Background Reduction Using Collimators on a Portable HPGe Nuclide Identifier

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ABSTRACT
The portable germanium detector based HHRIDs are generally intended to be operated in low to medium radiation fields with as much sensitivity as possible. However, in some circumstances the interfering radioactive background may be significant with respect to 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 searching operation. To do this, it is helpful to restrict the field of view of the instrument by collimation. Previous work showed the performance of two simple collimators (tungsten and steel) to be somewhat ineffective in reducing high energy (>1 MeV) gamma rays and that the tungsten fluorescence (59.3 keV) caused false positive misidentifications. A new graded-Z collimator was constructed of tungsten, tin and copper. The performance of this collimator was measured for all angles and for multiple energies to determine its effectiveness in reducing the count rate from material beyond the desired field of view. Results show the sensitivity for off-axis positions to be improved when locating a particular nuclide source in an area where other significant radioactive materials are present.

Keywords: radioisotope; portable systems; germanium detectors; HPGe; illicit trafficking; collimators

INTRODUCTION
The Detective was designed to be sensitive enough to meet the ANSI N42.34 and IAEA specifications for detecting and identifying radionuclides in a variety of situations. In some cases, however, it is necessary to shield against gamma rays from materials other than the object of interest or to reduce the gamma ray flux from the object itself.

Previous work [1] showed the performance of a tungsten collimator (4.7 mm thick) which did not have sufficient attenuation for side-incident gamma rays. In addition, the fluorescence X-ray from tungsten was shown to cause potential interference problems with the principle gamma ray of ^{241}Am. A second collimator was designed and built to improve the performance in high gamma ray fluxes. Since the Detective is intended to be a portable instrument, the collimator was made as small as possible.

The effectiveness of the collimator to reduce background gamma rays and the impact of the collimation on the efficiency are shown.

Equipment

The equipment was a Detective 100 and a tungsten collimator with removable tin and copper liners. The Detective has been described in previous work [2, 3] and is shown in Fig. 1. The copper layer was inserted inside the tin layer as shown in Fig. 2. The ^{57}Co, ^{60}Co and ^{133}Ba sources were moved in a circle with the center at the center of the detector in a computer-controlled source mover.

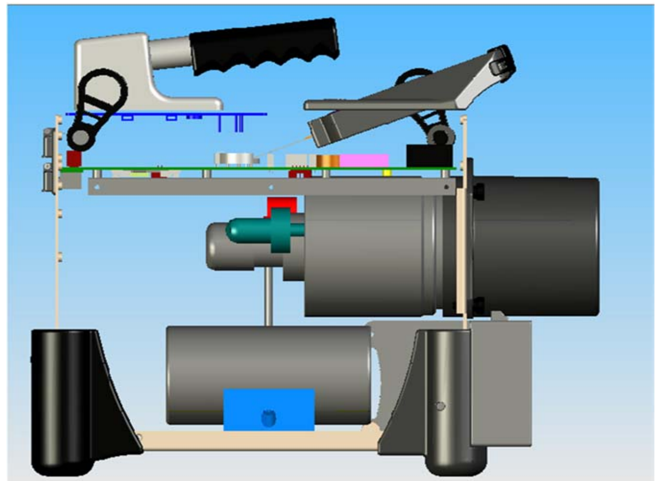

Figure 1 Detective 100

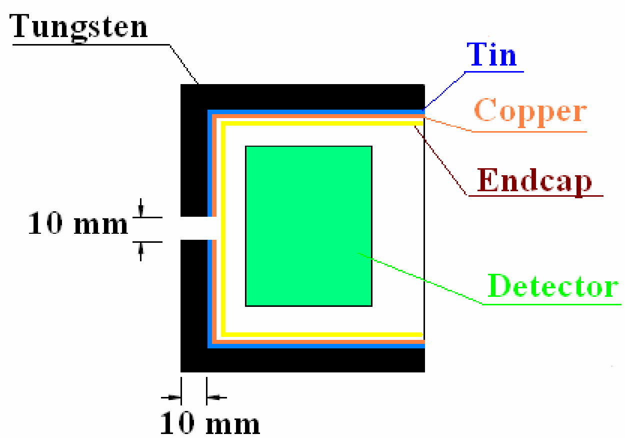

Figure 2 Collimator Construction

The source placement and Detective are shown in Fig. 3. 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 neutron detector was not used in these measurements. The data were collected using an external PC and GammaVision.

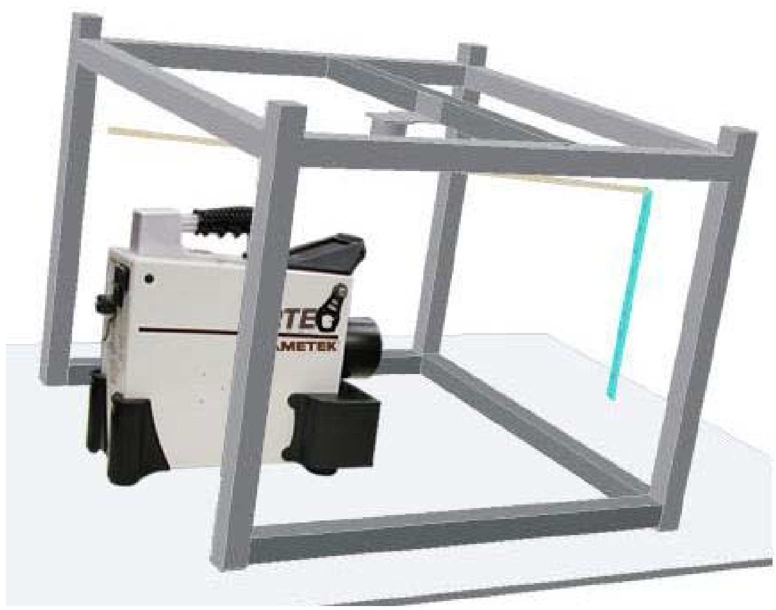

Figure 3 Detective 100 in Source Mover

Figure 4 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.

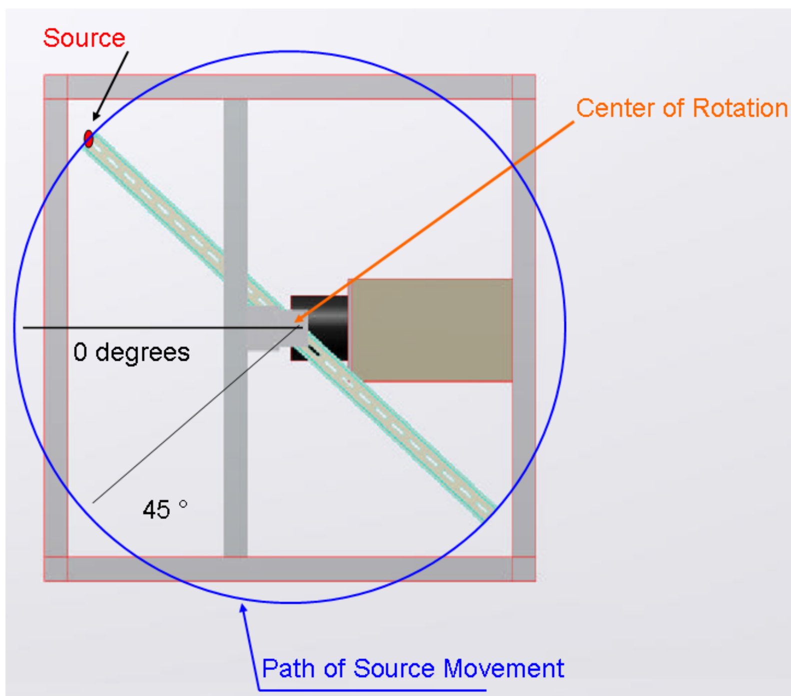

Figure 4 Angle Definition for Source Position Around Detective 100

Spectra were collected for the room background for the no-collimator, tungsten-only, tungsten-with-tin, and tungsten-with-tin-and-copper. Spectra were also collected for the collimator combinations with the sources on the source mover. The sources had 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 from ^{40}K was monitored as a quality check on the spectra, as it should be constant for each series of measurements.

RESULTS

Background

The background spectrum with no collimator is shown in Fig. 5 and is typical of unshielded detectors. The total count in the spectrum is 34.3 x 10^5 counts in 12 hours. With the tungsten collimator this is reduced to 6.9 x 10^5 counts and for the graded-Z collimator is 7.3 x 10^5 counts. Of interest is the spectrum region at 59 keV, (Fig. 6) which shows the tungsten X-ray at 59.2 keV for the shield without the tin or copper. This shows the need for the liners as this X-ray is easily falsely reported as ^{241}Am. The shield achieves a significant reduction in the counts per channel up to 1 MeV, and a noticeable reduction up to 3 MeV.

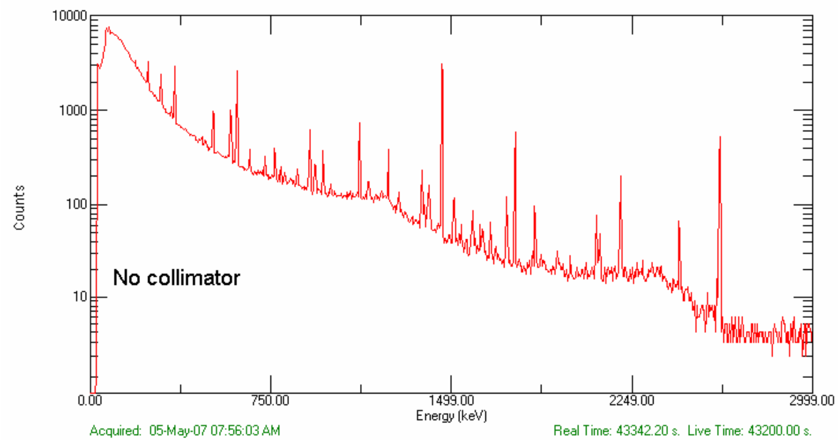

Figure 5 Background with no Collimator

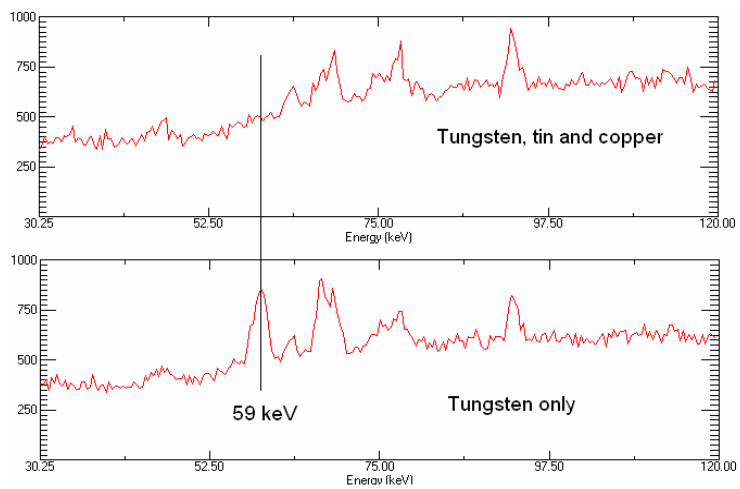

Figure 6 Comparison of Background Spectra with and without tin and copper liner

Angular Effectiveness of the collimator

The collimator surrounds the front and side of the detector. The compact construction of the Detective does not have space behind the detector for the addition of shielding materials. Figure 7 shows the relative response as a function of angle as defined in Fig. 4 for the case of no collimator. Only the 35, 81 and 1332 keV energies are shown. The response for other energies follows the same pattern with increasing penetration of the shield with increasing energy. Note that the efficiency above about 200 keV is nearly uniform for angles from 90° to 270° through 0°. The increase around 130° is due to the non-uniformity of the mounting structure. The sharp reduction at 180° is due to the shielding of the detector crystal mounting and support materials.

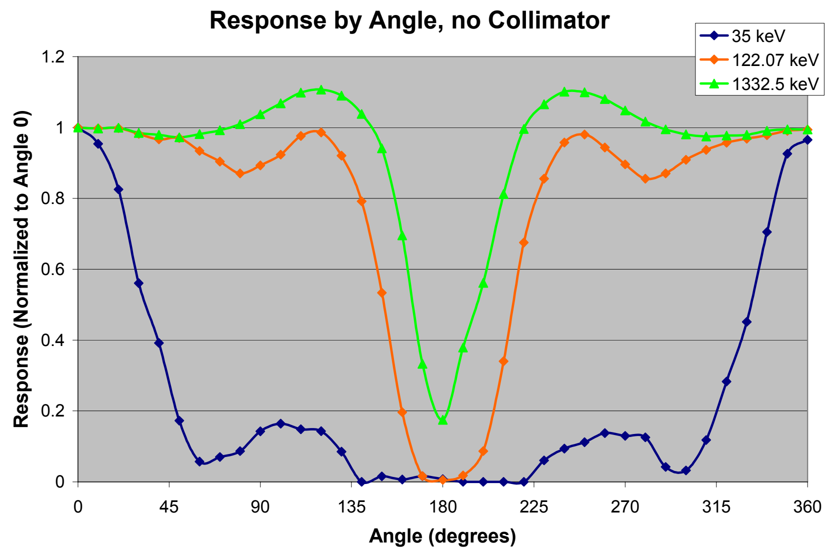

Figure 7 Relative Angular Response with No Collimation

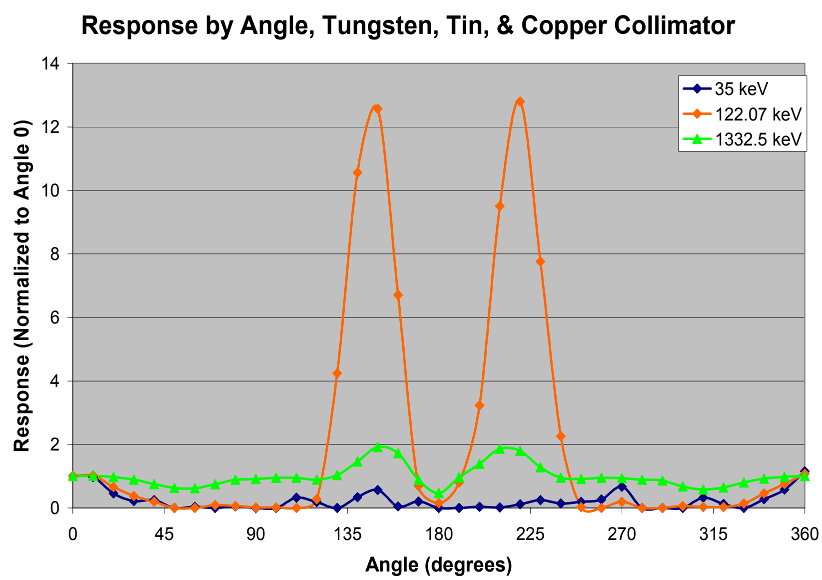

Figure 8 Relative Angular Response for Tungsten, Tin and Copper Collimator

Figure 8 shows the same curves for the collimator case. The collimator reduces the field of view more at low energies than at high energies (due to the fact that higher energy gamma-rays are not completely suppressed); reducing the low energy efficiency response at the front (0°) while having no effect at the back (180°), so the relative ratio at the low energies shows a proportionately greater increase than at the high energies which are not stopped by the collimator in the front.

Figure 9 shows the ratio of the count rates for the collimator on and off. This shows the collimator removes about 40% of the front high energy gamma rays and about 98% of the low energy gamma rays. The side incident gamma rays are reduced by 75% and 90% respectively. The collimator has no impact on the gamma rays from the back of the instrument.

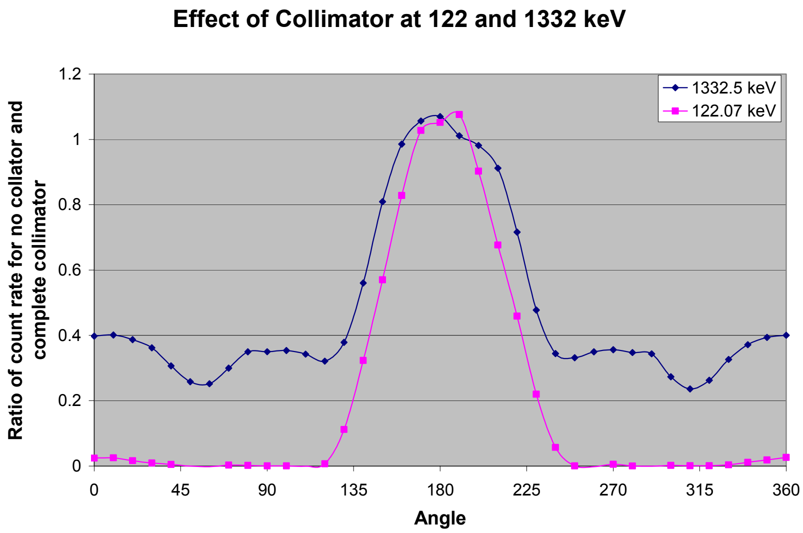

Figure 9 Affect of Collimator at 122 and 1332 keV

CONCLUSION

The addition of a graded – Z collimator to the Detective does reduce the count rate from the side and reduces the frontal field of view of the detector. The collimator used (10 mm tungsten, .030 tin and .020 copper) reduces the gamma flux by at least 40% in the frontal direction and removes at least 75% of the side-incident gamma-rays. The tin and copper suppress the tungsten X-ray to reduce the false identification of ^{241}Am. The collimator does not extend behind the detector leaving the detector unshielded from this direction, although some degree of shielding is provided by the instrument hardware and detector mounting cup.

REFERENCES

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