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A Study on the Beta-Coincidence Spectroscopy for measuring beta spectra

Hyeon Min Lee [a,b], Bo-Young Han [a*], Gwang Min Sun [a], Jaegi Lee [a] and Yongmin Kim [b]
[a]*Neutron and Radioisotope Application Research Division, Korea Atomic Energy Research Institute, Daejeon, Republic of Korea*
[b]*Department of Radiological Science, Daegu Catholic University, Gyeongbuk, Republic of Korea*
[*]*Corresponding author: byhan@kaeri.re.kr*

1. Introduction

We benchmarked the beta-coincidence spectroscopy (BCS) which designed by N. Haag, et. al [1] to measure beta-ray energy spectra. The BCS detector consists of a multi-wire chamber (MWC) for gamma-ray suppression and a plastic scintillator (PS) combined with a photo-multiplier tube (PMT) for measuring the energy spectrum during the emission of beta particles.

We described a method to obtain and process the coincidence signal. The coincidence signal processing method is a method of suppressing photon detection. Therefore, gamma-ray suppression is important. In this study, the gamma-ray suppression rate of BCS using the coincidence signal method was evaluated. Also we measured the beta-ray energy spectra of ^{137}Cs and ^{207}Bi sources.

2. Methods

2.1 Components of the MWC

The MWC [3] included the three boards in CF_4 gas. The wiring board, which has a hole with a 65-mm diameter, 17 sense wires and 18 potential wires coated with 6-um diameter gold-coated tungsten wires, was located between two grounded cathode boards. The hole of the cathode board was covered with a 6-um thickness aluminized Mylar foil. The aluminum collimator with an inner radius of 2.8-mm, an outer radius of 5-mm and a thickness of 10-mm was placed on the cathode board to consider the solid angle affected the energy resolution. The source used for the experiment were placed on the aluminum collimator. The high voltages of 2.4 kV and 0.6 kV were applied to the sense wires for the beta-ray detection and the potential wire to generate a potential difference [4]. The MWC was filled up by CF_4 gas to reduce the gamma-ray signal [5]. Since the charged particles will ionize surrounding gaseous atoms the resulting ions and electrons are accelerated by the electric field across the chamber and attached to the sense wire.

2.2 Components of the PS

The PS consisted of: (1) BC-404 (Saint-Gobain Crystal PS) [2], (2) reflector (Vikuiti™ Enhanced Specular Reflector, 3M) to transfer the visible light from the PS to PMT (ETI-9390B 5-inch PMT, ET Enterprises) without leakage and (3) dark plastic housing to minimize the leakage of light and block the background signals, which come from the external light and natural radioactivity. The top of the dark plastic housing was removed during the measurements to avoid the energy loss of incident beta-ray. The high voltage of 1 kV was applied to the PMT. The PS was located at 1 cm below the lower cathode board of the MWC (Fig. 1).

Fig. 1. The beta-coincidence spectroscopy.

2.3 Setup of the BCS and data acquisition (DAQ)

The pulse width of the MWC signal (200 us) was relatively large compared to the pulse width of the PS signal (0.15 us). It made a problem to detect the coincidence signal. To solve this, the pulse width was reduced to 2 us by using the fast filter amplifier (Ortec 579) on the MWC signal. Finally, each signal was acquired through Flash Analog to Digital Converter (FADC, nkfadc500-4, notice Korea) (Fig. 2). Each pulse was stored in the FADC at 500 MHz sampling rate.

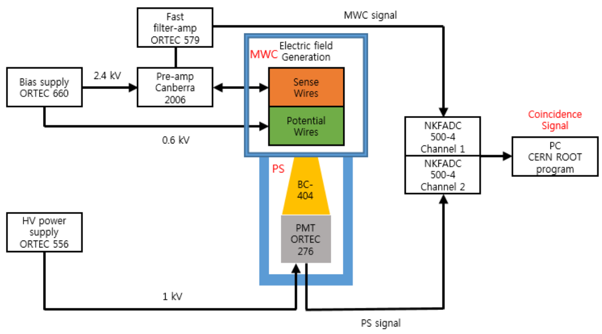

Fig. 2. The schematic diagram of the BCS measurement system.

2.4 Principles of acquisition and processing of coincidence signal

There were two signal trigger methods of FADC. The pulse count (PC) mode selected and stored only those pulses that exceeded the specified voltage threshold. The pulse width (PW) mode selected and stored only those pulses that exceeded the specified voltage threshold and pulse width (Fig. 3). When selecting the MWC signal, the reason of using PW mode was to prevent counting several times in one pulse when PC mode was used because of random fluctuation of the signal [6].

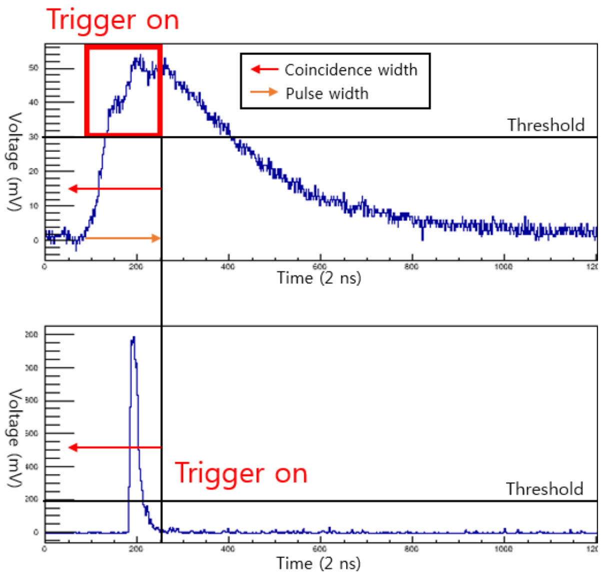

Fig. 3. Selecting process of coincidence signal.

In order to obtain a coincidence signal, the time width (coincidence width, CW) should be specified. When both signals were received within the CW, the coincidence signal event was selected (Fig. 3). The time difference between the two signals was checked to determine CW. The CW was determined 150 ns.

2.5 Reduction of backgrounds

Background that mimic signals were addressed by analyzing signals outside the normal range using the time difference between the two signals from offline data. In addition, events with excessively high pulse height were also considered. The selected backgrounds were as follows: (1) when the stretched tail of the MWC signal was recognized as a coincidence signal, (2) an external signal that was not a beta-ray accidentally entered the CW and was recognized as a coincidence signal, (3) when two coincidence signals captured within one record length and (4) when a large muon signal was saturated and recorded. The second case was solved by reducing the PW or CW, and the first, third and fourth cases were removed by using a selection cut.

3. Results

3.1 Gamma suppression rate of the BCS

To calculate gamma suppression rate of the BCS, we used the ^{60}Co (Eckert & Ziger, 37 kBq) source to compare the count rate for 600 s with CW and without CW. Nature backgrounds was taken into account for the same measurement time. Each count rate was shown in Table I, and the gamma suppression rate was calculated by the following equation (1) and found to be 98.2%.

Table I: Count Rate

	With Coincidence (cps)	Without Coincidence (cps)
^{60}Co source	50.4	3239
Background	0.44	395
^{60}Co - background	49.96	2844

$$\left(1-\frac{With}{Without}\right)\times 100\%, \quad (1)$$

3.2 Beta-ray energy measurement of ^{137}Cs and ^{207}Bi

Internal conversion is likely when the nucleus emits photons, which photons interact with and absorb one of the electrons surrounding the nucleus. The final effect is that gamma-ray photons are converted to emitted electrons. All of these converted electrons have the same clear energy as the gamma-ray energy subtract the energy needed for the electron to escape from the atom. These electrons produce peaks in the spectrum of emitted electrons [7]. ^{137}Cs (isotope products LAB, 370 kBq) and ^{207}Bi (RITVERC, 102 kBq) sources were used for beta-ray energy measurements because the peaks could be observed. The results were shown in Fig. 4. The internal conversion lines of both sources were identified.

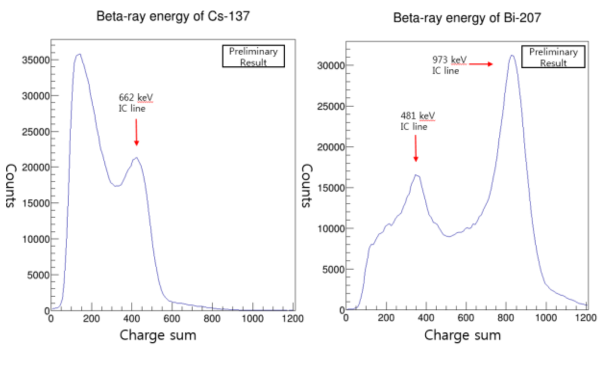

Fig. 4. The beta-ray energy spectra of ^{137}Cs (left) and ^{207}Bi (right) sources. The x-axis is the area (charge quantity) of the signal.

4. Conclusion

In this study, we measured the gamma-ray suppression rate to 98.2% with ^{60}Co source and beta-ray energy spectra of the ^{137}Cs and ^{207}Bi sources with the beta-ray coincidence signal.

In the follow-up study, the energy calibration and resolution are being studied with GEANT4 Monte Carlo method. Finally we will measure positron energy spectra of the ^{22}Na source. To do this we will study the energy response of positron, which has to understand the interference of two gamma-rays generated by positron annihilation in the PS.

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