Radiation Mapping Applications

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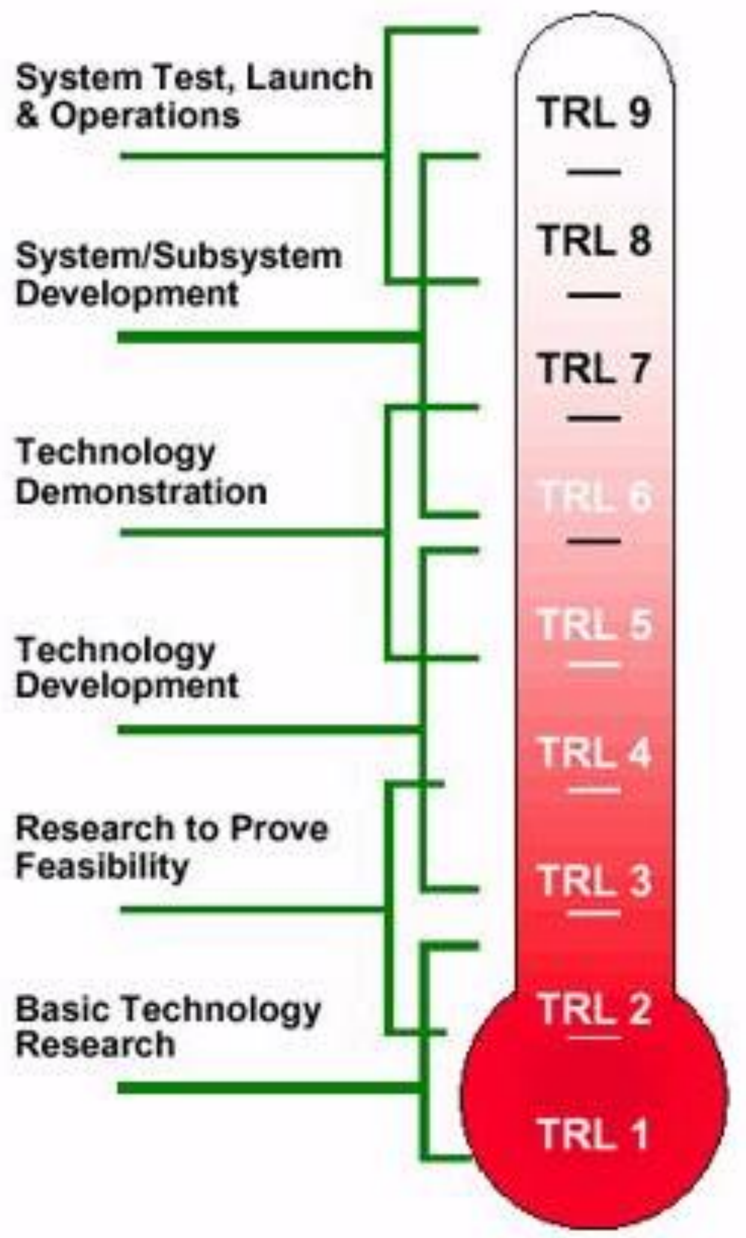
Radiation Mapping

- Overview of select commercial technologies
- Performance in decommissioning scenarios
- Next generation imaging
  - Single element
  - Multi element
  - Advanced Scene Data Fusion
- SIGMA detector



What constitutes a gamma imager?

- A detector, or detectors, sensitive to gamma radiation
- A means of measuring the direction of each detected gamma ray
- A means of displaying the data as an image showing the spatial distribution and intensity of gamma radiation.
- This ‘gamma image’ is usually superimposed onto an image from a conventional optical camera so that the physical location of the sources can be readily identified.

Test scenarios

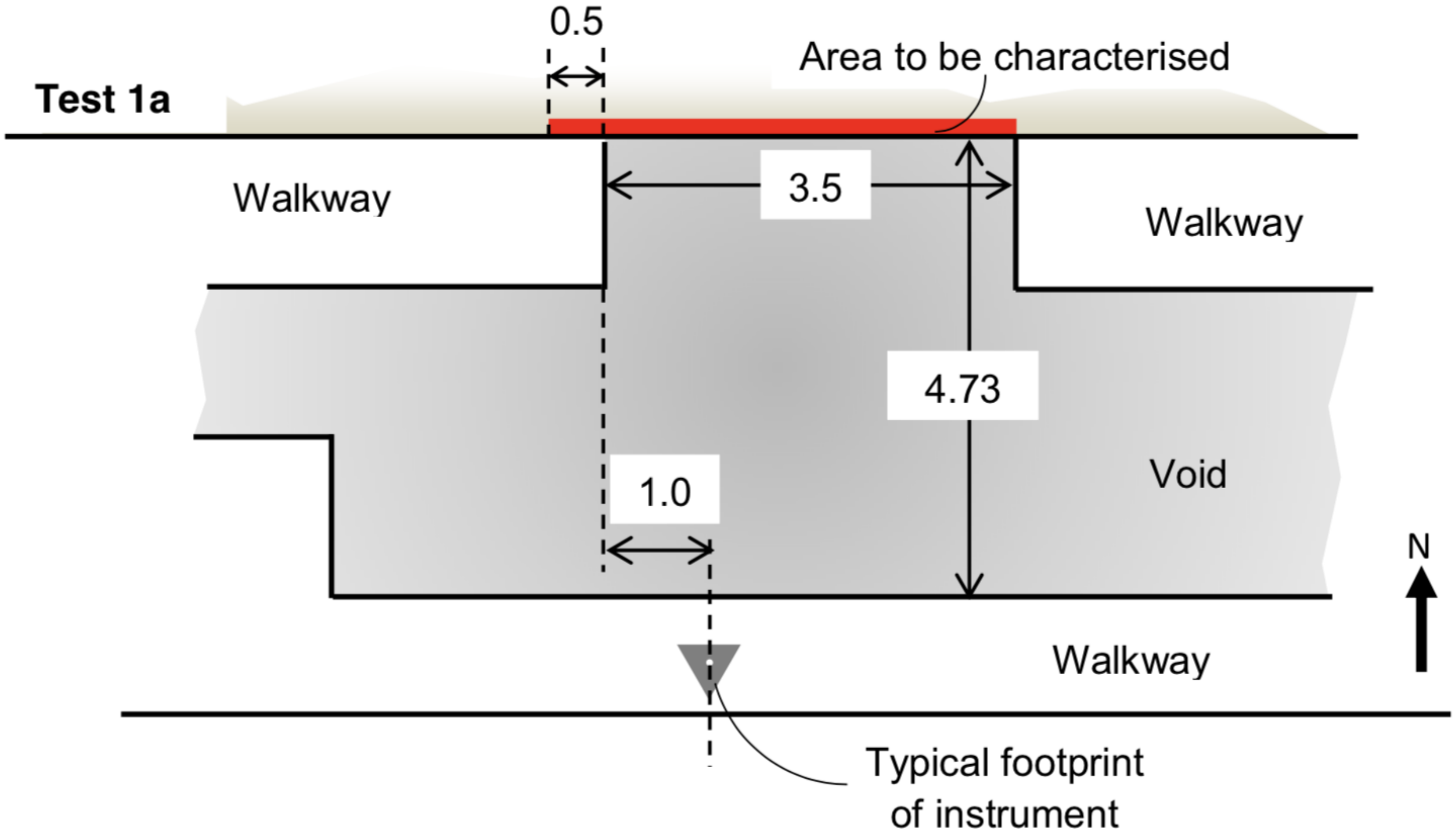
- Ability to image areas of distributed activity.
  - Systems are commonly tested in laboratory conditions using point sources.
  - Distributed sources are not only more challenging, but are more representative of the scenarios in which these imaging systems will be used.
- Performance in the presence of strong off-axis sources of radiation.
  - Gamma imaging systems are susceptible to giving spurious results caused by radiation outside of the field of view (FOV) hitting the detector.

Sellafield Nuclear Reprocessing Plant

- Measuring the dose environment and the location of radioactive sources
- Faster acquisition of results and improved deployment options could save >£100million over the lifetime of the site
- Nine systems tested and evaluated, with two devices purchased

The test scenario

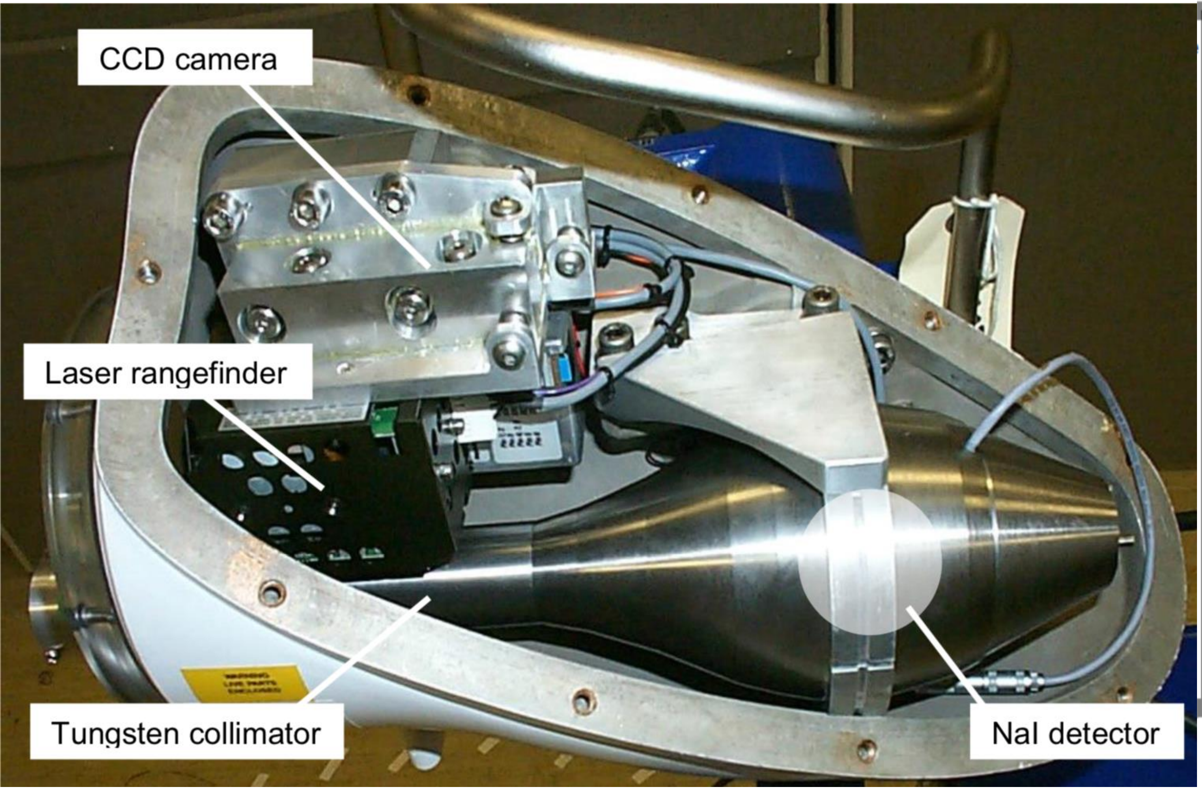
- Large distributed hotspots

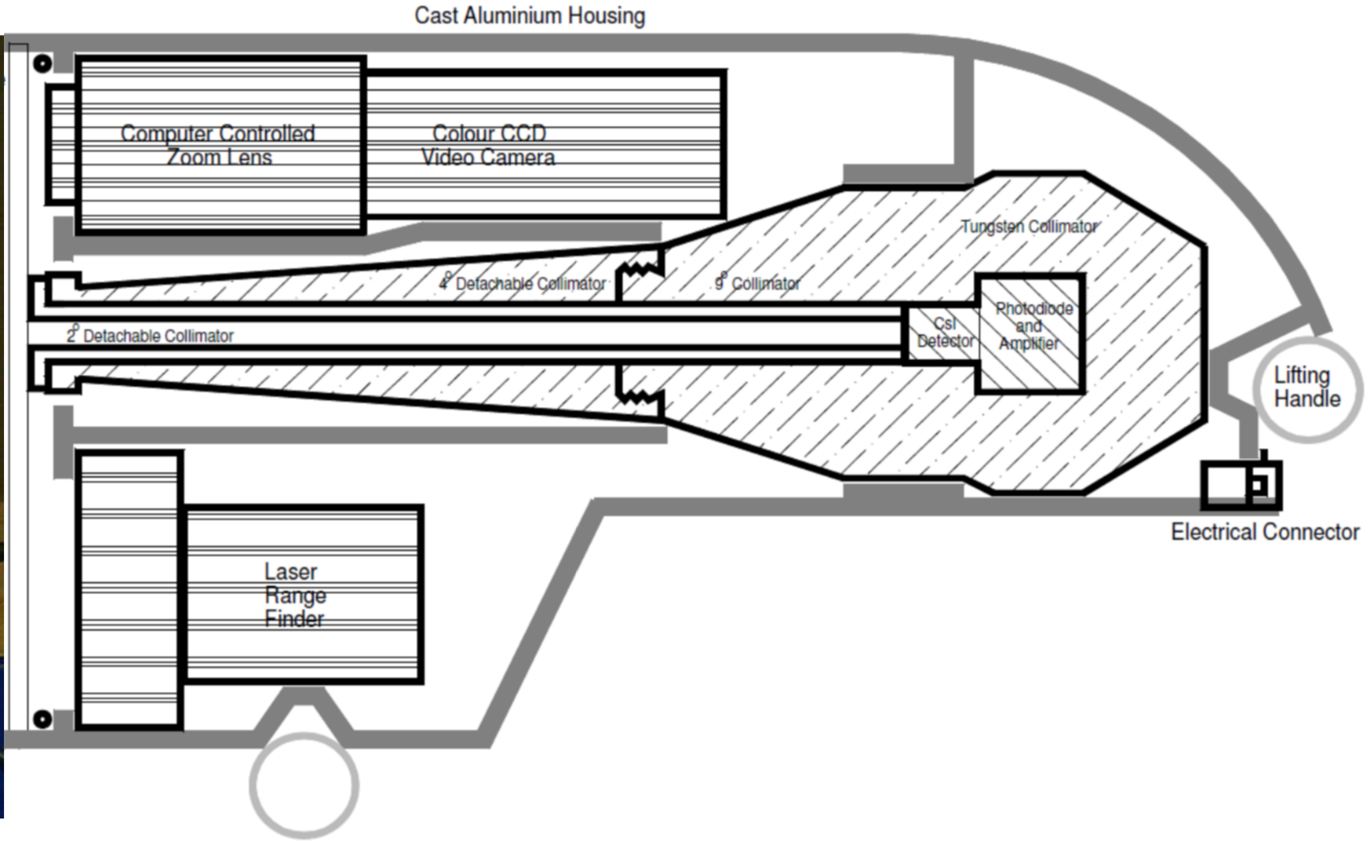


Canberra : ISOCs

- In Situ Object Counting System
- Characterised detector
- Model allows activity to be derived in real life use
- Integrates with standard commercial software

Radscan 800/900 – Cavendish Nuclear





NaI, CsI or $CeBr_3$ Scintillator, mechanical collimator, pan and tilt unit, optical CCD

Deployed imager on site

N-Visage Gamma Imager

- Small cadmium-zinc-telluride detector
- Surrounded by spherical tungsten shielding with a slit collimator
- Pans and rotates to cover 4pi

MIRION
TECHNOLOGIES

Radiation. Safety.

CZT 1cm^3 detector
Coded aperture grid

iPIX

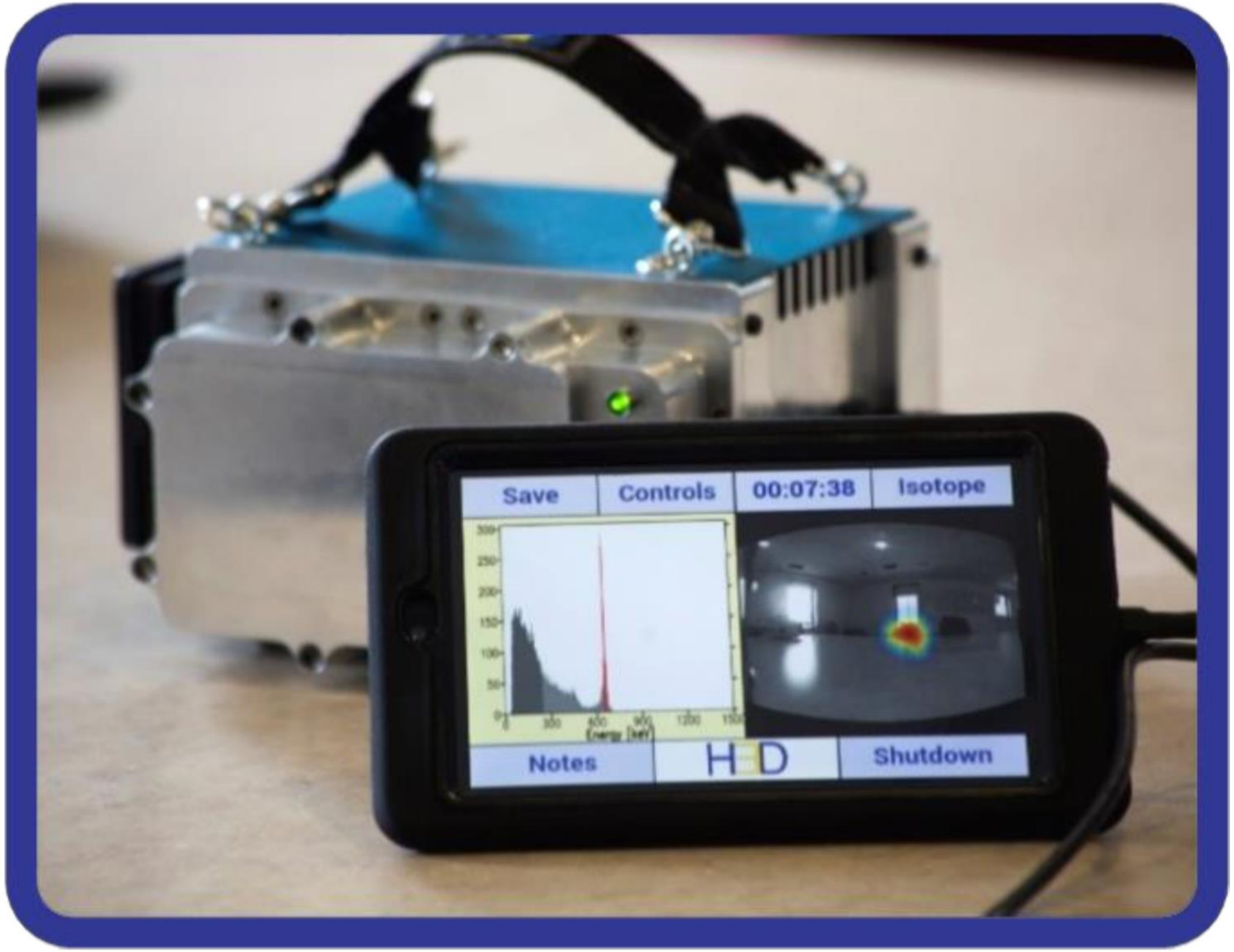
Ultra Portable Gamma-Ray
Imaging System

Imager deployed onsite

- Large collimated CZT added alongside the iPIX
- Energy resolution considerations
- Note external casing

Polaris-H – H3D

- $6cm^3$ CZT
- Compton Camera
- Fisheye camera
- Can include laser Range F
- 360^o FoV
- High efficiency
- Energy resolution
- 30^o -> 20^o Angular Range



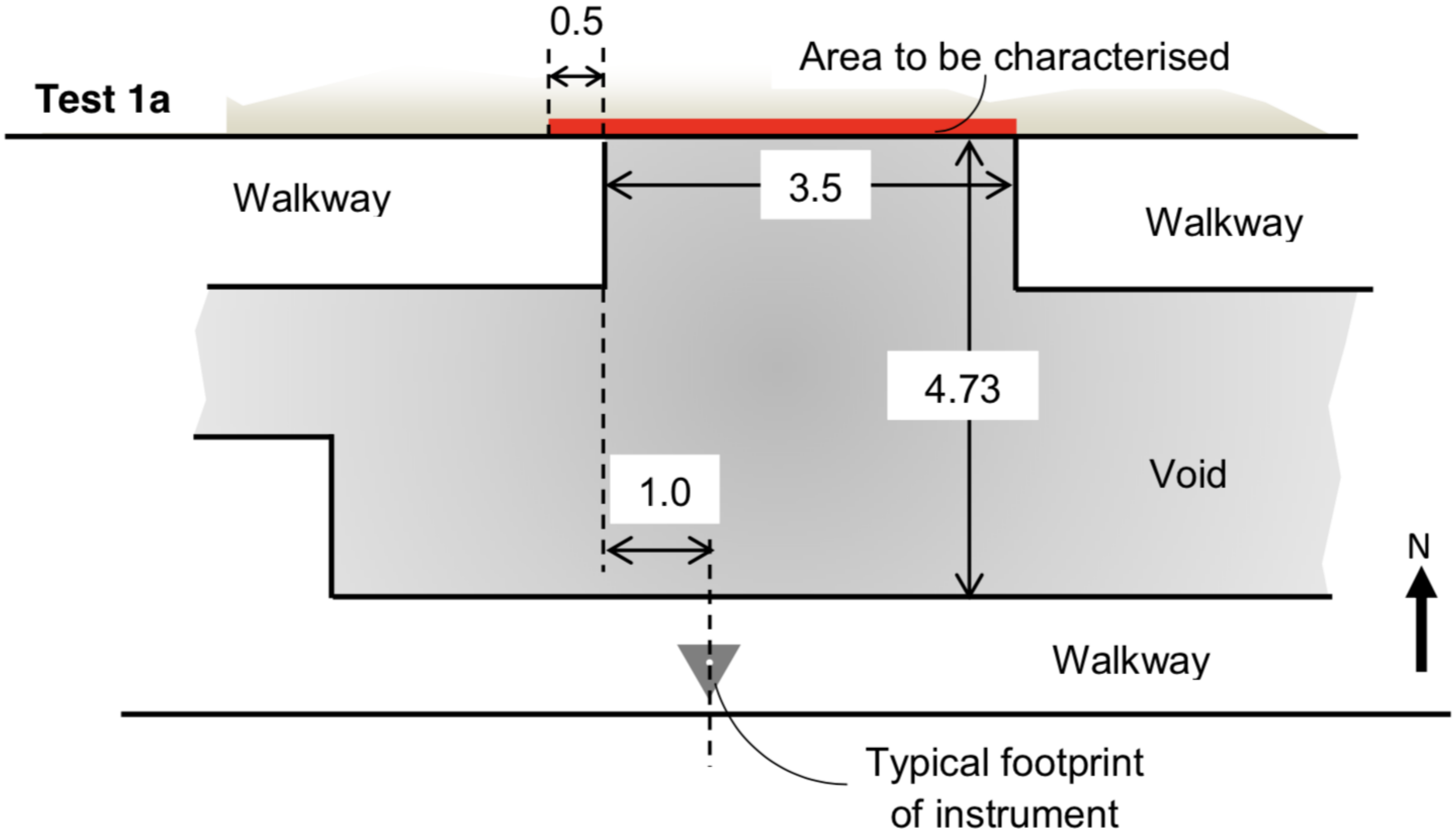
GeGI - PhDs

- 90mm diameter
- 10mm thick
- DSGSD
- Compton Camera
- PSA

- Fast low dose rate applications

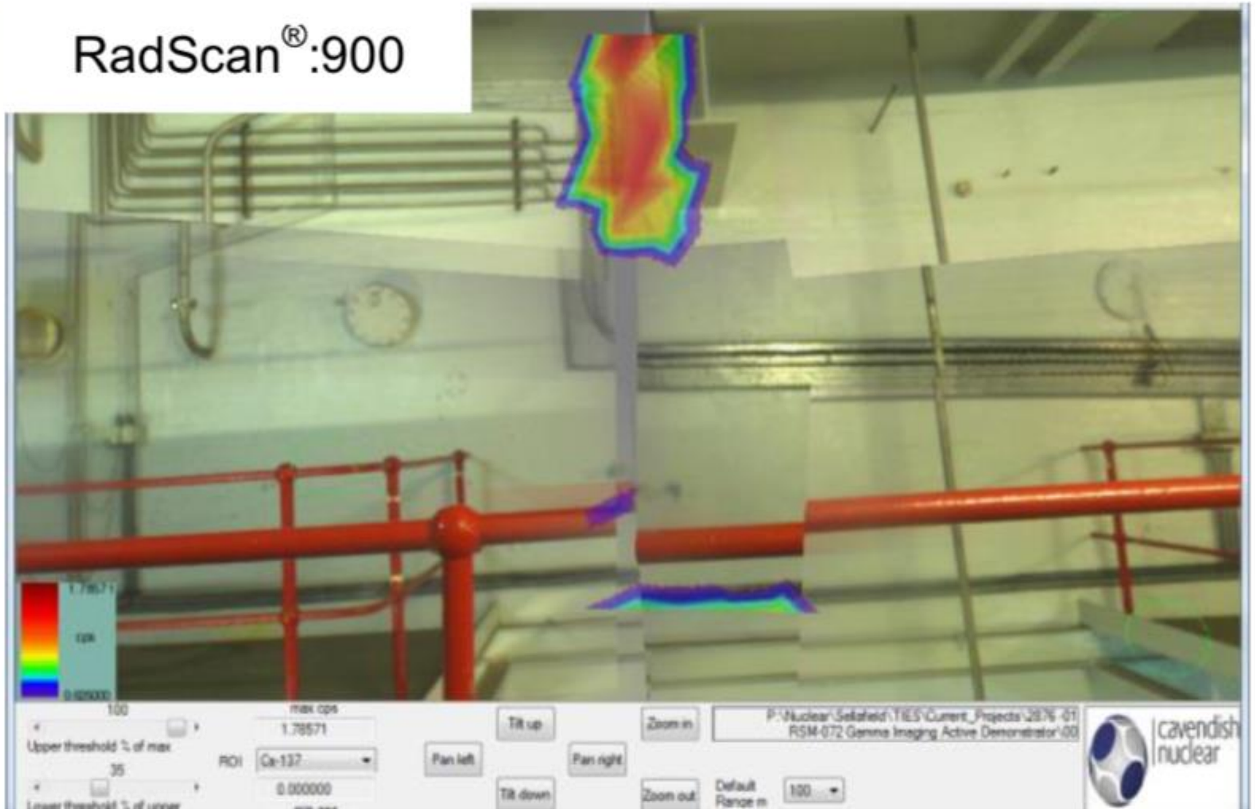
Example images from tests

- Large distributed hotspots: Dose rate ~200 µSv/h : ^{137}Cs



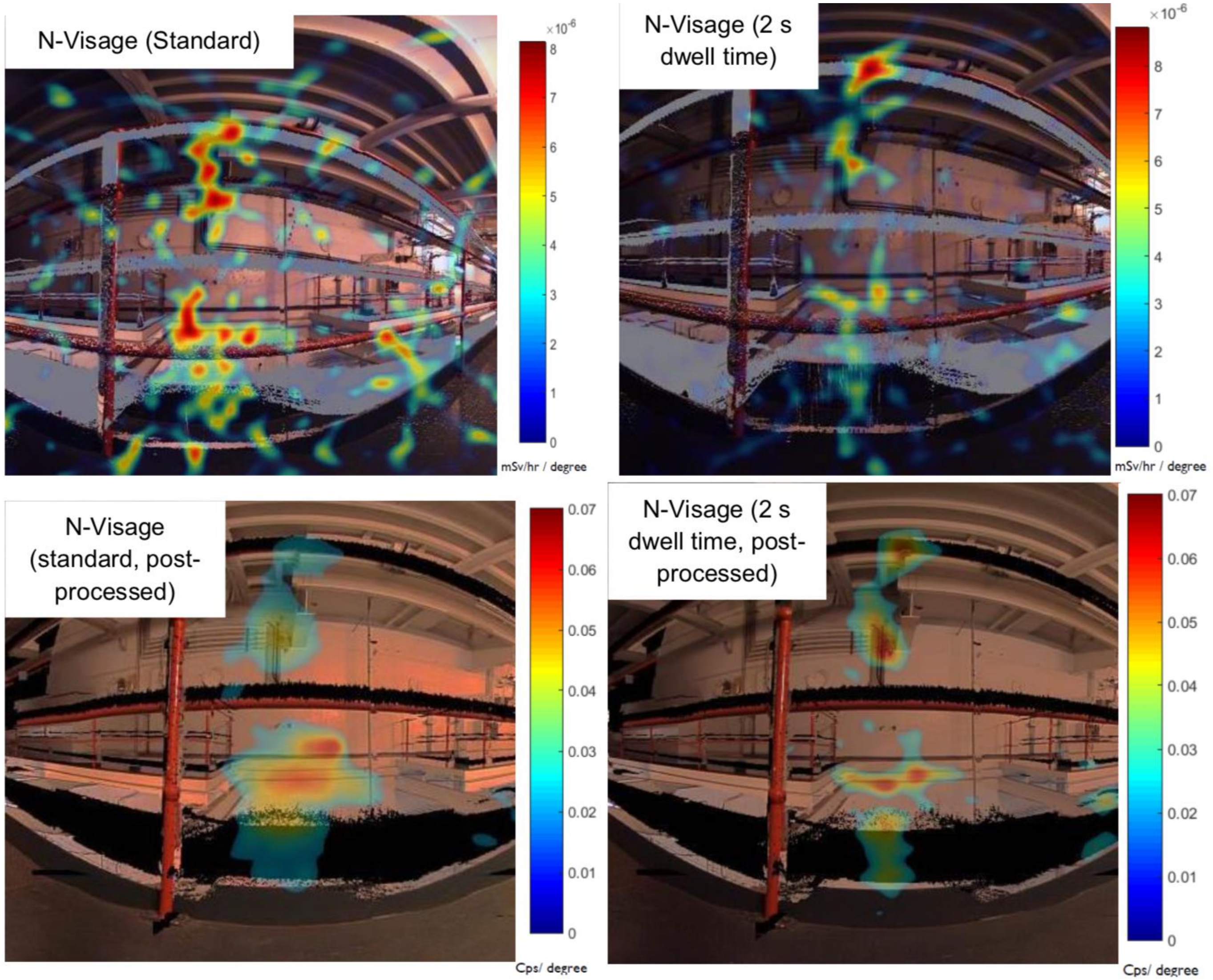
Example Images Radscan

- Measurement time is long but can be targeted

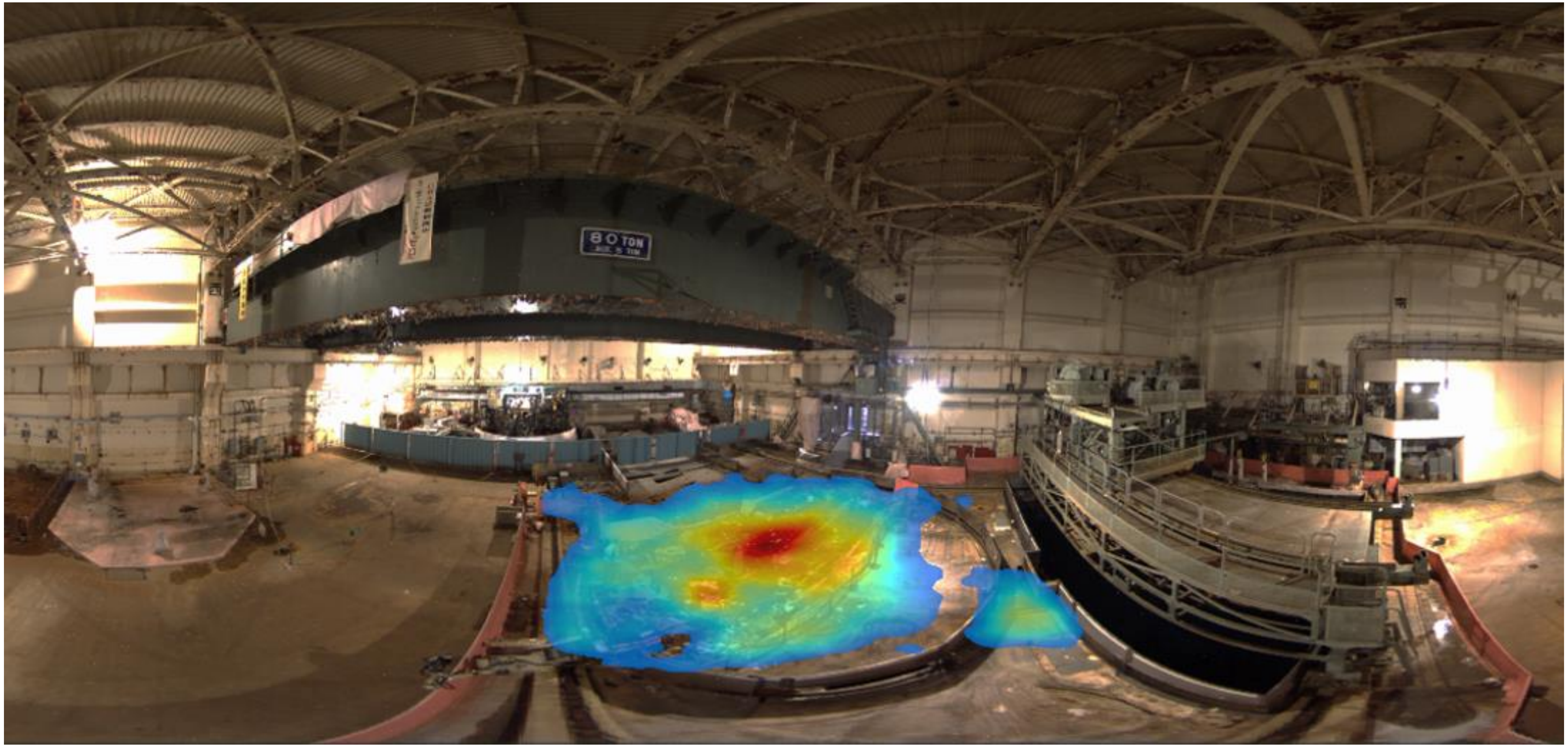


Example Images N-Visage

- Artifacts
- 2 hour measurement (long)
- N-Visage Gamma Imager is best suited to relatively high-dose environments with narrow access



N-Visage: Fukushima example

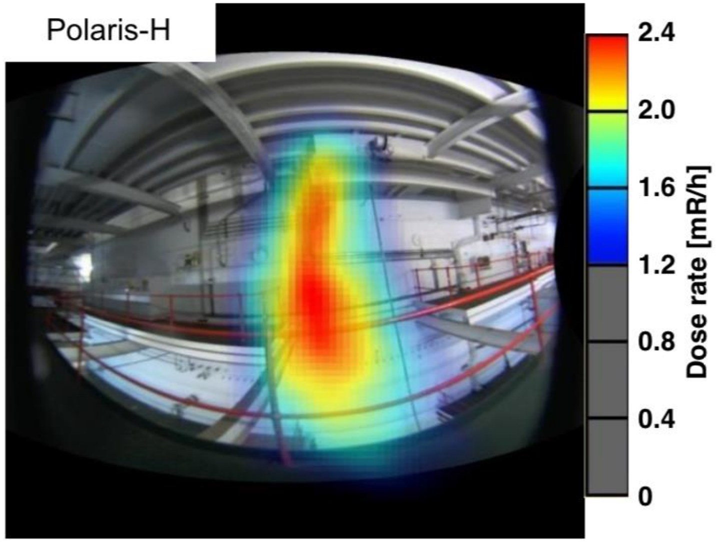


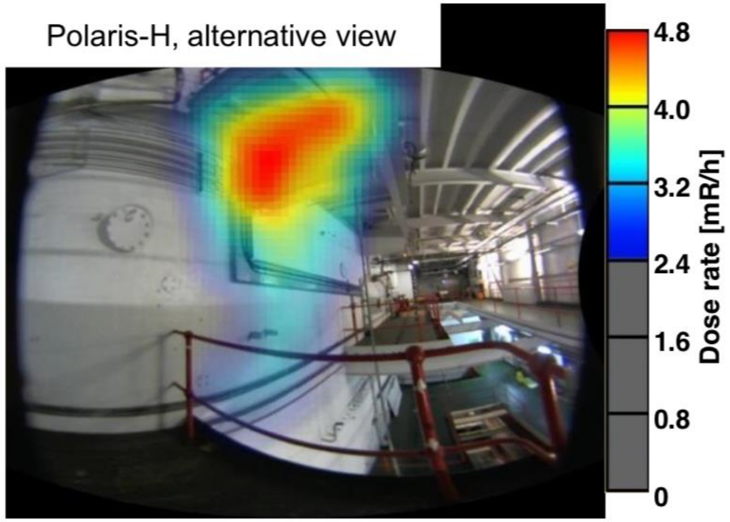
Example Images: iPIX

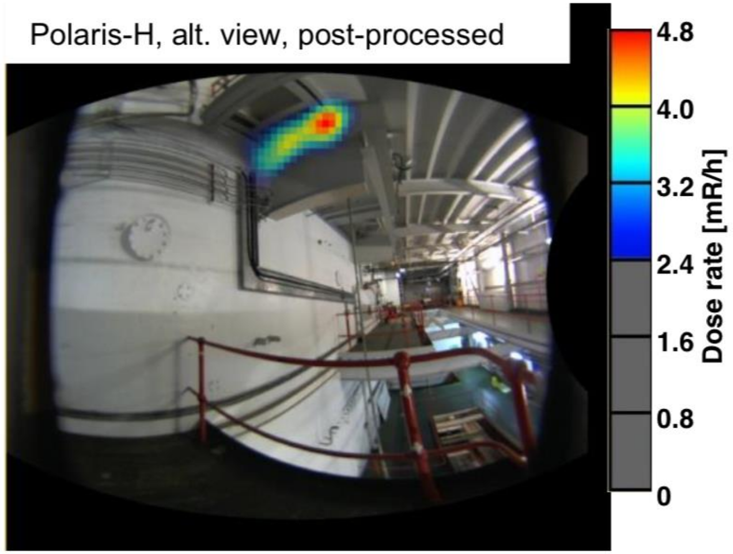
- Thresholding tends to make sources distributions look like points (85% default)
- Best used for quick measurements of point like sources

Example Images: Polaris-H

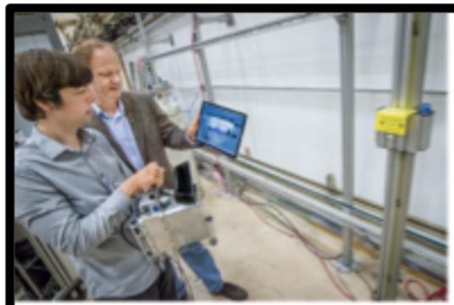
- Spatial resolution was relatively low compared with other systems.
- Short measurement time and light weight of the instrument meant that measurements in multiple locations could be readily carried out in a short space of time.
- Algorithm iterates to points….





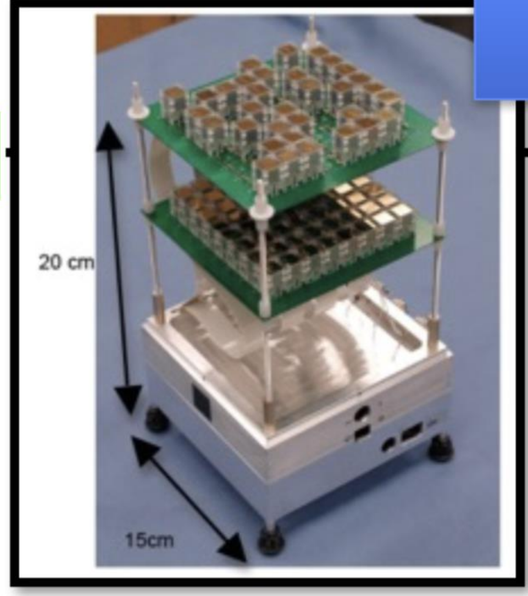


HEMI : LBL



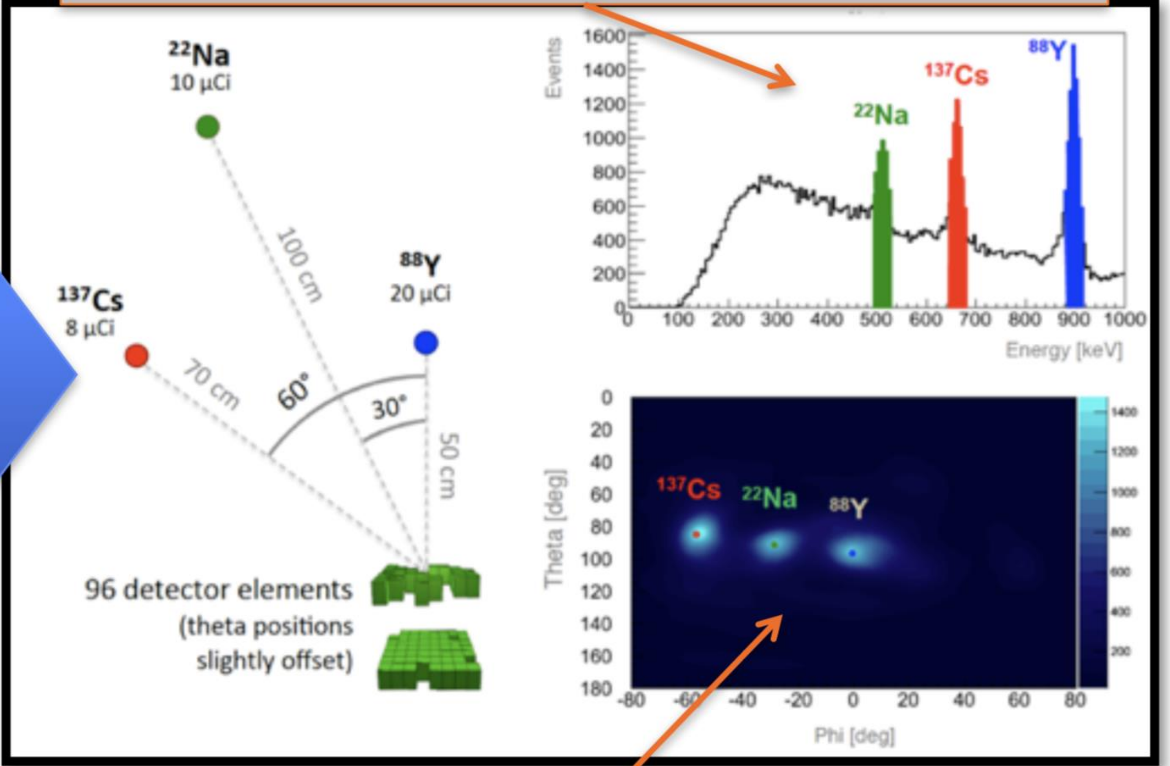
Microsoft Kinect

HEMI



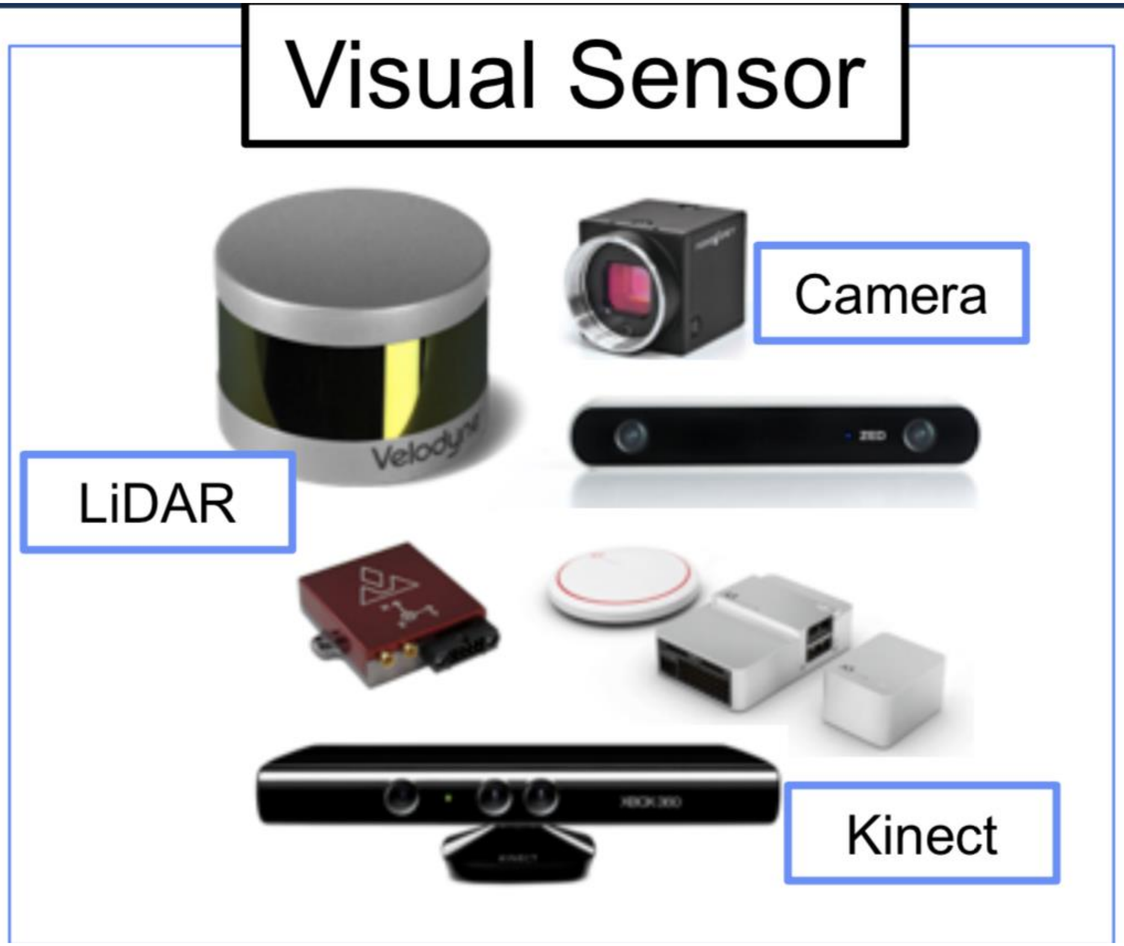
“Color” (energy) of gamma rays

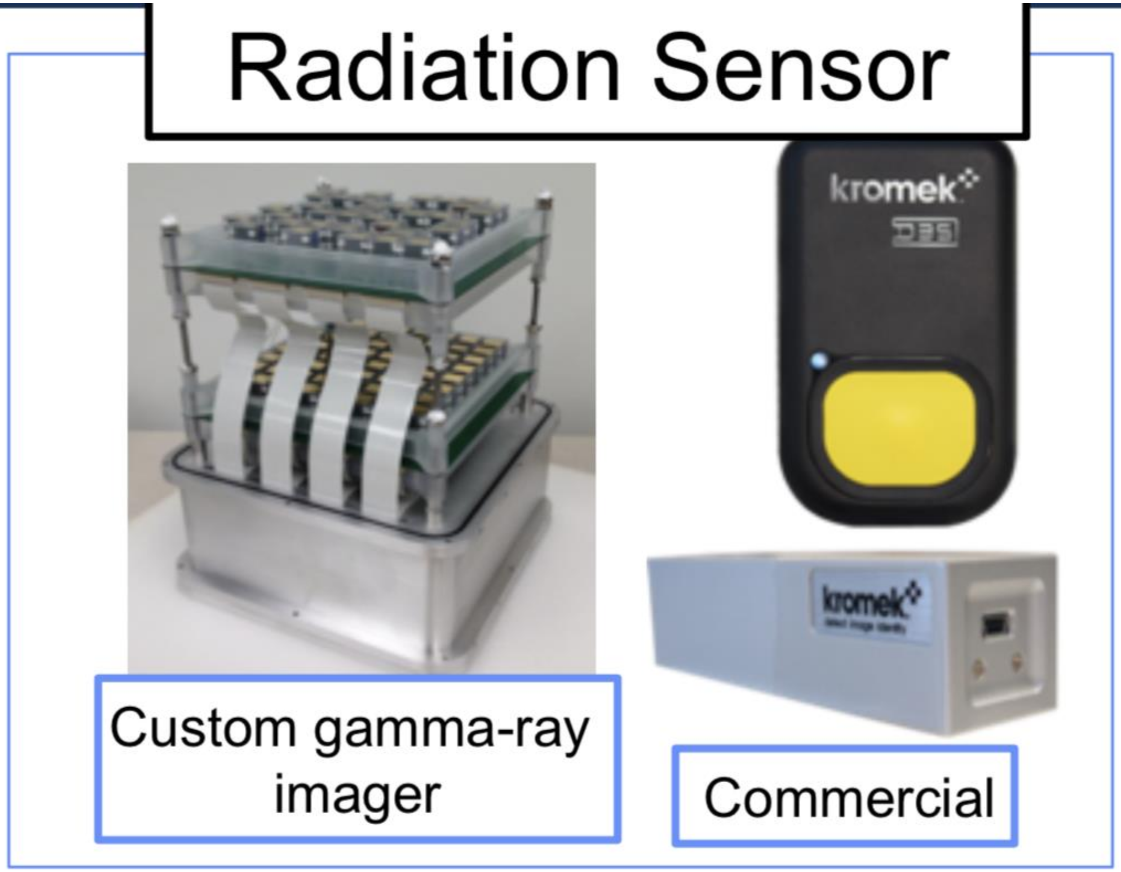
- Fingerprint of specific radioisotopes such as Cs-137 or I-131



Localization of gamma-ray sources

Scene Data Fusion - LBL





Double sided germanium strip detector

Detector systems fully characterized

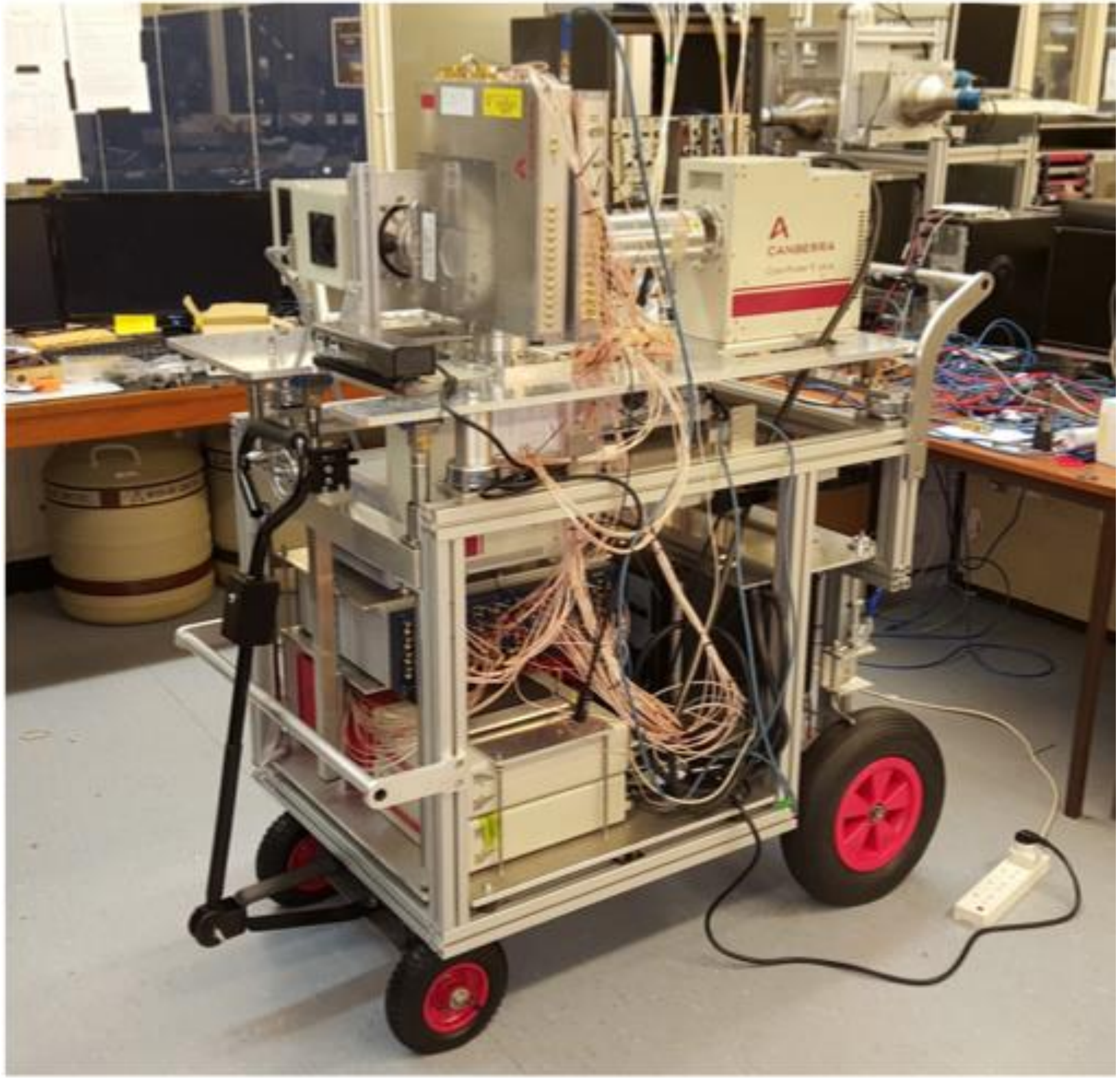
ADL simulations performed

Grid search algorithm

MIRION TECHNOLOGIES

Gri+: System status

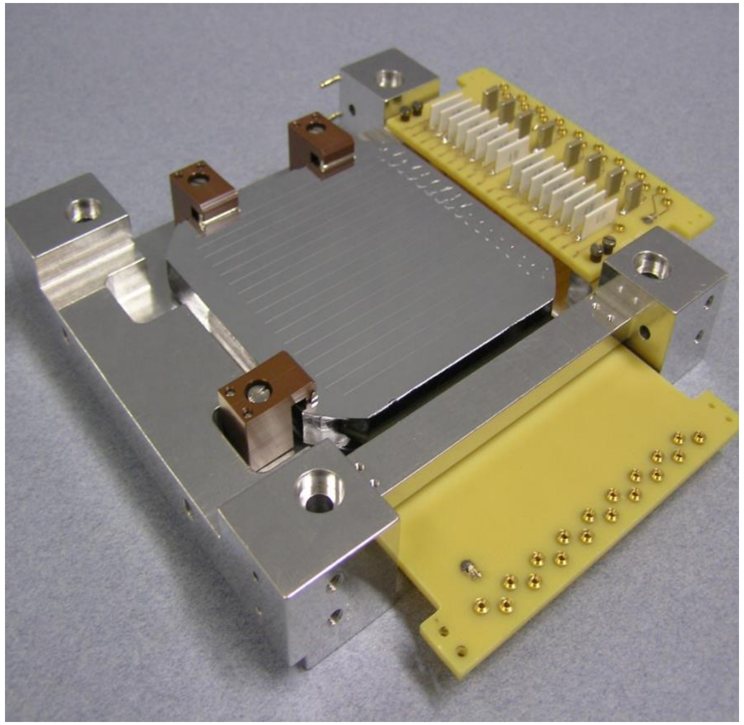
- Si(Li) and Ge detectors returned following vacuum issues
- New thicker cryostat side plates (window unaffected)
- Performance restored
- Firmware upgrades to Caen digitisers, new readout software
- Range verification for Proton Therapy
- Active demonstrator facility tests

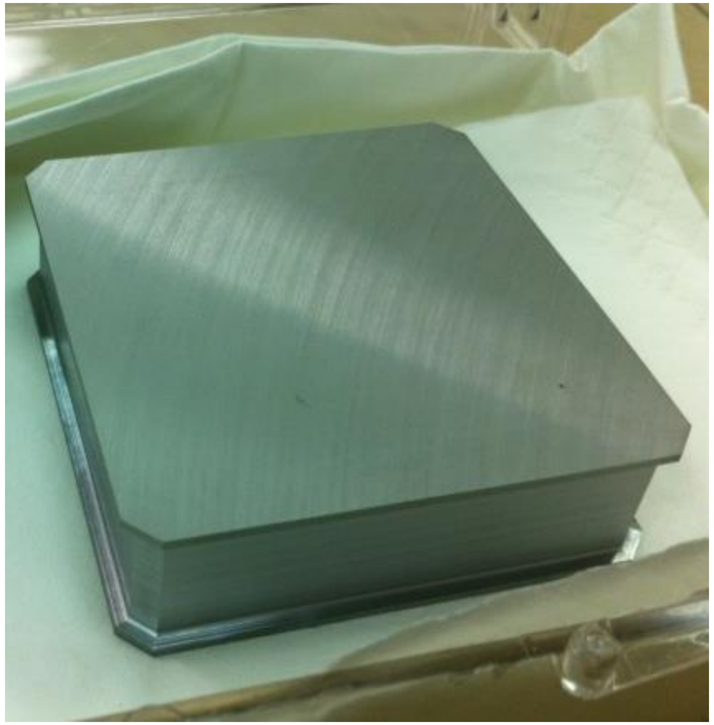


ORTEC

ProSPECTuS: Compton Camera

- 9 mm Si(Li) detector and 20mm HPGe detector housed in a single cryostat custom-built by STFC Daresbury Laboratory
- Optimised for imaging 141 keV – 511 keV





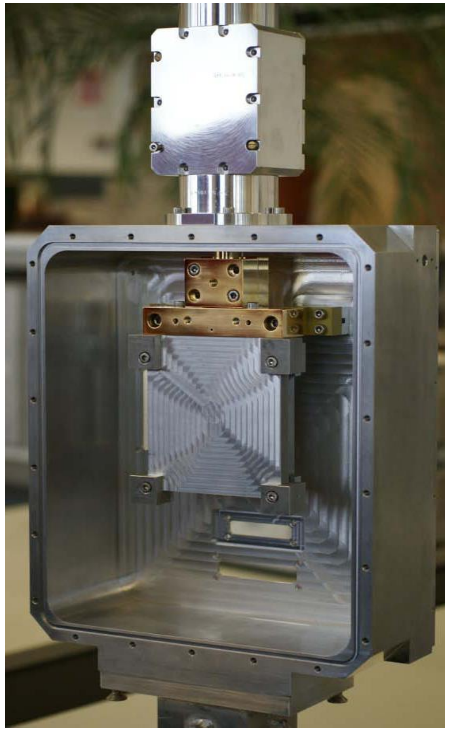


Image reconstruction algorithms

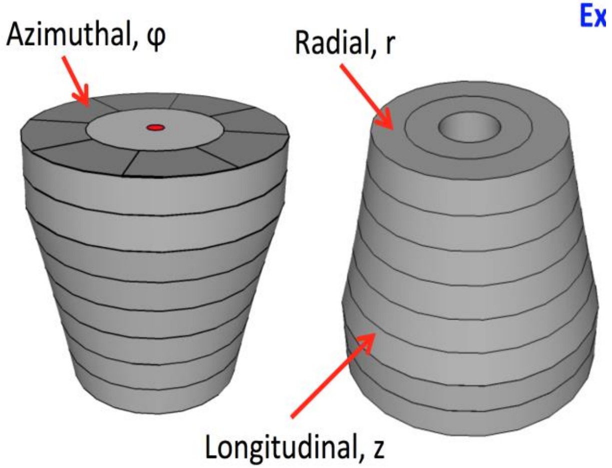
1. Analytic (quantitative)
2. Stochastic Origin Ensemble (SOE)
3. MLEM/OSEM (with GPU acceleration)

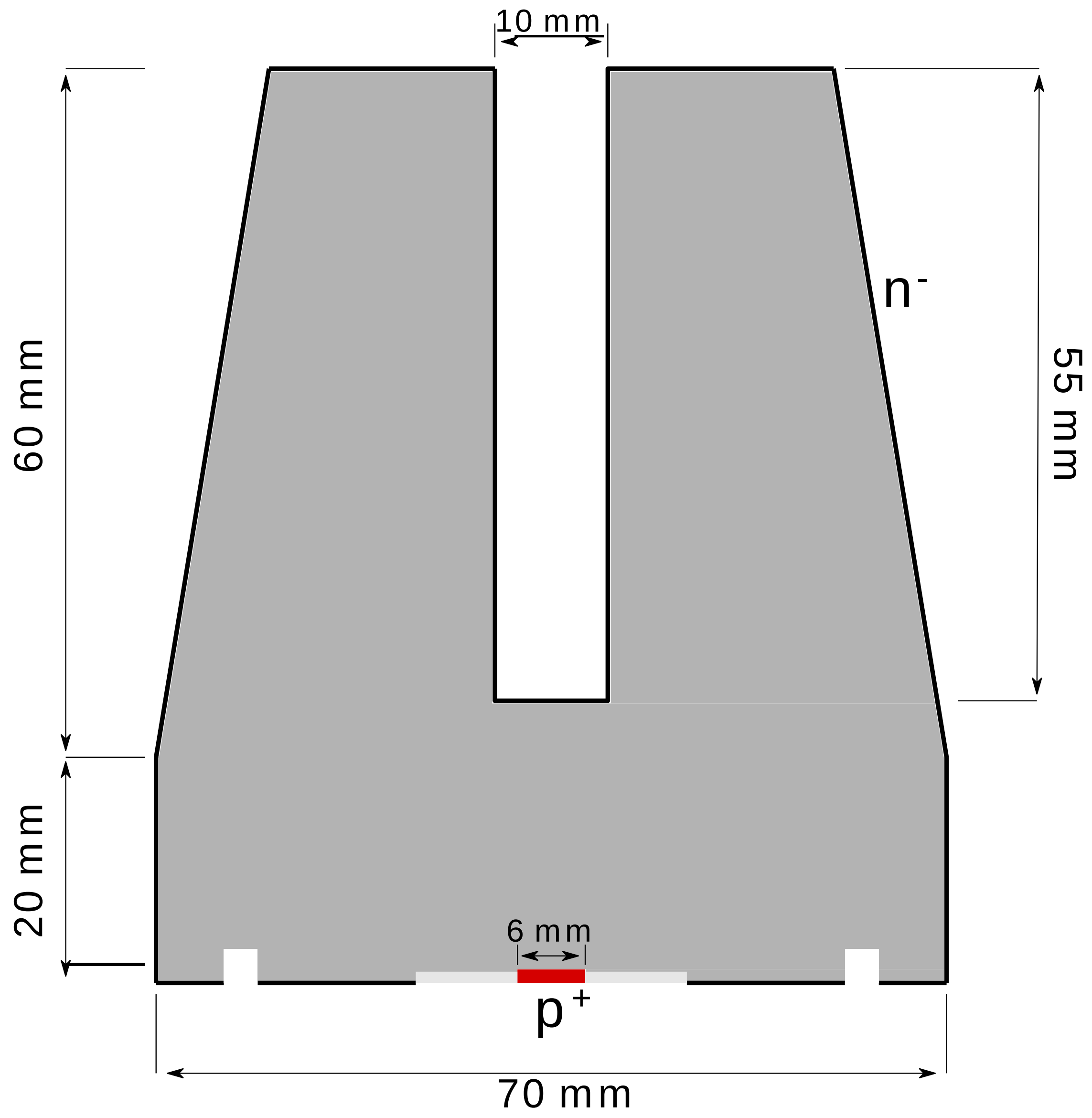
(1) and (2) are real time or near real time

A. Andreyev et al., Resolution recovery for Compton camera using origin ensemble algorithm, Med. Phys. 43, 4866-4876 (2016).

SIGMA: detector status

- Spectroscopic gamma-ray imaging with a Segmented, Inverted-coaxial GerMAnium detector
- Potential single detector γ-ray imaging system for energy, security, healthcare & environment
- P-type material for improved charge collection
  - 8 wedges
  - 8 circular segments
  - 1 front and bore

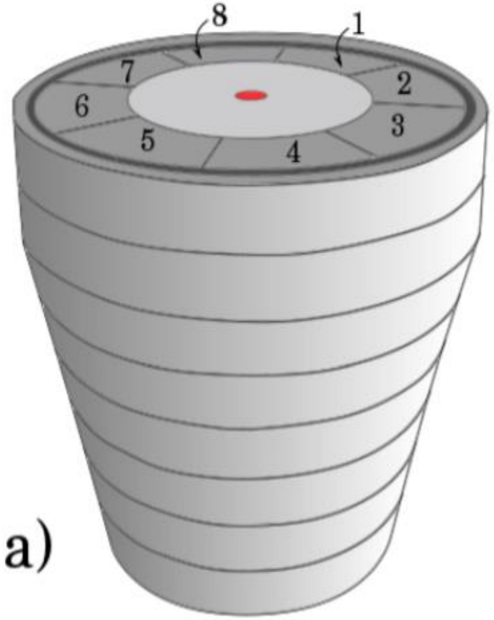


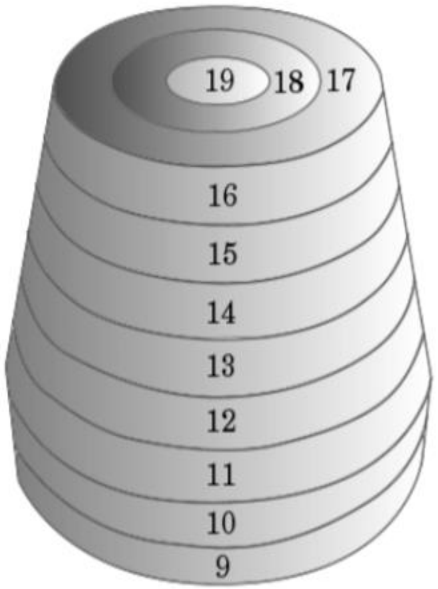


J. Wright et al. NIM, A 892 (2018) 84–92
M. Salathe et. al, NIM. A 868 (2017) 19-26

SIGMA: performance

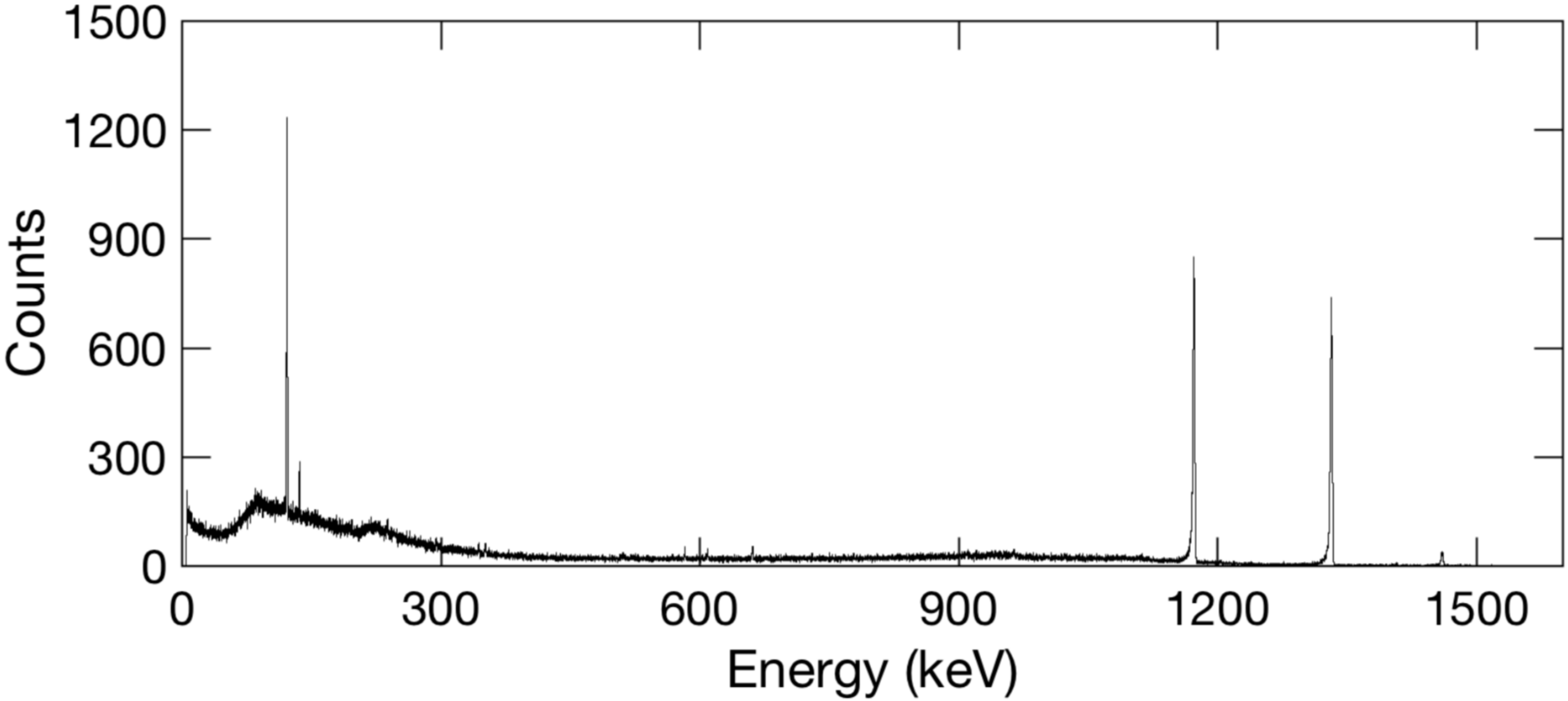
- Relative efficiency 43%





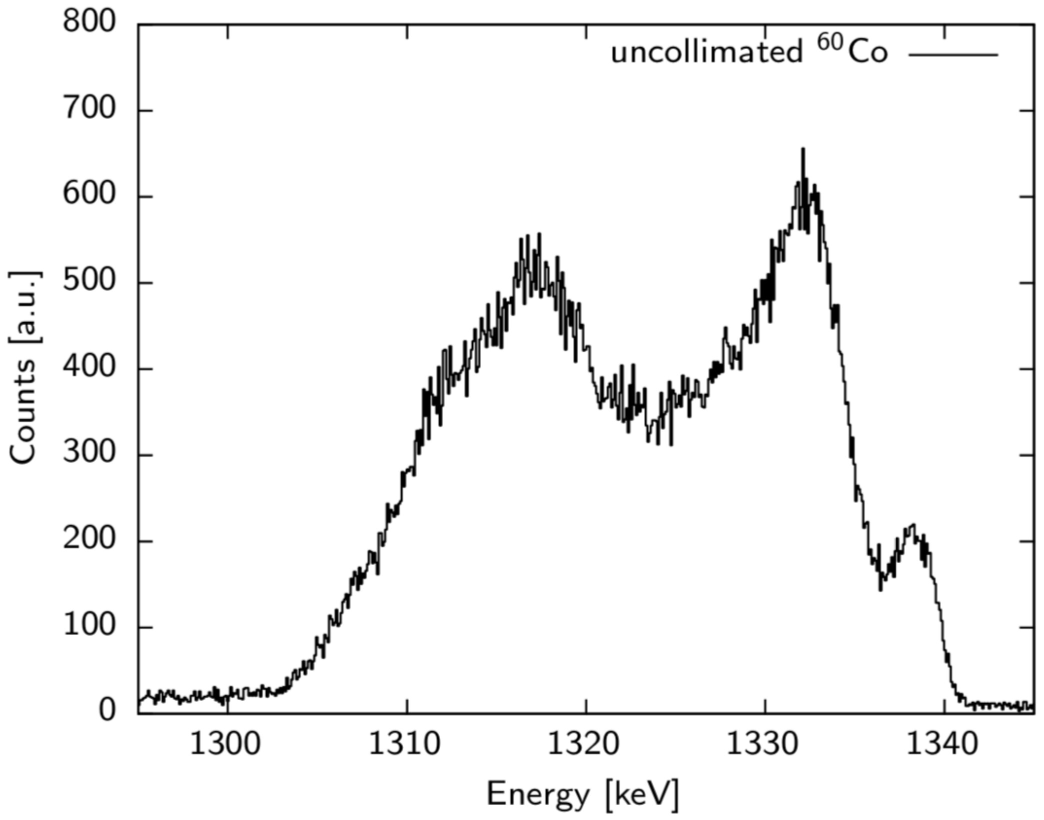
Segment	122 keV FWHM (keV)	1332 keV FWHM (keV)
PC	0.85	2.21
1	1.15	2.82
2	0.93	2.22
3	0.82	2.35
4	0.95	2.58
5	3.38	3.59
6	1.00	2.82
7	1.06	2.13
8	1.03	2.43
9	2.83	3.40
10	1.39	2.07
11	1.27	2.05
12	1.15	2.13
13	1.11	2.04
14	1.16	2.06
15	1.31	2.13
16	2.48	2.99
17	1.16	1.81
19	1.42	2.81

SIGMA: Point contact energy spectrum



N-type characterised at LBL

A fraction of the charge carrier in germanium detector gets stuck (trapped) during the drift from the interaction site to the read-out electrode

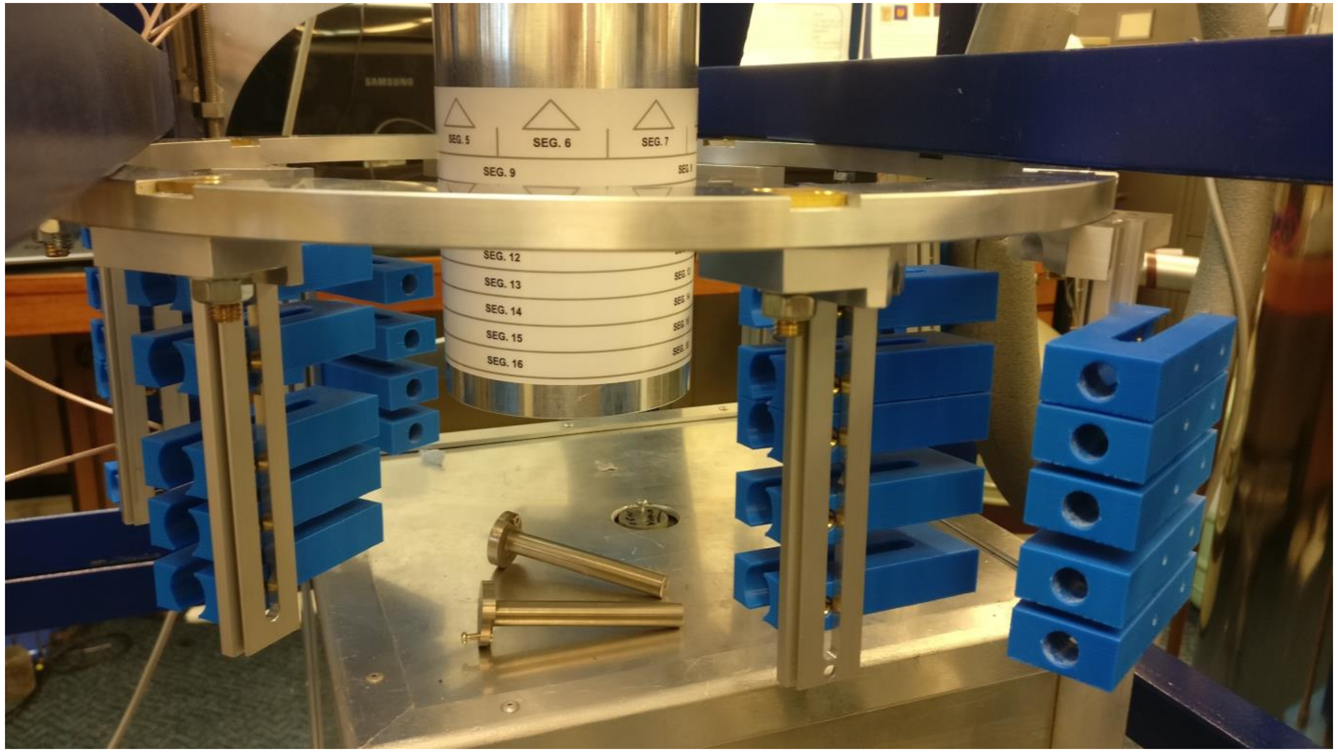


- In n-type material electron trapping (majority charge carrier) even at standard impurity levels
- Charge trapping degrates peak shape

Is there a way to restore the characterstic resolution of germanium detectors?

SIGMA: characterisation

- Scans of charge collections profile
- SSE cuts applied



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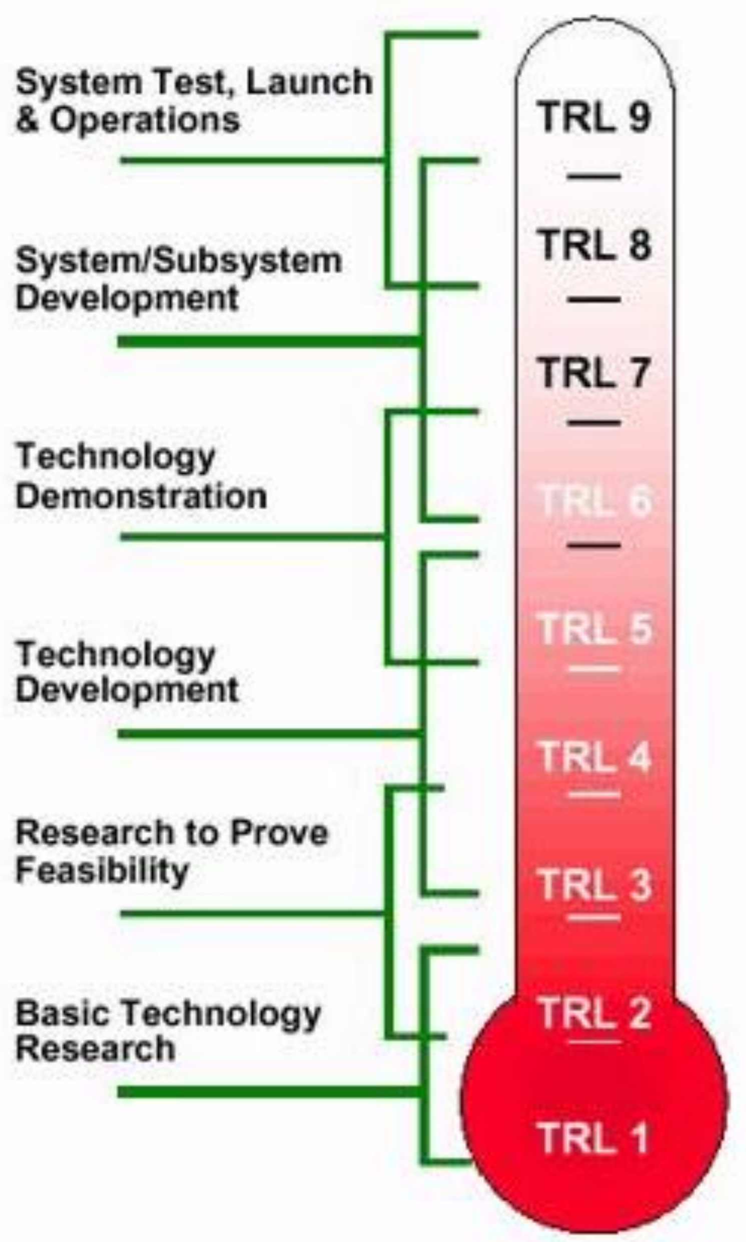
- SIGMA detector



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