## Engage. Explore. Empower.

Connecting Visionaries in Radiation Safety, Science and Industry

# MIRION Connect 24

## Annual Users' Conference

July 29 - August 2 | Omni Dallas Hotel, Dallas, TX

MIRION TECHNOLOGIES

# Exploring the Latest Advancements in Custom HPGe Detectors

**Gabriela ILIE, Ph.D.**

Product Line Manager – Specialty Detectors and Education

Mirion Connect | Annual Users' Conference 2024

Dallas, Texas

MIRION Connect 24
Annual Users' Conference

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# Outline

- Introduction of Specialty Products
- Building block technologies for custom detectors
- Example of custom detectors
- Summary
- Q&A

# Mirion Specialty Products

Unique position and capacity with respect to development and manufacturing of custom solutions

**Lingolsheim, FR** – focus on **project based** challenging research application using **innovative HPGe detector solutions**

- 50+ years of experience
- Project team organized in skill based approach (detectors, cooling, electronics, mechanics)
- All required manufacturing capabilities in house
- Serving customers worldwide

**Meriden, CT** – focus on **standard HPGe** innovative **detector solutions**

- 50+ years of experience
- Organized to enable industrial manufacturing of innovative HPGe detector solutions
- All required manufacturing capabilities in house
- Serving the US and Asia


**Olen, BE** – focus in **standard HPGe and PIPS detector solutions**

- 35+ years of experience
- Organized to enable industrial manufacturing of innovative HPGe and PIPS detector solutions
- All required manufacturing capabilities in house
- Serving Europe, Middle-East on HPGE and worldwide for PIPS detectors

# Specialty Products Building block technologies

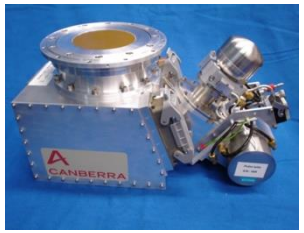
# Mirion building blocks technology

## 1. Electrical cooling

- **No compromise** on detection performance
- **Highly reliable** electrical coolers
- Adapted for **all types of applications**


**Airborne**


**Synchrotron**





**Industrial and/or In-situ**

**Nuclear Physics**

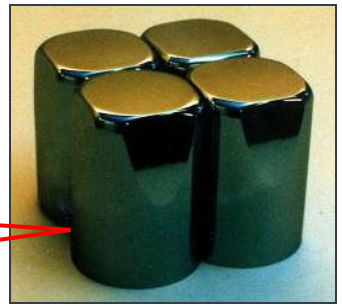


**Medical Applications**

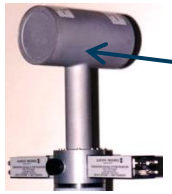
# Mirion building blocks technology

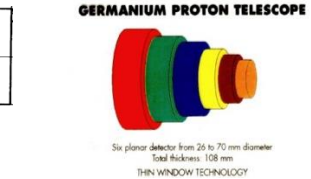
## 2. Array detectors → Maximized detection efficiency or specific needs

### CLOVER Detectors

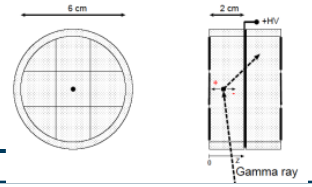



### STACK Detectors





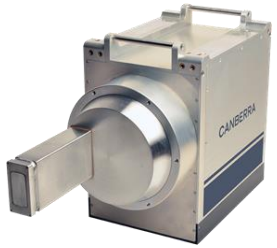

Telescope




Proton Telescope

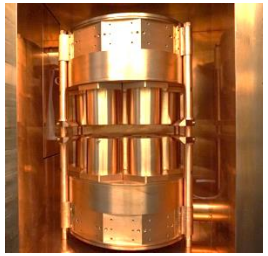
Grape Telescope

### MULTIELEMENTS Detectors





### ULB detectors « cup » array

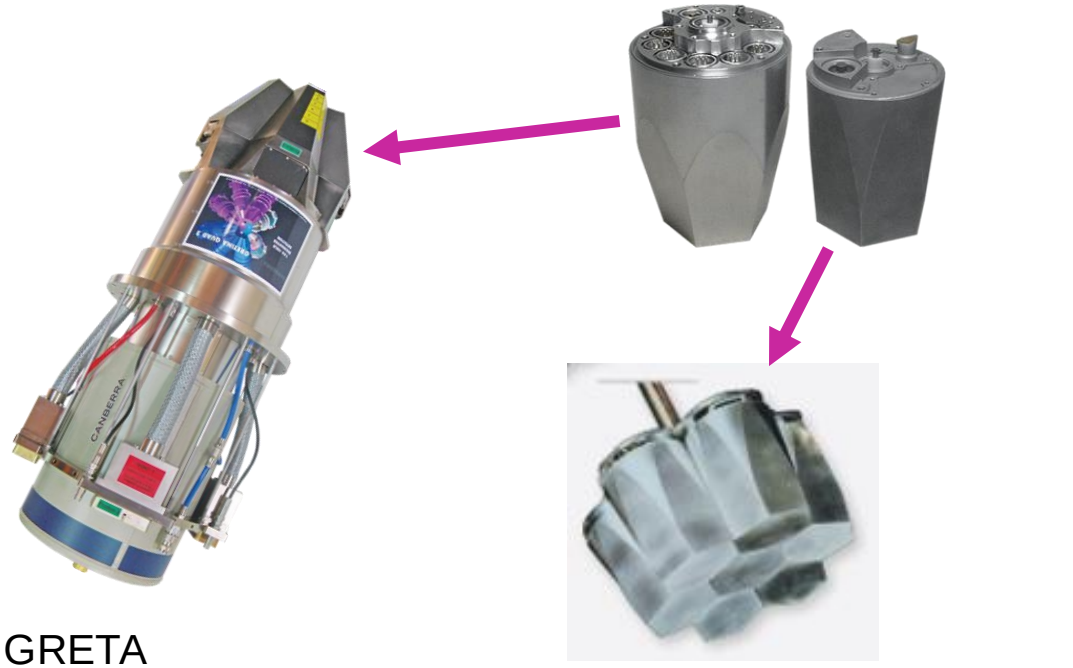



# Mirion building blocks technology

## 3. Encapsulation

- The solution for addressing **close packing arrays** or **rough motion application**

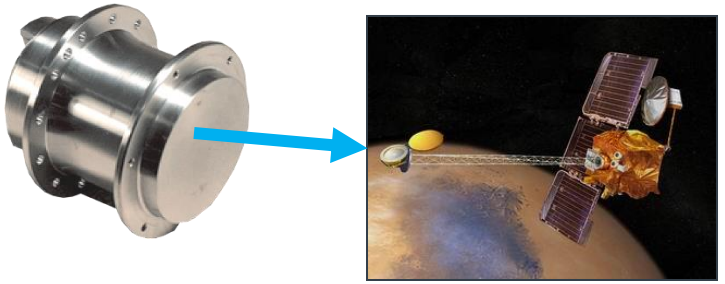
**Nuclear physics scientific experiments**



GRETA

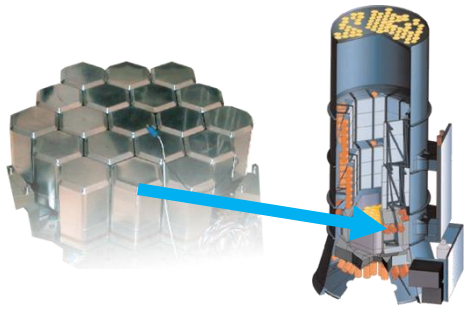
EUROBALL, MINIBALL, AGATA…

**Space projects**



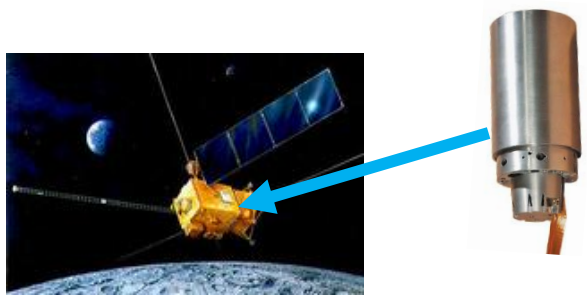
MARS ODYSSEY

Since 2001



SPI INTEGRAL

Since 2002



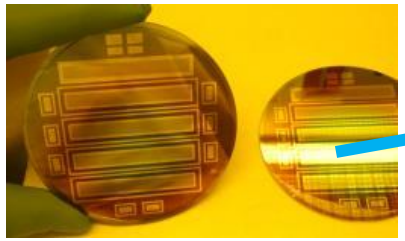
SELENE Lunar Orbiter

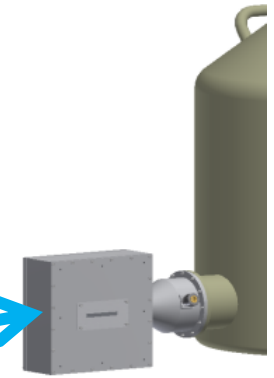
2007-2009

# Mirion building blocks technology

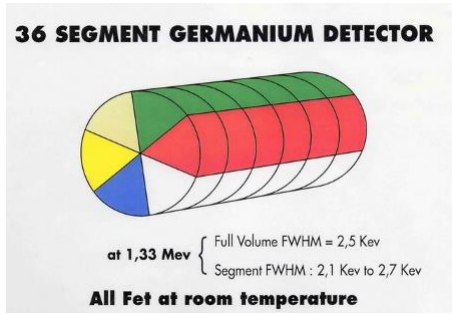
## 4. Segmentation

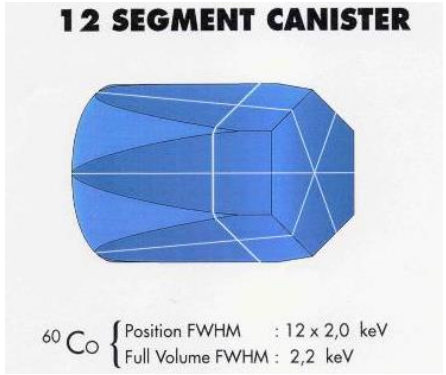
- Segmented Planar HPGe Detectors

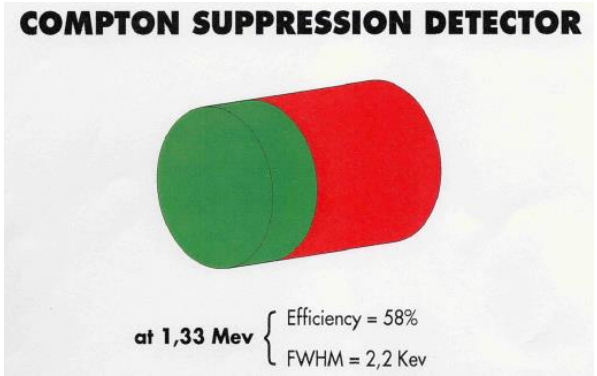





- Segmented Coaxial HPGe Detectors




**Applications:**

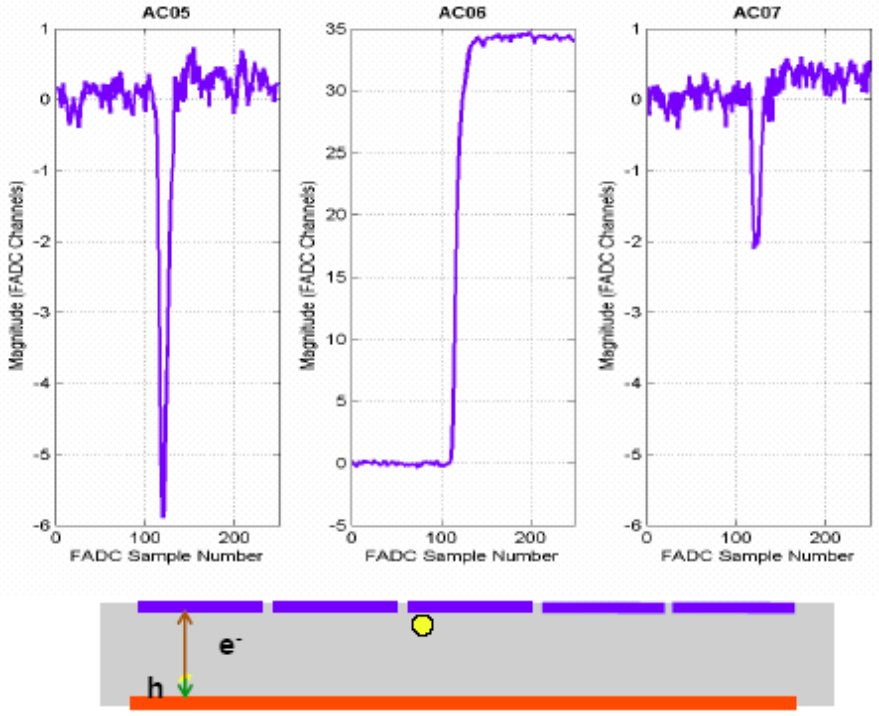
- Imaging
- Compton camera
- Doppler correction
- Polarization measurement
- Tracking
- Compton Suppression

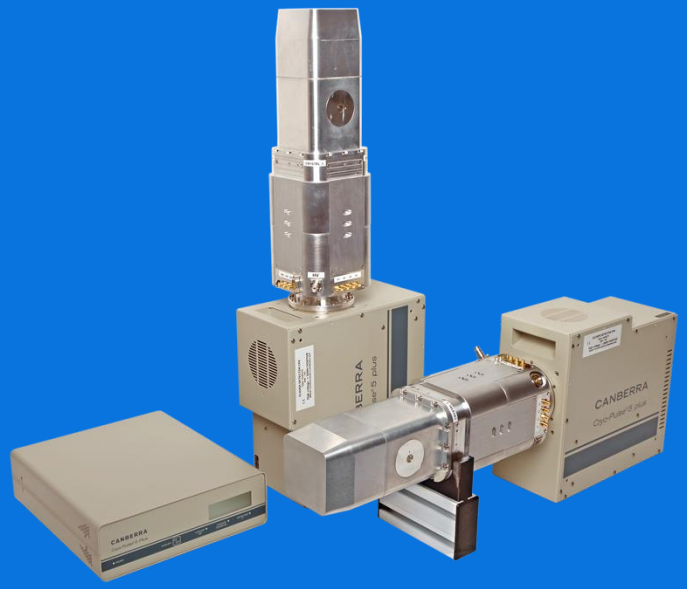
# Mirion building blocks technology

## 4. Segmentation

- Double-sided Strip Detectors
  3D localization of the interaction into the crystal


- The typical maximum size of an image charge pulse is 15% that of the real charge signal.
- $^{241}$Am pulse response.

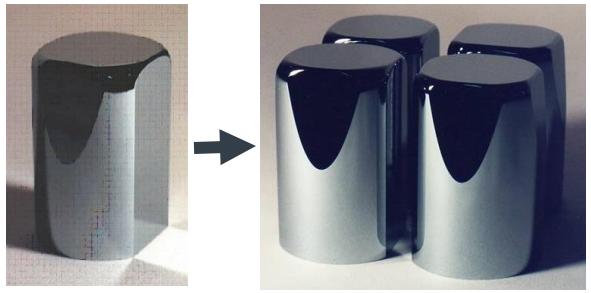





# Nuclear Physics Fundamental Reseach

# Mirion Clover Detectors

- EUROBALL Clover is an array consisting of four N-type detectors with initial dimensions of 50 mm diameter and 70 mm length
- The close four crystal array is surrounded by a very minimum of material to minimize any Compton scattering
- A unique cryostat with a common vacuum enables best conditions to combine the highest efficiency with the best energy and timing performance



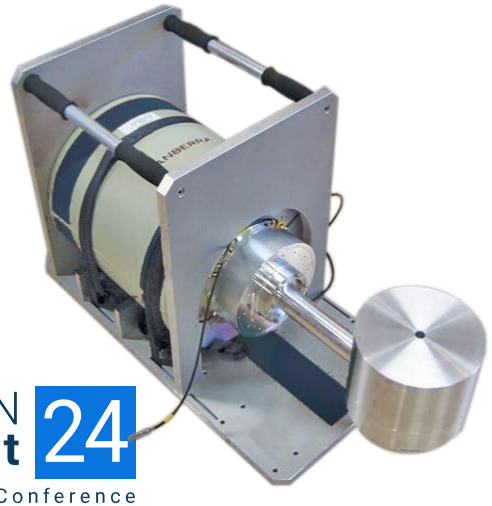
# Mirion Clover Detectors – Key Features

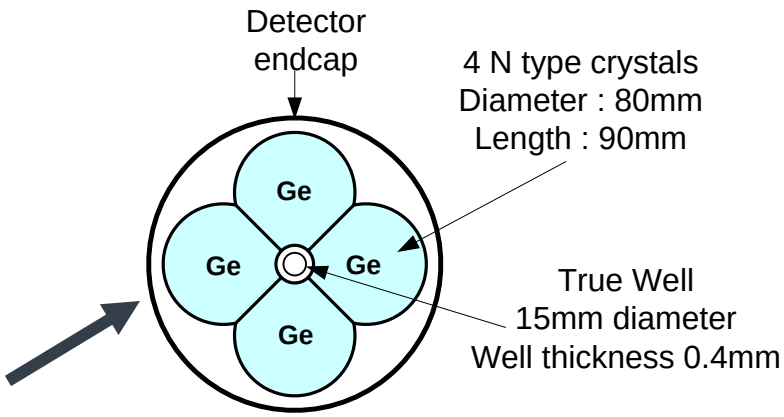
| Key Features | User benefits |
|---|---|
| Highest photopeak efficiency in “add-back” mode | Best signal-to-noise ratio in add-back mode |
| Highest photopeak efficiency and timing response | Best data quality for multi-parametric physics experiment |
| FWHM performance<br>1.33 MeV ($^{60}$Co): <2.1 keV (typ <1.9 keV)<br>122 keV ($^{57}$Co): <1.2 keV (typ <1.0 keV) | Excellent resolution performance for enhanced nuclide identification and quantification |
| Relative Efficiency per diode for a 4x50x70 20% (typ >23%) | Best high-energy efficiency considered the crystal shape |
| Position information through segmentation | Reduce Doppler Broadening |
| Extended energy range<br>Spacer between two neighboring diodes of 0.3 mm | Best add-back capabilities - no dead layer between HPGe |
| Special cryostat design | HPGe temperature around. The colder is Ge material -> reducing the neutron damage. Longer uptime before annealing in neutron rich environment |
| Holding time of >24 hours, typical 28 hours | Easy maintenance operation, minimization of the number of $LN_2$ filling required Increased uptime during experiment |
| Electrical cooling | Electrical is compact, all attitude, safer vs $LN_2$ |
| Reduced vulnerability to neutron damages | Less annealing maintenance |
| Easy access to pumping port | Easy annealing procedures (baking & pumping of the detector) |

**Compact arrangement of four coaxial Ge crystals in one single cryostat for large efficiency γ spectroscopy.**

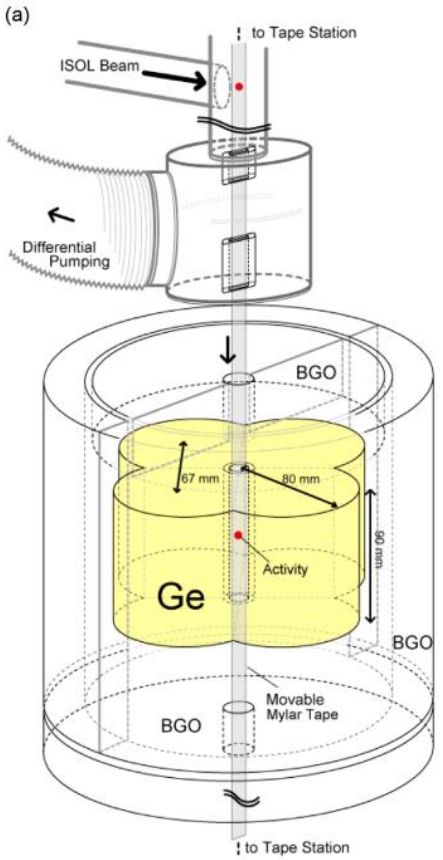
# Mirion Clover Detectors – True Well

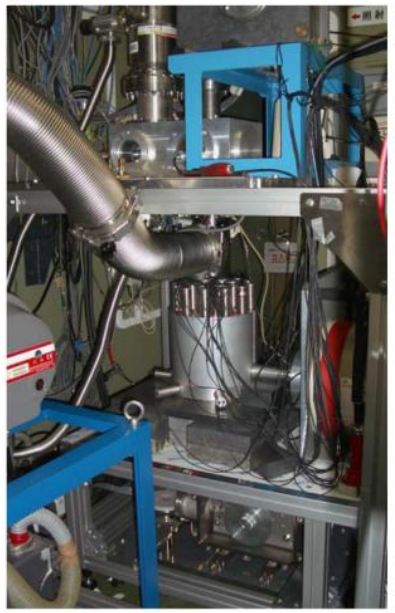
- Application: measurements of beta-decay energies to improve accuracy of atomic mass
- Experimental setup: True Well Coincidence counter
  - A total of **10 kg** of HPGe
  - Remote cryostat configuration to ease the use of a veto surrounding detector
  - Typical add-back efficiency: 500% at 1.33 MeV starting with 90% diodes






The largest Well Type detector ever built worldwide



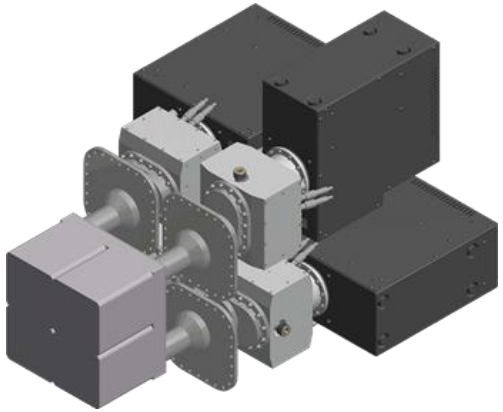




*NIM in Physics Research A747(2014) 41–51*

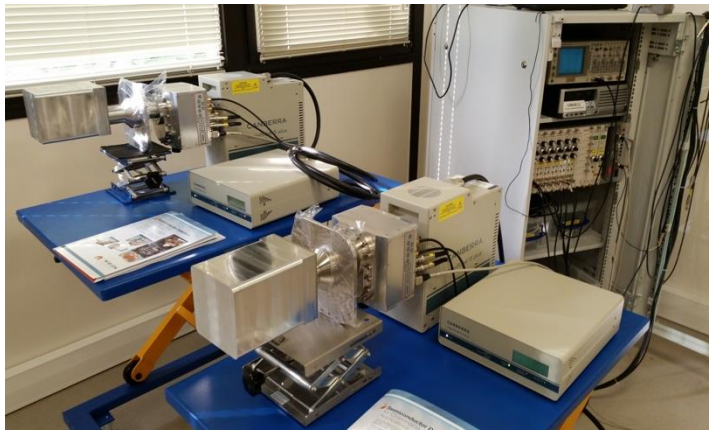
# Mirion Clover - Latest Developments

## First Electrical Cooled Clover worldwide

- COMPEX: New Electrical Cooled Clover Design
  4x50x50x50 (cube-shaped crystals)
- Typical performance of each individual HPGe crystal:
  - FWHM @ $^{60}$CO: 1.90 keV
  - FWHM @ $^{57}$Co: 800 eV
  - Relative efficiency for single diode 28%
- Total HPGe material weight per clover: 2.6 kg
- Large Area array configuration possible due to special off-centered cryostat
- Possible to use the Clover design in vacuum chamber



20 cm by 20 cm Ge wall



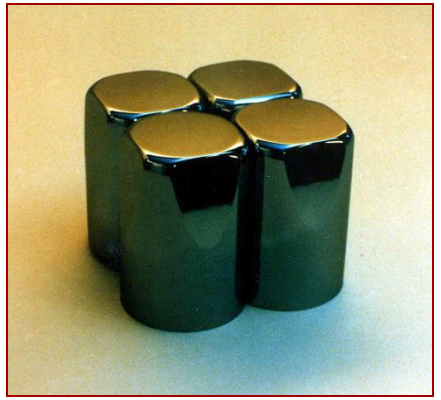

**First experiment at GSI involving 4 Compex Clovers**
*Courtesy Prof. D. Rudolph, Lund University*

# Mirion Clover Detectors

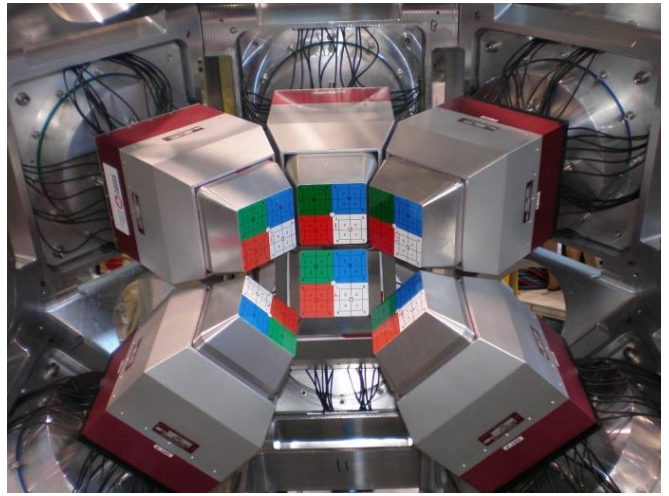
- Different type of Clover detectors already delivered:
  - (4x diameter [mm] x length [mm])
    - 4x50x70 (total ~3kg of HPGe material) & 4x50x70S
    - 4x50x80 (total ~3.3kg) & 4x50x80BCT
    - 4x60x60 (total ~3.6kg)
    - 4x60x90 (total ~5.4kg) & 4x60x90-seg16 & 4x60x90-seg32
    - 4x70x70 (total ~5.7kg)
    - 4x70x140 (total ~11.5kg)
    - 4x50x50x50 (cube-shaped crystals)

Largest database of Clover references available!

340 Clover Detectors Delivered!



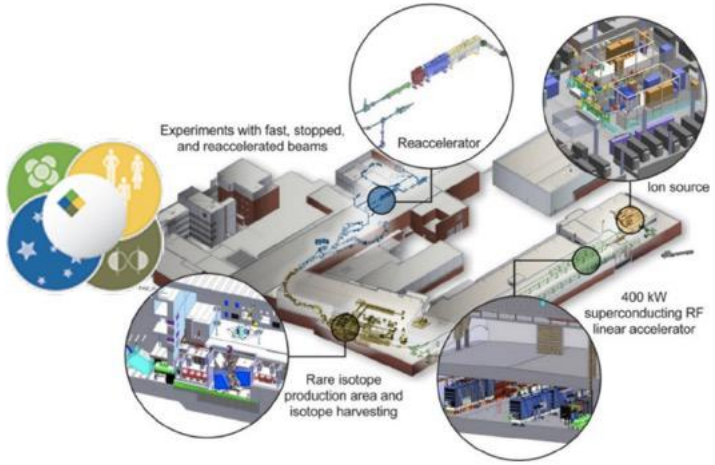
**Adaptable design of four HPGe crystals for Nuclear Physics applications worldwide**

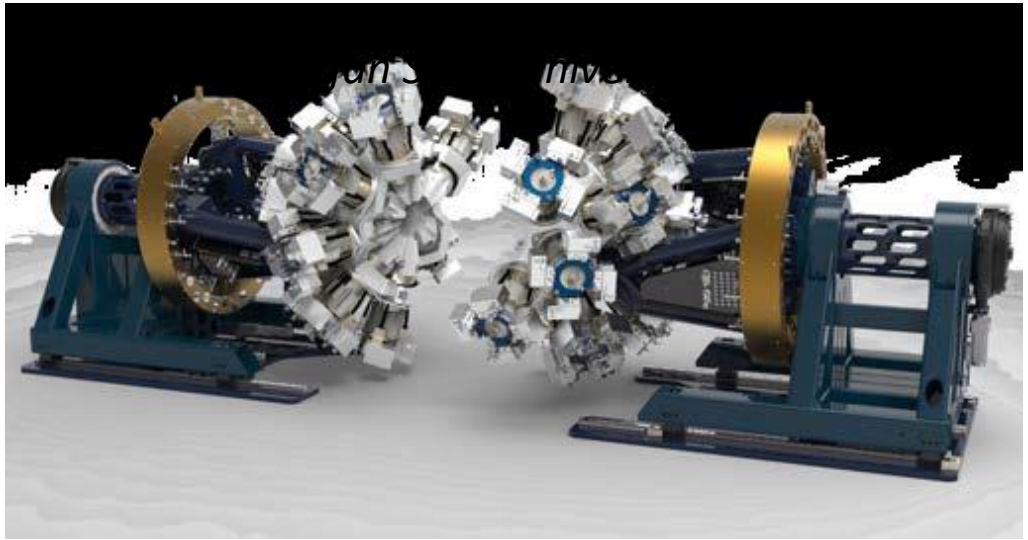


**TIGRESS array at Triumf**
Courtesy of Prof Carl Svensson – University of Guelf

# Mirion Solution for Nuclear Physics

- GRETA: A premier gamma-ray tracking detector for FRIB
- The Facility for Rare Isotope Beams (FRIB) is a world leading accelerator facility to understand the properties of exotic nuclei and how the elements are synthesized
- GRETA will be a key instrument at FRIB capable of reconstructing the energy and three-dimensional position of g-ray interactions
- Its design provides the unprecedented performance (combination of full solid angle coverage and high efficiency, excellent energy and position resolution, and good background rejection) needed to carry out a large fraction of the nuclear science programs at FRIB

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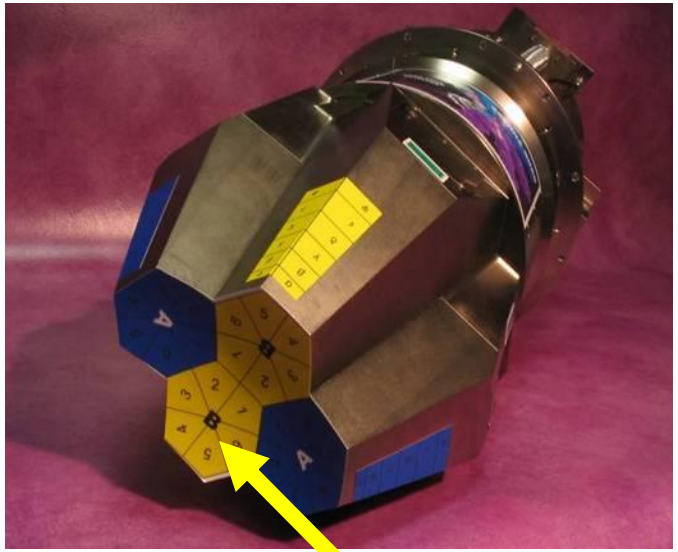
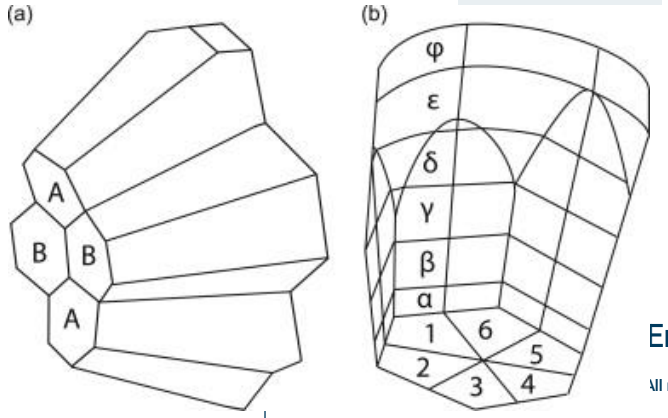
# Mirion solution for GRETINA/GRETA

- **A complete detector solution consisting of**:
  - Coaxial N type 80 mm diameter x 90 mm length
  - Segmented in 36 folds (6 longitudinal x 6 transverse)
  - Encapsulated in an aluminium canister
  - 4 capsules mounted in a Quad detector module
  - 2 hexagonal detector shapes
  - A common cryostat for the 4 capsules
  - Dedicated preamplifier electronics
  - High cooling power cryostat with LN2 dewar



X4



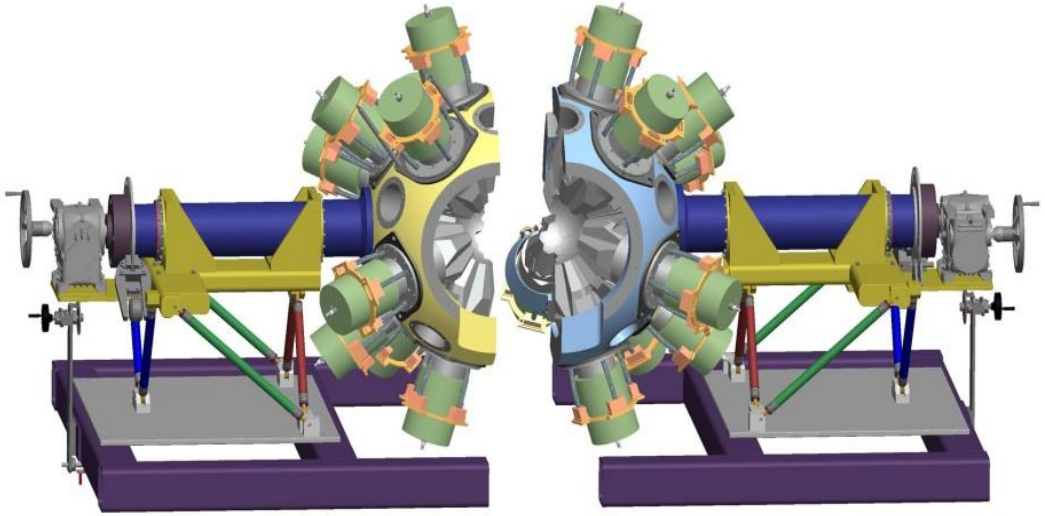
# GRETINA/GRETA concept

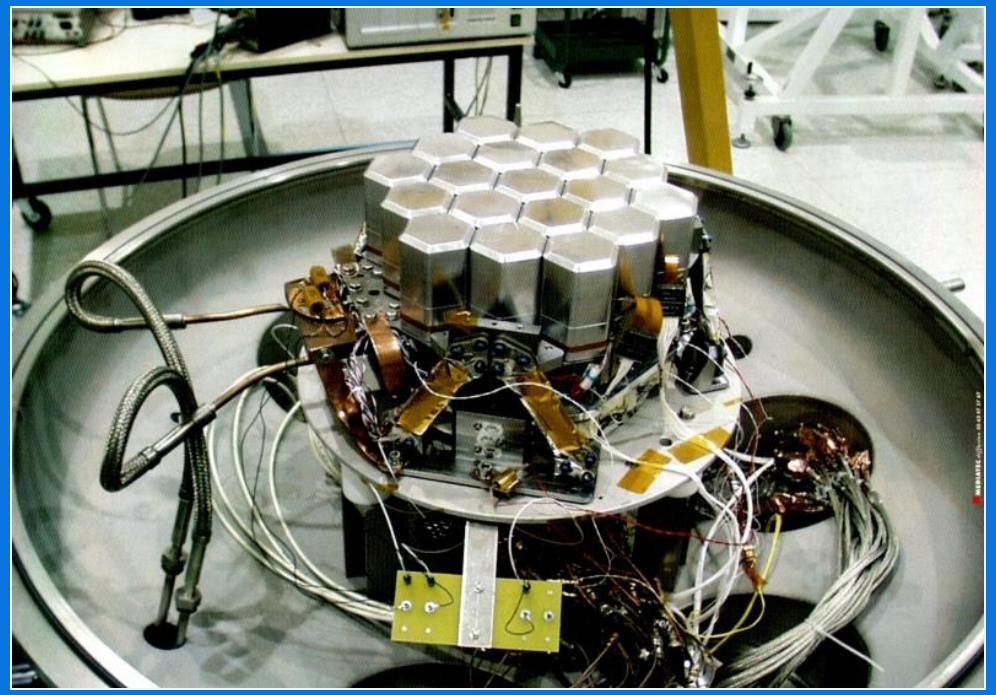
- A shell of closely packed Ge crystals
- Combines (120) highly segmented, hyper-pure germanium crystals with advanced digital signal processing techniques

- Identify the position and energy of g-ray interaction points within a compact “shell” of detectors

- Track g-ray path both within and between detector elements, using the angle-energy relation of the Compton scattering process
  - Maximizes and Optimizes

    Efficiency, Energy Resolution, Peak-to-Total





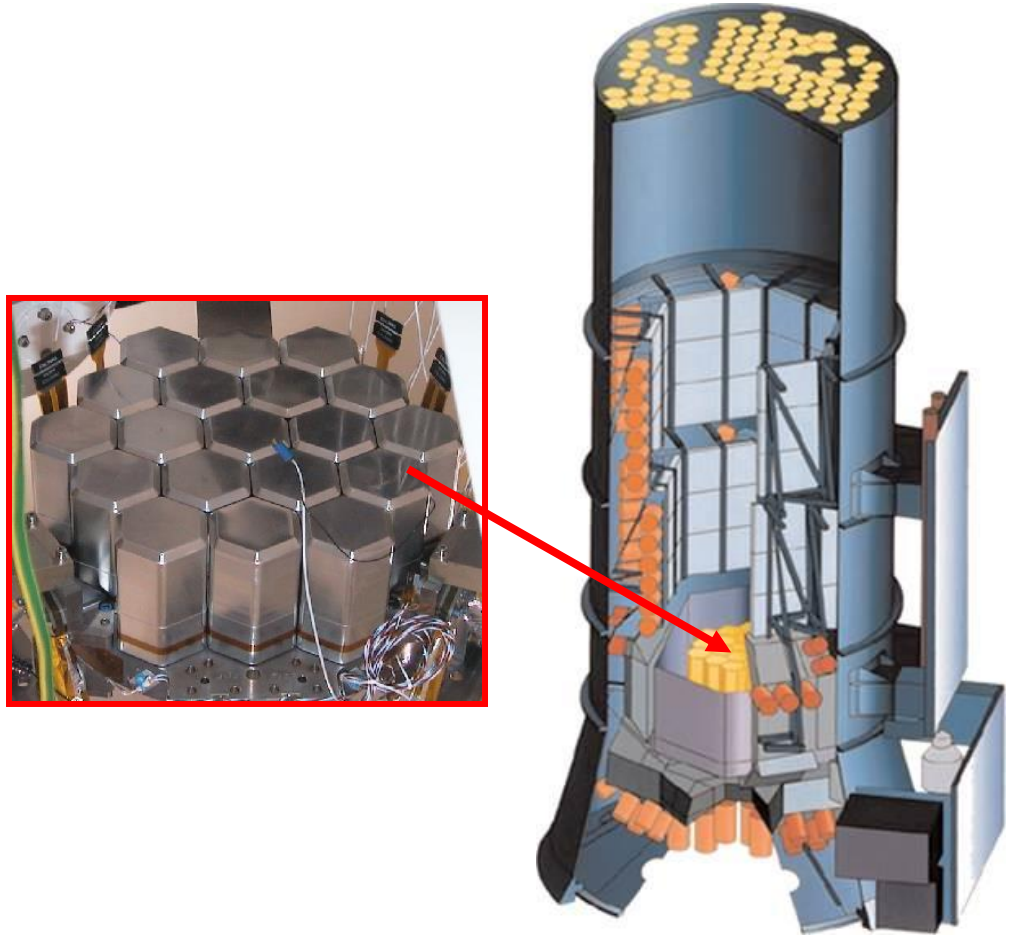
# Specialty Detectors Space Applications

# INTEGRAL-SPI Mission

- **INTEGRAL-SPI: INTE**rnational **G**amma-**R**ay **A**strophysics **L**aboratory, on which is installed the **SP**ectrometer for **I**ntegral
  - An international project, involving the ESA, NASA, RKA
  - Several Instruments: SPI (Spectrometer), IBIS (Imager on Board the Integral Satellite), JEM-X (Joint European X-ray Monitor), OMC (Optical Monitoring Camera)
- **Mission**
  - Goal: Gamma-Ray Astronomy
  - Launch date: 17th October 2002
  - Status: still ongoing, at least until 2029
  - https://www.cosmos.esa.int/web/integral

# INTEGRAL-SPI Mission

- **Spectrometer for Integral is a gamma spectrometer**
  - **Measures radiation from 20 keV to 8 MeV**
  - **Array of 19 encapsulated HPGe detectors**
    - Each detector is a hexagonal 40% (200 cc) HPGe detector that with stands 50g vibrations
    - Energy resolution: 2 keV @ 1MeV
    - Gap between each detector: 3.5 mm
    - Cooling: YES, electrical
    - Annealing: YES
- **Application**
  - Detect, localize and measure gamma rays emitted by black holes, neutron stars, etc
- **Key accomplishments**:
  - Advancements of astrophysical models and our understanding of the universe

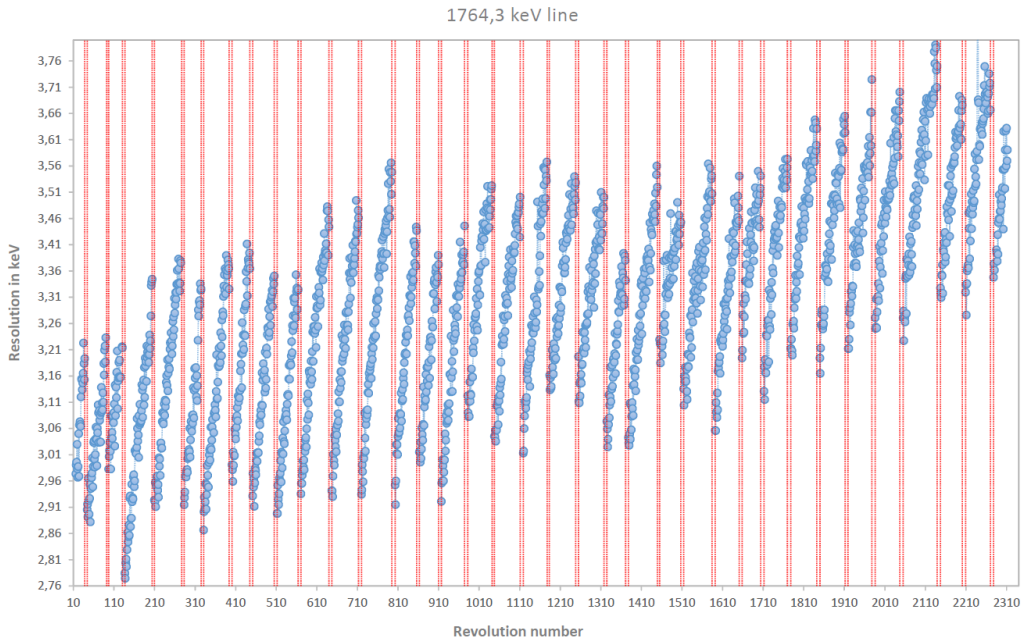


# INTEGRAL-SPI: current status

- Still in **excellent working conditions** even 20 years later after the rocket launching
  - More than 35 annealing cycles of 200 hours (7000 hours)
  - Energy FWHM comparison

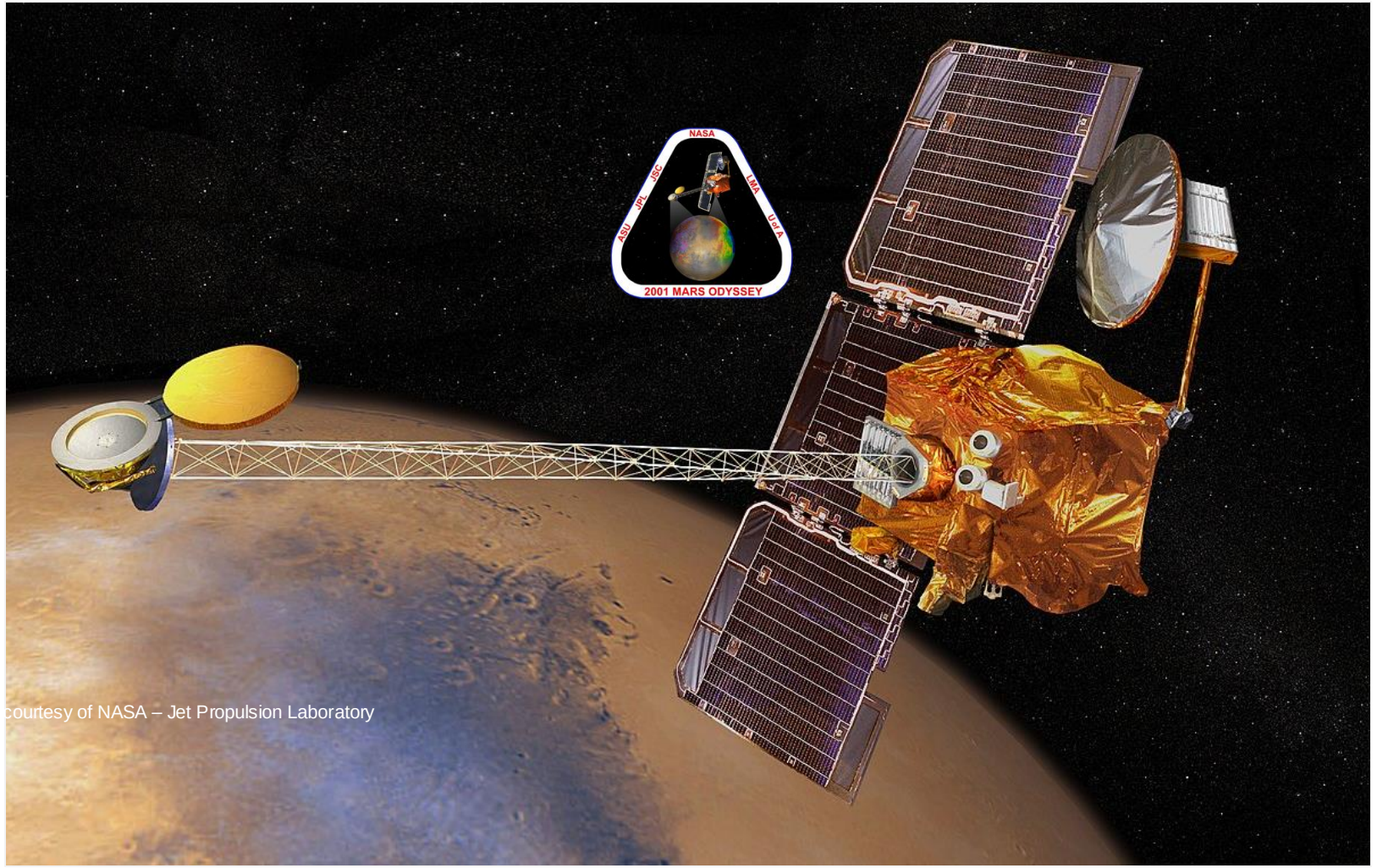
| Energy | Initial FWHM | Current FWHM |
|---|---|---|
| 198 keV | 1.87 keV | 2.01 keV |
| 1764 keV | 2.97 keV | 3.07 keV |
| 2754 keV | 4.11 keV | 4.30 keV |

$^{205}$Bi peak energy resolution monitoring over time (and annealing cycles)




- **Future**
  - INTEGRAL probably run out of fuel some time in the early 2020s
  - The plan is to continue the scientific observations until the satellite will fail: the satellite will probably fail before the spectrometer!
  - Re-entry in Earth's atmosphere and destruction in 2029?

# MARS Odyssey Mission




courtesy of NASA – Jet Propulsion Laboratory



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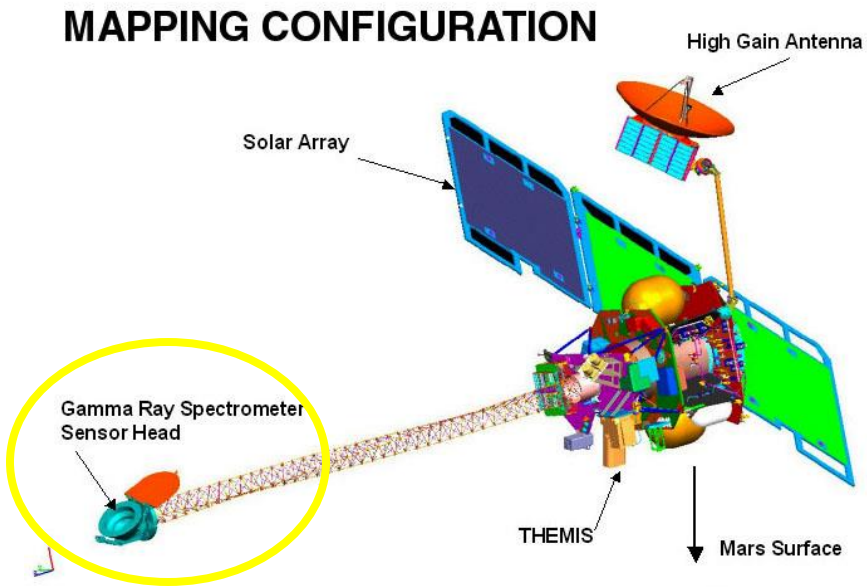
# MARS Odyssey Mission

- **MARS Odyssey Mission**
  - Launch Date: April 7, 2001
  - Arrival Date: October 23, 2001
  - 3 instruments:
    - **GRS – Gamma-Ray Spectrometer**: measures how much hydrogen is present in the upper 3 feet of the planet's soil
    - THEMIS – THermal Emission Imaging System
    - MARIE – Mars Radiation Environment Expriment

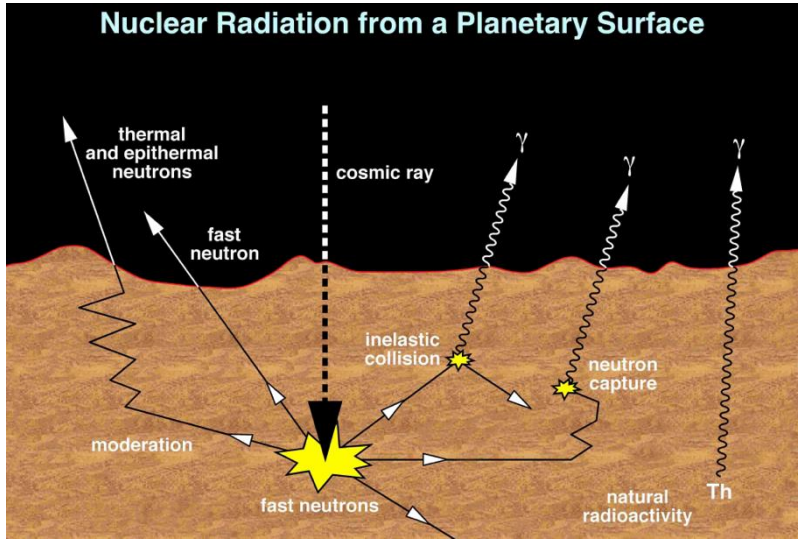
- **Mission**: 2 years study of elemental composition and radiation on Mars
  - August 24, 2004: official end of MARS Odyssey's primary science mission. Total of 250 gigabits of data.
  - Available flight system resource capabilities through the next 10 years: operations continue today as a communications relay for rovers and landers on Mars ("Spirit" and "Opportunity“, “Phoenix” and “Curiosity”).

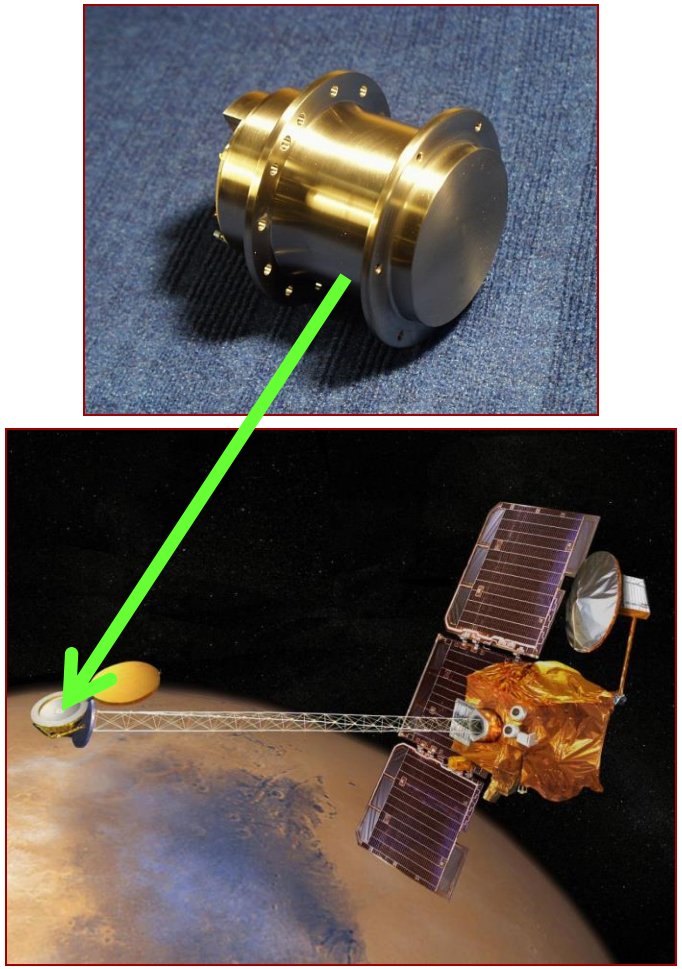



https://mars.nasa.gov/odyssey/index.cfm

# MARS Odyssey: focus on GRS

- The **GRS instrument**
  - 1.2 kg HPGe crystal in a Titanium capsule
  - Cooling through radiative cooler and thermal shield
- Martian soils **elemental composition study** using gamma-ray fluorescence thanks to “cosmic ray activation”



https://science.nasa.gov/mission/odyssey/



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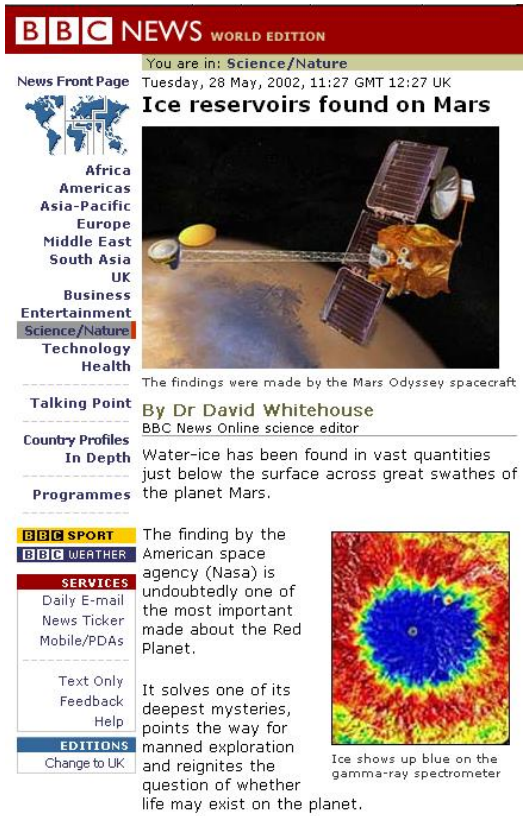
# MARS Odyssey: results

- **Major key accomplishment**
  - 28 May 2002: **Ice was found on Mars!**



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Tuesday, 28 May, 2002, 11:27 GMT 12:27 UK

**Ice reservoirs found on Mars**

The findings were made by the Mars Odyssey spacecraft

By Dr David Whitehouse
BBC News Online science editor

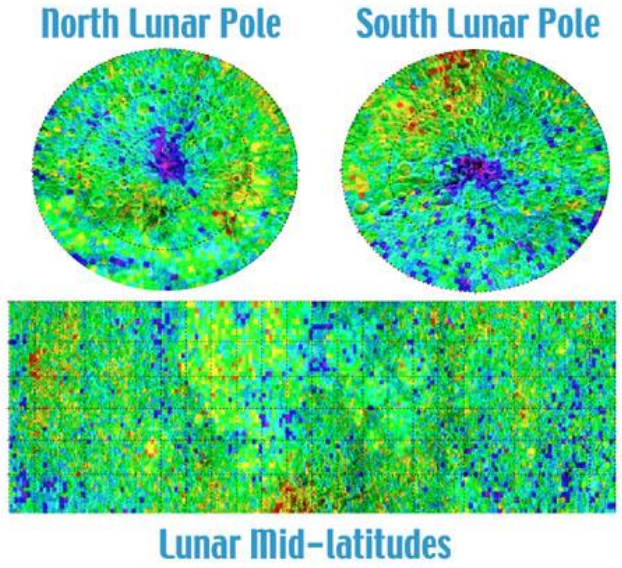
Water-ice has been found in vast quantities just below the surface across great swathes of the planet Mars.

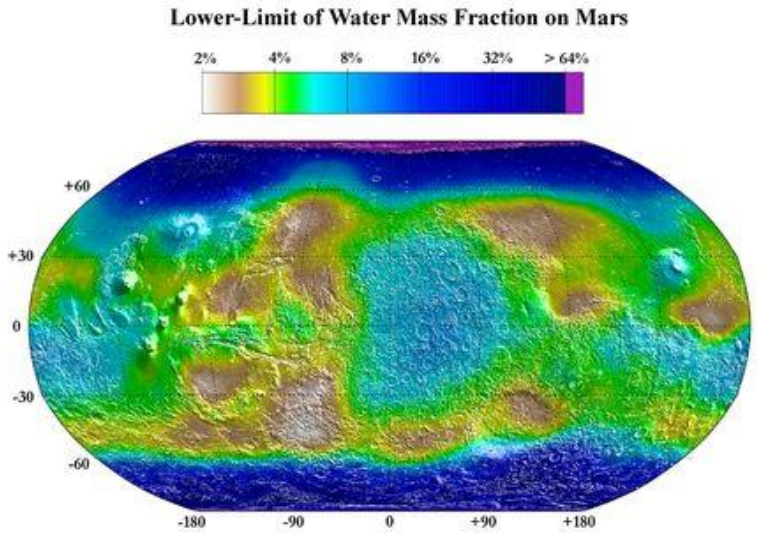
The finding by the American space agency (Nasa) is undoubtedly one of the most important made about the Red Planet.

It solves one of its deepest mysteries, points the way for manned exploration and reignites the question of whether life may exist on the planet.

Ice shows up blue on the gamma-ray spectrometer

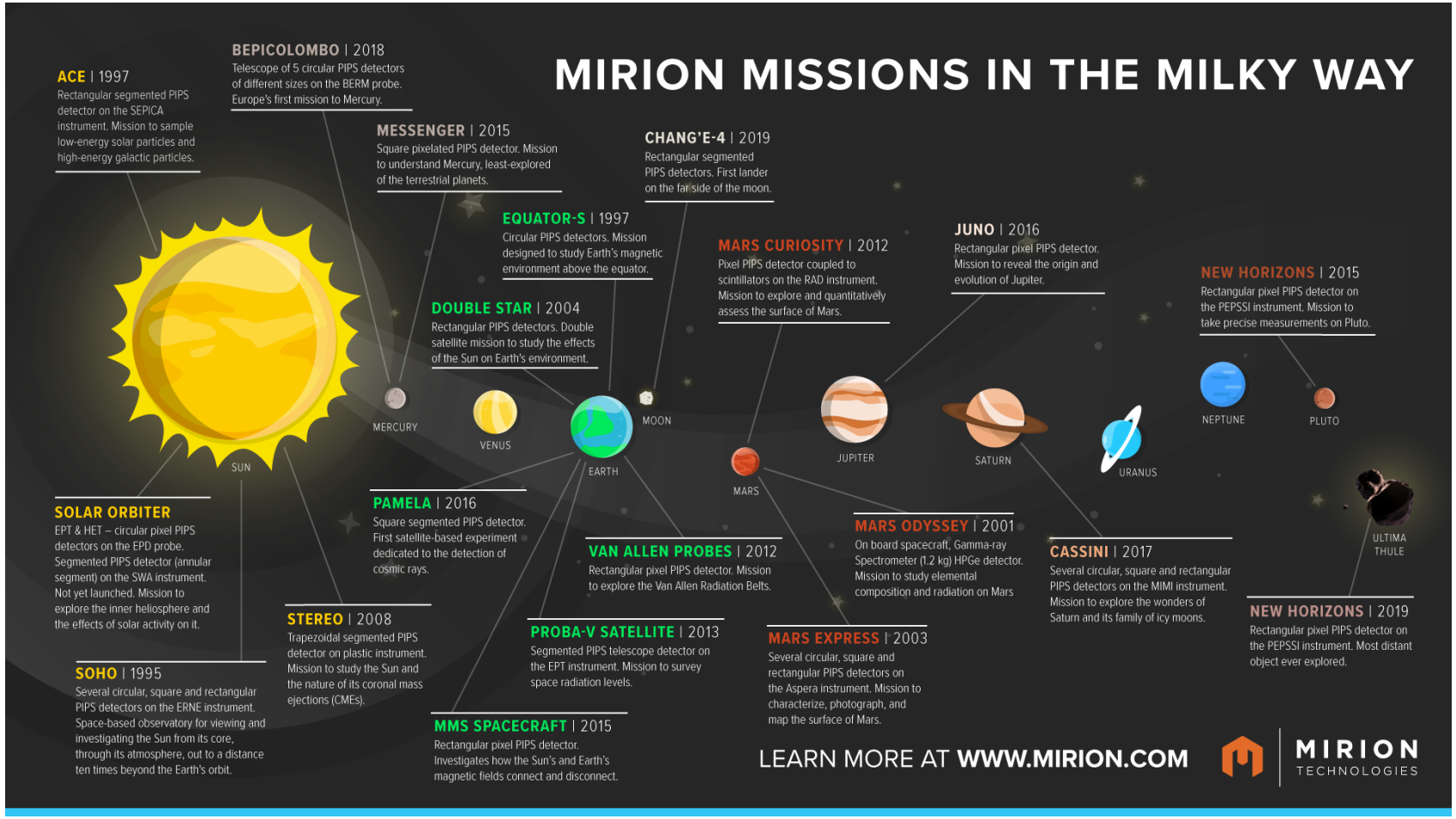
- GRS on board NASA's Mars Odyssey spacecraft have revealed more underground ice on the Red Planet than scientists expected
  - Confirmed the presence of water on Mars
  - Mapping of water on Mars



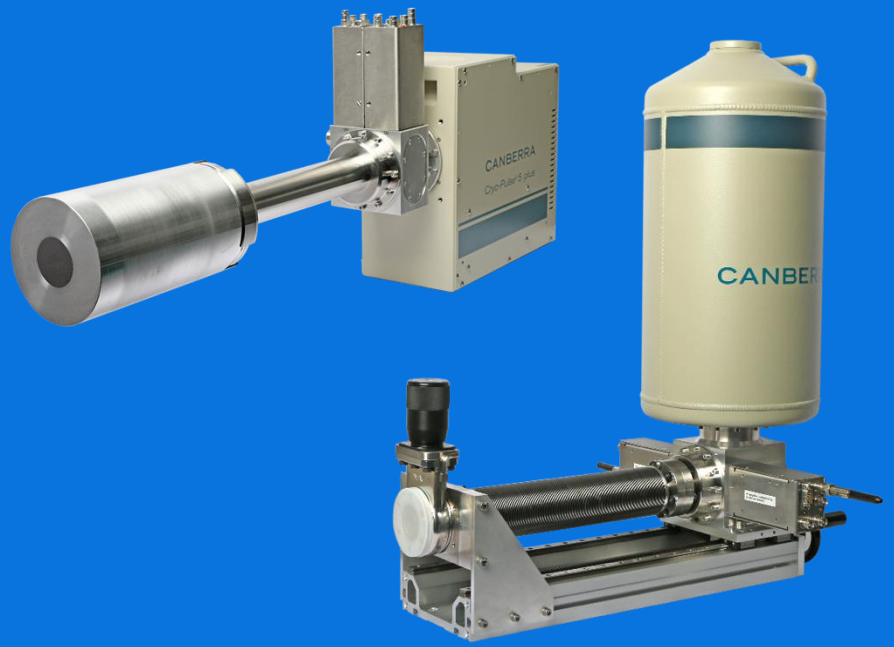




http://news.bbc.co.uk/2/hi/science/nature/2009318.stm

# Mirion Space Mission




https://www.mirion.com/solutions/research-education/protecting-astronauts-in-space

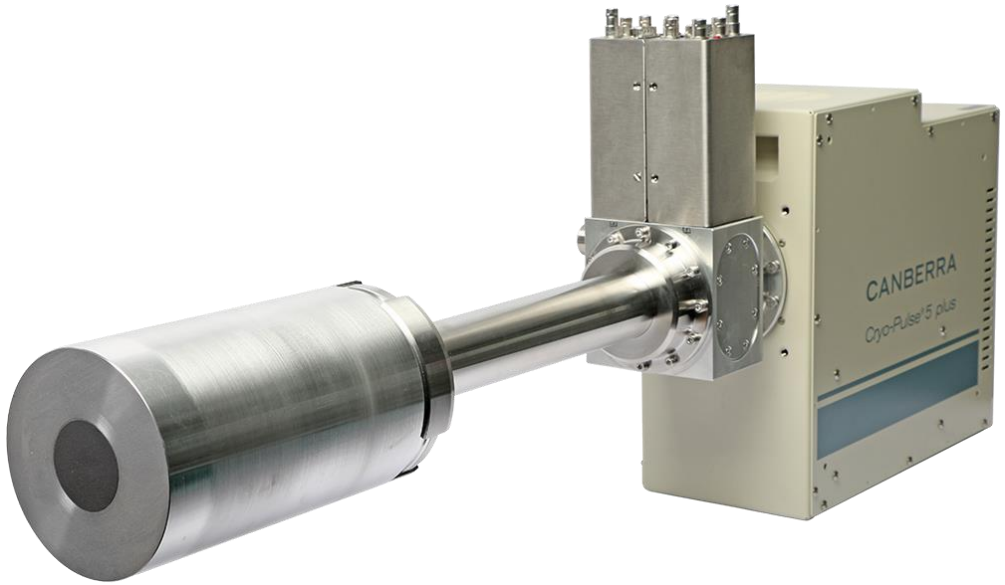


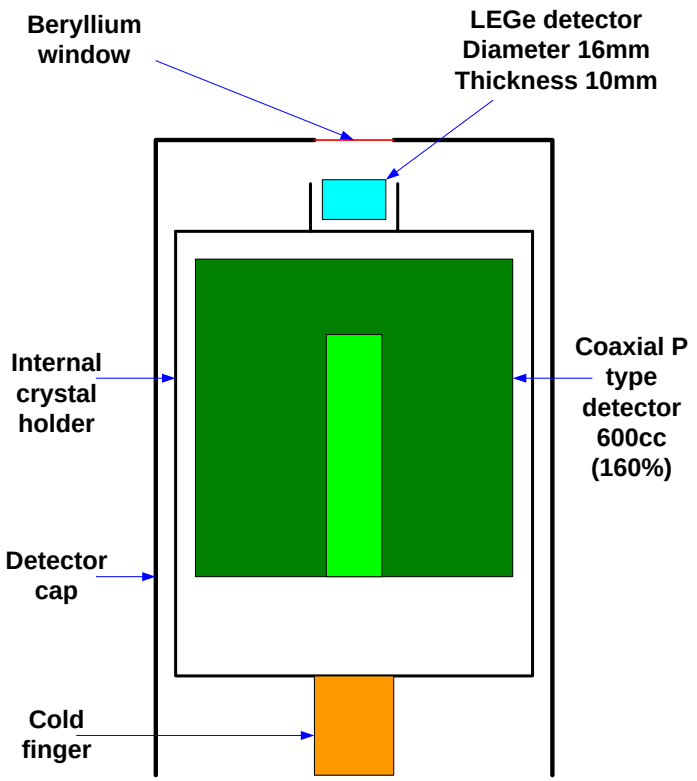

# Special custom configurations HPGe detectors

MIRION Connect 24
Annual Users' Conference

# Example of Mirion Custom Detectors

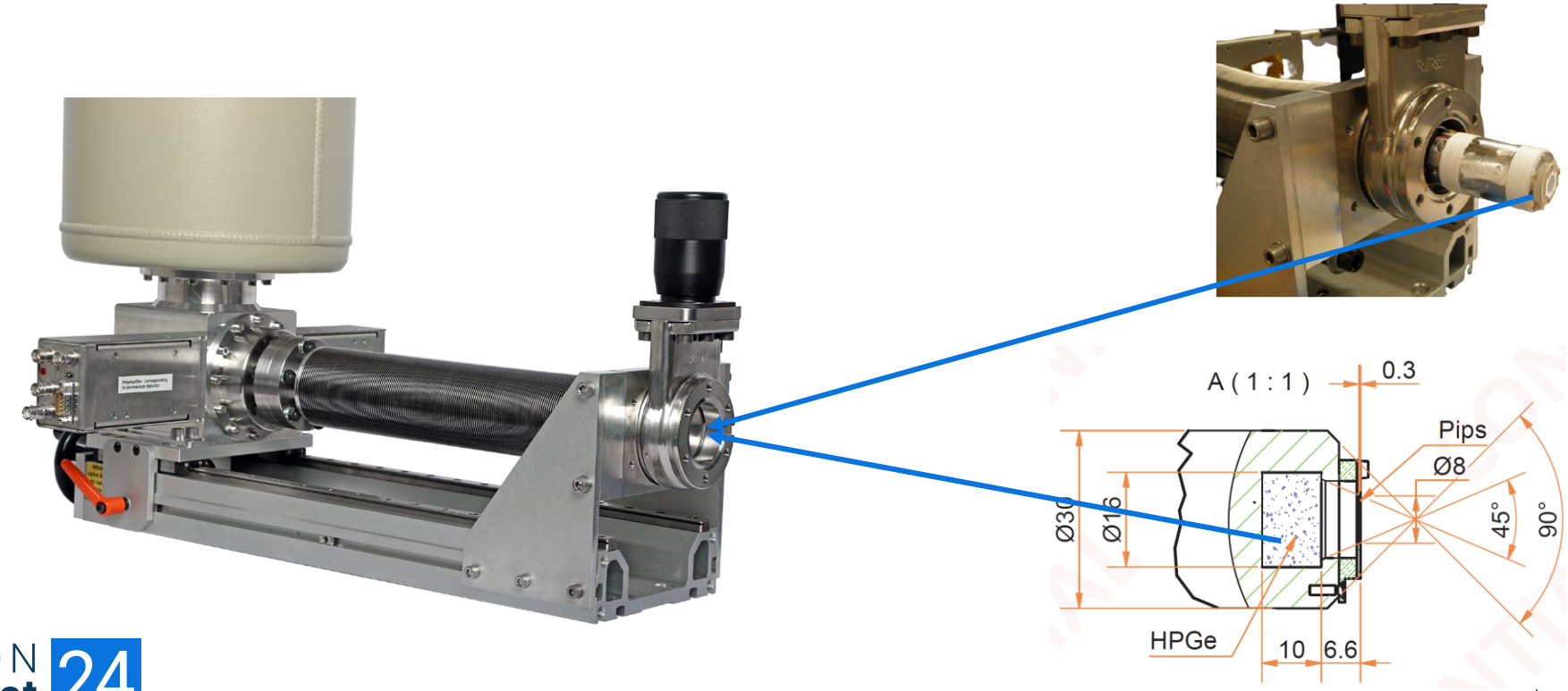
- **Ge-Ge telescope combines:**
  - **Very high gamma detection efficiency** thanks to the rear 600cc coaxial detector
  - **Ultimate energy resolution at very low energies** thanks to the front LEGe detector
  - **Key Feature ➔** Time correlated events measurement



# Example of Mirion Custom Detectors

- HPGe-PIPS telescope combining
  - Rear Ge detector (diam 16 mm – 10 mm thickness) for Photon measurement
  - Front PIPS (diam 8 mm – thickness 0.3 mm) for Charge Particle measurement
  - **Movable and retractable cold finger** to bring the bare sensitive part into a vacuum chamber




*Reference: Nuclear Materials and Energy 38 (2024) 101586*

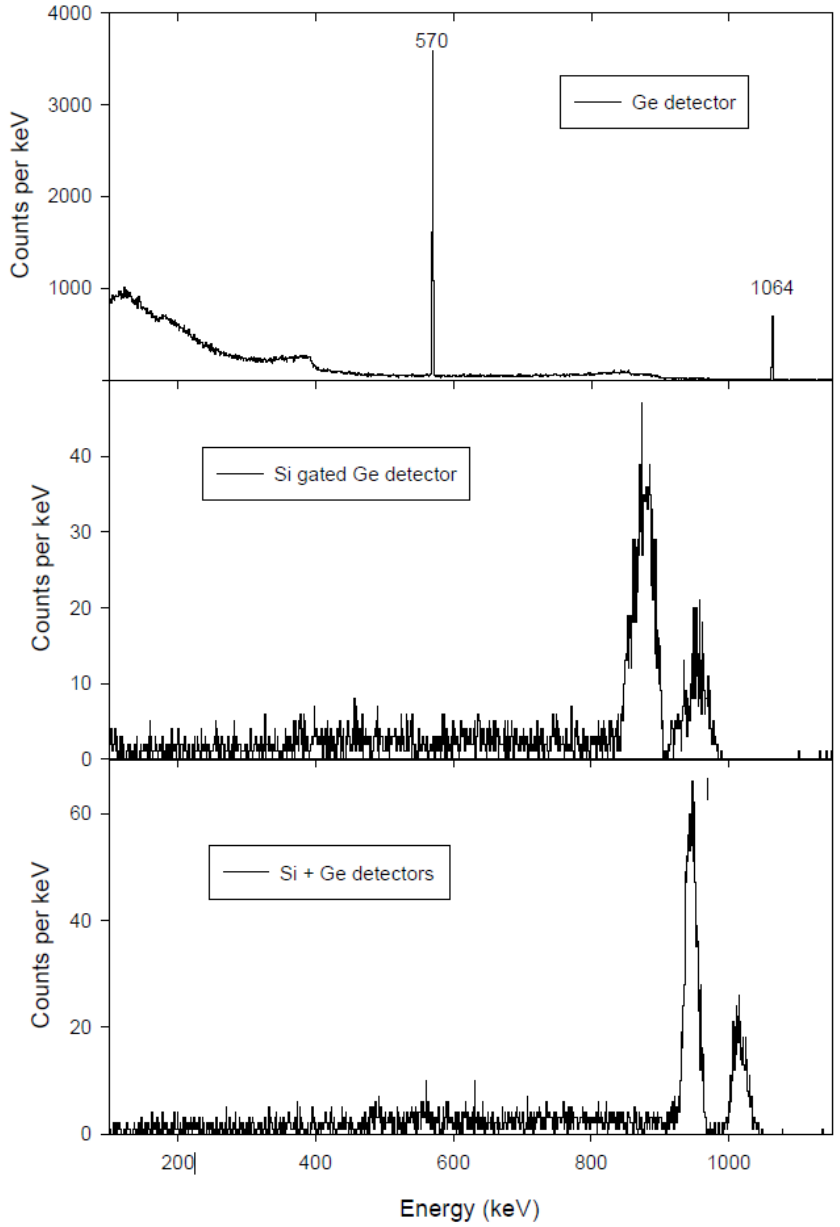
# Example of Mirion Custom Detectors

**Three spectra taken with a 207Bi source: preliminary performance 22 keV resolution for 1 MeV electrons.**


**Normal gamma-ray spectrum of Bi-207 from the Ge detector**

**Ge spectrum but with a condition of a silicon detector signal arriving within 100 ns of the Ge detector signal. This leaves only the electrons**

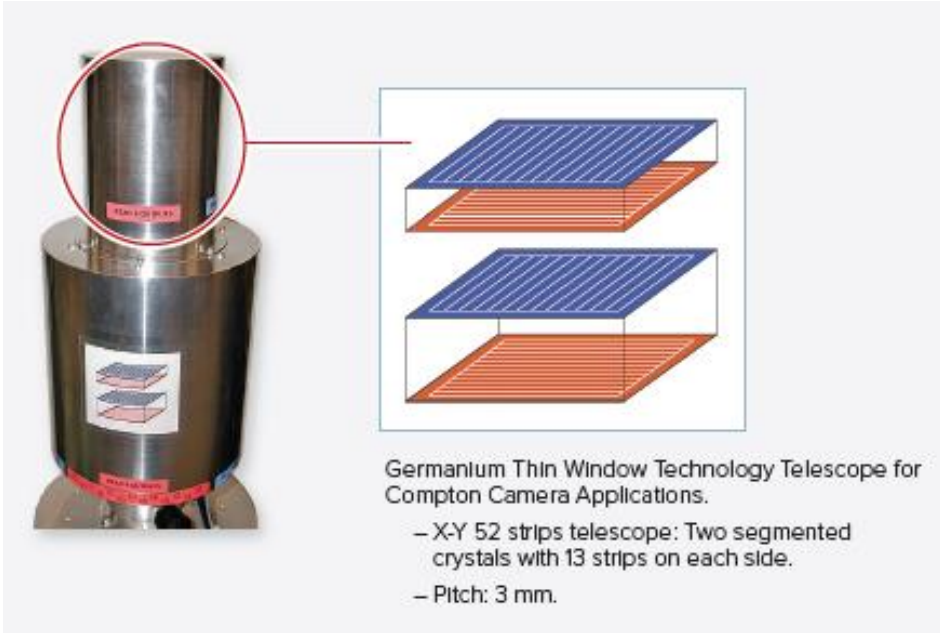
**Si and Ge detector energies are added. This improves the resolution and makes the electron energies almost correct**

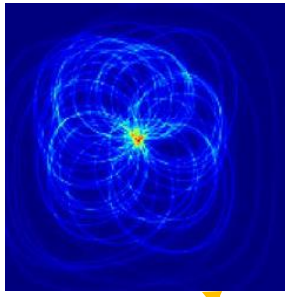



*Courtesy: Dr Matej Lipoglavsek, Jozef Stefan Institute, Ljubljana, Slovenia*

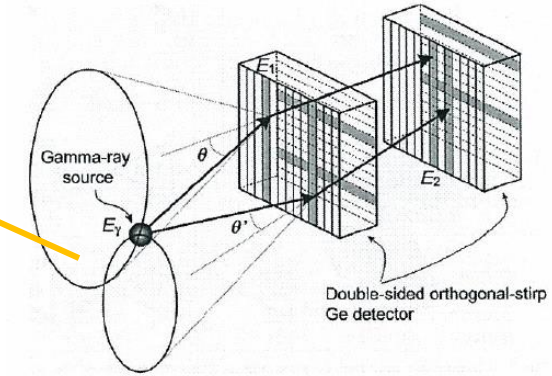
# Example of Mirion Custom Detectors

- **DSSD telescope**:
  - Use of Ge or (and) Si(Li) material depending on use (energy range)
  - Telescope arrangements with two or more diodes are possible to optimize the use
  - Strip pitch: a few mm or less
  - LN2 free operation possible
  - Expected FWHM (typical):
    - 60 keV: 1.5 keV
    - 1.33 MeV: 3.0 keV



- **Application**
  - Compton Camera for gamma imaging (medical, fuel cycle, D&D, security, etc…)



# Specialty Ultra-Low Background HPGe Detectors

# Mirion Specialty Ultra-Low Background HPGe Detectors

## Typical requirements for S-ULB projects

- **Non-standard** challenging techniques for ensuring radiopurity
- All materials inside the detector are screened for radiopurity
  - Special & selected materials:
    - Fresh germanium and copper
    - Very old steel and lead, high purity Al
    - Other metals
  - Selected and “hidden” electronic components
  - Specific soldering
  - Assembly in clean room environment
  - Underground storage at all possible times to minimize cosmic ray exposure
- **Sea level transportation is mandatory to avoid activation**
- Special detector **packing** (air-tight envelopes to avoid radon, neutron moderator materials…)
- Typical Detectors
  - Coax P-type / N-type
  - BEGe – up to 100 mm diameter
  - SAGe Well 250cc and 400cc active volume
- Compatible with CP5 Plus

ver.

# Mirion Specialty Ultra-Low Background HPGe Detectors

- **Massive array ULB detection system**
  - 2x seven 70% HPGe crystals
  - Global relative efficiency: 980%
- Average resolution FWHM on 14 crystals
  - 0.85 keV @ 122 keV
  - 1.90 keV @ 1332 keV
  - High sensitivity measurement of U and Th contamination

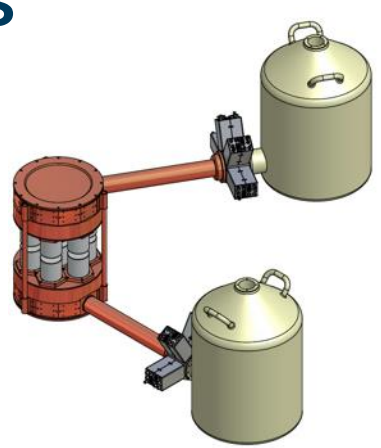
**Application**: sample assay ($MoO_3$ enriched powder) and physics research (rare decay exploration like $^{180m}Ta$)

| Isotopes | | Peak (keV) | Efficiency (%) |
|---|---|---|---|
| $^{232}Th$ | $^{228}Ac$ | 911 | 5.8 |
| | | 968 | 5.5 |
| | $^{212}Pb$ | 238 | 9.7 |
| | $^{212}Bi$ | 727 | 6.8 |
| | $^{208}Tl$ | *2615* | 2.0 |
| | | *583* | 4.7 |
| | | 860 | 4.7 |



Detector array[1] operated by CUP, IBS. Image copyright CUP, IBS, 2017.
[1] D.S. Leonard et al. NIM A 989 (2021) 164954

# Mirion Specialty Ultra-Low Background HPGe Detectors



## Ultra Low Background HPGe detectors for underground labs

- Configuration: coaxial, well or SAGe Well with the best radio-purity for all the parts involved (Ge, Cu, Al, electronics)
- Applications:
  - Material screening for large experiments in Underground Labs
  - Low level spectroscopy (sediments, dating)

## New Point Contact (SAGe) technology Neutrino Physics and Dark Matter search

- Combine best spectroscopy performance: lowest noise, highest efficiency, lowest background
- Application:
  - Neutrino physics, MAJORANA, GERDA, LEGEND

# Mirion Specialty Ultra-Low Background HPGe Detectors

- Example of MIRION S-ULB performance detectors using our ULB materials
- Boulby Mine, UK

| | Detector | Count Rate ($kg^{-1}$ $d^{-1}$) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Integral 100–2700 keV | 351 keV $^{214}$Pb | 609 keV $^{214}$Bi | 238 keV $^{212}$Pb | 1461 keV $^{40}$K | 2615 keV $^{208}$Tl | 46.5 keV $^{210}$Pb |
| SEGe 160% | Belmont | 90(9) | 0.2(1) | 0.4(2) | 0.13(8) | 1.0(2) | 0.3(1) | - |
| SEGe 100% | Merrybent | 145(12) | 2.5(3) | 1.8(3) | 0.3(1) | 1.9(3) | 0.8(2) | - |
| | Lunehead | 540(25) | 5.6(5) | 4.7(4) | 8.3(5) | 9.1(6) | 2.0(3) | - |
| BEGe 6530 | Roseberry | 130(11) | 0.15(7) | 0.15(7) | 0.8(3) | 0.8(2) | 0.2(1) | 0.4(6) |
| | Chaloner | 1045(30) | 5(1) | 4(1) | 7(1) | 8.4(14) | 2.1(5) | 1.8(11) |
| **S-ULB & CP5-plus upgrade** | Lumpsey — 2021 | 515(25) | 1.1(7) | 1.3(3) | 1.1(7) | 1.7(7) | 0.2(2) | 1.7(6) |
| SAGeWell standard ULB version | Lumpsey — 2019 | 36880(6) | 114(4) | 68(3) | 172(5) | 8(1) | 11(1) | 14(2) |

https://www.boulby.stfc.ac.uk/Pages/Ultra-low%20Background%20Material%20Screening.aspx

https://iopscience.iop.org/article/10.1088/1748-0221/19/01/P01017

# Mirion Specialty Ultra-Low Background HPGe Detectors

- Measured Spectroscopy Performance:
  - At 122keV: 660eV
  - At 1.33MeV  1.72keV
  - Symmetry factors at 1.33MeV:
    - FWTM/FWHM: 1.84
    - FWFM/FWHM: 2.56
  - Relative efficiency at 25cm : 91%
  - Peak to Compton ratio 76:1
- Carbon entrance window 0.6 mm thick

- 100 mm diameter and 35 mm lenght custom BEGe type

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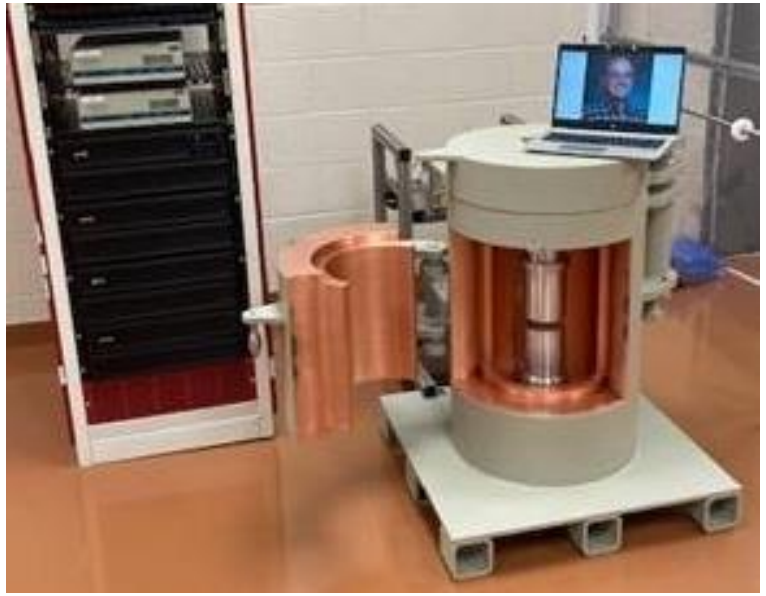
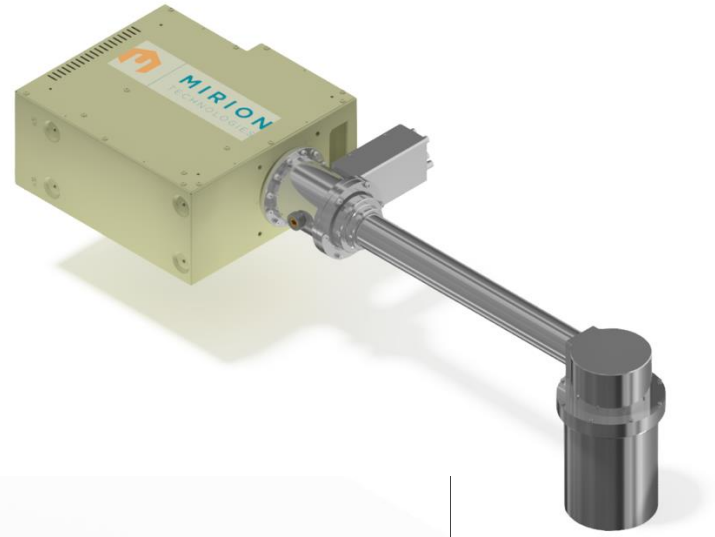
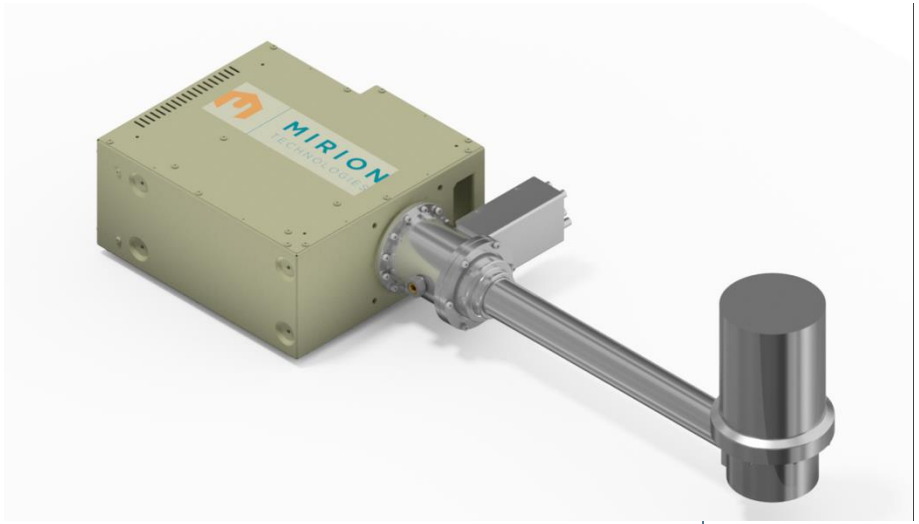
# Mirion Specialty Ultra-Low Background HPGe Detectors

- Top Bottom configuration:
- two custom BEGe type detectors
- CP5+
- Close to 4pi solid angle configuration
- Possibility for coincidence / add-back



- S-ULB BEGe in coincidence configuration



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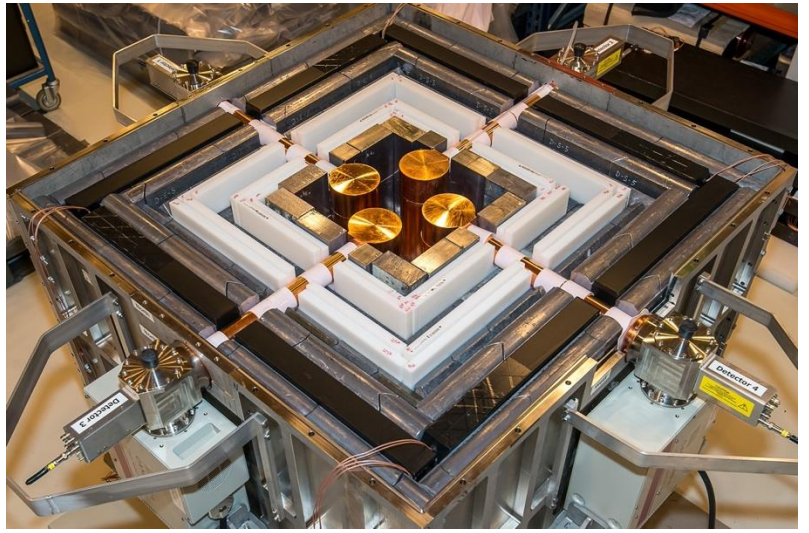
# Mirion Specialty Ultra-Low Background HPGe Detectors

**SAGe detector array in S-ULB configuration for the CONUS project: detection of coherent elastic neutrino nucleus scattering**

- Point Contact detector technology on P type HPGe crystals with minimized time exposed to cosmic activation
- Crystal size: diameter 62 mm – length 62 mm
- Ge weight: 1kg
- Fresh OFHC high purity copper cryostat with minimized time exposed to cosmic activation
- CP5+ in custom cryostat configuration
- Pulsed low noise preamplifier
- Measurement performed with analogue Canberra NIM electronics at 12μs shaping time



*Max-Planck-Institut für Kernphysik*

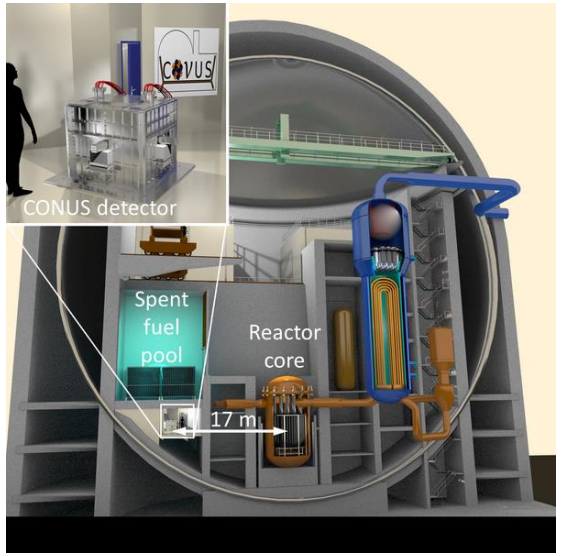
| TEST (pulser) | 241Am (60keV) | 57Co (122keV) |
|---|---|---|
| 75eV | 300eV | 470eV |

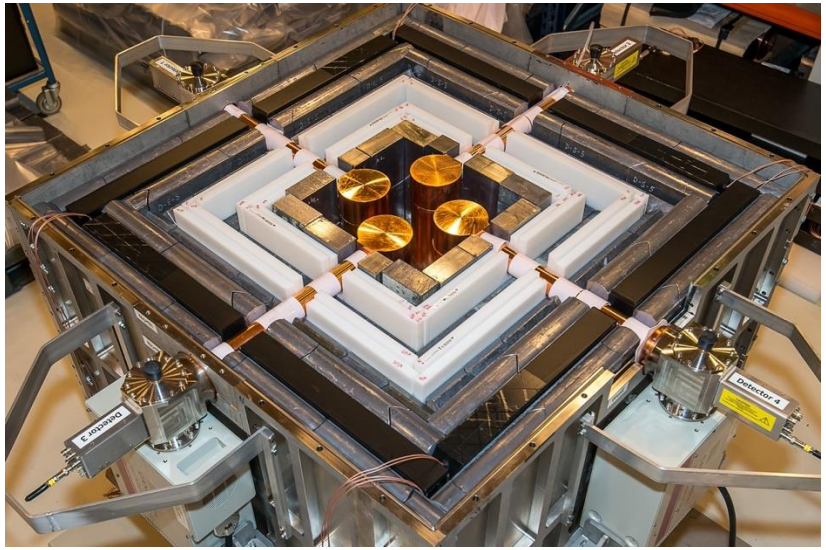


Reference:
J. Hackenmueller et al at TAUP2017 conference
W. Maneschg et al at NEUTRINO2018 conference

# Mirion Specialty Ultra-Low Background HPGe Detectors

- Detection and precise measurement of coherent neutrino-nucleus scattering
  - Insight into microscopic processes and are crucial for basic research
- Neutrinos play a key role in several significant astrophysical and cosmological events, where they undergo coherent scattering processes with nuclei during their propagation through imploding star layers
  - Important astrophysical events
- The CONUS experiment at the Brokdorf NPP aims to measure coherent neutrino-nucleus scattering in the energy range of reactor neutrinos using advanced germanium detector technology
  - Potential applications in reactor monitoring, safeguard applications, thermal power determination




# In-Situ Specialty HPGe Probes

# Mirion Speciatly HPGe Probes

- More a products *range* than a product: **numerous different configurations possible**
  - Various possible HPGe crystals sizes (<1% to 160%) and types (SEGe, SAGeWell, etc.)
  - Optimized choice of cooler, especially to meet footprint constraints
  - Housing selection: low-energies measurement, operation temperature range, waterproofing, IP rating, decontaminable feature…
  - UHV technology is possible
- **Adaptable** to needs and constraints
- **Varying integration degrees**
  - Fully turnkey and/or integrated solutions
  - Sub-system solutions that can be integrated by the customer

# Mirion Specialty HPGe Probes

## Applications

- **Wherever HPGe detection performance is needed**
  - Initially designed for the **mining industry**: prospecting into boreholes, etc.
  - **Environment**: ground-based or underwater (deep- or shallow-deep water) environmental monitoring, etc
  - **Defense, homeland security**: spectrometric monitoring (critical facilities: NPPs, ports, airports, etc) and deep-water surveillance
  - **Nuclear industry**: cooling pools monitoring, reactor monitoring, etc
  - **D&D**: spectrometric monitoring of D&D operations, nuclear waste storage monitoring, etc
  - **Others**: scientific experiments, use in hot cells, use in contaminated environments, etc

# Mirion Speciatly HPGe Probes

*20% HPGe probe for mining prospecting*
*HPGe probe for particularly harsh environments, later integrated by the customer into a complete measurement system*

## Technical specifications

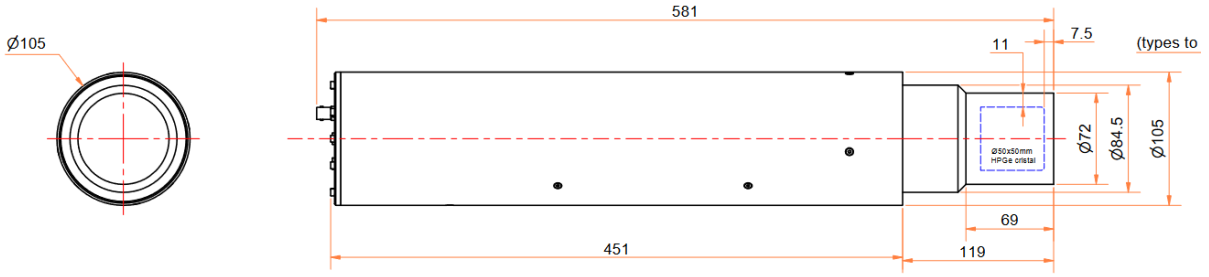
- 50x50mm coaxial HPGe crystal
- Aluminum all attitude cryostat with high-performance electrical cooler
- Fixing points for an easy integration
- Operated with the LYNX II MCA

## Detection properties

- Energy range: 50 keV to 10 MeV
- Measured energy resolution:
  - 1332.5 keV: 2.13 keV
  - 122.1 keV: 1.28 keV

## Application

- Prospecting (mining), use in boreholes

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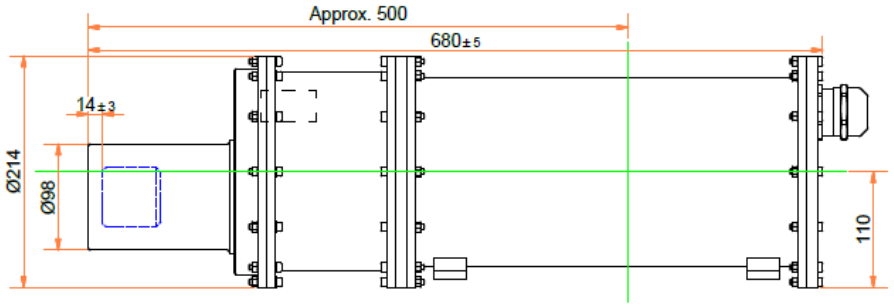
# Mirion Speciatly HPGe Probes

*25% watertight HPGe probe for environmental monitoring*
*Fully integrated HPGe-based solution for drinking water fine spectroscopic monitoring*

**Technical specifications**
- 54x54mm coaxial P-type HPGe crystal
- Aluminum housing with anti-corrosion paint
- High-performance all-attitude linear CP5+ electrical cooler
- Completely watertight for underwater operation (few meters depth)
- Operated with the LYNX II MCA

**Detection properties**
- Energy range: 50 keV to 3 MeV
- Measured energy resolution:
  - 1332.5 keV: 1.70 keV
  - 122.1 keV: 0.70 keV




**Application**
- Drinking water monitoring
- Environmental monitoring

# Mirion Speciatly HPGe Probes

*20% HPGe probe for deep-water monitoring*
*User-centered development of a highly reliable HPGe probe, which was later integrated into a titanium housing suitable for use at a considerable water depth*

**Technical specifications**

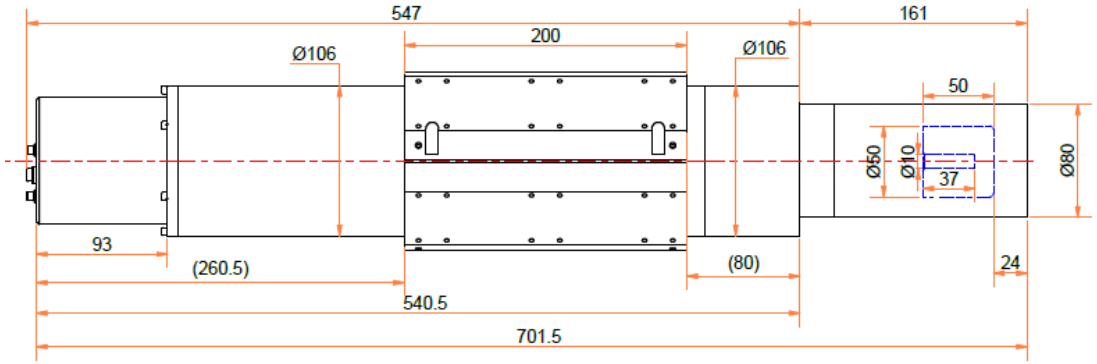
- 50x50mm coaxial HPGe crystal
- Aluminum all attitude cryostat with high-performance linear electrical cooler
- UHV technology: thermal cycle free system
- Fixing points for the integration into a Titanium housing
- Operated with the LYNX MCA, placed inside the pressure housing
- Need for an ultra-reliable system: maintenance possible only every six months

**Detection properties**

- Energy range: 50 keV to 10 MeV
- Measured energy resolutions:
  - 1332.5 keV: 2.10 keV
  - 122.1 keV: 1.28 keV

**Application**

- Deep-water (2500m depth) scientific experiment



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# Mirion Speciatly HPGe Probes

*Integration of a MicroGe, possibly in a watertight housing for monitoring in highly radioactive environments (cooling pool, nuclear reactor, etc.)*

**Technical specifications**

- 10x10mm HPGe crystal (<1% rel. detection efficiency)
  ⇔ MicroGe™ detector
- UHV technology: thermal cycle free system
- Low power: <15W in routine
- Ready for use in less than 30 min
- Operated with the LYNX II or DSA-LX

**Detection properties**

- Energy range: 40 keV to 2 MeV
- Guaranteed energy resolution (MicroGe™) :
  - 1332.5keV: 2.5keV
  - 661.7keV: 1.7keV
  - 122.1keV: 1.2keV

**Application (examples)**

- Nuclear reactor primary circuit moniroting
- Nuclear fuel cooling pool monitoring

# Mirion Speciatly HPGe Probes

**Technical specifications**

- 54x54mm Coaxial P-type HPGe crystal
- 25% rel. detection efficiency
- Aluminum housing with anti-corrosion paint
- Watertight housing connected to a remote supply station
- CP5+ electrical cooler
- Completely watertight for underwater operation (few meters depth)
- Operated with the LYNX II MCA

**Detection properties**

- Energy range: 50 keV to 3 MeV
- Measured energy resolution:
  - 1332.5keV: 2.00 keV
  - 122.1keV: 1.0 keV

**Application**

- water monitoring





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# Mirion key expertise

**Product Development**

- Long background in both developing advanced technologies (specialty detectors) and large-scale products (standard detectors)

**Semiconductor Process**

- Know-how and proprietary processes e.g. segmentation, passivation, crystal growing capabilities

**Mechanics, vacuum, and cryogenics**

- Development of low-vibration and long-life cryocoolers for HPGe, encapsulation, UHV

**Ultra-low background**

- Characterization, traceability, underground storage of radiopure materials, collaboration with Ultra-low labs and experiments

**Electronics**

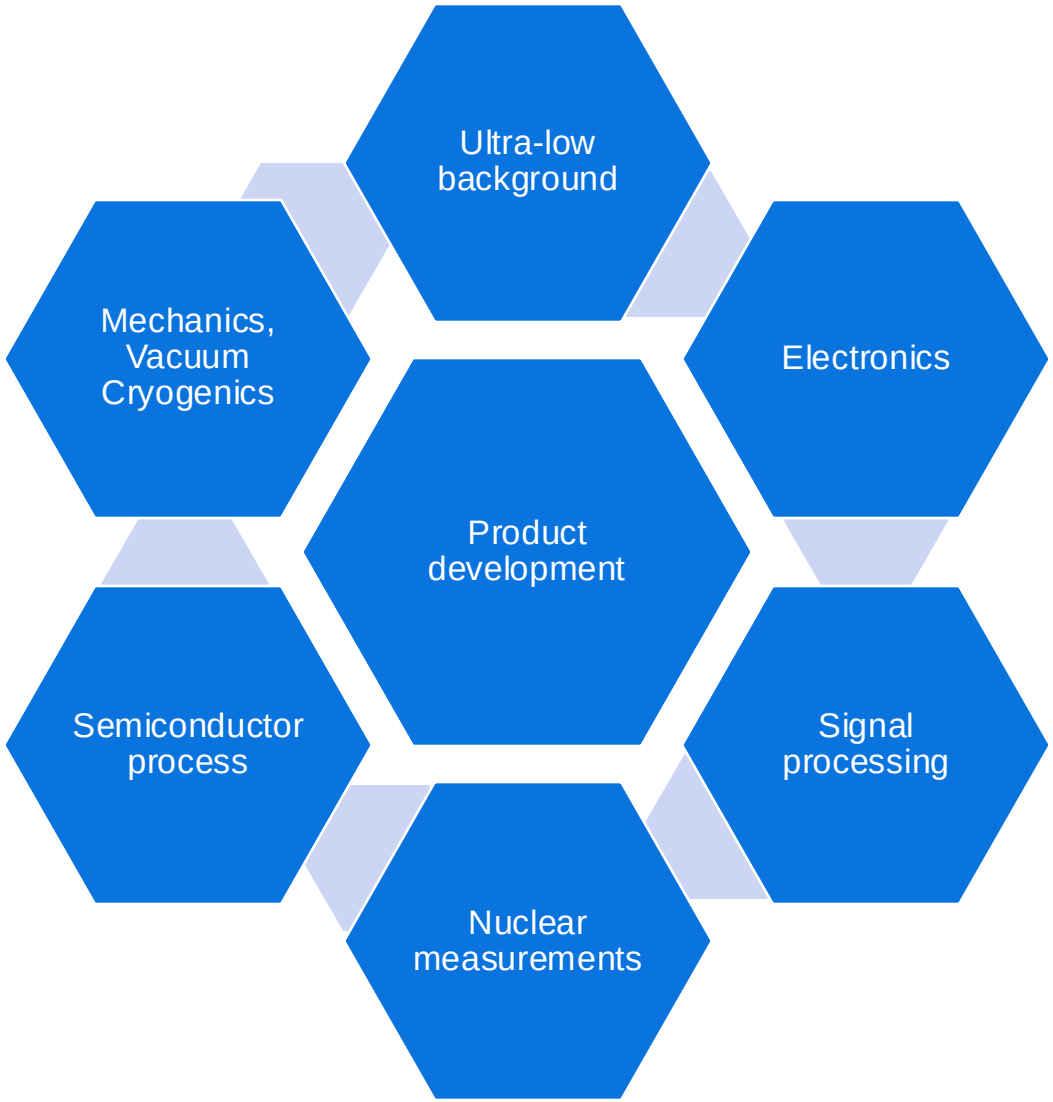
- Experience low-noise, high count rate, low power, integrated electronics

**Signal Processing**

- Pulse shape analysis techniques transferred from physics to industrial applications

**Nuclear Measurement**

- Experience with low background, low noise; in-depth modelling of detectors



# Thank you for your attention!

# Q&A

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Mobile: 203.623.2700