Development of High Gradient Superconducting CH-Cavities

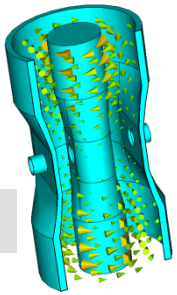
LINAC AG

Marco Busch ● Michael Amberg ● Florian Dziuba ● Markus Basten
Holger Podlech ● Ulrich Ratzinger

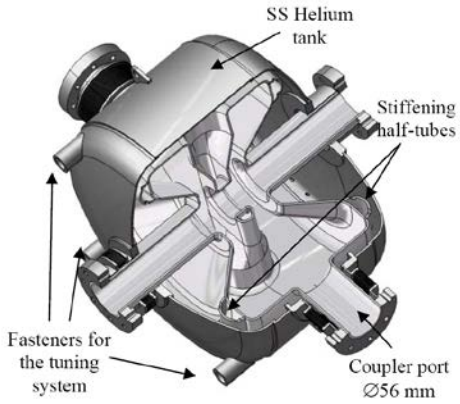
Institut für Angewandte Physik (IAP)
Goethe-Universität Frankfurt am Main

Superconducting low- and medium-β Cavities

INFN Legnaro

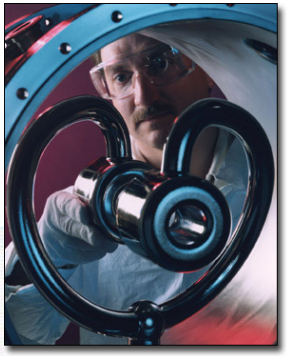


MSU

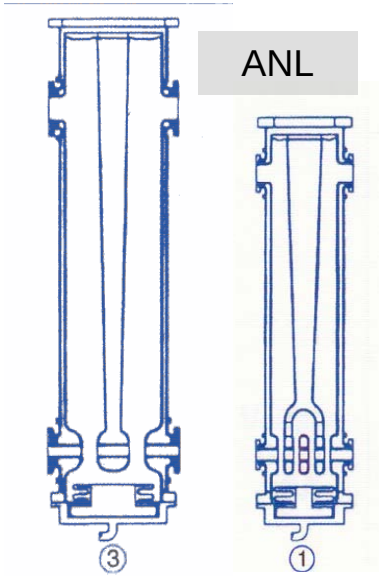


IPN, Orsay

ANL

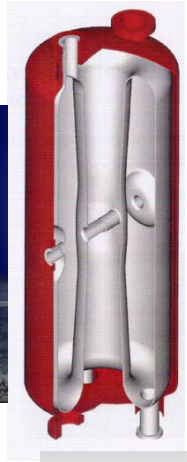


ANL

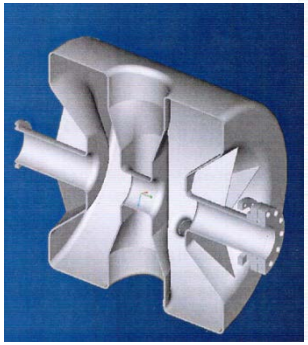


ANL

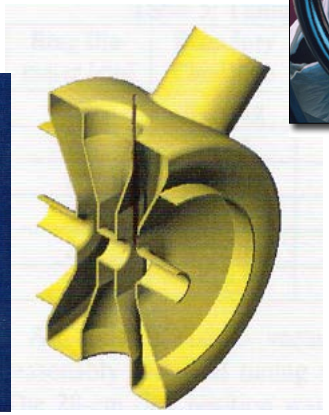
IAP Frankfurt



ANL

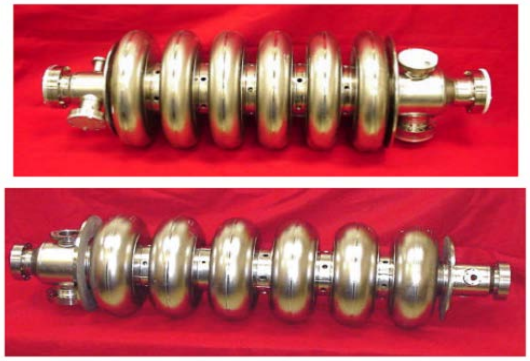


IPN, Orsay



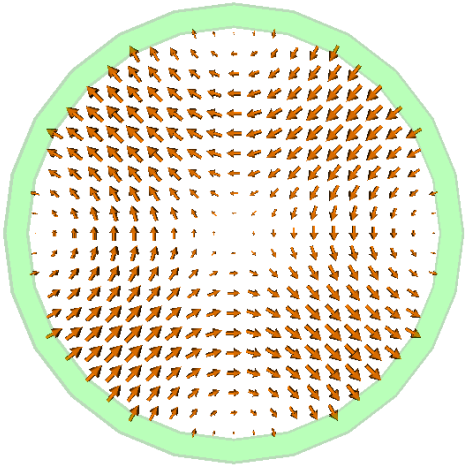
LANL

SNS



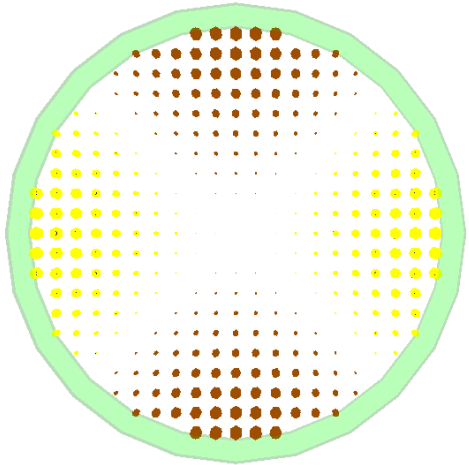
Principle of a CH-Structure

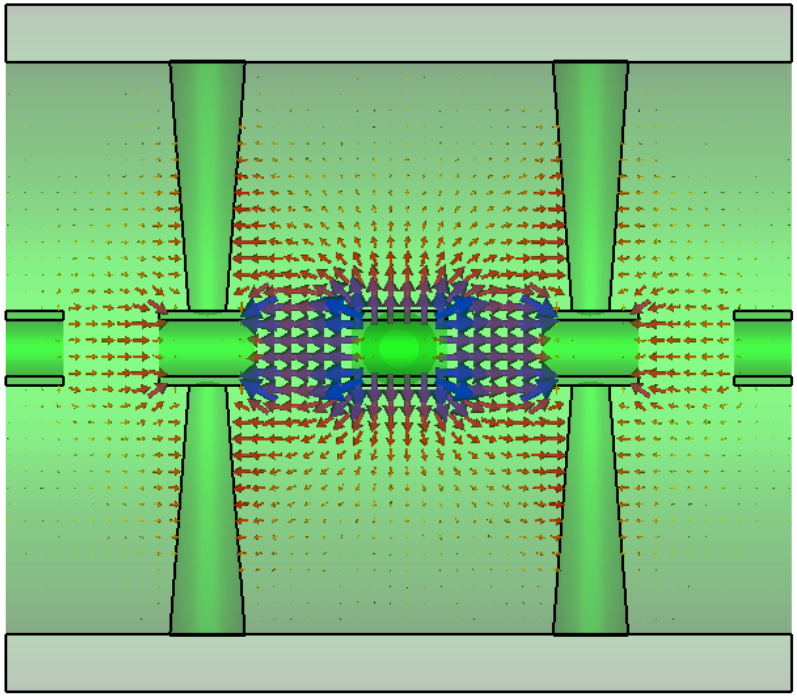
E-Field



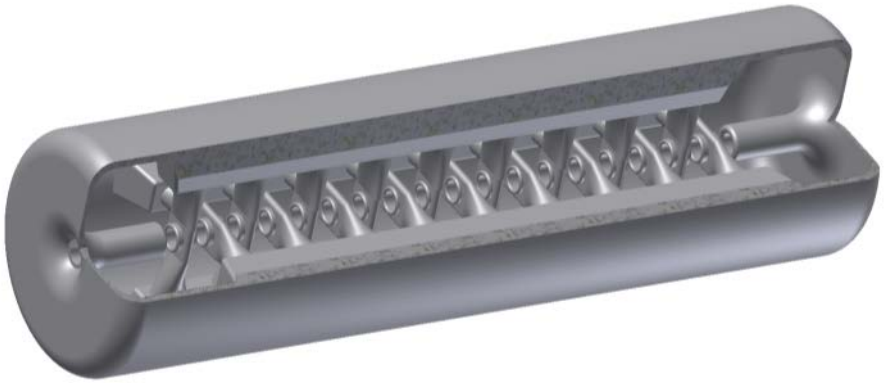
H_{211}

B-Field



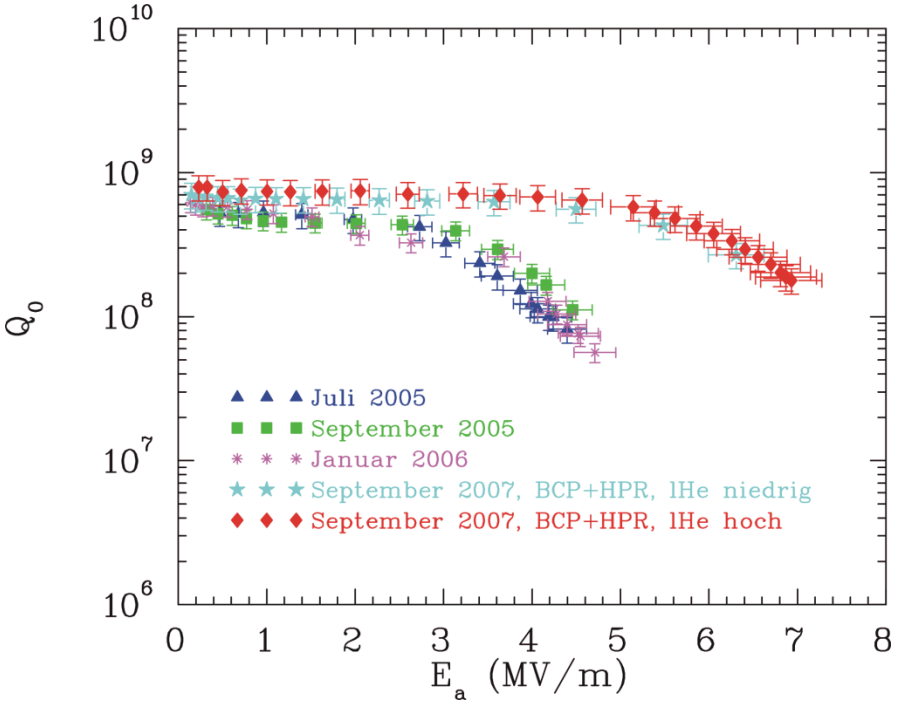


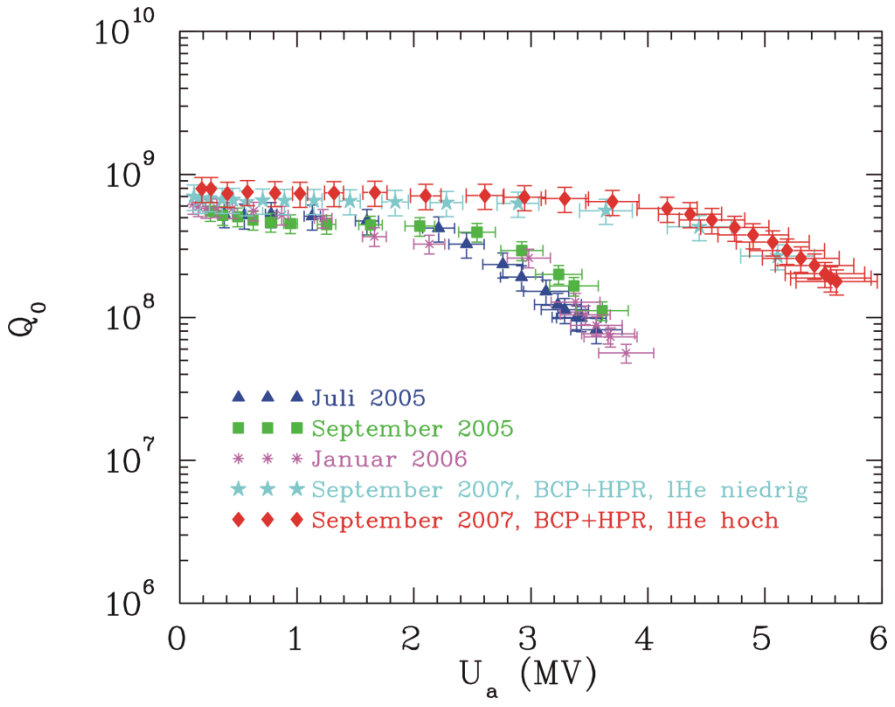
360 MHz Prototype Cavity



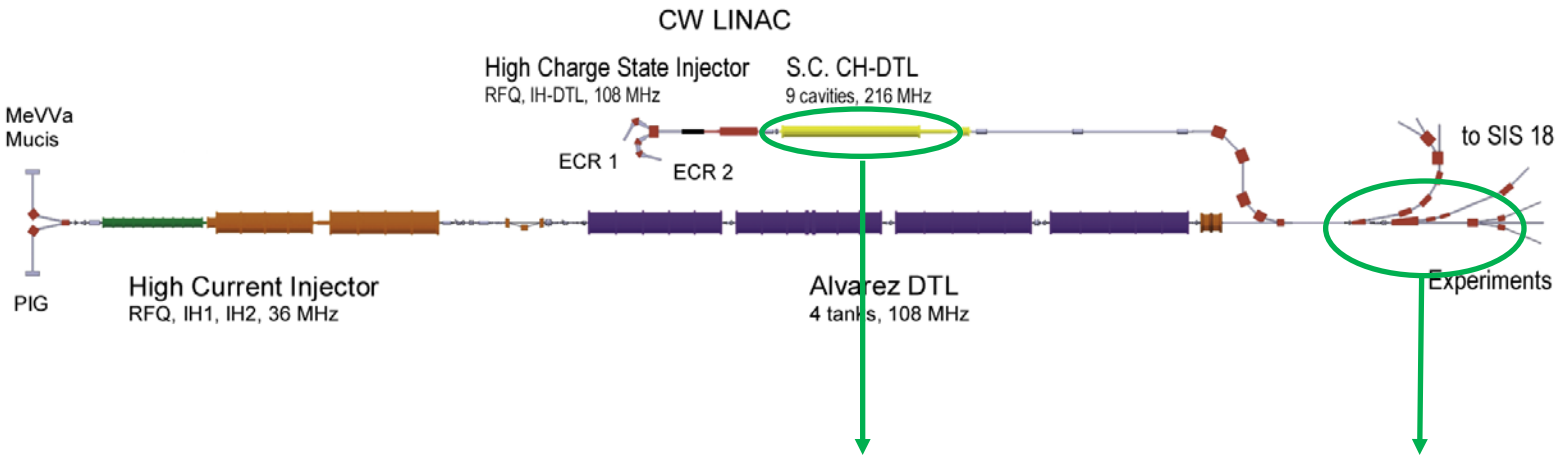
Number of Gaps	19
Length (mm)	1048
Frequency (MHz)	360
β	0.1
E_p/E_a ($\beta\lambda$-definition)	5.2
B_p/E_a [mT/(MV/m)]	5.7
$G=R_sQ_0$ (Ω)	56
R_a/Q (Ω) (T incl.)	3180
$(R_a/Q)G$ (Ω^2)	178000
Q_0 (BCS, 4.2K, 360 MHz)	1.5×10^9
Q_0 (total R_s=150 nΩ)	3.7×10^8
W [mJ/(MV/m)^2]	92

Q vs E Curve


10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
Q_0
0 1 2 3 4 5 6 7 8
E_a (MV/m)
Juli 2005
September 2005
Januar 2006
September 2007, BCP+HPR, lHe niedrig
September 2007, BCP+HPR, lHe hoch


10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
Q_0
0 1 2 3 4 5 6
U_a (MV)
Juli 2005
September 2005
Januar 2006
September 2007, BCP+HPR, lHe niedrig
September 2007, BCP+HPR, lHe hoch

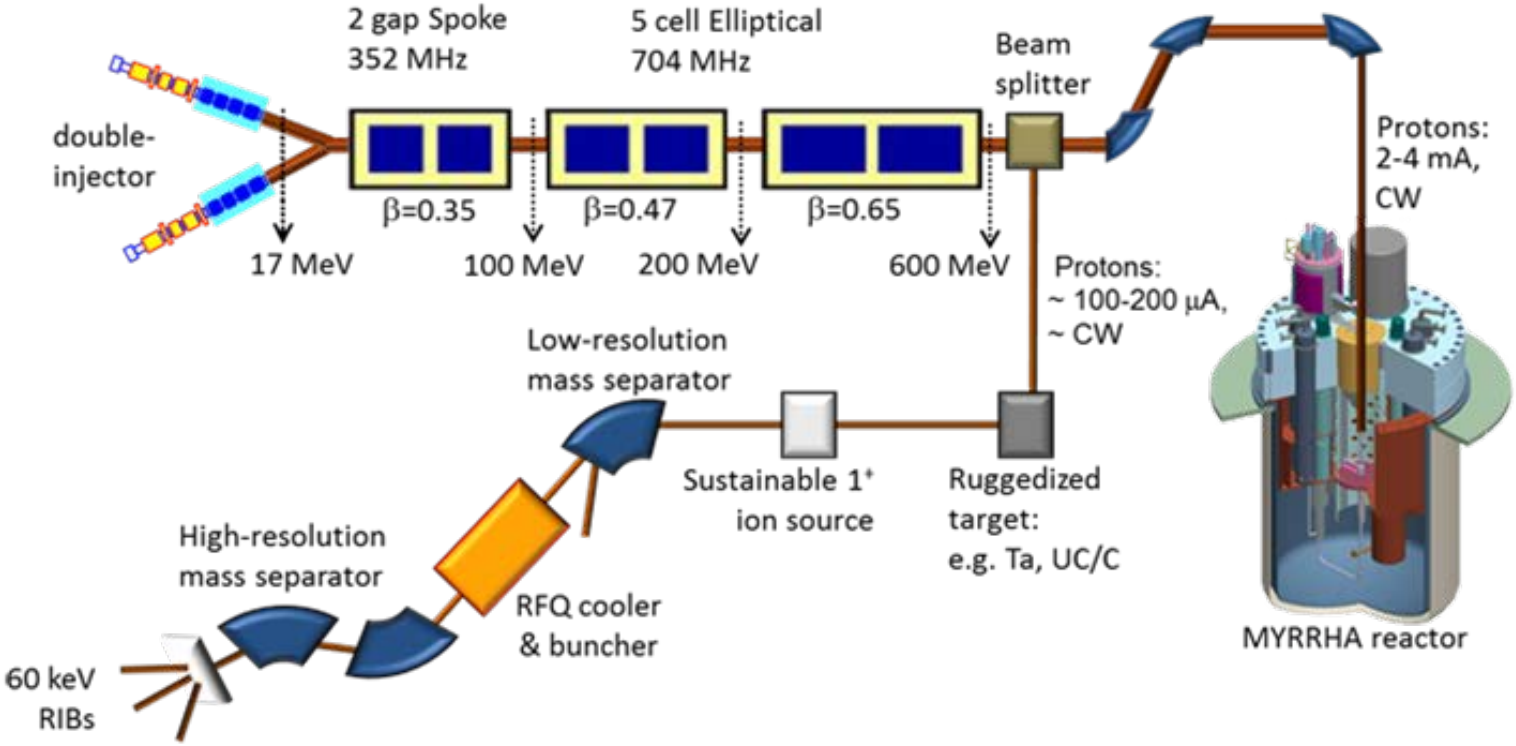
Projects: UNILAC Beam Test / SHE Linac

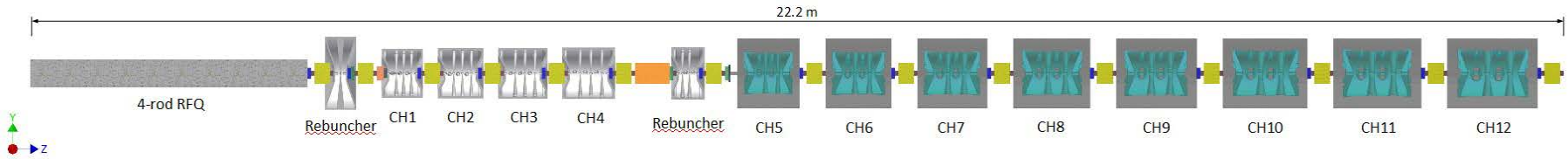


Parameter	unit	C1	C2	C3	C4	C5	C6	C7	C8	C9
Gap number		15	17	19	10	10	10	10	10	10
Total length	mm	613	811	1054	639	639	726	726	813	862
Cell length	mm	40.8	47.7	55.5	63.9	63.9	72.6	72.6	81.3	86.2
Synch. veloctiy		0.059	0.069	0.080	0.092	0.092	0.105	0.105	0.118	0.125
Aperture diameter	mm	20	22	24	30	30	30	30	30	30
Eff. gap voltage	kV	225	274	317	356	362	408	411	459	538
Voltage gain	MV	3.13	4.14	5.42	3.27	3.30	3.73	3.73	4.18	4.43
Phase Factor		0.93	0.89	0.90	0.92	0.91	0.92	0.91	0.91	0.82
Accelerating rate	MV/m	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1

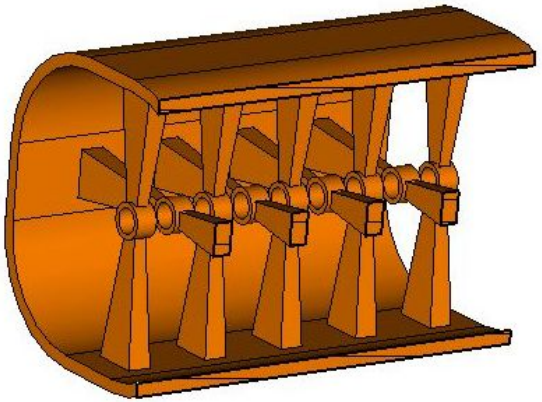
- f = 325,224 MHz
- E_{in}= 11,4 MeV/u
- β = 0,155
- 7 cells
- 30 mm aperture

Project: MYRRHA

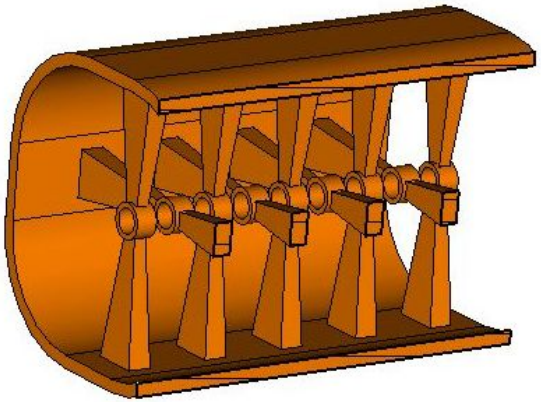


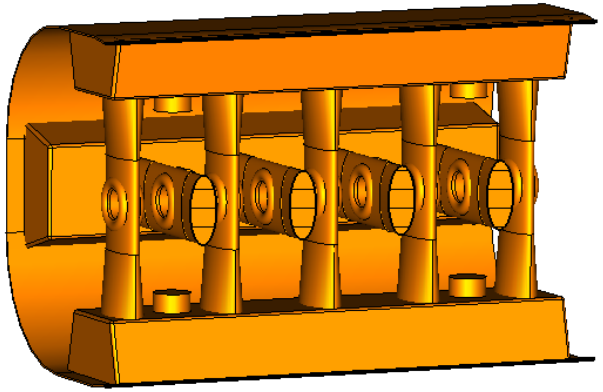


Start from the Scratch

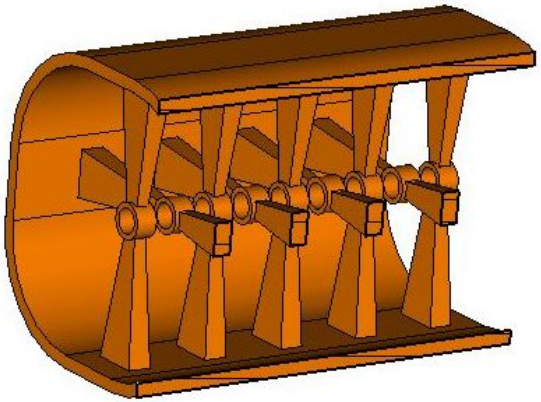


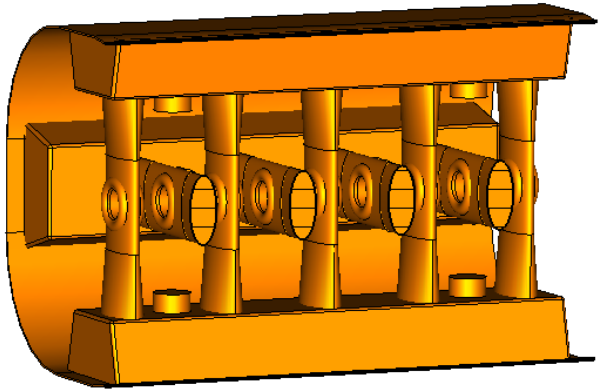
Start from the Scratch

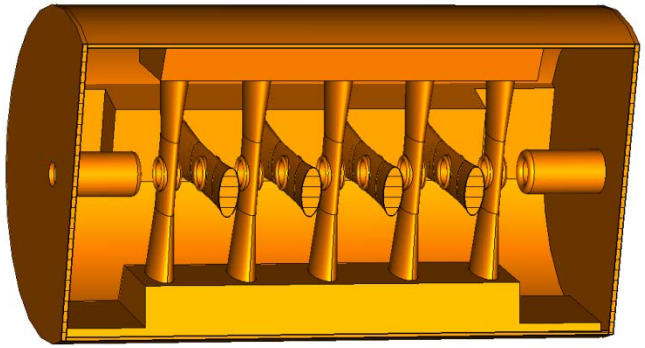




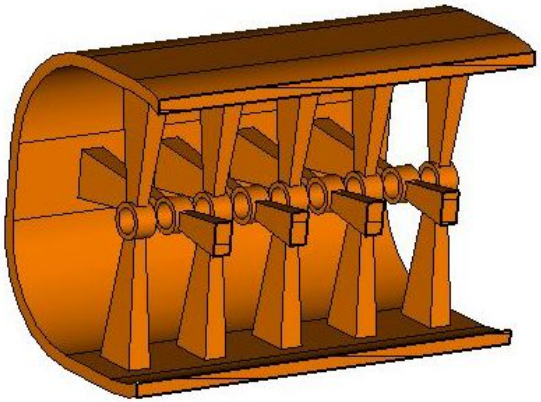
Start from the Scratch

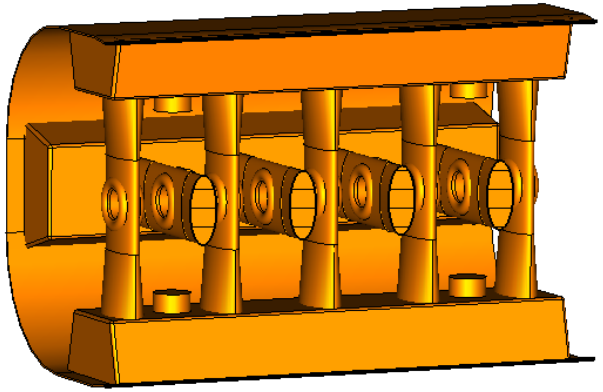


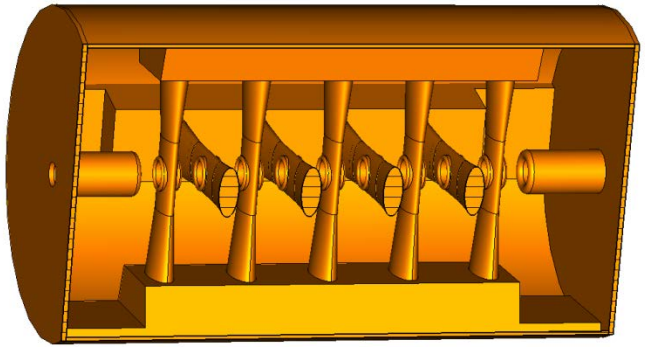


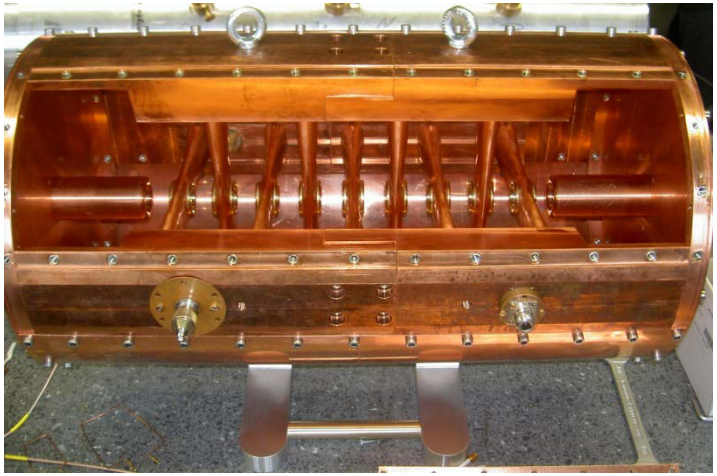


Start from the Scratch



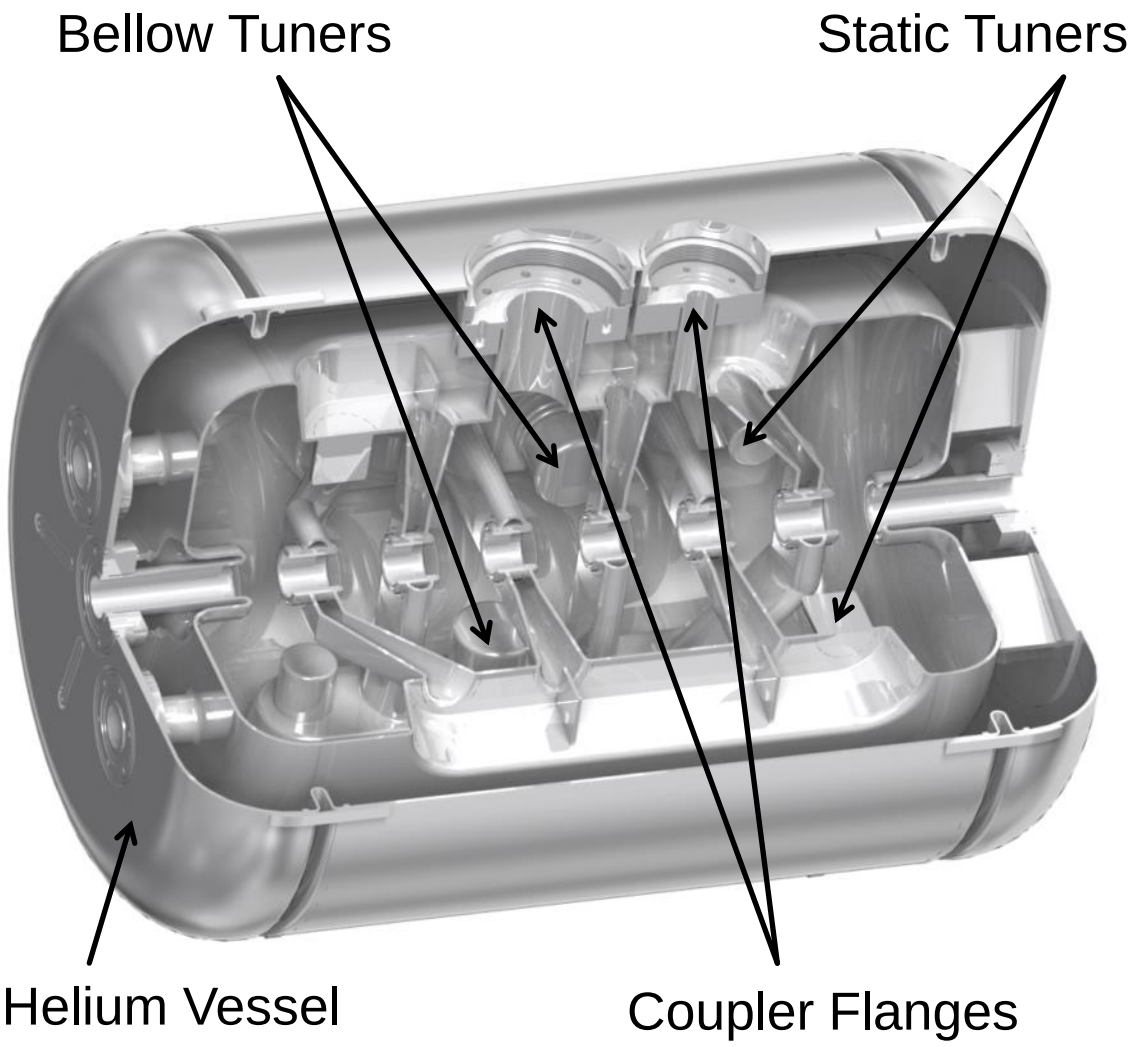






Layout of the final s.c. CH-Cavity

β	0.155
Frequency (MHz)	325.224
Cells	7
Length βλ-def (mm)	505
Diameter (mm)	350
E_a (MV/m)	5
E_p/E_a	5.1
B_p/E_a [mT/(MV/m)]	13
G (Ω)	66
R_a/Q_0 (Ω)	1260
R_aR_s (Ω²)	80000



Strategy to Hit the Final Frequency

Bad circumstances:

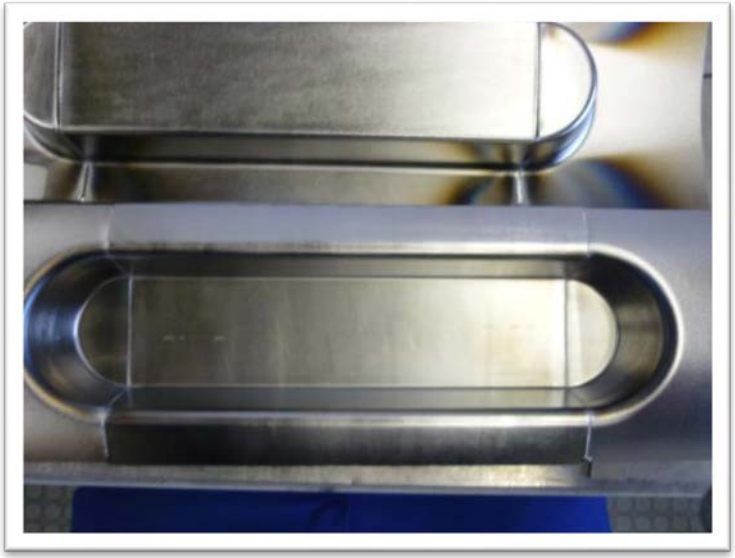
- fabrication inaccuracy (Δf = 0.3-3 MHz)
- thermal shrinkage (Δf ≈ 420 kHz)
- pressure sensitivity (Δf ≈ 100 kHz)
- surface preparation (Δf = 200-800 kHz)
- underground noise (Δf = ±50 Hz)
- helium bubbles

Countermeasures:

- tank / end cell offset 10 mm (Δf ≈ ±1 MHz)
- static tuners (Δf ≈ +1.3 MHz, -2.2 MHz)
- slow bellow tuners (Δf ≈ ±250 kHz)
- fast bellow tuners (Δf ≈ ±300 Hz)

Fabrication Steps

Fabrication Steps



Fabrication Steps

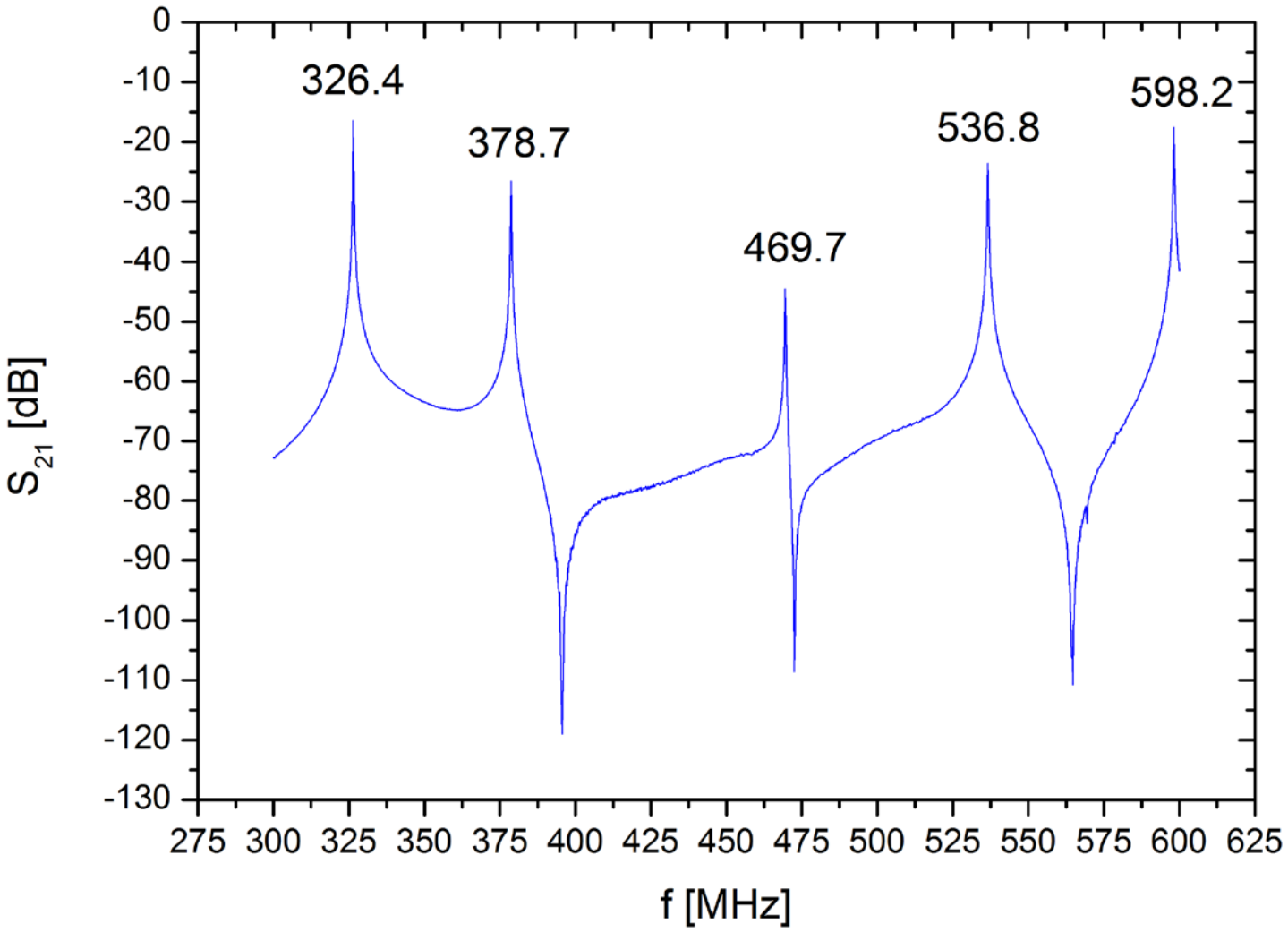
Fabrication Steps

Fabrication Steps

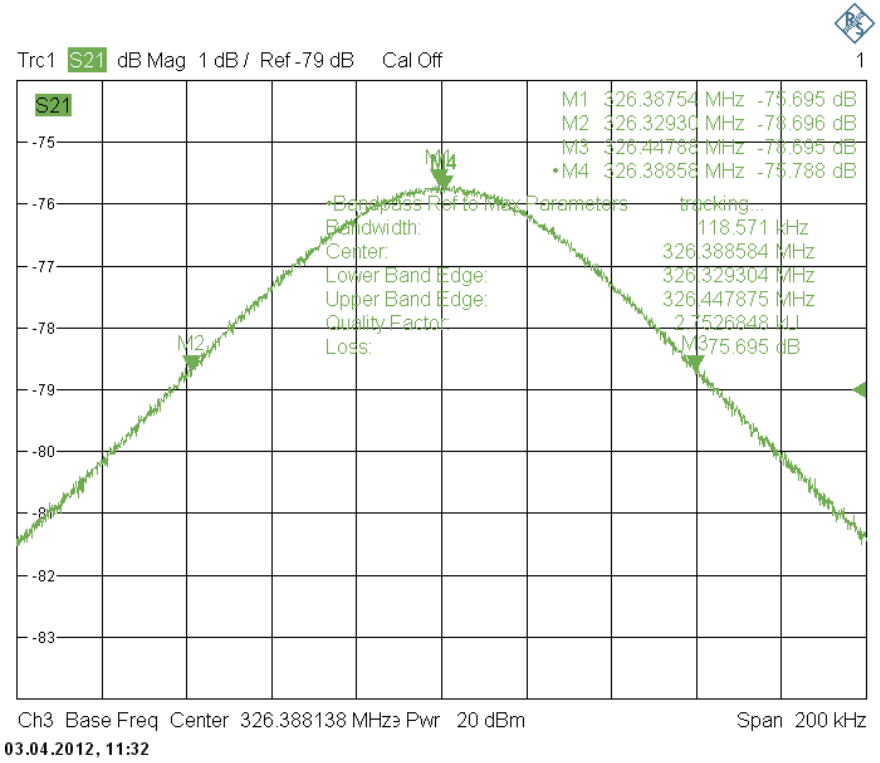
Intermediate Measurements at Research Instruments

First view on the assembled cavity

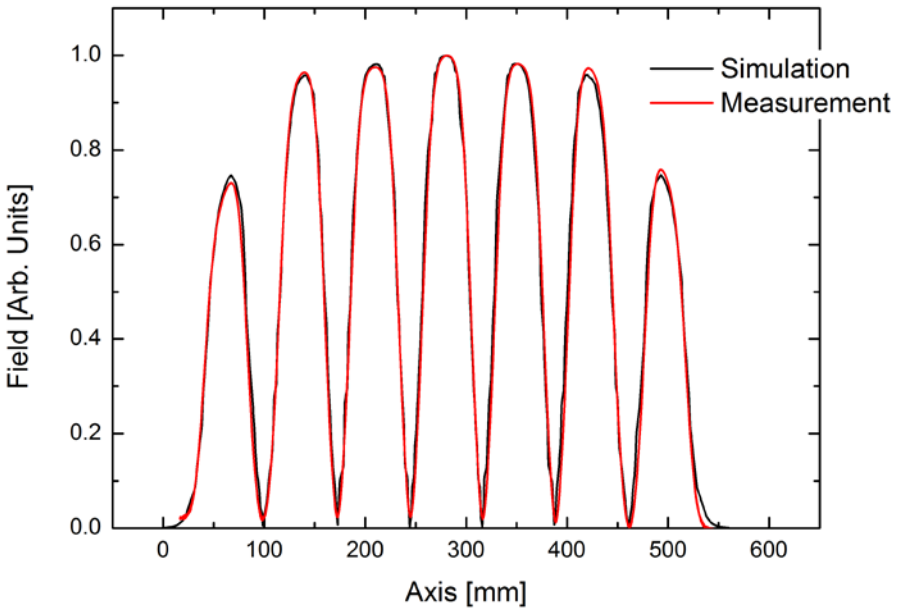
Mode Spectrum



Frequency and E-field

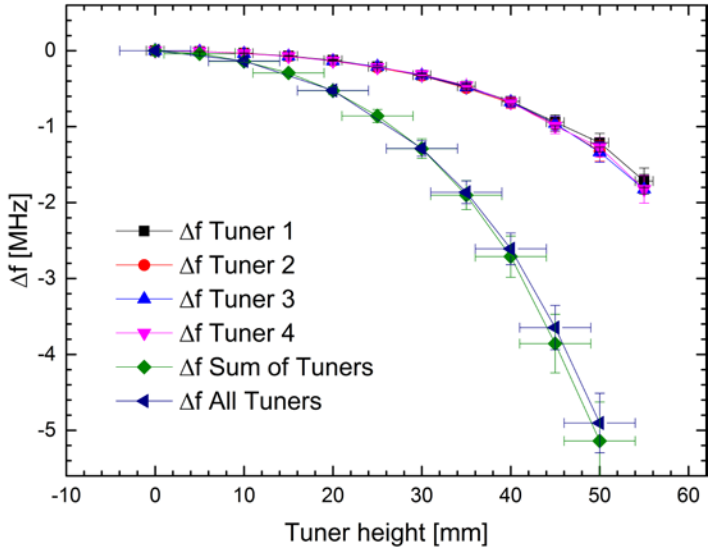


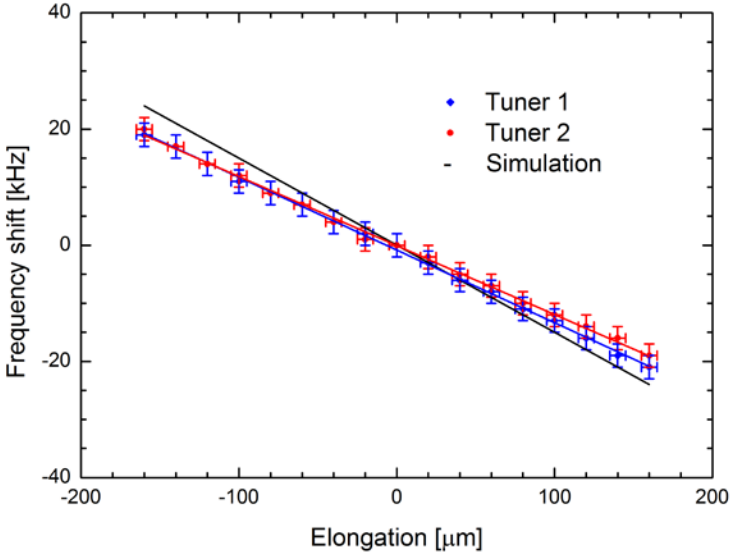
Frequency and Q-value



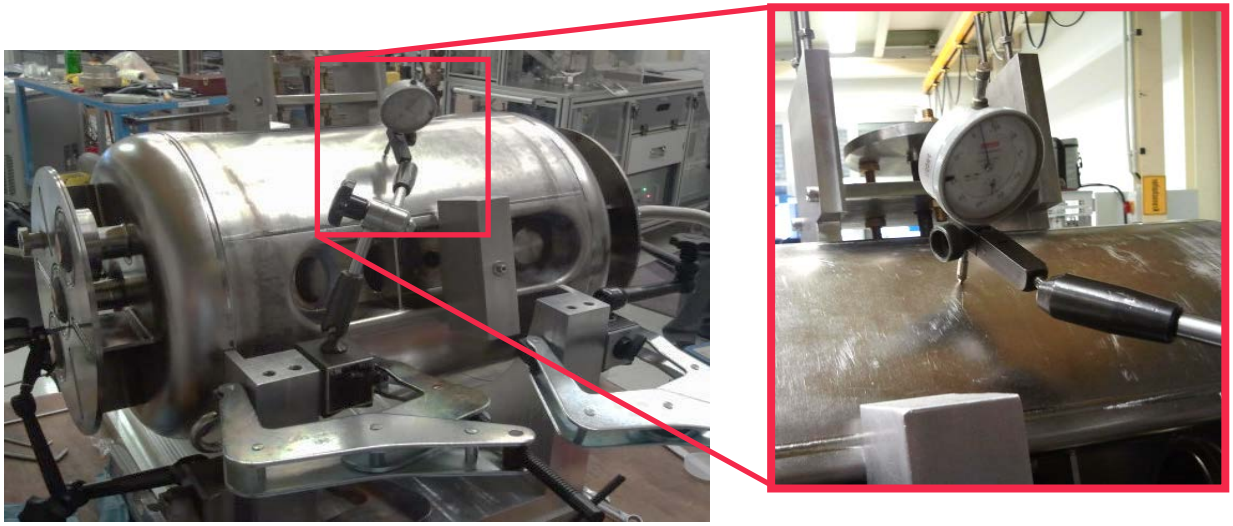
Bead-pull measurement

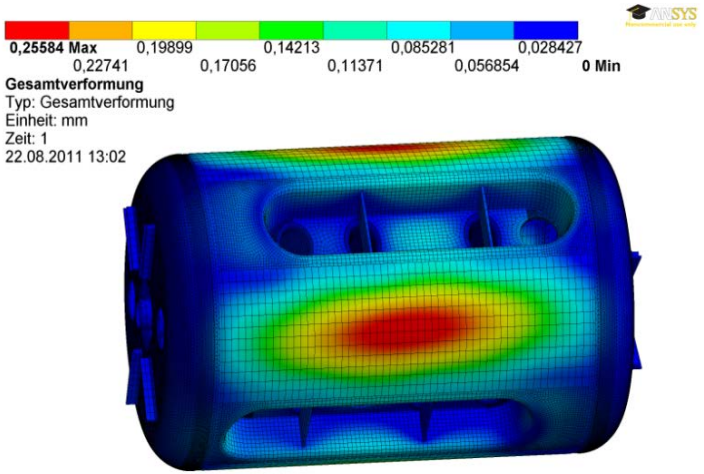
Stroke of Static & Dynamic Tuners

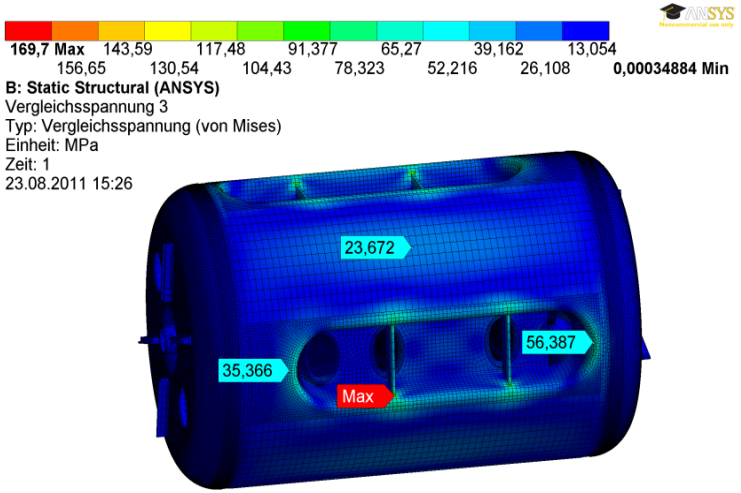




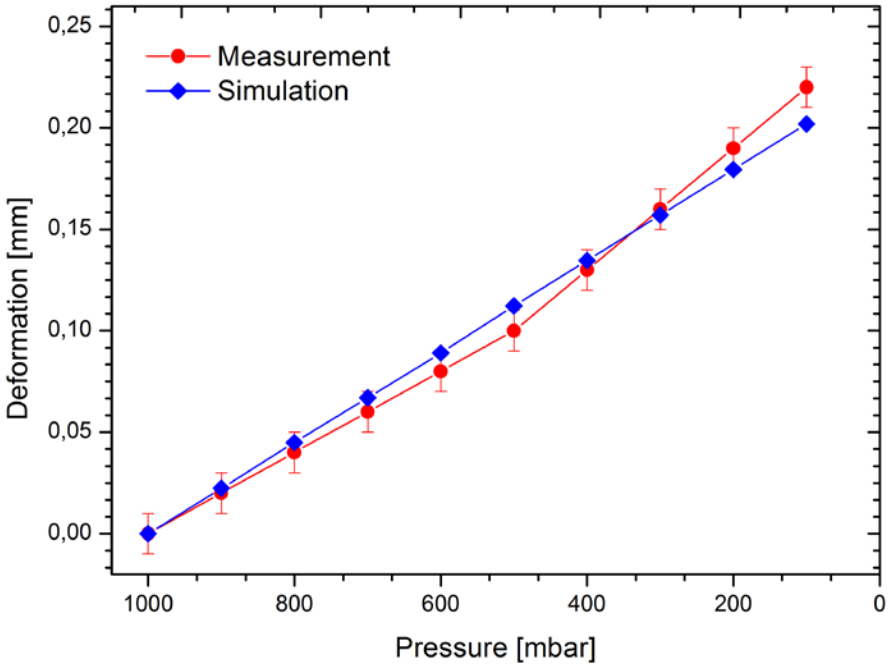
Pressure Sensitivity Measurement

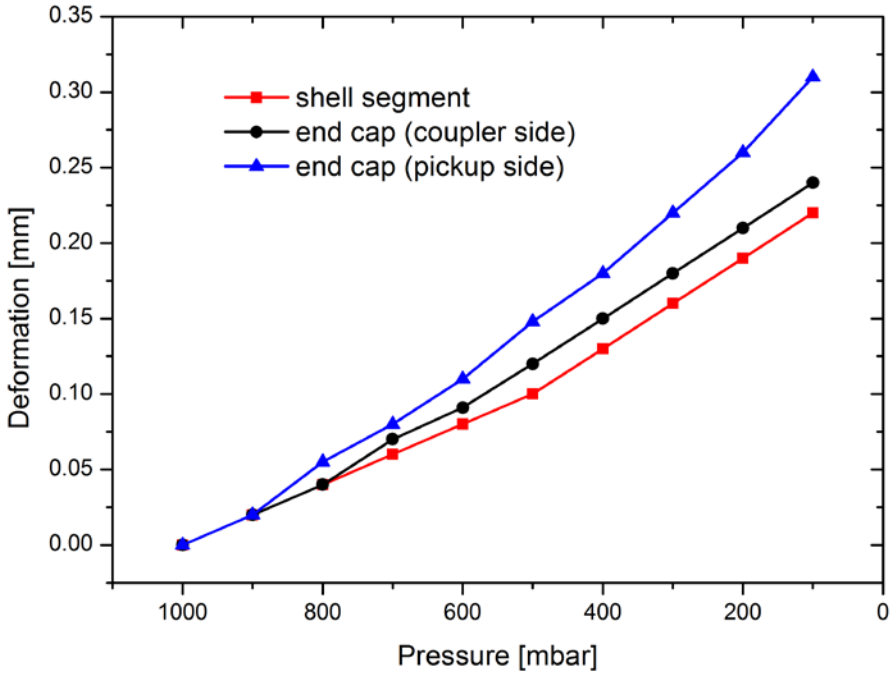






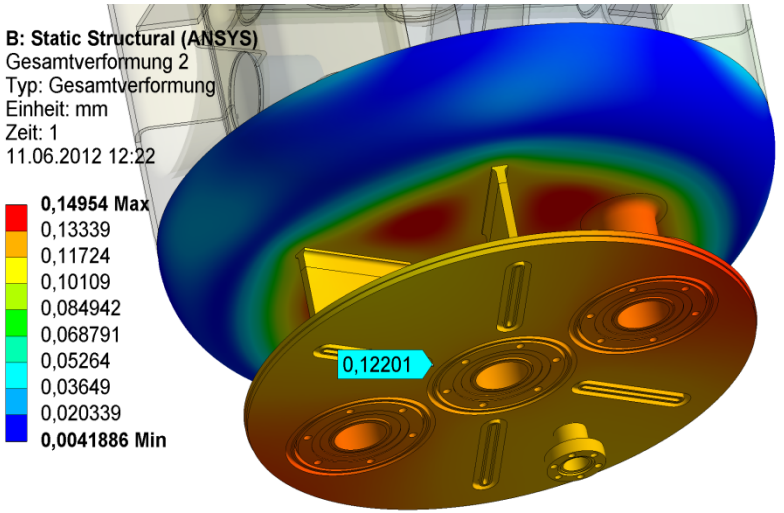
Pressure Sensitivity Mechanical Measurements





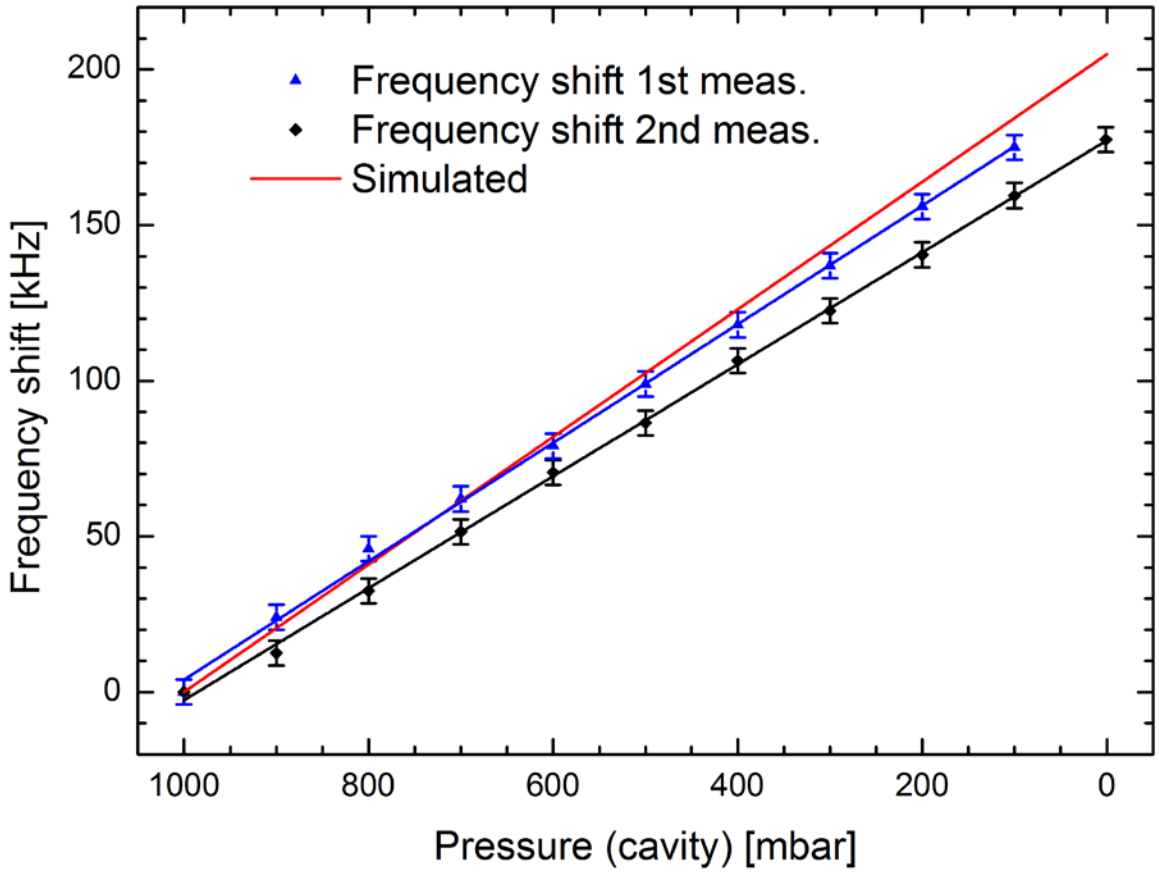
Pressure Sensitivity – Deviation from Results

Deformation of the end cap: **0.24 mm (0.31mm)**
@ 100 mbar residual pressure



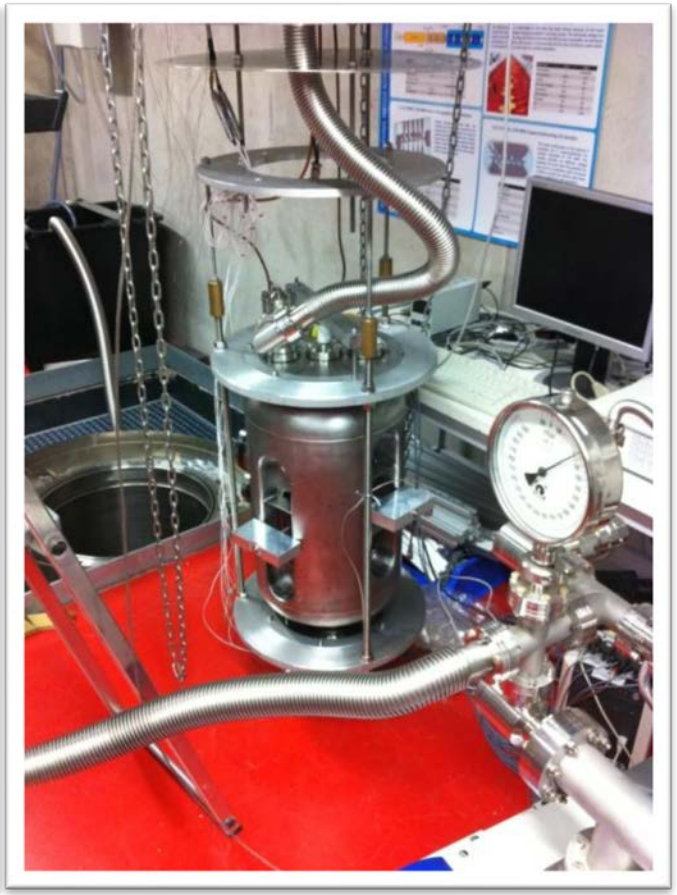
Deformation of the end cap: **0.12 mm**
@ 100 mbar residual pressure

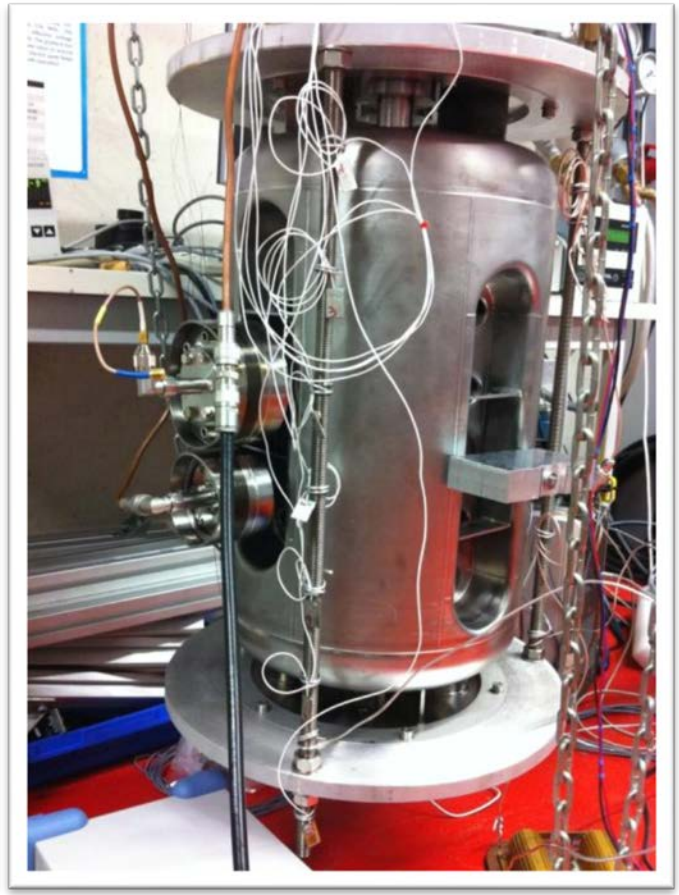
Pressure Sensitivity – RF Results



$\varepsilon_{r,air}$ included (100 kHz)

Measurements at IAP

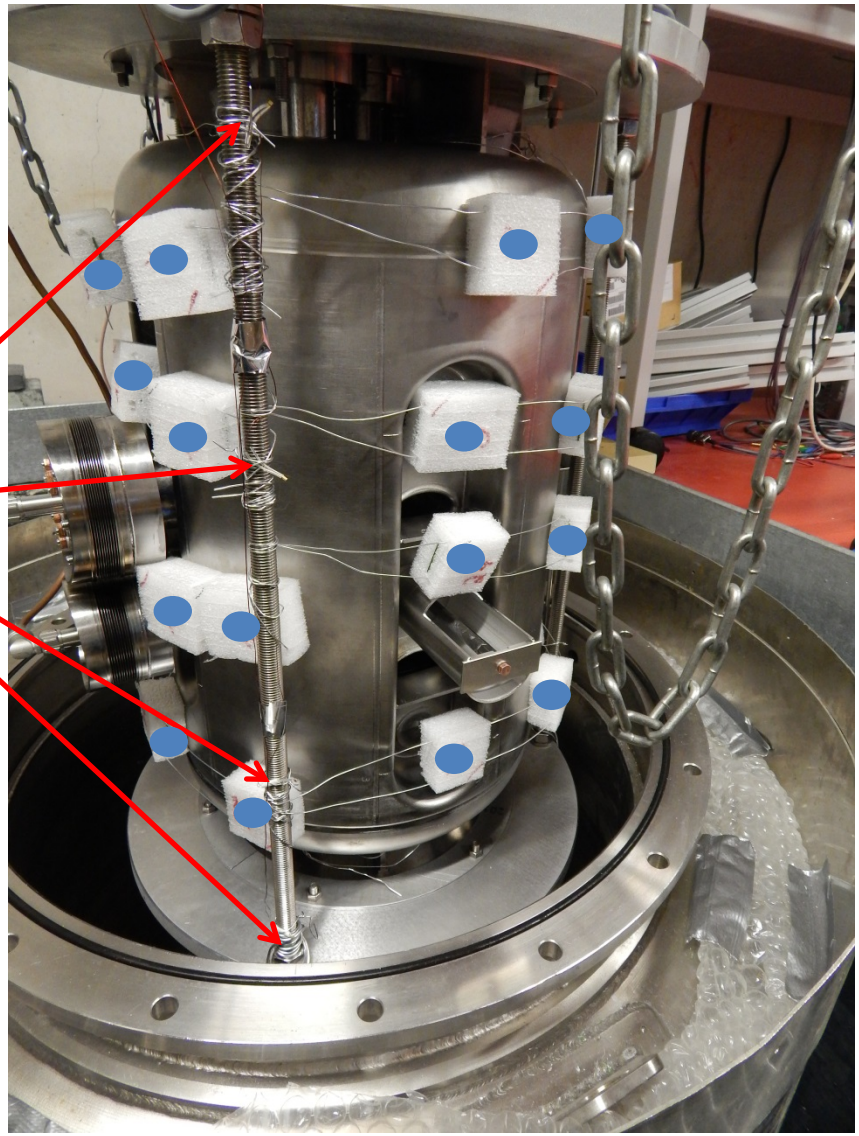




Measurements – Rack setup

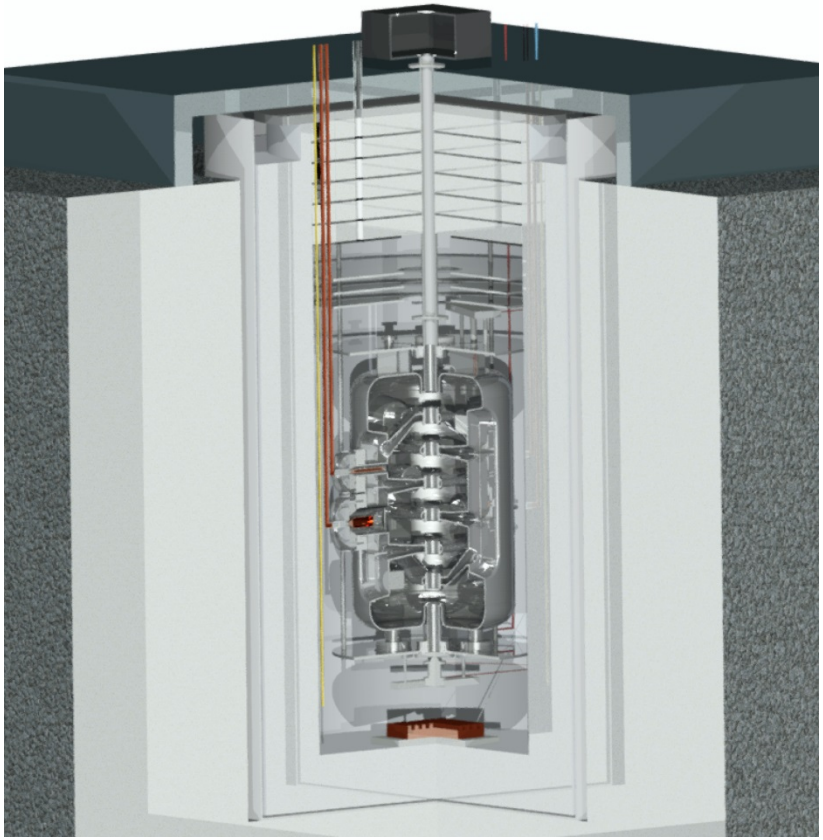
Equipped Cavity

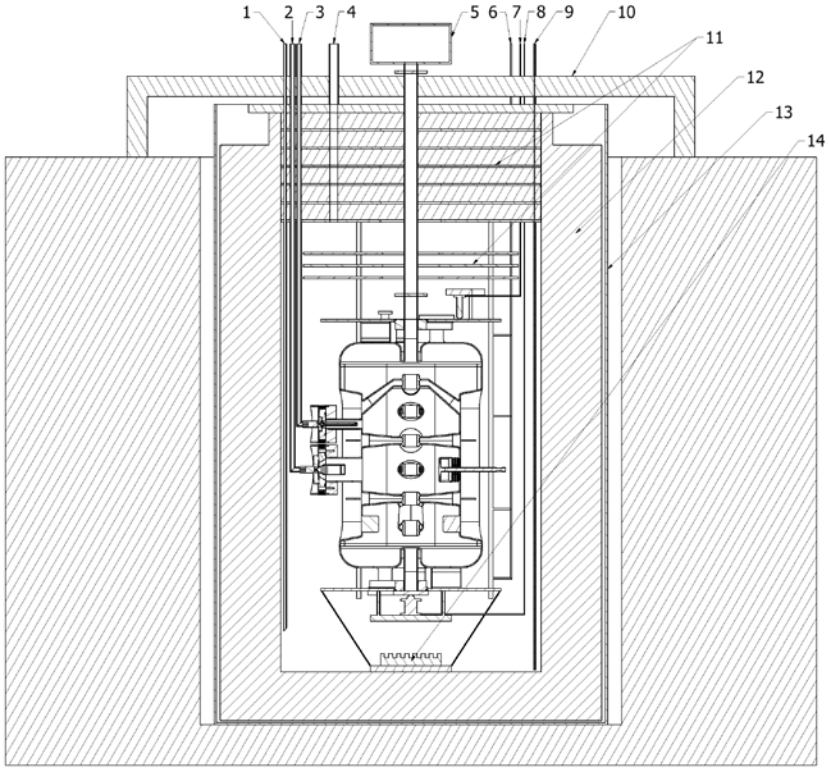
Temperature Probes



TLD (Thermo-Luminescence-Dosimeter)

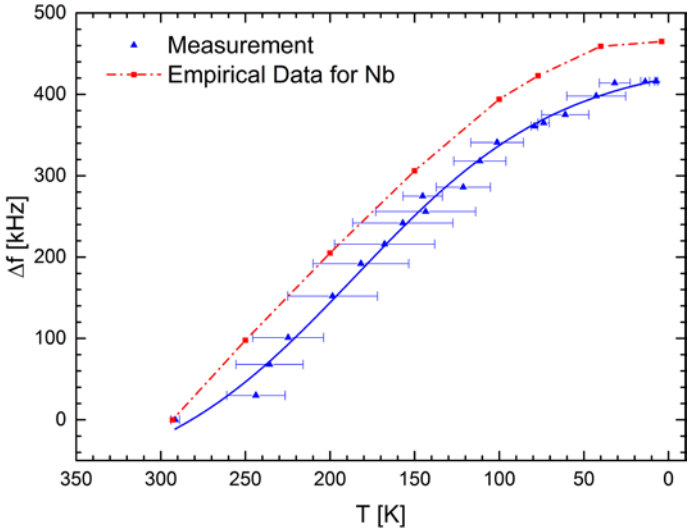
Cryostat Overview

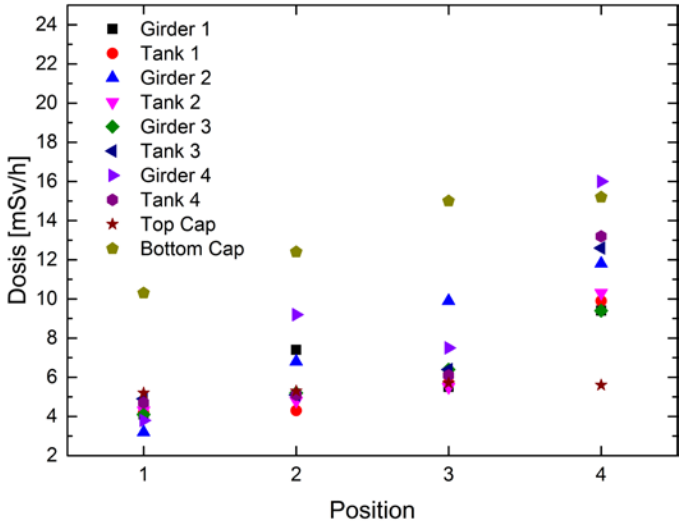


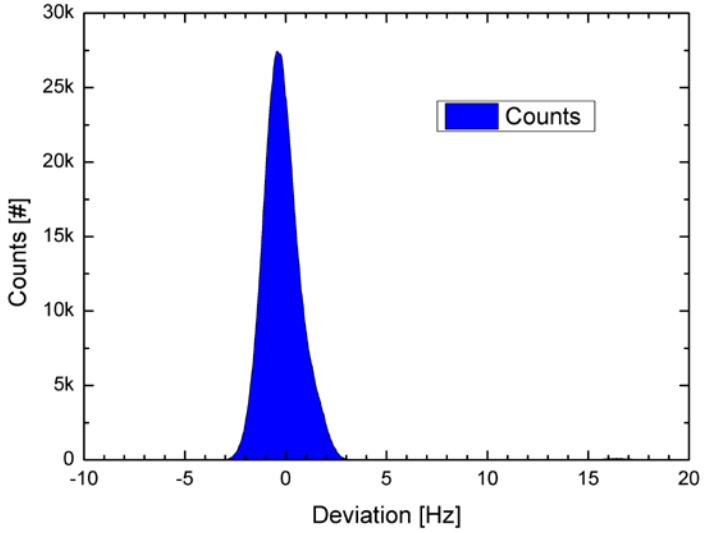


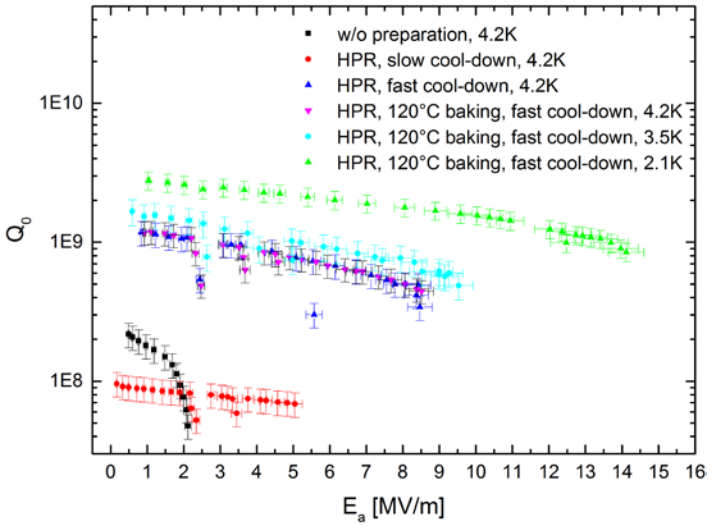
1	Helium transfer line
2	Coupler
3	Pick-up
4	Helium recovery
5	Ion getter pump
6	Temperature probes
7	Piezoactuator drive
8	Piezosensor drive
9	Helium filling level probe
10	Lead shielding
11	Ray shielding
12	Superinsulation
13	Magnetic shielding
14	Heater

Measurements

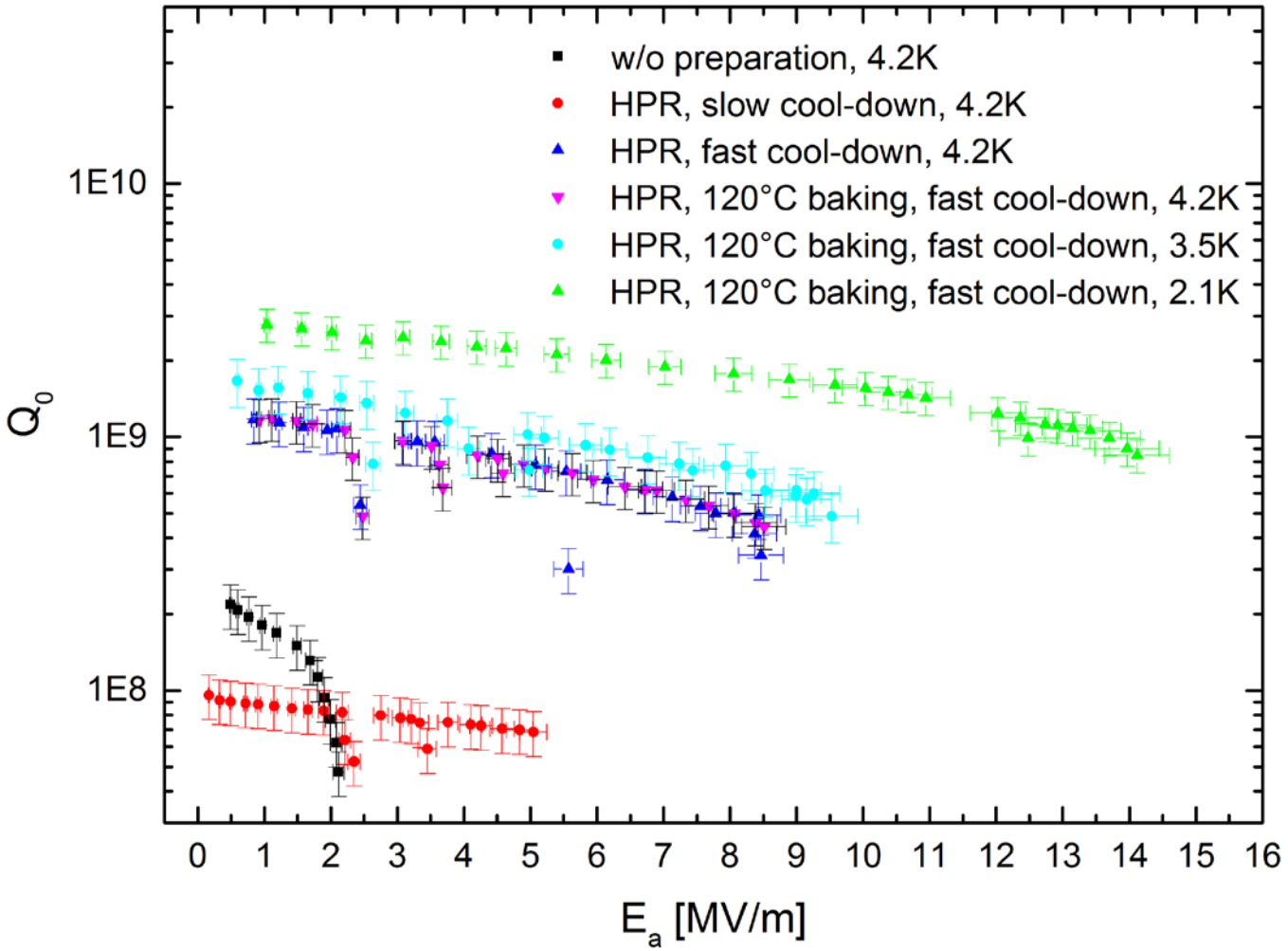








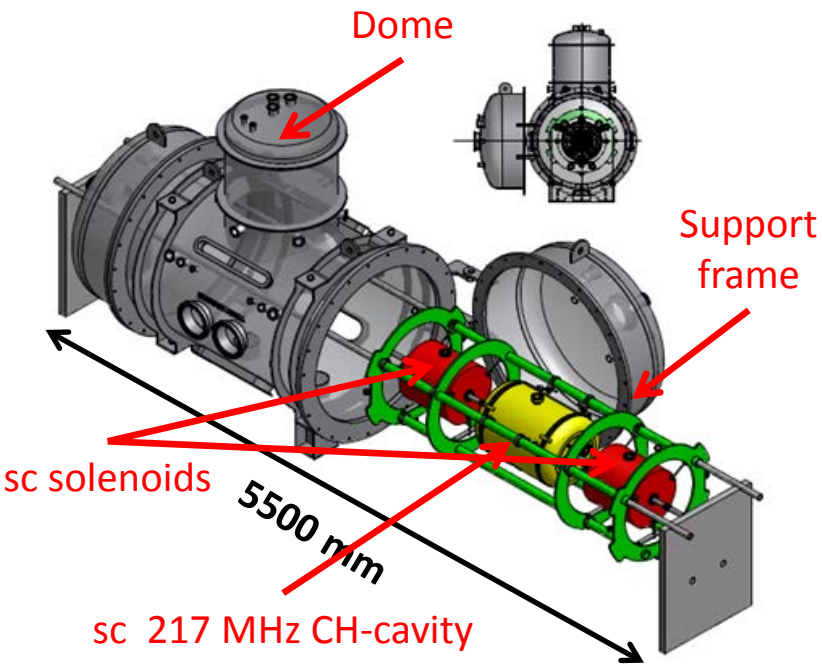
Measurements



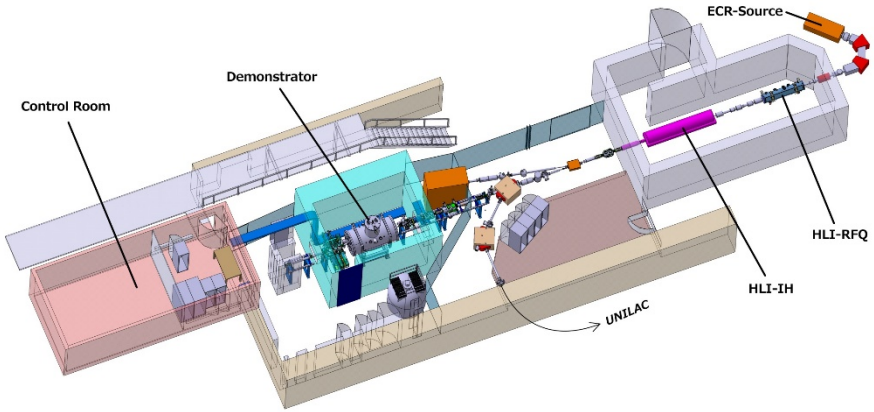
The cw LINAC Demonstrator Project financed by the Helmholtz Institut Mainz (HIM), GSI, and IAP

A full performance test of the demonstrator in 2014/15 is one important milestone on the way to a new sc cw LINAC at GSI

The HLI will be used as an injector for the cw LINAC demonstrator



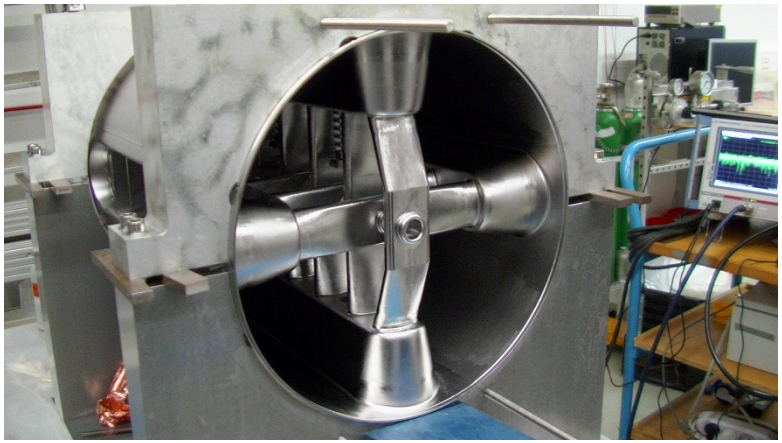
First layout of the horizontal universal cryostat for the cw demonstrator from Babcock Noell

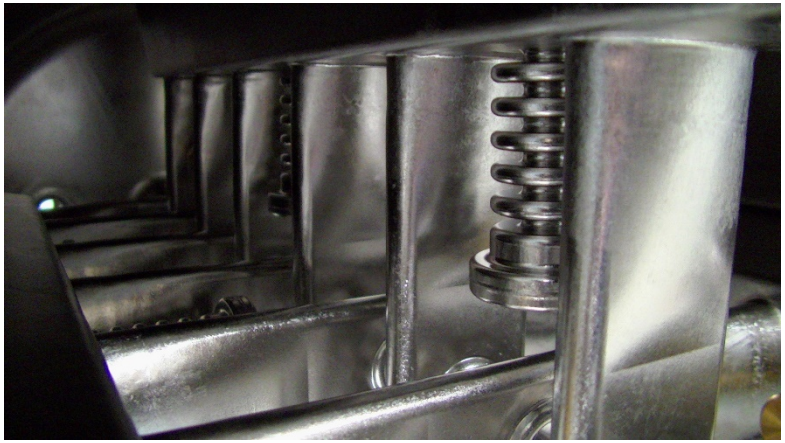


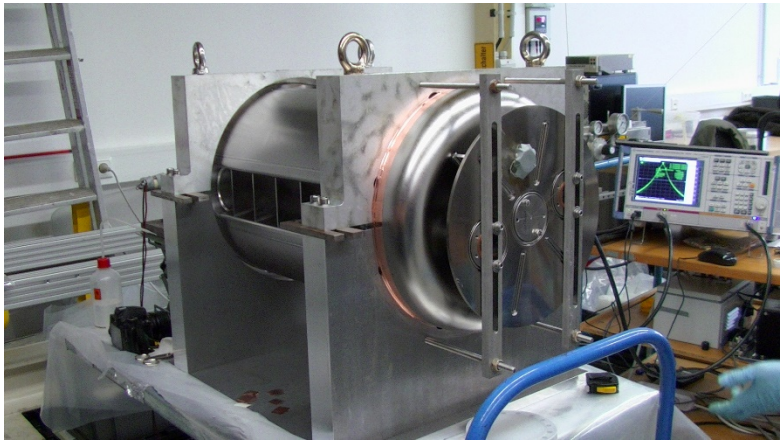
The cw demonstrator mounted after the HLI at GSI

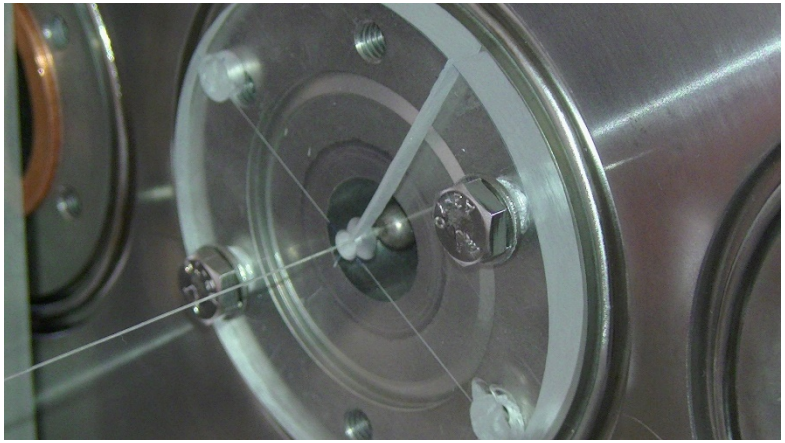
1. RF measurements of the sc 217 MHz CH cavity (with attached end caps, without static tuners)

Setup

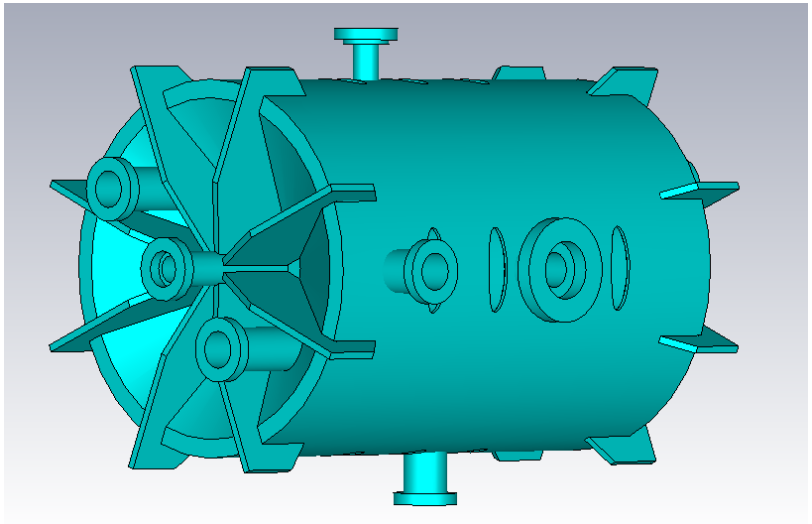


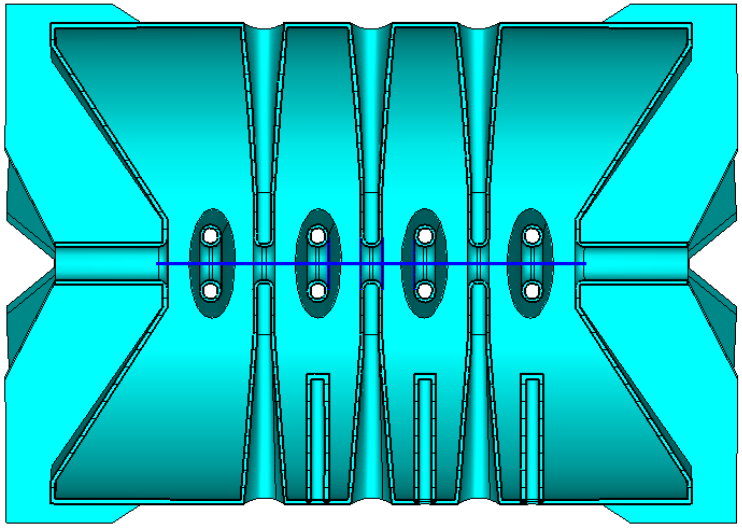






Advanced Demonstrator for GSI SHE Linac





217 MHz 8-Gap Structure

- advanced demonstrator for the SHE-Linac at the GSI
- CH-Structure without girders
- stiffening brackets for high stability and reduced displacement
- constant β design
- low E_{max}/E_a to achieve high electric fields
- small pressure sensitivity (ca. 5 Hz/mbar)