HiCARI: High-resolution Cluster Array at RIBF

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The RIKEN Nishina Center and the RIBF have been conducting in-beam γ-ray spectroscopy experiments at the forefront of nuclear structure research. Studies on exotic nuclei have focused on experiments employing beams with the largest possible isospin asymmetry. Low beam intensities require thick secondary reaction targets to achieve reasonable luminosity for measurements as well as a high efficiency γ-ray detector. The NaI(Tl) detector array DALI2[1)] features a very high detection efficiency, ~20% for 1 MeV γ rays, but it has very limited resolution for the transition energies (approximately 10% FWHM for typical in-beam experiments). This detector is ideally suited for first spectroscopy experiments for nuclei at the limits of the known nuclear chart, as well as for studies featuring low level densities or selective population of states such as magic nuclei or Coulomb excitation. The detailed spectroscopy of complex level schemes and measurements of excited state lifetimes are not possible with the DALI2 array.

To overcome these limitation for in-beam γ-ray spectroscopy experiments at the RIBF, the HiCARI project was initiated. The HiCARI array comprises segmented high-purity germanium detectors. This provides excellent energy resolution to in-beam experiments by improving both the intrinsic energy resolution of the detector material itself and the position resolution for the interaction points of the γ ray with the detector material, which is required for the Doppler reconstruction of transition energies. The high resolution also allows determining the lifetimes of excited states by analyzing the shape of the peak in the Doppler reconstructed spectrum. For the HiCARI array, eight Miniball triple cluster detectors,[2)] 8(4)-fold segmented Clover detectors from IBS Korea (two clusters) and IMP China (four clusters), the RCNP quad-type 36-fold segmented tracking detector, and a triple segmented tracking detector P3 from LBNL Berkeley, which is also 36-fold segmented, are available. The final array installed at the F8 focus for experiments employing the ZeroDegree spectrometer comprises six Miniball triples, four Clovers, and the two tracking detector modules; it is shown in Fig. 1.

The readout electronics is based on the digital data acquisition of the GRETINA array.[3)] The signals of each central contact and segment electrode are digitized with a 100 MHz sampling rate and recorded. The energy is derived using a trapezoidal filter algorithm. For the tracking detectors, the energy and three-dimensional position information of individual interaction points within the segments is derived from the GRETINA signal decomposition analysis.

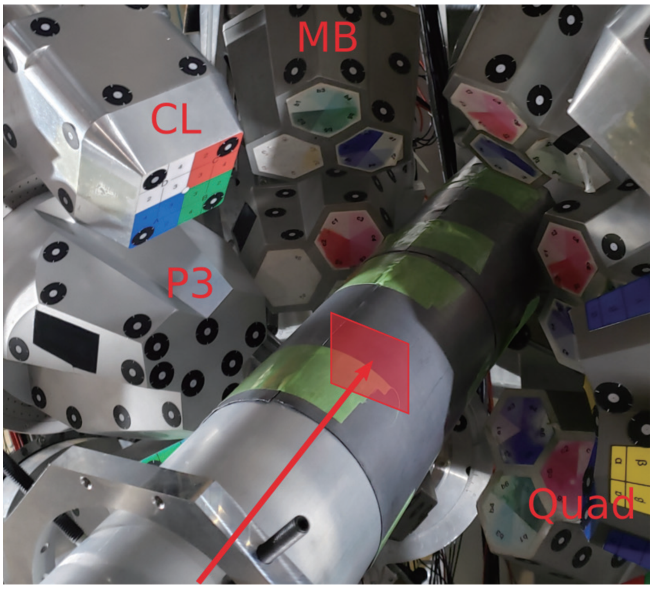

Fig. 1. HiCARI array located at the F8 focus. The beam enters through the beam pipe from the left. The forward ring ($\theta_{\rm lab} \sim 22$–55°) comprises six Miniball detector modules (MB). The tracking detectors (P3 and Quad) are located in the horizontal plane, with the Clover detectors (CL) arranged on top and bottom of the $\theta_{\rm lab} \sim 60$–85° ring.

Before the experimental campaign (for details on individual experiments, see contributions in this volume), a series of characterization and commissioning measurements was performed. In-beam measurements using an intense ^{82}Ge beam of approximately 260 MeV/nucleon impinging on Be and Au targets of various thicknesses were used to characterize the in-beam efficiency and resolution of the HiCARI array. The response to the high-intensity, low-energy radiation from atomic processes in the collision of beam and target was also investigated, and the effect of different shielding materials was explored.

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