Determination of Experimental Correlations Using the Sampler Sequence Within SCALE 6.2

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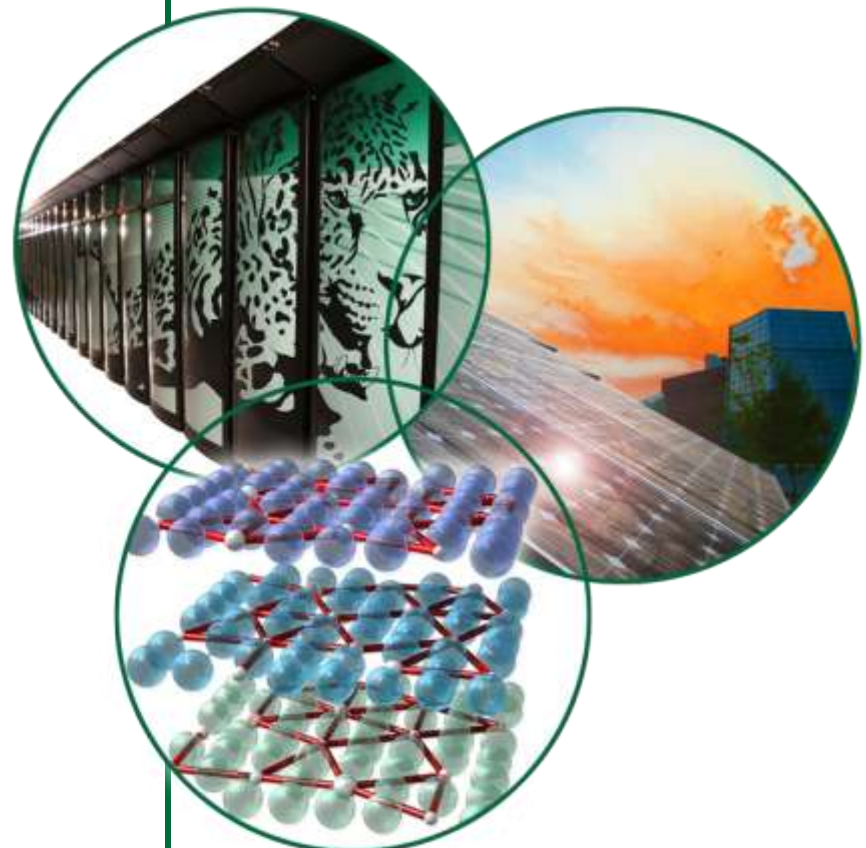

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Outline

1. Introduction
2. Sampler description and methods
3. Analysis of LEU-COMP-THERM-042 correlations
4. Results
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6. Conclusions

Introduction

- Criticality safety validations typically use many cases from a single series of critical experiments
- The potential impact of correlations among the different cases has not been fully investigated
- Most methods currently used in validation assume independence of experiments
- Different methods, resulting in changed biases and potentially increased uncertainties, may be needed
- Analysis technique and results for 7 cases in LCT-042 presented

Sampler Description and Methods

- New sequence available in SCALE 6.2 allowing for random sampling of essentially any input for almost any sequence
- Can be used to quantify uncertainties, or to calculate correlation coefficients
- User selects appropriate distribution and parameters for sampling composition and geometry inputs
- Available distributions are uniform, normal, and beta
- Expressions can also be used to calculate perturbed inputs
- Perturbations applied to specified cases allowing identical realizations for shared characteristics

Sampler Description and Methods

Sampler input snippet:

```
read variable[wo_u235]
  distribution = normal
  value = 2.35 stddev = 0.00333
  minimum = 2.34  maximum = 2.36
  cases = Case1 Case2 Case3 Case4 Case5 Case6 Case7 end
end variable
```

- Defines variable named "wo_u235"
- Values sampled from a normal distribution
  - Average of 2.35 and standard deviation of 0.0033
  - Truncated at 2.34 and 2.36
- Sampled enrichment used in each of the 7 cases since they use the same fuel material

Sampler Description and Methods

- Independent parameters sampled uniquely in each case
  - Experiment temperature one possible example
- Three step process for executing calculations:
  1. Generate requested number of input realizations for each case
  2. Execute SCALE for all generated inputs
  3. Sampler post-processes output files to generate output files

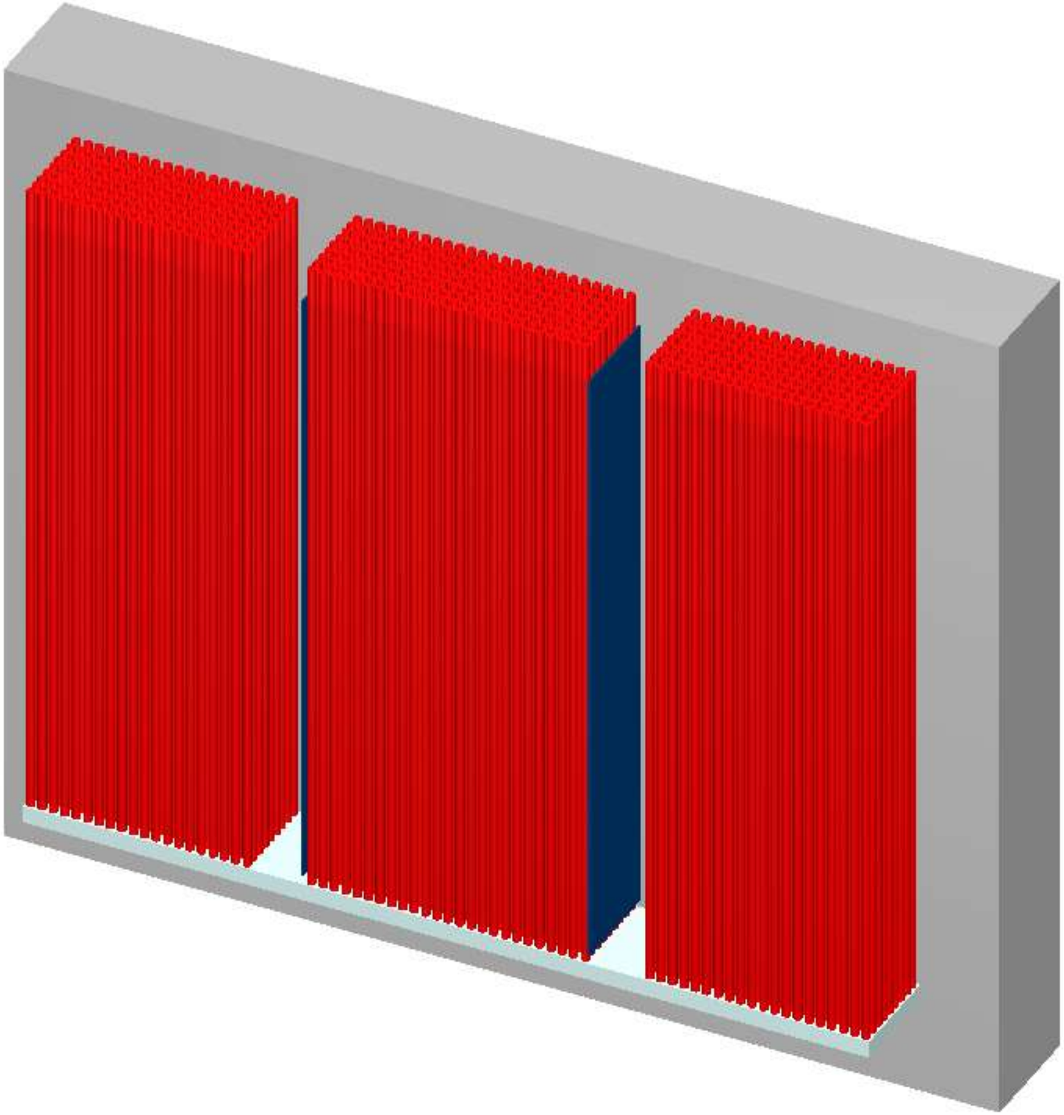
Sampler Description and Methods

- Experimental correlations generated by Sampler in post-processing mode
- Random sampling to generate correlations based on theoretical developments of Buss, Hoefer, Neuber, and Schmid [PHYSOR 2010]
- Correlation coefficient calculated as covariance divided by product of standard deviations:

$$c_{i,j} = \frac{\mathrm{cov}(i, j)}{\sigma_i \sigma_j}$$

- Essential to include random uncertainty from both shared and unique features to generate accurate correlation

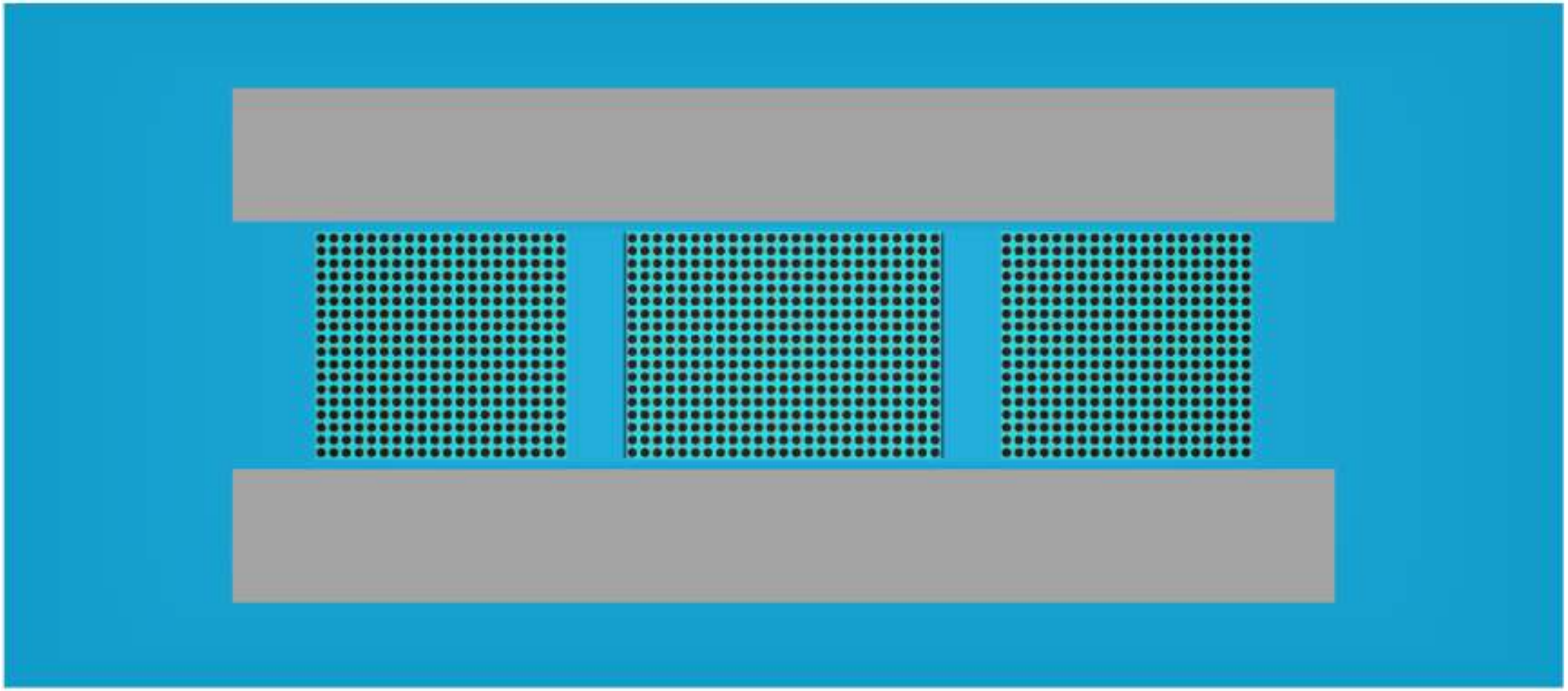
LCT-042 Experiment Description



KENO V.a Model

- Front half removed
- All water hidden
- Red - Cladding
- Blue - Poison panel
- Grey - Reflecting wall
- White – Lower support plate (acrylic)

LCT-042 Experiment Description



Top view of model with top half removed

Blue in reflector and aqua around pins are both water with identical compositions but different cross section processing

Analysis of LCT-042

- Dimension and material uncertainties described in Section 2 of IHECSBE evaluation
- Vast majority of input values are modified
  - Many sampled directly
  - May be more that have to recalculated based on sampled inputs
- Assessment of shared or independent uncertainties needed
  - Poison panels clearly unique
  - Fuel material clearly shared
  - Other components unclear: reflecting wall, fuel rod pitch, etc.
  - Assumed to be shared unless otherwise specified

Analysis of LCT-042

- Distributions must be selected for sampling, but these are not specified in evaluation
- Most are assumed to be uniform because this seems likely to yield higher uncertainties and higher correlation coefficients which seems likely to be conservative
- Some parameters, notably enrichment, specifically mention standard deviation and are thus assumed to be normal
  - Obviously this is somewhat bogus as a uniform distribution has a standard deviation as well, so consider this an arbitrary choice
- No sensitivity study has been performed to examine the effect of these assumptions

Results

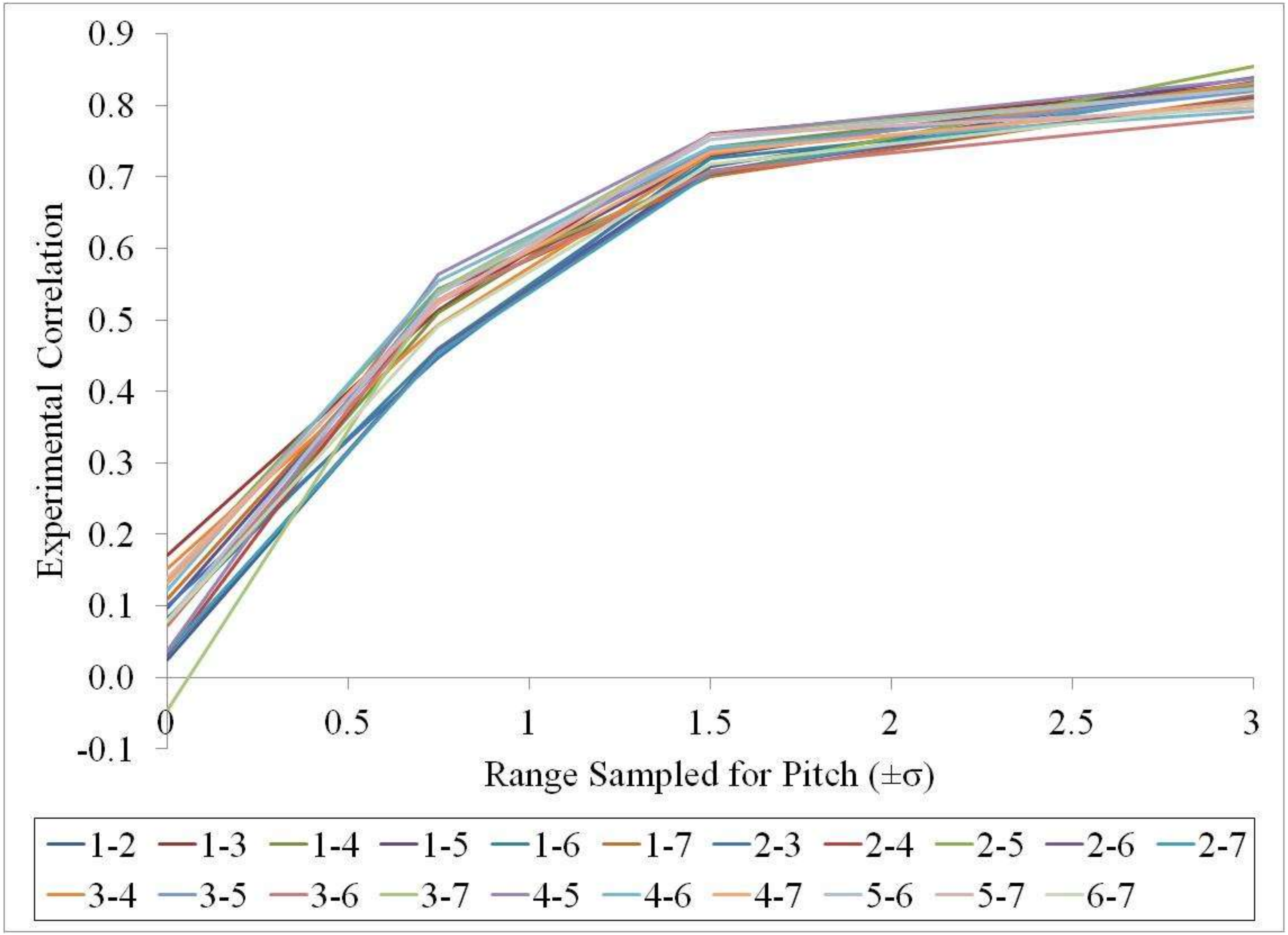
- Sampler created 275 realizations of each of the 7 cases
  - 1925 total KENO jobs
- Output files post-processed with Sampler to generate correlation coefficients between 0.784 and 0.854

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Case 1	1	0.832	0.830	0.826	0.838	0.803	0.814
Case 2		1	0.831	0.831	0.854	0.810	0.829
Case 3			1	0.831	0.820	0.784	0.823
Case 4				1	0.837	0.791	0.806
Case 5					1	0.823	0.796
Case 6						1	0.803
Case 7							1

Results

- All rod pitches were assumed to be fully correlated, and sampled within ±3 standard deviations of nominal
- New realizations created and correlations recalculated assuming ±1.5 and ±0.75 standard deviations and fixed rod pitches
  - Reducing uncertainty in a shared component should reduce correlation coefficient
  - Sensitivity of correlations to pitch sampling will be examined
  - Recall: Original concern largely driven by use of same fuel rods in multiple experiments
  - This study shows rod pitch treatment is likely the primary driver in correlation coefficients

Results



Experimental Correlation
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
0
0.5
1
1.5
2
2.5
3
Range Sampled for Pitch (±σ)
1-2 1-3 1-4 1-5 1-6 1-7 2-3 2-4 2-5 2-6 2-7
3-4 3-5 3-6 3-7 4-5 4-6 4-7 5-6 5-7 6-7

Other Observations

- Stochastic sampling to generate correlations presents many challenges
- Uncertainties are not known or provided for all parameters in Section 2 of IHECSBE evaluations
- Distributions of uncertain parameters is not addressed
- Details of experiment have been lost
  - Cd foil (Case 5) mounted on something in some orientation
  - Pitch uncertainty from measurements of triangular pitch support plate, but LCT-042 has square pitch rods
- Collecting all sampling input is nearly impossible

Conclusions

- Stochastic sampling method to determine correlation coefficients can be performed using Sampler in SCALE 6.2
  – Also calculated uncertainties which can be compared to estimated uncertainties derived in Section 2 of IHECSBE evaluation
- Initial assumptions lead to high correlation coefficients
- Different assumptions related to rod pitch variation reduce coefficients to less than 0.2
  – Fixed pitch results likely similar to totally random pitch variations
- Application of method to entire handbook is daunting

Acknowledgement

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