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**Author**
Milburn, J.

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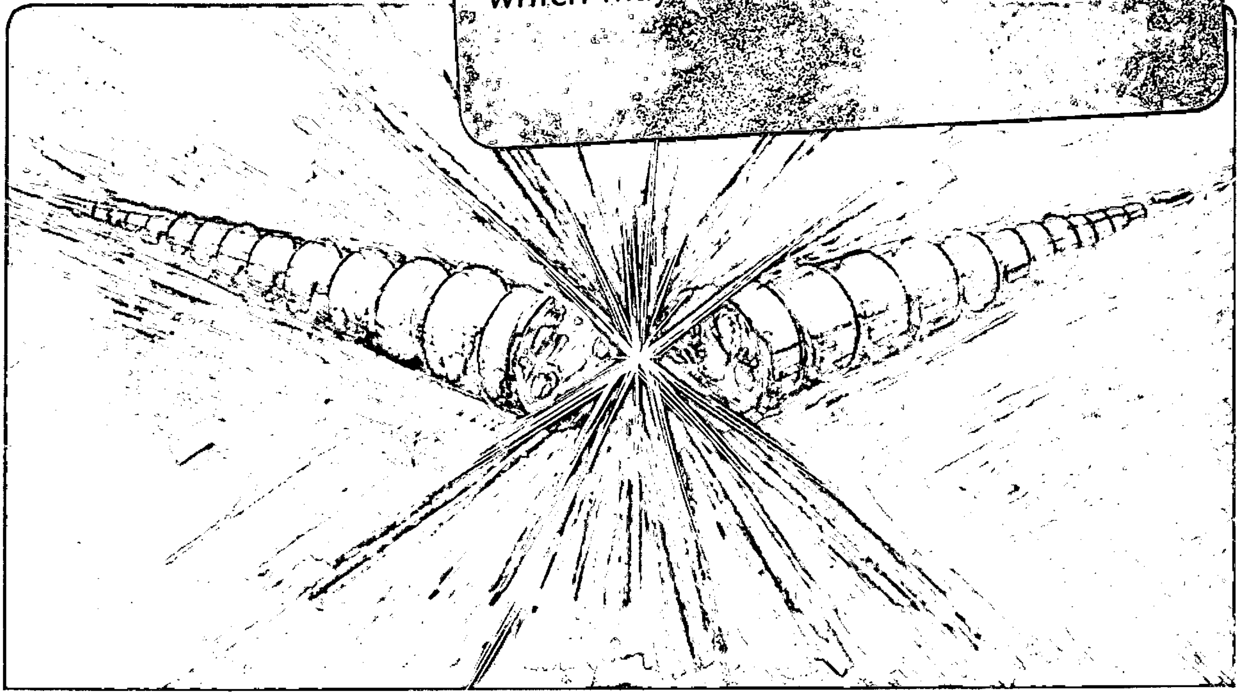

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# DESIGN OF A THREE CHANNEL SEPTUM MAGNET*

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J. Milburn, J. Porter, J. Tanabe, R. Caylor, and R. Reimers
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

## Abstract

A three channel septum magnet has been designed to service the three primary beam lines at the exit of the SuperHILAC. A pulsed switching magnet located in the next to last drift tube in the SuperHILAC poststripper diverts the beam ± 1.09° into either the north or south port of the septum magnet. The central channel allows an undiverted beam to pass into another distribution magnet downstream. All channels may be active simultaneously and each may be tuned independently. Each septum channel contains four separate field regions and bends the beam 14.91°. Various important aspects of the design, including geometry, material selection, thermal characteristics and power requirements, are discussed.

## Introduction

The new septum magnet is designed as a drop-in replacement for an existing tape-wound, freon-cooled septum magnet. The existing magnet is located one meter downstream of the SuperHILAC end-wall. A small entrance septum leads to high local power densities which cannot be adequately cooled in a magnet of this type, and improvements need to be made in the magnetic shielding so that field changes in one channel of the magnet will not affect the tune of the central channel. This is important because the SuperHILAC beam is time-shared among several users, and it is often an operational requirement to re-tune one channel while leaving the tune in the other channels undisturbed. Investigation of possible modifications to the existing magnet lead to no satisfactory solution to these problems.

The decision was made to design a replacement magnet which uses conventional water cooled, hollow core conductor. Such a magnet represents a significant gain in reliability and performance due to the ability to adequately cool the conductor directly at the location of heat generation. However, the unavoidable penalty paid to meet the new requirements is a higher power consumption and greater current densities associated with the lower conductor packing factor.

The objectives of this design are to match entrance and exit beams to existing beam lines, to provide high reliability at full field operation, to maintain present beam transmission characteristics, to minimize fabricating and operating costs, and to minimize stray magnetic field in the center (drifted) beam channel.

The new assembly functions as two independent magnets, each separately adjustable and capable of operating with any beam with a rigidity less than or equal to 25 kilogauss-meters. Magnet parameters are shown in Table 1. The plan view of the magnet is shown in Figure 1.

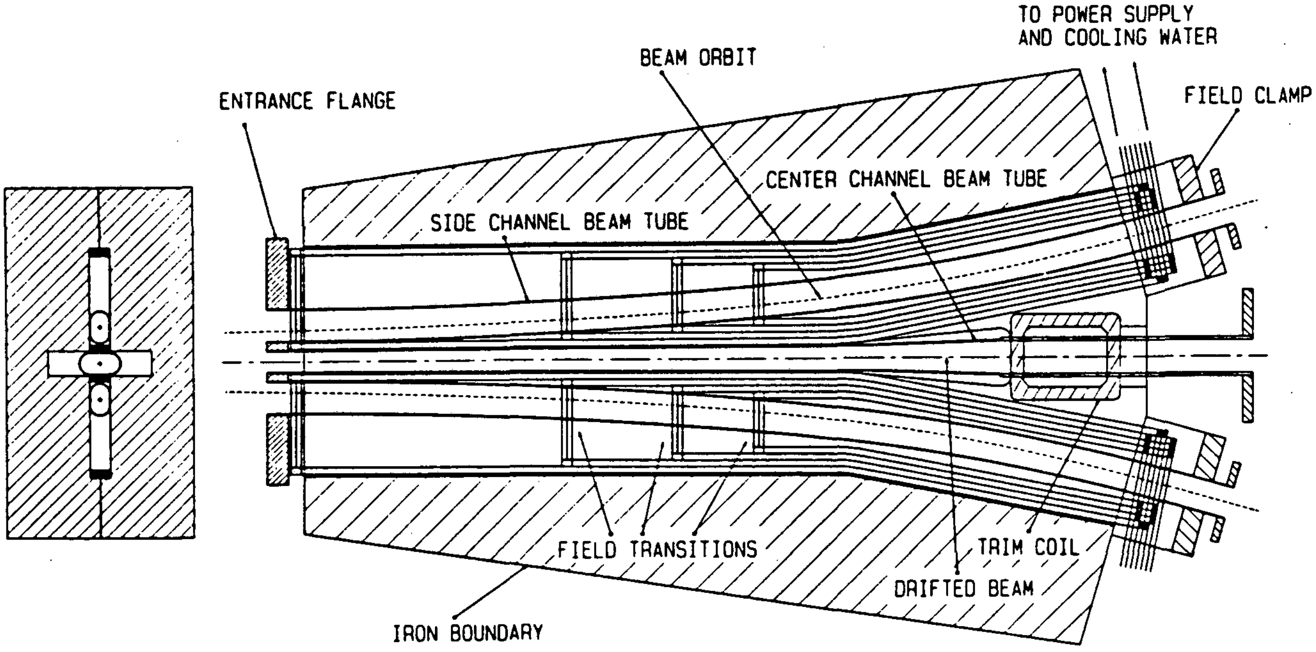

Fig. 1 SEPTUM MAGNET LAYOUT

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Table 1
Septum Magnet Design Parameters

| | |
|---|---|
| Magnetic field in region 1 | 2.48 kilogauss |
| " " " region 2 | 4.96 kilogauss |
| " " " region 3 | 7.44 kilogauss |
| " " " region 4 | 9.92 kilogauss |
| Maximum magnet current | 1250 amperes |
| Maximum voltage drop | 55 volts |
| Maximum power consumption | 69 kilowatts |
| Coil inductance | 920 microHenry |
| Stored energy | 720 Joules |
| Number of water circuits | 16 |
| Water flow | 55 liters/min |
| Iron weight | 850 kilograms |
| Coil weight | 7.9 kilograms |

## Conductor Selection

The coil conductor was chosen early in the design process. A custom 5.1 mm x 7.1 mm conductor was selected. The 5.1 mm dimension allows four stacked conductors and their insulation to fully fill the magnet gap. The 7.1 mm dimension permits one conductor to entirely fill the available clearance at the entrance septum. A rectangular conductor such as this requires an oblong cooling channel due to tooling and forming requirements. A 1.27 mm wall thickness presents an optimum conductor to cooling channel area relationship. The conductor cross section is shown in Figure 2.

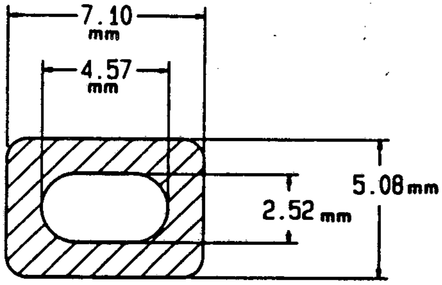

Fig. 2 CONDUCTOR CROSS SECTION

## Field Shape and Beam Orbit

Because of the limited space along the beam orbit and the limited septum clearance allowed by the adjacent beams, a four stage septum magnet design was developed. As the lateral clearance increases along the beam path, additional conductor layers are added to increase the magnet field. Thus the relative fields increase in the ratio 1:2:3:4 in the four magnet sections. The magnetic field along the beam axis in one of the bending channels is shown in Figure 3. The magnetic field in the transition regions is modeled by a series of step functions. The model assumes that the space between the step functions at the boundary of the different field levels is a region of zero field and thus a drift space for the beam. Information about the placement of the steps was obtained from data generated by the program POISSON.[1] Initial beam orbit calculations are made using the step function model. Once the pole tip lengths were chosen using this model, the beam orbit was verified using the POISSON magnetic field data in the ray tracing code ORBIT.[2] The step function model proved to be adequate for obtaining a good estimate of the required geometry.

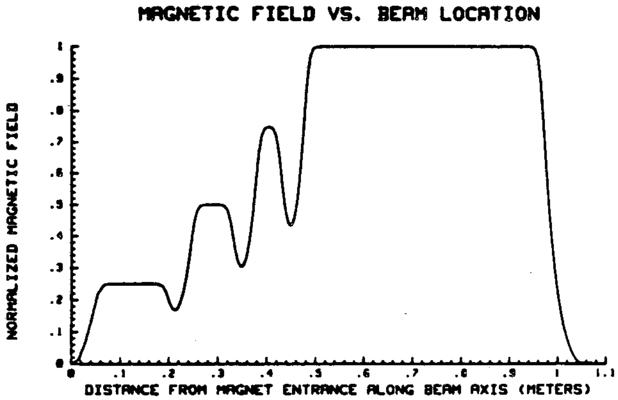

Fig. 3 MAGNETIC FIELD PLOT

## Magnetic Shielding in the Center Channel

One of the primary design considerations is the minimization of stray magnetic field in the center beam channel. A 1.1 mm wall type 410 stainless steel beam tube is used for magnetic shielding. Type 410 stainless steel is chosen for its relatively high permeability coupled with its resistance to corrosion. The return yoke thickness is increased to lower the field below saturation in the region. This results in a lower fringe field. Calculations show the maximum stray field in the central channel, with both steering channels fully energized, to be less than 0.5 gauss.

## Power Requirements

For the SuperHILAC maximum beam rigidity of 25 kilogauss-meters, the required bending field in the first field region is 2.48 kilogauss. This leads to a required current of 1250 amperes in each conductor. Because of the small cross sectional area of the copper, the coil resistance and the current density are high. The current density in the copper is 4,900 amperes/cm$^2$. The coil resistance is .044 ohms. The total voltage drop across each magnet is 55 volts. Power consumption at full field is thus 69 kilowatts per channel.

## Heat Transfer

The high current density of this magnet requires that each turn be cooled independently. Thus there are 16 parallel cooling circuits per magnet. For the longest turn in the magnet, a 35 kPa pressure drop leads to a 40°C temperature rise. Flow required in the longest turn is 1.52 liters/min. The maximum allowed conductor temperature is 70°C.

## Reference

[1] POISSON is an LBL 2-dimensional magnetostatic code.

[2] ORBIT is an LBL 3-dimensional ray tracing code written by J. Staples.

TECHNICAL INFORMATION DEPARTMENT
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720