Development of auto-focusing and auto-centering system for the BigRIPS separator (II)

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We are developing a fully-automatic system for radioactive-isotope (RI) beam production based on our technological developments and experiences to reduce the operation time. As the first step, an auto-focusing and auto-centering system[1,2] to tune the superconducting triplet quadrupole (STQ) and dipole magnets of the BigRIPS separator was developed. This is the second report on the auto-focusing and auto-centering system.

In a previous development,[2] auto-focusing or auto-centering, including data taking, analysis, and magnet adjustment, were performed for each focal plane. In the present development, we aimed to fully automate the focusing and centering at all the focal planes.

^{79}Ni-beam production using the auto-focusing and auto-centering system was conducted for the mass measurement around the ^{78}Ni region (NP2012-RIBF202-02). The ^{79}Ni yield was not high enough to perform centering and focusing quickly, and the ^{82}Ga beam was used instead. To center the ^{79}Ni-beam positions on the beamline, the goal of the ^{82}Ga positions were calculated as -2.7, -6.4, and -3.0 mm at F3, F5, and F7, respectively.

The STQ and dipole magnets were changed simultaneously to perform auto-focusing and auto-centering simultaneously at each focal plane. The focal plane for auto-tuning was automatically changed from upstream to downstream, *i.e.*, from F1 to F7. The position-detector PPACs installed at F2 were used only for RI-beam tuning at F2. The F2-PPACs were moved automatically on and off the beamline before and after the auto-tuning at F2. Figure 1 shows the positions and phase spaces at each focal plane after auto-focusing and auto-centering. For the auto-centering, the dipole magnet was tuned so that the center position of the distribution x_0 at the focal plane obtained from the result of Gaussian fitting became the goal of the ^{82}Ga position. For auto-focusing, the STQ magnets were tuned so that the first-order coefficient $p1$ obtained by fitting the phase space with the first-order polynomial function was greater than 10, which corresponds to $(x|a)$ less than 0.1. After confirming that auto-focusing and auto-centering were successful, the focal plane for these tunings was changed to the next one. A sequence of these procedures started by simply clicking an "AUTO TUNING" button on the web browser, after selecting the gate of the ^{82}Ga beam on an analysis program. The results shown in Fig. 1 demonstrate the success of focusing and centering.

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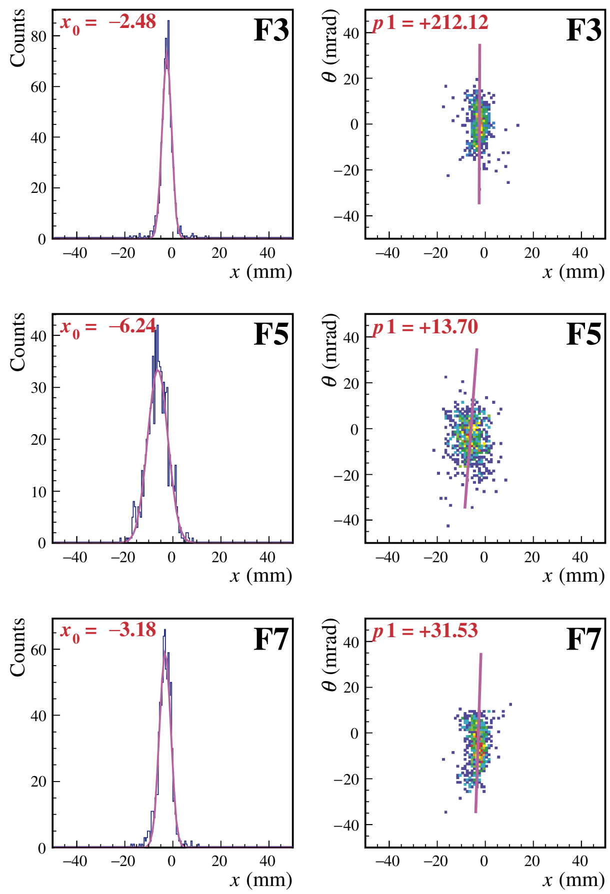

Fig. 1. Positions (left column) and phase spaces (right column) at each focal plane (F3, F5, and F7) after the auto-focusing and auto-centering. The pink curves and lines show the best-fit functions of the Gaussian and first-order polynomial, respectively. The x_0 and $p1$ values show the fit results.

Thus, the development of a novel auto-focusing and auto-centering system was completed. An operation test will be conducted by RI-beam physicists to confirm that this system is applicable to the regular operation of RI-beam production.

References
1) T. Sumikama *et al.*, RIKEN Accel. Prog. Rep. **54**, 82 (2021).
2) Y. Shimizu *et al.*, RIKEN Accel. Prog. Rep. **54**, 83 (2021).