Momentum acceptance of the Rare RI Ring studied from revolution frequency measurements

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The Rare RI Ring was constructed[1,2] to investigate the nuclear structure and nucleosynthesis of unstable nuclei. The ring is a storage ring that measures the masses of unstable nuclei. Aiming at a relative mass precision of 10^{-6}, we employ the isochronous mass spectrometry method in the ring having precisely tuned isochronism. We developed a resonant Schottky pick-up for measuring revolution frequency.[3] Electromagnetic field is induced in the cavity by a circulating ion which periodically passes through it. The revolution frequency is obtained from frequency measurement of the field stored in the cavity. Basic parameters representing the performance of the resonant cavity, such as resonance frequency $f_{\rm res} = 172.9 \pm 1.6$ MHz, shunt impedance $R_{\rm sh} = 161$ kΩ, and unloaded quality factor $Q_0 = 1880$, were acquired.

The first commissioning of the Rare RI Ring using a 168-MeV/u Kr beam was conducted in June 2015. In the experiment, the signal of a single Kr nucleus was detected with the resonant Schottky pick-up. A frequency resolution of 1.3×10^{-6} was obtained from 32 ms-long measurements[4]. We observed that the revolution frequency gradually varies with time during the ion accumulation for 5 s. This is caused by the imperfection of isochronism and momentum change due to a finite vacuum condition. Under the current vacuum condition of 3.9×10^{-5} Pa, the momentum decrease shown in Fig. 1 is expected. This enables us to convert the time to the momentum change.

We acquired 14 events, each exhibiting their revolution frequencies as functions of time. Figure 2 shows the individual trajectories for the 14 events in a momentum change-frequency two-dimensional plane, for which the momentum change is obtained by the conversion from time according to Fig. 1. We note here that the initial momenta for the individual events are unknown and may not be identical, and some of the trajectories seem to be discontinued owing to possible hard collisions. Since the revolution frequency trajectories should be identical as far as the machine condition remains constant, each event in Fig. 2 has been appropriately shifted along the horizontal axis to conform to a single trajectory. The conformability is imperfect as evident in Fig. 2, because the momentum change shown in Fig. 1 is a stochastic process. Each event may not cover full momentum acceptance. The full momentum width in the total data, however, could be identified as the momentum acceptance of the ring. The estimated momentum acceptance is approximately 0.6%.

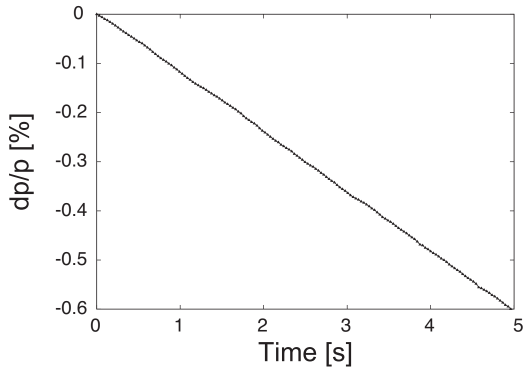

Fig. 1. Simulation result of momentum change as a function of time under the vacuum condition of 3.9×10^{-5} Pa.

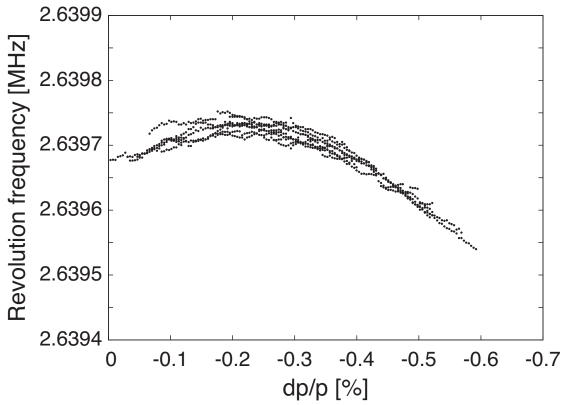

Fig. 2. 14 events of revolution frequency as a function of the momentum change obtained through the conversion from time according to Fig. 1.

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