PERFORMANCE CHARACTERISATION OF CANBERRA STRIP DETECTOR SYSTEM FOR IMAGING APPLICATIONS

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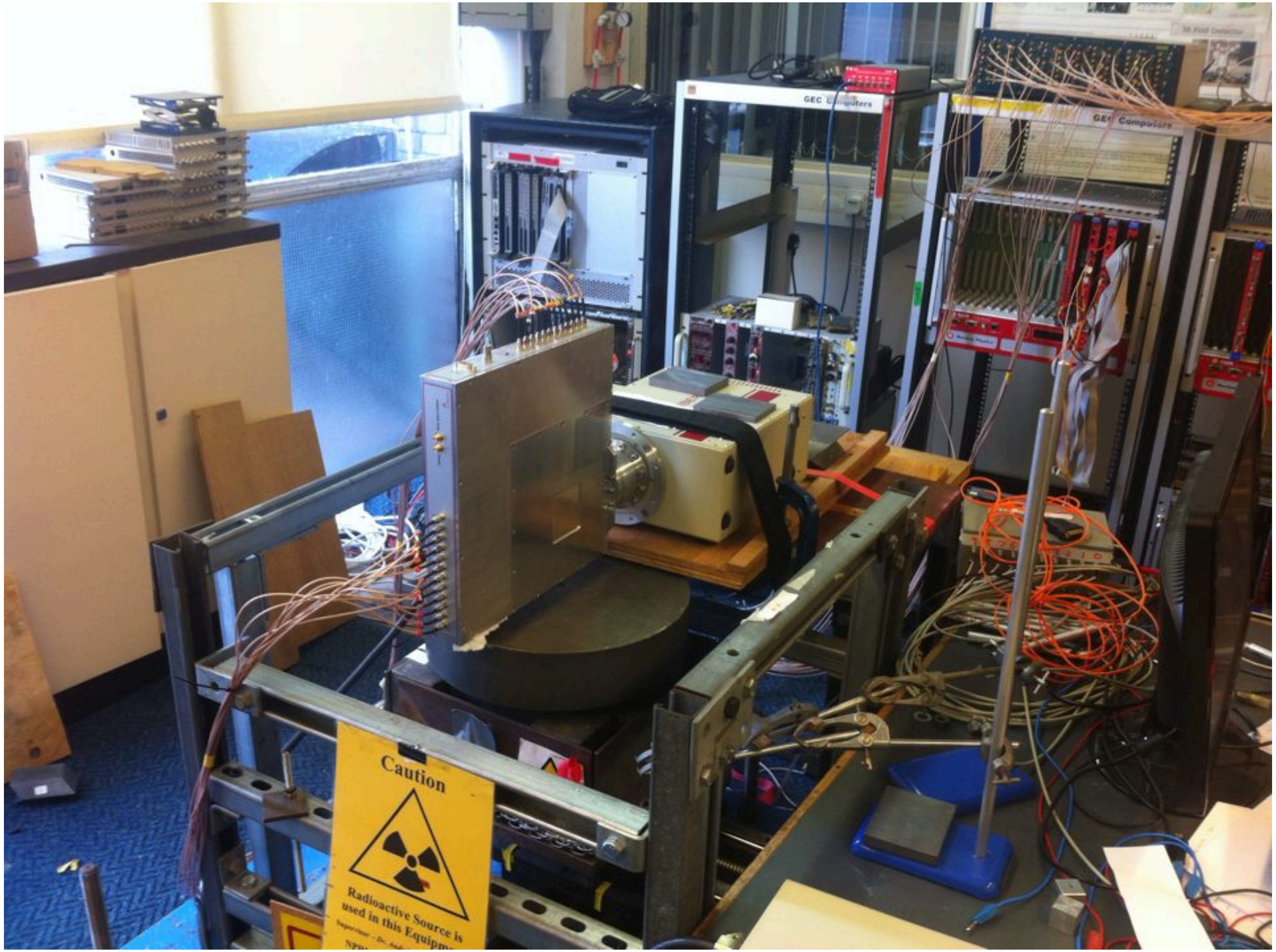
Why Characterise

- HPGe planar detector for use in Liverpool Compton camera system (along with planar Si(Li) and HPGe coaxial)
- Imaging relies on position and energy resolution
- Improve position resolution through PSA
- What is the uniformity of the detector's response
- How can we correct for variations in the response for imaging
- Field lines within the detector

The Detector



- HPGe detector manufactured in 2015 by Canberra
- Electrically cooled by Cryo-Pulse 5
- Record power draw and crystal temperature

Detector information

- HPGe crystal of 60x60x20mm^3 active volume with an outer guard ring of 7.5mm
- Horizontal n+ contacts (AC) , vertical p+ (DC) - 5mm strip pitch

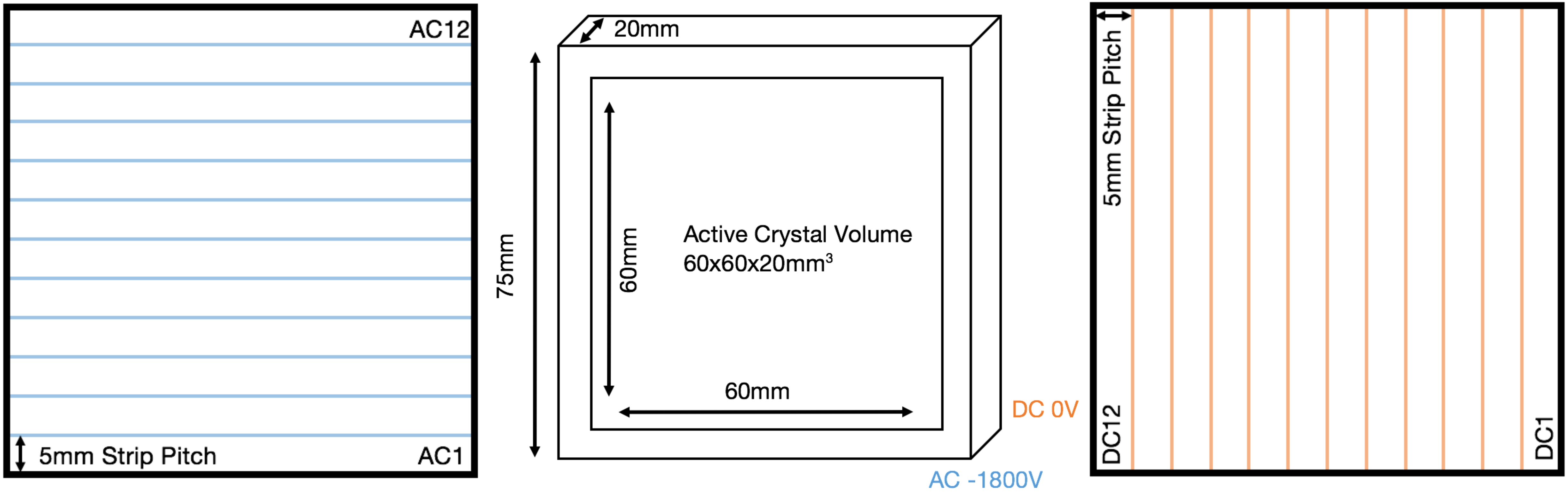
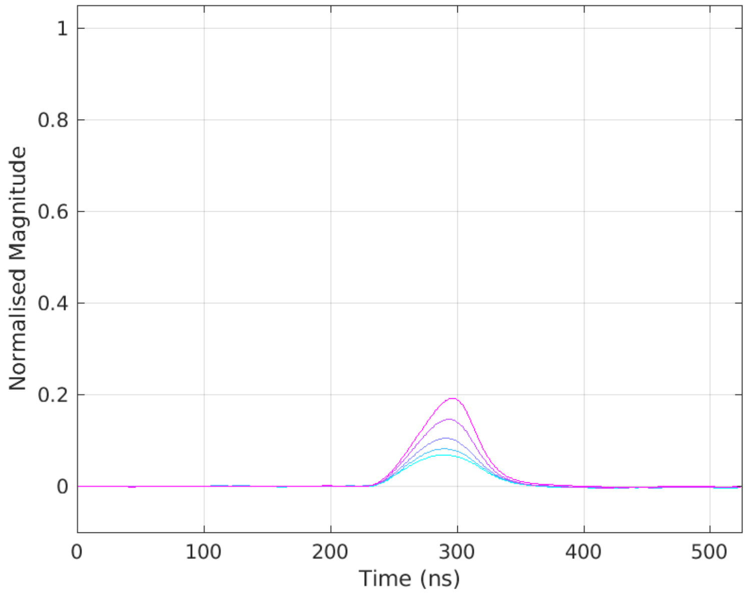


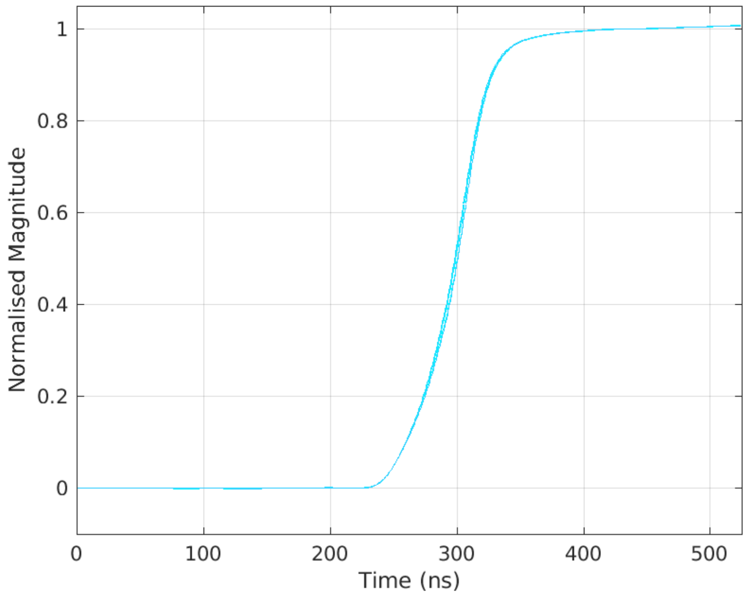
Image Charges Response

- Averaged pulses at 1mm positions across detector strip
- Good image charge response
- Uniform pulse across hit strip

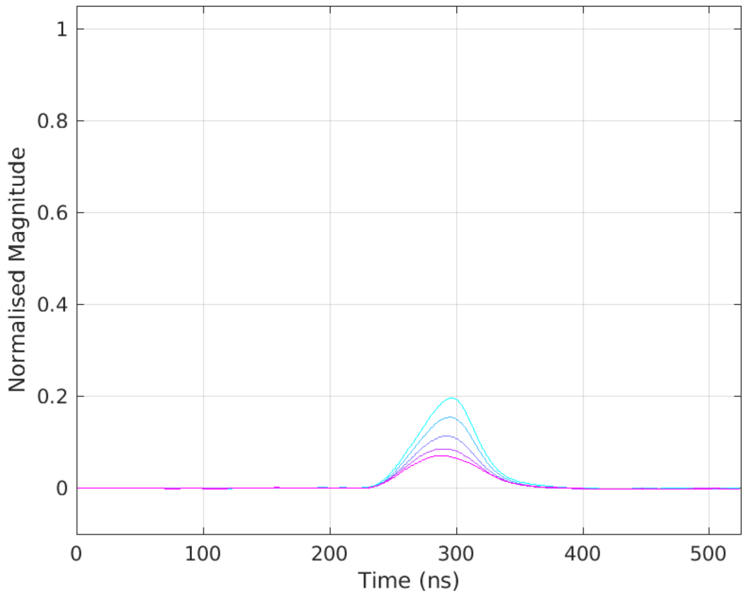
DC05



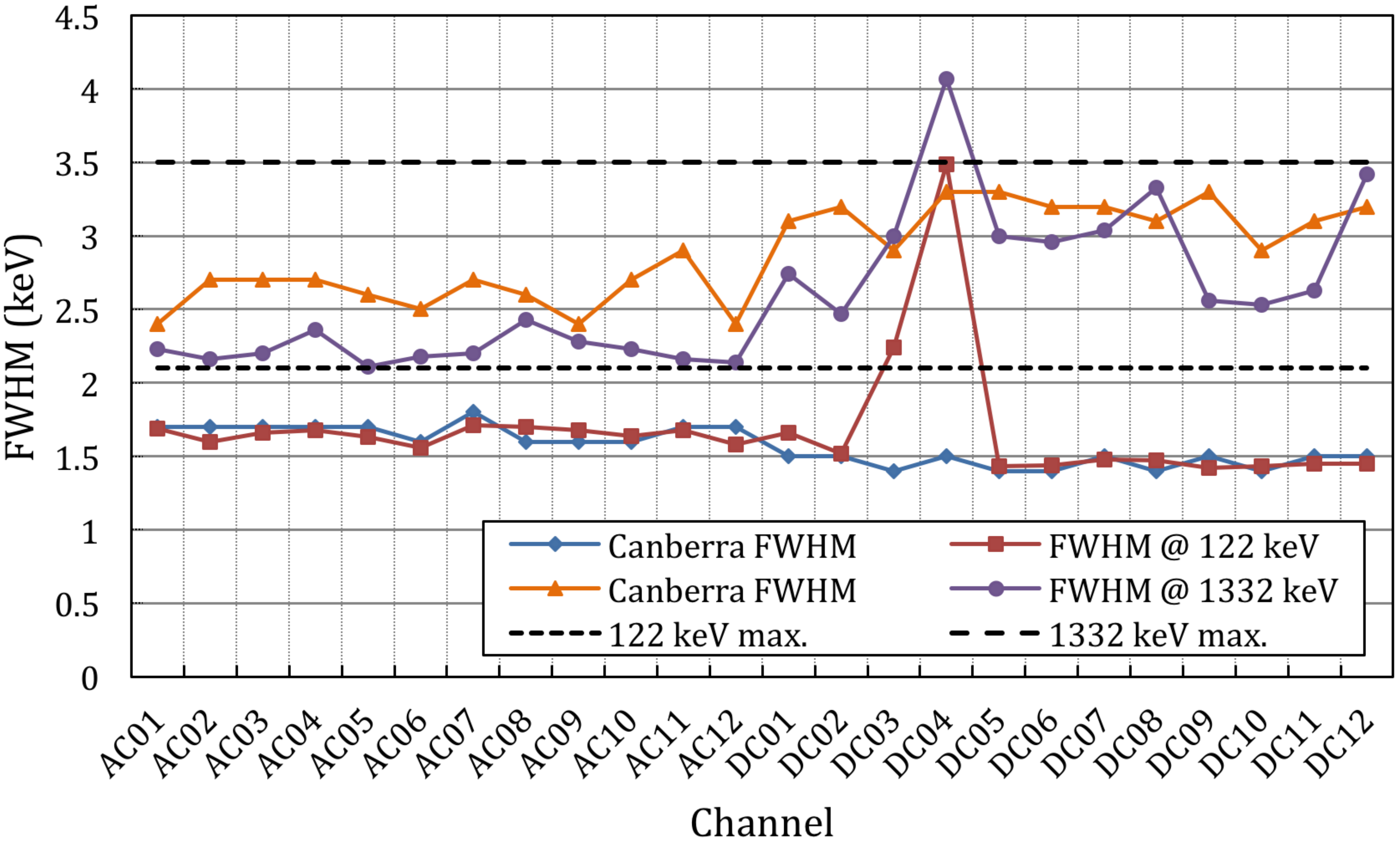
DC06



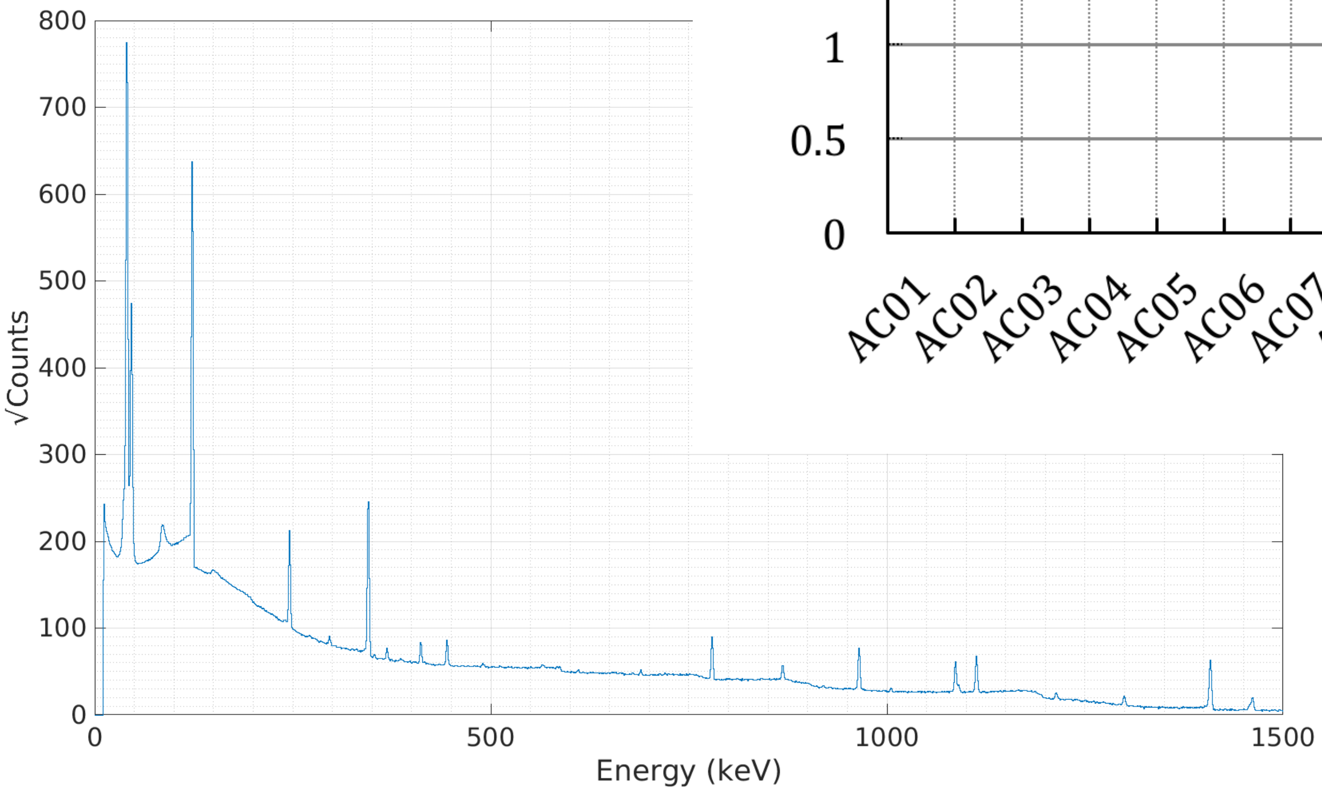
DC07



FWHM



Energy Spectrum – Eu-152



- Crosstalk present – proportional corrected for:

- 0.67% AC side
- 0.31% DC side

Scan Set-up

- 1640 MBq ^{241}Am with 1mm Tungsten collimator in lead block
- Scanned in 1mm steps using automated scanning arm, 10 seconds per position.
- ~4500 photopeak events per 1mm step
- 59.5keV photopeak – Actual Compton scatter events very low (5% that of the photoelectric absorption cross section)

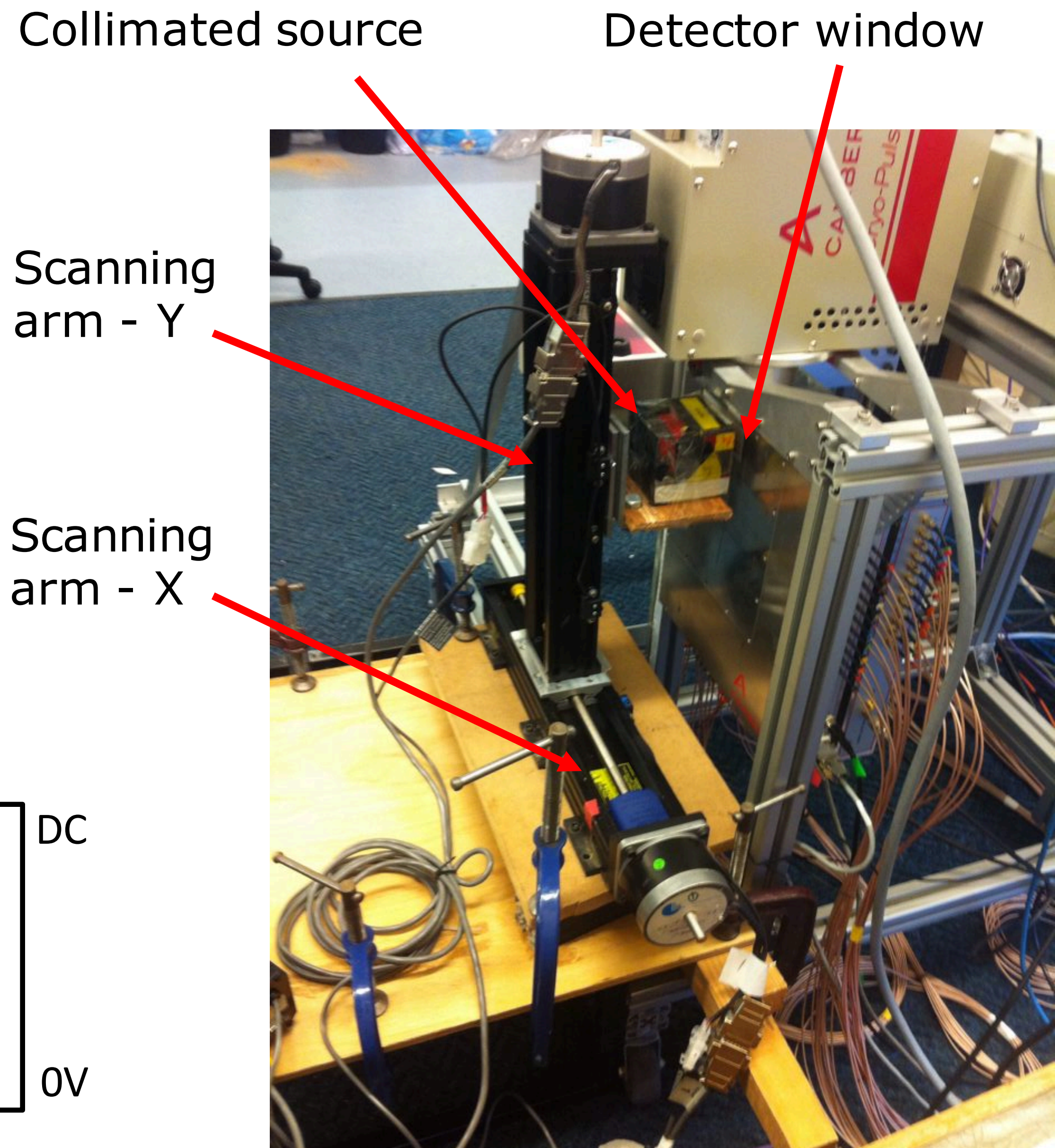
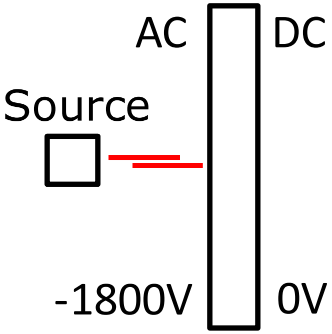
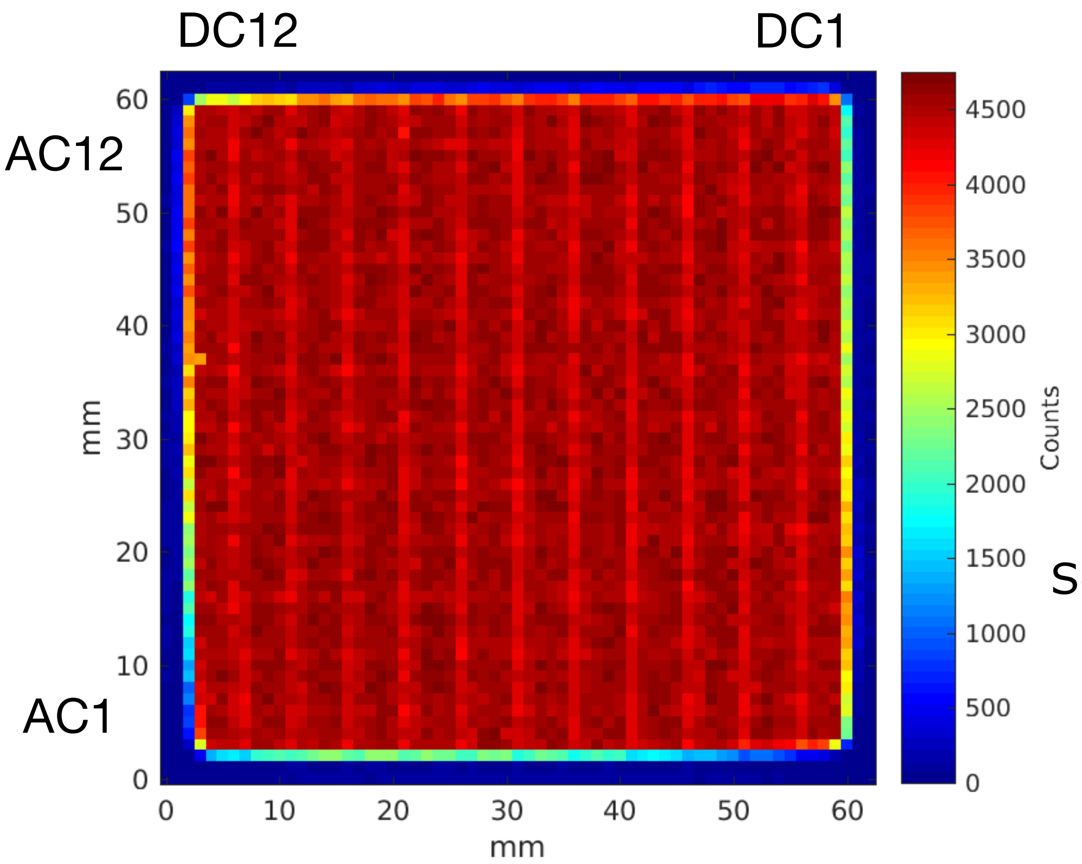


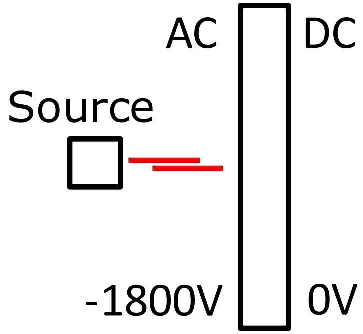
Diagram showing source location for each slide – response on AC or DC

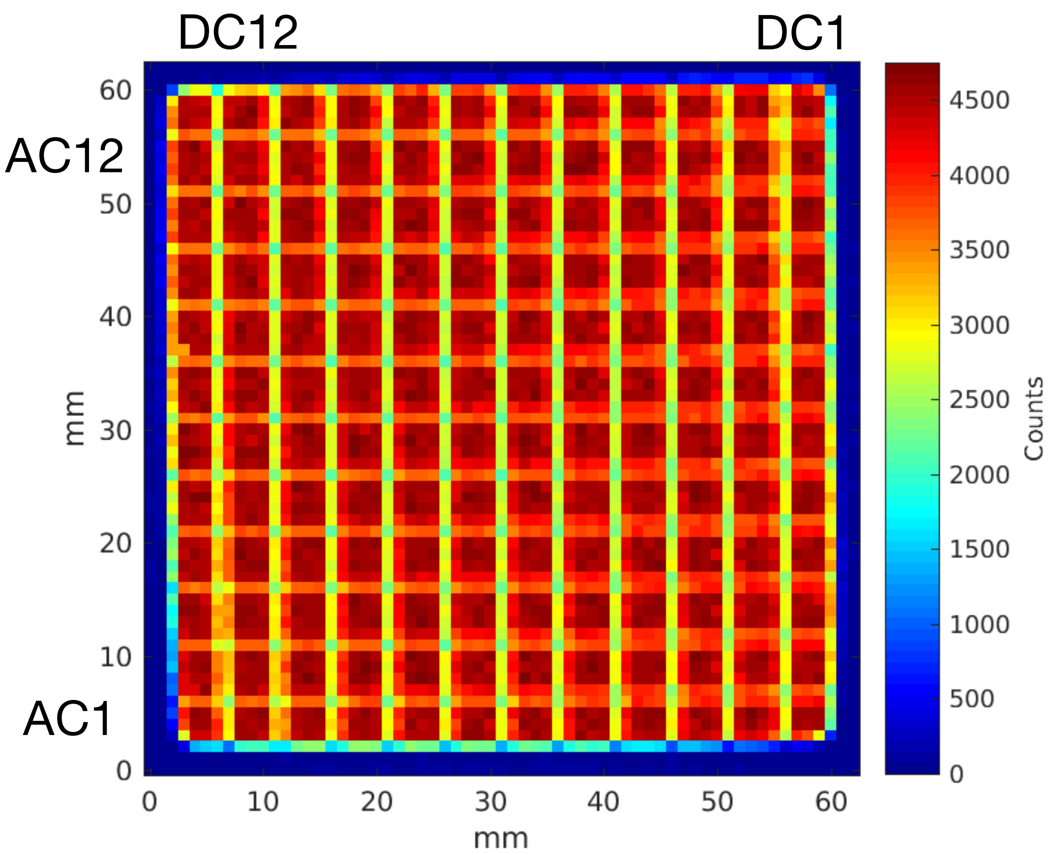


Uniformity Maps – AC Scan

- Left: Full photopeak event registered on AC and DC face – any fold
- Right: Full Photopeak on both sides but ALSO fold 1 on both sides

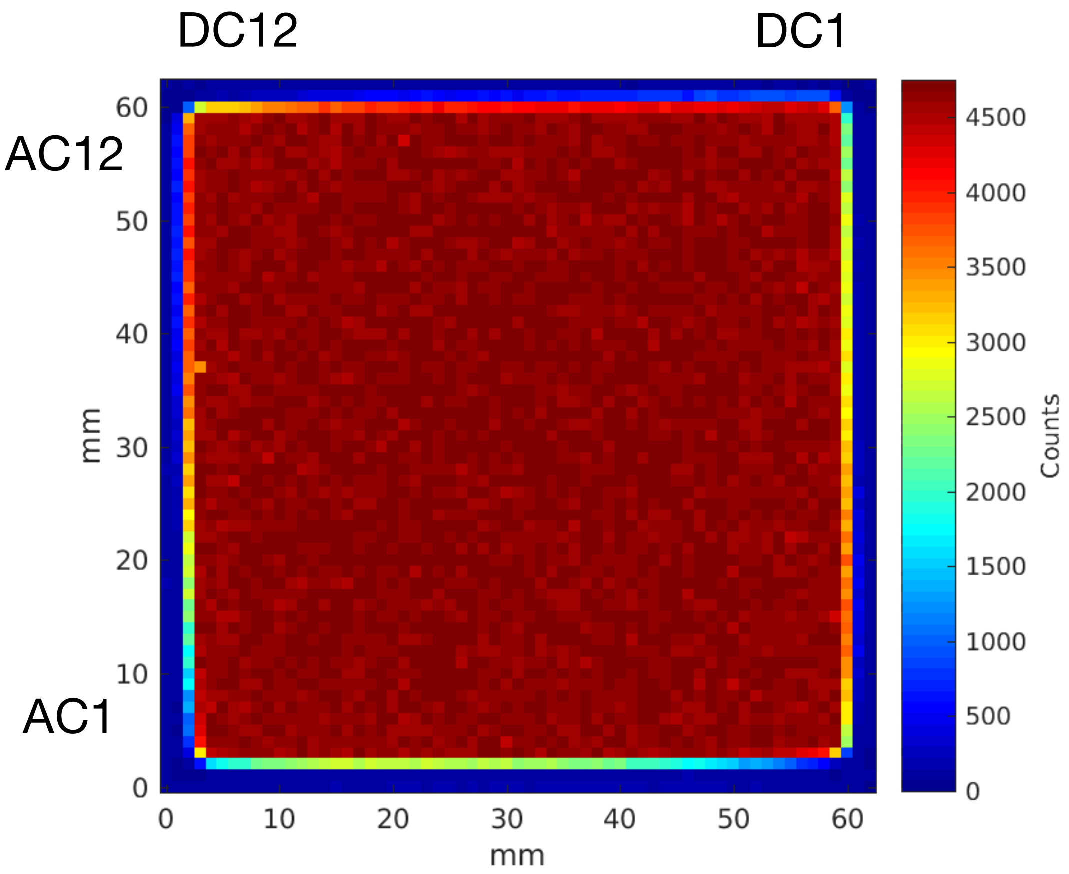






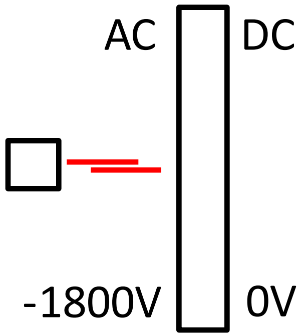
Intensity Slice – Wider Gates

- Low energy gate on photopeak reduced by 4keV to 52keV – uniform response seen



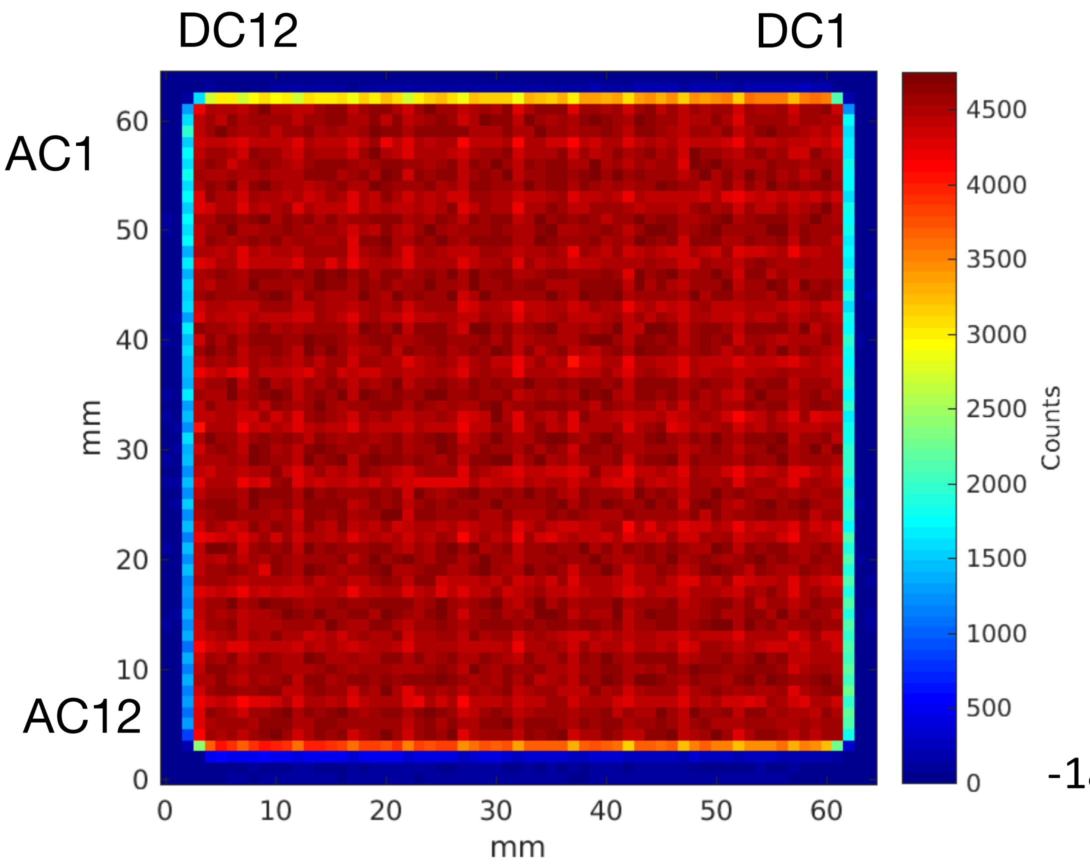
- Charge sharing – charge below threshold not seen

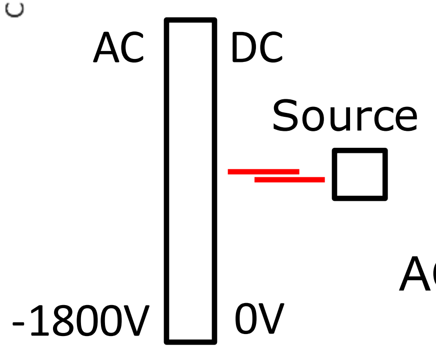
- Weak field lines – ballistic deficit = incomplete pulse seen

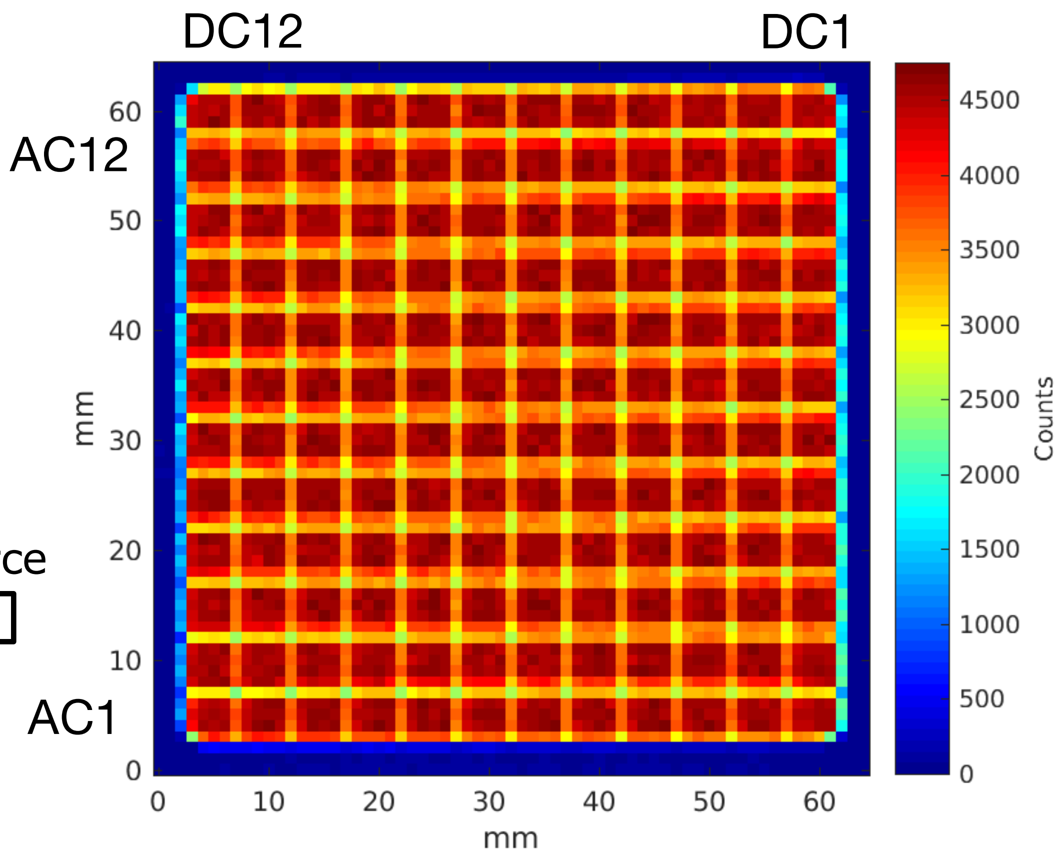


Uniformity Maps – DC Scan

- Left: Full photopeak event registered on AC and DC face – any fold
- Right: Full Photopeak on both sides but ALSO fold 1 on both sides



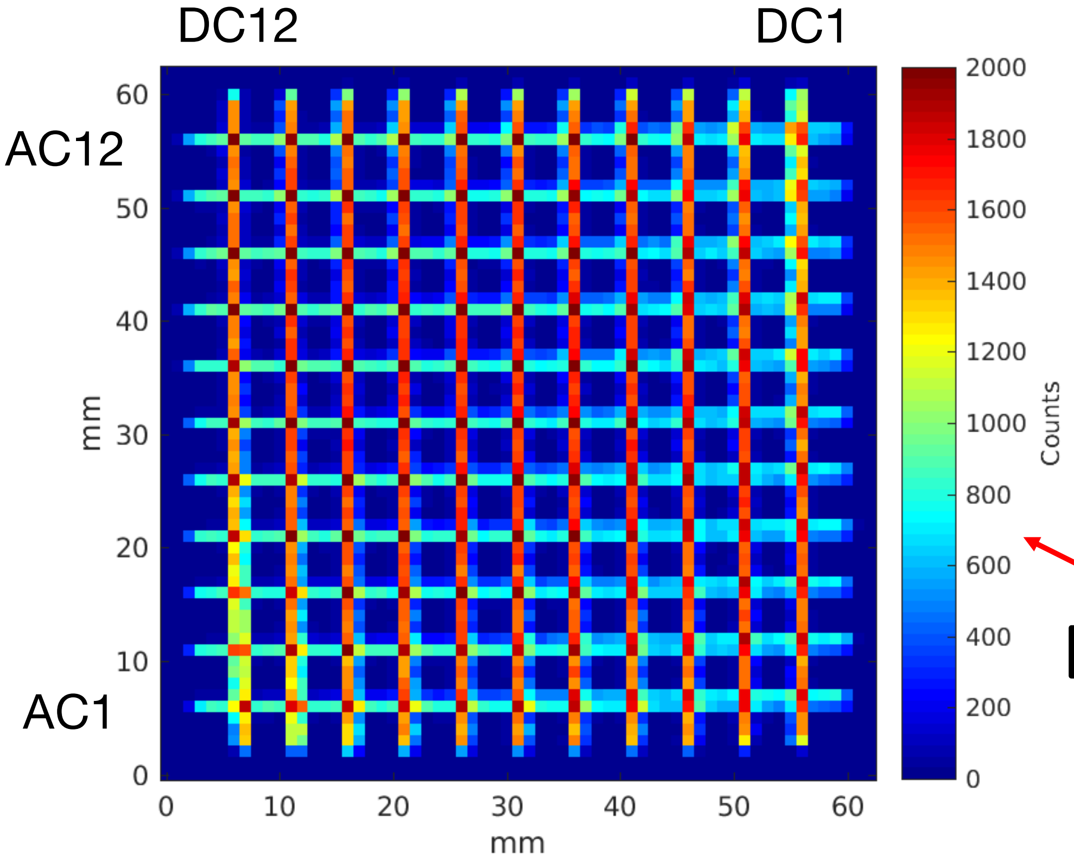


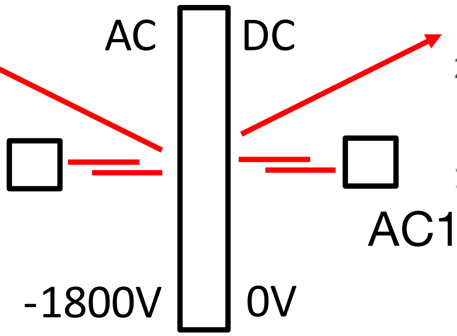


Uniformity Maps

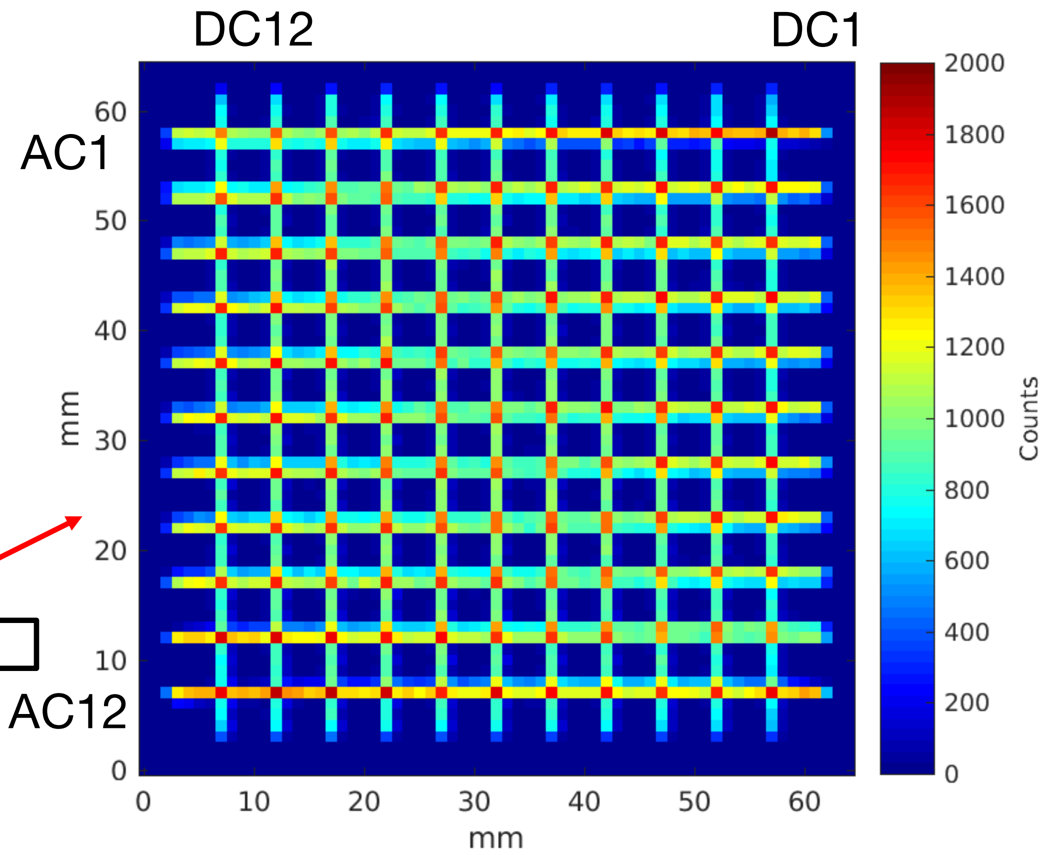
- Difference of adjacent plots from last two slides – faces see at least one multi-fold events

12% of total photopeak events





10% of total photopeak events



Charge sharing in inter strip gap

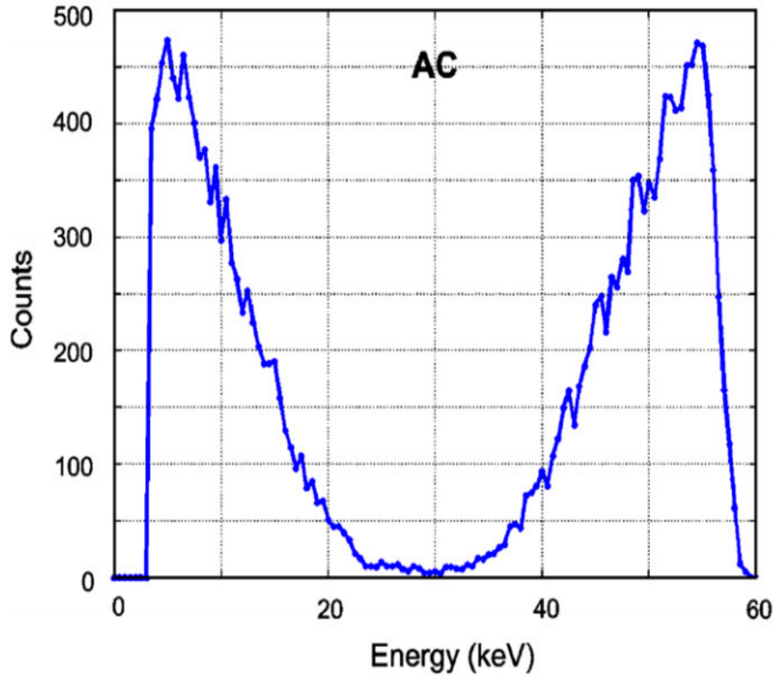
- Results from SmartPET Ortec made segmented HPGe detectors

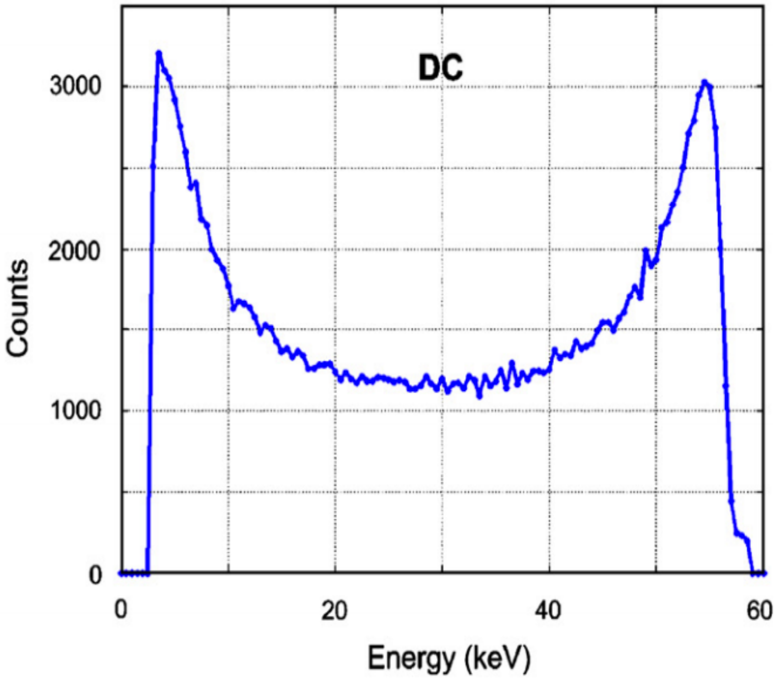
- Am-241: 59.54keV

$$E = \frac{E_0}{1 + \frac{E_0}{mc^2}(1 - cos\theta)}$$

$$E_0 = 59.4keV$$

Allowed energies: 0-11.4keV and 48.3-59.5keV

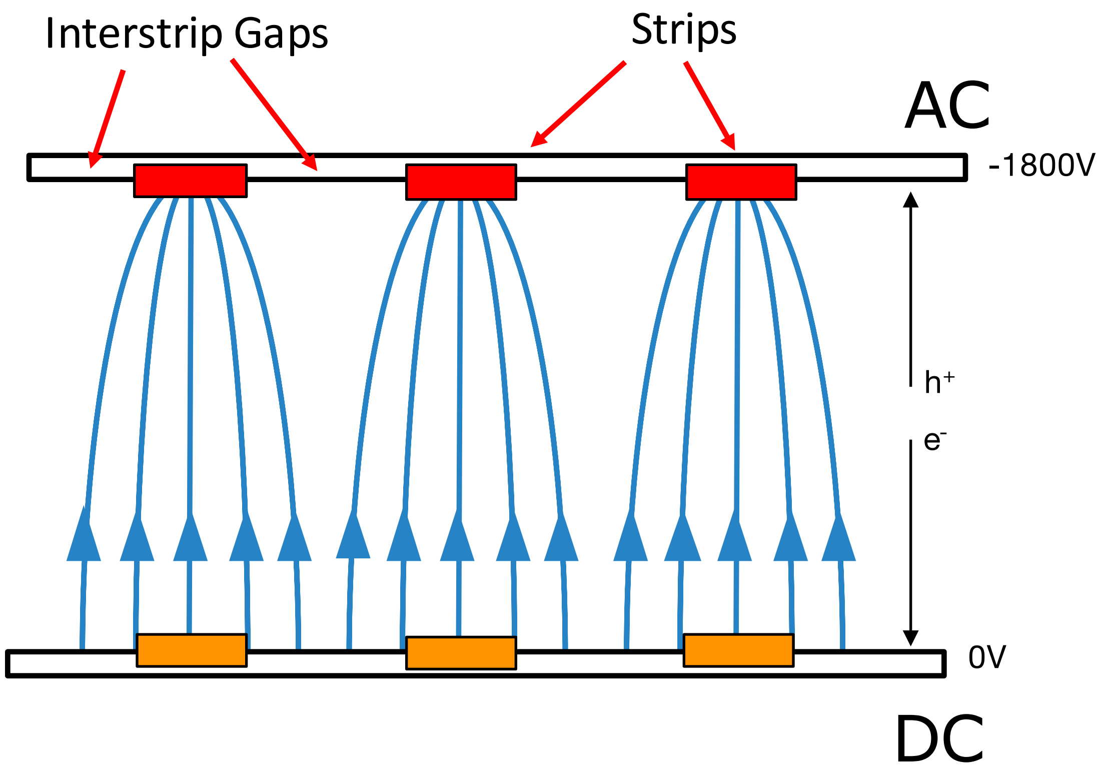




R.J. Cooper, et al., Nucl. Instr. and Meth. A 595 (2008) 401-409

Field Lines

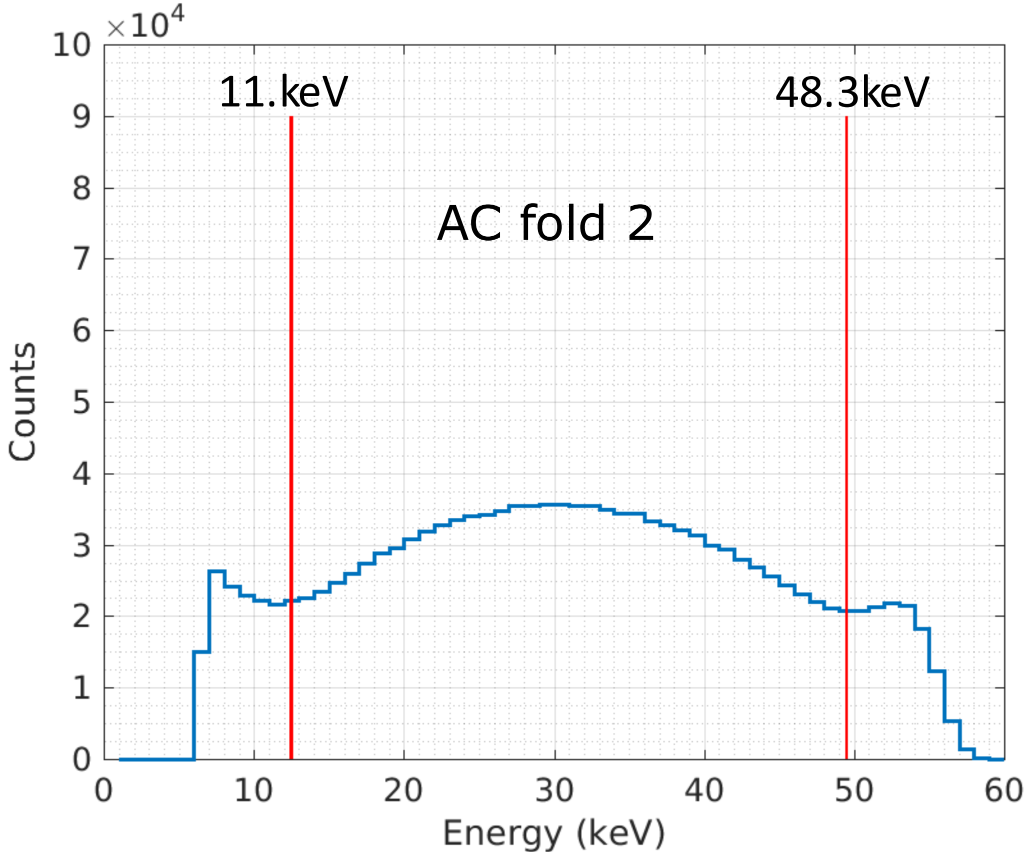
- Stronger lateral field line splitting near AC contacts
- Weaker splitting near DC
- Leads to increased charge sharing at DC contacts if interaction near AC face

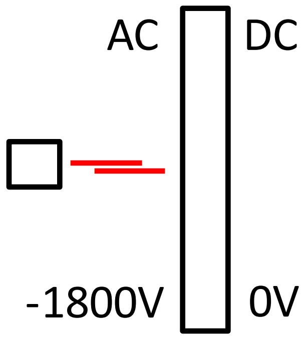


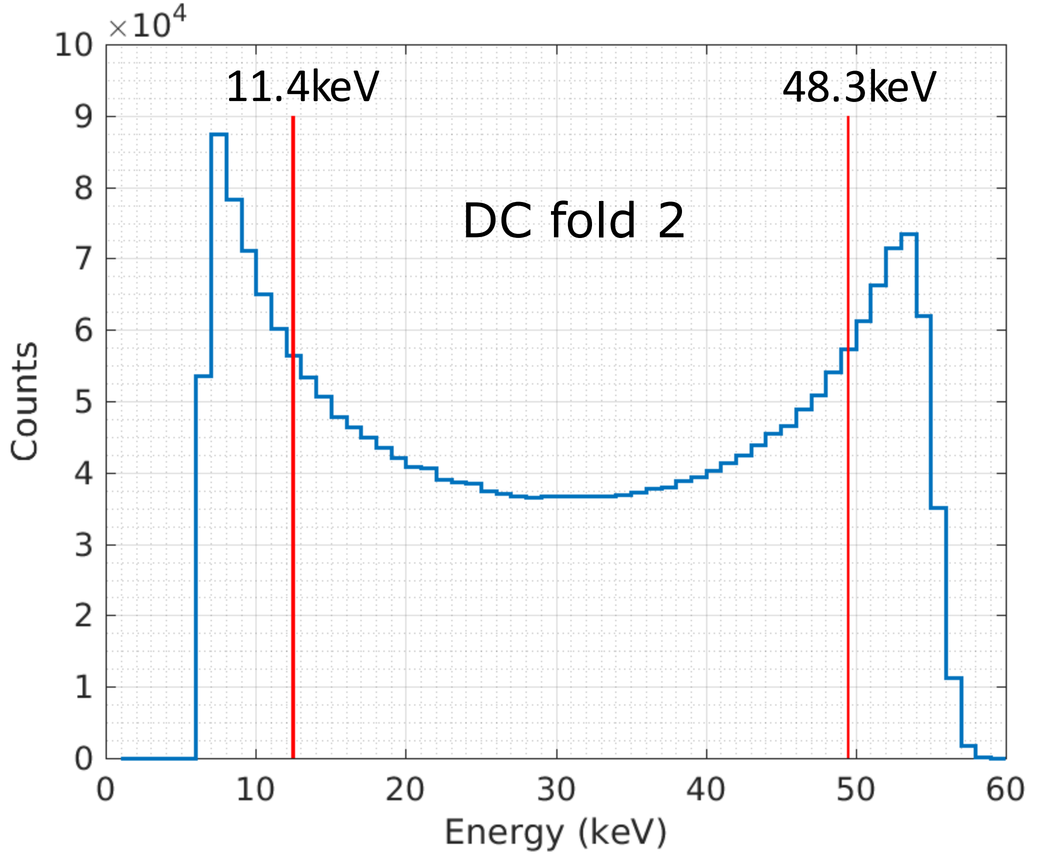
Fold 2 Energy Distribution - AC

- Fold 2 event occurs on AC side (for left) or DC side (for right) and the two events sum to give full photopeak

- Also require other face sees Fold 1 full photopeak event

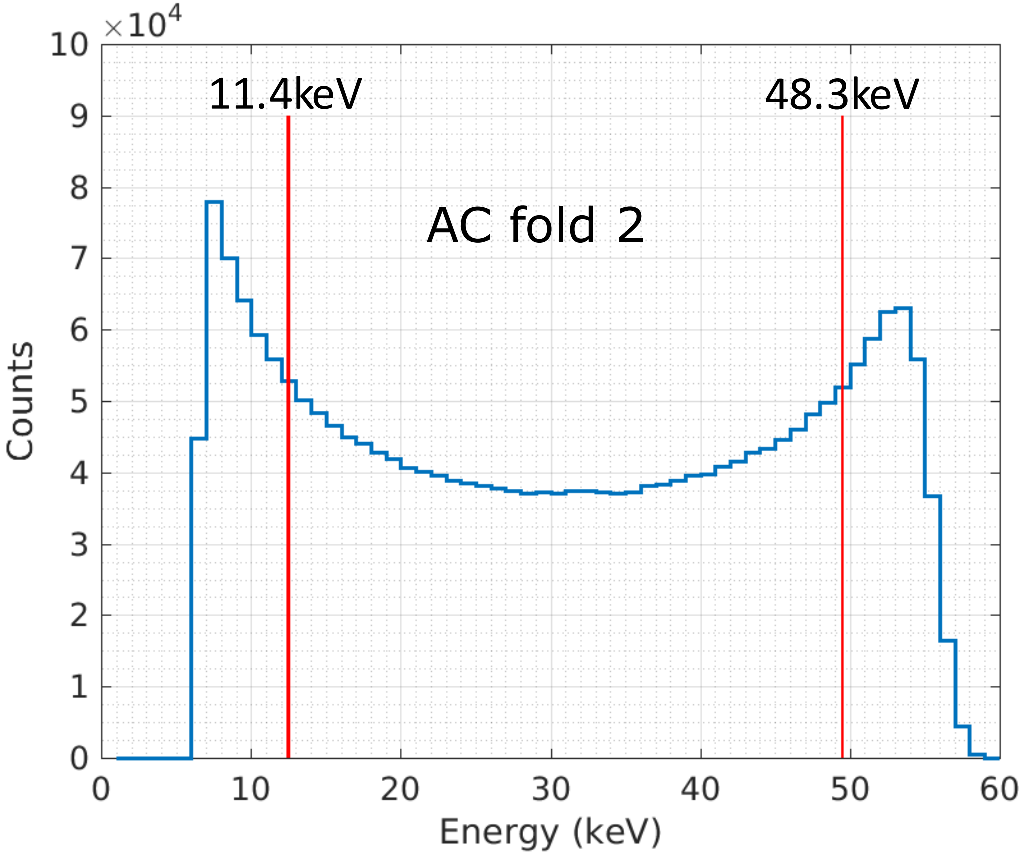


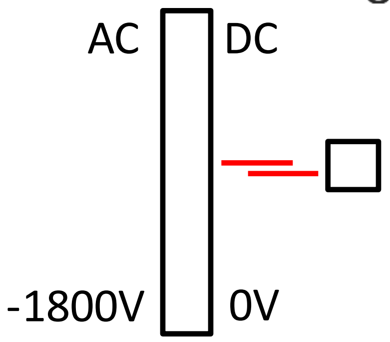


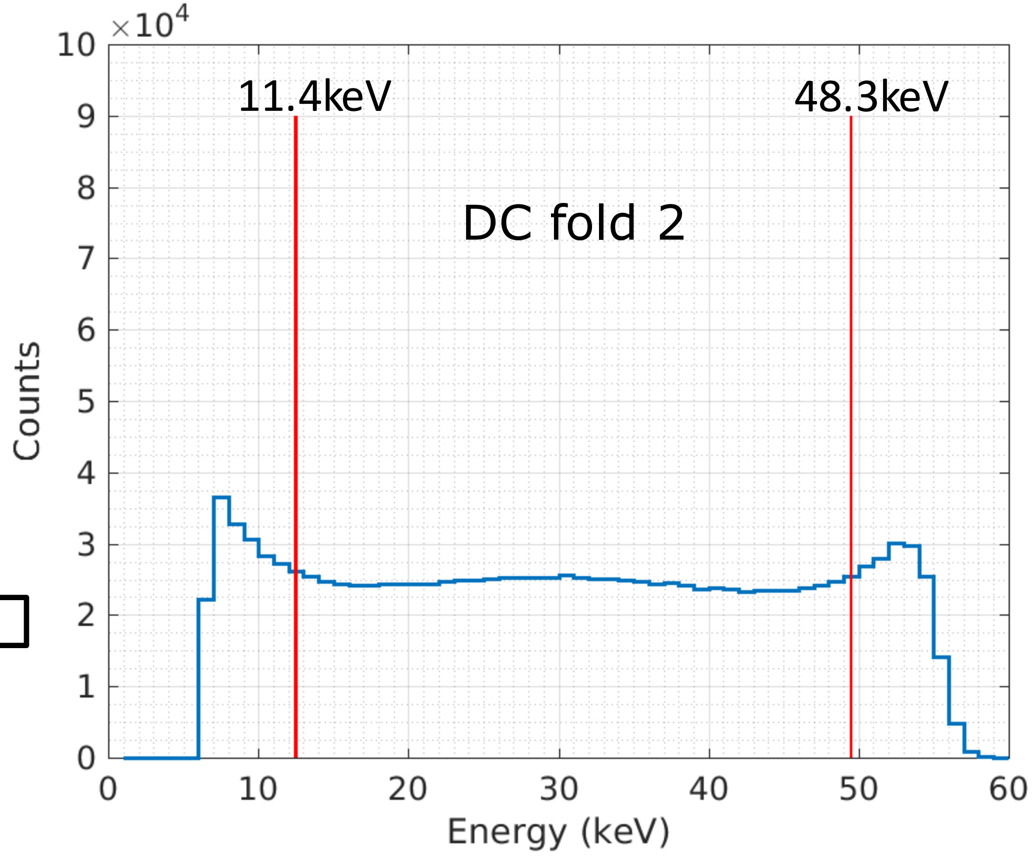


Fold 2 Energy Distribution - DC

- Same as before but DC side scan
- ’Hump’ on near side contacts less prevalent

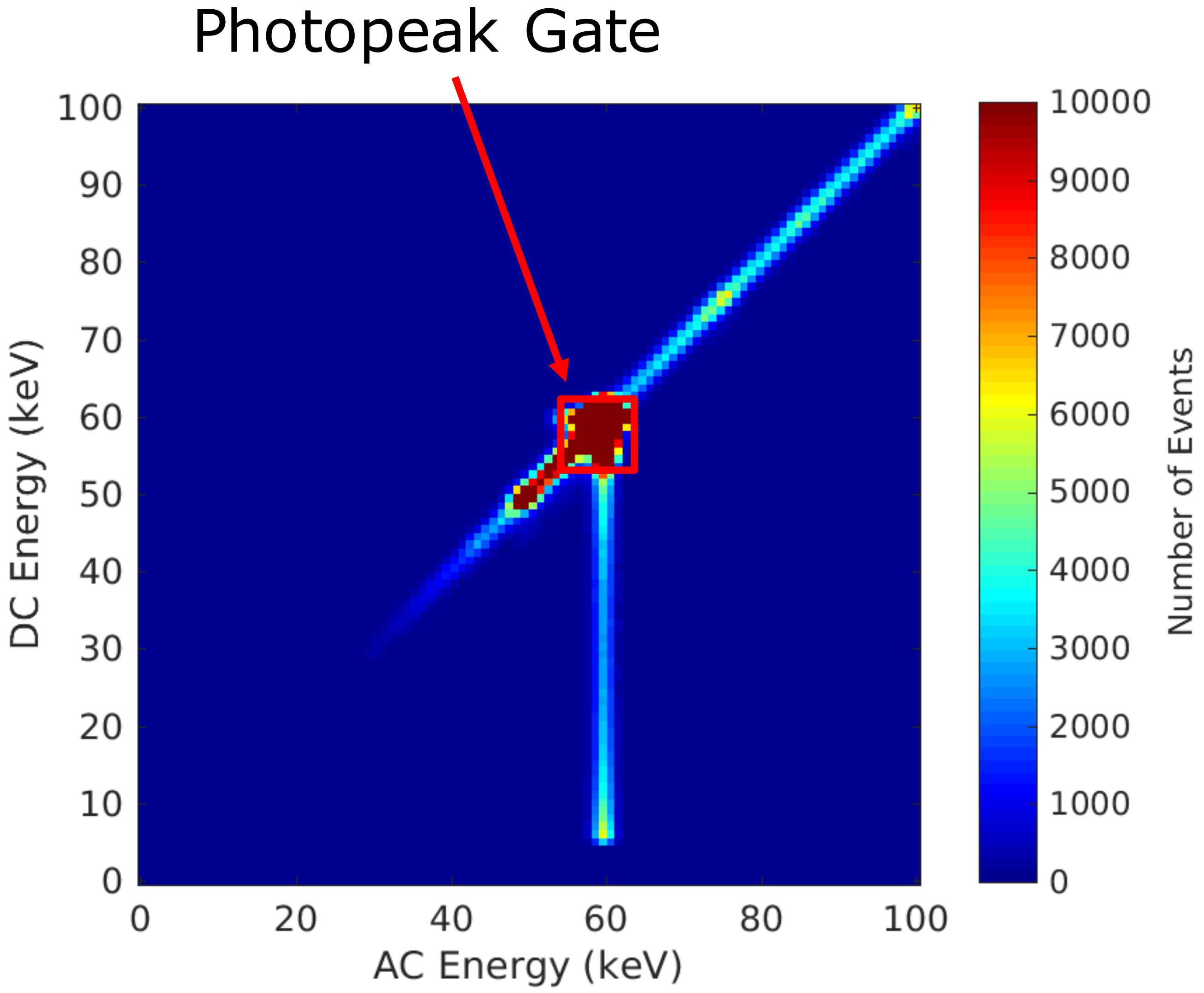






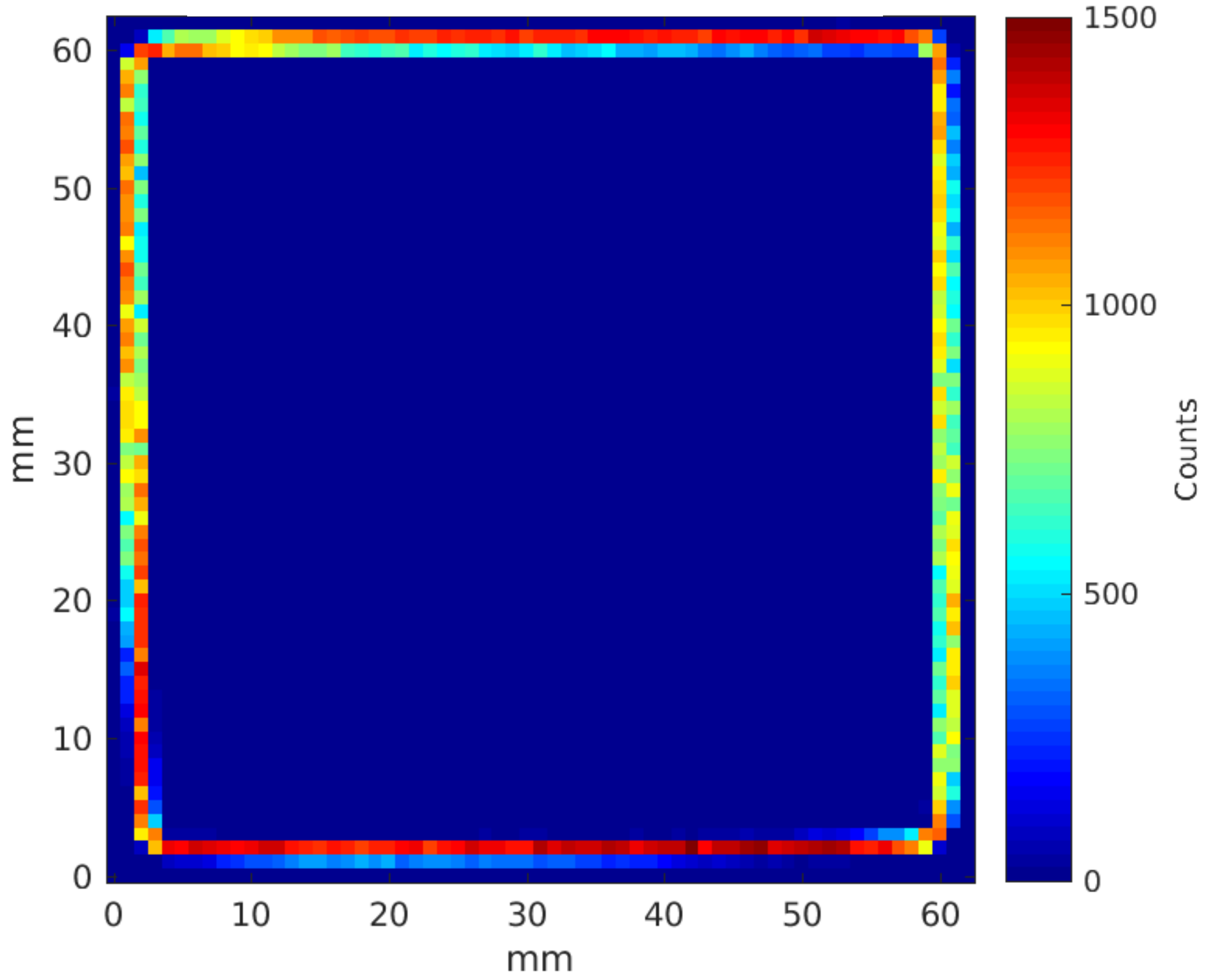
Charge Loss - Charge Collection

- DC is not collecting full charge on events where AC side registers full photopeak
- These occur fold 1 single interactions, not fold 2
- Avoidable in imaging – require full photopeak seen on both sides



Where does it occur?

- Loss of charge from the DC collection occurs at the boundary between strips and guard ring
- More seen when scanned from AC side than DC side
- Follows same pattern as preference for DC charge sharing

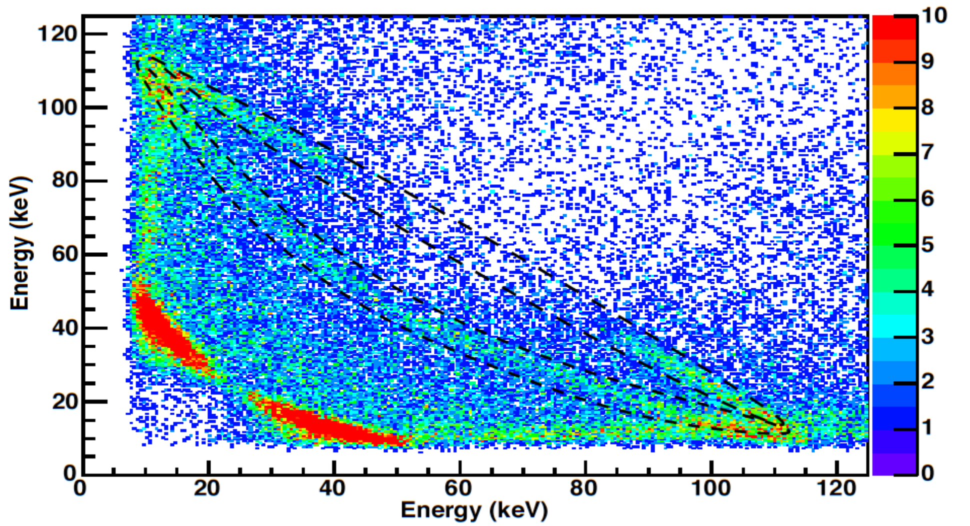


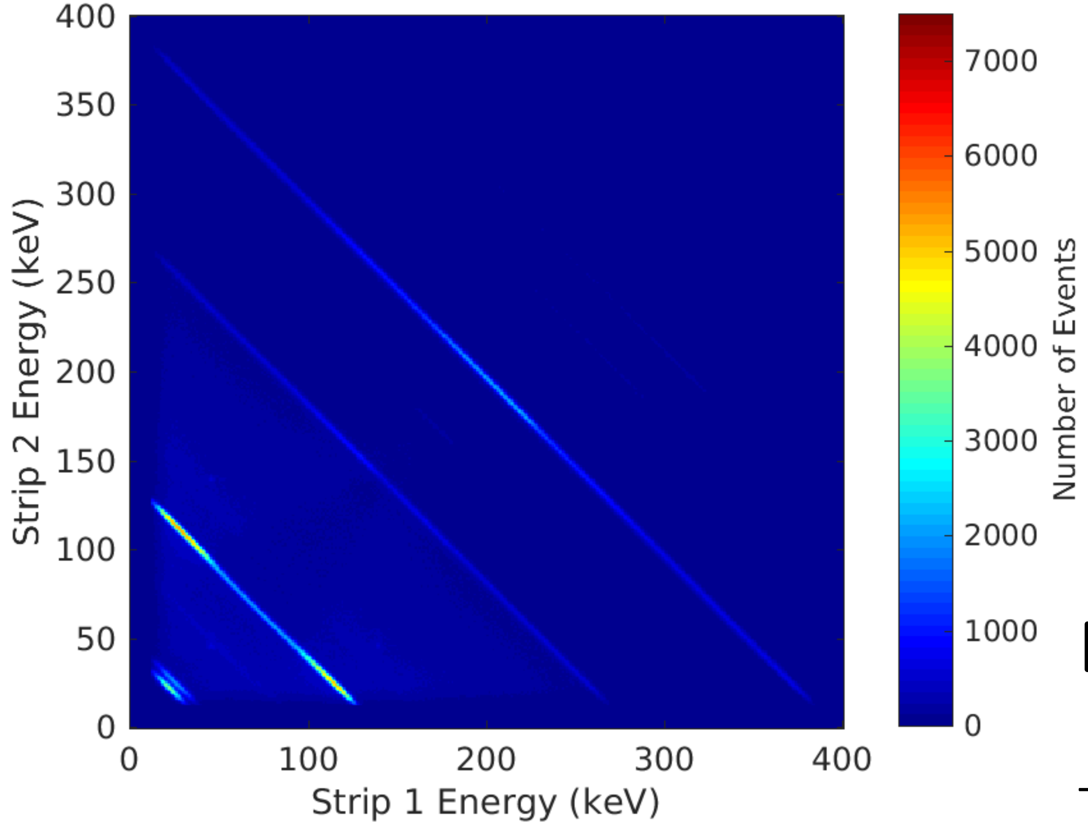
Charge loss - Gaps

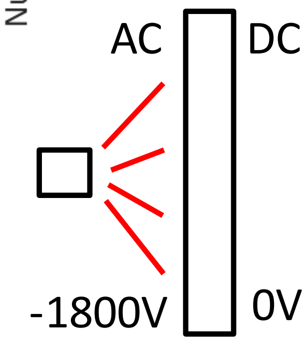
- Flood Eu-152 Source

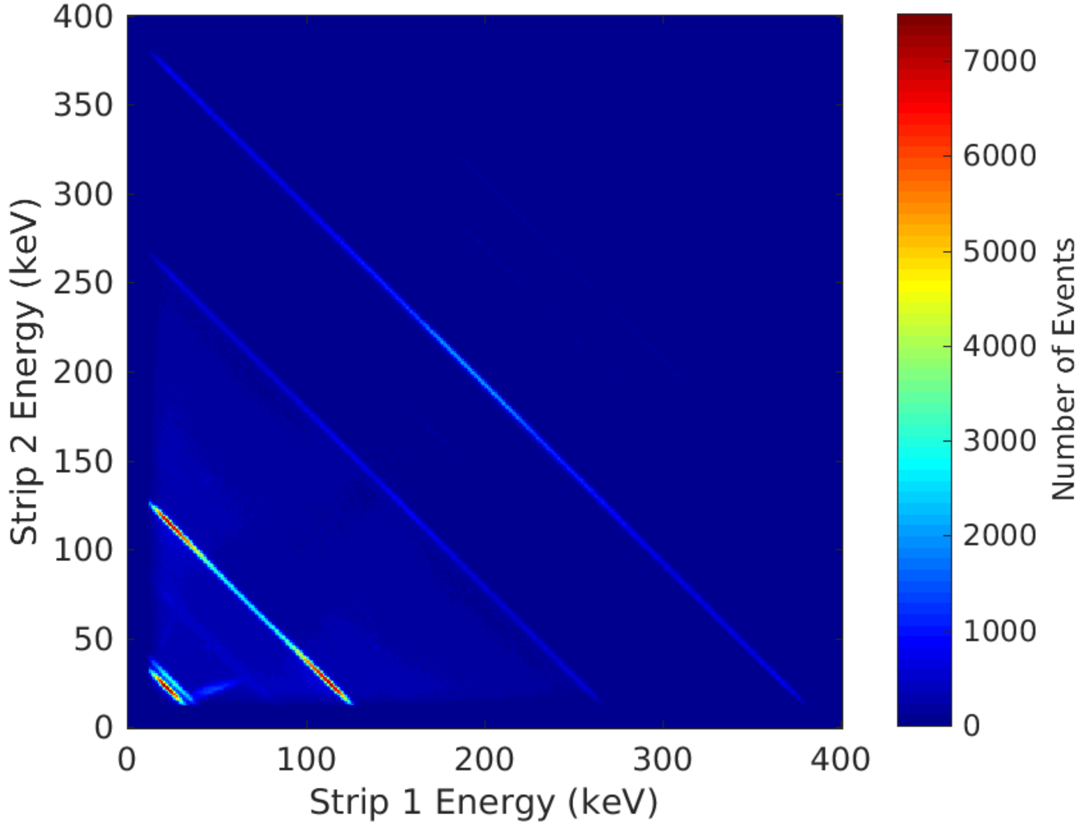
- No significant charge loss at any energies

J.L. Dobson, The characterisation and position resolution of a planar germanium strip detector, PhD Thesis





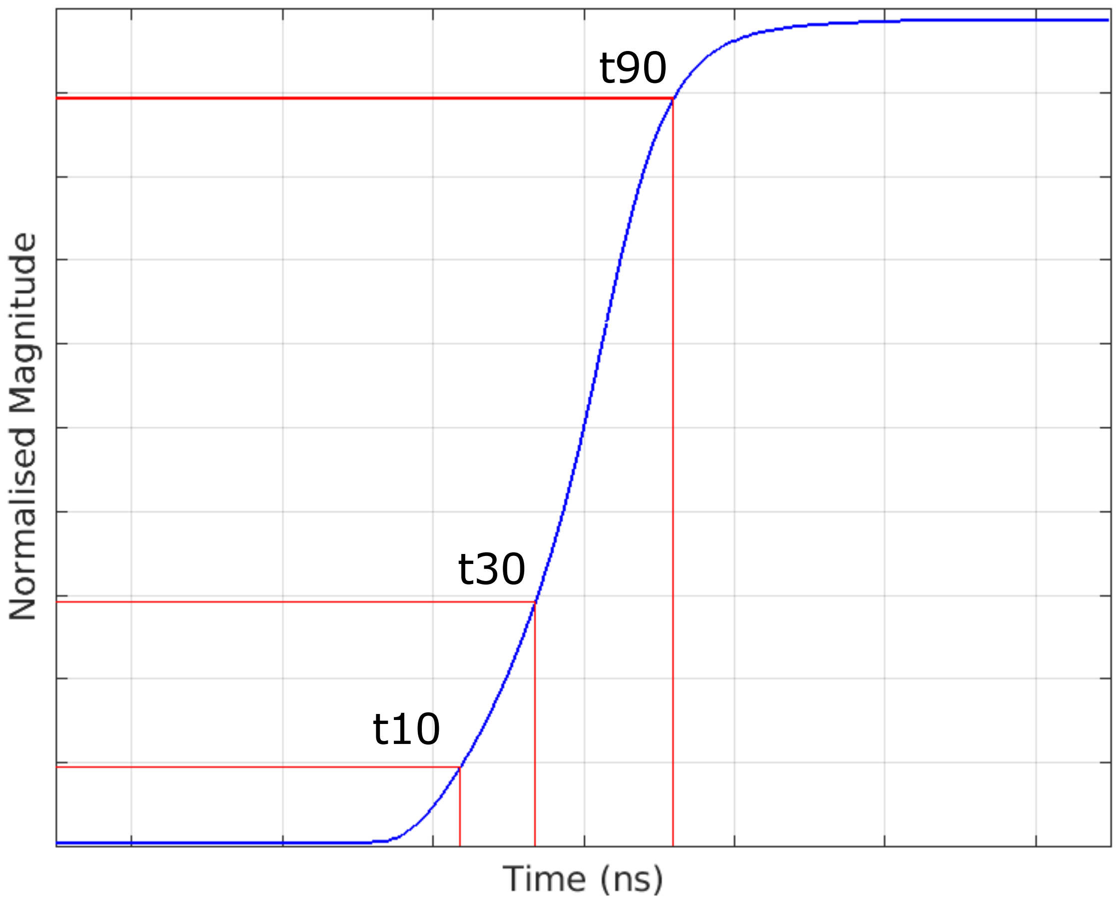




Risetimes

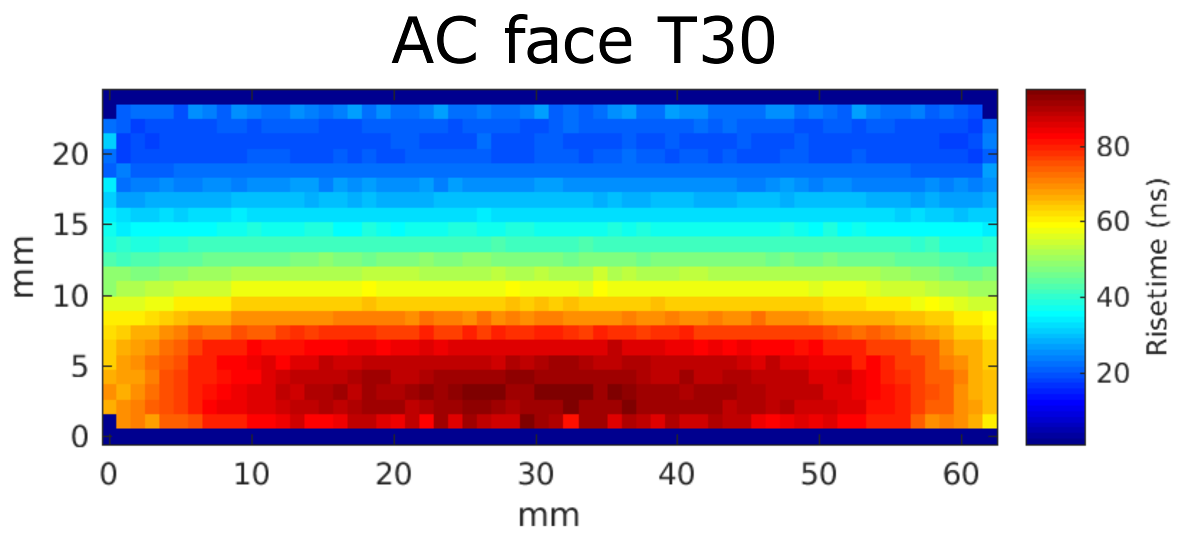
- Generic normalised pulse
- Parameterise this for depth PSA
- Surface scan revealed risetime behavior in front
- Side scan was also performed for risetime depth map

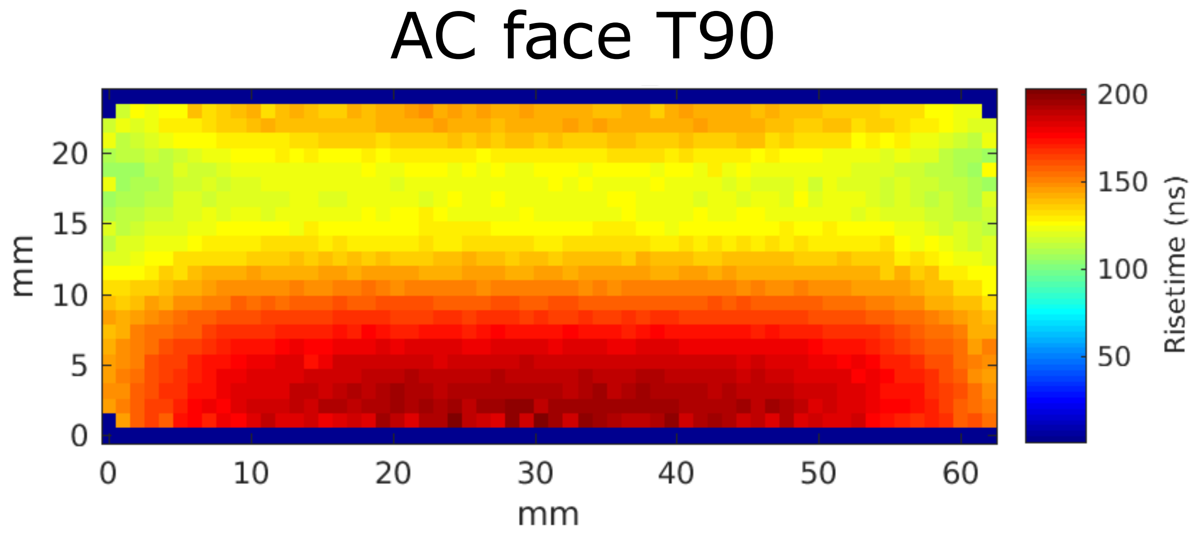
T90 = t90– t10
T30 = t30 – t10



Risetimes - Depth

- Detector was side scanned
- Risetime depth maps produced for use in PSA
- Lack of sensitivity seen in first and last few mm
- Investigated this area through the surface scans

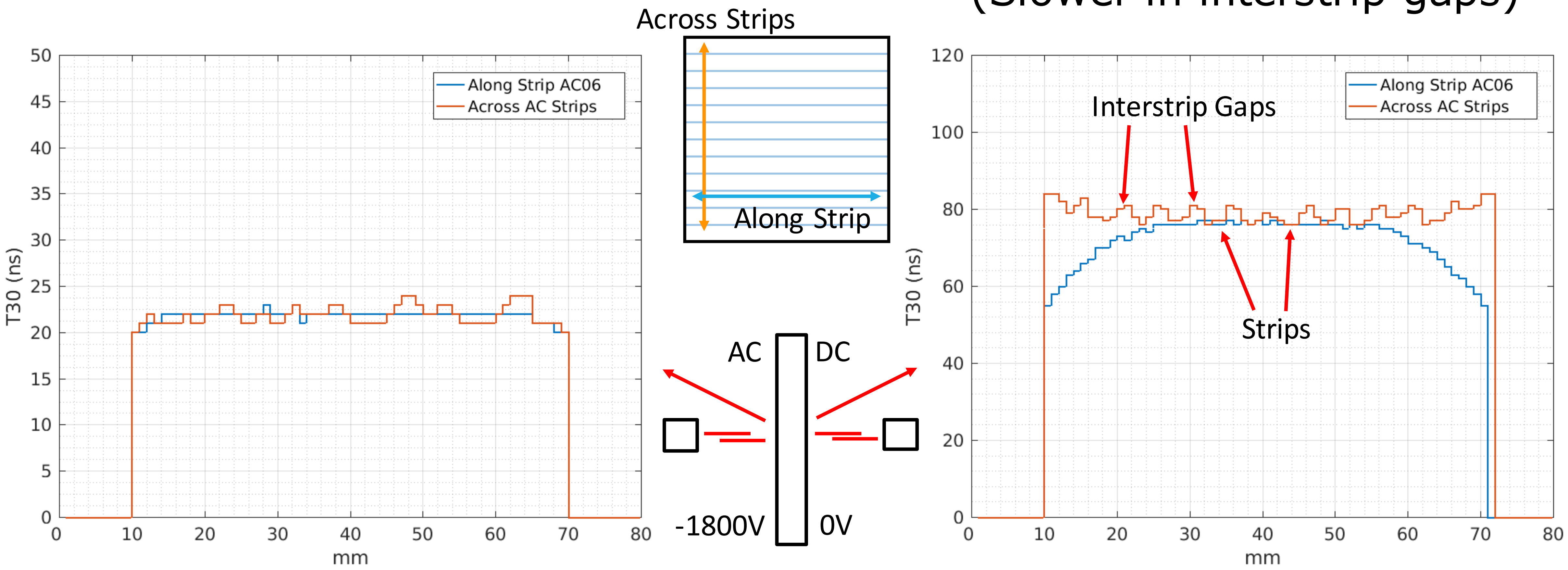




Risetime Slice – AC T30

- Mostly linear risetime along strip

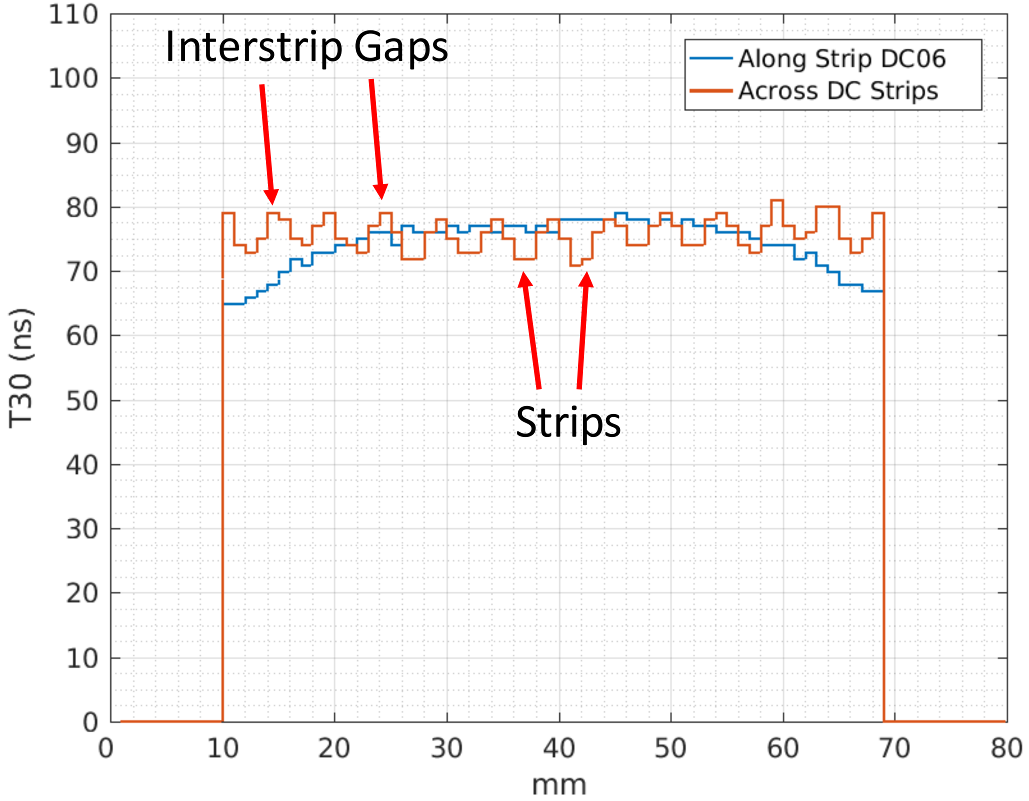
- Faster risetime at strip ends
- Faster risetime on AC strips (Slower in interstrip gaps)

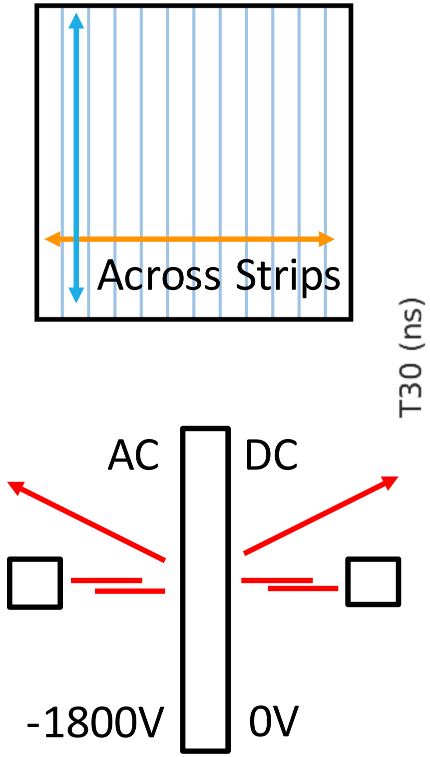


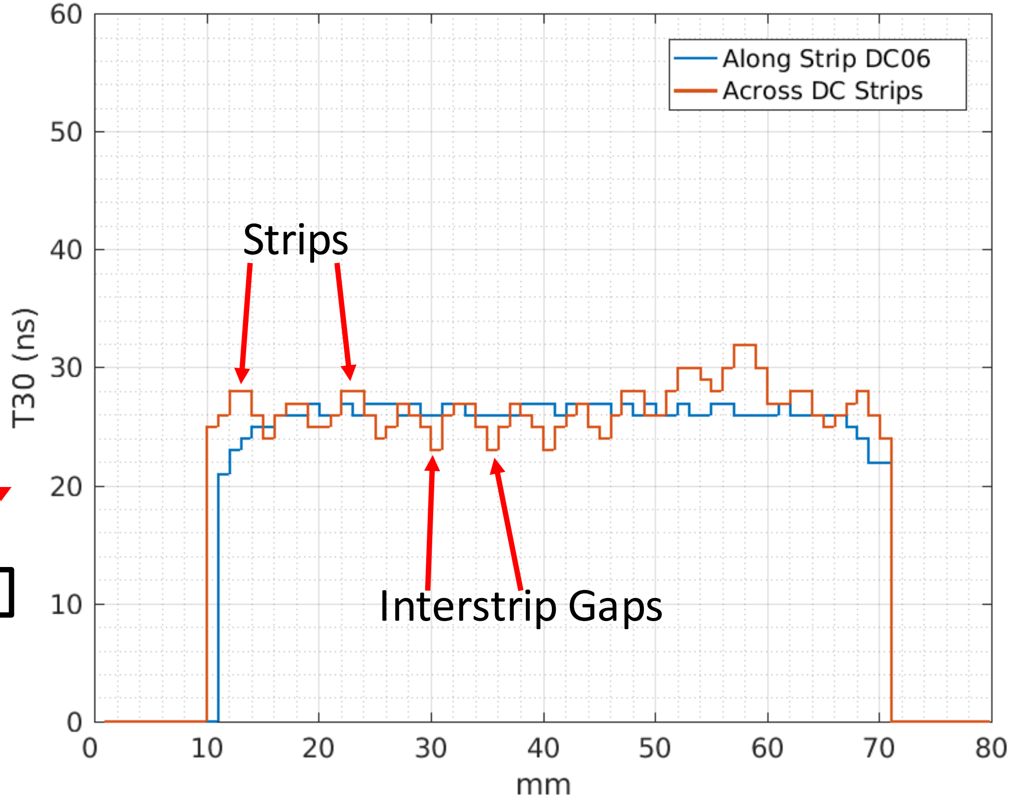
Risetime Slice – DC T30

- Faster risetime at strip ends
- Shorter risetime on strip (Faster in interstrip gaps)

- Faster risetime at strip ends
- Faster risetime on DC strips (Slower in interstrip gaps)

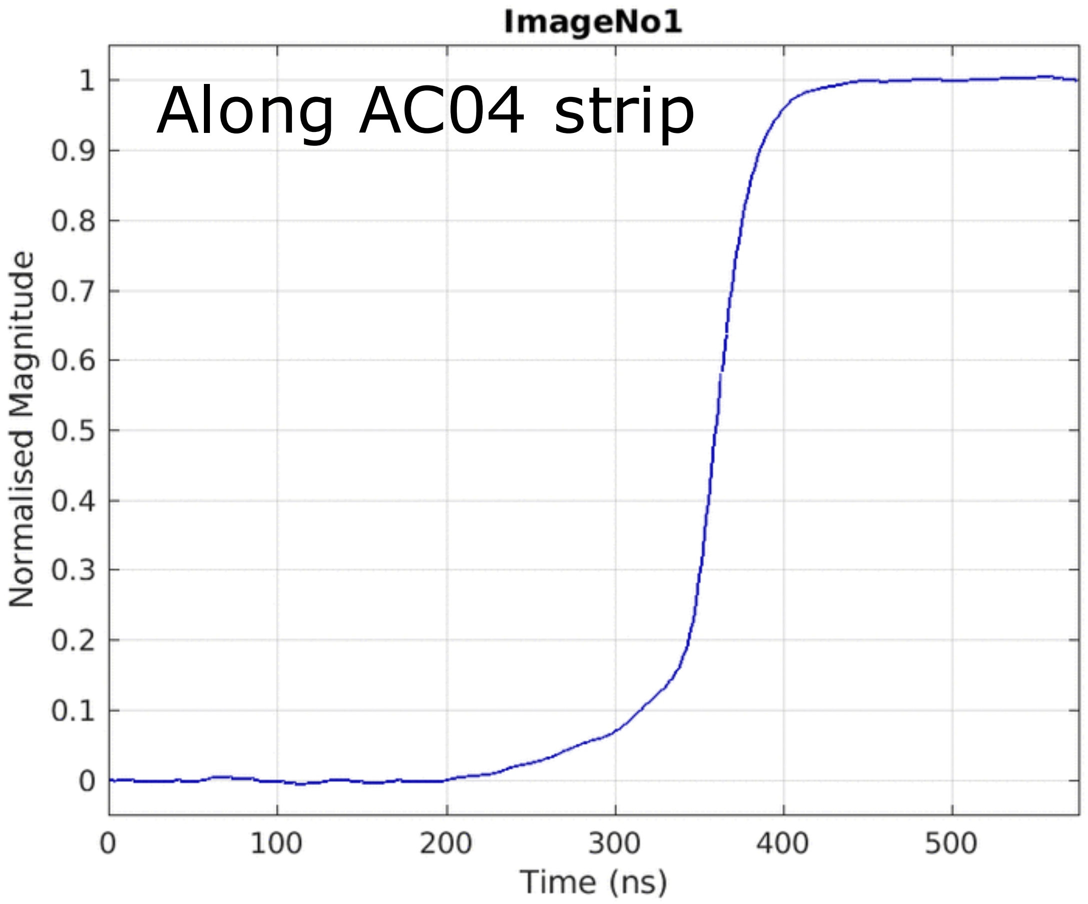


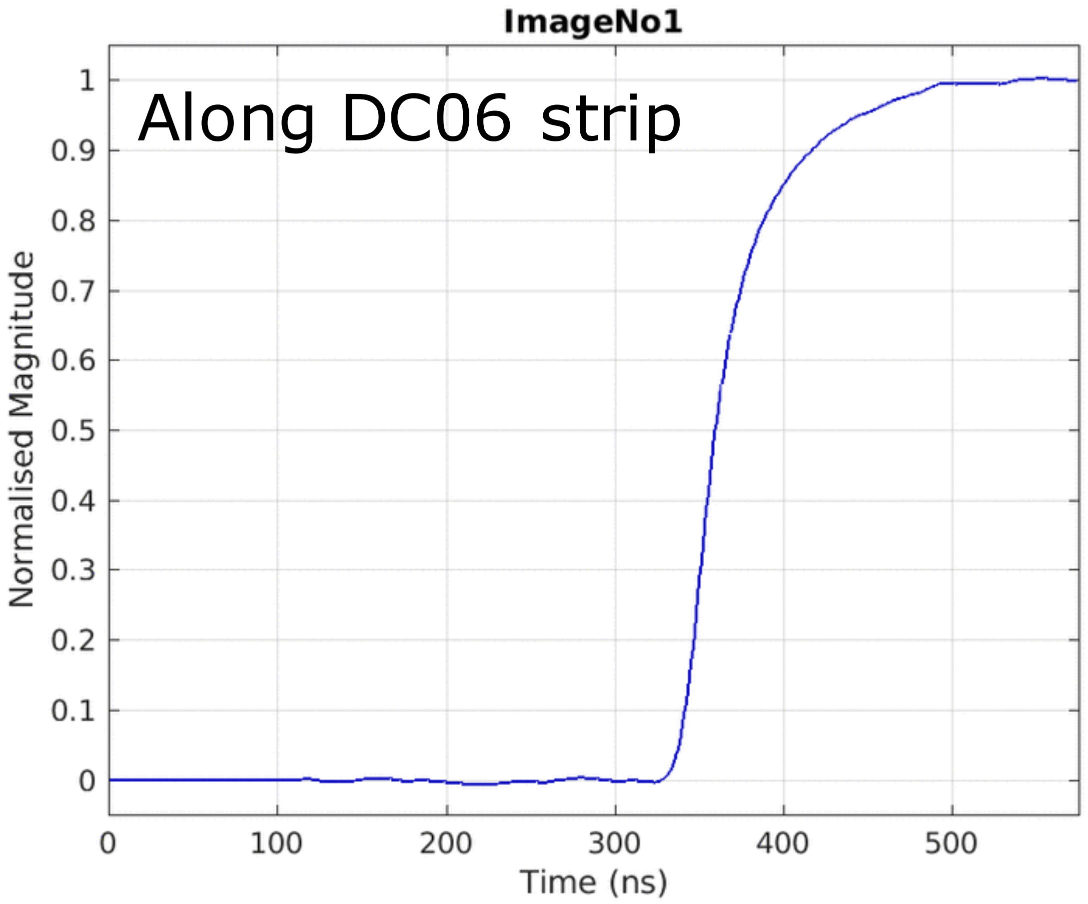




Pulses Along Strip – DC Scan

- Averaged Pulse formed of 200 fold 1 events – every 2mm along strip
- Aligned at t30 (Noise relative to pulse height too large for t5/t10)

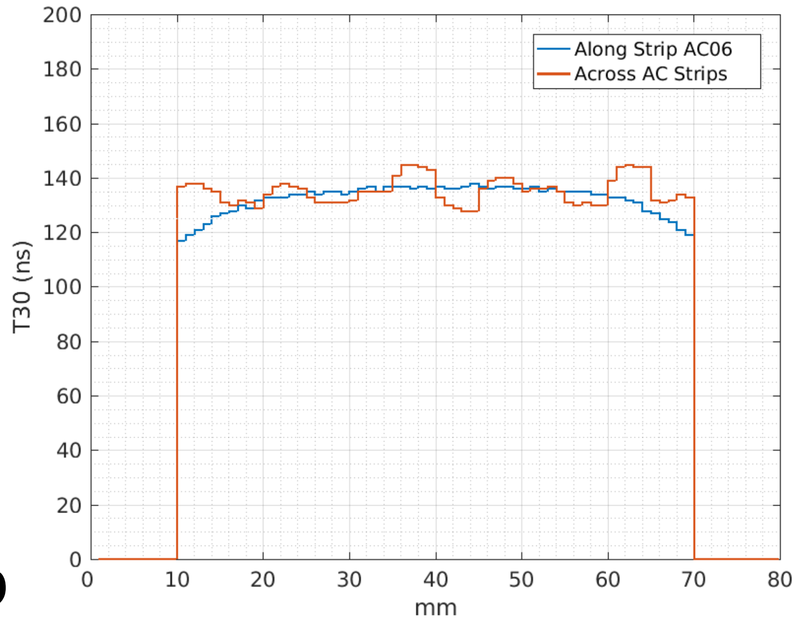




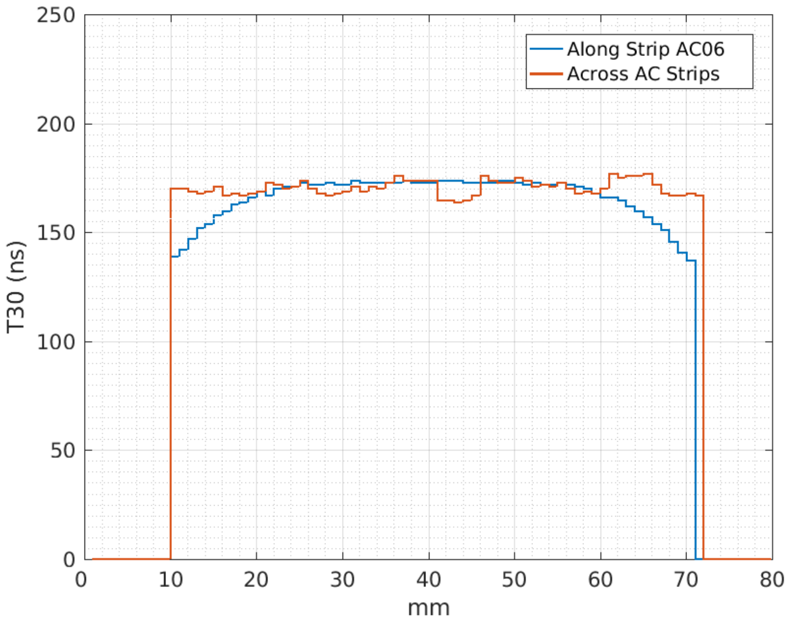
Risetime Slice – T90

- Large difference in some strip risetimes
- Up to 20ns variation between strips
- Will require risetime ‘gain matching’ or custom strip-by-strip risetime gates for PSA

AC strips AC scan

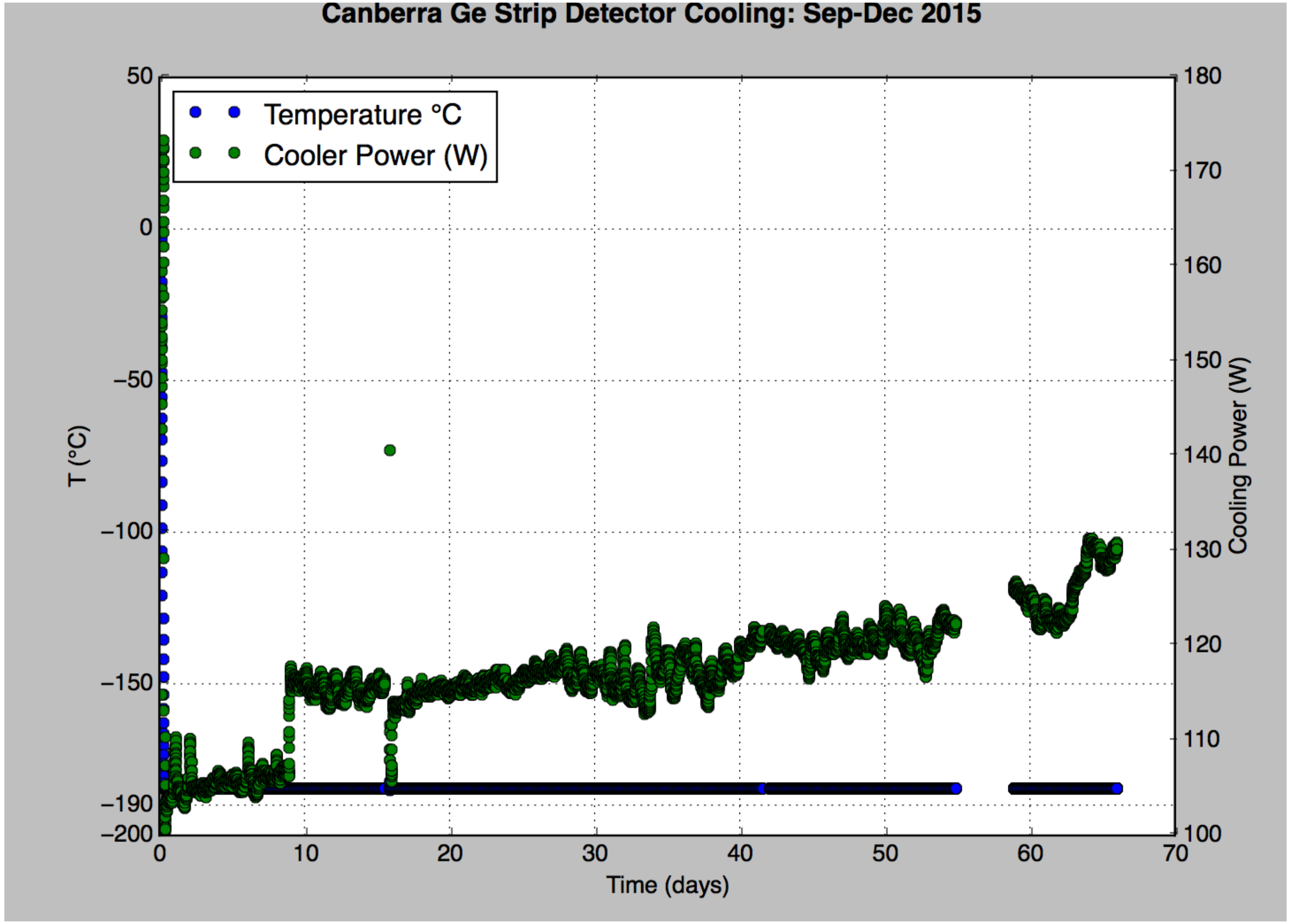


AC strips DC scan



Vacuum Issue

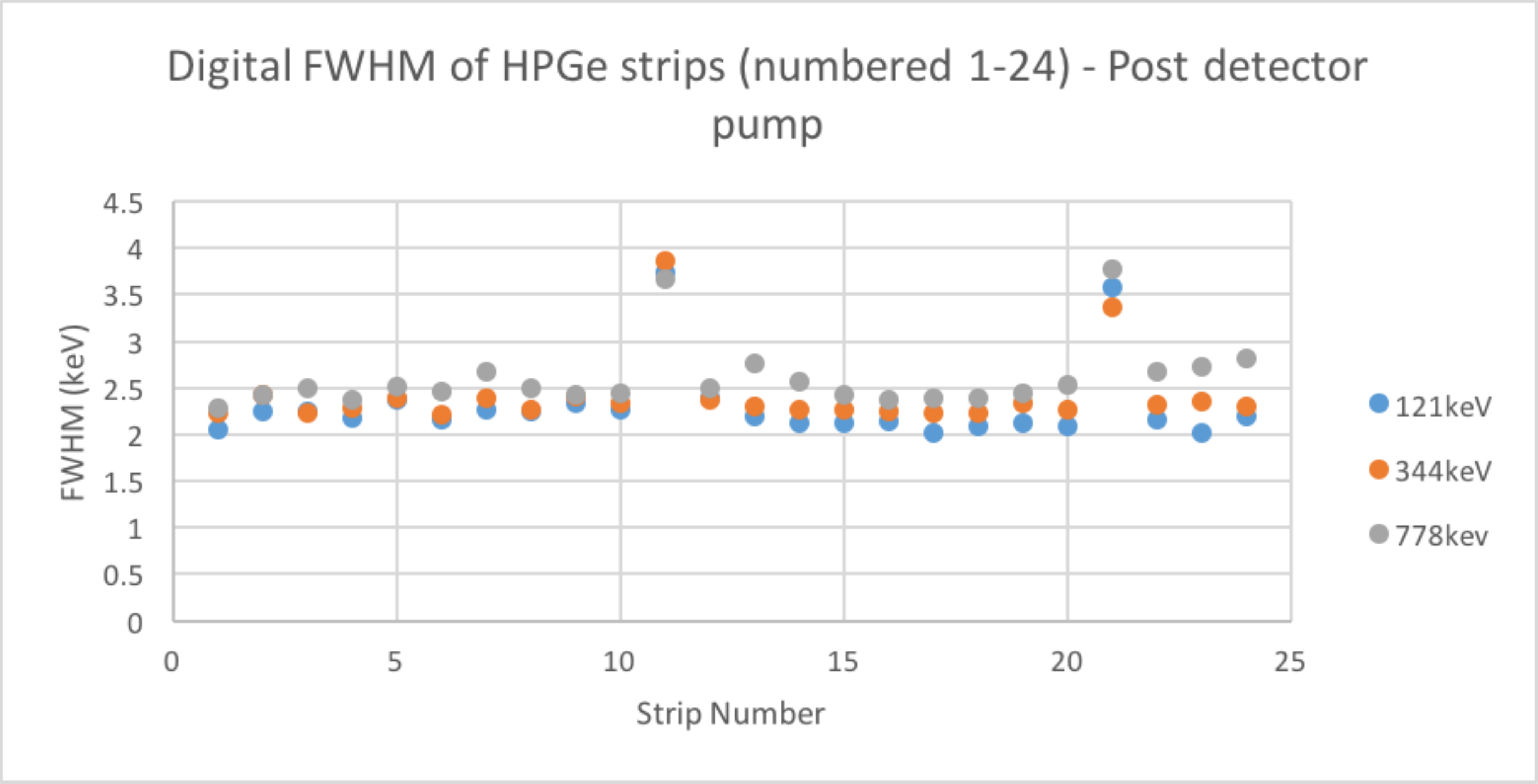
Investigation and fix carried out by Dr. Dan Judson



- CP5 control units allows detector temperature and CP5 power draw to be plotted as a function of time
- Temperature is constant but power draw increases slowly
- Baseline power draw increases exponentially
- Indicates probable problem with vacuum leak
- Pumping 'resets' power draw

Lab Temperature

Strips AC11 and DC9 Systematically degraded by > 1 keV



Summary

- Overview of the HPGe detector – FWHM and Pulses
- Detector face scans and uniformity maps
- Preliminary charge sharing results
- Charge loss summary
- Strip risetime variation and pulses
- Vacuum issues and subsequent pumping/baking

Liverpool Nuclear Instrumentation Group

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Thanks and Questions