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PRELIMINARY DESIGN OF EXPERIMENTAL INSERTIONS
FOR VERTICALLY STACKED RINGS IN THE CERN 400 GeV STORAGE RING FACILITY

by

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Introduction

During the early design stages of the CERN 400 GeV storage ring facility the question has arisen whether the two rings should be horizontally or vertically stacked. In the discussions the straightforward assumption was made that the beams would cross horizontally if the two rings were placed on top of each other. Consequently, the design of both horizontal and vertical crossing experimental insertions and evaluation of their problems are important for the decision on the preferred physical stacking scheme.

The details of experimental insertions employing horizontal crossings were described in Ref. 1. In the present note, preliminary results of the design work on possible vertical crossing insertions are given and some comparison is made. Three insertions aimed at fulfilling the experimental requirements quoted in Ref. 1, have been worked out: a high luminosity (low β) region, a high β region suitable for small angle scattering and a general purpose region with reduced luminosity and a long free space at either side of the intersection point.

All three insertions are bounded by horizontal dispersion function suppressors*. These consist of a normal lattice cell in which the quadrupole gradients have been modified to bring x_p and x_p' to zero at its end. ($x_p = 0$ is required in the interaction region for maximum luminosity because the luminosity depends on the horizontal beam size in case of vertical crossing.)

An optimal distance of 1 m between the two rings has been assumed.

Only insertions with a symmetric or antisymmetric arrangement of the magnets have been considered.

General Considerations

The beam gymnastics required for vertical crossing introduces a non-zero vertical dispersion function. A fully matched insertion

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requires that this function remains equal to zero in the normal lattice. This can be accomplished in two ways:

a) by an asymmetric placement of the bending magnets (requiring at least 4),

causing the beams to go from upper to lower ring and vice versa. Here the condition for a fully matched insertion requires $y_p = 0$ at the centre while y_p' can have any value there.

b) by a symmetric placement of the bending magnets (requiring at least 6),

always leading to a collinear interaction region. Here the beam will start out and end up in the same ring and it is necessary to meet the condition $y_p' = 0$ while no restriction is put on y_p itself.

High Luminosity Insertion

A luminosity of $\sim 10^{33} \text{cm}^{-2} \text{sec}^{-1}$ can be reached with a circulating current of 5 A if the horizontal β function is ~ 1 m at the intersection point and the crossing angle ~ 1 mrad. A 10 m free space on each side of the interaction region is adequate for most high luminosity experiments. Figure 1 shows a possible layout of an insertion that fulfills these requirements. Although the figure shows a collinear interaction region a small crossing angle can easily be obtained by slight adjustment of the bending fields. The sequences of outward and inward bends (rather than single bends) serve two purposes: a) the beams are brought together at relatively large angles, making it possible to avoid common quadrupoles for the two beams without having an excessively large

chromaticity; b) non-zero values for the vertical dispersion function are obtained in all quadrupoles making available the possibility of chromaticity corrections.

Horizontal and vertical β -functions as well as the vertical dispersion function are shown as function of distance in Fig. 2. The horizontal and vertical chromaticity obtained for the whole insertion (including the horizontal dispersion function suppressors) are also indicated on the graph.

High β Insertion

The high β insertion is used for small angle scattering experiments for which a luminosity of $\sim 10^{30} \text{cm}^{-2} \text{sec}^{-1}$ is needed. To go down to scattering angles of $\sim 20 \text{ } \mu\text{rad}$, B_H and B_V have to be approximately 400 m and $y_p' \sim 0$ with interaction region. Additional conditions are imposed at the place of the detector to assure high angular resolution. It is required that $y_p = 0$ here and that the betatron phase advance is $\sim \pi/2$ relative to the interaction region.

A non-zero angle crossing, made possible by asymmetric placement of the bending magnets, would lead to $y_p = 0$ (for symmetry reasons) and $y_p' = 0$ (for angular resolution) at the centre, which cannot be achieved in a simple way, taking into account all the other constraints mentioned. One is then forced to go to a symmetric insertion having a collinear interaction region and requiring $y_p' = 0$ only. Such an insertion was designed for ISABELLE and a somewhat changed version of it, applicable to the CERN 400 GeV device, is shown in Fig. 3. The length of the collinear interaction region is limited by the permissible beam-beam tune shift and the beam current would have to be kept below 5 A to keep $\Delta\nu \leq 0.005$. Corresponding β and y_p functions are shown in Fig. 4, together with the chromaticities.

It should be pointed out that there exists a close relationship between the maximum detectable scattering angle and the aperture of the magnets upstream of the detector. In the present arrangement a 9.7 mrad bend was chosen to allow for the possibility of making the high β and

general purpose insertions interchangeable. If this requirement is dropped sharper bends could be introduced, possibly by the use of superconducting dipoles, reducing the length of the bending section (and the insertion as a whole) and relaxing the aperture requirements for a given maximum detectable scattering angle. Another arrangement in which the focussing elements are inside the bend was also tried but did not seem to be able to fulfill the requirements $\alpha_x = \alpha_y = y'_p = 0$, $L_H \approx \delta V \approx 400$ m at the centre.

General Purpose Insertion

The specifications for the general purpose insertion call for a crossing angle of approximately 20 mrad, $\delta_H \approx 20$ m, $\delta_V \approx 60$ m at the intersection point and a long free space in the centre. A luminosity of $\sim 10^{31}$ can be reached with 5 A, and the beam-beam shift is as low as 5×10^{-6} .

It would be convenient if such an insertion could be achieved by minor rearrangement of the elements in the high β region, described in the previous paragraph. Figure 5 shows a configuration in which a doublet has been added and a bending magnet has been removed. (The doublet could possibly be left in and turned off for small angle scattering experiments.) A magnet-free length of 40 m is obtained on either side of the interaction region. The arrangement of course assumes that the beams can go in either direction in the rings. β and y_p functions are shown in Fig. 6.

The general purpose insertion can be shortened if it is not to be used in an interchangeable way with the high β region. Figure 7 shows a layout where the length of the drift space following the first doublet has been reduced by 20 m without changing the general pattern of beam behaviour, as can be seen from Fig. 8.

Discussion

It seems appropriate at this point to make some comparison between the insertions described here and those described for horizontal

crossings rather than making any general statements on the relative merits of horizontal and vertical crossing insertions.

Both the high luminosity and the general purpose insertions seem, at least potentially, to be quite comparable. In the high luminosity case there seem to be no major discrepancies. The general purpose insertions differ mainly in the amount of free space available around the interaction point (± 80 m for horizontal crossing, ± 40 m for vertical crossing). This comes from the two rings being separated by 2.5 and 1 m respectively and has nothing directly to do with horizontal versus vertical crossing. One could increase the distance between the vertically stacked rings in the beginning of the insertion by an outward bend; the way it is done in the high luminosity region. Alternatively, a smaller crossing angle could be used in order to simulate more closely the geometry of the existing horizontal crossing insertion. The beam-beam tune shift would then go up to ~ 0.001 but this does not appear too serious.

The two high β insertions are considerably different because of the finite angle versus collinear intersections. In the horizontal crossing case a non-zero angle geometry was achieved by a non-symmetric arrangement eliminating the constraint that the horizontal dispersion function itself be zero at the centre. This could possibly be tried for the vertically stacked rings. However, the simultaneous matching of betatron and vertical dispersion function will probably be more difficult because y_p is zero, at the ends of the insertion, while in the horizontal crossing case, x_p^D is ~ 2 m there (no horizontal dispersion suppressor was used).

Finally, the horizontal crossing insertions, especially the high β one, allow for more complete chromaticity correction. It is felt that further theoretical studies are required to determine the necessity, and possibly the desirability, of having chromaticity compensation in the experimental straight sections.

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Fig.1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 5

Fig. 6

Fig. 7

Fig. 8