THE CYCLOTRON FACILITY AT THE LABORATORY OF APPLIED NUCLEAR ENERGY (L.E.N.A.) OF THE UNIVERSITY OF PAVIA

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Abstract

A cyclotron facility has been recently installed at the Laboratory of Applied Nuclear Energy (L.E.N.A.) [1] of the University of Pavia for the production of radioisotopes for medical use. L.E.N.A. is a laboratory where a TRIGA MARK II research nuclear reactor [2] is used for several scientific applications since 1965. The accelerator is an IBA CYCLONE 18/9 [3] with fixed energy of 18 MeV for protons and 9 MeV for deuterons equipped with three targets (two of which for ^{18}F production and one for ^{13}N-Ammonia) with the possibility of extension to eight targets. The site also includes a radiochemical laboratory for radioisotope packaging and delivery in shielded cases. The cyclotron building is separated from the reactor one with a stand-alone system for area radiation monitoring and other safety systems. Present applications are dedicated to radioisotopes production for PET medical centres. In the future this facility will offer the opportunity of the installation of an external beam line for a wide range of applications (e.g., radiobiological research). Since the cyclotron is installed in a university laboratory this can also be used as a training facility for particle accelerator courses.

CYCLOTRON FACILITY

The cyclotron facility has been installed in a three-floors building beside and separated from L.E.NA. On the underground floor there are the Bunker room, the Power Supply room and the Control room. On the ground floor there are the Radiochemical Laboratory and the Decontamination room. Technical room is on the first floor.

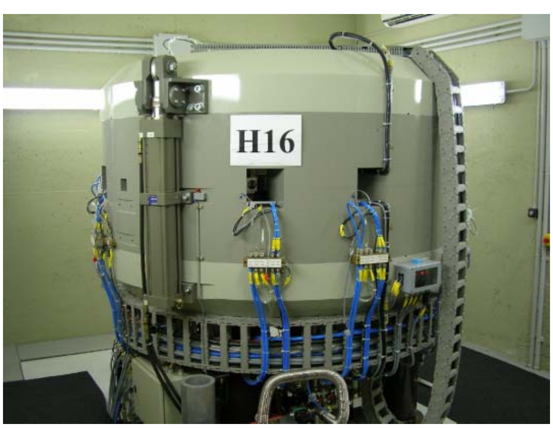

Figure 1: IBA CYCLONE 18/9 – H16 inside the bunker

Bunker, Power Supply and Control rooms

The cyclotron is located inside the bunker (Fig. 1) designed to shield neutron and gamma radiations according to the national laws corcerning radioprotection. Walls are made of concrete (density 2.35 g/cm^3) whose thickness ranges from 180 to 210 cm. During the irradiation it is closed by a 13-ton concrete door. The shields are designed in order to limit the dose to the workers to 0.5 mSv/year for a working production of 80000 μA-year.

The ventilation system of the entire building is designed in order to ensure a depression greater than 100 Pa inside the Bunker with respect to the outdoor and 75 Pa with respect to the Control room. When the beam is ON, the depression inside the Bunker is reached with minimal air ventilation in order to avoid undesidered discharge of ^{41}Ar outside the building. The air extracted from the building is continuously monitored by a NaI crystal before the discharge into the environment.

Figure 2: Operators in Control room. In background Radio Frequency (RF), magnet and ion source cabinets

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The Control room is located beside the Power Supply room (Fig. 2). A large window allows the operators to check and control vacuum, Radio Frequency (RF), magnet and ion source cabinets. All the cyclotron operations are controlled by a personal computer connected to a PLC. In this room there are also the area radiation monitoring system and the ventilation control computers.

Radiochemistry Laboratory

A cell for dispensing unit model DMC has been installed by TEMA SINERGIE [4] in the Radiochemistry Laboratory (Fig. 3). Air tightness and ULPA (Ultra-Low Penetration Air) filters together with the vertical laminar flow assure a Class 10 working environment and a high sterility. The shielding thickness of the cell (75 mm Pb for each side) keeps a dose rate below 5 µSv/h on cell's surface and below 0.5 µSv/h at a distance of 1 meter, with an internal activity of 3000 mCi (111 GBq) of ^{18}F.

Figure 3: Cell for dispensing unit: an operator during the manipulation of ^{18}F before the activity measurement

This cell allows to perform delivery processes from targets to vials in sterile conditions with an high radioprotection level for the operators (Fig. 4). After the delivery the vial activity is measured by CAPINTEC CRC-15 PET radioisotope dose calibrator [5], and then the vial is packaged into a lead shielded container (Fig. 5) for the delivery to the Radiopharmaceutical Laboratory for the final synthesis.

Figure 4: Internal view of dispensing unit model DMC

Figure 5: Vials and a lead shielded container for the delivery

ACCEPTANCE TESTS

On July 2007 a series of tests were performed on the machine and first radioisotopes were produced in the site. IBA CYCLONE 18/9 – H16 installed in Pavia is equipped with three targets; two of which for ^{18}F production and one for ^{13}N-Ammonia production.

$^{13}NH_3$ Target

Volume: 1600 µL
Target Reaction: $^{16}O(p,\alpha)^{13}N$
Target Material: H_2O (natural) + 5 mmol Ethanol
Beam: 18 MeV Protons
Target Current: 20 µA
Irradiation Time: 10 min
Recovered Activity EOB (End Of Beam): 11.1 GBq (300 mCi)

^{18}F Target (Small Volume)

Volume: 520 µL
Target Reaction: $^{18}O(p,n)^{18}F$
Target Material: $H_2{}^{18}O$ (> 96%)
Beam: 18 MeV Protons
Target Current: 15 µA
Irradiation Time: 60 min
Recovered Activity EOB (End Of Beam): 34.0 GBq (920 mCi)

^{18}F Target (Large Volume)

Volume: 1840 µL
Target Reaction: $^{18}O(p,n)^{18}F$
Target Material: $H_2^{18}O$ (> 96%)
Beam: 18 MeV Protons
Target Current: 37.5 µA
Irradiation Time: 1200 min
Recovered Activity EOB (End Of Beam): 178.3 GBq (4.82 Ci)

PRESENT ACTIVITIES

Present applications are mainly dedicated to radioisotopes production for PET medical centres. The cyclotrons produces ^{18}F isotope and ^{13}N in the chemical form of ammonia. These isotopes will be sent into lead shielded containers to Radiopharmaceutical Laboratory of Policlinico San Matteo of Pavia [6] to synthesize Fluorodeoxyglucose [^{18}F]FDG for PET scanning and new experimental tracers.

FUTURE PROJECTS

The distance between the Radiopharmaceutical Laboratory of Policlinico San Matteo and the Cyclotron Radiochemistry Laboratory is about 200 meters. There is already a project to connect them directly through a pneumatic delivery system in order to speed up the delivery time and reducing further on the dose rate for the operators.

Beside the cyclotron bunker, in the L.E.N.A. building, a room will be arranged, in agreement with the Biological Department [7], as a Radiobiological Laboratory in order to study neutrons (from the TRIGA MARK II reactor) and protons (from the cyclotron) radiation effects on cells. A hole in the bunker wall has already fixed up in order to connect the rooms and it is temporarily closed with bricks, lead and polyethylene caps. An external beam line, about 5 meters long, will be installed from the bunker to the laboratory.

A second short external beam line (Fig. 6), about 1 meter long, will be installed inside the bunker for research purposes, for solid and liquid targets, and for a wide range of applications in agreement with the Chemistry Department [8], the Nuclear Physics Department [9] of University of Pavia and the National Institute of Nuclear Physics (I.N.F.N.) [10].

Since the cyclotron is installed in a university laboratory it will also be used as training facility for particle accelerator courses.

Figure 6: Cyclone® 18/9 fitted with Vectio® external beam line for advanced research [3]

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