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Title: The Tri-modal Imager: Imaging and Source Identification at Standoff Distances

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CAARI 2012
22nd International Conference on the Application of Accelerators in Research and Industry

The Tri-modal Imager: Imaging and Source Identification at Standoff Distances

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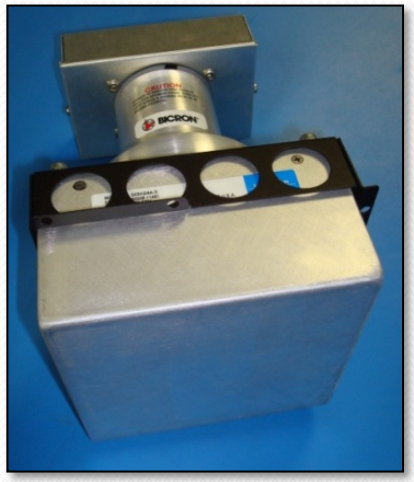
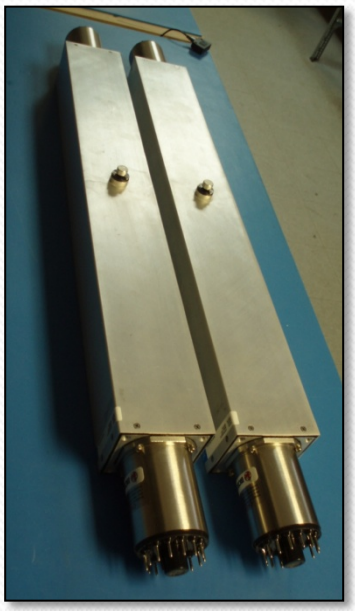
Outline

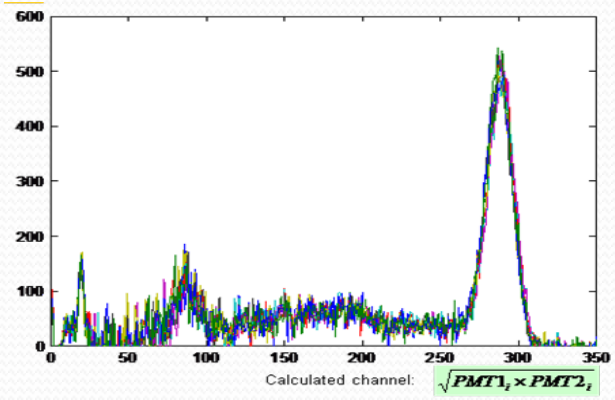
- Overview
  - System
  - Data Management
- Why Imaging?
- Imaging Modalities
  - Compton
  - Coded aperture
  - Hybrid
- Non-Imaging Modality
  - Isotope Identification
- Simulations
- Validation
- Examples
- Energy/Imaging Spectra
- Acknowledgements

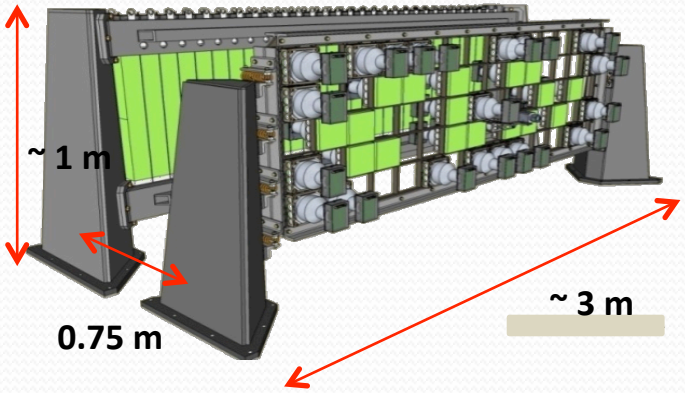
Overview - System

- Scattering Detectors
  - Active Coded Aperture Mask
  - 35 – 5 x 5 x 2 inch NaI Tiles (random)
  - 4 inch PMT
  - 6.75% FWHM @ 662 keV (average)
  - Reconfigurable
- Absorbing Detectors
  - 30 – 3 x 24 x 2.5 inch NaI Bars
  - 6.75% FWHM @ 662 keV (average)
  - 1.5” position resolution (collimated)
- Custom Electronics
  - Lightweight custom designed PMT
  - FGPA readout
  - Integrated GPS
  - Integrated camera
  - Real-time processing









Overview – Data Management

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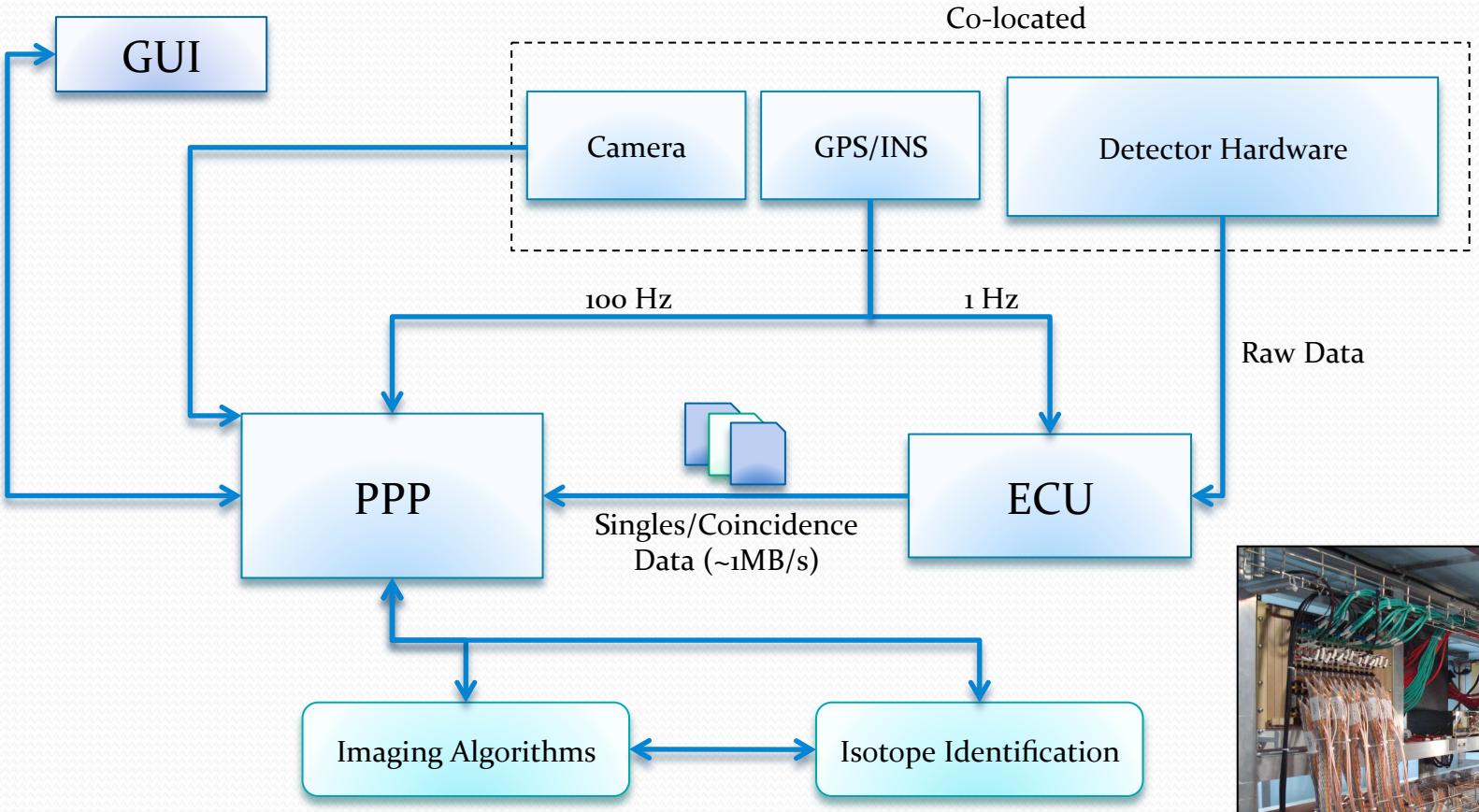
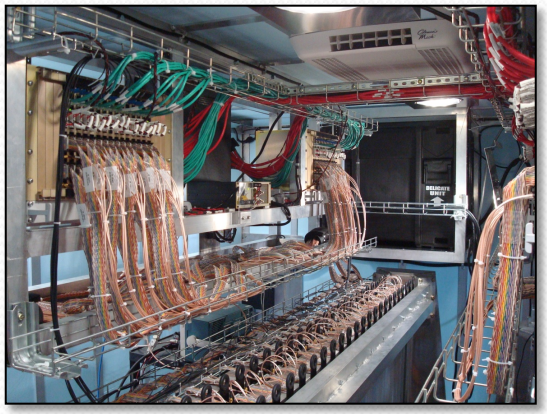
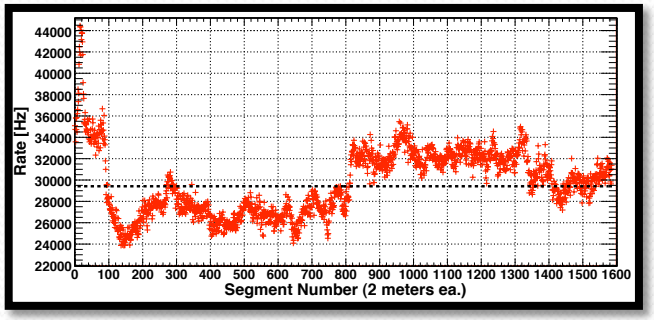
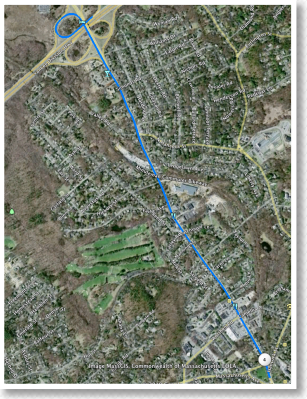


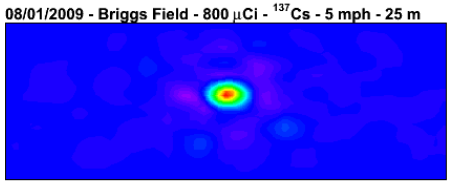


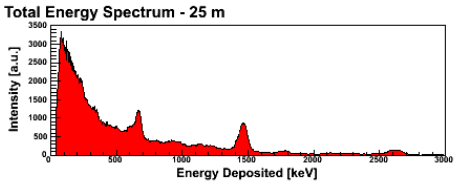
Why Imaging?

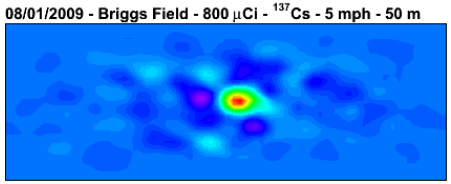
- Background rates fluctuate over time and position making thresholds difficult
- Imaging provides localization
- Imaging can improve identification
- Imaging can improve detection

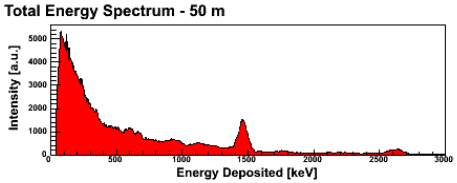


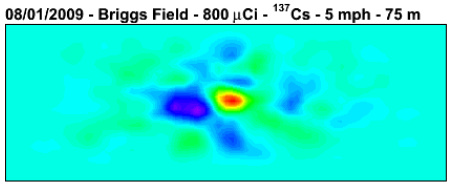


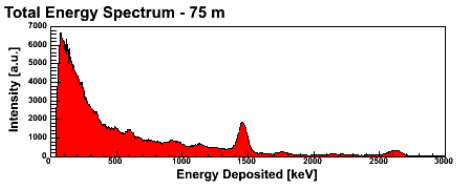


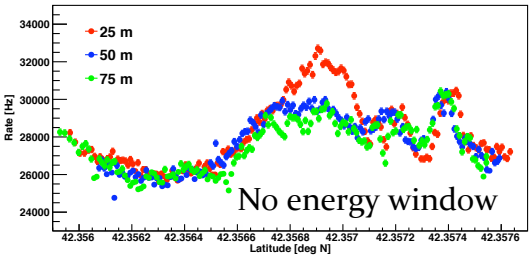


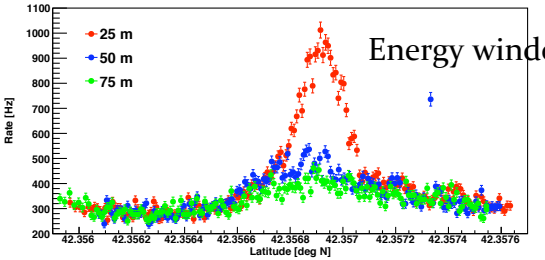












Compton Scatter Imaging

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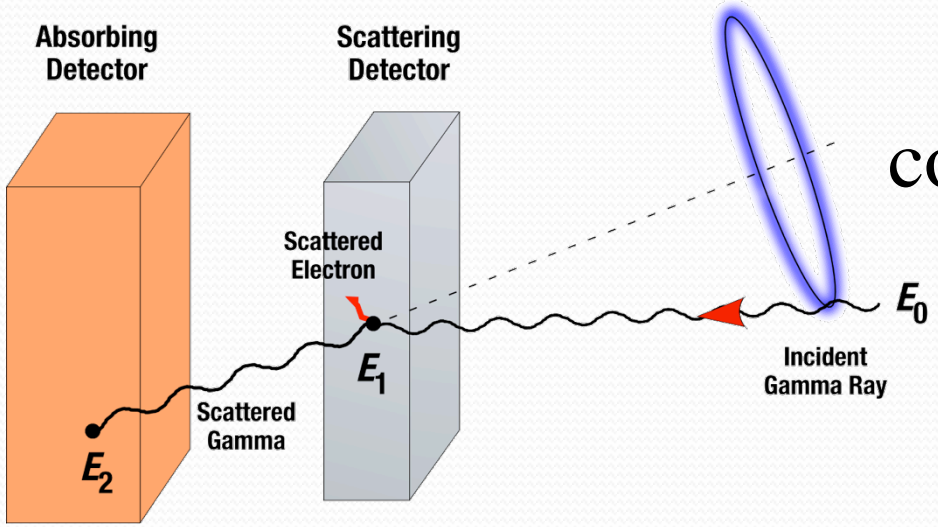
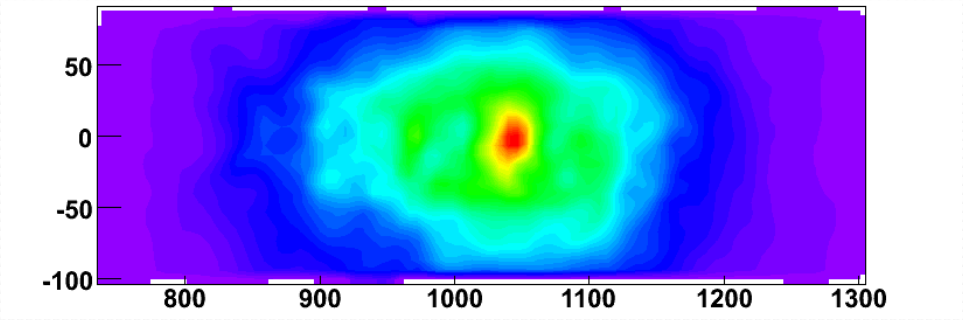
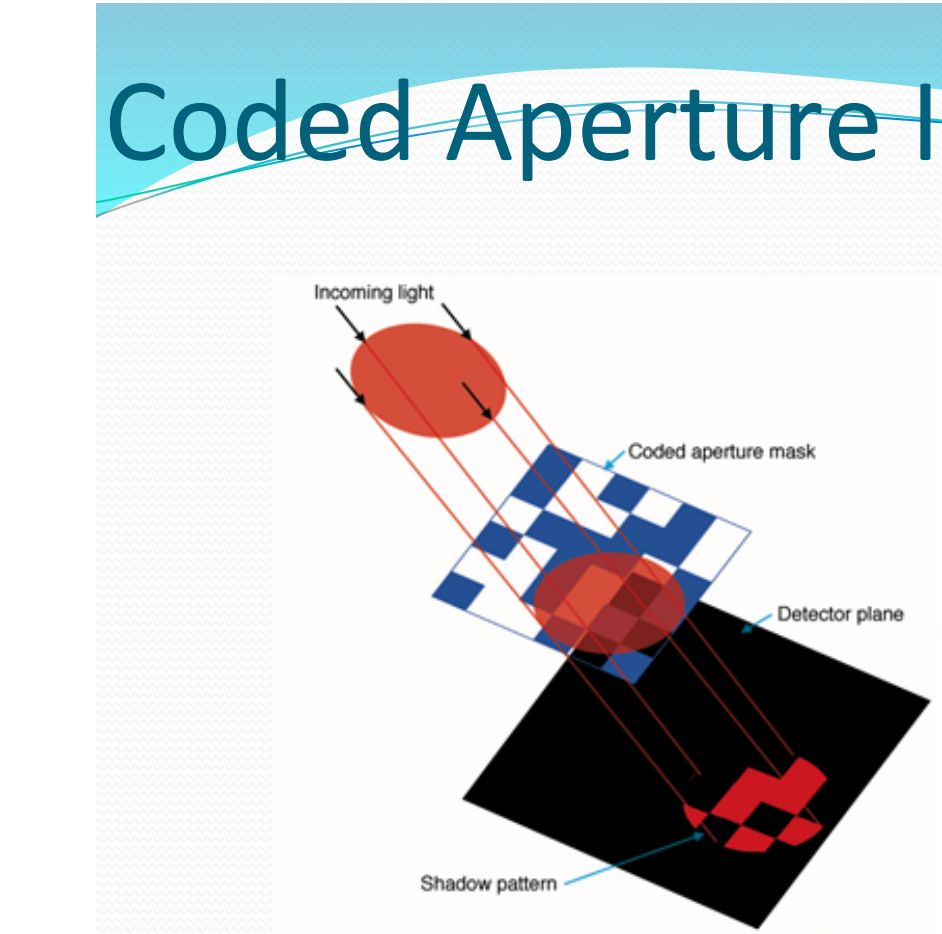


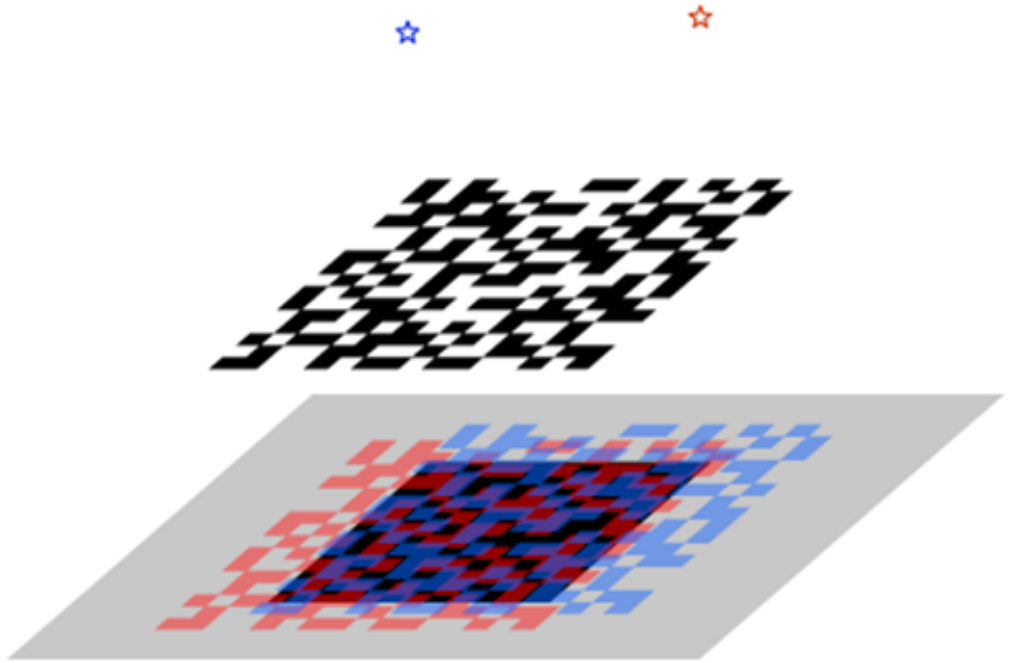
$$\cos\theta = 1 + \frac{m_e c^2}{E_1 + E_2} - \frac{m_e c^2}{E_2}$$

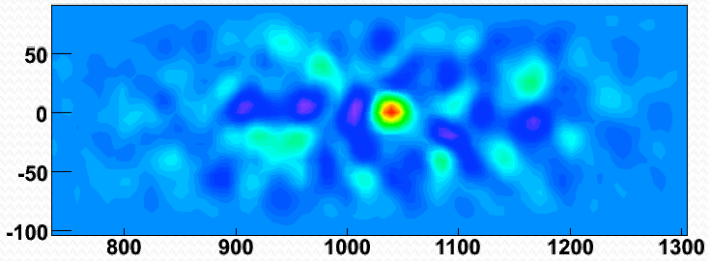


Less effective for low energy due to absorption in first detector and many other issues.

Coded Aperture Imaging



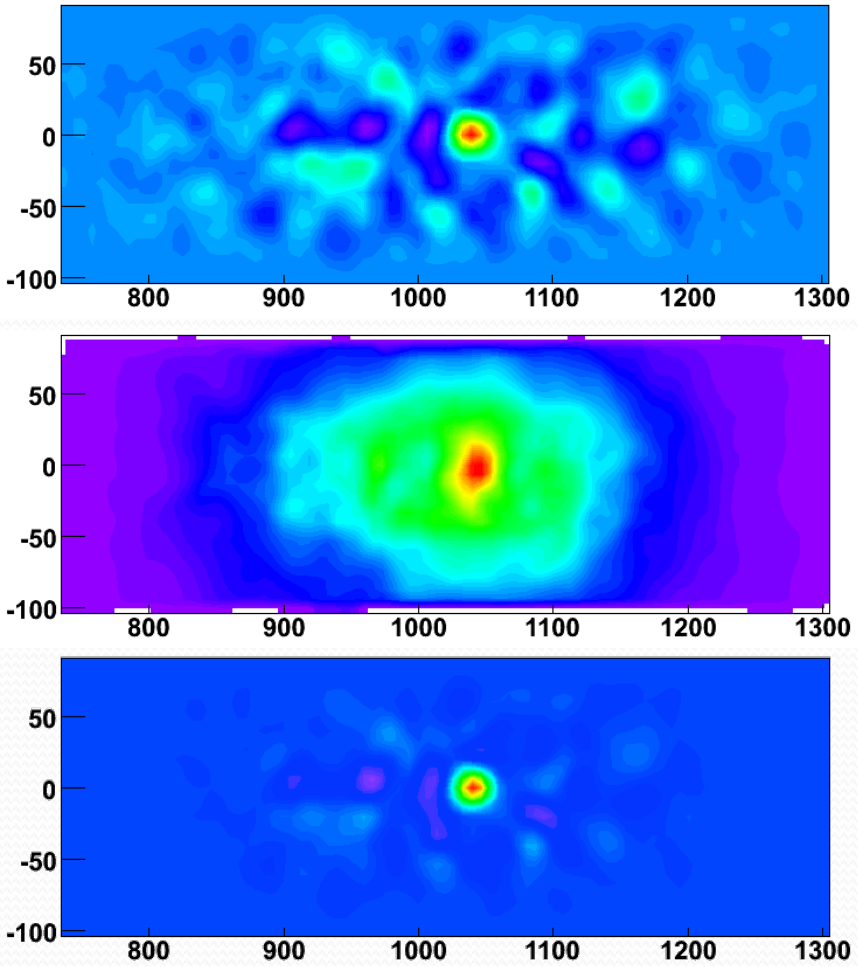




Less effective for high-energy due to transmission through the mask

Hybrid Imaging

- Combining Compton and coded aperture imaging provides an increase in the SNR, improving sensitivity and reducing false alarms.
- Data are independent (singles, coincidence) but parallel.
- Algorithms manifest background very differently while producing similar source images.
- Algorithms are complementary in different energy ranges with large overlap.



Coded Aperture

Hybrid

Compton

Hybrid Imaging Performance Assessment

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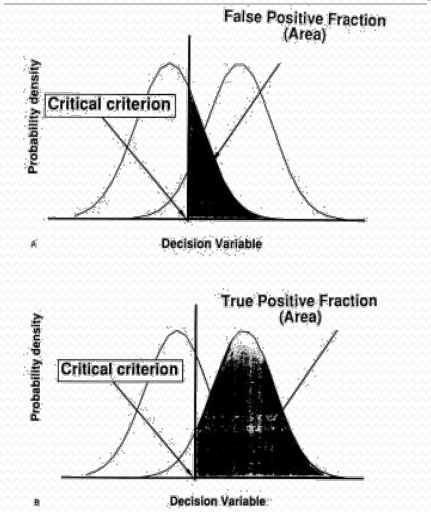
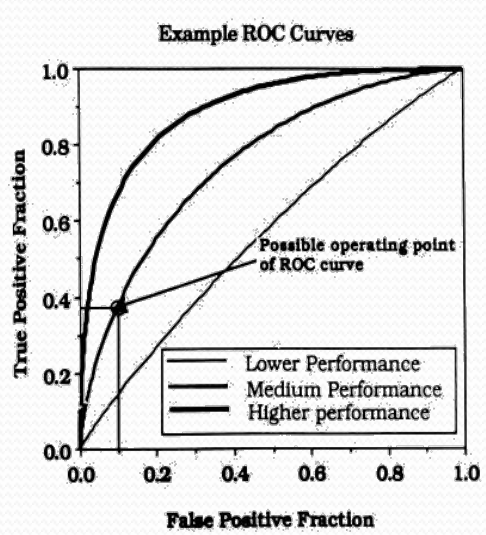
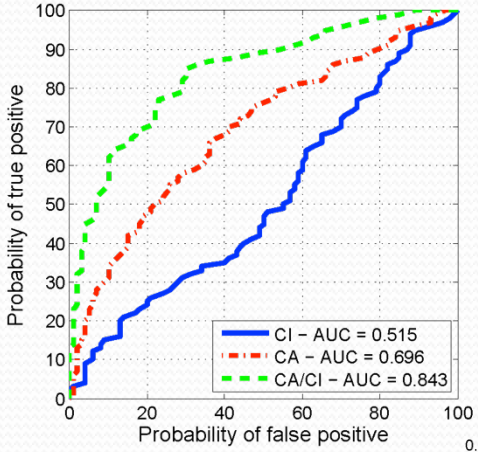
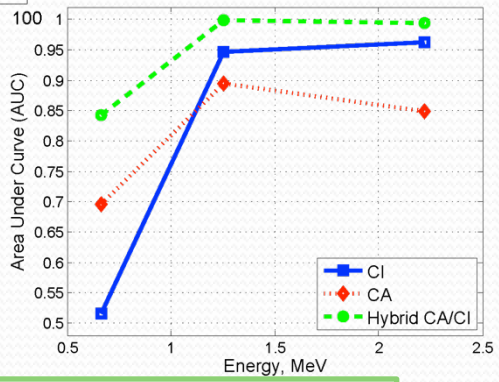








- ROC analysis of simulated data sets show an improvement over Compton or coded aperture modalities alone.
- Improvement over the energy range of interest.

Non-Imaging (Isotope Identification)

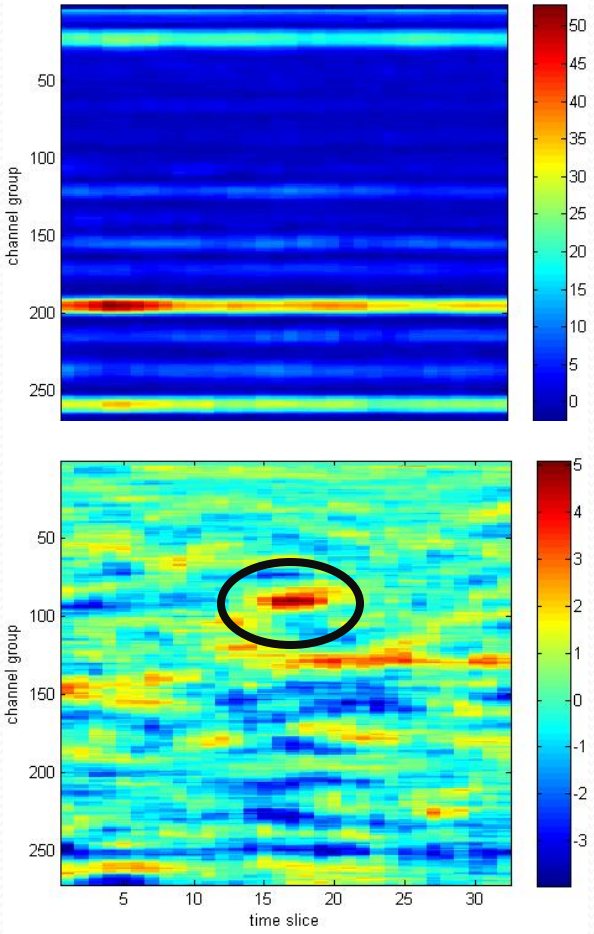
SORDS uses BTI spectroscopic isotope identification algorithms developed for weak source detection/ID from mobile platforms:

- ***Dynamic Background Compensation algorithm***
- ***Optimized time and position integration of spectral data***
- ***Peak finding/fitting, shape fitting, and template fitting***

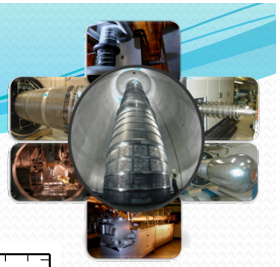
- Isotope library with 40 isotopes of interest

Dynamic Background Compensation and shape fitting detects and identifies the source, with low false alarm rate

Raw spectra provided to algorithm
(50 uCi I-131 at 25m stand-off, at 15mph)



Simulation & Modeling



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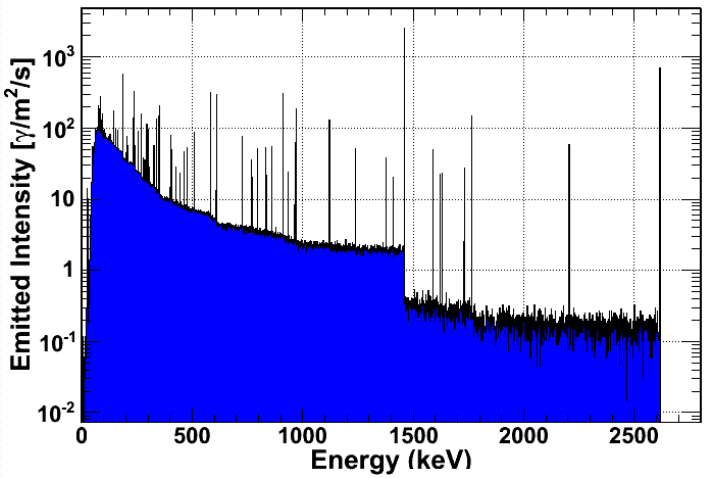
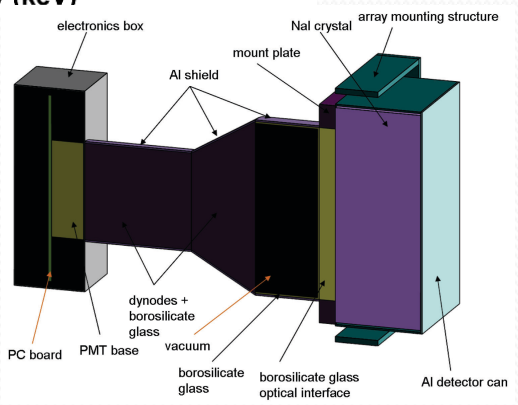
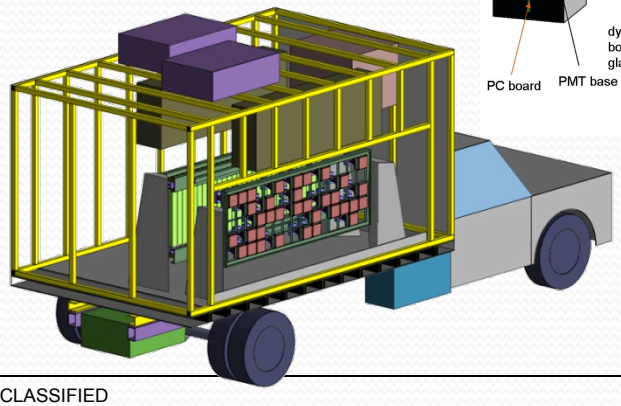
- An extensive simulation framework was used to simulate performance before the PTU was built.
- This allowed for algorithm development parallel to hardware development
- Simulations used GRESS an extension to GEANT4 which now includes many facilities for simulating moving sources/detectors
- Built a custom background model and many sources models that can now be used as injection sources.
- Simulations allowed for extensive ROC studies to guide algorithmic decisions.



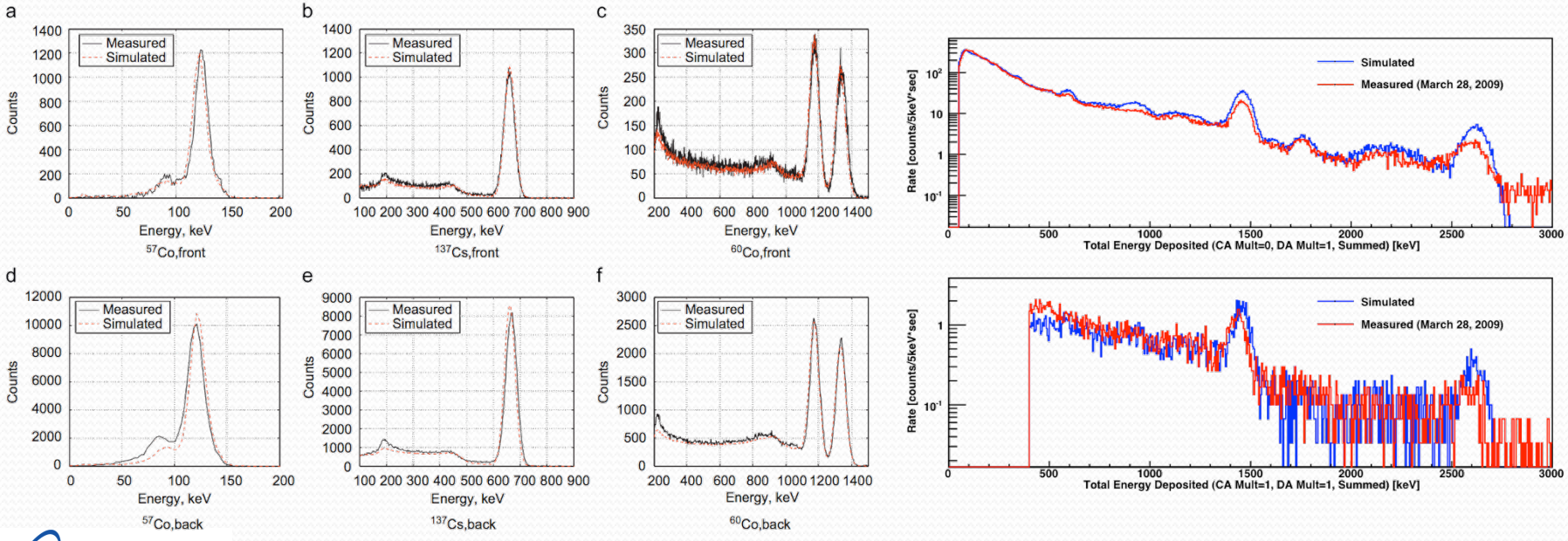


Simulations allowed for parallel algorithm development and detector optimization



Simulation Validation

- Simulations were based on validated physics packages used on many other programs (ACT, GLAST, etc.)
- Simulations were also validated against measured data and showed very good agreement.



Simulations show very good agreement with measurements

Examples

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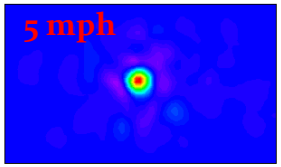
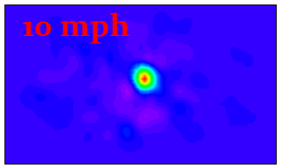
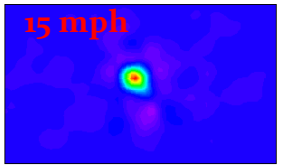
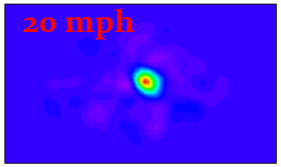
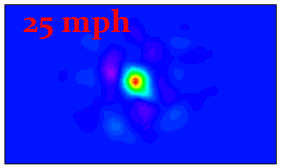
The TMI system has been demonstrated and tested in many scenarios.

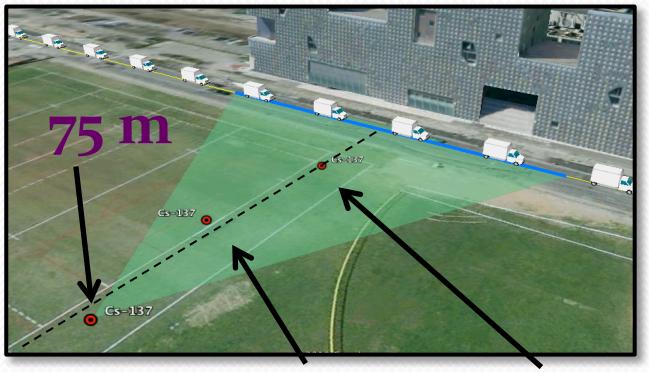




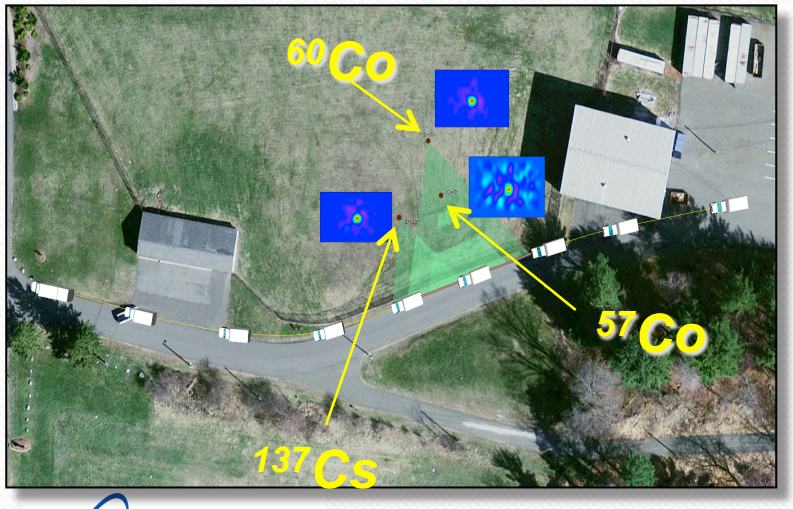


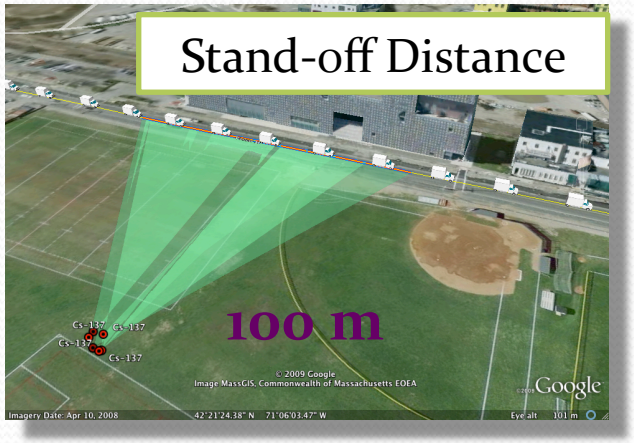






Multiple Sources





Performance

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Imaging Resolution:

- Compton Imaging: 13.5 degree FHWM
- Coded Aperture: 11.8 degree FWHM

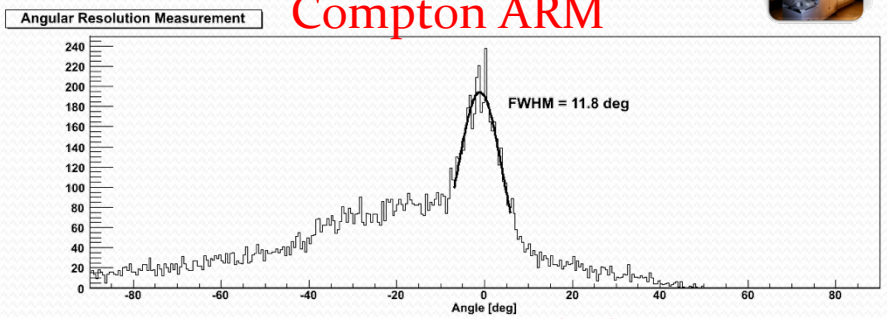
Field of View:

- +/- 1.01 radians (static)

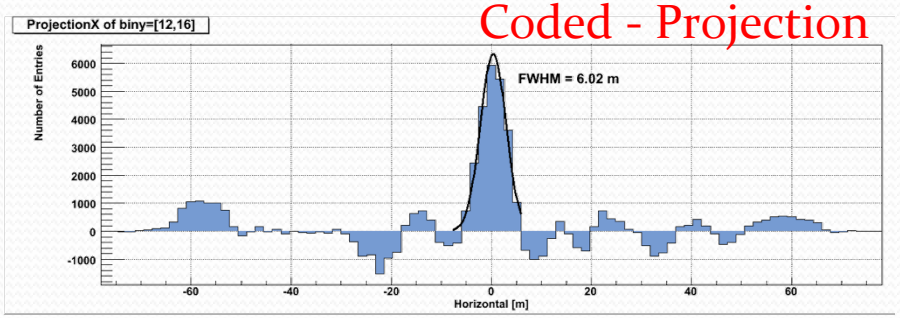
Sensitivity:

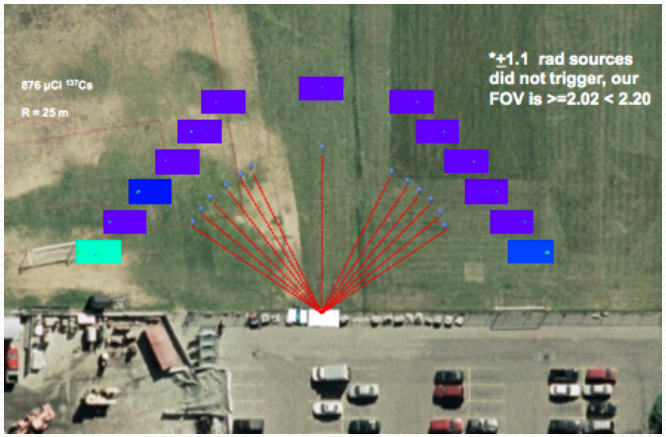
- Example: able to detect 1mCi Cs-137 at up to 100 meters, driving 20 mph.
- Characterization and algorithm development is ongoing

Compton ARM



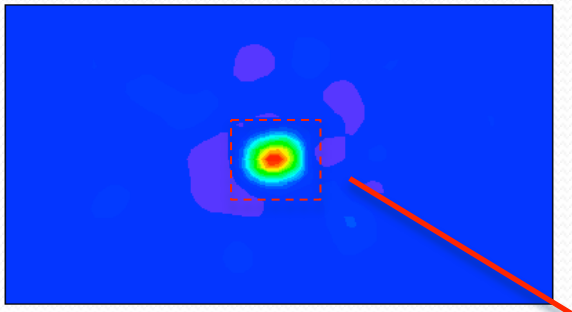
Coded - Projection



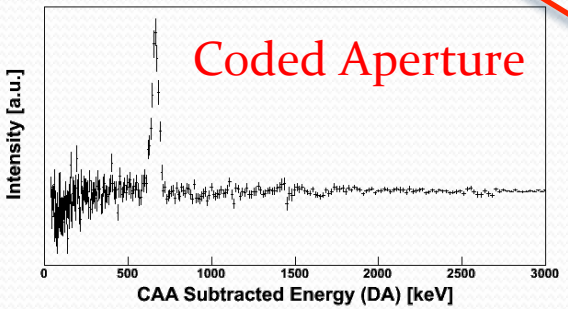


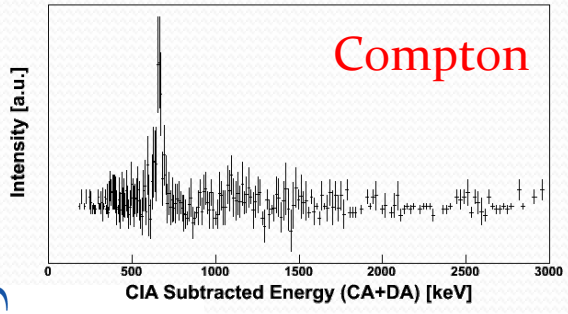
On-going spiral development effort to improve system performance

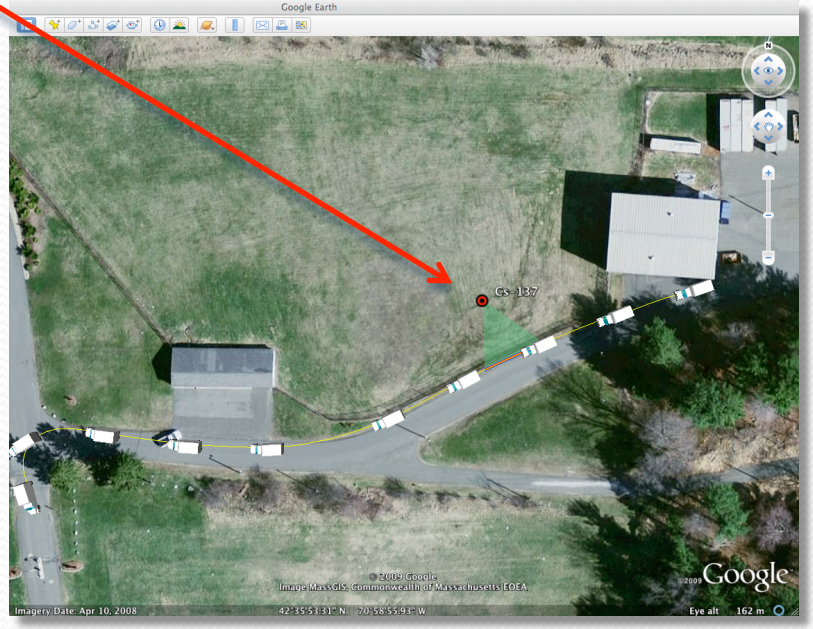
Energy/Imaging Spectra



Localization provides enhanced isotope identification ability by reducing background in the spectrum.







Thank You! – Questions?

- Thanks to our collaborators at BTI, Raytheon, MIT, UofM and RMD.

- Thanks to the Department of Homeland Security's (DHS) Domestic Nuclear Detection Office (DNDO) for funding this work.