GAIN CORRECTION ALGORITHM FOR $LaBr_3(Ce)$ DETECTORS

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In this paper is reported the development of a new algorithm for performing gain corrections of spectra recorded with $LaBr_3(Ce)$ detectors. The code is based on the shape overlap of spectra instead of peak-searching. The change of the signal amplification with the counting rate was observed during γ spectroscopy experiments performed at the 9 MV Tandem Accelerator of IFIN-HH. This effect is most probably produced by the photomultiplier tube (PMT) and it's mechanism is related to the charge collection.

Keywords: γ spectroscopy, algorithm, $LaBr_3(Ce)$ detectors, gain correction

1. Introduction

During nuclear spectroscopy experiments, a very good precision is required for measuring nuclear observables such as the energy and time distribution of γ rays following nuclear reactions. The statistics recorded influences directly the precision, therefore, by using multi-detector arrays, spectra of all the detectors of the same type can be summed up. The main condition which makes the summing operation possible is a good energy calibration of the individual detectors. During the experiment, the calibration ideally would remain constant, but slight variations can be controlled and corrected offline.

The ROSPHERE [1] multi-detector array of the 9MV Tandem Accelerator of IFIN-HH uses HPGe detectors and fast $LaBr_3(Ce)$ scintillators for performing in-beam fast-timing experiments [2]. The $LaBr_3(Ce)$ crystals are coupled to special photomultiplier tubes (PMT) with 8 stages of amplification such as the Photonis XP20d0 and Hamamatsu R9779. The energy information is recorded from the signal of the last dinode and the timing is extracted from the rapidly saturating anode signal. During the experiments performed with ROSPHERE, a calibration variation is produced, as shown in Fig. 1, depending on the counting rate of the $LaBr_3(Ce)$ detectors and is due to the charge collection in the

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$LaBr_3(Ce)$ PMTs. The calibration variation of the HPGe detectors is not significant, the slight changes depending mostly on the temperature. The energy resolution of the HPGe array is very good, the photopeak full-width at half maximum (FWHM) is ~ 0.2% for 1 MeV photons. Therefore, correcting the gain variations between runs is performed by programs which use a peak-searching function.

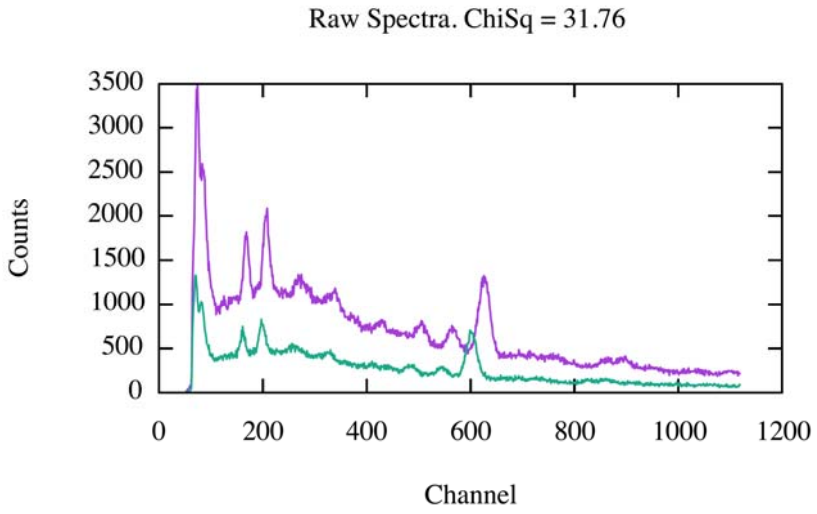

Fig. 1. Amplification (gain) variation of the spectra recorded with the same $LaBr_3(Ce)$ detector between two different runs of the same experiment.

The energy resolution of $LaBr_3(Ce)$ detectors (~3%) is an order of magnitude higher compared to the HPGe detectors and the peak-searching technique cannot be applied reliably all the time, especially for experimental spectra where the peak density is high and, due to the poor energy resolution, many peaks are overlapping. The corrections could be performed manually, but this was possible for a small number of detectors and runs. Taking into account that ROSPHERE has 11 $LaBr_3(Ce)$ detectors and the data from an usual experiment is split into 50 - 200 runs, the manual correction is not feasible any more. Therefore, an automatic procedure to correct the gain shift between each run (run-by-run) was required and a dedicated code was built specifically for this task.

2. Technical description of the code

The *gcor* (Gain Correction) [3] code is written in the C programming language and uses the GNU Scientific Library [4] for the fitting subroutines and GNU Plot [5] for displaying the results in real-time. As input files it uses binary spectra specific to the GASPware data analysis package in the format A#B.000C, where A is the detector name, B is the detector number and C is the run number.

The algorithm is based on comparing a narrow region from the total spectrum of a run with the spectrum from a reference run. The best overlap is evaluated using the χ^2 minimization depending on the number of channels the selected region was shifted relative to the reference spectrum. After the shift corresponding to the best overlap was found, the program moves to the next region and starts over the procedure. Finally, the shift of each region is plotted against the centroid energy, as shown in Fig. 2. A systematic study was performed during the development of the code and it was observed that the dependence between shift and energy is linear, as seen also from Fig. 2. After the program performs the linear fit and writes the coefficients in an output file, it cycles over the remaining runs and detectors, repeating the steps.

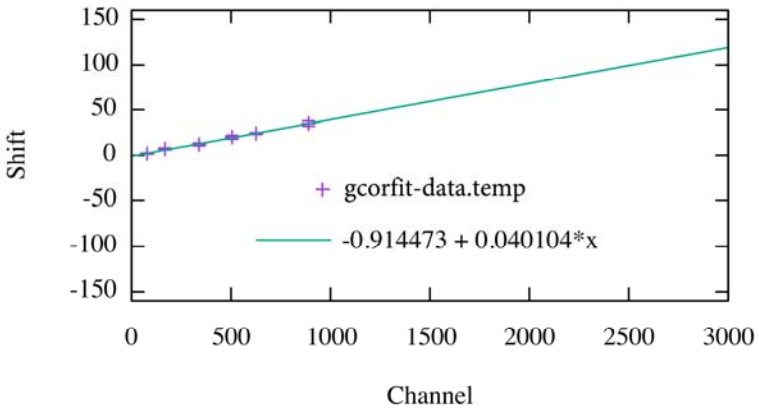

Fig. 2. Gain variation (shift) of each individual region as a function of energy (channel).

Prior to using the *gcor* code, the spectra should be calibrated using standard calibration sources (^{152}Eu) in order to correct the intrinsic nonlinearities of the detectors. To optimize the best overlap searching algorithm, the raw spectra are first smoothed (averaging on several channels), normalized to the reference spectrum and then the derivatives of the two spectra are analyzed. The resulting

derivative spectra of two runs with considerably different statistics can be seen in Fig. 3. By applying the aforementioned methods, only the shape information is preserved and the best overlap can be tested.

3. Results

In Fig. 4 is shown the text output of the code. It uses the default parameters from the configuration file. The user can modify the configuration file according to each individual spectrum requirements.

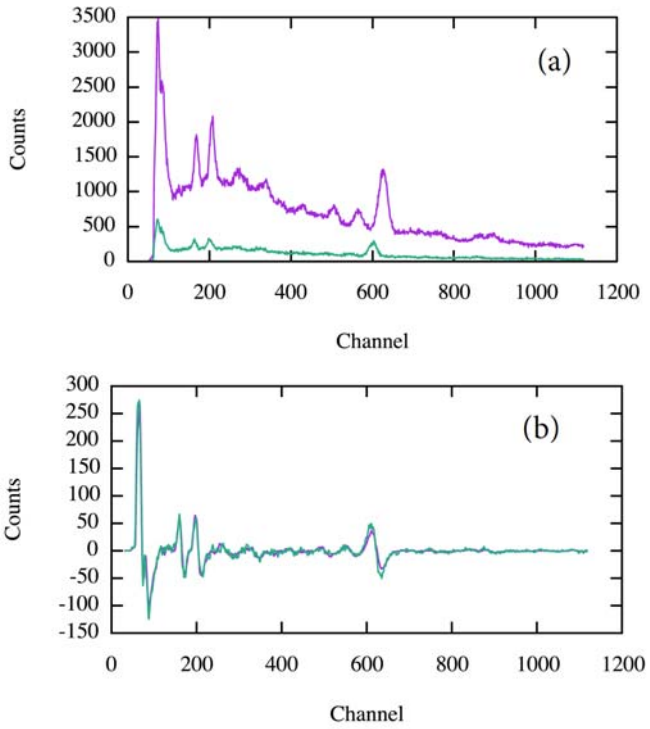

Fig. 3. Comparison of two raw spectra with significantly different statistics (a). Using the smoothing, normalizing and derivation procedures, only the shape information is preserved. After finding the best overlap and applying the correction coefficients, the two derivative spectra (b) look almost identical.

The input parameters, accessible to the user through *gcor_settings.txt*, are the following:

- Chan: total number of channels in each spectrum
- DetNum: total number of detectors
- RefFile: the reference run number

- EndFile: the last run that will be analyzed
- Sweep: the maximum number of channels over which a region will be shifted relative to the reference run to find the best overlap
- Sensitivity: sets the ratio between the highest peak in the region and the background level. Regions which have a ratio lower than one set here will be excluded from the best overlap searching algorithm.
- MaxChiSq: the maximum value of the χ^2 for which the code will consider the gain correction a success. If, after applying the correction, the χ^2 is higher than MaxChiSq, the code will display a warning message.
- LEFT RIGHT: a list with the left and right limits of the regions that will be selected in the spectrum. They will be automatically changed, when the code is running, to be centered on the highest peak in the region.

```
======= GCOR v1.4 - Automatic Gain Correction =======
       R. Lica, IFIN-HH, February 2014

Settings taken from 'gcor_settings.txt'.
------------
Chan    8192
DetNum  11
RefFile L0.0001
EndFile L0.0200
Sweep   150
Sensitivity=4.000000
MaxChiSq        10
LEFT | RIGHT
------------
  30     100
 110     180
 190     310
 320     430
 440     570
 580     780
 790     990
----> 47 runs were successfully read

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Detector #00
--------------------

L0#00.0002       OK (cal/raw = 2.16/4.33)       Going to next? [y]/n/a

L0#00.0003: Recalibration is not required (cal/raw = 0.43/0.43)         Going to next? [y]/n/a

L0#00.0004       OK (cal/raw = 0.88/19.64)      Going to next? [y]/n/a

L0#00.0005       OK (cal/raw = 1.15/35.47)      Going to next? [y]/n/a
```

Fig. 4. Text displayed in the terminal when the *gcor* code is running.

In Fig. 5 is shown the graphical output of *gcor*. The linear fit parameters of the shift versus energy will be applied to the analyzed run so that it will overlap with the reference run. The parameters are also saved in the ASCII output file *gcor.cal* for each individual detector and run, so that they can be used for run-by-run calibration in the data sorting programs.

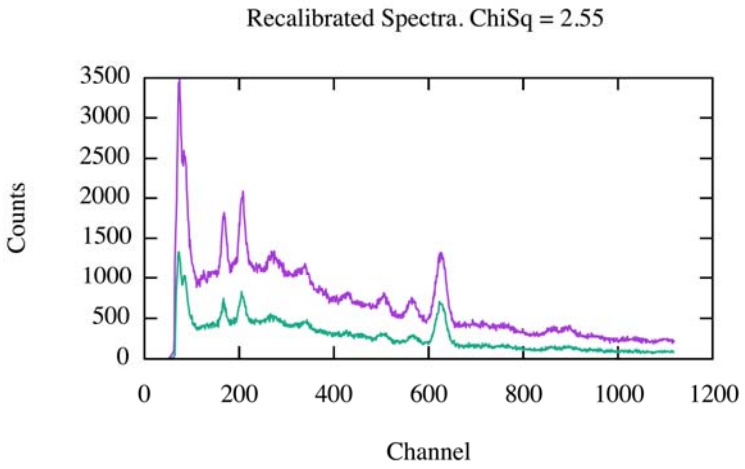

Fig. 5. The result of applying the linear correction from Fig. 2 to the analysed spectrum from Fig.1. A significant improvement of the overlap is observed, the χ^2 changing from 31.76 to 2.55.

6. Conclusions

A problem related to the gain variation of the $LaBr_3(Ce)$ detectors was observed during spectroscopy experiments at the ROSPHERE multi-detector array of the 9MV Tandem Accelerator of IFIN-HH. A dedicated code was developed in order to correct offline the calibration in a run-by-run basis for each individual detector. The gain correction algorithm *gcor* is based on finding the best shape overlap of spectra instead of peak-searching. The results obtained have proven that it works and the code was already used reliably on several experimental data sets [6, 7].

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