A POSSIBLE BEAM BYPASS FOR THE SSC CLUSTERED IR REGION

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Summary

The possibility of installing a beam bypass around one or more of the experimental areas described in the CDR lattice[1] has been examined and is described below. The purpose of this investigation was to determine the feasibility of such a beam bypass and to evaluate its impact upon the civil construction and incremental costs of the SSC. For this purpose, the experimental optics of the clustered IR's described in the CDR were left unchanged and labeled the "normal" line. Two additional bypass lines are described, containing either two or four straight sections between groups of horizontal dipoles. Detailed experimental optics for these potential IR's were not included in this study.

Introduction

The SSC lattice described in the CDR consists of two arcs made up of fully-packed normal cells and two clustered regions each of which consists of experimental IR's, utility IR's and dispersion-suppressing cells. It has been suggested that it would be useful to be able to bypass a few of the IR's in one of the clusters, or possibly bypass one entire clustered region. In this way, it would be possible, for example, to gain access to one or more of the experimental IR's for detector installation or repair or for civil construction while continuing to operate the accelerator for either beam studies or for the experimental program in the other IR's. In addition, it might be possible to simplify the civil construction of the experimental areas by minimizing the size of the detector assembly areas. Ideally, one might wish to individually bypass each separate IR, if such bypasses were economically feasible. The question to be answered here is what can be done without totally redesigning the SSC.

The main problem with building a beam bypass around a particular area is one of space in the lattice. The SSC lattice has been reduced in circumference to very nearly the minimum possible. Both the arcs and the clustered regions are as closely-packed with magnets as they can be and no unnecessary empty spaces have been allowed except for the IR's. In addition, the dipole magnets are bending the normal beam as hard as they can. In order to have a bypass, somewhere in the lattice there must be two possible beam paths, one which bends very hard and so curves toward the inside, and one which bends less hard and thus splits away from the first. This means that the two possible beams must go through a string of dipole magnets some of which are not on in the case of the outer beam. In the CDR SSC lattice, this is impossible as all of the dipoles are needed and no empty free space exists into which splitting dipoles could be inserted. If a bypass is to be considered without removing magnets, either additional space must be provided in the arc sections or in the clustered regions, or splitting dipoles must be put into some of the IR regions. The most economical of the above choices is to make space available in the arcs by increasing their length with some partially empty cells.

A second problem with making a beam bypass is to be able to split the beams apart in a manner that does not require impossible magnets. The first part of a beam splitter has both potential beams going through common magnets. In this section, the required aperture must not be impossibly big. The next part of the splitter is some length of drift space which allows the beams to separate enough so as to be able to go into separate (or 2-in-1) magnets. This drift must be short enough so as not to create optical problems. The two beams then reach totally separated channels and produce the bypasses. In order for the bypass to be of any interest, the beam-beam separation around the IR's should be sufficient to allow access to one line while permitting beam in the other line. This sets both the amount of differential bending and the length of the splitting section.

A solution to the above problems which does not involve moving magnets is to add to the end of each arc six normal cells which are each half filled with dipoles. This can be done without disturbing the optical properties of the lattice and will allow space for putting in the special splitting dipoles. These 6 cells can then be followed with the standard cluster region as described in the CDR and can be thought of as the "normal" CDR lattice modified so as to permit a bypass. By adding additional Lambertson and regular dipoles, which would be turned off in the "normal" case, a bypassed beam can be split to the inside of the normal machine. A layout of such a bypass is shown in Fig. 1. Note that the naming of the normal beam does not depend upon whether it is on the inside or the outside. This arrangement of splitting cells can produce a suitable beam-beam separation at the IR's if the entire cluster is bypassed. A total of 12 cells are used to separate the two beams and recombine them. This is sufficient because of the long lever-arm of the cluster. Attempting to bypass a single experimental region would require that at least 12 half-empty cells be added to the cluster on each side of the IR (lengthening the other cluster as well) and has not been seriously studied.

Beam Splitter

The beam splitting section considered in this paper consists of six normal cells with every other half cell free of dipoles in the case of the "normal" beam. This will not effect the betatron functions of the machine, nor, since since the total phase advance of the section is 360° will it change the dispersion function. Thus these sections are modules which may simply be inserted into the CDR lattice at will. In order to bypass one clustered region and to close the machine geometrically, four such sections have been inserted into the lattice between each end of an arc and the beginning of the dispersion-suppressors for the cluster. In order to have the proper amount of total bend in the machine, six

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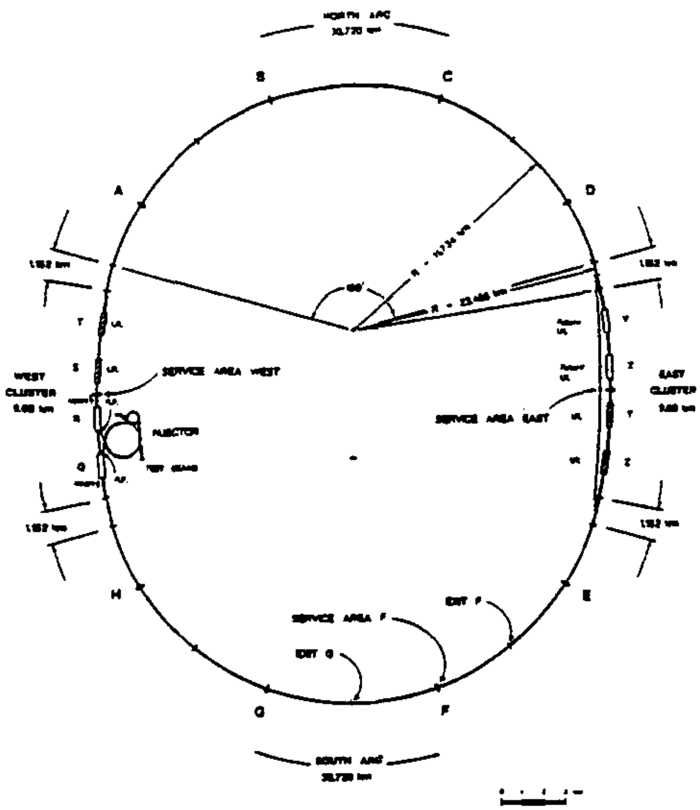

Figure 1. SSC site layout showing a bypass of the East experimental cluster.

cells in each arc have been removed, so that the total increase in the circumference of the "normal" machine is 12 cells. Since the dipoles have simply been shifted from one location to another, the only additional magnets are the 12 cells worth of quadrupoles.

Having put empty spaces into the normal machine, there are now positions in which to insert additional dipoles to do the beam switching. Three 16.6 m Lambertson dipoles running at 5.2 T followed by two missing dipoles put into an empty half-cell will produce a beam-beam separation of $\approx$ 25 cm at the normal lattice position of the next quadrupole — enough to allow two separate magnets in a single cryostat to be at that location. This half-cell can then be followed by half cells filled with dipoles to produce the desired total separation. A drawing of the first part of this splitter with beam-beam separations is shown in Fig. 2 and the entire six cell structure is shown in Fig. 3. Some dipoles have still been left out of the "bypassed" beam line in order to not introduce a mismatch into the dispersion function. At the end of the splitter section the total separation is $\approx$ 12 m. The optics at the end of the section are the same as those of the normal line and can easily match into desired bypass optics.

Bypass Designs

Having introduced the beam splitting sections into the basic lattice, it is now quite easy to design generic bypass lines around one entire clustered region. Two possible designs are listed which can serve as a basis for cost analysis and impact on the SSC civil and technical construction. Other designs are possible, but will not differ greatly on the overall increase to the CDR. The first case considered was to essentially replicate the CDR cluster optics in the bypass line – that is, to have two legs each containing four sections free of horizontal bends. In this example, the bypass leg will have four potential crossings each with a total free-space of $\approx$ 1150 m and will be separated by $\approx$ 95 μrad. For this example, the separation between the two legs of the cluster is roughly 50 m.

Another possibility for a bypass would be to combine the present four straight-sections into some fewer number of straights with more free space. In order to match the CDR lattice, there must be an even number of beam crossings within a cluster, so the most natural option would be to have two, long dipole-free sections. A design with two $\approx$ 2400 m sections has been examined where the crossing points are separated by 106 μrad of bend and $\approx$ 3650 m of distance. In this case, the two legs of the bypass are some 170 m apart. Such an option would allow for the installation of a very forward spectrometer, as has been proposed.[2]

In terms of components and civil construction, the two examples listed above are nearly the same. Adding the half empty cells in order to permit the beam splitting sections increases the CDR circumference of 82944 m by 2304 m and the magnet total for both rings of 9200 by 48 quadrupoles. The four-crossing bypass then additionally increases the circumference by 11898 m for a total of a 17% increase over the CDR. It also requires another 628 dipoles and 140 quadrupoles leading to a total magnet increase of 9%.

Conclusions

A bypass of an entire experimental cluster of the SSC CDR is technically feasible and can be accomplished with few optical changes to the present lattice design. In order to provide for the future addition of a bypass line, without the necessity of magnet removal, the overall machine circumference would need to be increased by less than 3%. This would allow considerable flexibility for future experiments without a substantial increase in the present SSC design. An actual bypass, on the other hand, would have a very significant cost associated with it. This additional cost may be offset by (a) the ability to run the machine in one leg of the bypass while constructing experimental areas or detectors in the other leg, (b) the ability to construct new, very long experimental areas which may be of interest several years after the commissioning of the SSC, and (c) some savings in the experimental hall/assembly area civil construction.

References

1. *Superconducting Super Collider Conceptual Design*, SSC–SR–2020 (1986)

2. J. D. Bjorken, *Forward Spectrometers at the SSC*, Fermilab–Conf–86/22, (1986).

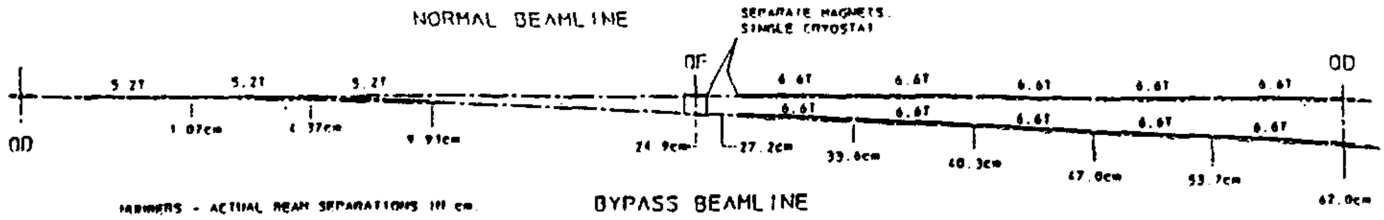

Figure 2. Layout of the second cell of the bypass splitting section showing the beam separation. The vertical scale is blown up by a factor of ten.

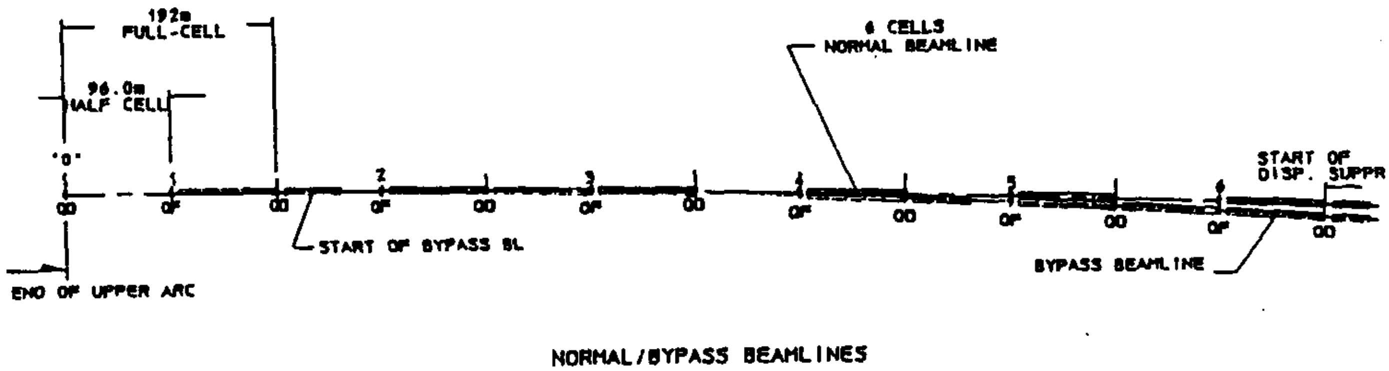

Figure 3. The full six cells of the bypass splitting section.