BESSY

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

HOM Damped Cavities for High Brilliance Synchrotron Light Sources

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Leibniz Gemeinschaft

Why Do We Need HOM Damped Cavities ?

High brilliance: use undulators implemented in a low emittance lattice

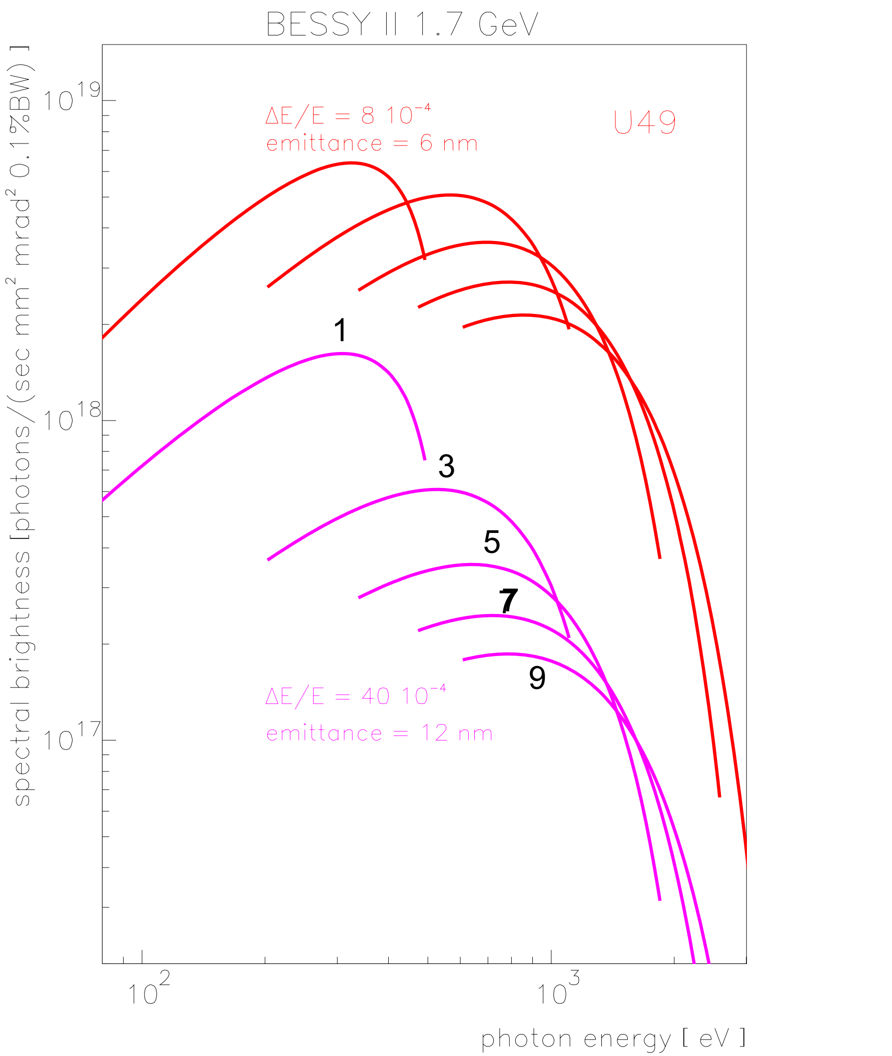
Minimize $\varepsilon \sim \gamma^2 \theta^3 <H>$
- ♦ small θ → many lattice cells
- ♦ small <H> → many magnets per cell

Low emittance is an expensive ingredient !

► **Avoid emittance degradation**

Narrow band impedance of the cavities excite coupled bunch oscillations if Fourier components of I_b coincide with HOMs

- ♦ Emittance increase due to transverse oscillations
- ♦ Large energy spread ΔE/E due to longitudinal oscillations
- ♦ Potential beam current limitations by large amplitude oscillations



Cures for Coupled Bunch Oscillations

♦ Detuning of the dominant HOM
  - by changing cavity temperature
  - by a second tuner

♦ Higher harmonic rf system for Landau damping

♦ Lower harmonic rf system and/or rf quadrupoles for decoupling of synchrotron and/or betatron frequencies

♦ Use selective damping antenna for individual HOMs

♦ Use broad band feedback systems

All these methods have their specific limitation

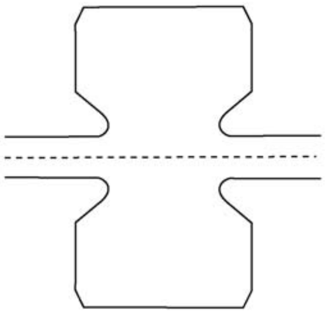
► **Damp all HOMs in the cavities in a broadband way**

Concepts for HOM Damped Cavities

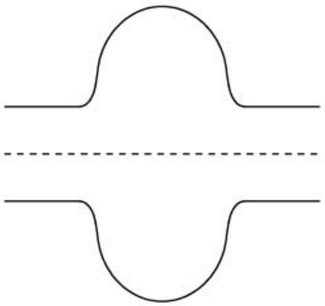
$$1 / I_{threshold} \propto Z_{tot} = N_c \left(\frac{R}{Q_0} \right)_{HOM} Q_{ext}$$

- ♦ Minimize number of cells N_c
- ♦ Minimize R/Q_0
- ♦ Minimize Q_{ext}

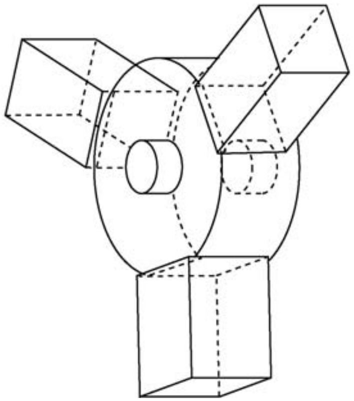
Copper cavity R_S optimisation by nose cones



Superconducting cavity shape inherently low R/Q

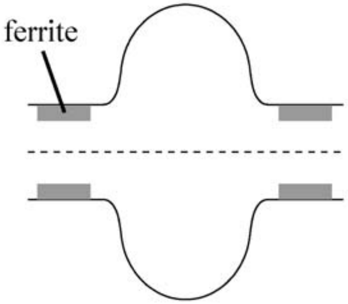


HOM-damping by three wave guides



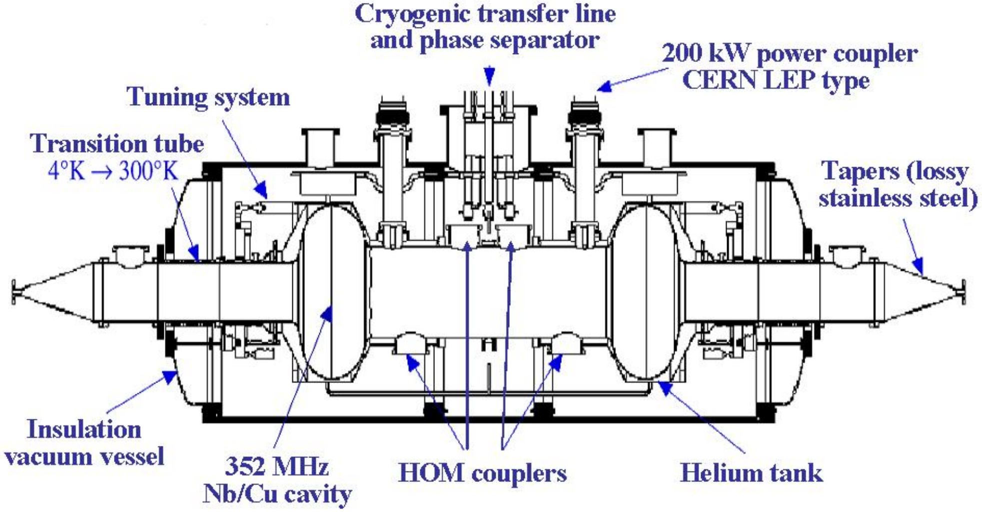
$f_{rf} < f_{cutoff} < f_{HOM}$

HOM-damping by ferrites in the beam tube



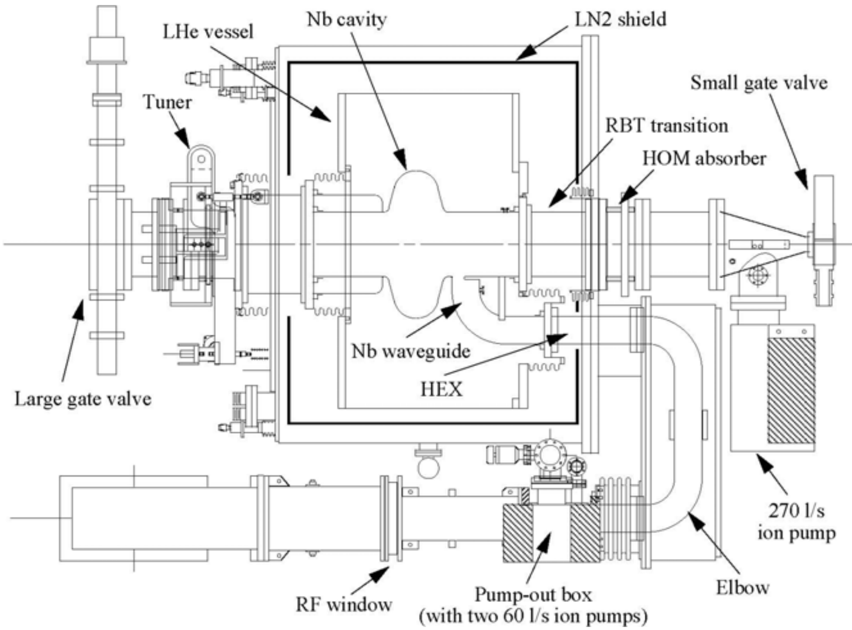
Superconducting Cavities

SOLEIL Cavity



- ♦ Nb sputtered on Cu
- ♦ 4 coaxial loop type HOM couplers
- ♦ 2 coaxial input couplers
  200 kW each
- ♦ cooling capacity:
  100 W at 4.5 K, 20 l/h LHe

CESR-B Cavity

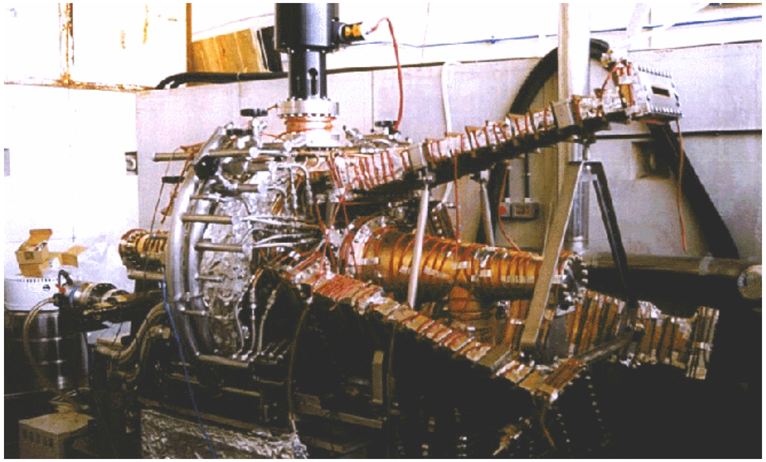


- ♦ Nb sheet material
- ♦ 2 cylindrical HOM loads
- ♦ rectangular waveguide
  input coupler, 500 kW
- ♦ cooling capavity:
  100 W at 4.2 K

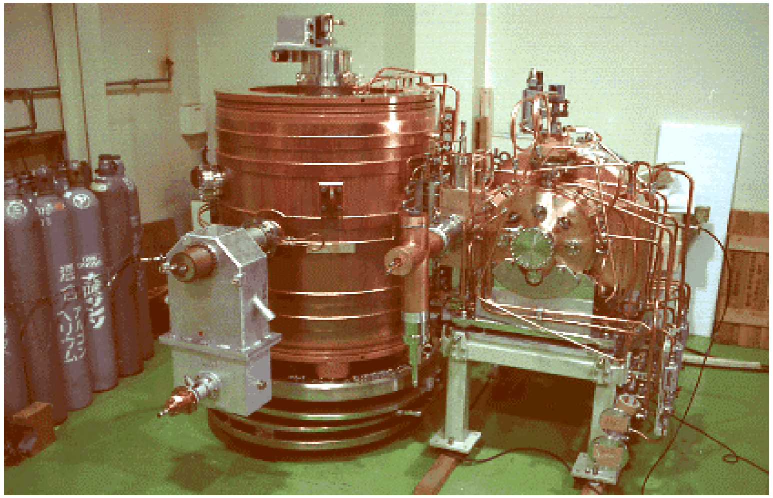
Cavity used at

CLS/Canada
NSRRC/Taiwan
SLS/China
DIAMOND/England

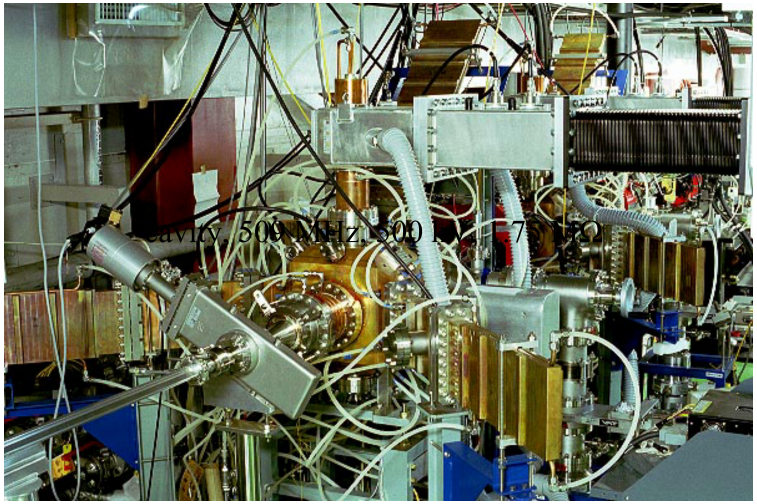
Room Temperature Cavities



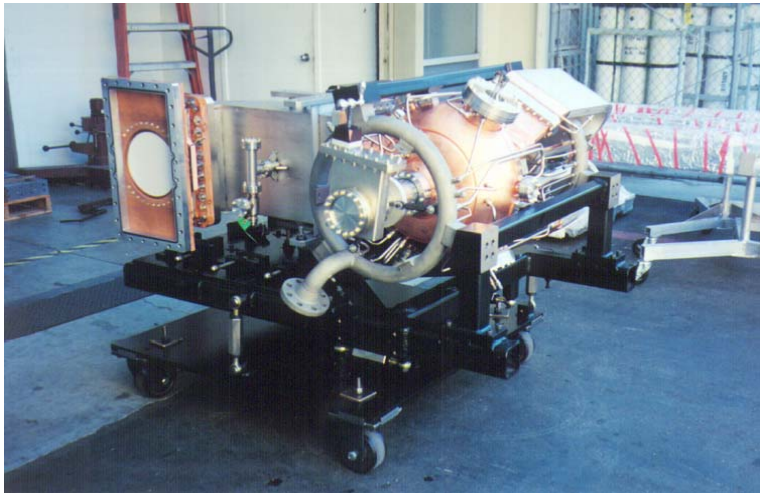
Daphne cavity, 368.26 MHz, 250 kV, 2 MΩ



KEK ARES cavity, 509 MHz, 500 kV, 1.7 MΩ

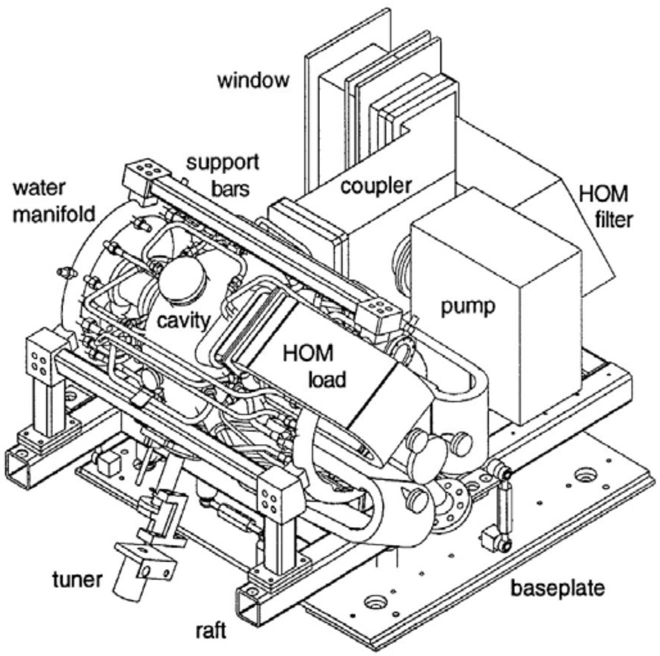


ATF cavity, 714 MHz, 250 kV, 1.8 MΩ

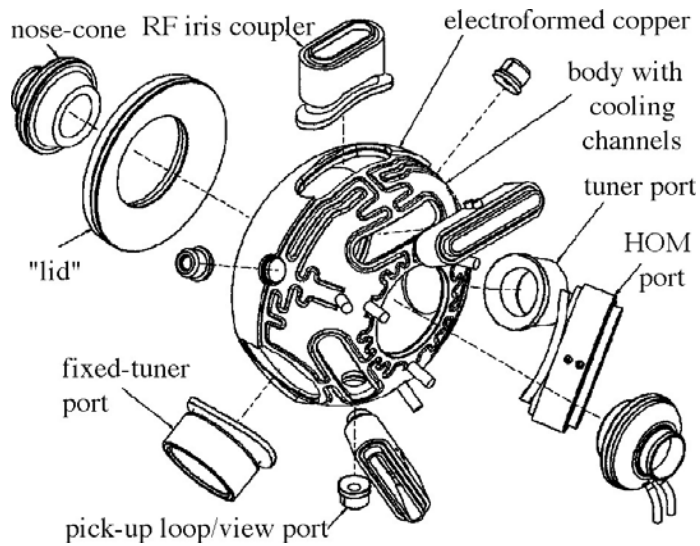


PEP-II cavity, 476 MHz, 850 kV, 3.7 MΩ

Room Temperature Cavities, cont.



PEP-II RF cavity raft assembly

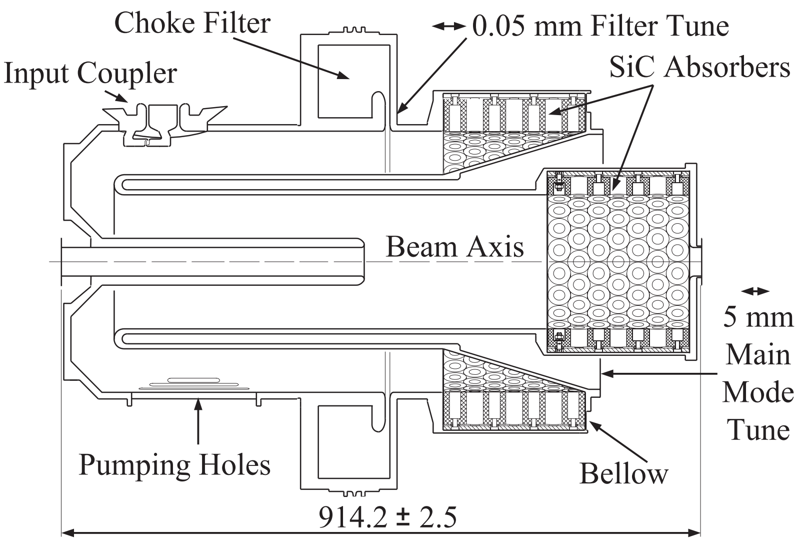


PEP II Cavity:

- ♦ 3 rectangular HOM waveguides, 10 kW each
- ♦ thermal design for 150 kW
- ♦ complex mechanical design
- ♦ circular Al_2O_3 rf window for 500 kW

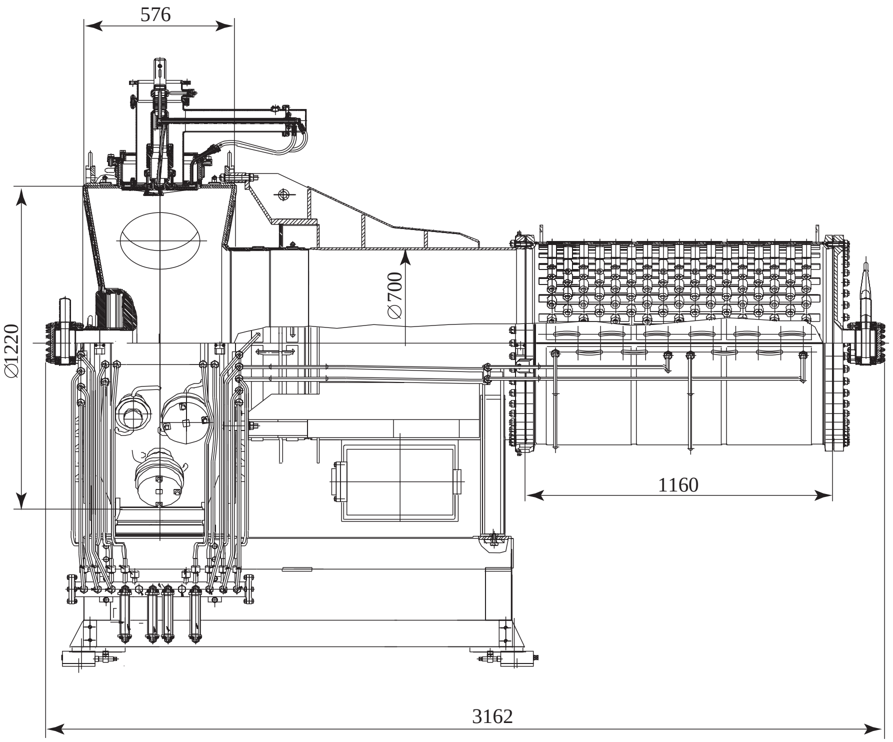
Room Temperature Cavities, cont.

Cavities developed at BINP / Novosibirsk



VEPP-2000 cavity

172.1 MHz, 120 kV, 0.23 MΩ



Cavity for the DUKE-FELL

178.5 MHz, 730 kV, 3.46 MΩ

Superconducting vs Normal Conducting Cavities

SC cavities:

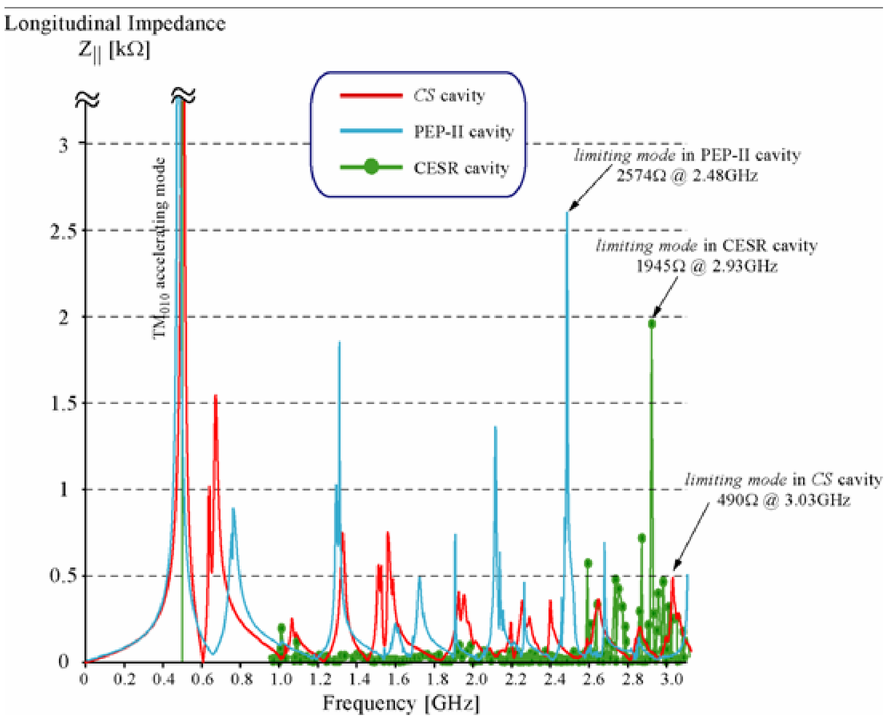
- ♦ high rf voltage per cavity
- ♦ lower electic power cost for higher energy rings
- ♦ need for cryogenic system
- ♦ high complexity
- ♦ MTBF:
  7 days/cavity @NSRRC
  23 days/cavity @CERN/LEP

NC cavities:

- ♦ HOM impedance per cell competitive with sc cavities
- ♦ cost efficient and simple technology
- ♦ MTBF: 28 days/cavity @BESSY II

Table 1. Performance parameters of several cavities ($R_s = V_{cy}^2/2P_{cy}$, L insertion length)

	f_0	V_{cy}	R_s/Q	Q_0	P_{cy}	L	f_{HOM} ∥	R∥	f_{HOM} ⊥	R⊥
	MHz	MV	Ω		kW	m	MHz	kΩ	MHz	kΩ/m
CESR	500.	2.5	44.5	-	-	2.9	2253.	0.18	715.	32.
SOLEIL	352.	2.5	45.	-	-	3.65	699.	2.1	504.	49.
		V_{cy}	R_s							
		kV	MΩ							
PEP II	476.	850.	3.8	32400	103.	~1.5	1295.	1.83	1420.	144.
DAPHNE	368.2	250.	2.	33000	16.	1.9	863.	259.	-	-
ARES	509.	500.	1.75	118000	72.	~1.1	696.	1.35	989.	10.
VEPP2000	172.1	120.	0.23	8200	29.	0.95	2460	0.4		<10.
DUKE-2	178.5	730	3.46	39000	77	3.16	-	-	-	-
BESSY	500.	780.	3.1	26700	100.	0.5	670.	1.6	1072.	54.



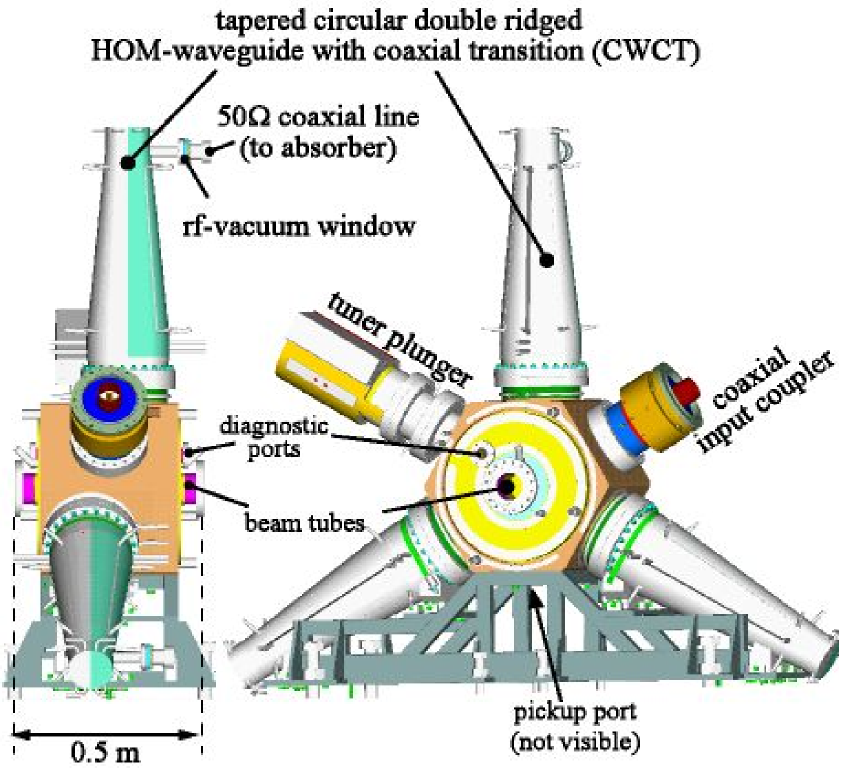
Longitudinal impedance spectra as calculated for the *BESSY(CS)*, PEP-II and CESR cavity

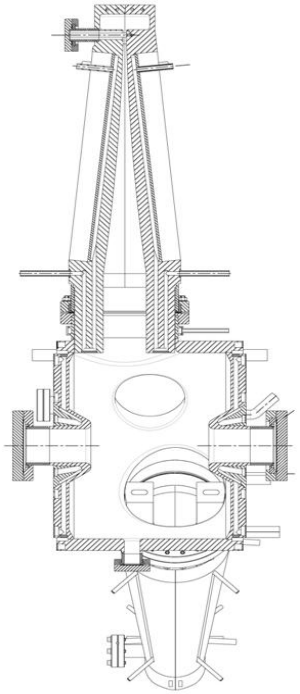
BESSY HOM Damped Cavity

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

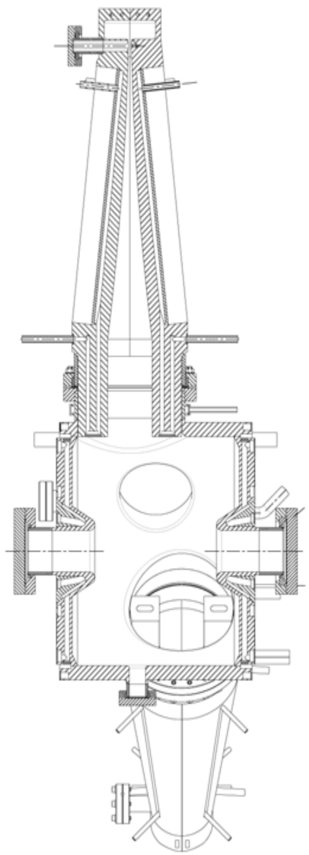
Design Goal

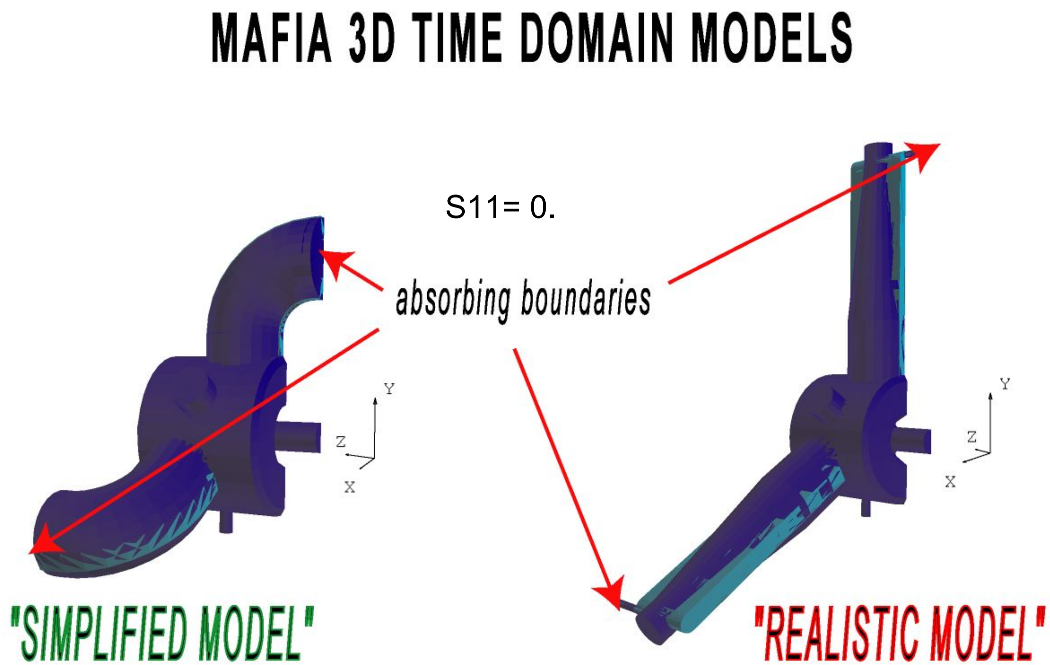
- **Frequency**
  f_{rf} **= 500 MHz**
- **Insertion length**
  L < 0.7 m
- **Shunt impedance**
  R ≈ 4 MΩ
- **Max. thermal power**
  P = 100 kW
- **Compact design to fit <u>existing</u> ring tunnels**





Simulation Models





~ 10^6 mesh points
2-3 days cpu time

~18* 10^6 mesh points
6-7 weeks cpu time

Today: ~ 2 days cpu time

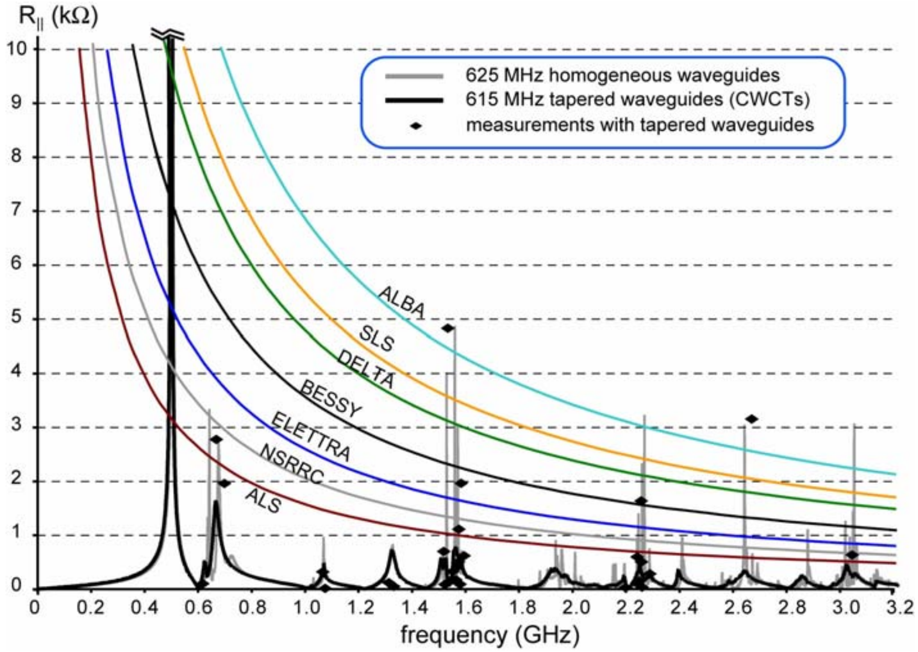
Impedance Spectra and Critical Impedances

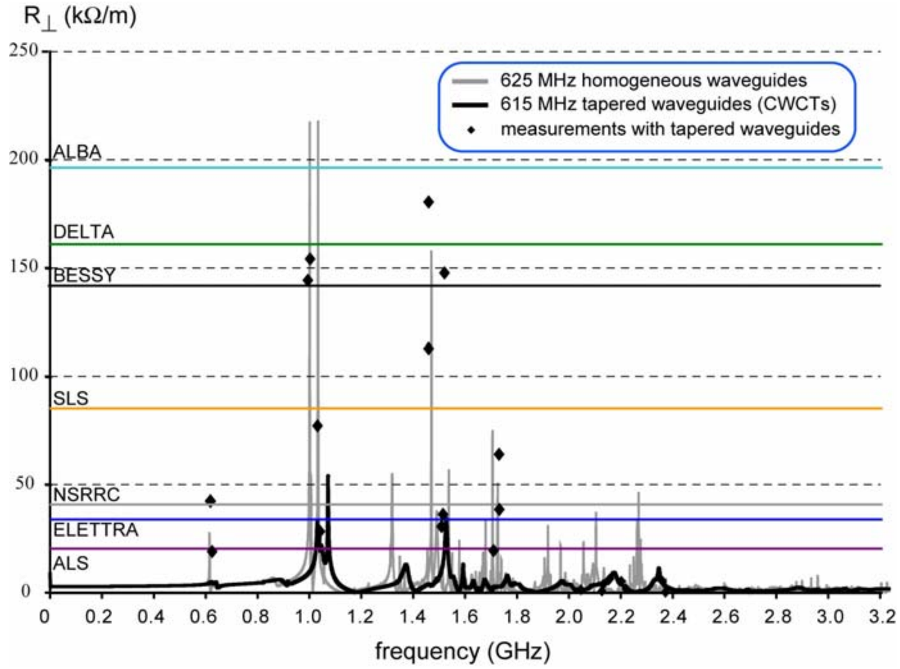
Longitudinal Impedance

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

Transverse Impedance

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



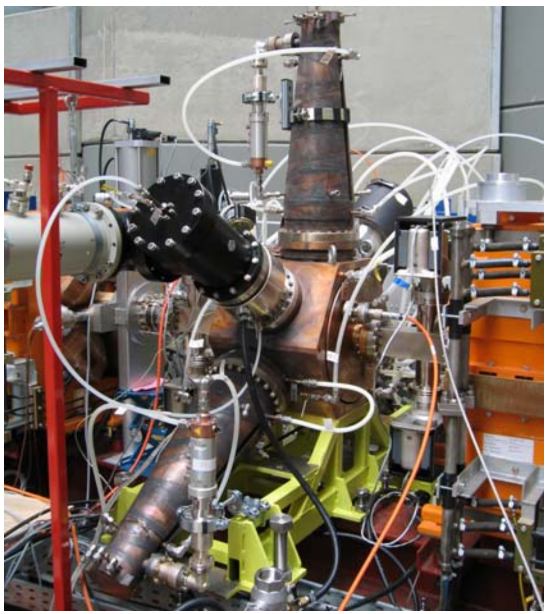


First Beam Tests in DELTA

CBM beam spectra: (longitudinal case)

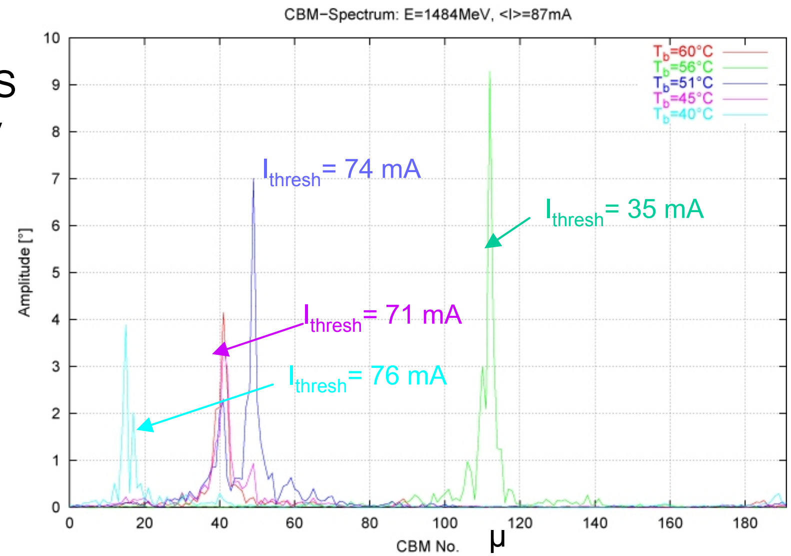
$$f_{\mu m}^{\pm} = nf_{rf} \pm (\mu f_0 + mf_s)$$

Prototype cavity installed in the DELTA ring

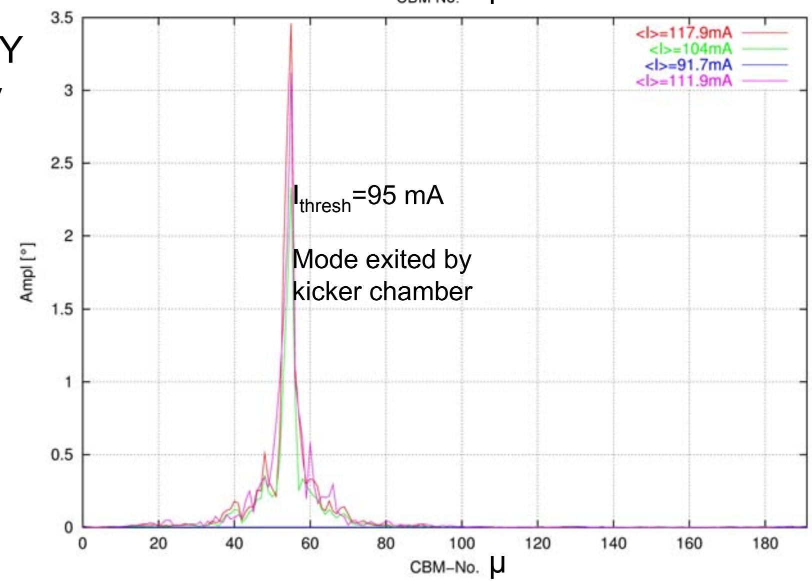


No cavity driven CBMs excited in DELTA

DORIS Cavity

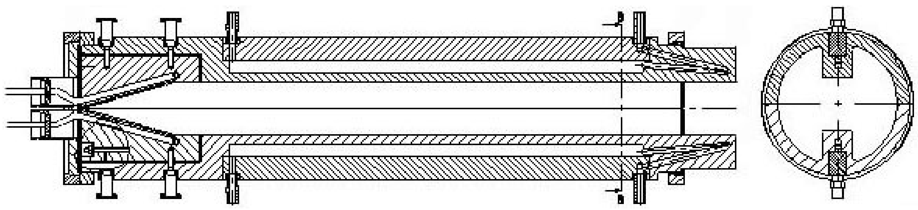


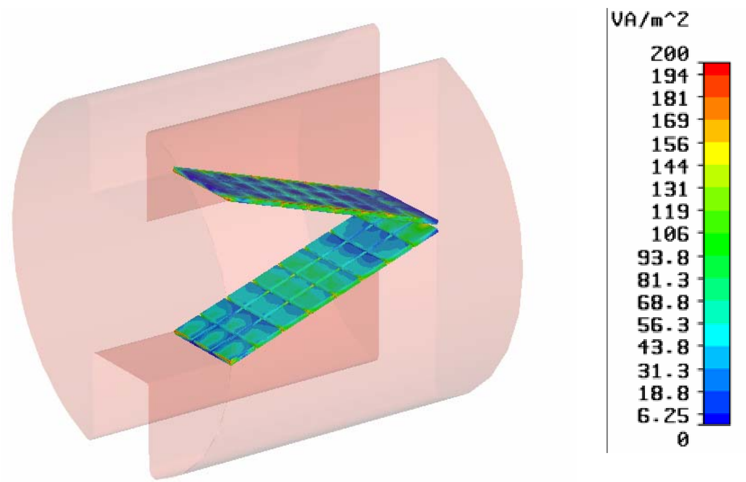
BESSY Cavity

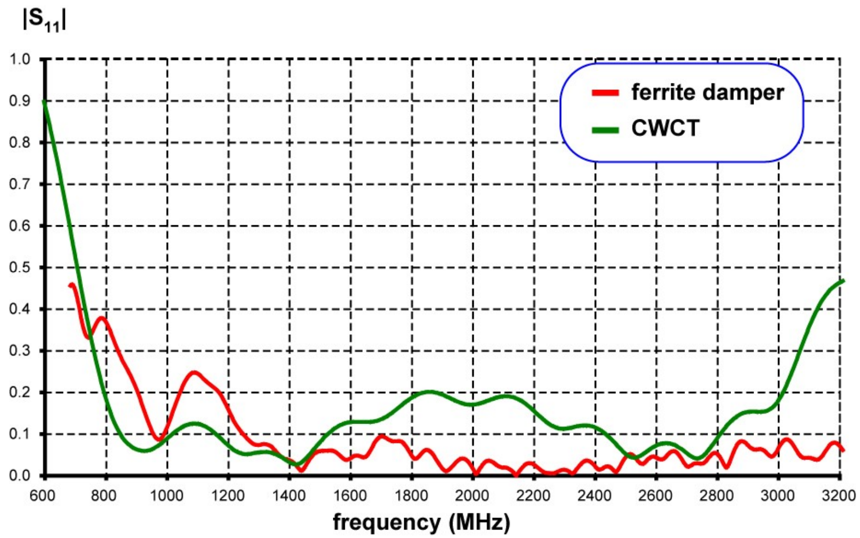


Homogenous Wave Guide Dampers

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







Time domain reflectrometry measurement of S11

Cavity will be use for

- Metrology Light Source PTB / Berlin
- ALBA Facility / Spain

Conclusions

- ♦ HOM damped cavities are mandatory for state of the art high brilliance storage ring sources
- ♦ Several sc and nc HOM damped cavites are in use, which have been designed for collider rings, e.g. CESR cavity, SOLEIL cavity, PEPII cavity
- ♦ SC cavities have benefits for SR sources at higher energies

  high rf voltage per cell
  low power consumtion

- ♦ Optimized nc cavities with reasonably high fundamental mode shunt impedance and a short insertion length are coming into operation in SR sources, e.g. PEPII and BESSY cavity, offering

  high reliability
  moderate investment costs

- ♦ HOM impedances can be reduced down to a level which allows that most synchrotron light sources can operate below threshold for multi-bunch instabilities