A NaI(Tl) detector array for measurements of γ rays from fast radioactive isotope beams †

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The recent development of fast radioactive ion (RI) beams requires a new type of γ-ray detector array for in-beam spectroscopic studies. Experiments are performed in inverse kinematics by using fast RI beams with a high velocity of $v/c \simeq 0.3 - 0.6$ that causes a large Doppler shift for γ rays emitted. In order to extract the transition energy in the rest frame of the projectile, precise measurements of emission angles of γ rays as well as a good intrinsic energy resolution are required. Another requirement for γ-ray detection is high efficiency, because the secondary-beam intensity for nuclei far from stability is typically low. The RIKEN RIBF provides the world's highest intensity exotic beams to study unstable nuclei. To capitalize on the performance of RIBF, we have constructed a new γ-ray detector array called DALI2 (Detector Array for Low Intensity radiation 2) for in-beam γ-ray spectroscopy experiments.

The design of the DALI2 array follows a concept similar to the original array DALI[1,2], which was developed for experiments at the old facility at RIKEN that provides light exotic beams with $v/c \simeq 0.3$. In experiments performed at the new RIBF facility providing higher-velocity exotic beams with $v/c \simeq 0.6$, the performance of DALI is not optimized. Therefore, DALI2 was designed to fulfill the required conditions for experiments performed at the RIBF facility by improving the angular resolution and the detection efficiency. In order to compromise on requirements such as intrinsic resolution, detection efficiency, and cost, we adopted NaI(Tl) as the detector material. The DALI2 array consists of a large number of detectors, 160-186, which, depending on the experimental conditions, are at various distances from the target. As shown in Fig. 1, the detectors are arranged to form twelve layers that are set perpendicularly to the beam axis, and a detector matrix covers the forward angles. Each layer consists of 6-14 detectors and the forward matrix consists of 64 detectors. In this standard configuration, DALI2 can cover a polar angle between 15° and 160°.

The performance of DALI2 was examined by using measurements with standard γ sources and by performing the Monte Carlo simulations with the GEANT3 code[3]. Simulations reproduce measurements well, including results obtained by in-beam experiments. A typical full-energy-photopeak resolution of 10% (FWHM) and 20% efficiency are achieved for 1-MeV γ rays emitted from moving nuclei with $v/c \simeq 0.6$ without applying add-back analysis. This resolution is satisfactory for spectroscopy of low-lying states in even-even nuclei. The high efficiency enables γ-γ coincidence measurements even for beam intensity as low as 1 Hz. The DALI2 array has been applied successfully to a variety of experiments at the old RIKEN facility and more recently at the new RIBF facility. This will be used in many more experiments to study nuclear structures of exotic nuclei at RIBF. For further spectroscopic studies of heavy or odd-mass nuclei, the SHOGUN array with superior energy resolution is planned[4].

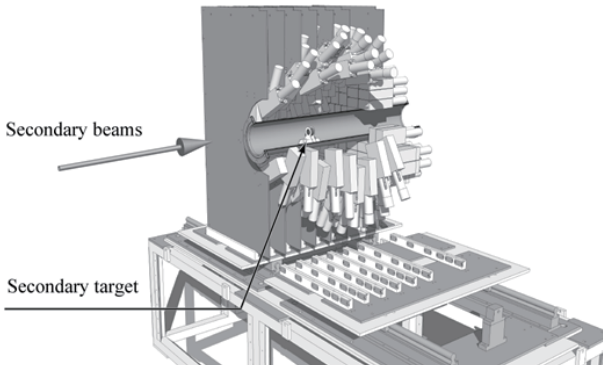

Fig. 1. Schematic view of DALI2 in its standard configuration consisting of 186 NaI(Tl) crystals.

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