1 Efficiency estimation

For calculating differential cross-sections we need to know the detector efficiency. Previously, the pre-calculated look-up table was used for this purpose. However, the setup was changed and now you need to calculate the efficiency yourself :) Remember that efficiency is an energy-dependent parameter and what you will get is $\epsilon = f(E)$, so for each angle it will be different given that there is a shift in energy with a change in angle value!

The γ-ray flux on the detector can be defined as:

$$\Phi_{\text{det}} = A_\gamma \cdot \frac{1}{4\pi l^2}, \tag{1}$$

where l is a distance between the γ-ray source and the detector and A_γ is an activity of the radioactive probe, which you can find in the table below. **Note** that the activity values A_0 given in the table are determined on 16.04.2021 for Cs137, Na22 and Co60 samples, and on 09.07.2021 for Co57, so you need take into account the time passed since that day t_{passed} via:

$$A_\gamma = A_0 \mathrm{e}^{-\lambda t_{\text{passed}}}, \tag{2}$$

where λ is a radioactive constant being dependent on the half-life of the radioactive isotope $t_{1/2}$:

$$\lambda = \frac{\ln 2}{t_{1/2}}. \tag{3}$$

Since the half-life time $t_{1/2}$ is given in years, the time t_{passed} in the Eq[2] should be in years as well.

Having the flux Φ_{det} now we can calculate the detector rate R:

$$R_\gamma = \Phi_{\text{det}} \cdot F_{\text{area}} = \Phi_{\text{det}} \cdot \pi r^2, \tag{4}$$

where F_{area} is a detector area with a crystal radius r.

The efficiency is then:

$$\epsilon = \frac{N_{\text{ph}}}{t_{\text{meas}} \cdot R_\gamma}, \tag{5}$$

where t_{meas} is a duration of measurement, which is equal to 300 s, and N_{ph} is a number of photons in the photopeak. To get the number of photons you need to estimate the area under the peak, e.g. to integrate the curve. It is not enough just to take the amplitude of the Gaussian peak, which is one of the most common mistakes, since what you get after the measurement is a histogram (binned distribution, where each bin contains a certain number of photons) and the amplitude only corresponds to the bin with a maximum number of photons, but not to the total number of photons in the entire photopeak. Given that for different radioactive probes used for the detector calibration and efficiency estimation photopeaks are located at different energies as a result you will get efficiency values at different energies. Finally, by interpolating the obtained points you will get a smooth dependence of the detector efficiency ϵ on energy, from which you can draw the efficiency values corresponding to the energies at which you measure peak for each angle for the differential cross-sections calculation.

Table 1: Activity of radioactive probes

Isotope	**Activity, in Bq**	**Half-life, in years**	**E, in keV**
Cs137	$2.8 \cdot 10^5$	30.2	662
Na22	$1.1 \cdot 10^4$	2.6	511 1276
Co60	$6.39 \cdot 10^4$	5.27	1173 1332
Co57	$6.01 \cdot 10^6$	0.744	14.4 122 136