PAUL SCHERRER INSTITUT

PSI

Wir schaffen Wissen – heute für morgen

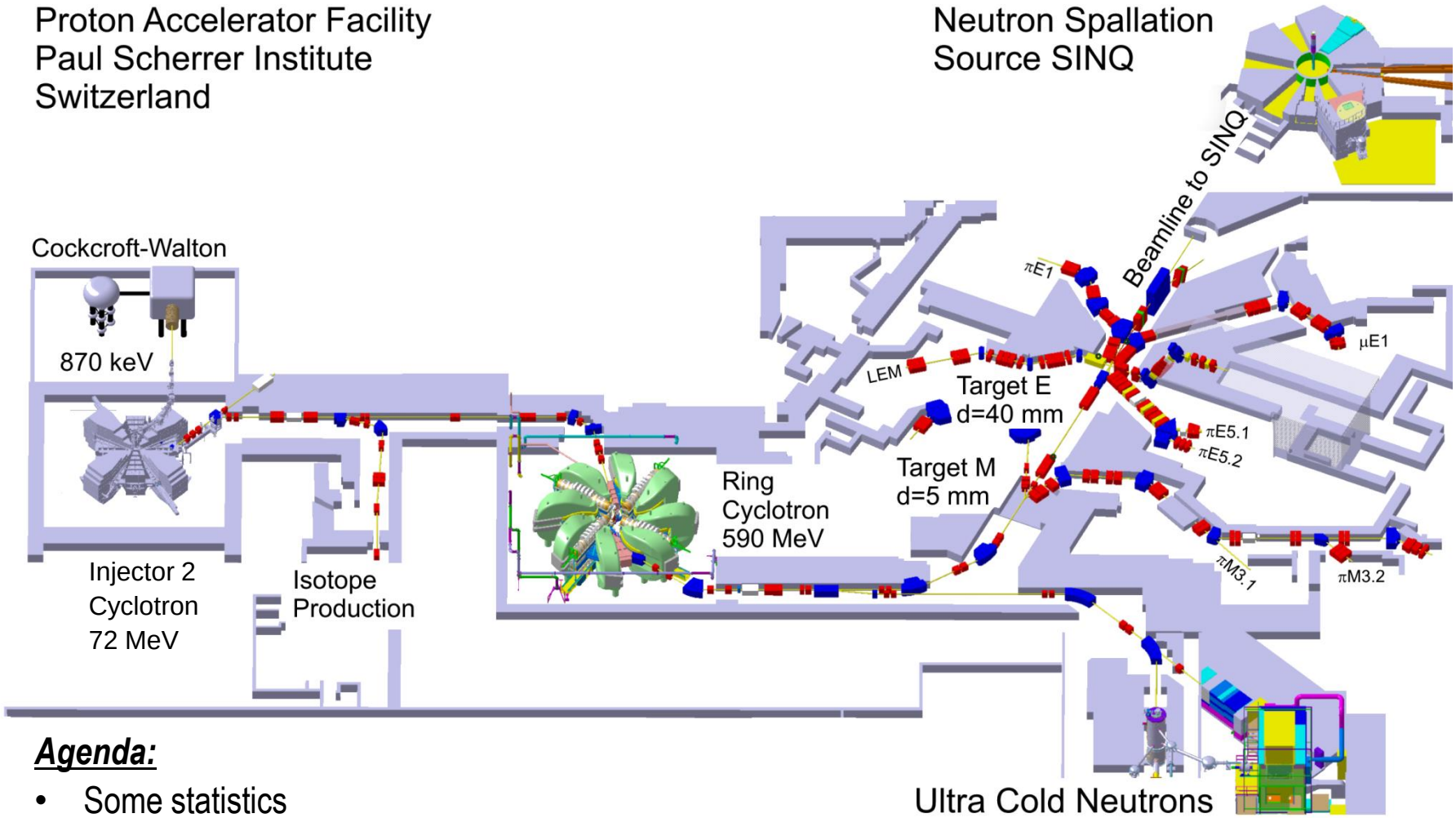
Paul Scherrer Institut

Markus Schneider

Status of the rf-system for the high intensity proton accelerator facility at PSI

Overview High Intensity Proton Accelerator

Proton Accelerator Facility
Paul Scherrer Institute
Switzerland

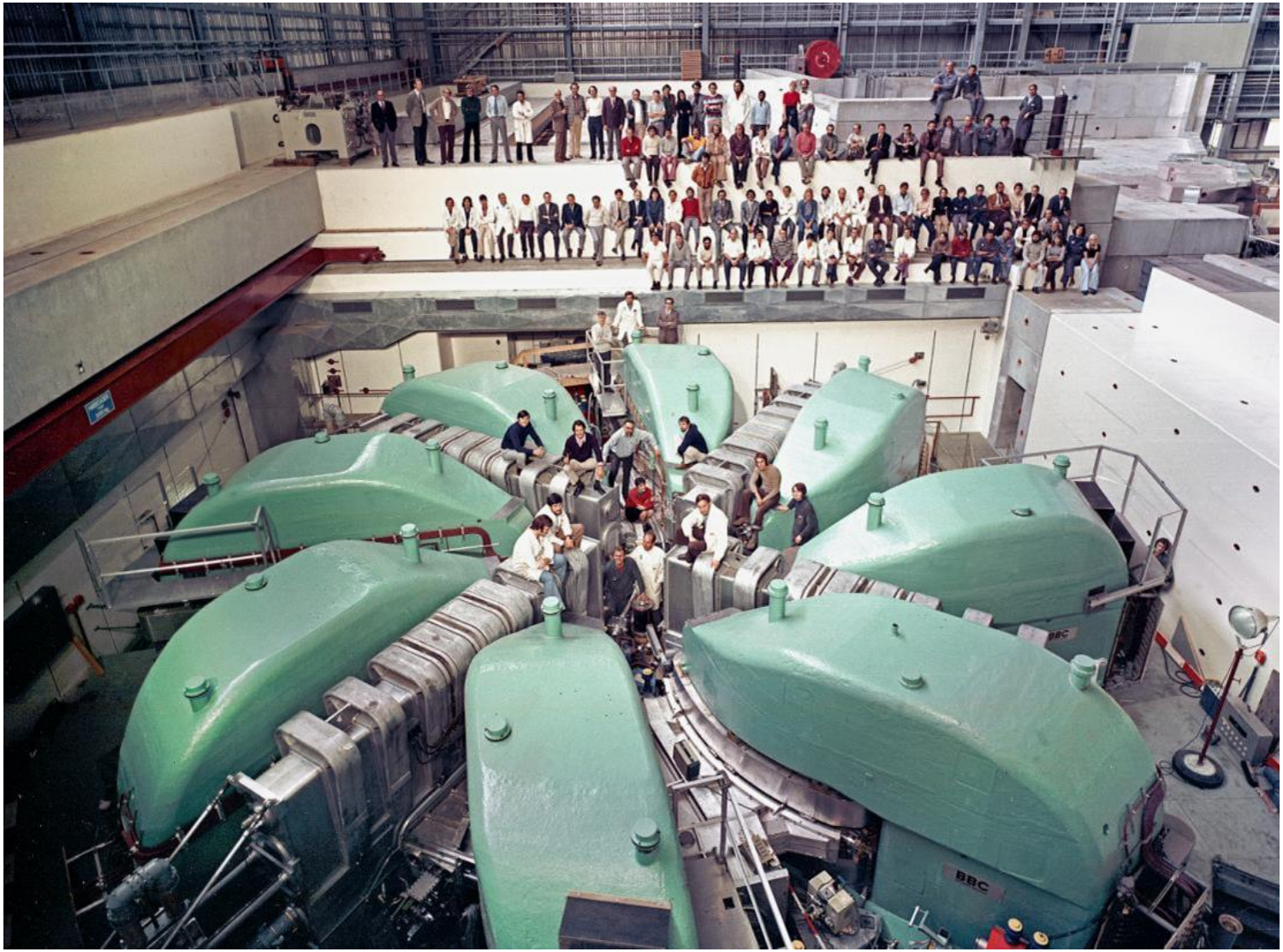


Agenda:

- Some statistics
- Status of Injector 2 rf upgrade
- Ring cyclotron: problems with flattop cavity

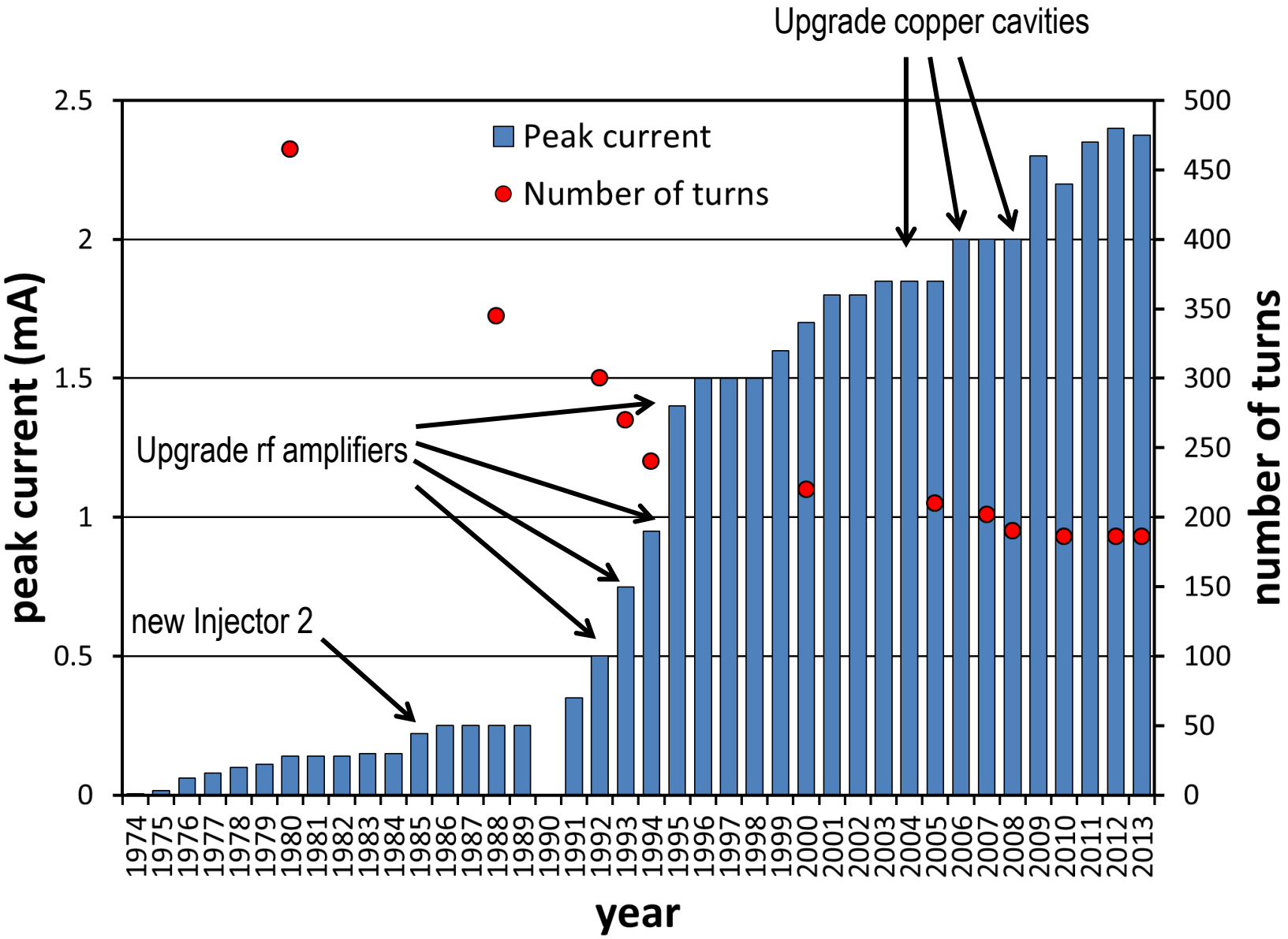
2.2 mA operational beam current
2.4 mA maximal achieved beam current
(1.4 MW beam power)

40 Years since first beam extracted from Ring cyclotron

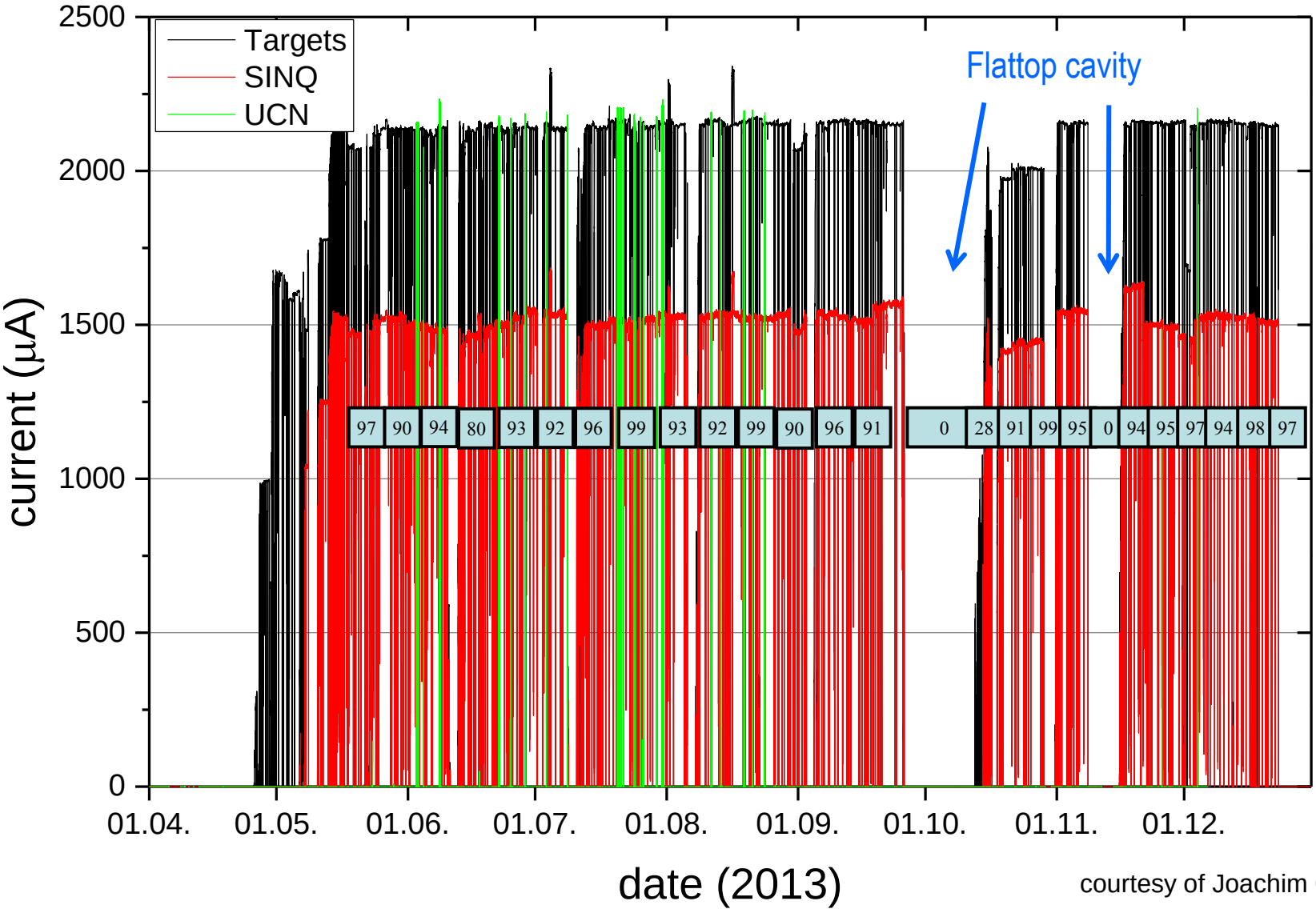


Ring cyclotron in 1974

Beam current at HIPA over 40 years



Operation HIPA in 2013



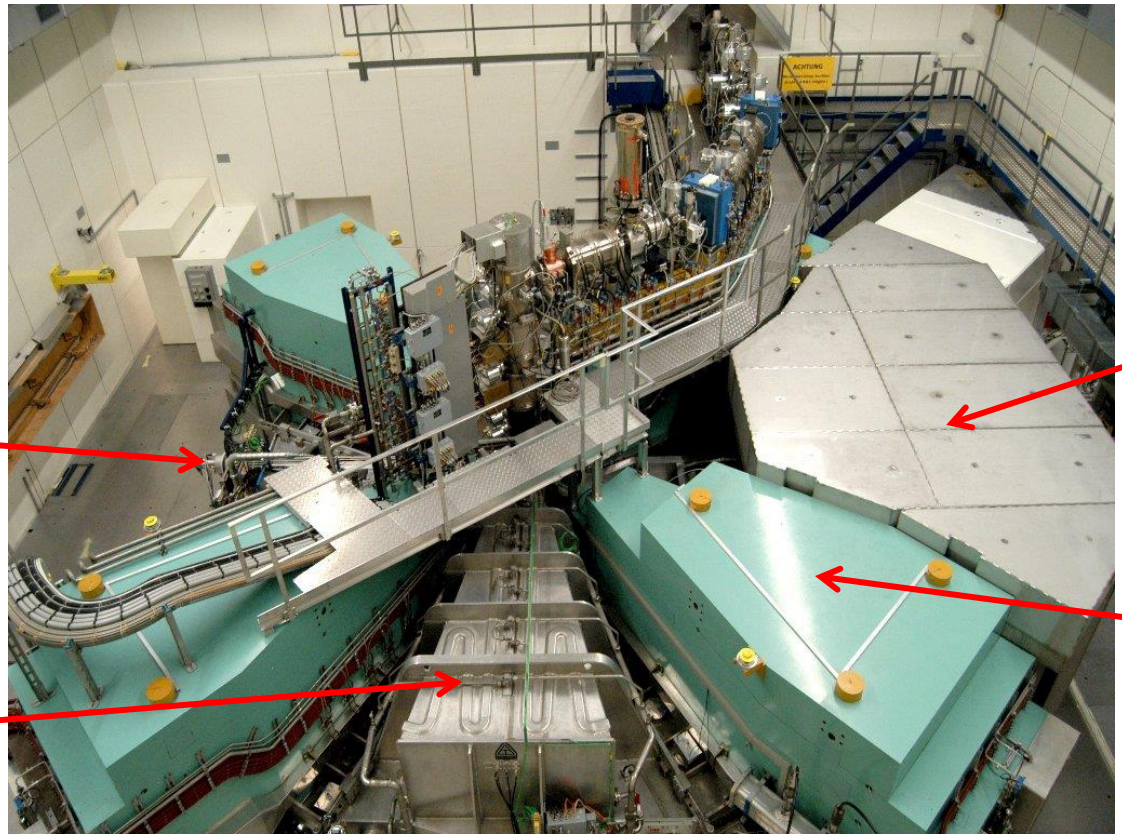
courtesy of Joachim Grillenberger

Statistic 2013

Beam time statistics	2012	**2013**
Beam time Target-M/E Delivered charge	4936 h 10.4 Ah	**4436 h** **8.9 Ah**
To SINQ Delivered charge	4885 h 7.1 Ah	**4147 h** **6.0 Ah**
UCN delivered charge	0.06 Ah	**0.05 Ah**
Outages		
Short interruptions < 5 min	205 h (180/week)	**305 h** **(260/week)**
Overall outage (I < 1 mA)	276 h	**690 h**
Availability	93.5%	**82.2%**

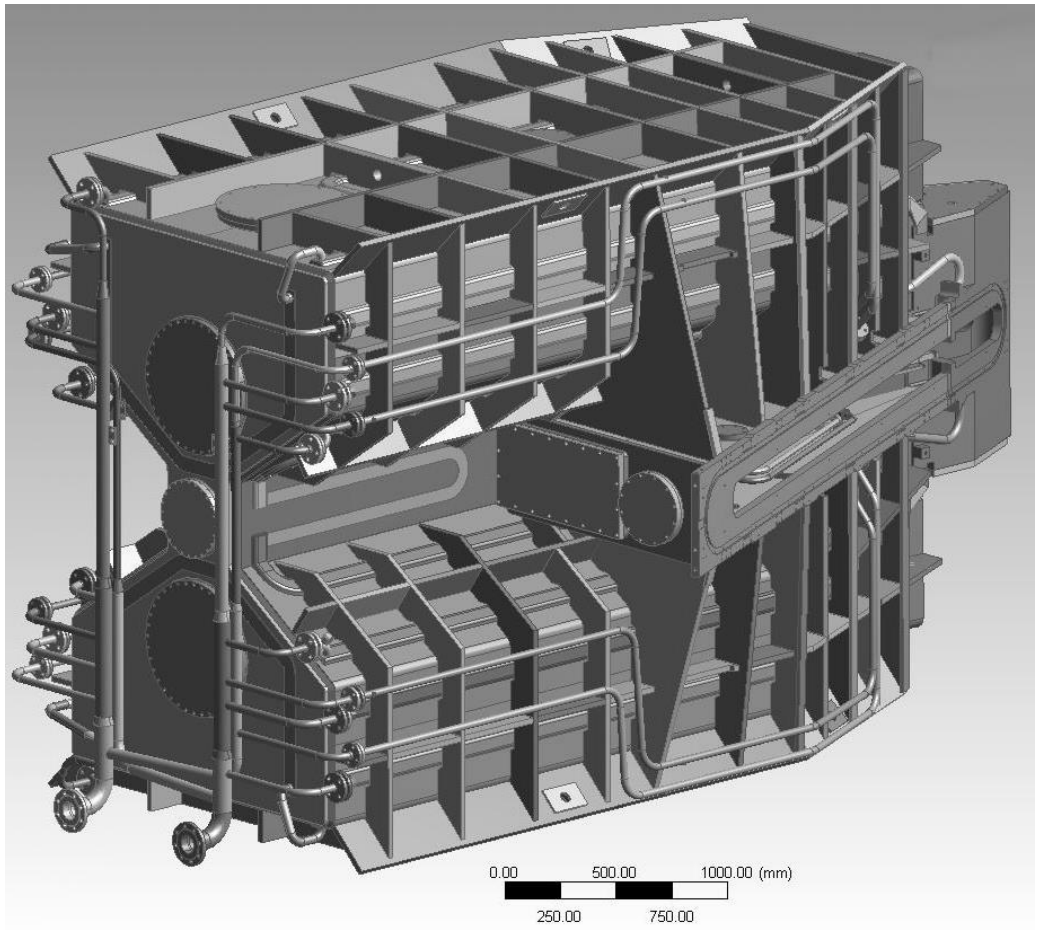
courtesy of Joachim Grillenberger

Injector 2 cyclotron



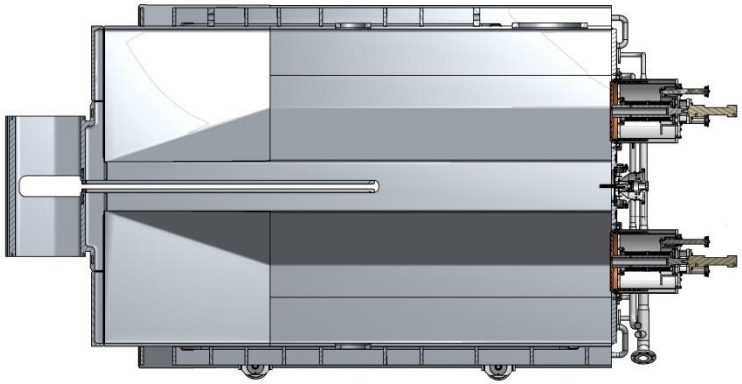
Resonator	type	material	frequency	gap voltage	Wall losses in cavity	incident power @ 2.4 mA Beam
1 & 3	Double gap cavity	aluminum	50 MHz	~ 420 kVp	~ 150 kW	~ 225 kW
2 & 4	Flattop cavity	aluminum	150 MHz	~ 31 kVp	~ 5 kW	~ 14 kW
2 & 4 new	Single gap cavity	aluminum	50 MHz	~ 400 kVp @ extraction	~ 50 kW	

New 50 MHz Resonator 2 & 4 for Injector 2

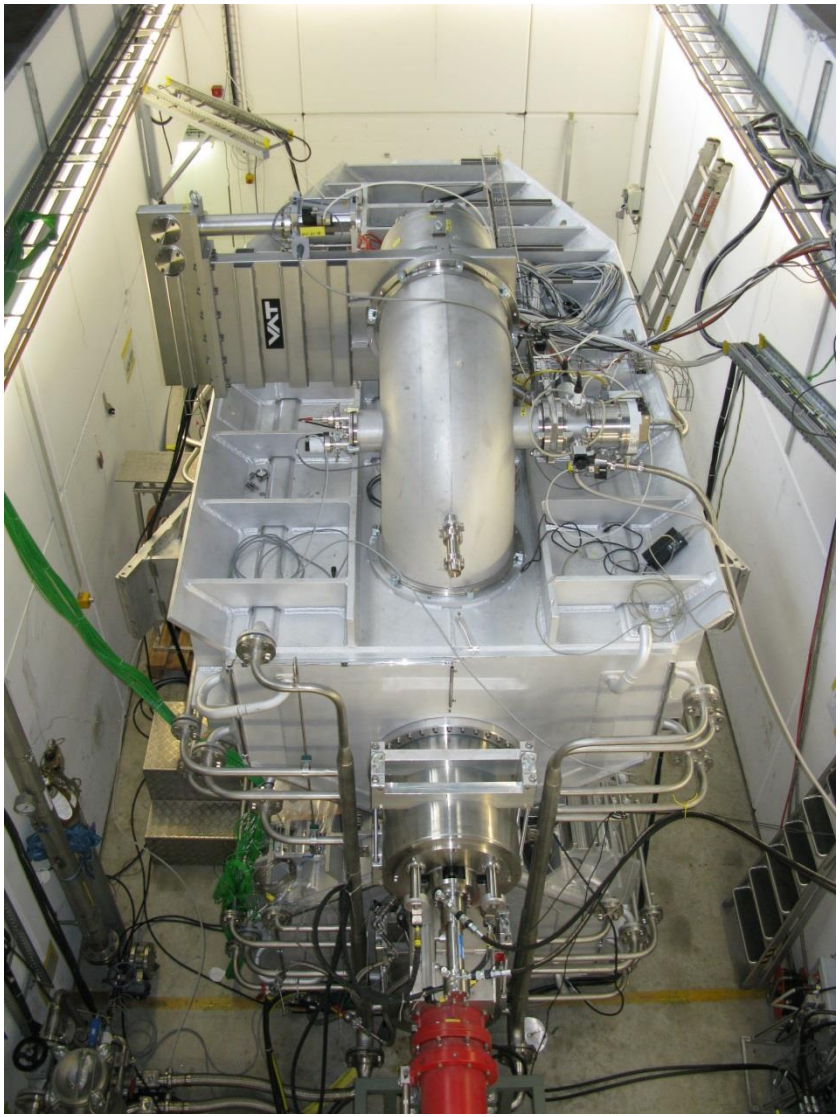


Specification

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**



Status resonators



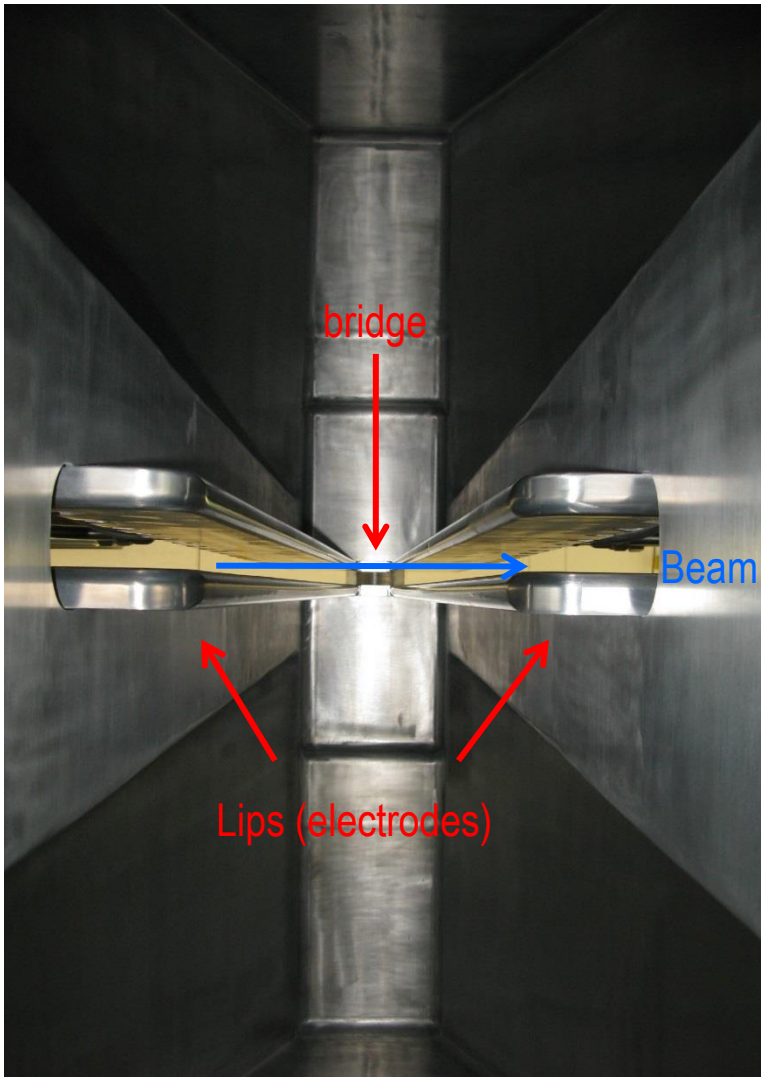
50 MHz Resonators manufactured by SDMS in France.

Resonator 2:	Delivered in 2009
	Power test in 2010 + 2011
Resonator 4:	Delivered in April 2012
	Power test summer 2012 + 2013

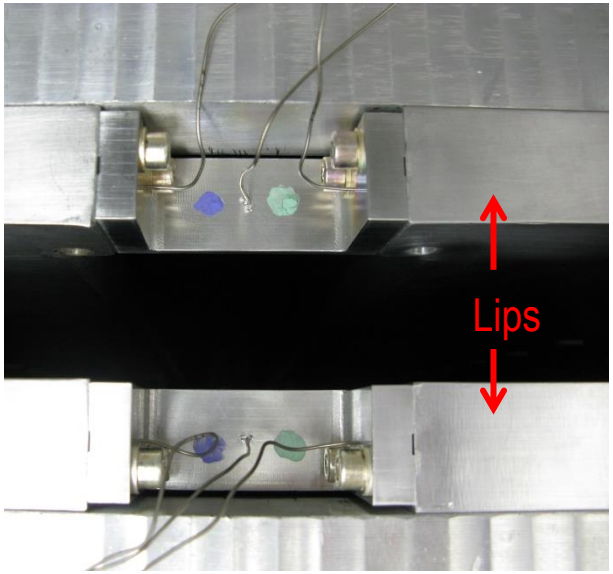
Tests stopped due to tests of new amplifier and moving of test bunker.

Open tasks:
Calibration of gap voltage
Problems with bridge between lips

Bridge between lips of Resonator



Inside Resonator 2 towards center of cyclotron

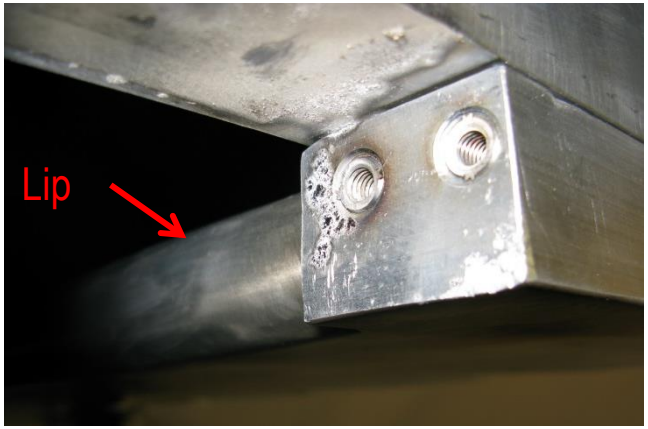


Bridges with thermocouples

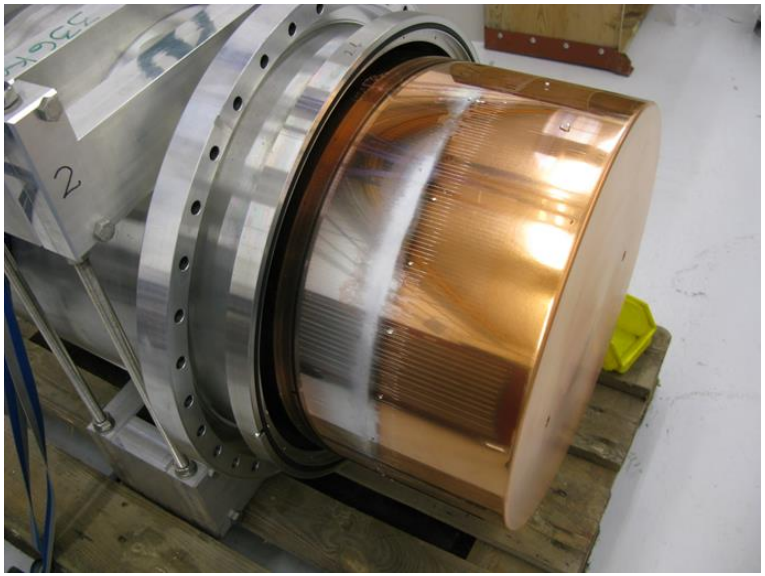
Bridges are getting to hot

redesign

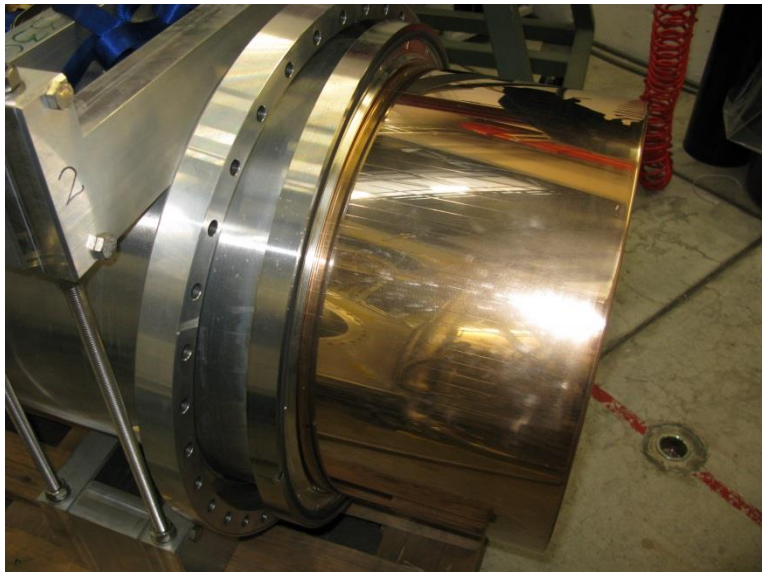
Arcing during power tests ⇒ bad contact



Status tuners



Plunger for tuning presented at CWRF2012



Gold plated tuner after power tests

Gold plated tuner was tested under power.
Final tuner design in production.
Assembly summer 2014

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

Contact area:
copper with 4 µm hard gold plating

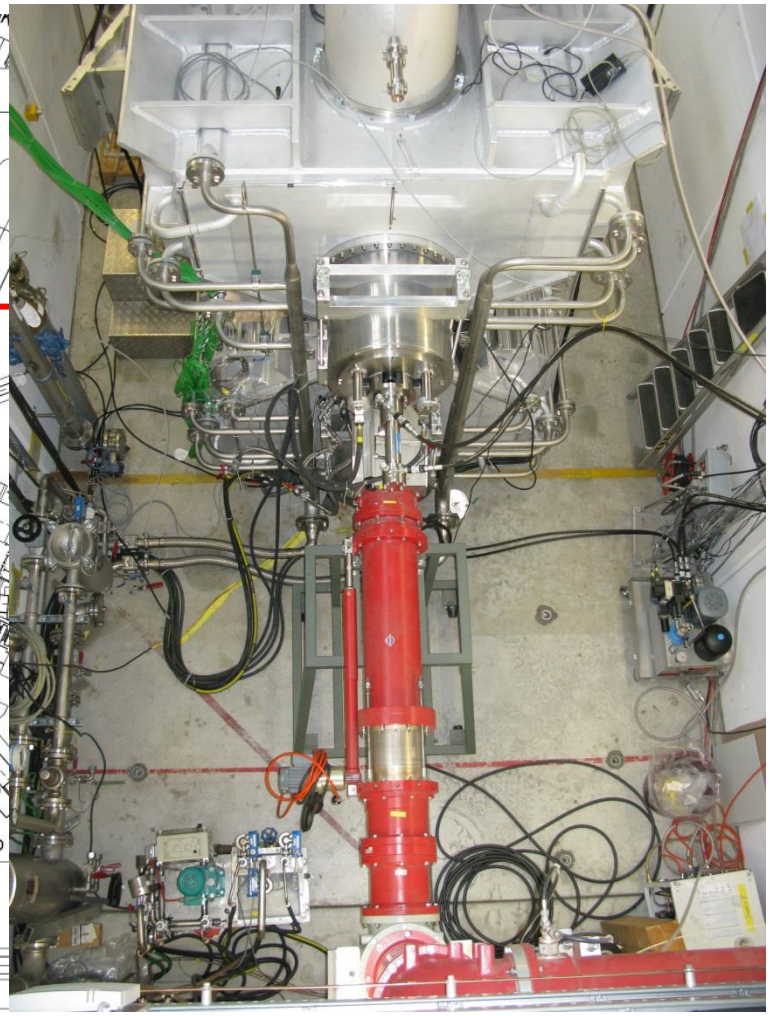
Moving of test stand

Due to Gantry 3 for proton therapy space for test stand lost.

New place found.

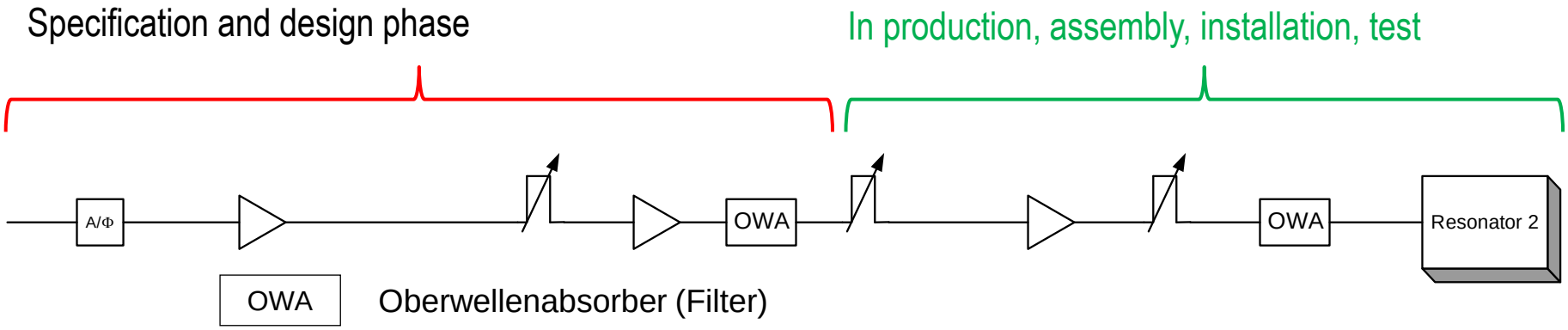
Ready for next tests in fall 2014

Resonator and cooling circuit moved to new test bunker



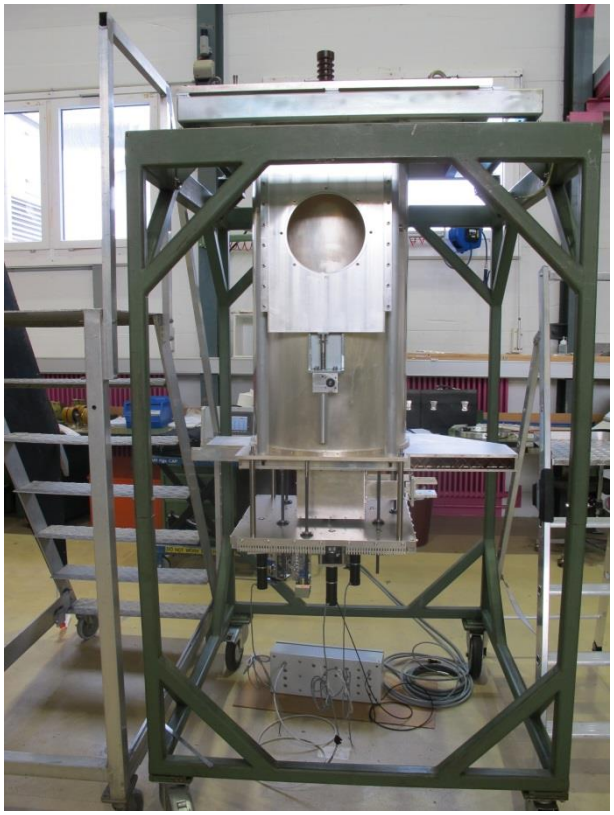
Resonator in old test bunker

Overview amplifier chain



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

Status final stages



Assembly of circuits in machine shop

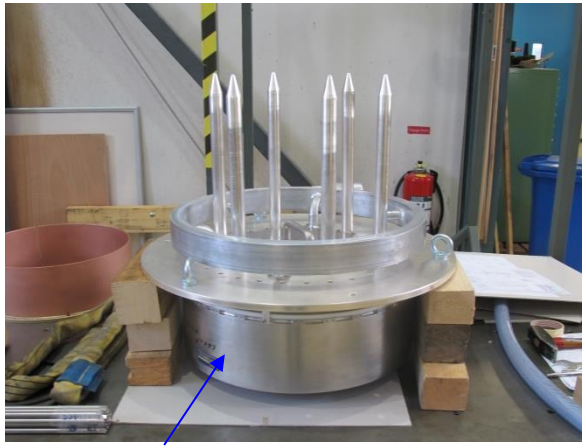
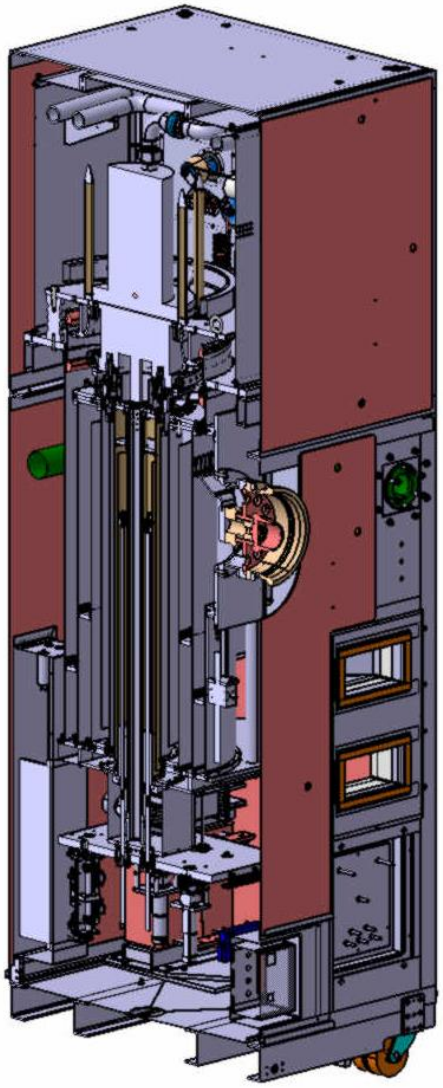


plate-capacitor

Teflon capacitor, new supplier?



First amplifier assembled in 2013 ⇒ tests summer till end 2013
Parts for 4 more amplifiers machined.
Soldering and silver plating until August 2014
Start of assembly of next two amplifiers parallel in August 2014
Last 2 amplifiers assembly starts close to the end of 2014

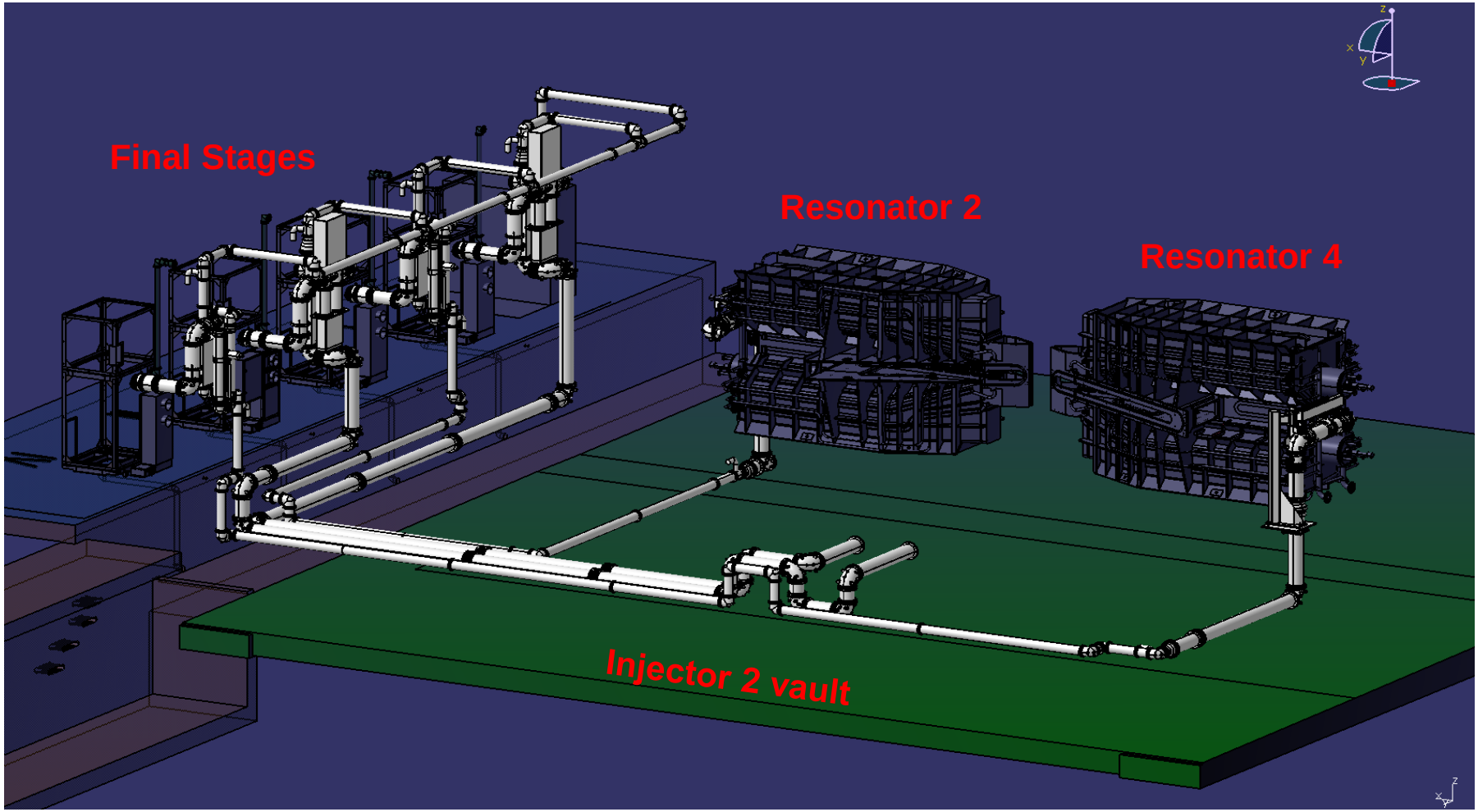
Status final stages

Transport of first amplifier to test stand

Power tests on 50Ω - load:
up to 600kW.

Performance as known from existing final stages for Ring cyclotron.
Continuing of production

Coaxial transmission line



Coaxial transmission lines (RL 100-230, 6 1/8” EIA) from final stages to cavities.
Manufactured by Spinner Munich, Germany.

Coaxial transmission line delivery in 2012

Where is box number 47 with 90°-elbow for Resonator 2 transmission line?

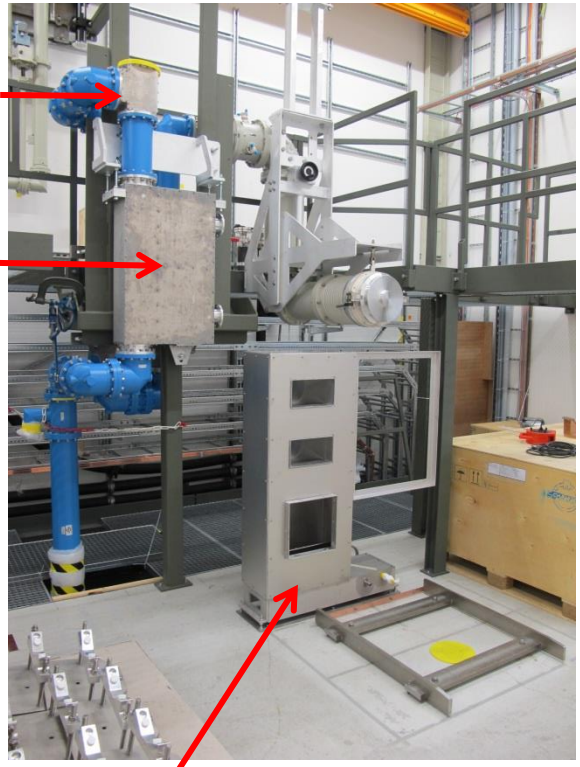
Boxes in first floor WHFA

Boxes in ground floor WHFA

Coaxial transmission line installation

Installation in WHFA and Injector 2 bunker

Amplifier platform for final stages in WHFA



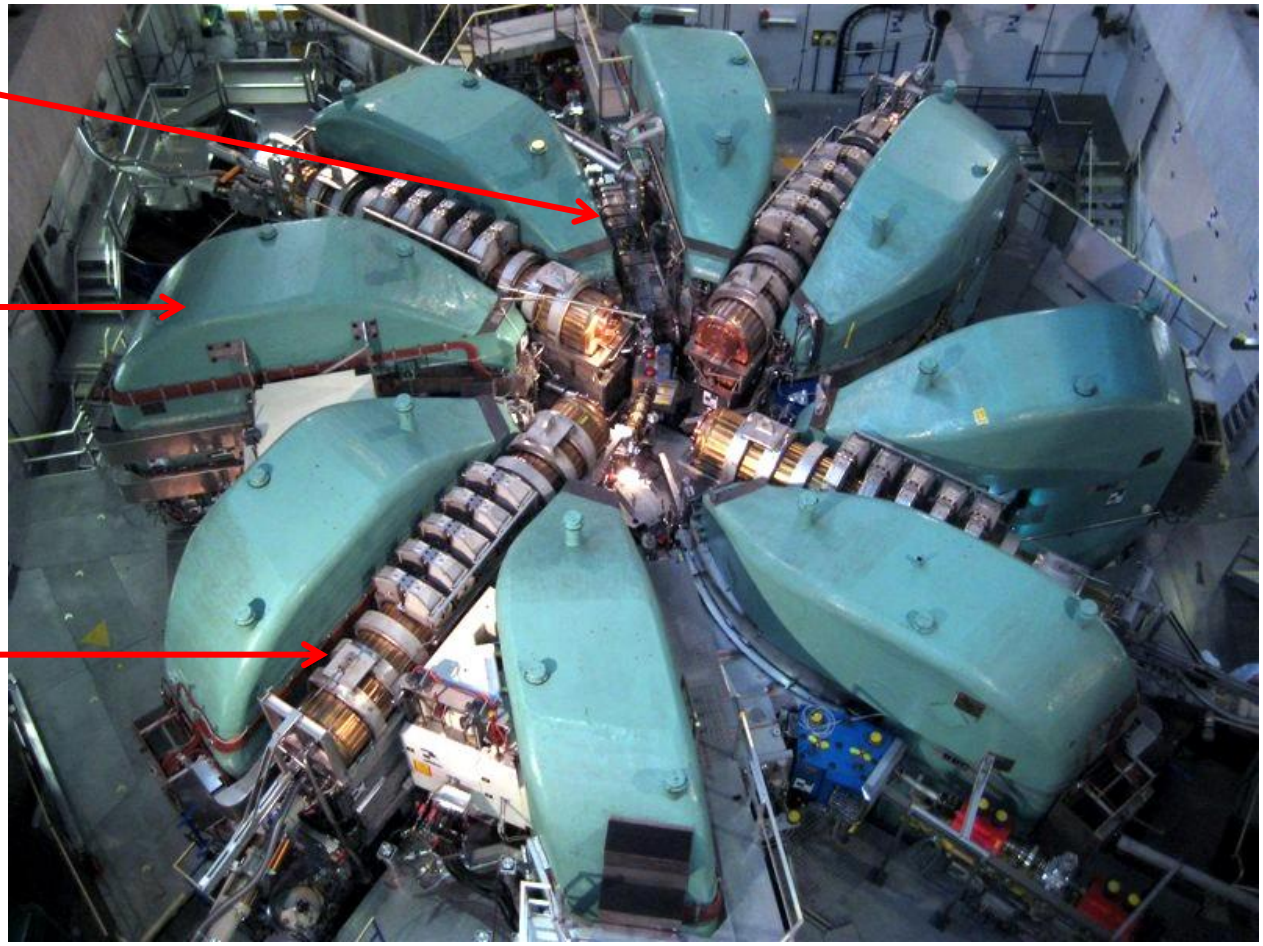
Outlook Injector 2 rf upgrade

Installation in WHFA 9. Mai 2014

Next tasks for 2014:

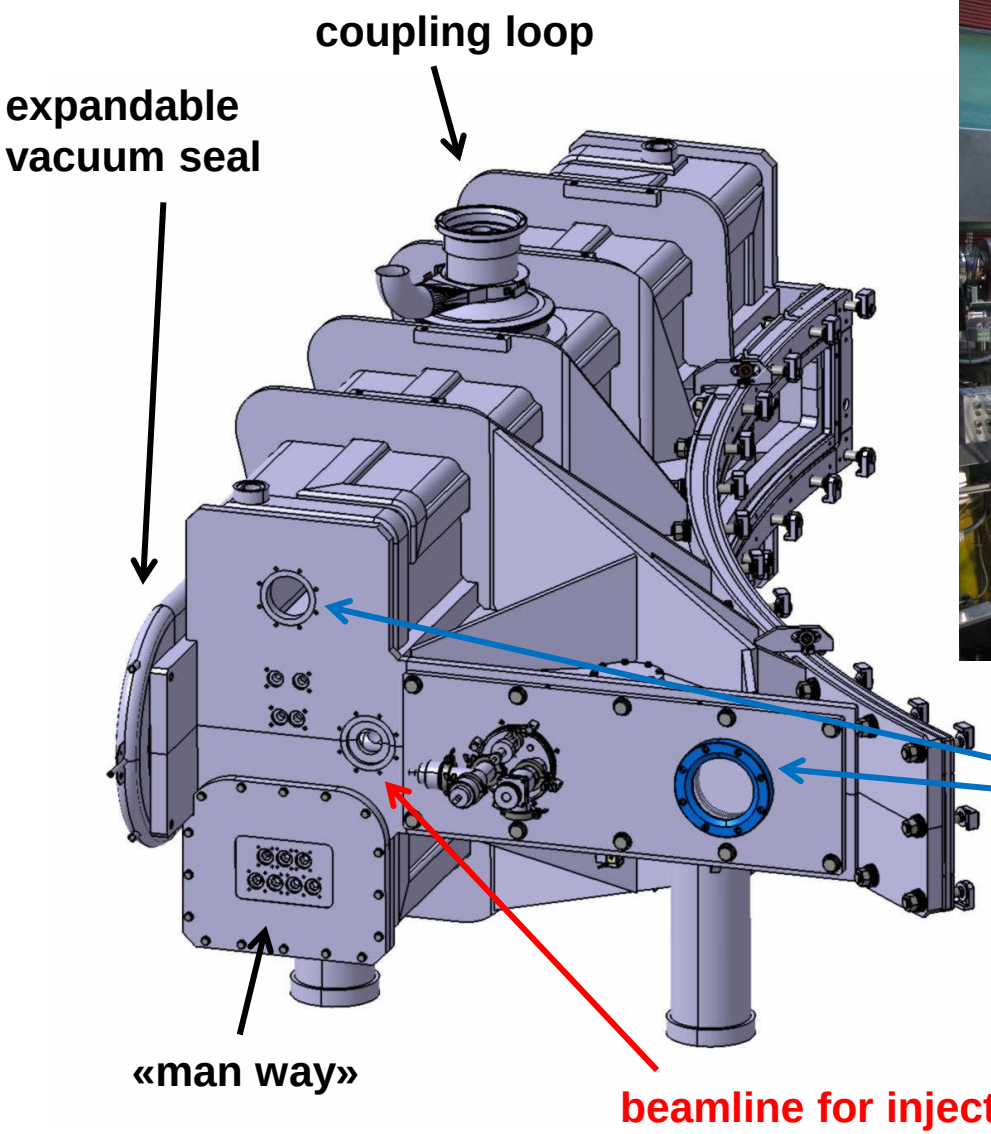
- Installation of transmission line and support for amplifiers in WHFA
- Assembly and test of final stages
- Design driver stage
- Finish moving of test stand
- Assembly of tuners
- Continuing tests of new resonators

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

The flattop cavity



Cavity material: pure aluminum

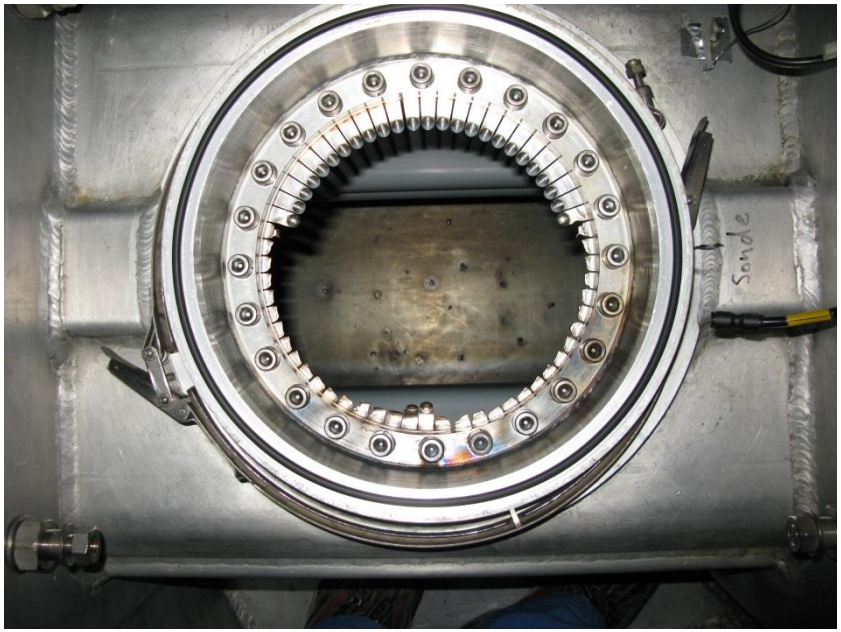
Size: 2.7 m x 43 cm x 98 cm

Problem on Flattop cavity

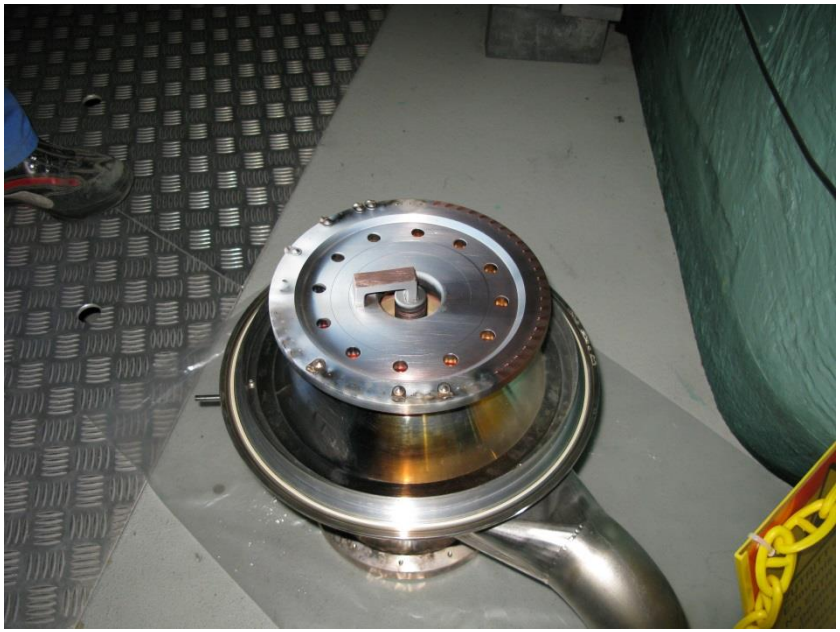
25. September 2013 Called in: Problems to get flattop cavity on nominal voltage

Many events on probe at coupling loop
⇒ Status of ceramic at coupling loop ??

Venting the machine for change of coupling loop, but…..



Burned finger contacts at cavity opening for coupling loop

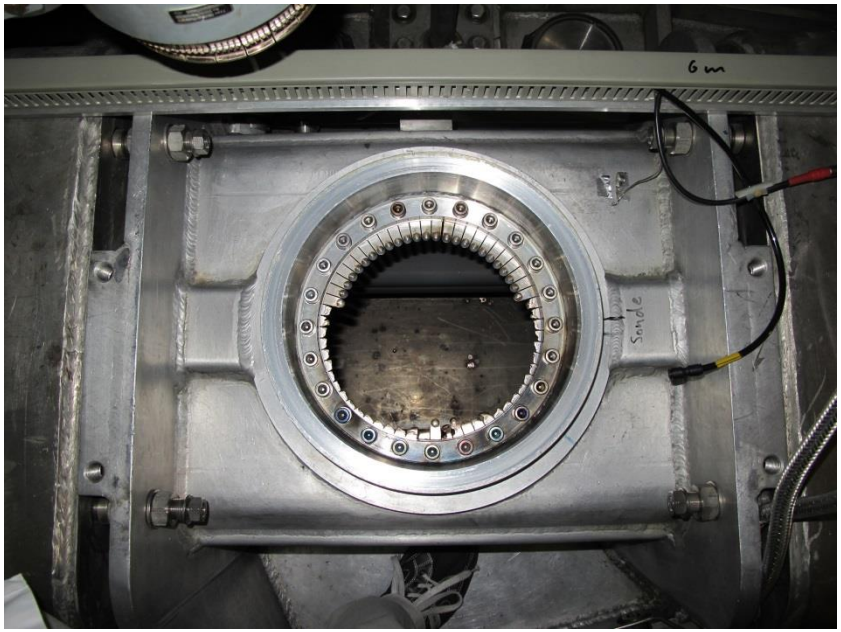


Coupling loop

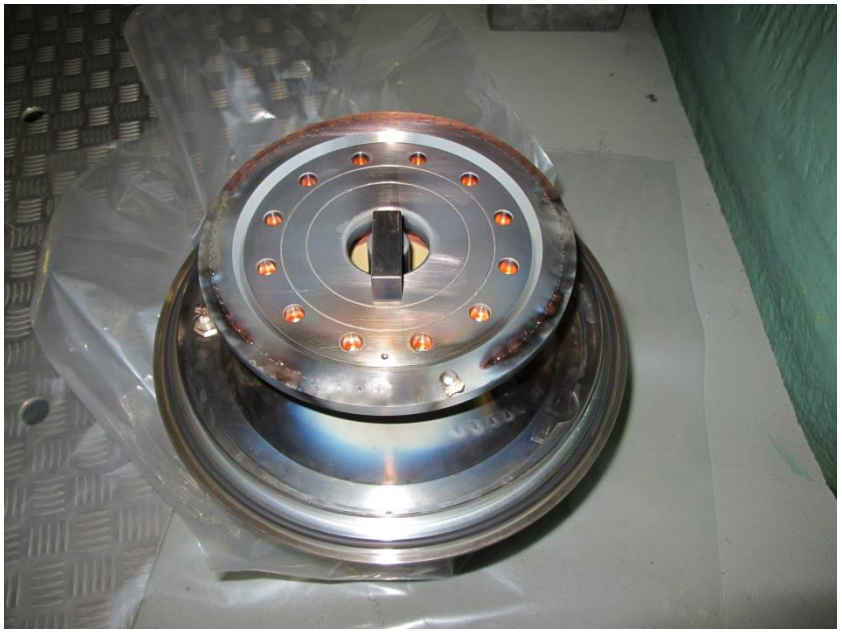
Problem on Flattop cavity

27. September 2013 — Finger contacts and coupling loop replaced
Conditioning of cavity
at about 480 kVp gap voltage start of getting events on probe at coupling loop
Over night run at 300 kVp

28. September 2013 — 450 kVp for short time, event on probe at coupling loop
after that only 200 kVp achievable.
$\Rightarrow$ venting the machine and inspection of coupling loop



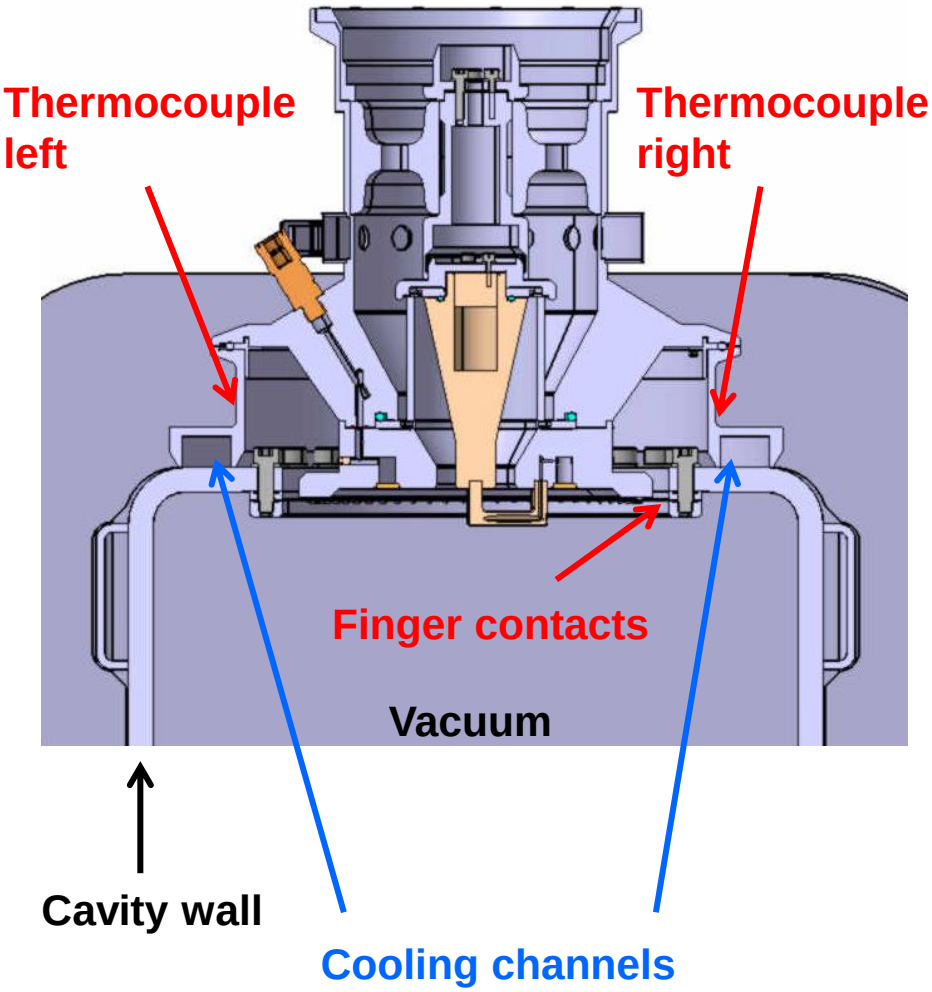
2nd time burned finger contacts



Coupling loop

Problem on Flattop cavity

Cross-section of coupling loop on flattop cavity



Last set of finger contacts installed.
New coupling loop installed.
Cooling channels checked for sufficient cooling.

Installation of two Thermocouple close to finger contacts.

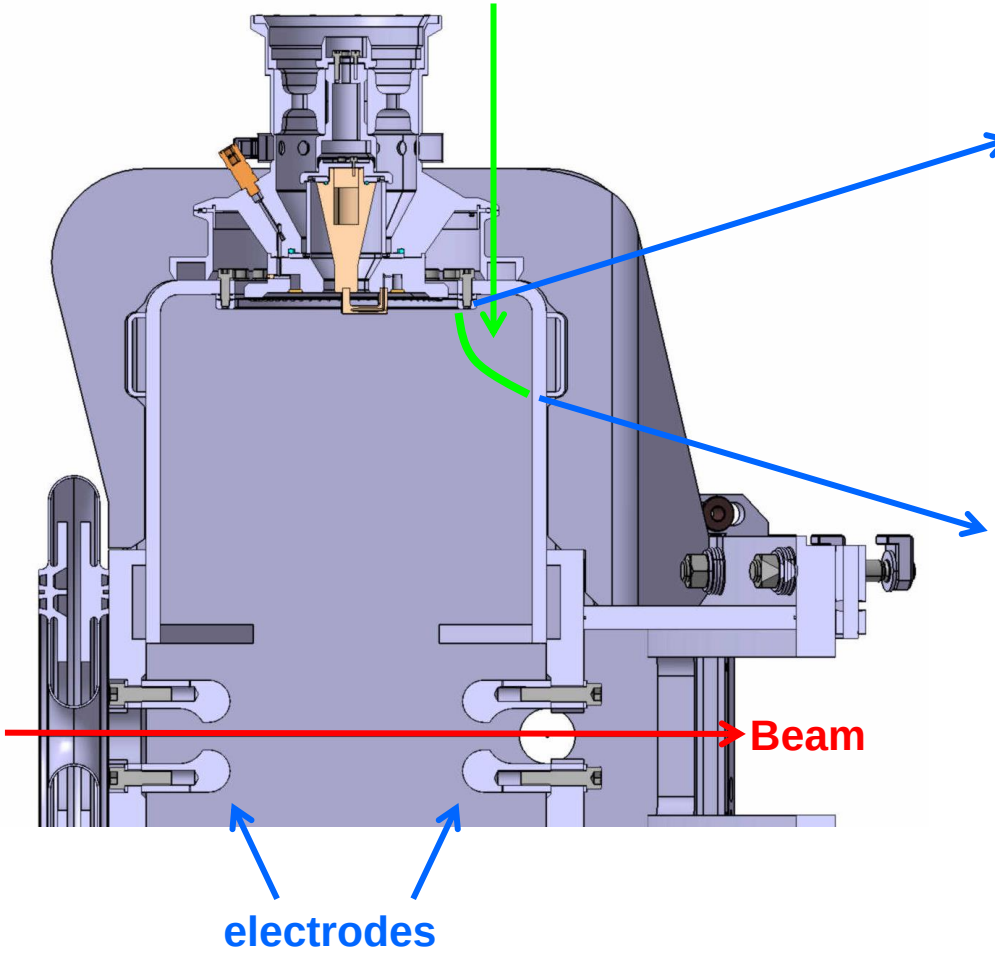
Very careful start to feed cavity with rf

Temperature rises on right side faster than on left side of coupling loop. This matches to the arrangement of the molten finger contacts.

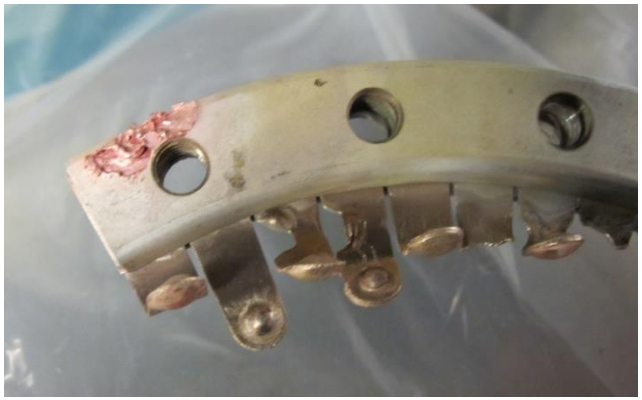
Change of main magnetic field of cyclotron has an impact on temperature on the right side of the coupling loop !

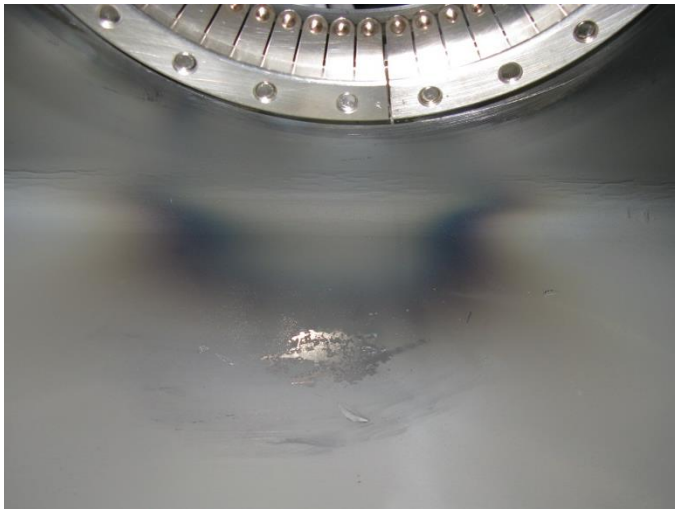
Multipactoring in flattop cavity

Trajectory of electrons affected by stray field of main magnets



Molten ring of finger contacts

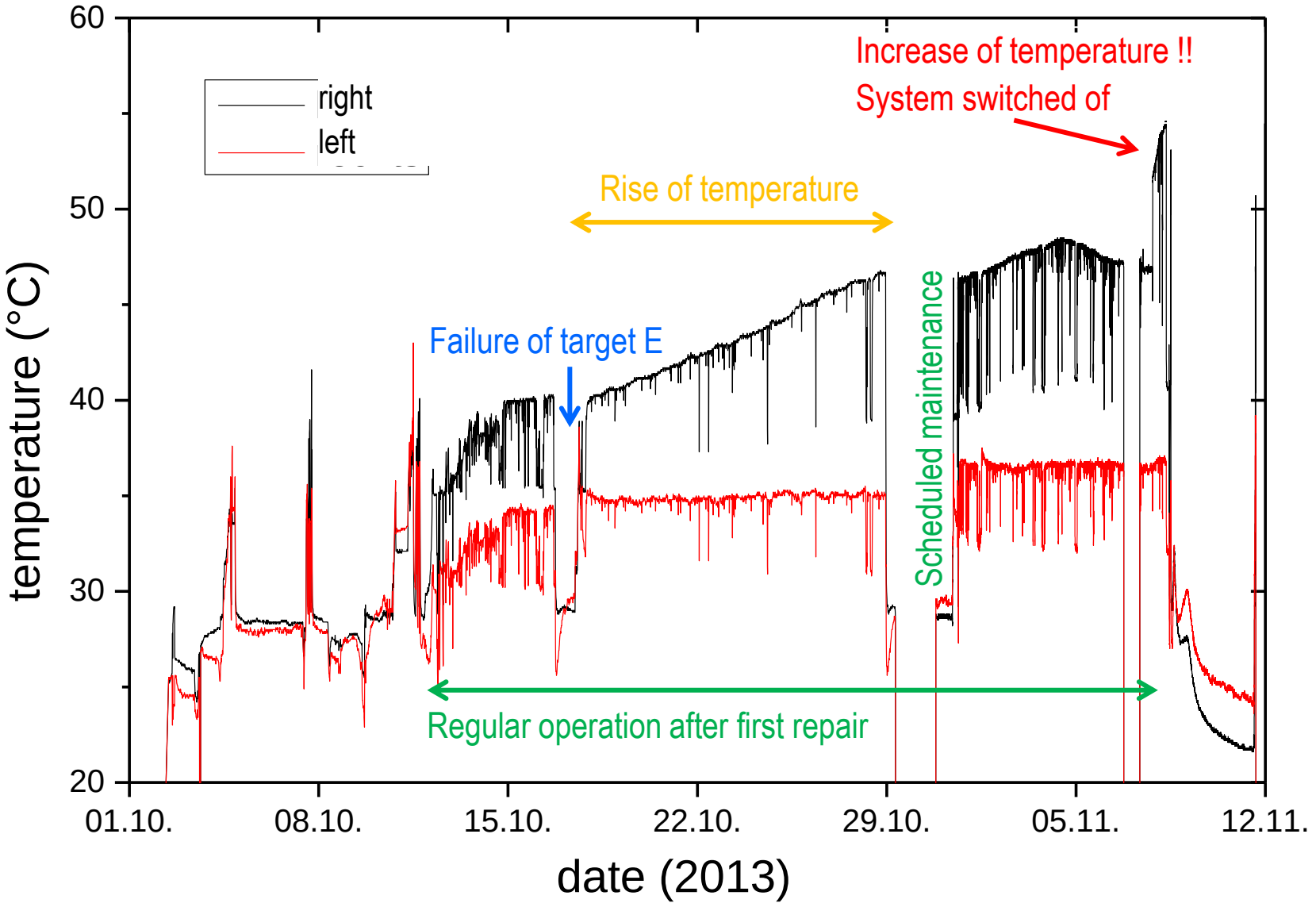




Spot on cavity wall

Painting of spot with “Aquadag 18” from Acheson (Colloidal graphite in water)

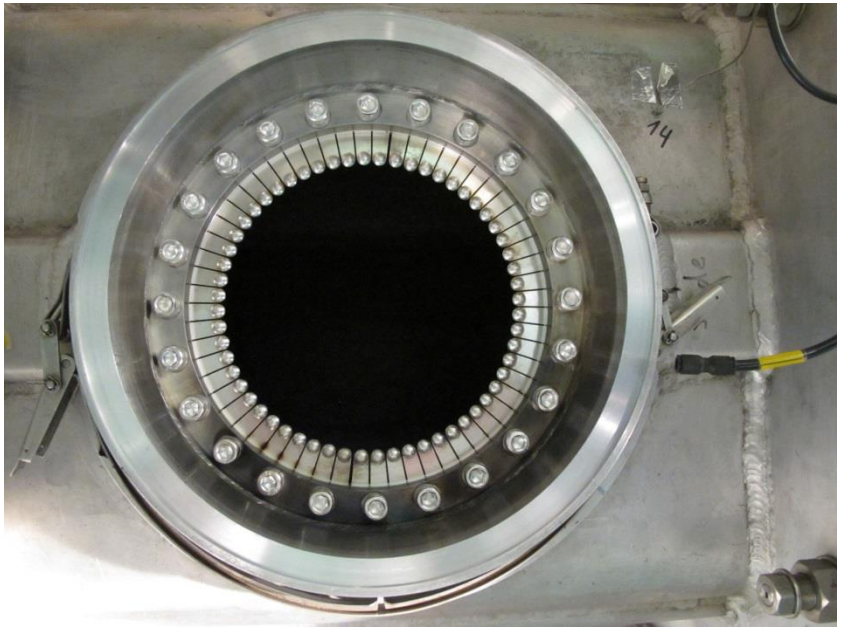
Again temperature rise on coupling loop



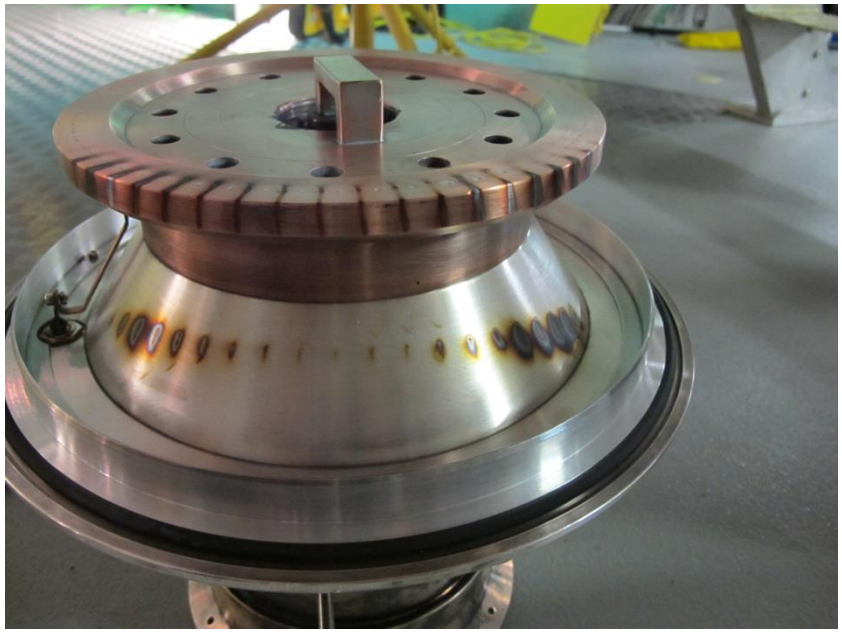
3rd time taking out the coupling loop

11. November 2013 temperature rise on coupling loop ⇒ take out coupling loop

Oil found under cavity ⇒ oil leak on hydraulic tuning system ?

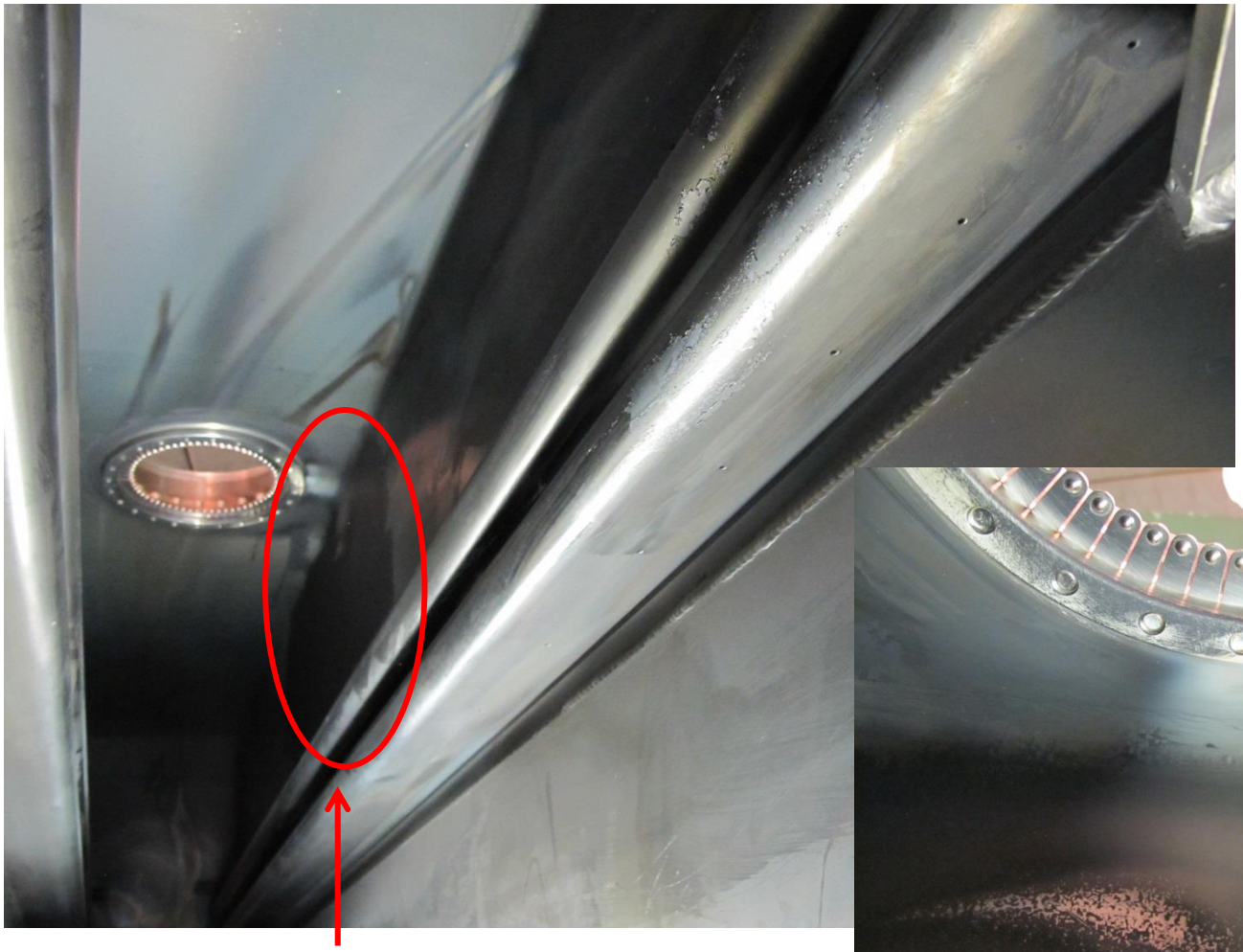


Finger contacts intact, but hanging down

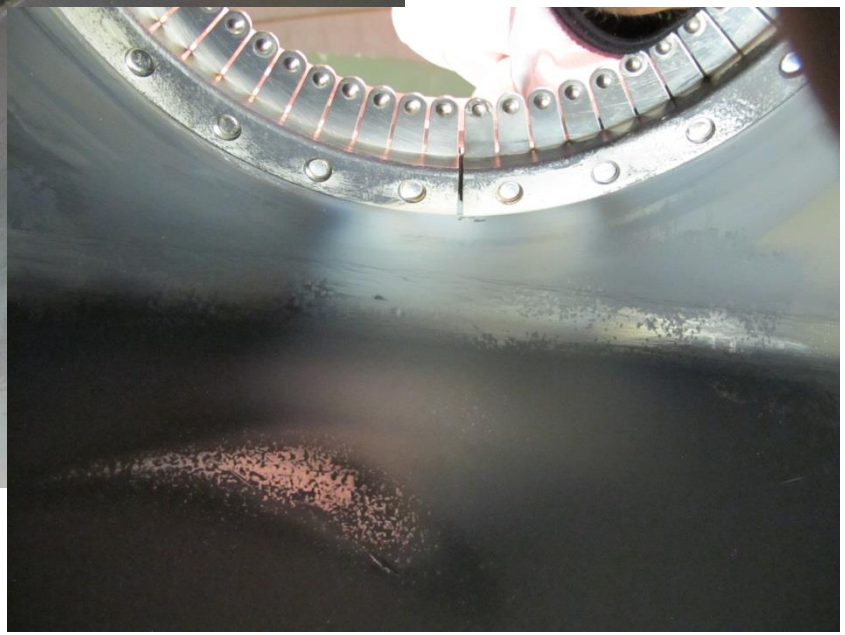


Shadows on coupling loop

Inspection of flattop cavity



First time with «aquadag» painted area



Again spot on cavity wall close to coupling loop

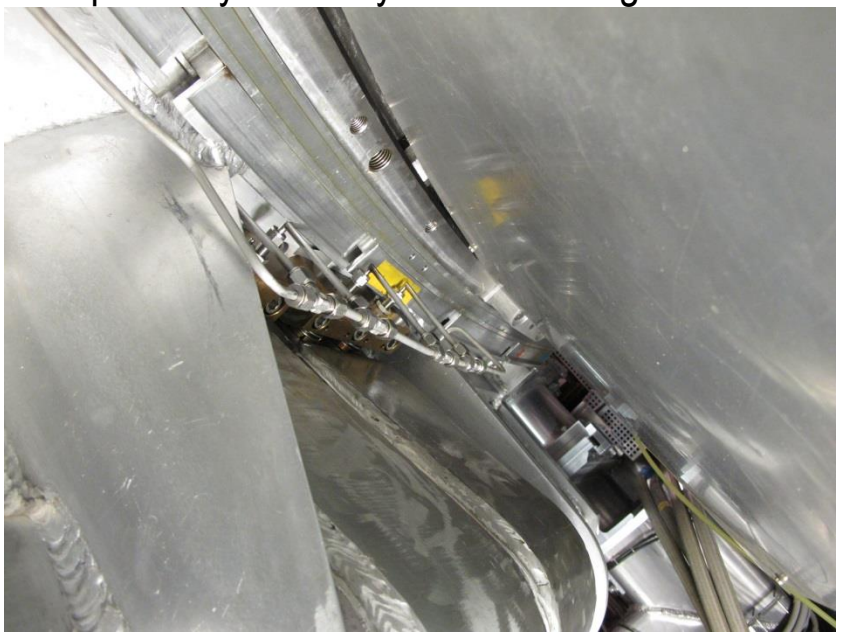
Generous painting of cavity

Cavity walls painted with «Aquadag», new contacts and new coupling loop installed

Service on tuning system

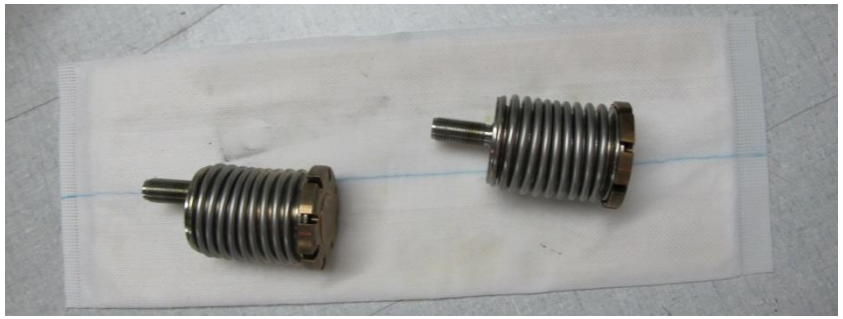
Comfortable workplace underneath the cavity

Clamp with hydraulic system for tuning



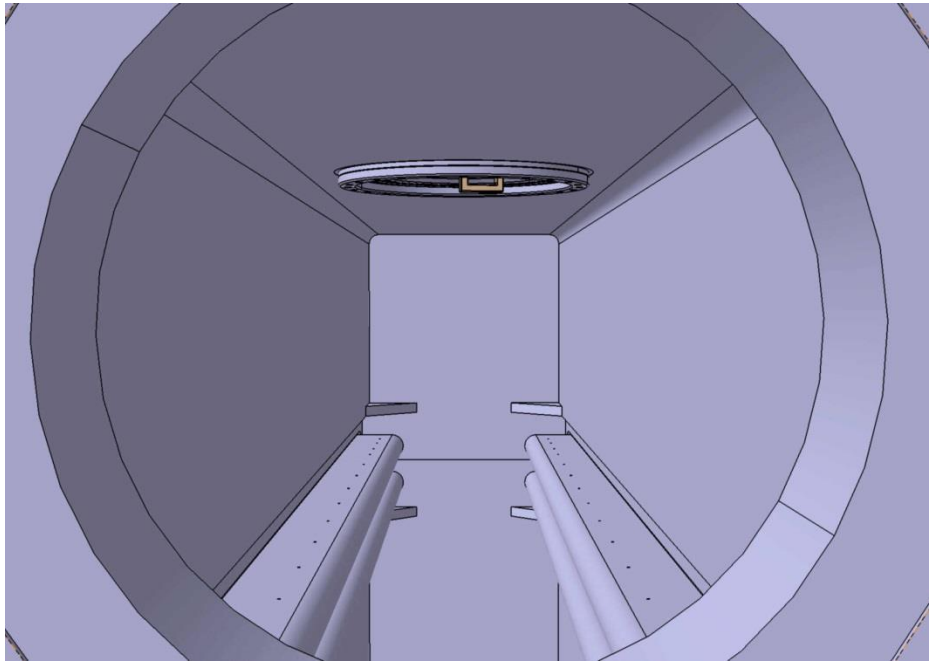
Hydraulic bellows replaced on oily clamps
Old bellows are bent and stretched

But no oil leak found

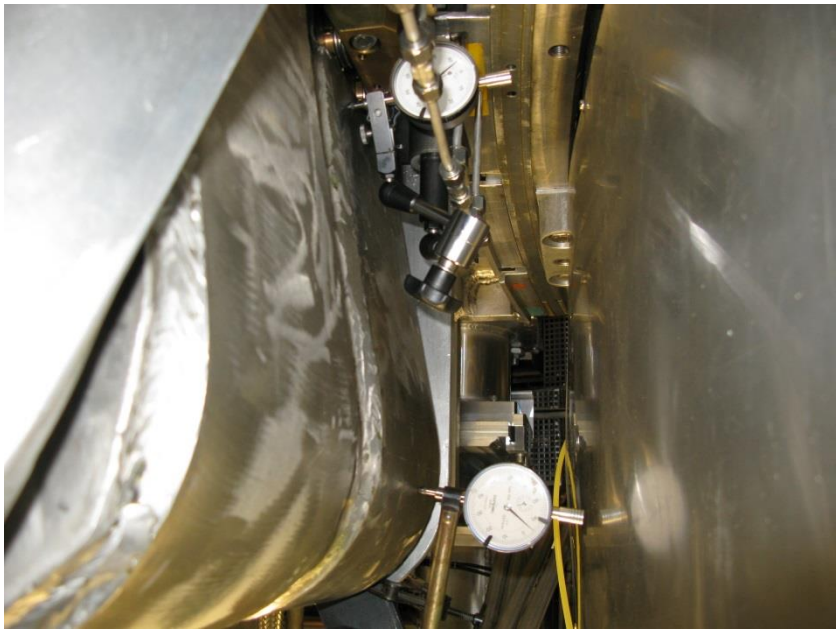


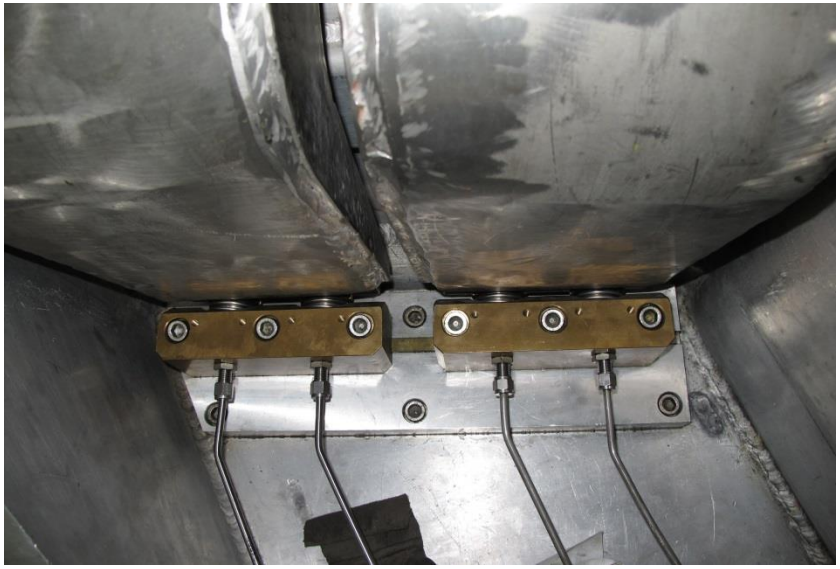
Removed hydraulic bellows

View inside the cavity during conditioning



Activities on flattop cavity during Shutdown 2014





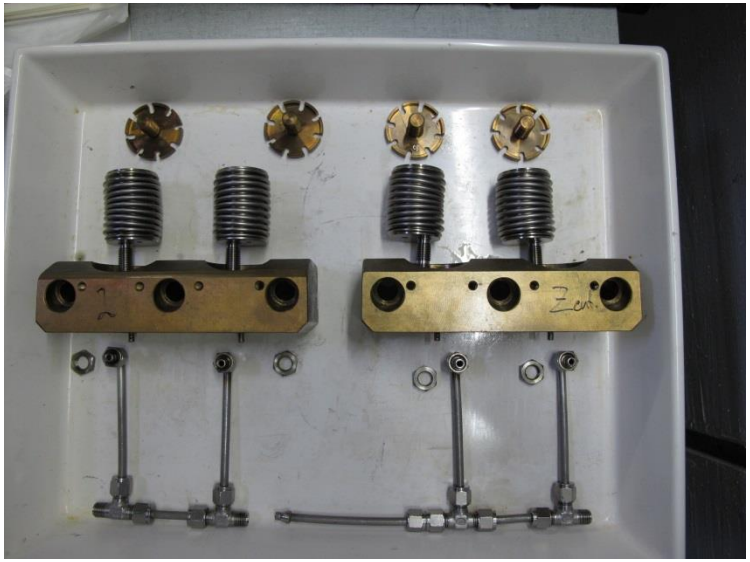
Replacement of Hydraulic bellows. 12 of 16 replaced

To order more bellows exact specification needed

Way	+/- 5 mm
Max Pressure	120 Bar

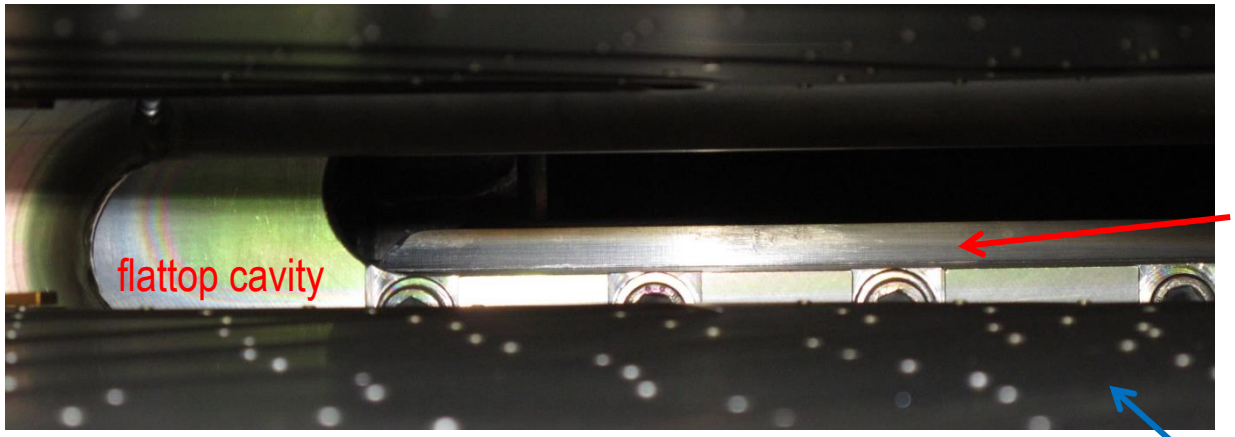
Tuning system:	way of below	~ 5mm
	pressure	0 … 120 Bar
	frequency range	460 kHz

Beam loss (~ 300 per week), swing from 103 to 87 Bar



Lift of expandable vacuum seal in shutdown 2014

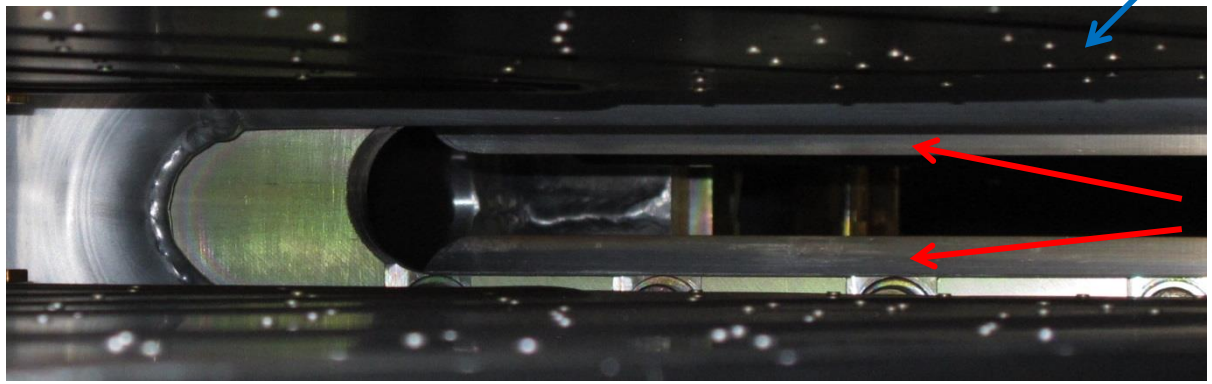
View through sector magnet 6 toward flattop cavity



Lip (electrode) of flattop cavity

Position of expandable vacuum seal at the end of 2013.
Upper lip not visible

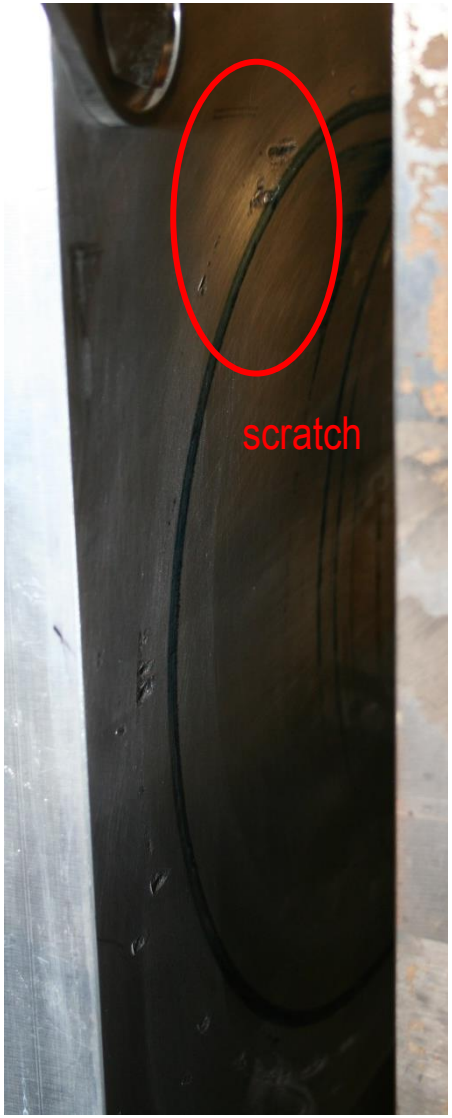
Trim coils in sector magnet



Lips (electrode) of flattop cavity

Lifted position of expandable vacuum seal after shutdown 2014

Activities on flattop cavity during shutdown 2014

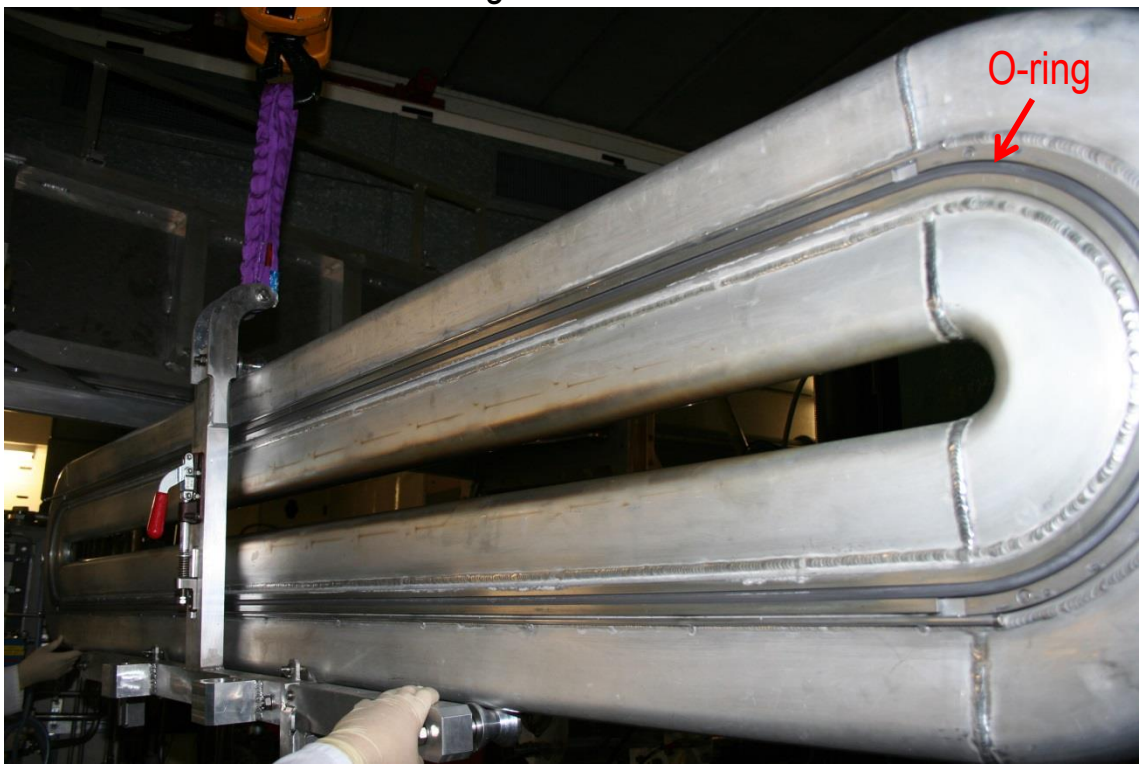


Cavity surface for vacuum seal

Vacuum leak on lifted expandable vacuum seal.

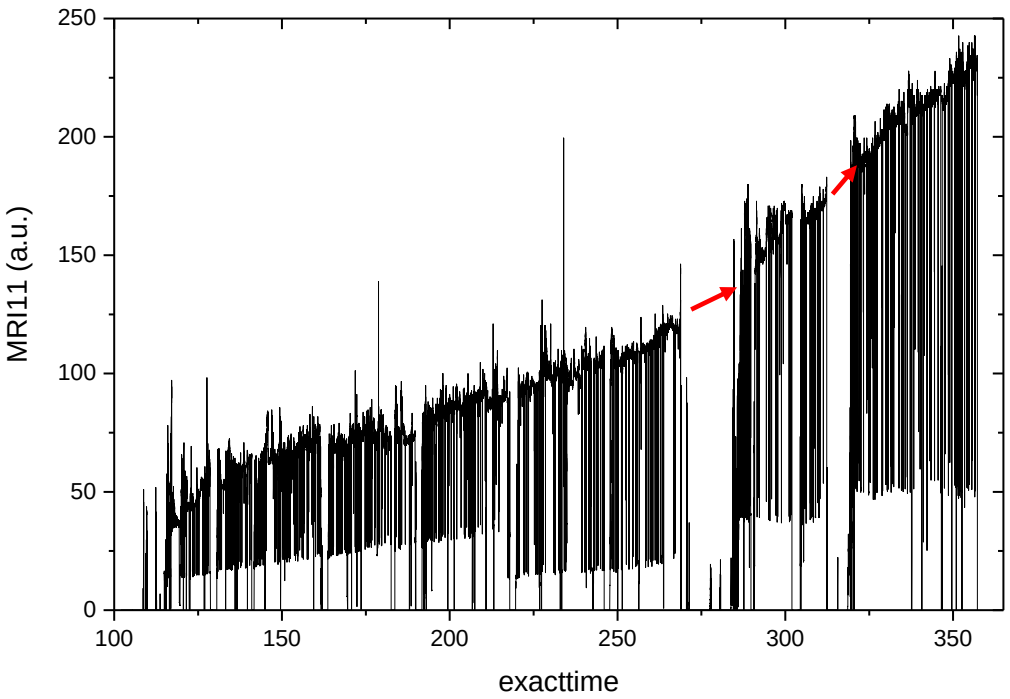
Viton O-ring on cavity side replaced by glued square – ring from chloroprene elastomer ⇒ lifetime in this area unknown (radiation)

Helium leakage rate	on cavity side	$3 * 10^{-6}$ mBar *l/s
	on magnet side	$5 * 10^{-5}$ mBar *l/s



Expandable vacuum seal (0.7 Bar compressed air)

Outlook flattop cavity



Measurement on ionization chamber on flattop cavity during 2013

Still same behavior in 2014 since shutdown

- Have a closed look on temperatures on cavity (new interlock system already installed)
- Further measurements with ionization chamber
- Planing or polishing of cavity surface for vacuum seal to get ride of scratches. For this action cavity has be take out of cyclotron and bunker.
  $\Rightarrow$ task for shutdown
- Improvements on expandable vacuum seal to avoid scratches on surface of cavity (rf-shielding ?)

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Job description to work in the rf-group:

Advanced painting skills