

# Help:Coincidence Summing Corrections++ - NucleonicaWiki

From NucleonicaWiki

Coincidence summing corrections for gamma-ray spectrometry.

## Introduction

**True Coincidence Summation** occurs when two gamma-rays are emitted during the same decay event of the nucleus, so that they appear to be emitted instantaneously. This seemingly instantaneous emission of separate gamma-rays is known as coincidence. In this situation the detector will see both of the gamma-ray energies as one larger energy deposited in the detector. A tell-tale sign of coincidence is a summation peak that appears at the combined energy of the two characteristic gamma-rays of the source.

Advantages of the web application:

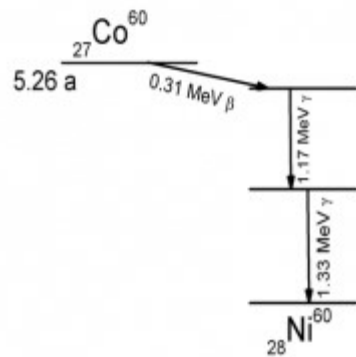
- The advantages of the web application are that there is no software to install and it is available worldwide - only a web browser and an internet connection are required
- Time consuming calibrations avoided
- Easy to use
- User friendly interface

## Theoretical Background

True coincidence summing occurs whenever two (or more) different gamma-rays emitted from the same decay are registered simultaneously by the detector. As such, it should always be distinguished from the random coincidence summing, which involves two gamma-ray from two different decays registering simultaneously. The rate of random coincidences is proportional to the activity of the sample, whereas the rate of true coincidences is not. Rather, it is a feature of the geometry of the measurement setup, i.e., the detector size and the distance between the detector and the sample.

As an example, let us consider a radionuclide like Co-60 decays with a two-step cascade in which two gamma-rays are always emitted. When the first of these interact with the detector and deposits all of its energy in it, the corresponding

count would end up in its full-energy-peak if Co-60 were a single-gamma emitter. But in reality, the second gamma ray can also interact with the detector, resulting in an increase in the deposited energy in the detector and causing the count of the first gamma-ray to be “lost” from its full-energy-peak.



Cascade gamma emission in Co-60.

What exactly do we mean by that? One has to bear in mind that the full-energy-peak efficiency is defined with reference to single-gamma emitters. Here is the basic formula of gamma-ray spectrometry, which is used in the calibration process and in the analysis of the spectrum and the determination of the activities of the radionuclides in the sample:

$$N = A b t \varepsilon$$

In this equation,  $N$  is the number of counts in a full-energy-peak,  $A$  is the activity of the radionuclide emitting the gamma-ray,  $t$  is the life-time and  $b$  the emission probability of the gamma ray. The full-energy-peak efficiency is denoted by  $\varepsilon$ . To calibrate the detector, the formula is used with known values of  $N$ ,  $A$ ,  $b$  and  $t$  to determine  $\varepsilon$ , and in the analysis phase the unknown activity  $A$  is determined from the known quantities  $N$ ,  $t$ ,  $b$  and  $\varepsilon$ . In both cases it is assumed that the radionuclide in question is a single-gamma emitter. This is clearly necessary in order to keep the definition of the full-energy-peak efficiency radionuclide independent, i.e., to make the efficiency a function of gamma-ray energy only.

In the case of Co-60, however, the formula no longer applies, because not all the events with a full deposition of the energy of the first gamma-ray end up in its full-energy-peak, as discussed above. We therefore need to introduce a correction factor  $C$ , which is radionuclide dependent and also has a different value for each of the gamma-lines of a given multi-gamma radionuclide:

$$N = A \cdot b \cdot t \cdot \epsilon \cdot C$$

The value of  $C$  is a complex function of the detector and sample size, composition, density and relative distance, as well as the entire decay scheme of the radionuclide. In practice it can therefore only be calculated using a computer code. The only alternative is to prepare a standard that matches the measured sample in all of its characteristics, including the radionuclide vector, and carry out a simple relative measurement.

The correction factor should be applied both in the calibration and in the analysis phase.

EFFTRAN offers the possibility of calculating the coincidence summing correction factors for a large number of radionuclides and for virtually any detector and sample size, density and composition. The results are given gamma-line by gamma-line, with the unaffected lines having a correction factor of 1.

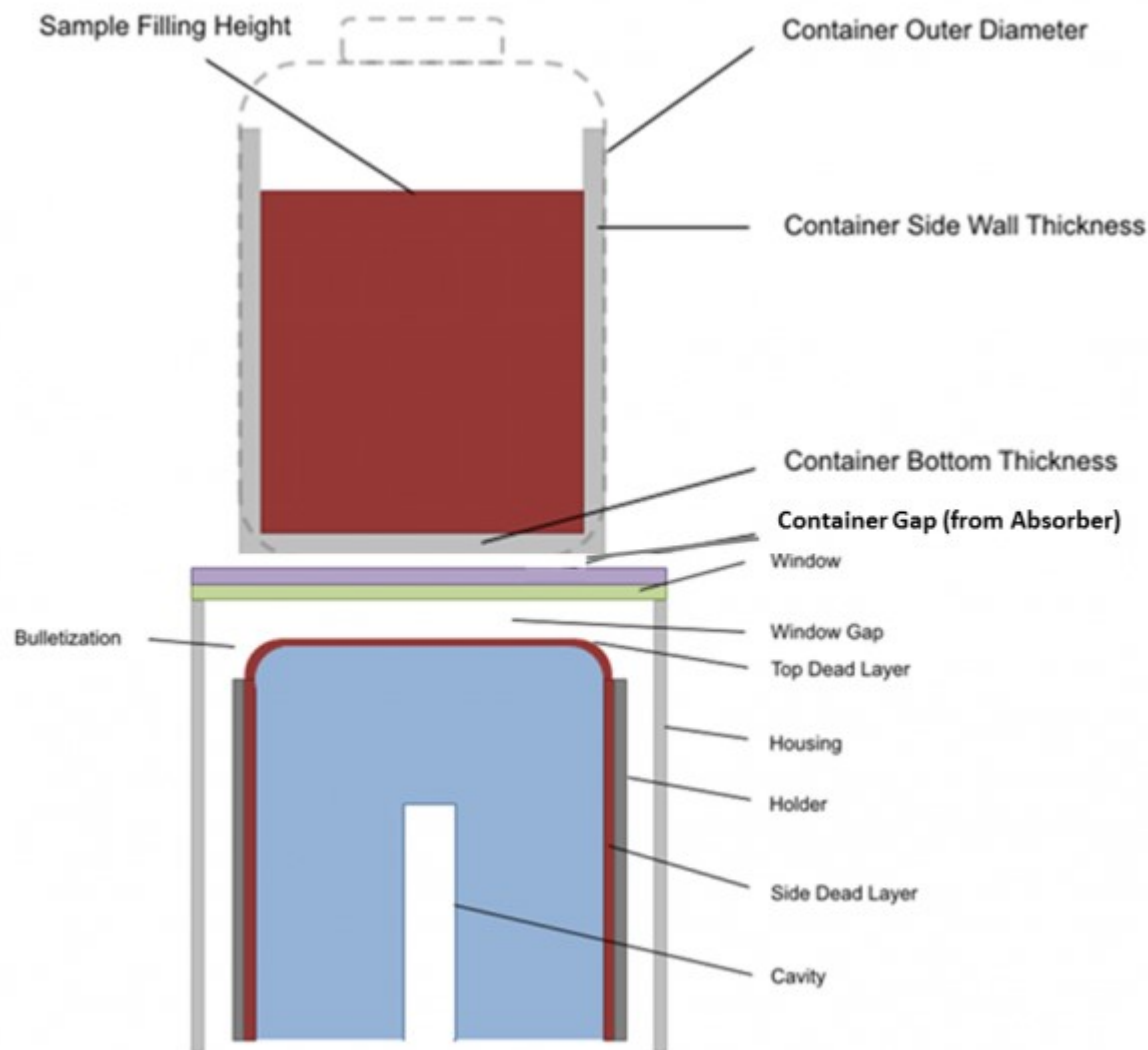
The general characteristics of the true coincidence summing effect to bear in mind are as follows:

- Is **also called** “cascade summing” or “true summing”
- Does **NOT** depend on the activity of the source
- **Depends** on the decay scheme (cascading gamma-rays)
- **Depends** on the geometry
- Is **only important** for close distance between source and detector
- Is **less important** for smaller detectors
- Well-type detectors **suffer most** coincidence summing
- Summing with **X-rays** can be very important (**n-type** detectors) – use an absorber
- Generally results in a **lower detection efficiency** for a specific peak (summing-out)
- Sometimes results in a **higher detection efficiency** for a specific peak (summing-in)
- Is the main reason for errors of **10-50%** in gamma-ray spectrometry
- Is almost always present with **complex decay schemes**

- **Affects calibration**, as well as sample analysis

## Source / Detector Configuration

The basic Source (Sample) / Detector configuration in the Coincidence Summing Corrections++ application is shown below. Here the Source / Sample is shown on top of the Detector. A detailed description of the Source / Sample and the Detector can be setup in My Detectors and My Source described below.





Source / Detector configuration showing the source on top of the detector.

## Coincidence Summing Corrections Web Application

### My Detectors

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**Co60**  
10.47 m 5.271 y

## Coincidence Summing Corrections++

Getting started

My Detectors My Sources Coincidences About

User defined Detectors

Detector	Dimension(mm)	Type	Date modified	Delete
(Create a new Detector)				
HPGe, L x D = 60mm x 60mm	60x60	Ge	2/19/2016 8:35:30 AM	
Nal, L x D = 2 in x 2 in	50.8x50.8	Nal	2/19/2016 8:38:19 AM	
LaBr3, L X D = 1.5 in x 1.5 in	38x38	LaBr3	2/19/2016 8:39:20 AM	
DET-24	69x54	Ge	4/27/2016 2:30:30 PM	
Total: 4		Page: 1 / 1		

**Detector** All dimensions in mm

Name: DET-24

Description: Medium size coaxial low-energy detector

Crystal diameter: 69 End cap (housing) diameter: 90

Crystal length: 54 End cap (housing) thickness: 1

Crystal bulletization radius: 1.6 End cap (housing) material: aluminium

Top dead layer: 0 Mount cup thickness: 1

Side dead layer: 0.2 Mount cup material: aluminium

Crystal cavity length: 31.7 Window thickness: 1

Crystal cavity diameter: 6 Window to Crystal Gap: 5

Crystal material: Ge Window material: carbon-epo

Absorber diameter: 120

Absorber thickness: 1

Absorber material: polystyrene

Save Save Predefined



Coincidence Summing Corrections: my Detectors [Enlarge](#)

- The **window-to-crystal gap** is the distance between the top dead layer of the crystal and the detector window.
- The **crystal diameter** includes its side dead layer. Similarly, the **crystal length** includes its top dead layer.

- The upper edge of the crystal may be rounded. The amount of rounding is given in terms of the **bulletization (crystal rounding) radius**.
- The **crystal hole (cavity)** is the central void drilled in the crystal, which contains the cooling pin (cold finger). The latter is not part of our model. The cavity diameter should include the surrounding germanium dead layer, which is also not modelled explicitly.
- The **absorber** is assumed to be placed directly onto the detector window.
- The crystal **mount cup (holder)** keeps the detector crystal in place.
- The term **end cap (housing)** refers to the the detector cryostat, sometimes also called the detector can.

## My Sources

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Co60  
10.47 m 5.271 y

## Coincidence Summing Corrections++

Getting started

My Detectors My Sources Coincidences About

User defined Sources

Source	Dimension(mm)	Material	Date modified	Delete
(Create a new Source)				
Point	0x0	vacuum	2/18/2016 4:24:58 PM	
Filter, D x H = 80mm x 1mm	1x80	cellulose	2/19/2016 11:15:49 AM	
Water, D x H = 90mm x 40mm	40x90	water	2/19/2016 11:18:15 AM	
Filter 11 cm	0.45x105	cellulose	4/27/2016 2:44:22 PM	
Total: 4			Page: 1 / 1	

**Source** All dimensions in mm

Name: Filter 11 cm

Description: Sample: Diameter 11 cm cellulose filter  
Source is just a thin filter paper, wrapped in a foil and placed

Source filling height: 0.45 Container diameter: 105

Source material: cellulose Container bottom thickness: 0.1

Container side wall thickness: 0.1

Container material: polystyrene

Container-to-absorber gap: 0

Save Save Predefined

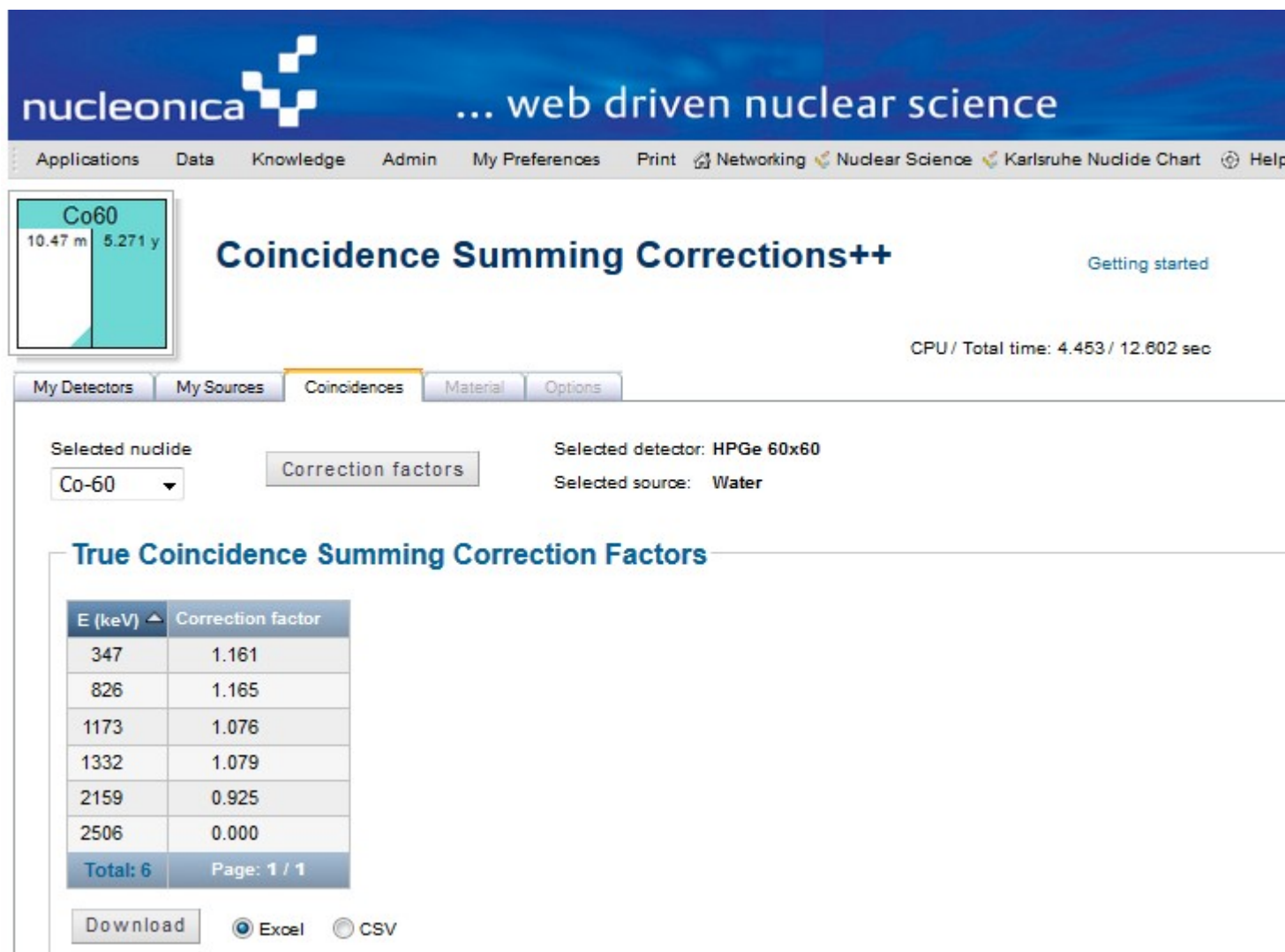
Coincidence Summing Corrections: My Sources [Enlarge](#)

- To simulate a point source, set all the numerical parameters to zero (except the container-to-absorber-gap) and all the materials to "vacuum"
- The **container-to-absorber gap** is the distance between the top of the detector absorber and the bottom of the sample container.
- The **sample filling height** refers to the sample material only, excluding the container bottom thickness.



- The **container diameter** includes (both) its side walls.
- The source material is assumed to tightly fill the space in the container in its radial dimension.

## Coincidence correction



The screenshot shows the Nucleonica web application interface for Coincidence Summing Corrections++. The header features the Nucleonica logo and the tagline "... web driven nuclear science". A navigation bar includes links for Applications, Data, Knowledge, Admin, My Preferences, Print, Networking, Nuclear Science, Karlsruhe Nuclide Chart, and Help.

The main content area displays the title "Coincidence Summing Corrections++" and a "Getting started" link. A small inset shows a Co60 nuclide card with half-life values of 10.47 m and 5.271 y. The CPU / Total time is shown as 4.453 / 12.602 sec.

Below the title, there are tabs for My Detectors, My Sources, Coincidences (selected), Material, and Options. The "Selected nuclide" is set to Co-60, and the "Selected detector" is HPGe 60x60. The "Selected source" is Water. A button labeled "Correction factors" is visible.

The section "True Coincidence Summing Correction Factors" displays a table with the following data:

E (keV)	Correction factor
347	1.161
826	1.165
1173	1.076
1332	1.079
2159	0.925
2506	0.000
<b>Total: 6</b>	<b>Page: 1 / 1</b>

At the bottom, there is a "Download" button and radio buttons for "Excel" (selected) and "CSV".



Coincidence Summing Corrections [Enlarge](#)

## **How is the actual efficiency curve corrected with the correction factors?**

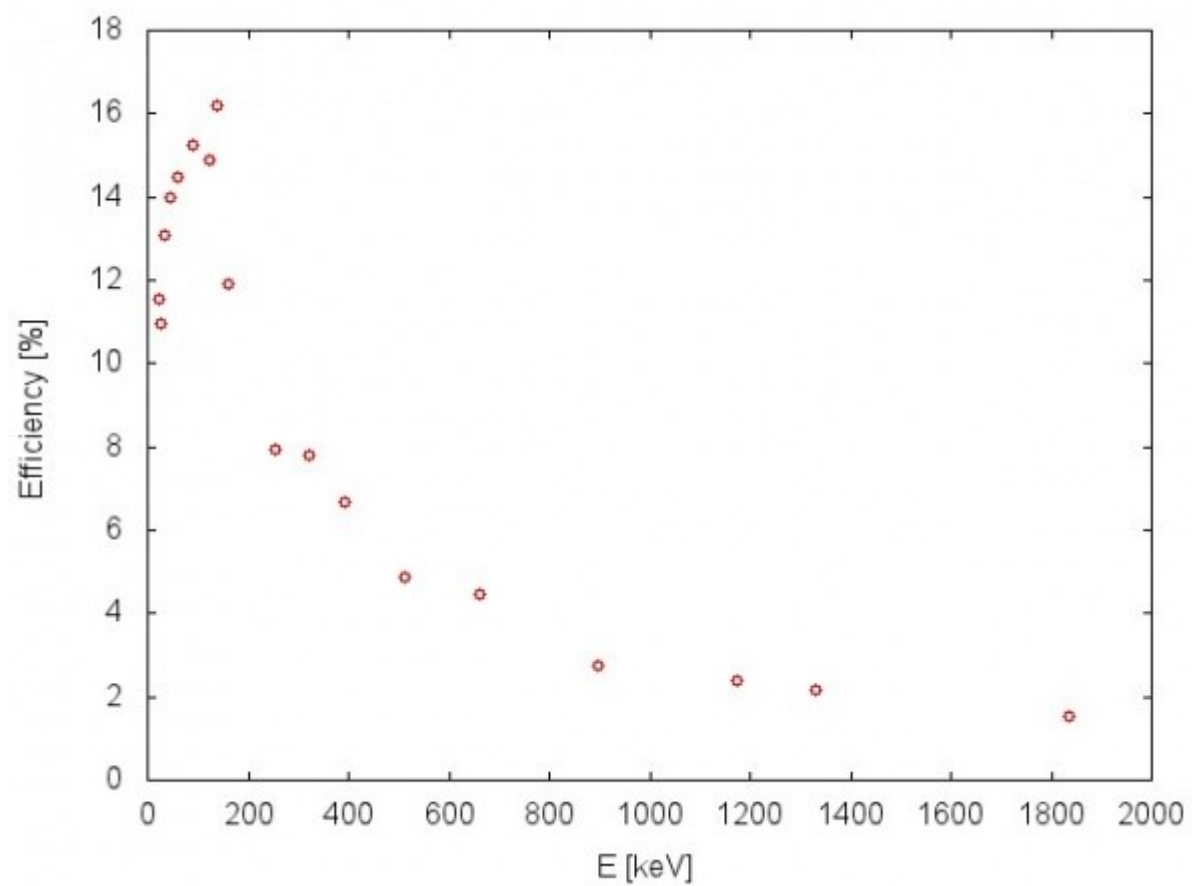
The measured efficiency should simply be multiplied with the appropriate coincidence summing correction factor. This refers to the calibration phase of the analysis and is described in more detail in the following section.

When determining the unknown activities in a measured sample (using a calculated or measured efficiency curve from the calibration phase), the activities obtained from the uncorrected peaks should be multiplied with the appropriate coincidence summing correction factor.

## **Example: Calibration Curve Correction for Coincidence Summing Effects**

In this section an example of the data and the plots for a HPGe calibration curve corrected for the coincidence summing effects are given. This data was provided by the gamma-rays spectrometry laboratory of the SCK•CEN.

The efficiency curve (raw data) was established by measuring a calibrated filter of 11 cm in diameter containing Cd-109, Cs-137, Pb-210, Am-241, Co-57, Te-123m, Sn-113, Cr-51, Sr-85, Co-60 and Y-88 directly on the detector window of a medium-size, low-energy HPGe detector. The efficiency (raw) data is shown in the figure below.



Efficiency (raw) data before correction [Enlarge](#)

The corrections computed with the EFFTRAN code are shown below.

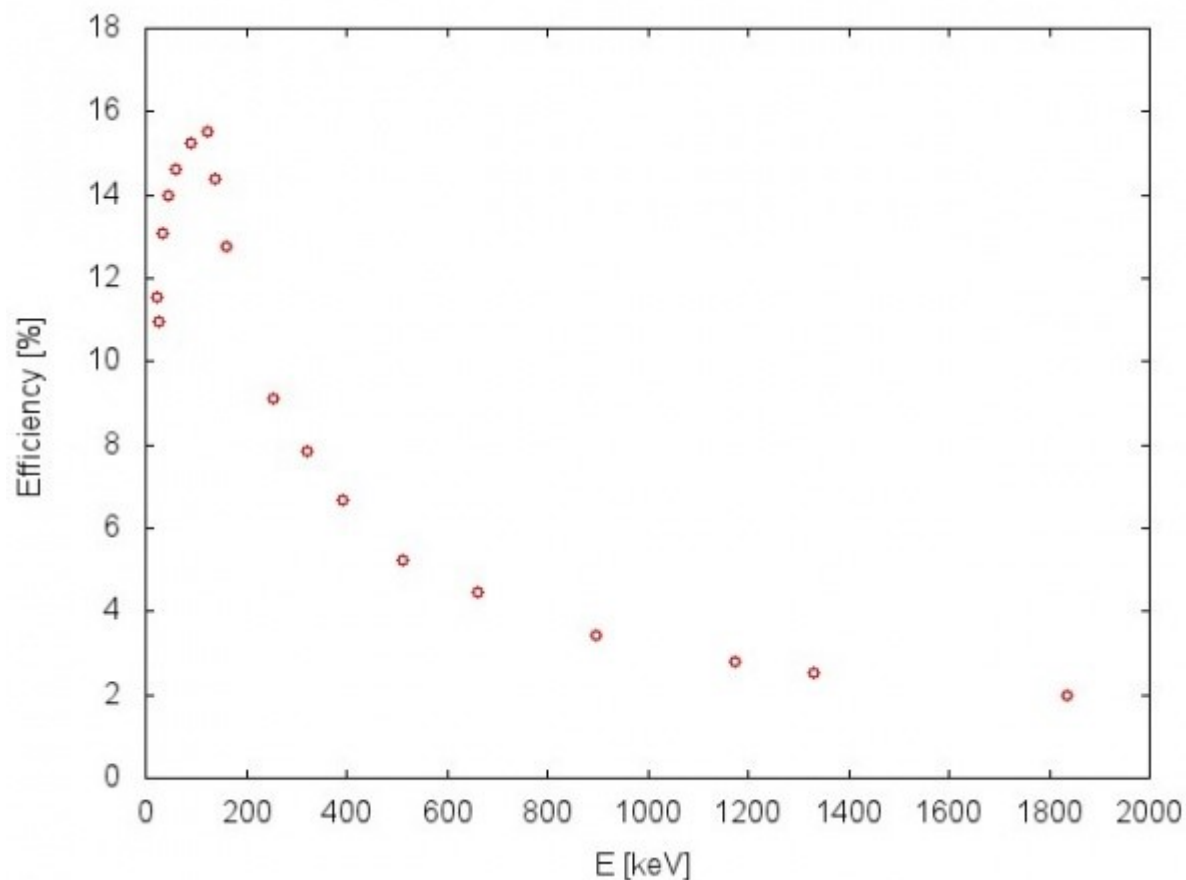
Energy (keV)	Correction Factor	Efficiency [%] Uncorrected	Efficiency [%] Corrected
22.1	1.001	11.537	11.544
25.07	1.001	10.943	10.949
32.06	1.000	13.073	13.073
46.54	1.000	13.995	13.995
59.54	1.009	14.489	14.613
88.03	1.002	15.227	15.261
122.06	1.043	14.882	15.528
136.47	0.888	16.198	14.389
158.97	1.074	11.894	12.774
255.13	1.146	7.939	9.100
320.08	1.006	7.820	7.870
391.7	1.004	6.663	6.688
514	1.075	4.858	5.224
661.66	1.000	4.469	4.469
898.04	1.245	2.747	3.420
1173.23	1.161	2.401	2.787
1332.49	1.166	2.162	2.522
1836.05	1.265	1.555	1.967



Correction factors, uncorrected and corrected efficiencies as a function of energy [Enlarge](#)

The above corrections factors have been calculated using the stand-alone version of EFFTRAN. The correction factors can, however, be calculated using the web application. In this case the calculation should be done for each of the nuclides (Cd-109, Cs-137, Pb-210, Am-241, Co-57, Te-123m, Sn-113, Cr-151, Sr-85, Co-60 and Y-88) individually. This will result in small changes to the values given above for the correction factors due to the statistical process of Monte Carlo integration employed, and the fact that the version of EFFTRAN used is not exactly the same as the one for Nucleonica.

Finally the efficiency data are corrected using the results in the table. The final efficiency (corrected) data are shown below.



Efficiency data after correction [Enlarge](#)

We see that the energy dependence of the efficiencies is now a smooth one, as expected.

It should be noted that the energy of a gamma line as such does not have anything to do with the magnitude of its coincidence summing correction, at least not directly. And neither does, indeed, the emission probability, except if lines overlap. It all depends on the entire decay scheme of a given radionuclide, and on the efficiency values, especially total efficiencies.

## References

[Coincidence Summing Basics](#)

[Advanced gamma-ray spectrometry dealing with coincidence and attenuation effects](#)

[True Coincidence Summing Corrections](#)

[True Coincidence Summing Corrections - Theory](#)

[Cascade summing corrections for HPGe spectrometers by the Monte Carlo method](#)

Arnold, D. and Sima, O., 2004. Application of GESPECOR software for the calculation of coincidence summing effects in special cases. Applied Radiation and Isotopes 60, 167–172.

Berger, M. J. and Hubbell, J. H., 1987. XCOM: Photon Cross Sections on a Personal Computer. NBSIR 87-3597, National Bureau of Standards (former name of NIST), Gaithersburg, MD.

Vidmar, T., 2005. EFFTRAN - a Monte Carlo efficiency transfer code for gamma-ray spectrometry. Nuclear Instruments and Methods A 550, 603-608.

Vidmar, T., et al., 2010. Testing efficiency transfer codes for equivalence. Applied Radiation and Isotopes 68, 355-359.

Vidmar, T., Kanisch and G., Vidmar, G., 2011. Calculation of true coincidence summing corrections for extended sources with EFFTRAN. Applied Radiation and Isotopes 69, 908-911.