# HIGH POWER TEST OF THE WAVEGUIDE LOADED RF CAVITY FOR THE FRASCATI Φ-FACTORY MAIN RINGS

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*Abstract*

The Φ-Factory DAΦNE is a high current, multibunch electron-positron double ring collider in construction in Frascati. The high order modes (HOMs) of the accelerating cavities can drive longitudinal and transverse coupled-bunch instabilities. A single-cell cavity connected to the vacuum chamber through long tapered beam tubes and loaded with rectangular waveguides to damp the HOMs has been designed, fabricated and high power tested. This paper reports the results of the power tests and the up to date progress of the whole DAΦNE RF system.

## 1 INTRODUCTION

The accelerating cavity for the Frascati Φ-Factory [1] is a normal conducting single cell made of oxygen free high conductivity (OFHC) copper.

The cavity design was optimised to reduce as much as possible both the HOM content, the primary source of longitudinal and transverse coupled-bunch instabilities, and the contribution to the broadband machine impedance [2].

The cavity cell has a rounded shape without nose cones and is connected to the ring vacuum chamber through large tapered tubes 80 cm long.

This unusual choice allows to reduce significantly the cavity loss factor as well as the impedances of the HOMs (i.e. the R/Q values), even without external damping devices. On the other hand, this solution impacts negatively on the fundamental mode shunt impedance, but this is not of primary importance in DAΦNE since the required accelerating voltage is rather low (250 KV/ring). The HOM Q damping is accomplished by 5 waveguides, 3 connected to the cavity cell and aimed to couple out the low frequency HOMs, and 2 connected on the tapers, where the high frequency HOMs are essentially located. The main characteristics of the DAΦNE RF cavity are summarized in Table I, while a picture of the first DAΦNE cavity, not including the taper waveguides, is shown in Fig. 1.

Table I: DAΦNE RF Cavity parameters

| | | |
|---|---|---|
| $f_{RF}$ | Resonant frequency | 368.32 MHz |
| $V_c$ | Cavity voltage | 250 kV |
| $Q_0$ | Cavity unloaded quality factor | 33,000 |
| $R_s$ | Cavity shunt impedance | 2 MΩ |
| $\beta$ | Cavity input coupling factor | 2.5 |
| $P_{MAX}$ | Max klystron RF power | 150 kW |
| $I_b$ | Max beam current | 5 Amps |
| $E_r$ | Energy loss / turn | 15 keV |
| $P_{HOM}$ | Cavity HOM power | ≈ 3 kW |
| $\Delta f_{bl}$ | Max. beam loading detuning | ≈ - 500 kHz |

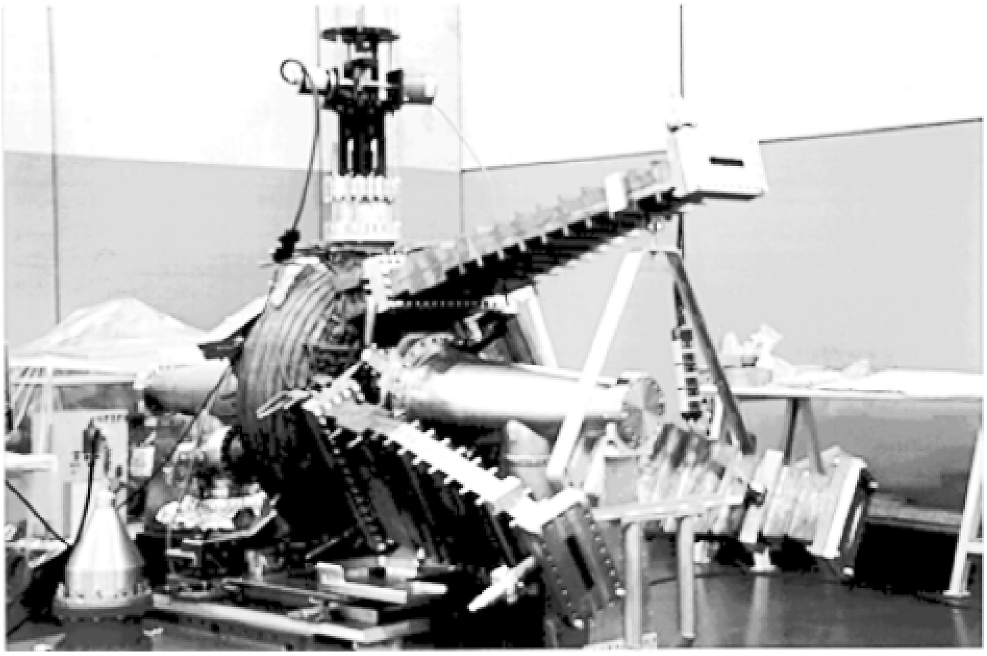

Figure 1: The first DAΦNE RF cavity

## 2 THE DAΦNE RF CAVITY

The cavity, manufactured by Zanon (Italy), is made from a single copper billet to avoid large vacuum tightness weldings. The internal surface was entirely worked out by automatic milling machine. The long taper tubes are joint to the cavity with 300 mm diameter flanges.

The circular ports of vacuum pumps, tuner and power coupler are TIG welded; conflat flange to copper joints are made with the electron beam welding (ebw) technique. The cavity water cooling is guaranteed by circular tubes brazed onto the surface. The cooling system has been designed with the code ANSYS [3] which takes into account the distribution of the cavity RF wasted power.

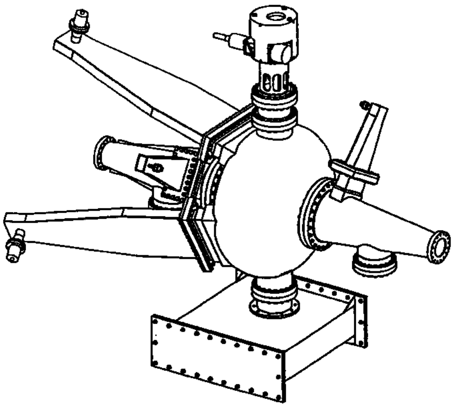

Figure 2: DAΦNE RF cavity sketch.

The HOM damping system consists of three rectangular 305 x 40 mm waveguides (WG) connected at 120° to the cavity main body. Their position is optimised in order to have the highest coupling to the most dangerous HOMs which can propagate in the TE10 dominant WG mode. The WG frequency cut-off is above the cavity FM which therefore is trapped in. Two additional 140 x 40 mm rectangular WGs are located on the tapers with a relative angular position of 90°. They extract those highest frequency HOMs which propagate through the tubes. The WGs are then converted to coaxial by means of a smooth broadband double ridge transition [4]. Figure 2 shows a sketch of a fully equipped DAΦNE cavity. The HOM power is dissipated on an external standard 50 Ω load via a 7/8" coaxial $Al_2O_3$ feedthrough designed at Frascati and manufactured by Meta.Ceram (France). The feedthrough frequency response is flat (VSWR < 2) from DC to 3 GHz; the device has been power tested up to 4 kW-cw at 370 MHz. The WG to Coaxial Transitions avoid the use of under vacuum RF lossy materials for HOM power dissipation. They consist of two OFHC Copper half shells longitudinally brazed together. Water cooling is provided on the transition broader side to dissipate the evanescent FM. Ribs are used to reinforce the structure against the atmospheric pressure. A picture of one WG to coaxial transition is shown in Fig. 3. Elicoflex gaskets are used for the vacuum tightness of the WG rectangular flanges and the RF contact is obtained with Cu-Be springs.

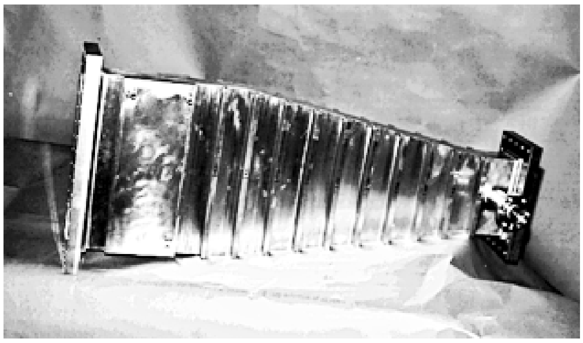

Figure 3: DAΦNE WG-to-Coaxial transition.

Cavity tuning is made with a stepping motor driven cylindrical plunger; the RF power coupler consists of a WG to coaxial transition terminated with a rotating loop to adjust the cavity-generator coupling; the vacuum separation is made with a cylindrical ceramic window. To protect the ceramic in case of arcs or overheating, the vacuum window is monitored by arc detector and infrared sensor.

## 3 CAVITY POWER TESTS

The cavity power station comprises one 368 MHz - 150 kW-cw klystron amplifier (Thomson, France), linked to the cavity with a 6-1/8" coaxial line via a three port ferrite circulator (AFT, Germany) for protection against high standing wave regime.

Figure 4: DAΦNE RF Test Hall

A coaxial line instead of a waveguide was chosen to improve the system compactness. To avoid any mechanical stress on the klystron ceramic window, the coaxial line, made by Spinner, is provided with flexible sections and is internally air cooled to prevent over-heating. Figure 4 shows a picture of the DAΦNE RF test hall. The low power control electronics includes the tuning system and the servo-loops to control and stabilize the amplitude and phase of the RF cavity voltage.

A RF feedback circuit around cavity and klystron has been developed to prevent the beam loading instability [5]. The first DAΦNE cavity has been power tested in April '96. The nominal accelerating field $V_C$ = 250 kV, corresponding to a cavity power dissipation of ≈ 16 kW, has been reached in less than 24 hours of cw RF conditioning. No evidence of multipacting or discharge phenomena has been remarked, in spite of the fact that the evanescent penetration of the fundamental mode in the plane, parallel surface region of the waveguide HOM couplers is a potential source of resonant discharges.The cavity has been kept continuously powered for 2 weeks at various accelerating field levels up to 350 KV without faults, so that the RF test has been considered completely satisfactory. The cavity vacuum was limited to $2 \cdot 10^{-8}$ mbar because, to make the RF tests quickly, we made only a moderate and short baking to 150° C. Therefore the cavity shall be newly cleaned and baked before the next power test, scheduled on the late summer.

## 4 HOM DAMPING

As already mentioned, the HOM damping was the principal cavity design goal. In order to have an evaluation of the achieved damping rate, a measurement of the residual HOM longitudinal impedances based on the wire technique has been carried out. The plots of the cavity longitudinal spectrum up to 1.5 GHz with shorted and matched damping waveguides are shown in Fig. 5.

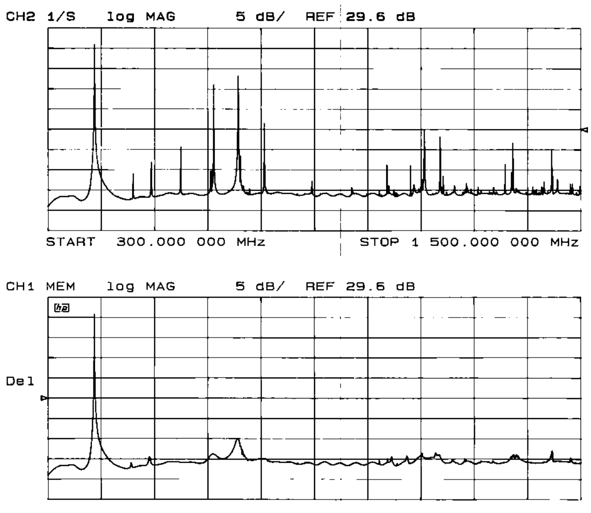


Figure 5 : DAΦNE Cavity longitudinal spectrum. Damping waveguides terminated on shorts (up); Damping waveguides terminated on matched loads (down).

The reference impedance of the wire-beam tube system is ≈ 260Ω. The wire technique has been preferred to other methods (port-to-port measurements, bead perturbations) since it allows to have an immediate picture of the behaviour of those modes having significant fields nearby the beam axis (the only modes affecting the beam dynamics) and it is especially effective in low-Q mode measurements.

On the other hand we are aware that the wire perturbs significantly the resonant frequencies, and the impedance measurements are not very much accurate.

No modes appear to remain undamped in Fig. 5, and the damping factor in some cases exceeds 30 dB. The highest impedance in the damped plot is located around 700 MHz and corresponds to the first monopole TM011. The damped peak impedance is ≈400 Ω, giving a coupled bunch instability rise time of ≈ 0.5 msec in case of full coupling at the maximum machine current. This growth rate strongly dominates the natural damping (17 msec) but it is still at well manageable level for the DAΦNE bunch-by-bunch longitudinal feedback system[6].

More accurate longitudinal and transverse impedance measurements are in program in the very near future.

## 5 CONCLUSIONS

The first DAΦNE cavity, fully equipped with RF main coupler, tuner, waveguide HOM dampers and special coaxial ceramic feedthroughs, has been power tested far beyond the nominal accelerating field in the DAΦNE RF test hall. A power station, reproducing the final RF system configuration, including the TH2145 DAΦNE klystron, the high power circulator, the RF transmission line complex and the low level control electronics, has been assembled to perform the test. No multipacting or discharge phenomena, as well as other kind of RF system faults, have been observed during two-weeks of continuous operation.

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