

Performance of an Improved HPGe-based Radioisotope Identifier (RIID) in the Identification of SNM and SNM Mixtures

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Abstract

The Detective-EX handheld radionuclide identifier has proven useful in the detection and interdiction of illicit trafficking of radioactive and nuclear materials in shipments and other important situations. The high number of medical, industrial and Naturally Occurring Radioactive Materials (NORM) legitimately present in many places require that the nuclides must be accurately and rapidly identified. The RIID (Radioisotope Identifier) is used to identify the nuclides in the shipment as the second step in the interdiction process. To meet the need for detecting smaller quantities of radionuclides, a RIID with a larger HPGe detector was developed. The first instrument contained a nominal 12% (IEEE relative efficiency) detector while the new instrument contains a nominal 45% detector. This improves the sensitivity while maintaining the accurate identification of nuclides and the reduction of the false positive rate and the innocent alarm rate. In this work, the performance of the two HPGe instruments in the identification of uranium and plutonium is compared. The ANSI N42.34 requirements are the basis for the tests. Previous work also showed the performance of a HPGe-based RIID with mixtures of nuclides. The single nuclides and certain mixtures of nuclides for both shielded and unshielded sources in the standard were used. Results comparing the performance of both systems, with the standard and with each other are given. The results show the larger HPGe system provides the correct identification more rapidly on the test samples, indicating that smaller amounts of material can be detected in the specified times.

Introduction

The currently deployed HPGe-based RIIDs have proven useful in many situations. In some cases, more sensitivity was desired. The higher sensitivity would enable the detection and identification in a shorter time or for a smaller quantity in the specified time. The identification is important because of the large number of legal shipments in the US containing enough radioactive material, either NORM, medical or industrial (as classified by ANSI 42.34) to cause a significant number of gross activity alarms. Previous work showed the ability of the HPGe-based RIID to locate material and identify SNM in spoofing or masking mixtures as defined in the standard ANSI 42.34. The recent papers show that the smaller sized HPGe-based RIIDs can be used to efficiently locate the

radioactive material in a container and this work shows the higher efficiency HPGe-based RIIDs are better able to identify the SNM in unshielded, shielded and masking situations [1, 2, 3, 4].

Equipment

The Detective-EX-100 is an extension of the Detective-EX, which has been described earlier [3]. The Detective-EX-100 (shown in Fig. 1) differs from the Detective-EX by having a larger HPGe detector. The Detective family has a nominal 50 mm diameter by 30 mm deep crystal (about 12% relative efficiency at 1.3 MeV [5]) and the Detective 100 family has a nominal 65 mm diameter by 50 mm deep crystal (about 45%). The overall height increased of the instrument by 0.5 cm and the length by 2 cm. The Stirling mechanical cooler, MCA electronics, batteries and the neutron detector are identical. The increased diameter of the HPGe crystal increases the surface area by about 70%, which increases the low-energy sensitivity. The relative efficiency increase is due to both the increased surface area and the increased depth.



Figure 1 Detective-EX-100.

Experiment

The identification tests were performed by placing the unit on a concrete floor with the source positioned vertically at the center of the detector and on axis in front of the detector. The dose was measured using the internal dose meter. The source was positioned at a horizontal distance to obtain the required dose (from ANSI N42.34) of 500 nSv/h. For the shielded sources, the 5 mm thick stainless steel plate was positioned as near the source as possible. When masking sources were used, the source was placed in a manner similar to the SNM source in such a way that it contributed an additional 500 nSv/h to the dose.

To obtain the identification time, the identification mode was started and the screen was observed. The display shows the identification and the elapsed time of the spectrum collection. The elapsed time is in integer seconds, so the minimum time observed is 1 sec. When the list of identified nuclides showed SNM (either uranium or plutonium) was detected and identified, the elapsed time was observed and recorded.

In addition, separate spectra were collected for various elapsed times using a PC running MAESTRO job files. The spectra shown as examples here were collected in this manner.

The detector resolution is important to resolving the individual gamma-ray energies. The typical resolution for various energies is shown in Fig. 2 which includes ^{57}Co , ^{137}Cs , ^{60}Co and natural thorium. The resolutions shown are more than adequate for the identification process.

A typical spectrum for the identification of unshielded uranium is shown in Fig. 3. This is a spectrum of 75% enriched uranium (HEU) collected for 1 second with the dose rate at 500 nSv/h. Note the amplitude of the 185 keV peak is about 80 counts and the 143, 163 and 205 keV peaks are clearly visible above the background and Compton continuum.

A 1-second spectrum of the same HEU source with mask and 5 mm steel shield is shown in Fig. 4. This is a spectrum of HEU (500 nSv/h dose) with the addition of ^{137}Cs to add 500 nSv/h to the dose at the detector. Note that the amplitude of the 185 keV peak (compared to Fig. 3) has increased due to the reduction of low-energy gamma rays from the spectrum and thus reducing the dose. The background and Compton continuum have increased under the 185 keV peak, but not enough to hinder the identification.

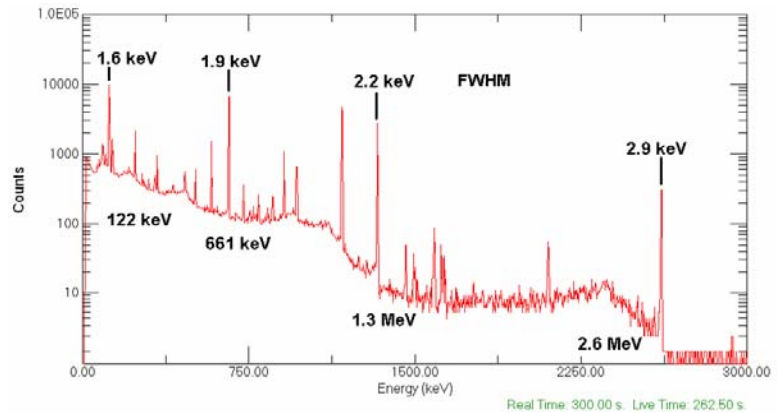


Figure 2 Detector resolution at different energies.

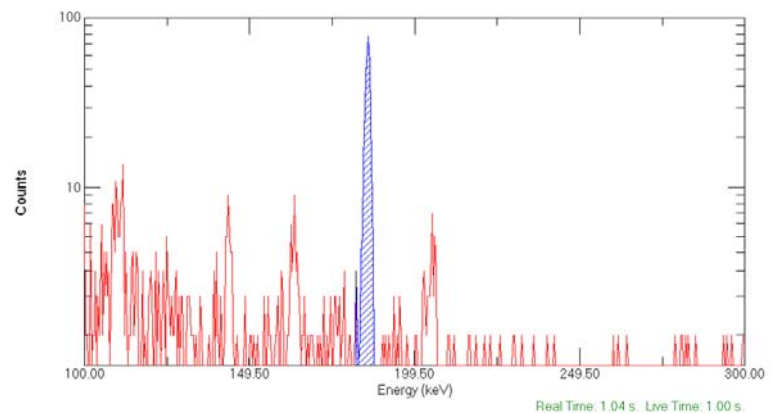


Figure 3 HEU spectrum from Detective-EX-100.

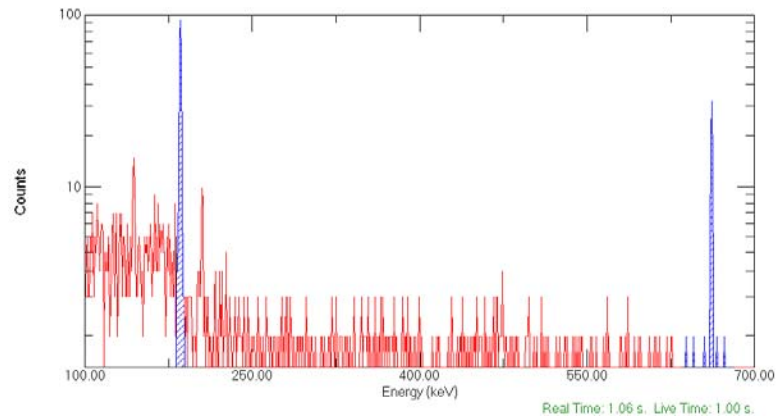


Figure 4 HEU with ^{137}Cs shielded by 5 mm steel.

A 1-second spectrum of unshielded LEU (2.9% enrichment) is shown in Fig. 5. The 185 keV peak has a maximum count of 13 and an area of 48, but this is enough for the identification.

The unshielded plutonium spectrum is dominated by the ^{241}Am peak at 59 keV. The specification for the identification to be done at 500 nSv/h dose means that the contribution to the spectrum from plutonium is small. The spectrum in Fig. 6 shows this. The spectrum was collected for 20 seconds. The main peaks of 375 and 413 keV are visible as well as the lesser peaks at 380 and 392 keV.

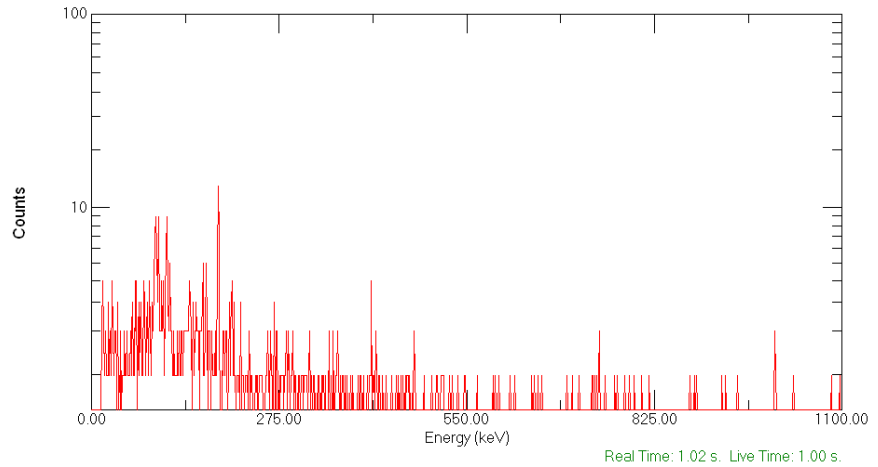


Figure 5 Unshielded 2.9% LEU

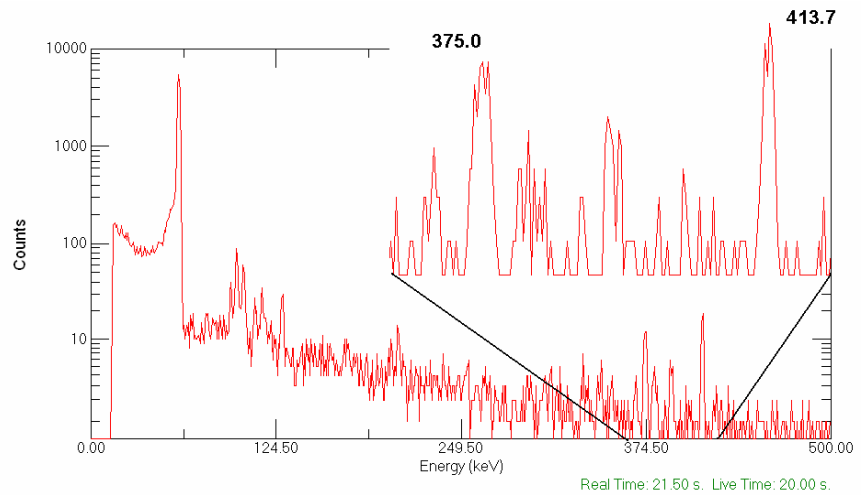


Figure 6 Plutonium with no absorber (20 sec).

With the 5 mm steel absorber in place, the 59 keV peak is significantly reduced and the spectrum is shown in Fig. 7. Note that the 375 and 413 peaks are about the same area, but the counting time is 4 seconds vs 20 seconds for Fig. 6.

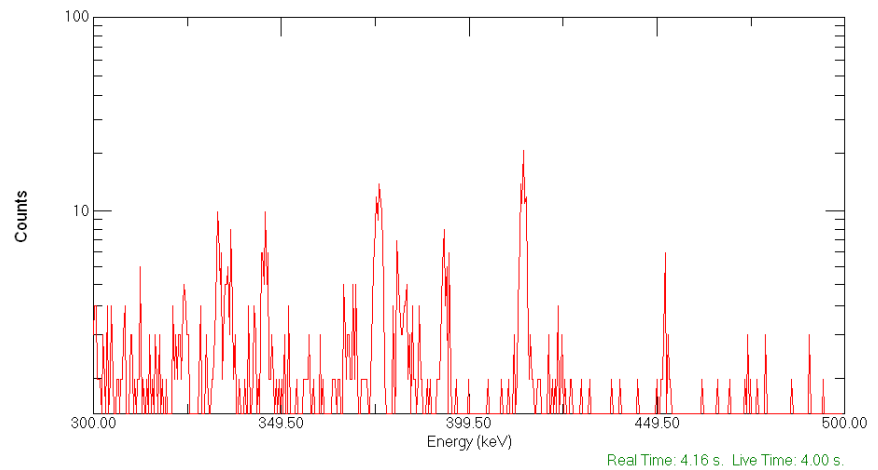


Figure 7 Plutonium with absorber (4 sec).

Of more importance is the plutonium spectrum with the ^{133}Ba mask. Figure 8 shows the spectrum in the energy range of 300 to 500 keV for the shielded case. The data collection time is 5 secs. The ^{133}Ba lines are separated from the ^{239}Pu lines allowing the identification software to identify plutonium.

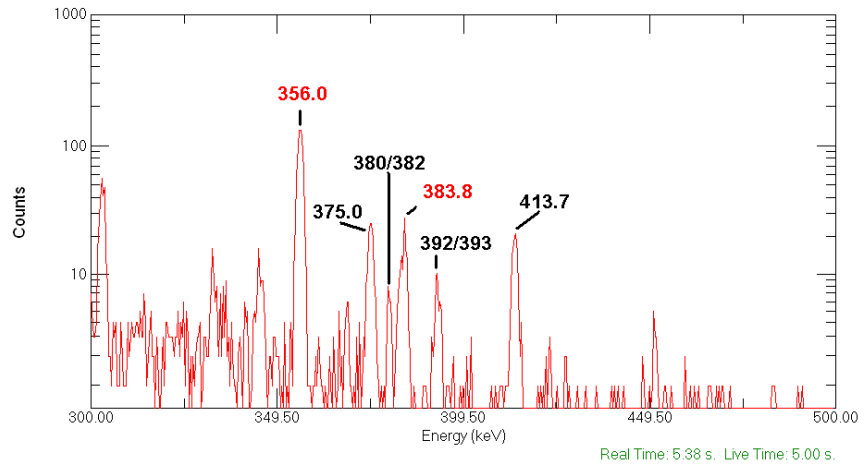


Figure 8 Plutonium and barium mixture showing interfering gamma rays (5 second collection).

Results

The times for identification of uranium in samples of different enrichment for the Detective-EX and the Detective-EX-100 are compared in Fig. 9. The times are well below the ANSI N42.34 maximum times are similar for both units for low enrichment samples, but the Detective-EX-100 is clearly much faster for highly enriched samples. This is attributed to the increased efficiency in the 1 MeV region. The 1001 keV gamma ray is one of the factors used to determine enrichment.

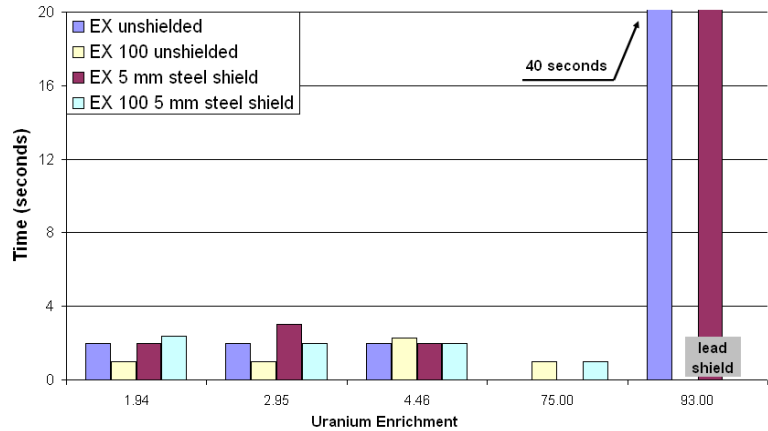


Figure 9 Uranium time to identify, shielded or unshielded.

For the case of uranium mixtures, the identification time is shorter than 1 second for both sizes of detectors when the dose is set to the required level. However, Fig. 10 shows the relative peak heights for the two units for a 1-second acquisition, indicating that the larger detector would be able to detect smaller quantities of material.

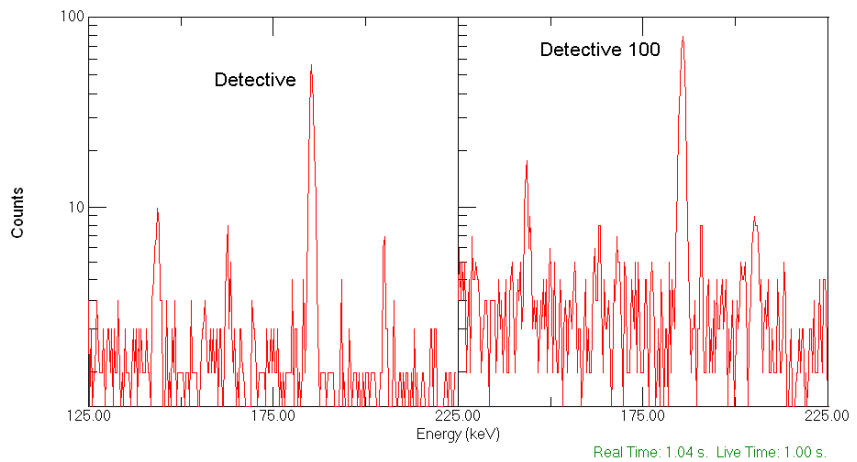


Figure 10 Comparison of small and large detectors for HEU with ^{137}Cs masking nuclide.

The time to identify plutonium (weapons grade) is shown in Fig. 11. The shielded (5 mm steel) and unshielded for both plutonium alone and with ^{133}Ba masking nuclide are shown. The unshielded time is longer than the shielded time because the majority of the dose is from the ^{241}Am daughter as seen in Fig. 6.

Conclusions

The improvement of a larger detector in the Detective-EX-100 has shown lower identification times for some cases of SNM alone and in mixtures. The identification times are all significantly shorter than the ANSI N42.34 requirements. In cases where the smaller detector also provided short identification times, the increased detector size will detect smaller quantities of material in short times.

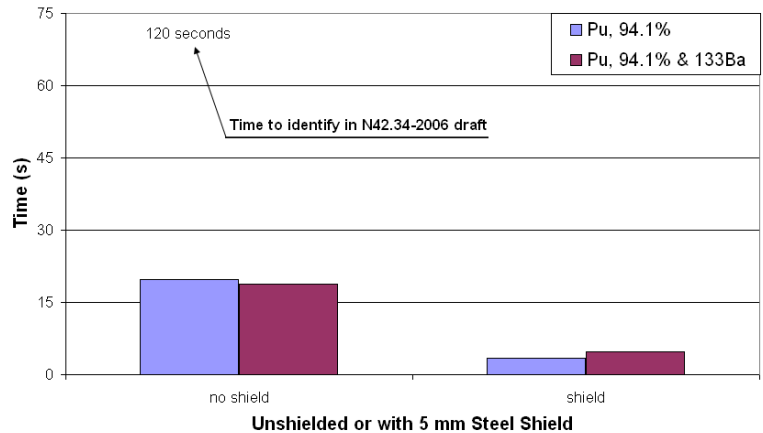


Figure 11 Plutonium time to identify unshielded or shielded, single or with ^{133}Ba .

References

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2. R.M. Keyser and T.R. Twomey, "Performance of a Portable HPGe-based Nuclide Identifier on Multiple Nuclide Mixtures", INMM 2004 Annual Meeting.
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5. IEEE 325-2001, "IEEE Standard Test Procedures for Germanium Gamma-Ray Detectors".