Isochronism of Rare RI Ring

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A precise isochronous condition for reference particles is essential to precisely determine the mass of nuclei using the Rare RI Ring (R3)[1]; therefore, one of the main purposes of a machine study for R3 is the isochronous tuning with beams. An isochronous field is formed by a combination of the edge-angle and gradient magnetic field of dipoles that are equipped with 10 trim coils.

In the first machine study, a first-order isochronous field tuned to a ^{78}Kr primary beam was successfully formed by adjusting the trim coils. The time-of-flight (TOF) spectrum after extraction as a function of momentum can be used to verify the isochronism, as shown in Fig. 1. Although it is natural that the secondary component remains in the distribution, the TOF width is broad overall. Because TOF width affects the experimental uncertainty of mass determination, it must be reduced as much as possible. Before conducting the third machine study,[2] we investigated the cause of the TOF broadening using simulation. It was found that the non-uniformity of the pole face of dipoles influence the TOF width. However, it could be improved by correcting the secondary component remaining in the distribution.

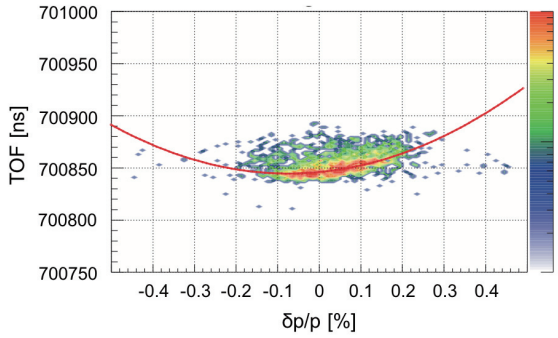

Fig. 1. TOF spectrum of ^{78}Kr after extraction as a function of momentum. The red line shows a quadratic fitting curve.

In the third machine study, we performed the isochronous tuning with ^{78}Ge, which was produced by in-flight U fission. The upper panel of Fig. 2 shows the TOF of extracted particles as a function of momentum before adjusting the isochronism by the second order. The full width of the TOF is almost as large as that of ^{78}Kr case. From this figure, it seems that isochronism is not satisfied on the high momentum side, in contrast to the low momentum side; thus, we tuned mainly the outer trim coils of R3. This resulted in the disappearance of the secondary component and the reduction of TOF width simultaneously as shown in the lower panel of Fig. 2. Consequently, the isochronism with the full momentum of 0.6% was improved. The TOF width after projection on the y-axis direction is 3.6 ns in sigma, and therefore, the degree of isochronism is approximately 5 ppm.

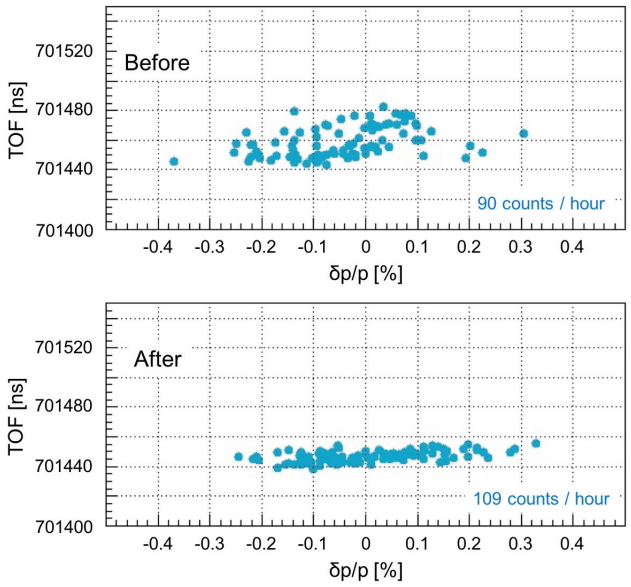

Fig. 2. TOF spectra of ^{78}Ge after extraction as a function of momentum. Upper and lower figures show the results obtained before and after adjusting the isochronism by the second order, respectively.

This value is at the level of the main magnetic-field fluctuation of R3 during the measurement time of about 1 day. There is no strong correlation between the TOF data and the fluctuation of magnetic field; however, it may be necessary to reduce the fluctuation of the magnetic field to further improve the isochronism. Another possibility is that the isochronism will further improve by third- or higher-order correction. The optimum value would be 1 ppm or less, which is quite challenging and requires step-by-step improvement.

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References

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