SOME CHARACTERISTICS FROM ORLEANS AND LIEGE CYCLOTRONS

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Abstract

A small size medium energy AVF cyclotron, dedicated to chemical application, of 45 MeV for alpha particles, has been built for the National Scientific Research Center of Orléans, France. Recent results obtained with this machine will be presented.

A compact AVF cyclotron of 24 MeV P associated with a 8 targets ports beam handling system including two analyzing magnets has been built for the University of Liège in Belgium. The facility will be described with its characteristics and the results obtained presented.

1. Introduction

After the completion of the 90 MeV-proton AVF cyclotron (930 S Model) in spring 1972 at the University of Louvain, Louvain-la-Neuve, Belgium, and of its copy but with derated power supplies (930 Model) in spring 1974, at the National Institute for Radiological Science, Chiba, Japan, two new types of AVF cyclotron of CGR-MeV are now under beam test.

Of the first type (680 Model), a medium-energy cyclotron, a machine has been installed at the Centre National de Recherche Scientifique (CNRS), Orléans, France, and another under construction for the University of Tohoku, Sendai, Japan.

Of the second type (520 Model), a low-energy compact cyclotron, one machine is installed at Liège, Belgium, one at Orsay and a third under construction for Gand University, Belgium.

2. Orléans cyclotron

2.1 Performances

Guaranteed performances may be summed up as follows :

Table 1

Energy

Proton energy range	3-38 MeV
Deuteron energy range	5-24 MeV
α particle energy range	10-45 MeV
3 He++ energy range	8-64 MeV

Current

Maximum extracted current for proton : 100μA
Maximum extracted current for alpha-particle : 40μA.

For safety, extracted beam power is limited to 2 kW.

For the Tohoku University machine, RF system will be boosted to rise the proton energy up to 40 MeV.

2.2 Characteristics

The general conception is similar to that of Louvain machine : four sectors, two dees powered from two separate RF cavities. However, as this machine is devoted to applications requiring high current as well as to physics, new improvements have been brought for reliability and high current production.

Efforts have been done to make the operation easy and interventions as quick as possible : typically a filament change takes 15 minutes, a deflector change 45 minutes and big intervention requiring the lifting of the magnet yokes can be done in half a day.

The high current characteristic and the compactness requirement make necessary a good knowledge of the vertical behaviour of particle beam in the central region. For this reason most of our attentions were made on this region. The details of the study are given in a separate paper of this conference 1).

Turn separation at extraction radius is about 3 mm, not including the effect of harmonic coils, ensuring a possible single-turn and high-current extraction.

The radiofrequency range is chosen from 20 to 40 MHz. Three harmonics, namely 2, 3 and 4 are then required in order to cover the energy range.

For the simplicity of operation, the puller is assumed to be fixe with a single orbit for all energies and particles.

The main parameters of the cyclotron are summerized in table 2.

Table 2

Electromagnet

Number of sectors	4
Weight (metric ton)	110.
Maximum average induction at extraction radius (kG)	15.

Proc. 7th Int. Conf. on Cyclotrons and their Applications (Birkhäuser, Basel, 1975), p. 88-91

Number of trim-coils (pair)	8
Number of harmonic coils (pair)	4

Radiofrequency

Number of dees	2
Number of cavities	2
Dee angle (°)	60.
Maximum dee voltage (kV)	50.
RF power available (kW)	2x55.

Ion source

Location : internal, vertically introduced
Maximum arc power (kW) 1.

Extraction

Electrostatic deflector :	
Maximum field (kV/cm)	130.
Angular span (°)	55.
Magnetic channel	passive

Figure 1 shows a photograph of the machine.

2.3 Present status

At the beginning of the beam test an important beam loss at the center region has been observed. A new center is designed and tested. Some typical results are given in table 3.

Table 3

Particle	Harmonic	Energy MeV	Extracted current µA
Alpha	3	50	36
	3	30	20
	3	20	11
Deuteron	3	25	80
	3	10	62
Proton	2	25	20
	3	15	100
	3	10	50
	4	5	30

The maximum proton energy guaranteed at Orléans, 38 MeV, is not yet achieved. The limitation comes from the too high deflecting voltage required, due to a not very happy choice of the septum curvature. The septum is now redesigned and beam test will take place again this fall.

3. Liège cyclotron

The cyclotron facility of Liège University comprises a compact cyclotron and an important beam transport system.

3.1 The cyclotron

3.1.1 Performances

The cyclotron, a compact 520-Model, is designed to meet the following performances (table 4).

Table 4

Energy

Proton energy range	3 to 24	MeV
Deuteron energy range	3 to 12.5	MeV
3 He++	6 to 33	MeV
4 He++	6 to 25	MeV

Current

Maximum guaranteed current for proton and deuteron beam :	70 µA
Maximum guaranteed current for alpha and 3 He++ :	50 µA

3.1.2 Characteristics

Figure 2 shows the lay-out of the machine and figure 3 shows a photograph. Table 5 shows its main characteristics.

Table 5

Electromagnet

Number of sector	4
Weight (metric ton)	28.
Maximum average induction at extraction radius (kG)	14.
Number of trim coils (pair)	7
Number of harmonic coil (pair)	4

Radiofrequency

Number of dee	2
Number of cavities (coaxial type)	2
Dee angle (°)	50.
Maximum voltage (kV)	35.
Radiofrequency range (MHz)	20. -40.
RF power (kW)	30.

Ion source

Location : internal, vertically introduced
Maximum arc power (kW) 1.

Extraction

Electrostatic deflector :	
Maximum field (kV/cm)	130.
Angular span (°)	52.
Magnetic channel	passive

As in the Orléans machine, the center region of Liège cyclotron is designed for three harmonics operations, although only harmonics 2 and 3 are needed to cover the guaranteed energy range. Hovewer harmonic 4 makes possible eventual acceleration of heavy ions with low charge to mass ratio.

3.1.3 Present status

Two identical machines are installed at the same time at Liège and at Orsay. Beams are being tested in parallel with emphasis on high current at Orsay and on beam quality at Liège, due to the importance of the beam transport system.

We give in table 6, the performances already obtained (july 1975) :

Table 6

Particle	Harmonic	Energy MeV	Extracted current µA
Proton	3	6	25
	3	10	56
	2	15	55
	2	17	60
	2	19	50
	2	21	30
Deuteron	3	5	50
	3	7	70
	3	10	70
	3	12	80
	3	13	80
Alpha	3	10	10
	3	14	27
	3	20	35
	3	24	40
	3	26	37

Beam tests are going on and show already that maximum energies available from this cyclotron will exceed the design values. Energy of 25 MeV for proton , 13.5 MeV for Deuteron and 27 MeV for alpha-particle are expected.

3.2 Beam transport system

3.2.1 General lay-out

The lay-out of the beam transport system is shown in figure 4. It comprises mainly three switching magnets, a double symmetric magnet spectrometer and a great number of quadrupoles and sextupoles, ensuring a large dynamic in beam size adjusment on 8 multipurpose targets.

Targets 1, 2, 3 and 4 are devoted to radioisotopes production. Irradiated products are sent to the hot laboratory via four rabbit systems. About 50 m from the hot laboratory is the medical area where patients are received for diagnostics.

Target 5 is devoted to neutron production. A collimator is planned.

The last three targets 6, 7 and 8 have been planned for nuclear physics experiments. Target 8 is devoted to low noise experiments.

Some applications require a very defined beam geometry and a very narrow energy spectrum.

3.2.2 The spectrometer

The spectrometer is designed to provide a momentum resolution better than 2 x 10^{-4}. Its main characteristics are given in table 7.

Table 7

Nominal magnetic rigidity (T.m)	0.7
Horizontal acceptance (mm.mrad)	50.
Vertical acceptance (mm.mrad)	40.
Nominal defining slit width (mm)	1.
Deviation angle (°)	90.
Mean radius (m)	1.15
Angle of entrance pole face (°)	10.45
Angle of exit pole face (°)	19.

Beam matching and aberrations corrections are performed respectively by quadrupoles and sextupoles lenses.

For the study of the spectrometer, an ionic simulation has been employed 2). A low-energy Cs^+ beam is used to simulate a light ion beam of higher energy.

3.2.3 Present status

Beams have been sent at almost every terminal. Transparency is quite good and varies between 95 % to 100 % excepted through the spectrometer.

The spectrometer have been tested with proton of 5.8 MeV. The mementum spectrum has been measured after the third defining slit. One observes a momentum resolution better than 10^{-4} with a defining slit width of 0.5 mm and better than 2 x 10^{-4} with 1 mm width (theoretical value : 1.8x10^{-4}). Most of residual aberrations have been suppressed by sextupoles adjustment. The transparency of the system is 10^{-2}.

Tests are going on now with other energies.

The ultimate verification will be done by observing the absorption pic of 15 MeV proton on carbon.

4. Conclusion

The acceptance protocole of Orléans cyclotron is forseen at the end of this year as well as for the Liège facility, due to the importance of the beam transport system of this latter.

Reference

1) A. Dupuis and Al. "Cyclotron center region study and beam diagnostic at Orléans cyclotron" - This conférence.

2) J. Kervizic, B. Launé and D.T. Tran "Study of a high-resolution spectrometer with a Cs+ ion beam" (to be published in Nucl. Instr. and Meth. 127 (1975)).

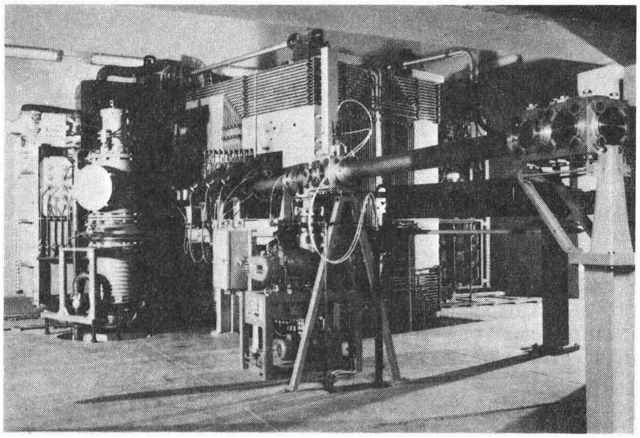

Figure 1 - Orléans Cyclotron
(680 - Model)

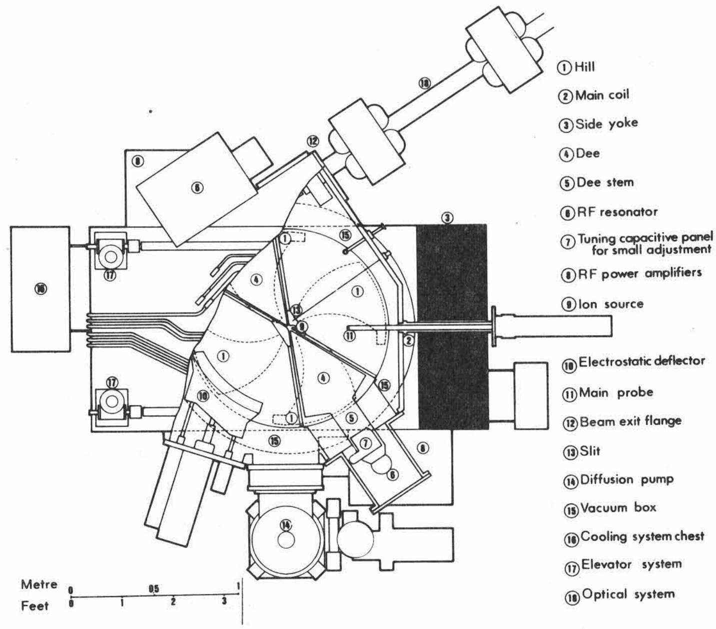

Figure 2 - Compact Cyclotron
(520 - Model)

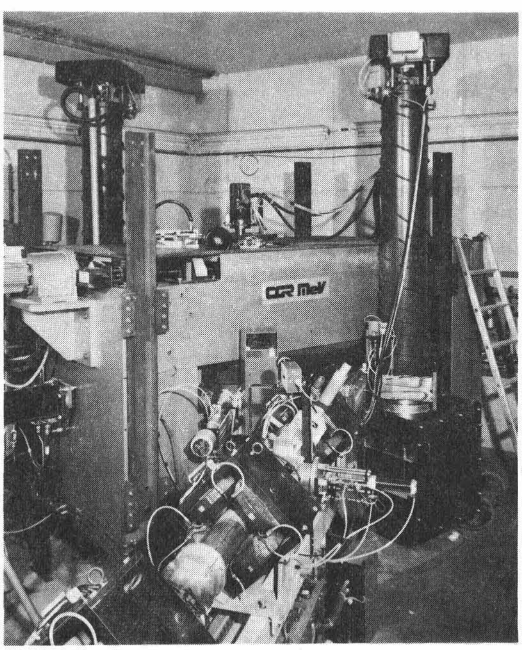

Figure 3 - Liège Cyclotron

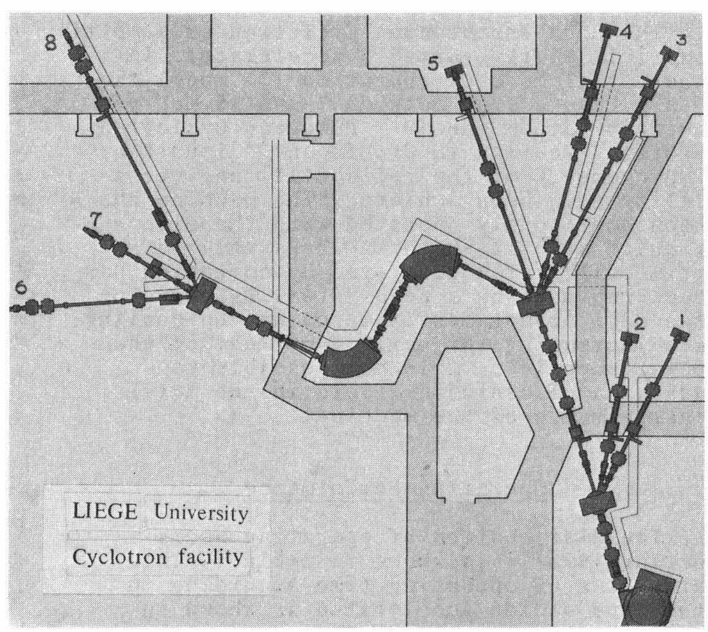

Figure 4 - Cyclotron Facility of
Liège University, Belgium