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Python Software for Data Processing and Quality Control in HPGe Detectors

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1. Introduction

Python is an extremely popular high-level programming language that can be used for data analysis, scientific programming, and many other purposes. This popularity is due to the readability of Python code. Many of its expressions and functions are very similar to the English language. The language aims at high productivity and a high degree of readability, in addition to adding excellent libraries and resources.

Radiation detectors made of High Purity Germanium (HPGe) are in the front line of fundamental research since their first development, mainly used as gamma-ray detector [1].

2. Methodology

2.1. Get Calibration Measurements

Daily calibration measurements are performed by the user places an uncalibrated detector-specific stacked $^{57+60}$Co source at the specified position and performs a 600s real-time acquisition. Spectra are analyzed using suitable software [2] (called CAX) that calculates peak position, resolution, area (in counts per second of real-time acquisition) and uncertainty [3].

2.1.1. Old Method

The program saves this verification data in a .csv file which, using the previous method, was manually transcribed onto a paper spreadsheet, along with the date and time of the measurement and who carried out this verification, which were later typed into an electronic spreadsheet in order to store these data.

2.1.2. Method GPB

The program written in python named Gamma Precision Balance (GPB), takes this .csv file, imports/extracts its necessary data, and using repetition structures it finds the determined peak of the 2 elements with a margin of variation that is commented in section 2.2. When it finds a value between these limiting parameters, it takes that value, which in this case is the energy, extracts the position of this data in the variable, with this position it takes the other relevant data in the other variables, such as the resolution.

The collected data are stored in the same digital spreadsheet used by the old method, but the first difference and advantage is that it is done automatically and in an extremely short period of time. After storing the calibration data for this day of $^{57+60}Co$ source measured, the program imports/extracts all the calibration data for that particular month present in this worksheet to perform the quality control plots, on Results and Discussion, with certain parameters, section 2.2, which are later automatically saved as a .png file in the directory.

And other benefits will be discussed later in the section 2.3.

The GPB was divided into two parts, in Fig. 1, in purple and pink, they are the parameters and the blue part, which is the final plot of the quality control graph, which are executed through the subprocess module in Python which allows you to execute other parts of the code.

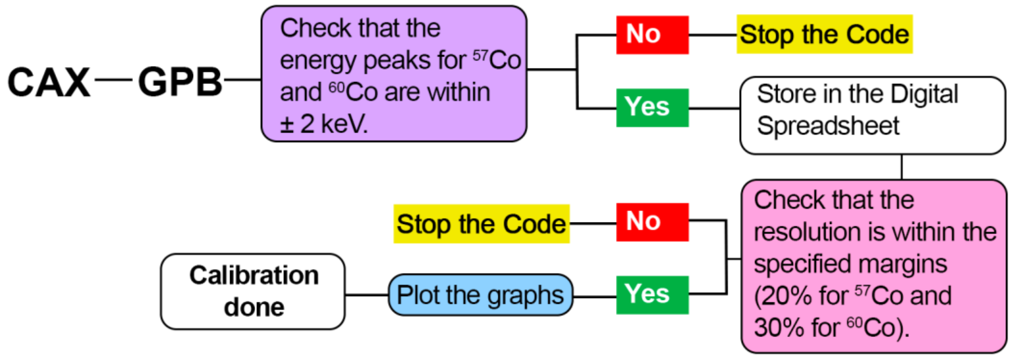

Figure 1: GPB Method.

The quality control chart tests were carried out using data from 177 months, from 2006 to 2022, from the same equipment (see Appendix extra information).

2.2. Quality Parameters

For the Energy subplot, the acceptable limits were added (green and red lines) is the maximum and minimum parameters where the calibration is considered good, and a variation of 2 keV up and down was used, that is 120.06 and 124.06 for ^{57}Co and 1330.5 and 1334.5 for ^{60}Co.

In the subplots of the resolution, it is possible to notice a blue line, which represents the average of the resolution of the previous month, using this average the acceptable limits are plotted, of which a variation of 20% was used for ^{57}Co and 30% for ^{60}Co.

These subplots are very important since they show the existence of factors that can affect the efficiency and/or resolution of HPG detectors, and include problems in the detector's crystal (such as defects induced by neutrons or contact migration, for example), in the assembly of the detector (loss of vacuum is usually the dominant factor) or in the associated electronics [4].

2.3. Errors

The Excel spreadsheets, were first checked for obvious typing errors, as problems with dates and/or the decimal separator; in this process some of the data had to be discarded as the results were completely incompatible with the whole, indicating some form of unidentified experimental mistake[4], that in the chart plotting process can cause errors of the ”ValueError” type, which indicates an incompatibility between the amount of data on the X and Y axes, which occurs when the data that were imported from these spreadsheets have sizes/quantity different.

It is also possible to comment on the TypeError, which occurs when we have an incompatibility of data types, which basically originates when it contains a word instead of a numerical value, such as observations about the equipment, which prevents the graph from being generated. By automating the old process, 2.1.1, these errors can be eliminated.

3. Results and Discussion

The quality control chart tests carried out, in addition to allowing the testing of the code for quality control, showed the efficiency of the equipment over the years, allowing the identification of days on which the calibration carried out was outside the ideal usage parameters or even.

In Fig. 2 we can see a large dispersion of data for the resolution of ^{57}Co.

In Fig. 3 it is possible to see a reasonably good calibration as it is within the quality parameters described in 2.2 section, however, for ^{60}Co, the average is very close to the maximum limit of 2 keV, while for the resolution, which is based on the average result from the previous month, the maximum limit is almost outside the range set as acceptable, in other words, it is a calibration that is ok but indicates that the equipment needs to be checked.

The Fig. 4 show the energy rising and the resolution falling in the image at the end of the month, when the equipment vacuum was redone, leading to an increase in energy and a significant drop in resolution.

A good calibration will maintain a certain constancy in the data as seen in Fig. 5.

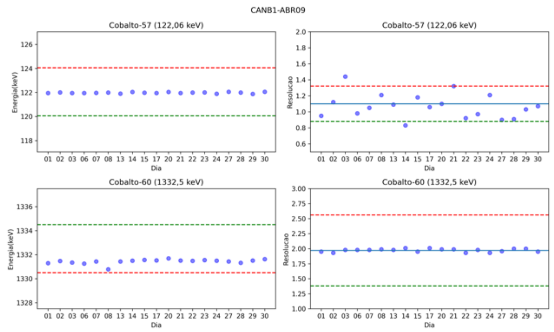

Figure 2: April 2009.

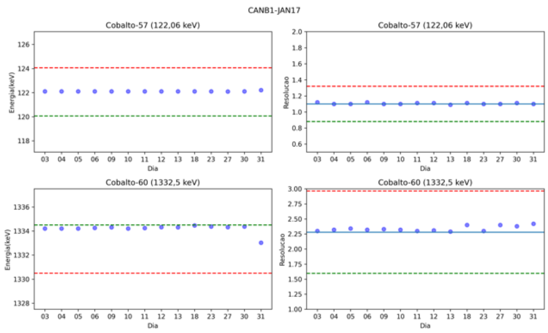

Figure 3: January 2017.

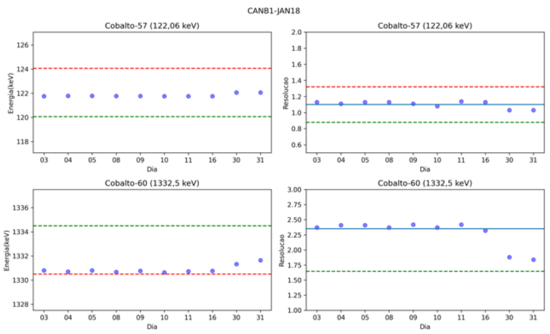

Figure 4: January 2018.

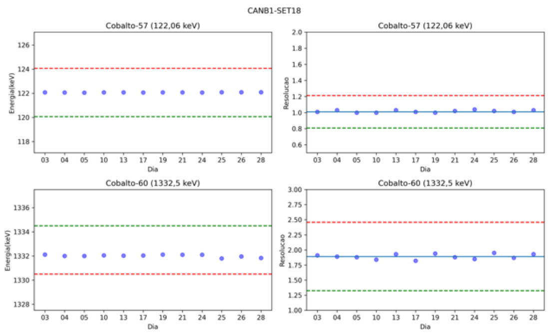

Figure 5: September 2018.

4. Conclusions

Automation ends up bringing benefits, considering that many users of detectors do not calibrate because of the old process and precisely Automating eliminates human errors like ValueError and TypeError that were described in the 2.3 section.

In addition, the GPB quality control in a visual way, taking the time to analyze and even some prior knowledge, considering that it is not a fixed parameter, but rather a constancy of the data. In addition, it avoids calibration if there are errors or unusual parameters using this data constancy, thus providing data of greater credibility and confidence.

Appendix extra information

The detector using at IPEN's Neutron Activation Analysis Laboratory, which used the data to carry out the tests, was manufactured by Canberra Industries with a resolution of 2.0 keV.

The Open Source code discussed in this document can already be found in the repository available on GitHub further information is available upon reasonable request to the corresponding author.

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