BEAM TRANSPORT SYSTEM FOR THE IFUSP MICROTRON

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Abstract

This work describes the beam optics design of the two transport lines of the IFUSP cw microtron. The first one links the two stages of the accelerator, while the second one connects them to the experimental hall. Placement of the active elements along the beam line, as well as the optimization of their operational parameters were done by simulation of the beam optics with two different codes.

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) [1-3]. This two-stage microtron includes a 1.8 MeV injector linac feeding a five-turn microtron booster that increases the energy to 4.9 MeV. After 28 turns, the main microtron delivers a 31 MeV electron beam. In order to minimize the background radiation, the experimental hall, with two beam lines, is located 2.68 m below the accelerator room. Figure 1 shows an isometric view of the machine in the accelerator building. In the experimental hall, one of the beam lines will be dedicated to experiments using tagged photons, while the remaining line will be used for high beam intensity experiments, such as nuclear resonance fluorescence (NRF) or production of X-rays by coherent bremsstrahlung [4].

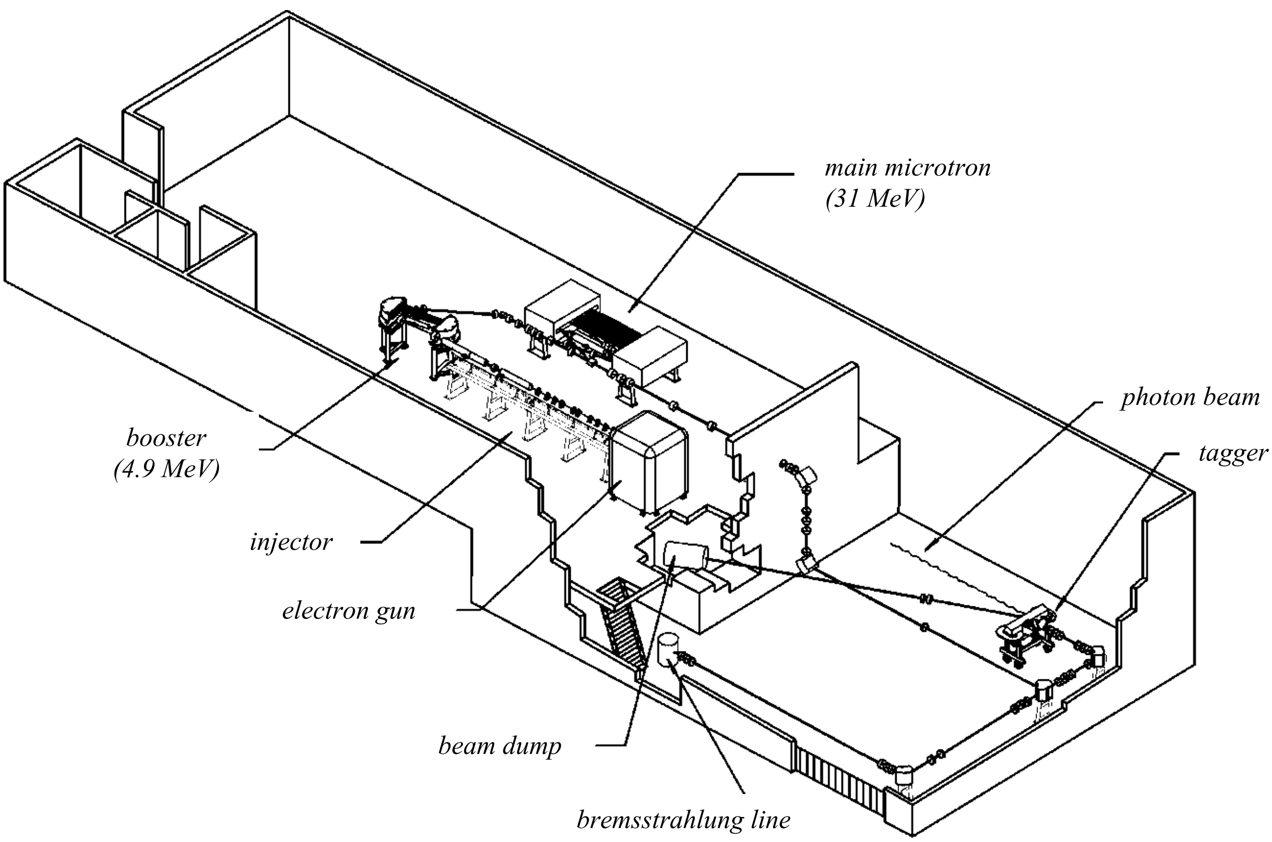

Figure 1 – Isometric view of the accelerator in the accelerator building.

BEAM LINE OPTICS DESIGN

The standard design procedure of beam transport systems includes the following steps:

1. “Zeroth” order calculations, to be used as ansatz to the next step;
2. Envelope simulations to optimize the operational parameters of the active elements and their placement along the beam path;

3. Particle tracking through the obtained transport system.

The first step is usually done by analytical calculations, the last two using computer simulations codes such as TRANSPORT [5,6] and PTRACE [7] respectively.

In this particular project it was not possible to use the TRANSPORT code to simulate the beam characteristics of the microtron booster, due to the low energy of the electron beam, which lead to large accelerating phase slips between consecutive orbits and, consequently, to varying path differences.

PTRACE is a particle tracking code specifically developed to design microtrons, and its main feature is the correct calculation of the phase slip of the electrons, regardless their energy. On the other hand, it presents a severe limitation on the number of simulated tracks per batch (only 10 on the original code). To overcome this limitation we developed a macro to a spreadsheet application that allowed easy simulation of large numbers of electron tracks, as well as determination and visualization of the main characteristics of the beam [8]. This macro was also used as a tool to facilitate the optimization of the operational parameters of the electromagnets of the booster. It allowed the simulation of a large number of electron tracks (typically several thousands) and statistical determination of the beam characteristics.

On the transport lines, *i.e.*, on the lines linking the microtrons and connecting them to the experimental hall, it was possible to use the ordinary designing steps. The main difficulty found was the need of large angular deviations on both vertical and horizontal planes, with small curvature radius, including a switching magnet to select between the two possible experimental lines [9].

RESULTS AND DISCUSSION

Using the methods outlined above, it was possible to obtain a beam of good optical quality along the path.

Figure 2 shows the beam profile along the microtron booster, with marks pointing the last simulation element of each synchronous accelerating turn, as well as the insertion and extraction turns.

As expected, the beam divergence in both horizontal and vertical planes are bigger on the insertion step, since it is not possible to neither introduce correcting elements nor even change the distance between the insertion dipole and the end magnet.

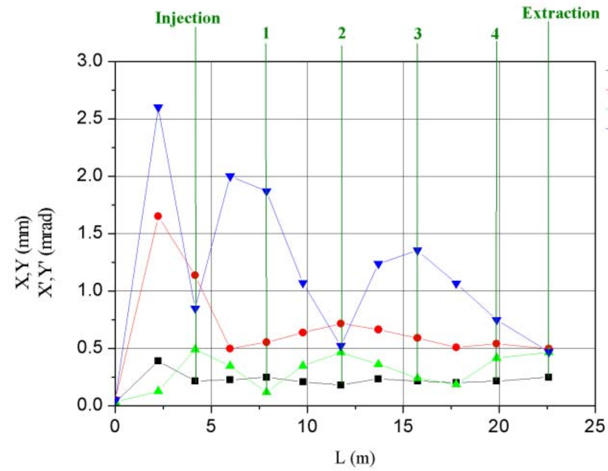

Figure 2 – Beam profile along the microtron booster: horizontal beam size, X (black squares); horizontal beam divergence, X' (red circles); vertical beam size, Y (green triangles); vertical beam divergence, Y' (blue triangles).

Figure 3 shows the beam profile along the transfer line, with its main steps marked.

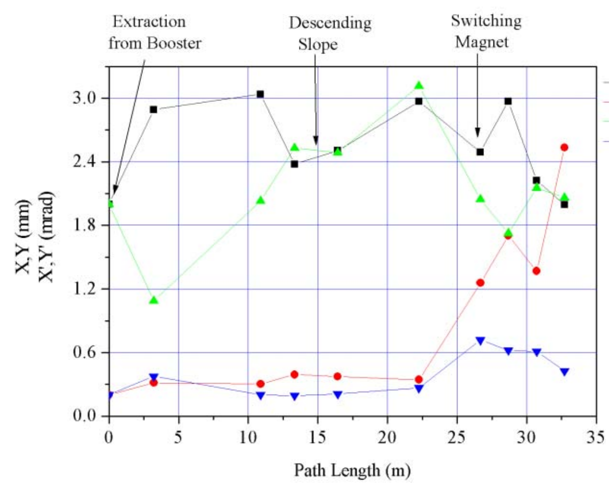

Figure 3 – Beam profile along the transport line: see caption of Fig. 2

We also have space limitations on the extraction line from the booster, where there is not enough room to place correcting elements, and the beam is required to follow two non-symmetrical deviations to (*i*) clear the end magnet, and (*ii*) reach the main transport path, as shown in Fig. 4.

The descending slope is a parallel vertical displacement of 90^o with a bending radius of 35 cm, followed by a 6-m long straight section and the switching magnet, where the beam turns horizontally by 90^o with an 11-cm radius of curvature. This sharp curve increases the divergence at the end of the trajectory, but the beam still presents characteristics suitable for the intended uses.

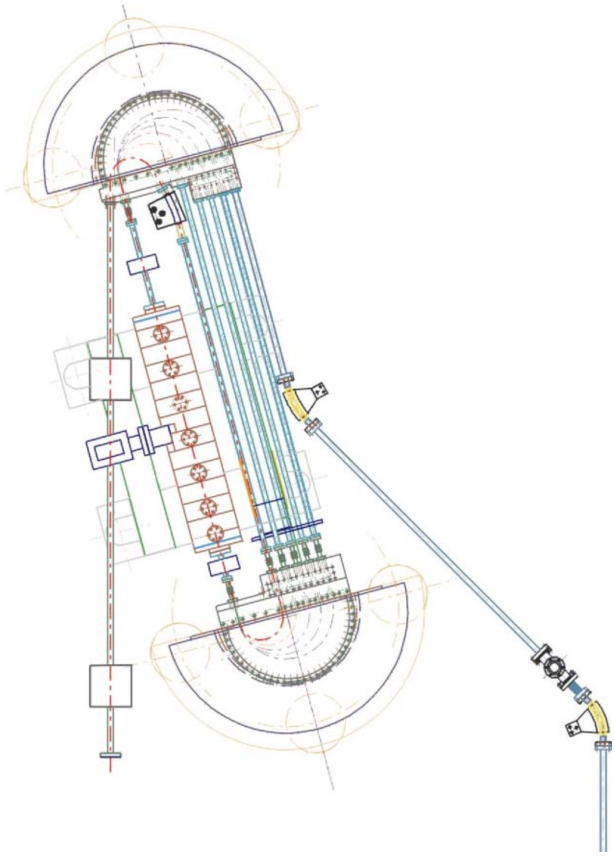

Figure 4 – Schematic drawing of the microtron booster, showing the insertion and extraction lines. The separation between the end magnets is 1.5 m.

CONCLUSIONS

The use of different simulation codes, due to project restrictions, imposed some extra labour but did not introduce any major discrepancies between them.

Spreadsheet applications made the statistical analysis easier and faster, which allowed us to compare results and improve our design. But the need for a dedicated beam transport design tool for low energy microtrons still remains.

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