STATUS REPORT ON THE CNRS ORLEANS' CYCLOTRON

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ABSTRACT : Status report on the CNRS Orléans' cyclotron.

1. INTRODUCTION

This status report summarily describes the cyclotron, the beam lines and the irradiation system used, and shows the results obtained from 1986 to 1988.

1986 will certainly be a reference year, with an irradiation time of 2156h (68,5% of the total time), as it will be difficult to produce any more beams in the 2 shift system in use in the laboratory (from 6h to 14h and from 14h to 22h). Moreover, in 1987 and 1988 the irradiation time has slightly decreased (1987 = 2013h and 1988 = 1935h) while the maintenance time increased.

We have now to increase the development time so as to keep and if possible, improve the fiability and performances of the installation.

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
particle energy range :	10 - 50 MeV
He^{++} energy range :	10 - 60 MeV
INTENSITY BEAM :	
Maximum extracted beam intensity for protons and deuterons :	55 µA
Maximum extracted beam intensity for α particles and helium 3 :	10 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	$\pm$ 0.2°
Extraction :	
Electrostatic deflector :	
Maximum field (kV/cm)	110
Angular span	65°
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 BEAM LINES AND THE IRRADIATION SYSTEMS (Fig 1)

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 radioisotopes production. A horizontal 27°30 bending magnet located in shielded room 1 allows us to have two different irradiation systems at our disposal.

The first one is a gaseous target, which is connected to the NUCLEAR MEDICINE unit, where short-lived gaseous radioisotopes are used.

The second one is used for solid radioisotope production. An automatic irradiation system allowing the irradiation of solid targets with high intensity beam is located behind the 25 µm titanium foil which closes the beam line.

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 ot the target and the titanium foil are cooled by air or helium gas : the irradiated area on the target is about 5 cm².

3.2 Line 2 (0°) and Line 3 (27°30 left)

These beam lines are mainly used for ACTIVATION experiments and ions IMPLANTATION : activation with fast neutrons, particularly in shielded room n° 2, and activation with various ions, particularly in shielded room n° 3.

Different irradiation devices are used :

3.2.1 Beryllium target : for fast neutron production, thickness 4 mm to be used with deutons or HH^+ beams.

3.2.2 Irradiations systems for archaeometry purpose : allowing the automatic irradiation of a batch of old coins : A rotating system used with neutrons, and a linear displacement system used with ion beams.

3.2.3 Irradiation system for wear experiments with accurate control of the beam position on the target.

3.2.4 Irradiation system for ion implantation with a high amplitude electromagnetic sweeping of the beam (20 cm²).

3.2.5 Irradiation system for irradiating targets in vacuum. The target is cooled by thermal contact with a water-cooled copper target holder.

3.3 Line 4 (45° left) :

This line was added in March and April 1980 and is used for NEUTRONTHERAPY [1].

After a horizontal 45° (M_1) bending and a vertical 90° (M_2) bending, the beam impinges a 5 mm thick beryllium target[1]. 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

Table 3 shows the regular running of the cyclotron in 1986, 1987 and 1988.

Table 3 :

YEAR	1986	1987	1988
Total time	3153	3055	2862
Irradiation time (Beam on target)	2157h **68,5%**	2013h **66%**	1935h **67,5%**
Setting time (4 beams each day)	495h **15,5%**	464h **15%**	380h **13,5%**
Developments	61h **2%**	95h **3%**	66h **2,5%**
Maintenance	358h **11,5%**	391h **13%**	404h **14%**
Break downs	82h **2,5%**	89h **3%**	77h **2,5%**

4.1 Irradiation time

This time can be divided as follows according to the type of experiments (table 4).

Table 4 :

YEAR	1986	1987	1988
IRRADIATION TIME	**2156h**	**2013h**	**1935h**
RESEARCH Materials character. - Activat. Analysis - Archaeometry - Wear measurements Ion implantation Isotope preparation Radiobiology	1359h **63%**	1300h **64,5%**	1339h **69%**
NEUTRONTHERAPY (Service Activity) Patients treated	628h **29%** 122	601h **30%** 111	562h **29%** 104
NUCLEAR MEDICINE (Service Activity)	116h **5,5%**	101h **5%**	34h **2%**
ISOTOPE PRODUCTION (Service Activity)	53h **2,5%**	11h **0,5%**	-

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

Table 5:

YEAR	1986	1987	1988
	Irradiation time	Irradiation time	Irradiation time
Protons	1311h 61%	1273h 63,5%	1330 h 68,5 %
Deuterons	657h 30%	582h 29%	267h 14%
Alphas	61h 3%	96h 4,5%	55h 3%
$^3He^{++}$	127h 6%	58h 2,5%	42h 2%
HH^+		3 h 0,5%	240h 12,5%

4.2 Beam preparation :

Table 6 :

YEAR	1986	1987	1988
Nbr of beams days	191	184	185
Total setting time (H)	495	464	381
Nbr of beams prepared in the year	694	780	797
Nbr of beams prepared during a day	3,63	4,24	4,31
Average setting time per beam (H)	0,71	0,60	0,48

Table 6 shows the average setting time evolution during the last three years. It has steadily been decreasing, and now we are daily producing more than 4 beams and the average setting time is around 30 minutes.

4.3 Machine developments

4.3.1. With the cyclotron running. During these 3 years the developing time was very low, between 2 and 3% of the total time. It is the consequence of an important request of irradiation time by experimenters. The developing time was used mainly for :

. Formating deflector electrodes and R.F. cavities after the various interventions on the electrostatic channel (1986).

. Adjusting the accelerating parameters of the various beams routinely used after the replacing of the power supplies of the correcting coils (1987).

. Improving the characteristics of the ions sources mainly for the production of alpha and helion particules.

. Improving the electromagnetic sweeping of the beam on line 3 (1988).

4.3.2 Without the cyclotron running.

. Replacing in 1986 the power supply of the cyclotron main coils

(1200A, 130V $\frac{\Delta I}{I} = 510^{-6}$).

. Replacing in 1987 the power supply of the cyclotron correcting coils (10 units :

300A, 25V, $\frac{\Delta I}{I} = 10^{-5}$),

and the aerorefrigerant towers (90 m³/h, 3b) of the water supply of the cyclotron and the beam lines.

. Replacing in 1988 the power supplies of the ion sources and the programable automate of the pumping system of the cyclotron.

4.4 Break downs

They were mainly due to the failures in :

. **Power supplies of the :**
Ions source (300A, 6V and 500V, 3A),
RF power tubes (10KV, 20A),
Switching magnet Mo (800A, 60V),
Bending magnet M41 (300A, 30V),
Bending magnet M42 (350A,, 35V),
. **Ion sources**
. **Beam plugs**
. **Pneumatic devices**
. **Beryllium targets**
. **Pumping system**
. **RF system** : RF power tubes 50KW and 800W. Electronics racks "servo loop of resonants cavities".
. **Phase probe**, main probe, protection finger of the electrostatic channel entrance (vacuum leakage).

5. FUTURE DEVELOPMENTS

5.1 Cyclotron

Construction of :

- New electronics racks for RF system : "Automatic tuning of resonants cavities, and grid circuits of 50kw RF power tubes".
- New RF 800w preamplifiers built with solid state MOSFET power transistors.
- A second electrostatic deflector, from the first device used on the machine.
- An electronic system allowing the automatic setting of the magnetic parameters of the cyclotron and the beam lines.

Replacing :

- the central viewing of the machine parameters by a new one built around an industrial microprocessor PC circuit.
- the water pump supplying cyclotron and beam lines (45 m³/h, 8b)
- the beam intensity probes on the beam lines.

5.2 Beam lines

Construction of a second beam line for NEUTRONTHERAPY. A new beam line for Neutrontherapy has been studied. This beam line would allow the use of horizontal neutron beams for treatments. The vertical 90° bending magnet would be mechanically rotating and drive the Be target in its motion.

Thus a horizontal neutron beam would be free for use in a 2nd treatment room. A beam plug could allow the patient's positionning in a treatment room, while a 2nd patient would be under treatment in the 2nd room.

5.3 Applications

Radioactivation analysis

The current trend is to obtain improved sensitivities in order to study the metallurgy of ultra pure semiconductors (GaAs, InP,...) and to establish correlations betwen impurities and physical properties. Improved sensitivities are obtained on the one hand by using higher energies and higher intensities, and on the other hand by developing fast and reliable radiochemical separations.

Neutrontherapy[2]

The new horizontal neutron beam foreseen would allow a better use of the beam time, with an improvement on the treatment quality.

6. REFERENCES

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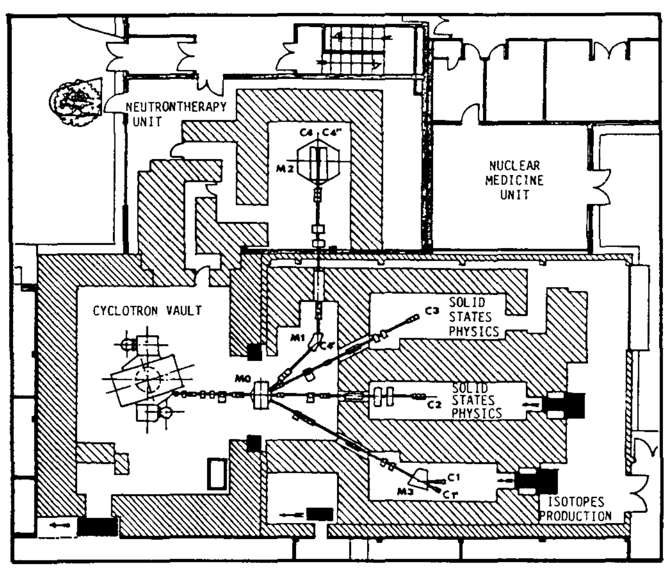

Figure 1 : shows the general lay out of the machine, the experimental area and beam transport lines.