

STATUS REPORT ON THE INSTALLATION OF PROTON AND NEUTRON THERAPY IN CENTRE ANTOINE-LACASSAGNE.

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Abstract: In January 1987, the Centre Antoine-Lacassagne (CAL) was authorized to install the Medicyc cyclotron (65 MeV protons) for proton therapy and neutron therapy.

Construction of the final building to house the cyclotron and the radiotherapy, radiobiology and maintenance services began in January 1988 and has been completed in July 1989, allowing the reinstallation of the cyclotron, construction of beamlines and installation of treatment rooms.

Characteristics of the Medicyc cyclotron

Medicyc is a fixed-frequency isochronous cyclotron designed by P. Mandrillon and built under his control for the Centre Antoine-Lacassagne to accelerate protons to an energy of 65 MeV. Close collaboration with CERN, CNRS and IN2P3, allowed the project to concretize. Presently, the characteristics of the magnet are as follow: length: 4m, height: 2.3m, width: 1.7m, weight: 140 tons, 4 spiraled sectors, 9 trim coils.

Axial injection and central region:

Medicyc is a medical machine and this influenced initial design and further modifications as important as the decision to switch from positive to negative charged ions (H⁻) acceleration, in order to increase ion source duration of life and simplify extraction of proton beam. Consequently ion source was substituted, axial injection and central region redesigned, RF system and extraction modified.

H⁻ ions are produced in a multicusp source supplied by Ion Beam Application (IBA, Louvain-la-Neuve). The source is mounted on a platform at 33 kV vertically above the axial injection line. A pseudo cylindrical inflector deflects the beam in median plane. The central region has been designed to accept a $h=1$ for protons and $h=2$ acceleration mode for deuterons and other fully stripped light ions. The new geometry operates at 24.8 MHz. Central magnetic field is around 1.7 Tesla.

RF system

The RF system consists of two opposed dees with a 75 deg. aperture, now operating at 24.8 MHz after an

enlargement of the cone of the dee. The peak voltage is 50 kV. Each dee is independently excited by its own amplifier which is in turn driven by a master oscillator. The dees resonate as $\lambda/4$ lines.

Poles sectors and trim coils:

The azimuthally varying magnetic field is obtained in Medicyc by means of four pairs of spiraled sectors with hill and valley gaps of 130 and 280 mm, an average spiral of 60 deg./m. In order for a 24.8 MHz operation to be optimized, several sector modifications were necessary, notably in the extraction region. For achieving isochronous magnetic field shape and better beam control, a total of nine trim coils are mounted on the surface of the sectors. Recent magnetic field measurements have shown that a satisfactory degree of field isochronization can be achieved with this trim coil arrangement. The final energy of 64.5 MeV will be reached at the extraction radius of 68.8cm.

Beam extraction and transport:

Initially designed and tested resonant extracting system was substituted by stripping extraction consisting of a 100 $\mu\text{g}/\text{cm}^2$ carbon foil mounted on a movable support. Following the stripper, the positive proton beam is transported 35m down the beamline to the two treatment rooms equipped for neutron and proton therapy. The transport consists of a quadrupole pair at the cyclotron exit and a FODO channel consisting of two identical bending magnets and three equally spaced quadrupoles, which has unit magnification. This arrangement is followed, for the neutron therapy beamline, by a quadrupole pair and a vertical bending magnet directing the beam to the vertical neutron collimator. In order to reduce the cost of the focusing elements, the design seeks to achieve a small beam diameter throughout the transport system. The calculated beam size is within 2.4cm, both horizontally and vertically. The bending magnets and the quadrupoles have been constructed by Bruker and Sigmaphi.

Shieldings:

Shieldings necessary around the cyclotron, beam lines and treatment rooms were determined using the

formulas proposed by Braid, Tesch and Stevenson (IAEA Report, 1986), taking into account the radioprotection recommendations. As construction materials, barium concrete, concrete and earth were used. The choice between those materials is a result of a compromise between price and available space for a given mass surface density. Shieldings are in general equivalent to 2,40m concrete. The access to treatment rooms is through labyrinths avoiding the use of large heavy doors, costly and psychologically intolerable for patients.

The proton treatment room is located in front of beamlines deviation area and over the labyrinth of access to the neutron treatment room. Barium concrete was used to build the walls of proton room perpendicularly to the proton beamline, in order to increase the length of this room. The access labyrinth runs around two sides of the treatment room.

Covering of the deviation area, protontherapy room and partly cyclotron vault is made of movable concrete blocks, in order to facilitate further evolutions of the installation and allowing the access of the overhead travelling crane for heavy maintenance of the cyclotron.

Treatment rooms:

The beam leading to the proton treatment room is left to spread freely from the last dipole magnet and is collimated to 35mm before entering the treatment area. This diameter is the maximum width of the eye tumor. Only the central part of the beam is selected so as to obtain a flat dose profile. For an initial beam intensity of 120nA, only 9nA are transmitted, corresponding to a rate of 50pA/cm².

Once inside the treatment area, the proton beam continues to travel in air before being modulated by a rotating plexiglass wheel with variable thickness angular sectors. The diameter of the beam is kept at 35mm by Al collimators mounted on the optical bench. At the end of the bench, it is finally collimated to the treated tumor shape. These arrangements follow closely those of Clatterbridge. The protontherapy chair has been built in the workshops of the Medical Research Council in Clatterbridge and set-up in May 90. Optical bench elements are now under construction.

The neutrontherapy room is located under the deflection area. Neutrons are produced in a Beryllium target which is retractable at the end of each treatment, avoiding unnecessary irradiation of the staff. The intensity of proton beam on target is around 15 μ A. The emerging neutron beam is defined to obtain fields varying from 5x5 to 25x25cm at 160cm from the target by using two collimators, the first one made of iron with a fixed aperture, while the second is a continuously adjustable

multileaf collimator of the Scanditronix design, modified for 65MeV p/Be neutrons and constructed by the "Cyclotron Research Center" in Louvain-la-Neuve and set up in Nice during April and May 90. This multileaf collimator consists in 44 independent steel leaves placed in two groups of 22 parallel and opposed leaves. Each leaf can reach and pass over the beam axis to obtain complex field shapes avoiding interposition of heavy metallic shielding blocks in the beam. The Oldelft treatment table equipped with a wooden couch has also been set up.

The choice of a vertical beam for neutrontherapy has been imposed by economical considerations and does not exclude a future isocentric gantry. General design of the building took into account all these considerations together with medical ones.

General organization of the buildings:

The buildings are in two parts, one housing the cyclotron related facilities and one housing, for one third, technical workshops and offices, and for two thirds, medical and radiobiological facilities.

The technical building has been made with a metallic frame supporting on its whole length the overhead travelling crane. Under that structure are built the cyclotron vault, beamlines gallery and treatment rooms. Beside the cyclotron are located the mechanical workshop, electric power supply and cooling systems. The treatment rooms are between two areas devoted to future developments. The need for an underground level below the cyclotron and the possibility of superimposing the two treatment rooms induced us to design the building on two levels, with a basket supporting the beamlines at the upper level. In order to preserve all the future evolutions, the developmental areas have been left without intermediate floor.

The second building is also on two levels: patients will enter the facility at the upper level, where take place the protontherapy waiting room, laboratories devoted to radiobiology and, for the technical team, design office. The lower level receives electronics workshops and technical offices, and for the medical part, the neutrontherapy waiting room, radiotherapy and medical physics facilities. One fourth of the total surface of this building is devoted to further developments. This building has also been designed to be easily surmounted by three additional levels.

Lastly a third building could be added in the rear of the first one. It has been started by the installation of the command and controls room, placed at half-height of the technical building, behind and above the mechanical workshops. Further developments are also possible in this room, only one half of the surface being occupied by the

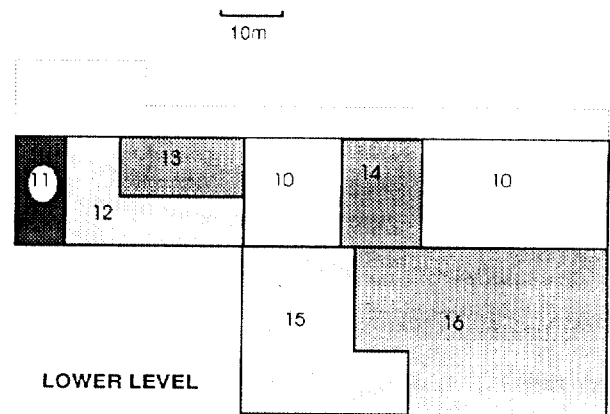
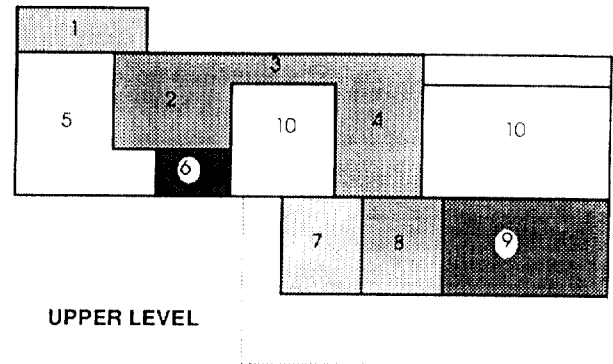
command and controls systems of Medicyc.

Medical programme:

Protontherapy will be the first application to start, firstly for ocular melanoma treatment, with the same protocols used in Boston, Villigen and Clatterbridge. Furtherly, we plan to use protons in the treatment of some relatively superficial head and neck tumours. The first treatments are planned in the very beginning of 1991.

Neutrontherapy would start a few months later. Main tumours concerned are: salivary gland and facial sinuses adenocarcinomas, bulky head and neck tumours and/or nodes, advanced prostatic carcinomas, soft tissue and bone sarcomas, cutaneous melanomas, rectal adenocarcinomas. The depth dose profile given by a $p(65)+Be$ neutron beam authorizes the treatment of deep seated tumours, while avoiding side effects occurring in healthy tissues with low or medium energy neutrons; 50% of the entrance dose is given at a 16cm depth, compared to 10cm for cobalt and 6cm for 200kV. This depth dose profile looks like a 8MV photon beam from a modern LINAC. The facility in Nice will be the third in Europe (after Louvain-la-Neuve and Clatterbridge) to enter into the high energy neutron group ($>60MeV$) encompassing, out of Europe, three machines: one in Fermilab(USA), one in NAC(South-Africa) and one in South-Corea. The interest for high energy neutrons has been clearly demonstrated by the RTOG(Radiation Therapy Oncology Group): there is a strong relation between low energy neutron and high complication rate. Increasing energy decreases complications and allows to treat deep seated tumours for which good results of neutrons are annihilated, due to high rates of severe problems occurring in healthy tissues.

But a lot of progresses remain achievable in the field of neutrontherapy and the absolute necessity of radiobiological research appears at evidence. This is the reason why the facility contains a large laboratory mainly devoted to radiobiology and cellular kinetics. Major progresses in neutrontherapy are to be expected of a better patients selection based not only on some radiosensitivity assays, but also on a better individual knowledge of cell kinetics parameters for both healthy and tumoural tissues. The laboratory will open during the second part of 1990. Main goals of our team for the near future are to set up short life isotope production and PET camera facility, in order to develop immunolabelling techniques, both for diagnosis and treatment. Furtherly, we plan to develop protontherapy at higher energy.



- 1 - command/control
- 2 - cyclotron
- 3 - beamlines
- 4 - protontherapy room
- 5 - mechanics workshop
- 6 - clean room
- 7 - design office
- 8 - entrance of medical facility
- 9 - radiobiology
- 10 - developmental areas
- 11 - cooling systems
- 12 - electrical alimentations
- 13 - cyclotron underground
- 14 - neutrontherapy room
- 15 - technical offices and electronics workshop
- 16 - radlotherapy and medical physics

CENTRE ANTOINE-LACASSAGNE BIOMEDICAL CYCLOTRON