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Enhancement of Energy Spectra through Constant Fraction Timing Method

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Abstract. The energy spectra of ^{137}Cs, ^{60}Co and ^{14}C were achieved by using the spectrometers composed of different types of detectors. In this work, constant fraction timing method was used to enhance their energy spectra. Energy resolution values of ^{137}Cs and ^{60}Co gamma energy spectra were improved through this timing method. In addition, electronic noise appeared in the energy spectrum of ^{14}C was discriminated through the timing method, leading to clear beta energy spectrum.

INTRODUCTION

The scintillation detector is undoubtedly one of the most often and widely used particle detection devices in nuclear and particle physics today. It makes use of the fact that certain materials when struck by a nuclear particle or radiation emit a small flash of light, i.e. scintillation. When coupled to an amplifying device such as photomultiplier, these scintillations can be converted into electric pulses which can then be analyzed and counted electronically to give information concerning the incident radiation [1].

Semiconductor detectors are solid-state devices that operate essentially like ionization chambers. The charge carriers in semiconductors are not electrons and ions, as in the gas counters, but electrons and holes. The advantages of semiconductor detectors are linear response over a wide energy range, higher efficiency for a given size, because of the high density of a solid relative to that of a gas, ability to operate vacuum, insensitivity to magnetic fields [2].

For detectors which are designed to measure the energy of the incident radiation, the most important factor is the energy resolution ($R(E_0)$). This is extent to which the detector can distinguish two close lying energies [1]. The width, measured at half of the maximum of the bell-shaped curve, is indicated by Γ or by full width at half maximum (FWHM).

$$R(E_0) = \frac{\Gamma}{E_0} \tag{1}$$

where E_0 is centroid of the peak in the energy spectrum [2].

Timing in nuclear and particle physics refers to the measurement of very small time intervals. Accurate measurements of very small time intervals require special techniques. Probably the most efficient and versatile method available today is the constant fraction timing method [1]. The principle of constant fraction timing is shown in Fig. 1. First, the original pulse (Fig. 1a) is attenuated by a factor f equal to the fraction of the pulse height on which the timing will be based (Fig. 1b). The original pulse is inverted and delayed (Fig. 1c) for a time longer than its rise time (is defined as time interval between the times at which the pulse reaches 10% and 90% of its final amplitude [3]). Finally, the signals in Fig. 1b and 1c are added to give the signal in Fig. 1d [2].

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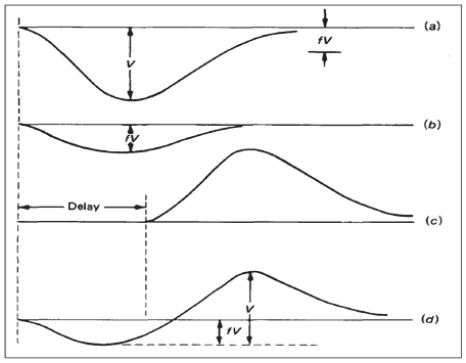


FIGURE 1. Constant fraction timing method [2].

Jastaniah and Sellin used digital pulse processing technique for neutron/gamma separation in liquid scintillators [4]. ^{60}Co pulse height and time spectra were achieved through NE102 scintillator by Kawada et al. [5]. Abuelhia et al. determined the coincidence timing resolution value of the spectrometer consisted of high purity germanium (HPGe) detector [6]. The digital constant fraction discrimination method was used to obtain accurate timing information in positron emission tomography system by Aykac et al. [7].

In this work, energy spectra of the different radioactive sources were achieved via the spectrometers which were consisted of various detector types. And also, constant fraction timing method was used to improve the energy spectra of the used radioactive sources.

METHODS

^{137}Cs, ^{60}Co and ^{14}C solid point radioactive sources were used in this work. Their activities and half-lives were listed in Table 1.

TABLE 1. The activities and half-life values of ^{137}Cs, ^{60}Co and ^{14}C solid point radioactive sources.

Radioactive Source	Half-life (year)	Activity (μCi)
^{137}Cs	30.17	5.00
^{14}C	5730.00	100.00
^{60}Co	5.27	0.15

In the first section of the study, a spectrometer consisted of a NaI(Tl) inorganic scintillation detector with the dimensions of 3 inch diameter x 3 inch length was used. ^{137}Cs, ^{60}Co sources were placed in 1 cm far away from the detector surface. Data acquisition time was chosen as 300 s.

The experimental setup which was used in the first section is shown in Fig. 2.

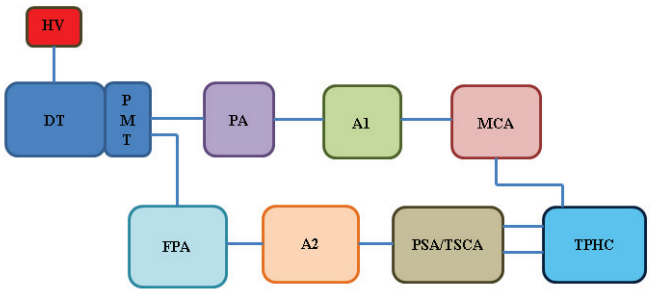


FIGURE 2. The experimental setup of NaI(Tl) inorganic scintillation detector.
(HV: High voltage supply, DT: Detector, PMT: Photomultiplier tube, PA: Preamplifier, FPA: Fast preamplifier, A1 and A2: Amplifier, PSA/TSCA: Pulse shape analyzer/timing single channel analyzer, TPHC: Time to pulse height converter, MCA: Multichannel analyzer)

In the second part of the study, ^{14}C energy spectrum was achieved by means of a spectrometer which was consisted of BC400 type plastic scintillation detector. Its dimensions were 3 inch diameter x 3 mm thickness. The same experimental setup shown in Fig. 2 was used in this section. The detector was substituted for NaI(Tl) inorganic scintillation detector. The distance between source and detector was chosen as 1 cm. Data acquisition time was set to 3600 s.

In the third section of the work, ^{14}C beta energy spectrum was obtained by using silicon surface barrier detector (SBD) (ORTEC, CA-18-50-100). The used experimental setup is shown in Fig. 3.

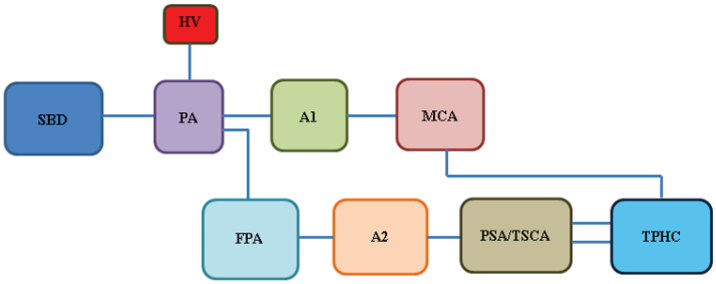


FIGURE 3. The experimental setup of SBD detector.
(HV: High voltage supply, SBD: Silicon surface barrier detector, PA: Preamplifier, FPA: Fast preamplifier, A1 and A2: Amplifier, PSA/TSCA: Pulse shape analyzer/timing single channel analyzer, TPHC: Time to pulse height converter, MCA: Multichannel analyzer)

RESULTS

Comparison of the obtained energy spectra of ^{137}Cs and ^{60}Co by means of the spectrometer consisted of NaI(Tl) inorganic scintillation detector before and after constant fraction timing method is shown in the following figures.

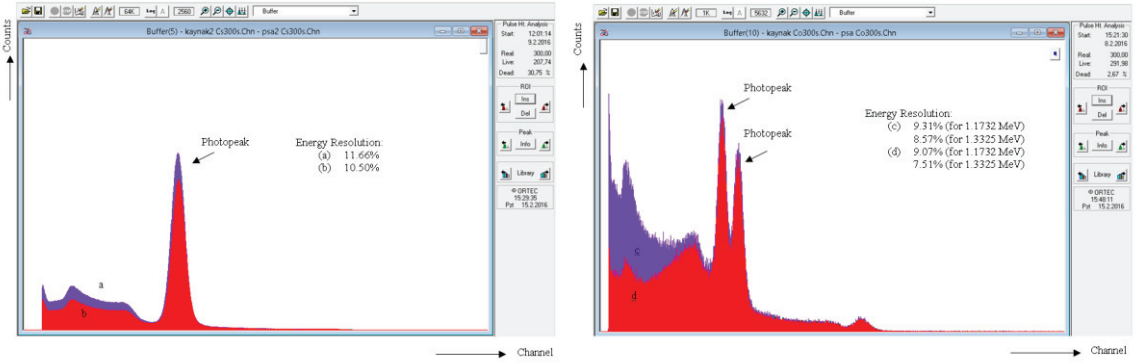


FIGURE 4. Comparison of the obtained energy spectra of ^{137}Cs and ^{60}Co using NaI(Tl) inorganic scintillation detector before (a, c) and after (b, d) constant fraction timing method.

Energy spectra of ^{14}C which were achieved through spectrometers consisted of BC400 type plastic scintillation and SBD detectors were shown in Fig. 5.

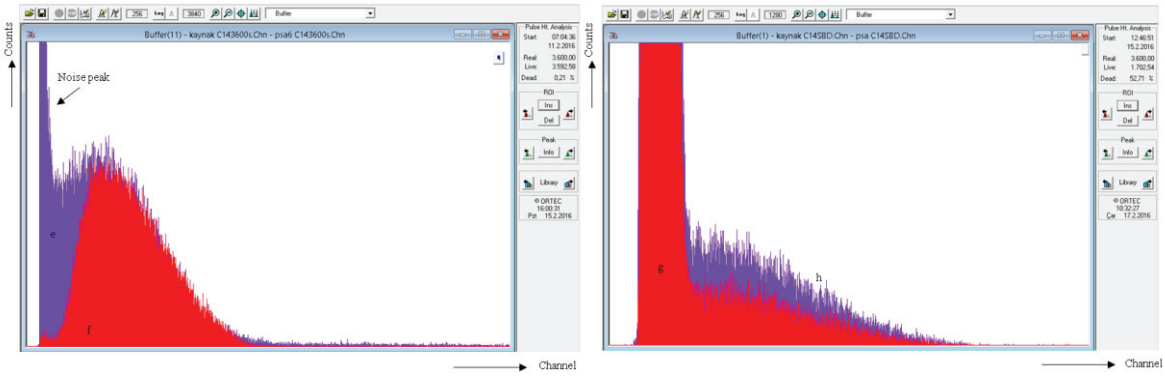


FIGURE 5. Comparison of the obtained energy spectra of ^{14}C using BC400 type plastic scintillation and SBD detectors before (e, g) and after (f, h) constant fraction timing method.

CONCLUSION AND DISCUSSION

Energy spectra of the used isotopes were achieved by means of the spectrometers which were consisted of appropriate detectors in this work.

Energy spectra of ^{137}Cs and ^{60}Co isotopes were obtained through NaI(Tl) inorganic scintillation detector. These energy spectra were gated with the signals obtained by using constant fraction timing method. As a result of the process, energy resolution values of the spectra were enhanced. As can be seen in Fig. 4, the energy resolution value of ^{137}Cs was improved from 11.66% to 10.50%. Energy resolution values of 1.1732 and 1.3325 MeV-energy photopeaks for ^{60}Co were decreased from 9.31% and 8.57% to 9.07% and 7.51%, respectively (Fig. 4).

^{14}C energy spectrum was also achieved using BC400 type plastic scintillation detector. In the spectrum, the improvements were observed by means of constant fraction timing method (Fig. 5).

In order to show validity of the constant fraction timing method in both scintillation detectors and other detector types, the energy spectra of ^{14}C was obtained using SBD detector. The same processes were repeated for this section. As can be seen in Fig. 5, the energy spectrum of ^{14}C was discriminated from the noise as a result of the timing process.

Finally, the energy spectra of the different isotopes using various types of the detectors and electronic modules were achieved in this work. Electronic noise was discriminated in their energy spectra by means of the constant fraction timing method, leading to improvement in the energy resolution.

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