ON THE ITERATION OF COINCIDENCE SUMMING CORRECTION FOR DETERMINATION OF GAMMA-RAY INTENSITIES

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Abstract

In order to determine the γ-ray emission intensities of nuclei far from the β-stability line with HPGe detectors under large solid-angle geometry, coincidence summing corrections should be performed, even if full energy peak efficiencies of detectors are accurately measured with standard sources. Because the summing effects depend on decay scheme and emission intensities, the correction needs to be iterated several times starting from the initial values of intensities obtained directly from the measured peak counts of γ-rays. Considering ^{134}Cs, ^{154}Eu and ^{56}Co as typical examples, we discuss the number of iterations of summing correction required for self-consistency with respect to the total efficiencies of the detectors.

Objective

Coincidence summing correction is needed for determination of reliable **γ-ray intensity of short-lived nuclei far from the β-stability line** with HPGe detectors in close geometry measurements.

β-branching ratios, log-*ft* values : calculate from the γ-ray intensity imbalance at each excited level.

The summing correction should be iterated several times according to the level structure.

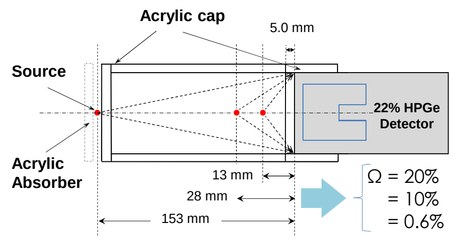
How many iterations of correction are required for reliable γ-ray intensities determination?

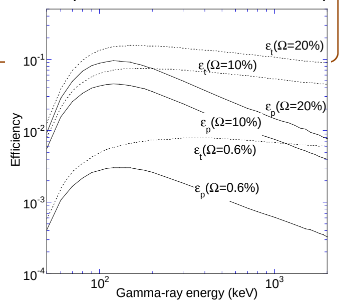
Test nuclides

- ^{134}Cs : simple decay scheme
- ^{154}Eu : more complicated decay scheme (wide energy range)
- ^{56}Co : β^+ emitter and high energy γ-rays above 3 MeV

Experiments

22% HPGe detector :
Solid angles : **0.6%**,**10%**, **20%**, with acrylic β^- and β^+ absorber
ϵ_p and ϵ_t : uncertainty: 2% and 5%, by measurements (^{109}Cd, ^{137}Cs, ^{54}Mn, ^{60}Co) and GEANT4
Nuclides of interests : ^{134}Cs, ^{154}Eu, ^{56}Co





Analysis

- Correction of the coincidence summing using the pre-determined ϵ_p and ϵ_t by means of Shima *et al.* (2014) :

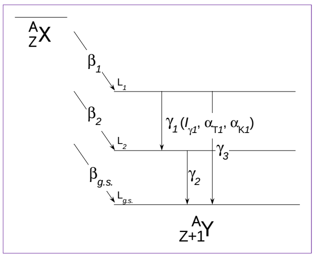
Randomly sampled the decay path from an excited level to the ground state in the decay scheme of each nucleus (ENSDF 2004)using Monte Carlo simulation. (The 10^7 events were generated)

- ➢ The energy deposition events of no-coincidence or coincidence summing were randomly simulated.
- ➢ iterate the procedure step by step by adopting the measured peak counts of each γ ray as the initial intensity $I_{\gamma i;0}$

$I_{\gamma i;0} = \frac{C_{\gamma i;0}}{\epsilon_{p\gamma_i}}$ $C_{\gamma i;0}$: the measured counts (no correction), $\epsilon_{p\gamma_i}$: peak efficiency for γ_i

- The corrected $I'_{\gamma i;1} = f_{\gamma i;0\to1} \times I_{\gamma i;0}$. $f_{\gamma i;0\to1}$: correction factor derived from the above procedure.
- Renormalize the corrected $I'_{\gamma i;1}$ (by the corrected $I_{\gamma 604.7;1}$ in ^{134}Cs, $I_{\gamma 1274.7;1}$ in ^{154}Eu, $I_{\gamma 846.8;1}$ in ^{56}Co).
- The 2nd correction : deduce $f_{\gamma i;1\to2}$ using the renormalized $I_{\gamma i;1}$.
- If the β-branching ratios became negative at some level, those were regarded as zero.
- Successively, the corrected intensities $I'_{\gamma i;j+1} = f_{\gamma i;j\to j+1} \times I_{\gamma i;0}$ (j=1 to 10)

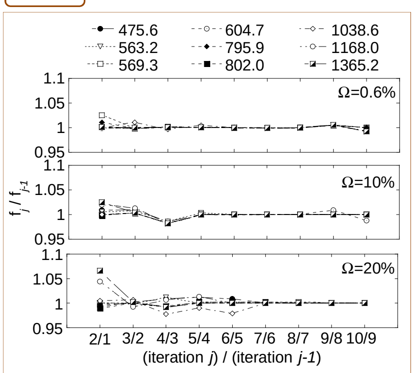
Concept of summing correction by Monte-Carlo simulation



Results

Trend of the ratio of the correction factor $f_{\gamma i;j\to j+1}/f_{\gamma i;j-1\to j}$ from *j*=1 to 10.

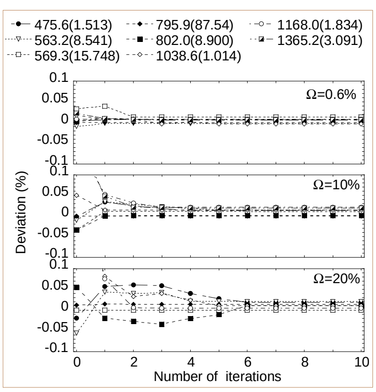
^{134}Cs



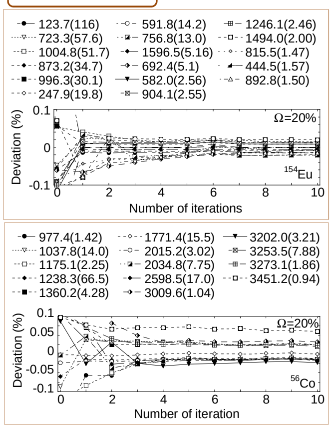
- ➢ Most correction factors converge at 6 iterations.

The results for 0.6%, 10%, 20% in ^{134}Cs, 20% in ^{154}Eu and ^{56}Co.

^{134}Cs

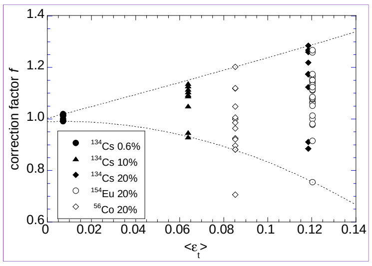


^{154}Eu & ^{56}Co



- ➢ Converged at 6 iteration for three nuclides.
- ➢ In agreement with the reference values of NUCLIDE (2013).
- ➢ At least 4 iterations of summing correction are needed.

The last correction factors versus the effective ϵ_t ; $\langle\epsilon_t\rangle = \frac{\sum \epsilon_t \times I_\gamma}{\sum I_\gamma}$



- ➢ f_{γ_i} ~ the order of $\langle\epsilon_t\rangle$

Uncertainty evaluation

- ➢ $\sigma_{\gamma i;j} = \sqrt{\sigma_{\epsilon_p}(2\%)^2 + \sigma_{\gamma i;j-1}(2\%)^2} \approx 0.03$
- ➢ The uncertainty by *n* iterations is $\sum_1^n 0.03^n \sim 0.031$ at 6 iterations.

Conclusion

The correction for coincidence summing required several iterations. The number of iteration of coincidence summing depended on the decay scheme. At least 4 iterations were needed in case of the 20% solid-angle measurement in order to determine the intensities within 5% uncertainty. In practice, it is important to analyze γ-ray spectra carefully and determine the peak counts as initial conditions reliably.

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