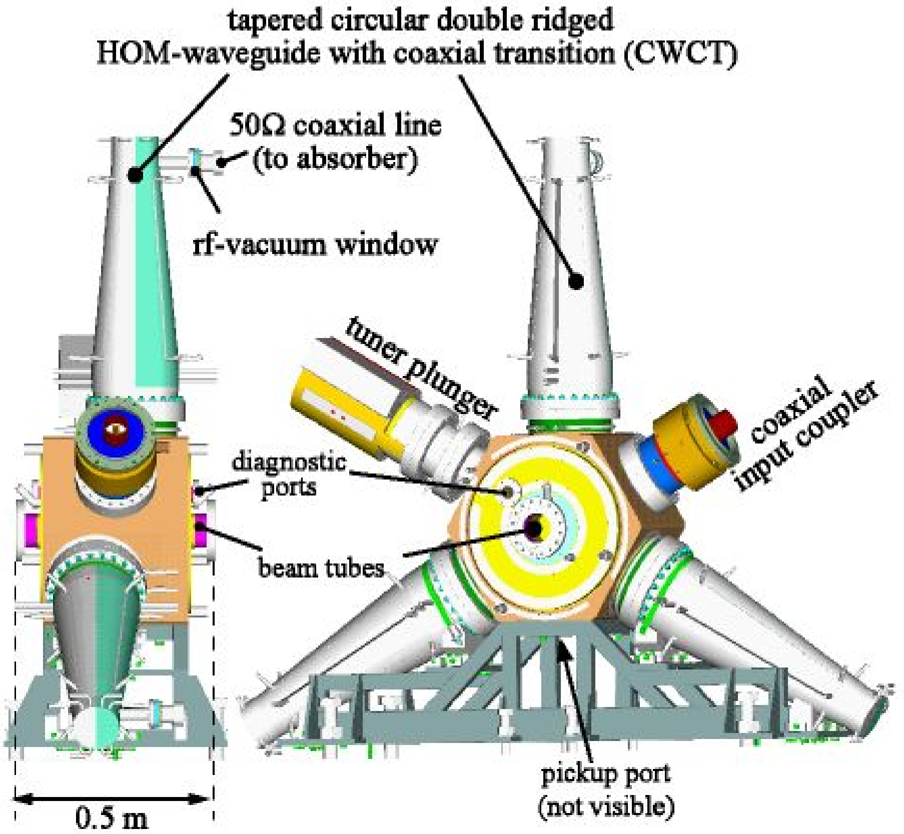
The BESSY HOM Damped Cavity with Ferrite Absorbers

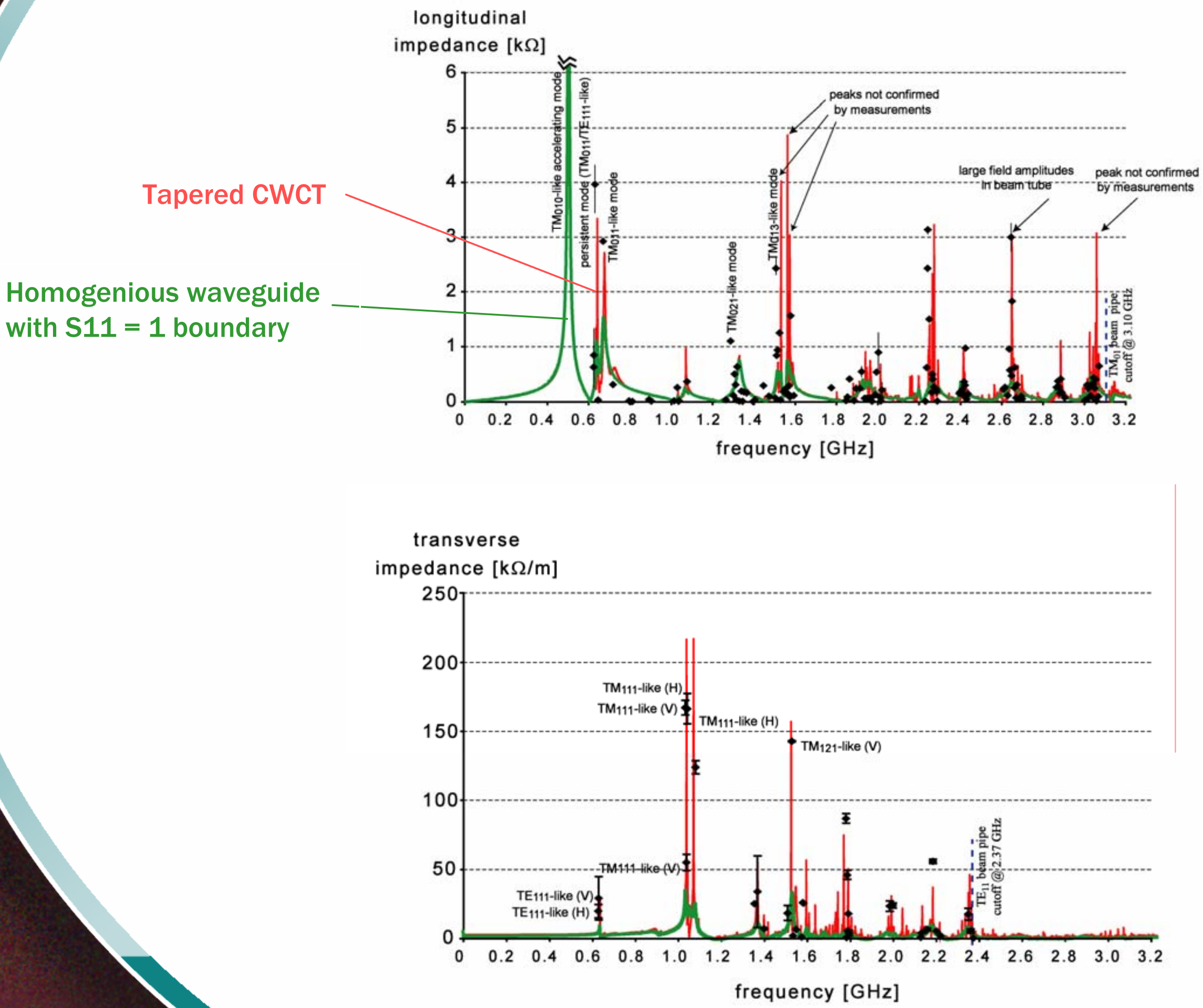
E. Weihreter / BESSY

- Review of prototype cavity test results, tapered waveguides vs homogenous waveguides
- Design of a ferrite loaded ridged circular waveguide
- Mechanical and manufacturing considerations
- Test procedure for ferrite absorber elements

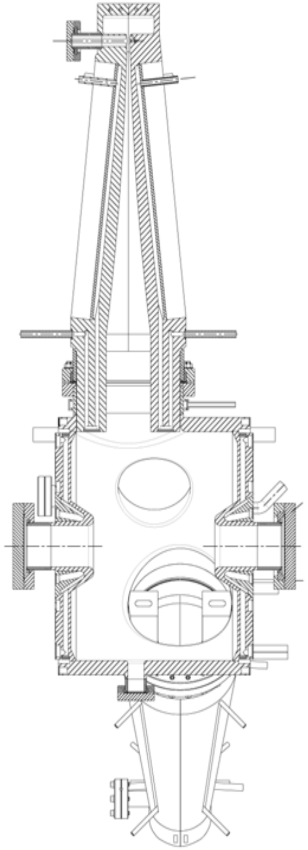
Cavity Concept

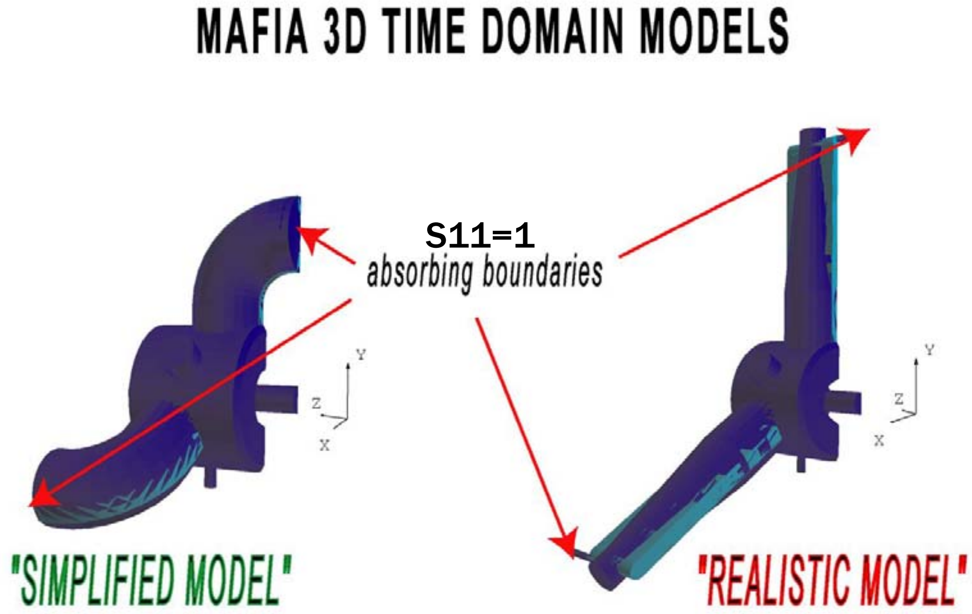


Simulations and Impedance Measurement Results



Simulation Models

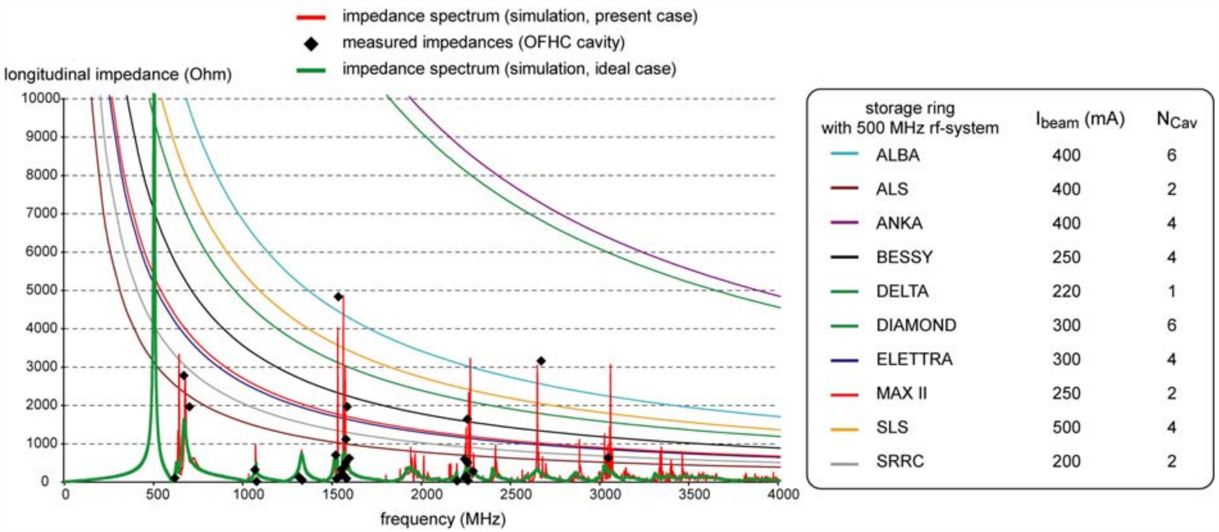




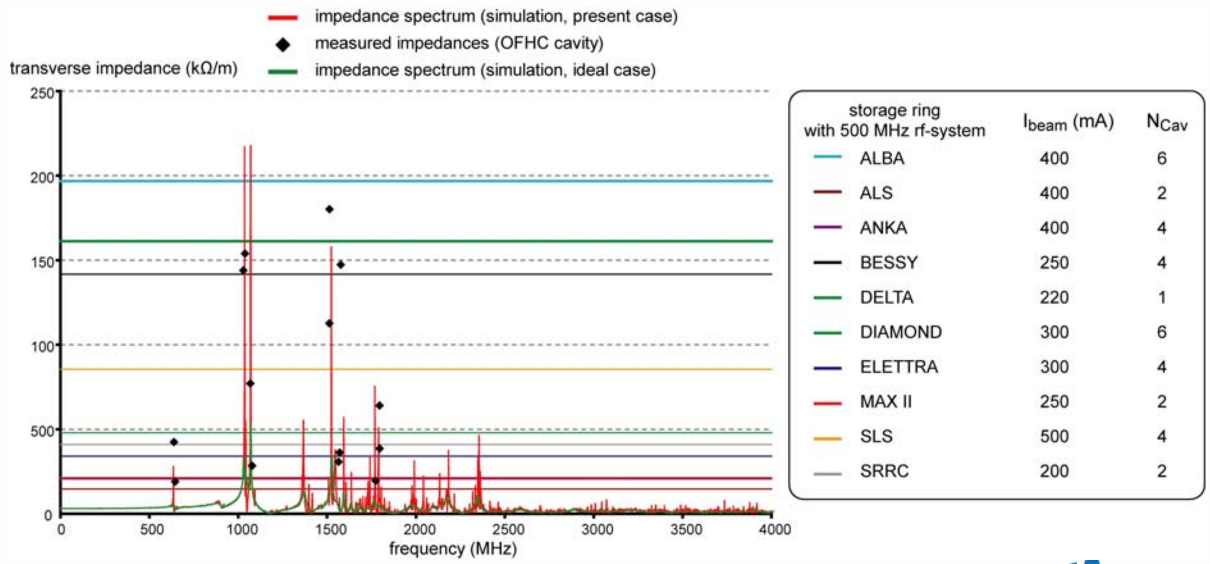
~ 10^6 mesh points	~18* 10^6 mesh points
2-3 days cpu time	6-7 weeks cpu time
(in 2002)	(in 2002)

Threshold Impedances for Different Facilities

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



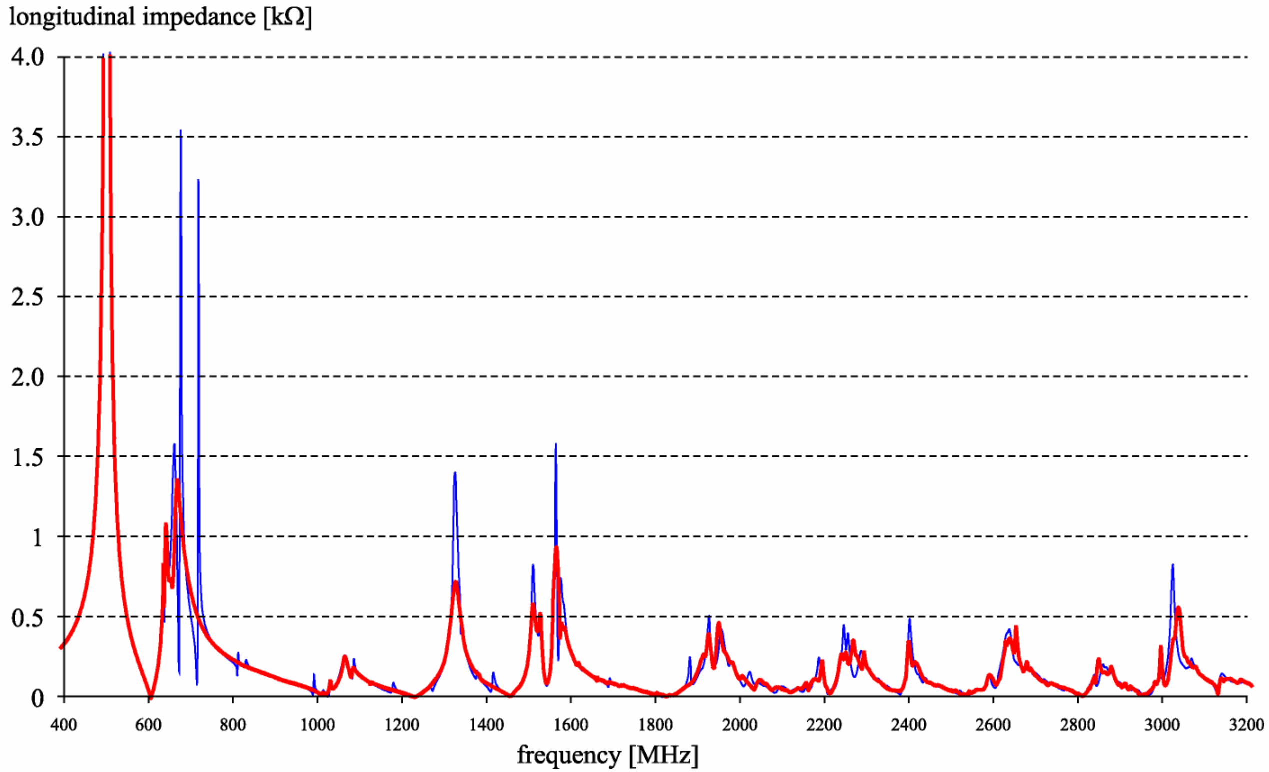
$$Z_{x,y}^{thresh} = \frac{1}{N_C}\cdot\frac{2\cdot E_0}{f_{rev}\,I_b\,\beta_{x,y}\,\tau_{x,y}}$$



Influence of Wave Guide Tapering on HOM Spectrum

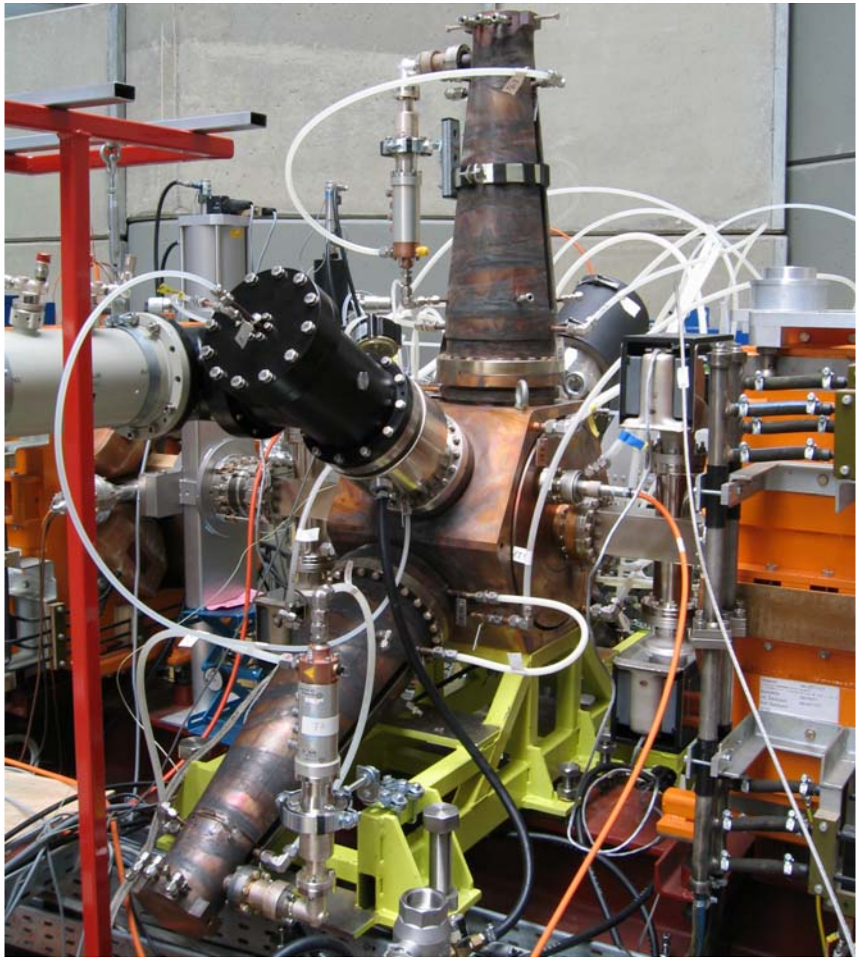
EU cavity + 3 homogeneous double ridged waveguides (2 bended, 1 straight, 650MHz cutoff)
200m wake (HOMs resolved)

EU cavity + 1 tapered double ridged waveguide + 2 homogeneous double ridged waveguides (650MHz cutoff)
200m wake (some HOMs may be not fully resolved)



Prototype cavity installed in the DELTA Ring

Cavity is in routine user operation in the DELTA ring

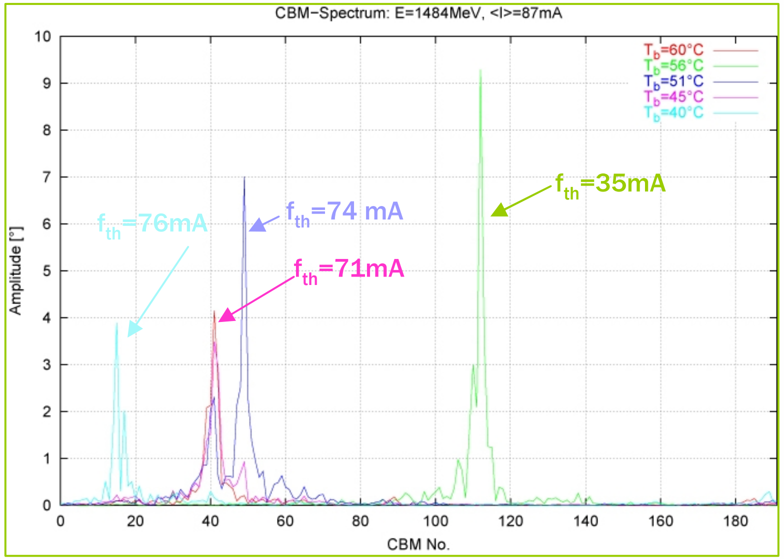


First Beam Observations at DELTA @ 1480 MeV

<u>CBM beam spectra</u>

$f_{n,\mu} = (\mu * M + n + m * Q_s) f_0$

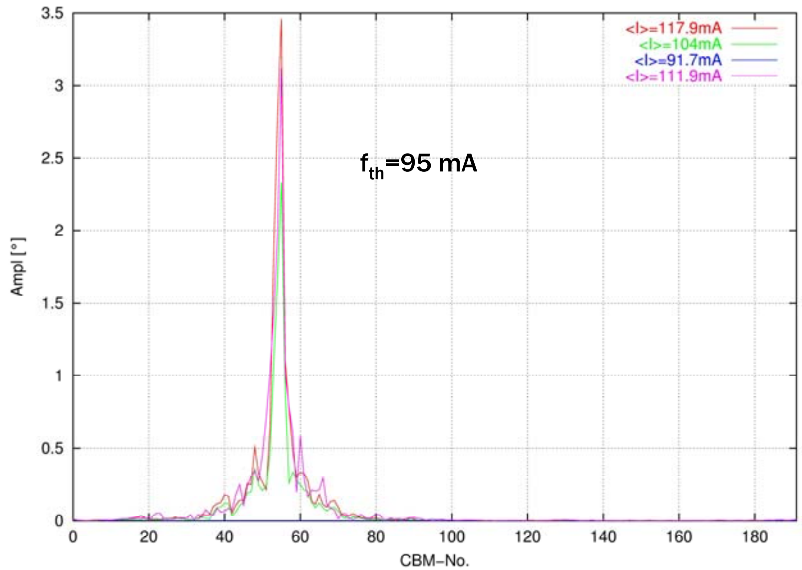
DORIS Cavity:



HOM Damped Cavity:

CBM 55 is not driven
by the cavity !!

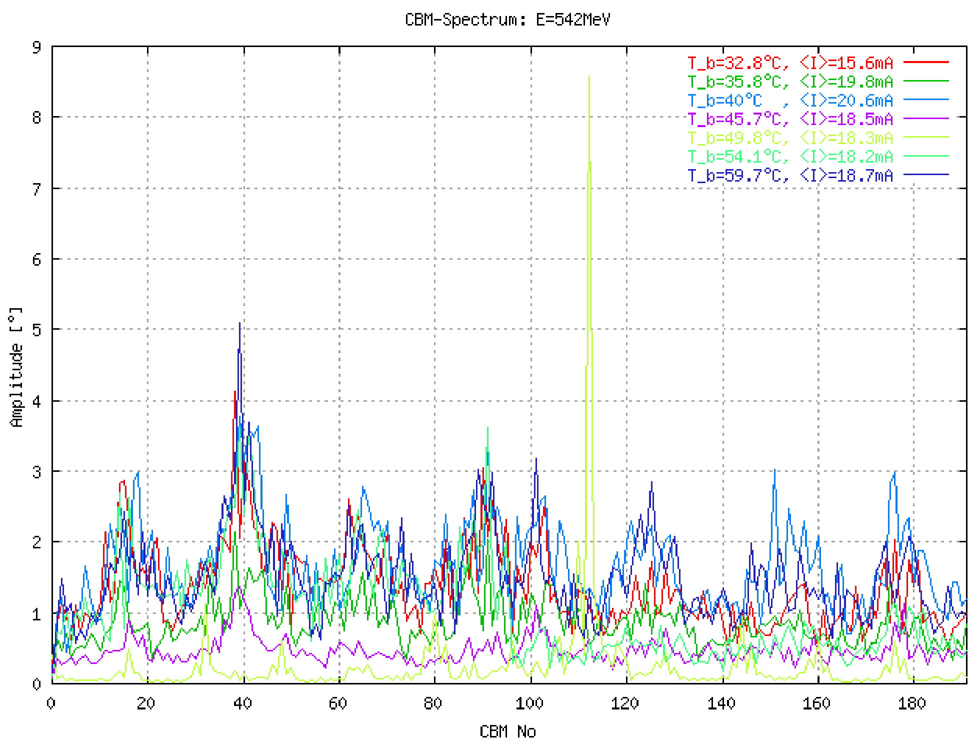
Most probable culprit: injection kickers
Long. impedances in the range of
several 10 kOhm (from simulations)!!



Planed Beam tests at DELTA @ 500 MeV

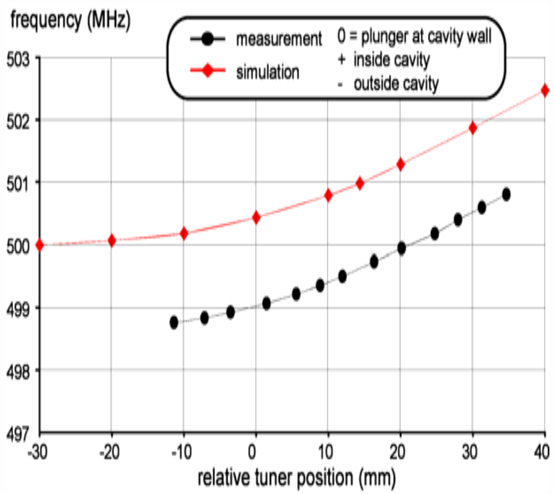
- ♦ **Evaluation of CBM current thresholds from CBM beam spectra at 500 MeV**

DORIS Cavity:



Measured Cavity Parameters

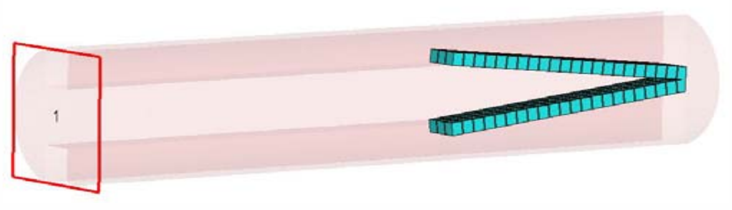
Parameter	3D MWS Simulation Standard/New Method	Measurement
f0 (MHz)	500.98	499.65
Q0	32557 / 28410	26692
Reff/Q0 (Ω)	114.5	115.4
Reff (MΩ)	3.73 / 3.25	3.1

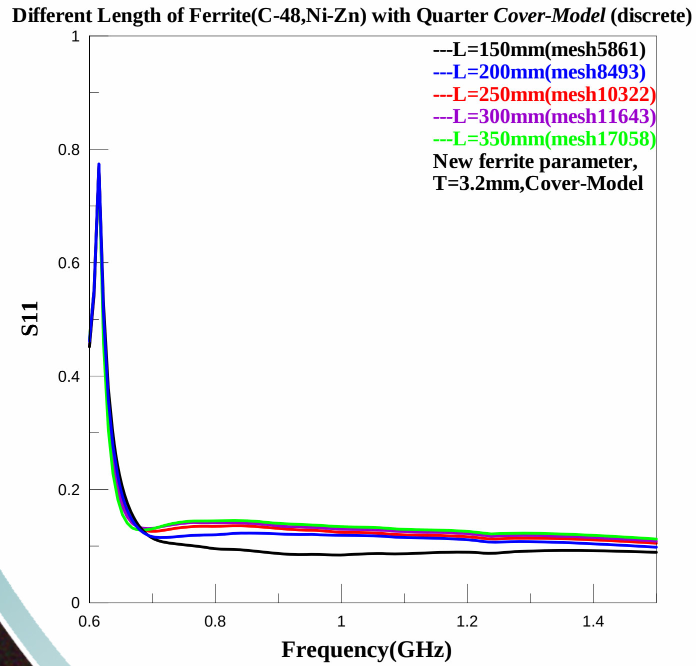


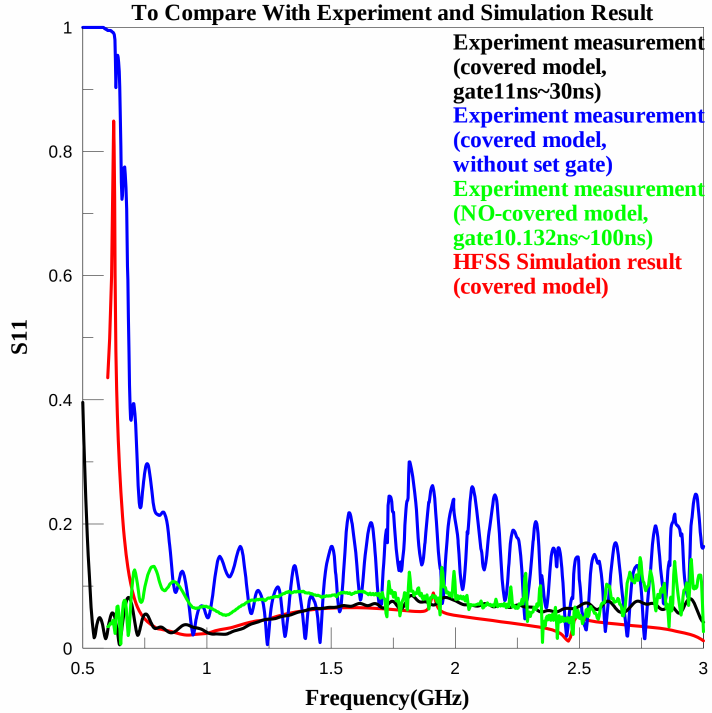
Resonant frequency vs. plunger position
as measured and calculated.

Nominal Frequency	499.65	MHz
Tuning Range	2	MHz
Shunt Impedance	3.1	MΩ
Unloaded Q	26692	
Thermal Power Capability	100	kW
Longitudinal HOM Impedance	≤ 4.8	kΩ
Transverse HOM Impedance	≤ 180	kΩ/m
Waveguide cut-off	615	MHz
Coupling Range	0-8	
Insertion Length	50	cm
Beam Hole Diameter TE11 cut-off TM01 cut-off	74 3.74 2.31	mm GHz GHz

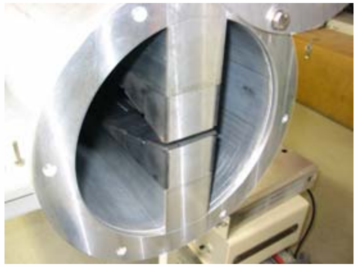
Ferrite Loaded Homogenous Circular Waveguide







HFSS in collaboration with Pei Zong Rao
NTHU / Taiwan



Criteria for the Selection of Ferrite Absorber Materials

- ♦ suitable rf damping capability
- ♦ UHV compatible
- ♦ dust free
- ♦ amenable to bonding to a metallic substrate
- ♦ material shall not break during manufacturing or during rf operation

<u>Potential ferrite materials:</u>

Ferrite-50	Trans-Tech Inc.
TT2-111R	Trans-Tech Inc.
CMD-10	Ceramic Magnetics Inc.
C48	Countis Industries

C48 has been used successfully for the sc CORNELL cavity

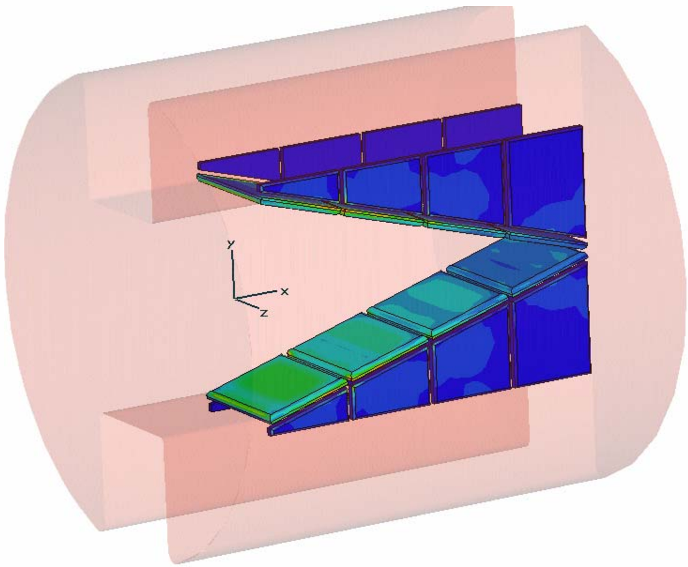
→ selected also for the BESSY HOM damped cavity

Absorber Layout

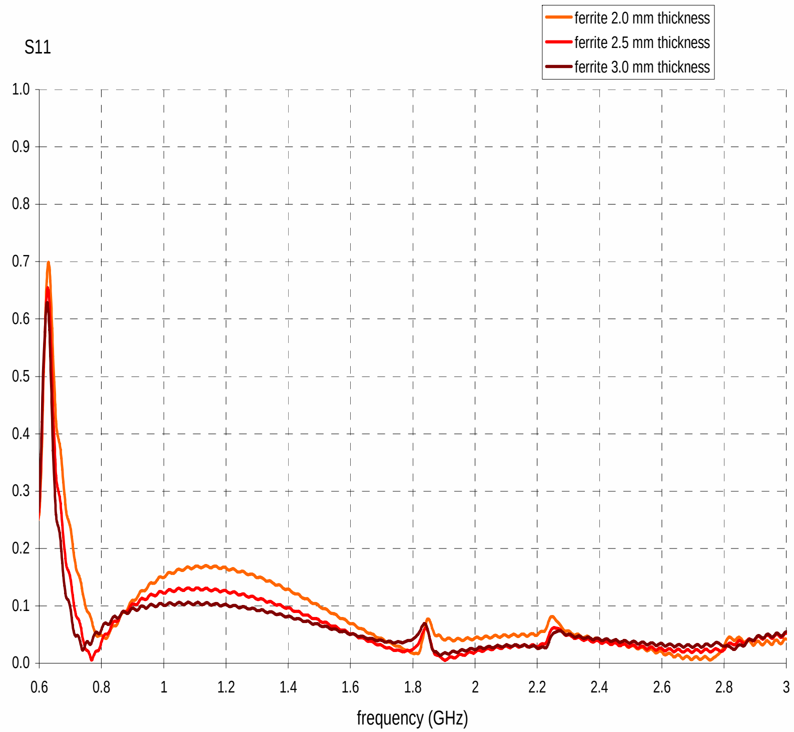
Homogenous waveguide: Cut-off frequency 625 Mhz

Ferrite material: NiZn ferrite, UHV compatible, C48 used also for CORNELL sc cavity

Optimisation parameters:
- ♦ Length of ferrite wedge ≈ 150 mm
- ♦ Ferrite tile thickness ≈ 3 mm
- ♦ Simulation with Microwave Studio code (latest version)



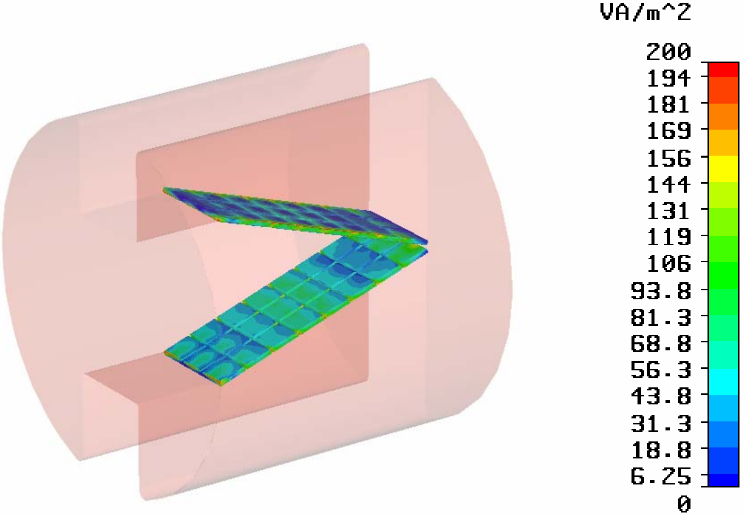
Ferrite thickness: 3mm

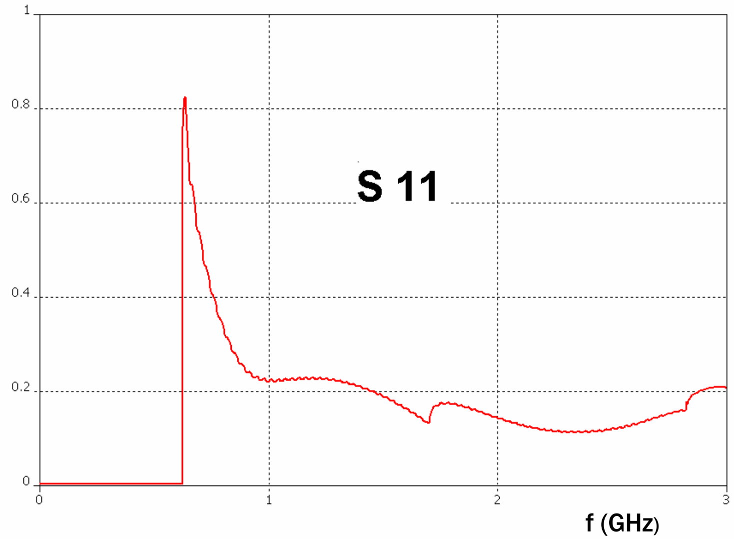


Absorber Layout

Layout compromise:

- ♦ No ferrite on side walls of the wedge
- ♦ Ferrite thickness 2.7 mm
- ♦ Ferrite tile dimensions 19 x 16 mm





Ferrite thickness: 2.7 mm

P_{input} = 1 W

HOM Power Considerations

	BESSY-II		ELETTRA	ALS	SLS	ANKA	SRRC	MAX-II
σ [mm]	4.8		5.4/11	9	4	9	7.5	6
$k_{\parallel,HOMs}$ [V/pC]	**0.7**		**~0.64/0.41**	**0.5**	**0.8**	**0.5**	**0.52**	**0.6**
E_0 [GeV]	1.7		2	1.5	2.4	2.5	1.5	1.5
U [m]	240		259.2	196.8	288	110.4	120	90
multibunch-mode								
I_{beam} [mA]	400	250	300	400	500	400	240	200
n_b / max.	260 400	260 400	432	328	480	184	200	150
$T_b = 1/f_{rf}$ [ns]	2							
Q_b [nC]	1.231 0.8	0.769 0.5	0.6	0.8	1	0.8	0.24	0.4
P_{HOMs} [W]	**530/ 224**	**207/ 88**	**115/74**	**160**	**400**	**160**	**60**	**48**
singlebunch-mode								
I_{beam} [mA]	30		-	2*20 (two-bunch mode)	-	-	25	-
T_b = [ns]	800		-	328	-	-	400	-
Q_b [nC]	24		-	2*6.56	-	-	10	-
P_{HOMs} [W]	**504**		-	**66**	-	-	**130**	-

Maximum HOM-power per BESSY type cavity in various SR sources using 500 MHz RF-systems for longitudinal multibunch oscillations

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

Max HOM power per cavity: P_{long} = 600 W
P_{transv} = 600 W

Safety factor for future upgrades: 2

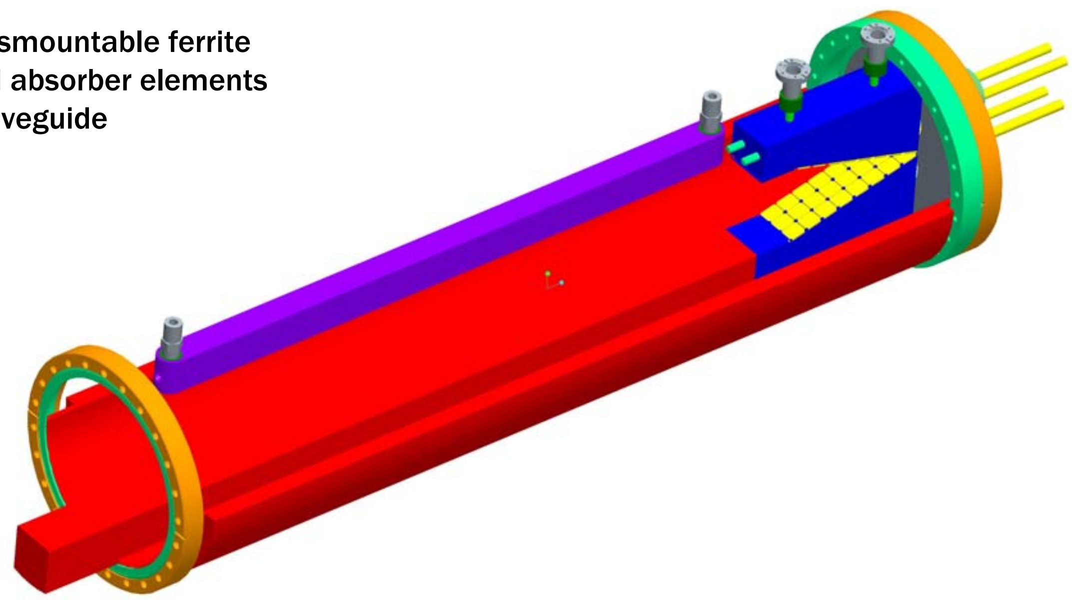
→ P_{HOM} = 2.4 kW per cavity

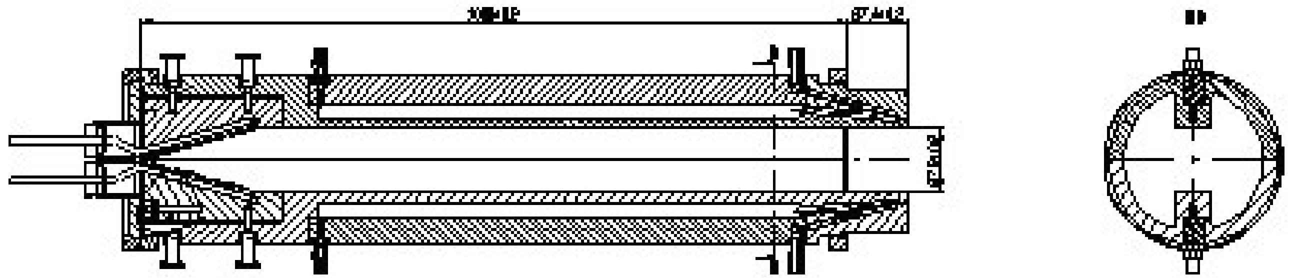
Design power density on ferrite: 15 W/cm^2

→ P_{HOM} = 7.1 kW per cavity

Ferrite Damping Waveguide Mechanical Design

Two dismountable ferrite loaded absorber elements per waveguide





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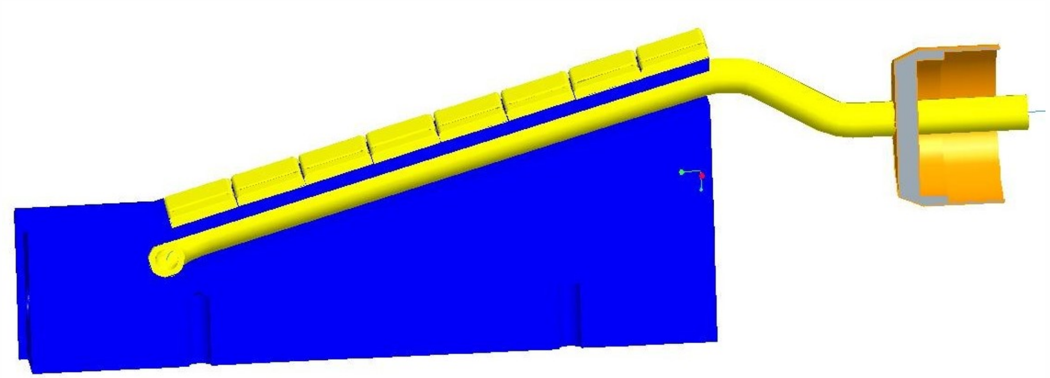
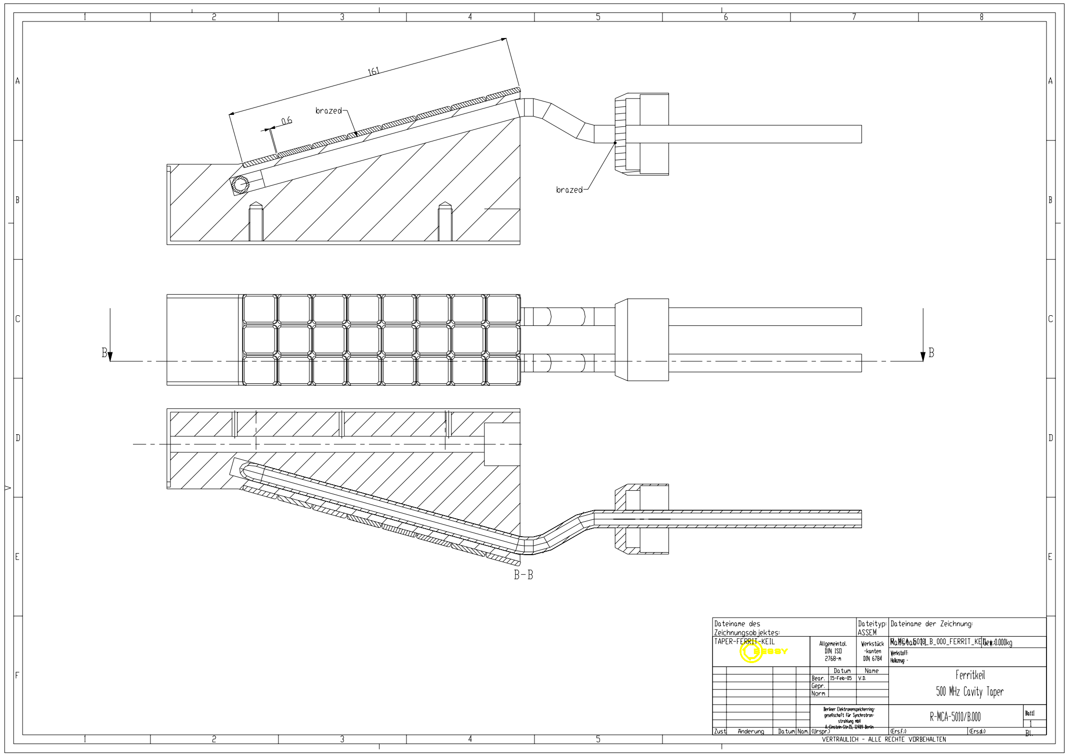
Ferrite Absorber Wedge Element

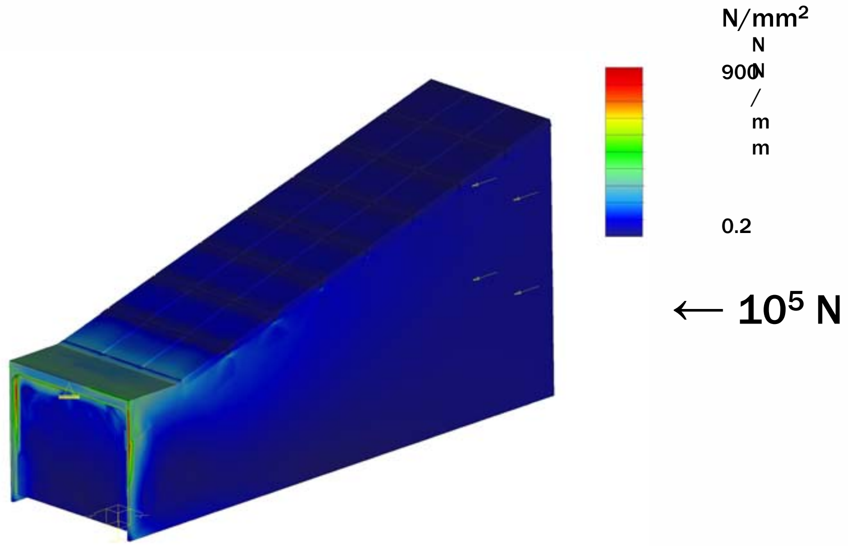




Mechanical and Thermal Simulations

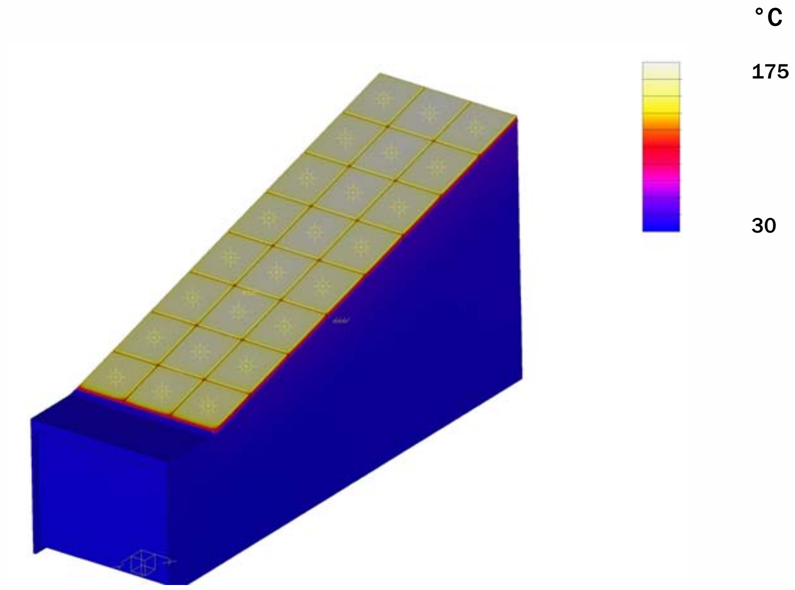
Stress distribution

Applied force:	10^5 N
Max. stress on copper :	870 N/mm^2
Max. stress on ferrite :	90 N/mm^2



Temperature distribution

Power density on ferrite:	15 W/cm^2
Cooling water temperature:	30 °C
Thermal transfer coeff. λ:	5 W/m^2 °C
Ferrite surface temperature:	175 °C
Temperature gradient on ferrite (top - bottom):	100 °C



Technical Challenge: Brazing of Ferrite on Copper

Thermal expansion coefficient (10^{-6} / °C):		
	Copper	16.8
	C48 ferrite	8.

→ use small sized ferrite tiles
→ use low temperature for brazing
→ effective cooling of ferrite during operation

Possible brazing materials: e.g. Sn(90%) Ag(10%) or Au(80%) Sn(20%) with low melting point

Two options: i) Use intermediate layer of sintered Cu/W composite material (Elconite) to match thermal expansion of ferrite → solution adopted for CORNELL cavity

ii) Use annealed copper with very low mechanical yield point (dead soft copper)
However: any internal stress must be avoided, no work hardening after annealing
→ solution under study for the BESSY cavity

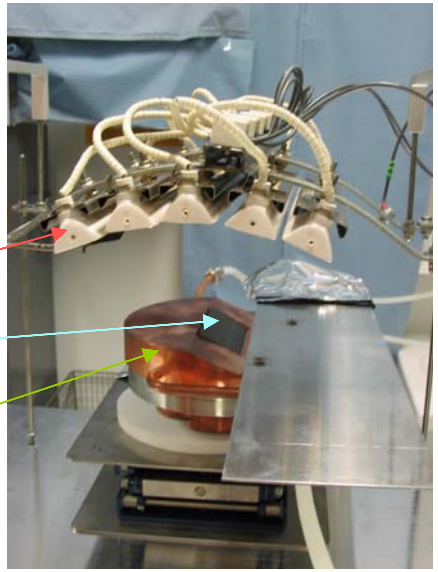
Power Tests for Absorber Elements

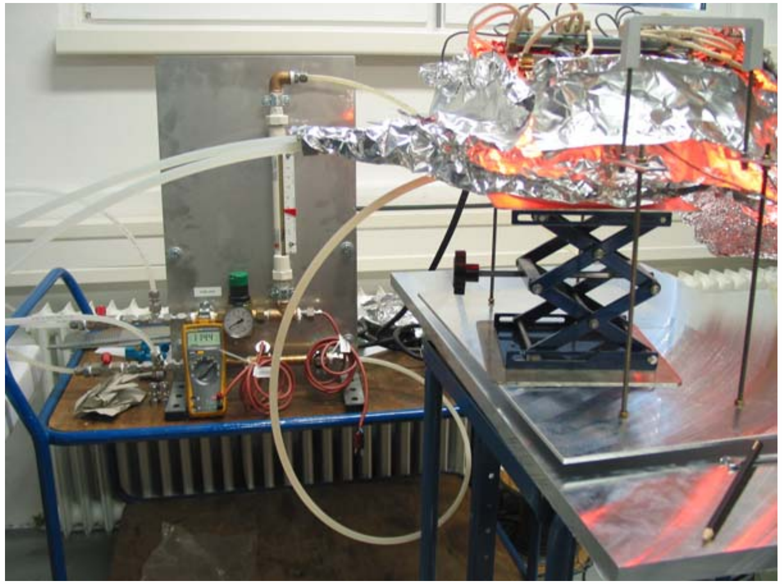
Experimental setup: measurement of power density

IR radiator elements

Ferrite tiles

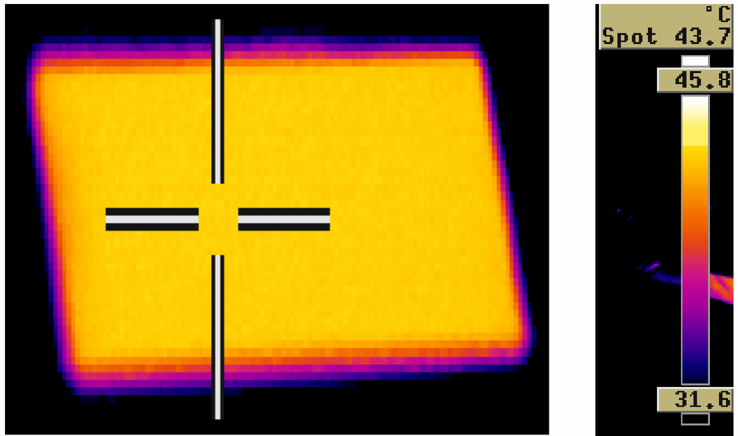
IR radiation shield





IR Camera picture of ferrite surface :

Homogenious intensity distribution
→ good brazing quality



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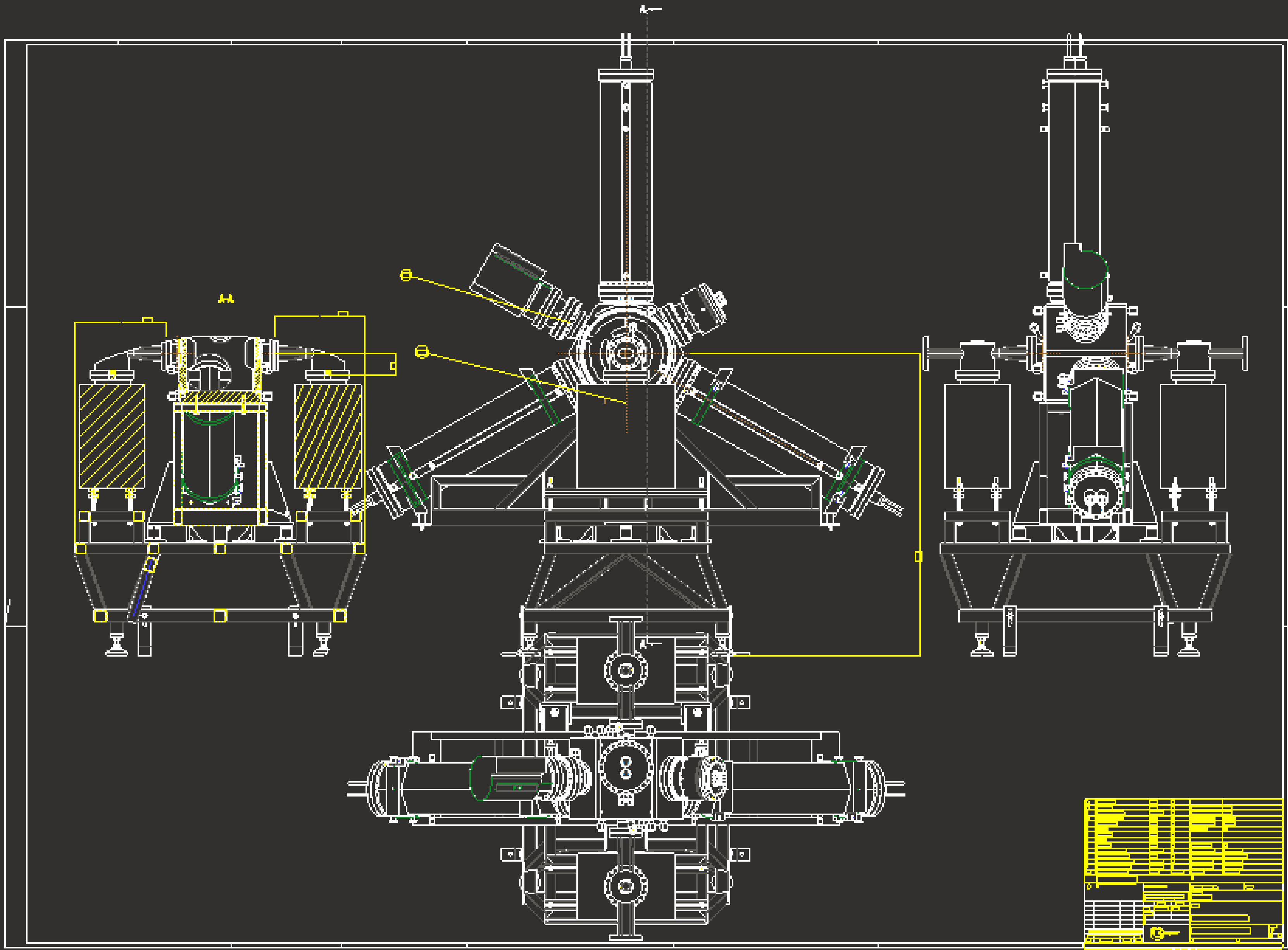

X.X ±0.1
X.XX ±0.01
X.XXX ±0.001
ANG. ±0.5

REP : Master Rep
E : ASSEM NAME : 500-MHZ-CAVITY-KOMP SIZE : A0

Conclusions

- With homogenous damping waveguides the residual HOM impedances can be reduced by a factor of ~ 4, which would allow to operate all existing 3rd generation rings with 500 MHz rf-systems below threshold for longitudinal multibunch oscillation modes
- A homogenous damping waveguide with low S11 has been designed using C48 ferrite material
- Technical challenges: Thermo-mechanical layout of the absorber elements
  Brazing of the ferrite tiles on copper
- Absorber elements can be power tested before installation in the cavity

Outlook

- A first cavity with homogenous damping waveguides will be ready in June 2006 for the PTB Metrology Light Source in Berlin. Tests with 80 KW input power are foreseen in autumn 2006