Polaris Gamma-Ray Imaging Spectrometers for Nuclear Power Plants

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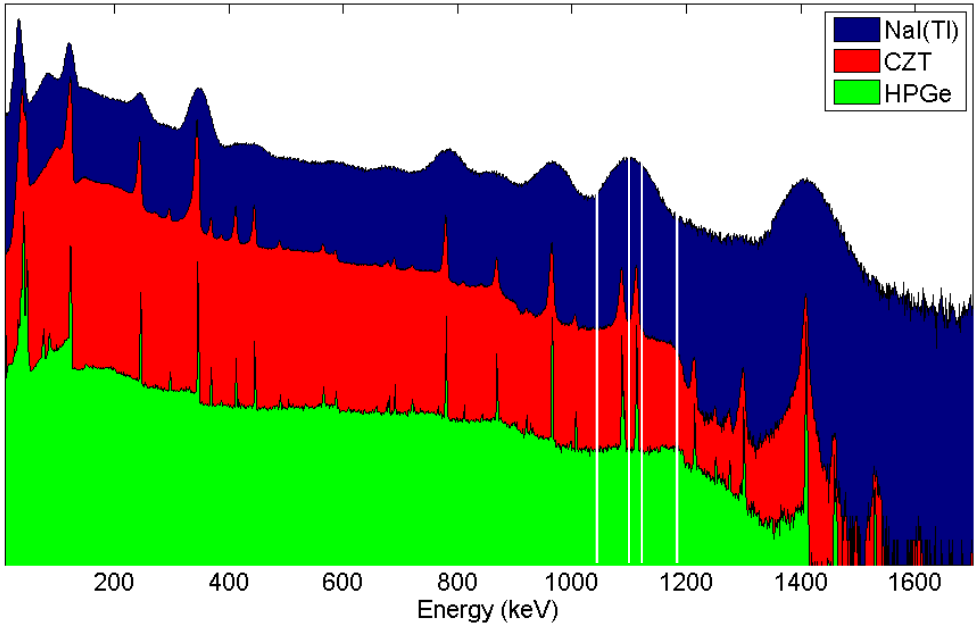
Acknowledgements:
Dept. of Defense, Dept. of Energy and DHS

What Can 3-Dimensional Position-Sensitive CdZnTe Detectors Offer?

(1) Can provide near HPGe energy resolution at room temperatures

(a) No cryogenic cooling → Instant turn on/off + lower power

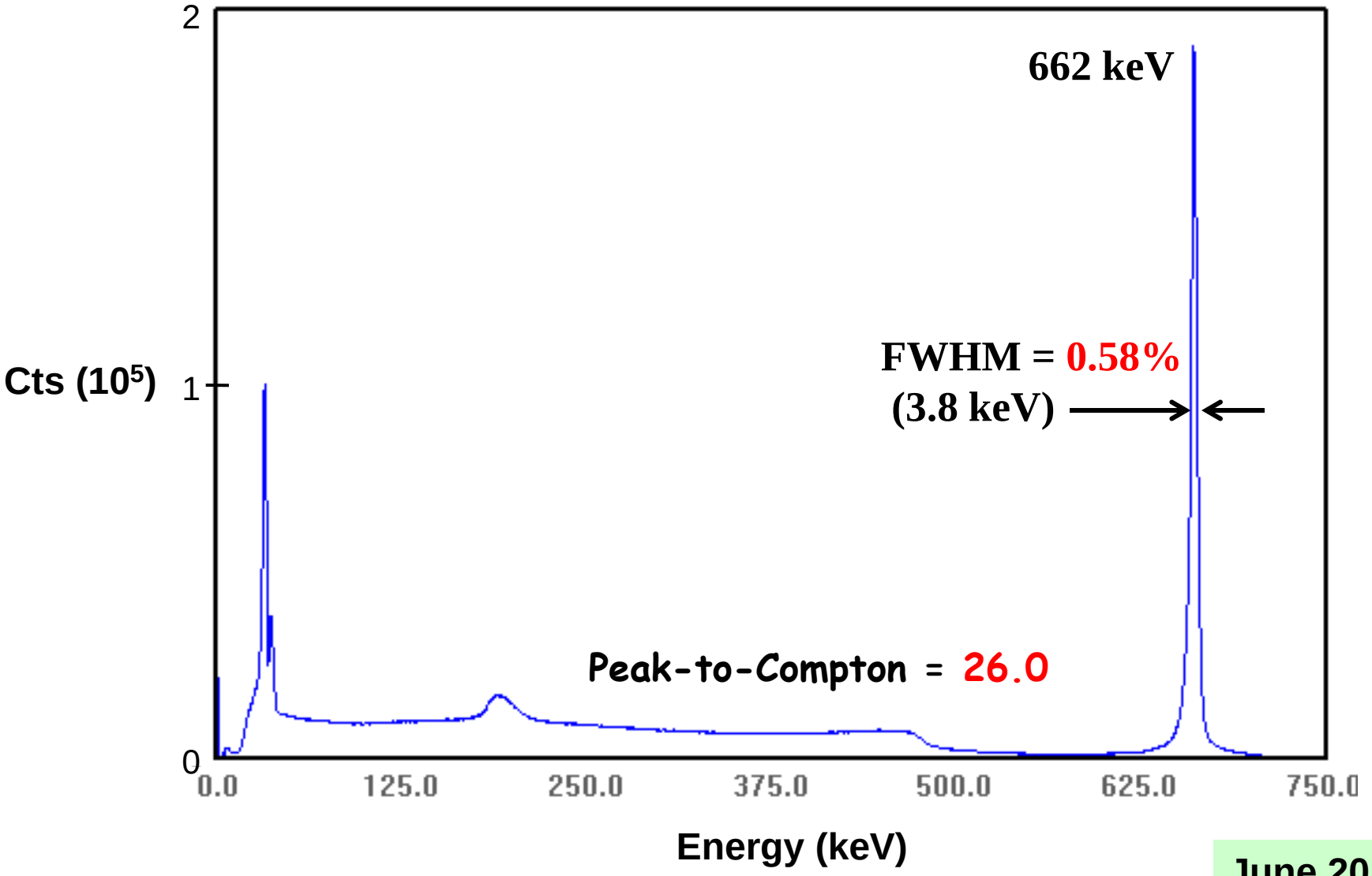
(b) Accurate isotopic characterization + significantly higher sensitivity



(2) Real-time isotopic gamma imaging in the entire 4-π field of view

(3) Simultaneous gamma & neutron imaging (current research at UM)

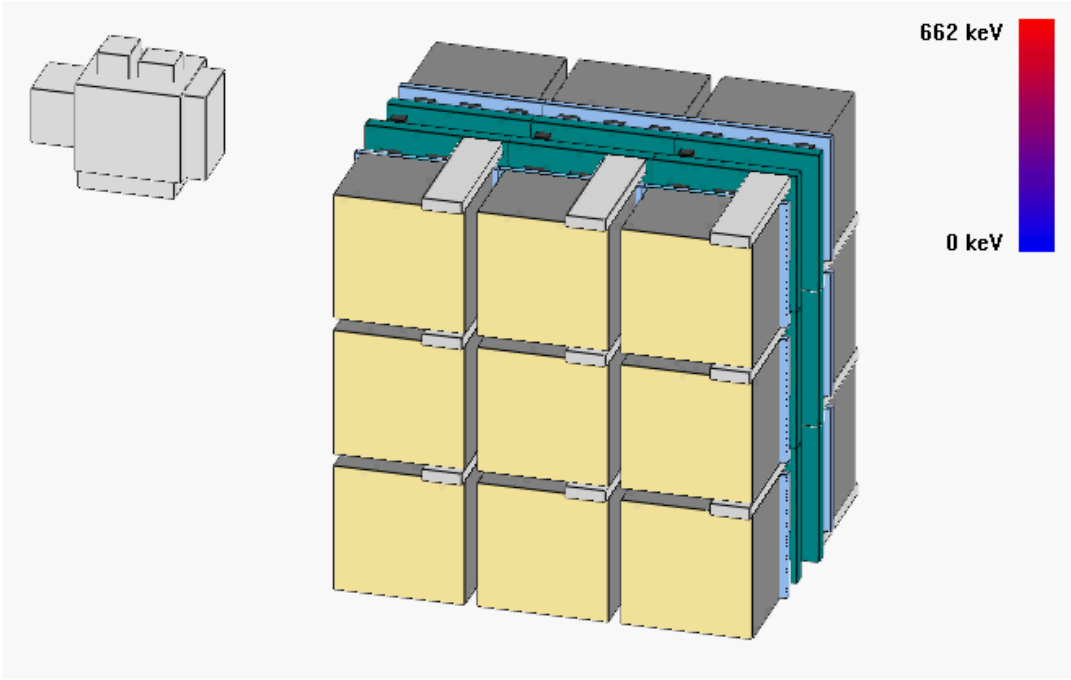
All-events (no selection)

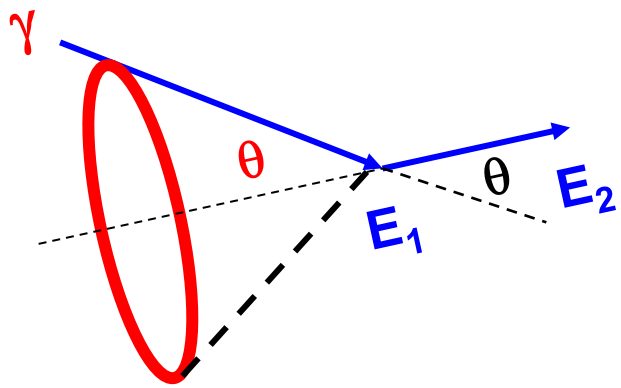


June 2013

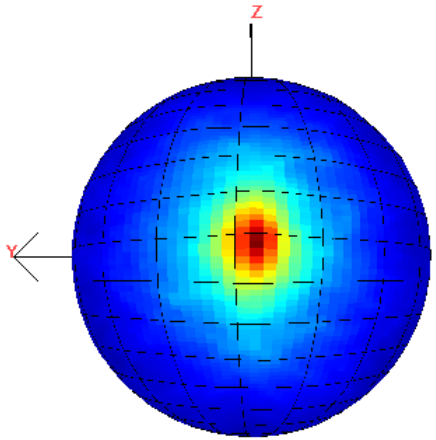
Compton gamma imaging

Each UM Polaris/Orion system has eighteen 2×2×1.5 cm³ CdZnTe detectors (108 cm³, 648 grams = 1.43 lb)



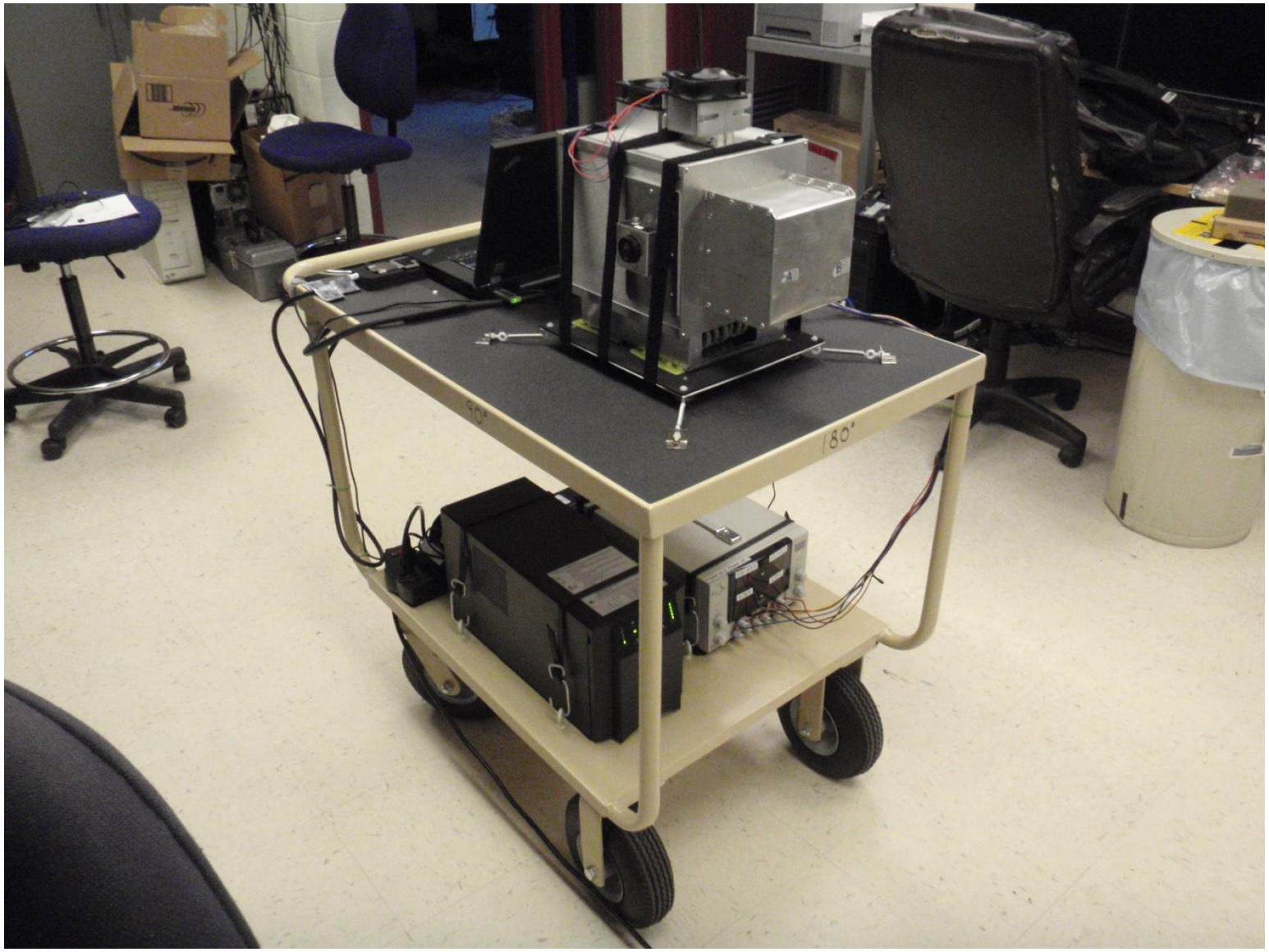


$$\cos\theta = 1 - \frac{E_1 m_e c^2}{(E_1 + E_2)\cdot E_2}$$



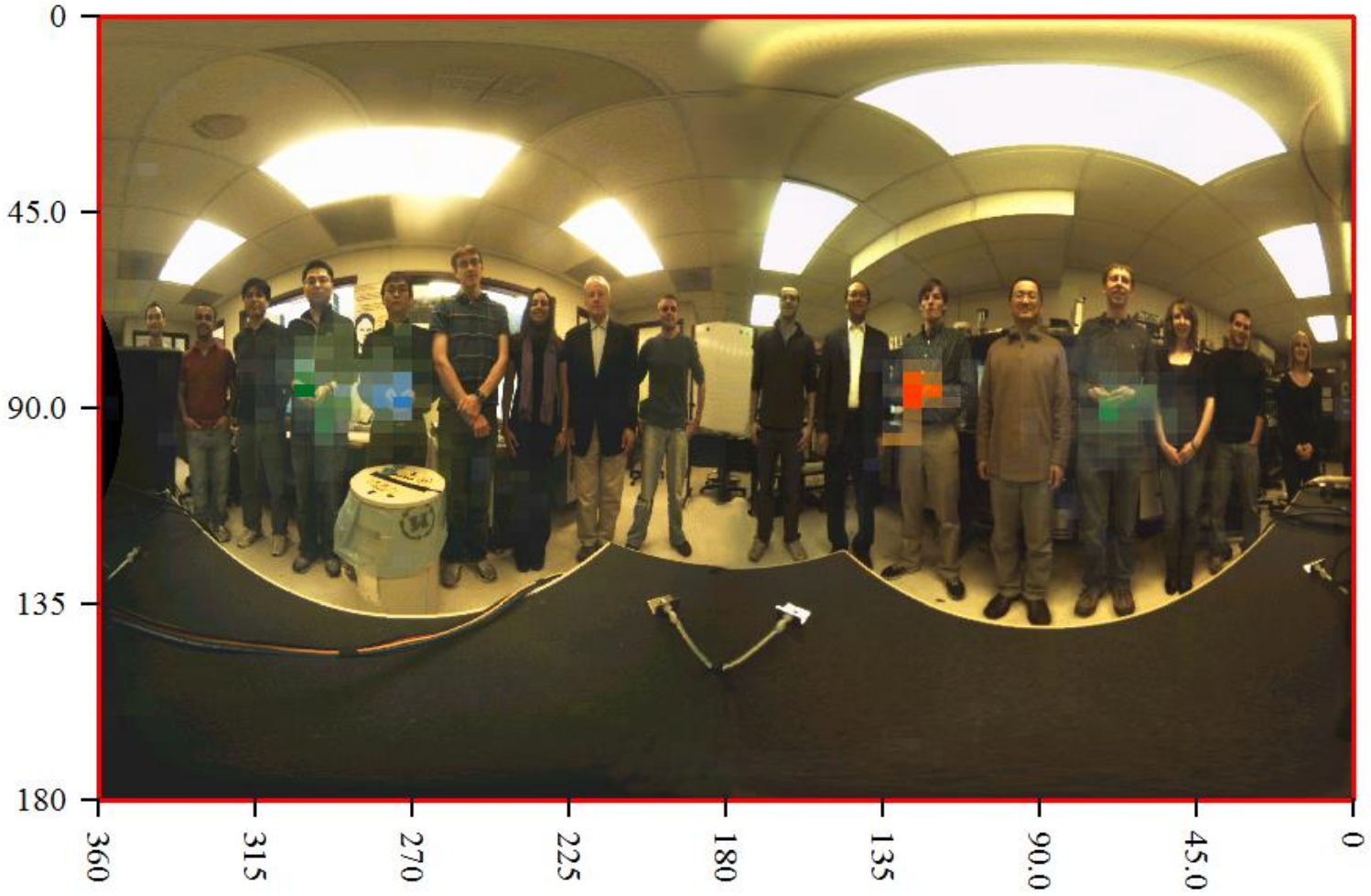
Number of photons: 2033

Polaris 1.1 (GMI ASIC) – August 2010



A Polaris System for DOD

Gamma Imaging Capability



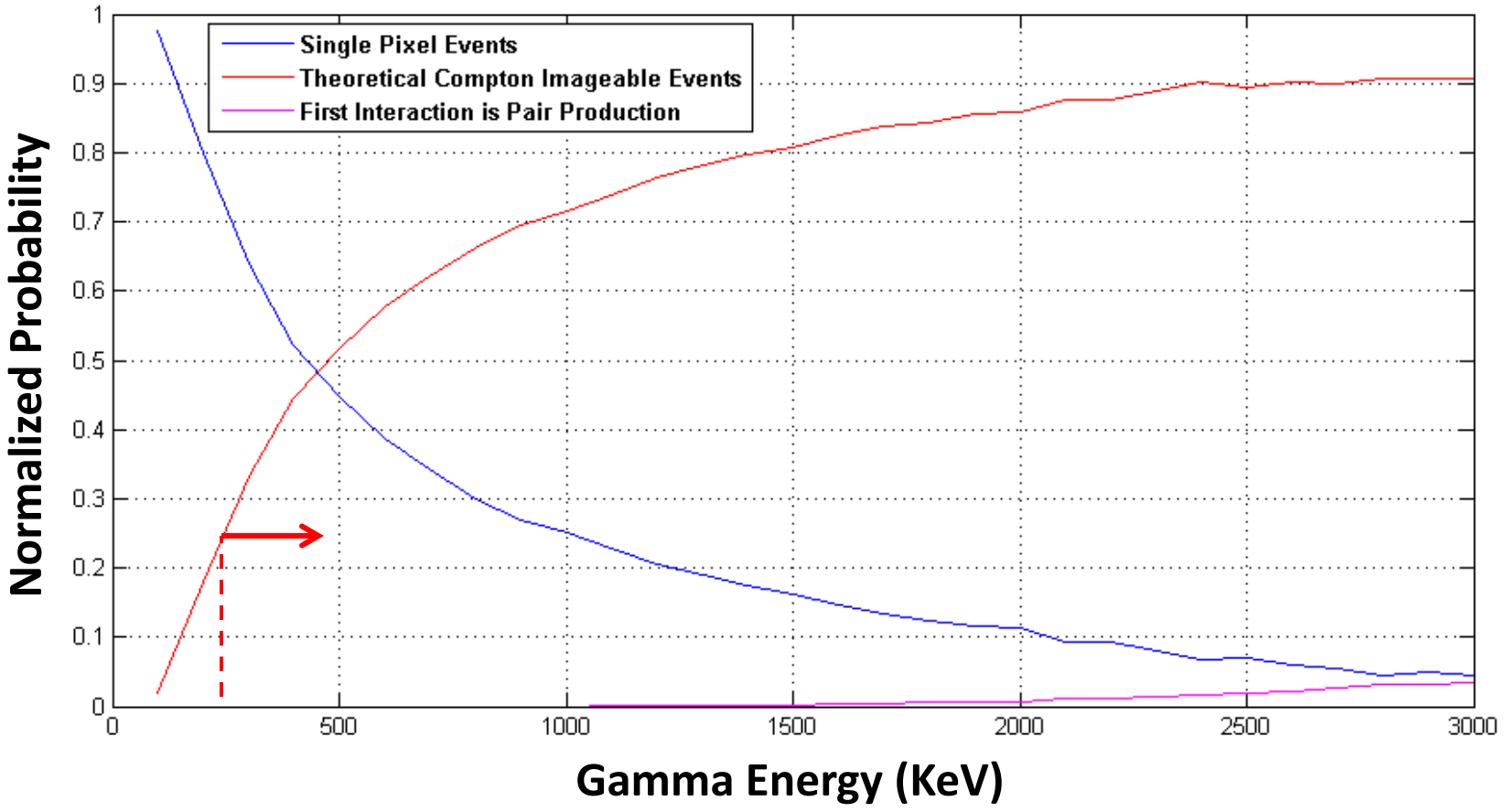
Intensity of:

^{22}Na ^{60}Co ^{137}Cs

1 minute data EIID

UM Research on Filtered Back-Projection

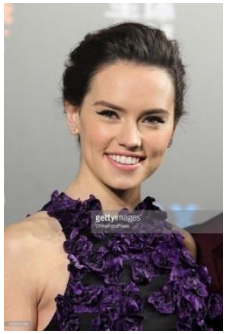
Energy Range of Compton Imaging



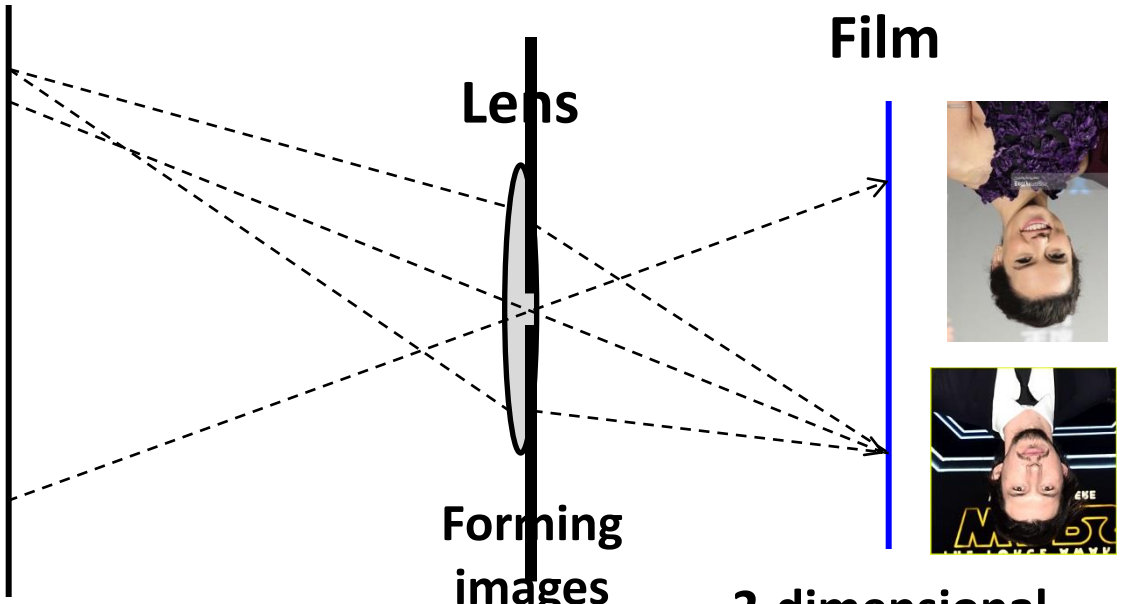
Polaris-H performs Compton imaging for γ-rays with E ≥ 250 keV

Principle of a low-energy gamma camera
(< 250 keV)

Adam Driver
(Kylo Ren)

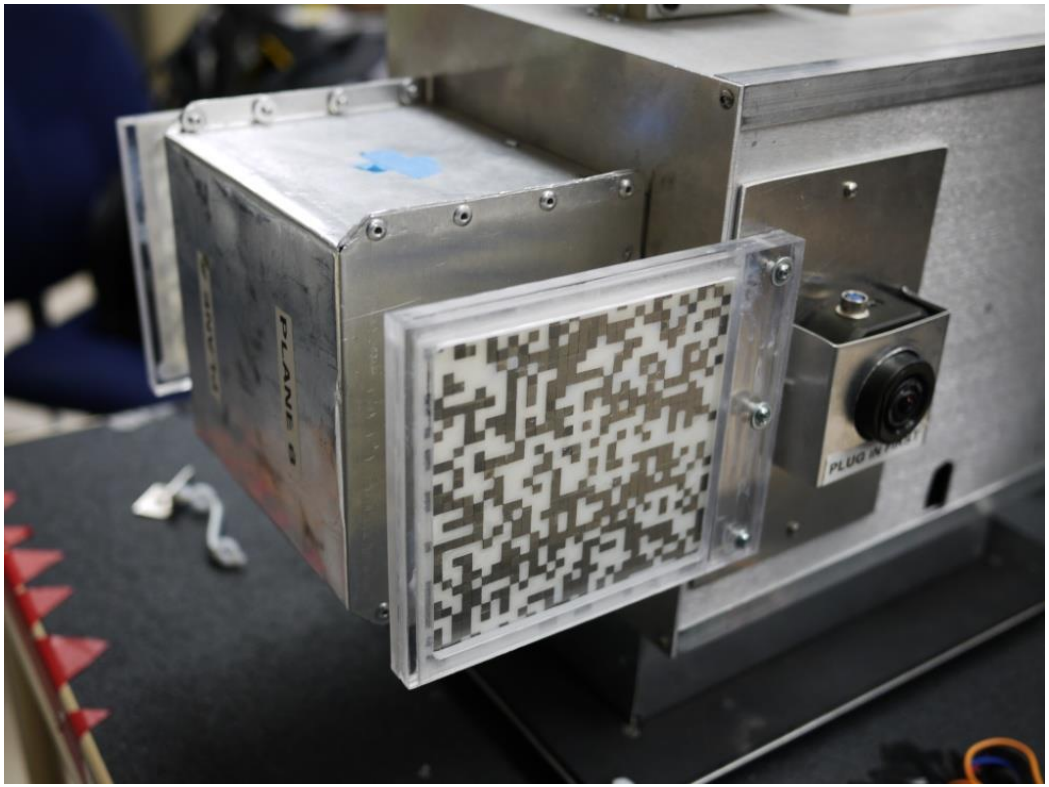


Daisy Ridley
(Rey in the Force Awakens)



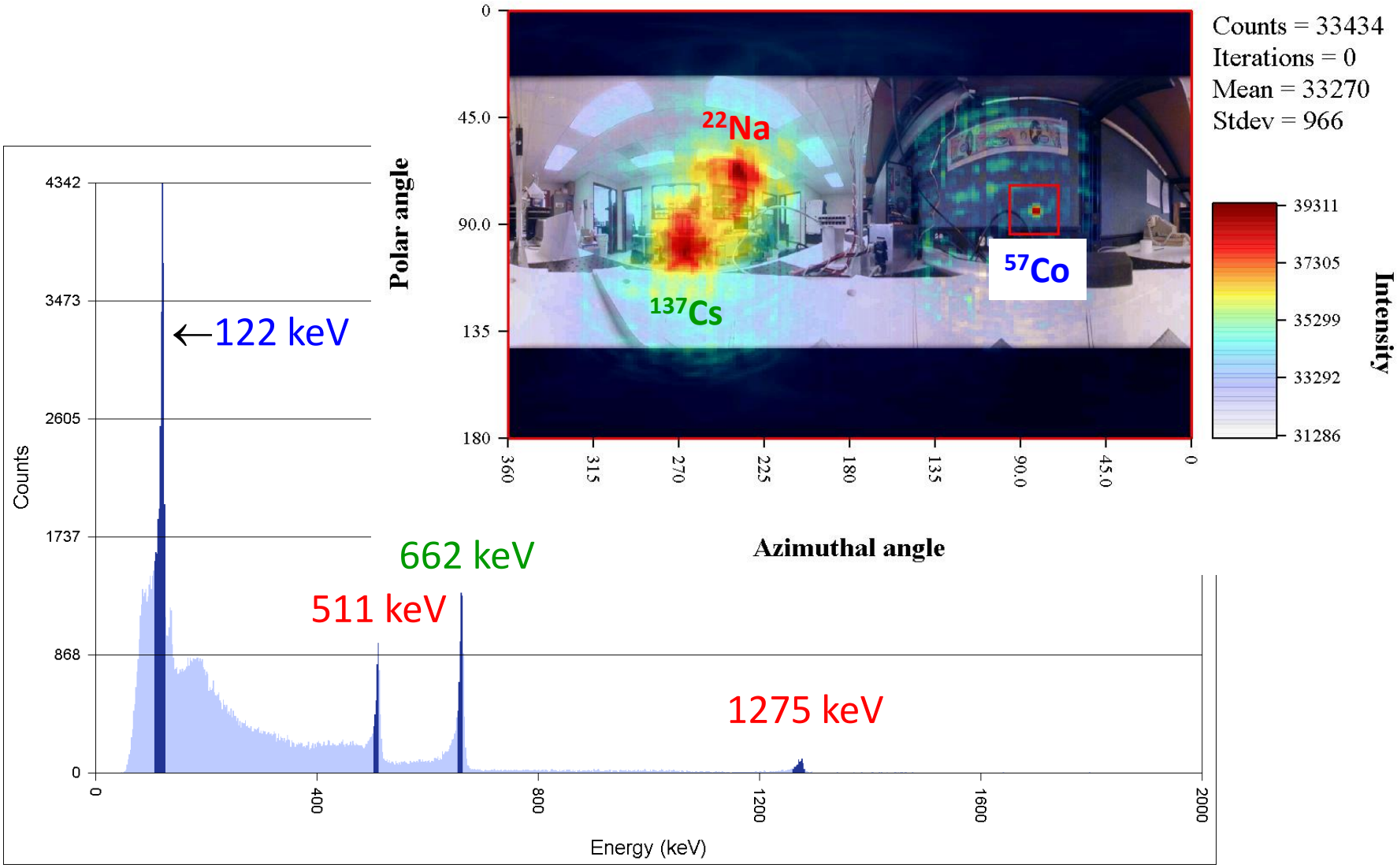
Note: Identity of isotopes is determined by γ-ray spectroscopy

Coded Aperture Imaging at E ≤ 250 keV

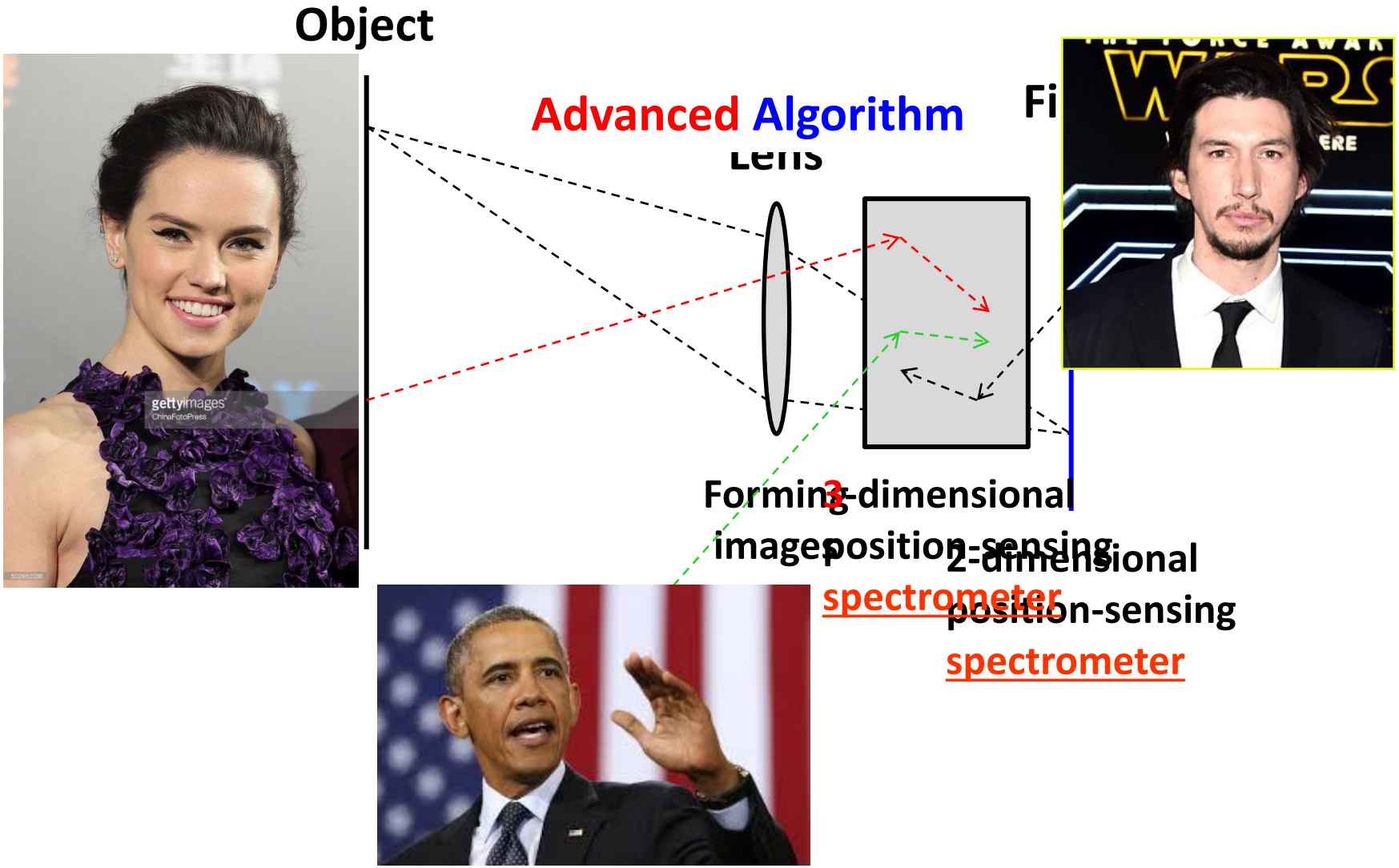


Principle: Recognize unique mask shadows from different incident gamma-ray angles

Real-Time Combined Coded Aperture and Compton Imaging



Principle of Compton Imaging for higher energy (> 250 keV, ^{137}Cs, ^{58}Co, ^{60}Co) γ-rays



Advanced Capabilities

Example 1

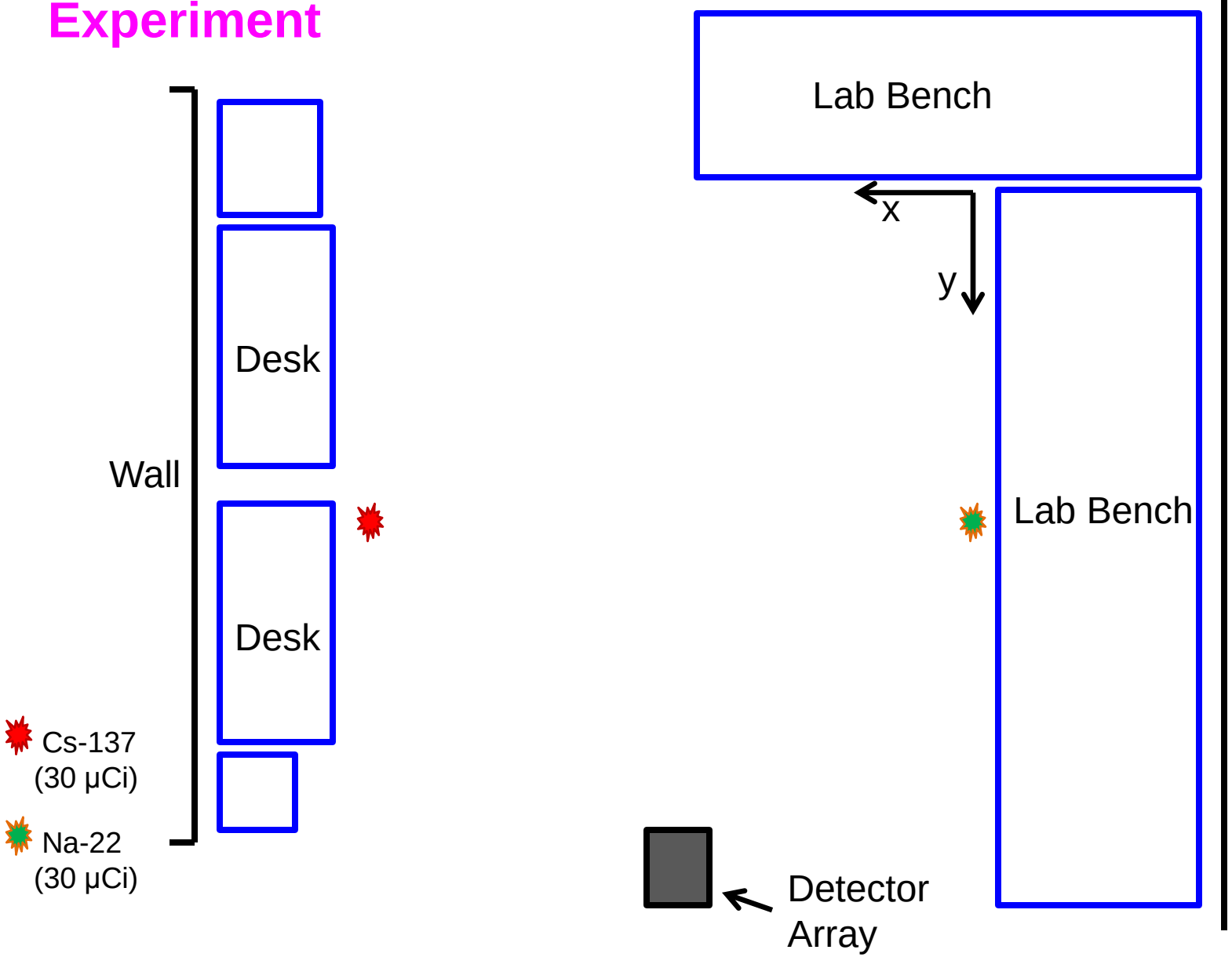
3-Dimensional Imaging

↓

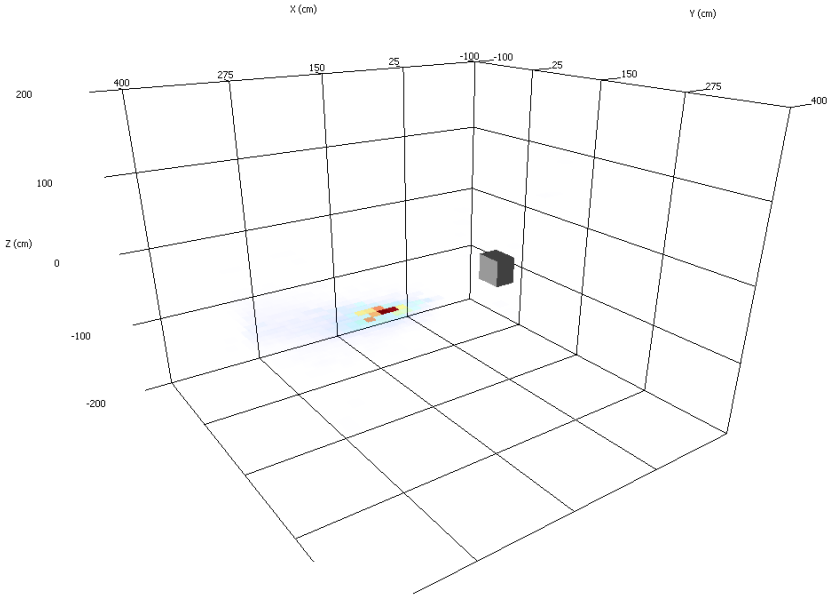
3-D Dose Mapping in Plants

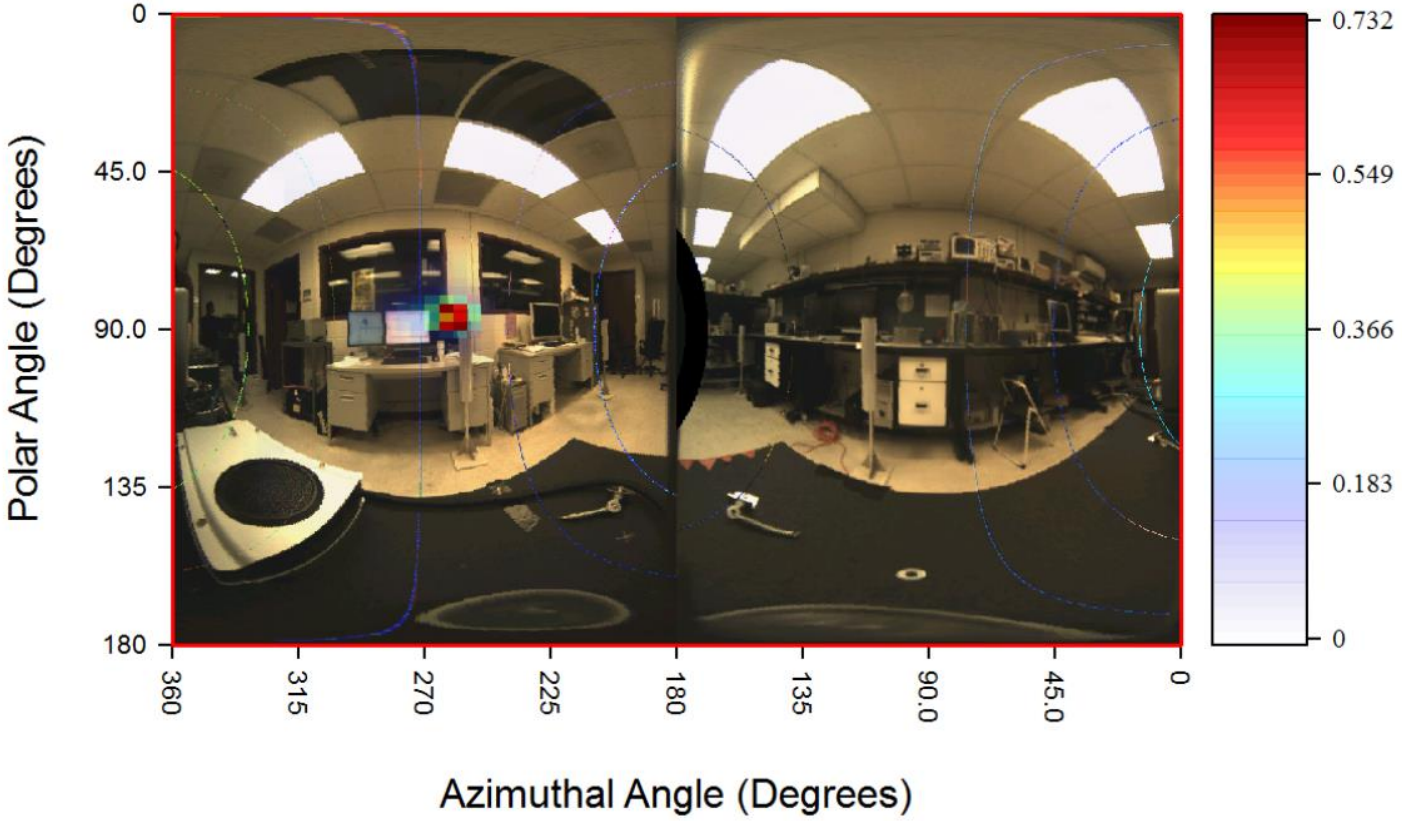
3D Imaging with a Moving Detector

Experiment



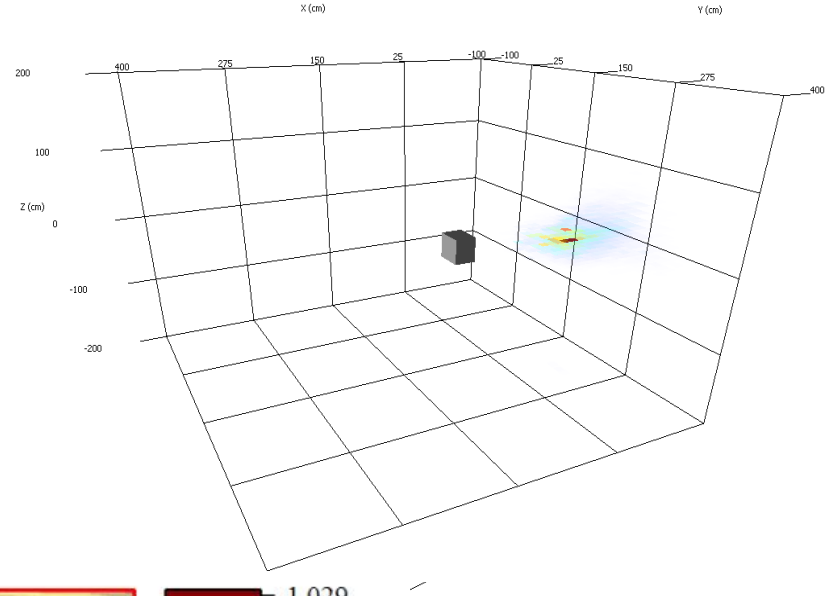
MLEM Imaging with a moving detector

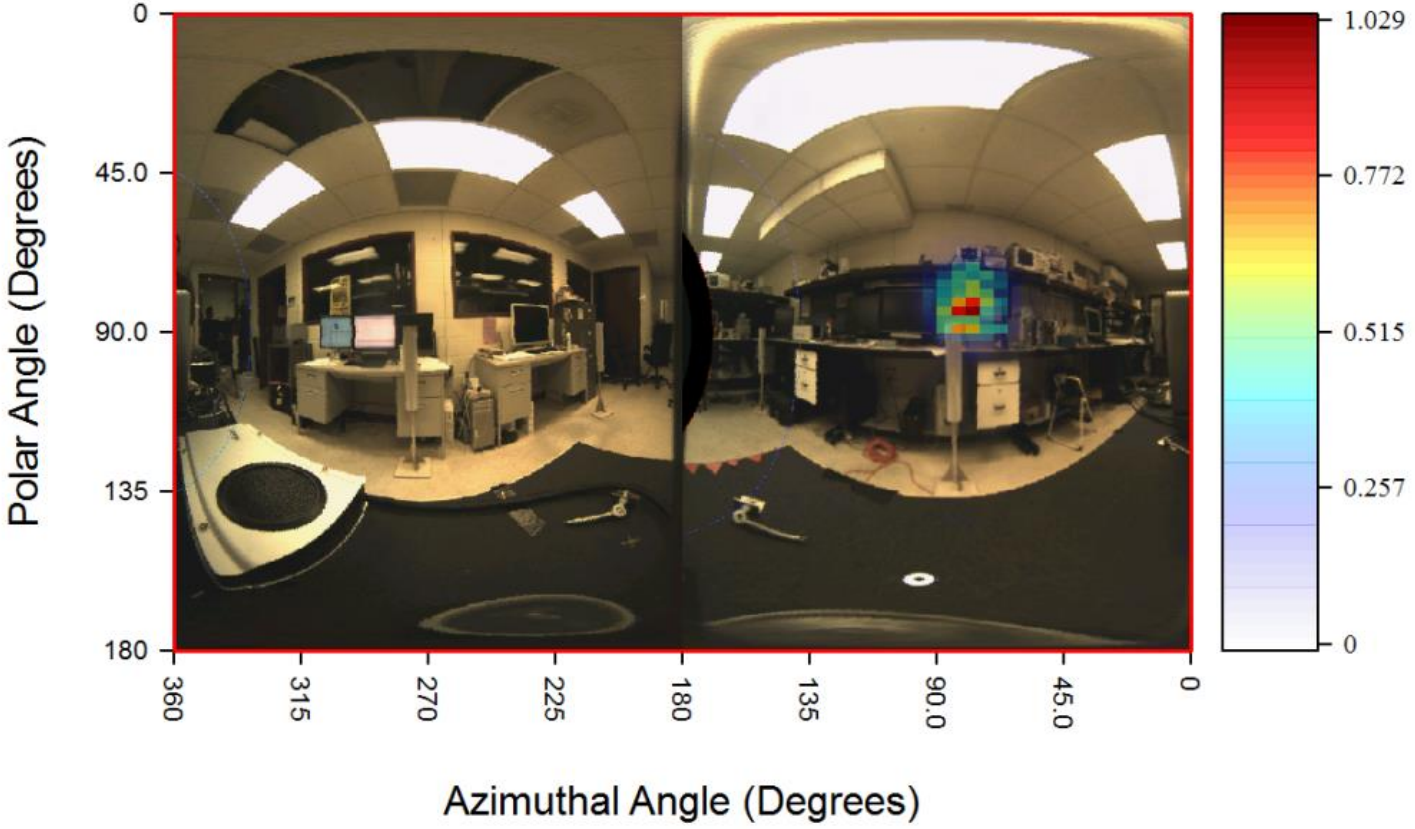




Energy Window:
Cs-137

MLEM Imaging with a moving detector





Energy Window:
Na-22

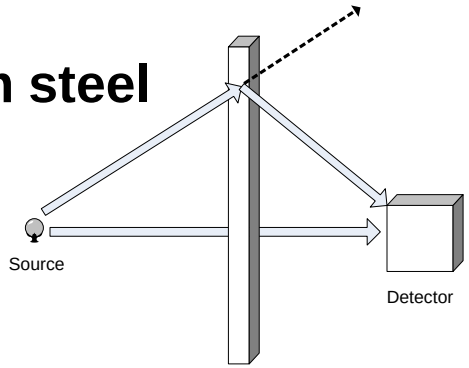
Advanced Capabilities

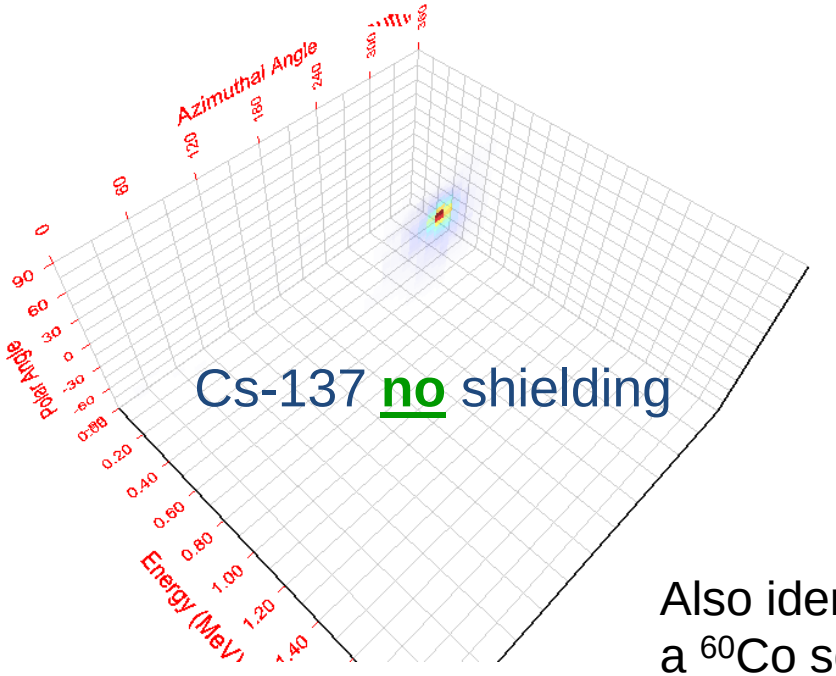
Example 2

Detect & Characterize Shielded Sources (DOE **Black-Box** Project)

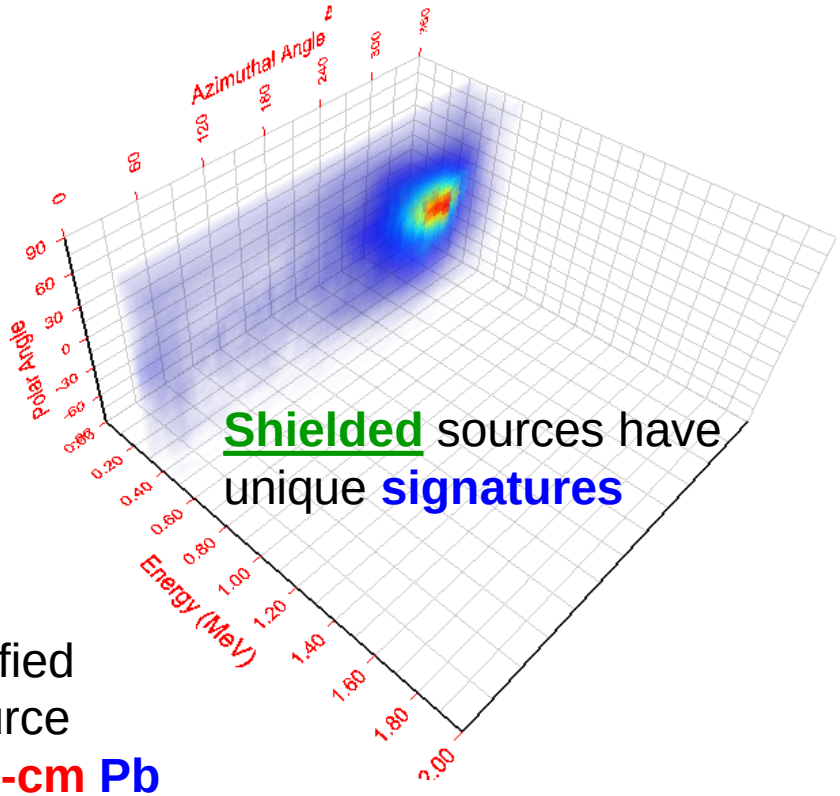
Detect & Characterize Shielded Sources

^{137}Cs behind 3.7-cm steel





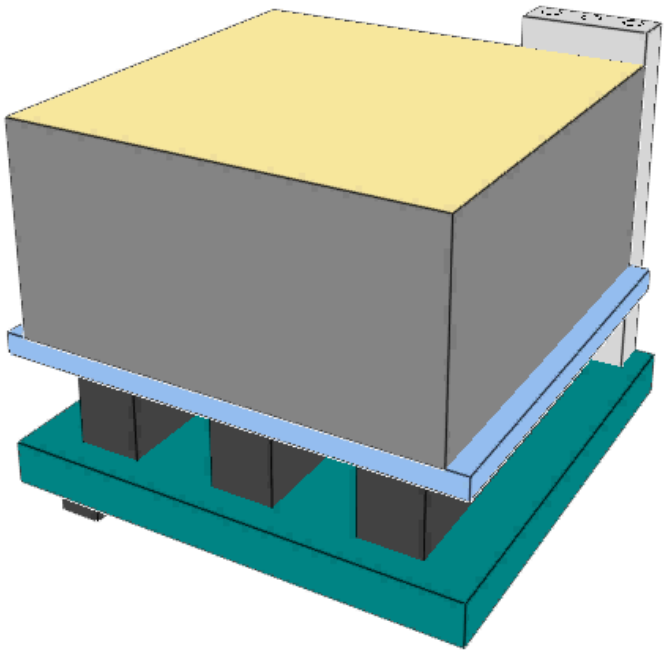
Cs-137 **no** shielding



Shielded sources have unique **signatures**

Also identified a ^{60}Co source behind **2.7-cm Pb**

Today and Tomorrow



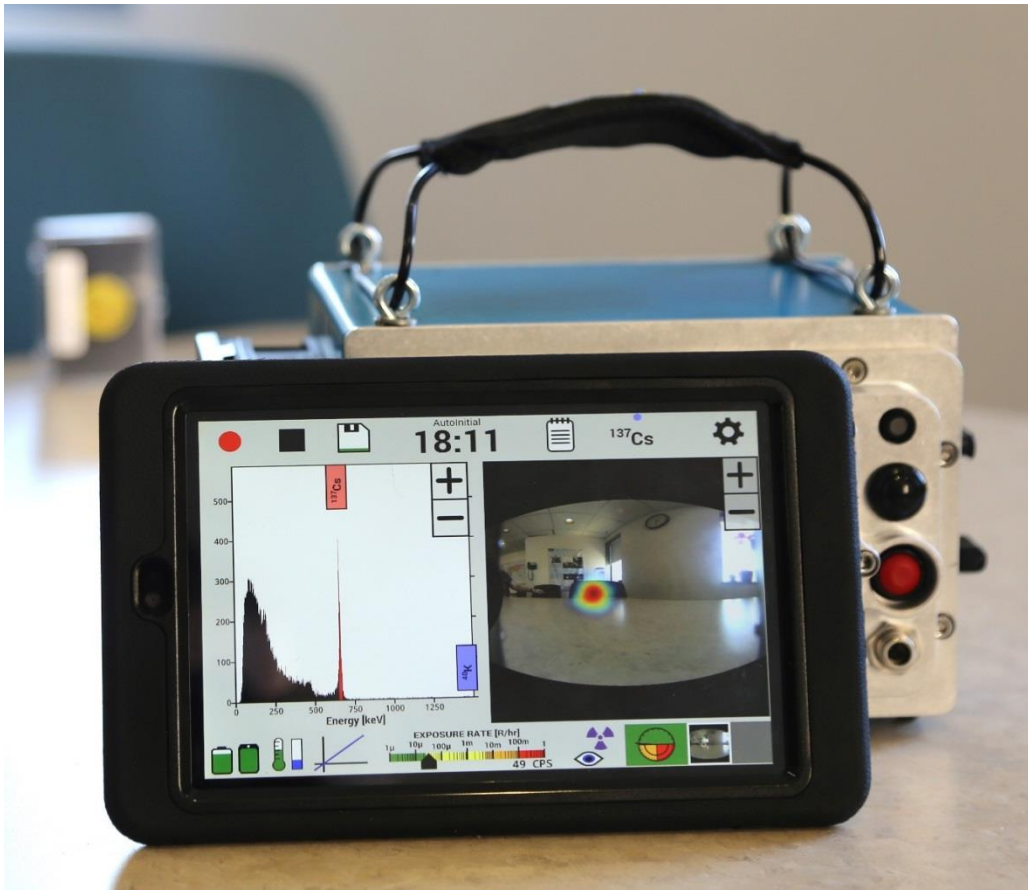
Applications

- National security, homeland security and international nuclear non-proliferation
- Nuclear power (dose reduction and diagnostic inspection)
- Medical imaging (proton cancer therapy)
- Planetary science, astrophysics and fundamental physics (NSF & NASA)
- Safeguard (IAEA workshop in Oct., 2015)
- Environmental monitoring (Gamma + SLAM)

Univ. of Michigan 3-D CZT Technology

↓ Licensed to

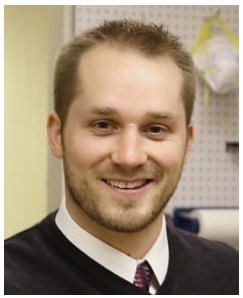
H3D, Inc.





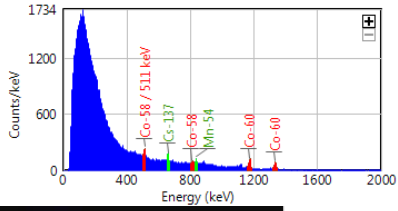







Dr. Brian Kitchen

Locating Unknown Source



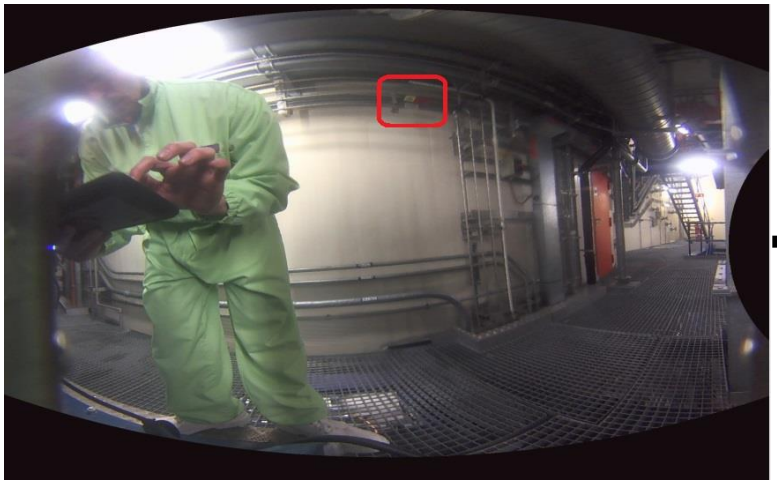
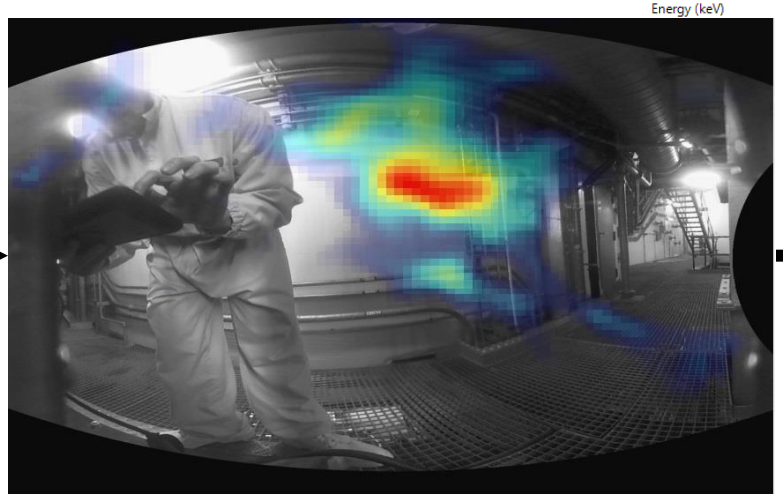
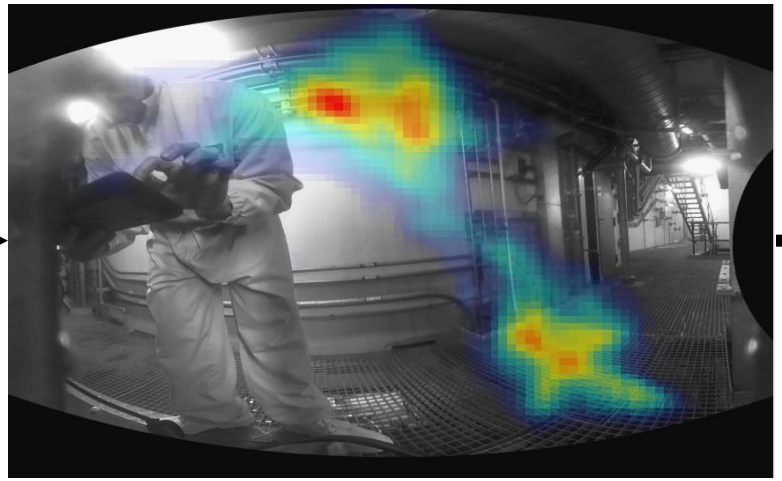


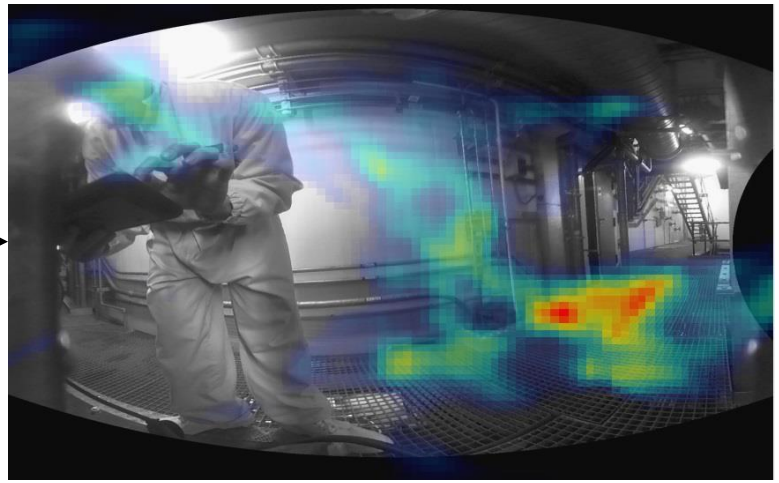
Image known hot spot (red box).



Cs-137 image primarily hot in expected direction.



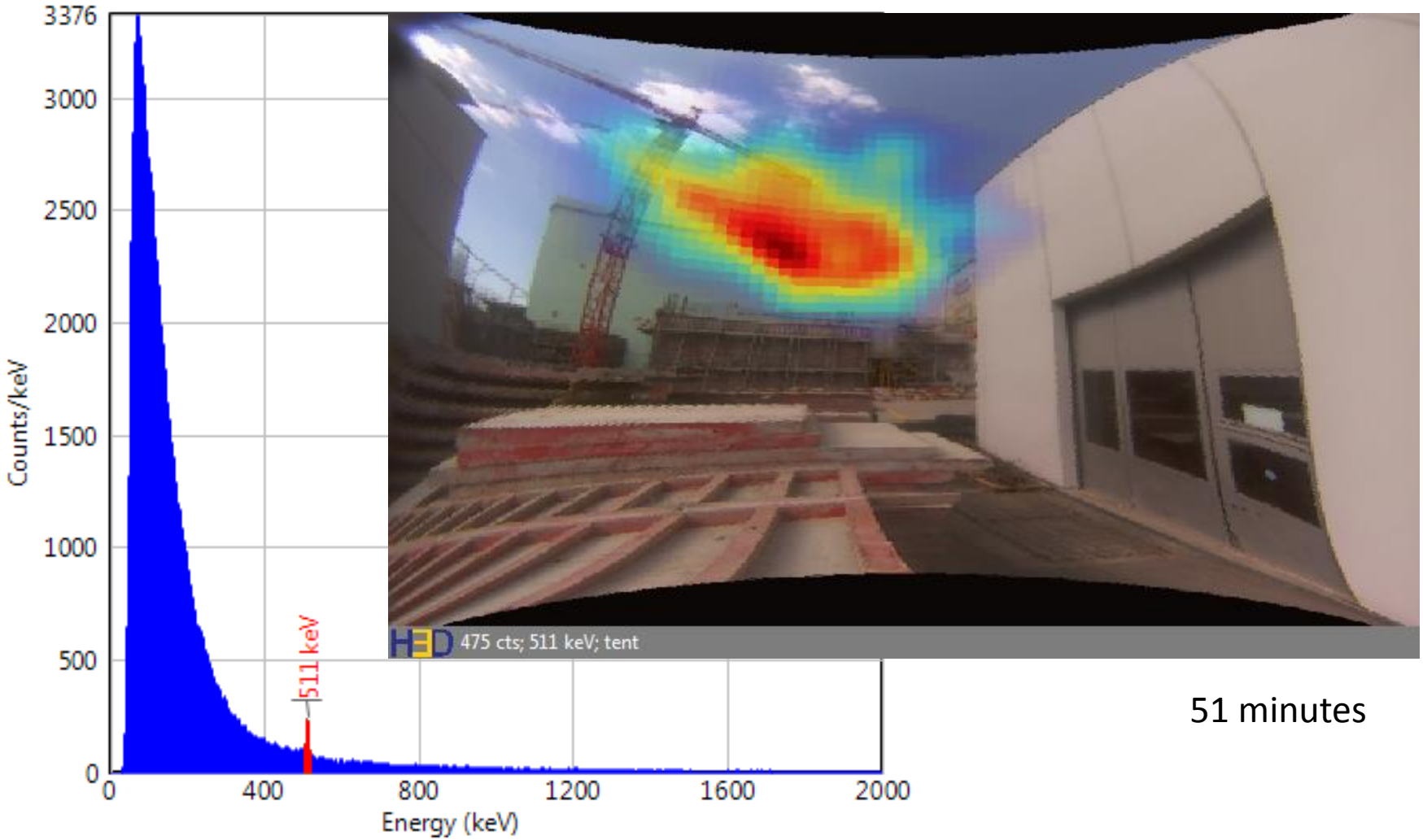
Co-60 image shows another previously unknown source near floor.



Co-58 primarily near floor.

2.5 minutes, ~4 mR/hr

Sky-Shine with Polaris-H



51 minutes

- Imaging 511-keV line from pair production, can image sky-shine outside of reactor building.

Acknowledgement:

Collaborators and customers in nuclear power community who have been **explorers** of this technology

Today:

Making our nuclear plants safer by understanding **unknowns**

Tomorrow?

Detect and recognize accidents **before** they **happen**!