Magnet Iron Reference Design Summary

E614 Technical Note #37

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Introduction

The E614 spectrometer will operate in a 2 T uniform axial magnetic field produced by a superconducting coil. The coil will be mounted in an iron (steel) enclosure which must meet these requirements:

- preserve a uniform field over the effective volume of the spectrometer wire chambers.
- provide suitable characteristics for the field near the axis at the entrance to preserve the polarization and phase space of the incoming surface muon beam.
- provide a flux return flux path in order to keep stray fringe fields to a manageable level.
- allow adequate access to the detector and cryostat during installation, commissioning and operation.

Design Studies

Various studies have been carried out to address the magnetic, mechanical and cost issues. These include:

- Alan Otter and Paul Reeve (c.1994) -- studies of Russian and western SC magnets with 3.2T field. Concluded cost of US$700 -- 800K.

- Don Lobb (c.1996) -- OPERA 2D (cylindrical return yoke) and 3D (1/8 model of square return yoke) studies of a used MRI SC coil manufactured by Oxford Magnet Technology and available from Cryomag Services in New Jersey, which we have subsequently purchased. These calculations also investigated the field strength possible with 5% over current (242A -->254A). Conclusions were:
  1. Square yoke with holes on the sides (one for cryostat services, three more for symmetry) gives field uniformity of +/-0.1% which was close to the limit of the sensitivity of the calculations.
  2. Ordinary (not premium) magnet steel is acceptable.
  3. Maximum field with 5% over current is 2.3T.
  4. Nominal length of iron of 3.2 m is acceptable for muon transmission.

- George Clark (1998) -- investigated relative costs of square vs. cylindrical configurations and concluded that the former was comparable with the cheapest cylinder at a ball park cost of C$260K.

- Mike Barnes (1999) -- initially with Peter Gumplinger, reviewed and confirmed Don's 2D calculations, and proceeded to study variations in total length, end plate thickness, and axial (beam) hole geometry to determine an optimum for muon transmission and polarization, in conjunction with Dennis Wright et al. and Jaap Doornbos. Conclusions were:
  1. Iron can be shortened to 2.8 m nominal length
  2. End plates thickness must be reduced from 10 cm to 8 cm to preserve field uniformity.
  3. Beam hole diameter should remain 40 cm.
  4. Qualitative 2D studies of return yoke radius indicated that the holes for the cryostat and detector services (cables and gas lines) should be on the centre of the sides in order to even out the return path reluctance and improve azimuthal field symmetry. These studies also gave an overestimate of the field non-uniformity of +/-1%; the result from Lobb's 3D calculation (+/-0.1%) is a better estimate.
  5. Fringe fields of order 0.1T will be expected in regions where the yoke iron is saturated --- on the end plates and near the access holes on the top.

- Frank Davis (Oxford, c.1992) -- 3D calculations done on a shield for a similar coil at Los Alamos. This configuration had end plates with holes and side plates, but no top or bottom. These results showed that with this asymmetric iron configuration and with misalignments of +/- 20 mm, forces on the magnet coils would be acceptable. Our iron is more symmetric and we intend to meet alignment tolerances of <<1 mm. The remaining sources of effective misalignment are the unknown internal position tolerance of the coils in the cryostat and any nonuniformity in the magnetic properties of the iron, both of which are expected to be small. These studies also gave values for field uniformity and shimming strategies. They are not relevant quantitatively, but nevertheless encouraging, qualitatively.

- Willy Andersson (1999) -- has begun design of mechanical details of construction to meet the alignment requirements and the mechanisms for access (e.g., the back door), as well as issues for location in the M13 area.

◇ <u>Preliminary Design Review</u>

The review committee concluded that further 3D calculations are unlikely to shed more light on the mechanical design, and that the detailed design could proceed based on the current information. Priority should be given to this so that the design can be reviewed and the steel and fabrication ordered in this budget year. The field uniformity will need to be addressed based on mapping of the magnet itself. Some shimming may be necessary. The committee also recommended that problems related to the significant fringe fields must be dealt with; where additional iron can be added without compromising the field uniformity, it should be; elsewhere, procedures or structures to assure safe operating must be devised and reviewed.

◇ Reference Design

Dimensions: (for manufacture in imperial units, actual dimensions could be rounded to 0.005"; other minor modifications may be made to accommodate standard material availability.)

	mm	in
end plate thickness	80.0	3.150
yoke thickness	200.0	7.874
length(inner)	2800.0	110.236
length(outer)	2960.0	116.535
width(inner)	2210.0	87.008
width(outer)	2610.0	102.756
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General Design Concepts:

- base plate will extend to outer dimensions to support all components: will be aligned and fixed to the floor with limited provision for removal and reinstallation.
- top plate removable by crane for installation of cryostat.
- upstream end plate removable by crane for initial installation, and subsequent (rare) upstream access to detector.
- downstream end plate mounted on hinge system for routine access to detector.
- end plates have 40-cm diameter holes on beam axis with provision for shimming.
- top yoke plate has central hole for cryostat services and slot on centre at downstream edge for detector services (approx. 500 cm^2); similar slot upstream for symmetry.
- Similar holes/slots on the sides and base plates could be provided for symmetry, although this would add to the cost and to the problem of fringe fields. A preferred strategy is to provide only the necessary holes and compensate by shimming with additional iron beside the holes.
- Cryostat mounted on baseplate and aligned to the centre of the iron assembly by a procedure to be worked out in conjuction with the detailed design.

Fig.1 illustrates side and end schematic views of the magnet iron, also showing the cryostat and approximate dimensions of the detector array.

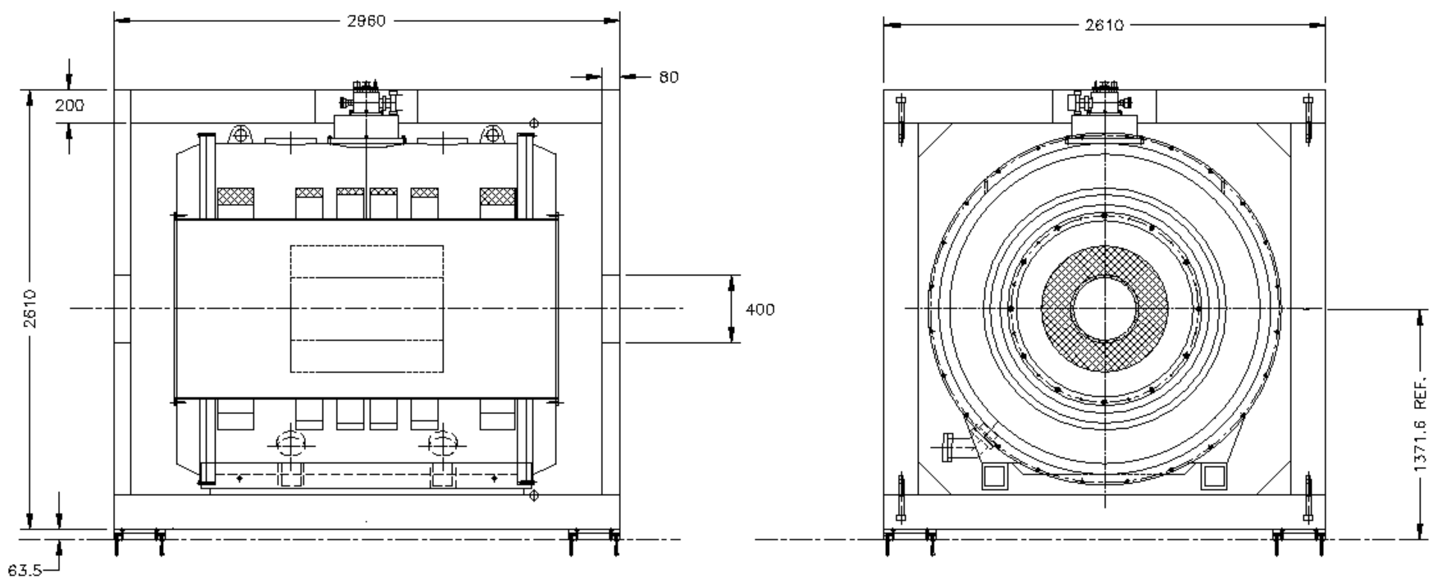

Fig. 1 Schematic of magnet iron showing cryostat