

July 25, 2023

**John Stempien, PhD**

TRISO Fuel PIE Technical Lead  
Idaho National Laboratory

# 2023 AGR-5/6/7 Fission Product Release

This presentation contains information that is preliminary in nature, and the results and conclusions may change as experiments and analyses continue.

**DOE ART Gas-Cooled Reactor (GCR) Review Meeting**

Virtual Meeting

July 25 – 27, 2023





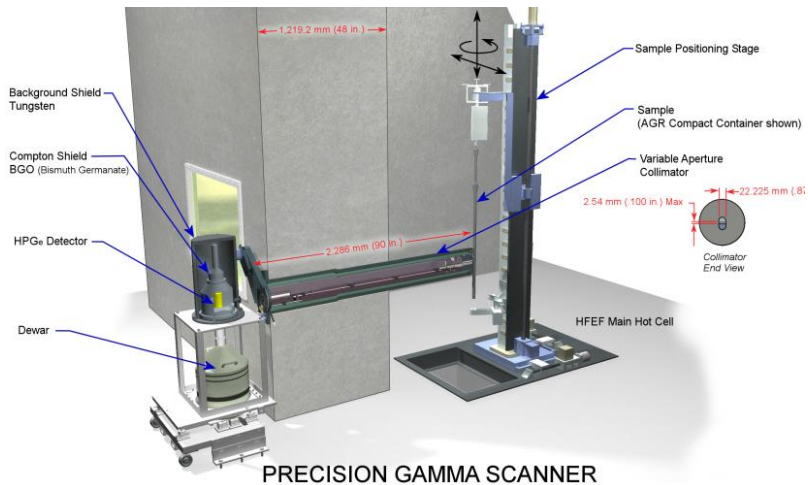
# Topics

- Fission product mass balance
- PGS of fuel compact holders
- PGS of fuel compacts

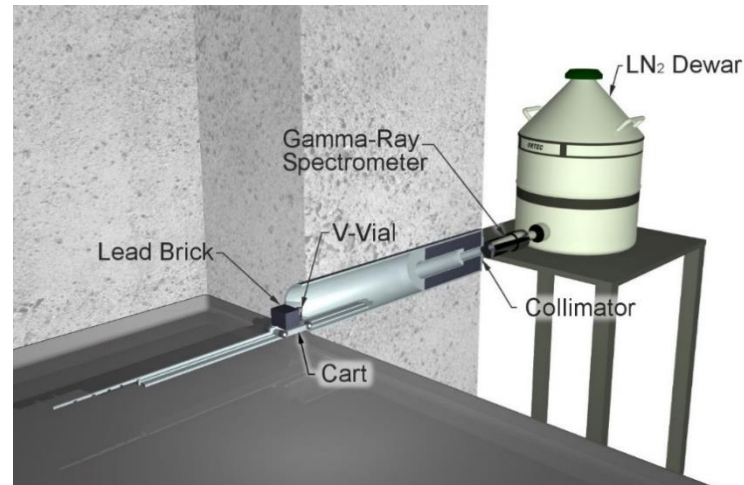
# Fission Product Mass Balance as Indicator of Fuel Performance

- Analyze irradiation experiment components to determine fission product release from fuel compacts

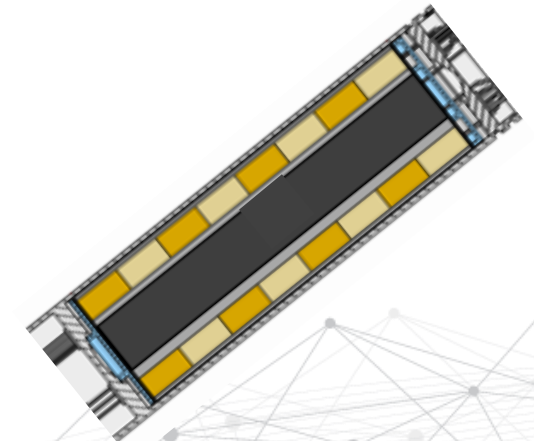
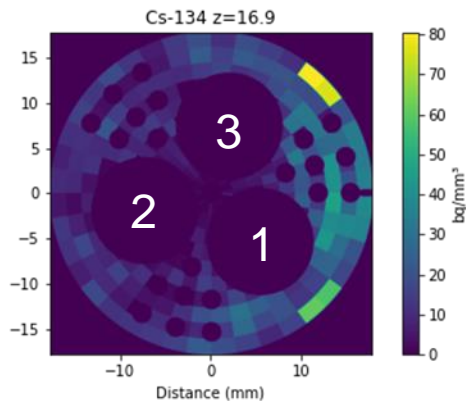
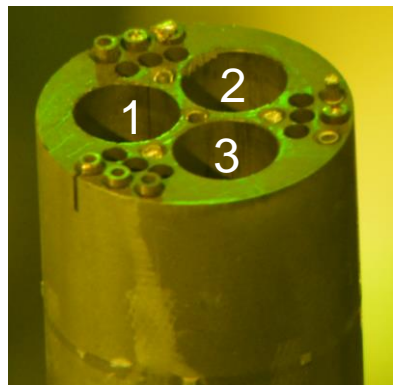
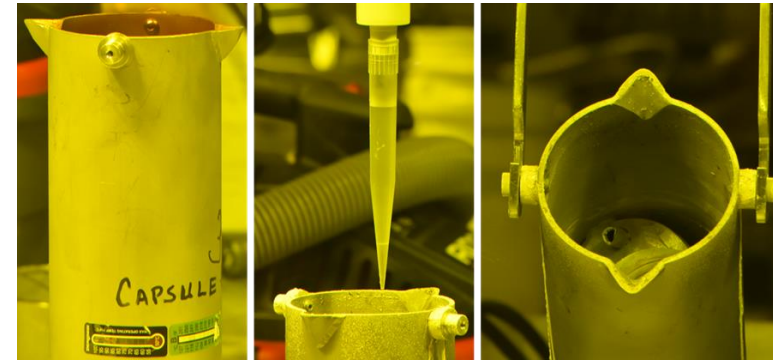
## Individual Fuel Compact and Graphite Holder Gamma Scanning



## Capsule Components Counting



## Leach of metal components for gamma-emitters and Sr-90



# All Precision Gamma Scanning Completed

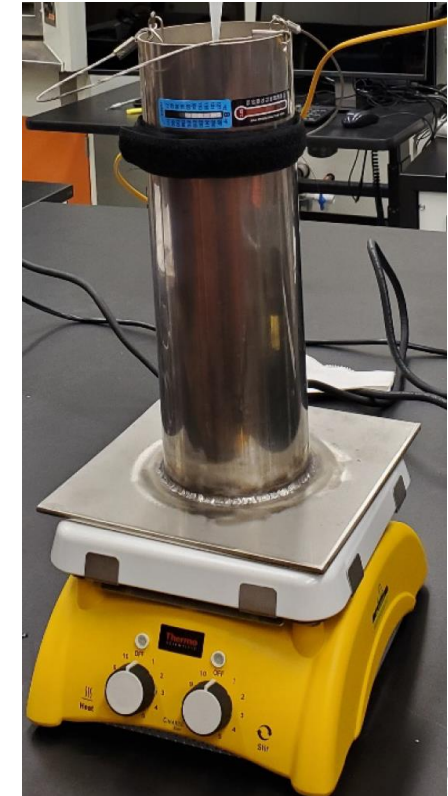
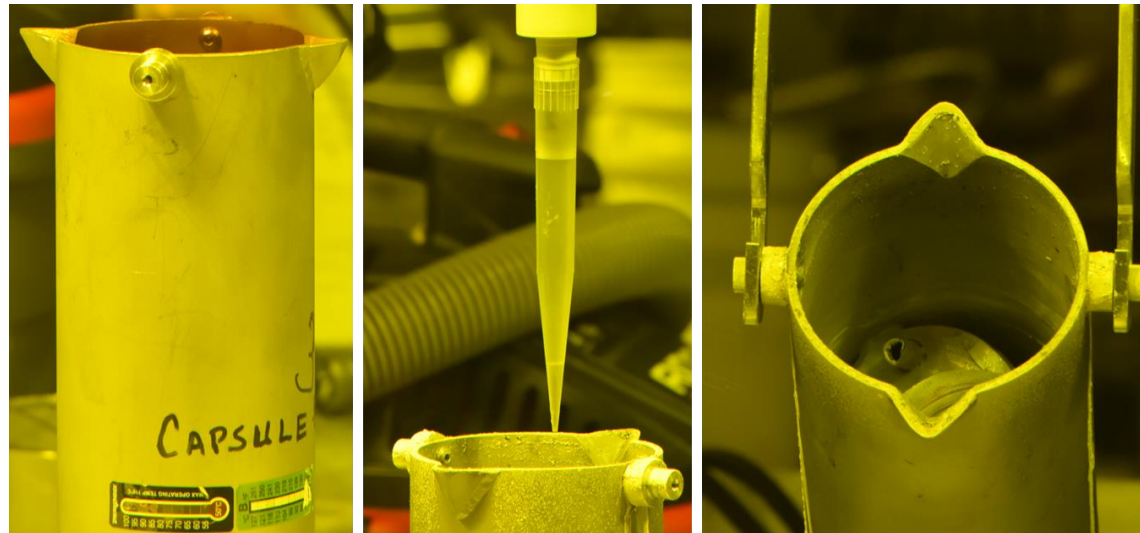
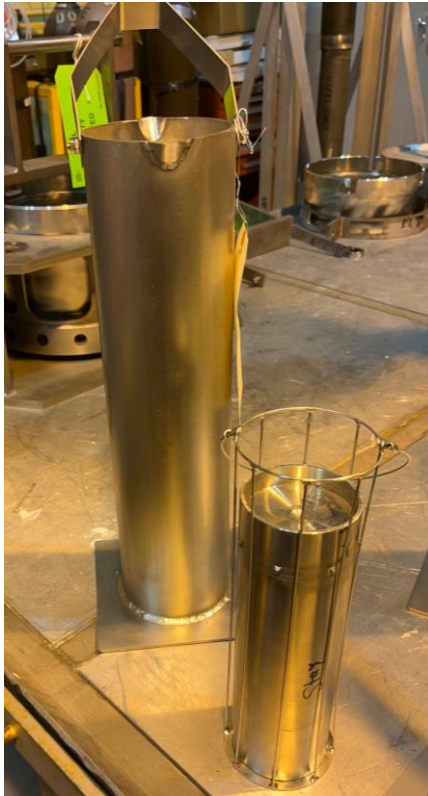
Level 2 Milestone  
Completed July 13, 2023

Components	Number Complete
<b>Compact Holders</b>	
Axial Scan	6/6
Tomographic Scans	Cap 1: 3 Cap 2: 2 Cap 3 inner: 4 Cap 3 outer: 1 Cap 4: 1 Cap 5: 1 TOTAL: 12/12
<b>Compacts</b>	
Overall	194/194
Capsule 1	90/90
Capsule 2	32/32
Capsule 3	24/24
Capsule 4	24/24
Capsule 5	24/24



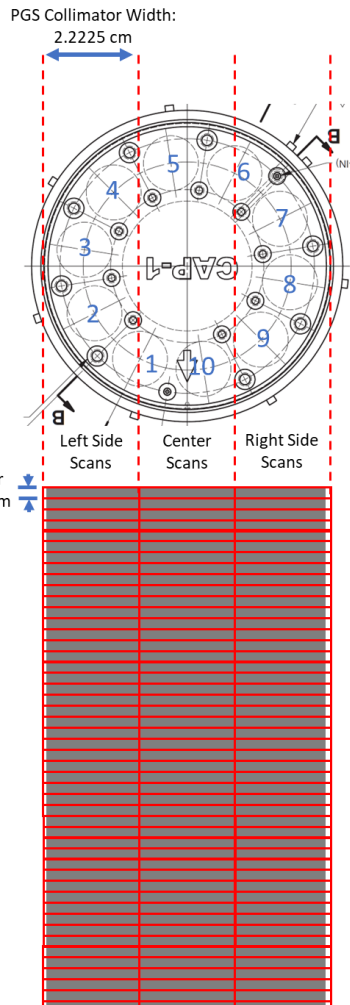
# Metallic Test Train Components Leaching

- Completed leaching all five capsule shells and metallic components in boiling  $\text{HNO}_3$  for a L2 milestone at the end of FY22
- **Analysis of leachates to assess fission product content out of the fuel is in progress for a L2 milestone due 9/15/2023**



# PGS is Used to Establish the Fission Product Inventory of Fuel Holders

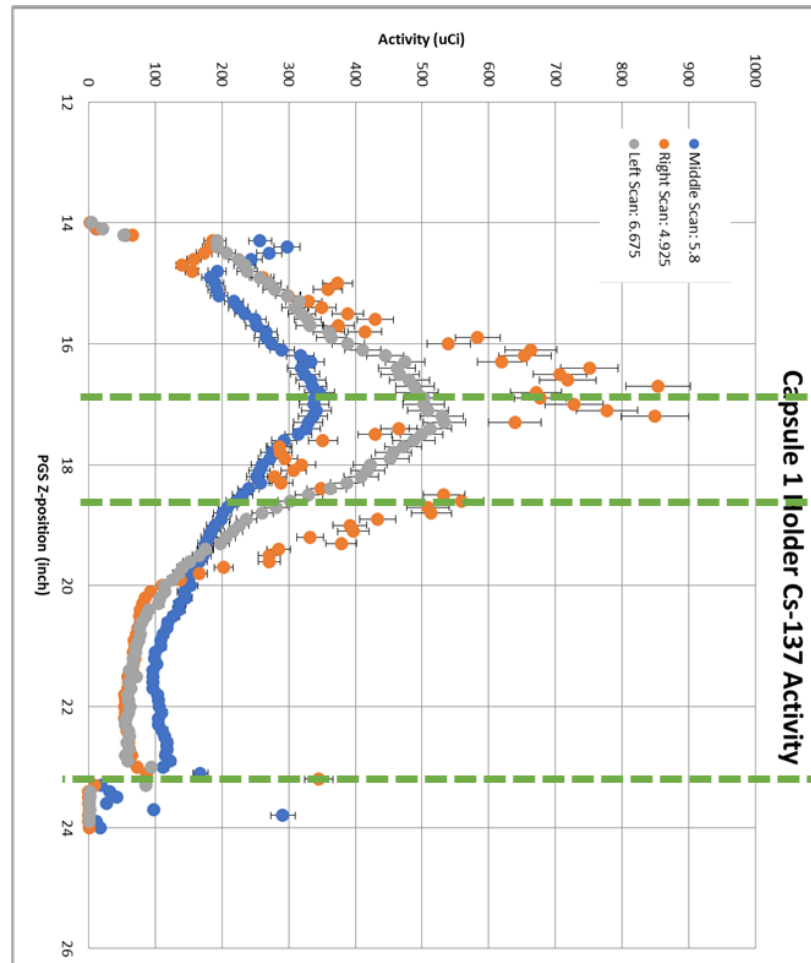
## Axial Scans



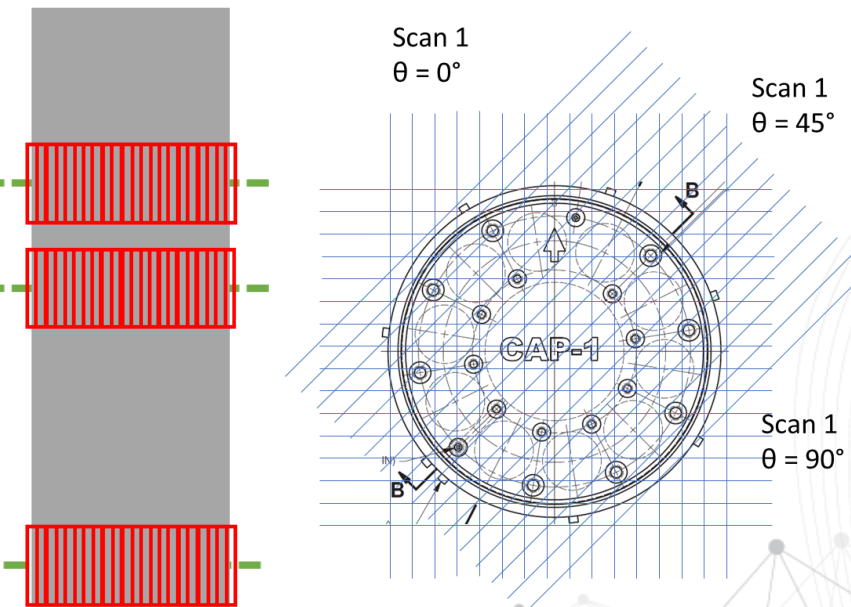
Top-down view of Capsule 1 Holder

Side view of Capsule 1 Holder

## Axial Scan Results Suggest Location for Tomography



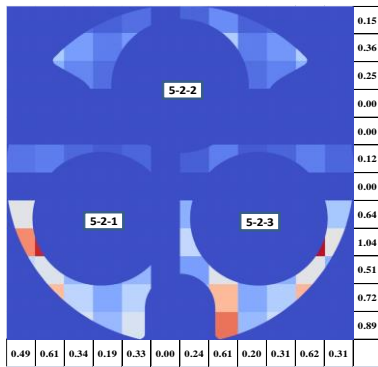
## Tomographic Scans Over Multiple Angles





# Fuel Holder Exams enable finding and studying failed particles

Identify compacts with leakers

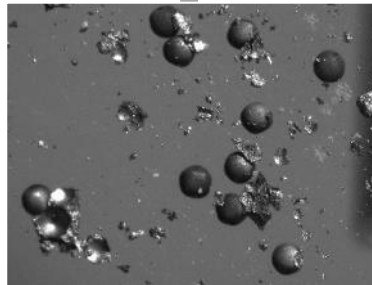


Gamma scan to identify cesium hot spots and compact location

Identify particles with failed coatings

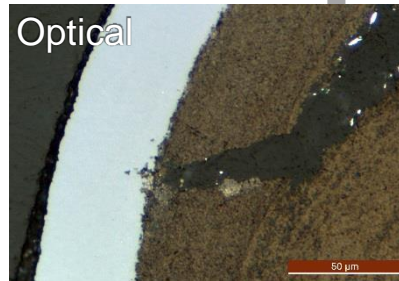


Gamma count to find particles with low cesium retention

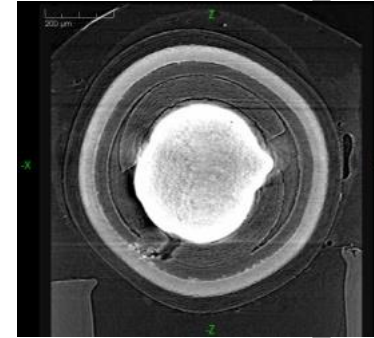
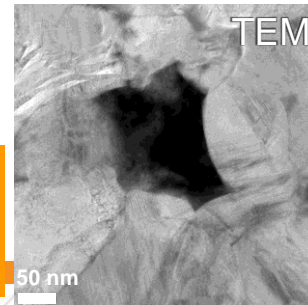


Deconsolidation to separate particles from compact

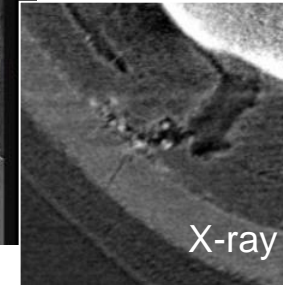
Study particles with failed coatings



Advanced microscopy to study coating layers in detail

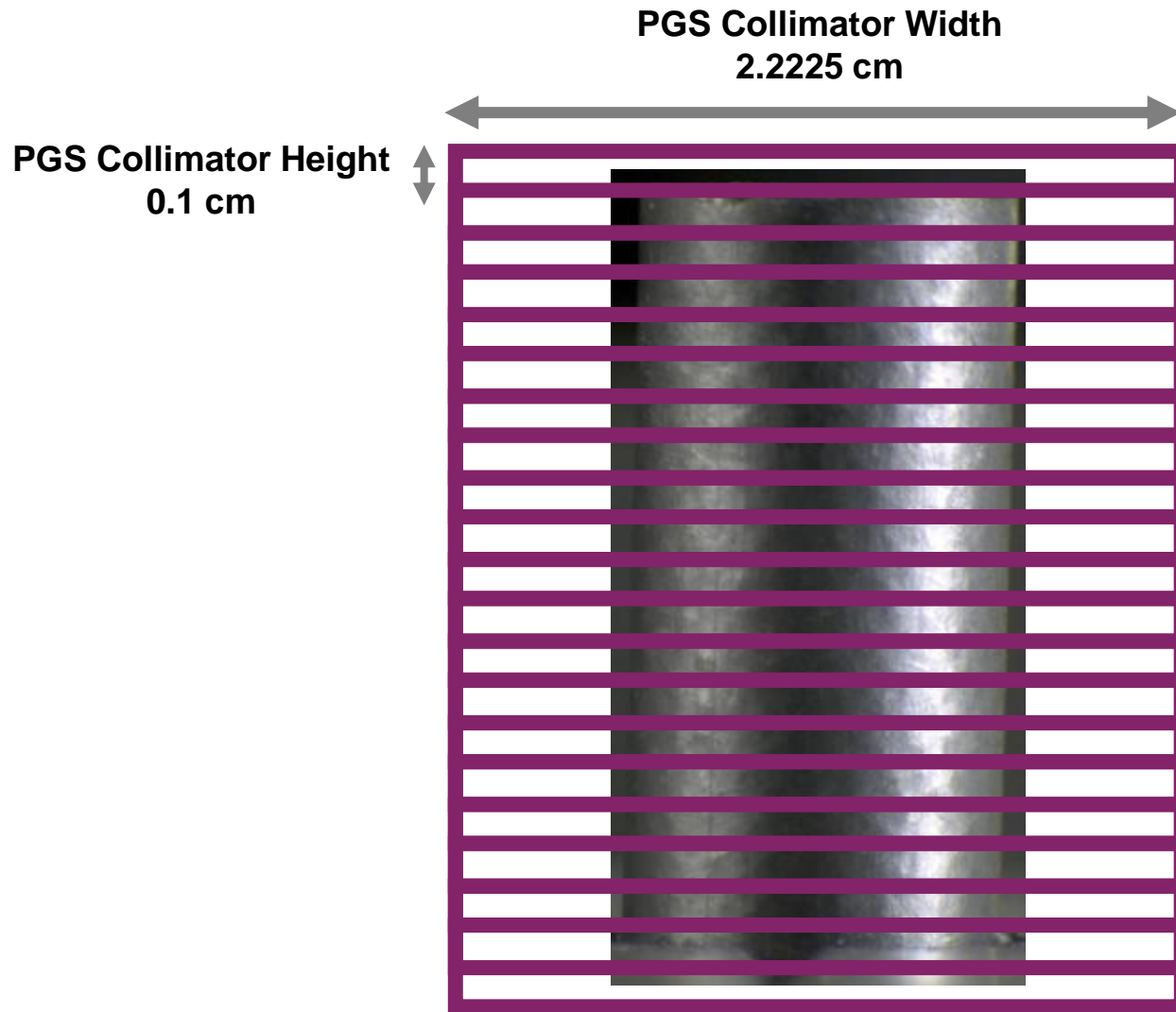


Materialography to expose defective region for analysis



X-ray tomography to locate failures

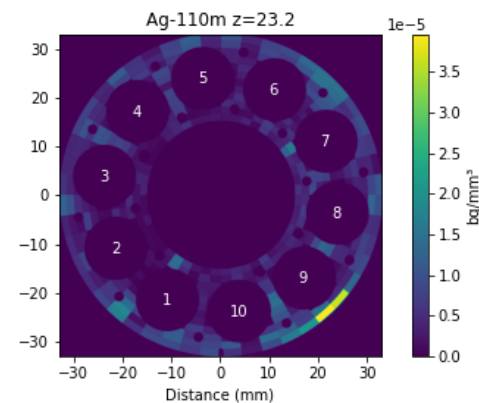
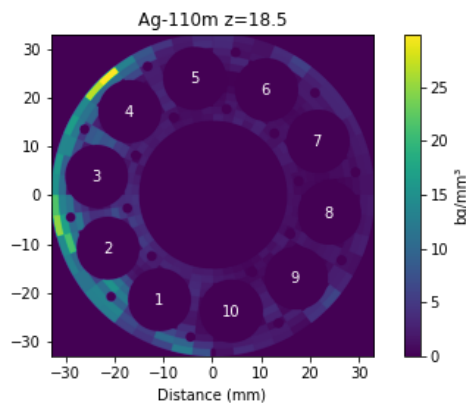
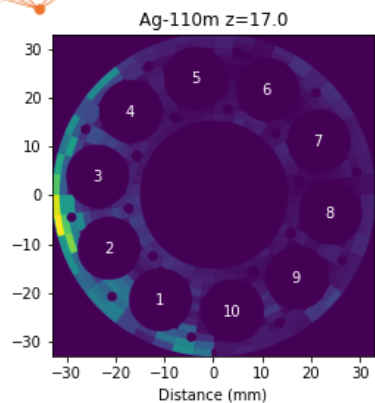
# All Fuel Compacts were also Scanned via PGS



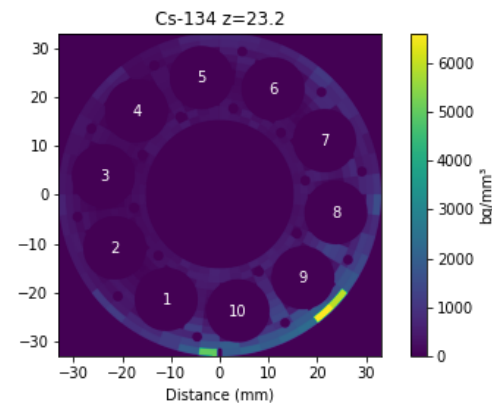
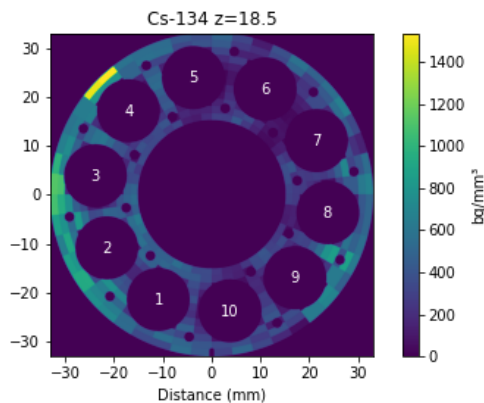
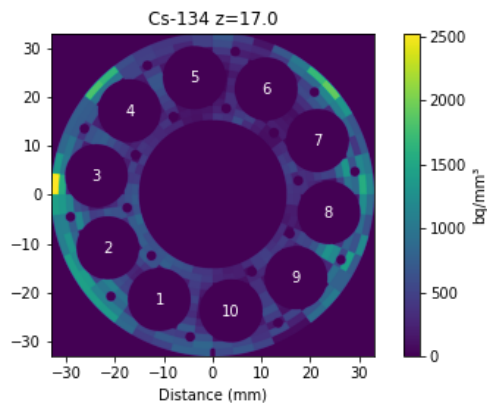


# Capsule 1 Holder Gamma Tomography

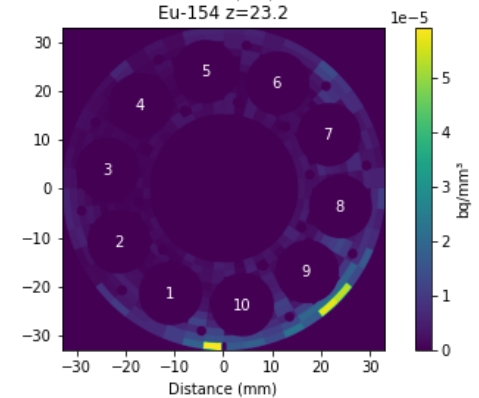
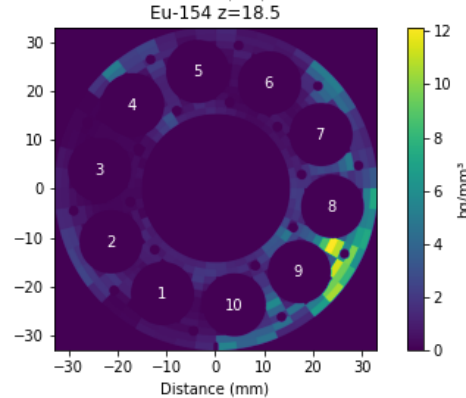
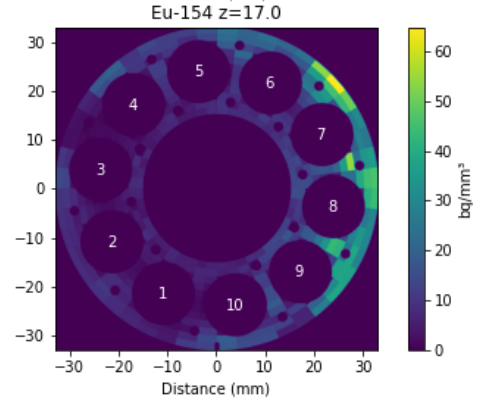
Ag-110m



Cs-134

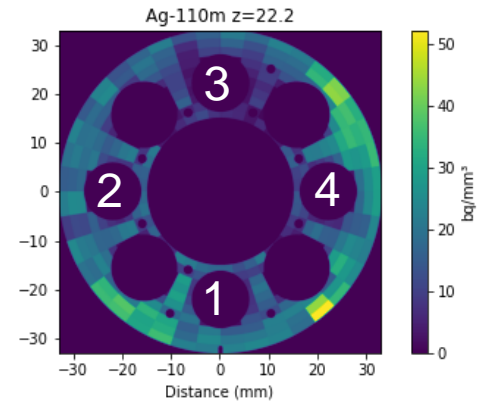
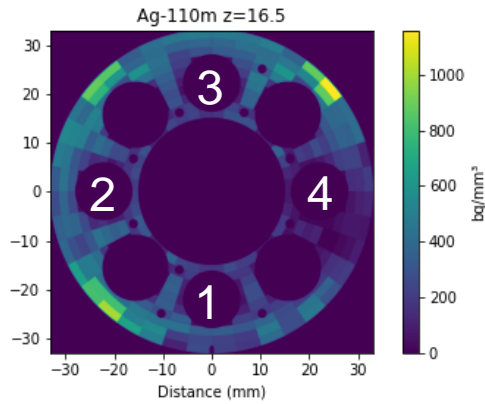


Eu-154

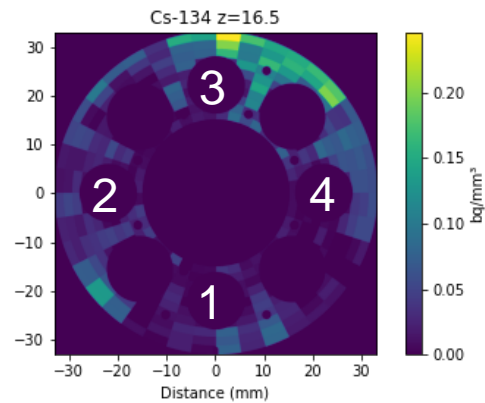


# Capsule 2 Holder Gamma Tomography

Ag-110m



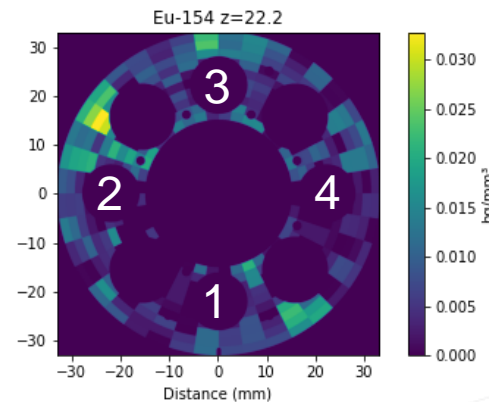
Cs-134



A little  
detected between  
Stacks 2 and 3

Eu-154

Checking  
results

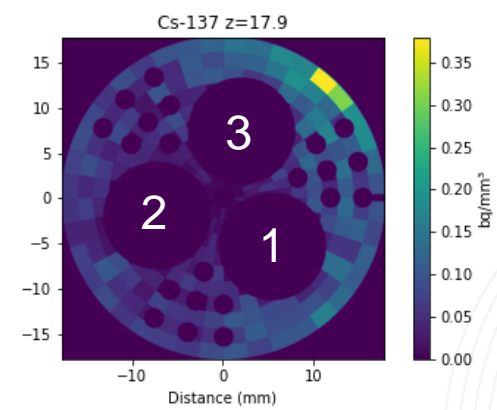
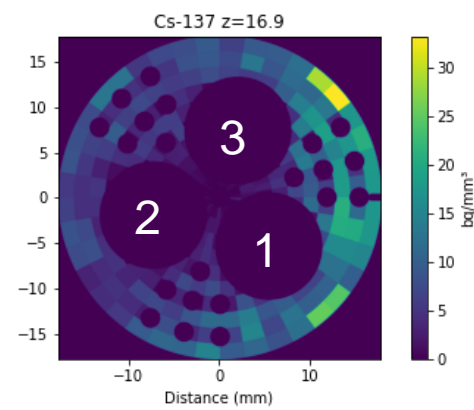
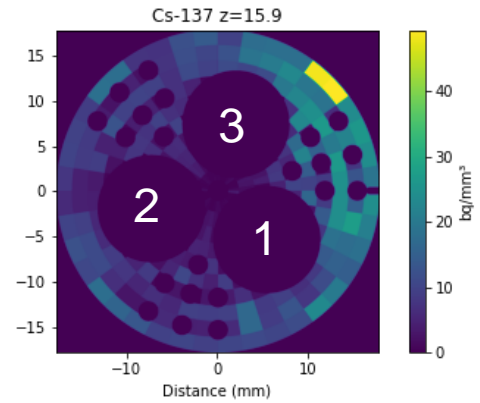
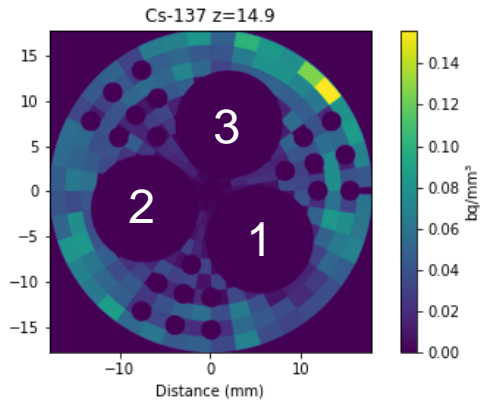


# Capsule 3 Inner Holder Gamma Tomography

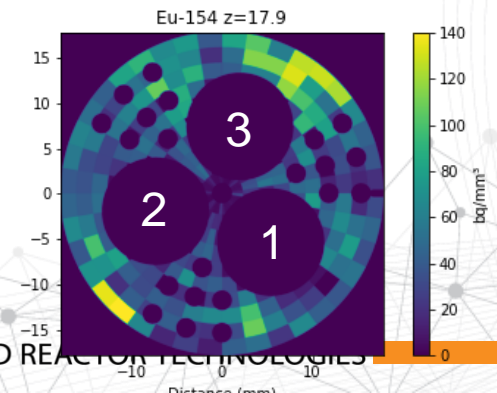
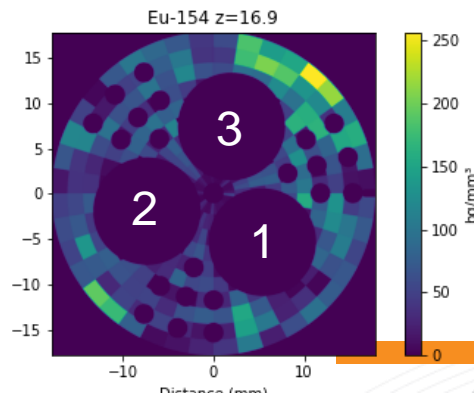
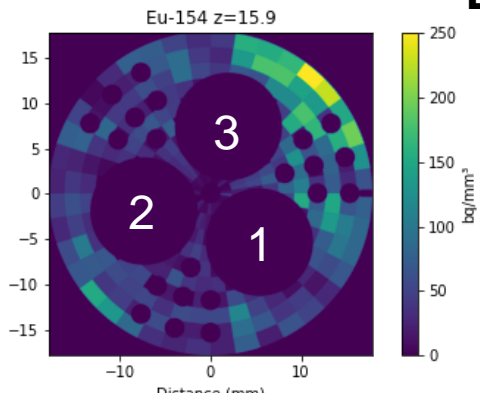
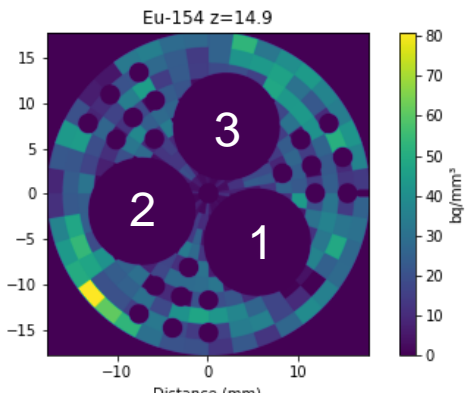
Ag-110m

Checking results

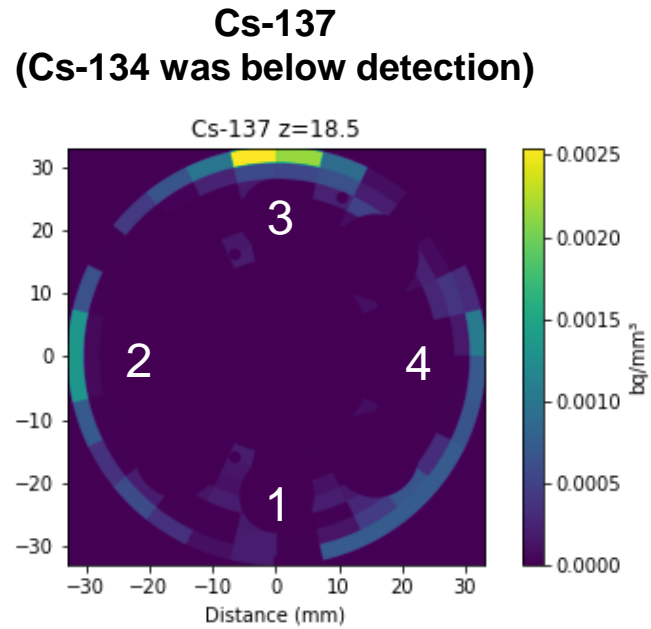
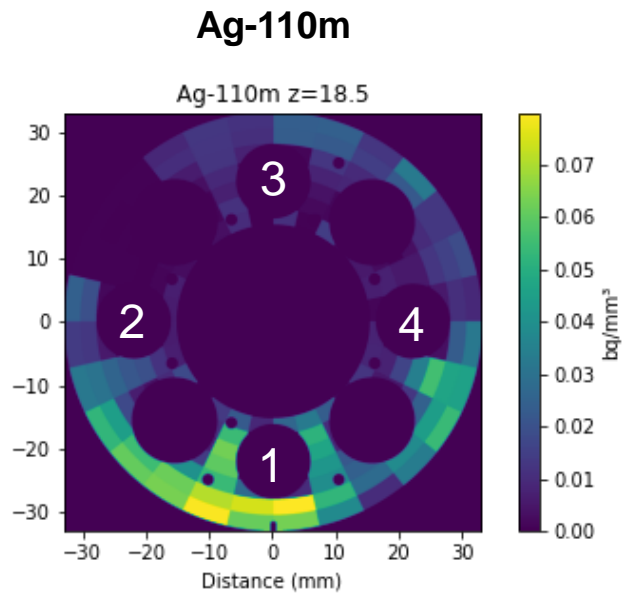
**Cs-137**



**Eu-154**



# Capsule 4 Holder Gamma Tomography



**Eu-154**

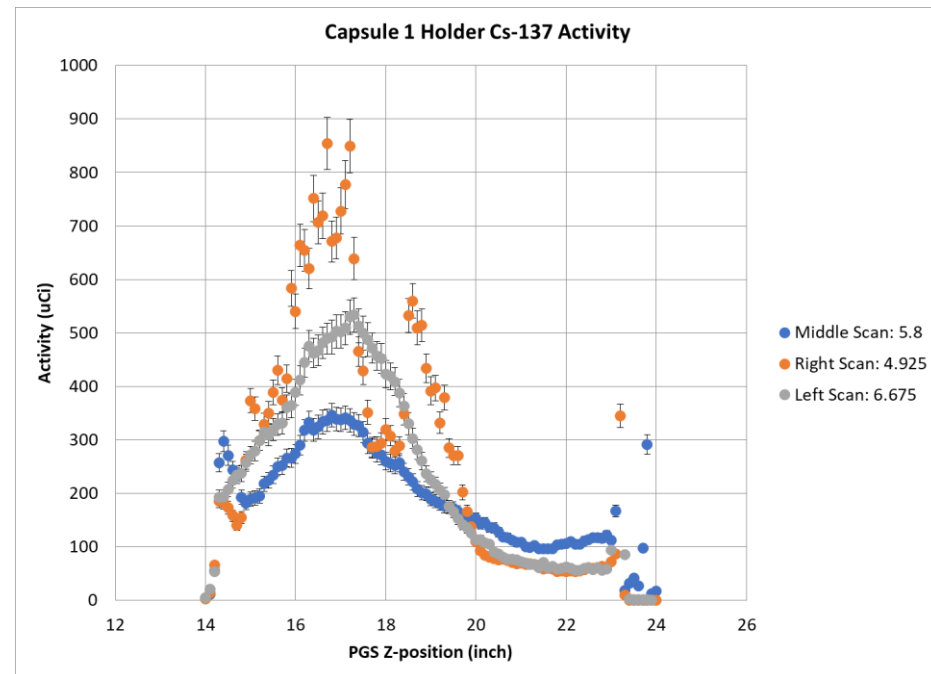
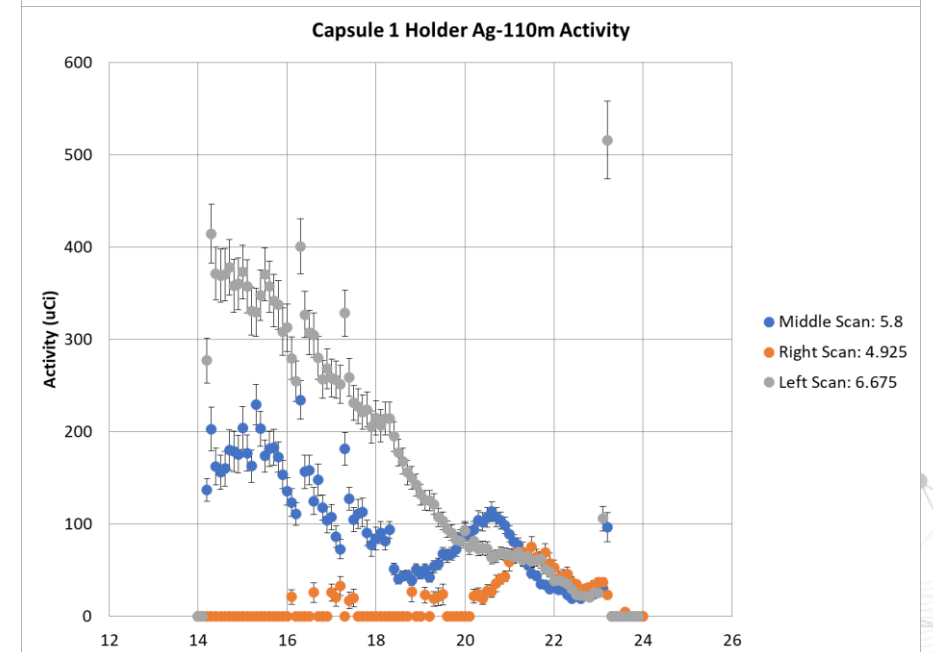
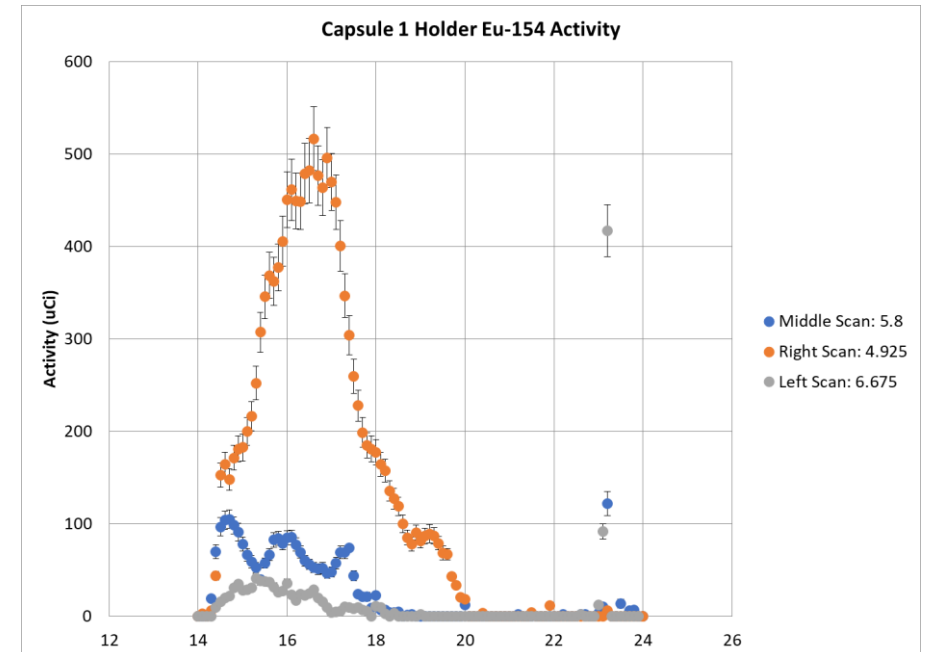
Below  
detection



# Capsule 1 Holder Inventories

Isotope	Capsule Fraction	Estimated Particle Equivalents
Zr-95	2.14E-3	661
Ru-106	2.21E-3	684
Ag-110m	1.10E-1	33930
Cs-134	2.96E-3	915
Cs-137	2.79E-3	861
Ce-144	3.74E-10	0
Eu-154	1.62E-2	5022
Eu-155	3.31E-3	1023

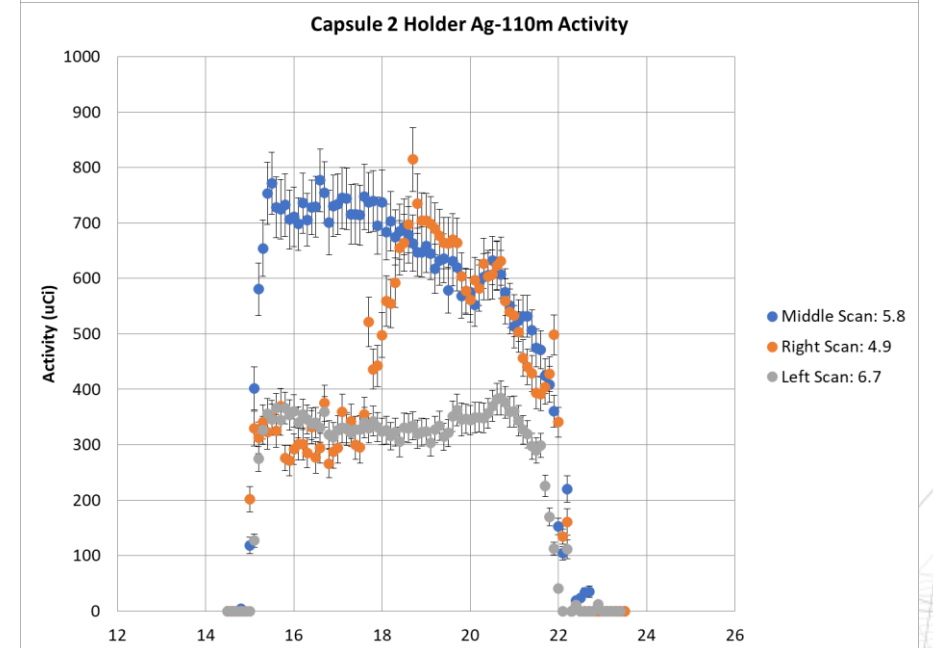
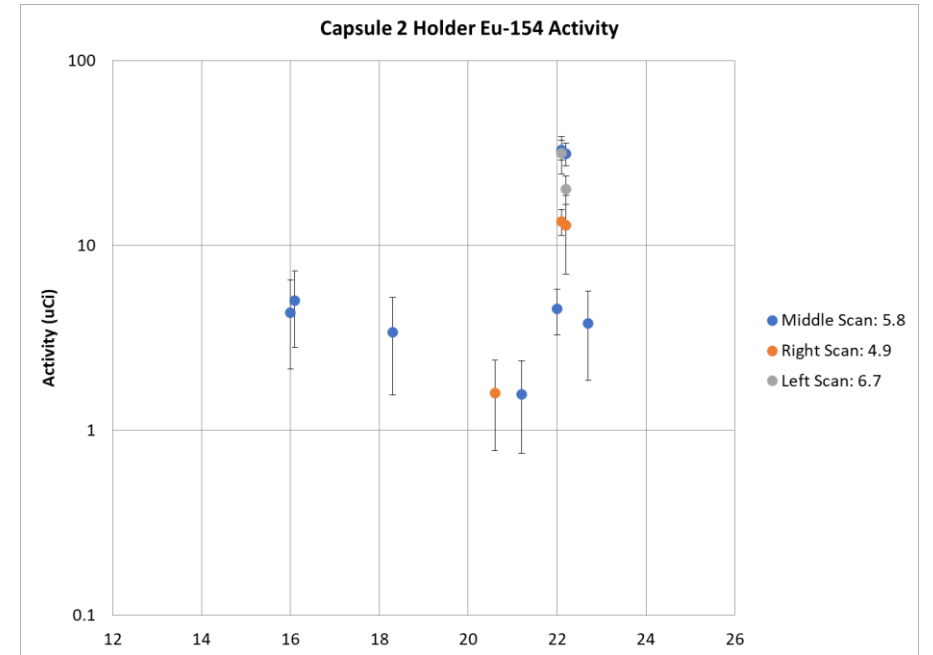
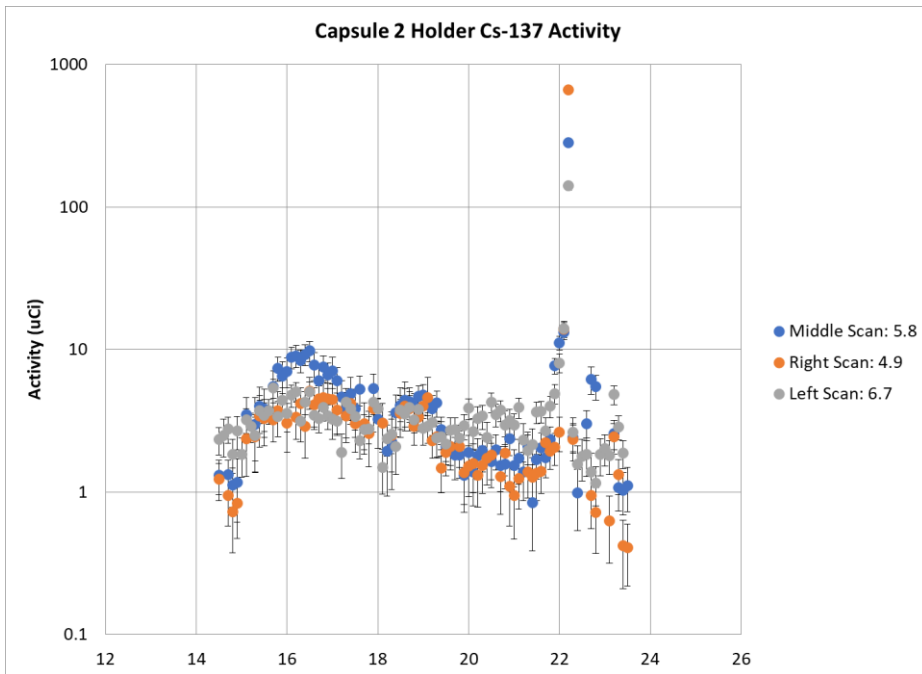
} Indicates many failed SiC and/or TRISO



# Capsule 2 Holder Inventories

Isotope	Capsule Fraction	Estimated Particle Equivalents
Zr-95	6.27E-3	454
Ru-106	1.26E-5	0.9
Ag-110m	4.21E-1	30465
Cs-134	2.97E-5	2.1
Cs-137	1.47E-4	10.7
Ce-144	3.48E-12	2.5E-7
Eu-154	2.71E-4	19.6
Eu-155	1.02E-4	7.4

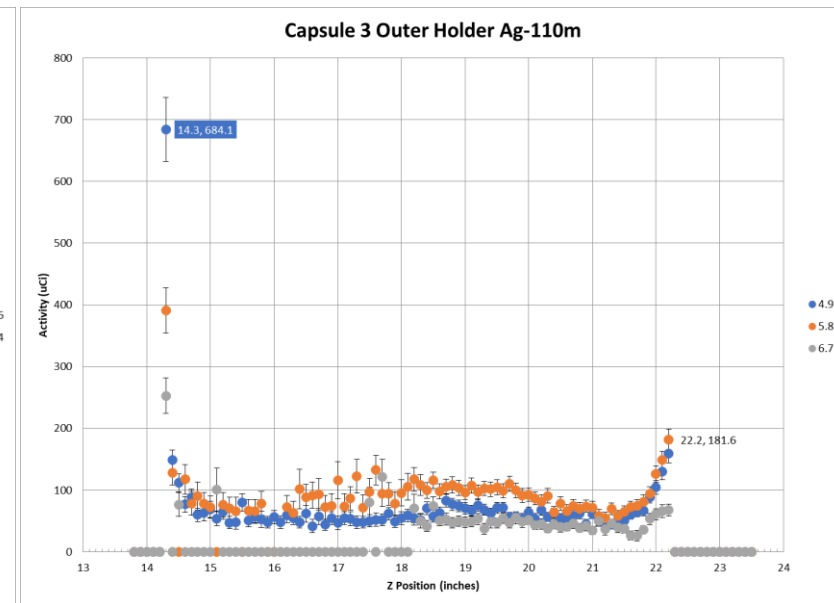
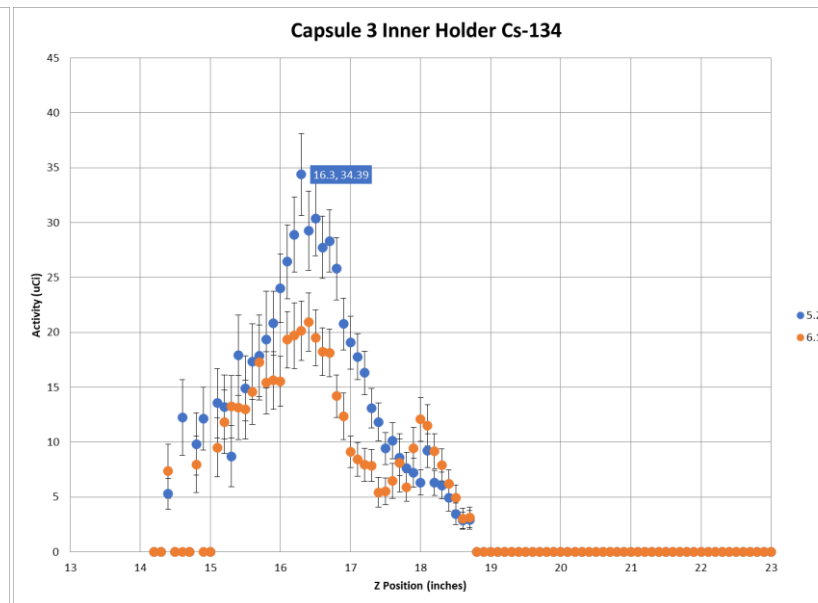
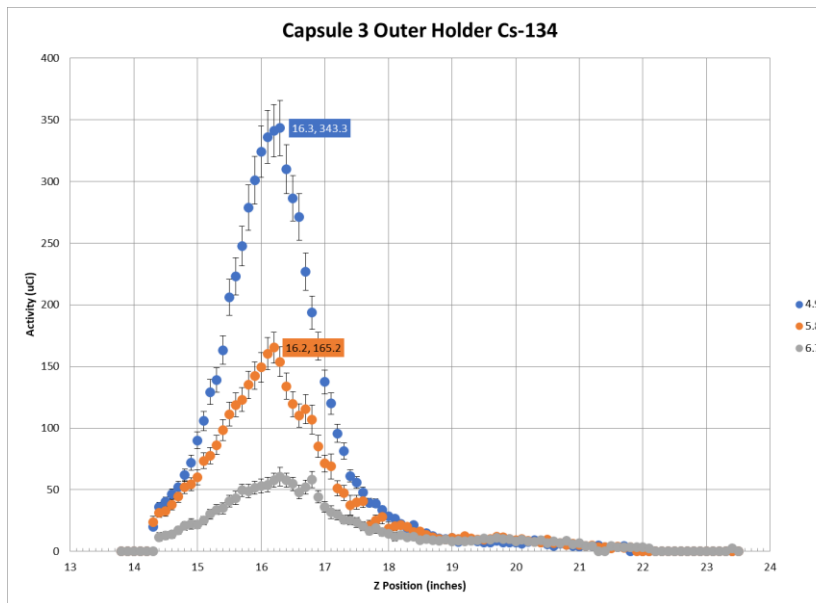
Indicates a couple exposed kernels



# Capsule 3 Inner and Outer Holder Inventories

Isotope	Capsule Fraction	Estimated Particle Equivalents
Zr-95	8.4E-4	45
Ru-106	2.8E-6	0
Ag-110m	8.1E-2	4387
Cs-134	8.3E-4	45
Cs-137	8.5E-4	46
Ce-144	0.0E+0	0
Eu-154	1.8E-2	967
Eu-155	1.4E-3	78

Indicates tens of failed SiC and/or TRISO in the hottest AGR capsule of all time

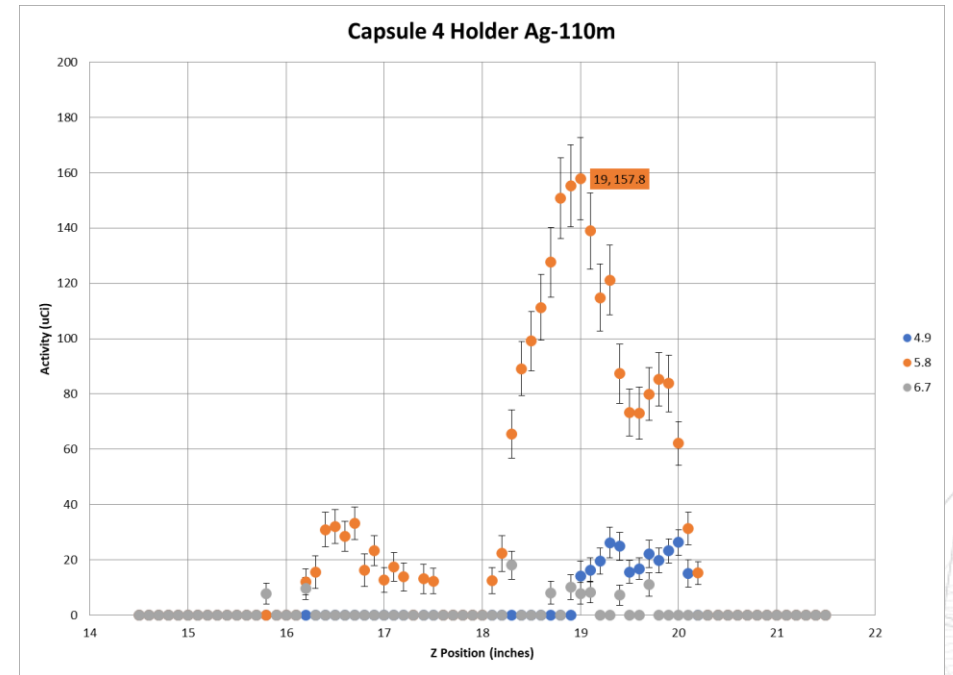
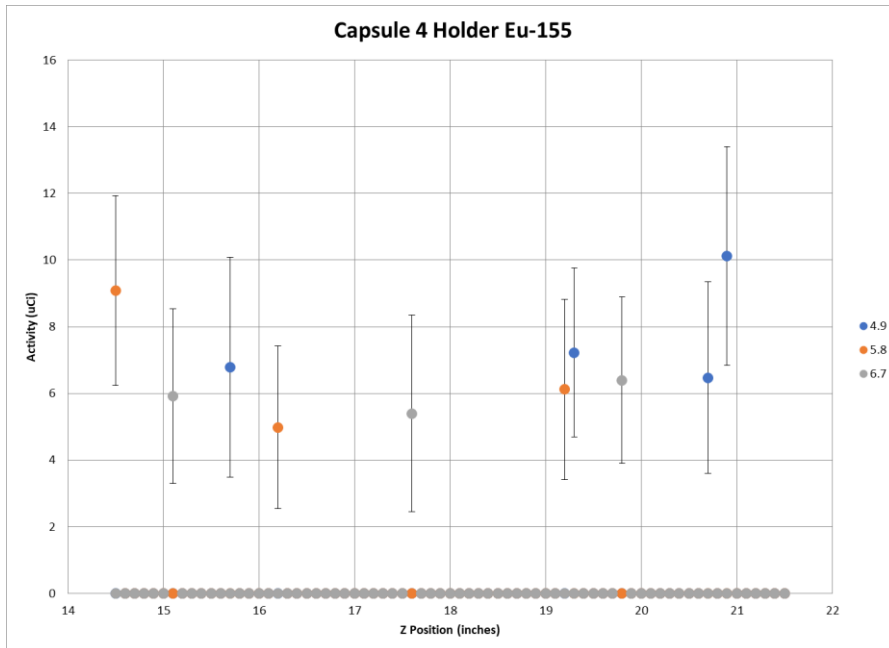
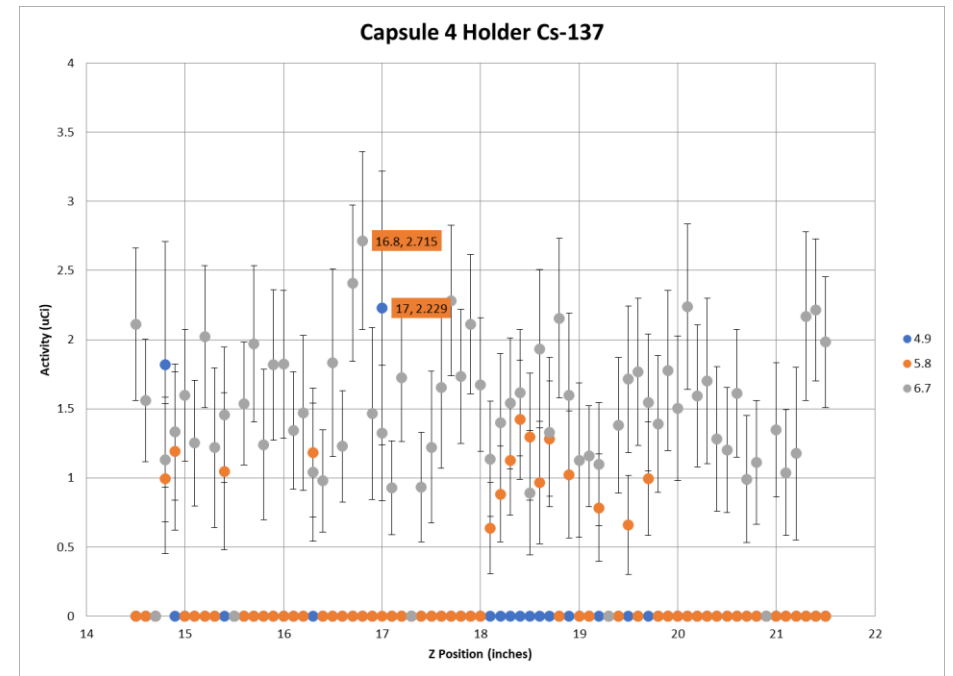


# Capsule 4 Holder Inventories

Isotope	Capsule Fraction	Estimated Particle Equivalents
Zr-95	3.92E-4	21
Ru-106	0.00E+0	0.0
Ag-110m	1.90E-2	1004
Cs-134	2.39E-6	0.1
Cs-137	1.25E-5	0.7
Ce-144	3.95E-5	2.1
Eu-154	Below Detection	
Eu-155*	1.70E-4	9.0

\*High uncertainty

No obvious exposed kernels



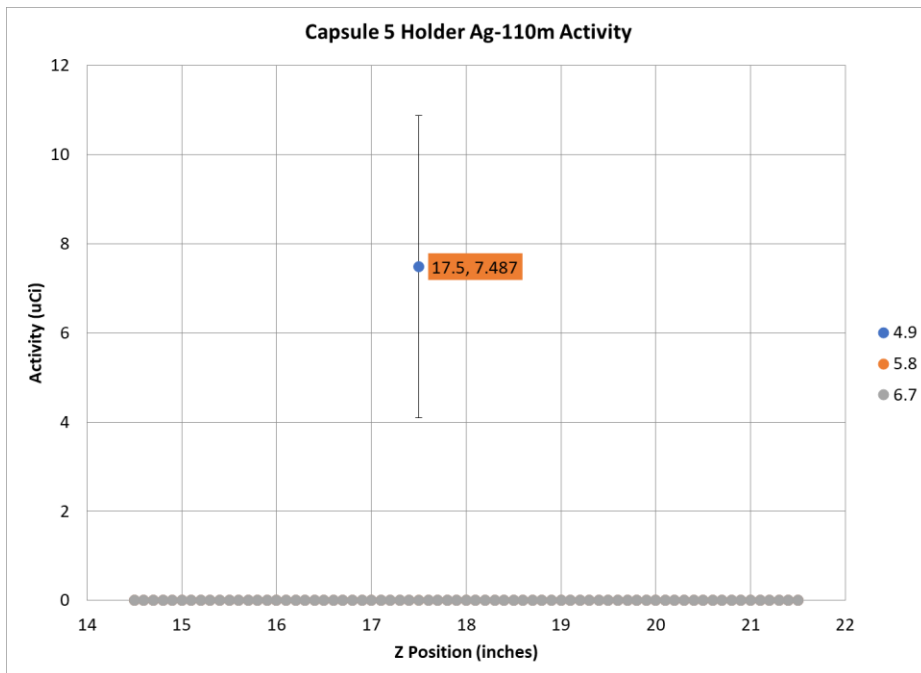
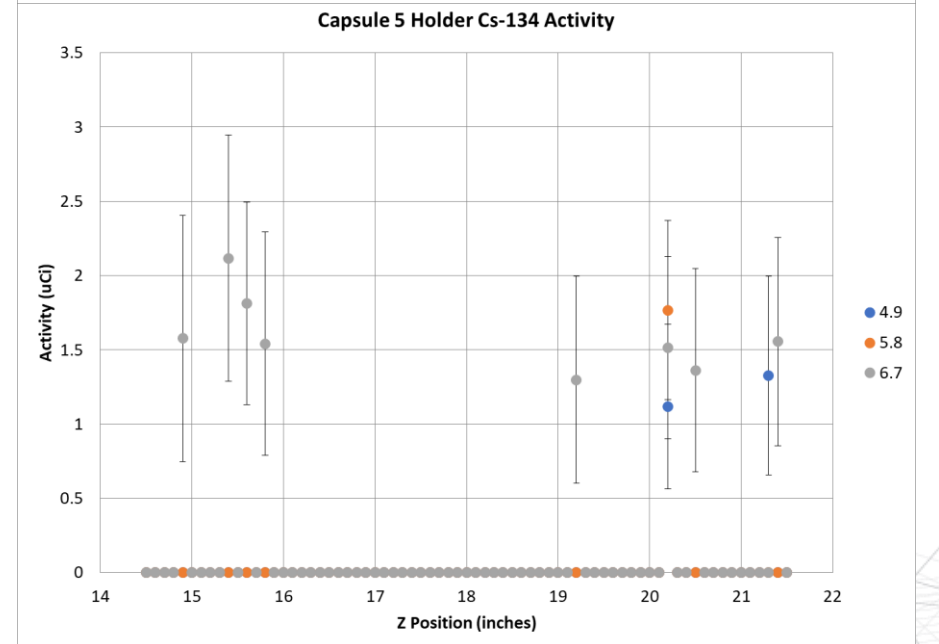
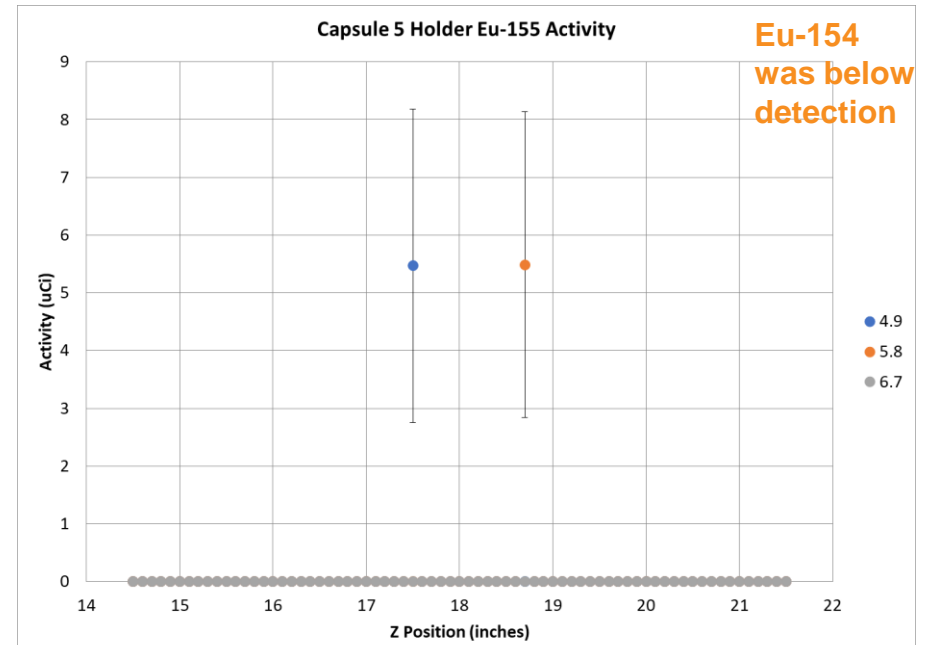


# Capsule 5 Holder Inventories

Isotope	Capsule Fraction	Estimated Particle Equivalents
Zr-95	Below Detection	
Ru-106	Below Detection	
Ag-110m	1.68E-04	13.68
Cs-134	2.07E-06	0.17
Cs-137	9.24E-06	0.75
Ce-144	2.28E-06	0.19
Eu-154	Below Detection	
Eu-155*	6.91E-05	5.63

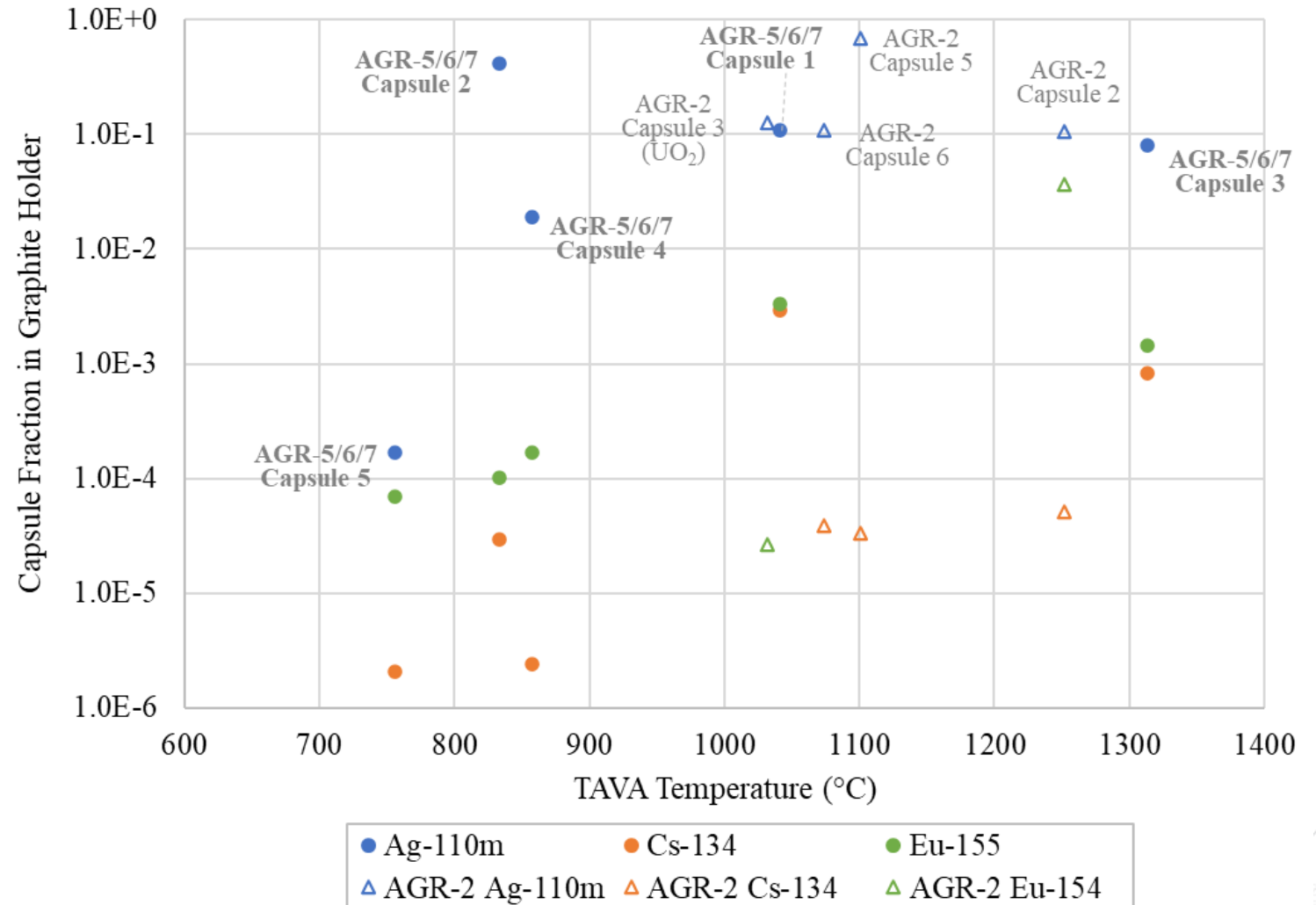
\*High uncertainty

No obvious exposed kernels

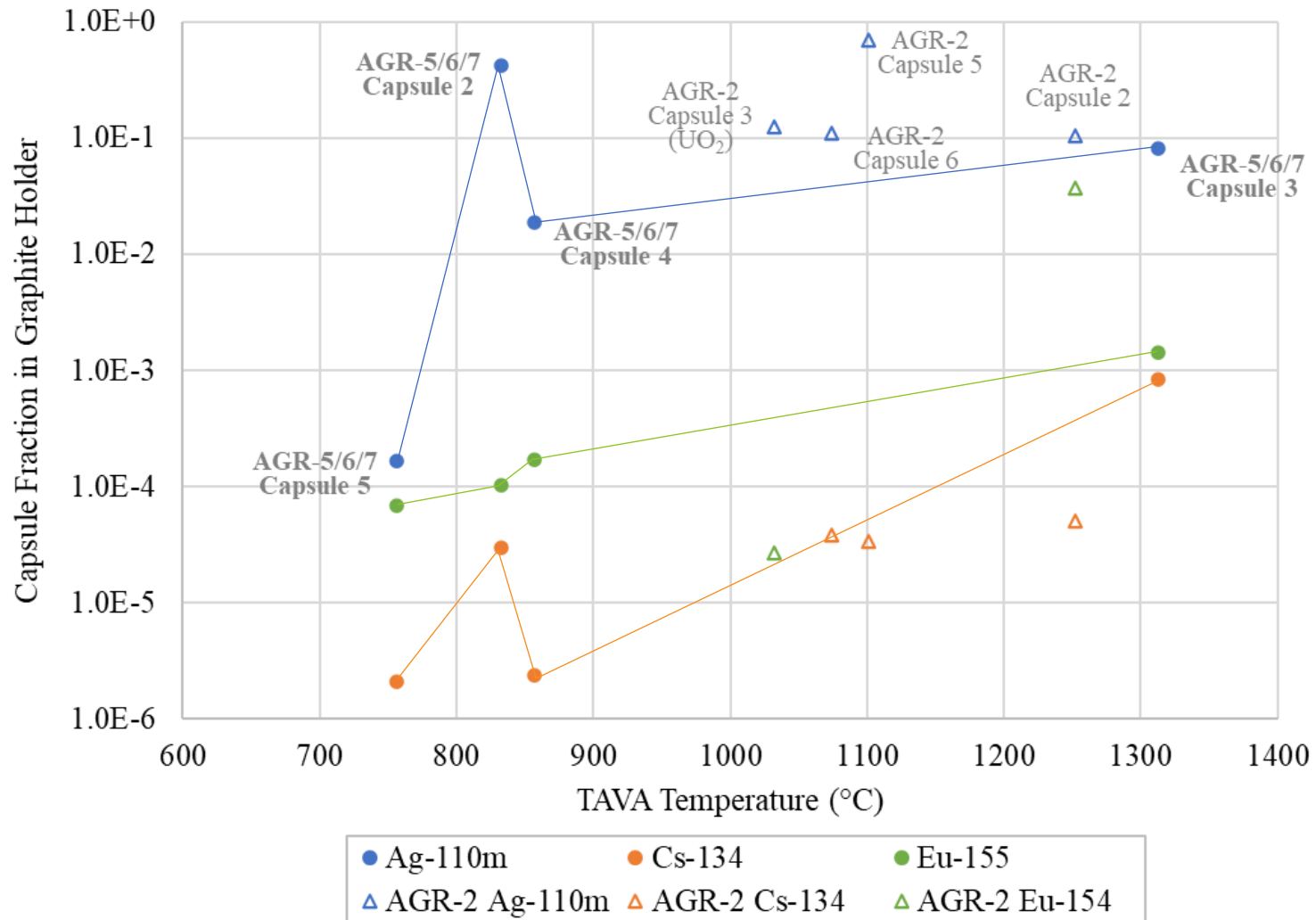


# Fission Product Inventories in Capsule Holders Compared to AGR-2

Capsule 1 is not a fair comparison because of all the fuel damaged by Ni.

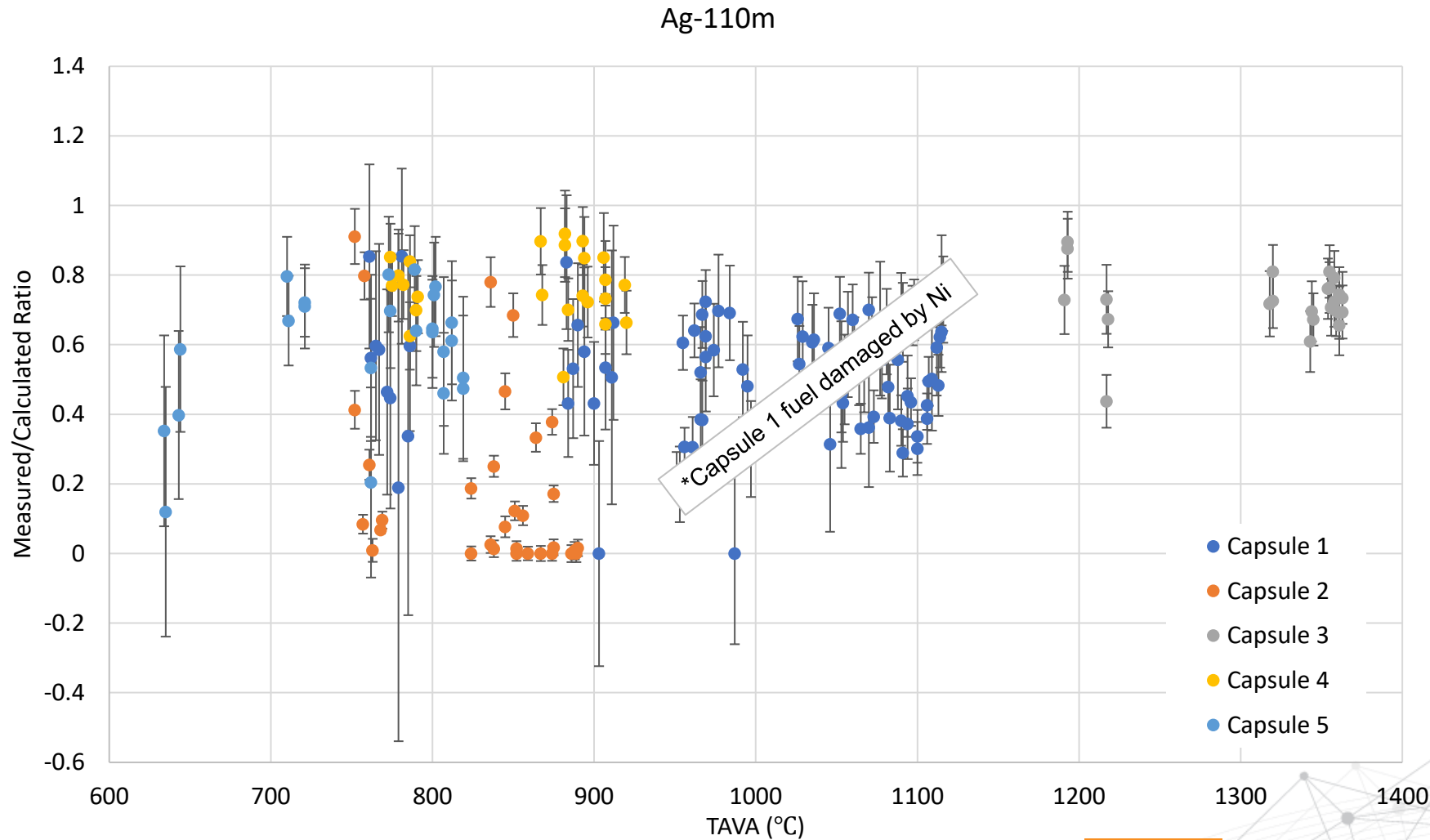


# Fission Product Inventories in Capsule Holders Compared to AGR-2



# Compacts PGS: Ag-110m M/C

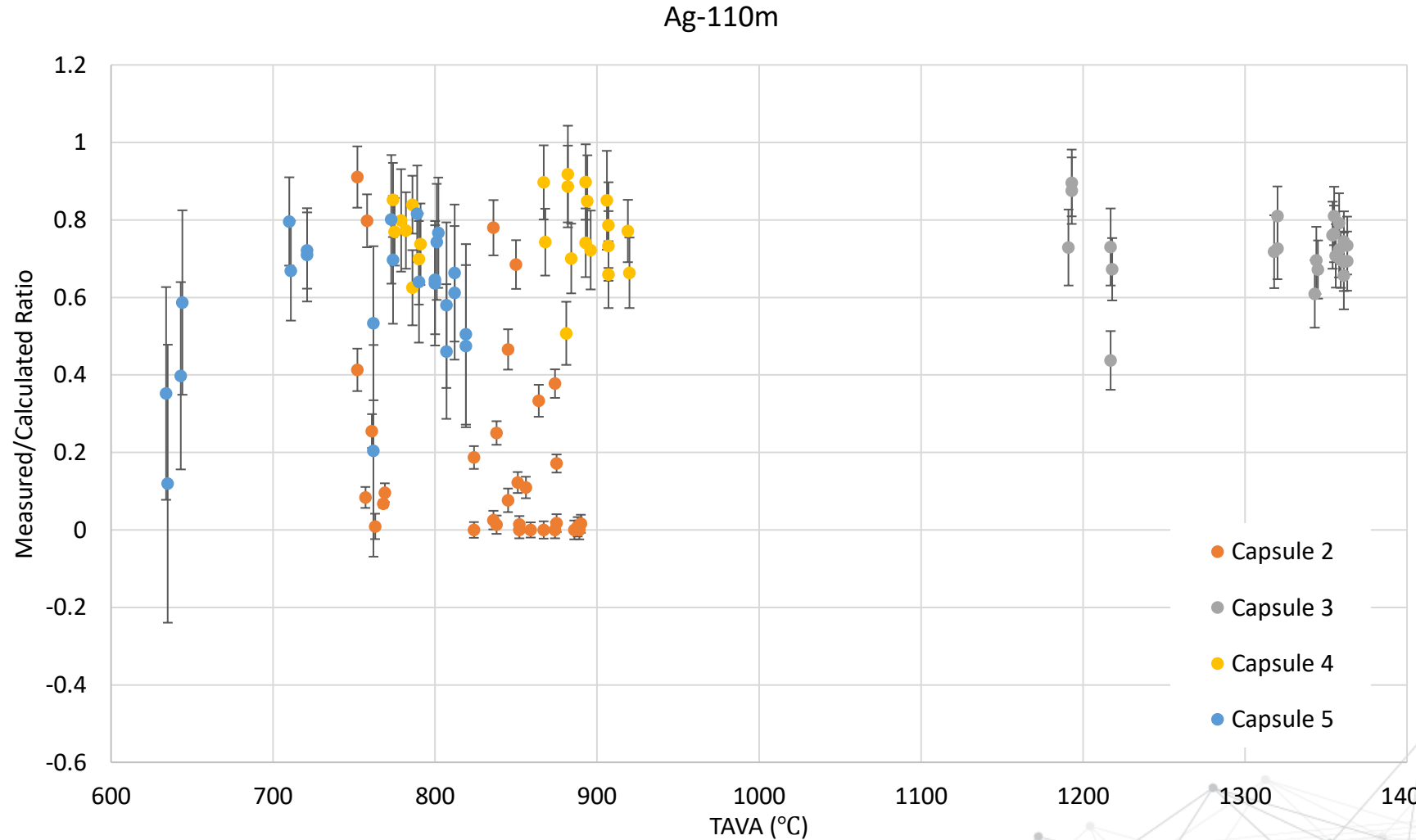
- Measured activities (M) divided by physics calculations (C)





# Compacts PGS: Ag-110m M/C

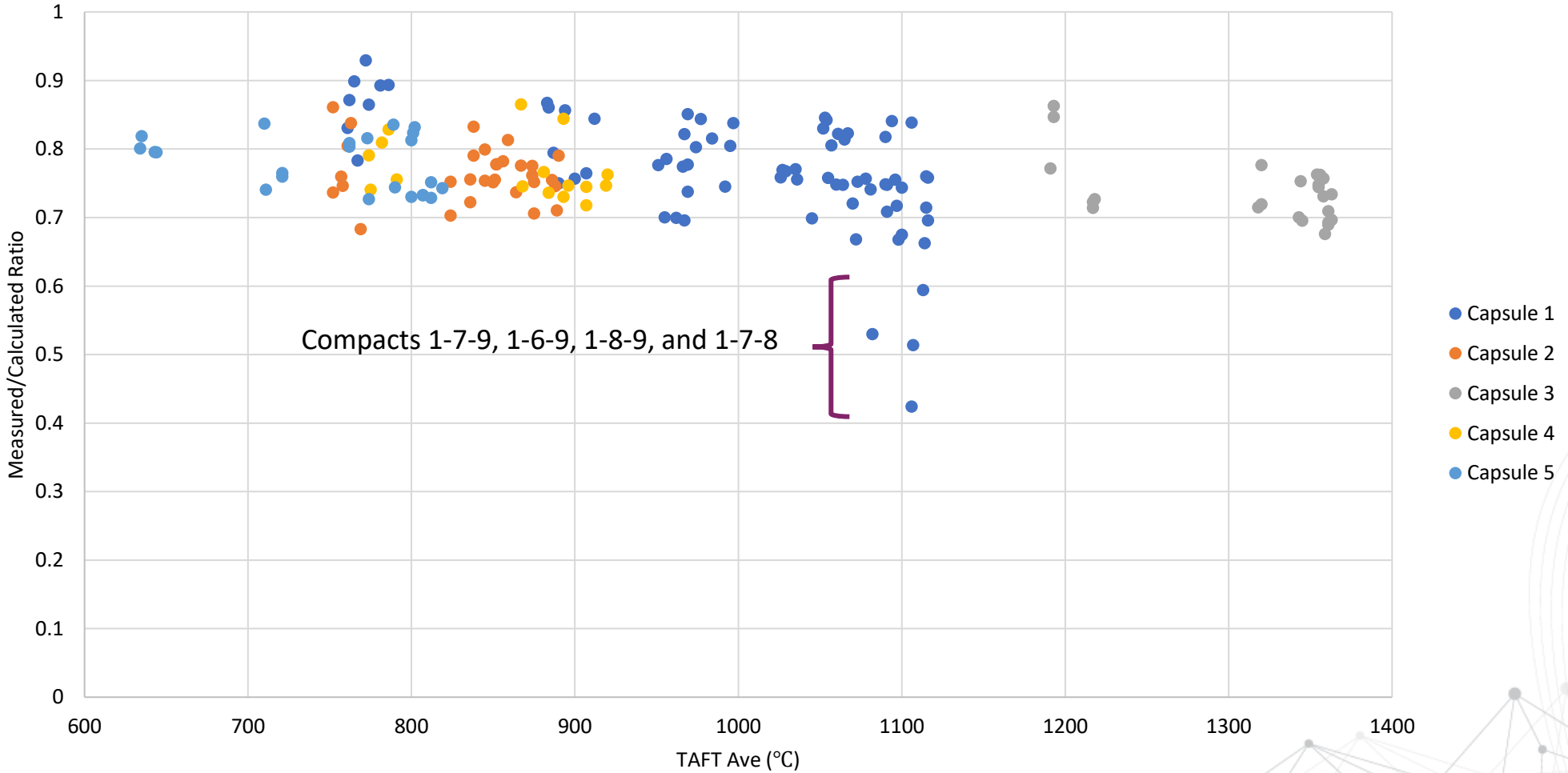
The scatter in Ag M/C at lower temperatures like in Capsule 2 and the relatively high M/C at higher temperatures in Capsule 3 are notable in these preliminary results.





# Compacts PGS: Eu-154 M/C

Eu-154



These are generally consistent with prior experiments.



# Conclusions

- PGS has been completed on the graphite holders and all fuel compacts
- Preliminary gamma tomograms have been made for the holders and will be used to guide compact selection for PIE
- The mass balance outside of the fuel has not been completed: radiochemical analysis of the metallic and ceramic test train components is in progress
- In the case of Ag-110m, the mass balance can be compared with the results from PGS to check for consistency

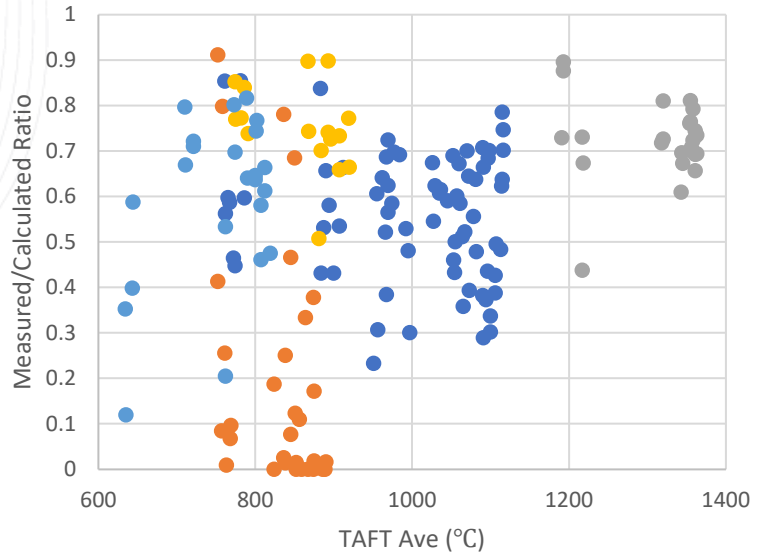


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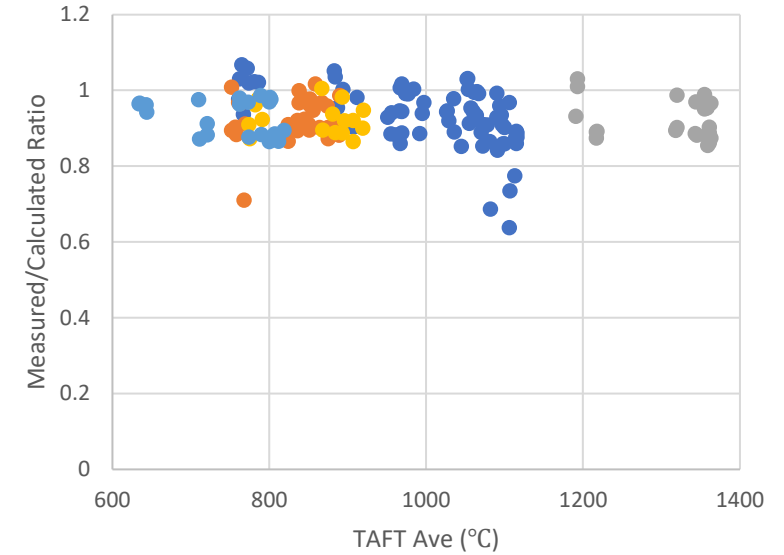
# Summary of PGS Compacts

### Ag-110m



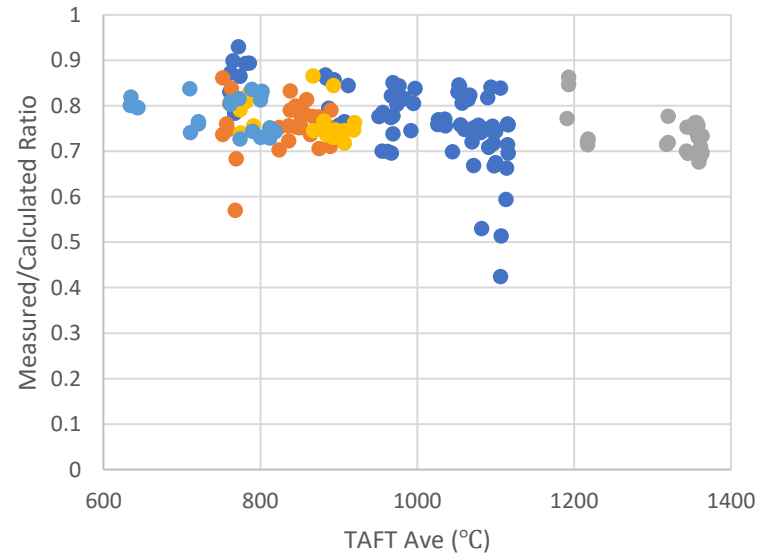
- Capsule 1
- Capsule 2
- Capsule 3
- Capsule 4
- Capsule 5

### Cs-137



- Capsule 1
- Capsule 2
- Capsule 3
- Capsule 4
- Capsule 5

### Eu-154



- Capsule 1
- Capsule 2
- Capsule 3
- Capsule 4
- Capsule 5