Coincidence summing in gamma-ray spectrometry

1. Introduction

Coincidence summing in gamma-ray spectra has been a well-known phenomenon for more than thirty years. The initial observation was the change of the relative peak intensities when changing the source-to-detector distance. It was established that this was linked to:

- Complex decay scheme
- Close geometry
- Lifetimes of nuclear levels << charge collection time in detectors (some µs)

This phenomenon is also referred as «true coincidence», «cascade summing», and should not be mixed with pile-up.

Coincidence summing corrections (a few %) are required for high accuracy measurements at the metrological level, for radionuclide activity determination and measurement of photon emission intensities. They should also be taken into account in low-level measurements due to the close source-detector geometry (Marinelli geometry or well-type detector); in these cases, the corrections factors can attain a few 10 %.

2. History

In 1972-1975, Andreev and Mc Callum raised the problem; they proposed a numerical method requiring the knowledge of full-energy peak (FEP) efficiency and total efficiency. For a point source and a simple decay scheme with two excited levels, the corrections for the peak areas corresponding to energies $E_1$, $E_2$ and $E_3$ are:

$$C_1 = \frac{1}{1 - P_{21} \cdot \varepsilon_{T_2}}$$

$$C_2 = \frac{1}{1 - P_{21} \cdot \varepsilon_{T_1}}$$

$$C_3 = \frac{1}{1 + \frac{I_{\gamma_1}}{I_{\gamma_3}} \cdot \frac{\varepsilon_{P_1} \cdot \varepsilon_{P_2} \cdot P_{12}}{\varepsilon_{P_3} \cdot P_{12}}}$$

Where:

- $P_{ij}$ is the conditional probability for emitting $\gamma_j$ simultaneously with $\gamma_i$
- $\varepsilon_{P_i}$ is the FEP efficiency for energy $E_i$
- $\varepsilon_{T_i}$ is the total efficiency for energy $E_i$
In 1979-1983: Specific codes were written:

- KORSUM (PTB)
- CORCO (LNHB) -> ETNA
- …

These methods were extended to complex decay scheme and to volume sources

- Computing the FEP and total efficiency for different source-to-detector distance for volume sources,
- Taking into account the decay scheme, including electron capture, beta+ decay, emission of X-rays…

New developments were carried out about twenty years later:

- Monte Carlo: IRA (using GEANT) (1992)
  - apparent FEP efficiency: \( \epsilon_a \)
  - True FEP efficiency: \( \epsilon \)
  - Correction factor: \( \epsilon / \epsilon_a \)
- Other developments with mixture of Monte Carlo (for computing efficiencies) and numerical computation of the correction factor

- Practical applications
  - Empirical methods using monoenergetic radionuclides to establish corrective factors
  - Matrix approach
  - LS (linear-to-square) curve
  - Combinatorial Method
  - Methods based on Monte Carlo simulation

3. ICRM

In the last thirty years, several attempts were made in the frame of the ICRM to analyze the coincidence summing correction situation:

  - Enquiry with the objective of preparing a «Guide» …
  - 17 participants
    - CSC used by 15 participants
    - Program supplied by 4 participants

- 2001: proposition for a comparison
  - Enquiry: 24 possible participants!

- 2005: Interest inquiry on ICRM actions in the Gamma Spectrometry working group
  - (10 high + 3 medium) / 13 replies …
2007: Among about 50 participants in the ICRM Gamma Spectrometry working group, more than 40 shown their interest in an action about coincidence summing correction.

4. 2008 Proposal

An intercomparison of the methods used for computing the coincidence summing corrections is proposed in the frame of the Gamma Spectrometry Working Group of the ICRM. Nowadays; there are several ways of computing these corrections and each method has advantages and drawbacks (accuracy, easiness, speed, …) that could be compared during this action.

In a first step, the comparison should be restricted to point sources and two or three radionuclide such as $^{152}\text{Eu}$, $^{60}\text{Co}$ and $^{134}\text{Cs}$. The same decay scheme and photon emission intensities should be used by all the participants (NUCLÉIDE database) to avoid bias linked to data discrepancies.

In a second step, the exercise could be extended to volume sources (cylinder and Marinelli).

The suggested list of data provided by LNHB for this computation includes:
- accurate description of the source-detector geometry,
- spectra obtained with monoenergetic radionuclides (sources with reference activity at different source-to-detector distances; this should provide full-energy peak and total efficiency calibration for the direct methods and should validate the Monte Carlo simulations.
- spectra obtained with the multi-energetic nuclides at different source-to-detector distances.

The spectra can be provided to participants in several formats.

The results should be the coincidence summing correction factors for the multi-energetic nuclides for several FEP energies and several source-to-detector distances.

Remark: Unfortunately, LNHB will not be able to provide experimental data to examine the case of well-type detector. If another laboratory with such detector can provide relevant data, this could be considered as a third step of the comparison.

5. Questions to interested participants

This is a first proposal, and the opinion of potential participants is required to conceive a comparison that should be useful for each of them. Thus, do not hesitate to make remarks and suggestions to improve this draft, and please fill in the interest form and send it back by e-mail by March 31st, 2008.