ORTEC®

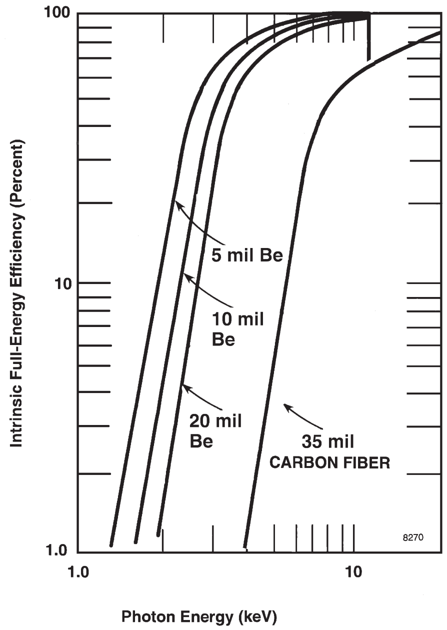
Low-Background Germanium Gamma-Ray Detectors

ORTEC can provide all GEM, GMX, LO-AX, and GWL detectors in low-background configurations, including SGD and PROFILE series GEMS.

The principles of the approach to reducing the background in a HPGe detector operate in two directions: reduction of the background intrinsic to the materials used to make the detector, and secondly reduction of the amount of radiation from any such materials which reach the detector element itself.

ORTEC Low-Background Detector Materials

- Standard endcaps for low-background GEM and GMX detectors without Be windows are Carbon Fiber. Carbon fiber endcap thickness for low-background detectors is 0.035". Low-background GWL detectors have oxygen-free high conductivity (OFHC) copper endcaps with low-background high purity aluminum well tubes of 0.02” wall thickness.
- If lower energies are required, copper endcaps with low-background Be windows are standard for low-background GMX and LO-AX detectors. The Be window is 0.020" thick for up to 3-1/4" endcaps and 0.030" thick for 3-1/2" endcaps.
- Detector internals (cup, cooling rod, cooling rod clamp and pedestal) are made of OFHC Copper for standard low-background detectors.
- Activated Charcoal is used as the cryo pump, having lower background than sieve.
- Detector flange is made of low cobalt steel.
- XLB option includes a 2 cm thick aged lead back shield between the preamplifier/HV and crystal.



Intrinsic Full-Energy Efficiency of GAMMA-X or LO-AX Detectors Equipped with Carbon Fiber or Beryllium Windows.

Low-Background Options for Streamline Detectors

The LB option is constructed as described above.

The XLB option offers an improvement (in most cases) over the LB, by the introduction of the aged lead back shield behind the crystal. (There are instances in which the absence of the lead back shield is preferable, such as when the secondary Pb x rays may create more background at the energy of interest than the additional background present due to the lead back shield’s absence.)

Low-Background Options for PopTop Detectors

The RB option is essentially the same construction as the LB, but the sieve pack in the capsule is retained in order to provide adequate pumping. The detector is shielded from the sieve by an OFHC copper cup.

The RB-B option provides a Be window in a Cu endcap instead of the Carbon Fiber endcap (for GMX and LO-AX detectors only).

LB Series HJ Cryostat Configuration

The popular HJ configuration is a side-looking cryostat with the preamplifier and high-voltage filter next to the dewar and thus remote from the detector; therefore, the lead back shield immediately behind the detector is unnecessary. Generally, this is the optimum configuration for shielding the detector element from the dewar, the cryogenic pumping material, the preamplifier, and much of the cryostat.

Factors Affecting Low-Background Gamma Spectroscopy with HPGe Detectors

The radiation background of standard cryostats used by ORTEC for germanium detectors is lower than that required for the majority of users. Net area peak counting rates ~0.1 counts/min are typical at energies of interest. Nonetheless, those measuring environmental samples who require the lowest MDAs in the shortest possible counting time will be best served by a large germanium detector in a LB or XLB cryostat. Coaxial detectors of efficiency from 80% to 175%, with their exceptionally high peak-to-Compton ratios (approaching 100 to 1), are also recommended (Ref. 1).

There are a number of naturally-occurring radionuclides that contribute to the gamma-ray background observed by spectroscopists using a germanium detector system. Contributions from the cosmic-ray induced background, ^{40}K from building structures, and radon, can be markedly reduced by appropriate shielding (including in some cases an underground location) and flushing the shield with “aged” nitrogen. The principal sources of activity from the cryostat are the primordial emitters, ^{238}U, ^{232}Th, ^{235}U and their daughters, man-made radionuclides including ^{137}Cs fallout, and the activation product ^{60}Co. There are both full-energy photopeaks and associated Compton background from 46 to 2600 keV.

In some materials, the natural emitter chains may not be in equilibrium. Therefore, ORTEC reports the measured background at all the energies shown in Table 1.

Different spectroscopists have different “low-background” requirements and energies to which the phrase “low-background” applies. Therefore, low-background cannot be rigorously defined as, for example, energy resolution at the 1.33-MeV line of ^{60}Co. For this reason various laboratories use different nomenclature and different report formats when describing measured background.

Table 1. Environmental Radionuclide Full-Energy Photopeak Energies.

Isotope (Parent Nuclide)	Energy in keV	Isotope (Parent Nuclide)	Energy in keV
U x-rays	13.0, 13.3*	^{137}Cs	661.6
^{231}U	25.6*	^{214}Bi (^{238}U)	727.2
^{137}Cs	31.8, 32.2, 36.4*	^{234m}Pa (^{238}U)	766.6
^{210}Pb (^{238}U)	46.5	^{228}Ac (^{232}Th)	911.0
^{234}Th (^{238}U)	63.3	^{228}Ac (^{232}Th)	969.0
^{234}Th (^{238}U)	92.6	^{234m}Pa (^{238}U)	1001.0
^{235}U, ^{226}Ra	185.7, 186.2	^{214}Bi (^{238}U)	1120.3
^{212}Pb (^{232}Th)	238.6	^{60}Co	1173.0
^{214}Pb (^{238}U)	295.2	^{214}Bi (^{238}U)	1238.0
^{214}Pb (^{238}U)	351.9	^{60}Co	1332.5
Cosmic	511.0	^{40}K	1460.8
^{208}Tl (^{232}Tl)	583.1	^{214}Bi (^{238}U)	1764.5
^{214}Bi (^{238}U)	609.3	^{208}Tl (^{232}Tl)	2614.5

* The lines lower than 46 keV are reported only for LO-AX and GMX detectors.

To satisfy the needs of spectroscopists, ORTEC does the following:

- Carefully selects low-background materials
- Characterizes completed HPGe detectors in a specialized low-background facility
- Produces the world’s largest detectors in the lowest-background cryostats — the ultimate for gamma spectroscopy of low-level samples
- Provides with each detector an activity report of the 22 most common isotopes
- Remains current with technology for low-background materials. Environmental spectroscopists seeking to minimize MDA while maximizing sample throughput should read: The Benefits of Using Super-Large Germanium Gamma-Ray Detectors for the Quantitative Determination of Environmental Radionuclides.
- For customers that require special configurations, ORTEC can work with the user to supply various materials or utilize customer supplied materials where possible.

Low-Background Spectroscopy Laboratory and Detector Background Certification Program

Low-background detectors are measured in the ORTEC Low-Background Test Facility, and a certificate is provided reporting the intensity of the lines listed in Table 1.

As a result of the differences in altitude and the extent of radioactivity in materials near to the detector, the background that will be observed at your location may be lower or higher than that measured in the ORTEC Low-Background Test Facility.

The ORTEC Low-Background Test Facility houses two lead shields, configured to accommodate detectors in various configurations. Each shield consists of a 3 inch OFHC copper “well” surrounded by eight inches of low-radiogenic lead. The copper virtually eliminates the lead x-rays resulting from photoelectric interactions of gamma rays with the lead.

For characterizing the materials to be used for detector cryostat construction, the low-background laboratory has a graded-Z (Pb, Cu, Cd) shield containing an ultra-low-background detector. Quality control limits have been established for each type of material dependent on its location in the finished cryostat.

Each completed detector is placed in the appropriate shield and calibrated.

Then, with the source removed, a detector background spectrum is acquired for 100,000 seconds. The background spectrum is searched using a second-difference peak-search algorithm. All identified peaks are visually examined. For any peaks that are part of the list reported as “not found,” a region-of-interest (ROI) is set manually, and the net area is computed by the MCA Emulation software. Finally, a report that lists the ROI net count rates is created.

The data are reported as intensities rather than activities because the activities are a function of the geometry of the calibration, while the intensities are geometry-independent.

The logarithmic plot (Fig. 1), linear plot (Fig. 2), and low-background analysis reports (Tables 2 and 3) show, for comparison, the gamma background spectra of two GEM detectors of identical relative efficiency (56%), one in a standard cryostat and the other in an extra-low-background (XLB) cryostat (Fig. 3). The difference in background is substantial. The background report can be supplied on disk if requested, and can be used in conjunction with the ORTEC MAESTRO MCA Emulation program to visually examine the data or to plot it.

It must be emphasized that the gamma background measured in a detector cannot be better than the background in the laboratory where the detector is operated. For example, health physicists making in vivo measurements should be aware that the beds or chairs in which the subject is placed are generally not made of materials selected for low gamma background and, also, that the subjects being measured emit gamma rays at a rate consistent with the 40–120 nanocuries of ^{40}K normally found in the human body. Therefore, while every precaution must be taken to obtain good, reliable measurements, it is useless to strive for the “ultimate in low-background” as some physics researchers operating in sophisticated underground laboratories must and can do.

The data obtained at ORTEC are representative of the low-background characteristics of the detector/shield combination in our facility in Oak Ridge, Tennessee. Since background results are dependent upon the shielding, better results may be obtained in sophisticated laboratories (e.g., with active shields or in deep mines).

An example of this for a 40% GEM in a vertical XLB cryostat is shown in Table 4. The third column is from the report of the ORTEC Low-Background Facility. The fourth column contains the reported results on the same detector in a sophisticated low-background laboratory (Ref. 2). Another example is given in Table 5, which reports results obtained at the Gran Sasso National Laboratory, an Italian research facility located under 3500 meters of rock, with a resulting cosmic background reduction of a factor of 10^6. The ORTEC detector has a measured efficiency of 96%. Extraordinary precautions were taken to minimize the gamma background.*

When comparing the data in Tables 2, 3, and 4, the following considerations must be kept in mind:

As there is no standard, laboratories use different formats for such tables; hence, the obvious differences between Tables 2 and 3 (both obtained at ORTEC) and 4 (obtained at the U.S. National Institute of Standards and Technology).

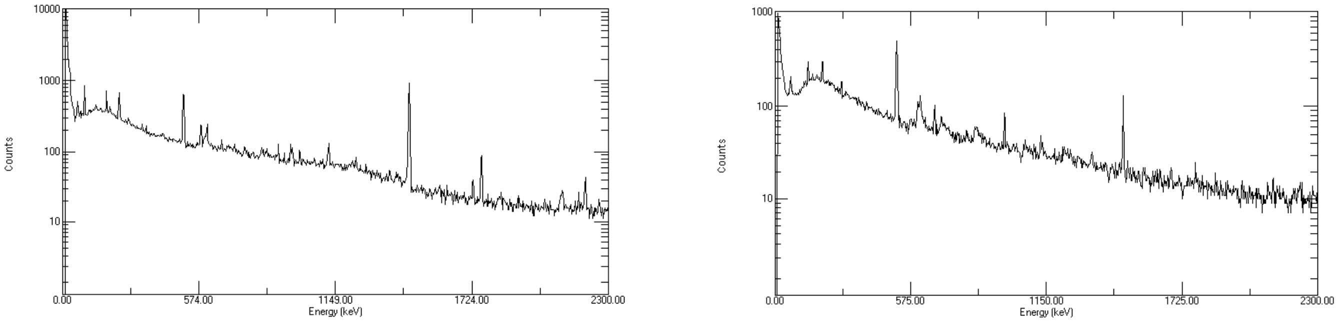


Fig. 1. Logarithmic Plots of Super High Efficiency 205% GEM Detectors in (a) Standard Cryostat and (b) LLB Cryostat.

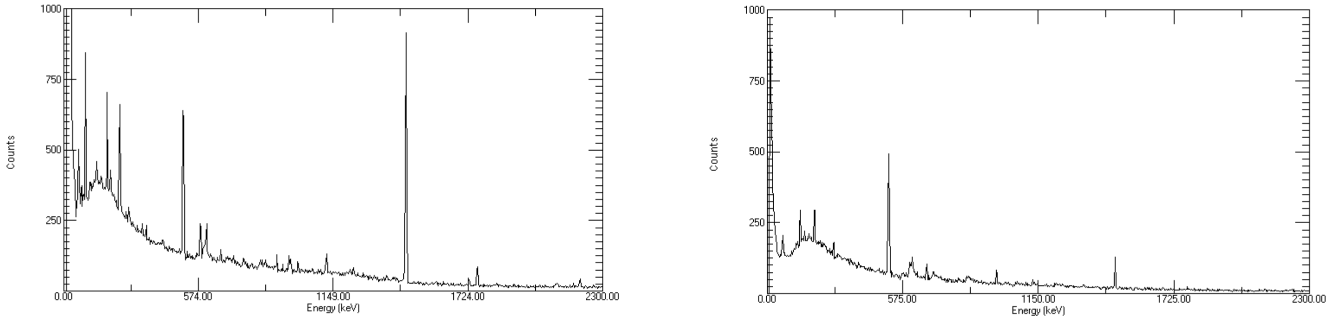


Fig. 2. Linear Plots of Super High Efficiency 205% GEM Detectors in (a) Standard Cryostat and (b) LLB Cryostat.

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The computer printout reports energy centroids rather than the energy of the nuclides. Therefore, some interpretation is required to understand the centroid/nuclide relationship between Tables 2 and 3 and Table 1. For example, Region #1 in Table 2 (centroid at 45.72 keV) indicates the counts due to ^{210}Pb in Table 1 (46.5 keV).

When comparing gamma background data obtained from detectors with different efficiency, the difference in efficiency should be factored in, at least in an approximate (linear) way.

A less sophisticated way of characterizing low-background detectors is reporting the total counts per second in a given energy interval, typically from 100 keV to 3 MeV. A large (96% efficiency) ORTEC detector measured at Gran Sasso, the world-class Italian laboratory under a mountain, registered 100 counts per second in that energy interval.

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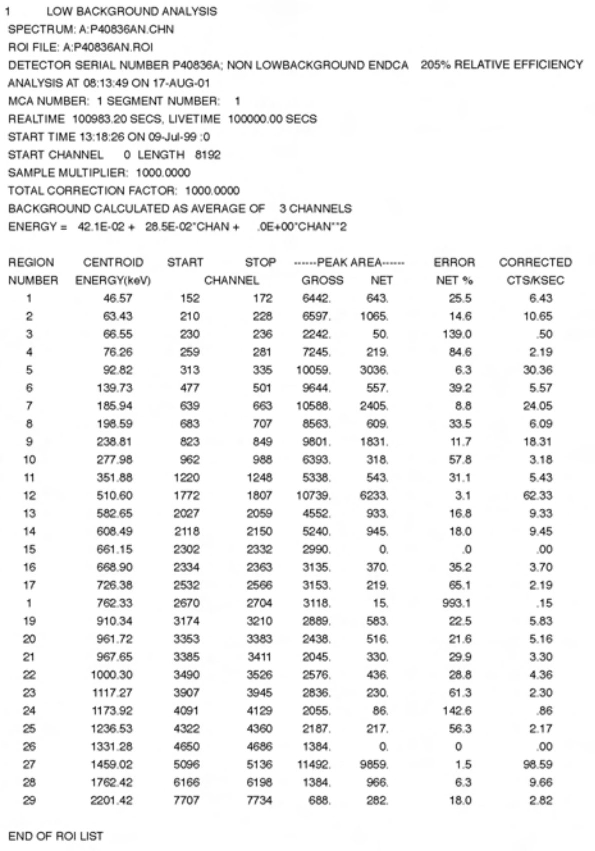
*C.R. Arpesella, et al., “A Low Background Counting Facility at Laboratori Nazionali del Gran Sasso.” (Internal Report LNGS – 92/35 July 1992).

Table 2. Low-Background Analysis Report for “Standard” Detector.



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1        LOW BACKGROUND ANALYSIS
 SPECTRUM: A:P40836AN.CHN
 ROI FILE: A:P40836AN.ROI
 DETECTOR SERIAL NUMBER P40836A; NON LOWBACKGROUND ENDCA   205% RELATIVE EFFICIENCY
 ANALYSIS AT 08:13:49 ON 17-AUG-01
 MCA NUMBER:  1 SEGMENT NUMBER:    1
 REALTIME  100983.20 SECS, LIVETIME  100000.00 SECS
 START TIME 13:18:26 ON 09-Jul-99 :0
 START CHANNEL     0  LENGTH   8192
 SAMPLE MULTIPLIER:  1000.0000
 TOTAL CORRECTION FACTOR:  1000.0000
 BACKGROUND CALCULATED AS AVERAGE OF    3 CHANNELS
 ENERGY =   42.1E-02 +   28.5E-02*CHAN +     .0E+00*CHAN**2

 REGION    CENTROID    START      STOP   ------PEAK AREA------     ERROR    CORRECTED
 NUMBER   ENERGY(keV)        CHANNEL       GROSS      NET          NET %     CTS/KSEC
    1         46.57      152       172     6442.      643.          25.5        6.43
    2         63.43      210       228     6597.     1065.          14.6       10.65
    3         66.55      230       236     2242.       50.         139.0         .50
    4         76.26      259       281     7245.      219.          84.6        2.19
    5         92.82      313       335    10059.     3036.           6.3       30.36
    6        139.73      477       501     9644.      557.          39.2        5.57
    7        185.94      639       663    10588.     2405.           8.8       24.05
    8        198.59      683       707     8563.      609.          33.5        6.09
    9        238.81      823       849     9801.     1831.          11.7       18.31
   10        277.98      962       988     6393.      318.          57.8        3.18
   11        351.88     1220      1248     5338.      543.          31.1        5.43
   12        510.60     1772      1807    10739.     6233.           3.1       62.33
   13        582.65     2027      2059     4552.      933.          16.8        9.33
   14        608.49     2118      2150     5240.      945.          18.0        9.45
   15        661.15     2302      2332     2990.        0.            .0         .00
   16        668.90     2334      2363     3135.      370.          35.2        3.70
   17        726.38     2532      2566     3153.      219.          65.1        2.19
    1        762.33     2670      2704     3118.       15.         993.1         .15
   19        910.34     3174      3210     2889.      583.          22.5        5.83
   20        961.72     3353      3383     2438.      516.          21.6        5.16
   21        967.65     3385      3411     2045.      330.          29.9        3.30
   22       1000.30     3490      3526     2576.      436.          28.8        4.36
   23       1117.27     3907      3945     2836.      230.          61.3        2.30
   24       1173.92     4091      4129     2055.       86.         142.6         .86
   25       1236.53     4322      4360     2187.      217.          56.3        2.17
   26       1331.28     4650      4686     1384.        0.          0            .00
   27       1459.02     5096      5136    11492.     9859.           1.5       98.59
   28       1762.42     6166      6198     1384.      966.           6.3        9.66
   29       2201.42     7707      7734      688.      282.          18.0        2.82

 END OF ROI LIST
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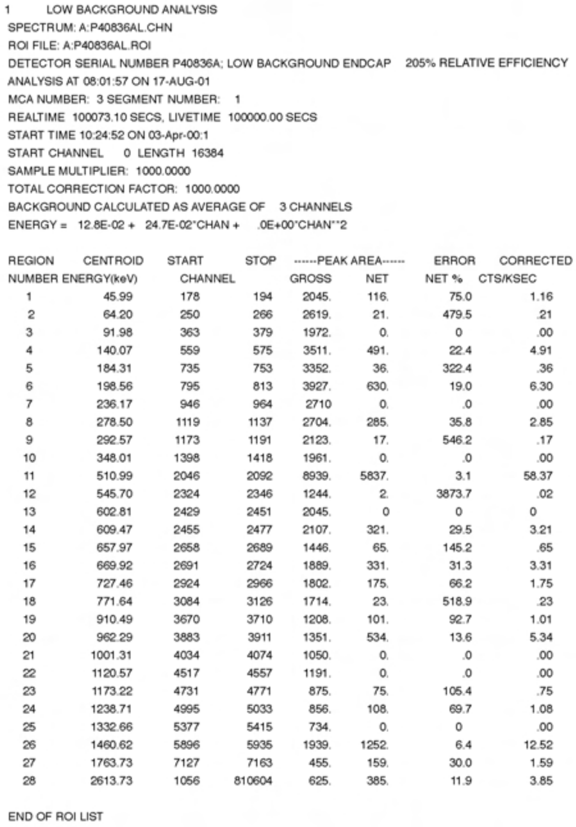
Table 3. Low-Background Analysis Report for “Low-Background” Detector.



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1        LOW BACKGROUND ANALYSIS
 SPECTRUM: A:P40836AL.CHN
 ROI FILE: A:P40836AL.ROI
 DETECTOR SERIAL NUMBER P40836A; LOW BACKGROUND ENDCAP    205% RELATIVE EFFICIENCY
 ANALYSIS AT 08:01:57 ON 17-AUG-01
 MCA NUMBER:  3 SEGMENT NUMBER:    1
 REALTIME  100073.10 SECS, LIVETIME  100000.00 SECS
 START TIME 10:24:52 ON 03-Apr-00:1
 START CHANNEL     0  LENGTH  16384
 SAMPLE MULTIPLIER:  1000.0000
 TOTAL CORRECTION FACTOR:  1000.0000
 BACKGROUND CALCULATED AS AVERAGE OF    3 CHANNELS
 ENERGY =   12.8E-02 +   24.7E-02*CHAN +     .0E+00*CHAN**2

 REGION      CENTROID    START      STOP   ------PEAK AREA------     ERROR    CORRECTED
 NUMBER ENERGY(keV)        CHANNEL          GROSS      NET          NET %   CTS/KSEC
    1          45.99      178       194     2045.      116.          75.0        1.16
    2          64.20      250       266     2619.       21.         479.5         .21
    3          91.98      363       379     1972.        0.          0            .00
    4         140.07      559       575     3511.      491.          22.4        4.91
    5         184.31      735       753     3352.       36.         322.4         .36
    6         198.56      795       813     3927.      630.          19.0        6.30
    7         236.17      946       964      2710        0.            .0         .00
    8         278.50     1119      1137     2704.      285.          35.8        2.85
    9         292.57     1173      1191     2123.       17.         546.2         .17
   10         348.01     1398      1418     1961.        0.            .0         .00
   11         510.99     2046      2092     8939.     5837.           3.1       58.37
   12         545.70     2324      2346     1244.        2.        3873.7         .02
   13         602.81     2429      2451     2045.        0           0           0
   14         609.47     2455      2477     2107.      321.          29.5        3.21
   15         657.97     2658      2689     1446.       65.         145.2         .65
   16         669.92     2691      2724     1889.      331.          31.3        3.31
   17         727.46     2924      2966     1802.      175.          66.2        1.75
   18         771.64     3084      3126     1714.       23.         518.9         .23
   19         910.49     3670      3710     1208.      101.          92.7        1.01
   20         962.29     3883      3911     1351.      534.          13.6        5.34
   21        1001.31     4034      4074     1050.        0.            .0         .00
   22        1120.57     4517      4557     1191.        0.            .0         .00
   23        1173.22     4731      4771      875.       75.         105.4         .75
   24        1238.71     4995      5033      856.      108.          69.7        1.08
   25        1332.66     5377      5415      734.        0.          0            .00
   26        1460.62     5896      5935     1939.     1252.           6.4       12.52
   27        1763.73     7127      7163      455.      159.          30.0        1.59
   28        2613.73     1056    810604      625.      385.          11.9        3.85

 END OF ROI LIST
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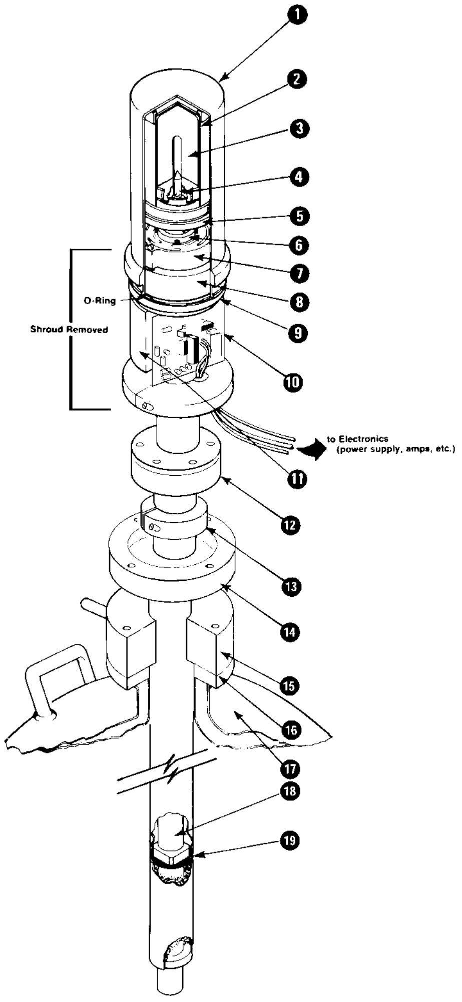

Legend:

1 **Endcap (Ni-plated magnesium) (with low-background Be, or carbon fiber window for GAMMA-X or LO-AX)**
2 **Detector mount cup (OFHC copper or, at additional expense, ultra pure aluminum)**
3 **Germanium detector element**
4 **Pedestal nut (stainless steel)**
5 **Pedestal (OFHC copper)**
6 **Cooling rod clamp (OFHC Cu)**
7 **Thermal insulator (plastic)**
8 **Shield (virgin lead), ~2 cm thick**
9 **Cryostat flange (stainless steel, low cobalt)**
10 **Preamplifier**
11 **HV filter (with Al shroud)**
12 **Pumpout port**
13 **Cryostat clamp**
14 **Collar mounting hardware**
15 **Fill collar (RTV rubber)**
16 **Dewar flange**
17 **Dewar**
18 **Cooling rod (OFHC copper)**
19 **Cryosorption material (charcoal)**

Fig. 3. Cutaway View of Model CFG-SV-XLB.

References

1. R. Keyser, T. Twomey, and S. Wagner, “Benefits of Using Super-Large Germanium Gamma-Ray Detectors for the Quantitative Determination of Environmental Radionuclides,” *Radioactivity and Radiochemistry* Vol. 1, No. 2, pp. 46–56 (Spring 1990).
2. R.M. Lindstrom, *et al.*, “A Low-Background Gamma Ray Assay Laboratory for Activation Analysis,” *Nucl. Instr. and Meth.*, **A299** (1990) 425–429.

Table 4. Comparison of ORTEC Low-Background Analysis with that in a Sophisticated Laboratory (NIST).

LOW-BACKGROUND ANALYSIS

DETECTOR SERIAL NUMBER P33P, GEM-40195,
Low Background Detector

REALTIME 100014.40 secs, LIVETIME 100000.00 secs

CENTROID ENERGY (keV)	NUCLIDE	NET Counts/1000 s (ORTEC LAB.)	NET Counts/1000 s (NIST)
53.6	^{73*}Ge	1.1	0.4
122.1	^{57*}Fe	0.33	0.3
145.3	^{238}U	0.7	Not detected
186.2	^{226}Ra	0.5	Not detected
238.6	^{212}Pb	1.3	0.5
295.2	^{214}Pb	0.9	0.4
352.0	^{214}Pb	1.5	1.0
511.03	ß+ annihilation	28	29
583.1	^{208}Tl	1.1	0.3
609.3	^{214}Bi	1.6	1.0
661.7	^{137}Cs	0.6	Not detected
727.1	^{228}Ac	0.5	Not detected
1120.0	^{214}Bi	0.6	0.3
1173.2	^{60}Co	0.3	0.6
1332.5	^{60}Co	0.1	0.6
1460.8	^{40}K	9	0.3

Table 5. Counting Rate of Main Gamma Lines for the 96% ORTEC Germanium Detector at Gran Sasso Facility. (1σ errors are indicated.)

Isotope	Energy	Counts/1000 s
^{238}U	295.2	0.22 ± 0.03
	351.9	0.44 ± 0.04
	609.3	0.33 ± 0.03
	1764	0.06 ± 0.01
^{232}Th	238.6	0.08 ± 0.02
	583.1	0.04 ± 0.01
	2614.7	0.02 ± 0.01
^{40}K	1460.7	0.09 ± 0.02
^{137}Cs	661.6	0.05 ± 0.01
^{60}Co	1173.2	0.04 ± 0.01
	1332.5	0.03 ± 0.01
^{125}Sb	427.9	
	600.6	
	635.9	
^{106}Ru	621.8	
	1050.1	

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