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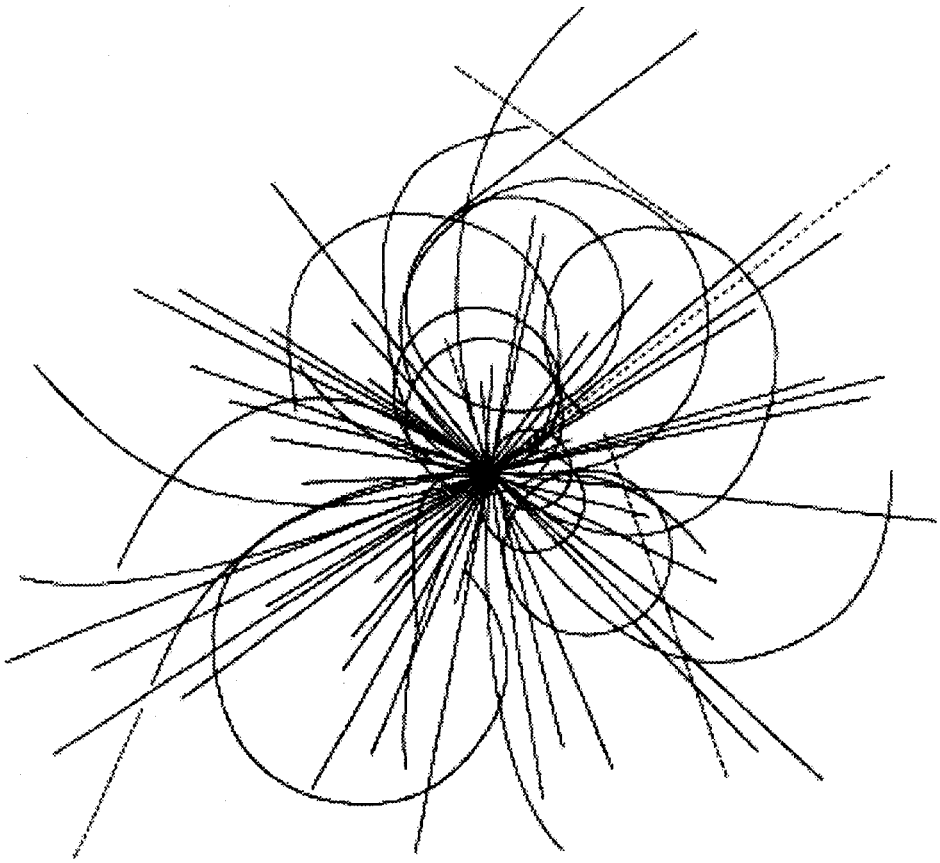

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MAGNETIC DESIGN CONSIDERATIONS FOR THE SSC VERTICAL BENDING (BV1C) MAGNET

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INTRODUCTION

The BV1C magnet is a large aperture, vertical bending magnet to be used to bend proton beams in the interaction region. An aperture larger than 80mm is required. The central field has to be a minimum of 6T with a 10% margin. The lattice requirements for field quality are stringent because two counter beams traverse this magnet off the center axis. This magnet's transfer function sag is specified to match closely the transfer function sag of the low beta quadrupoles. With these specifications in mind, suitable designs for the 2-d magnetic cross-sections have been analyzed.

DESIGN CONSIDERATIONS

A magnetics design study was carried out on hundreds of designs ranging from a 75mm to 100mm aperture dipole magnet two-dimensional cross-section. Both single layer and two layer designs were considered. The design studies yielded input into the possible solutions to beam bending and optics requirements. The design solutions were governed by the harmonic requirements listed in table 1. The resulting conceptual design of the BV1C is an 87mm aperture cross-section which produces 6.4585T at 6714A which is the present baseline high field operating current.

It is useful to review several of the decisions which generated this atypical design. First, this large aperture magnet has an inductance of 167mH for a 16.3 meter magnetic length which represents a large stored energy relative to the collider dipole magnets (CDM). Consequently, this design has potential quench protection issues. Test data from the ASST prototypes suggest that the outer cable for the CDM magnets limited that design from being

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Table 1. DSC magnet field quality tolerance goal

Normal Terms	Field Quality at 20 TeV [at 1.0 cm, x 10-4] (max. values)	Skew Terms	Field Quality at 20 TeV [at 1.0 cm, x 10-4] (max. values)
b1	0.8280	a1	1.3240
b2	0.2112	a2	0.3504
b3	0.1235	a3	0.2477
b4	0.0727	a4	0.0292
b5	0.0102	a5	0.0102
b6	0.0036	a6	0.0036
b7	0.0013	a7	0.0013
b8	0.0005	a8	0.0005
b_n; $(n \geq 9)$	0.0002	a_n; $(n \geq 9)$	0.0002

self-protected. To prevent the requirement of a new cable or even a new strand for the outer cable, the design team elected to use CDM inner cable both in the inner and outer layers of this BV1C design. This allows for a significantly higher MIITS margin during a quench. It does, however, bring into question whether protection heaters should be placed on the inner or outer coil since the design has a very high margin on the outer coil. This issue will be resolved within the framework of the model magnet program.

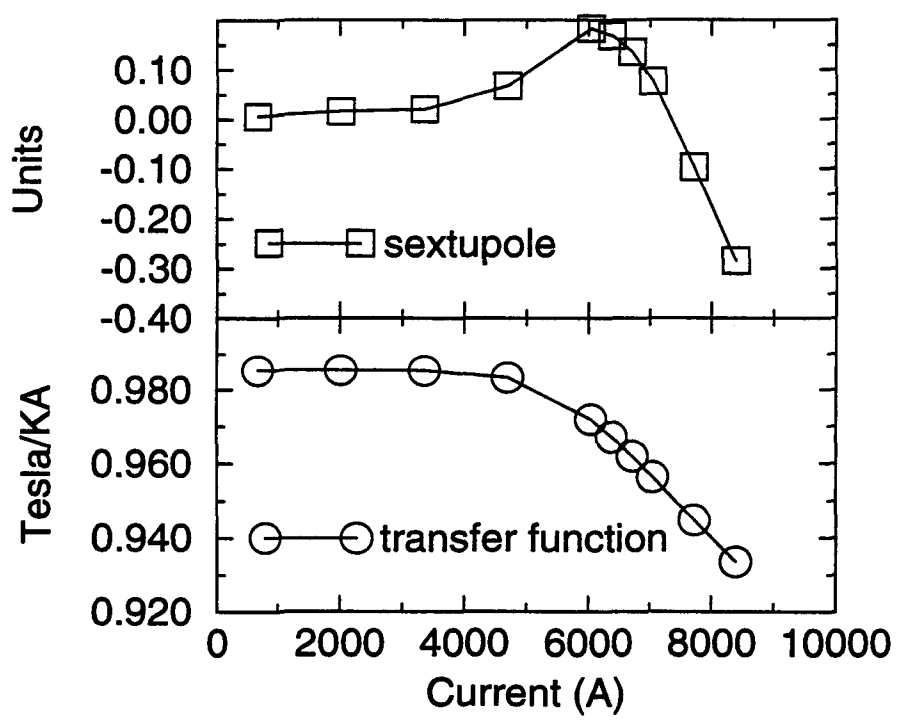

Figure 1. Transfer function and saturable sextupole harmonic.

The second non-standard feature for this design, is that four wedges are used in the cross-section rather than the usual three wedges. This was an added requirement for the sole purpose of increasing the margin of the magnet. Lessons learned from the DSB program suggested that moving Ampere-turns from the pole of the magnet improved the margin of the design. The addition of a wedge near the pole of this design represents a margin increase of approximately 2%. This pole turn wedge did not play a key role in the harmonics optimization. The cross-section is presented in ref 1. The analytic optimization program SSCMAG[2] was used to perform the design study.

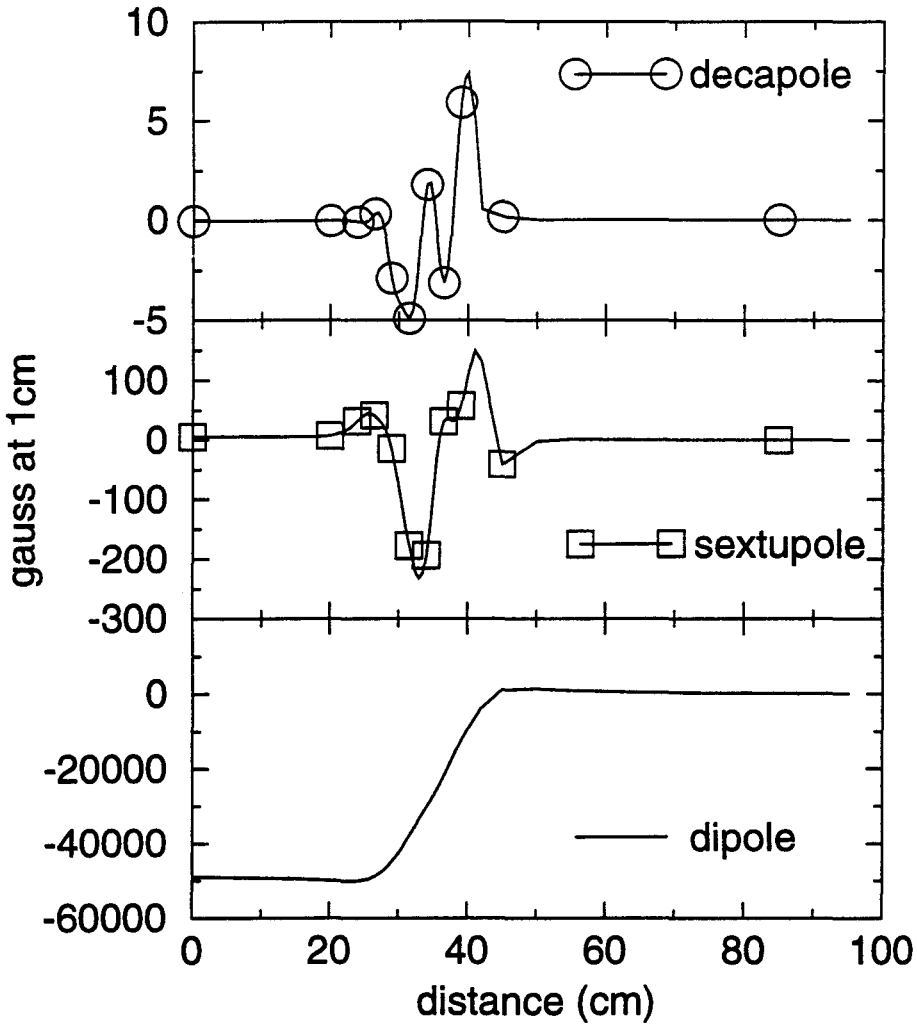

Figure 2. End fields produced by ENDS3D.

The next step in a magnet design is a two dimensional saturable iron finite element calculation. This allows design input into the yoke outer diameter and yoke features. Again, lessons learned from the DSB program are that inner diameter features as well as the standard CDM non-magnetic key play a role in the sextupole saturation profile as a function of current. The stated saturation requirements are to track the CDM within 1.5%. In figure 1, the sextupole and transfer function profiles are presented. Care was taken not to allow the pole alignment key to adversely effect the sextupole performance. When satisfied with the two-dimensional cross-section performance, the next step is to provide a magnetics input into the end-turn design. The design team generated an initial mechanical end part design from the BEND program developed by J. Cook[3]. This program provides input into a pro-

gram called END3D developed by Lilly, Orrell, and Snitchler[4]. This provides an estimate to the dipole field, sextupole, and decapole harmonics from the end design. The lengths of the end parts are adjusted to lower the end harmonics. In figure 2, the field and harmonics are plotted.

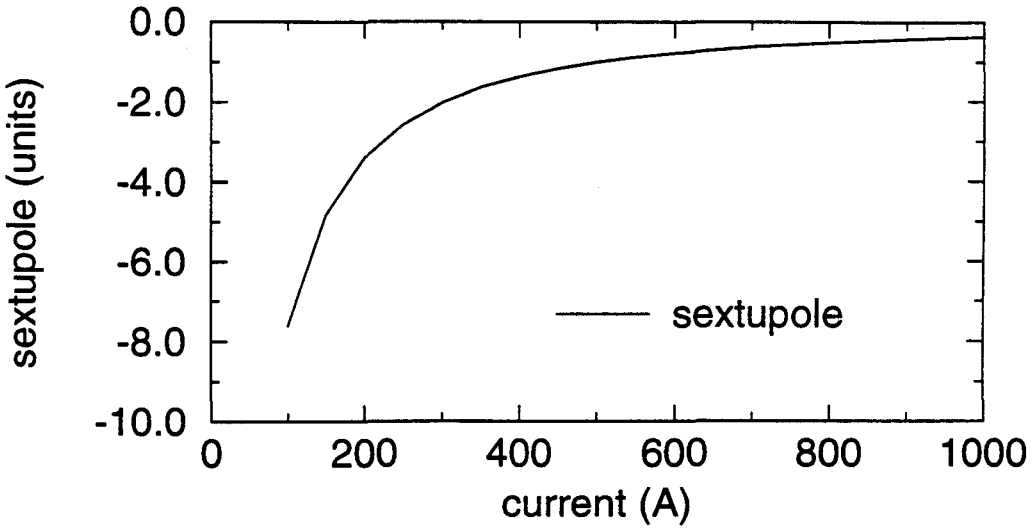

Figure 3. Superconductor magnetization sextupole harmonic.

Other estimates were made to ensure that no major contributor to the field harmonics was ignored. A finite element calculation was performed addressing the collar permeability. Since high-Manganese steel has been selected, there is a very low contribution to the sextupole. No cross-section adjustment was made. Also, the superconductor magnetization sextupole is analyzed using AHARM[2] and are presented in figure 3. The injection sextupole is approximately -.75 units at injection field.

The preliminary BV1C design has been presented. As the detail design progresses, design modifications may be required. A major concern for this design is the amount of pre-stress required to constrain the ampere-turns. Estimates and solutions are presented in ref 1. Special concerns for quench performance remain an open issue. In general, the design parameters meet the requirement guidelines in allowed harmonics, saturable performance, and required field.

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2. B. Archer, D. Orrell, G. Snitchler, "SSCMAG User's Manual," internal MSD document MD-END-92-A-005.(1992)
3. J. Cook, private communication.
4. Lilly, Orrell, and Snitchler, private communication.