PAUL SCHERRER INSTITUT

PSI

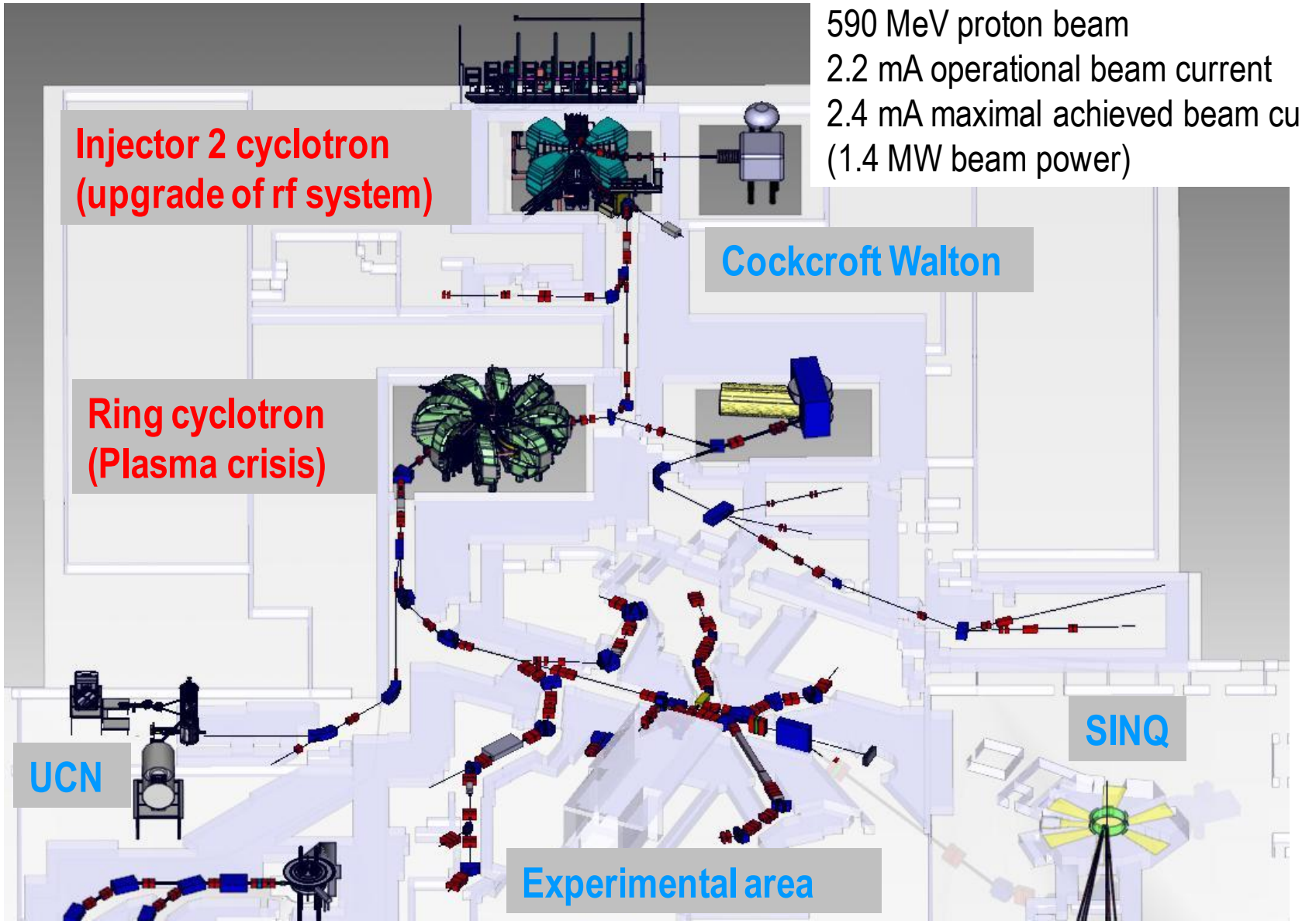
Wir schaffen Wissen – heute für morgen

Paul Scherrer Institut

Markus Schneider

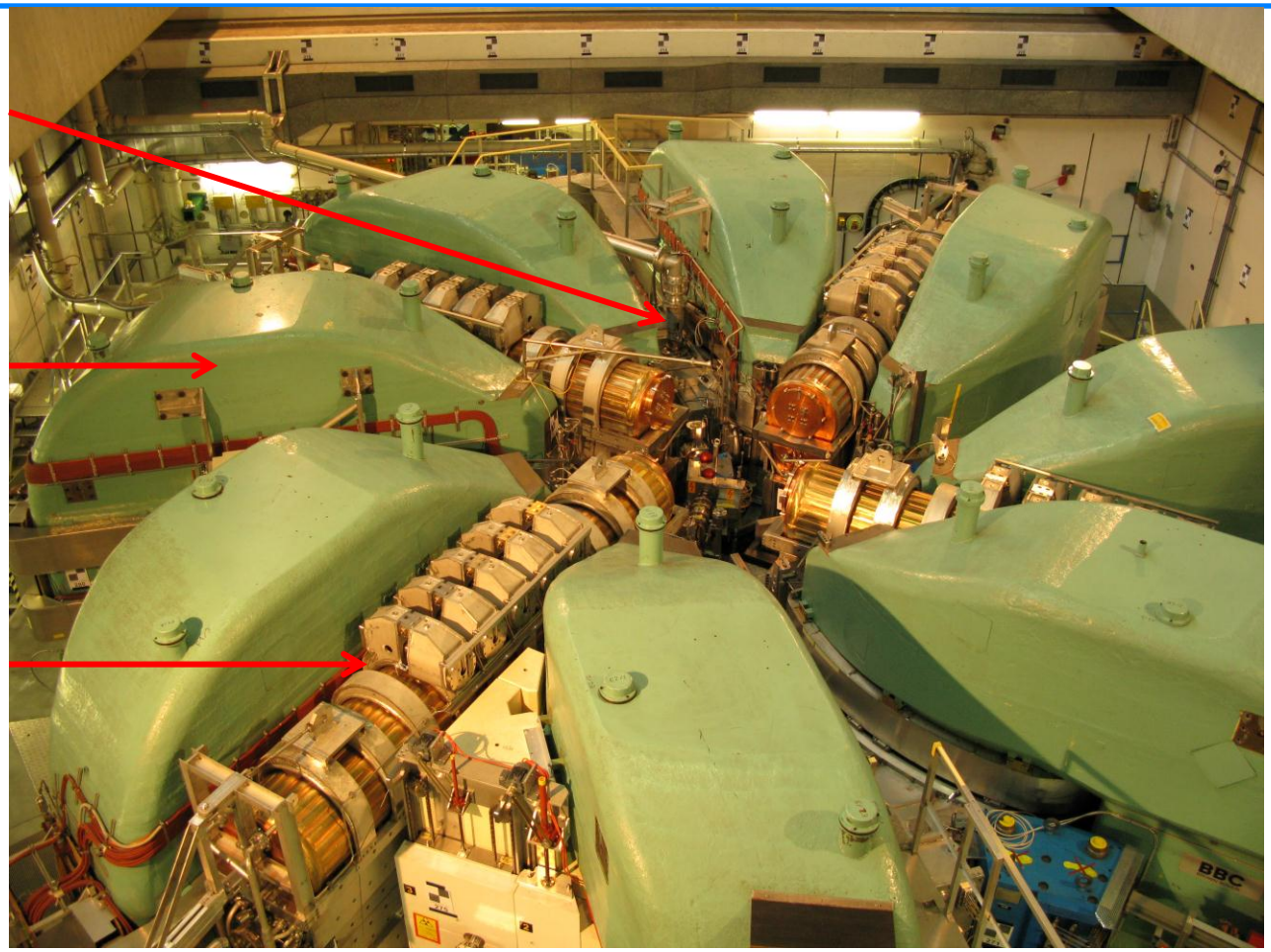
Current activities on the rf-system for the proton accelerator facility at PSI

High intensity proton accelerator facility



590 MeV proton beam
2.2 mA operational beam current
2.4 mA maximal achieved beam current
(1.4 MW beam power)

The Ring cyclotron

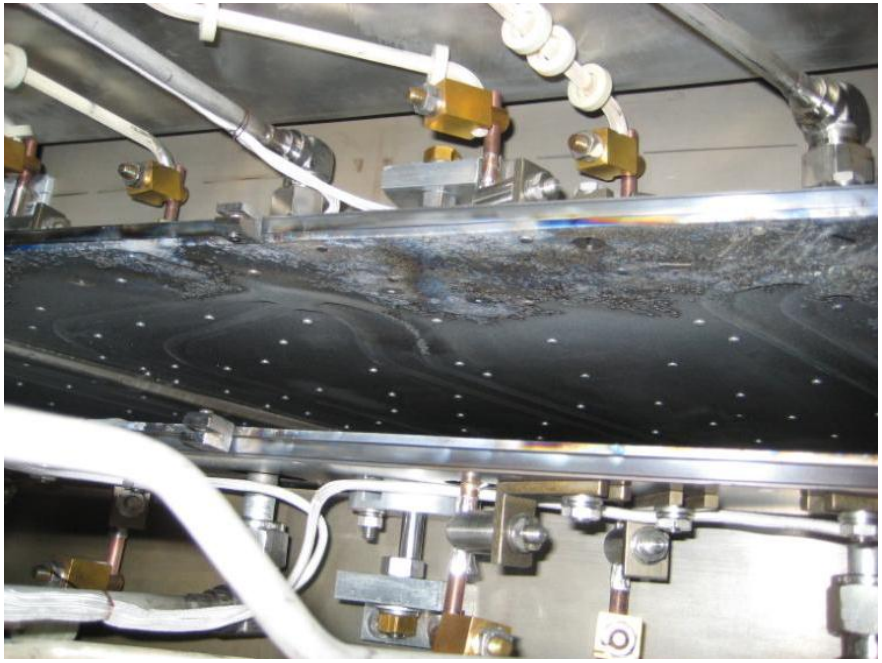


numbers	type	material	frequency	gap voltage	incident power no Beam	incident power @ 2.4 mA Beam
4	Main cavity	copper	50 MHz	~ 850 kVp	~ 250 kW	~ 600 kW
1	Flattop cavity	aluminum	150 MHz	555 kVp	~ 90 kW	~ - 30 kW

Like a firework in the maschine

During operation in 2010 a failure of the cooling system for trim coils in sector magnets occured. The Magnet power supplies were switched off, rf was still running. Temperatures of trim coils went up to 100° C. Since this event the voltage of cavity 3 had to be reduced from 850 kVp to 650 kVp. At higher levels there was a lot of arcing in the cavity and no stable operation possible.

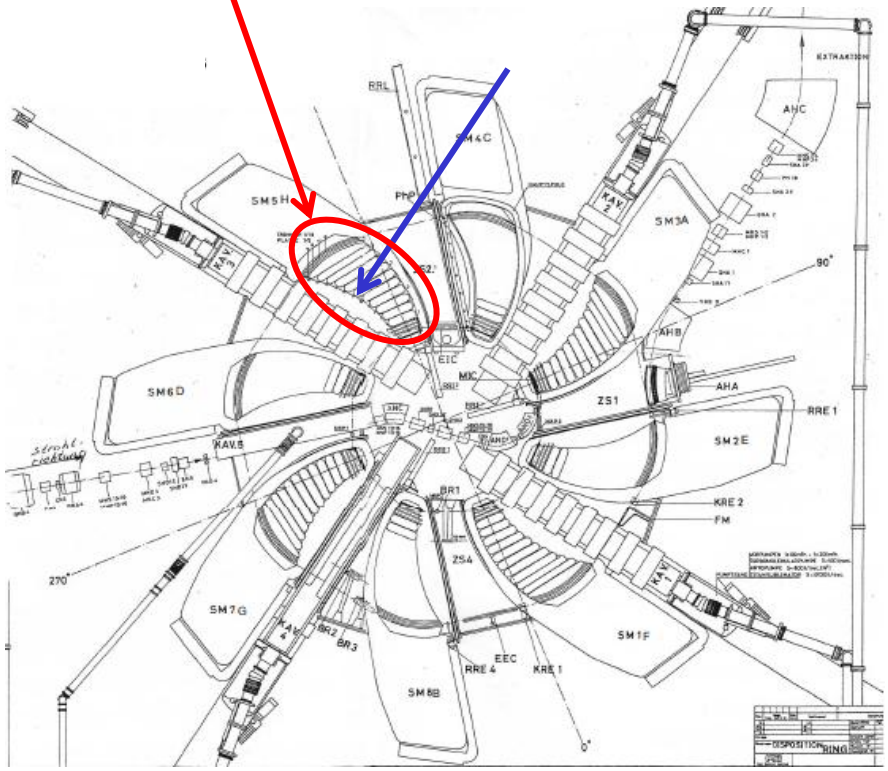
View inside the cycloton at the end of operation period 2010 during tests to push the cavity 3 to nominal voltage.



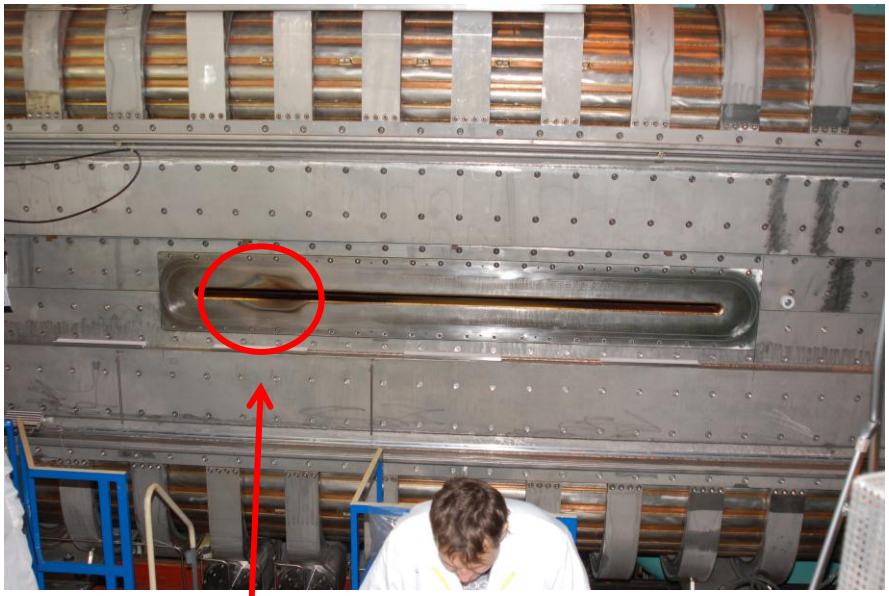
Trim coils of sector magnet 5.
During shutdown 2010 they were replaced.

cavity 3 suffered from the trim coils SM5

Trim coils SM5

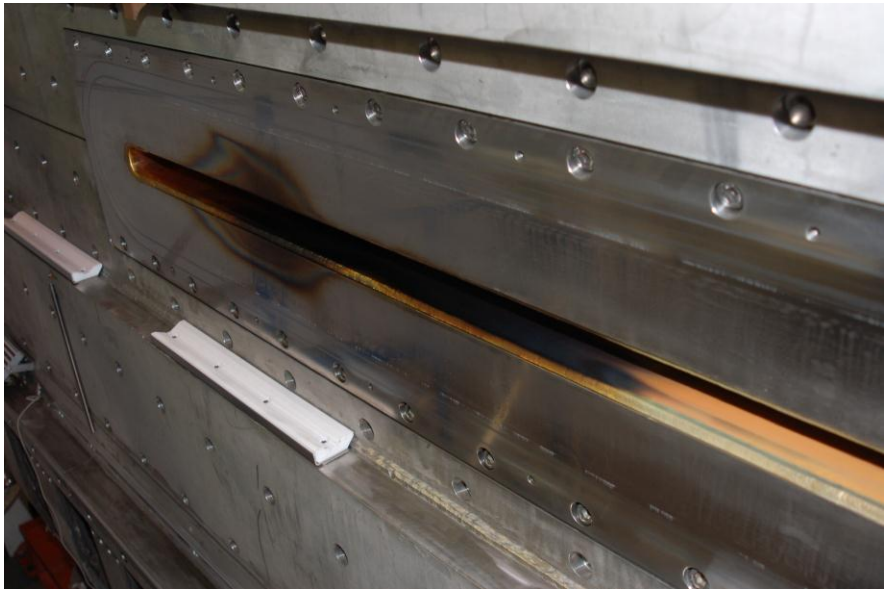


View on cavity 3

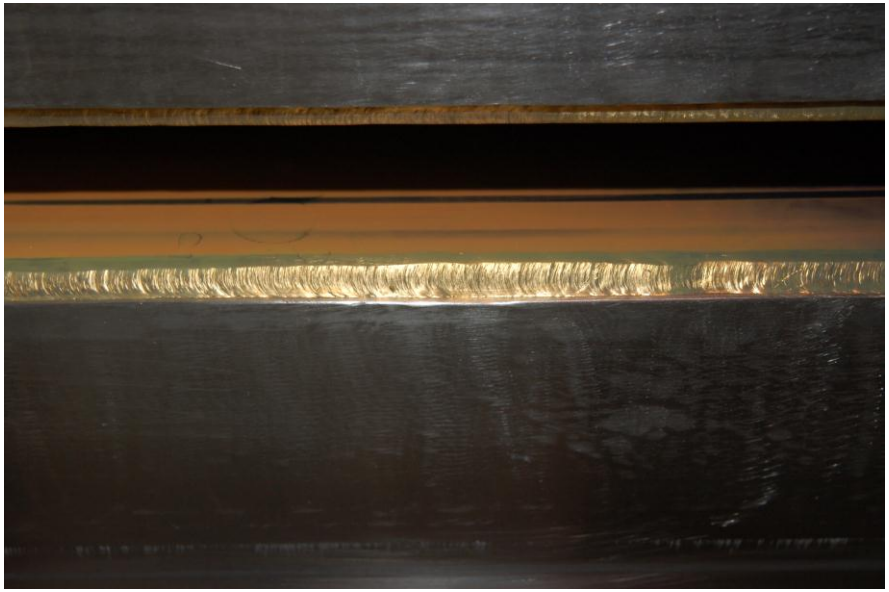


Marks from the „fire work“ in the cyclotron

Outside of cavity 3

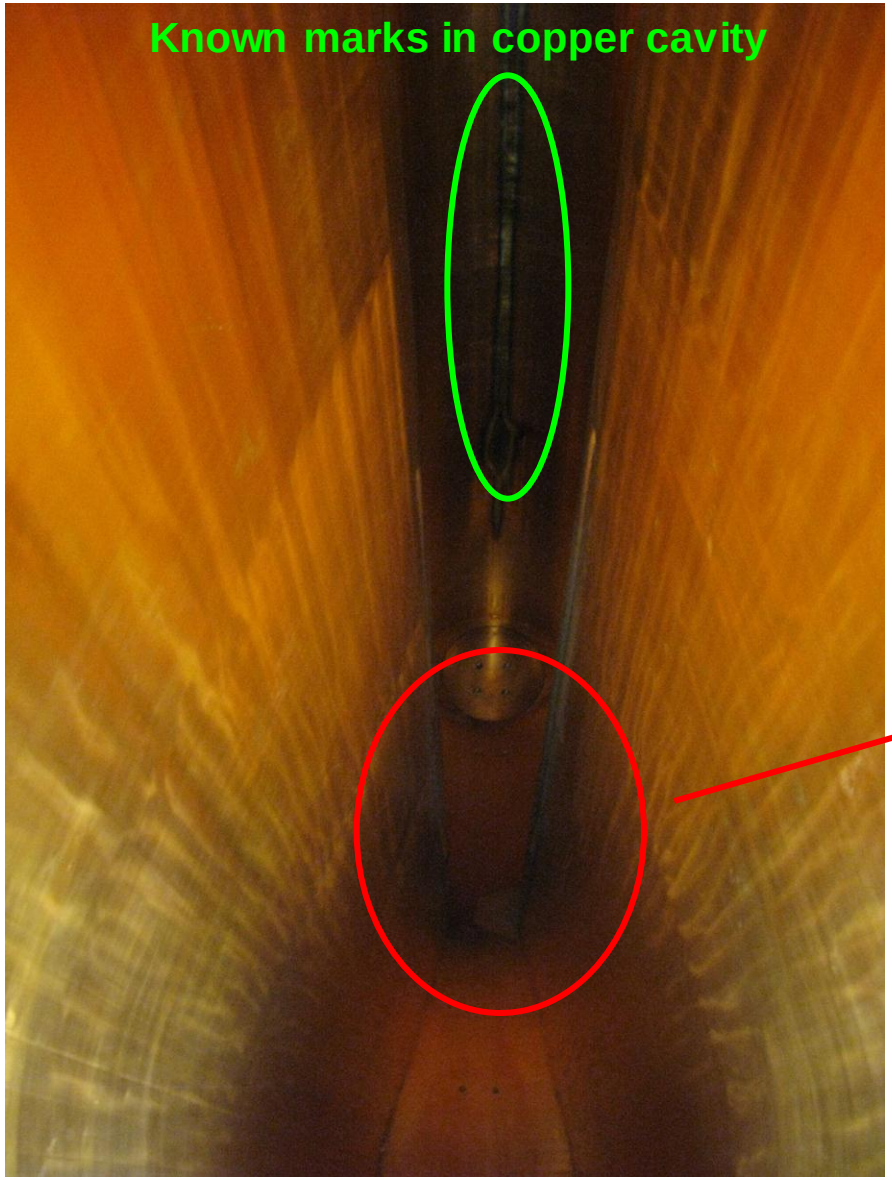


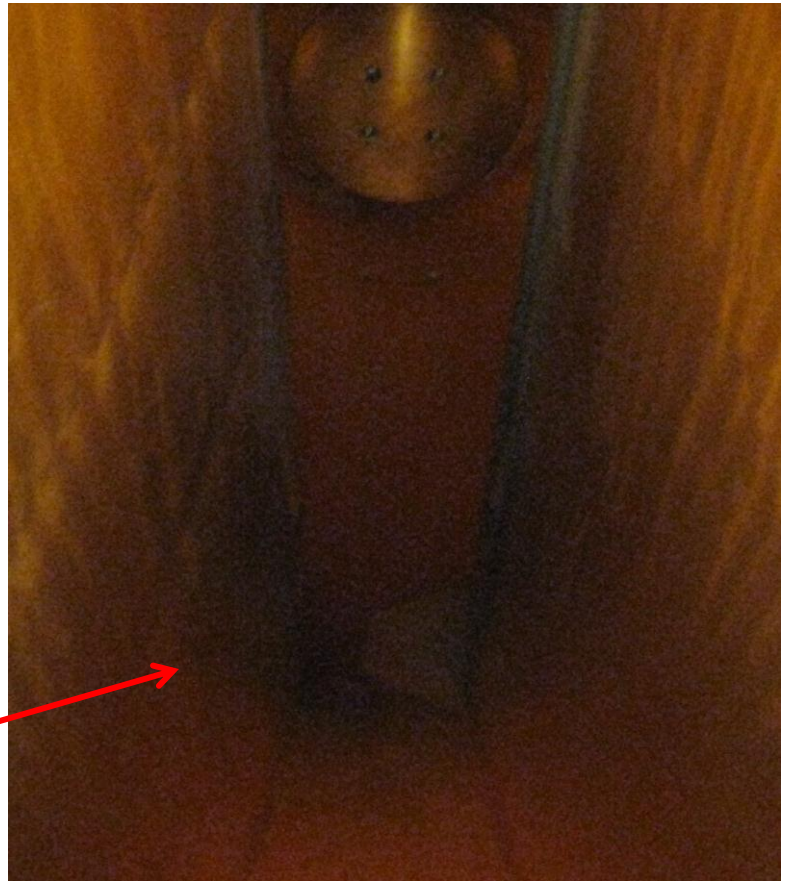
Closed view on cavity 3



Beam slit of cavity 3

Inside cavity 3



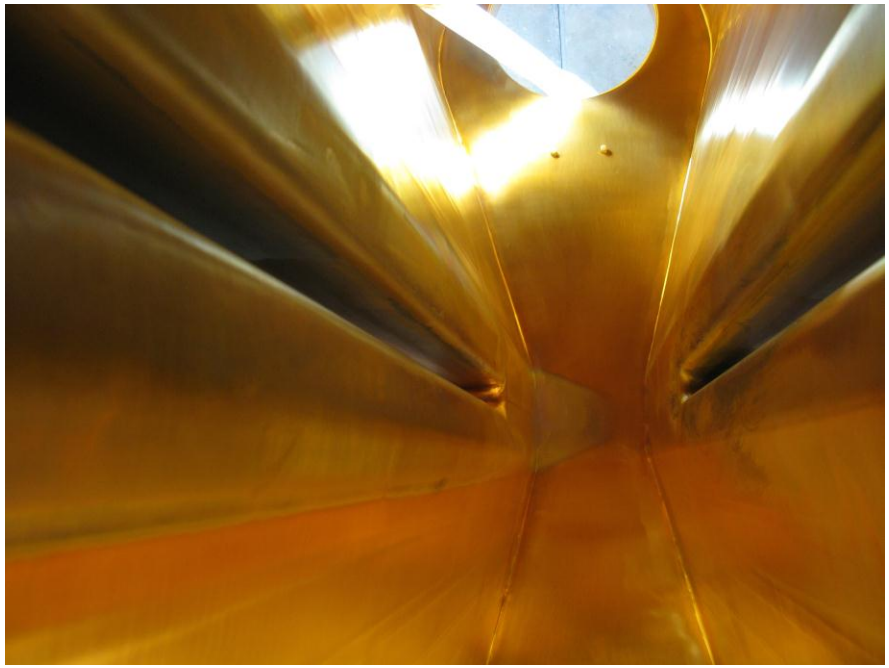


Dirt (aluminum an stainless steel)
➔ material from trim coils

Cavity 3 cleaned during shutdown 2010 and afterwards conditioned to 900 kVp

Cleaning of cavity 2

During operation in 2011 we observed in cavity 2 about 7 to 10 times more micro sparks than in the other cavities. A micro spark is a short spark in the cavity and the rf is switched of for about 200 µs. Inspection of cavity 2 in shutdown 2012.



Inside cavity 2.
The same mark as in cavity 3 but from the other direction.

Cleaning of cavity 2 with „Miobrill“ and alcohol. After this procedure cavity condition to 900 kVp. Reduction of micro sparks ? ⇨ result in one year.

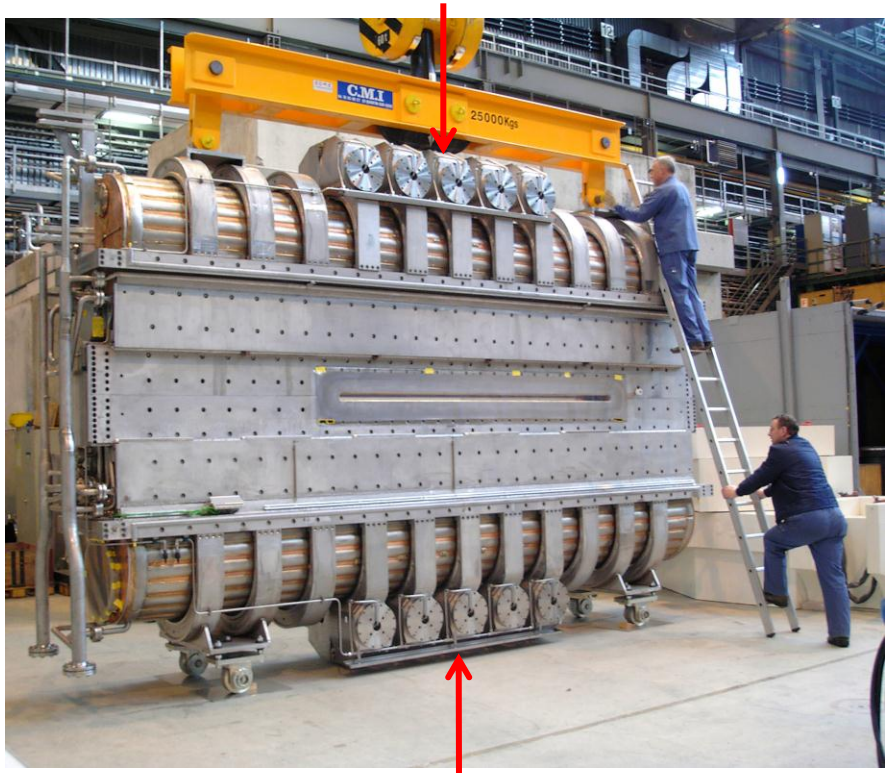
Tuning system of copper cavity

A very expensive barometer

Change of resonance frequency

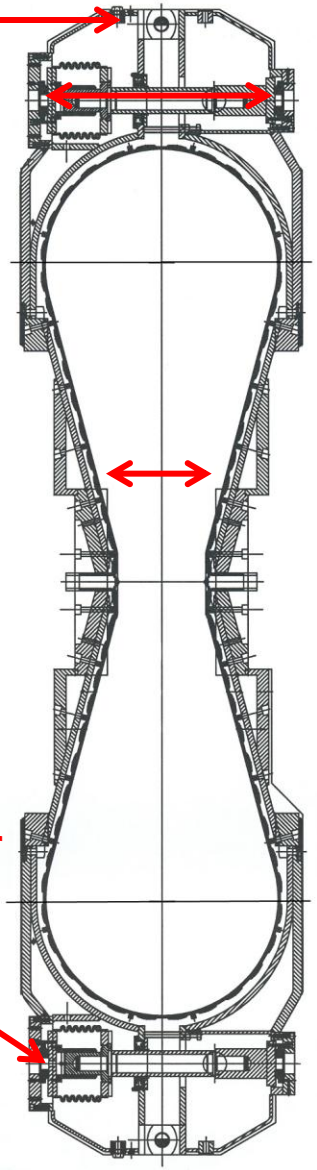
Hydraulic pressure	~ 800 kHz / Bar
Atmospheric pressure	~ 670 Hz / mBar

5 upper hydraulic tuning yokes



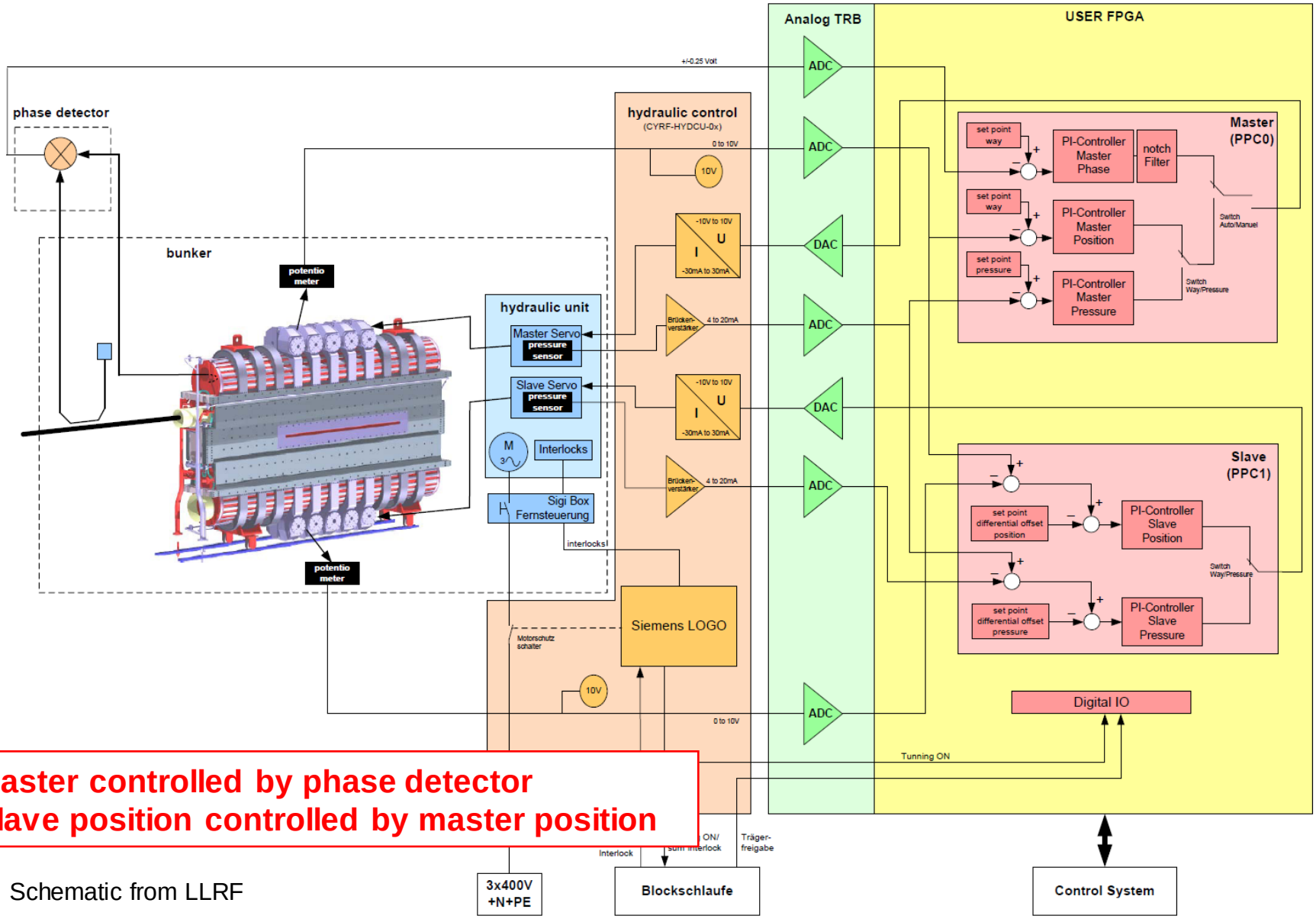
5 lower hydraulic tuning yokes

swivel joint



hydraulic cylinder operation at about 33 Bar

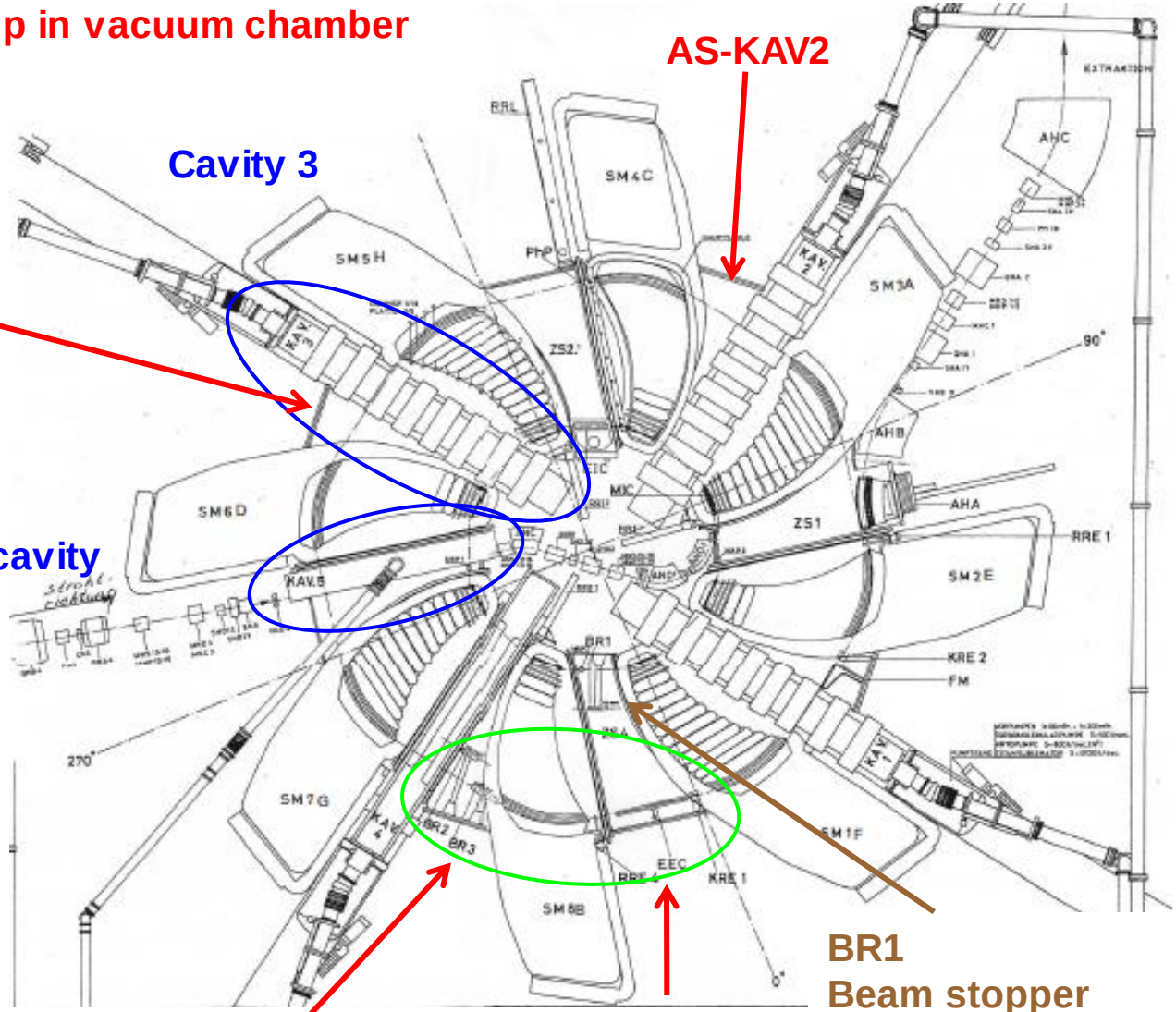
Differential tuning system on cavity 3



Master controlled by phase detector
Slave position controlled by master position

Schematic from LLRF

Measurements of radiated rf in cyclotron



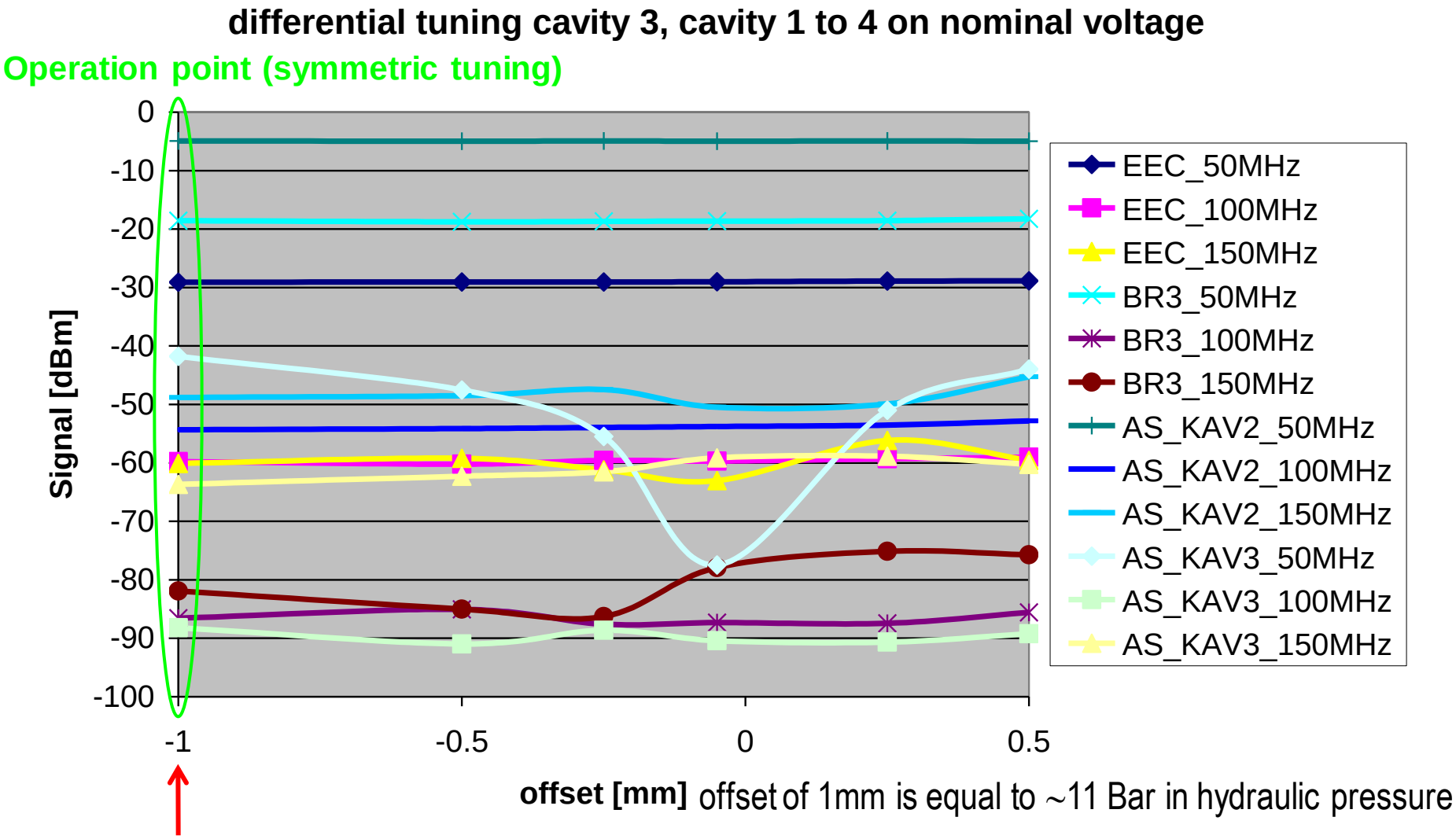
Radiated rf from flattop cavity ignites "plasma" in SM7.
Effect seen on BR3 and EEC.

Differential tuning system on cavity 3 and flattop cavity

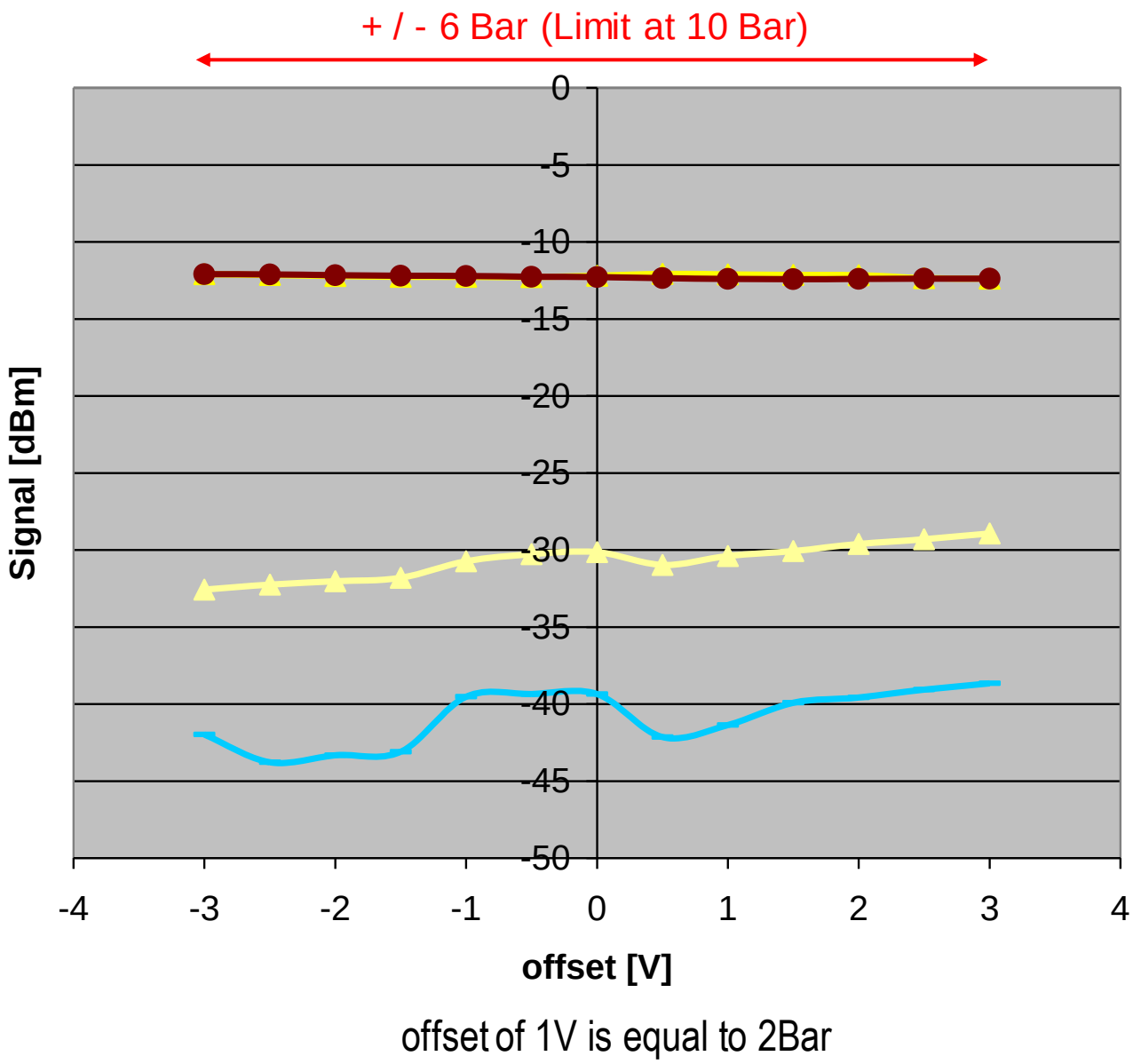
rf measurements on pickups, BR3, EEC

BR1 has an impact on measured rf at BR3 and EEC

Differential tuning cavity 3



Differential tuning flattop cavity



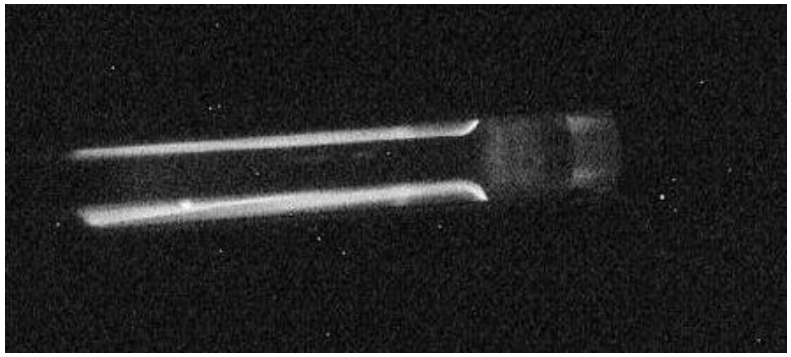
offset of 1V is equal to 2Bar

Master controlled by phase detector

Slave pressure controlled by master pressure

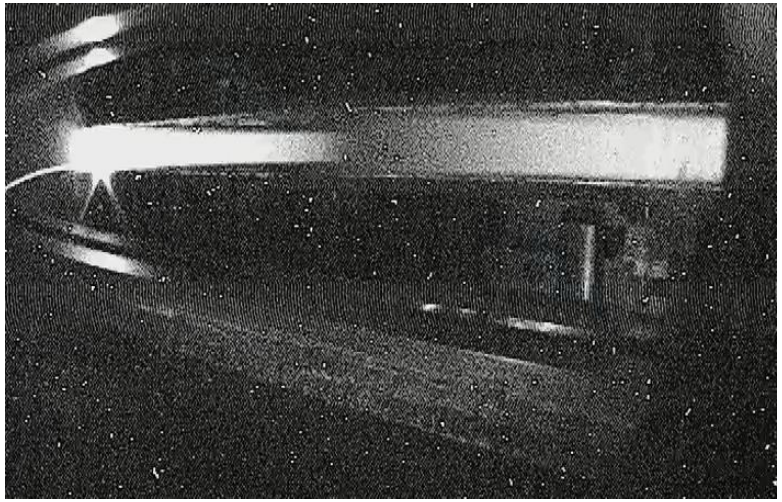
Hydraulic pressure of Flattop cavity during regular operation is at about 100Bar. Maximal pressure 120Bar. Cavity is working on the limits. High risk of damaging cavity!

Summary of „plasma crisis“ in Ring cyclotron



View in flattop cavity

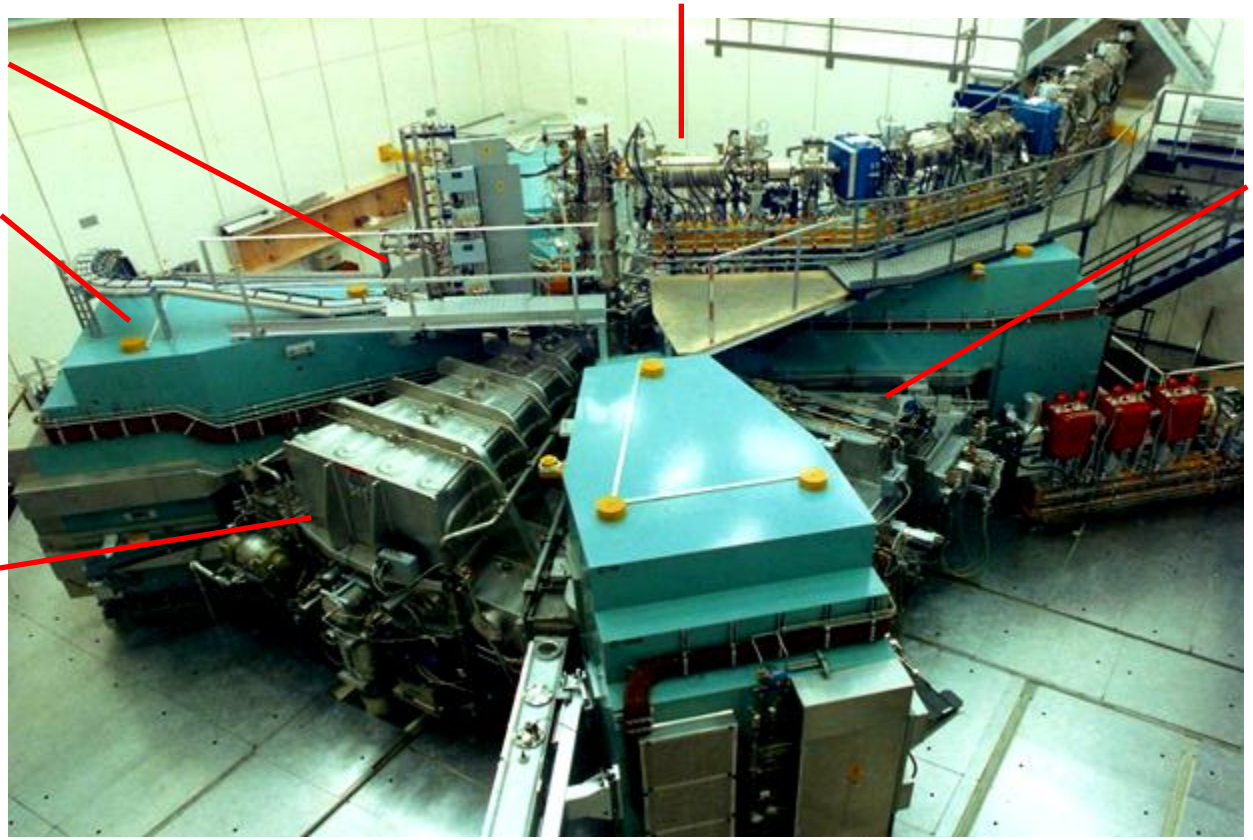
We have to live with some glowing in the cyclotron...
maybe it was there during the last 35 years



View at plasma from window
at flattop cavity toward SM7

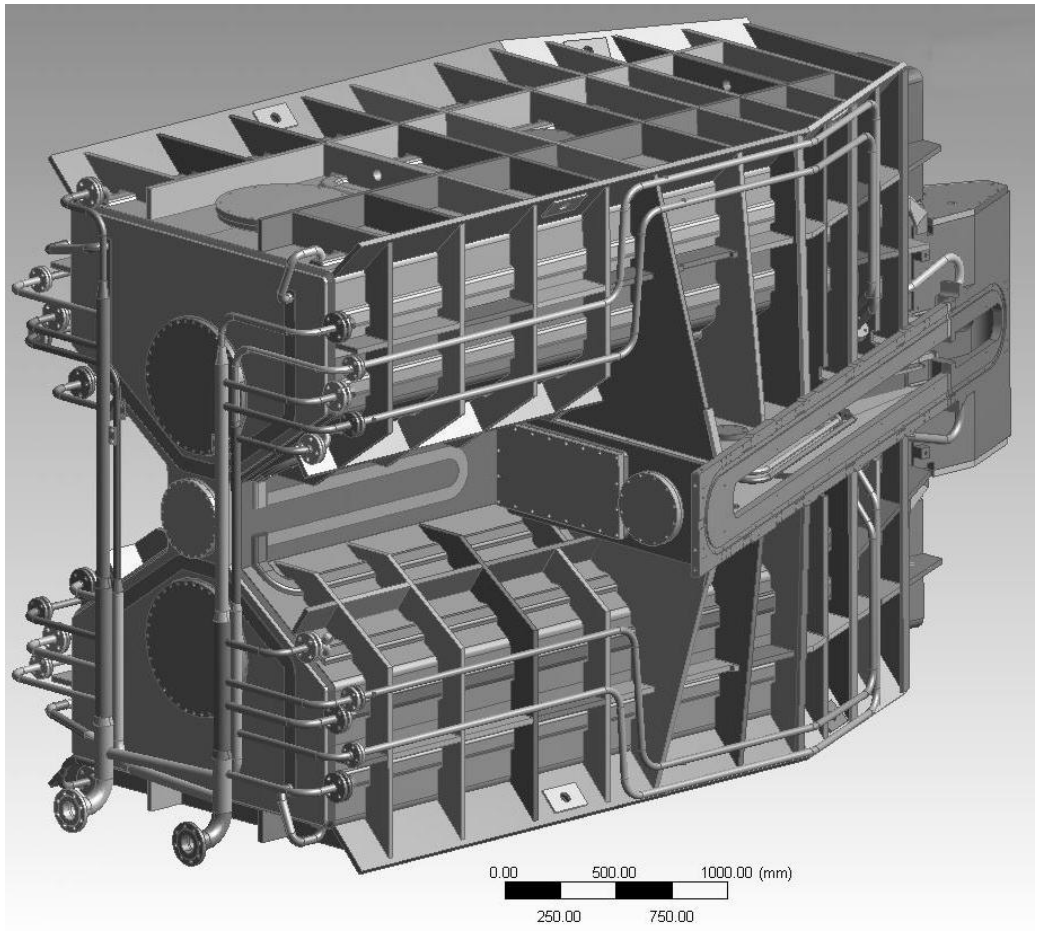
- Interlock on rf when cooling system for trim coils fails
- Cavity 3 cleaned and again up to nominal gap voltage
- Cavity 2 cleaned. Reduction of micro sparks?
- Differential tuning system on cavity 3 installed. Disadvantage of slower tuning, improvement on radiated rf in cyclotron only on AS-KAV3 measured. Offset -1mm ⇨ symmetric tuning during regular operation.
- BR1 (beam stopper) can not be installed
- Differential tuning system on flattop cavity tested. No effect seen during measurements. Back to symmetric tuning system.
  Extension of differential tuning range? Risk of permanent deformation of flattop cavity!

Injector 2 cyclotron



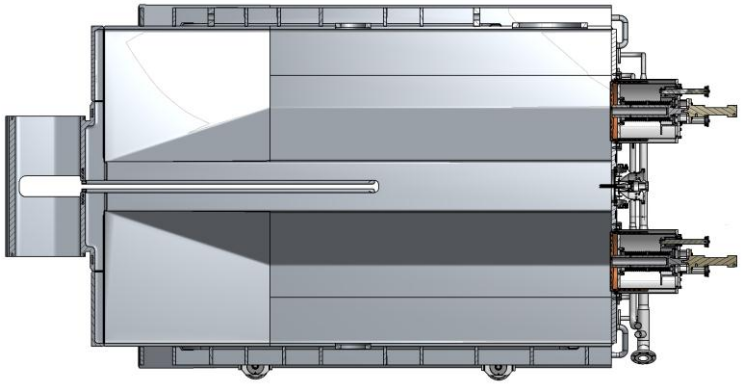
150 MHz resonator 2 and resonator 4 will be replaced by 50 MHz resonators.
Amplifier chain and LLRF for all resonators will be renewed.
Project delayed due to priority given to SWISSFEL. Lack of manpower.

New 50 MHz Resonator 2 & 4 for Injector 2

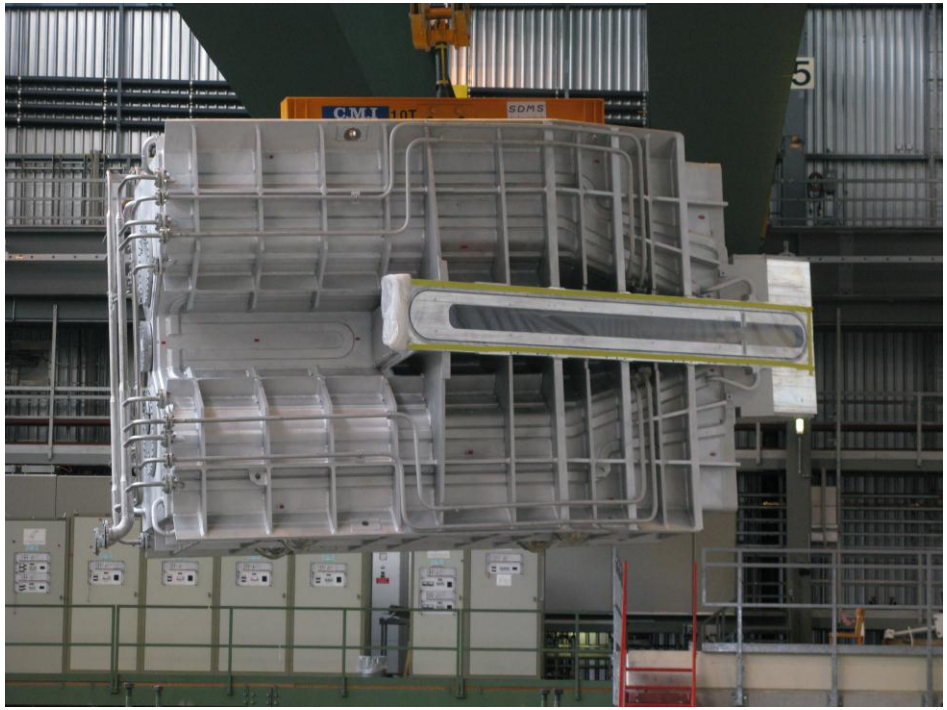


Specification

Resonance frequency:	**50.6328 MHz**
Accelerating voltage:	**400 keV**
Dissipated power:	**45 kW@400kV**
Tuning range:	**200 kHz**
Cavity RF-wall:	**EN AW 1050**
Structure:	**EN AW 5083**
Vacuum pressure:	**1e-6 mbar**
Cooling water flow:	**15 m3/h**
Dimension:	**5.6x3.3x3.0 m**
Weight:	**7‘000 kg**



New 50 MHz Resonator



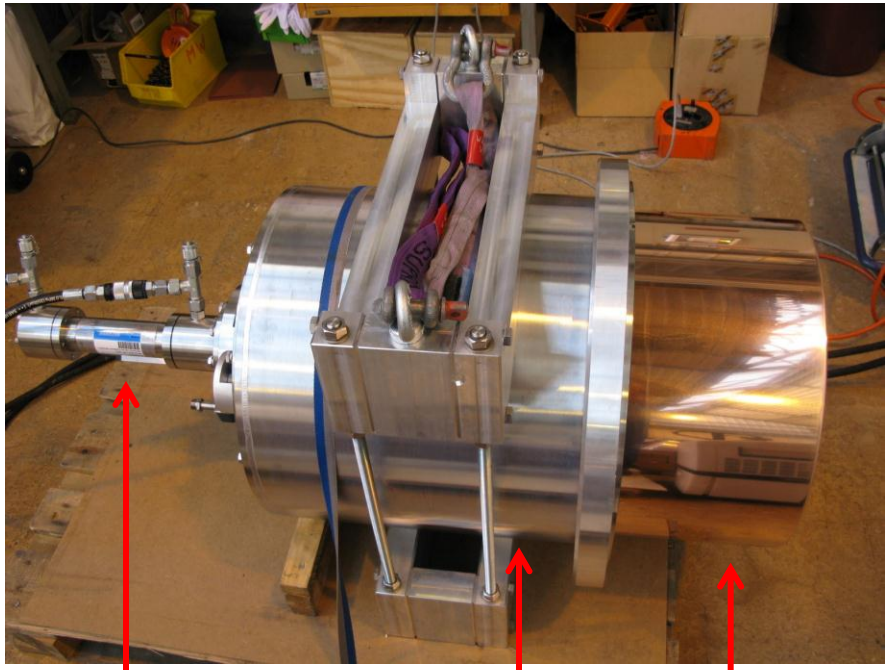
The new 50 MHz Resonators were manufactured by SDMS in France.

Resonator 2: Delivered in 2009
Power test in 2010 + 2011

Resonator 4: Delivered to PSI April 2012
Power test during summer 2012

Inside the Resonator
Lip (electrode) on lower right side removed

Tuner for new 50 MHz Resonator



Hydraulic cylinder

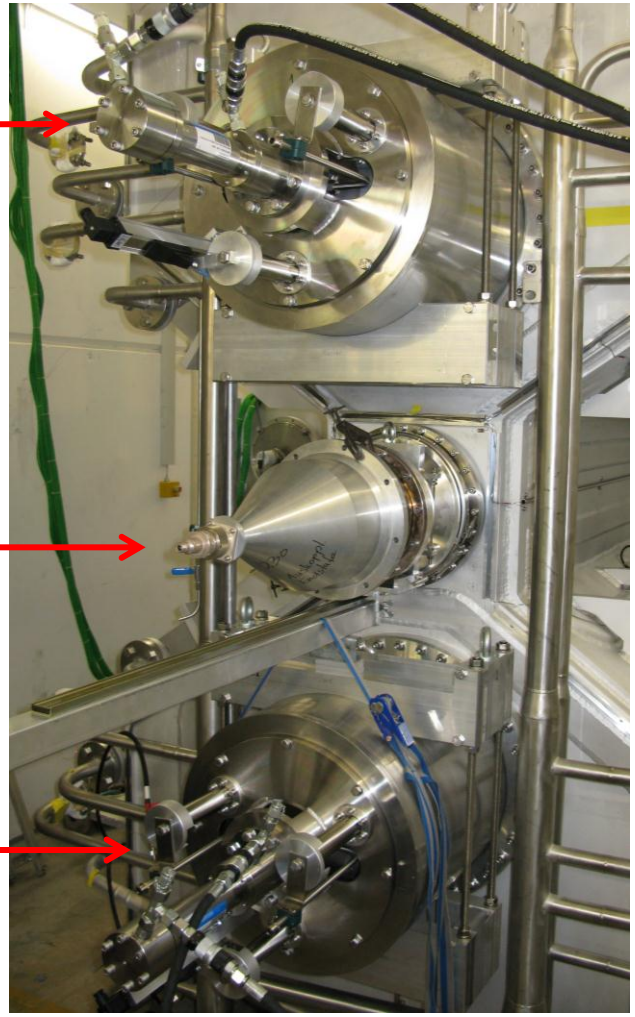
Vacuum vessel with mounting structure

plunger

upper tuner

Coupling loop with cone for measurements

lower tuner

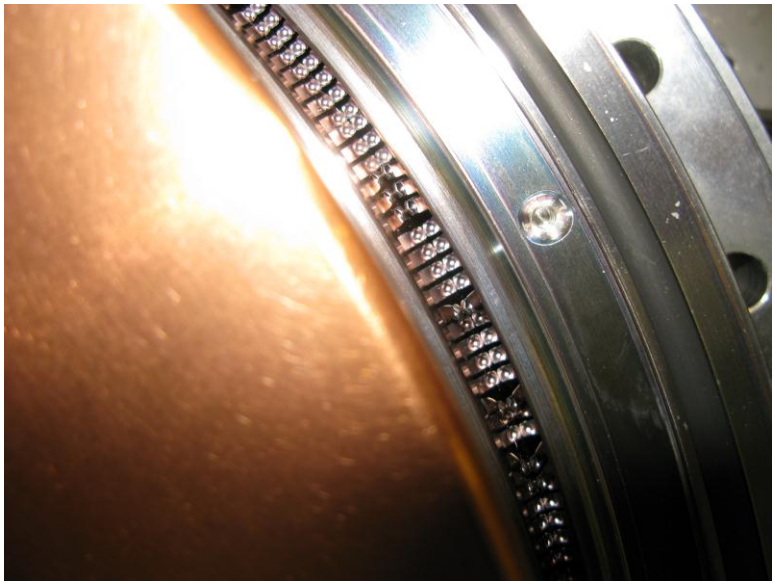


Power test of new resonator 2 (2010)

Resonator tested for 24 hours at 100 kW.
Nominal operation at 50 kW.

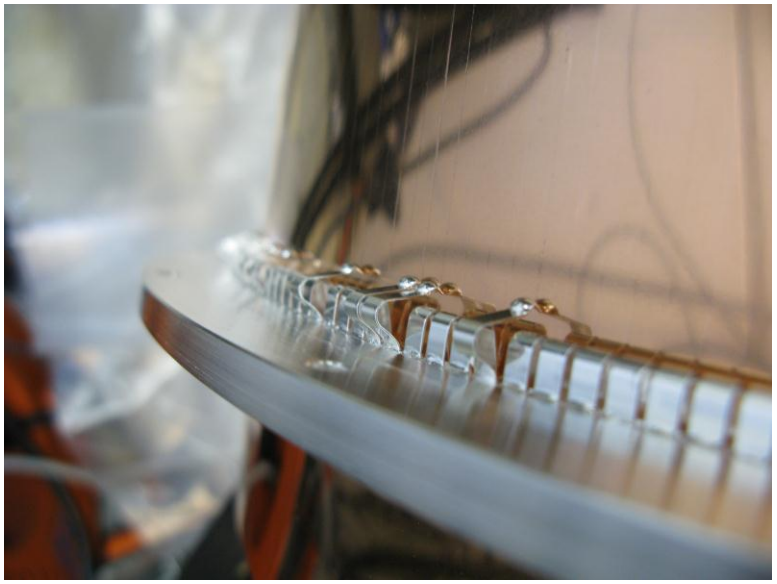
Multipactoring levels observed between 3.6 and 10 kW.

Mechanical resonance at 24.6 Hz.



Finger contacts of upper and lower tuner were bent.
Distance between plunger and contact was wrong calculated.

New contact rings were machined and plungers were polished



Second power test of new resonator 2 (2011)

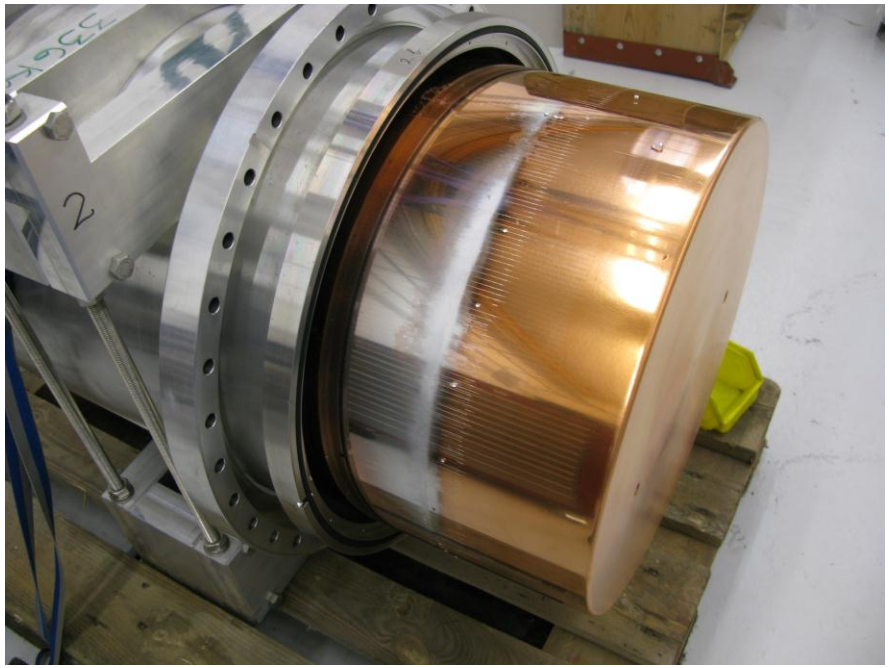
The Resonator 2 was again tested for further characterization:

- Pulse power for startup procedure was measured.

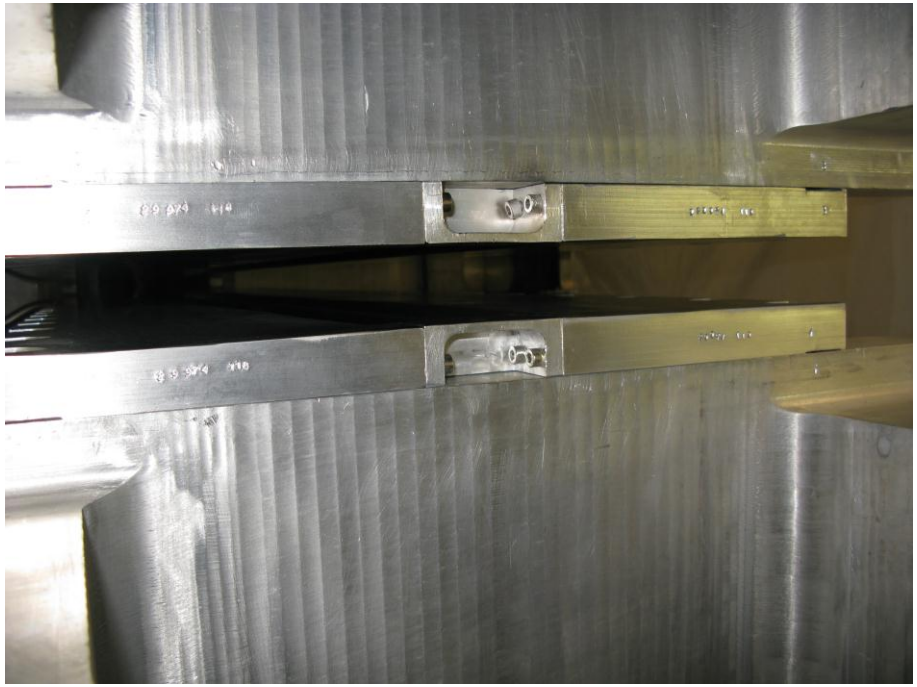
- Calibration of gap voltage by measuring the bremsstrahlung.

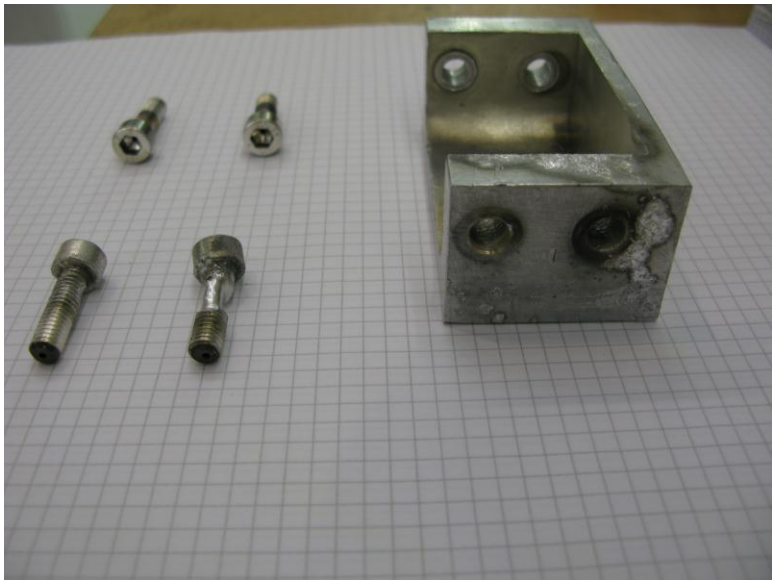
During this second test sequence the resonator was fed with power between 150 kW and 200 kW by a mistake.

Later again a strange behavior of the tuning system was observed.
⇨ Melt down of finger contacts



Power test of Resonator 2



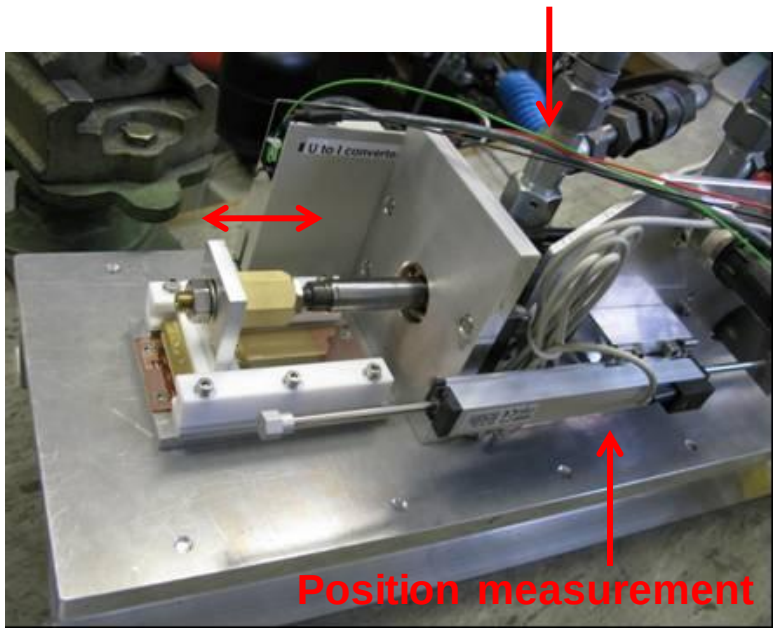


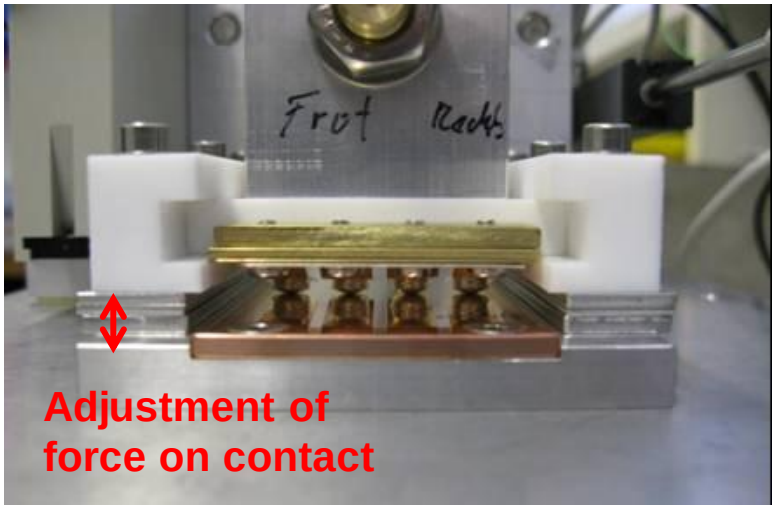
Resonator was inspected after power tests.

Bad rf contact at the bridge between the lips in the central region. Molten screws and marks from arcing were found.

Redesign of bridge?

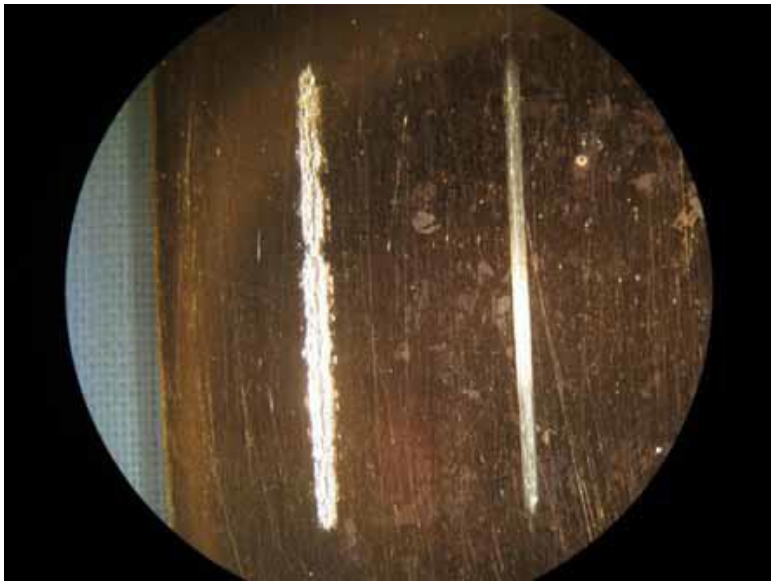
Mechanical test of finger contacts



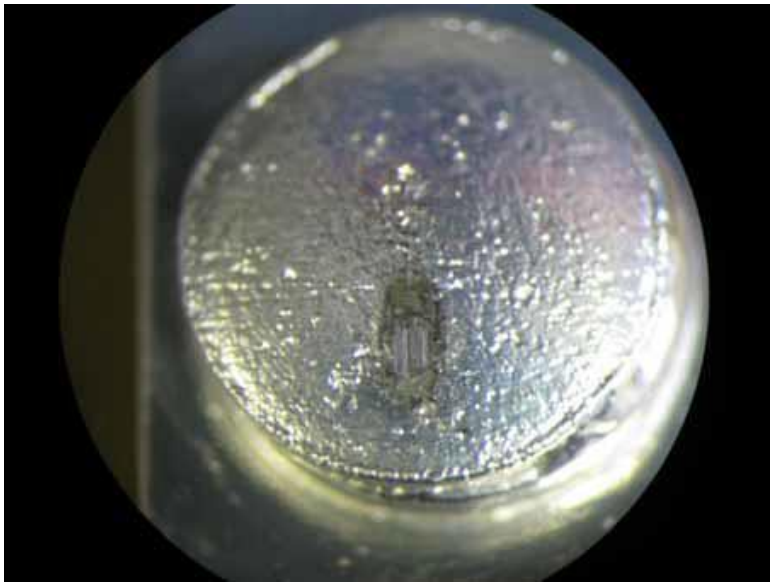


Automatic controlled test setup for finger contacts.
Only mechanical test, no current on contact

Copper plate after 800 moves over a distance of 50mm. →



Test of finger contacts

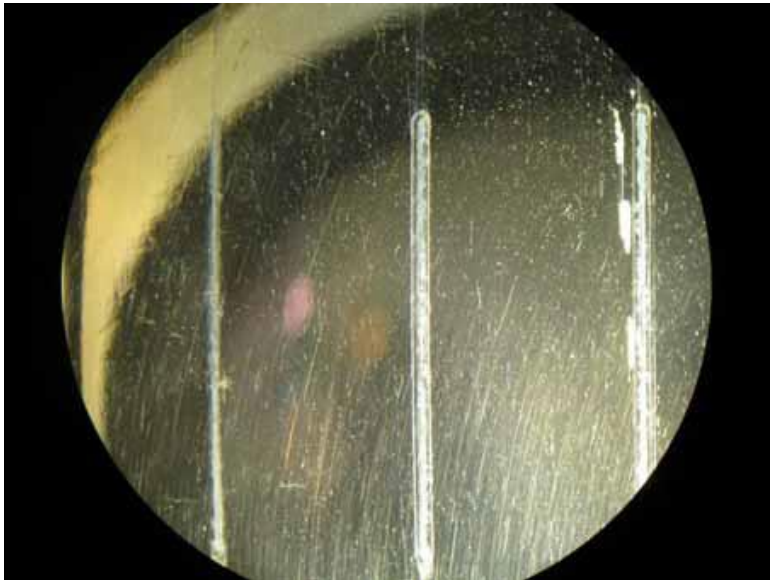


Finger contacts from:
Sumitomo Heavy Industries, Ltd, Japan
(Material: silver and graphite)

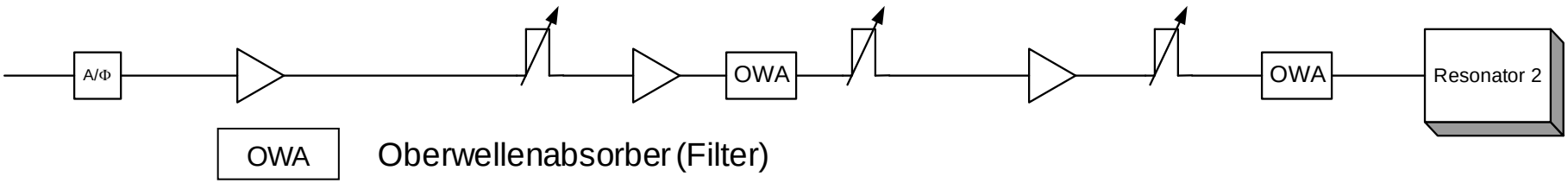
Contact area:
copper with 4 µm hard gold plating

After 30'000 movements over a distance of 50mm (speed 12 sec / 50 mm) still good contact.

Solution found for tuners. Will be tested in summer 2012.



New amplifier chains



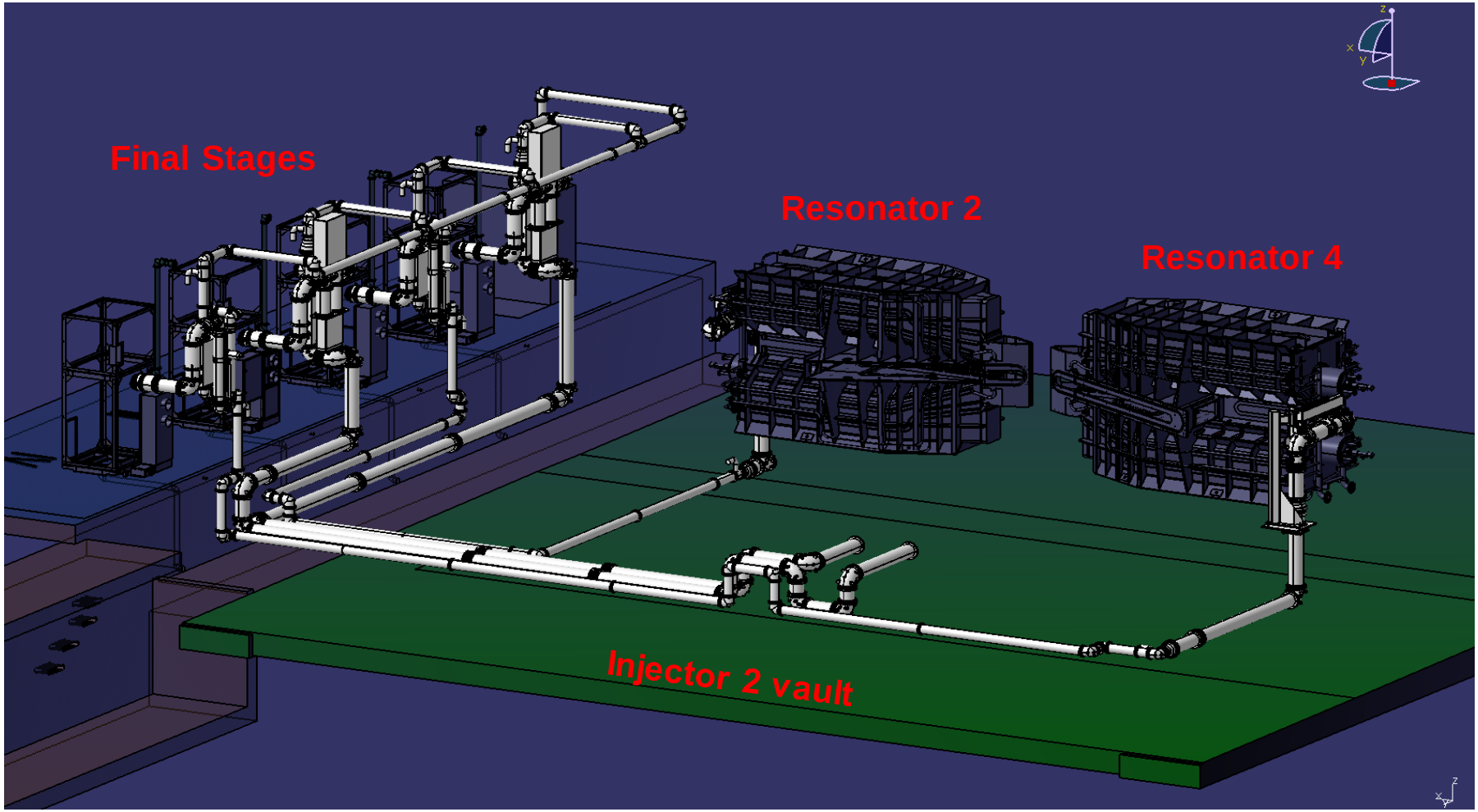
LLRF	Pre amplifier (2 kW) Solid state amplifier	Driver stage (35 kW) Tetrode amplifier Thales RS 2048 CJC New design PSI	Final stage (180 / 360 kW) Tetrode amplifier Thales RS 2074 HF Copy of 1MW amplifier Ring Smaller power supply

↓

Contract with Thomson Broadcast AG, Turgi, Switzerland, for 4 plate voltage power supplies

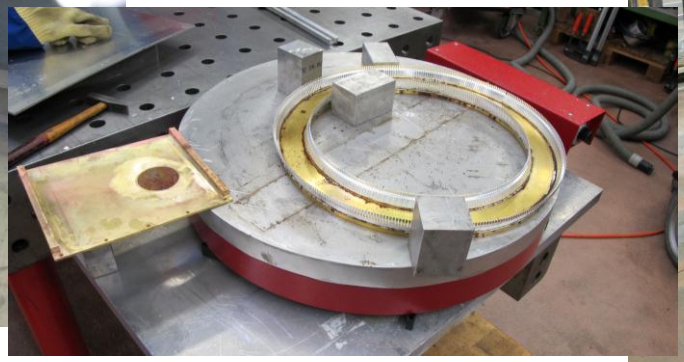
Site acceptance test summer 2014

Coaxial transmission lines



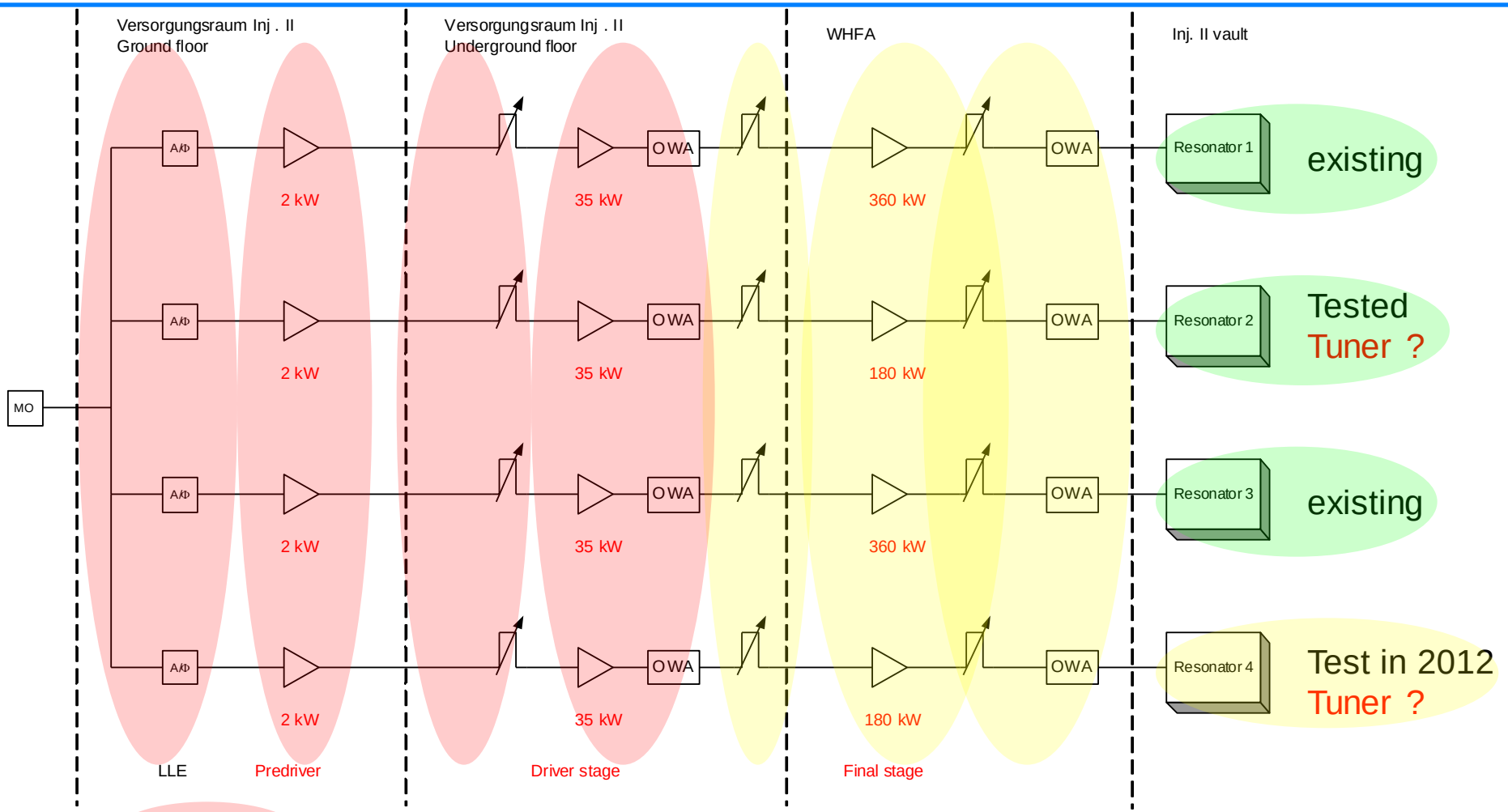
Coaxial transmission lines (RL 100-230, 6 1/8" EIA) from final stages to cavities.
Ordered at Spinner Munich, Germany.
Delivery autumn 2012, Installation 2012 / 2013

Final stages (4 + 1 spare)



Parts for 5 final stages in the machine shop.
First amplifier will be assembled until begin of 2013.
Test of this amplifier in 2013.
Afterwards assembly of the others.

Status of project



To be specified / designed / ordered

Ordered / in production

Ready for installation

More news on the CWRF 2014
Workshop in ????

How many cavities shall be cleaned?

Thanks to my colleagues from the RF and LLRF group. Especially to:
Hansruedi Fitze, Markus Bopp, Wolfgang Tron, Erich Wuethrich, Arthur Schmidheiny, Sebastian Jetzer, Oliver Brun, Harald Siebold, Manuel Brönnimann, Stefan Mair, Andreas Hauff