

Defense Nuclear Nonproliferation Research & Development

Nuclear Weapons and Material Security Portfolio Review

WMS 2016

Directional Spectrometer Software

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Directional Spectrometer Software



Project title: Directional Spectrometer Software

Project number: SL15-V-DirectSoftware-PD2Jc

Participating laboratories: SNL, ORNL, NSTec

Participating Contractors: H3D, University of Michigan

Status: Finished Year 2 of 3



Directional Spectrometer Software



- **Participants**

- **Sandia National Laboratories**

- Dean Mitchell (PI)
 - Steve Horne
 - Lee Harding
 - Greg Thoreson
 - Lisa Theisen

- **Oak Ridge National Laboratory**

- Klaus Ziock

- **NSTec**

- Rusty Trainham

- **H3D, Inc**

- Willy Kaye
 - Jason Jaworski
 - Chris Wahl

- **University of Michigan**

- Zhong He
 - Jiyang Chu

Project Overview

- **Goals**

- **Utilize spectroscopic information collected by directional sensors**
 - Traditionally, directional sensors have provided information via images rather than spectroscopic analysis
 - Enable capability for synthesizing directional spectra
 - Signal-noise ratio is expected to decrease when observing specific spatial regions
 - Utilize spatial dimension in data
- **Improve search capabilities by utilizing directional information**
 - Assess Compton crosstalk methods from NSTec
- **Incorporate directional sensor analysis algorithms into GADRAS**

Project Overview

- **Technology**

- **Compton Camera**

- Polaris system developed by H3D and UM
 - CZT segmented detector system
 - 4π field of view
 - More sensitive to high energy photons (> 350 keV)

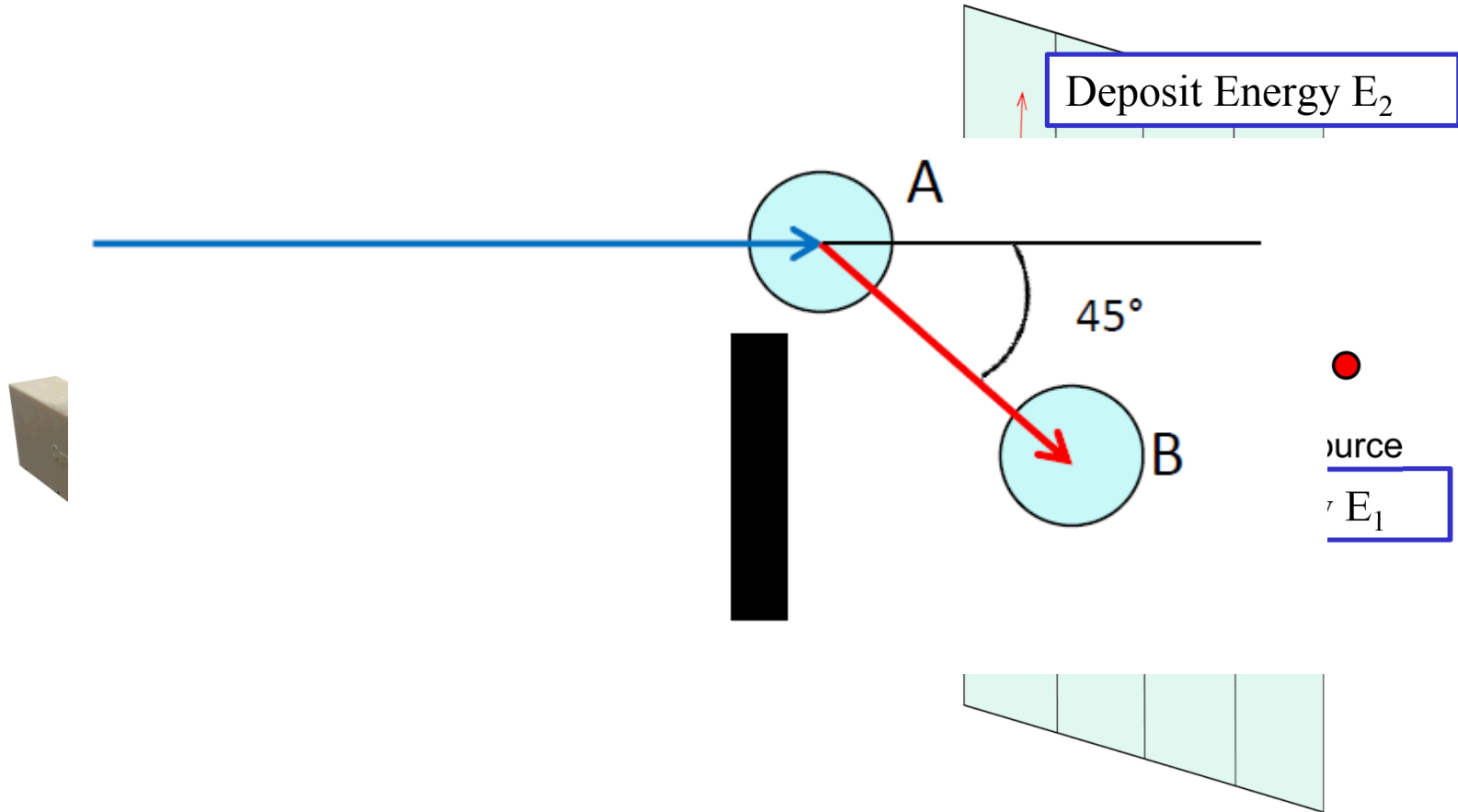
- **Coded Aperture**

- GeGI Double-sided Strip Detector utilized by ORNL
 - Used with tantalum mask
 - More sensitive to low energy photons (< 400 keV)

- **Compton Cross-Talk**

- Baby Janus utilized by NSTec
 - 4 NaI crystals
 - Tested for suitability in search applications against standard methods

Project Overview





Project Overview



- **Approach**
 - **Develop Detector Response Function for Compton cameras and coded aperture imagers in GADRAS**
 - **Define standard interface for directional spectrum functions**
 - **Extend GADRAS analysis tools for use with directional sensors**
 - **Evaluate Compton Cross-Talk method for search**

Project Overview

- **Deliverables**

- **FY15**

- SNL create preliminary detector response function algorithms for Polaris and GeGI systems
 - SNL revise SNM Analysis algorithm to run with CZT detectors (Polaris)
 - H3D and ORNL provide calibration data to SNL
 - H3D and ORNL provide libraries conforming to standard for accessing directional sensor data
 - NSTec demonstrate Compton Cross-Talk methods for sensitivity enhancements

- **FY16**

- SNL complete accurate response functions for Polaris and GeGI
 - SNL implement directional software analysis routines into GADRAS
 - SNL modify GADRAS GUI to allow visualization of spatially resolved gamma-ray spectra
 - H3D and ORNL provide software updates as needed for directional sensor libraries
 - ORNL provide WMC measurement data for GeGI



Capability Enhancements

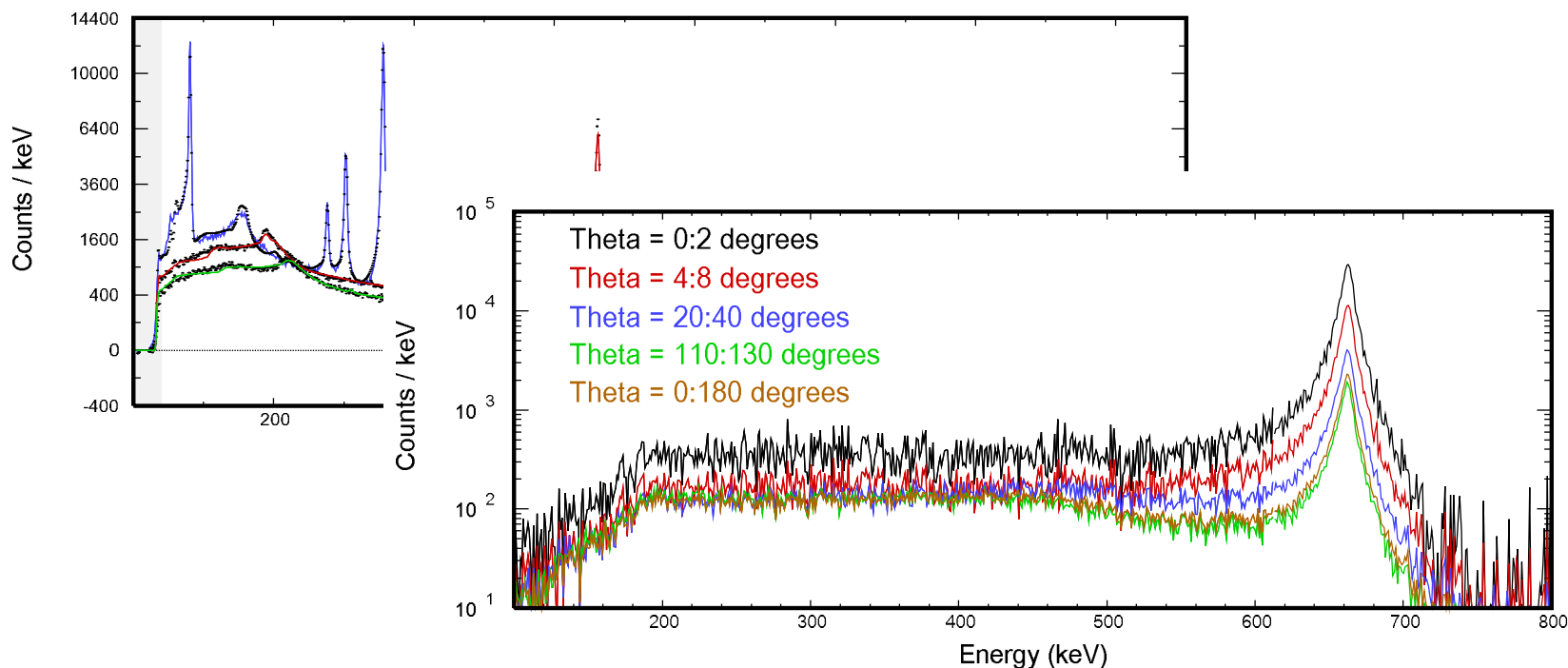


- **Applications**
 - Treaty verification for arms control
 - Diagnostics for emergency response and counter-terrorism
 - Search
 - Cargo-inspection

- **Reduce time/resources needed for analysis**
 - Obtain usable spectra
 - Eliminate requirement for interaction with developer
 - Compute spectra for point sources
 - Reduce time from CPU-months to seconds
 - Compute spectra for 3D models
 - Reduce time from CPU-months to minutes
 - Analyze for isotope identification
 - Reduce time from CPU-months to seconds
 - Inverse modeling
 - Reduce time from CPU-years to minutes/hours

Compton Camera Progress

- **Detector response function**
 - All parameters from non-direction sensors plus...
 - Angular resolution of system
 - Correct pixel for given event
 - Solid angle covered by neighboring detector elements



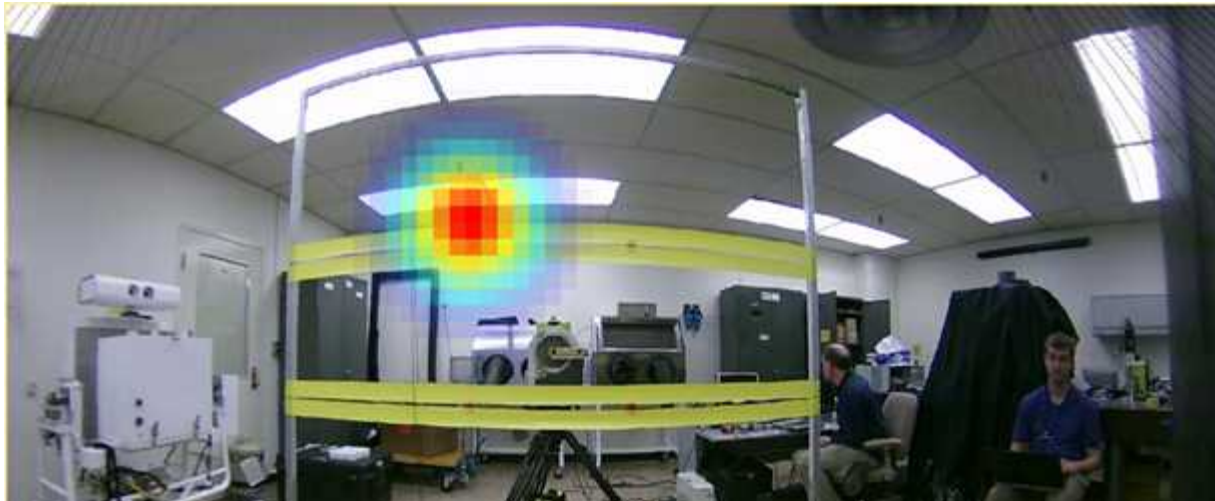


Compton Camera Progress



- **Energy-Image Integrated Deconvolution**
 - University of Michigan
 - Provides good separation between sources
 - Difficult to obtain variance for inverse modeling purposes
 - Lots of memory / time
 - Working toward combining Compton camera and coded aperture information
- **Directional Unfolded Source Term (DUST)**
 - Uses DRF and measurement data to unfold source term for specified spatial region
 - Using nonlinear regression, the source term for each spatial region is calculated using the distance specified by the user
 - Calculates discrete and continuum components
 - Issues with unreasonable source terms

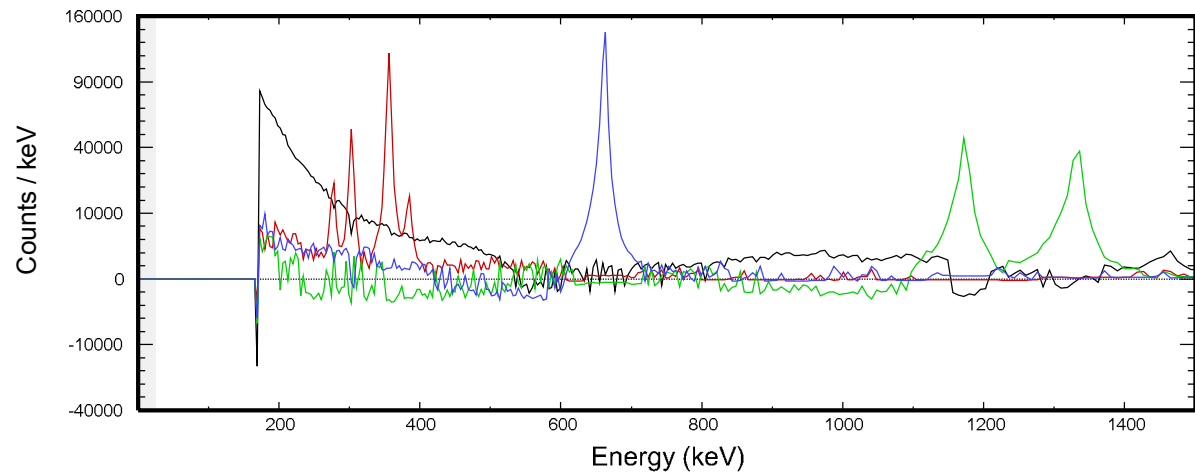
Compton Camera Progress



HED 110855 Imaged Cts; Ba-133;

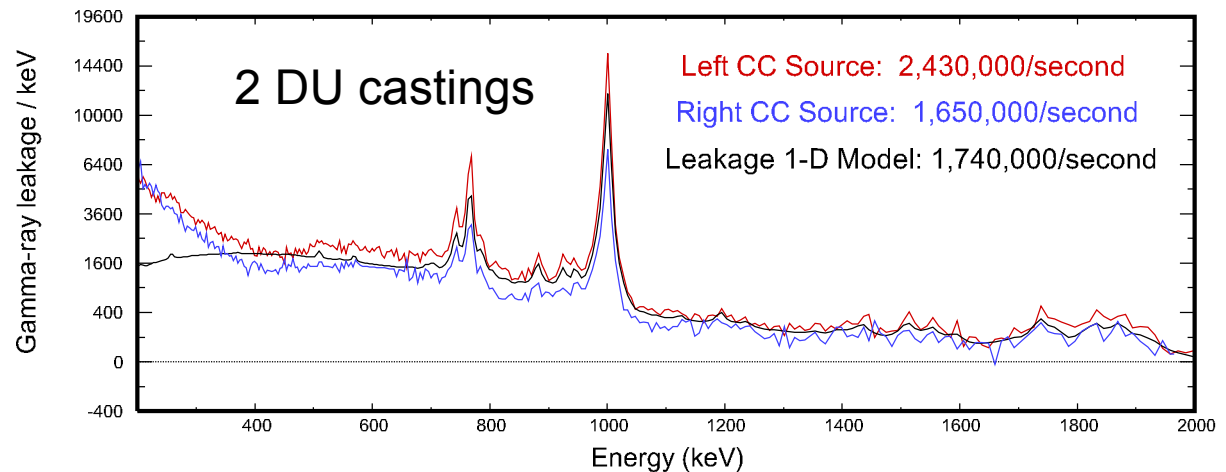
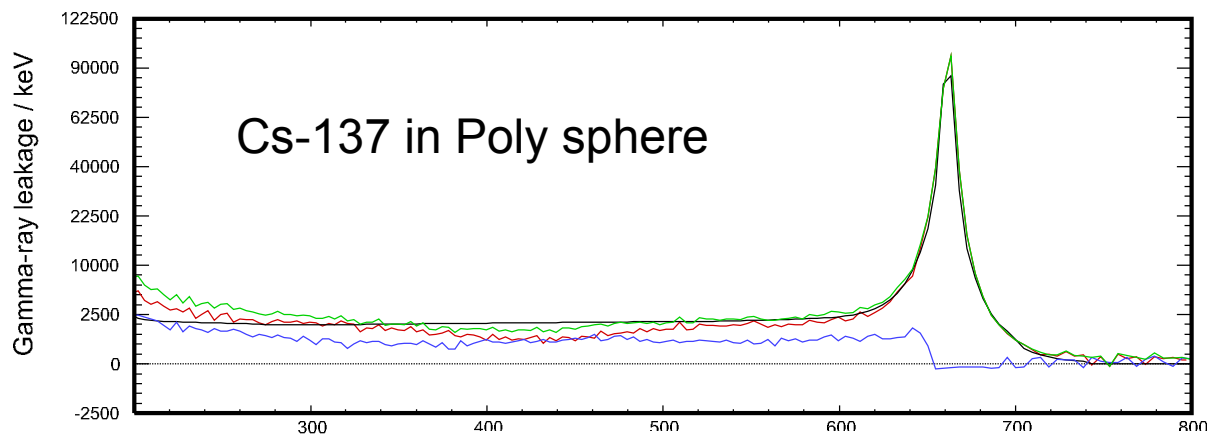
Foreground-20cm

live-time(s) = 1.00

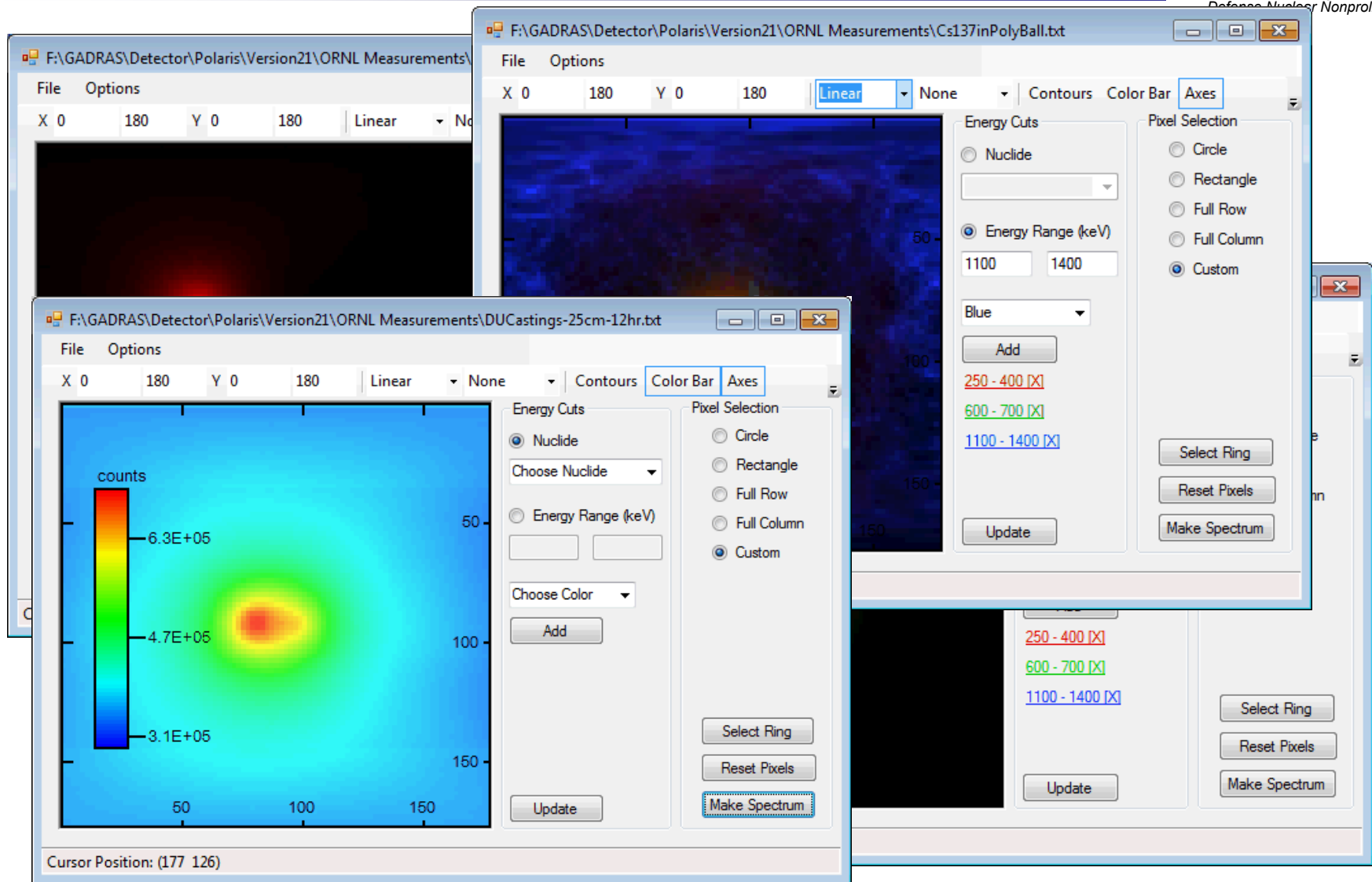


Compton Camera Progress

- Tested extended sources

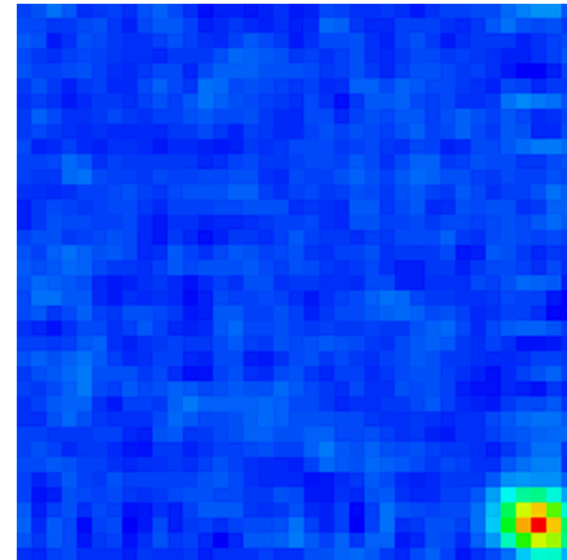
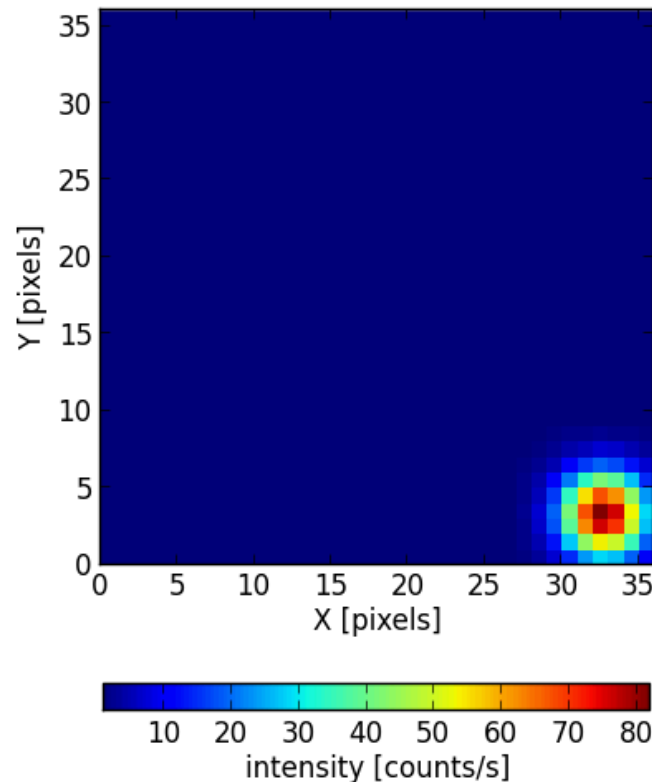


Compton Camera Progress

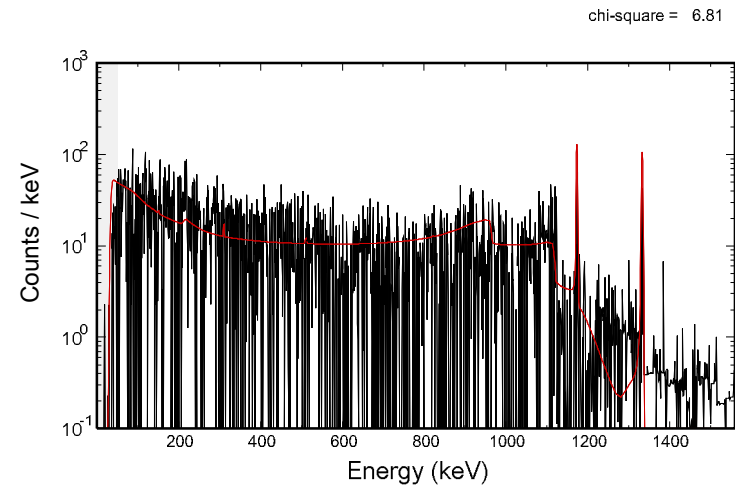
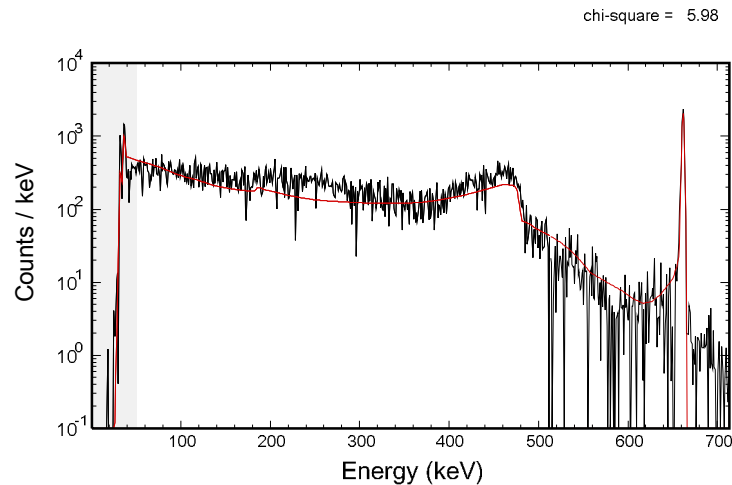
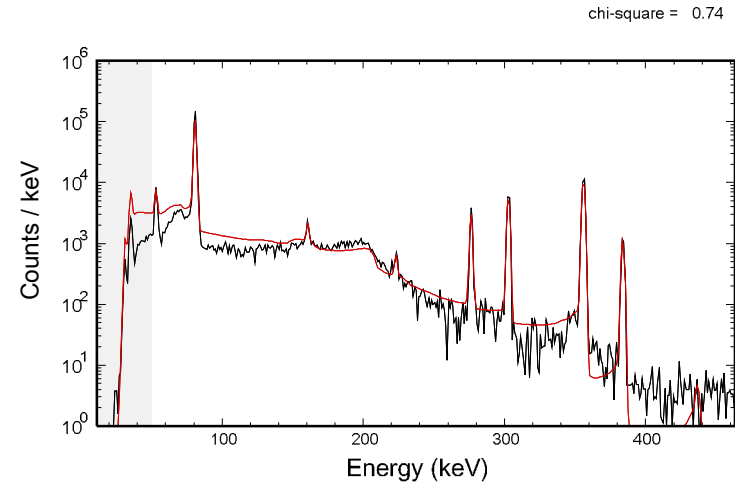
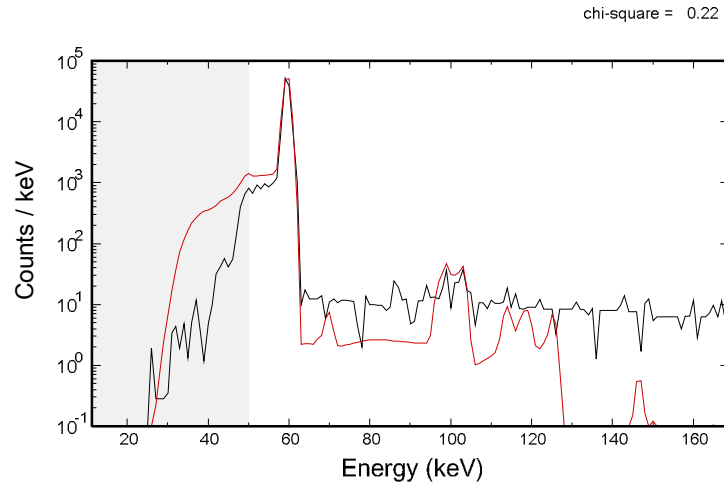


Coded Aperture Progress

- **Detector response function**
 - All parameters from non-direction sensors plus...
 - Measurement focal length
 - Mask info (dimensions, AN, AD)
 - Number of detector pixels



Coded Aperture Progress



- **Initial detector response function developed**
- **More data needed to advance**
 - **Detector not functioning correctly**
- **ORNL provided library for accessing coded aperture data**

Compton Cross-Talk Progress

- **Blind test performed in lab at SNL**
- **Sources between 10 and 100 μCi used at 10-20 feet from detector**
- **GADRAS used as baseline for ID**
- **Compton cross-talk method was data starved for this situation**
 - **Not useful in detection limits achievable in spectroscopic algorithms**

Future Work

- **Compton Camera**
 - Finish GUI implementation, expose to general community
 - Further automate directional spectrum analysis
 - Implement spectral analysis and model estimation
 - Continue working with UM to incorporate EIID method into GADRAS analysis tools
 - Test weak sources in high background
- **Coded Aperture**
 - Implement library provided by ORNL into GADRAS
 - Get more data
 - Implement analysis techniques
- **Compton Cross-Talk**
 - Algorithm not suitable for search