Not All Benchmark Experiments are Created Equal: Words of Caution for Data Adjusters

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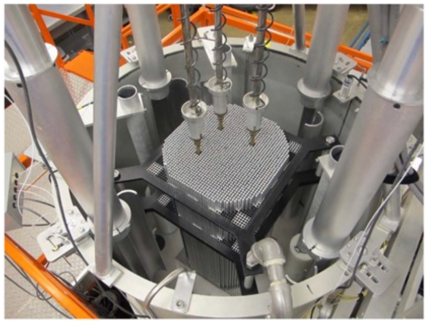
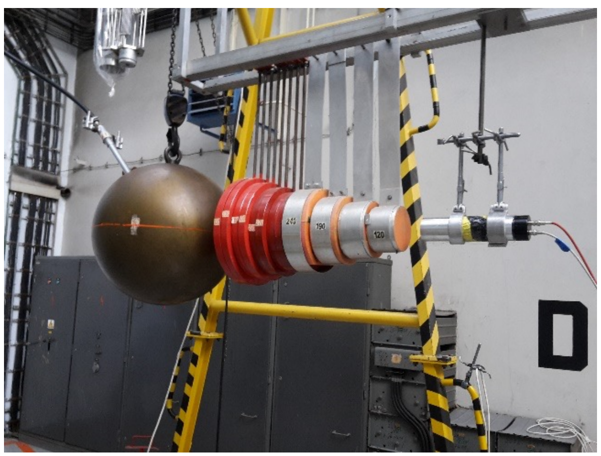
Integral Experiments

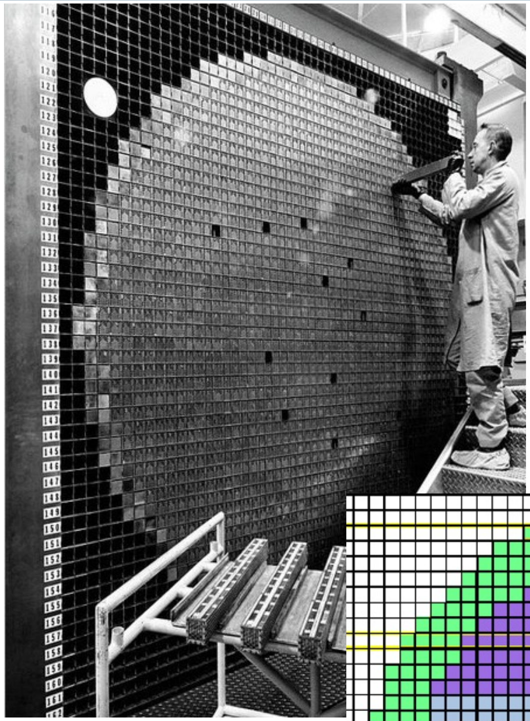


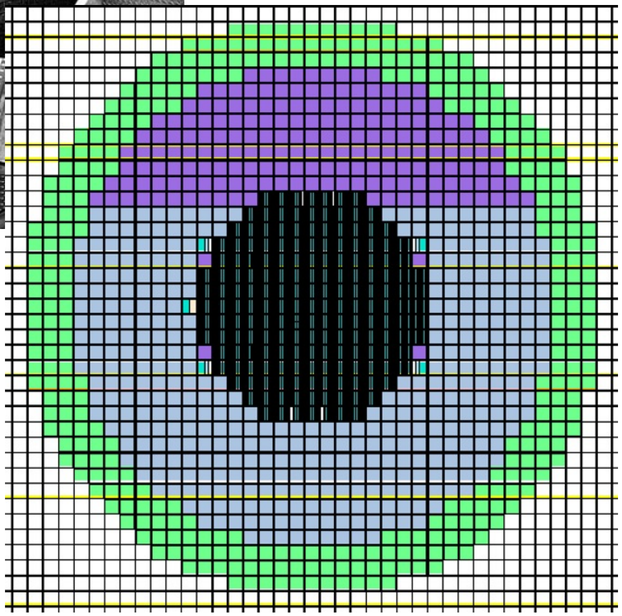


- Tests multiple data (isotopes, reactions, energies) at once
  - May be designed to be particularly sensitive to one piece of data
- Examples:
  - Critical assemblies
  - Subcritical assemblies
  - Engineering mockup critical assemblies
  - Reactor startup experiments
  - Reactor operation data
  - Shielding experiments

Benchmarks Are Evaluated Experiments

- Well characterized experiments
- Evaluate all experimental uncertainties
- Bias and uncertainty for model simplifications
  - Geometry simplifications
  - Room return
  - Material impurities
- Describe benchmark model
- Sample calculation results
- Disseminate for broader use





Sources of Benchmark Uncertainty

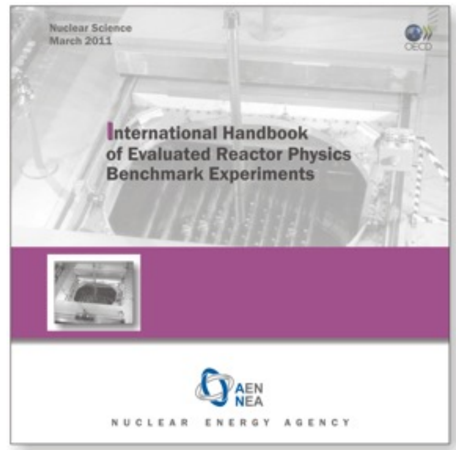
- **Experimental:** How certain are the experimenters of the data reported?
  - Uncertainty in measurement technique, reproducibility measurements, etc
  - Small contribution for k_{eff} and reactivity worth
  - Larger contribution for direct radiation measurements

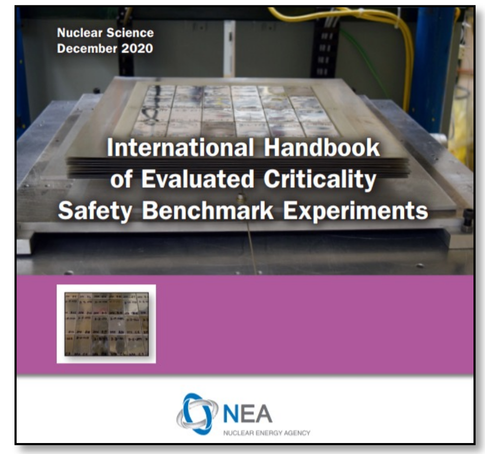
- **Benchmark Model Uncertainties:** How certain are the evaluators of the benchmark model? Model vs. Reality
  - Mass (are all masses or densities well known?)
  - Dimensions (were all parts measured? How do they fit together?)
  - Composition (what are the constituents of all parts, including impurities?)
  - Irradiation history

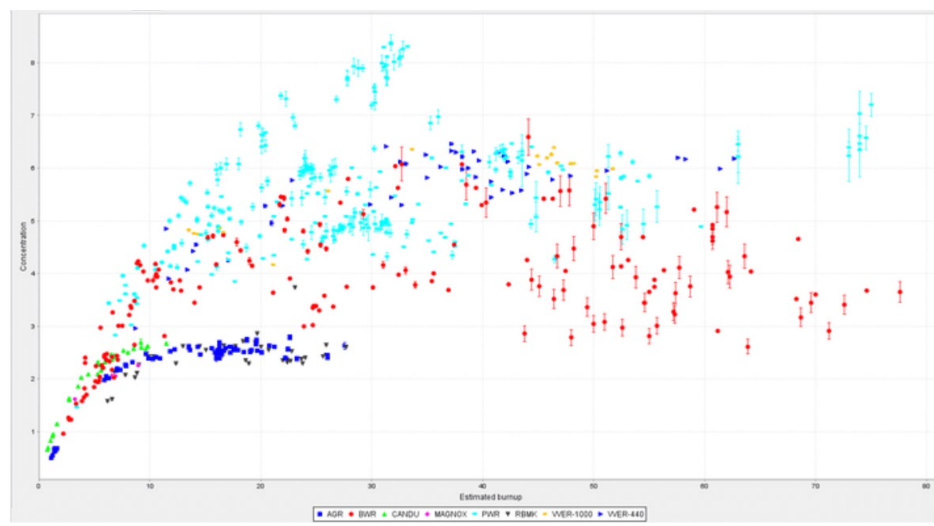
- **Complication:** Many benchmarks were evaluated decades after the experiment without access to the original experimenters

Established Integral Benchmark Handbooks

- **International Criticality Safety Benchmark Evaluation Project (ICSBEP)**
  - >5000 Critical, subcritical, and physics configurations
- **International Reactor Physics Evaluation Project (IRPhEP)**
  - 200 Reactor benchmarks
  - 200 Spectra benchmarks
- **Shielding Integral Benchmark Database (SINBAD)**
  - reactor shielding (46)
  - fusion neutronics shielding (31)
  - accelerator shielding (23)
- **Spent Fuel Composition (SFCompo)**
  - 700 Samples







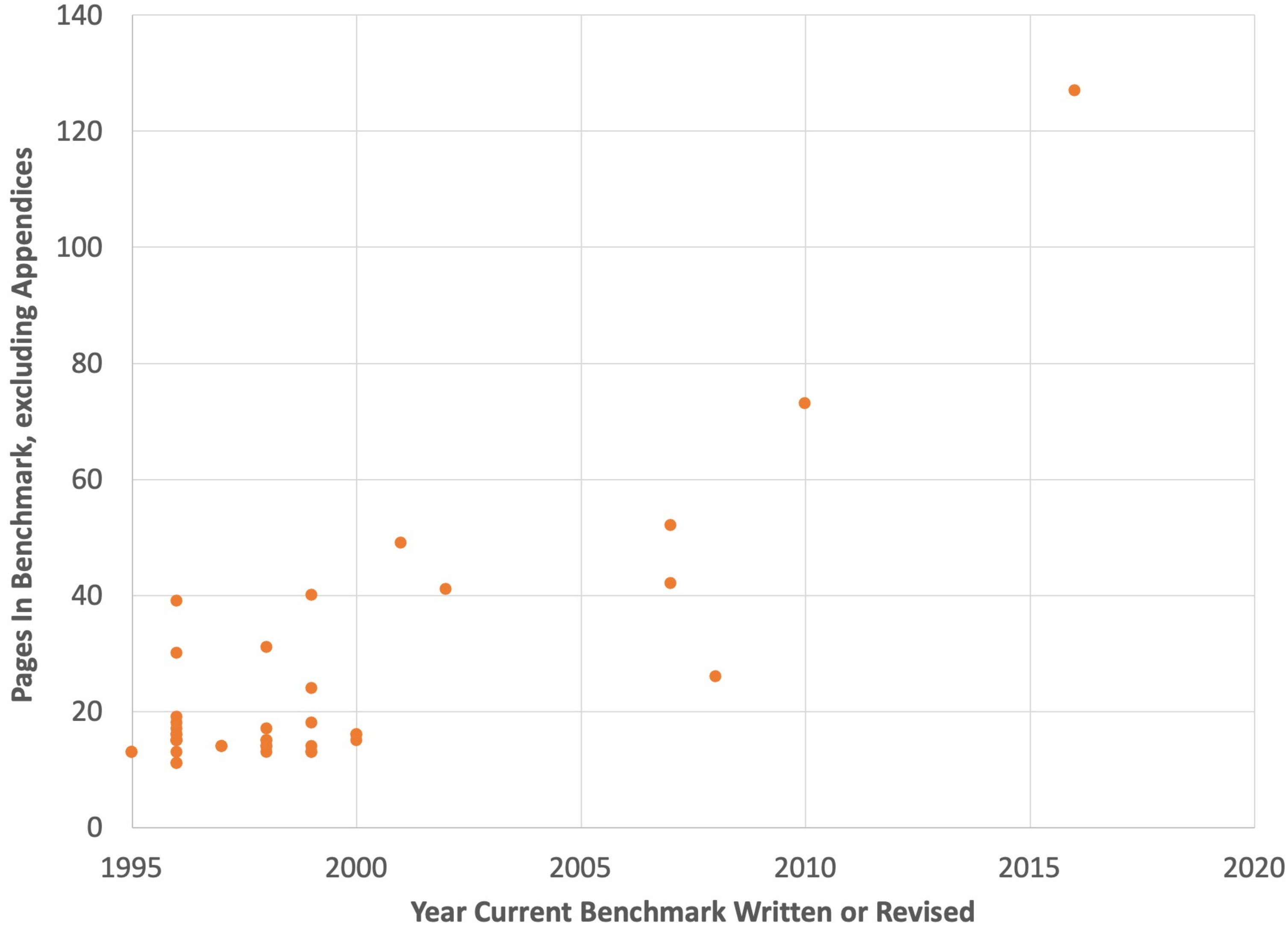
Remember Context of the Benchmarks

- For ICSBEP, Criticality safety validation was the driving force behind many of the evaluations, not nuclear data validation or adjustment

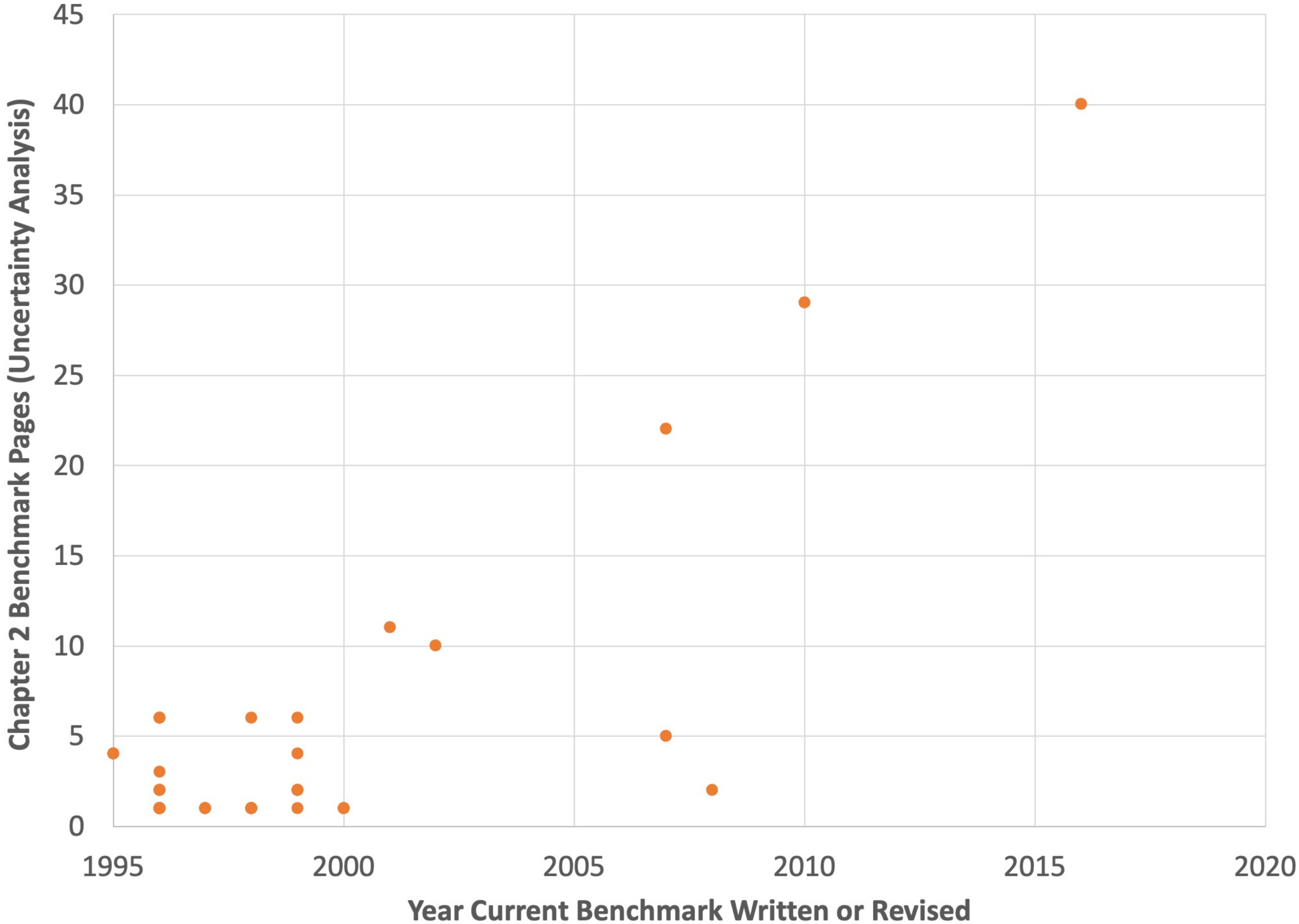
- Expectations have evolved over time with increasing computational power
  - Earlier evaluated benchmarks tend to be more brief
  - Many evaluated benchmarks are missing major sources of uncertainties

Example: PU-MET-FAST-001 (Jezebel) Section	Revision 2 pages (2007)	Revision 4 pages (2016)	Increase
1 (Experimental Data)	6	33	x5
2 (Experiment and Uncertainty Evaluation)	< 1	40	x40
3 (Benchmark Model)	3	46	x15
4 (Sample Calculations)	1	8	x8
Appendix (Supporting Documentation)	5	46	x9

Total Page Count for Fast Pu Metal Cases over Time
(excluding appendices- sample inputs, etc)



Uncertainty Analysis for Fast Pu Metal Cases over Time
(Length of Chapter 2)



Some Benchmarks Have Significantly Less Uncertainty Assessment

- HMF-001, Benchmark is subcritical shell experiments completed to inform Lady Godiva design
- "Uncertainties" are only experimental- from extrapolation to idealized critical sphere from subcritical shells
  - Shell radii were not well known!
- Missing **MAJOR** Uncertainties:
  - Uranium Mass
  - Dimensions of shells
  - Uranium composition
  - 100 pcm uncertainty is likely not right

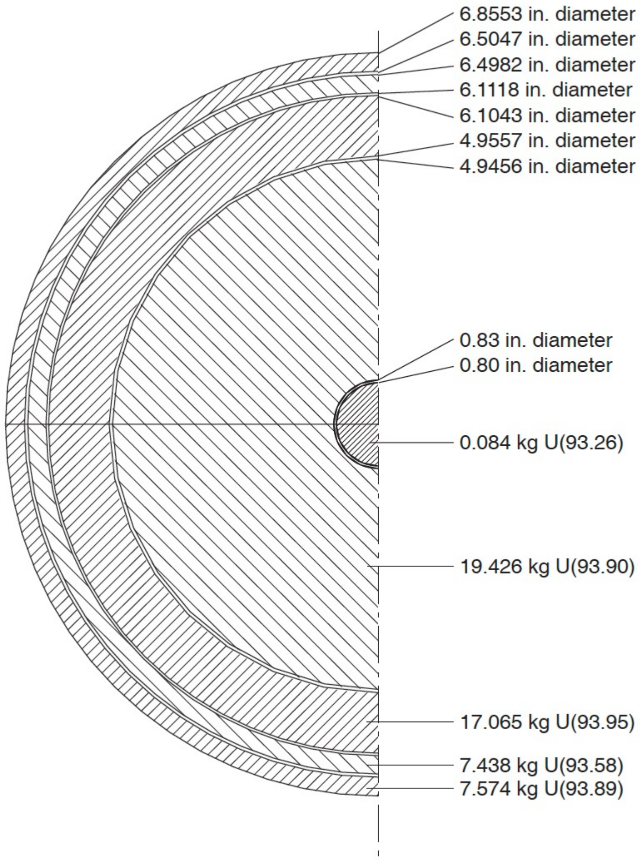
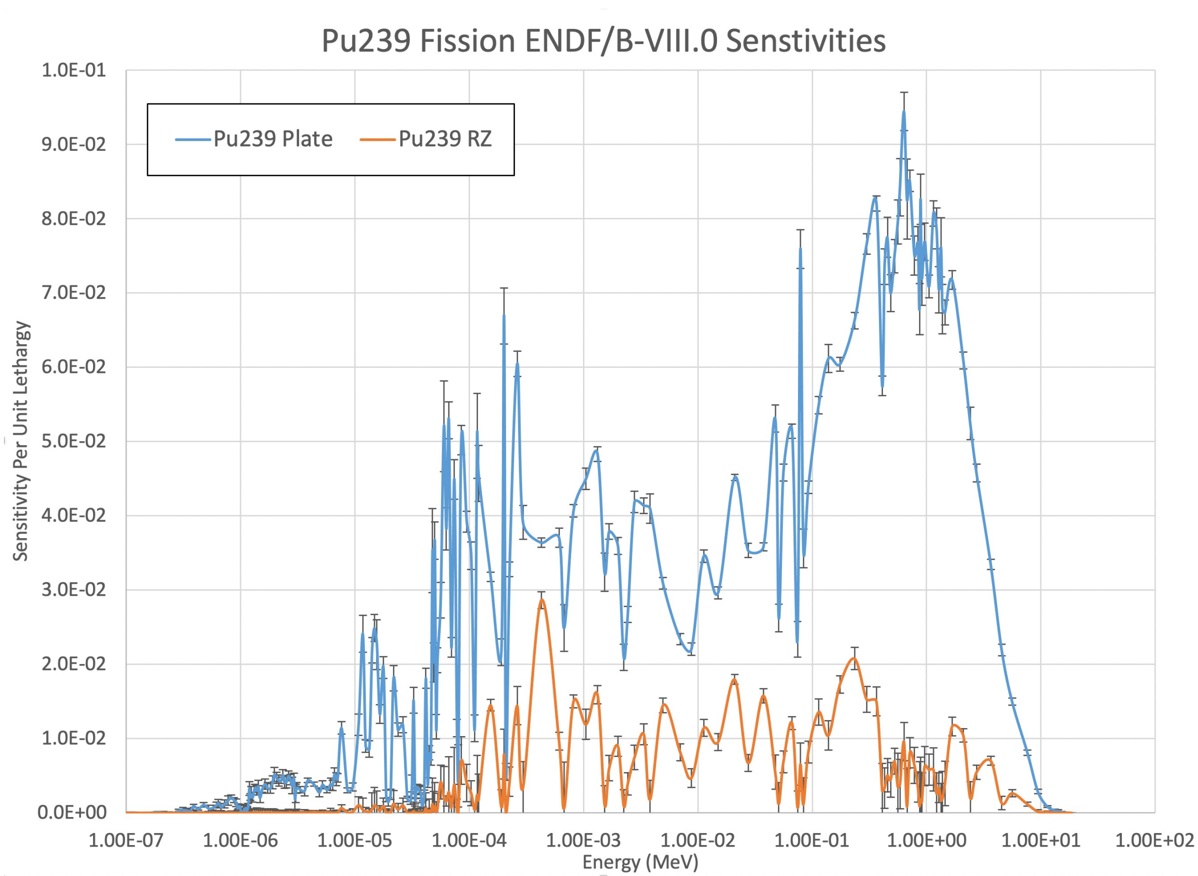


Figure 2. Idealized Final Configuration of Subcritical U(94) Spherical Shells.

Simplified Benchmark Models can have Marked Physics Differences from Detailed



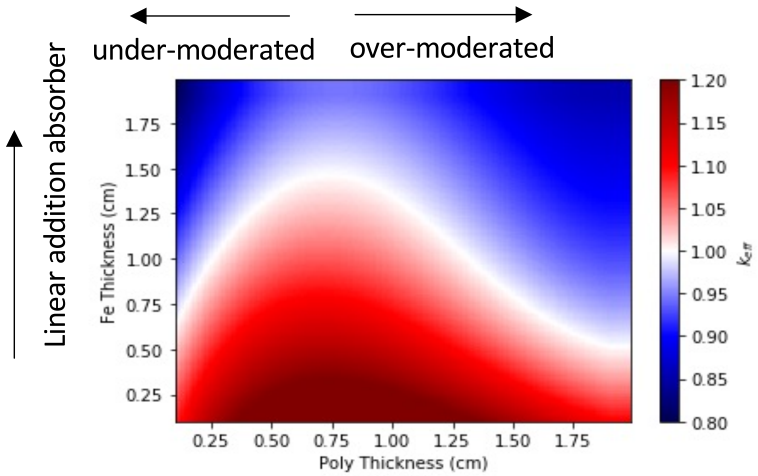
MCNP6.1 Calculated Sensitivities for ICSBEP PU-MET-INTER-002, *ZPR-6 Assembly 10: A Cylindrical Plutonium/Carbon/ Stainless Steel Assembly with Stainless Steel and Iron Reflectors* for both detailed and simplified (homogenized) models

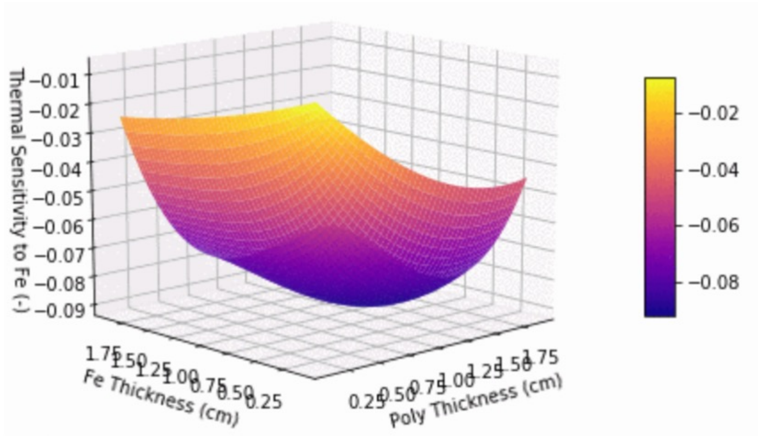
Words of Caution for Benchmark Users

- Current OECD/NEA Working Party for Nuclear Criticality Safety (WPNCS) Subgroup working to document ICSBEP evaluation concerns
  - WPNCS SG-8: Preservation of Expert Knowledge and Judgement Applied to Criticality Benchmarks
- Ongoing Effort to Revitalize SINBAD and create a format and content guide for shielding benchmarks
- **All users of benchmarks should read through the available documentation with a critical eye before using the benchmark**

Designing Modern Critical Experiments for Benchmarks

- Optimize experiment design to provide the best possible test of some variable
  - Targeting averaging neutron energy of a system
  - Sensitivity to specific reaction of specific nuclide at a specific energy
  - Representativity of criticality safety application
- Can be ideal use for Machine Learning, to find unique solutions and minimize designer and simulation time





Figures from D. Siefman (LLNL)

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