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Automatic Efficiency Calibration (AEC) Software Manual

ABSTRACT

The AEC software was designed to validate a precise method for calibrating the efficiency of GeHP detectors, detailed in the article "Automatic efficiency calibration method with high precision for GeHP detector". It offers a graphical interface to manipulate calibration formulas and can be used in addition to other gamma analysis tools.

Currently, AEC integrates five formulas, including one of the new method. Its open source nature allows users to customize the code to add formulas or features tailored to their needs, making it a powerful and flexible tool for various applications.

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1.Introduction

In the field of gamma spectroscopy, accurate spectra analysis is a crucial step for many scientific and industrial applications, such as radionuclide characterization, radiation protection, environmental monitoring, and nuclear medicine. Calibrating the efficiency of gamma detectors is essential to obtain reliable and interpretable results. In order to contribute to these needs, AEC (Automatic Efficiency Calibration) has been developed as an open source software, designed to facilitate and automate the efficiency calibration process in gamma spectra analysis.

AEC offers four efficiency calibration formulas, each adapted to different types of applications and detector configurations. These formulas include logarithmic and exponential models, which are commonly used in the field to adjust the efficiency according to the measured energy. The software allows the user to choose the most appropriate formula according to their data, while offering the possibility to apply an automatic calibration method.

With this automatic method, AEC analyzes the input data and selects the most suitable formula for each particular case, based on the results obtained. This process considerably simplifies the user's work, minimizing the need for manual intervention and reducing the risk of errors. The software is designed to be intuitive, while offering maximum flexibility to adapt to the varied needs of users.

AEC thus represents a powerful and accessible tool, which allows efficiency calibrations to be carried out accurately and quickly, while being accessible to all thanks to its open source nature.

2. Presentation of the AEC software

To effectively present the AEC (Automatic Efficiency Calibration) software, the graphical interface has been divided into three distinct sections, designed to provide a clear and intuitive user experience. This structure aims to facilitate interaction with the software and the understanding of the displayed data:

Button section: Located at the top left of the interface (Fig. 1), this section contains the main commands needed to interact with the software. It offers essential features such as loading files containing radionuclides and selecting appropriate calibration functions. The buttons are ergonomically organized for smooth and quick navigation, **Radionuclide table section** and **Graph section**: Located at the bottom of the interface, this section is dedicated to the visual representation of the results in the form of graphical curves. Users can observe trends, compare experimental data to theoretical curves, and verify the quality of the performed calibration. The graph is designed to be interactive, offering zoom options for more precise analysis.

This modular organization of the interface allows users to easily navigate between the different features while maintaining an overview of the data and results.

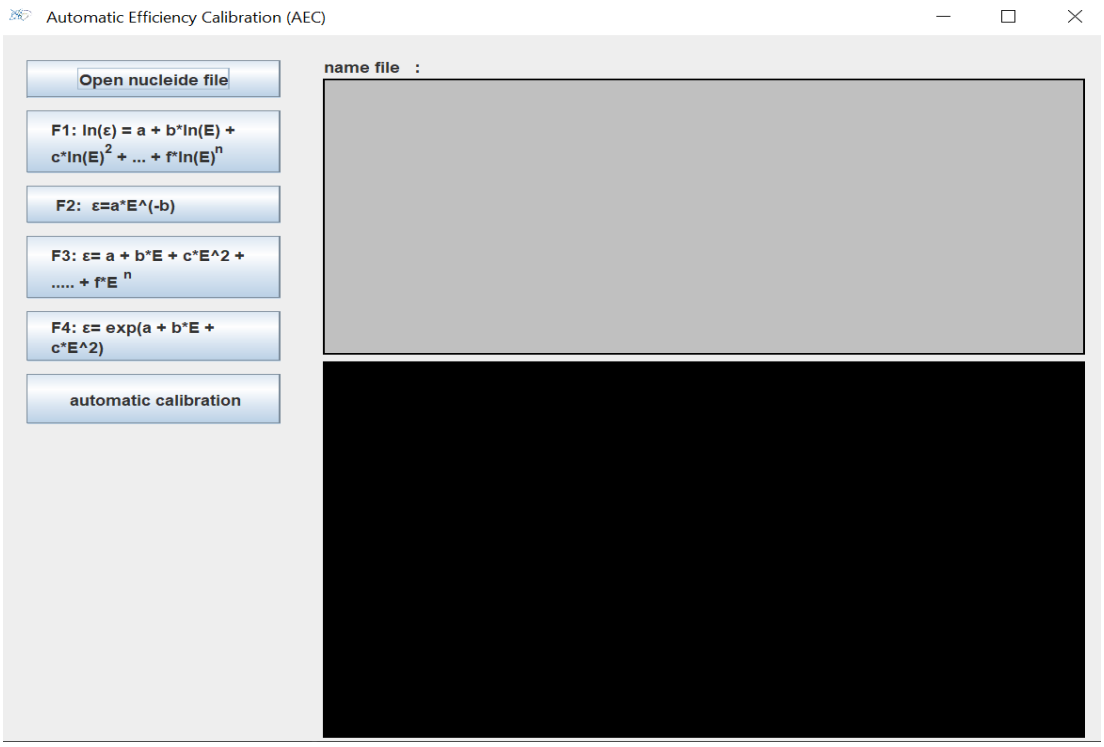

Fig.1 AEC Software GUI.

2.1 Button section

The **buttons section** consists of six buttons, each with a specific and essential function for using the software. Here is a detailed description of the functionalities of each button:

1. Open nuclides file: This button, the first in the series, allows you to load a file containing the radionuclides information (see Fig. 2). Once the file is loaded, the data is automatically displayed in the central table and represented in the form of a graph (see Fig. 3). This functionality simplifies the visualization of radionuclides and associated data.

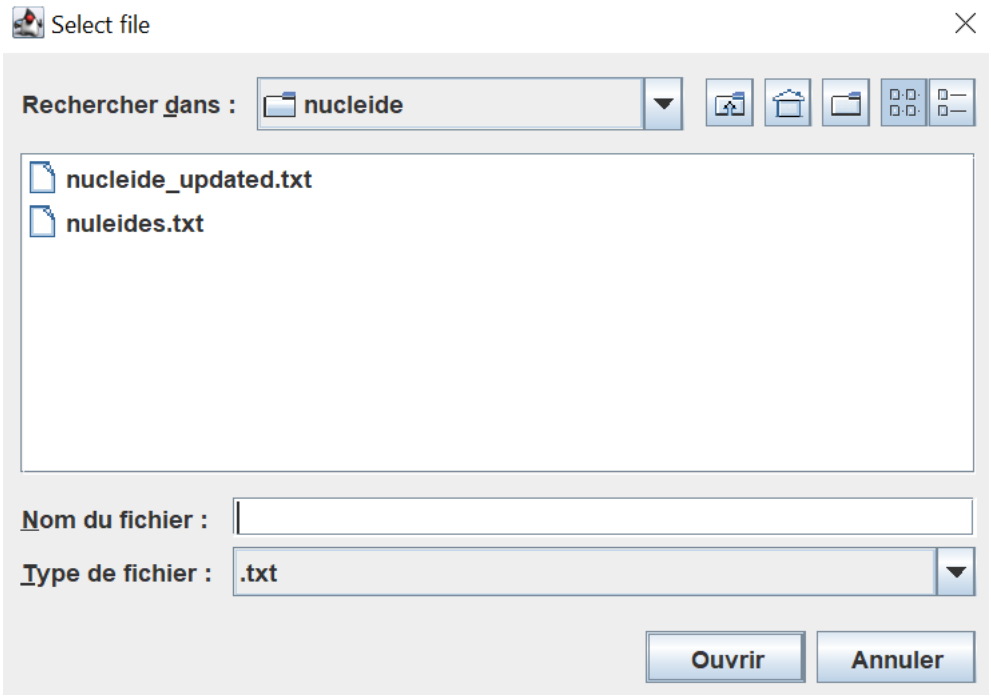

Fig.2 window to import the radionuclear file including energies and their efficiencies.

On the other hand, when selecting the file containing the radionuclide data, the path of the selected file is clearly displayed to inform the user. This path appears at the top of the table, in a dedicated area, with a clearly visible red color (Fig. 3). This choice of color allows immediately capturing the user's attention and avoiding any confusion. The user can thus quickly identify the file used for the current analysis. This is particularly useful when working with several similar files or performing successive analyses. This feature improves the clarity and transparency of the process. It also guarantees an analysis without errors related to misidentification of files.

Regarding the radionuclide table, the user has an interactive interface that allows him to add, modify or delete the data relating to each radionuclide. This data includes the name of the nuclide, its energy, the probability of emission, as well as the value of its efficiency. This flexibility allows the user to customize the data according to his specific needs or to adjust the values if necessary. When the user clicks the "**Add**" button after making a change, it is important to note that the changes are not saved in the original file that was initially loaded. Instead, the modified data is saved in a new file, which guarantees the integrity of the original file. This process protects the initial data while providing the possibility of keeping the adjustments made. In this way, the user can manage their files safely and avoid any loss or confusion between versions. The graph below the table represents a visualization of the points corresponding to the radionuclides, where the efficiency is plotted as a function of energy. This graphical representation makes it easy to visualize the trends and relationships between these two essential parameters. The user has complete freedom in interacting with this graph, making the tool both intuitive and practical. Through direct manipulation with the mouse, it is possible to zoom in to examine specific details or zoom out to have an overview. In addition, the graph can be moved in all directions by clicking on the graph sides, thus providing maximum flexibility to explore the data. This interactivity greatly improves the user

experience by allowing in-depth analysis of the data without requiring external tools. The user can thus adapt the view according to their needs to better interpret the results. By combining clear visualization and easy manipulation. It is important to note that the zoom on the graph is done by directly selecting, with the mouse, the desired area on the graph. To move the view, simply click and drag the mouse in the desired direction. Finally, to return to the initial state of the graph, a simple drag of the mouse resets the view.

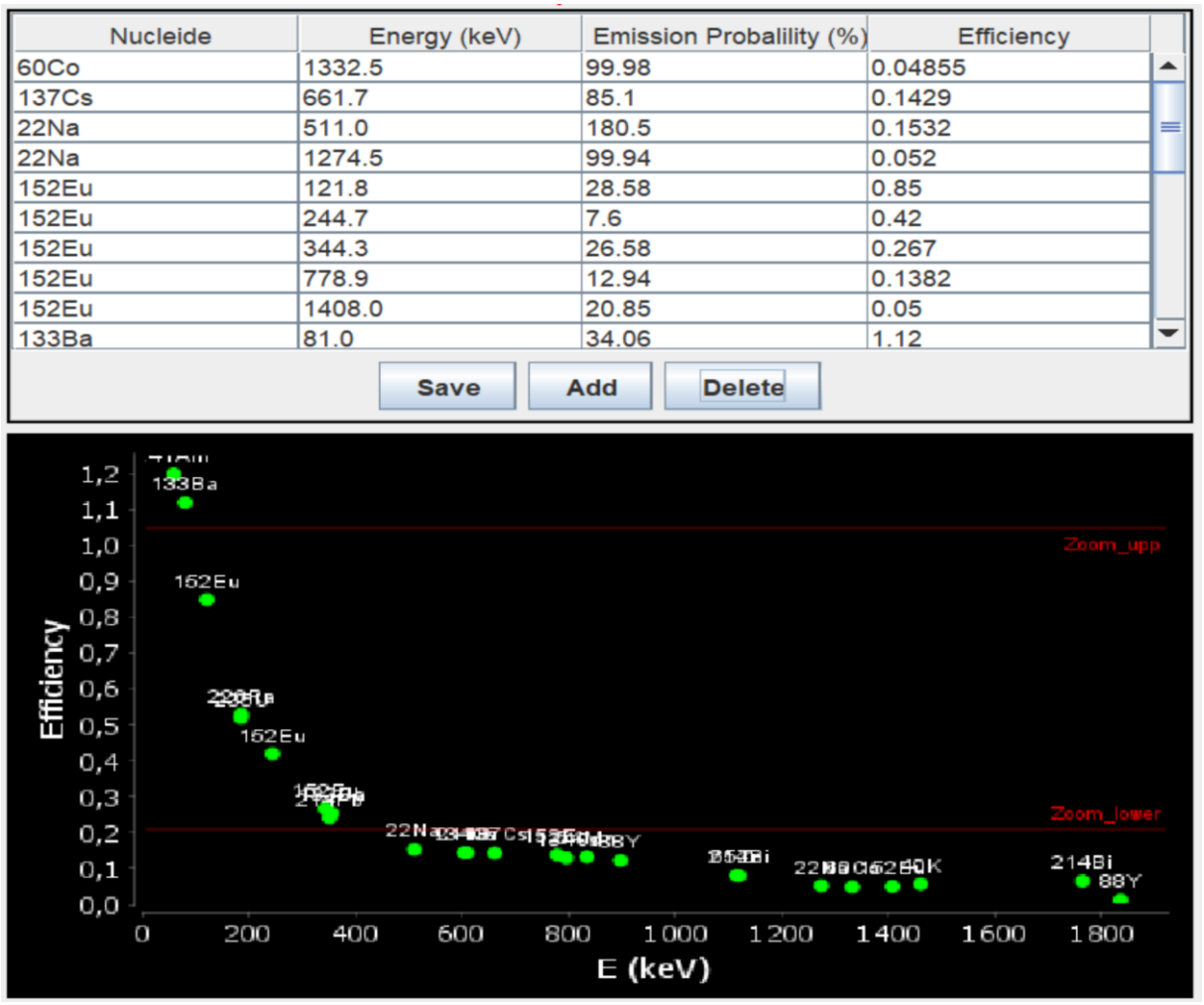

Fig.3 Visualization of data entered in the table and graph

2. Logarithmic formula for efficiency calibration: The second button of the application allows selecting and applying the logarithmic formula used for efficiency calibration. This formula is represented by the following equation:

$$\ln(\varepsilon)=a+b\cdot\ln(E)+c\cdot\ln(E)^2+\cdots+f\cdot\ln^n$$

This formula is particularly useful for calibration models requiring a

When this button is clicked, a new window opens, offering an interactive interface allowing the user to configure the parameters of the formula (4). In particular, it is possible to define the degree n of the formula, with options to increase or decrease it as needed. This flexibility allows adapting to the different requirements of the experimental data.

Another button in this window triggers the automatic calculation of the coefficients a,b,c,…,and f from the data provided. The calculation results appear directly in dedicated boxes, ensuring easy and quick consultation. In addition, the window also displays a graphical representation that superimposes the fitted curve from the logarithmic formula on the radionuclide data points. This visualization helps to assess the quality of the fit at a glance. Figures 4 and 5 illustrate this operation, before and after applying the formula. These steps make the process intuitive while providing powerful tools for analysis and calibration. Thus, the user can explore different configurations of the formula and obtain optimal results while maintaining a clear view of the data and the adjustments made.

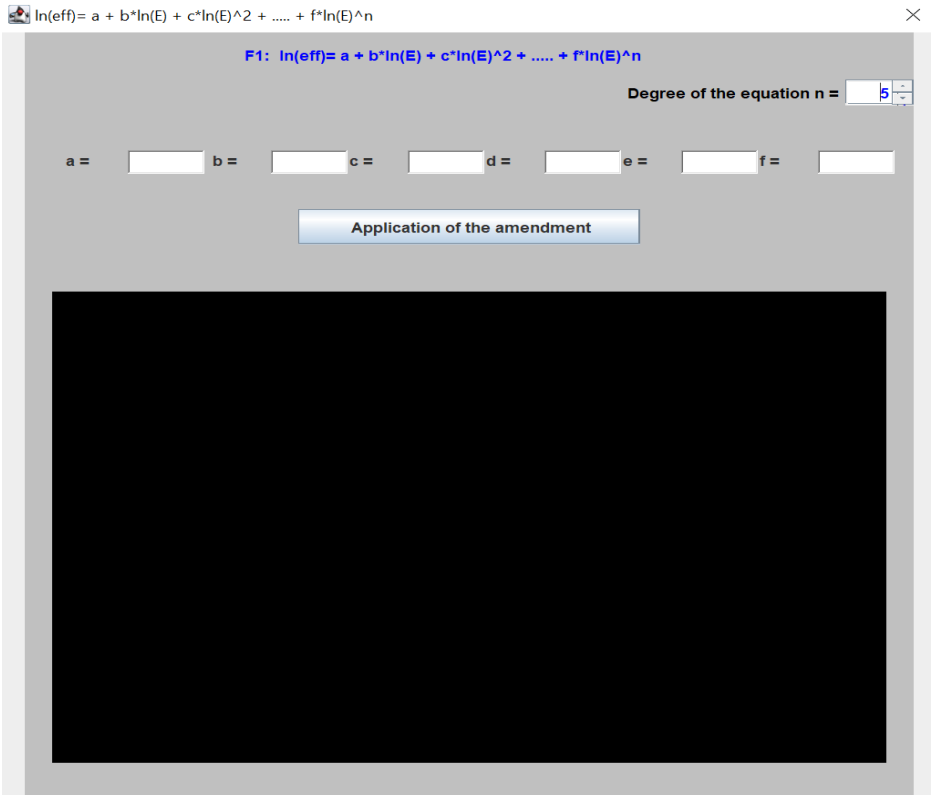

Fig. 4 Window dedicated to the logarithmic formula

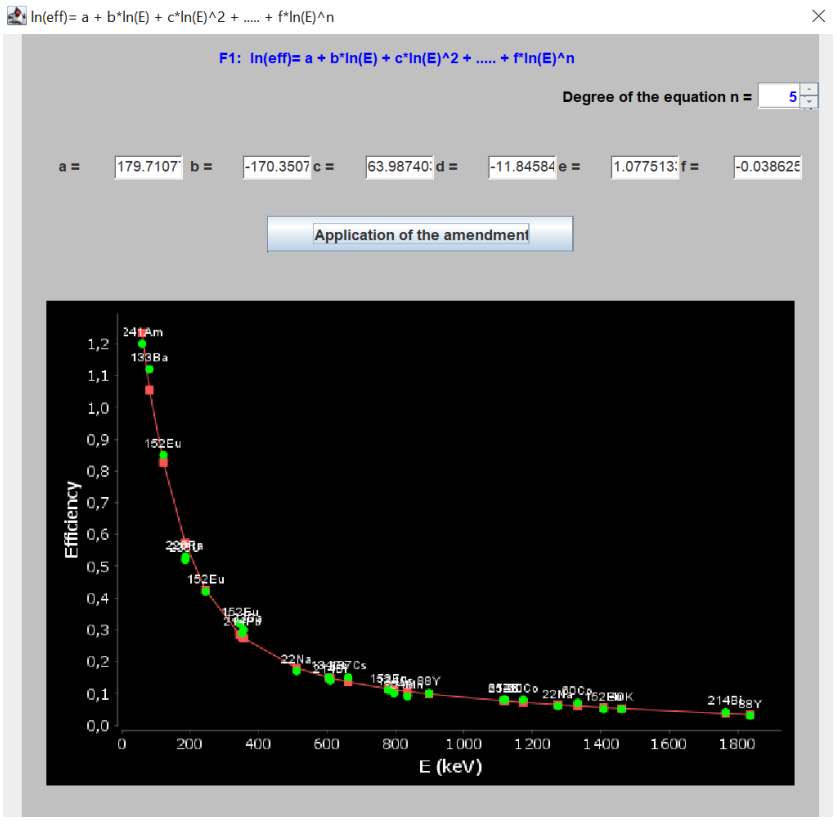

Fig. 5 window after fixing degree number and automatically calculates the coefficients of the formula

3. Simplified exponential formula: The third button of the application allows to apply another widely used formula for efficiency calibration, expressed as follows:

$$\varepsilon = a \cdot E^{-b}$$

This formula is particularly suitable for modeling situations where the efficiency follows an exponential decay as a function of energy. This type of behavior is often observed in gamma detectors, especially when studying higher energy ranges, where the efficiency decreases significantly.

When this button is clicked, a dedicated window opens, providing the user with a clear and user-friendly interface. the "**application of the amendment**" button automatic calculation generates the coefficients a and b, which define the curve corresponding to the model.

To help the user visualize the results, the integrated graph overlays the fitted curve on the experimental data points. This allows to immediately verify the relevance of the fit. The user can thus compare the fits to the raw data while benefiting from a precise and fast analysis. This feature is essential for calibration work requiring an exponential model and guarantees a better understanding of the relationships between energy and efficiency.

4. Simple polynomial formula: The fourth button is dedicated to the calibration polynomial formula in the form:

ε=a+b·E+c·E^2+…+f·En^n.

This formula is ideal for calibrations requiring a direct and progressive relationship between energy and efficiency. The window dedicated to this formula is similar to that of the first formula accessible via the first button.

5. Advanced exponential formula: The fifth button allows you to use a complex formula:

ε=exp(a+b·E+c·E^2).

This option is useful when the calibration model requires a more sophisticated exponential growth or decay.

6. Automatic calibration: The last button is dedicated to automatic calibration, an advanced feature that allows you to successively apply all the formulas mentioned above. The software analyzes the data provided and automatically selects the most appropriate formula for each case, based on the results obtained. This method guarantees optimal calibration, without complex manual intervention.

The window associated with this feature (shown in Figures 6 and 7) contains several specific parameters. At the top of the window, boxes are dedicated to defining the energy intervals, classified into three categories: low energy, medium energy and high energy. By default, these intervals are defined as follows: from 0 to 200 keV, from 200 to 1000 keV, and from 1000 to 2500 keV. However, the user can adjust these ranges according to their specific needs, thus offering great flexibility in the analysis.

Two other boxes allow specifying the degree of the polynomials used in the logarithmic formulas (formulas 1 and 3) for the efficiency calibration. This customization helps to refine the results according to the characteristics of the experimental data.

A button called "**Application of the amendment**" triggers the analysis and automatically fills a table containing the average of the errors calculated for each formula in the different energy intervals. Once the analysis is complete, the software automatically proposes the most consistent formula for each energy interval. The selected formulas appear clearly on the left of the graph, allowing the user to follow the adjustments applied.

Finally, a curve is plotted by combining the three formulas on the different intervals. This visualization allows seeing the continuity and consistency of the adjustments over the entire energy range. the developed formula appears automatically under the graph.

Thanks to this organization and the modularity of the buttons, the software offers an intuitive, flexible use adapted to the varied needs of users, while guaranteeing reliable and precise results.

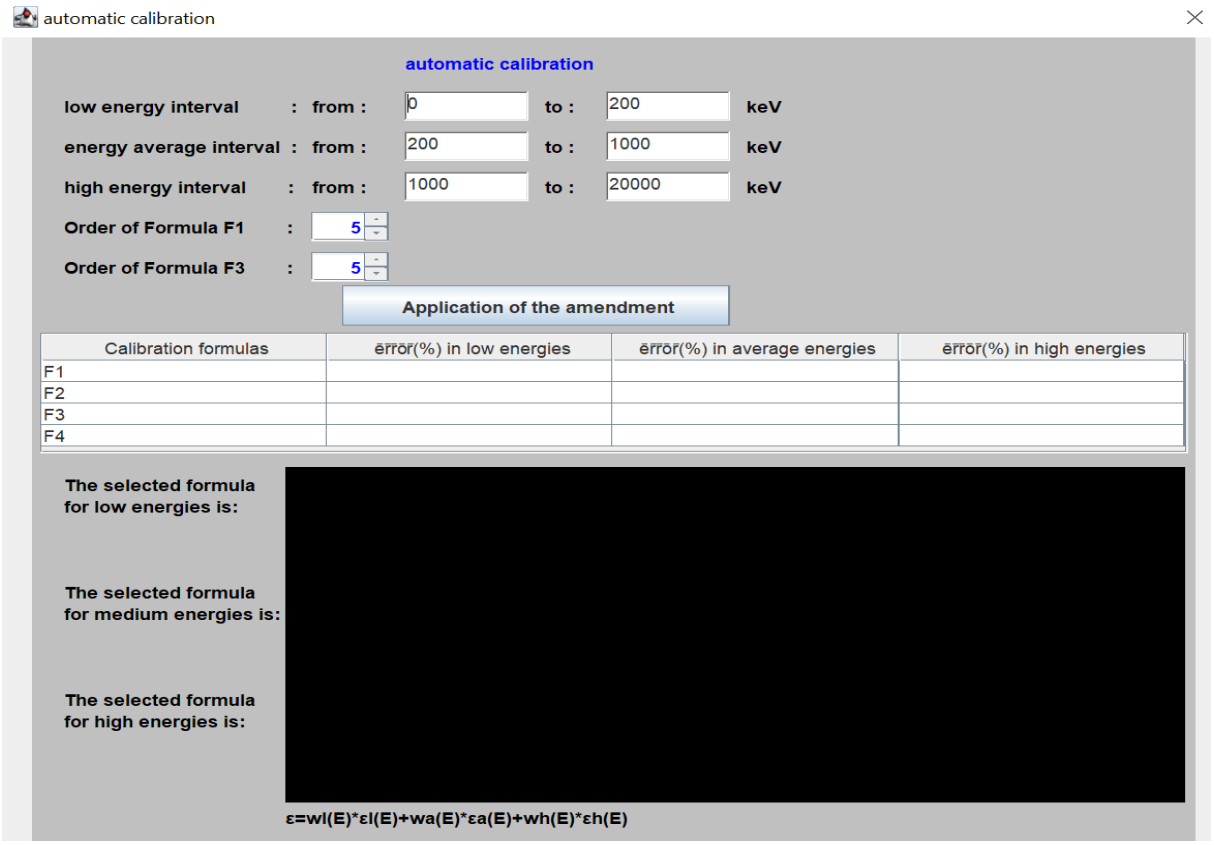

Fig. 6 Window dedicated to the parameters of the develop method

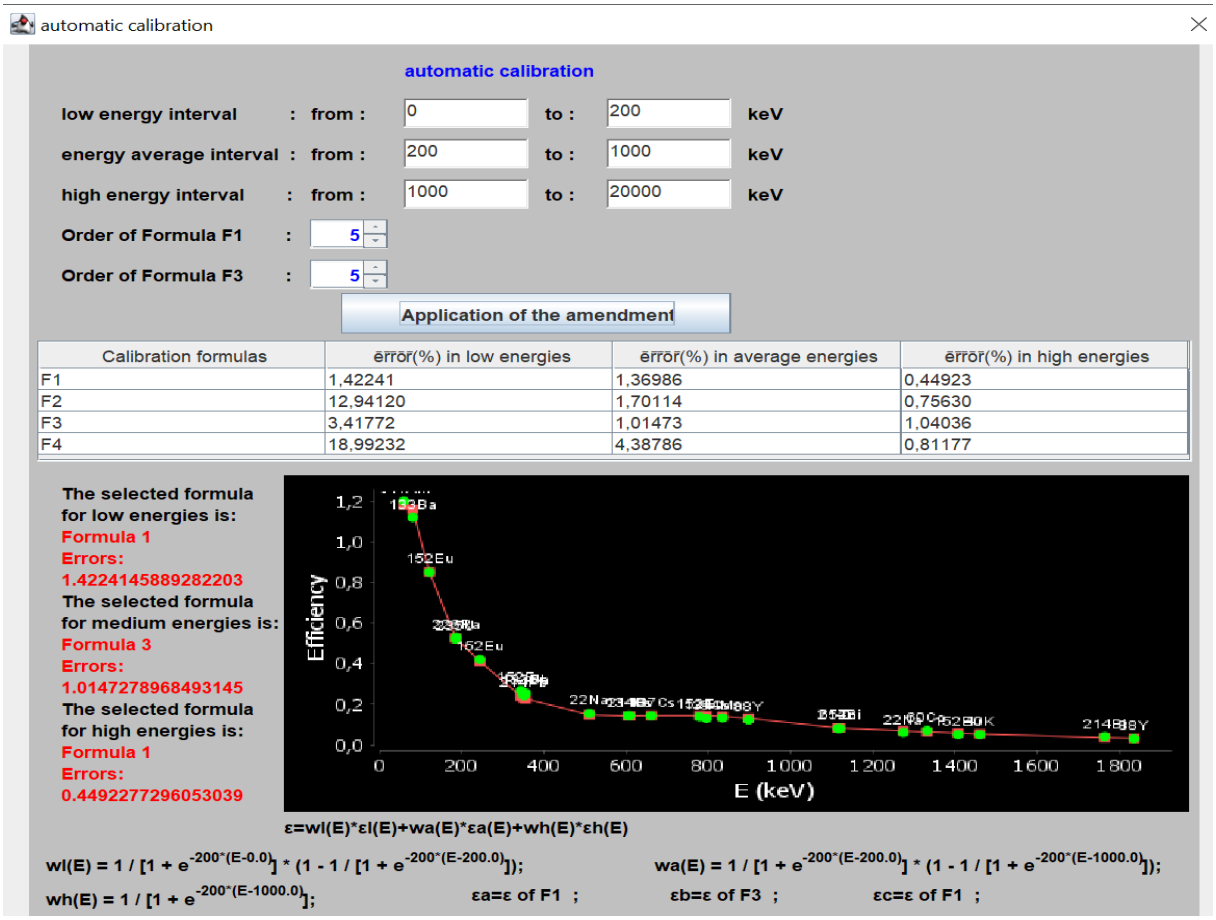

Fig. 7 An example of the parameter values of the new method after an automatic calculation

2.2 Radionuclide table section: Positioned at the center and upper part of the interface, this section displays a detailed list of the analyzed radionuclides. The table includes several key columns of information, such as the gamma photon energy, the detector efficiency at each energy, and the probability of photon emission for each radionuclide. This arrangement ensures a clear and structured visualization of the data.

2.3 Graph section: Located at the bottom of the interface, this section is dedicated to the visual representation of the results in the form of graphical curves. Users can observe trends, compare experimental data to theoretical curves, and verify the quality of the performed calibration. The graph is designed to be interactive, offering zoom options for more precise analysis.

This modular organization of the interface allows users to easily navigate between the different features while maintaining an overview of the data and results.

Conclusion

AEC (Automatic Efficiency Calibration) presents itself as an effective tool for gamma spectroscopy professionals, offering an efficient and accessible solution for detector calibration. Thanks to its four calibration formulas and its automatic method, it can significantly simplify the analysis of gamma spectra while ensuring accurate and reliable results. Its open source nature allows the scientific community to adapt and improve the software according to the specific needs of each user. AEC is thus a valuable asset in many fields, such as radiation protection, nuclear medicine and environmental monitoring, contributing to the advancement of research and industrial applications. Its flexibility and user-friendly interface make it a choice for those looking for a powerful and personalized calibration tool.