Office of Defense Nuclear Nonproliferation
Research and Development

University Program Review (UPR) 2021 Meeting

Proof-of-Concept Testing of a Modified Parallel-Slit Ring Collimator Neutron Imaging Tomography System for Spent Fuel Verification (NSSC)

NSSC – Nuclear Science & Security Consortium

Sept. 8, 2021

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University of Tennessee, Knoxville

NUCLEAR SCIENCE and SECURITY CONSORTIUM

September 8 - 10, 2021

Introduction

- **4th Year PhD student at UTK**
  - Department of Nuclear Engineering
  - Academic Advisor: Jason Hayward
  - Detector Development and Characterization
- **National Lab Collaboration with ORNL**
  - Lab Mentor: Paul Hausladen
- **Focus: Nuclear Nonproliferation**
  - Emphasis on Materials Management and International Safeguards/Nuclear Verification
- **Projects**
  - Glass for Cargo Scanning and SNM Detection
  - Fast Neutron Tomography for Spent Fuel Verification

Project Overview

1. Design an innovative spent fuel imager in simulation space

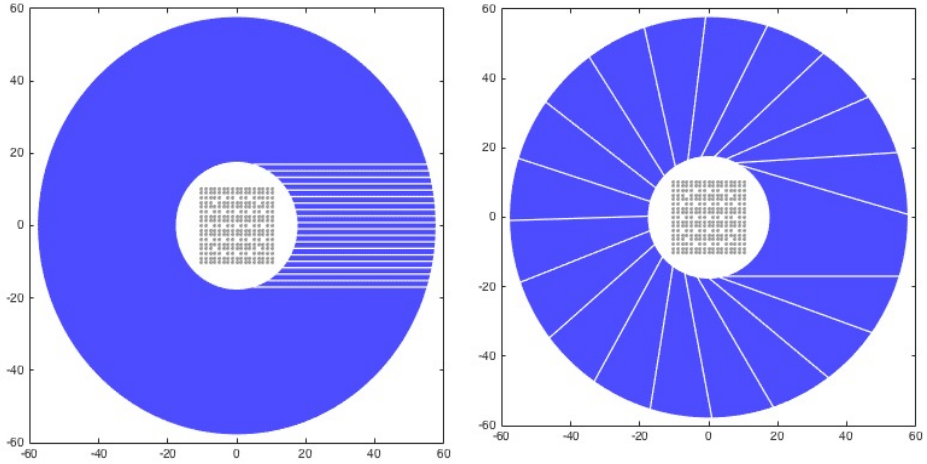
2. Develop an image reconstruction method to resolve both real and simulation data

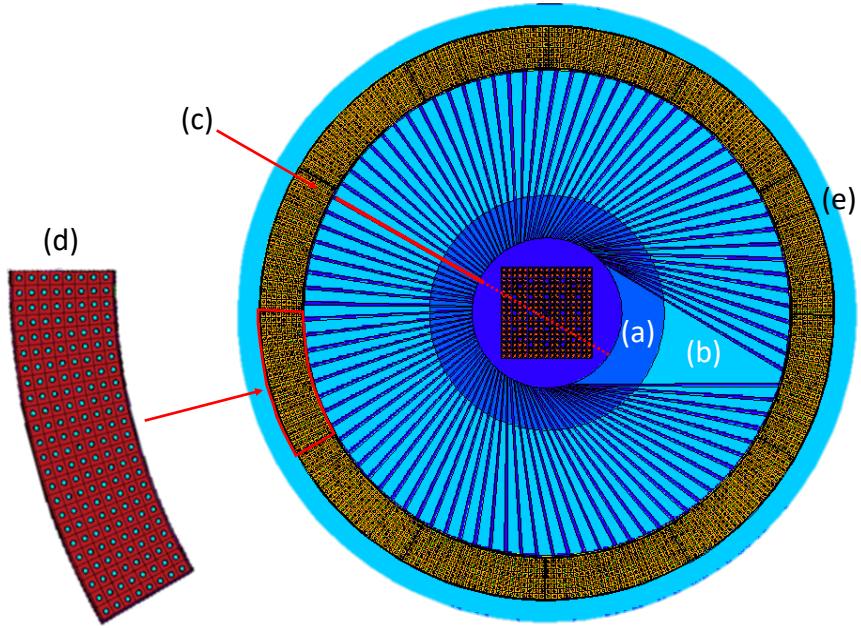
3. Build and test a proof-of-concept imager

Safeguards Context

- **Verification of SNF**
- **Monitoring and prevention of misuse of SNF**
- **PGET is currently used**
  - Neutron technology is still worth investigating
  - Burnup profiles
  - Active measurements for spent fuel

Parallel-Slit Ring Collimator Fast Neutron Emission Tomography System

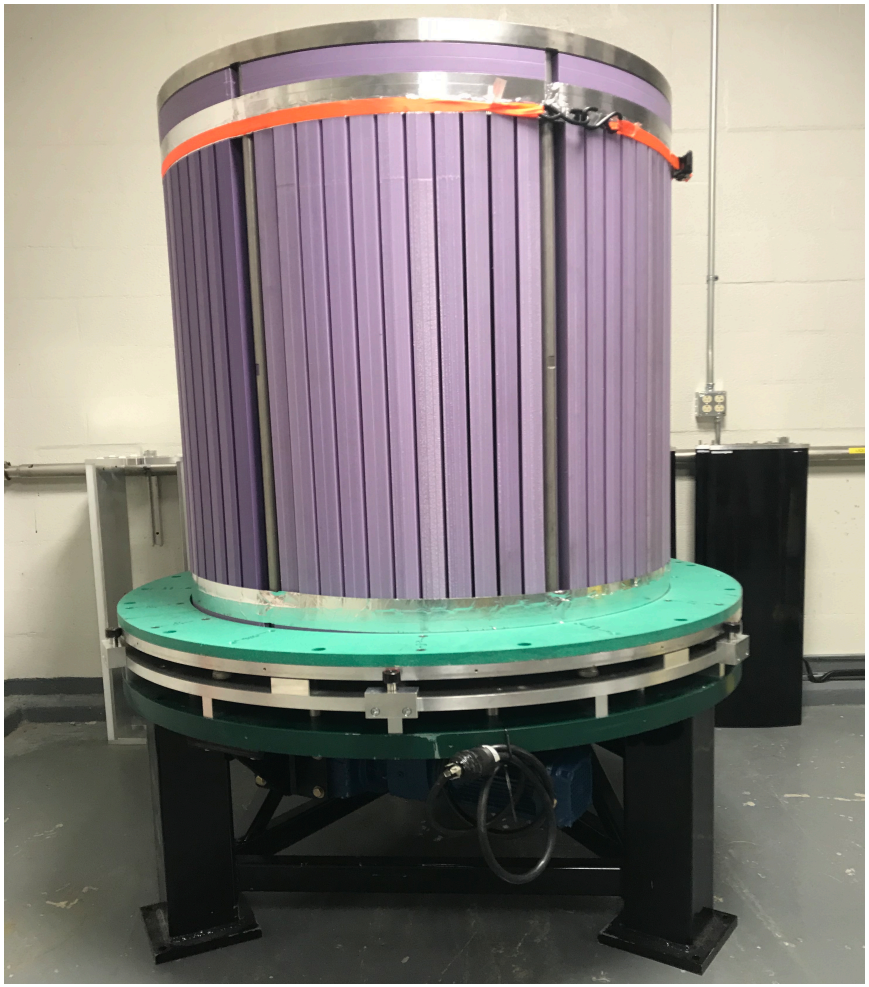




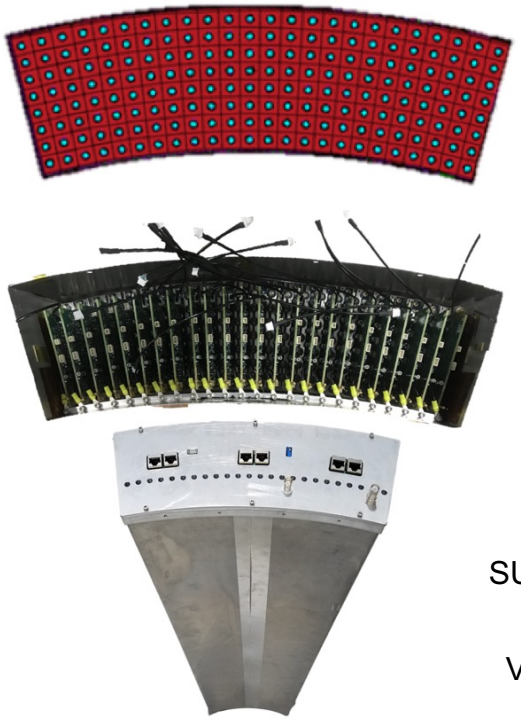
- **Collimator annulus**
  - **(a) inner stainless steel**
  - **(b) outer borated polyethylene ring**
  - **(c) 96 slits - define lines of response across the field of view.**
- **Neutron detection**
  - **(d) 12 detector modules - 24 rows of 8 boron straws each and inner and outer edges lined with Cd**
  - **(e) 5-cm-thick ring of borated polyethylene shielding**

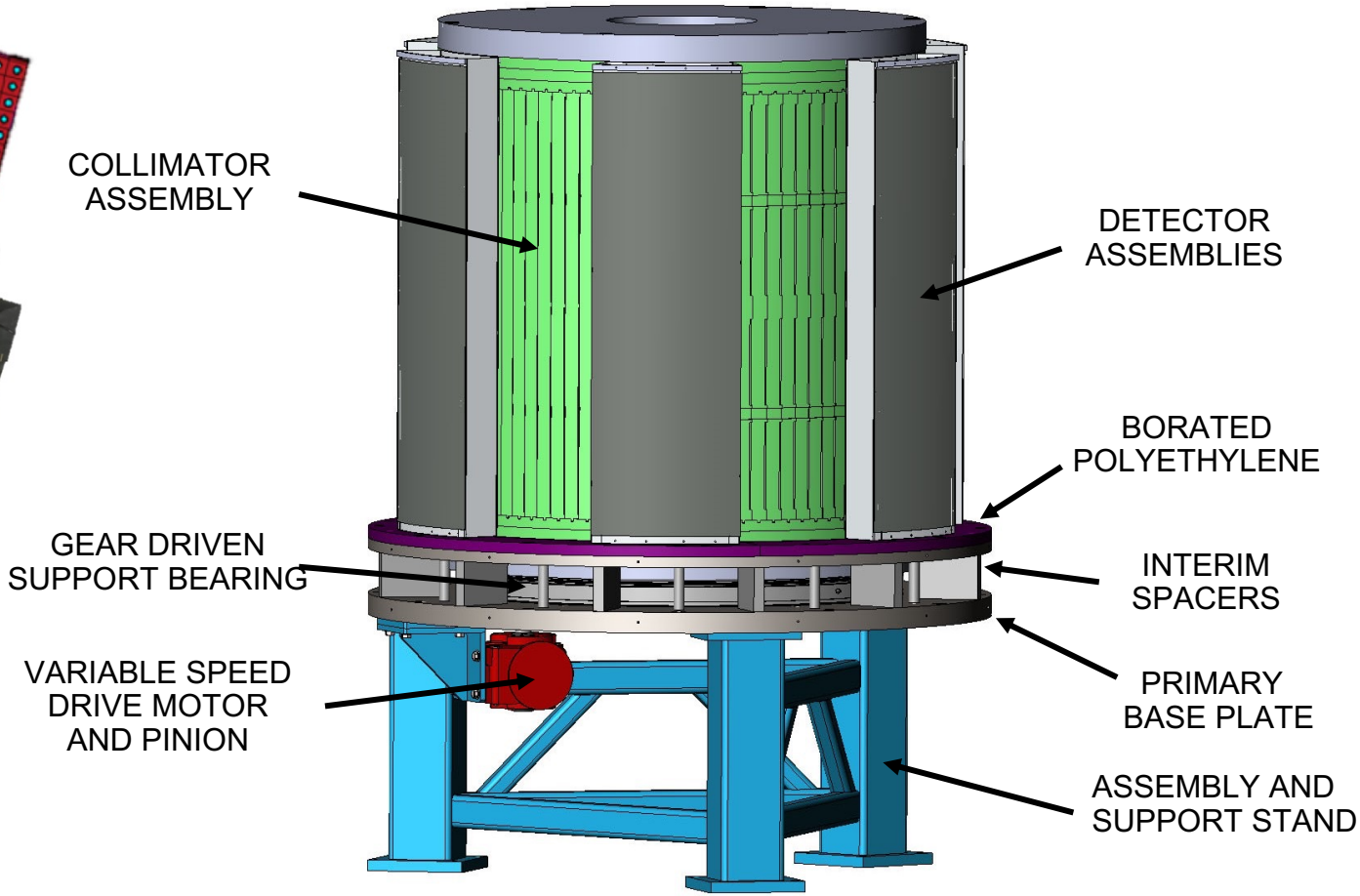
Changes from Analytical Model

- **72 slits instead of 96**
  - Half of the slits are offset by .5 slit width
- **6 detector modules**
- **Cost considerations played a significant factor**

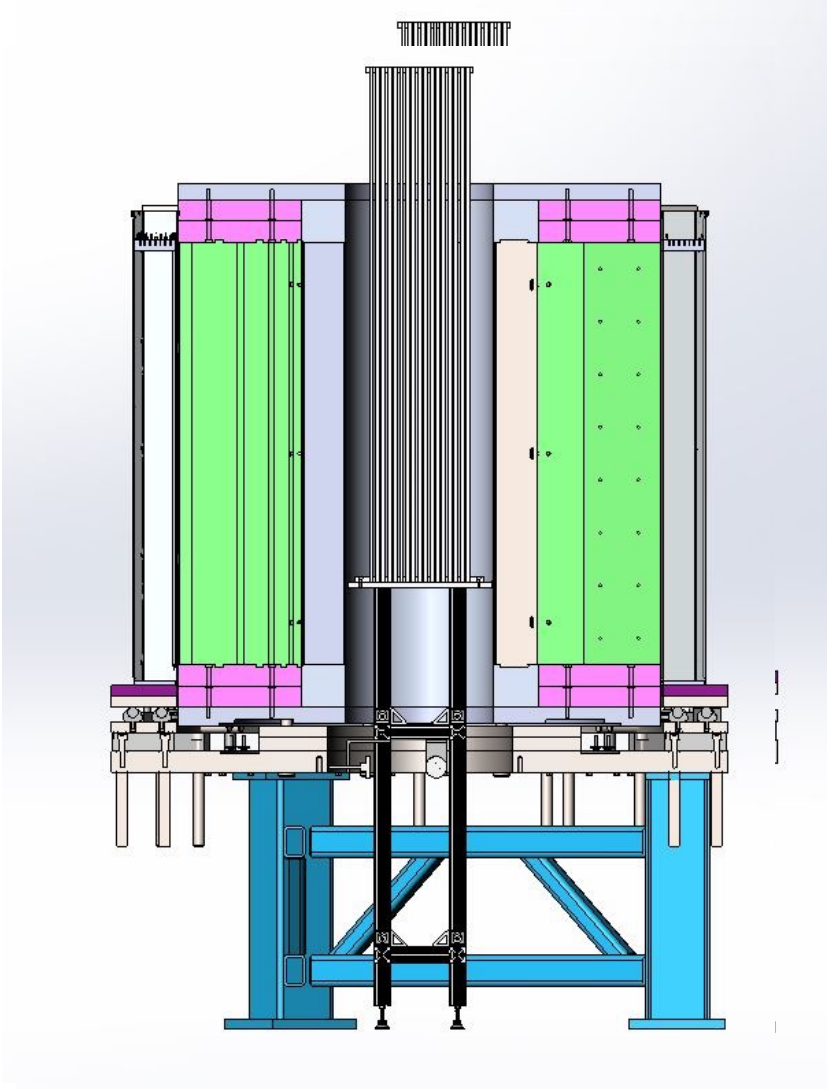


Proof-of-Concept Imager





Experimental Setup



- **Mock 17 x 17 fuel assembly table**
- **Next Steps:**
  - Calibration of each detector
  - Calibration of source at origin
  - Images with no mock fuel rods
  - Images with mock fuel rods

Neutron Response Components

Direct interaction	• direct from source to detector unimpeded by collimator
Edge scattering	• collimator wall partially/fully occludes direct path but neutrons manage to traverse
Inter-detector scattering	• neutrons traverse one slit but then scatter into a surrounding detector
Collimator penetration	• neutrons traverse collimator as if it were solid but lower density
Efficiency variation	• Variation in detection efficiency across individual straw rows

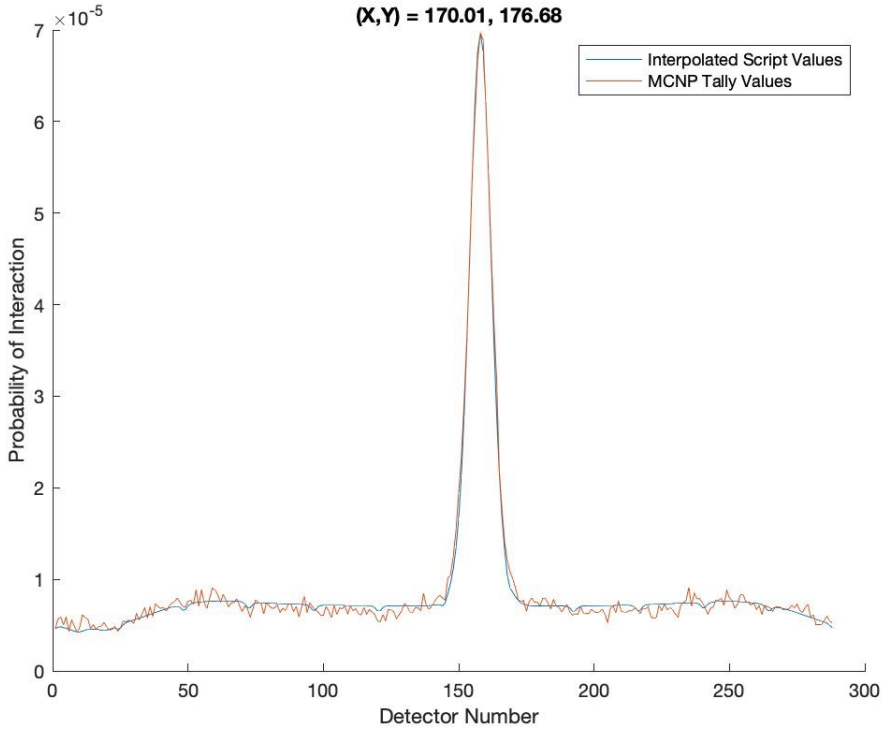
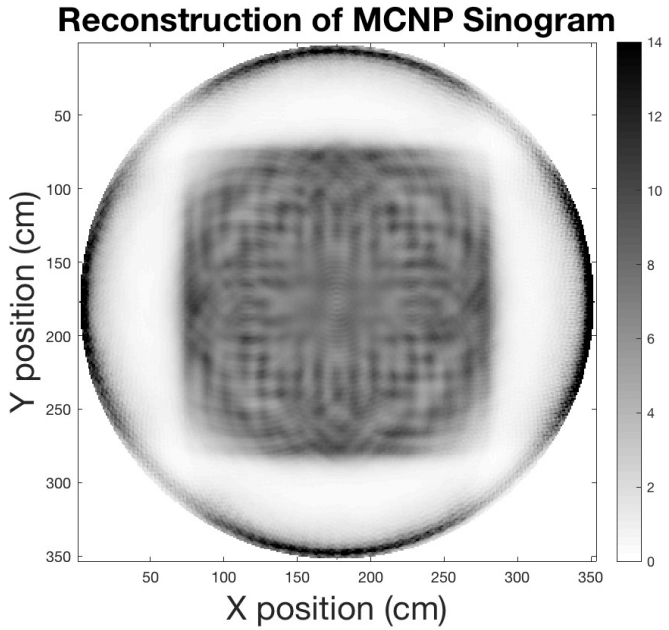
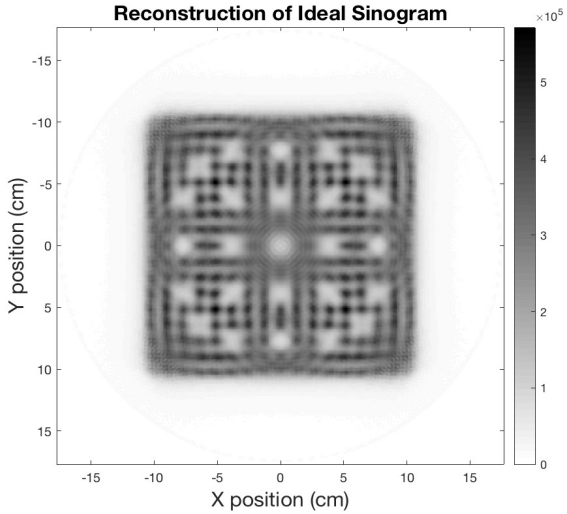


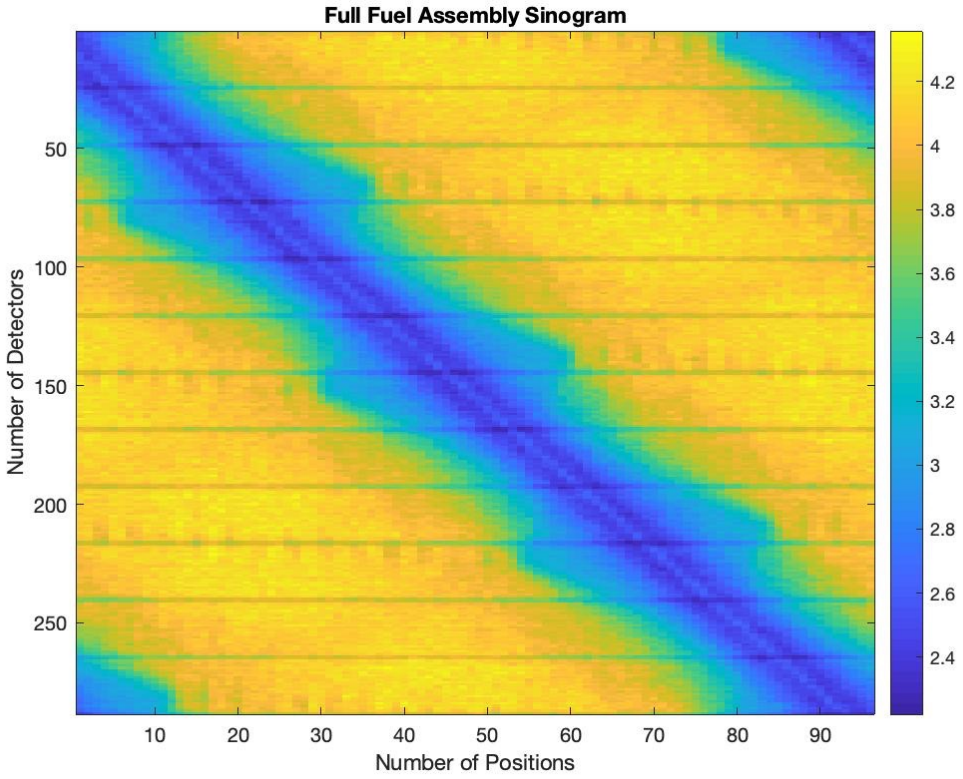
Image Reconstruction Difficulties

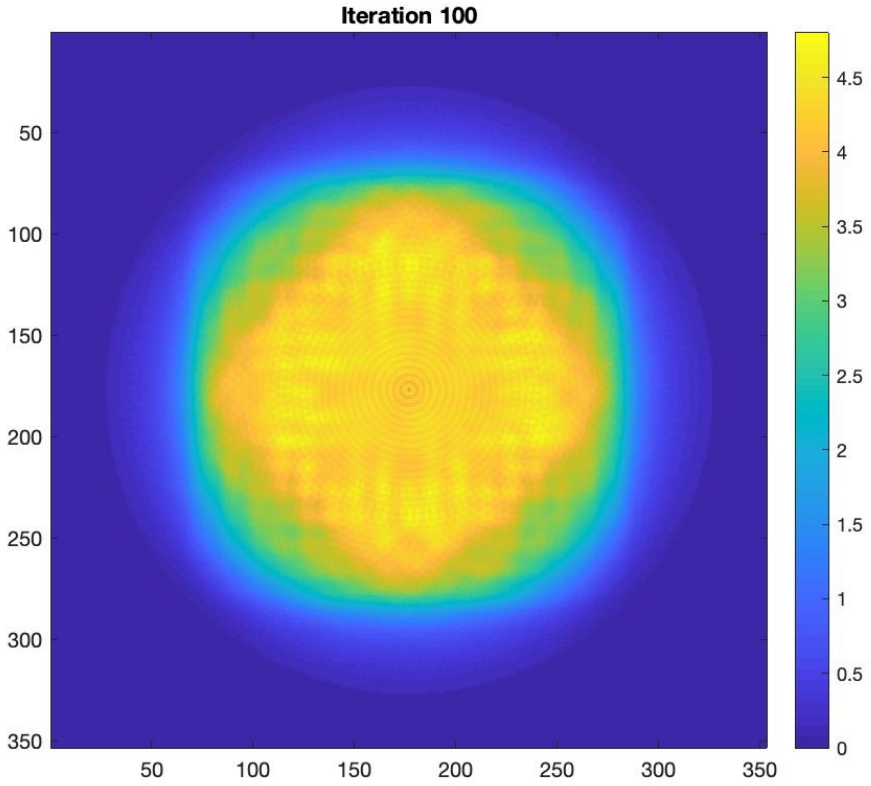




- **Inaccuracies along edges**
  - Missing corners
  - Source attributed to edge of FOV
- **Overlapping artifacts**
  - Rings around center
  - 4 quadrant artifacts

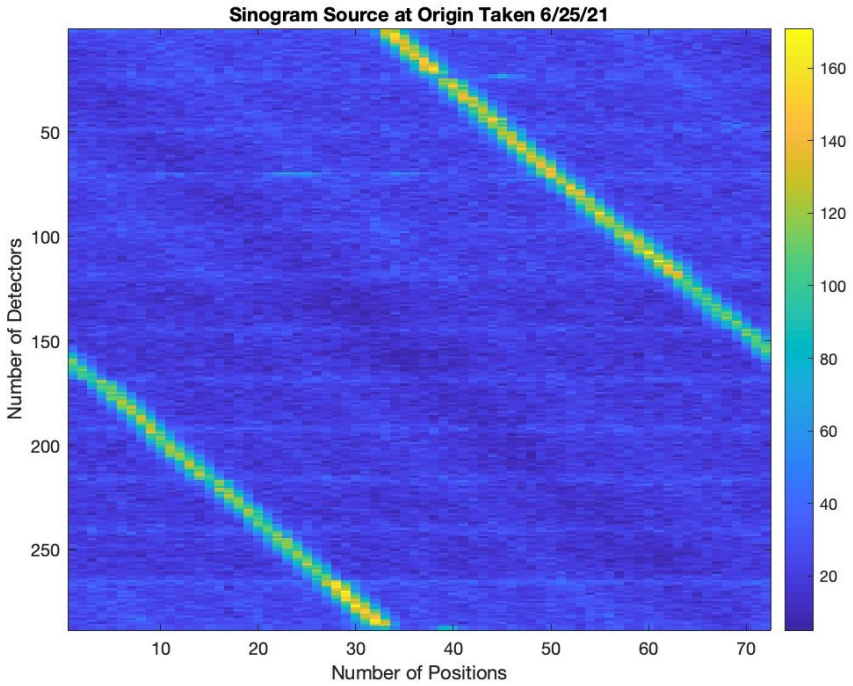
Improvements to Reconstruction



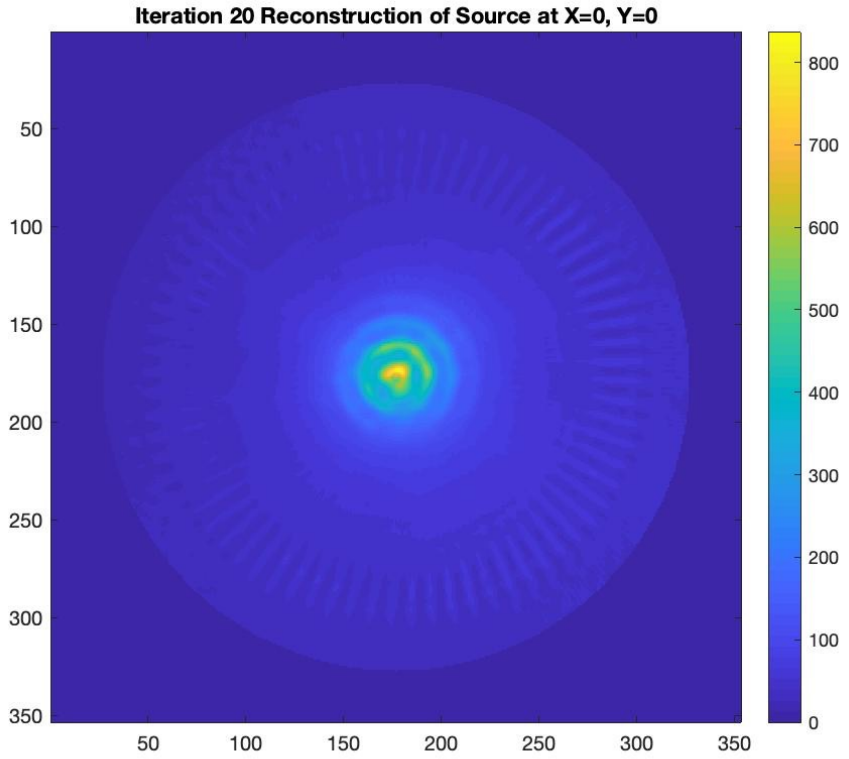


Reconstructions From Experimental Data

Sinogram At (0,0)



Reconstruction at (0,0)

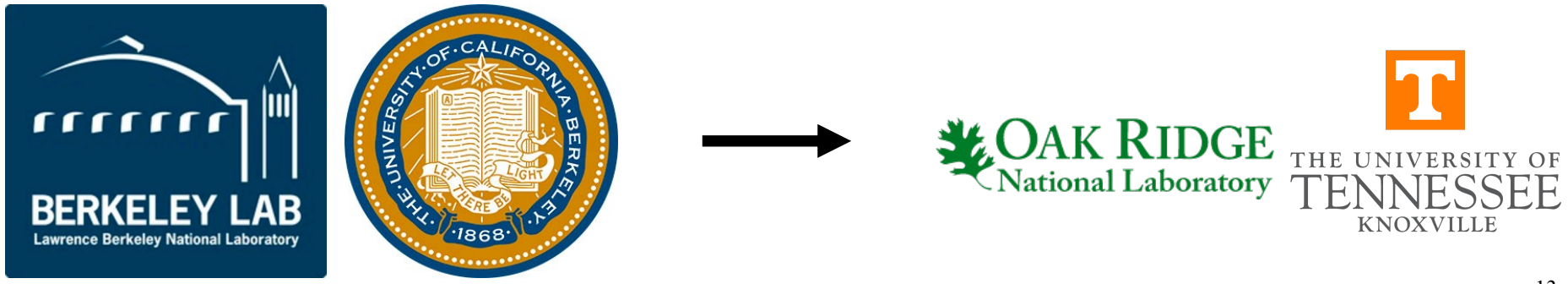


Moving Forward

Simulation Response	• Continued improvements on response code • Collimator penetration accuracy • Transition to 72 slit model
Proof-of-Concept Testing	• Testing with all mock fuel rods • Testing with stronger Cf-252 sources
Reconstructions	• Improve period of convergence • Removal of artifacts from reconstructions

NSSC Experience

- **NSSC Graduate Fellow 2020-Present**
  - In residence work at ORNL PhD work with Dr. Paul Hausladen
  - GWU's Nuclear Security Bootcamp – June 14-18
  - NSSC Webinar Attendance
  - NSSC Virtual Scholar Showcase – June 2020
- **NSSC Undergraduate Affiliate 2017-2018**
  - Academic Advisor: Bethany Goldblum
  - Lab Mentor: Dr. Darren Bleuel at LBNL
  - Competitive graduate applicant



Acknowledgements

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