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A Study on the Sub-Detectors of Beta-Coincidence Spectroscopy

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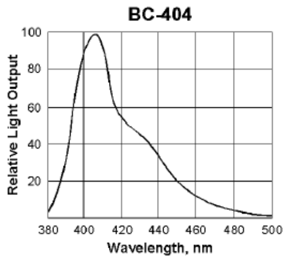
1. Introduction

Recently, Korea atomic energy research institute (KAERI) is researching the construction of an in-beam positron annihilation spectroscopy (PAS) system based on the High-flux Advanced Research Reactor (HANARO) research reactor. The measurement of positron yield is considered as part of in-beam PAS. The beta-coincidence spectroscopy designed by N. Haag, et. al.'s research [1] has been studied to measure the positron production yield. The beta-coincidence spectroscopy consists of a multi-wire chamber (MWC) for gamma-ray rejection and a plastic scintillator (PS) combined with a photo-multiplier tube (PMT) for measuring the energy spectrum during the emission of all beta particles.

In this study, the following experiment was conducted to evaluate the performance of a PS and MWC in the beta-coincidence spectroscopy: (1) the study on the detection ability of a PS by a reflector and (2) the beta-ray measurement of ^{207}Bi with MWC.

2. Methods and Results

2.1 The measurement of gamma-ray energy spectrum by using PS



Properties	BC-400	BC-404
Light Output, % Anthracene	65	68
Rise Time, ns	0.9	0.7
Decay Time, ns	2.4	1.8
Pulse Width, FWHM, ns	2.7	2.2
Light Attenuation Length, cm*	160	140
Wavelength of Max. Emission, nm	423	408
No. of H Atoms per cm^3, (x10^{22})	5.23	5.21
No. of C Atoms per cm^3, (x10^{22})	4.74	4.74
Ratio H:C Atoms	1.103	1.100
No. of Electrons per cm^3, (x10^{23})	3.37	3.37
Principal uses/applications	general purpose	fast counting

Fig. 1. The relative light output and properties of BC-404 [2].

The PS consists of: (1) BC-404 (Saint-Gobain Crystal, Fig. 1) PS, (2) reflector to transfer the visible light from the PS to PMT without leakage and (3) dark plastic housing to minimize the leakage of light and block the background signals, which is from the external light and natural radioactivity.

The schematic diagram was constructed as shown in Fig. 2. For the gamma-ray energy spectrum measurements, the ^{137}Cs source located with the 10 cm of distance to the upper direction from the PS and PMT with the high voltage of 800 V. The top of the dark plastic housing was removed during the measurements to avoid the beta-ray blocked.

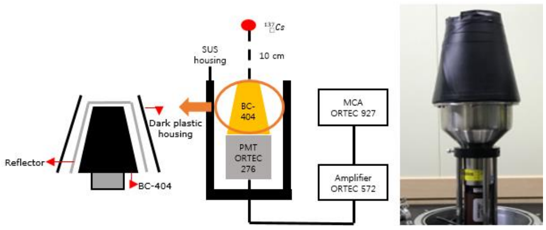


Fig. 2. The schematic diagram of the PS measurement system.

The measurement of Photopeak from the gamma-ray energy spectrum, by using the BC-404 PS, is impossible due to the low atomic numbers materials composing the PS. Therefore, maximum Compton electron reaction signal was acquired and the energy spectrum was measured.

The energy spectrum of ^{137}Cs was measured to evaluate the energy resolution of the PS depending on the reflector types. To compare the gamma-ray energy spectrum depending on materials of reflectors, Vikuiti^{TM} Enhanced Specular Reflector and Tetratex were employed. The measurement results are shown in Fig. 3. The measurement results using Vikuiti^{TM} as a reflector revealed the Compton edge of ^{137}Cs, whereas the tetratex exhibited lower energy resolution and were difficult to identify.

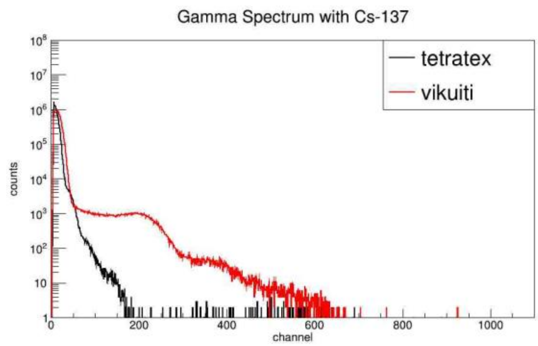


Fig. 3. ^{137}Cs gamma-ray energy spectrum according to the reflector type.

2.2 The measurement of beta-ray energy spectrum by using MWC

The MWC includes the three boards in the CF_4 gas. The wiring board is located between two grounded cathode boards: over a hole with 65 mm diameter, 17 sense wires and 18 potential wires are stretched 6 um diameter gold-coated tungsten wires. The hole of cathode boards is covered with 6 um thickness aluminized Mylar foil (Fig. 4).

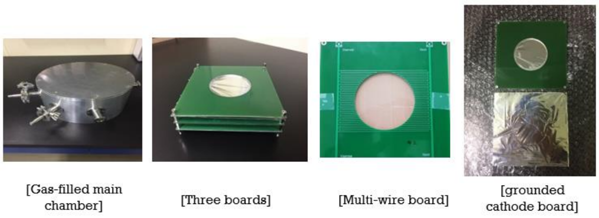


Fig. 4. Components of an MWC.

The schematic diagram was constructed as shown in Fig. 5 to measure the beta-ray of a ^{207}Bi. The 2.4 kV and 0.6 kV of high voltage were applied to the sense wire for the beta-ray detection and the potential wire to creating a potential difference. The MWC was filled up by CF_4 gas to reduce the gamma-ray detection and forms the electric field [3]. The signals of beta-ray, from the particle attachments to the sense wire by an electric field, were measured by MWC. These signals were recorded through the pre-amp and main-amp. In this study, the ^{207}Bi source was placed 8 mm above the Mylar foil and measured for 600 seconds.

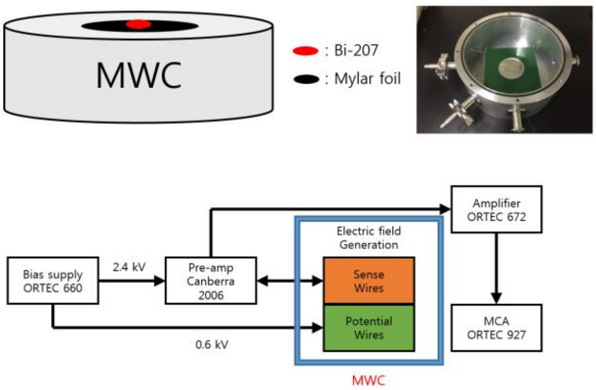


Fig. 5. The schematic diagram of MWC measurement system.

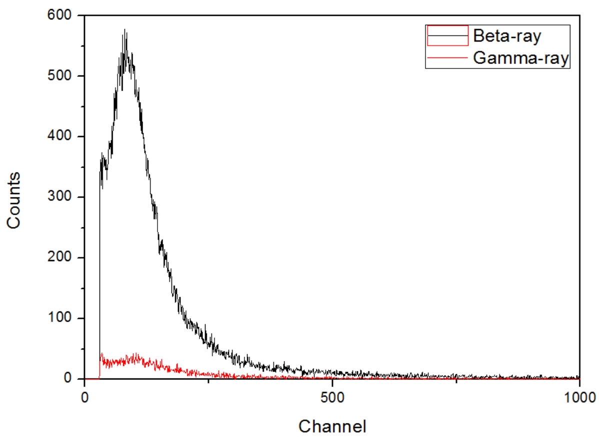


Fig. 6. The measurement of ^{207}Bi beta-ray energy spectrum by using MWC.

To confirm that the origin of the counts, the spectrum was re-measured with the same condition as blocking the ^{207}Bi source by using an aluminum plate of 6 mm thickness. As a result, the intensities were dramatically reduced. This result revealed that the signals for the previous experiment are occurs from the beta-ray spectrum.

3. Conclusions

In this study, two kinds of reflectors were used to measure the difference of the energy spectrum according to reflector type of PS. As a result, it was found that the energy resolution of Vikuiti^{TM} was better than that of Tetratex. The energy spectrum of the ^{207}Bi was measured to confirm whether or not the beta-ray was detected in the MWC, and the ^{207}Bi was shielded and re-measured to confirm that it was due to the beta-ray. As a result, it was confirmed that the MWC detects about 98% of the beta-ray. In a follow-up study, we will provide more accurate beta-ray measurements by using beta-coincidence spectroscopy and will ensure reliability by comparison with MCNP simulation.

REFERENCES

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