# MIRION Connect 25

Annual Users' Conference

## INNOVATION AT WORK

Connecting Visionaries in Radiation Safety, Science and Industry

Conrad Orlando Resort, FL –July 28th – August 1st

MIRION TECHNOLOGIES

# The Role of Mirion Specialty Detectors in Advancing Fundamental Research in Nuclear Physics

**Gabriela ILIE, Ph.D.**

Specialty Detectors - Product Line Manager

Mirion Connect | Annual Users' Conference 2025

Orlando, Florida

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# Outline

- Mirion Specialty Detector Portfolio Overview
- Advancing Nuclear Science with Specialty Detectors
- Worldwide projects using Mirion Custom Detectors
- Highlighted examples

# Mirion Detector Portfolio Overview

### Meriden, CT – Center for Innovative HPGe Solutions

- Over **50 years of expertise** in HPGe detector technology
- Dedicated to **industrial-scale manufacturing of advanced solutions**
- Providing **standard and innovative HPGe detectors** for research and industry
- Serving customers across the **United States** and **Asia**

### Lingolsheim, France – Hub for Advanced Project-Based Research Applications

- Over **50 years of experience** in innovative HPGe detector solutions
- **Specialized in challenging, research-driven projects**
- **Skill-based project teams** covering detectors, cooling, electronics, and mechanics
- Proudly **serving customers worldwide**

### Olen, Belgium – Center for HPGe and PIPS Detector Solutions

- Over **35 years of experience** in detector technology
- **Industrial-scale manufacturing** of innovative HPGe and PIPS detectors
- **Regional focus:** Europe and Middle East for HPGe solutions
- **Global reach:** Worldwide supply of PIPS detectors



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All required manufacturing capabilities in house!

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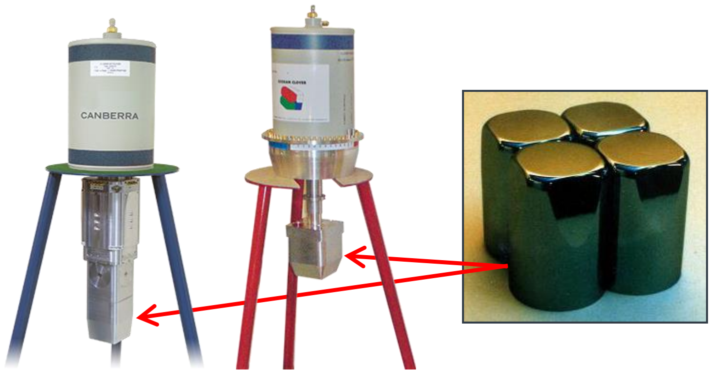
# Specialty Products building block technologies

- Combination of **several detectors** in a **single cryostat** (detectors array)
- **Segmentation** (position information added to spectrometry)
- **Encapsulation and Ultra-high vacuum (UHV) sealing**: for close-packing arrays and rough-motion applications
- **Electrical cooling,** with different types of cooler available

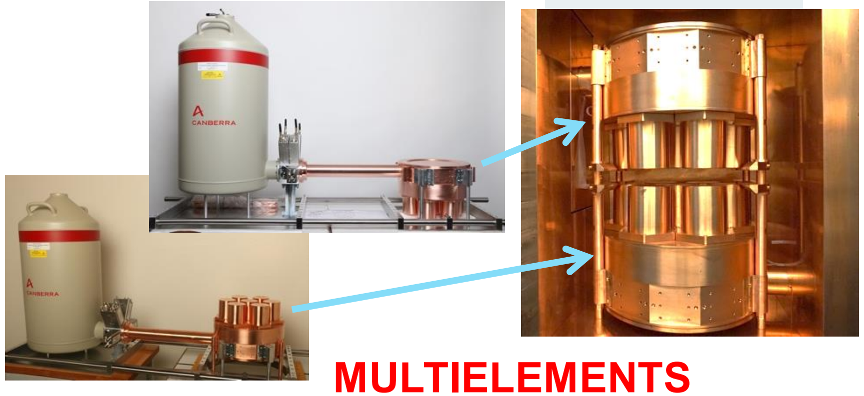
# Mirion Technology Building Blocks: Array Detectors

- Several crystals inside a unique cryostat
- Various purposes
  - Doppler correction
  - Flux dilution
  - Interaction localization information
  - Enhance efficiency
  - Solid-angle coverage
  - Cost reduction vs. multiple cryostats

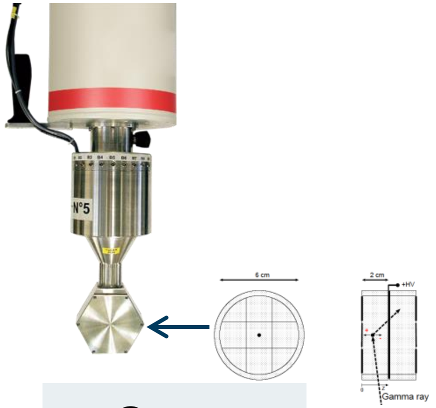
**CLOVER Detectors**




**CUP Array**



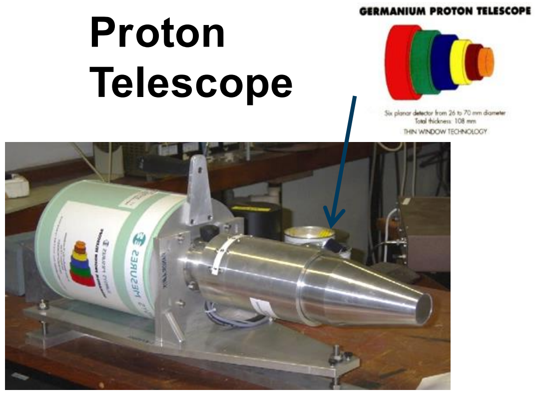

**MULTIELEMENTS Detectors**



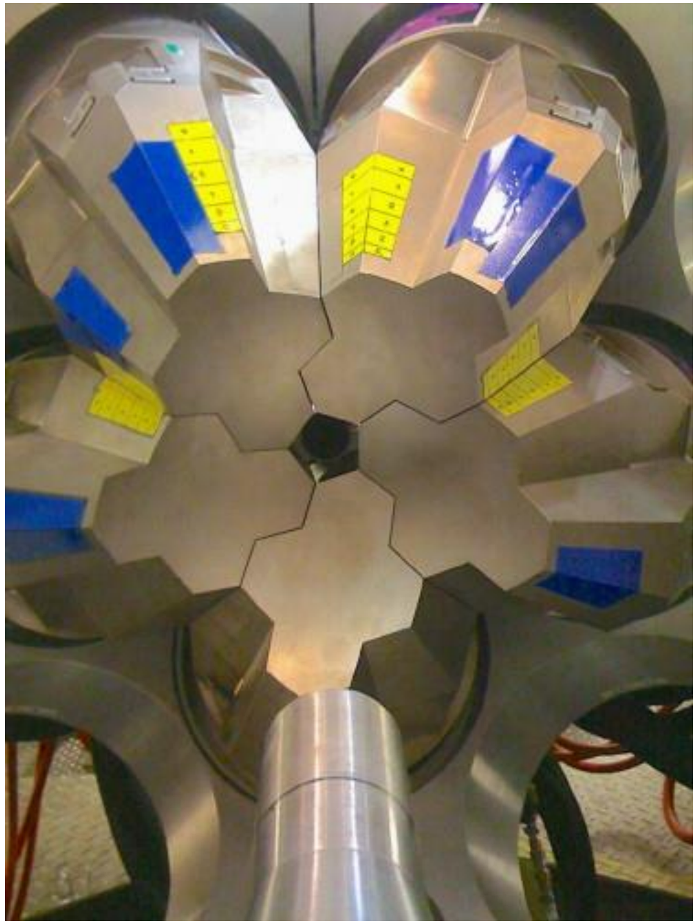

**Grape Telescope**

**STACK Detectors**

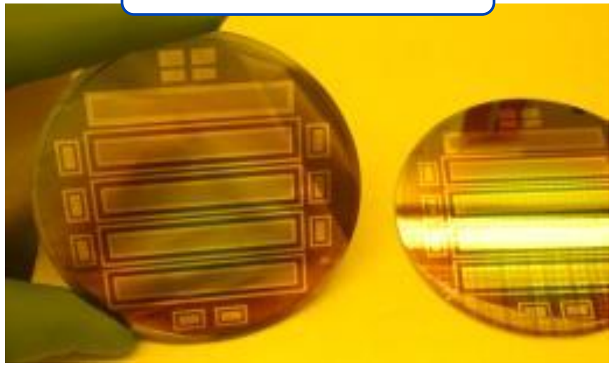
**Proton Telescope**



# Mirion Technology Building Blocks: HPGe segmentation

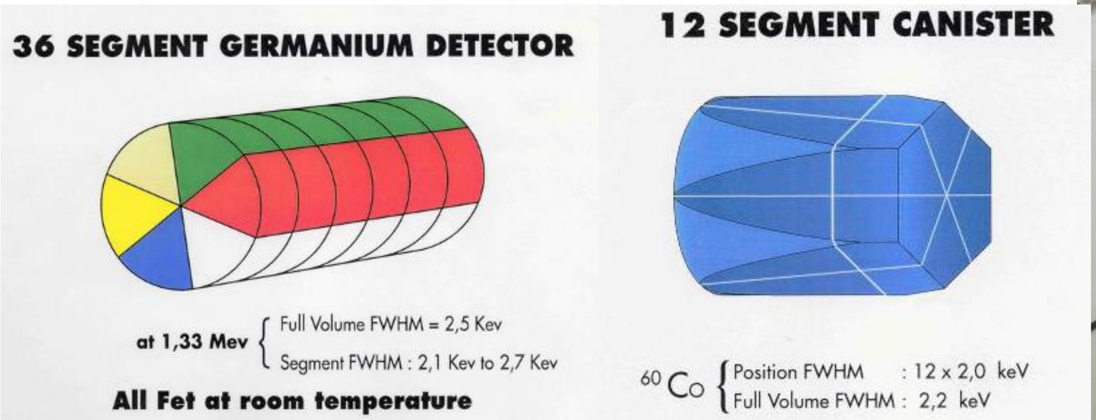


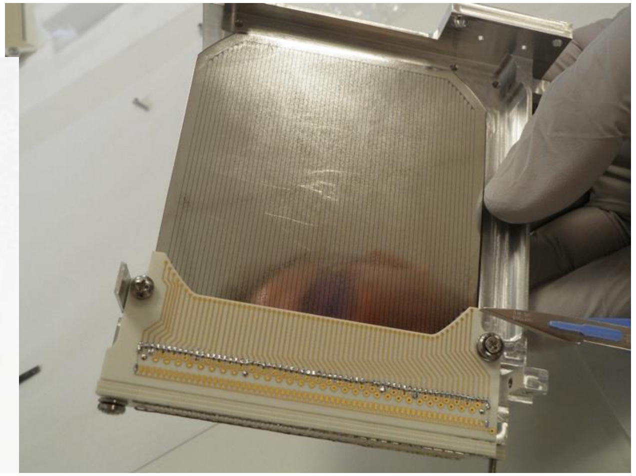
Wafers



DSSDs

N-type coax



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# Mirion Technology Building Blocks: Encapsulation

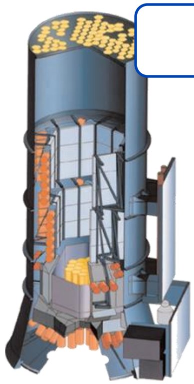
- Place the HPGe crystal inside a separate, sealed, canister
- Protect HPGe from athmosphere
- Allows for versatile and modular HPGe assemblies inside various cryostat configuration

EUROBALL, MINIBALL, AGATA…

MARS ODYSSEY

SELENE

SPI-INTEGRAL



NASA DRAGONFLY mission to TITAN
On-going

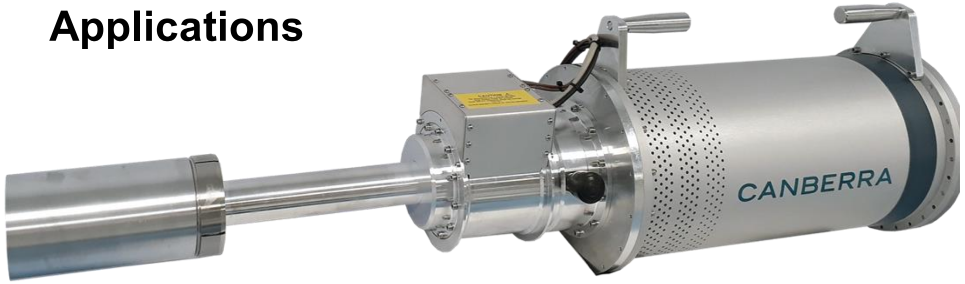
# Mirion Technology Building Blocks: Electrical cooling

## Key unit: CP5-Plus Pulse-tube cooler


**Synchrotron Applications**

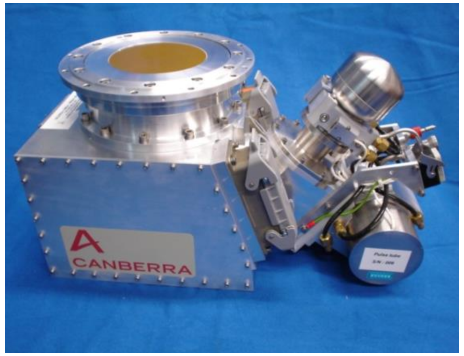
**Nuclear Physics Applications**


**Airborne Applications**

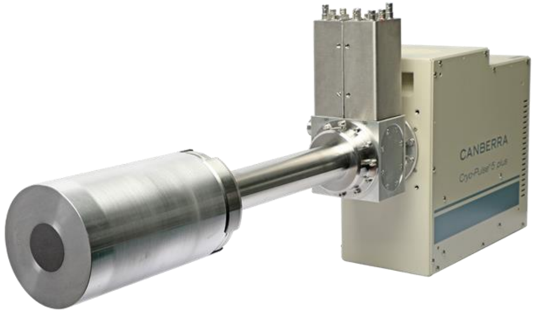

**Medical Applications**

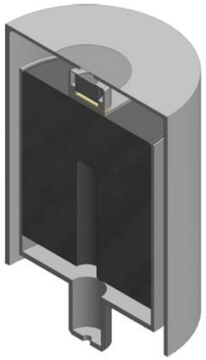
**Special Applications**

# Mirion Technology Building Blocks: Electrical cooling

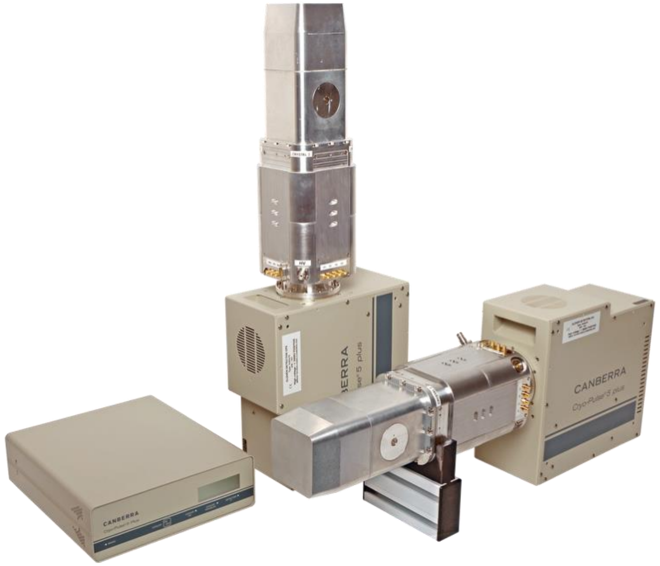
- Telescope
  - 160% D90 L100 coax P-type
  - D16 L10 LEGe
  - 3.4 kg HPGe
  - 2 cold FETs



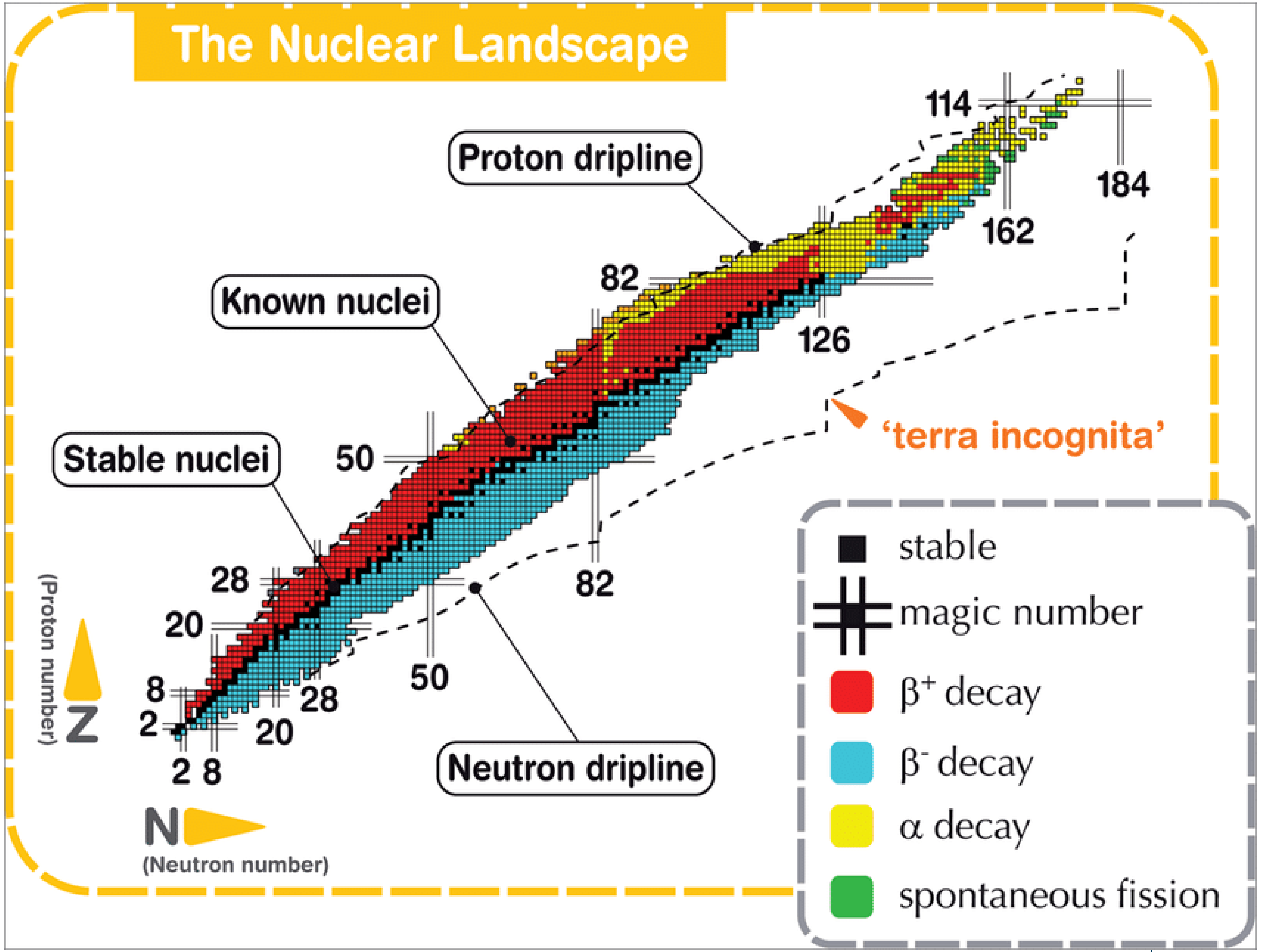

- Clover-like detector
  - 4x 50x50x50 mm encapsulated HPGe
  - 2.5 kg HPGe
  - 4 cold FETs

- Airborne HPGe
  - 7x 100% coax facing down
  - 14 kg HPGe
  - 7 cold FETs
- 2x CP5 in parallel

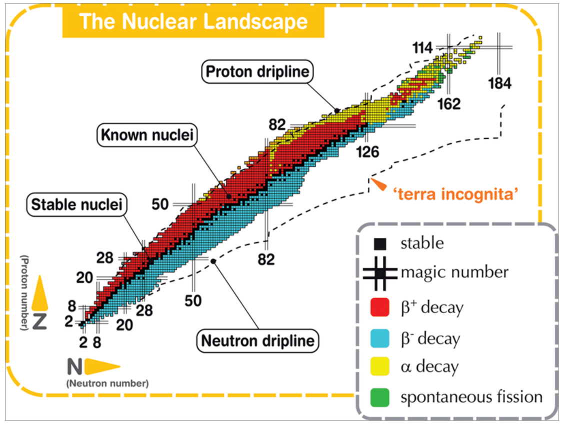

- Clover 457
  - 4x D50 L70 coax
  - 2.6 kg HPGe
  - 4 cold FETs
- **Same spectroscopic performance**

# What is the current Nuclear Physics Research Landscape?



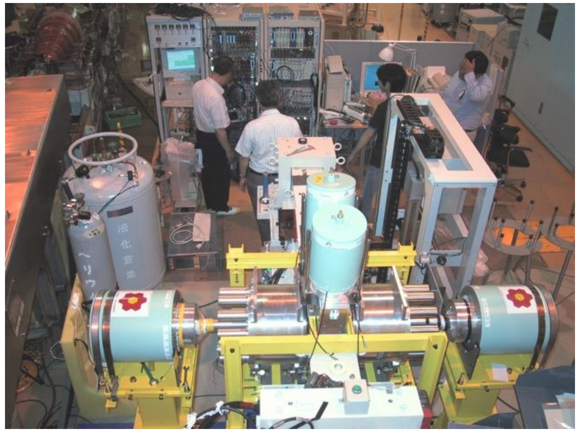
# What is the current Nuclear Physics Research Landscape?

- **Rare-Event Physics, Nuclear Structure and Astrophysics**
- Aim: **Understand atomic nuclei across the nuclear chart**, including regions beyond current experimental reach
- **Challenge:**
  - Rare isotopes often **deviate from textbook nuclear behavior**, showing significantly altered structures compared to stable nuclei
  - Predictive models are **limited in unexplored regions**, leaving key questions unanswered
- **Scientific Relevance:**
  - **Nuclear astrophysics** – insights into stellar nucleosynthesis
  - **Neutron-star physics** – understanding matter under extreme conditions
  - **Fundamental symmetries** – testing the limits of the Standard Model



# Key Enablers for Advancing Fundamental Research in Nuclear Physics

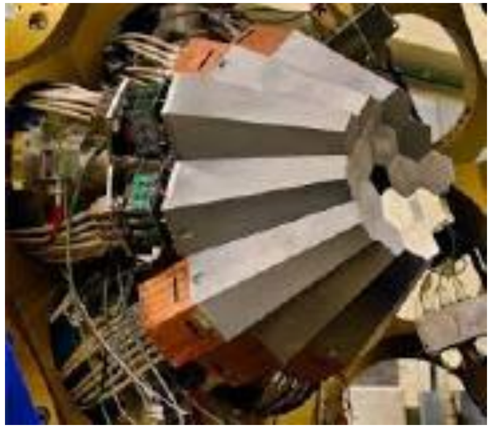
Experiments



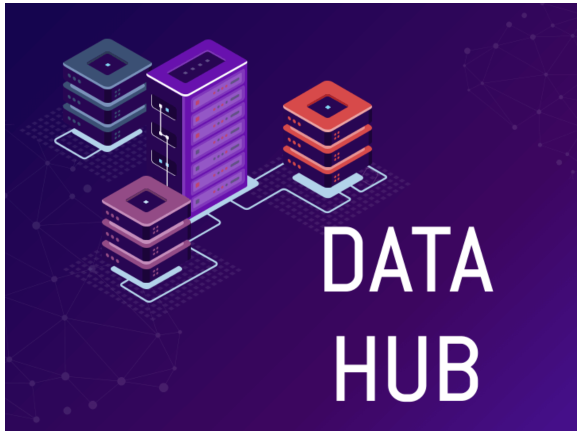
Theory


New/upgraded facilities

"CLEVER" Detectors



Computation



# Key Enablers for Advancing Fundamental Research in Nuclear Physics

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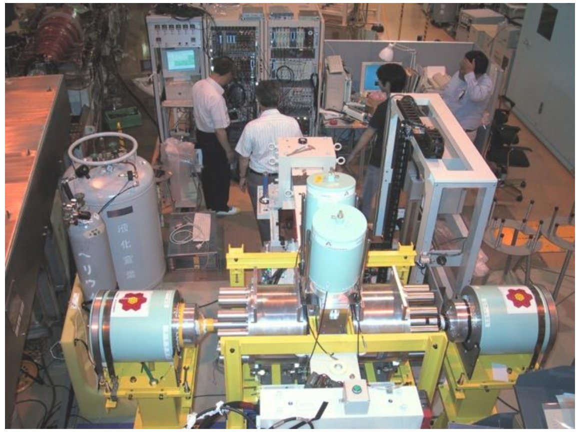

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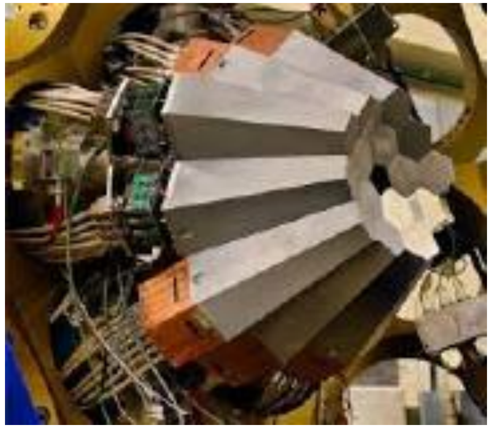
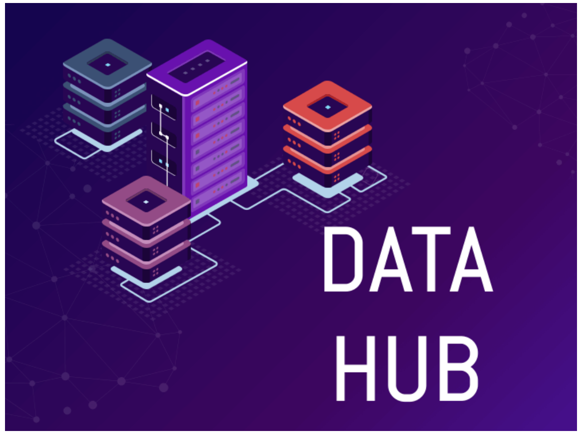


Computation

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# Custom Gamma-Ray HPGe Detector

## Key Features

- Composed of **1 or several HPGe crystals in a single cryostat** (e.g. Clover/Cluster/GRETA, etc)
- Enables **high efficiency and gamma-ray coincidence measurements**

## Research Impact

- Widely used in **nuclear structure studies** at facilities like FRIB, Universities, National Lab, etc
- Provides **high multiplicity gamma detection** for complex decay schemes
- Searching for the Needle in the Haystack: **Neutrinoless Double-Beta Decay Experiments**

# Mirion Clover Detectors

- Mirion developed for the EUROBALL project the so-called Clover detector consisting of 4 HPGe crystals put closely together in a unique cryostat. This allows high detection efficiency combined with best energy and timing resolution.
- One of the primary benefits of a close packed array design is the enhanced efficiency arising from the reconstruction of inter crystal Compton scattered events.
- It was demonstrated that with four 20% crystals the total relative efficiency in add-back mode (time stamped) could be as large as 130% at 1.33MeV.
- Reference publication : **Duchene et Al NIM A 432 (1999) 90-110**.

**From a raw HPGe crystal to a Clover**

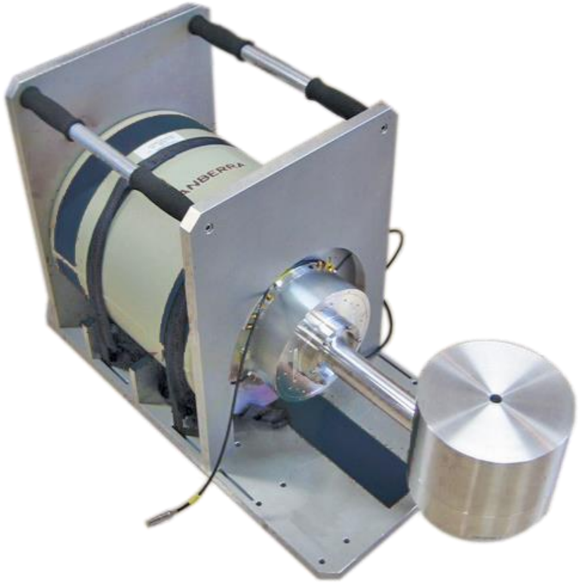
# Mirion Clover Detectors – Key Features

| 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<br>Better polarization information |
| 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 | The colder is HPGe material -> reducing the neutron damage. Longer uptime before annealing in neutron rich environment |
| Reduced vulnerability to neutron damages | Less annealing maintenance |
| Easy access to pumping port | Easy annealing procedures<br>(baking & pumping of the detector) |

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

# Mirion Clover Detectors - Cryostat

- Evolutions of cryostat design customization
  - Euroball type Clover
  - EXOGAM type Clover with “Back Catcher” cryostat
  - RDC ”design”

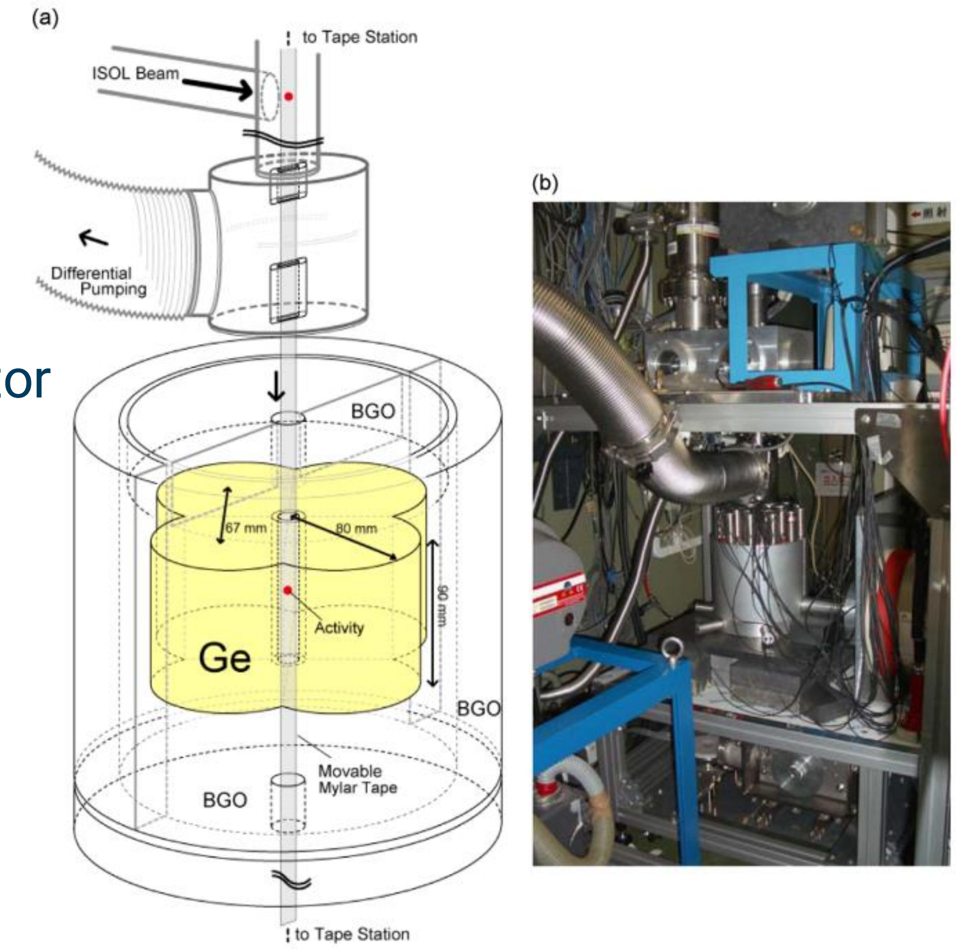



# Mirion Clover Detector – True Well

- **Application:** continuous measurement of a tape transport system going through the detector well
- **Goal:** Measurements of High-energy Excited States

and gamma-rays of Fission Products with a 4π Clover Detector

- **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

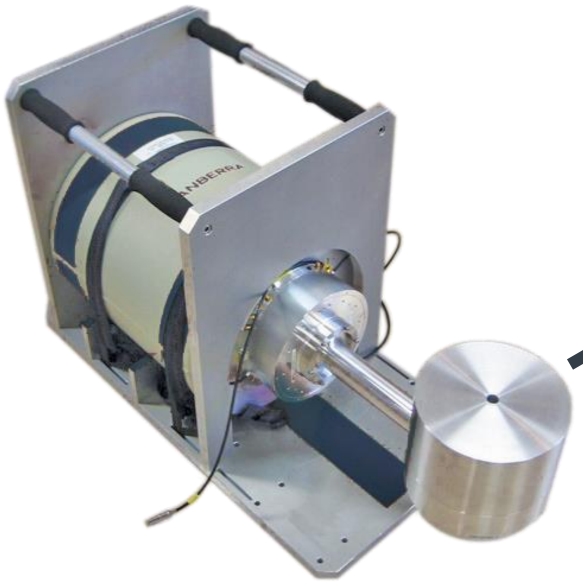


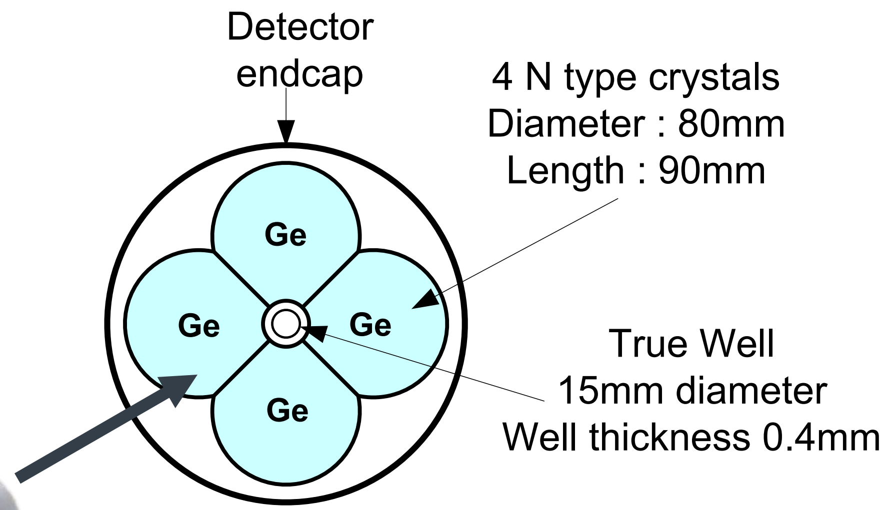

A schematic view of the total absorption clover Ge detector and the tape transport system

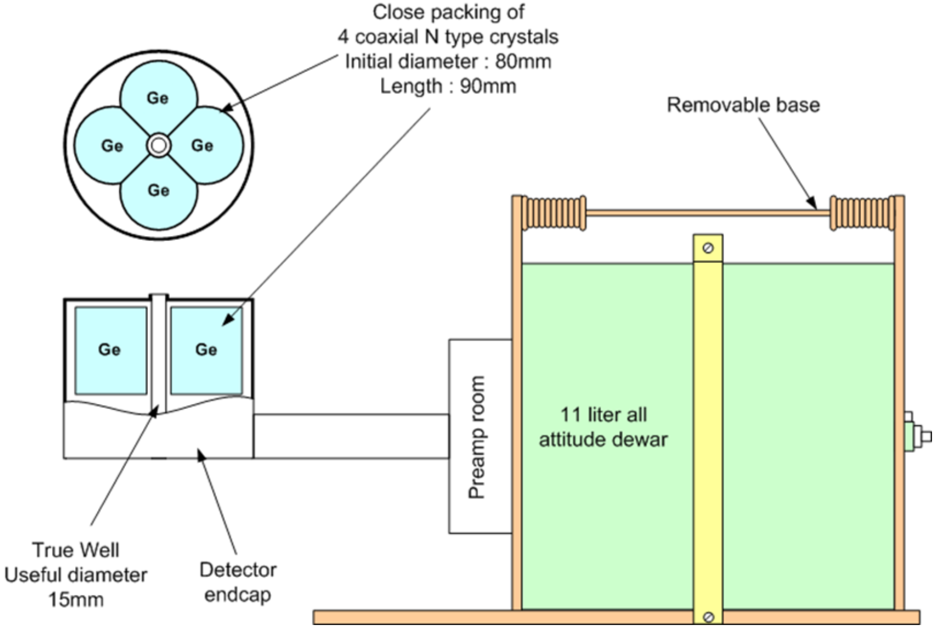
*NIM in Physics Research A747(2014) 41–51*

# Mirion Clover Detector – True Well

- True Well Coincidence counter






The largest True Well Type detector ever built worldwide

# Mirion Clover - Latest Developments

## First Electrical Cooled Clover worldwide

COMPEX: New Electrical Cooled Clover Design
4x50x50x50 (cube-shaped crystals)

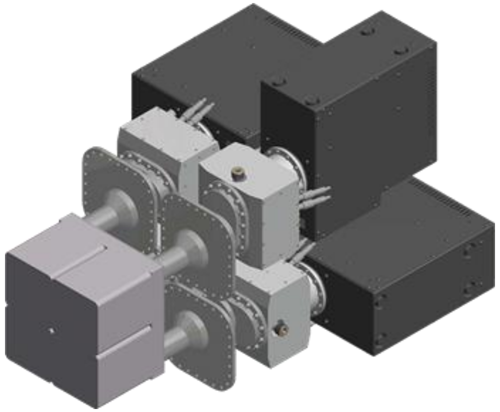
Typical performance of each individual HPGe crystal:

- FWHM @ $^{60}$CO: 1.90 keV
- FWHM @ $^{57}$Co: 800 eV
- Relative efficiency for single diode 28%

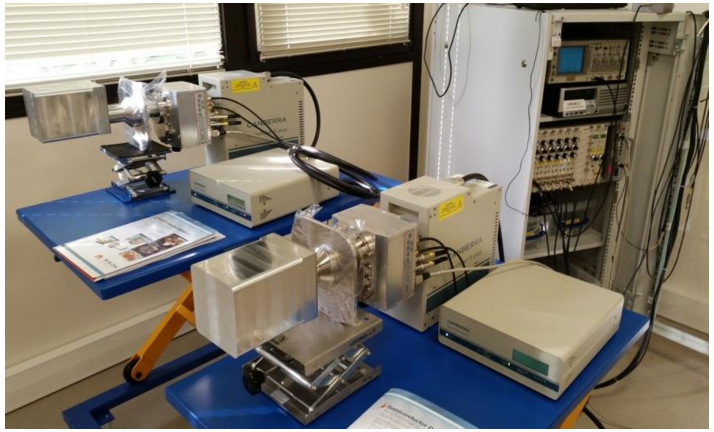
Total HPGe material weight per clover: 2.6 kg

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 – Latest Developments

- **Key features**
- A new cryogenic development to minimize heat loses but without compromises towards the previous $LN_2$ design
- Identical performance in any orientation
- All previous features are still available
  - e.g. easy FET change, in-situ neutron damage annealing, etc
- 5-year full warranty on the electrical cooler

**NOTE:** Upgrade option of previous $LN_2$ Clovers is available

Previous Clover with LN2 dewar

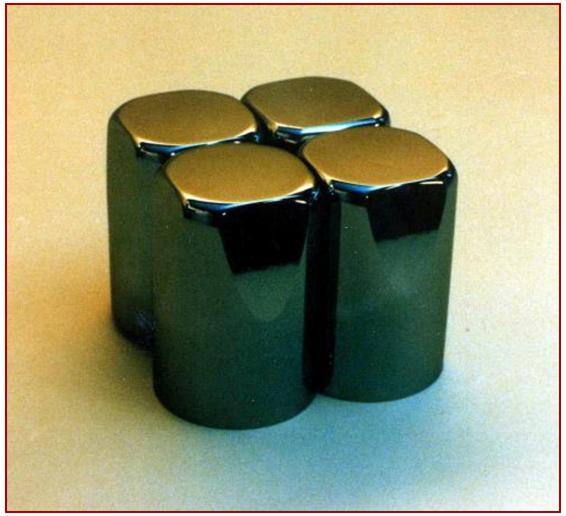

New Clover with CP5-plus

# Mirion Clover Detectors

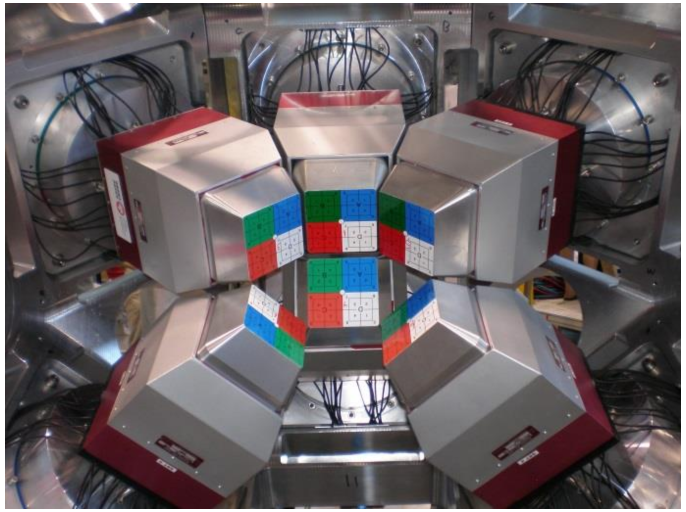
- Different type of Clover detectors available
  - (4x diameter [mm] x length [mm])
    - 4x50x70 (total ~3kg of HPGe material)
    - 4x50x80 (total ~3.3kg)
    - 4x60x60 (total ~3.6kg)
    - 4x60x90 (total ~5.4kg)
      - 4x60x90-seg16
      - 4x60x90-seg32
    - 4x70x70 (total ~5.7kg)
    - 4x70x140 (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 Segmented Detector

## Key Features

- Multiple segments enable **3D event localization** inside the crystal
- **Anti-coincidence** operation improves signal-to-noise ratio

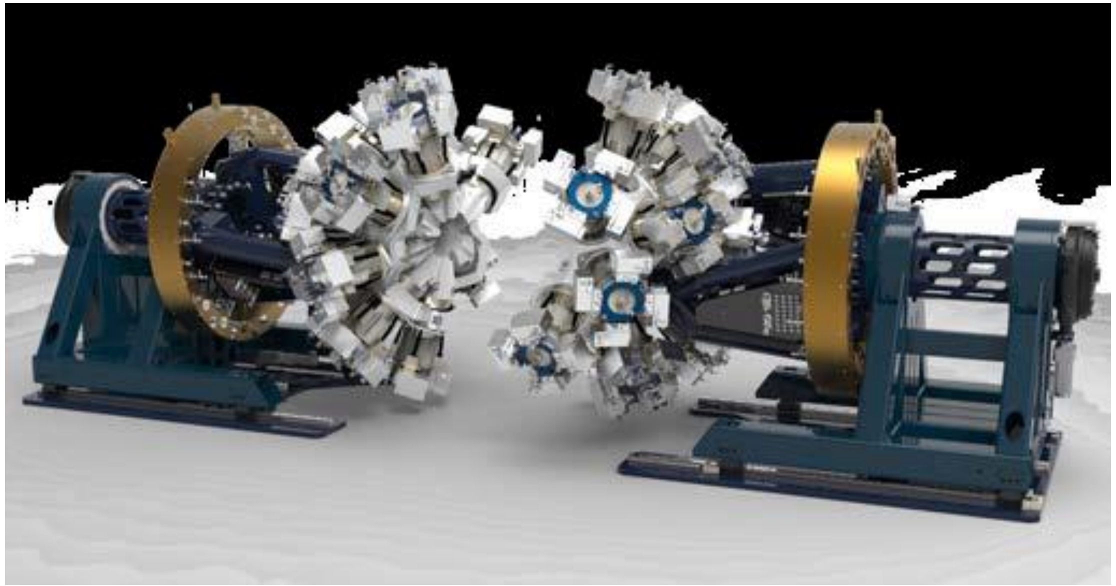
## Research Impact

- Enables **background rejection and event reconstruction**
- Useful in **gamma-ray tracking arrays** for nuclear structure studies

# Mirion Solution for Nuclear Physics: GRETA

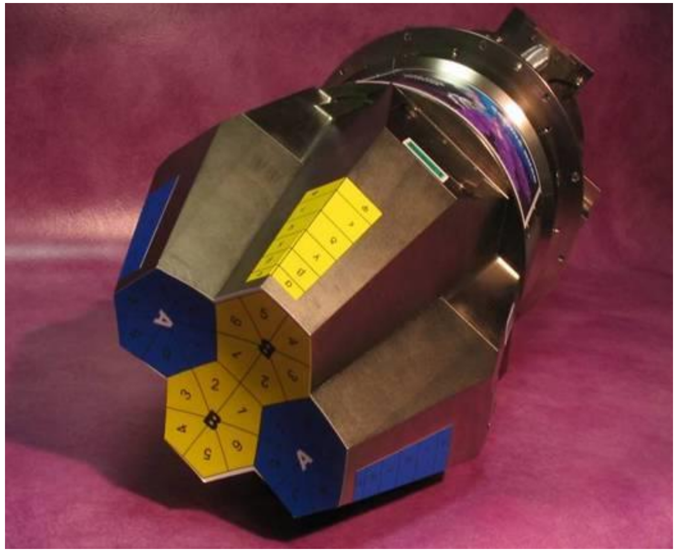
- The **Facility for Rare Isotope Beams** (**FRIB**) is a world leading accelerator facility to understand the properties of exotic nuclei and how the elements are synthesized
- **GRETA** is a state-of-the-art gamma-ray detector system
- Designed to revolutionize gamma-ray spectroscopy with **enhanced resolution, efficiency, Peak-to-Total**, and **tracking** capabilities
- Provide unparalleled insight into the structure of atomic nuclei
- Enable precision measurements in **nuclear physics**, **astrophysics**, and **fundamental symmetries**

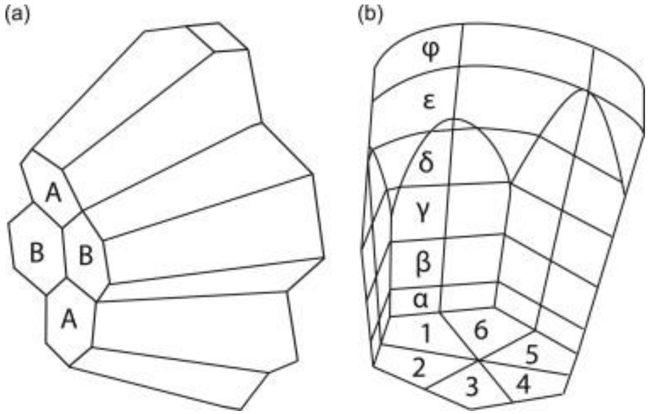
Gamma-Ray Energy Tracking Array (GRETA) will be a major instrument at FRIB and provides the sensitivity to enable a broad range of physics with both fast-fragmentation and reaccelerated beams



# Mirion Solution for Nuclear Physics: GRETA

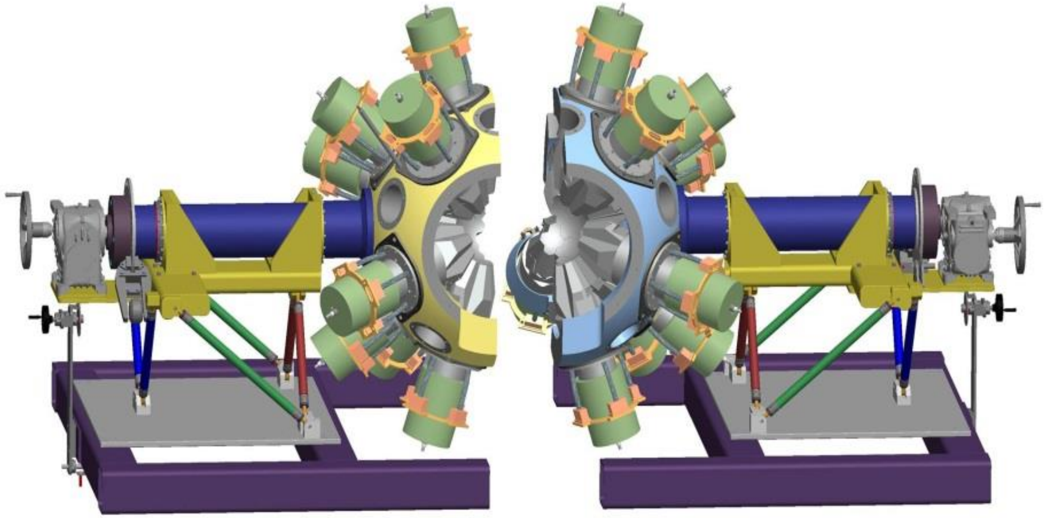
- **120 HPGe crystals** arranged in a 4π geometry
  - **Signal digitization** and real-time gamma-ray tracking using sophisticated algorithms
  - 3D position sensitivity to reconstruct gamma-ray interaction paths
- **HPGe detector solution**
  - Coaxial N type 80 mm diameter x 90 mm length
  - Segmented in 36 folds (6 longitudinal x 6 transverse)
  - Encapsulated in an aluminum canister
  - 4 capsules mounted in a Quad detector module
  - 2 hexagonal detector shapes
  - A common cryostat for the 4 capsules
  - Dedicated preamplifier electronics





# Mirion Solution for Nuclear Physics: GRETA

- A shell of closely packed HPGe crystals
- 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
- Will offer **unprecedented insight into nuclear reactions**
- Essential for understanding **r-process nucleosynthesis**, **rare isotopes**, and **new modes of decay**
- A flagship project for the **U.S. nuclear physics community**



# Example of GRETA Detectors

23 Quads at FRIB – Photo by Shumpei Noji (FRIB)

# Mirion Solution for Nuclear Physics: AGATA

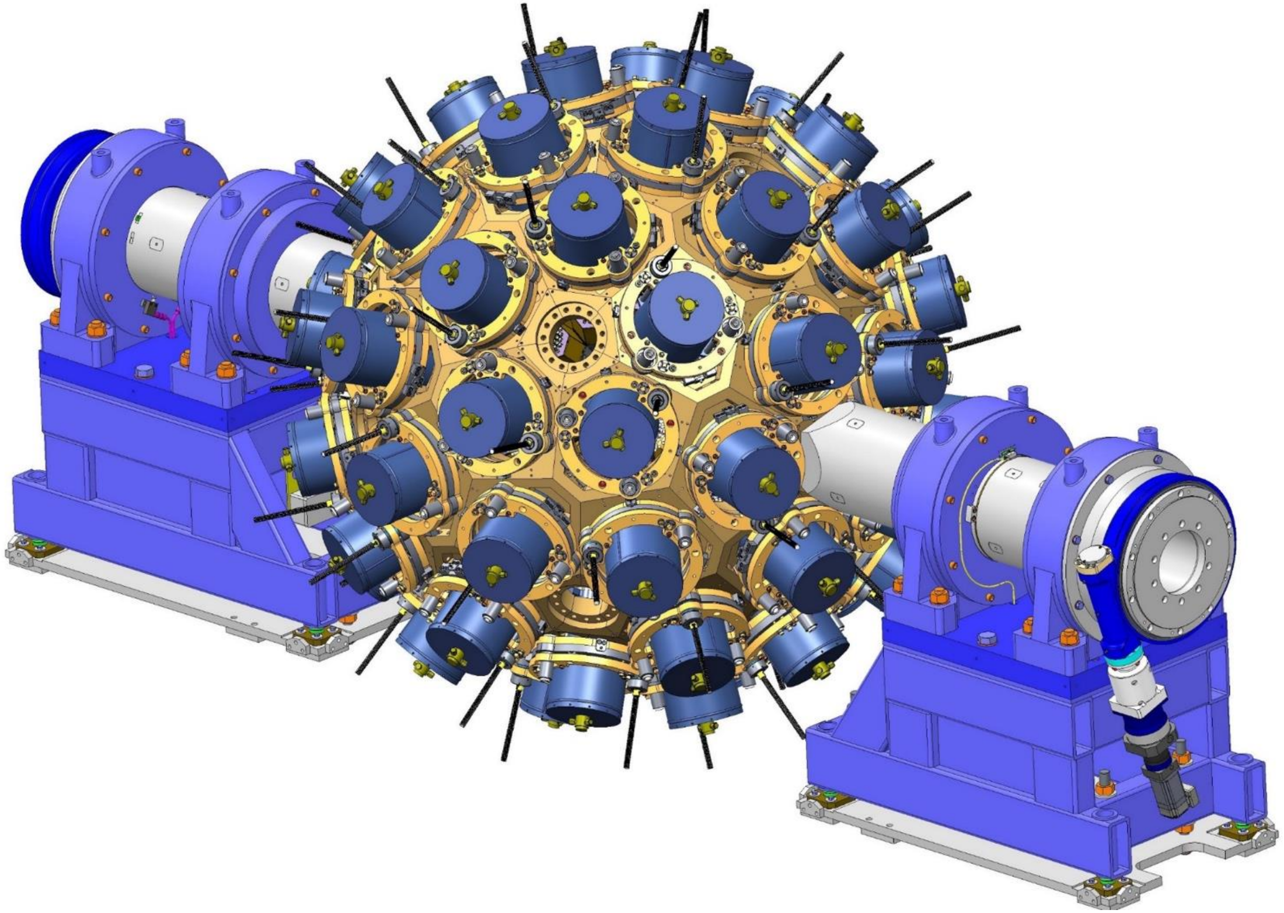
Advanced GAmma Tracking Array is a new generation **high-resolution** g-ray spectrometer providing unprecedented Doppler-correction capabilities thanks to a combination of fine **detector segmentation**, **efficient pulse-shape analysis algorithms**, and implementation of an innovative **g-ray tracking** concept.

Left: Current configuration of AGATA at LNL.

Right: CAD images of the $2\pi$ structure equipped with detectors, and of the future $4\pi$ structure. Figure taken from NuPECC LRP 2024.

# Mirion Solution for Nuclear Physics: AGATA

Design view of the AGATA spectrometer showing the mechanical holding frame (orange) and cryostat dewars (blue) of the Ge detectors

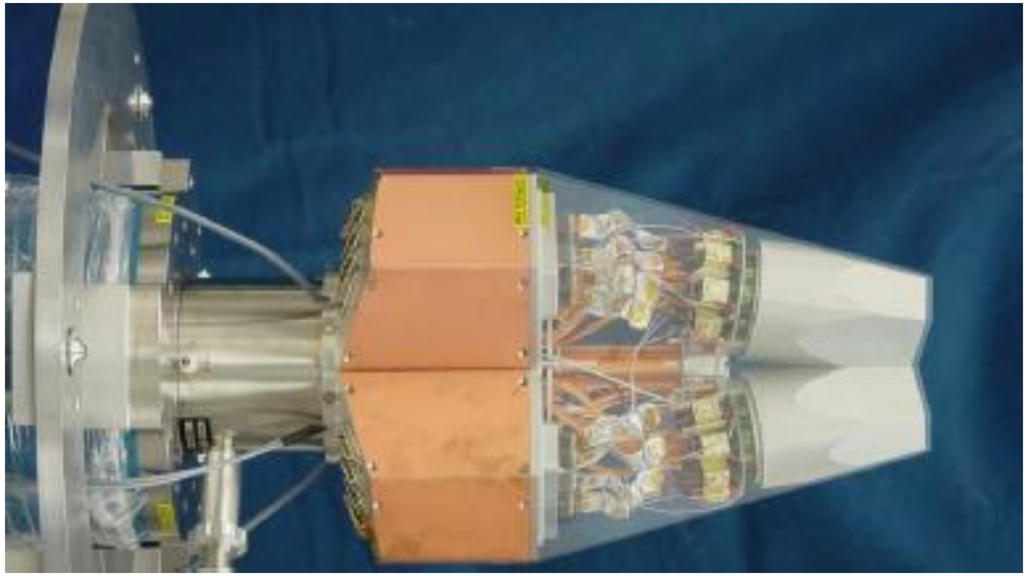


# Mirion Solution for Nuclear Physics: AGATA

- The AGATA Triple Cluster (ATC) detector is a state-of-the-art instrument designed for high-resolution gamma-ray spectroscopy, playing a crucial role in nuclear-structure studies.
- It consists of three asymmetric, 36-fold segmented, hexagonal-shaped, encapsulated, and tapered HPGe detectors.
- Each ATC integrates 111 high-resolution spectroscopy channels, combining core contacts and segment signals from each crystal to provide exceptional performance.

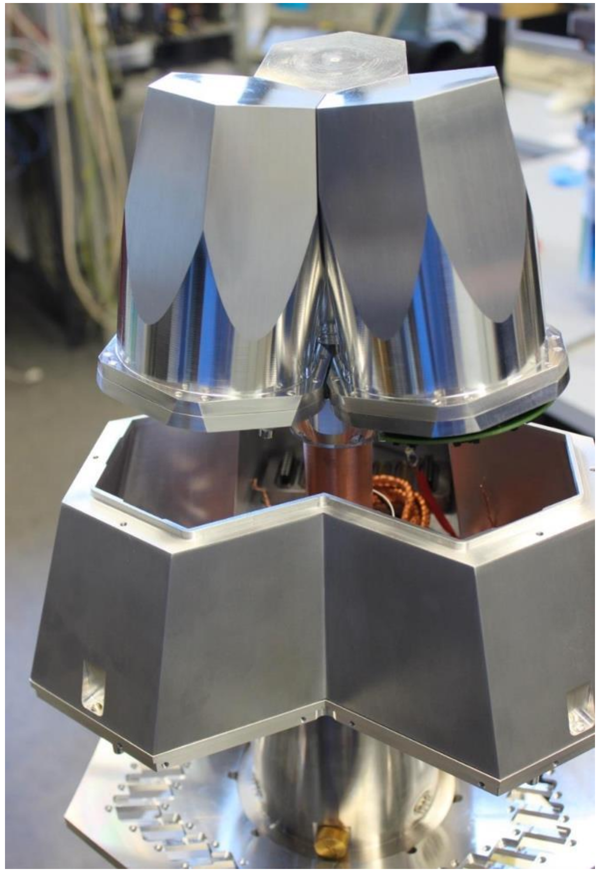
Uses **pulse-shape analysis** and **real-time gamma-ray tracking** to reconstruct full interaction paths

Supported by **digital electronics** and sophisticated data acquisition systems



# Mirion Solution for Nuclear Physics: AGATA

- AGATA has been deployed at several major facilities (GSI, GANIL, LNL, etc.).
- Ongoing development to expand coverage and integrate with next-generation beamlines.
- Long-term plan: Complete the full 4π array (~180 crystals) for maximum efficiency.
- Critical for advancing knowledge in **nuclear structure**, **astrophysical processes**, and **rare isotope behavior**.
- A cornerstone for experimental campaigns at **Europe's nuclear physics laboratories**.



# Specialty Ultra-Low Background HPGe Detectors

### Key Features

- Built from **radiopure materials** to minimize natural radioactivity
- Shielded and often operated **underground** to reduce cosmic ray background
- Capable of detecting **extremely rare nuclear processes**

### Research Impact

- Essential for **rare decay searches** and **environmental background measurements**
- Example: Detectors for **LEGEND project**

# 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 and selected materials
  - 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
  - Custom BEGe – up to 100 mm diameter
  - SAGe Well 250cc and 400cc active volume

# Mirion Specialty Ultra-Low Background HPGe Detectors

- **Application**: physics research (rare decay exploration like $^{180m}$Ta)
- **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

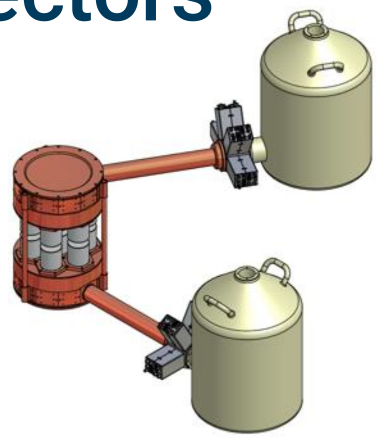
| Isotopes | | Peak (keV) | Efficiency (%) |
|---|---|---|---|
| $^{232}$Th | $^{228}$Ac | 911 | 5.8 |
| | | 968 | 5.5 |
| | $^{212}$Pb | 238 | 9.7 |
| | $^{212}$Bi | 727 | 6.8 |
| | $^{208}$Tl | *2615* | 2.0 |
| | | *583* | 4.7 |
| | | 860 | 4.7 |



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)

## 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 « on-the shelf » S-ULB detectors using our ULB materials
- Boulby Mine, UK

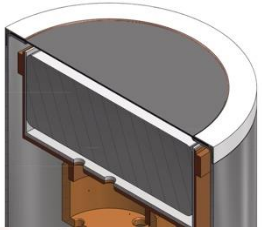
| | Detector | Count Rate ($kg^{-1}$ $d^{-1}$) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Integral 100–2700 keV | 351 keV $^{214}Pb$ | 609 keV $^{214}Bi$ | 238 keV $^{212}Pb$ | 1461 keV $^{40}K$ | 2615 keV $^{208}Tl$ | 46.5 keV $^{210}Pb$ |
| SEGe 160% | Belmont | 90(9) | 0.2(1) | 0.4(2) | 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-plusupgrade** | 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) |

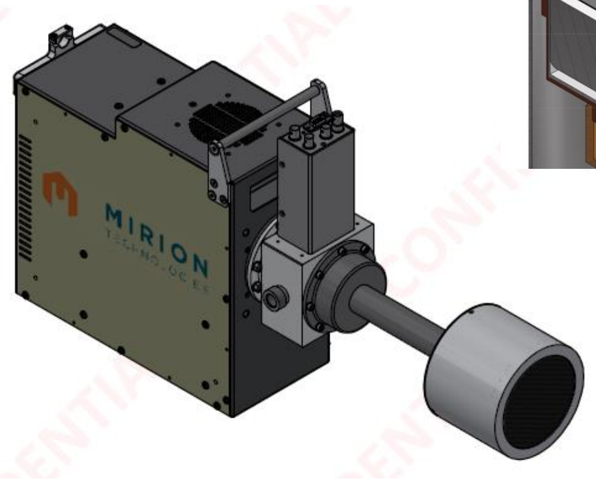
https://www.boulby.stfc.ac.uk/Pages/Ultra-low%20Background%20Material%20Screening.aspx

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

# Mirion Specialty Ultra-Low Background HPGe Detectors

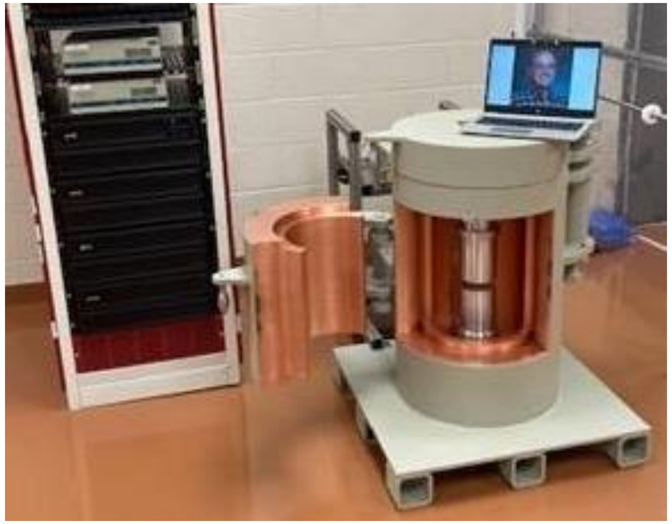
- HPGe crystal: diameter 100 mm, thickness  35 mm
- Measured Spectroscopy Performance:
  - At 122keV: 660eV
  - At 1.33MeV  1.72keV
  - Symmetry factors at 1.33MeV:
    - FWTM/FWHM: 1.84
    - FWFM/FWHM: 2.56
  - Relative efficiency at 25cm : 91%
- Carbon entrance window 0.6 mm thick

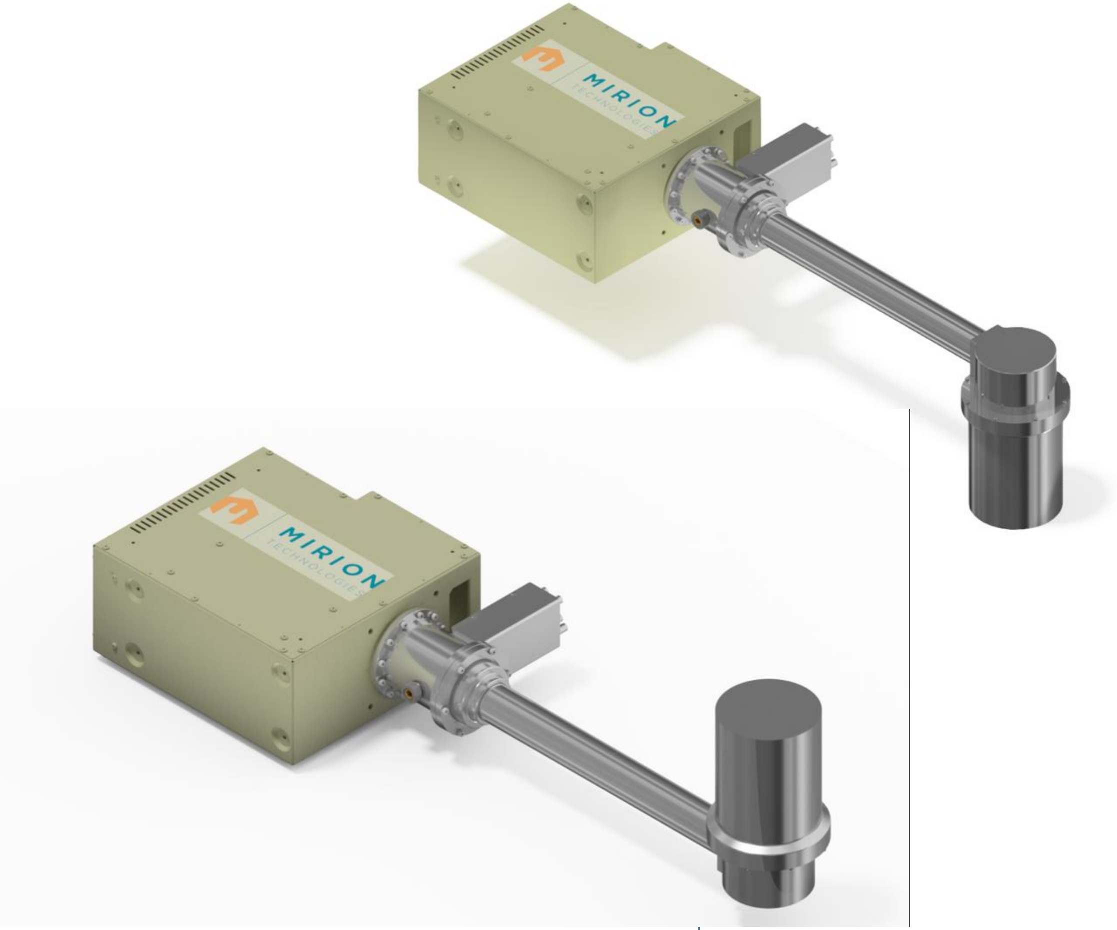


# Mirion Specialty Ultra-Low Background HPGe Detectors

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



- S-ULB BEGe in coincidence configuration



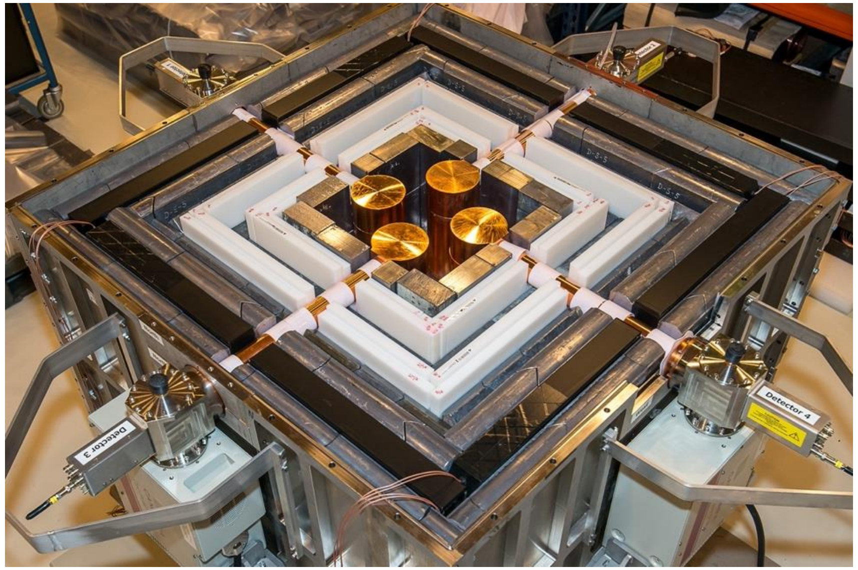
# “Exotic” Mirion Specialty Ultra-Low Background HPGe Detectors

**Primary application:**

**Detection and precise measurement of coherent neutrino-nucleus scattering**

Point Contact detector technology on P-type HPGe crystals with minimized time exposed to cosmic activation with best pulser resolution for Rare Events detection

- CMOS electronics for best low-energy threshold
- PPC detectors
- Radiopure: Ultra-Low background materials
- <80 eV FWHM test pulser with 2.4 kg crystal



https://en.wikipedia.org/wiki/CONUS-Experiment#/



Innovation at Work

# Specialty Detectors Space Applications

## Key Features

- Radiation-hardened for cosmic radiation and solar events
- Compact for spacecraft and satellite payloads
- Wide detection range: gamma rays, X-rays, and charged particles
- High sensitivity and excellent energy resolution for spectroscopy
- Long-life, low-maintenance operation for multi-year missions

## Research Impact

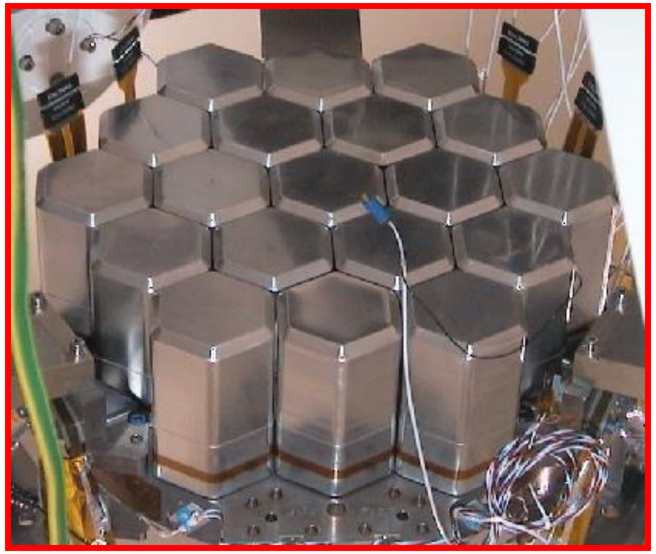
- Planetary Science: Elemental and isotopic analysis of planetary surfaces and atmospheres
- Detect gamma-ray bursts, solar flares, cosmic rays
- Radiation Environment Monitoring: Supports spacecraft and crew radiation safety
- Enables extended observations of Space

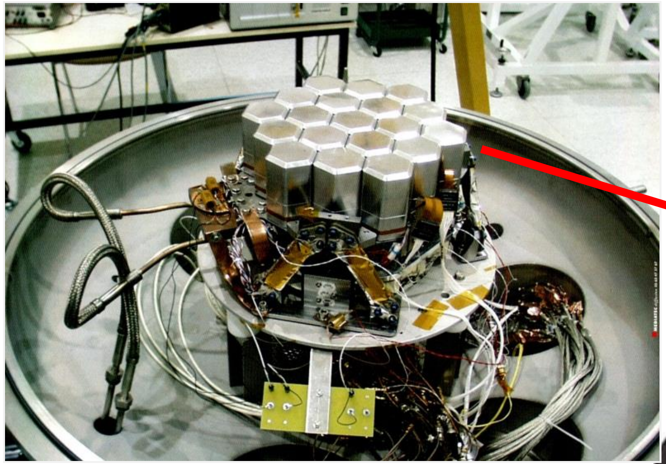
# INTEGRAL-SPI Mission

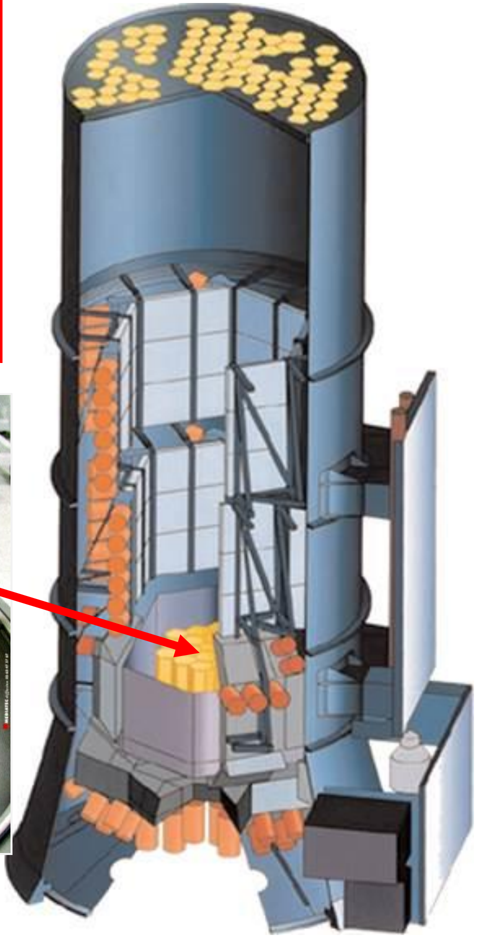
- **INTEGRAL-SPI: INTE**rnational **G**amma-**R**ay **A**strophysics **L**aboratory, on which is installed the **SP**ectrometer for **I**ntegral
  - An international project, involving the ESA, NASA, RKA
  - Several Instruments: SPI (Spectrometer), IBIS (Imager on Board the Integral Satellite), JEM-X (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







MIRION Connect 25
Annual Users' Conference



Innovation at Work

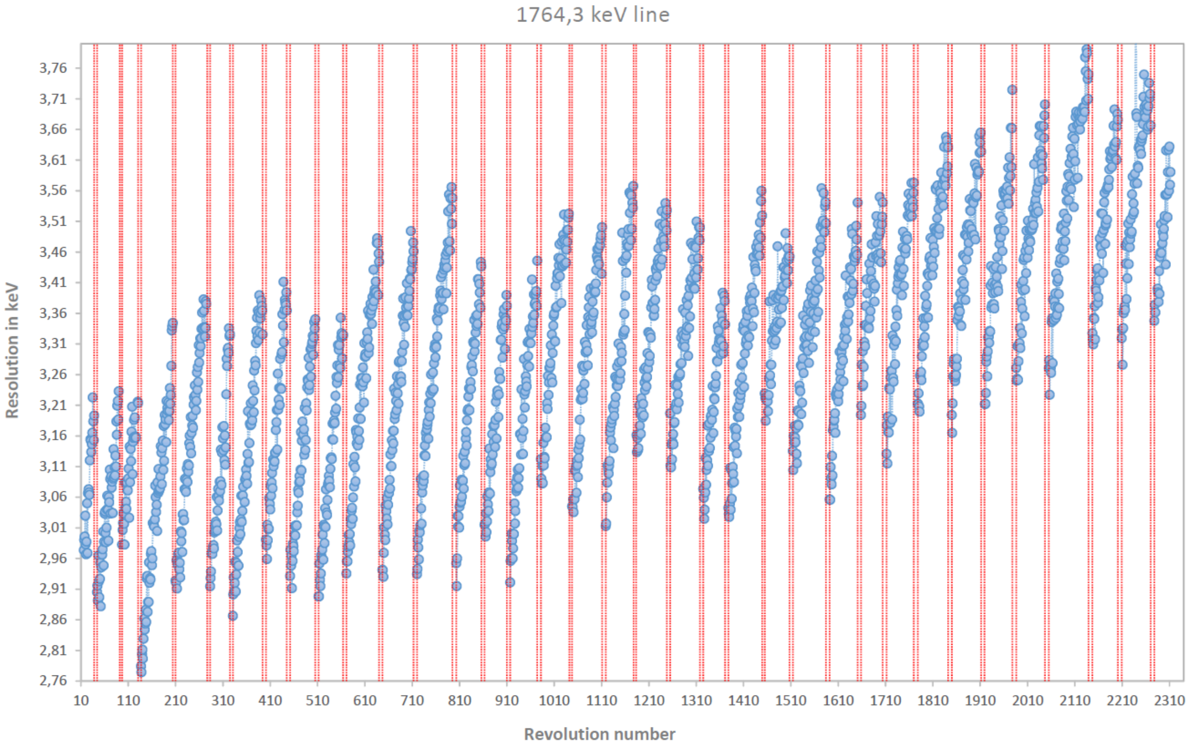
# INTEGRAL-SPI: current status

- 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

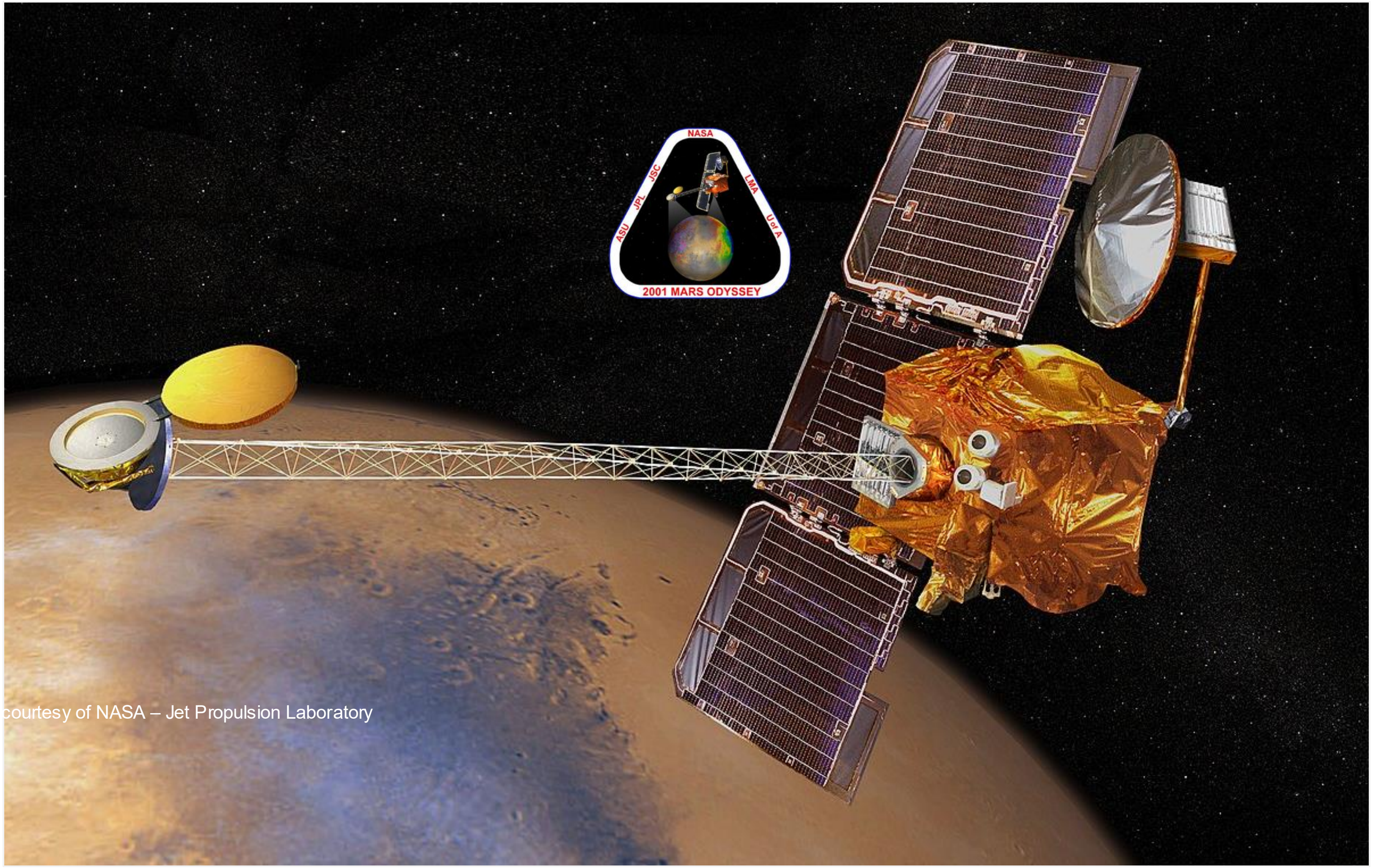
| Energy | Initial FWHM | Current FWHM |
|---|---|---|
| 198 keV | 1.87 keV | 2.01 keV |
| 1764 keV | 2.97 keV | 3.07 keV |
| 2754 keV | 4.11 keV | 4.30 keV |

- **Future**
  - 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?

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

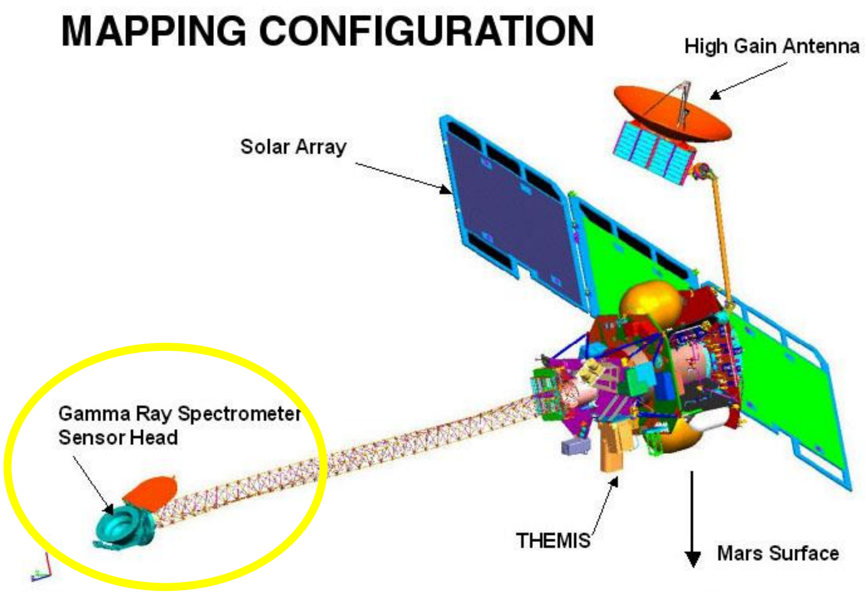


# MARS Odyssey Mission



# 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

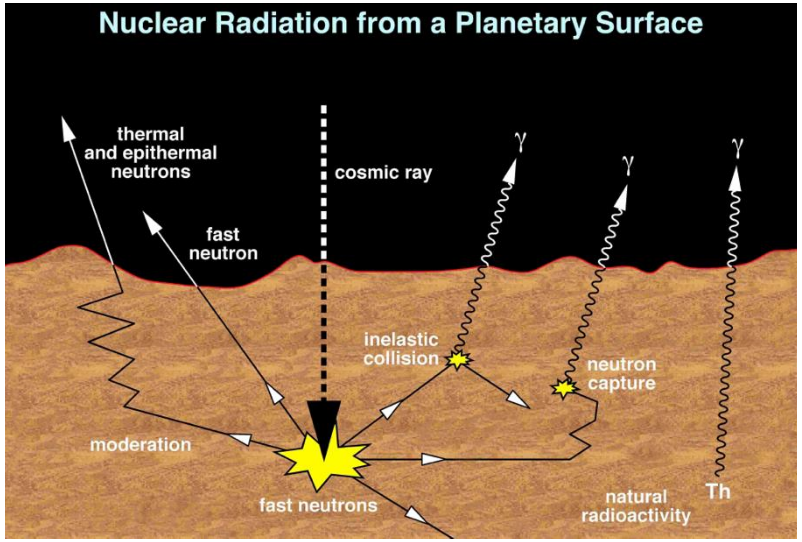


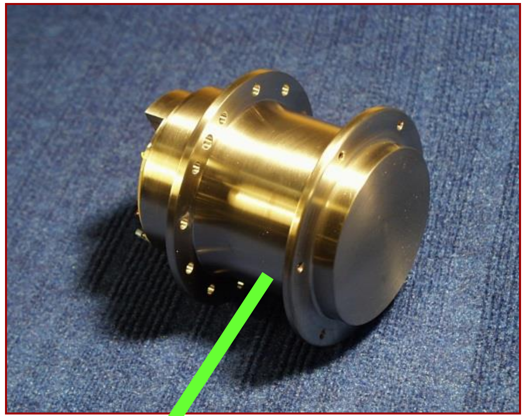

- **Mission**: 2 years study of elemental composition and radiation on Mars
  - August 24, 2004: official end of MARS Odyssey's primary science mission.
  - Available flight system resource capabilities through the next 10 years: operations continue today as a communications relay for rovers and landers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

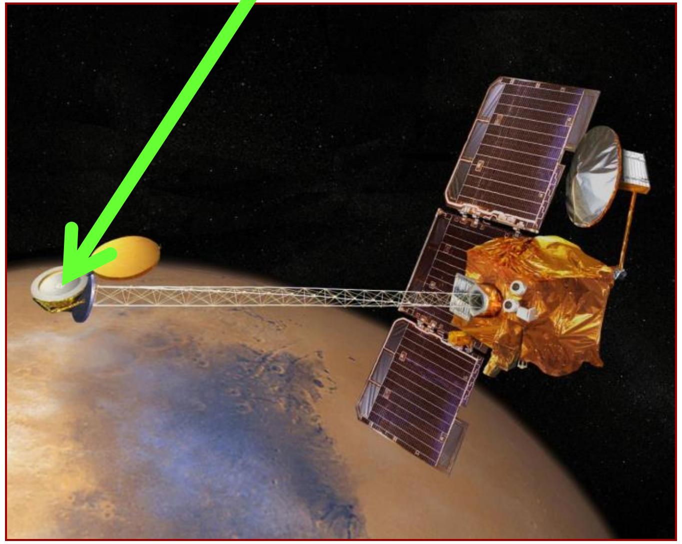
https://mars.nasa.gov/odyssey/index.cfm

# 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”



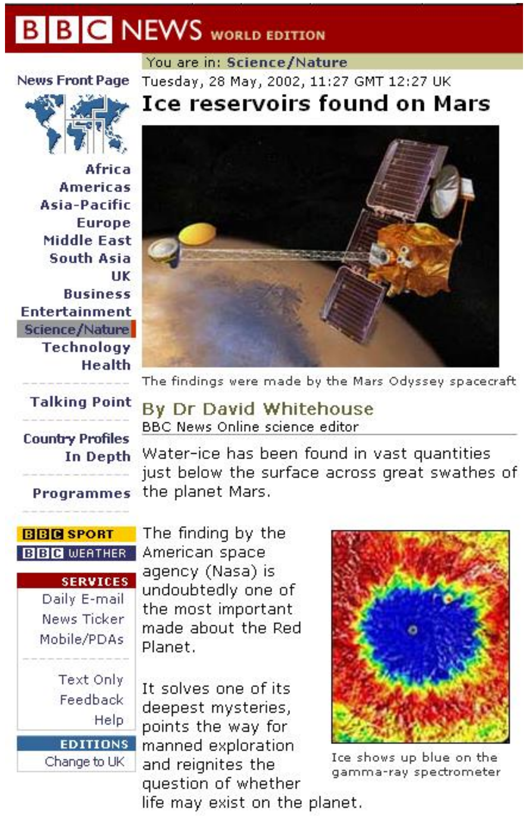





https://science.nasa.gov/mission/odyssey/

# MARS Odyssey: results

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



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**Ice reservoirs found on Mars**

The findings were made by the Mars Odyssey spacecraft

By Dr David Whitehouse
BBC News Online science editor

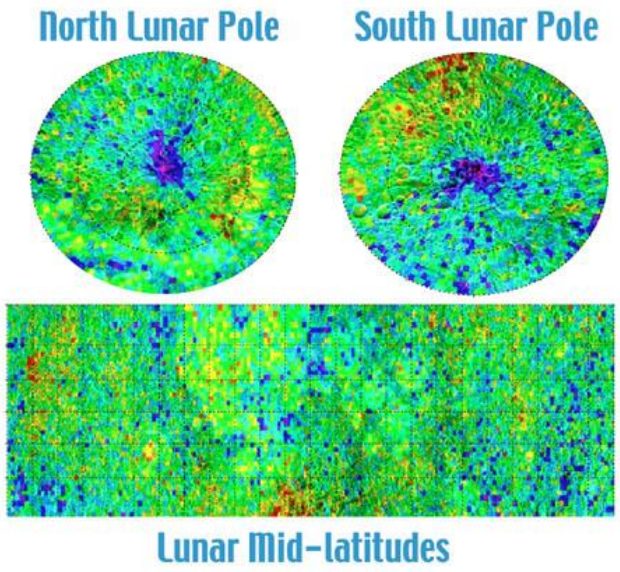
Water-ice has been found in vast quantities just below the surface across great swathes of the planet Mars.

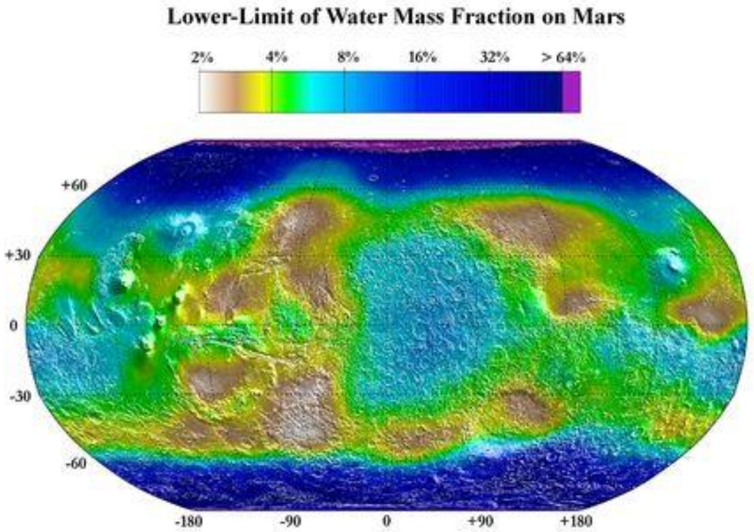
The finding by the American space agency (Nasa) is undoubtedly one of the most important made about the Red Planet.

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

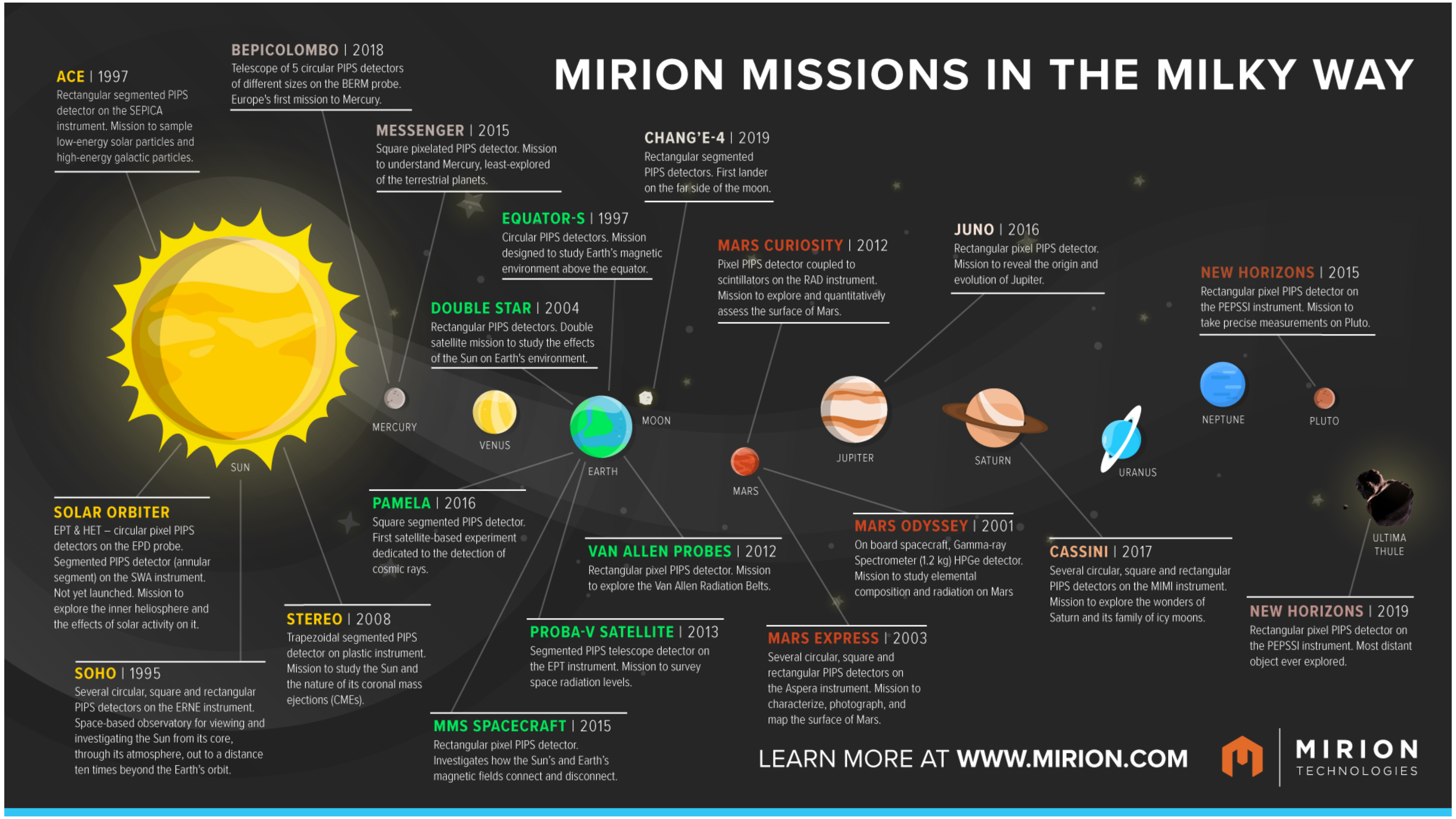
- GRS on board NASA's Mars Odyssey spacecraft have revealed more underground ice on the Red Planet than scientists expected
  - Confirmed the presence of water on Mars
  - Mapping of water on Mars




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

# Summary

- These detectors collectively **advance fundamental research** by:
- Enabling **unprecedented energy resolution** and **ultra-low background** performance
- Supporting **rare-event searches** and **nuclear structure studies**
- Allowing **scalable arrays** for large international experiments

# Questions?

# Thank you!