STATUS REPORT ON THE SUPERCONDUCTING CYCLOTRON AGOR

S. GALES for the AGOR Team*

Institut de Physique Nucléaire BP n°1, 91406 ORSAY CEDEX, France
KVI Groningen, Zernikelaan 25, 9747 AA GRONINGEN, Netherlands

I - Introduction

The AGOR cyclotron, a joint undertaking of the KVI Groningen and the Institut de Physique Nucléaire (IPN) in Orsay, will be a compact cyclotron with superconducting coils, capable of accelerating protons as well as heavy ions at central field strength ranging from 1.7 to 4.07 T [1]. This average field is generated by a set of two superconducting coils housed in a split cryostat.

The major components of the machine (yoke, superconducting coils, RF structure, poles and valleys and axial injection line) which is a compact, three sectors, three dees cyclotron are shown in fig.1. The energy range for protons is 127-207 MeV. Heavy ions with Z/A ratios in the range 0.1 to 0.5 will be accelerated to 6 MeV/A for the lower charge state and to 36-95 MeV/A for fully stripped ions, using external ions sources. The operating diagram T/A versus Z/A as well as the operating ranges of 24 to 62 MHz for the accelerating frequency are shown in fig.2.

The main cyclotron parameters are listed in table I.

Table 1 - Cyclotron parameters

Bending limit K = 600	Focusing limit K_F = 220
Pole diameter 118 cm	Number of sectors 3
Min hill gap 7 cm	Max hill gap 84 cm
Main current density coil 1 = 4271 A/cm² max	
Main current density coil 2 = 3270 A/cm² max	
Central field min-max = 17.5-40.7 K gauss	
Number of trim coils = 15 ; max current 500 A	
Number of dees = 3 in valleys	
RF range = 24-62 MHz	Operating harmonics = 2,3,4
Peak Dee Voltage at R = 0.85 kV	

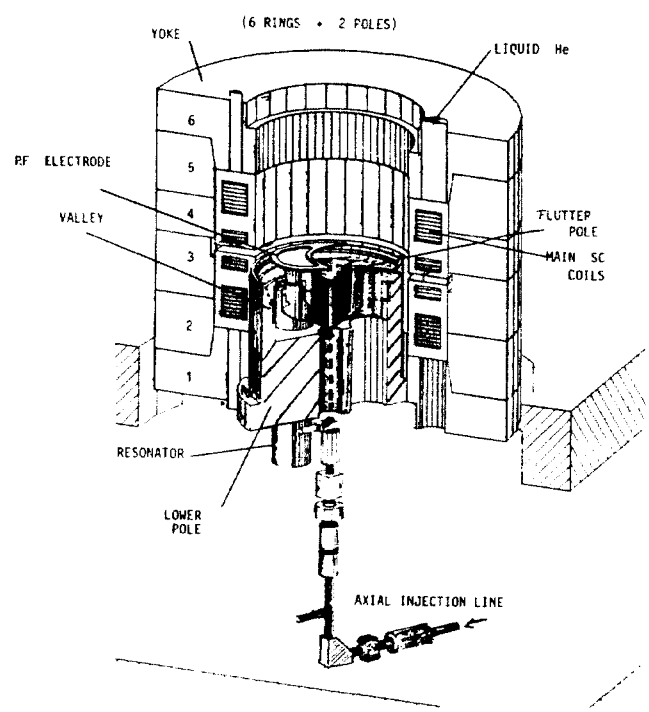

Fig.1 - Simplified cutaway view of the magnet assembly.

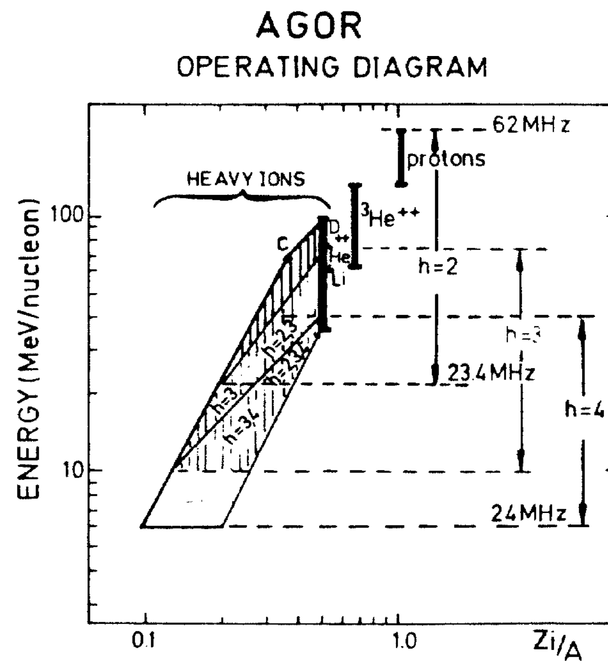

Fig.2 - Ions energy versus Z/A and boundaries the operating range of the RF frequency.

II - Magnet Structure

The magnet will have a cylindrical yoke consisting of 6 cast steel rings and two removable cylindrical poles. The overall dimensions of the yoke are of 4.4. m in diameter and 3.6 m in height. The total weigth is of about 320 Tons (see fig.1). The various components of one of the poles are shown in fig.3. As it can be seen, additional small valleys are introduced in the middle of the flutter poles to reduce the scalloping of the orbits for light and energetic ions (200 MeV protons)[2]. The hills are split in two parts in order to provide space for winding the fifteen trim coils around the upper part.

The magnet steel has been ordered in Dec. 87 and the production of the 6 rings plus 2 poles is now completed. The machining of all these elements has been started last month and the delivery of the complete yoke at Orsay is expected in February 89. The design of the correction coils is completed and call for tenders for this subsystem has been launched as well as the pole lifting mechanisms.

Design of the field mapping system is under progress.

III - The superconducting coils and the split cryostat

The current density needed in the two pairs of coils J_1, J_2 in order to produce an isochronous field for all ions and energies are displayed in fig.4.

The geometry of the coils system is unique in the sense that a large gap exists between the inner and outer coils (0.325 m). This feature leads to relatively "low" axial Lorentz forces between the coils. It was then possible to design a split cryostat which provide a large area of room temperature access in the midplane[3]. A general view of the cryostat is given in fig. 5. The cryostat consists of two parts which are connected by six rods in the midplane. The superconducting coils will

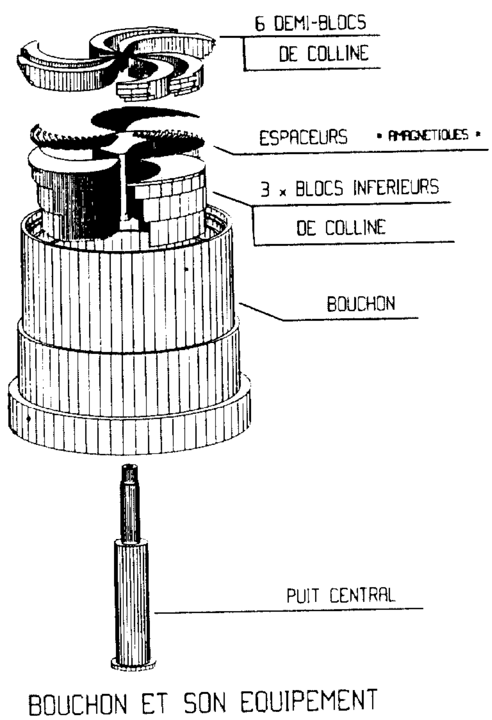

Fig.3 - Main components of the pole.

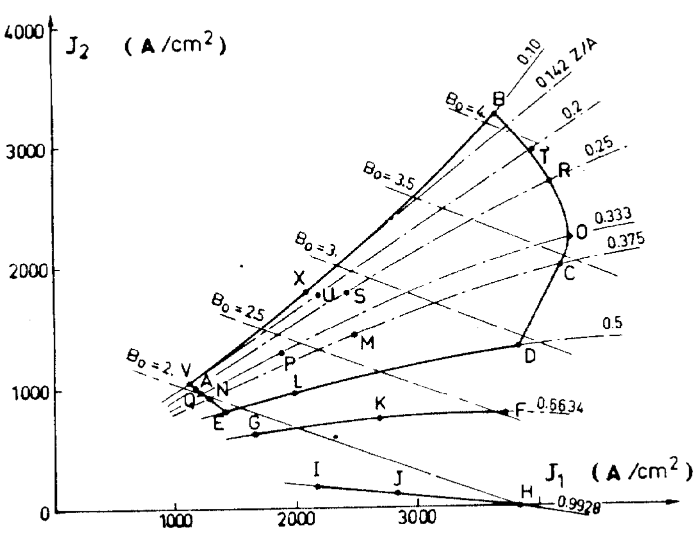

Fig.4 - Cyclotron operating diagram in the (J_1,J_2)plane.

be fully vacuum impregnated. Thermal stability is improved by liquid helium in direct contact with the winding package at all sides. The coil support structure has been studied using the 3D computer code CASTEM in order to minimize the deflection of the midplane flanges when the coils are loaded at full current.

The basic features of the external cryogenic system are a liquefier operating effectively as a refrigerator and a 80 K radiation shield mounted inside the cryostat vacuum to reduce heat loads on the coils (see fig.5). The production of the cryostat and superconducting coils system will start in July 88, the external cryogenic system (liquefier, transfer lines etc ...) will be ordered before the end of 1988 and the delivery of an operating system is foreseen for July 90.

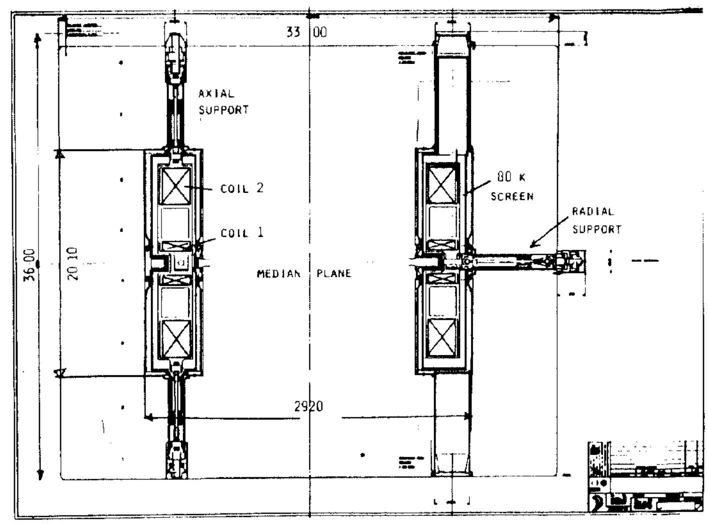

Fig.5 - Overall view of the cryostat and the coils.
All dimensions are in mm.

IV - The RF system

The RF system consists of three compact half-wave length resonators with continuous and smooth connection to the dees as shown in fig.6. A careful adjustment of the shape and position of the connections between the stem and the electrode has been made to minimize the RF power and the length of the stem. The maximum power at 62 MHz is limited to 35 kW with a current density around 40 A/cm [4]. Experiments have shown that the sliding contacts, which we have developped, with stand such current densities with reasonable security factor (60 A/cm at 62 MHz).

The pre-mechanical studies have been completed and a wooden full scale model resonator has been built. The resonant frequencies measured in a limited RF range (62 to 45 MHz) agree with the predictions of the short-circuit within 3% with respect to the calculations. The measurements of the voltage distribution at 62 MHz are shown in fig.7. An additional original aspect of the RF system is design a vacuum chamber which will at the same time be the RF liner. A overall view of the vacuum chamber (copper) and one of the RF electrode and resonator is shown in fig. 6.

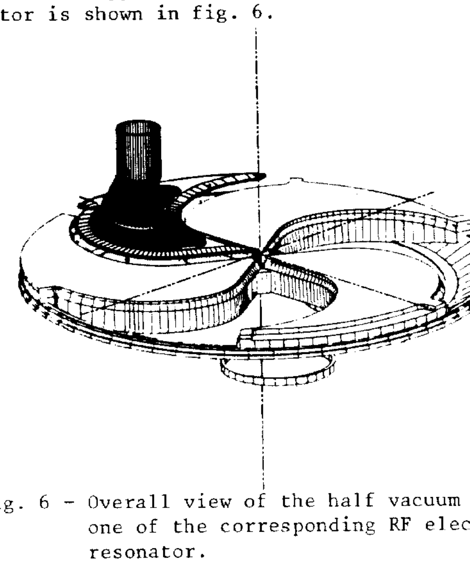

Fig. 6 - Overall view of the half vacuum chamber and one of the corresponding RF electrode and resonator.

The three RF amplifiers have been ordered and will be delivered around march 1989. The detailed mechanical study of the RF system is underway, the construction is scheduled to start around April 89.

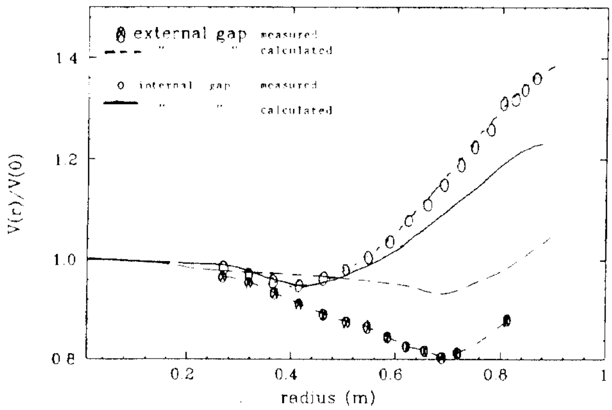

Fig.7 - Comparison between calculated and measured voltage distribution at 62 MHz.

V - Axial Injection and Central Region

The axial injection system for the superconducting cyclotron is designed to operate with three ion sources (light ions, polarized, p,d, ECR for heavy ions).

The first section is under construction and will be completed in the fall of 1988. A buncher operating at the RF of the cyclotron and common to the 3 harmonics modes h = 2,3,4 will be placed at about 50 cm from the median plane. A final version of the buncher system is being tested.

The central geometry has been designed in conjonction with a spiral inflector. A design study taking into account various parameters (space, voltage limitations, RF shielding) has been completed [5] and the electrical equipotential surfaces have been measured on a 5 to 1 scale model.

Phase and geometrical vertical focusing have been achieved using a magnetic bump on one hand and posts on the other hand. A view of the central region geometry common to the 3 harmonic modes is displayed in fig. 8.

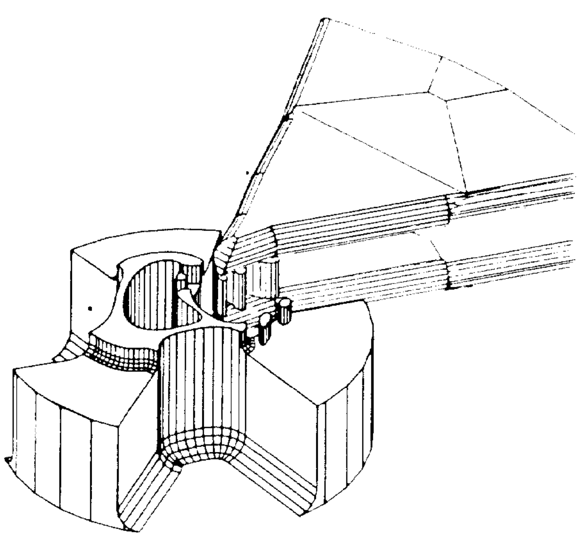

Fig. 8 - View of the central region of the cyclotron AGOR.

VI - Project Status

The engineering work including building modification at Orsay and the construction of the cyclotron pit are now completed. The equipments necessary to assemble the cyclotron have been ordered (crane, subassemblies elements etc ...)

The fabrication of a prototype of the cryopanels has been started and final tests will be made in September 88.

The control system of the injection line are nearly completed. Other parts of this system which has a modular architecture consisting of a number of microcomputers are already being tested.

A final version of a complete RF regulation system will be ready by the end of this year.

Design studies, both on the theoretical and technological aspects of the extraction system and elements are underway.

It is an anticipated that the mechanical assembly of the yoke will be made during the first semester of 1989 and that the first field maps could be measured during the third trimester of 1990.

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