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Validation of Important Fission Product Evaluations Through CERES Integral Benchmarks

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Serco Assurance

AID -172

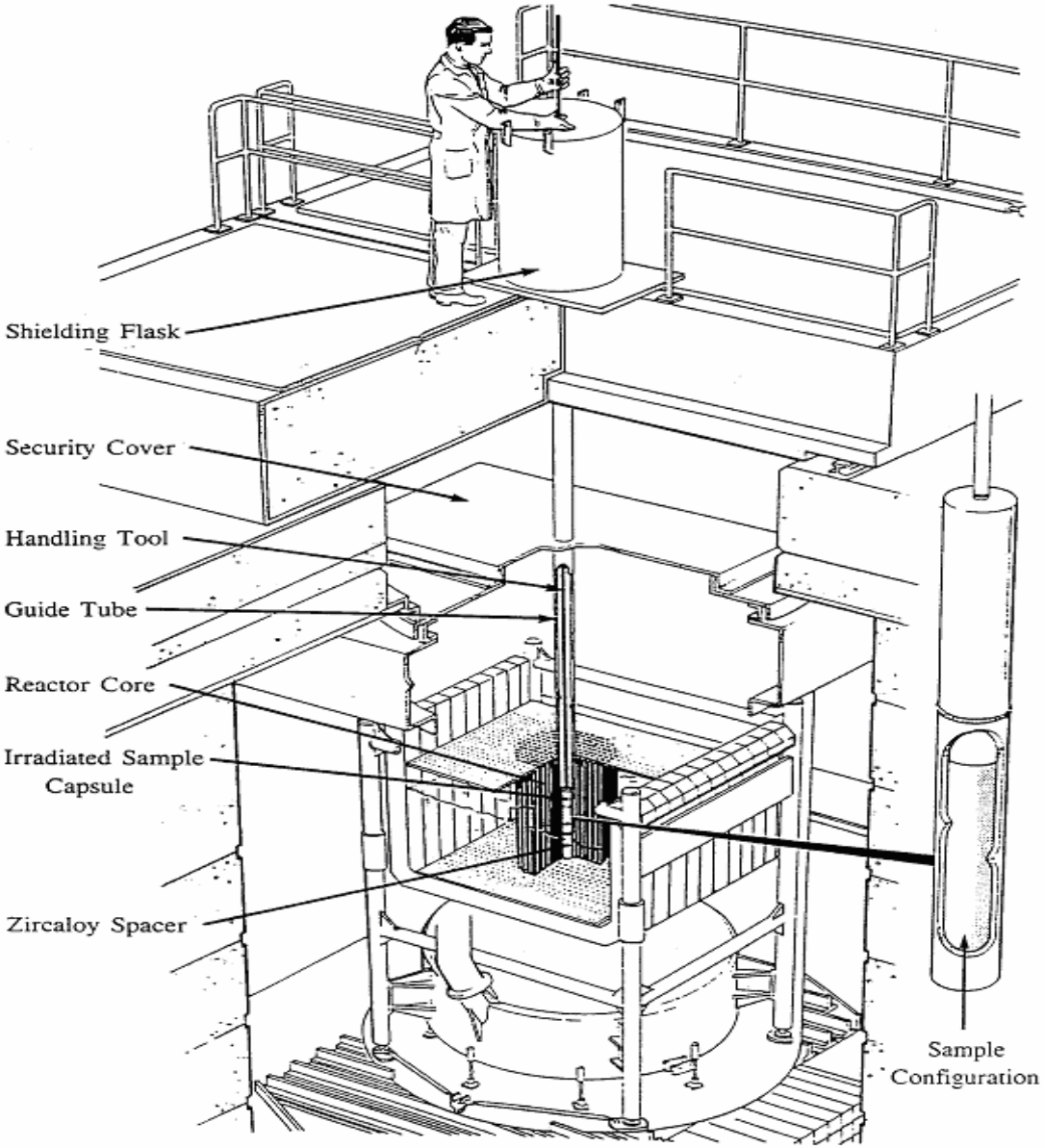
Background

- WPEC 23 -Evaluated Data Library for the Bulk of the Fission Products
- JEF2.2 Fission Products are from Mughabghab 4th Edition (1981-1984)
- JEFF3.1 Adjusted/selected evaluations based on JEF2.2 CERES benchmarking
- WPEC23 Fission Products are from Mughabghab 5th Edition (2006)
- Benchmarking JEF2.2, JEFF3.1, WPEC23 Against CERES Measurements.
- CERES Sensitive to Thermal cross section + Lowest Energy Resonances
- CERES Phase II Considers 12 Important Fission Products (FP)
- They Contribute~50% of FP Absorption in 3% Enriched PWR fuel @30GWd/Te
- They Contribute ~75% Absorption for Burn-up Credit (5 years storage)

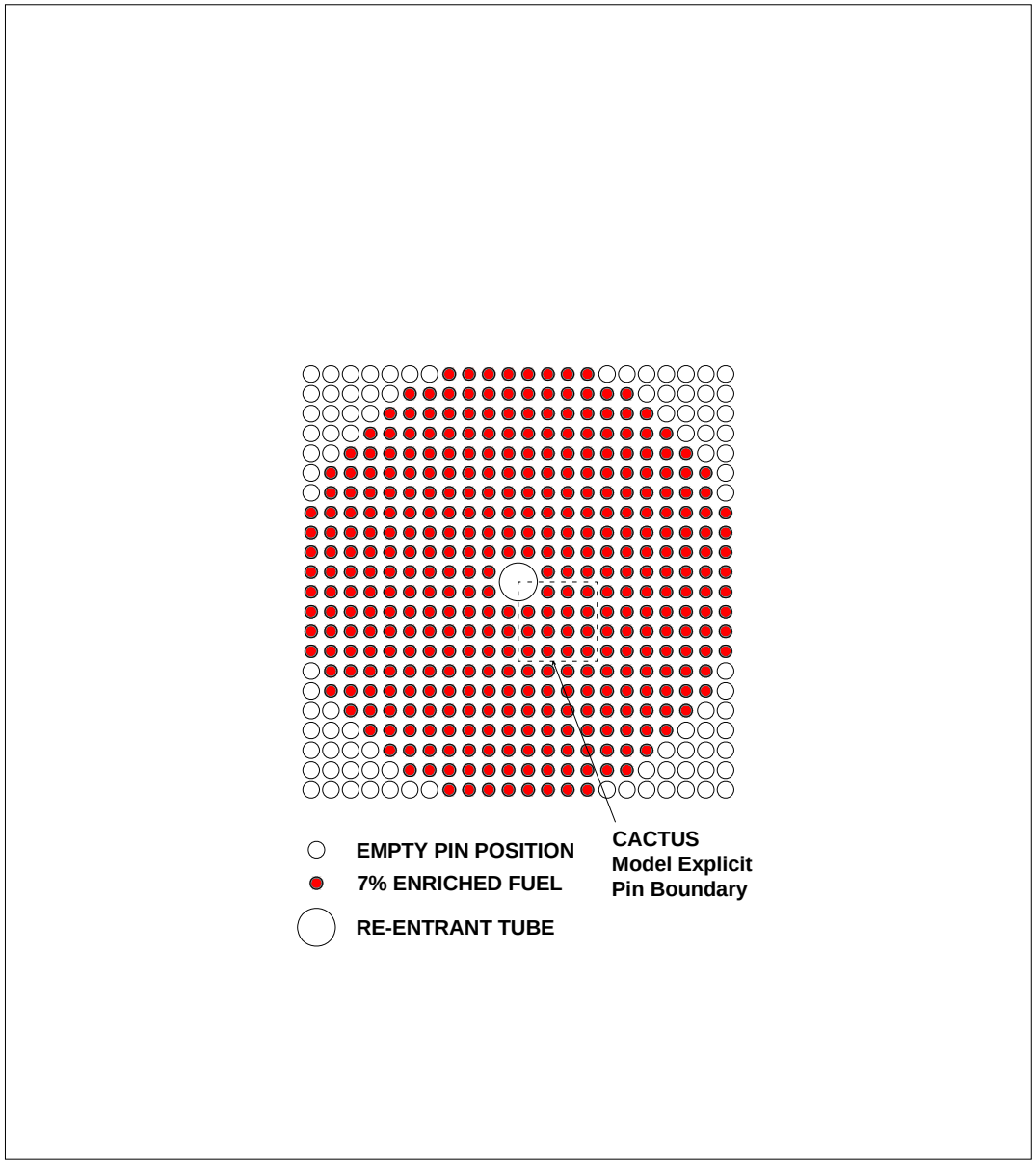
CERES Fission Product Measurements

- Calibration Samples are Natural + 3 + 4% Enriched UO2 Fuel + Cu +Steel +Zr +Al.
- Fission Products Samples are Natural + 4% Enriched UO2 Fuel +Doped with Each Fission Product Isotope.
- Manufactured in France.
- Irradiated in Minerve @ Cadarache and in Dimple @ Winfrith
- Analysis of Minerve with Apollo
- Analysis of Dimple with WIMS
- Reactivity Worth from Transient Power Response was Measured with Flux Detectors – Accuracy ± 0.4pcm (Prevents Monte Carlo Analysis)

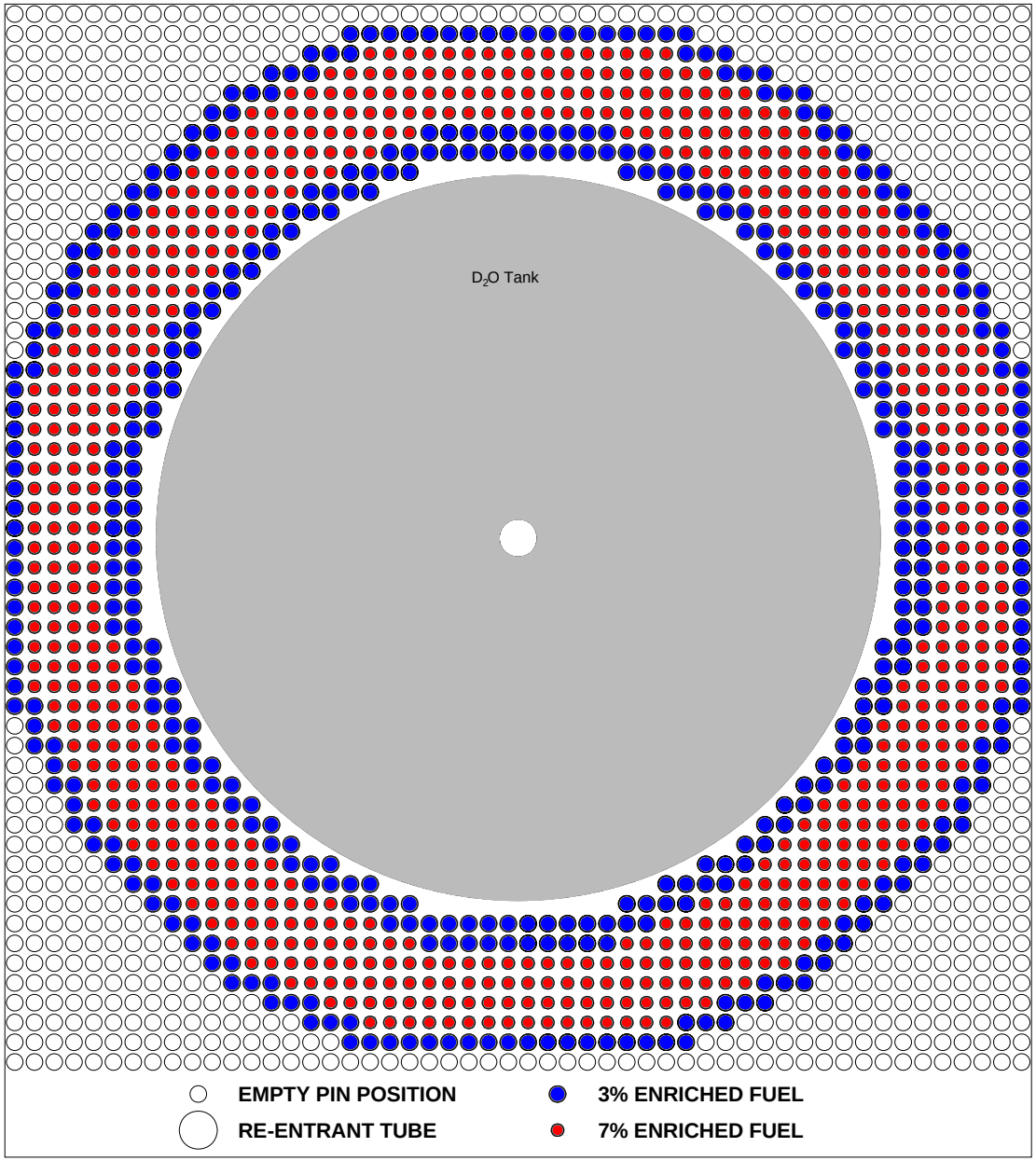
DIMPLE Arrangements for Sample Measurements



CERES Assembly II - PWR Spectrum



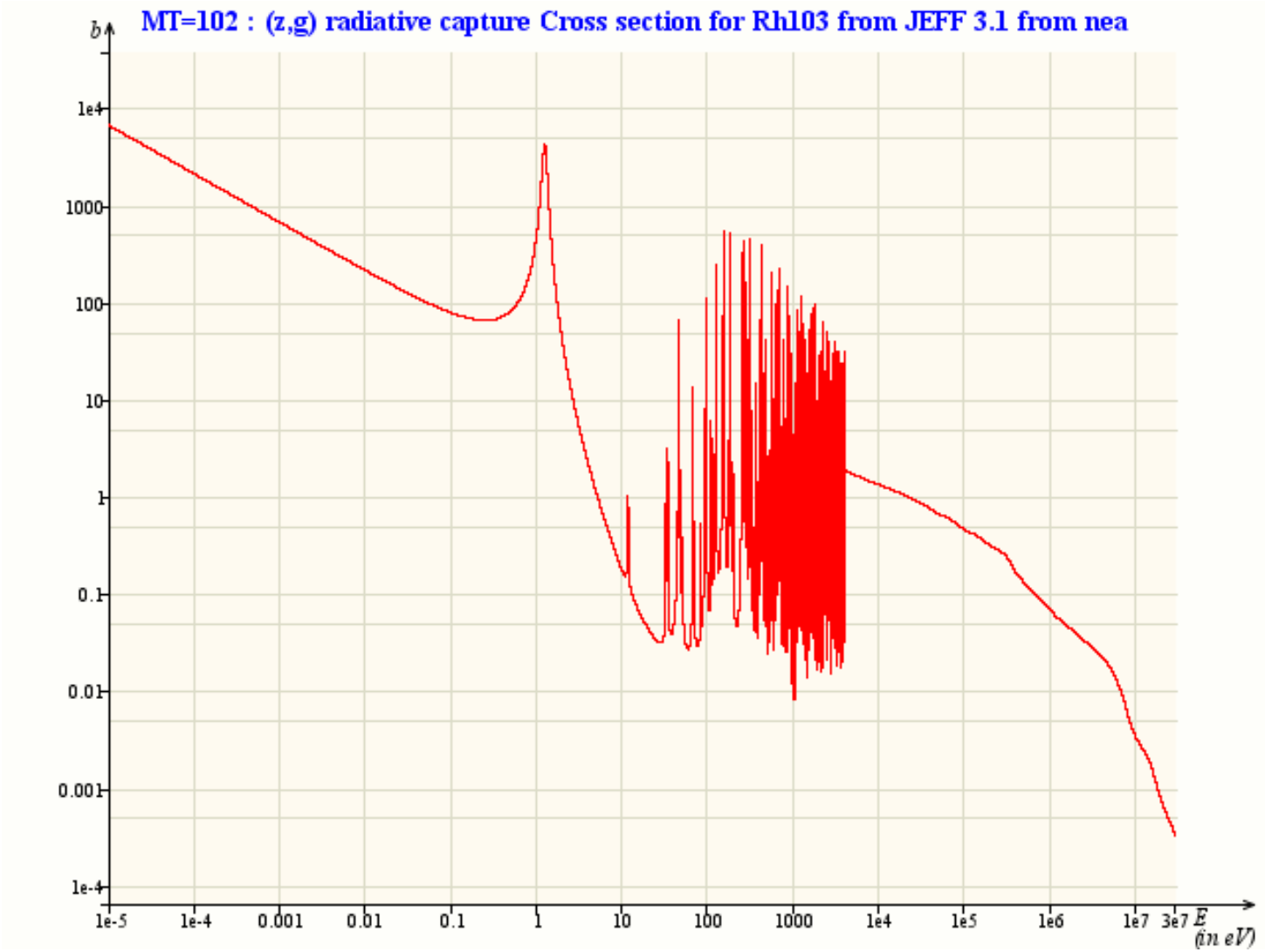
CERES Assembly III – Soft Spectrum



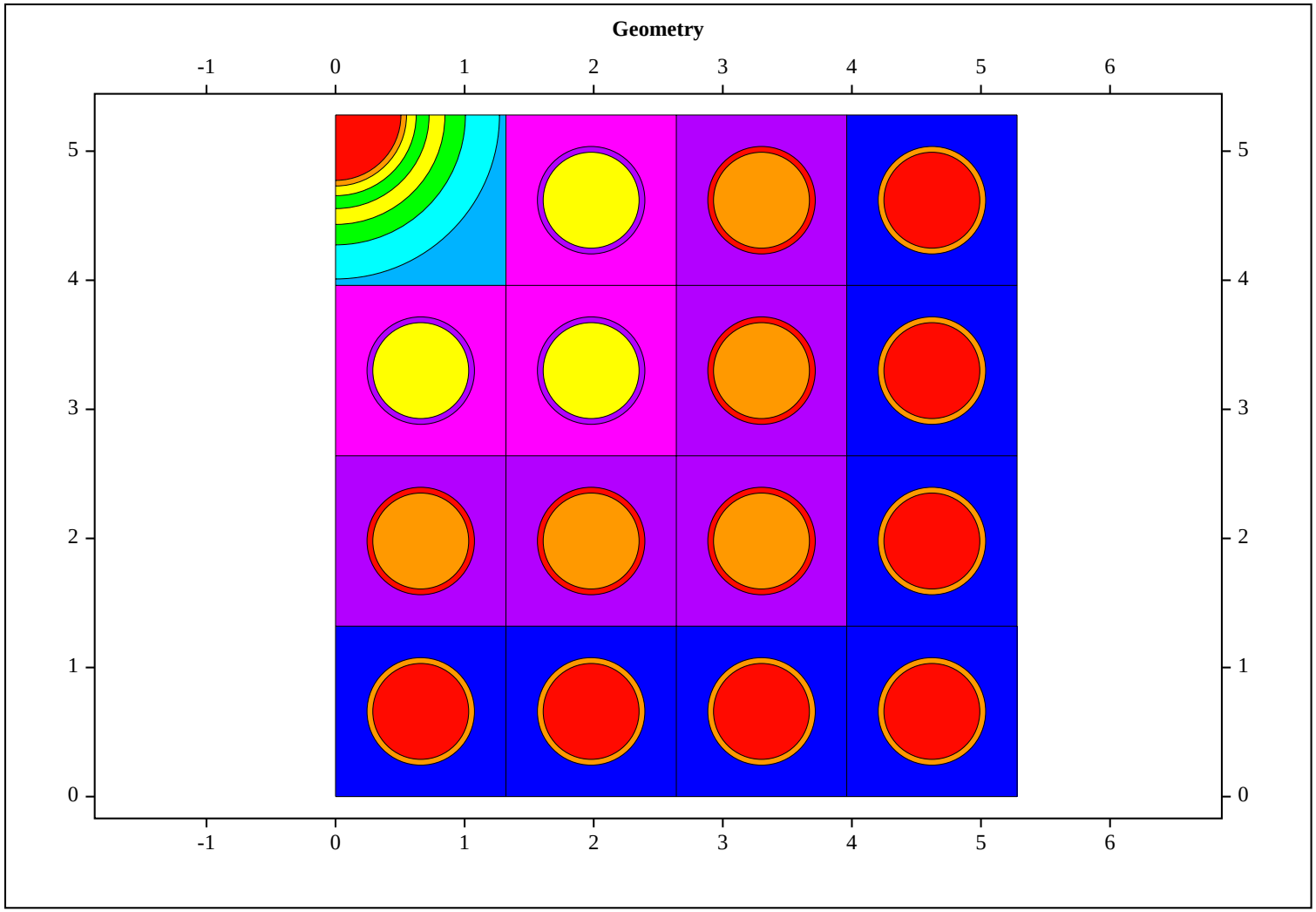
Measured Reactivity Worth – PCM (10^{-5} in Keff)

Fission Product	PWR	SOFT
Mo-95	-9.94	-9.15
Tc-99	-15.07	-10.01
Rh-103	-16.11	-9.37
Ag-109	-17.81	-10.46
Cs-133	-17.88	-11.62
Nd-143	-17.91	-20.96
Nd-145	-16.62	-14.97
Sm-147	-47.66	-43.80
Sm-149	-24.02	-27.07
Sm-152	-24.89	-20.89
Eu-153	-27.33	-19.14
Gd-155	-19.27	-29.49

Rh103 Capture Thermal and 1.3eV Resonance Impact



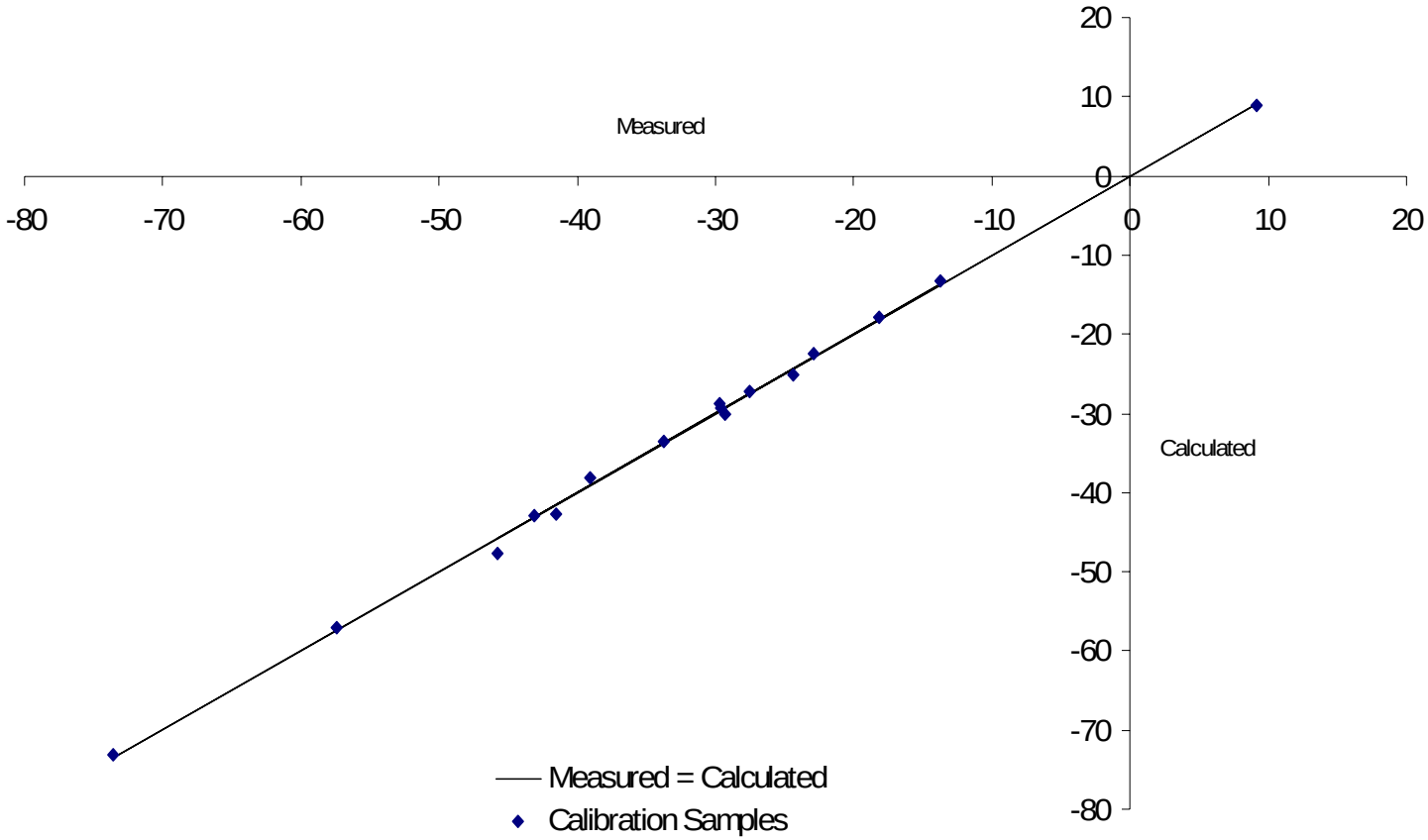
WIMS10 model of Assembly II - PWR



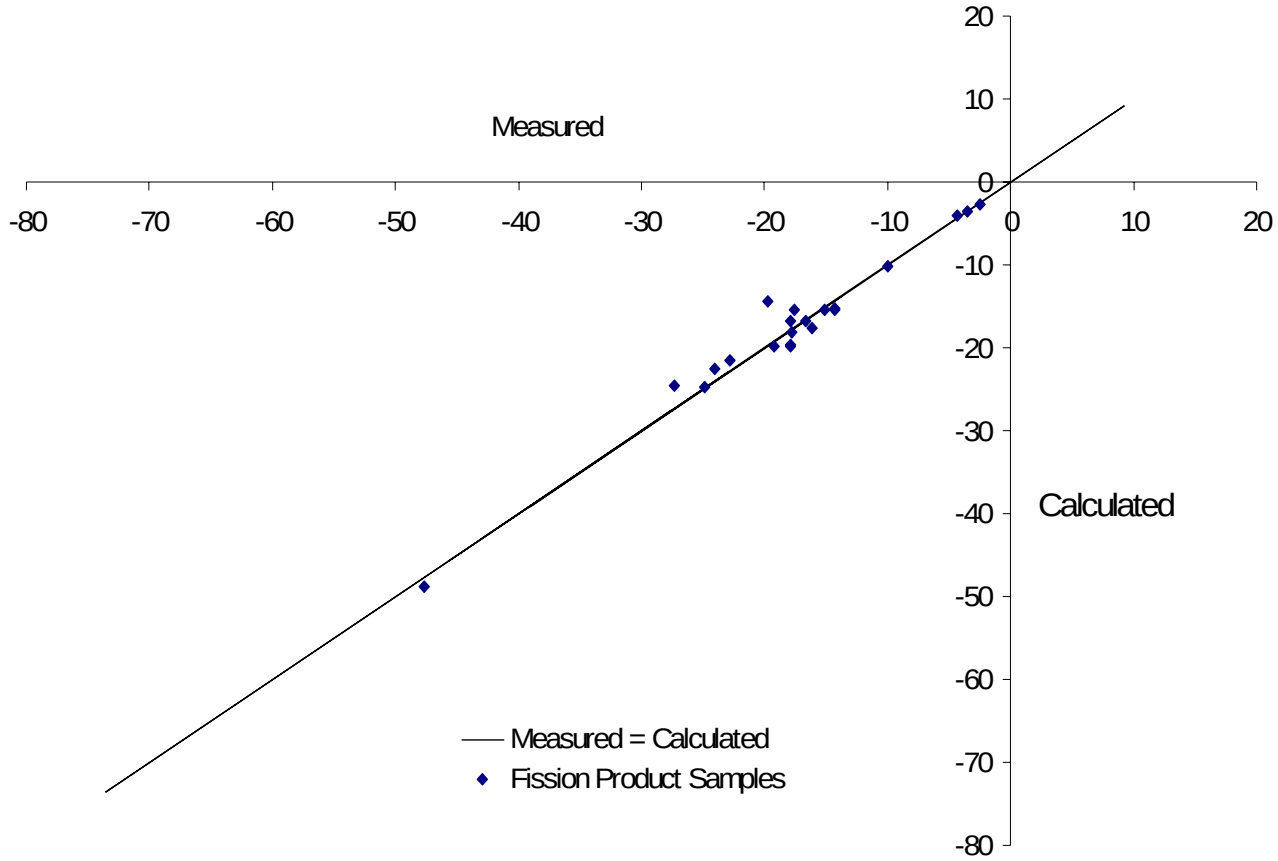
Method in WIMS10

- HEAD – Equivalence Theory for Less Important Nuclides.
- PRES/CACTUS/RES – Subgroup theory for U-235,U-238 + Fission Product. E>4eV
- PERSEUS/PIP – 172 group flux.
- CONDENSE – 15 group cross sections.
- CACTUS – 2D Characteristics method.
- CRITIC/SMEAR – Normalise K-eff to Critical Spectrum, Smear Sample for Exact Perturbation Theory Calculation.
- Resonance Shielding for all Fission Products above 4eV.
- Resonance Shielding for Scatter + Absorption.
- Fine Group Treatment (Cs-133).

Calibration Samples in Assembly II – PWR (all within 2%)



Fission Product Samples on Calibration line



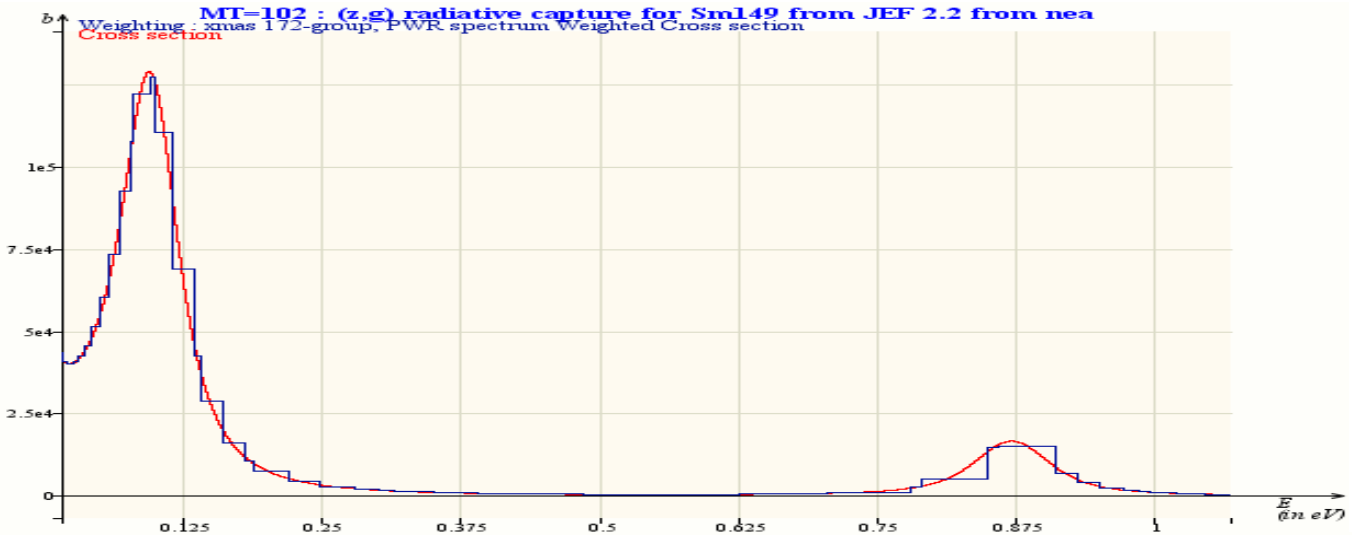
Results for Assembly II - PWR (C-E/E) – 4%σ

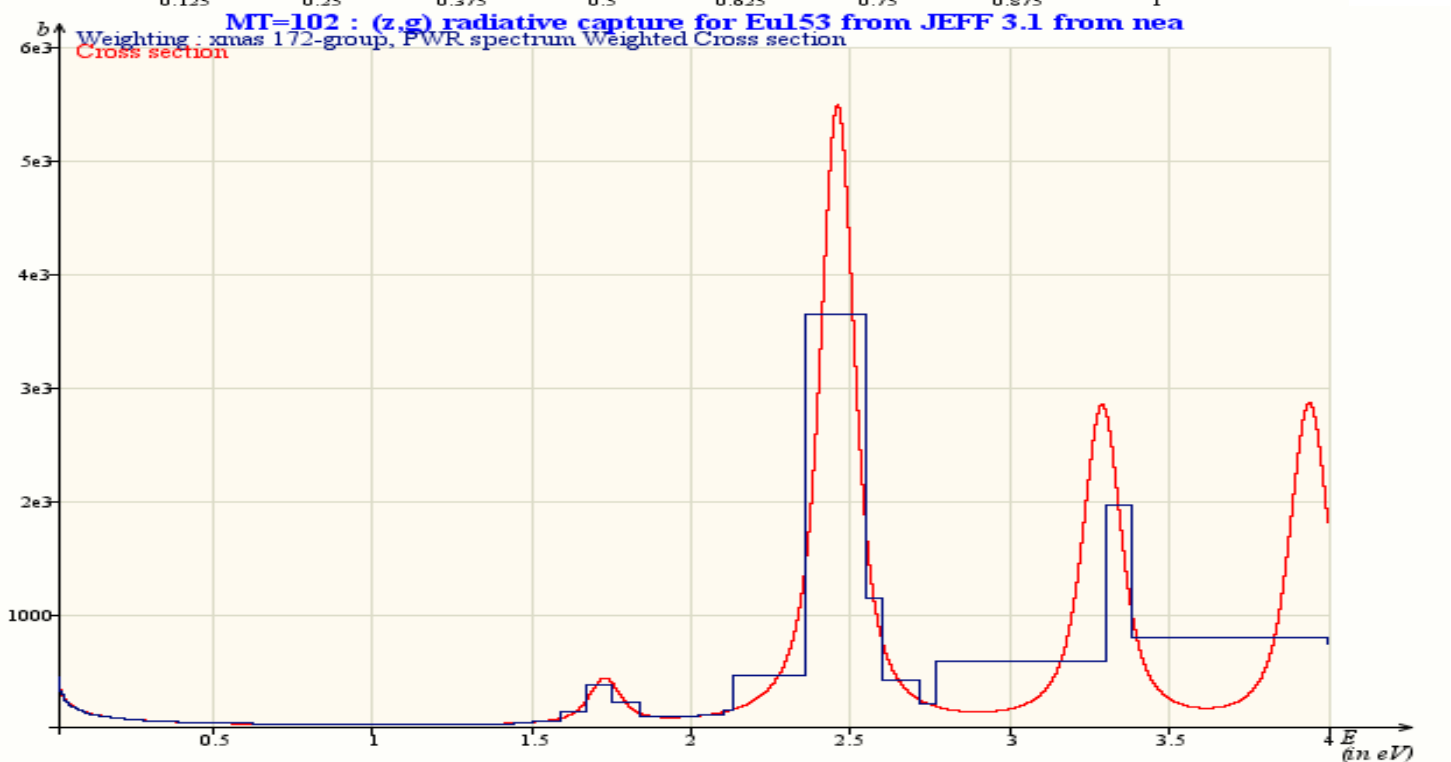
Fission Product	JEF2.2	JEFF3.1	WPEC23	JEFF3.1 Action
Mo-95	+2	0	0	Pre ENDF/BVII
Tc-99	+3	+8	+10	Gunsing ,Serot
Rh-103	+10	+6	+8	Dupont, Moxon
Ag-109	+2	+2	+2	JEF2.2
Cs-133	+10	+10	+10	Early WPEC23
Nd-143	-6	-3	-6	JEF2.2 Γ_n+4% DOC885
Nd-145	0	+1	+11	JEF2.2
Sm-147	+2	+4	0	JEF2.2
Sm-149	-6	-4	-6	ENDF/B-VI rel. 4 DOC885
Sm-152	0	0	0	JEF2.2
Eu-153	-10	-6	-6	JENDL3.2
Gd-155	+3	+3	+3	JEF2.2

Results for Assembly III – SOFT (C-E/E) – 4%σ

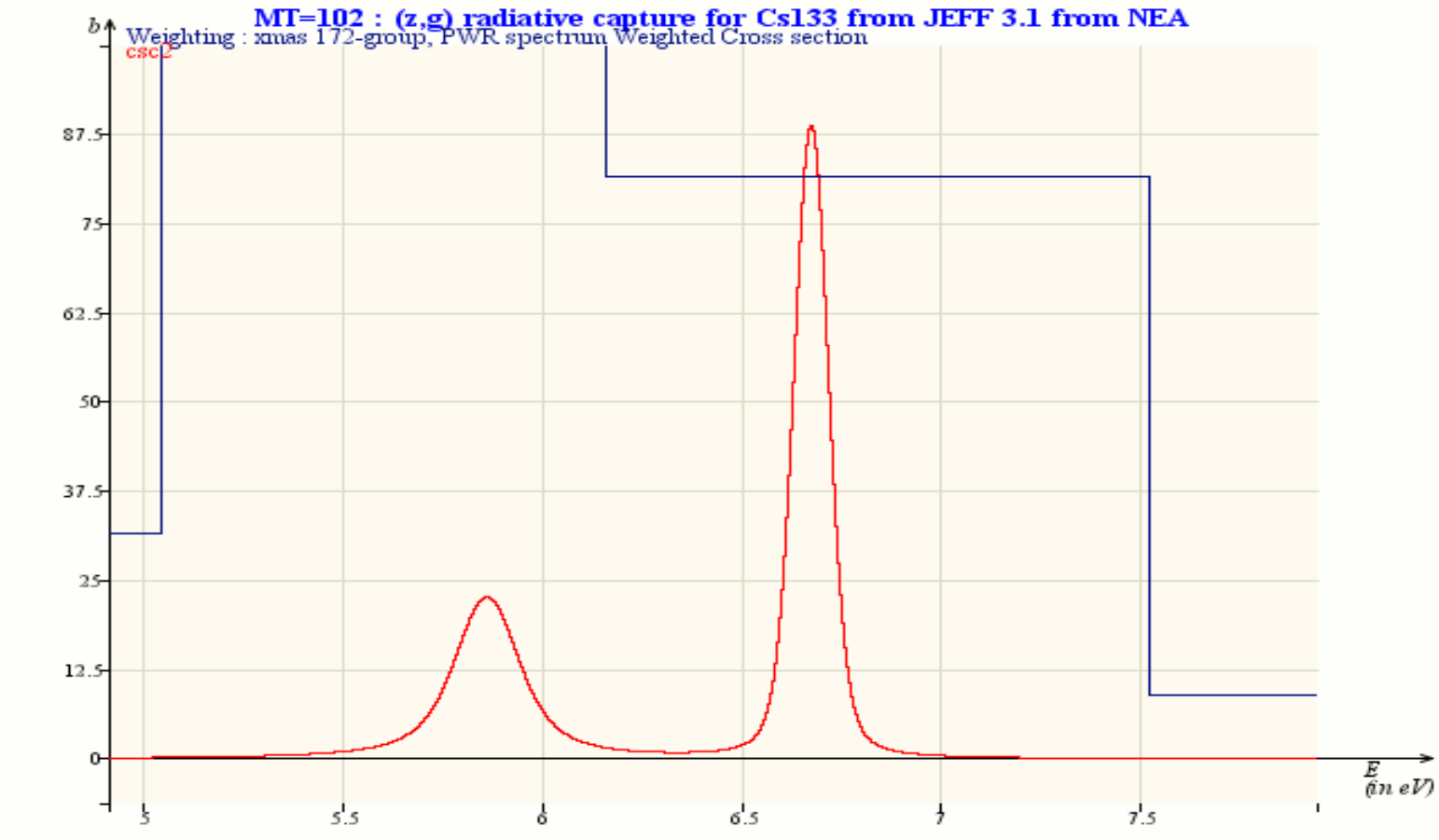
Fission Product	JEF2.2	JEFF3.1	WPEC23
Mo-95	+11	+9	+9
Tc-99	-3	+9	+10
Rh-103	+13	+10	+12
Ag-109	+5	+5	+5
Cs-133	+12	+11	+11
Nd-143	-3	-1	-2
Nd-145	0	+1	+13
Sm-147	+5	+7	+3
Sm-149	0	+2	0
Sm-152	-1	0	-1
Eu-153	-17	-11	-11
Gd-155	+4	+4	+4

XMAS Group Structure Generally Good (Sm-149) – Eu-153 Poor





Scaled Σ Showing Separable Cs-133 and U-238 resonances



Measured Reactivity Worth – PCM (10^{-5} in Keff)

Fission Product	Accuracy	PWR	SOFT
Mo-95	3σ	-9.94	-9.15
Tc-99	3 σ	-15.07	-10.01
Rh-103	3 σ	-16.11	-9.37
Ag-109	2 σ	-17.81	-10.46
Cs-133	3 σ	-17.88	-11.62
Nd-143	2 σ	-17.91	-20.96
Nd-145	3 σ	-16.62	-14.97
Sm-147	1 σ	-47.66	-43.80
Sm-149	2 σ	-24.02	-27.07
Sm-152	1 σ	-24.89	-20.89
Eu-153	Method	-27.33	-19.14
Gd-155	1 σ	-19.27	-29.49

Conclusions

- Analysis of CERES Fission Product Experiment with the Latest UK Codes + International Data have been Submitted to WPEC23.
- CEA Analysis is Required to Confirm Results, Possibly with SHEM Mesh – but Current CEA Trends are Said to be Similar to Ours.
- No Dramatic Improvement in Differential Data.
- Integral Trends Still Need to be Considered on an Isotopic Basis.
- New Rh103 and Tc99 Evaluations Still Need Attention.
- Attention must Revisit CERES Benchmarking as well as the Evaluation.
- The CERES Benchmark is Very Important for Both Fission Product Data and Overall Assessment of the Accuracy of Data for Irradiated Fuel.