The Isochronous Mode for Mass Measurements in the CR Storage Ring

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Exotic nuclei will be produced and separated in flight with the Super-FRS [1] at FAIR. The separated fragments will be injected and stored in the 13 Tm Collector Ring (CR) [2]. It will be used in the isochronous mode as a time-of-flight (TOF) spectrometer for short-lived exotic nuclides ($T_{1/2} > 20\mu s$), a method which has been developed at the ESR [3]. The mass-to-charge ratio m/q of the stored ions circulating in the ring can be measured from the revolution frequency (f) and the velocity (v) of the ions.

$$\frac{\Delta f}{f} = -\frac{1}{\gamma_t^2} \cdot \frac{\Delta(m/q)}{(m/q)} + \Big(1 - \frac{\gamma^2}{\gamma_t^2}\Big)\frac{\Delta v}{v},$$

where γ is the relativistic Lorentz factor and γ_t the transition point of the ring. The isochronous condition is reached when ($\gamma = \gamma_t$). The CR can be operated at a γ_t of 1.84. This condition can be achieved by an increased dispersion function. Although, we kept the maximum of the dispersion function below 30 m, it still reduces the momentum acceptance to $\pm 0.5\%$. The transverse acceptance is 100 mm mrad in the both planes, see Fig. 1. The calculation was done with the GICOSY and MIRKO codes.

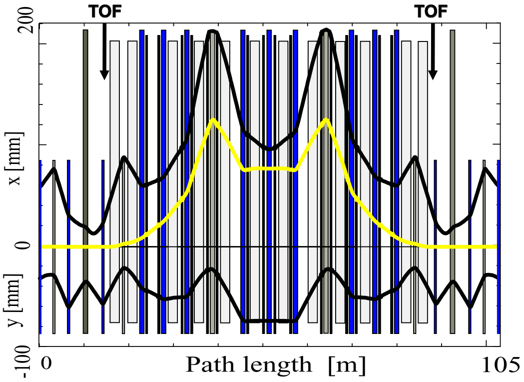

Figure 1: The Calculated beam envelope in x (upper part) and y (lower part) directions and the dispersion function (white line) for one half of the CR. The positions for two TOF detectors are indicated.

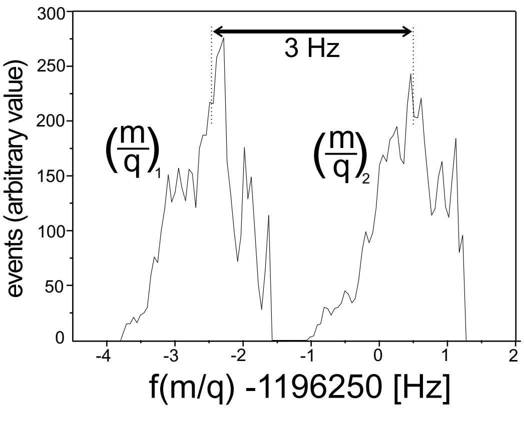

Figure 2: Calculated frequency spectrum with 10 mm mrad transverse emittances. The beam consists of two species of particles separated by $\Delta(m/q) = 2.1 \cdot 10^{-5}$.

We developed a special code which allows us to simulate the motion of stored ions and to obtain frequency spectra of isochronous particles with different m/q values. An example of such calculations is presented in Fig. 2. With this code we calculated the dependence of the revolution frequency on the transverse emittance, see Fig. 3. The calculations were done under ideal conditions, i.e. without the influence of the chromaticity, the fringing fields, and multipole components of the magnets.

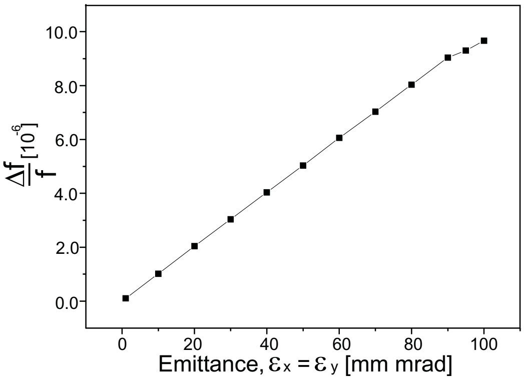

Figure 3: Calculated spread of revolution frequency as a function of transverse emittances. The change of the slope is due to particle loss in the ion motion.

In reality ions are mainly injected at velocities which do not perfectly match γ_t [5]. For analysis and calibration of such data we need to measure the velocity or magnetic rigidity of each ion in addition to the revolution frequency since:

$$\frac{(m/q)_1}{(m/q)_2} = \frac{f_2 \cdot \gamma_2}{f_1 \cdot \gamma_1}.$$

The velocity measurement can be done with two TOF detectors placed in a straight section of the CR. The distance between them is about 30 m. The aimed accuracy in magnetic rigidity is $\Delta B\rho / B\rho \sim 10^{-4}$ [6].

References

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