MIRION

TECHNOLOGIES

28-30 November 2022 – VKTA – HZDR - Dresden

Cellar Meeting 2022

Pascal QUIRIN – Mirion Technologies (Canberra)
Lingolsheim Facility – France

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Latest developments in Mirion Technologies (Canberra) specialty detector manufacturing.

Mirion Technologies (Canberra) Detector Solutions

Unique positioning and capacity with respect to development and manufacturing

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

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

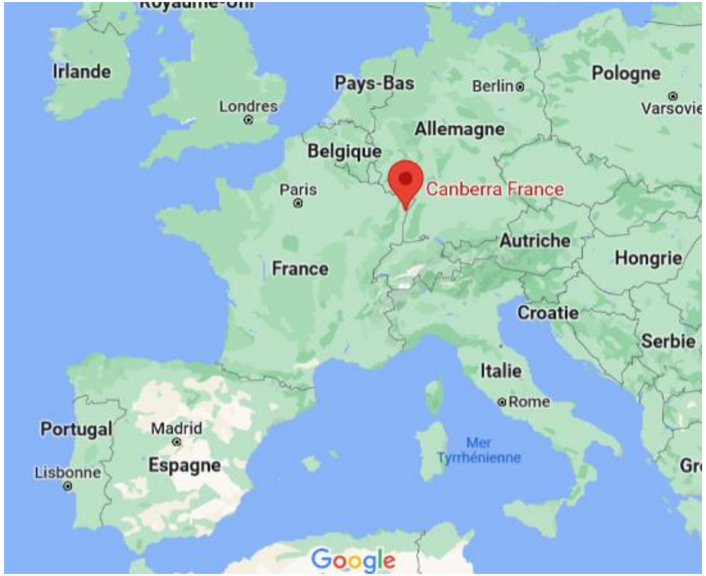
Meriden, CT – focus on **standard HPGe detector solutions**

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

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

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

Lingolsheim Facility in one slide



- **32 people**
  - **4 PhDs**
  - **8 engineers**
  - **10 technicians**
  - **+ support functions**

- **Key skills**
  - **HPGe processing**
  - **Electronics**
  - **Mechanics**
  - **Measurement / final control / service**

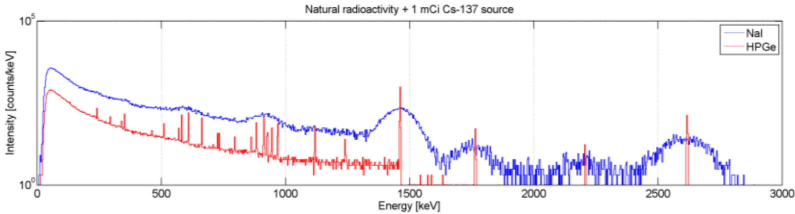
Germanium Technology State-of-the-Art

- Why HPGe?
  - With respect to other solid-state materials, Germanium presents major advantages for high-sensitivity γ-ray detection:
  - Excellent electrical properties: lowest band gap, good mobility, etc.
  - Best energy resolution for spectroscopy applications
  - High detection efficiency due to high density and capability to grow large crystals
- Cryogenic cooling and compactness
  - The only limitation in operating HPGe detectors is the need for cooling at cryogenic temperature (typically below 100K).
  - The advances in thermal design, cryogenic materials, detector encapsulation, and the recent development of light electrical cryogenic coolers to replace classical liquid nitrogen dewars, now allow portable detection systems.

Semiconductor	Ge (77 K)	Si	GaAs	CdTe	CdZnTe	HgI_2
Density [g cm^{-3}]	5.32	2.33	5.32	5.85	5.78	6.3
Band gap [eV]	0.66	1.12	1.43	1.50	1.57	2.13
Pair creation energy [eV]	2.95	3.62	4.2	4.43	4.64	4.2
Electron mobility [cm^2 V^{-1} s^{-1}]	3900	1100	8000	1100	1000	60
Hole mobility [cm^2 V^{-1} s^{-1}]	1900	480	400	100	50 to 80	8

Semiconductor properties (all data measured at room temperature, except for Ge)

Synthetic spectra of typical natural ground radioactivity with a Cs137 source, comparison with NaI(Tl) & HPGe



Why the focus on HPGe detectors?

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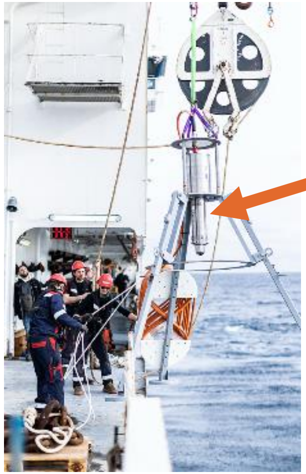
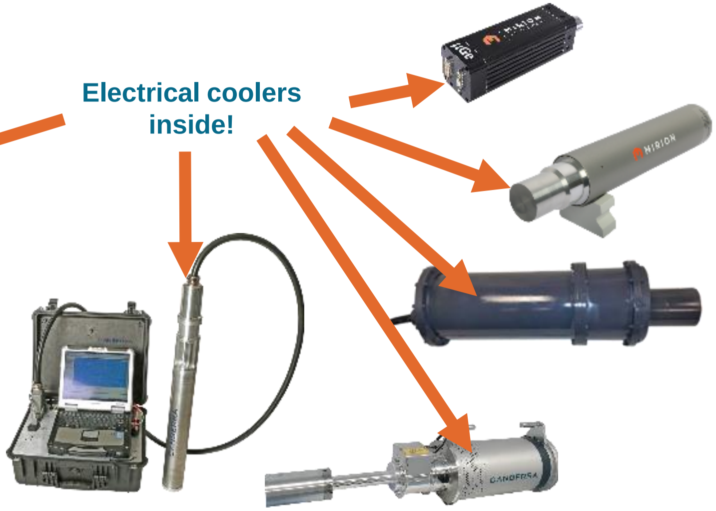




S-ULB HPGe Detectors

Ultimate HPGe detector solutions for underground applications:

Detector array operated by CUP
Courtesy of D.S. Leonard et al. NIM A 989 (2021) 164954

- ✓ Radiopurity thoughts
- ✓ Current performance
- ✓ New Large BEGe
- ✓ SAGe
- ✓ SAGeWell

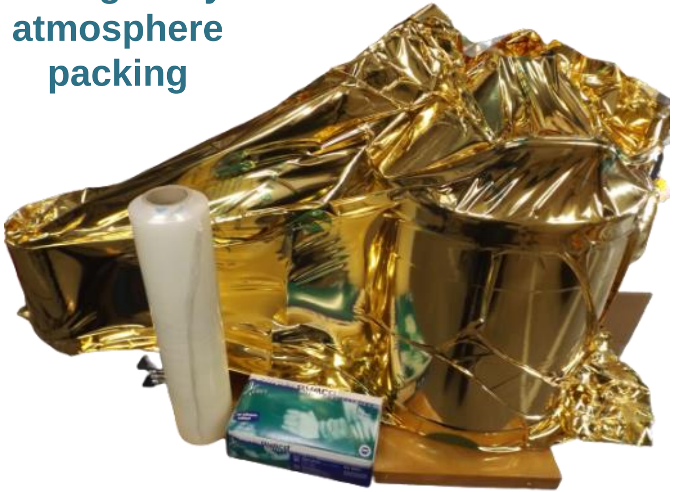
Radiopurity = Continuous Work

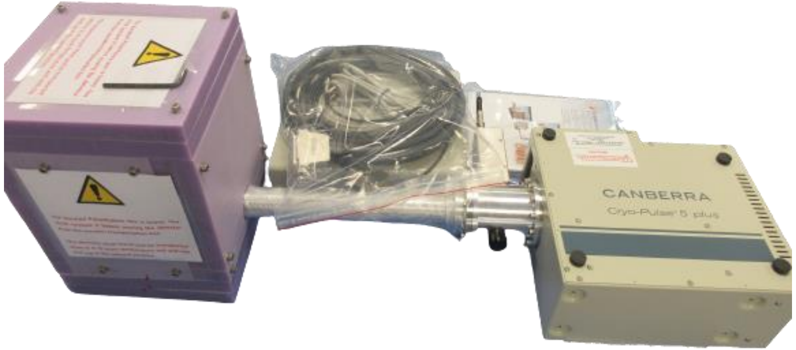
- Pointless to search for rare events if the detector itself acts as a radioactive source
  - High Purity Germanium means that the crystal is intrinsically radiopure at the time it is pulled
  - Selection of radiopure materials for the cryostat/electronics through long experience with suppliers, materials to avoid and to select.
    - Long and fruitful collaboration with the ultra low background community
    - Continuous tests and screening of new batches of known material or completely new material
  - The enemies are:
    - Decay chains of U235, U238, Th232
    - Cosmogenic activation creating Ge/Cu related radioisotopes continuously while stored at sea level
    - Several short-lived isotopes but also possibly Co60 (5 year half-life)
    - Air transport is forbidden (higher activation compared to sea level)
  - Mirion Lingolsheim uses a dedicated underground storage (800mwe overburden) to keep raw material and/or detectors safe relative to cosmic radiations during waiting time.
  - Mirion Lingolsheim uses specific packing for long cruises (air-tight envelopes, neutron moderator materials, etc…).

S-ULB Packing

- S-ULB detector packing for road transportation and over sea transportation

Air-tight dry atmosphere packing





Borated Polyethylene Neutron Shielding

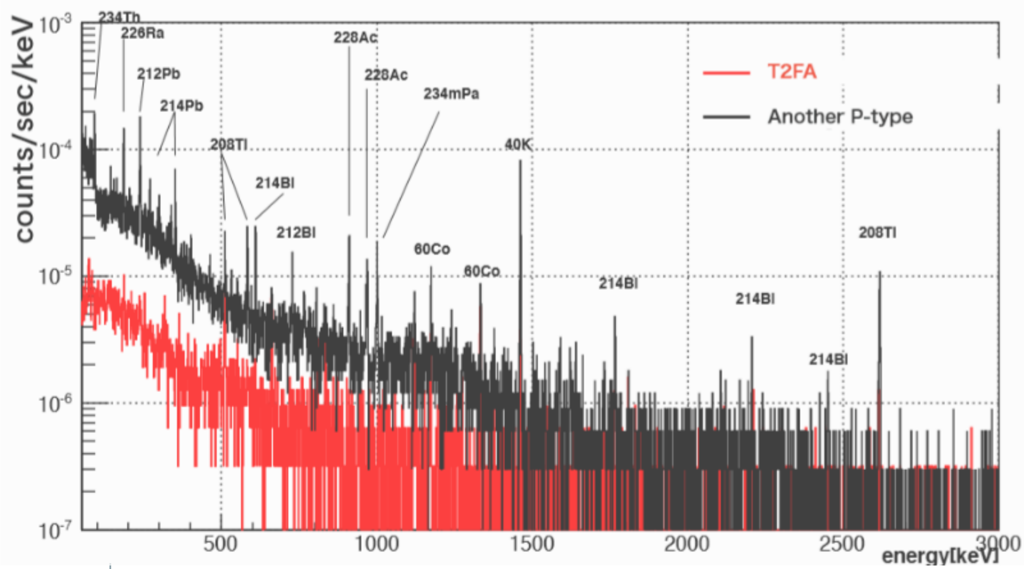
Delivered S-ULB detector performance

Detector	Crystal size (mm)	Weight (kg)	Location Lab	122 keV FMHM	1332 keV FWHM	Background 40-2700 keV
	[mm]	[kg]		[keV]	[keV]	[counts per kg per day]
EGMP 90-30-R BEGe Detector	90 x 30	1.03	Boulby UK	0.63	1.73	150 [2]
EGMP90-33-R BEGe Detector	90 x 33	1.13	SURF USA	0.61	1.75	X
EGMP 100-35-R BEGe Detector	100 x 35	1.48	CANADA	0.66	1.72	X
SAGeWell detector 400P21 (copper)	80 x 85	2.13	Canfranc Spain	0.69	1.91	640 [5]
SAGeWell detector 400P21	80 x 85	2.13	Modane France	0.74	1.87	505 [3]
SAGeWell detector 250P21	80 x 63	1.33	Hades Belgium	0.68	1.88	795 [6]
EGPC 80-185-R Coax P-type	75 x 73	1.68	Kamioka Japan	0.85	1.9	115 [4]
EGPC 120-215-R Coax P-type (copper)	84 x 84	2.44	CJPL China	0.93	1.98	X

- References
  - [2] Courtesy P.R. Scovell, STFC Boulby underground Laboratory
  - [3] Courtesy P. Sabatier, University Savoie Mont Blanc
  - [4] Courtesy K. Ichimura, Tohoku University
  - [5] Courtesy G. Zuzel, Jagiellonian University
  - [6] Courtesy M. HULT, JRC-Geel

Recently delivered S-ULB detectors

- SAGeWell 400P21 with Copper Cryostat [5] preliminary lead shield at LSC.

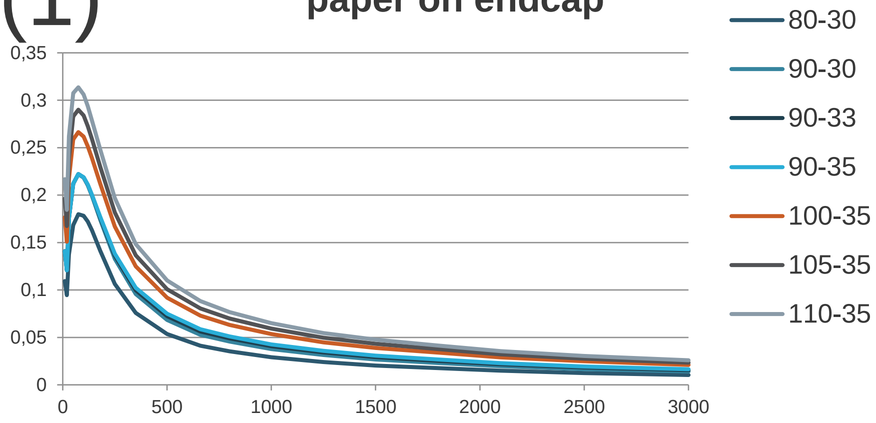


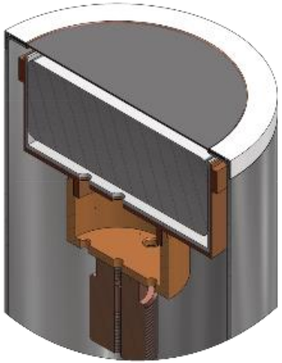
- Background spectra: comparison ''another'' P-type detector and Mirion P-type ''T2FA'' (S-ULB) [4] at Kamioka.

Large BEGe Detectors (1)

- New Large BEGe detectors
  - Active diameter :
    - ≥ 100mm (7850mm²)
    - up to 120mm on request
  - Active thickness :
    - 35mm (~90% relative efficiency for diam 100mm)
    - 40mm (~105% relative efficiency for diam 100mm)
    - Thicker crystals available on request.
  - Thin window detector technology, not sensitive to heat cycling nor long-term storage at room temperature.
  - LabSOCS characterization.
  - Available in different cryostat configuration
  - LN2 or electrical cooling.
  - Large references of 80mm & 90mm in S-ULB cryostats used in underground Labs. A first 100mm delivered.

Absolute efficiency with 12cm filter paper on endcap



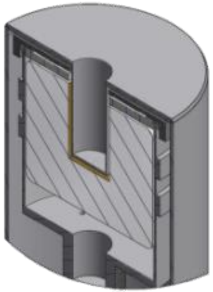


Large BEGe Detectors (2)

- Recently delivered EGMP 100-35-R in U integral cryostat and S-ULB grade material for an Underground Lab.
- Measured Spectroscopy Performance:
  - At 122keV : 660eV
  - At 1,33MeV : 1.72keV
  - Symmetry factors at 1.33MeV:
    - FWTM/FWHM : 1.84
    - FWFM/FWHM : 2.56

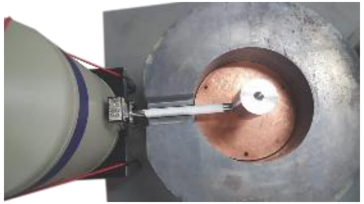
    } = **Symmetric Peaks**
  - Relative efficiency at 25cm : 91%
  - Peak to Compton ratio 76:1
- Mechanical:
  - Aluminum endcap - 125mm diameter
  - Carbon composite entrance window 0.6mm thick
  - Cryostat arm length 303mm.

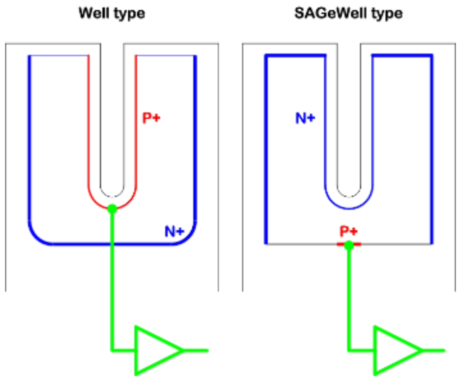
SAGeWell Detector Technology

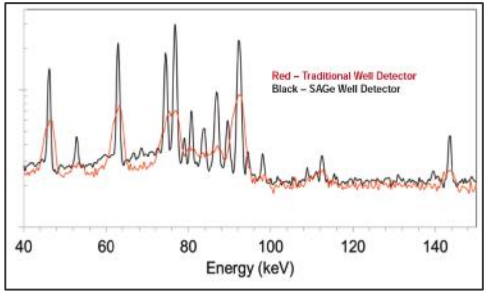


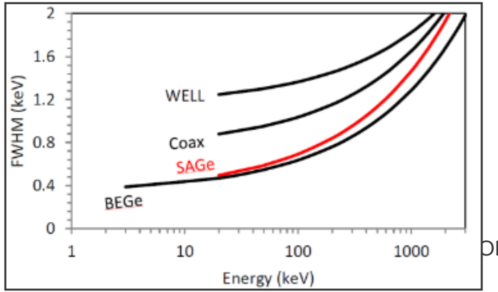
- SAGeWell : the NEW Well detector for environmental measurements in a 4PI geometry with optimized FWHM.
- This technology is available with highly selected S-ULB material
  - Typical FWHM performance:
    - At 1.33MeV : < 2.10 keV
    - At 122keV : < 750 eV
    - Three times better at low energies compared to the previous Well detectors

    FWHM less depending on crystal size than before (applies to the two values above)
  - Active volume 250cc & 400cc (as a standard)
  - Useful Well diameter 21mm
  - LN2 or CP5-plus cooling
  - References are available for SAGeWell in Underground Labs.







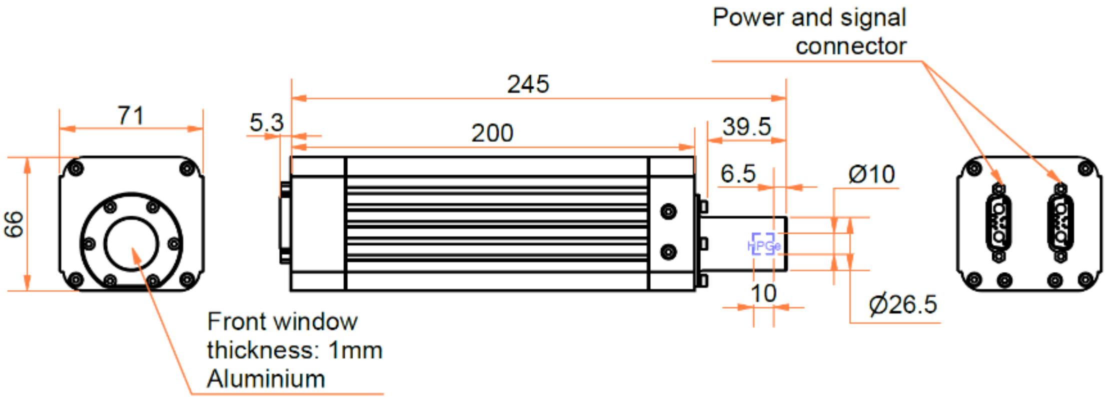


MicroGe™

State-of-the-art ultracompact HPGe detector for immediate field use

MicroGe Operational Features

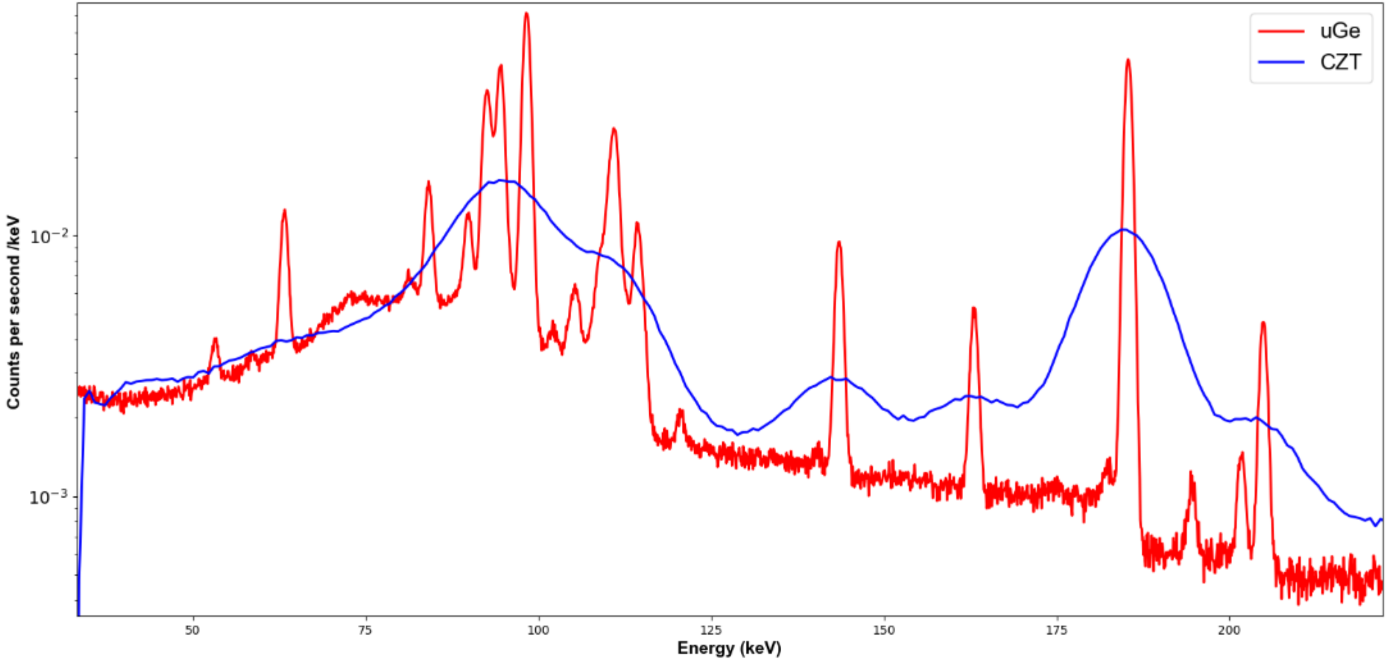
- HPGe spectrometer with :
  - Ultracompact : easy portable/integrable and all attitude - see drawing for the dimension
  - Lightweight : 1.7 kg (probe) - 6 kg (complete system)
  - Low-power : < 15 W in routine use
- Electrically-cooled: LN2-free & passive system cooling (fanless)
- **Fast cooling time : < 30 min before use**
- Thermal cycle free: accept partial heat cycle



Complete system
MicroGe - Supply station - Cable set
+ DSA-LX or LYNX
+ Computer/tablet & GENIE2000

MicroGe Key Features and Benefits

- Measuring Uranium Spectra (4.5 w% ^{235}U)
  - Comparing MicroGe detector (red) versus a CZT detector (blue)



HPGe Probes

Ruggedized HPGe detector systems for in-situ applications

Ruggedized Systems

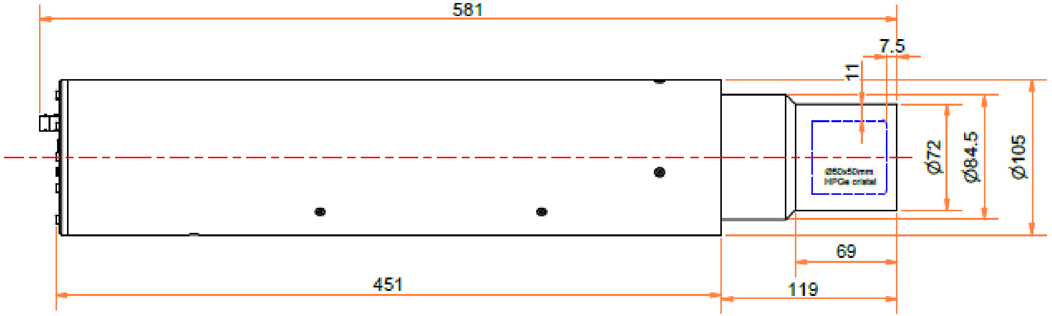
Submersible or even deep-water applications with HPGe detectors up to 160% relative efficiency

- Lab HPGe Spectroscopy performance now available in the field:
  - Complete integrated spectroscopy solutions.
  - Watertight solutions or adaptation to deep water conditions.
  - Embedded high reliable electrical cooling.
  - For environmental survey or emergency response.
  - Compatibility with hostile environment (contamination)
- High level of customization depending on constraints
  - Battery operation – operation on vehicles/aircrafts
- Wide detector choice.

Sealed probe with a 20% relative efficiency HPGe detector

New HPGe Probe

- 20% relative efficiency with REGe type crystal (n type)
  - Up to 70% in such a configuration
- Probe diameter 105mm
- Power consumption once cooled ~30W
- Performances:
  - Optimized for high dose / count rates
  - 1.1 keV @ 122 keV
  - 2.0 keV @ 1332 keV
  - Handle up to 0.5 mSv/h without saturation (tested on irradiator).



Deep Underwater Applications

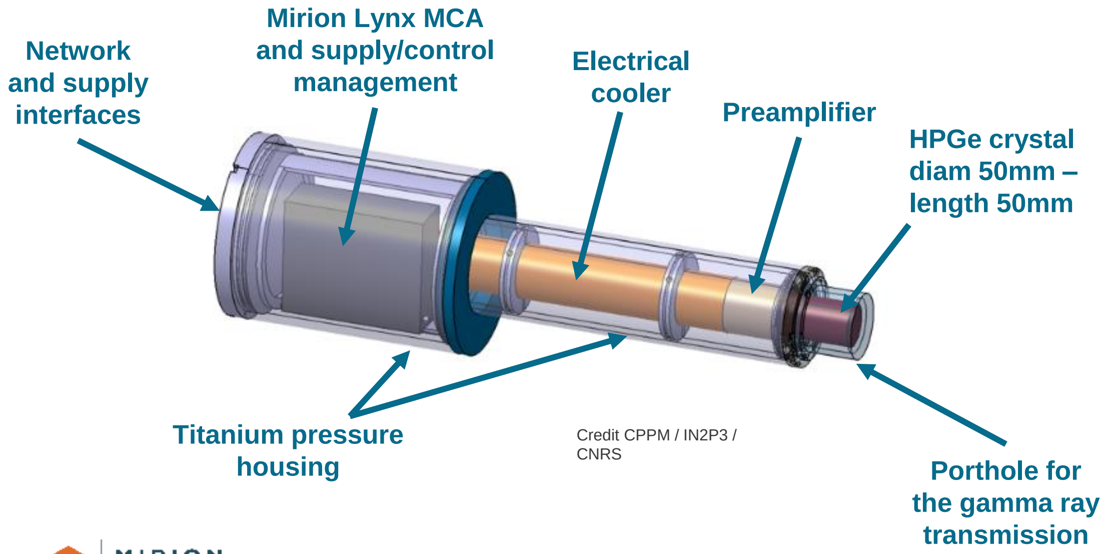
Gamma ray measurement NUMerEnv project for the Antares Observatory

Deep Underwater Applications

- In February 2022 the Mirion HPGe probe with its pressure housing was dropped at 2500m depth on the Mediterranean seabed, 40kms away from Toulon (France).
  - Application: gamma spectroscopy complementary to the Cosmic Neutrino Experiment (Antares).
  - A high reliability cooler was mandatory - only twice a year a submarine will access the system connected to the Antares network and supply hub.
  - For more details and photos: https://www.mio.osupytheas.fr/en/seas-and-oceans-global-change/emso-wl-bathycruise
- Close collaboration required with the customers to discuss and develop :
  - Pressure housing in deep water environment to surrounding closely the probe.
  - Gamma ray transmission through the pressure housing and probe housing
  - Mechanical constraints and heat interface
  - Signal transmissions – electrical supply
  - Remote management of the probe, cooler and Lynx MCA

Deep Underwater Applications

- NUMerEnv detector:
  - Objective: continuous monitoring of radioactive tracers like ^{137}Cs, ^{60}Co, ^{90}Sr. They are key indicators for understanding the impact of anthropogenic activities in the marine environment.



Credit CPPM / IN2P3 / CNRS

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