iii. Chromatic Effects

If the insertions are all identical and set up for $\beta^* = 10$ m the natural chromaticities ($\chi = p\, d\nu/dp$) are $\chi_H \approx \chi_V \approx -42$ to which the six arcs contribute -23 units. These large negative values of the chromaticities must be reduced to zero or a small positive value. This can be done by having sextupoles next to each quadrupole in which there is significant dispersion. A configuration with 24 sextupoles per arc was adopted (the sextupole at the quadrupole Q9 in the 3-4, 7-8, 11-12 o'clock insertion is functionally part of the arc). The placement of the sextupoles of one ring relative to their associated quadrupoles is antisymmetric with respect to the crossing point; the sextupole placement in the two rings has mirror symmetry with respect to a radius through the crossing point. A plan view of the sextupole configuration is shown in Fig. 11-10.

All the leads to the sextupoles are available so that any sextupole configuration can be implemented. The simplest sextupole scheme is a two family scheme involving the families S_F and S_D as shown in Fig. 11-10. Figure 11-11 shows the variation of lattice functions for off-momentum particles in an idealized lattice with no magnetic errors. The increases of the β- and X_p-functions affect the linear aperture, and indirectly affect the dynamic aperture. One way to decrease these distortions is to increase the number of sextupole families, especially in the arcs adjacent to experimental (low-beta) interaction points. The day-one nominal configuration invokes two sextupole families and two octupole

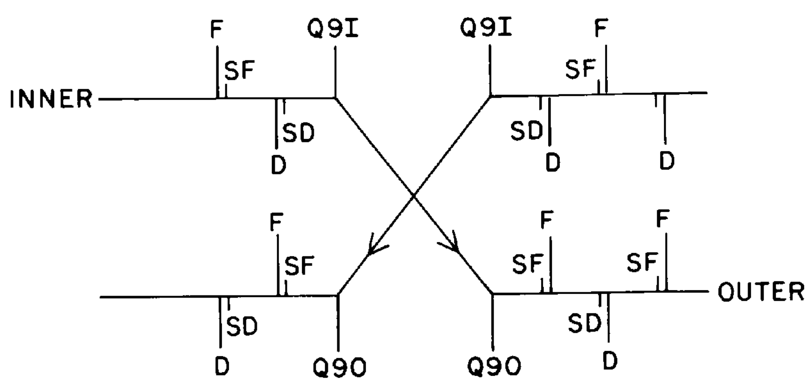

Fig. 11-10. Sextupole arrangement in the inner and outer arcs (shown at 6 o'clock insertion).

families. This will certainly be adequate for $\beta^* = 10$ m operation. Figure 11-12 shows the tune variation with momentum, in the absence of magnetic errors. The linear and quadratic parts of the chromaticities will be corrected by the sextupole and octupole families, respectively.

Chromatic optics distortions and nonlinear chromaticities are much stronger in error free optics when the value of β^* is relatively small, since the main sources are the insertion region quadrupoles. Systematic magnetic errors are also important, for example in the arc dipoles, but the chromatic effects caused by magnetic errors tend to be independent of the optical configuration. Commissioning will decide whether the $\beta^* = 1$ m low-beta optics require activation of more sextupole families per arc, or of the two decapole families that are also available, but which are not nominally activated. The use of additional families of correctors would require additional power supplies but no modification of the electrical bus configuration of the magnets.

The sextupoles required in the lattice to correct the chromaticity introduce intrinsic nonlinear effects by which the betatron tunes will be shifted proportionally to the particle emittances. For the worst case where $\beta^* = 1$ m in two insertions and with the arrangement described above one finds

$$\Delta\nu_H = -(0.38\,\epsilon_H + 1.20\,\epsilon_V) \times 10^{-3}/\pi \text{ mm}\cdot\text{mrad}$$

$$\Delta\nu_V = +(0.13\,\epsilon_V - 1.20\,\epsilon_H) \times 10^{-3}/\pi \text{ mm}\cdot\text{mrad}$$

where ϵ_H and ϵ_V are actual emittance values. The coefficients drop an order of magnitude for $\beta^* = 10$ m. Thus this effect does not seem to be very important.

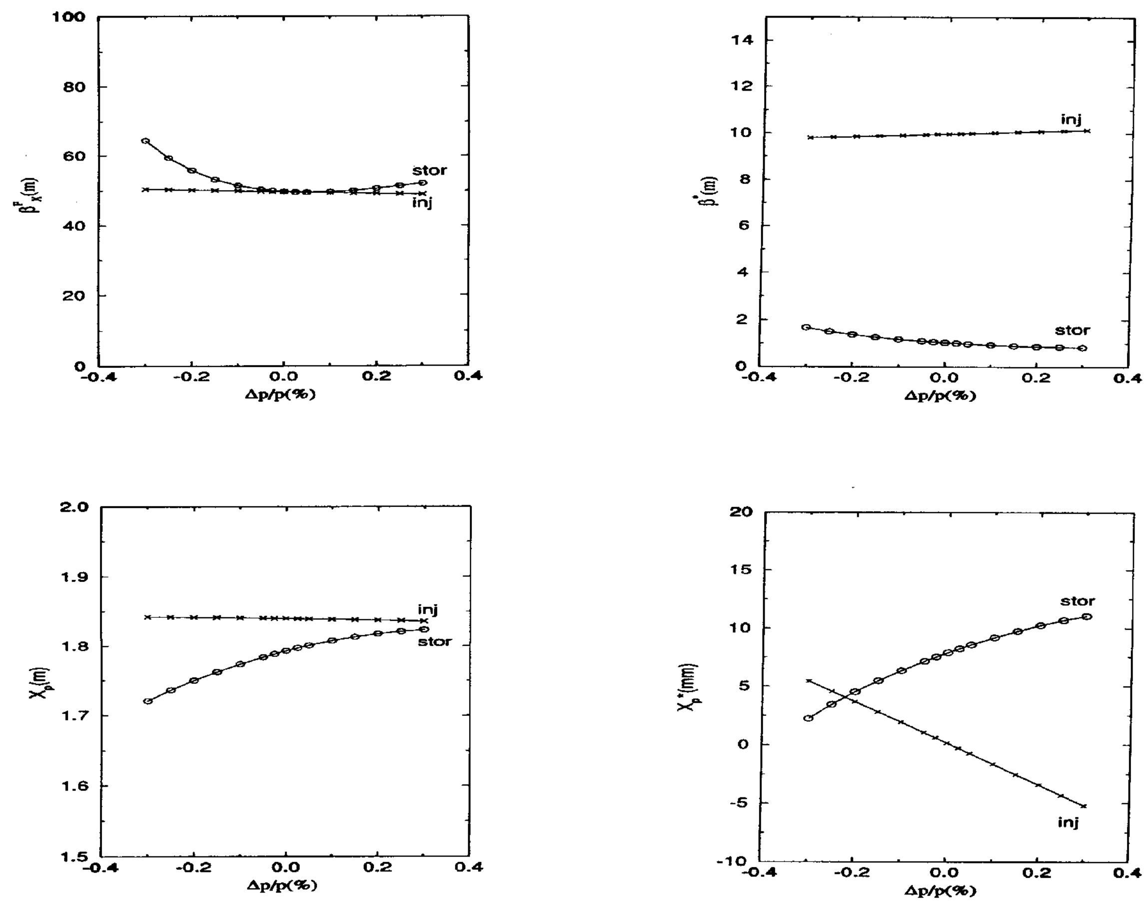

Fig. 11-11. Variation of betatron and dispersion functions versus momentum at the center of inner arcs (left) and at the crossing point (right) at injection (6 × β*=10 m) and storage (2 × β*=1 m & 4 × β*=10 m). The chromaticity is corrected with 2 families of sextupoles.

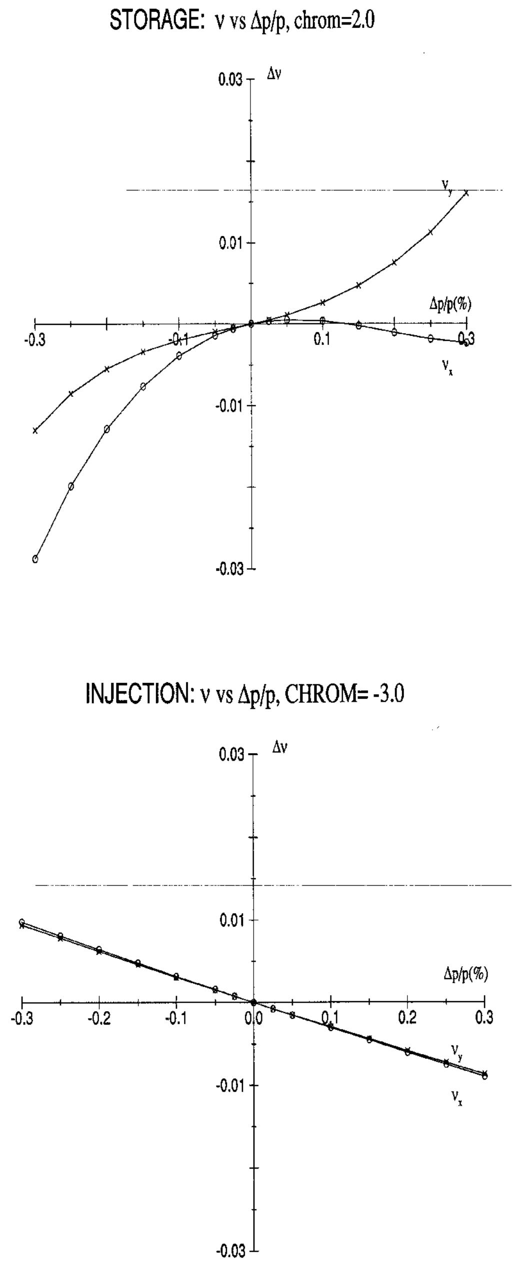

Fig. 11-12. Variation of betatron tunes with momentum at injection ($6 \times \beta^*=10$ m) and storage ($2 \times \beta^*=1$ m & $4 \times \beta^*=10$ m). The chromaticity is corrected with 2 families of sextupoles.