THE NEW BERN CYCLOTRON LABORATORY FOR RADIOISOTOPE PRODUCTION AND RESEARCH

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Abstract

A new cyclotron laboratory for radioisotope production and multi-disciplinary research is under construction in Bern and will be operational in 2012. A commercial IBA 18 MeV proton cyclotron, equipped with a specifically conceived 6 m long external beam line, ending in a separate bunker, will provide beams for routine ^{18}F production as well as for novel detector, radiation biophysics, radioprotection, radiochemistry and radio-pharmacy developments. The accelerator is embedded into a complex building which hosts physics laboratories, four GMP radiochemistry and radio-pharmacy laboratories, offices and two floors for patient treatment and clinical research activities. This project is the result of a successful collaboration among the University Hospital in Bern (Inselspital), the University of Bern and private investors, aiming at the constitution of a combined medical and research centre able to provide the most cutting-edge technologies in medical imaging and cancer radiation therapy. Furthermore, the establishment of a proton therapy centre on the campus of Inselspital is in the phase of advanced study.

THE SWAN PROJECT IN BERN

Molecular imaging and cancer radiation therapy are the focus of a remarkable scientific and technological development, leading to constantly improving diagnostic and treatment options. In particular, accelerator based facilities for radioisotope production and proton therapy [1] are now mature technologies to be integrated in the context of an academic clinical and multi-disciplinary research setting. In this framework, SWAN – standing for SWiss hAdroN - aims at the constitution of a combined centre for radioisotope production, proton therapy and research on the campus of the Inselspital, the University Hospital in Bern [2].

Following a detailed scientific, technical and economical study aimed at identifying the fundamental steps towards the implementation of proton therapy together with radioisotope production and multi-disciplinary research, the SWAN group was founded at the end of 2007. The Inselspital, the University of Bern and private investors are its shareholders. The SWAN group is governed by SWANtec AG, a holding with two subsidiary companies: SWAN Isotopen AG is engaged in the commercial production of radiopharmaceuticals for molecular imaging, and SWAN Hadron AG is dedicated to plan, implement and run a proton therapy centre. In parallel, the Swiss Hadron Foundation has been created to support patients and to foster scientific research.

The first phase of SWAN has been approved and financed in 2008 and consists on the realization of a cyclotron based laboratory with related infrastructure for radioisotope production, patient care and multi-disciplinary research.

The second phase of SWAN aims at the realization of a proton therapy centre able to offer to patients the best medical care and to researchers a unique environment at the forefront of science and technology, also thanks to the synergies with the isotope centre. The area inside the campus has been individuated and this new facility is in phase of advanced study.

THE CYCLOTRON LABORATORY

Multidisciplinarity and public-private partnership are the main features of SWAN. To fulfil the goals of the first phase, a project team has been set-up featuring physicists, radio-chemists, radio-pharmacists, architects, engineers and experts of industrial processes. Most of their work has been naturally centred on the main piece of equipment: the IBA 18 MeV proton cyclotron equipped with an external beam line dedicated to research.

The Multi-function Infrastructure

A dedicated building (Fig. 1) has been planned to host radioisotope production, research activities and patient care, paying special attention at the integration of this new structure into the existing hospital environment.

Figure 1: The “SWAN Haus” at the Inselspital in Bern (left) where cyclotron and its external beam line have been “rigged” in June 2011 (right).

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The heart of this five floor building is the cyclotron laboratory located underground, as presented in Fig. 2.

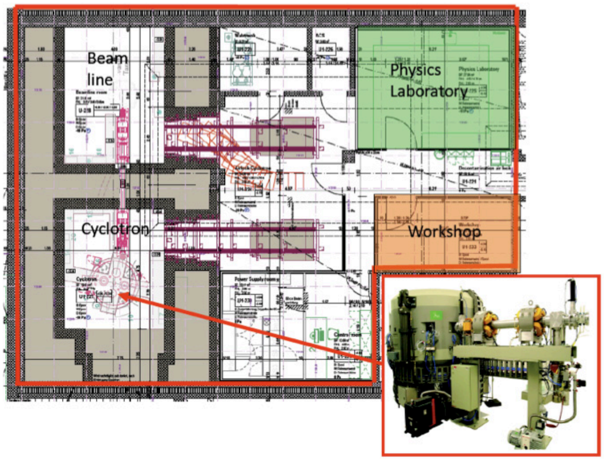

Figure 2: The underground floor of the isotope building hosts the cyclotron, the beam line, the physics laboratory, the workshop and the related technical equipment.

To perform production and research activities in parallel and with minimal interference, two bunkers have been designed, the former hosting the cyclotron and the latter a 6 m long beam line dedicated to research. On the same floor, the control room, the technical areas, a physics laboratory and a workshop are connected to the bunkers by means of specific underground pipes, as shown in Fig. 3. The laboratory has been designed to be as flexible as possible for offering a multi-disciplinary platform for research activities. Special pipes have been installed for the extraction of solid targets without the need of opening the bunker doors.

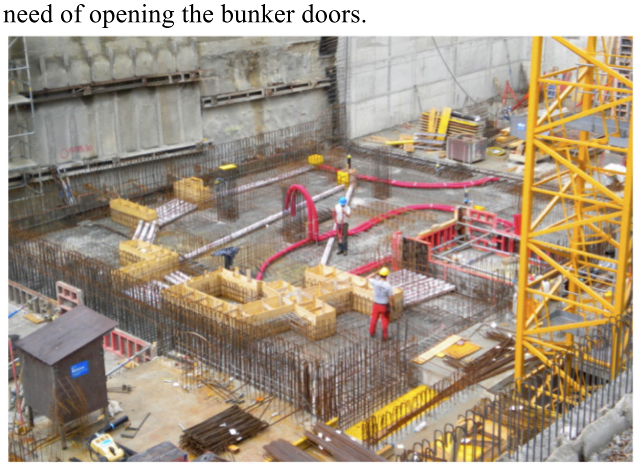

Figure 3: The construction of the cyclotron laboratory in June 2010: the trench lines for the cyclotron and the external beam line are visible together with the structure of the bunkers, the underground pipes for the laboratories and for the automatic transport of solid targets.

On the ground floor, four GMP laboratories are dedicated to the production of radiotracers and to research activities in radiochemistry and radio-pharmacy. They are equipped with cutting-edge technology hot-cells supplied by TEMA Sinergie. On the first floor, offices together with physics and radiochemistry laboratories offer the possibility to work together and share their competences to the teams involved in production and research. The two upper floors will host special rooms for nuclear medicine and oncological patients

The construction of the building started in March 2009 with the excavation of 25000 cubic meters of ground. The civil engineering works proceeded on schedule and the main infrastructure is foreseen to be ready by the end of 2011. The first accelerated beams are foreseen right after while GMP radiopharmaceutical production will begin by mid 2012.

The Cyclotron, the Targets and the Beam Line

The first and main scope of the project is the GMP radiopharmaceutical industrial production of FDG and of other ^{18}F based PET radiotracers. For this purpose the IBA Cyclone 18 MeV cyclotron has been selected with the dual H^- ion source option. Although still adaptable to accelerate deuterons with a minor modification, this option offers the possibility of switching from one ion source to the other almost instantaneously, thus avoiding the loss of the production batch in case of problems with the ion source. This machine provides large beam currents up to 150 μA in single or dual extraction mode, allowing the production of more than 500 GBq of ^{18}F within two hours of irradiation. The main characteristics of the Bern cyclotron are reported in Table 1 and the internal part of the accelerator is shown in Fig. 4.

Table 1: Main Characteristics of the Bern Cyclotron

Type	IBA Cyclone 18/18 HC
Acc. particles	H^- (D^- on option)
Energy	18 MeV (9 MeV for D^-)
Max. current	150 μA (40 for μA D^-)
Ion sources	2 internal PIG H^- ion sources
Extraction ports	8 (one of which connected with the BTL)
Extraction	Carbon foil stripping (single or dual beam)
Isotope targets	4 $^{18}F^-$, ^{15}O, ^{11}C
Beam Transport Line (BTL)	6.5 m long; two quadrupole doublets (one in each bunker); neutron shutter; adjustable beam size on target.

The cyclotron will be equipped with four liquid targets for $^{18}F^-$ production to allow redundancy for maintenance and future needs. For clinical research and routine activities, one target for ^{11}C production and one for ^{15}O are foreseen. Due to the very short half-life of ^{15}O, a specific 100 m long transfer line has been designed to connect the target directly to the nearby PET scanners. Any of the $^{18}F^-$ targets can be connected to any of the hot-cells via a specific switching system.

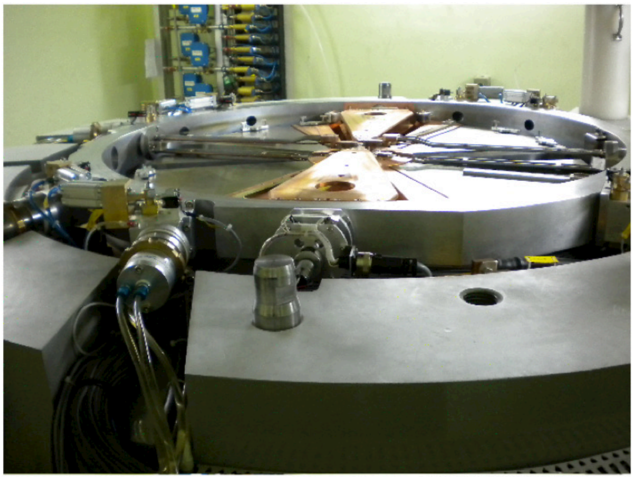

Figure 4: The IBA Cyclone 18 MeV cyclotron during the Factory Acceptance Tests (FAT) in Beijing in March 2011. The characteristic structure of the "Dees" and the eight extraction ports for the targets are visible.

One of the eight extraction ports of the cyclotron is permanently connected to the Beam Transport Line (BTL), equipped with two focusing quadrupole doublets (Fig. 5). A neutron shutter together with local shielding will allow access to the beam line vault also during the irradiation of standard targets in the cyclotron vault, minimizing interference between production and research activities. The beam line is designed to transport high current beams and to obtain a variable beam spot on target down to 5 mm diameter. This set-up is ideal for solid target irradiation, new target developments and multi-disciplinary research activities.

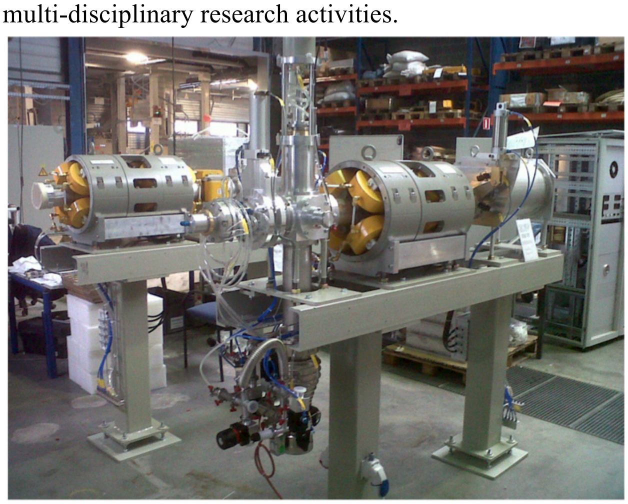

Figure 5: The external beam - assembled in Belgium - consists of two parts, one for each bunker. The quadrupole doublets and the neutron shutter are visible.

In a so complex installation, where very high activities are produced, the Radiation Protection Monitoring System (RPMS) is crucial. Supplied by TEMA Sinergie, the RPMS is composed by about 50 sensors able to monitor on line ambient radiation levels, air contamination and residual neutron fluxes. In case of failure in the hot-cells, the radioactive exhausted gases will be compressed and stored into Waste Gas Handling System (WGHS) and, after decay, evacuated through the general exhaust chimney monitored by a specific system supplied by Berthold Technologies.

RESEARCH ACTIVITIES

The Laboratory for High Energy Physics (LHEP) of the University of Bern is engaged in the development of innovative particle detectors for medical applications. In this framework, the first proton radiography using nuclear emulsion films has been performed [3], using technology developed at LHEP for neutrino physics.

A beam monitor device based on silica doped and scintillating fibres has been developed and tested with the 2 MeV RFQ linac at LHEP [4]. Scintillating silica doped fibres are advantageous, allowing the conception of small, inexpensive and easy to use devices. This first prototype consists on a single doped fibre moving across the beam.

The external beam line of the Bern cyclotron and the connected laboratories will be the main instrument for pursuing future research activities on particle detectors, radiation biology, material sciences, neutron dosimetry and radiation protection, in particular. For many of these applications low currents down to the nA are needed and solutions based on beam defocusing and collimators are under study using simulation codes.

The Laboratory of Radio and Environmental Chemistry of the University of Bern and the Paul Scherrer Institute will pursue research activities at the new SWAN cyclotron laboratory in collaboration with LHEP [5].

In June 2011 the First Bern Cyclotron Symposium [6] was organized by LHEP to stimulate ideas, synergies and collaborations in view of the scientific activities that will be pursued at the new Bern cyclotron laboratory.

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