Magnets for a muon front-end chicane

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Abstract. A magnet system for transfer of muons from a pion decay channel to a linear accelerator is described. The decay channel is followed by four sets of combined function, triplet magnets, arranged as an achromatic chicane for 190$\pm$70 MeV muons.

1. Introduction

Use of an achromatic bending chicane to give muon beam bunches a longitudinal, reverse phase-slip is outlined in a companion paper [1]. An optimum slip occurs in a 17 m magnet lattice if gamma transition is 1.68 for its four sets of combined function triplets. The basic three-dipole unit bends the beam successively by 64°, -27° and 64°, but the second two sets provide equal and opposite bends to the first two. Focusing is provided both by edge-angles and by shaping the poles for an FFAG-type, vertical, field law, $B = B_0\,(r/r_0)^{-n}$. Achromatic paths result for 120 to 270 MeV muon energies.

2. Magnet design

Parameters of the symmetrical B1-B2-B1 triplet units are given in Table 1.

The 0.5 m spacing of the magnets is comparable with their 0.3 m vertical gap heights and it has thus been important to determine whether field requirements are met and if the energising coils clash. The magnet program Opera-3d has been used for separate designs of the B1 and B2 units, with yoke length adjustments made to compensate for the considerable excess magnetic lengths resulting from the large apertures.

Table 1. B1 and B2 magnet parameters.

	B1	B2
Bend angle (°)	64.0	-27.0
Edge angle (°)	21.275	13.5
B_0 (Tesla)	1.4615	0.8221
r_0 (m)	0.63026	1.12045
n value (negative)	0.15496	0.34746
Radial width (m)	-0.6 to 0.6	-0.4 to 0.6
Vertical gap (m)	0.3	0.3

Return yokes of both magnets have been increased in size to carry the large fringe fields. When both B1 and B2 magnets are combined in a model of the B1-B2-B1 triplet, there are no physical clashes found but the simulations show the fringe fields merging.

The particle tracking facility of Opera-3d has allowed studies of the off-energy muon orbits. Triplet magnetic fields have been set so that a pencil beam of 190 MeV muons is bent symmetrically through the required 101° angle. Pencil beams of muons in the energy range 120 to 270 MeV should then enter the triplet at an angle of 50.5° to the z-axis and emerge as a dispersed, parallel beam at -50.5°, as shown in Figure 1. Correction for the low energy muons is obtained by increasing the inside fields of both the B2 and B1 units. This has led to poor high energy muon orbits, however, because the magnet lengths are short in comparison with their widths and the steel in B1, in particular, is very highly saturated.

It has proved necessary to change from an FFAG field law and to vary both the pole profile and the yoke length in the beam direction in order to achieve parallelism of the emergent muons. This has resulted in the required edge angles of the B1 magnet not being maintained, and the effect on muon beam optics is currently under study. The

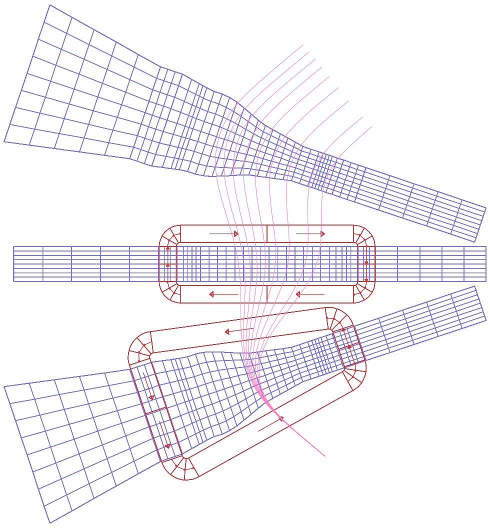

Figure 1. Off-energy orbits in a chicane triplet.

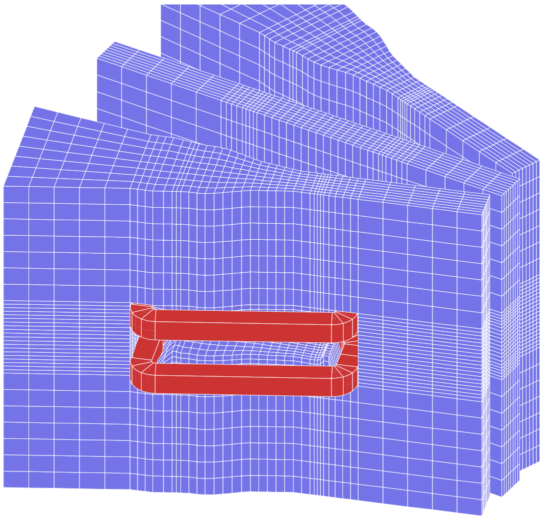

Figure 2. Chicane triplet arrangement.

emergence angles of the 120 to 270 MeV muons are within -0.5° and +0.6° of the required -50.5°, and magnet shimming should reduce these errors to the required precision.

Figure 2 gives an idea of the appearance of the magnets, though their dimensions have not been optimised for minimum steel weight. The file FB1B2.OPPRE has been used for storing magnet modelling data.

Approximate weights and power consumptions are 30 tonnes and 225 kW for the B1, and 25 tonnes and 100 kW for the B2, respectively, for 340 tonne and 2200 kW totals. Work continues on the magnet designs, together with detailed muon tracking studies [1] of transmission efficiencies. The chicane lattice option proposed [1], with a zero gradient in B1 and a reduced gradient in B2, is also under consideration.

References

[1] G.H. Rees et al., Muon front end chicane and acceleration, Proceedings of NuFact02.