Pixel Array Germanium (PAGe) Detectors for Nuclear Physics

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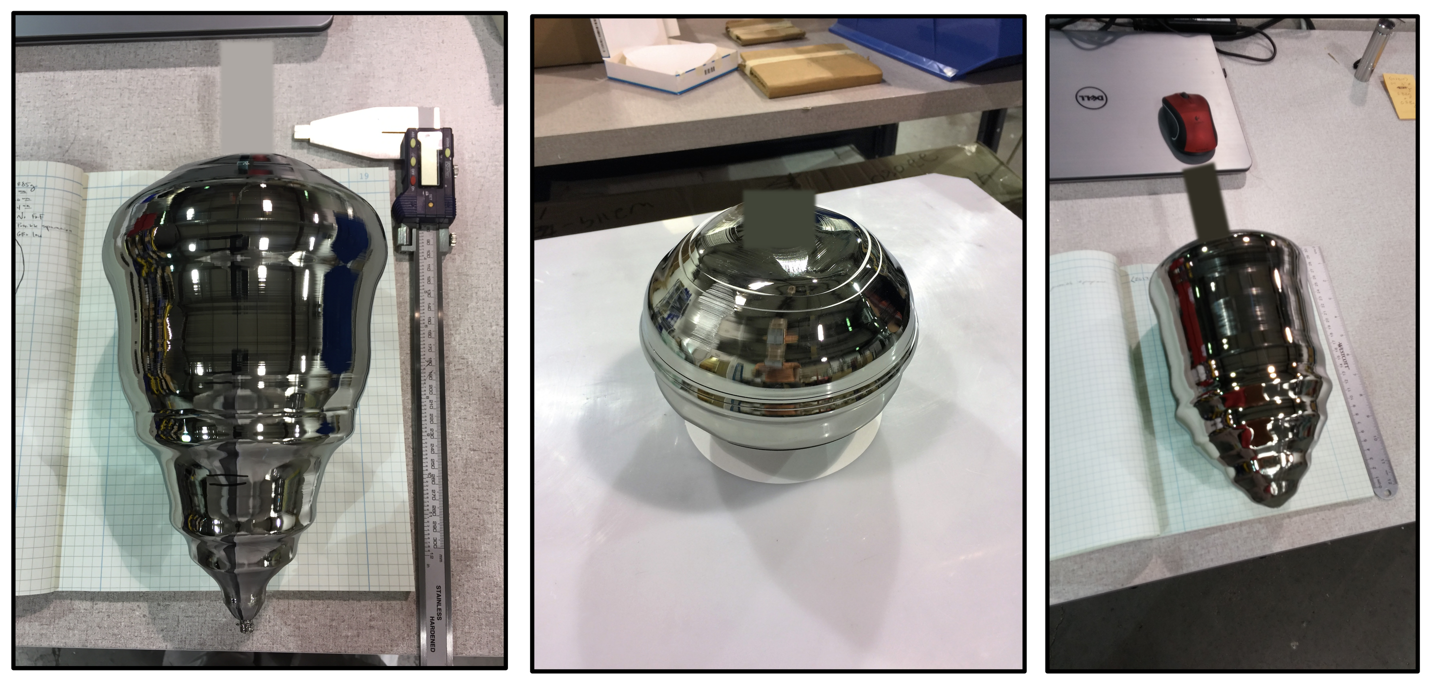
PHDS Gamma Ray Imaging Detectors

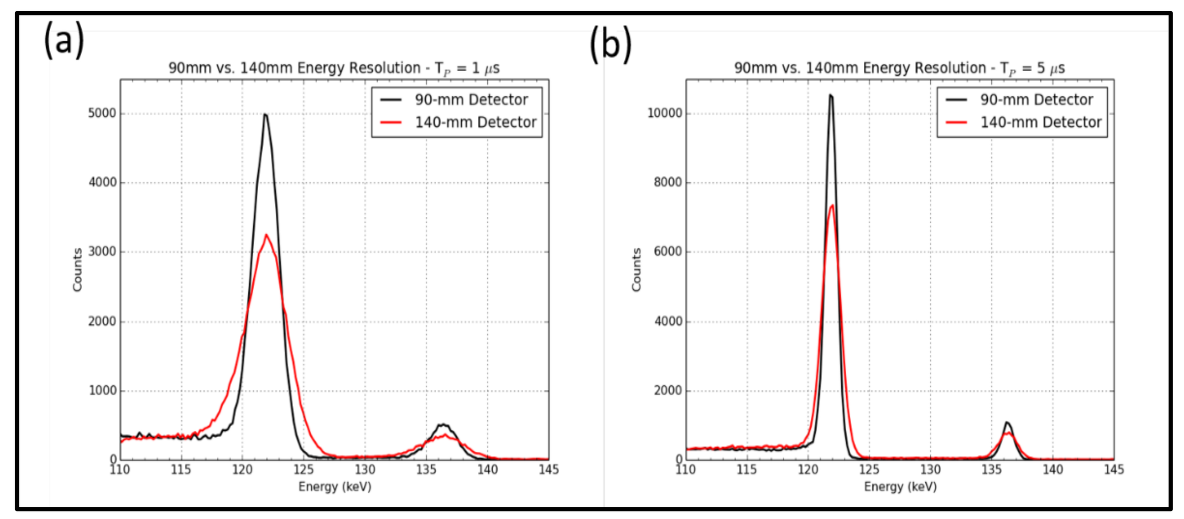
Why Pixel Array Germanium?

- PHDS growing ever-larger germanium crystals
- Investigating best strategy for fabricating position-sensitive gamma-ray detectors with excellent spectral and spatial resolution
- PHDS traditionally focused on orthogonal-strip design, but this approach has limitations



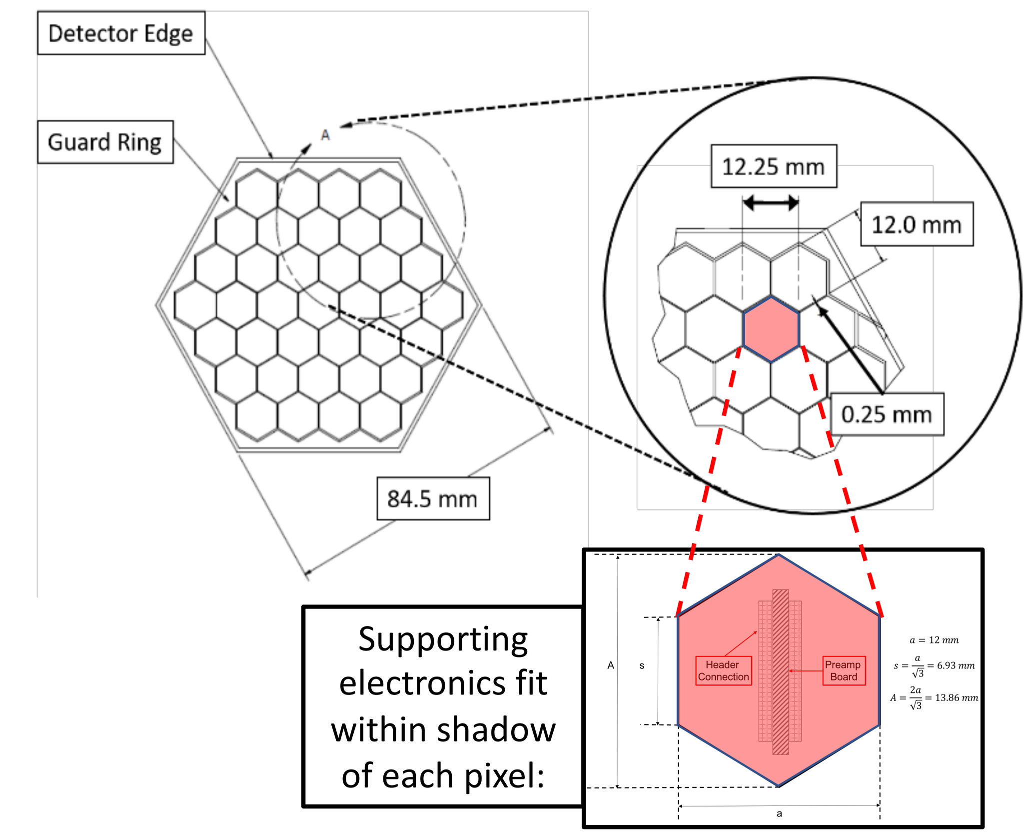
Orthogonal Strip Limitations

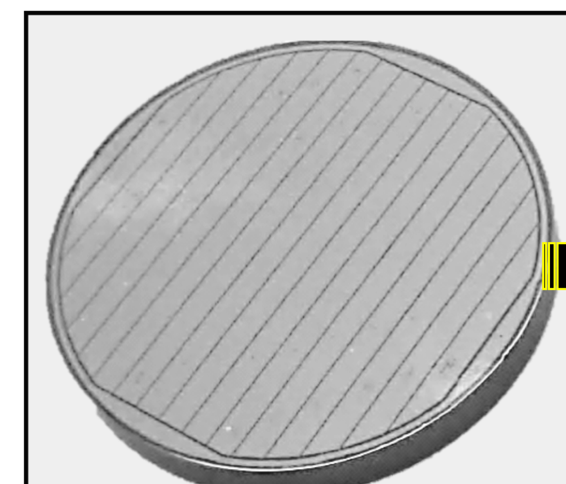
- Best obtainable high-frequency (series) noise when capacitance of detector segment is less than that of JFET (BF862 10 pF JFET)
- Strips are necessarily longer (higher input capacitance) as detector area grows:
  - 90-mm GeGI strips: 5-mm wide = 45 pF
  - 140-mm 16-channel strips: 7.75-mm wide = 76 pF
- Can make strips more narrow, but this solution is not readily scalable

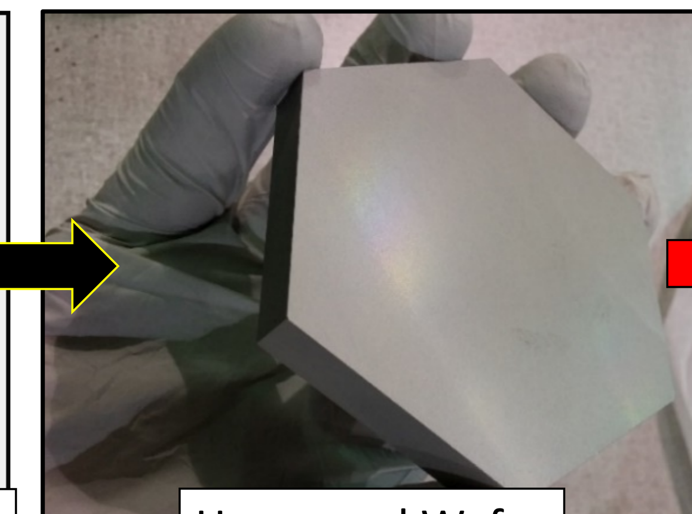


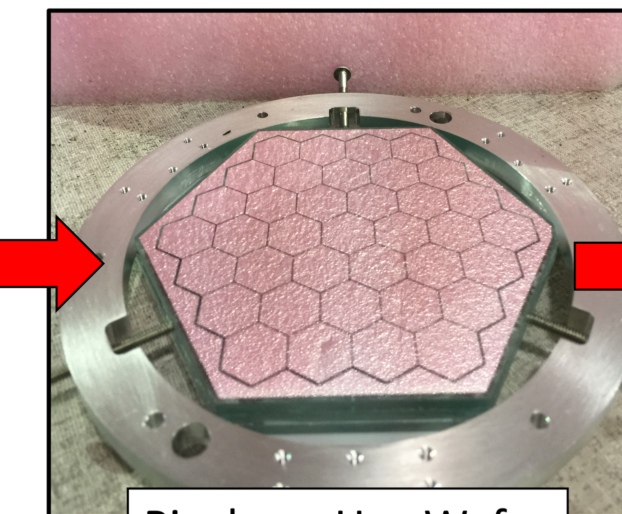
Pixel Approach Advantages

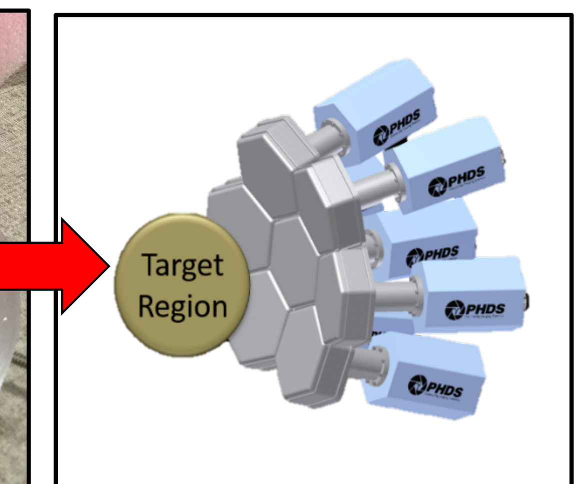
- Design pixel geometry for minimal series noise (~10 pF)
- Readily scalable: solution for 90-mm wafer same as for 140+ mm wafer (at the expense of more data processing channels)
- Count-rate capacity naturally improved
- Apply well-tested waveform decomposition algorithms for optimal spatial resolution
- Hexagonal design for improved solid angle coverage (packing fraction)




Orthogonal Strip Detector


Hexagonal Wafer


Pixels on Hex Wafer

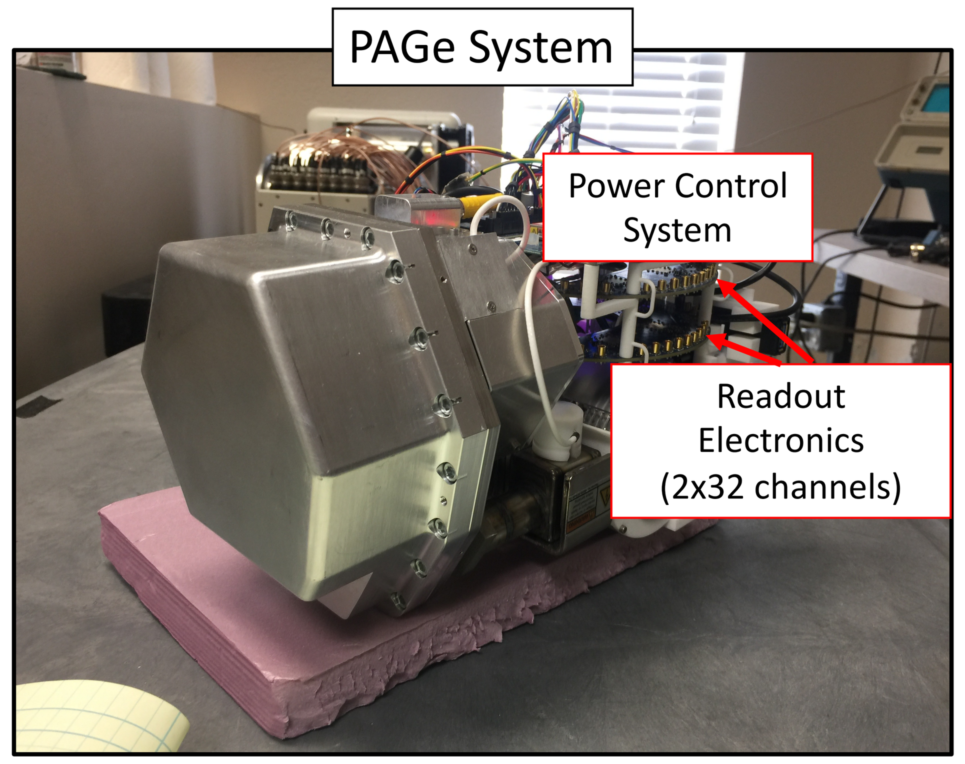


Hex Array Concept

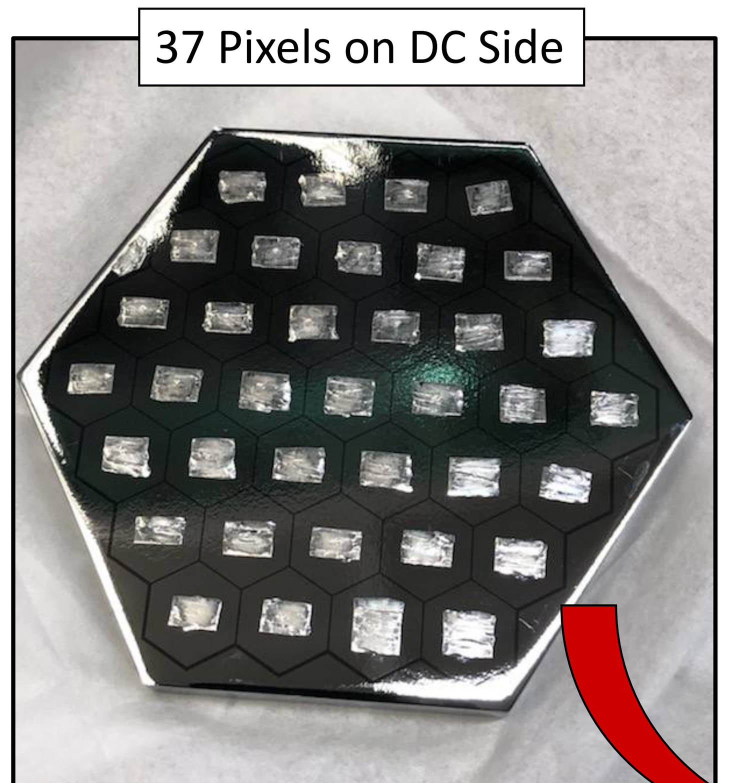
Prototype PAGe System

- Compact design to facilitate close packing in arrays of large germanium detectors
- New smaller preamplifier to fit in pixel shadow (shown above, in inset of pixel diagram)
- 37 DC pixels + DC guard ring + AC contact + AC guard ring = 40 channels in data processing chain
- Prototype leverages existing GeGI electronics and support supports up to 64 channels

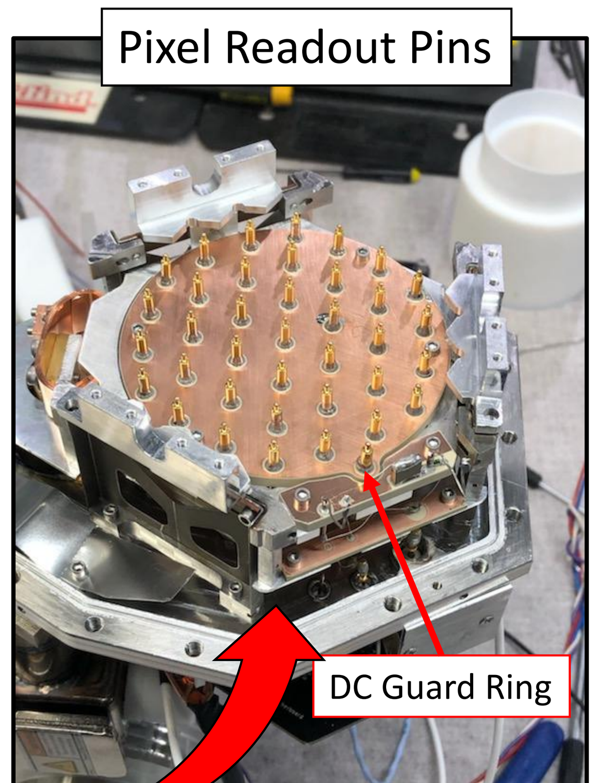
PAGe System



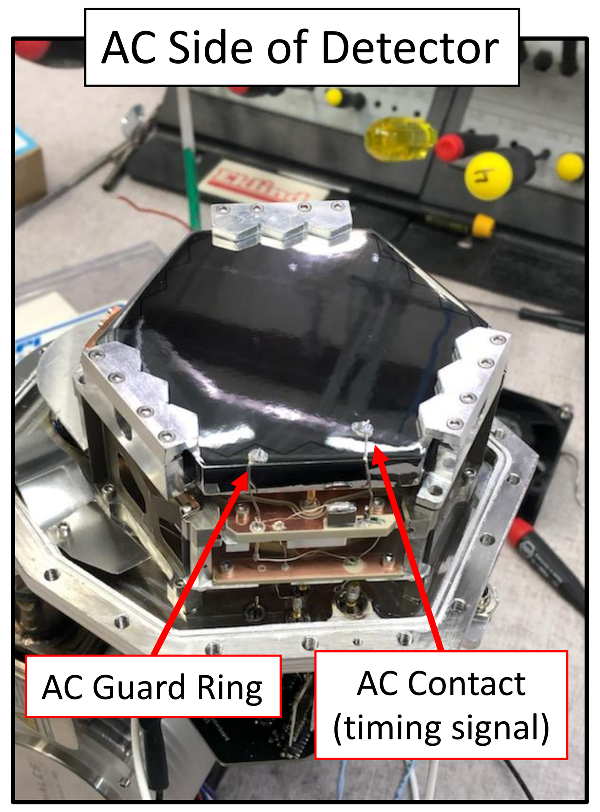
37 Pixels on DC Side



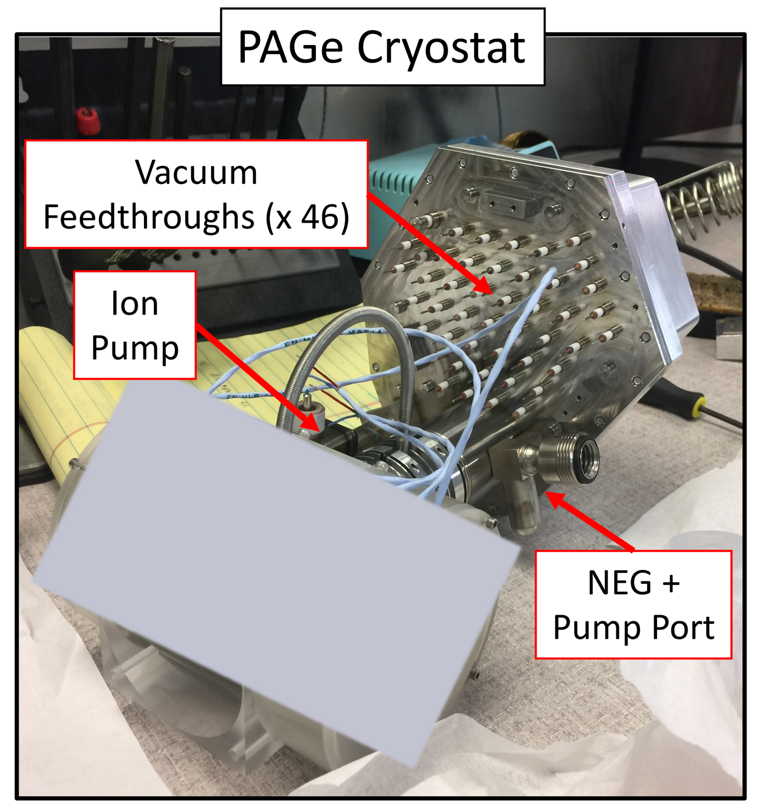
Pixel Readout Pins



AC Side of Detector

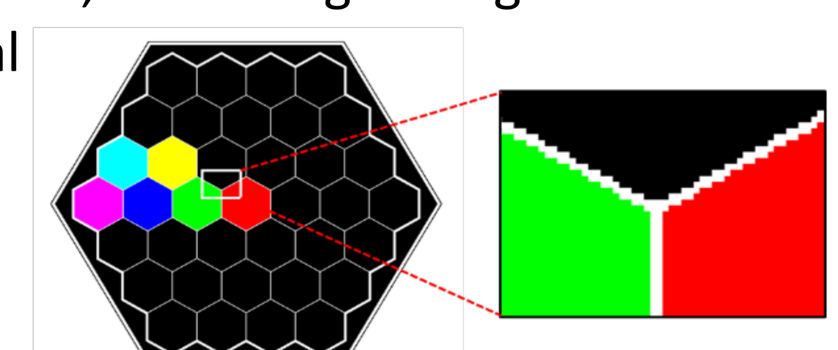


PAGe Cryostat

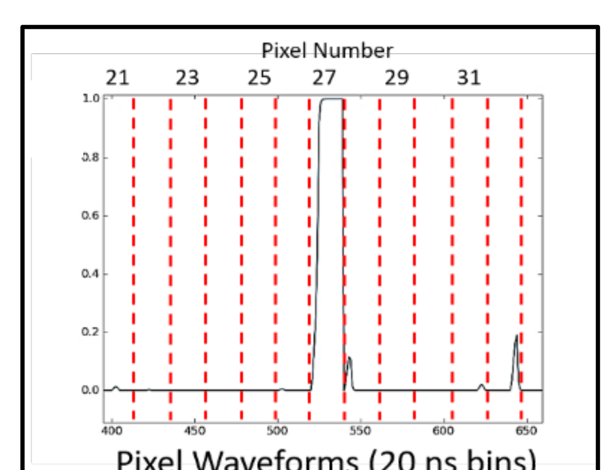


Waveform Decomposition

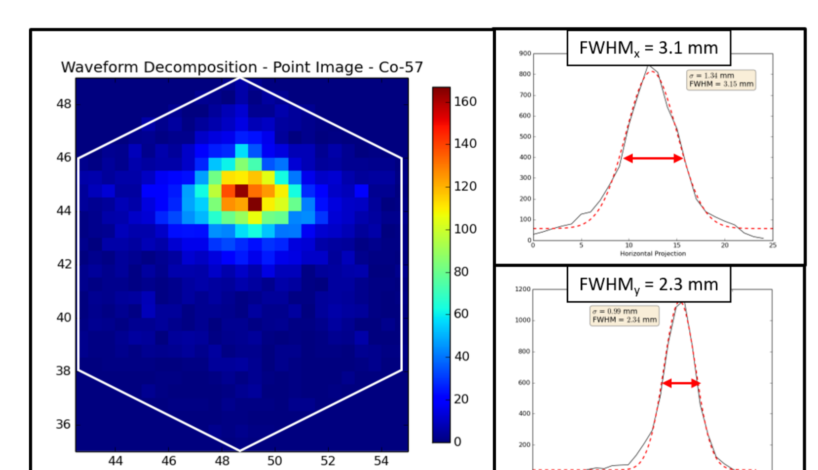
- Collaboration with David Radford at ORNL (leverage significant GRETINA development/experience)
- Uses a "signal basis" – a set of simulated signals
- Digital signal processing to determine the number, positions, and energies of gamma interactions in the crystal



(1) FIELDGEN-HEX: calculates weighting potential on 0.125-mm grid (3D)
(2) SIGGEN-HEX: generates basis signals to fit measured pixel signals (0.5-mm grid)
(3) Signal Decomposition: determine number, position, and energy of interaction(s)

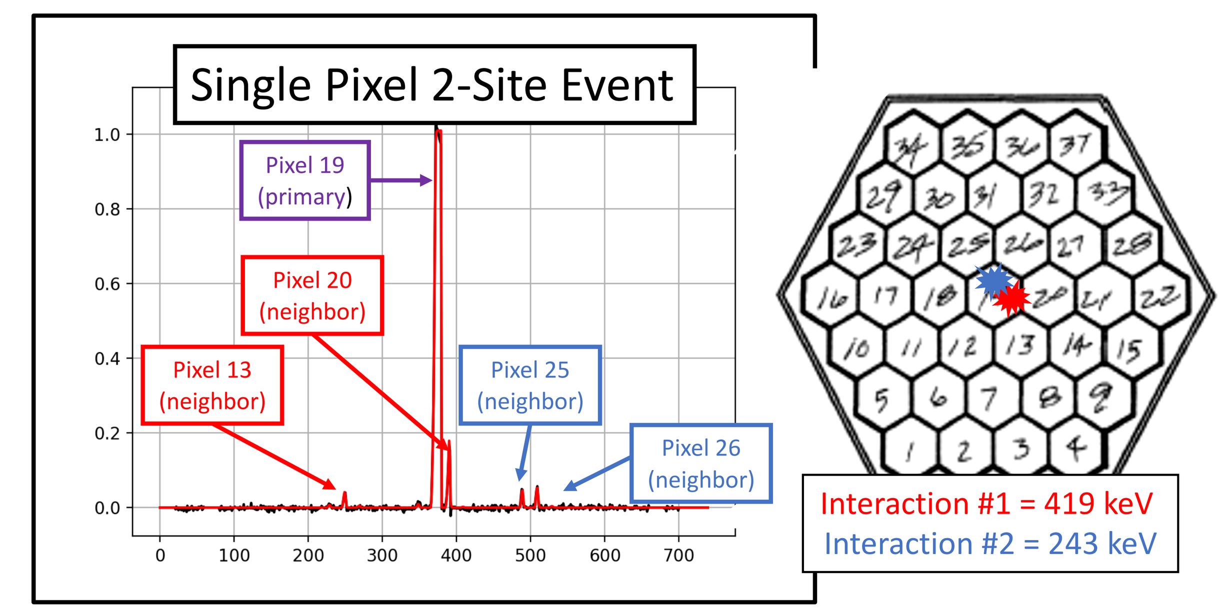


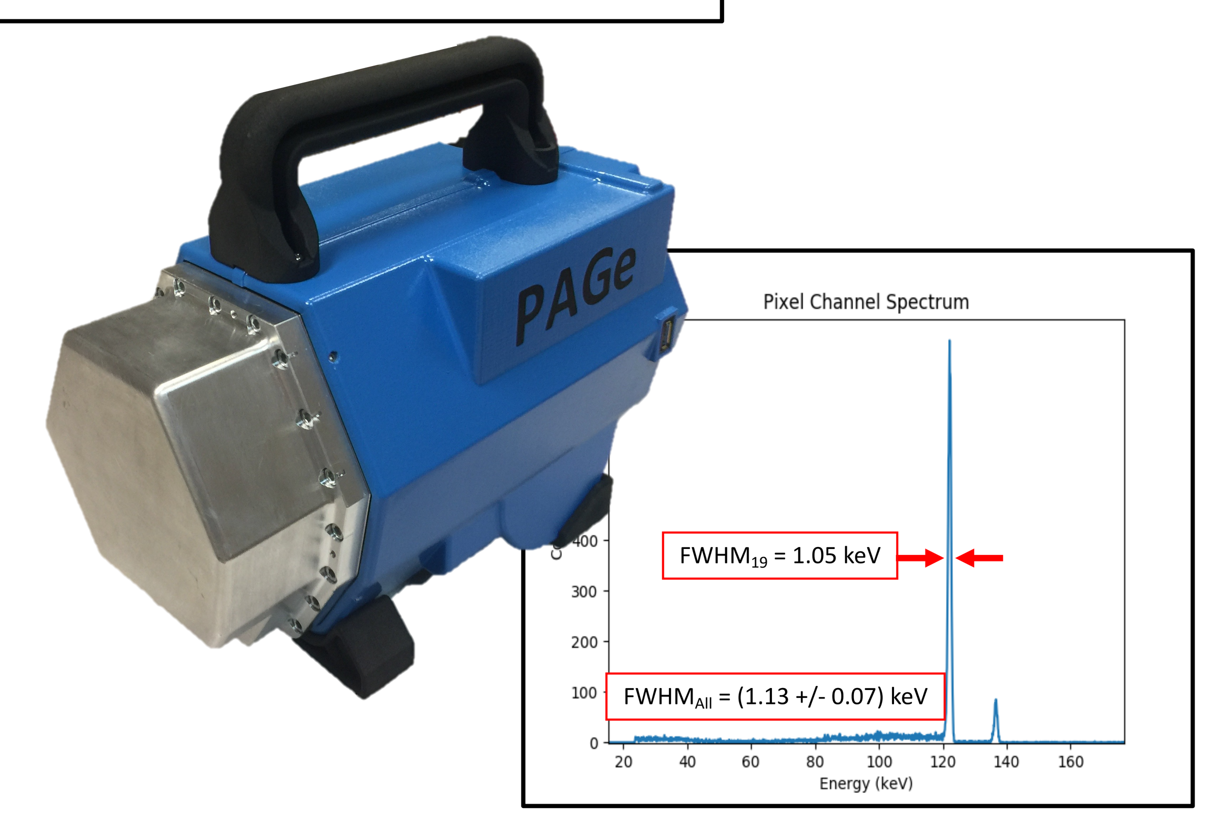
Serialized Data



Point-like Source Results

Prototype Performance





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