Fine tuning of isochronism in Rare RI Ring using resonant Schottky monitor

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Rare RI Ring (R3)[1)] is a storage ring that measure the masses of highly unstable exotic nuclei. According to the r-process, the masses of neutron-rich nuclei are crucial to understand nucleosynthesis. We employed a time-of-flight mass spectrometry method in an isochronous storage ring (R3). Because the target precision in mass determination was 10^{-6}, isochronism with a precision of 10^{-6} was required. R3 has a hexagonal symmetric structure that alternates between the sector section and straight section. The sector section consists of four bending magnets. The two magnets on both ends are equipped with ten trim coils to tune the isochronous condition. A monitor that measures the isochronous condition with 10^{-6} precision is required for precise isochronism tuning. This can be achieved through revolution time measurement for several sample particles with evenly distributed momentum over acceptance. However, it is not practical because it takes a long time. In this paper, we report another way using a resonant Schottky pick-up,[2)] which measures the revolution frequency with a precision of 10^{-6}, to evaluate the isochronism. The revolution frequency of an accumulated single-ion is temporally varied, as already shown in Ref. 3), because the momentum is smoothly decreased with time owing to the collision with the residual gas under the vacuum level of 10^{-5} Pa. The advantage of the new method is that the isochronism over the full range of momentum acceptance is precisely monitored with a single event, and the measurement is completed within a few seconds.

We practically applied this method to measure the isochronism of R3 using $^{78}Ge^{32+}$ beam with an energy of 166 MeV/nucleon, and attempted to fine tune the isochronism. Figure 1 shows the momentum dependence of the revolution frequency. The momentum acceptance of R3 and the beam transport line up to R3 is limited to ±0.3% and the good field region in R3 is provided within ±0.3%. Although a particle with momentum less than −0.3% can be accumulated, its isochronism is unestablished. Therefore, we discuss here the isochronism within the momentum region of ±0.3%. The black line indicates the momentum-dependent revolution frequency under the expected setting of the trim-coil current. The initial momentum, which is indicated at the right edge of the plot, was obtained from the horizontal position measured at the dispersive focal point F5 in BigRIPS. The third-order correlation between the revolution frequency and momentum remains. It is suppressed by fine tuning the trim-coil current using the known response functions of each trim-coil current to the isochronism. Among the ten horizontally arranged trim coils, the currents for the inner trim coils were slightly decreased by a few percent and those for the outer trim coils were oppositely increased in this case. This tuning procedure was repeated for some time. The red line shows the revolution frequency after the tuning procedure and it is nearly constant within the momentum acceptance. We can reduce the variation in frequency within the momentum acceptance from 46 Hz before tuning to 15 Hz after tuning. This corresponds to the isochronism of 5.4×10^{-6}. The data outside the acceptance are ignored because they are out of the good field region. We succeeded in the quick tuning of isochronism with a resonant Schottky pick-up and frequency variation within the momentum acceptance was easily achieved in the order of 10^{-6}.

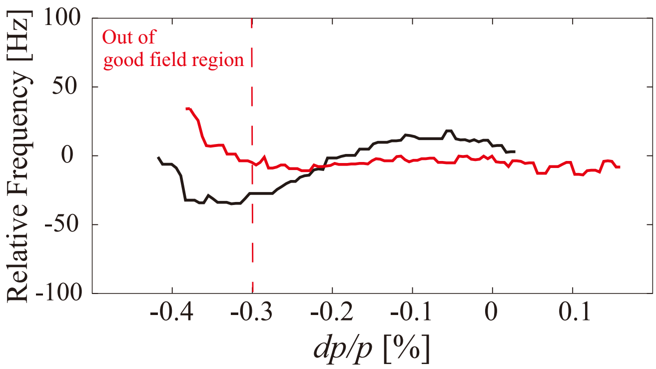

Fig. 1. Revolution frequency as a function of momentum converted from the accumulation time. The black and red solid lines indicate the revolution frequency before and after the fine tuning procedure, respectively. Two lines correspond to one event each. We subtracted the center frequency of the observational range from each revolution frequency. The momentum region less than −0.3% is out of the acceptance. Third-order correlation between the revolution frequency and momentum disappeared owing to fine tuning. The isochronism was obtained to be 5.4×10^{-6}.

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References

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