A Design for a 2 km Experimental Straight Section for the SSC

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Summary

The design of an experimental insertion for the SSC suitable for a very forward spectrometer is presented. This design has a usable space of ±1000 m around the interaction point and can achieve a luminosity of approximately 10^{30} cm^{-2} s^{-1}. The design utilizes large-aperture quadrupoles which are part of the spectrometer array to focus the two beams. In order to achieve the necessary free space for this design, a beam bypass of one of the clustered straight sections is utilized. This bypass allows for the possibility of two, approximately 2.5 km sections free of horizontal dipole magnets. The bypass stubs needed to permit this possibility to be implemented in the future would increase the overall circumference of the SSC by roughly 3%.

The SSC lattice design presently contains two utility sections, two low-beta sections, two medium-beta sections, and two straight sections reserved for future development into experimental areas. Currently, all of these straight sections are some 1260 meters long. There has been some interest expressed in the possibility of a future experiment to look at very forward scattering in the SSC.[1] One way to allow for such a possibility in the future is to consider a beam bypass of one of the cluster regions. A study of the SSC lattice has resulted in the design of such a cluster bypass which could be a future modification to the SSC and which would permit the installation of some very long experiments.[2] The possible designs included one which had two experimental areas bypassing one of the cluster regions. In this design, the available experimental areas each had a horizontally bending free region of roughly 2400 meters. A layout of this design is shown in Fig. 1.

The previous study looked only at the possibility of producing a beam bypass and did not concern itself with optics for the experimental region. This paper will present a design for the bypass IR's which is compatible with a very-forward scattering experiment in which detectors may cover a total of 2.4 km length along the beam and which incorporate the necessary beam-focussing elements into the experimental apparatus.

Experimental Optics

There are two basic problems in producing an experimental area which has a free space of ±1000 meters:

1. In order to maintain a reasonable beam size in the focussing quadrupoles nearest the interaction region, either the magnets need to be relatively close to the IP or the beta-function value at the IP must be very large and hence the luminosity will be low.
2. In order to avoid excessive long-range beam-beam effects, the two beams must not have many bunch-bunch near encounters before being split apart. Thus the two beams must either populate few of the available bunches or they must cross at relatively large angles.

The beam-beam effects can be rather easily avoided by considering the minimum possible crossing angle as determined by beam-beam tune shifts and synchro-betatron resonances.[3] Fig. 2 shows a plot of possible beam crossing angles as a function of β^* along with curves of the beam separation, beam tune shifts, and maximum angle tolerable without inducing synchro-betatron resonances. In order to satisfy all of the requirements, the beam crossing angle must lie within the area indicated by the two arrows on Fig. 2.

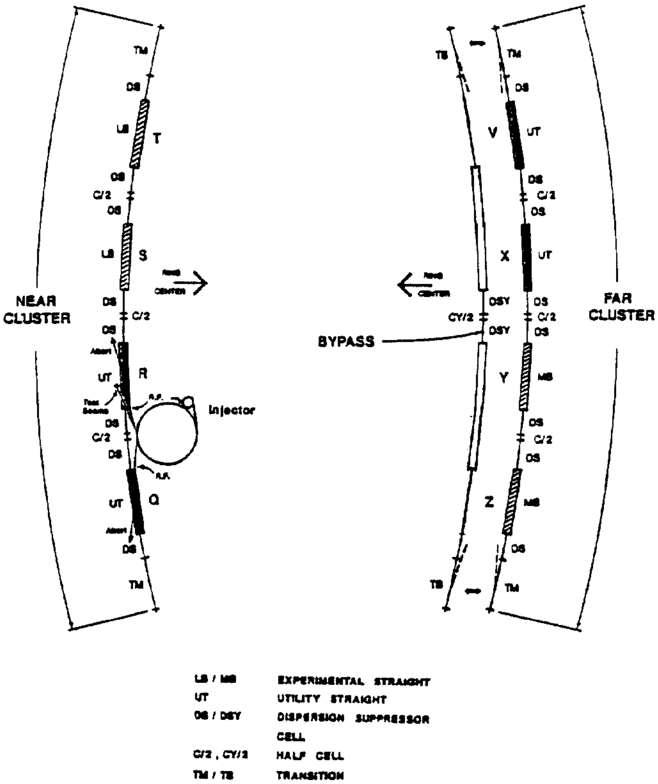

Figure 1 – SSC cluster layout with a bypass containing two very long experimental regions

For values of β^* in the range of 100 to 1000 meters, the beam crossing angle must be approximately 500 μrad. At such a crossing angle, standard SSC quadrupoles must be within 80 meters of the IP in order for the two beams to fit within the aperture. On the other hand, if the beams are to go into separate quadrupoles, they must be at least 560 m from the IP. This causes severe problems in terms of keeping the beam beta functions under control. Not only can the beta values not get too large, but they must be small and matched into the normal cell structure at the end of the experimental region, in this case within 1200 m of the IP.

It is possible to produce an optics design which will satisfy the above conditions by incorporating magnets within the detector which are required for good momentum and particle resolution

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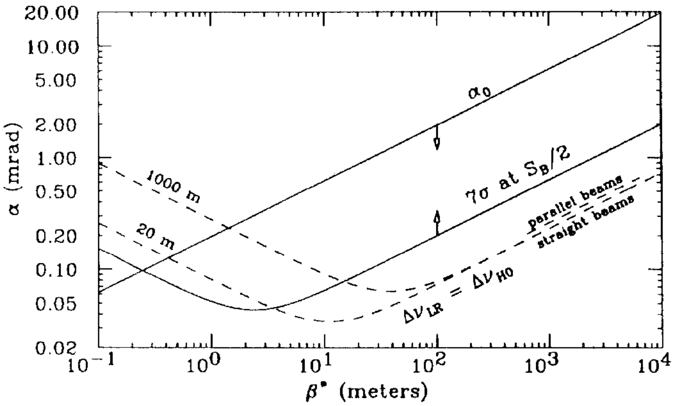

Figure 2 – Possible beam crossing angles vs. β^*

with the circulation beam control. Figs. 3 and 4 show the layout and lattice functions for one-half of such an experimental region. This design uses as the inner four quadrupoles magnets which have a coil winding diameter of 80 cm which have a pole-tip field of less than 6.5 T. The two outer quadrupoles are standard SSC separated magnets. All of these quadrupoles are an integral part of the forward spectrometer and are longitudinally placed roughly at unit increments in pseudorapidity as experimentally desired.[1]

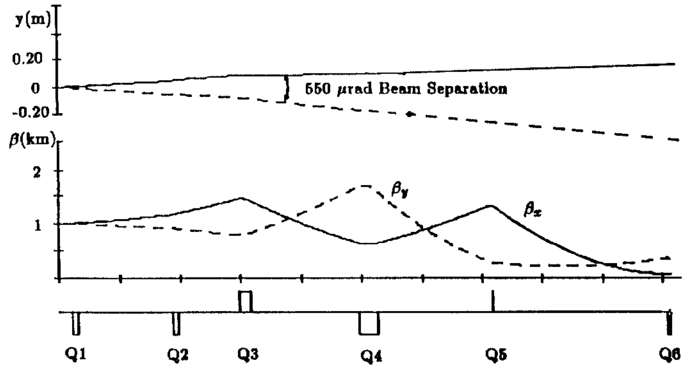

Figure 3 – Very-forward Experimental Optics
$\beta^* = 1000$ meters

Table I gives the quadrupole parameters for two tunes of the experimental IR. Fig. 3 shows the optics for a low-luminosity tune while Fig. 4 shows the tune for a luminosity of $\mathcal{L} = 2 \times 10^{30}$. The reason for considering the lower luminosity case is that the inner quadrupoles are getting very long (30 meters) and do not seem to be too practical. This design could be pushed to even higher luminosities but the inner quadrupoles get to be very long. In terms of the beam-beam separation, the coil winding diameters could easily be made smaller, and so keep the quadrupole length within reason, but in order not to block scattered particles at the edge of the rapidity step, the quadrupole apertures can not be much less that 80 cm.

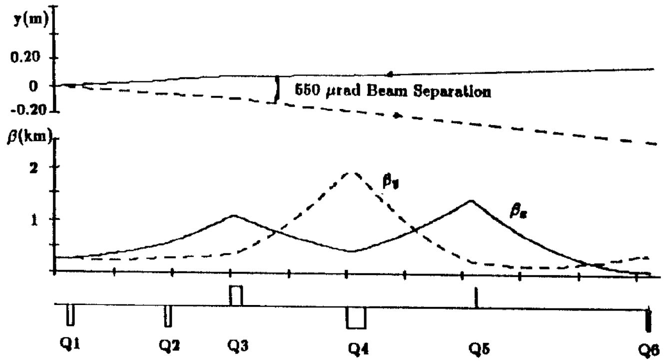

Figure 4 – Very-forward Experimental Optics
$\beta^* = 250$ meters

Table I

Tune Table for the Very-Forward Experimental Insertion
Z is the inner face quadrupole
distance from the IP

Quad	Length	Coil ϕ	Z	$\beta^* = 1000$m	250m
Q1	10.0m	80cm	20.0m	−2.5T/m	−10.1T/m
Q2	10.0	80	185.0	−3.6	−7.3
Q3	20.0	80	295.0	9.7	15.8
Q4	30.0	80	495.0	−10.6	−14.1
Q5	2.0	4	715.0	163.0	182.6
Q6	4.0	4	1007.0	−165.8	−182.9

Conclusion

The design of the SSC lattice as presented in the CDR will accommodate interaction regions with a free space of ±1000 m and a luminosity of 10^{30} cm^{-2}s^{-1} using reasonable magnetic elements as described above. By incorporating a beam bypass around the experimental areas cluster, this capability can be provided without affecting the mix of IR's envisaged in the CDR.

References

1. J. D. Bjorken, *Forward Spectrometers at the SSC,* Fermilab–Conf–86/22 (1986).
2. D. E. Johnson, *A Possible Beam Bypass for the SSC Clustered IR Region,* **Proceedings of the 1986 Summer Study on the Physics of the Superconducting Supercollider** (to be published).
3. D. E. Groom, A. A. Garren and D. E. Johnson, *A Very Large β^* Interaction Region for the SSC,* in the Proceedings of this Conference (1987).