Determination of effective point for calibration of Beta channel

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Introduction

In the beta-gamma coincidence spectroscopy systems that were developed for radioxenon measurement, the beta channel was calibrated with compton scattering of $^{137}$Cs gamma rays [1,2]. It is efficient method in the interested energy range but $^{137}$Cs position can change the calibration equation. It is due to unusual geometry of beta detector and optical photon transport. In this article, the dependency of energy calibration with gamma source position was position and effective point of calibration was determined.

Detection system

The gamma detector is well-type NaI(Tl) fabricated by Scionix. The detector has a crystal height and diameter of 76.2 mm, and well depth and diameter of 52 and 25.4 mm, respectively. The well of detector is covered by 0.5 mm thick aluminum layer. The cylindrical beta detector cell was fabricated from BC400 plastic scintillator material. It is used both as the gas cell to contain radioxenon samples and for detection of conversion electrons and beta particles. Beta detector has outer diameter and length 20 mm, and 52 mm, respectively. The thickness of the scintillator is 2 mm that is sufficient to detect most of the beta particles and conversion electrons of radioxenon isotopes. To enhance the light collection efficiency, all outer surfaces were coated with diffuse reflective paint. Plastic scintillator with a thin layer of silicone grease was coupled to XP3132 Photomultiplier tube which has a low background borosilicate entrance window. A 1/16 in. stainless steel pipe was inserted through small hole on the wall of the plastic scintillator and glued onto the beta detector to inject gaseous sample into detection cell. Fig. 1(a) shows the configuration of detectors schematically.

Calibration of Beta channel

Beta detector was calibrated using Compton scattering of 661.7 keV gammas from $^{137}$Cs in the plastic scintillator. In this method $^{137}$Cs source is placed between gamma and beta detectors. Because plastic scintillator has low effective atomic number, Compton scattering is dominant interaction of gamma ray with this. The recoil electrons and scatter gammas deposit their energy respectively in the plastic scintillator and NaI(Tl) and generate coincidence events. These coincidence events were detected using circuitry. In this figure, diagonal line is the result of the events that deposit full energy in both detectors. For these events, the sum of the energy between recoil electrons energy and scatter gamma energy are equal to 661.7 keV.

Results

The energy distribution and population of scattered electrons in the plastic scintillator was recorded for each source position and shown in Fig. 3. In this case, the scattered electrons were spread in the total volume of detector. The last distribution is related to situation that $^{137}$Cs is at the bottom of plastic scintillator. As expected, the far positions related to PMT have high concentration of scattered conversion peak is according to P2 calibration curve. So P2 point is 0.5 mm above the bottom of well, which is in the middle of Beta cell height was selected as calibration effective point.

Conclusions

This research paper focuses on determination of effective point for beta calibration. The plastic scintillator that was used for detection of beta particles has hollow to contain radioxenon samples. This non-uniformity of geometry lead to optical photon attenuation and scattering. Therefore, $^{137}$Cs position can change the beta calibration. It has been found experimentally and confirmed by simulation that the effective point is in the middle height of beta cell where point source behave similar to volume source.

References


Fig. 1. Schematic representation of the detection system (a) and electronics for coincidence data acquisition (b).

Fig. 2. $\beta$–$\gamma$ coincidence spectrum from a $^{137}$Cs source with a $\beta$ spectrum at selected $\gamma$ channel.

Fig. 3. Scattered electrons distribution in the plastic scintillator for top, middle and bottom positions of $^{137}$Cs point source between NaI(Tl) and plastic scintillator.

Fig. 4. Left: Variation of beta calibration curve with $^{137}$Cs source position. Right: Positions of $^{137}$Cs between plastic scintillator and well-type NaI(Tl).

According to Fig. 4 (left), channel versus energy of $^{132}$Xe conversion peak is according to P2 calibration curve. So P2 point that is in the middle of Beta cell height was selected as calibration effective point.