SHARAQ spectrometer for high-resolution studies for RI-induced reactions†

S. Michimasa,[*1] M. Takaki,[*1] Y. Sasamoto,[*1] M. Dozono,[*2] T. Nishi,[*3] T. Kawabata,[*4] S. Ota,[*1] H. Baba,[*2] T. Baba,[*4] T. Fujii,[*1] S. Go,[*1,*2] S. Kawase,[*1] Y. Kikuchi,[*1] K. Kisamori,[*1,*2] M. Kobayashi,[*1] Y. Kubota,[*1,*2] C.S. Lee,[*1,*2] H. Matsubara,[*2] K. Miki,[*5] H. Miya,[*1,*2] S. Noji,[*6] H. Tokieda,[*1] M. Tsumura,[*4] K. Yako,[*1] R. Yokoyama,[*1] H. Takeda,[*2] Y. Yanagisawa,[*2] T. Kubo,[*2] N. Inabe,[*2] N. Fukuda,[*2] D. Kameda,[*2] H. Suzuki,[*2] Y. Shimizu,[*2] H. Sato,[*2] T. Ichihara,[*2] A. Stolz,[*6] R.G.T. Zegers,[*6] H. Sakai,[*2] T. Uesaka,[*2] and S. Shimoura[*1]

The SHARAQ project[1], which began in 2004, aims at high-resolution spectroscopy for reactions induced by radioactive ions (RI's) at 100A–350A MeV using the missing-mass method and at exploring new experimental techniques in the field of nuclear physics. In 2009, the construction of the High-Resolution Beamline (HRB)[2] and SHARAQ spectrometer[1] was completed at the RI Beam Factory (RIBF). The design specifications of the SHARAQ spectrometer are provided in Ref.[1]. To date, the SHARAQ and HRB have been used for six experiments involving charge exchange reactions with radioactive isotope beams.

For experiments at SHARAQ, detector developments and ion optics studies are underway to improve the performance for high-resolution nuclear spectroscopy. A CVD diamond detector was developed in collaboration with NSCL/MSU to measure beam timings at achromatic foci with extremely good time resolution. The detector consists of a CVD diamond crystal of active area 28 mm^2 and thickness 0.2 mm, with four strips on one side and one pad on the other side. We performed a test of the diamond detector using a 32-MeV α beam. The time resolution was deduced to be 27 ps (σ). Details of the test and the performance of the CNS diamond detector were reported in Ref.[3].

Multi-wire drift chambers operating at low gas pressure (LP-MWDC's) were successfully installed at the beamline foci. A tracking detector with high-rate capability and good position resolution enables us to obtain high-statistics data and to correct them through event-by-event momentum tagging. In our previous experiments, because the beam and reaction products were light nuclei with Z = 1–7, operation with low gas pressure was essential for reducing energy straggling and multiple scattering in the tracking detectors. The LP-MWDC achieved a position resolution of better than 300 μm (FWHM) for light ions and successfully operated with RI beams of intensities greater than 1 Mcps during a 1-week experiment. The high-rate performance is described in detail in Ref.[4].

As in the ion-optics studies for SHARAQ, we also report here the results of the high-resolution achromatic (HA) and dispersion-matching (DM) transport modes. The HA mode is achromatic transport to the secondary target. One advantage of the HA mode is a wider momentum acceptance ($\Delta p/p = 2\%$) compared to the DM mode ($\Delta p/p = 0.6\%$), and thus, higher intensity RI beams can be delivered to the SHARAQ spectrometer. Momentum tagging by LP-MWDC at the intermediate dispersive focus (F6) enables us to improve the spectroscopic resolution of the reaction kinematics with respect to the momentum spread of the radioactive beam. We demonstrate the validity of the correction in Fig. 1.

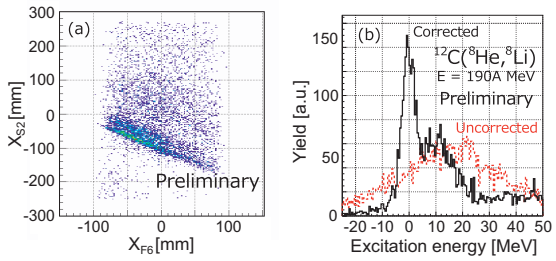

Fig. 1. (a) Correlation plot between F6 and the final dispersive focus of the SHARAQ spectrometer (S2). (b) Energy spectra with and without the event-by-event momentum correction.

The DM mode of SHARAQ spectrometer and HRB was designed to achieve extremely high resolution of reaction kinematics by the lateral and angular dispersion matching conditions in the entire system. Thus far, in the DM mode, we have achieved a momentum resolution of 1/8100 (FWHM) by taking into account the positions and angles of the beam constituents at the third focal plane (F3) of BigRIPS.

References
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*1 Center for Nuclear Study, the University of Tokyo
*2 RIKEN Nishina Center
*3 Department of Physics, the University of Tokyo
*4 Department of Physics, Kyoto University
*5 RCNP, Osaka University
*6 NSCL, Michigan State University