SAND2017-2214PE

Defense Nuclear Nonproliferation Research & Development

DNN R&D NSARD 2017

Directional Spectrometer Software

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SAND2017-????

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:	**Finishing Year 3 of 3 (1 year no-cost extension requested)**

- **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

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Supporting Technology

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- **Polaris**
  - Developed by H3D and UM
  - CZT segmented detector system
  - Both Compton Camera (CC) and Coded Aperture (CA) imaging modes
    - Ability to synthesize directional spectra for both methods developed for this project
- **Germanium Gamma-ray Imager (GeGI)**
  - Commercial imager by PHDS, software by ORNL
  - CA imager using tantalum mask
  - More sensitive to low energy photons (< 400 keV)
- **Compton Crosstalk / Occlusion Methods / Baby Janus**
  - Imaging software developed by NSTec applicable to multi-element sensors
  - Compton crosstalk demonstrated for Baby Janus detector
  - Occlusion method evaluated for Polaris
- **Gamma Detector Response and Analysis Software (GADRAS)**
  - Extensive capabilities for forward calculations and analysis of gamma-ray and neutron measurements

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Project Goals

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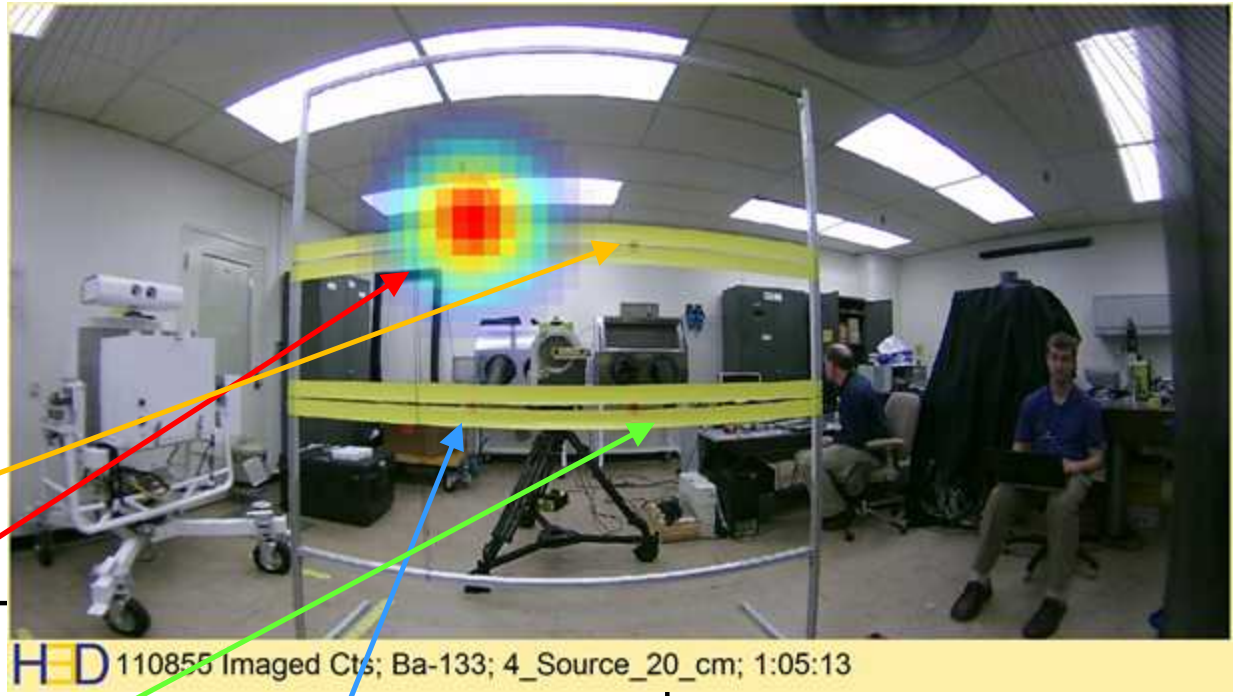
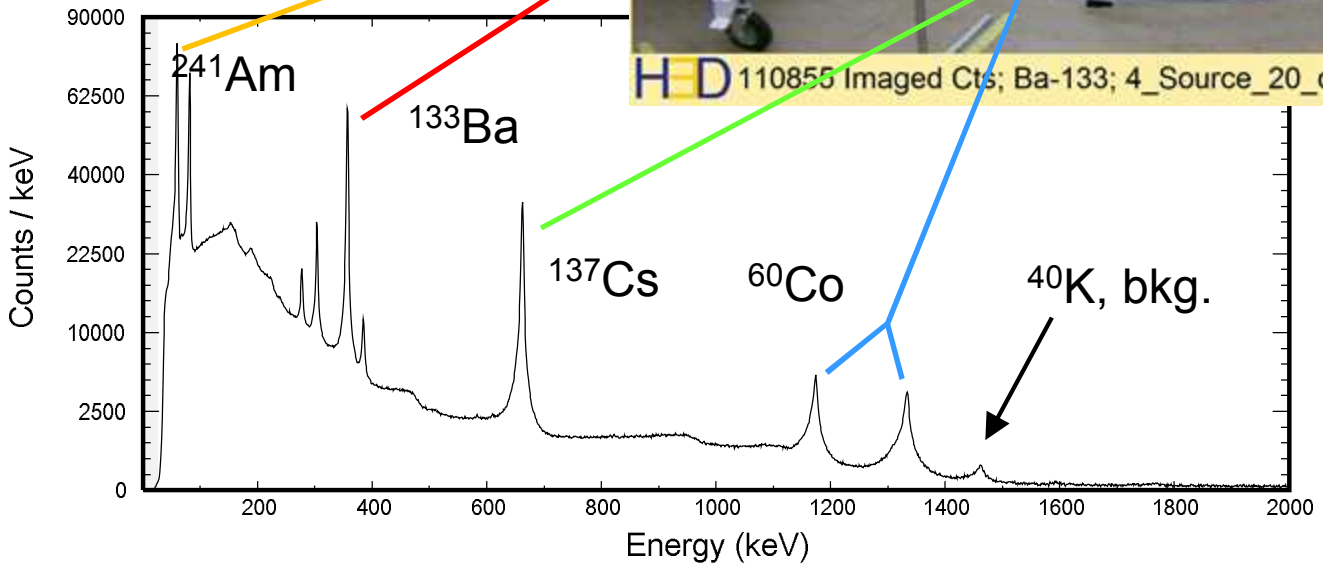
- **Utilize spectroscopic information collected by directional sensors**
  - Utilize directional spectra for analysis (normal focus is imaging)
  - Develop DRF for use in forward calculations and analysis
- **Explore alternative directional processing methods**
  - Assess Compton crosstalk and occlusion methods developed by NSTec
- **Develop common interface for data processing and analysis**
  - Application Programming Interface (API) developed and used by GADRAS to display and process data collected by Polaris and GeGI
  - Common GUI for CA and CC, analysis tools enabled for directional spectra
- **Evaluate Limitations and Compare Performance**
  - Non-imaging sensors (best statistics by using all data)
  - Coded Aperture (best for low-energy gamma rays)
  - Compton Camera (best for high-energy gamma rays)
  - Combined CA and CC (extended energy range developed for Polaris)
  - Energy-Image Integrated Deconvolution (EIID) / Filtered Back-Projection (FBP) / Directional Unfolded Source Term (DUST)

Experiment at ORNL

Measurements with Polaris and GeGI:

- Calibration sources at series of separations (1, 2, 5, 10, 15, 20, 30, 50 cm)
- DU cylinders
- Thorium plate





Gross spectrum recorded by Polaris shows all sources, but no location information

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Compton Camera Analysis

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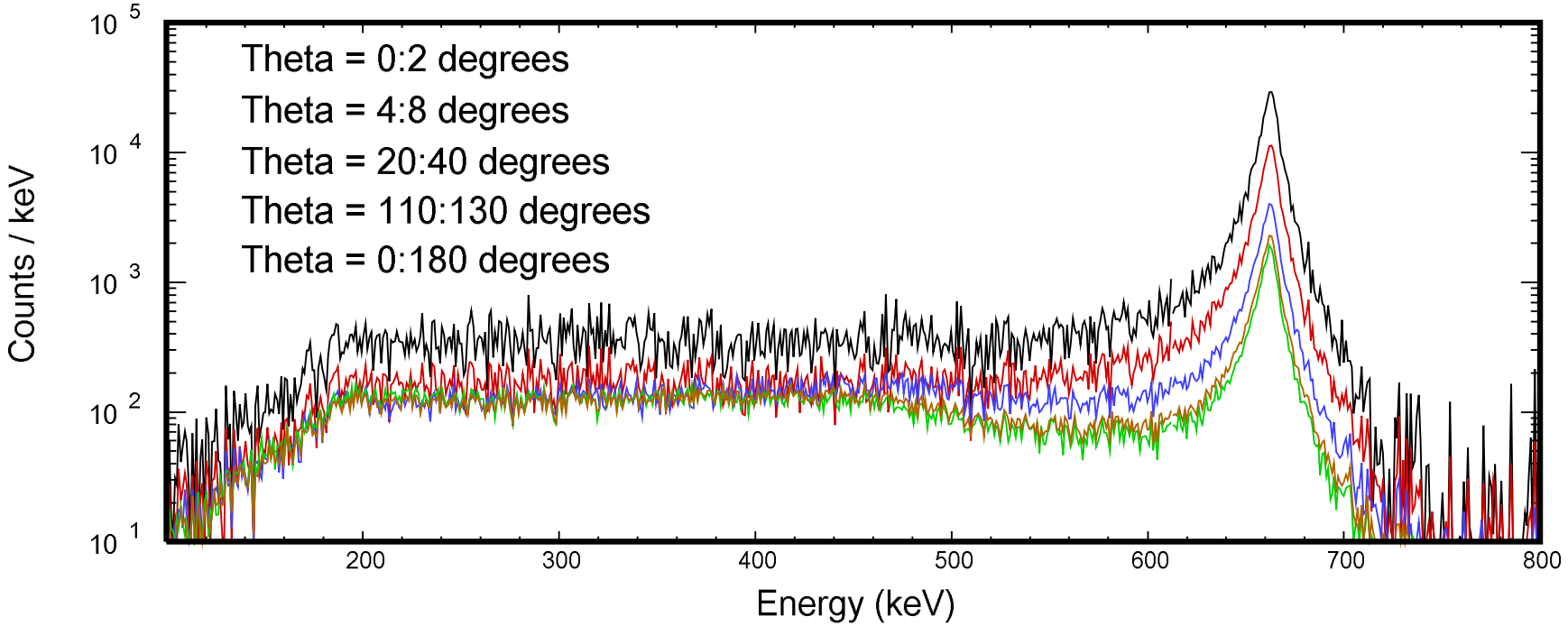
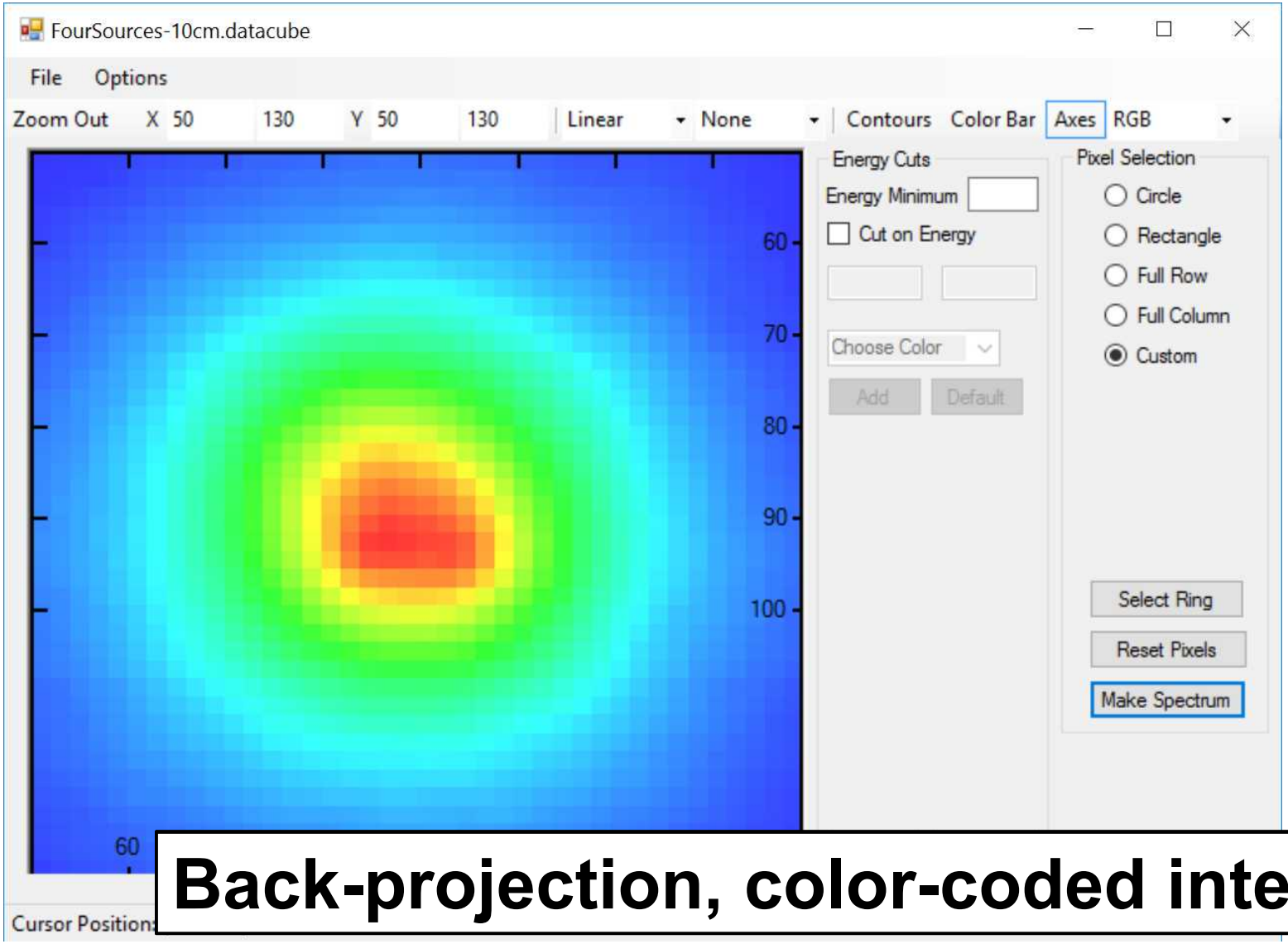
- **Analysis of spectra recorded in CC mode is particularly challenging because probability cones render peaks in all spatial regions**
  - Methods developed by UM, H3D, and SNL unfold source profiles
- **Plot below shows Compton back-projection spectra at various angles relative to the actual location of a ^{137}Cs source**

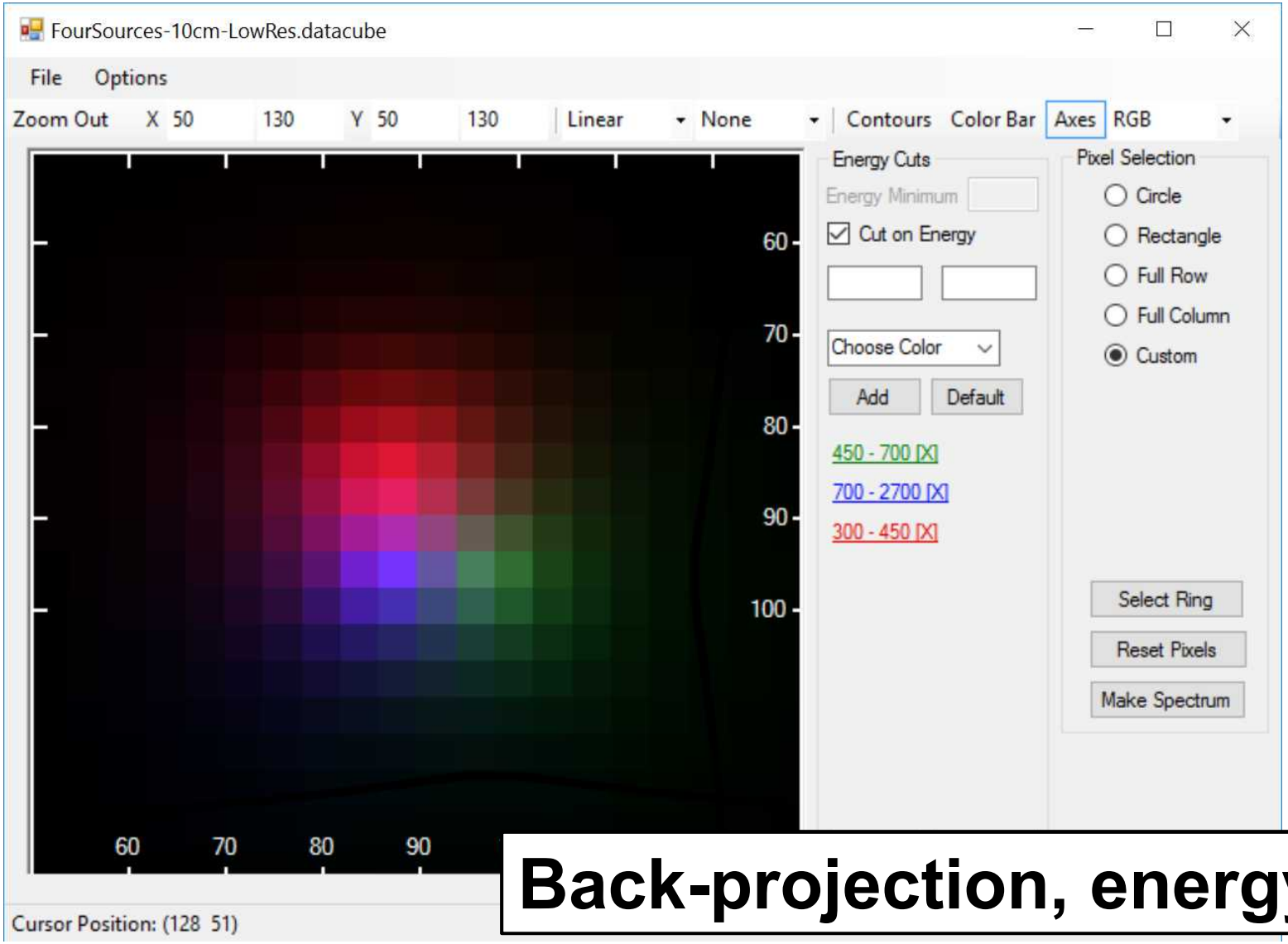


Polaris CC, DUST Analysis



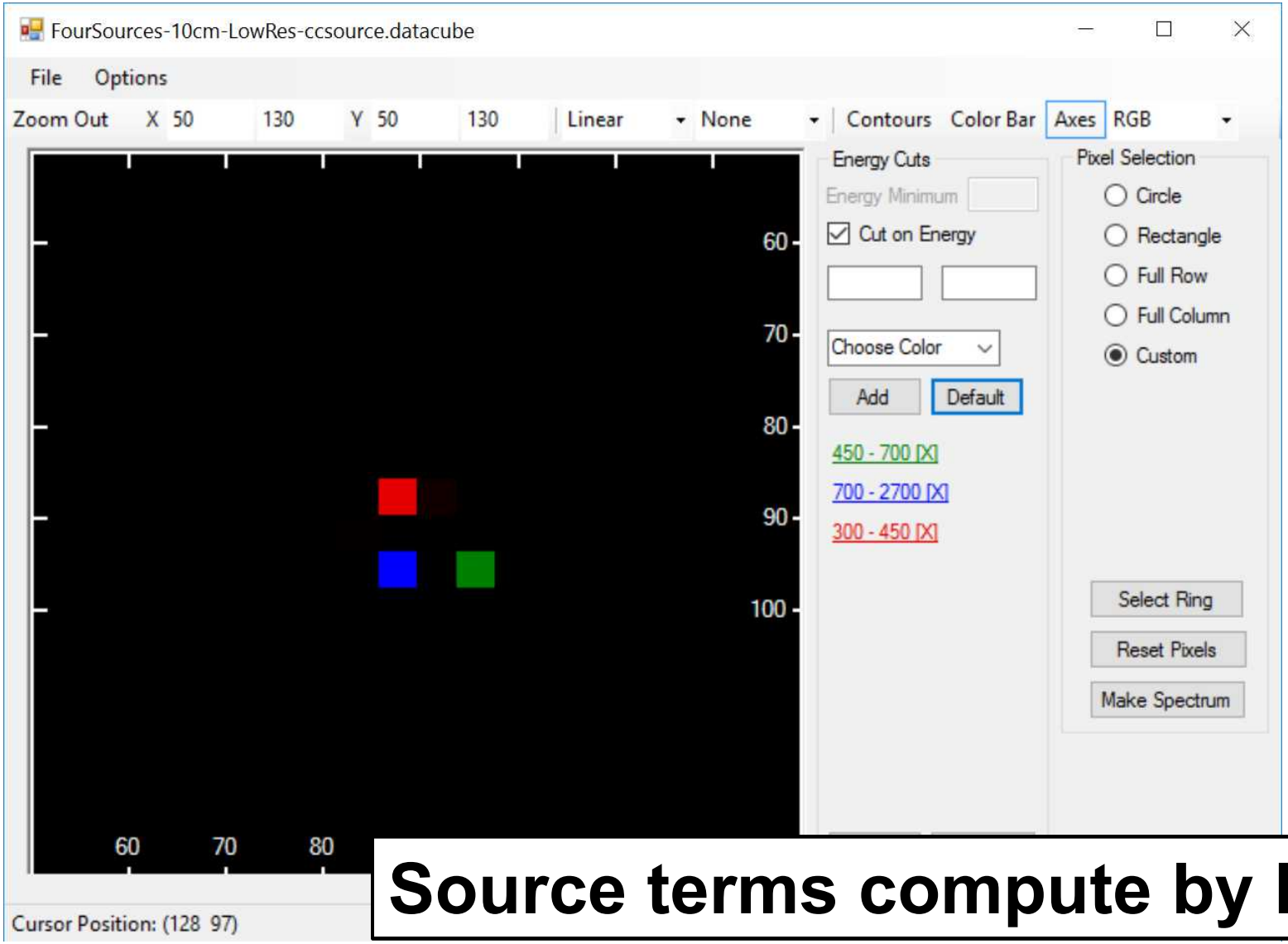
Back-projection, color-coded intensities

Polaris CC, DUST Analysis



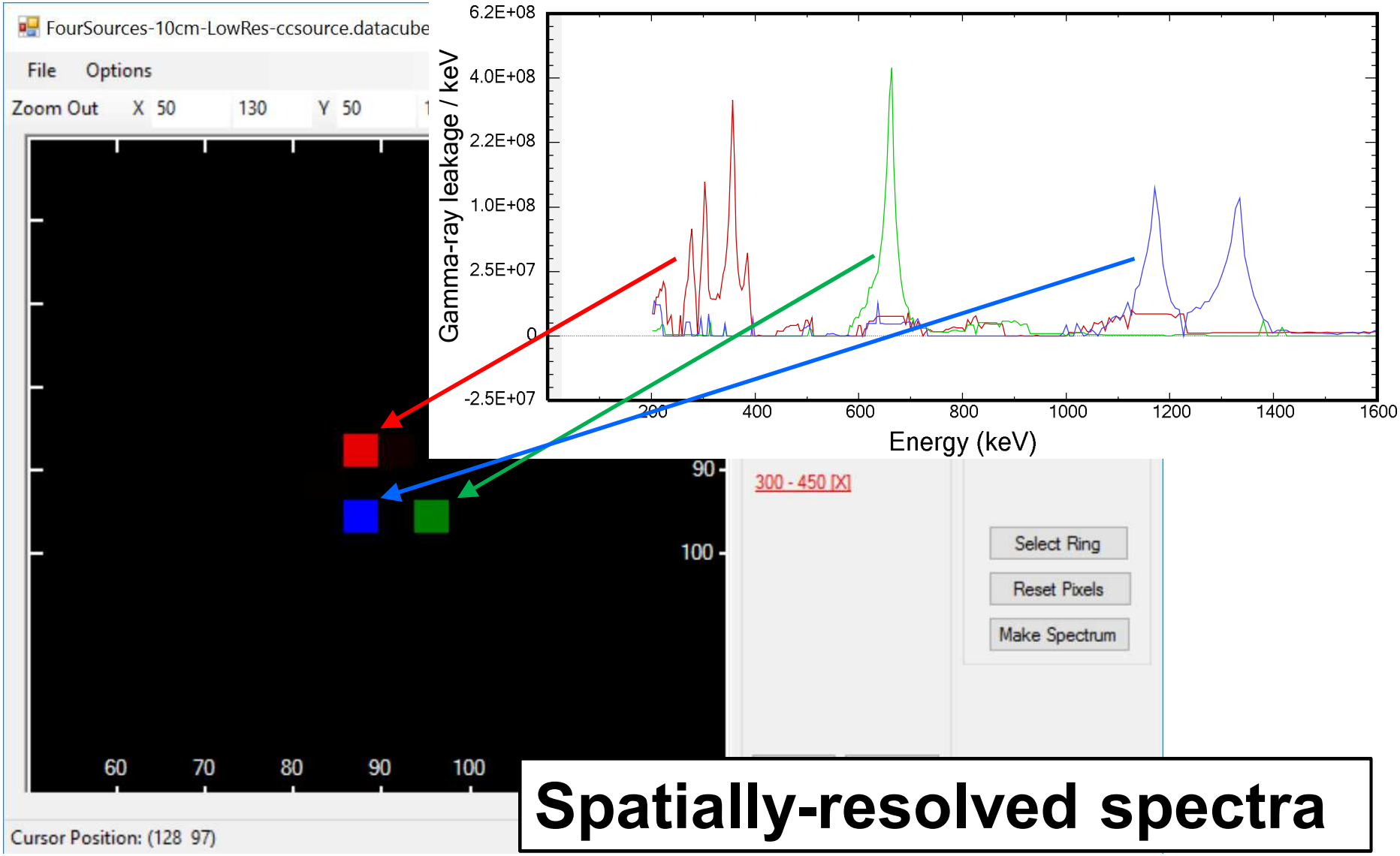
Back-projection, energy cuts

Polaris CC, DUST Analysis



Source terms compute by DUST

Polaris CC, DUST Analysis



Spatially-resolved spectra

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Polaris CC, DUST Analysis DU

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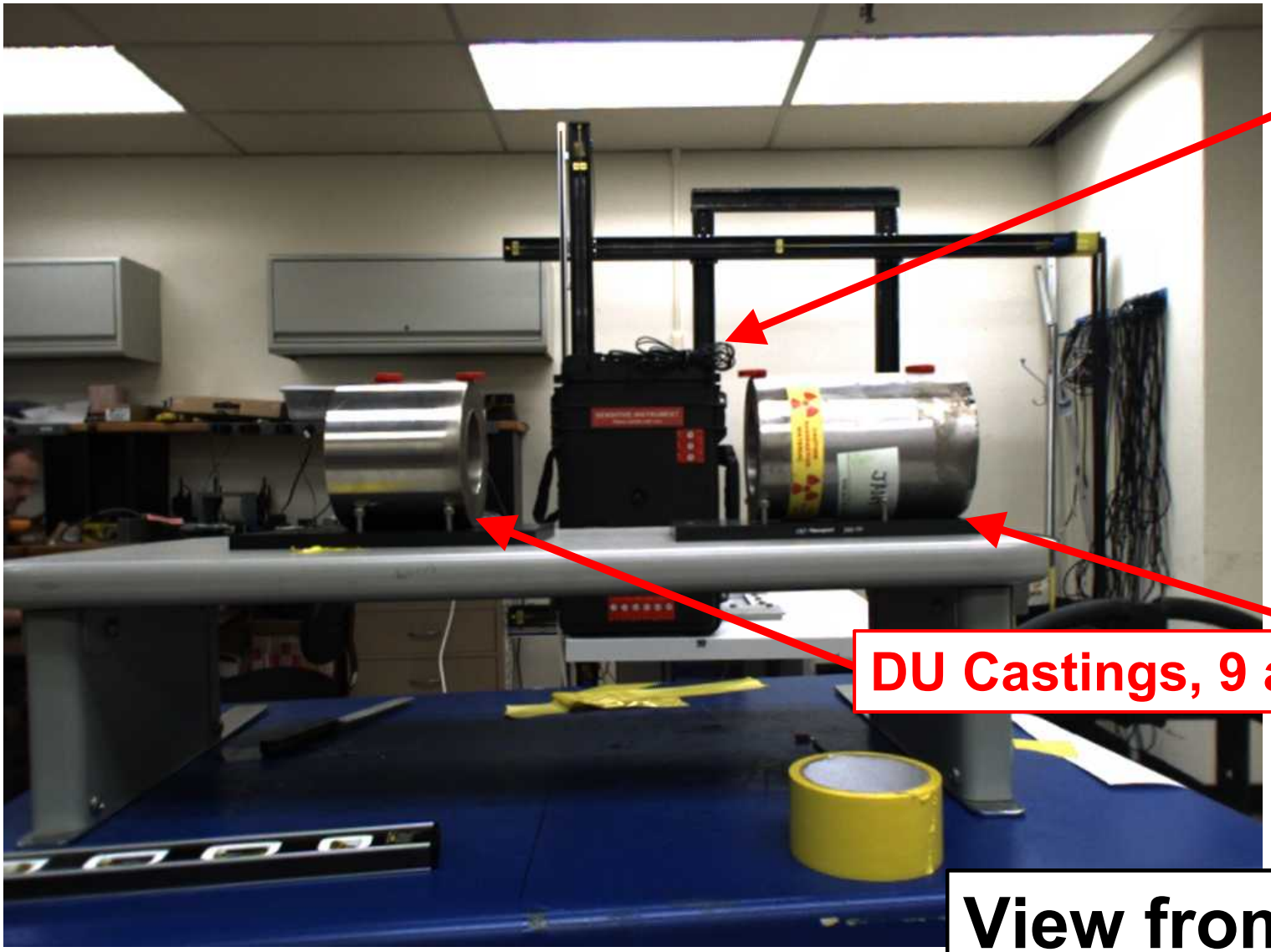
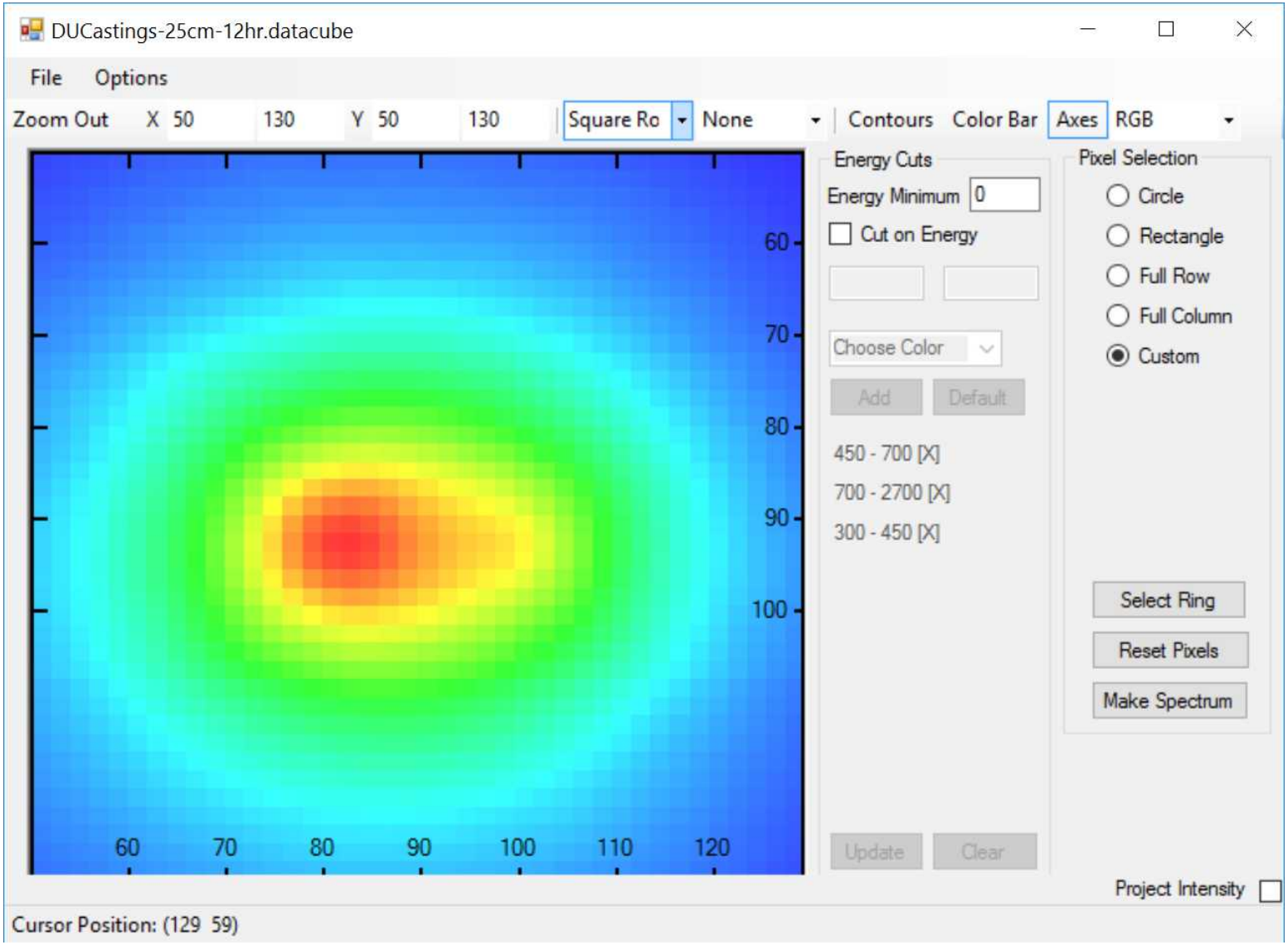
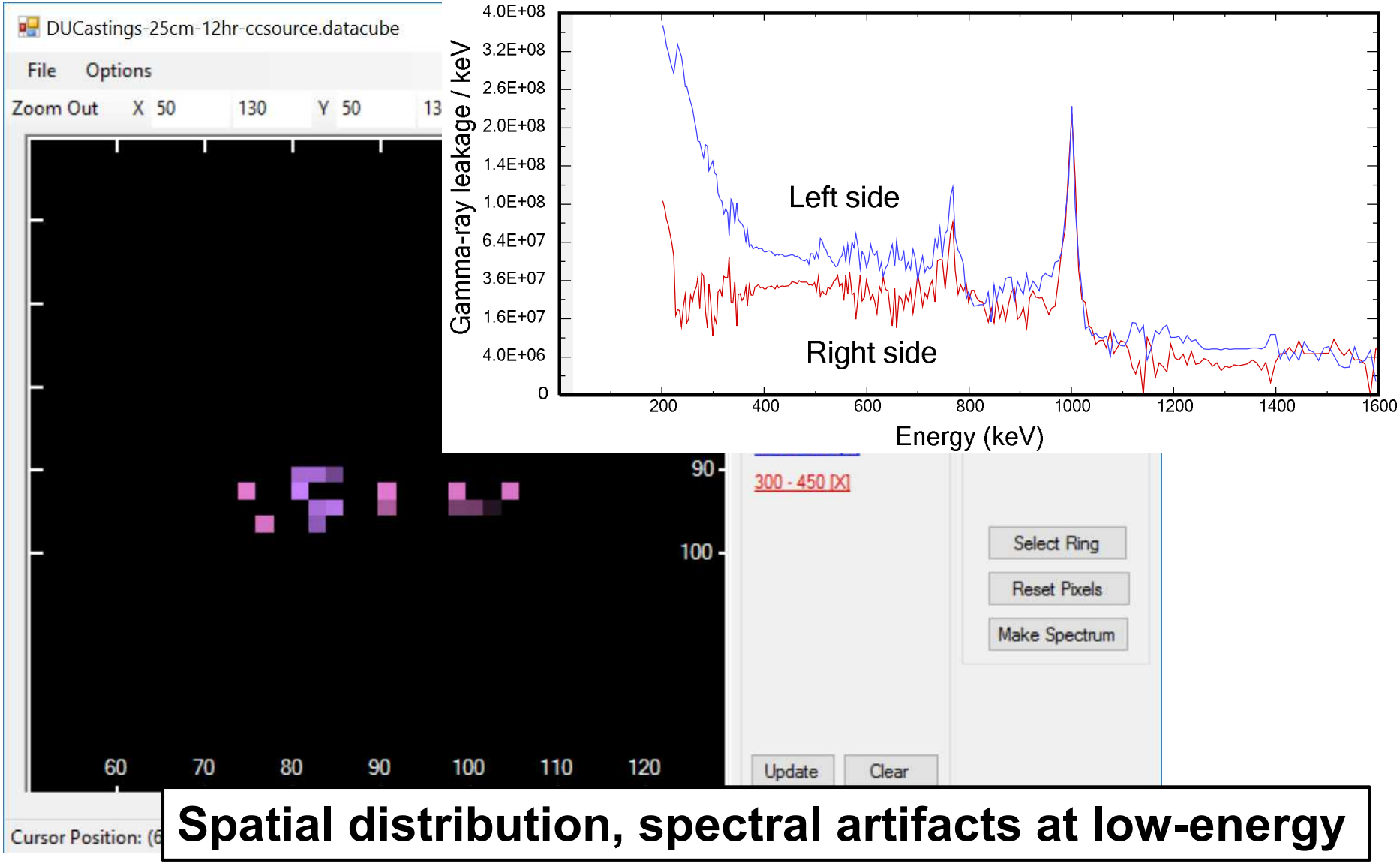


View from GeGI

Polaris CC, DUST Analysis DU

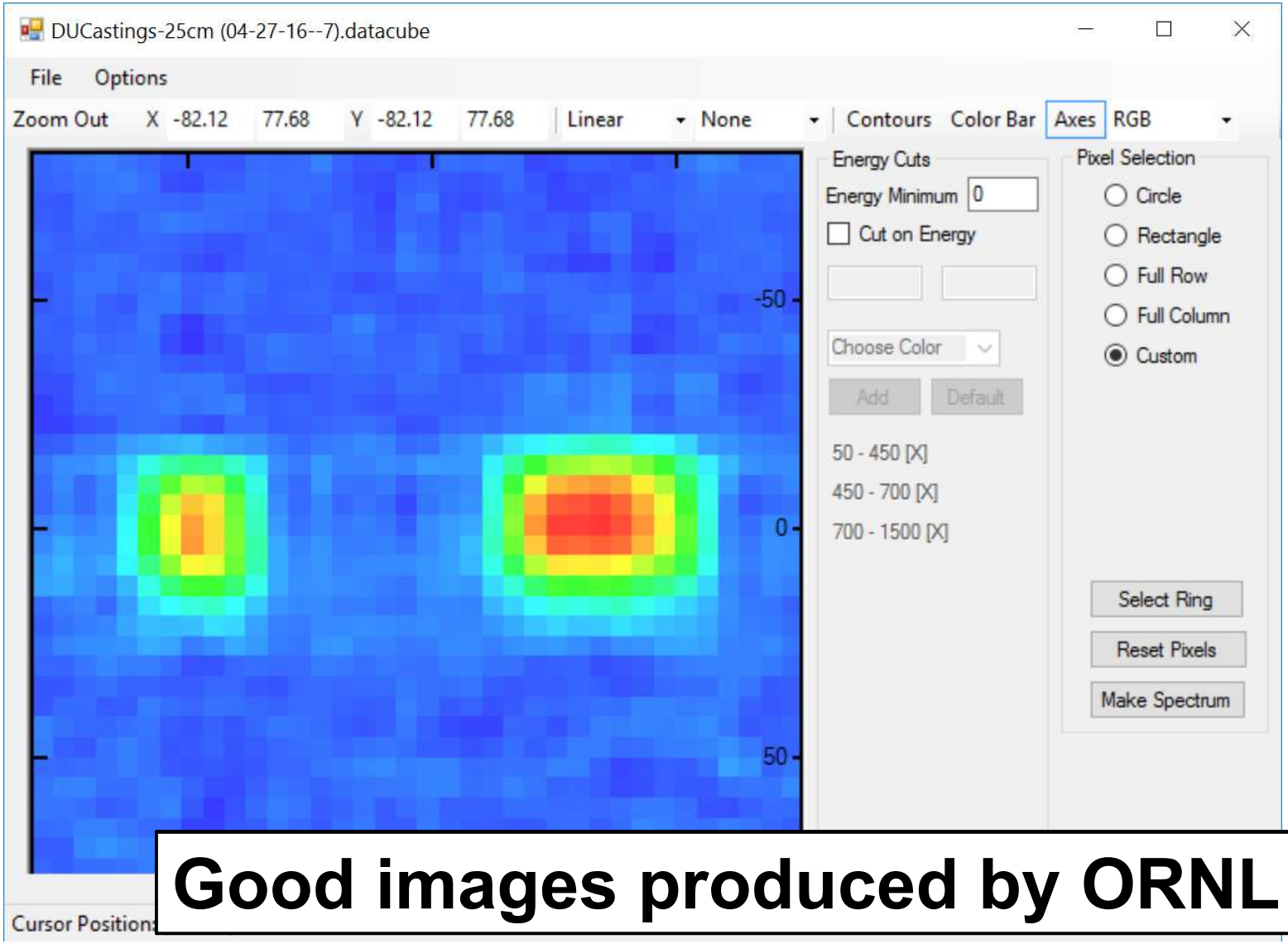


Polaris CC, DUST Analysis DU



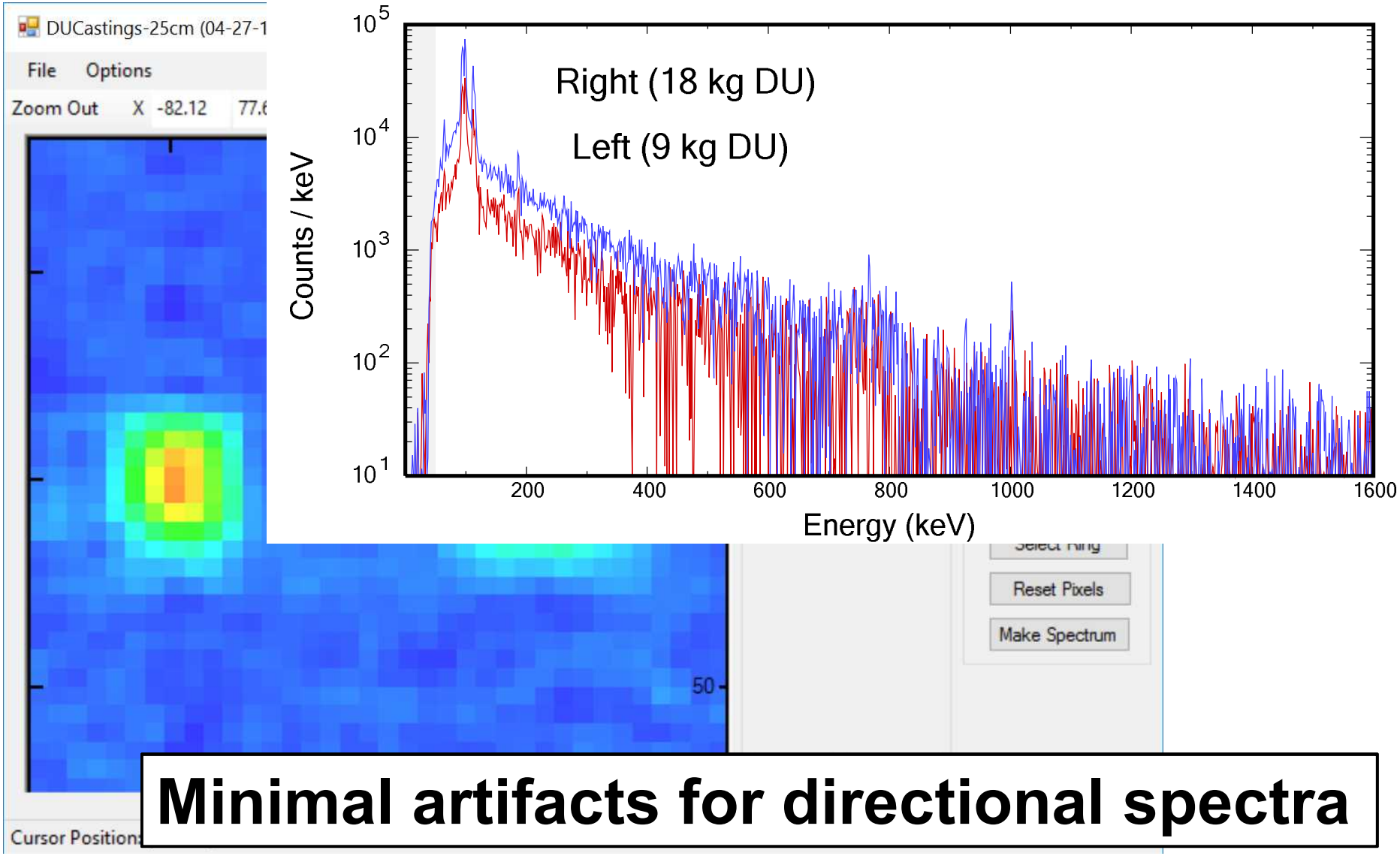
Spatial distribution, spectral artifacts at low-energy

GeGI CA, ORNL Analysis DU



Good images produced by ORNL DLL

GeGI CA, ORNL Analysis DU



Minimal artifacts for directional spectra

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Polaris Algorithm Evaluation

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- **The performance of various algorithms will be evaluated:**
  - DUST (SNL) fast
  - EIID (UM) powerful but slow
  - FBP (UM) fast
- **DLLs for EIID and FBP not yet functional under GADRAS**
- **Not yet able to provide useful directional spectra for Polaris coded aperture mode**
  - Directional spectra cannot be computed below about 250 keV
    - Polaris Version 2.2 will use thicker coded-aperture mask
    - ORNL is willing to modify their analysis algorithm to process Polaris data

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Summary/Milestones

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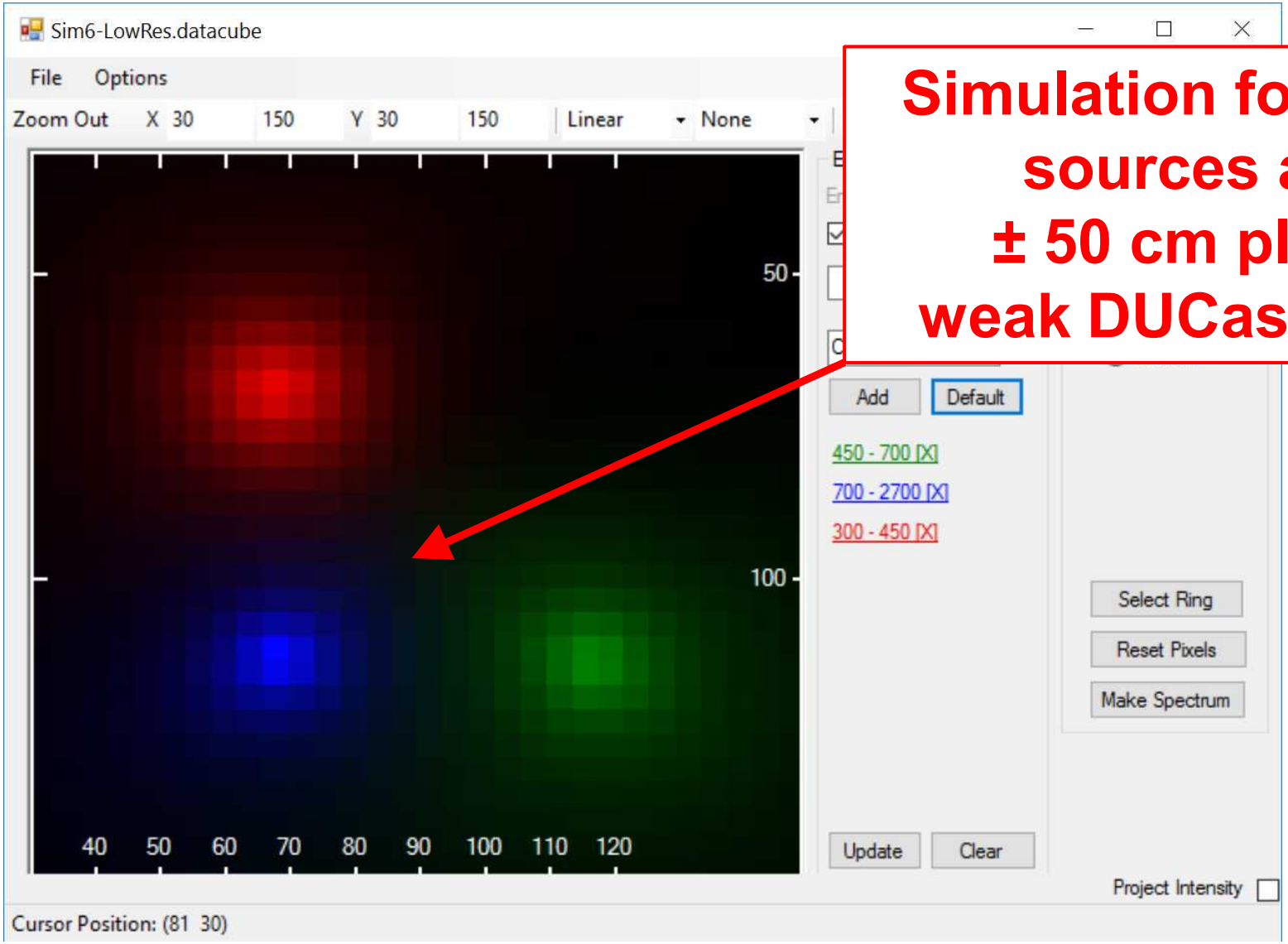
- **FY15**
  - Calibration data for Polaris and GeGI collected and DRF developed
  - Analysis algorithms modified to process Polaris data
  - API developed that specifies common interface for imaging sensors
  - DLLs conforming to API developed for Polaris and GeGI
- **FY16**
  - Compton crosstalk method evaluated
  - DUST algorithm developed to unfold CC data for Polaris
  - Polaris and GeGI DLLs integrated into GADRAS and GUI developed
  - Numerous software refinements
- **FY17**
  - DUST algorithm revised to automate analysis, CA analysis in progress
  - DLL developed by UM for filtered back-projection (FBP) method
  - DUST vs. FBP vs. EIID (Polaris) vs. GeGI to be evaluated
- **FY18: Consolidation and Reports (if extension granted)**
  - Process data for complex 3-D objects (new DAF measurements, WMC?)
  - Complete EIID, FBP integration and CA processing for Polaris

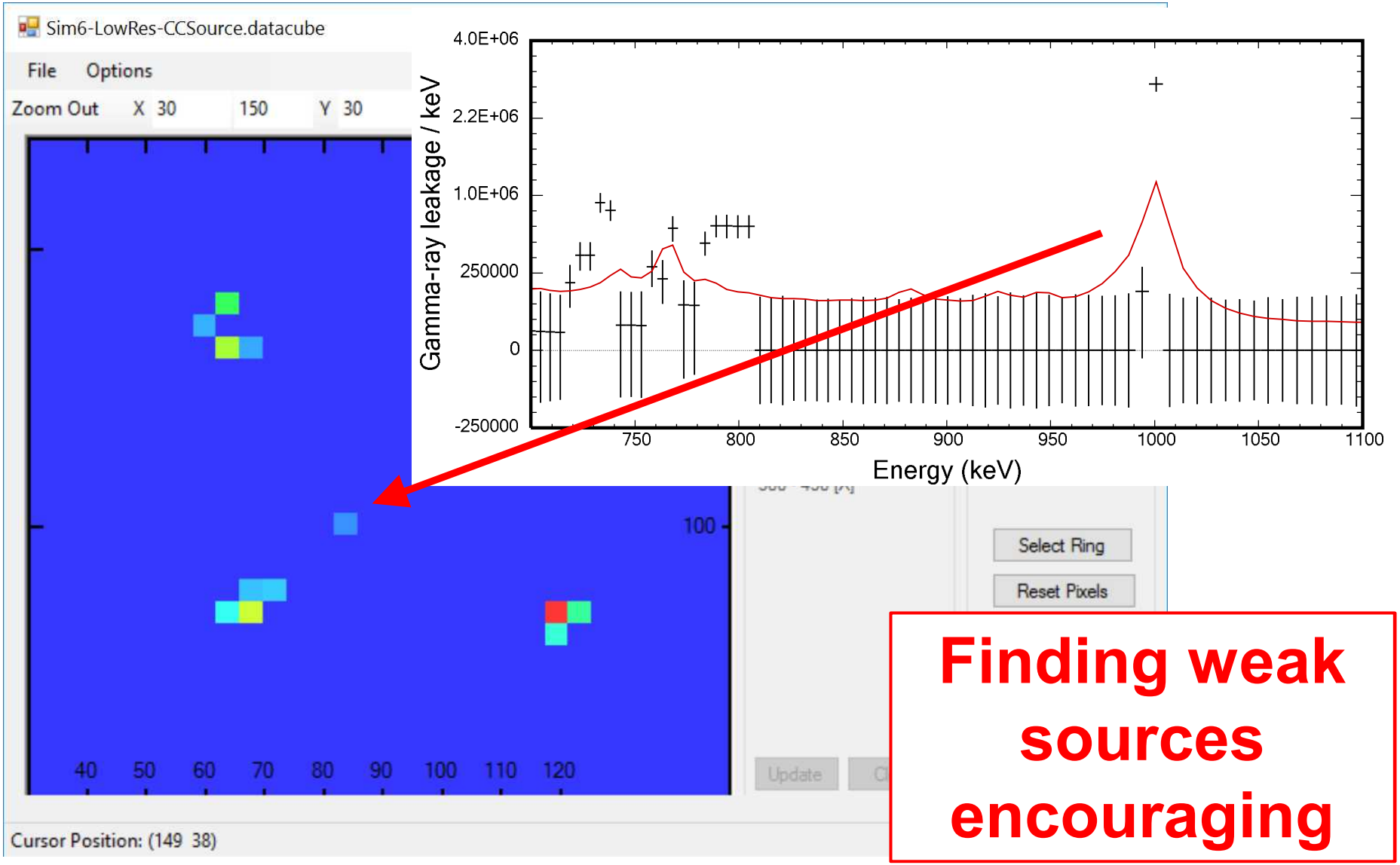
Extras

Polaris CC, Simulation



Simulation for four sources at ± 50 cm plus weak DUCastings

Polaris CC, Simulation



Finding weak sources encouraging