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HIGH-LUMINOSITY INSERTION SCALING

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ABSTRACT

The SSC CDR high-luminosity insertion design has been examined in order to determine the relations between maximum quadrupole gradient, length of free space around the IP, and minimum β^* value. The conclusions are that with the present quadrupole gradient limit of 230 T/m, β^* can not be decreased without an accompaning increase of $\hat{\beta}$, even with a decrease in L^*. Curves of maximum luminosity and minimum β^* vs. L^* are given for different maximum gradients.

The CDR high-luminosity insertion was designed to have the following constraints:

$$\beta^* = 0.5\text{m}, \quad L^* = \pm\, 20\text{m}$$

and a maximum quadrupole gradient of 230 T/m. The final design was optimized to have $\hat{\beta}_x \approx \hat{\beta}_y$ and to have both values be as small as possible.[1,2] The quadrupole lengths were adjusted so as to run the insertion magnets on as few power supplies as possible. The resulting value for $\hat{\beta}$ was 7.96 km.

Given an optimized low-β insertion design, it is of some interest to see what can be gained in terms of either luminosity or free space and at what expense. In order to do this, different low-β designs were examined with the constraints that the maximum-β values remain between 7.9 and 8.0 km and that the insertions still remain matched into the rest of the CDR lattice. Three different possibilities were considered:

1. The magnetic lengths taken in the CDR design were used with a maximum gradient of 230 T/m but could be retuned, given more power supplies and moved;

2. The maximum gradient remained 230 T/m but the magnets could change in length and number; and

3. The magnets could change and could reach a maximum gradient of 270 T/m†

For a given β^*, the luminosity obtainable using the main CDR parameters can be calculated from the folowing equations:

$$\mathcal{L}_0 = \frac{\gamma c}{4\pi\epsilon_N S_B} \times \frac{N_B^2}{\beta^*}$$

$$\mathcal{L} = \mathcal{L}_0/\sqrt{1+(\alpha/\alpha_0)^2}$$

where γc are the usual relativistic quantities, ϵ_N is the normalized emittance, N_B the number of bunches, S_B the bunch spacing, α the crossing angle, and $\alpha_0 = 2\sigma^*/\sigma_l$ is the ratio of transverse to logitudinal beam size. $\mathcal{L}_0$ and $\mathcal{L}$ are the head-on and finite crossing angle luminosities. In all cases, the CDR parameters of bunch spacing, number of bunches, crossing angle, *etc.*, are fixed for this comparison.

For case number one above, it was found that the CDR design could not reach a smaller β^*. If the free-space were lengthened, β^* would have to increase as expected in order to keep $\hat{\beta}$ under 8 km. As L* was decreased, however, β^* again had to be increased. This is because the triplet quadrupoles were already focussing as hard as possible and so could not maintain $\hat{\beta} \leq 8$ km without raising β^*. A list of L*, β^* and luminosities found is given in the Table and are plotted in the Figures. Case number one is plotted with solid curves.

Case number two, where the quadrupole lengths could change was somewhat better than case number one. While there is a small improvement available by making longer quadrupoles, it is very small as the effective focal planes move farther away from the IP and again $\hat{\beta}$ increases. In the Figures, case number two is indistinguishable from number one.

† This corresponds roughly to a 230 T/m quadrupole run at 2° K.

Finally the possibility of going to higher gradient magnets was examined. If a 270 T/m magnet could be built, there is indeed the possibility of increasing the maximum luminosity by ~ 30% at the expense of L^* before one reaches the limiting triplet focal length. Case three designs are listed below and are plotted as dashed lines in the two figures. It should be noted, however, that as the bunch size gets very small, synchro-betatron resonances could limit performance unless the beam crossing angle in decreased at the expense of the long-range beam-beam tune shift.

Minimum β^*	L^*	α/α_0	$\mathcal{L}_0$	$\mathcal{L}$
0.65 m	± 19.5 m	0.49	0.97×10^{33}	0.79×10^{33}
0.54	15	0.52	1.05	0.93
0.50	20	0.54	1.14	1.00
0.75	32	0.44	0.76	0.69
1.00	43	0.38	0.57	0.53
2.00	75.5	0.27	0.28	0.27

Case No. 1, $\widehat{B}' = 230$ T/m

Minimum β^*	L^*	α/α_0	$\mathcal{L}_0$	$\mathcal{L}$
0.40 m	± 12.5 m	0.61	1.42×10^{33}	1.21×10^{33}
0.37	14	0.63	1.54	1.30
0.42	19	0.59	1.35	1.16
0.70	32	0.46	0.81	0.74
1.00	45	0.38	0.57	0.53
2.00	75.5	0.27	0.28	0.27

Case No. 3, $\widehat{B}' = 270$ T/m

In the tables above, $\mathcal{L}_0$ is the head-on luminosity and $\mathcal{L}$ is the luminosity for a 75 μrad crossing angle in units of $cm^{-2}\text{-}s^{-1}$.

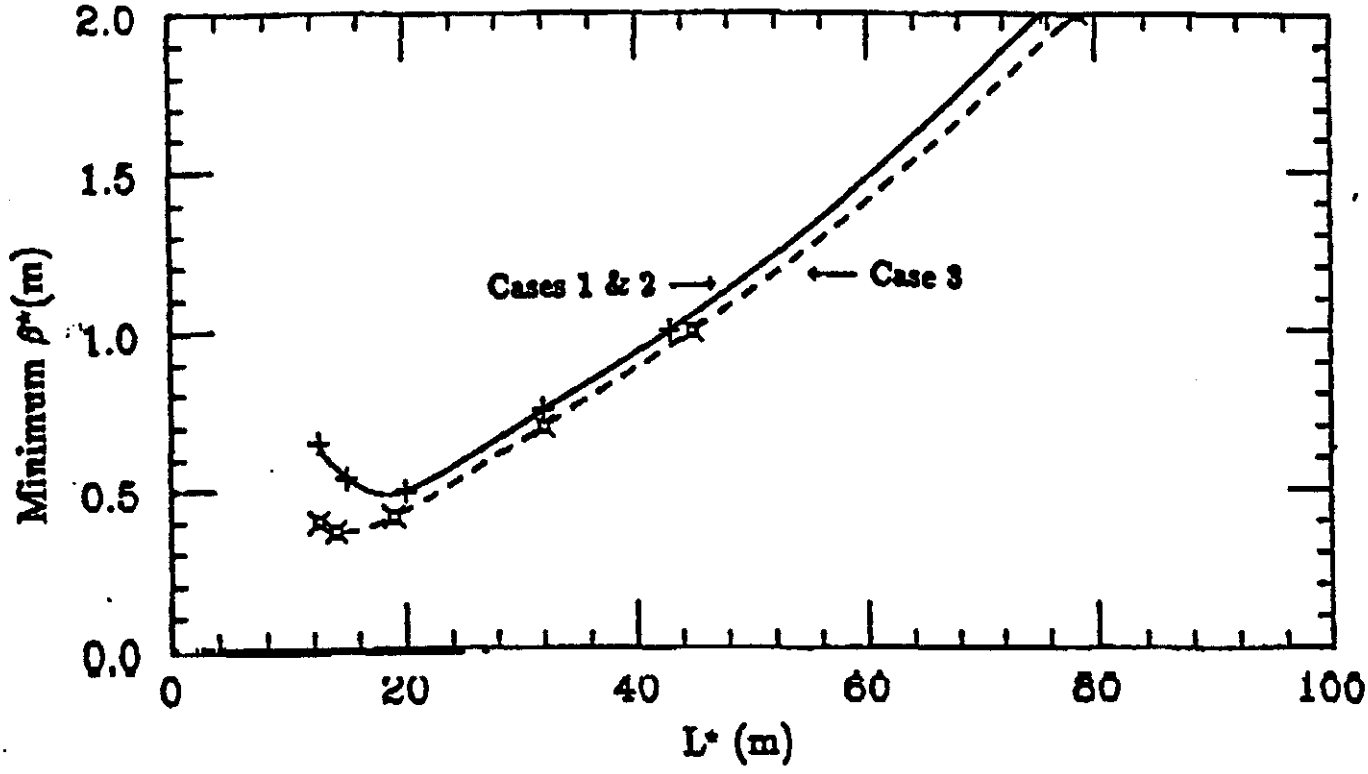

Figure 1

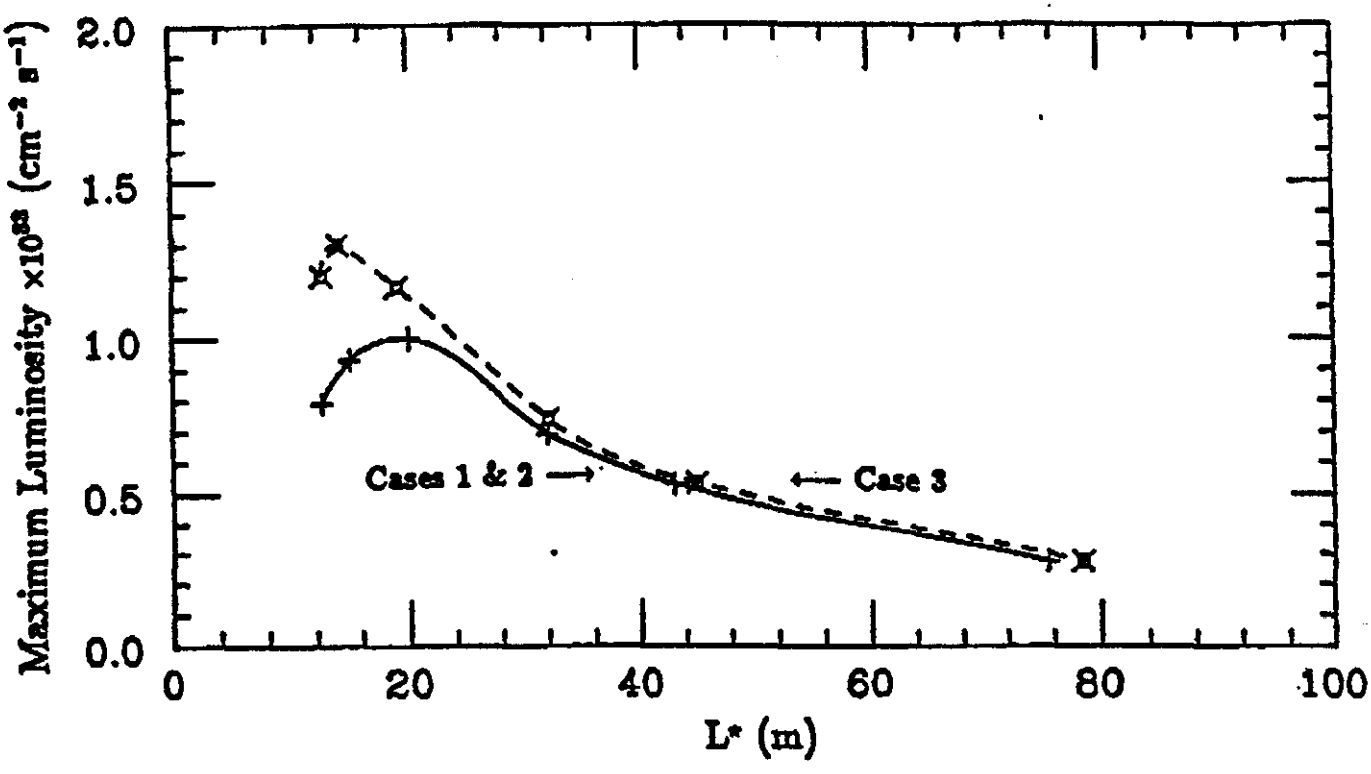

Figure 2

Plots of minimum β^* and maximum luminosity as a function of L^*. The solid and dashed curves correspond to different IR designs representing cases 1, 2 and 3.

REFERENCES

1. SSC Conceptual Design Report Lattice, E. D. Courant, *et al.*, SSC–N–139
2. SSC Medium and Low β IR Tuning Curves, A. A. Garren and D. E. Johnson, SSC–N–140