Development of dispersion-matching optics of primary beam for SRC-BigRIPS system

S. Y. Matsumoto,[*1,*2] D. S. Ahn,[*1] N. Fukuda,[*1] N. Fukunishi,[*1] H. Geissel,[*3] N. Inabe,[*1] K. Itahashi,[*1]K. Kusaka,[*1] T. Nishi,[*1] Y. Shimizu,[*1] T. Sumikama,[*1] H. Suzuki,[*1] M. Takaki,[*4] H. Takeda,[*1]Y. K. Tanaka,[*1,*3] T. Uesaka,[*1] Y. Yanagisawa,[*1] and K. Yoshida[*1]

We are working toward the development of a new optics[1)] for SRC-BigRIPS system that can be used for two types of experiments based on missing-mass spectroscopy: search double Gamow-Teller giant resonance and systematic high-precision spectroscopy of pionic atoms (piAF). In these experiments, the largest contribution to the missing-mass resolution is the momentum spread of the primary beam. Therefore, we applied a technique for dispersion matching[2,3)] to suppress the contribution from the momentum spread. The dispersion-matching condition is fulfilled when the dispersions of the BigRIPS spectrometer and its upstream beam-transfer lines are properly adjusted to eliminate the contribution factor as follows:

$$(x_{\mathrm{F5}}|\delta_{\mathrm{F0}}) + (x_{\mathrm{F5}}|x_{\mathrm{F0}})(x_{\mathrm{F0}}|\delta_{\mathrm{SRC}}) = 0.$$

Here, x is the horizontal position and δ is the relative momentum deviation from a reference particle.

In constructing the dispersion-matching optics, we investigated phase distributions of beam transfer-line, *i.e.*, the upstream section between SRC and F0. In the preceding piAF experiment,[4)] the dispersion in SRC-F0 was not properly controlled owing to insufficient information regarding SRC. In addition, we require momentum compaction (ideally achromatic-focus) condition at the intermediate point (T11), thereby isolating the uncertainties in the optical properties of the in-coming beam and design T11-F0 by realizing flexible designs at F0.

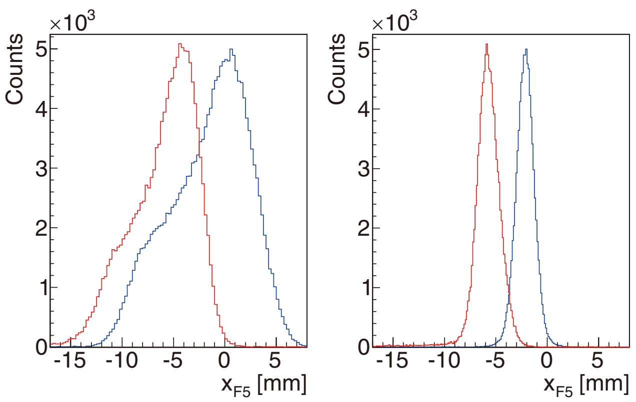

Fig. 1. Position distribution at F5 with the standard (left) and dispersion-matching (right) optics. Red and blue lines represent data with or without target at F0, respectively.

Table 1. Measured and designed matrix elements.

Matrix element	Measured value	Designed value
$(x_{\mathrm{F5}}\|\delta_{\mathrm{F0}})$	62.3 ± 0.5 mm/%	62.0 mm/%
$(x_{\mathrm{F5}}\|x_{\mathrm{F0}})$	-1.67 ± 0.03	-1.82
$(x_{\mathrm{F0}}\|\delta_{\mathrm{SRC}})$	29.1 ± 0.3 mm/%	33.4 mm/%

To deduce the phase distributions at T11 and F0, we used particle trajectories measured by detectors in BigRIPS and traced them back to the upstreams. The matrix elements in T11-F0 and BigRIPS required for the trace-back method are measured by decoupling the corresponding sections by inserting thick degraders at the entrances.

We performed an experiment to examine the beam-transfer line in June 2018. The goal of this experiment is to achieve the dispersion-matching condition by tuning the optics in the beam-transfer line. A primary beam of $^{18}O^{8+}$ with an energy of 230 MeV/nucleon was utilized up to F7 to measure the optical matrices. The beam was detected by PPACs at F3, F5, and F7. According to the measurements, we optimized optics in the beam-transfer line to ensure that T11 and F0 have momentum compaction and dispersion, respectively.

We evaluated the resolving power of the dispersion-matching optics by simulating the reaction Q-value by the energy loss at F0. Figure 1 shows a comparison of position distributions at F5 measured with an Al (75 μm thickness) target represented by red curves and a through-hole represented by blue curves for the standard optics (left panel) and the dispersion-matching optics (right panel). The right panel seemed to exhibit better separation with difference in energy loss of 4.2 MeV. Table 1 presents the measured and designed values of matrix elements related to the dispersion-matching condition. Consequently, we succeeded in separating $\delta = 0.056\%$ of momentum deviations in 3.6σ. The corresponding resolving power is estimated to be 7300.

In summary, we constructed a new optical system to improve the missing-mass resolution by dispersion matching. A precise analysis is in progress.

*1 RIKEN Nishina Center
*2 Department of Physics, Kyoto University
*3 GSI Helmholtzzentrum für Schwerionenforschung GmbH
*4 Center for Nuclear Study, University of Tokyo

References
1) T. Nishi *et al.*, in this report.
2) B. L. Cohen, Rev. Sci. Instrum. **30**, 415 (1959).
3) T. Wakasa *et al.*, Nucl. Instrum. Methods Phys. Res. A **482**, 79 (2002) and references therein.
4) T. Nishi *et al.*, RIKEN Accel. Prog. Rep. **48**, 235 (2015).