INL/CON-24-81069-Revision-0

Constrained Tomographic Reconstructions of Gamma Scans in AGR 5/6/7 Capsules

October 2024

Adriaan Anthony Riet

Changing the World's Energy Future

INL is a U.S. Department of Energy National Laboratory operated by Battelle Energy Alliance, LLC

DISCLAIMER

This information was prepared as an account of work sponsored by an agency of the U.S. Government. Neither the U.S. Government nor any agency thereof, nor any of their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness, of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. References herein to any specific commercial product, process, or service by trade name, trade mark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the U.S. Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the U.S. Government or any agency thereof.

INL/CON-24-81069-Revision-0

Constrained Tomographic Reconstructions of Gamma Scans in AGR 5/6/7 Capsules

Adriaan Anthony Riet

October 2024

Idaho National Laboratory
Idaho Falls, Idaho 83415

http://www.inl.gov

Prepared for the
U.S. Department of Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

Pacific Basin Nuclear Conference

PBNC 2024

Constrained Tomographic Reconstructions of Gamma Scans in AGR 5/6/7 Capsules

Adriaan Riet

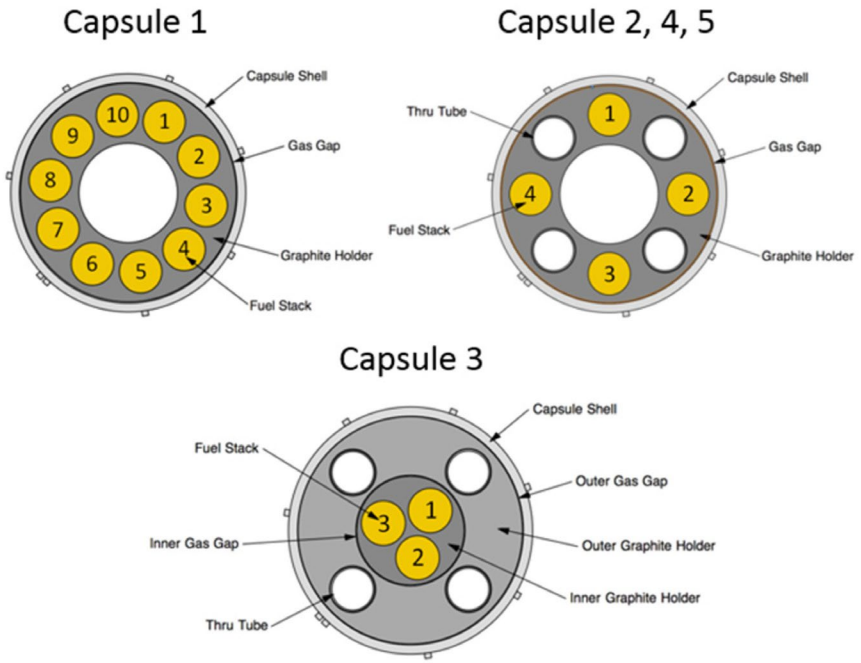
Nuclear Fuel Systems Principal Investigator

Idaho National Laboratory

ANS® American Nuclear Society

Overview

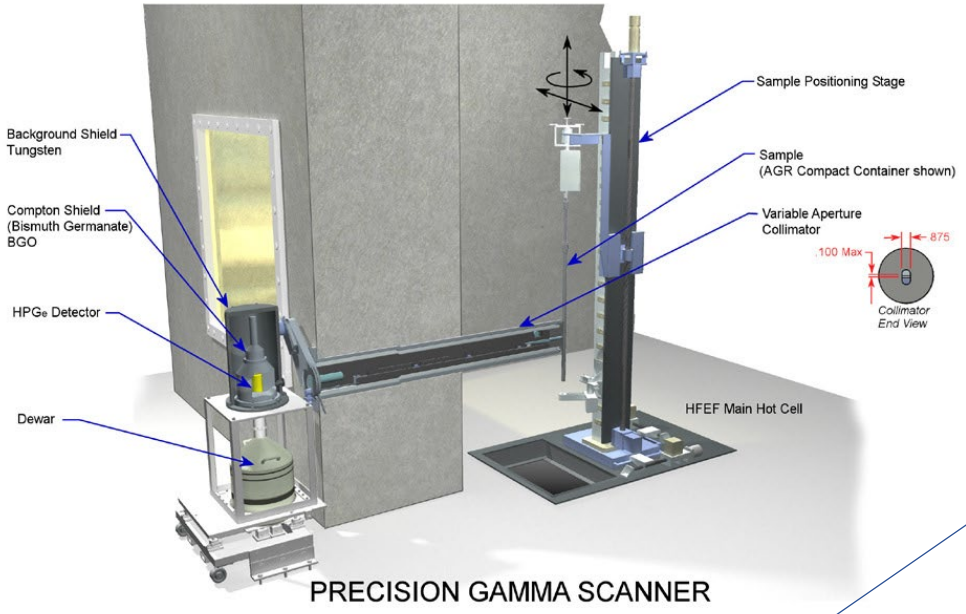
- Final in a series of experiments in INL's Advanced Test Reactor to investigate TRISO Fuel Performance
- Nondestructive examinations performed to focus PIE efforts
- Gamma signals too attenuated in capsule holders to obtain a large number of tomographic measurements in a reasonable amount of time
- Constraining the reconstruction of signal to physically possible geometries reduces the degrees of freedom and allows for low-quality tomographic sampling to provide useful insights



Idaho National Laboratory

ANS

Constrained Tomographic Reconstruction Process



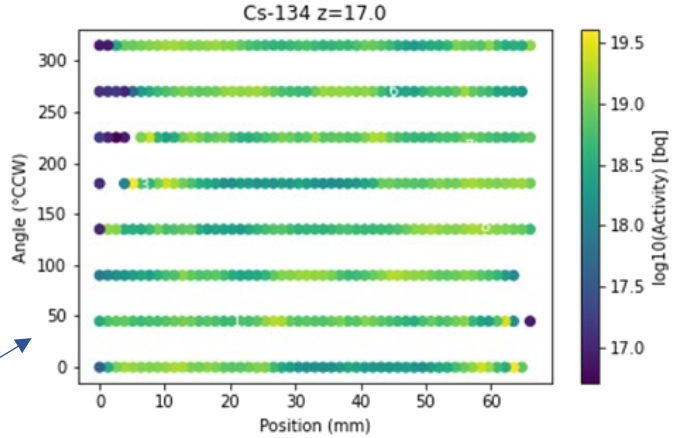
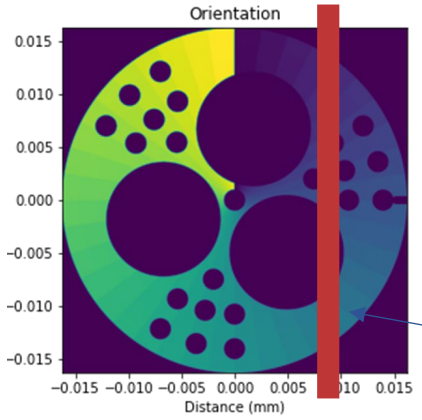


Image (pixel vector)

Scanned activities



$$\|Mf - g\|_2^2 + \lambda^2 \left| \frac{\partial^2 f}{\partial r \partial \theta} \right|_2^2$$

Tikhonov regularization parameter

Viewing matrix (basis set)

Idaho National Laboratory

ANS

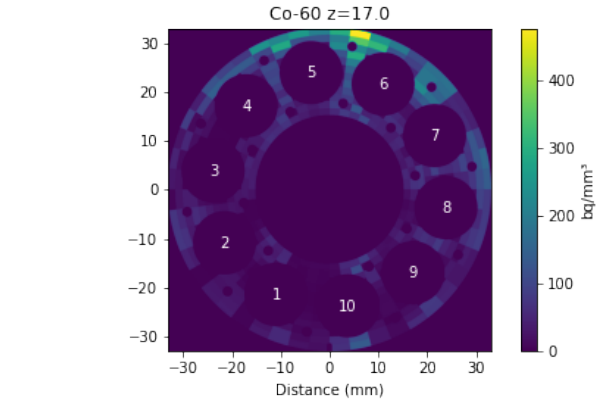
Finding the Center

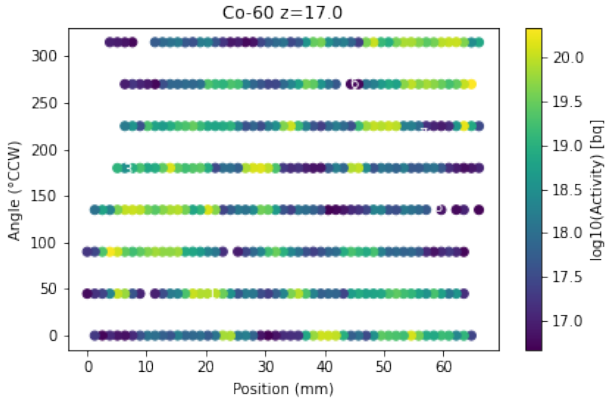
- A separate algorithm is used to determine the center and center of rotation of the cylinders
  - First, estimate the center of rotation is estimated minimizing the variation in activity as a function of cylinder rotation ϕ, $\sum_x \big(g(x,\phi)\big) = C$
  - Second, perform nonlinear optimization with (x_0, x_{cor}, y_{cor}) as parameters to minimize the function $\|Mf - g\|^2$
    - f found iteratively according to rules listed on the right
  - Faster method and results in a smoother objective function but tends to underestimate concentrations at boundaries.

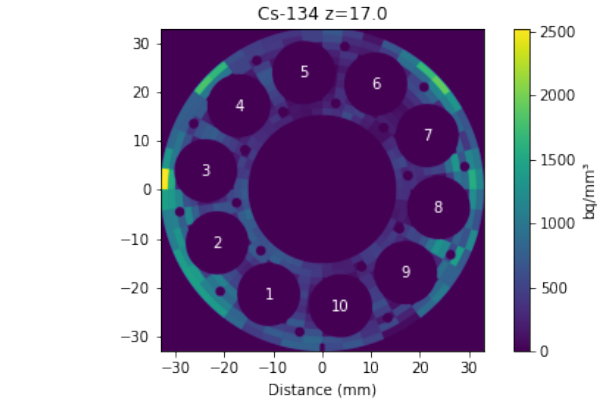
$$f^{k+1} = f^k + b^k \frac{\sum_j \left(\frac{M_{ij}\left(g_j - M_j^T f^k\right)}{\sum_{i=1}^N M_{ij}} \right)}{\sum_j M_{ij}}$$

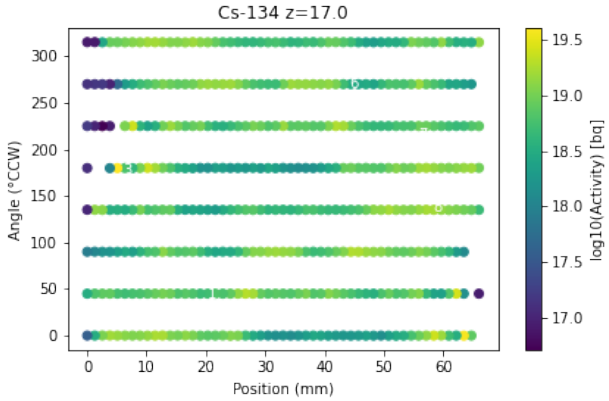
$$b^{k+1} = \begin{cases} 0.5b^k, & \|Mf^{k+1} - g\|^2 > \|Mf^k - g\|^2 \\ \min\left(1.1\, b^k, 1.5\right), & \|Mf^{k+1} - g\|^2 < \|Mf^k - g\|^2 \end{cases}$$

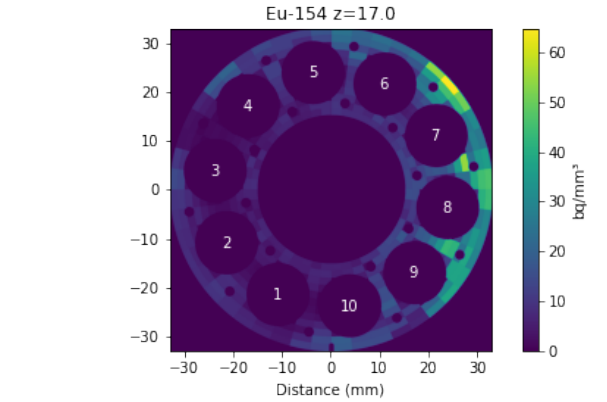
Capsule 1 Results

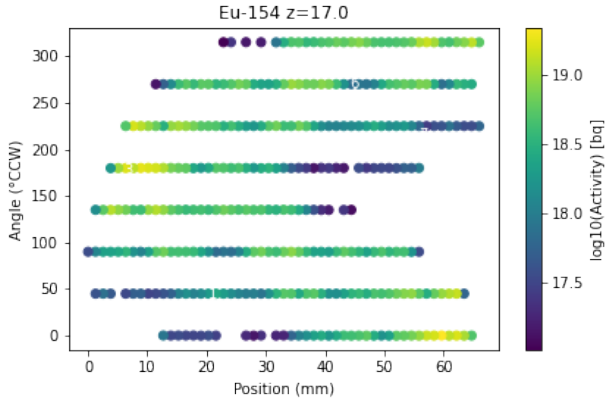








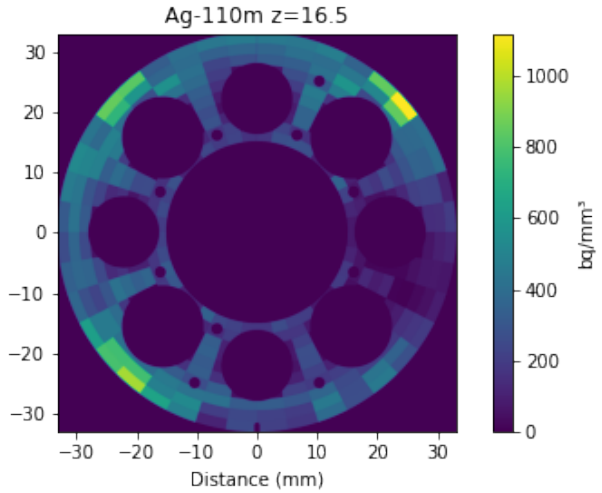


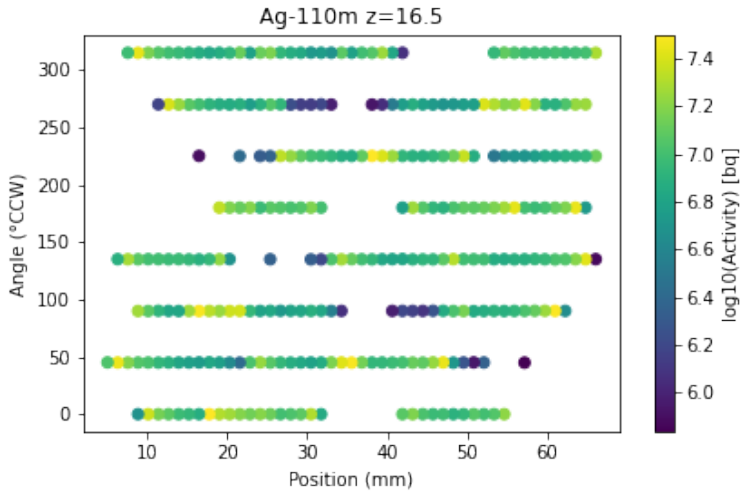


Idaho National Laboratory

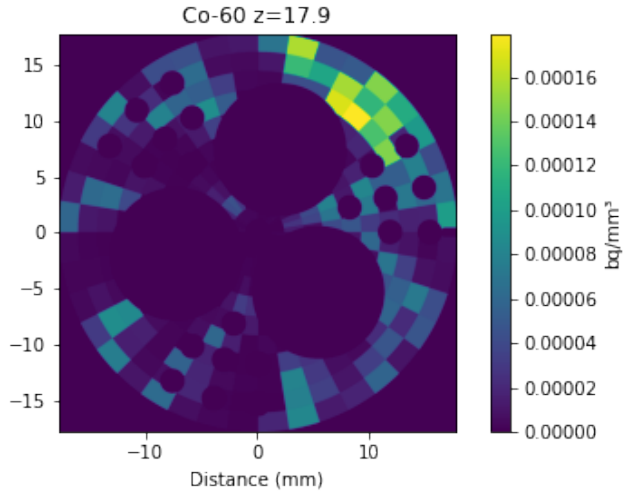
ANS

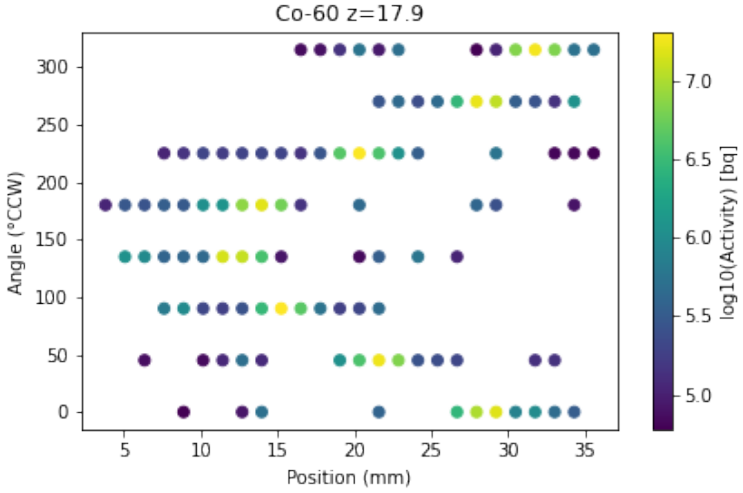
Capsule 2



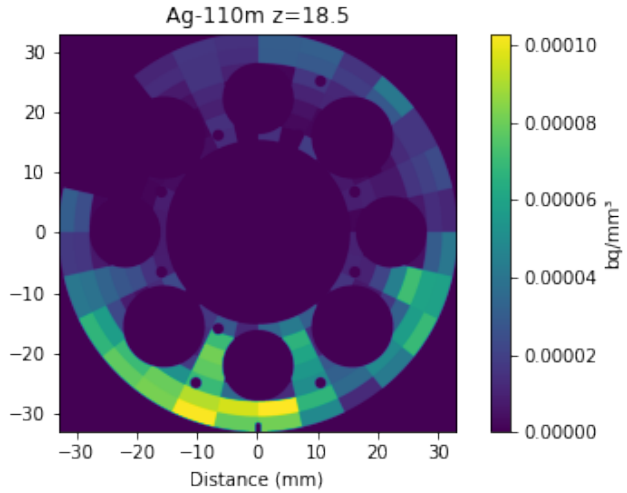


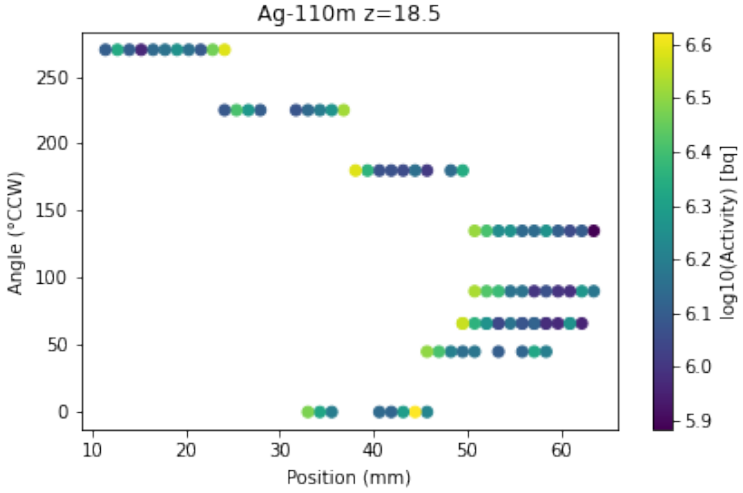
Capsule 3





Capsule 4





Idaho National Laboratory

ANS

Thank You!