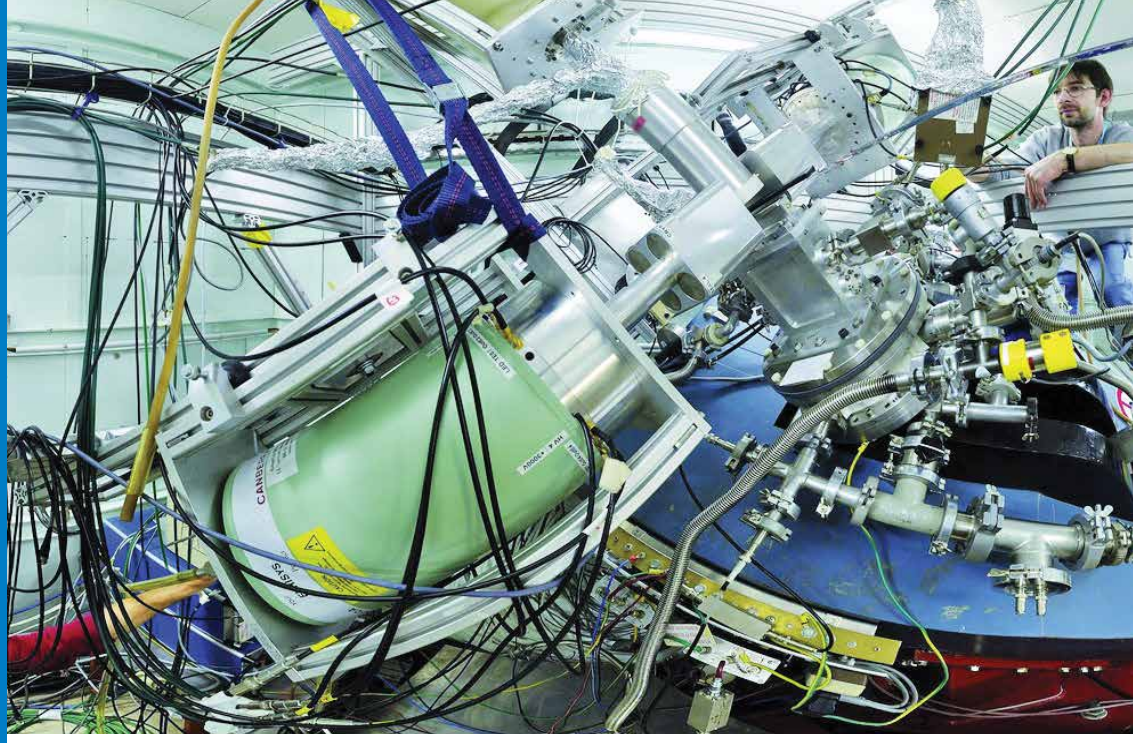
MIRION
TECHNOLOGIES

Detectors for Challenging Applications



Mirion is a leading provider of innovative and cost-effective nuclear measurement solutions used to maintain safety, assess the health of nuclear facilities and safeguard the public and the environment.

Since 1968, Mirion has also been committed to the development, manufacturing and service of unique specialty detectors for international scientific experiments and specialty designs.

Driven by diverse needs in fundamental and applied research applications, a range of technologies has been developed over many years that enables Mirion to maintain its technological leadership in semiconductor detector development.

Mirion has been supplying detectors and instrumentation used in cutting-edge materials analysis, physics, and space studies to some of the world's leading industries and research institutes. The dedicated R&D structure of Mirion allows us to deliver innovative nuclear detection systems based on a comprehensive exploration of all available and emerging technologies.

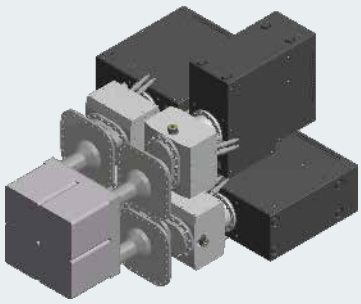
Our passion for fully understanding the needs of our customers is key to our ability to provide the best solutions to contribute to their success.

State-of-the-art breakthrough technologies developed by Mirion include:

- Array of several detectors in a unique cryostat
- Encapsulation and Ultra High Vacuum (UHV) sealing
- Segmentation of detector electrodes

These versatile technologies are not only the tools with which Canberra™ nuclear detection systems are built, but also the tools that are building the future of the nuclear industry.

Compex: First Electrically-Cooled Clover™ Array Detector



MIRION
TECHNOLOGIES

Mirion Has Been Serving The Nuclear Community For Over Five Decades

It is our policy that:

All products and services we offer will meet or exceed the specified requirements and anticipated expectations of our customers. This policy is supported at all levels within the organization.

Our approach to quality is modeled after the concept of Total Quality Control. This approach places the responsibility for quality of work on each employee. All are empowered to stop work or processes if they believe quality is in question, and they are encouraged to report quality issues immediately to management.

The goal of this approach is 100% Customer Satisfaction. By focusing on our chosen marketplace, continuously improving our products and processes, and constantly innovating, we believe we create the greatest value for our customers.

- Mirion detectors are particularly environment friendly. They are designed according to ECO design rules.
- Mirion detector manufacturing is therefore in conformity with the RoHS or REACH norms as well as OHSAS 18001 certification.
- Systems are designed to comply with European Directives (EC).
- The Mirion quality system meets ISO 9001 standards, and the company holds appropriate certifications in all countries and regions in which we operate. Certificates can be obtained by contacting your local sales or service office.

Compton camera – DSSD telescope

Detectors for Nuclear Physics Research

Solutions for highest gamma ray efficiency using HPGe array detectors in specific mechanical shapes to accommodate any constraint.

Mirion developed array detectors in response to a demand for new solutions to replace typical HPGe detectors in the 1980s. Customers required a large volume of HPGe to achieve the highest efficiency without compromising performance. Since that time, Mirion's large portfolio of Clover and encapsulated detectors has become a reference in nuclear physics.

Clover Detectors — Worldwide Reference for Highest Performance

Ideal for nuclear physics experiments and any application requiring highest efficiency

FEATURES

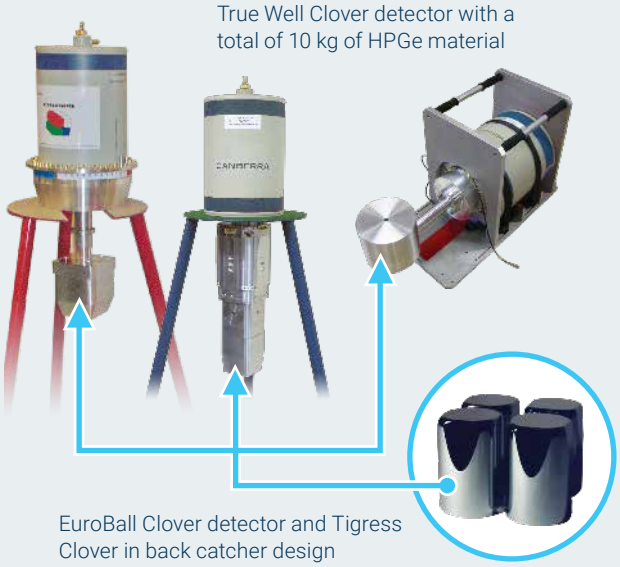
- Four special shaped Ge crystals for a close array – with or without segmentation
- Up to 12 kg of HPGe material in one cryostat
- LN_2 free cooling available on request
- User-friendly features and associated tooling for on-site neutron annealing
- Good sensitivity to gamma-ray polarization
- Electrical cooling available

PERFORMANCE

- Excellent energy and timing resolution
- 130% relative efficiency in add-back mode with a Clover array 4 x 50 x 70 (4 x 20%)
- Can address applications other than nuclear physics where highest efficiency or MDAs are required
- Low background configurations on request
- Thin entrance window for extended energy range to low energy photons available on request

APPLICATIONS

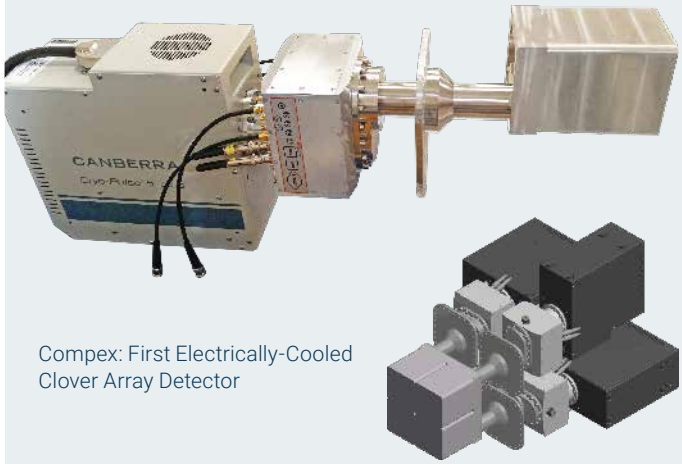
- Nuclear physics
- Health physics or low activity environment measurements in well-type configuration



True Well Clover detector with a total of 10 kg of HPGe material

EuroBall Clover detector and Tigress Clover in back catcher design

Innovative Detector Solutions for Research



Compex: First Electrically-Cooled Clover Array Detector

Detectors for Nuclear Physics Research

4Pi HPGe Array Solutions

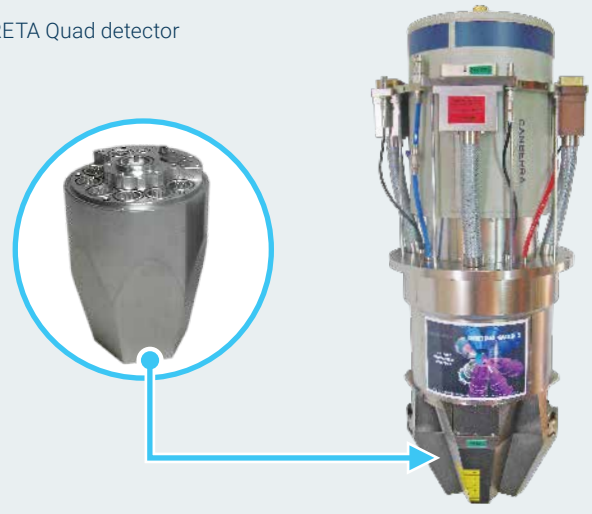
Demand has been growing over the past decade for gamma-ray spectrometers with the highest resolving power for each interaction point for a gamma in the array. State-of-the-art instruments are needed to study nuclear structures at the very limits of stability. A 4Pi shell is therefore required involving more than 100 detectors to precisely track any event even if a scattering has occurred in the neighbor element. Veto scintillator detectors, such as BGO, are no longer needed for this application.

FEATURES

- Up to four HPGe crystals in one cryostat
- Each crystal has 36 segments
- Up to 148 channels per array detector
- Up to 10 kg of HPGe material in one cryostat
- LN_2 free cooling available on request
- Special irregular hexagonal shape to accommodate a complete 4Pi detection ball consisting of only HPGe material
- High performance electronics to achieve best energy and timing performance

We can address applications other than nuclear physics where highest efficiency or localization (tracking) is required.

GRETA Quad detector



Cluster Detectors for Nuclear Physics

A cluster detector consists of encapsulated HPGe detectors. The goal is to bring the highest amount of Ge detectors as close together as achievable within a unique cryostat.

Scientists using EUROBALL cluster detectors over two decades reported an add-back relative efficiency of about 600% with seven 300 cc detectors.

FEATURES

- Highest efficiency due to best area coverage
- High reliability: first EUROBALL detectors in operation since beginning of the 90s
- Easy maintenance
- Easy neutron damage repair at customer site
- Compatible with electrical cooling
- Segmentation available for precise gamma tracking or Doppler correction

EUROBALL Cluster detector

Custom Designed ULB Detector Systems

Mirion is a leading supplier of germanium detectors for the most demanding ultra low-background spectroscopy applications.

We have many years of experience in materials selection and the necessary laboratory facilities to screen materials and to build and test complete detector systems. Dedicated tooling and skills are required to maintain the lowest achievable levels of contamination on the detector element and cryostat assembly.

Mirion continuously searches for new materials and components to improve detector performance and achieve even lower levels of background radiation. This effort has led to the development of Specialty Ultra Low-Background Detector Systems. Additionally, Mirion dedicates significant efforts to improve the electronic noise threshold through development of special detector geometries and low noise electronics.

Specialty Ultra Low-Background Cryostats S-ULB

Cryostat designs from selected grades of materials and tailored to the specific requirements of each application, achieving world-class performance for the most demanding underground laboratory environments. An example is an integral of 0.09 counts/min (15-1500 keV) measured at the Laboratoire Souterrain de Modane (LSM).

FEATURES

- Large detectors available (up to 910 cc)
- Custom designs to fit existing shielding constraints
- Selected materials like fresh OFHC copper or high-purity aluminum (< 0.3 ppb U/Th)
- Compact endcap design accommodating scintillator guard detectors in close proximity

Ogoya tunnel (Japan): total of 21
Canberra S-ULB detectors

Small Anode Germanium (SAGe™ Well)

For several years Mirion has been making these special germanium detectors for customers engaged in fundamental research in neutrinoless double beta decay, dark matter, and related cosmological science. These detectors are compatible with any of Mirion cryostat model as well as with standard or Specialty Ultra Low-Background (Custom-built) options.

FEATURES

- Variety of shapes and sizes
  - Diameters up to 90 mm
  - Lengths up to 85 mm
- Mass up to 2.7 kg
- 1.6 keV FWHM at 1.33 MeV
- Electronic noise as low as 65 eV FWHM
- External AC-coupled preamp for veto systems
- Fresh OFHC copper or highly selected
- Available as an array of several detectors in a unique cryostat to further increase the detection volume

1 kg Small Anode Ge detector with preamplifiers on both contacts for neutrino search

Imaging Detectors

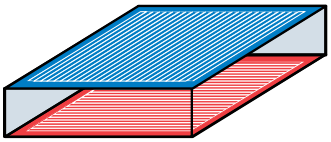
Mirion detectors are manufactured using a proprietary technology enabling the design of the best segmented HPGe or Si(Li) detectors available worldwide.

Mirion uses photolithography techniques, thus allowing for a wide variety of segmentation patterns (straight or curved strips, pixels, etc.), including double sided thin window segmentation for imaging applications. Mirion segmentation techniques are highly reliable and stable. Repetitive heat cycling will not affect HPGe detector quality and even neutron annealing can be performed. Our mature segmentation technology is even a good candidate for space applications.

Segmented Planar Detectors

APPLICATIONS

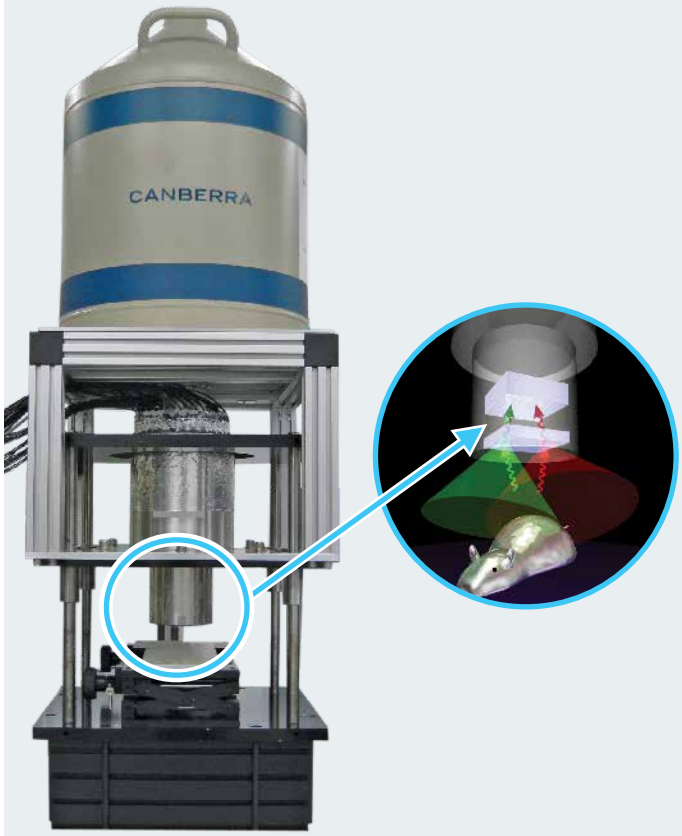
- Compton camera, imaging, homeland security, polarimetry, gamma tracking



FEATURES

- HPGe and Si(Li) material available
- Choice of cryostat
- Pixel or strip segmentation patterns available
- LN_2 or Cryo-Pulse® 5 Plus cooling
- Stack of several DSSD (Double Sided Strip Detectors) within the same cryostat

DSSD Telescope detector for medical gamma camera EuroBall Cluster



Segmented Coaxial Detectors

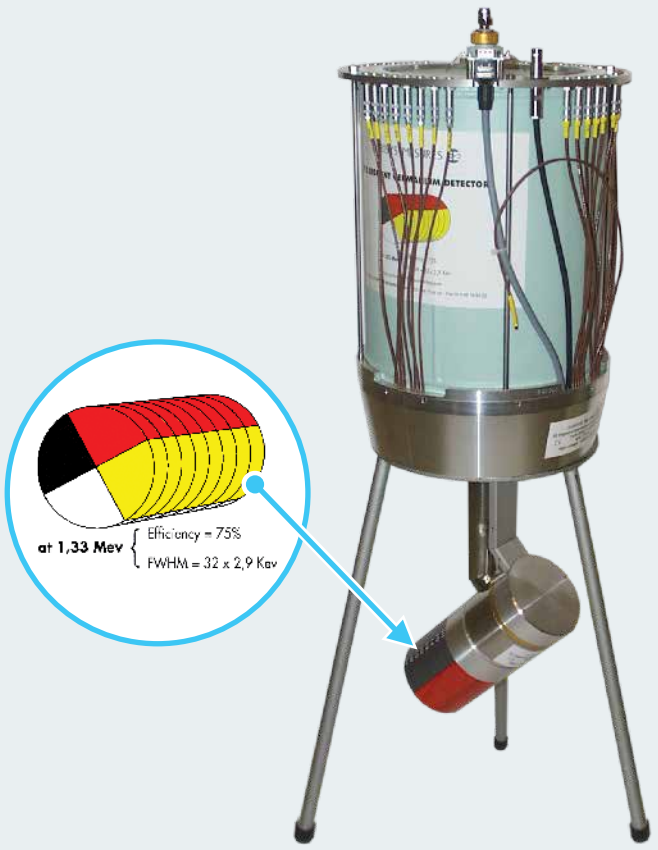
APPLICATIONS

- Gamma tracking, polarimetry, doppler correction, beta decay suppression, Compton camera

FEATURES

- Longitudinal and transversal segmentations of the outer contact by photolithography (up to 36 segments), on various N-type crystal geometries
- No dead zone or absorbing material between segments
- Monolithic detectors
- No measurable crosstalk effects
- Increased granularity of multi-detector systems
- Localization of the interaction and gamma ray
- Tracking capability through coincidence between internal core signal and segment contact signals

32 Segment Germanium Detector



Ruggedized Detector Systems

The combination of our extensive experience with the evolution of new technologies (encapsulation, ultra-high vacuum, waterproof design, shock absorption devices) makes Mirion a world leader in scientific and special applications involving HPGe detectors.

Mirion delivers innovative and reliable detection instruments for the most demanding industries and research centers. Researchers have come to depend on these specialized instruments for critical applications such as mining, space, D&D projects, military, etc. The Canberra detector can be used for spectroscopy measurements in all types of external conditions without any compromise on performance, safety or reliability.

Sealed HPGe Probe

This probe offers high resolution with electrical cooling, ultra-high vacuum with a minimum of power, weight and volume compared to existing HPGe detectors.

APPLICATIONS

- **Mining:** Used in borehole logging, such a probe will provide direct and more accurate measurement of uranium for exploration mapping.
- **Recycling, Decontamination and Decommissioning projects:** Light and compact probes for remote and complex measurement geometries.
- **Water Monitoring:** On-line spectroscopy information on water exhaust or fuel pools.
- **Fuel and nuclear power plant outages:** Portable high-resolution LN_2-free probe for hold-up measurements before and during outage operations. The design can easily be mounted on a rover.
- **Emergency Response:** Thanks to a high quality assembly of reliable building blocks developed by Mirion, this sealed probe is ideal for spectroscopy in emergency situations where immediate nuclide identification is required.

New sealed probe for user-friendly applications outside laboratories in rugged conditions

Airborne Systems

Mirion developed this unique turnkey and versatile HPGe solution for mobile radionuclide identification and mapping. The high-resolution and high-efficiency spectrometer design relies on advanced technologies such as the encapsulation in ultra-high vacuum (UHV), low vibration electrical cooling through Cryo-Pulse 5 Plus modules, special cryostat design, digital signal processing with add-back mode or real-time data analysis and mapping display.

This large ruggedized HPGe system combines high efficiency and unbeatable energy resolution for greatest sensitivity performance with respect to scintillator based systems. Precise dosimetry and source identification capabilities are possible even in high background conditions.

APPLICATIONS

- **Mobile Survey:** Used on board aircraft, vehicles or boats and accommodates their respective constraints. Highest sensitivity to separate anthropogenic and natural nuclides. Human interface for pilot guidance and other parameters (dose meter, temperature, altimeter, etc.)
- **Emergency Response:** High efficiency combined with ideal energy resolution allows quick and precise ground contamination evaluation on aircraft in emergency situations.

FEATURES

- Up to seven HPGe detectors in Ultra-High Vacuum capsules
- A unique cryostat with powerful electrical low vibration cooling
- Rugged hardware design
- DSP-based multichannel MCAs of the latest generation
- Adaptable power supply to fit any vehicle
- Small footprint to accommodate even small planes
- Special attachments and dedicated handling of the cabinets
- On-line and off-line access on spectroscopic information, gamma dose, localization
- Enhanced efficiency through embedded add-back rework of spectra
- Mapping features at request

Hardware overview of the Mirion airborne system consisting of two cabinets (one for the detectors array, the other for the acquisition system)

View of detector cap through a hole in aircraft cabin. Each colored circle shows the location of an individual coaxial detector. The seven detectors are in a single common cryostat

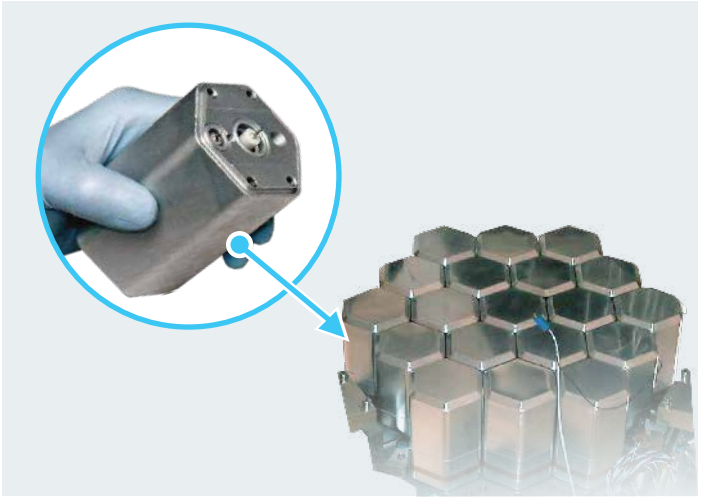
Space Applications

HPGe detectors can be arranged in single or array systems for space telescopes or satellites.

It is well known that Ge material is sensitive to neutrons and protons and to vibration (especially during take-off). Mirion has developed solutions for the successful use of Ge in space. The highest reliability can be demonstrated on existing projects still in operation such as Integral-SPI and the Mars Odyssey among others.

FEATURES

- Accurate gamma cartography in galaxies (study of supernovae, black holes, etc.)
- Shock-proof design (100 g)
- Highest reliability extended scientific program on existing system launched many years ago
- Remote neutron repair ability
- Compatible with electrical cooling



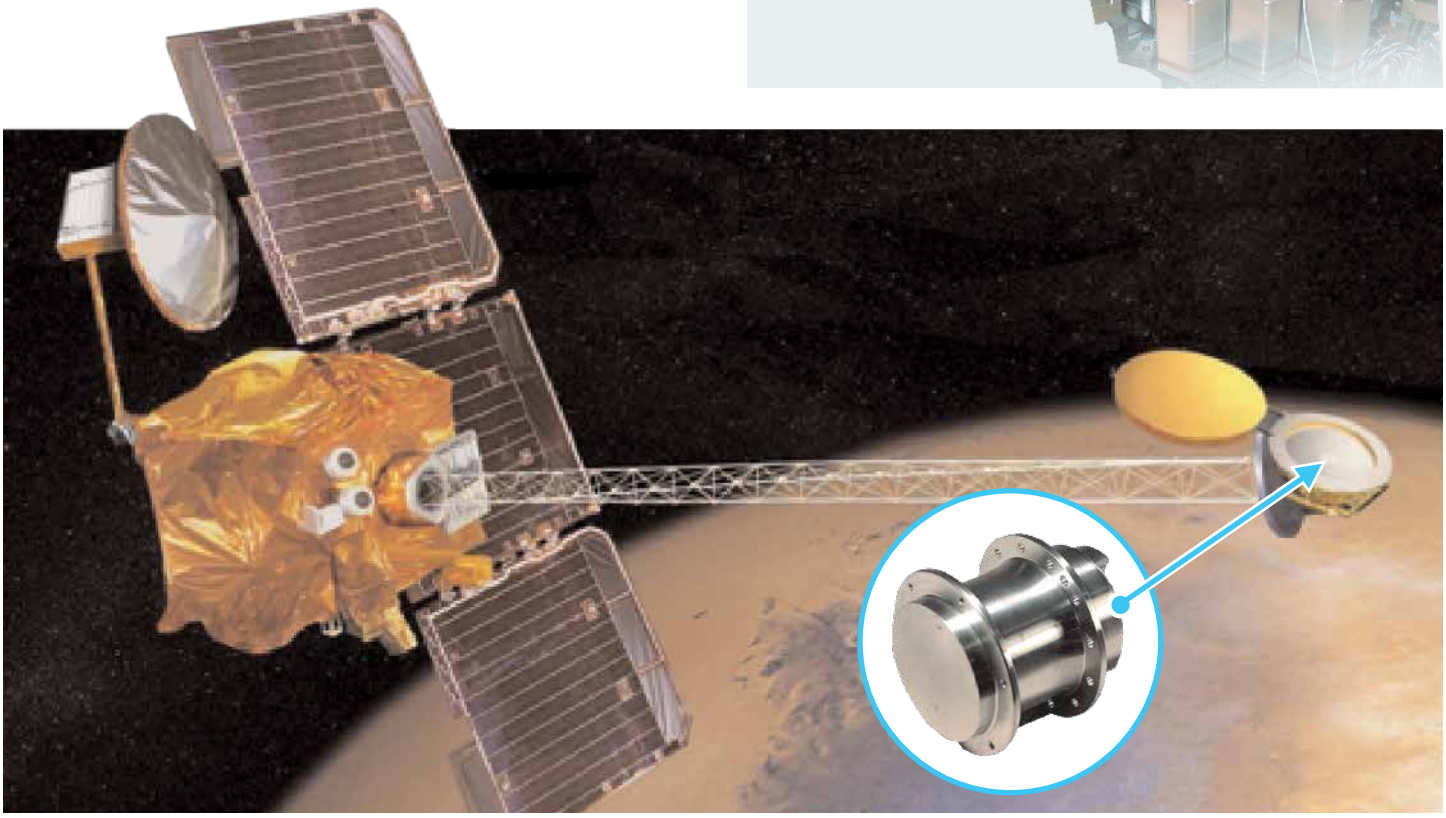


Photo-Diodes for Scintillator Read-Out

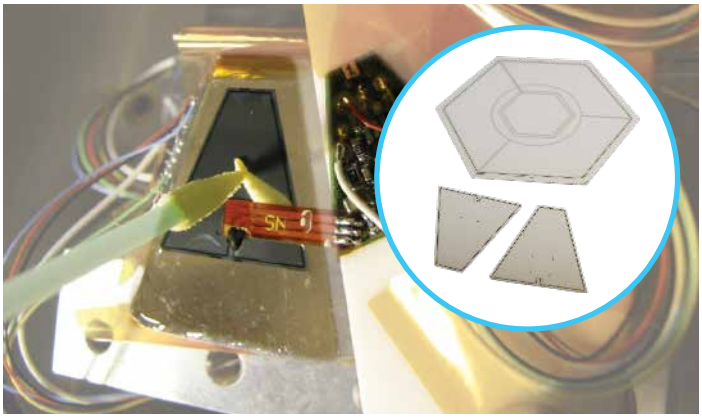
Advanced Photon Detection on the MARS ROVER

FEATURES

- Size: Custom Design
- Thickness: 200 to 500 µm

ADVANTAGES

- Anti-reflective coating with QE > 80%
- Low dark current
- Direct coupling to scintillator
- Optimization for specific scintillators



2D Position Sensitive Double-Sided Strip Detectors – PF-CT-CD Series

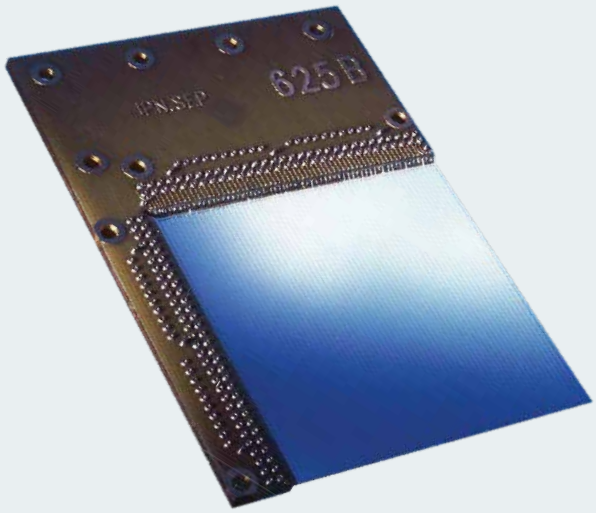
FEATURES

- Strip detectors mounted on epoxy boards
- Size: from 40 x 60 mm² and larger or others on request
- Active thickness: 200 to 1000 µm

ADVANTAGES

- Good timing performance
- Can be assembled on customer board
- Models available from stock

2D Position
PF-CT-CD Series



X-Ray Detectors for Synchrotron Applications

Mirion has a comprehensive product offering of germanium, silicon and Si(Li) detectors for synchrotron beamlines.

For every application, requirements are thoroughly evaluated by the Mirion team of scientific experts to ensure that the appropriate solution and support can be offered. Our stringent Quality Management ensures compliance with customer specifications, as well as confirms that factory and/or site testing requirements are met to satisfaction.

OUR OFFERING INCLUDES

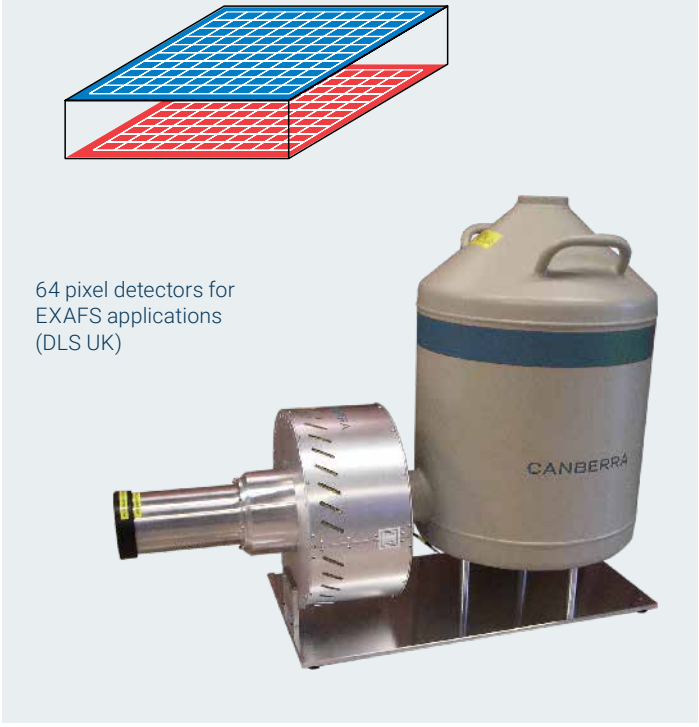
- Monolithic Array Detectors
- Discrete Element Array Detectors
- Single Element X-ray Detectors
- Photodiodes for beam alignment

Monolithic HPGe Pixel Detectors

3 to 100 pixels on a single HPGe or Si(Li) substrate

FEATURES

- Energy range: 3 keV and up
- Best possible packing density, ideal for EXAFS applications
- High resolution with moderate to short pulse processing times
- Good peak/background with optional internal collimator to reduce charge sharing between pixels
- Synchronous preamplifier reset with built-in electronics
- Automatic (rate-induced) or manually selected pixel disabling feature (SAFE mode) prevents system paralysis from diffracted (high-rate) beams
- Optional electrically cooled cryostat



64 pixel detectors for EXAFS applications (DLS UK)

Discrete Element Array Detectors

FEATURES

- 2 to 32 individual HPGe or Si(Li) elements
- Energy range:
  - LEGe™ detector (3 keV and up)
  - Ultra-LEGe detector (1 keV and up) elements
- Low crosstalk (permitting non-synchronous or synchronous preamp reset modes)
- High resolution even with very short pulse processing times
- Count rates up to 1 Mcps
- Excellent peak/background without collimation
- Windowless cryostats available for Ultra-LEGe detectors to achieve energy sensitivity down to 300 eV
- Optional electrically cooled cryostat

X-Ray Detectors for Synchrotron Applications

High Count Rate Multichannel Detectors

Optimized for EXAFS applications

FEATURES

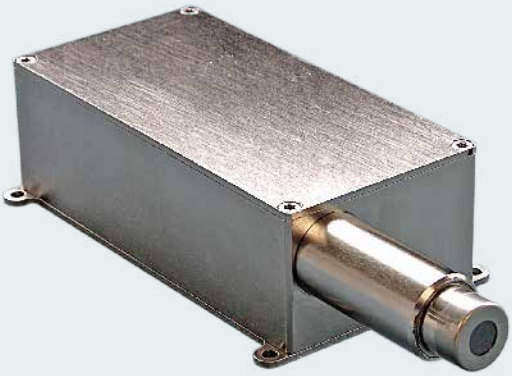
- New generation Multichannel X-ray detectors with CMOS preamplifier
- From 1 to 25 channels available in highly customizable configurations
- Both pixelated monolithic and multiple individual crystals available
- Major breakthrough in performance compared to JFET-based detectors
  - 10x increase in throughput (up to several Mcps/channel demonstrated on synchrotron beamlines)
  - FWHM divided by two at short shaping time (typical 150 eV@6 keV and 0.125 µs)
  - Rise time divided by five (typical 35 ns/event)
- Electrical cooling for maintenance-free operation and compact footprint (water chiller option available)
- Fully compatible with new generation digital readout electronics (Xia FalconX and Quantum Xspress 3)

18 element detector with electrical cooler, fine-tuned for EXAFS optimized high count rate applications

Single Element X-Ray Detectors

FEATURES

- Low Energy Germanium (LEGe) Detectors for 3 keV and up
- Ultra Low-Energy Germanium Detectors for 1 keV and up (300 eV with windowless cryostat)
- Lithium-Drifted Silicon (SiLi) Detectors for 1-25 keV
- X-PIPS™ Detectors for 1-30 keV (Miniature Peltier-Cooled Devices)

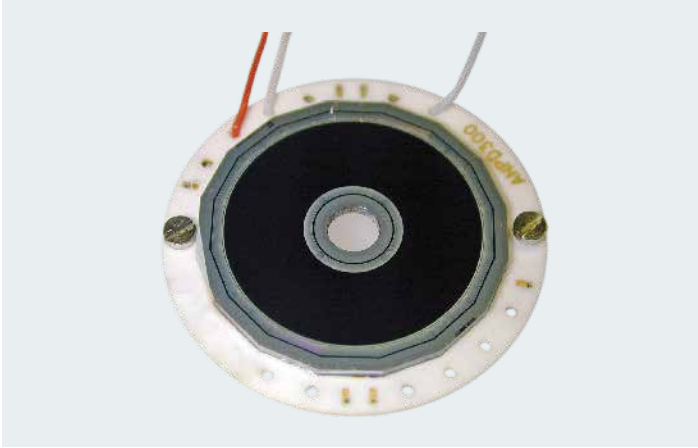


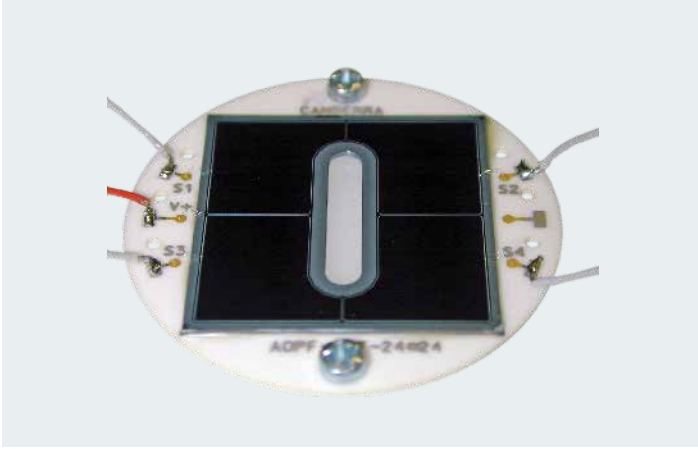
- 1 x 100 mm² Ultra-LEGe Detector
- Windowless, Retractable™ Cryostat

Photodiodes for Beam Alignment

FEATURES

- Low dark current
- Fast read-out
- Used in photovoltaic or biased mode
- No optical window





High Count Rate Multi-Element SDD Array

The X-PIPS detector array is a spectroscopy sub-system that is sensitive to X-rays and low-energy gamma rays. It comprises of several (up to 13 or even more) Silicon Drift Detectors (SDD) with a low noise CMOS reset type preamplifier, a HV bias supply and a cryogenic cooler. The detector elements and CMOS preamplifiers are cooled and temperature regulated, ensuring stable operation in changing environmental conditions. The Beryllium entrance window is 1 mil (25 µm) thick which allows for measurement of X-rays as low as 1 keV.

The CMOS preamplifiers have a fast reset mechanism which reduces dead time and allows the detector to perform well at very high count rate performance. The high performance SDD combined with a CMOS preamplifier provides a very fast, low noise response, which results in extremely good energy resolution with fast peaking times. The signal rise time is well below 50 ns which makes for excellent energy resolution at high count rates.

PERFORMANCE

- Collimated Active Area – 30, 50 or 80 mm² per element
- Thickness – 0.5 mm
- Guaranteed resolution – 135 eV FWHM (typ. < 125 eV)
- Energy Range – 1 to 30 keV
- Maximum throughput per element – > 3.5 Mcps
- Peak-to-back ratio – > 10 000:1

FEATURES

- Up to 13 or more elements
- Cryogenic (pulse-tube) cooler
- Easily customized
- Planar of focused configurations
- Air or water cooled heat sink
- No active pumping required (no ion pump)
- Thermal cycle free

13-Element Array

7-Element Array

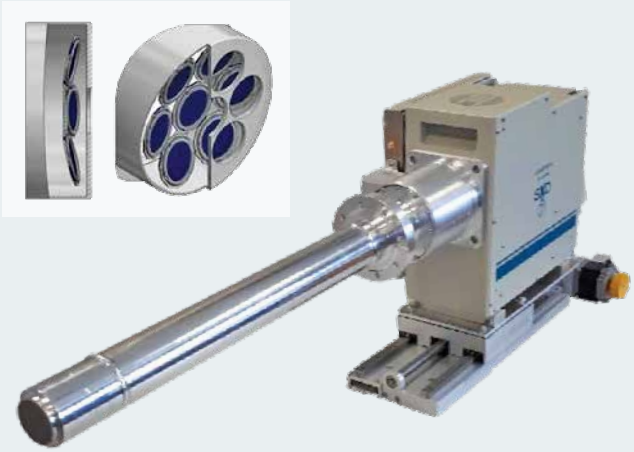
Examples of Custom Configurations

EXAMPLE 1

- 7 x 50 mm² collimated elements
- 1.5 W Pulse-Tube cooler
  - High reliability and long life (> 10 years)
  - Low power consumption (< 50 W)
- Air or water cooled heat sink

EXAMPLE 2

- 7 x 80 mm² collimated elements
- 5 W Pulse-Tube cooler
  - High reliability and long life (>10 years)
- Focused arrangement
- Air or water cooled heat sink



EXAMPLE 3

- 8 x 80 mm² collimated elements
- Focused arrangement

Si(Li) Detectors

Silicon Lithium Si(Li) detectors play an important role alongside Silicon detectors and HPGe detectors.

They excel in the spectroscopy of X-rays, charged particles and conversion electrons. These detectors are fabricated to exacting quality standards, to offer highest performance and excellent long-term reliability even in rough conditions. Si(Li) detectors can be made with thicknesses up to 5 mm, which means they have a much higher stopping power than SDD's (max. 500 µm) and can be used up to higher energy X-rays. Compared to germanium, however, silicon has a lower stopping power, and thus lower efficiency, for the same detector thickness. But the big advantage of silicon is that it has characteristic X-rays at much lower energies (around 1.7 keV) compared to germanium (10-11 keV) and are therefore much less likely to interfere with those X-rays being studied.

- Thickness from 2 mm to 5 mm
- Available in multi-element arrays
- Stackable for dE/dX measurements

APPLICATIONS

- PIXE (microprobes)
- Synchrotron (EXAFS, medical beam lines)
- Nuclear Physics
- Non-destructive assay
- Radiography
- Imaging (gamma cameras)
- CAM (Continuous Air Monitoring) on beta particles

FEATURES

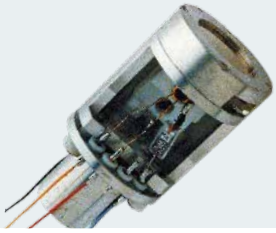
- Designed for highly penetrating charged particles up to 3 MeV Betas, 30 MeV protons, 140 MeV
- Alphas. More if detectors are stacked in telescope arrangements
- Wide range of active areas, thicknesses and mount shapes available depending on application
- Can be cooled to improve performance for conversion electron spectroscopy
- Available in multi-element arrays

Si(Li) array for backscattered X-ray detection

Double-sided strip detector (DSSD) Si(Li) detector with electrical cooling. The application is Compton camera for medical imaging applications

Si(Li) detector for charged particles

Si(Li) detector for conversion electron spectroscopy. It can be provided with a cryostat with a removable flange for easy connection on a vacuum chamber

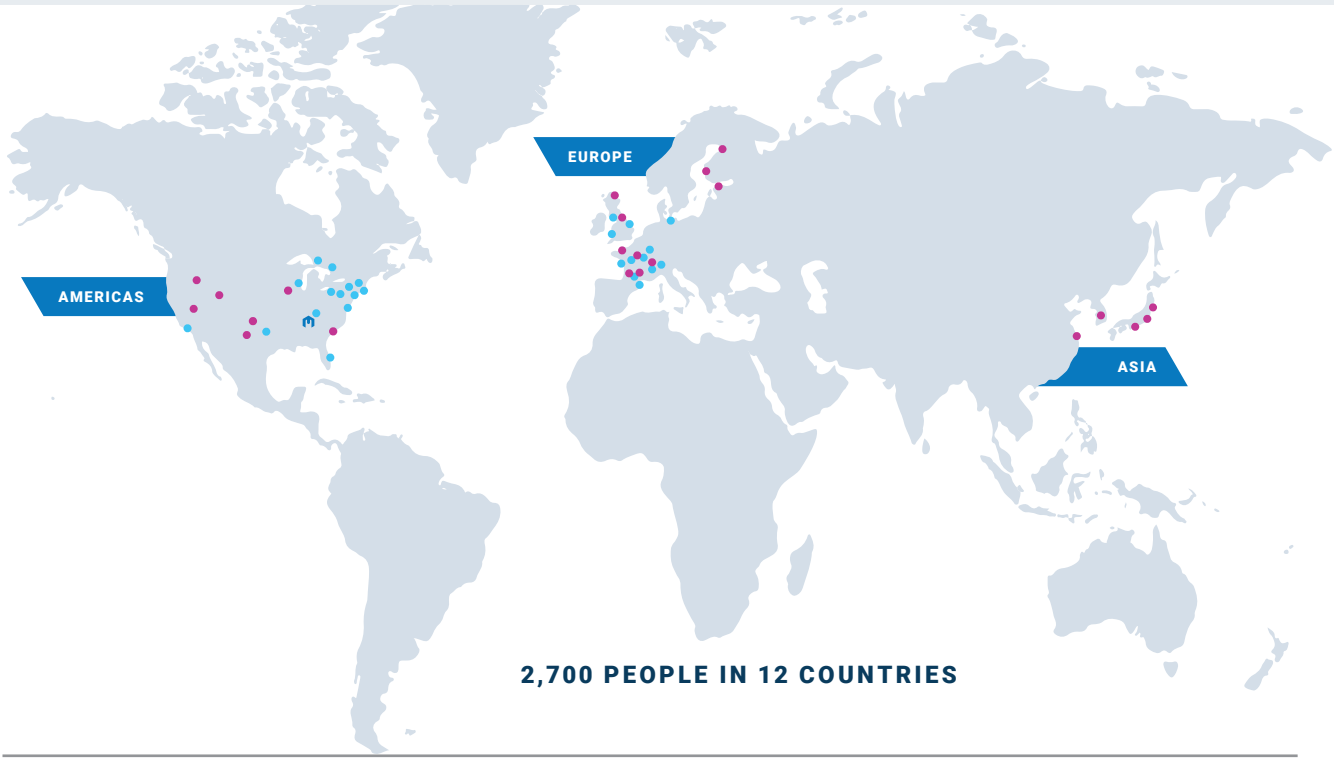


Empowering Progress Across Continents

Mirion Technologies combines innovative radiation safety technologies with unrivaled expertise, cultivated over decades of collaboration with reactor manufacturers and operators, nuclear fuel facilities, regulators, national labs (such as the U.S. DOE), nuclear institutes, universities, and national military/ security organizations worldwide.

Trust us to provide the solutions and support you need to safeguard your valuable assets and ensure a secure and sustainable future.

CORPORATE HQ (ATLANTA, GA) MANUFACTURING SITES SERVICE & SALES CENTERS



2,700 PEOPLE IN 12 COUNTRIES

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