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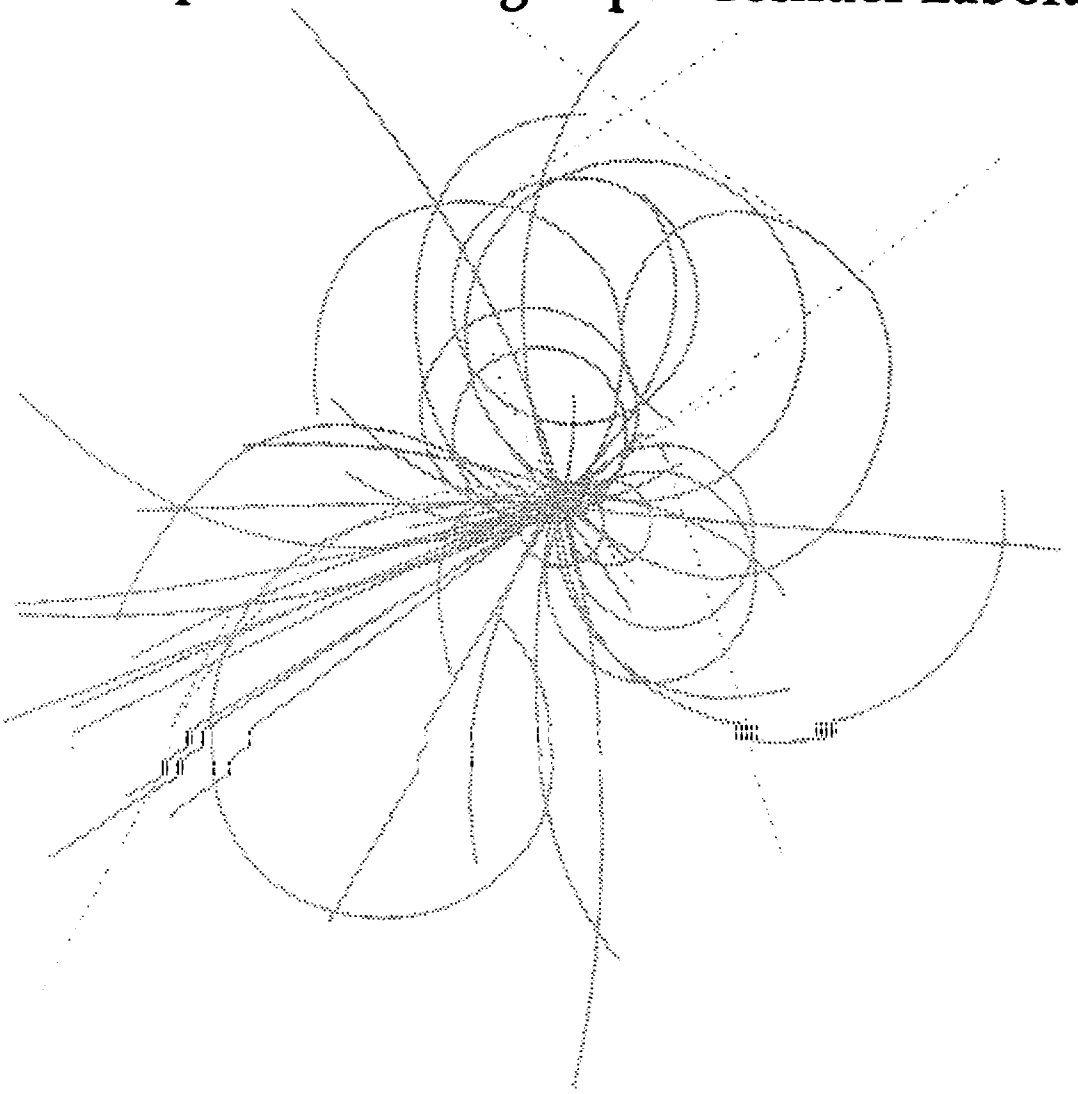
Superconducting Super Collider Laboratory



Preliminary Lattice Proposal for Polarized Beam Acceleration in SSC

K. Steffen

June 1985

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PRELIMINARY LATTICE PROPOSAL FOR POLARIZED BEAM ACCELERATION IN SSC*

by

Klaus Steffen

June 1985

* Operated by Universities Research Association for the Department of Energy.

PRELIMINARY LATTICE PROPOSAL FOR POLARIZED BEAM ACCELERATION IN SSC

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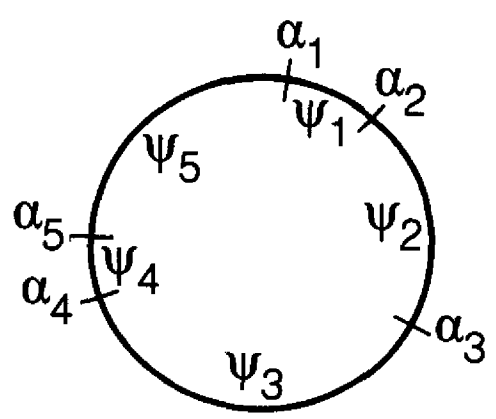
GENERAL ON SNAKES

A snake is an alternating sequence of horizontal and vertical bends designed to rotate the spin about an axis that lies in the horizontal plane. The overall spin rotation of the snake can be described by an 180° rotation about the transverse horizontal x-axis, followed by a rotation by an angle α about the vertical z-axis. α may be called the "precession angle" of the snake. Special examples are the "snake of the 1st kind" with α = 180° and of the "2nd kind" with α = 0°. Examples of snakes for any value of α are given in reference 1.

By inserting n snakes in the ring, any desired fractional spin tune can be obtained. $\vec{n}$ should be an even number in order to have the equilibrium spin direction (vector $\vec{n}$) vertical in the arcs. For a configuration as sketched, the spin tune is:

$$\nu = \frac{1}{360°} \sum_{i=1}^{n} (-1)^i (\alpha_i + \psi_i)$$



*Visitor to the SSC Central Design Group.

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where ψ_i, the spin precession angles between snakes, depend on energy while the snake precession angles do not. We must therefore insert the snakes such that $\sum_i (-1)^i \psi_i = 0$ and then have

$$\nu = \frac{1}{360°} \sum_i (-1)^i \alpha_i$$

One possibility, for example, is to insert n-2 snakes of the same kind and two snakes with $\alpha_2 - \alpha_1 = \nu \cdot 360°$.

PROPOSED TYPES OF SNAKES

There is one snake of outstanding compactness and small overall bending that we propose to insert in SSC in all but a few places. It is described in references (2) and (1) and is schematically shown in Figure 1. It's precession angle is $\alpha = 180°$. For the few other places we propose the snakes shown in Figure 2, with precession angle $\alpha = \pm 135°$ or $\alpha = \pm 150°$, respectively.

SSC RING CONFIGURATIONS

Two types of ring configurations are considered:

A) With 2 clusters of 3 chromatically corrected interaction regions each.

B) with equally distributed 6 interaction regions

There will probably be 2 long utility straights in the ring and trombones for adjusting the horizontal and vertical betatron tune; they are ignored here for simplicity.

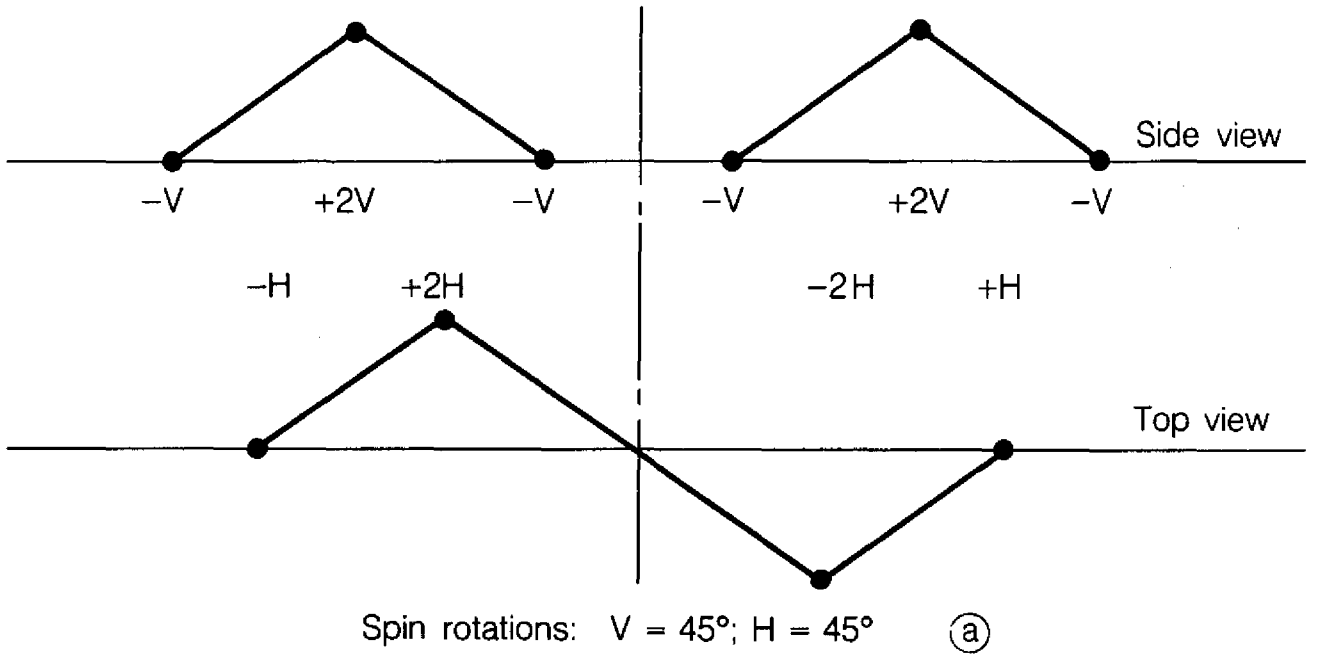


Fig. 1. Suggested Siberian snake with precession angle α = 180°.

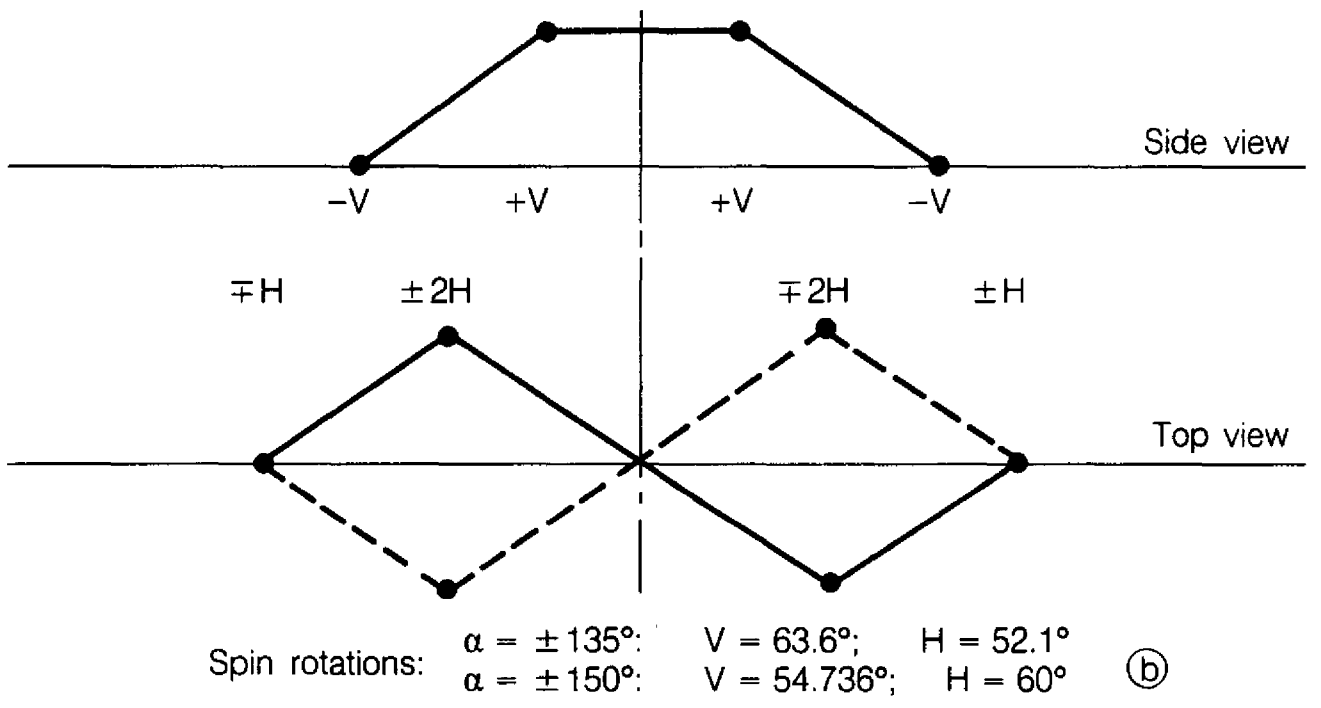
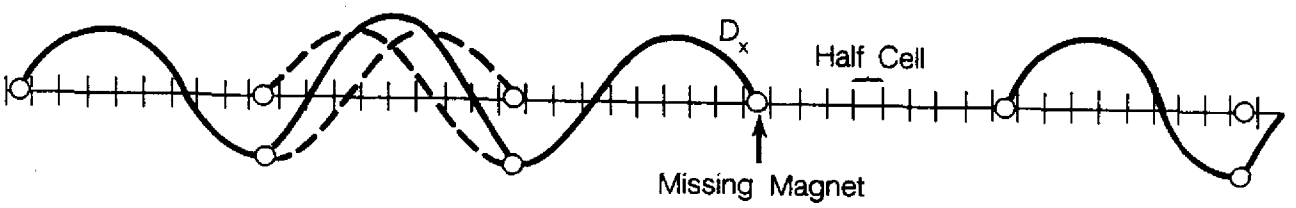


Fig. 2. Suggested Siberian snake with precession angles α = ± 135°and ± 150°.

PLACING OF SNAKES IN THE RING

We assume here that all snakes will be placed in the normal cells in the arc of the ring. The half cell is assumed to be 100 m long and to have a betatron phase advance of 30°. There are 5 magnets in the half cell, each 16.6 m long, with a nominal radius of curvature ρ = 11118.8 m corresponding to 6T at 20 TeV. This means that the machine has in the vicinity of 4208 bending magnets. We propose, as a working model, to leave out every 45th magnet in the regular arc; this yields the following spurious dispersion pattern:



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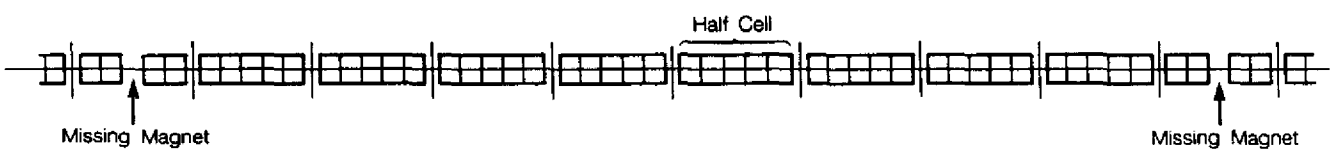
Blown up in scale, the cell magnet pattern looks as follows:



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The number of cells in the arc is now adjusted to accommodate this structure with an even distribution of missing magnets up to the ends of the arc, in order to allow a constant tunnel curvature. Then, 4 or 6 special snakes of type b are installed in a rather symmetric pattern, and the remaining missing magnet gaps are then filled with as many snakes of type a as required for resonance suppression. The number of type a -snakes must be even an should preferably maintain the superperiodicity of the ring.

A. Clustered IR's: Each arc has 9 x 39 + 1 = 352 half cells with 40 missing magnets, i.e. with 5 x 352-40 = 1720 magnets total. Another 384 magnets are incoporated in the achromatic IR cluster design*, such that the ring has a total of 4208 magnets and can take up to 80 snakes in the arcs.

B. Distributed IR's: Each arc has 9 x 15 + 1 = 136 half cells with 16 missing magnets, i.e. with 5 x 136-16 = 664 magnets total. Thus, the ring has 6 x 664 = 3984 magnets and can take up to 96 snakes.

Figure 3 shows the ring configurations A and B with IR and snake positions. It is envisaged that snakes of type a would be inserted into the arc in multiples of 6 in order to give a rather equidistant spacing and, in case of configuration B, maintain the superperiodicity of the ring.

* Will be explained later.

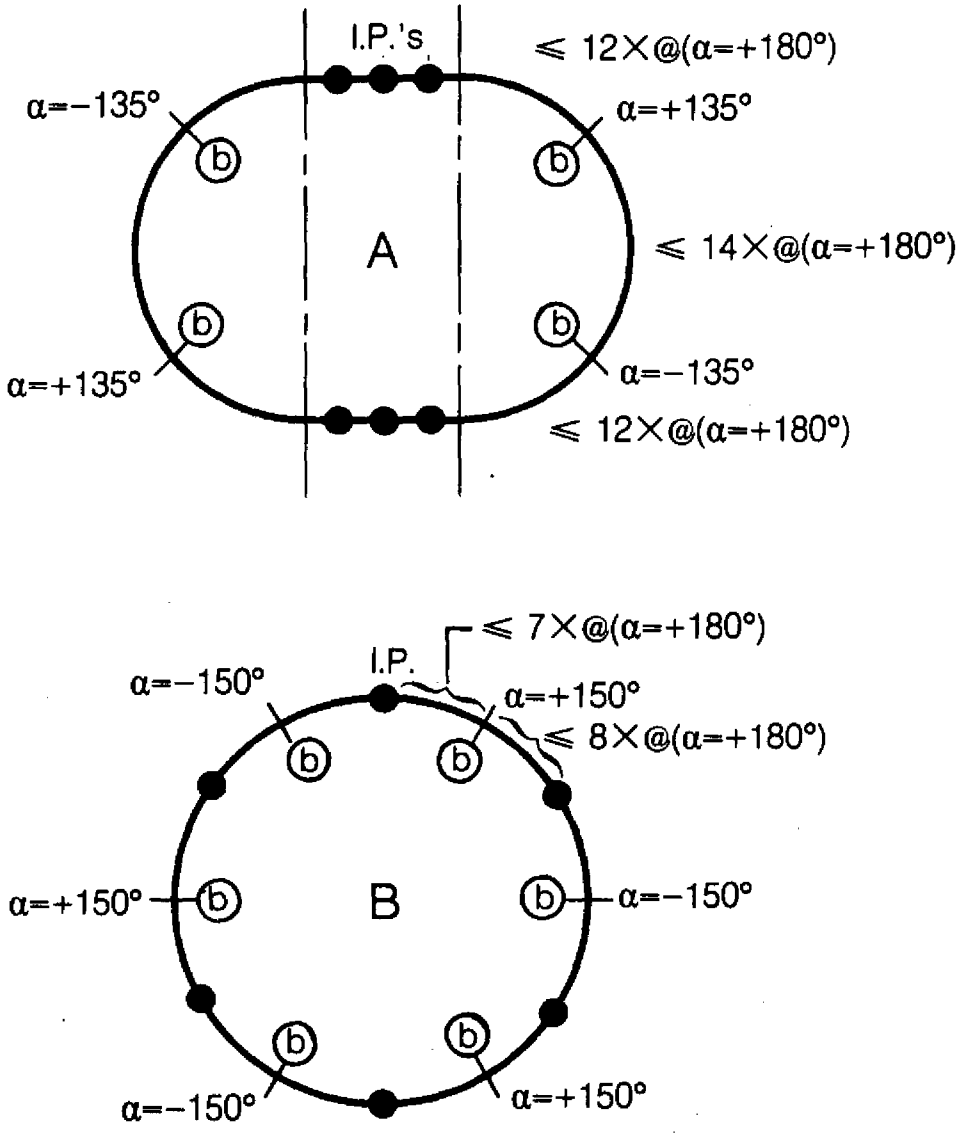

Fig. 3. Ring configuration A and B with clustered and distributed IR's, respectively.

INTERACTION REGION DESIGN

We assume that, in the arcs, the two rings are on top of each other at a vertical separation of, say, 60 cm. For interaction, they are translated into the median plane. This translation must be arranged such that the created vertical dispersion effectively vanishes at the I.P. as well as in the arc. Also, it must not upset the vertical spin orientation in the arc, which is avoided by having no horizontal bend within. At the I.P., a longitudinal spin orientation may be required. At 20 TeV, a spin rotation of $\psi = 90°$ is obtained with a beam deflection $\varphi = .560/20000 \times \psi = 44$ μrad; a crossing angle of 2 x 44 μrad will therefore give longitudinal polarization at 20 TeV. For transverse polarization, the crossing angle, when using it as a spin rotator, would have to be 2 x 88 μrad.

With a longitudinal polarization in the insertion quadrupoles, the spin motion in these quads will depend on horizontal betatron motion and will thus, in general, excite <u>intrinsic horizontal spin resonances</u> in addition to the - always present - intrinsic vertical spin resonances excited by vertical betatron oscillations. In order to avoid the horizontal intrinsic resonances and to reduce the strength of the vertical intrinsic resonances by avoiding their excitation in the high beta insertion quadrupoles, I propose to spin-match the pair of <u>insertion multiplets</u> such that it is <u>spin-transparent</u> for horizontal and for vertical betatron oscillations. This simply means that every trajectory leaves the second multiplet in the same direction as it enters the first multiplet independent of its betatron amplitudes and phases. In

optical terms: The quadrupole strengths are so adjusted that in the transformation matrices of the multiplet and the sign-inverted multiplet, denoted by

$$\begin{pmatrix} C_x & C_x \\ C'_x & S'_x \end{pmatrix} \quad \text{and} \quad \begin{pmatrix} C_y & S_y \\ C'_y & S'_y \end{pmatrix} \quad \text{respectively,}$$

we have $C'_x = -C'_y$

and $S'_x = S'_y$

An "artist's conception" of the interaction optics suggested for ring configuration A with clustered IR's is shown in Fig. 4. It contains essential design features contributed by several members of the SSC design group, especially by A. Chao and A. Garren. So far, it is a layout only, that needs more quantitative exploration and interactive improvement. Figure 3 shows two of the three interactions in a cluster, each spin-transparent, and surrounded by a 360° FODO channel on each side. The two IR multiplets have opposite polarity, and so have the surrounding FODO channels which generate a strong horizontal dispersion at the two chromaticity correcting sextupoles, and then suppress it again. The sextupoles are spaced exactly 180° apart such that their geometric aberrations cancel. The beam evelopes E_x, E_z are matched into the FODO channel with $\alpha_x = \alpha_z = 0$ by the insertion multiplet. The amplitudes of the envelopes in the FODO channel are chosen to produce a large beat such that their ratio is large at the place of the sextupoles, and the chromatic corrections in x and z are decoupled.

At the beginning and end of the IR cluster shown in Fig. 4, there must be a vertical dispersion suppressor. Figure 4 shows a two-step version with an

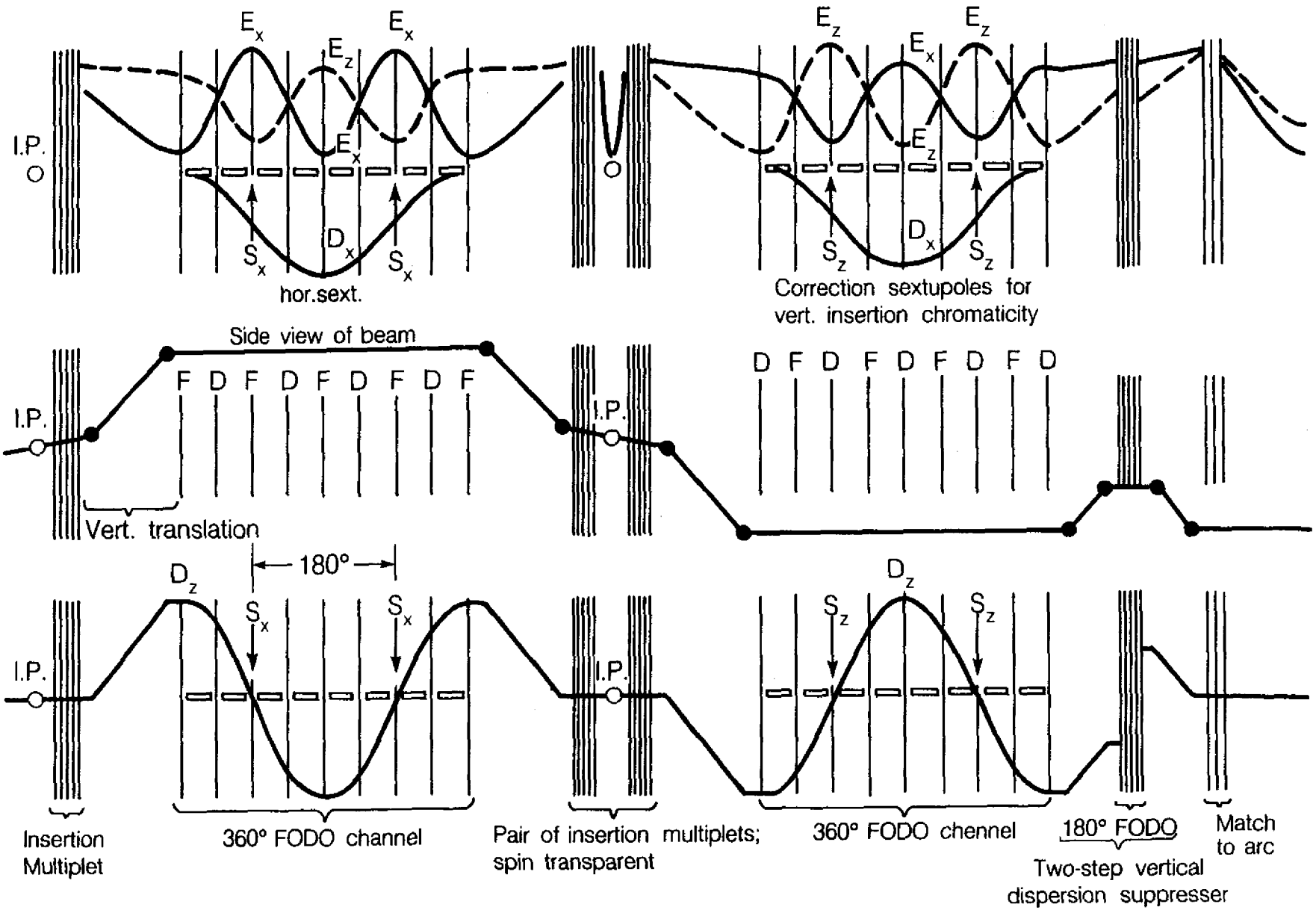

Fig. 4. Suggested optics for clustered interaction regions, schematic.

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inserted 180° FODO channel as proposed by A. Garren. There are matching quadrupoles behind the dispersion suppressor which match the envelopes E_x, E_z into the periodic ring structure.

In the lattice example described in this note we assume that, in order to generate a large dispersion for sextupole action, the length of the half cell in the FODO channels of the IR cluster is increased to 220 m, containing 12 magnets of 16.6 m length. The whole IR cluster will then have 4 x 8 x 12 = 384 magnets which must be subtracted form the arc (see above).

For the ring configuration B with 6 evenly distributed IR's we assume here that the correction of IR chromaticity is done in the adjacent arcs and that, therefore, the special FODO channels around each IR are omitted. The IR is spin-transparent again and is, after the vertical beam separation, directly followed by the vertical dispersion suppressor and the quadrupoles for envelope matching into the arc.

ACKNOWLEDGMENTS

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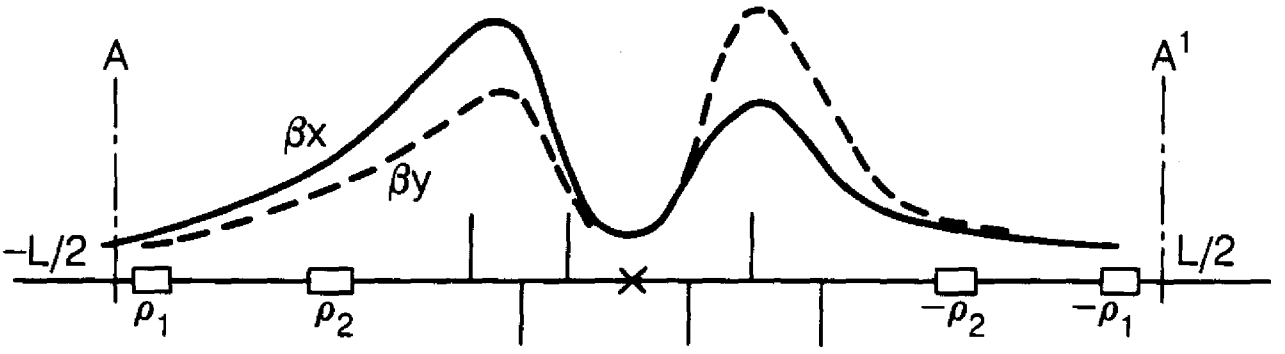
REFERENCES ON SNAKES

1. K. Steffen, DESY 83-124 (Nov. 83)
2. K. Steffen, DESY/PET 78/11 (Nov. 78)


A
A1
βx
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−L/2
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ρ1
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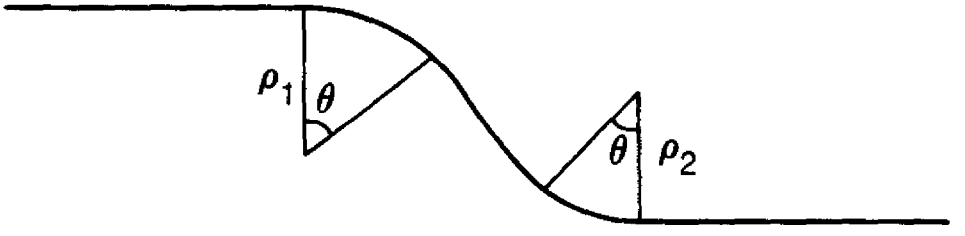
ρ1
θ
θ
ρ2