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DEVELOPMENT OF AN ANALYSIS METHODOLOGY APPLIED TO 4πβ–γ SOFTWARE COINCIDENCE DATA ACQUISITION SYSTEM

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ABSTRACT

The present work describes the new software methodology under development at the IPEN Nuclear Metrology Laboratory for radionuclide standardizations with 4πβ–γ coincidence technique. The software includes the Coincidence Graphic User Interface (GUI) and the Coincidence Analysis Program. The first results for a ^{60}Co sample measurement are discussed and compared to the results obtained with two different conventional coincidence systems.

1. INTRODUCTION

The Nuclear Metrology Laboratory (LMN) at IPEN developed a new data acquisition system for 4πβ–γ software coincidence measurements [1, 2] and radionuclide standardization. With this technique, the radioactive activity is obtained in two steps: the measurement (or data acquisition) and the software data analyzing. Many advantages become from this software approach. Several system and program parameters should be optimized in the analysis process, in order to get better accuracy results.

The acquisition system was implemented by using a National Instruments (NI) acquisition card and LabVIEW graphical software [3]. The card is coupled to a microcomputer and to the beta (a proportional counter in 4π geometry) and gamma (two NaI(Tl) scintillation systems) detectors, with respective signal amplifying, via a proper NI connection panel. This system performs the registering, into disk files, of the amplitude voltages and time of occurrence, for all the detected beta and gamma pulses.

The recorded data is then processed by special software, called the Coincidence Analysis Program, in order to obtain the beta, gamma and coincidence counts (and respective counting rates) and determine the activity value. The final calculation process takes into account some corrections due to the system dead-times, background (BG) rates, accidental coincidences and sample radioactive decay. The present work describes the software under development at LMN, presenting and discussing the obtained results.

2. COINCIDENCE SYSTEMS OVERVIEW

The necessary information is here briefly presented in few topics, as a base for the software methodology understanding:

- coincidence methodology;
- new concept of *software coincidence systems*.

2.1. The Coincidence Methodology

The coincidence methodology [4, 5] is considered an absolute technique for radionuclide standardization. With a few observable quantities, the activity of a radioactive sample, constituted by a dominant radionuclide, can be obtained with a high accuracy. Based on the radionuclide specific decay scheme, the method consists in the determination of the counting rates related to the main decay events, such as the beta-gamma transitions.

The LMN standardizations are mainly based on beta-gamma decaying radioisotopes. In addition to the beta and gamma counting rates, the coincident beta-gamma pairs must be computed into the coincidence counting rate, by using a Coincidence Module. As detailed on the references, the activity can be then determined from these three counting rates, independently of the beta and gamma counting system efficiencies. The method takes into account several corrections to compensate system dead times, BG counting rates, sample decay and accidental coincidences, improving the accuracy of the results.

Some radioisotopes decay by gamma-concurrent transition events, such as internal conversion. Consequently, the beta counting rate increases, in detriment of the gamma rate, and the beta counting system efficiency significantly affects the results. In these cases, the efficiency extrapolation method [5] is frequently used to correct the obtained activity value, consisting of performing several measurements, for several beta counting efficiency values. Normally, the efficiency changes are accomplished by changing a related system parameter, like the beta discrimination level (slightly increasing a mono-channel lower threshold), or by inserting electron absorbers on the sample source. Thus, the resulting activity values are then plotted in function of the efficiency. More precisely, the *activity versus beta inefficiency* graph is plotted, leading to the curve fitting and to the actual activity value determination, as the extrapolated value for the null inefficiency (unitary efficiency).

2.2. Software Coincidence Systems

As explained on the above item, nevertheless its good accuracy, the coincidence method can take several days to obtain the results, mainly if the beta efficiency extrapolation is needed. Many measurements implies on the need of many interventions of the system operator, increasing the necessary time as well as the probability of mistake occurrences.

The answer to the pointed matters is the software coincidence technique (references [1, 2]). Hardware and software tools have evolved in the last years. New methods could be developed and older methodologies, like Monte Carlo simulation, could be widely implemented using microcomputers, as practical substitutes for the main frame computers.

A software coincidence measurement takes place in two steps. At first, the beta and gamma detected pulses are digitalized into data files, saving all the information of pulses timing (instants) and voltage amplitudes (heights). Virtually, the detection signals can be reproduced at any desired time. Finally, the stored data files are processed by special software. This step is called, here, the software analysis. The main task of this software is the determination of the counting rates needed to the beta-gamma coincidence methodology. The coincidence counts are obtained from the beta-gamma timing relationship, comparing the occurrence instants and establishing the optimal coincidence time range. However, much more stuff can be implemented, like simulations, corrections and calculations. In fact, from a single measurement, the software can perform itself all the beta system efficiency changing, in order to obtain the extrapolation curve. So, the advantages of software techniques are evidenced by an easier and faster measurement process.

3. THE LMN SOFTWARE COINCIDENCE SYSTEM (SCS)

Traditionally, the LMN team takes efforts on systems and methodologies updating. In this way, LMN is developing its own software coincidence system (SCS). The recently implemented data acquisition hardware and the coincidence software, under development, are described in this item, with emphasis on the software.

3.1. Coincidence System Hardware

The acquisition system was conceived to perform the necessary data storing described above (the first step of the software technique – item 2.2).

An acquisition NI [3] card, PCI6132, was employed, with the capability of independent digitalization of up to four analog input channels, at 14 bits resolution and up to 3.0MS/s (Mega-samples per second). This card is connected to a microcomputer, via PCI slot. The card configuring and controlling, as well as the acquisition managing, is done by software, developed with the NI LabVIEW graphic programming tool.

The beta and gamma detectors are connected to signal amplifying modules. The amplified pulse signals are connected, via BNC cables, to a NI panel. The panel, via a proper NI cable, is then connected to the PCI6132 card. This hardware is very simple, if compared to the several nuclear modules of a conventional coincidence system (discriminators, delay lines, coincidence unit, pulse counters, etc.).

In order to reduce the data file sizes, only the pulse amplitude voltages are registered, not the entire pulse digitalized information, since this approach satisfies all the LMN needs. For future applications, where the pulse shaping becomes significant, the entire pulse sampled voltages could be saved. A normal 2.5 MS/s sampling rate is enough for accurate time and amplitude registering, since the amplifying shaping times are set to 3.0μs pulse widths.

The occurrence time of each detected pulse is also stored into the data files, completing the pulse data pair information. Thus, an individual channel data file is a sequence of records with two fields: time and amplitude, referring to a specific detected pulse and constituting the essential pulse information for the coincidence software.

The amplitude voltages range from 0V to ~12V (0-10V nominal). The PCI6132 sampling 2.5MHz internal signal is internally used as the time-stamp for the time registering. Data are recorded into blocks of 1 second and the time is relative to the beginning of each block.

3.2. Coincidence System Software

The coincidence software, under development at the LMN, is written in C++ Object Oriented Programming (OOP) language, to provide a graphic user interface (GUI) and the coincidence analysis program. Software development free tools (listed below) are employed to create a portable code that compiles under the main used platforms (Linux, Mac, Windows, etc.).

The used software developing free tools:
- gcc (GNU C/C++ Compiler), under mingw/Windows;
- Dev-C++ IDE (C/C++ Integrated Development Environment);
- FLTK (Fast Light Tool Kit) – C++ class library for Graphic User Interface (GUI) design.

3.2.1. The coincidence algorithm

The coincidence algorithm is the core of the analysis software. Its development started before the hardware implementation. The data files were then obtained by Monte Carlo simulation, with another specially developed program [6]. The former code was improved and modified to accept the actual data files, including the proper time corrections, since the new acquisition system time reference is restarted at each data block beginning (3.1).

One of the major improvements is the new coincidence algorithm. The coincidence analysis program reads the beta and gamma pulse data from the files and builds a mapping of all the possible combinations of beta-gamma times, candidates to be a coincident pair; then, in an iterating process, it searches for the lesser time differences. The new algorithm also includes system dead time simulation, neglecting subsequent pulses, inside the software stipulated dead time range. This *software dead time* (SDT) improvement is a useful tool for the accuracy improvement, leading to the new SDT methodology development [7]. The pulse amplitude information is used to select the significant pulses, acting as a software discrimination or windowing, discarding the low level (energy) noise beta pulses and the gamma ones that remain outside of the total absorption energy ranges. Thus, the correspondent electronic modules are not needed.

3.2.2. Activity determination

The beta, gamma and coincidence gross counts are obtained from the radioactive sample measurement data files. Another set of files is obtained from a measurement performed with no radioactive sources, in order to obtain the BG counts. The activity calculation takes into account the source and BG data, obtaining the proper net counting rates. System dead times, accidental coincidences and sample decay are also compensated. Decay corrections consider the total measurement time and the time difference from the reference to the measurement dates. From here, the calculation process is the same of a conventional coincidence system, widely discussed in many other publications, such as the mentioned above (v. [4, 5]).

3.2.3. Coincidence graphic user interface (CGUI)

CGUI consists of a set of windows and dialog boxes in the graphical platform styles. The main window is shown in Fig. 1.

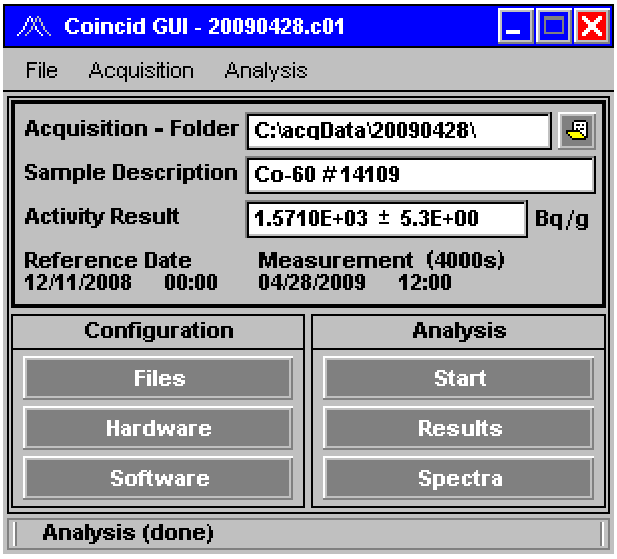

Figure 1. Coincidence graphic user interface main window.

At CGUI main window bar the program name is showed, followed by the name of the loaded (or just defined and saved) configuration file. The menu bar offers the same options available on the button sets (Configuration and Analysis). The acquisition frame shows the main information about a loaded (or just concluded) acquisition:

- Acquisition Folder: the main path on disk containing data and output files;
- Sample Description: a brief description of the object radioactive sample;
- Activity Result: the final obtained activity value for a loaded or just concluded analysis;
- Reference Date: the reference date and hour referred to the activity value;
- Measurement: date, start hour and total time of the measurement.

At the starting, all the fields are blank. Users can define and save the configuration file for a given set of measurement data files or load a previously defined and saved one.

Configuration file contains all the software and hardware parameters of a given acquisition, such as the data file names, the analysis output file names, software variable values, the used acquisition card channels description, etc.

The buttons in the Configuration frame provide the functionality to the system acquisition and analysis setting.

Pushing the Files button, the file setting dialog box opens, as showed in Fig. 2. The acquisition main folder can be defined, as well as the configuration file name, where all the software and hardware settings will be saved. A previous saved configuration file also can be loaded. The acquired data file names, of the object source and BG measurements can be here defined or loaded from disk. The analysis output data file names also can be defined, or previous obtained results can be printed.

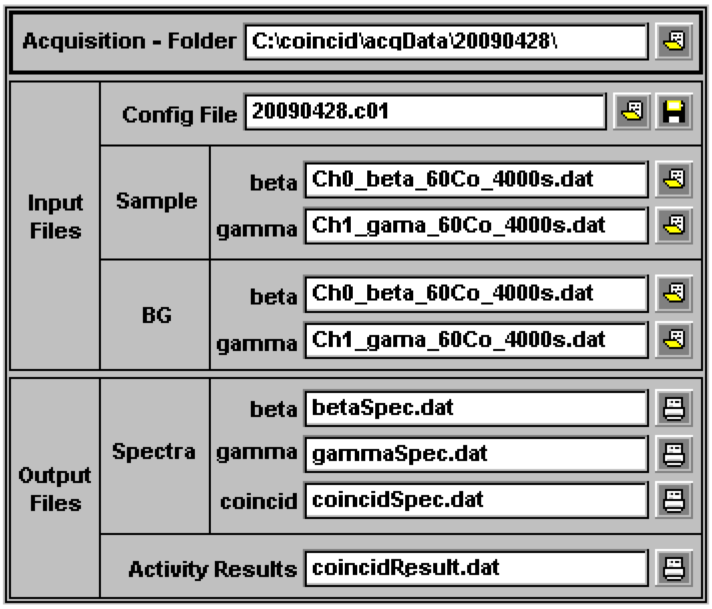

Figure 2. The coincidence data and analysis file setting dialog box.

The Hardware and Software pushbuttons open, respectively, the PCI6132 channel setting dialog box and the analysis program variable values, as shown in Fig. 3.

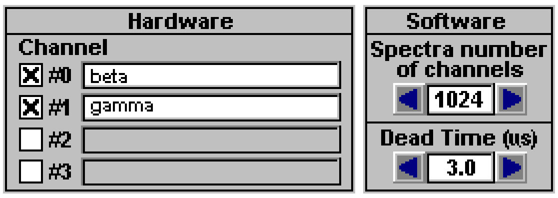

Figure 3. Dialog boxes for the PCI6132 channel and analysis program variables settings.

The Analysis frame provides buttons that call child dialog boxes for analysis controlling (start, cancel), results and spectra showing and printing. In the spectra dialog box, Fig. 4, the spectra channel ranges (software parameters) could be trimmed in order to improve the analysis results. The same input data file set can be analyzed with different software parameters. In a few iterations, the analysis optimization could be reached, much faster than the conventional process, in which many hardware adjustments are needed.

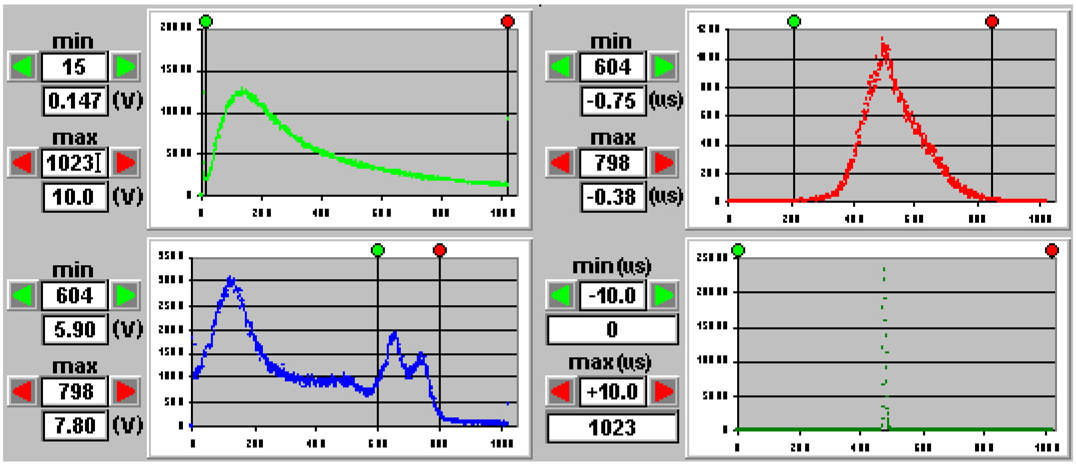

Figure 4. Spectra dialog box, showing the beta (channel 0), gamma (channel 1) and coincidence obtained spectra.

3.2.4. SCS measurement of a ^{60}Co sample

This item describes one of the most significant sets of measurements, performed for hardware experimentation and software development, and presents the results. All the above presented figures show information from this particular acquisition – a 4000s measurement for a ^{60}Co sample. The detection amplified pulses were derived to simultaneously feed the SCS and a conventional coincidence system, composed by amplitude discriminators, a coincidence module and pulse counters. The hardware parameters of the conventional system were adjusted as closer as possible to the SCS software parameters. However SCS parameters are *a posteriori* trimmed and possibly the perfect matching is intangible. Other LMN coincidence system was also employed for results comparison. This system is composed by delay modules, a Time to Amplitude Converter (TAC) and a Multi Channel Analyzer (MCA). The arrangement output pulse amplitudes depend on the TAC start/stop combination (beta/gamma or gamma/beta) producing a particular spectrum on the MCA, with three well defined peaks, from which the beta, gamma and coincidence counting rates are easily obtained.

Thus, three results for the same radioactive source are showed in Table 1, obtained with different coincidence systems: conventional – Counters and TAC –, and SCS. The SCS value is the very first value obtained by applying the SDT methodology [7], but better accuracy results are expected by improving the methodology.

Table 1. Three ^{60}Co standardization results, obtained with different systems

^{60}Co #14109	Counting rates (s^{-1})						Activity / Uncertainty (Bq/g)	
	Source			BG		Accidental		
System	beta	gamma	coincidence	beta	gamma	coincidence		
Counters	1322.12	64.86	55.44	1.43	2.64	0.11	1561.10	2.40
TAC	1305.24	63.80	53.80	2.41	2.76	0.21	1562.80	6.30
SCS	1321.06	65.04	55.06	2.73	2.91	0.11	1566.92	5.31

The obtained source gross counting rates, BG and accidental coincidences rates are listed in Table 1 for each measurement system (v. 3.2.2). The values comparison points to about 0.5% maximum discrepancies, with greater differences in the BG and accidental coincidence rates. The final corrected activity values, also listed, are consistent inside the uncertainty ranges. The SCS final value is about 0.37% greater than that obtained with the conventional systems. With software refinement, lesser differences should be obtained.

4. CONCLUSIONS

The SCS final result was considered satisfactory, with a maximum 0.37% discrepancy, when compared to the values obtained with conventional systems. The SCS is very promissory, with a large improvement potential, both in the hardware and software fields. Some of them will be soon concluded and many other features and tools will be added, increasing the SCS accuracy and ease of use. As examples, the extrapolation curve attaining algorithm will soon be completed and a software tool for library creation, establishing easy access to the main parameters for any kind of radioisotopes, will be developed.

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