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Recycler Closed Orbit Distortion from a Systematic Mismatch between Long and Short Combined Function Magnet Strengths

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The Recycler Ring is designed with two lengths of combined function magnets, one of length 4.064 m and one of length 2.709 m. The ratio of integrated strengths is set at precisely 2/3 for suppression of dispersion in the transition between arcs and straight sections, and the ring central orbit is defined accordingly. The purpose of this note is to quantify the impact on the horizontal closed orbit in the Recycler due to a systematic offset in the strength of the shorter magnet relative to the desired value of 2/3 the strength of the longer magnet.

The closed orbit as observed at each specified horizontal beam position monitor has been calculated for a systematic integrated strength offset of $1\text{x}10^{-4}$ in the of the 2.709 m combined function magnet. Recycler lattice RRV6 is used in this exercise and the closed orbit is calculated using the expression:

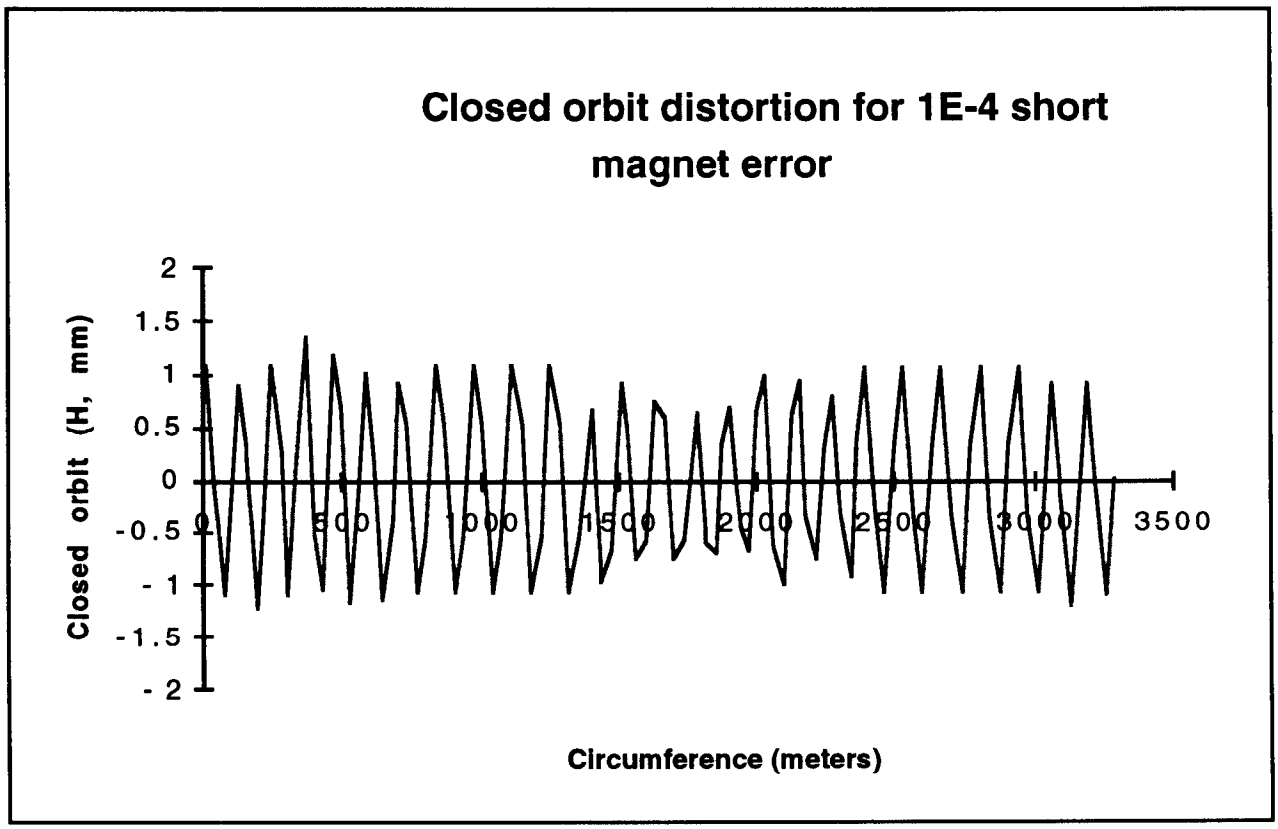
$$x_{c.o.}(s) = \frac{\sqrt{\beta_x(s)}(\Delta\theta)}{2\sin(\pi\nu_x)} \sum_i \sqrt{\beta_{x_i}} \cos(\left|\phi_x(s) - \phi_{x_i}\right| - \pi\nu)$$

where the sum is taken over all (128) 2.7 meter combined function magnets and $\Delta\theta$ is $1\text{x}10^{-4}$ of the nominal short magnet bend angle (13.901 mr). Results are shown in the figure below. The peak closed orbit amplitude is about 1.4 mm and the rms deviation (as measured at the horizontal BPMs) is 0.78 mm.

Conclusion

A $1\text{x}10^{-4}$ (a.k.a. 1 unit) systematic mismatch in the strength of the short combined function magnets relative to 2/3 the strength of the long magnets will produce a closed orbit deviation of up to 1.4 mm. The orbit distortion is linear in the mismatch. Since we presumably would like to keep orbit distortions of this type less than ~2 mm millimeters, this implies that the strength of the 2.7 m combined function magnets would have to be matched to 2/3 the strength of the 4.1 m magnets to ~1.5 parts in 10^4. However, since these magnets have a gradient-to-central-field ratio (B'/B) of 4.9 m^{-1}, a $1.5\text{x}10^{-4}$ dipole field error is equivalent to a transverse displacement of only

20 μm--well beyond our ability to survey and align these magnets in the ring. Assuming an alignment accuracy of 0.25 mm, the effect of systematic errors in the short combined function magnet sould be kept small relative to 0.25 mm × 4.9 m^{-1} = $12x10^{-4}$. Thus, we would expect that a measurable systematic error under ~$5x10^{-4}$ should be sufficient for the contribution to the closed orbit from this effect to be minor.



Horizontal closed orbit resulting from a $1x10^{-4}$ error in the integrated strength of all 2.7 meter combined function magnets. Orbit is plotted only at horizontal BPM positions.