Optimization of sextupole magnets in the BigRIPS fragment separator for a high-purity RI beam

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The purification of radioactive-isotope (RI) beams is one of the most important issues especially for nuclear reaction studies with the intensity of 10^5 particles per second or more, to reduce the total beam rate at beam-line detectors, which are used for the particle identification of RI beams. The reaction studies for the long-lived fission products at a low energy of 20 or 50 MeV/nucleon are typical examples.[1] The first stage of the BigRIPS fragment separator is used for the separation of RI beams.[2] Higher-order aberrations of the ion optics in the separator have negative influences on not only the beam size and transmission efficiency but also the separation from contaminants. Sextupole magnets have been employed to reduce the higher-order aberrations of one given isotope in standard optics. For the contaminants, however, the higher-order aberrations remained. In the present study, the sextupole magnets were optimized for the separation of contaminants to obtain high-purity RI beams.

One of the largest aberrations is the focus shift as a function of the momentum. It is given by the $(x|a\delta_{B\rho})$ term of the ion optical matrix elements, where a is the beam angle in the x direction, and $\delta_{B\rho} = (B\rho - B\rho_0)/B\rho_0$. The magnetic rigidity, $B\rho$, is used instead of the momentum to consider both the given isotope and other contaminants. The aberration of $(x|a\delta_{B\rho})$ was removed by two sextupole magnets between two dipole magnets, D1 and D2, in the first stage. However, extra aberrations appeared. The aberrations were compensated by two more sextupole magnets with the opposite polarity in standard optics.

The magnetic rigidity of the contaminants is changed by a wedge-shaped degrader placed between D1 and D2. The focus shift of contaminants can be removed by the forth sextupole magnet after D2, but in standard optics, the shift increased because of the opposite polarity. To reduce the aberrations not only for the given isotope but also for the contaminants, the polarity of the forth sextupole magnet was inverted, and the first one before D1 was not used, for simplicity in the present study. Figure 1 shows the third order calculation of the ion optics of the first stage of BigRIPS by using the COSY INFINITY code.[3]

A ^{93}Zr beam was used to test this optimization. A 4-mm-thick Al wedge degrader was used for the isotope separation. The dependece of a and $\delta_{B\rho}$ on x at F2 were measured for ^{93}Zr and neighboring isotopes. The sextupole magnets were tuned so as to cancel out the a and $\delta_{B\rho}$ dependences. Figure 2 shows the a versus x plot for ^{93}Zr with and without the sextupole magnets. The blur at the large a region in Fig. 2(a) was reduced by applying the sextupole magnets as shown in Fig. 2(c). The distribution obtained for ^{92}Zr was similar to that for ^{93}Zr, as shown in Fig. 2(d). The separation between these isotopes was improved from 1.7σ to 2.5σ.

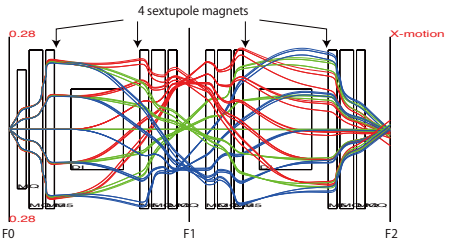

Fig. 1. Third-order ion optics of the BigRIPS first stage with the modified optimization of the sextupole magnets (SXs). The polarity of the forth SX is inverted from standard optics. The red and blue lines are −3% and +3% from the central momentum, respectively.

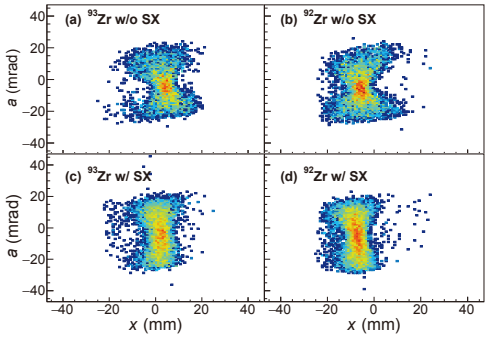

Fig. 2. Angle versus position distributions in the lateral direction at F2 for (a) ^{93}Zr without SX, (b) ^{92}Zr without SX, (c) ^{93}Zr with SX, and (d) ^{92}Zr with SX. The momentum distribution was ±3%.

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References

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