CRISP 72-88
ISABELLE PROJECT

BROOKHAVEN NATIONAL LABORATORY
Associated Universities, Inc.
Upton, New York

ACCELERATOR DEPARTMENT
Informal Report

MASTER

HIGH MOMENTUM DISPERSION-LOW BETA MATCHED INSERTION

M. Month

November 9, 1972

NOTICE
This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Accelerator Department
BROOKHAVEN NATIONAL LABORATORY
Associated Universities, Inc.
Upton, New York

CRISP 72-88
ISABELLE PROJECT

INTERSECTING STORAGE ACCELERATOR NOTES

High Momentum Dispersion-Low Beta Matched Insertion*

M. Month

Brookhaven National Laboratory, Upton, New York, 11973

ABSTRACT

The general difficulties connected with the design of a matched insertion which has a free straight section with high X_p and low β_H are discussed. A practical resolution of these problems is provided. A specific example of a matched symmetric insertion is presented. Some general aspects related to storage ring design are also considered.

* Work performed under the auspices of the U.S. Atomic Energy Commission.

I. Introduction.

Recently, Keil and Sessler¹ suggested a form of energy stacking as a means of injection into a storage ring. In order not to impose additional aperture requirements on the normal ring lattice, the matched injection insertion should be designed so that at the kicker location, the momentum dispersion function, X_p , is much larger than in the normal lattice, while the horizontal β -function, β_H , is smaller. It is our aim here to propose a practical means of achieving this.

In principle, a way of obtaining high X_p and low β_H is simply to use quadrupoles for focusing β_H to small values while simultaneously increasing X_p to high values with bending magnets. This is always possible since dipoles have, roughly speaking, no influence on the β -function. There are, however, two difficulties. In the first place, quadrupoles affect the X_p function in generally the same way as they affect the horizontal β -function. Thus, focusing β_H tends to reduce X_p . Secondly, we are greatly restricted in the choice of bending strengths. In fact, the bending strength is not a free parameter, since the geometric curvature must be of the same order at high as well as at low fields. Since the high field bending strength is optimal, the low field strength is fixed at a value determined almost entirely by the injection energy. This means that the X_p function must be built up with bending length.

Taking the above two points together, we can see how the practical problem develops. One tries to keep β_H relatively constant while building X_p with bending magnets. If we were free to choose the bending strength, this could always be achieved in a feasible distance. However, since bending strength is only obtained with bending length, we must continually focus horizontally without turning the X_p function downward. But this need to continually focus β_H means a slowing up of the whole process and a need

for more length to accomplish the end of high X_p , low β_H . This then is the problem. Nonetheless, it is also the source of the practical solution we propose.

The general idea is then to build X_p with bending length while periodically maintaining β_H at moderate values with mild focusing. Now it is important to recognize that as X_p is built up, the slope of the dispersion function, X'_p , is also increasing. Thus, when we have reached the required large value of X_p , and remember β_H has been kept moderate and relatively flat, then we can strongly focus β_H . This focusing will then decrease β_H to some low value, but it will only weakly affect X_p . This is because the focusing can be chosen so as to reduce X'_p to roughly zero, but no further. Thus, in the space in which β_H is brought to a low minimum, X_p remains relatively constant at its high value.

To demonstrate the above notions, we will design a matched insertion suitable for use in a storage ring with the energy stacking mode of injection. A length of about 12 m. free straight section occurs around the center of the insertion. This is the region of low β_H , high X_p and is the position of the kicker magnet. A length of about 10 m. is allowed for the septum at the beginning of the insertion. The septum location is chosen to be about 90° in phase from the kicker location. The magnetic elements comprise a series of units, each composed of a quadrupole doublet and some bending length. The general characteristics of the doublet are to provide mild horizontal focusing and sufficient vertical focusing to keep the vertical β -function at moderate values. The details are given in the next section.

II. Matched Injection Insertion

We consider an insertion point in a ring lattice² with the following characteristics:

$$\beta_H = 40 \text{ m.}, \beta_V = 7 \text{ m.}$$

$$\alpha_H = \alpha_V = 0$$

$$X_p = 1.7 \text{ m.}$$

We want to design an insertion with the following characteristics:

1. Around the center point (kicker location) we desire

$$X_p \geq 4 \text{ m.}$$

$$\beta_H \leq 10 \text{ m.}$$

$$\beta_V, \text{ moderate}$$

2. Total horizontal phase advance = $\Phi_H \approx 180^\circ$.
3. Total length should be some reasonable fraction of the total bending length in the lattice.

In Fig. 1, we show the characteristics of the insertion developed as a solution to the above problem. In Table I, we list the specific characteristics of this matched insertion together with the strengths of the magnetic elements.

As can be seen from the figure, the notions we have previously discussed have been applied to achieve the desired end of high X_p , low β_H . In order to attain the low β_H within a set distance from the last doublet and in order to speed up the process of building X_p , we allowed the β_H -function to rise substantially in the first two doublets. This is not absolutely essential, but it does allow us to obtain an insertion with a total bending angle of 30 degrees, i.e. a total insertion length of about 150 m.

When we try to evaluate whether or not this bending contribution from the insertion is reasonable, we must consider how the insertion will fit into the main lattice. In practice, the intricacies and peculiar qualities of each particular lattice must be taken into consideration. We will not go into these. There is, however, one difficulty of a general nature that can be mentioned. In order to avoid structural or intrinsic resonances, one requires a reasonable symmetry of the total lattice. The accelerator art may have advanced to the point where one can question this requirement. Nonetheless, we will consider the implications resulting from the assumption of four-fold symmetry. This means that four such insertions are included in the lattice. Following this argument, we are led to the fact that the four insertions will account for 120° of bending or $1/3$ of the total bending length. Now, the question is: Is this reasonable? An affirmative answer can be given as follows: The physical structure of the insertion is similar to the main lattice cells in the sense that it is formed out of a periodic alternation of focusing and bending with period similar to that in the main cells.² The only difference might be in the specific use of doublets to accomplish the focusing. The main lattice cells might, for example, use singlets. However, one could establish programmed magnetic elements in the insertion such that at the lowest energy, the insertion would have the characteristics required for injection, while at high fields, the focusing elements could be changed in such a way that each of the insertions closely resembles a certain number of normal cells of the lattice. The insertions therefore produce a minimal perturbation of the lattice and, with a symmetry of four, clearly provide a reasonable lattice structure from the point of view of orbit dynamics.

References

1. E. Keil and A. M. Sessler, BNL Accelerator Dept. Informal Report, CRISP 72-74 (1972).
2. The parameters used in this paper are roughly related to the lattice for the storage rings being considered at BNL. See, "A Preliminary Design Study", BNL Report 16716 (May, 1972).

TABLE I

Symmetric Matched Insertion-Characteristics

Insertion Characteristics

At center (Kicker location)-

$$\beta_H = 6.2 \text{ m}, \beta_V = 45.2 \text{ m}, X_p = 4.65 \text{ m}$$

Phase advance-

$$\phi_H = 243.8^\circ (\delta_V = 0.68)$$

$$\phi_V = 400.2^\circ (\delta_V = 1.11)$$

Total Length: 148.8 m.

Number of bending magnets: 30

Number of doublets: 10

Total bending angle: 0.52 radians (30°)

Fraction of total bending: 0.083

Magnetic Elements:

Bending Magnets: Length - 2.9 m.

Bending radius - $\rho = 166.2 \text{ m}$.

<u>Quadrupoles:</u>	<u>Length(m)</u>	<u>q (Integrated strength-m⁻¹)</u>
Singlet:	0.2	+0.0066 (HF)
Doublet D1:	1.0	-0.25 (HD)
	1.0	+0.21 (HF)
Doublet D2:	1.0	-0.17
	1.0	+0.15
Doublet D3"	1.0	+0.13
	1.0	-0.14
Doublet D4:	1.0	-0.09
	1.0	+0.09
Doublet D5:	1.0	+0.17

Figure 1

Symmetric Matched Injection Insertion (Low θ_{II} -High X_p)

The first magnetic element is a horizontally focusing quadrupole.

B signifies bending magnets. The insertion is totally symmetric about its midpoint. There are five quadrupole doublets in each half. F means the quadrupole is horizontally focusing, D means it is horizontally defocusing. For purposes of comparing with Table 1, the five doublets are characterized, from left to right, as D1, D2, D3, D4 and D5. C refers to the center point of the symmetric insertion. K is the kicker location and S is the septum location.