Capacitive Multiplexing in Germanium Radiation Imagers

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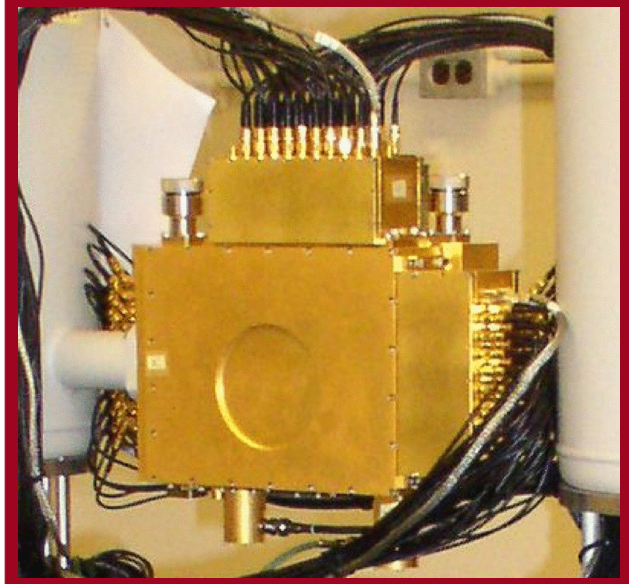
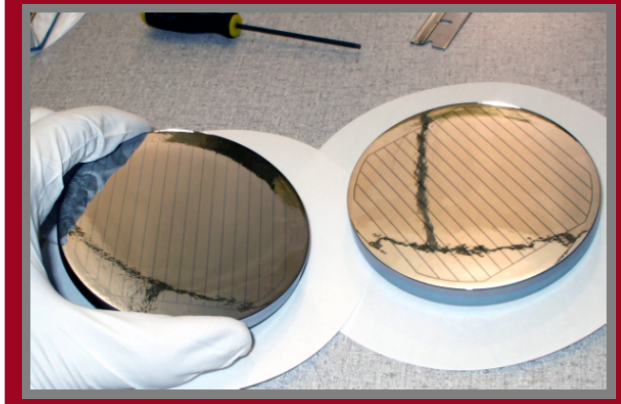
This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Overview

- Introduction
- Setting up the Detector
- Predicting Peaks
- Reconstructing Peaks
- Inter-Strip and Ground Capacitances
- Conclusions and Future work





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Introduction

- How was this research funded?
  - DOD/DOE/IAEA
- Why was this research funded?

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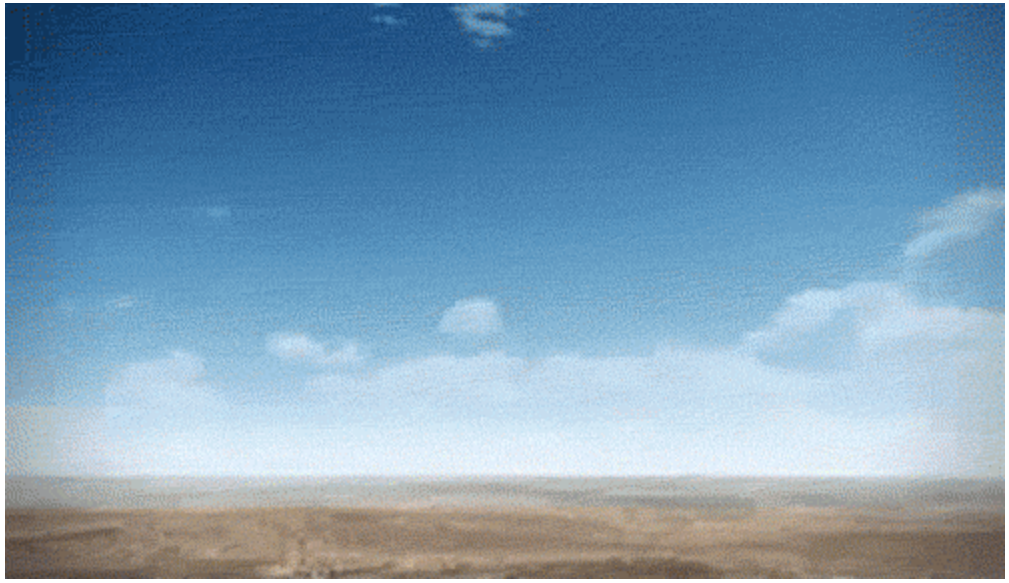
Introduction Cont.



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Introduction Cont. Cont.

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Introduction Cont.^3

- What's a HPGe imager?
- Why optimize?
- What's already been done?

- Applications
  - Compton Telescope
  - Coded Aperture**
  - Compton Camera

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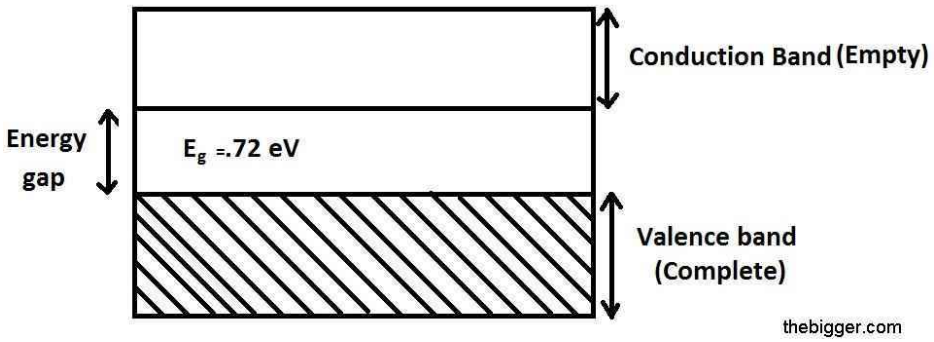
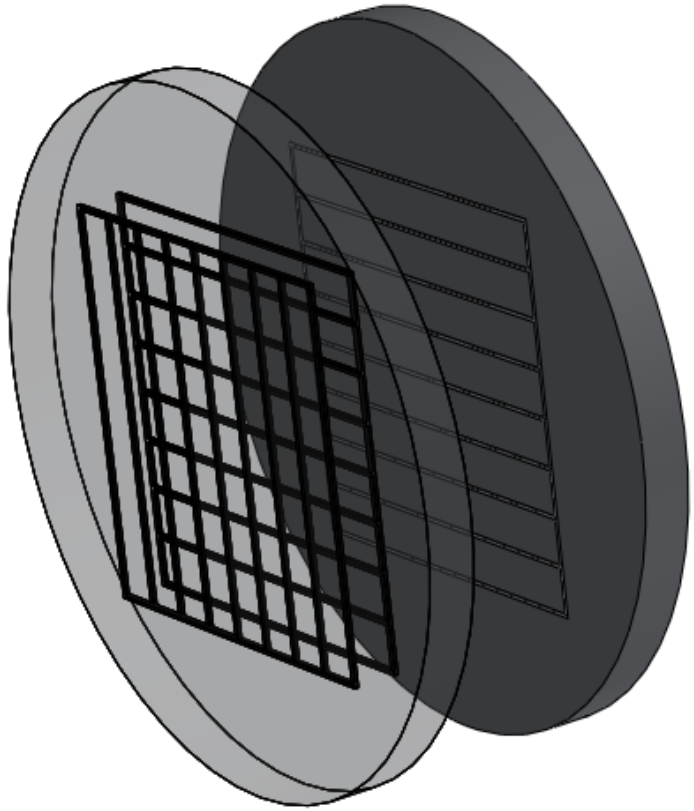
HPGe Imagers





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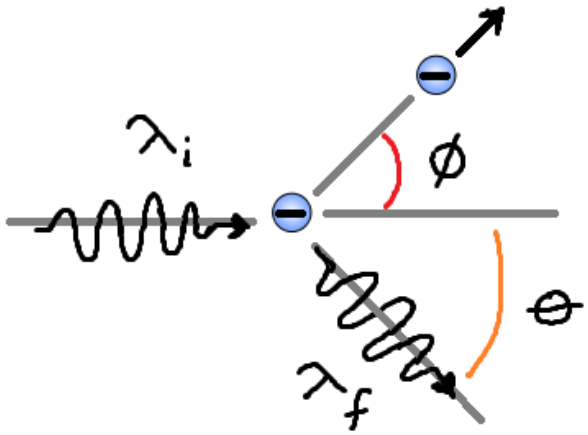
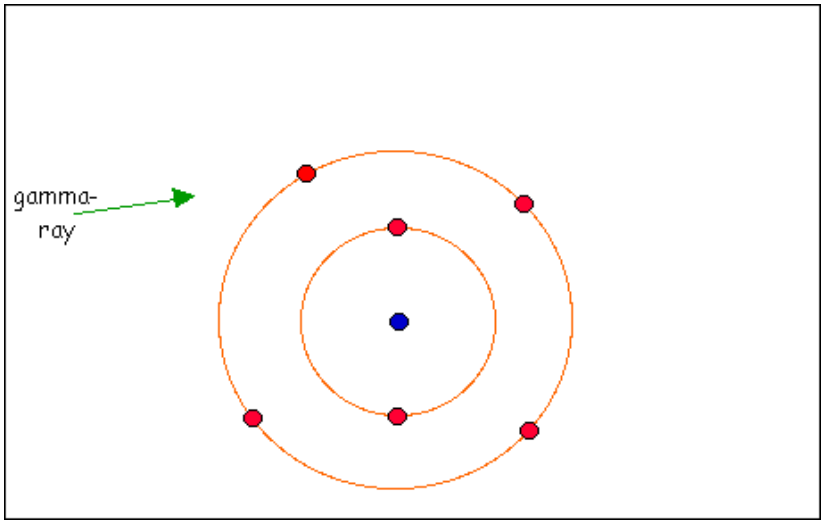
Compton Scattering





$$E_{\gamma'} = \frac{E_\gamma}{1 + \frac{E_\gamma}{m_0 c^2}(1 - \cos\theta)}$$

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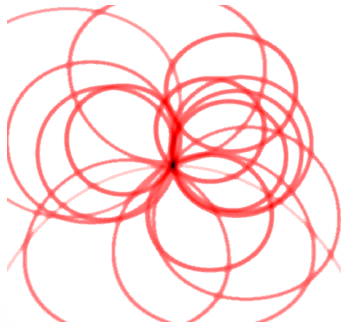
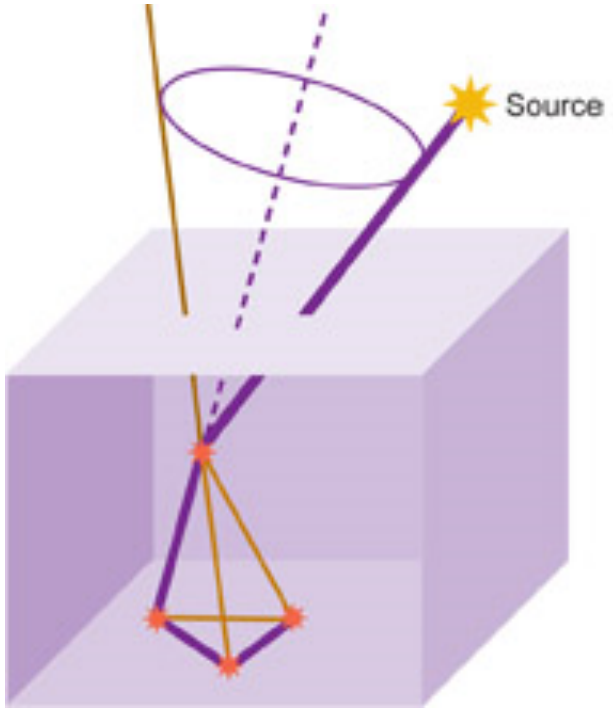
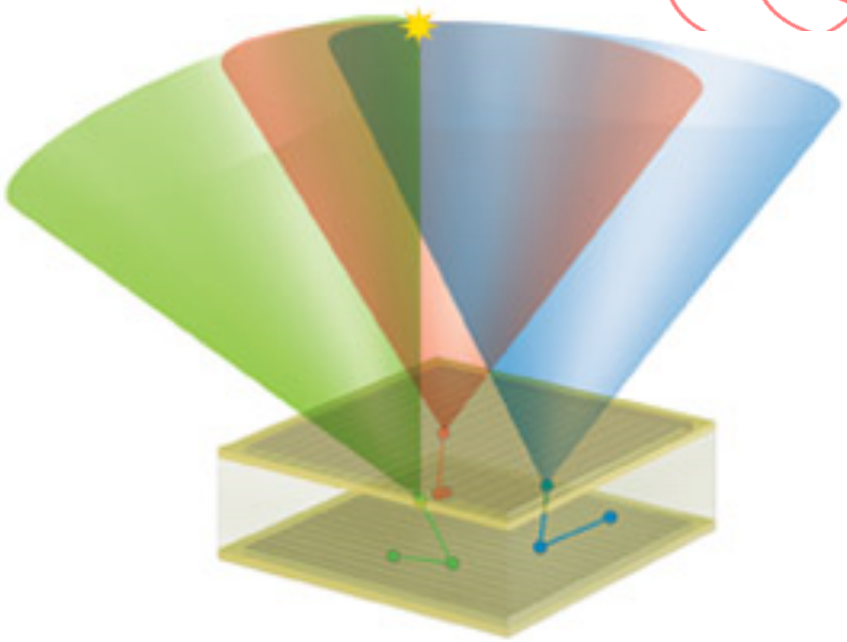
Compton Scattering







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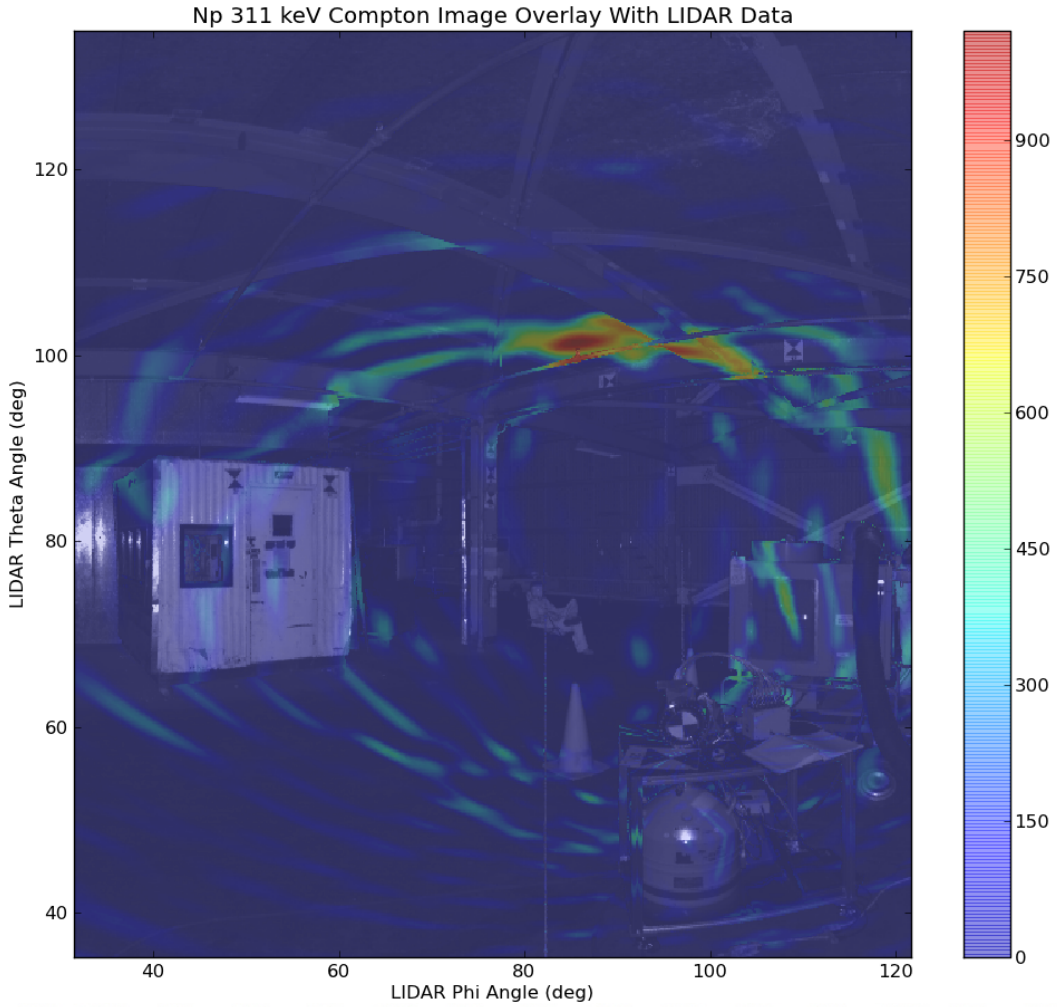
Example of an Imaged Source



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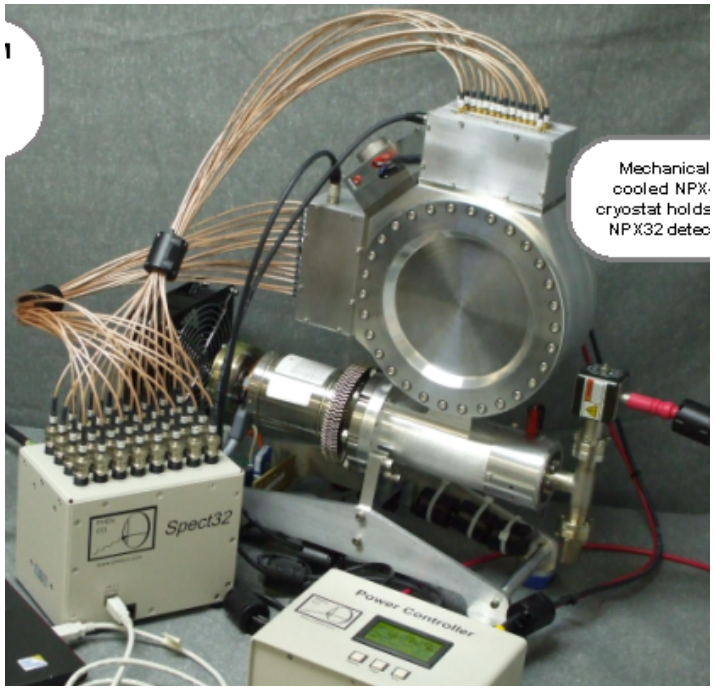
So many channels!

Tons of Data File Output!



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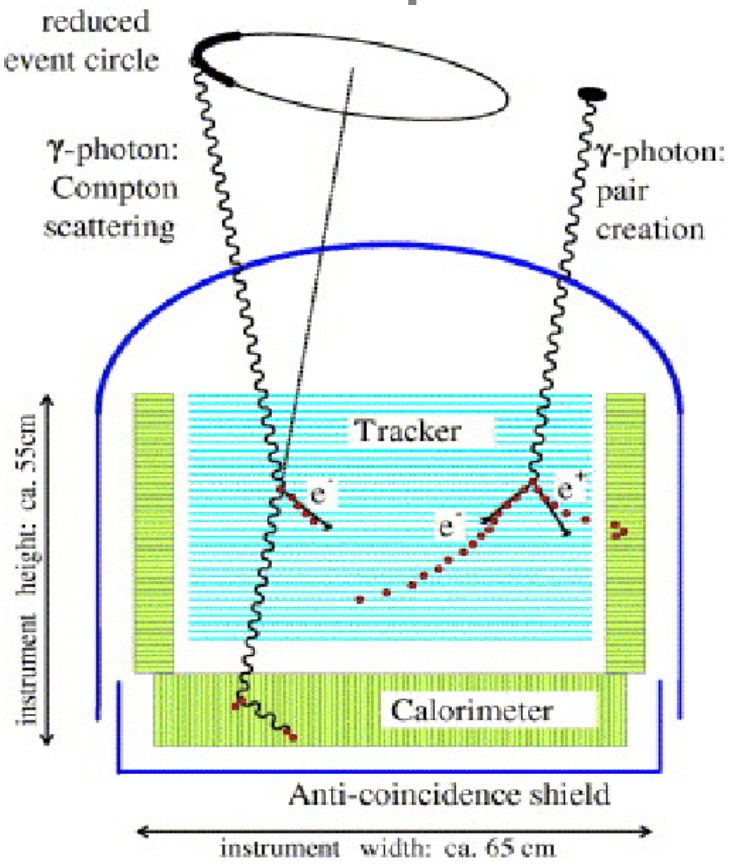
Application: Compton Telescopes



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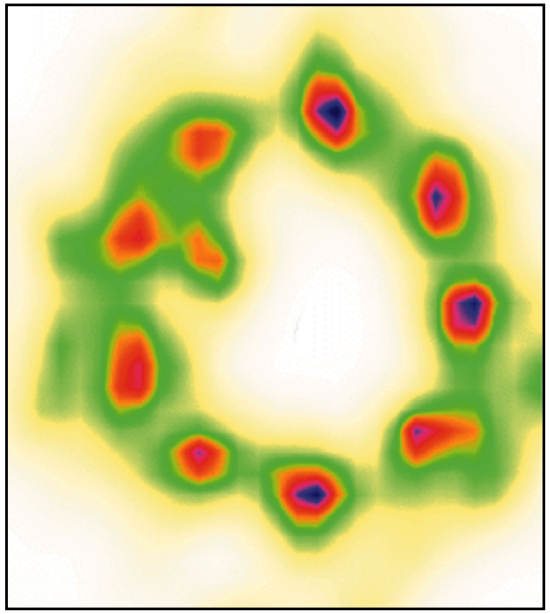
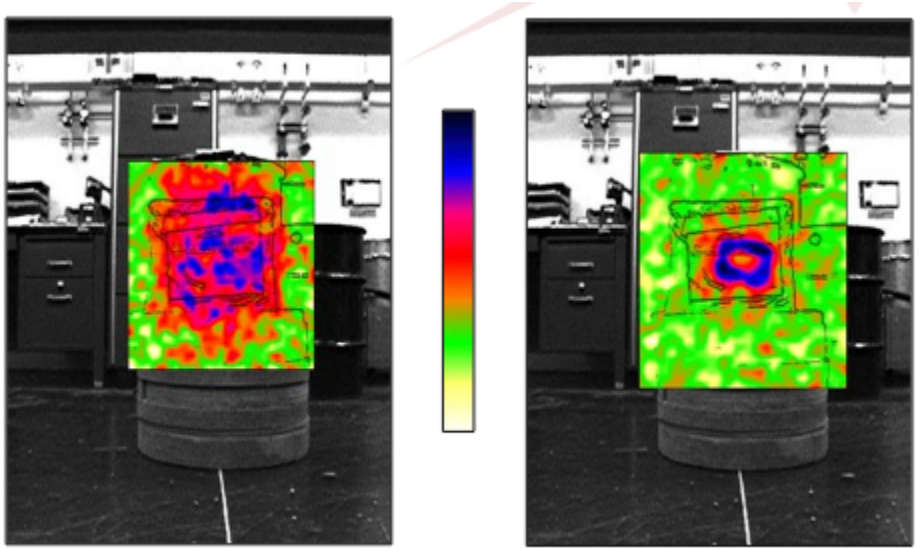
Application: Coded Aperture





Depleted uranium source

Plutonium source

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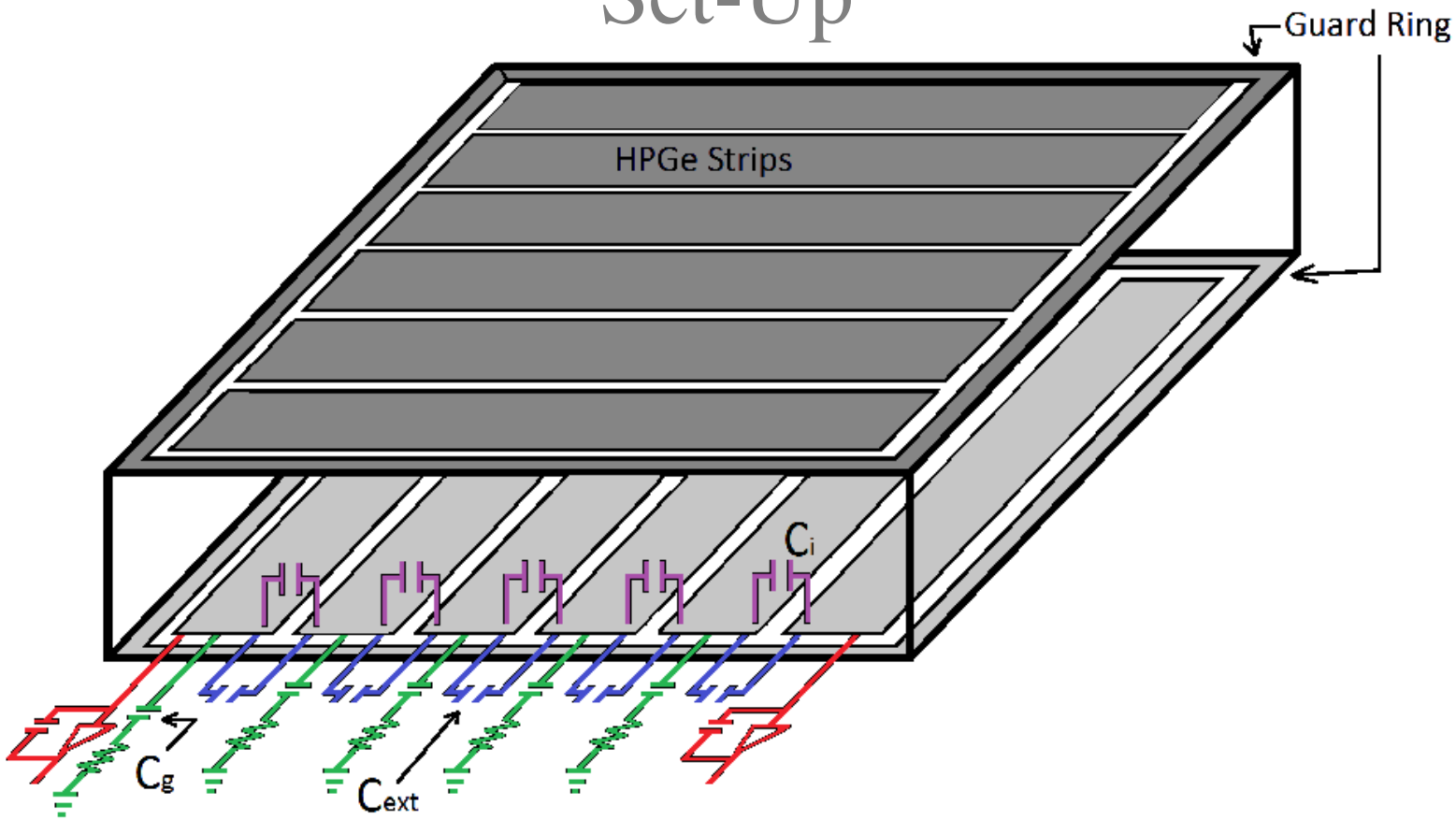
Set-Up



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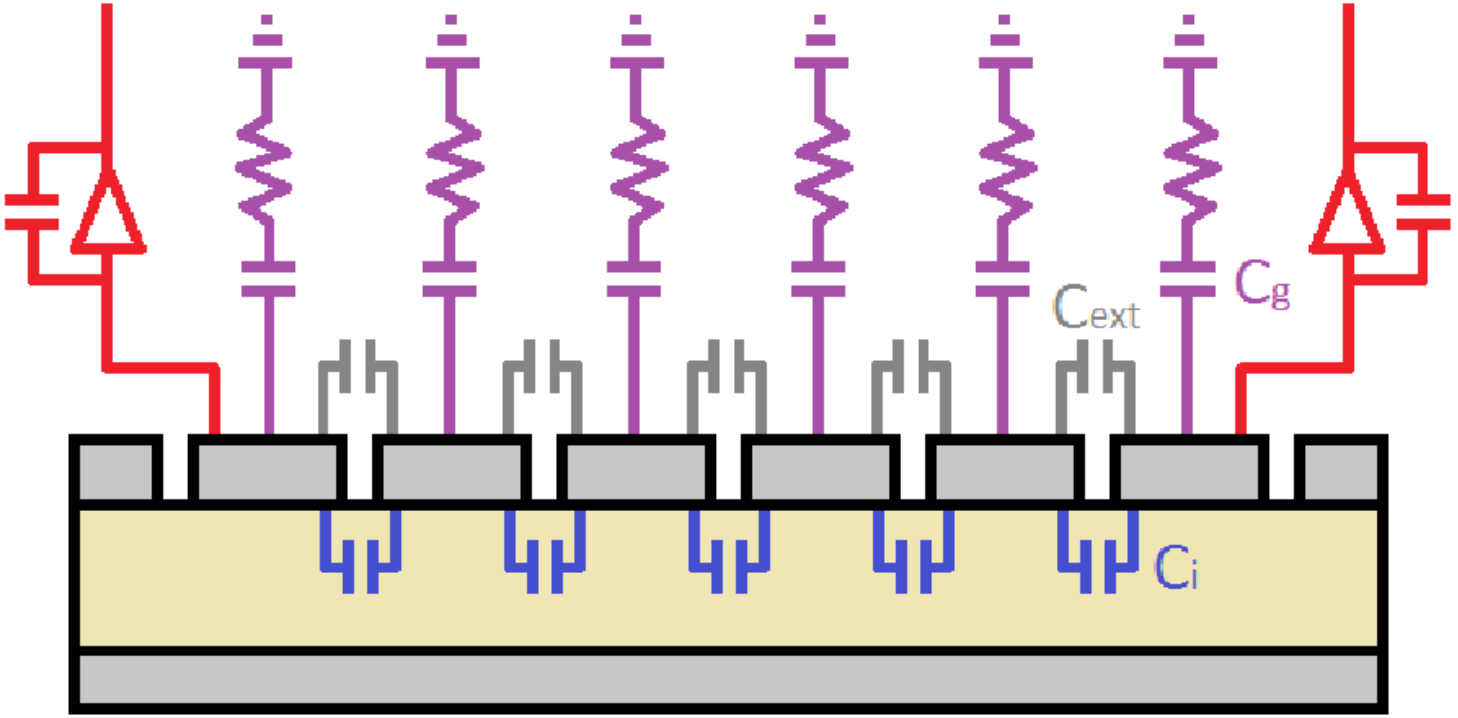
Set-Up Cont.



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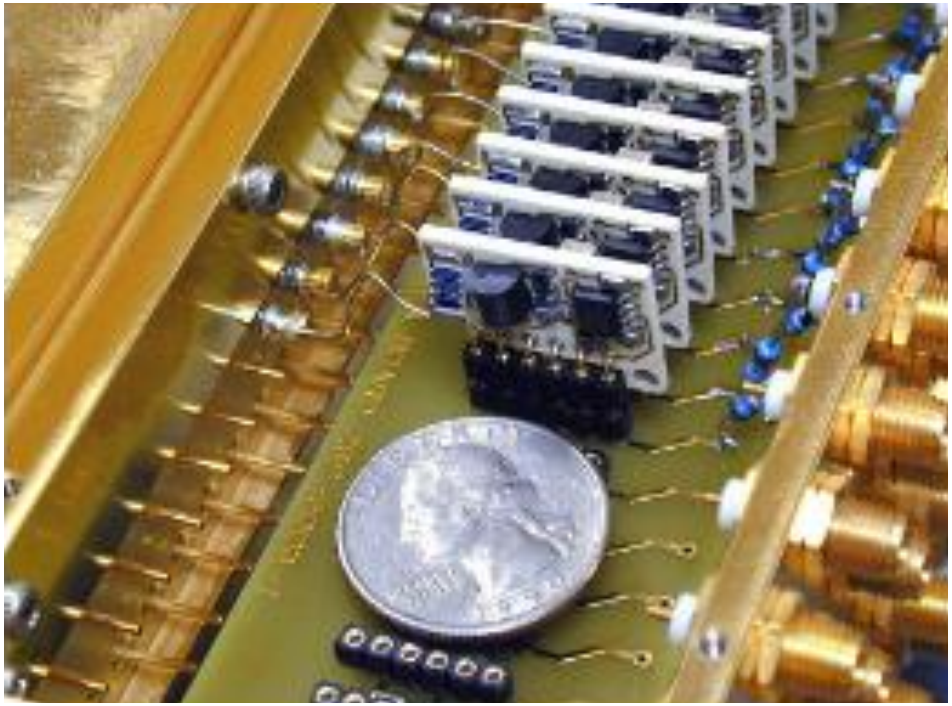
Set-Up



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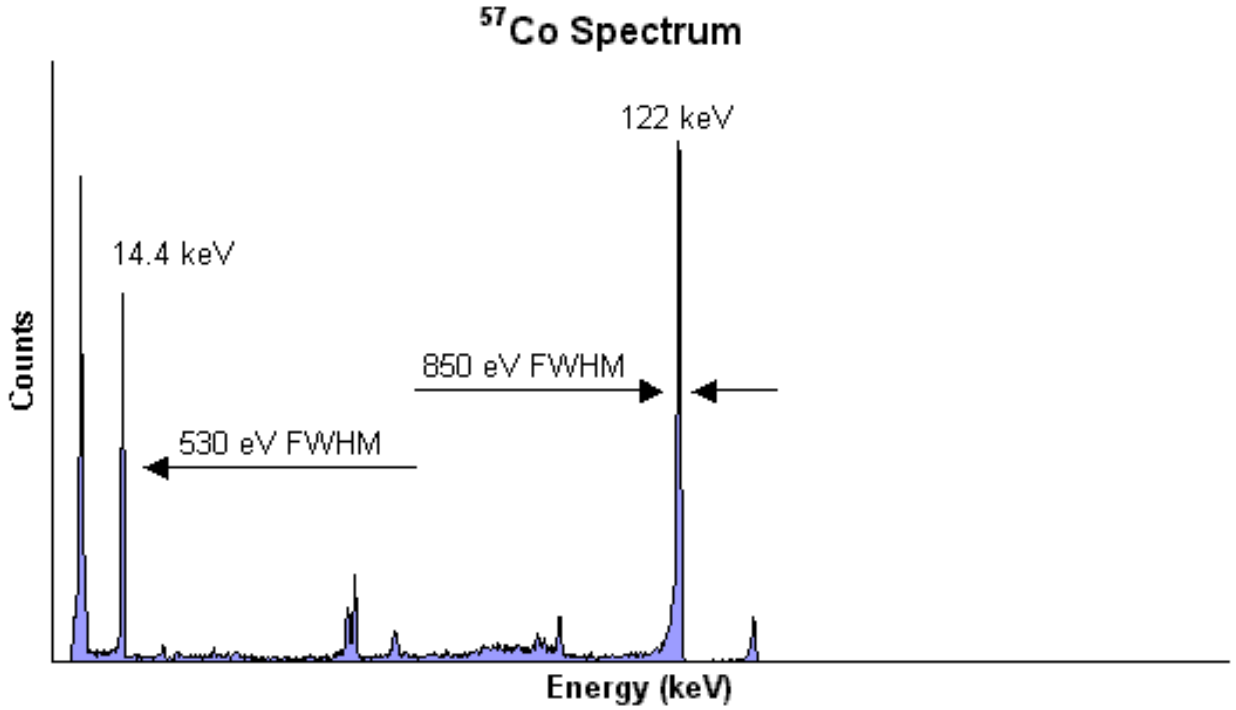
What's the End Goal?



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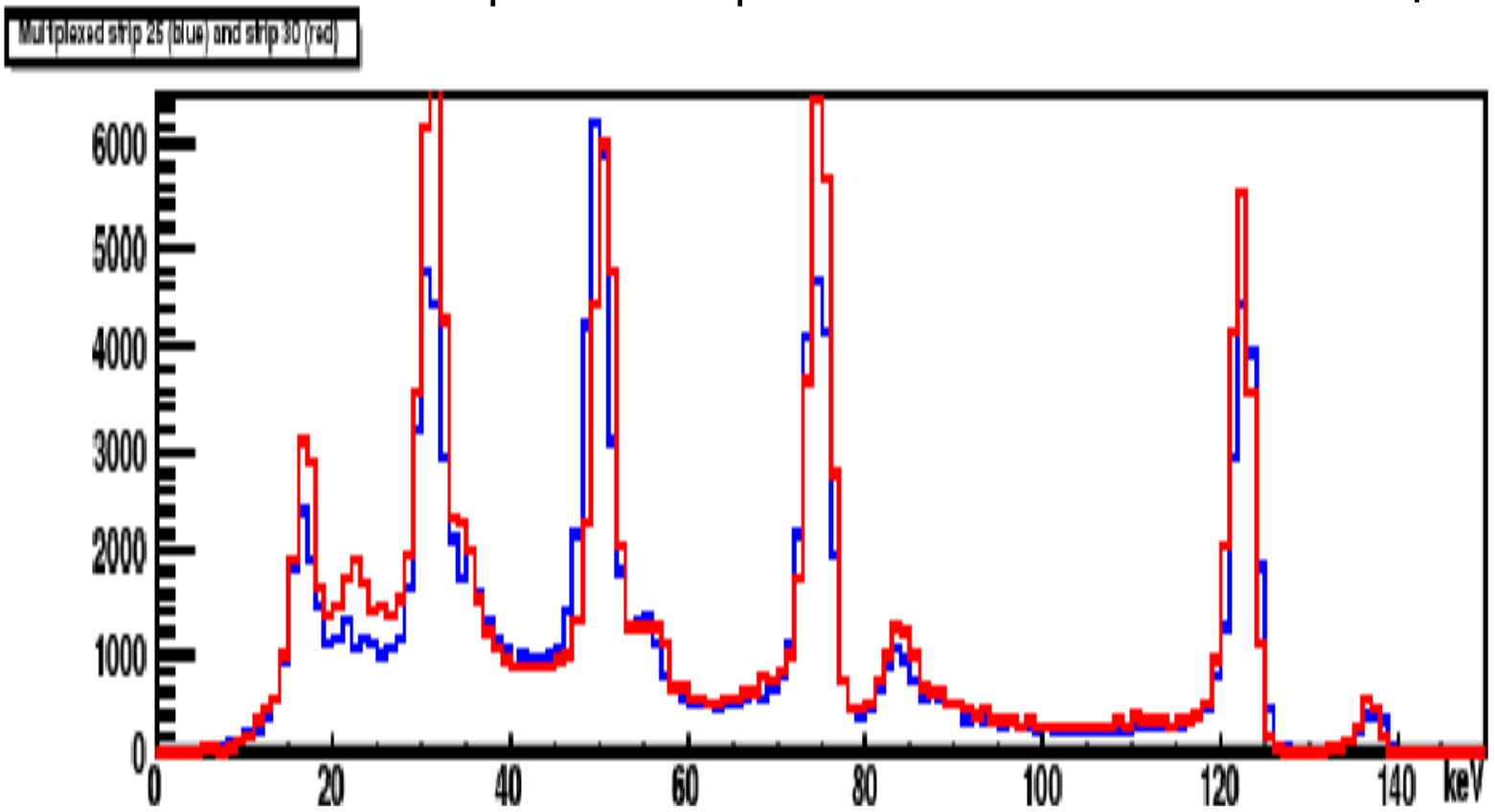
6- Strip Multiplexed Output

Red – Preamp A
Blue – Preamp B



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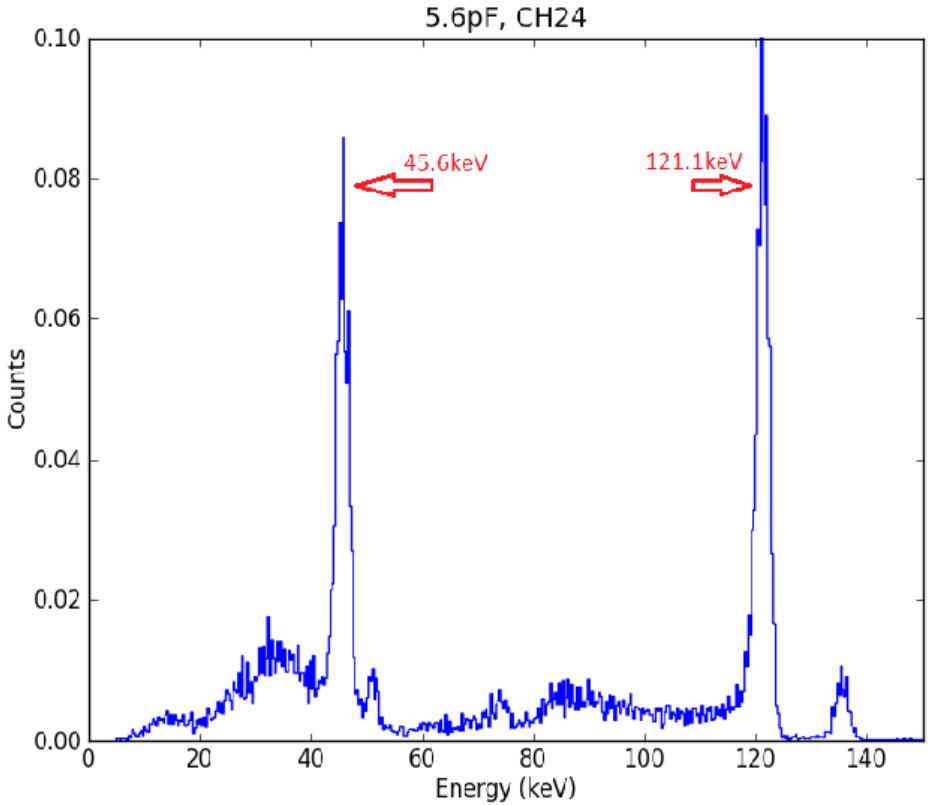
Three-Strip Spectra: Co-57



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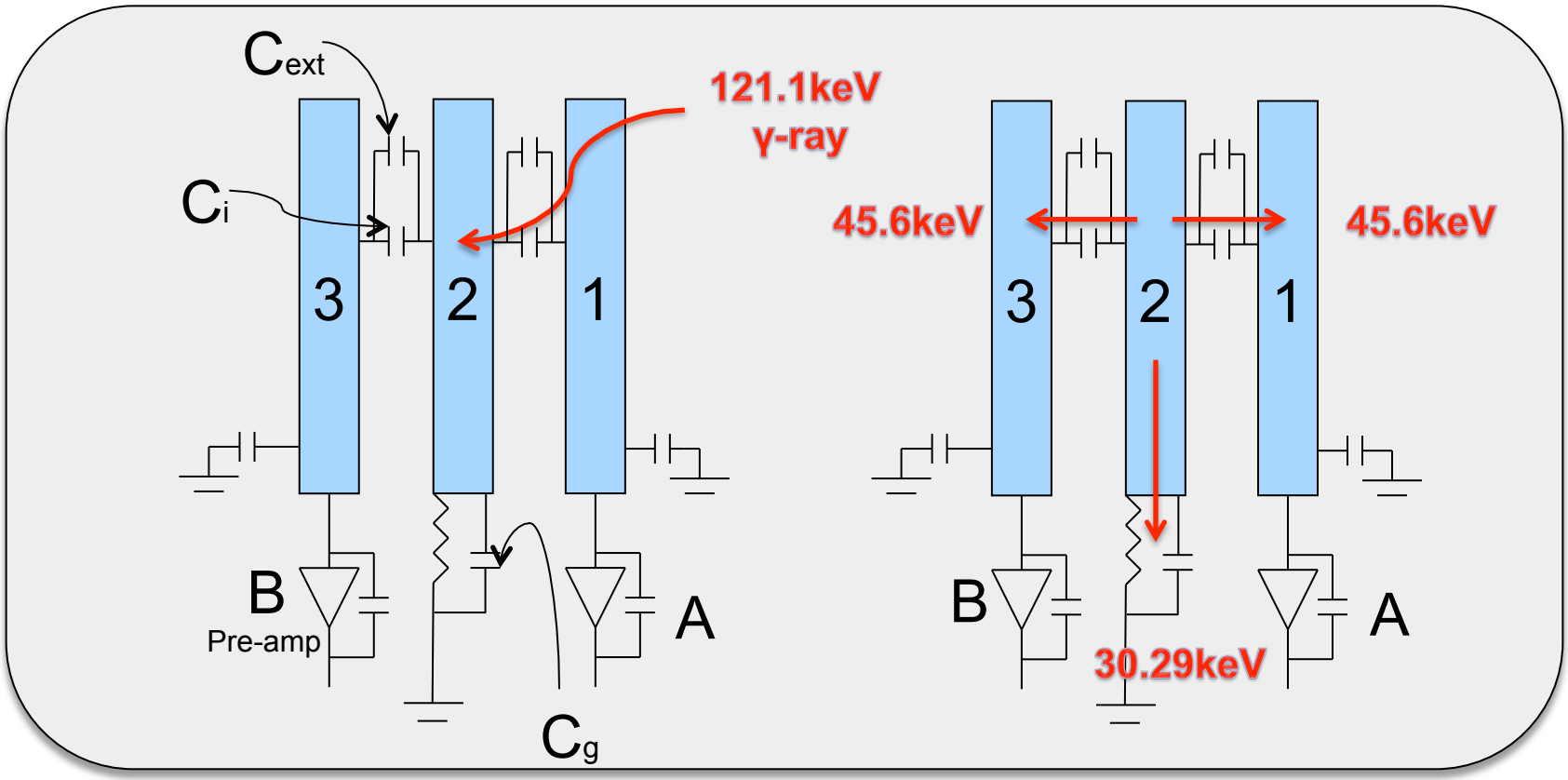
Capacitive Sharing



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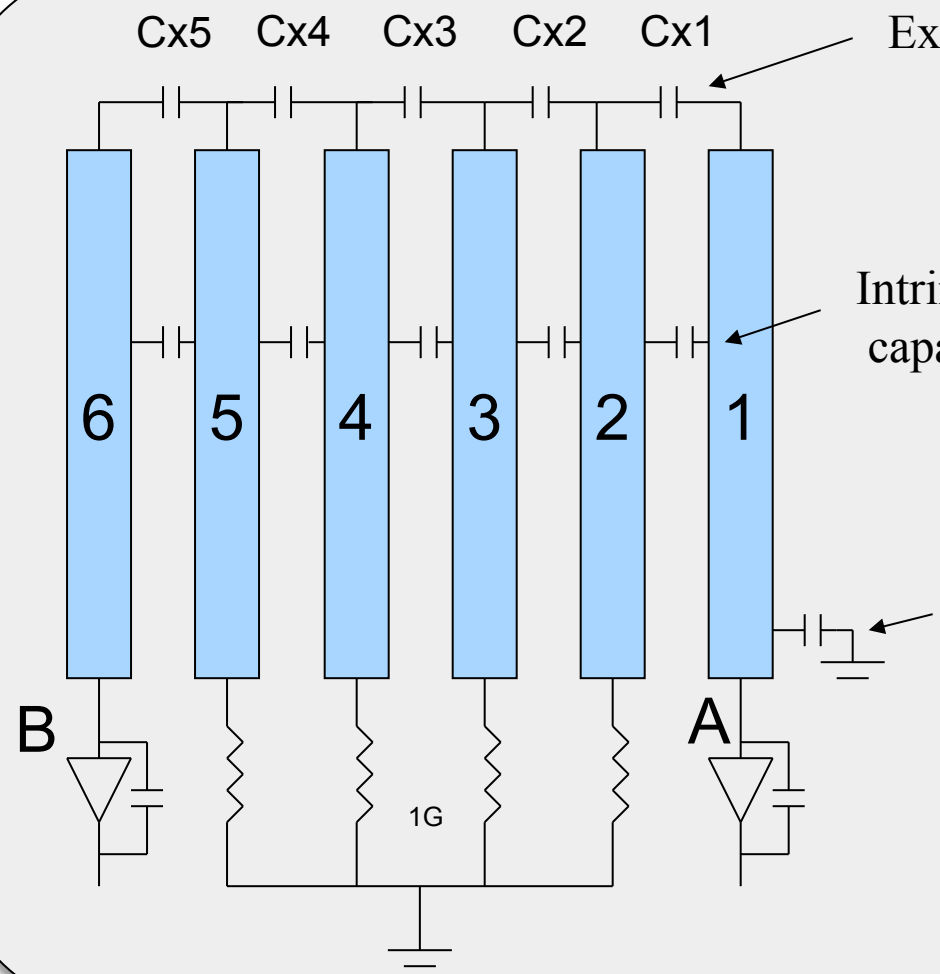

Six Strip Multiplex

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4-Strip All Peak Prediction Equations

Find the total capacitance at channel 29:

$$C_{total} = C_{ext1} + C_i + C_{g1} + C_{eqA}$$

$$C_{eqA} = \frac{(C_{ext2} + C_i)C_{eqB}}{(C_{ext2} + C_i) + C_{eqB}}$$

$$C_{eqB} = C_{ext3} + C_i + C_{g2}$$

$$C_{total} = C_{ext1} + C_i + C_{g1} + \frac{(C_{ext2} + C_i)(C_{ext3} + C_i + C_{g2})}{(C_{ext2} + C_i) + (C_{ext3} + C_i + C_{g2})}$$

Find the 2^{nd} peak read out from pre-amp 1, channel 30:

$$Peak_2 = (Energy)\frac{C_{ext1} + C_i}{C_{total}}$$

Find the 3^{rd} peak read out from pre-amp 1, channel 30:

$$Peak_2 = (Energy)(\frac{C_{ext2} + C_i}{C_{total}})(\frac{C_{ext1} + C_i}{C_{ext1} + C_{ext2} + C_i + C_g})$$

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Six Strip Peak Prediction Equations

- Too long to fit on slide!

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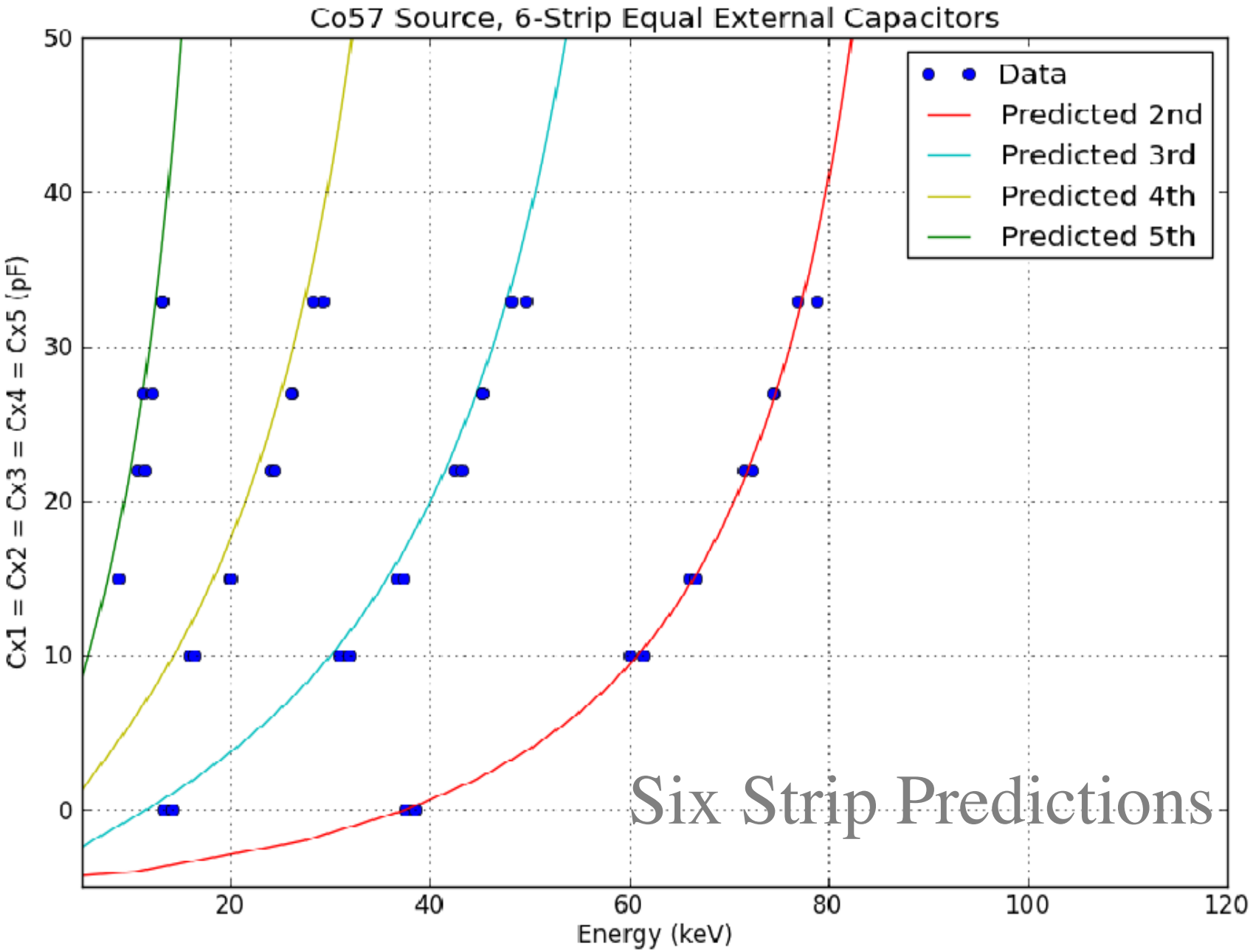
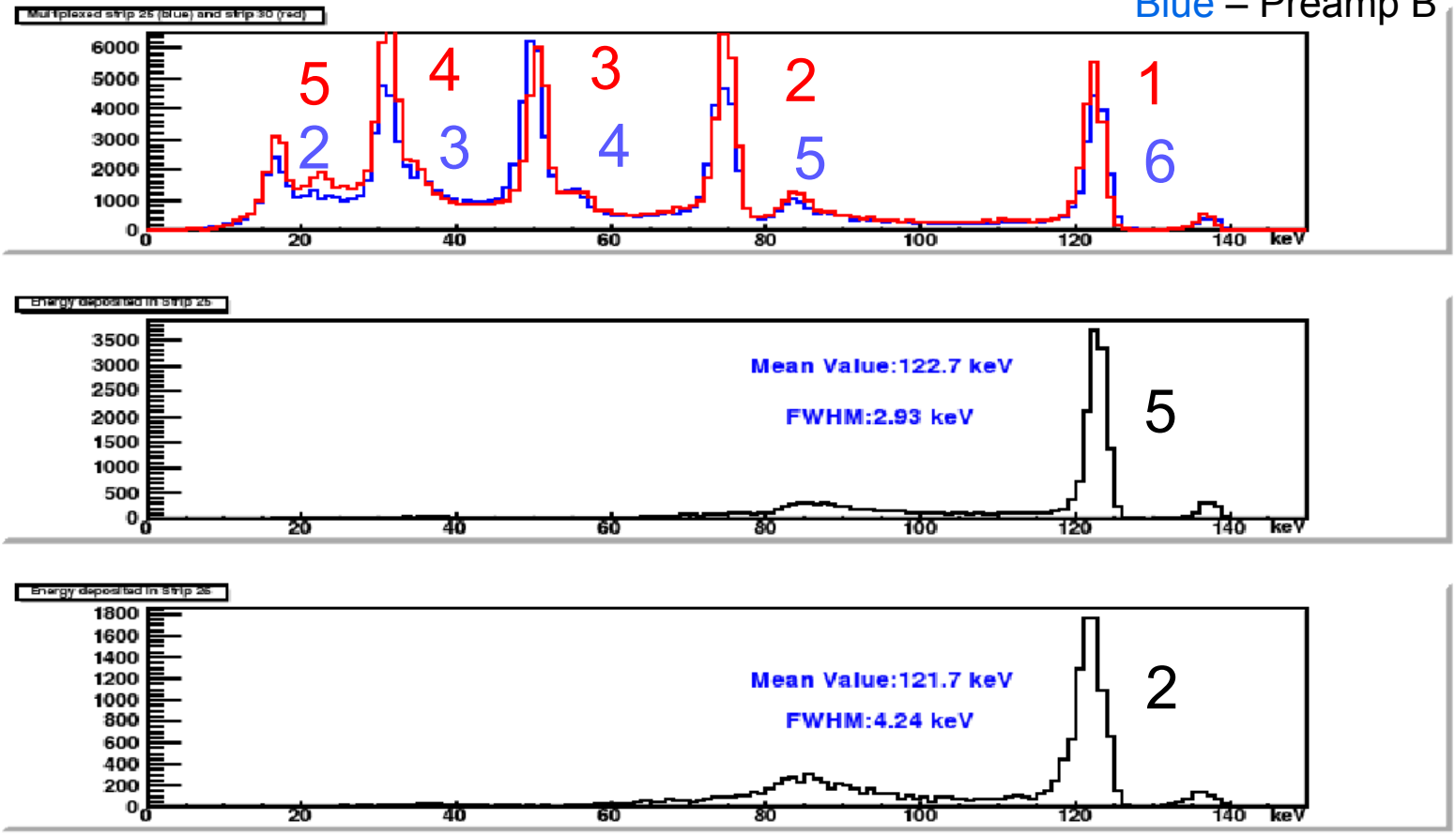

Co57 Source, 6-Strip Equal External Capacitors
Data
Predicted 2nd
Predicted 3rd
Predicted 4th
Predicted 5th
Cx1 = Cx2 = Cx3 = Cx4 = Cx5 (pF)
Energy (keV)
0
10
20
30
40
50
20
40
60
80
100
120
Six Strip Predictions

Peak Reconstruction

Red – Preamp A
Blue – Preamp B



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Peak Reconstruction Cont.

- How can we improve resolution?
  - Averaging both sides
  - “Better” electronics

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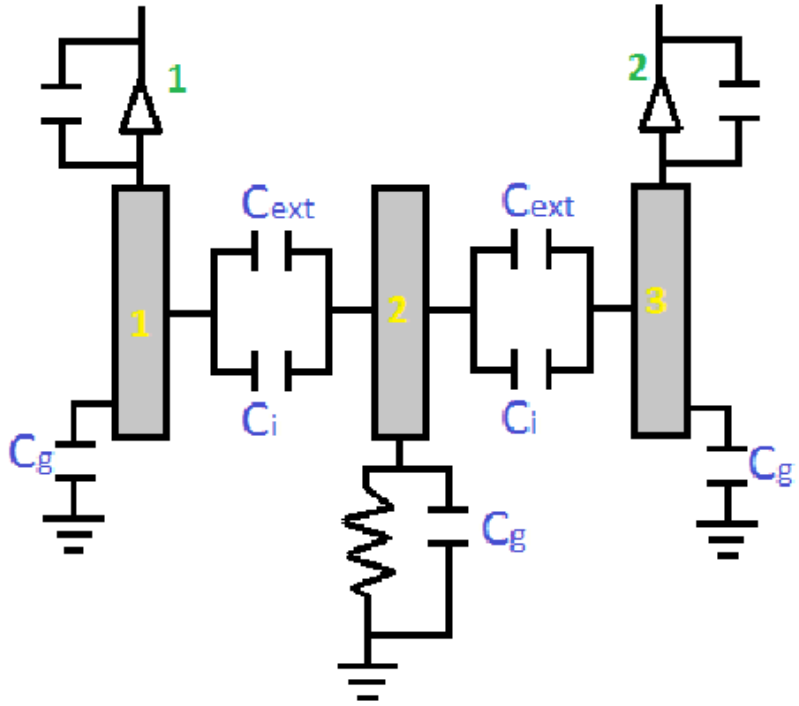
Intrinsic Capacitances

- Inter-strip
- Strip-to-Ground

$$Ci = \frac{\frac{Pb2}{Pb1} - 2}{\frac{Pa2}{Pa1} - \frac{Pb2}{Pb1}} Cextb$$

$$Cg = (\frac{Pa1}{Pa2} - 2)(\frac{\frac{Pb2}{Pb1} - 2}{\frac{Pa2}{Pa1} - \frac{Pb2}{Pb1}} Cextb)$$



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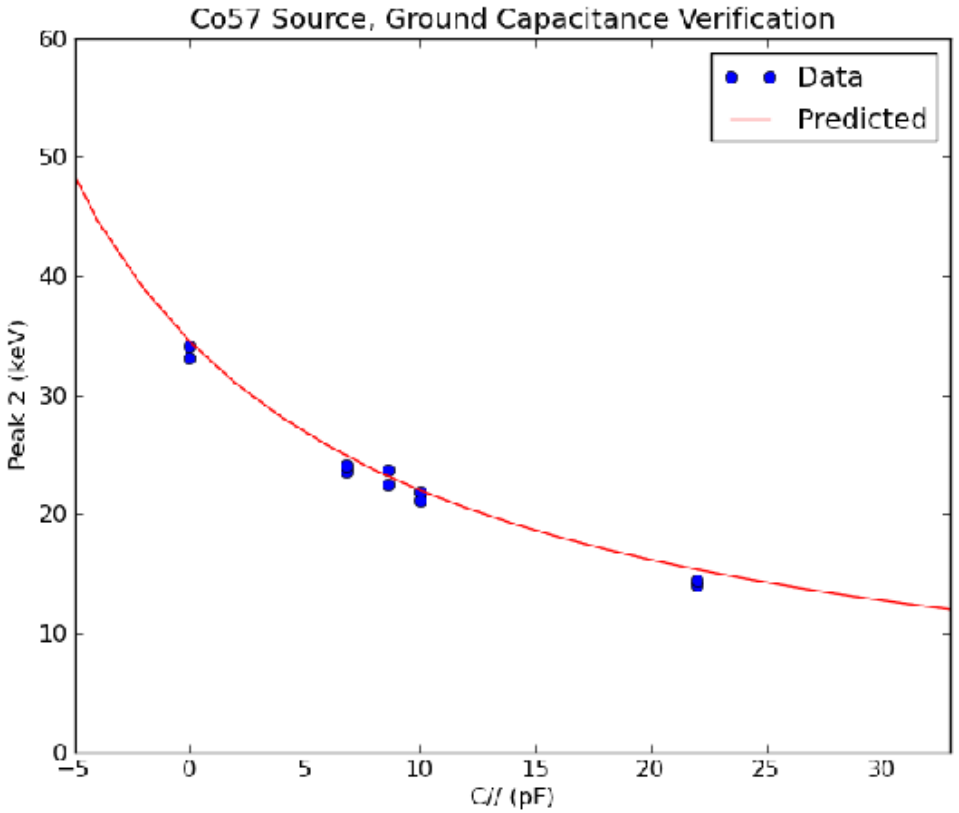
Intrinsic Capacitance Results Cont.

- Theoretical
  - Ci = 4.5pF
  - Cg = 7.0pF
- Measured
  - Ci = 4.74pF
  - Cg = 7.37pF
- Sources used:
  - Cs-137
  - Co-57



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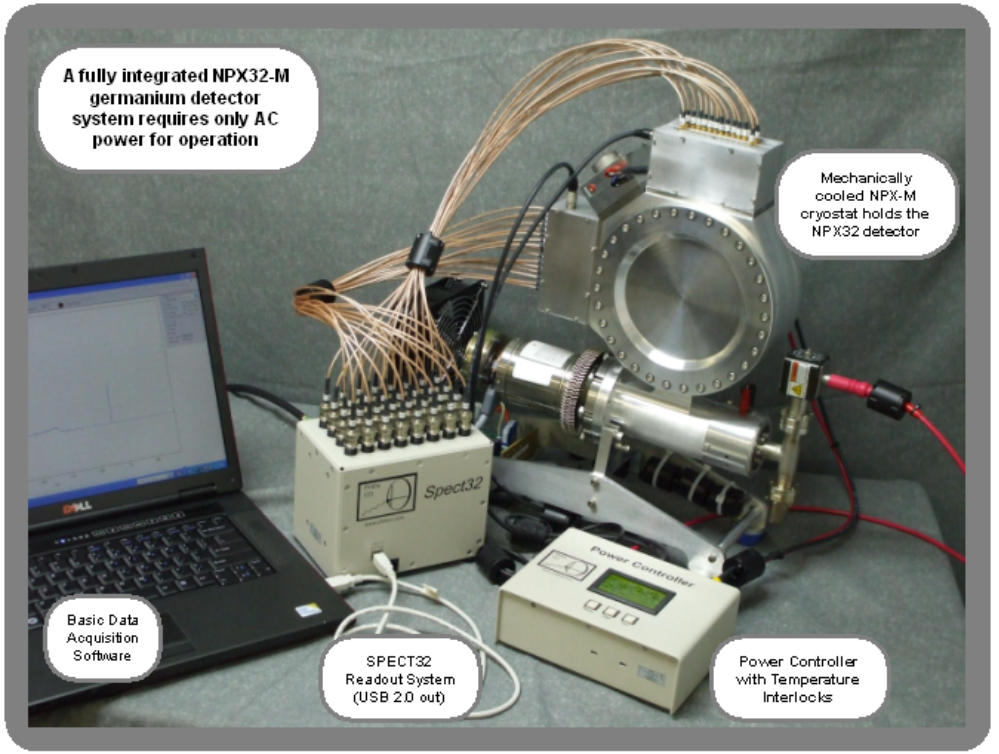
Future Work

- Parallel wiring set-up
- Use both sides of the detector
- Try it out on a coax detector



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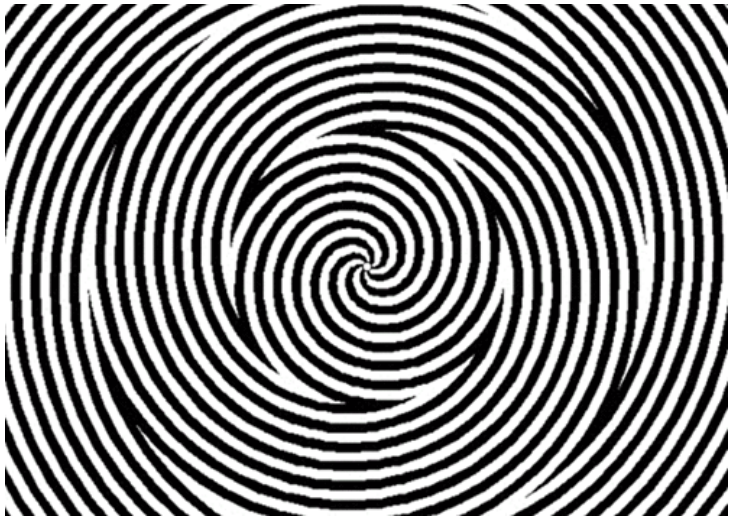
Questions?



References:

[1] Vetter, K., Burks, M., Mihailescu, L., "Gamma-ray imaging with position sensitive HPGe detectors", NIM-A 525: 322-327 JUN 1 2004 (2004).

[2] U. Kotz et al. Nucl. Intrs. and Meth. A235 (1985) 481-487.

[3] W. R. Th. Ten Kate et al., Nucl. Intrs. and Meth. A234(1985) 389-400.

[4] W. Dabrowski et al. Nucl. Intrs. and Meth. A349 (1994)424-430.

[5] R. A. Kroeger et al. IEEE Trans. on Nucl. Sci. Vol.42,NO. 4, (199) 428-431.

[6] J. B. A. England et al. Nucl. Intrs. and Meth. A185(1981) 43-47.

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References:

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Errors in Measurement

- Electronic Noise
  - 60 Hz peaks (inadequate notch-filters)
  - Cables adding capacitance
  - Ground loops & extra peaks
- Mechanical Noise
  - Vibrations
  - Ice crystal frosting
- Thermal Noise
  - Poor IR shielding (adds to background)
  - Dewar (refilling N2)
- Crystal Noise
  - Strip damage
  - Incorrect calibration

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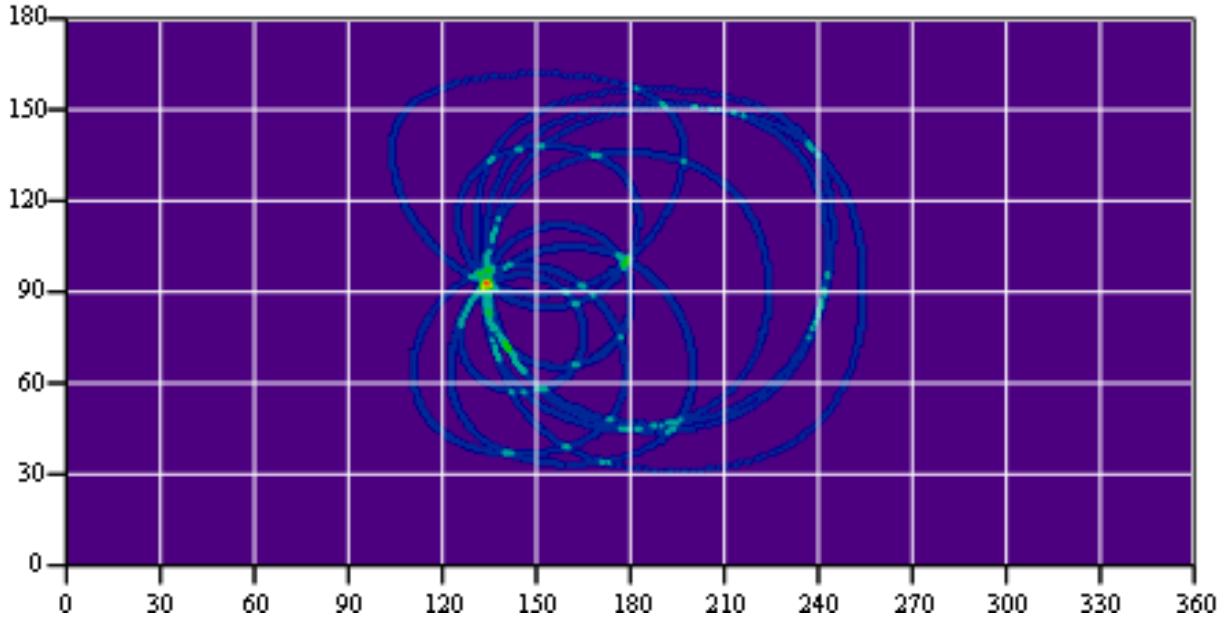

image1

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HPGe Imagers

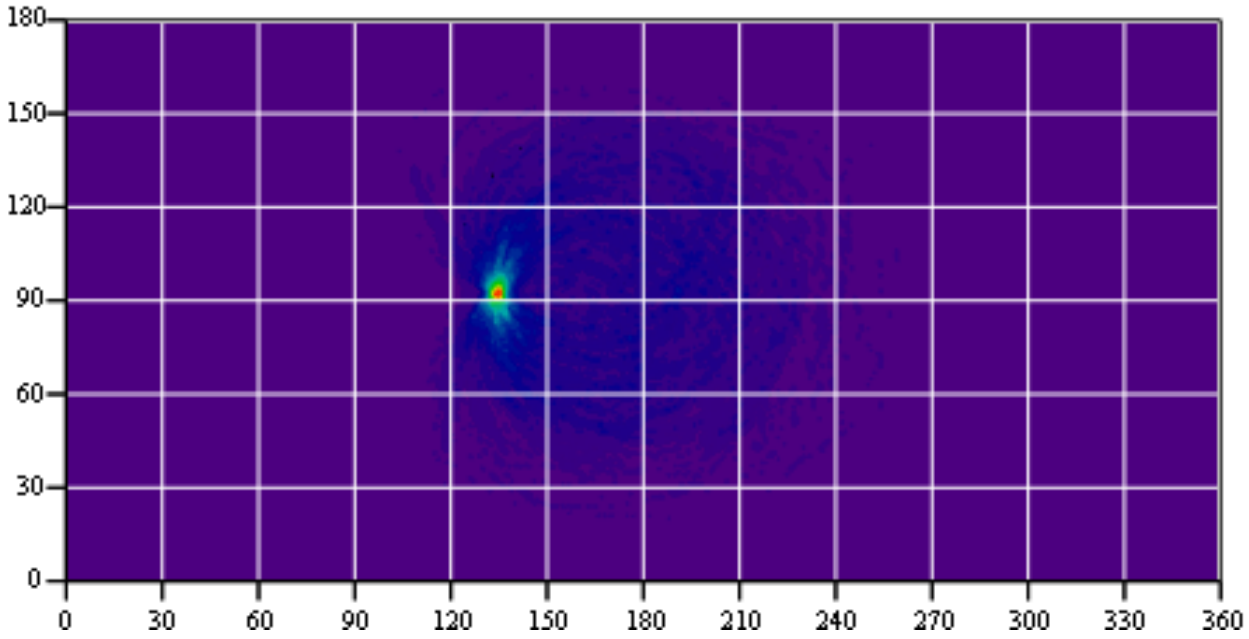

image1

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