Polaris 3-D CdZnTe Gamma-Ray Imaging Spectrometer Systems

Zhong He

On behalf of the Orion group

UNIVERSITY OF MICHIGAN

2014 North America ISOE ALARA Symposium
Ft. Lauderdale, Florida, January 13 2014

Acknowledgements: DOD DTRA, DOE NA-22 & DHS DNDO

How did Polaris technology get started in 1997?

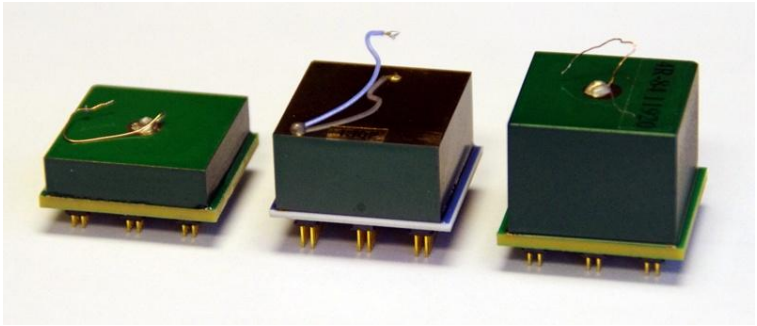
To develop a **high resolution** gamma-ray spectrometer that can be operated at **room temperature**

Why has it taken so long (1997 – 2013)?

(1) **Large volume CdZnTe detectors:** UM has been the **ONLY** customer

Began with:
Digirad
eV
Yinnel ↔
Orbotech

Redlen
has shown
the most
promise



$2\times2\times$**0.5** $cm^3 \rightarrow 2\times2\times$**1.0** $cm^3 \rightarrow 2\times2\times$**1.5** cm^3
(2006 → 2007 → 2009 → 2014)

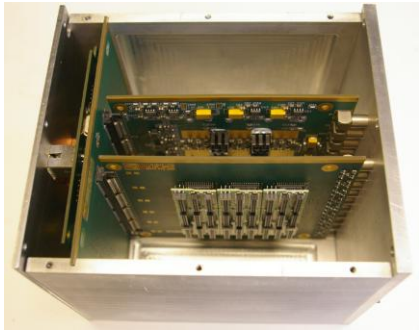
(2) **ASIC readout electronics:**

1998 – 2005: Four design iterations on **Norwegian** analogue ASICs – 3.5 keV noise (**used on Polaris-H**)

2006 – 2012: Four design iterations on an advanced **BNL** analogue ASIC – **2.0 keV** noise **(for DOD)**

2009 – 2014: Three design iterations of **Norwegian digital** ASIC – current research at Univ. of Michigan

2014 – 2016: Two planned design iterations on **BNL digital** ASIC

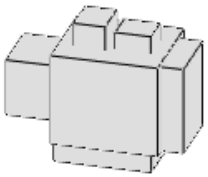


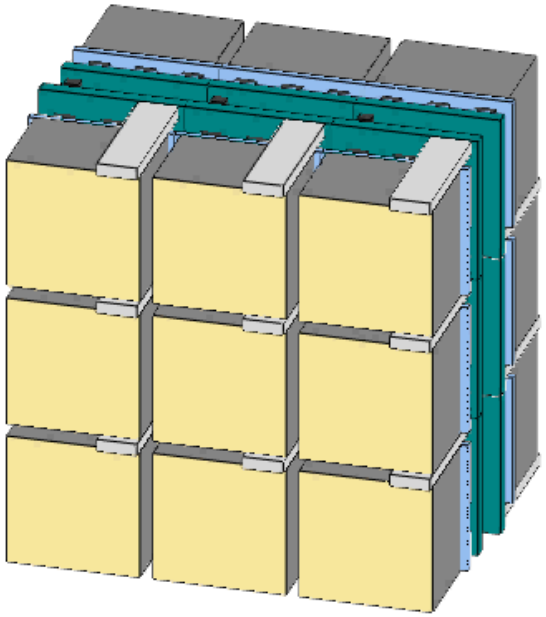
(3) **Four-generations** of Ph.D graduate students

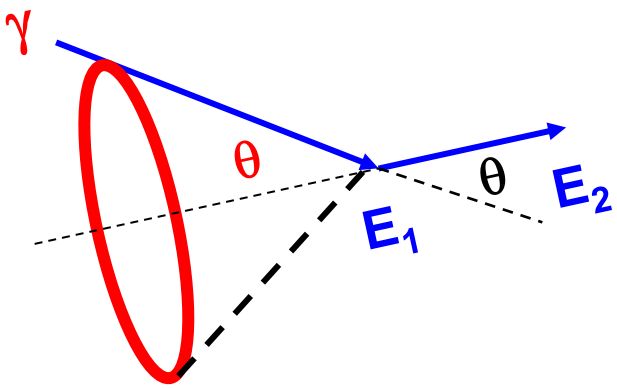
(4) Survived multiple DOD field tests and demonstrations since **2010**

Principle

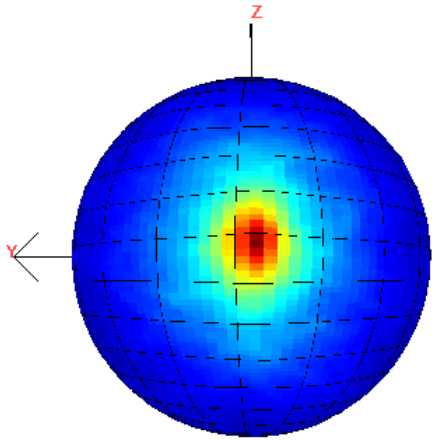
Eighteen 2×2×1.5 cm³ CdZnTe detectors
(108 cm³, 648 grams = 1.43 lb)







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



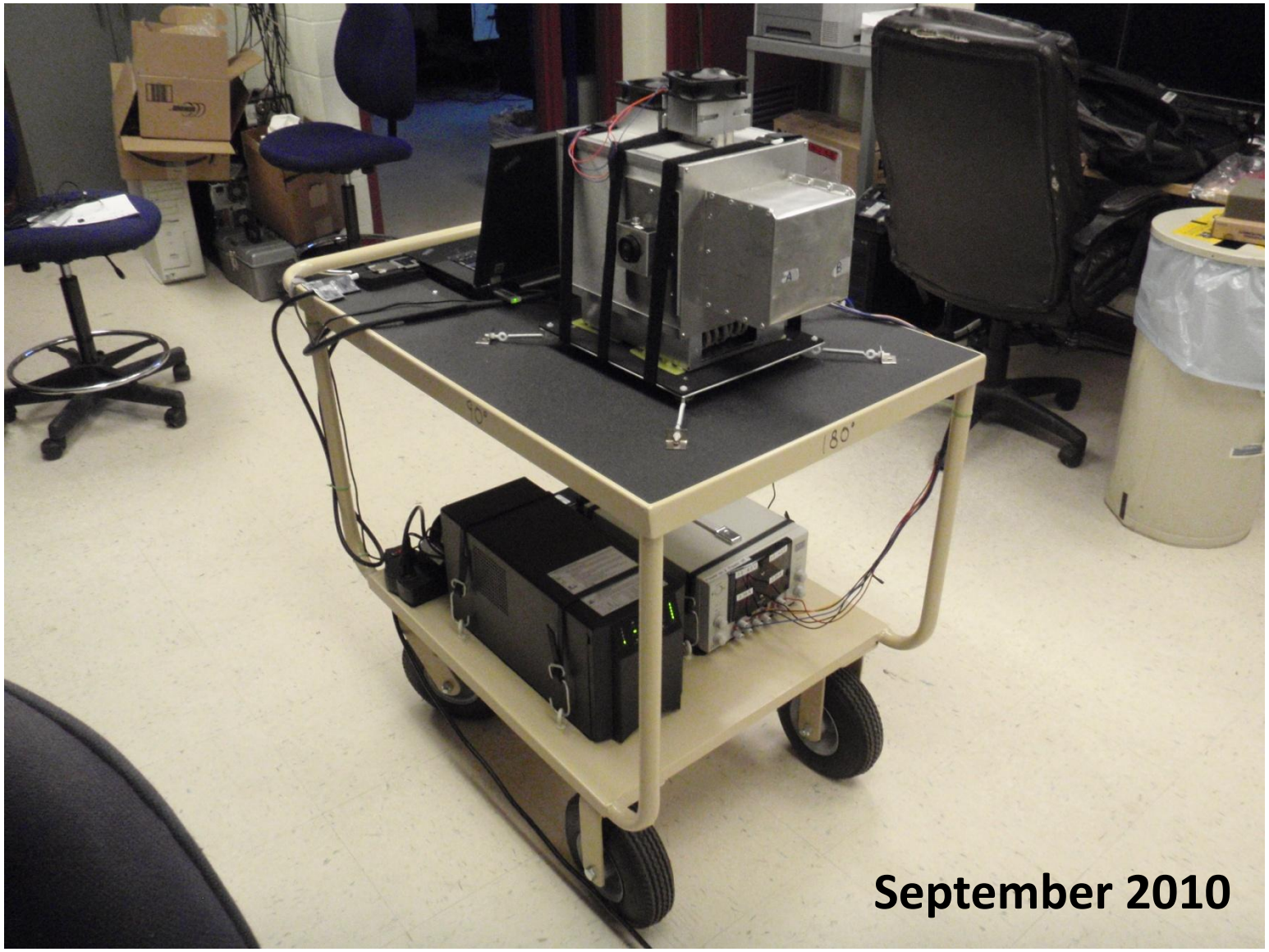
Performance Goals

ΔE/E ≤ 1% FWHM (at 662 keV)

Real-time γ Imaging + isotope I.D.

Number of photons: 2033

First UM Polaris 3-D CZT detector system



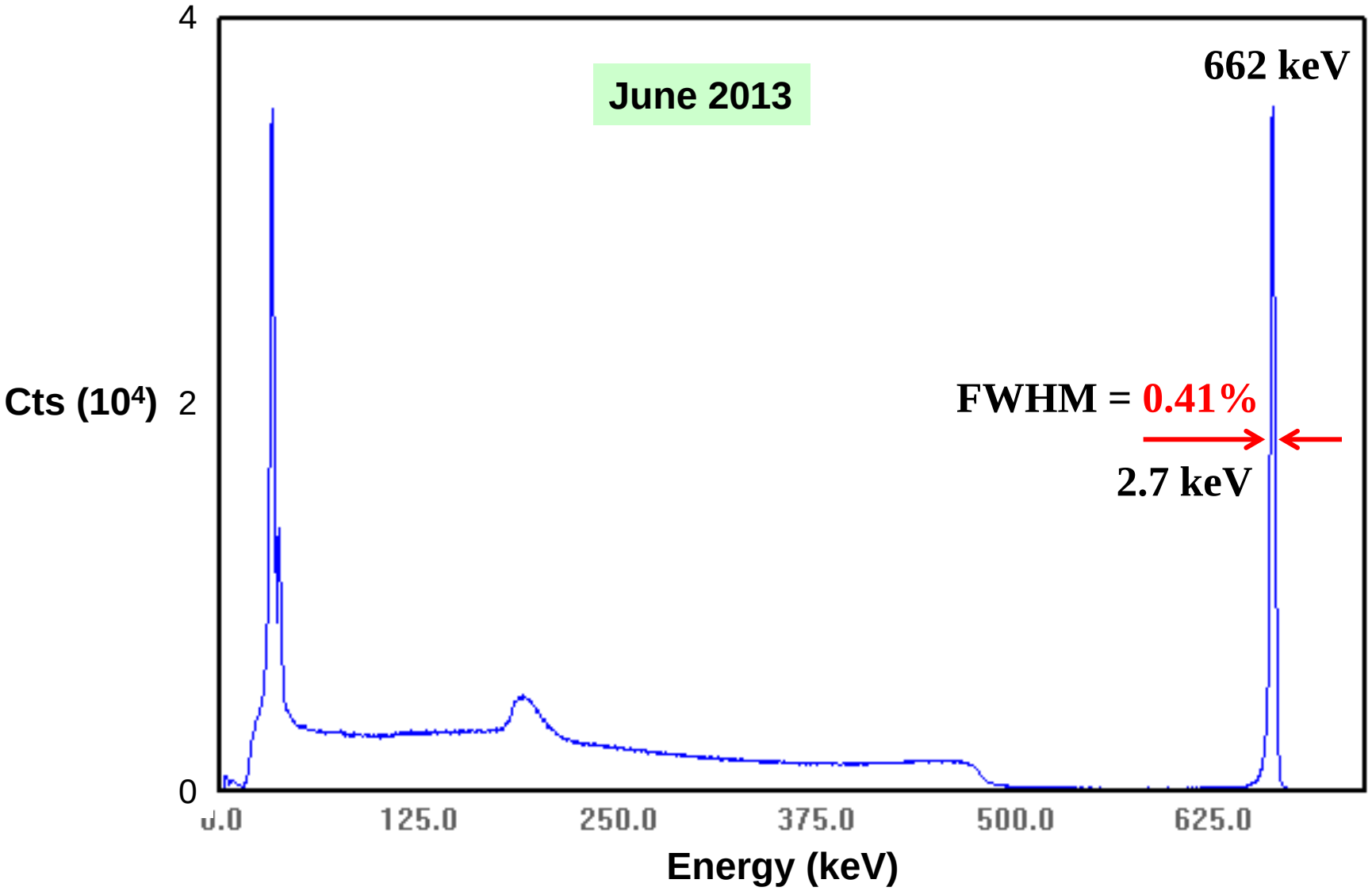
Performance of a 2nd-Generation Polaris System (DOD)

(108 cm³ CZT – BNL/UM analogue ASIC by H3D-Locolabs-BNL)

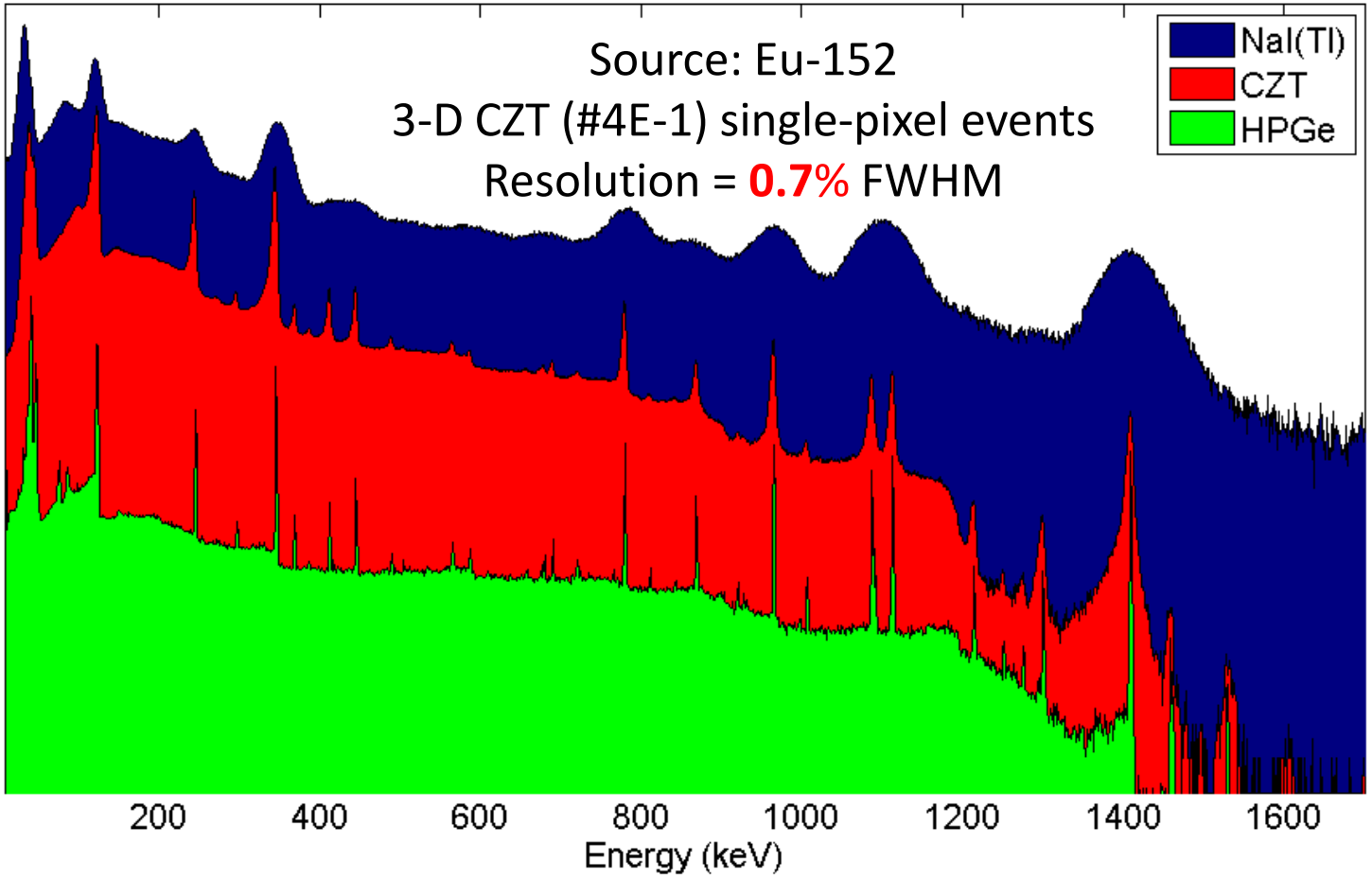
July 2012

Closer to HPGe resolution

(Single-pixel events from the best 6 cm^3 CZT (#4E-1))

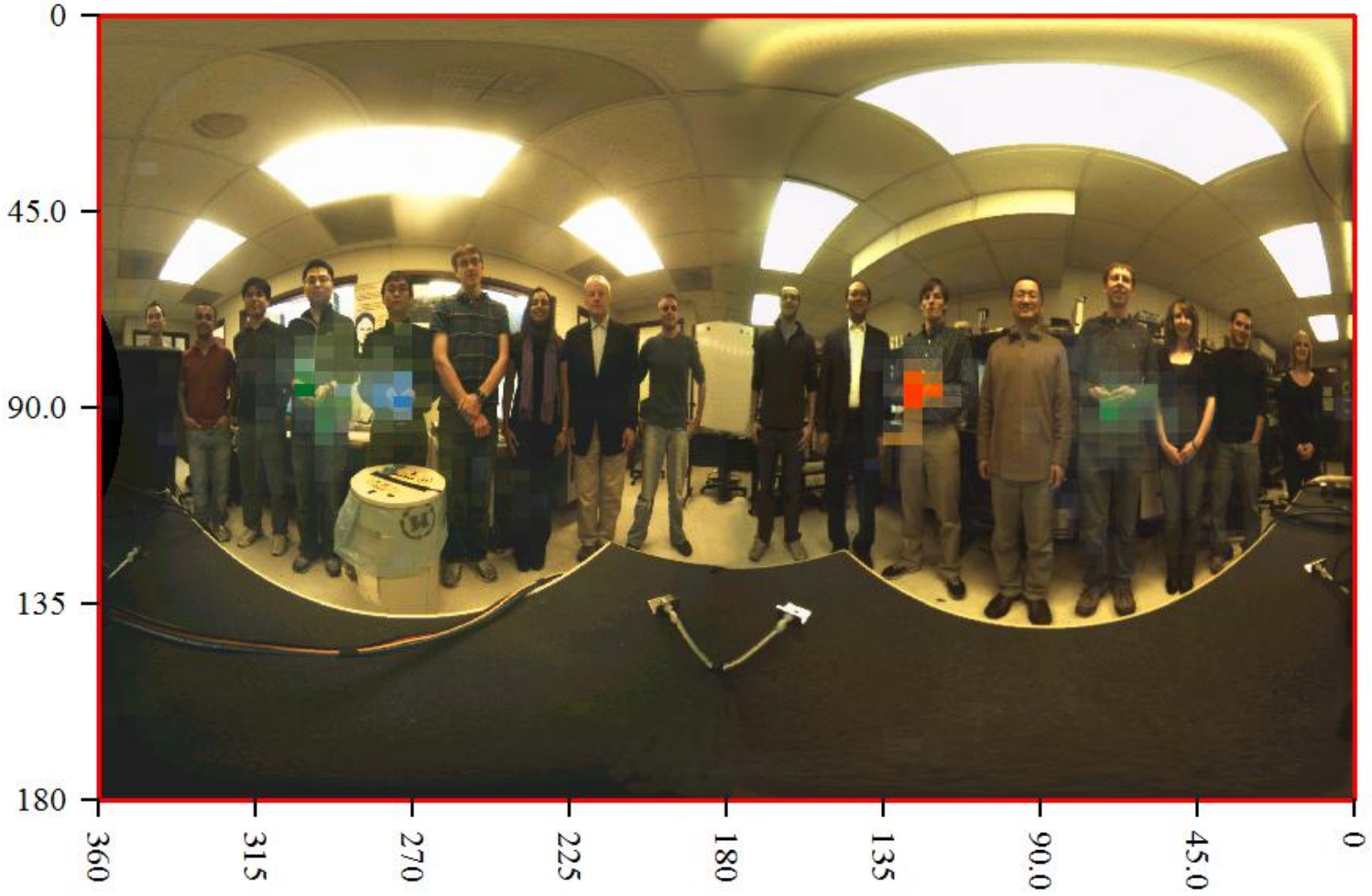


Comparing to Other γ Spectrometers



2006

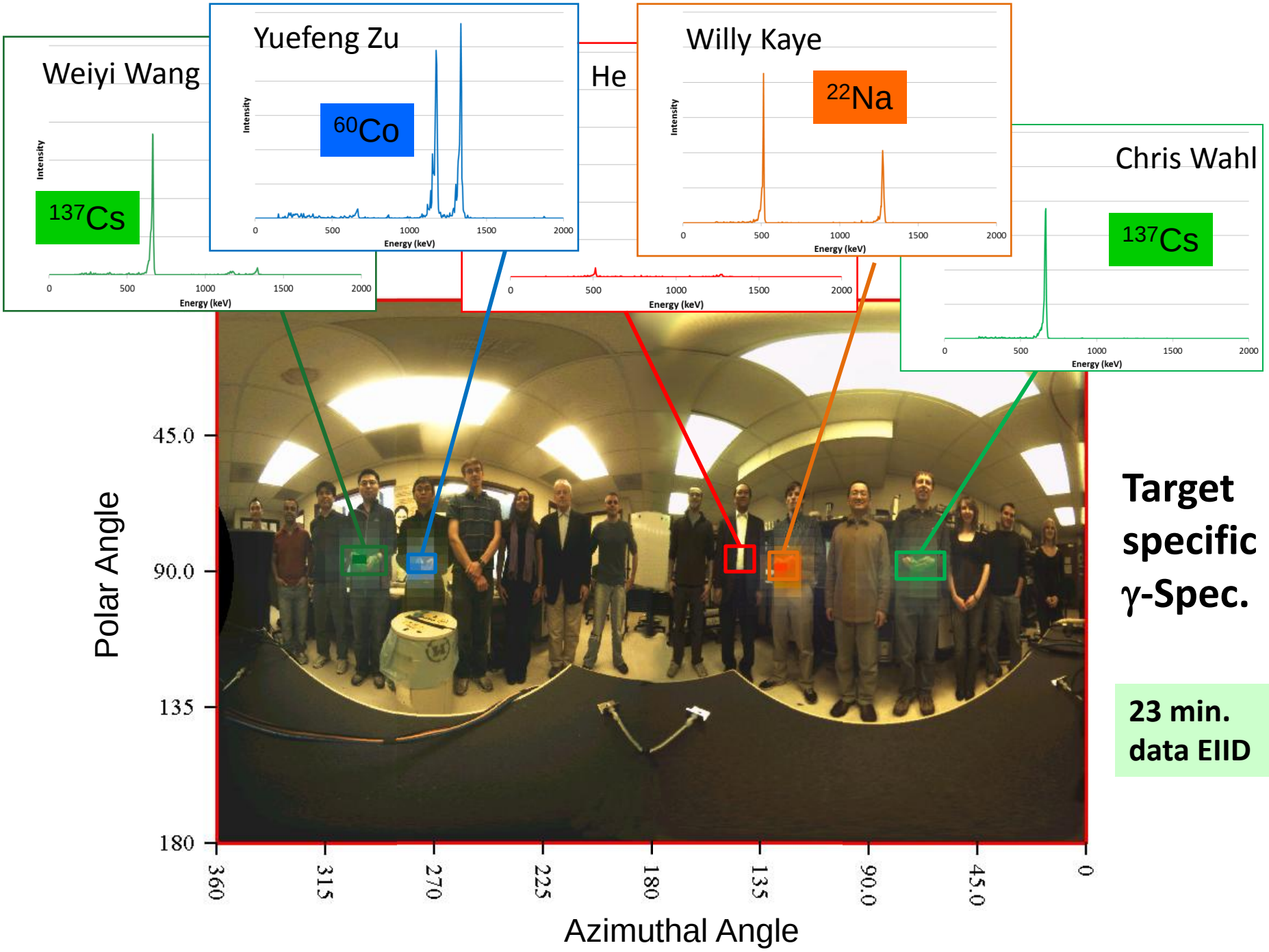
Gamma Imaging Capability



Intensity of:

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

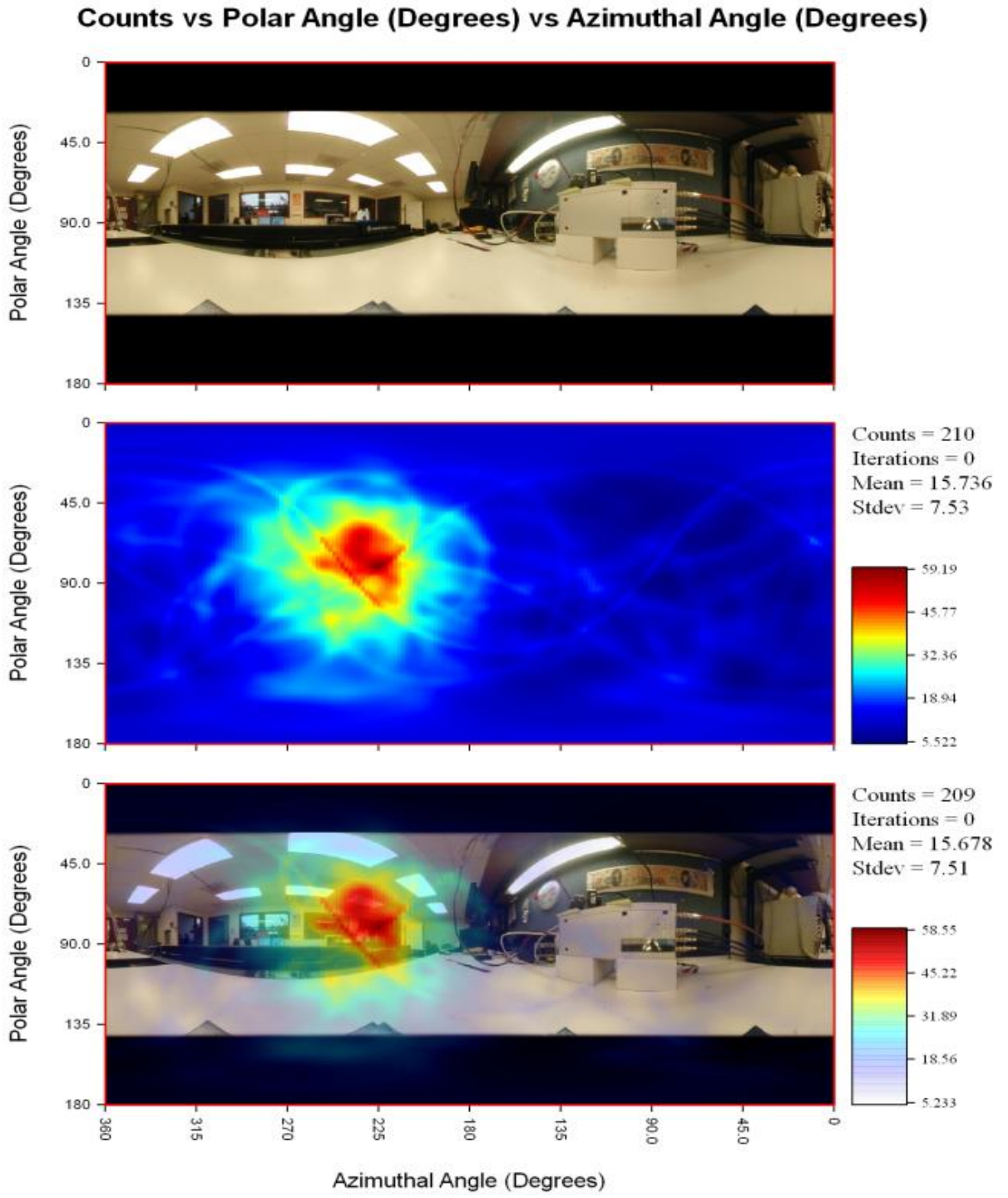
1 minute data EIID



Target specific γ-Spec.

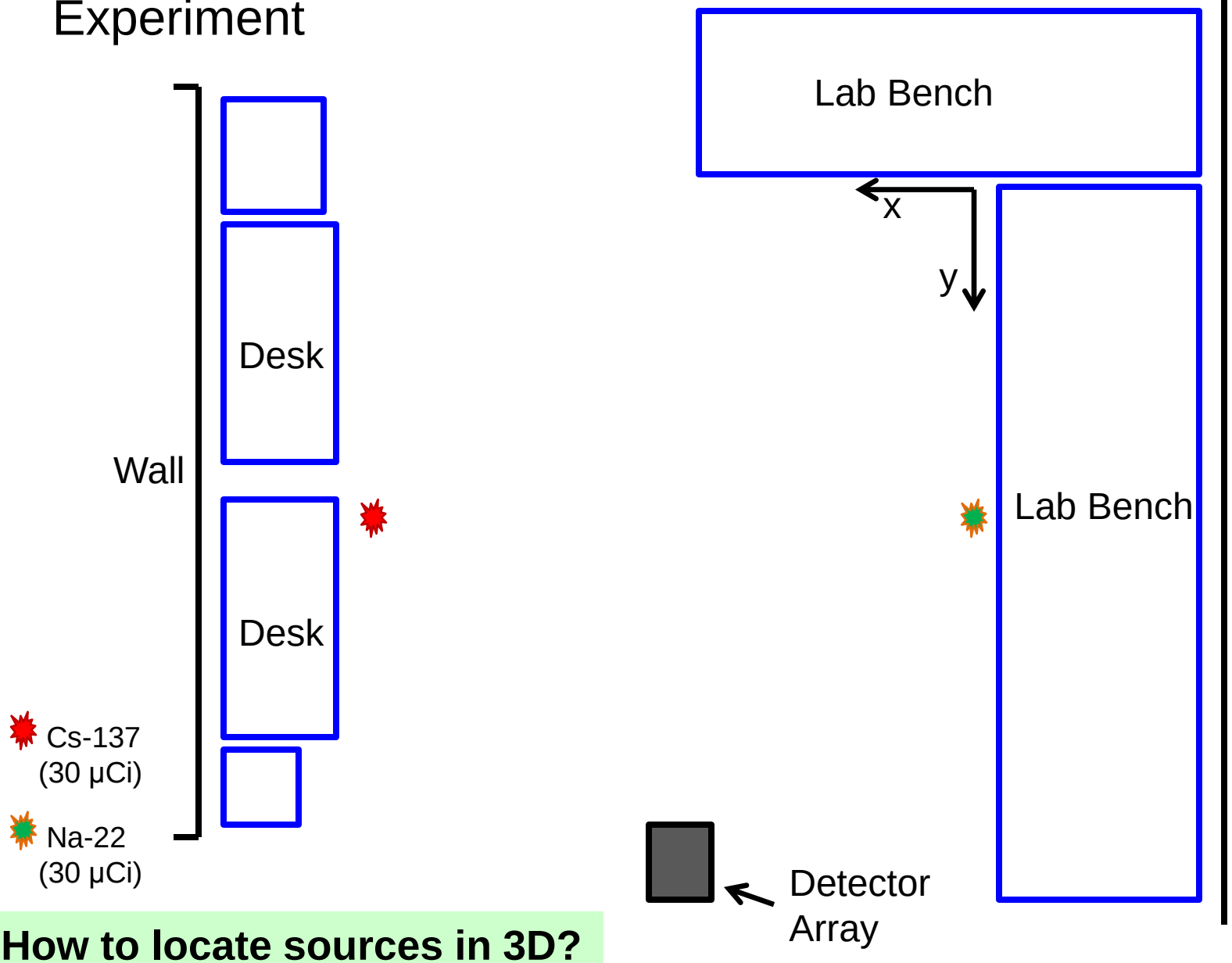
23 min. data EIID

Tracking Moving Gamma Targets



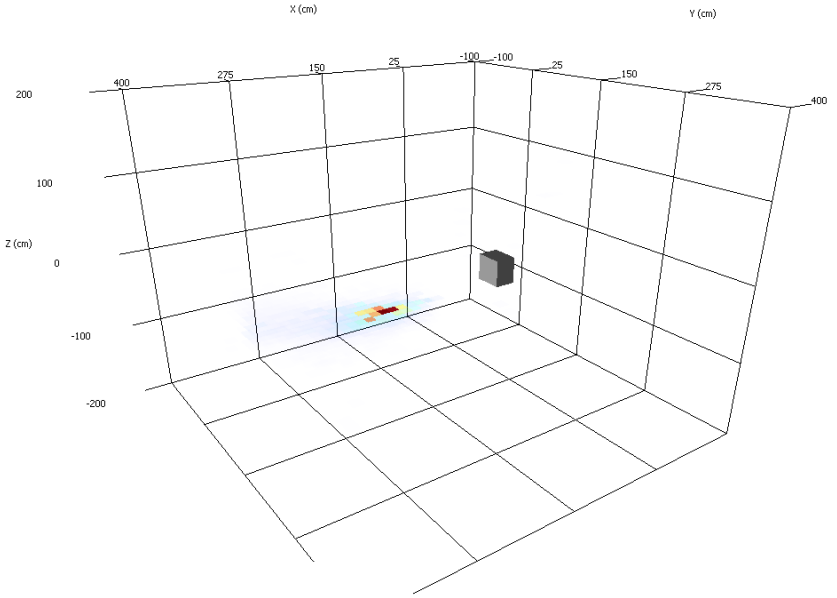
3D Imaging with a Moving Detector

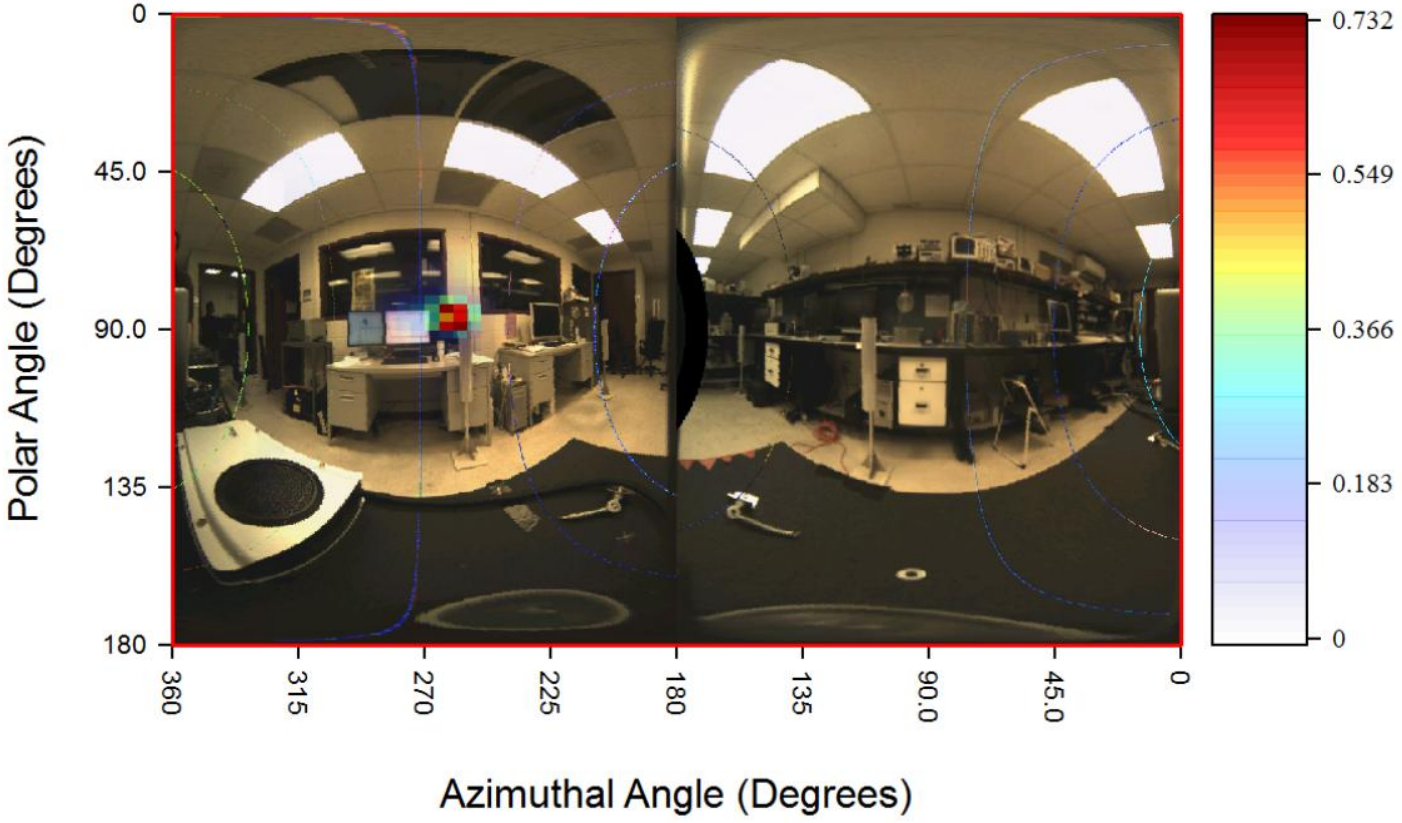
Experiment



How to locate sources in 3D?

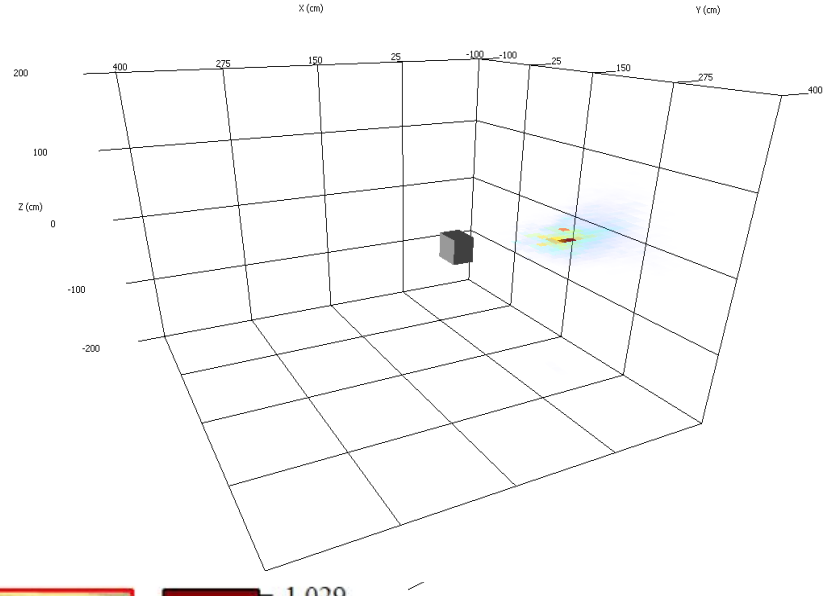
MLEM Imaging with a moving detector

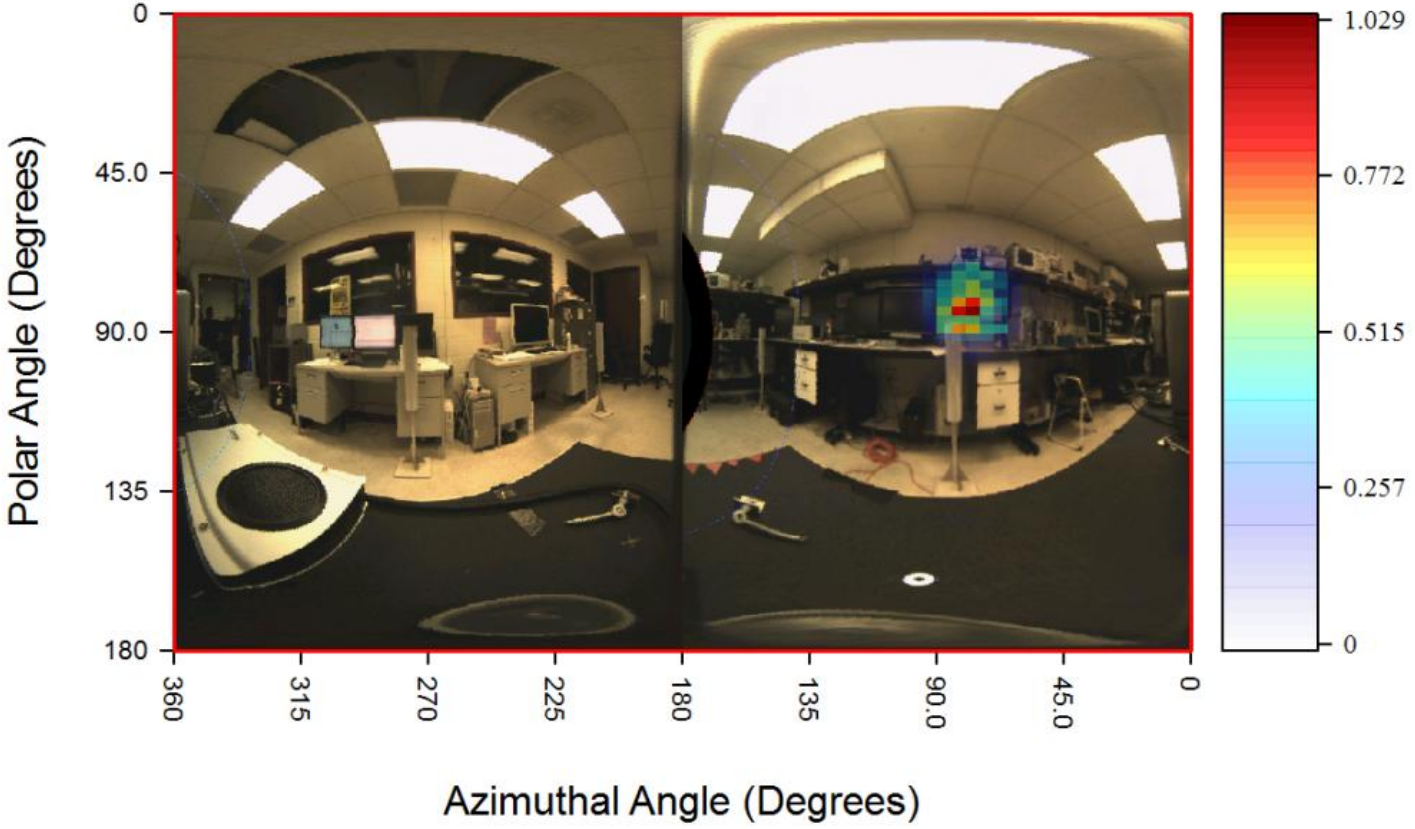




Energy Window:
Cs-137

MLEM Imaging with a moving detector





Energy Window:
Na-22

Sensitivity of Polaris Systems

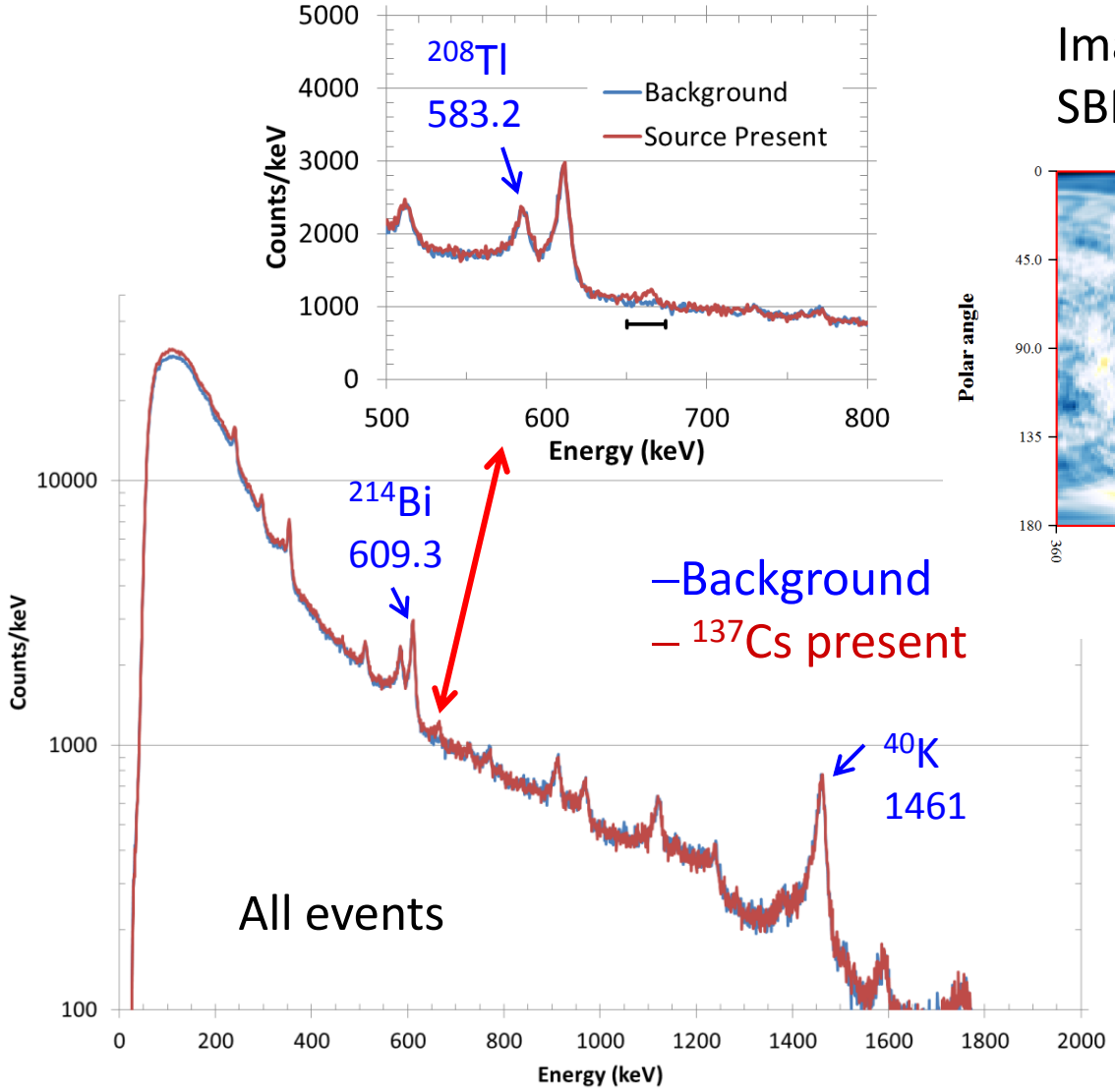
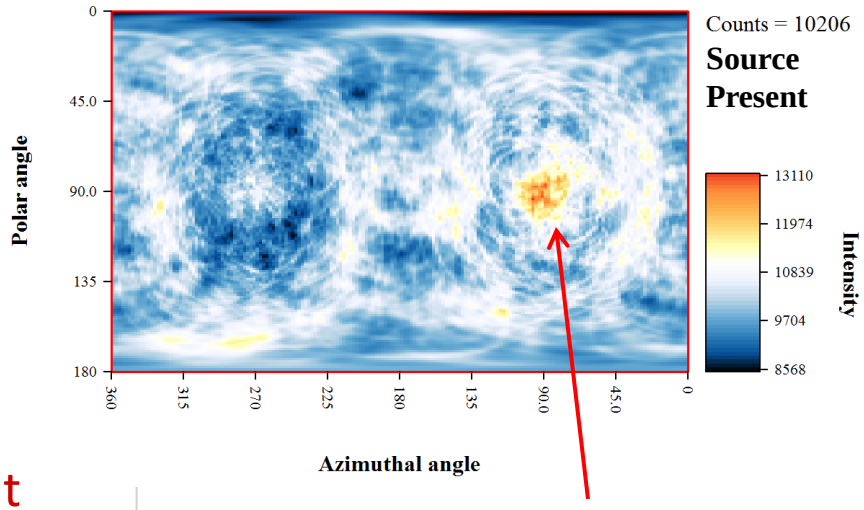
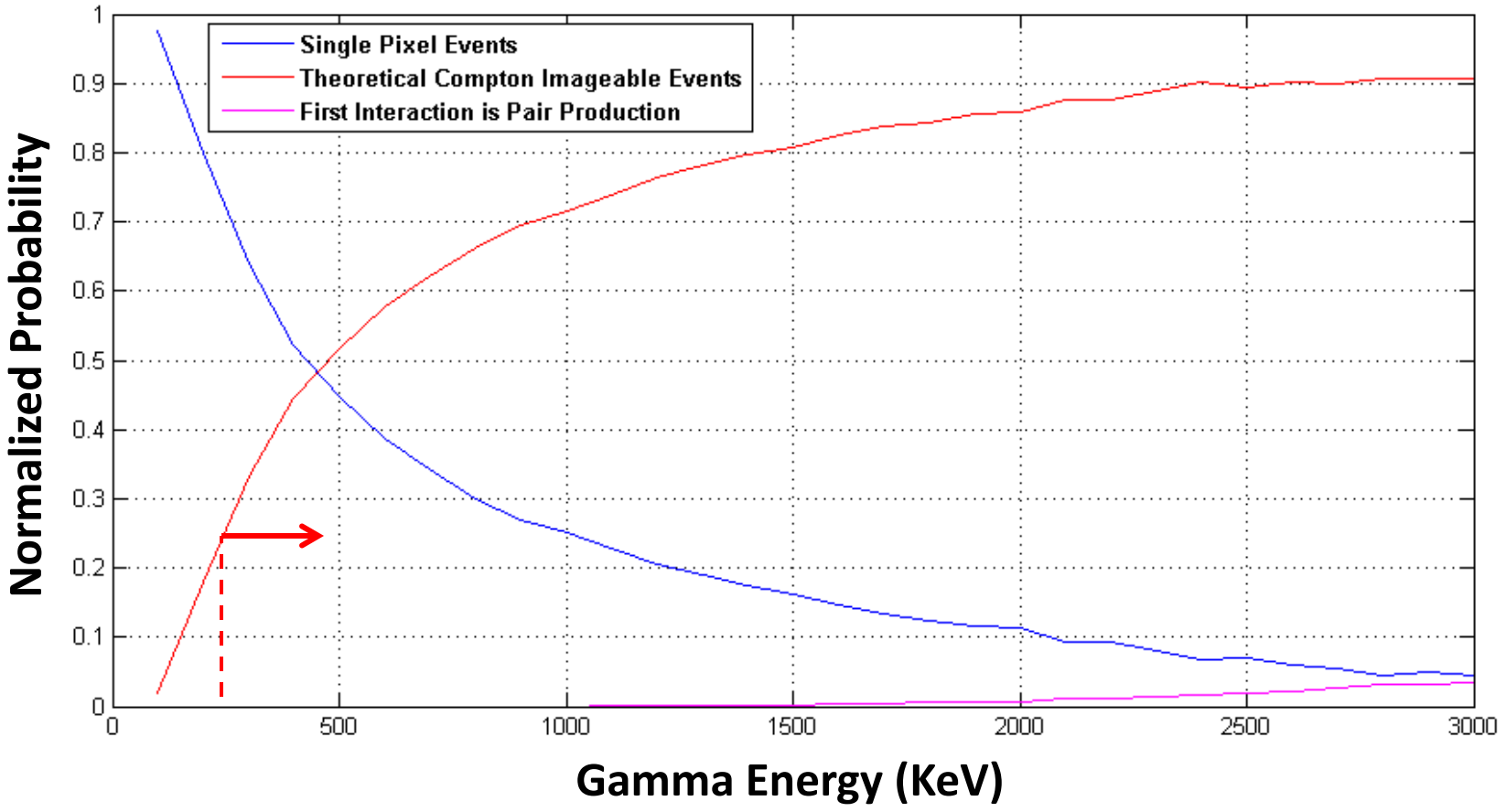


Image of $650 \leq E\gamma \leq 674$ keV
SBP with 2 – 4 pixel events



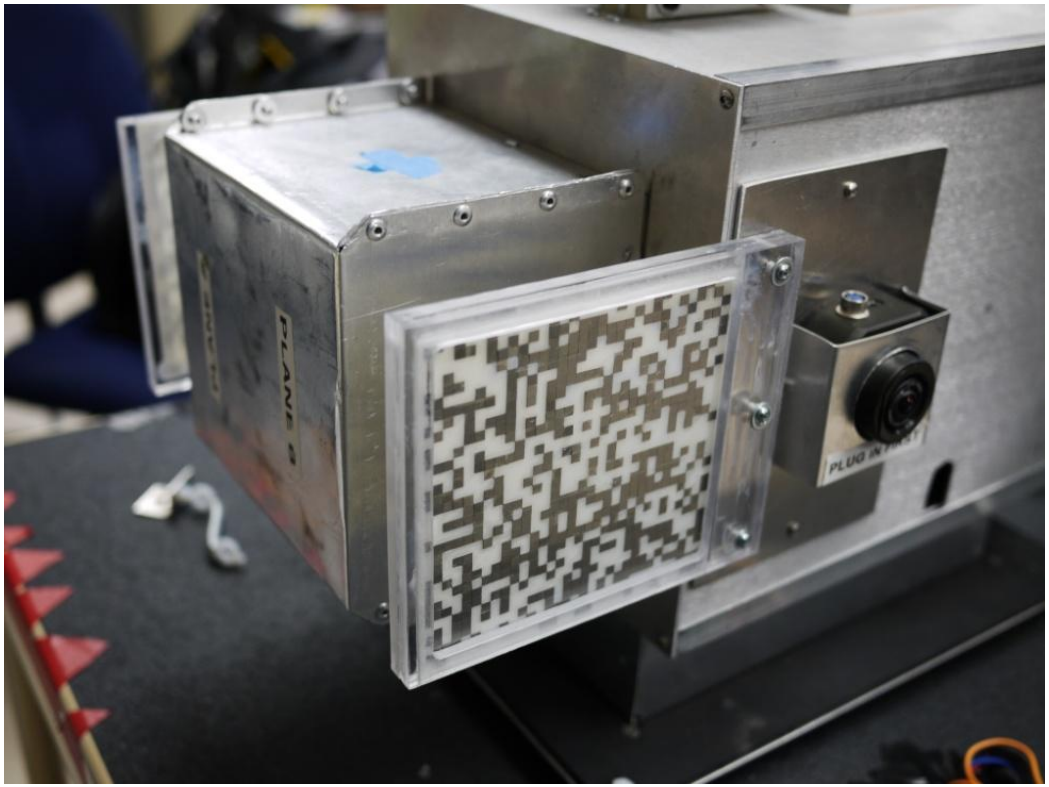
Discovered a 30 μCi ^{137}Cs source behind a wall at ~4m the next morning (12 hours data collection)

Energy Range of Compton Imaging



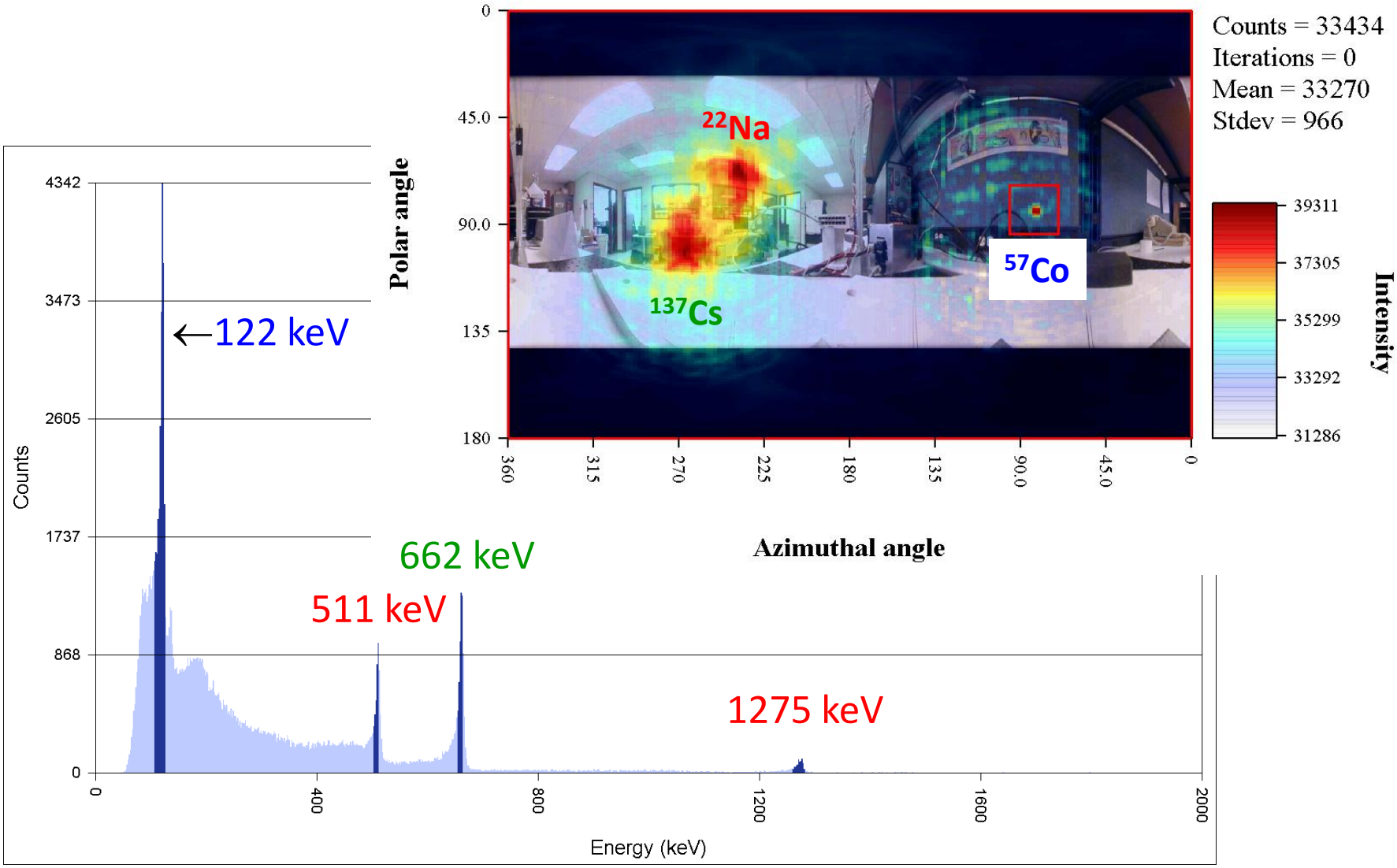
Polaris-H performs Compton imaging for γ-rays with E ≥ 250 keV

Coded Aperture Imaging at E ≤ 250 keV

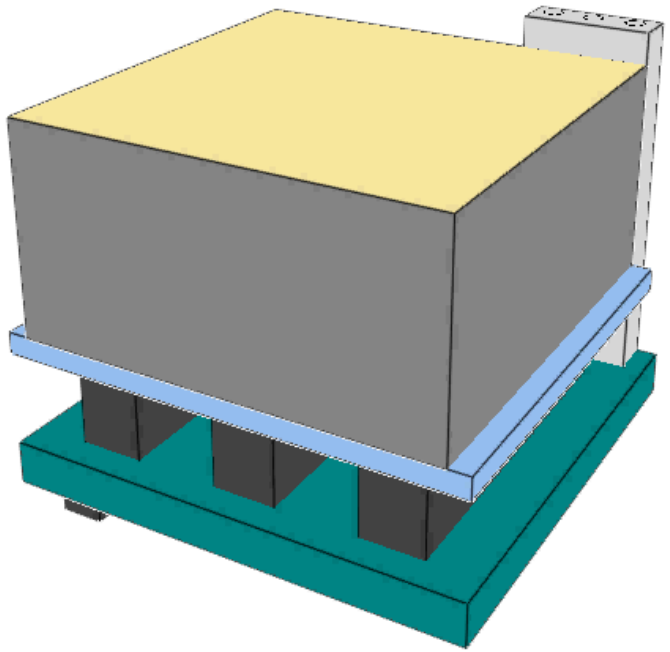


Principle: Recognize unique mask shadows from different incident gamma-ray angles

Real-Time Combined Coded Aperture and Compton Imaging



Today and Tomorrow



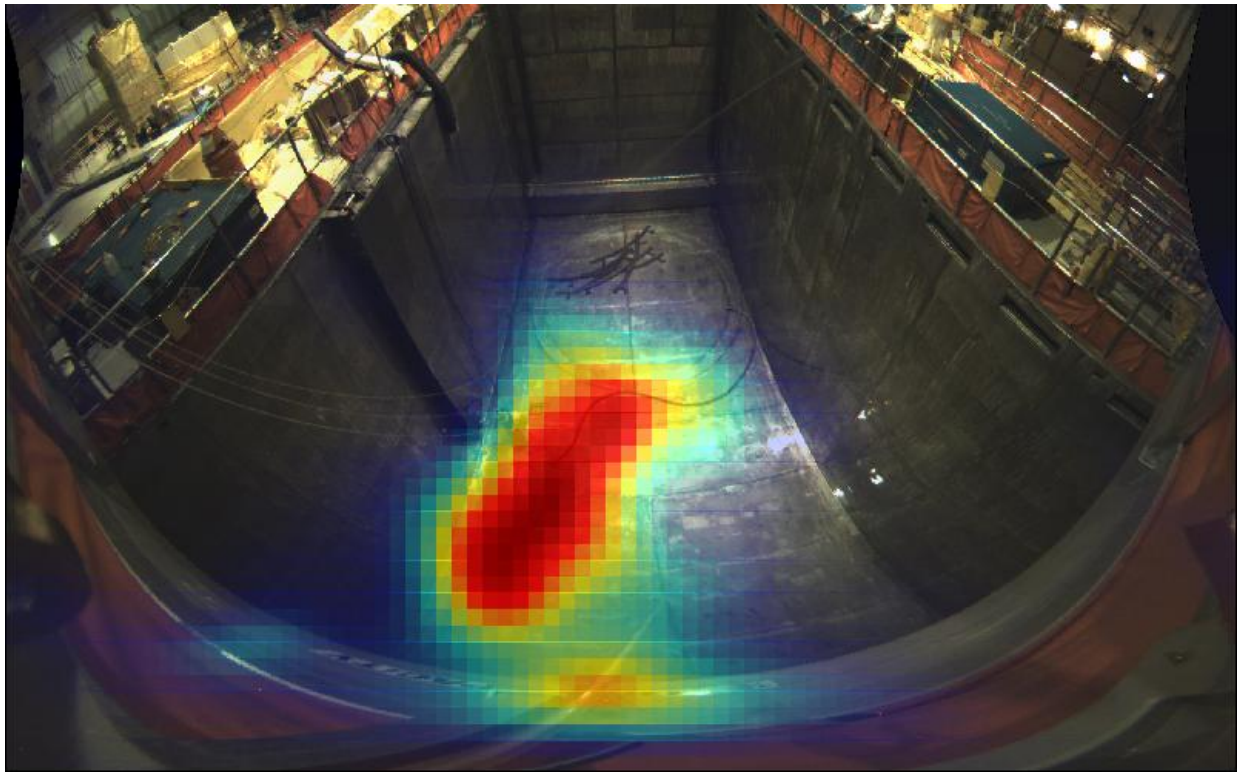
Research → Commercialization

(UM) (H3D, Inc.)

First Demonstration at Fermi in March 2012

Optical & (^{60}Co) Gamma Images

Measurements at Dryer Separator Pit



Co-60
Co-58
image

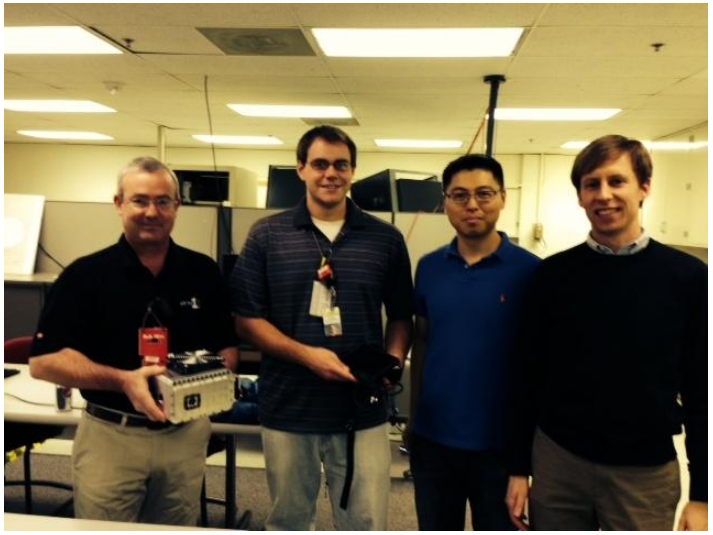
Distributions of different isotopes can be visualized for safety inspection

Detection on changes of isotope distributions over time can be very sensitive to detect fuel leaks or contaminations

<u>Acknowledgements</u>: Cook Nuclear Plant

Dr. David Miller, Bob Hite, Joe Beer & Derek Hultquist

Cook bought the 1st Polaris-H on **Dec. 31, 2012**. They have been doing measurements & beta testing since then



October 2013

See demo by Dr. Willy Kaye and Dr. Chris Wahl from H3D

See later presentation by Bob Hite