Performance of the True Coincidence Correction Method in GammaVision

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Summary

Some nuclides emit multiple gamma rays or X-rays when they decay to the ground state. If these gamma rays and X-rays are emitted essentially at the same time, it is possible that multiple photons will be detected at the same time in the detector and appear as one full-energy peak in the spectrum.[1] This is known as "Cascade" or "True Coincidence" summing. The most common example of this is ^{60}Co, where the 1173 and 1332 keV gamma ray peaks are emitted in cascade and can sum to become the 2505 keV gamma ray peak. This True Coincidence Summing has two effects, one is the reduction of the net peak count in the individual component peaks in the cascade. The second is the creation (or increase) of the extra peaks in the spectrum of the summation of the individual peaks. Both of these can cause the spectrum analysis to give erroneous results.

The details of how to measure the impact of coincidence summing on the analysis results are given in ANSI N42.14[2]. In this standard, it is stated that the coincidence summing effect depends on the nuclide and the source-detector geometry. The coincidence summing is measured using the ratio of the areas of two peaks in the spectrum of the mixed Eu-Sb source. The 591 keV gamma ray of ^{154}Eu is part of a cascade and is subject to summing. The 600 keV gamma ray of ^{125}Sb is not subject to summing if the x-rays are not observed in the detector. With a point source centered on the endcap, spectra were taken at several distances from the endcap. The ratio of the peak areas was calculated for each source position. The 12 cm distance is used as the reference point.

A different way to measure the impact is to analyze known samples, in the geometry of interest, with nuclides with coincidence summing. A round robin analysis of blind samples for ^{134}Cs and ^{137}Cs, showed the ^{134}Cs samples to be undercounted by 15% while the ^{137}Cs to be correctly counted.[3]

While methods for correcting peak areas for point sources have been well known for some time, true coincidence correction for volume sources such as Marinelli beakers and bottles have not previously been implemented due to the complexity of self-absorption and the subsequent cascade summing with partial peak energies. A new method has been developed which (a) solves the problem of volume sources, and (b) provides a one-step calibration method to make implementation by the user straightforward. The method for correction of the peak areas implemented in GammaVision is based

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[1] Glenn F. Knoll, *Radiation Detection and Measurement*, 3rd edition, p. 323, Wiley and Sons, 2000

[2] ANSI N42.14, Calibration and Use of Germanium Detectors for the Measurement of Gamma-Ray Emission Rates of Radionuclides.

[3] QAP46 Report (EML-591), March 1997

on the work by Blaauw et al[4,5,6]. In this method, the probability of recording a count in the full energy peak is given by:

$$P_{Ei} = g_i \varepsilon_{fullenergy,Ei} \prod_{j \neq i} \left(1 - g_j \varepsilon_{total,Ej}\right)$$

Where

P_{Ei}	= the probability of a count in the full-energy peak
$\varepsilon_{full\,energy,\,Ei}$	= the full-energy efficiency at energy E_i
$\varepsilon_{total,\,Ei}$	= the total efficiency at gamma ray energy E_i
g_j	= the transition probability for E_j

Thus the correction is reduced to knowing these two efficiencies and the decay schemes of nuclides with cascade gamma rays. In addition to the full-energy efficiency, the total efficiency includes the peak-to-total ratio, an absorption correction, and terms that correct the efficiency for an extended source. The implementation in GammaVision includes the automatic calculation of these efficiencies from either a set of single nuclide standards or from a single standard containing a particular mix of nuclides.

The method has been tested using these sources: 3 liter Marinelli beaker, 500 ml Marinelli beaker, 1 liter bottle, 5 cm diameter glass fiber filter paper and point source. The following nuclides are used: ^{139}Ce, ^{134}Cs, ^{137}Cs, ^{109}Cd, ^{203}Hg, ^{54}Mn, ^{113}Sn, and ^{88}Y. In addition, the ^{154}Eu, ^{155}Eu and ^{125}Sb mixed nuclide point source was used for the ANSI N42.14 tests. Figure 1 shows the general setup for collecting the spectra.
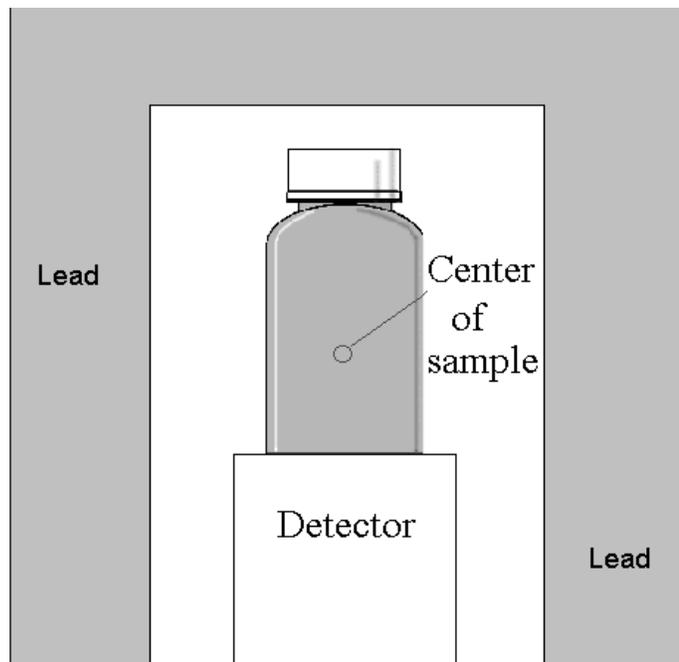

Figure 1

[4] Menno Blaauw, "The use of sources emitting gamma-rays for determination of absolute efficiency curves of highly efficient Ge detectors," NIM A322, 1993, pp. 483-500

[5] Menno. Blaauw, "The Accuracy of k-1-Standardized INAA Applied to a Gold-Lined Well-Type Detector", J.Radioanal.Nucl.Chem. 245 (2000) 185-188

[6] Sjoerd J. Gelsema, "A three-curves approach for dealing with true coincidense summing effects in gamma-ray spectrometry of absorbing sources", Ph.D. Thesis (200), Technical University, Delft, The Netherlands.

N42.14 test

The ^{154}Eu gamma ray at 591 keV is subject to cascade summing while the ^{125}Sb gamma ray at 600 keV is not subject to summing if the X-rays are not observed in the detector. This pair of gamma rays are used as an easy test to estimate the worst-case magnitude of the cascade summing effect. The spectrum is shown in Figure 2. It is assumed that any change in detection efficiency as the geometry is changed is the same for these two peaks.
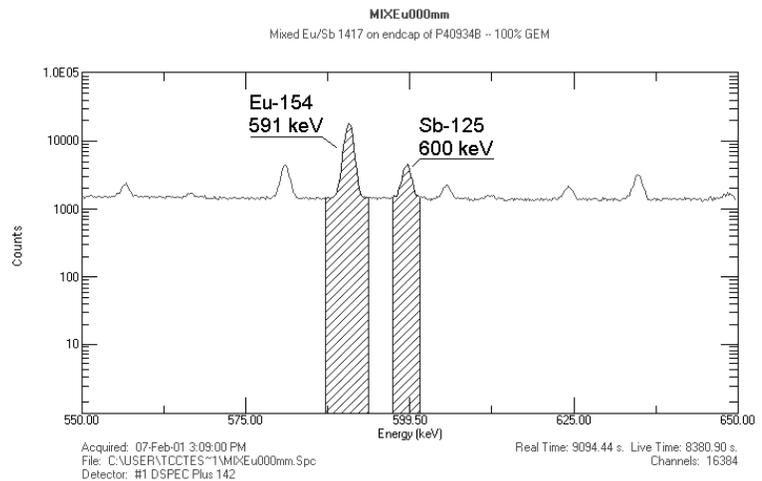
MIXEu000mm
Mixed Eu/Sb 1417 on endcap of P40934B -- 100% GEM

Eu-154
591 keV

Sb-125
600 keV

Acquired: 07-Feb-01 3:09:00 PM
File: C:\USER\TCCTES~1\MIXEu000mm.Spc
Detector: #1 DSPEC Plus 142

Real Time: 9094.44 s. Live Time: 8380.90 s.
Channels: 16384

Figure 2

Figure 3 shows the peak area ratio figure from N42.14.

Peak Area Ratio (591/600) Normalized to 12 cm Distance (from ANSI N42.14)

- 7% Detector
- 24% Detector
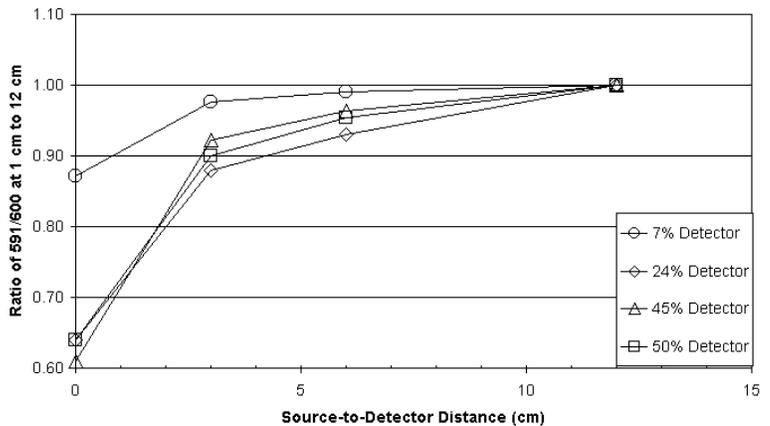- 45% Detector
- 50% Detector

Figure 3.

Figure 4 shows the results of this test on the 100% GEM detector used here added to Figure 3. Note that the curve has the same shape as the curves for the other, smaller detectors. The maximum effect of about 40% is reached for all detectors except the very small 7% detector.

Impact of True Coincidence Summing with Various Detectors using ANSI N42.14 Method

- 100% Detector
- 7% Detector
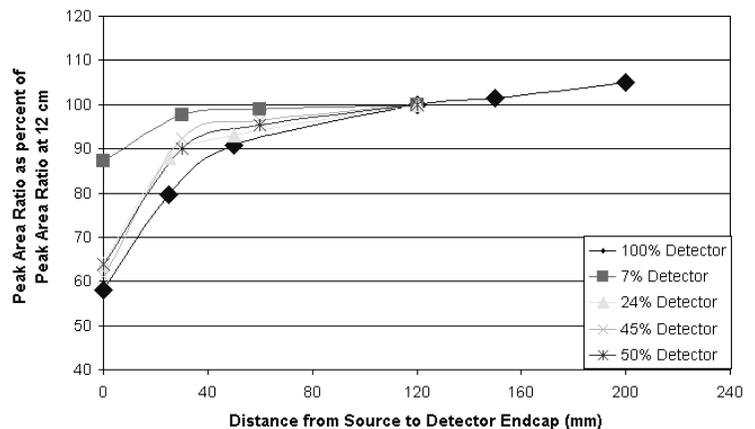- 24% Detector
- 45% Detector
- 50% Detector

Figure 4

General Activity Test

For the test using the various sample geometries, spectra were taken for each sample using a DSPEC Plus. Sufficient counts were collected so that the counting uncertainty in the peaks was mainly below 5%. Figure 5 shows a typical spectrum.

For each spectrum, the system was calibrated for energy, efficiency and TCC correction factor using the GammaVision calibration wizard. Then each spectrum was analyzed with GammaVision once with the cascade correction turned on and then again with the correction turned off.

To show the magnitude of the correction, the ratios of the activity results (TCC On/Off) for each nuclide was taken. This ratio is shown in Figure 6. Note the ratio is near 1 for all the non-cascade-summing nuclides and range above 1.5 for the cascade-summing nuclides. The value of 1.5 or 60% is consistent with the results of the N42.14 test on this detector.

The point source and the filter source can be counted at different distances, but the other sources can not. In Figure 6, the summing for the filter and point sources at the 10 cm distance is much lower than the summing when the sources are counted directly on the endcap. While the summing is lower, the efficiency is much lower for the far geometries, as shown in Figure 7. The efficiencies have been calculated here using the non-summing nuclides (plus 1836 keV) in the mixture.

MixGamFilter60482000mm
Analytics SRS 60482 filter paper standard, 47 mm dia, 0cm from endcap

Acquired: 15-Mar-01 7:40:33 AM   Real Time: 107331.88 s. Live Time: 100000.00 s.
File: C:\User\TCC Test and paper\MixGamFilter60482000mm.spc   Channels: 16384
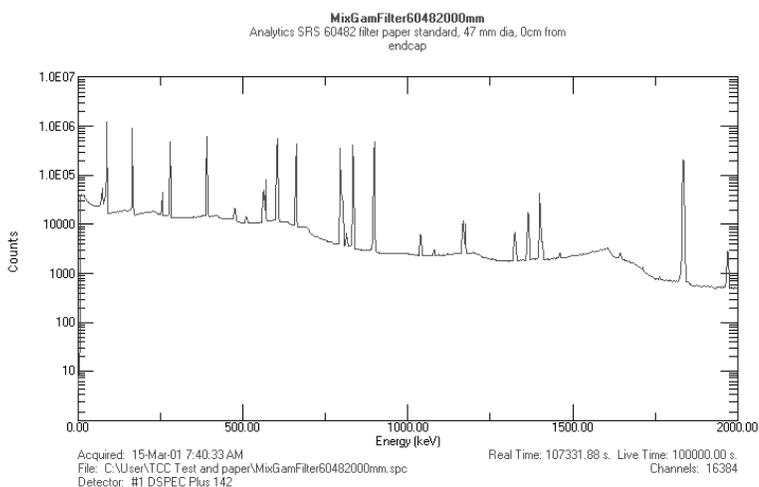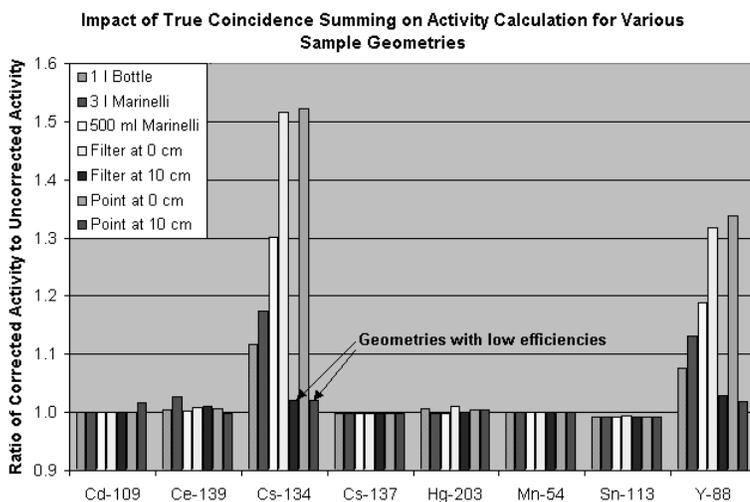Detector: #1 DSPEC Plus 142
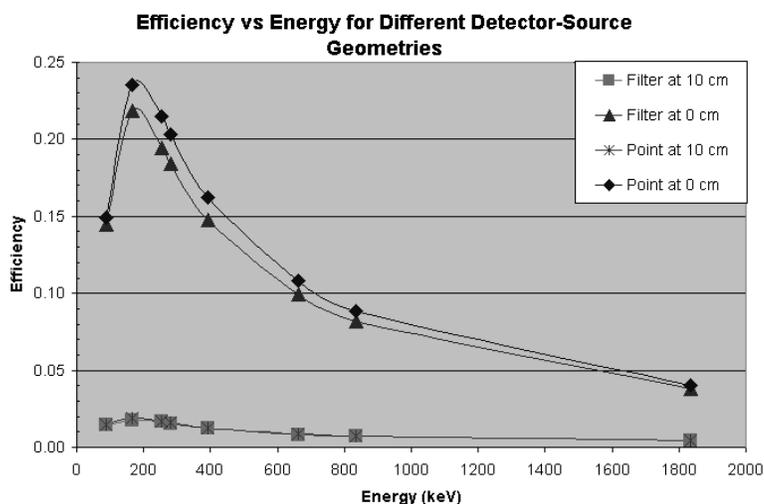
Figure 5

Figure 6

Figure 7

Figure 8 shows the ratio of the calculated activity to the stated activity as analyzed by GammaVision. The non-cascade-summing nuclides give results near 1 for all cases, while the ^{134}Cs and ^{88}Y show significant under reporting when the cascade correction is not applied.
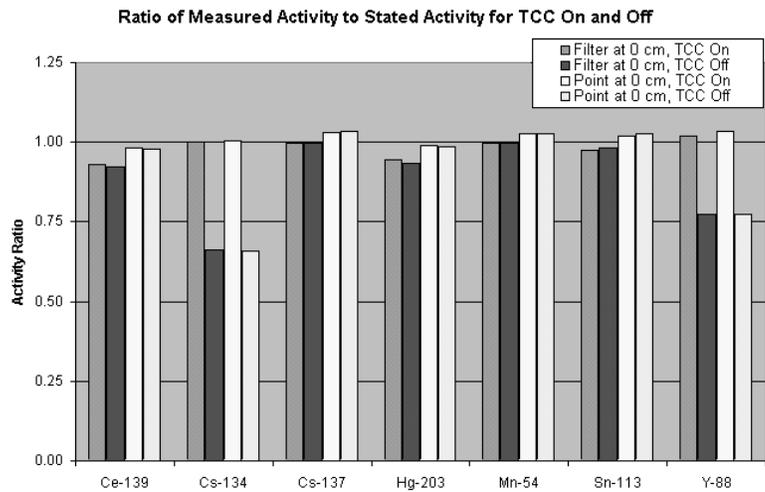

Figure 8

Conclusion

From these results, we see that 1) the cascade tests of N42.14 are useful in predicting the impact of cascade summing and 2) the cascade summing methods of Blaauw as implemented in GammaVision are an easy way to correct for true coincidence effects. This allows the counting of samples in the geometries, both simple and volume sources, with the best efficiency on the largest detectors possible.