# Measurement of the Gamma-Ray Branching of the Mirror Decay of Mass-Separated 57Cu

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# I. 6. Measurement of the Gamma-Ray Branching of the Mirror Decay of Mass-Separated $^{57}$Cu

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The $^{57}$Cu is the nucleus of proton number 29 and neutron number 28, and decays to its mirror nucleus $^{57}$Ni by the superallowed $\beta$ transition. The decay scheme is shown in Fig. 1. The decay was observed by using the TArget ROtation system (TARO); we measured the half-life, the $\beta^+$ end-point energy, and the branching ratio of the 1111 keV gamma ray occurring in its daughter nucleus to be, respectively, 225±0.047 MeV, and 3.7±1.7%.[1] Then, we introduced the IGISOL (Ion-Guide Isotope Separator On-Line) and succeeded in on-line mass-separation of $^{57}$Cu and measured its half-life precisely to be 199.4±3.2 ms.[2] The mirror transition plays an important role to study the quenching problem of the Gamow-Teller strength. The systematic behavior of the quenching of GT matrix element, defined as the ratio of an experimental GT matrix element to the theoretical one calculated with the shell model, has been studied in the region of lighter nuclei. Especially in the $f_{7/2}$ shell region, we measured the half-lives of mirror transitions precisely by use of IGISOL.[3]

The decay of $^{57}$Cu is interesting and important because it is a nucleus consisting of the $^{56}$Ni core and one proton in the $p_{3/2}$ shell. So the reliable data of GT matrix element was wanted, but the data of the branching ratio of the 1111 keV gamma ray had a large error, because in the measurement using TARO $^{57}$Cu was not mass-separated. The purpose of the present study is to measure precisely the gamma-ray branching ratio of the decay of $^{57}$Cu which is mass-separated in IGISOL and brought to a low-background region.

The IGISOL system, which is in the second target room of CYRIC, is shown in Fig. 2. Recently an ultra-low-background gamma-ray detector[4] was constructed and put on the tape-transport line about 46 cm far from the collector station. The tape-transport system is shown in Fig. 3 and the detector system in Fig. 4. For the use of this detector, a radioactive sample must be brought fast from the collector station to the detector station. But in the previous tape-transport system[5] the transport time was 0.6 s and, besides, many troubles happened. So we improved this tape-transport system.

In the previous system the capstan was connected to a stepping motor whose angle of rotation was proportional to the number of control pulses, and the two tape reels were connected to servo motors whose torque were proportional to the control voltage. The capstan motor, which was controlled by a computer, can control the speed and distance of a tape transport. The reel motors, which were controlled by the local feedback method using each tension arm, took or fed the tape. But when this local feedback method was used, the limit of tape speed was small and many troubles happened. Therefore we exchanged the three motors for three stepping motors which are of high-speed type and have a large torque for the purpose of the study of short-lived nuclei. And we used a new one-board micro-computer which can control three motors simultaneously. In this way we attained a transport time of 0.35 s for 46 cm transport distance, and besides troubles became much less frequent.

Our experiment was done by using the above system. The $^{57}$Cu nuclei were produced via the $^{58}$Ni(p,2n)$^{57}$Cu reaction with 30 MeV proton beams. They were mass-separated by the IGISOL, and implanted into the tape. In the tape transport system, the collection and detection time was 1 s and the transportation time was 0.35 s in one cycle. At the detector station, the gamma ray spectra were taken by $\beta$-$\gamma$ coincidence method using a Ge detector and a plastic scintillator. The spectrum is shown in Fig. 5. The 1111 keV gamma-ray peak is seen and its existence is confirmed.

For the determination of the branching ratio we have to know the number of decays, which we measured via the 511 keV annihilation gamma rays which should be proportional to the beta-decay intensity. We have to know in turn the number of 511 keV gamma ray per one beta-decay. Therefore, we measured gamma rays of $^{58}$Cu whose end-point energy of beta ray is similar to that of $^{57}$Cu, and we calculated this value to be about 2. By using this procedure the branching ratio of the 1111 keV gamma ray in the decay of $^{57}$Cu is calculated to be 5.7±0.6%. From this value the experimental data of ft-value and GT matrix element for the beta decay from the ground state of $^{57}$Cu to the ground and the second excited states of $^{57}$Ni were calculated. The result is shown in Table 1 and 2.

In Table 3, for reference, the theoretical value of matrix element calculated by Miyatake et al. is shown. In this calculation $^{40}$Ca is considered to be a doubly closed-shell nucleus; (a) is for the single-particle model, (b) is for the model in which only one particle in the $f_{7/2}$ shell can be excited, and (c) is for the model in which upto two particles in the $f_{7/2}$ shell can be excited.

Compared with these theoretical values of GT matrix element the experimental values are small. For the reason of this quenching we can consider the core polarization of the $^{56}$Ni core and so on.

The result of the present study shows that the method of measuring weak-branching gamma rays of short-lived nuclei has been established by improving the tape-transport system and using the ultra-low-background gamma-ray detector system, and that the gamma ray branching ratio of mass-separated $^{57}$Cu has been measured precisely by using our system.

## References

1) Miyatake H. et al., Nucl. Instr. Meth. **A245** (1986) 271; see also Shinozuka T. et al., Phys. Rev. C **30** (1984) 2111.
2) Yoshii M. et al., Nucl. Instr. Meth. **B26** (1987) 410.
3) Hama H., Tohoku Univ. doctor thesis (1986).
4) Taguchi K., Tohoku Univ. master thesis (1986).
5) Arai Y. et al., Nucl. Instr. Meth. **186** (1981) 231.

Table 1. $^{57}$Cu ground state → $^{57}$Ni ground state.

$E_{\beta_{max}} = 7.726 \pm 0.047$ MeV

| | present data | previous data |
|---|---|---|
| Branching ratio | 94.3 ± 0.6% | 96.3 ± 1.7% |
| log ft | 3.655± 0.013 | 3.640± 0.016 |
| $\lvert\langle\sigma\tau\rangle\rvert$ | 0.483± 0.026 | 0.516± 0.032 |

Table 2. $^{57}$Cu ground state → $^{57}$Ni 2nd excited state.

$E_{\beta_{max}} = 6.614 \pm 0.047$ MeV

| | present data | previous data |
|---|---|---|
| Branching ratio | 5.7 ± 0.6% | 3.7 ± 1.7% |
| log ft | 4.555± 0.051 | 4.738± 0.200 |
| $\lvert\langle\sigma\tau\rangle\rvert$ | 0.331± 0.020 | 0.268± 0.062 |

Table 3. Theoretical values.

| $\lvert\langle\sigma\tau\rangle\rvert$ | (a) single particle | (b) 1-jump | (c) 2-jump |
|---|---|---|---|
| (1) | 1.2910 | 0.6811 | 0.9439 |
| (2) | 1.1547 | 0.5733 | 0.8039 |

(1) $^{57}$Cu ground state → $^{57}$Ni ground state.

(2) $^{57}$Cu ground state → $^{57}$Ni 2nd excited state.

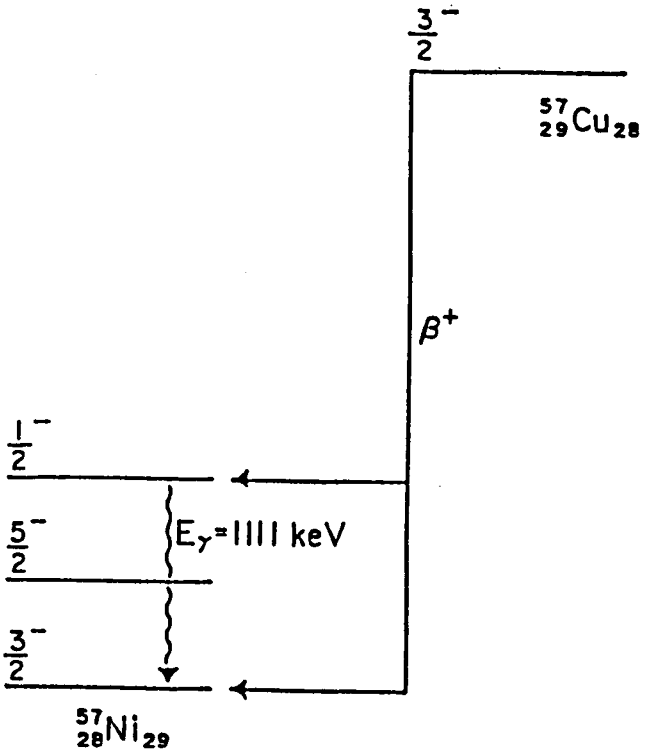

Fig. 1. The decay scheme of $^{57}$Cu.

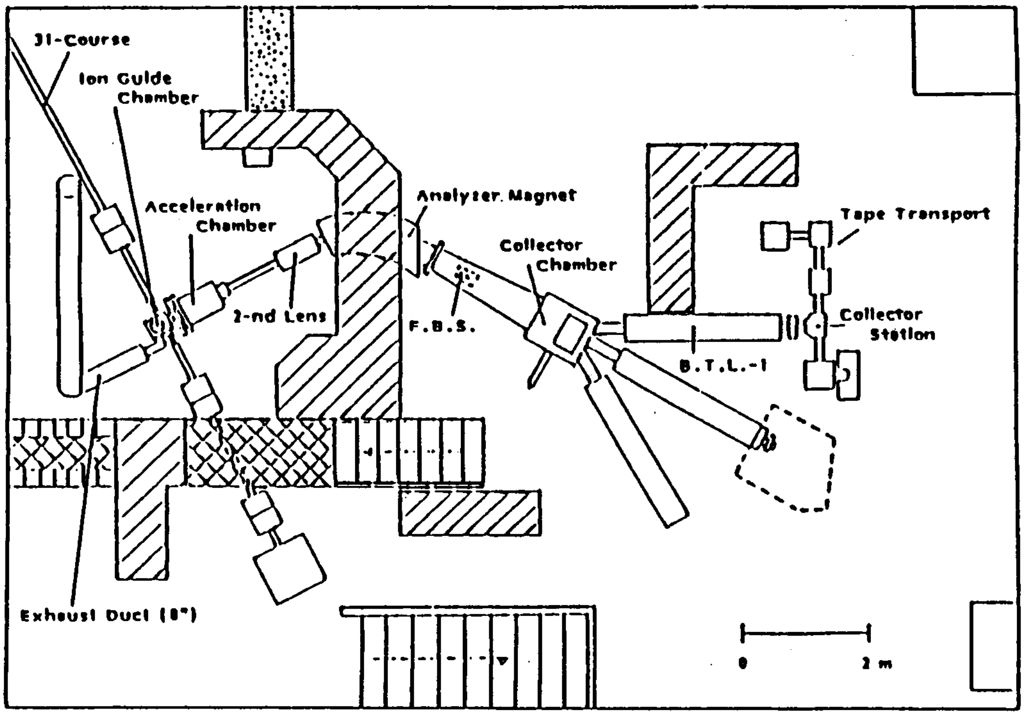

Fig. 2. IGISOL.

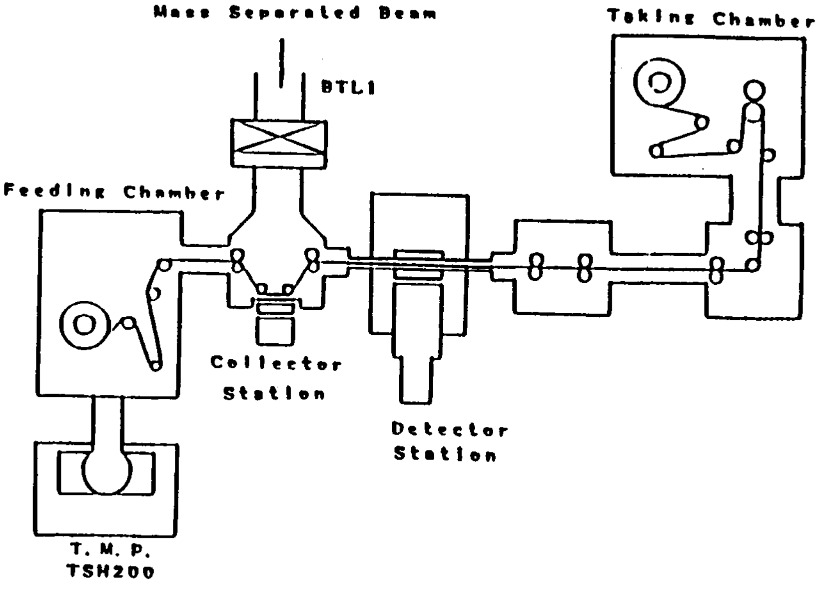

Fig. 3. The new tape-transport system.

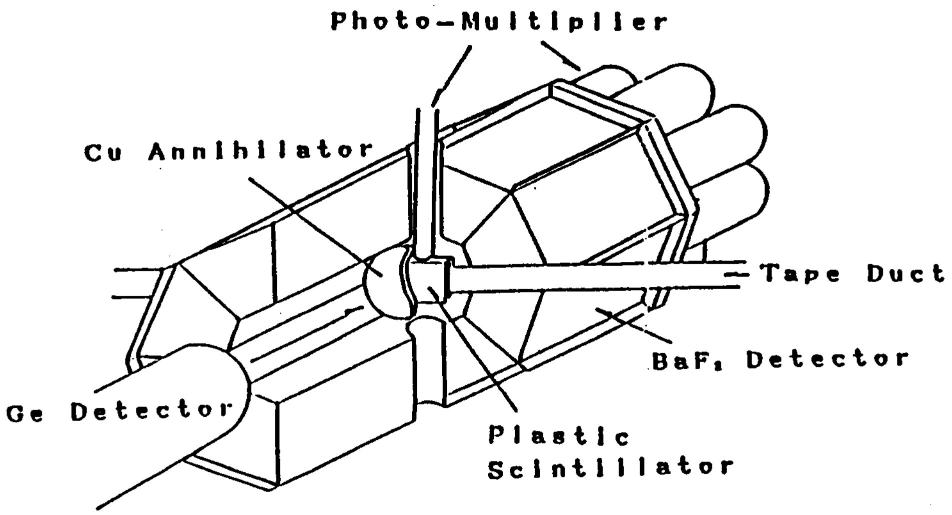

Fig. 4. Ultra-low-background γ-ray detector system.

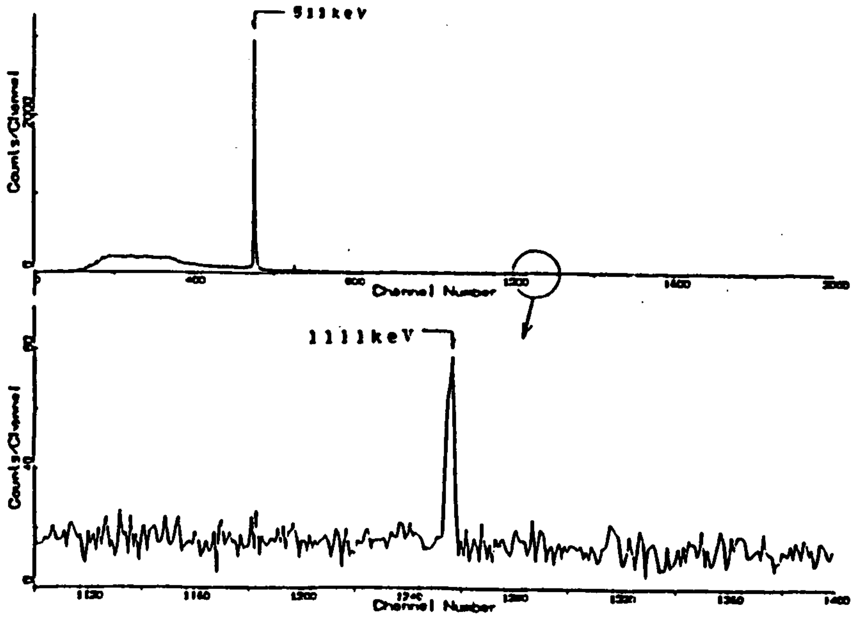

Fig. 5. γ-ray energy spectrum of $^{57}$Cu.