STATUS OF THE SUPERSTRUCTURE

J. Sekutowicz, C. Albrecht, R. Bandelmann, B. Dwersteg, J. Eschke, B. Horst, N. Jakubowski, G. Kreps, R. Lange, M. Liepe, J. Lorkiewicz, A. Matheisen, W.-D. Möller, H.-B. Peters, D. Proch, D. Reschke, W. Singer, X. Singer, K. Twarowski, G. Weichert, H. Wenhui, G. Wojtkiewicz, DESY, Notkestrasse 85, Hamburg 22603, FRG, M. Ferrario, INFN, Via Enrico Fermi 40, Frascati 00044, Italy, C. Pagani, INFN, Via Fratelli Cervi 201, Milan 20090, Italy.

Abstract

The first prototype of the superstructure, seen as the alternative solution to the standard TTF cavity, will be tested with beam in April 2002. Since the last SRF'99 Workshop, a new version, based on 9-cell sub-units has been proposed. In this report we present this version and status of components we prepare for the beam test.

1 INTRODUCTION

The beam test of the Nb prototype of the superstructure was proposed in January 1999. The first superstructure version, made of four 7-cell subunits (SST1), was seen, at that time, as an attractive alternative to the standard 9-cell TTF type cavities [1]. The bigger fill factor in both TESLA linacs and substantially smaller number of fundamental mode couplers (one coupler per 28 cells) are the main advantages of SST1. Before the test was proposed, extensive computer studies of the RF properties and extensive measurements on copper models had been performed. Meanwhile the second version, SST2, has been studied. It is made of two 9-cell TTF structures, with a geometry of the interconnection identical to the interconnection of SST1. SST1 is 3.4 m long. Thus production and preparation have to be done for each sub-unit separately. SST2 is shorter, 2.38 m, and can be produced, cleaned and tested as one piece. It is technically easier and the well-established technology of the standard cavities can be applied to its production and preparation. The price is less saving in regard to fundamental mode couplers (one coupler per 18 cells). The test preparation of SST1 was well advanced at the moment SST2 was proposed. The decision was made to perform beam test on two 2x7-cells superstructures.

2 THE NEW SUPERSTRUCTURE

Fig.1 shows details of SST2. The superstructure will have one fundamental mode coupler based on Ø60 mm coaxial line technique, four welded HOM couplers of the DESY type [2], two cold tuners and one pickup probe. The parameters of SST2 are listed in Table 1. There are 18 resonances in the fundamental mode (FM) passband. The field profile (E_z component on axis) of the accelerating mode and the next mode from the π-group are shown in Fig. 2.

Table 1: Parameters of SST2

Parameter		unit
Number of cells	18	-
Length	2.38	[m]
F of accelerating mode, π-0	1300	[MHz]
R/Q of accelerating mode, π-0	1966	[Ω]
Cell-to-cell coupling	1.9	[%]
Subunit-to-subunit coupling, π-group	0.03	[%]
E_{acc} at 500 GeV	22	[MV/m]
U, nominal voltage for 500 GeV	46	[MV]
Input power at U and I_{beam}= 9.5 mA	437	[kW]

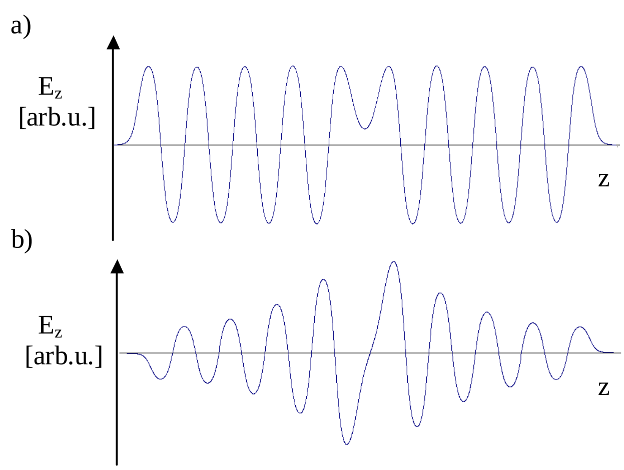

Figure 2: Field profile. a) π-0 mode, b) π-π mode

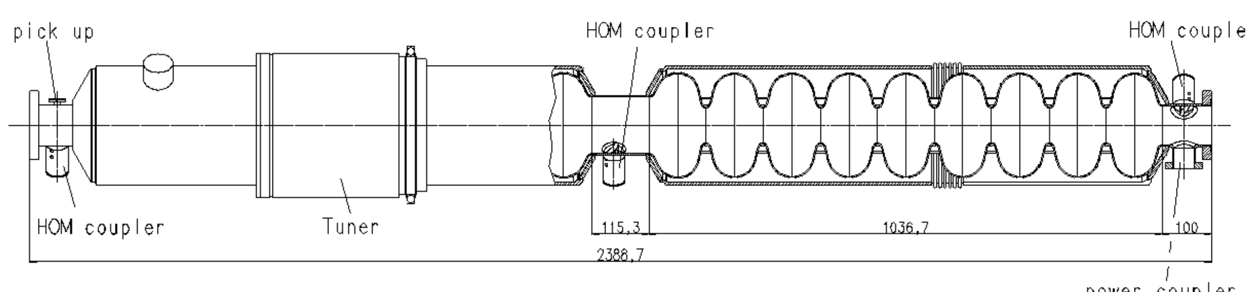

Figure 1: 2x9-cell superstructure

2.1 Field flatness and energy spread

Each 9-cell subunit will be equipped with a mechanical tuner for the individual frequency adjustment. This will allow for the additional compensation for fabrication errors. The diagrams below illustrate computer simulation for 10000 superstructures of type 2 and 10000 standard 18-cell cavities of the TTF shape. In both cases the frequency of individual cells was perturbed randomly with ± 30 kHz. The mean field flatness error is 1.6 times smaller for the SST2 due to this compensation.

a)

b)

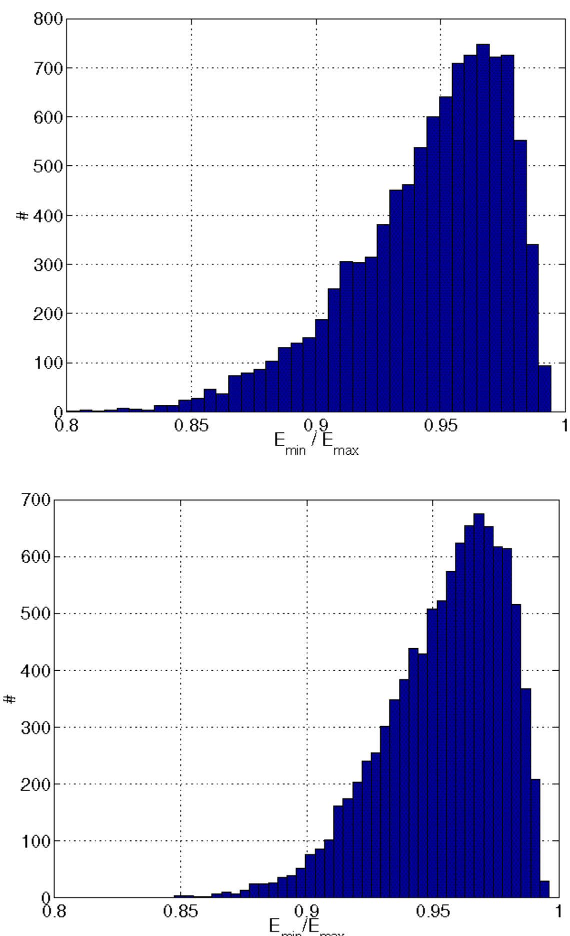

Figure 3: Field flatness statistics

a) 18-cell cavities, mean value E_{min}/E_{max}= 94.5 %

b) 2x9-cell SST2, mean value E_{min}/E_{max} = 96.5 %

Refilling of stored energy in all cells in the time interval between two successive bunches has been simulated for the whole TESLA train of 2830 bunches. The result is shown in Fig. 4. As for SST1 also for SST2 the expected energy spread is small of the order of $\pm 5\cdot 10^{-5}$. This means the energy flow from an input coupler through the whole chain of cells is sufficient to refill the stored energy.

2.2 HOM damping

As it was already mentioned SST2 will be equipped with 4 HOM couplers, one on each end-beam tube and

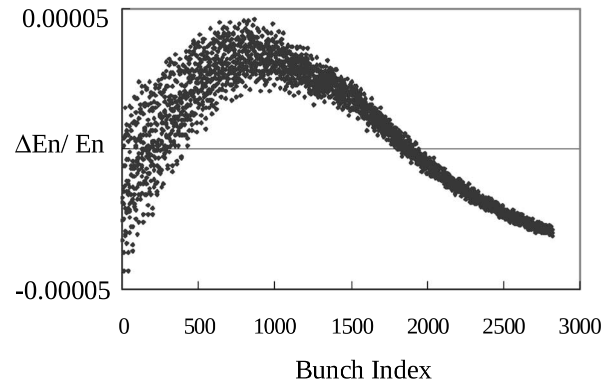

Figure 4: Energy spread for the nominal operation

two at the interconnection to damp dipole modes below the BBU limit [3]. The copper model of SST2 will be ready in next future. To get a preliminary estimation of the HOM damping, we have measured HOM damping on a Cu model of 2x7-cells superstructure, made of subunits built for the model of SST1. This model could be equipped with 3 HOM couplers only. Damping of transversal modes was more than sufficient. The total impedance of all dipole modes up to 3.1 GHz was smaller than BBU limit by a factor of 7 (see Fig. 5). The monopole modes are well damped as well. The Q values stay below 10^5. This ensures that for the nominal TESLA current of 9.5 mA only few watts of mean power will be coupled out.

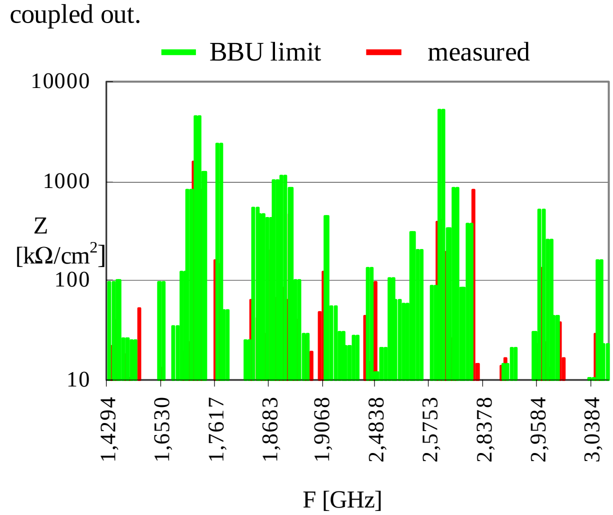

Figure 5: 2x7-cells, damping of dipole modes

3 BEAM TEST PREPARATION

The beam test of SST1 was proposed at the time when the infrastructure installed at DESY could be used for cavities made of no more than 9 cells. To avoid time and money consuming re-building of the infrastructure, the decision was made to prepare all four 7-cell subunits individually and to use superconducting Nb gaskets squeezed between NbTi flanges for the final assembly. The preliminary cold test of this sc connection gave encouraging results. Two Nb gaskets withstood 11 MV/m, maximum field of the 2-cell test cavity. Unfortunately this result was never obtained in many vertical tests of 7-cell subunits we did up to now. All 7-cells results were not conclusive and no explanation was found for the bad performance. Neither material we used for the gaskets nor its preparation or assembly of gaskets could give us a hint why good 2-cells results could not be repeated for the 7-cell cavities. The investigation is still continued, but schedule does not allow to rely on this solution. Since the subunits of the final superstructure for TESLA will be welded, we decided to use EB welding technique to connect subunits in both Nb prototypes. For that, subunits which are already tuned, cleaned and assembled in the LHe vessels, will be sent back to the vendor. Before the final welding of two subunits, NbTi flanges must be removed. After the welding but before assembly in the cryostat, few microns BCP and HPWR will be done. One should point it out that no mechanical deformation of cells can be corrected after the welding, because subunits are already in LHe vessels. It is obvious that the price for an "abnormal" sequence of preparation, we have to do, could be the unbalanced field in these prototypes.

3.1 Status of components

Many components needed for the test are ready now or will be ready soon. Four cavities which will be assembled in two 2x7-cell superstructures are ready. We have done test assembly of pairs to check the pre-tuning. Individually well pre-tuned subunits (field flatness 98.5%), equipped with dummy tuners, were installed on the assembly table (Fig. 6) The measured field profile after the assembly is shown in Fig. 7. It agrees very well

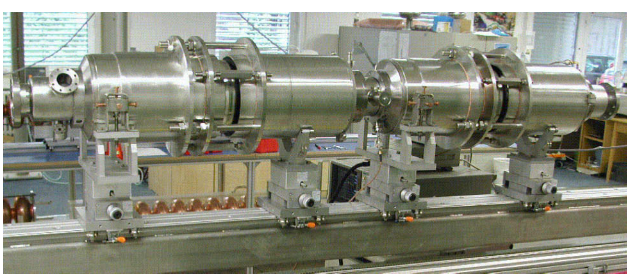

Figure 6: 2x7-cell superstructure on the assembly table.

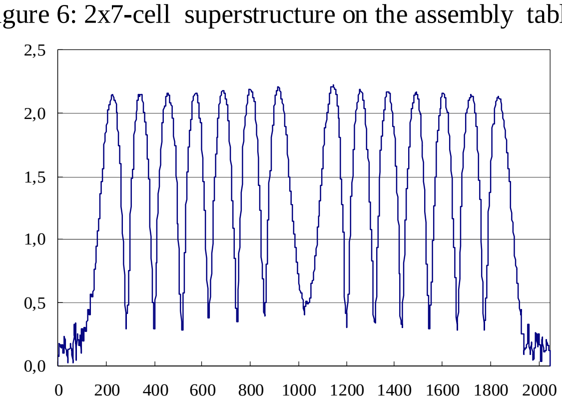

Figure 7: Measured field profile (arbitrary units) at room temperature of the 2x7-cell Nb superstructure.

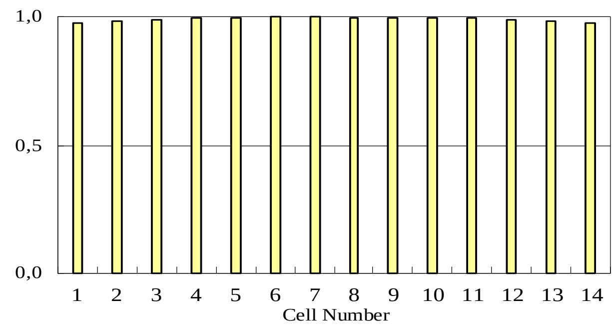

Figure 8: Theoretical field profile of Nb 2x7-cell superstructure at room temperature.

with the theoretical one (Fig. 8). Slightly lower field amplitudes in end cells result from the measurement method and overlapping of neighbouring modes due to low Qo value.

All parts of tuners and LHe vessels are in place. In May this year the first tuner version (Fig. 9) was tested in horizontal cryostat at 2 K. Over the whole 500 kHz range the resolution of the tuner was 0.4 Hz/step, i.e. better than the specification. The test showed that the tuner is not stiff enough. The next version has a spring tube made of Ti (Fig. 10). It will be tested cold by mid September. The stiffness of this version has been already measured and is 12 μm/kN, 5 times better than that of the first version.

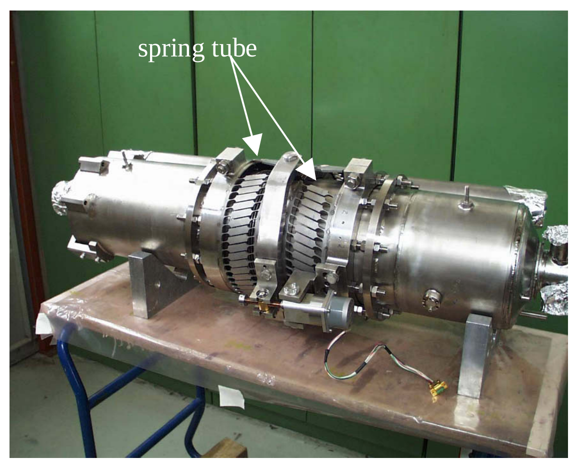

Figure 9: The tested prototype of the tuner

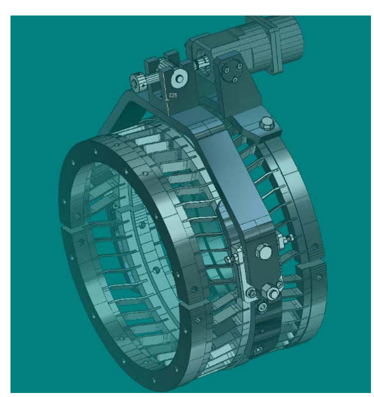

Figure 10: New spring tube made of Ti as proposed by C. Pagani.

The cryostat for the beam test is in place. The way both superstructures will be assembled in the cryostat is schematically shown in Fig. 11. The distance between both superstructures is almost 700 mm and no coupling for the FM passband is expected. The situation is different for HOMs. The computer simulation is in progress to find out if there are some additional modes with high (R/Q) in this interconnection. We should answer this question to be able to make a proper interpretation of the beam test afterwards. After the test will be finished the cryostat with eight standard 9-cell cavities will be used as the spare cryomodule for the TTF linac.

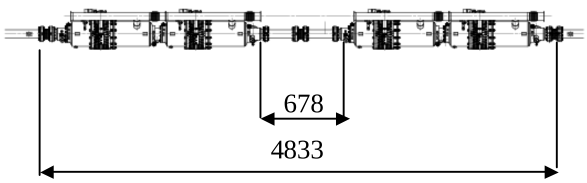

Figure 11: Position of two superstructures in the cryostat.

3.2 Vertical test of subunits

There are two types of subunits: type I with port for the input coupler and type II without port (Fig. 12). The poor performance of sc gaskets is the reason why the subunits have not been tested vertically to their limit yet. The results were always limited by gaskets placed 24 mm from end iris (on the right side in Fig. 12). They varied from 1.5÷5 MV/m only and were irreproducible. To enable final welding of two subunits together, an extension tube must be welded to the right side of subunits type I. We choose to make this tube as long as the left side tube of type II (91.3 mm). In this stage two subunits of type I have been delivered from vendor back to DESY and will be tested by mid September. The modification of type II subunits is different. Here the end-groups, similar to those on the left side of subunits type I but without input coupler port, will be welded by the mid of October. After these modifications in both types of subunits the nearest gasket (needed only for the vertical test) will be placed 91.3 mm apart from the end iris, instead of previous 24 mm. It will be exposed to much smaller magnetic field and should not be a limit in this test.

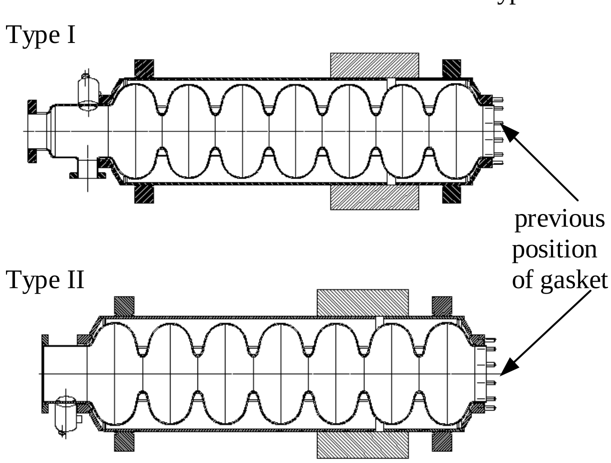

Figure 12: Subunits of the 2x7-cell superstructure.

4 BEAM TEST PROGRAM

The cold test of the superstructure will consist of three phases. We comment them briefly in this section.

4.1 Phase I: RF measurements without beam

At the beginning we will measure the following RF properties of both prototypes:

- spectrum of the FM passband,
- Q_{ext} of modes from FM,
- spectrum of HOMs and their Q_{ext}.

Also, in this phase we will verify:

- two proposed methods to balance the field profile of accelerating mode in all subunits,
- computed sensitivity of the field profile vs. frequency of each subunit,
- maximum E_{acc} and its limitation.

4.2 Phase II: Bunch to bunch energy spread

This phase is the main part of the whole beam test. The expected energy spread for the 2x7-cell superstructure is shown in Fig. 13. It is almost in the same range of as the energy spread of SST2. The test cryostat will be placed in the TTF linac at the second position, after one standard cryomodule (Fig. 14). We will need very good energy measurements, before and after the test cryostat, to analyse the expected energy spread. The diagnostics

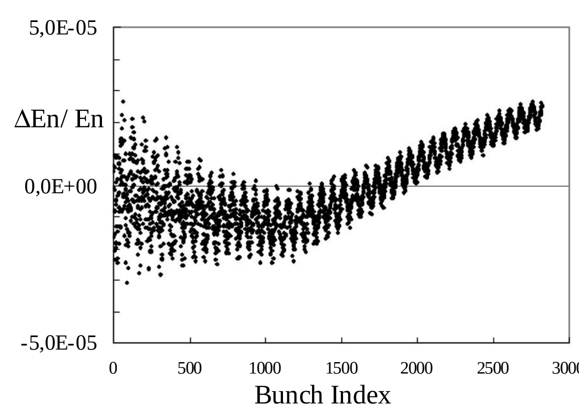

Figure 13: Computed ΔEn/ En of 2x7-cell superstructure

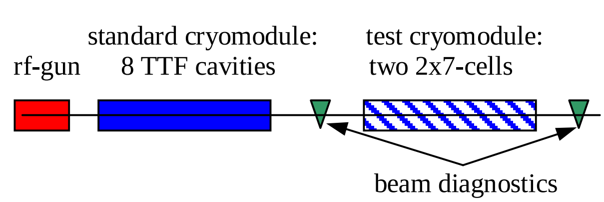

Figure 14: Position of the test cryomodule in TTF.

installed at present allows measurements with precision of the order of $5\cdot10^{-4}$. An additional method of the energy spread estimation can be applied here. The method is based on the precise measurements of end-cells' voltages vs. time during the bunch train. Each subunit has two pickup probes, one on each side. They will be calibrated together with their feedtroughs and cables. Numerical simulation shows that the voltage (or E_{acc}) amplitude of individual cells, in a standing wave cavity operated in the π-mode, is modulated by one order of magnitude stronger than the integral voltage V experienced by a single bunch passing the whole cavity. The voltage V of 14 cells in 2x7-cell prototype varies vs. t in the range of $\pm 4\cdot10^{-5}$ (see Fig. 15). The voltage Ve, sum of all end cells' voltages, is modulated stronger (dotted line in Fig. 15) in the range of $\pm 4\ 10^{-4}$. The measured amplitude of this voltage will give estimation of the voltage V and thus estimation of the energy spread.

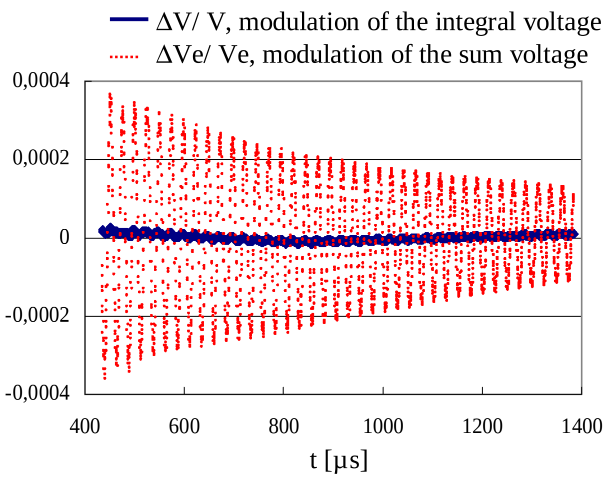

Figure 15: Modulation of the integral voltage V and of the sum Ve in the 2x7-cell superstructure.

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4.3 Phase III: HOM measurements

The way we would like to measure interaction between the accelerated beam and parasitic modes (mainly dipoles) of both prototypes is the same as it was done for standard TTF structures by S. Fartoukh [4]. The HOMs will be excited by beam with the modulated bunch charge passing prototypes off axis. The modulation generates additional spectral lines which can be shifted to hit HOMs' frequencies. Two deflecting magnets will be installed in front of the test cryomodule to displace beam off axis in vertical and horizontal direction. This will allow us to define the angular position of non monopole modes [5] and to excite both their polarisations. Recently this method was applied successfully second time to measure HOMs of the new accelerating module in the TTF linac [6]. In the first step we will calibrate diagnostics station downstream to the test cryomodule. For this we will excite HOMs with known, from Phase I, frequencies and Q_t's and we will measure parameters of the beam trajectories. In the second step we will scan the spectrum of both prototypes up to 4 GHz to detect contingent trapped modes with high beam impedance.

5 REFERENCES

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[5] N. Baboi, private communication

[6] C. Magne et al., "Measurements with beam of the deflecting Higher Order Modes in the TTF Superconducting Cavities", PAC2001, Chicago, June 18-22, 2001.