PRELIMINARY DESIGN FOR A 30 MEV, 500 μA H^- CYCLOTRON

Y. Jongen and G. Ryckewaert
Centre de Recherches du Cyclotron
Louvain-la-Neuve, Belgium

Abstract: The proposed cyclotron is the first step of a program aiming at developing high intensity, energy efficient cyclotrons. The 30 MeV, 500 μA, H^- cyclotron is designed to use less than 100 kW main power. The magnet has four 54 degree straight sectors on a common yoke. The hill gap and field are 3 cm and 1.8 T. The valley gap and field are 110 cm and 0.04 T. Two 30 degree dees operate at 93 MHz with H = 6. The vertical λ/2 cavities are located entirely in the valleys. The H^- are produced by an external E.C.R. source biased at 50 kV. They are injected axially using a permanent magnet periodic focusing channel. The prototype is expected to deliver beams in 1988.

1. Introduction

A preliminary design for a 40 MeV, 5 mA proton industrial cyclotron was proposed by Jongen in 1984 [1]. The design presented in this paper is a first step in a program aiming to develop such high-intensity, energy efficient cyclotrons.

The goals of this project are :

1) to test some of the ideas presented in [1] on a small scale, relatively inexpensive prototype.
2) to realize a cyclotron able to produce most of the radioisotopes availables by (p,n) and (p,2n) reactions, with an extremely low operation cost.

2. General design features

The proposed cyclotron is a fixed field, fixed frequency machine, accelerating H^- ions up to 30 MeV. The energy of the extracted beams is variable from 10 MeV to 30 MeV by a variation of the radius of the stripper foil. Two beams can be extracted simultaneously using partially intercepting strippers.

3. Magnetic structure

The magnetic structure has been specially designed to use a minimum power : only 7 kW D.C. power are necessary in the main coils. No trim-coils are foreseen : the field (fixed) will be ajusted only by shimming..

This original magnetic structure* combines the advantages of a separated sector cyclotron and of a compact cyclotron

- separated sector cyclotron advantages
  - small gap
  - low dee capacity
  - possibility to locate the cavities in the valley
  - good stripping optics
  - 4-fold symmetry
- compact cyclotron advantages
  - simple, low current density, circular main coils
  - simple vacuum chamber
  - no sector alignment problems
  - uniform field at the center, allowing a low axial injection energy.

4. Injection and extraction

The H^- ions are produced in an external source, using the Electron Cyclotron Resonance (E.C.R.) at 2.4 Ghz. The magnetic structure of this source is made of permanent magnets only. The source is biased at - 50 kV, D.C. relative to ground. The H^- beam is injected axially, using a permanent magnet periodic structure, as developed by O.C. Dermois et al., [2].

This design avoids the two main problems of existing low energy H^- cyclotrons

- the use of an external source allows very low pressure in the cyclotron with moderate size pumps.
  Stripping of the H^- on the residual vacuum is strongly reduced.
- the extracted beam crosses the magnetic field gradients at an angle not too small. Furthermore, sextupole contributions are minimized. Therefore, the optical properties of the extracted beam are excellent and, for production targets located close to the cyclotron, no further focusing element is required.

5. R.F. system

Two 30° dees are operated at H = 6 from the ions orbital frequency (i.e. the electrical length of the dees is 180°). The dees are supported on a vertical line, making a half-wavelength resonance at 93 Mhz.

The cavity is entirely located in the valley. The R.F. power needed to obtain 50 kV on the dee is less than 5 kW for one cavity. The two dees are connected at the center, below the median plane, to allow room for the injection inflector. Only one R.F. amplifier is used.

The R.F. final tube is directly coupled to the cavity by an inductive loop avoiding the problem of detuning of the cavity coupling due to the beam load (15 kW).

6. Planning

The budget for the construction of this prototype has not yet been obtained. However, if the budgets are obtained by the end of this year (1985), the cyclotron should be operational by the end of 1988.

7. References

[1] Y. Jongen, "Conceptual design for a high intensity (5 mA) industrial cyclotron", in Proceedings of 10th Int. Conf. on Cyclotrons, East Lansing, May 1984 of IEEE 84CH1996-3, pp. 465-468.

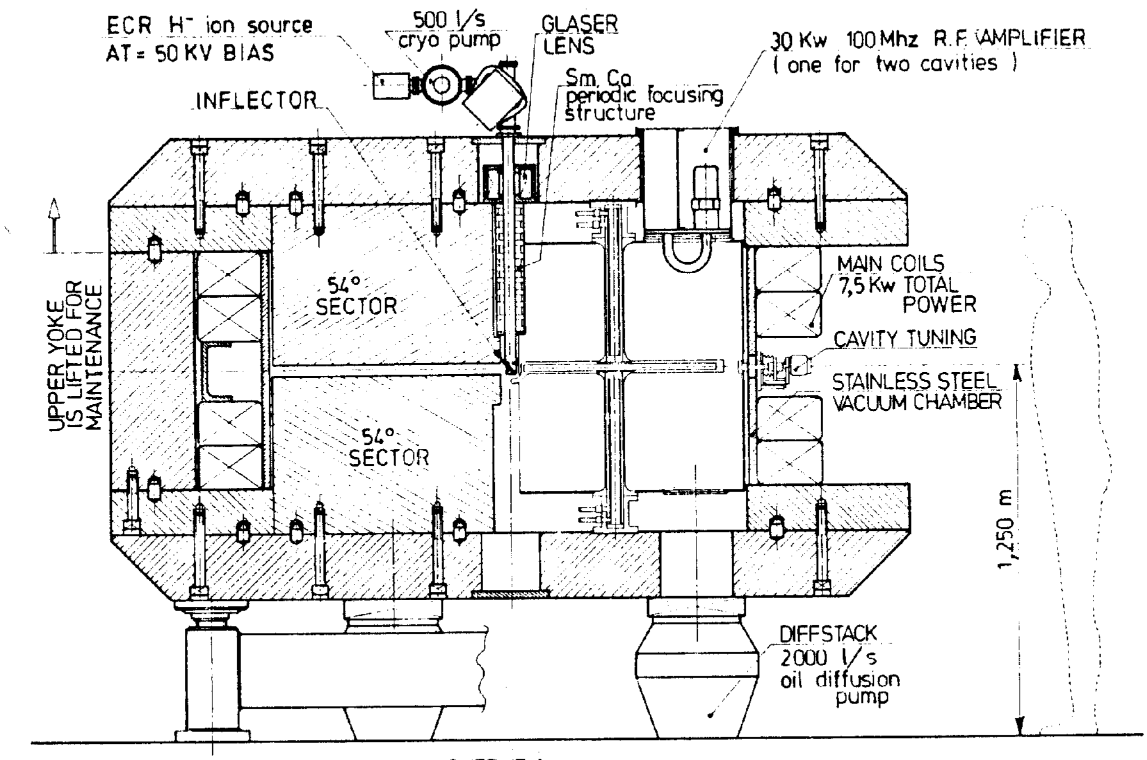
[2] W.K. van Asselt, O.C. Dermois et al., in Proceedings of 9th Int. Conf. on Cyclotrons, Caen, Sept. 1981, pp. 267-272.

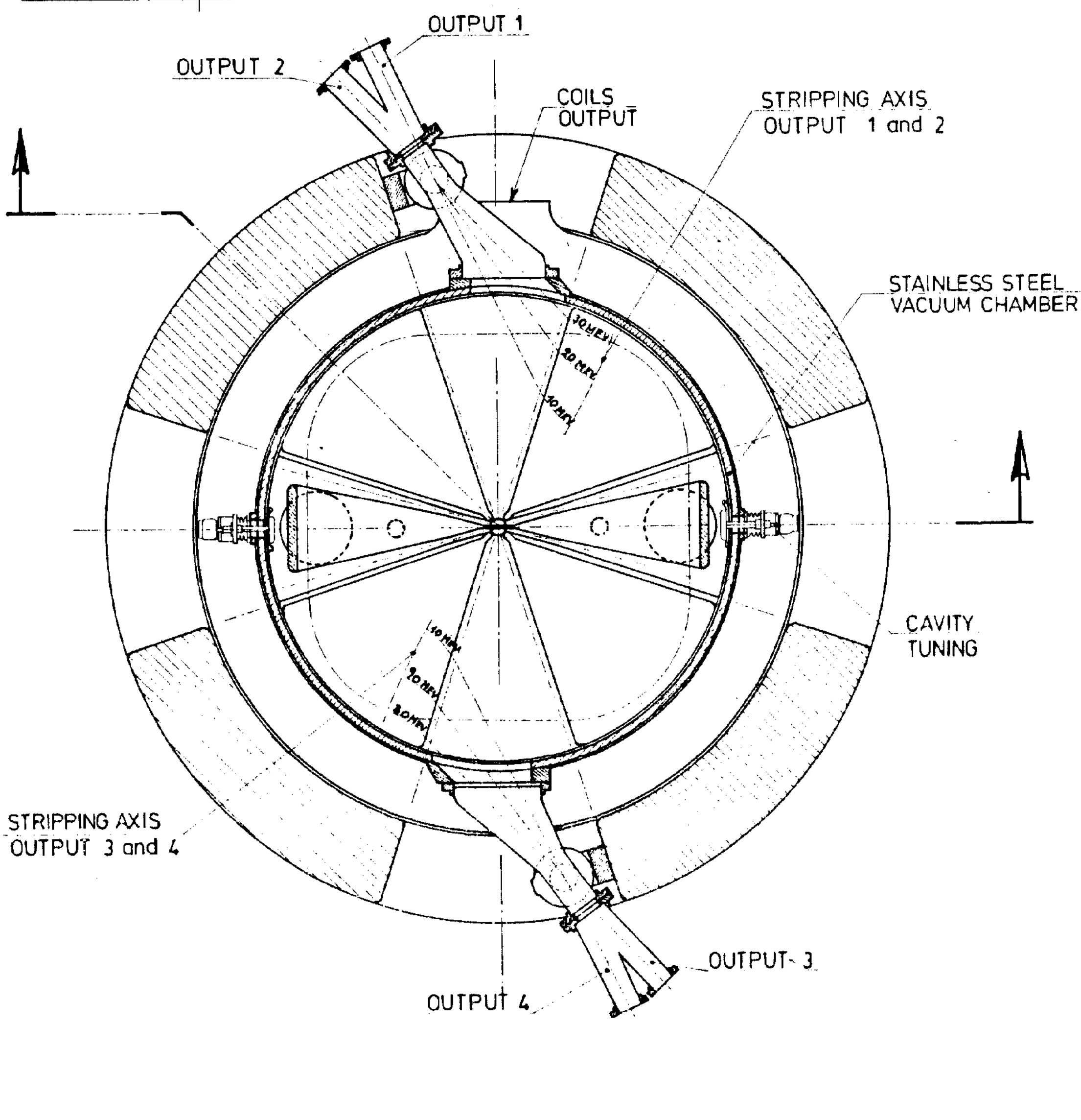
* a patent is pending for

0018-9499/85/1000-2703$01.00© 1985 IEEE

Table 1 : Main parameters

Beam	
type of ions	H^-
energy variable from	10 to 30 MeV
intensity variable from	0 to 500 μA
number of beam lines	4
number of simultaneous extracted beams	2
Magnetic structure	
number of sectors	4
sector angle	54°
hill field	1.8 T
valley field	0 04 T
number of ampere-turns	6.6 10^4 At
average current density in the main coils	50 A/cm²
D.C. power in the main coils	7.2 kW
Iron weight	46.5 tons
Coils weight	3.5 tons
R.F. system	
number of dees (connected at the center)	2
dee angle	30°
harmonic mode	6
frequency (fixed)	93 Mhz
nominal dee voltage	50 kV
dissipated power (at nominal dee voltage)	5 kW/cavity
beam acceleration	15 kW
Beam injection	
type of source	E.C.R., external
E.C.R. frequency	2.4 Ghz
D.C. bias	50 kV
normalized emittance	10 mmrad


ECR H⁻ ion source
AT = 50 KV BIAS
500 l/s
cryo pump
GLASER
LENS
Sm. Co
periodic focusing
structure
30 Kw 100 Mhz R.F. AMPLIFIER
(one for two cavities)
INFLECTOR
UPPER YOKE
IS LIFTED FOR
MAINTENANCE
54°
SECTOR
54°
SECTOR
MAIN COILS
7,5 Kw TOTAL
POWER
CAVITY TUNING
STAINLESS STEEL
VACUUM CHAMBER
1,250 m
DIFFSTACK
2000 l/s
oil diffusion
pump


OUTPUT 1
OUTPUT 2
COILS
OUTPUT
STRIPPING AXIS
OUTPUT 1 and 2
STAINLESS STEEL
VACUUM CHAMBER
CAVITY
TUNING
STRIPPING AXIS
OUTPUT 3 and 4
OUTPUT 3
OUTPUT 4