Feasibility test of β-ray measurement by a Ge detector

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Nuclei with Z=10-12 and N=20-22 known as those in "island of inversion" [1] are considered to have deformed shape, though the neutron number 20 is a spherical magic number. In order to study the neutron-rich $^{28-32}$Mg isotopes, experiments were planned to investigate the β decay of polarized neutron-rich $^{28-32}$Na nuclei at TRIUMF. The most of spin-parities of the excited states in these nuclei have not been assigned yet. The experimental β-decay asymmetry using polarized nuclei enables unambiguous spin-parity assignments of the states in daughter nuclei for allowed transitions, as the asymmetry strongly depends on the spins of the initial and final states.

In the experiment at TRIUMF, β and γ rays were planned to be measured by Ge detectors. In order to check the possibility to measure the high-energy β-rays by a Ge detector, an experiment using recoil catcher method using EN course [2] was carried out. The nucleus of ^{98}Rh was used as the high-energy β-ray emitter with Q-value of 5.06 MeV for the β^+ decay.

This ^{98}Rh was produced by the fusion reaction of ^{nat}Mg+^{86}Kr. The 8.7 MeV/u ^{86}Kr^{21+} beam with the intensity of 1 pnA was directly provided by the AVF cyclotron and bombarded a 11 μm ^{nat}Mg target. Reaction products recoiling out from the target were transported to the 16.3 m downstream using EN course. This beam line consists of 2 dipole and 7 quadrupole magnets. As primary target (F0), dispersive (F1) and achromatic (F2) focal planes were separated by the concrete wall, β and γ rays were detected under the low-background condition at F2. A 42 mg/cm^2 Pb catcher foil at F2 was surrounded by four Ge detectors which were set at perpendicularly to the beam axis. The β rays were detected by one telescope consisted of a 2 mm thin plastic scintillator and a Ge detector. Beta and γ rays were distinguished depending on whether the plastic scintillator gives pulses of reasonable heights for β rays. Gamma rays were detected by the other 3 Ge detectors in coincidence with the β rays.

Experimental β-ray spectrum gated on the 652 keV γ ray attributed to the β decay of ^{98}Rh is shown in Figure 1 by the dotted line. Although the β-ray maximum energy of this decay is 3.48 MeV, the measured end-point energy was 2.69 MeV because of the energy losses in the catcher foil, the vacuum window foil (50 μm Kapton) of the target chamber, the plastic scintillator and the 1 mm aluminum cap.

In order to obtain the unknown β-ray maximum energies, it is important to correctly estimate the energy losses in the materials placed between the Pb catcher foil and a Ge crystal. The β-ray spectrum calculated by the GEANT4 [3] is shown in Figure 1 by the solid line. The GEANT4 code is a simulation program for the passage of particles through matter. The GEANT4 simulation well reproduces the experimental β-ray spectrum. As results, it was confirmed that this telescope detector consisting of a plastic scintillator and a Ge detector is good tool to measure the high-energy β rays.

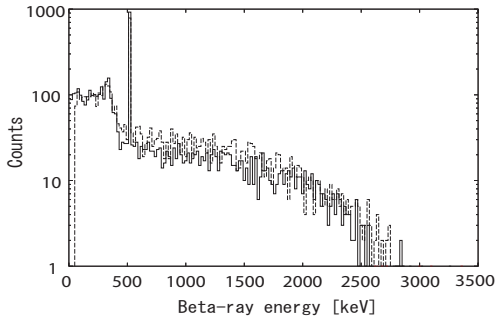

Figure 1: Beta-ray spectra of ^{98}Rh β decay feeding the 2^+ state at 652 keV in ^{98}Ru obtained in this experiment (dashed line) and by the GEANT4 simulation (solid line).

References

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