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 in 1980 and during the first six months of 1981.

In 1980, the main achievements were, first six months : *the installation of beam line 4 and fast neutron collimating system* associated for NEUTRON-THERAPY purposes [Be(p,n) nuclear reaction, with a 34 MeV proton beam], this precise work required a 2.5 month shut down, then, in september the beam was used for *neutrons dosimetry experiments by the Orleans Hospital staff*. In addition, on october 15th *the iodine 123 production was started* [$^{124}Te(p,2n)^{123}I$ with a 25 MeV proton beam] for the radioisotopes service in SACLAY. The first patient was treated on January 20th 1981. Ever since the cyclotron has been under routine operation.

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

Table 1 : Performances (CGR-MeV 680 Type)

ENERGY :		
	Proton energy range	: 5 - 38 MeV
	Deuteron energy range	: 5 - 25 MeV
	α particle energy range	: 10 - 50 MeV
	$^{3}He^{++}$ energy range	: 10 - 60 MeV
INTENSITY BEAM :		
	Maximum extracted beam intensity for protons and deuterons	: 100 µA
	Maximum extracted beam intensity for α 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)	50
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 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 located in the cyclotron vault is used for short-lived radioisotopes production. The end of the line can be equipped at choice, with various gaseous targets, 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.

- 4 π *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.

- 4 π *irradiation system for archeometry 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.

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 irradiation 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 1 mn, and the back of the target is water-cooled while the front 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 9 mm thick beryllium target. It is composed of two Be discs 3 mm and 6 mm thick, with water under pressure (8b) in-between, 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 (γ 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, 2088 H for 1980, and 1341H30 for the first six months of 1981 was divided as follows (table 3) :

Table 3

YEAR	1980		1981 first 6 months	
TOTAL TIME	2088H	100%	1340H30	100%
IRRADIATION TIME (time when the beam is on the experimenters' targets).	545H	26%	772H	57.5%
SCHEDULED SHUT DOWNS	580H	28%	12H	1%
DEVELOPMENTS	506H	24%	259H	19.5%
MAINTENANCE	303H30	14.5%	211H	15.5%
BREAK DOWNS	153H30	7.5%	87H30	6.5%

The above table clearly shows :

- the regular running of the cyclotron in 1981, as opposed to 1980.

- the running time will be higher in 1981, as we have been working on a regular schedule of 13 hours a day, 5 days a week (2 shifts) since May 1rst 1981.

4.1. Irradiation time. This time can be divided as follows, according to the type of ions (table 4).

Table 4

Year	1980		First six months of 1981	
Particles	Irradiation time	%	Irradiation time	%
Protons	469H25	86	660H	85.5
Deuterons	42H20	8	62H30	8.1
$^3He^{++}$ particles	20H30	3	32H30	4.2
α particles	18H	3	17H	2.2
TOTAL.......	545H	100	772H	100

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

Table 5

YEAR	1980 (545H)	1981 (772H)
1. BIO-MEDICAL APPLICATIONS :		
Neutrontherapy..........	199H55 (only neutron dosimetry)	466H
Nuclear Medecine........	34H25	51H30
Animals Metabolism Studies	-	13H30
	234H20 43%	531H 69%
2. SOLID STATE PHYSICS :		
Activation analysis.....	71H	107H30
Archaeometry............	83H	57H
Wear measurements.......	18H45	17H
Geochemistry............	-	2H30
	172H45 31.5%	184H 24%
3. ISOTOPE PRODUCTION :		
Iodine production.......	102H30	54H
Various.................	35H30	3H
	138H 25.5%	57H 7%

4.2. Machine development. The developing time in 1980 was mainly used to optimize the setting of the 34 MeV proton beam used for NEUTRONTHERAPY (extraction efficiency 65%) as well as the beam transmission along beam line 4 (transmission efficiency : 95%). During the first six months of 1981, the developing time was only used for the setting of the beams.

4.3. Scheduled shut downs. The longest ones were for the C.G.R. MeV firm in 1980 to install the beam line, and the collimation system for NEUTRONTHERAPY. The C.N.R.S. staff took advantage of this to remove the puller and the septum input, to adjust the deplacements of the electrostatic channel and of the various machine probes to install and operate the various units built in the laboratory :

- neutrons and gamma dose and dose rate measurement system.

- integrator and intensity measurement rack.

- steering magnet power supply and magnetic sweeping commutation system.

- irradiation system for radiobiological experiments.

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

- 350 A power supply for the magnet M_{41} (current regulation rack).

- 10 kV, 20A high power supply (break down on 1 kV stages).

- arc and filament power supplies.

- power tubes 800 W on radio frequency system.

- ion sources.

- electronic racks associated at the turbomolecular pump.

- irradiation systems.

- neutrons collimation system.

- cooling system of the Be target in beam line 4.

5. Future developments.

5.1. Applications.

5.1.1. Neutrontherapy. We hopefully expect the number of the patients treated by neutrontherapy or under nuclear diagnosis to increase in the near future.

5.1.2. Wear experiments. This new activity should develop, as much as much as new irradiation systems are under study.

5.2. Cyclotron and beam-lines.

5.2.1. Improvement of the cyclotron fiability by :

- replacing the electronic control unit of the vacuum system.

- replacing the 2 ion sources.

- adding a fast vacuum valve at the exit of the cyclotron accelerating chamber.

- extending beam line n° 1 to shielded room n° 1.

5.2.2. 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.

5.2.3. Improvement of the beam control along the lines by the use of :

- an automatic emittance measuring device.

- an automatic beam density measuring device.

- a profile beam measuring device.

References.

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2. N. BRETEAU and R. SABATTIER, C.H.R. Orléans.- J. GUEULETTE, U.C.L. Louvain-la-Neuve (Belgique) - J.Cl. BAJARD, CNRS Service du Cyclotron Orléans. "The Orléans NEUTRONTHERAPY facility". Presented at the 9th International Conference on cyclotrons and their applications. Caen 1981.

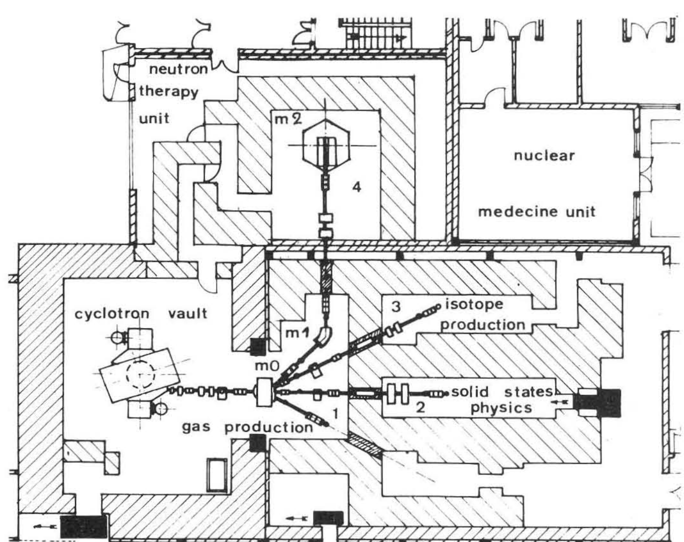

figure 1: schows the general lay out of the machine the experimental area and beam transport lines