PHDS
Gamma Ray Imaging Detectors

Modular Planar Germanium (MPGe) Detector Systems for High Resolution Gamma-ray Spectroscopy and Tracking Arrays

DE-SC0009639
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Ethan Hull PI , PHDS Co.

A collaboration with C.J. Lister at U. Mass Lowell

- PHDS Co. Introduction
- MPGe Concept
- MPGe Evolution

Introduction to PHDS Co.

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- Est. Fall 2004 – Nuclear and Solid State Physics Origin
  - History: Custom Nuclear-Physics Detectors
  - Recently: Modular turnkey Systems (GeGI)
- Small Company, Lean-Organic Growth Model
- Complete Germanium Detector Manufacturing Facility
  - Concept Design & R&D
  - Crystal Growth
  - Detector Fabrication
  - System Integration
  - Software application
  - Sales & Service

Make an Impact with Imaging Germanium Technology

Product Portfolio & Markets

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PHDs Co. sells into 3 broad markets

Nuclear Physics
NPX-M

Nuclear
Security
GeGI

Nuclear
Medicine
GGC

all imaging capable detectors

10,000 ft^2 Manufacturing and R&D Facility in Knoxville, TN

Manufacturing onsite in Knoxville

Manufacturing

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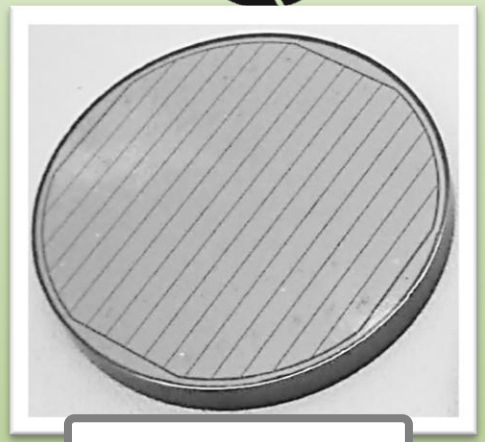
Growth

Evaluation



Fabrication

Integration
+ software
+ imaging

Shipping,
sales and
support

Large diameter/volume HPGe Crystals
DOE NP Development

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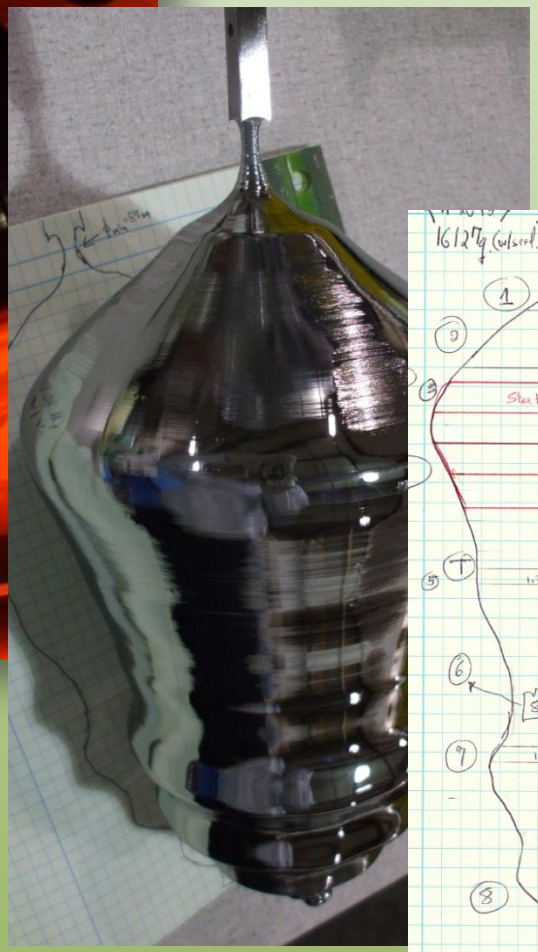

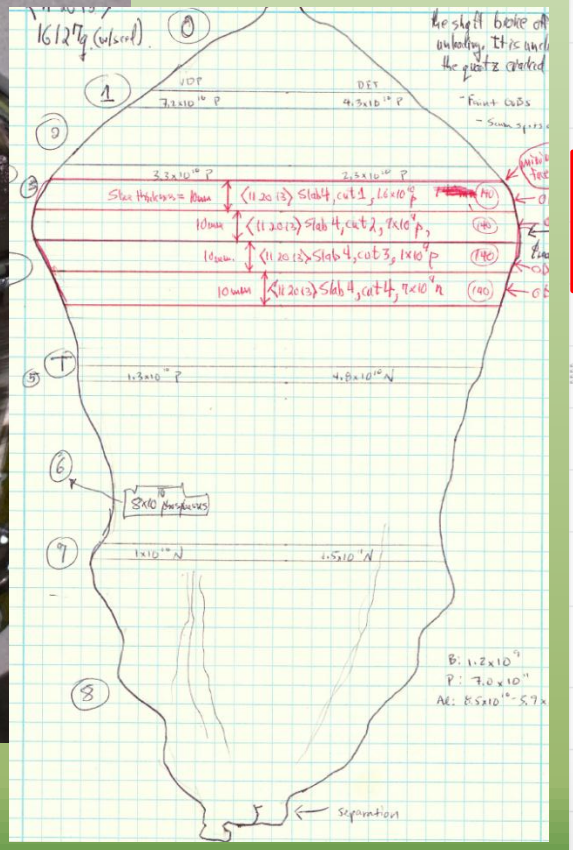

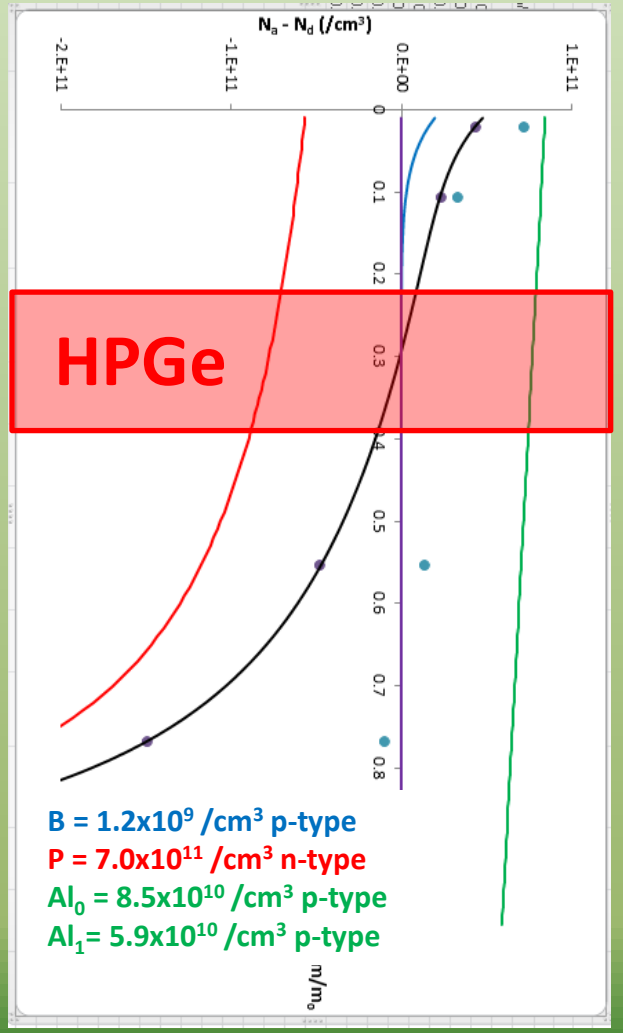

Segmented HPGe detector fabrication DOE NP Developed

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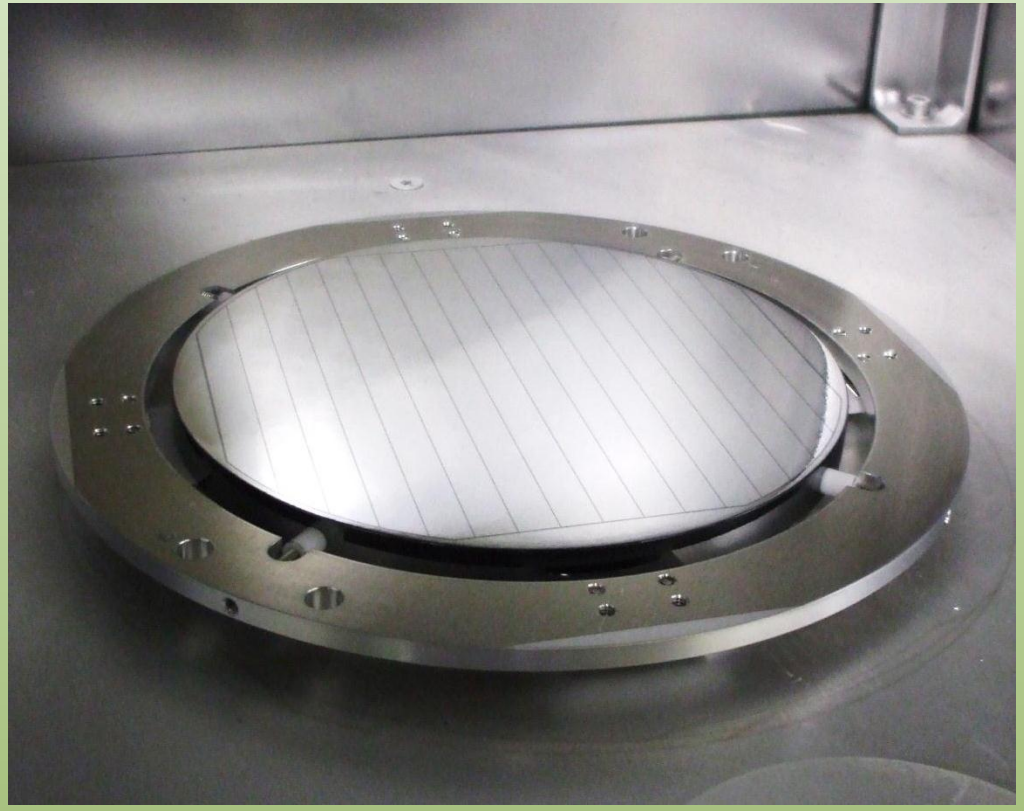

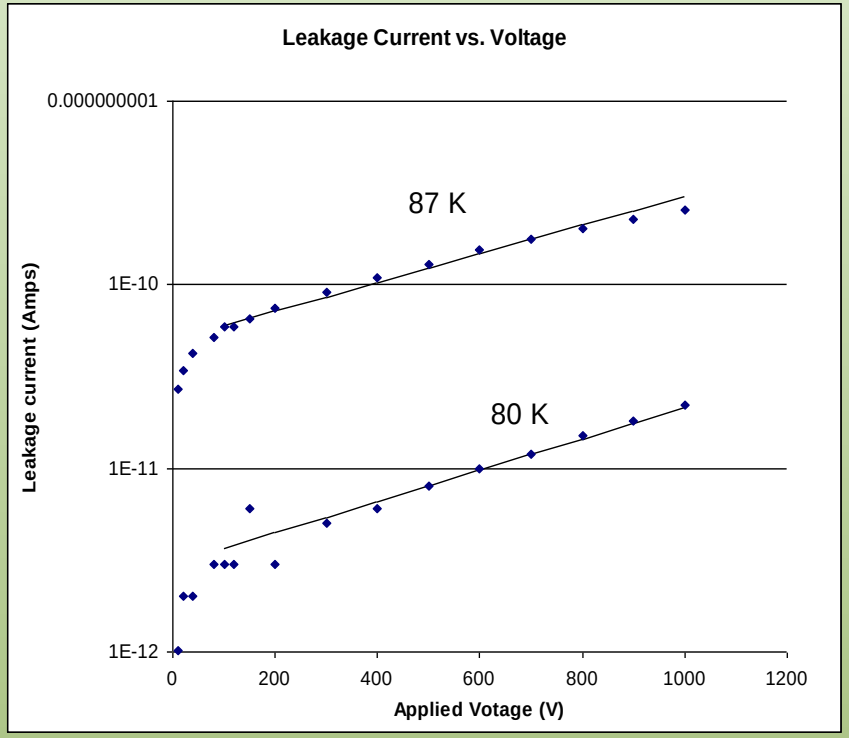

- Charge Injection Barriers
- Electronically segmented
- Two sided – fully depleted
- Function at ~ 77 K
  - Non-standard semi

Surface contact physics: αGe, Y, Ag, …

$$j = j_{\infty}\exp(-\{\phi - [(\varepsilon_0\varepsilon_{Ge}/N_f)^{1/2}(V+V_{depl})/d]\ \}/k_BT)$$

E.L Hull, R.H. Pehl, "Amorphous germanium contacts on germanium detectors," Nuclear Instruments and Methods A, **538**, Issues 1-3, (2005), Pages 651-656.

Hull EL, R.H. Pehl, J.R. Lathrop, B.S. Suttle, "Yttrium hole-barrier contacts for germanium semiconductor detectors." Nucl. Instr. and Meth. A 626–627 (2011) p. 39–42 (2011), doi: 10.1016 / j.nima.2010.10.029.

Manufacturing

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Product Progression – Overall system size decrease
Detector size constant

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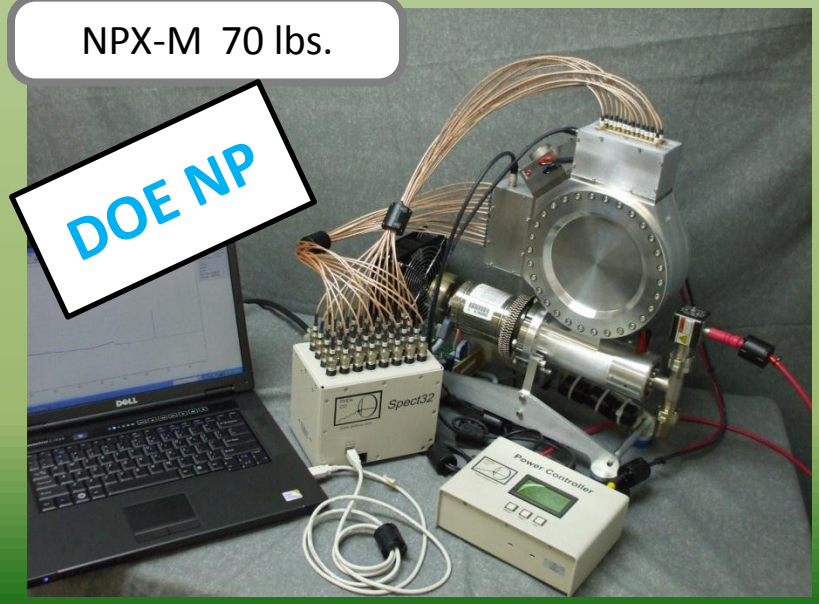

Sales, Service, Support

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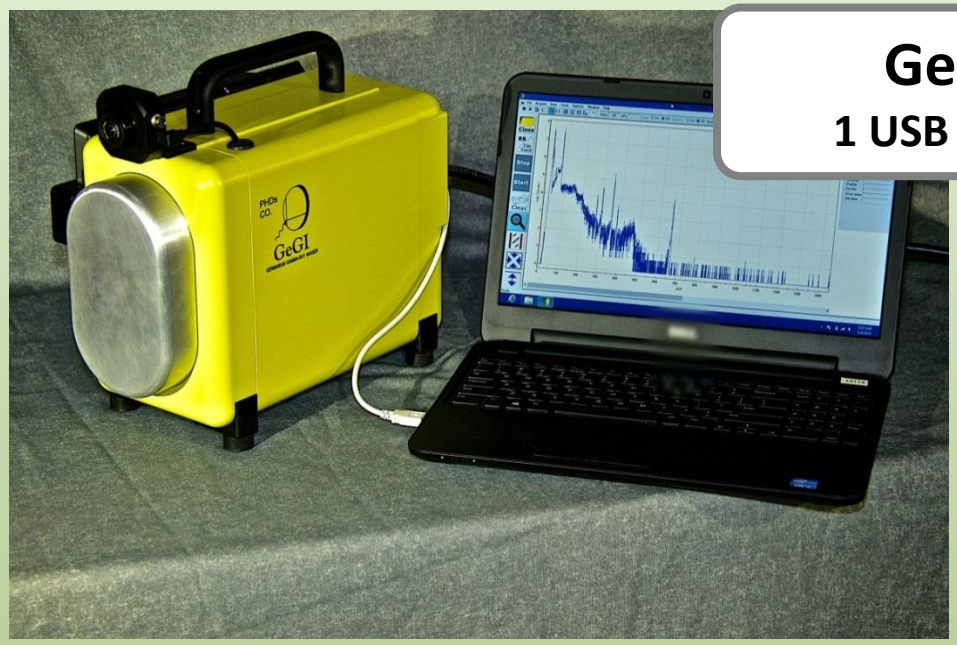
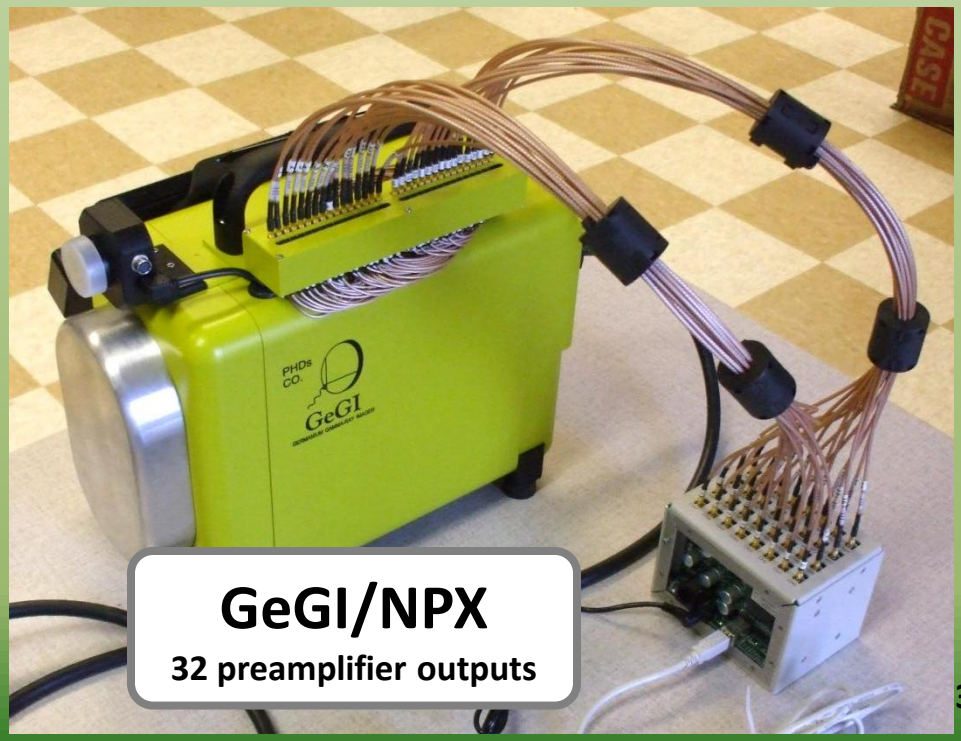


GeGI

1 USB cable



GeGI/NPX

32 preamplifier outputs

NPX

32 preamplifier outputs

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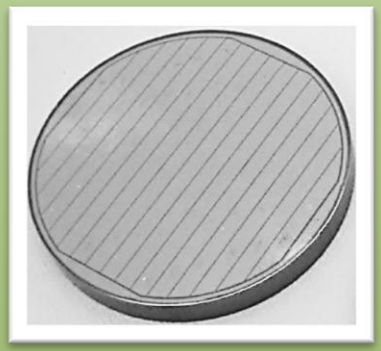
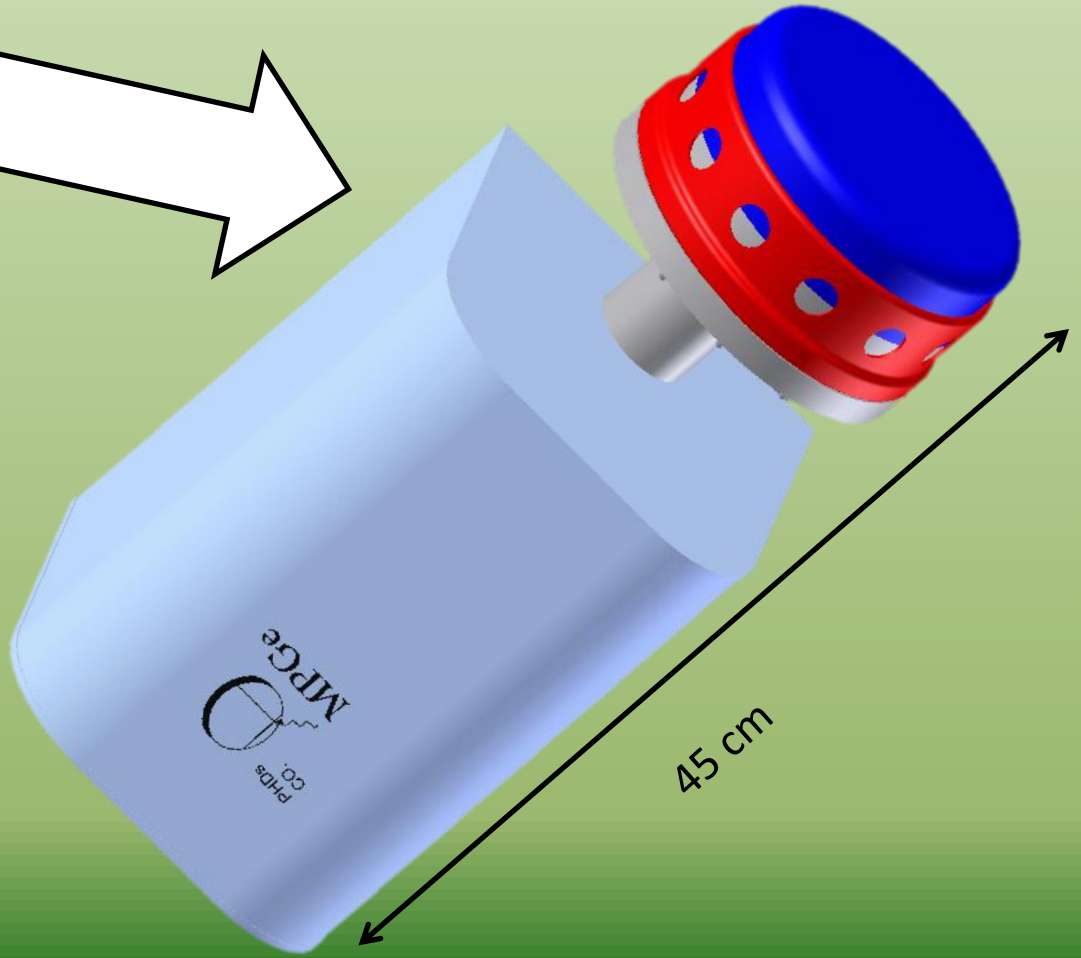
The modular GeGI/NPX led to MPGe



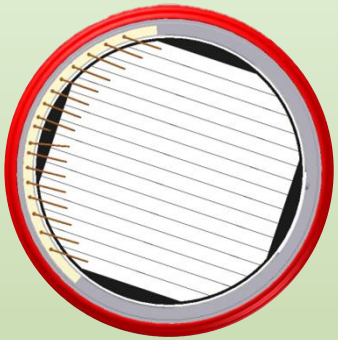
(x, y, z, Energy)



MPGe

140-mm dia.

133 cm^2 active
(x2.4)



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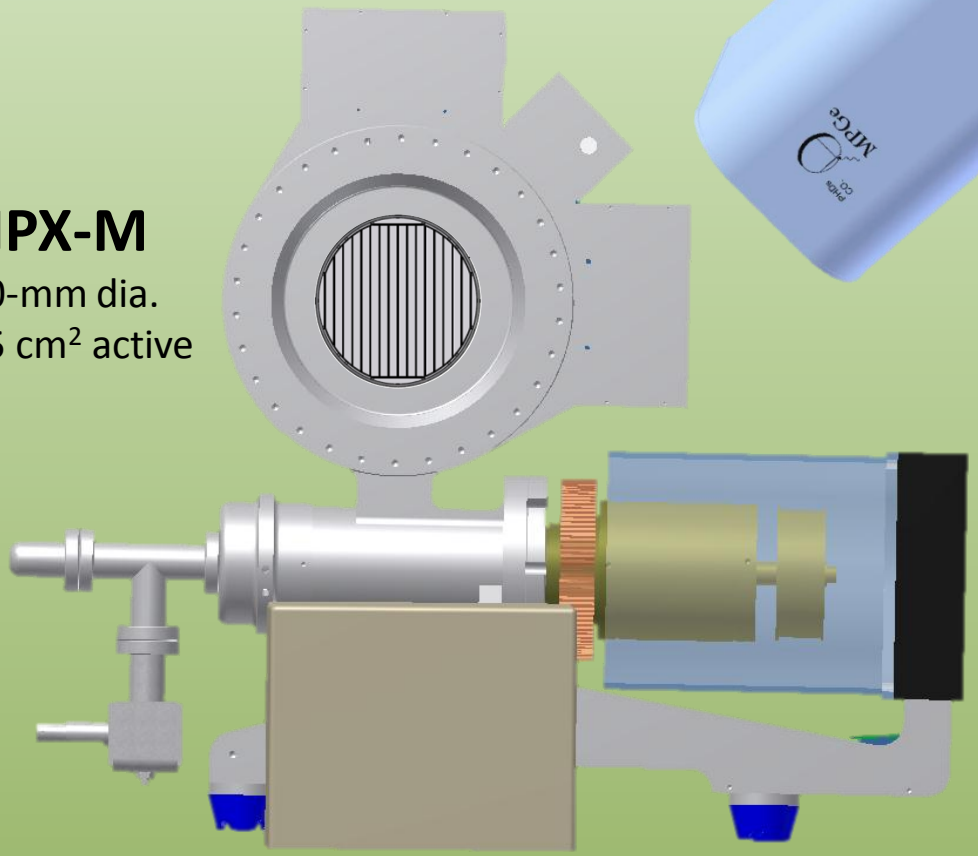
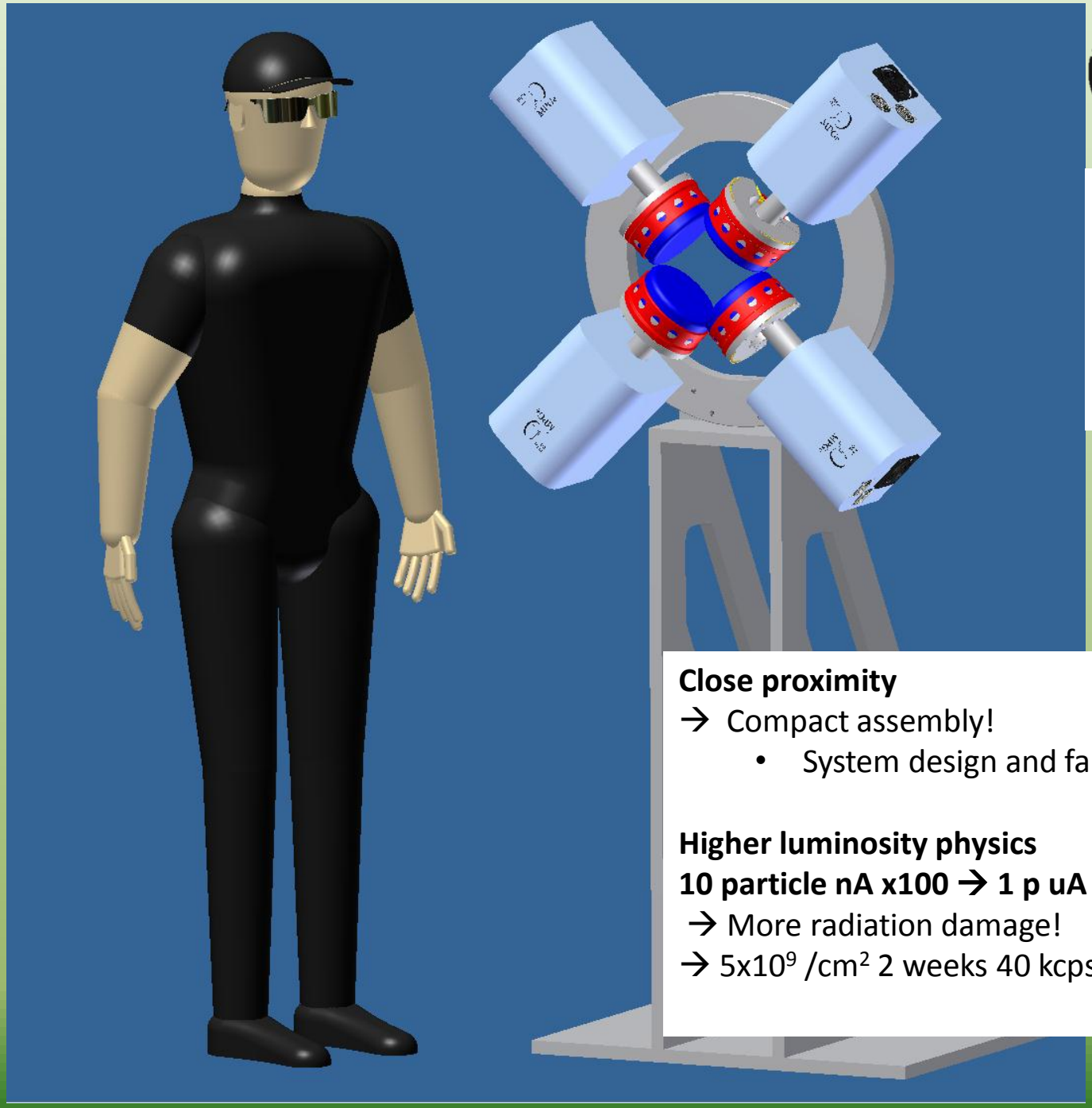
NPX-M

90-mm dia.

55 cm^2 active



Less hardware around the detector
Greater detector area



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MPGe
4-Detector Array

14.7 cm face to face
2π solid angle coverage
6 ft. tall

Close proximity
→ Compact assembly!
- System design and fabrication challenges

Higher luminosity physics
10 particle nA x100 → 1 p uA
→ More radiation damage!
→ 5×10^9 /cm^2 2 weeks 40 kcps (10 cm 1 mg/cm^2 Pb)

The Complete MPGe design

Mechanical – close OD

Electronic – optional trap corrector

Vacuum/Cryogenic – In Situ anneal

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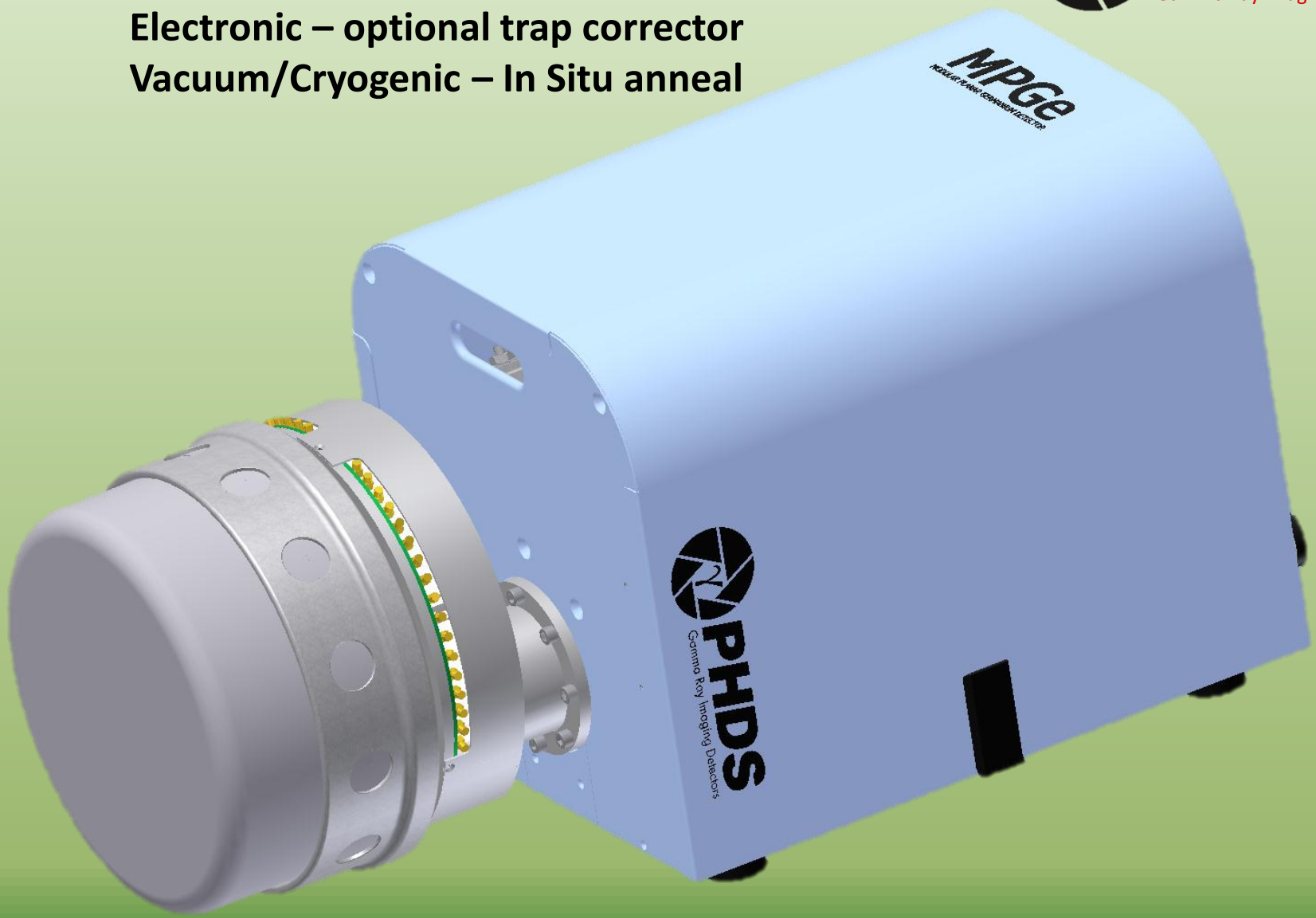

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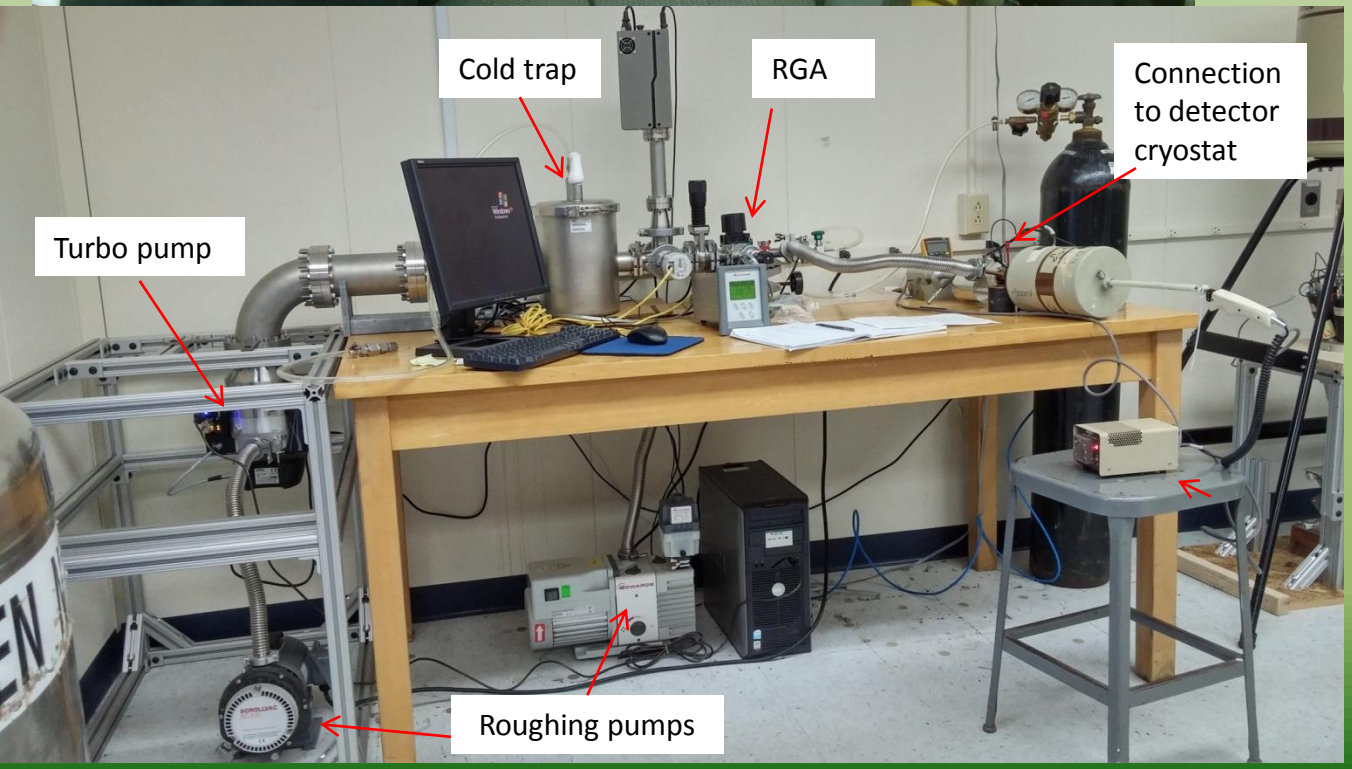
C.J. (Kim) Lister

Radiation Damage Annealing

New contact fabrication survives 70°C and now 100°C!!



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E.L. Hull, E.G.Jackson, C.J.Lister, R.H.Pehl, "Charge-trap correction and radiation damage in orthogonal-strip planar germanium detectors." Nucl. Instr. and Meth. A 762 p.125-129 (2014).

- **Radiation Damage**
- **Preserve performance to delay annealing**

E.G.Jackson, E.L. Hull, C.J.Lister, R.H.Pehl, "Ameliorating neutron damage in orthogonal-strip planar germanium detectors." Nucl. Instr. and Meth. A 774 p.34-41 (2015).

- **Radiation Damage**
- **Annealing**

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