RIBF181: γ-ray spectroscopy in the vicinity of ^{78}Ni

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The NP1912-RIBF181 experiment with the HiCARI setup[1)] was conducted for 7 days in April 2021. Its objective is the spectroscopy of the nuclei in the vicinity of ^{78}Ni, which is expected to be doubly magic ($Z = 28$, $N = 50$).[2,3)] The experiment aimed to prove for the possible shape coexistence phenomena associated with shell-quenching in both proton and neutron gaps at and beyond this anchor-point nucleus, especially by the detailed spectroscopy of the proton single-particle states in ^{79}Cu. ^{80}Zn and the one-proton removal channels were centered in the BigRIPS and ZeroDegree (ZD) spectrometers, respectively.

The secondary beam was produced with a 4-mm beryllium target at the F0 focal plane by a 90-particle nA ^{238}U primary beam at an energy of 345 MeV/nucleon. The beam was purified using the $B\rho$-ΔE-$B\rho$ method through the first stage of BigRIPS with a wedge-shaped 8-mm aluminium degrader installed at F1 and the second stage with a 2-mm aluminium degrader at F5. To enhance the production yield of the ^{80}Zn beam, we selected the magnetic rigidity for a high total beam rate at F7 of about 5×10^4 counts per second (cps). This is much higher than the upper limit (10 kcps) of the previous in-beam γ-ray spectroscopy experiments at the ZD spectrometer. A secondary target consisting of 6.8-mm-thick beryllium was selected for an efficient population yield of the γ rays after the secondary reaction without eroding the advantage of the high-resolution spectrometer array.

The data acquisition (DAQ) system consisted of two parts, the BigRIPS and HiCARI DAQs. The former processed all the data except the data from the HiCARI detector arrays, *i.e.*, the data from the beamline detectors and the timestamp values of the HiCARI DAQ with a shared dead-time mode within the subsystems. The latter recorded the waveforms of the HPGe detector signals with a certain time window generated from the external trigger pulse with practically no dead time. A live-time ratio of ≈87% with a trigger rate greater than 5 kHz was achieved in the BigRIPS DAQ owing to a recently developed data acquisition system, MPV.[5)] To establish both good timing and energy measurements with a high beam rate in each plastic detector, a charge-to-time converter (QTC) module[6)] was utilized in addition to the standard circuits.

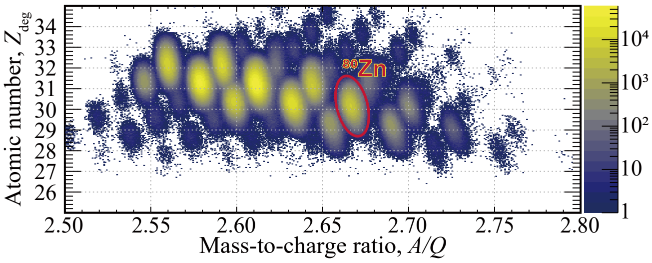

Fig. 1. Preliminary particle identification plot in BigRIPS with the $Z_{\rm deg}$ method. ^{80}Zn is highlighted with a red ellipse.

The particle identification for the secondary beams was performed with the TOF-$B\rho$-ΔE technique. Instead of using the standard MUSIC detector at F7, which suffered from a large number of pile-up hits, the $Z_{\rm deg}$ technique was confirmed to be functional with a reasonable resolution (Fig. 1). This method is to calculate the energy loss in the degrader at F5 from the difference in the reconstructed momenta between F3-F5 and F5-F7 and has been applied before in other experiments in higher Z regions around $Z \approx 50$.[4)] The purity of the ^{80}Zn beam is tentatively deduced as 4.8%. The same method was applied to the scattered particles with the ZD spectrometer. As a backup for the energy loss measurement, another 1-mm plastic scintillator was installed at F11 after the standard one.

A set of high-statistics data is expected to provide not only γ-ray energy spectra disentangling high density levels that were not resolved in the previous studies[2,3)] but also systematic inclusive nucleon-removal reaction cross sections with a variety of isotopes in the vicinity of ^{78}Ni.

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