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ABSTRACT

Experimental results from a set of low level RF measurements on the first cavity are presented and discussed in view of the RF requirements of the superconducting cyclotron.

1. - INTRODUCTION

This paper is intended to present the results of preliminary measurements on the first RF cavity for the Milan Superconducting Cyclotron.

The main characteristics of the machine are extensively reported elsewhere[1-5]. For the sake of completeness let us just recall that the machine has a $K_{foc} = 200$ and a $K = 800$, enabling maximum energies from 100 MeV/n for fully stripped light ions to 20 MeV/n for Uranium. The machine has a 3 sectors geometry, with an average magnetic field ranging between 22 and 48 kG. The corresponding RF frequency range is between 15 and 48 MHz, for harmonic operation from $h = 1$ to $h = 4$ and 100 kV peak dee voltage. The operating diagram of the cyclotron is shown in Fig. 1 while the plot of the RF frequency vs energy per nucleon at extraction is presented in Fig. 2.

Looking at Fig. 2 it is apparent that a very large RF frequency range is necessary in order to accelerate all most interesting ions using only harmonic number 2. This choice is very important when the machine operates with an internal ions source or axial injection, because the central region is strictly connected to the harmonic in use.

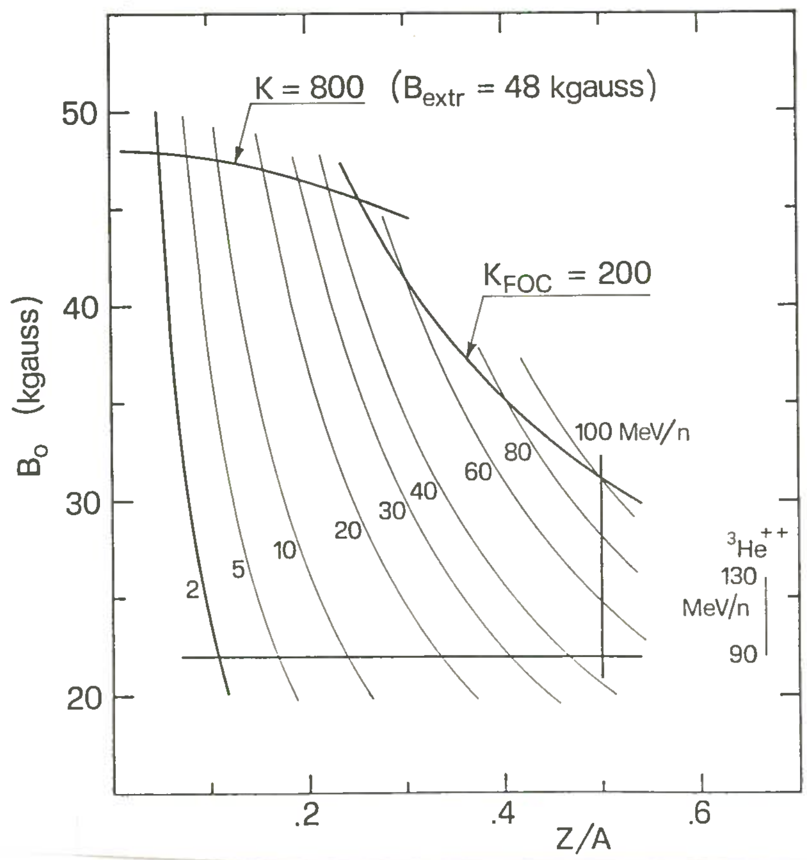

FIG. 1 - Operating diagram of the Milan superconducting cyclotron in the $(Z/A, B_o)$ plane. Lines of constant energy per nucleon are also shown.

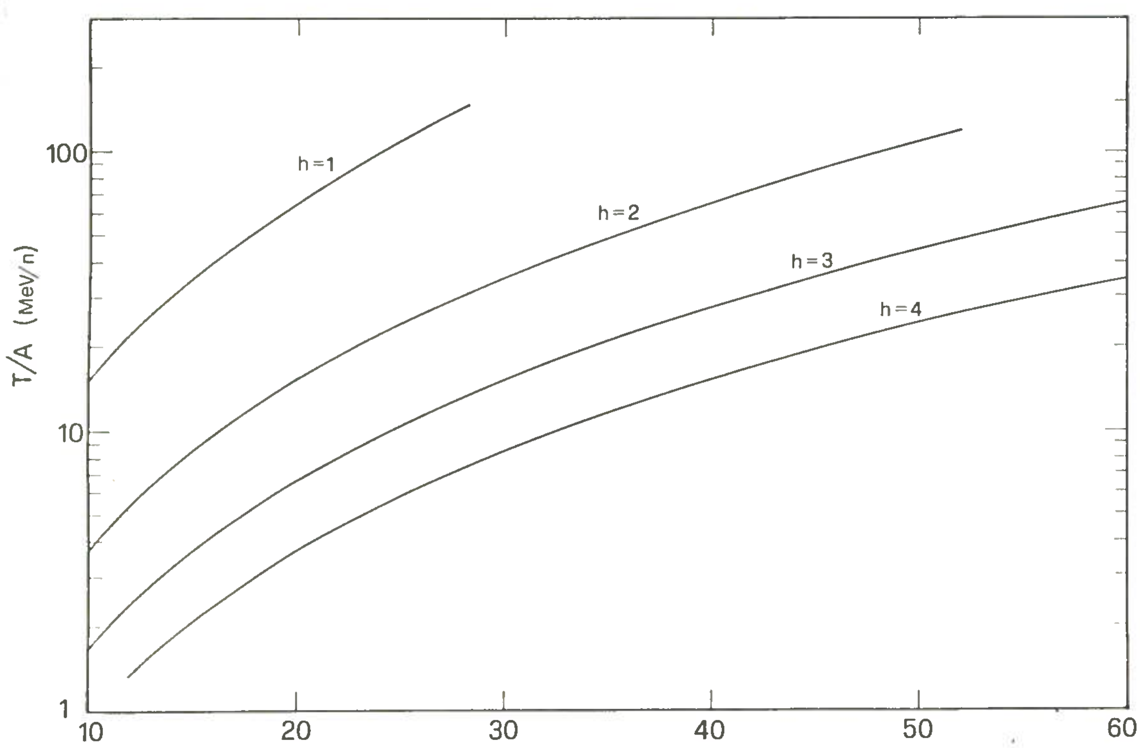

FIG. 2 - Final energy per nucleon vs the RF frequency for different harmonic modes.

2. - FIRST RF CAVITY

The three cavities of the Milan Superconducting Cyclotron differ only in the dee region. This is due to the fact that the central region geometry and the extraction path of the beam determine for each dee a different shape. In particular the dee which is located between the two electrostatic deflectors is larger because it must contain the partially extracted beam(3). This dee, which is more capacitive and consequently determines a lower maximum frequency for the cavity, has been chosen for the cavity prototype.

The general design of the cavity has been presented elsewhere(3) and a more detailed discussion of the electrical and technological aspects will be published in the near future. Only a few comments are in order :

- The diameters of the holes into the magnet for the coaxial dee stems are the maximum which can be reasonably compensated.
- The ceramic insulator, whose importance has been discussed elsewhere(3), reduces the movement of the sliding short and, because of the characteristic impedance of its region, increases the total power dissipation. Moreover, the insulator region is mainly dictated by high voltage requirements and power dissipation on the ceramic.
- The dee must have enough empty space inside in order to install the high vacuum pumping system and, perhaps, beam diagnostic probes.

Fig. 3 shows the cavity fully assembled. The 3 mm thick aluminum cover of the two edges and some of the water collectors are not in place yet. Fig. 4 shows the upper coaxial during assembly, while Fig. 5 presents one half dee fitted into the liner. The water cooling of the dee is not in place.

3. - THEORETICAL RESULTS

The main electrical characteristics of the cavity have been computed using a computer code based on trasmission line theory. Some aspects of this code are described elsewhere(4). This code, together with a graphical calculation of the dee characteristic impedances, gives, with a good approximation, all the informations needed to design an optimized cavity. A previous version of the same code has been successfully used by one of the authors to compute the RF model (without insulator) of the Milan Superconducting Cyclotron(4) and three types of GANIL cavities(6).

Fig. 6 shows the predicted values for the short circuit distance from the median plane and the total power dissipation, as a function of the resonating frequency together with the Q factor. We note that the curve of the power dissipation is slightly

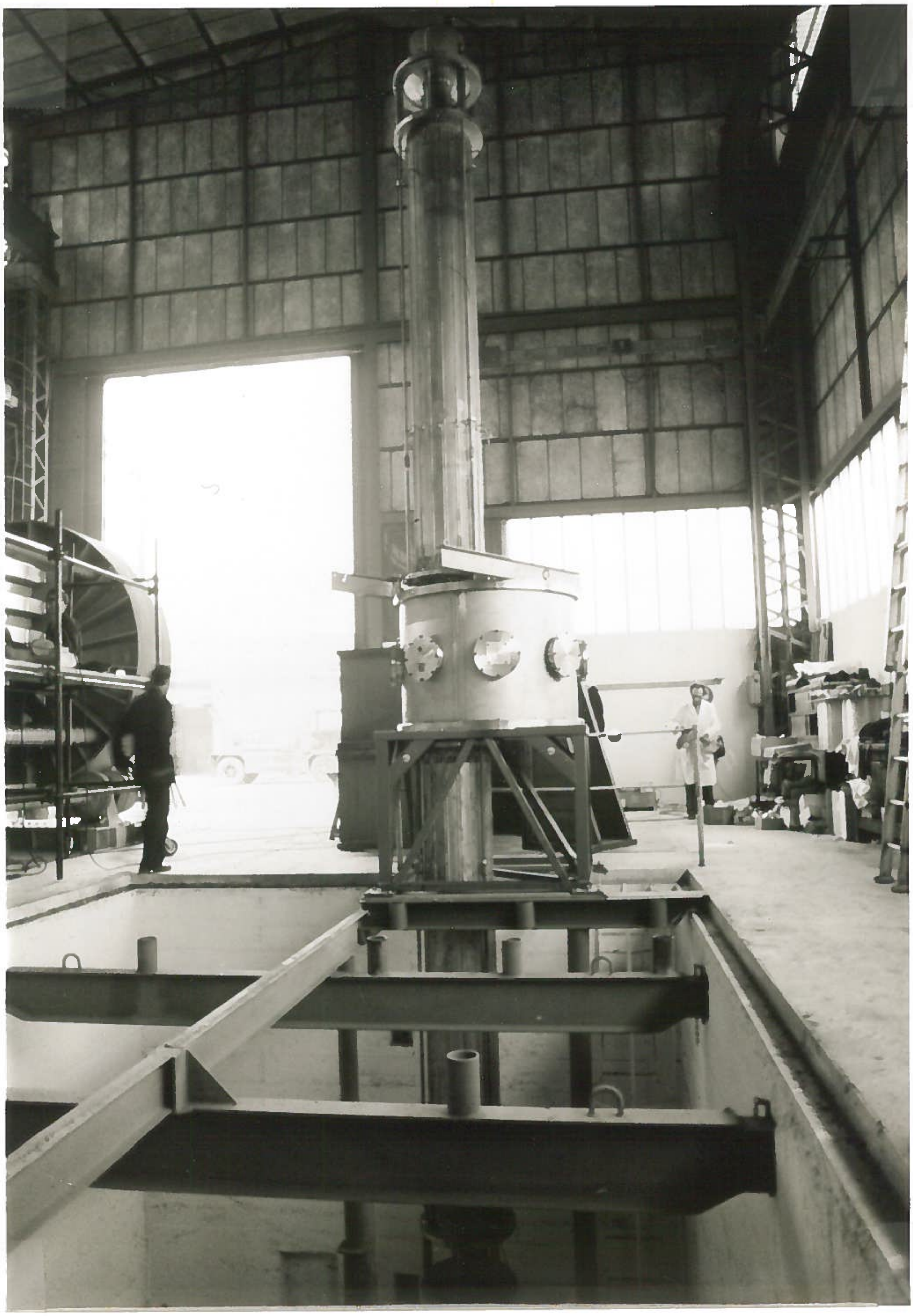

FIG. 3 - The first RF cavity fully assembled. The 3 mm thick aluminum cover of the two edges and some of the water collectors are not in place yet.

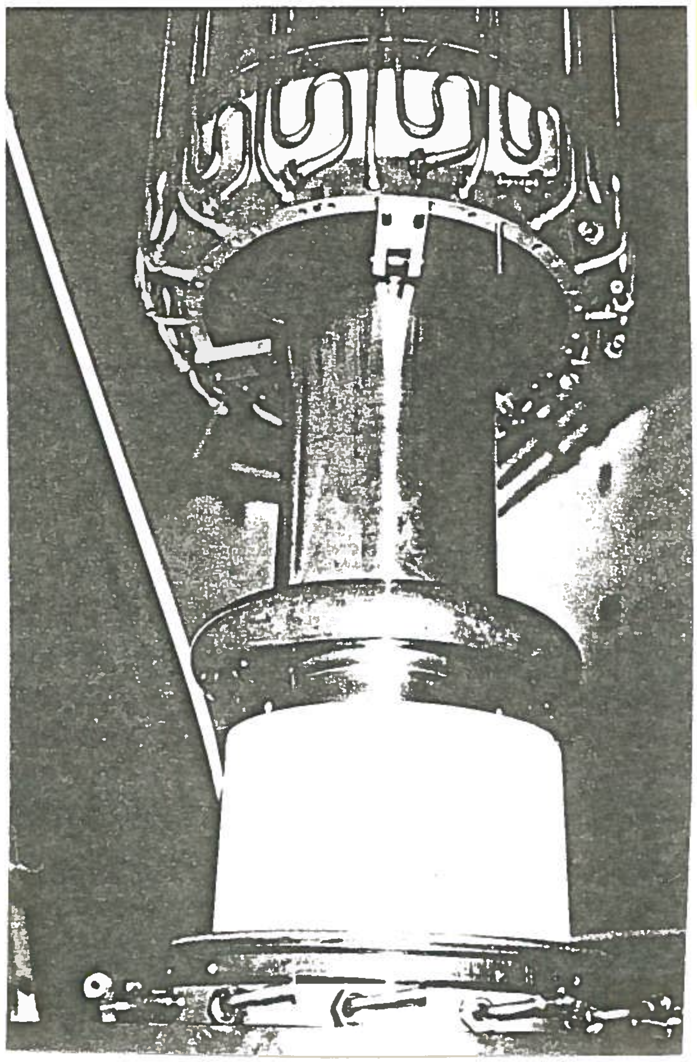

FIG. 4 - The upper coaxial during assembly. The alumina insulator supported by an air cushion is also shown.

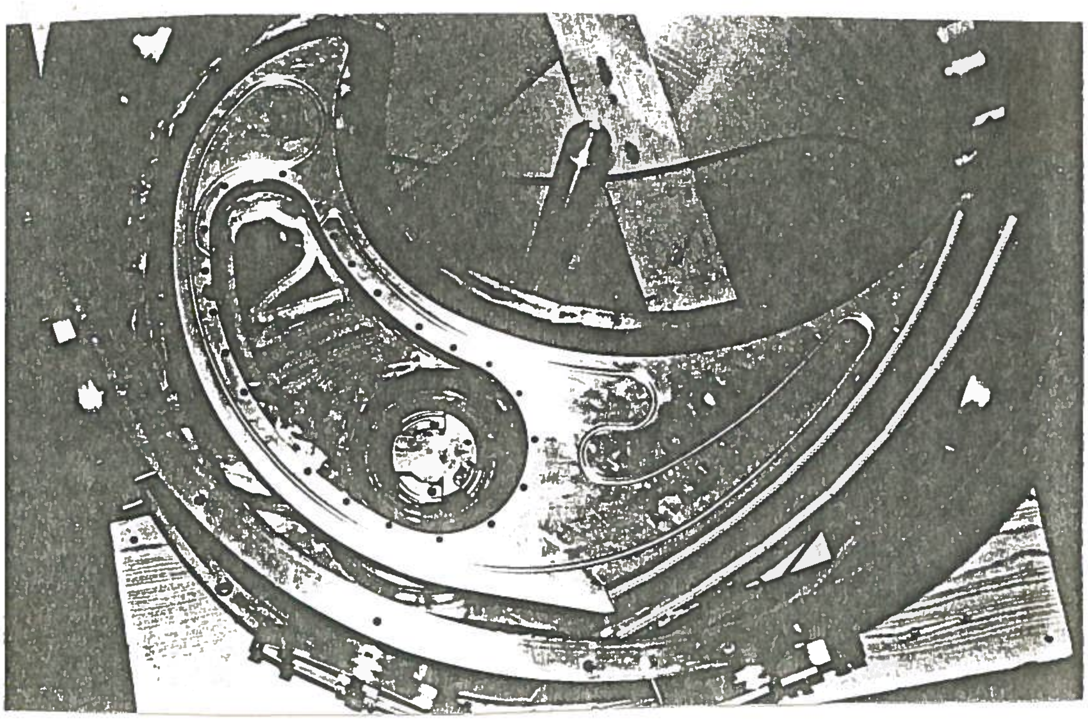

FIG. 5 - One half dee fitted into the liner. The water cooling of the dee is not in place yet.

different from the one previously presented at the Caen Conference[2]. This discrepancy is mainly due to the dee and insulator regions which have been modified: the dee is a little more capacitive and the insulator region has been modified according to the high voltage requirement.

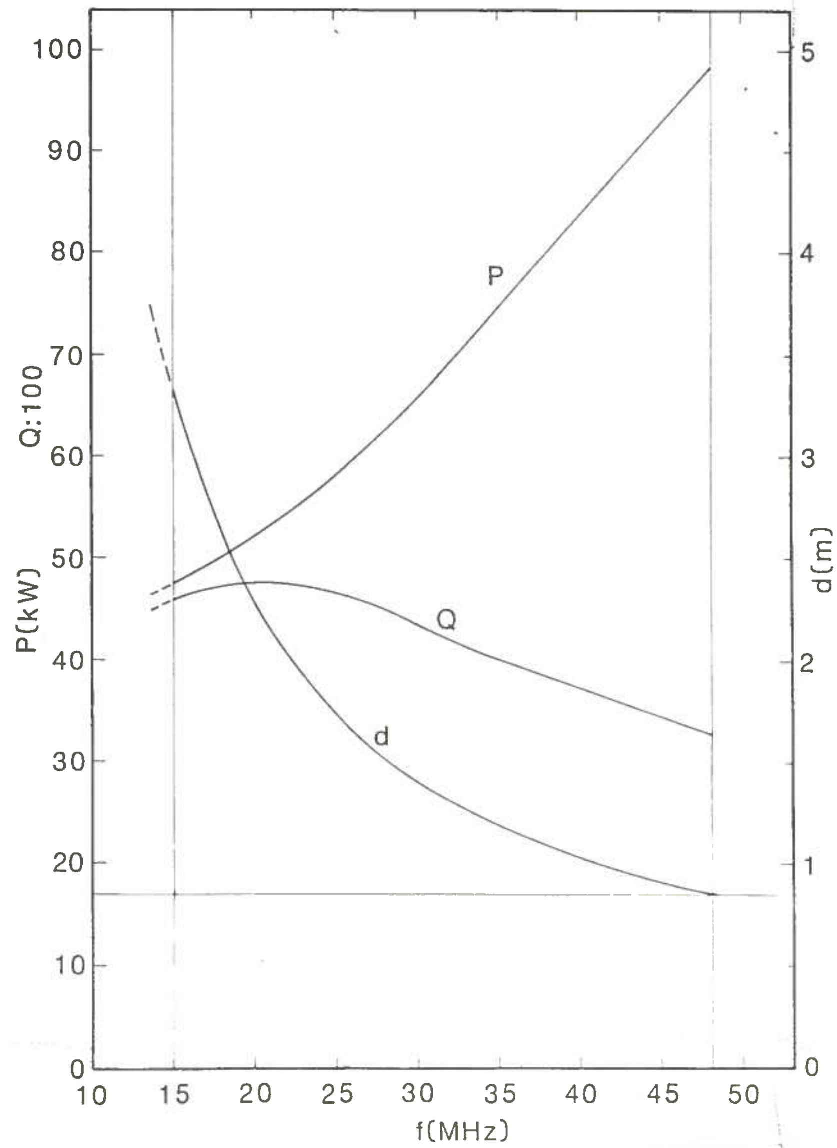

FIG. 6 - Predicted values for the short circuit distance from the median plane (d), the quality factor (Q) and the total power dissipation (P), as a function of the resonating frequency. Frequency range requirements and minimum short distance are also presented to guide the eyes.

4. - EXPERIMENTAL RESULTS

Due to a significant delay in the construction of the new building which will house the cyclotron, the full cavity has been assembled in the machine shop where it has been constructed. The assembling was carried out in order to:

- verify the overall mechanics and the assembling procedure;
- verify the vacuum tightness of the system;
- perform a preliminary set of electrical measurements for checking the computed data.

The last point was of particular importance because we can install in the present cyclotron building only one half of the cavity. This installation, while adequate for power tests on the system, cannot provide informations on the resonant frequency and power dissipation of the whole cavity.

Electrical measurements have been carried out with a standard set of instruments, exciting the cavity in a non perturbative way. Small probes have been instal led on the two symmetrical sliding shorts, coupling and trimming capacitors. We used for this set of measurements dummy sliding shorts and dummy trimming and coupling capacitors. All measurements have been performed in air.

Fig. 7 shows the experimental results relatively to the short circuit distance from the median plane and the Q factor. Also total power dissipation is presented like an extrapolated figure.

We note that:

- the maximum frequency is just 47 MHz instead of the calculated 48 MHz;
- at low frequency Q factor is smaller by about 10% and the power is therefore grater than expected.

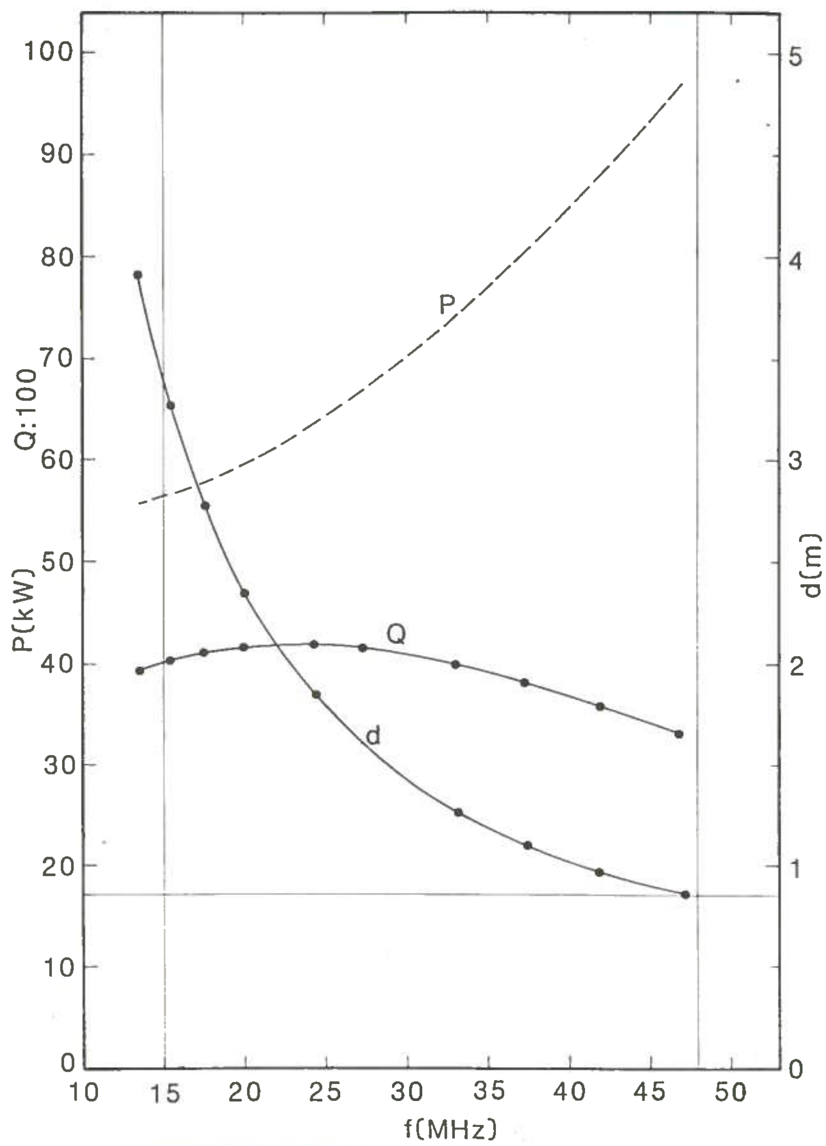

FIG. 7 - Experimental results relatively to the short circuit distance from the median plane (d) and quality factor (Q). Also total power dissipation (P) is presented like an extrapolated figure.

5. - DISCUSSION

We think that these results are rather successful, looking at the complexity of the cavity geometry and consequently at the number of approximations introduced in the computer code[(4)].

Looking at the RF requirements of the Milan Superconducting Cyclotron, the two main discrepancies quoted above have a different weight. The lower Q factor at low frequencies is probably due to poor polishing of the coaxials and in any case the RF power amplifiers can supply much more power than needed. Nevertheless we expect an increase of the Q factor after proper polishing of the cavity.

Concerning the maximum frequency, we must recover the MHz which has been lost; we plan to do so by modifying the insulator region, slightly reducing the charac teristic impedance. This will be done when the dee geometry, including the central region, will be definitely frozen. Obviously such a modification asks for a new optimization of the insulator region also from the high voltage and power dissipation points of view. We are confident that it will be possible, limiting the total power to 100 kW, which is the maximum power reliably supplied by the RF power amplifiers without major modifications.

In conclusion we note that the first cavity is the one with the most capacitive dee. For the other two cavities we expect the frequency problems to be much easier and, in one case, even nonexsistent.

REFERENCES

(1) - E. Acerbi et al., Status of the Milan Superconducting Cyclotron Project, IEEE Trans. on Nuclear Science, NS-30, (June, 1983).

(2) - E. Acerbi et al., The Milan Superconducting Cyclotron Project, Proceedings of the 9th Intern. Conf. on Cyclotrons and their Applications, Caen (France), 1981 (Les Editions de Physique, 1981).

(3) - C. Pagani, G. Varisco, V. Venturini and F. Alessandria, RF Design of the Milan Superconducting Cyclotron, Proceedings of the 9th Intern. Conf. on Cyclotron and their Applications, Caen (France), 1981 (Les Editions de Physique, 1981).

(4) - C. Pagani and G. Varisco, Model Study of the RF Cavity for the Milan Superconducting Cyclotron Project, IEEE Trans. on Nuclear Science, NS-26 (April, 1979).

(5) - E. Acerbi et al., Status of the Superconducting Cyclotron Project in Milan, INFN Report INFN/TC-82/17 (1982).

(6) - C. Bieth et al., Ganil RF Systems, 1979 Particle Accelerator Conference, San Francisco (IEEE Trans. on Nuclear Science, NS-26, April, 1979).