The SHARAQ spectrometer [1] and the high-resolution beam line [2] have been constructed in the RI Beam Factory (RIBF) at RIKEN. In March and May, 2009, we performed the beam study to examine dispersion-matching ion optics and to evaluate performances of detectors installed in the beam line and the spectrometer. In November, the first experiment has been done by measuring the \((t,^3\text{He})\) reaction induced by triton beam at 300 MeV/u. Through the beam studies and experiment, valuable information has been obtained on the basic performances of the high-resolution spectrometer system. This report describes basic performances of detector system installed at the dispersive focal plane of SHARAQ.

Figure 1 shows the detector setup used in the experiment. Two tracking detectors and three plastic scintillators were installed in the final focal plane of the SHARAQ spectrometer. The focal plane is located 3.04-m downstream from the exit of the SHARAQ D2 magnet and inclined at 35 degrees relative to the central orbit. Beam passed through the tracking detectors installed in vacuum, and went out to the air through a 10 mm-thick aluminum window. The plastic scintillators were placed downstream of the aluminum window.

The plastic scintillators were used to measure the timings passing through the focal plane, and to measure energy deposits in them. The three-layer configuration of scintillators is efficient for rejecting cosmic-ray events. Each scintillator is read out by two photomultiplier tubes attached on both sides. The effective area of the plastic scintillator is 650 \((H) \times 400 \,(V) \,\text{mm}^2\). Their thicknesses are 5 mm, 10 mm and 20 mm, respectively. Charge and timing data of the scintillators were obtained by utilizing the charge-to-time conversion (QTC) technique and multi-hit TDC modules [3].

Tracks of beam particles were measured by the tracking detectors, which are cathode-readout drift chambers (CRDCs) [4]. The CRDCs have manufactured in the fiscal year of 2008 by collaboration with an experimental group of GANIL. Detailed structure of the CRDC is described in Ref. [5]. The CRDCs were operated with isobutane gas at 15 or 30 torr in this study and the experiment. The CRDC has 2 signals from the anode wires and 2 multiplexed signals from the cathode pads. The anode signals were utilized to deduce drift time and charge amount of secondary electrons in the CRDC. Preamplifiers for anode signals were charge sensitive type and were set to be gain of 0.9 V/pC and time constant of 20 \(\mu\text{s}\). Since the anode signal is generated when avalanche occurs around anode wires, the drift time are determined by difference between an anode timing signal and a timing signal of the plastic scintillator. For a calibration of drift velocities of secondary electrons in CRDCs, a plastic scintillator with horizontal slit apertures was installed on the focal plane. Slits were located at every 10 mm and their width was 0.2 mm. By using the plastic scintillator, the drift velocities were estimated to be 5.9 cm/\(\mu\text{s}\) with 83.3-V/cm drift field at 15 torr and 5.3 cm/\(\mu\text{s}\) with 140-V/cm drift field at 30 torr, respectively. These values are consistent with the ones evaluated by using the GARFIELD code [6].

The horizontal hit position is determined by a charge distribution induced on the cathode pads. The charge signals from the cathode pads were read out by using GASSIPLEX chips [7]. With its capability of high multiplexing, the charge signals from 256 cathode pads can be transmitted through a single signal line and read out with a CAEN sequencer with a CRAM module [8]. In this study and experiment, the track-and-hold signals for GASSIPLEX chips were generated by the timing of anode signal of the CRDC under the condition that plastic scintillators and the anode were coincident.

Figure 2 shows detection efficiencies of 250-MeV/u \(^{14}\text{N}\) particles with 15- and 30-torr operations as the function of high voltage supplied to the anode wires. Compared with the 30-torr operation, the gas amplification at 15 torr was roughly 5 times smaller. However, in the tracking of heavier elements, the 15-torr operation of CRDC is considered to be sufficiently sensitive.
Detection efficiencies for light particles were shown in Fig. 3. The three panels show the data on $^9$Li, $^6$He and triton. In each panel, a solid (dashed) line indicates detection efficiencies by anode (cathode) as the function of anode HV. The detection efficiency is estimated by coincident ratio with 2 anode (2 cathode) outputs from one CRDC and plastic scintillators installed downstream. A difference of detection efficiencies between anode and cathode is caused by small mismatching of their preamplifier gains. The CRDCs of SHARAQ achieved 100-% detection efficiency by low-pressure operation for light ions such as tritons. In the next step of the optimization, we are analyzing HV dependence of anode in horizontal position resolution.

Discussions about achieved position resolution of the tracking detectors are described in the report by Tokieda [9].

In the summary, we performed the beam study using light radioactive isotopes at 200 A–250 A MeV and examined the detector system installed in the final focal-plane of the SHARAQ spectrometer. All the detectors operated successfully even for light particles and we obtained basic data of their performance in order to optimize the detectors’ parameters and to improve their data analysis algorithm. In November, we have performed the first experiment by using the ($t$, $^3$He) reaction at 300 MeV/u. The details on the experiment is described in Ref. [10].

References

[9] H. Tokieda et al., described elsewhere in this report.
[10] K. Miki et al., described elsewhere in this report.