Development of a γ-ray calorimeter for the measurement of highly excited states

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The γ-ray calorimeter CATANA (**CA**lorimeter for γ-ray **T**ransitions in **A**tomic **N**uclei at high isospin **A**symmetry) has been developed to measure highly excited states such as the pygmy dipole resonance and/or the giant dipole resonance. CATANA will be used with the SAMURAI facility at RIBF.[1)] The excitation energy spectrum will be reconstructed by combining the invariant mass of the reaction products measured by SAMURAI and γ-ray energies from CATANA. CATANA is focused on achieving a high detection efficiency because the probability of multiple γ-ray emissions is high in the decay of the highly excited states. Our goal is to achieve 55% photo peak efficiency for a 1 MeV γ ray from a beam with velocity $\beta = 0.6$.

The cross-sectional view of the CATANA array is shown in Fig.1. The array consists of 200 CsI crystals, whose thickness ranges from 9 cm to 15 cm. The colors indicate the different crystal shapes. The array is composed of six crystal shapes to minimize the empty space between the crystals. The crystals at the forward angle are thicker to cope with the Doppler shift of the γ energy. The array covers angles from 10° to 120° along the beam axis. The angular coverage per one crystal along the beam axis is about 9 degrees, and perpendicular to the beam axis, it is 18 degrees. The space inside the array is of ellipsoidal shape, whose major radius is 25 cm and minor radius is 20 cm. R11265 (Hamamatsu) PMTs will be used for two types of forward detectors, shown as yellow and saffron yellow in Fig. 1, and R580 (Hamamatsu) PMTs will be used for other detector shapes. Signal from a PMT will be processed in the spectroscopic amplifier 4494 from Clear Pulse Corporation. The pulse height information from the amplifier is digitized by a Mesytec MADC32 ADC. The timing information is processed in the 4494 amplifier using a build-in constant fraction discriminator, and digitized by a CAEN V1190A TDC. The logic trigger signal is generated as an "or" signal from the timing information.

The detection efficiency and the energy resolution of the CATANA array was estimated by using a Monte-Carlo simulation based on the code GEANT4. The thickness of the crystal housing and the space between the housing and crystal were assumed to be 1 mm in the simulation. The efficiency was calculated as 56% and 36% for 1 MeV and 10 MeV γ rays, respectively, from a beam with velocity of $\beta = 0.6$.

The prototype CsI crystal was tested at the Tokyo Institute of Technology. Fig. 2 shows the prototype CsI(Tl) crystal. The thickness of the crystal is 9 cm, and the shape of the prototype crystal corresponds to the blue one in Fig.1. The R11265 PMT is attached at the top side of the crystal. The crystal is wrapped by the ESR film (3M) of 65 μm and Teflon tape as reflectors. An energy resolution of 8.5% was achieved for the 662 keV γ ray with the prototype crystal. Based on the measured resolution, the energy resolution (FWHM) of 13% and 9% for 1 MeV and 10 MeV γ rays, respectively, from a beam at $\beta = 0.6$ is expected with the entire CATANA array.

The fabrication of 200 crystals will commence in spring 2014, and the entire system will be completed by spring 2015.

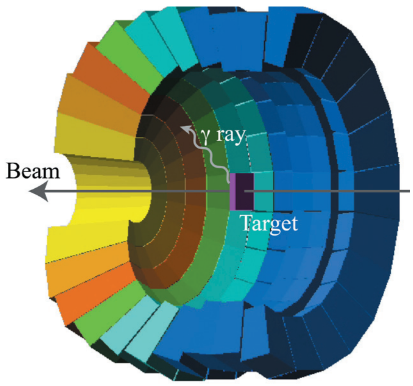

Fig. 1. Cross-sectional view of the CATANA array. Colors of crystals correspond to their shapes.

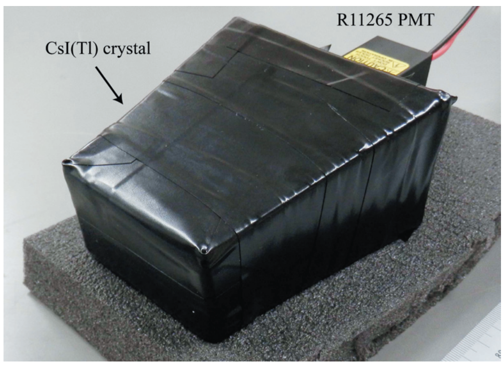

Fig. 2. Photograph of the prototype CsI(Tl) crystal.

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References
1) T. Kobayashi et al.: Nucl. Instr. Meth. B **317**, 294 (2013).