COMMENTS ON THE USE OF SUPERCONDUCTING BEAM TRANSPORT MAGNETS

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ABSTRACT

Comments on quadrupole aperture, magnet dimensions, and magnet heating by secondary beams are made in the particular context of the plans for target-area 2 developed in this summer study. The qualitative effect on these plans of the choice between superferric and conventional bending magnets appears small.

To permit developing concrete secondary beam proposals for target-area 2 the members of Group A have assumed a set of magnet dimensions:

	Aperture W×H (cm)	Coil W×H (cm)	Outside W×H×L (cm)
Bending magnet (thick septum type)	10×7.5	3.8×7.5	64×100×300
Quadrupole[1] ("front end type")	10×10	10×5	32×60×300

These are shown in Fig. 1 of H. White's report SS-37. It was intended that these dimensions be realizable in either superferric or conventional designs so that the choice would be open for the proposed beams. The desirability of keeping the option as long as practical seems clear in view of the short lead time for area 2, limited experience with cryomagnets on one hand and the substantial operational economy predicted for them[2] on the other. If one could rely on having not only superconducting bending magnets but quadrupoles as well, additional economic advantage might be obtained by going to smaller aperture. Not only magnet size but also overall beam length could be reduced in proportion. The discussion of Danby and Good[1] leading to the recommendation of four-inch quadrupoles is based on current density feasible in a copper coil. Structural imperfections do, of course, set some lower limit on quadrupole aperture, which is probably about two inches for 15-kG pole-tip field.

A closer examination of the assumed bending magnet indicates that the desired aperture and outside dimensions are reasonable but that a thick septum width of 1.5 in. is obtainable only with a superconducting or cryogenic coil.[3] For a copper coil with the not very conservative current density of 7.5×10^3 amp/in.^{2} the necessary 1.2×10^5 amp-turns requires a coil width of five inches. However, a four-inch wide gap and

15-kG iron field requires a return yoke of only 12 in. Thus, a minimum size iron-copper thick septum magnet would have approximately the dimensions following:

	Aperture W×H (cm)	Coil W×H (cm)	Outside W×H×L (cm)
Bending magnet (thick septum type)	10×7.5	12.5×7.5	68×68×300

Such a magnet would probably not be run at 20 kG for many applications, because even at 200 BeV/c the ~ 1.5 cm sagitta represents a significant loss in aperture. For general use one may indeed prefer to pay the price in space and capital for five cm more of horizontal aperture. Then for up to thirty mrad bend one would have the 3:4 horizontal to vertical aspect ratio found desirable in the detailed deisgns.

The increased septum thickness certainly requires some adjustment of the detailed proposals for target-area 2, but the necessary changes to not appear catastrophic on the face of it. In the 2.5-mrad unseparated beam, for instance, either another wide-aperture bending magnet or else a few meters extra drift space is required before the Y. At least for the two small-angle beams, no change in production angle or target distance is required and the choice of magnet type is not biased in a major way by the above considerations.

It seems, however, that the heat load due to beam bombardment should be further examined for its economic effect on the choice. In the report of Stekly, Fast, and Cohn,[2] it is assumed that only heating due to muons need be counted. It is clear, however, that regardless of collimation and pole face shielding, some off-momentum hadrons will be bent into the pole tips. Undoubtedly this flux is hard to calculate. Certainly it depends on specific beam designs. Probably it represents a small fraction of secondary production. Nonetheless, because much of the energy of such particles will be deposited in the magnets the economic perturbation may be significant. The whole first section of a beam is liable to significant hadron irradiation. The collimator for the 2.5 mrad beam, for instance, will accept 800 W of diffracted proton beam. For lower momentum tune some appreciable fraction, of the order of 10%, will be scraped off in the bending magnets. The field lens is also in a vulnerable location. Since a magnet represents roughly three interaction lengths of iron perhaps 10% of the intercepted energy or some two watts per magnet will be deposited in the first section of the beam.

Because target-station 2 has a rather short lead time and because it was desired to handle as many conventional beams as practical, hyperon beams and short-lived neutral beams have not been included in this area. In discussing their inclusion, however, it became clear that this sort of thing would be easier to handle if high-field magnets were available. It would be desirable for NAL to mount a high-field development program which would produce some useful magnets for target-area 3. The usefulness of these magnets would be greatly increased by their ability to cope with high particle and radiation levels.

REFERENCES

[1] G. Danby and H. Good, Quads and Bending Magnets for NAL, National Accelerator Laboratory FN-145, May 1968.

[2] Z. J. J. Stekly, R. W. Fast, and C. Cohn, NAL Superconducting Magnet Program, in Research Facilities Design Concepts–Summer 1969, National Accelerator Laboratory Internal Report TM-181, May-June 1969.

[3] S. C. Snowdon, private communication.