BESSY

Berliner Elektronenspeicherring-Gesellschaft
für Synchrotronstrahlung m.b.H.

# Status of the HOM Damped Cavity for the Willy Wien Ring

Ernst Weihreter / BESSY

- **Short** Review of HOM Damped Cavity Prototype
- Modifications for the Willy Wien Ring Cavity
- Results of Low Power Measurements
- Operation Experience and Limitations
- Outlook

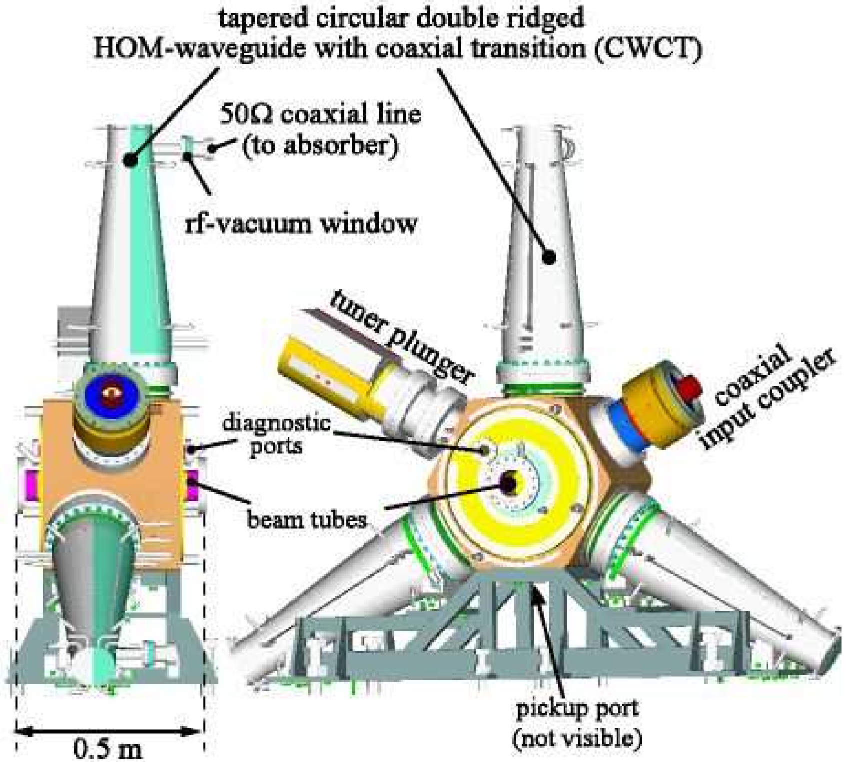
Leibniz Gemeinschaft

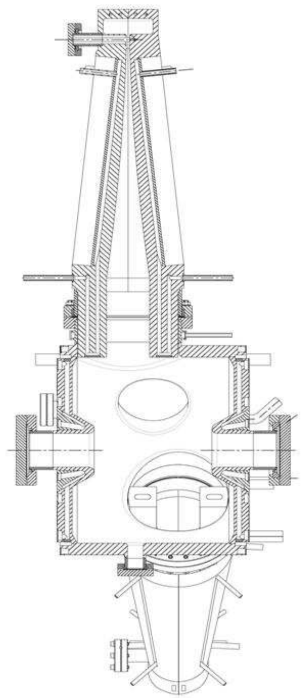
# HOM Damped Cavity Prototype

**Project collaboration:** BESSY / Germany
**(EC funded)** Daresbury Lab / England
DELTA / Dortmund University, Germany
National Tsing Hua University / Taiwan

## Design Goal

- **Frequency**
  $f_{rf}$ = 500 MHz
- **Insertion length**
  L < 0.7 m
- **Shunt impedance**
  R > 3 MΩ
- **Max. thermal power**
  P = 100 kW
- **Compact design to fit existing ring tunnels**

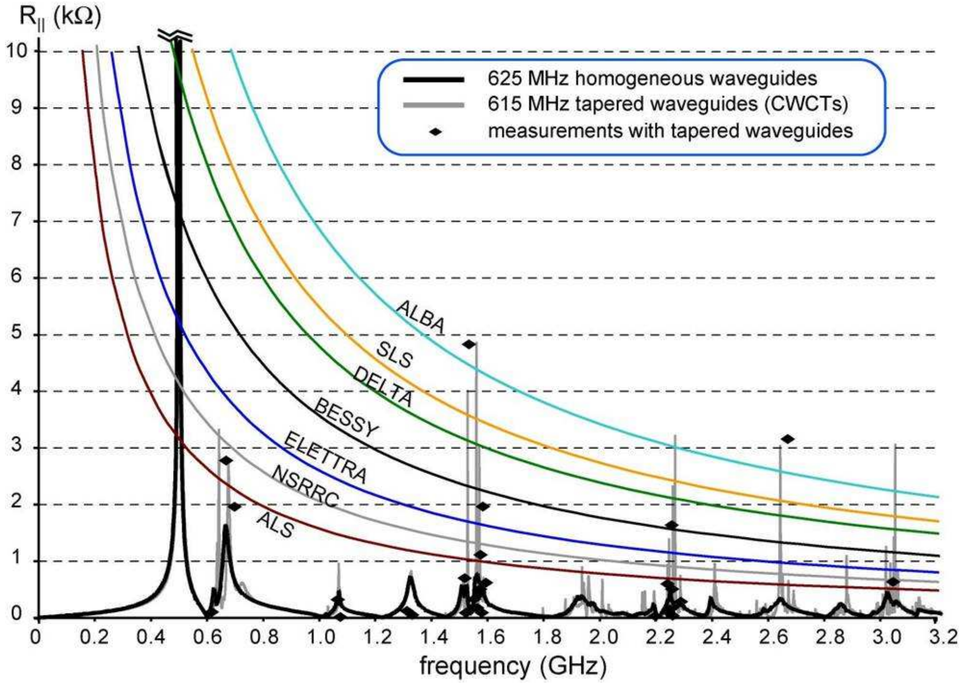


# Impedance Spectra and Critical Impedances

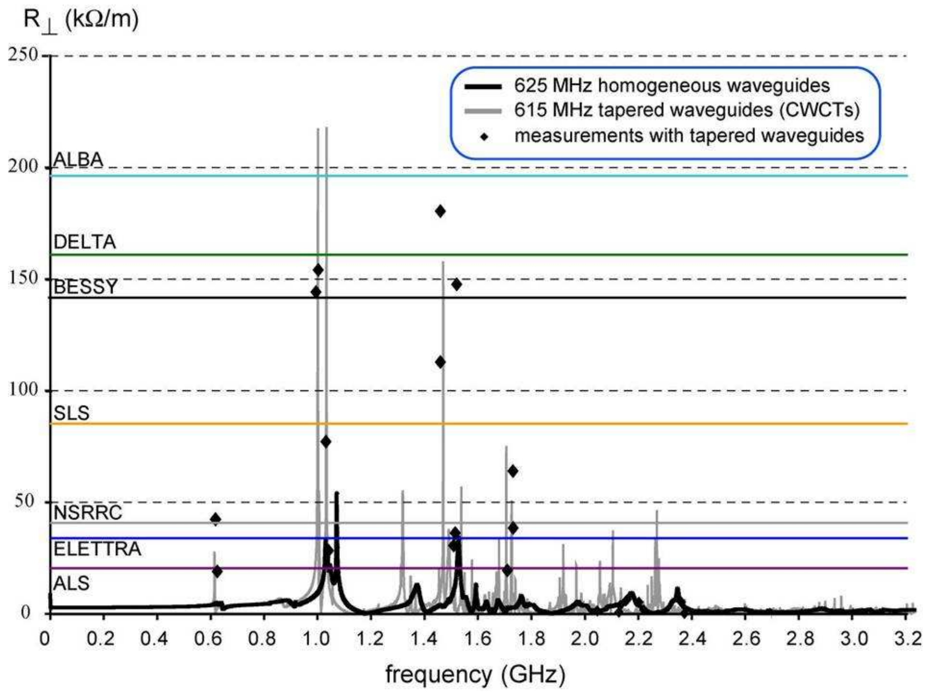
Longitudinal Impedance

$$Z_{\parallel}^{thresh} = \frac{1}{N_C} \cdot \frac{1}{f_{\parallel,HOM}} \cdot \frac{2 \cdot E_0 \cdot Q_s}{I_b \alpha \tau_s}$$



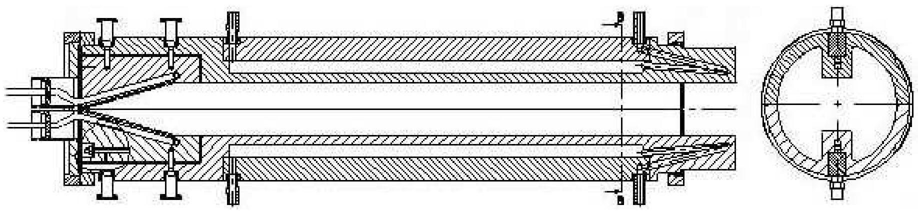

Transverse Impedance

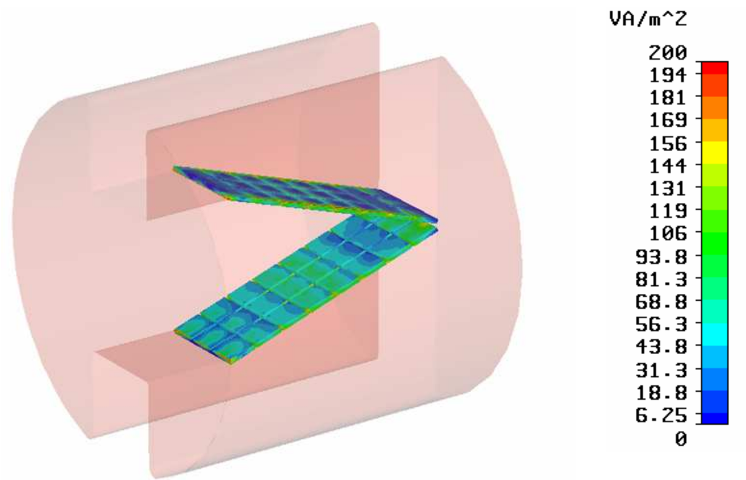
$$Z_{x,y}^{thresh} = \frac{1}{N_C} \cdot \frac{2 \cdot E_0}{f_{rev} I_b \beta_{x,y} \tau_{x,y}}$$

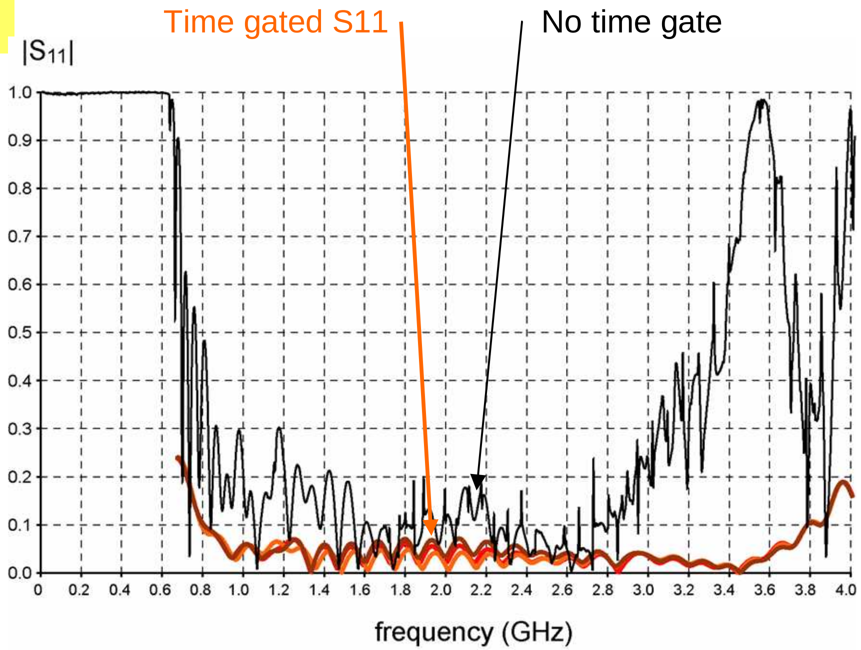


# Homogenous Wave Guide Dampers

| | Tapered WG | Homogenious WG |
|---|---|---|
| Max. $Z_{long}$ [kΩ] | 5. | 1.8 |
| Max. $Z_{transv}$ [kΩ/m] | 200. | 50. |






Time domain reflectrometry measurement of S11

Optimisation parameters:
- ♦ wedge length
- ♦ ferrite layer thickness

# Fabrication and Test of Ferrite Absorber Elements

**Challenge: Bonding of ferrite on copper**

♦ NiZn ferrite tiles soldered on „soft“ copper

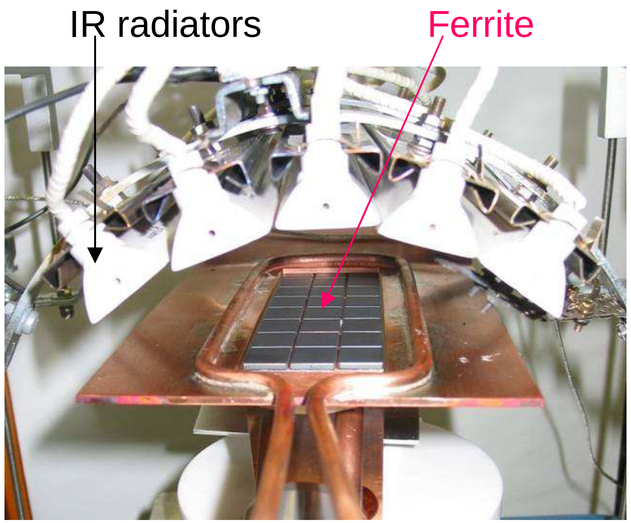
♦ Bonding layer: sputtering of Ti and Cu

♦ SnAg(0.1%) solder material, $T_{melt}$= 295 ℃

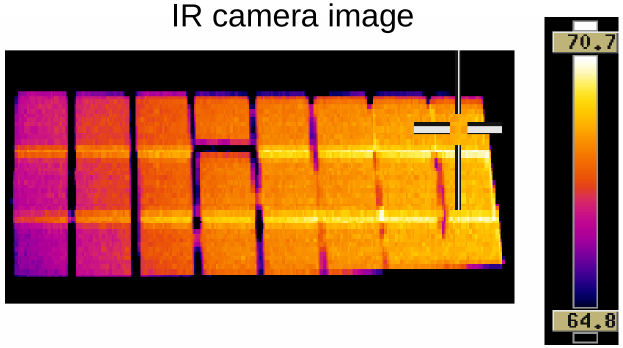
♦ Quality test of solder process:
Homogeniety of surface temperature

**RF power test:** $P_{rf}$ = 600 W @ 1.3 GHz

**IR Test:** Thermal power density up to 14 W/cm2 ,




IR camera image



$$P_{HOM} = (I_b / n_b)^2 (1/T_b) k_{//}(\sigma)$$

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# HOM Power Considerations

| | BESSY II | ELETTRA | ALBA | ALS | SLS | ANKA | NSRRC |
|---|---|---|---|---|---|---|---|
| σ [mm] | 4.8 | 5.4 | 4.6 | 9. | 4. | 9 | 7.5 |
| $k_{\|\|}$ [V/pC] | 0.7 | 0.64 | 0.72 | 0.5 | 0.8 | 0.5 | 0.52 |
| E [GeV] | 1.7 | 2. | 3. | 1.5 | 2.4 | 2.5 | 1.5 |
| h | 400 | 432 | 448 | 328 | 480 | 184 | 200 |
| Multi-bunch | | | | | | | |
| I-beam [mA] | 400 | 300 | 400 | 400 | 500 | 400 | 240 |
| n-bunch | 260 | 432 | 360 | 328 | 480 | 184 | 200 |
| Q-bunch [nC] | 1.23 | 0.6 | 1.0 | 0.8 | 1. | 0.8 | 0.24 |
| P-HOM [W] | 530 | 207 | 360 | 160 | 400 | 160 | 60 |
| Singel-bunch | | | | | | | |
| I-beam [mA] | 30 | - | | 2 x 20 | - | - | 25 |
| Q-bunch [nC] | 24 | - | | 2 x 6.6 | - | - | 10 |
| P-HOM [W] | 504 | - | | 66 | - | - | 66 |

$$P_{HOM} = Q_{bunch}^{\;2} (1/T_{bunch}) k_{//}(\sigma)$$

$$k_{//}(\sigma) = \sum_{n=1}^{\infty} \frac{\omega_n}{2} \left(\frac{R}{Q}\right)_n \exp(-\omega_n^2 \sigma^2)$$

Max HOM power per cavity: $P_{long}$ = 600 W
$P_{trans}$ = 600 W
$P_{total}$ = 1.2 kW

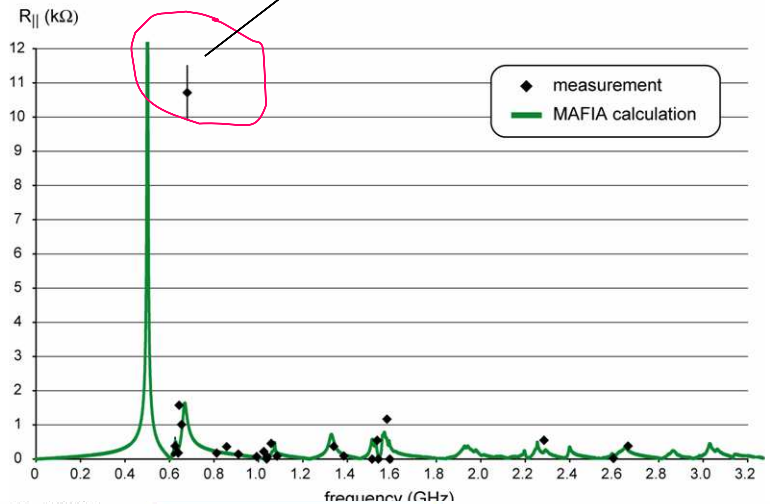
Test power density on ferrite: 14 W/cm$^2$

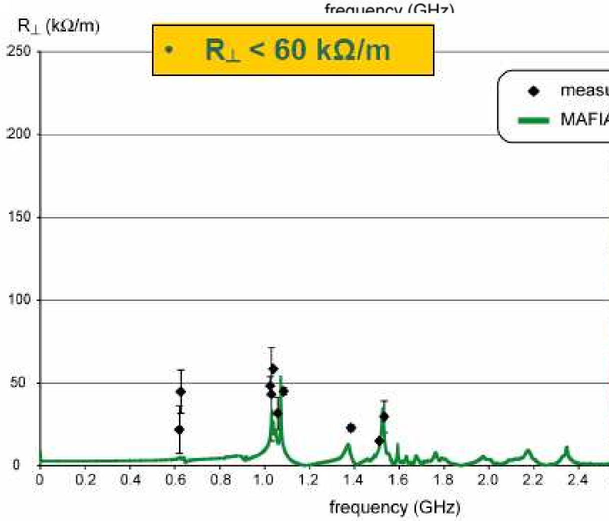
→ $P_{HOM}$ = 6.6 kW per cavity

# Cavity for the „Willy Wien“ Ring

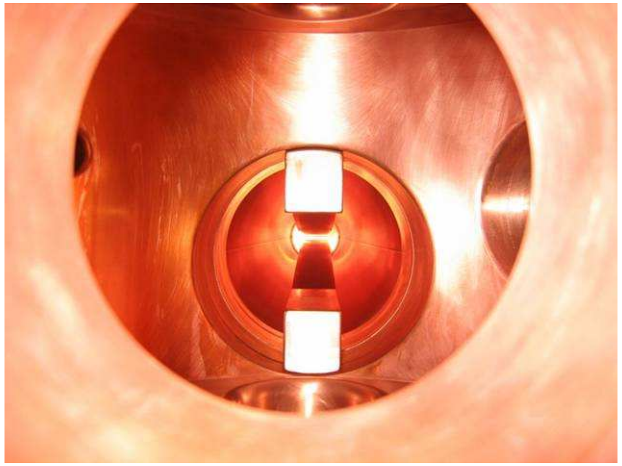
Bead pull measurements to verify reduction of long. HOM impedance (WG cutoff 625 MHz)

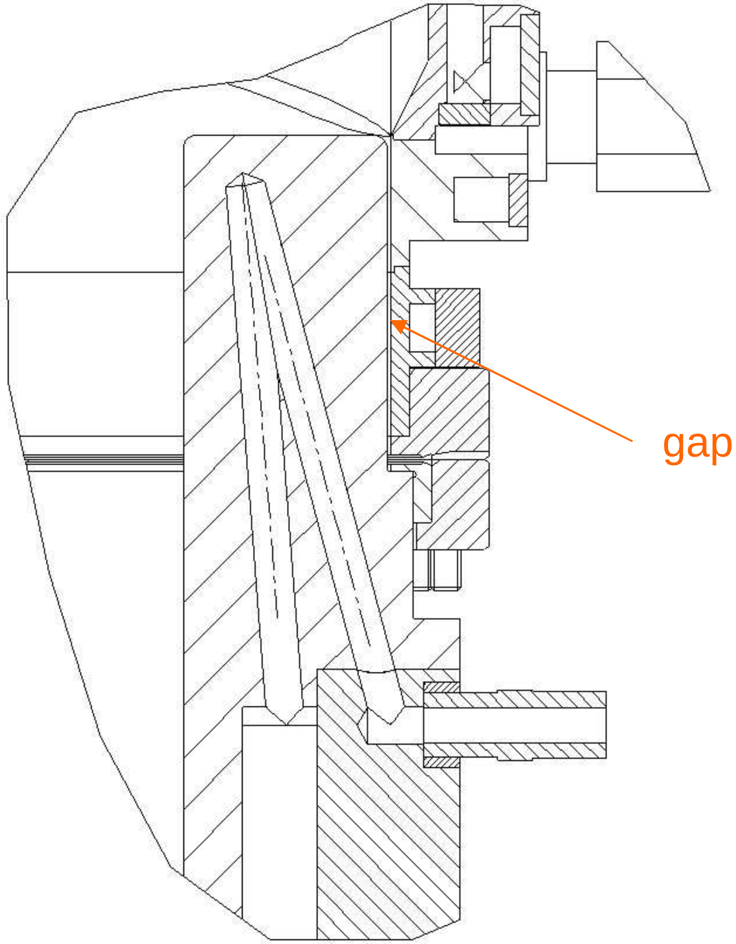
impedance not predicted by simulations (TM011)




# Gap between Ridge and Cavity Wall





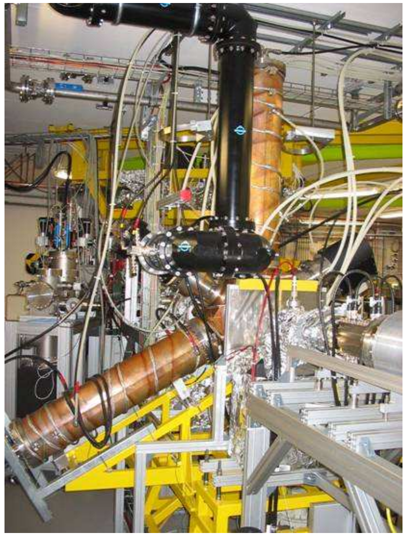

High TM011 impedance of 10.8 kOhm not confirmed by simulations

Measurements at CELLS with pre-series ALBA cavity with 615 MHz WG cut off frequency:

♦ TM011 impedance still 12 kOhm
♦ Closing the gaps provisionally gives 5 kOhm for TM011 impedance

→ high TM011 impedance is related with the gap

# „Willy Wien“ Cavity Commissioning



**Results of low power measurements**

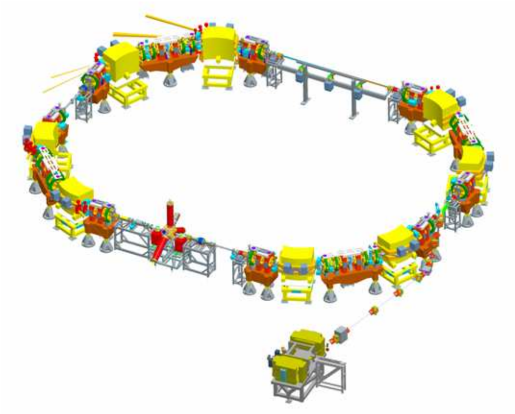
| | | |
|---|---|---|
| Resonance Frequency @ RT | 499.515 | MHz |
| Tuning Range | 2 | MHz |
| Shunt Impedance @ RT | 3.5 | MΩ |
| Unloaded Q | 29628 | |
| Max.Longitudinal HOM Impedance | ≤ 10.8 | kΩ |
| Max. Transverse HOM Impedance | ≤ 60 | kΩ/m |
| Waveguide cut-off | 625 | MHz |
| Coupling Factor for TM010 (adjustable) | 0-8 | |

**Commissioning at high power**

- After baking at 130 °C for 5 days: $p = 3\ 10^{-10}$ mb
- RF conditioning up to 45 kW in only 2 days: excellent quality of inner cavity surfaces with respect to roughness and contamination
- No serious multipacting levels

However:

- Vacuum poblem at 45 kW at the WG flanges due to non-homogenous temperature incresase in the ridge area

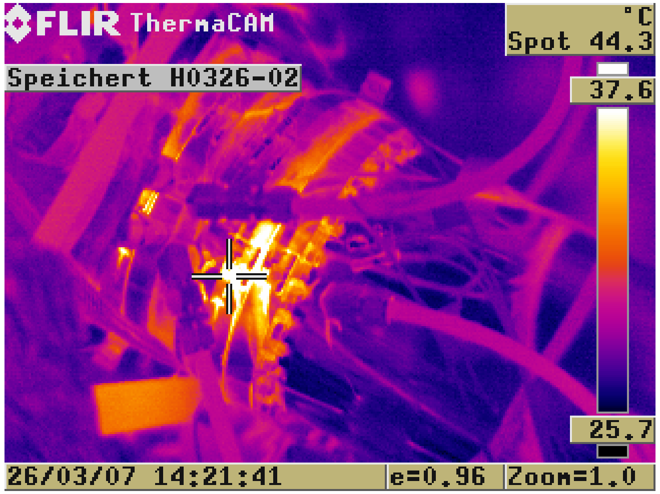


Status of Willy Wien Ring:

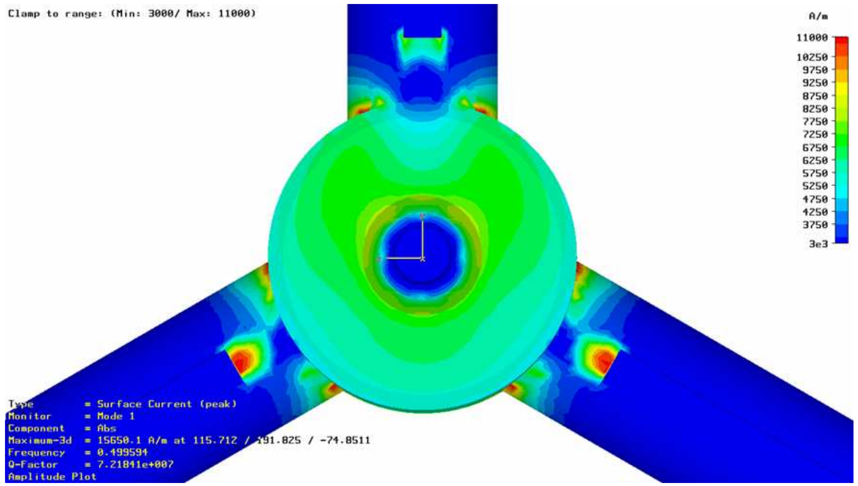
15 mA accumulated beam @10 MeV
2 mA ramped up to 600 MeV

# Problem: Heating of Flanges in the Gap Region

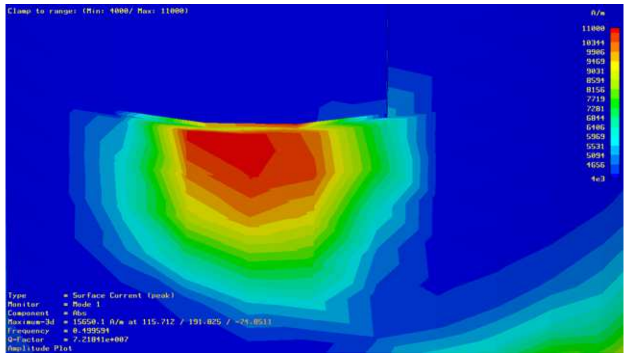
IR Image of Damping Waveguide




Magnetic field strength
MWS calculation




Max. power per gap region: 244 W



# Initial Thermal Design

ANSYS Calculations
( Daresbury Lab)

Max. power desity (@ 100 kW): 56 W/cm2

Max surface temperature rise: 42 °C

Max. van Mieses stress: 15 MPa

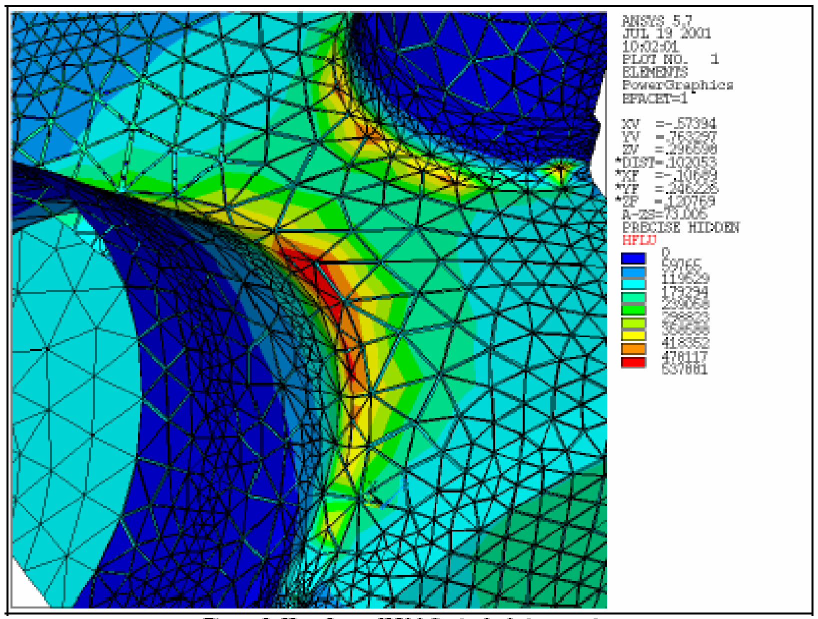



*Figure 5: Heat flux at HOM-Cavity body intersection*

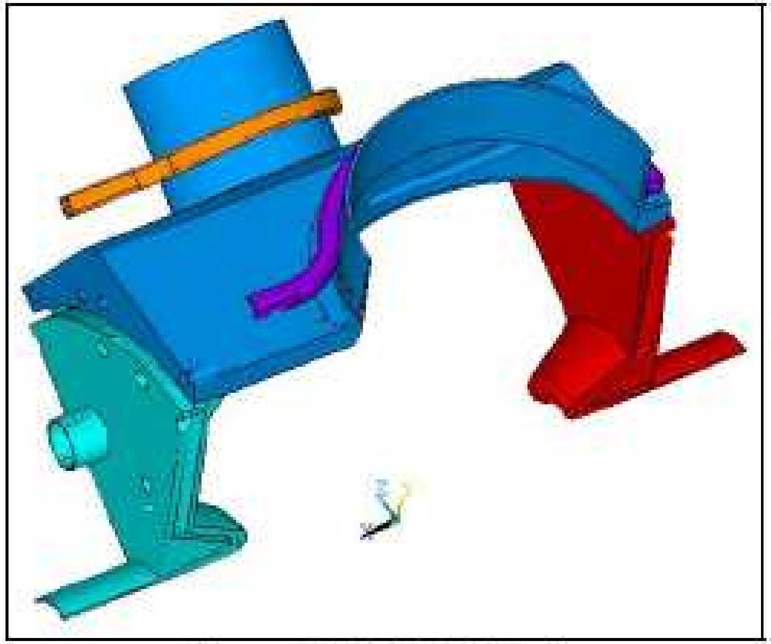
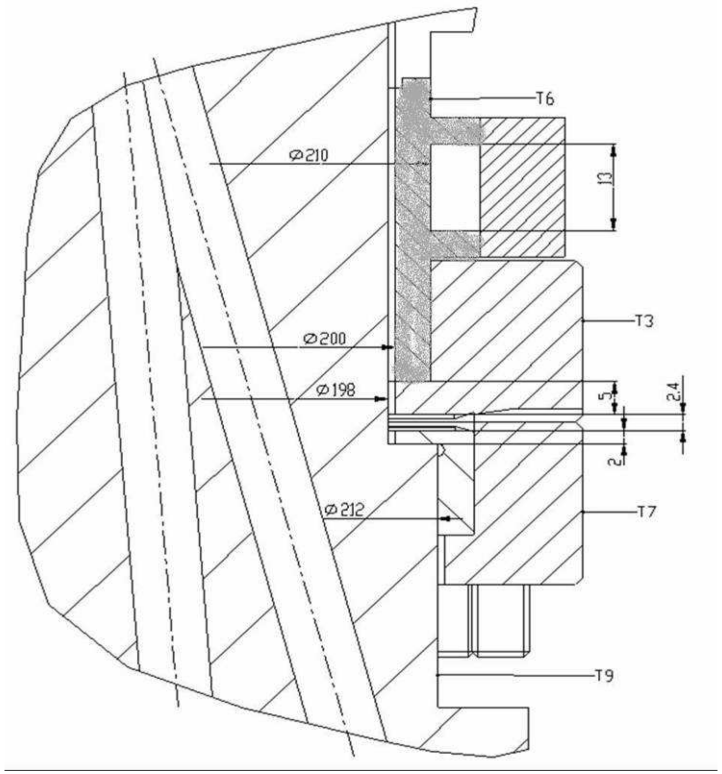


Figure 4: 1/6 Model of cavity

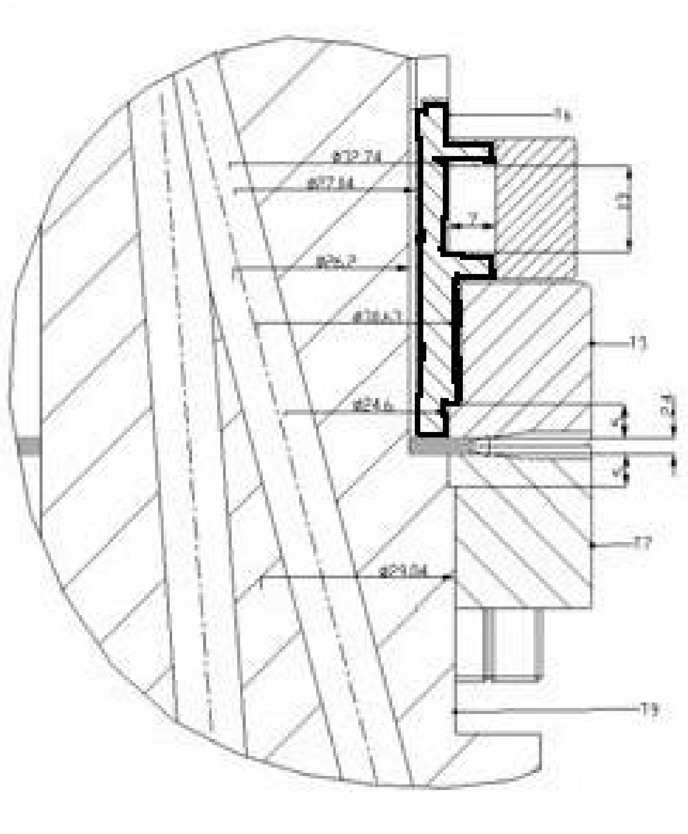
Analysis of fields and power density in the area of the gap was impossible due to lack of resolution (and cpu time)

# Cut through Flanges in the Gap Region

**Old geometry, rotatable flange**

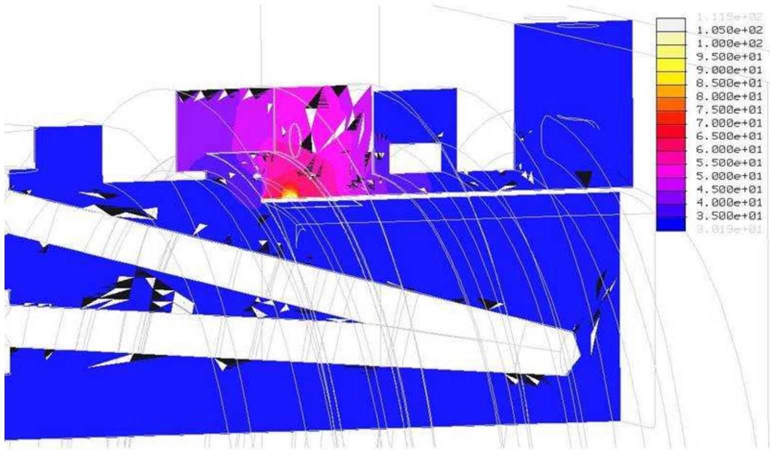


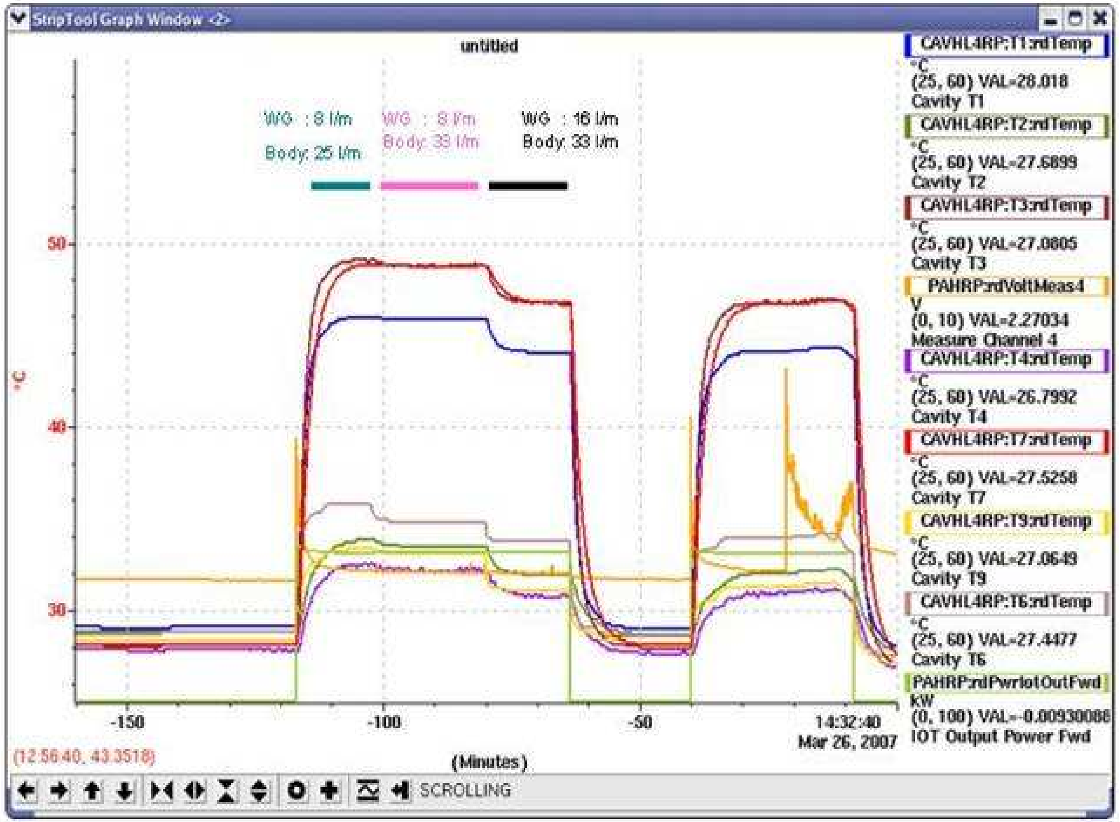

**New geometry, fixed flange**



# Thermal Simulation and Measurement

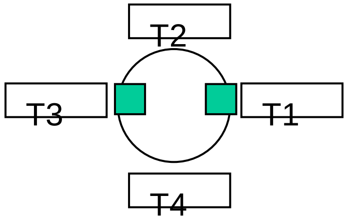
P-cavity: 25 kW
P-local: 210 W
P-gasket: 80 W
Heat transf.
Coefficient: 5000 W/(m2 ℃)



# Simulation and Measurement Results

| | Measure-ment Old geometry @ 25 kW | Simulation Old geometry | Simulation New geometry | Simulation New geometry scaled to 56 kW | Measure-ment Old geometry @ 40 kW | Simulation New geometry Scaled to 80 kW |
|---|---|---|---|---|---|---|
| P-ridge (W) | | 210 | 210 | 470 | | 672 |
| P-gasket (W) | | 80 | 80 | 180 | | 256 |
| Flange at body: T3 (°C) | 50.5 | 50.6 | 41.2 | 54.9 | 59.5 | 66 |
| Cu at body: T6 (°C) | 37. | 32.5 | 32. | 34.9 | 39 | 37 |
| Cu at WG: T9 (°C) | 34.3 | 33.1 | 33.5 | 38. | 33 | 41.4 |
| Flange at WG: T7 (°C) | 51. | 44 | 37.2 | 46.5 | 60 | 53.6 |
| T-max inside | | 111 | 50 | 75.4 | | 94.9 |
| T2 (°C) | 34. | 34 | 32 | 36.1 | 34 | 38.7 |
| T4 (°C) | 32. | 33 | 32 | 34.5 | 32.5 | 36.4 |
| T3/T4 | 1.58 | 1.53 | 1.29 | 1.59 | 1.83 | 1.81 |

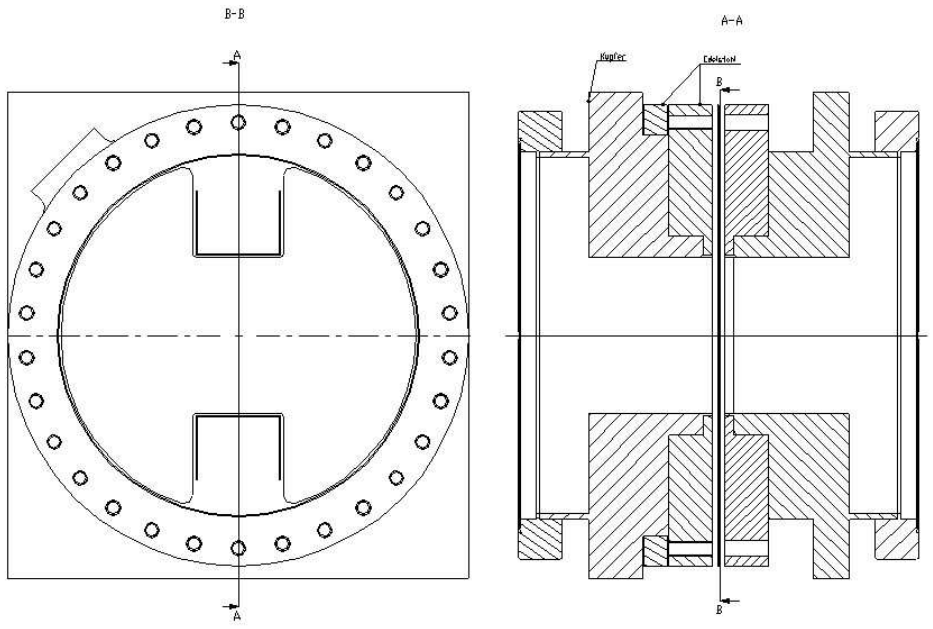


# First Ideas to Avoid the Gap

Gap seems to limit performance in two respects: i) TM011 impedance

ii) Power capability

→ is there a possible engineering solution to avoid the gap?



# Conclusions and Outlook

♦ With homogenous ferrite loaded damping waveguides the max. transverse HOM impedance could be lowerd by a factor of 4 down to 50 kOhm as expected. A similar reduction of the max. longitudinal HOM impedance, however, could not be realised. The impedance of the TM011 mode is 10.8 kOhm.

♦ The fundamental mode shuntimpedance improved from 3.1 to 3.5 MOhm thanks to increased waveguide length and higher cutoff frequency (615 →625 MHz)

♦ Cavity operated in the Willy Wien ring routinely at 40 kW thermal power (V-rf = 530 kV). Power limit given by inhomogenous heating of waveguide flanges. Upper limit will be determined soon at CELLS with the ALBA pre-series cavity.

♦ Modifications of the cooling design in the ridge area of the cavity ports promise increase of thermal power capability to at least 80 kW (V-rf = 748 kV) based on thermal simulations

♦ Both limitations –- TM011 impedance of 10.8 kOhm and inhomogenous heating of waveguide flanges -- are related with the gap between the ridge and the cavity port inner wall. Ongoing R&D effort to avoid the gap and thus reduce TM011 impedance to about 4 kOhm and increase power capability up to 100 kW (V-rf = 836 kV)

♦ Thanks to the RF groups at CELLS and at ESRF for the cooperative and efficient collaboration in analysing the problems resulting from the gap.