Development of new particle identification method by pulse shape analysis of the GAGG(Ce) calorimeter

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Recently, we have launched the complementary projects: "ESPRI$^+$" and "ONOKORO,"[1] to investigate uniform and nonuniform properties in nuclei and nuclear matter. ESPRI$^+$ is an upgrade program from ESPRI[2] to apply the proton elastic scattering method to rare RIs whose production rate is less than 10 kcps. Under these projects, at RIBF, we plan to perform experiments to measure proton elastic scattering and proton-induced cluster knockout reaction from ^{52}Ca in inverse kinematics by developing a new telescope array, "TOGAXSI."[3] The telescope comprises 100-µm-thick strip-silicon detectors (SSDs) and GAGG(Ce) calorimeters. Although the performance of each detector has already been reported in the previous works,[4] it is still difficult to perform particle identification (PI) using the conventional ΔE-E method owing to the small ΔE in thin SSDs. Thus, we have developed a new PI method by utilizing differences between the signal pulse shapes of charged particles from the GAGG(Ce) calorimeter.

In this report, we show preliminary results of the test experiment by using 230 MeV proton beams and the "Grand Raiden (GR)" spectrometer[5] at RCNP, Osaka University. The GAGG(Ce) calorimeter was placed at downstream of the focal plane detectors. The spectrometer system was used for the momentum analysis and the PI of scattered charged particles. Two PMTs (HAMAMATSU, R11265U-20) were attached on both sides of the GAGG(Ce) crystal ($35 \times 35 \times 120$ mm^3). The pulse shapes of the signals from the PMTs were recorded using a digitizer (CAEN, V1730SB).

We obtained various data sets of high-energy protons at proton energy, $E_p = 50$–200 MeV and deuterons at whose energy, $E_d = 10$–100 MeV by changing the magnetic field of GR. We analyzed the data where the particles stopped in the crystal and reduced the pulse shape to the integrated total charge Q and the pulse height H. It was found that they have different but small position dependence($\pm 0.5\%$) from each other along the long side of the crystal, which is primarily owing to the difference in the concentration of the doped Ce. From the Q information, typical energy resolution of 0.7% at $E_p =$ 100 MeV was achieved. As shown in Fig. 1, we also found the quenching effect of $Q/E_{p(d)}$, which corresponded to the lightoutput per energy $\mathrm{d}L/\mathrm{d}E$ as a function of the energy loss $\mathrm{d}E/\mathrm{d}x$.

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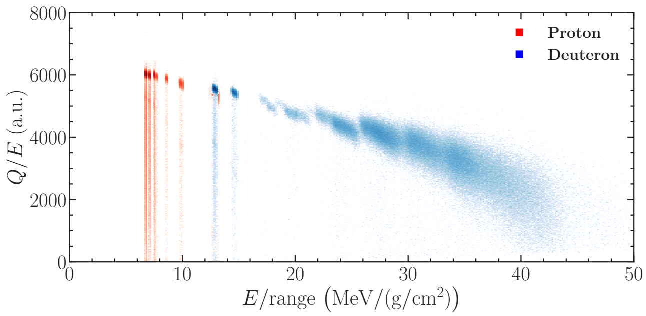

Fig. 1. $Q/E_{p(d)}$ ($\propto \mathrm{d}L/\mathrm{d}E$) plot as a function of $E_{p(d)}$/range ($\sim \langle \mathrm{d}E/\mathrm{d}x \rangle$). Red and blue points correspond to protons and deuterons data, respectively. The spots are correspond to the data acquired in each magnetic field settings of GR.

From the Q and H information, we obtained the good separation between protons and deuterons in the Q/H vs Q correlation. We finally deduced a universal calibration function depending on $\mathrm{d}E/\mathrm{d}x \propto AZ^2$ as shown in Fig. 2. The 2σ separation between p and d was achieved at $E_p > 30$ MeV.

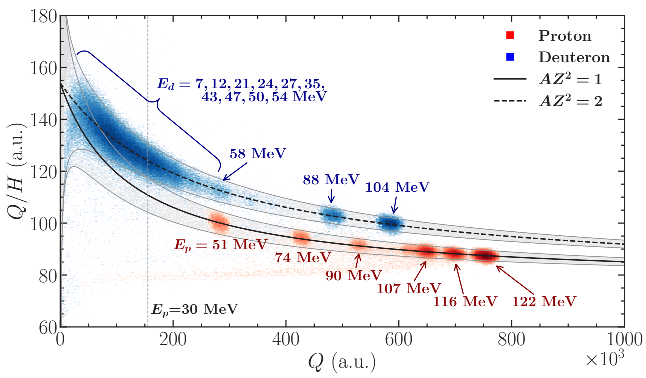

Fig. 2. Correlation between Q/H and Q. Proton (red) and deuteron (blue) loci are clearly separated. Lines show the calibrated response function depending on AZ^2. The hatched area represents the interpolated 2σ region.

References
1) T. Uesaka *et al.*, RIKEN Accel. Prog. Rep. **55**, 29 (2021).
2) T. Harada *et al.*, RIKEN Accel. Prog. Rep. **56**, 18 (2022); Y. Hijikata *et al.*, in this report.
3) J. Tanaka *et al.*, Nucl. Instrum. Methods Phys. Res. B **542**, 4 (2023); Y. Kubota *et al.*, in this report.
4) R. Tsuji *et al.*, RIKEN Accel. Prog. Rep. **56**, 83 (2022); K. Higuchi *et al.*, RIKEN Accel. Prog. Rep. **56**, 82 (2022).
5) M. Fujiwara *et al.*, Nucl. Instrum. Methods Phys. Res. A **422**, 484 (1999).

DOI:10.34448/RIKEN.APR.57-171