Study of the energy resolution and uncertainties of germanium detectors using bayesian methods

Germanium detectors have wide fields of application for γ- and X-ray spectrometry thanks to their excellent energy resolution. The energy resolution of these detectors is defined as the width of the detected energy spectra peaks (FWHM); it depends on

- the statistics of the charge creation process
- the properties of the detector, and primarily its charge collection efficiency
- the electronics noise

The resolution can be expressed as the squared sum of two terms

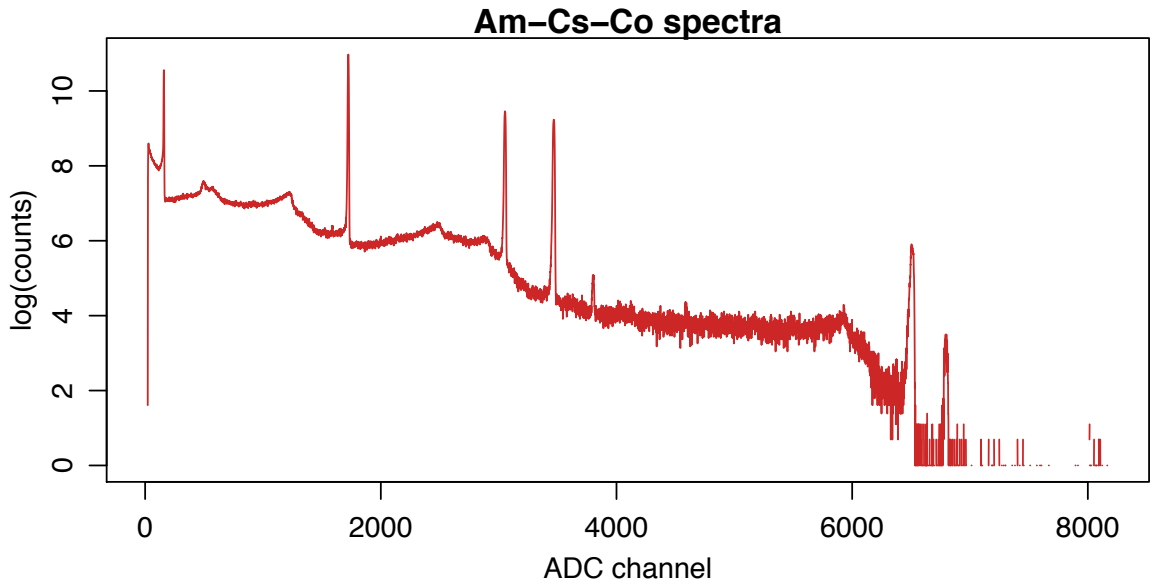
$$\text{FWHM} = \sqrt{w_d^2 + w_e^2}\ , \tag{1}$$

where the first term depends on the detector properties as

$$w_d = 2\ \sqrt{(2\ln 2)\cdot F\cdot E_\gamma \cdot w}\ , \tag{2}$$

with F the Fano factor[1], E_γ the energy of the photon deposited energy and w is the electron-hole production energy threshold in germanium (w $\sim$ 3 eV)[1] The other term in eq. 1, w_e is connected with the readout electronics and depends on the detector capacitance, the size of the detector and the bias voltage.

The following plot shows an uncalibrated energy spectrum collected with a Germanium detector irradiated by a combination of three sources: ^{241}Am, ^{60}Co and ^{137}Cs[2].



According to [2], the source nuclides emit the following photons:

Nuclide	^{241}Am	^{137}Cs	^{60}Co	
Photon energy (keV)	59.54	661.66	1173.24	1332.51

and these are the first four peaks (starting from the left side) visible in the figure. Similar spectra have been collected with other gamma sources (i.e. Th-228).

1. using statistical methods similar to that presented during the course, infere the FWHM of each γ peak for all available γ sources

[1] The Fano factor is an inherent property of the material.

2. assuming a linear response of the detector, as a function of energy, perform a calibration of the detector, associating the centroid of each peak to the nominal value of the detected γ full energy peak

3. using a MCMC method (with either JAGS or stan), study the behavious of the energy resolution as a function of the photon energy and infere the parameters of eq.1 and 2.

Bibliography

[1] K. Debertin and R. G. Helmer, *Gamma- and X-ray spectrometry with semiconductor detectors*, North-Holland, 1988

[2] Laboratoire national Henri Becquerel, tables of eveluated data on radioactive nuclides, `http://www.nucleide.org/DDEP_WG/DDEPdata.htm`