RECENT ACTIVITIES OF THE CYCLOTRON LABORATORY IN NICE

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ABSTRACT

This paper presents the results of the first year of operation of the MEDICYC cyclotron in Nice and the medical programme of the laboratory. It outlines also the involvement of the laboratory in the 2 year work of the EULIMA feasibility study group and future projects.

1. INTRODUCTION

The Centre Antoine Lacassagne in Nice is one of the 20 cancer centers in France. Considering the frequency with which various types of cancer treatment were applied in the 80's in the french cancer centers, it appeared that radiotherapy was used in 66.3% of treatment including 24.1% in association with other forms of therapy. This high frequency determined the need expressed by the radiotherapists to develop their techniques and the MEDICYC programme based on a compact 65 Mev H^- cyclotron was initiated [1]. The cyclotron is presently used for protontherapy and radiobiology, in the coming months neutrontherapy will start. In the near future, the negative ion design of the cyclotron will allow for simultaneous production of F^{18} for PET scanning for various medical teams. The general layout of the facility is shown on the Fig1.

MEDICYC is used by a wide collaboration with several cancer centers and university hospital in France extended also to Barcelona (Spain) Genova and Sienna (Italy), Essen (Germany). A communication and data exchange network is being implemented.

2. PROTONTHERAPY

The low intensity beam for protontherapy is left to spread out at the exit of the last 90 degrees horizontal bending magnet, then diffused through a 50 nm tantalum foil and collimated to 35 mm before entering the treatment room. The characteristics of a standard proton beam are listed in the table 1.

Table 1

Maximum range measured on the 90 % distal isodose	32.2 mm
Bragg peak thickness on the 50 % isodose	3 mm
Lateral penumbra between 90 and 10 % isodoses	1.7 mm
Rotating plexiglass modulator	2000 rpm
Dose homogeneity in the plateau	± 1 %

By July 1st, a total number of 103 patients have completed their treatment.

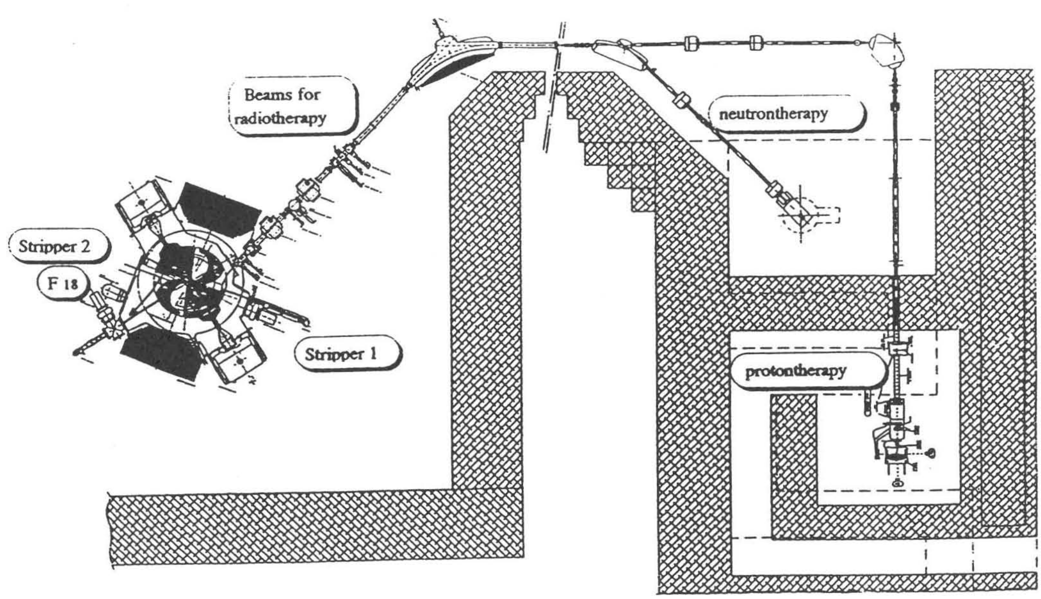

Fig 1 : MEDICYC 65 MEV H^- cyclotron for neutrontherapy, low energy protontherapy and F^{18} production.

3. RADIOBIOLOGY

The RBE of the 65 MeV protons, measured on the 15 cm spread out Bragg peak, of a human melanoma cell line, has been recently published by A. Courdi[2]. Figure 2 presents the survival curve of this cell line for proton and cobalt irradiation. A slightly decreasing value of the RBE versus the delivered dose has been found, from 1.15 at 2 Gray to 1.12 at 10 Gray. Therefore a provisional clinical value of 1.1 has been adopted for the treatment. Further experiments on different cell lines are in progress.

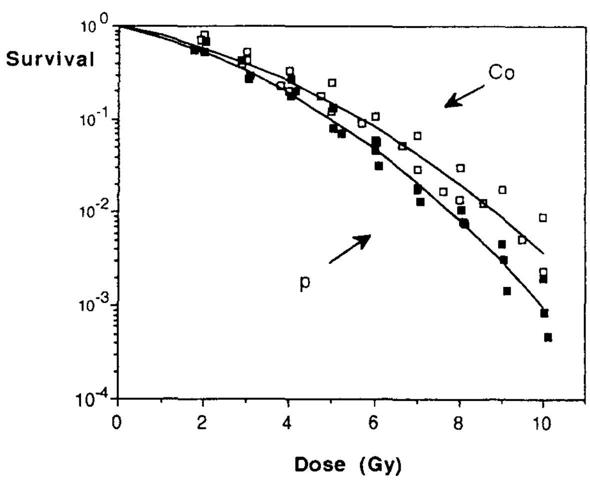

Fig 2 : Survival curve of human melanoma cell lines after proton and cobalt irradiation.

4. NEUTRONTHERAPY

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 µA. The emerging neutron beam is defined to obtain maximum fields up to 20 x 20 cm at 170 cm from the target. A continuously adjustable multileaf collimator of the Scanditronix design, modified for 65 MeV p/Be neutrons has been constructed by the "Cyclotron Research Center" in Louvain-La-Neuve. This multileaf collimator consists in 44 independent steel leaves placed in 2 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.

A system which permits a 290 deg rotation of the collimator around the vertical axis has been recently installed.

The early control sequence for achieving the collimator setting for a specific field was performed through an analogic system which gave positioning errors of the leaves which were not acceptable. Therefore a new system was developed using a PC giving the obvious advantage of a easy access to the desired field and to the best reproducibility of the settings during the treatment course.

The following Fig 3 shows the layout of the treatment rooms.

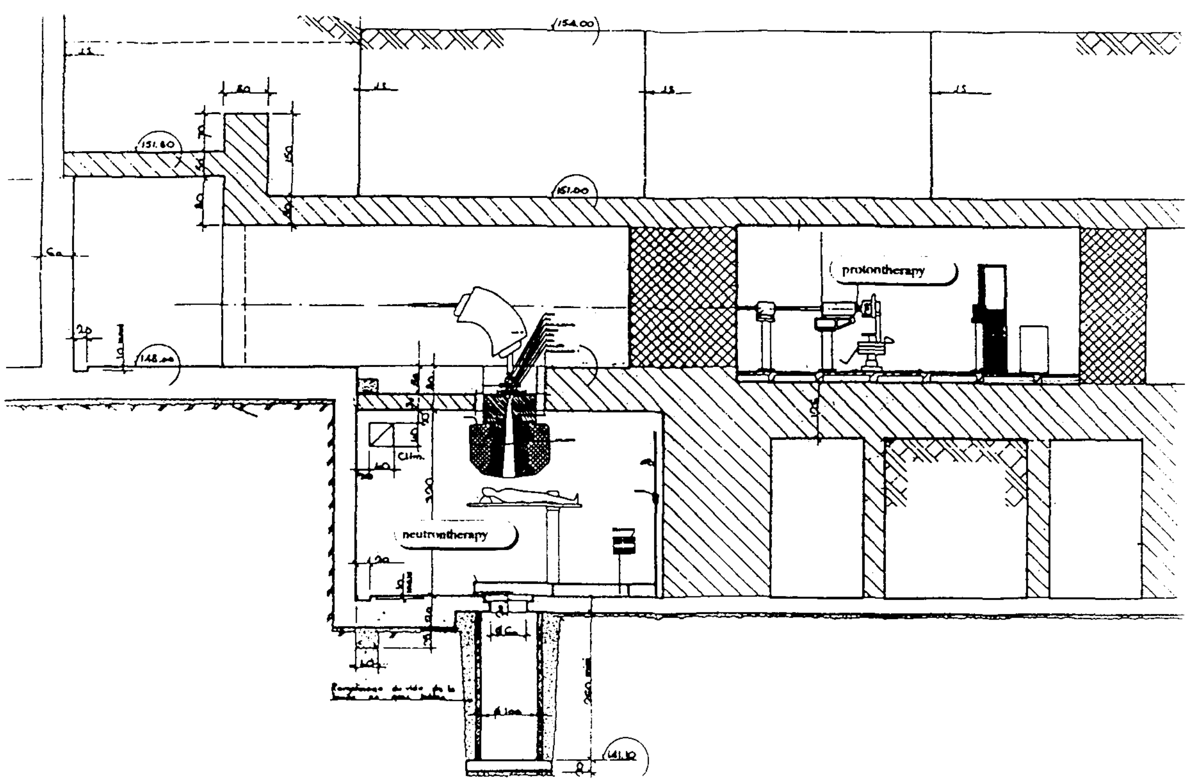

Fig 3 : Layout of the treatment rooms

5. F^{18} -DEOXYGLUCOSE PRODUCTION

A group of physicians from various medical disciplines such as neurology, oncology, cardiology and psychiatry have recently set-up a group of users of the MEDICYC facility for the production of F^{18} -DG. In order to avoid any interference with the radiotherapy schedule it was proposed to investigate the possibility of a beam sharing system based on a simultaneous extraction of two beams using two strippers at different azimuth. Figure 4 presents the two symetric simultaneous extracted beams.

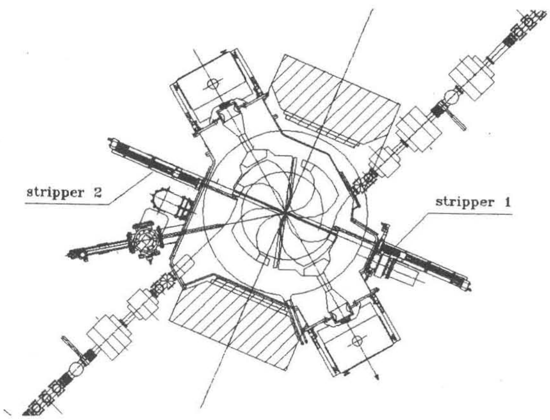

Fig 4 : Simultaneous extracted beams

6. EULIMA COLLABORATION

The Cyclotron laboratory was also involved with several european institutes in the feasibility studies of the EUropean Light Ion Medical Accelerator (EULIMA) project[2] which were partly funded by the Commission of the European Communities and by the Conseil Général des Alpes Maritimes (Nice, France).

Two approaches to a 400 MeV/nucleon machine design have been investigated, namely a superconducting cyclotron and a synchrotron. The Cyclotron laboratory together with the CRC Louvain-la-Neuve which investigated ECR source performances and the possibility to produce radioactive light ions (C^{11},O^{15},Ne^{19}) for postacceleration[2], contributed significantly to the technical (mechanical studies and construction of wooden and copper half scale model of the RF cavity) and theoretical (axial injection and central region) studies of the superconducting cyclotron option. Being partly hosted by CERN, Geneva, the feasibility studies profited from the CERN technical expertise in superconducting magnets and cryogenics for the cyclotron, and conceptual and technical studies for the synchrotron.

6.1 Superconducting cyclotron

A fixed-frequency super-conducting cyclotron design was investigated, and a solution comprising a single super-conducting coil (external radius ; 2.32 m) and moderately spiralled sectors was found to be feasible.

Numerical calculations to assess the general strength of the magnet structure assuming a cylindrical vacuum chamber have shown that this solution fulfils the mechanical requirements.

Accelerating peak voltages on the 2 cavities are increasing from 100 kV at injection up to 250 kV at extraction. The total RF power losses are about 150 kW per cavity.

Light ion beams to be injected into the cyclotron are produced in an Electron Cyclotron Resonance Source (ECRIS), which in its latest version delivers intensities of completely stripped Carbon, Nitrogen, Oxygen and Neon ions, several orders of magnitude above what is needed for treatment. An axial injection scheme using a spiral inflector was foreseen. A preliminary layout of the beam extraction system consisting of two electrostatic deflectors and one electromagnetic channel was analysed.

For the coil and cryostat design a solution in which the coils are wound in the double-layer pancake technique, and are cooled in direct contact at 4.2°K in a liquid helium bath at atmospheric pressure, was studied.

6.2 Synchrotron

The great advantage of this type of accelerator is the possibility to vary the energy covering the interval from 100 to 400 MeV/n. This energy range is very similar to the LEAR accelerator at CERN, and several technical concepts developed for this machine could be used. Two possibilities to design a more compact machine have been investigated : a separate function machine (SFM) of 59 m of circumference, more flexible for developments, and a combined function machine (CFM), if space is crucial. In this case a further reduction in size can be achieved.

A classical injection scheme has been designed, with an ion source of Electron Cyclotron Resonance type (ECR) feeding a small Radio Frequency linac (RFQ) followed by a conventional linac (5 MeV/n) with a repetition rate of about 1Hz. This basic design could be developed to include better monitoring of the extracted beam, and a storage and cooling facility[3].

6.3 Accelerator choice

The continuous and highly intense output beam of the cyclotron permits simultaneous treatment in different rooms by splitting the beam. Moreover, the operation of such a fixed frequency accelerator is very simple. The drawback is the fixed energy, so to change the range in tissue the energy of the ions must be degraded to the value corresponding to the deepest range for a given tumour. Nevertheless such a high energy cyclotron is more of a new design : in order to avoid a large number of RF periods high dee voltages should be used and the magnetic field should be accurately shaped. The magnet is heavy and if faults develop, access to the interior will be time consuming.

On the other hand, the synchrotron requires costly injectors and sophisticated controls devices to take profit of the inherent flexibility in energy, but has the following advantages :

- short repair time, i.e. repairs within 6 hours.
- possibility for further increase of intensity through beam cooling. Hence, modulation of the beam intensity and programming of dose across the irradiation volume could become possible.
- well known techniques, important for the reliability of a medical accelerator, which should reduce the construction time and the running-in time.

Based on these arguments, the project management board has recommended the synchrotron option but funding is not available.

7. FUTURE PLANS

Evidence is progressively established that high-LET radiations (the cheapest are of course neutrons with physical properties reaching nearly the same level as the modern medical linac) will play a role in radiotherapy for some well defined patient series. In order to take the full benefit of neutrontherapy, physicians are asking for variable incidence beams. Therefore an isocentric gantry will be investigated. The other promising way in radiotherapy is to develop low LET radiations with high physical selectivity and reflexions towards an high energy protontherapy programme have started. Of course, the MEDICYC cyclotron which is fully dedicated to medical applications, should also continue to develop beam lines for the production of the most commonly used radioisotopes.

8 . ACKNOWLEDGEMENTS

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9 . REFERENCES

[1] P.Mandrillon et al. "Commissioning and implementation of the MEDICYC cyclotron programme", Proceedings of the 12th International Conference on cyclotrons and their applications, Berlin, May 1989.

[2] A. Courdi et al. Efficacité biologique relative des protons de MEDICYC sur une lignée de mélanomes humains, Bulletin du cancer, 1992,79,613, Elsevier, Paris.

[3] G. Berger and al. "Radioactive ions beams : results and perspectives for light ion therapy and diagnostic purposes. Proceedings of the EPAC90, Nice, June 1990.

[4] G. Cesari, P. Lefèvre and D. Vandeplassche, "Feasibility study of a synchrotron for the European Light Ion Medical Accelerator", Proceedings of the EPAC92, Berlin, March 1992.

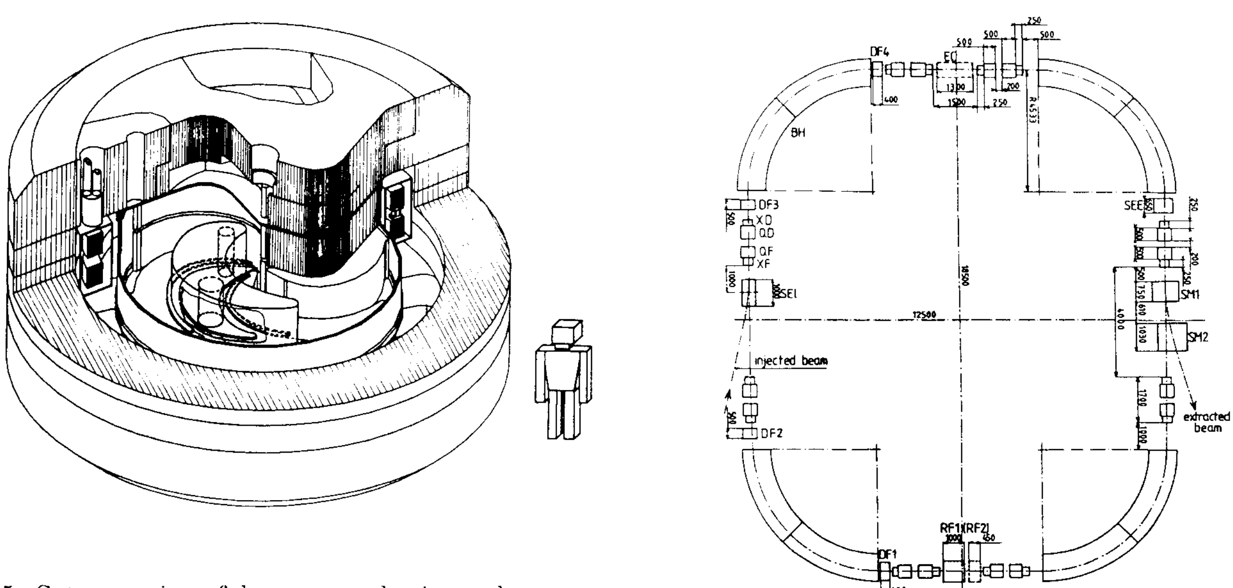

Fig 5 : Cut away view of the superconducting cyclotron and general layout of the SFM synchrotron proposed for EULIMA.