DESIGN OF THE END MAGNETS FOR THE IFUSP MAIN MICROTRON

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Abstract

In this work we describe the characteristics of the end magnets for the IFUSP main microtron. The magnets are part of the main acceleration stage, which increases the energy from 4.9 to 38 MeV. The magnets will have a region of useful field of approximately 2x1 m^2. The dipoles have a 0.1410 T magnetic field and a homogeneity of 1 part in 1000 without active correcting devices. Using a 2D magnetic field code (FEMM), we illustrate the use of homogenizing gaps and non parallel pole faces to achieve the necessary homogeneity. The use of active clamps to produce reverse fields in order to reduce the vertical defocusing strength on the beam is also described. The beam trajectories in the gap and the magnetic field strength within the useful region were calculated with a 3D magnetic field software (TOSCA).

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 [1-3] is a two-stage microtron that includes a 1.8 MeV injector linac feeding a five-turn microtron booster that increases the energy to 4.9 MeV.

The main microtron will deliver a 38 MeV cw electron beam after 40 turns. The maximum current of the beam is 50 μA.

Table 1 summarizes the main microtron parameters.

Table 1: Main microtron parameters

Input energy	4.94	MeV
Maximum output energy	38	MeV
Mean energy gain per turn	0.828	MeV
RF wave length	12.24	cm
Total number of turns	40	
Radius of first orbit	12.3	cm
Radius of last orbit	91.1	cm
Maximum beam current	50	μA
Distance between magnets	256	cm

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.

MAGNET DESIGN

The magnet design was based on a previous design [4]. The last orbit radius in the old project was about 71 cm, therefore the magnet region of interest was about 1.5x0.75 m^2. To allow for a 7 MeV energy increase, the number of orbits was increased to 40, with the last orbit radius reaching 91 cm. So the region of uniform field was increased should be about 2x1 m^2.

Figure 1 shows the magnet cross section design and Figure 2 shows a 3D drawing of the magnet (with the adopted coordinate system). The design uses homogenizing gaps and non parallel pole faces. Those features were included using a 2D magnetic field solver – FEMM [5] – increasing the field homogeneity from 1% to 0.1%. Figure 3 shows the field profile in the region of interest. Note that the normalized field (B/B_{max}) is shown, and the ordinate ranges from 0.99 to 1.00.

The homogenizing gaps can be seen on Figure 1. This is a modified version of the homogenizing gaps described in [4]. This version is shorter and has a variable gap height, which improves the field uniformity in the region close to the yoke. Then results are better than those obtained using flat gaps.

The use of non parallel faces is also represented in Figure 1 (it is the region marked with arrows inside the magnet). In this region we have introduced a slight slope which means that magnet gap is reduced in about 2% on the right side compared with the left.

Figure 4 shows the whole magnetic field profile along the Y axis. We can also observe a negative magnetic field region. This was obtained using reverse clamps to decrease vertical focusing effects due to the fringe fields [6]. The clamps are shown on the right side of Figure 1.

Table 2 shows the microtron main magnets parameters.

Table 2: Magnets parameters

Nominal magnetic field	0.1410	T
Main coils total current	4500	A
Reverse clamps coils total current	2250	A
Magnet weight	14200	kg
Magnetic field homogeneity	0.12	%

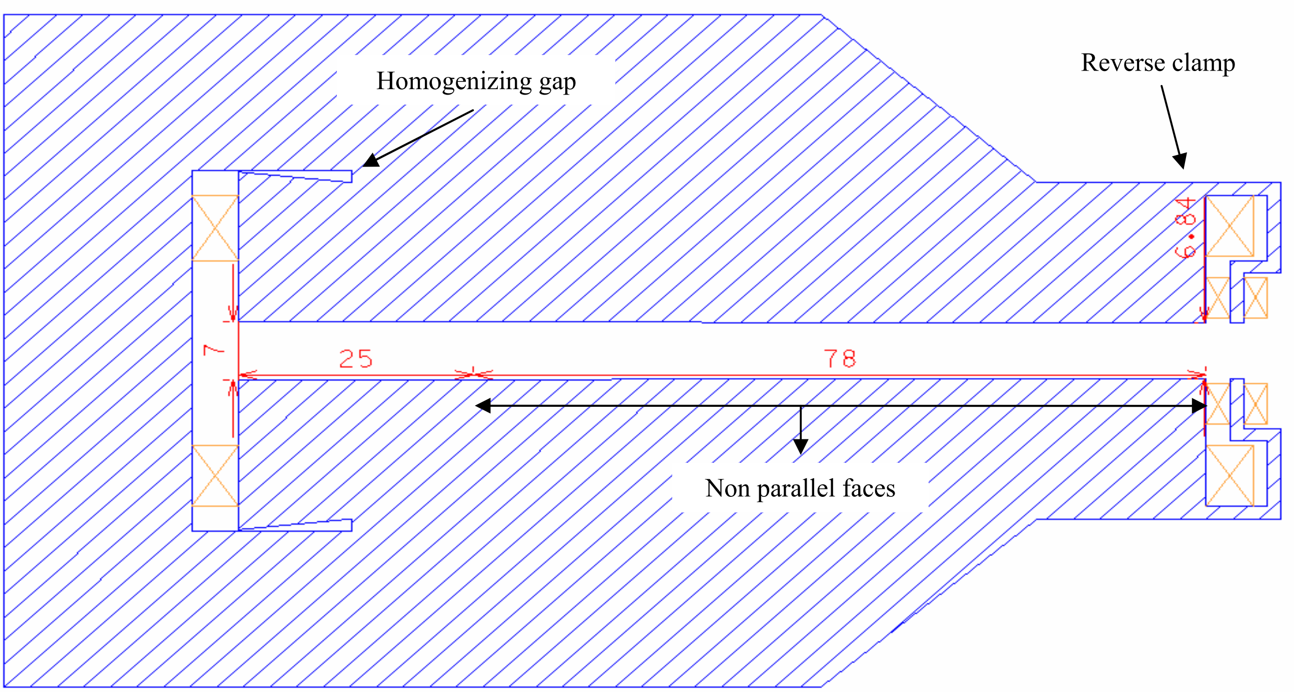

Figure 1: The new magnet cross section (measurements are cm)

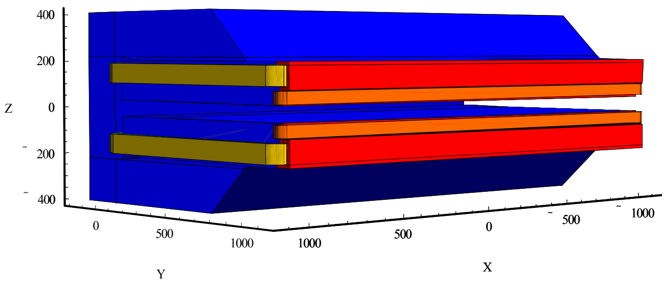

Figure 2: 3D model of the magnet and the adopted coordinate system (measurements are mm)

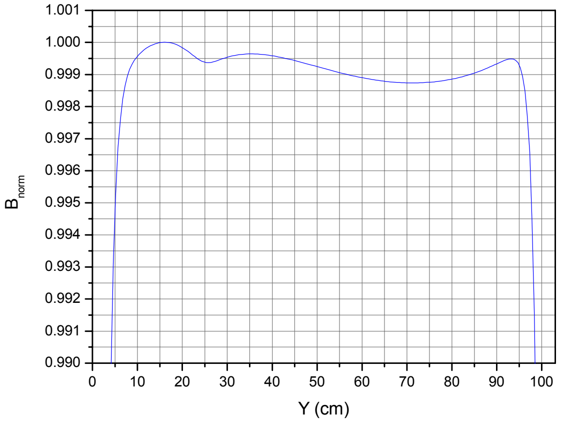

Figure 3: Magnetic field profile in the region of interest.

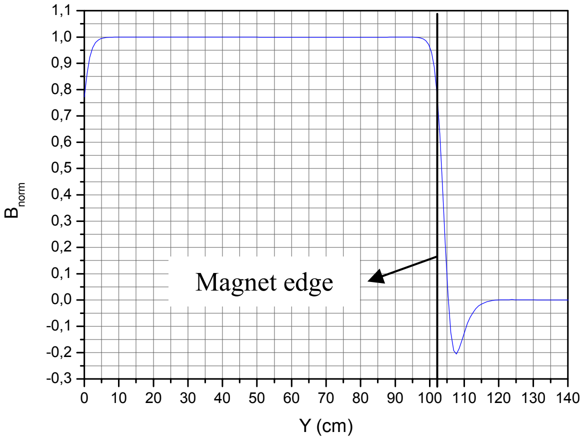

Figure 4: Magnetic field profile along Y axis

After the optimization process using the 2D code, we simulated the magnet with a 3D code – TOSCA [7] – to study the magnetic field along the X axis. The result of this calculation is shown in Figure 5 (once again note that the vertical scale corresponds to 1% of the total). The field uniformity of this magnet along the X axis is about 0.1 %.

Therefore the total field uniformity is about 0.1 %. We plan to use correcting coils [8] to improve the field uniformity to 0.01%.

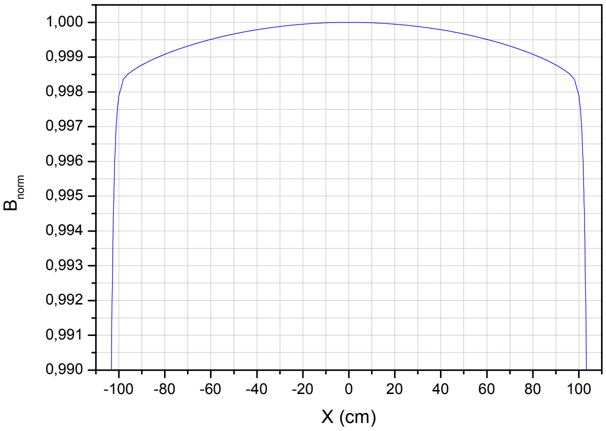

Figure 5: Field profile along the X axis at the mid plane of the pole piece (at y=50 cm according to Figure 4).

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