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# Field of View Measurements on a Collimated Transportable HPGe System Used in Search Systems

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Abstract:

Mobile search systems are used to locate and identify radioactive material as the system is transported along a path. Both low and high resolution detectors are used in these systems. Low resolution detectors are often overwhelmed by high NORM background to the extent that the source signal is hidden. High resolution germanium detectors are more selective with easily identifiable peaks and the sensitivity can be improved further with background reduction. The detection efficiency is peaked in the forward direction, but to achieve the highest sensitivity possible the gamma ray flux from other directions must be reduced. In some circumstances the interfering radioactive background flux may be much higher than the flux from the source of interest. For example: a shipping container full of NORM may be used in an attempt to mask the presence of a concealed SNM source. It is therefore often desirable to examine only one area, object or container at a time to localize a source in a search operation. To do this, it is helpful to restrict the field of view of the instrument by shielding. For a mobile system, the shielding must be as small as possible to reduce the total weight of the system. The performance of a large diameter HPGe detector in a mobile housing was measured for all angles and for multiple energies to determine its effectiveness in reducing the count rate from material outside the desired field of view. Results show the need for the off-axis shielding to be increased to improve the detection of a particular nuclide source in an area where other significant radioactive materials are present.

**Keywords:** radioisotope; portable systems; germanium detectors; HPGe; search systems

## INTRODUCTION

The Detective 200 is a transportable, high sensitivity nuclide identifier based on a High Purity Germanium (HPGe) detector cooled by a Stirling cycle cryo-cooler and shown in Fig. 1.


**Figure 1 Detective-200**

It is designed to be used in a variety of applications such as mobile search systems and is transportable and battery operated. The instrument is self-contained, can operate on vehicle power, and withstand the vibration and shock expected in the field of use. It meets the requirements of IP67, is waterproof, dustproof, and floats in water. A companion device (Fig. 2) that operates on mains power is the IDM 200 which is suited for fixed-installation applications. The advantages of high resolution spectra have been described [1], with the main feature being that the peak-to-background (signal to noise) ratio is high. The detection efficiency is highest in the forward direction, that is, from the front of the crystal, which improves the source location ability for mobile systems. The signal-to-noise can be further improved by reducing the interfering counts from directions other than the front.

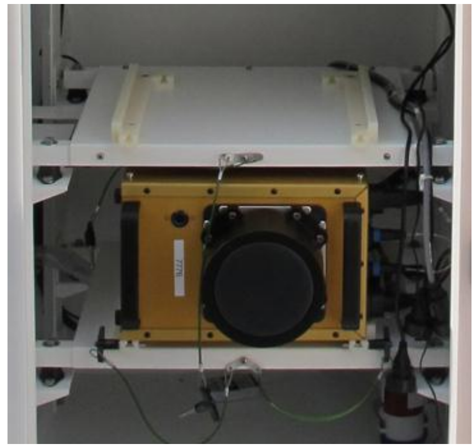

**Figure 2 IDM-200 installed in a Detective-SPM portal monitor**

To determine the sensitivity from all directions and thus show where the shielding should be placed for maximum effectiveness, the response to a multi-energy gamma ray source was measured in two perpendicular planes through the detector crystal axis. The results show that collimation on the rear and sides could be used to reduce the gamma rays from materials other than from the direction of the objects being scanned. The amount and quality of the shielding needed will depend on the expected environment.

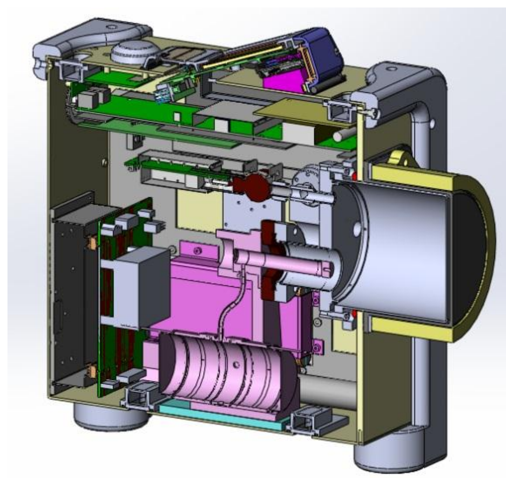

**Figure 3 Detective 200 vertical Cross section**

Previous works [2, 3] showed the performance of different tungsten collimators on earlier models of the Detective. Neither collimator reduced the background totally for those devices.

## Equipment

The equipment used in the test was a Detective 200 with only the built-in, removable steel collimator around the crystal. The crystal dimensions are 85 mm diameter and 30 mm long.

The Detective cross section is shown in Figs. 3 and 4 for two planes measured. The detector mount, cryostat, and other internal

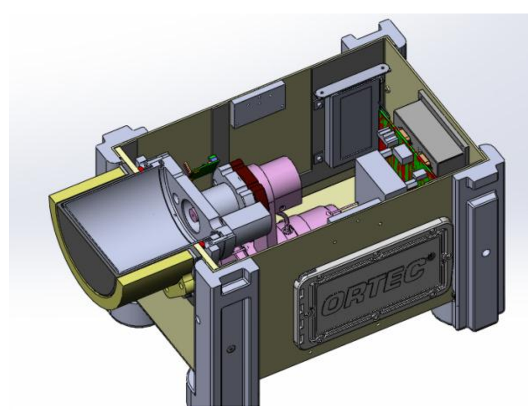


**Figure 4 Detective 200 horizontal Cross section**

parts provide some attenuation of the gamma ray flux in certain directions.

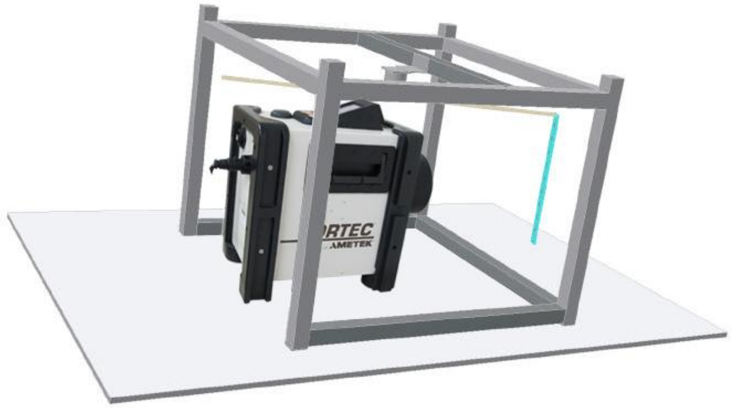


Figure 5 Detective 200 in Source Mover

The mixed gamma ray source ($^{241}$Am, $^{137}$Cs, and $^{60}$Co) was moved in a circle with the center at the center of the detector in a computer-controlled source mover.

The source placement and Detective are shown in Fig. 5. The source-to-detector distance selected is the minimum distance needed to rotate completely around the Detective. The sources were vertically located at the center of the detector. The data were collected using an external PC and GammaVision.
Figure 6 shows the angular measurements with the angles measured counterclockwise. Data were collected in 10 degree increments and the 0 degree measurement was repeated at 360 degrees. The data were collected with the motion in the counterclockwise rotation and then repeated in the clockwise rotation. The two sets of net peak areas are summed.

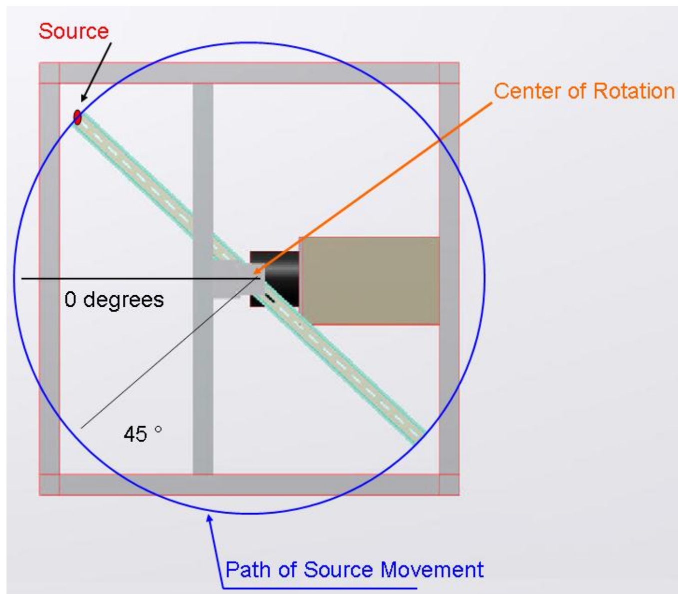


Figure 6 Angular Definition for Source Position Around the Detective 200

The sources have gamma-ray energies covering the energies of principal interest for SNM detection, namely from 30 keV to 1.3 MeV. The 1.4 MeV gamma-ray peak from $^{40}$K and the 2.6 MeV gamma-ray peak from $^{208}$Tl were monitored as a quality check on the spectra, as it should be constant for each series of measurements.

## RESULTS

Background

The background spectrum in the laboratory used for the measurements is shown in Fig. 7 and is typical of unshielded detectors. The total count in the spectrum is about 88.3 counts per second over the energy range of 30 keV to 3.0 MeV.

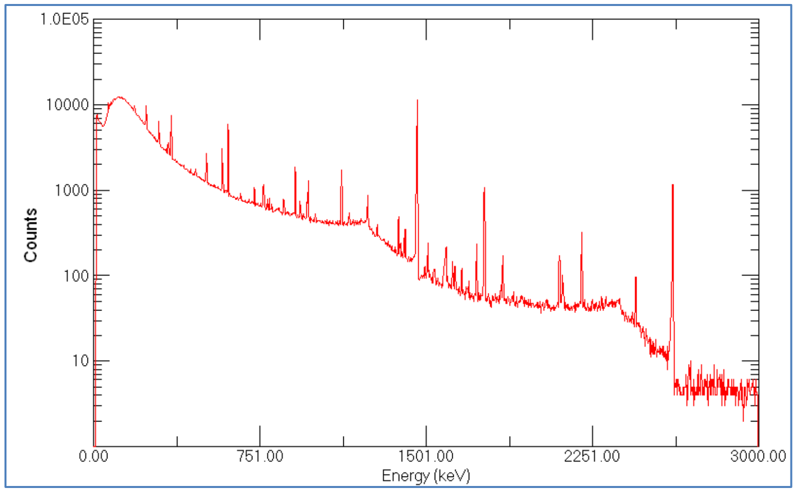


**Figure 7 Laboratory Background of Detective 200 (100000 s)**

The measured efficiency using a point source at 25 cm from the front face of the detector is shown in Fig. 8. This shows the usual efficiency curve for a p-type detector with a reduced thickness front surface contact. The IEEE relative efficiency for 1.3 MeV is about 50%.

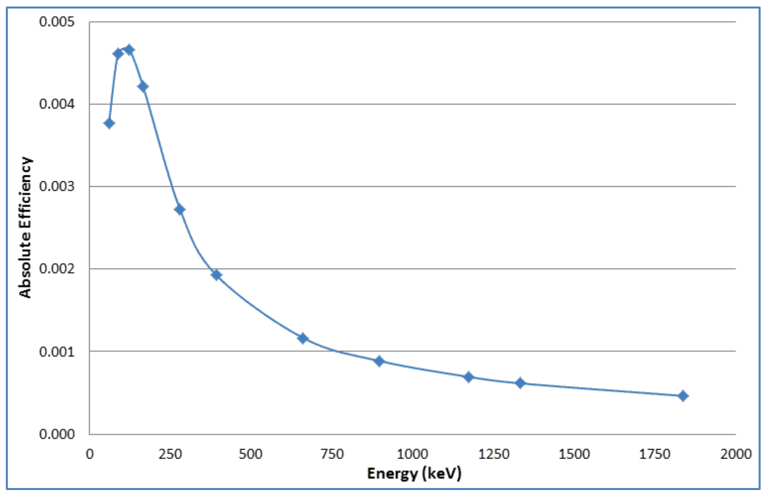


**Figure 8 Absolute efficiency of point source at 25 cm by energy**

The standard collimator is a 12 mm thick steel cylinder concentric with the detector. The compact construction of the Detective does not have space directly behind the detector for the addition of shielding materials.

Figure 9 shows the relative response as a function of angle as defined in Fig. 4 with the steel collimator. The 59, 661, 1173, and 1332 keV energies are shown. The 1460 keV line from the background is shown as a monitor. At 59 keV, the horizontal field of view is about ± 48° for the 50% detection level. The field of view widens to about ± 70° at higher energies. The field of view determines the

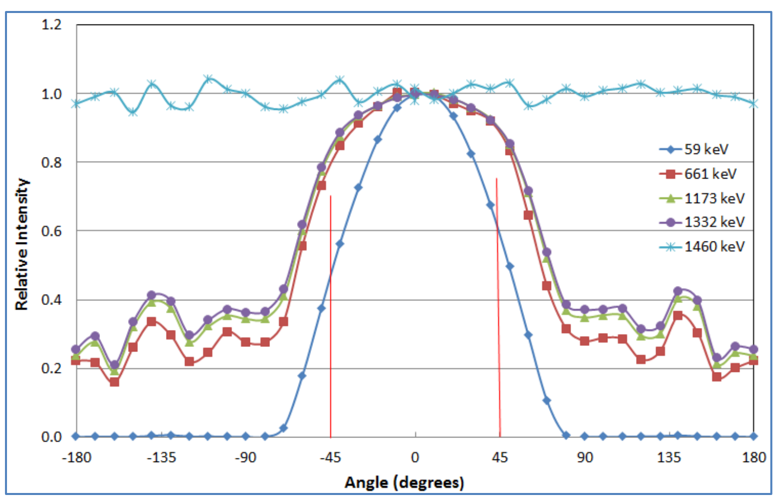


**Figure 9 Relative Angular Response in the horizontal plane for several energies**

width of the area in front of the Detective for searching or localization.

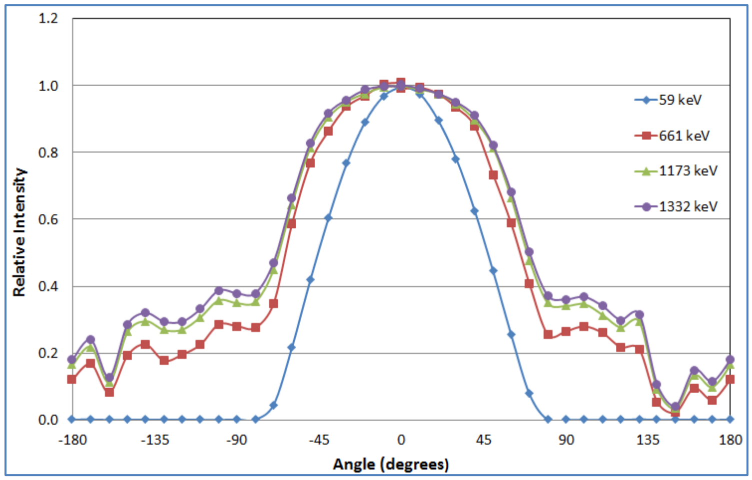


**Figure 10 Relative Angular Response in the vertical plane for several energies**

The collimator reduces the background from the side. Equally important is the reduction in the counts from the remaining area, especially from the rear. Figure 9 shows that with only the internal material for shielding, the reduction at low energies is nearly 100%, but at higher energies, the reduction in count rate is 60 to 70% of the front face count rate. The variation with angle depends on the path through the internal components, as shown in Fig. 4. Note the reduced attenuation at about 135° from the front direction.

Figure 10 shows the same measurement for the vertical plane. The results are similar for the front and side sensitivities because the unit is symmetric about the detector axis for the front hemisphere. Note that the reduced attenuation seen in Fig. 9 is not as pronounced in Fig. 10. The transmission through the back is different in the vertical horizontal planes because of the placement of internal components. From the rear, the vertical plane intersects the cooler and other metal parts.

## CONCLUSION

The Detective 200 efficiency is forward peaked with a field of view ranging from 90° at 60 keV to 140° at 1.3 MeV. The field of view is limited by a steel collimator around the detector. The restriction increases the sensitivity to materials in the field of view by reducing the interference from gamma radiation from other directions. The internal components reduce the interference due to gamma radiation from behind by 60 to 70% at 600 keV and above, and by 100% at 59 keV. The background could be further reduced by placing shielding directly behind the instrument. This extra shielding would improve the detection and localization ability, especially in areas with elevated background or other sources of interference.

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