HPGe technologies in MIRION: status and future

November 2024

4th AGATA-GRETINA/GRETA collaboration meeting

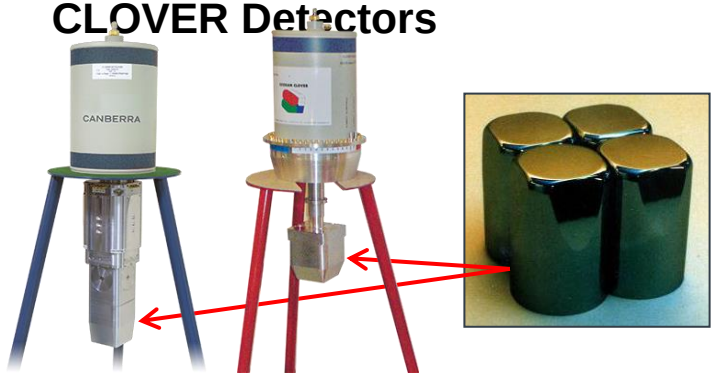
M.GINSZ

MIRION TECHNOLOGIES

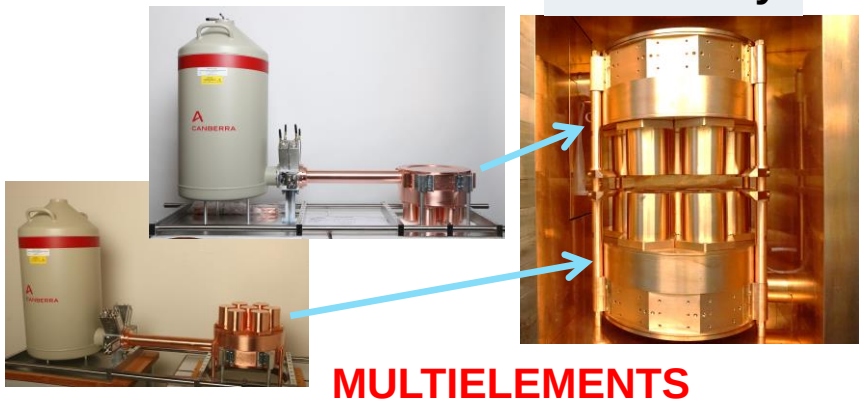
Major Technology : Array Detectors

- Array detector: several crystals inside a unique cryostat
- Various purposes
  - Doppler correction
  - Flux dilution
  - Interaction localization information
  - Enhance efficiency
  - Solid-angle coverage
  - Cost reduction vs. mulltiple cryostats

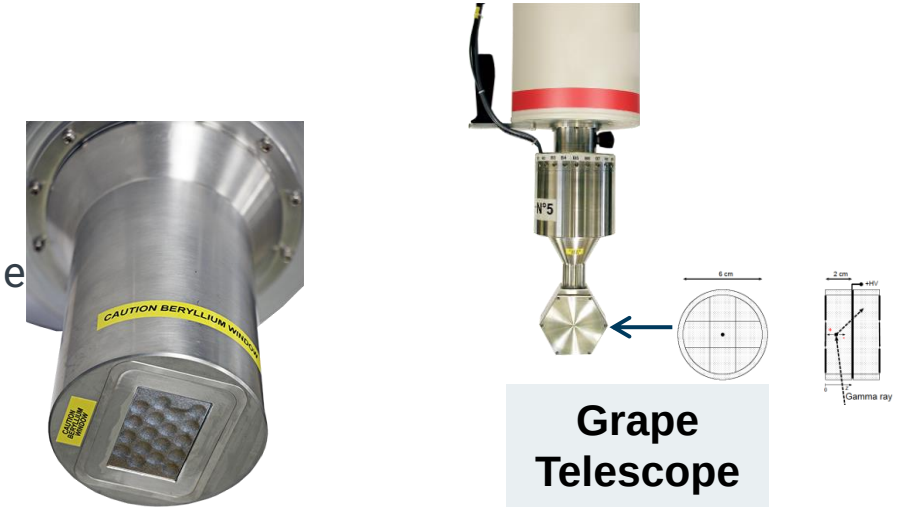
CLOVER Detectors



CUP Array



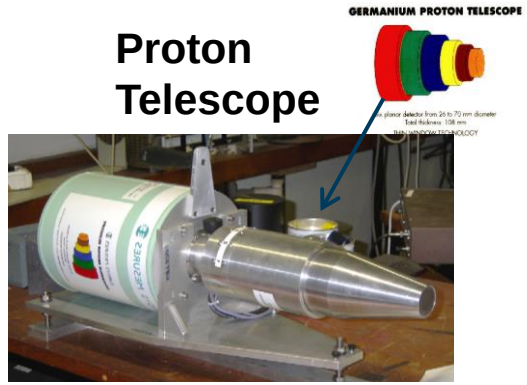
MULTIELEMENTS Detectors



Grape Telescope

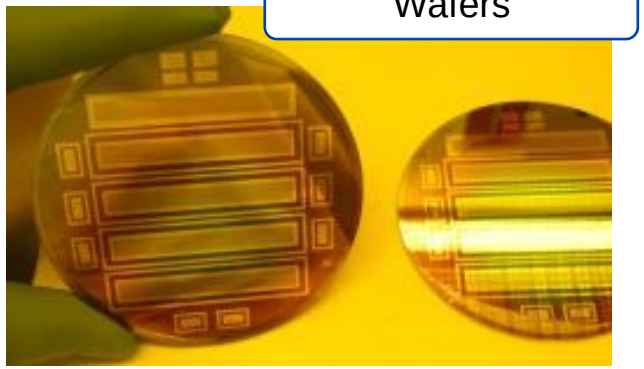
STACK Detectors

Proton Telescope

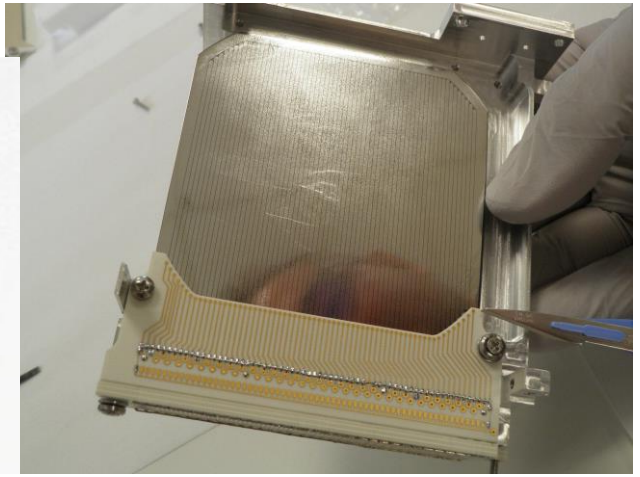


Major Technology : HPGe segmentation

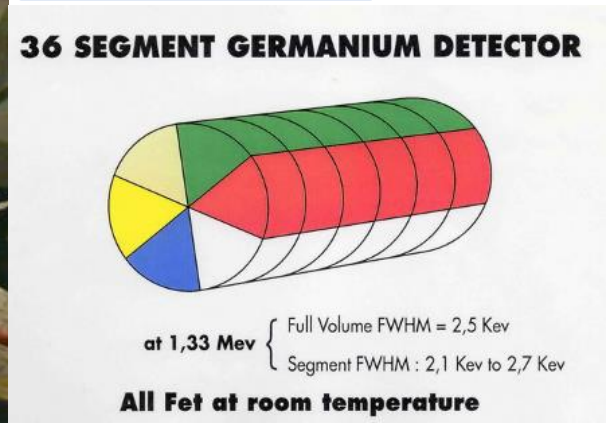
Wafers

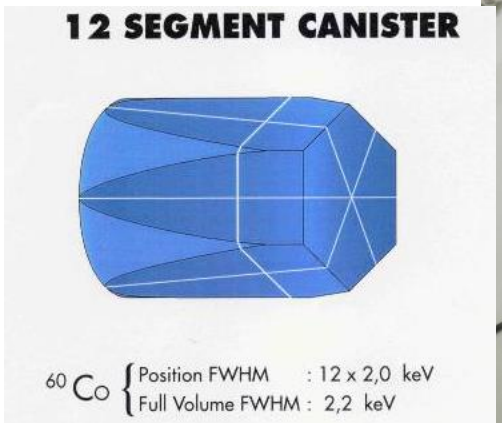


DSSDs



N-type coax





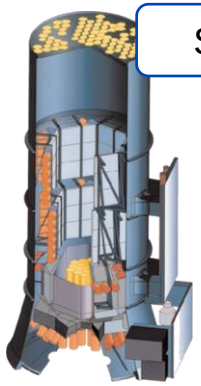
Major Technology : Encapsulation

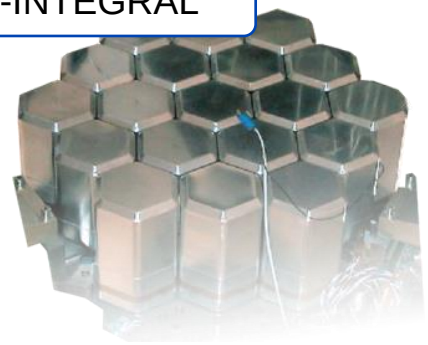
- Place the HPGe crystal inside a separate, sealed, canister
- Protect HPGe from athmosphere
- Allows for versatile & modular HPGe assemblies inside various cryostat configuration

MARS ODYSSEY

SELENE

SPI-INTEGRAL





NASA DRAGONFLY mission to TITAN
On-going

Major Technology : Electrical cooling

Key unit:

CP5-Plus Pulse-tube cooler

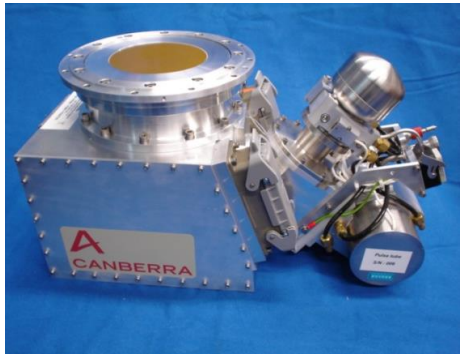
Synchrotron Applications

Nuclear Physics Applications

Airborne Applications

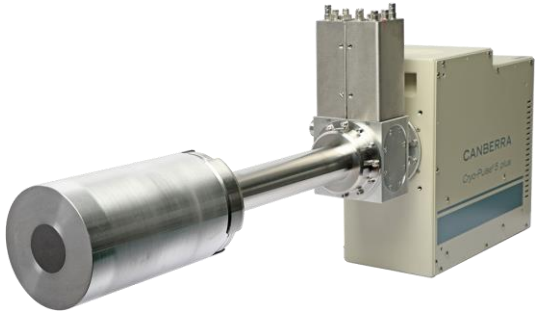
Medical Applications

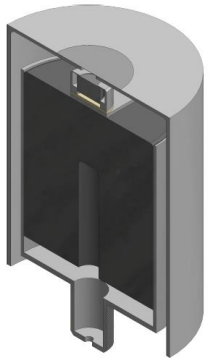
Special Applications



ELECTRICAL COOLING

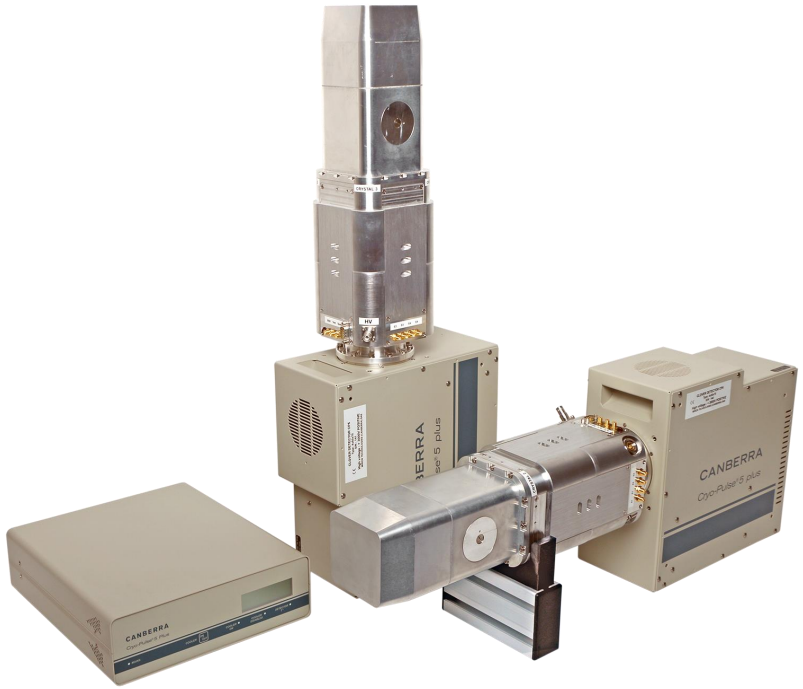
- Telescope
  - 160% D90L100 coax P-type
  - D16 L10 LEGe
  - 3.4 kg HPGe
  - 2 cold FETs





- 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

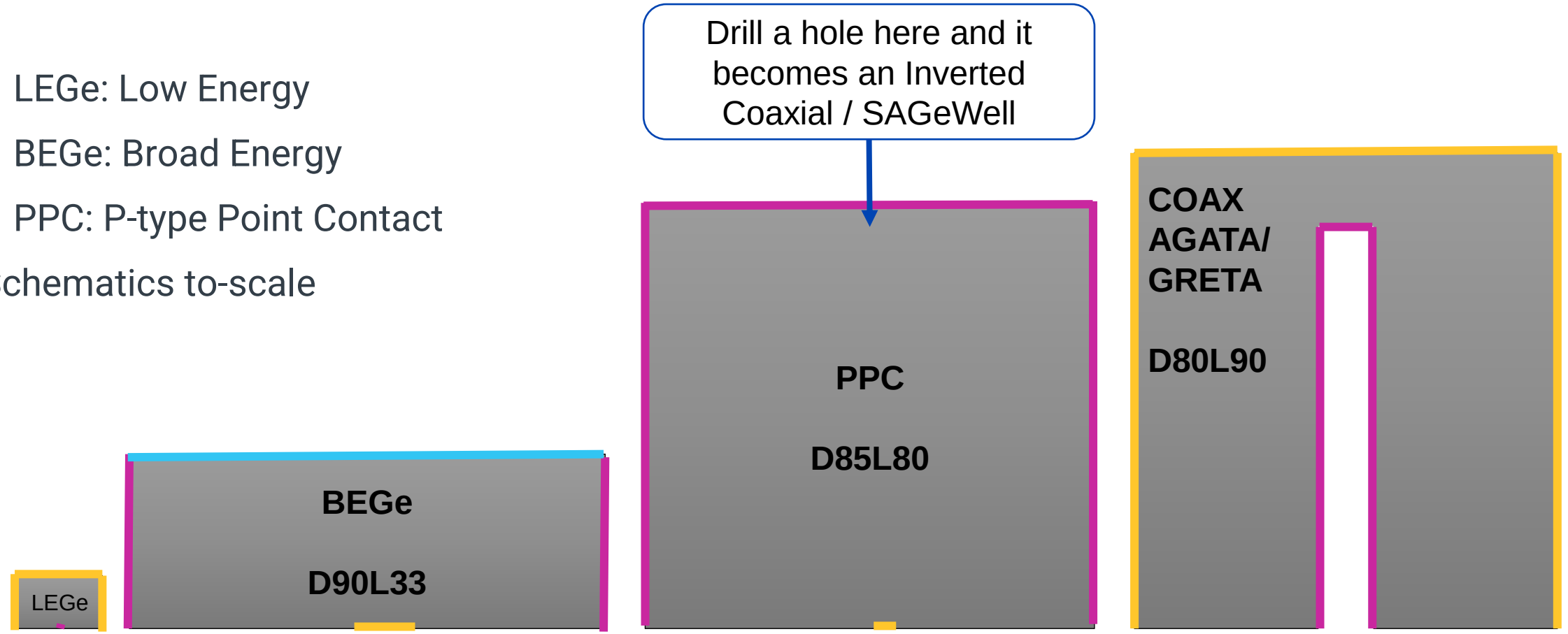


- Clover 457
  - 4x D50L70 coax
  - 2.6 kg HPGe
  - 4 cold FETs
- Same heas as the LN2 one
- **Same spectroscopic performance**

HPGe crystal types

- LEGe: Low Energy
- BEGe: Broad Energy
- PPC: P-type Point Contact

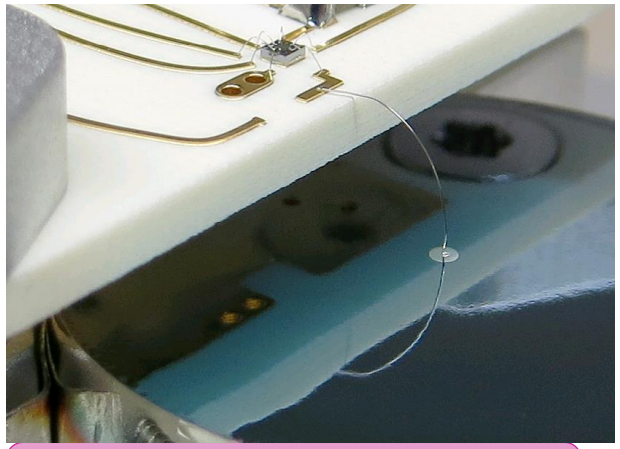
Schematics to-scale



ASICS for HPGe

Improve noise performance

Commercial ASICS for HPGe



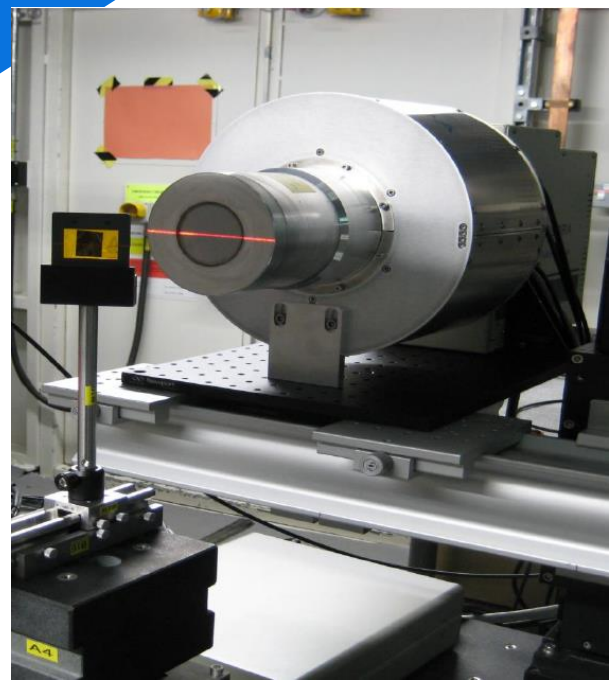
BARTON (2016) NIMA 812-17

What kind of ASICS ?

- Single-channel ASICS: one die -> one channel
- Several Asics can be placed inside a cryostat, like several FETs
- Better electronical noise
- Better rise-time
- **Pulsed-Reset preamplifier**

MIRION Detectors coupled with ASICS				
Year	**HPGe Mass [g]**	**HPGe type**	**Energy Range**	**Application**
2015	~4g	LEGe	4-60 keV	Hard X-ray / Synchrotron
2017	~4g - 19 crystals	LEGe	4-60 keV	Hard X-ray / Synchrotron
2021	Up to 2.4 kg	PPC	0-20 keV	Neutrino
2024	85g	BEGe	5 keV - 1.5 MeV	Gamma
2025	1.5 kg	Coax	20 keV - 10 MeV	Gamma

ASICS + LEGe FWHM



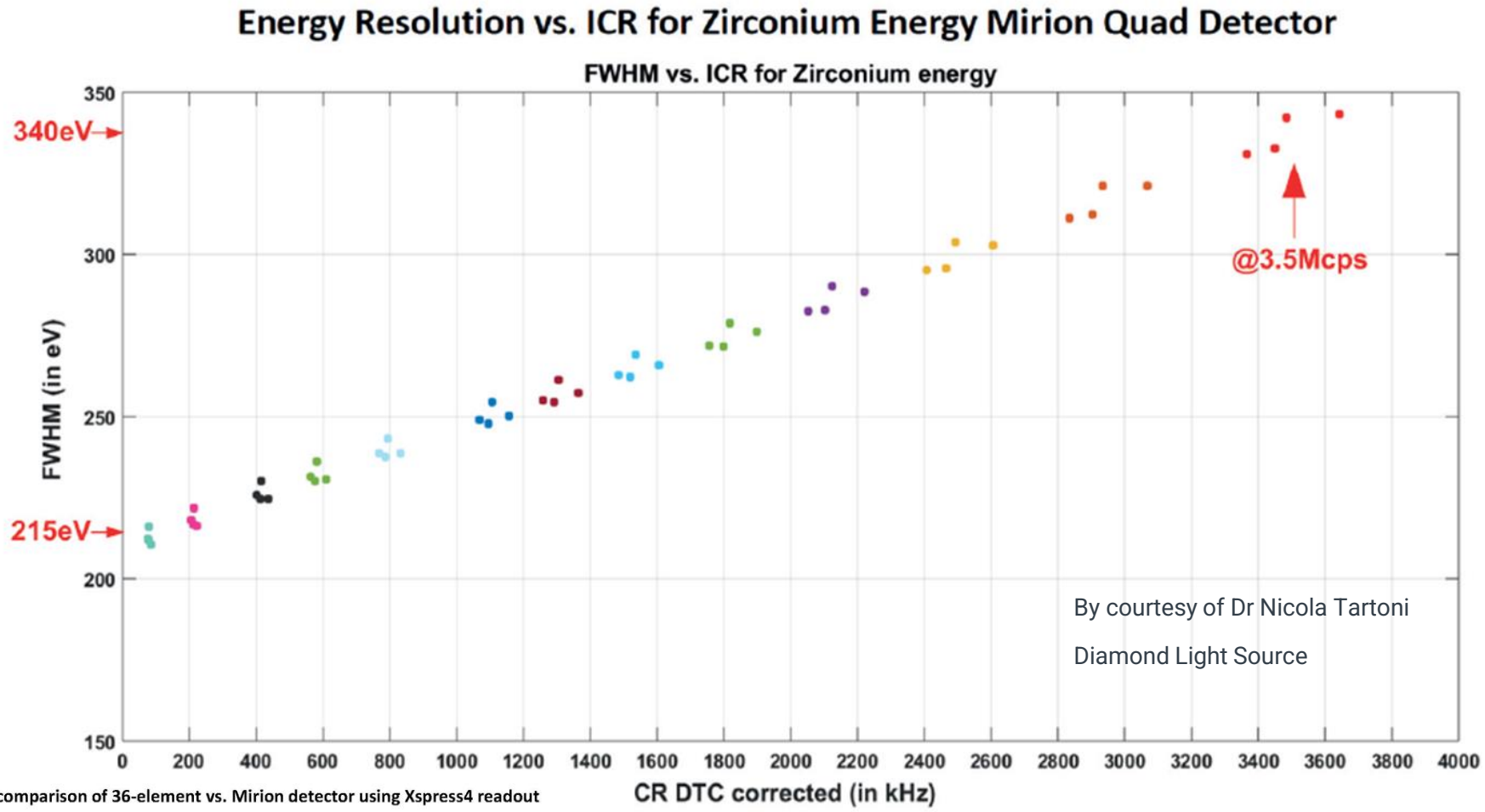
VOIE / CHANNEL	**RESOLUTION (ENERGIE / TAUX DE COMPTAGE / SHAPING TIME)** ENGERGY RESOLUTION (ENERGY / COUNTRATE / SHAPING TIME)			
	6 KEV 1KCPS 4 µS	6 KEV 100KCPS 0.5 µS	60 KEV 1KCPS 4 µS	122 KEV 1KCPS 4µS
1	124	125	329	483
2	119	128	341	487
3	117	126	328	472
4	126	134	340	483

4-pixel X-ray HPGe detector

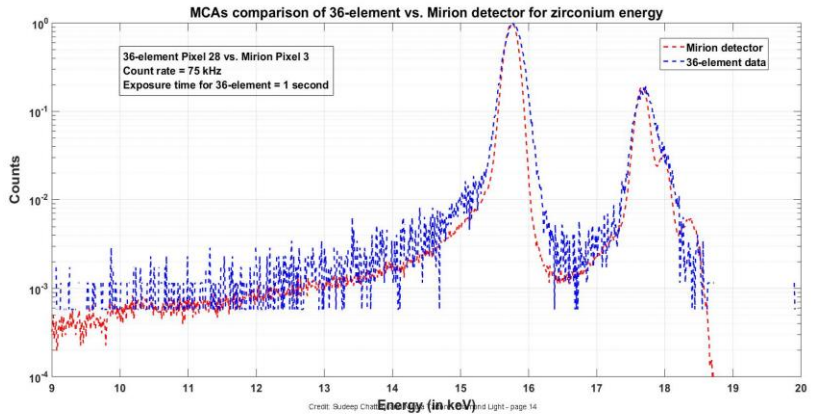
- 6mm-thick HPGe
- 9x9mm pixels

Zoom on performance FWHM

ASICS + LEGe Count-Rate



MCA comparison of 36-element vs. Mirion detector using Xspress4 readout



- 16 keV Lines
- Count-rates achievable only using **XIA falconX or Quantum Xspress readout**

ASICS + BEGe

- BEGe 32mm diameter x 20mm thick ~2% rel. eff
- **Pulsed Reset electronics**
- CP5 cooler
- Lynx v2 MCA readout (standard MIRION MCA)
  - 32k channels spectrum

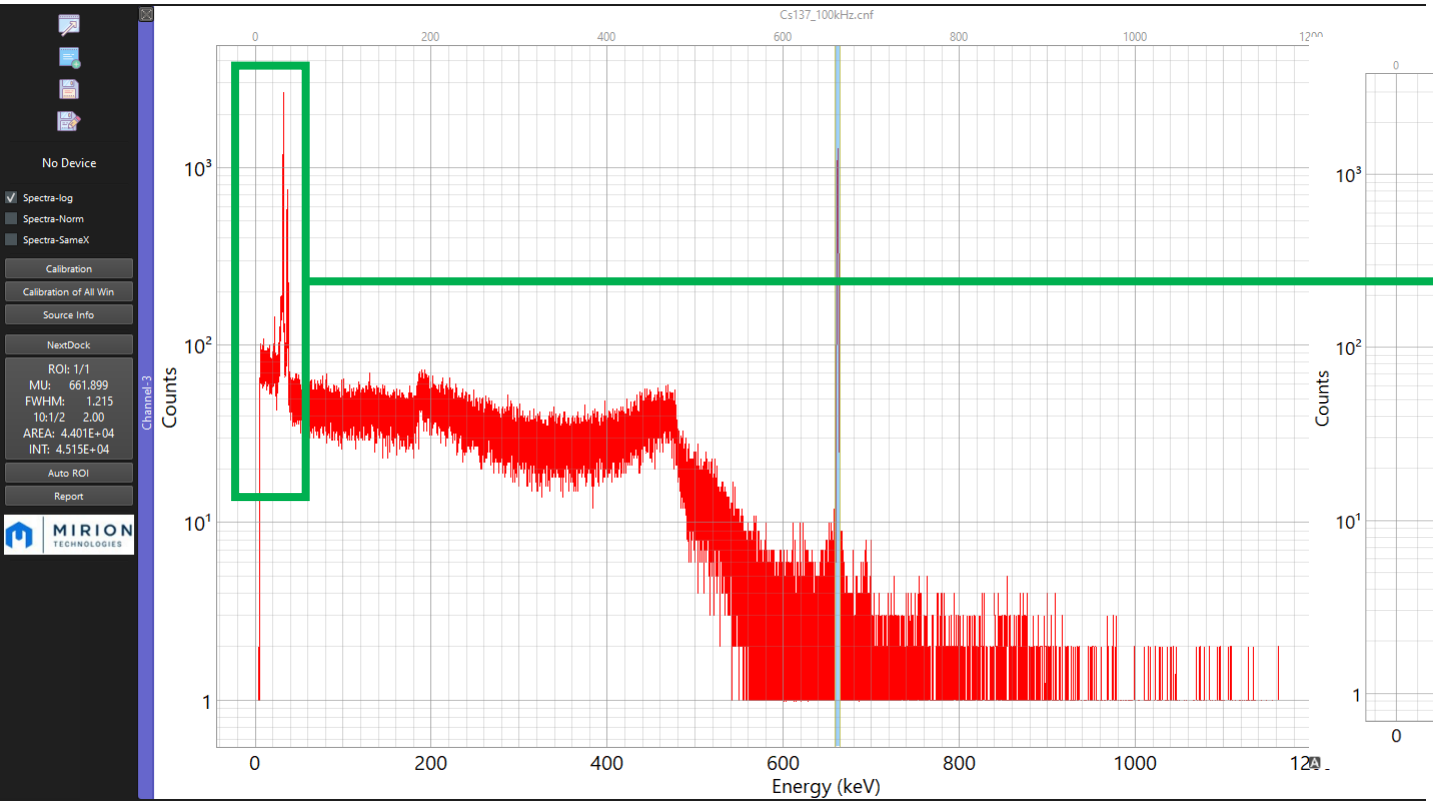
- 340 eV FWHM at 60 keV at 100 kHz countrate !
- 1.2 keV FWHM at 662 keV at 100 kHz countrate !

Very nice low AND high energy performances even at high count-rate

Cs137 measurement at 100 kHz

- D32L20 BEGe for hard-X-ray measurement
- Spectral Range up to Co60

32k Spectrum:
BEGe D32L20-ASIC & Lynx v2
Cs137 @100 kHz ICR
[0 ; 1200 keV] range



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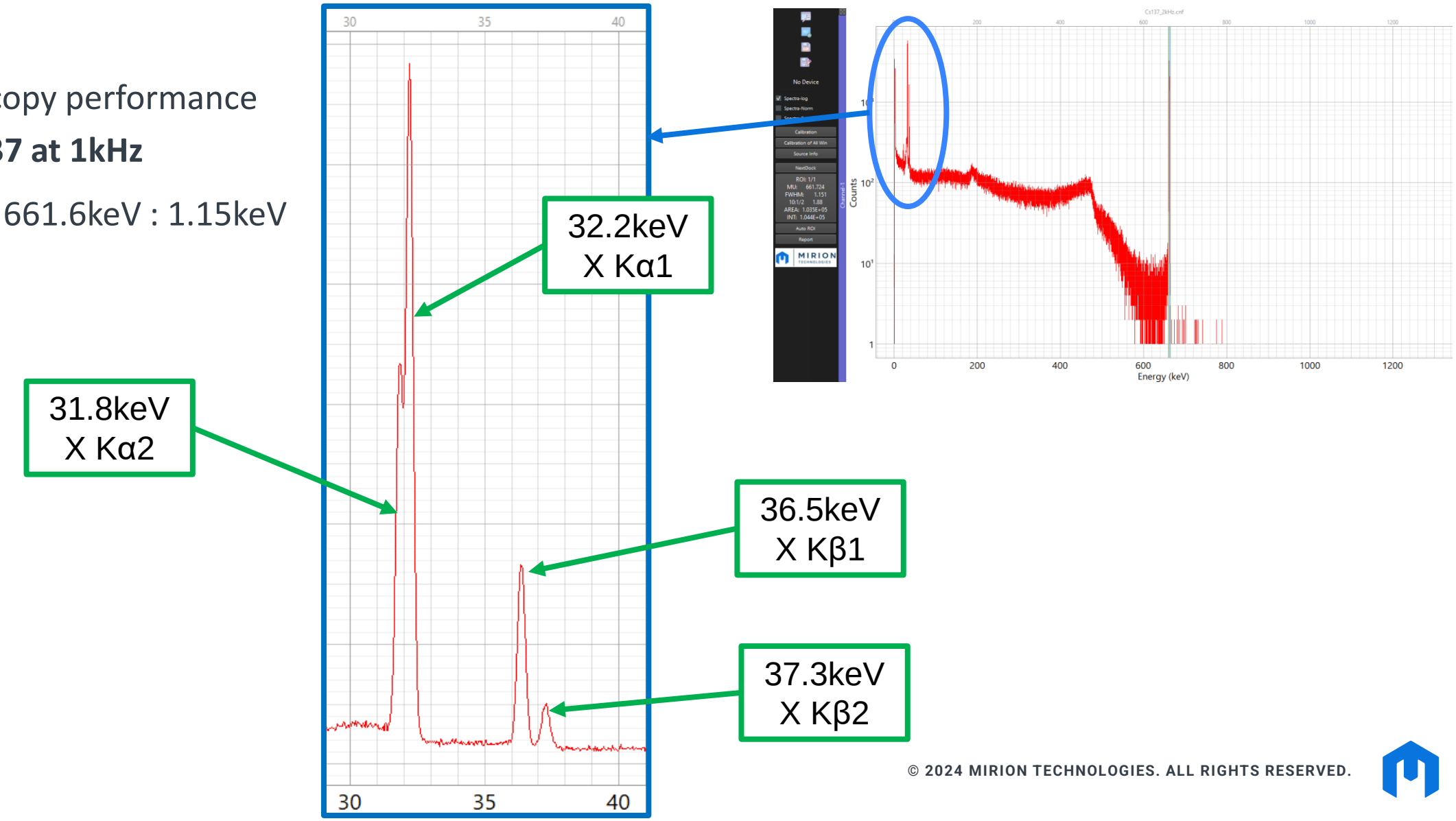
Cs137 measurement at 1 kHz

- Spectroscopy performance with **Cs137 at 1kHz**
- FWHM @661.6keV : 1.15keV



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Resolution FWHM with Lynx v2 MCA

- Various shaping times, energies and countrates

Lynx RiseTime-1_FlatTop-0.4					
Resolution FWHM [eV]					
Isotope	Energy [KeV]	1 kHz	10 kHz	50 kHz	100 kHz
Fe55	6	170	168	172	173
Am241	59.5	340	346	356	349
Co57	122	496	494	486	513
Cs137	662	1470	1520	1540	1540

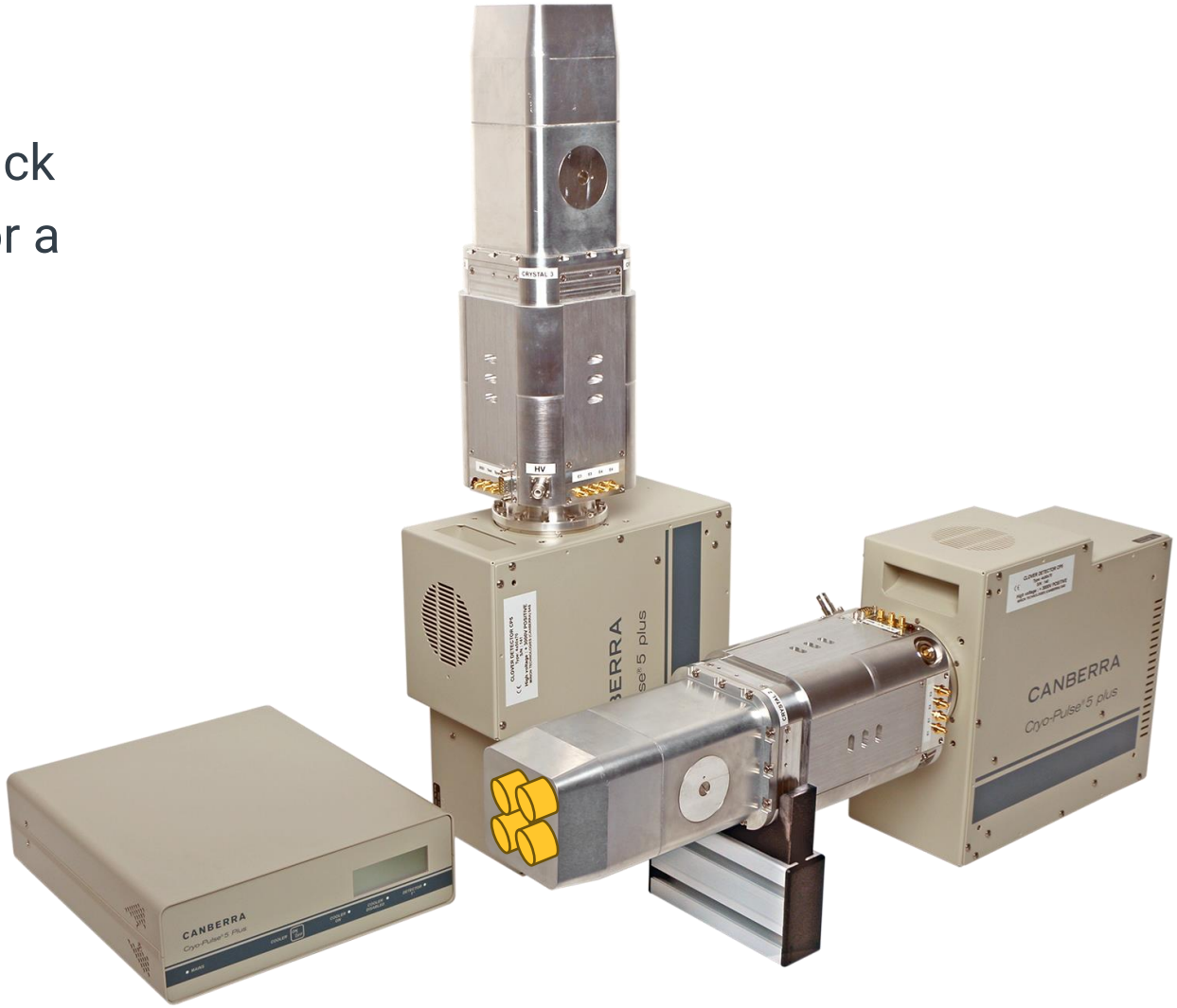
Lynx RiseTime-2_FlatTop-0.5					
Resolution FWHM [eV]					
Isotope	Energy [KeV]	1 kHz	10 kHz	50 kHz	100 kHz
Fe55	6	162	163	162	160
Am241	59.5	339	339	345	337
Co57	122	464	457	469	484
Cs137	662	1150	1170	1210	1210

Dead Time [%]					
Isotope	Energy [KeV]	1 kHz	10 kHz	50 kHz	100 kHz
Fe55	6	0.68%	4.00%	14.97%	24.90%
Am241	59.5	0.47%	4.18%	15.72%	26.15%
Co57	122	0.62%	3.86%	15.83%	27.16%
Cs137	662	0.51%	4.92%	19.67%	33.33%

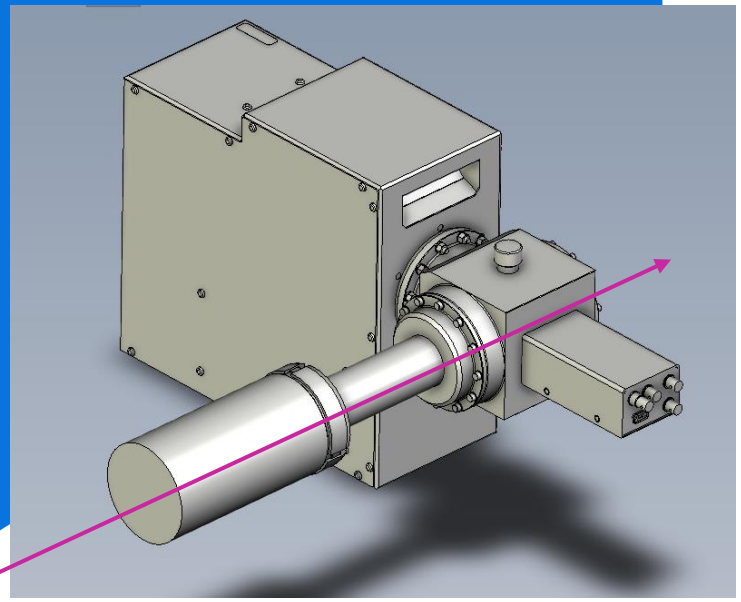
Dead Time [%]					
Isotope	Energy [KeV]	1 kHz	10 kHz	50 kHz	100 kHz
Fe55	6	1.48%	7.73%	28.15%	49.13%
Am241	59.5	1.21%	7.14%	26.05%	46.86%
Co57	122	0.96%	8.63%	25.15%	48.32%
Cs137	662	1.42%	9.04%	29.78%	45.54%

Low energy Clover ?

Dedicated low-energy clovers with 2-3 cm-thick HPGe could be built out of this technology for a focus on low energy measurement



ASICS + Coax



- On-going development
- Pulsed reset preamplifier coupled with D60L90 Coaxial N-type detector
  - 80 MeV preamplifier dynamic
  - Expected spectral range 0-15 MeV
- **Application:**
  - **High count-rate & High energy**

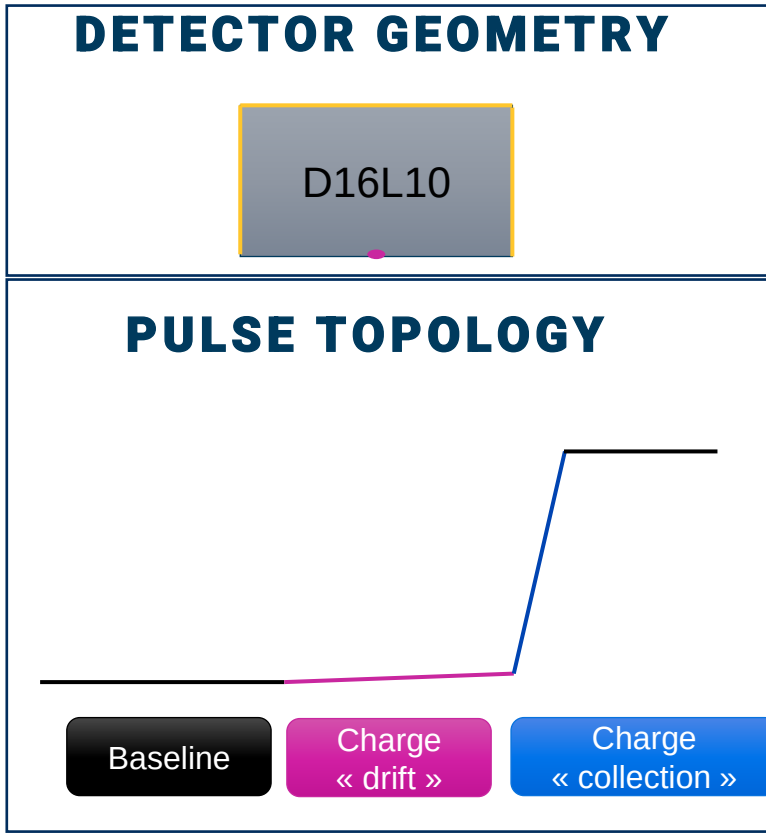
Results expected Feb 2025

ASICS for Timing ?

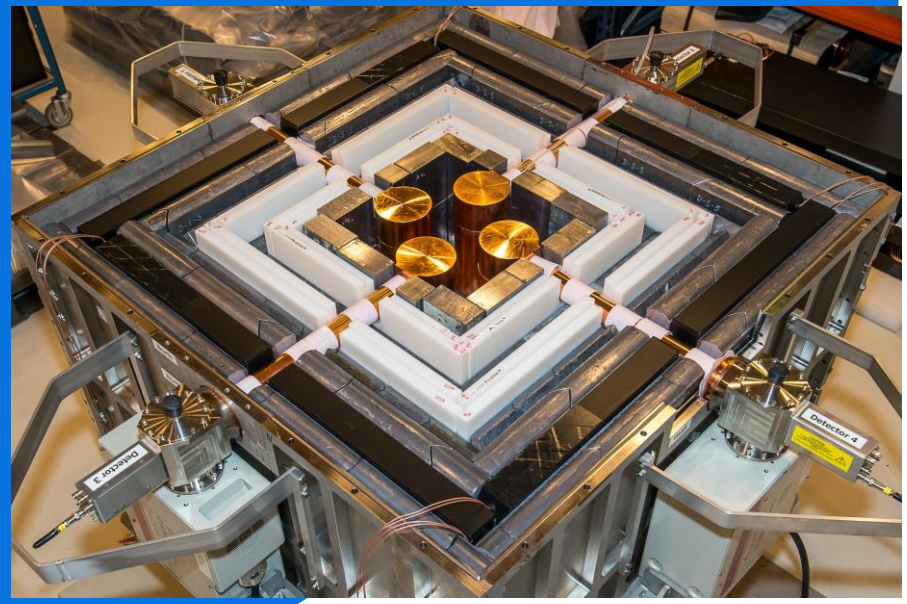
Single element X-ray detector

- Small LEGe crystal D16L10

- ASICS coupled with ultra-low capacitance detectors show very sharp risetime
  - **25 ns risetime** for 60 keV evt
- Resolution FWHM
  - 100 eV @ 5.9 keV
  - 130 eV @ 0.1 us @ 5,9 keV @ 1 Mcps
  - 350 eV @ 0.1 us @ 60 keV
- Measured **timing: ~50 ns**
  - Na22 source (limited preamp dynamic)
  - Low elec field detector
- Explanation:
  - Ultra small electrode: you do not see charges before they reach the contact



ASICS + PPC



CONUS
Photo by courtesy Prof Manfred Lindner
© Max-Planck-Institut für Kernphysik
https://en.wikipedia.org/wiki/CONUS-Experiment

- Coupling
  - Largest HPGe volume
  - Lower Electronical Noise
  - Ultra-Low Background environment
- Meant for neutrino physics
- Looking at rare, ultra-low energy events just above a ~100eV trigger-edge level

- CP5 again

Future of ASICS

- Since 2015 ASICS has become the new standard for X-ray HPGe detectors and Synchrotron applications
- Detector design did not significantly changed from JFET times
  - Internal cold board
  - Outside warm preamp-like power-and-gain board
- Extremely sensitive chips, definitely not as easy as replacing FETs

- We investigate the use of these ASICs for various applications
- The muti-channel ASICS that could replace 36-segment of an AGATA-GRETA does not exist yet (or we are not aware)

French cooking out of an american idea …

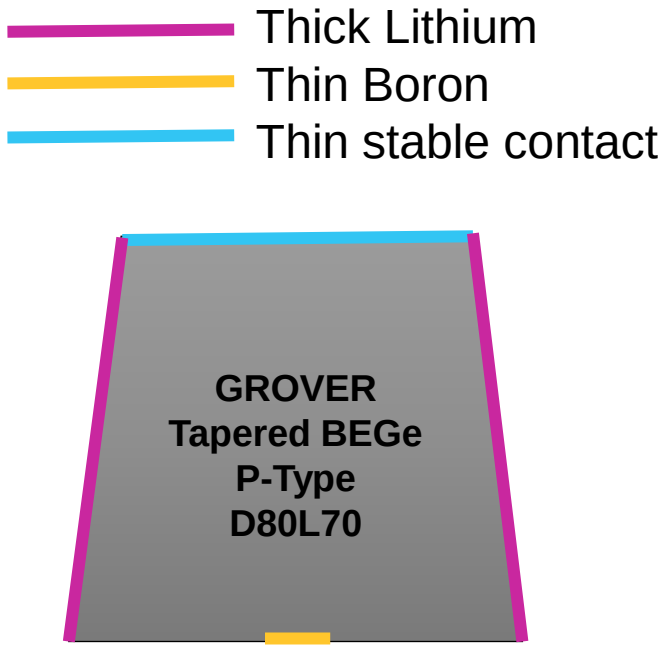
Take a P-type Point Contact HPGe
Taper it into a GReta crystal shape
Sprinkle with a low-FWHM electronic
Mold it into a clOVER-like cryostat

that’s the GROVER !

GROVER in a slide

- **CRYSTALS**
  - like big, tapered BEGe,
  - P-type,
  - Thin entrance window
  - NOT segmented
  - 20mm shorter than GRETA
- **CRYOSTAT**
  - Back-catcher-compatible
  - LN2
  - Not usual Clover preamps
- **APPLICATION**
  - FRIB decay-station

GROVER crystal spectroscopic performance inside test cryostat	
analog shaping	6 µs
122 keV FWHM	0.64 keV
1332 keV FWHM	1.89 keV
FWTM/FWHM	1.93
rel. Eff [%]	70

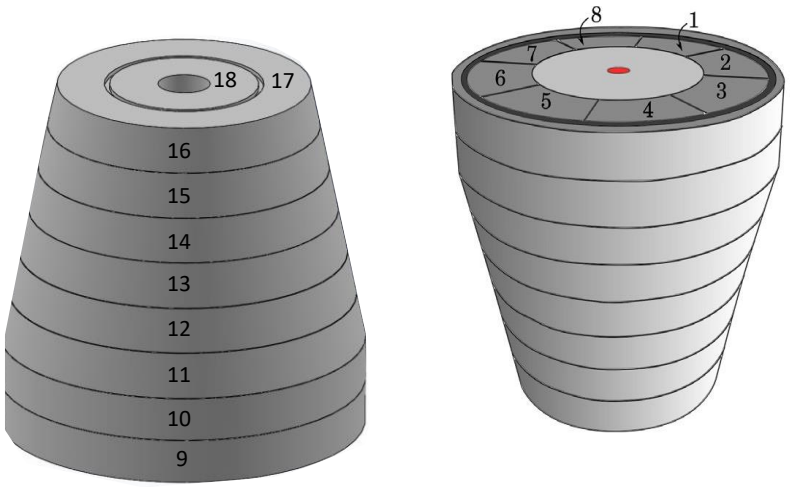


Hybrid windowless Silicon/HPGe telescope for Beta/Gamma measurement

- 1 PIPS silicon detector in front
- 1 LEGe detector in the back, 0.59 keV FWHM @ 122 keV
- UHV valve to open into experiment vacuum
- Detection head can move forward & backward

Segmented P-type

- 3D segmented large P-type coaxial detectors are NOT industrial-scale right now (2024)
  - AGATA / GRETA P-type is not for yet
  - SIGMA is a succesful proof of concept but technology for detector manufacturing is not mature enough
  - **… But work is on-going**

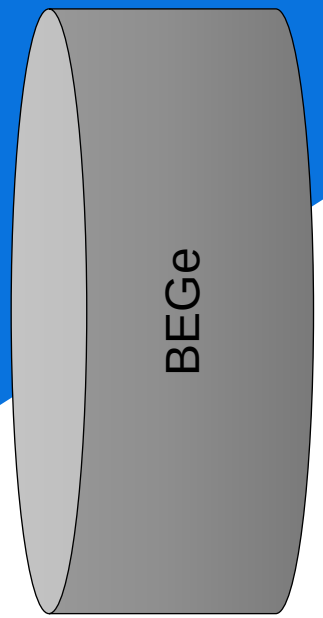


Segmented P-type

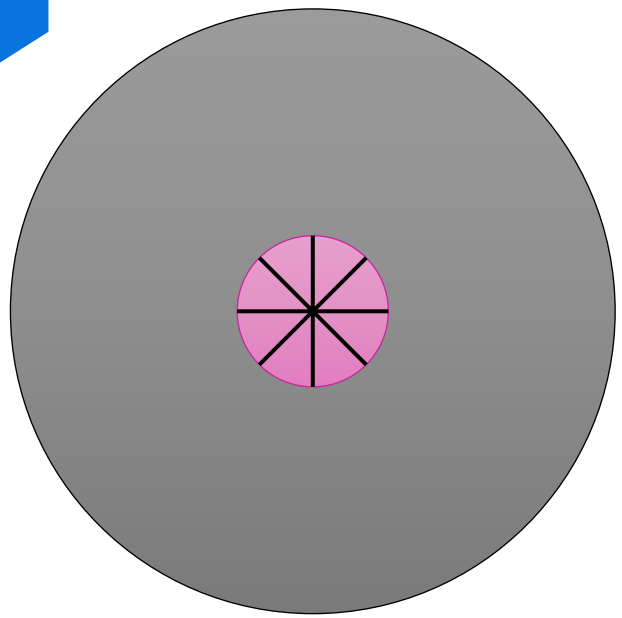
The closest AGATA/GRETA/SIGMA-like P-type detector that could be built asap

- A standard BEGe with **segmented spot**
  - Thin, stable entrance window → low energy capability
  - Segmented spot → position resolution capabilities

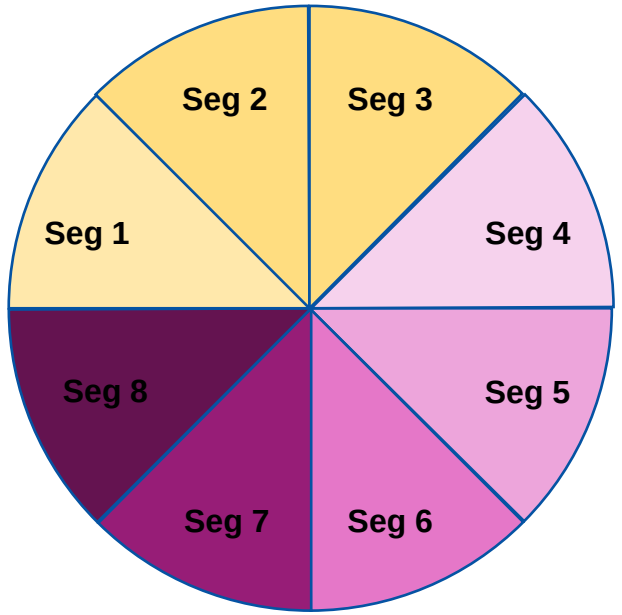
Side view



Rear « Spot » view



Front « effective segmentation » view



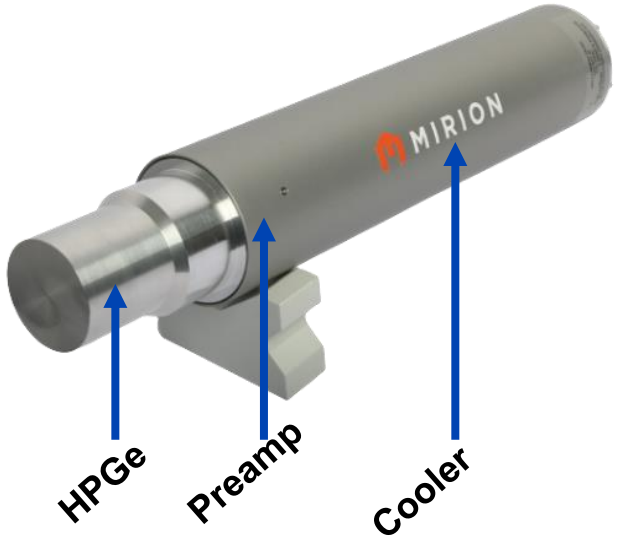
Industrial applications

cryocooler + HPGe as an OEM device to integrate inside larger systems

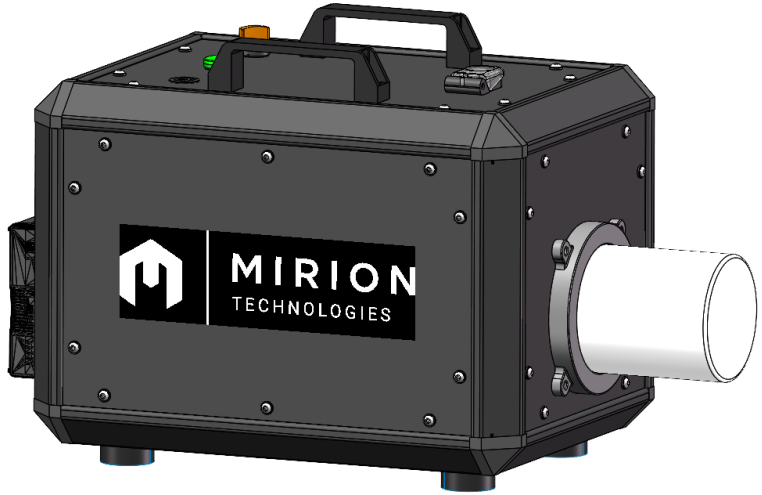
MicroGe
1.8 kg detector
4g HPGe
15min cool-down time

Watertight 50% system

Tubular 25% N-type with cryocooler



Complete battery-powered 140% system



Other

CRAZY IDEAS

YOU SCIENTISTS HAVE THE BEST CRAZY IDEAS

We will certainly say no …

then think about it …

then find mitigations…

and eventually we should make better detectors thanks to you

Thank you for your attention