

Defense Nuclear Nonproliferation Research & Development

# Nuclear Weapons and Material Security Portfolio Review

## WMS 2016

## Directional Spectrometer Software

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<b>Project title:</b>	<b>Directional Spectrometer Software</b>
<b>Project number:</b>	<b>SL15-V-DirectSoftware-PD2Jc</b>
<b>Participating laboratories:</b>	<b>SNL, ORNL, NSTec</b>
<b>Participating Contractors:</b>	<b>H3D, University of Michigan</b>
<b>Status:</b>	<b>Finished Year 2 of 3</b>

- **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

- **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**

- **Technology**

- **Compton Camera**

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

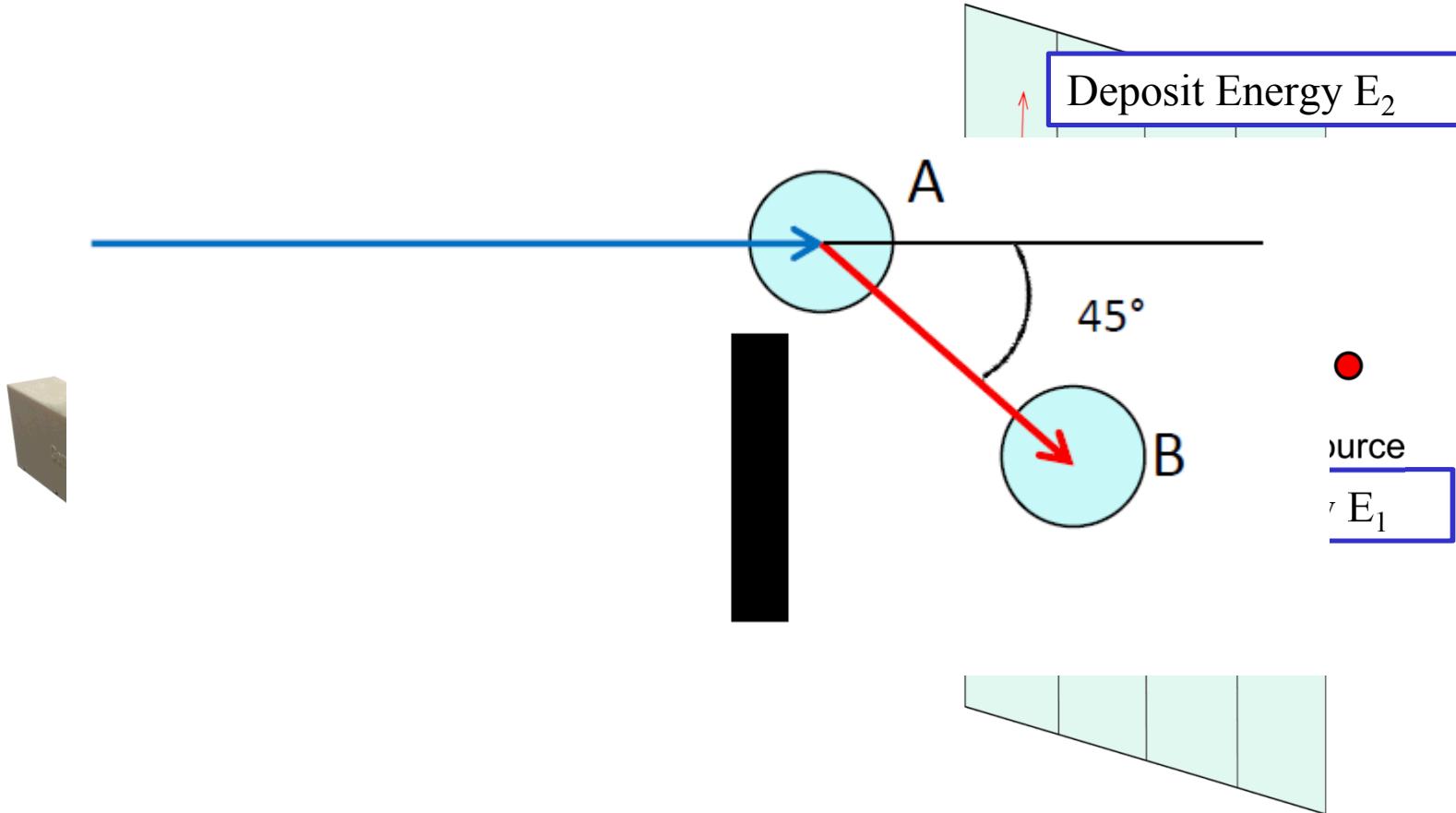
- **Coded Aperture**

- **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



- 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

- **Deliverables**

- **FY15**

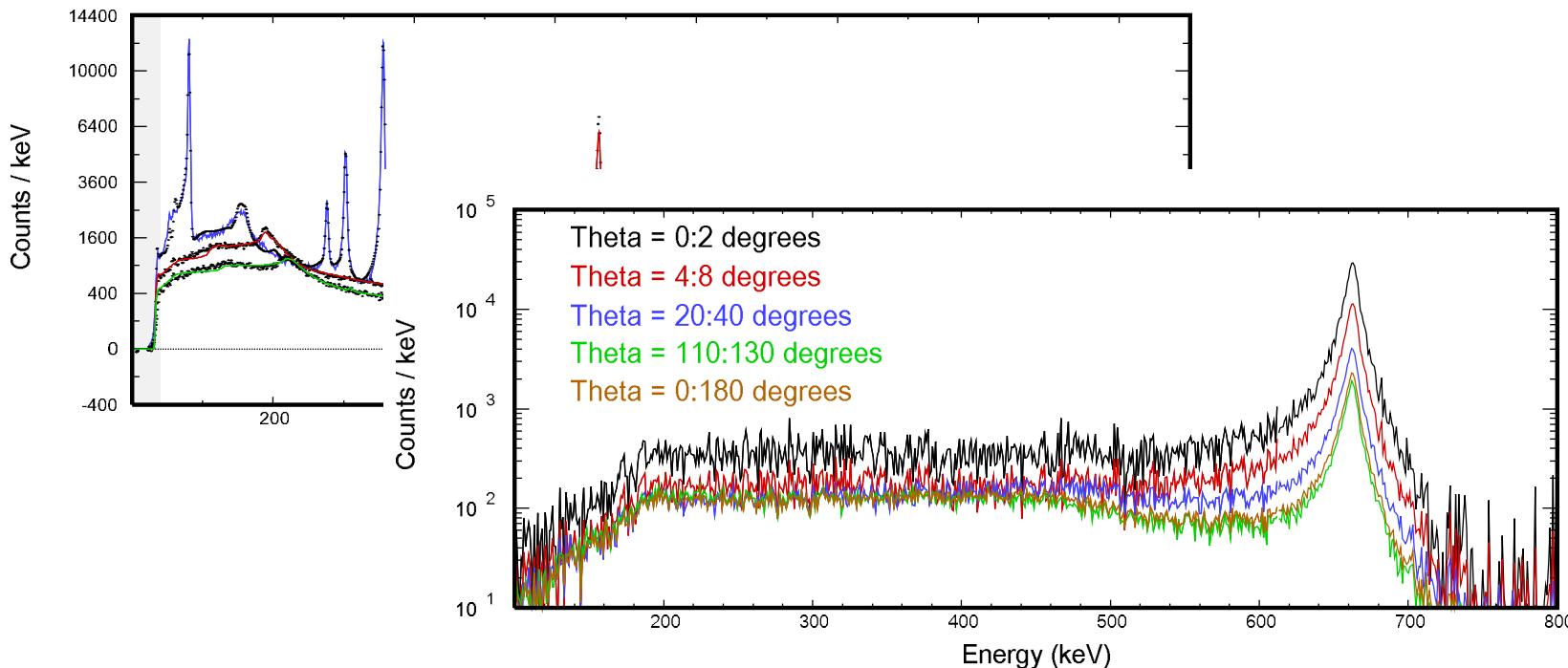
- SNL create preliminary detector response function algorithms for Polaris and GeGI systems
    - SNL revise SNM Analysis algorithm to run with CZT detectors (Polaris)
    - H3D and ORNL provide calibration data to SNL
    - H3D and ORNL provide libraries conforming to standard for accessing directional 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

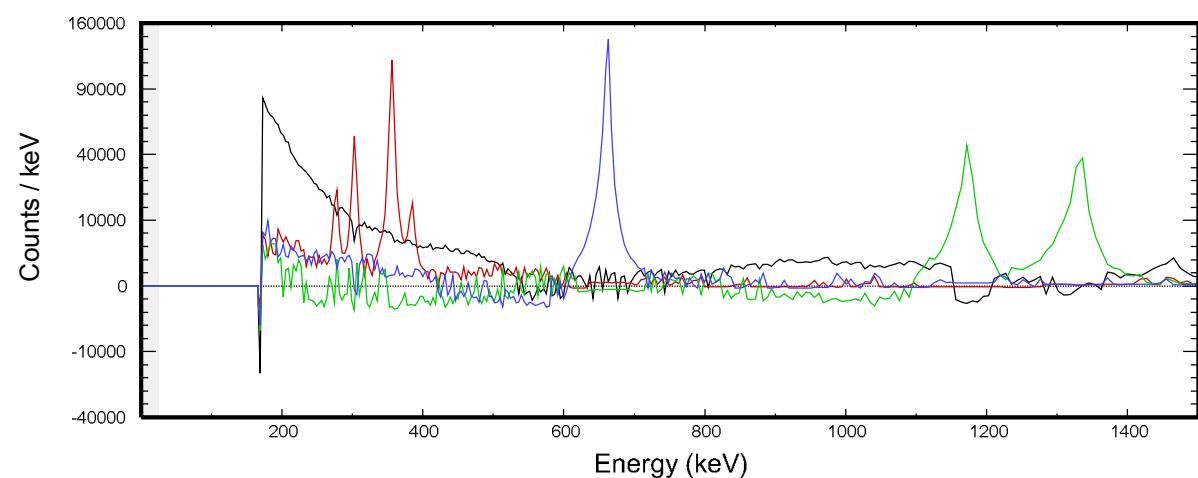
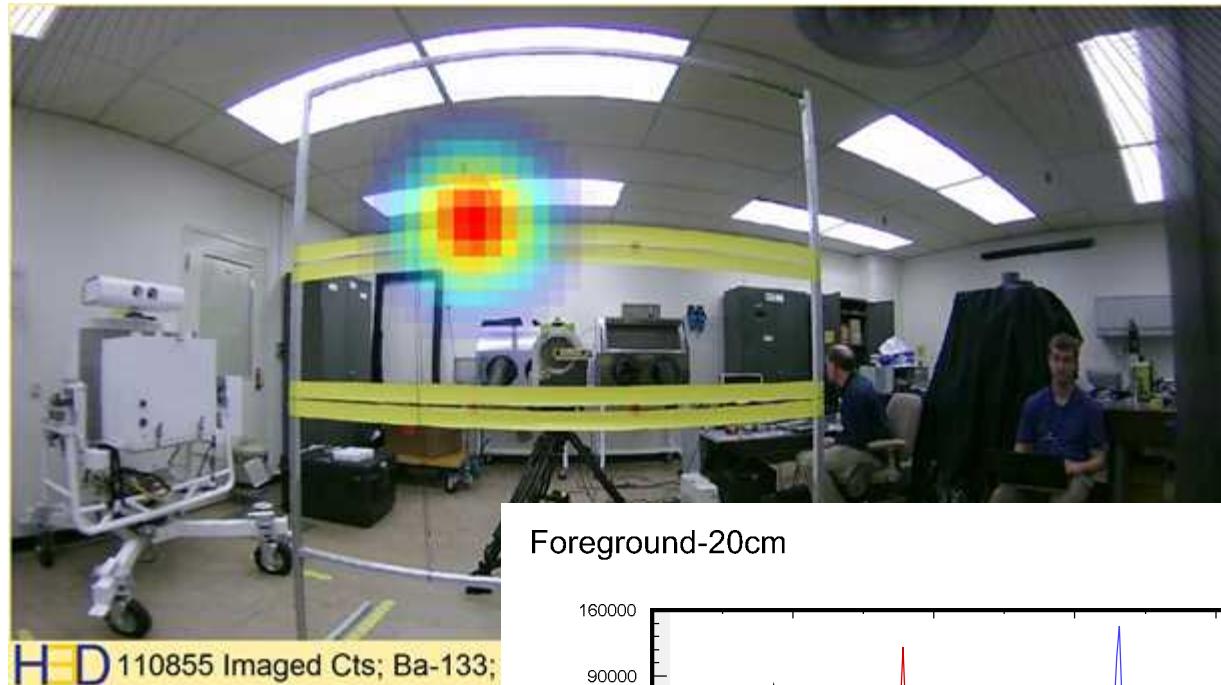
- **Applications**
  - Treaty verification for arms control
  - Diagnostics for emergency response and counter-terrorism
  - Search
  - Cargo-inspection
- **Reduce time/resources needed for analysis**
  - Obtain usable spectra
    - Eliminate requirement for interaction with developer
  - Compute spectra 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

- **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

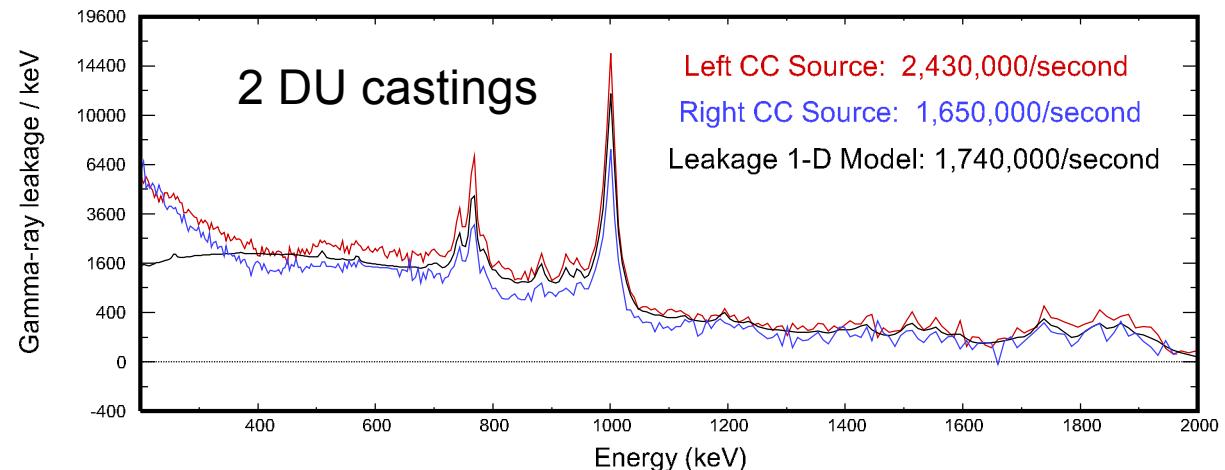
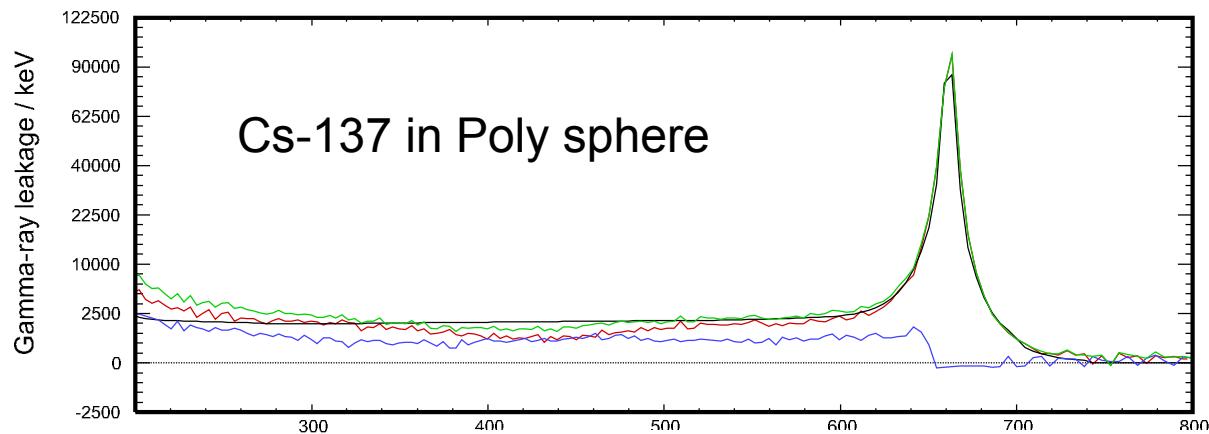


- Energy-Image Integrated Deconvolution
  - University of Michigan
  - Provides good separation between sources
  - Difficult to obtain variance for inverse modeling purposes
  - Lots of memory / time
  - Working toward combining Compton camera and coded aperture information
- Directional Unfolded Source 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

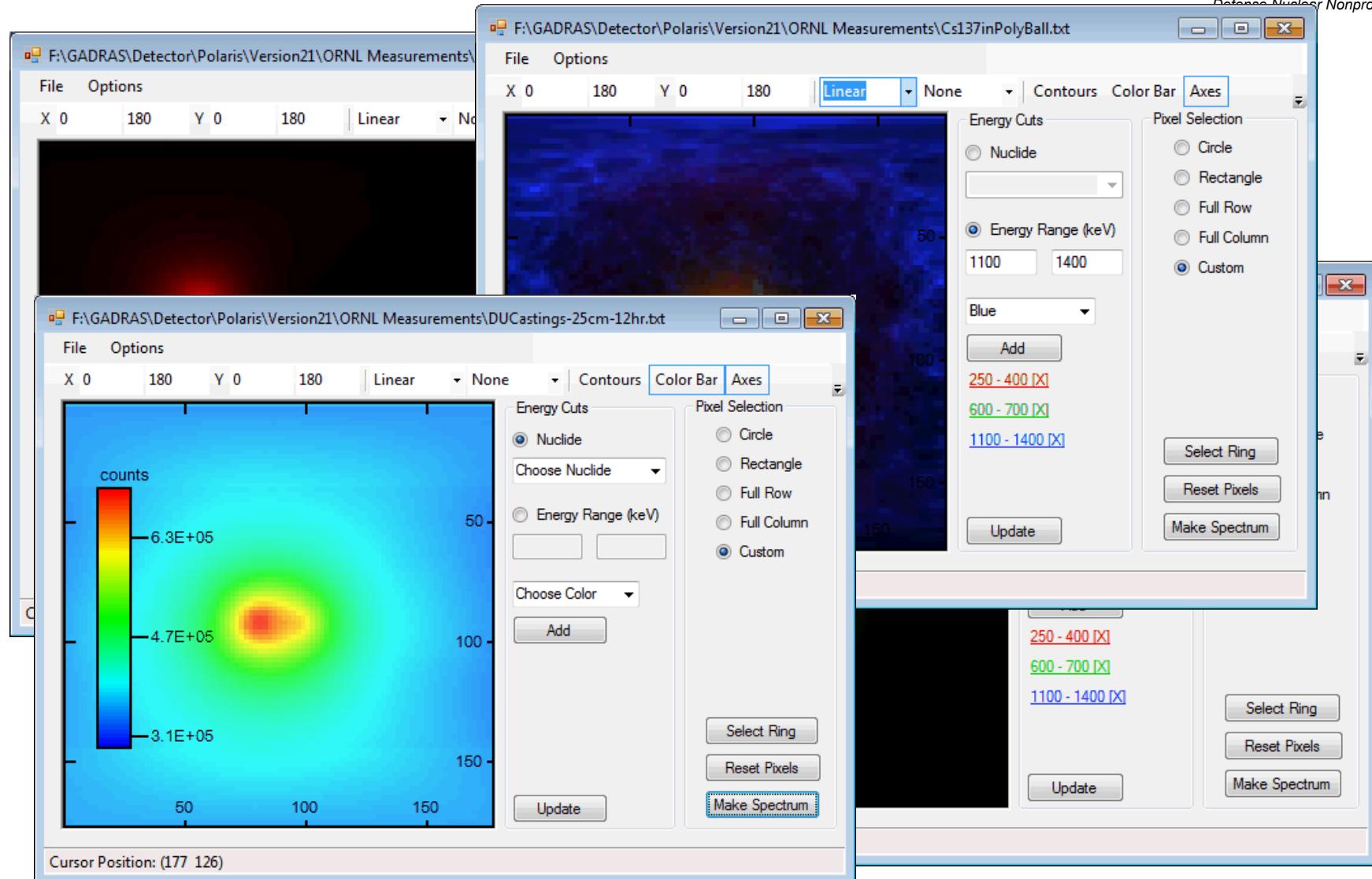
# Compton Camera Progress



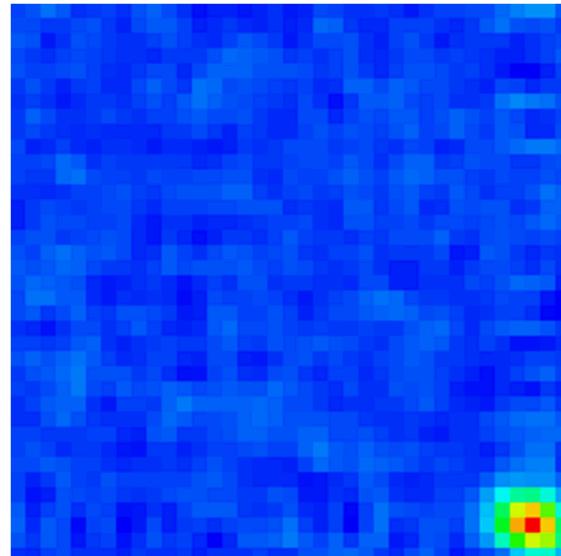
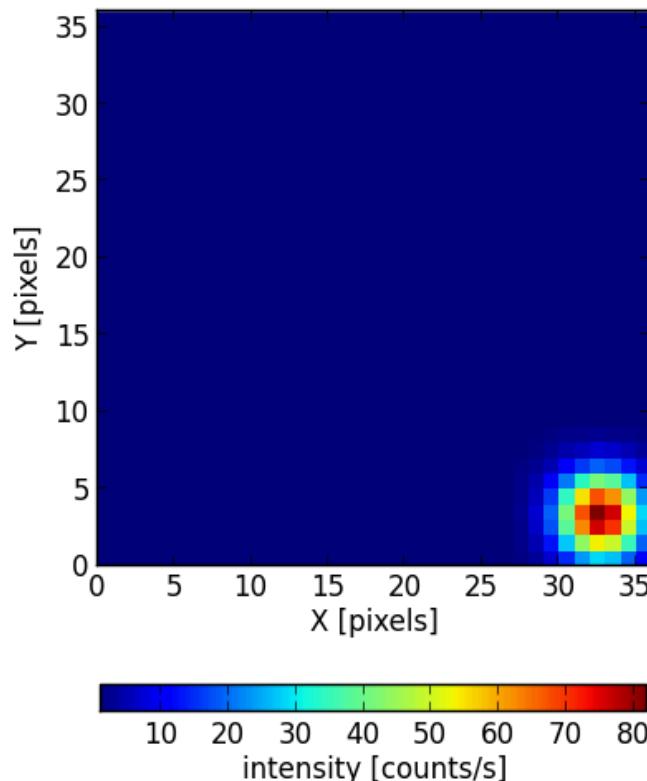
- Tested extended sources



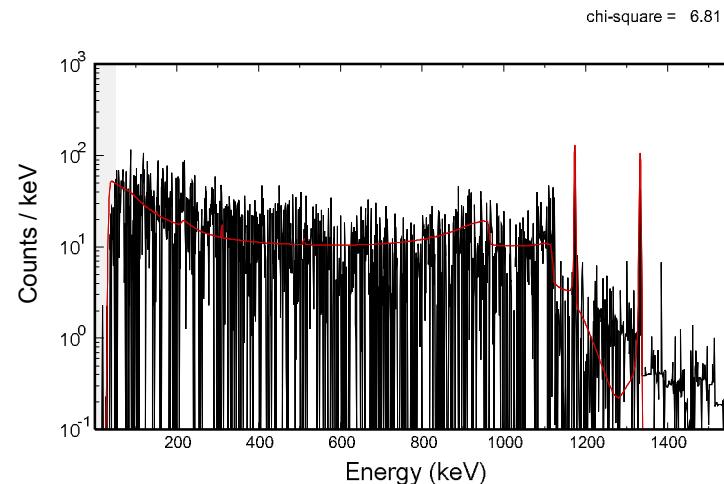
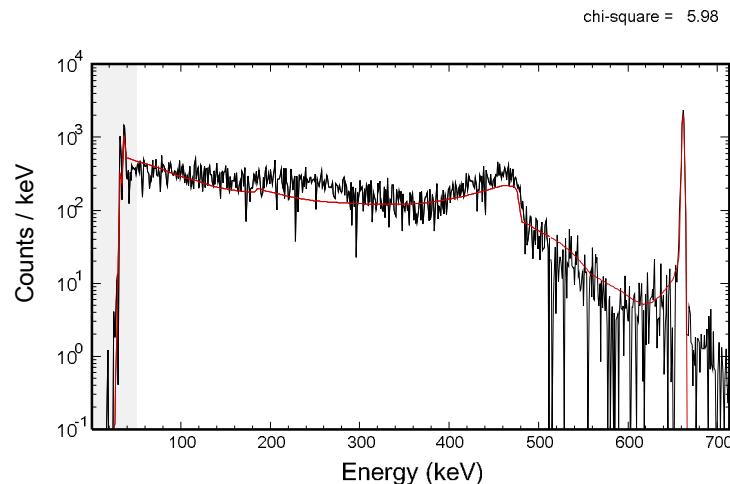
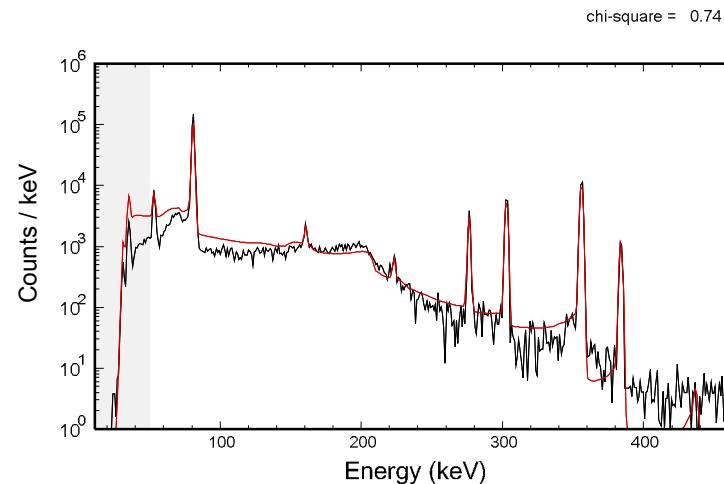
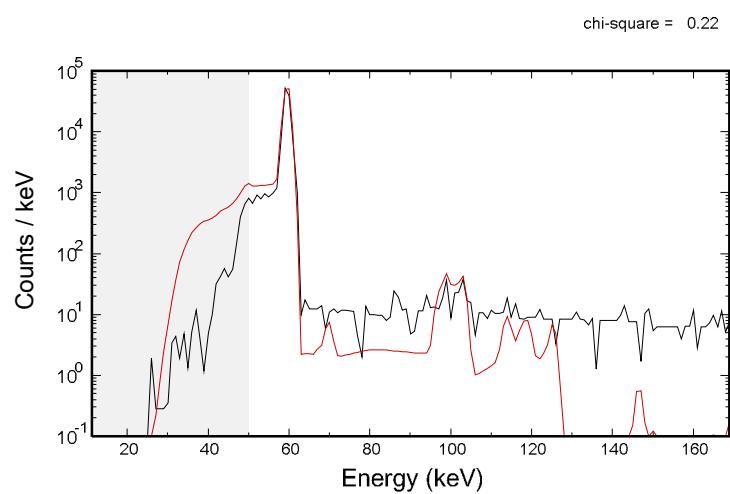
# Compton Camera Progress



- **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**

- **Blind test performed in lab at SNL**
- **Sources between 10 and 100  $\mu\text{Ci}$  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**

- **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