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COG Preliminary Results for a SILENE Criticality Excursion Benchmark Experiment

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Background

- In October 2010, a series of single-pulsed experiments was performed in SILENE reactor, changing the reflecting materials; bare, lead, and polyethylene,
- About 100 neutron activation foils, 60 TLDs used, and CAAS detectors tested, to obtain data for the first criticality accident alarm (CAAS)/shielding benchmark,
- Provide valuable data for radiation transport code validation, COG, MCNP, SCALE,
- Preliminary COG simulation results and comparisons to Collimator A measurement data for the 1st pulse experiment are presented.

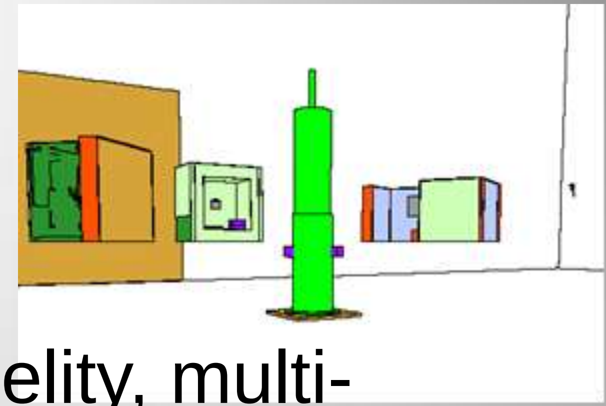
SILENE Pulse 1 Experiment

CAAS Detector, TLD, and Foils in Collimator A

Collimator A Foil and TLD Measurement Data (from CEA report, N°2011/014.a)

ESSAI	REF. DOSIMETRE(S) REACTION D'ACTIVATION	RESULTAT	NORME	TECHNICIEN
1	**Au05-A10** $^{197}Au(n,\gamma)^{198}Au$	$(1.812 \pm 0,057)\ .10^{5}$ Bq/g	ASTM E181	G. ROUSSEAU X. JACQUET
1	**Ni011** $^{58}Ni(n,p)^{58}Co$	$(14,36 \pm 0,44)$ Bq/g	ASTM E181	
1	**In005** $^{115}In(n,n',\gamma)^{115m}In$	(8030 ± 250) Bq/g	ASTM E181	
1	**In005** $^{115}In(n,\gamma)^{116}\ In$	$(9,11 \pm 0,35)\ .\ 10^{6}$ Bq/g	ASTM E181	
1	**Fe021** $^{54}Fe(n,p)^{54}Mn$	$(0,2062 \pm 0,0082)$ Bq/g	ASTM E181	
1	**Fe021** $^{56}Fe(n,p)^{56}Mn$	(2310 ± 61) Bq/g	ASTM E181	
1	**Mg032** $^{24}Mg(n,p)^{24}Na$	$(61,1 \pm 2,3)$ Bq/g	ASTM E181	
1	**Co013** $^{59}Co(n,\gamma)^{60}Co$	$(66,1 \pm 1,7)$ Bq/g	ASTM E181	
2	**TLD n°9**	$(6,61 \pm 0,29)$ Gy (kerma air eq. ^{60}Co)	ASTM E668	G. ROUSSEAU X. JACQUET

COG11



- Modern, general purpose, high-fidelity, multi-particle, Monte Carlo transport code,
- Can solve complex 3-D shielding, criticality, and activation problems,
- Reaction rates calculated in 1-step using CRITICALITY source and DETECTOR options and normalized to one fission event,
- Can calculate various reaction rates (66) including (n,γ), (n,n’γ), and (n,p).

Activity in Bq/g

$$A = \lambda N \sigma \Phi F / \rho,$$

where **λ** is decay constant, **N** is atomic number density, **σ** is microscopic cross section, **Φ** is neutron flux, **ρ** is foil density, and **F** is a total number of fissions. The reaction rate, **NσΦ,** is calculated by COG. Total number of fissions generated from Pulse 1 was 1.88×10^{17}.

COG Results and Experimental Data for Collimator A (Bq/g)

Reaction	Measurement Data		COG11		C/E
	Activity (E)	Relative Uncertainty (σ)	Activity (C)	Relative Uncertainty (σ)	
$^{59}Co(n,\gamma)^{60}Co$	66.1	1.3%	57.00	3.1%	0.862 ± 3.4% [a]
$^{197}Au(n,\gamma)^{198}Au$	1.812×10^5	1.6%	6.302×10^4	8.6%	0.348 ± 8.6%
$^{115}In(n,\gamma)^{116m}In$	9.11×10^6	1.9%	8.96×10^6	6.4%	0.984 ± 6.4%
$^{115}In(n,n'\gamma)^{115m}In$	8.03×10^3	1.6%	3.44×10^4	5.3%	4.284 ± 5.5%
$^{115}In(n,n'\gamma)^{115m}In$ (IRDF-2002)	8.03×10^3	1.6%	7.32×10^3	5.4%	0.911 ± 5.6%
$^{54}Fe(n,p)^{54}Mn$	0.2062	2.0%	0.1952	5.5%	0.947 ± 5.9%
$^{56}Fe(n,p)^{56}Mn$	2310	1.3%	116	9.3%	0.958 ± 9.4%
$^{55}Mn(n,\gamma)^{56}Mn$			2097	9.3%	
$^{24}Mg(n,p)^{24}Na$	61.1	1.9%	65.7	7.7%	1.075 ± 7.9%
$^{58}Ni(n,p)^{58}Co$	14.36	1.6%	15.26	7.1%	1.063 ± 7.3%
TLD	6.61	2.2%	5.74	7.2%	0.868 ± 7.5%

[a] Root-sum-of squares combination for C and E.

Discussion of COG Results

- COG results compare well with measurement data except for 3 cases discussed below,

  - ^{197}**Au(n,γ)**^{198}**Au** experimental data need to be verified.

Experiment	Collimator A (A)	Free-Field (F)	A/F
Pulse 1	1.81×10^4	6.95×10^4	2.61
Pulse 2	6.88×10^4	6.43×10^4	1.07
Pulse 3	6.51×10^3	5.55×10^3	1.17

Discussion of COG Results (Continued)

- Activity of **^{115}In(n,n'γ)^{115m}In** calculated using **ENDF/B- VII.0** cross-sections is a factor of three lower whereas the calculated result using **IRDF-2002** cross section data library is in much better agreement with measured data,
- Calculated **^{56}Fe(n,p)^{56}Mn** activity is about 5% of the measured value. When the known 0.3 wt% ^{55}Mn impurity in iron is considered, and the reaction, **^{55}Mn(n,γ)^{56}Mn**, is taken into account, COG results compare very well with the measured value indicating that Mn impurity is a primary contributor.

Future Work

- Demonstrated that the 1-step COG criticality/detector calculations are feasible,
- Additional large scale runs on massive parallel supercomputers needed to significantly reduce COG calculational uncertainties,
- New 1-step hybrid criticality/shielding-detector method developed and parallelization in progress,
- Foil activity and TLD dose evaluations for Collimator B, Free-field, and Scattering box,
- Modeling and analyses for Pulse 2, and Pulse 3 experiments.