A high accuracy calculation software for β(LSC)-γ coincidence counting system

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Abstract

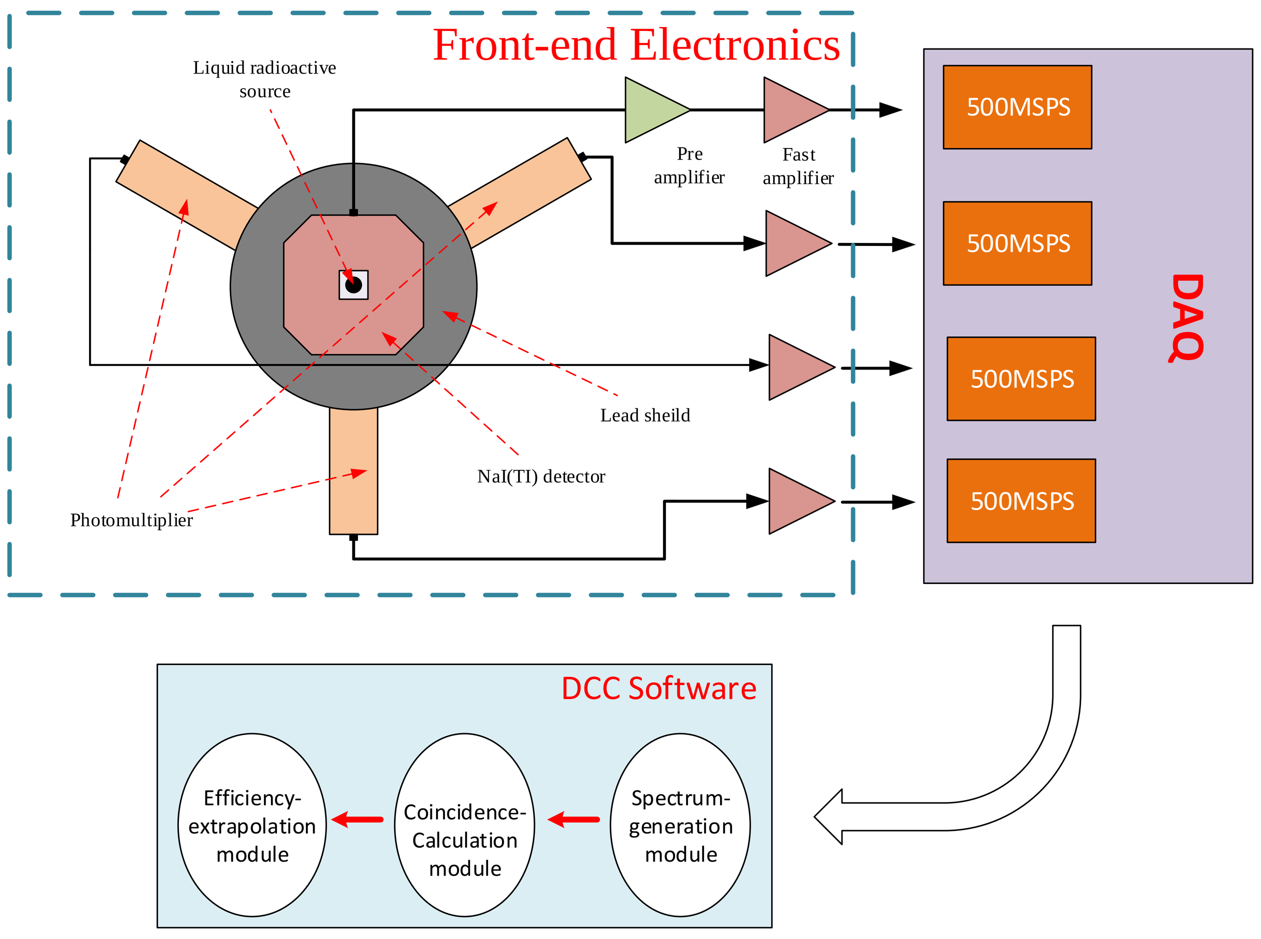
Liquid scintillation counting(LSC) is widely used in the absolute radioactivity measurement for its advantages in no self-absorption, simple preparation and relatively easy application to many radionuclides, for example, to Co60. Base on the existing liquid scintillation detection system and the commercial waveform digitizer CAEN DT5730, we developed a high accuracy calculation digital coincidence counting calculation software. In this study, we developed a set of method for the LSC system, especially in coincidence counting process and counting rate correction. The experiments on Co60 indicates that this software can work well in the absolute radioactive measurement。

Introduction

The LSC system consists of the FEE (front-end electronics) subsystem , DAQ subsystem and SCC software subsystem, as fig.1 shown. The FEE subsystem is made up of the detectors(including beta detectors and gamma detectors), pre-amplifiers and fast amplifiers, with which the unclear signals can be transferred into electronic signals. The DAQ subsystem is acted as by the CANE DT5370,which is a commercial waveform digitizer able to run online advanced algorithms for digital pulse process. The DAQ subsystem generates a file recording the energy information and trigger time information of the nuclear signals and this file is used for SCC subsystem to calculate the absolute radioactivity determinations.

the SCC subsystem is coded by C# and constitutes "Spectrum-generation module", "Coincidence-calculation module " and "correlation and extrapolation module". The "Spectrum-generation module " is aimed to obtain the energy spectrums and delay-time spectrum from the recording information. The "Coincidence-calculation module" is employed to calculating the particle count rate and coincidence counting rate. Finally, all of these results are entered into the "correlation and extrapolation module". In the "Efficiency-extrapolation module" , the counting rates are corrected for dead-time loss and accidental-coincidence and then extrapolated to obtaining absolute radioactivity determinations.

Figure 1. the diagram of the LSC system



Critical Algorithm

The software can work out the absolute radioactivity determination relays on following aspects:

On the one hand , **the living time method** is applied in our software to correcting the dead time loss. In the LSC system, the beta pulse sequences are inputted into extendable dead- time process to eliminating the impact of after-pulse and this process can cause the dead-time loss. Different to Muller formula correction, The living time method can correct the counting rate loss by recording the actual length of dead-time.

On the other hand, accidental coincidence correction is carefully studied in our software. A major flaw of the living time method is that it cannot correct the counting rate caused by accidental coincidence. A viable solution is to rearranging the Muller correction formula and separated it into dead-time correction section and accidental correction:

$$R_c = R_f + R_{\beta\gamma} \quad (1)$$

$$R_{\beta\gamma} = \Pi_{\beta\gamma} * \rho_{\beta\gamma} \quad (2)$$

$$\Pi_{\beta\gamma} = 1 - \frac{t_{dead\_time}}{t_{total}} \quad (3)$$

$$\rho_{\beta\gamma} = (R_c - R_f)/\Pi_{\beta\gamma} \quad (4)$$

$$R_f = \frac{e^{-\rho_{\beta\gamma} * \tau}}{\rho_{\beta\gamma}} (1 - e^{-\rho_{\beta\gamma} * \tau})(\rho_\beta * (\rho_\gamma - \rho_{\beta\gamma}) + \rho_\gamma * (\rho_\beta - \rho_{\beta\gamma})) * e^{-(\rho_\gamma + \rho_\beta - 2 * \rho_{\beta\gamma}) * \tau} \quad (5)$$

where R_f represents the accidental coincidence counting rate.

Figure 2. DT5730 digitizer and DCC software interface

Results

We need to verify the reliability of the software from two aspects: firstly, the corrected rate is not sensitive to the change of dead time value; secondly, the measured value and the reference value should be consistent within a certain deviation range.

On the analysis of the above, we use Co60 with known reference value as the test object, and the results is shown below:

Figure 3. the stability of the living time method

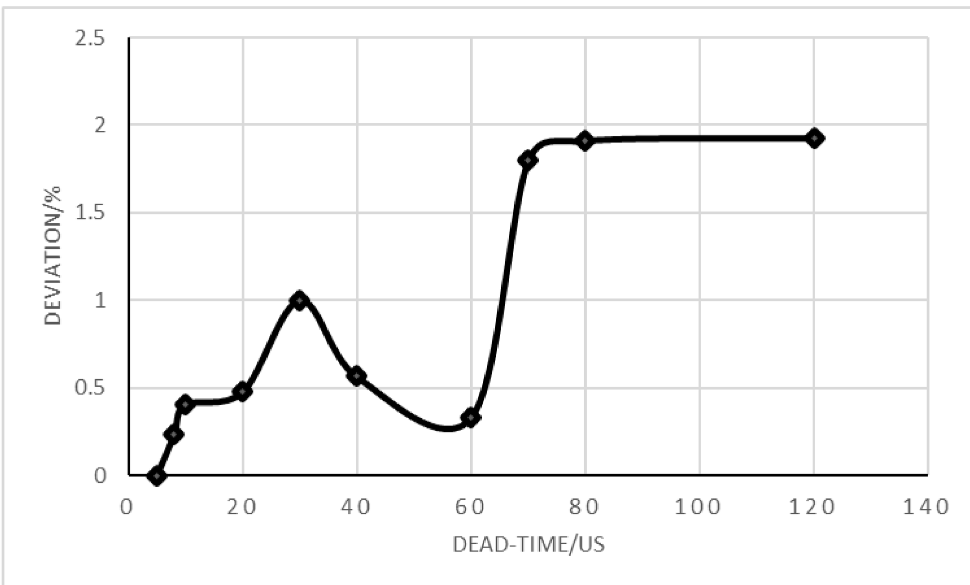


Figure 4. the calculation result

Reference value (Bq)	Extrapolation method	Fitting method	Measured value (Bq)	Error (%)
6212	$(1-\varepsilon_\beta)$	Linear	6209.25	-0.044
	$(1-\varepsilon_\beta)$	Quadratic	6215.32	0.053
	$(1-\varepsilon_\beta)/\varepsilon_\beta$	Linear	6201.65	-0.16
	$(1-\varepsilon_\beta)/\varepsilon_\beta$	Quadratic	6214.88	0.046
Average			6210.275	-0.003

Discussions and Conclusions

As the fig.3 and fig.4 illustrate, the software can work stably when the value of dead-time change from 5us to 120us and calculate the absolute radioactivity determination with a deviation less than 0.16%. On the basis of this data, a high precision DCC software is developed for the LSC system.

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