Improvement of detection efficiency of time-of-flight detector with large effective area

S. Ishizawa,[*1,*2] K. Morimoto,[*1] D. Kaji,[*1] and F. Tokanai[*3]

A time-of-flight (TOF) detector was developed in a large entrance foil of 140 mm in diameter for GARIS-II.[1)] One of the important characteristics of the TOF detector is the detection efficiency for charged particles passing through the TOF detector. The TOF detector consists of an entrance foil, three wire grids for the formation of electric fields, two side panels, and a micro-channel plate (MCP), as shown in Fig. 1.

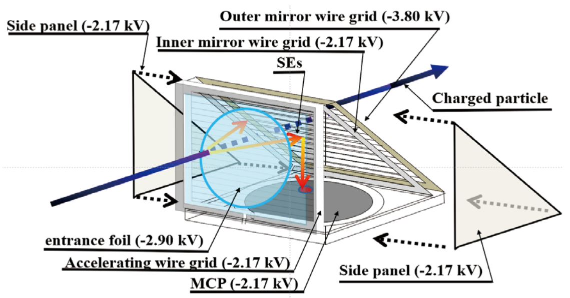

Fig. 1. Schematic view of the TOF detector and typical applied voltage. When the charged particles pass through the TOF detector, secondary electrons (SEs) are emitted from the entrance foil and guided to the MCP along the electrostatic field.

In previous work,[2)] it was found that the detection efficiency decreased in the horizontal space of a region more than ±30 mm away from the center of the entrance foil. This is because there are cases where the SEs emitted from edge of the entrance foil are not collected at the MCP.

In order to improve this problem, correction voltages were newly applied to the side panels of the TOF detector for the modification of electric field in the horizontal space. The detection efficiency was checked by impinging alpha particles from an ^{241}Am standard source on the entrance foil. Nine Si detectors were set with suitable intervals behind the TOF detector and operated in coincidence mode. Thus, the position dependence of the detection efficiency was obtained as shown in Fig. 2. The detection efficiency was defined as the ratio N_{TOF}/N_{Si}, where N_{TOF} and N_{Si} are the number of alpha particles detected by the TOF and that detected by Si detectors, respectively. The correction voltages for the side panels were −350 V lower than the applied voltage for the upper surface of the MCP, the accelerating wire grid, and the inner mirror wire grid.

As a result, we improved of the detection efficiency up to 99% at the edge region of the entrance foil with the correction voltage. The improvement can be verified by comparison with the trajectories of the electrons using an ion optics simulation program (SIMION 3D),[3)] as shown in Fig. 3.

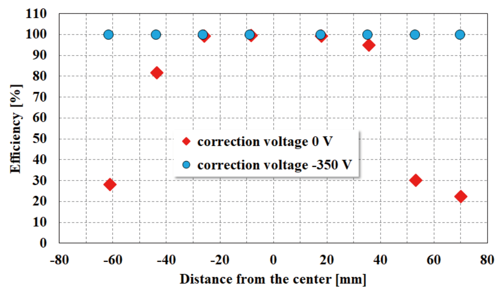

Fig. 2. Measured detection efficiency at the entrance foil in the horizontal space. The horizontal axis indicates the incident position of alpha particles.

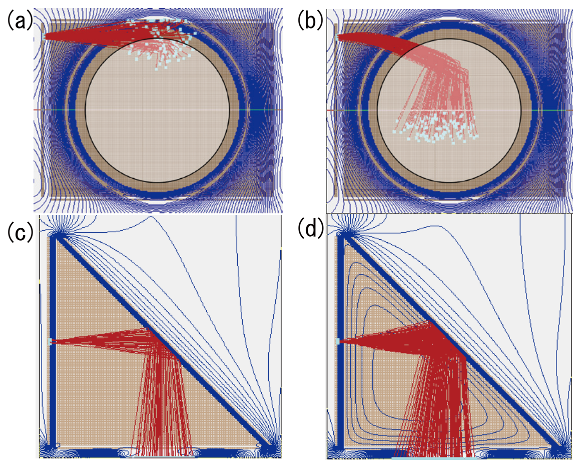

Fig. 3. Simulation results of trajectories of SEs obtained using SIMION 3D. The equipotential lines (blue) and the electronic tracks (red) are calculated with an correction voltage of 0 V (a, c) and −350 V (b, d). MCP is indicated by the white region (a, b).

References
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2) K. Morimoto *et al.*, RIKEN Accel. Prog. Rep. **46**, 191 (2013).
3) D. A. Dahl, SIMION 3D; `http://www.simion.com`

*1 RIKEN Nishina Center
*2 Graduate School of Science and Engineering, Yamagata University
*3 Department of Physics, Yamagata University