In-beam γ-ray spectroscopy of exotic ^{79}Cu with HiCARI

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^{78}Ni is an emblematic nucleus for the study of nuclear structure far from stability. Although it is expected to have a doubly magic character for proton ($Z = 28$) and neutron ($N = 50$) shells, theoretical and experimental studies around this region hint to a weakening of this magicity, with possible shape coexistence phenomena associated with shell quenching in proton and neutron gaps.[1)] To address these questions, the RIBF181 experiment aiming at the in-beam γ-ray spectroscopy of nuclei in the vicinity of ^{78}Ni was conducted at RIKEN for 7 days in April 2021. In this report, we focus on the analysis of the spectroscopy of ^{79}Cu, which contains one proton above the core of ^{78}Ni.

A wide range of exotic isotopes including ^{80}Zn were produced after the induced in-flight fission of a primary beam of ^{238}U at 345 MeV/nucleon and 90-particle nA on a 4-mm-thick primary beryllium target. These nuclei were sent through the BigRIPS separator onto a secondary 6.8-mm-thick beryllium target, in which knock-out reactions took place. The outgoing fragments including ^{79}Cu were subsequently identified in the ZeroDegree spectrometer. The emitted γ-rays were detected by the HiCARI germanium array[2)] placed around the secondary target. To carry out event-by-event particle identification (PID) of the beam nuclei, we used the combination of the ToF-$B\rho$-ΔE and two-fold $B\rho$ methods in both the BigRIPS and ZeroDegree spectrometers to obtain the atomic number (Z) and mass-to-charge ratio (A/Q). To reduce the number of contaminating events, we applied conditions in correlations within different detectors. The removed events include the δ-electrons in the parallel-plate avalanche counters (PPACs), the changing charge states, and the pile-up events in the plastic scintillators and ionization chambers. The combination of these cuts reduced the total number of events during PID in BigRIPS by 11%.

To enhance the A/Q resolution, we applied optical corrections up to the third order using a multidimensional fit to eliminate the dependencies of the A/Q values on the position and angular variables at different focal planes. This resolution improved from 0.11% to 0.08% in BigRIPS for ^{80}Zn isotopes and from 0.22% to 0.15% in ZeroDegree for ^{79}Cu isotopes.

The cores and segments of the 10 available germanium clusters (4 Miniballs, 4 Clovers, P3, and Quad) were calibrated in energy with sources of ^{60}Co, ^{152}Eu, ^{133}Ba, and ^{88}Y. A preliminary Doppler correction of the γ-ray energy for the ^{80}Zn(^{9}Be, X)^{79}Cu channel was applied. Figure 1 shows the spectrum of the Miniballs and Clovers. This was produced using the photogrammetry positions of the detectors and a fixed velocity at the target center. The latter was estimated using the mean values of the measured velocity distributions in BigRIPS and ZeroDegree and LISE++ simulations to correct for the energy loss in the intermediate materials upstream and downstream from the target. In this γ-spectrum, the 656 keV transition[3)] from the first $(3/2^-)$ excited state to the $(5/2^-)$ ground state can already be confirmed. We foresee to optimize the Doppler correction by using an event-by-event velocity and apply γ-γ coincidences to find the remaining transitions and reconstruct the resulting level scheme.

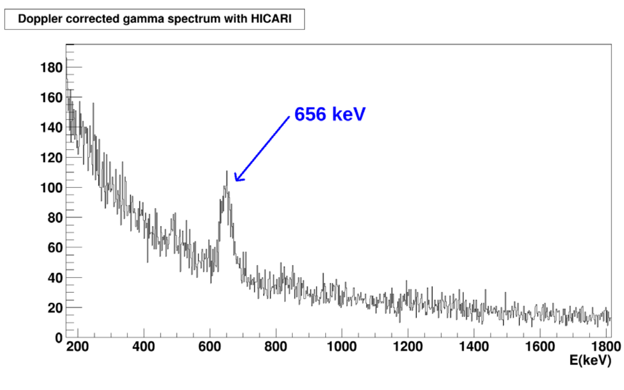

Fig. 1. Preliminary Doppler corrected γ spectrum of ^{79}Cu.

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