iv. γ_T-jump

With the exception of protons, all ions are injected below the transition energy and, consequently, have to be accelerated through transition to reach the top energy for storage. The acceleration is provided by the 28.15 MHz rf system with a maximum peak voltage of 600 kV. In order to successfully transfer the ion beams from the acceleration rf system (28.15 MHz) to the storage rf system (197 MHz), it is of primary importance to avoid particle loss and to preserve the initial bunch area of 0.3 eV·s/u during the transition crossing.

Problems related to transition crossing can mainly be divided into two categories: single- and multi-particle. The former category mainly includes the effect of chromatic non-linearities, while the latter includes bunch-shape mismatch and microwave instability induced by low- and high-frequency self fields, respectively. In addition, the remnant voltage of the 197 MHz rf cavities induced by the circulating beam causes further complication.

Both analytical and numerical studies have been performed to investigate the various problems. It has been shown that the transition crossing can be achieved with no particle loss and negligible bunch-area growth, when a γ_T-jump of 0.8 unit is employed in a time period of 60 ms. The γ_T-jump scheme will be used with the RHIC lattice when all the insertions are tuned to $\beta^* = 10$ m where $\gamma_T = 22.89$. A γ_T-jump of 0.8 units could be achieved with one family of b_1-correctors located at the horizontally focussing quadrupoles in the arcs. However, since γ_T can only be increased by this second-order scheme, a symmetric γ_T-jump *cannot* be achieved. A first-order matched γ_T-jump can be obtained with two quadrupole families and will be used in the RHIC lattice.

One family of quadrupoles will change the dispersion function through the dipoles which provides essentially linear dependence of γ_T on quad excitation. A second family of quadrupoles is added in low-dispersion regions of the lattice to correct for any tune change. These families are arranged in pairs of quadrupoles (denoted as doublets) with phase differences of $\pi/2$ to cancel any betatron waves.

The first family of doublets determines the value of the γ_T change. The γ_T change achievable is given by

$$\Delta\,(1/\gamma_T^2) = -\frac{1}{C}\ \Sigma\ \ K_i\ \ X_p^* X_p$$

where C is the ring circumference, K_i the quadrupole strength and X_p^* and X_p are the dispersion functions at the places where the additional quadrupoles are when the jump is "on" and under regular conditions, respectively. The maximum contribution to $\Delta\,(1/\gamma_T^2)$ is obtained where $(X_p)^2$ has a maximum. This condition shows that the best positions for the γ_T jump quadrupole doublets are where the horizontal dispersion has maximum values. The design follows this condition by placing this family of four b_1 correctors per sextant at the arc quadrupoles.

The second family of quadrupole doublets is located within the insertion where the dispersion is very close to zero. This family does not affect the value of the γ_T change; they are used to keep the tunes unchanged. The condition for the tunes to remain unchanged ($\Delta v_x = 0$) is:

$$\Delta v_x = \frac{1}{4\pi} \Sigma\, \beta_i K_i = 0$$

There are two doublets per interaction region where the dispersion has maximum values and an additional two doublets at locations where the dispersion is close to zero. Because the RHIC basic FODO cell has a phase difference close to $\pi/2$, the conditions for the γ_T design are very favorable. The total number of the additional γ_T quadrupoles per ring in RHIC is 48.

A total $\Delta\gamma_T = 0.8$ can be achieved symmetrically with $\Delta\gamma_T = +0.4$ and $\Delta\gamma_T = -0.4$ units by positive and negative quadrupole excitations as shown in Fig. 11-13. The properties of the correction γ_T quadrupole are listed in the Magnet System section of this manual. The nominal value of the strength of the correction γ_T jump quadrupoles at the current of $I = 50$ A is $K\gamma_T = 0.0084\ \mathrm{m}^{-1}$. The required change of the γ_T is thus obtained with one half of the "nominal" $I = 50$ A condition.

The betatron and dispersion function dependence on the γ_T quadrupole excitation were examined and are shown in Fig. 11-14. As mentioned above, the horizontal and vertical betatron tunes were always kept unchanged. The maximum value of the dispersion function in the present RHIC lattice, with the horizontal and vertical tunes split by one integer, is $X_{pmax} = 1.841$ m.

The RHIC γ_T-jump will maintain a physically small beam size during the jump and will not exceed the beam size at injection.

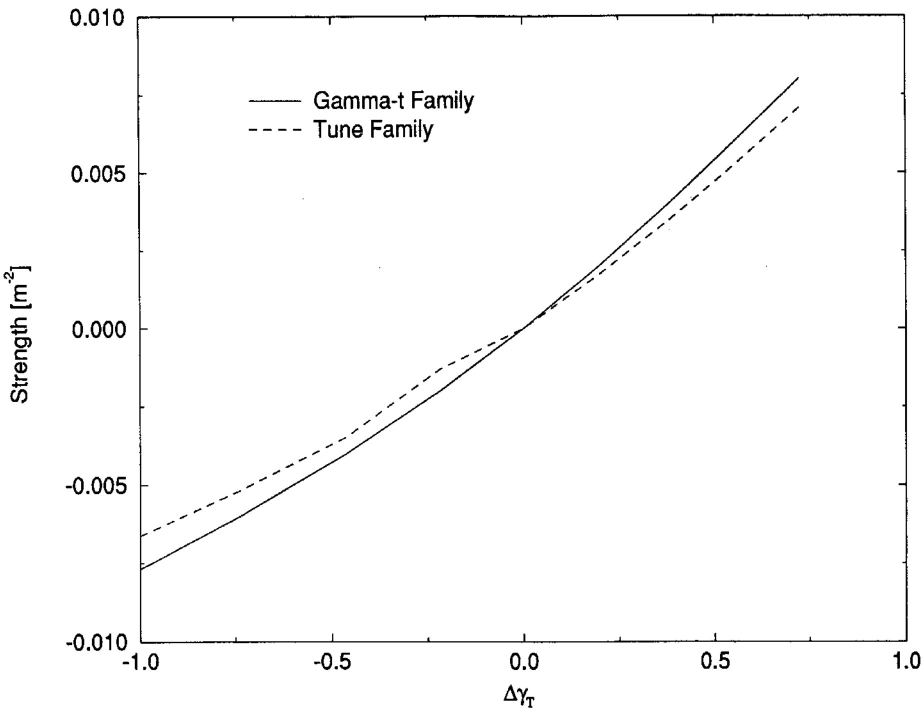

Fig. 11-13. b_1-corrector strength versus the change in γ_T .

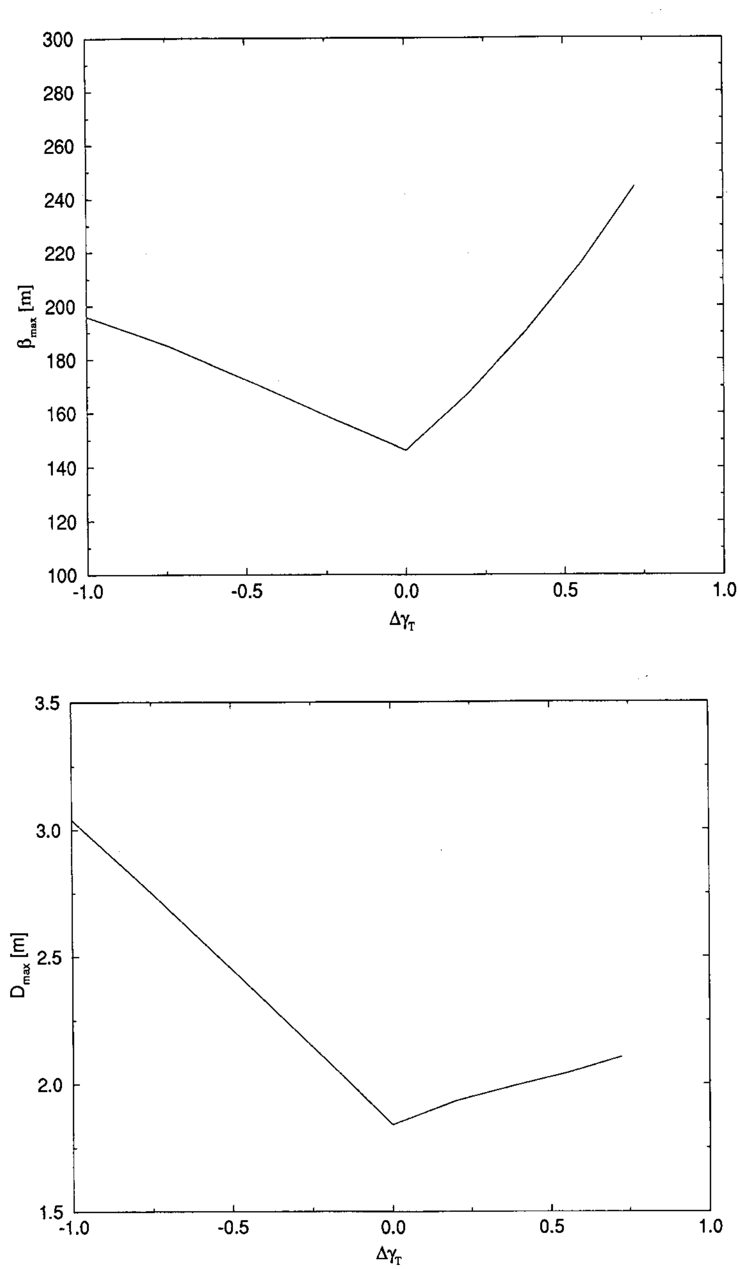

Fig. 11-14. The maximum beta function and the maximum dispersion during the γ_T-jump.