Chapter 4

Magnets

The two spectrometer arms of the BRAHMS Experiment have a total of five dipole magnets. The magnets are conventional iron-dominated magnets with coils constructed of copper conductor and epoxy/glass insulation. The design considerations, preliminary cost estimates, and the support utilities for the magnets will be presented below.

Several parameters control the overall design of the magnets. The desired angular acceptance is the main determining factor in the horizontal and vertical gaps of the magnets and the momentum resolution determines the necessary integrated Bdl of the dipoles. The magnets are of window frame design with return yoke on one side, with the exception of D4, to accommodate the forward operating angles of the spectrometers. The window frame design provides good field quality in the magnet aperture and reduces the fringe field on the collider beam. The maximum operating field has been chosen to minimize the effects of the stray field but be high enough to achieve the needed integrated Bdl in the allotted space. Typically, the magnets have a maximum operating field of 12 kG. A summary of magnet parameters is given in Table 4.1.

The final physical parameters of the magnets are controlled by the design of the return steel and the coil. The return steel dimensions have been established by requiring that the iron thickness be one half of the horizontal gap and coil width multiplied by the ratio of the maximum operating field to 12 kG. Thus, at the maximum field the return iron is starting to saturate. The coil dimensions and conductor size are established by the available space, required Ampere-turns, and cooling requirements. The top and bottom saddle coils are run in series. The cooling paths in the conductors have been sized to provide sufficient cooling and have pressure drops and temperature rises consistent with similar systems at the AGS. The parameters of the steel and the coils are presented in Table 4.1.

4.1 Design Features

The physical layout of the magnets in the experimental area of the 4 O'clock hall is shown in Figure 4.1. The plan view of the magnets depicts their present conceptual design with the criteria summarized in Table 4.1. Detailed designs of several of the magnets have begun. Figure 4.2 shows the preliminary details of steel for D5 and Fig 4.3 details of the D5 coils.

Magnetic modeling of each of the conceptual designs will be done in both two and three dimensions to quantify the magnetic properties of the design and to aid in considering design alternatives. 2-D modeling has been completed on the five magnets using the program POISSON. Since the magnets are long relative to the gap, the two dimensional modeling will provide a good characterization of the gap field and also the fringe field on the beam side of the magnet. We present a few results for magnet D1 to demonstrate the magnet modeling. The permeability table for Inland steel 1001 has been used to reduce the fringe field. The vertical field component across the gap is shown in Figure 4.4. The good field quality across the gap is evident. The vertical component of the fringe field on the collider side of the magnet as a function of distance is shown in Figure 4.5. It is seen that the field on the collider beam is about 7 Gauss (near the front of the magnet), while the central field in the gap exceeds 12 kG. 3-D modeling has started with the program TOSCA. The three dimensional modeling will provide for estimates of the field clamp thickness, end fields into detector volumes and fringe fields which may affect the collider beam. A preliminary TOSCA result for the vertical field along the center of the D1 magnet gap is shown in Figure 4.6. The magnetic modeling will continue in conjunction with the magnet design effort.

4.2 Estimated Costs

A preliminary cost estimate has been done for the magnets. A price of $2 per pound for the machined magnet steel has been assumed. This should be a conservative estimate, but will vary based on the size of the magnet, the amount of machining and the quality of steel specified. It is expected that most of the magnet iron will be a low carbon steel such as 1006 but several magnets may be constructed of higher quality magnet steel such as 1001. Preliminary designs of the magnet coils were submitted to a vendor for estimation. The cost for assembly, testing, and cabling of the magnets is contained in the estimates for the experiment installation. It is anticipated that possible changes in the magnet designs will be well within the allowed contingency.

The present design of D4 utilizes an existing magnet. The steel will be modified to increase the vertical gap. The existing coil is sufficient for the desired 12kG field. An option to upgrade the coil package for 17kG has been considered but at present is unnecessary. The final design of the collider magnet, DX, may affect this decision. If the close proximity of DX and D3 limits the D3 design below the designed 24kG-m, then an increase in the D4 field with an upgraded coil package could compensate for the decreased bending in D3. The present solution is the most cost effective and meets the experimental requirements.

Several alternatives were considered for magnet power supplies. We are obtaining magnet power supplies from the decommissioned LBL Bevalac Facility. These supplies will require considerable work to repackage for use in BRAHMS. However, new water cooled supplies would be considerably more expensive. Finally, the option of using existing power supplies from the AGS program has been examined, although the availability of such supplies will probably not be known for several years. This option is the most cost effective but the least certain. Therefore, we have chosen the option of repackaging LBL supplies but will continue to examine future options to minimize costs.

4.3 Magnet Support Carriages

The intended ranges of angular motion are shown in Fig. 4.1 for both the Forward and Mid-rapidity spectrometer arms. For the Forward arm, note that the symmetry axes defined by the magnet opening gaps (D1 through D4) do not lie on a straight line, but are necessarily articulated in angle. The separate carriages required to support these elements (3 in number) are outlined briefly below.

(1) MID-RAPIDITY ARM

Elements of the Mid-rapidity arm will be mounted on a carriage platform positioned to rotate (on wheels) about a vertical axis through the nominal vertex position. The platform is extended on its outboard side in order to support three equipment racks containing the power supplies and electronics needed for the detector elements as indicated: TPC1, TPC2, TOFW, GASC and BACK.

(2) FORWARD ARM - Front Section

Dipole magnets D1 and D2 are mounted on a platform pivoted at the vertex, but with a provision which allows D2 to be offset relative to the axis of D1. This can be accomplished using a single support carriage, but using a remotely controlled motor-driven adjustment which slips D2 between two previously defined positions. This front carriage element of the Forward arm will also support detector elements T1, T2, H1, and C1, so that this section can be de-coupled from the trailing part of the spectrometer in order to extend measurements to larger angles.

(3) FORWARD ARM - Rear Section

Elements D3 and D4 will be mounted on a separate carriage, which also supports the detector elements T3, T4, T5, H2, RICH and T6. The most plausible scheme assumes the carriage will be tracked on rails (independent of the front section) to predetermined stops, or remotely measured positions, to obtain the desired configurations over the limited angular range selected for this rear section.

DESIGN EFFORTS

Preliminary discussions with design engineers indicate the desired movements can be accomplished within the accuracy specified for the momentum measurements. Note that for the Midrapidity and the Front Section of the Forward Arm, the carried loads are dominated by the magnets supported, namely 8 tons and 20 tons, respectively. Since the vertex pivot point is well-defined, the above scheme resembles closely the mechanical arrangement utilized previously in AGS Experiment-802 which entailed similar rotations and loads, and was found to work quite well. The supported load for the Rear Section of the Forward Arm is substantially heavier than for the 60-ton Henry Higgins magnet described for E-802. However, the desired simple motion over a limited range ($<20°$) again resembles the arrangement used previously for the extended Čerenkov Complex of E-802.

Brahms Spectrometer Magnets

	D1	D2	D3	D4	D5	Totals
Gap						
height (in)	3.15	6	10	12.6	4	
width (in)	7.874	10.75	15.75	20	14	
length (in)	78.75	63	78.75	72	28	
Nominal Field (KG)	12	15	12	12	12	
current (amps)	3200	3570	2813	2400	2210	
voltage (volts)	160	101	100	113	57	
DC power (kw)	512	361	281	271	126	**1551**
Coil Parameters						
weight (lbs)	110	862	3902	7000	271	
no. turns	24	54	96	96	48	
resistance (ohms)	0.049	0.028	0.035	0.0471	0.0255	
temp rise (deg F)	60	60	60	72	60	
flow (gpm)	58	41	32	26	28.4	**185**
no. paths	24	8	6	8	8	
pressure drop (psi)	78	94	81	150	54	
Magnet Parameters						
length (in)	88.5	79	103	96	39	
width (in)	19.3	38.6	56	94	40	
height (in)	22	44	58	56.6	40	
shield thickness (in)	1	2	4	6	1	
weight (lbs)	9064	30050	65200	112515	14500	
Power Supply						
AC power (kw)	602	424	331	319	148	**1825**
AC current (amps)	1234	869	678	653	304	

Table 4.1: Magnet parameters

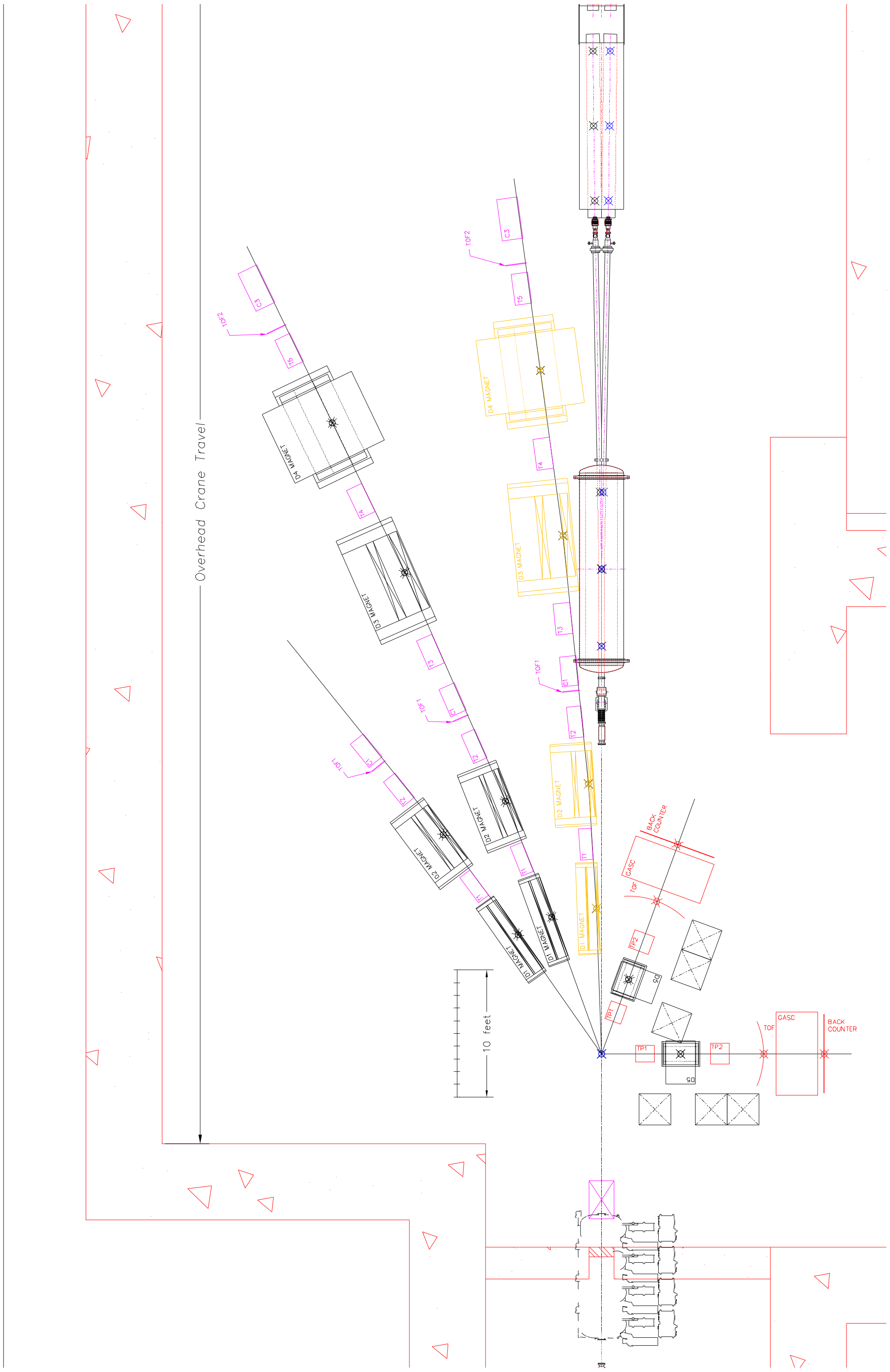

Figure 4.1: Layout of the 4 o'clock area.

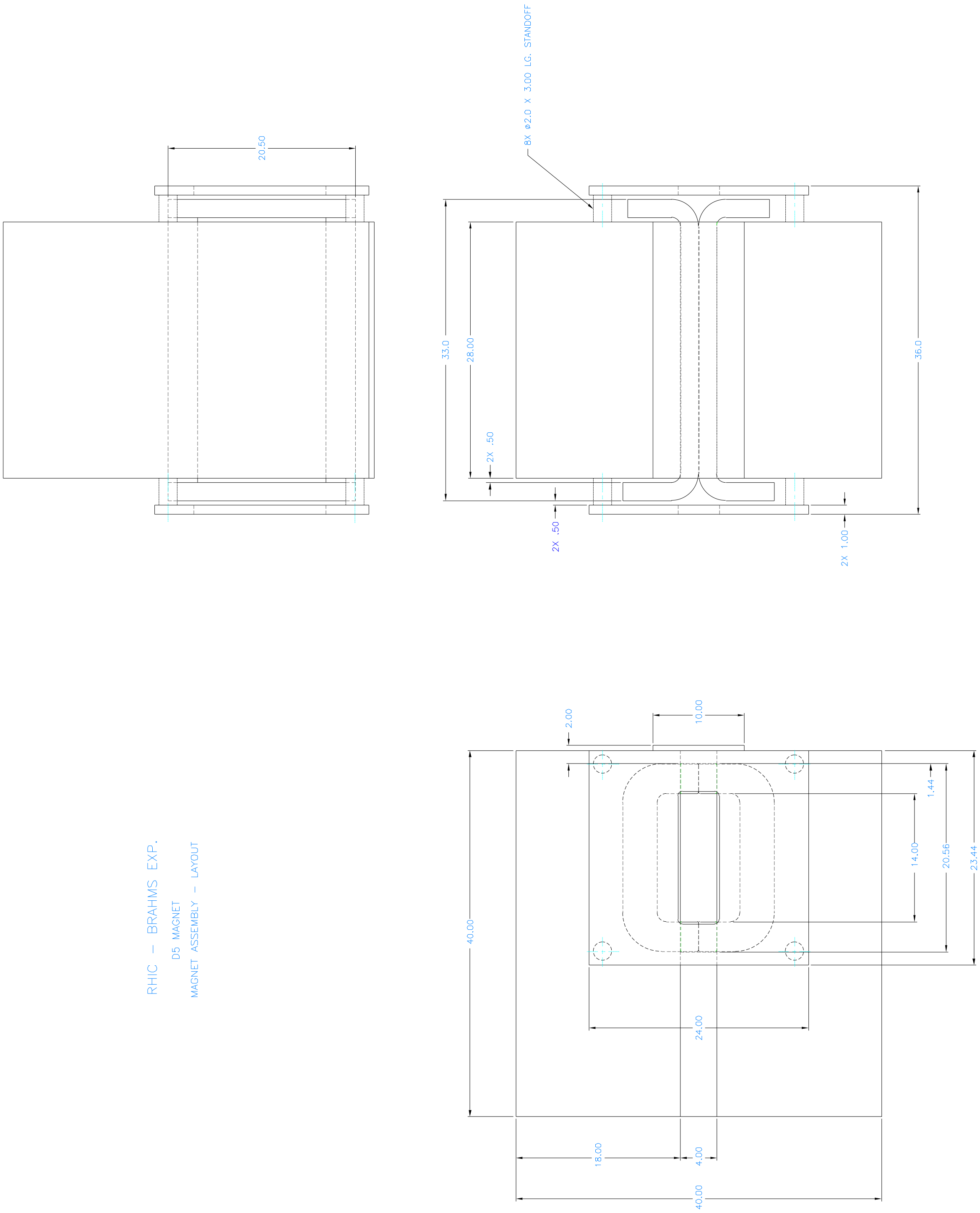

Figure 4.2: Steel design for D5.

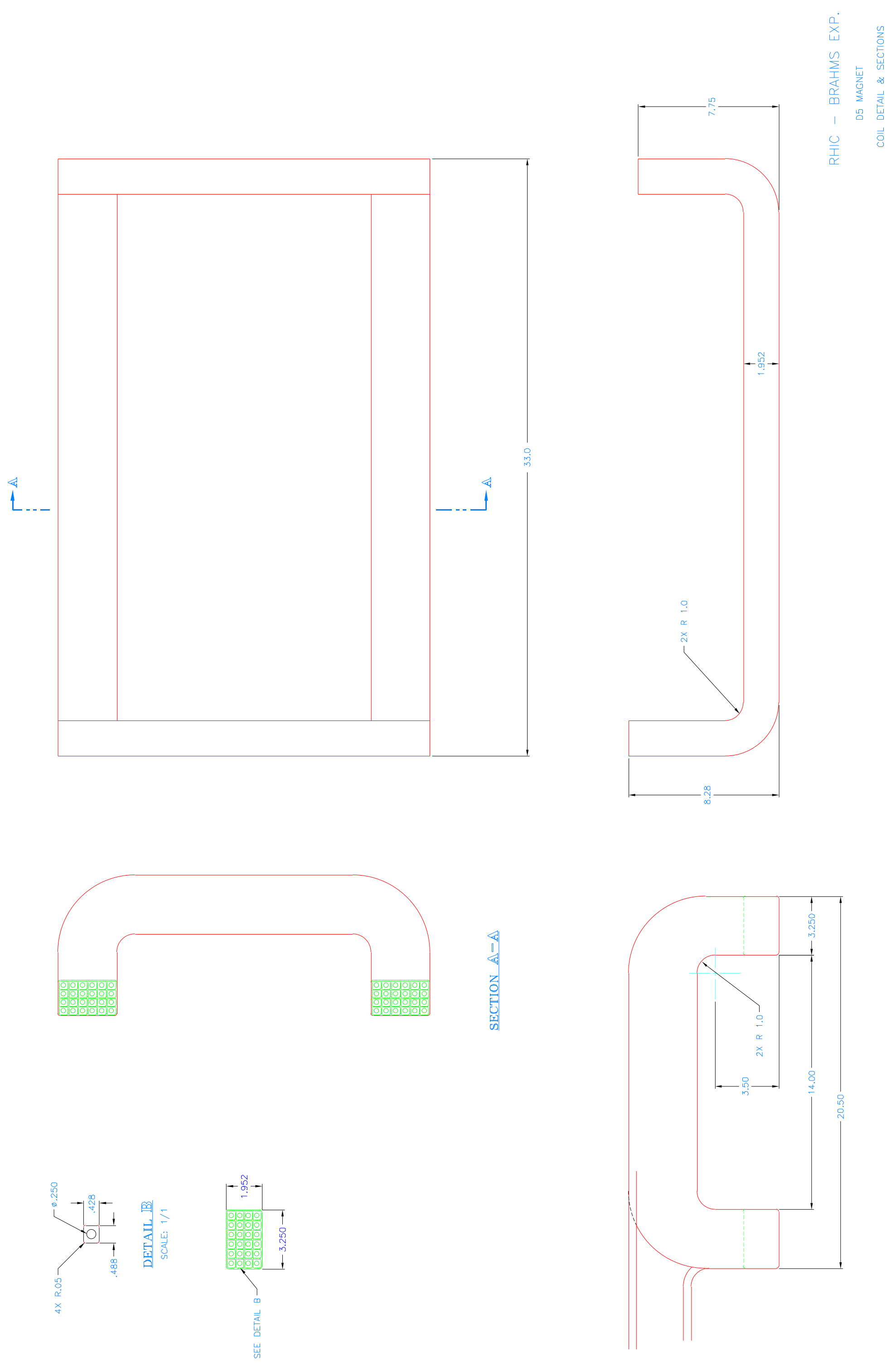

Figure 4.3: Coil design for D5.

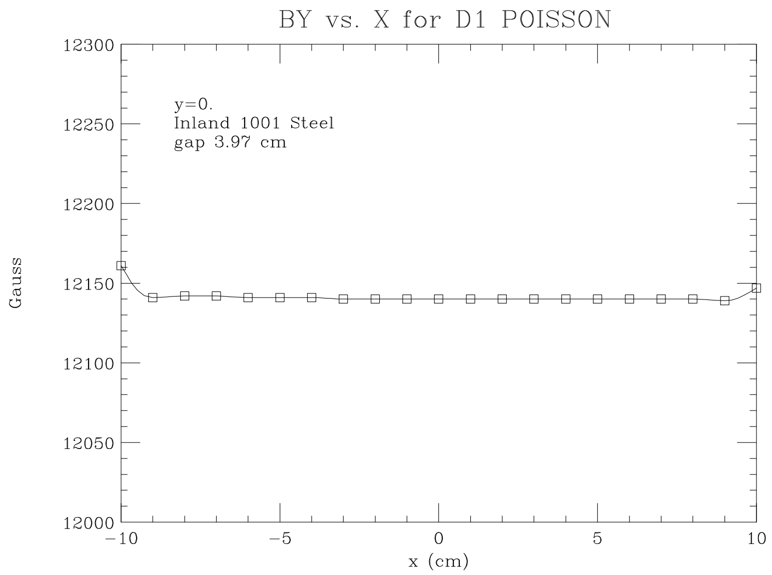

Figure 4.4: Field across the gap in D1.

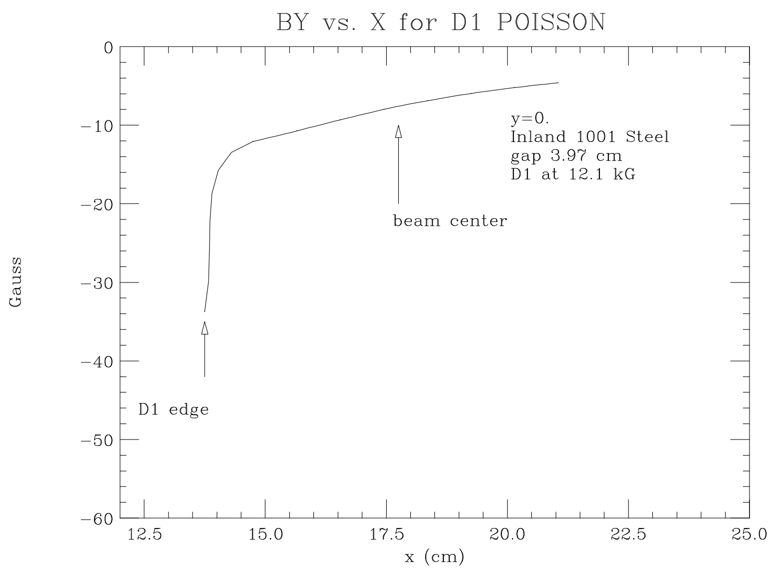

Figure 4.5: Fringe field in D1.

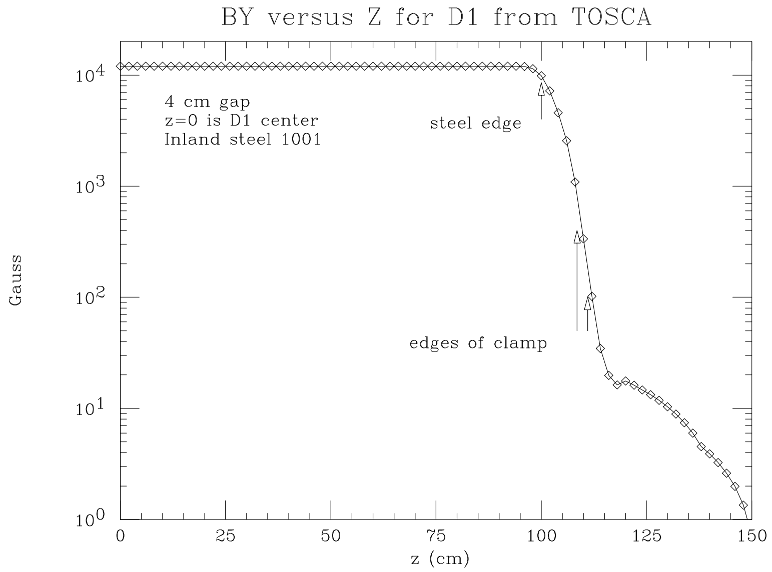

Figure 4.6: Vertical field in D1.