Polaris 3-D Position-Sensitive CdZnTe Gamma-Ray Imaging Spectrometers

Zhong He

On behalf of the **Orion** group

UNIVERSITY OF MICHIGAN

and **H3D Inc**.

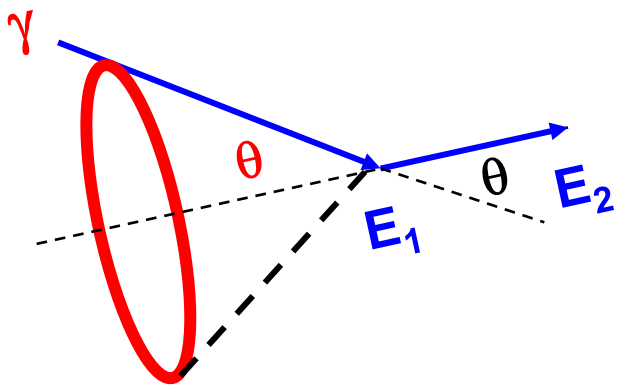
Los Alamos National Laboratory, P-25

August 12th, 2013

This project has been jointly funded by
DOD DTRA and **DOE NA-22**

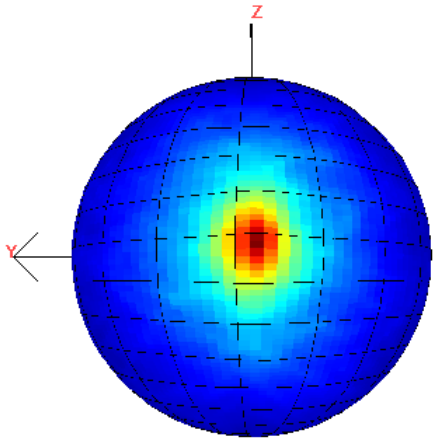
Polaris Systems

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



The two movies on Polaris operation, principle of gamma-ray imaging, and "Today and Tomorrow" were deleted since they take too much memory to be sent by E-mail (Please contact Zhong He at UM if people are particularly interested in those movies.)

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



Number of photons: 2033

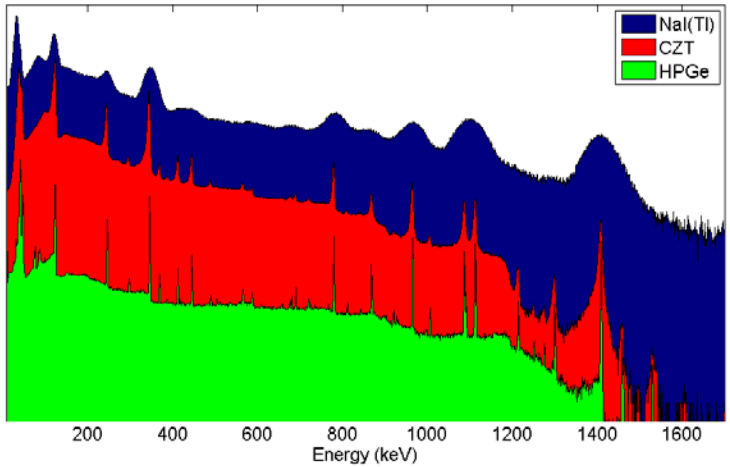
Performance Goals

ΔE/E ≤ 1% FWHM (at 662 keV)

Real-time γ Imaging + isotope I.D.

Goals

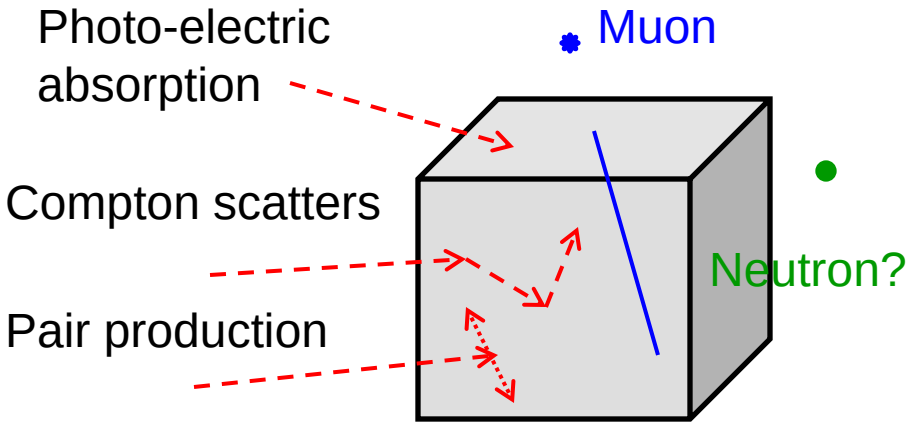
Close to HPGe resolution at RT



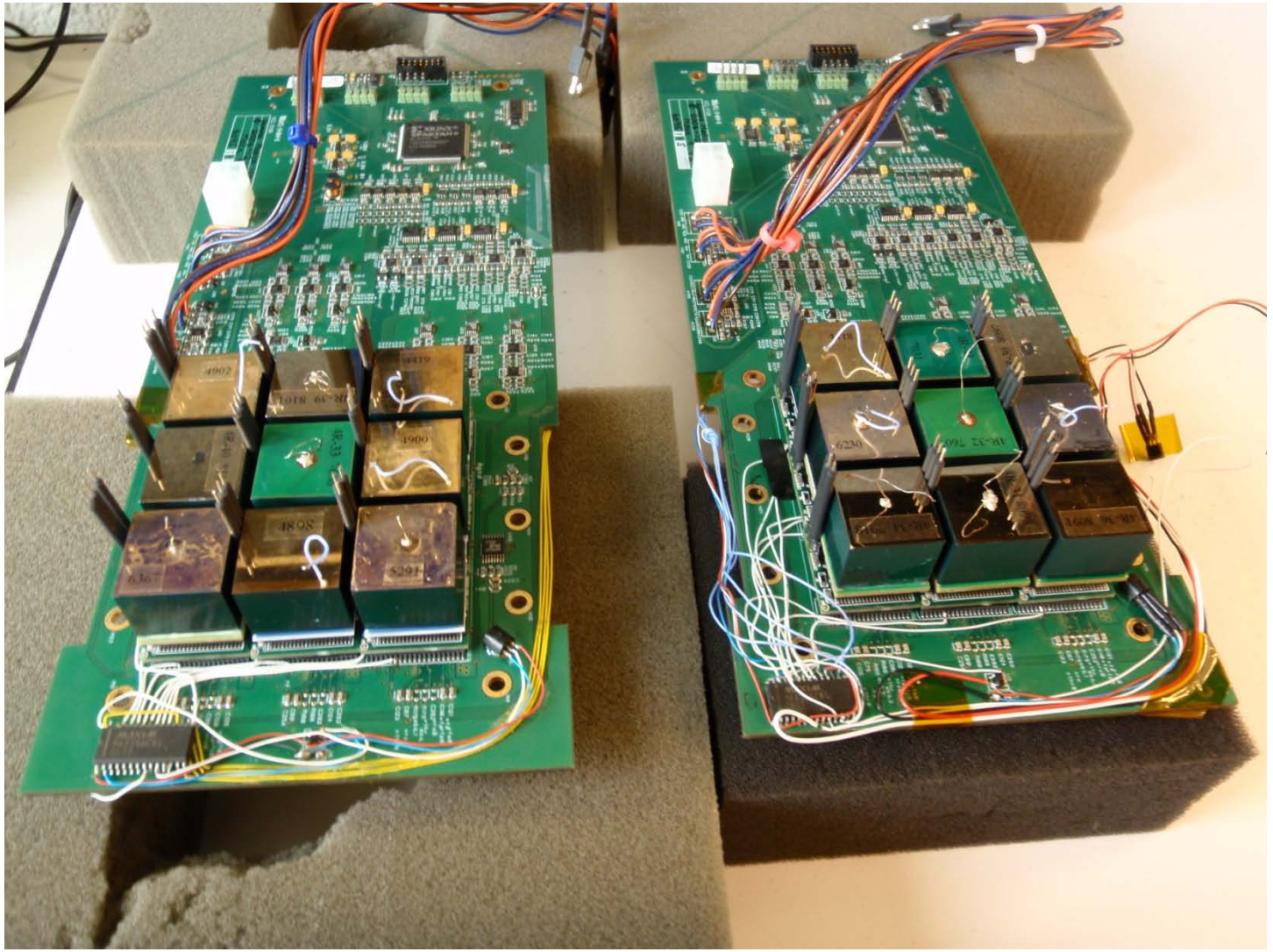
Minimize impacts of imperfections of commercially available crystals

Real-time γ-ray imaging

Intelligent data analysis based on signature of radiation interactions



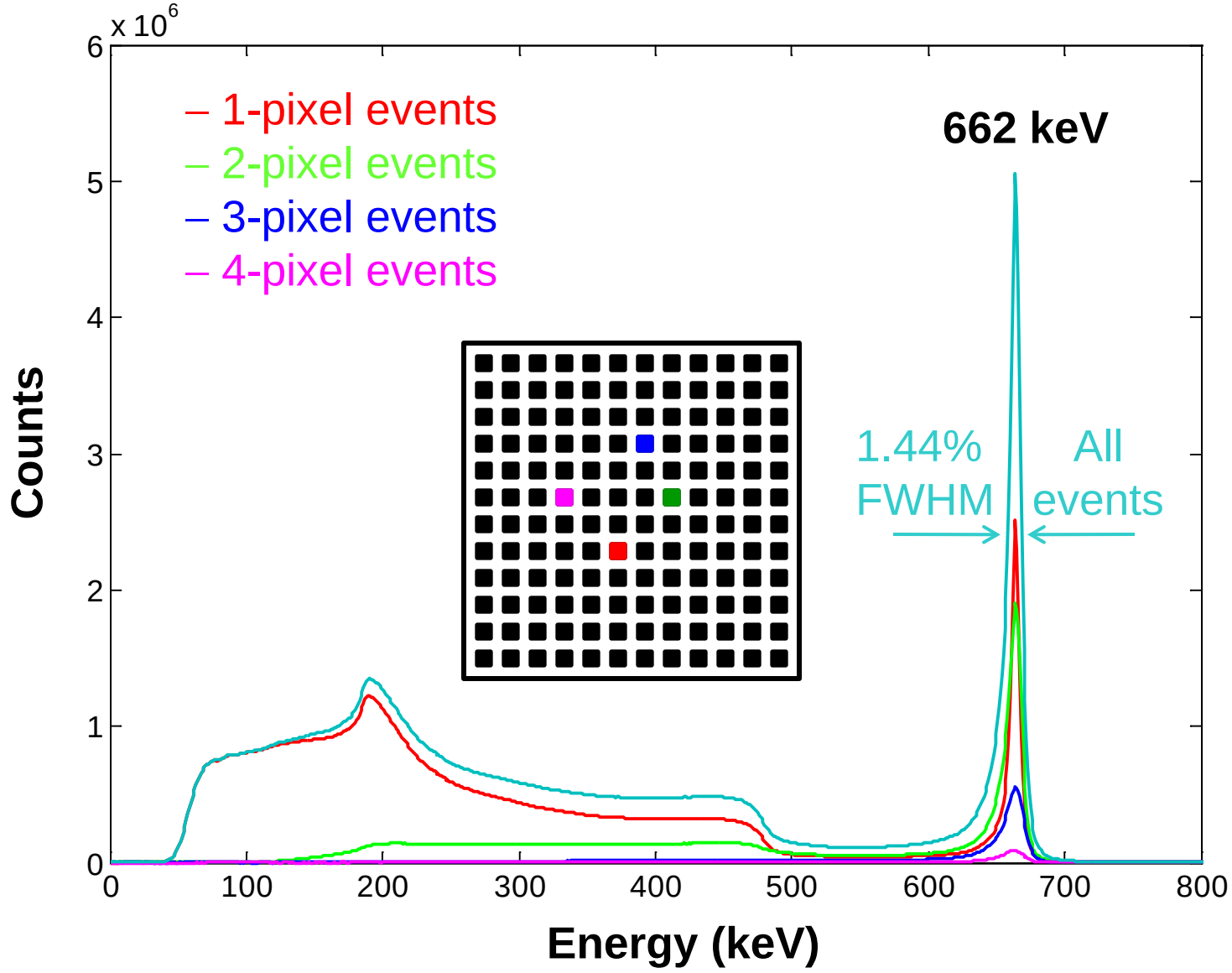
Polaris 1.1 (GMI ASIC) – August 2010



Polaris 1.1 (GMI ASIC) – August 2010

^{137}Cs Energy Spectra of the 1st Polaris system #1.1

(From **all 18 detectors** of Polaris, 24°C, uncollimated **^{137}Cs**)



2nd-Generation Polaris System v2.0 (BNL ASIC)

(From **all 18 detectors**, room-temperature, uncollimated ^{137}**Cs**)

July 2012

Single-pixel events

662 keV

0.61%
(4.0 keV)
FWHM

Counts per keV

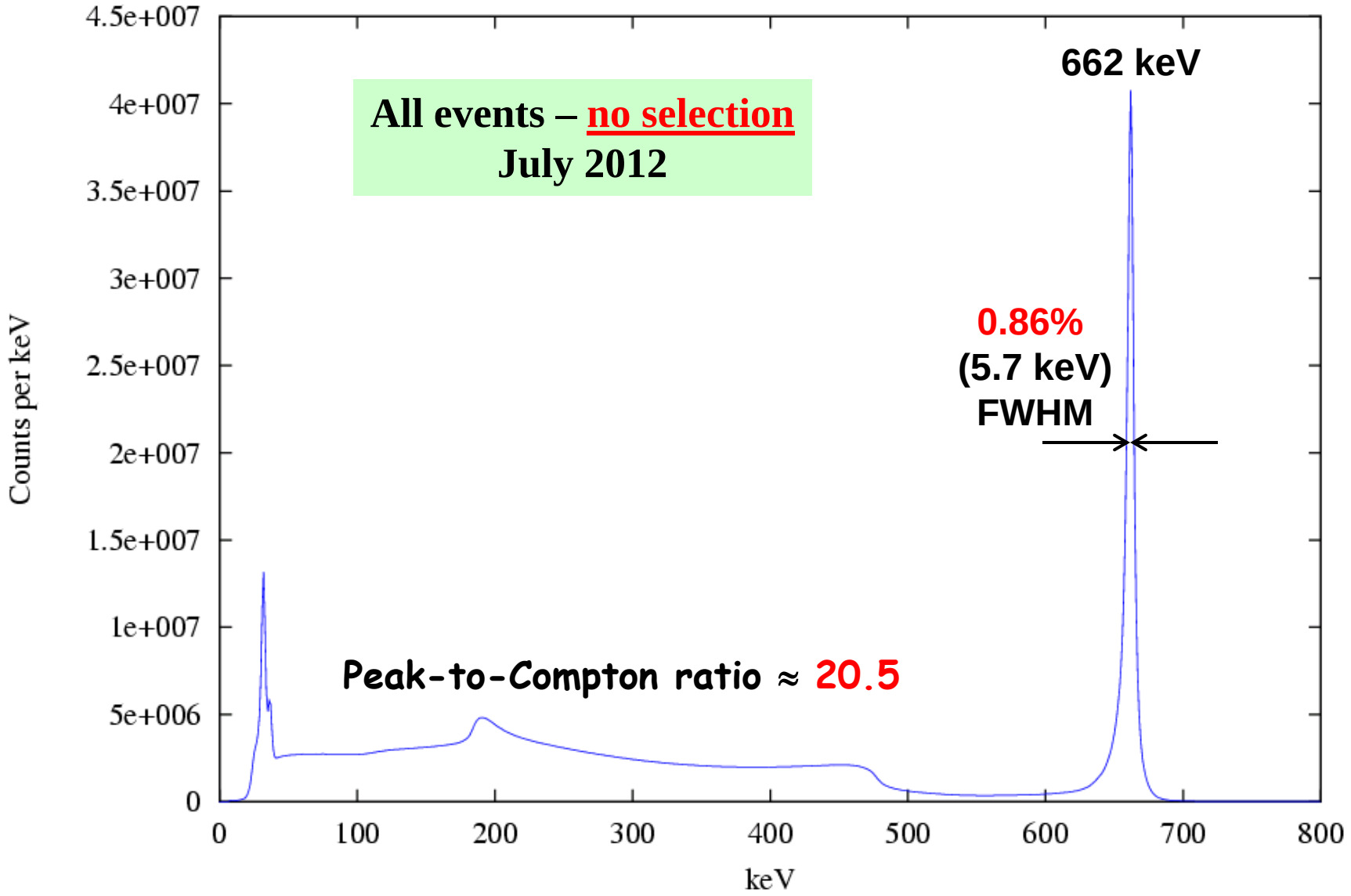
2e+007
1.5e+007
1e+007
5e+006
0

0 100 200 300 400 500 600 700 800

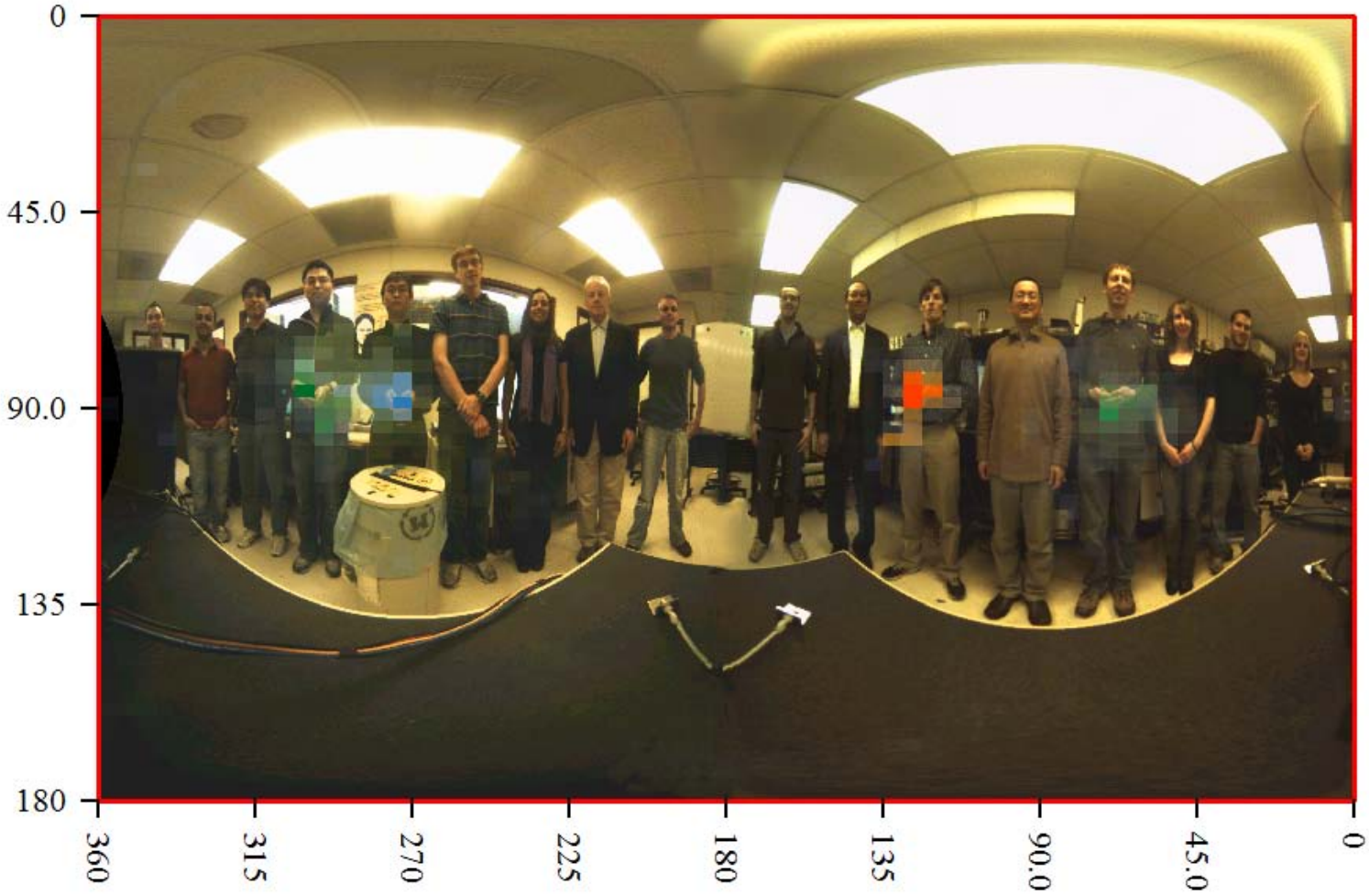
keV

2nd-Generation Polaris System v2.0 (BNL ASIC)

(From **all 18 detectors**, room-temperature, uncollimated ^{137}**Cs**)



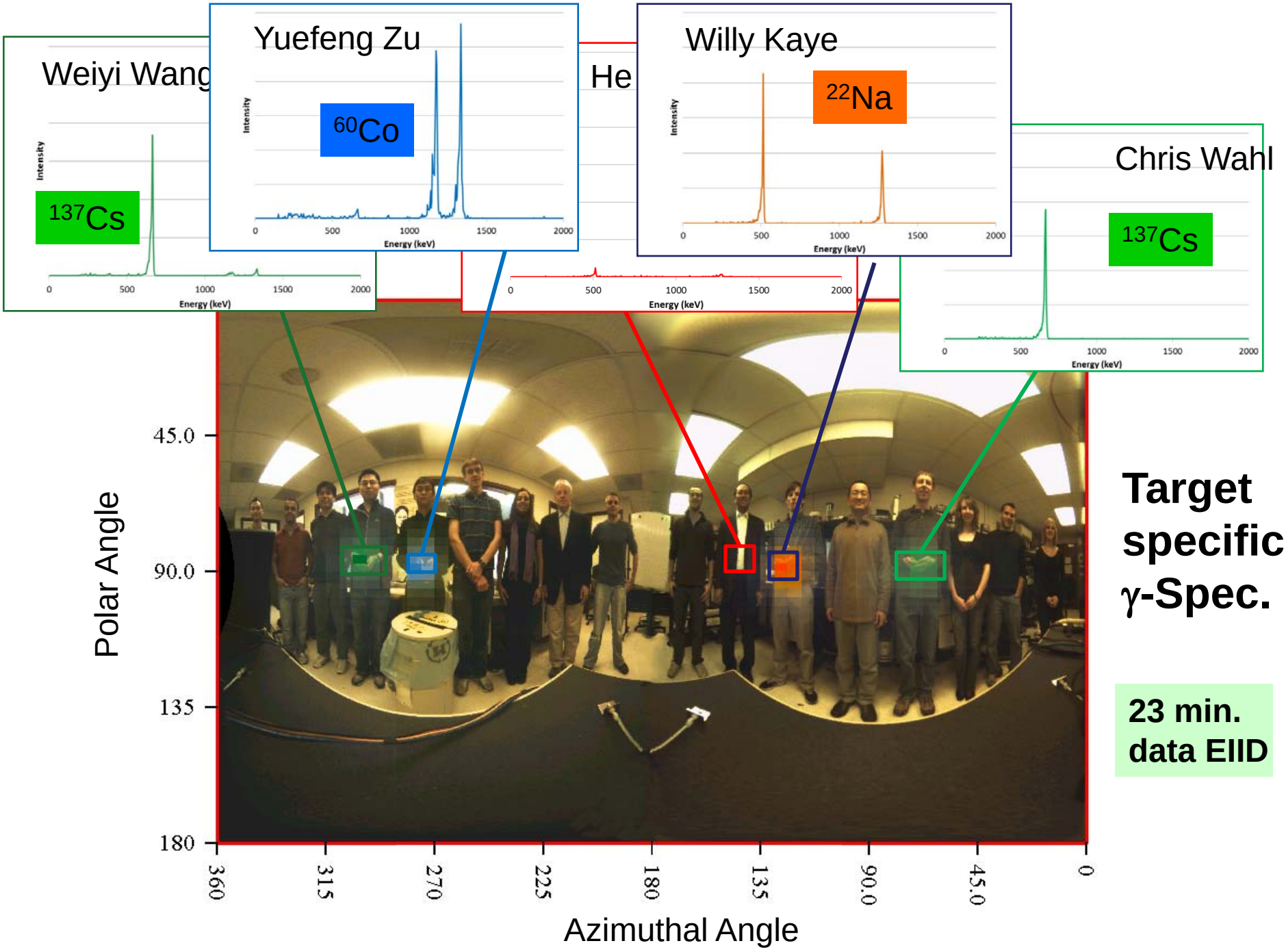
Gamma Imaging Capability



Intensity of:

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

1 minute data EllDs.

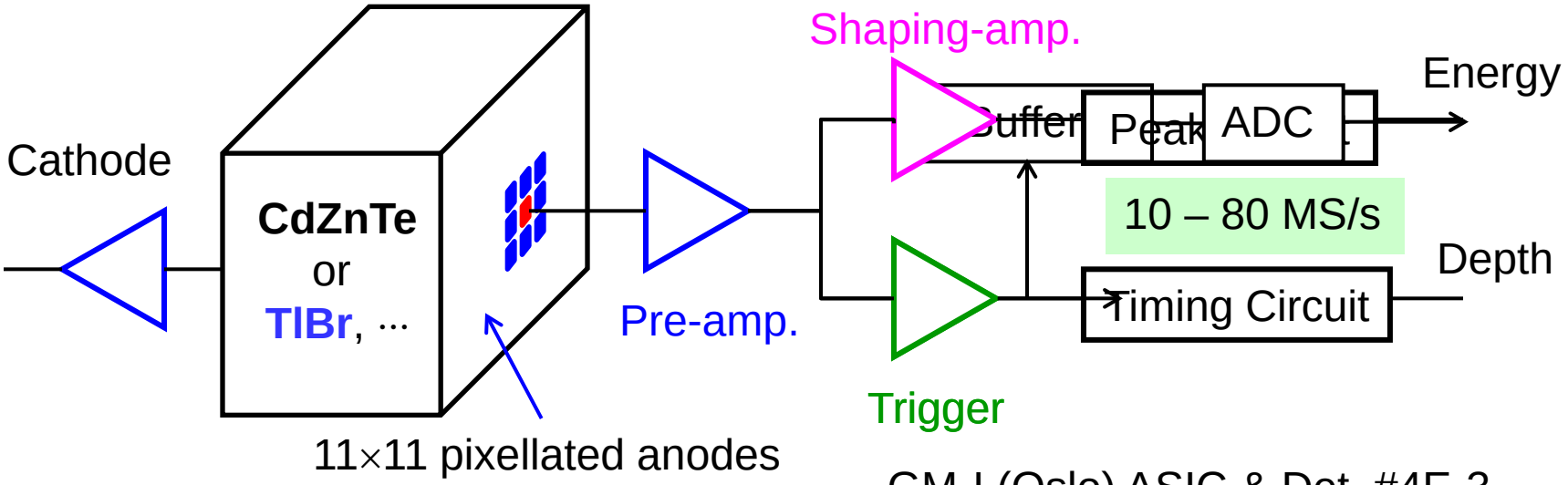


Target specific γ-Spec.

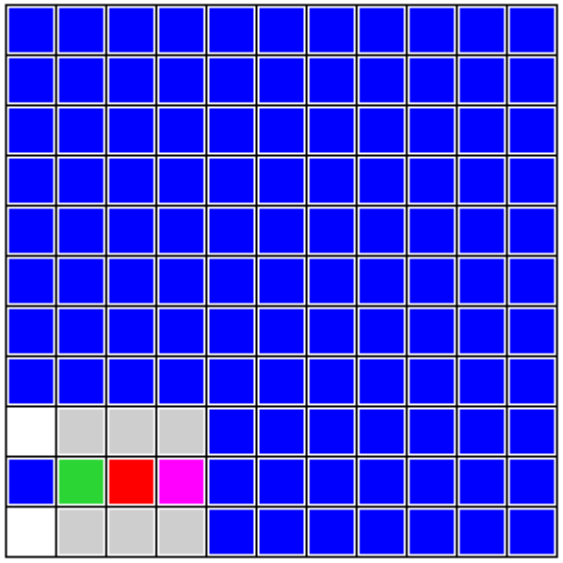
23 min. data EIID

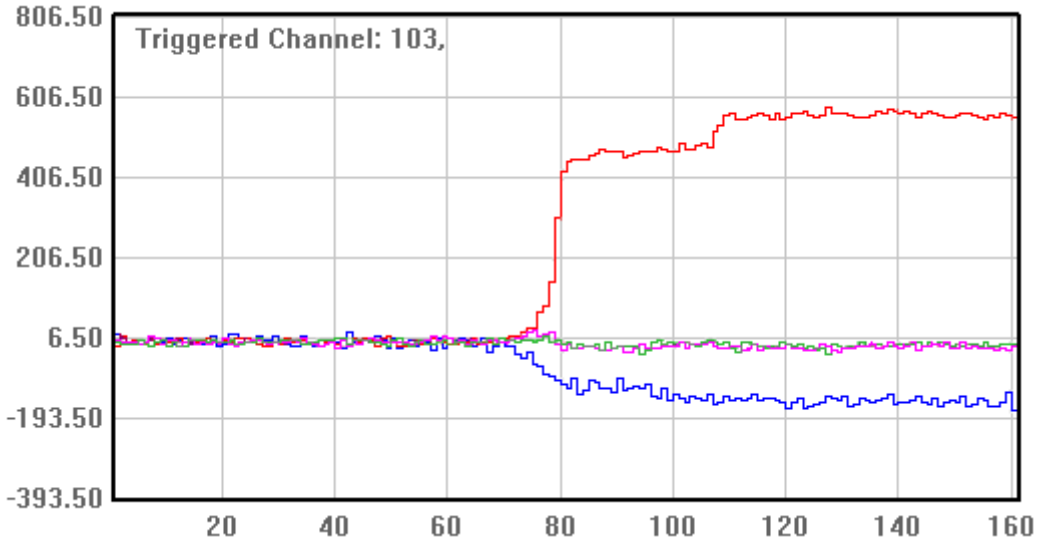
Next-Generation
Digital Polaris Detectors

From analogue to digital detectors



GM-I (Oslo) ASIC & Det. #4E-3





Advantages of digital detectors

(1) **Sub-pixel position resolution** (better γ-ray energy & imaging resolutions)
Δx & Δy reduced from 1.72 mm pixel pitch $\rightarrow$ 0.3 mm FWHM at 662 keV
(sub-pixel position resolution is inversely proportional to energy deposition)

(2) **Improved energy & position reconstruction using digital signal processing,** including on multiple-interaction events under the same anode pixel and significantly improved performance at higher gamma energies

(3) **More accurate event classification** (identifying photo-electric, Compton, pair production and charge particle interactions)

(4) **Lower power** (from ~3 mW/ch. on analogue ASIC to **1.65 mW/ch**.)

(5) **Universal ASIC** for **all room-temperature** semiconductor detectors
CdZnTe, HgI_2,TlBr,···

Acknowledgements/Deliverables

DOD DTRA (Award #: HDTRA1-12-C-0034)

Support development on CdZnTe detectors & ASICs + staff

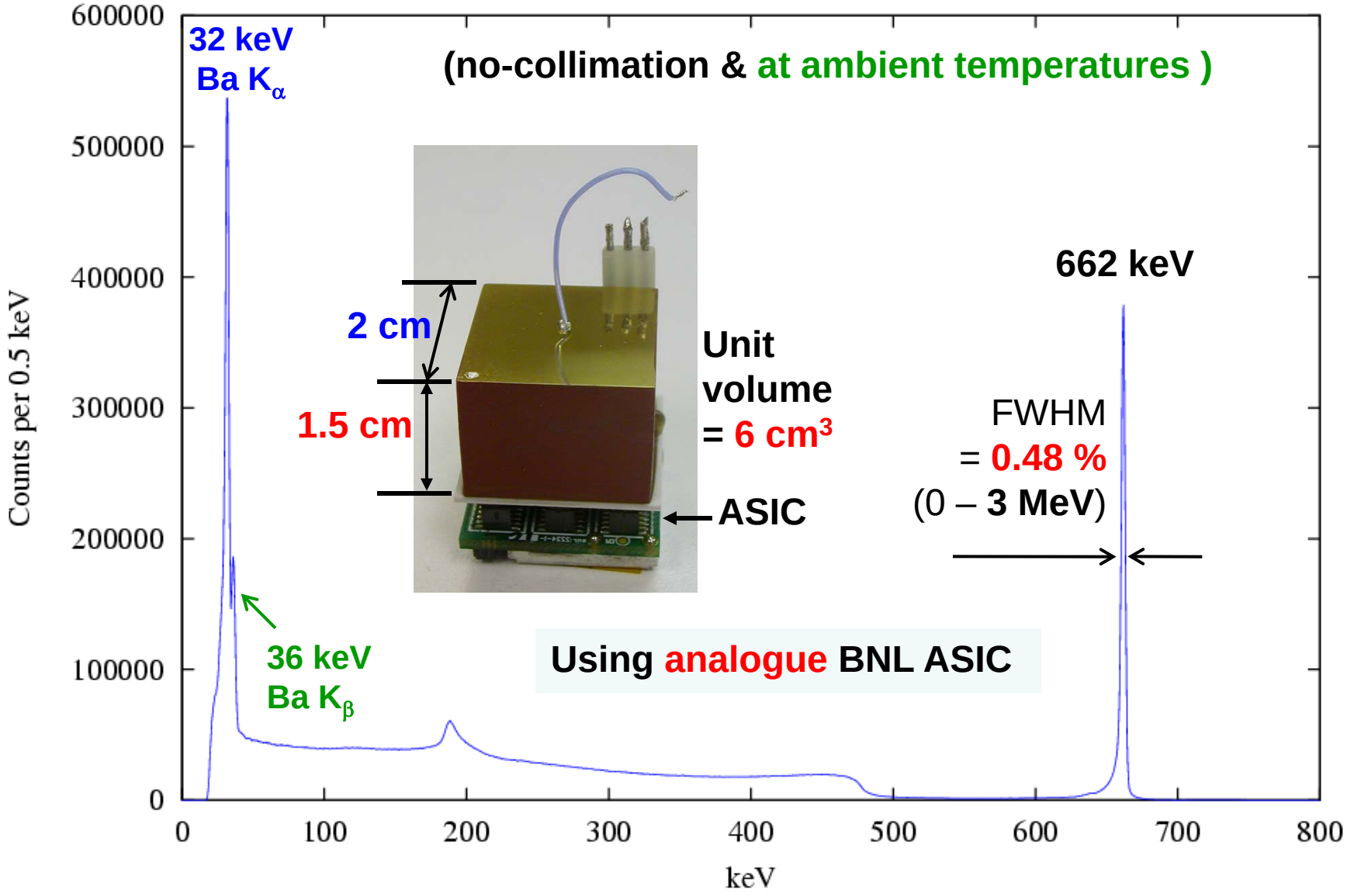
U.S. DOE NA-22

Support graduate students on **digital algorithm** development

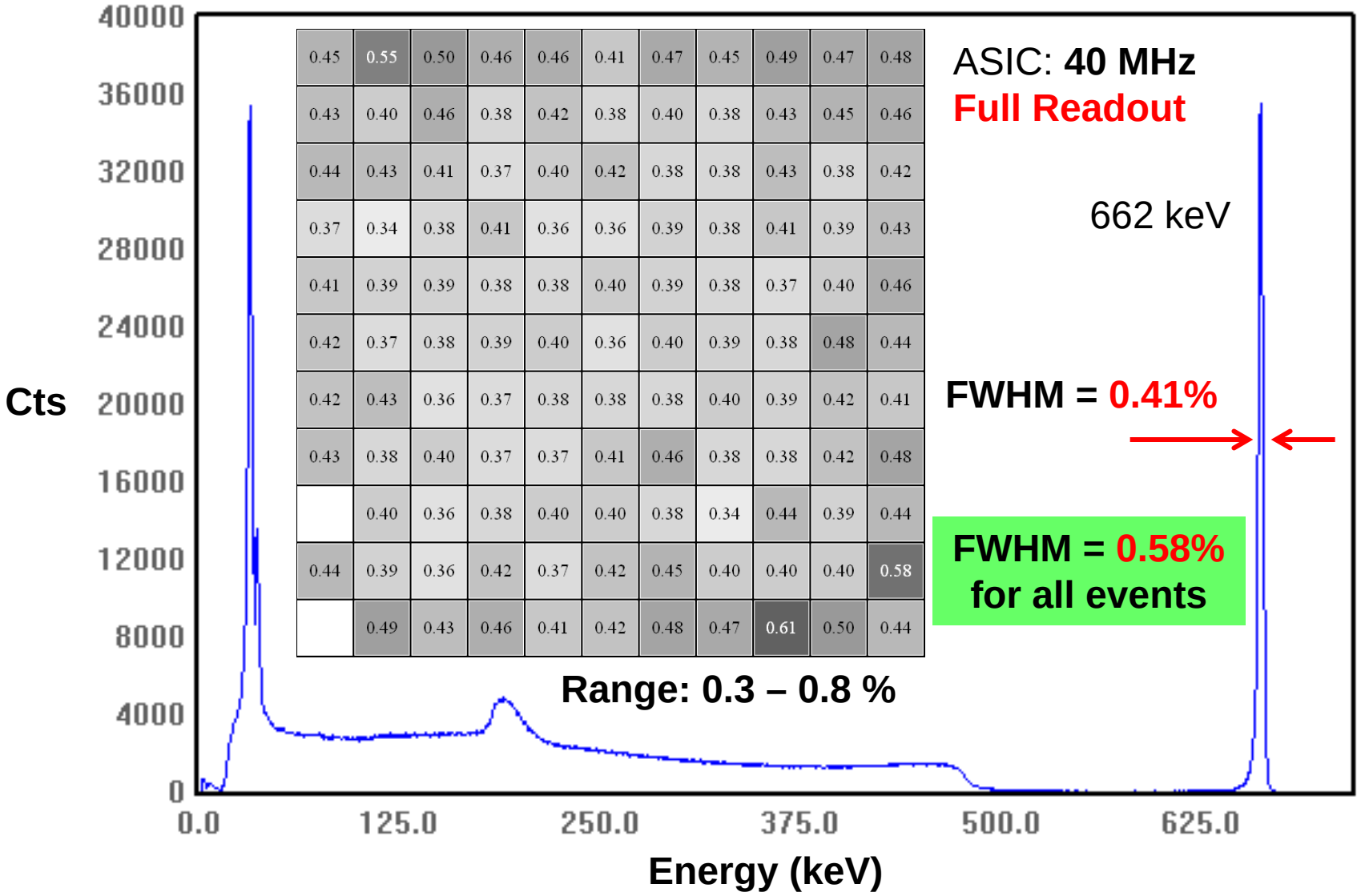
Impact of improved electronic noise

2.5 keV → 2.0 keV FWHM

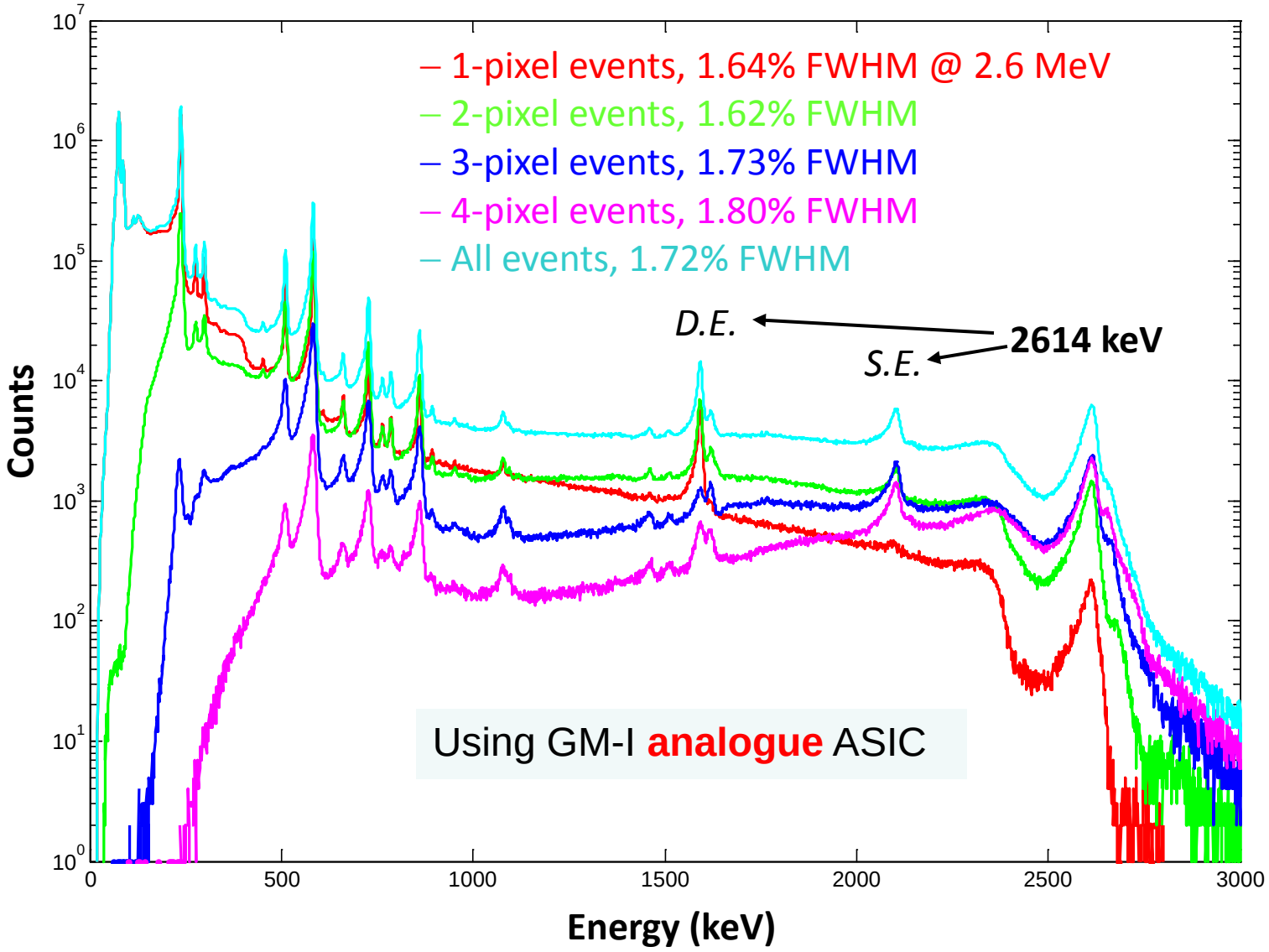
Close to HPGe resolution is possible
(1-pixel ^{137}Cs spectrum of CZT #4E-1 & BNL ASIC)



Closer to HPGe resolution
(1-pixel ^{137}Cs spectrum of CZT #4E-1 & digital ASIC)



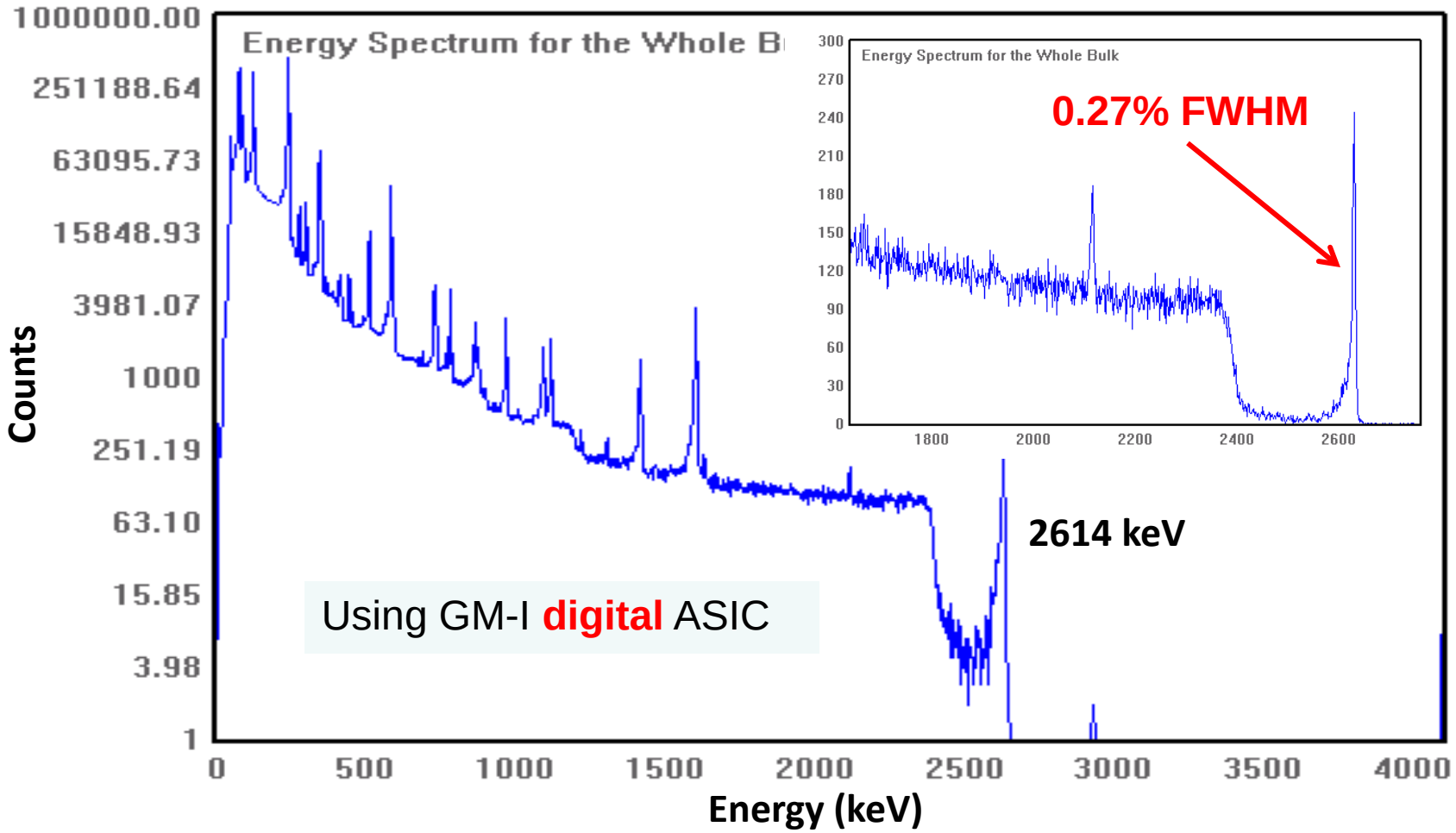
^{228}Th Energy Spectra Polaris-2



Single-Pixel Energy Spectrum of ^{228}Th & ^{135}Eu on Detector #4E-1

– 1-pixel events, **0.27%** FWHM @ 2.6 MeV

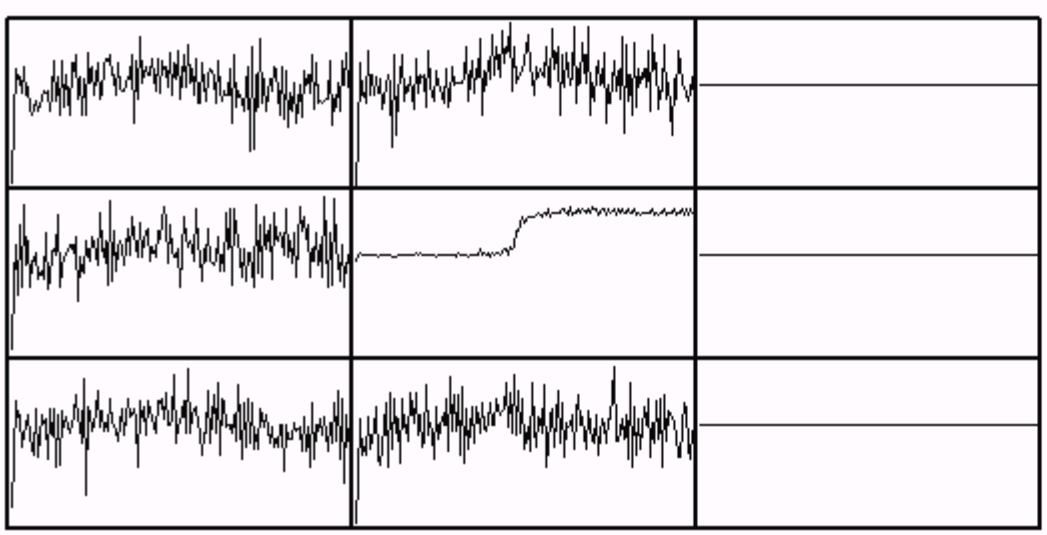
– 2-pixel events, **0.49%** FWHM; 1 – 4 pixel events, **0.74%** FWHM

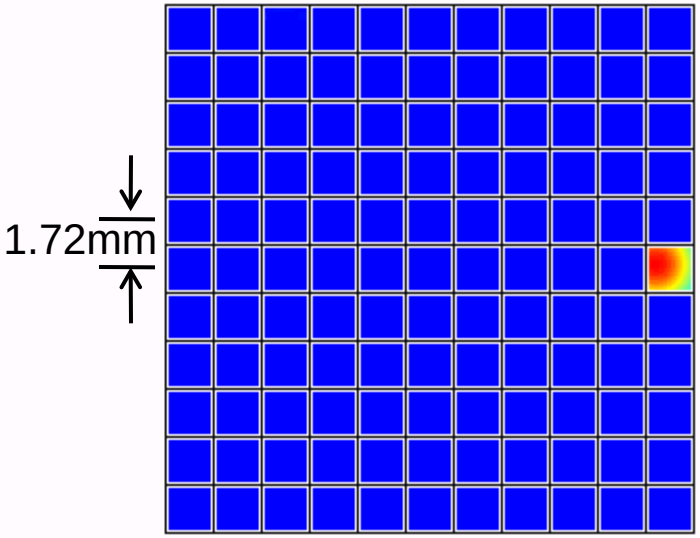


Impact of sub-pixel position resolution

Real-Time Sub-Pixel Position Sensing

GM-I **digital** ASIC & CdZnTe detector #4E-3

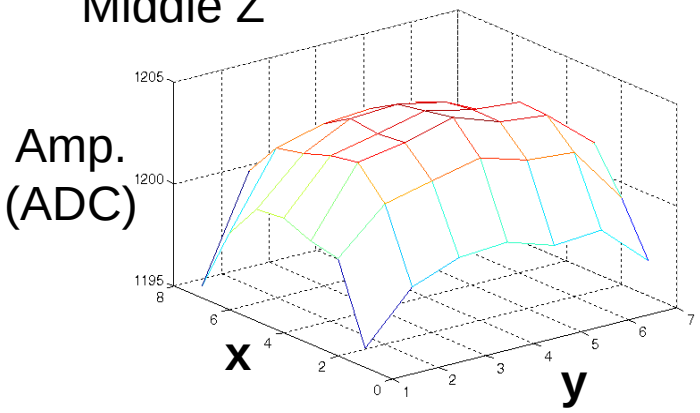




662 keV Signal Amplitude versus Sub-Pixel Position

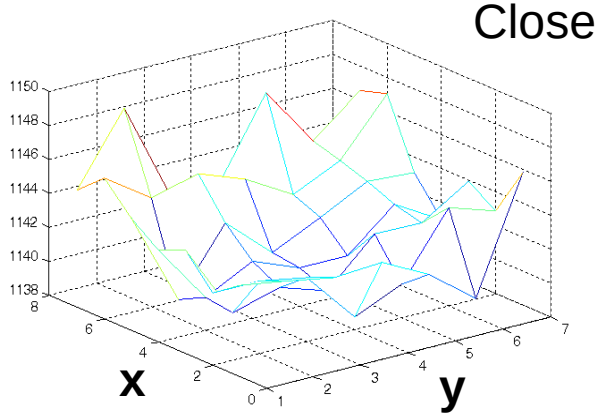
Depth = 20 (total 40 depth)

Middle Z



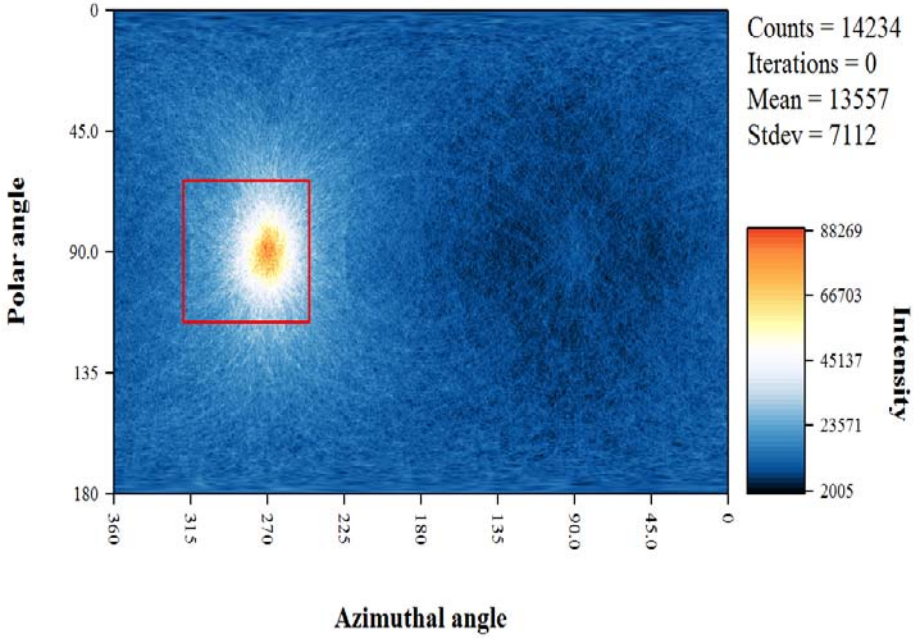
Depth = 6 (total 40 depth)

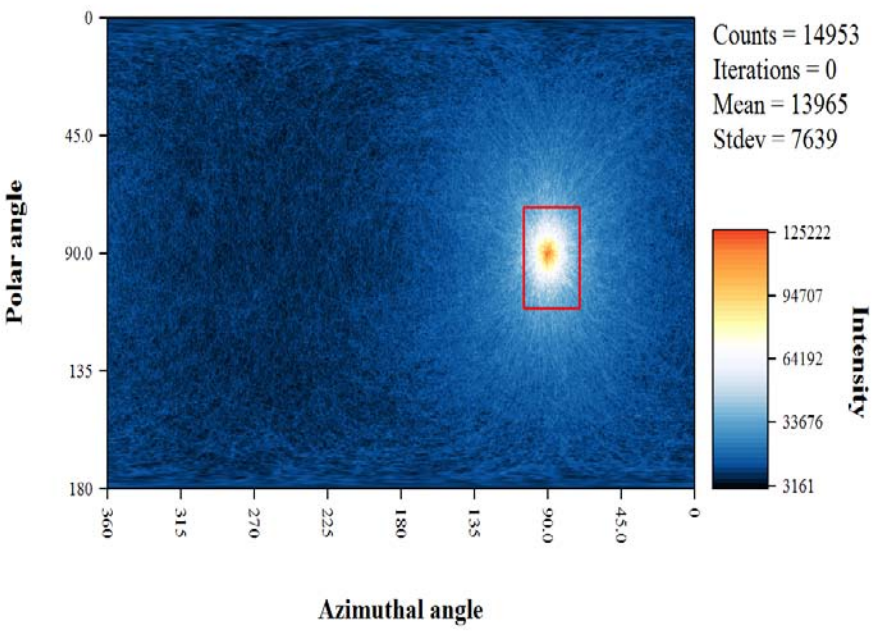
Close to anode



Improved Simple Back-Projection Gamma-Ray Imaging

^{60}Co – 1.3 MeV





Without sub-pixel position sensing

With sub-pixel position sensing

High-Flux Experiment Results

Photopeak shift and spectral degradation vs. flux