# Study of the position dependence of the large GAGG(Ce) calorimeter

R. Tsuji,[*1,*2] J. Tanaka,[*2] T. Uesaka,[*2] J. Zenihiro,[*1] Y. Kubota,[*2] K. Higuchi,[*2,*3] T. Sugiyama,[*3] S. Kurosawa,[*4] H. Baba,[*2] S. Takeshige,[*5] Y. Hijikata,[*1,*2] S. Ogio,[*1] K. Yahiro,[*1] and T. Yano[*1]

A telescope named TOGAXSI array has been developed for proton induced cluster knockout measurements of reactions with inverse kinematics in ONOKORO project.[1,2] It consists of silicon strip detectors and total energy calorimeters which detect knock-outed cluster and the recoil proton. The requirements of the calorimeter are high energy resolution ($\sigma \sim 1$ MeV), durability for high count rate ($\leq$100 kcps) and large stopping power because the knockout clusters which has high energy up to 250 MeV/nucleon are scattered in forward angle with high count rate. We employed the large GAGG(Ce) scintillator ($35 \times 35 \times 120$ mm$^3$) which has high energy resolution, high stopping power, fast response and no hygroscopic nature.

In the pervious work, avalanche photo diodes which size are $10 \times 10$ mm$^2$ are attached to GAGG(Ce) directly and the position dependence of the light output is drastic ($\sim$30%).[3] The behavior is similar to photon collection efficiency which is mainly caused by solid angle of photo sensor.[4] The suppression of the position dependence is necessary because it cause worse energy resolution and linearity. We tested the light guide and the photo diode (Hamamatsu, S3584-08) which has relatively large effective area ($28 \times 28$ mm$^2$) to suppress the position dependence as shown in Fig. 1.

The beam test was performed at QST HIMAC to research the response such as energy resolution and position dependence in new setup with proton and $\alpha$ beams at 100–230 MeV/nucleon. The energy resolution for focused proton beam at 100 MeV is about 1 MeV ($\sigma$). To measure the position dependence, the proton beam at 100 MeV was defocused and tracked by silicon strip detector. The definition of the coordinate is shown in Fig. 1. The position dependence in $y$ and $z$ direction is suppressed to less than 1% with the new setup.

Figure 2(a) shows the position dependence in $x$ direction. The position dependence of left and right light output is relatively small at the region far from the each photo diodes. On the other hands, the light output of them decrease and increase near the each photo diodes. The photon collection efficiency explains this phenomenon. Figure 2(b) shows the result of the simulation of the photo collection efficiency with Monte Carlo simulation. In this simulation, the photons which are emitted isotropically from the designated point in the crystal are totally reflected at the surface of the crystal and light guide and refracted at the boundary of materials. The behavior of position

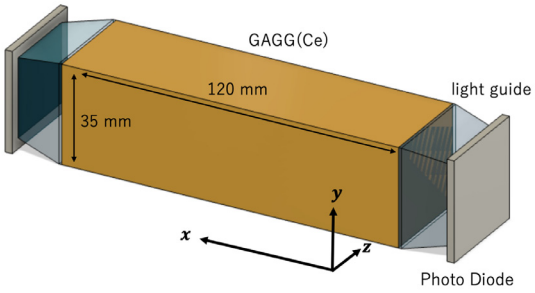


Fig. 1. The setup of GAGG(Ce) calorimeter.

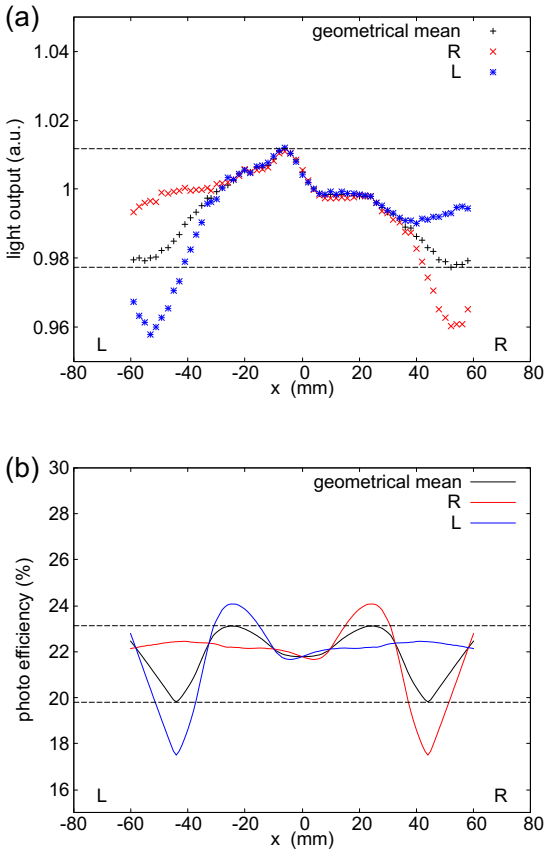


Fig. 2. The position dependence of the GAGG(Ce) calorimeter. (a) The light output measured with 100 MeV proton beam. (b) The photon collection efficiency simulated with Monte Carlo method.

*1 Department of Physics, Kyoto University
*2 RIKEN Nishina Center
*3 Department of Physics, Saitama University
*4 NICHe, Tohoku University
*5 Department of Physics, Rikkyo University

dependence near the photo diodes is similar to the experimental results but the absolute value is not duplicated. The light outputs of left and right photo diodes matches at $|x| < 30$ mm in Fig. 2(a) and it supports that effect of photon collection efficiency is small at the region far from photo diodes. Another cause of position dependence is the nonuniform composition of the crystal such as concentration of the doped cerium. The increase of the light output of both left and right photo diodes around $x = -10$ mm can be caused by this effect. In the new setup, the position dependence in $y$ and $z$ direction is suppressed and the total position dependence decreases under 4%. With the correction with silicon strip detectors, the energy resolution can be improved to under 1% for 100 MeV proton in this data.

References

1) T. Uesaka *et al.*, RIBF Construction Proposal, NP2112-SAMURAI72 (2021).
2) T. Uesaka *et al.* Grant-in-Aid for Specially Promoted Research, "Comprehensive research of cluster formation in nuclear matter" (2021).
3) R. Tsuji *et al.*, RIKEN Accel. Prog. Rep. **55**, 76 (2021).
4) R. Tsuji *et al.*, Master thesis, Kyoto University (2022).