THE GHENT STATE UNIVERSITY LINEAR ELECTRON ACCELERATOR FACILITIES: STATUS AND PERSPECTIVES

W. Mondelaers
Nuclear Physics Laboratory
Proeftuinstraat 86
9000 Gent, Belgium.

Abstract

The Ghent State University disposes of 2 linear electron accelerator facilities: a 90 MeV low duty factor linac and a 15 MeV high beam power accelerator. Both facilities were initially designed in view of an extensive program of fundamental nuclear physics research. During some recent years a large effort has been devoted to the expansion of the field of machine applications. The accelerators have now evolved into versatile tools both for fundamental nuclear and solid state research, for medical therapy and radiation applications. The program and the necessary machine modifications and results are described with emphasis on original features: slow positron production and transport, high power electron beam handling and bremsstrahlung target design, radiation processing equipment and a high gamma dose setup for extracorporeal irradiation in bone tumours therapy.

Introduction

During 1985, a 15 MeV 2% duty factor linear electron accelerator was build at the Nuclear Physics Laboratory of Ghent State University, as a valuable complement to the existing .1% duty factor 90 MeV linac. Both accelerators are installed back to back in the same building. The overall lay-out of the accelerator facilities is shown in figure 1 and the main accelerator specifications are given in table 1.

These accelerator facilities were designed to perform experiments in the field of photo- and electrofission, photonuclear reactions, materials research and radiation dosimetry.

The shift of intrest of the nuclear physics research community using electron and photon probes towards larger duty factor machines, necessitated a carefull reconsideration of the 90 MeV machine program. We decided to construct a high intensity slow positron production facility. The slow positron beam will mainly be used to do materials research on surfaces, multilayerd samples, interfaces.

The 15 MeV high-power high-resolution linac has made possible a whole series of new and exciting experiments. It has permitted investigations of nuclear processes near-treshold with small cross sections. It has also brought a greater precision in the performance of experiments, due to the high beam repetition frequency and the high mean beam intensity remaining even under high resolution conditions. This results in a substantial reduction of back-ground and increased data-taking rates. A linearly polarized bremsstrahlung facility, devoted to nuclear resonance fluorescence experiments, a very lively field in nuclear physics, is installed.
In addition to greatly broadening the scope of low energy nuclear studies with electron and photon probes, the existence of this 15 MeV facility, covering the energy and beam power range of medical and industrial accelerators, but with better performances (flexibility,

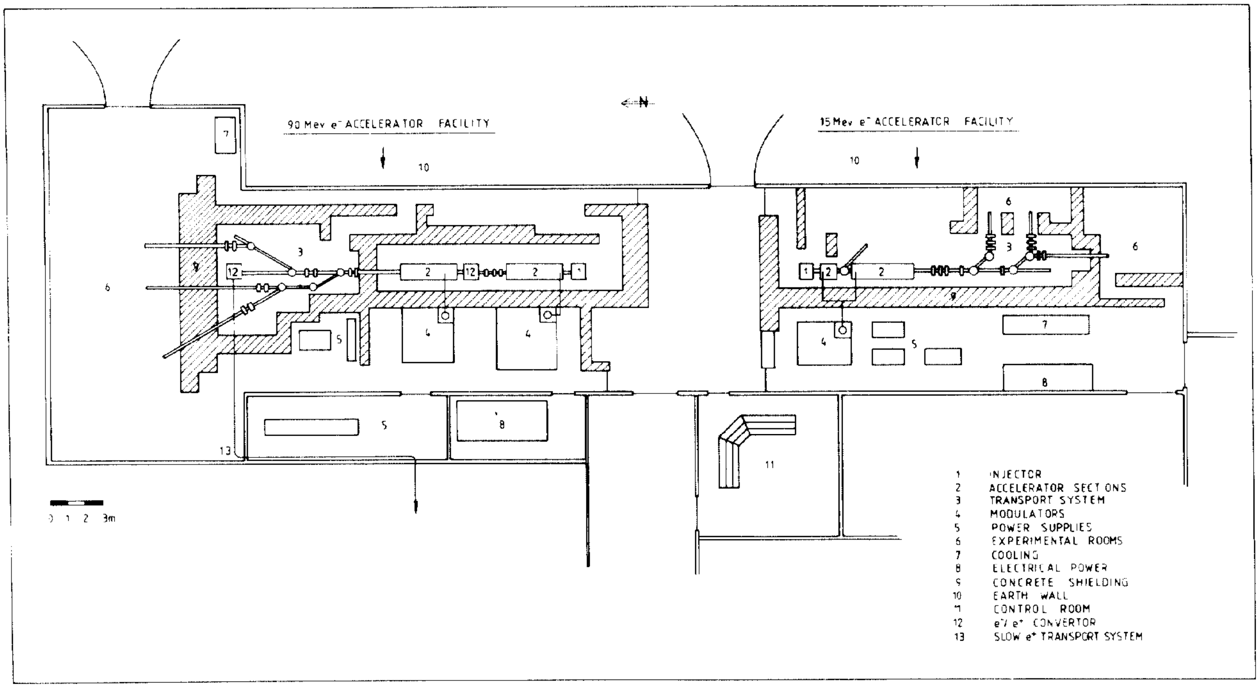

Fig.1. Lay-out of Ghent linear electron accelerator facilities

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Table 1 : Main accelerator characteristics

	15 MeV LINAC	90 MeV LINAC
Beam energy range	1.75 - 15 MeV	10 - 90 MeV
Duty factor	2 %	.1 %
Max. beam pulselength	10 μsec	3.3 μsec
Max. beam puls repetition rate	5000 Hz	300 Hz
Max. average beam current	2 mA	100 μA
Max. average beam power	20 kW	6 kW
Accelerated current in 1 % energy bin	Up to 80 % of I_{max}	Up to 50 % of I_{max}
Emittance	2.7 πmm mrad (9 MeV)	20 πmm mrad (25 MeV)
Electromagnetic frequency	2999 Mhz	2856 Mhz
Number of accelerating sections	2	2
RF source	1 klystron TV2013	1 klystron TV2015 1 klystron ITT8568
Sections per RF source	2	1
RF power per source	1.5 MW peak 30 kW mean	24 MW peak 24 kW mean
Klystron modulator type	hard tube	pulse line

beam energy spectrum and emmitance), has opened a wide range of accelerator based applications. Average electron beam powers up to 20 kW at 10 MeV are routinely obtained providing intense fields of ionizing radiation.

The first part of this paper gives a short description of the slow positron facility at the 90 MeV machine. The second part decribes the high power beam handling system of the 15 MeV accelerator, with emphasis on photon production targets and a high gamma dose setup used in medical therapy, a polarized bremsstrahlung facility and radiation processing equipment.

Slow positron facility.

At the 90 MeV linac a source of low energy positrons (energy between 100 eV and 40 keV) is installed. Bremsstrahlung is used to produce electron-positron pairs in a water-cooled tantalum target, with a thickness optimised for maximum positron yield. The thus obtained positrons are thermalized in a moderator consisting of annealed tungsten foils, set in a venetian blind geometry. The slow positrons emerging from the moderator surface are accelerated perpendicular to the electron beam, extracted from the target region and injected into a solenoïdal transport system with four 90° bends. The positrons are guided magnetically over a distance of 41 m to the experimental room, away from the high radiation background at the production site.

For many experiments a quasi-DC slow positron beam is required. To get a better duty cycle of the positron beam, a pulse stretching system was installed, in order to smear out the positron pulses from 3.3 μsec up to a width of a few ms. The stretching system consists of a Penningtrap, which is filled with positrons during the accelerator pulses. During the interpulse interval the slow positrons are gradually released from the storage unit by ramping an electric field.

Further improvements on the installation such as brightness enhancement based on remoderation and positron beam bunching are under investigation.

The slow positron production facility and stretching unit are described in more detail elsewhere [1,2].

High beam power transport system with photon production targets.

The 15 MeV accelerator is capable of delivering electron beams with a mean intensity of 2 mA and a diameter of 4 mm, corresponding to a beam power density of 150 kW/cm^2. This power density is capable of inflicting thermal damage to nearly any unprotected beam line component in time intervals shorter as 1 s. Apart from the usual protection against failures (power or pump failure, entry of water at water-cooled parts, entry of air if parts are melted through by the beam ...), fast non-intercepting beam monitoring and protection units, reacting under faulty conditions, are

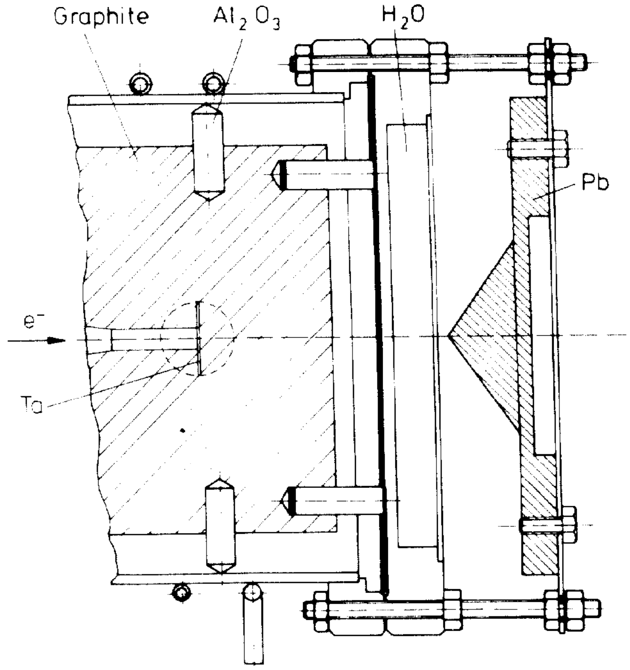

Fig.2. High power bremsstrahlung target / electron beam stop configuration with Pb-flattening filter for radiotherapy.

placed at strategic locations in the transport system. In each unit, the beam current, position and spill are measured continuously.

Control-systems involving HF pulse-to-pulse stabilisation, analysed beam intensity feed-back and online HF power pulse shaping proved to be very valuable in reaching stable operation [3]. The machine is routinely running autonomous at full power during runs of at least 100 hours/week, with only minor operator interventions.

For measurements of photofission and photonuclear reactions near treshold, an intense cone of forward-directed bremsstrahlung radiation is needed. The high power bremsstrahlung production targets are designed to dissipate the whole electron beam power. Each target consists of a cylindrical graphite core with a re-entrant conical hole. At the top of the conical hole (and in close thermal contact with the graphite) a tantalum slab of optimum thickness is incorporated.

We have chosen a double-layered configuration. The tantalum radiator, whose thickness is optimised to produce the maximum bremsstrahlung yield in a certain angle in the forward direction, can easily be replaced depending on the experimental requirements. The graphite stops the electrons, transmitted through the tantalum converter. We have chosen graphite to minimise the concomitant absorption of high-energy photons and to provide the appropriate cooling.

The heat is removed by radiation from the outer surface of the graphite core to the surrounding stainless steel water-cooled vacuum enclosure. Thermal and electrical insulation between core and vessel is provided by cylindrical ceramic Al_2O_3 supports.

The construction of the energy-analyzing slits is based on the same principles.

This type of target and slit construction was chosen because it is very reliable under high power conditions and it has a low cost, it is easy to manufacture, has no movable parts and no high pressure cooling system is needed. An eventual failure does not result in spilling water into the vacuum system.

Extracorporeal irradiation facility.

The dose rates produced with these high power bremsstrahlung targets offered an unique opportunity to develop a new medical accelerator based treatment technique in bone tumours therapy: en bloc resection of the bone affected by cancer, extracorporeal irradiation with a homogeneous dose of 300 Gy and reimplantation of the irradiated bone. Up to now 60 patients have been treated in this way, with very promising results [4]. Conventional radiotherapy machines are not well suited for such a kind of treatment, due to their rather low dose rates and accordingly long irradiation times.

The intense photon beam produced with the bremsstrahlung targets gives a sharply peaked absorbed dose distribution in planes perpendicular to the beam axis. A Pb-flattening filter is fixed to the endplane of the target/beam stop configuration, to compensate for off-axis dose reduction. At 25 cm from the target we obtain a dose rate of 1 Gy/sec, with a homogeneity of better than 10% over a lateral distance of 25 cm [5].

Polarized bremsstrahlung facility.

The high beam intensity of the accelerator in the 5-15 MeV range makes it possible to use off-axis bremsstrahlung with reasonable intensity as a source of linearly polarized photons for low energy nuclear resonance fluorescence experiments. We build a polarized bremsstrahlung facility based on a Giessen design [6]. Two sets of two steering magnets in front of a thin (50 μm) aluminum radiator target, make it possible to change, in a symmetric way from four directions, the angle of incidence of the intense electron beam on the target, to select the off-axis angle by a subsequent fixed collimator, in order to produce linearly polarized bremsstrahlung. Polarization is measured online via deuteron-photodesintegration. Not only the high mean intensity but also the high beam pulse repetition rate of 5000 Hz is an advantage, because possible counting rates of the γ-spectrometers are limited to a fraction of repetition rate in order to avoid pile-up effects.

Electron Irradiator.

With the object of the extension of our high dose electron irradiation applications we developed an electron beam scanning system to distribute the electron beam power uniformily over specimens to be irradiated. Our irradiation system, now under construction, is of the hybrid type: a dynamic magnetic scanner in the vertical direction, and a static magnetic system, combined with mechanical scanning in the horizontal direction.

A slowly changing (2 Hz) magnetic field from a soft-iron magnet deflects the high power beam up and down, the beam being defocused horizontally by a quadrupole lens system, to cover an area of 4cmx30cm. To improve vertical dose-uniformity at the specimen, the triangular excitation current waveform of the deflecting magnet can be deformed. Uniform beam power distribution in the horizontal direction is not critical, because the irradiation setup includes a remotely controlled travelling specimen carriage to provide horizontal dose rate control.

The scanned electron beam leaves the vacuum through a water-cooled aluminum window designed to withstand the power deposited by the beam.

Spatial dose uniformity is monitored (at reduced beam pulse repetiton rate) with a motor-driven ionisation chamber scanning system.

Conclusion.

An intense slow positron production facility has successfully been installed at the 90 MeV linac, resulting in an unique tool for materials research.

The actually achieved performance of the high intensity 15 MeV facility opens possibilities for new valuable experiments on nuclear physics near-treshold and for innovative developments in the field of radiotherapy and radiation testing.

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