Construction status of the TOGAXSI telescope for the cluster knockout measurements in inverse kinematics

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Nuclear clustering is a cutting-edge topic with a rich historical background. It has been investigated in case of light and alpha-decay nuclei; however, research on medium and medium heavy nuclei remains limited. Furthermore, a unified understanding of the mean-field and the cluster pictures remains an open question. The ONOKORO Project, initiated in 2021 with KAKENHI funding, aims to tackle this question by measuring cluster knockout reactions at three facilities: RIBF, RCNP, and HIMAC, providing different types of beams. The first comprehensive measurement for ^{40}Ca was performed at RCNP in July 2023.[1] Further measurements are planned in 2024 for stable ^{42,44,48}Ca at RCNP and for unstable $^{50-52}$Ca at RIBF.

The construction of the TOGAXSI telescope for the cluster knockout measurements in inverse kinematics is in progress. It primarily comprises a silicon tracker and a GAGG:Ce calorimeter, aiming to determine the separation energy of light clusters from deuteron to α with a resolution of 2–3 MeV.[2]

The tracker comprises 100-µm-thick silicon strip detectors manufactured by Hamamatsu Photonics with a pitch size of 100 µm. The method for bending the flexible printed circuit has been established, and the fabrication of the detector in a rectangular shape has been completed.[3] Further, the construction of the supporting frame with water-cooling functionality is in progress. Currently, the efforts are focused on the design for the detector in a trapezoidal geometry.

The GAGG:Ce crystal measures $35\times35\times120$ mm^3 and is read out using one or two photo diodes: Hamamatsu S3584-08. For proton detection, signals are read from both ends to minimize the position dependence of the light yield, whereas signals are read from only one side to maximize the acceptance for cluster detection.

The detector is in mass production, and the current focus is on the development of an offline calibration method using cosmic rays.[4] Also, ongoing research in focused on the realization of real-time event building, combining the modern timestamp-based data with the conventional data employing the common trigger scheme.

The efforts to strengthen the international collaborative research has resulted in offers from Peking University (China) and IBS (Korea) for the production of additional 10 GAGG:Ce crystals each. This will significantly improve the efficiency, particularly for deuterons and tritons, thereby maximizing the outcome.

A proof-of-concept experiment for the TOGAXSI telescope was conducted via p-α elastic scattering measurement using a CH_2 target at HIMAC.[5] The results demonstrated the successful (1) reconstruction of reaction vertices, (2) identification of $Z = 1$ and 2 particles, and (3) discrimination of p-α events using kinematics. However, the silicon detector used as ΔE detector is too thin, which poses a challenge in the identification of high-energetic ^{3}He and ^{4}He. In addition, to achieve the high granularity required for the planned $(p, 3p)$ measurements, we decided to add a plastic-based segmented ΔE detector for cluster measurements.

A prototype of this new ΔE detector was constructed, and its performance was evaluated using a beam and was confirmed to function as anticipated in simulations. Currently, the design is being optimized based on the requirements for each experiment.

TOGAXSI is expected to be used in conjunction with the liquid hydrogen target system of STRASSE, developed at TU Darmstadt. A conceptual design is in progress for the coupling and the development of a target chamber and support structure for installation within the SAMURAI spectrometer.

The TOGAXSI + STRASSE setup, optimized for cluster knockout measurements, and the STRASSE + CATANA setup, specialized for $(p, 2p) + \gamma$ measurements, are expected to be the de facto standard setups at SAMURAI. To facilitate quick setup changes, the construction of a dedicated cryogenic system for TOGAXSI that relies only on the STRASSE target cell is being considered.

In summary, the basic development of each component of TOGAXSI is near completion. The first-generation telescope is under construction, with the goal of completion by the summer of 2024, and the operational deployment in the fall of 2024 at RIBF.

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DOI:10.34448/RIKEN.APR.57-122