# The IFUSP Microtron - Status and Perspectives

M.N. Martins, J. Takahashi, A.A. Malafronte, P.B. Rios, M.L. Lopes,
A.L. Bonini, and R.R. Lima

*Laboratório do Acelerador Linear, Instituto de Física da Universidade de São Paulo,
CP 66318, 05315-970 São Paulo, SP, Brazil*

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In this paper we summarize the status of the racetrack microtron that is under construction at IFUSP, showing the achievements obtained in the transport, RF, control and vacuum systems. A description of the experimental equipment that will be available to the users is also presented.

## 1 Introduction

The Laboratório do Acelerador Linear (LAL) of the Physics Institute of the University of São Paulo (IFUSP) is building a 31 MeV continuous wave (cw) racetrack microtron [1][2]. This two-stage microtron comprises a 1.8 MeV injector linac, a five-turn microtron booster that increases the energy to 4.9 MeV, and the main microtron, which delivers a 31 MeV cw electron beam after 28 turns. The injector consists of a 100 keV electron gun, chopping and bunching systems, a capture section and a pre-accelerating section; therefore the complete accelerator has four RF accelerating structures, operating at 2450 MHz. This cascaded configuration was adopted in order to maximize the final energy of the system while keeping the RF power under 45 kW, so that the whole system could be powered with a single RF source, namely a 50 kW cw klystron, to minimize costs. Table 1 summarizes the characteristics of the accelerator.

The experimental hall, with two beam lines, is located 2.68 m below the accelerator room. 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 or production of X-rays by coherent bremsstrahlung [3]. Fig. 1 shows a view of the machine in the accelerator building.

## 2 Design and optics calculations

The design was achieved using computer simulation codes PARMELA [4], for the injector linac and accelerating structures; PTRACE [5], for the microtrons; and TRANSPORT [6][7], for the transport lines linking the microtrons and connecting them to the experimental hall. Several challenges were encountered in this phase, in special the design of the microtron booster, for it operates outside the phase stability region due to the low injection energy (1.8 MeV) [8].

Recirculating magnets for the booster, and several of the magnets and focusing lenses for the beam transport system, were built and characterized [9], others are under construction.

## 3 Vacuum, RF and control systems

The accelerator is kept under high vacuum. This is accomplished using several ionic pumps, designed and built at the laboratory, keeping internal pressure under $10^{-7}$ mbar.

The whole RF system is powered by a single 50 kW cw klystron, and the RF power is distributed to the four accelerating structures and chopping and bunching systems through a distribution and control network. The distribution is done through WR340 wave guides, and couplers, attenuators, and phase shifters designed and built in house [10].

The control system is PC-based and has been developed [11] with focus on simplicity and low cost. Several successful tests were performed, including full control of the e-gun and other devices already installed (power supplies, temperature monitors, microwave and vacuum instrumentation). A host computer, acting as an operator console, and front-end computers that acquire the data from the different parts of the accelerator compose the system. The Human-Machine Interface (HMI) was constructed using the Labwindows/CVI tool.

## 4 Experimental perspectives

The experiments that will be performed with the accelerator can be divided in two categories: those that will be possible with the first stage - 5 MeV - that are restricted to the study of nuclear bound states, using the nuclear resonance fluorescence (NRF) technique; and those that will be possible when the second stage - 31 MeV maximum energy - becomes operational.

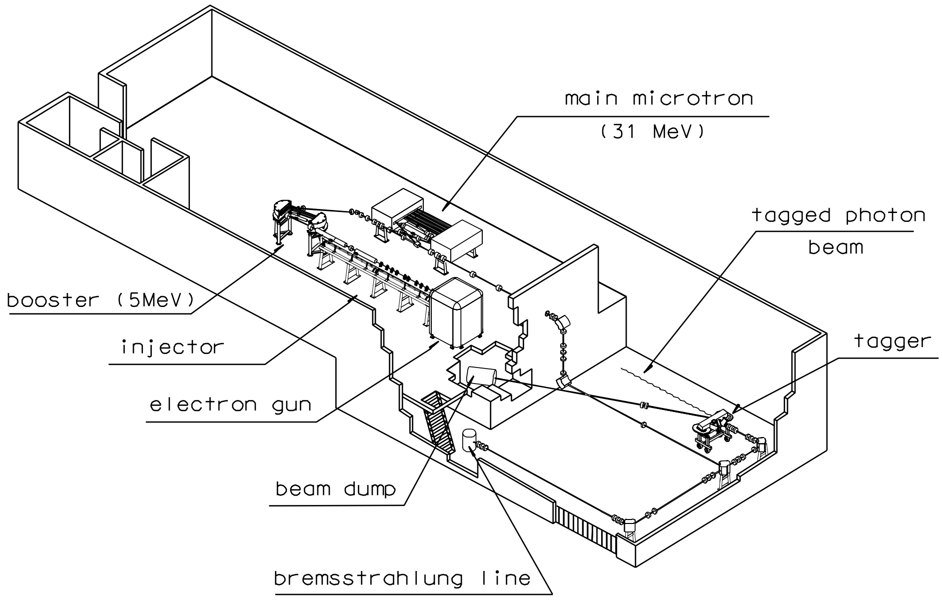


Figure 1. Isometric view of the microtron in the accelerator building.

TABLE I. Characteristics of the IFUSP microtron

| | |
|---|---|
| Electron gun | |
| Energy | 100 keV (± 0,1 %) |
| Current | 2,0 mA |
| Beam diameter | <2 mm |
| Injector | |
| Input energy | 0,1 MeV |
| Output energy | 1,8 MeV |
| Booster | |
| Input energy | 1,8 MeV |
| Output energy | 5 MeV |
| Maximum current | 50 $\mu$A |
| Number of turns | 5 |
| Main Microtron | |
| Input energy | 5 MeV |
| Output energy | 31 MeV |
| Maximum current | 50 $\mu$A |
| Number of turns | 28 |

### A. NRF

The experimental setup needed for NRF measurements is very simple and is sketched in Fig. 2. This kind of measurement allows for the determination of the excitation energy, and, through the analysis of the angular distribution of the scattered radiation, the spin of the excited nuclear states (for even-even nuclei). The cross section is obtained analyzing the spectra of the scattered photons, and allows obtaining the decay width for the ground state and, thus, in a model independent way, the reduced transition probability, B(El/Ml).

### B. Photonuclear reactions

In the Giant Dipole Resonance (GDR) energy region (between 10 and 30 MeV) the photoabsorption may develop into different excitation-decay processes, which will end

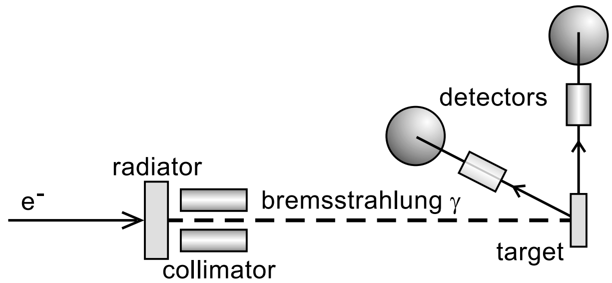


Figure 2. Experimental setup for NRF measurements. The electron beam hits the radiator, producing a bremsstrahlung photon beam. After collimation, the photon beam hits the target, and the scattered radiation is detected by the HPGe detector array.

with the excited nucleus decaying through the emission of particles and/or gamma rays. The study of GDR properties by means of the experimental determination of its decay modes, measuring spectral and angular distributions of the emitted particles, presents great interest to the theoretical description of these processes.

Neutron detection is possible only by means of nuclear reactions. We plan to use thin plastic scintillators, lightly shielded with lead to reduce photon background and so avoid excessive dead time from the detection of photons. Pulse shape discrimination will be used to separate neutron and photon signals. Besides plastic scintillators, we will also use HPGe detectors, which are sensitive to neutrons above $\sim$600 keV [12,13]. Neutron detection with HPGe detectors is very interesting because the large detector volume (several tens or hundreds of cm$^3$) allows for high detection efficiency. Preliminary tests with detectors available at the lab showed intrinsic efficiency of $\sim$10%, taking into account only those events within a resolution time of 10 ns. The experimental setup is shown in Fig. 3. The detectors have their symmetry axes converging to the center of the target, forming different angles with the beam direction. To reduce the contribution from positron annihilation photons, detectors are placed avoiding $180^0$ separation between any pair.

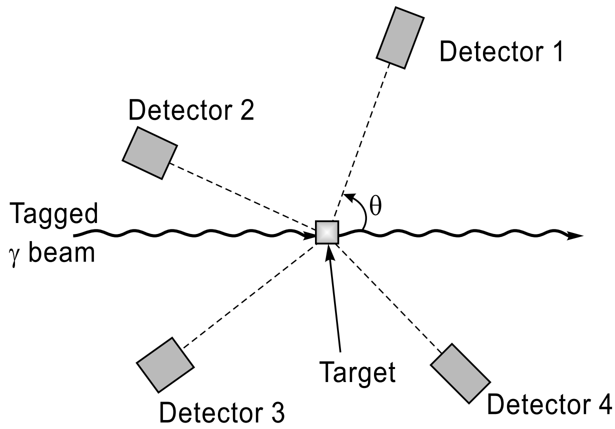


Figure 3. Experimental setup for the detection of photons and neutrons emitted in photonuclear reactions.

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