

## Advances in large-diameter, low-energy HPGe detectors

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The preparation of large diameter germanium crystals of both P- and N-types has made possible the construction of coaxial detectors of relative efficiency exceeding 100% for commercial exploitation. A new development involves large diameter (70 mm) N-type coaxial detectors of low length-to-diameter ratio ("LO-AX" detectors). These new detectors have similar resolution to available 50 and 60 mm diameter crystals; thus the low-energy photon efficiency of a 70 mm device is nearly twice that of a standard 50 mm detector. Spectra are presented and discussed from the monitoring of plutonium and americium lung phantoms and the study of mining samples as examples of two cases where the larger diameter detectors have advantages over the smaller detectors.

### 1. Introduction

The availability of large diameter germanium crystals of both normal and reverse electrode types has made possible the construction of coaxial radiation detectors of relative efficiency exceeding 100% for commercial exploitation. Several recent publications [3–5] have recently demonstrated the improvements in minimum detectable activity (MDA) or reductions in counting time that can be achieved by the use of such large coaxial detectors in applications of high resolution gamma-ray spectroscopy.

A new development involves large diameter (70 mm) N-type (reverse electrode) coaxial detectors of low length-to-diameter ratio ("LO-AX" detectors). This type of detector is optimized for X-rays and low energy gamma-rays, with resolution of 495 keV at 5.9 keV. The high efficiency and good resolution make this detector applicable to uses with low count rates and complicated spectra. Two such applications are lung counting and mineral analysis. In the health physics application of lung counting the detection of plutonium and uranium is needed for the protection of workers in the nuclear power industry. The growing concern over radionuclides in common materials has resulted in the need to perform analyses of mineral feedstocks to ensure that the resultant products meet local regulations.

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### 2. LO-AX construction

A cross-sectional drawing of a LO-AX is shown in Fig. 1. In order to achieve the low background requirements needed in some applications (e.g., lung counting), the endcap is constructed of selected low-background magnesium. The entrance window is constructed of selected low-background beryllium foil (0.75 mm thick) to allow for highest possible transmission of

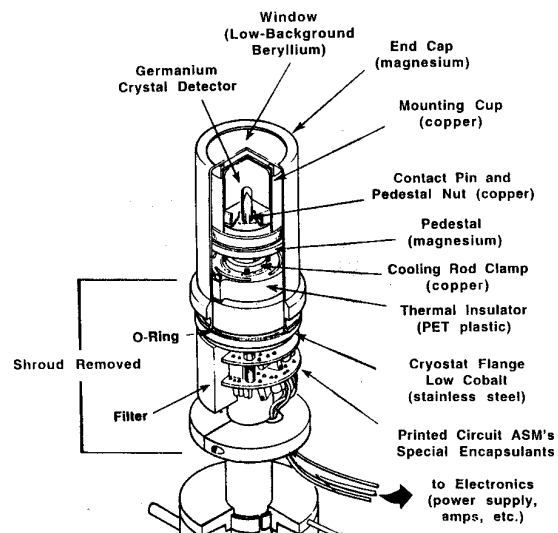


Fig. 1. LO-AX cross section.

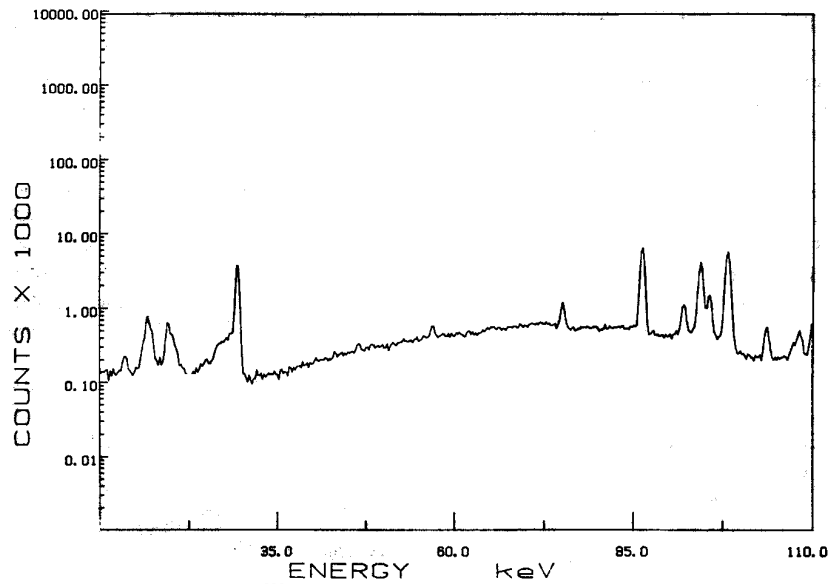


Fig. 3. Spectrum of  $^{239}\text{Np}$  in lung phantom using 70 mm LO-AX detector.

lung, which corresponds to the center of activity in the lung.

Fig. 5 shows the ratio of the net peak areas for the maximum position for both detectors as a function of

energy. The ratio of the two front surface areas is 1.88. The efficiency for the low energy photons is most dependant on the detector area, while the efficiency for the higher energy photons is affected by the detec-

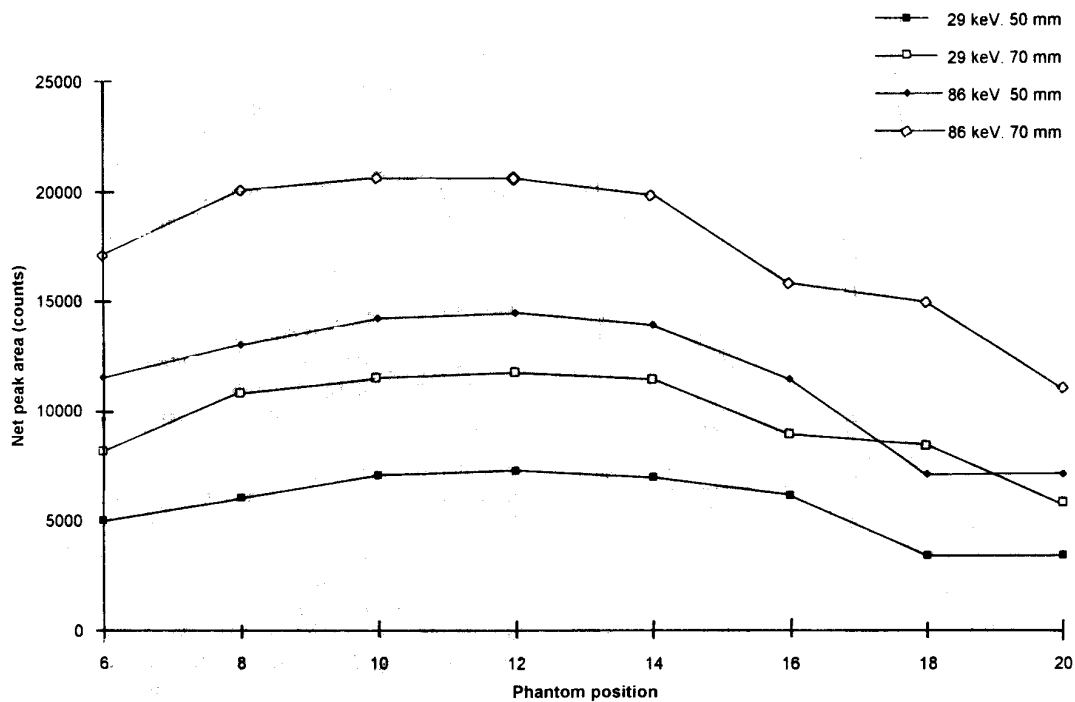


Fig. 4. Net peak area at 29 and 86 keV for 70 mm and 50 mm detectors on phantom grid F6 to F20.

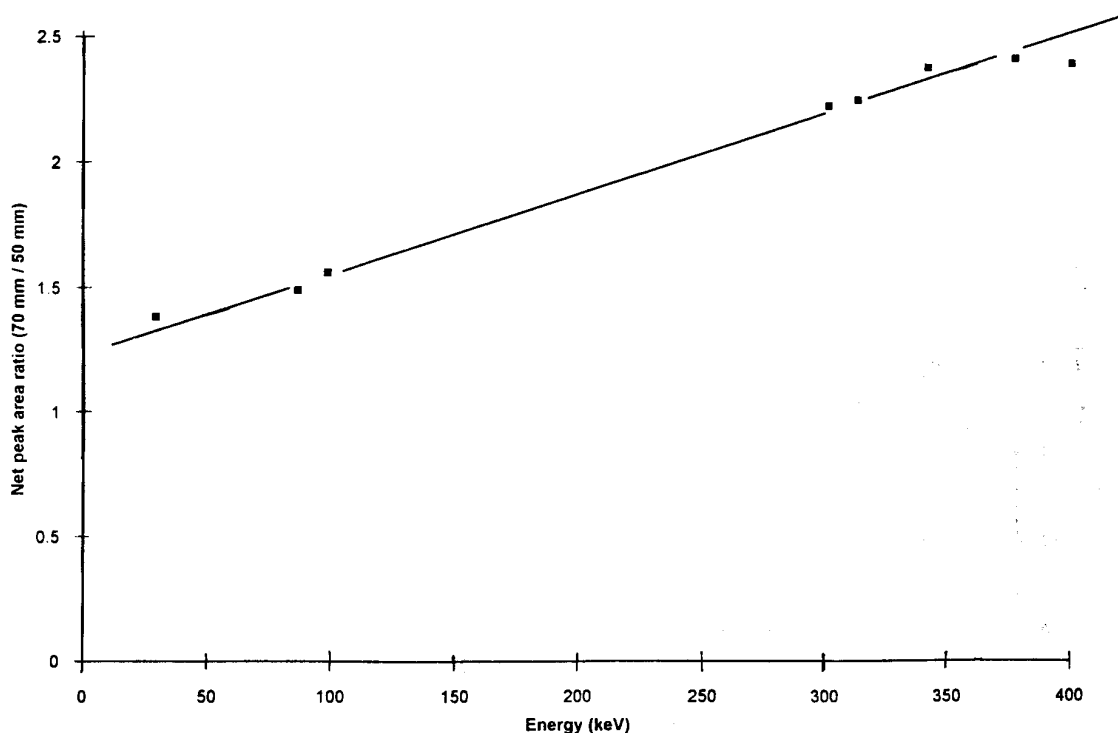


Fig. 5. Ratio of net peak area for 70 mm and 50 mm at maximum grid position.

tor volume (area and depth). Ratios of other detector positions are similar in shape and magnitude. The variation from the expected ratio at low energy can be attributed to photons striking the cylindrical side of the detector, increasing the effective surface area of both

detectors. The ratio for high energy photons shows the effect of the added depth.

In lung monitoring, which is a low count rate application, the background of the detector is also an important consideration. The background is the major

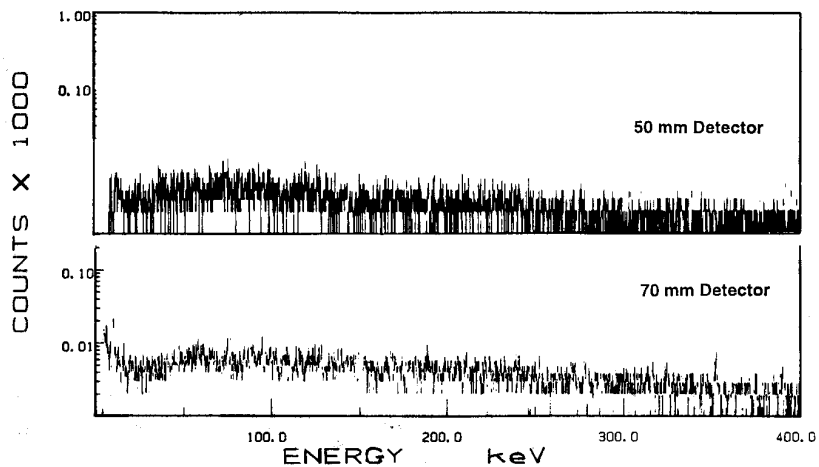


Fig. 6. Background spectrum with <sup>40</sup>K.

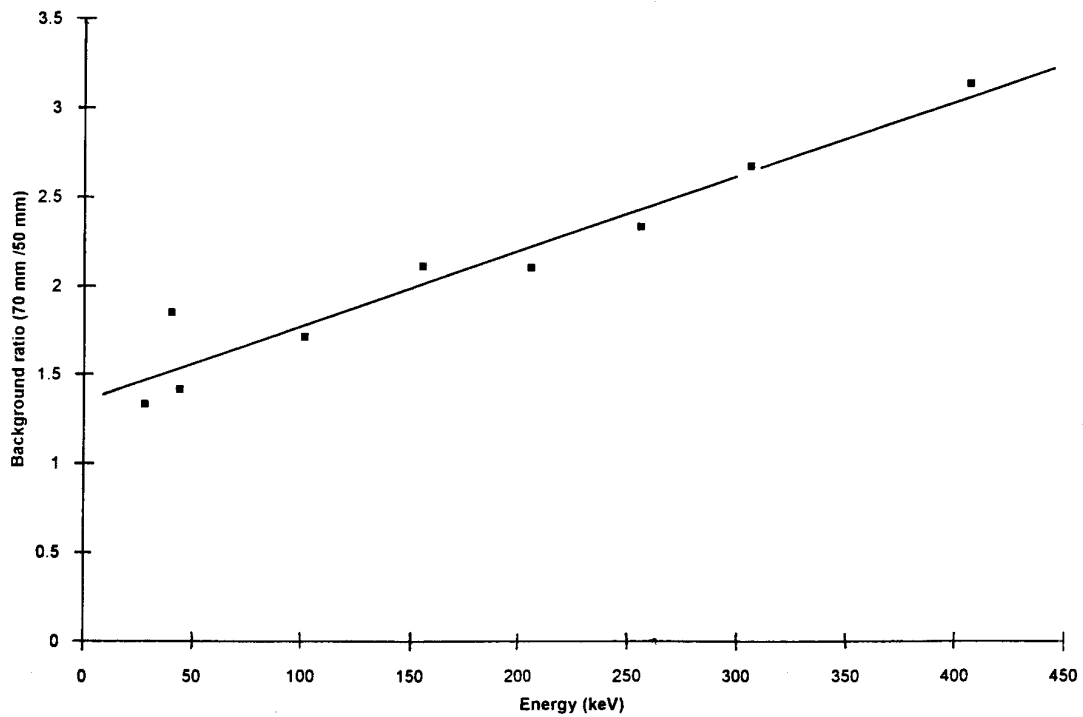


Fig. 7. Ratio of backgrounds (70 mm/50 mm) as a function of energy.

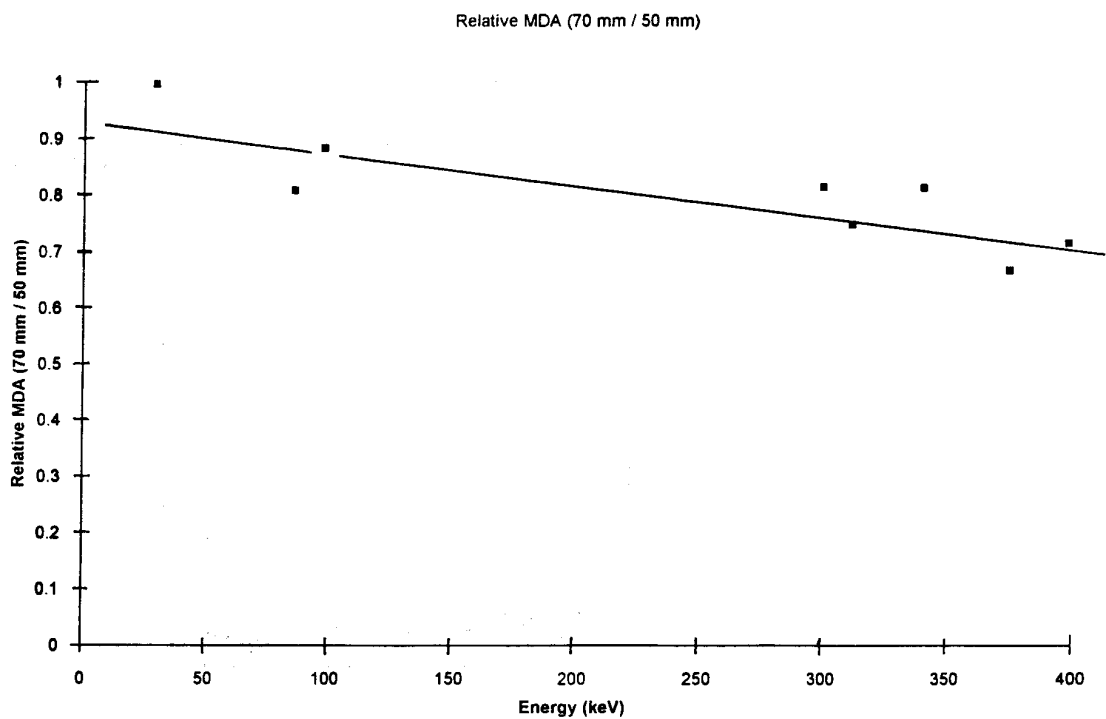


Fig. 8. Ratio of MDA (70 mm/50 mm) as a function of energy.

Table 1  
Resolution for 50 mm (planar) and 70 mm (LO-AX) detectors

Energy [keV]	FWHM [keV]	
	50 mm	70 mm
29	0.53	0.51
86	0.63	0.64
98	0.69	0.70
300	0.94	1.04
311	0.97	1.05
340	0.96	1.04
375	0.87	1.27
398	1.06	1.22

contributor to the MDA for the isotopes under consideration. Fig. 6 shows the background spectra for both types of detectors for a typical lung count, with 2.6 kBq of  $^{40}\text{K}$ . The human body has from 2 to 6 kBq of  $^{40}\text{K}$ , which is the major contributor to the background. Fig. 7 shows the ratio of the background for several energies of interest.

Using the formula for relative MDA [3], the relative MDA can be calculated using the background ratios and the net area ratios. Fig. 8 shows the relative MDA ratio as a function of energy. This is based on a gamma ray yield of 100%; different yields for different isotopes can give dramatically different MDAs for the same gamma ray energy. Relative MDA is used here because it separates the detector contribution from the other factors affecting MDA.

The detector resolution and peak shape are important when the spectrum is complicated, i.e. there are many overlapping peaks. In this case, analysis software must be used to determine the peak areas of the overlapping peaks.

#### 4. Mineral counting

The same two detectors were used to count uranium mine tailing samples. The samples were 9 cm diameter by 1 cm high plastic petre dishes. The data were collected in the shielded steel room, used for the lung counting. The background spectra in this situation would be the same as above, but often this type of sample is counted in low background shields and Fig. 9 shows the background in a good low background shield.

In this situation, the counting geometry was identical between the two detectors. The petre dish was placed in contact with the endcap and the center of the dish was centered on the detector center. A typical spectrum is shown in Fig. 10.

The comparison of the two types of detectors was done by comparing resolution and net peak area for several X or gamma rays in the spectrum. The FWHM resolution for several energies is shown in Table 2 which shows the same results as in Table 1.

Fig. 11 shows the ratio of the net peak areas for both detectors as a function of energy. As above, the ratio of the two detectors varies from the expected ratio at low energy. High energy photon efficiency is more important for mineral samples because of the likelihood that the sample will contain higher energy emitters.

Since the background for a mineral sample is usually dominated by the sample activity, Fig. 12 shows the ratio of the null and active-sample background for several energies near peaks in the sample spectrum.

The relative MDA can be calculated [2] from the background ratios and the net area ratios. Fig. 13 shows the relative MDA ratio for the null and sample-dominated case. As above, this is based on a gamma ray yield of 100%.

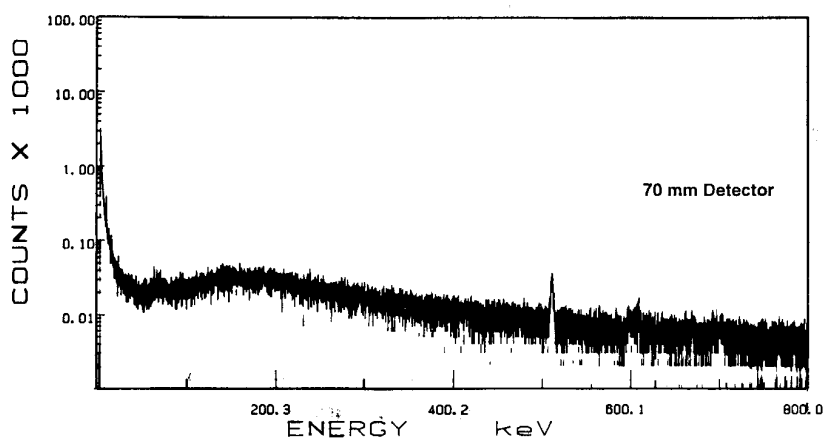


Fig. 9. Background (no  $^{40}\text{K}$ ) for 70 mm and 50 mm detectors.

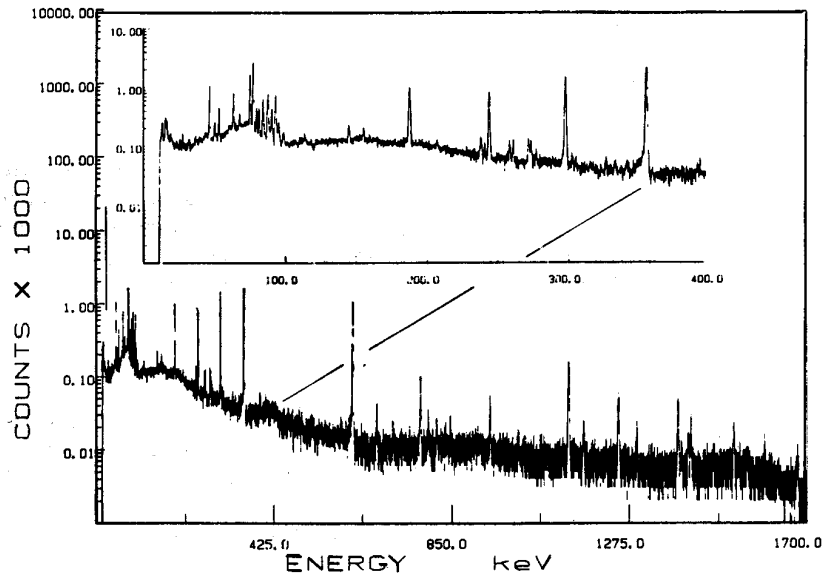


Fig. 10. Mineral sample spectrum.

5. Conclusion

The results for a 70 mm detector show the advantages over 50 mm devices for plutonium and uranium

counting in lungs and for monitoring the radioactive content in mineral samples. The 70 mm detector can be made with essentially the same resolution as the 50 mm device. At low energies, the larger device shows

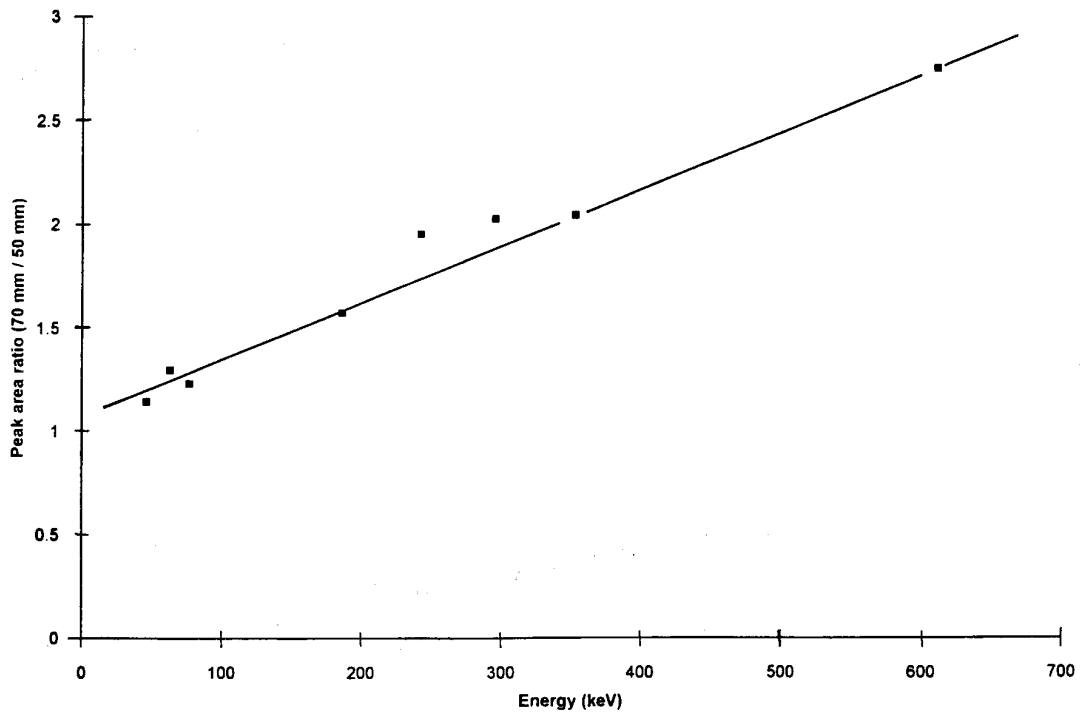


Fig. 11. Ratio of net peak areas (70 mm/ 50 mm) as a function of energy.

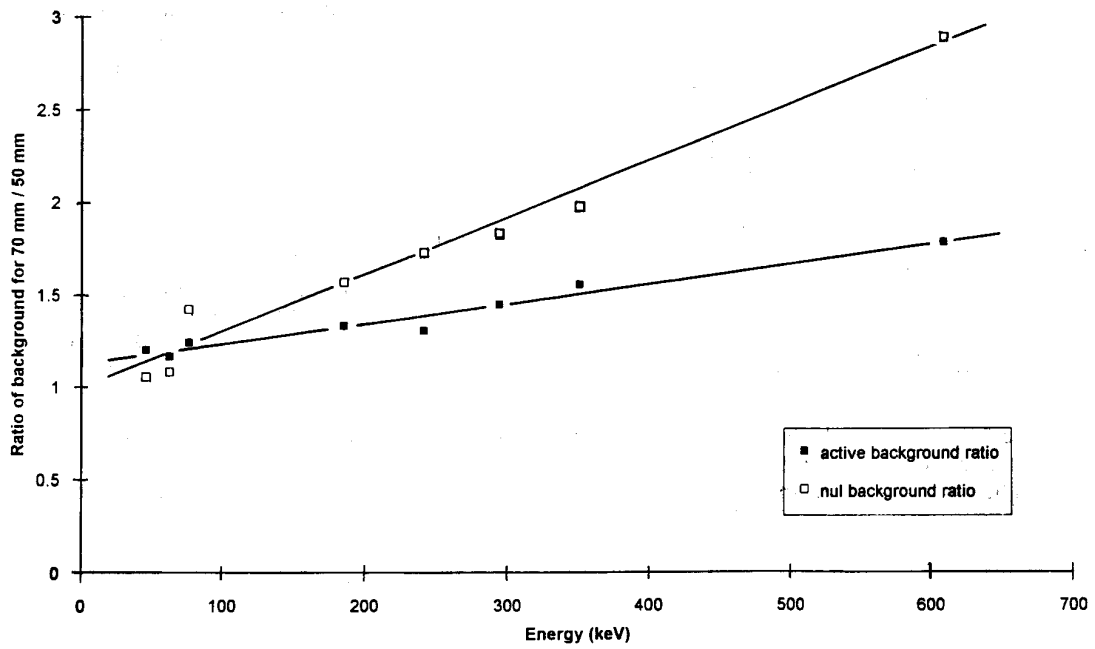


Fig. 12. Ratio of the background (70 mm/50 mm) for the null and active sample cases.

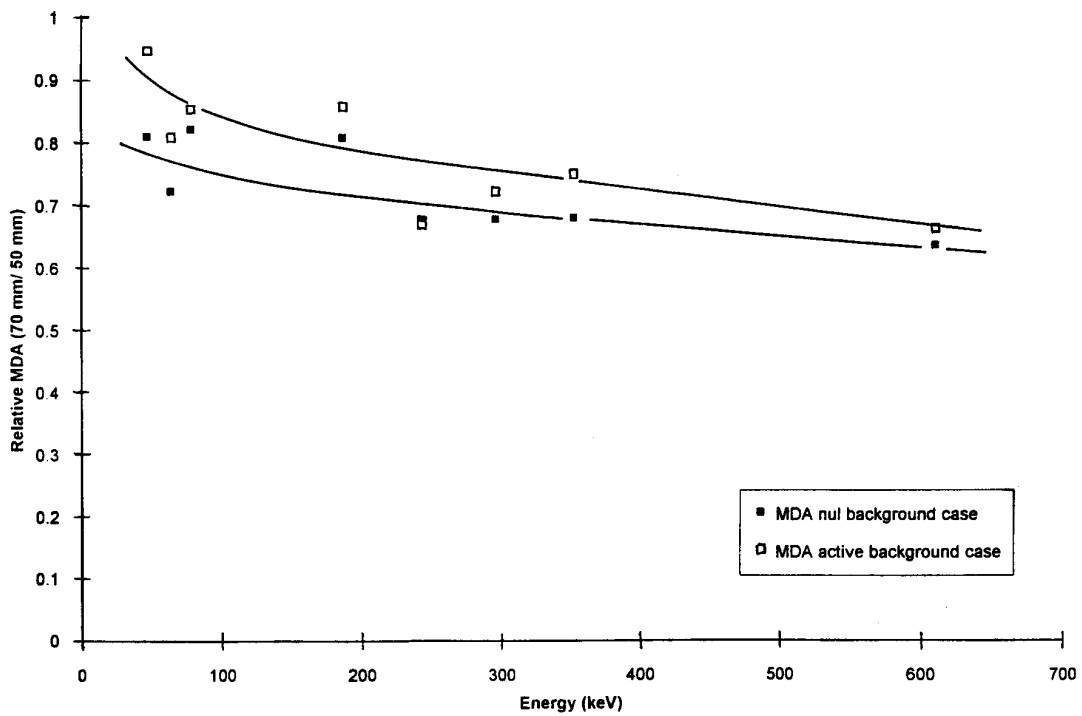


Fig. 13. Relative MDA (70 mm/50 mm) for null and active background cases.

II. RADIATION DETECTION

Table 2  
Mineral sample resolution for 50 mm (planar) and 70 mm (LO-AX) detectors

Energy [keV]	FWHM [keV]	
	50 mm	70 mm
46	0.55	0.55
52	0.53	0.59
63	0.54	0.66
76	0.65	0.66
185	0.89	1.02
294	0.94	1.06
351	1.02	1.21
609	1.28	1.73

increased efficiency due to the larger surface area. At higher energies the greater crystal thickness gives an additional benefit in efficiency. In cases where a single

large detector will perform as well as two smaller detectors, a single detector is preferable to multiple smaller detectors, from the standpoint of lower cost and operational simplicity.

Further studies are in progress to determine ways to change the design to improve the performance.

#### References

- [1] IEEE Standard Test Procedures for Germanium Gamma-Ray Detectors, ANSI/IEEE Std 325-1986 (1986).
- [2] M.S. Andreaco, R.S. Seymour and G.N. Martin, *J. Radioanal. Nucl. Chem.*, Art. 156 (1992) 323.
- [3] R. Keyser, T. Twomey and S. Wagner, *Radioact. Radiochem.* 1 (1990) 46.
- [4] J. Verplanke and W. Schoenmaekers, *Phys. Scripta VT32* (1990) 218.
- [5] R.M. Keyser, *Trans. Am. Nucl. Soc.* 64 (1991) 219.