MEDICYC : A 60 MeV PROTON CYCLOTRON ASSOCIATED WITH A NEW TARGET DESIGN FOR NEUTRONTHERAPY

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INTRODUCTION

MEDICYC[1] is a medical cyclotron programme undertaken by the Nice Cancer Center. Its major goal is radiotherapy based on protons and fast neutrons. This cyclotron satisfies also the medical requirements for the Nuclear Medicine Department of the hospital. Table I presents the possibilities of the machine and Table II summarises its characteristics. The construction of the main components of the machine has now been achieved. The two radiofrequency cavities have been tested, the ejection system is partly manufactured and the magnetic measurements have been started.

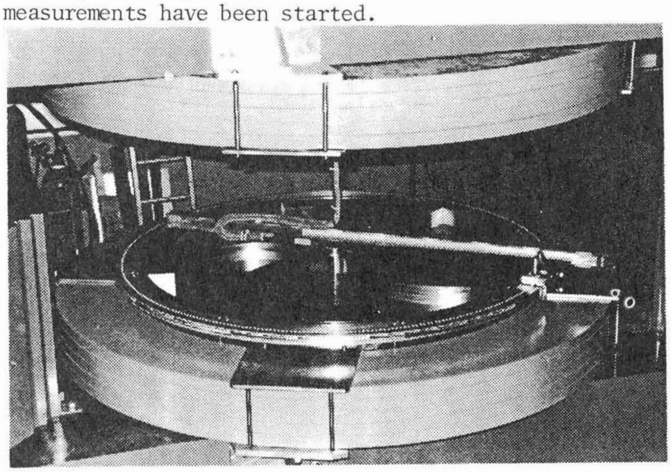

Figure 1 : Cyclotron with the upper yoke raised

Fig. 1 shows the field measuring system which consists of a bar in a cast aluminum on which 51 Hall plates (SBV 601-S1 SIEMENS) are mounted with a spacing of 2cm. Azimuthal positioning procedure and scane cycle is controlled by an on-line computer.

TABLE_II

CHARATERISTICS
. MAGNET LENGTH : 4.0M HEIGTH : 2.3M WIDTH : 1.7M SECTORS : 4 TRIMCOILS : 10
. INJECTION EXTERNAL SOURCE : DUOPLASMATRON BUNCHING : SINGLE HARMONIC BUNCHER FOCUSING : 2 MAGNETIC CYLINDRICAL LENSES INFLECTOR: SPIRAL TYPE.
. RADIOFREQUENCY SYSTEM 2 DEES OF 75° APERTURE FREQUENCY : 24 MHZ PEAK VOLTAGE : 50 KVOLTS FOR H=1 30 KVOLTS FOR H=2 POWER : 2 CW 25000 EIMAC
. EJECTION FIRST SECTION : ELECTROSTATIC E=100 KVOLTS/CM SECOND SECTION : ELECTROMAGNETIC B=2500 GAUSS G=+400 G/CM THIRD SECTION : 1 MAGNETOSTATIC CHANNEL = + 1000 G/CM

EXTERNAL SOURCE, AXIAL INJECTION AND CENTRAL REGION

A number of important argument exist in favour of external[2] sources. The principle of separating the func-

TABLE_I

OPERATING_PARAMETERS

	NEUTRONTHERAPY	PROTONTHERAPY	NUCLEAR MEDECINE
MEDICAL REQUIREMENTS	NEUTRONS . MEAN ENERGY 20 MEV . DOSE RATE 3.36cGy/MIN . 50% DOSE D ≫14 CM	PROTONS . ENERGY 60 MEV	$^{11}C.^{13}N.^{15}O.^{18}F.^{123}I$
CYCLOTRON BEAMS	PROTONS 60 MEV INTENSITY I = 15 μA	PROTONS 60 MEV	PROTONS 60 MEV DEUTONS 30 MEV PROTONS 15 MEV FROM H2
OPERATING HARMONIC MODES	FONDAMENTAL	FONDAMENTAL	FONDAMENTAL AND SECOND HARMONIC

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tions of an accelerator, even for a compact cyclotron, should lead to a more reliable machine especially for medically orientated application.

A duoplasmatron with good performances (normalized emittance 0,15π mm x mrad) has been chosen. The beam is axially injected (inflector type spiral) in a cyclotron central region which satisfies the double mode of operation (fundamental and second harmonic), avoiding any puller motion in the injection gap[3]. Figure 2 shows the results obtained with electrolytic tank measurements and orbit calculations with programme AGORA[4].

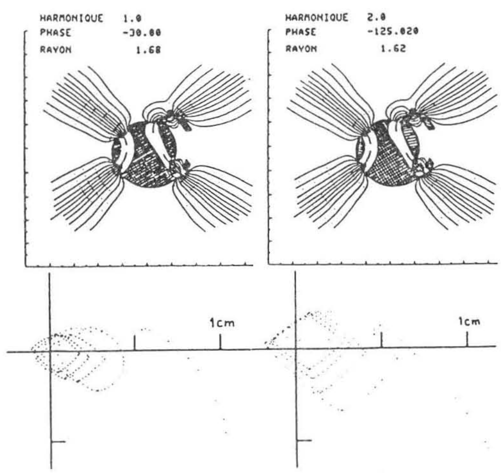

Figure 2 : Equipotential lines distribution and central trajectories for protons (h=1) and deuterons (h=2) starting from the inflector exit in the median plan. Centers of curvature motions for both modes show a residual off-centering less than 1mm after 5 turns. The injection energy is 33.4 keV for protons and 15.6 keV for deuterons. A single harmonic buncher is located just at the top of the magnet yoke. The vertical components of the inflector electric field are 17.2 kV/cm (h=1) and 10.1 kV/cm (h=2).

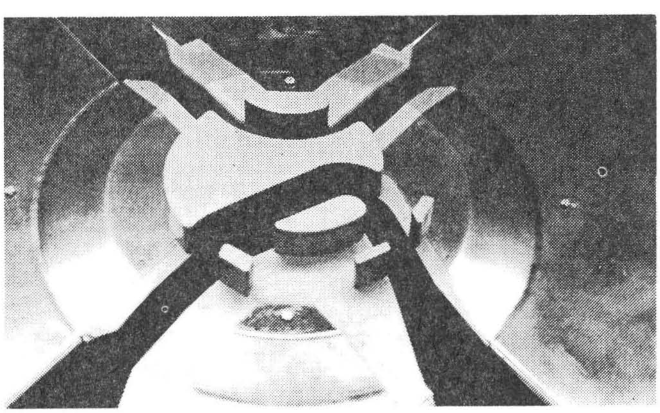

Figure 3 : Central region model for electrolytic tank

EXTRACTION

Figure 4 presents a plan view of the extraction system composed by a first electrostatic section (ESC) followed by an electromagnetic channel (EMC) whose main element is a current-bearing septum of 5mm thickness and whose stray field is compensated by auxiliary conductors (see Fig. 6)

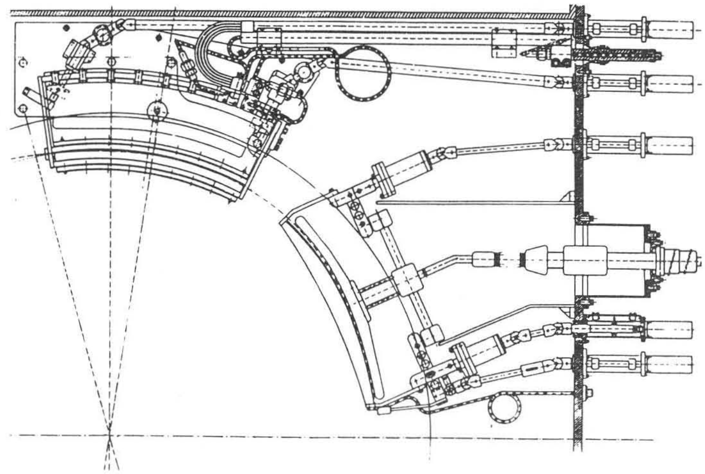

Figure 4 : The extraction channel

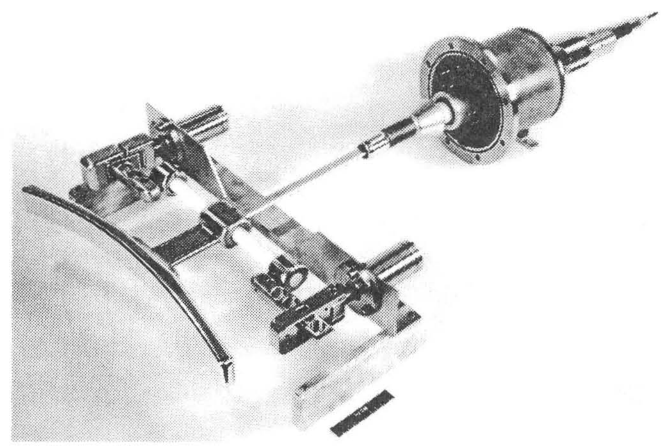

Figure 5 : High voltage part on the electrostatic channel with the high-voltage feedthrough

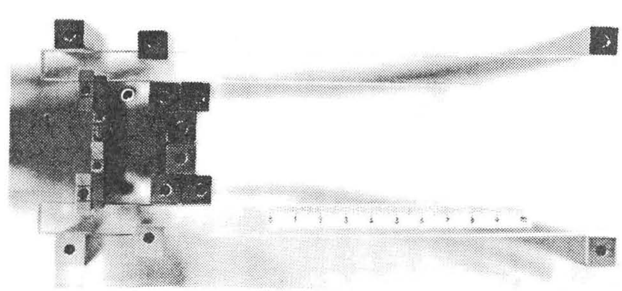

Figure 6 : Cross-section of the electromagnetic channel prior to brasing. The septum itself is 5mm thick and carries a 3200 Amperes current.

THE CONTROL SYSTEM

The universal question "How to make it simple" has a particular meaning for we who are very few in number.

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The system is based on two CAMAC crates directed by two powerful TMS 9900 (or later TMS 99000) based crate controllers (STACC) and a large capacity programmable controller (PC). The first STACC checks the interrupts of the modules connected to these parts of major components of the cyclotron which need supervision. One of these modules is linked to the PC which is in charge of the security tasks. This crate is called CLE.

The second STACC controls the system through panels and keyboards. Displaying, on request, all the status of the machine, it takes the part of a computer console. This crate is called CDE. Both crates are linked together via I/O registers, CDE being master and CLE slave.

Software problems have been solved in two ways depending on the tasks priority

- low priority tasks : software written in NODAL which is a powerful on board interpretive language ;
- high speed interventions : as NODAL is rather slow, the software is written in TMS 9900 assembly language.

In CLE, the programme is continuously checking the interrupts of the system, acting quickly by executing special functions, when the event occurs. The main colour screen of the control room is connected with this programme.

In CDE, the programmes are called from a set of pseudo-touch panels. They are standing on a high speed access Winchester disk.

Actually, the basic structure has already been written and tested.

THE NEW LID TARGET

It has been developped from a new and original idea of improving the performances of the beryllium targets usually used for neutrontherapy. It consists of a half-thickness lithium deuteride target composed by several small disks cooled by a forced helium gaz circulation (see Fig. 7).

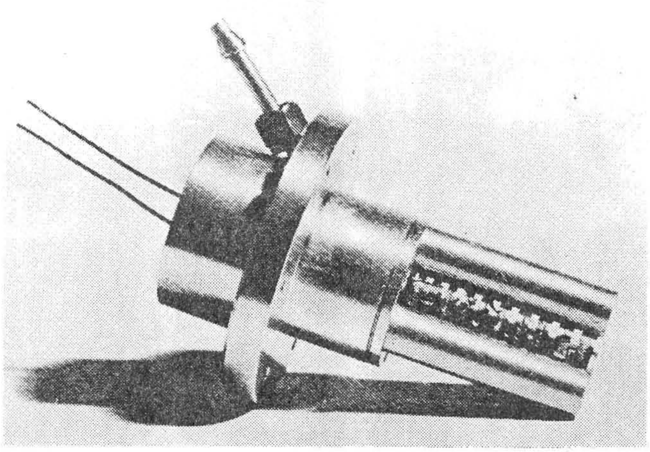

Figure 7 : The LID target support (10 disks)

The emerging protons after a deflection by a small permanent magnet ($SmCo_5$) are stopped outside the neutron field by a carbon beam catcher.

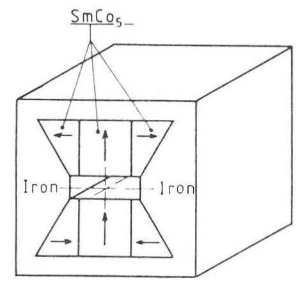

Figure 8 : The permanent magnet deflector

After a preliminary experiment necessary to check the feasibility of such a target, made with the 34 MeV proton beam of Orléans (France) the physical characteristics of the neutron beam and longevity tests have been performed at 55 MeV on the Louvain-La-Neuve Cyclotron. The conclusions of these studies and experimental programmes are that LiD is better adapted for neutrontherapy than the usual Be. For 35 MeV equivalent thickness, we have found (see Fig. 9) :

- a higher neutron yield

The overall advantage reaches about 60% more neutrons ;

- a higher neutron mean energy.

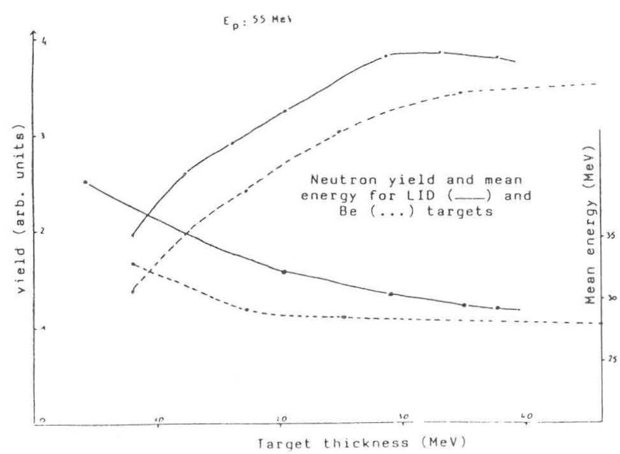

Figure 9 : Neutron yield and mean energy comparison

The neutron time of flight spectroscopy made at Louvain[5] has shown the variations of these parameters versus the target thickness (cf. Fig. 9). A 30 MeV optimum target thickness appears for LiD (bigger thickness will only increase the less energetic neutron contribution) which gives a 1.41 cGy/min/µA measured dose rate at 1.4 meter SSD.

For these experiments, the emerging protons were stopped in a carbon block, giving a 10 to 20% neutron yield reduction. This is the reason why we have chosen to use a permanent magnet deflector. This concept of a half thickness LiD target associated with a permanent magnet deflector is very interesting because for a fixed dose rate, it will require a smaller proton intensity from the cyclotron than usual Be targets.

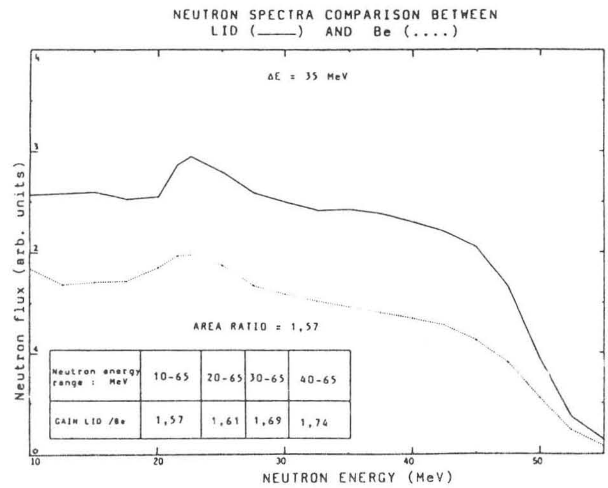

Figure 9 : Neutron spectra comparison

Recent experiments have shown that the target cooling system allows the LiD to support the beam power required for therapy : a 30 MeV thickness LiD target has been bombarded for 8 hours by 15 μA of 55 MeV protons without sensible decrease in the produced neutron yield.

ACKNOWLEDGEMENTS

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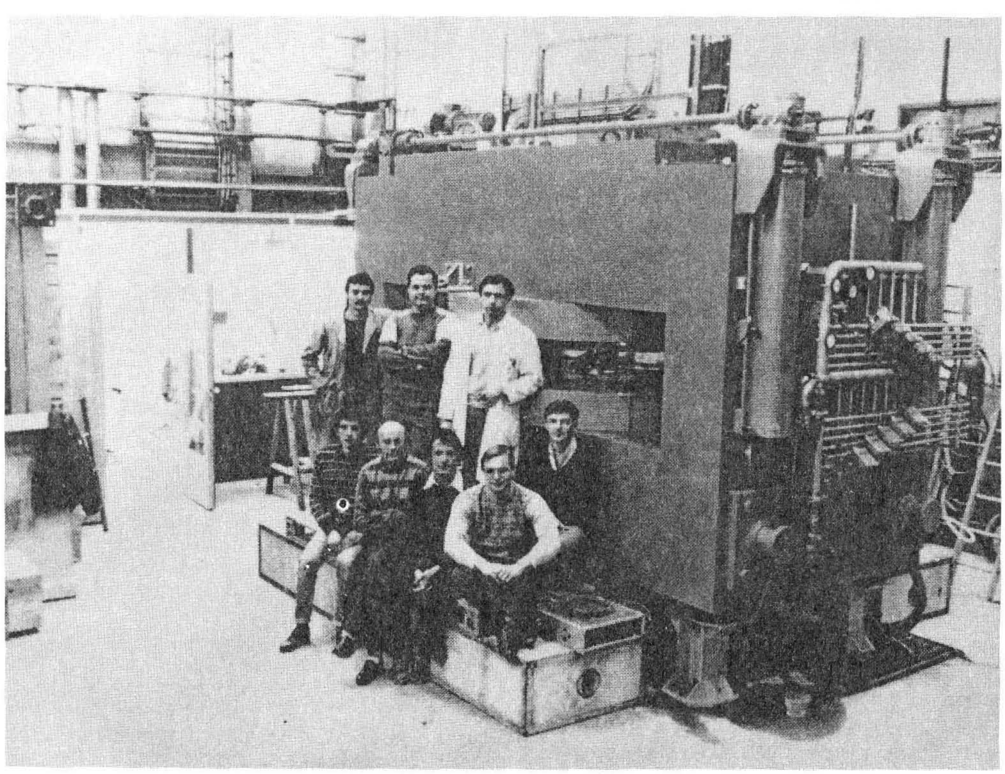

General view of the cyclotron