A SWITCHING MAGNET FOR THE IFUSP MICROTRON

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Abstract

In this work we present the design of a Switching Magnet for the IFUSP Microtron beam line. A configuration with azimuthal symmetry was adopted in order to comply with the boundary conditions of the accelerator building and to ease the machining process. The distribution and uniformity of the magnetic field are presented, as well as the project and construction of the vacuum chamber.

INTRODUCTION

The Laboratório do Acelerador Linear (LAL) of the Instituto de Física da Universidade de São Paulo is building a continuous wave (cw) electron race-track microtron (RTM). The IFUSP RTM [1-8] is a two-stage microtron that includes a 1.8 MeV injector linac feeding a five-turn microtron booster that increases the energy to 5 MeV. The main microtron delivers a 31 MeV cw electron beam after 28 turns. The maximum current of the beam is 50 mA. The Lab will have two main beam lines, one serving the photon tagger (bremsstrahlung monochromator), and the other dedicated to the production of X-rays by coherent bremsstrahlung as shown in Figure 1. This work describes the characteristics and design of the magnet that was built to perform the switching between these two lines.

Due to the distribution of the equipment in the experimental hall, the switching magnet must deviate the beam in angles of $\pm 90^o$ relative to the main pipeline that comes from the accelerator hall. The magnet should be able to deviate the beam independently of the energy, that may vary from 5 to 31 MeV. Besides that, we wanted the magnet as compact as possible, but avoiding field strengths too close to the saturation of the iron (< 2 T).

The chosen configuration was that of an "H" dipole, with cylindrical symmetry. Figs. 2 and 3 show two views of the adopted design. The main characteristics of the magnet are summarized in Table 1.

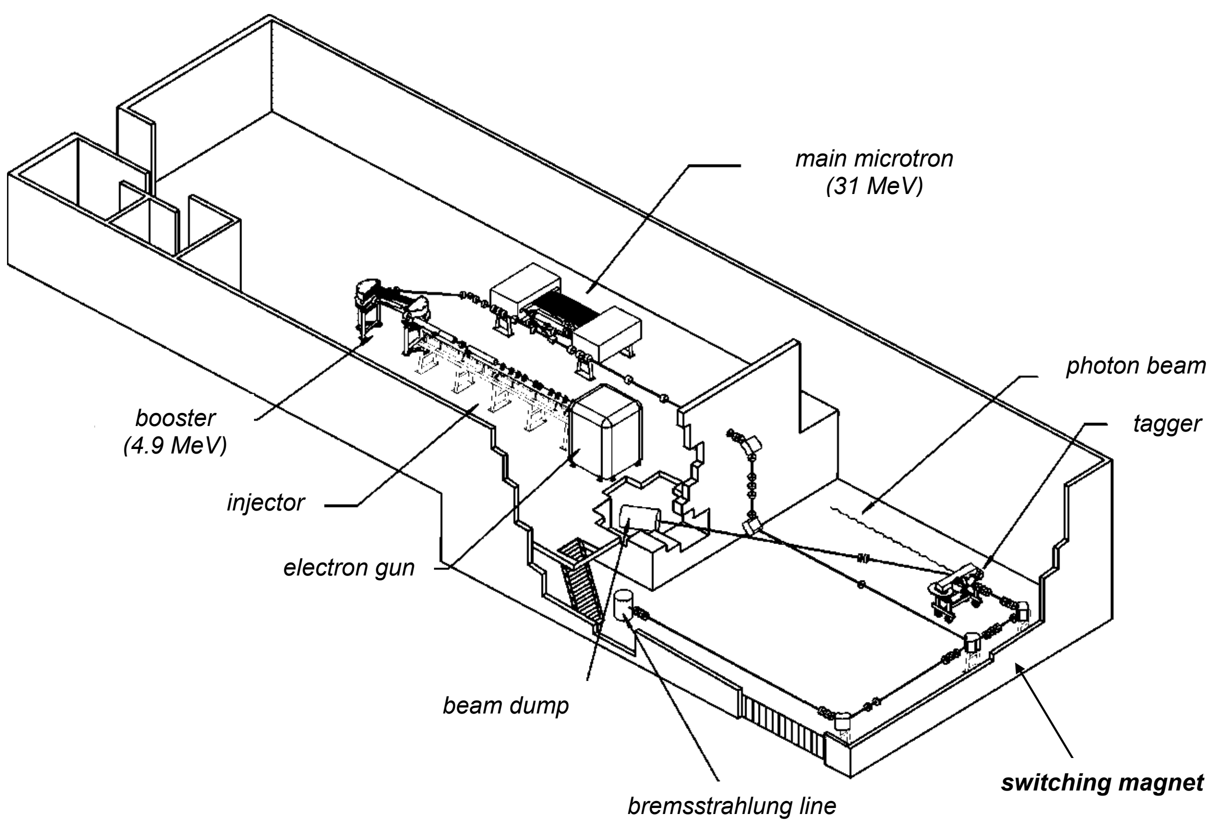

Figure 1: Isometric view of the accelerator in the accelerator building.

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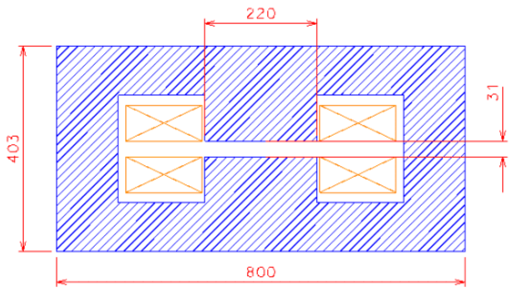

Figure 2: Cross section of the adopted design. Measures in mm.

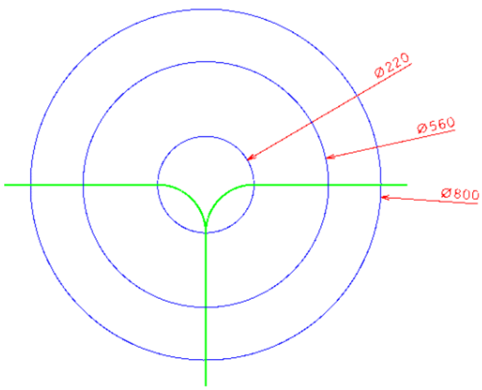

Figure 3: Top view of the magnet. Measures in mm.

Table 1: Magnet Specifications

Radius of curvature of the beam	0.11 m
Pole face diameter	0.22 m
Magnet diameter	0.80 m
Number of coils	2
Operating field @ 31 MeV	0.955 T
Operating field @ 5 MeV	0.166 T

THE MAGNET

Magnetic Design

The dimensions of the switching magnet were chosen in order to keep the magnet as compact as possible, but avoiding field strengths too close to the saturation of the iron (< 2 T). So we set the pole face radius in 0.11 m, because this gives an operational magnetic field of approximately 1 T for a 31 MeV beam. The final design was defined by simulations on the POISSON [9] and FEMM [10] codes, used to solve 2D magnetostatics problems. Figure 4 shows the field profile along a diameter of the magnet. The vertical lines indicate the pole face limits. Figure 5 shows a contour plot of the 2D relative field distribution over the mid-plane of the magnet. The advantage of this geometry is that the fringe fields are very small compared with field in the pole face region.

Mechanical Construction

The magnet was built with 1010 steel in three parts: two discs and a spacer ring. Each of the discs presents a deep channel to house one of the coils. The spacer ring is responsible for the gap. It also presents four ports for beam passage (3) and instrumentation (1). The ports are mounted with 19-mm pipes terminated with CF-25 vacuum flanges, in order to connect the magnet to the beam line.

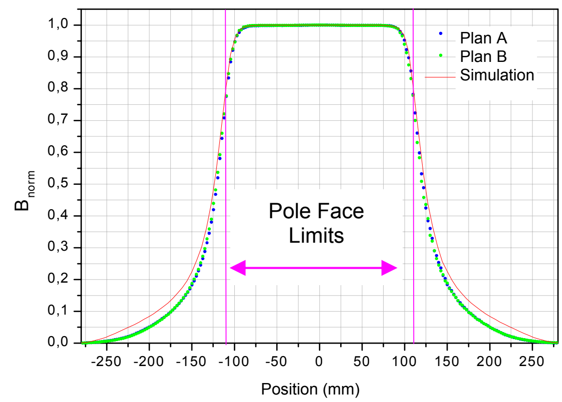

Figure 4: POISSON simulation results of the relative magnetic field along a diameter contained in the mid plane of the magnet (line) and the experimental data (dots). The vertical lines indicate the pole face limits.

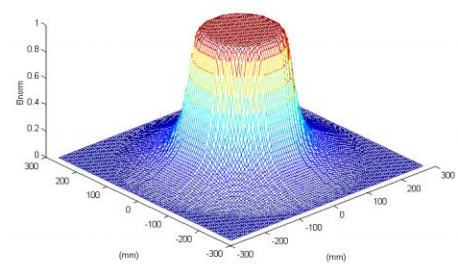

Figure 5: The relative magnetic field distribution over the mid plane.

The whole transport line is kept under high-vacuum. In the case of the switching magnet, in order to keep the gap as small as possible, we decided to use the magnet structure as part of the vacuum chamber. Figure 6 illustrates the system. The internal region of the ring is evacuated. Two brass covers were necessary to isolate the coils from the evacuated region, preventing, this way, virtual leaks proceeding from the coils.

A 4 mm groove was made in each of the iron discs to place the respective brass cover. It is also used for the gasket, which is made of a tin wire (99.7% purity) with a diameter of 1 mm. Figure 7 shows the final aspect of the switching magnet.

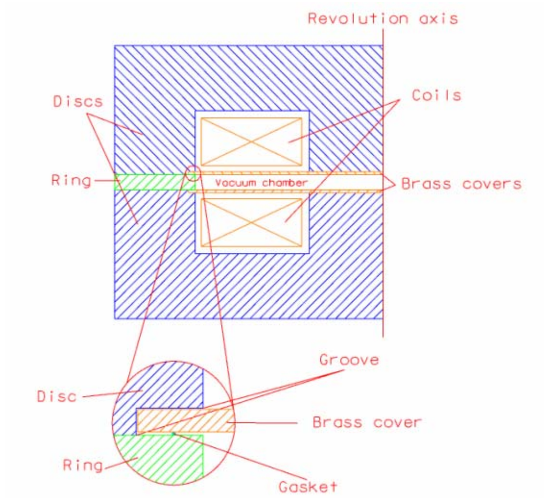

Figure 6: Details of the vacuum chamber design.

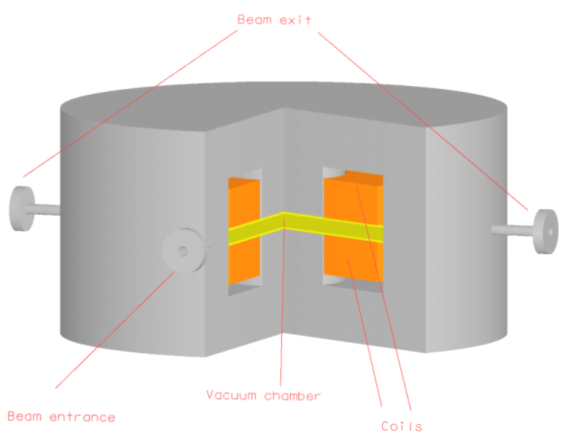

Figure 7: View of the assembled magnet.

RESULTS

For the magnetic characterization of the magnet, we used a Hall probe mounted on an automatic scanning system, operating with a step size of 2.52 mm. The measurements were made along a diameter contained in the mid plane of the magnet. The data acquisition was made in a PC with an analog to digital converter (ADC) board.

Figure 4 shows the results of the magnetic field mapping. We have mapped two different diameters (Plan A and Plan B in the figure), with good agreement between them. We can see that the experimental data agree with the results of the POISSON simulation. A magnetic field uniformity of 10^{-3} was achieved within a 0.16 m-diameter circle centered in the pole face region. The measured field is actually better than the simulated profile, since it falls faster outside the pole face region. This ensures that most of the bending is done in the pole face region.

The leak detection test evidenced that there were no leaks greater than 10^{-9} mbar.l.s^{-1} (for helium). The chamber was easily evacuated with a high-vacuum pumping system (mechanical plus ionic pumps), allowing the connection of the magnet to the rest of the beam pipeline without restrictions.

ACKNOWLEDGMENTS

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