# NCS Applications Using SCALE 6.3.0

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# Outline

- Applicability of the Sum-of-Fractions for Moderated Systems
- Effect of $c_k$ Threshold on Computational Bias Prediction


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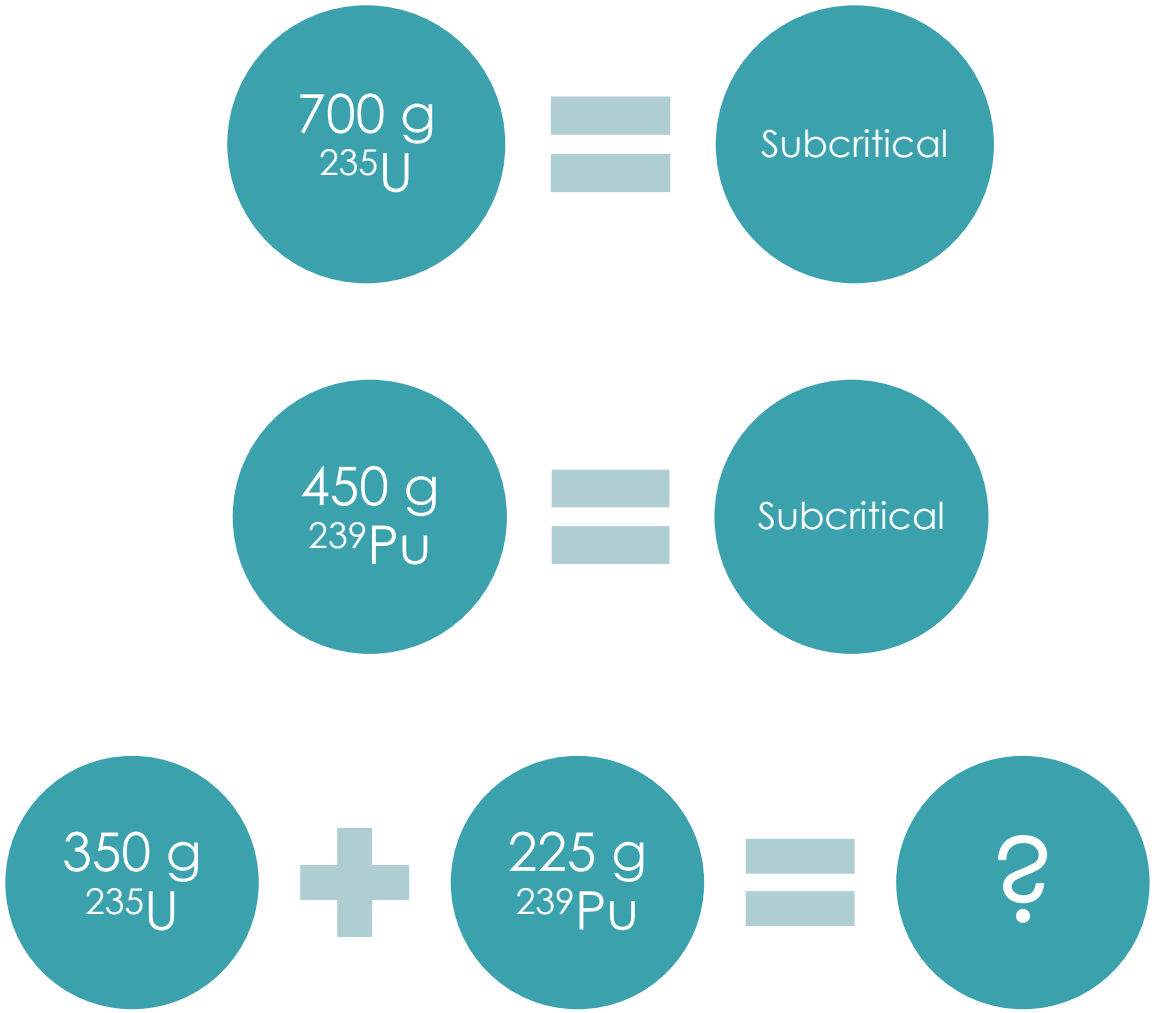
# Applicability of the Sum-of-Fractions for Moderated Systems

# Sum-of-Fractions

- Background
  - For a mixture of isotopes $i$ with masses $a_i$ and minimum subcritical mass $A_i$ subcriticality is defined as:

$$\sum_i \frac{a_i}{A_i} \leq 1$$

  - The minimum critical masses for all the nuclides is based on a system that is more reactive than the specific system evaluated





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# Sum-of-Fractions

- Methods
  - Calculate $k_{eff}$ for established set of mixtures with $^{233}U$, $^{235}U$, and $^{239}Pu$ with **CSAS5/KENO V.a** for light-water and polyethylene moderated and reflected systems
  - Generate sensitivity data for application models with **TSUNAMI-1D**
    - Sensitivities confirmed with direct perturbation calculations
    - Adequacy of MG 1D method confirmed with comparisons with CE **TSUNAMI-3D**
  - Benchmark applications compared with **TSUNAMI-IP**
    - VALID used as source of benchmarks
    - $C_k$ threshold of 0.9 used
  - Upper subcritical limits and statistical testing with **VADER**


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# Sum-of-Fractions

- Two Isotope Mix – Water Moderated and Reflected

| | Peak k-eff | | |
|---|---|---|---|
| **Actinides** | U-233 | U-235 | Pu-239 |
| **U-232** | 0.94332 | 0.95189 | 0.95796 |
| **U-234** | 0.69109 | 0.67946 | 0.68568 |
| **Np-237** | 0.68676 | 0.67217 | 0.68742 |
| **Pu-236** | 0.96967 | 0.96872 | 0.97081 |
| **Pu-238** | 0.66242 | 0.61224 | 0.66893 |
| **Pu-240** | 0.68269 | 0.65830 | 0.67526 |
| **Pu-241** | **0.97086** | **0.97123** | **0.97253** |
| **Pu-242** | 0.75328 | 0.73399 | 0.74228 |
| **Am-241** | 0.66117 | 0.65010 | 0.65946 |
| **Am-242m** | 0.96814 | 0.96539 | 0.96490 |
| **Am-243** | 0.68339 | 0.67944 | 0.68780 |
| **Cm-242** | 0.86555 | 0.88714 | 0.89897 |
| **Cm-243** | 0.96894 | 0.96540 | 0.96855 |
| **Cm-244** | 0.77865 | 0.81193 | 0.83088 |
| **Cm-245** | 0.96499 | 0.96368 | 0.96333 |
| **Cm-246** | 0.86374 | 0.87935 | 0.88773 |
| **Cm-247** | 0.97451 | 0.97275 | 0.97582 |
| **Cf-249** | 0.96597 | 0.96284 | 0.96381 |
| **Cf-251** | 0.97096 | 0.96770 | 0.96947 |


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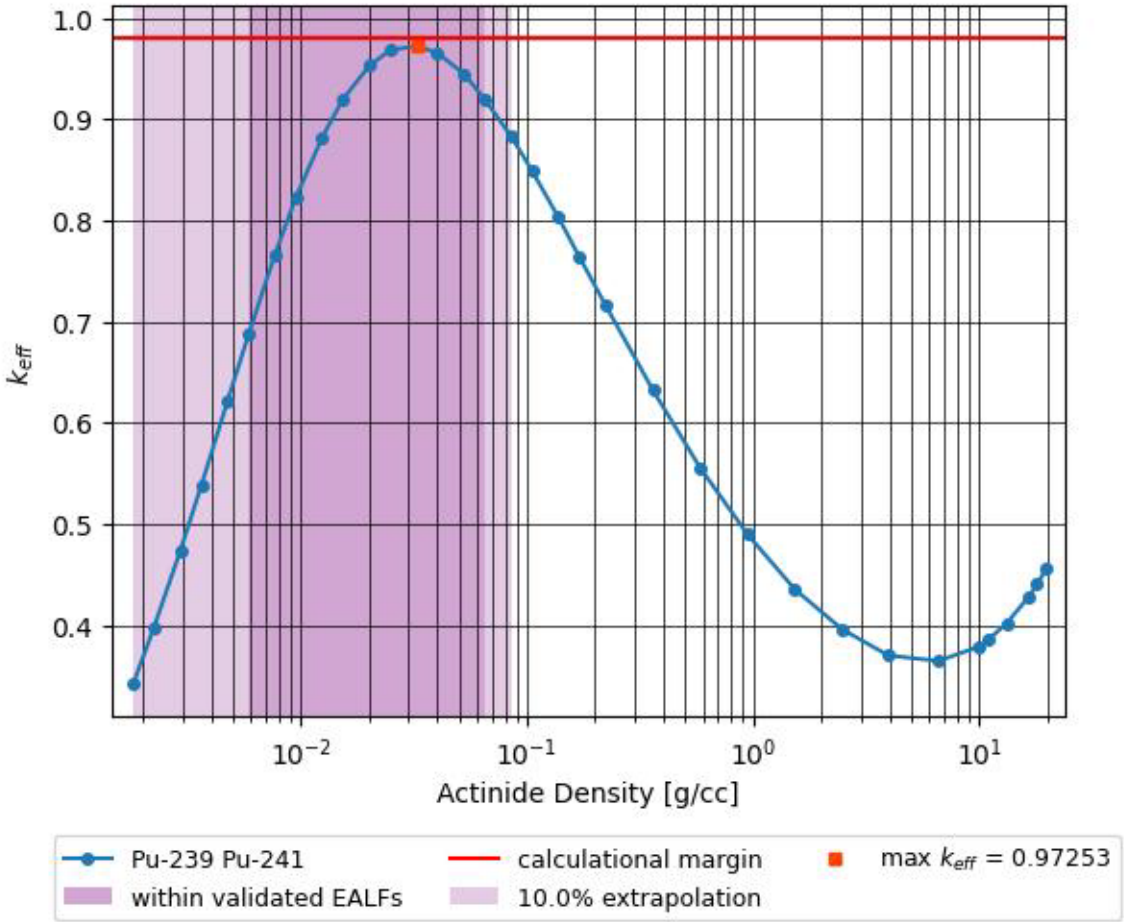
# Sum-of-Fractions

- $^{239}$Pu and $^{241}$Pu Mix





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# Effect of $c_k$ Threshold on Computational Bias Prediction

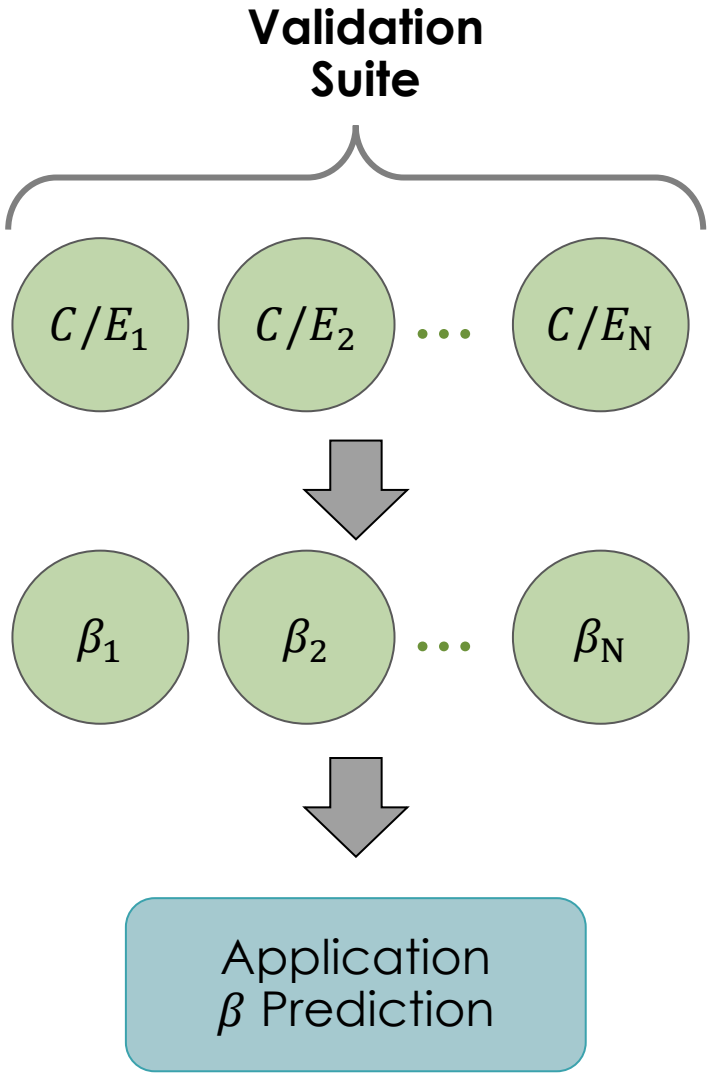
# Correlation Coefficient Threshold

- Background
  - For an application, there will be some **computational bias** in the calculated $k_{\mathrm{eff}}$
  - A **validation suite** of **similar benchmark experiments** is used to predict bias

$$\beta = C/E - 1$$

$$C = \text{Calculated } k_{\mathrm{eff}}$$
$$E = \text{Evaluated } k_{\mathrm{eff}}$$

  - How do you quantify similarity?





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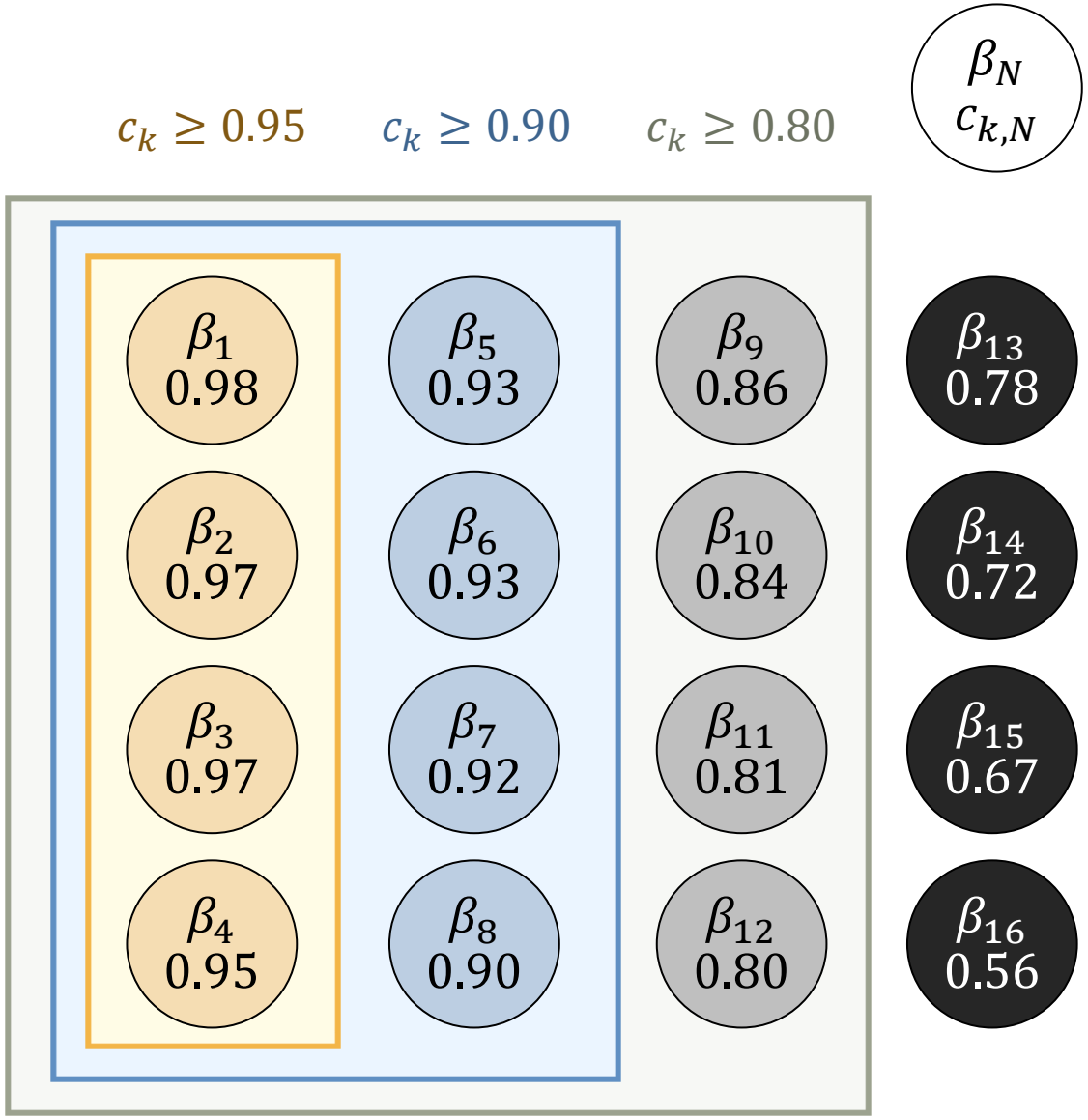
# Correlation Coefficient Threshold

- Motivation
  - **Sensitivity/Uncertainty (S/U)** methods can be used to quantify similarity between reactor systems
  - The S/U-based **correlation coefficient**, $\boldsymbol{c_k}$, can be used as the similarity selection criteria
    - $c_k$ ranges between -1 and 1
    - Typical cutoffs 0.8, 0.9, or 0.95
  - What impact does $c_k$ cutoff have on bias prediction?





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# Correlation Coefficient Threshold

- Method
  - Develop a tool to predict computational bias for a given application as a function of the $c_k$ threshold
  - Apply this tool to critical experiment benchmarks with known computational biases
    - E.g., The SCALE Verified, Archived Library of Inputs and Data (VALID)
    - Required for each benchmark experiment:
      - C/E value
      - $c_k$ between each application and every other benchmark
        - Generated with **TSUNAMI-IP** using sensitivity data for each benchmark
  - Then assess the <u>bias misprediction</u>:
    - The difference between the predicted and actual computational bias


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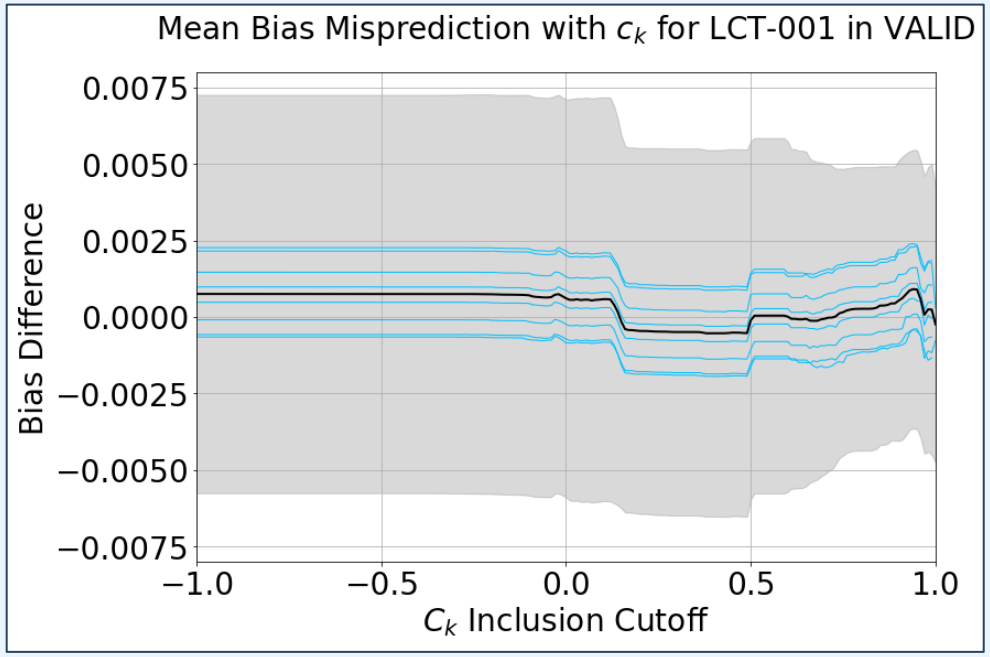
# Correlation Coefficient Threshold

- Results: LEU-COMP-THERM-001

**Bias Misprediction for LCT-001**
8 Cases (001→008), **(blue)**
Mean of LCT-001 ($\pm 1\sigma$), **(black/grey)**




- Benchmarks are excluded as minimum $c_k$ threshold increases
- Effect on each case and evaluation mean shown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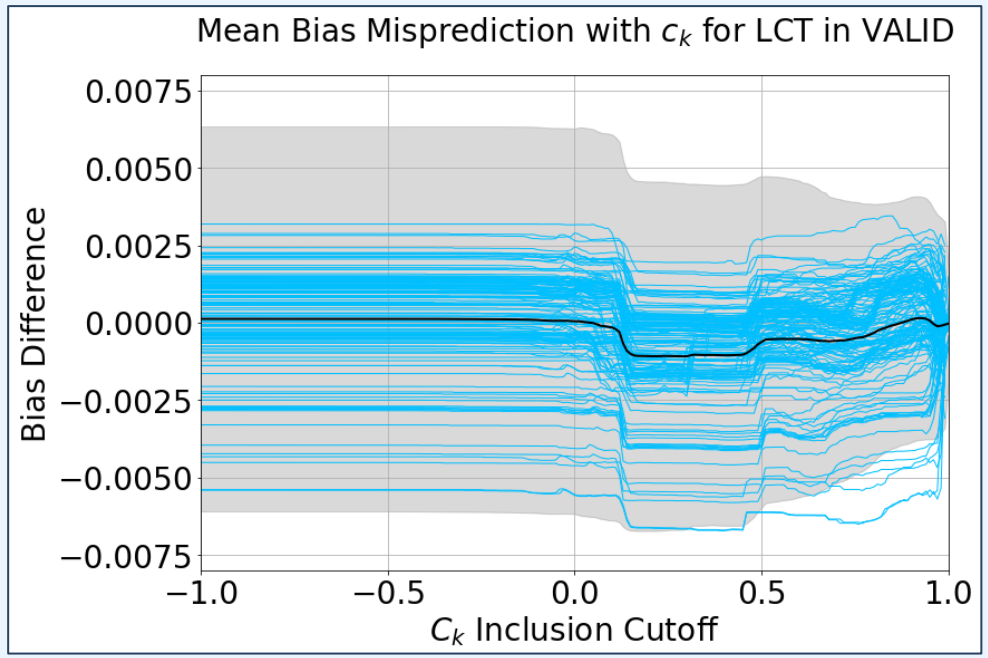
# Correlation Coefficient Threshold

- Results: All 140 LEU-COMP-THERM cases in VALID

**Bias Misprediction for LCT in VALID**

9 Evaluations, 140 Cases, **(blue)**

Mean of LCT ($\pm 1\sigma$), **(black/grey)**




**Future Work:**

- Analyze results across more categories of fissile systems in VALID and understand the impact of these findings
- Assess consistency for other bias determination methods and other integral parameters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# Acknowledgement

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