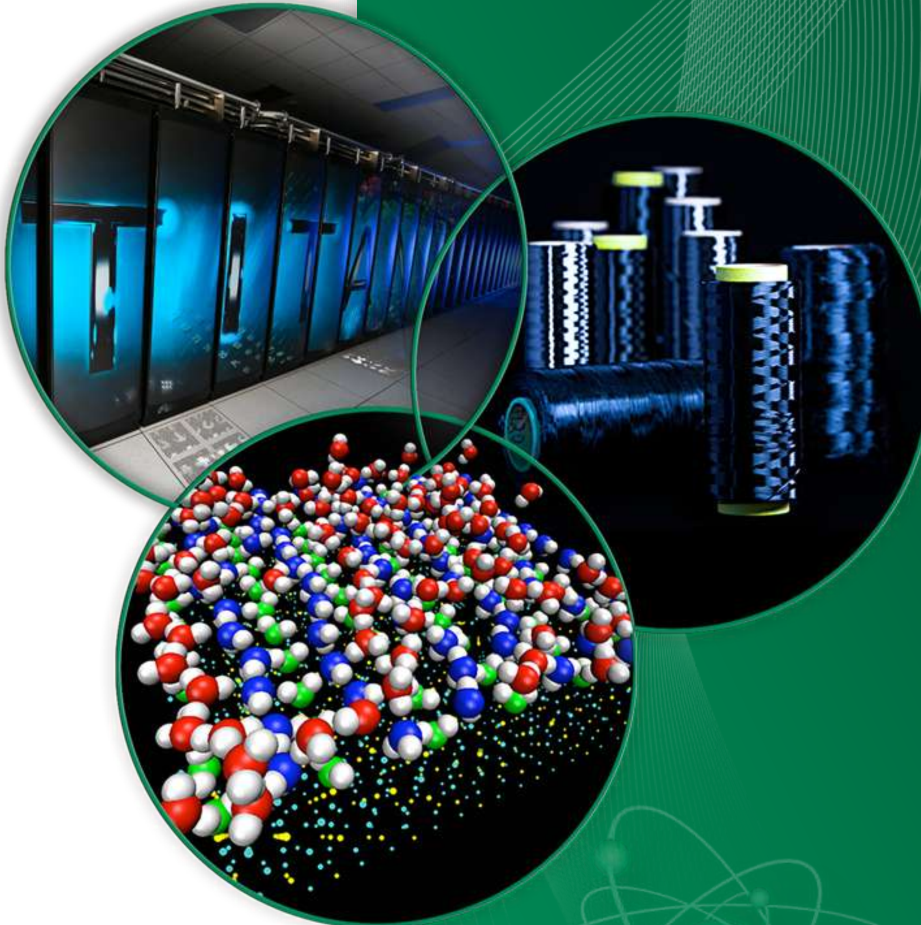
Analysis of Measured Data from Experiments 2 & 3 of the 2010 CAAS Benchmark at the CEA Valduc SILENE Facility



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Institutions involved in SILENE CAAS benchmarks

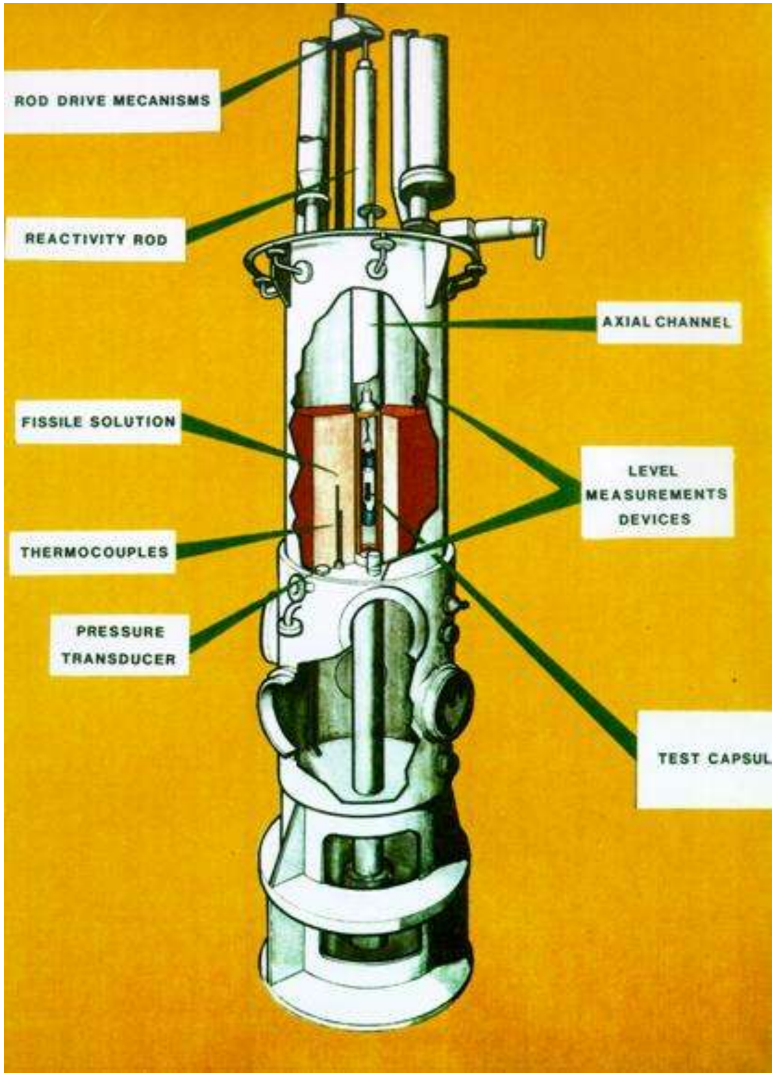
- Oak Ridge National Laboratory
  - Design, measurements, documentation, and evaluation
  - T. M. Miller, M. E. Dunn, J. C. Wagner, and K. L. McMahan
- CEA Valduc
  - Design, irradiation, measurements, and documentation
  - N. Authier, X. Jacquet, G. Rousseau, H. Wolff, J. Piot, L. Savanier and N. Baclet
- CEA Saclay
  - Shielding materials and evaluation
  - Y. K. Lee, V. Masse, J. C. Trama, E. Gagnier, S. Naury, and P. Blanc-Tranchant
- Lawrence Livermore National Laboratory
  - Rocky Flats CAAS
  - S. Kim and G. M. Dulik
- Babcock International Group
  - CIDAS CAAS
  - R. Hunter
- Y-12 National Security Complex
  - BoroBond shielding materials
  - K. H. Reynolds

Outline

- Brief introduction to SILENE
- Summary of experimental details
- Comparison between measurement & computational results
  - SCALE 6.1
  - TRIPOLI-4
- Summary and conclusions

Introduction to SILENE

- Annular core
  - Internal cavity diameter 7 cm
  - Outer fuel diameter 36 cm
  - Typical critical height ~35 – 45 cm
- Uranyl Nitrate fuel Solution
  - ~93% ^{235}U
  - ~71 g of uranium per L
- Power level ranges from 10 mW to 1000 MW
- Three operating modes
  - Single pulse
  - Free evolution
  - Steady State



Summary of experimental details (1)

- More details & pictures in ICNC 2011 paper
- Experiment 2
  - Single pulse, SILENE surrounded by lead reflector (shield)
  - Collimator A – unshielded
    - Full set of neutron activation foils
    - Valduc Al_2O_3, ORNL HBG & DXT TLDs
    - Rocky Flats CAAS
  - Collimator B – 20 cm standard concrete
    - Full set of neutron activation foils
    - Valduc Al_2O_3, ORNL HBG & DXT TLDs
    - Rocky Flats & CIDAS CAAS

Summary of experimental details (2)

  - Free-field location
    - Full set of neutron activation foils
    - Valduc Al_2O_3, ORNL HBG & DXT TLDs
  - Scattering Box (2 magnetite & 4 standard concrete shields)
    - Full set and 3 partial sets of neutron activation foils
    - 4 Valduc Al_2O_3, 2 ORNL HBG, and 2 ORNL DXT TLDs
    - Rocky Flats & CIDAS CAAS
- Experiment 3 modifications
  - Single pulse, SILENE surrounded by cadmium lined polyethylene reflector (shield)
  - Collimator B concrete replaced by 3” (7.62cm) of BoroBond

Photographs of experiments

Benchmark evaluation

- Also a joint effort between the US DOE and French CEA
  - ORNL is evaluating these benchmarks with SCALE and MCNP
  - LLNL is performing an evaluation with COG
  - Saclay is performing an evaluation with TRIPOLI
- High level overview of computational process
  - Perform an eigenvalue calculation and tally the spatial and energy dependence of the fission source
  - Complete any a priori variance reduction (source biasing, importance map/weight window generation, etc.)
  - Perform a fixed source transport calculation and tally the detector responses.

OR

  - Perform an eigenvalue calculation and tally the detector responses.
- Cross sections & tally response functions
  - ENDF/B-VII.0 and JEFF-3.1.1, except IRDF-2002 for $^{115}In(n,n')^{115m}In$
  - ICRU air kerma factors for TLDs

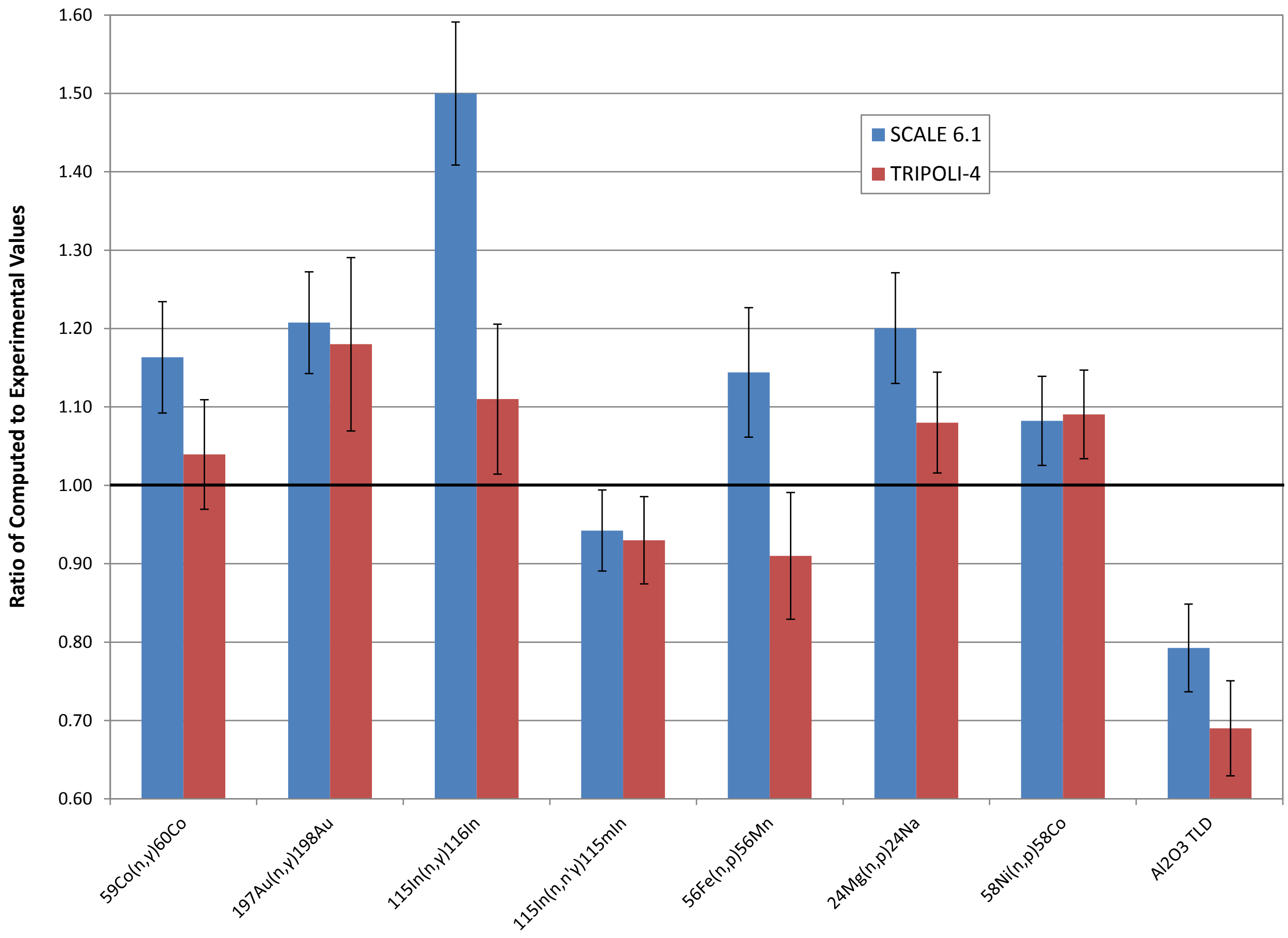
Comparisons between calculations and measurements for experiments 2 and 3

Comparison of computational and measured results for simulations of Collimator A

		SCALE 6.1		TRIPOLI-4®	
Position	**Reaction**	**Ratio: C/E**	**Relative Uncertainty (2 sigma)**	**Ratio: C/E**	**Relative Uncertainty (2 sigma)**
Experiment 2 Collimator A	$^{59}Co(n,\gamma)^{60}Co$	1.16	4.62%	1.04	5.40%
	$^{197}Au(n,\gamma)^{198}Au$	1.21	3.59%	1.18	8.47%
	$^{115}In(n,\gamma)^{116m}In$	1.50	4.58%	1.11	7.63%
	$^{115}In(n,n'\gamma)^{115m}In$	0.94	3.75%	0.93	4.44%
	$^{56}Fe(n,p)^{56}Mn$ + $^{55}Mn(n,\gamma)^{56}Mn$	1.14	6.01%	0.91	7.93%
	$^{24}Mg(n,p)^{24}Na$	1.20	4.30%	1.08	4.42%
	$^{58}Ni(n,p)^{58}Co$	1.08	3.39%	1.09	3.31%
	TLD - Al_2O_3	0.79	5.81%	0.69	7.82%
Experiment 3 Collimator A	$^{59}Co(n,\gamma)^{60}Co$	0.95	5.50%	0.93	7.04%
	$^{197}Au(n,\gamma)^{198}Au$	0.87	7.93%	0.89	13.4%
	$^{115}In(n,\gamma)^{116m}In$	1.14	5.97%	0.89	7.53%
	$^{115}In(n,n'\gamma)^{115m}In$	0.83	3.58%	0.96	4.40%
	$^{56}Fe(n,p)^{56}Mn$ + $^{55}Mn(n,\gamma)^{56}Mn$	0.86	4.47%	0.92	5.43%
	$^{24}Mg(n,p)^{24}Na$	1.00	8.82%	0.90	8.87%
	$^{58}Ni(n,p)^{58}Co$	0.90	3.55%	0.95	5.28%
	TLD - Al_2O_3	0.62	5.53%	0.71	5.62%

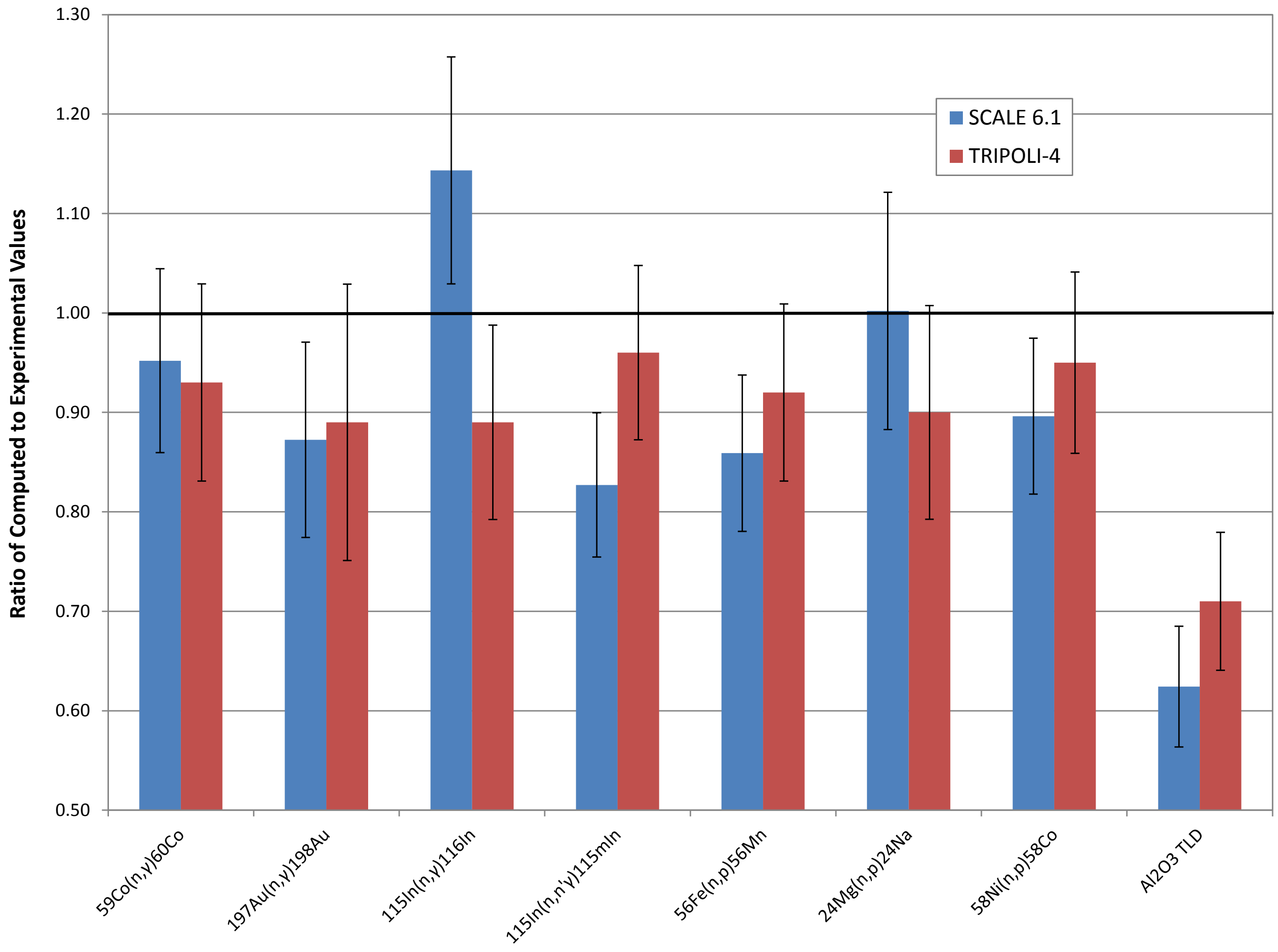
- Comparison in table only considers computational uncertainty and measurement uncertainty of foil activity

Comparisons between calculations and measurements for experiment 2



- Comparison in figure considers computational uncertainty, measurement uncertainty of foil activity, and uncertainty on number of fission events

Comparisons between calculations and measurements for experiment 3



- Comparison in figure considers computational uncertainty, measurement uncertainty of foil activity, and uncertainty on number of fission events

Summary and conclusions (1)

- The final measurement data for the 2010 SILENE CAAS benchmark experiments 2 and 3 is published in the conference paper
- Experiment 2 – SCALE and TRIPOLI results statistically the same and over predict measurements except for:
  - $^{115}In(n,n')^{115m}In$ & TLD – under predicts measurement
  - $^{115}In(n,\gamma)^{116}In$ & [$^{56}Fe(n,p)^{56}Mn$ + $^{56}Mn(n,\gamma)^{56}Mn$] – not statistically the same
- Experiment 3 – SCALE and TRIPOLI results statistically the same and under predict measurements except for:
  - $^{115}In(n,\gamma)^{116}In$ – not statistically the same

Summary and conclusions (2)

- Issues needing further investigation before submission to the ICSBEP
  - CE TRIPOLI $^{115}In(n,\gamma)^{116}In$ results agree better with experiment, is SCALE group structure a problem
  - TLD response function
  - Uncertainty analysis for experiments 2 and 3
    - Stay tuned for uncertainty analysis for experiment 1 (Kevin Reynolds & Thomas Miller at 2:30)

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