STATUS REPORT ON THE CNRS ORLEANS' CYCLOTRON

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1. Introduction

This status report summarily describes the cyclotron, the beam lines and the irradiation system used, and shows the results obtained in 1982 and 1983.

During this period, the cyclotron has been under intensive use, mainly in 1983 when the irradiation time was 1693 h 45 as opposed to 1483 h in 1982. This increase is due to the NEUTRONTHERAPY unit which has used 765 h 15 of 34 MeV proton beam. So, now more than half of the beam time (880 h 15 that is 52 % of the total time) is used for medical applications.

During the same period we have installed **a new beam line for short lived gaseous radioisotopes production** (line 1) and **beam plugs** on beam lines 2 and 3.

In spite of a low rate of break downs 7 % of the total time : 198 h in 1982 and 206 h in 1983, we have had a lot of trouble with the electrostatic channel, sparks and current leakage with the NEUTRONTHERAPY beam (34 MeV proton beam, 40 µA intensity on the Be Target), and it will be necessary at short notice, to replace this channel by a new one which will run with a lower voltage.

2. The cyclotron (CGR-MeV 680 type)

Performances and characteristics of the machine can be summarized as follows in table 1 and table 2.

Table 1 : Performances

ENERGY :		
Proton energy range	:	5 - 36 MeV
Deuteron energy range	:	5 - 25 MeV
α particle energy range	:	10 - 50 MeV
$^3He^{++}$ energy range	:	10 - 60 MeV
INTENSITY BEAM :		
Maximum extracted beam intensity for protons and deuterons	:	100 µA
Maximum extracted beam intensity for particles and helium 3	:	40 µA

Table 2 : Characteristics

Electromagnet characteristics :	
Weight (metric ton)	110
Pole diameter (m)	1.60
Number of spiralled sectors	4
Gap maximum (cm)	27
Gap minimum (cm)	13
Maximum average induction at the extraction radius 67,5 cm (kG)	15
Number of ampere turns in the main coils	250.000
Number of trim coils (pair)	8
Number of harmonic coils (pair)	4
Radiofrequency : Range from 20 to 40 MHz	
Number of dees	2
Number of cavities	2
Dee angle	60°
Maximum dee voltage (kV)	40
RF power available (kW)	2 x 50
Frequency stability	10^{-6}
Dee voltage stability	5×10^{-3}
Phase stability	± 0.2°
Extraction :	
Electrostatic deflector :	
Maximum field (kV/cm	110
Angular span	58°
Magnetic channel	passive
Gradient corrector	
Ion source : Type Livingstone	
Location : internal, vertically introduced	
Maximum arc power (W)	800
The center region is designed for 2, 3, 4 harmonic operations with a single orbit for all energies particles.	

3. The beams lines and the irradiation systems (Fig1)

From the switching magnet Mo, the beam can be bent in four directions:

3.1. Line 1 (27°30 right) : This line built and installed in 1982, is used for short-lived radioisotopes production. A horizontal 27°30 bending magnet located in shielded room 1 allows us to have two different gaseous targets at our disposal. They are connected to the NUCLEAR MEDICINE unit where short-lived radioisotopes are used.

3.2. Line 2 (0°) : This beam line is mainly used for activation experiments. The end of the line located in shielded room 2, can be equipped with different irradiation devices :

An irradiation system within vacuum. The target is cooled by thermal contact with a water-cooled copper target holder. The maximum irradiated area is 7 cm^2.

Two beryllium targets : for fast neutron production. The first one, thickness 10 mm to be used with a 34 MeV proton beam - Be(p,n) nuclear reaction -.The second one, thickness 3 mm to be used with a 25 MeV deuton beam - Be(d,n) nuclear reaction -.

An irradiation system for archaeometry purpose allowing the automatic irradiation of a batch of old coins. The beam-line is closed by a 25 µm titanium foil, the irradiation is carried out at atmospheric pressure.

An irradiation system for wear experiments with accurate control of the beam position on the target.

3.3. Line 3 (27°30 left). This line is used for radioisotope production, mainly for iodine 123 production[1]. Its end is located in shielded room 3.

In this room irradiation is carried out at atmospheric pressure and the beam line is closed by a 25 µm titanium foil. Ahead of this foil, an automatic irradiation system allows the irradiation of solid targets with high intensity beams.

A pneumatic transfer system connects this irradiation system with a hot cell located in a high activity laboratory. A control unit in the hot laboratory enables all the irradiations and handling operations. When the rabbit in which the target is, has reached its irradiation position, two jacks automatically connect it with a water circuit : 8 b, 4 l/min, and the back surface of the target is water-cooled while the front surface of the target and the titanium foil are cooled by air or helium gas : the irradiated area on the target is about 5 cm^2.

3.4. Line 4 (45° left). This line was added in March and April 1980 and is used for NEUTRONTHERAPY[2]

After a horizontal 45° (M_1) bending and a vertical 90° (M_2) bending, the beam impinges a 5 mm thick beryllium target. It is composed of a Be disc 5 mm thick and of a carbon stopper disc 2,5 mm thick with water under pressure (8b) in-between the two so as to ensure an efficient cooling.

(During the running period, the target is hit by a 34 MeV proton beam with 40 µA intensity). This cooling water comes from a circuit different from the others (water activation). The target is continued by a movable mechanical system which allows to interpose polyethylene filters in the neutrons beam (low energies filtration) or a lead sheet 6 cm thick (protection during patient positioning). After the latter system come the ionisation chambers for monitoring the treatment, and the vertical neutrons collimating system located in the treatment room in the basement of the NEUTRONTHERAPY unit. It is composed of a fixed part built in heavy concrete, in which are introduced the inserts which determine irradiation fields.The patient is treated 1.35 m from the target.

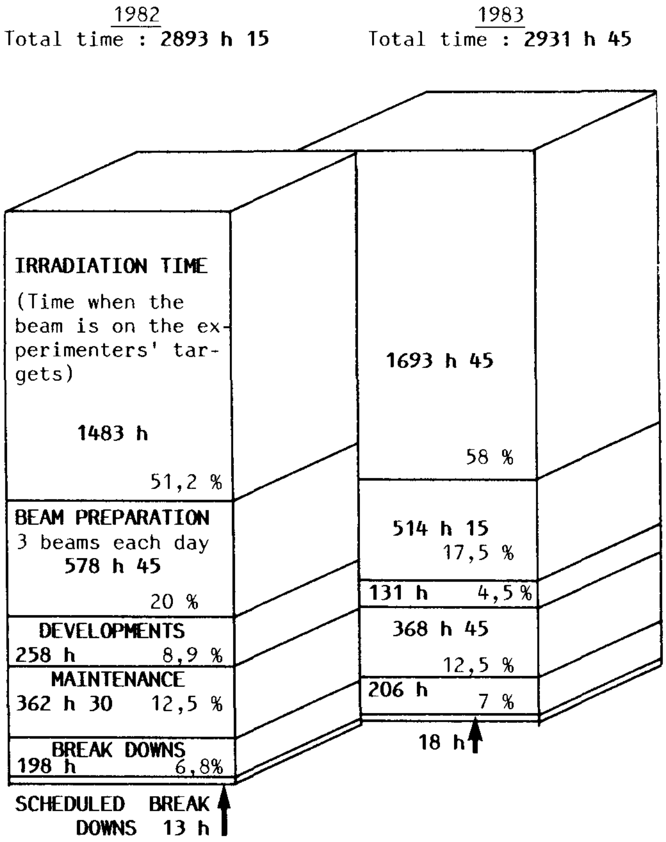
4. Results achieved so far

The total time, 2.893 h 15 for 1982 and 2.931 h for 1983 was divided as follows (table 3).

Table 3 shows :

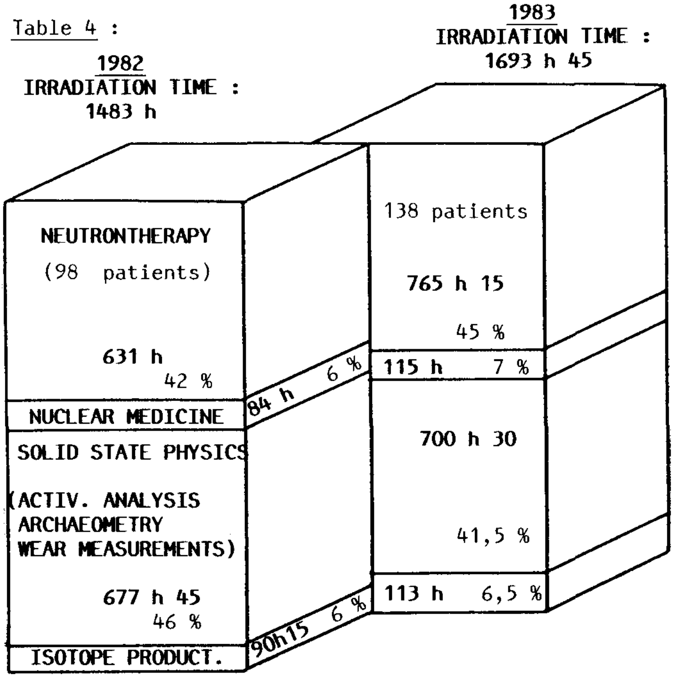
- the regular running of the cyclotron in 1982, as opposed to 1983.

Table 3 :



4.1. Irradiation time : This time can be divided as follows, according to the type of experiments :

Table 4 :



The distribution of the irradiation time according to the type of ions can be divided as follows :

Table 5 :

Particles	1982		1983	
	Irradiation time	%	Irradiation time	%
Protons	1172 h 25	79	1395 h 15	82
Deuterons	196 h 35	13	207 h 30	12
$^{++}_{3}$He	57 h	4	74 h 30	5
α	57 h	4	16 h 30	1

4.2. Beam preparation : The time used in 1983 for preparing the beams has decreased, whereas the number of prepared beams has increased. **514 h 15**, that is **17,5 %** of the total time for preparing **582 beams**, as opposed to 578 h 45 which took 20 % of the total time, for preparing 559 beams in 1982. We always prepared 3 beams a day but the average preparing time (1 hour) has decreased by about 10 % : that is due to the fact that our operators are more experienced and also that we use beam plugs on the beam lines which allow the experiment preparation in a shielded room while the beam is on a target in the neighbouring shielded room..

4.3. Machine developments. The developing time 258 h (9 % of the total time in 1982) as opposed to 131 h (4,5 % of the total time in 1983) has considerably decreased. It is the consequence of the important request of irradiation time by experimenters, mainly medical ones who thus become the first users of the cyclotron : 52 % of the irradiation time. The developing time was used for :

electrodes deflector formation, after the interventions required by the defective electrostatic channel, with the 34 MeV proton beam (sparks and current leakage) (5 interventions in 1982, 3 interventions in 1983).

testing some thin Be target configurations with a 34 MeV proton beam. The aim of this work was to find out the right thickness of the Be target used for improving the depth dose of the fast neutron beam, keeping a good dose rate : After these experiments we have replaced the 9 mm thick beryllium target used since January by a 5 mm thick one.

Dose rate at D_{max} 20 CGy min^{-1} 34 MeV protons - 40 µA

10 x 10 cm field size at 135 cm SSD

Depth of $\frac{D_{max}}{2}$ = 12 cm

improving the characteristics of the ion source and developing new beams.

4.4. Break downs : They were mainly due to the failures in :

Electrostatic channel : High voltage electrode, septum and insulating holder.

Power supplies of the :

- trimming coils (C_3 C_6 and C_7) (150 A)
- switching magnet (800 A)
- ion source filament, electrostatic channel (80 kV)
- ion source arc.

Radio frequency system : power tubes 800 W and 50 kW, and also poor electric contact in n° 1 dee voltage detector, limiting the maximum energy of the cyclotron with a proton beam of about 30 MeV for a few days. HF oscillations on cavity n° 1

Ions source with α particles and $^{++}_{3}$He particles.

Vacuum pumping system.

Water cooling circuits.

5. Future developments

5.1. Applications

Neutrontherapy

We hopefully expect the number of the patients treated by neutrontherapy (48 patients in 1981, 98 patients in 1982 and 138 patients in 1983) or under nuclear diagnosis to increase in the near future.

Activation analysis.

- The trend for improving the sensitivity of traces determination on high purity materials, is to use high energy beams (20-30 MeV) at a high intensity (10 µA).
- Development and use of a special target for activation analysis of liquids.
- Continuation of wear and corrosion experiments with an irradiation system built recently.

Radiobiological research.

- Study of the mechanisms responsible for the high fast neutron E.B.R. in living material
- Study of the defects induced by fast neutrons in the ADN of mammals' cells.

5.2. Cyclotron

Improvement of the cyclotron fiability by

-replacing power supplies of : anode power tubes, main coils, correction coils

- replacing 800 W preamplifiers by 1000 W preamplifiers.
- replacing the electrostatic channel by a new one which runs with a lower voltage (50 kV instead of 60 kV for 34 MeV protons).

Improvement of the cyclotron performances by :

- replacing the phase splitter and the phase discriminators with new devices now under study, reacting less to frequency and to amplitude ;
- replacing the phase probe by a new one with a remote control of the slit width ;
- the installation of an automatic acquisition system of the cyclotron parameters.

5.3.Beam lines

Developing a new beam line with perhaps a isocentric head for NEUTRONTHERAPY.

REFERENCES

1) G. GOIN and J. VERNOIS,
CNRS Service du Cyclotron ORLEANS (France)
C. CIMETIERE and J. LEGER,
CEA-ORIS GIF-SUR-YVETTE (France)
"Iodine 123 production by irradiation at the CNRS cyclotron ORLEANS".
Presented at the 9th International Conference on cyclotrons and their applications. CAEN 1981.

2) N. BRETEAU and R. SABATTIER, CHR ORLEANS
J. GUEULETTE, UCL LOUVAIN-LA-NEUVE (Belgique)
J.C. BAJARD CNRS Service du Cyclotron ORLEANS.
"The Orléans NEUTRONTHERAPY facility".
Presented at the 9th International Conference on cyclotrons and their applications. CAEN 1981.

3) N. BRETEAU, R. SABATIER
Unité de Neutronthérapie CHR d'Orléans
G. GOIN, L. LE POLOTEC, M. VALLADON
CNRS Service du Cyclotron, 3A rue de la Férollerie 45045 ORLEANS CEDEX
Effect of target structure on $^{9}_{4}$Be(p,n)$^{9}_{5}$B fast neutron beam's.
XIXème congrès Européen sur les cyclotrons. Juin 1982. Grenoble.

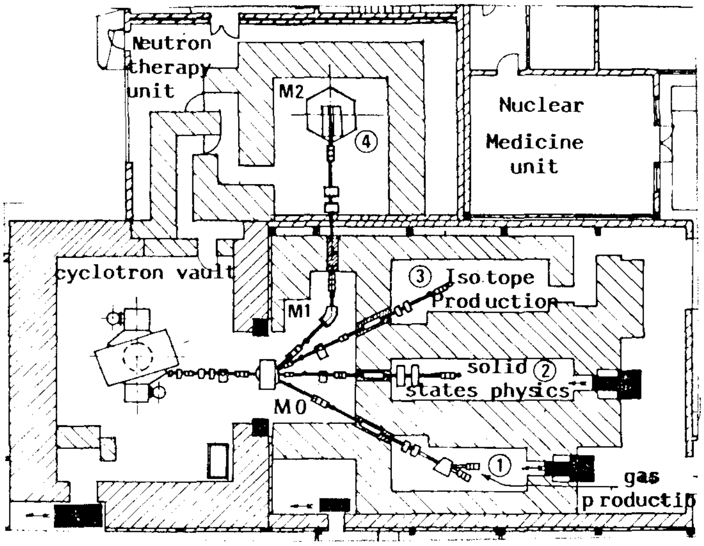


Figure 1 : shows the general lay out of the machine, the experimental area and beam transport lines.