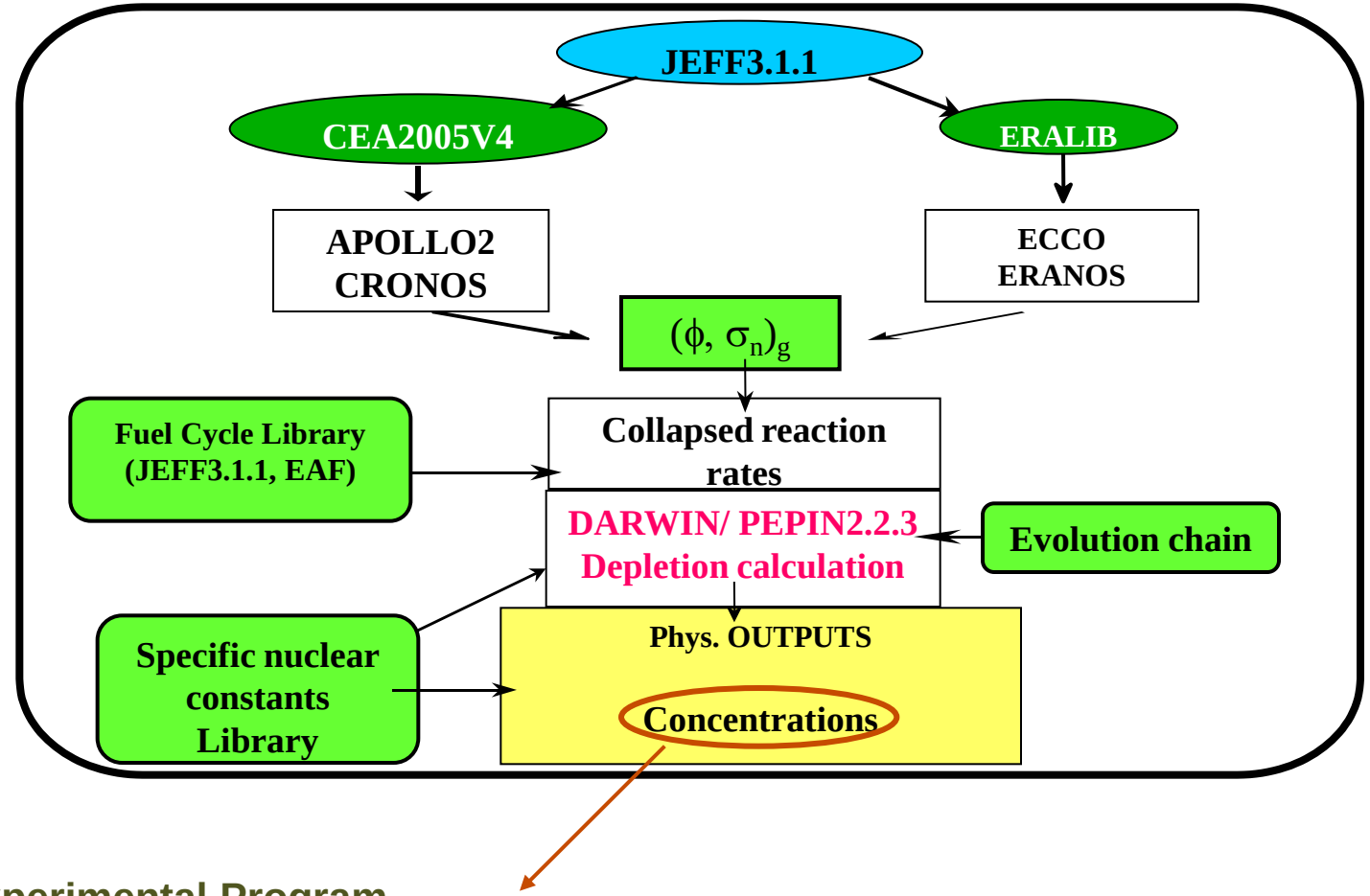
Main references : ICNC'95, FJSS'98, PHYSOR2002, TMC2005, ICNC'07

French PWR UO_2 BUC Calculation Route / BUC nuclides



Actinides : ^{234}U, ^{235}U, ^{236}U, ^{238}U, ^{237}Np, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, ^{241}Am, ^{243}Am

15 FPs : ^{95}Mo, ^{99}Tc, ^{101}Rh, ^{103}Rh, ^{109}Ag, ^{133}Cs, ^{143}Nd, ^{145}Nd, ^{147}Sm, ^{149}Sm, ^{150}Sm, ^{151}Sm, ^{152}Sm, ^{153}Eu, ^{155}Gd

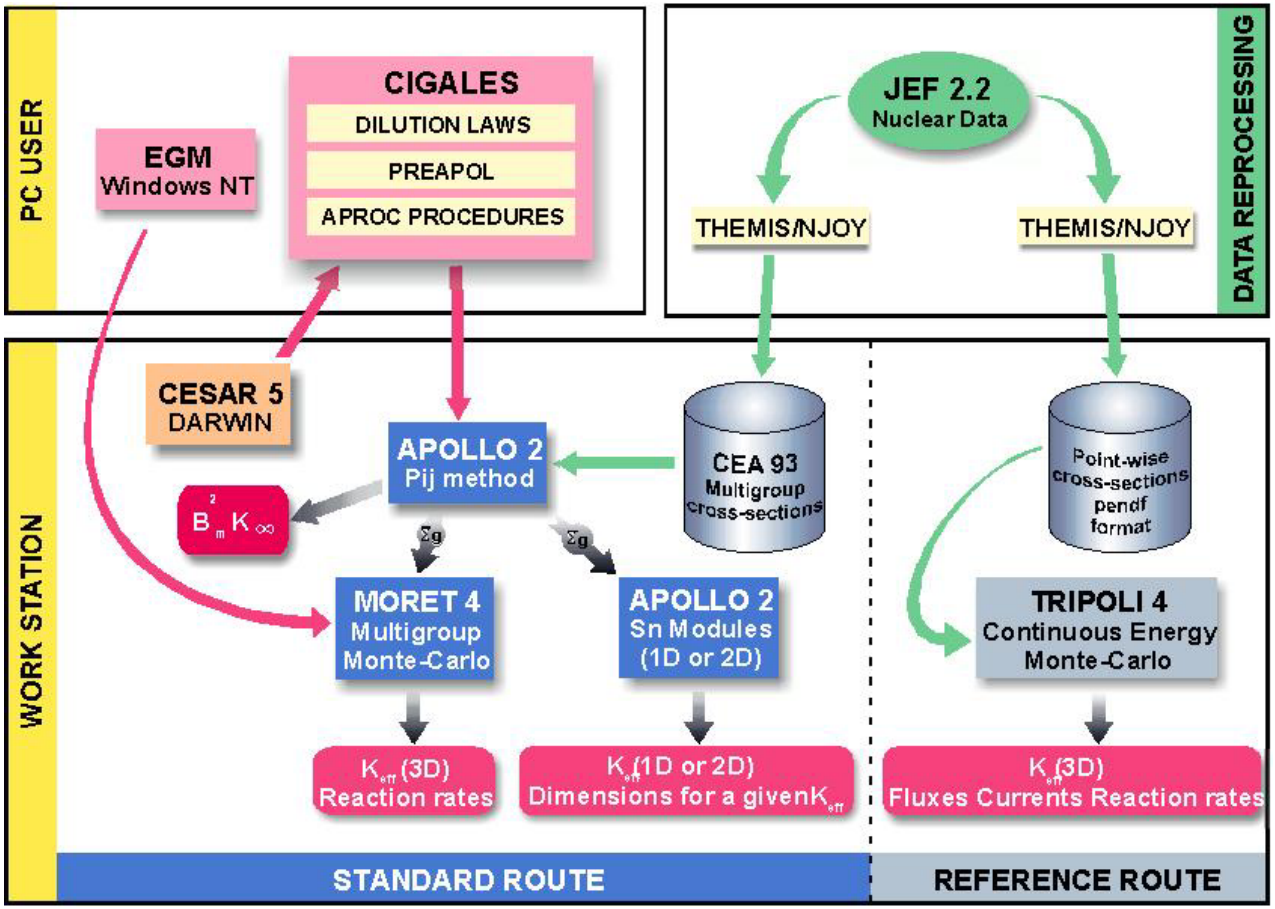


BUC experimental Program

1/ PIE for the validation of Spent Fuel Inventory Calculation

- Destructive analysis of fuel rod cuts from PWR-UO_2 assemblies
- Accurate measurements of isotopic content with mass-spectrometry techniques

Criticality calculations : CRISTAL V1 package



BUC experimental Program

2/ Oscillations experiments in the MINERVE reactor : reactivity worth of individual FPs and overall [actinides + FP] vs BU

Samples of separated FP isotopes in UO_2 pellets, natural elements in Al_2O_3 matrix, Spent fuel samples, Calibration samples (^{235}U, Borated UO_2)

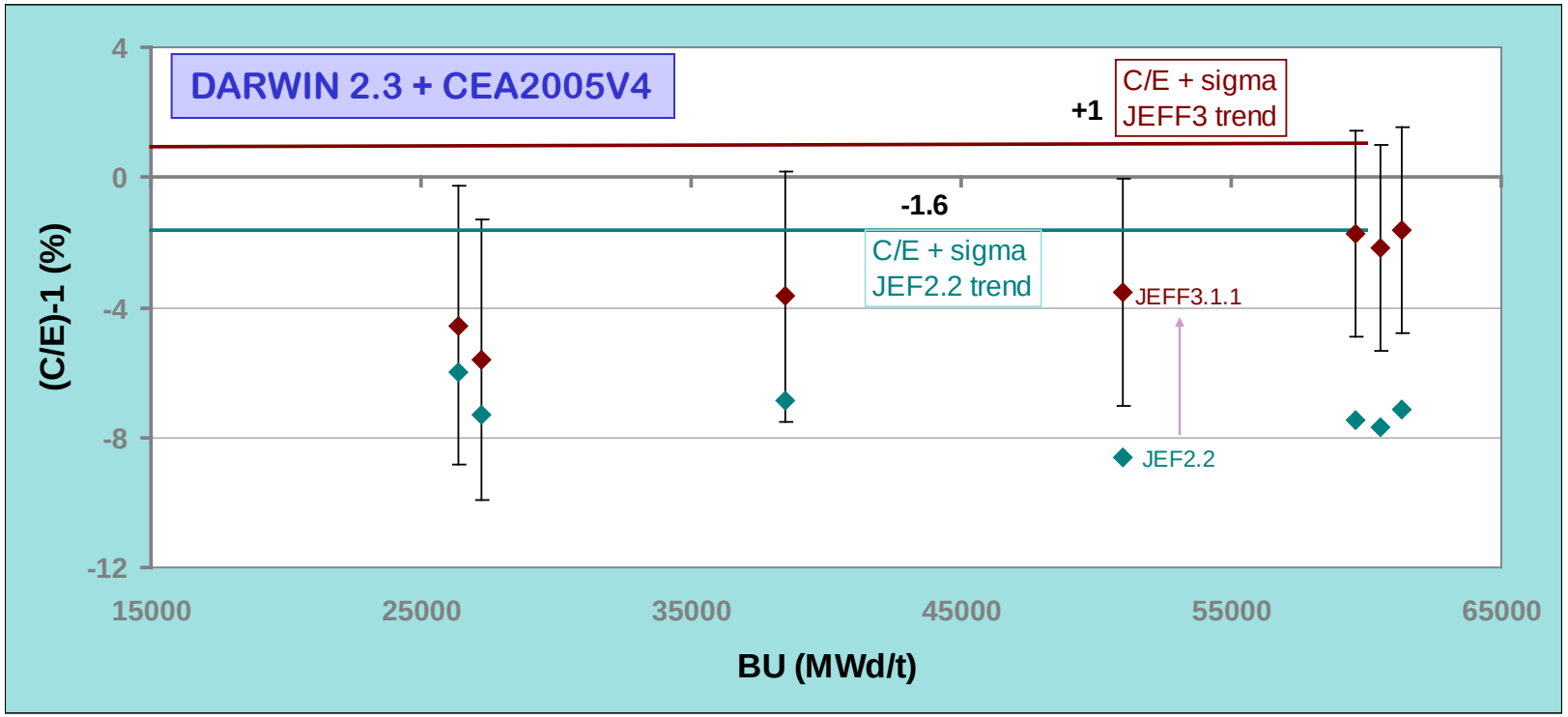
1/ Validation of the DARWIN 2 Depletion Code for SF inventory

- **Calculation route :** Validated reference sheme ‘REL2005’ of the APOLLO2.8 package

  ref J-F VIDAL et al., « New Modelling of LWR Assemblies using the APOLLO2 Code Package », M&C2007, Monterey (USA).

- **Depletion calculation**
  - Accurate description of Operating Power (PEPIN2)
  - Fuel, Clad and Moderator Temperatures calculated with a thermo-mechanics code (METEOR)
  - ‘Effective Temperature’ of fuel (^{238}U capture rate)
  - Mean Boron concentration + Stretch-out modelisation
- **Calculation to experiment comparison**
  - PWR UO_2 BUC database**:**
    - $^{235}U^{Init}$: 3.1% to 4.5%
    - BU : 15 to 60 GWd/t
    - 22 samples
  - (C-E)/E versus burnup uncertainty (σ) versus burnup

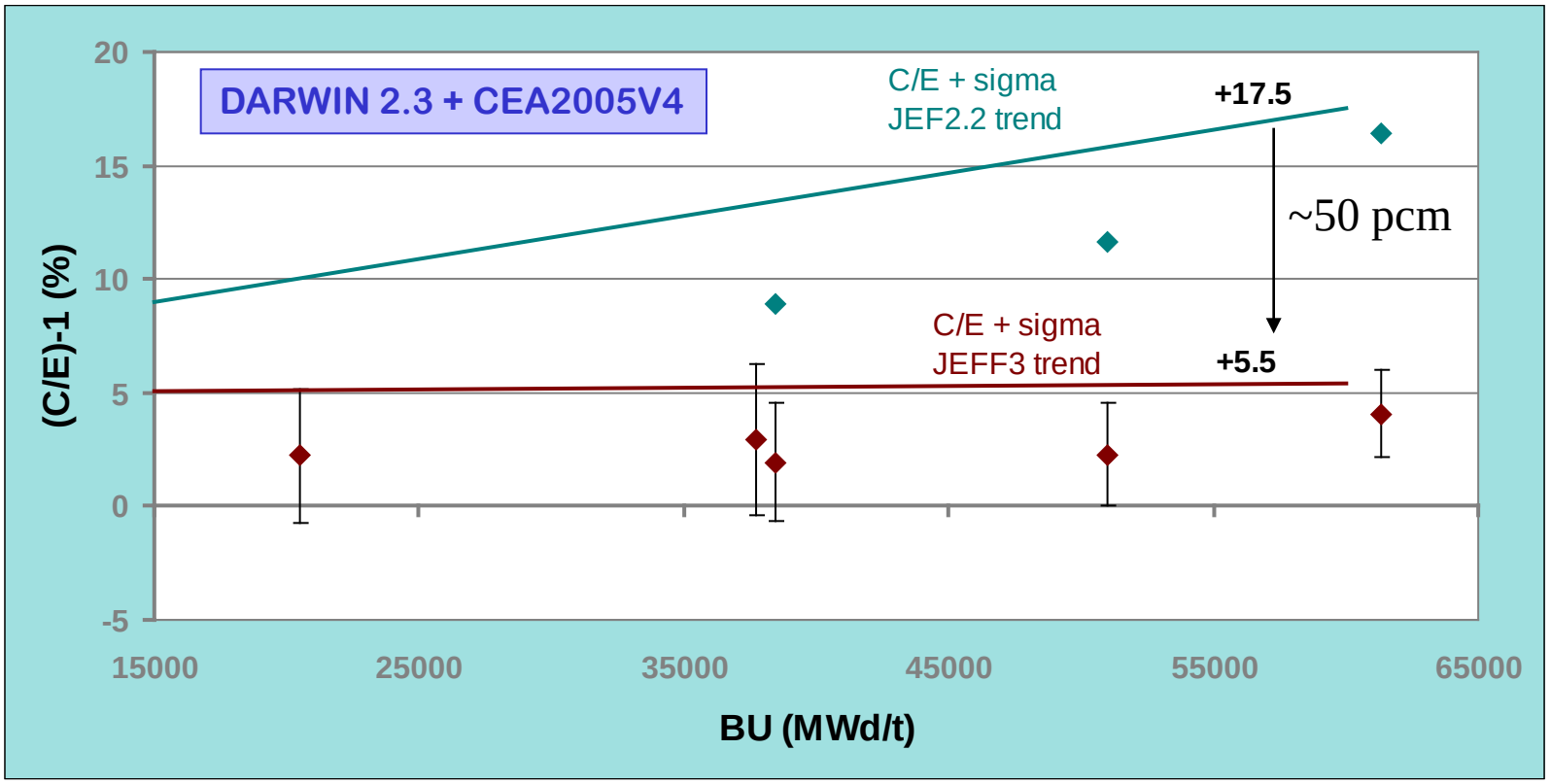
Full Propagation of errors:
Chemical analysis, Burnup determination, Mod. Temp., Fuel Temp., Operating History



^{242}Pu Calculation – Experiment deviation in part of the French P.I.E. database

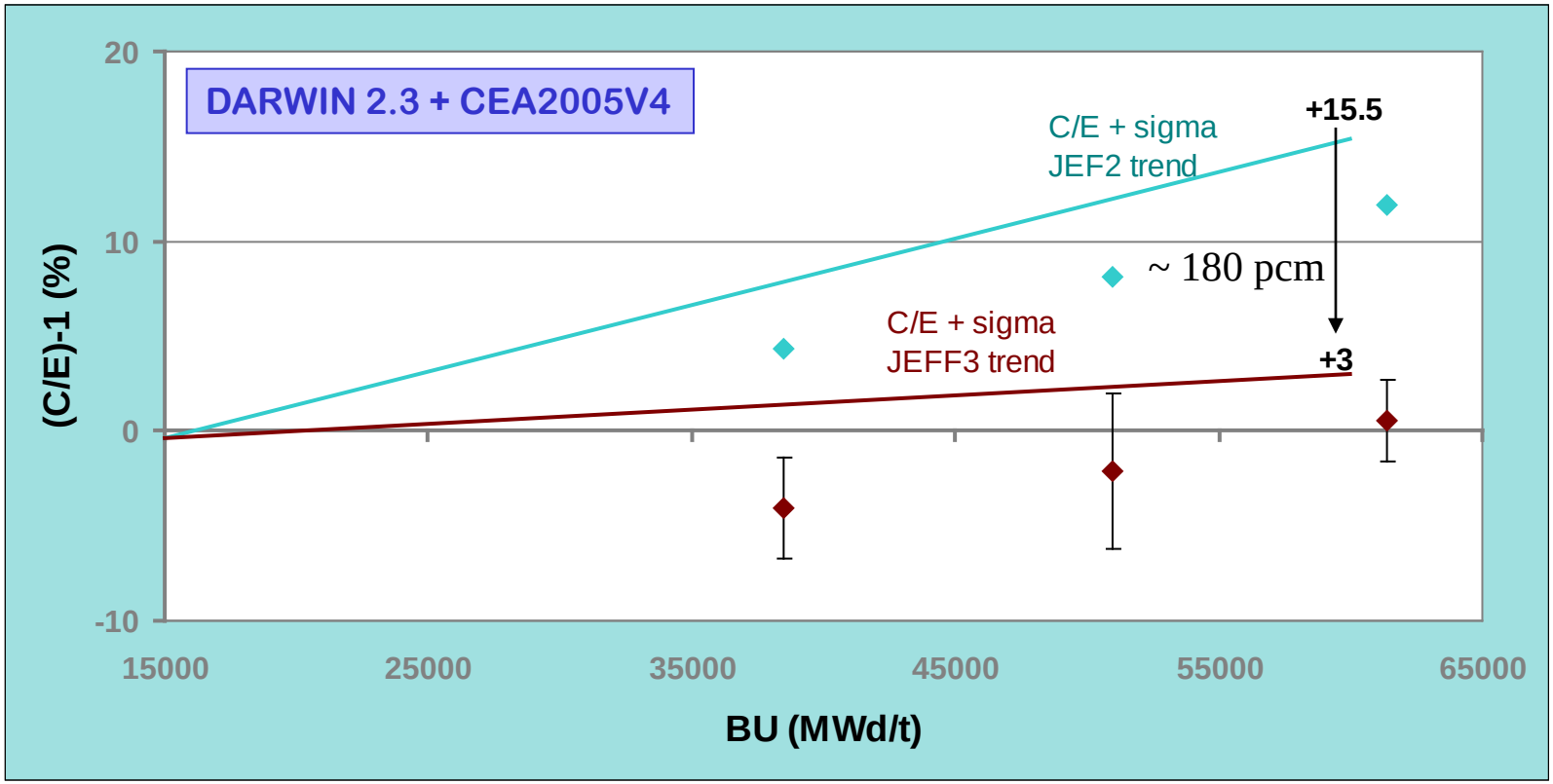
The linear trends are calculated on the whole PIE database

Maximum deviation [(C-E)/E $\sigma]_{BU}$ = retained value for the determination of CF excepted ^{235}U and ^{239}Pu (exact linear trend retained)



^{153}Eu Calculation – Experiment deviation in part of the French P.I.E.

(The linear trends are calculated on the whole PIE database)



^{155}Gd Calculation – Experiment deviation in part of the French P.I.E. database

(The linear trends are calculated from the whole PIE database)

- The application of these correction factors enables us to correct the underestimation of some fissile isotopes and the overestimation of some absorbent isotopes for the total calculated reactivity worth; If it is not the case, Fc = 1 (the calculated concentration is not modified), in order to maintain the conservatism of the concentration.

Isotope	Partial Correction Factor JEFF3
^{236}U	0.99
^{240}Pu	0.99
^{241}Pu	1.08
^{242}Pu	0.99
^{241}Am	0.98
^{133}Cs	1
^{143}Nd	0.99
^{151}Sm	1
^{152}Sm	1
^{153}Eu	0.95
^{155}Gd	0.97

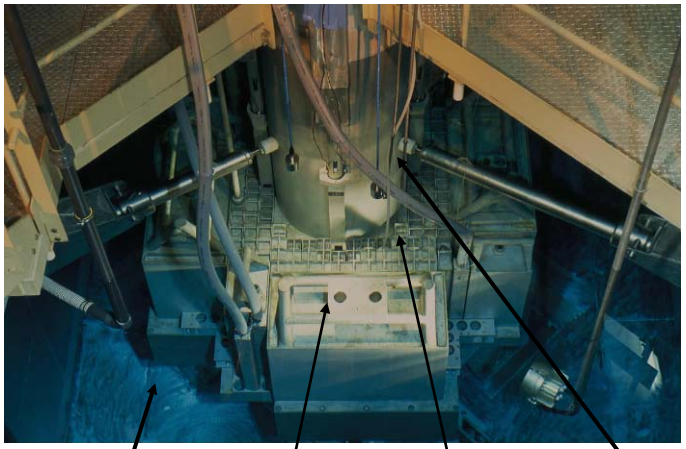
2/ Validation of the CRISTAL V1 code for FP poisoning worth calculation

- **Calculation route: deterministic transport Code APOLLO2.5 in CRISTAL V1; experiment analysis by Exact Perturbation Theory**
  - **Limited multicell geometry 2-D 11x11**
  - **Pij – UP1 model**
- **From (C-E)/E bias in R1-UO2 (LWR experimental lattice)**
  - **(C-E)/E uncertainty (σ) for each FP isotope**

Ref Santamarina et al., ICNC95

Quadratic combinaison of errors:
Chemical analysis of the sample material balance, experimental uncertainty of Δ (sample – reference) signal, calibration of the experimental worth signal

Minerve core



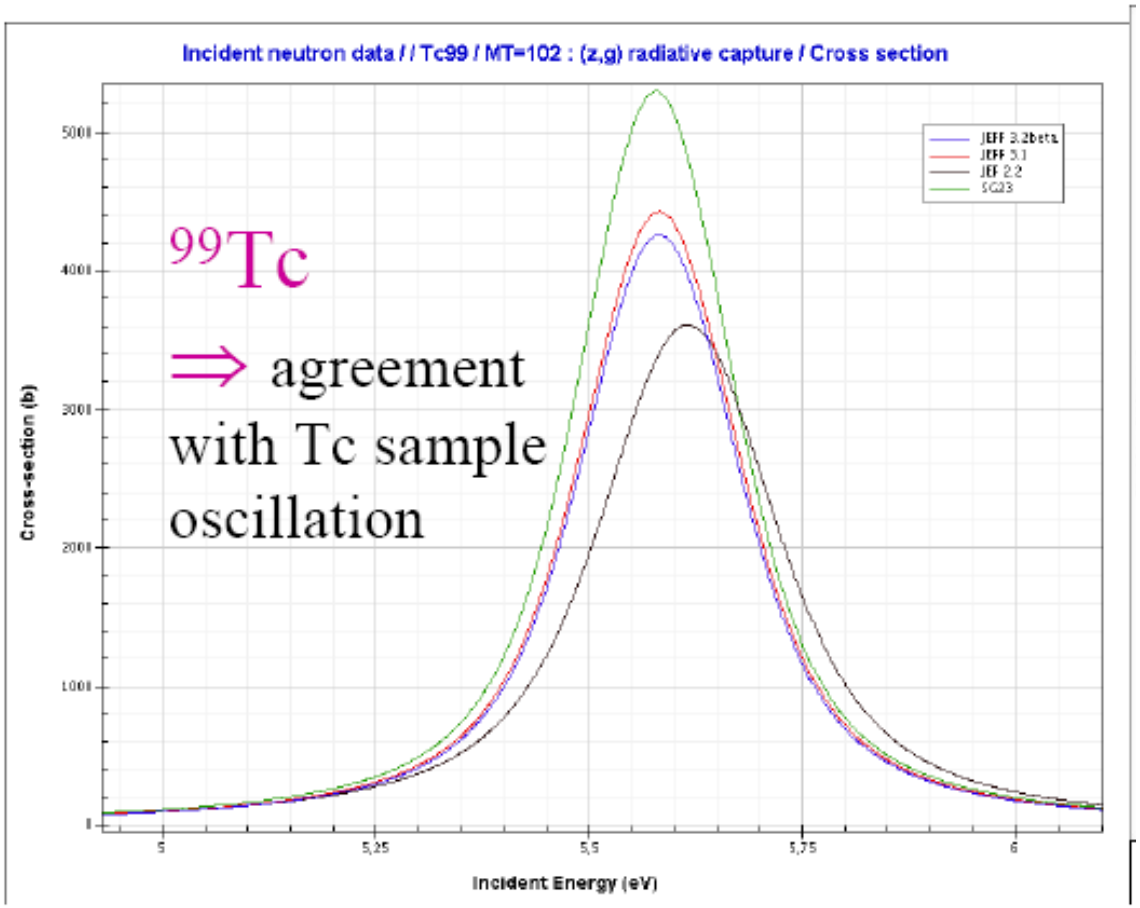
- JEF2.2 results

Calculation – experiment biases of FP poisoning worth in R1-UO2 with CRISTAL V1

Isotope	(C-E)/E	Uncertainty
	[%]	[%]
Sm-149	-5.7	2.1
Nd-143	-4.5	2.5
Rh-103	13.3	4.0
Cs-133	4.3	1.9
Gd-155	-1.9	2.9
Sm-152	-0.2	3.2
Nd-145	0.4	4.1
Mo-95	-3.6	3.4
Eu-153	-1.6	4.4
Ag-109	-1.7	4.0
Tc-99	4.2	3.8

Maximum deviation [(C-E)/E + σ] = retained value for the determination of CF

Improvements in JEFF3.1.1 : new FP evaluations



A. SANTAMARINA et al., JEF-DOC 1263

- **Global Correction Factors applied to the BUC nuclides calculated with DARWIN2 / JEF2.2 for criticality calculations involving PWR-UO2 fuels**

Actinides	CF	Fission Product	CF
^{234}U	0.94	^{95}Mo	0.94
^{235}U	1.01	^{99}Tc	0.87
^{236}U	0.98	^{101}Ru	0.70
^{237}Np	0.98	^{103}Rh	0.80
^{238}Pu	1.00	^{109}Ag	1.00
^{240}Pu	0.97	^{133}Cs	0.96
^{241}Pu	1.06	^{143}Nd	0.98
^{242}Pu	0.99	^{145}Nd	0.94
^{241}Am	0.94	^{147}Sm	0.99
^{243}Am	0.98	^{149}Sm	0.97
		^{150}Sm	0.97
		^{151}Sm	0.84
		^{152}Sm	0.90
		^{153}Eu	0.83
		^{155}Gd	0.86

Improvement of the spent fuel inventory bias with CEA2005V4 for:

Pu242
Am241
Nd143
Sm147
Sm151
Sm152
Eu153
Gd155

Full BUC approach based on Global Isotopic Correction Factors applied in front of the criticality calculation, derived from the Qualification reports of the French reference codes :

- DARWIN 2.3 Spent Fuel inventory calculation
- CRISTAL Criticality and FP reactivity worth calculation
- The recommended fuel cycle Library CEA2005V4

Forthcoming :

Significant reduction of the global CF / JEF2.2 due to the CEA2005V4 library for ^{147}Sm, ^{151}Sm, ^{152}Sm, ^{153}Eu and ^{155}Gd isotopes + improvement of ^{99}Tc reactivity worth prediction.