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Proposed Strength Specifications for Magnet Correctors Distributed in the Dipoles

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ABSTRACT

The required strengths of sextupole, octupole, and decapole correction elements are estimated for the SSC, assuming that these correctors are included in every dipole magnet.

Most of the conceptual designs for the SSC specify that some correction elements be included with the main dipoles of the rings. These elements could be bore tube windings, as in the CDR, or they could be short correction packages installed at one end of every magnet. Regardless of the design of the correctors, their integrated strengths are determined on the basis of the expected random and systematic errors in the dipoles. In this paper, we consider the normal sextupole (b_2), octupole (b_3), and decapole (b_4) corrections, and we recommend a set of strength specifications for those multipoles. We assume that these distributed elements are used only for the correction of the three systematic multipole errors, and the random sextupole error of the dipoles. Global adjustments of parameters such as the chromaticity are done by separate correction elements.

The required corrector strength is the linear sum of two contributions, one for compensating the systematic multipole and the other for the random multipole. The systematic multipoles depend on the excitation of the magnet, and are dominated at low energy by persistent currents in the superconductor, at intermediate energy by the coil geometry, and at high energy by geometry and iron saturation. The maximum corrector strength is required at 20 TeV. The present specifications for b_2, b_3 and b_4 due to geometrical effects is 1.0, 0.1 and 0.2 units (10^{-4} of the dipole field at one centimeter radius) respectively.[1] We are suggesting that these specifications be taken to be the multipoles at 20 TeV.

To compensate for the random b_2 multipoles, it is envisioned that the dipoles are "binned" [2] by assigning each to one of n bins, depending on the value of its b_2 error, and by powering the correction elements of every dipole in a given bin with a separate power supply. Previous calculations have shown that binning in seven bins, with the most remote bin having a strength given by 2.04 times the rms width of the distribution is sufficient to reduce the effective variance to 0.2 times the initial width.[3] The rms width of the b_2 distribution of the dipoles is expected to be about two units, so a sextupole corrector strength of 4.1 units will reduce the width of the random b_2 to 0.4 units, an acceptably low level.* #

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* It is conceivable that the need to correct the random b_2s by binning is strongest at injection, but relaxes during ramping from 1 to 20 TeV (because the beam size is smaller and the room needed for the beam operation during ramping is presumably smaller than during injection). If so, the corresponding corrector strengths can conceivably be less than 4.1 units at 20 TeV. However, the 20 TeV optics demands a higher quality because it must assure an extra long beam lifetime in the presence of beam-beam interactions. It is, therefore, suggested here that the binning correction necessary at injection is to be imposed also at 20 TeV.

The correction of random b_2 is such that the b_2 variance is reduced by a factor of five from 2.0 to 0.4 units. Implicit in this is the requirement that the geometric b_2s of all dipoles be measured with an accuracy small compared with 0.4 units.

At present, the only random multipole being planned to be corrected by binning is the sextupole. Hence, we do not include any strength allocation for correcting the random b_3 and b_4. The systematic and random contributions are summarized in the first two rows of the following table, where the results are in "unit-meters."

	b2	b3	b4	
Systematic	1.0	0.1	0.2	
Random	4.1	----	----	
Contingency	3.0	0.1	0.2	
Total (units)	8.1	0.2	0.4	
Total (Tesla-meters)	0.089	0.0022	0.0044	(at 1 cm radius)

The third row of the table gives our feel of how much allowance for uncertainty (contingency) is to be included in the corrector strength specification. The relative uncertainties of inputs that led to the systematic specifications (POISSON calculations, scaling from Tevatron and CBA magnets, etc.), and the sensitivity of the machine to systematic errors lead one to conclude that the contingency on systematic specifications should be large. The contingencies listed are given by the sum of 100 percent of the systematic requirement and, for the case of b_2, 50 percent of the random requirement. By adding the three rows together, the resulting b_2 corrector ought to have a maximum strength of $8.1 \times 10^{-4} \times 6.6T \times 16.6m = 0.089$ T-m at 1 cm radius. Similarly, the b_3 and b_4 correctors are to have 0.0022 T-m and 0.0044 T-m, respectively.+

The writers realize that the recommendation presented here is for a substantially larger sextupole corrector strength than has been contemplated previously. This is due to the additional requirement for binning, which was not included in the CDR or in previous specifications. The assignment of specific contingencies is also new, and our policy in this area may be regarded as liberal. An alternative that could be traded for the increased strength of the correctors would be tightened tolerances on the dipole field quality.

References

1. A. Chao and M. Tigner, SSC-N-183, May, 1986
2. R. Talman, SSC-N-401, October, 1987
3. R. Meller, SSC-N-237, September, 1986

+ For comparison, the HERA sextupole corrector strength is 0.056 T-m at 1 cm radius (0.35 T-m at 2.5 cm). Their correctors are 5.9 m long and there are two per half cell.