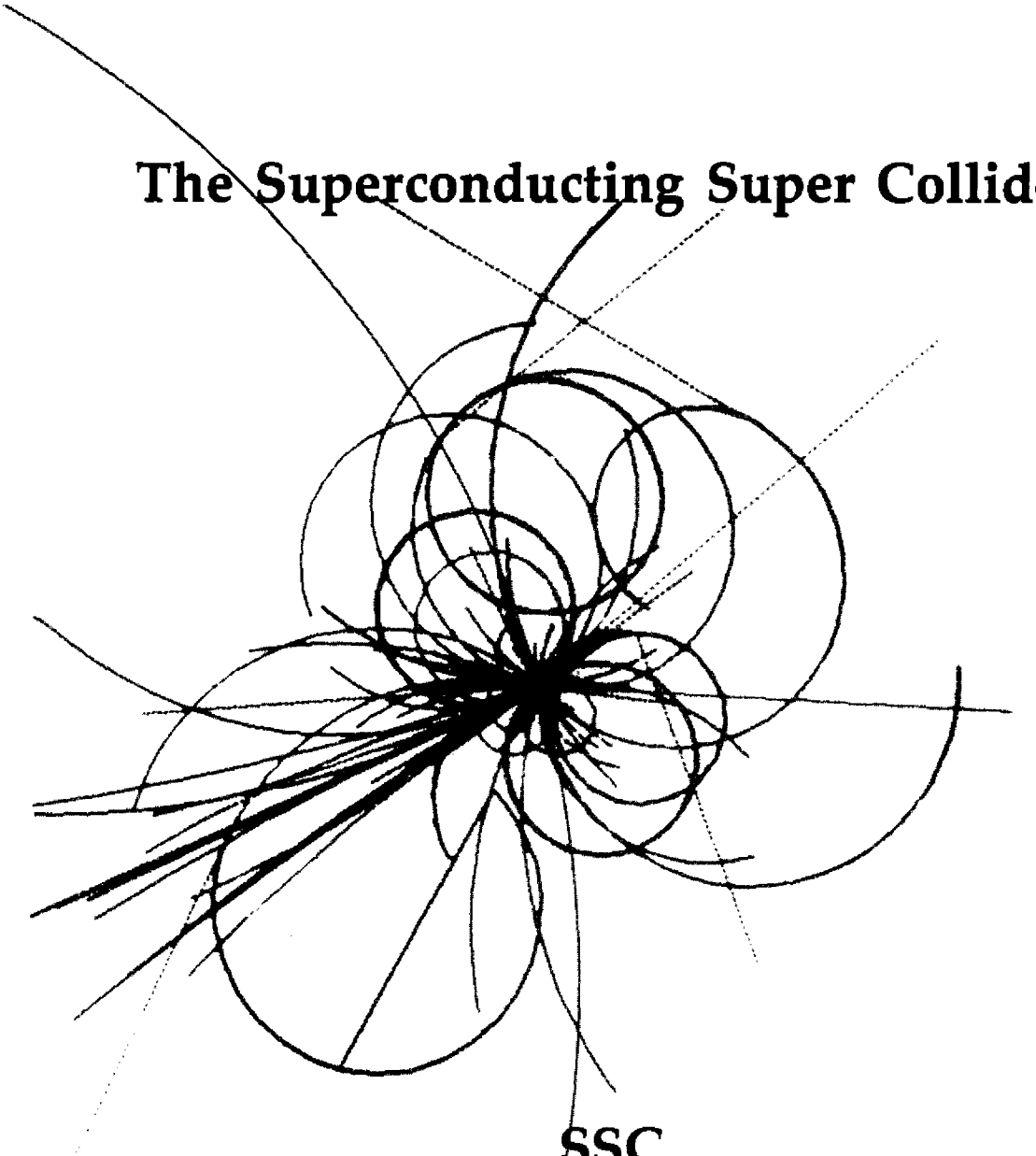
SSC-60

The Superconducting Super Collider



SSC Injection Simulation Results

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SSC INJECTION SIMULATION RESULTS

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ABSTRACT

A computer model of the SSC lattice composed of 60° normal cells, dispersion suppressors and empty FODO cells has been developed in order to study the needed aperture for 1 TeV injection. The model has all elements as thin-lens kicks. Chromatic sextupoles have been included as well as all of the dipole random multipole errors, both normal and skew. Dipole magnets have been shuffled on b_2 in order to reduce the large sextupole errors. A set of slow horizontal and vertical dampers has been included.

Ensembles of 500 randomly generated particles have been injected into this lattice with typical injection errors, and the effective beam size increases after 100 turns have been observed. The lattice modeled in this study, with dipole errors corresponding to a 4 cm winding diameter, has an aperture sufficiently large to accomodate injection errors within the tolerances which have been adopted with an acceptable amount of beam dilution.

The lattice used for this study closely resembles the lattice used for the SSC Conceptual Design Report. It consists of 60° normal cells 196 m long with 10 6.4 T dipoles per cell. The design consists of two arcs of cells which end with standard missing-magnet dispersion suppressors and which are connected by two straight sections made of empty FODO cells which represent the present clustered geometry. The arc cells have two families of sextupoles in order to zero the natural chromaticity. Sextupoles are not placed in the straight-section cells. For this study, dispersion-suppressor cells were included in order to be able to inject particles into a zero-dispersion region and examine the effects of injection momentum errors. The interaction regions and utility sections were not included for simplicity. Previous studies have shown that the additional chromaticity due to these regions can be compensated in the arcs with little damage to the linear aperture[1] . The primary purpose of this study was to examine the effects of the non-linear random dipole errors on the aperture required for realistic injection errors. The main parameters of the lattice are:

$$\nu_x = 75.28 \quad \nu_y = 75.28$$

$$\xi_x = -71.57 \quad \xi_y = -71.55$$

$$\hat{\beta} = 338.1 \text{ m} \quad \check{\beta} = 110.8 \text{ m}$$

For tracking, all of the magnets were represented as thin-lens elements and were treated as appropriate point kicks. The dipoles have been given randomly distributed errors b_1 through b_{10} and a_1 through a_{10} as defined by the Magnetic-Errors Working Group for a magnet winding diameter of 4 cm and a filament size of 9μ[2] . The dipoles have been shuffled on b_2 in lots of 60 to minimize the sextupole effect. In selecting the magnets, it has been assumed that all of the systematic errors have been corrected. In addition any magnets with random errors exceeding 2.5σ have been rejected.

Batches of 500 particles were randomly generated in phase space with a normalized emittance of $\epsilon = 1\pi$ mm-mrad and an rms momentum spread of 1.5×10^{-4} and then injected into the zero-dispersion straight section at a point of maximum normal beta. Realistic injection errors in position and momentum were given to the batch[3] . Each

particle was then tracked through the lattice elements for 100 turns while the maximum orbit distortion and beam dilution due to smearing were watched. Slow horizontal and vertical damping systems capable of giving a $\pm$ 2 μrad kick at $\pm$ 1 cm were applied to the beam at points of normal maximum beta and with a phase advance of 120° between pick-up and kicker. These systems give damping times of some 45 turns. A plot of the horizontal beam centroid for the case of a beam injected with a horizontal error of 1.5 mm is shown in Fig. 1. Fig. 2 shows the horizontal rms beam size as a function of turns for the same case.

The tables below show the percentage increase in rms beam size at the end of 100 turns for various injection conditions. The columns represent horizontal, vertical, and momentum errors, and the batch momentum distribution. The first table is with no momentum spread, the second with momentum spread and the bare lattice chromaticity corrections, and the third with the chromaticity of the bare lattice plus the chromaticity due to non-linear random errors corrected. Case # 14 in Table III represents the vertical position error caused by one of the injection kicker modules misfiring. The vertical beam blow-up is large; however, the beam envelop does not get out far enough to quench magnets and the beam could be safely aborted. Table IV shows the effects of different random number seeds for totally corrected chromaticities. The cancellation of the non-linear chromaticity was very difficult for case # 16 of Table IV and the large percentage increase is more a reflection of the tune spread within the batch than of the dipole errors. Finally, Table V gives an example of tunes vs. momentum and horizontal closed orbit error for the lattice generated by the random seed used in Table III.

#	X_{offset}	Y_{offset}	P_{offset}	σ_δ	$\Delta\ \sigma_x$	$\Delta\ \sigma_y$
1	1.5 mm	0.0 mm	0.0	0.0	1.6 %	0.1 %
2	0.0	1.5	0.0	0.0	< 0.1	< 0.1
3	1.5	1.5	0.0	0.0	1.9	0.5

Table I

Rms beam increase for on-momentum particles

#	X_{offset}	Y_{offset}	P_{offset}	σ_δ	$\Delta\ \sigma_x$	$\Delta\ \sigma_y$
4	0.0 mm	0.0 mm	0.0	1.5×10^{-4}	0.7 %	0.4 %
5	0.0	1.5	0.0	1.5	2.9	0.5
6	1.0	0.0	0.0	1.5	17.0	1.0
7	1.5	0.0	0.0	1.5	45.6	1.9

Table II
Rms beam increase for off-momentum particles
Linear lattice chromaticity correction

#	X_{offset}	Y_{offset}	P_{offset}	σ_δ	$\Delta\ \sigma_x$	$\Delta\ \sigma_y$
8	0.0 mm	0.0 mm	0.0×10^{-4}	3.0×10^{-4}	1.4 %	7.6 %
9	1.5	1.5	0.0	1.5	2.4	7.4
10	1.5	1.5	1.5	1.5	1.7	14.3
11	2.5	0.0	0.0	1.5	2.8	2.4
12	2.5	2.5	0.0	1.5	5.6	17.3
13	0.0	0.0	4.5	1.5	2.1	14.2
14	1.5	6.0	1.5	1.5	8.6	102.3

Table III
Rms beam increase for off-momentum particles
Non-linear lattice chromaticity correction

#	X_{offset}	Y_{offset}	P_{offset}	σ_δ	$\Delta\ \sigma_x$	$\Delta\ \sigma_y$
15	1.5 mm	1.5 mm	1.5×10^{-4}	1.5×10^{-4}	5.6 %	2.8 %
16	1.5	1.5	1.5	1.5	13.9	36.0

Table IV
Rms beam increase for different random seeds

δ \ x	-3.0 mm	-1.5 mm	0.0 mm	1.5 mm	3.0 mm
-0.030 %	.288	.285	.283	.285	.288
-0.015 %	.288	.285	.283	.285	.288
0	.288	.285	.283	.285	.288
0.015 %	.288	.285	.283	.285	.288
0.030 %	.288	.285	.283	.285	.288

$\nu_x(x,\delta)$

δ \ x	-3.0 mm	-1.5 mm	0.0 mm	1.5 mm	3.0 mm
-0.030 %	.260	.260	.260	.278	.288
-0.015 %	.258	.258	.258	.278	.288
0	.255	.258	.258	.268	.275
0.015 %	.256	.257	.256	.254	.252
0.030 %	.256	.255	.255	.255	.248

$\nu_y(x,\delta)$

Table V
Horizontal and vertical tunes as a function
of horizontal injection error and momentum

The author would like to acknowledge several useful discussions with A. Chao and programming assistance from L. Schachinger.

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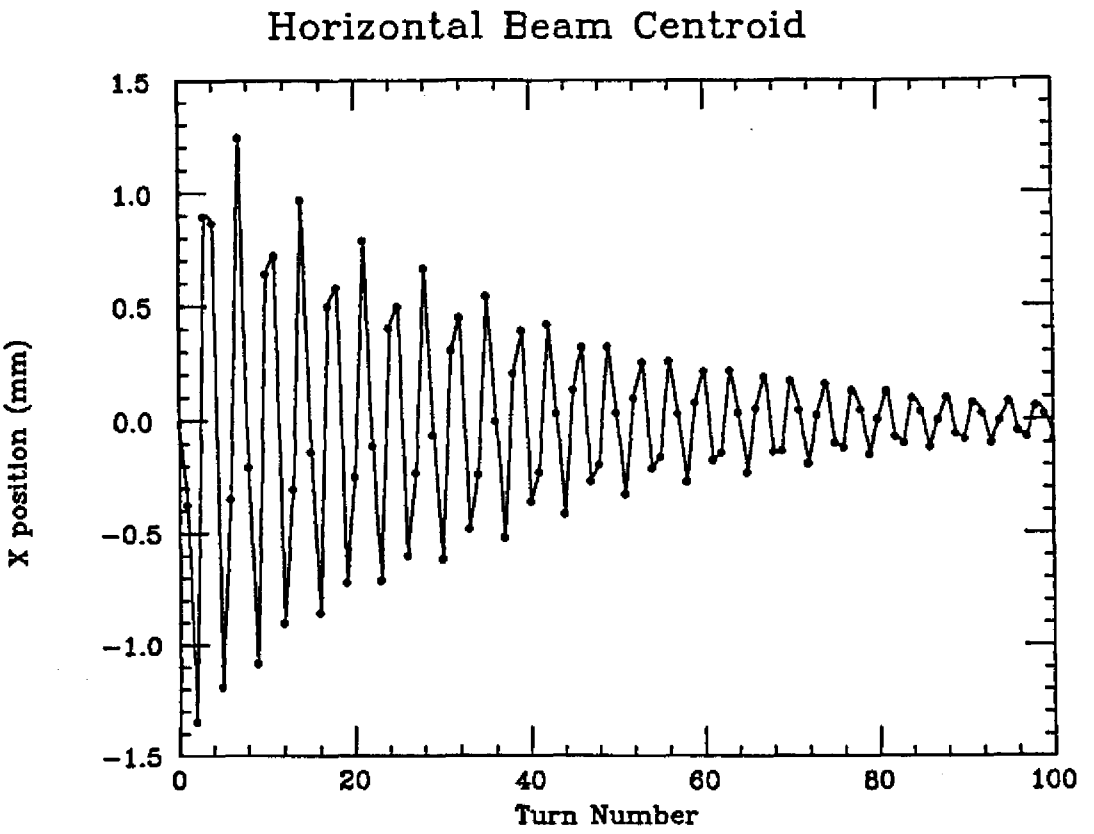

Figure 1

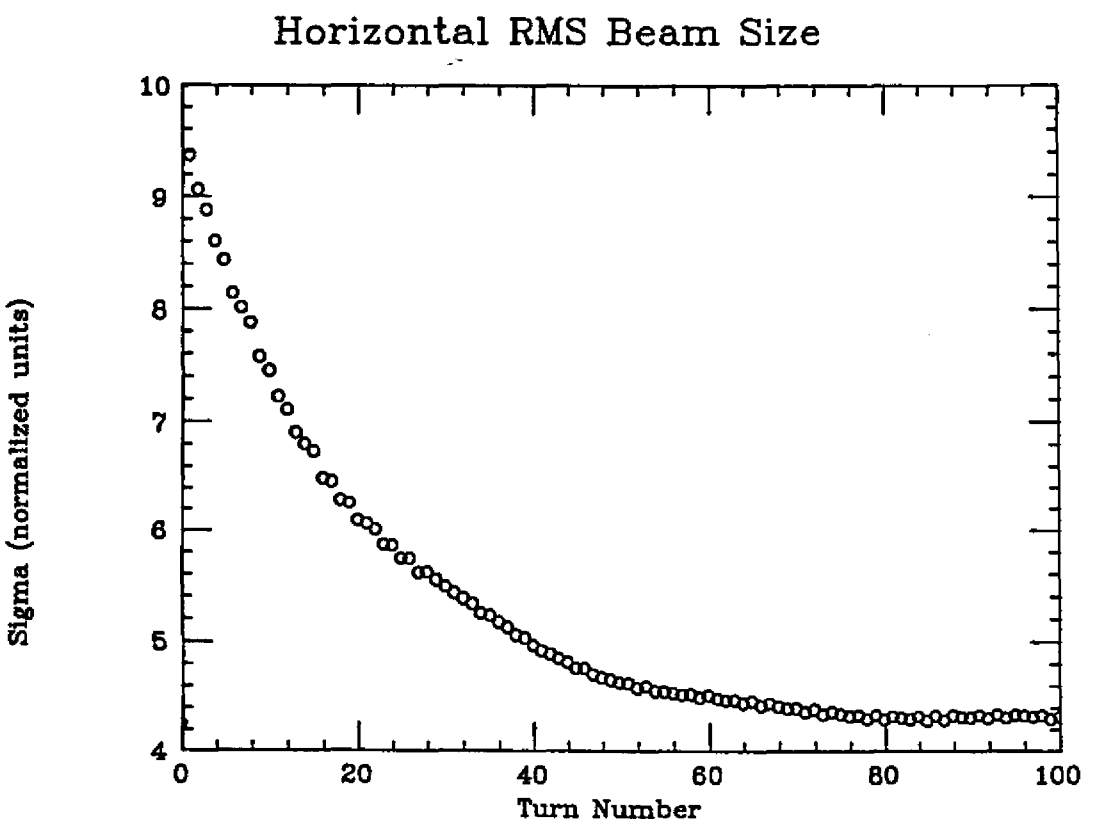

Figure 2