THE GANIL ACCELERATING SYSTEM

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Abstract

The GANIL accelerating system actually consists of 10 RF systems : 2 for the injectors cyclotrons, plus 2 fundamental and 2 flat-topping dees for each of the two large cyclotrons. The fundamental dees (3 to 14 MHz) must provide 1 MV voltage per turn for the large cyclotrons. In order to achieve high beam currents with low energy spread, harmonic, or flat-topping dees will be mounted within the fundamental dees. The flat-topping dees will operate on the 3rd or 5th harmonic of the fundamental frequency.

Preliminary designs of the RF structures will be presented, along with computed values of voltage, current and power requirements.

1. Introduction

The proposed radio frequency system for the GANIL project is based on the following considerations :

1.1 Voltage distribution

The voltage distribution along the dee lips must be increasing from the injection radius to the extraction radius. In this case the quarterwave cantilever structure can't be used and the dee stem needs to be placed as close as possible to the center. To respect the vertical symetry of the dee voltage two stems must be used. In order to reduce the stem length, additional dee capacity is added for the low frequencies [1, 2].

1.2 Frequency range

The decision to reduce the frequency tuning range to 5.85 - 13.4 MHz (instead of 3 - 13.4 MHz) by using 4th and 16th harmonic acceleration has greatly decreased the size of the additional dee capacity.

1.3 Minimum dee voltage

The minimum dee voltage at each frequency is determined by the possibility to inject and extract with a reasonable gain per turn. This curve is given on Fig. 1. As the dee voltage is rapidly decreasing with the frequency it is possible to increase the dee capacity in such a manner that the lower frequency can be reached without any movable short-circuit. Fig. 2 shows a schematic view of a 2 stem structure with only two movable panels.

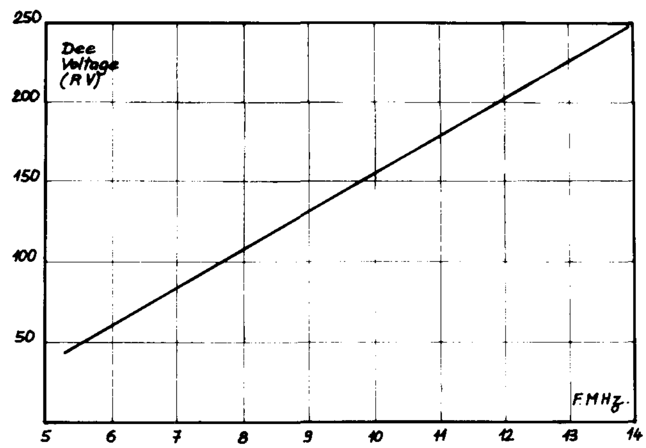

Fig. 1 Peak dee voltage vs frequency

1.4 Dee angle

With a 52° magnet, the free space between two consecutive magnets allows a 30° dee. The center of this angle is the same as the center of the machine and the gap size is increasing from the center to the maximum radius.

1.5 Flat-topping dee

To obtain the beam quality requirements the use of a flat-topping dee is necessary. As the cyclotron is not isochronous on one quarter of a turn we need to put the FT dee inside the main dee. The use of high harmonic number (5 to 3) permits to reduce the frequency range (29.3 - 40.2 MHz), the dee voltage - Fig. 3 - (4.3 % - 11.6 % of the main dee voltage) and the phase and amplitude precisions. The first orbit calculations have shown that the relative radial voltage distribution of the FT dee must not be far from the main dee voltage distribution (within ± 20 %). In order to obtain these conditions the thickness of the main dee is increased (to reduce the FT dee capacity) and the stem of the flat-topping dee (which is inside the stem of the main dee) must be connected to the dee by a large conical section (Fig. 2) [3].

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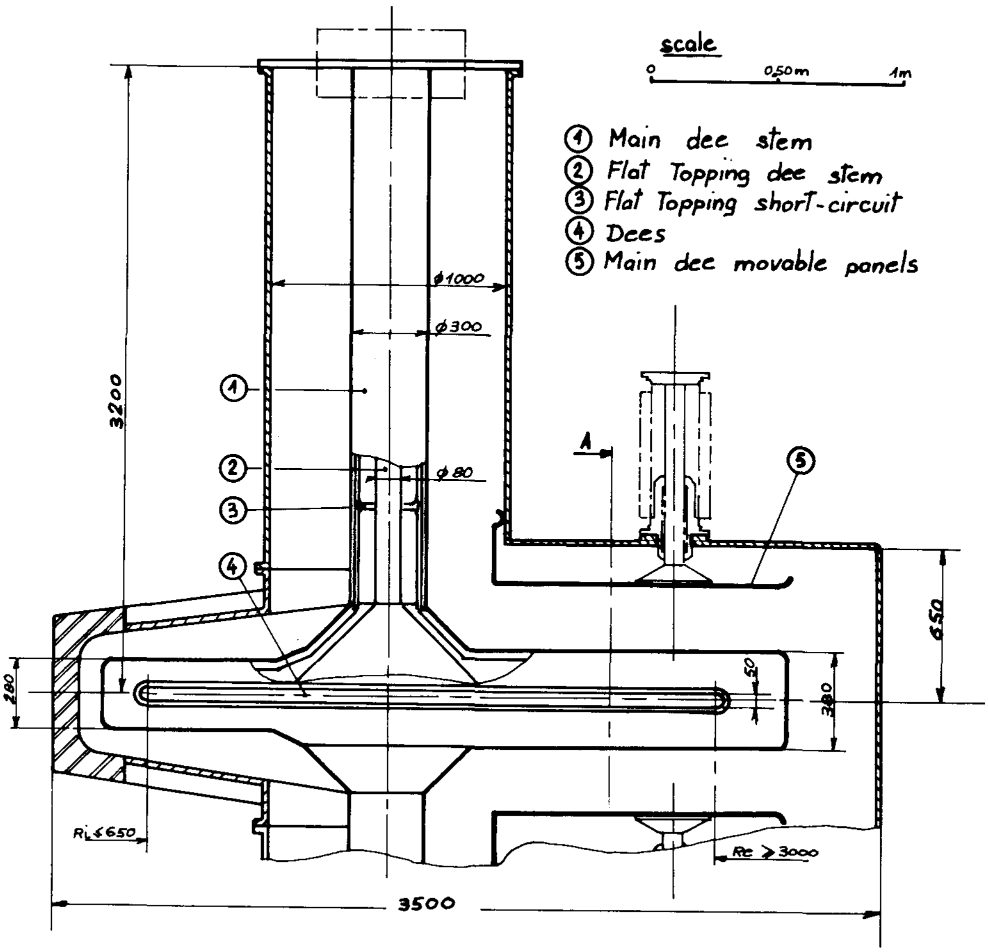

Fig. 2 A schematic cross-section of the cavity

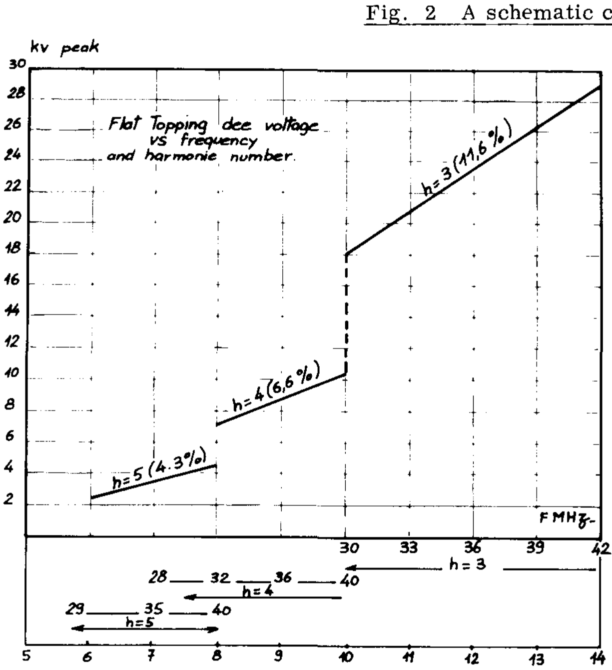

Fig. 3 Flat-topping dee voltage vs frequency

2. Main dee cavity

Presently the main dee cavity has been completly calculated by the computer program REGAN (REsonateur GANil). Dee and stem are cut in many sections where the characteristic impedance, the RF resistance (with a non uniform current density), are calculated. Then the impedances, voltage, current, losses, energy, Q factor, are evaluted for each section. This is done for all the frequency range by recalculating the characteristic impedance for all the panel movements. The curves on Fig. 4, 5, 6 give the results for one cavity. We can see that the RF power is rather low ($\simeq$ 80 kW max for one dee, 160 kW for one SSC) and is decreasing as the frequency decreases. The minimum distance between dee and ground (panel) for 5.85 MHz is 1.75 cm with 60 kV peak. The panel is placed only in the extraction region where the magnetic fringing field is zero, in order to reduce the sparking probability. If we assume that the maximum electric field around the corners of the dee is twice the mean value (35 kV/cm x 2 = 70 kV/cm), the Kilpatrick criterion shows that the product $WE^2\ e^{-\frac{1.7\ 10^5}{E}} = 2.6\ 10^{13}$ is lower than 1. 8 10^{14} , value for which sparks begin to appear. A quarter scale model is under construction. In order to test the type of sliding contacts for the panels a 3 meter tank cavity will be used in november associated with a 35 kW wide band amplifier. We will be able to produce 80 kV rms with a total current in the capacity around 2600 A rms.

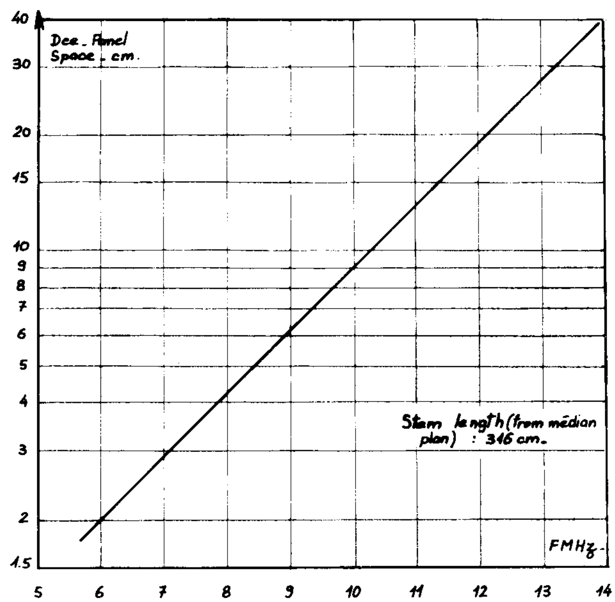

Fig. 4 Dee to panel distance vs frequency

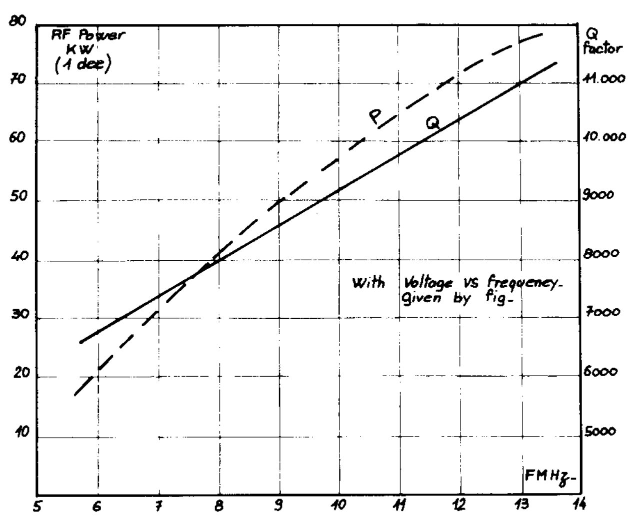

Fig. 5 Main cavity RF power vs frequency

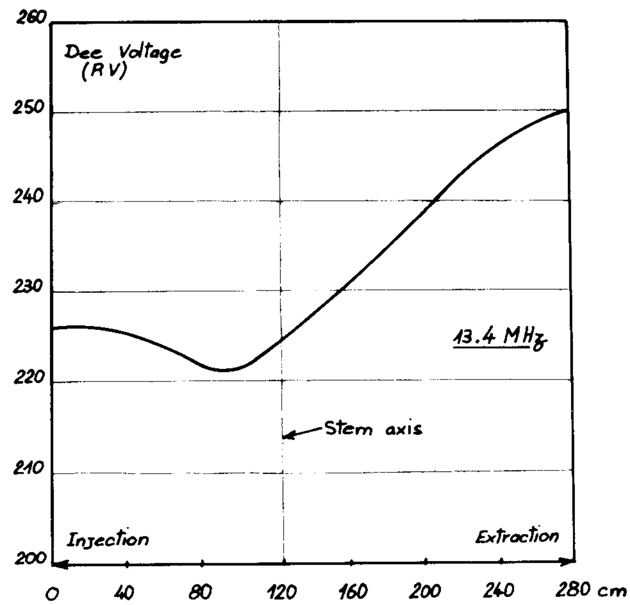

Fig. 6 Radial voltage distribution for the main dee

3. Flat-topping dee cavity

The same calculation as for the main cavity has been done for the FT cavity - using the dee voltage curve vs frequency shown on fig. - Two possible structures can be used : quarter wave line with movable short-circuit inside the stem of the main dee or 3/4 wave line with variable capacity and inductance outside the stem (4). The $\lambda/4$ system requires only 10 kW at 40 MHz and 2 kW at 29 MHz but the movable short and the coupling system to the amplifier is rather difficult due to the small free space inside the stem. The $3\lambda/4$ system has two virtues : the stem is static and the coupling system is easy. There is one disadvantage : the total power is three times (30 kW) than required for the $\lambda/4$ system.

With a conical section between the dee and the stem we can see on Fig. 7 that the relative radial voltage distribution of the flat-topping dee is in the range of $\pm$ 20 %.

4. Coupling system and RF amplifier

We plan to couple capacitively the power tube to the dee resonator as shown on Fig. 8 . The total shunt impedance varies from $4.10^5\Omega$ at 13.4 MHz to $1.10^5\Omega$ at 6 MHz and for a coupling capacity of 20 pF the capacity C_2 changes from 400 pF at 13.4 to 200 pF at 6 MHz if the plate impedance of the tube is around 1 kΩ.

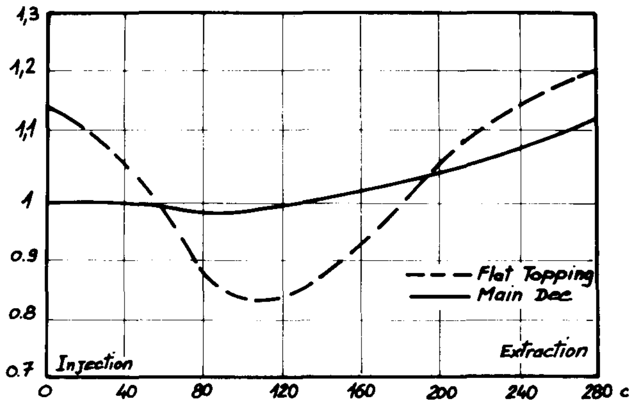

Fig. 7 Relative radial voltage distribution for the main and FT dee

For a 100 kW tetrode tube the driving power is less than 500 W, and the input capacity is small enough to permit the grid to be driven broad band with an input impedance around 12.5 Ω (four paralleled 50 Ω water cooled resistors) and with total input power of 4 to 5 kW. Such an amplifier system permits to change the frequency only by matching the plate impedance of the tube,

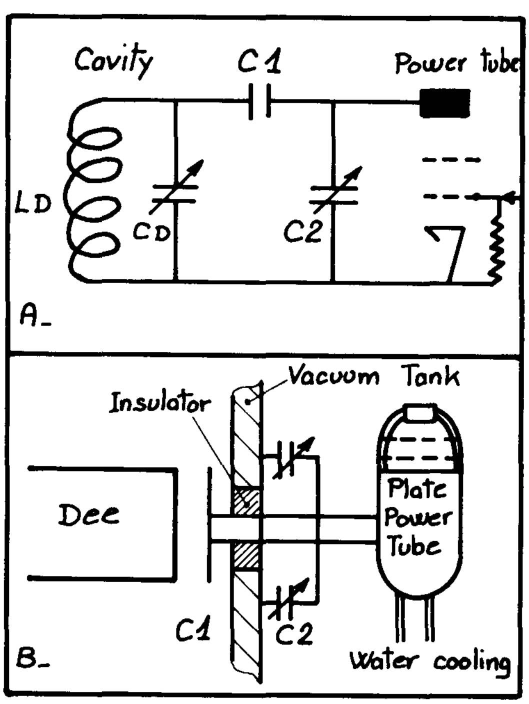

Fig. 8 A - Equivalent circuit of the coupling system
B - Schematic view of the coupling and power tube

5. Regulation systems

The beam quality requires a dee voltage stability of the order of 5.10^{-2} and between the two dees of each cyclotron a phase stability $\Delta\varphi \leqq 1°$. For the FT dee the maximum requirements are (h = 3) $\frac{\Delta V}{V} \leqq 10^{-2}$ and $\Delta\varphi_{FT} \leqq 0.2°$ (compare to the main dee).

We think that the tuning system of the main dee cavity would be devided in three parts :

- rough tuning by the large movable panels
- fine tuning with low response by a trimmer panel
- very fine tuning with fast response by a ferrite system (5) coupled to the cavity.

The phase regulation system will use a fast electronic phase shifter with two inputs : phase reference and a beam phase probe.

The voltage regulation system will use an electronic attenuator with also two inputs : level reference and a beam probe proportional to the beam position at the entrance of the extraction channel.

References

(1) Details of 3 RF systems for GANIL, J. Riedel, int. report 4, 1975, GANIL.

(2) Results of 2 RF systems for GANIL, C. Bieth, int. report 3, 1975, GANIL.

(3) Results of the λ/4 flat-topping resonator, C. Bieth, int. report 3, 1975, GANIL.

(4) Flat-topping RF systems for GANIL, J. Riedel, int. report 75-20, 1975, GANIL.

(5) GANIL RF systems, J. Riedel, int. report 75-5, 1975, GANIL.