CHROMATIC PROPERTIES OF THE 90° (SEPTEMBER, 1987) SSC LATTICE

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ABSTRACT

The orbit properties of the 90° SSC lattice with optical configurations corresponding to a number of different operational conditions are described. As was previously found for the Conceptual Design Report lattice,[1] the results show that each IR may be tuned independently.

Introduction

The lattice of the SSC[2] is a racetrack design consisting of two arcs connected by two nearly straight clusters, each of which contains four straight sections, see Fig. 1. Two straight sections in each cluster contain vertically crossing interaction regions. The IR's in one cluster are the medium-β regions *M1* and *M2* with ±120 m free space about the interaction points; those in the other cluster are the low-β IR's *L1* and *L2* with ±20 m each. The two straight sections *U* are utility regions providing areas for rf cavities, beam injection and abort, and possible test beam extraction. The two areas labeled *XF* in the other cluster are identical to the *U* straight sections, but are reserved for development as future IR's.

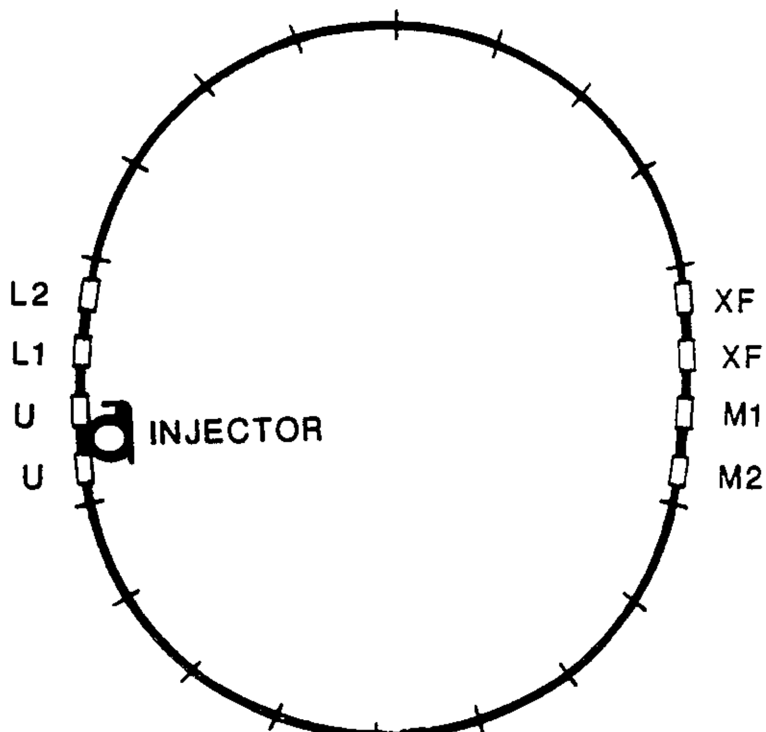

Figure 1 – SSC straight section layout.

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Two principal optical configurations are included in the lattice design, an injection optics in which all of the interaction points have relatively large beta values, and an experimental optics where the betas are much smaller. For each optics, the two medium-β IR's are tuned so as to be identical as are the low-β IR's. The reason that this clustered arrangement works well is that the interaction points of each pair of IR's are designed to be exactly an odd multiple of 90° from each other in betatron phase, which results in a cancellation of chromatic perturbations from the two paired IR's. The question arises as to the feasibility of operating the ring in configurations that partly violate the pairing of the IR's, as it would be highly desirable to be able to choose β^* arbitrarily at each of the four IP's, at any value between the injection and lowest possible collision levels. This report presents the results of a study intended to answer this question.

Description

For this study, the chromatic properties of the lattice were studied for three different tuning conditions. These three optics, defined by the β^* values at the four IP's, are displayed in Table I. Cases 1 and 3 are the collision and injection optics respectively. In both of these optics the low and medium-β IR's are paired. Optics 2 represents a possible experimental configuration in which one of the low-β IR's is tuned to the lowest β^* value, 1/2 m, while the other one is at its highest obtainable value. This will give the maximum amount of pairing mismatch possible.

Table I – Beta function values at IP's for the optics cases studied. L1, L2 are low-beta IP's and M1, M2 are medium-beta IP's.

	L1		L2		M1		M2	
Optics	β_x^*	β_y^*	β_x^*	β_y^*	β_x^*	β_y^*	β_x^*	β_y^*
1	.5	.5	.5	.5	10	10	10	10
2	8	8	.5	.5	10	10	10	10
3	8	8	8	8	60	60	60	60

The calculations were done using the SYNCH program. For each of nine values of the momentum deviation $\Delta p/p$ between ± 0.002, the program calculates the closed orbit, tunes and betatron functions. By way of comparison, the rms momentum spread at injection is $\pm 1.9 \times 10^{-4}$. For each optics, the sextupoles have been adjusted to produce zero chromaticity at $\Delta p/p = 0$.

Tunes

The chromatic behavior of the tunes is displayed in Table II and plotted in Fig. 2. In order of increasing momentum dependence, the ranking of the optics cases is 3, 2, 1;

it appears that larger β^* values at any IP improve the tune behavior, even if the pairing is compromised. This result is not too surprising, since the proper phase relations are maintained, giving partial chromatic cancellation, while the larger β^* values lower the sextupole strengths.

Table II – Momentum dependence of the tunes for the optics cases of Table I. $\Delta p/p$ is in parts per thousand.

$\Delta p/p$	Optics 1		Optics 2		Optics 3	
($^o/_{oo}$)	ν_x–95	ν_y–95	ν_x–95	ν_y–95	ν_x–95	ν_y–95
−2.0	.3076	.2856	.2796	.2624	.2854	.2654
−1.5	.2962	.2750	.2830	.2645	.2854	.2653
−1.0	.2886	.2683	.2846	.2652	.2853	.2652
−0.5	.2855	.2654	.2850	.2650	.2853	.2652
0.0	**.2850**	**.2650**	**.2850**	**.2650**	**.2853**	**.2651**
0.5	.2845	.2644	.2853	.2653	.2853	.2652
1.0	.2812	.2610	.2865	.2667	.2853	.2652
1.5	.2739	.2529	.2895	.2695	.2853	.2652
2.0	.2634	.2390	.2949	.2742	.2853	.2653

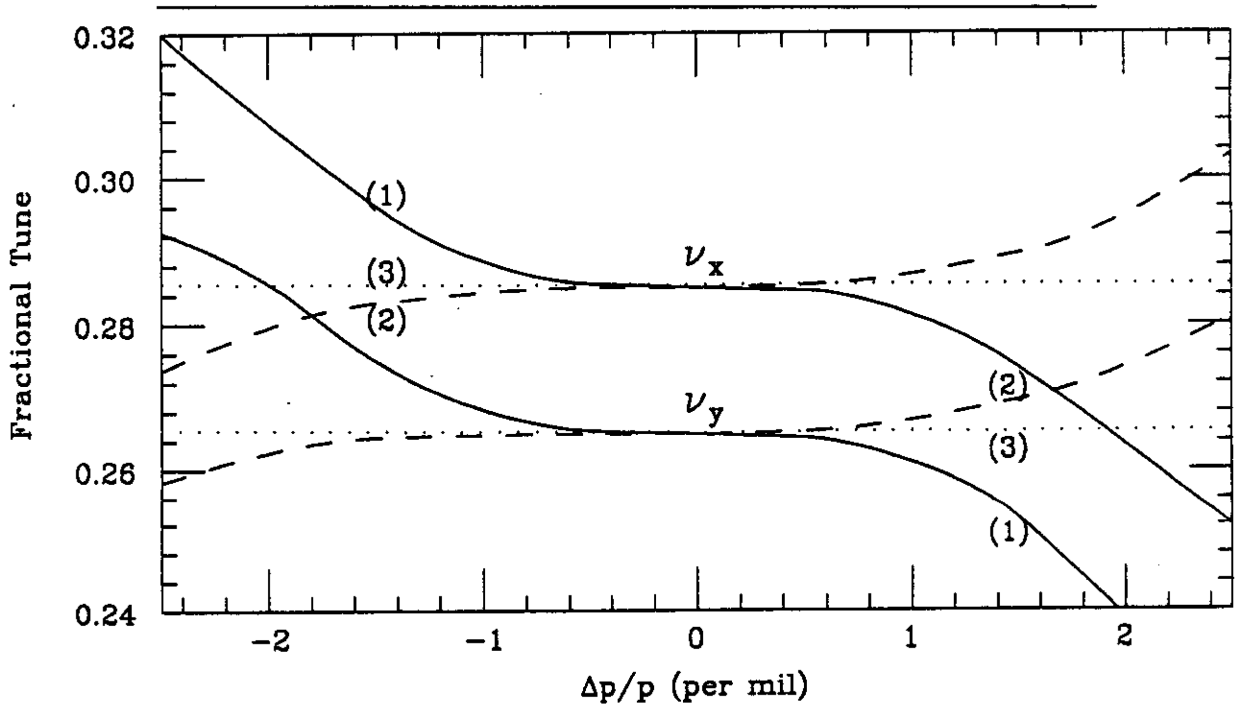

Figure 2 – Momentum dependence of the tunes for the cases of Table I

Beta Functions

The chromatic behavior of the beta functions at the IP's, shown in Table III and in Figs. 3 and 4, is different from that of the tunes. In terms of relative β^* variation, the ranking from best to worst is 3, 1, 2. For the betas, pairing is more important than lower sextupole strength, at least in some cases.

Table III – Momentum dependence of the beta function at the IP's for the optics cases of Table I. $\Delta p/p$ is in parts per thousand, beta in meters.

Optics	$\Delta p/p$ (‰)	L1 β_x^*	L1 β_y^*	L2 β_x^*	L2 β_y^*	M1 β_x^*	M1 β_y^*	M2 β_x^*	M2 β_y^*
	−2	.352	.392	.388	.361	.12.37	9.98	10.03	12.23
	−1	.460	.471	.471	.461	10.28	9.66	9.66	10.27
1	**0**	**.500**	**.500**	**.500**	**.500**	**10.00**	**10.00**	**10.00**	**10.00**
	1	.457	.475	.474	.456	10.47	9.76	9.75	10.45
	2	.369	.396	.400	.356	12.83	9.82	9.77	12.80
	−2	8.37	5.91	.538	.535	6.05	5.70	15.54	16.22
	−1	8.63	7.16	.498	.498	7.67	7.57	12.73	12.85
2	**0**	**8.00**	**8.00**	**.500**	**.500**	**10.00**	**10.00**	**10.00**	**10.00**
	1	6.70	8.19	.543	.535	13.12	12.86	7.67	7.82
	2	5.07	7.70	.640	.607	17.07	15.93	5.83	6.27
	−2	7.63	8.04	8.06	7.64	58.42	58.21	58.19	58.39
	−1	7.82	8.03	8.03	7.83	59.15	59.17	59.16	59.13
3	**0**	**8.00**	**8.00**	**8.00**	**8.00**	**60.00**	**60.00**	**60.00**	**59.98**
	1	8.18	7.96	7.96	8.18	61.07	60.69	60.64	61.01
	2	8.35	7.92	7.92	8.35	62.32	61.27	61.17	62.21

Alpha Function

The α^* momentum dependences are shown in Table IV. All of the IP's are tuned to $\alpha^* = 0$ for the on-momentum particles.

For the other cases, the non-zero α^* values for off-momentum particles show that the waist positions vary with energy. Specifically, the minimum beta value β_0 and the waist displacement Δs are given by:

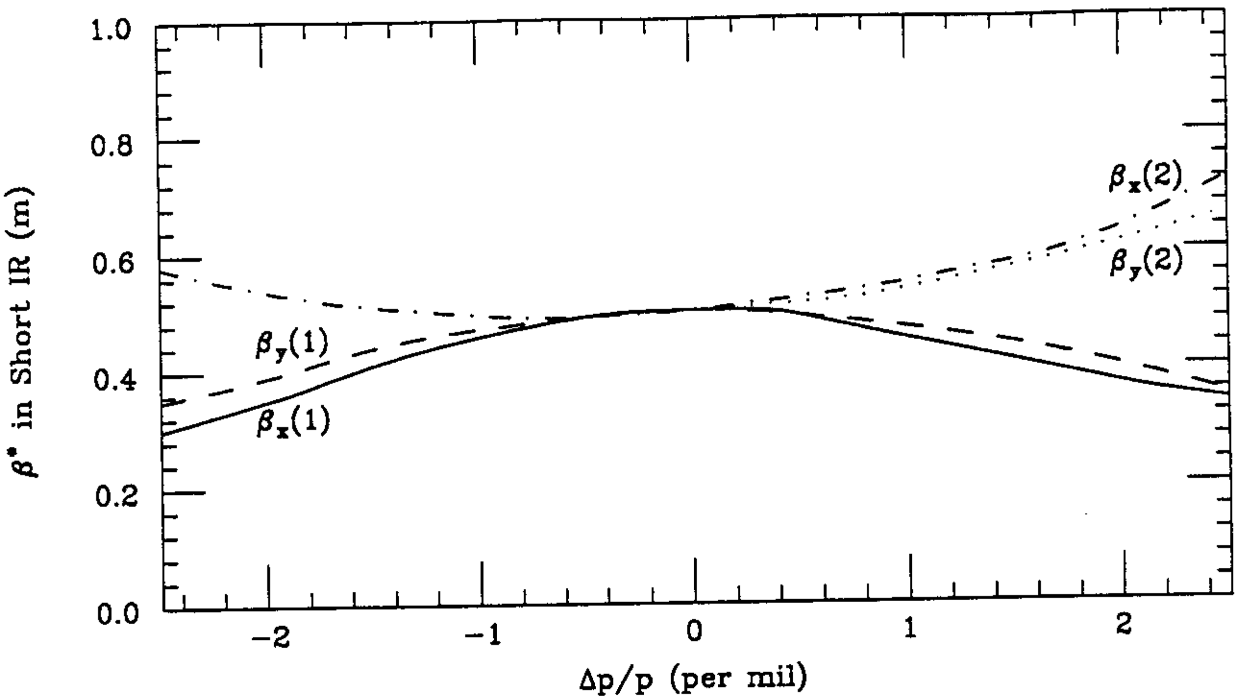

Figure 3a – Momentum dependence of β^* at $L2$ for the optics of Table I

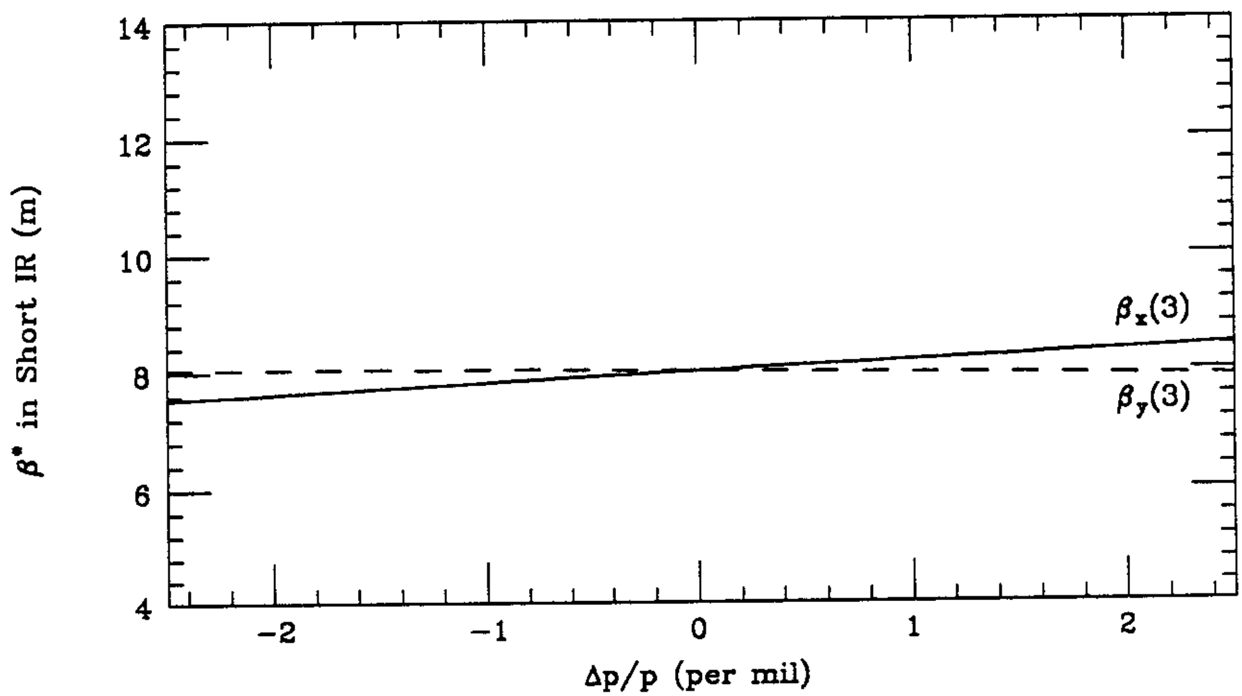

Figure 3b – Momentum dependence of β^* at $L2$ for the optics of Table I

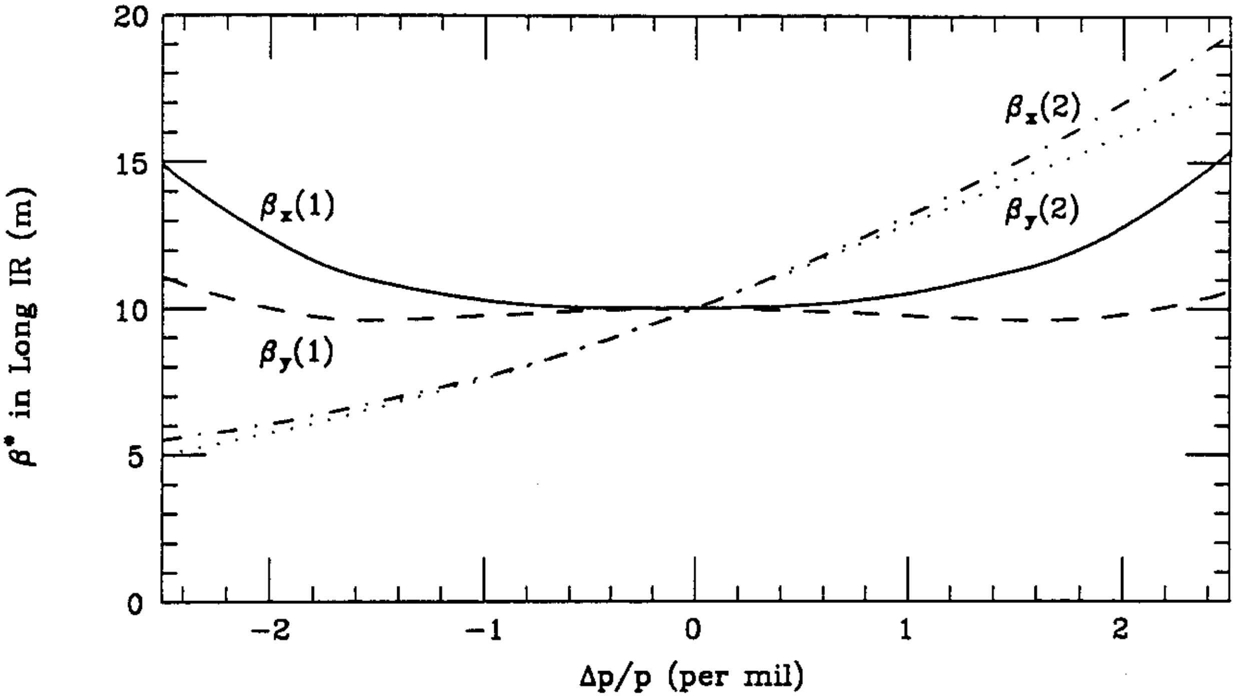

Figure 4a – Momentum dependence of β^* at $M1$ for the optics of Table I

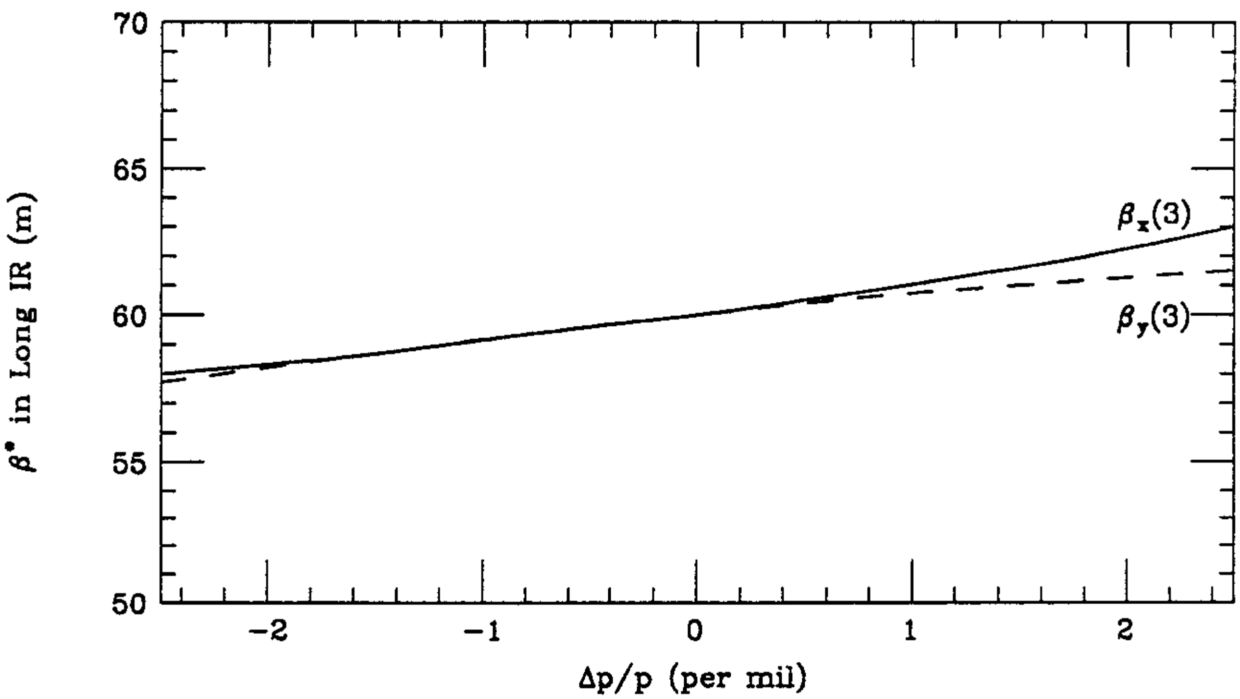

Figure 4b – Momentum dependence of β^* at $M1$ for the optics of Table I

$$\beta_0 = \frac{1}{\gamma_0} = \frac{1}{\gamma^*} = \frac{\beta^*}{1+\alpha^{*2}}$$

$$\Delta s = -\frac{\alpha^*}{\gamma^*} = -\frac{\alpha^*\beta^*}{1+\alpha^{*2}}$$

For example, we find from Tables III and IV for optics 1 at $\Delta p/p = -0.001$, that $\beta_{0x} = 0.44$ m, and$\Delta s = 0.10$ m at *L1* and that $\beta_{0y} = 9.6$ m, and $\Delta s = 0.67$ m at *M1* .

Table IV – Momentum dependence of the alpha function at the IP's for the optics cases of Table I. $\Delta p/p$ is in parts per thousand.

	$\Delta p/p$	L1		L2		M1		M2	
Optics	(‰)	α^*_x	α^*_y	α^*_x	α^*_y	α^*_x	α^*_y	α^*_x	α^*_y
	−2	−.25	−.34	.41	.19	.36	.42	−.44	−.35
	−1	−.22	−.26	.28	.20	.05	.07	−.08	−.05
1	**0**	**.00**	**.00**	**.00**	**.00**	**.00**	**.00**	**.00**	**.00**
	1	.18	.26	−.24	−.19	.22	.20	−.20	−.22
	2	.11	.35	−.28	−.17	.74	.66	−.66	−.74
	−2	−.49	−.31	.02	−.11	.02	−.09	.09	.30
	−1	−.25	−.21	.02	−.04	−.01	−.08	.03	.14
2	**0**	**.00**	**.00**	**.00**	**.00**	**.00**	**.00**	**.00**	**.00**
	1	.19	.27	−.03	.01	.06	.14	.00	−.12
	2	.25	.53	−.06	−.02	.19	.34	.02	−.23
	−2	−.01	.00	.00	.01	−.01	.01	−.01	.01
	−1	.00	.00	.00	.01	.00	.00	.00	.00
3	**0**	**.00**	**.00**	**.00**	**.00**	**.00**	**.00**	**.00**	**.00**
	1	.02	−.01	.01	−.01	.01	−.01	.01	−.01
	2	.03	−.01	.01	−.03	.01	−.02	.02	−.01

Closed Orbit Deviations

The closed orbit displacement momentum dependences are shown in Table V. The small horizontal and vertical displacements represent non-linear dispersion. The vertical values come from the energy dependence of the vertical dispersion-matching system.

Table V – Momentum dependence of the closed orbit displacements at the IP's for the optics cases of Table I. $\Delta p/p$ is in parts per thousand, displacements in μm.

	$\Delta p/p$	L1		L2		M1		M2	
Optics	(‰)	x^*_{co}	y^*_{co}	x^*_{co}	y^*_{co}	x^*_{co}	y^*_{co}	x^*_{co}	y^*_{co}
	−2	.5	.3	−1.7	−.2	−2.8	.3	1.0	.2
	−1	.0	.1	−.3	−.1	−.9	.3	−.4	.2
1	0	.0	.0	.0	.0	.0	.0	.0	.0
	1	−.4	.1	−.1	.0	−.8	.8	−.5	.9
	2	−1.9	.5	−.6	.0	−1.8	4.9	−.2	5.4
	−2	−.6	−2.3	−.7	.8	−1.4	2.9	−3.9	−3.8
	−1	−.4	−.5	−.2	.2	−.5	.9	−.8	−.8
2	0	.0	.0	.0	.0	.0	.0	.0	.0
	1	−1.2	−.2	−.2	.1	−.3	−.1	−.4	−.5
	2	−5.5	.3	−.7	.5	.5	−.5	−1.3	−1.5
	−2	−.3	−1.5	−2.8	2.8	1.9	−2.1	−7.1	−1.7
	−1	−.1	−.5	−.9	.9	.4	−.6	−2.2	−.5
3	0	.0	.0	.0	.0	.0	.0	.0	.0
	1	−.5	−.5	−.8	.8	−.5	−.4	−1.8	−.5
	2	−1.6	−1.7	−2.9	2.7	−2.1	−1.1	−5.7	−1.9

These values should be compared to the beam size at 20 TeV. The beam momentum spread is 0.5×10^{-4} and the beam sigmas for the optics #1 are 4.8 and 21.7 μm for the low-β and medium-β IR's respectively.

Conclusion

Since the momentum dependences of the tunes and orbit functions for various combinations of β^* values are rather moderate, it is predicted that the IR's may be operated independently without undue difficulty.

References

1. A. A. Garren and D. E. Johnson. *Chromatic Properties of the SSC Conceptual Design Report Lattice,* **SSC–N–162** (1986).
2. A. A. Garren and D. E. Johnson, *The* 90° *(September, 1987) SSC Lattice,* **SSC–N–374** (1987).