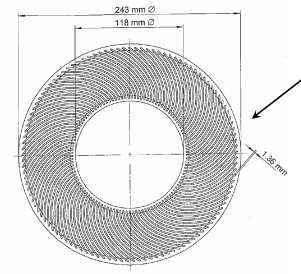
Calibration with Monte Carlo Calculations of a Neutron Collar for the Verification of FRM-II Fuel Elements

M. Looman[1], P. Peerani[1], P. Schwalbach[2]
1) European Commission, DG-JRC, IPSC, Ispra (Italy)
2) European Commission, DG-TREN, ESO, Luxembourg



Cross-section of the FRM-II fuel element

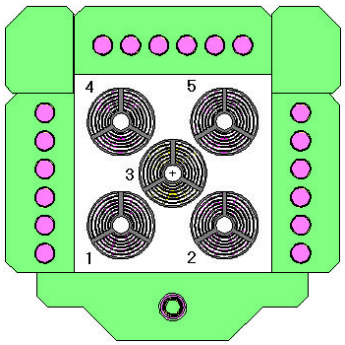
Principle

The FRM-II reactor is a high-flux research reactor operated by the Technische Universität München (TUM) at the Garching Research Center (Germany). The reactor core consists of a single cylindrical fuel element, containing U_3Si_2-Al-dispersion fuel in combination with high-enriched uranium (HEU, with about 93% ^{235}U). The fuel contains about 8 kg of uranium and is placed in 113 involutely curved fuel plates.

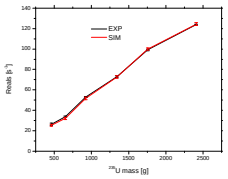
The verification of the ^{235}U content in this element can be based on active neutron interrogation assay using a coincidence collar. The main difficulty in implementing neutron measurements on the FRM-II elements comes from the unavailability of certified materials identical or even similar to the real items for the calibration of the instrument.

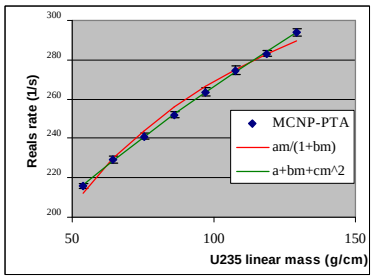
To overcome this problem we tested a calibration procedure based on the Monte Carlo simulation of the Reals and Totals count rates with the MCNP-PTA code developed at JRC Ispra. The procedure is based on the following steps:

- measurement in the PERLA laboratory of the available HEU standards (MTR type fuel elements),
- comparison between MCNP-PTA calculations and the experimental results in order to validate the computational model of the detector,
- generation with MCNP-PTA calculations of the response function of the detector with FRM-II fuel elements,
- verification of real FRM-II elements at the CERCA plant.



Monte Carlo model of the collar with MTR fuel





Calibration curve for FRM-II elements

SETUP					Masses		Experimental		Simulated		Sim/Exp	
1	2	3	4	5	U	^{235}U	T	R	T	R	T	R
-	-	-	-	-	0	0	4317	0	4098	0	0.949	-
-	-	270	-	-	514	462	4523	26.4	4329	25.4	0.957	0.960
-	-	C27	-	-	697	649	4614	33.9	4395	32.1	0.952	0.948
270	269	-	-	-	1026	922	4707	53.0	4517	51.7	0.960	0.976
270	269	283	-	-	1492	1340	4865	73.1	4679	72.5	0.962	0.993
270	269	-	283	284	1956	1757	5145	99.1	4930	100.0	0.958	1.009
270	269	C27	283	284	2653	2407	5289	124	5083	124.4	0.961	1.004

Comparison Exp/Sim for PERLA elements

	Reals rates			^{235}U mass				
	MCNP calculation	Measure	Corrected	Declared	Calculated calibration 1	Diff.	Calculated calibration 2	Diff.
Nominal	274.60		274.60	7538	7491		7589	
Element 006 (single)		254.38 ± 2.23	275.13	7572	7540 ± 215	-0.42%	7628	0.73%
Element 006 (average)		256.07	275.99	7572	7620	0.64%	7691	1.57%
Element 007		251.66 ± 2.21	274.09	7573	7445 ± 209	-1.70%	7552	-0.28%

Verification of FRM-II elements

Conclusion

Using this method the ^{235}U content in the fuel element was verified with an uncertainty lower than 2%.

The results proved that computational modelling is now a mature technique for application to NDA measurements and can really help in reducing experimental effort and requirements of calibration standards.

PERLA laboratory