Reevaluation of Room Return Corrections for Two ORCEF HEU-Metal-Cylinder Benchmark Evaluations

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Acknowledgments

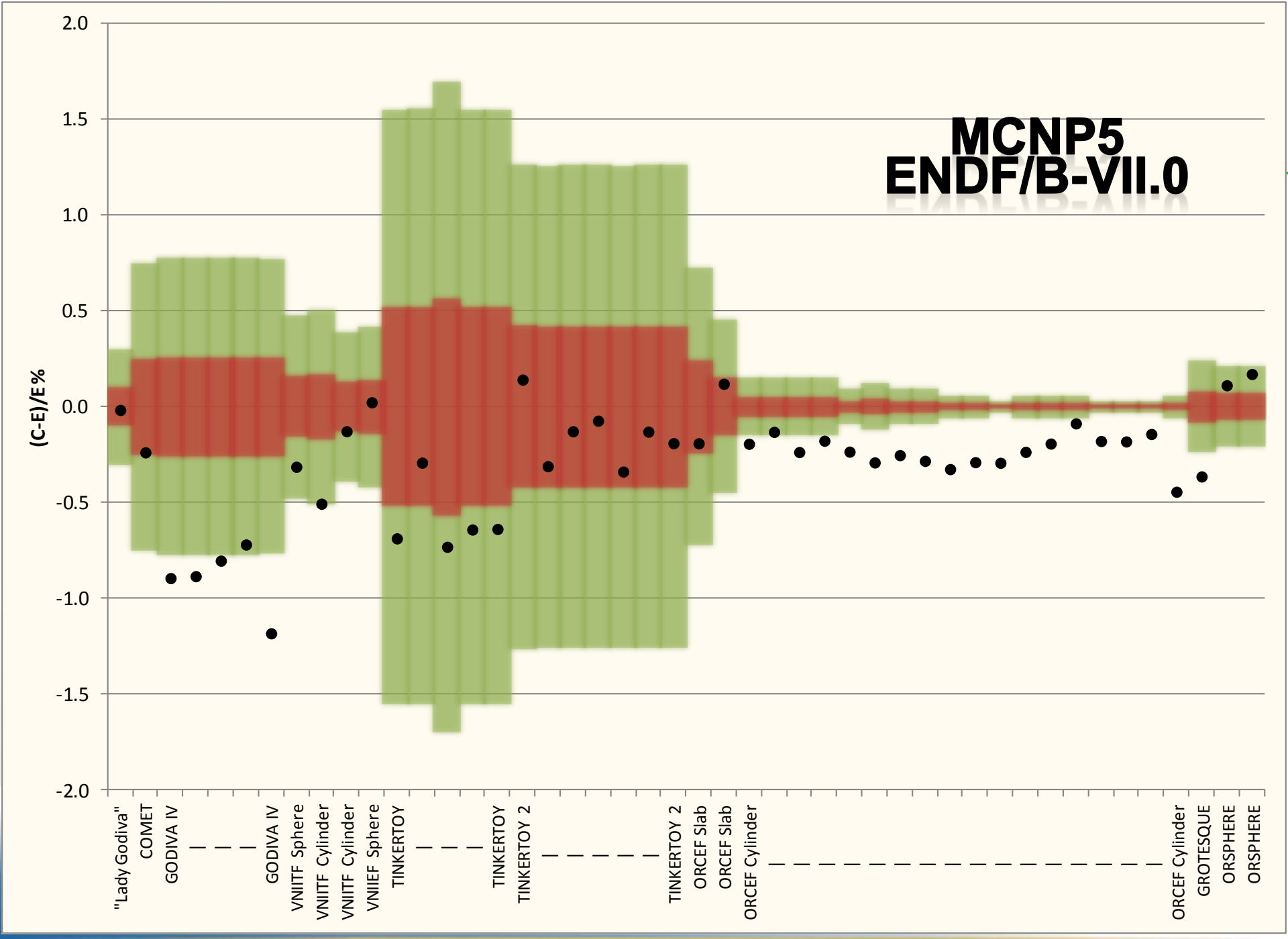
- **Yevgeniy Rozhikin – IPPE**
  - **Recommendation to reevaluate room return effects and subsequent review of results**
- **Scientists, engineers, and administrative support from 20 countries collaborating in the ICSBEP**

Outline

- Background
  - Previous Work
- Experiments
  - History
  - Benchmarks
- Analysis
  - Room Return
  - Method
- Results
  - Summary
  - Comparison of Revised Data
- Conclusion

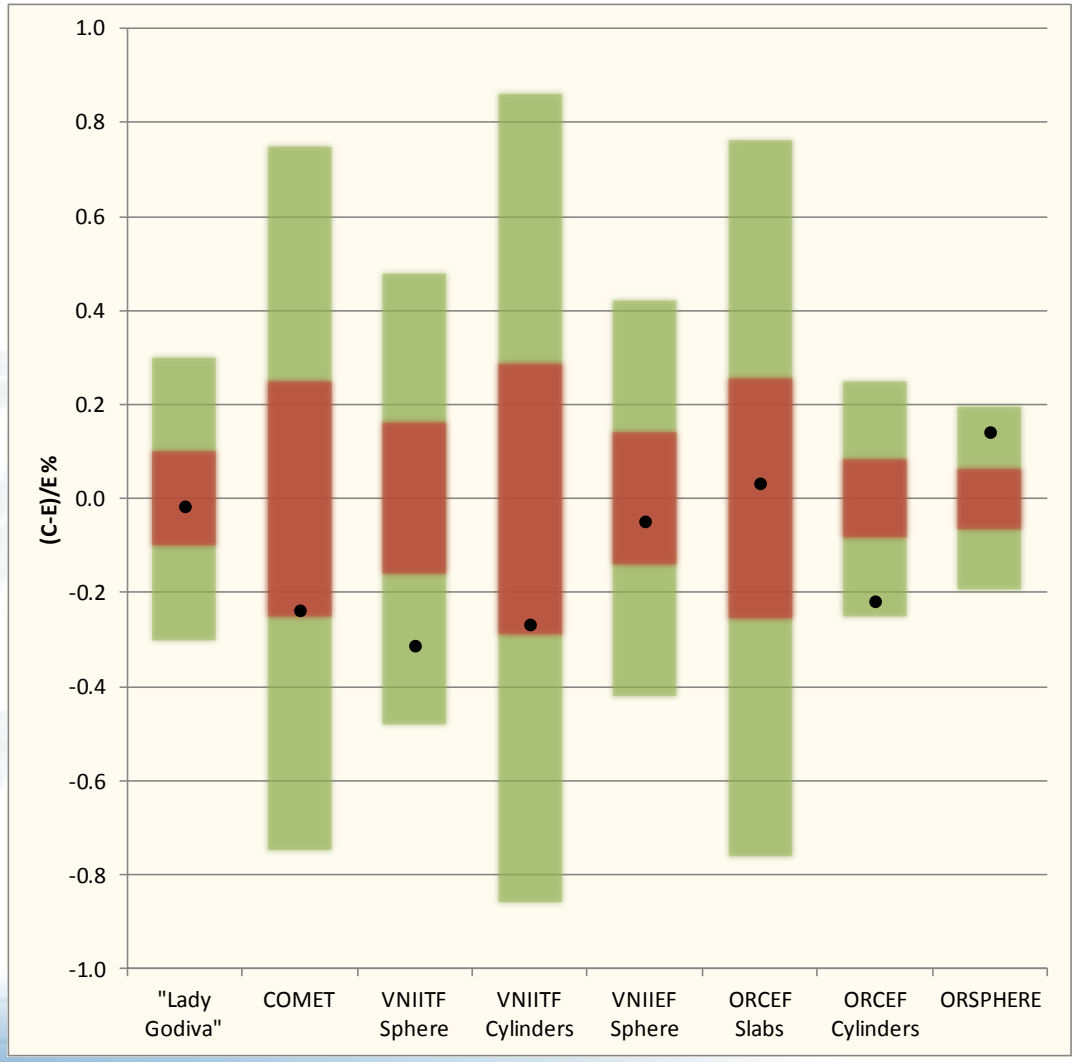
Conclusions from NCSD 2013

- **Comparison of 46 bare HEU benchmark experiments**
  - **Basic spherical, slab, and cylindrical geometries are within 3σ of the benchmark values**
    - **When accounting for variations in correlated experiments with increased uncertainties**
  - **Reasonable results for spheres and slabs**
  - **Cylindrical system calculations appear low**
    - **Even for complex systems with cylinders**
    - **Need to investigate scatter in ORCEF cylinders**


MCNP5
ENDF/B-VII.0
(C-E)/E%
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
"Lady Godiva"
COMET
GODIVA IV
GODIVA IV
VNIITF Sphere
VNIITF Cylinder
VNIITF Cylinder
VNIIEF Sphere
TINKERTOY
TINKERTOY
TINKERTOY 2
TINKERTOY 2
ORCEF Slab
ORCEF Slab
ORCEF Cylinder
ORCEF Cylinder
GROTESQUE
ORSPHERE
ORSPHERE

Spheres, Slabs, and Cylinders

- Consolidate data for basic geometries
- Combined correlated experiments
  - Variance-weighted average
  - Standard deviation



ORCEF Experiments

- 1960s and 1970s
- Critical experiments to support Y-12 storage, casting, and handling limits
- Verification of calculations methods and cross-sections for criticality safety
- HEU metal Oak Ridge alloy (oralloy)

ORCEF Measurement Uncertainties

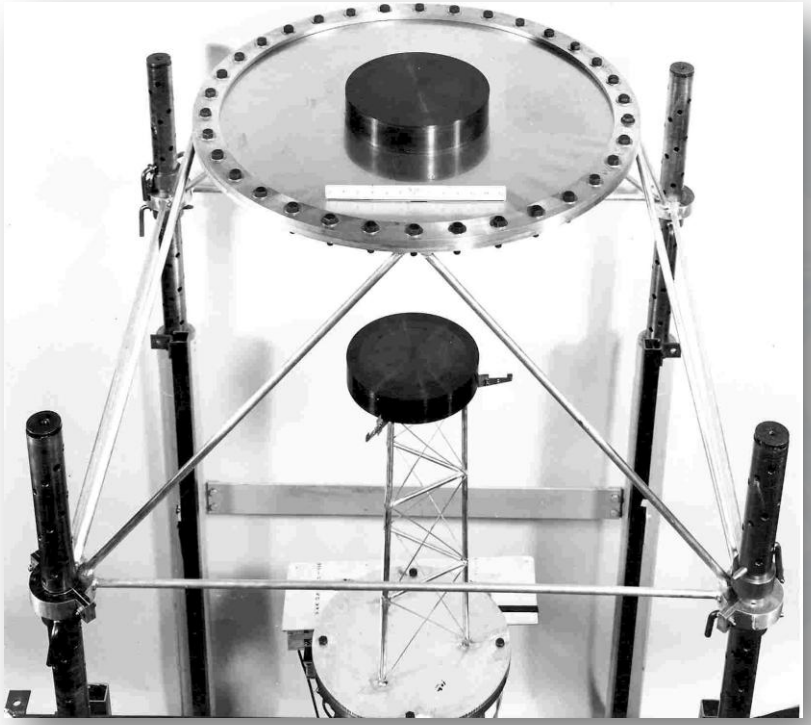
- Very precise measurement capabilities at Y-12
  - Dimensions
    - ±0.0001 in.
  - Mass
    - ±0.01 g
  - Isotopics
    - ±1% ^{234}U
    - < ±0.02 wt.% ^{235}U & ^{236}U
  - Impurities
    - ~500 ppm average content

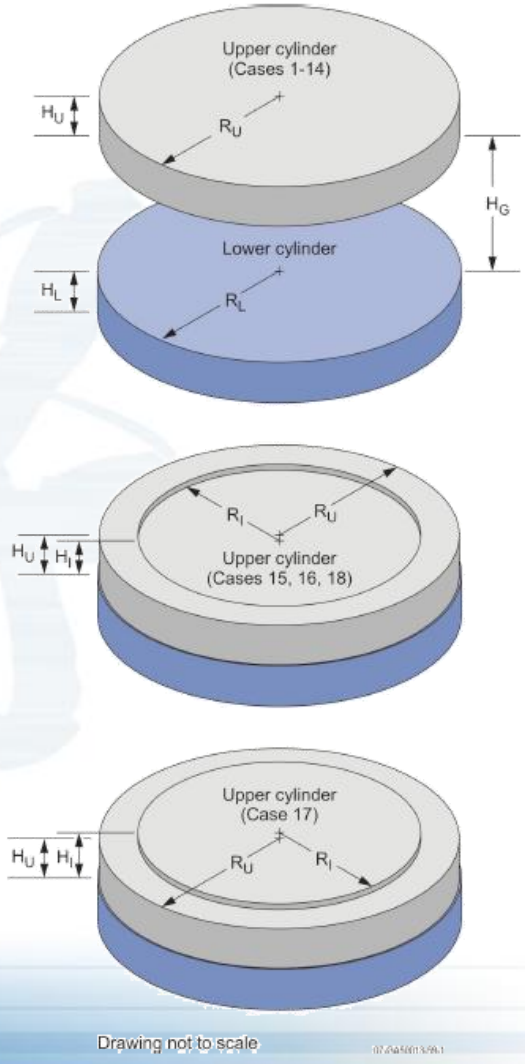
- John T. Mihalczo
  - Experimenter still available for collaboration
- Further information available
  - ORNL/TM-2012/32

Existing Oralloy Series and Benchmarks

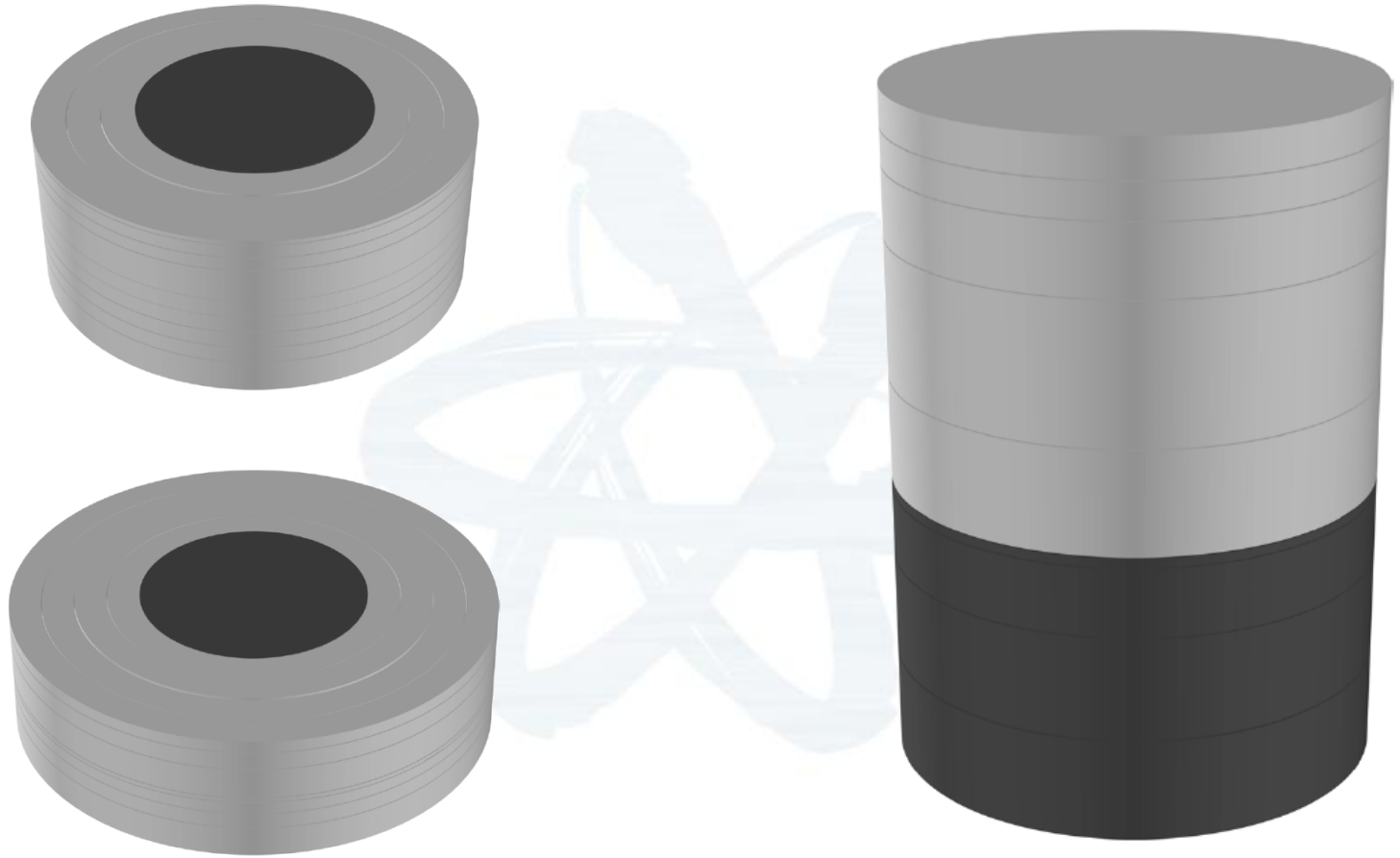
- Bare Cylinders
  - HEU-MET-FAST-051
- Beryllium Reflected
  - HEU-MET-FAST-059
  - HEU-MET-FAST-069
- Thin Graphite Reflected
  - HEU-MET-FAST-071
- Poly Reflected
  - HEU-MET-FAST-076
- GROTESQUE
  - HEU-MET-FAST-081
- ORSPHERE
  - HEU-MET-FAST-100
- *Potassium Worth*
- *Complex Annuli*
- Bare Annuli
- Interacting Cylinders
- Thick Graphite Reflected

Bare Cylinders (HEU-MET-FAST-051) revised

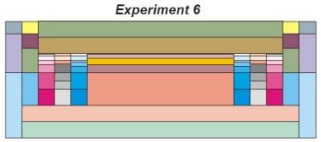




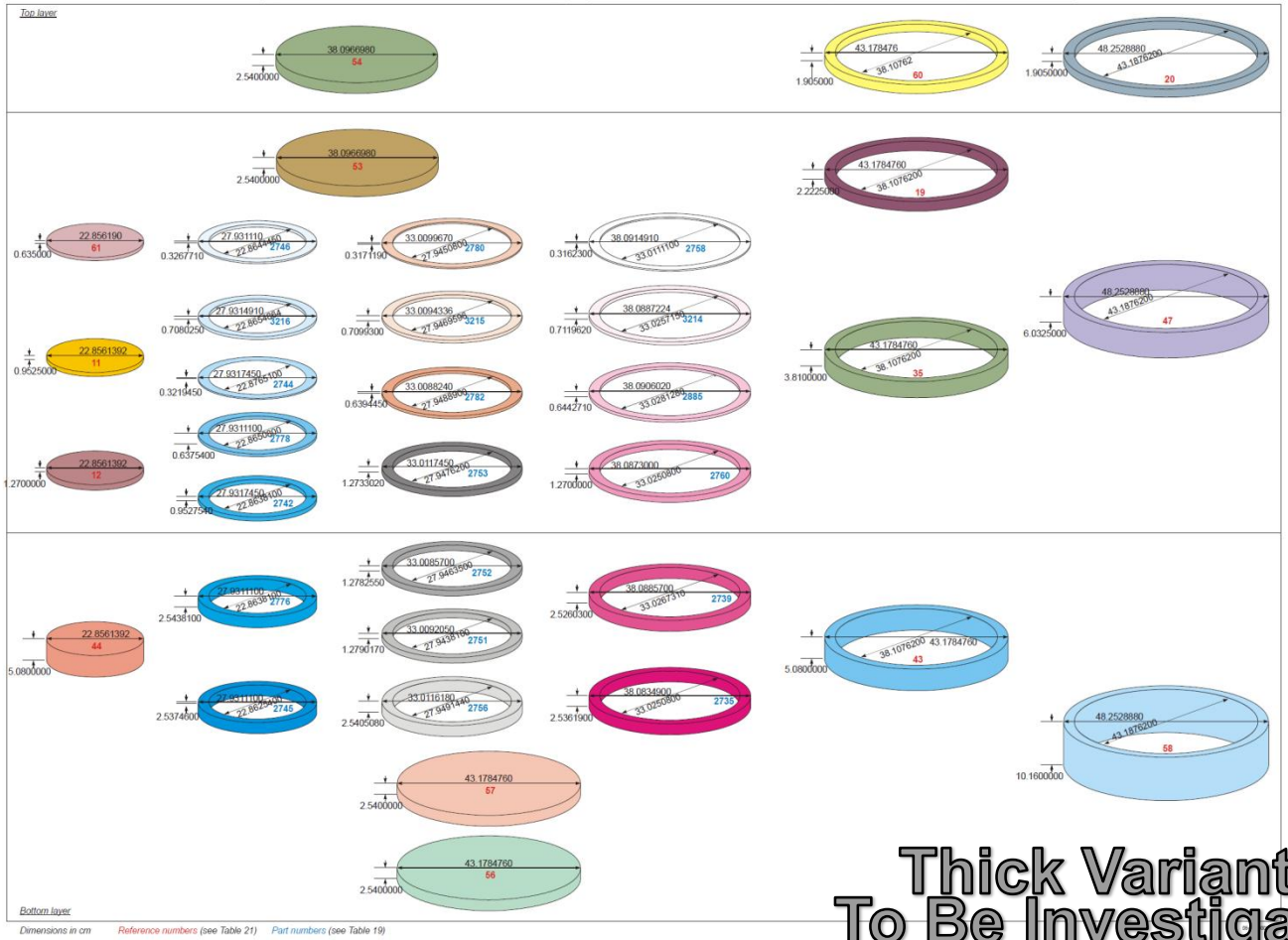
Beryllium Reflected (HEU-MET-FAST-059, -069)



Thin Graphite Reflected (1” and 2”) (HEU-MET-FAST-071) revised

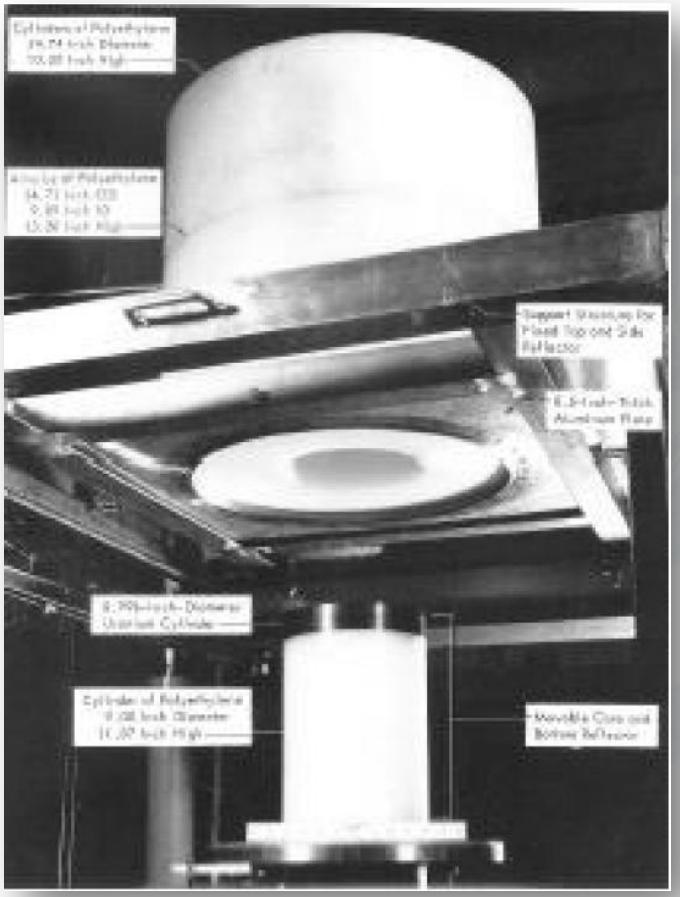


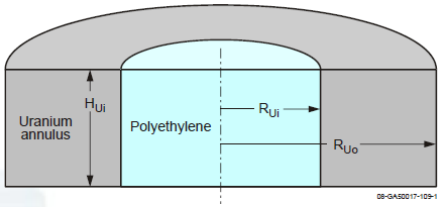
Region (nominal)	Height (cm)	Average Gap (cm)
Fuel height, 22.86 cm ID, 27.94 cm OD region	8.037322	0.00150368
Fuel height, 27.94 cm ID, 33.02 cm OD region	8.049260	0.00194818
Fuel height, 33.02 cm ID, 38.10 cm OD region	8.050022	0.00906780
Graphite stack, 43.18 cm OD, 38.10 cm ID	18.177256	0.02658618
Graphite stack, 48.26 cm OD, 43.18 cm ID	18.186654	0.0445770
Graphite core	7.957312	0.00660400

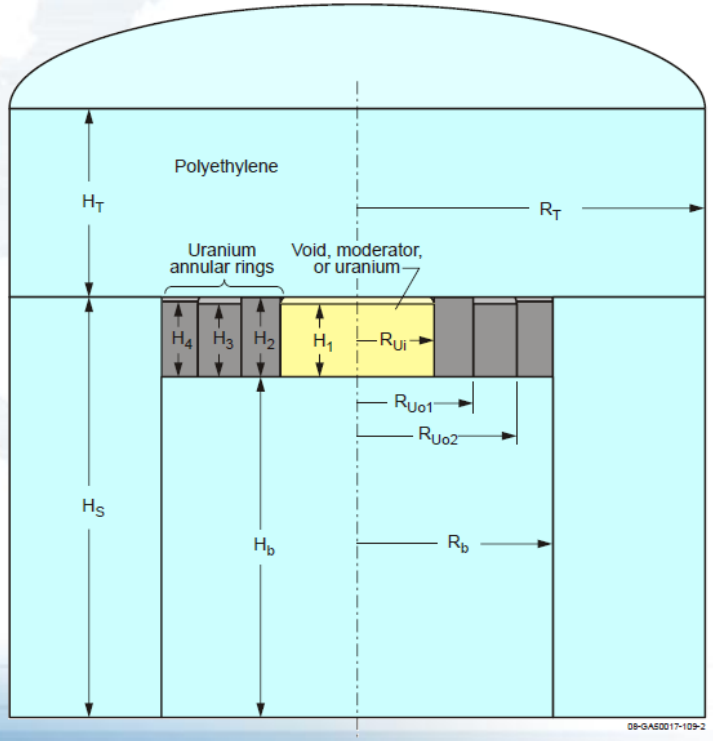


Thick Variants To Be Investigated

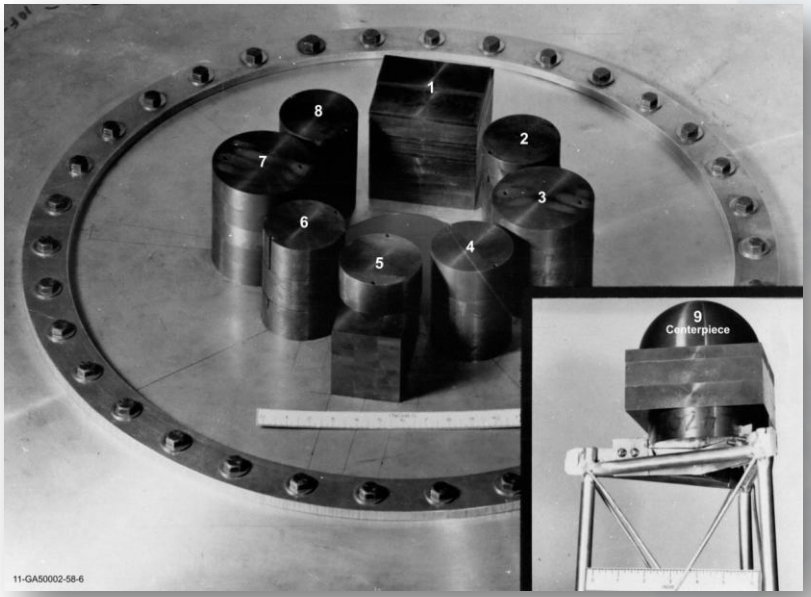
Polyethylene Reflected (HEU-MET-FAST-076)

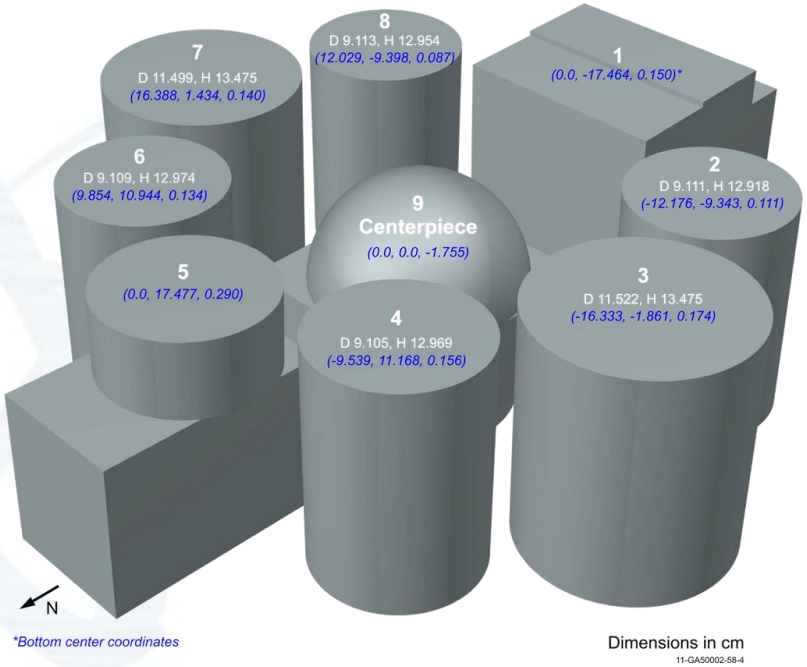




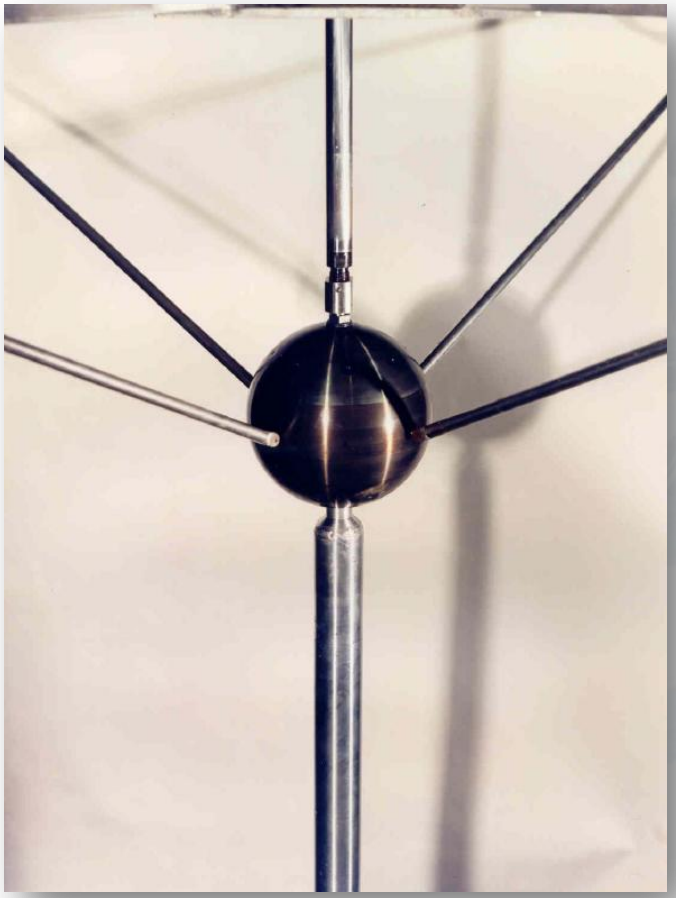


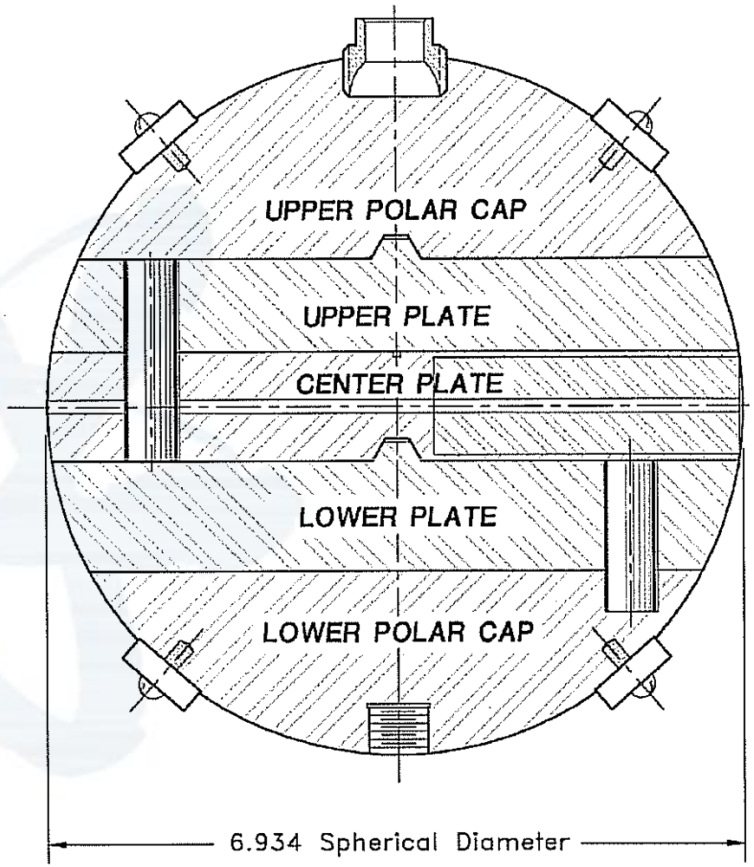
GROTESQUE (HEU-MET-FAST-081)



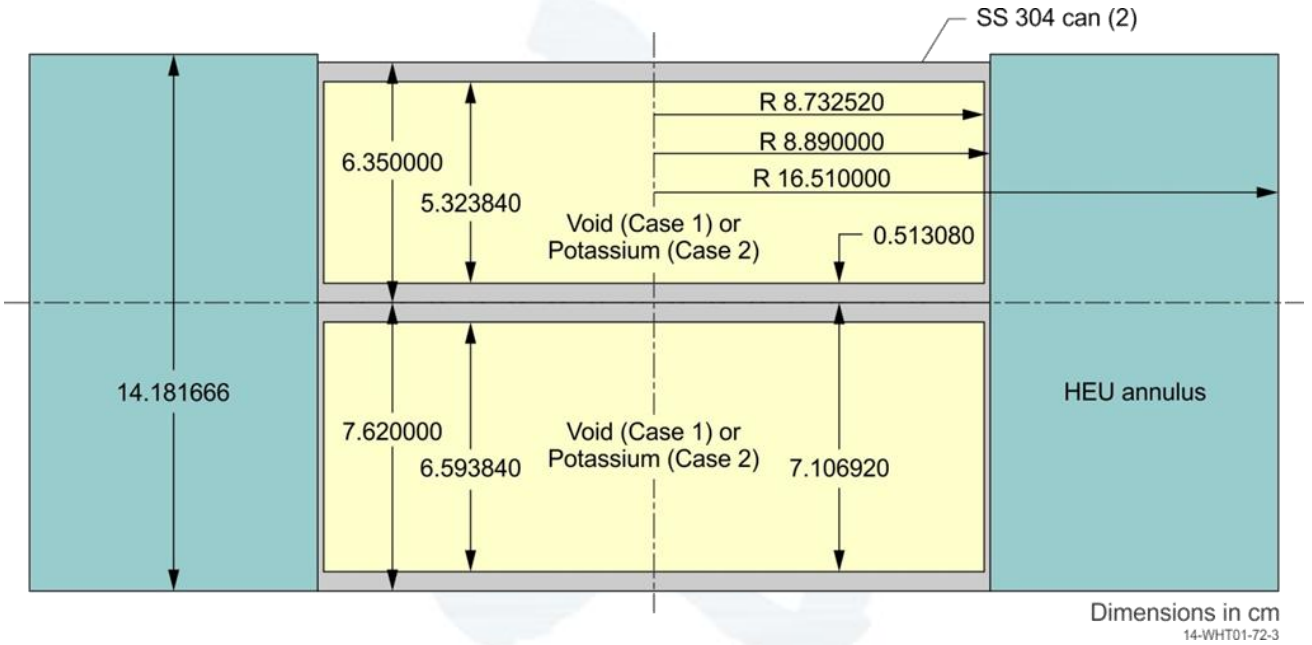


ORSPHERE (HEU-MET-FAST-100)

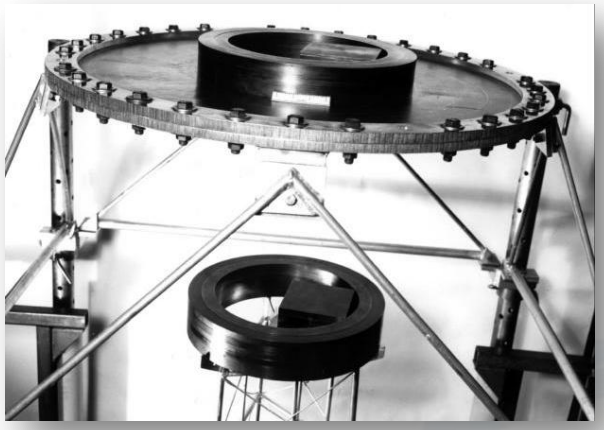


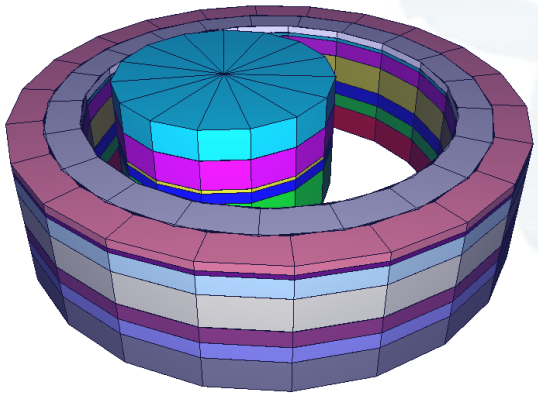


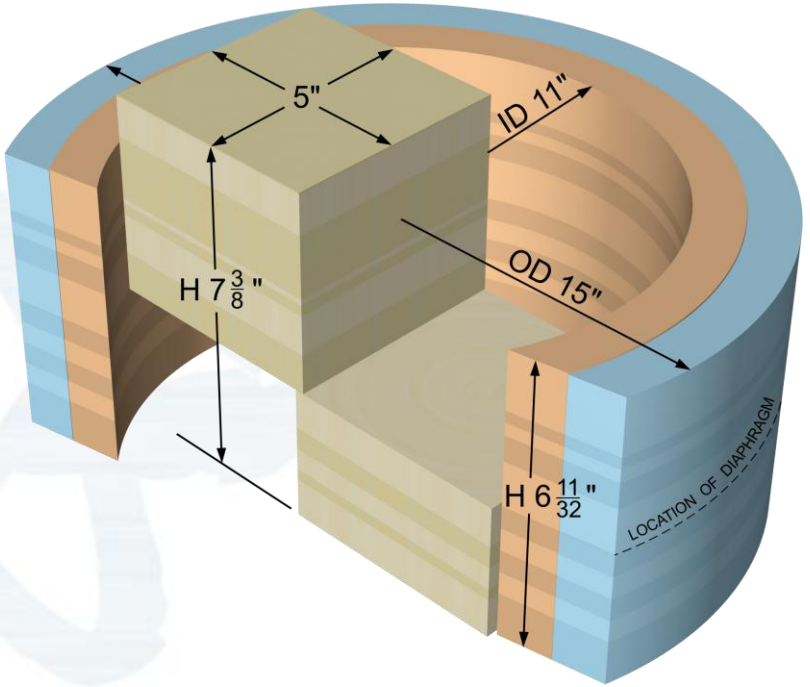
Potassium Worth Measurement (In Progress)



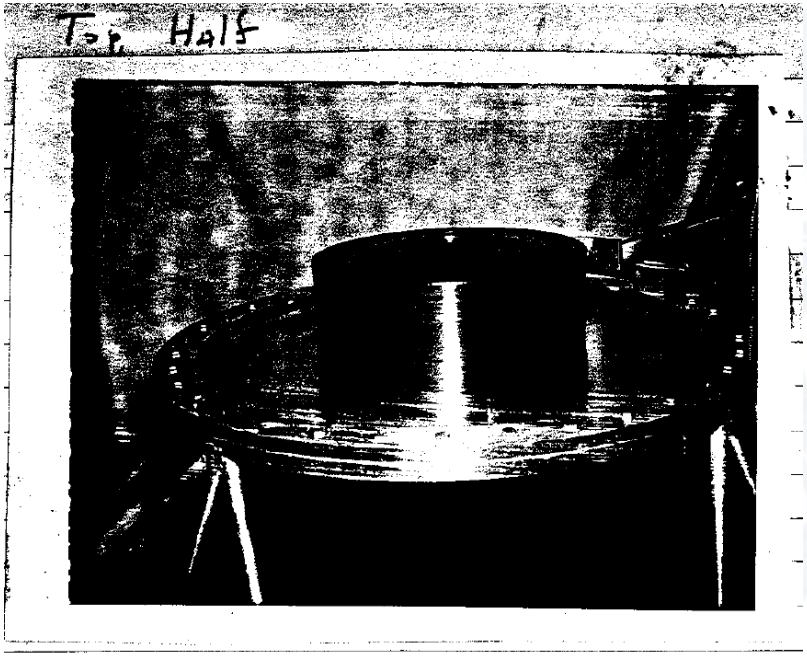
Complex Annuli (In Progress)

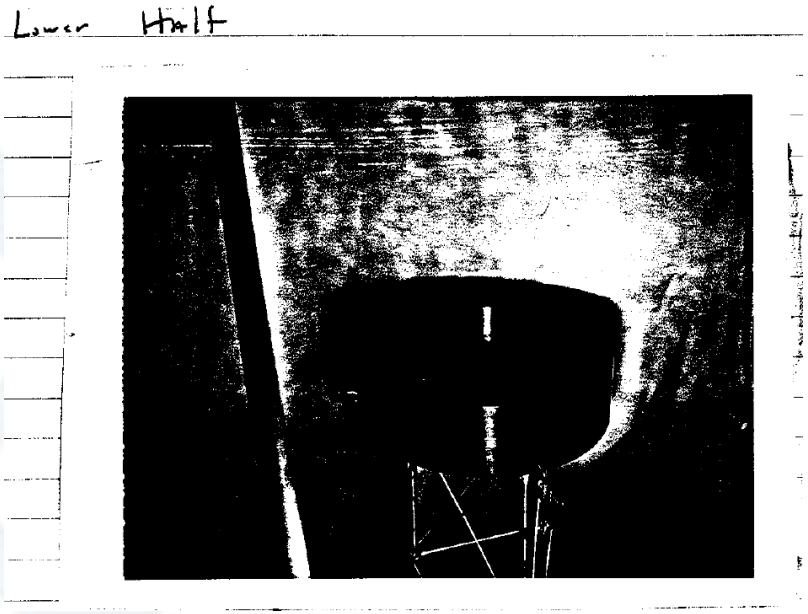






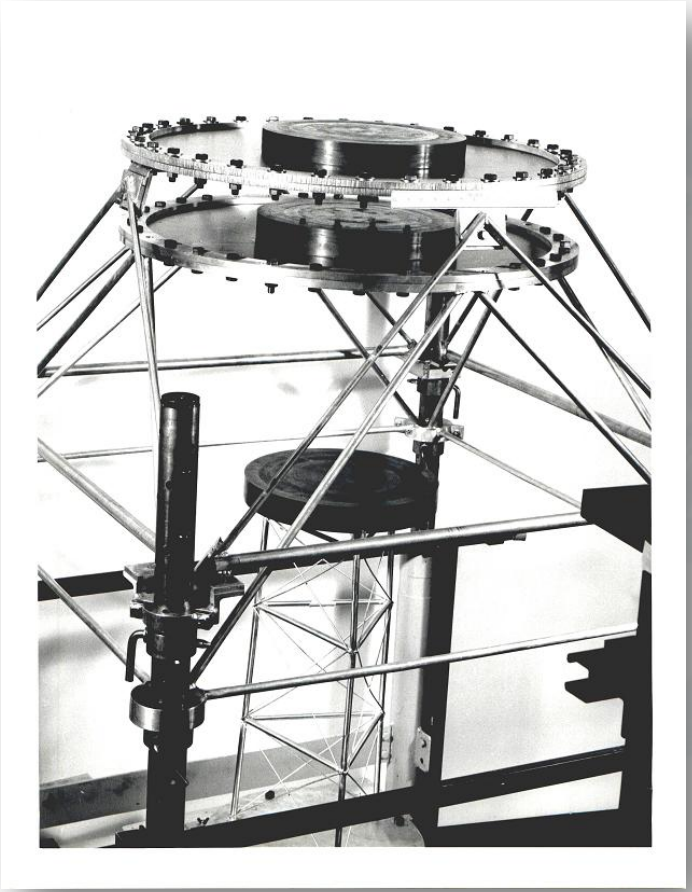
Bare Annuli (To Be Evaluated)

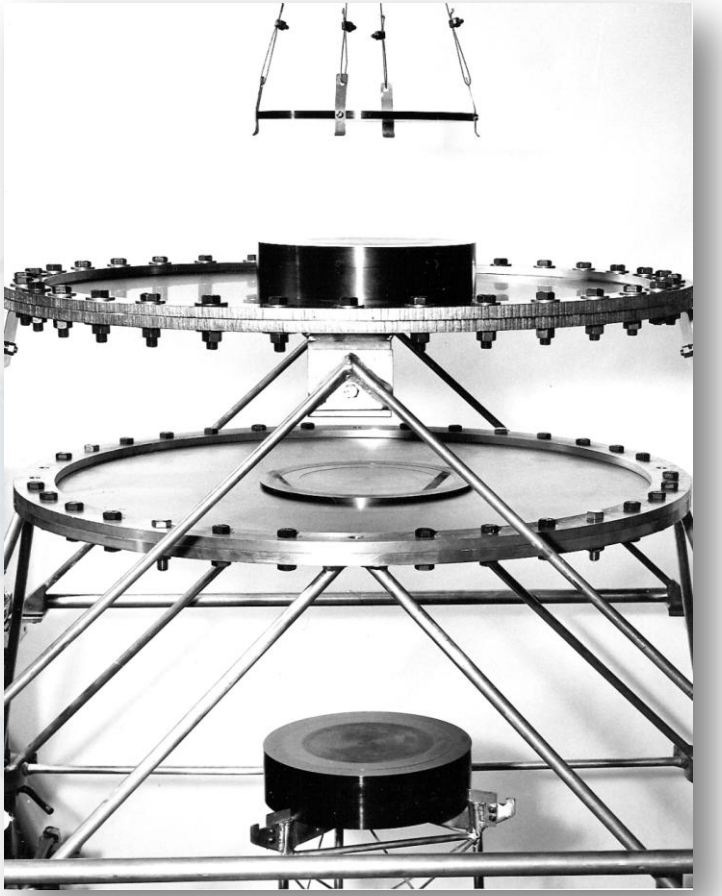




Prompt Neutron Decay Constant Measurements Were Performed on Bare Cylinders and Annuli

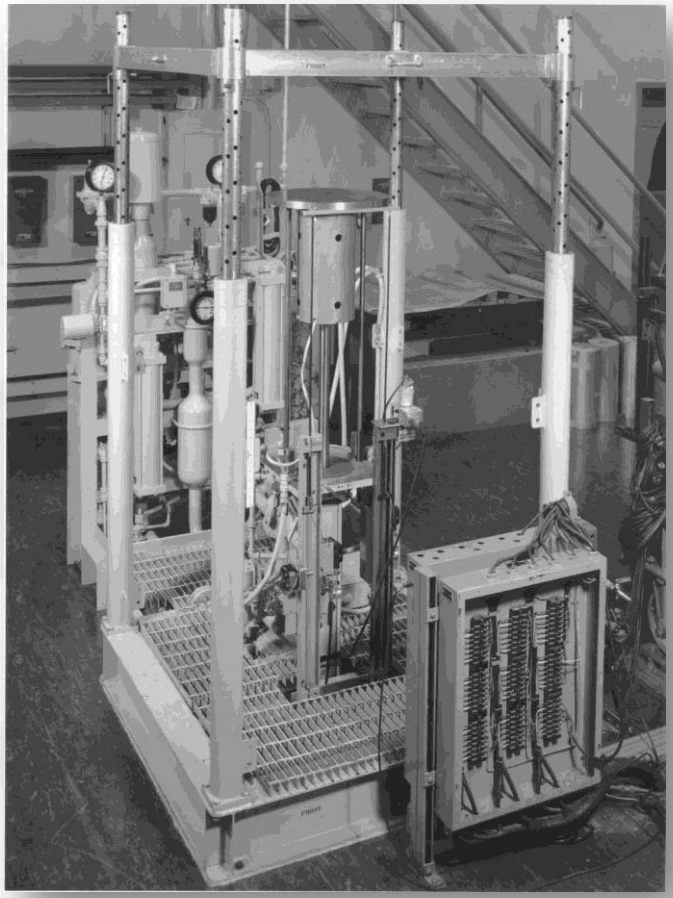
More Interacting Cylinders (To Be Evaluated)





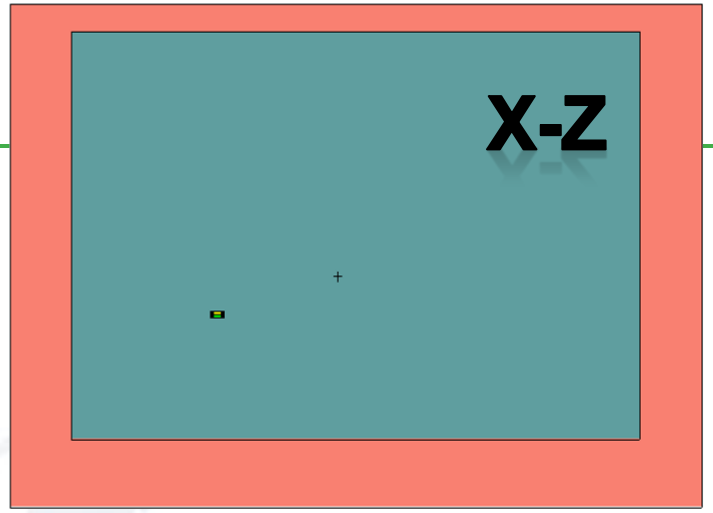
Room Return Effects – Previous Treatment

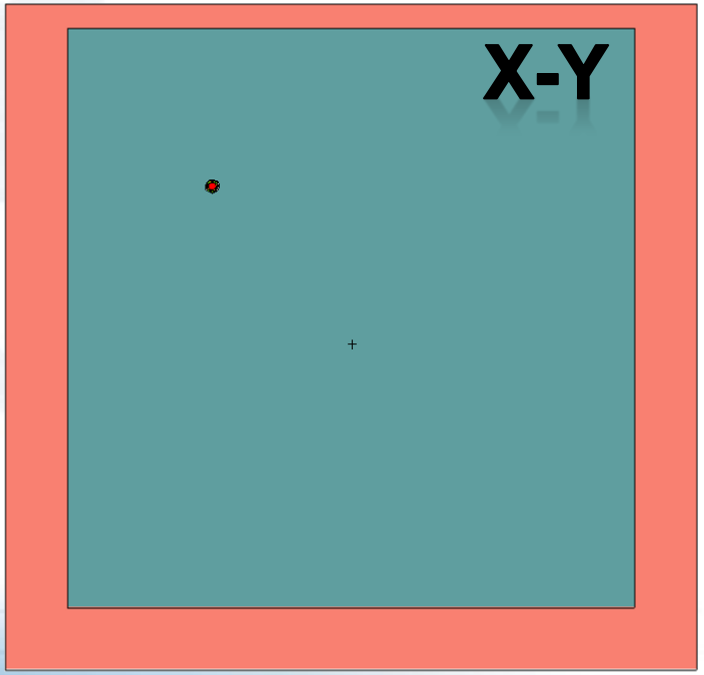
- HMF-051 & -071
- Treated as -3 ¢ and -2 ¢, respectively
  - Based on GODIVA room return measurements
- Room return effects varied among other oralloy benchmark experiments



Room Return Effects – Evaluated

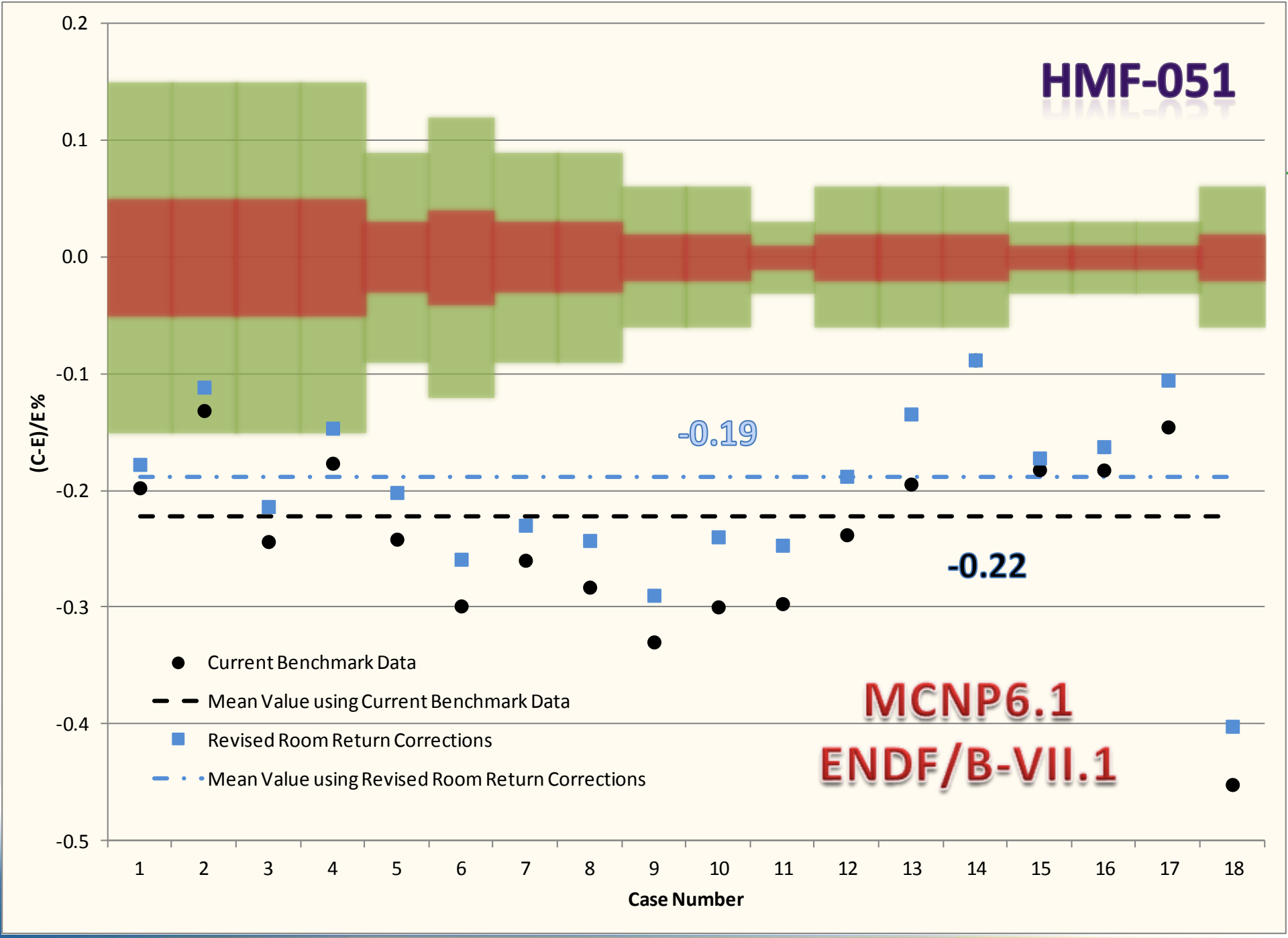
- 35 × 35 × 30 ft
- 5 ft or 2 ft thick concrete
- 11.7 ft from West
- 12.7 ft from North
- Concrete were prepared with crushed limestone
- Calculations:
  - MCNP6.1
  - ENDF/B-VII.1

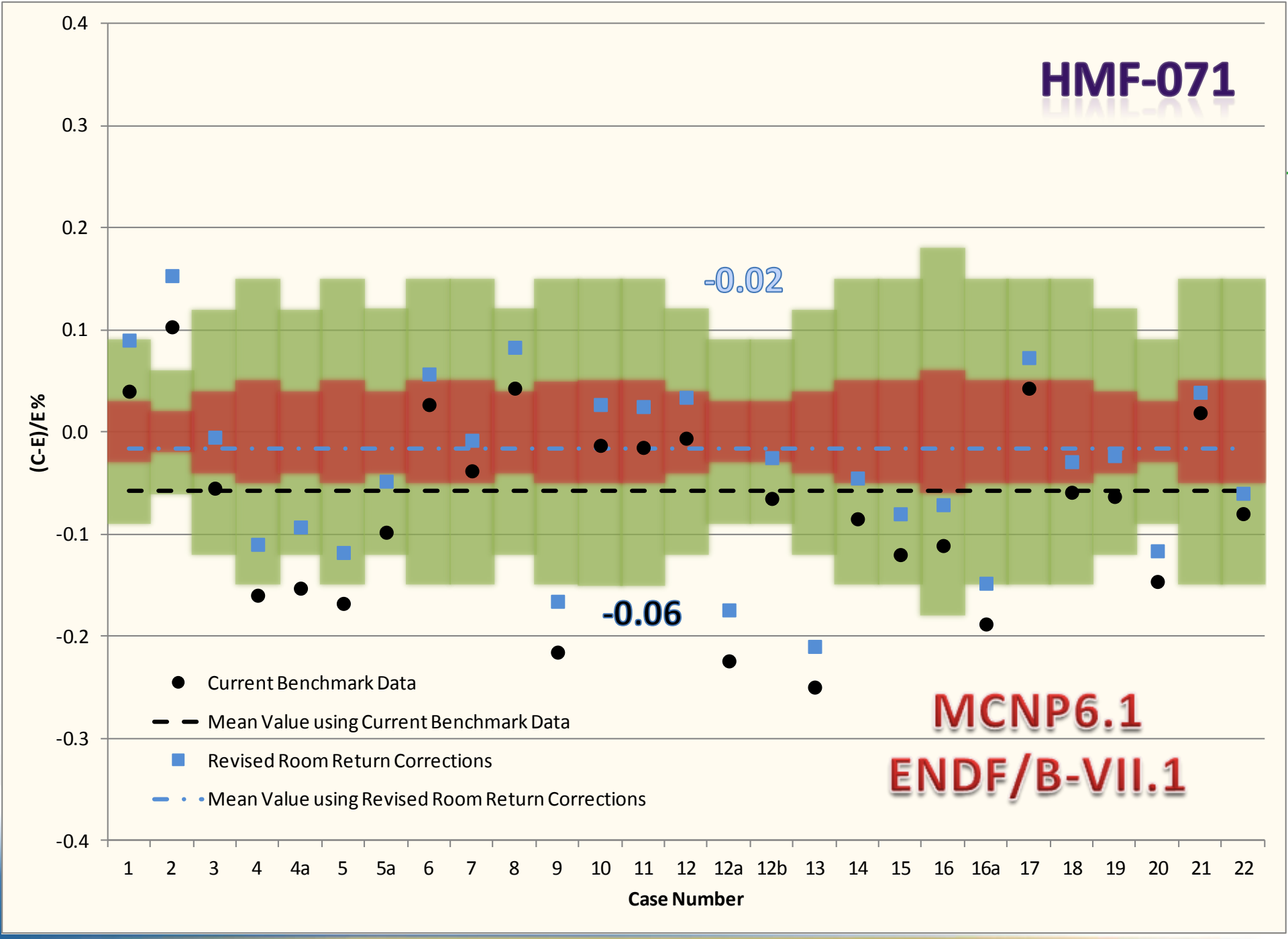




Results

- Calculated Results
  - Between -3.5 ¢ and -12 ¢
  - Greater than initial assumptions
- Increases as diameter of cylinder increases
  - -3.5 ¢ for 7” Ø
  - -11 ¢ for 15” Ø
- Increases as distance between interacting cylinders increases
  - More mass/volume
- Thin graphite reflectors dampened room return effects
- Uncertainty ±0.42 ¢ (1σ)


HMF-051
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
(C-E)/E %
-0.19
-0.22
Current Benchmark Data
Mean Value using Current Benchmark Data
Revised Room Return Corrections
Mean Value using Revised Room Return Corrections
MCNP6.1
ENDF/B-VII.1
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Case Number


HMF-071
-0.02
-0.06
MCNP6.1
ENDF/B-VII.1
Current Benchmark Data
Mean Value using Current Benchmark Data
Revised Room Return Corrections
Mean Value using Revised Room Return Corrections
(C-E)/E%
Case Number
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
1
2
3
4
4a
5
5a
6
7
8
9
10
11
12
12a
12b
13
14
15
16
16a
17
18
19
20
21
22

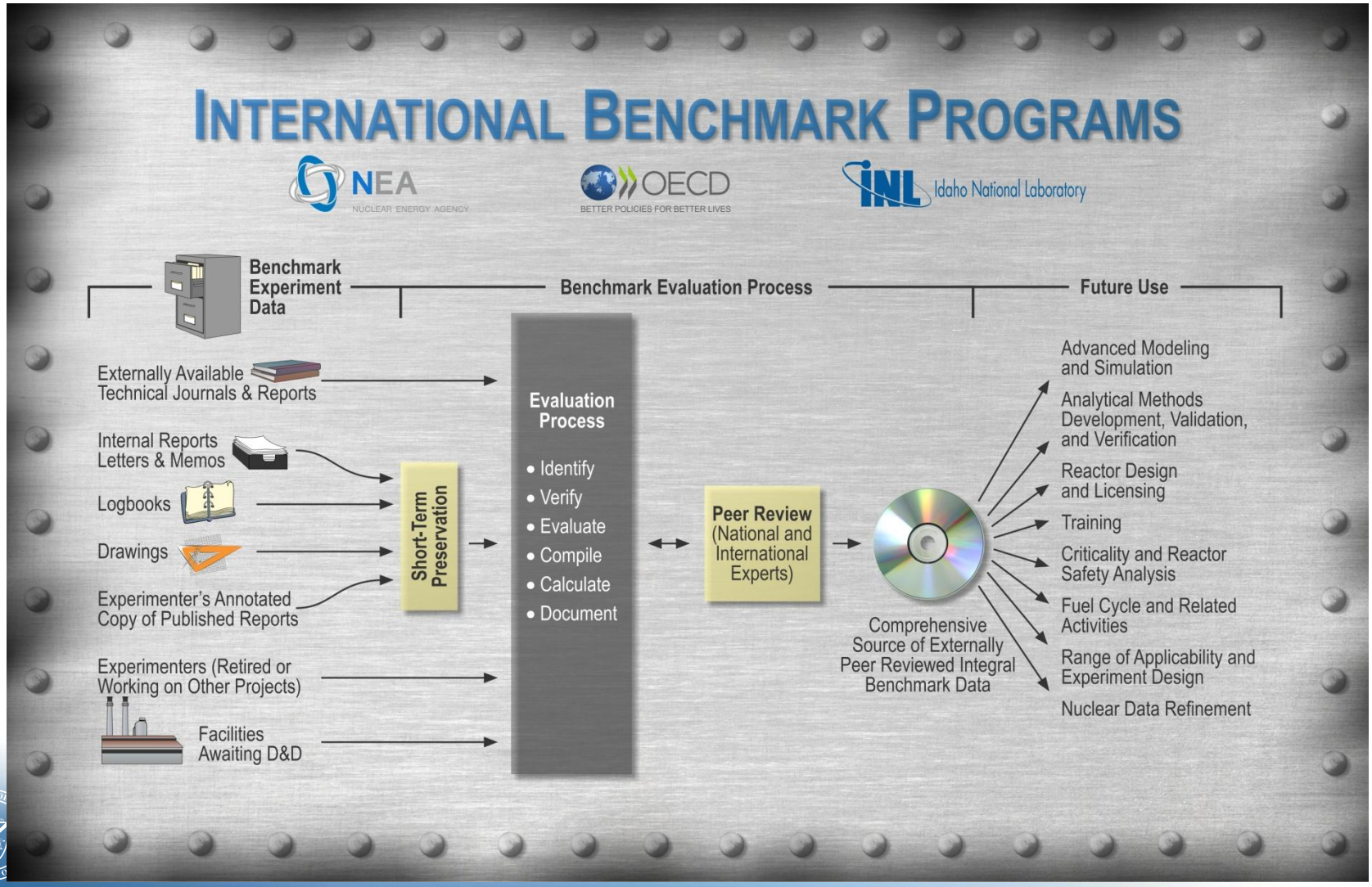
Conclusions

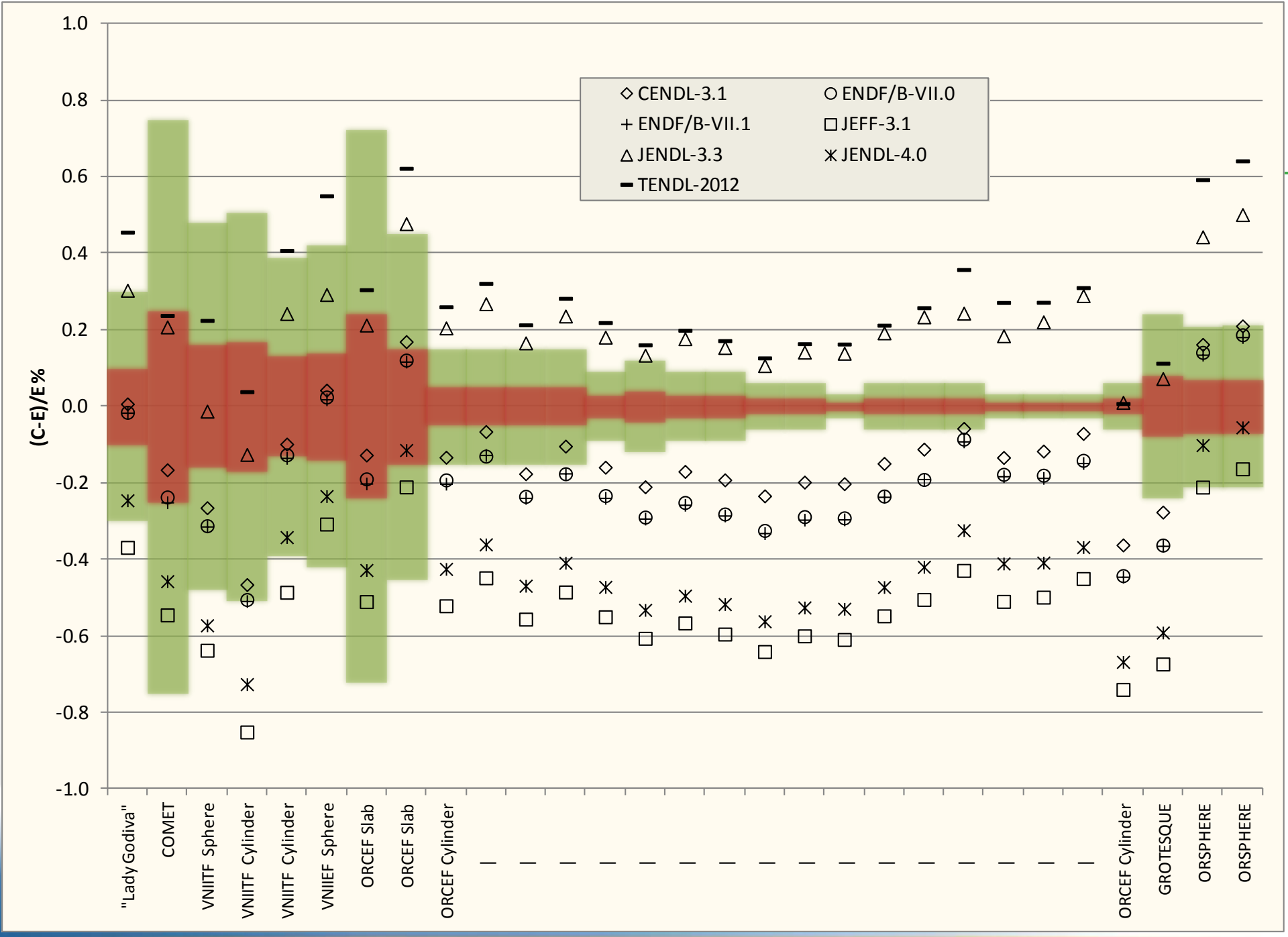
- Room return corrections revised
  - HEU-MET-FAST-051
  - HEU-MET-FAST-071
- Improvement in comparison between calculated and benchmark values
- Bare cylinders still calculate low
- Future work
  - Evaluate additional ORCEF oralloy critical experiments
    - Potassium
    - Bare/Complex annuli
    - Thick graphite reflectors
    - Interacting cylinders
  - Evaluate non-critical measurements

Questions?

Extra Slides

The Benchmark Evaluation Process




1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
(C-E)/E%
CENDL-3.1
ENDF/B-VII.0
ENDF/B-VII.1
JEFF-3.1
JENDL-3.3
JENDL-4.0
TENDL-2012
"Lady Godiva"
COMET
VNIITF Sphere
VNIITF Cylinder
VNIITF Cylinder
VNIIEF Sphere
ORCEF Slab
ORCEF Slab
ORCEF Cylinder
ORCEF Cylinder
GROTESQUE
ORSPHERE
ORSPHERE

Eigenvalue Calculations

- **Monte-Carlo N-Particle (MCNP) 5-1.60**
  - **1050 cycles, skipped 50, 1E6 histories/cycle =1E9**
  - **Statistical uncertainty 0.00002 Δk**
- **ENDF/B-VII.0 neutron data**
  - **ENDF/B-VII.1 has ENDF/B-VI.8 delayed neutron data for uranium isotopes and covariance data**
    - **Negligible impact on k_{eff}**
- **Compared against benchmark experiment eigenvalue and uncertainty**