

Nuclear Physics Gamma-ray Imaging System for Real-Time Rare Isotope Harvesting, Monitoring and Radiochemical Separation – NP Imager

DE-SC0017245 5/21/2018 – 5/20/2021

Ethan Hull Ph.D PI, CEO and Technical Director

Matt Kiser, Ph.D. Director of Physics

Desmond Longford NP Imager Product Manager and Radiochemist

A collaboration with: ORNL (Jared Johnson, Jon Garrison)

MURR (Heather Hennkens and Alan Ketring)

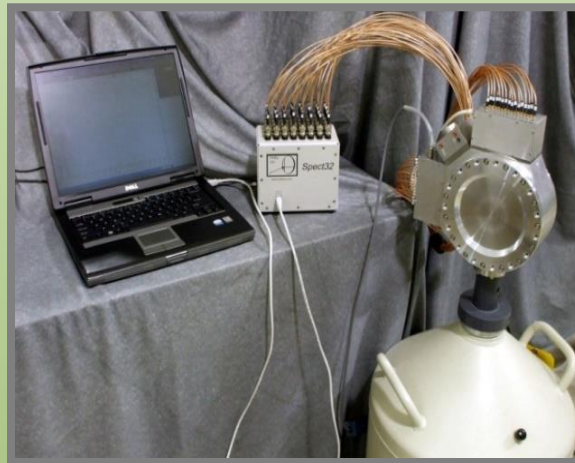
NSCL (Greg Severin)

- **PHDS Co. Introduction**
- **NP Imager Concept**
- **Continued NP Imager Prototype Development**
- ***Sales of NP Imager Products!!***
 - ***Already sold 3 NP Imager systems + 1 pending!!***

Introduction to PHDS Co.



- Est. Fall 2004 – Nuclear and Solid-State Physics Origin
 - History: Custom Nuclear-Physics Detectors like NPX
 - Recently: Modular HPGe Systems like GeGI
- Complete Germanium Detector Manufacturing and R&D
 - Concept and Design
 - HPGe Crystal Growth
 - Detector Fabrication
 - System Integration
 - Software application
 - Sales & Service



2008 NPX (150 lbs.)



2017 GeGI-5 (15 lbs.)



**Fulcrum
(7 lbs.)**

**Specialty
Tactical
(9 lbs.)**



GeGI[®]

Gamma-ray Imaging Spectrometer



HPGe Isotope Identification

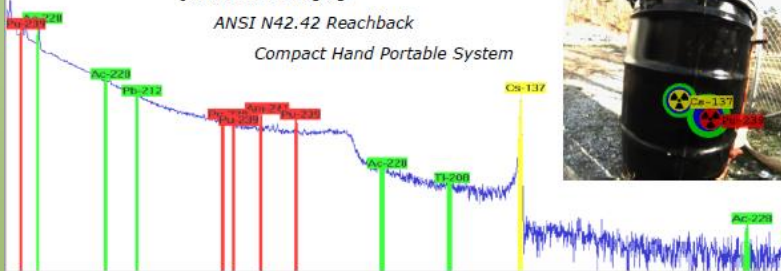
Source Location Imaging

Source Distribution Imaging

Quantitative Imaging

ANSI N42.42 Reachback

Compact Hand Portable System



Fulcrum[®]

Compact HPGe Gamma-ray Spectrometer



HPGe Isotope Identification

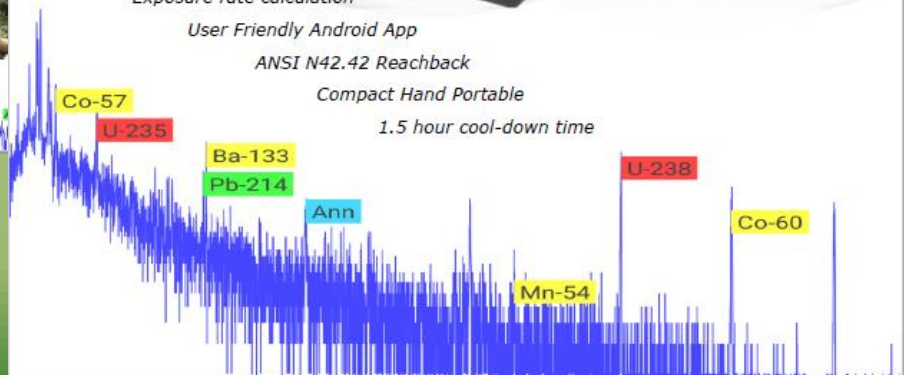
Exposure rate calculation

User Friendly Android App

ANSI N42.42 Reachback

Compact Hand Portable

1.5 hour cool-down time





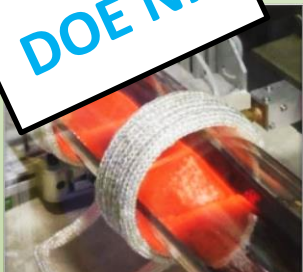
**10,000 ft² Manufacturing
and R&D Facility in
Knoxville, TN**



Vertical manufacturing at PHDS Co.



DOE NP



Ge Zone Refine

DOE NP



HPGe Crystal Growth

DOE NP



Analysis

DOE NP

Commercial



Fabrication

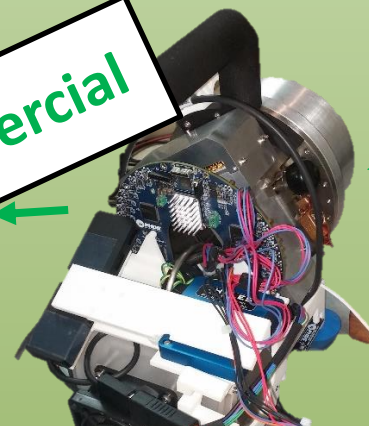
Commercial Products

Commercial

Commercial



Integration



Electronics



Cryogenics



Motivation CBRNE Team Training

^{239}Pu ID and Location



Imager - [20160202_155120-5GMT.img]

File Acquire View Tools Options Show Window Help

Time: 2256
CPS: 0 39 uR/hr

Temp (K): 0.0

Log (Counts)

keV

^{239}Pu

^{137}Cs

Th-232

Th-232

Cs-137

Pu-239

Th-232

Auto:142

Auto:202

Th-232

Pu-239

Pu-239

Ready

Compton

500 μCi ^{137}Cs
+ 2.5 cm Pb

^{239}Pu
1.4 g

^{137}Cs

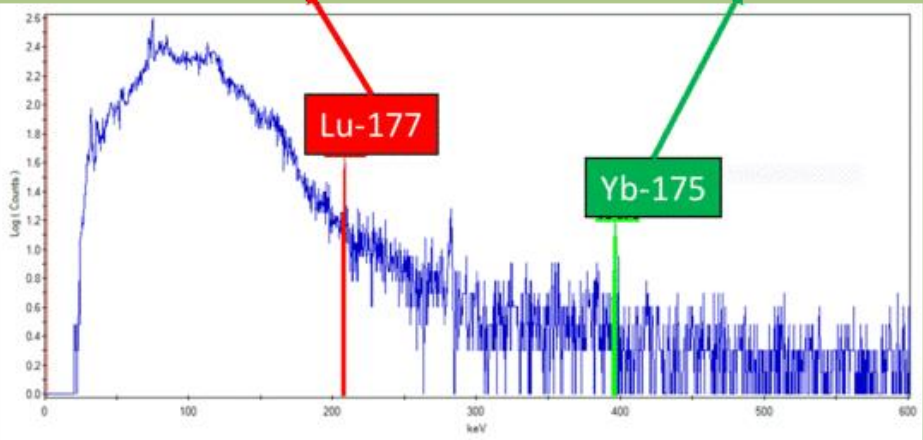
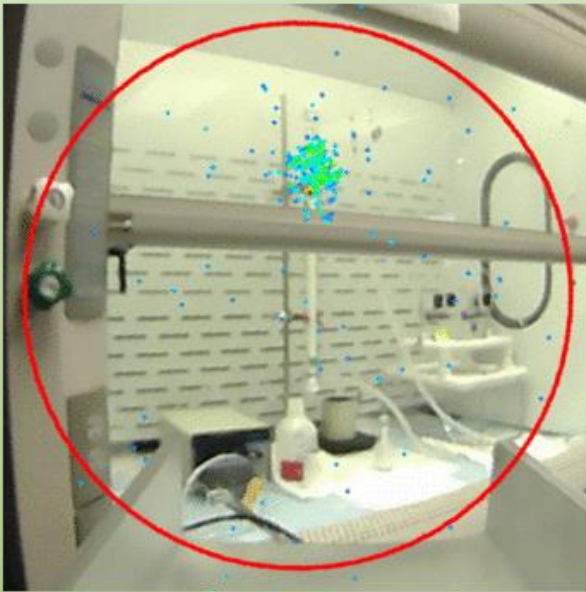
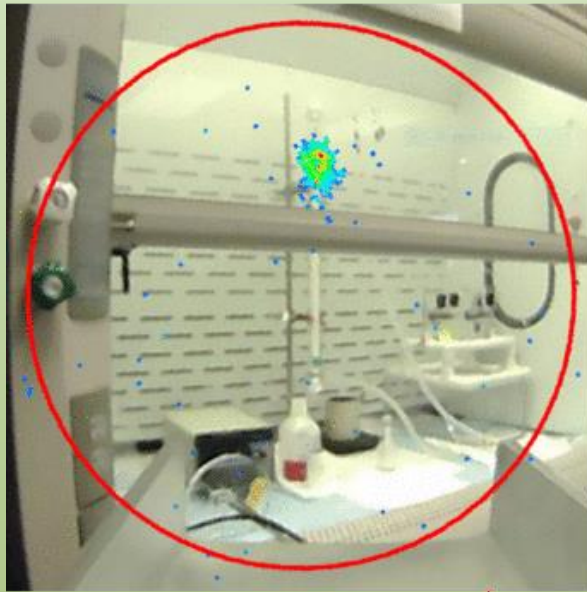
^{239}Pu

Static

Radiochemistry is Dynamic → Things necessarily move
NP Imager combines *Imaging, Spectroscopy and Time*.

$^{177}\text{Lu}/^{175}\text{Yb}$ Column Separation at MURR

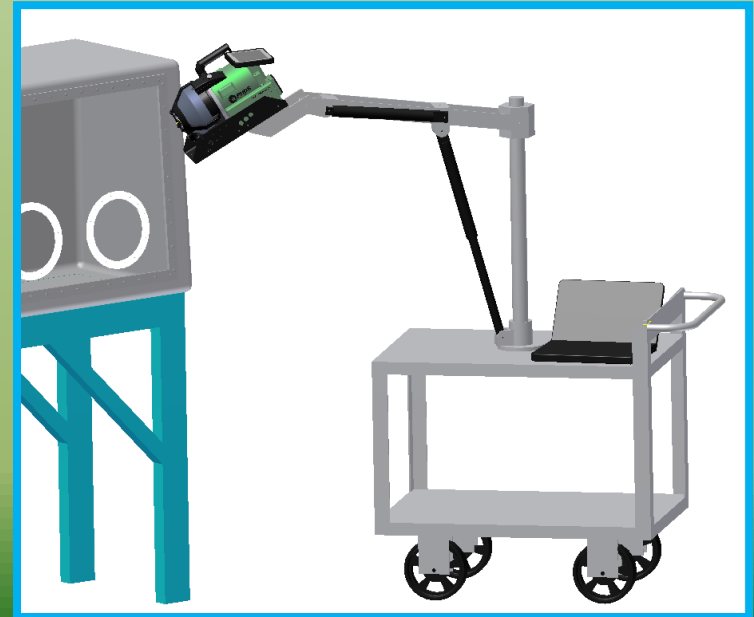
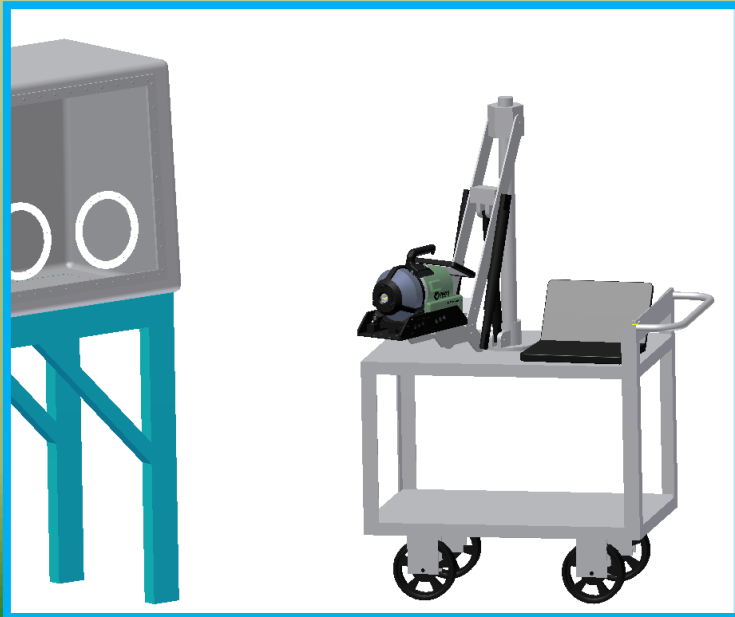
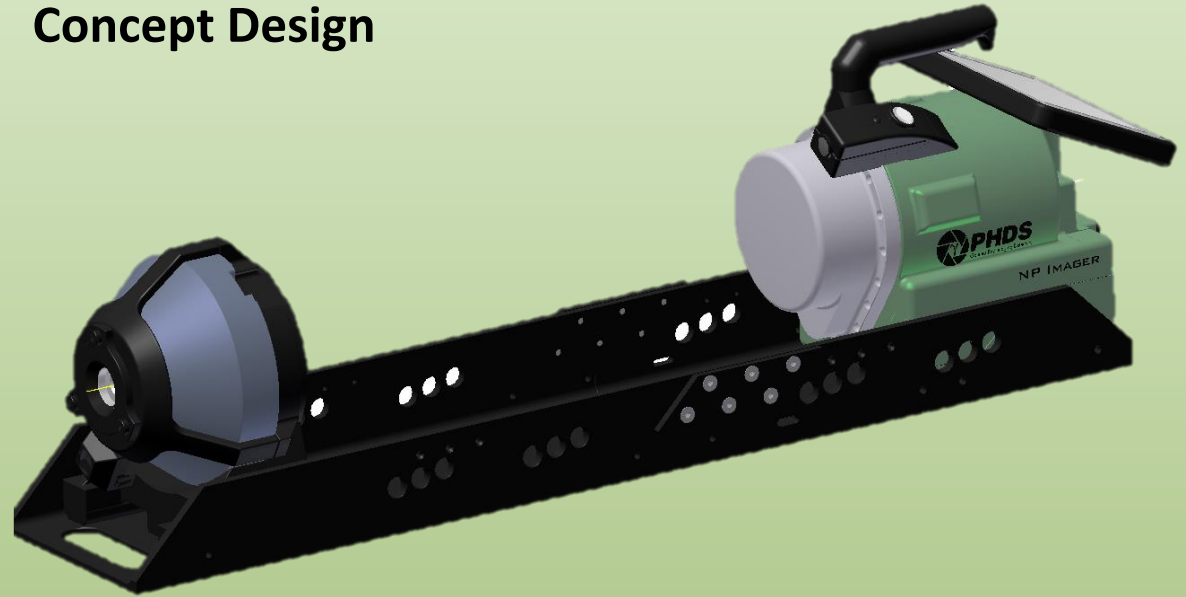
t = 0 - 10 minutes

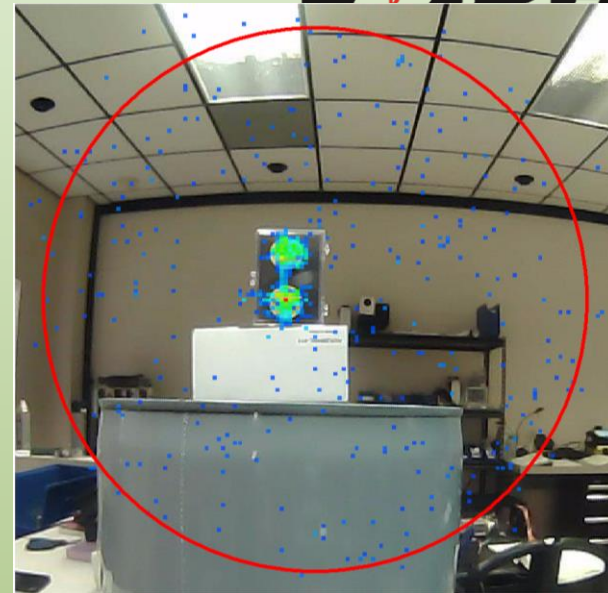
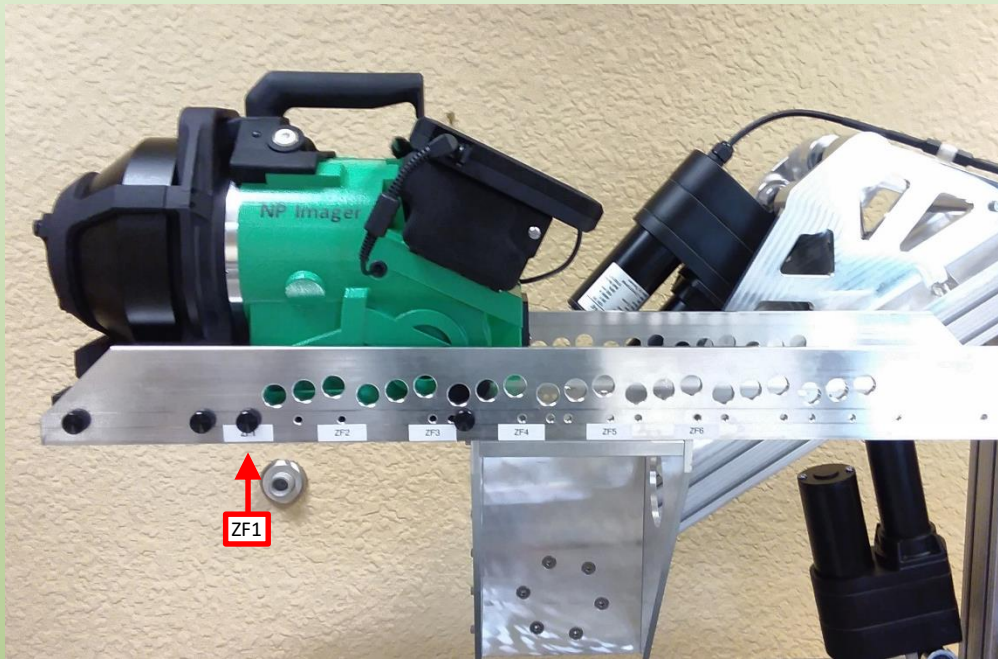


NP Imager Technical Development Phase-II Prototypes

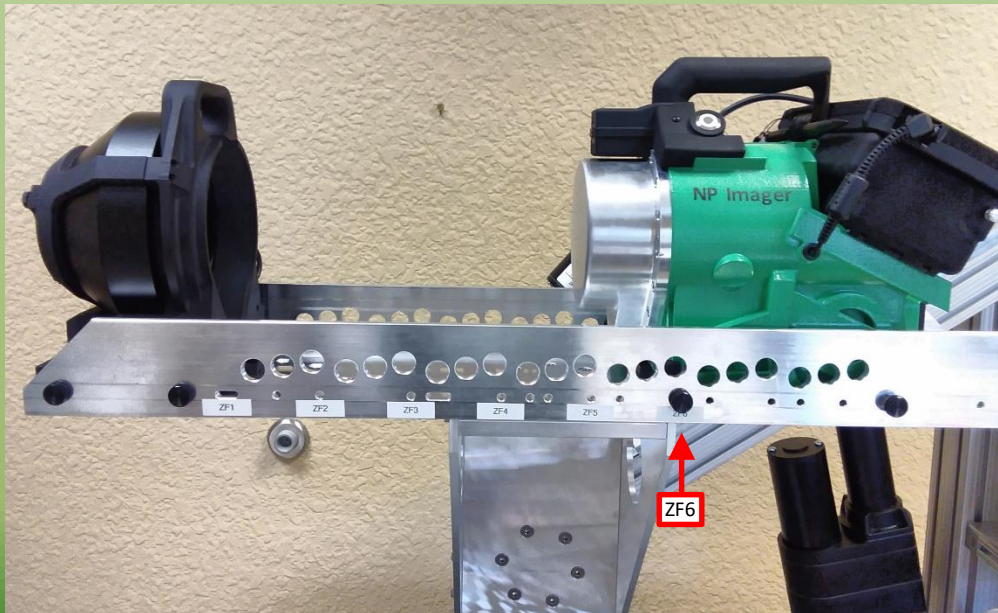


Concept Design





ZF1



ZF6

NSCL Rare Isotope Imaging – NP Imager 102



Imager - [20190510_230705-4GMT-Kr77_129keV.img]

File Acquire View Tools Options Show Window Help

Time: 1003 Live: 0.964 **Saved File** PC:0 SC:0 PU:0 TC:0 RJ:0 F2:0.00

CPS: 0 16 uR/hr Temp(K): N/A

Threshold 0 - 100% Distance(m) 1.700 +/- 0.000 Events 46747

Show All Energy Windows

Isotope	Energy (keV)
<input type="checkbox"/> Th-232	57.8
<input type="checkbox"/> Th-232	72.8
<input type="checkbox"/> Auto:87	87.3
<input type="checkbox"/> Amm.	511.0
<input checked="" type="checkbox"/> Kr-77	129.1
<input type="checkbox"/> Th-232	85.4
<input type="checkbox"/> Auto:138	137.8
<input type="checkbox"/> NEU:847	845.9
<input type="checkbox"/> Auto:143	143.3
<input type="checkbox"/> Auto:286	286.0
<input type="checkbox"/> Auto:375	375.1
<input type="checkbox"/> Auto:417	417.1
<input type="checkbox"/> Auto:635	635.1
<input type="checkbox"/> Th-232	911.2
<input type="checkbox"/> Auto:820	819.7
<input type="checkbox"/> Auto:900	900.4
<input type="checkbox"/> Th-232	1501.6
<input type="checkbox"/> Auto:1041	1041.1
<input type="checkbox"/> Auto:1098	1097.7
<input type="checkbox"/> Auto:1294	1294.4
<input type="checkbox"/> Auto:2019	2018.8

Intervening Materials

Material	Density(g... Thick(cm)

ROI Materials

ROI	Material	Density(g... Thick
1		0.0000 20.72
2		0.0000 45.95

ROI	Isotope	Energy	Count	Activity (Ci)	Radioactive Mass (g)	Activity Conc. (Ci/g)
1	Kr-77	129.1	1908	3.92e-03 +/- 9.24e-05	1.83e-04 +/- 4.32e-06	N/A
2	Kr-77	129.1	4718	8.74e-03 +/- 1.67e-04	4.09e-04 +/- 7.82e-06	N/A
BG	Kr-77	129.1	3088			

Units: Curies (Ci)

129 keV 77Kr 3.9 mCi

129 keV 77Kr 8.7 mCi

Ready X=151 Y=11 Rel.Count=0.00

Last year



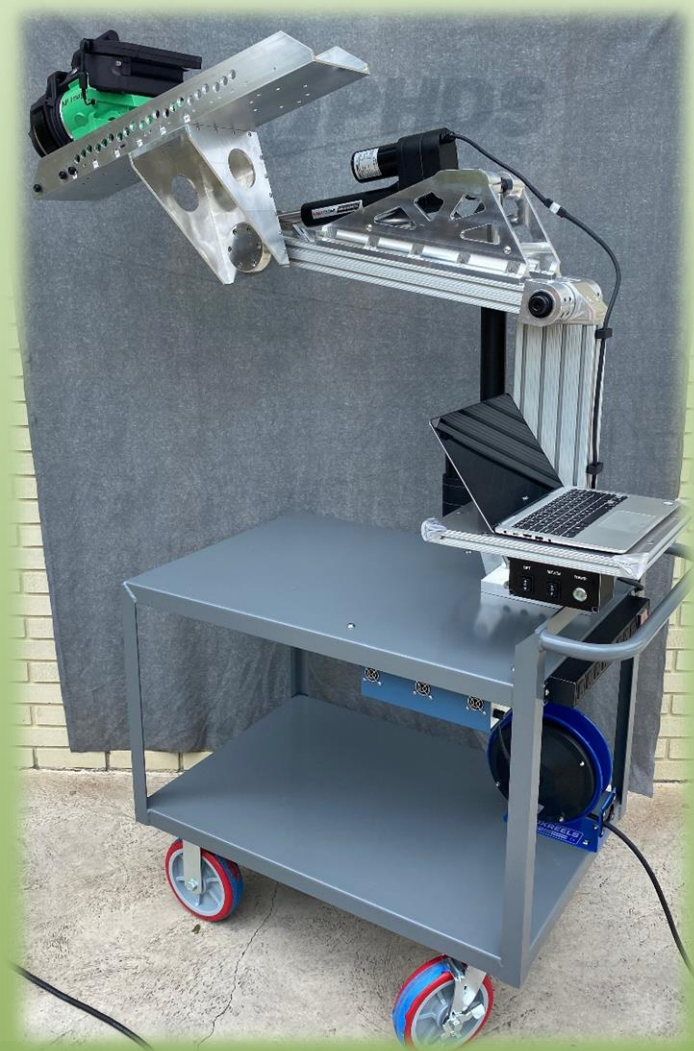
Highlights of the recent year:

1. Continued work on prototype NP Imager systems
 - a. Built a gantry for NP Imager 102
 - b. Delivered NP Imager 102 and gantry to ORNL REDC, October 2019
 - c. Built new NP Imager 103 prototype
 - a. Modified the detector geometry
 - d. NP Imager 103 to NSCL for ^{48}Ca beam imaging measurements
 - i. Several novel isotopes observed during beam and after collection
 - ii. New Imaging observations – ghosts
 - e. Coded Aperture Development – a tool for enhanced imaging sensitivity
2. NP Imager Product Development
 - a. Sold 3 (soon 4) Commercial NP Imager Systems
 - b. NP Imager was featured at the RRMCM in October 2019

Built a gantry for NP Imager 102

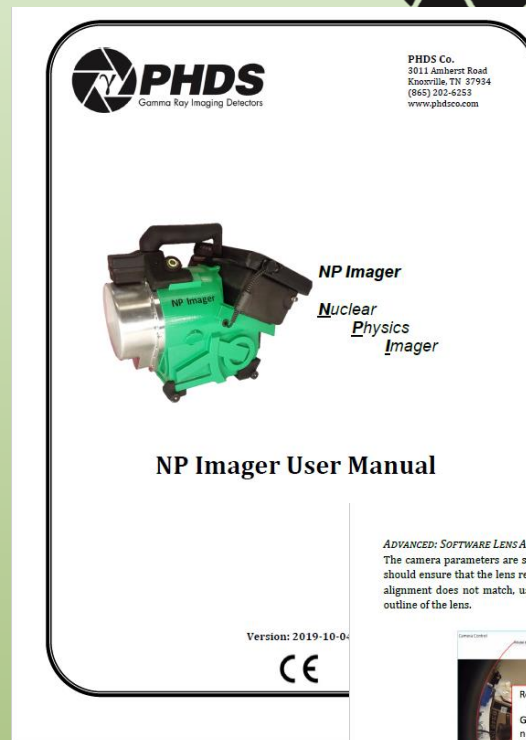
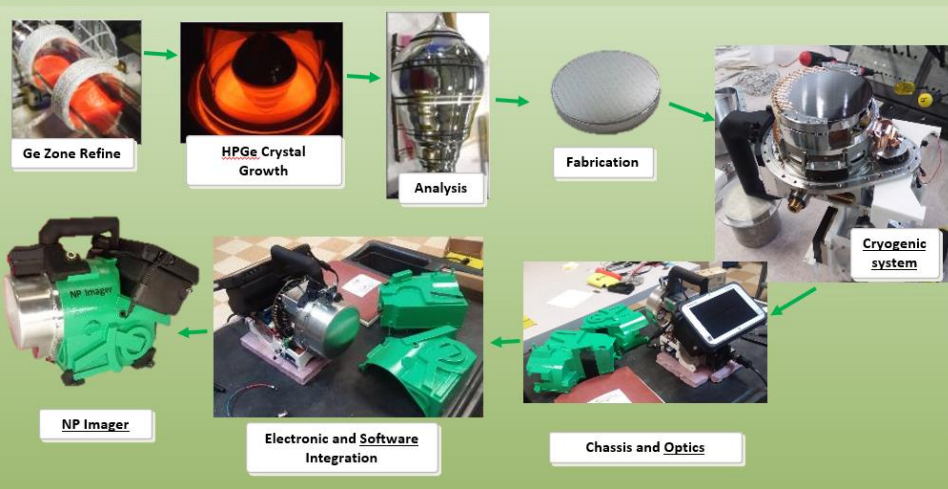


Built a gantry for NP Imager 102



Delivered NP Imager 102 + Gantry to ORNL REDC, October 2019

1. REDC Gathered ~ 15 people
2. Presentation of PHDS Co. Technology - EH
3. Training Presentation – DL (MK)
NP Imager User Manual Refinements
4. REDC has been using their NP Imager for daily activities



ADVANCED: SOFTWARE LENS ALIGNMENT

The camera parameters are set at the Factory and should not need user adjustment. However, the user should ensure that the lens region of the camera image is bounded by the red circle. If the lens software alignment does not match, use the arrows and sizing buttons to align the red circle with the circular outline of the lens.



OPERATION OF THE NP IMAGER GANTRY

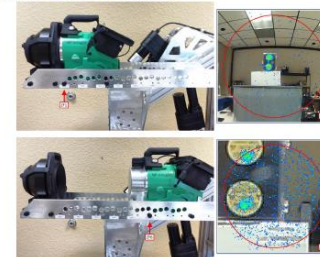
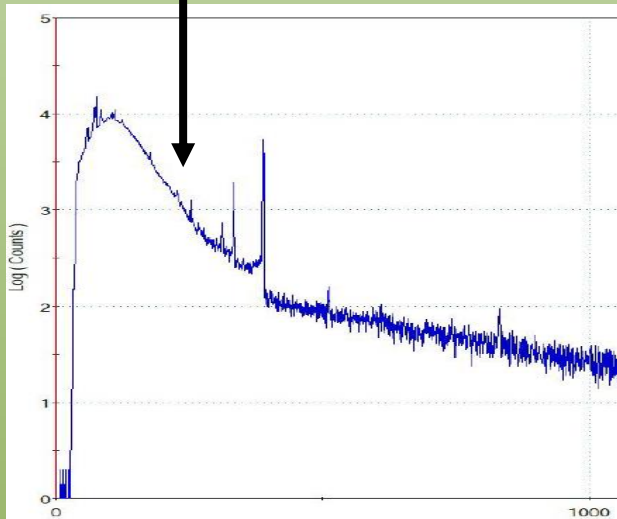


FIGURE 6. THE APERTURE AND DETECTOR CAN BE ALIGNED AT VARIOUS ZOOMFACTOR SETTINGS USING THE GANTRY IMAGING PLATE. THE LEFT-HAND VIEWS SHOW THE CONFIGURATION FOR ZOOMFACTORS OF 1 AND 6. THE RIGHT-HAND VIEWS SHOW IMAGES MADE OF THE SAME SOURCE CONFIGURATION WITH ZOOMFACTORS OF 1 AND 6. NOTE THE BLACK THUMB SCREWS RIGIDLY HOLD THE APERTURE AND DETECTOR IN THE PLATE.



$^{227}\text{Th} - ^{239}\text{Pu}$ Separation

236 keV
 ^{227}Th



^{227}Th

Built new NP Imager 103 prototype

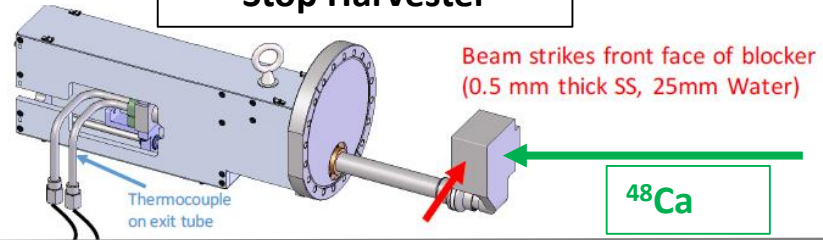


NP Imager Process Modification:

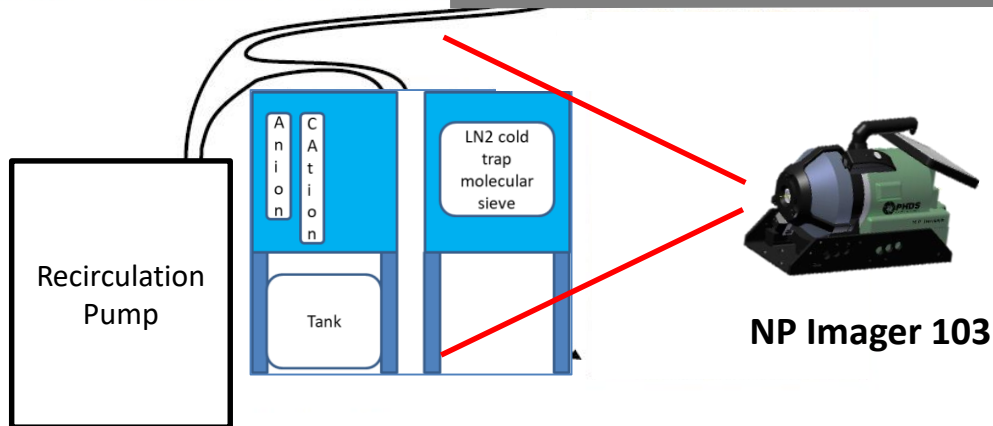
NSCL ^{48}Ca beam December 20, 2019

PHDS Co.: Desmond Longford
(Radiochemist and NP Imager Product Manager), Ethan Hull (CEO, PI)
MSU/NSCL: Greg Severin, Katharina Domnanich, David Morrissey, Brad Sherrill, Chloe, Colton, Wes Walker

Recirculating Beam Stop Harvester



vault wall



NP Imager 103 to NSCL for 48Ca beam imaging measurements



1.9 meters from the columns and gas trap

NP Imager 103 to NSCL for 48Ca beam imaging measurements



Imager - [20191221_174557-5GMT_4th irr segment.img]

File Acquire View Tools Options Show Window Help

Time: 408 Live: 0.921 Saved File PC:0 SC:0 PU: 0
CPS: 0 432 uR/hr Temp(K): N/A TC:0 RJ:0 F2: 0.00

Threshold 0 -100% Distance(cm) 1.910 +/-

Events 74998 Search Pixels Edit ROIs Switch to Polygon ROIs

Show All Energy Windows

Isotope	Energy (keV)
<input checked="" type="checkbox"/> Be-7	477.6
<input checked="" type="checkbox"/> Sc-47	159.4
<input checked="" type="checkbox"/> K-43	1274.5
<input checked="" type="checkbox"/> Co-60	1332.5
<input checked="" type="checkbox"/> K-43	1463.1
<input checked="" type="checkbox"/> K-42	1524.7
<input checked="" type="checkbox"/> Sc-44	1157.0
<input checked="" type="checkbox"/> Sc-44m	271.1
<input checked="" type="checkbox"/> Sc-48	983.5
<input checked="" type="checkbox"/> Sc-48	1312.1
<input checked="" type="checkbox"/> Na-24	1368.6
<input checked="" type="checkbox"/> Mg-28	941.7
<input checked="" type="checkbox"/> Mg-28	400.6
<input checked="" type="checkbox"/> Ar-41	1293.6
<input checked="" type="checkbox"/> Ca-47	1297.1
<input checked="" type="checkbox"/> S-38	1941.9
<input checked="" type="checkbox"/> Co-60	1173.2
<input checked="" type="checkbox"/> Ann.	511.0
<input checked="" type="checkbox"/> Ca-47	807.9
<input checked="" type="checkbox"/> K-45	174.3

Intervening Materials

Material	Density(g... Thick(cm)
----------	------------------------

ROI Materials

ROI	Material	Density(g... Thick
-----	----------	--------------------

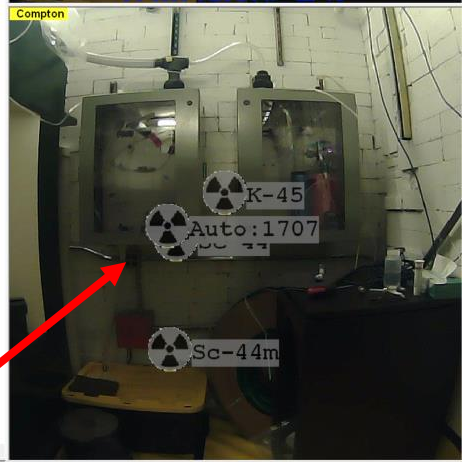
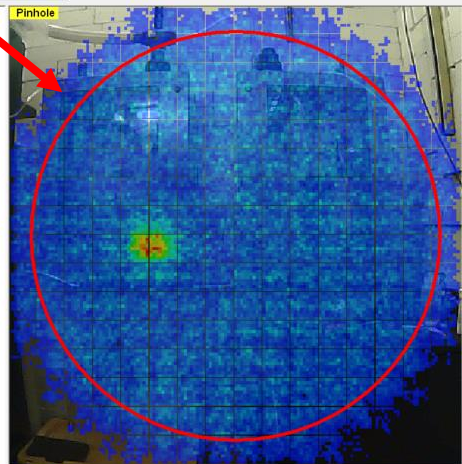
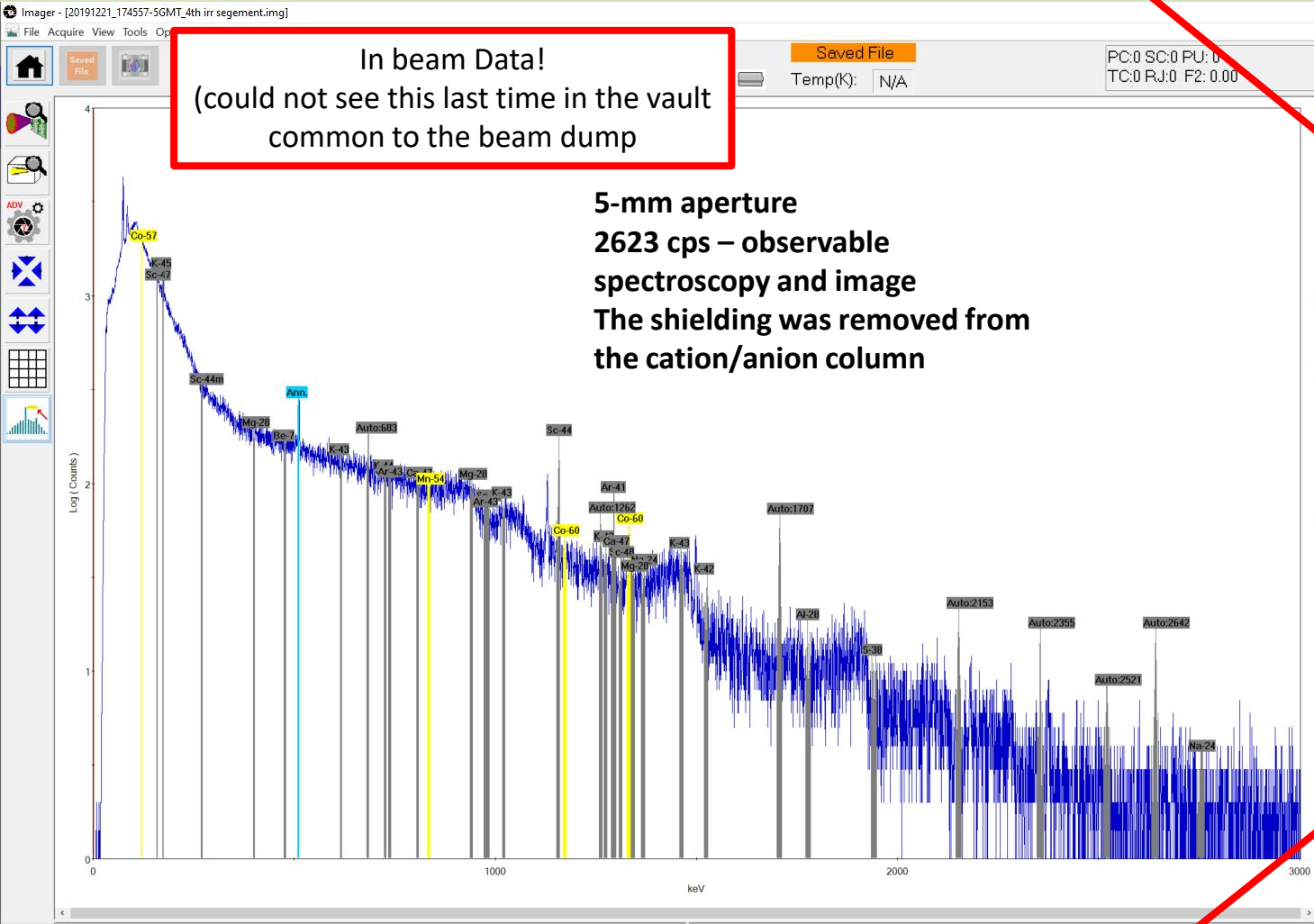
Units Curies (Ci)

ROI	Isotope	Energy	Count	Activity (Ci)	Radioactive Mass (g)	Activity Conc. (Ci/g)
-----	---------	--------	-------	---------------	----------------------	-----------------------

There are no items to show in this view.

Ready

Pinhole Image



Compton Image

Imager - [20191221_174557-5GMT_4th irr segment.img]

File Acquire View Tools Options Show Window Help

Time: 408 Live: 0.921 Saved File

CPS: 0 432 uR/hr Temp(K): N/A

PC:0 SC:0 PU: 0
TC:0 RJ:0 F2: 0.00

Threshold: 0 - 100 % Distance(m): 1.910 +/-

Events: 74998 Search Pixels Edit ROIs Switch to Polygon ROIs

Show All Energy Windows

Isotope	Energy (keV)
<input checked="" type="checkbox"/> Be-7	477.6
<input checked="" type="checkbox"/> Sc-47	159.4
<input checked="" type="checkbox"/> K-43	1274.5
<input checked="" type="checkbox"/> Co-60	1332.5
<input checked="" type="checkbox"/> K-43	1463.1
<input checked="" type="checkbox"/> K-42	1524.7
<input checked="" type="checkbox"/> Sc-44	1157.0
<input checked="" type="checkbox"/> Sc-44m	271.1
<input checked="" type="checkbox"/> Sc-48	983.5
<input checked="" type="checkbox"/> Sc-48	1312.1
<input checked="" type="checkbox"/> Na-24	1368.6
<input checked="" type="checkbox"/> Mg-28	941.7
<input checked="" type="checkbox"/> Mg-28	400.6
<input checked="" type="checkbox"/> Ar-41	1293.6
<input checked="" type="checkbox"/> Ca-47	1297.1
<input checked="" type="checkbox"/> S-38	1941.9
<input checked="" type="checkbox"/> Co-60	1173.2
<input checked="" type="checkbox"/> Ann.	511.0
<input checked="" type="checkbox"/> Ca-47	807.9
<input checked="" type="checkbox"/> K-45	174.3

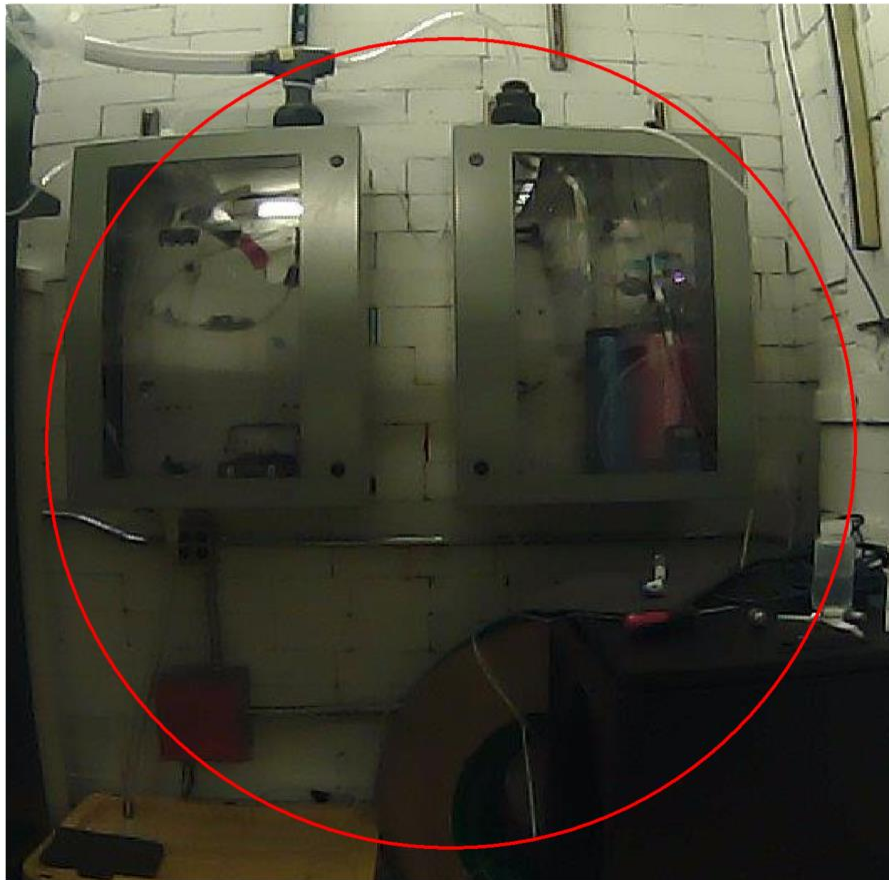
Intervening Materials

Material	Density(g... Thick(cm)

ROI Materials

ROI	Material	Density(g... Thick

There are no items to show in this view.



Units: Curies (Ci)

ROI	Isotope	Energy	Count	Activity (Ci)	Radioactive Mass (g)	Activity Conc. (Ci/g)
There are no items to show in this view.						

Imager - [20191221_174557-5GMT_4th irr segment.img]

File Acquire View Tools Options Show Window Help

Time: 408 Live: 0.928

Saved File

PC:0 SC:0 PU: 0
TC:0 RJ:0 F2: 0.00

CPS: 0 187 uR/hr

Temp(K): N/A

Threshold 0 -100 % Distance(m) 1.910 +/- 0.000

Events 9599 Search Pixels Edit ROIs Switch to Polygon ROIs

Show All Energy Windows

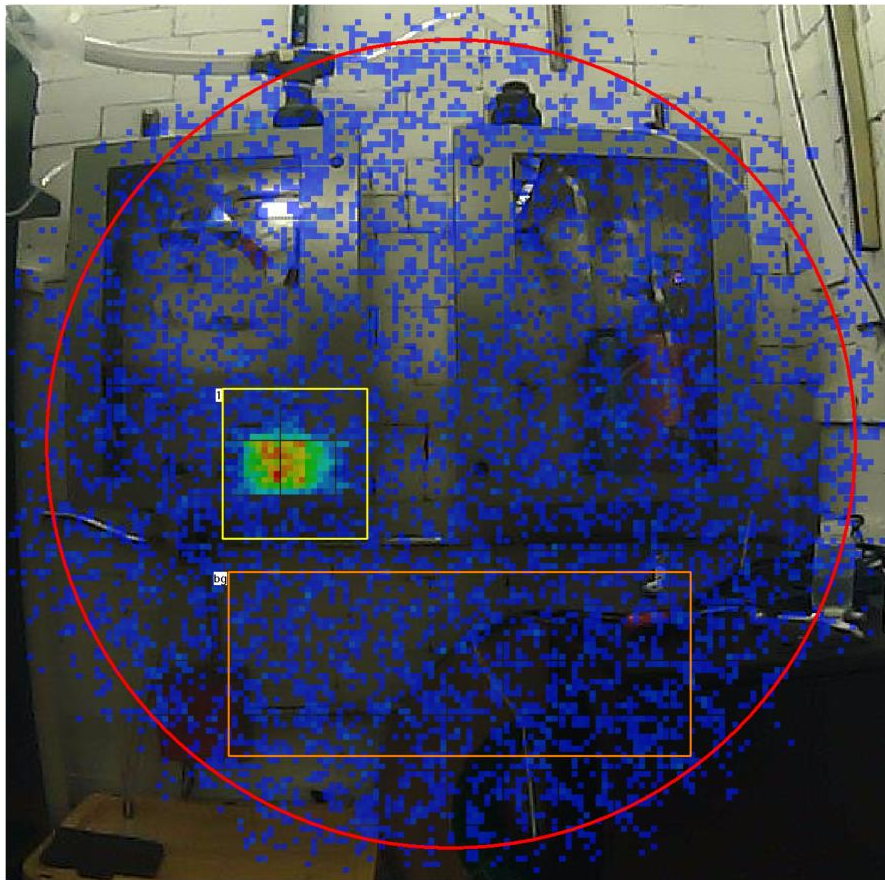
Isotope	Energy (keV)
<input type="checkbox"/> Be-7	477.6
<input type="checkbox"/> Sc-47	159.4
<input type="checkbox"/> K-43	1274.5
<input type="checkbox"/> Co-60	1332.5
<input type="checkbox"/> K-43	1463.1
<input type="checkbox"/> K-42	1524.7
<input type="checkbox"/> Sc-44	1157.0
<input type="checkbox"/> Sc-44m	271.1
<input type="checkbox"/> Sc-48	983.5
<input type="checkbox"/> Sc-48	1312.1
<input type="checkbox"/> Na-24	1368.6
<input type="checkbox"/> Mg-28	941.7
<input type="checkbox"/> Mg-28	400.6
<input type="checkbox"/> Ar-41	1293.6
<input type="checkbox"/> Ca-47	1297.1
<input type="checkbox"/> S-38	1941.9
<input type="checkbox"/> Co-60	1173.2
<input type="checkbox"/> Ann.	511.0
<input type="checkbox"/> Ca-47	807.9
<input checked="" type="checkbox"/> K-45	174.3

Intervening Materials

Material	Density(g...	Thick(cm)

ROI Materials

ROI	Material	Density(g...	Thick
1		0.0000	37.23



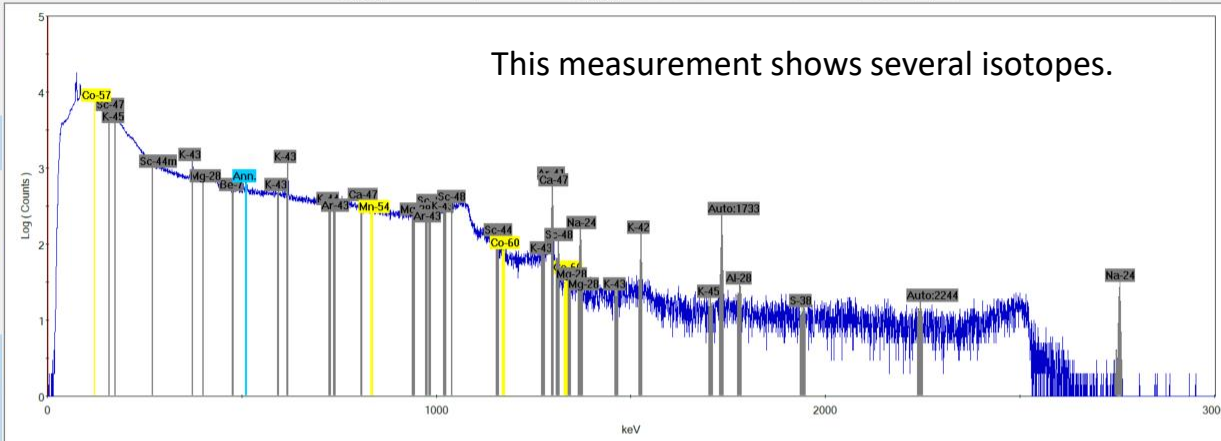
ROI	Isotope	Energy	Count	Activity (Ci)	Units	Curies (Ci)	Radioactive Mass (g)	Activity Conc. (Ci/g)
1	K-45	174.3	2420	1.05e-03 +/- 2.19e-05	0 +/- 0	N/A		
BG	K-45	174.3	1086					

5-mm aperture
1.05 mCi – ⁴⁵K (17 min)
⁴⁵K dominant in this collection

Ready

X=53 Y=8 Rel.Count=0.00

Time: 3857 Live: 0.951 Saved File PC:0 SC:0 PU: 0
 CPS: 0 6 uR/hr Temp(K): N/A TC:0 RJ:0 F2: 0.00



Detectors: Pixel Total

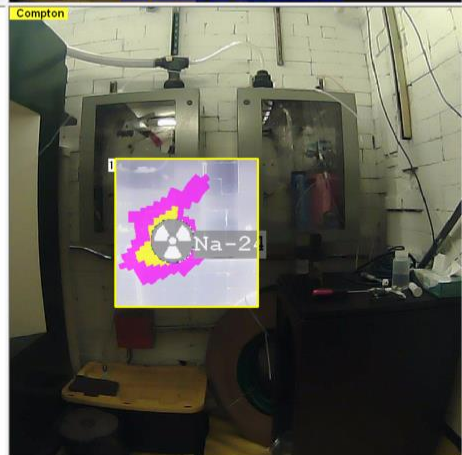
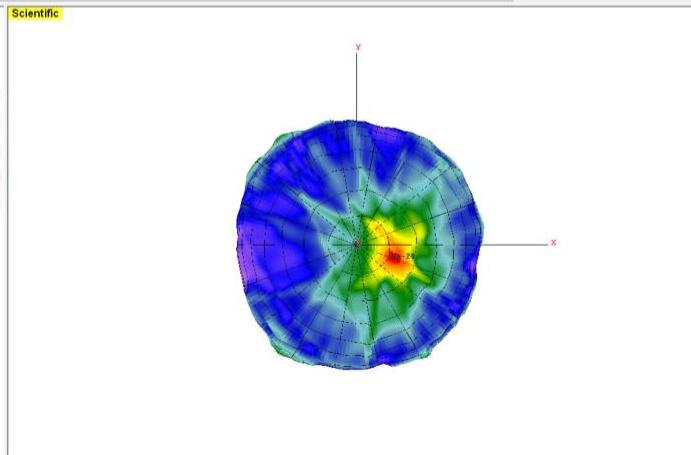
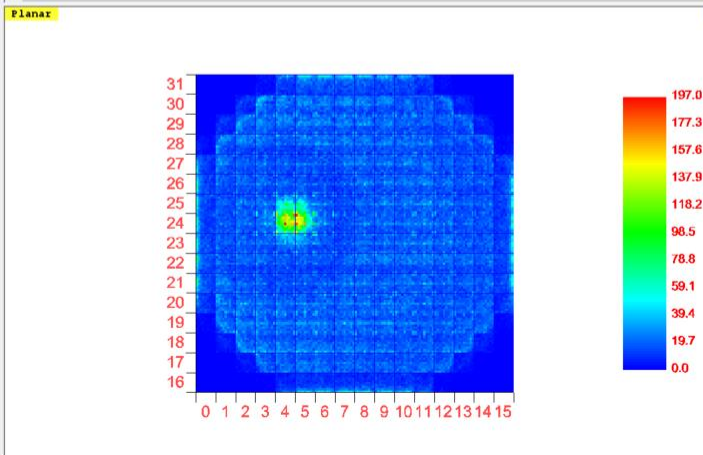
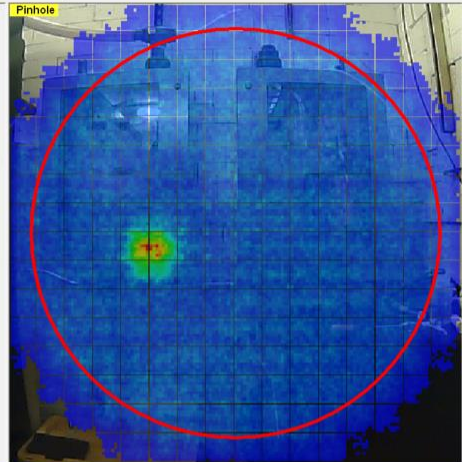
Find Gammas

Rebin: 2

Eng Spec Show all
 Ave Spec F/Eng
 Fast Chan Fpred-Fsucc
 Delta T Waveforms

Peak info:

Centroid: _____
 FWHM: _____
 FWTM: _____
 Gross area: _____
 Net area: _____

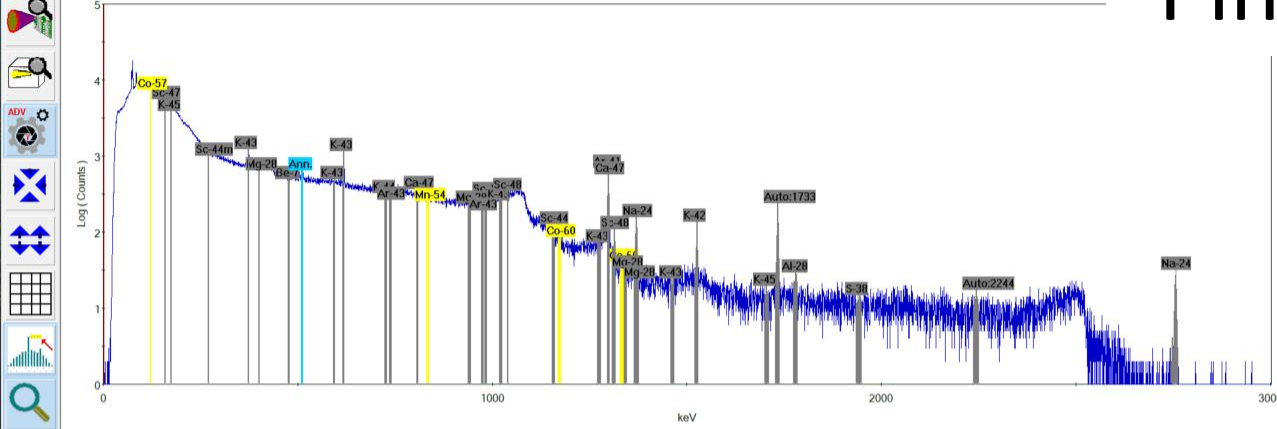


Imager - [20191222_065819.img]

File Acquire View Tools Options Show Window Help

Time: 3857 Live: 0.951 Saved File

CPS: 0 6 uR/hr ⚡ ⏪ ⏩ Temp(K): N/A



Pinhole

PRESET:

- Eng Spec
- Ave Spec
- Fast Chan
- Delta T
- Show all
- Eng
- Epred-Fsuoc
- Waveforms

Peak info:

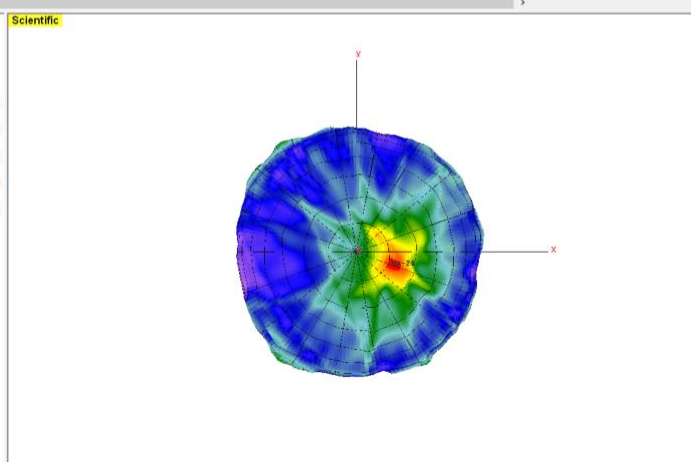
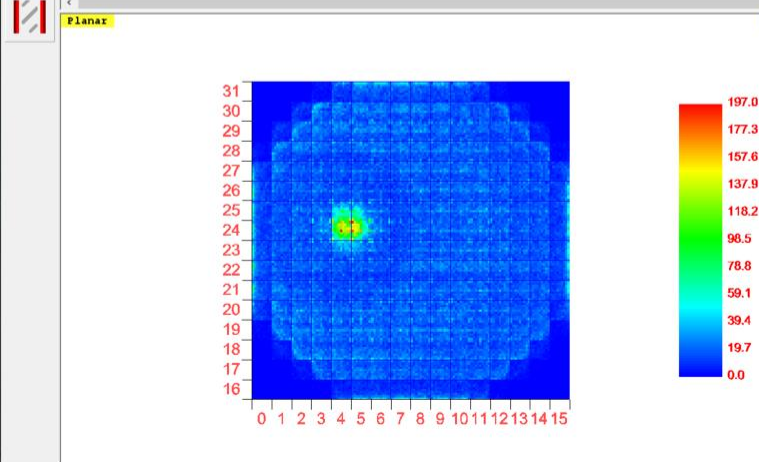
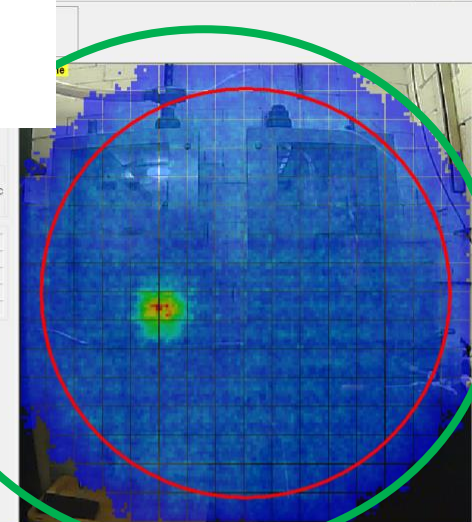
Centroid:

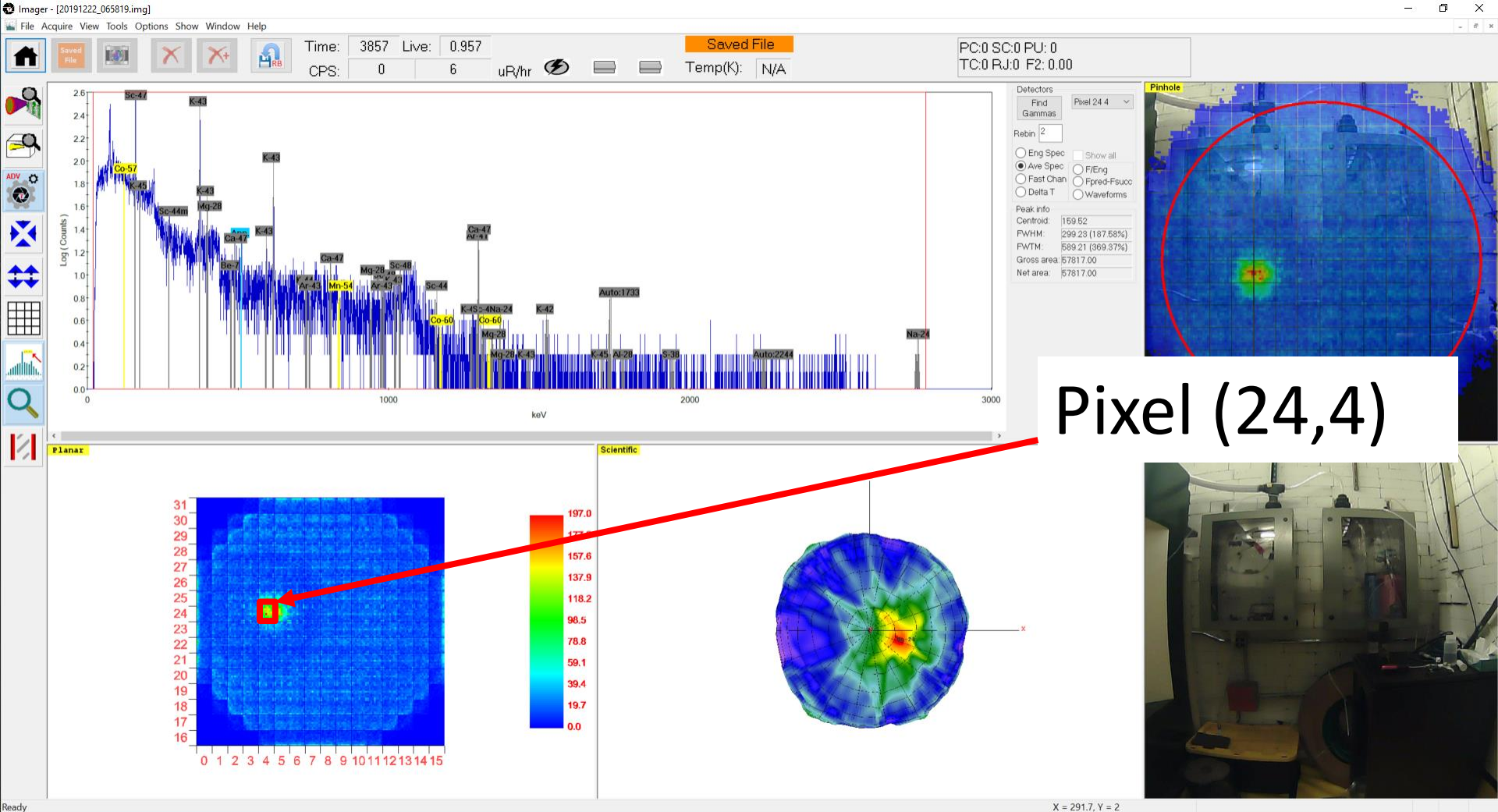
FWHM:

FWTM:

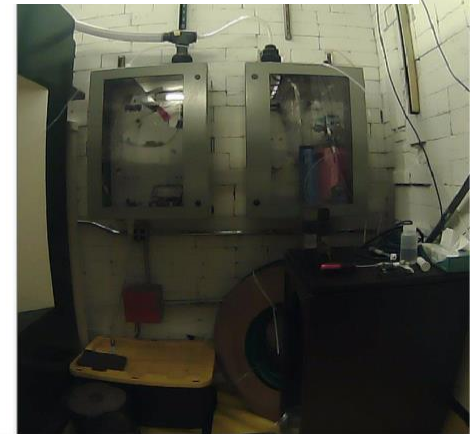
Gross area:

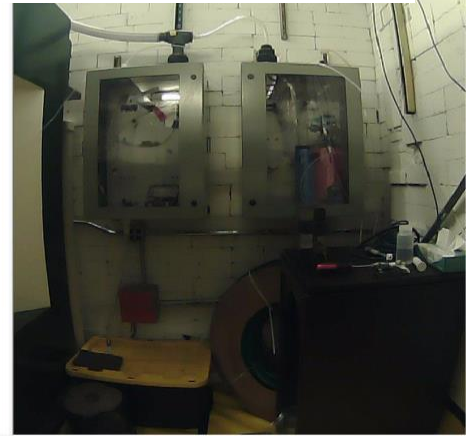
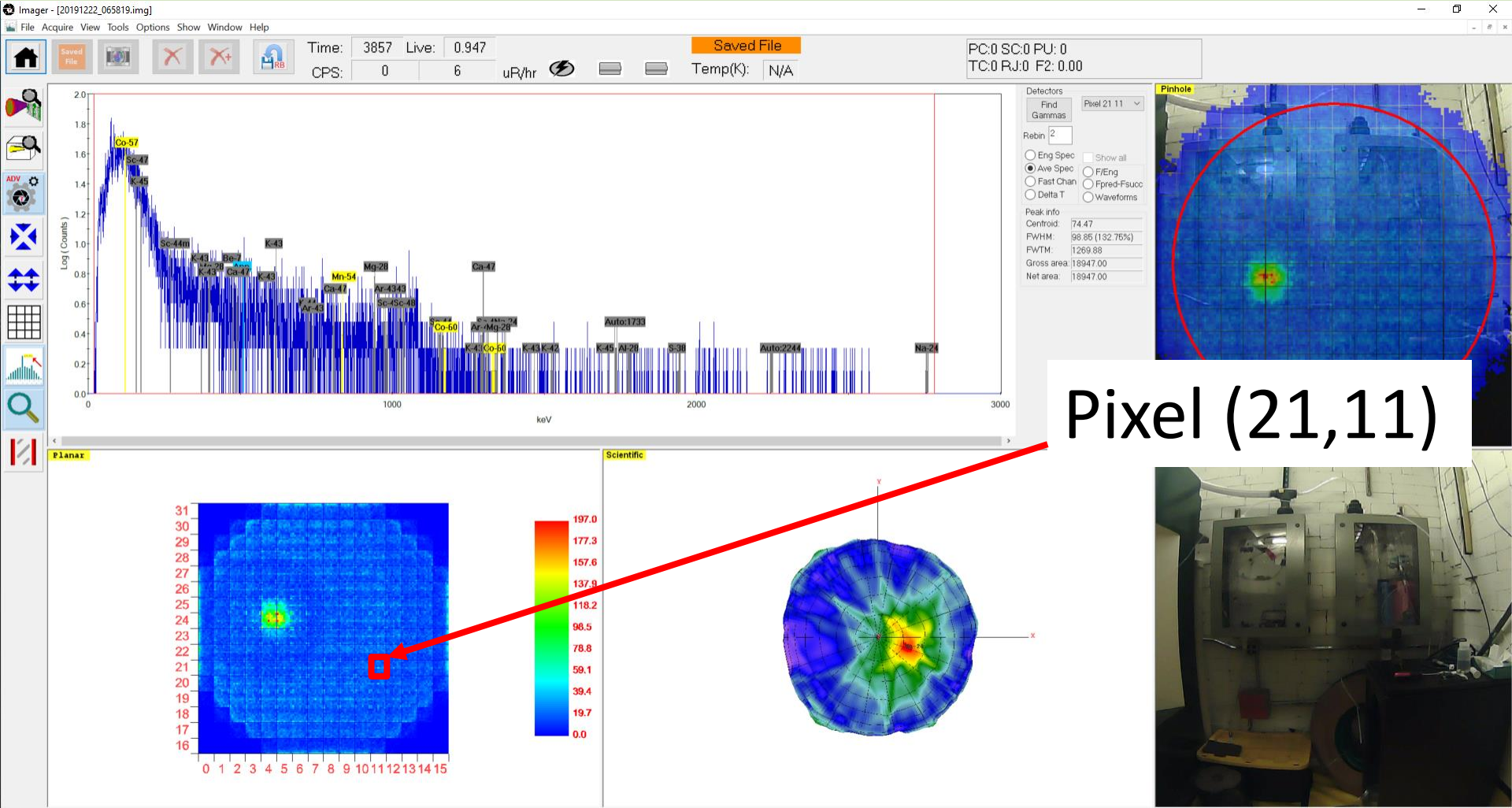
Net area:

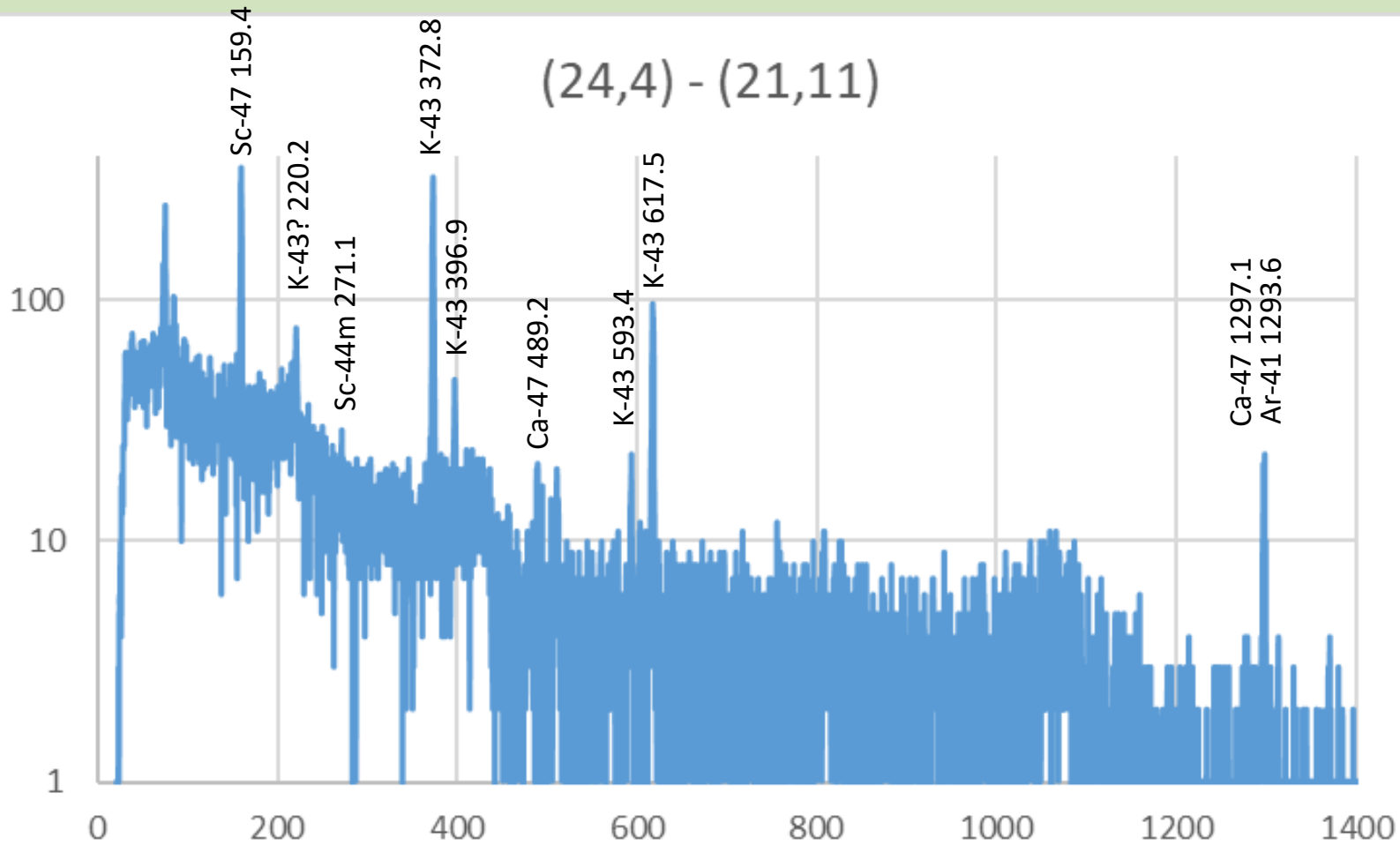




Pixel (24,4)







⁴⁷Sc
⁴³K
^{44m}Sc
⁴⁷Ca
⁴¹Ar

Identified
and localized
in the
column

Threshold 0 - 100 % Distance(m) 1.910 +/- 0.000

Events 93665 Search Pixels Edit ROIs Switch to Polygon ROIs

Show All Energy Windows

Isotope	Energy (keV)
<input type="checkbox"/> Be-7	477.6
<input checked="" type="checkbox"/> Sc-47	159.4
<input type="checkbox"/> K-43	1274.5
<input type="checkbox"/> Co-60	1332.5
<input type="checkbox"/> K-43	1463.1
<input type="checkbox"/> K-42	1524.7
<input type="checkbox"/> Sc-44	1157.0
<input type="checkbox"/> Sc-44m	271.1
<input type="checkbox"/> Sc-48	983.5
<input type="checkbox"/> Sc-48	1312.1
<input type="checkbox"/> Na-24	1368.6
<input type="checkbox"/> Mg-28	941.7
<input type="checkbox"/> Mg-28	400.6
<input type="checkbox"/> Ar-41	1293.6
<input type="checkbox"/> Ca-47	1297.1
<input type="checkbox"/> S-38	1941.9
<input type="checkbox"/> Co-60	1173.2
<input type="checkbox"/> Ann.	511.0
<input type="checkbox"/> Ca-47	807.9
<input type="checkbox"/> K-45	174.3



Intervening Materials

Material	Density(g... Thick(cm)

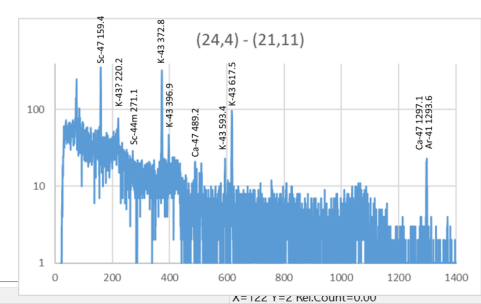
ROI Materials

ROI	Material	Density(g... Thick

There are no items to show in this view.

Units: Curies (Ci)

ROI	Isotope	Energy	Count	Activity (Ci)	Radioactive Mass (g)	Activity Conc. (Ci/g)
There are no items to show in this view.						



Threshold: 0 - 100 % Distance(m): 1.910 +/- 0.000

Events: 93665 Search Pixels Edit ROIs Switch to Polygon ROIs

Show All Energy Windows

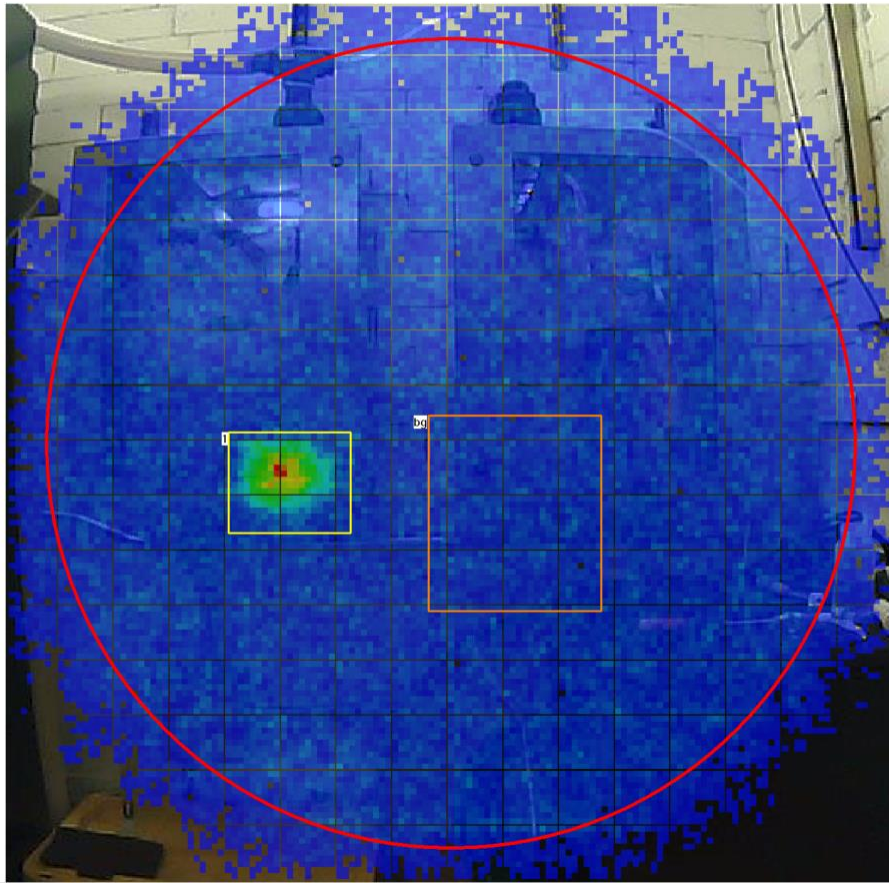
Isotope	Energy (keV)
<input type="checkbox"/> Be-7	477.6
<input checked="" type="checkbox"/> Sc-47	159.4
<input type="checkbox"/> K-43	1274.5
<input type="checkbox"/> Co-60	1332.5
<input type="checkbox"/> K-43	1463.1
<input type="checkbox"/> K-42	1524.7
<input type="checkbox"/> Sc-44	1157.0
<input type="checkbox"/> Sc-44m	271.1
<input type="checkbox"/> Sc-48	983.5
<input type="checkbox"/> Sc-48	1312.1
<input type="checkbox"/> Na-24	1368.6
<input type="checkbox"/> Mg-28	941.7
<input type="checkbox"/> Mg-28	400.6
<input type="checkbox"/> Ar-41	1293.6
<input type="checkbox"/> Ca-47	1297.1
<input type="checkbox"/> S-38	1941.9
<input type="checkbox"/> Co-60	1173.2
<input type="checkbox"/> Ann.	511.0
<input type="checkbox"/> Ca-47	807.9
<input type="checkbox"/> K-45	174.3

Intervening Materials

Material	Density(g...)	Thick(cm)

ROI Materials

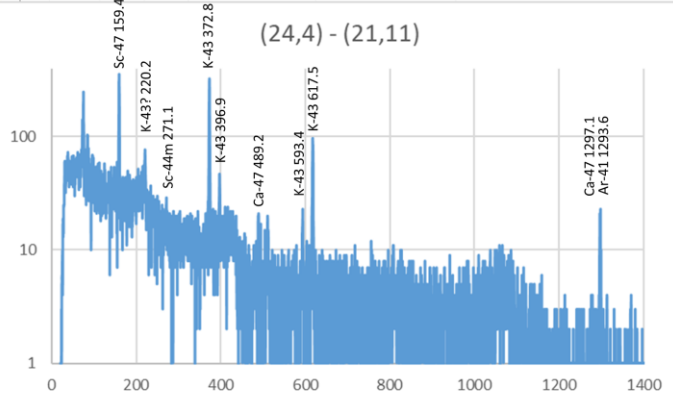
ROI	Material	Density(g...)	Thick
1		0.0000	28.01



Units: Curies (Ci)

ROI	Isotope	Energy	Count	Activity (Ci)	Radioactive Mass (g)	Activity Conc. (Ci/g)
1	Sc-47	159.4	4261	1.64e-04 +/- 2.66e-06	2.02e-010 +/- 3.27e-012	N/A
1	Sc-47	159.4	4266	1.64e-04 +/- 2.66e-06	2.02e-010 +/- 3.27e-012	N/A
BG	Sc-47	159.4	2291			
BG	Sc-47	159.4	2306			

Sc-47
159.4 keV
3.3 days
164 µCi



Imager - [20191222_065819.img]

File Acquire View Tools Options Show Window Help

Time: 3857 Live: 0.951 Saved File

CPS: 0 6 uR/hr Temp(K): N/A

PC:0 SC:0 PU:0 TC:0 RJ:0 F2: 0.00

Threshold: 0 - 100 % Distance(m): 1.910 +/- 0.000

Events: 12175 Search Pixels Edit ROIs Switch to Polygon ROIs

Energy Windows

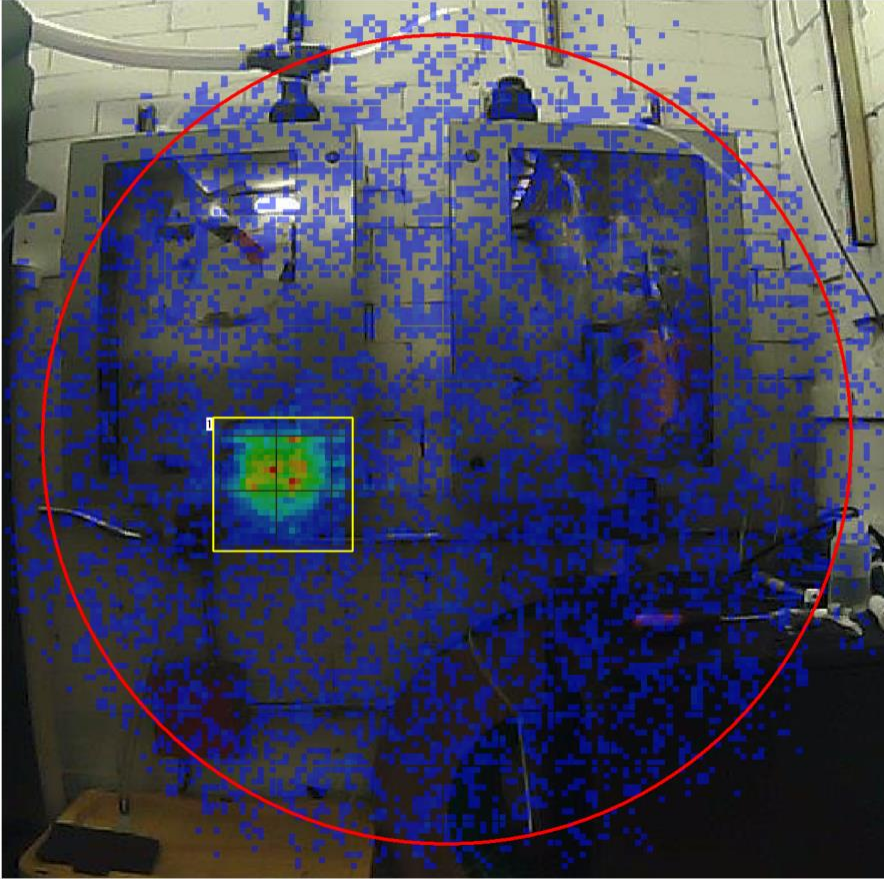
Isotope	Energy (keV)
<input type="checkbox"/> Ca-47	1297.1
<input type="checkbox"/> S-38	1941.9
<input type="checkbox"/> Co-60	1173.2
<input type="checkbox"/> Ann.	511.0
<input type="checkbox"/> Ca-47	807.9
<input type="checkbox"/> K-45	174.3
<input type="checkbox"/> Mn-54	834.9
<input type="checkbox"/> K-43	617.5
<input type="checkbox"/> Mg-28	1342.3
<input type="checkbox"/> K-43	1021.7
<input checked="" type="checkbox"/> K-43	372.8
<input type="checkbox"/> K-43	593.4
<input type="checkbox"/> Mg-28	1779.0
<input type="checkbox"/> Co-57	122.1
<input type="checkbox"/> Sc-48	1037.6
<input type="checkbox"/> K-45	1705.6
<input type="checkbox"/> K-43	396.9
<input type="checkbox"/> Mg-28	1372.9
<input type="checkbox"/> Sc-47	159.4
<input type="checkbox"/> Ca-47	489.2

Intervening Materials

Material	Density(g...)	Thick(cm)

ROI Materials

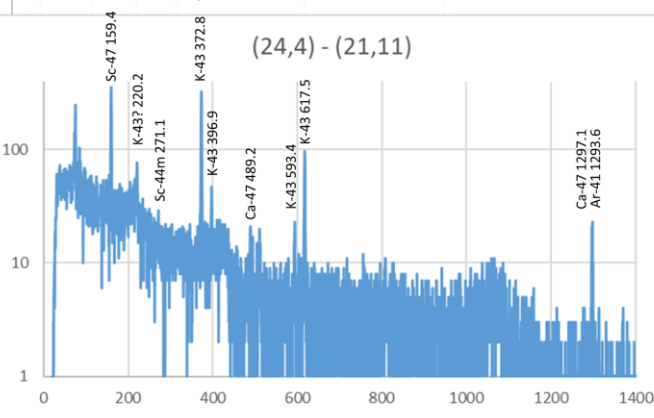
ROI	Material	Density(g...)	Thick
1		0.0000	33.71



Units: Curies (Ci)

ROI	Isotope	Energy	Count	Activity (Ci)	Radioactive Mass (g)	Activity Conc. (Ci/g)
1	K-43	372.8	4933	8.13e-04 +/- 1.16e-05	2.47e-010 +/- 3.52e-012	N/A

K-43
372.8 keV
22.3 hrs
813 µCi



(24,4) - (21,11)

Sc-47 159.4
K-43? 220.2
Sc-44m 271.1
K-43 396.9
Ca-47 489.2
K-43 593.4
K-43 617.5
Ca-47 1297.1
Ar-41 1295.6

X=110 Y=4 Net.Count=0.00

Threshold 0 - 100% Distance(m) 1.910 +/- 0.000
 Events 6828 Search Pixels Edit ROIs Switch to Polygon ROIs

Show All Energy Windows

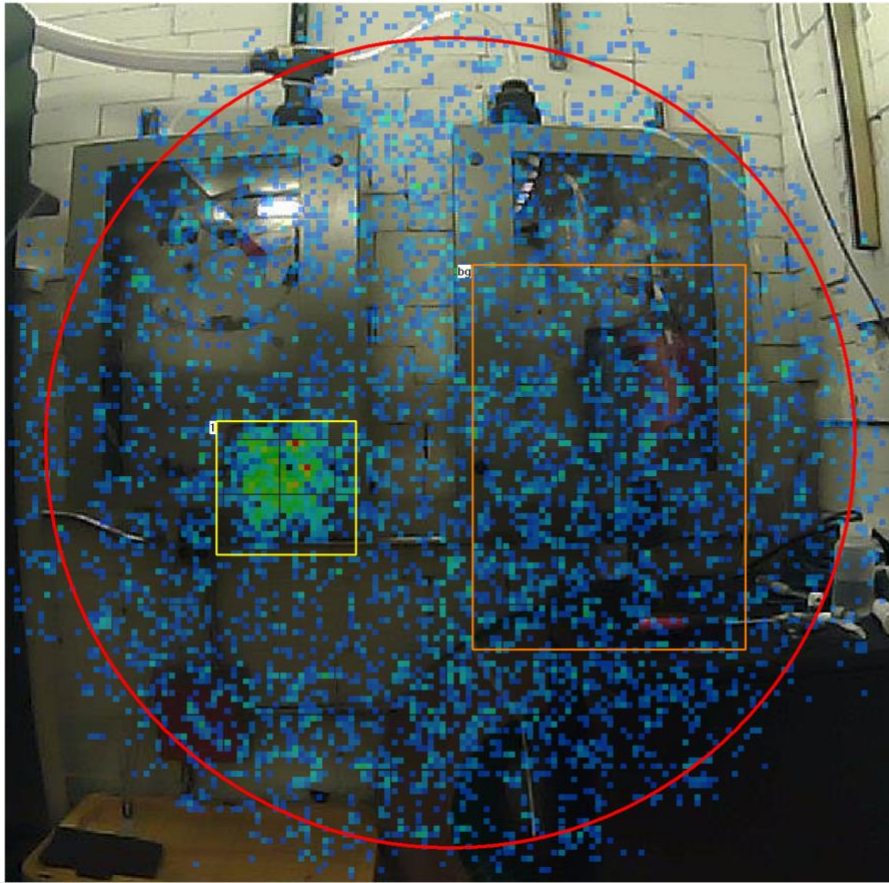
Isotope	Energy (keV)
<input type="checkbox"/> Sc-48	983.5
<input type="checkbox"/> Sc-48	1312.1
<input type="checkbox"/> Na-24	1368.6
<input type="checkbox"/> Mg-28	941.7
<input type="checkbox"/> Mg-28	400.6
<input type="checkbox"/> Ar-41	1293.6
<input type="checkbox"/> Ca-47	1297.1
<input type="checkbox"/> S-38	1941.9
<input type="checkbox"/> Co-60	1173.2
<input type="checkbox"/> Ann.	511.0
<input type="checkbox"/> Ca-47	807.9
<input type="checkbox"/> K-45	174.3
<input type="checkbox"/> Mn-54	834.9
<input type="checkbox"/> K-43	617.5
<input type="checkbox"/> Mg-28	1342.3
<input type="checkbox"/> K-43	1021.7
<input type="checkbox"/> K-43	372.8
<input type="checkbox"/> K-43	593.4
<input type="checkbox"/> Mg-28	1779.0
<input type="checkbox"/> Co-57	122.1

Intervening Materials

Material	Density(g... Thick(cm)

ROI Materials

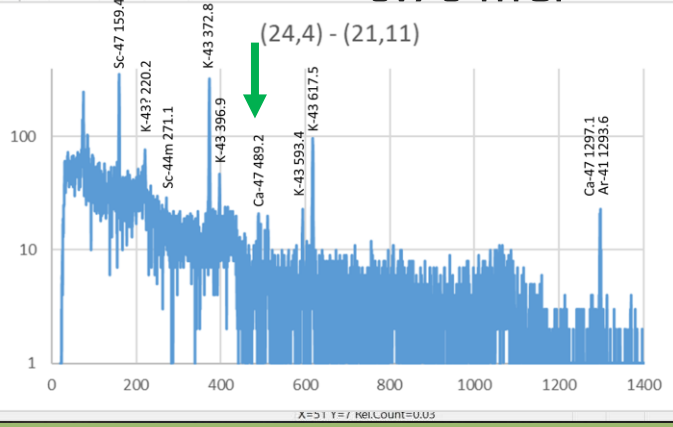
ROI	Material	Density(g... Thick
1		0.0000 33.71



ROI	Isotope	Energy	Count	Activity (Ci)	Radioactive Mass (g)	Activity Conc. (Ci/g)
1	Ca-47	489.2	718	1.63e-03 +/- 6.47e-05	2.66e-09 +/- 1.06e-010	N/A
BG	Ca-47	489.2	1247			

Units Curies (Ci)

Ca-47
 489.2 keV
 4.5 days
 $1.6 * .48 =$
 0.76 mCi



Imager - [20191222_065819.img] PC:0 SC:0 PU:0
TC:0 RJ:0 F2: 0.00

File Acquire View Tools Options Show Window Help

Time: 3857 Live: 0.951 Saved File

CPS: 0 6 uR/hr Temp(K): N/A

Events: 8914 Search Pixels Edit ROIs Switch to Polygon ROIs

Threshold: 0 - 100% Distance(m): 1.910 +/- 0.000

Energy Windows

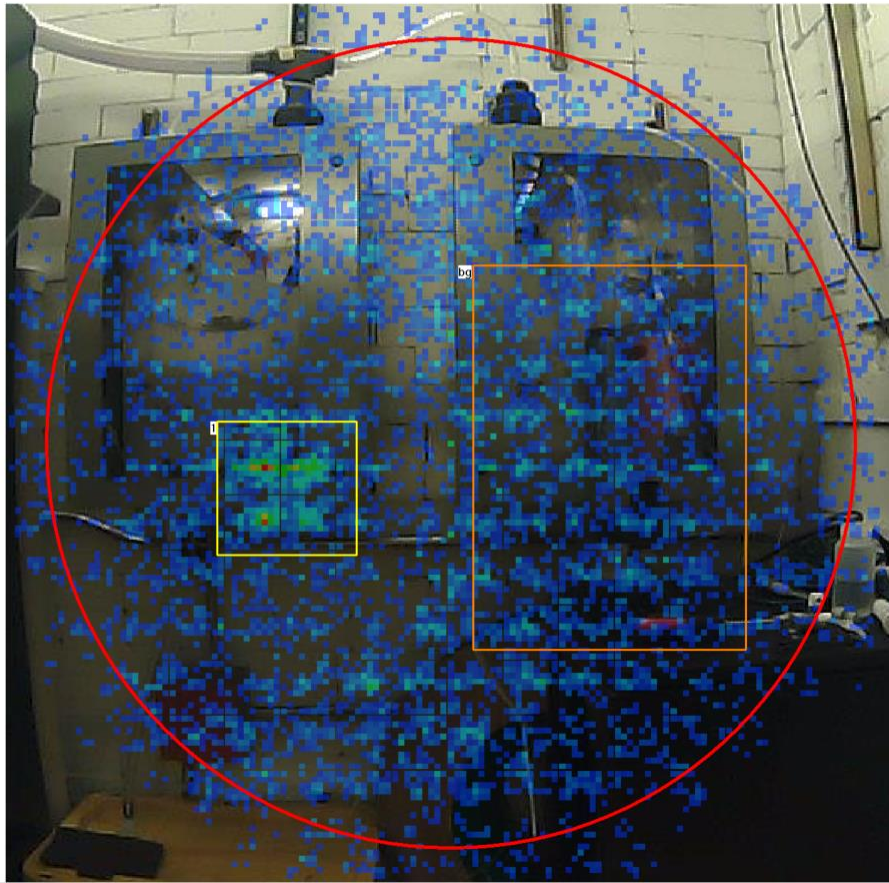
Isotope	Energy (keV)
<input type="checkbox"/> Be-7	477.6
<input type="checkbox"/> Sc-47	159.4
<input type="checkbox"/> K-43	1274.5
<input type="checkbox"/> Co-60	1332.5
<input type="checkbox"/> K-43	1463.1
<input type="checkbox"/> K-42	1524.7
<input type="checkbox"/> Sc-44	1157.0
<input type="checkbox"/> Sc-44m	271.1
<input type="checkbox"/> Sc-48	983.5
<input type="checkbox"/> Sc-48	1312.1
<input type="checkbox"/> Na-24	1368.6
<input type="checkbox"/> Mg-28	941.7
<input type="checkbox"/> Mg-28	400.6
<input checked="" type="checkbox"/> Ar-41	1293.6
<input type="checkbox"/> Ca-47	1297.1
<input type="checkbox"/> S-38	1941.9
<input type="checkbox"/> Co-60	1173.2
<input type="checkbox"/> Ann.	511.0
<input type="checkbox"/> Ca-47	807.9
<input type="checkbox"/> K-45	174.3

Intervening Materials

Material	Density(g...)	Thick(cm)

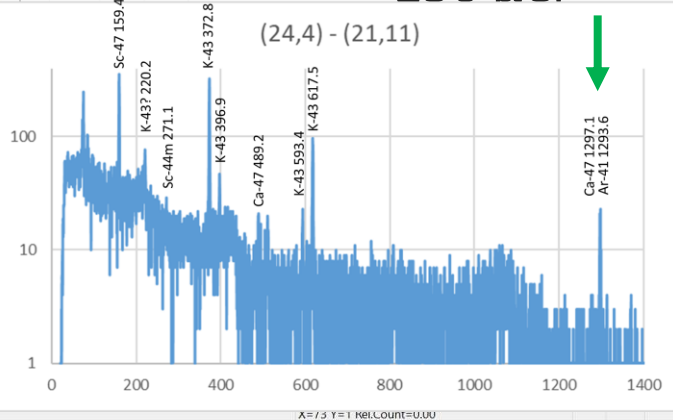
ROI Materials

ROI	Material	Density(g...)	Thick
1		0.0000	33.71

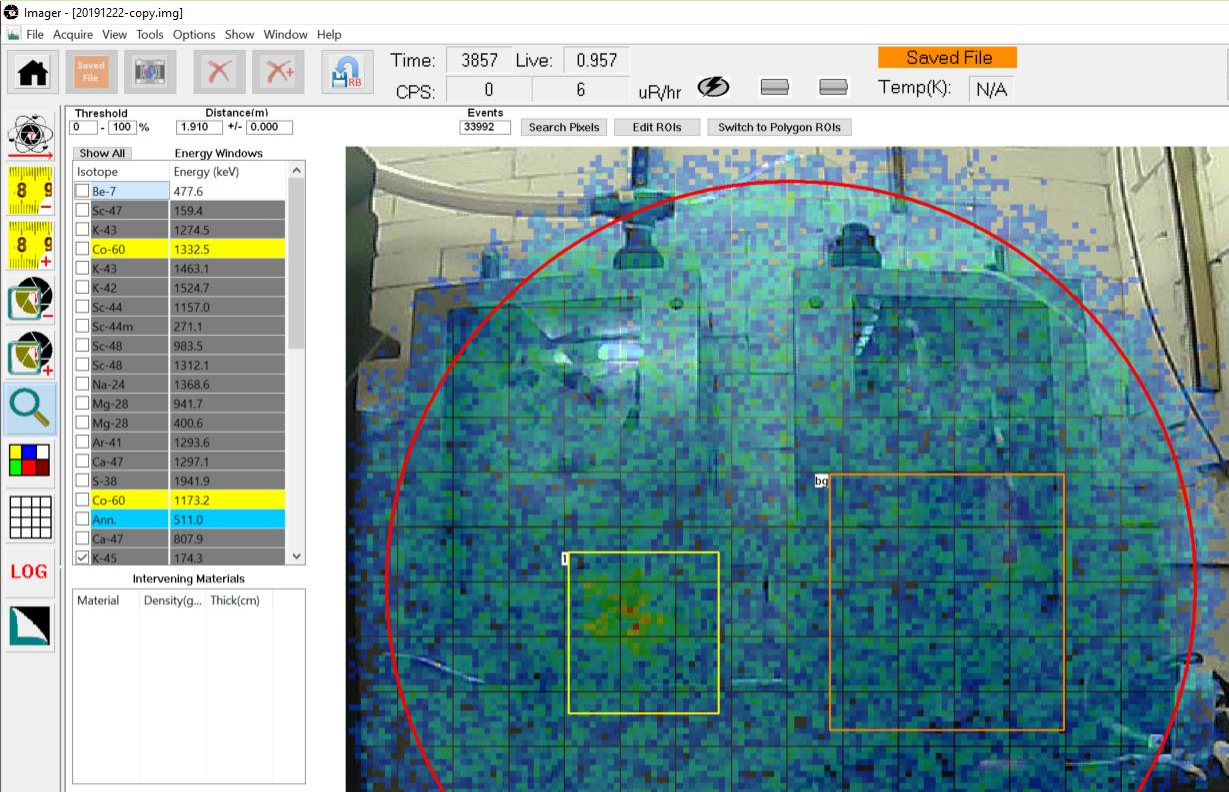


ROI	Isotope	Energy	Count	Activity (Ci)	Radioactive Mass (g)	Activity Conc. (Ci/g)
1	Ar-41	1293.6	802	2.72e-04 +/- 1.07e-05	6.52e-012 +/- 2.56e-013	N/A
BG	Ar-41	1293.6	1845			

Ar-41
1293.6 keV
109 min
272 - 16 =
256 uCi



Ghost Image !!



PC:0 SC:0 PU:0
TC:0 RJ:0 F2: 0.00

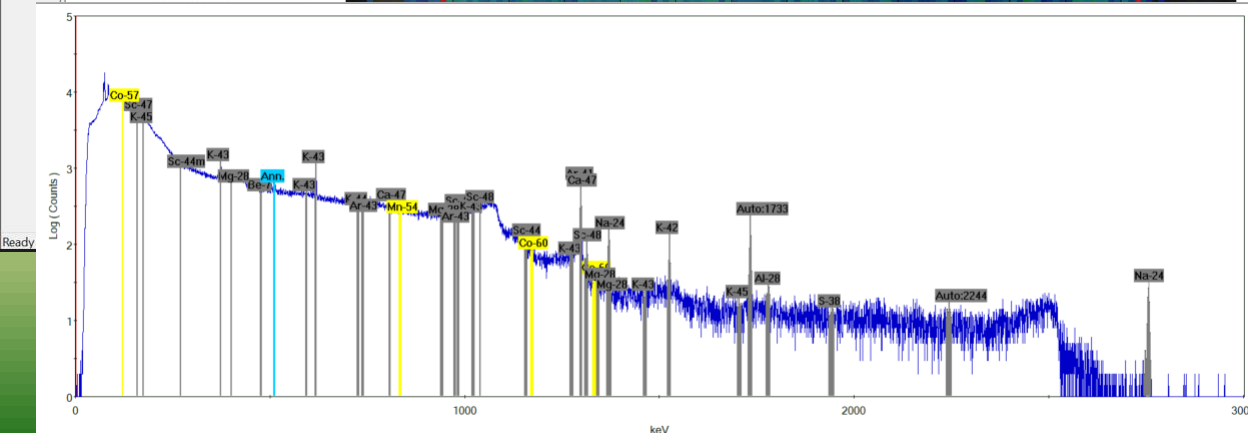
ROI	Isotope	Energy	Count	Activity (Ci)	Radioactive Mass (g)	Activity Conc. (Ci/g)
1	K-45	174.3	2097	4.02e-05 +/- 1.51e-06	0 +/- 0	N/A
BG	K-45	174.3	3196			

No actual ^{75}K !! (17 min, 74%)
 App says: 40 μCi !!
 Down-scatter ghost images are caused by regions of interest (ROIs) that are manually placed.

In many cases, an unrealistically high activity is represented from these peaks because the intensity of the non-existent isotopes tends to be low while their half lives tend to be long.

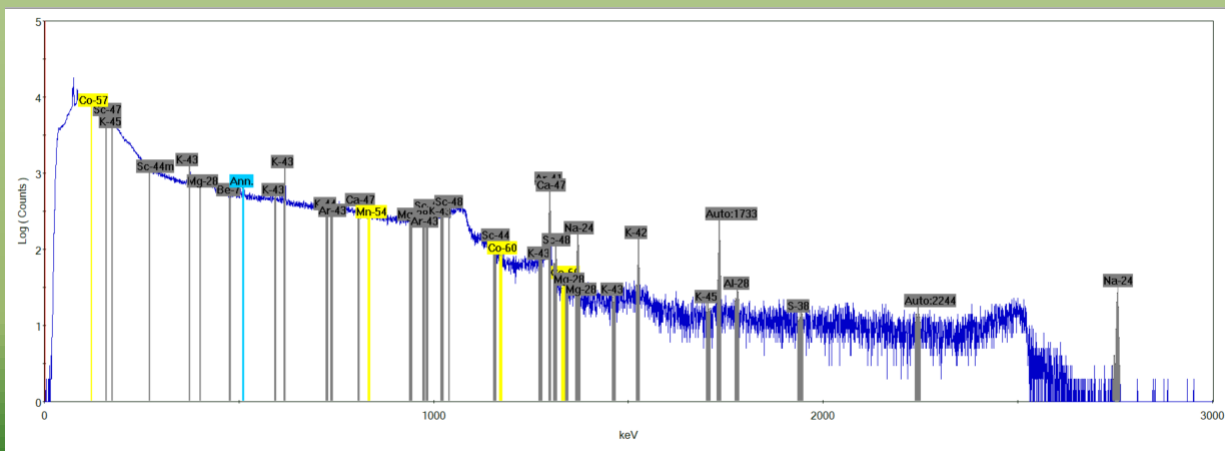
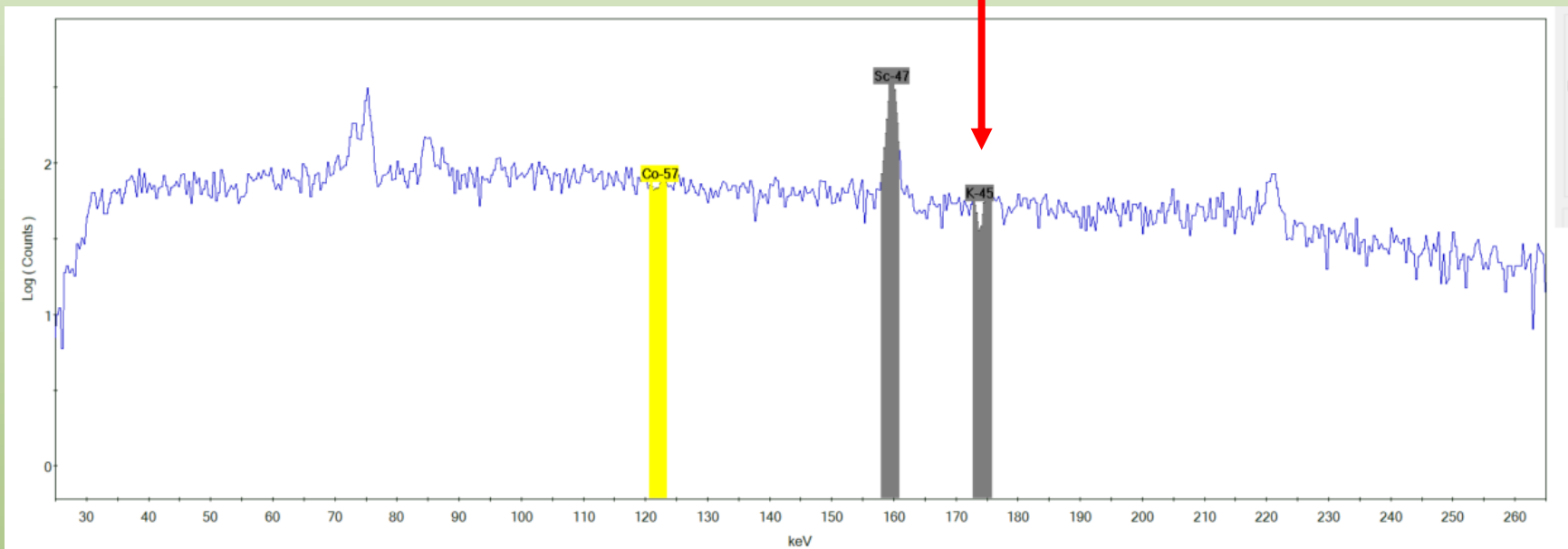
Important finding.

Autodetect? vs. bkrnd subtract?
 Being investigated/developed.



Ghost Image Peak

No 174 keV ^{45}K peak



37 ROIs

Several ghost images at lower energies

Auto Detect helps avoid

Compton Images at higher energies

Imager - [20191222_065819.img]

File Acquire View Tools Options Show Window Help

Time: 3857 Live: 0.951 Saved File

CPS: 0 6 uR/hr Temp(K): N/A

PC:0 SC:0 PU: 0 TC:0 RJ:0 F2: 0.00

Distance(m) 1.900 Events 2992 Switch to Tactical View Width 40%

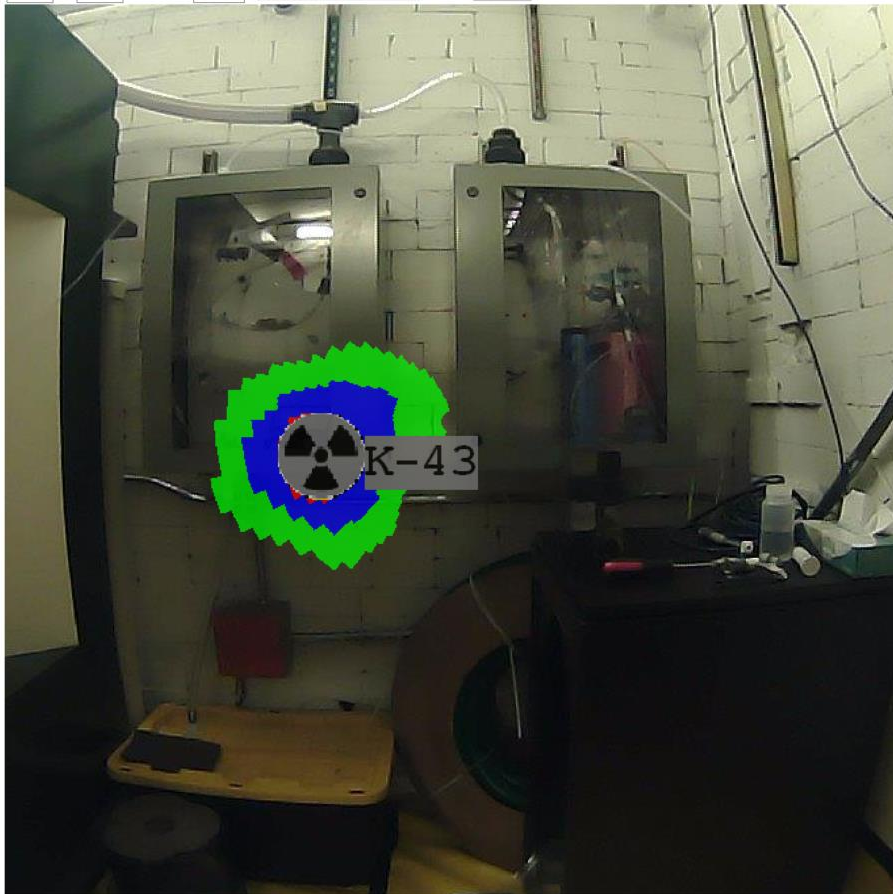
Isotope	Energy (keV)	Events
<input type="checkbox"/> Mg-28	941.7	844
<input type="checkbox"/> Mg-28	400.6	693
<input type="checkbox"/> Ar-41	1293.6	3324
<input type="checkbox"/> Ca-47	1297.1	1452
<input type="checkbox"/> S-38	1941.9	52
<input type="checkbox"/> Co-60	1173.2	676
<input type="checkbox"/> Ann.	511.0	1423
<input type="checkbox"/> Ca-47	807.9	1114
<input type="checkbox"/> K-45	174.3	1368
<input type="checkbox"/> Mn-54	834.9	671
<input checked="" type="checkbox"/> K-43	617.5	2992
<input type="checkbox"/> Mg-28	1342.3	321
<input type="checkbox"/> K-43	1021.7	1033
<input type="checkbox"/> K-43	372.8	2024
<input type="checkbox"/> K-43	593.4	986
<input type="checkbox"/> Mg-28	1779.0	207
<input type="checkbox"/> Sc-48	1037.6	1429
<input type="checkbox"/> K-45	1705.6	37
<input type="checkbox"/> K-43	396.9	783
<input type="checkbox"/> Mg-28	1372.9	80

Intervening Materials

Material	Density(g...	Thick(cm)

ROI Materials

ROI	Material	Density(g...	Thick
There are no items to show in this view.			



Rear View

Activity Units Curies (Ci)

ROI	Isotope	Energy	Count	Activity (Ci)	Radioactive Mass (g)	Activity Conc. (Ci/g)
K-43	K-43	617.5	2078	3.58e-05 +/- 2.49e-07	1.09e-011 +/- 7.56e-014	N/A

Ready

Radiochemistry back in the lab

Imager - [20191223_113835-5GMT-deathtraps.img]

File Acquire View Tools Options Show Window Help

Time: 4114 Live: **Death Traps** Saved File PC:0 SC:0 PU: 0
CPS: 0 6 uR/hr Temp(K): N/A TC:0 RJ:0 F2: 0.00

Threshold 0 -100 % Distance(m) 0.430 +/- Events 11063 Search Pixels Edit ROIs Switch to Polygon ROIs

Show All Energy Windows


Isotope	Energy (keV)
<input type="checkbox"/> Be-7	477.6
<input checked="" type="checkbox"/> Sc-47	159.4
<input type="checkbox"/> K-43	1274.5
<input type="checkbox"/> Co-60	1332.5
<input type="checkbox"/> K-43	1463.1
<input type="checkbox"/> K-42	1524.7
<input type="checkbox"/> Sc-44	1157.0
<input type="checkbox"/> Sc-44m	271.1
<input type="checkbox"/> Sc-48	983.5
<input type="checkbox"/> Sc-48	1312.1
<input type="checkbox"/> Na-24	1368.6
<input type="checkbox"/> Mg-28	941.7
<input type="checkbox"/> Mg-28	400.6
<input type="checkbox"/> Ar-41	1293.6
<input type="checkbox"/> Ca-47	1297.1
<input type="checkbox"/> S-38	1941.9
<input type="checkbox"/> Co-60	1173.2
<input type="checkbox"/> Ann.	511.0
<input type="checkbox"/> Ca-47	807.9
<input type="checkbox"/> K-45	174.3

Intervening Materials

Material	Density(g...	Thick(cm)
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ROI Materials

ROI	Material	Density(g...	Thick
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Units Curies (Ci)

ROI	Isotope	Energy	Count	Activity (Ci)	Radioactive Mass (g)	Activity Conc. (Ci/g)
-----	---------	--------	-------	---------------	----------------------	-----------------------

There are no items to show in this view.

Ready

Imager - [20191223_113835-5GMT-deathtraps.img]

File Acquire View Tools Options Show Window Help

Time: 4114 Live: 1.000

Saved File

PC:0 SC:0 PU:0
TC:0 RJ:0 F2: 0.00

CPS: 0

6

uR/hr

Temp(K): N/A

Threshold 0 -100 % Distance(m) 0.430 +/- 0.000

Events 11063

Search Pixels

Edit ROIs

Switch to Polygon ROIs

Show All Energy Windows

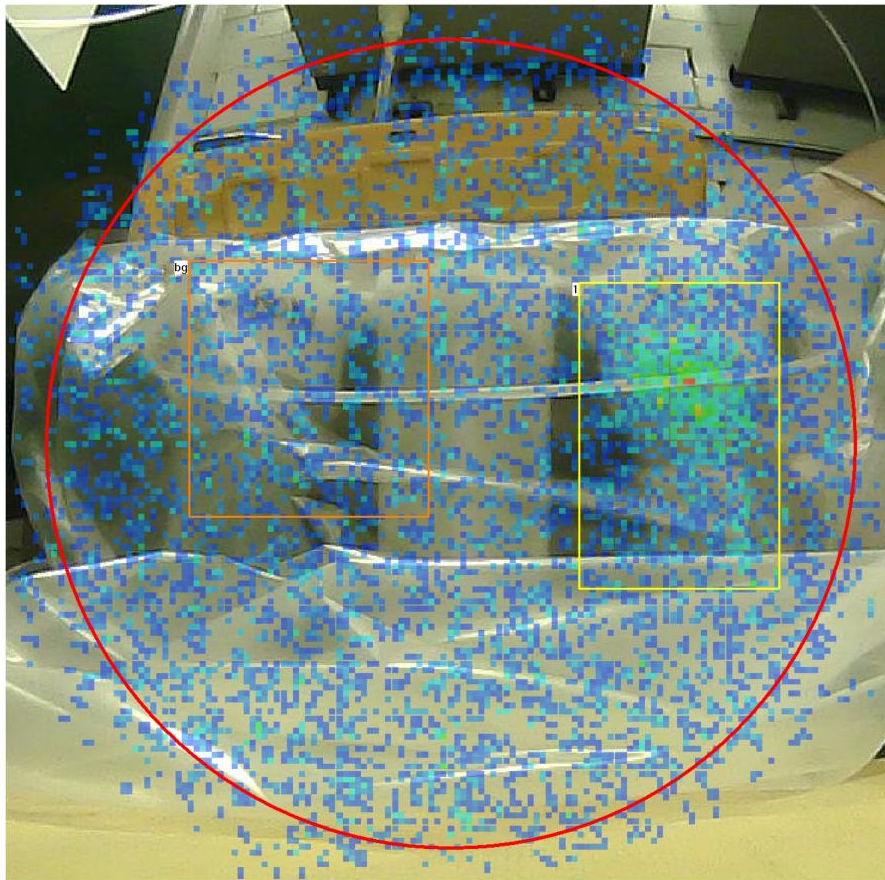
Isotope	Energy (keV)
<input type="checkbox"/> Be-7	477.6
<input checked="" type="checkbox"/> Sc-47	159.4
<input type="checkbox"/> K-43	1274.5
<input checked="" type="checkbox"/> Co-60	1332.5
<input type="checkbox"/> K-43	1463.1
<input type="checkbox"/> K-42	1524.7
<input type="checkbox"/> Sc-44	1157.0
<input type="checkbox"/> Sc-44m	271.1
<input type="checkbox"/> Sc-48	983.5
<input type="checkbox"/> Sc-48	1312.1
<input type="checkbox"/> Na-24	1368.6
<input type="checkbox"/> Mg-28	941.7
<input type="checkbox"/> Mg-28	400.6
<input type="checkbox"/> Ar-41	1293.6
<input type="checkbox"/> Ca-47	1297.1
<input type="checkbox"/> S-38	1941.9
<input checked="" type="checkbox"/> Co-60	1173.2
<input checked="" type="checkbox"/> Ann.	511.0
<input type="checkbox"/> Ca-47	807.9
<input type="checkbox"/> K-45	174.3

Intervening Materials

Material	Density(g...	Thick(cm)

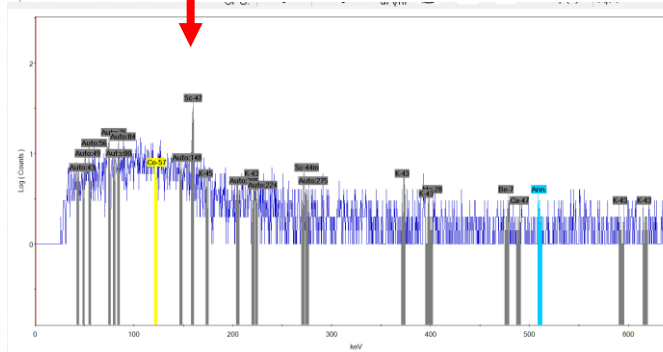
ROI Materials

ROI	Material	Density(g...	Thick
1		0.0000	14.58



ROI	Isotope	Energy	Count	Activity (Ci)	Radioactive Mass (g)	Activity Conc. (Ci/g)
1	Sc-47	159.4	1160	1.66e-06 +/- 7.44e-08	2.04e-012 +/- 9.15e-014	N/A
1	Sc-47	159.4	1166	1.67e-06 +/- 7.46e-08	2.05e-012 +/- 9.18e-014	N/A
BG	Sc-47	159.4	501			
BG	Sc-47	159.4	503			

Sc-47
159.4 keV
3.3 days
1.6 μ Ci



X=37 Y=2 Rel.Count=0.00

Ready

Time: 4114 Live: 1.000

Saved File

PC:0 SC:0 PU:0
TC:0 RJ:0 F2: 0.00

CPS: 0 6 uR/hr

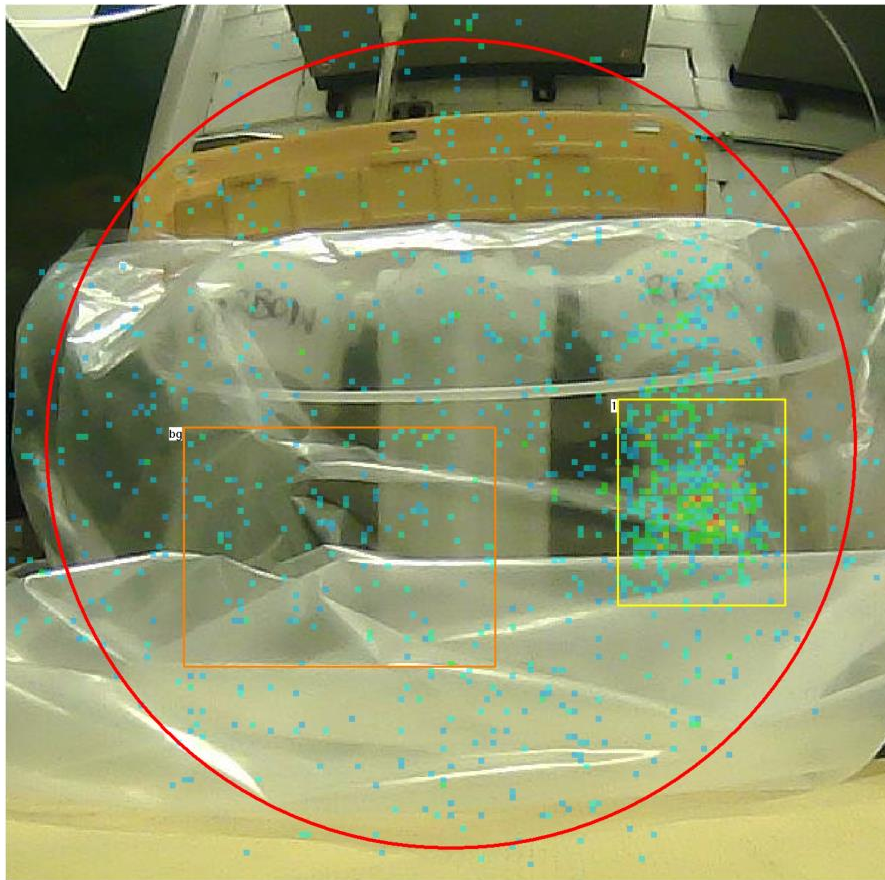
Temp(K): N/A

Threshold 0 -100 % Distance(m) 0.430 +/- 0.000

Events 1661 Search Pixels Edit ROIs Switch to Polygon ROIs

Show All Energy Windows

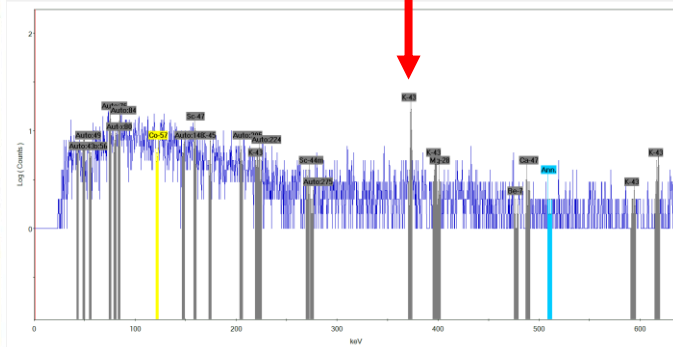
Isotope	Energy (keV)
<input type="checkbox"/> K-43	1021.7
<input checked="" type="checkbox"/> K-43	372.8
<input type="checkbox"/> K-43	593.4
<input type="checkbox"/> Mg-28	1779.0
<input type="checkbox"/> Co-57	122.1
<input type="checkbox"/> Sc-48	1037.6
<input type="checkbox"/> K-45	1705.6
<input type="checkbox"/> K-43	396.9
<input type="checkbox"/> Mg-28	1372.9
<input type="checkbox"/> Sc-47	159.4
<input type="checkbox"/> Ca-47	489.2
<input type="checkbox"/> K-44	1157.0
<input type="checkbox"/> K-44	726.5
<input type="checkbox"/> K-43	220.6
<input type="checkbox"/> Auto:157	156.6
<input type="checkbox"/> Ar-43	738.1
<input type="checkbox"/> Ar-43	975.0
<input type="checkbox"/> Auto:1733	1733.2
<input type="checkbox"/> Na-24	2754.0



Units: Curies (Ci)

ROI	Isotope	Energy	Count	Activity (Ci)	Radioactive Mass (g)	Activity Conc. (Ci/g)
1	K-43	372.8	513	3.81e-06 +/- 1.76e-07	1.16e-012 +/- 5.36e-014	N/A
BG	K-43	372.8	168			

K-43
372.8 keV
22.3 hrs
3.8 μ Ci



Intervening Materials

Material	Density(g...)	Thick(cm)

ROI Materials

ROI	Material	Density(g...)	Thick(cm)
1		0.0000	10.79

Rank-19 MURA at PHDS

- PHDS mask design
 - Manufactured for PHDS Co. by Brock Roberts at Electrodynamic
- Data collected at PHDS with mask positioned on platform
 - $c = 0.25$ cm
 - $f = 8$ cm
 - $z = 50$ cm
 - $m = 1.1905$
 - $\Delta\alpha = c/f = 0.031$ rad = 1.8° (1.6 cm at source plane)
 - $FOV_x = 29.7$ cm ($\sim 33^\circ$)
 - Image pixel size = 0.78 cm

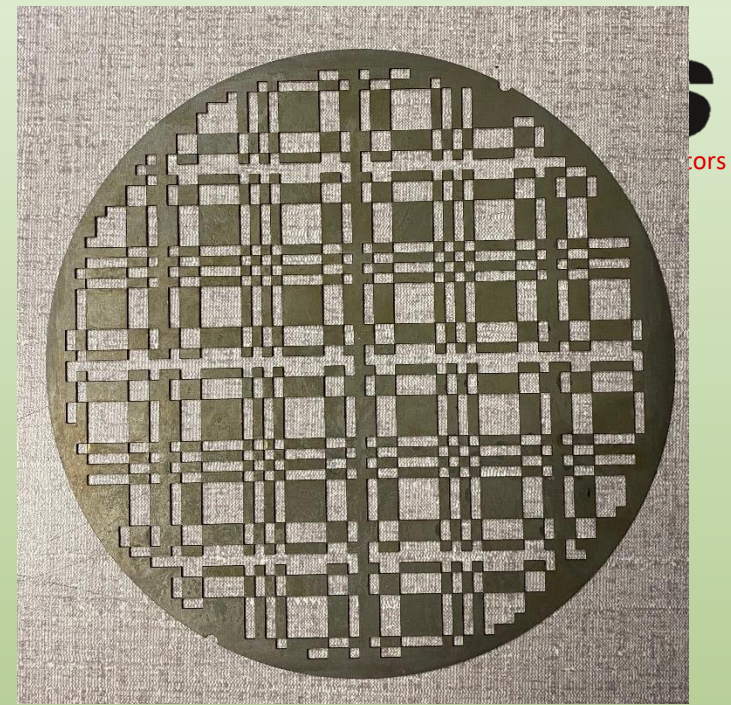
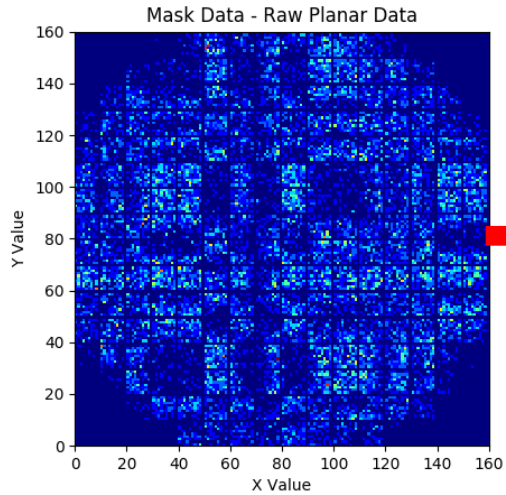
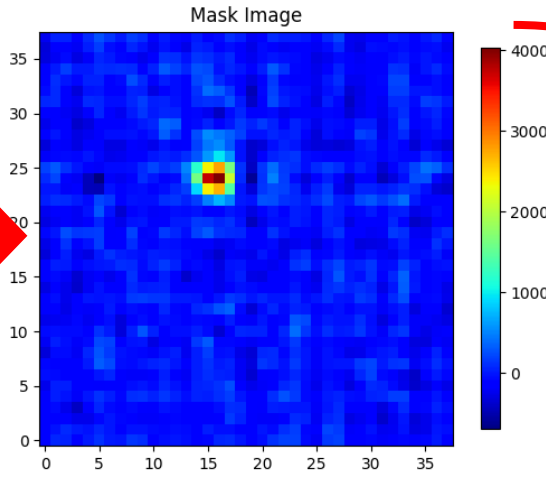


Image Reconstruction

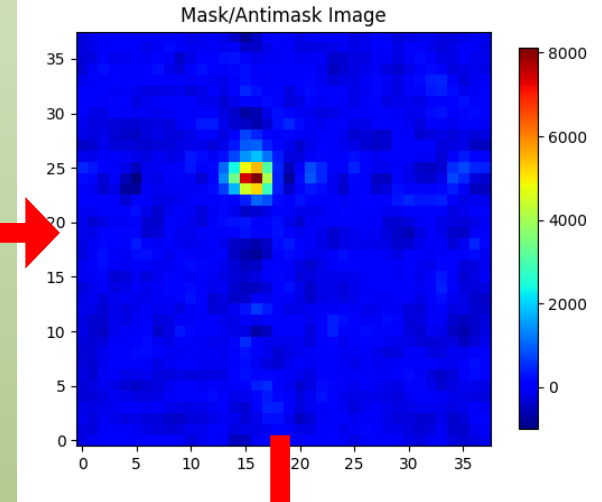
Mask Data



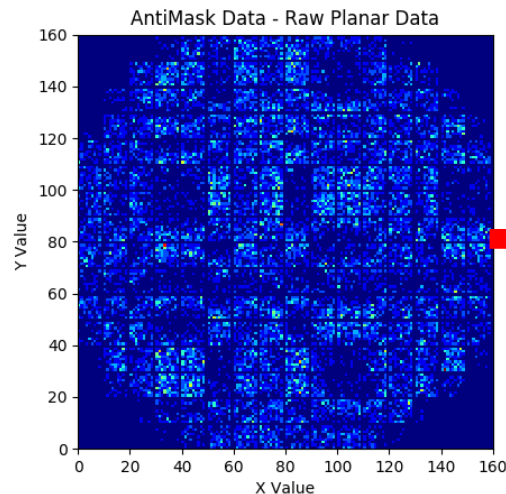
Mask Image



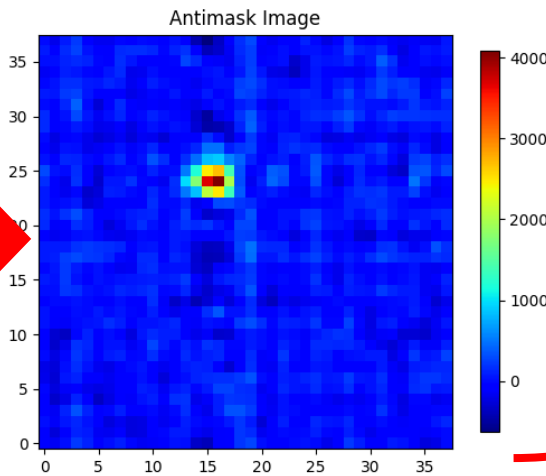
Mask + Anti-mask



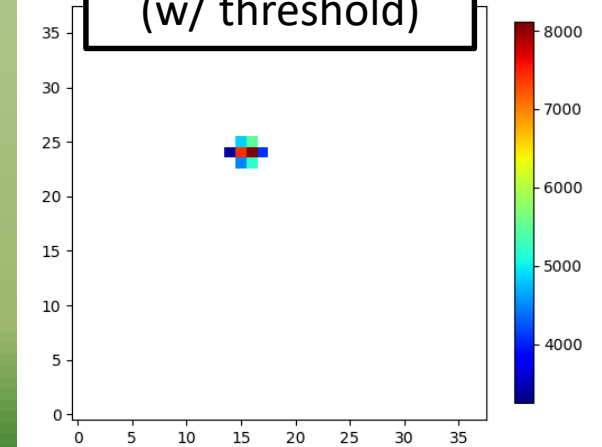
Anti-mask Data



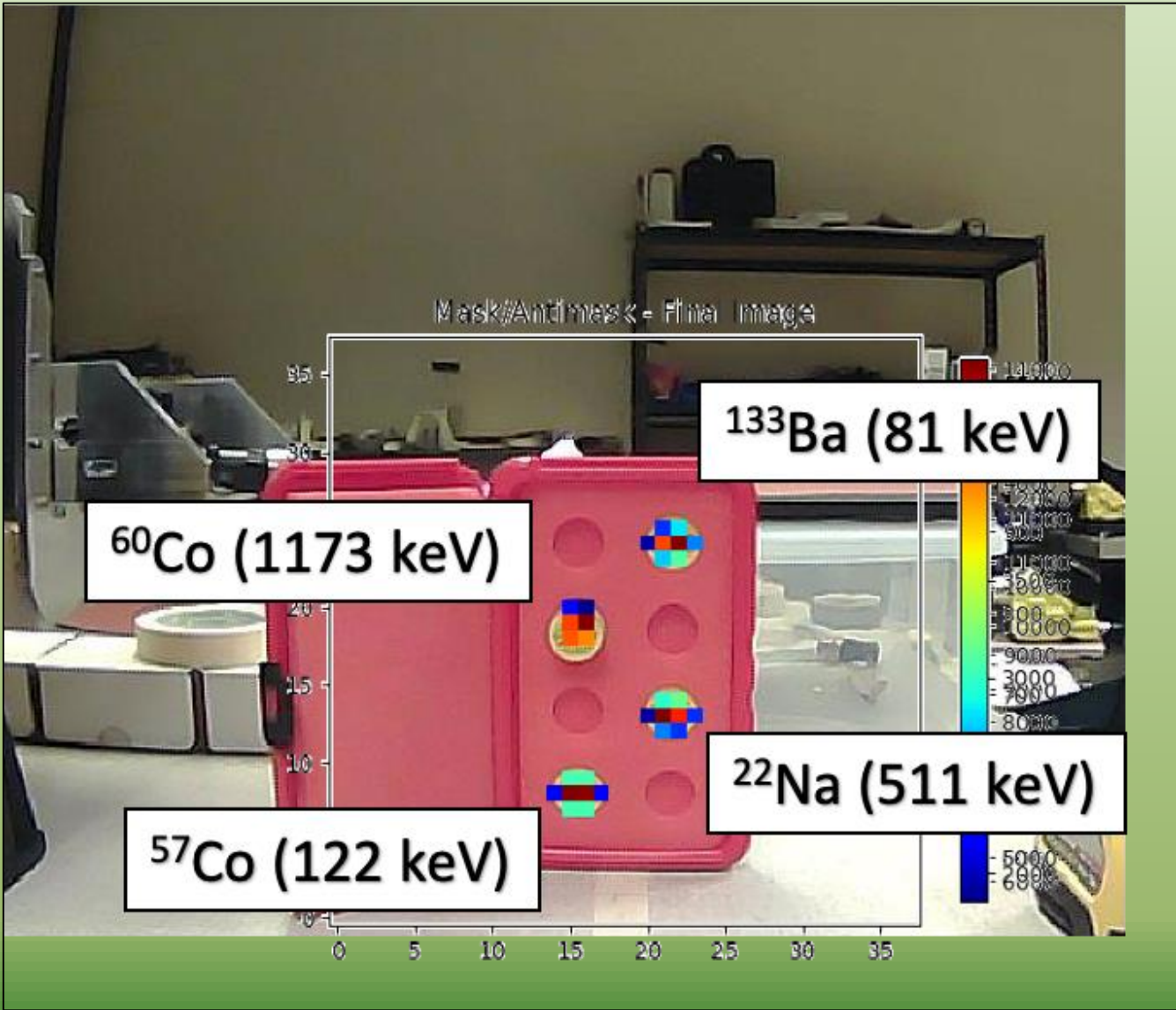
Anti-mask Image



Mask + Anti-mask
(w/ threshold)



Red Source Box:



Thank you

