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INTERSECTION STORAGE ACCELERATOR NOTES

ISA Closed Orbit Distortions and Corrections

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ABSTRACT

Some comments are presented on monitoring and correction of ISABELLE closed orbit distortions.

N O T I C E

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ISA CLOSED ORBIT DISTORTIONS AND CORRECTIONS*

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The Brookhaven proposal for building two 200-GeV intersecting storage accelerators, using high-field superconducting magnets, represents a new challenge for accelerator physicists and engineers. The successful operation of the machines will depend on being able to build, measure, reference, and align a large number of magnets whose field distributions depend entirely on the distribution of coil currents. New techniques must be developed to be able to perform these tasks under cryostat conditions. The problem is compounded in the ISABELLE proposal because the magnets for the two accelerators have a common support structure making independent adjustment of the magnets difficult.

At the present time, it is not known whether identical magnets can be produced which have the same diamagnetic and hysteresis behavior, and whether they can all be made to reproduce the same field distributions every time they are pulsed. While one can have a high degree of confidence that many of the possible difficulties will be overcome, the total system should be designed with a sufficient number of monitoring and correction devices to insure successful operation under the pessimistic assumption that some of the problems mentioned above will not be solved. Therefore, as mentioned in the Study Report, it is very important that a sufficient number of correction windings be supplied for both planes in both the dipole and the quadrupole magnets.

Beam position electrodes should be included in each cell. The logical location for these electrodes in the regular lattice structure is at the focusing element for the corresponding plane at the intersections of the dewar units as shown.

* ISABELLE Summer Study Report

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Additional position monitoring devices will be required in the matched insert sections.

Position monitoring during the acceleration period is at least made possible, if not easy, by the fact that the beam will be bunched. Since the beam currents will be large, the sensitivity of the position monitoring structures will not have to be very great. As a result, these structures need not present unduly large series reactances to the beam. The choice of position determining method, i. e. whether to use electrostatic or electromagnetic devices as beam position detectors is of some importance. Straight induction electrodes of sufficient capacity so as not to differentiate the beam signal when operated into circuits of reasonable input impedance and frequency response do not appear to be practical, both because of the problem of "sanitizing" them from the standpoint of high-order modes and because of space considerations. Traveling wave electrodes appear more attractive because of their inherently great band pass and freedom from high-order modes when properly terminated. They possess an additional advantage; they may be used as beam motion drivers both for damping instabilities and tune measurements. However, care must be taken to keep their characteristic impedance low so that they do not present too much series reactance to the beam.

Pickups that operate magnetically might be considered. A drawing that represents, conceptually, a possible design is shown in Fig. 1. The cores and coils are completely outside of the vacuum chamber and continuity for the beam image currents is supplied by the shield. A ferrite should be chosen for the cores whose permeability is almost completely imaginary at the bunching frequency and higher; for example, Allen Bradley WO-1. The series impedance seen by the beam can be made to depend only on the turns ratio and the impedance presented to the secondaries over a frequency range of several octaves through careful design. High-order modes will be damped by the core material itself. Again, these pickups can be used to either take signals from or impress signals on the beam.

All the suggested schemes have advantages and disadvantages. The particular approach chosen for development will depend on the personal prejudices of those actually responsible for the work. It is possible that a mixed system, utilizing magnetic pickups to sense "slow" closed orbit distortions and traveling wave pickups for sensing fast transverse beam motion and applying feedback, will be the final choice.

Based on a rough estimate, assuming 90° phase advance per sector and a Q value equal to $18-1/4$, the expected orbit distortions due to an average field error of $\Delta B/B$ in one cell is about $1.6 \Delta B/B$ meters. An average rotation of the dipole field in one cell by $\Delta\theta$ produces a midplane distortion of the same amount ($1.6 \Delta\theta$ meters). A displacement of the focusing quadrupole in one cell by Δx produces a distortion in the corresponding plane equal to $2.4 \Delta x$. Contributions from various cells will add or subtract depending on their phase. A

very unfortunate distribution of errors in the 90° quadrant sectors could increase the above numbers by a factor of six. Errors and misalignments in the matching straight sections will produce additional distortions.

Because of the structure of the machines, a conventional type harmonic analysis of the position error signals does not appear to be practical. With adequate programming, it should be possible to determine the locations of cell errors by paying very close attention to the phases of the position signals, as illustrated by the very much simplified examples shown in Fig. 2. Those error terms which do not show the indicated phase jumps must come from the matching straight sections.

Under the most pessimistic assumptions, the currents supplied to the correcting windings may need to be readjusted at every pulse and changed continuously during the pulse. In this event, the computing program for analyzing the error signals must be operated on line and should be used to automatically supply the correction currents. Since the system is designed to operate as a storage device, delays during injection and acceleration of the order of minutes due to computer calculations should not be serious. The accelerating "pulse" could conceivably be a series of stop and go operations as the computer makes the necessary corrections.

Instead of depending on the analysis of changes in the position signals to pinpoint possible dynamic errors during acceleration, it may be possible to use the signals from horizontal and vertical $\dot{B}$ coils. These coils could be an integral part of the inner cylinder, placed in accurately machined slots, one pair for each of the three magnets in each dewar unit. Although it may be possible to align these $\dot{B}$ slots with respect to the beam lines with more accuracy than the magnets themselves, one need not depend on the absolute value of the signals to detect errors. In particular, any changes in the $\dot{B}$ signal from the coil through the top and bottom slots during the pulse would indicate an effective rotation of magnetic dipole. Also, any differences in the signals from the horizontal coils of different cells may indicate that the fields are not rising at the same rate. It is possible that the signals from such coils could be used to determine correction coil currents directly.

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Fig. 1

If the reactance of the coils is large compared to Z_o , then the system is terminated for signals returning from the resistive mixer. The resistive component of the series reactance presented to the beam is, approximately

$$R \approx \frac{1}{4} \frac{Z_o}{n}$$

where n is the number of turns and there are four such coils (two vertical and two horizontal) on the core.

Fig. 2

Orbit Positions Caused by Error in Cell A

Orbit Positions Caused by Error in Cells A and B