The BESSY Higher Order Mode Damped Cavity
- Further Improvements -

Ernst Weihreter

- ♦ Reminder of Technical Problems
- ♦ Solutions
- ♦ Conclusions

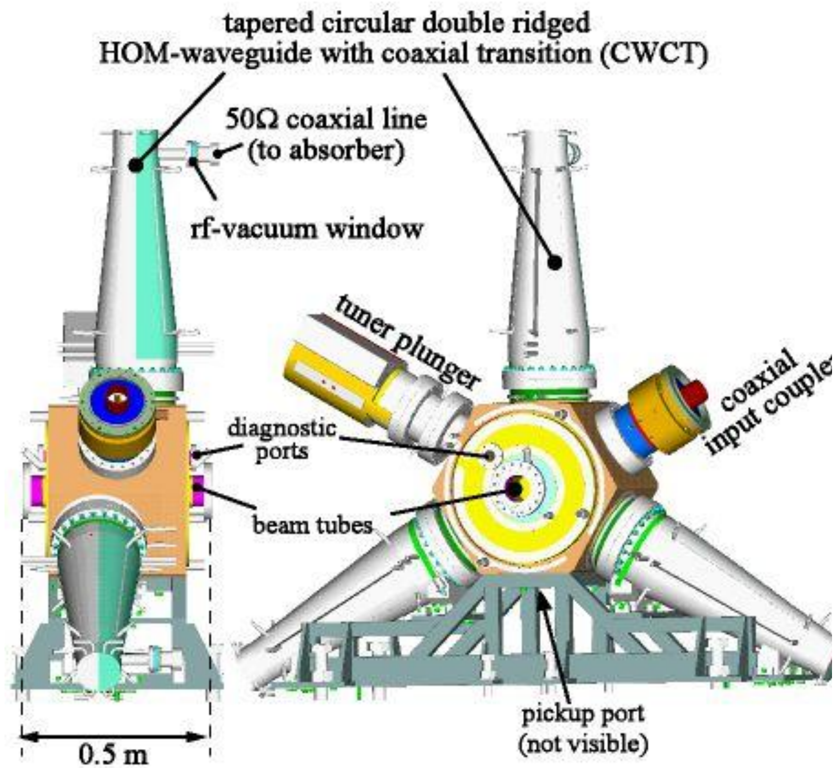
HELMHOLTZ
ZENTRUM BERLIN
für Materialien und Energie

BESSY HOM Damped Cavity

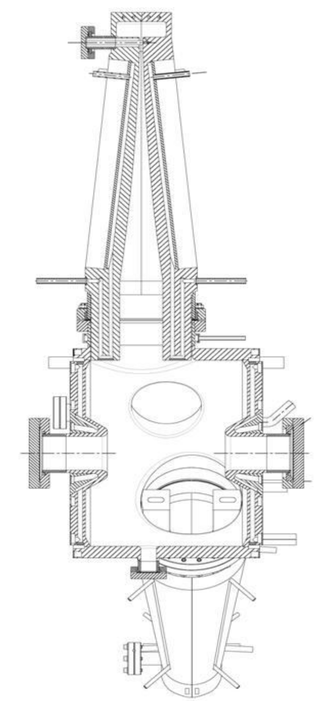
Project collaboration: **- BESSY / Germany**
(EC funded) **- Daresbury Lab / England**
- DELTA / Dortmund University, Germany
- National Tsing Hua University / Taiwan

Design Goals

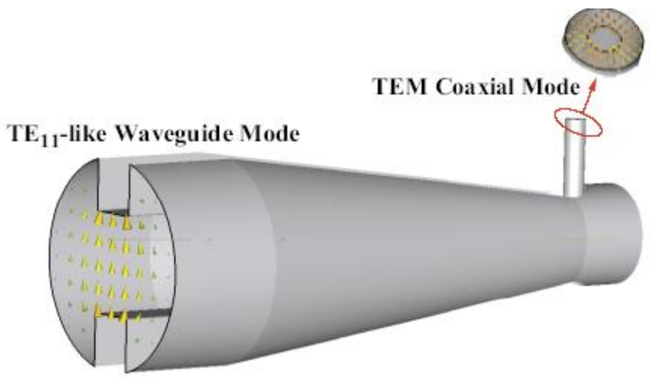
- **Frequency**
  f_{rf} = 500 MHz
- **Insertion length**
  L < 1 m
- **Shunt impedance**
  R ≈ 3 - 4 MΩ
- **Max. thermal power**
  P = 100 kW
- **Design to fit into**
  <u>existing</u> ring tunnels



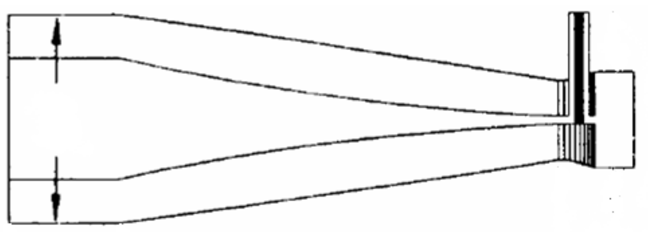
f-cutoff = 615 MHz

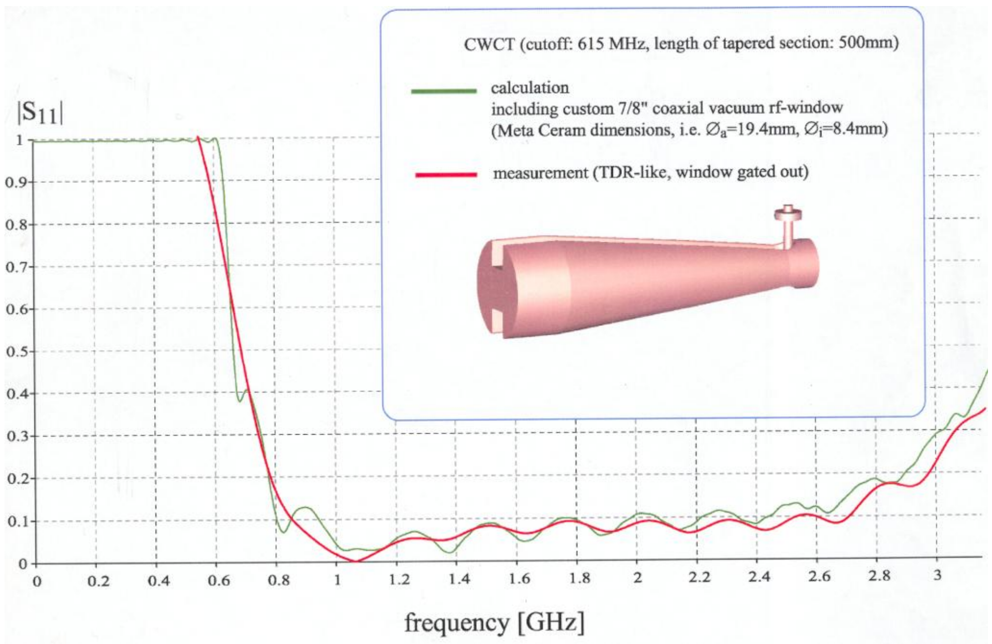


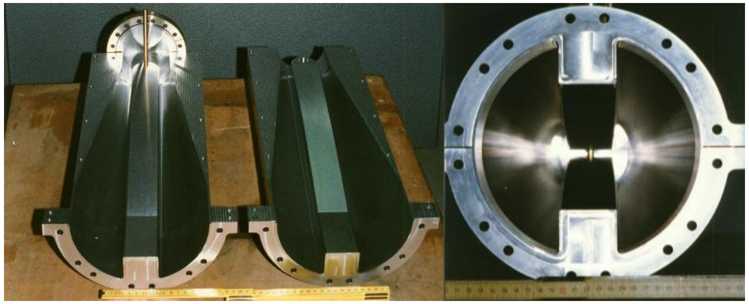
Tapered Circular WG to Coaxial Transition



Coaxial 7/8“ EIA ceramic vacuum window with commercial 50 Ohm load, 3 kW







low power model

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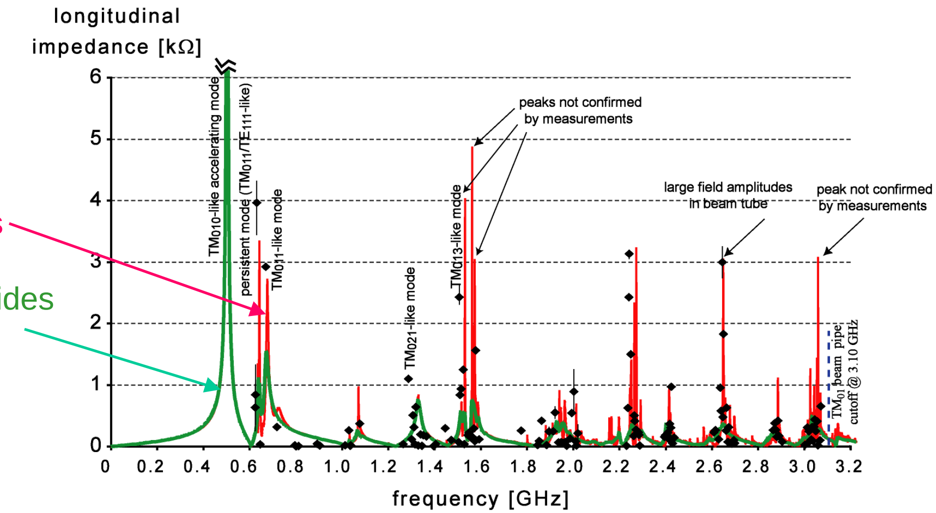
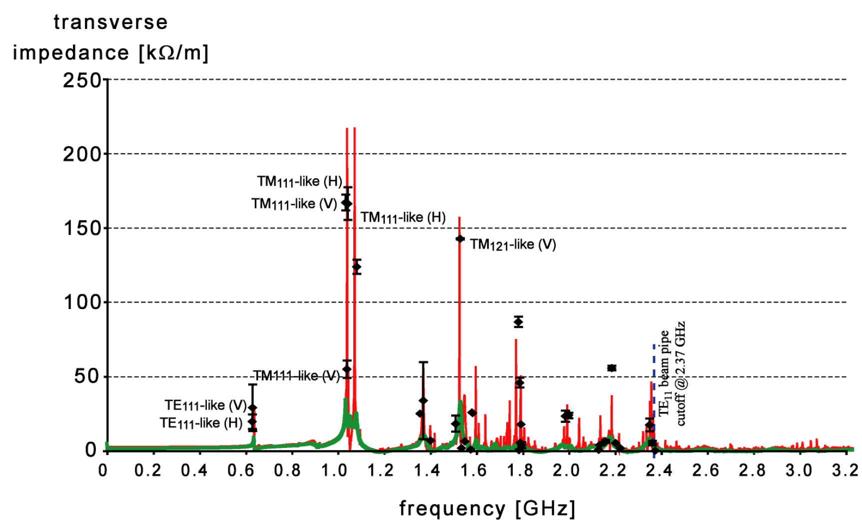
Prototype cavity:
Bead pull measurements

Tapered waveguides

Homogenious waveguides with S11 = 0 boundary





Prototype fabricated by ZANON SpA / Italy

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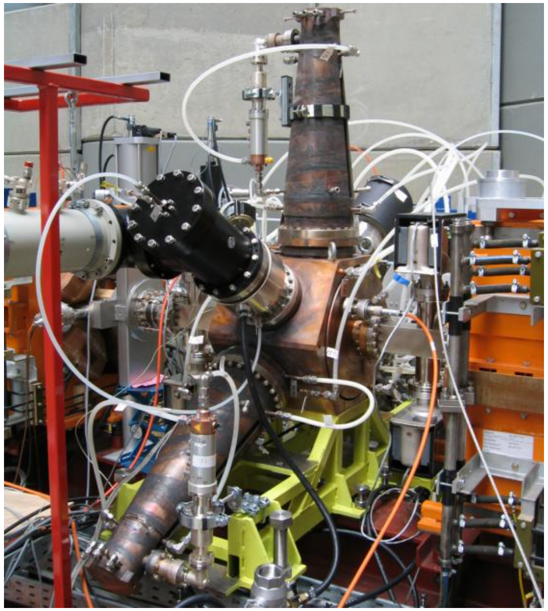
CBM beam spectra: (longitudinal case)

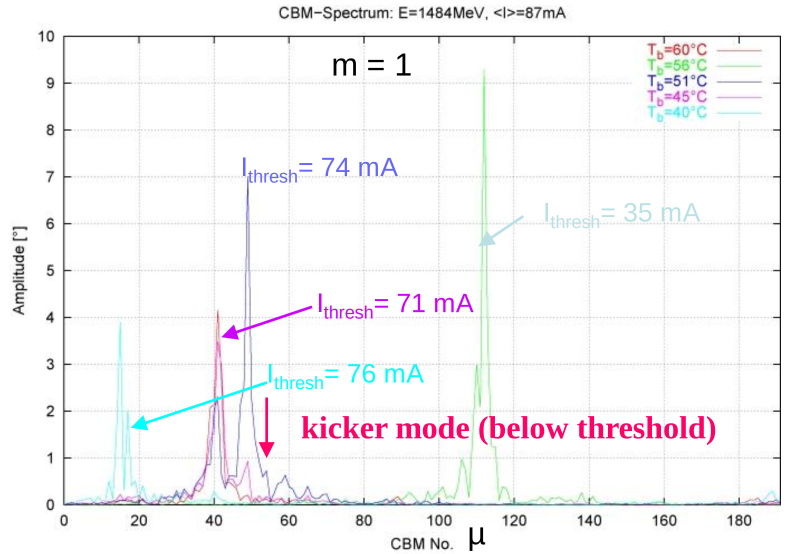
$$f_{\mu m}^{\pm} = nf_{rf} \pm (\mu f_0 + mf_s)$$

μ coupled bunch mode number

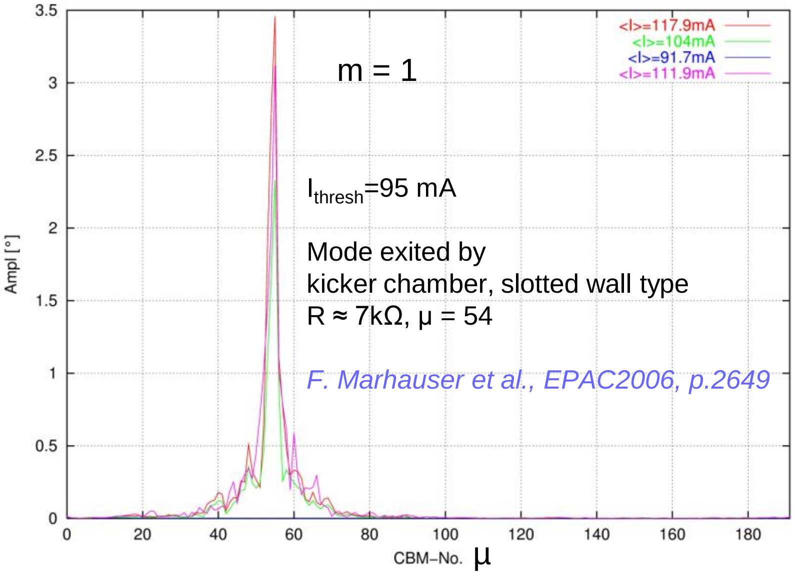
Prototype cavity installed in the DELTA ring / Dortmund University



DORIS Cavity



BESSY HOM Damped Cavity

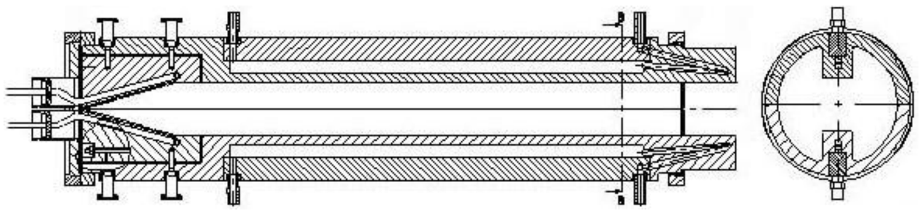


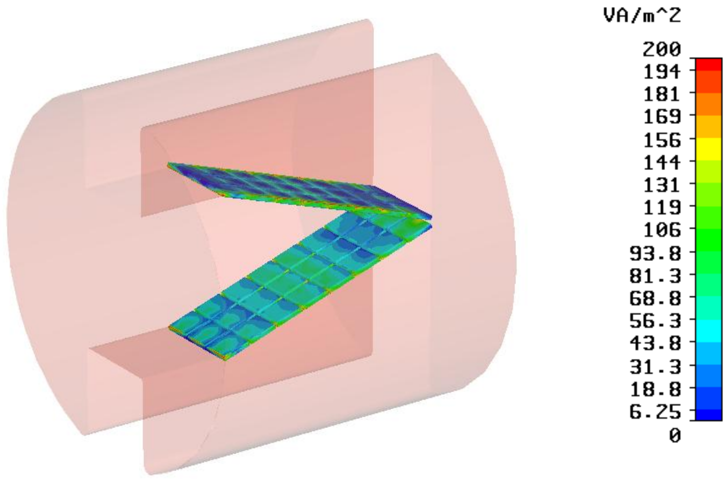
No cavity driven CBMs excited in DELTA

R. Heine et al., EPAC2006, p.2856

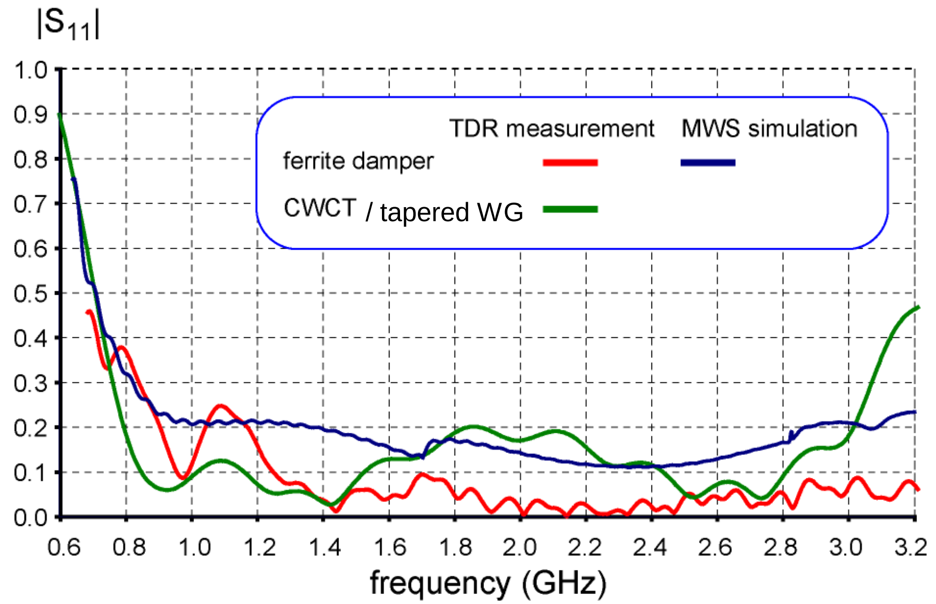
Homogenous Damping Waveguide Design

- constant cross-section
- wedge shaped ferrite absorber





Simulations and
time domain reflectrometry measurement

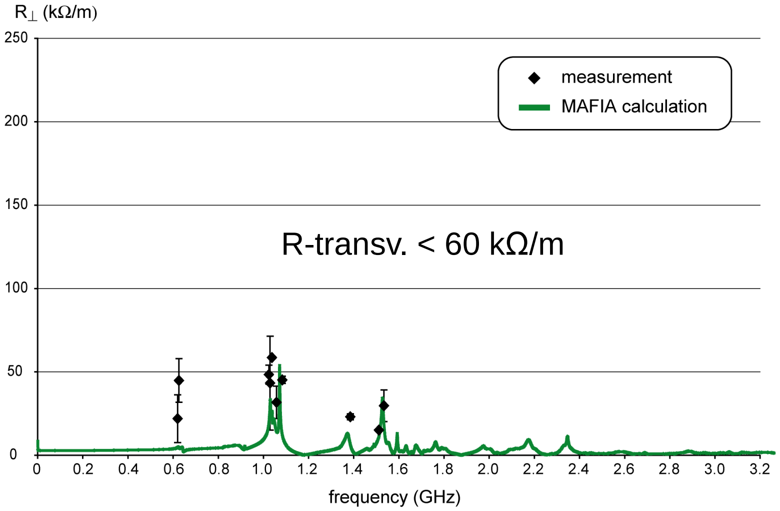


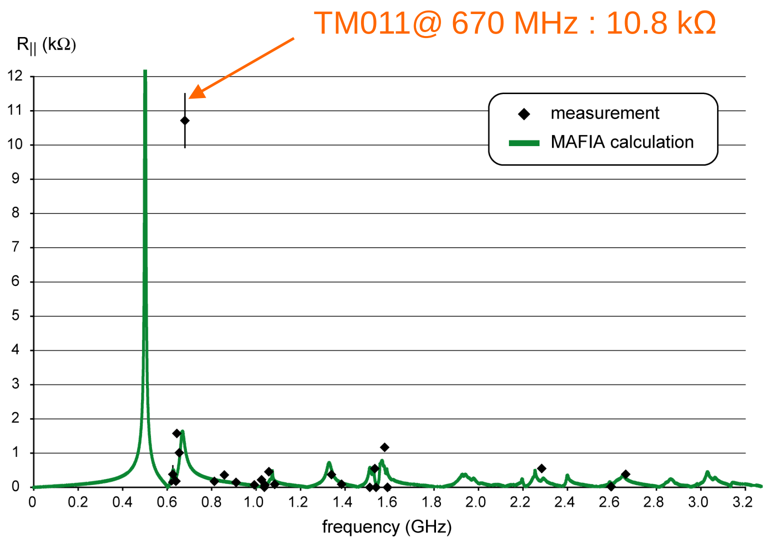
→ good matching, r < 20%

Metrology Light Source Cavity

- ♦ Cavity with homogenous ferrite loaded WG built by ACCEL (f-cutoff = 625 MHz, 30% less fundamental mode power absorbed in the ferrites)

- ♦ Bead pull measurements to verify the expected HOM impedances





- ♦ TM011 impedance of 10.8 kΩ not confirmed by simulations (MWS/CELLS, GdfidL/ESRF)

- ♦ Decision at CELLS to use the cavity for ALBA
  →Attempt to reduce TM011 impedance by a change of cut-off from 625 MHz to 615 MHz

Gap between Ridge and Cavity Wall

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

♦ TM011 impedance still ~ 12 kOhm

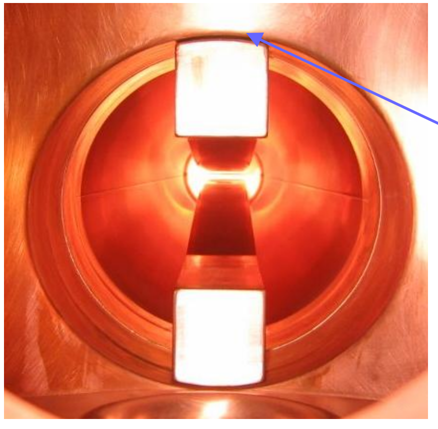
♦ Attempt to get more insight:
Closing the gaps provisionally by rf-springs reduces TM011 impedance to 5 kOhm

→ high TM011 impedance is related with the gap

→ M. Langlois et al.

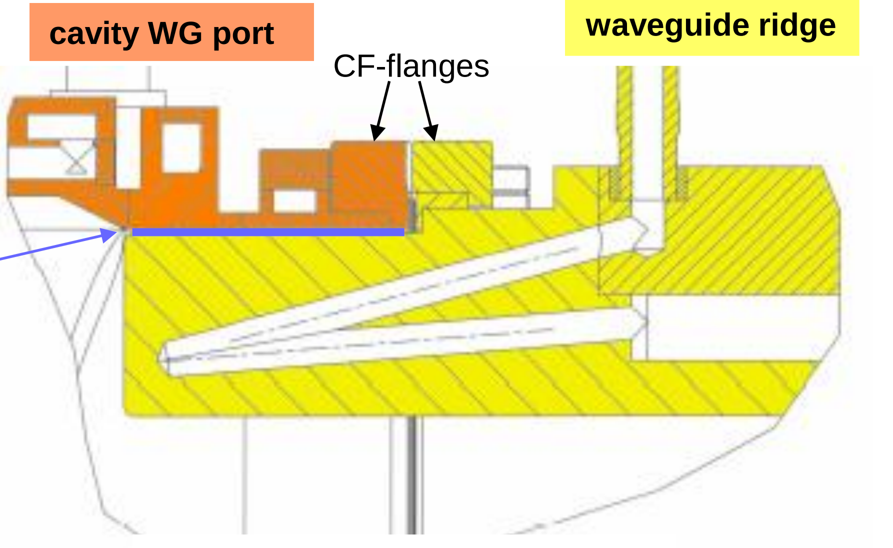
♦ Gap size 1mm, comparable with minimum mesh size of numerical model

→ simulations fail to provide quantitative explanation



View along the WG axis

gap
1 mm



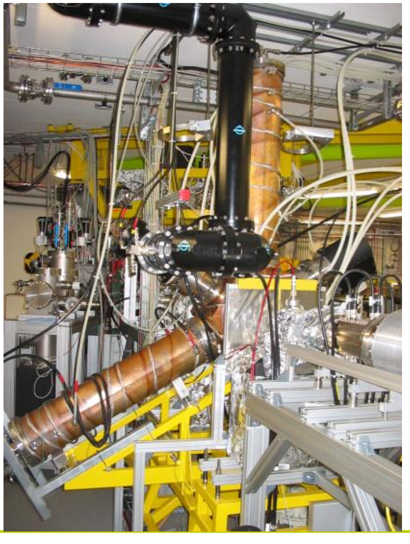
Cut through the cavity / WG flanges

Metrology Light Source Cavity Commissioning

Results of low power measurements

Resonance Frequency	499.515	MHz
Tuning Range	2	MHz
Shunt Impedance @ RT	3.4	MΩ
Max. Long. HOM Impedance	10.8	kΩ
Max. Transv. HOM Impedance	60	kΩ/m
Waveguide cut-off	625	MHz
Coupling Factor for TM010 (ad	0.5 - 8	

Installation in the MLS ring



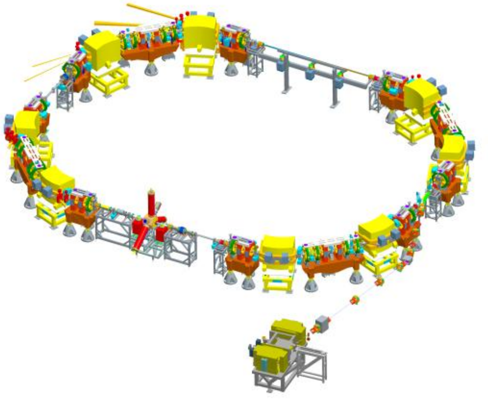
RF conditioning at high power

- After baking at 130 °C for 5 days: → base pressure 3 10 $^{-10}$ mb
- RF conditioning up to 40 kW cw in only 2 days: → good quality of inner cavity surfaces with respect to roughness and contamination
- No serious multipacting levels

Beam commissioning

- 200 mA accumulated at 100 MeV, 175 mA accelerated to 630 MeV
- Preliminary studies indicate: no cavity driven longitudinal and transverse MBO

→ *J. Feikes et al., EPAC 2008*



- However: Vacuum problem at 45 kW at the WG flanges related with a temperature incresase in the ridge area

→ Operation power limit so far: 40 kW

Power Limitation: Heating of Flange in the Gap Region

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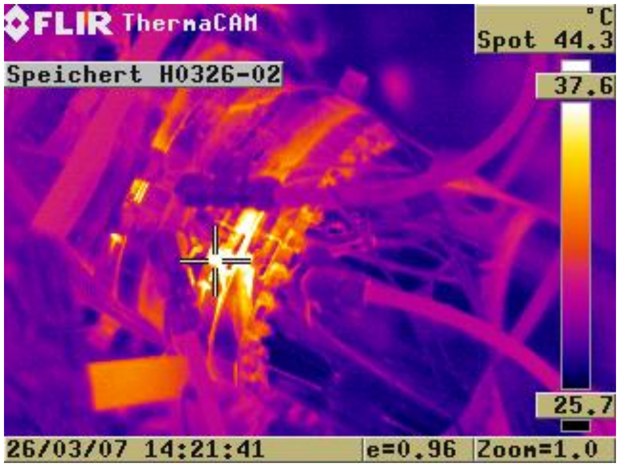
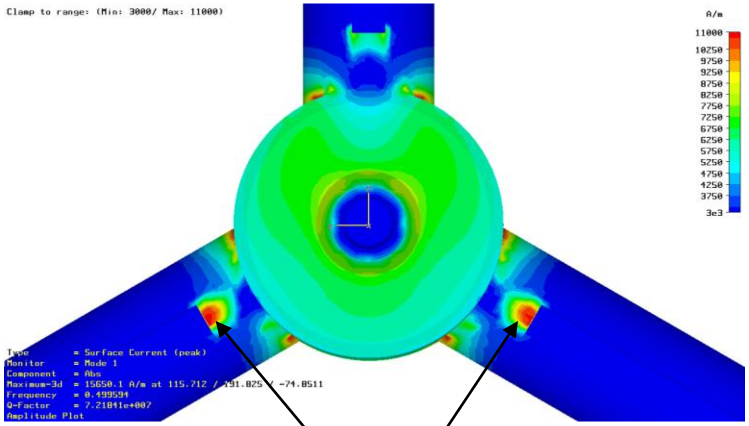
IR image of flange region



Measurement of temperature distribution on flange circumference: ΔT-max = 28°C @ 40 kW.
Max. differential axial deformation: 0.03 mm

→ CF-flange deforms due to non-homogenous temperature distribution, causing the vacuum problem

Magnetic rf field (MWS) calculation (CELLS) on inner cavity surfaces ~ sqrt (power density)

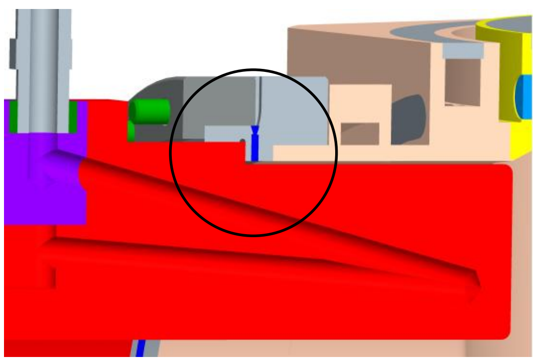


High power density in gap region

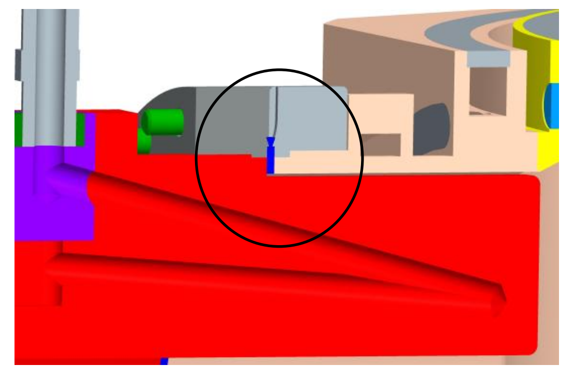
Gaps have not been included in the initial numerical model calculations because of mesh size limitations

Power in gap region:
340 W

ΔT-max on cavity CF-flange: 28 °C @ 40 kW
T-max (hot spot): 160 °C



ΔT-max on cavity CF-flange: 14 °C @ 40 kW
T-max (hot spot): 62 °C



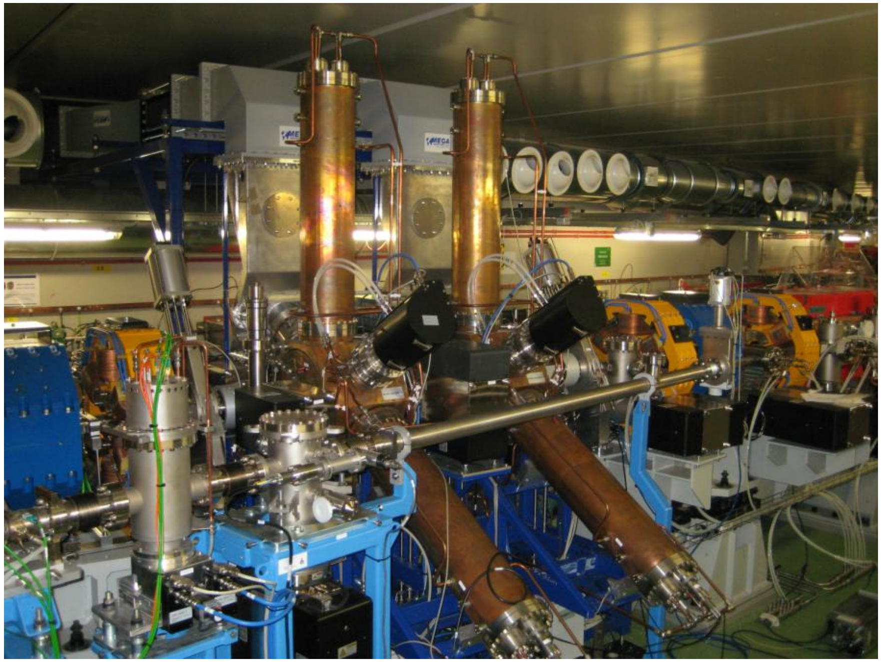
Scaling to 80 kW power: ΔT-max on cavity CF-flange: 28°C
T-max (hot spot): 95 °C

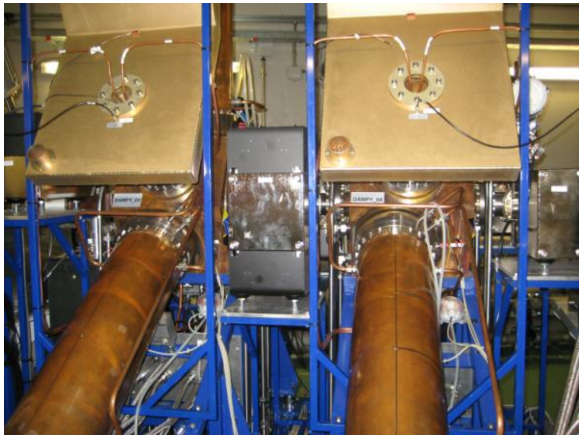
→ safe operation up to at least 80 kW rf power is expected
→ modification implemented in the series cavities for CELLS and for BESSY II, power tests at CELLS in fall 2008

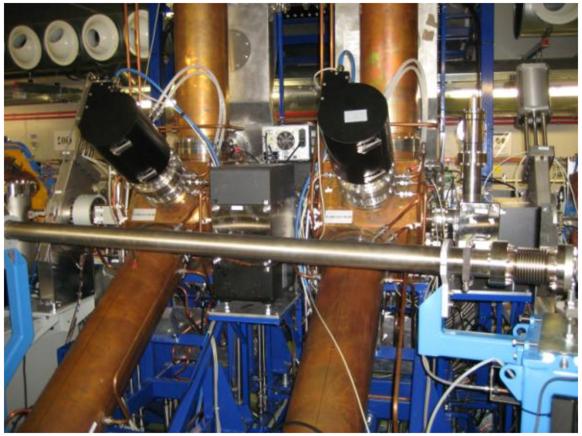
HOM Damped Cavities at CELLS

6 cavities installed in the ALBA ring at CELLS/Spain in 2010

- All cavities tested successfully up to P_{th} = 80 kW
- Beam test will start end of 2010
- Scaling the measured temperatures → $P_{max} \approx 100$ kW



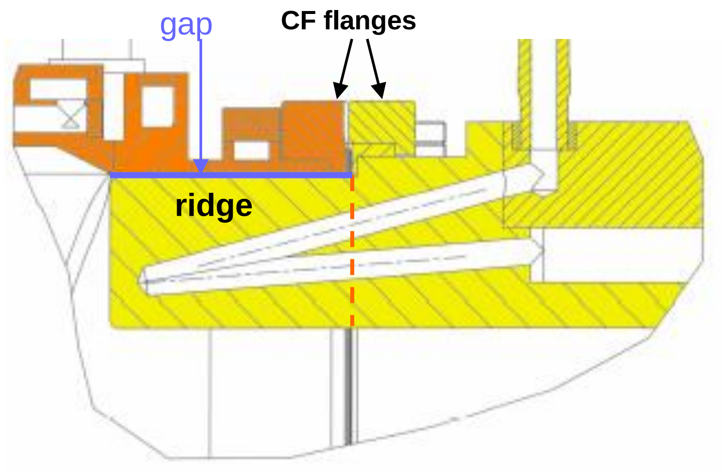




Can We Avoid the Gap?

♦ Gap causes both problems
- high TM011 impedance
- local heating in gap region

♦ But allows simple engineering solution to connect waveguide and cavity body

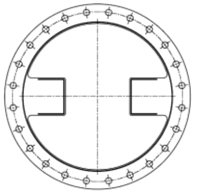


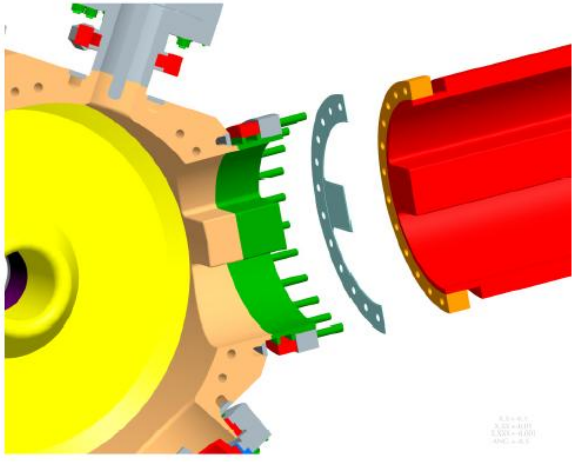
♦ Gap cannot be avoided by shortening the ridge
→ degradation of HOM damping efficiency

Concept how the gap could be avoided

♦ machining of the WG ridge as part of the cavity body

♦ special gasket following inner contour of the WG (e.g. VAT-seal technology)





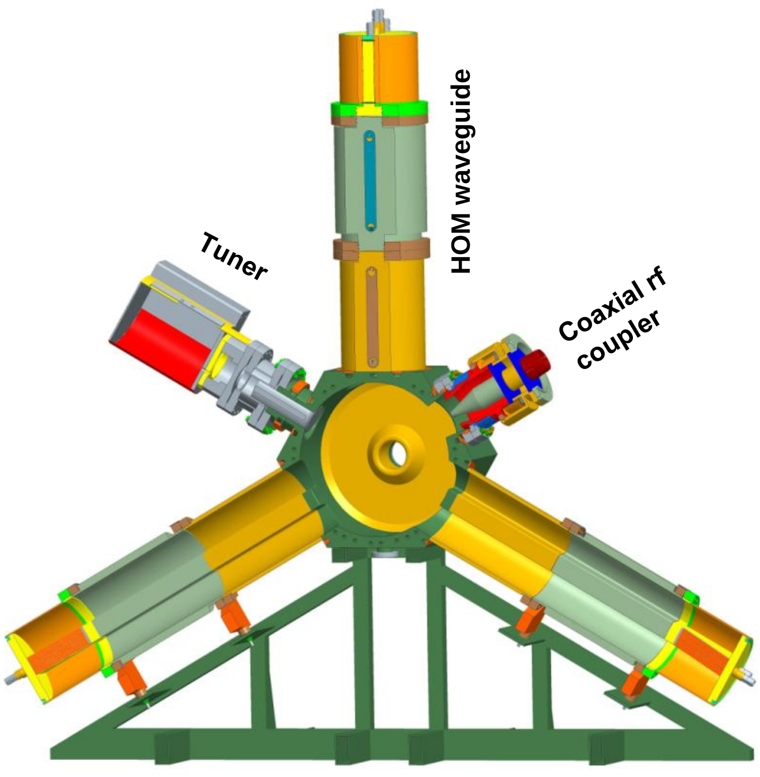
♦ higher complexity and cost
→ option to extend thermal power capability beyond 80 kW

Yes We Can !

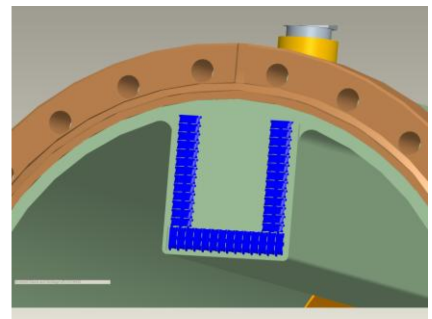
BESSY HOM Damped Cavity without Gap

Reduction of WG length by 15 cm after measurements at CELLS
Fabrication: Modular approach
Manufacturing of WG sections: EDMing
Cavity body / 1. WG section connection: brazing in one step
Connection between WG sections: CF-flange + rf joint for ridge

Potential: ♦ 100 kW thermal power capability
♦ Maximum HOM impedances
Z-long. ≈ 2kOhm, Z-transv. ≈ 50 kOhm/m

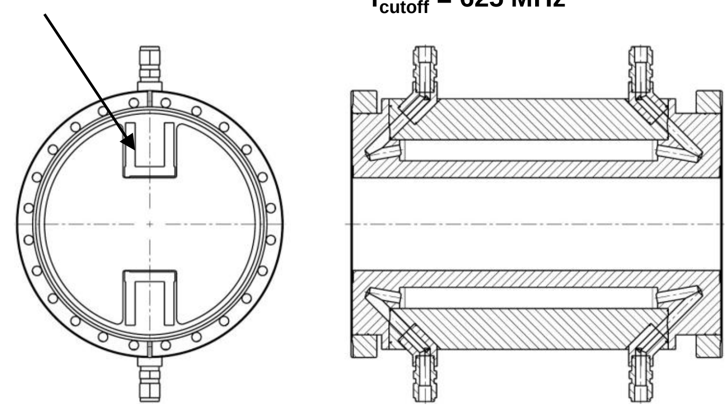


Ferrite rf absorber



rf joint

Double ridged HOM waveguide
f_{cutoff} = 625 MHz



Impedance Spectra and Threshold Impedances

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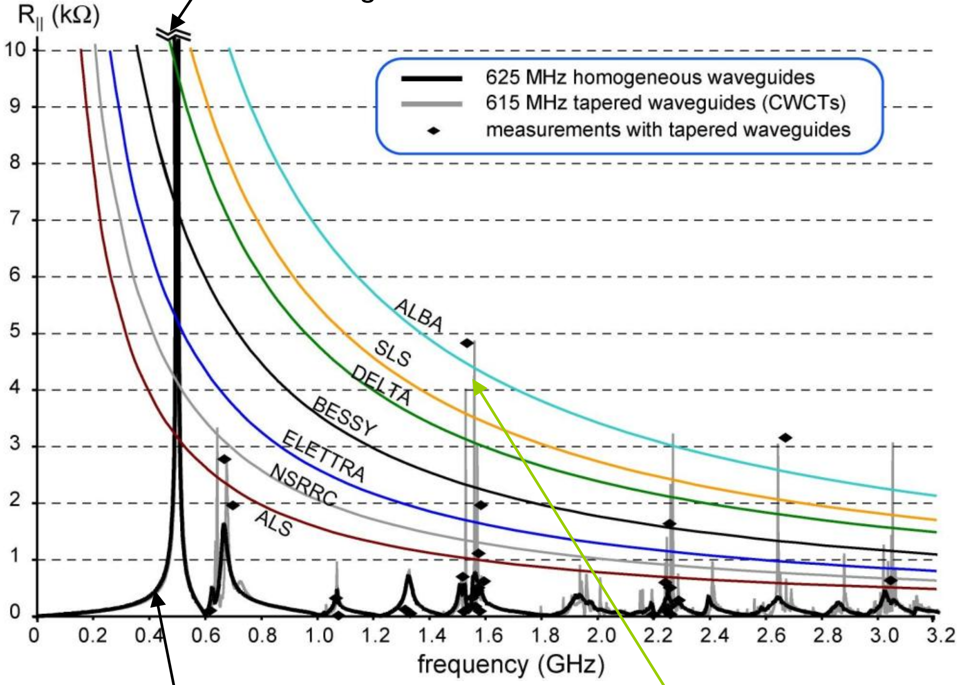
Longitudinal Impedance

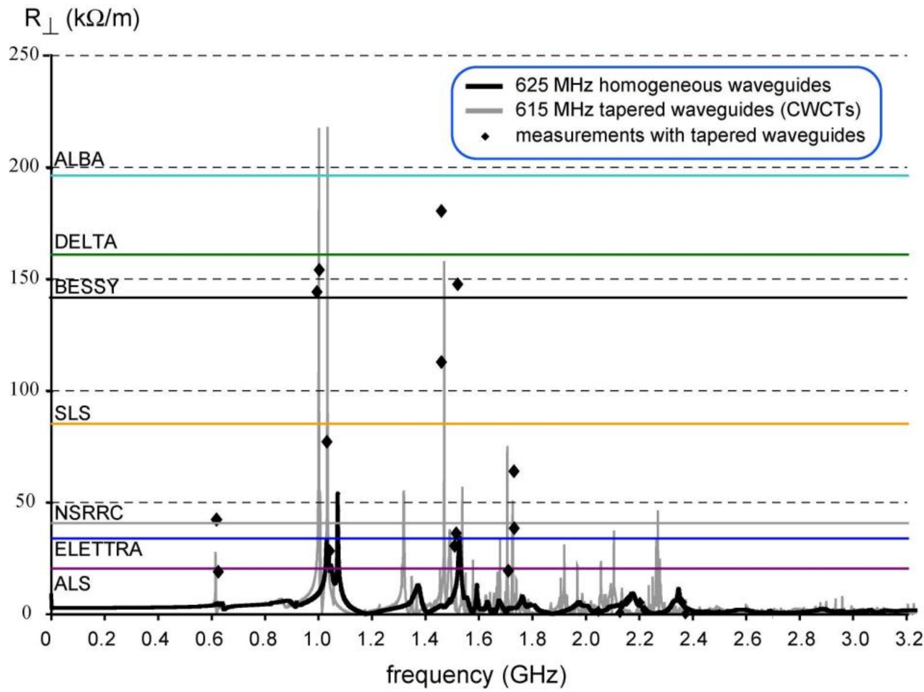
$$Z_{||}^{thresh.} = \frac{1}{N_C} \cdot \frac{1}{f_{||,HOM}} \cdot \frac{2 \cdot E_0 \cdot Q_s}{I_b \alpha \tau_s}$$

Transverse Impedance

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

accelerating mode





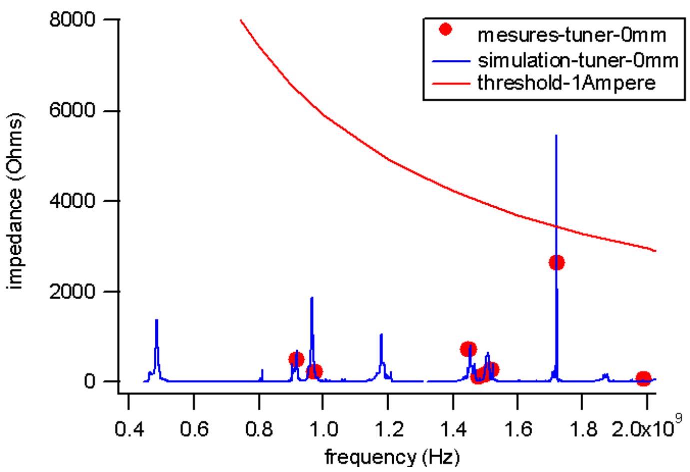
homogenous waveguides

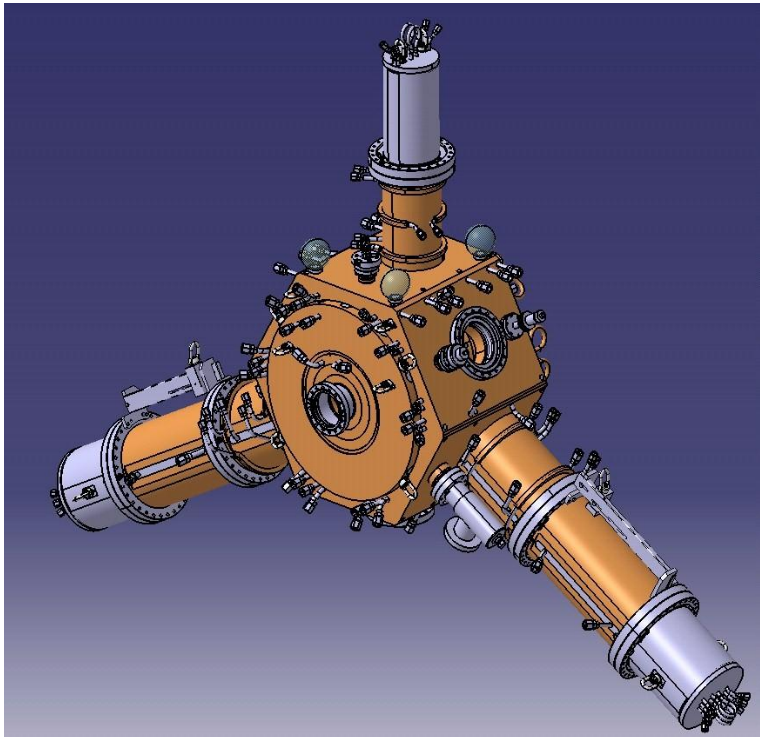
tapered waveguides

J. Jacob / ESRF

- **18 new single cell HOM damped cavities (352 MHz)**
- **18 x 150 kW Solid State Amplifiers for the Storage Ring**
- **4 x 150 kW Solid State Amplifiers for the Booster**

R&D based on BESSY design with ferrite loaded ridge waveguides for selective HOM damping





3 prototype cavities are under construction using different fabrication technologies

Summary

♦ The BESSY HOM damped cavity has demonstrated so far
- max. transverse impedance < 60 kΩ/m
- max. long. Impedance < 11 kΩ
- fundamental mode shuntimpedance ~ 3.4 MΩ
- demonstrated operation up to 80 kW (730 kV) at CELLS, expected safe operation up to 100 kW (820 kV)

♦ The cavity is in routine operation in the MLS ring, six cavities have been tested up to 80 kW and will start soon operation with beam at CELLS / Spain

♦ Engineering design to avoid the gap is finished. A first cavity is in the ordering process and four cavities will be installed in BESSY II in the (hopefully not so far) future.

♦ With the „no gap“ modification the HOM impedances can conceptually be reduced down to a level where most existing synchrotron light sources can operate below threshold for multi-bunch instabilities providing an accelerating voltage of 820 kV (@ 100 kW) per cavity

Many thanks go to
→ the cavity collaboration: Daresbury Lab, Nat. Tsing Hua University, DELTA, BESSY
→ the CELLS rf group F. Perez, P. Sanches, M. Langlois (now at ESRF), et al.
→ the ESRF rf group N. Guillotin (now at SOLEIL), J. Jacob, V. Serriere, et al.

for their excellent collaboration