Detector system for the KEK isotope separation system

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The KISS has been developed to study the β-decay properties of neutron-rich nuclei around neutron number N = 126 which determine the r-process path and form the third peak of the elemental abundance (A∼195).[1,2] The detector system of the KISS requires high detection efficiency for low-energy β-rays because the nuclei of interest have small Q-value around 2 MeV. In addition, the system should be operated in a low-background environment because of the low production rates of these nuclei. Although the tolerable count rate of the background depends on the production rates, our ultimate goal is to set around several tens of counts per day, allowing access to these nuclei.

The detector system of the KISS consists of β-ray telescopes, Ge detectors, and a tape transport system. A schematic view of the detector system is shown in Fig. 1. For particle identification, three Ge detectors are employed to detect K-X rays emitted from the nuclei of interest. To efficiently count low-energy β-rays with low background, the β-ray telescopes are composed of three double-layered thin plastic scintillators; the thicknesses of the first and second layers are 0.5 mm and 1 mm, respectively. The solid angle of the β-ray telescopes is 90% of 4π.

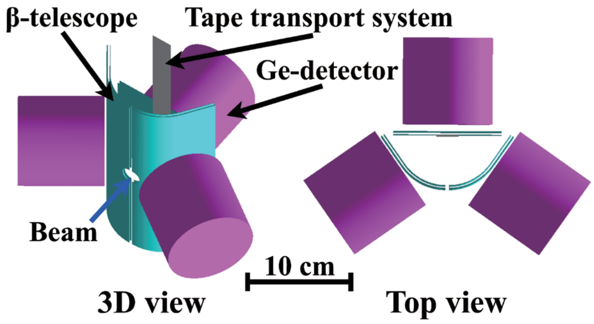

Fig. 1. Schematic view of the detector system.

The β-ray telescopes worked as designed. The energy spectra of the scintillators were in good agreement with Geant4 simulations. A comparison of energy deposit in the first layer between the simulation and the measured result is shown in Fig. 2. The measured efficiency of the β-ray telescopes for low-energy β-rays emitted from a ^{90}Sr/^{90}Y source was 55.4(15)% with an energy threshold of 20 keVee for the first layer and 30 keVee for the second layer.

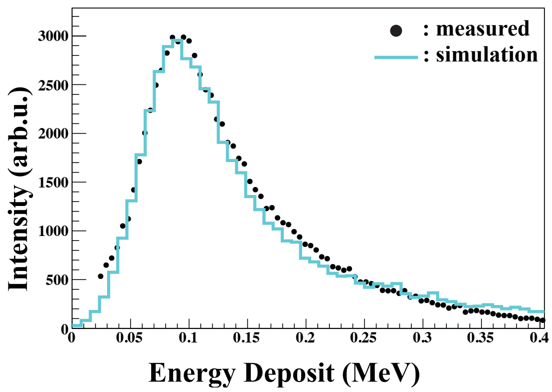

Fig. 2. Energy deposit distribution of the first layer for β-rays from the ^{90}Sr/^{90}Y source.

The background rate of the β-ray telescopes was measured to be 5 cps. The origins of the background were considered to be cosmic rays and electrons scattered by γ-rays from natural activities. Initially, to reduce the cosmic rays, a veto counter system was installed, which consisted of plastic scintillators. The configuration of the plastic scintillators was designed based on the Geant4 simulation, and the designed value of the veto efficiency was 92% for 1 GeV muon. The veto counter reduced the previous background rate by 1.1 cps. In addition, to reduce the room background of γ-rays from natural activities, we installed shields with low-activity Pb blocks and reduced the background rate by 2.4 cps. Finally, by raising the energy threshold of the second layer to 70 keVee without significant sacrifice of the detection efficiency for β-rays of interest, we reduced the background rate by 0.3 cps. In total, we reduced the background rate to 1.2 cps from 5 cps.

The main component of this background rate is environmental γ-rays and accidental coincidence rate in an extra active area of the scintillators. We will replace the present telescopes with new ones consisting of gas counters and thin plastic scintillators. Gas counters will be constructed with a small amount of materials to reduce the Compton scattering of γ-rays.

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