HIE-ISOLDE SRF development activities at CERN

HIE-ISOLDE annual workshop 5-7 Dec 2011

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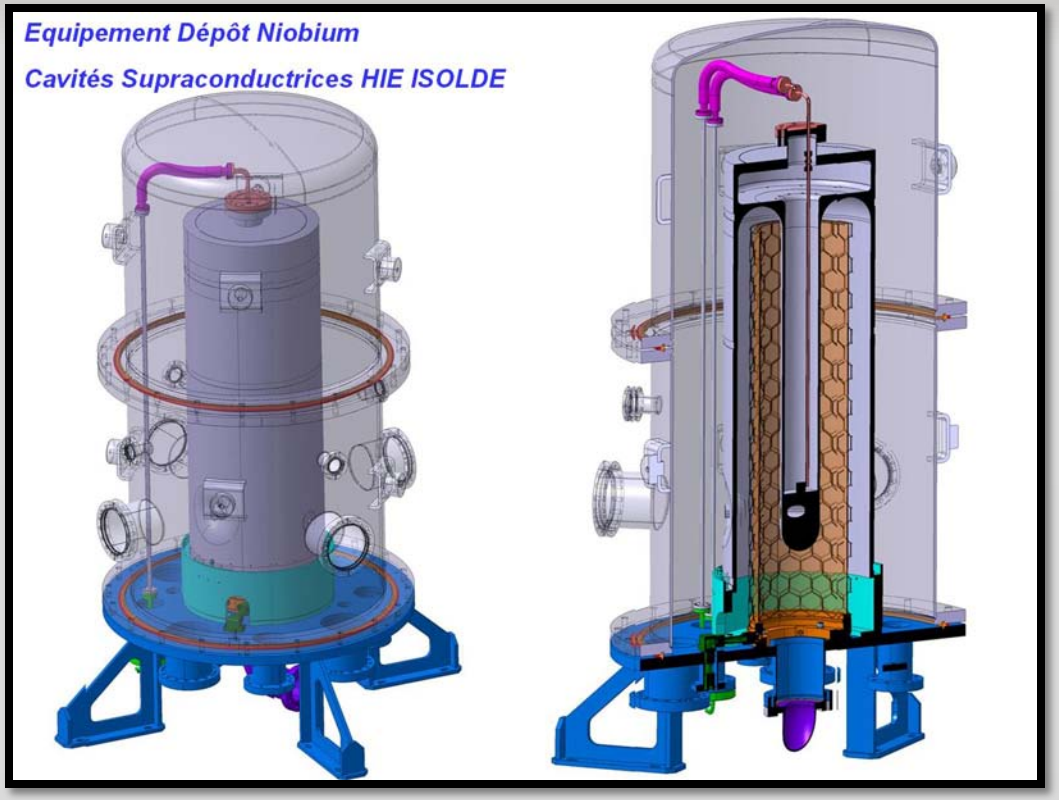
OUTLINE

- **QWR COATING FACILITY**
  - Design of the coating system
  - Cavity preparation for coating
  - Visual inspection system
  - Options for the sputtering procedure
- **LAST COATING TESTS**
  - Recommendations from the last Cavity review in May 2011
  - Magnetron coating without cooling
  - Diode coating without cooling
  - Conclusions from the tests
- **RF TEST FACILITY**
  - Cavity assembly at SM18
  - RF test stand
  - RF power coupler
  - New tuning plate
  - Assembly and RF testing : near future
- **RF TESTS**
  - Tests conditions
  - Coating tests parameters
  - RF tests results at 4.5K

QWR COATING FACILITY

Design of the sputter coating system



- Primary and a **turbo-molecular pumped**.
- Bake-out: **48 hours at 120 °C**.
- Base pressure ≈ **$5x10^{-9}$ mbar**.
- Residual Gas Analyser (**RGA**).
- **Cooling system**: compressed air or a refrigerant liquid

Optimisations for coating procedure are being tested:

- NEG pumping
- All-metal helicoflex sealing of flanges (better reliability / higher operating temperature)

Cavity preparation for coating

Chemical polishing : SUBU (Sulfamic acid, H2O2 , n-butanol, di-ammonium citrate), T = 72 C, 20 µm removed, 0.8 µm roughness

Rinsing : ISO 5 cleanroom, Ultra pure water and alcohol, 6 bars, Monitoring of R (18MΩ.cm), TOC (<60 ppb), particles

Conditioning and assembling : ISO 5 clean room

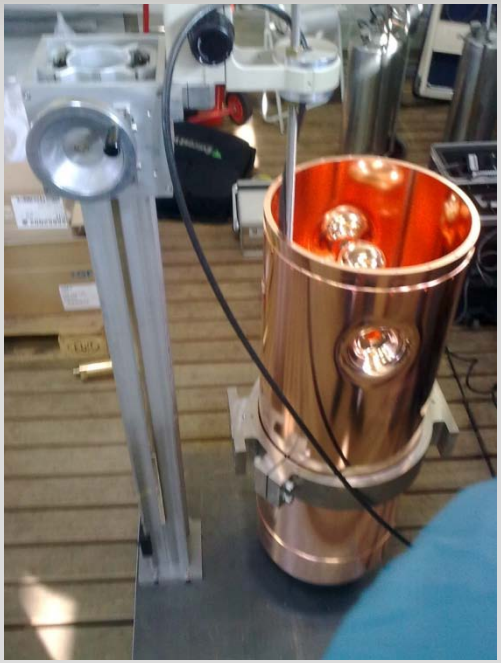
Chemical polishing

Transport to Sm18

Rinsing (b252)

Assembly in b252 CR

Visual inspection system



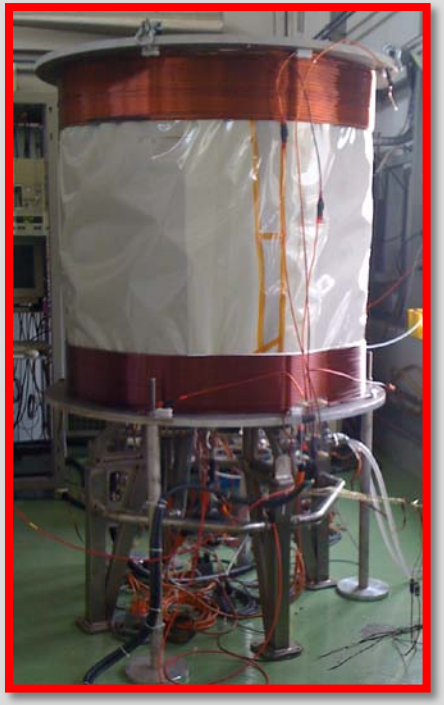
New infrastructure

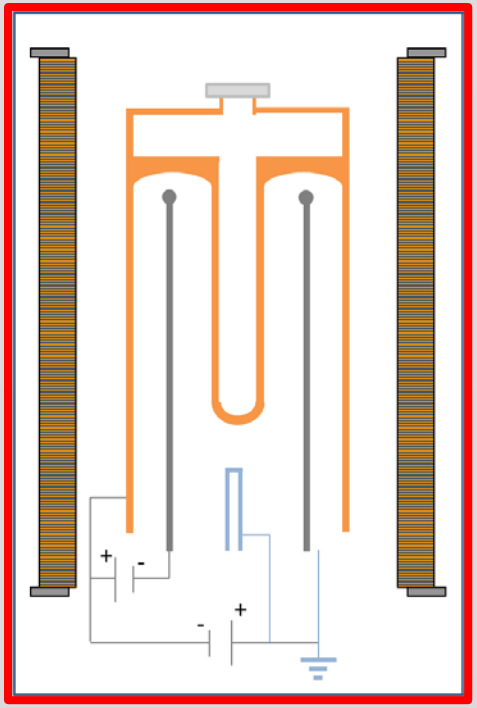
Endoscopic system to perform an inspection of all the surfaces and weldings of the cavity, avoiding scratching during the inspection

(Here with copper cavity Q2, early 2011)

Options for the sputtering procedure

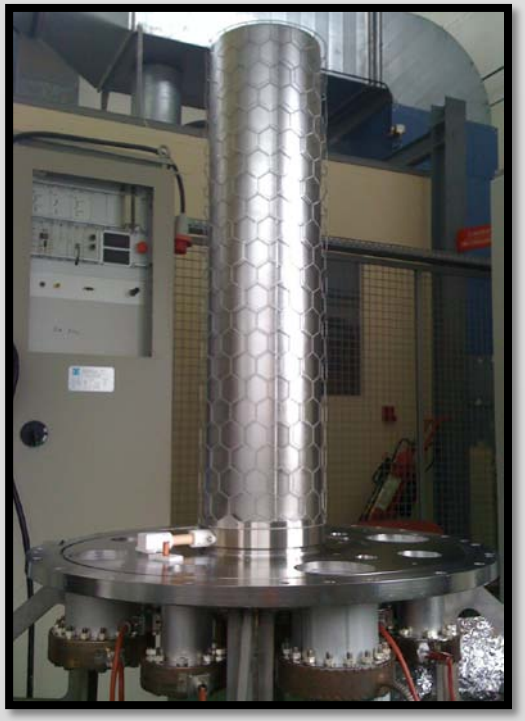
Magnetron sputtering

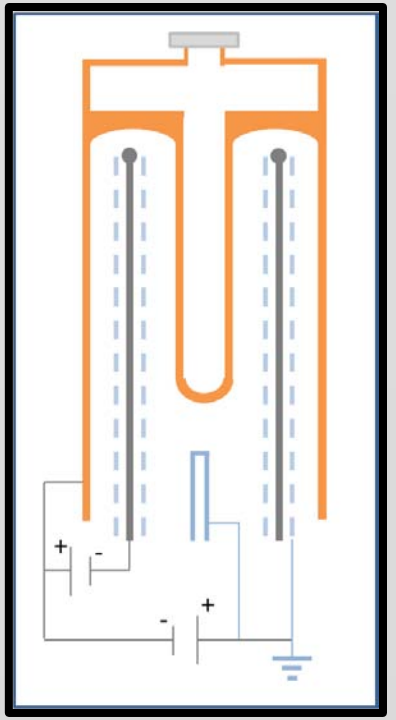




- The magnetic field keeps the plasma confined on the outer side of the cathode.
- Inside the cathode, the plasma is twice higher than outside, giving rise to a higher sputtering rate.

Diode sputtering





- The deposition rate is higher on the internal wall and on the top part of the cavity due to a non homogeneous distribution of the plasma

LAST COATING TESTS

Recommendations from the last Cavity review in May 2011

- **Increased RRR** fundamentally required to at least 20

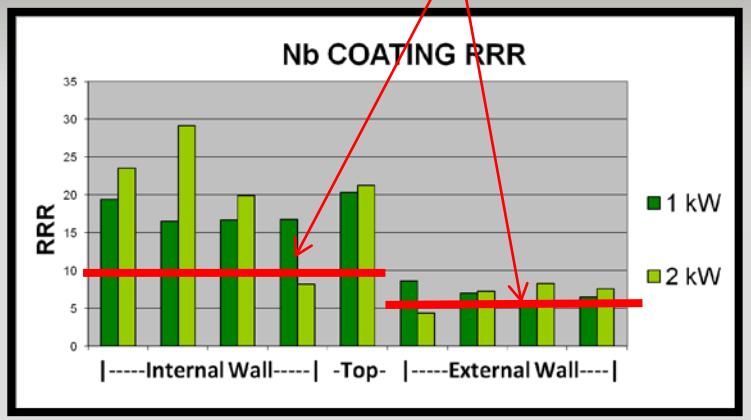
$\Rightarrow$increase ion energy, substrate temperature and/or sputtering rate.

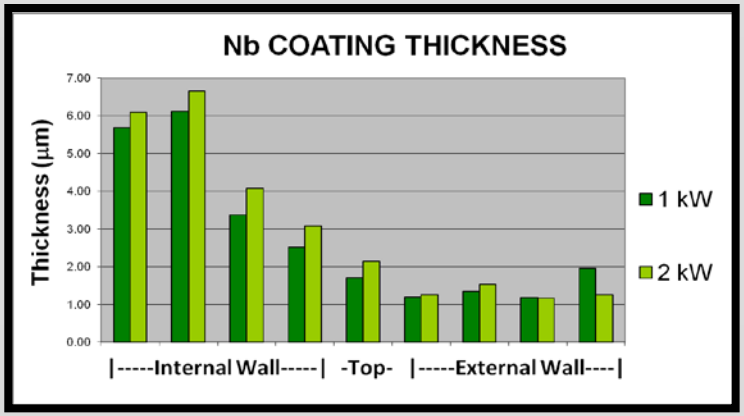
- Increase sample density in dummy cavity to characterize RRR profile.

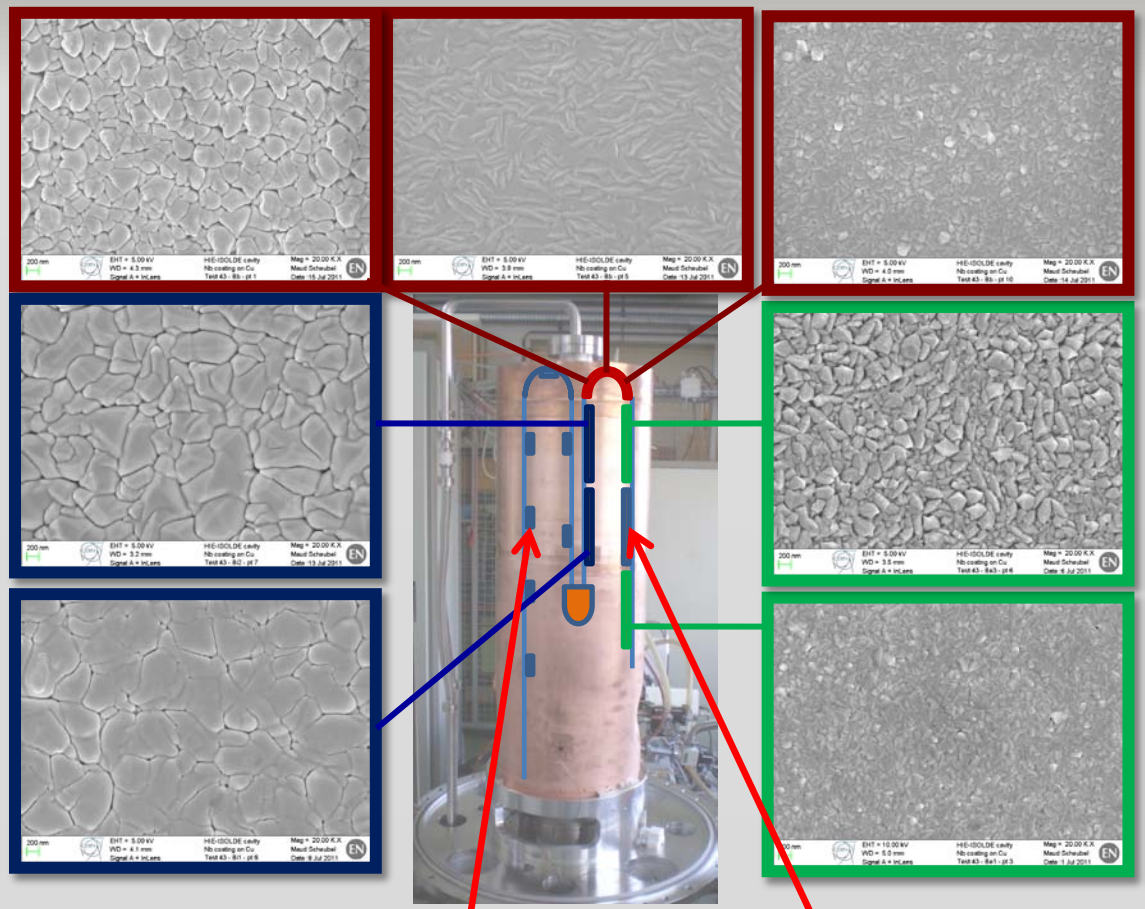
- Focus on a single sputtering technique and continue with second on a lower priority with samples.

Magnetron coating without cooling

RRR for 150 °C coatings





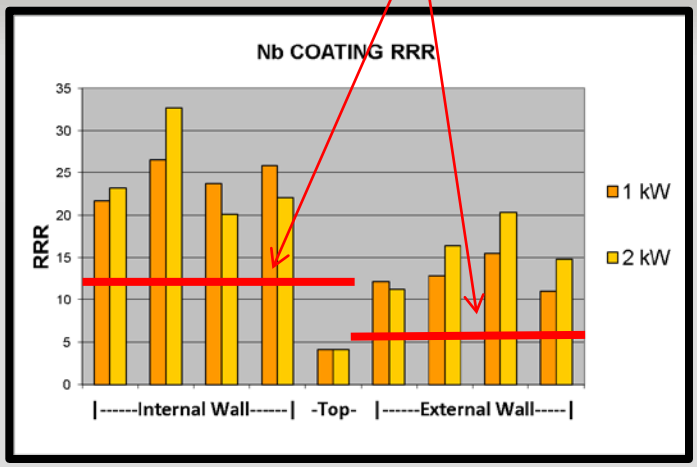


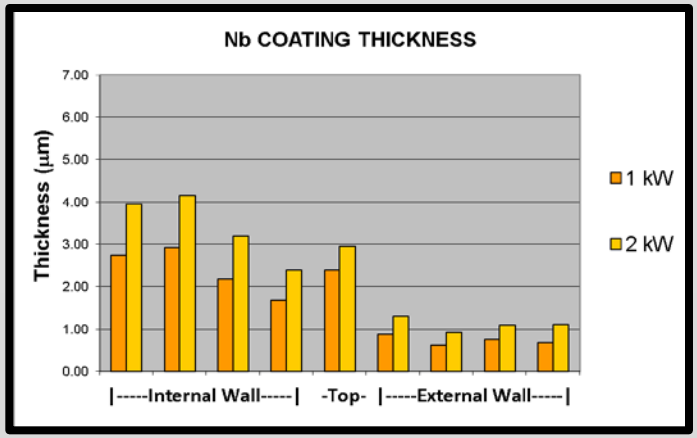
...”increase sputtering temperature”:
270 °C (1kW) and 330 °C (2 kW)

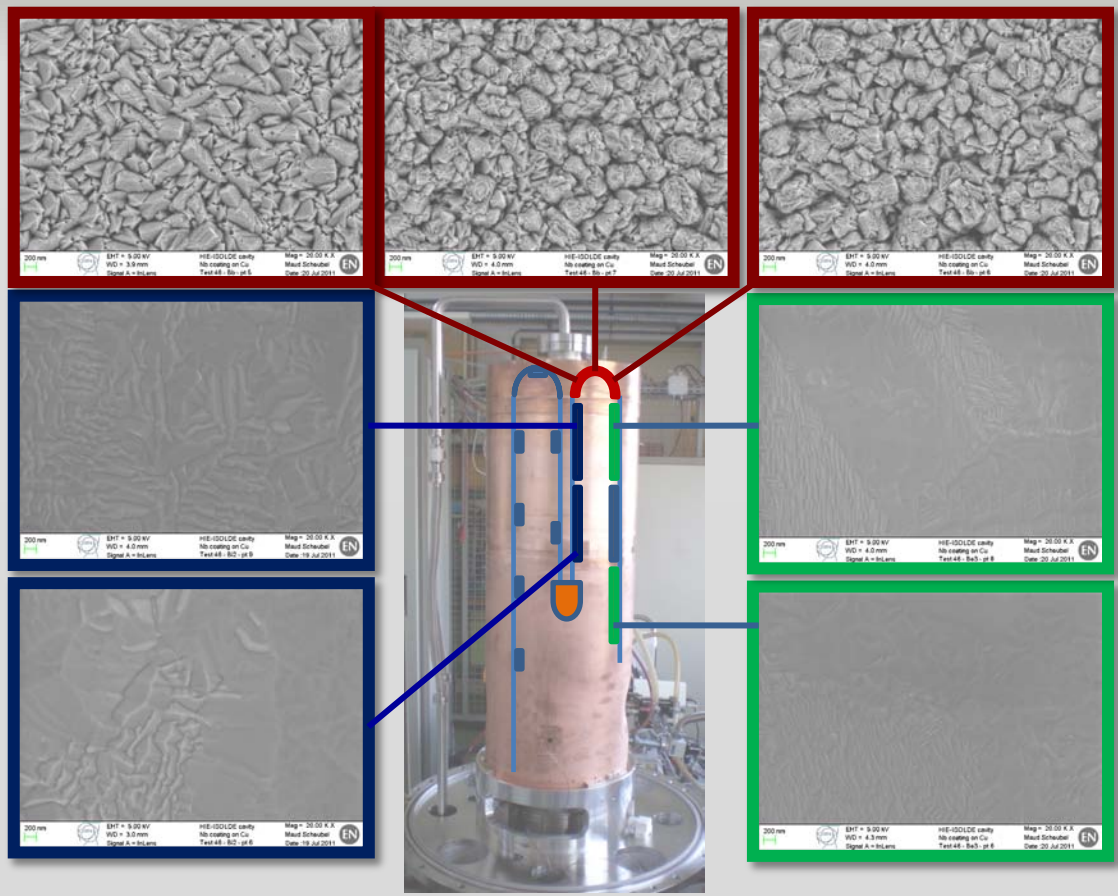
Double number of quartz samples (RRR measurement)
Full length of cavity surface lined with copper strips for SEM analysis

Diode coating without cooling

RRR for 150 °C coatings







..."increase sputtering temperature":
260 °C (1kW) and 340 °C (2 kW)

Conclusions from the tests

- **RRR** can be at least **doubled** on the RF-critical region compared to previous tests at 150 °C, for substrate temperatures around **300 °C** during coating.

- **RRR attains** specified value on **inner conductor**, **lower** value on **external conductor**.

- Diode coating shows a granular structure in the critical region.

RF TEST FACILITY

Clean room assembly

- HIE Isolde cavities are of "**common vacuum**" design

  → mounting and assembly must be performed in extremely clean conditions to avoid contamination of the RF surfaces of the cavities

- Clean room assembly, rinsing and transport procedures are established (coating system, bottom plate, RF coupler)
- "Clean area" built in SM18

Rinsing (b252)

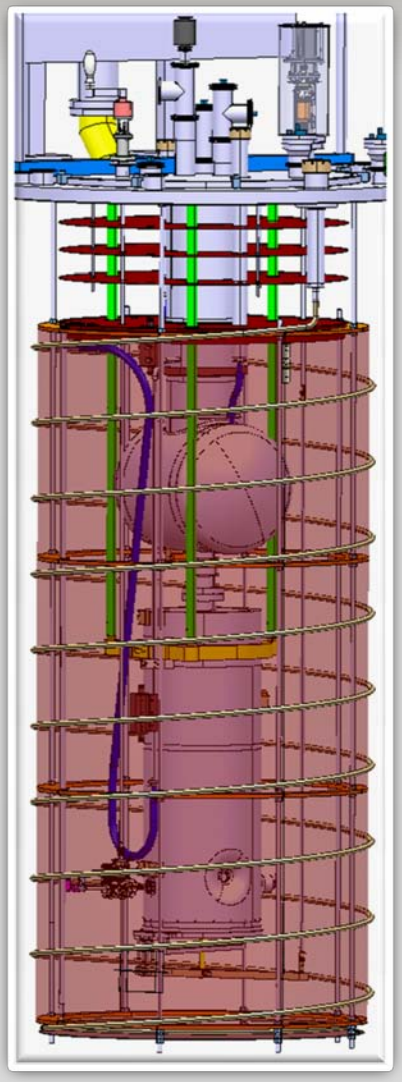
Transport to Sm18

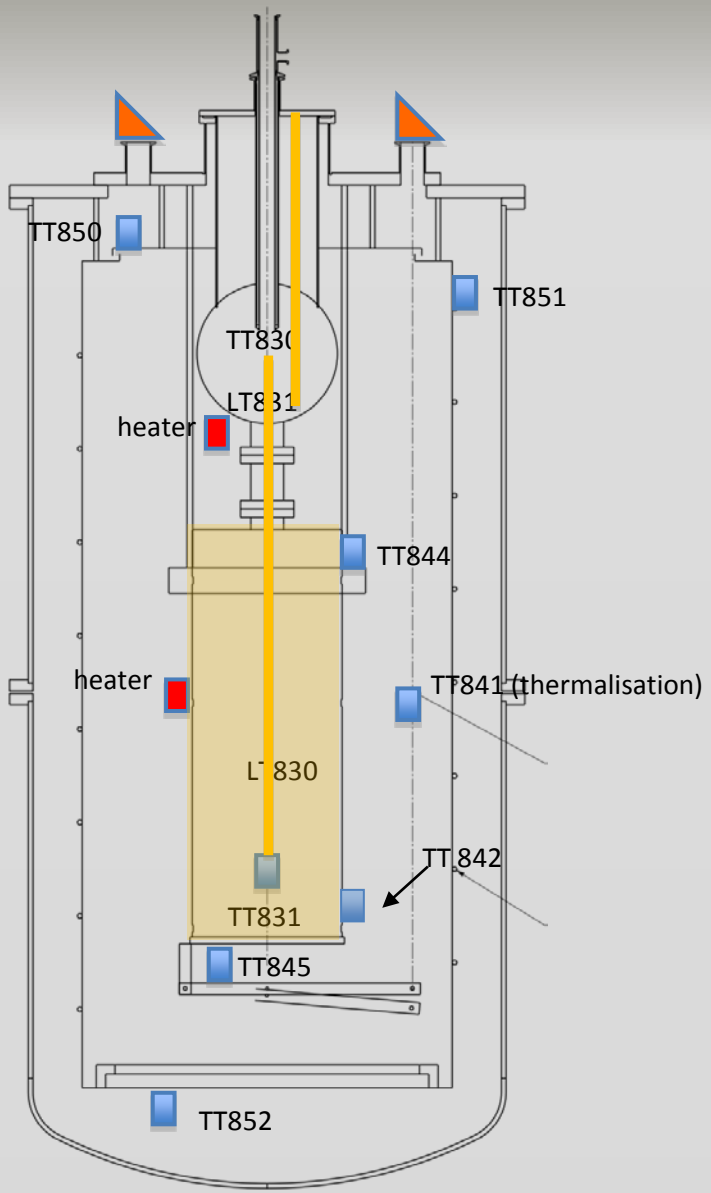
Assembly in Sm18 CR

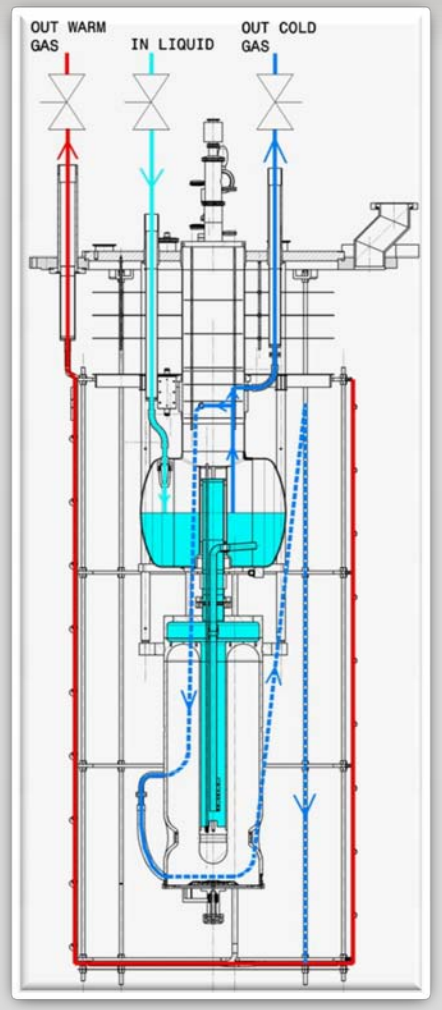
Transport to Sm18 RF test place

Insertion in cryostat

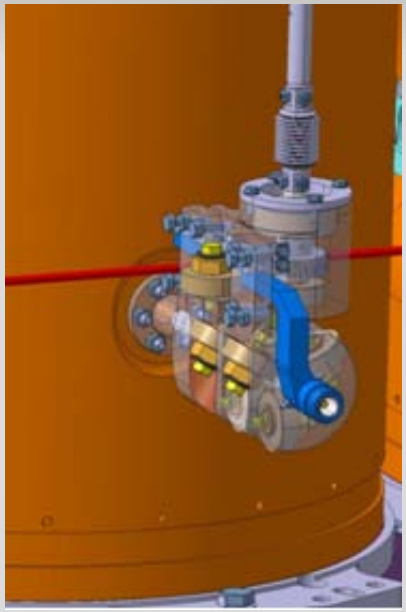
RF vertical test stand

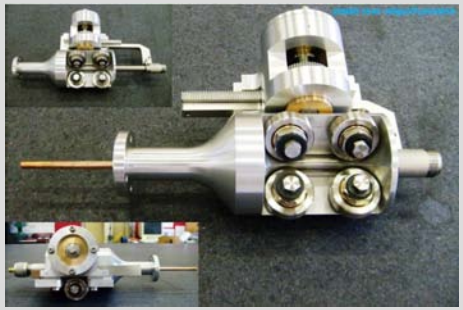


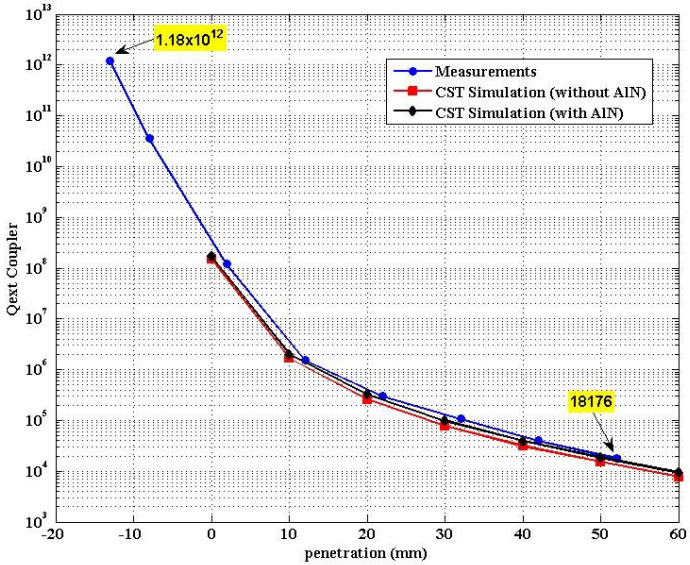




RF power coupler



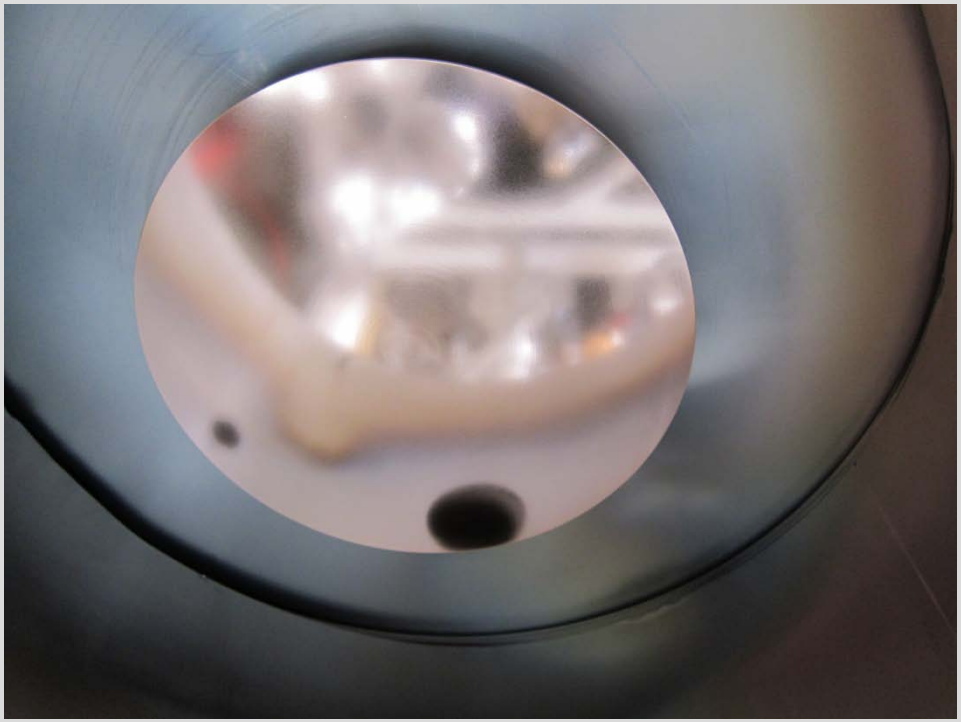




- Several problems during cavity tests
  - problems during cavity tests (blocked)
- Design review has started (E. Montesinos, BE/RF)
  - prototype: May'12
- Motorization and position control ready but not validated yet

New tuning plate

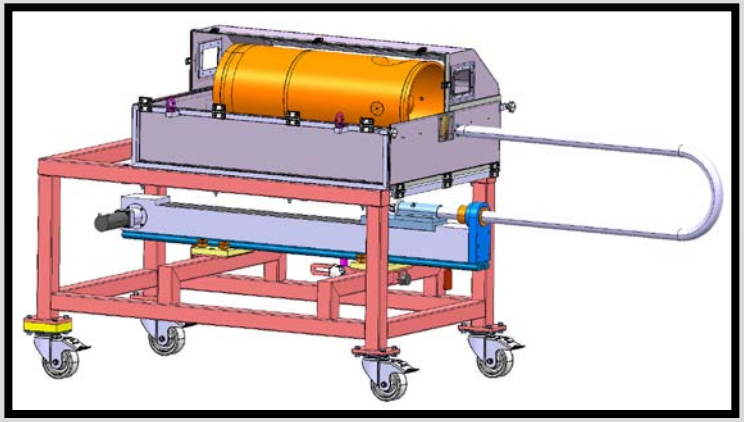
- Three new tuning plates of new design (solid Cu 3 mm thick) have been manufactured and coated (including surface treatment, rinsing...)



Pictured inside the coating system prior to coating

Assembly and RF testing: Near future

- **New insert and thermal screen assembly being built with revisited design**:
  - Construction/assembly improvements (material, welds, bellows,..)
  - Possibility to separate cavity and thermal screen cooling circuit (only with new SM18 LHe distribution line)
  - New heater system (with infrared lamps)



- **Clean room equipment**:
  - Automatic UP water rinsing system under construction

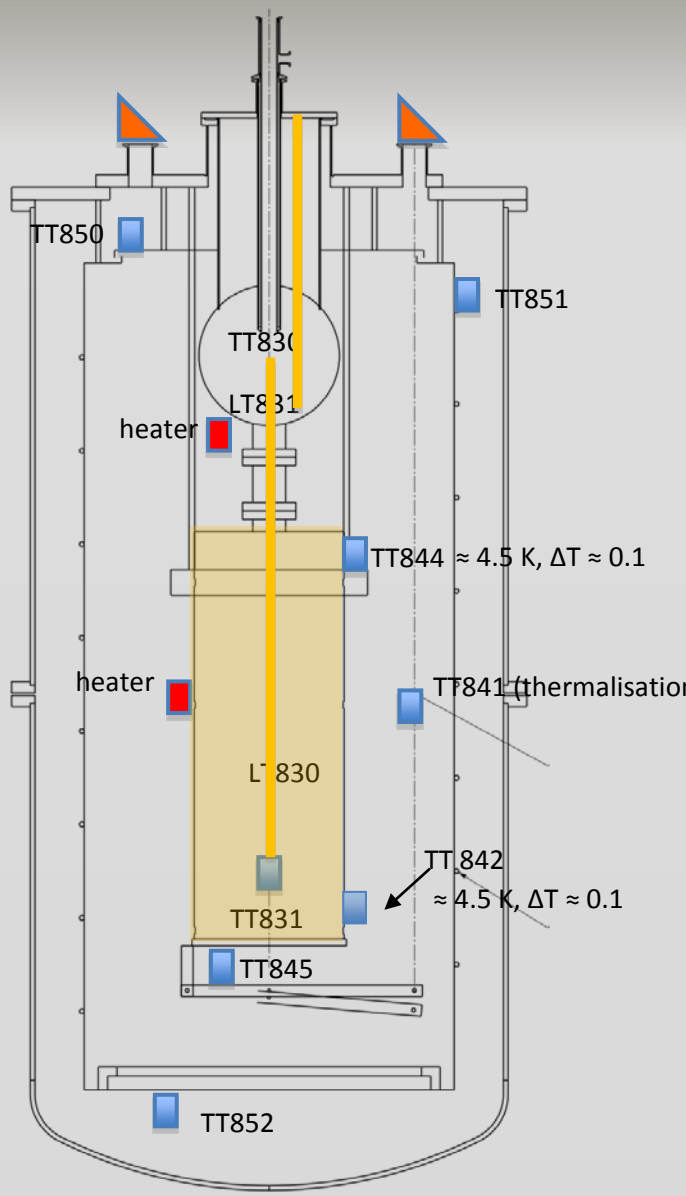
- **RF measurements**
  - New control and testing program
    - Automatic conditioning

RF TESTS

Tests conditions

- **Test conditions:**
  - Good vacuum (≈ 3 10^{-8} bars)
  - Cryogenic conditions:
    - Need stable pressure (≈ 1.3 bar)
      - not easy with existing set-up & cryo line
    - Cavity well thermalized
      - ΔT ≈ 0.1 K (with and w/o RF)

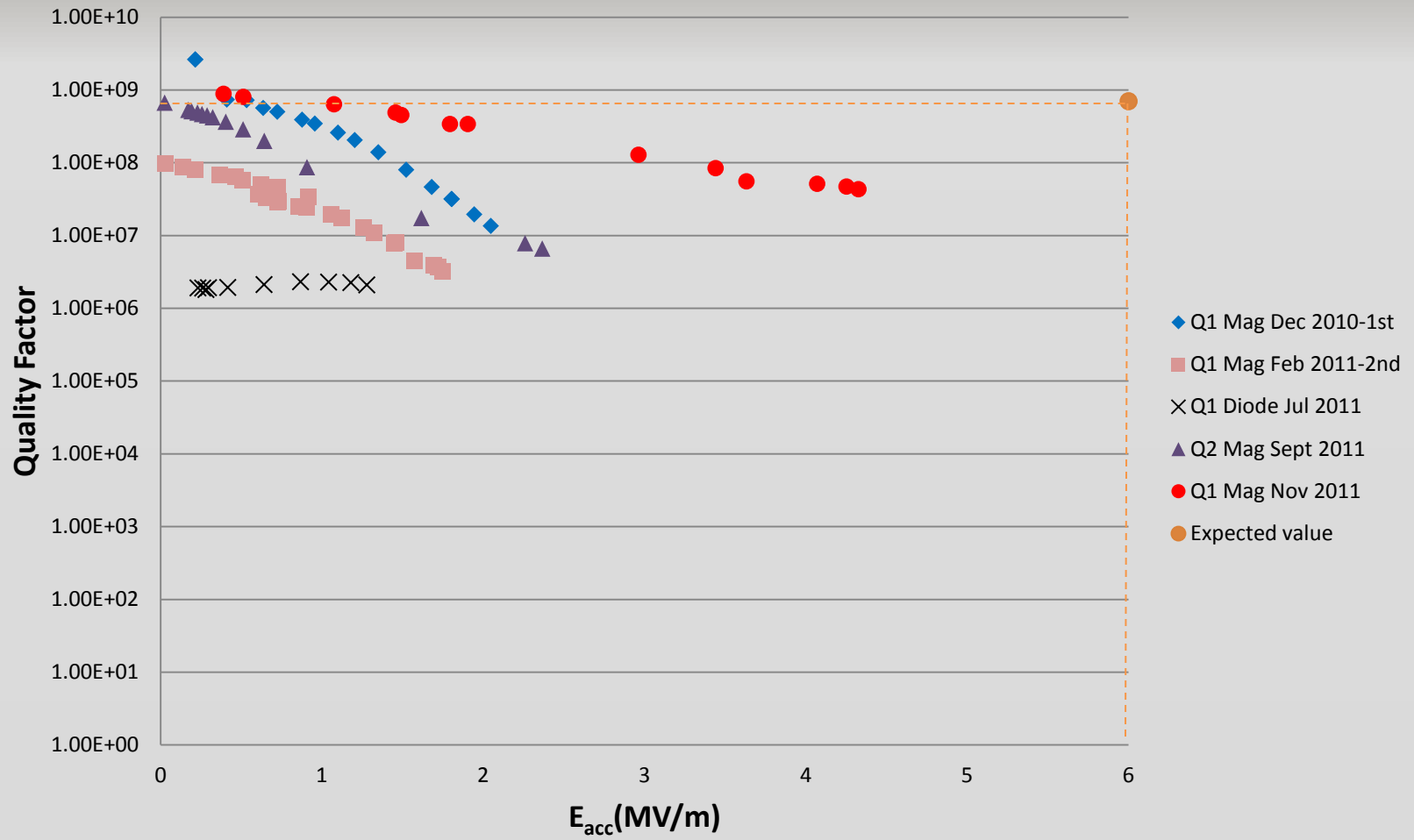
- **RF conditioning:**
  - Movable RF coupler
    - Not easy (low field multipactor barriers)
  - Fixed RF coupler (Q_{ext} = 5.1·10^7)
    - Not successful (could hardly jump over multipactor barriers after 4 days of conditioning)



Coating parameters

	Q1 - magnetron		Q1 - diode	Q2 - magnetron	Q1 - magnetron	Q2 - diode
Date of RF Meas.	Dec -10	Feb-11	June-11	Sept-11	Oct-11	Nov-11
Pressure (mbar)	$1.5\ 10^{-2}$		$1.5\ 10^{-1}$	$0.8\ 10^{-2}$	$0.8\ 10^{-2}$	$1.4\ 10^{-1}$
"Coating" power (kW)	0.8		0.8	0.9	2	2
Coating time (h)	8.4		38	8	3h47	15h35
Thickness (um)	1		0.5	1	1	0.5
Coating temp (°C)	150		150	150	380	480
Rem.	rinsed					Test next week

RF tests results at 4.5K

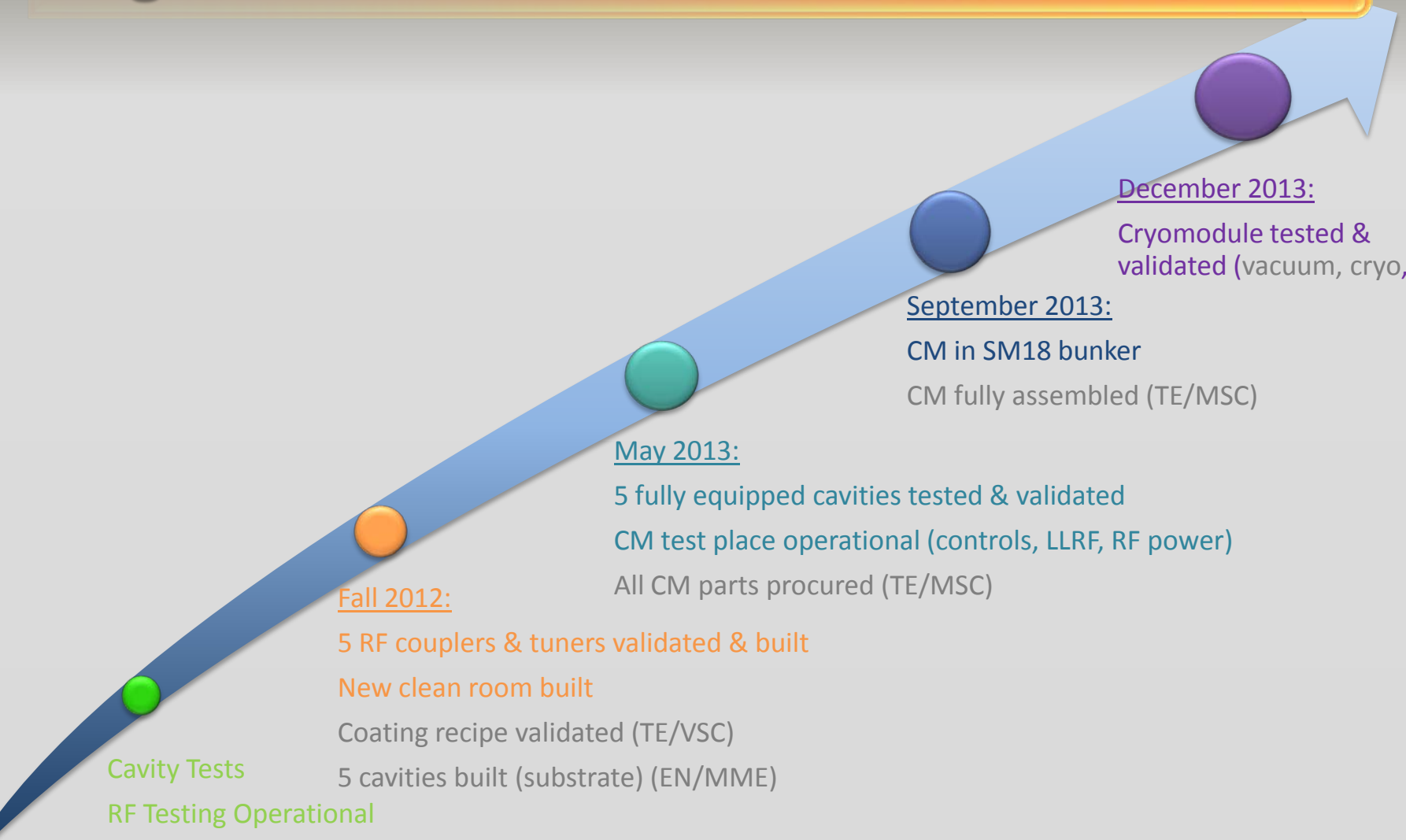


Next test: Q2 Diode high temperature (480°C)

Conclusions

- RF testing operational
- The increasing of temperature for the coating gave significantly better results than the previous coatings: **$Q_0 = 5\ 10^7$ at 4.5 MV/m**
- The diode coating at high temperature (480°C) will be tested next week
- Repeat the best result of the two sputtering techniques
- Focus on a single sputtering technique and improve the quality of the Nb coating (higher temperature)

A goal is a dream with milestones



Cavity Tests

RF Testing Operational

Clean room & RF Test Protocol Established

Coating tests in progress (VSC)

Fall 2012:

5 RF couplers & tuners validated & built

New clean room built

Coating recipe validated (TE/VSC)

5 cavities built (substrate) (EN/MME)

May 2013:

5 fully equipped cavities tested & validated

CM test place operational (controls, LLRF, RF power)

All CM parts procured (TE/MSC)

September 2013:

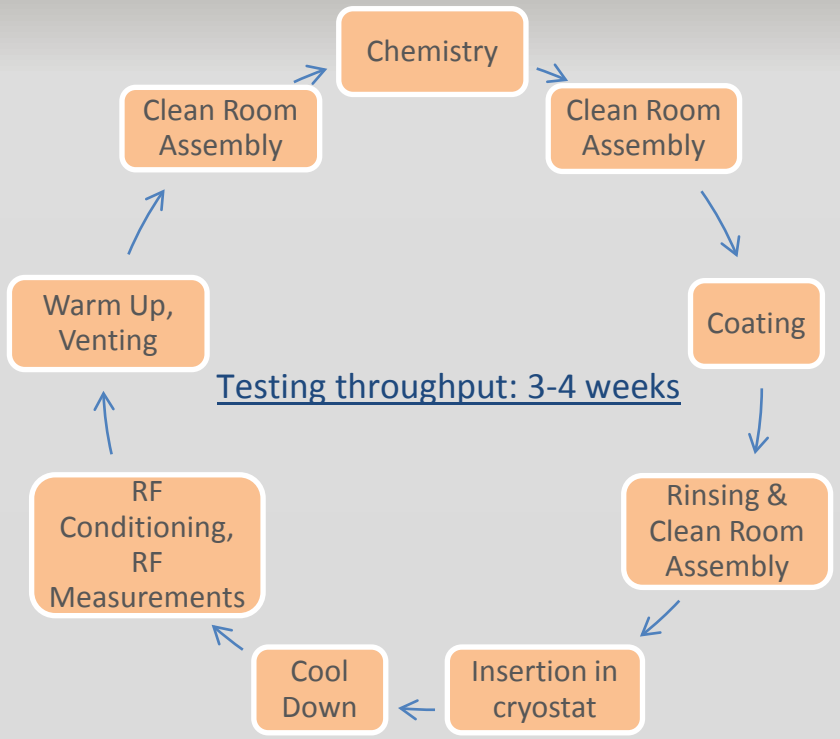
CM in SM18 bunker

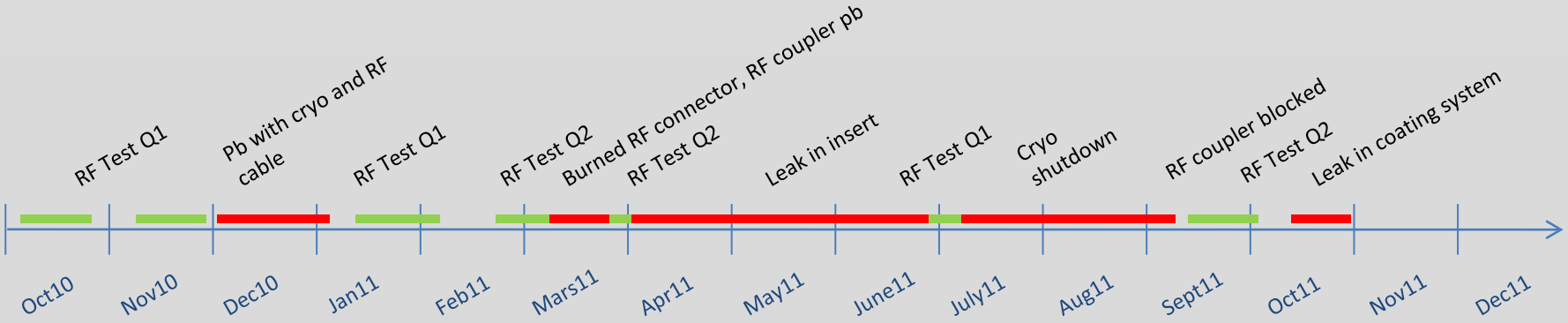
CM fully assembled (TE/MSC)

December 2013:

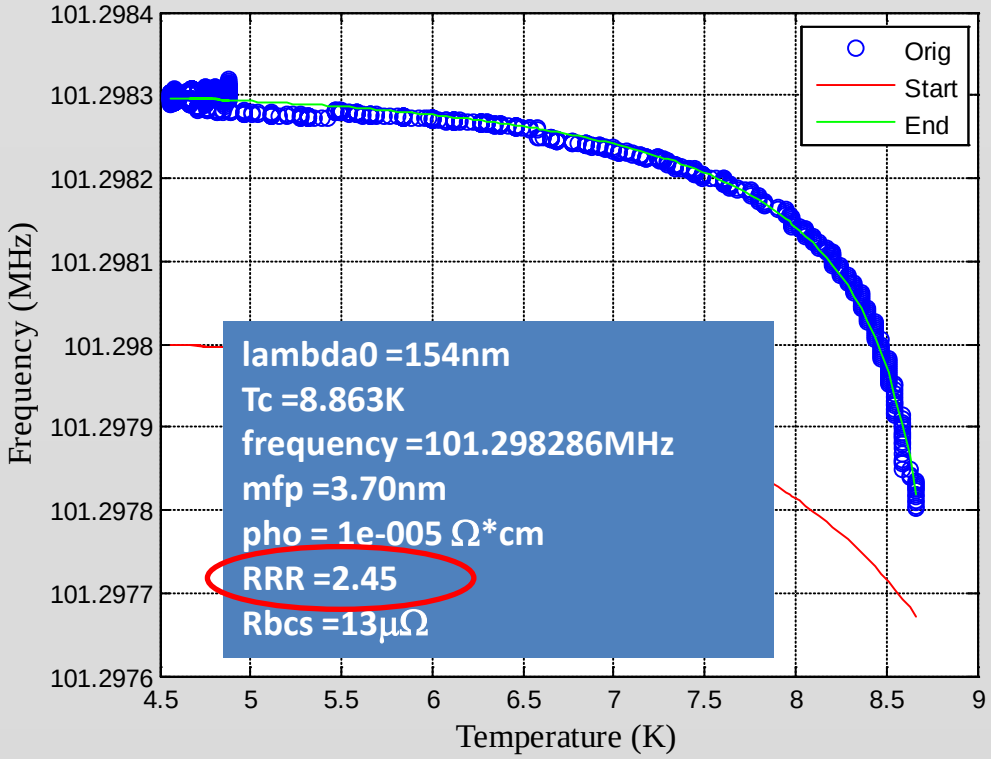
Cryomodule tested & validated (vacuum, cryo, RF)

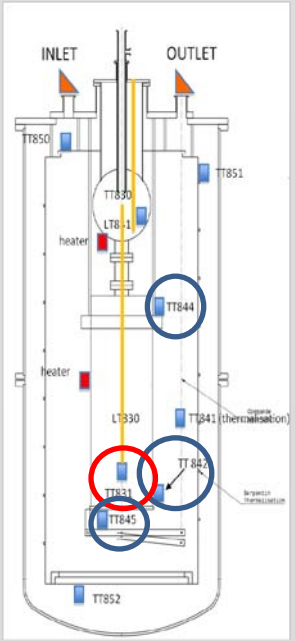
“A long and winding circle…”





Frequency vs temperature



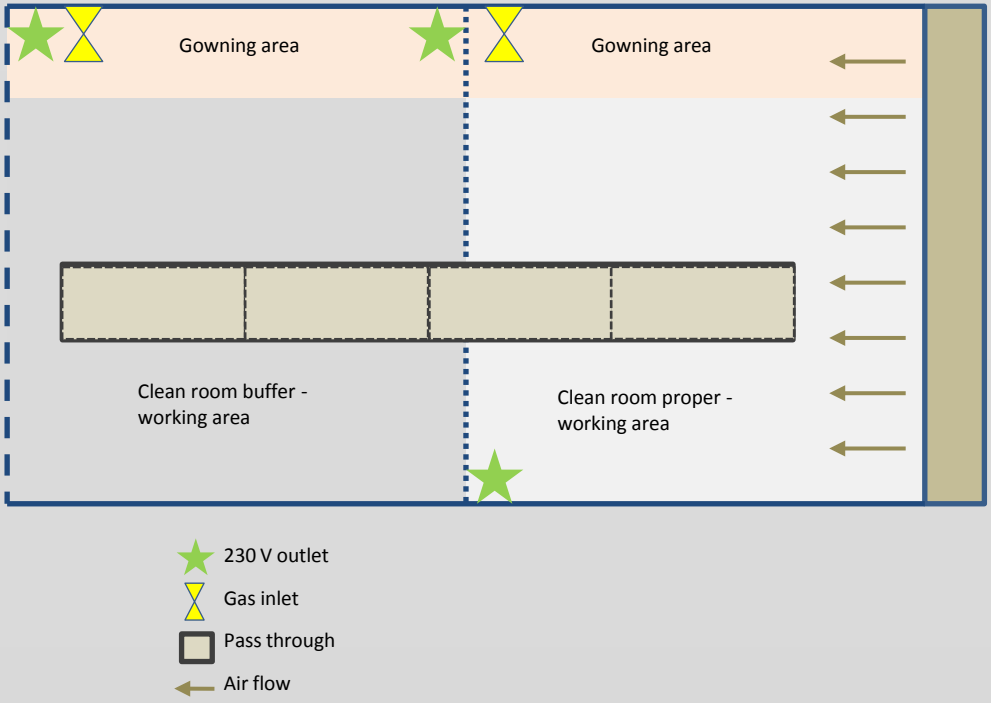


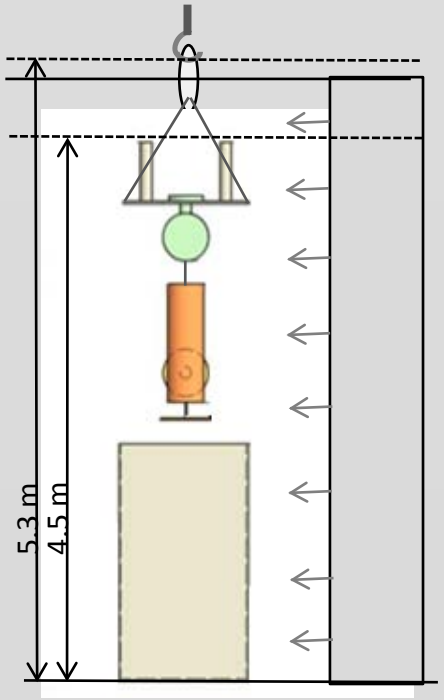
$$\ell = \frac{\xi_0}{\left(\lambda_0 / \lambda_L\right)^2 - 1} \quad \Rightarrow \quad \rho_{imp} = \frac{0.37 \times 10^{-11}\ \Omega \cdot \mathrm{cm}^2}{\ell} \quad \Rightarrow \quad \begin{cases} \mathrm{RRR} = \dfrac{\rho_{300K}\,(=1.45 \times 10^{-5}\ \Omega \cdot \mathrm{cm})}{\rho_{imp}} + 1 \\ \mathrm{R}_{BCS} = \dfrac{\omega^2 \mu_0^2\ \lambda_{Tin}^3}{2\,\rho_{imp}} \end{cases}$$

A. D'Elia, Q2 Measurement Report,EDMS no.

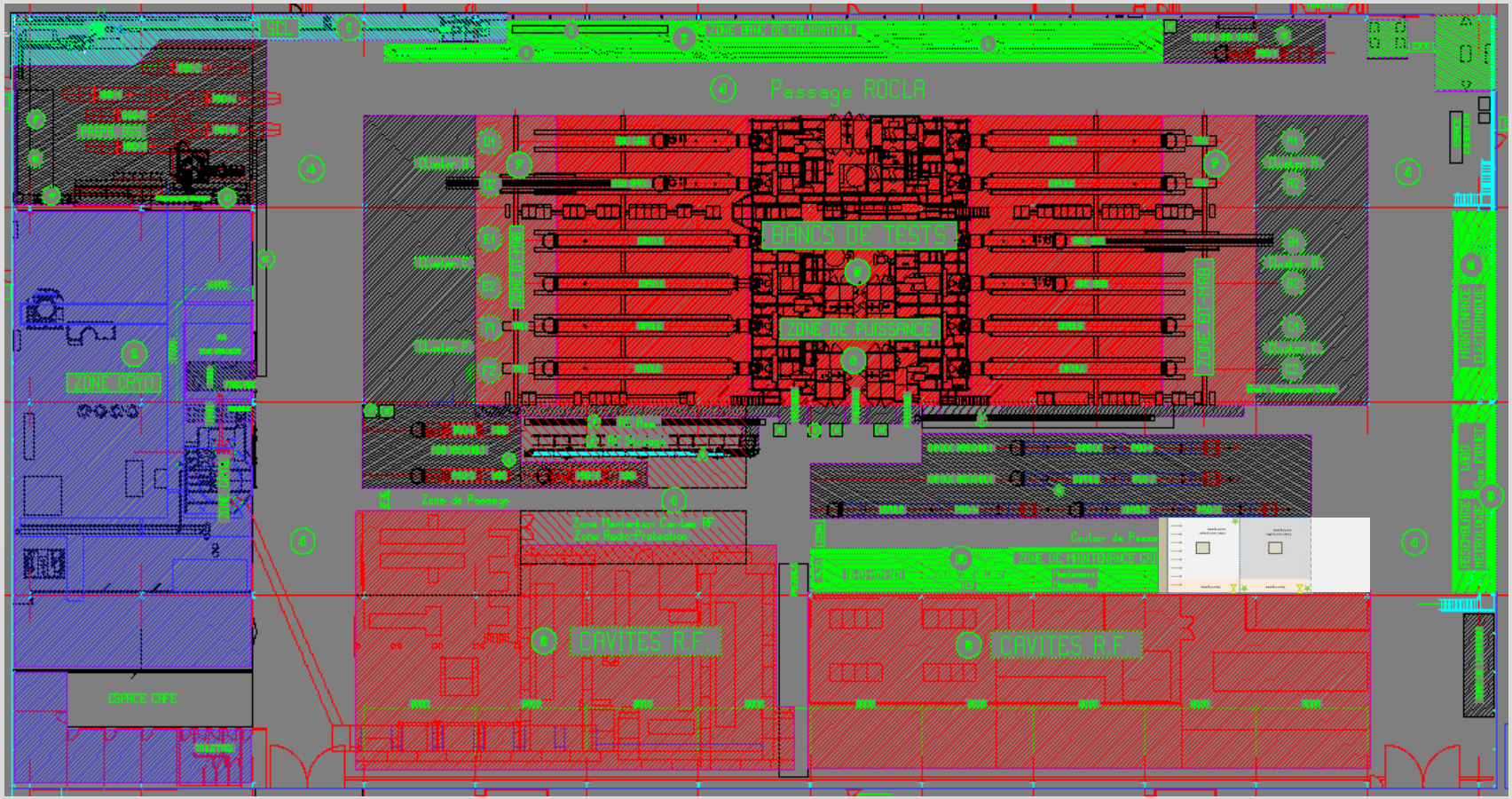
Infrastructure upgrade (1)

- New Lhe distribution line in SM18 (Summer ‘12)
- New “high” clean room facility required for cryomodule assembly:
  - Clean room proper CLASS 100, clean room buffer CLASS 10’000
  - Specification document ready



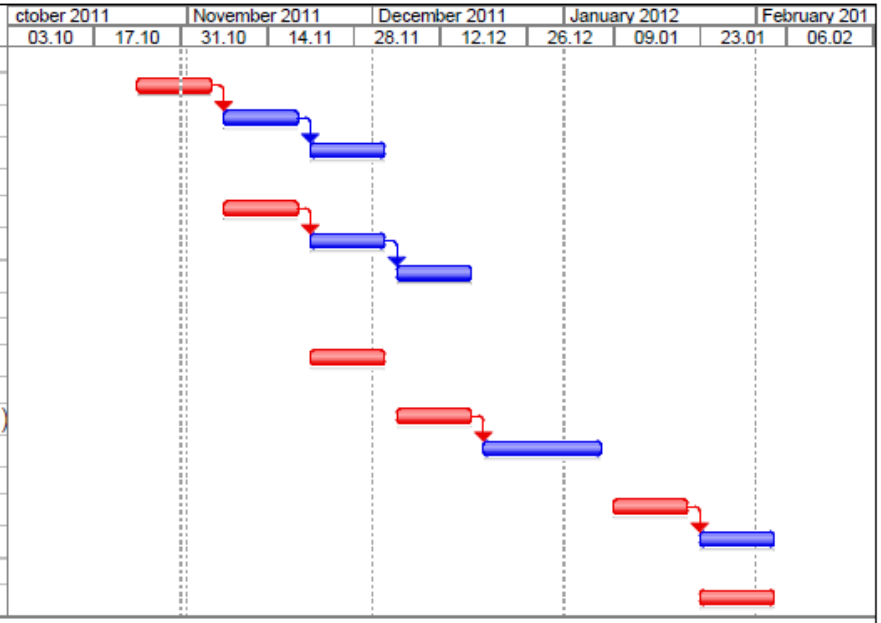


Infrastructure upgrade (2)



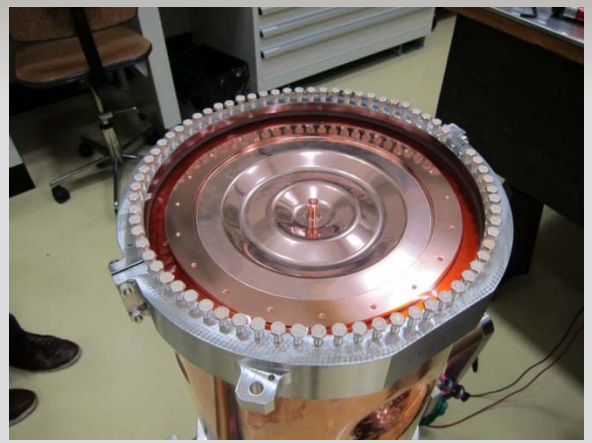
Future plans

ID		Task Name
1		
2		High temperature coating cavity Q1 (magnetron)
3		RF testing
4		Metrology
5		
6		High temperature coating cavity Q2 (diode)
7		RF testing
8		metrology
9		
10		
11		Sample testing (higher power)
12		
13		Repetition of best perfoming previous coatings (Q1)
14		RF testing
15		
16		High power liquid cooling coating (Q2)
17		RF testing
18		
19		Sample testing on Q4 / Coating of Q3



- Goals set by the project:
  - on-specs by March 2012
  - Production coatings start 1Q2013

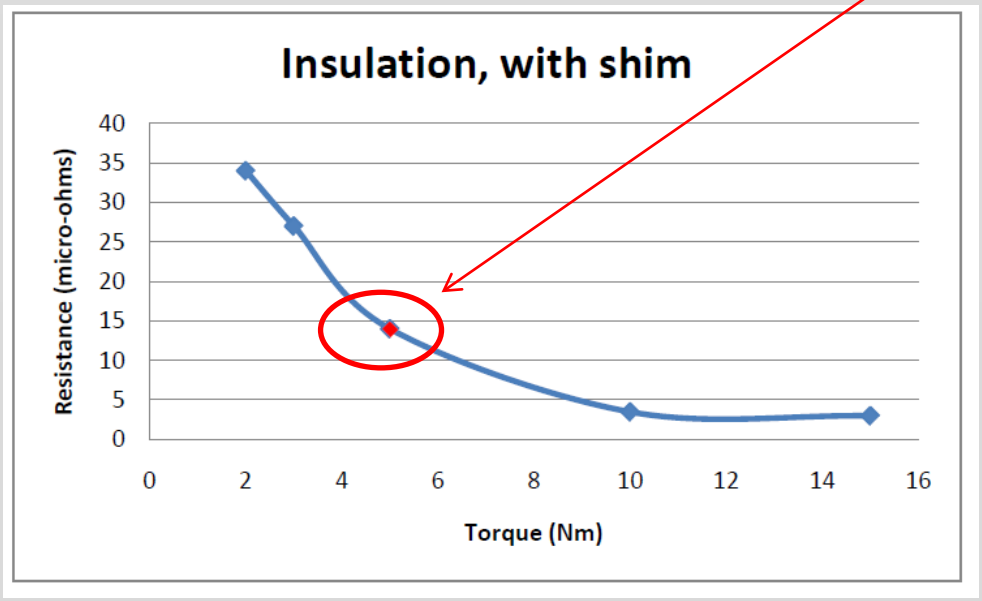
Contact resistance measurements



Will have a strong impact at nominal field

Test with indium wire for enhanced contact still to be performed in RF

Nominal torque used for assembly

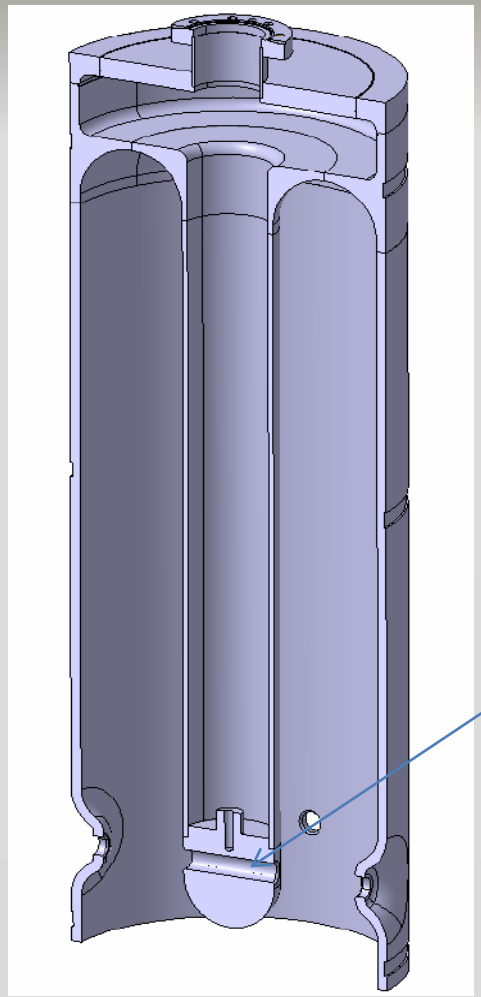


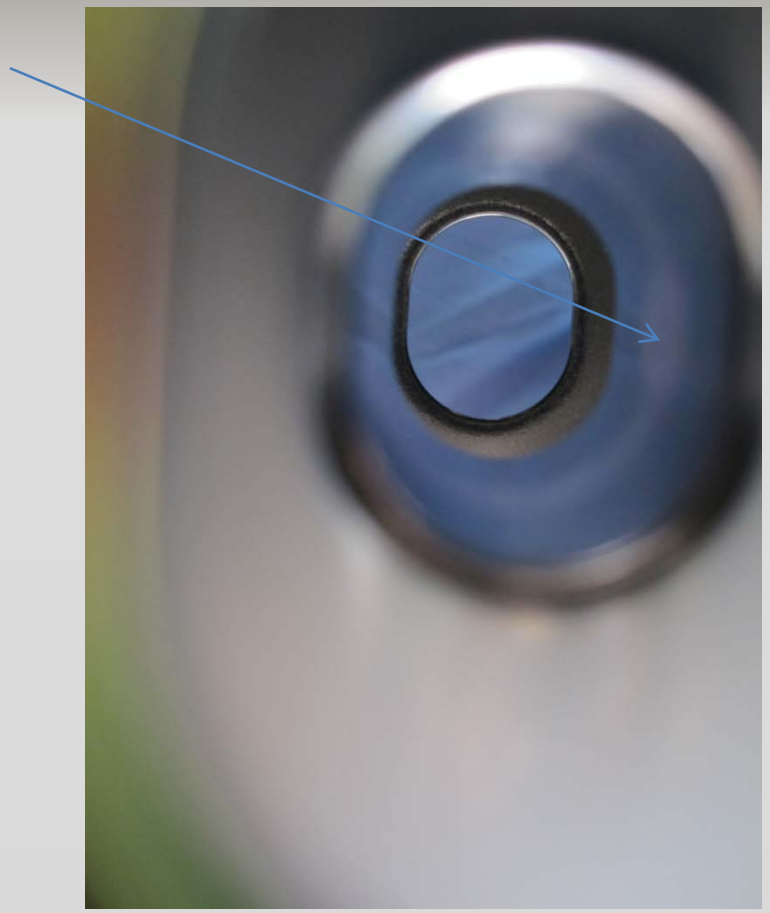
Dissipation due to the contact resistance			
Contact Resistance	R_C=4.5μΩ	R_C=5μΩ	R_C=14μΩ
$P_{junction}$(W) @6MV/m	3	3.34	9.34

From A d'Elia

4-point measurement of contact resistance
From cavity to tuning plate
(excluding contribution of flange)

Diode cavity Q1.5





Calculations by A. D'Elia indicate this should not affect RF performance
But: tests on Cu cavities have been decided for improving on this (Q1.6)