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ACCELERATOR DEPARTMENT
Informal Report

QUASI-COMBINED FUNCTION MAGNETS

FOR ISABELLE

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ABSTRACT

A magnet design in which the dipole and quadrupole windings are located concentrically in the same iron core is proposed. The resultant space saving in the lattice leads to a higher energy for ISABELLE without changing the overall ring size. Other advantages of this design are discussed briefly.

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Introduction

Three of the more obvious reasons for preferring a separated function lattice for a superconducting accelerator or storage ring are:

1. The higher field introduced by a gradient component limits the dipole field since this is determined by the properties of the superconductor and the peak field in the windings. It can be argued that it is better to construct dipoles operating at the highest field practical, thus permitting higher energy operation or a smaller ring.

2. Asymmetric windings are required to produce a gradient term since superconducting magnets are basically air core devices. Such windings, while not impossible to fabricate, are difficult to wind and probably subject to larger random errors in conductor location.

3. A combined function magnet does not allow independent adjustment of orbit parameters.

There are, however, certain advantages to a magnet type which incorporates some of the features of combined and separated function designs.

Quasi-Combined Magnet Design

Figure 1 shows schematically the cross section of a magnet in which the quadrupole winding is situated inside the dipole coils, becoming in effect a large "correction" winding. This design eliminates or minimizes the difficulties mentioned above, since all windings are symmetric and the dipole and quadrupole coils are separately powered. The high field produced by the gradient term can be partially compensated for by designing the coils so that the quadrupole winding has a minimal effect on the naturally occurring high field point in the dipole. The highest field point will then occur in the quadrupole coil and it can be allowed for by reducing the current density in this winding or using better (i.e. more expensive?) conductor. The bulk of the conductor (i.e. that in the dipole winding) would not be subject to the highest fields.

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FIG 1

Some of the advantages of this configuration are listed below:

1. Precise location of the quadrupole windings relative to the dipole field. The magnitude and orientation of the quadrupole term could be trimmed by a small auxiliary winding orthogonal to the main quadrupole winding. This would also allow easy compensation of the random quadrupole component of the dipole winding itself.
2. Elimination of the quadrupole dewars which are inordinately expensive on a unit length basis.
3. Improved "packing" of the lattice because the space between dipoles and quadrupoles and the transitions to room temperature could be used for more dipole length.
4. Series connection of the quadrupole windings at low temperatures over an octant resulting in reduced lead losses.

Implications for ISABELLE

If magnets of this type were substituted in the present ISABELLE lattice, the length of the dipoles would be almost 5.5 m if the present dipole to dipole distance (0.9 m) is maintained. Almost all the gains in dipole length come about because the end effects and transitions to room temperature are overlapping for the combined quadrupole and dipole. The difference in the two lattices is shown schematically in Fig. 2. For the magnet design of Fig. 1, the peak field seen by the dipole windings at a 40 kG central field is 45.7 kG which is only about 3 kG higher than the peak field in the pure dipole design. The gradient has been chosen as 1.5 kG/cm which should be close to the required value. With the longer dipole, the energy at the same peak field (42.5 kG) for the long magnet lattice would be 240 GeV. The design energy of 200 GeV would require a central field of 33 kG (35 kG peak) whereas an energy of 260 GeV would correspond to a central field of 40 kG.

Field and Force Calculations

Mark Barton has pointed out that the force distribution on the quadrupole winding is considerably more difficult to deal with in this design than in the pure dipole case. He has suggested that most of the gradient term could be supplied by an asymmetric main coil with ν variations being adjusted

by a smaller correction type quadrupole winding. P.F. Dahl has made some preliminary calculations of the magnetic field and force distributions in a quasi-combined function magnet using the computer program MAGFLD. The results of these calculations are shown in Fig. 1.

Conclusions

The quasi-combined magnet design appears to have some interesting properties. A more detailed design is necessary before it will be obvious if model studies are indicated. The author would appreciate any comments on the usefulness of this design.

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