# Approximation of gamma-ray Peaks Registered with Scintillators

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Gamma-ray peaks, especially FEP, SEP and DEP, registered in scintillators are relatively broad and observed on a high non-linear background, see Fig. 1. Any program dealing with the analysis of gamma-ray spectrum has to find peaks, to estimate the peak location, centroid, height, width and peak integration. It could include data smoothing as well.

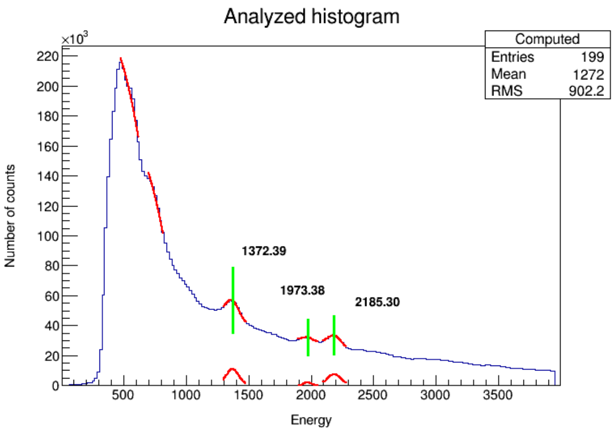


*Fig. 1. Experimental spectrum (blue histogram) registered with a 20×15 mm $CeBr_3$ scintillator during 14 MeV neutron irradiation measurements performed with the Frascati Neutron Generator [SOFT_GCU]. Solid red line: results of the approximation.*

A method is presented to analyse gamma-ray peaks registered in scintillators based on a Sensitive Nonlinear Iterative Peak (SNIP) algorithm [1]. Two types of SNIP algorithms are now implemented: Increasing Clipping Window and Decreasing Clipping Window but it is easy to include other SNIP methods. Due to the high sensitivity of the algorithm and possible false detection, a threshold mechanism was used.

The program is written in C++ in the Codeblocks environment using the CERN ROOT libraries. Compatibility with ROOT versions from 5.34.19 to 5.34.36 has been tested. The program can run on various hardware platforms. For testing purposes, the program was compiled and run in the Linux Debian 9 "stretch" and Windows 8.1 environments.

All parameters related to the approximation are set in the configuration file, which is loaded and analysed during program execution. A function for loading and analysing this configuration file allows easy addition of new functionalities to the program.

The results of the program are: a *text report* displayed on the console, a *text file* with a report containing the parameters of the detected peaks. In addition, an experimental histogram is displayed on the screen with the approximation results which can be saved to an image file, see Fig. 1.

A sum of linear and Gaussian functions is used to approximate the found peaks. The linear function depends on two parameters, the Gaussian function on thre. Because the sum of this function is non-linear, it has been implemented using iterative method to determine approximation parameters. The criteria ofmaximizing a likelihood function (Maximum Likelihood function) were implemented. The $\chi^2$ test was used to verify the reliability of the approximation obtained. The iterative algorithm requires correct starting points to be foundfor an approximation - otherwise, an appropriate minimum will not be found.

The method of determining starting points is based on an analysis of the histogram data. The iterative algorithm also requires a proper stop criterion. The stop criterion was determined based on the following conditions: the algorithm must be convergent, the error must be small, the top of the Gaussian function (Gauss mean parameter) must have a value in the peak range. A vector of error parameters consists of variances of computed parameters. These variances depend on the quality of the adjustment of the sum of the Gaussian and linear functions to a given histogram. The following parameters are calculated: NDF (Number ofDegrees of Freedom) and $\chi^2$ test results. These parameters depend on the quality of the fit of the function to the measurement data. Based on the above parameters, the best width of the histogram bins is calculated.

**Reference**

[1] C.G. Ryan et al., *SNIP, a statistics-sensitive background treatment for the quantitative analysis of PIXE spectra in geoscience applications*, Nucl. Instr. Meth. **B34** (1988) 396, https://doi.org/10.1016/0168-583X(88)90063-8

*This work was partly supported by the Polish Ministry of Science and Higher Education within the framework of the scientific financial resources in the years 2015-2018 allocated for the realization of international co-financed projects.*