Absolute Efficiency Calibration of HPGe Detectors for Photoactivation Experiments

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An absolute efficiency calibration of the High Purity Germanium detectors (HPGe) used in the photo activation experiments were done with eight different nuclides, all under the same geometry. The systematic uncertainties from the source calibration certificate was about 1.05 %. The samples were put directly on the top of three cadmium absorber layers with an overall thickness 1.535(4) mm which minimizes the coincidence summing with X-rays in case of multi-γ emitting nuclides [1].

The full-energy-peak efficiency as is defined as

$$\epsilon_p(E_\gamma) = \frac{N_\gamma}{N_s} = \frac{N_\gamma}{t_r p A_0 \exp\frac{-\Delta t}{\tau}}$$

with N_γ = Number of counts in the photopeak, corrected for dead-time and pile-up losses and N_s = Number of photons emitted from the source. The other terms describe themselves as Δt - time elapsed since calibration up to measurement, A_0 - activity of the source on the reference date, p - branching ratio corresponding to the energy E_γ, τ - the mean lifetime and t_r denotes the real time taken for the data run.

For a precise measurement of the efficiency, one of the important corrections to be applied arises from coincidence summing and one well known example for this type of nuclides is ^{133}Ba which owns a very complex decay scheme as in Fig. 1. In this particular case, two or more photons can be emitted in cascade for a single decay and an empirical method to correct for them is complicated [2].

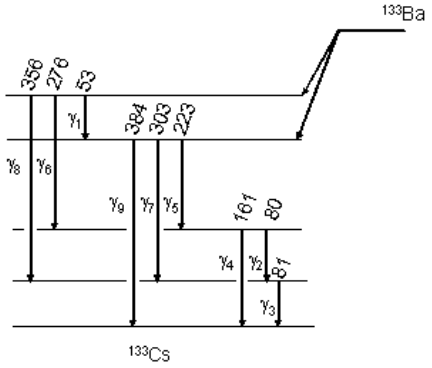

Fig. 1 *Decay scheme of ^{133}Ba with energies displayed in units of keV.*

Taking the example of 276 keV (γ_6) transition of this decay, we can divide the correction factors into two: One which comes out from the "summing-out" effects due to coincidence of γ_6 with γ_4, with γ_2-γ_3 cascade and the other factor from "summing-in" effects due to γ_1-γ_5 cascade The correction factor for this decay is given by the expression

$$\frac{1}{C_6} = \left(1 - f_{64}\epsilon_{t4} - f_{62}\epsilon_{t2} - \frac{\epsilon_{t3}}{(1+\alpha_3)}\right)\cdot\left(1 + \frac{p_1 f_{15}\epsilon_1\epsilon_5}{p_6\epsilon_6}\right)$$

with

$$f_{64} = \frac{p_4}{p_4(1+\alpha_4) + p_2(1+\alpha_2)}$$

$$f_{15} = \frac{p_5}{p_5(1+\alpha_5) + p_7(1+\alpha_7) + p_9(1+\alpha_9)}$$

etc. Here C_i denotes the correction factor, α_i - total internal conversion coefficients, p_i - γ emission probabilities, ϵ_i - full energy peak efficiencies and ϵ_{ti} - total efficiencies for the detector used with i = 1,..,9.

For analyzing the source spectra and extracting the peak area, the fit routine was designed manually so as to meet the experimental peculiarities [1]. The total and photopeak efficiencies were simulated using GEANT3 [3] and compared with the measured values. Corrections were applied for the self absorption in the source material and for the source-detector geometry offsets. An example of efficiency curve is shown in Fig. 2, which clearly shows that the absolute peak efficiency can be determined to an accuracy of 1.5 % by including the coincidence summing corrections.

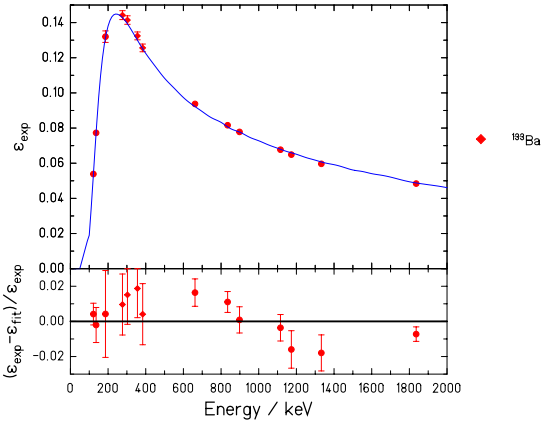

Fig. 2 *Efficiency curve for the HPGe detector with 100 % efficiency relative to a 3"×3" NaI detector. The χ^2 of the fit is 19.4 with 13 degrees of freedom. The upper part is the fit curve overlaid on experimental data and the lower part shows the residuals with error bars of the data points on the same scale.*

[1] C. Nair, A.R. Junghans et al., IKH Annual Report 2004, FZR-423 (2005) 18

[2] K. Debertin, R.G. Helmer, "γ and X-ray Spectrometry with Semiconductor Detectors", Elsevier Science Publ. (2001)

[3] CERN program Library Long Writeup Q121, CERN, Geneva (CH), 1994

[1] *also TU Dresden*