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

Y. Shimizu,[*1] N. Fukuda,[*1] H. Takeda,[*1] H. Suzuki,[*1] T. Sumikama,[*1] T. Baba,[*1] and K. Yoshida[*1]

Various radioactive isotope (RI) beams have been produced by the superconducting in-flight separator BigRIPS since 2007.[1] We are developing the technologies of the RI-beam separation[2,3] and particle-identification analysis.[4] We developed efficient RI beam production, including a control system for the magnetic field with a feedback algorithm.[5] In the case of a ^{132}Sn beam, the production time was reduced by a factor of approximately 1/4 in the past decade. To further improve the efficiency of RI beam production, we are developing a fully automatic RI beam production system based on our technological developments and experiences. As the first step, auto-focusing and auto-centering systems were developed to automatically tune the STQs and dipole magnets on the BigRIPS separator.

In the auto-focusing and auto-centering systems, we used the BYACO (BeYond Analysis, Control, or Operation alone) ecosystem developed for online operation of the BigRIPS separator by connecting the comprehensive analyses seamlessly with others, such as devices and data acquisition (DAQ) systems.[6] The sequencer programming of the auto-focusing and auto-centering includes an automated loop, which consists of 7 steps

1. Start DAQ,
2. Start analysis,
3. Provide analyzed results,
4. Stop DAQ,
5. Evaluate new magnet currents,
6. Apply new magnet currents, and
7. Output the stability of the magnets.

The realtime analysis program is always running to convert raw data into analyzed data stored as a TTree object in ROOT.[7] Presently, when the step shifts from 5 to 6, one of the choices "APPLY TO TUNE," "NEXT FOCAL PLANE," and "FINISH" must be selected on the browser interface.

The system test of the auto-focusing and auto-centering system was conducted online for the ^{82}Ge-beam production required for HiCARI commissioning. The auto-centering was performed for each focal plane in the order of F2, F5, and F7. Subsequently, the auto-focusing was performed for each focal plane in the order of F1, F2, F3, F5, and F7. Figure 1 shows the positions and phase spaces at each focal plane after the auto-focusing and auto-centering. These auto-tunings were successfully demonstrated. Furthermore, the operation time became shorter than that of conventional manual tuning.

In future work, the simultaneous tuning of the STQs and dipole magnets will be continuously automated in the order of F1 to F7.

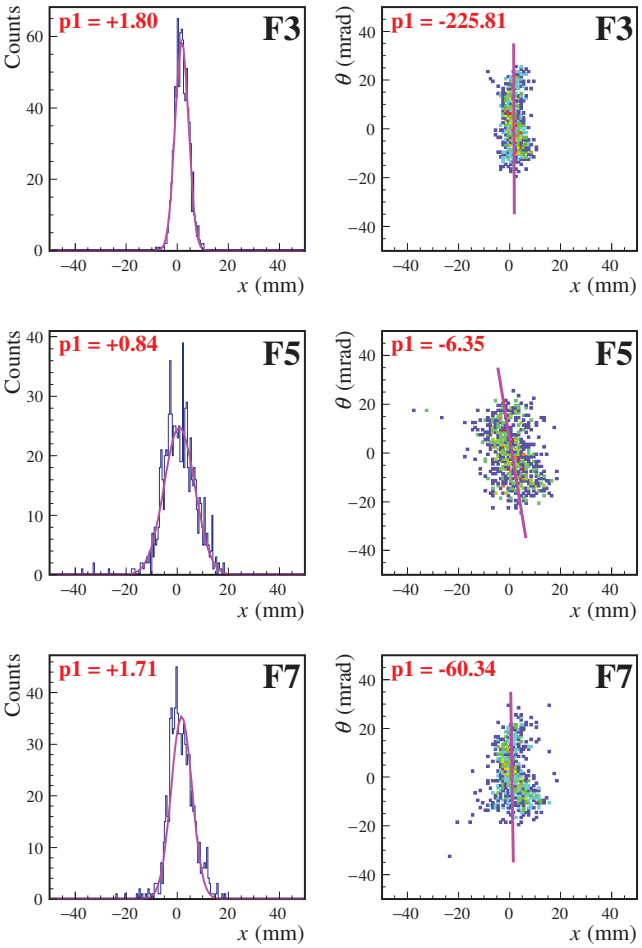

Fig. 1. Positions (left column) and phase spaces (right column) at each focal plane (F3, F5, and F7) after the auto-focusing and auto-centering. The pink curves and lines show the fitted functions of the Gaussian and 1st order polynomial, respectively. The p1 values show the fitted results.

*1 RIKEN Nishina Center

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