SSC Collider Arc Lattice

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Abstract

The new configuration for the SSC collider-ring arcs will be discussed. This design provides magnet-free spaces for future needs by omitting a fraction of the dipoles in the regular cell lattice. Previously, no space was available in either of the two 35 km long arcs for equipment that might be desirable at some future time. The placement of the new straight sections was based on usefulness for future upgrades such as beam scraping, beam polarization, transverse dampers, and correction magnet schemes, as well as on location of service shafts and on perturbations of the ring geometry.

I. DESCRIPTION OF A COLLIDER ARC

The main 20 TeV Collider ring for the SSC Laboratory is composed of a North Arc and a South Arc joined by East and West Cluster Regions. The Cluster Regions each contain a Utility Straight Section (UT) and two Interaction Straight Sections (IR); for the most part, these areas are made up of quadrupoles and are generally free of bending. Each arc contains 392 half cells; in its 1990 configuration[1], each half cell consisted of a quadrupole magnet, a spool piece, and five dipole magnets. Of these, 32 half cells contained 4 standard-length dipole magnets (15.165 m magnetic length) plus one short dipole magnet (12.6375 m magnetic length), while the remaining half cells contained 5 standard length dipole magnets. The space provided by the shorter dipoles is used for cryogenic section isolation, cryogen and power feed, and turn-around locations. This scheme thus results in an extra 2.5 m of straight section at six-cell intervals. In the lower ring, these extra straight sections were located next to horizontally focusing quadrupoles and therefore were next to defocusing quadrupoles in the upper ring. Throughout the entire 35 km of each arc, there was no free space to put in any future equipment, should that ever be desirable, nor was there any place where the beam pipe could be directly accessed.

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II. POSSIBLE USES FOR SPACE IN THE ARCS

As the design of the Collider matured and implications of the baseline design were studied, it became apparent that free space in the arcs of the Collider was desirable. This was viewed as a relatively small perturbation in the overall design of the accelerator; the philosophy of the modular lattice design would be retained – arc modules, IR modules, UT modules, with dispersion-matched bending regions in between. It was felt that free space in the 35 km arcs would greatly enhance the potential uses of the Collider as well as be contingency for meeting design requirements by providing space for equipment which could be added at a later time.

Examples for possible uses of free space in the arcs include room for beam scrapers to handle beam halo and emittance control. The present design calls for a few such devices located in the Utility Straight Sections, but one might envision the need to have a more global system, especially if the beam current were increased in the future. Room for these devices in the arc might also be desirable for scraping particles at regions of non-zero dispersion (the present design has zero dispersion nearly everywhere outside of the arcs). Other possible future uses for space in the arcs might include beam damping systems for handling beam instabilities, beam emittance cooling systems for maintaining or reducing the emittance of stored beams, and other special beam diagnostic equipment. Another feature which the overall SSC design has tried to maintain is the ability of the Collider to support polarized beams. Each of the booster accelerators as well as their interconnecting beamlines provide sufficient free space for insertion of devices which would permit them to transport and accelerate polarized beams. Once in the Collider, however, "Siberian snakes" must be provided in the arcs to maintain polarization. It has been estimated that a number of such devices, each roughly 10 meters long, are necessary in each arc[2]. Though it is hoped that none of the devices mentioned above will be required to meet the baseline design, it is hard to tell what devices might be needed in the event that certain baseline parameters are not met, or if one wishes to maintain upgrade potential.

It should be noted that the Fermilab Tevatron (and Main Ring) has 12 m of "free space" in each of its six arc sectors; each of these straight sections now contains equipment vital to the operation of the accelerators.

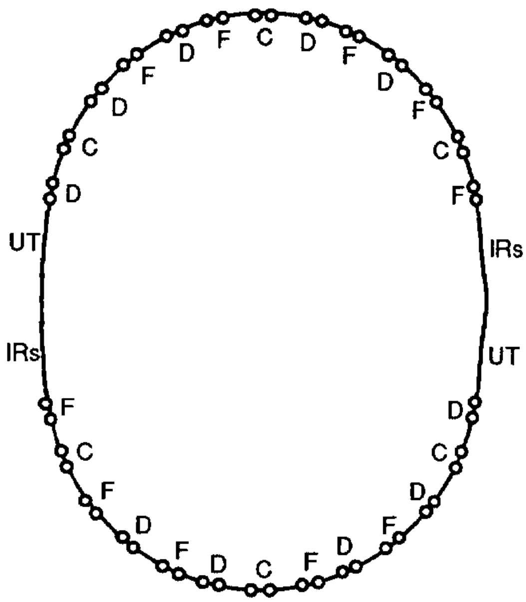

Figure 1. Sketch showing the approximate layout of the 15 m free spaces in the arcs of the Collider; the polarities shown are of the nearest quad in the upper ring.

III. DEVELOPMENT AND DESCRIPTION OF THE NEW DESIGN

For straight sections to be introduced into the Collider arcs, care had to be taken to place them at locations favorable for a variety of possible future applications. In addition, attempts were made to allow for placing utility shafts on the properties being offered by the state of Texas, a feature that the 1990 lattice could not accommodate without extra tunneling costs.

Over 30 different lattices were examined between February 1991 and August 1991. The new adopted design, referred to internally as SSC10F, is one in which dipoles are removed from the lattice in a pattern such that a pair of "holes" have 180° phase difference for dispersion matching, with some of these pairs displaced 90° in phase from other such pairs. The pairs come in three types: ones next to focusing quadrupoles("F"), ones next to defocusing quadrupoles("D"), and ones at mid-half cell locations("C"). The distribution of pairs is nearly uniform, so that the bend center of an arc sector was left nearly unchanged, thus keeping the geometrical layout of the Collider close to that of the original design. A sketch showing the approximate layout of the 15 m free spaces is found in Figure 1.

The introduction of pairs of "missing bends," 180° apart in betatron phase, generates local perturbations of the dispersion function. The maximum perturbation is roughly 0.45 m when the pairs are next to focusing quadrupoles, and only 0.07 m when next to defocusing quadrupoles.

In the new design, the total number of 2.5 m spaces and 15 m spaces is greater than the total number of 2.5 m spaces found in the 1990 design. The extra spaces are put in for two reasons. Firstly, they ensure that the largest distance between cryo-isolation points is six cells, the standard distance found in the baseline design. Secondly, the larger number of isolation points allows the design to conform more easily to the land acquisition strategy of the laboratory and the state of Texas; the positioning of the smaller and larger free spaces permitted choices of where to construct shafts to bring utilities into the Collider. In this way, the lattice contains either a 15 m space or a 2.5 m space, necessary for feed or turn-around spool pieces, within the boundaries of each service area site offered by the state of Texas.

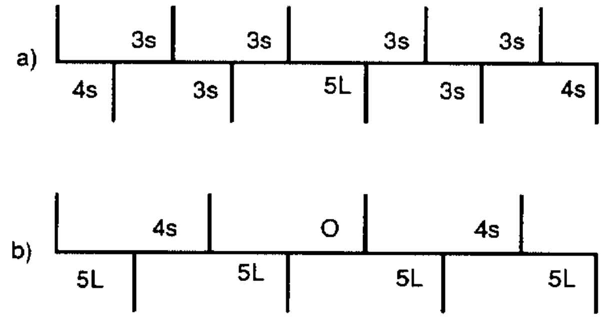

Figure 2. (a) 1990 design of bending region between two IRs within a cluster. (b) New design of this region, generating a high dispersion point in the middle half cell. The number of 13 m (s) and 15 m (L) dipole magnets in each half cell are indicated.

Changes to the horizontal bending were also made in the cluster region. The configuration of bending magnets between the Interaction Regions (IRs) and Utility Region (UT) has been slightly altered from the 1990 design in order to reduce the maximum geometric excursions from the original footprint. The new configuration keeps the ratio of bending in the arc to bending in the cluster roughly the same as in the baseline design.

In addition, the bending region between the two IRs within a cluster has also been reconfigured. Originally, this region contained mostly short dipoles with bending in every one of the seven half cells. The new design calls for mostly long dipoles, with the middle half cell free of bending. This provides a straight section where the dispersion function will be larger than that found in the arcs (2.85 m as opposed to 1.85 m). This region can be useful for diagnostics, and may be suited for scraping off-energy beam particles. The total integrated length of bending in this region is the same as in the 1990 design, and the change to the quadrupole count is minimal. A comparison of this region redesigned region with the 1990 design is shown in Figure 2.

Table 1 shows some of the relevant parameter changes introduced by the new design, which was officially adopted

Table 1. Changes of Relevant Parameters for One Ring

	Baseline	New Lattice
15m free spaces (arc)	0	26
2.5m free spaces (arc)	34	26
15m spaces (cluster)	0	2
2.5m spaces (cluster)	2	0
Long Dipoles (15m)	3978	3972
Short Dipoles (13m)	252	196
Stand. Quads	832	848
Disp. Suppr. Quads	60	40
Bend Field Increase	0	1.27%
Max. Dispersion in arc		
Top ring	1.87 m	2.26 m
Bottom ring	1.81 m	2.26 m
Max. Dispersion in ring		
Top ring	1.87 m	2.85 m
Bottom ring	1.81 m	2.85 m

in March, 1992. The required bend field is raised by 1.27%, assuming the same magnetic length for the dipole magnets.

IV. DESIGN IMPLICATIONS

The new lattice slightly alters the bend center of each half sector, thereby changing the geometry of the Collider rings. One of the constraints in the exercise was that the west utility straight section, where the High Energy Booster connects to the Collider accelerators, be held fixed to its location and orientation as of April 29, 1991. The original "footprint," used for land acquisition, was based on the 1989 lattice and featured a 1000 ft band with the ring center line located 250 ft from the inside of the band, and 750 ft from the outside of the band. The ring design could move radially by as much as ±65 ft and still satisfy shielding requirements. The new design satisfies this criterion. Muon vectors associated with a point loss around the ring, scraping in the utility straight sections as well as in the new straight sections near the ends of the arcs, IP interactions, and beam backstops, all fell within existing site boundary definitions.

The free space generated by the removal of a dipole in the arc could be filled by either an empty magnet cryostat or a warm beam pipe with a cryogenic bypass section. While it is assumed that a cryogenic bypass element could be designed to fit within the existing tunnel tolerances, the plan is to use empty cryostats in the new 15 m spaces. Warm bypasses would only be developed if and when future uses of the 15 m spaces dictate such action.

With the new arrangement of short dipoles and long free spaces, the cryogenic loops encountered within an arc are of the same order in length as those found in the original arc design.

The power supply system is the one most affected by the relocation of shafts. In the new design, some power loops between shafts are longer and others shorter than in the original 1990 design[1]. The furthest departure from the baseline occurs in the South Arc, where one shaft is 3 cells from its original location. The resulting inductive imbalance in the two legs of the power circuit raised the maximum voltage-to-ground difference to an uncomfortable level (larger than 1 kV). However, a decision was independently made to increase the number of energy dump switches in the power circuit by a factor of two, decreasing the maximum voltage-to-ground by the same factor. This makes the voltage level tolerable, even with the new lattice.

V. CONCLUDING REMARKS

The lattice design presented here was developed in 1991 in order to settle definitively the geometry of the Collider rings so as to permit land acquisition and the beginning of civil construction of the Collider tunnel. With the exception of a minor modification in the cluster regions, quadrupole magnet locations did not change with respect to the 1990 lattice; only the numbers and placement of dipole magnets were adjusted.

Already a use has been found for part of the new free space generated in the arcs[3]. By placing skew quadrupole correctors in these locations, stronger correctors could be used, and the need for skew quadrupoles in the middle of half cells, supported on the ends of a 15 m dipole magnet, has been obviated.

It should be pointed out that designs of the cluster regions continue to be studied[4, 5]. Possible future modifications to these regions affect only the numbers and positioning of quadrupoles, and perhaps vertical bending magnets, in or near the interaction regions. The horizontal geometry of the Collider arcs would not be affected.

VI. ACKNOWLEDGMENTS

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VII. REFERENCES

[1] *Site-Specific Conceptual Design Report of the Superconducting Super Collider*, SSCL, ed. J. R. Sanford, SSCL-SR-1056, July, 1990.

[2] E. Courant, internal SSCL memo dated January 17, 1991.

[3] Y. Cai, et al., "Decoupling Correction for the SSC Collider," these proceedings.

[4] Y. Nosochkov, et al., "Current design of the Interaction Regions at the SSC," these proceedings.

[5] B. Parker, "Design Status Report on the Collider Utility Straight Insertions," these proceedings.