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Emittance Growth due to ? -Jump Quadrupole Misalignment

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During the transition crossing of heavy ion beams in RHIC, the 48 γ_T–jump quadrupoles (quadrupole layer of the CRB type corrector) are pulsed to produce the required amount of change in transition energy. Any misalignment of the quadrupoles produces a feed–down dipole field which causes closed orbit mismatch and emittance growth.

According to the magnetic and survey measurement, the rms misalignment of the CRB magnets[1] is about 0.5 mm, and the quadrupole integral transfer function is equal to 0.765 Tm/kA at the reference radius of 2.5 cm. The maximum operating current of the γ_T–jump quadrupoles is ±50 A. At the transition energy of $\gamma \approx 23$, the total rms horizontal deflection angle produced by each quadrupole is

$$x'_{\rm rms} = \frac{0.1({\rm kA}) \times 0.765({\rm Tm/kA}) \times 0.5({\rm mm}) \times 0.039({\rm rad.})}{7.0({\rm Tm}) \times 25({\rm mm})} = 8.5 \times 10^{-6}({\rm rad.}), \quad (1)$$

where the bending angle from an arc dipole is 0.039 mr, and the integral transfer function of the arc dipole is approximately equal to 7.0 Tm at the time of transition. Assume that the γ_T–jump is accomplished in N revolutions, and the misalignment among the 48 transition quadrupoles is random. With horizontal $\beta_x \approx 50$ m at the location of the magnets, the maximum closed orbit distortion is in the horizontal direction. We can estimate the total growth in the 95% normalized transverse emittance

$$\Delta\epsilon_x \approx \frac{\pi\,(6\beta\gamma)}{2}\frac{48\;N}{\beta_x}\left(\frac{\beta_x x'_{\rm rms}}{N}\right)^2 \approx \frac{12}{N}\,(\pi{\rm mm}\cdot{\rm mr})\,. \quad (2)$$

[1] J. Wei, et al., *Effects of CQS and Dipole Misalignments in RHIC*, to be published as an AP Note (1995).

Obviously, the growth is proportional to the square of the rms misalignment. Since the design transverse emittance of the beam is 10 πmm·mr, the emittance growth would be more than 100% if the γ_T–jump were accomplished instantaneously within 1 turn. In order to eliminate the emittance growth at transition, the γ_T–jump should be performed adiabatically in a time of at least 1 ms ($N \sim 80$). Fortunately, this value is consistent with the current design of a γ_T–jump time to be less than 60 ms.

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