GE Hitachi
Nuclear Energy

MCNP5 Criticality Benchmark Validation for Uranium and Plutonium Metal Systems Using ENDF/B-VII.0

Christopher Geiser and Qi Ao

Data, Analysis, and Operations for Nuclear Criticality Safety

ANS Winter Meeting
November 15 – 19, 2009
Washington, DC

HITACHI


Disassembled Plutonium Jezebel Spher

Outline

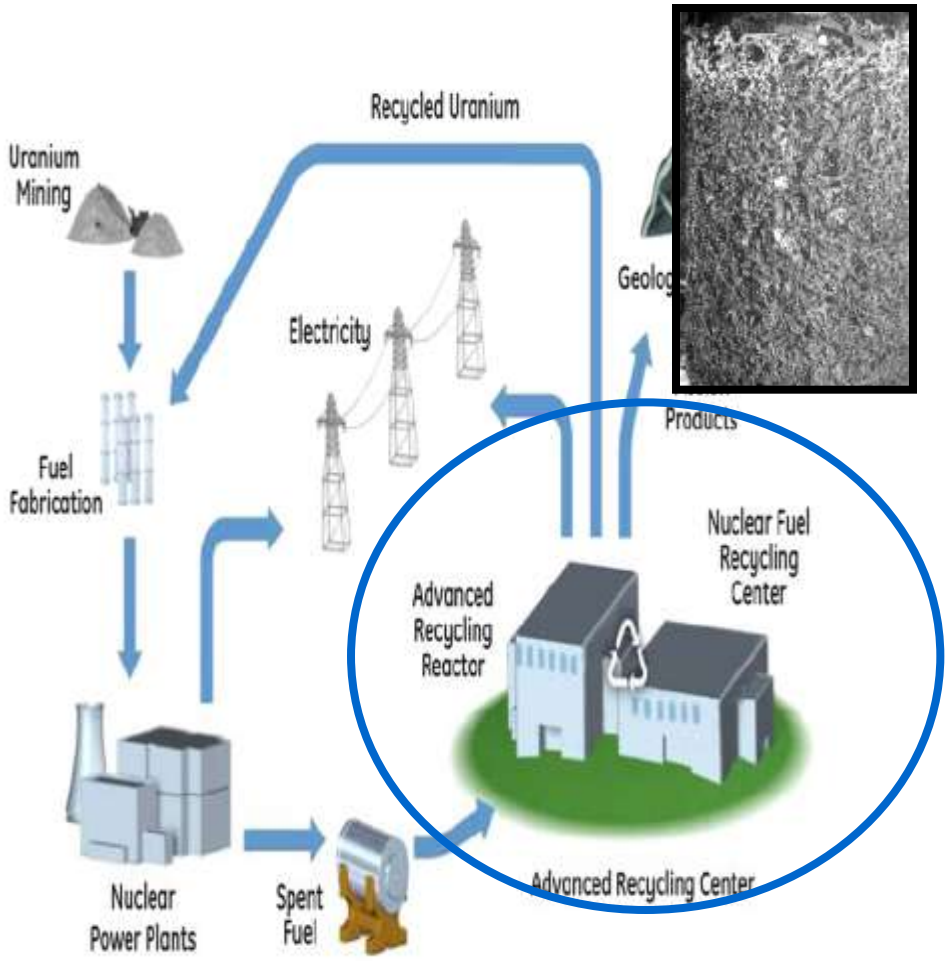
- Applications
- Validation Tasks
- Area of Applicability Case Determination
- USL Methods
- USL Trending for Non Normal Data
- USL Results for U & Pu Metal Systems

Metal System Criticality Validation Tasks

- Benchmark analysis for Areas Of Applicability (AOA)
- Develop Monte Carlo N-Particle (MCNP) inputs for benchmarks
- Update cross section inputs from natural to isotopic composition
- Run MCNP5
- Determine bias, uncertainty in bias, and USL using the USLSA Tool

Metal System Applications

- Support the Advanced Fuel Cycle Initiative (AFCI)
  - ➢ Recycling Center
- Reprocessing of spent/waste UO2
- Validate MCNP for Uranium and Plutonium Metal Systems for criticality analysis



Uranium Recycling Path

Benchmark Determination for AOA

Areas of Applicability:

- AOA 1: Low Enriched Uranium Metal: <10% U-235
- AOA 2: Mixed Enrichment Uranium Metal Systems
- AOA 3: Uranium and Plutonium Mixed Metal Systems
- AOA 4: Plutonium Metal Systems

Benchmark Sources:

International Handbook of Evaluated Criticality Safety Benchmark Calculations

AOA 1 & 2 Uranium Metal Systems

Table I. Uranium Critical Benchmark Parameters

Parameters	Critical Benchmarks	
Material	Uranium	Uranium
Chemical Form	U	U
Enrichment (wt.% ^{235}U)	0.72 - 2.0	10.0-93.4
Physical Form	Metal	Metal
Moderator	Heavy Water	N/A
Physical Form	Liquid	N/A
Reflector	N/A	Natural Uranium, Graphite, Aluminum, Polyethylene, Depleted Uranium
Physical Form	N/A	Solid
Neutron Energy	Thermal	Fast
No. of Experiments	3 (1)	12 (2)
No. of Configurations	35	30

Note: Benchmark Experiments were taken from reference 7.
(1) Leu-Met-Therm. (2) Ieu-Met-Fast

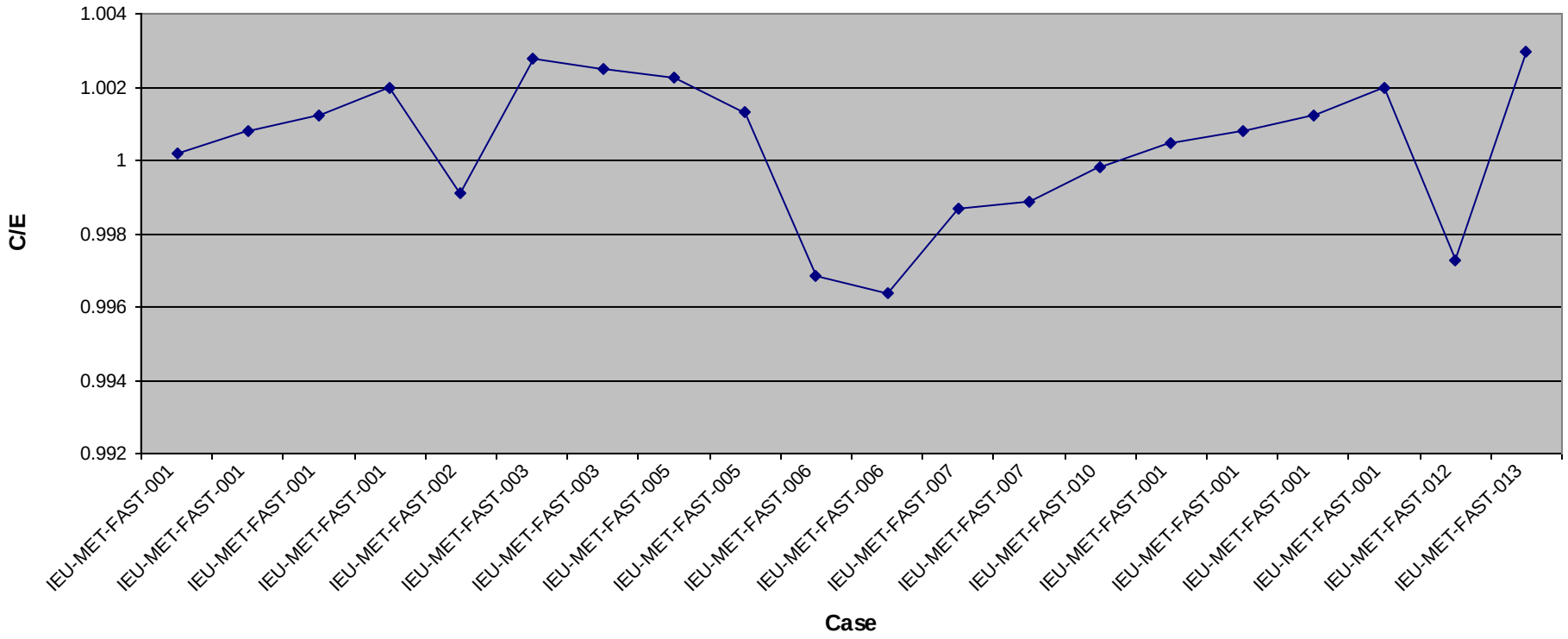
AOA 3 & 4 Uranium and Plutonium Metal Systems

Table II. Plutonium and Mixed System Critical Benchmark Parameters

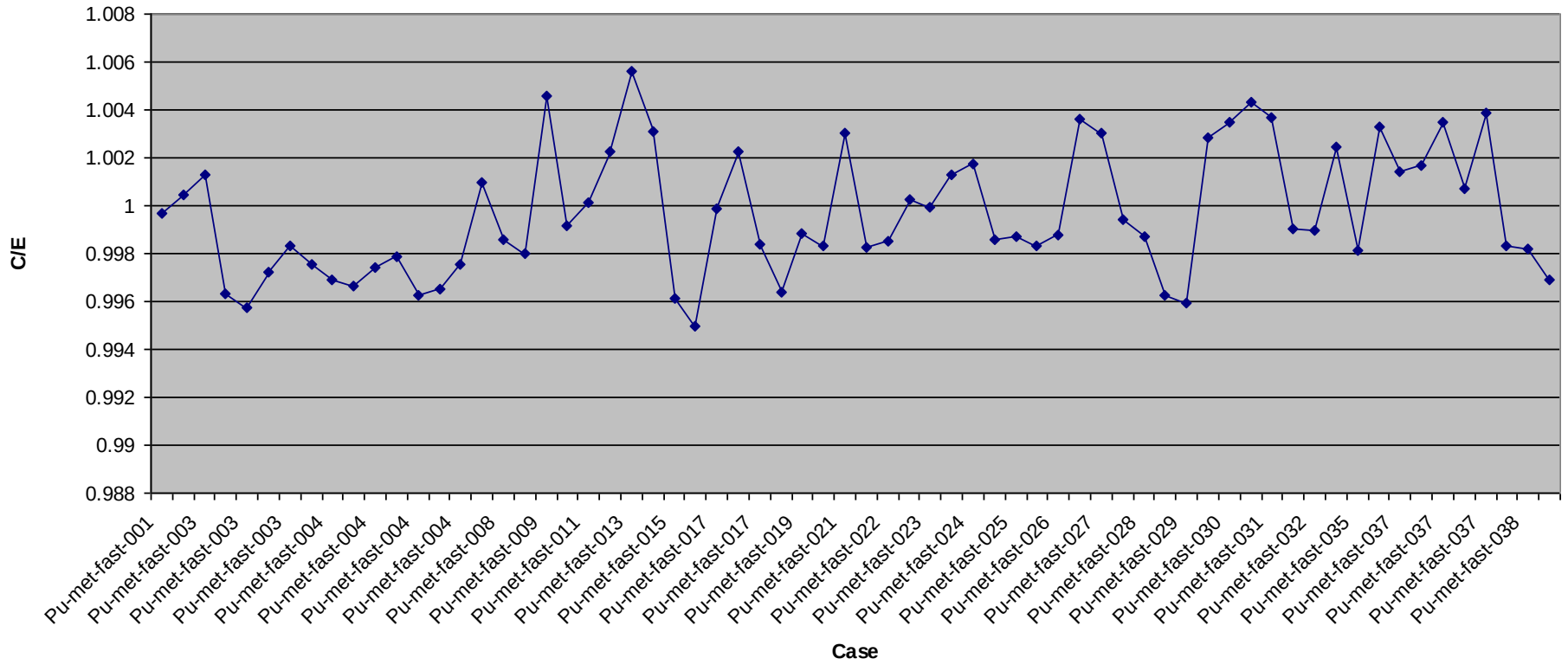
Parameters	Critical Benchmarks	
Material	Mixture	Plutonium
Chemical Form	Pu, U	Pu
Enrichment (wt.% ^{235}U or ^{239}Pu)	^{235}U: 6.8-93.2 ^{239}Pu: 87.5-94.8	76.4-97.6
Physical Form	Metal	Metal
Moderator	Graphite	N/A
Physical Form	Solid	N/A
Reflector	Natural Uranium, Be, BeO, Graphite, Aluminium	Polyethylene, Tungsten, Natural Uranium, Thorium, Light Water, Depleted Uranium, Copper,
Physical Form	Solid	Solid
Neutron Energy	Fast	Fast
No. of Experiments	10 (1)	38 (2)
No. of Configurations	17	73

Note: Benchmark Experiments were taken from reference 7.
(1)Mix-Met-Fast, (2) Pu-Met-Fast

IEU Keff Comparison (AOA-2)



Plutonium Keff Comparison (AOA-4)



Upper Subcritical Limit: Methods

- SSLTL – Single Sided Lower Tolerance Limit
- NPM – Nonparametric Method
- SSLTB – Single Sided Lower Tolerance Band

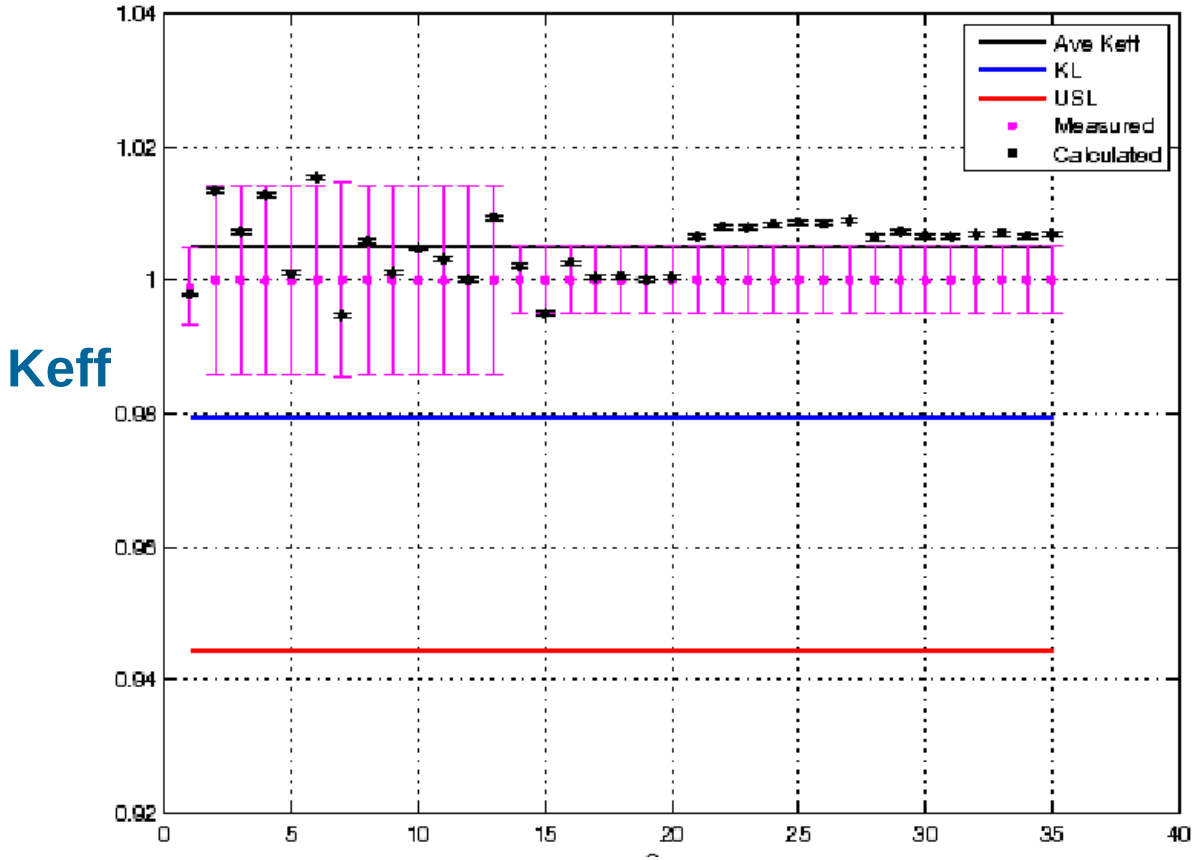
$$USL = 1 + Bias - Bias - MoS$$

What is determined by USLSA:

- Trending analysis
- Method Determination
- MoS (Margin of Subcriticality) = 0.03

- Q. Ao, "A Statistical Methodology for Validating Criticality Analysis Codes," *8th International Conference on Nuclear Criticality Safety, Proceedings, Vol. I, pp. 228-231*, St. Petersburg, Russia (May 2007).
- Q. Ao, "USLSA – A Statistical Tool for Criticality Analysis Code Validation, *Trans. Am. Nucl. Soc.,* **96**, *pp*. 271-273 (June 2007).

Statistical Analysis: USLSA SSLTL Method



Average Keff

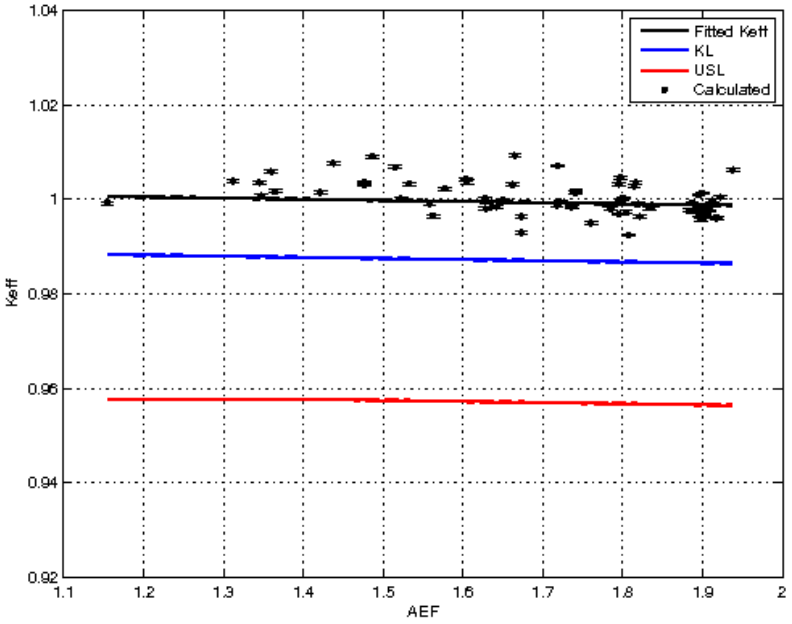
Lower Tolerance

USL

0.03 Safety Margin for USL Reference Purposes Only

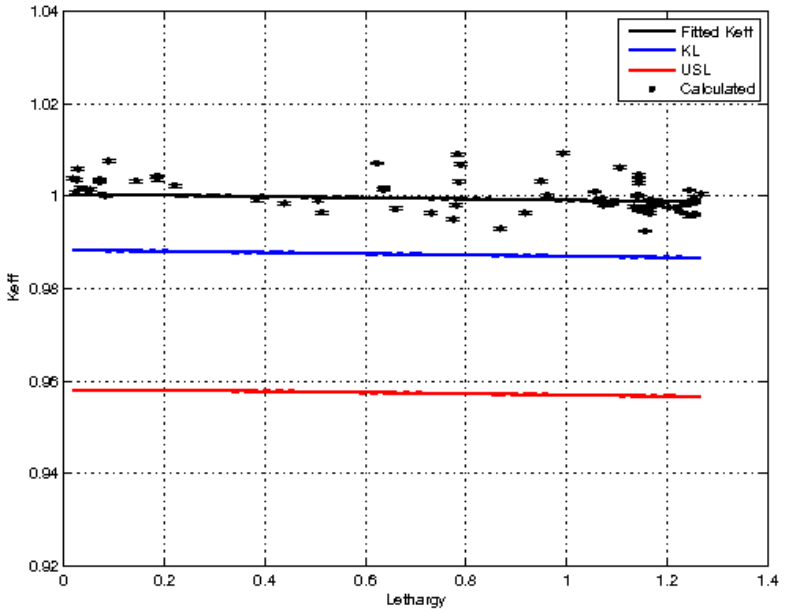
HITACHI

USLSA: Trending for Pu Non-normal Data



USLSA: SSLTB Trending

Linear: Keff vs. AEF



USLSA: SSLTB Trending

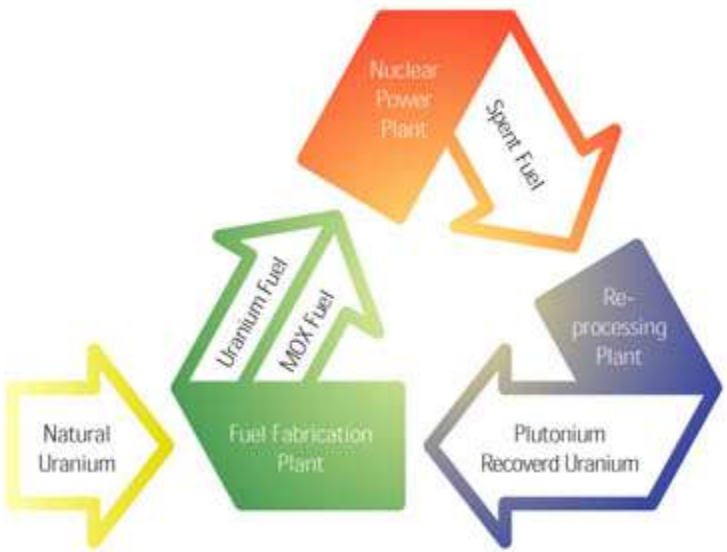
Linear: Keff vs. Lethargy

Linear Regression did not pass statistical tests

Upper Subcritical Limit Results

Area of Applicability	USL	Bias & Bias Uncertainty	USL Method
Low Enriched Uranium Metal	0.9444	-0.0256	SSLTL
Mixed Enrichment Uranium Metal	0.9517	-0.0269	SSLTL
Plutonium and Uranium Metal System	0.9524	-0.0176	SSLTL
Plutonium Metal	0.9602	--	NPM

Potential Validation Plans



- Development of Mixed Oxide (MOX) inputs
- Modeling of salt solution for reprocessing methods
- Further development of LEU metal systems


Questions?