

Segmented Rectifying and Blocking Contacts on Germanium Planar Detectors

Principal Investigator: Ethan Hull, Ph.D.

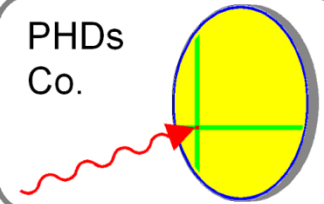
DE-SC0002477

Phase II: 8/15/2010-8/14/2013 (Including 1-yr NCE)

New surface contact technologies are being developed for the fabrication of segmented planar germanium detectors. Yttrium and other metal contacts have been determined to have the correct combination of physical properties to provide segmented low-noise germanium-detector contacts. Photolithographic fabrication techniques result in functional germanium detectors having small well-defined segmented contact features.

Collaboration with Kim Lister at UMass Lowell

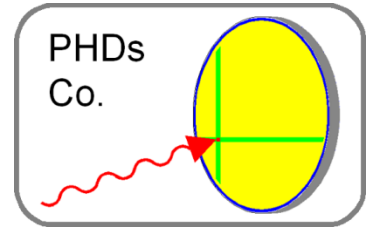
- Introduction to PHDs Co.
- Segmented rectifying and blocking germanium-detector contacts
 1. New contact technology
 2. Physically narrower inter-strip gaps
- Products – Nuclear Physics is the basis



PHDs Co. 3011 Amherst Rd, Knoxville, TN www.phdsco.com

- **Germanium Detector Systems**
 - **Concept**
 - **Germanium refinement and crystal growth**
 - **Mechanical-Vacuum-Cryogenic Engineering**
 - **Detector Fabrication**
 - **System Integration**
 - **Information output**
- **Est. Fall 2004, Ethan Hull CEO, Richard Pehl CFO**
- **9 FTEs + 2-3 Consultants – Technical Emphasis**
- **PHDs Co. sells germanium detector system products**
 - **Nuclear Physics - NPX-M**
 - **Security Applications - GeGI and SPG**
 - **Nuclear Medicine - MIX**





PHDs Co.
10,000 ft² Facility
Knoxville, TN

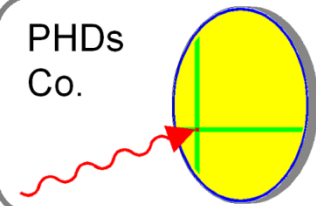


Technical area (~ 8000 ft²)



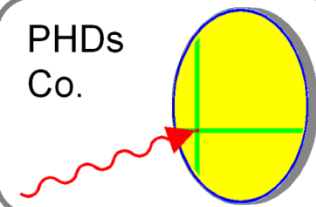
Office area (~ 2000 ft²)

PHDs
Co.

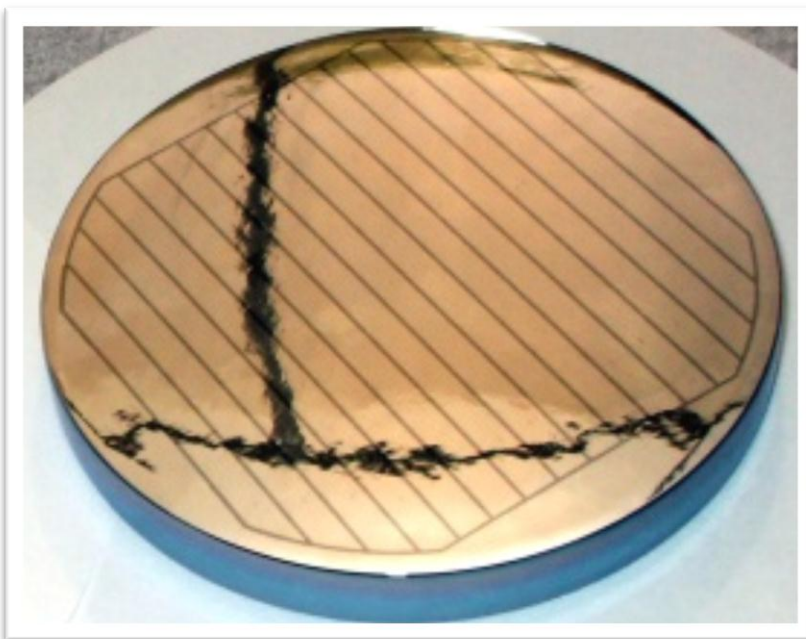


Germanium detector fabrication facility

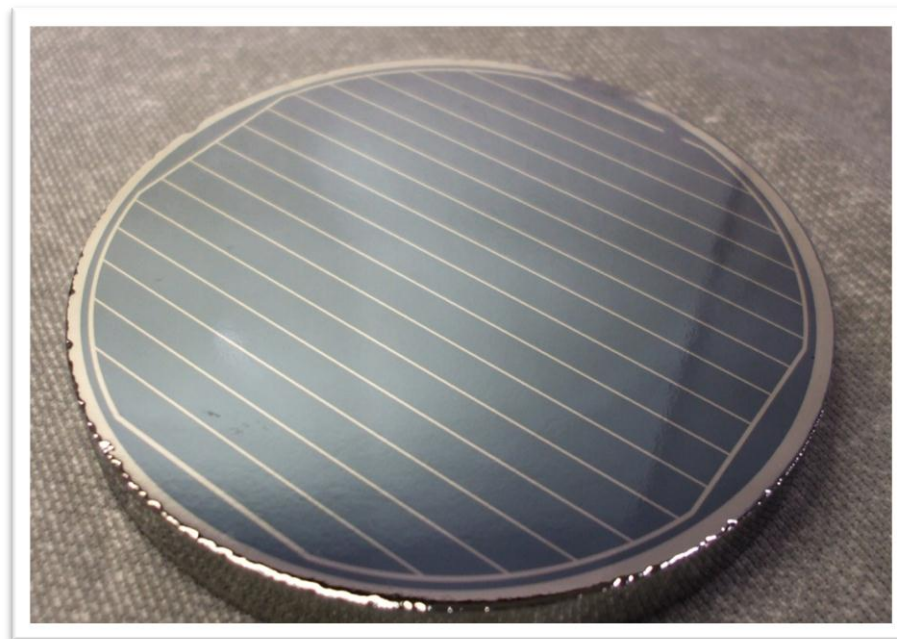




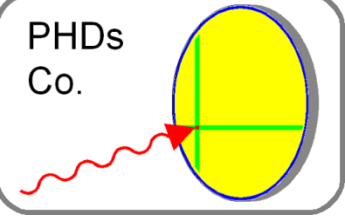
- Segmented rectifying and blocking germanium-detector contacts
 - New contact technology – Yttrium metal
 - Physically narrower inter-strip gaps



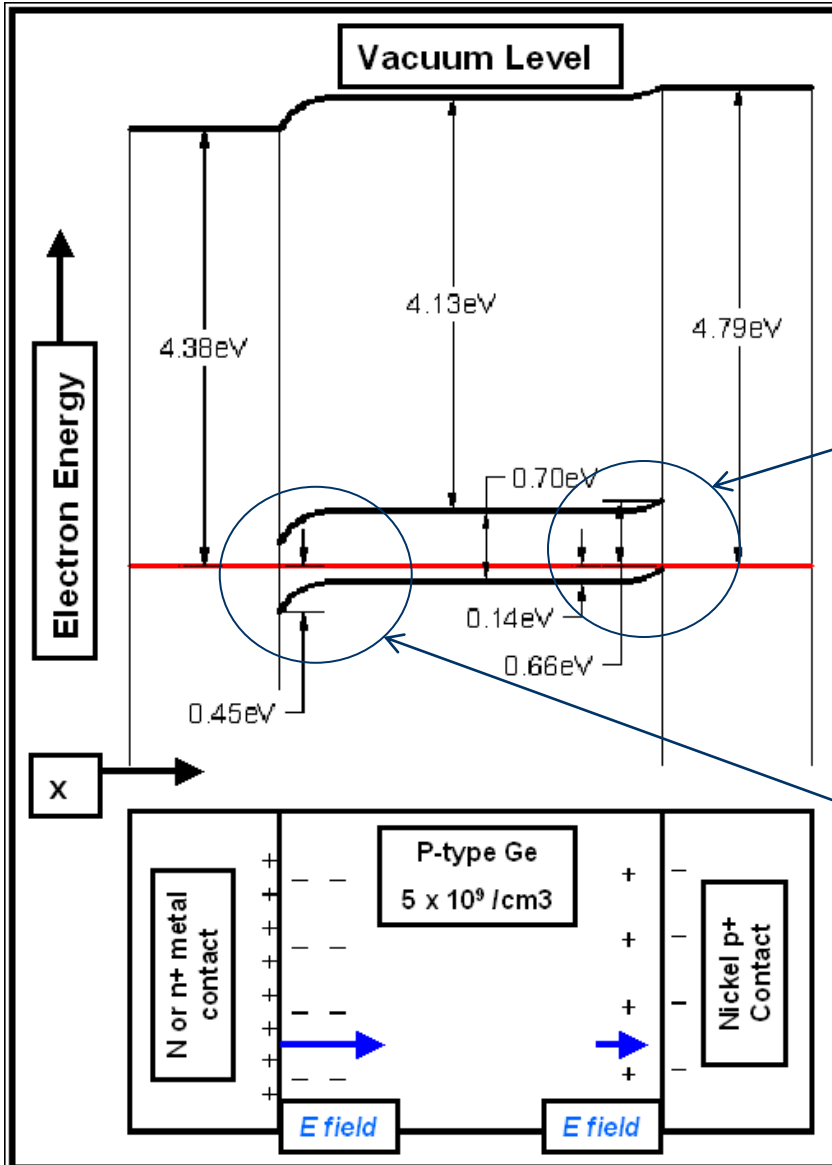
Amorphous-germanium
contact 500 μm gaps



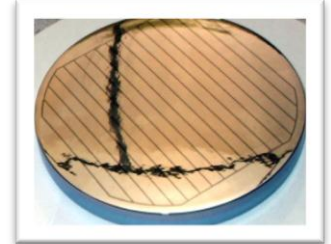
Yttrium contact 250 μm gaps



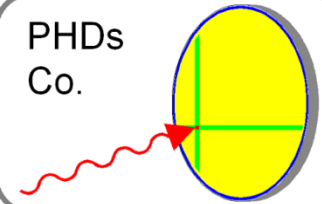
• New n+ (hole barrier) contact technology – Yttrium metal



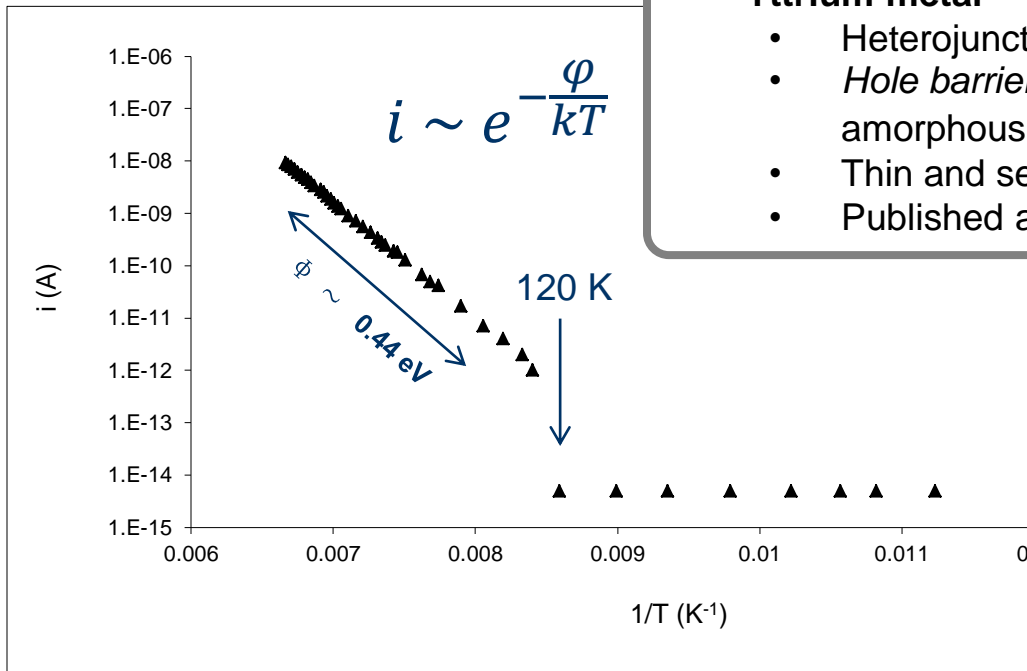
Historic dilemma: The surface (interface states) of crystalline HPGe is p type. Most materials form an electron barrier. Damage is p-type.



Lithium thermal diffusion ($\sim 500+ \mu\text{m}$) forms a rugged hole-barrier contact for 99% of Ge detectors. Thick, cannot be segmented easily. Amorphous-germanium and **Yttrium** metal form this type of contact.



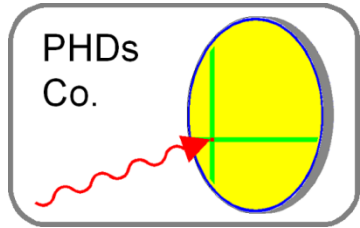
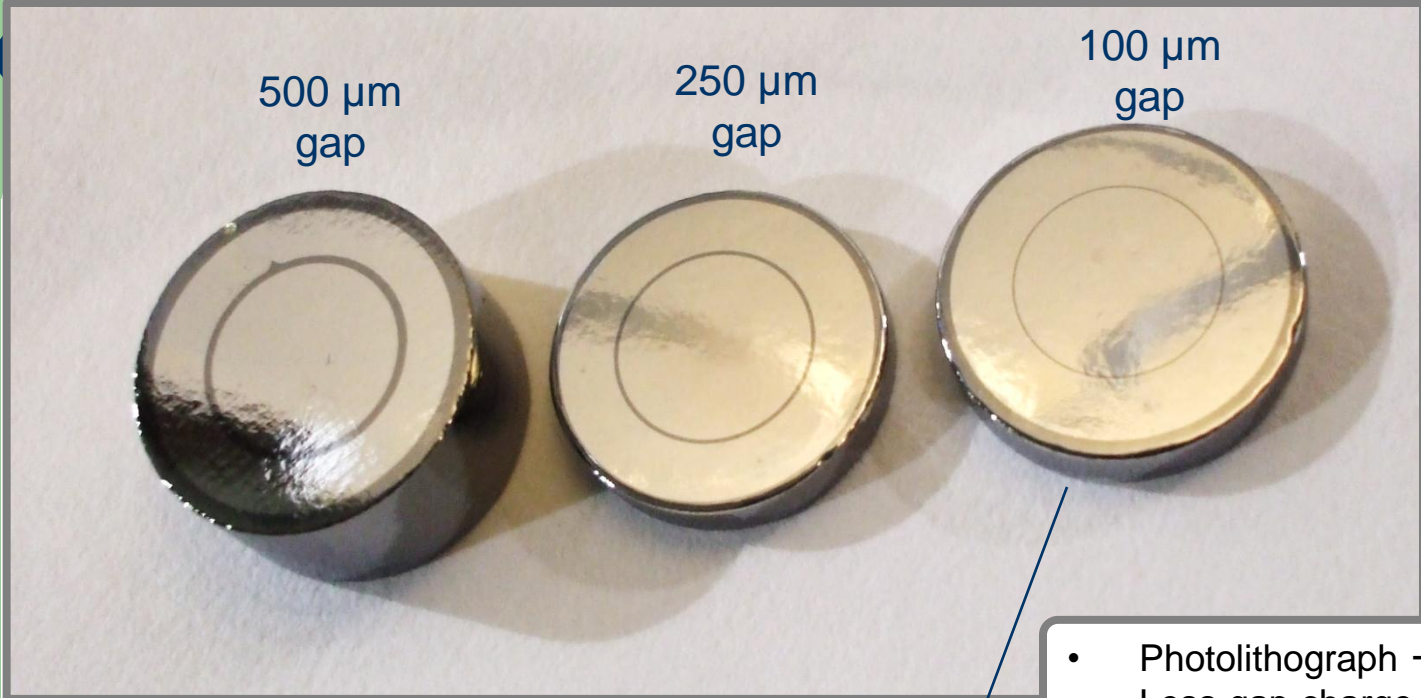
• **New n+ (hole barrier) contact technology – Yttrium metal**



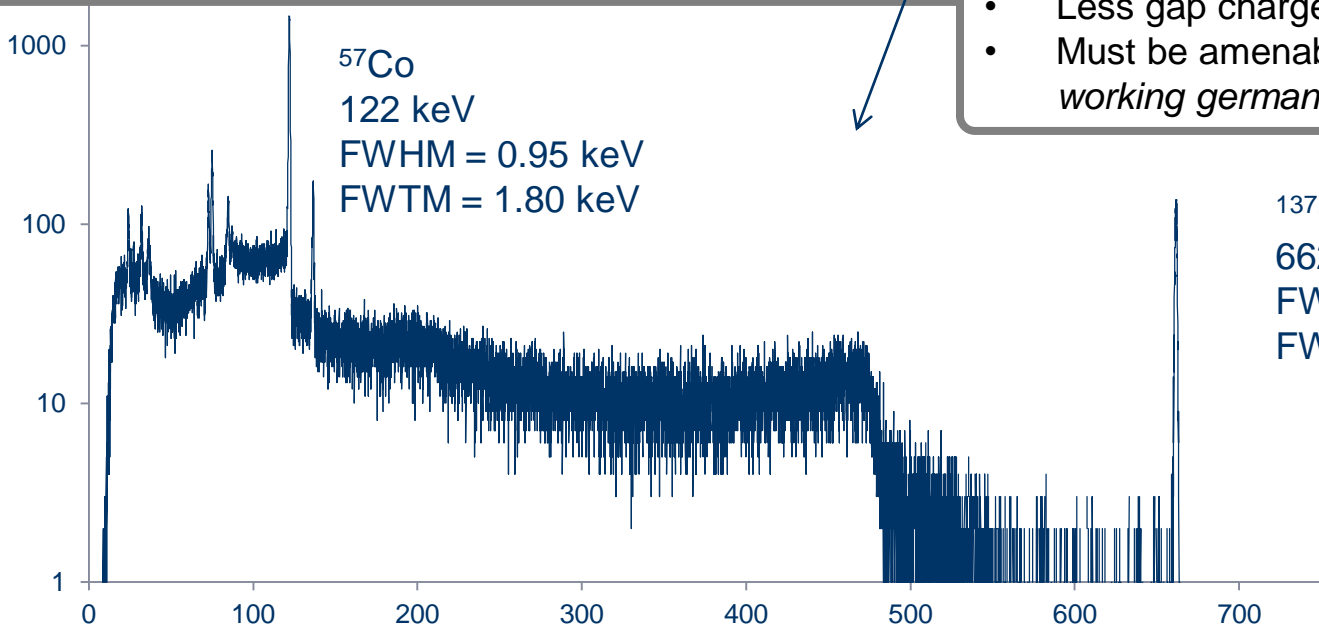
• **Yttrium metal**

- Heterojunction, not Schottky barrier
- *Hole barrier* height $\phi \sim 0.4 - 0.6 \text{ eV}$ – higher than amorphous germanium *but variable -- HJ*
- Thin and segmented with **photolithography**
- Published and Patent Pending



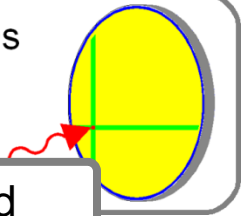


- Photolithograph \rightarrow Narrower gaps
- Less gap charge-collection problems
- Must be amenable to fabricating a *working germanium detector*

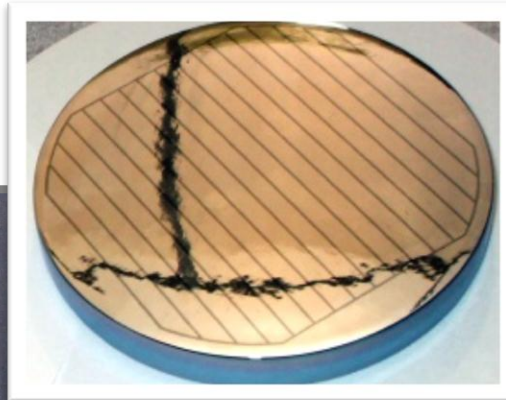


- Implications of narrower gaps for strip detectors

PHDs
Co.



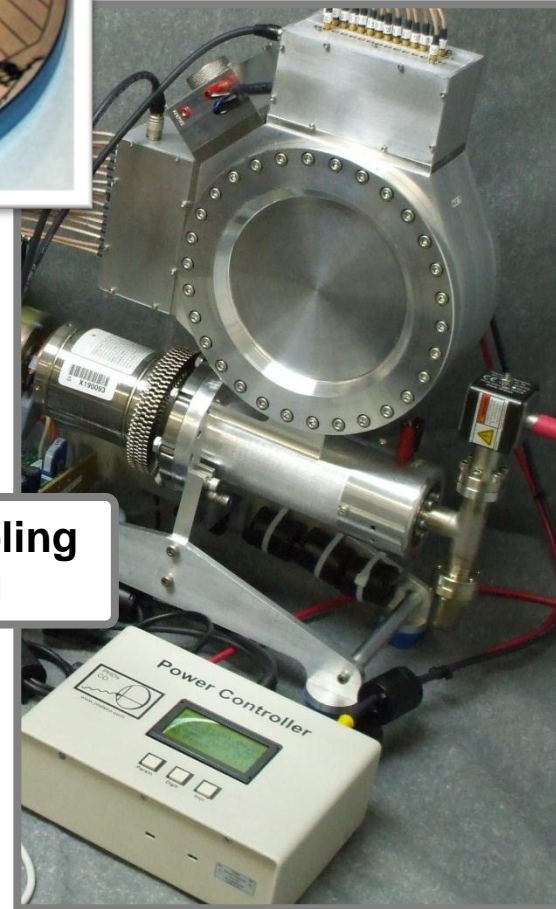
LN₂ Cooled
NPX Systems



Mechanically Cooled
NPX-M Systems

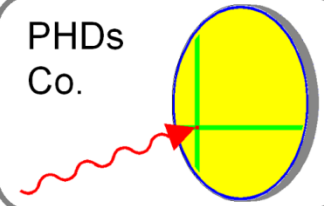


Significant enabling
leap forward

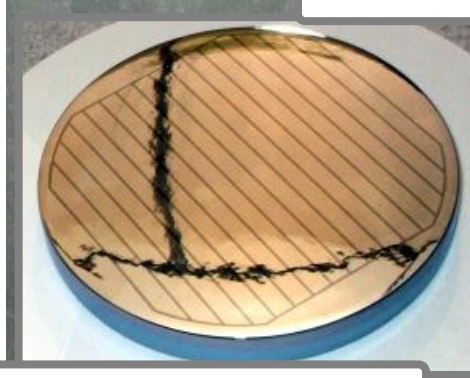


Implications of narrower gaps for strip detectors

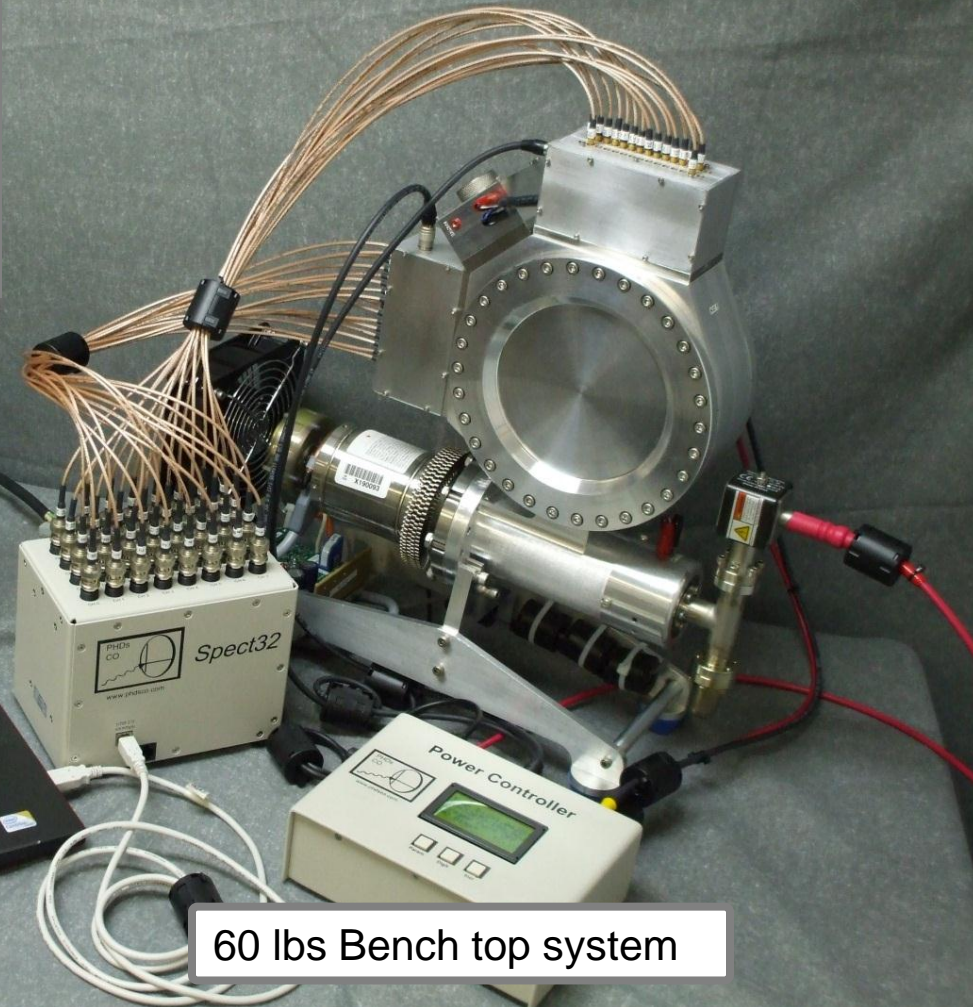
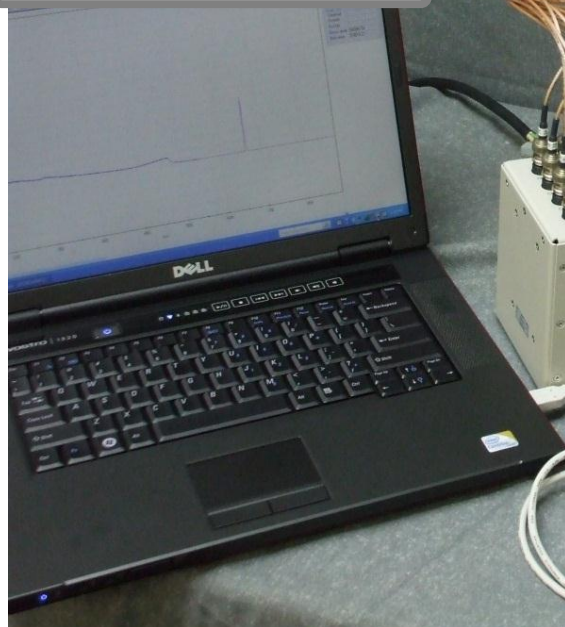
PHDs
Co.



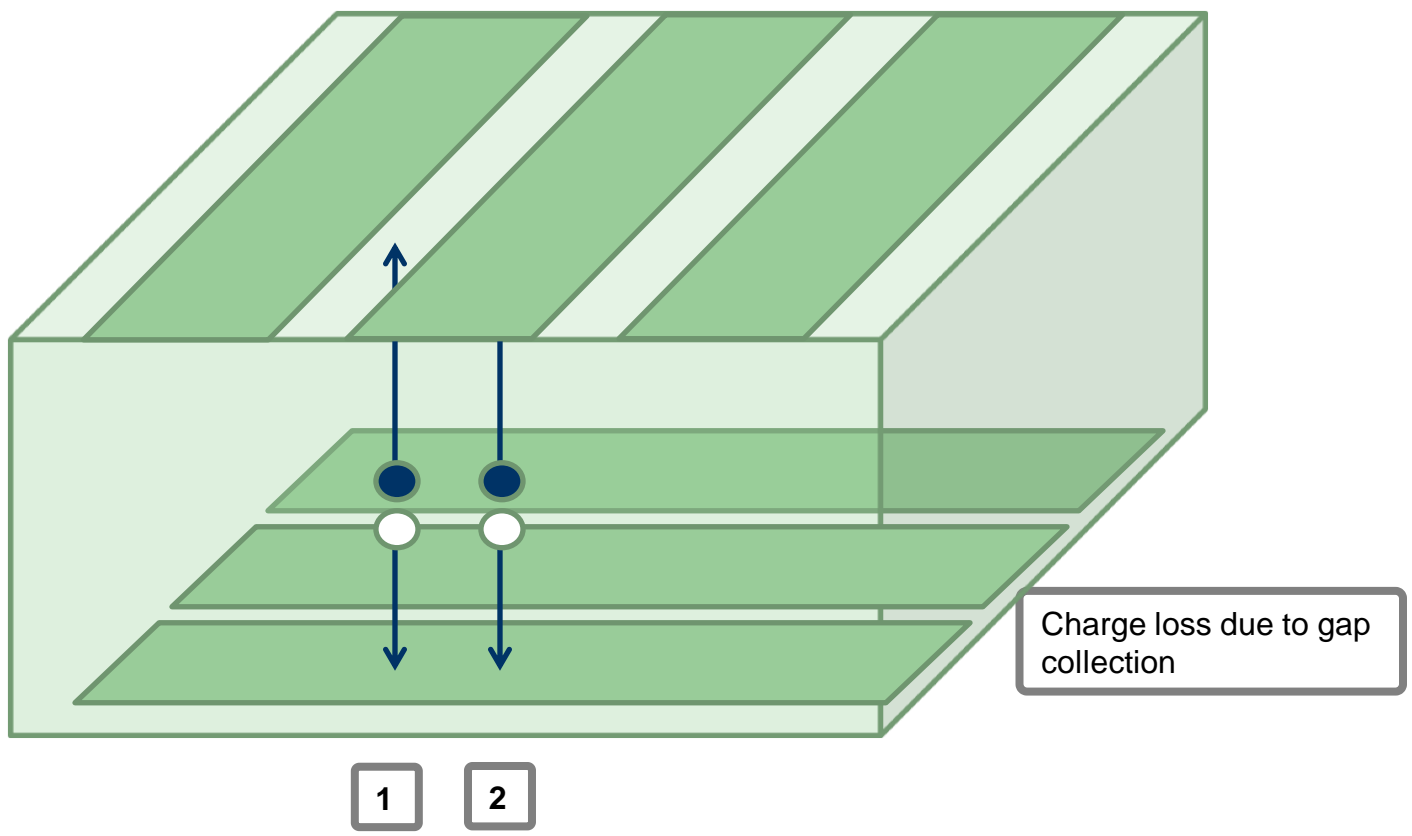
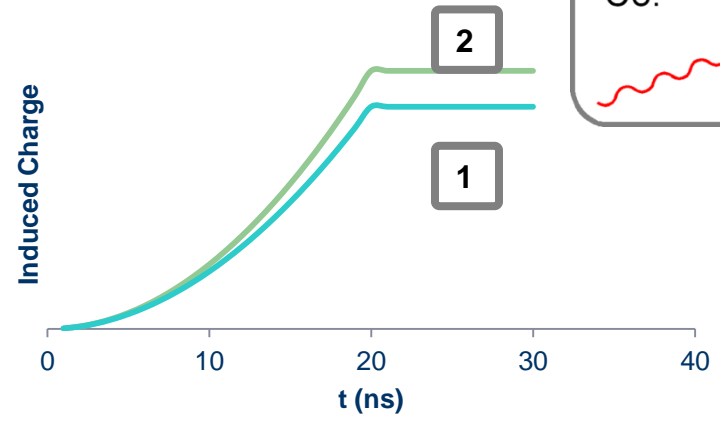
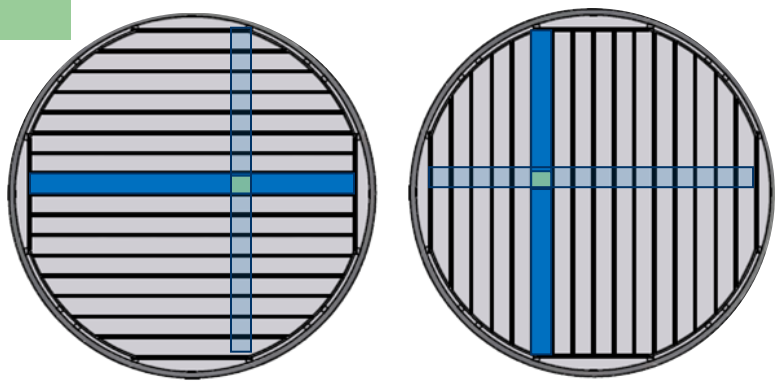
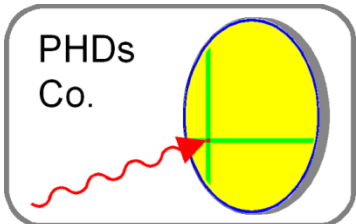
Complete NPX-M Germanium Strip Detector Systems for Nuclear Physics require only 120 VAC

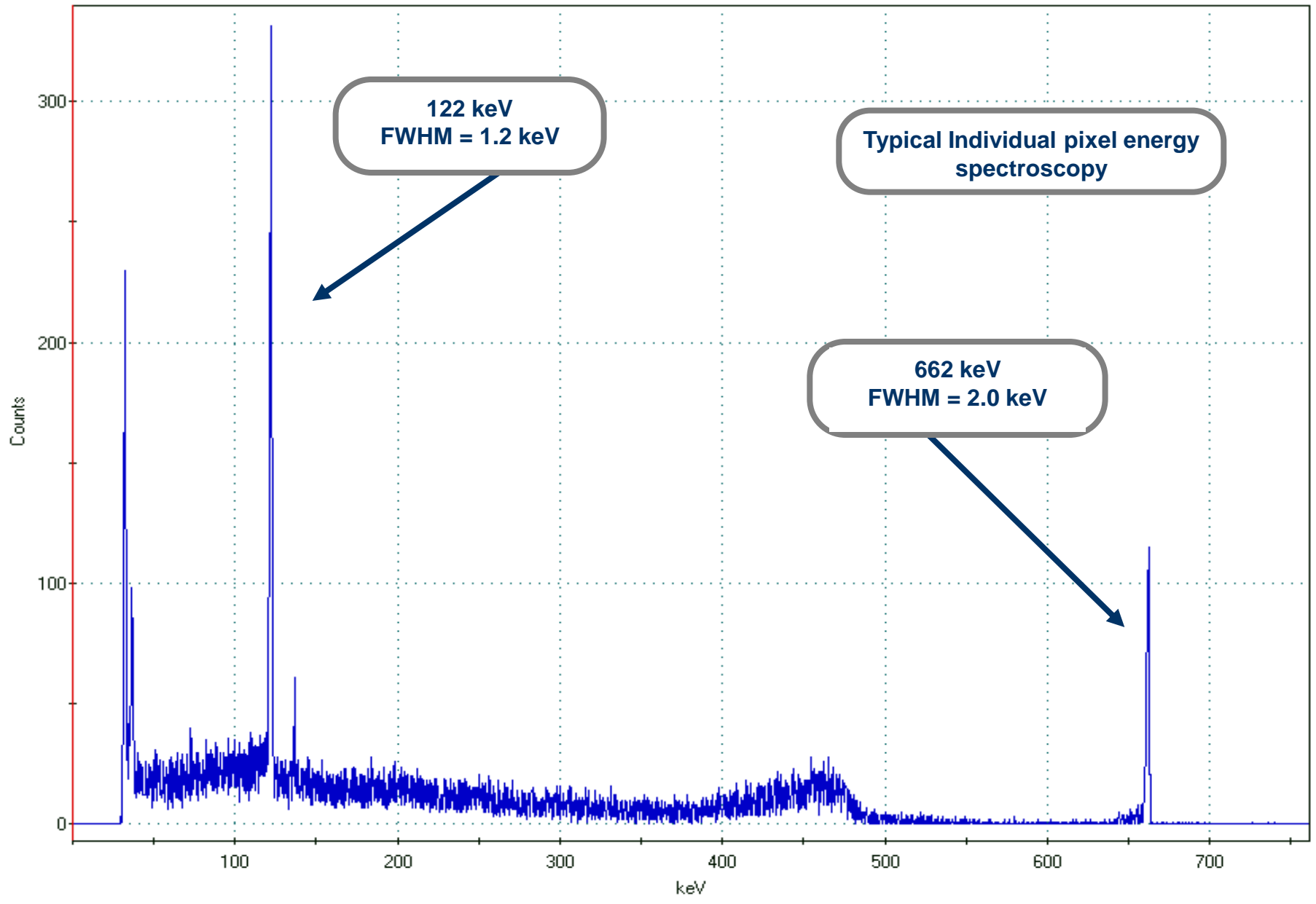


Amorphous-germanium
contact 500 μm gaps



60 lbs Bench top system

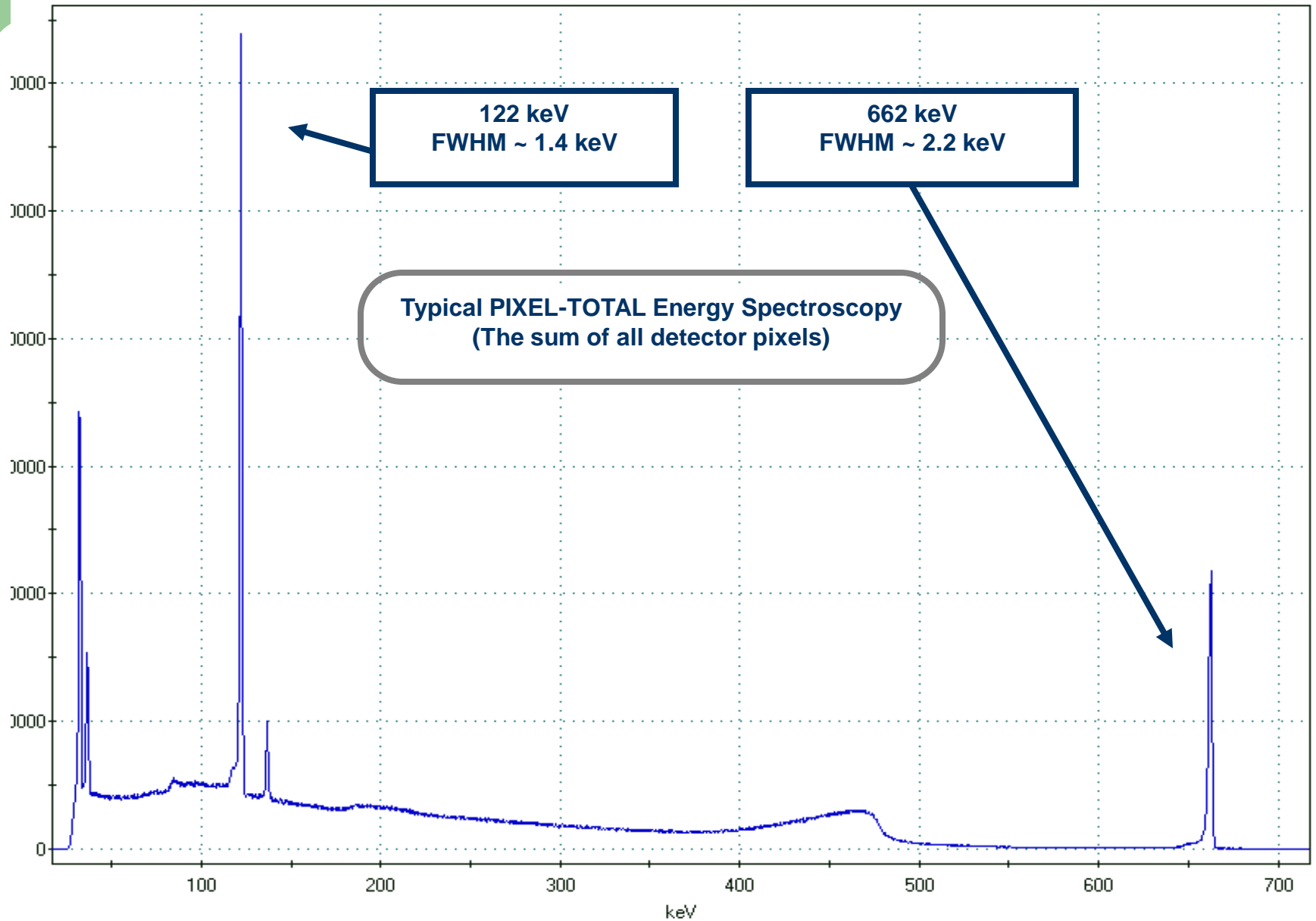
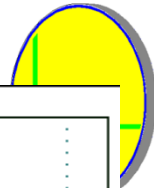




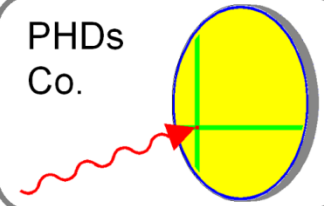
122 keV
FWHM = 1.2 keV

Typical Individual pixel energy spectroscopy

662 keV
FWHM = 2.0 keV



PHDs
Co.



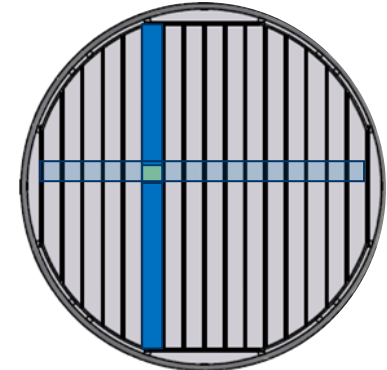
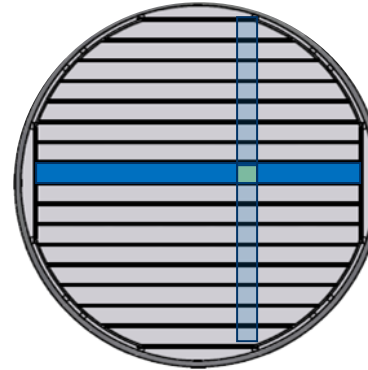
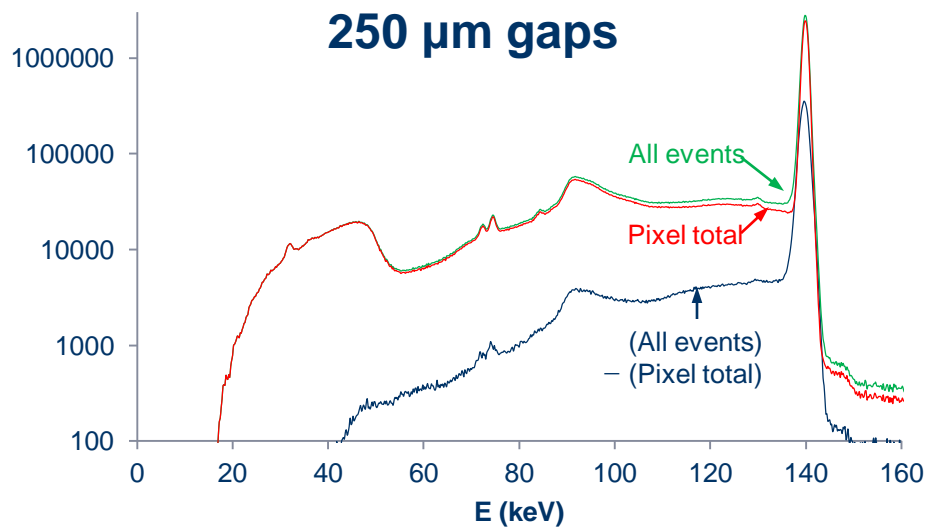
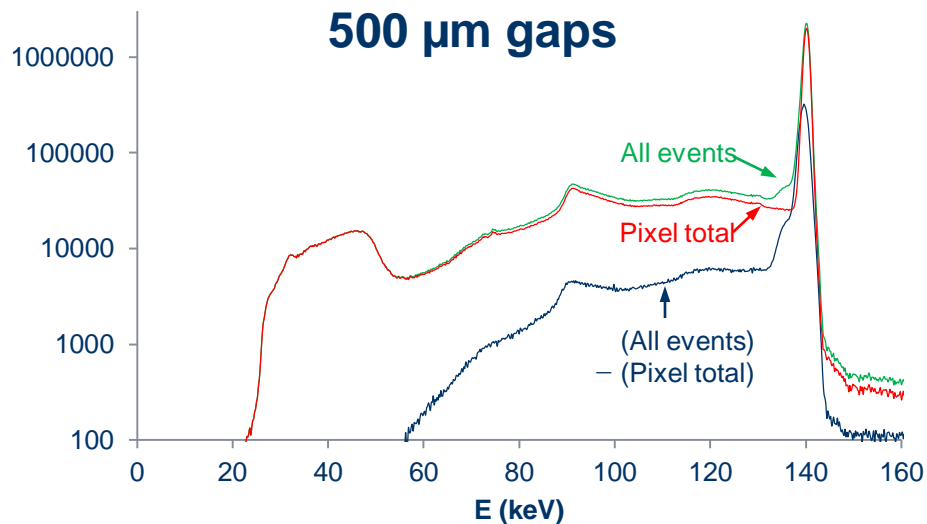
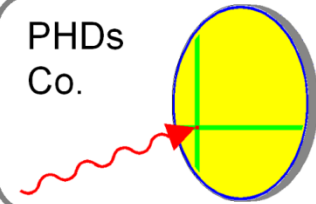
250 μm gaps
(NP7 – UMass
Lowell, Kim Lister,
May 2012)



500 μm gaps
(Previous NPX)



250 μm gaps
(NP7)



Compton = Photoelectric at $E_\gamma = 140$ keV in Ge
 → Substantial neighboring strip scattering
 → Less gap charge loss
 → 10 % higher efficiency at 140 keV

More efficient Polarimeter for Nuclear Physics

More efficient detector for Nuclear Medicine

