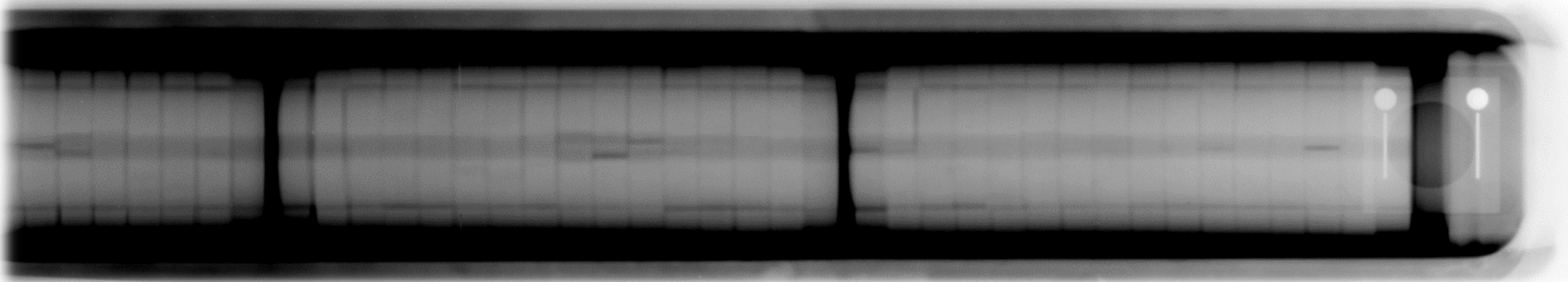


# Indirect Neutron Radiography at the Annular Core Research Reactor (ACRR)



**Sophie Brodish**

*brodishs@oregonstate.edu*

**Ryan Swinney**

*rswinne@sandia.gov*

**Richard Pratt**

*rjprat@sandia.gov*

**Steve Reese**

*steve.reese@oregonstate.edu*

**Melissa Teague**

*melissa.teague@nnsa.doe.gov*

**Exceptional Gratitude to:**

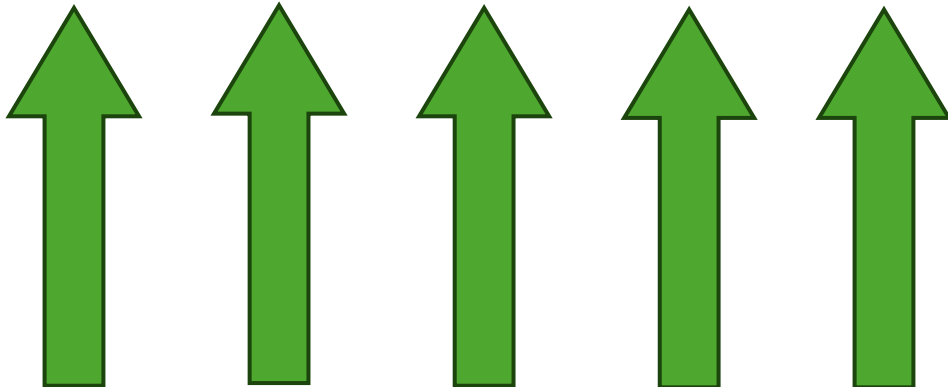
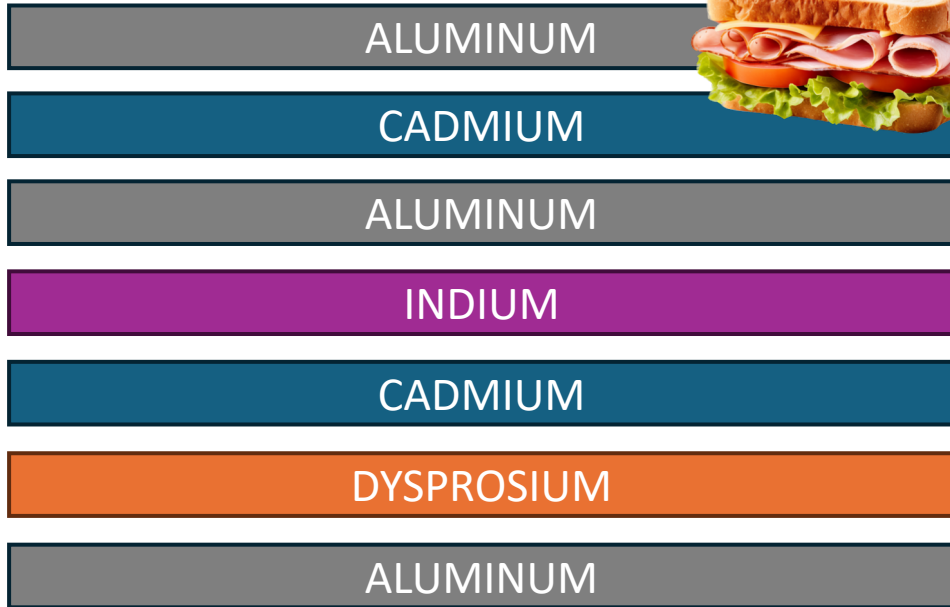
*Derek Balke, Billy Martin,  
Augie Chapa, Rafe Campbell,  
Lonnie Martin, and all ACRR  
Operators & EH&S Personnel*

# Presentation Roadmap

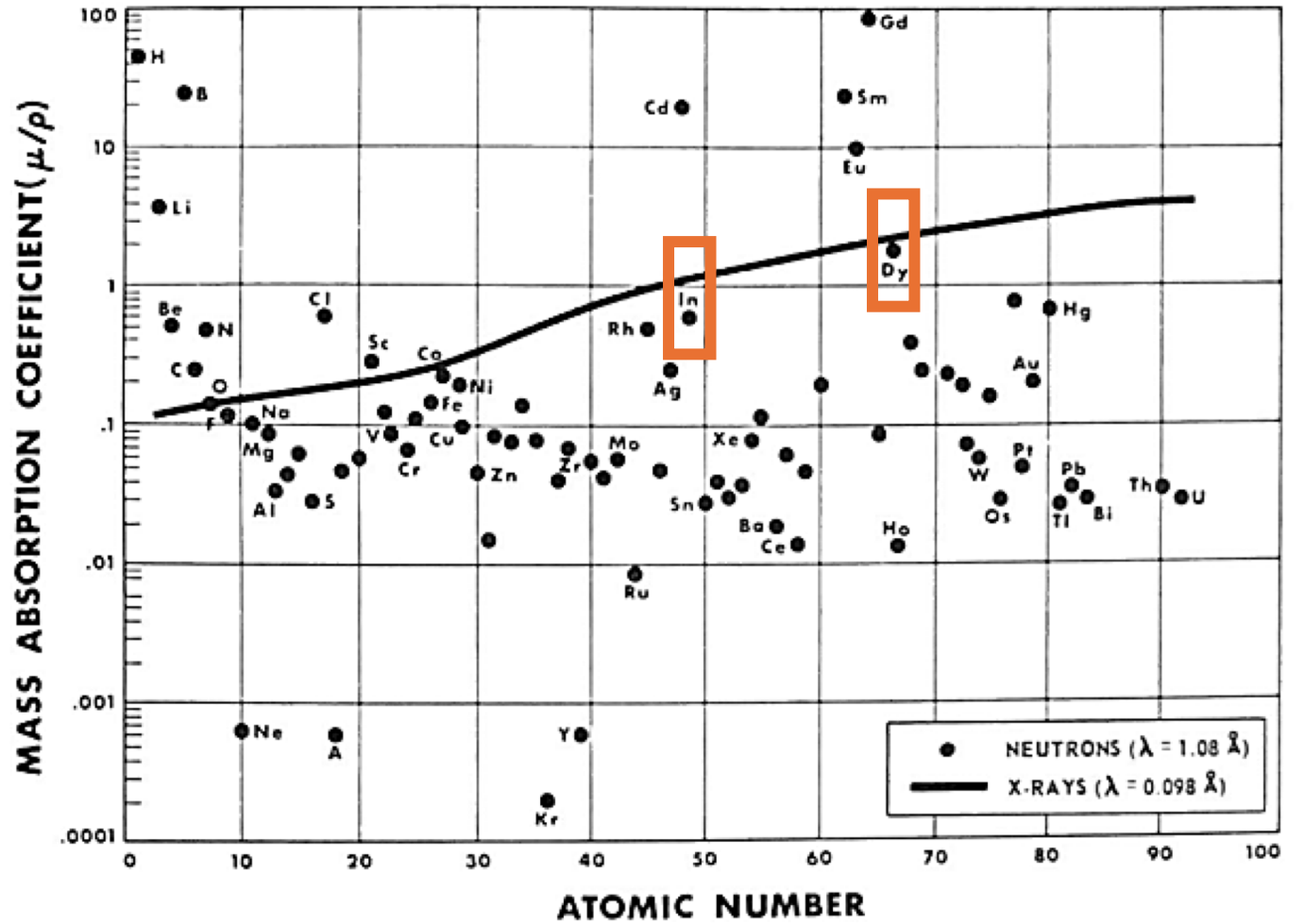
- Foil Sandwich and Other Applicable Materials
- RAW + Processed Histogram Compositions
- Brightness & Contrast
- SNR to CNR
- Characterizing Configuration
- Rapid Review of Iterations (1) through (3)
- Image Quality Indicators
- Quantification & Coordination
- Summary of Knowledge



# The Foil Sandwich:



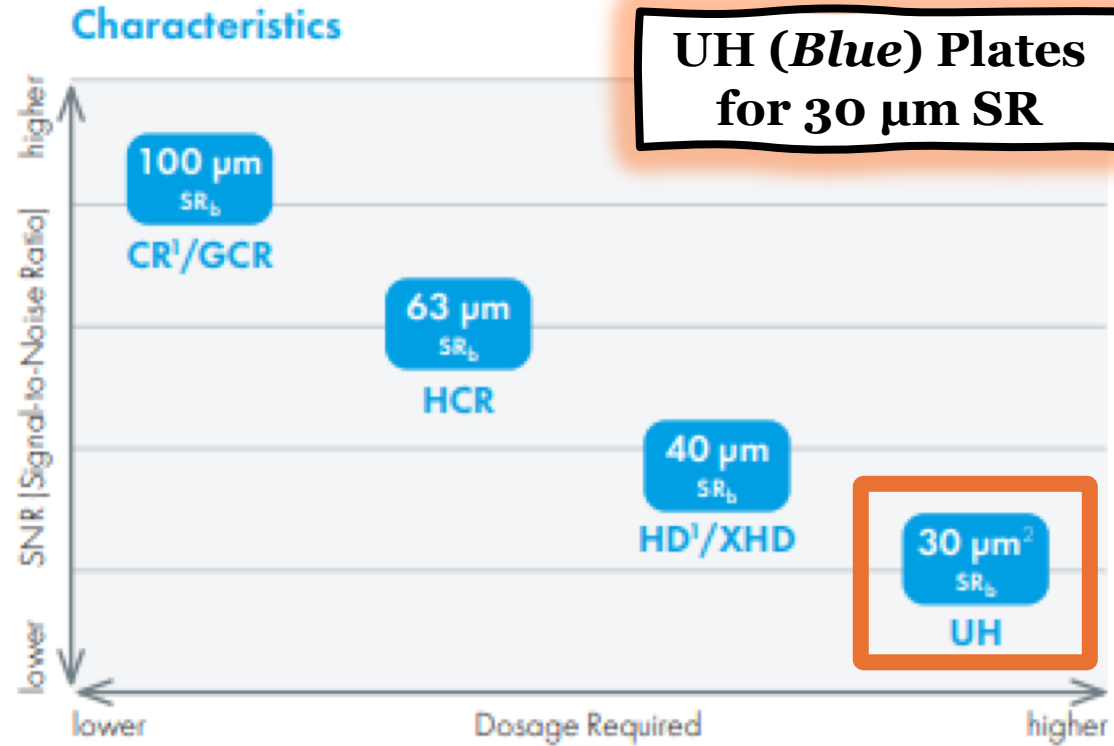
NEUTRONS!



# What else we used:

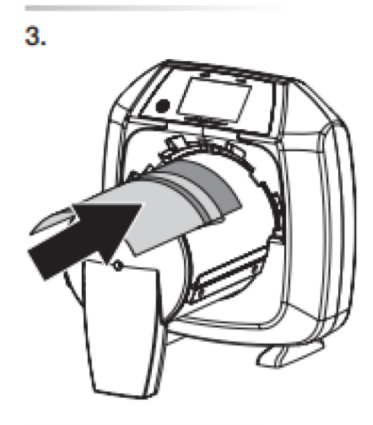
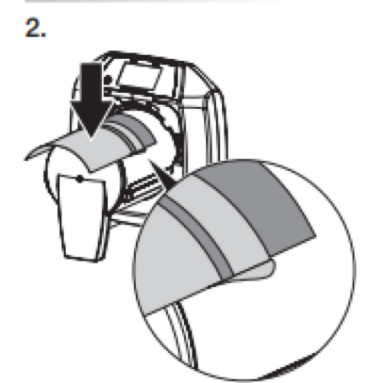
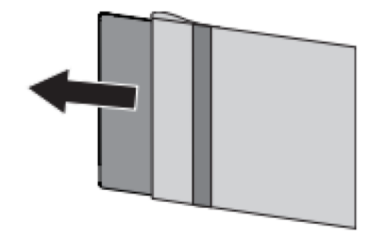


**DÜRR NDT  
HD-CR 35 NDT CR-Scanner**



**UH (Blue) Plates  
for 30 μm SR**

Flexible cassette

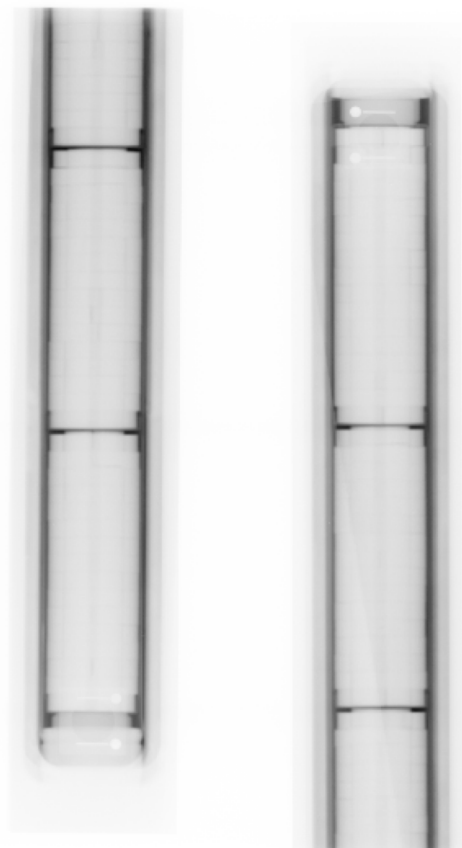


# ALARA

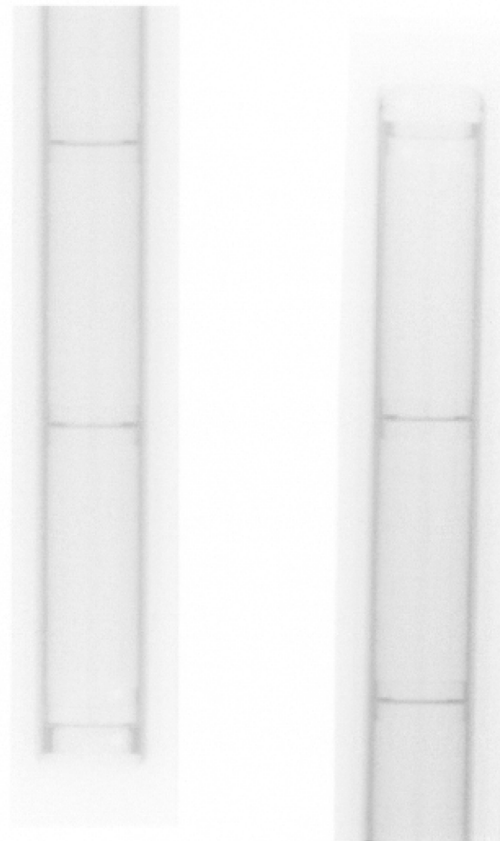


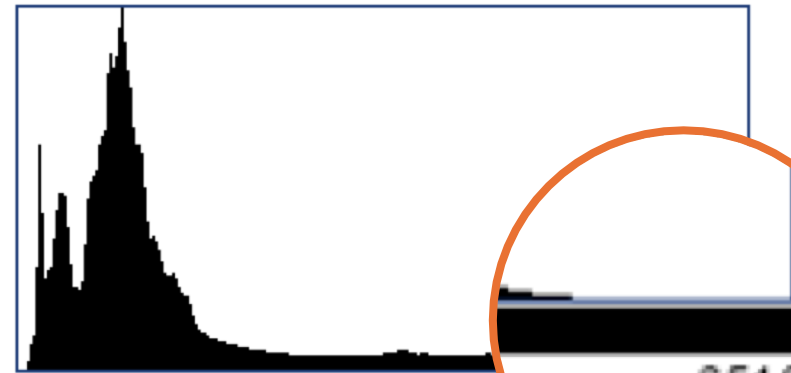
# Raw Images UH Phosphor IPs

bit (inverting LUT); 476MB



INDIUM20K.dcm (4.2%)  
356.04x432.43 mm (14110x17123); 16-bit (inverting LUT); 461MB





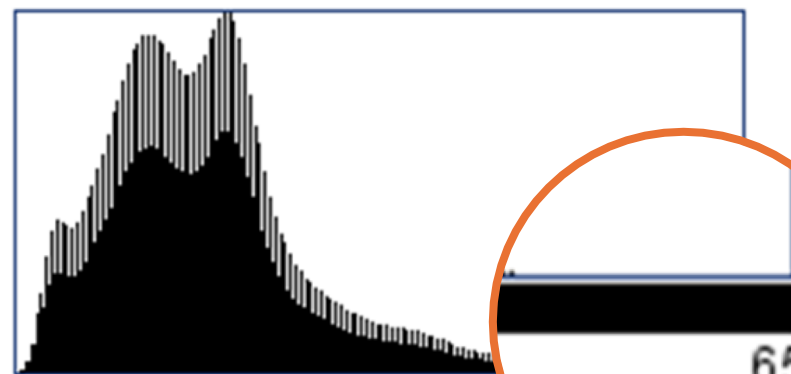
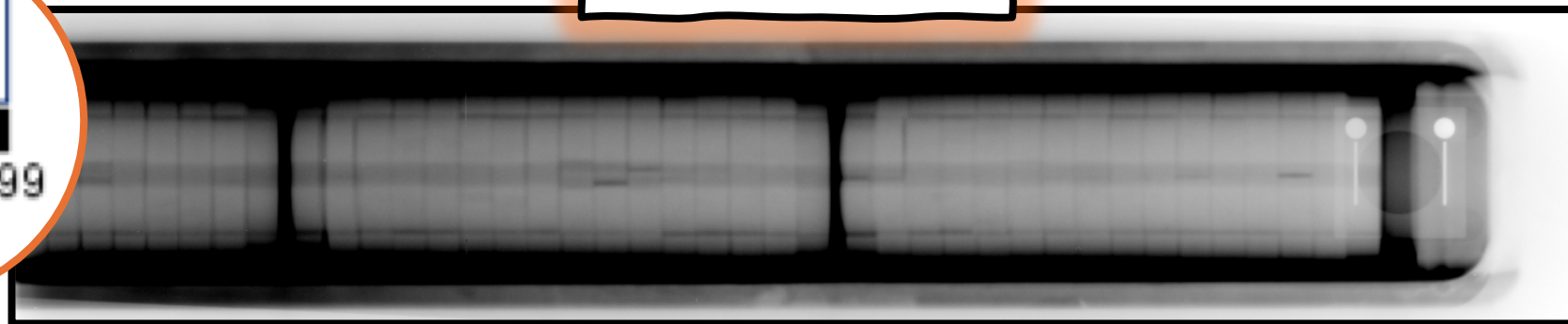
335

65199

N: 27753600  
Mean: 12962.645  
StdDev: 10286.978  
Bins: 256  
Value: 20858.375

Min: 335  
Max: 65199  
Mode: 9541 (851563)  
Bin Width: 253.375  
Count: 52773

**DYSPROSIUM**



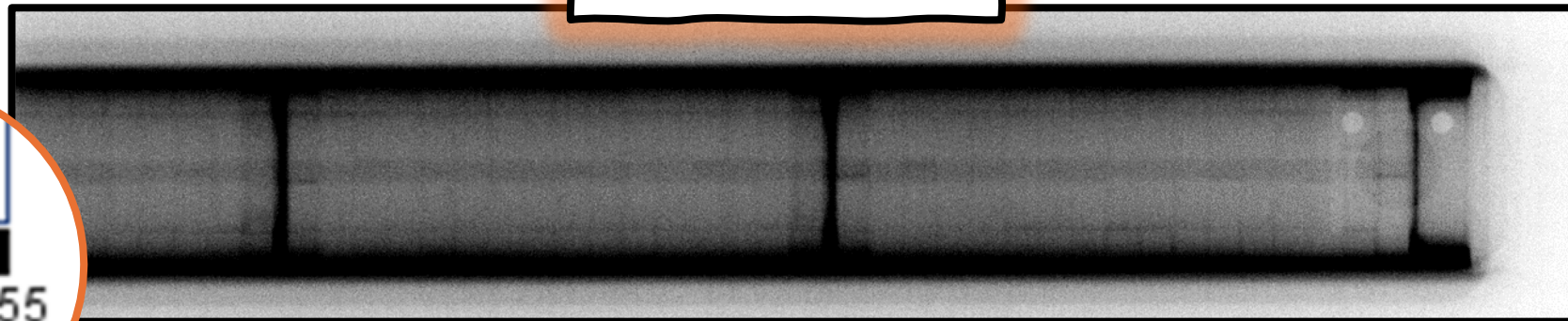
0

655

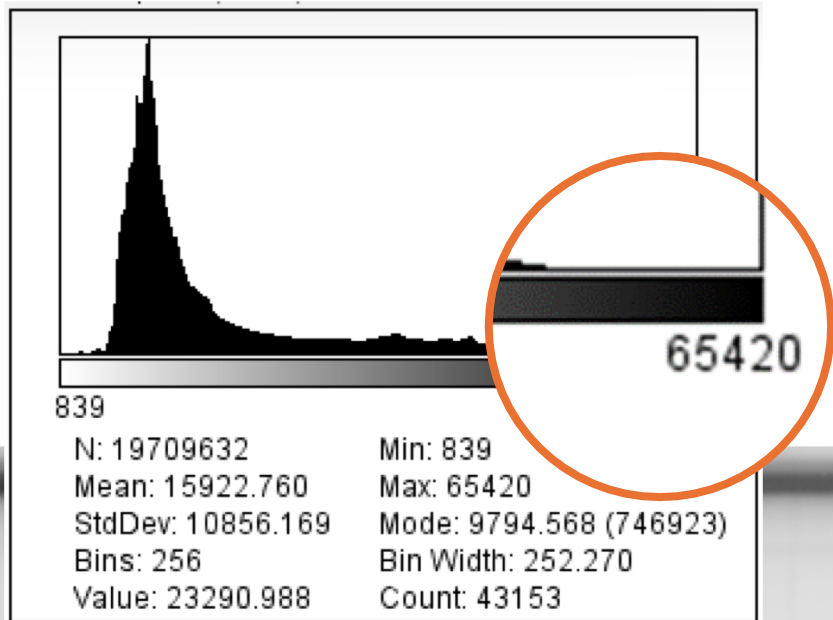
N: 27678336  
Mean: 168.081  
StdDev: 87.428  
Bins: 256  
Value: 647.324

Min: 0  
Max: 655  
Mode: 188 (439009)  
Bin Width: 2.559  
Count: 0

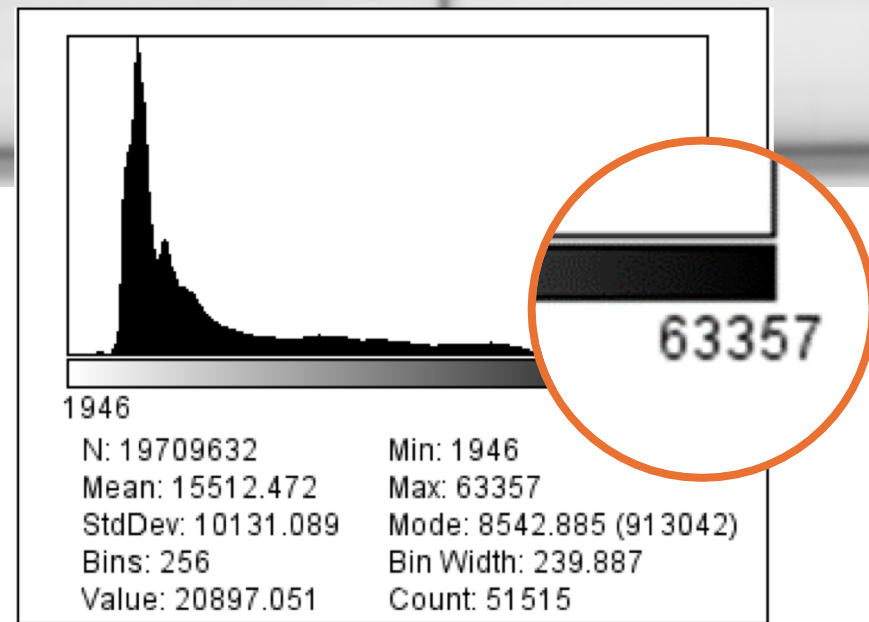
**INDIUM**



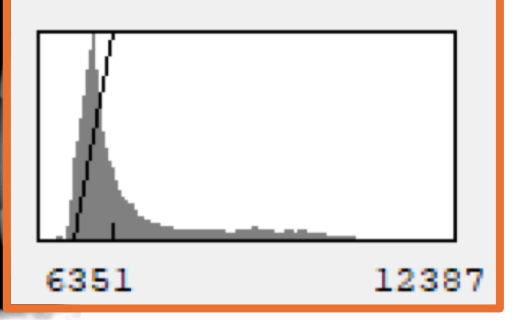
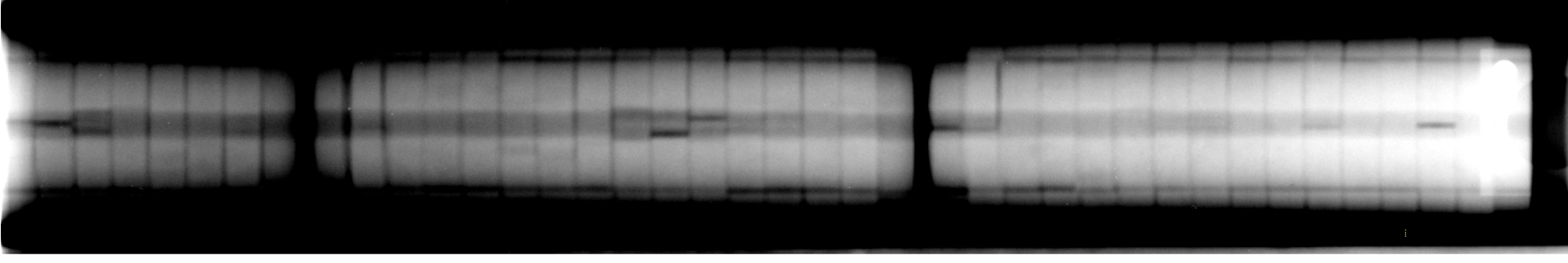
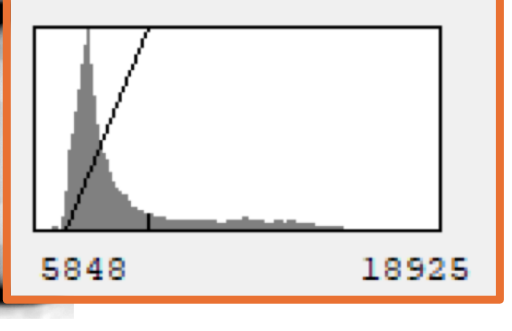
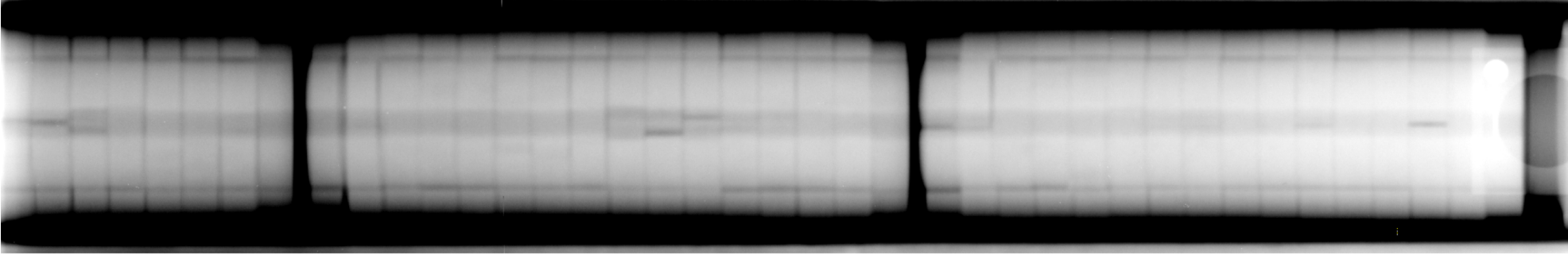
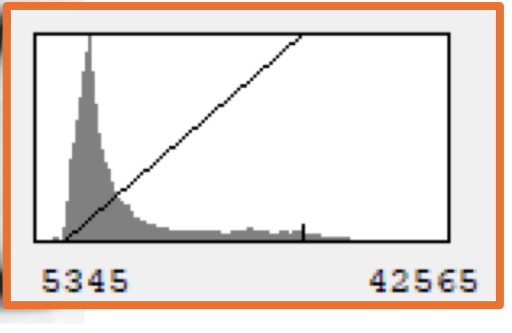
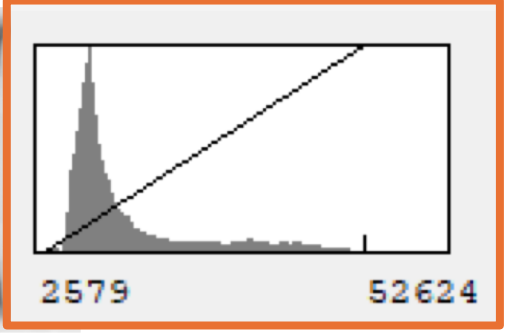


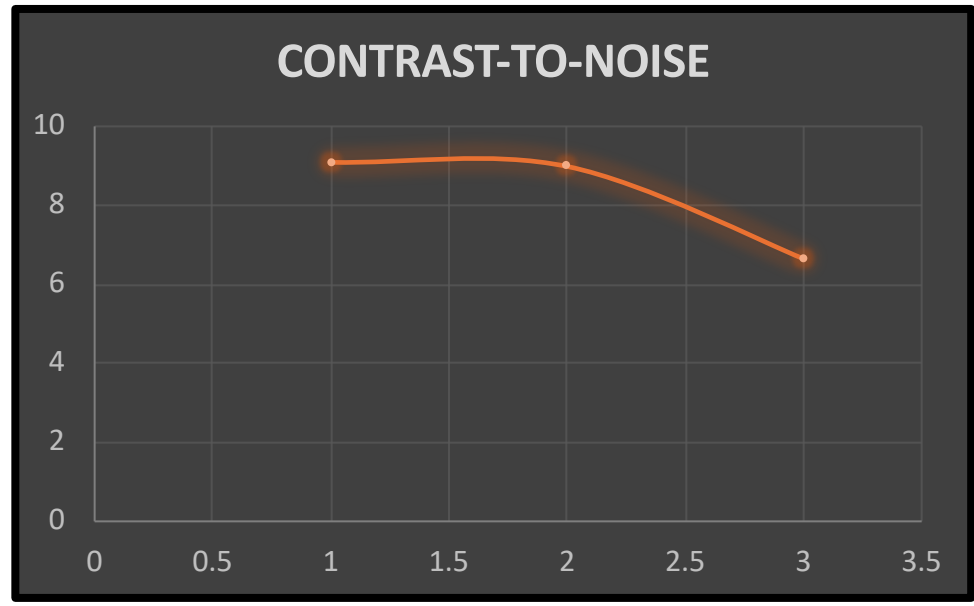
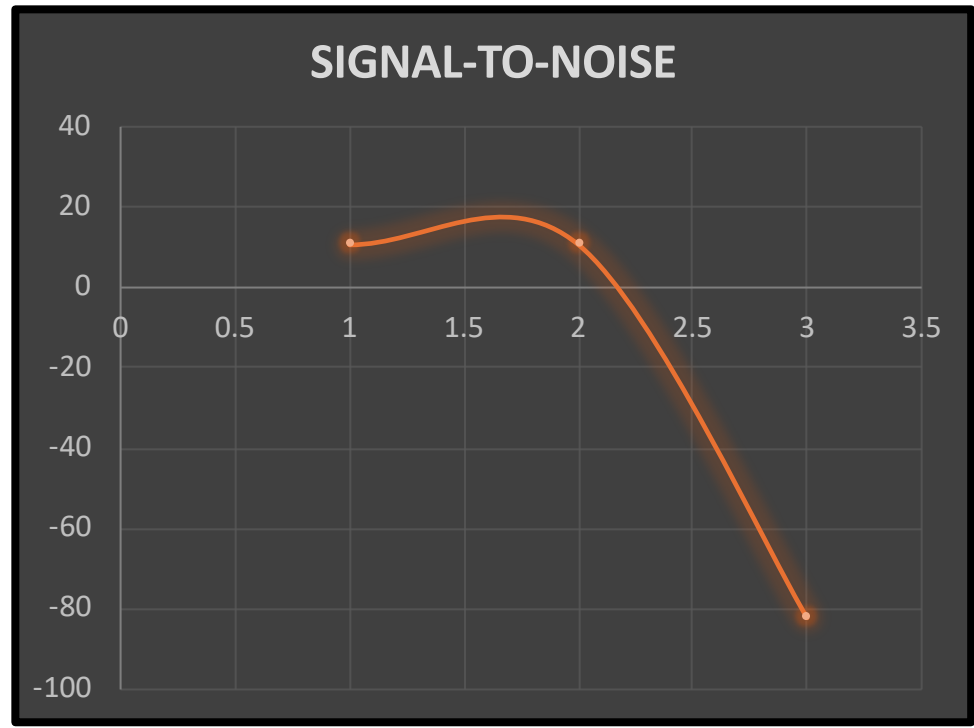
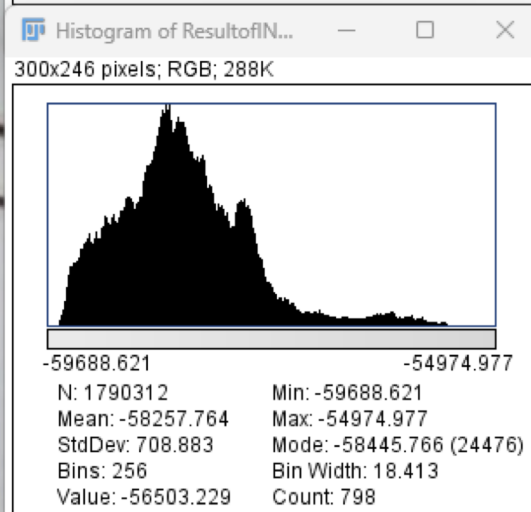
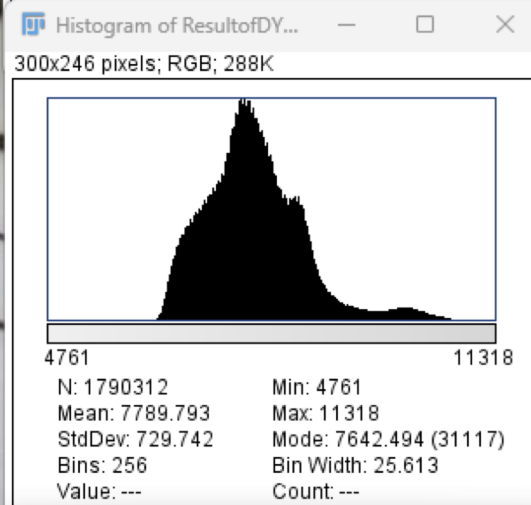
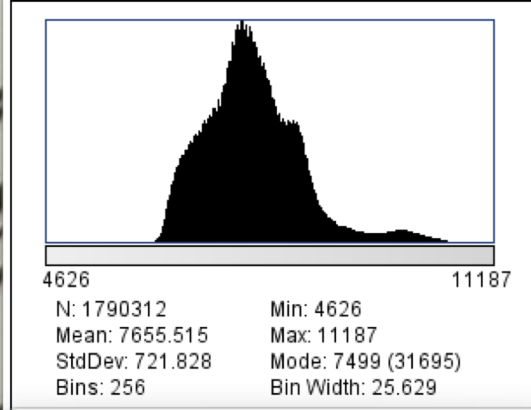
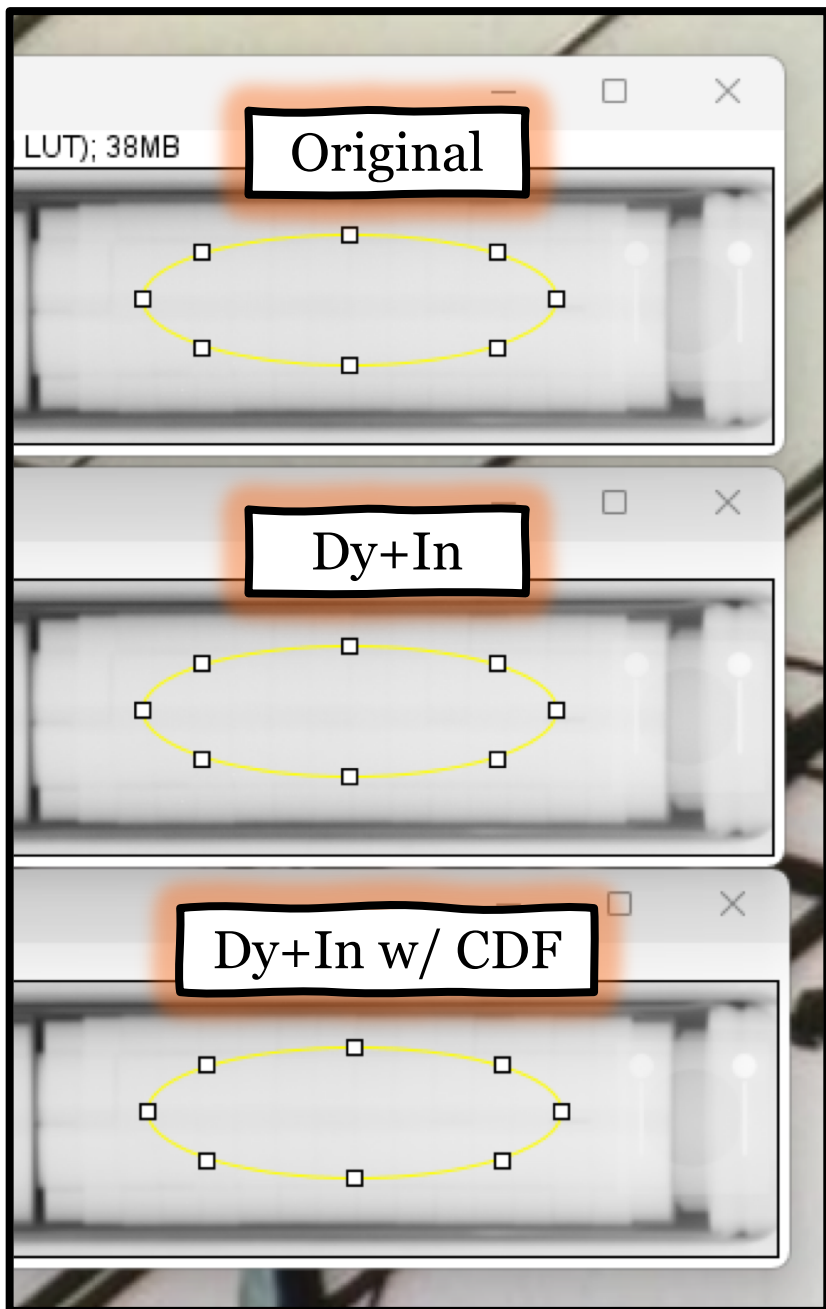


**COMBINED  
DY+IN  
HISTOGRAMS**



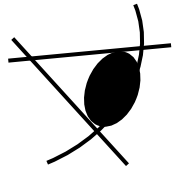
# Adjusting Brightness & Contrast



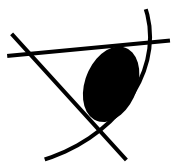
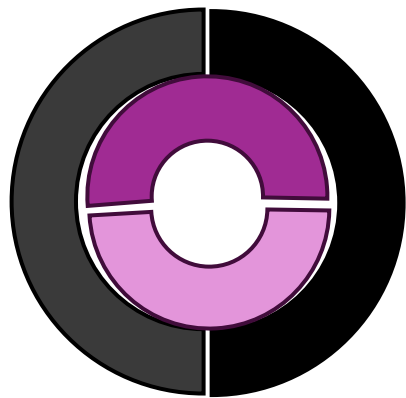




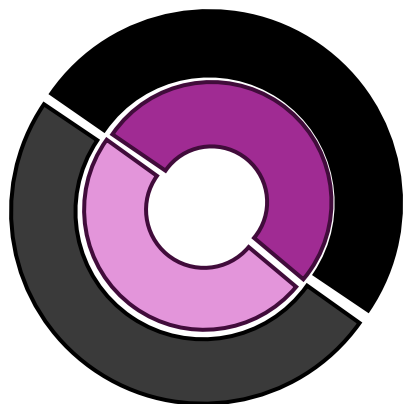
# Pellet Configuration/ Quantity per Cup



TOP CONFIG.  
[ TC ]



SEAM CONFIG.  
[ SC ]



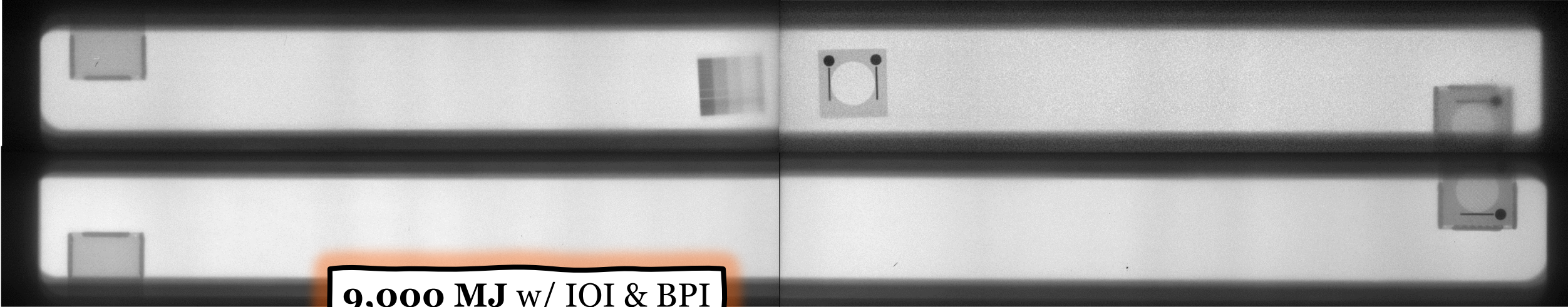
## Cup 1

1	— [ SC ]
2	— [ TC ]
3	— [ TC ]
4	— [ TC ]
5	— [ TC ]
6	— [ SC ]
7	— [ TC ]
8	— [ TC ]
9	— [ TC ]
10	— [ TC ]
11	— [ TC ]
12	— [ TC ]
13	— [ TC ]
14	— [ TC ]
15	— [ SC ]
16	— [ SC ]
17	— [ SC ]

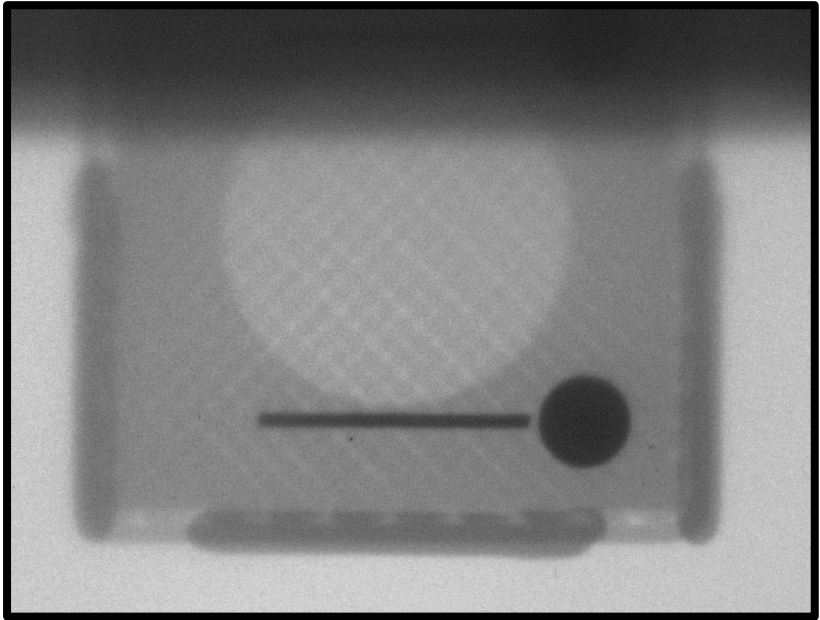
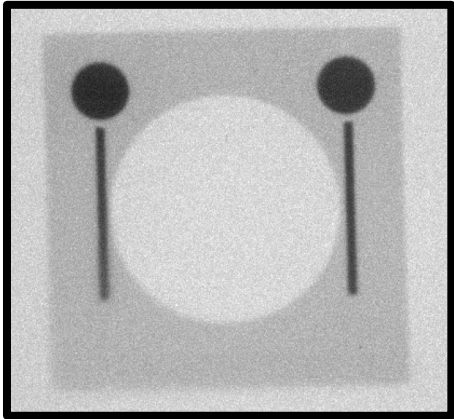
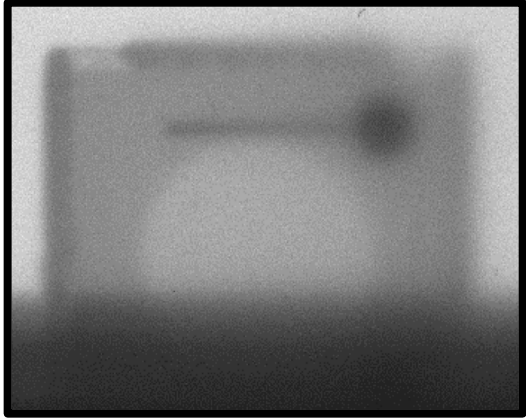
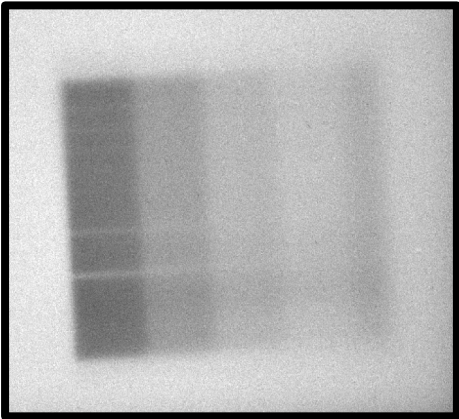
## Cup 2

1	— [ TC ]
2	— [ TC ]
3	— [ TC ]
4	— [ TC ]
5	— [ TC ]
6	— [ TC ]
7	— [ TC ]
8	— [ SC ]
9	— [ TC ]
10	— [ TC ]
11	— [ TC ]
12	— [ TC ]
13	— [ TC ]
14	— [ TC ]
15	— [ TC ]
16	— [ SC ]

**Preliminary Images, *December 2023***



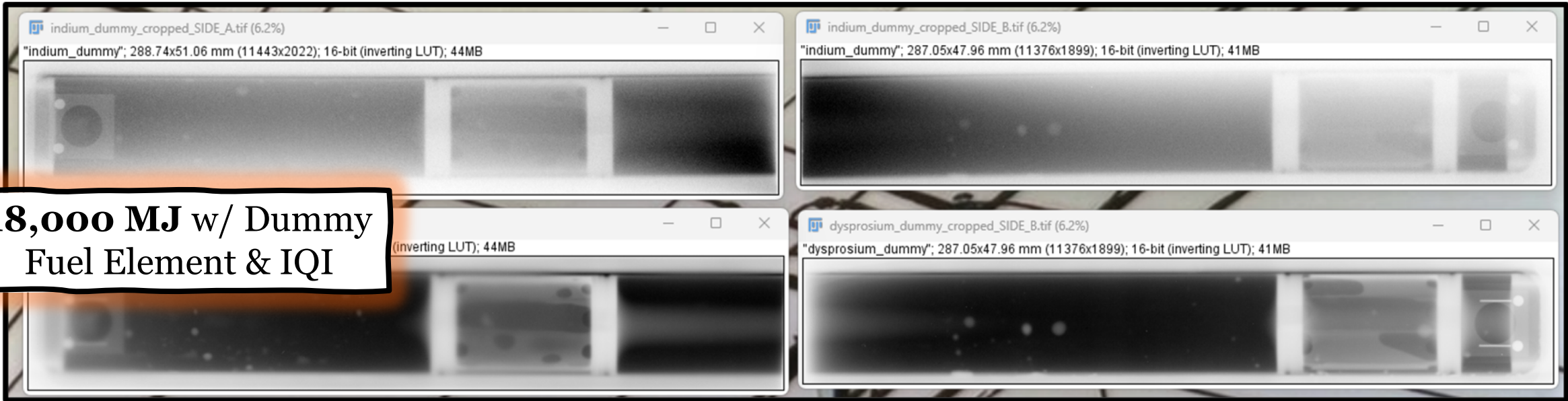
**9,000 MJ w/ IQI & BPI  
on PLA Foil Holder**



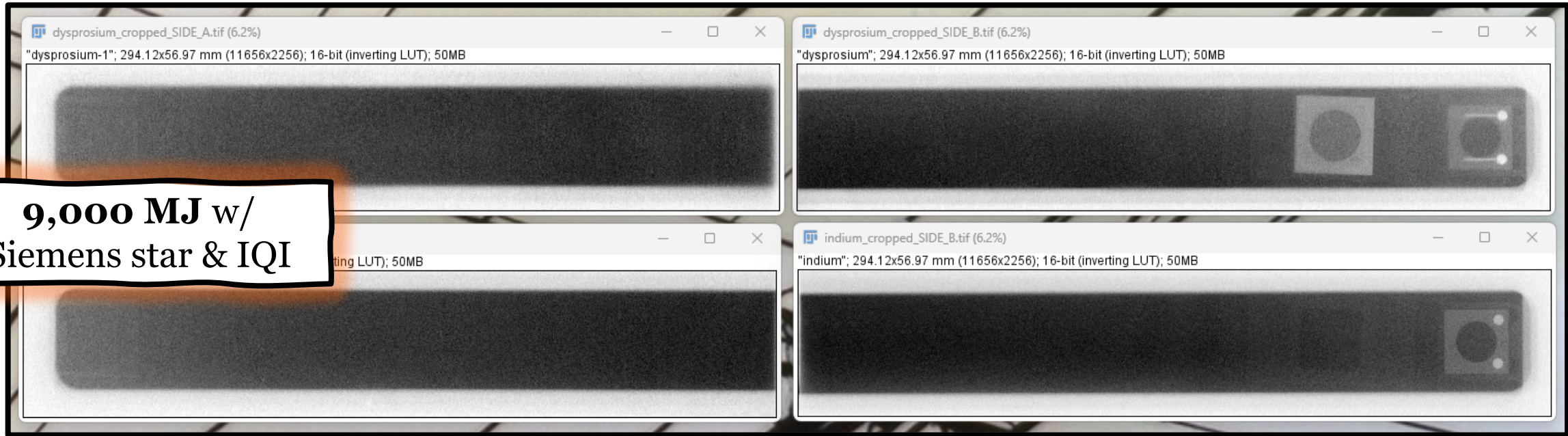


# Secondary Images, December 2023

**18,000 MJ w/ Dummy Fuel Element & IQI**



**9,000 MJ w/ Siemens star & IQI**

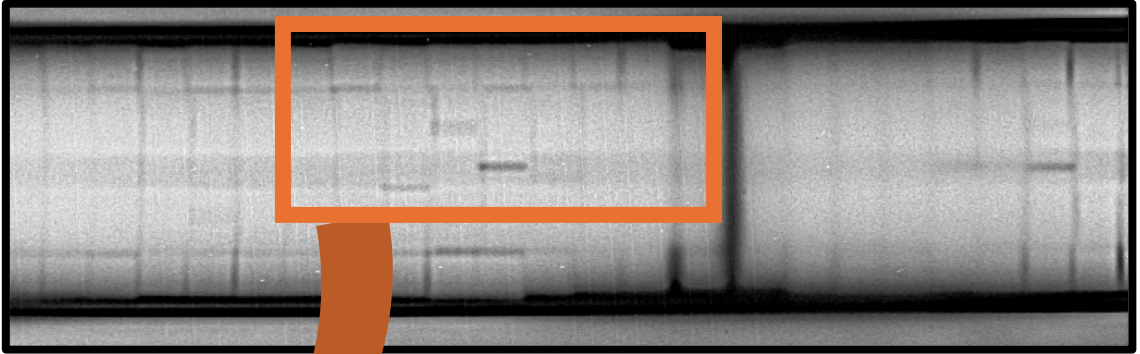
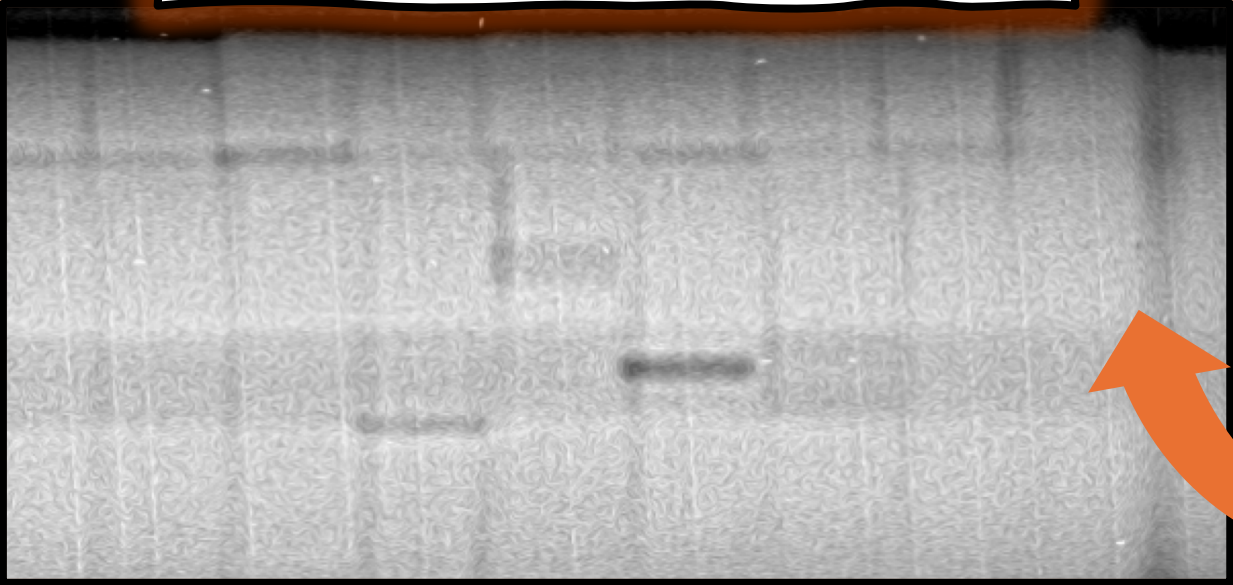


# Third Round Images, *January 2024*

**9,000 MJ w/ Siemens star & IQI**

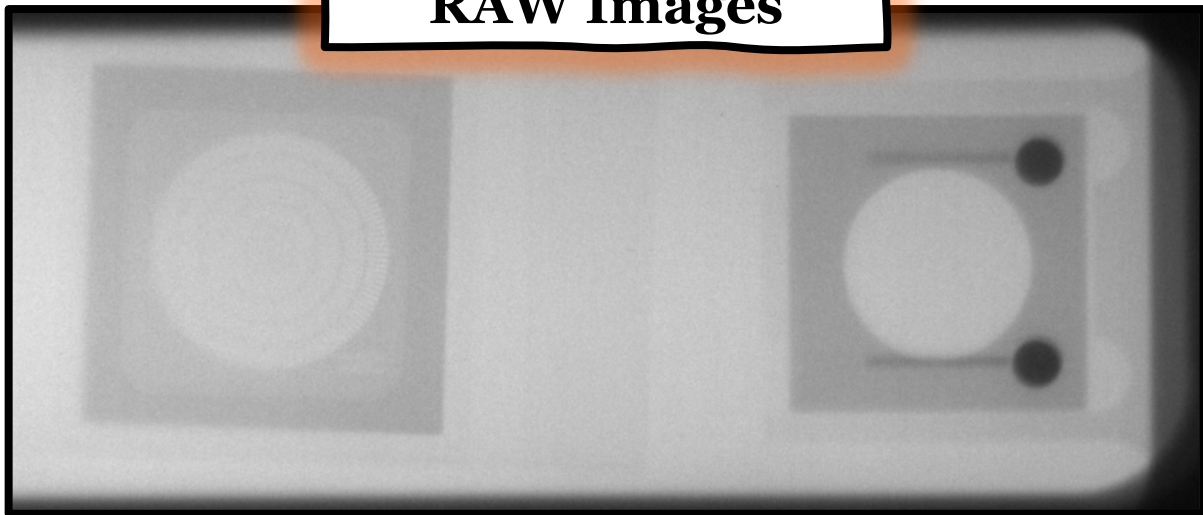


**20,000 MJ w/ Fresh Fuel Element**



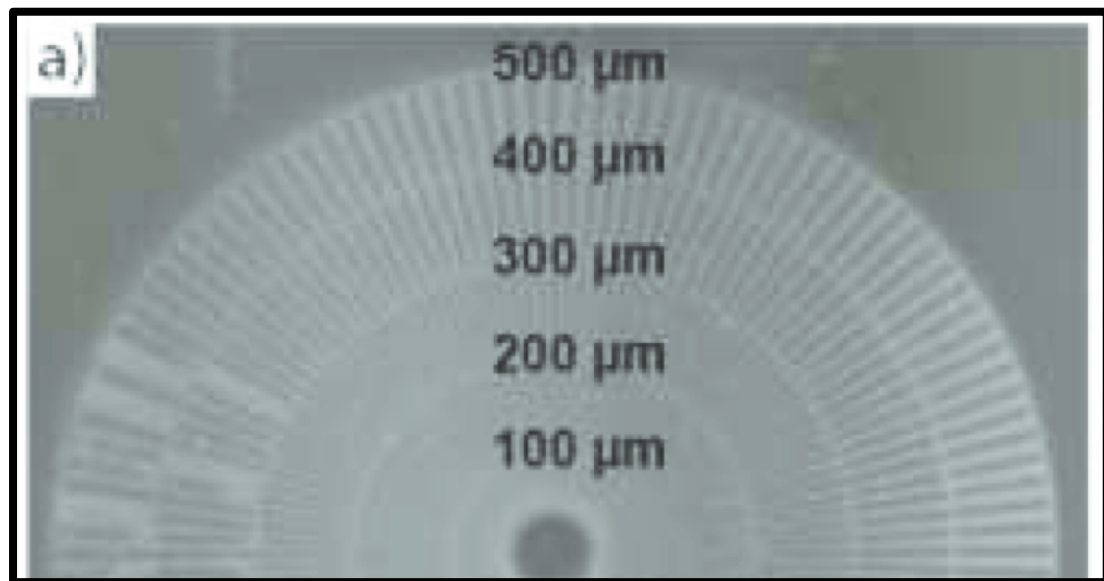
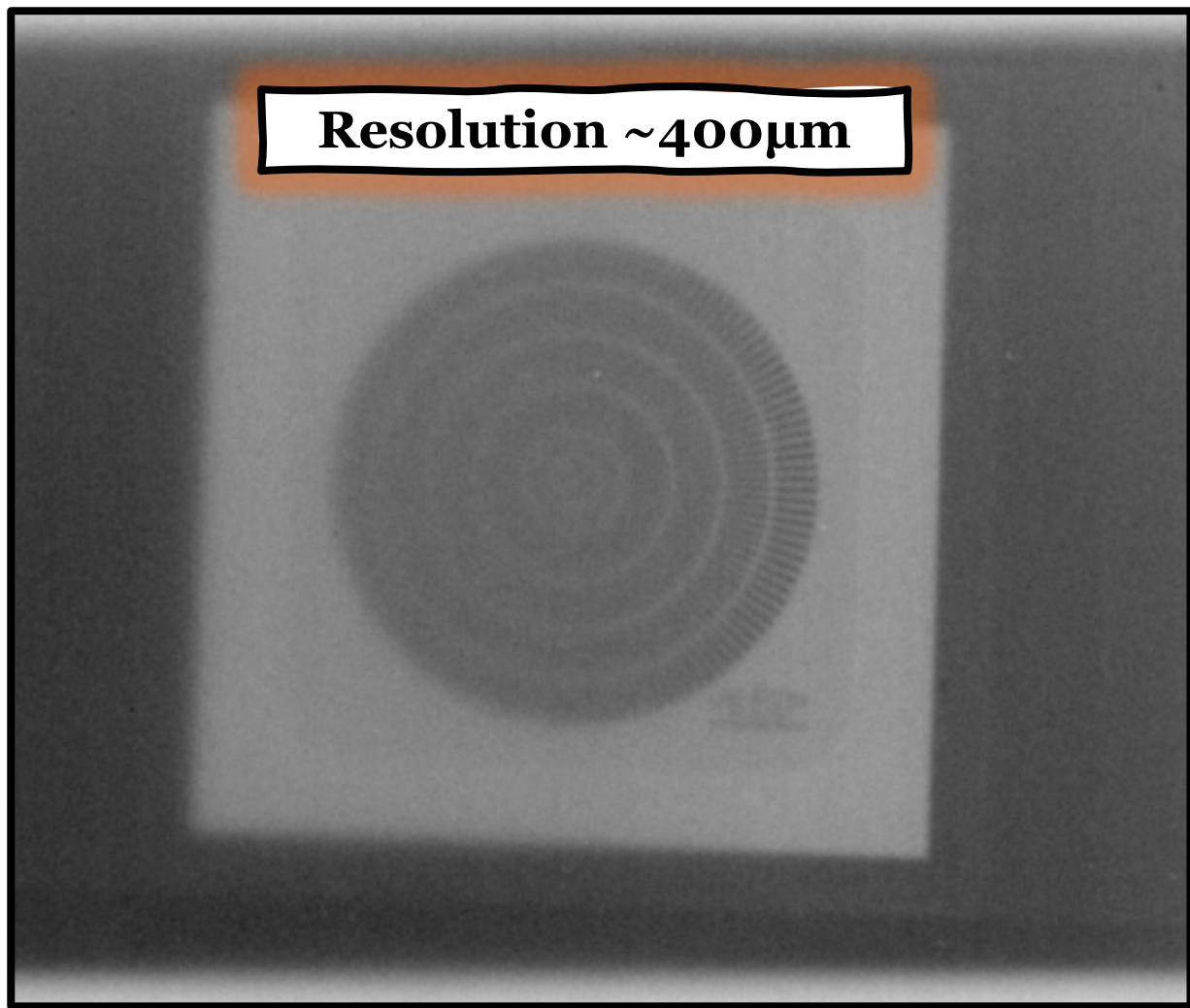


**Combined Dy + In  
RAW Images**

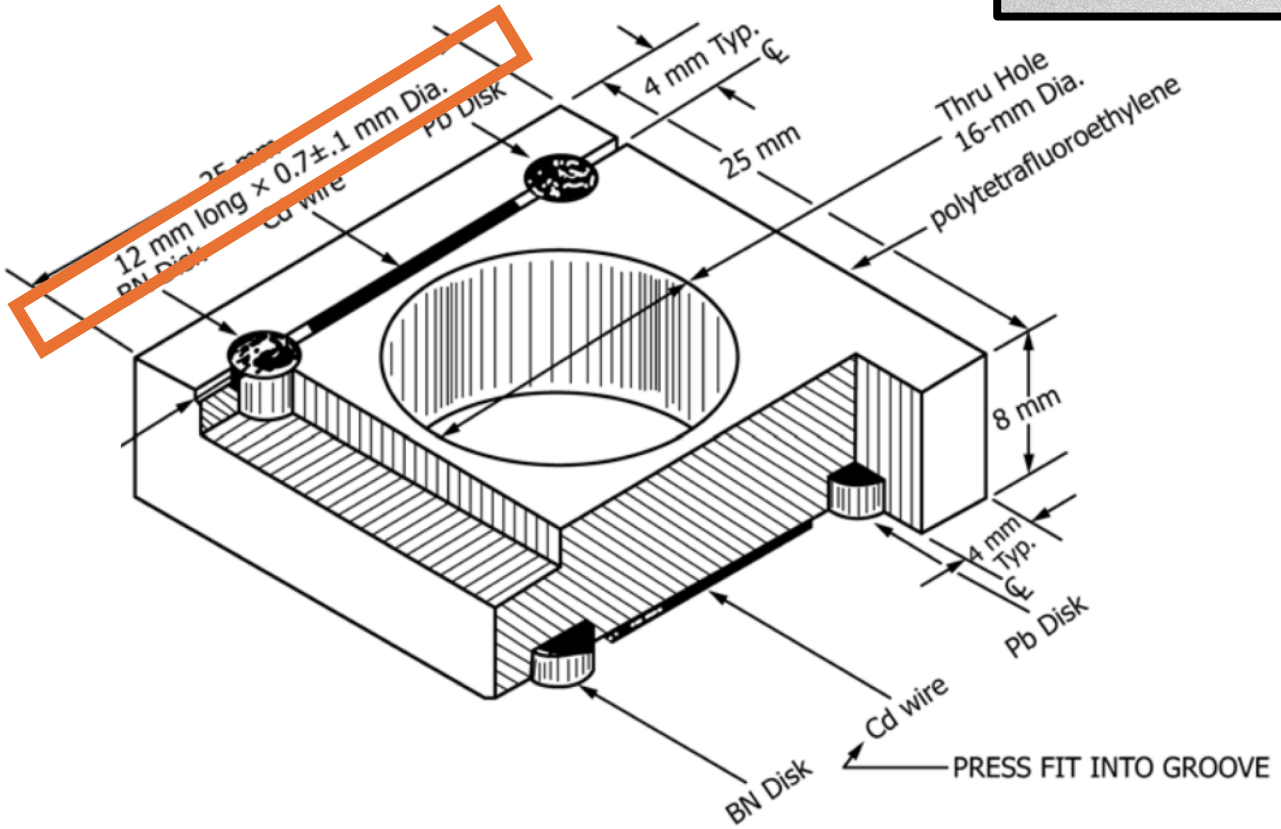
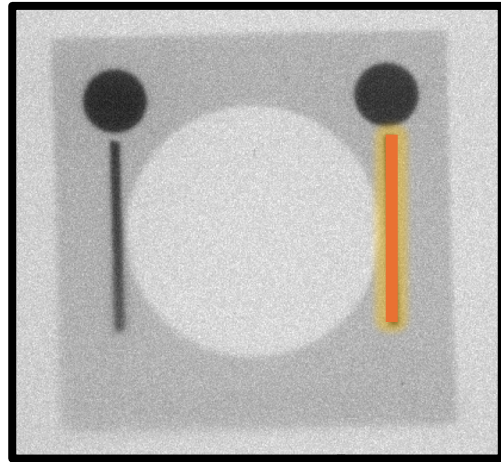


**Preliminary Resolution  
Evaluation, *December 2023***

**Resolution  $\sim 400\mu\text{m}$**



# Scaling the Data



DIUM20K\_RIGHT.tif (75%)  
nm (11048x1784); 32-bit (inverting LUT); 75MB

### Set Scale

Distance in pixels: 487.0164

Known distance: 12.30

Pixel aspect ratio: 0.999

Unit of length: mm

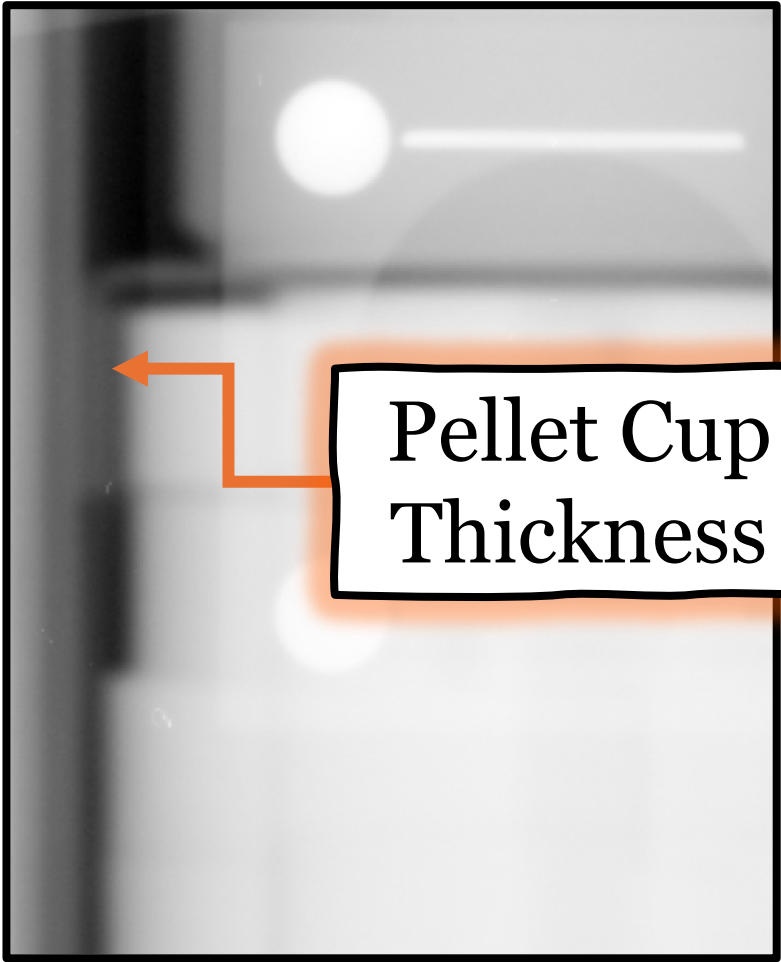
Click to Remove Scale

Global

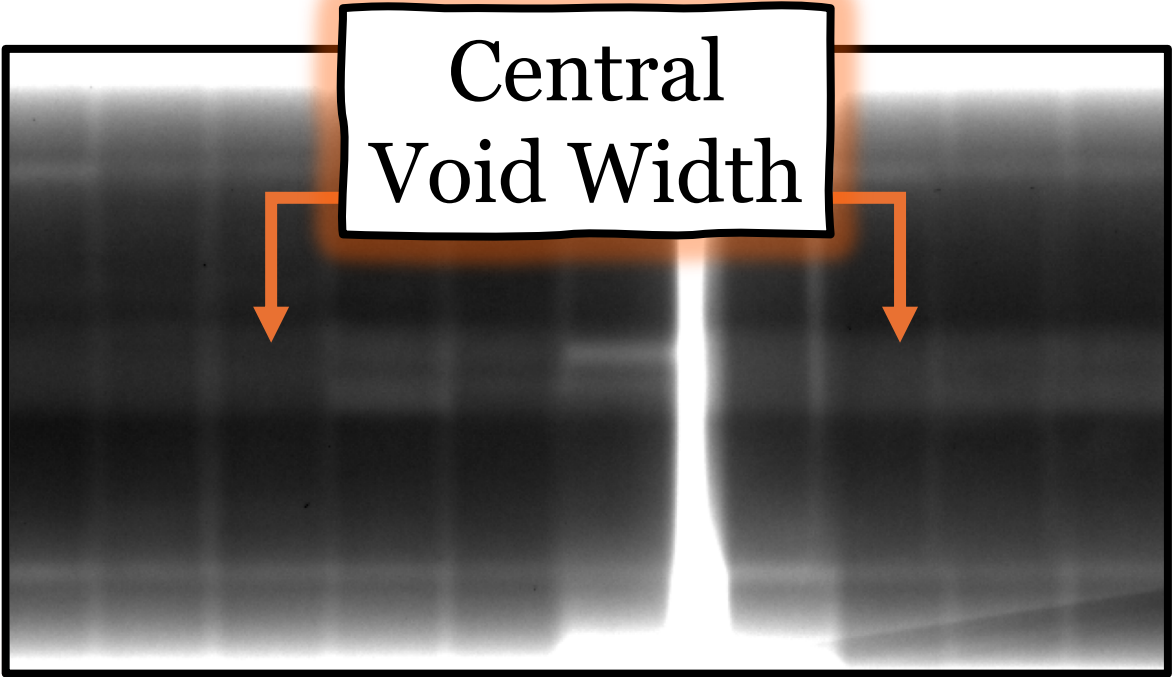
Scale: 39.5974 pixels/mm

OK Cancel Help

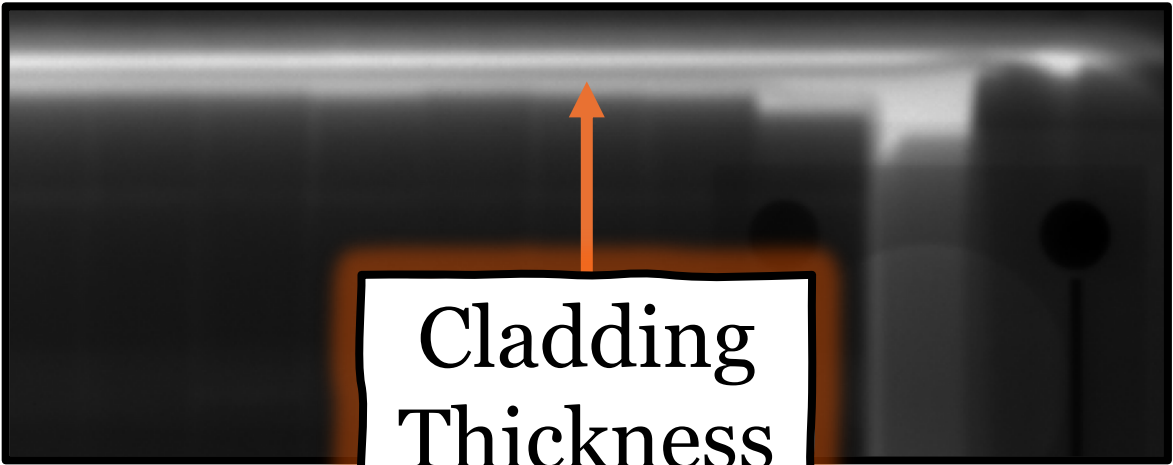
Quantification(s):



Pellet Cup Thickness



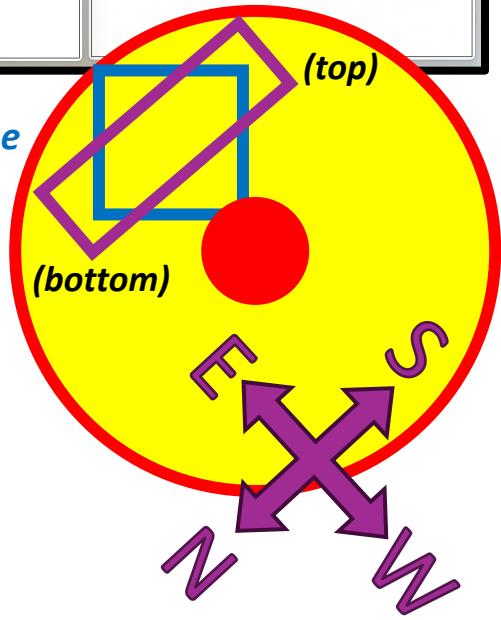
Central Void Width



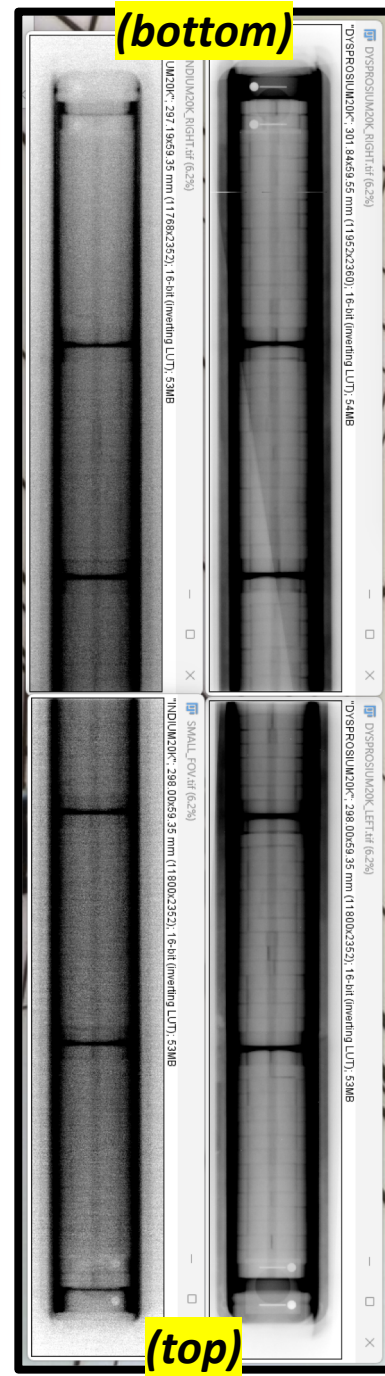
Cladding Thickness



# Translating the Experiment Sheet:

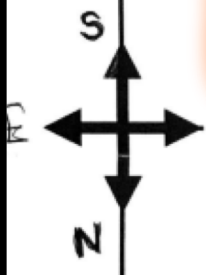


Imaging Plane  
FENICS Cask



Dots Left Side:

	<p><u>DYSPROSIUM</u></p>	<p>Time On <u>7409</u></p>	<p>Time Off <u>729</u></p>
	<p><u>INDIUM</u></p>	<p>Time On <u>105</u></p>	<p>Time Off <u>721</u></p>
		<p>Time On _____</p>	<p>Time Off _____</p>



# Summary of Knowledge

- Processing images time consuming and **highly variable** given the scanner feeding mechanism; does not leave a significant amount of room for automation
- Pellets **moved very little** (rotation/translation) throughout lifetime
- Several measurements should be collected (resolution, beam flatness, flux magnitude) to **characterize the ACRR beam**
- Other measurements include dimensions of the fuel, volumetric estimations of inner-void, and cup dimensions to compare the fuel to the manufacturing specifications

# Thank You!

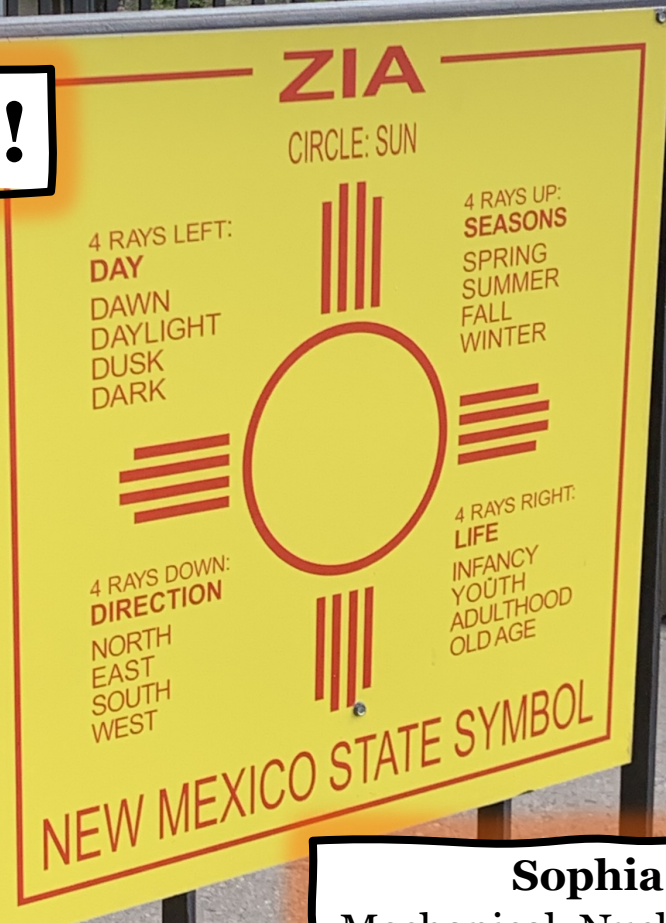
This work was funded by Sandia National Laboratory under contract purchase order 2449465. The authors are incredibly grateful for their support.



Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC (NTESS), a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration (DOE/NNSA) under contract DE-NA0003525. This written work is authored by an employee of NTESS. The employee, not NTESS, owns the right, title and interest in and to the written work and is responsible for its contents. Any subjective views or opinions that might be expressed in the written work do not necessarily represent the views of the U.S. Government. The publisher acknowledges that the U.S. Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this written work or allow others to do so, for U.S. Government purposes. The DOE will provide public access to results of federally sponsored research in accordance with the DOE Public Access Plan.”



**Thank you!**



**Sophia Brodish**  
Mechanical, Nuclear Engineer, RHP  
brodishs@oregonstate.edu

