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Radiation Safety. **Amplified.**

Recent developments in HPGe detectors

AT CANBERRA (MIRION TECHNOLOGIES)

Presentation Summary

Recent HPGe developments in HPGe detectors

- **Presentation of CANBERRA (Mirion Technologies)**
- **Key expertise and technologies**
- **Recent HPGe detector developments**

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CANBERRA

Presentation of the company

CANBERRA is part of Mirion Technologies since July 1st, 2016

- Key elements of the merger

Mirion - Canberra Overview

- 980 employees in 7 countries
- 11 production sites (in USA, Canada, France, UK, Finland)
- 100+ distribution channels worldwide
- Build-up from successive mergers since 2003

KEY INDUSTRY PLAYER IN :

- *Dosimetry Services*
- *Health Physics*
- *Radiation Monitoring Systems*
- *Sensing Systems*
- *Imaging Systems*
- *Maintenance / Repair Services*

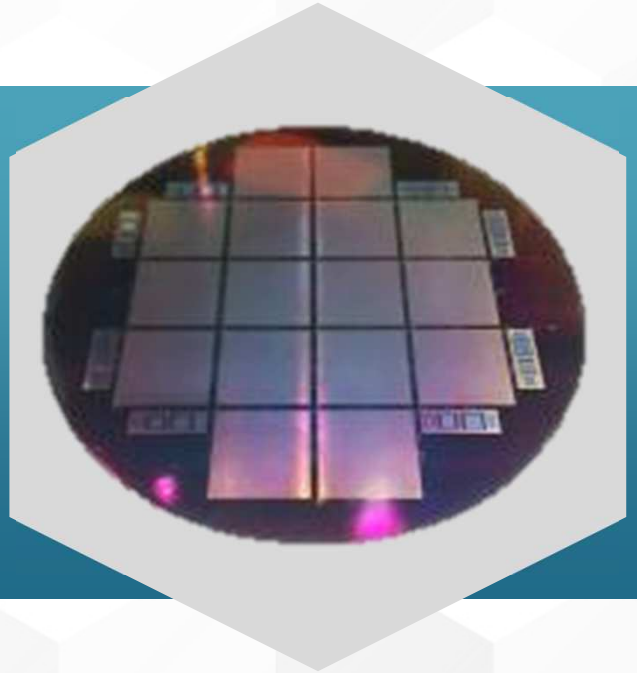
- 930 employees in 9 countries
- 5 production sites (in USA, Canada, France & Belgium)
- 35 independent distributors
- Build-up from acquisitions from 1965 - 2002

KEY INDUSTRY PLAYER IN :

- *Spectroscopy*
- *Health Physics*
- *Radiation Monitoring Systems*
- *Non-Destructive Assay*
- *Maintenance / Repair Services*
- *Measurement & Expertise*

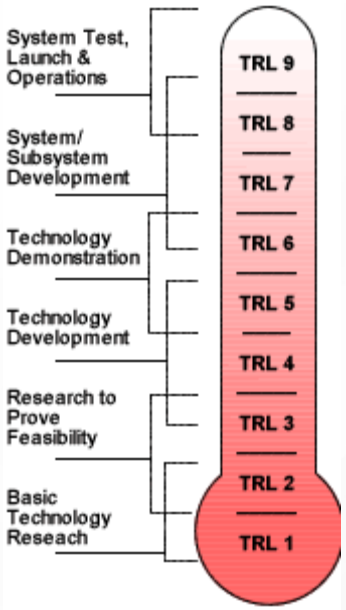
Technologies

Expertise and know-how overview



Key expertise and technologies

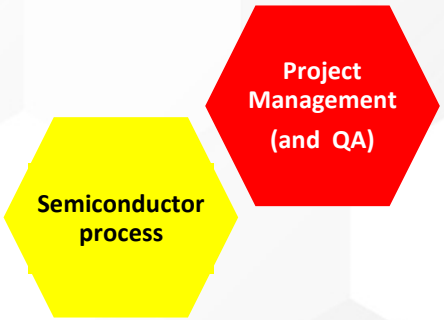
- Project Management
  - Long background in both developing advanced technologies (specialty detectors) and large-scale products (standard detectors)
  - Technology Readiness Level (TRL) typically from 3 to 9



Technology Readiness Levels as originally developed by NASA in the 1980s

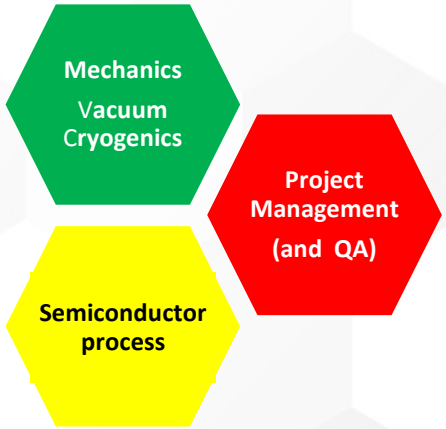
Key expertise and technologies

- Project Management
- Semiconductor Process
  - Large know-how and proprietary processes (segmentation, passivation)
  - Full and redundant set of process equipment for Si, Si(Li) and Ge: shaping, PVD, CVD, implantation, diffusion, outgassing / annealing capabilities
  - Thin layer characterization capability (thickness, stress, reliability, charge carrier life time)
  - Management of clean / radiopure environments



Key expertise and technologies

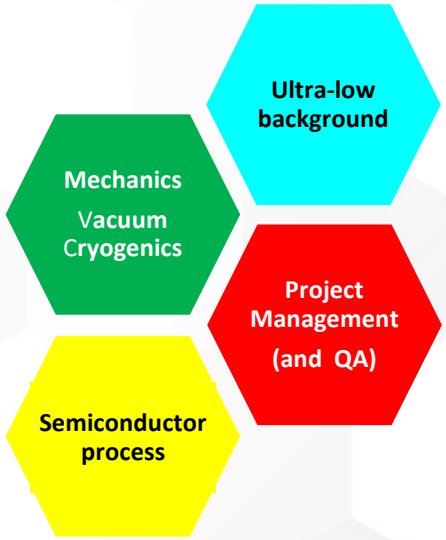
- Project Management
- Semiconductor Process
- Mechanics, vacuum and cryogenics
  - Development of low-vibration and long-life cryocoolers for HPGe



  - Improved thermal balance (necessary for electrical cooling)
  - Proprietary technologies to hold and encapsulated HPGe detectors, collaboration with Univ. of Cologne (IKP)
  - Long experience with UHV process

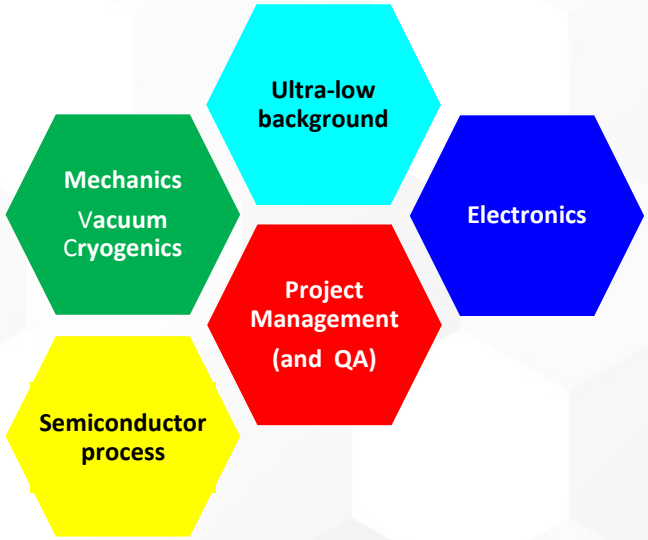
Key expertise and technologies

- Project Management
- Semiconductor Process
- Mechanics, vacuum and cryogenics
- Ultra-low background
  - Systematic characterization, traceability and underground storage of radiopure materials
  - Collaboration with international low-background laboratories and experiments (double B decay, Dark Matter, neutrino scattering)



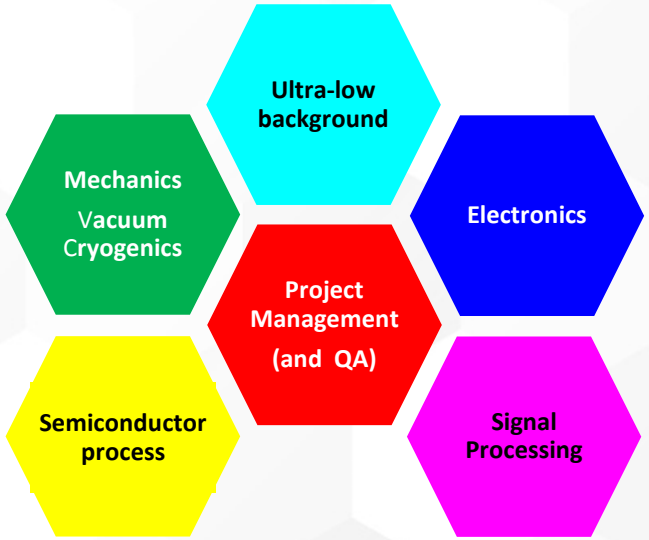
Key expertise and technologies

- Project Management
- Semiconductor Process
- Mechanics, vacuum and cryogenics
- Ultra-low background
- Electronics
  - Strong expertise in analog electronics
  - Continuous challenge for low-noise, high count rate, low power, multi-channel and more integrated electronics



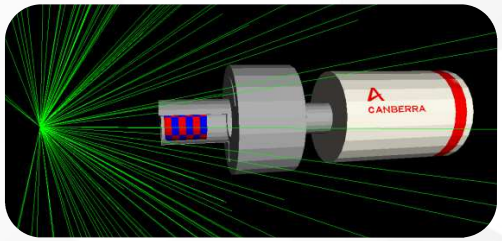
Key expertise and technologies

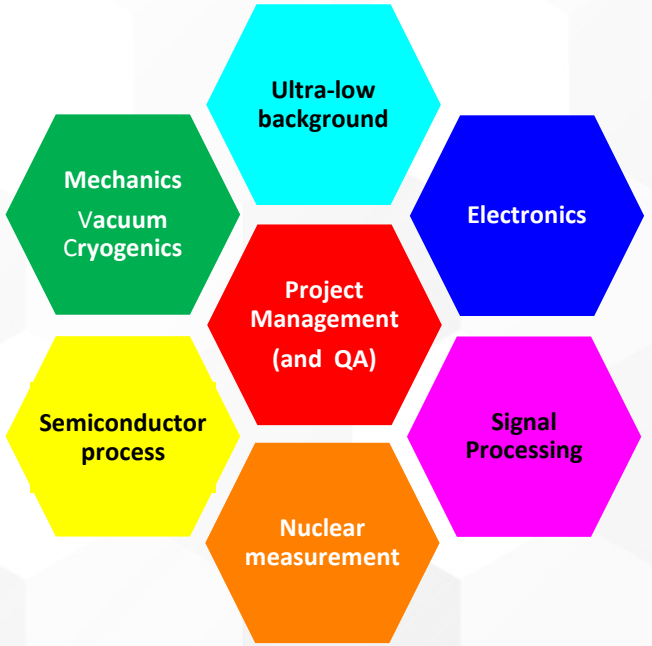
- Project Management
- Semiconductor Process
- Mechanics, vacuum and cryogenics
- Ultra-low background
- Electronics
- Signal Processing
  - Pulse shape analysis techniques transferred from physics to industrial applications
  - Growing know-how with digital acquisition to characterize multichannel detectors
  - Collaboration with IPHC (CNRS) and University of Liverpool



Key expertise and technologies

- Project Management
- Semiconductor Process
- Mechanics, vacuum and cryogenics
- Ultra-low background
- Electronics
- Signal Processing
- Nuclear Measurement (spectroscopy)
  - Alpha, beta, gamma and x-ray spectroscopy is recognised as core competency of CANBERRA
  - For Lingolsheim, particularly large experience with low background, low noise and multichannel spectroscopy
  - In-depth modelling of detectors during design and characterization phases



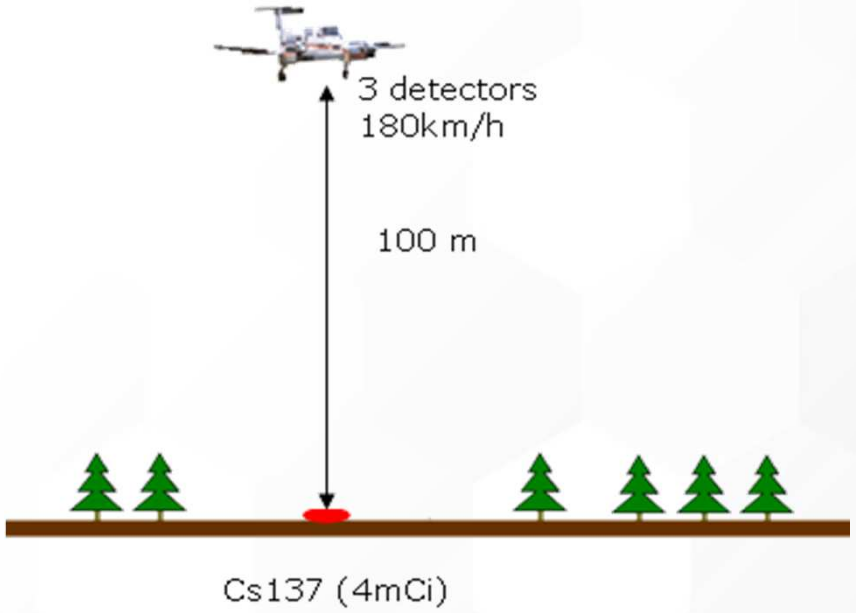


Recent developments

Overview of some specialty products

Large efficiency spectrometer

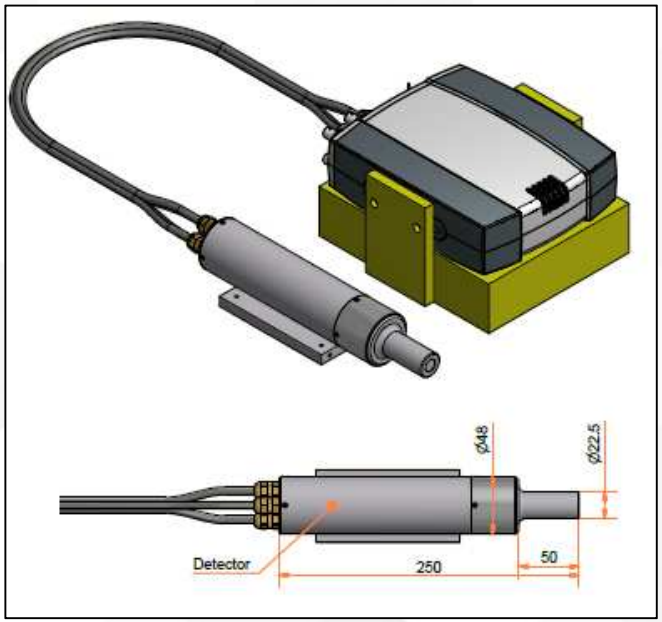
- Airborne HPGe spectrometer (2013)
- 7 encapsulated coaxial HPGe detectors (15kg of Germanium)
- Rel. efficiency up to 1100% in addback mode
- Electrically cooled (with UPS)
- Turn-key system for real time mapping of radionuclides



µGe: miniature HPGe detector

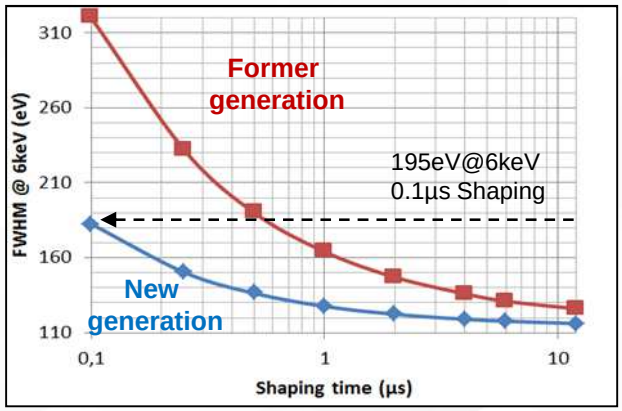
- Miniature HPGe detector initially developed for nuclear industry
  - Compact, low power, low weight
  - Improved energy resolution with respect to compact RSTD and scintillators

Parameter	Unit	Value
Cool-down time	[minutes]	15
Warm-up time	[minutes]	10
Energy range	[keV]	10 keV - 3 MeV
Max. FWHM @ 122 keV	[keV]	0.75
Max. FWHM @ 1332 keV	[keV]	1.95
Max. ICR	[cps]	>100kcps @662keV
Sensor mass	[g]	< 5
Detector mass	[kg]	1.2
Electrical consumption (detector)	[W]	10



Low-noise x-ray detector

- Ongoing development of ultimate low-noise x-ray spectrometer
  - Novel ultra low capacitance detector
  - New generation analog front-ends
  - Low noise and miniaturized contacting methods



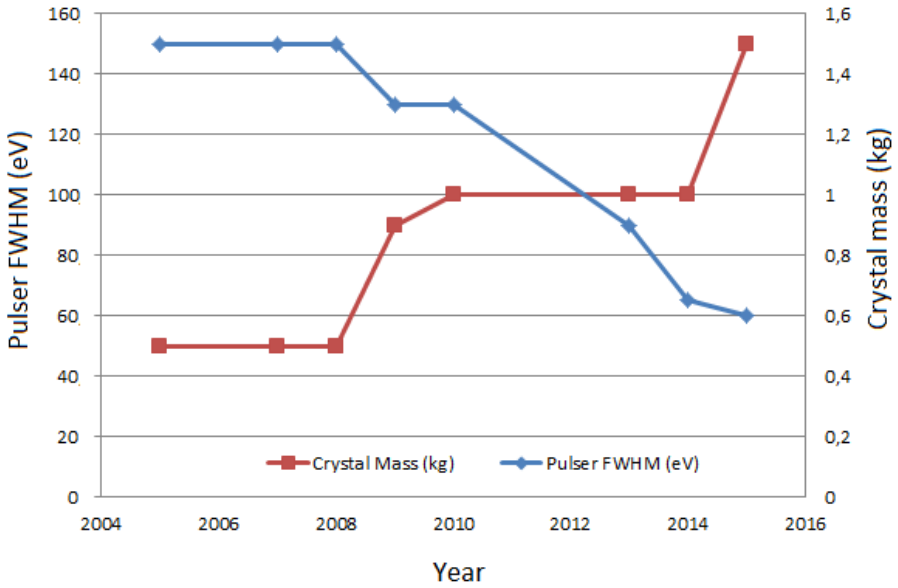
- Targetted performance:

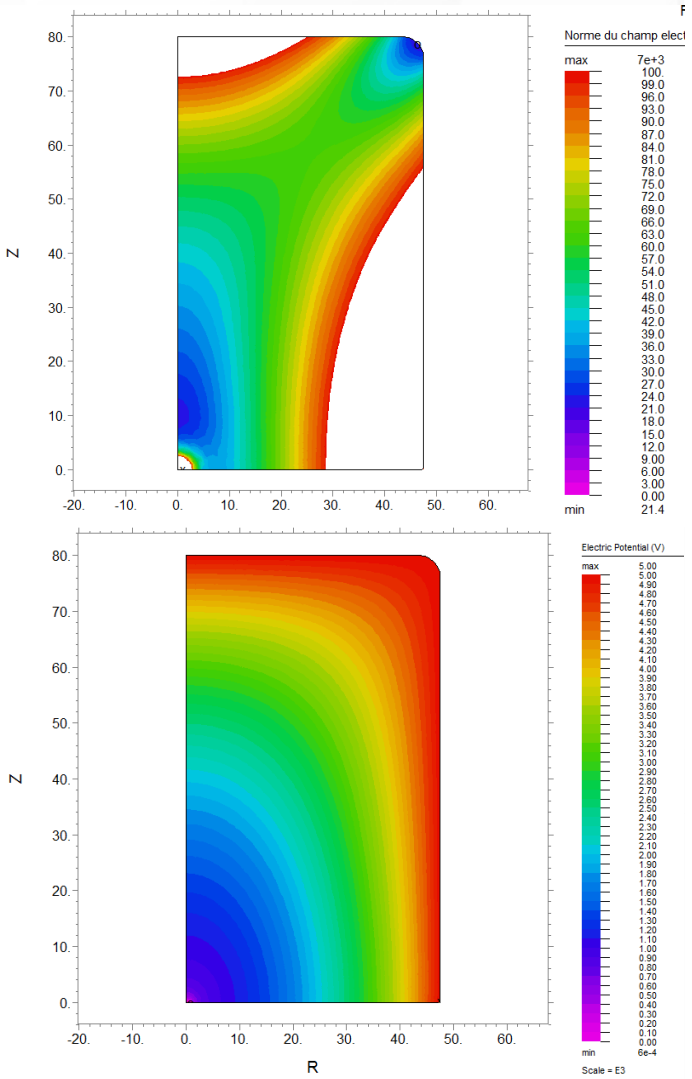
Parameter	Unit	Value
FWHM @ 6 keV 0.1µs	[eV]	160
FWHM @ 6 keV 12µs	[eV]	120
FWHM @ 14 keV 0.1µs	[eV]	200
FWHM @ 60 keV 12µs	[eV]	330
FWHM @ 122 keV 12µs	[eV]	450
Max. ICR	[cps]	2-3Mcps

- To be combined with advanced DAQ chains and signal processing techniques

Low noise - low background point contact detector

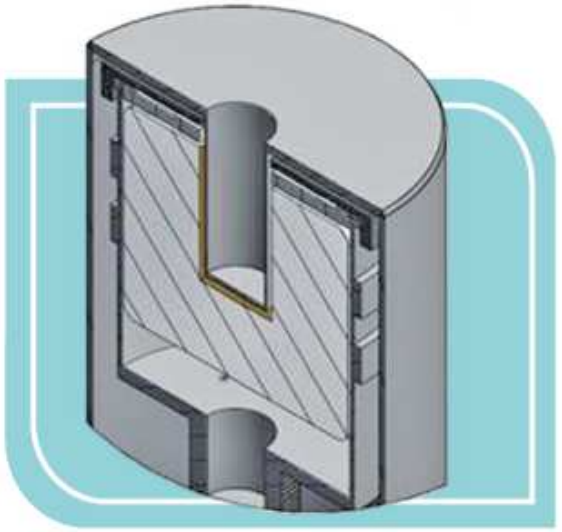
- Main applications: Dark Matter search and neutrino scattering experiments
- Continuous records in PC detectors volume
  - Current target: 2.4 kg
- Continuous improvement in electronic noise
  - Current target: FWHM < 50 eV @ pulser

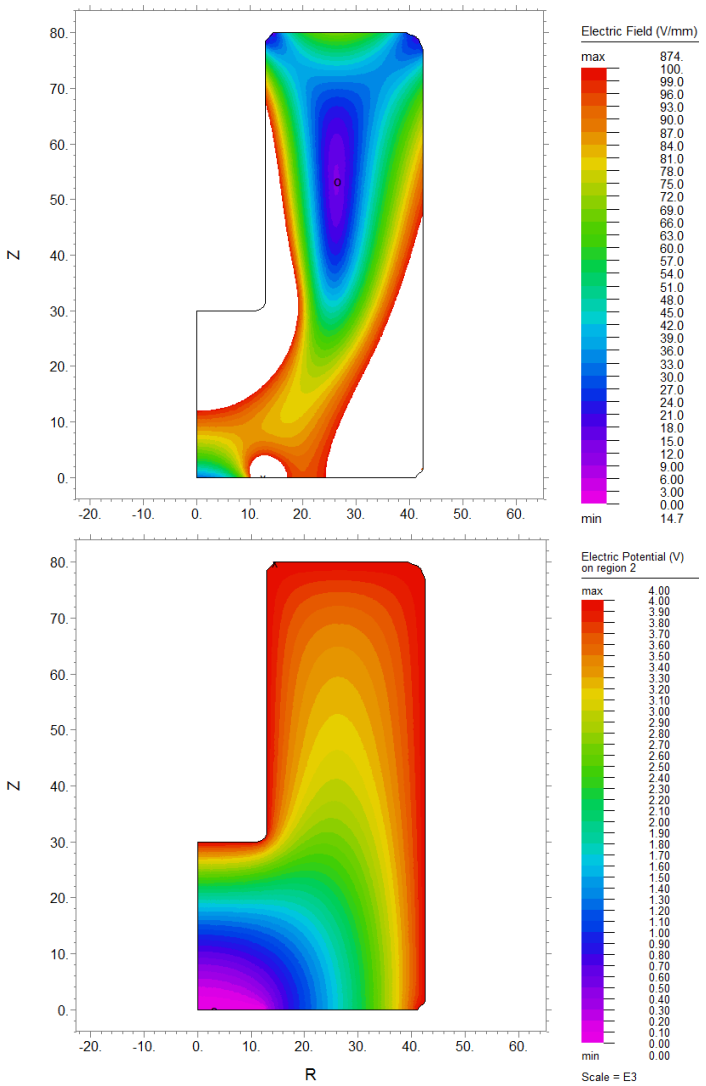




SAGe™ Well detectors

- Combination of
  - excellent energy resolution at low and high energies (simillar to Point Contact / BeGe configurations)
  - maximum efficiency (similar to well detectors)



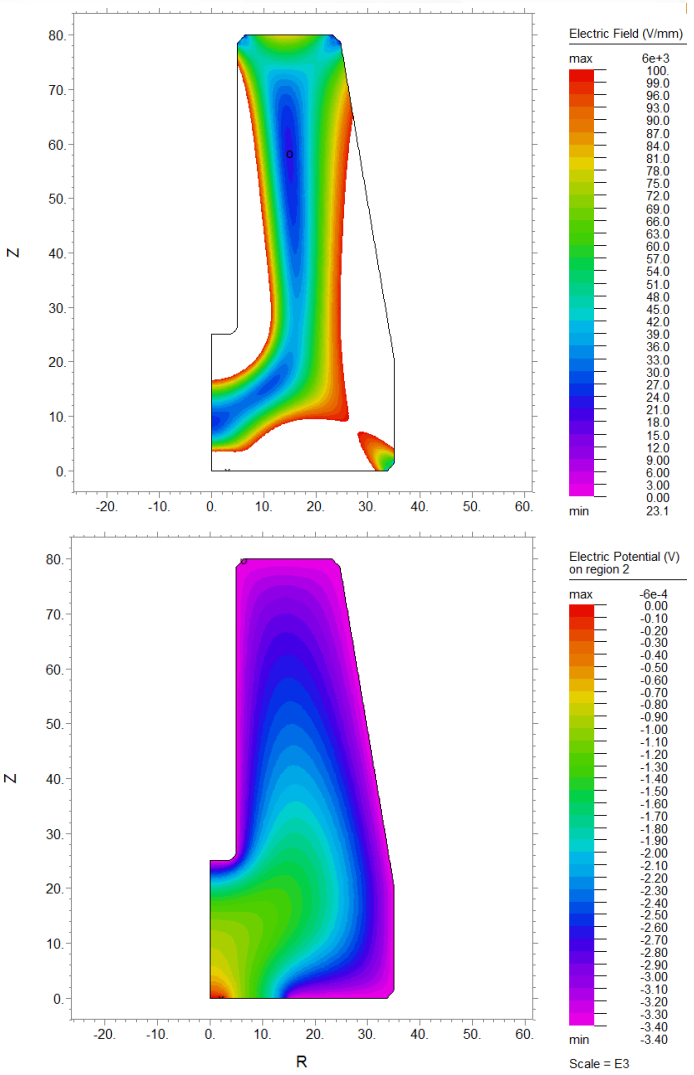


- Also offers lower depletion voltage with respect to point contact (SAGe) configuration of the same volume

Inverted (point contact) coaxial detector

- **Inverted Coaxial detector**
  - Long drift time on purpose for improved position resolution
  - See R.J. Cooper et al., NIM A 665 (2012) 25
- **1st segmented prototype (2012)**
  - For ORNL (D. Radford), currently tested in Berkeley
  - N-type crystal
- **2st segmented prototype (in indevelopment)**
  - For Univervisity of Liverpool (SIGMA)
  - P-type crystal

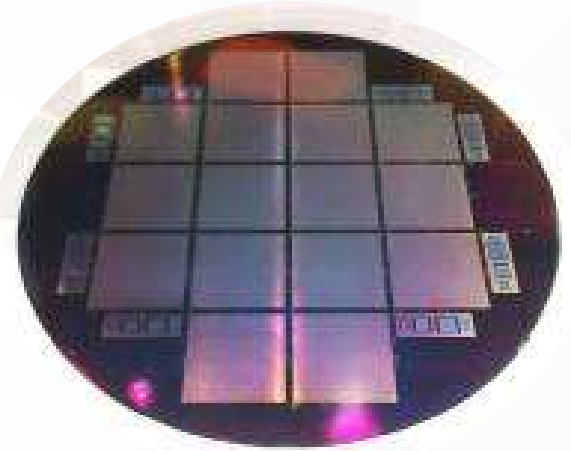
→ Talk of Laura Harkness in this workshop for details



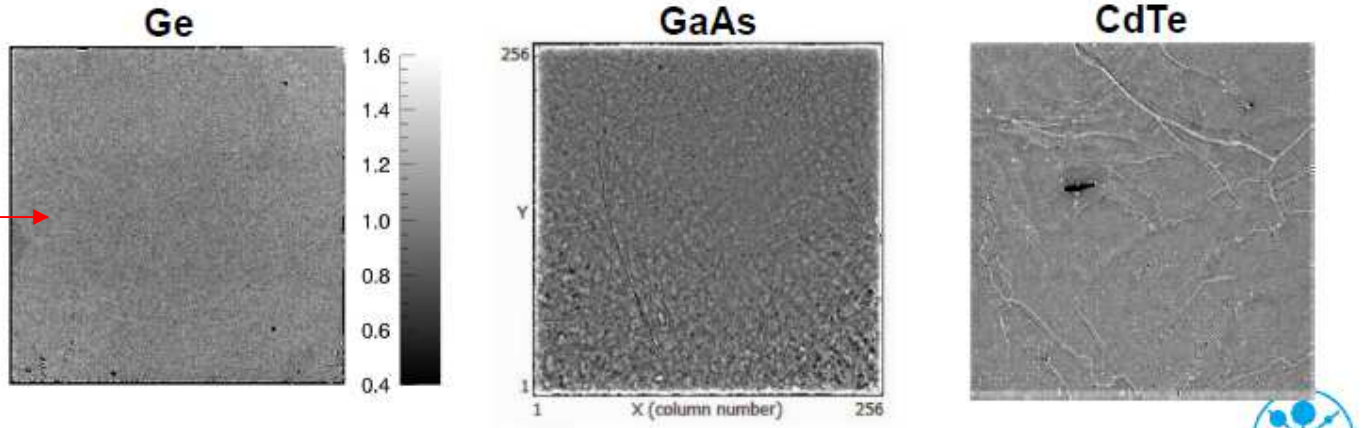
Fine pixel imagers

Developments of HPGe wafers with micrometric pixels

- Wafers are coupled to user ASICS (e.g. Medipix 3)
- Application: imaging or very high count rates
- Down to 55µm; arrays of chips possible
- Advantage of Germanium
  - High efficiency and stopping power
  - High quality & large diameter wafers available



Flat field with much less flaws than other high Z materials



Spectro-imagers (Compton cameras)

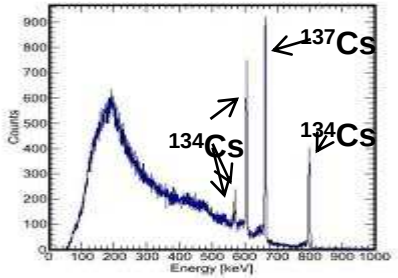
- Mid-term industrial challenge: development of 3rd generation radiation imagers, combining high detection efficiency and hig-resolution spectroscopy

Single electricaly-cooled DSSD for Compton imaging (Si(Li) or HPGe)

Example of industrial application: waste drum imaging in Fukushima

Courtesy of Dr. Motomura (Riken Kobe)

Setup of the imaging experiment



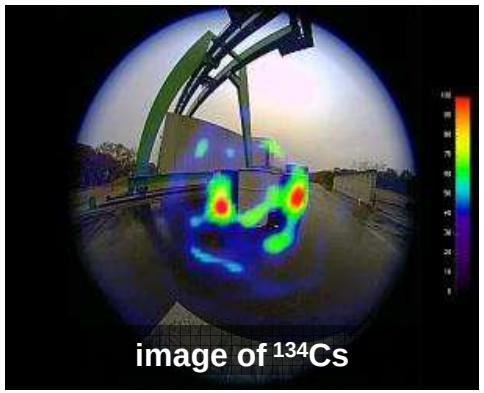


image of ^{134}Cs

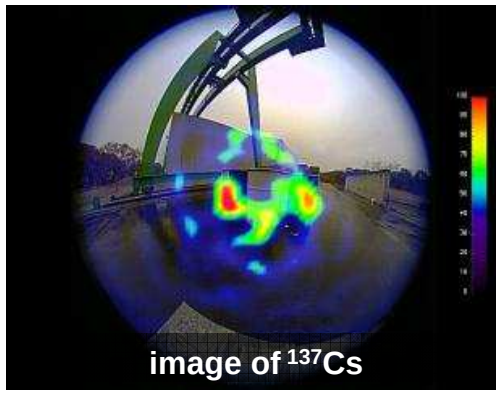


image of ^{137}Cs

Recent HPGe developements: trends

- Already good inputs (challenges) collected from previous talks in this workshop
- Energy resolution
  - Still room for noise improvement at low energy (from 100 eV down to a few tens eV):
    - Small detectors with high count rates, mostly for x-ray spectroscopy
    - large PCGe detectors have for Dark Matter experiments
  - Mitigation of trapping and microphonics effects at high energy
- Count rate
  - For x-ray spectroscopy, detectors, electronics and signal processing suited for more than 1Mcps without resolution degradation
- Position sensitivity
  - Consideration of charge drift time in pulse shape analysis: compatible with count rates requirements and sensitivity to trapping ?
  - No need for increased segmentation ?
- Detection efficiency
  - Very small (electrically cooled) HPGe detectors to compete with RTSD
  - Very large efficiency (up to 200% rel. eff. for single detectors, and 1000% for clusters)
- Operation
  - Increasing need for electrically cooled detectors, even for scientific applications