Intrinsic Germanium Detectors for Various Application

How to select your detector for your specific application

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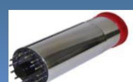
Canberra Packard SRL

Gamma Spectroscopy – the measurement chain

We are here



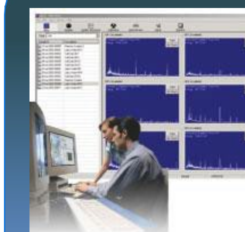
Detector

Passive shielding

Active shielding

Sample changer

MCA

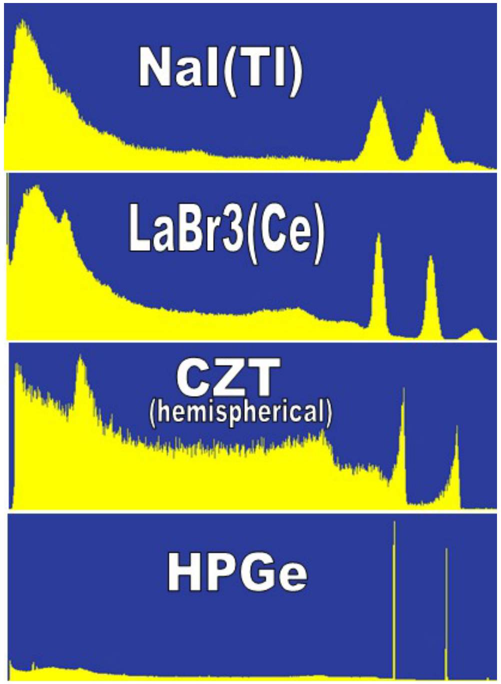


Software

Spectrum
Identification
Quantify
MDA

Types of Gamma Spectroscopy Detectors

- Scintillators:
  - NaI(Tl) – low resolution
  - LaBr3(Ce), CeBr3 – medium resolution
- Diodes:
  - CZT – medium resolution
  - HPGe – high resolution



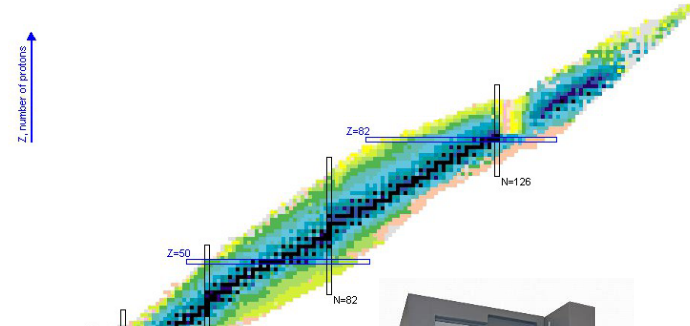
Types of Germanium Detectors

- The germanium detectors (often referred to as a germanium semiconductor detector, HPGe—High Purity Germanium Detector, or intrinsic germanium detector) represent the highest resolution gamma-ray spectroscopy instruments for laboratory and field measurements.
- These detectors are used when one requires the most accurate and complete identification and quantification of radionuclides.
- These instruments can be used in the laboratory, in-situ, and anywhere where radiological materials must be detected and quantified
- **Understanding the design principles and operational requirements can enable one to select and optimize the detector that best fits his/her application.**

Application Requirements

Criteria for selection

- Radionuclides to be assayed
- Types of samples to be measured
- Required accuracy
- Required sensitivity
- Sample throughput
- Other considerations



Application Requirements – energy range

Gamma-ray energy range

- NORM (Naturally Occurring Radioactive Materials): 40 keV to 3000 keV
  - ▶ Pb-210 (46 keV) [U-238/Ra-226 decay series]
  - ▶ Tl-208 (2614 keV) [Th-232 decay series]

- Industrial: 50 keV to 2000 keV
  - ▶ Co-57, Co-60, Cs-137, Ba-133, Eu-152 (also radioactive source standards)

- Special Nuclear Materials: 18 keV to 420 keV
  - ▶ Uranium, Plutonium, Americium, others
  - ▶ Isotopic ratios are important (low enrichment to weapons grade)

- Radiopharmaceuticals: 25 keV to 511 keV
  - ▶ F-18, O-15 (positron emitters)
  - ▶ Tc-99m, Ga-67, Se-75 (60 to 400 keV)
  - ▶ I-125 (27 to 35 keV)
  - ▶ Lu-177 (50 to 500 KeV)

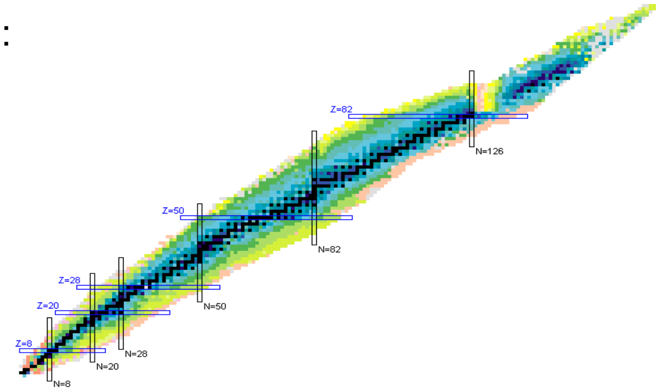
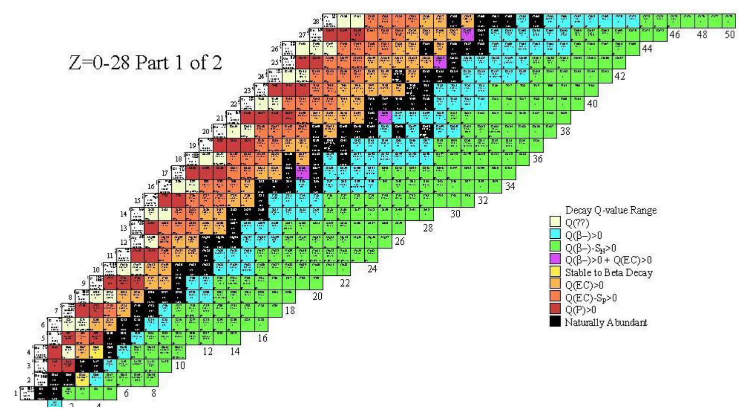


Table of Isotopes (1998)



Application Requirements - Types of Samples

- Laboratory Samples
  - ▶ Beakers (cylindrical, Marinelli)
  - ▶ Filter papers, iodine cartridge
- In-situ
  - ▶ Soil, walls, pipes, drums
- In-vivo
  - ▶ Whole body, thyroid, lung, wound,,,,
- Large Samples
  - ▶ Dismantling and decommissioning

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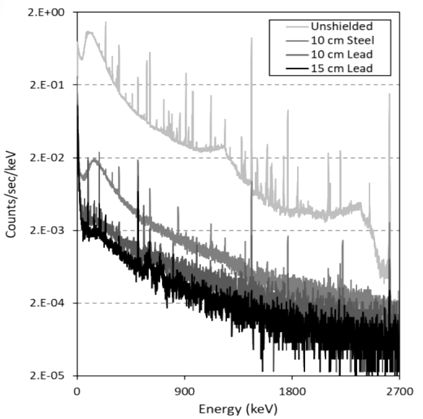
Application Requirements – Accuracy and MDA

- Accuracy and precision of the measurements
  - < 2% Very challenging (metrology, control all variables)
  - 2% - 10% Typical laboratory accuracy
  - 10% - 30% Typical in-situ accuracy

- Minimum Detectable Activity
  - ≥ MBq High count rate, high dead time
  - kBq Easy, no shielding, measure in minutes
  - Bq Moderate, some shielding, measure in hours
  - mBq Difficult, high shielding, special materials, measure in days, low background labs (Slănic Prahova)



- Sample throughput
  - How many measurements / day are needed to meet the objectives?

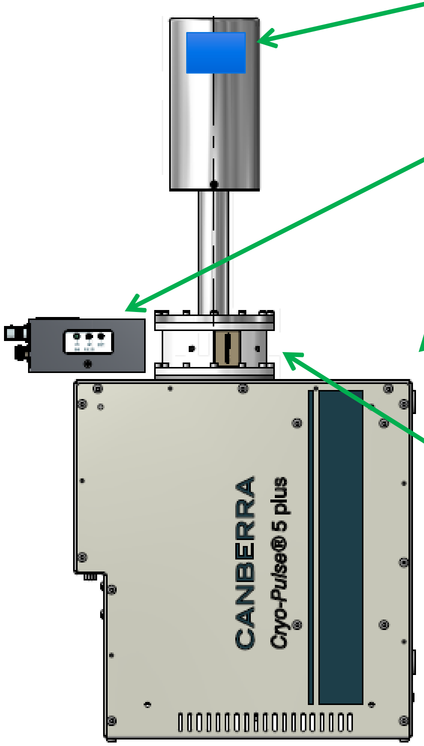
Application Requirements – Other Considerations

- Budget
  - ▶ Budget is always a factor
  - ▶ Maximize value against cost

- Environmental Constraints
  - ▶ LN2 handling restrictions
  - ▶ RoHS compliance

- Environmental Extremes
  - ▶ High Temperatures and / or Humidity
  - ▶ Underwater
  - ▶ Neutron Exposure (near reactor, near accelerator target...)

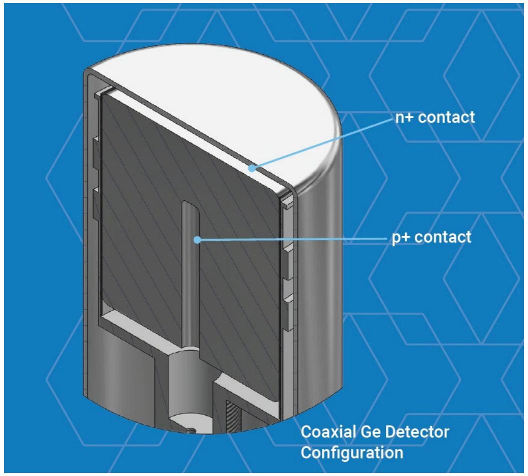
Components of a Germanium Detector

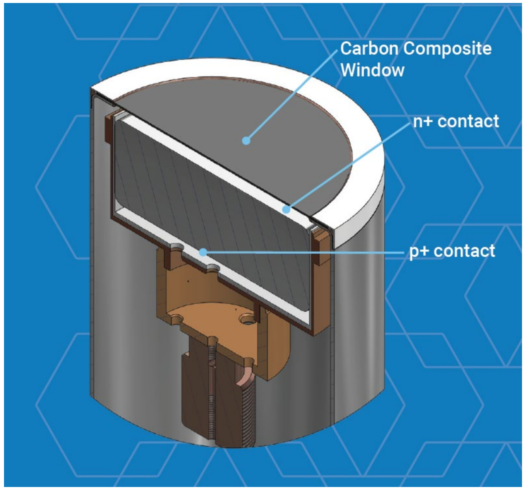


- Ge Detector
  - N-type / P-type, coaxial / planar, well detector
- Detector Preamp
  - RC-type: iPA, 2002C
  - Reset-type: 2101P/N, iTRP
- Cooler
  - CP5-PLUS
  - Cryo-Cycle II
  - D-30 Liquid Nitrogen
  - D-7905 Integral Dewar
  - D-7935-7 Big Mac Dewar
- Detector Cryostat
  - Slimline (with or without RDC)
  - Flanged ((with or without RDC)
  - Portable (e.g. AEGIS)

Choosing the Detector Type

- SEGe Standard Electrode Ge (coaxial, type p)
- REGe Reverse Electrode Ge (coaxial, type n)
- BEGe Broad Energy Ge (planar, type p / n)
- XtRa Extended Range Ge (coaxial, type p / n)
- SAGe Well Small Anode Ge Well Type (coaxial, type p / n)
- LEGe Low Energy Ge (planar, type n)
- U-LEGe Ultra-Low Energy Ge (planar, type n)





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Coaxial Detector Models

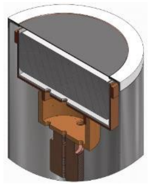
Coaxial SEGe (Standard-Electrode Ge)	
P-type Ge	General Purpose Detector
Outer Li Layer	
Rel. Eff. Range 5% to 150%	
Minimum Energy: 40 keV	

Coaxial XtRa (Extended-Range Ge)	
P-type Ge	Similar performance to SEGe
Stable Thin Front Window (Li on side)	Better low energy sensitivity than SEGe
Rel. Eff. Range 10% to 120%	
Minimum Energy: 3 keV	

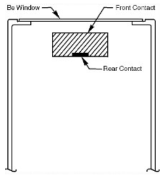
Coaxial REGe (Reverse-Electrode Ge)	
N-type Ge	Lowest attenuation from side
Stable thin window on outer surface	More neutron resistant than P-type
Rel. Eff. Range 10% to 100%	
Minimum Energy: 3 keV	

Planar Detectors

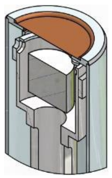
Planar BEGe (Broad-Energy Ge)	
N / P -type Ge	Wide Energy Range Detector
Stable Thin Front Window	Excellent low-energy resolution
Volume Range: 40 cc to 195 cc	High end general purpose detector
Minimum Energy: 3 keV	



Planar LEGe (Low-Energy Ge)	
N-type Ge	X-ray applications
Stable thin front window	SNM Isotopics Analysis
Volume Range: 0.25 cc to 40 cc	High-rate input rate
Minimum Energy: 1 keV	Can be mounted in multi-element arrays

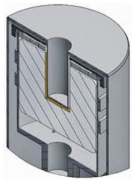


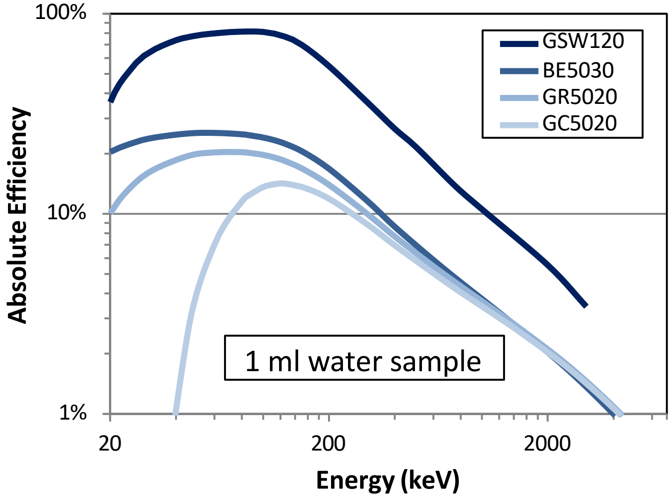
Planar Ultra-LEGe (Ultra-Low-Energy Ge)	
N-type Ge	X-ray applications
Stable thin front window	High-rate input rate
Volume Range: 0.15 cc to 1 cc	Can be mounted in multi-element arrays
Minimum Energy: 0.3 keV	



SAGe Well Type – Coaxial, well type

SAGe (Small Anode Ge) Well	
P-type Ge	Ideal for small low-activity samples
Stable Thin Window in Well	Excellent low-energy resolution
Volume Range: 120 cc to 400 cc	
Minimum Energy: 15 keV (in the well)	



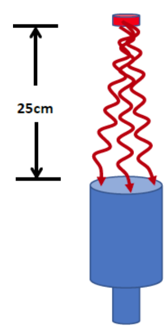


Relative Efficiency vs Absolute efficiency

- Relative Efficiency (Rel. Eff.) : Efficiency of the 1332 keV line from a Co-60 **point source** positioned 25 cm from the center of the detector endcap relative to the same measurement of a 3”x3” NaI(Tl) detector (≡0.0012).

- Meant to provide a reference value roughly correlated with the **size** of a germanium detector

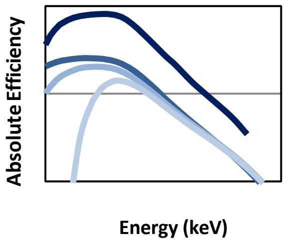
- The relative efficiency is not an indicator of the detector efficiency at other energies or sample geometries.



- The absolute efficiency of a detector for a given energy $E\gamma$ is the ratio between the number of gamma photons detected, and the total number of gamma photons emitted by the source in all directions during the same counting time.

- Absolute efficiency is the indicator of detector efficiency for a specific measurement geometry,

- The absolute efficiency has two components: intrinsic efficiency and geometric efficiency



Various HPGe detectors

Model Number	Typical Rel. Eff. (%) ≥	Full Width Half Max (FWHM) Resolution (keV)		Peak to Compton Ratio (P/C)	Peak Shape	Endcap diameter mm (in.)
		At 122 keV energy	At 1.3 MeV energy		FWTM/ FWHM	
GX1018	10	0.825	1.75	40	1.90	76 (3.0)
GX1020	10	1.00	2.00	36	2.00	76 (3.0)
GX1518	15	0.825	1.80	46	1.90	76 (3.0)
GX1520	15	1.00	2.00	42	2.00	76 (3.0)
GX2018	20	0.850	1.80	50	1.90	76 (3.0)
GX2020	20	1.10	2.00	46	2.00	76 (3.0)
GX2518	25	0.850	1.80	54	1.90	76 (3.0)
GX2520	25	1.10	2.00	50	2.00	76 (3.0)
GX3018	30	0.875	1.80	58	1.90	76 (3.0)
GX3020	30	1.20	2.00	54	2.00	76 (3.0)
GX3518	35	0.875	1.80	60	1.90	76 (3.0)
GX3520	35	1.20	2.00	54	2.00	76 (3.0)
GX4018	40	0.875	1.80	62	1.90	76 (3.0)*
GX4020	40	1.20	2.00	56	2.00	76 (3.0)*
GX4518	45	0.900	1.80	63	1.90	83 (3.25)
GX4520	45	1.20	2.00	58	2.00	83 (3.25)
GX5019	50	0.950	1.90	64	1.90	83 (3.25)*
GX5021	50	1.20	2.10	58	2.00	83 (3.25)*
GX5519	55	1.00	1.90	64	1.90	89 (3.5)
GX5521	55	1.20	2.10	60	2.00	89 (3.5)
GX6019	60	1.00	1.90	66	1.90	89 (3.5)
GX6022	60	1.25	2.20	60	2.00	89 (3.5)
GX6520	65	1.00	1.95	68	1.90	89 (3.5)
GX6522	65	1.25	2.20	62	2.00	89 (3.5)
GX7020	70	1.00	2.00	70	1.90	89 (3.5)*
GX7022	70	1.25	2.20	64	2.00	89 (3.5)*
GX8020	80	1.10	2.00	72	1.90	95 (3.75)
GX8023	80	1.30	2.30	66	2.00	95 (3.75)
GX9020	90	1.10	2.00	78	1.90	95 (3.75)
GX9023	90	1.30	2.30	70	2.00	95 (3.75)
GX10020	100	1.20	2.00	78	1.90	95 (3.75)*
GX10023	100	1.40	2.30	70	2.00	95 (3.75)*
GX11021	110	1.20	2.10	78	1.90	102 (4.0)
GX11023	110	1.40	2.30	70	2.00	102 (4.0)
GX12021	120	1.30	2.10	78	1.90	102 (4.0)
GX12023	120	1.50	2.30	70	2.00	102 (4.0)

GENERAL SPECIFICATIONS AND INFORMATION

Model Number	Area (mm²)	Thickness (mm)	Be Window Thickness mm (mils)	Guarant
				5.9
GL0055	50	5	0.025 (1)	1
GL0110	100	10	0.025 (1)	1
GL0210	200	10	0.13 (5)	195
GL0510	500	10	0.13 (5)	2
GL0515	500	15	0.13 (5)	2
GL1010	1000	10	0.25 (10)	3
GL1015	1000	15	0.25 (10)	3
GL2020	2000	20	0.5 (20)	4

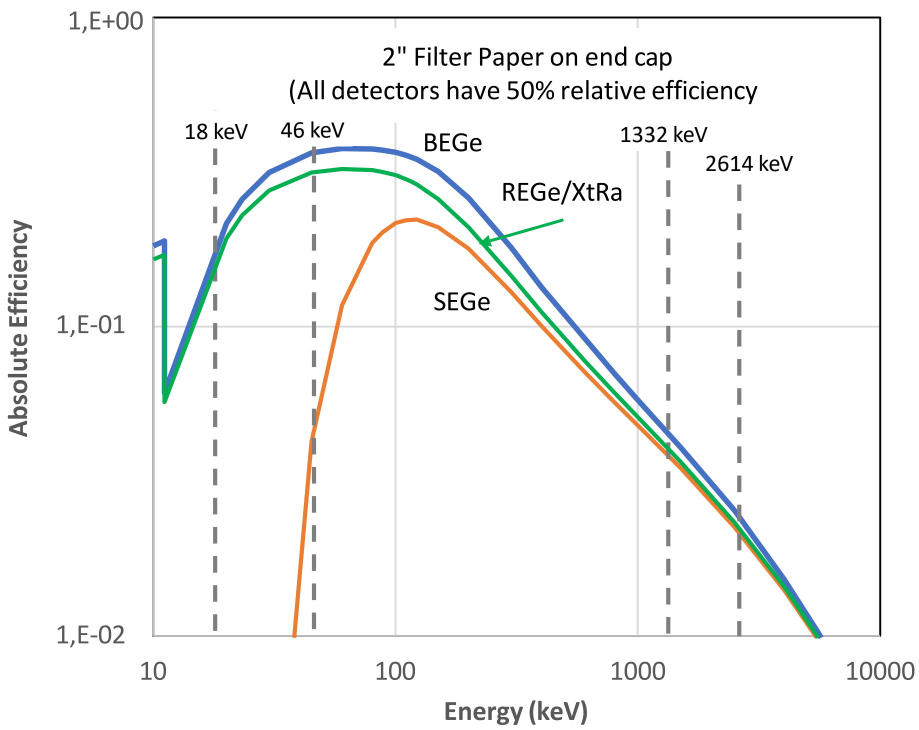
Model Number	Area (cm²)	Thickness (mm)	Typical Rel. Eff. (%) ≥	Full Width H… Resolu…			
				At 5.9 keV energy	At 12… en…		
BE2020	20	20	9	0.35	0.		
BE2820	28	20	13	0.40	0		
BE2825	28	25	18	0.40	0		
BE2825P	28	25	18	0.35	0.		
BE3820	38	20	20	0.45	0		
BE3825	38	25	26	0.45	0		
BE3825P	38	25	26	0.40	0.		
BE3830	38	30	34	0.45	0.72	1.90	89 (3.50)
BE3830P	38	30	34	0.40	0.65	1.80	89 (3.50)
BE5025	50	25	37	0.50	0.75	2.00	102 (4.0)
BE5030	50	30	48	0.475	0.72	2.00	102 (4.0)
BE5030P	50	30	48	0.425	0.675	1.80	102 (4.0)
BE6530	65	30	60	0.50	0.75	2.00	114 (4.5)

Model Number	Typical Rel. Eff. (%) ≥	Full Width Half Max (FWHM) Resolution (keV)		Peak to Compton Ratio (P/C)	Peak Shape	Endcap diameter mm (in.)
		At 122 keV energy	At 1.3 MeV energy		FWTM/ FWHM	
GR1018	10	0.825	1.8	38	1.90	76 (3.0)
GR1020	10	1.00	2.00	34	2.00	76 (3.0)
GR1518	15	0.825	1.8	44	1.90	76 (3.0)
GR1520	15	1.00	2.0	40	2.00	76 (3.0)
GR2018	20	0.850	1.8	50	1.90	76 (3.0)
GR2020	20	1.10	2.0	46	2.00	76 (3.0)
GR2519	25	0.850	1.9	54	1.90	76 (3.0)
GR2521	25	1.10	2.1	50	2.00	76 (3.0)
GR3019	30	0.875	1.9	56	1.90	76 (3.0)
GR3021	30	1.20	2.1	52	2.00	76 (3.0)
GR3519	35	0.925	1.9	56	1.90	76 (3.0)
GR3521	35	1.20	2.1	52	2.00	76 (3.0)
GR4020	40	0.925	2.0	56	1.90	76 (3.0)*
GR4022	40	1.20	2.2	52	2.00	76 (3.0)*
GR4520	45	0.950	2.0	58	1.90	83 (3.25)
GR4522	45	1.20	2.2	54	2.00	83 (3.25)
GR5021	50	1.00	2.1	58	1.90	83 (3.25)*
GR5023	50	1.20	2.3	54	2.00	83 (3.25)*
GR5522	55	1.10	2.1	60	2.00	89 (3.5)
GR5524	55	1.25	2.3	54	2.10	89 (3.5)
GR6022	60	1.10	2.2	60	2.00	89 (3.5)
GR6024	60	1.25	2.4	54	2.10	89 (3.5)
GR6523	65	1.20	2.3	60	2.00	89 (3.5)
GR6525	65	1.30	2.5	54	2.10	89 (3.5)
GR7023	70	1.20	2.3	60	2.00	89 (3.5)*
GR7025	70	1.30	2.5	54	2.10	89 (3.5)*
GR8023	80	1.20	2.3	60	2.00	95 (3.75)
GR8025	80	1.30	2.5	56	2.10	95 (3.75)
GR9023	90	1.20	2.3	60	2.00	95 (3.75)
GR9025	90	1.30	2.5	56	2.10	95 (3.75)
GR10024	100	1.30	2.4	60	2.00	95 (3.75)*
GR10026	100	1.40	2.6	56	2.10	95 (3.75)*

Model Number	Typical Rel. Eff. (%) ≥	Full Width Half Max (FWHM) Resolution (keV)		Peak to Compton Ratio (P/C)	Peak Shape	Endcap diameter mm (in.)
		At 122 keV energy	At 1.3 MeV energy		FWTM/ FWHM	
GC0518	5	0.825	1.75	32	1.90	76 (3.0)
GC1018	10	0.825	1.75	40	1.90	76 (3.0)
GC1020	10	1.00	2.00	36	2.00	76 (3.0)
GC1518	15	0.825	1.80	46	1.90	76 (3.0)
GC1520	15	1.00	2.00	42	2.00	76 (3.0)
GC2018	20	0.850	1.80	50	1.90	76 (3.0)
GC2020	20	1.10	2.00	46	2.00	76 (3.0)
GC2518	25	0.850	1.80	54	1.90	76 (3.0)
GC2520	25	1.10	2.00	50	2.00	76 (3.0)
GC3018	30	0.875	1.80	58	1.90	76 (3.0)
GC3020	30	1.20	2.00	54	2.00	76 (3.0)
GC3518	35	0.875	1.80	60	1.90	76 (3.0)
GC3520	35	1.20	2.00	54	2.00	76 (3.0)
GC4018	40	0.875	1.80	62	1.90	76 (3.0)*
GC4020	40	1.20	2.00	56	2.00	76 (3.0)*
GC4518	45	0.900	1.80	63	1.90	83 (3.25)
GC4520	45	1.20	2.00	58	2.00	83 (3.25)
GC5019	50	0.950	1.90	64	1.90	83 (3.25)*
GC5021	50	1.20	2.10	58	2.00	83 (3.25)*
GC5519	55	1.00	1.90	64	1.90	89 (3.5)
GC5521	55	1.20	2.10	60	2.00	89 (3.5)
GC6019	60	1.00	1.90	66	1.90	89 (3.5)
GC6022	60	1.25	2.20	60	2.00	89 (3.5)
GC6520	65	1.00	1.95	68	1.90	89 (3.5)
GC6522	65	1.25	2.20	62	2.00	89 (3.5)
GC7020	70	1.00	2.00	70	1.90	89 (3.5)*
GC7022	70	1.25	2.20	64	2.00	89 (3.5)*
GC8020	80	1.10	2.00	72	1.90	95 (3.75)
GC8023	80	1.30	2.30	66	2.00	95 (3.75)
GC9020	90	1.10	2.00	78	1.90	95 (3.75)
GC9023	90	1.30	2.30	70	2.00	95 (3.75)
GC10020	100	1.20	2.00	78	1.90	95 (3.75)*
GC10023	100	1.40	2.30	70	2.00	95 (3.75)*
GC11021	110	1.20	2.10	78	1.90	102 (4.0)
GC11023	110	1.40	2.30	70	2.00	102 (4.0)
GC12021	120	1.30	2.10	78	1.90	102 (4.0)
GC12023	120	1.50	2.30	70	2.00	102 (4.0)
GC13021	130	1.30	2.10	80	1.95	108 (4.25)*
GC13023	130	1.50	2.30	74	2.00	108 (4.25)*
GC14022	140	1.30	2.20	80	1.95	108 (4.25)*
GC14024	140	1.50	2.40	74	2.00	108 (4.25)*
GC15022	150	1.30	2.20	80	1.95	108 (4.25)*
GC15024	150	1.50	2.40	74	2.00	108 (4.25)*

Detector Type: Total Efficiency Comparison

For a common relative efficiency, BEGe type detectors have the best performance across the energy range for samples from the front.



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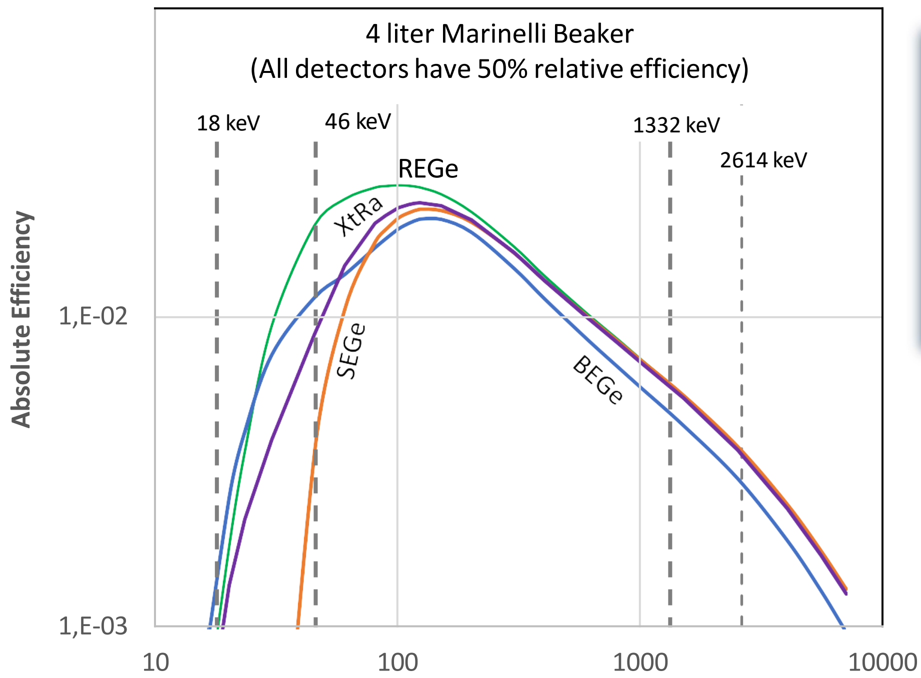
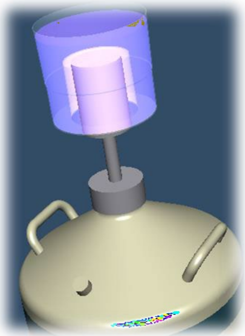
Large Geometric Efficiency Detectors

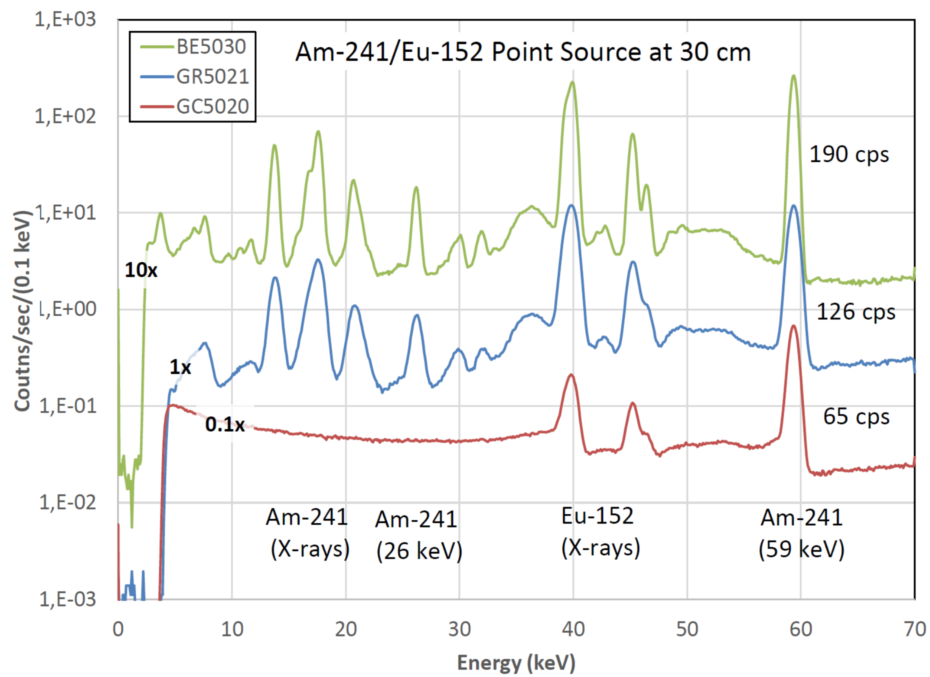
For Marinelli Beakers, coaxial n type detectors (REGe) have the best performance at low energy. Efficiency is similar to SEGe and XtRa at high energy.





Detector Resolution

Low-energy spectral comparison between BEGe, REGe, and SEGe detectors of similar relative efficiency



Minimum Detectable Activity

MDA (**M**inimum **D**etectable **A**ctivity)

- ▶ In physical measurements, it is not permitted to give a measurement result of 0. The detection threshold must therefore be quantified.
- ▶ Thus, a result of 0 will not be given in an analysis report for a nuclide being sought, but rather the value at which this nuclide can be detected with a significant result.

MDA Calculation methods

Currie algorithm

$$MDA = \frac{L_D}{t\varepsilon\gamma}$$

$$L_D = k^2 + 2k\sqrt{2B}$$

k: Confidence level, so if we are at 5% false positive and false negatives k=1.645, i.e.

$$L_D = 2.71 + 4.65\sqrt{B}$$

- Efficiency → ε
  - Detector type
  - Detector – sample geometry
  - Sample type
- Count time → t
- Isotope
  - Emission probability → γ
- Background level → B
  - Shielding thickness & material
  - Cryostat & detector materials (ULB)
  - Environmental background

MDA

- The greater the sample counting time and absolute efficiency, the lower the MDA will be.
- The better the FWHM of the detector and the lower the background noise, the lower the MDA will be.

- To reach a required MDA consider:
  - Sample counting time
  - Detector efficiency, FWHM and ULB option
  - Shielding quality
  - Sample Geometry

- MDA calculations can be performed if the nuclides involved and the expected counting time are known

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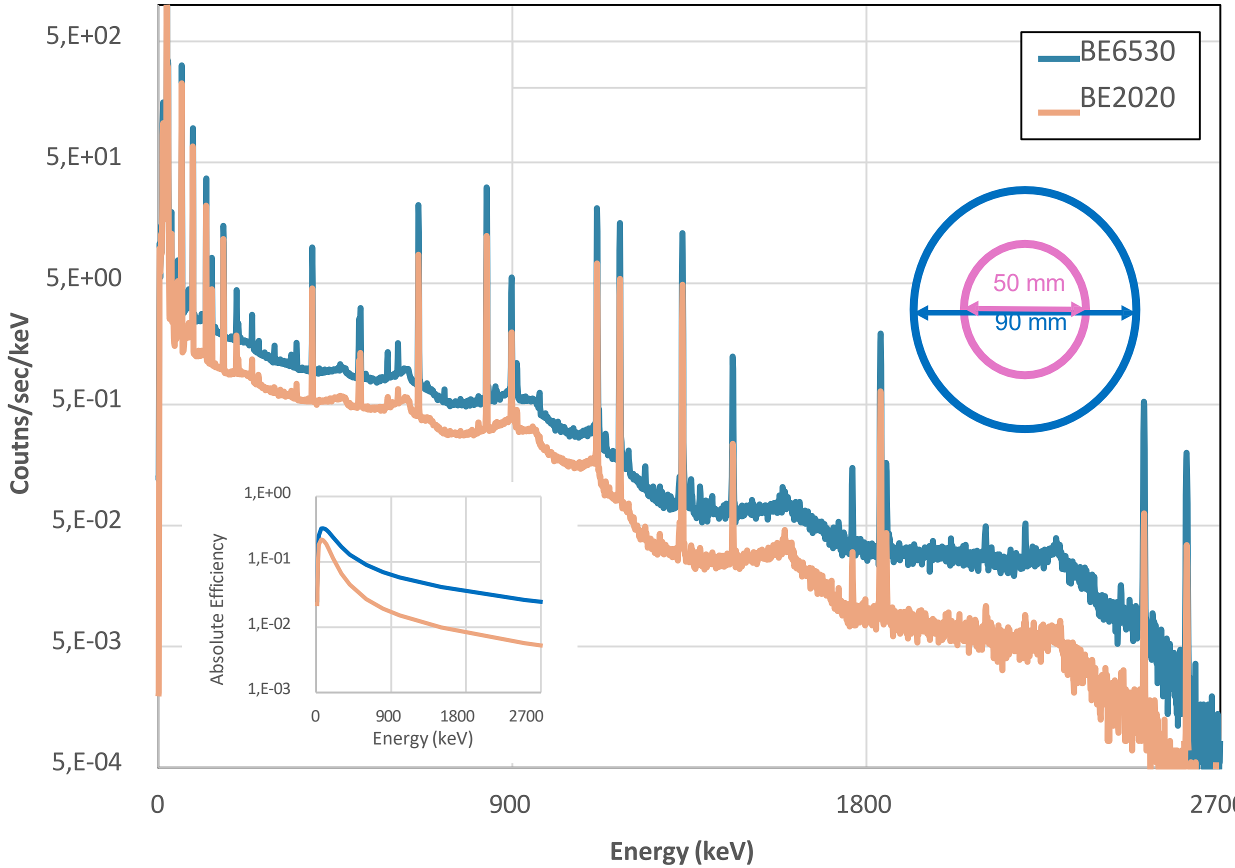
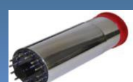
Key Considerations for Detector Type

- A general-purpose detector to handle most samples is required
  - ▶ Consider a BEGe type detector if cylindrical container samples are used
  - ▶ Consider a SEGe type detector if there is no need to measure below 40 keV
- Energies less than 100 keV are important.
  - ▶ Consider a BEGe (or REGe) type detector for best energy resolution but sometimes an XtRa type detector can also be used
- Most samples are in Marinelli beakers / MDA must be as low as possible.
  - ▶ Consider a REGe or XtRa type detector if low energy is important.
  - ▶ Consider SEGe type detector if energies below 40 keV are not important
- The detector will be exposed to neutrons.
  - ▶ An n type detector must be used: REGe, n type BEGe
- Low-activity samples are measured
  - ▶ Consider a SAGe Well type detector.

Efficiency Comparison for BEGe Detectors



We are here



Detector

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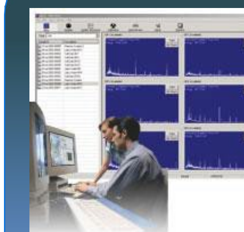
Passive shielding

Active shielding

Sample changer

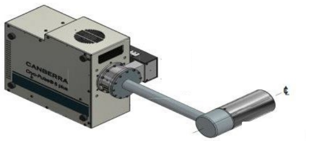
MCA



Software

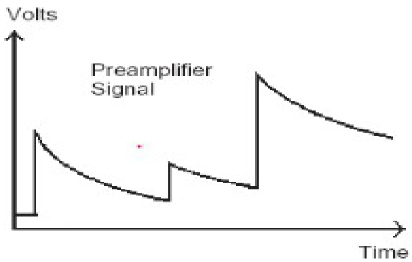
Spectrum
Identification
Quantify
MDA

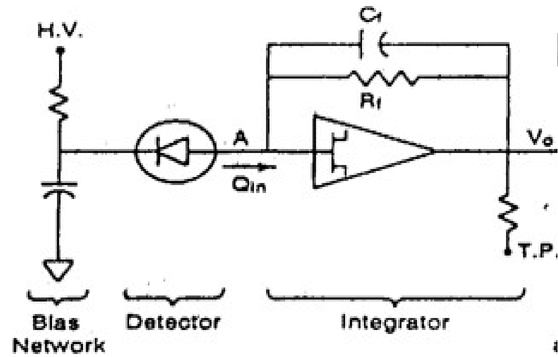
- **Detector configuration**
  - Preamplifier model
  - RDC option
  - ULB option
  - Cryostat type
  - Endcap / window type
  - Shielding



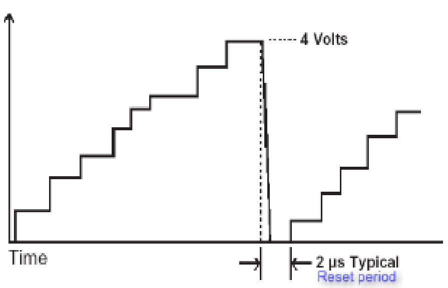
Preamplifiers

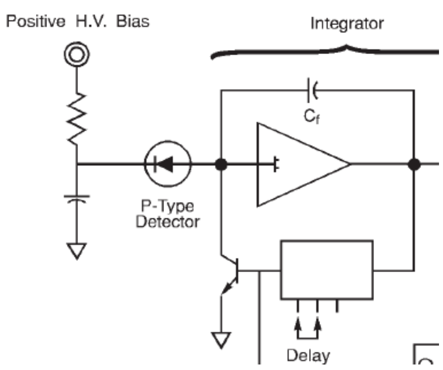
- Three models
  - IPA II (RC feedback)



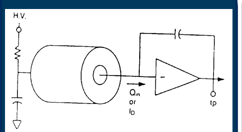


  - 2101 N/P (transistor reset)
  - ITRP (transistor reset)

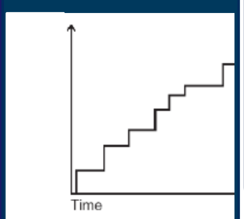




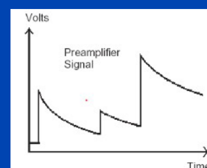
The three HPGe preamplifier models explained

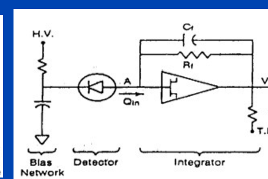


Charge-sensitive integrator: Q → V



Dynamic charge restoration (RC feedback)



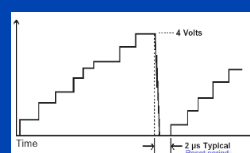


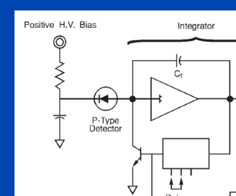
iPA II (Intelligent Preamp)

Max throughput

Energy-rate limited (<=200 GeV/s); P/Z regulation

Reset charge restoration (transistor reset)





2101N/P (transistor switch)

No energy rate limit;
OK for high energies

Throughput;
Noise impact (LEGe, BEGe)

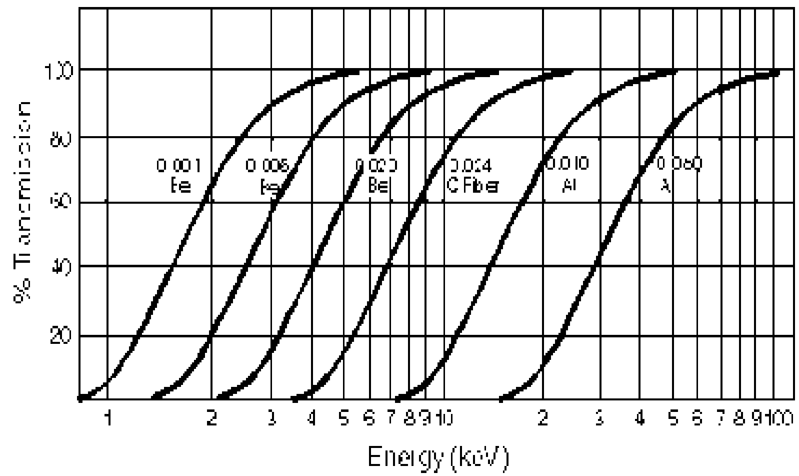
ITRP (integrated switch in FET)

No energy rate limit;
Best noise performance

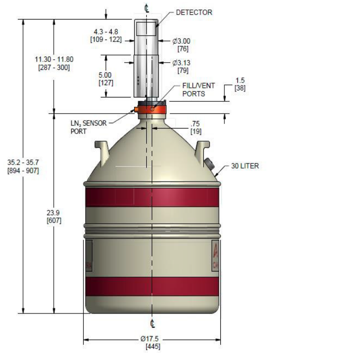
Only useable for low energies

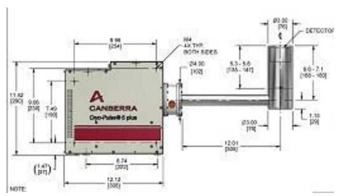
Cryostats and endcaps

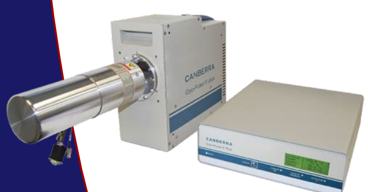
- Cryostat end cap window
  - Defines low energy (< 40 keV) response



- Cryostat and preamp type
  - To match available space, portability, holding time, …
  - To match source activity
- Liquid nitrogen cooling vs. electrical cooling…
  - Allows low energy response from all sides.







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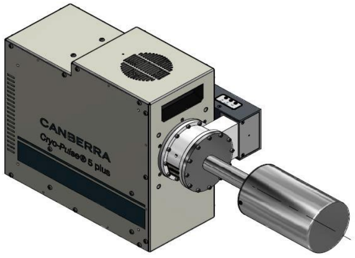
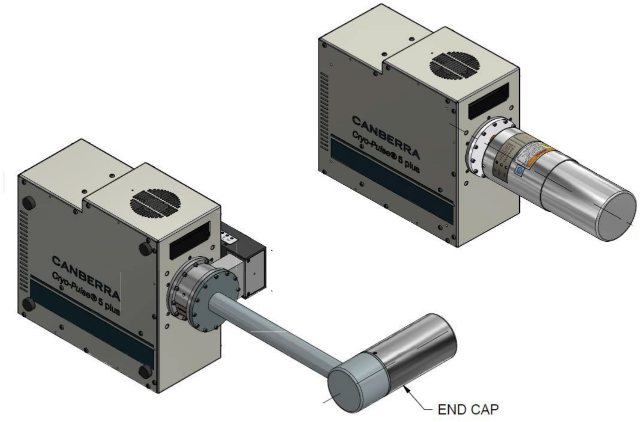
Choosing a Cryostat

- There are two basic Cryostat Designs
  - Slimline
    - Preamplifier Integrated with the detector head
    - Standard design for dipstick cryostats.
    - RDC options
  - Flanged
    - External (Box) Preamplifier
    - RDC options
- Remote Detector Chamber (RDC)
  - Separates preamp from detector
  - Lowers detector background
    - Separates most electronic components
    - Allows introduction of addition shielding behind detector.



- The U-style Cryostat
  - allows placement of the cooler and electronics to the side of the shield.
  - No direct "shine path" to the detector crystal.
  - Used for the maximum benefit of background reduction.



Choosing a Cooler

- Germanium detectors are required to be at about 110 K (-163° C) for proper operation.
- This temperature was typically achieved by placing the detector cryostat in a bath of liquid nitrogen (LN2).
- The temperature of LN2 is 77 K (-195° C).
- Within the past 15 years, electro-mechanical coolers have become sufficiently reliable and maintenance free that they are a viable option for standard cooling of germanium detectors.
- Traditional LN2 remains a standard cooling method, but the hybrid cooling or LN2-free reduce the need for LN2 infrastructure and handling.

RDC option

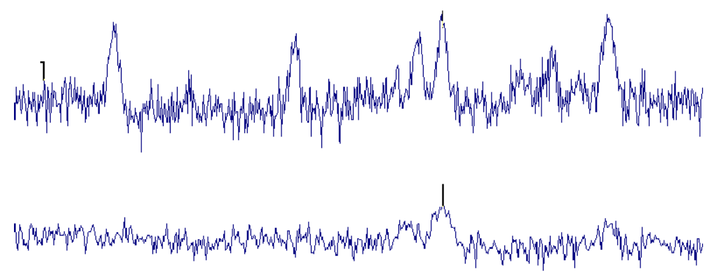
Remote **C**hamber **D**etector

- allows for better shielding of the rear of the detector to reduce background level
- RDC dimension will depend of the thickness of the shielding

ULB Cryostats

Ultra **L**ow **B**ackground detector

- Low background materials are used for detector chamber, holder, and internal hardware.
- Design offsets are used to allow the use of shielding materials between the detector element and hotter materials such as the preamplifier and adsorber (molecular sieves).
- Direct streaming paths for external (to shield) sources of radiation are eliminated.
- Materials having high cross-section for cosmic neutrons are avoided in construction



Low energy 40 keV to 100 keV

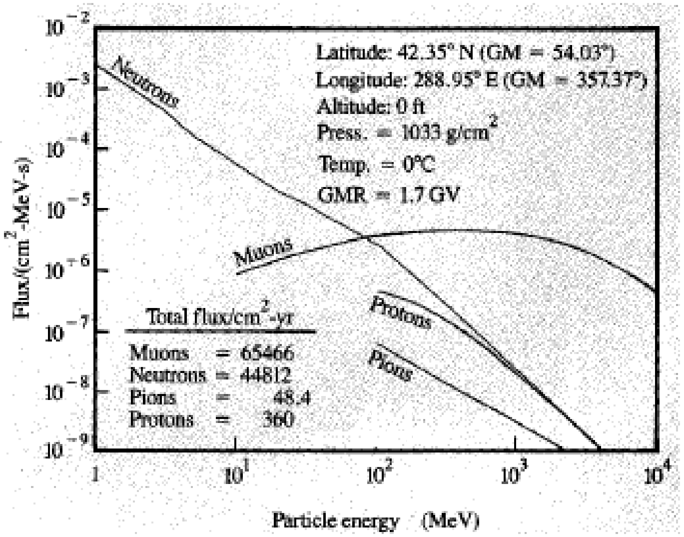
Detector Endcaps

Depending on the energy range, one may choose

- Standard Aluminum: 1.6 mm → 30 keV
- Carbon-Epoxy : 0.5 mm → 5 keV – usually standard for n-type detectors
- Thin Al : 0.5 mm → 15 keV
- Special windows:
  - Ceramic Well Insert (5 keV)
    - Used for SAGe Well ULB
  - Beryllium Windows
    - X-ray applications (LEGe, Ultra-LEGe)

Sources of background

- **Terrestrial radiation**
  - Naturally Occurring Radiological Material (NORM)
  - U-238 + daughters, Th-232 + daughters, K-40, others
  - **Passive Shielding**
- **Cosmogenic radiation**
  - Radiation from the Sun or other interstellar location interacts in the earth's atmosphere and creates high energy muons, neutrons, and other charged particles.
  - **Active Cosmic Veto**
- **Background from the sample**
  - Many samples of interest contain other radiological constituents (e.g. NORM) which are not of interest to the user.
  - Some of the full-energy lines may interfere with the nuclide of interest, but typically it is the Compton background that is most interfering.
  - **Active Compton Suppression**



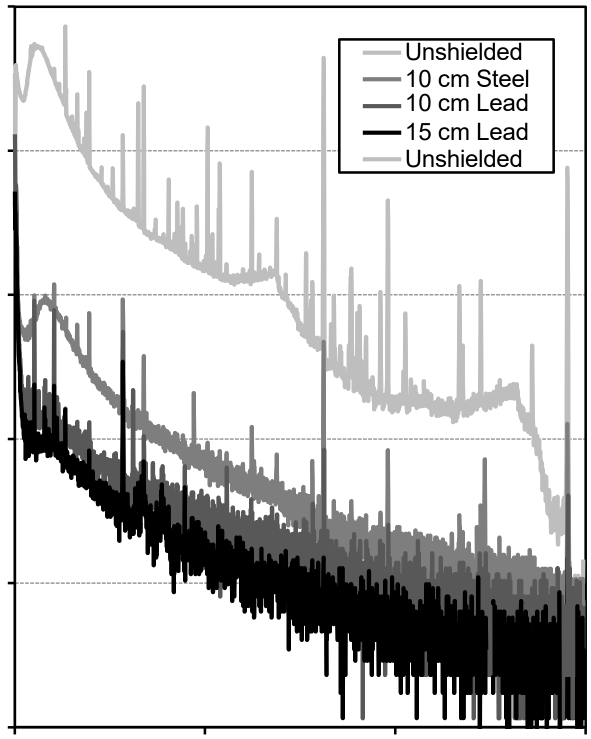
Lead shields for Standard HPGe

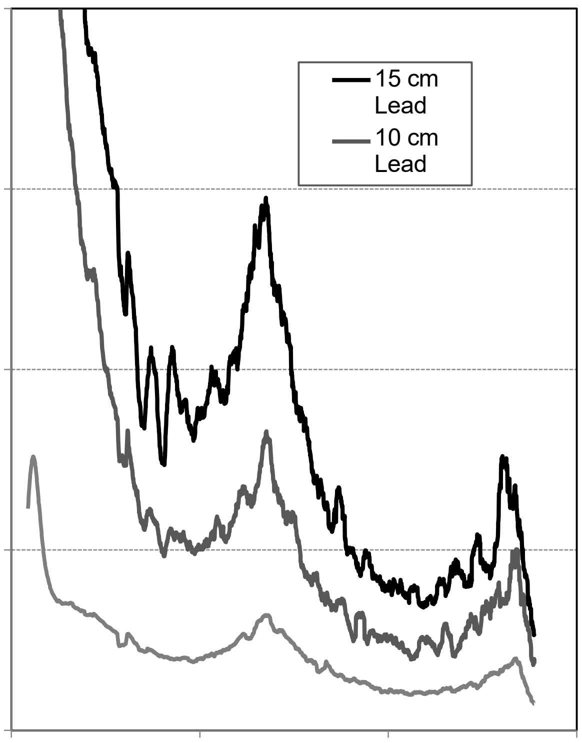
Active and Passive HPGe Detector Shielding

- Passive, standard (5 – 15 cm lead)
- Ultra Low-Background Shield: low content of radioactive lead isotopes (≤ 10 Bq/kg)

•Active – CosmicGuard Cosmic Veto Background Reduction System
•Provides improved background reduction over lead shielding alone
•Typical background reduction 15–40% resulting in lower MDA’s and count times

Passive background reduction



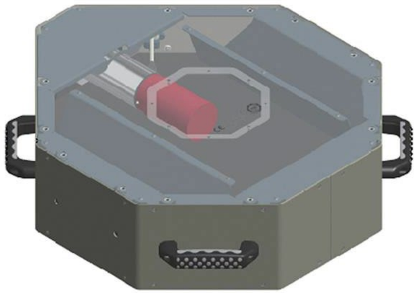


Cosmic Veto System

- Passive shielding is quite effective to suppress terrestrial radiation.
- Remaining radiation is typically of cosmogenic origin.
- This radiation is primarily muon radiation and high-energy neutrons.
- High-energy neutrons generally react with material via spallation reactions which, in turn, generate charged particles.
- Charged particles will readily generate signals in almost any radiological sensor.

Shield/Cryostat	Suppression Factor*
7500SL Slimline Cryostat ULB Ultra-Low Background Hardware RDC-6 Remote Detector Chamber 6-inch 777 (6-inch) shield 777-3 Split Backshield	35%
7500SL Slimline Cryostat RDC-6 Remote Detector Chamber 6-inch 777 (6-inch) Shield 777-3 Split Backshield	30%
7500SL Slimline Cryostat 747/767 (4-inch) shield CFE-4 Cold Finger Extension & 7X7-2 Backshield	20%
7500SL Slimline Cryostat 747/767 (4-inch) shield No 7X7-2 Backshield	10%

(*) Ratio of suppressed (CosmicGuard activated) counts over unsuppressed counts measured between 100 keV and 2500 keV for an environmental background in laboratory conditions at near sea level (Meriden, CT, USA).



References

1. *Glenn F. Knoll, Radiation Detection and Measurement, 4th ed., J. Wiley & Sons, 2010, ISBN 978-0-470-13148-0*
2. *Gordon R. Gilmore, Practical Gamma-ray Spectrometry – 2nd ed. J. Wiley & Sons, 2008, ISBN: 978-0-470-86196-7*
3. *Eric TISCHENBACH, Personal communication, 2025, Mirion Technologies*

Thank you!

...for your attention...

Questions?