Fabrication and material studies for SPL cavities at CERN

I. Aviles & N. Valverde
on behalf of SPL team

Overview

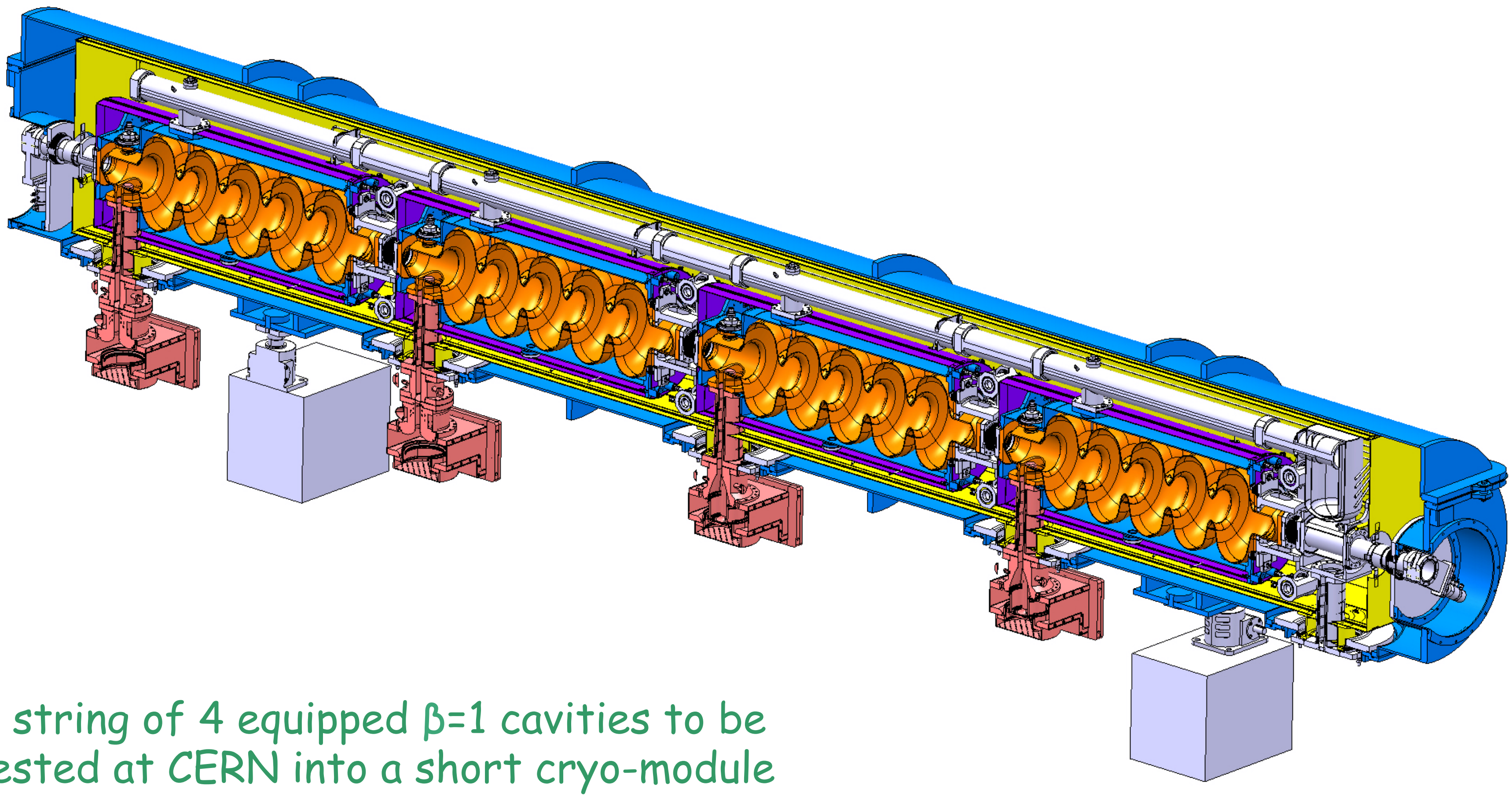
Copper cavity

Niobium cavity

R&D

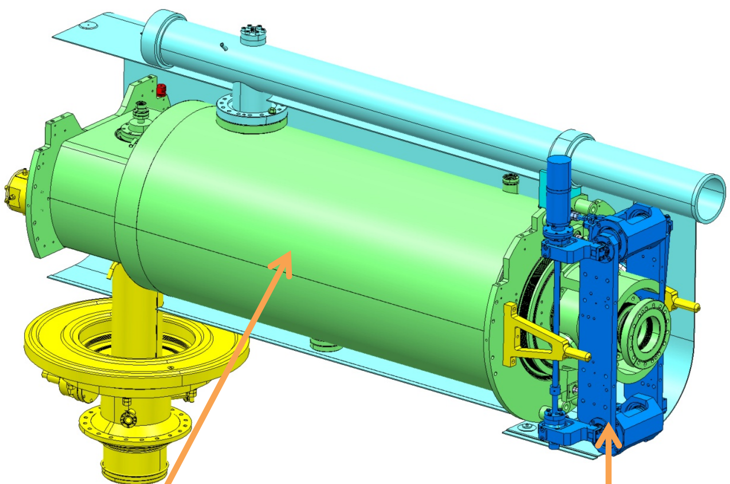
Conclusions

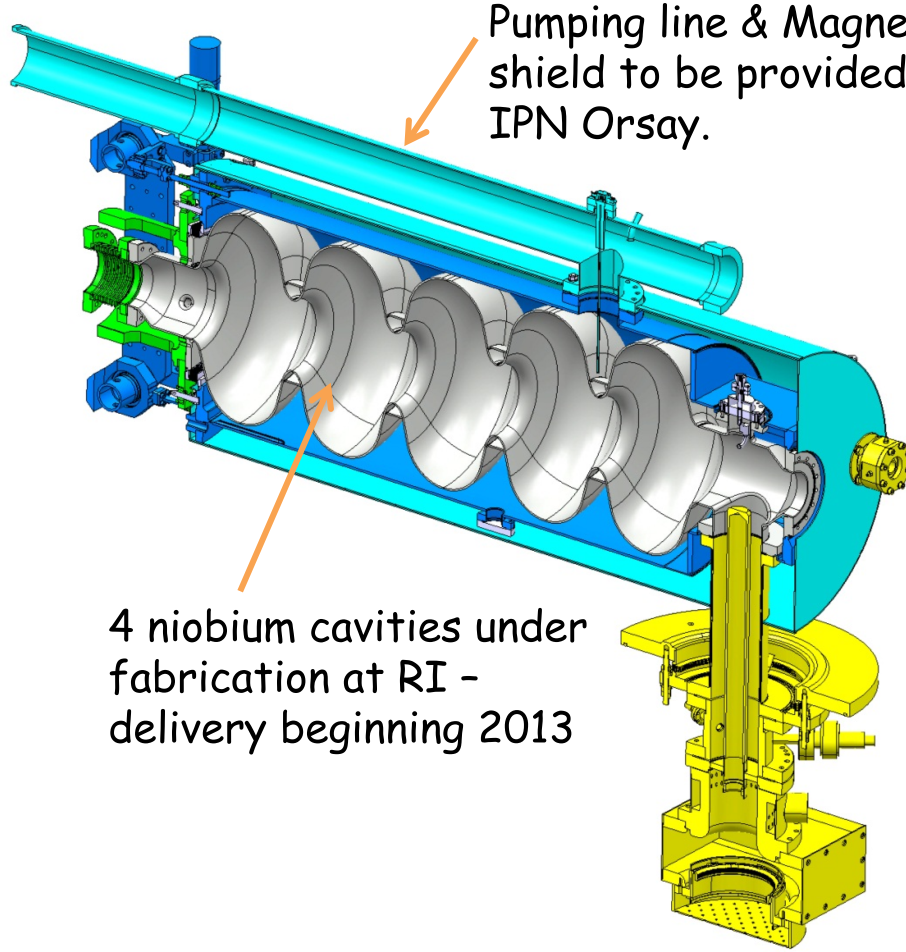
Overview



A string of 4 equipped β=1 cavities to be tested at CERN into a short cryo-module

Overview





Pumping line & Magnetic shield to be provided IPN Orsay.

Tuners provided by CEA. Under testing at CERN

4 niobium cavities under fabrication at RI – delivery beginning 2013

Stainless steel (316L /316LN) helium tank designed by **CERN**, supplied by **CEA** and welded to the cavity at **CERN**.
Design already validated by CERN.

Overview: 5-cell Cavity

PROPERTIES

5-cell cavity β=1

Material: Bulk Niobium RRR300

Flanges: 316LN

Frequency: 704.4 MHz

Quality factor: 10^{10}

Nominal gradient E_{acc}= 25 MV/m

Cavities under fabrication:

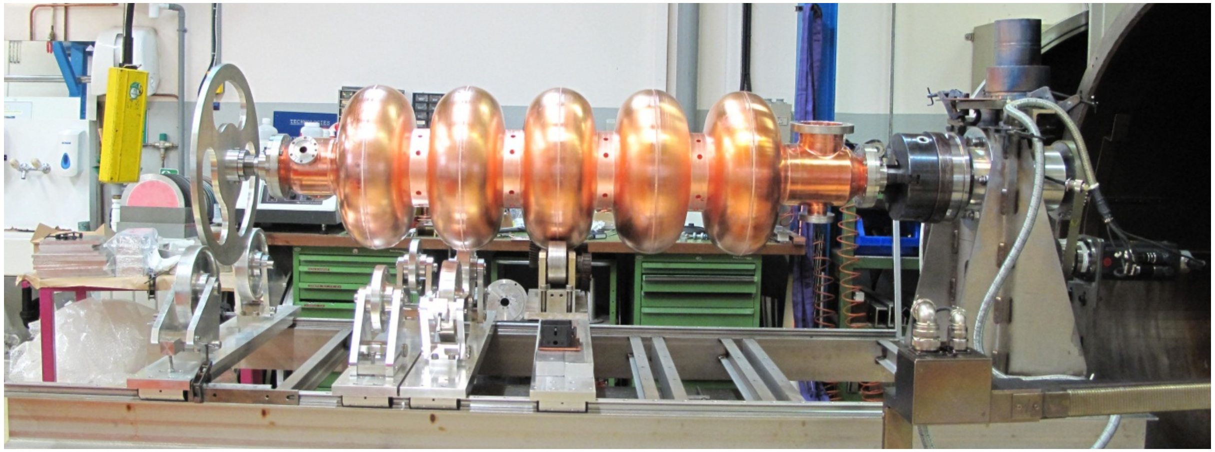
4 niobium 5-cell cavities β=1 at Research Instruments (RI)

1 niobium monocell already fabricated by RI

1 niobium 5-cell cavity β=1 at CERN

2 copper 5-cell cavities β=1 (prototypes) already fabricated at CERN

Cooper cavity



Two copper cavities fabricated for the following purposes:

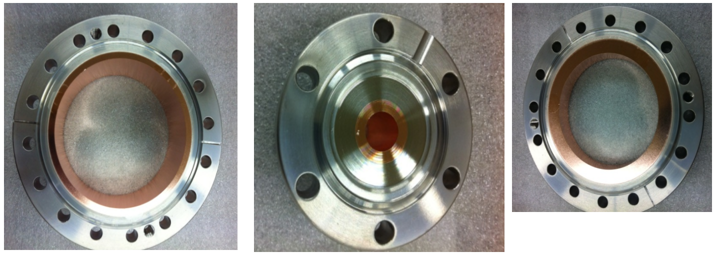
- Learning during the fabrication process
- RF measurements
- Bead pull measurement
- Validation of the tooling for the niobium cavity
- Surface treatments

Copper cavity

Half-cells shaped by Spinning

Cut-off tube shaped by spinning + extrusion

Brazing the SS flanges to the Cu tubes



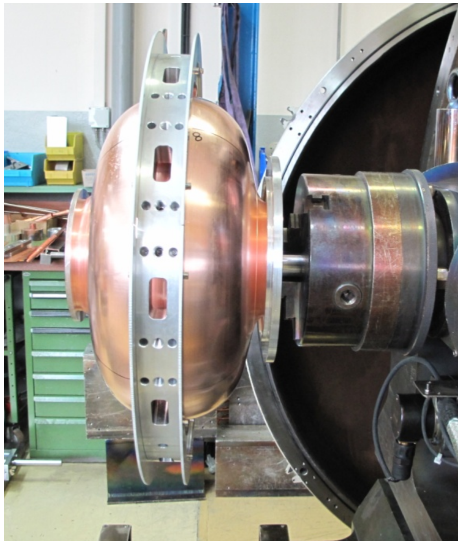
Cut-off tube

Cut-off tube + Extremity half-cell

Copper cavity-EB welding tests

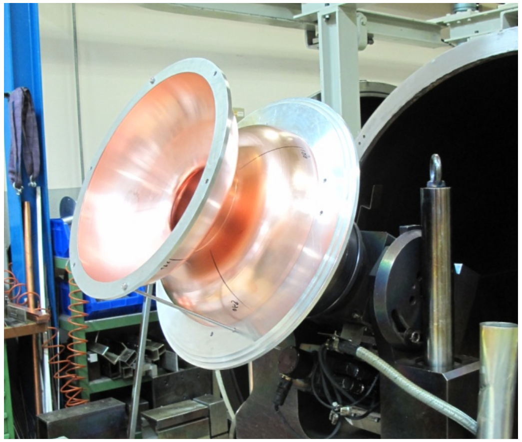
Equator:

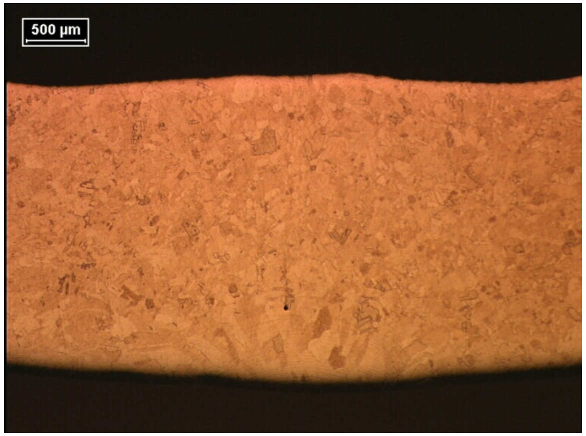
Weld from the outside
Full penetration: 2.4 mm



Iris:

Weld from both outside and inside
Full penetration: 2.4 mm

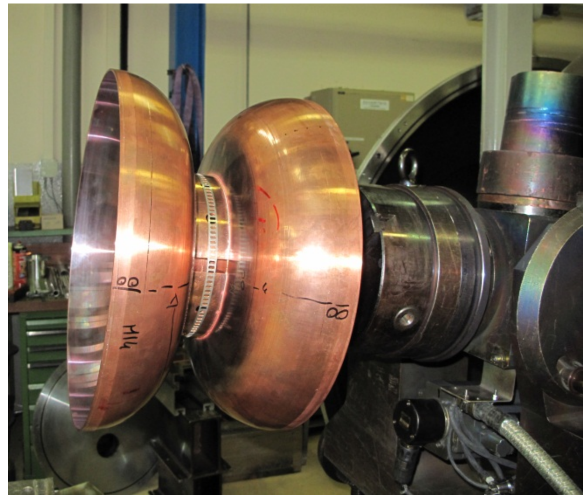


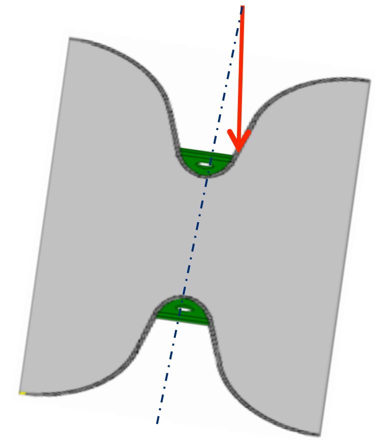


Copper cavity-EB welding tests II

Stiffening ring:

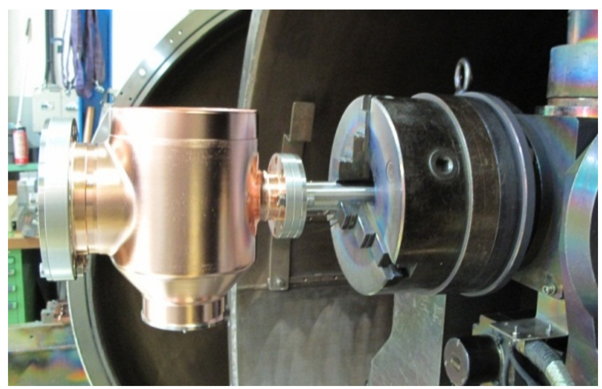
Weld from the outside
Full penetration: 2.4 mm

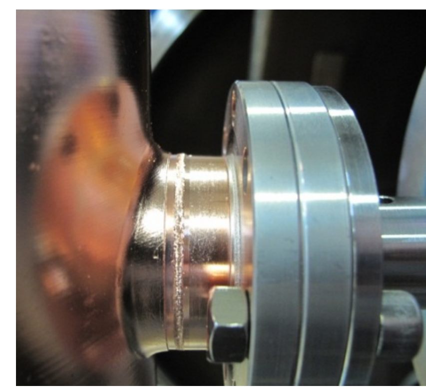




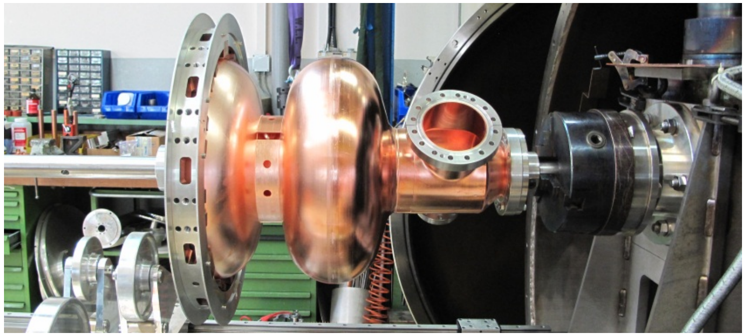
Pick-ups:

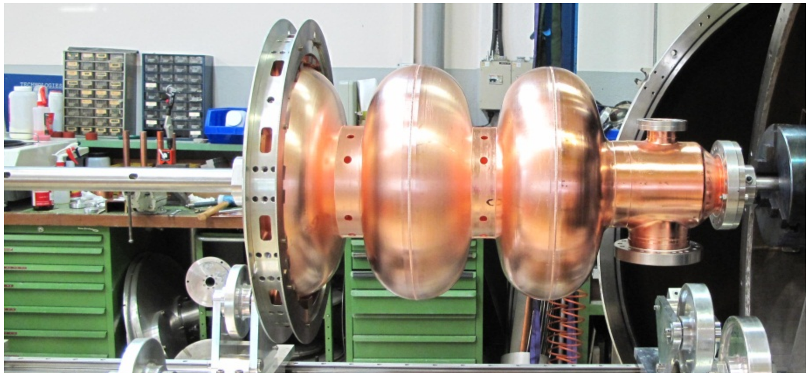
Weld from the outside
Full penetration: 2.2 mm

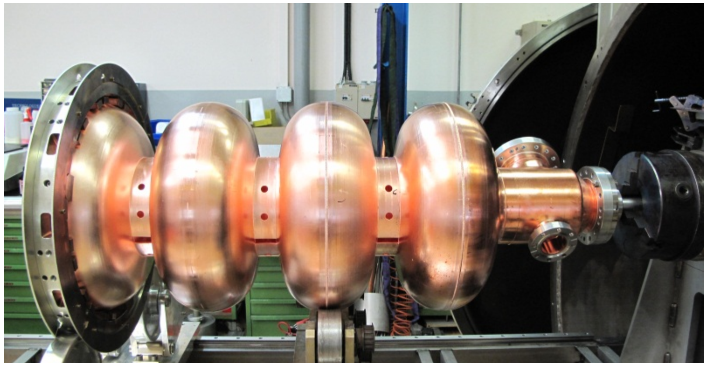


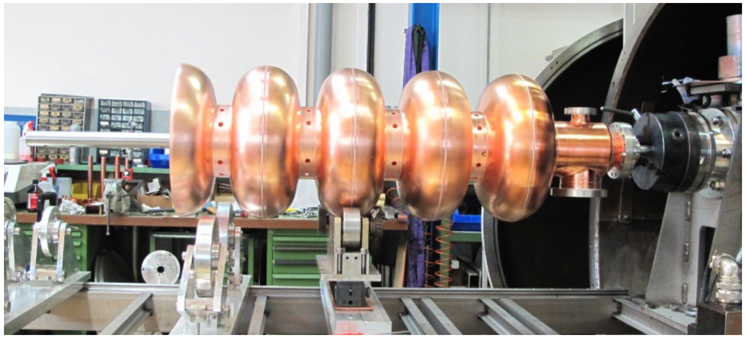


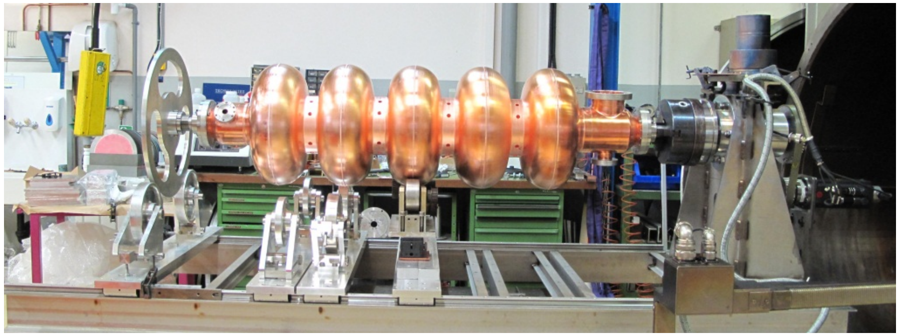
Copper cavity



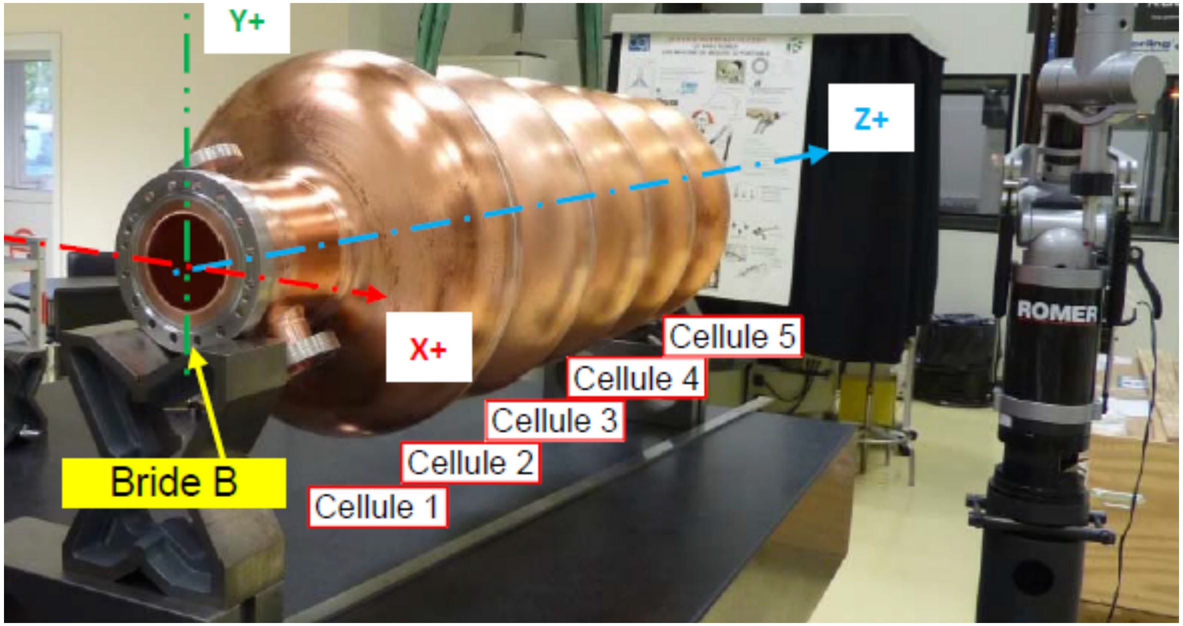




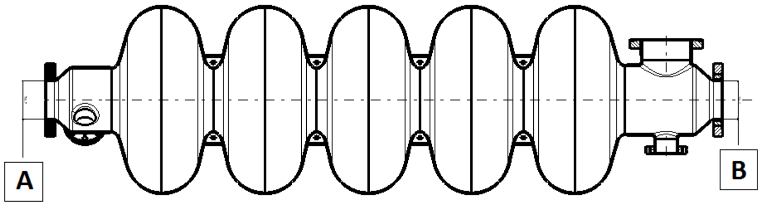




Copper cavity



Thanks to J.P. Rigaud



Concentricity between A and B:

Cavity 1 =0.12 mm

Cavity 2 = 0.09 mm

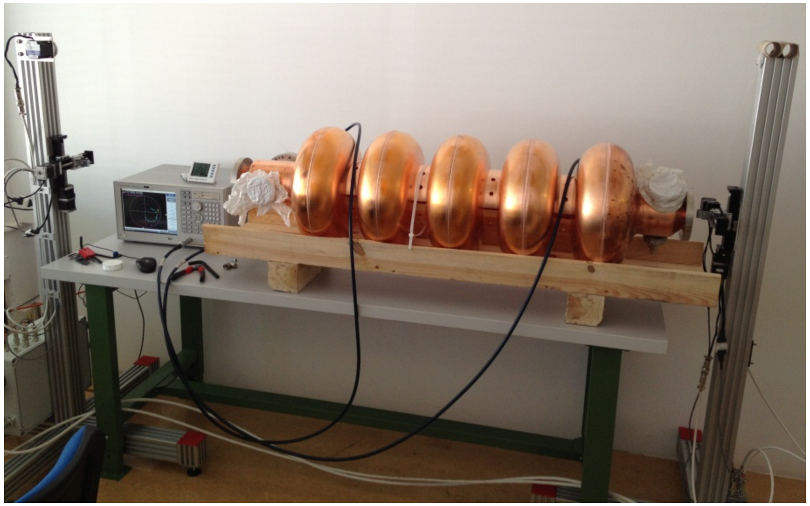
Perpendicularity face flange to the axe A-B:

Cavity 1: Face A 0.10 mm / Face B 0.08mm

Cavity 2: Face A 0.24 mm / Face B 0.28mm

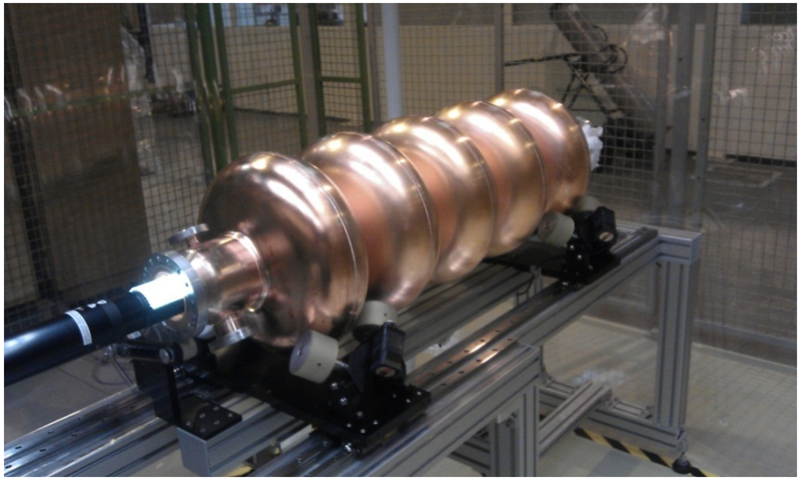
Copper cavity

Bead pull measurement



In house built equipment providing the cavity's field distribution through bead pull measurement by S. Mikulas and N. Schwerg .

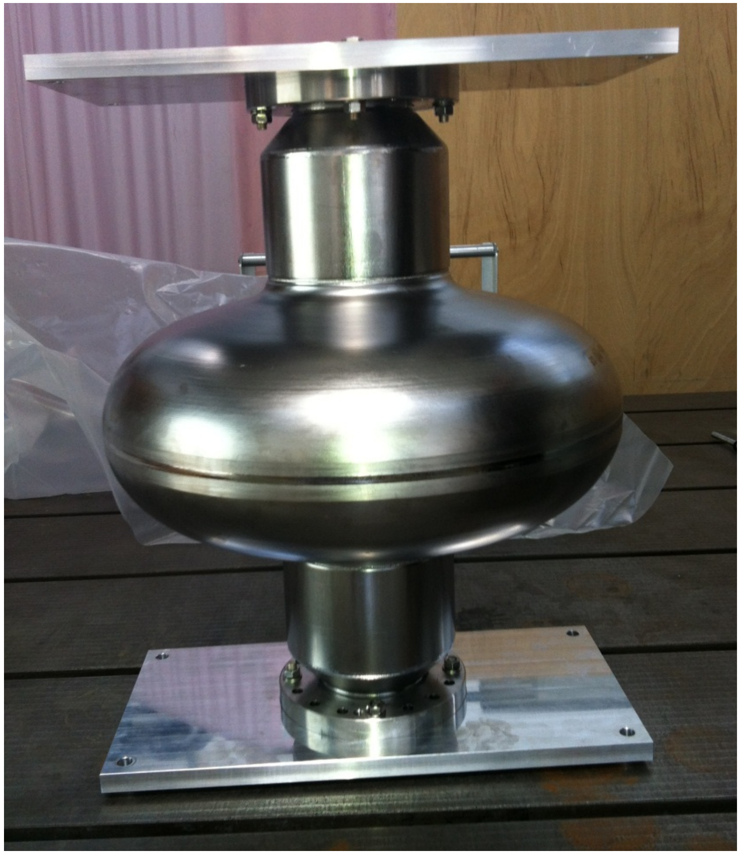
Optical inspection bench system

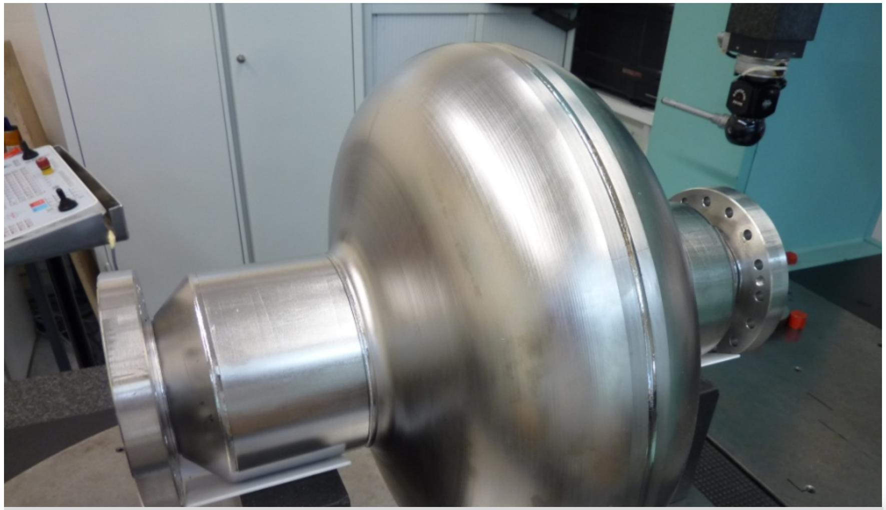


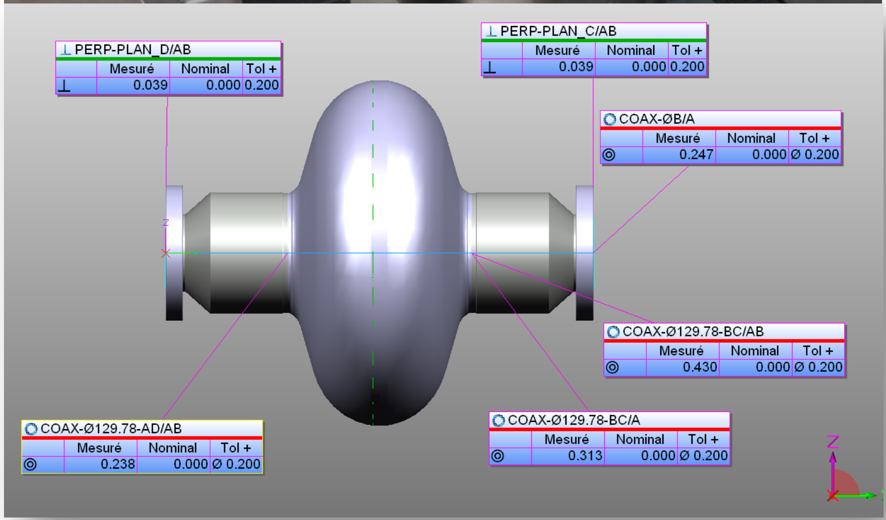
Inspection of the inner part of the welds with an optical inspection bench system by J.K. Chambrillon

Niobium cavity-Monocell from RI

Dimensional control by CMM





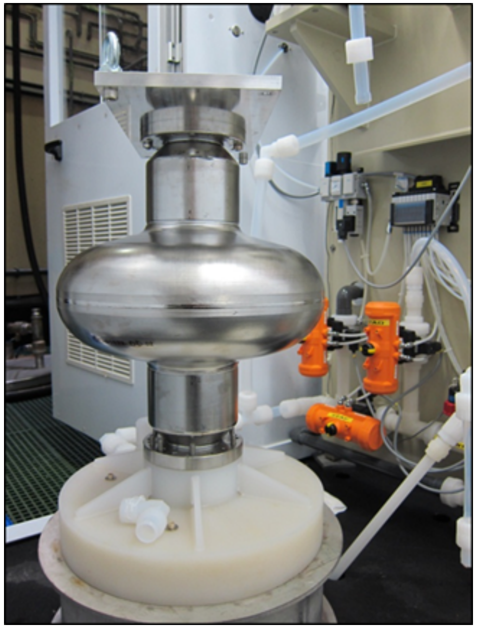


Thanks to D. Pugnat

Niobium cavity-Monocell from RI

Electropolishing (EP) is an electrochemical process used to polish, passivate, and deburr metal parts. It results in a very smooth and shiny surface. During the first test 90 microns were removed.

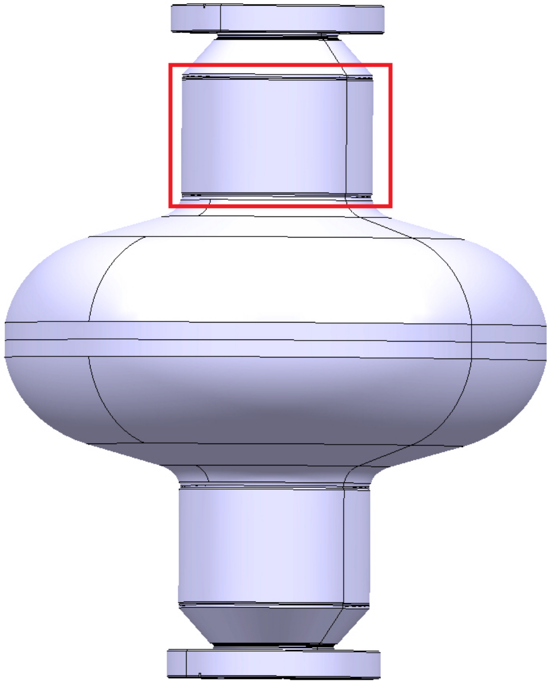
HF (48%) and H2SO4 (> 96%) mixed in a volume ratio of 1:9

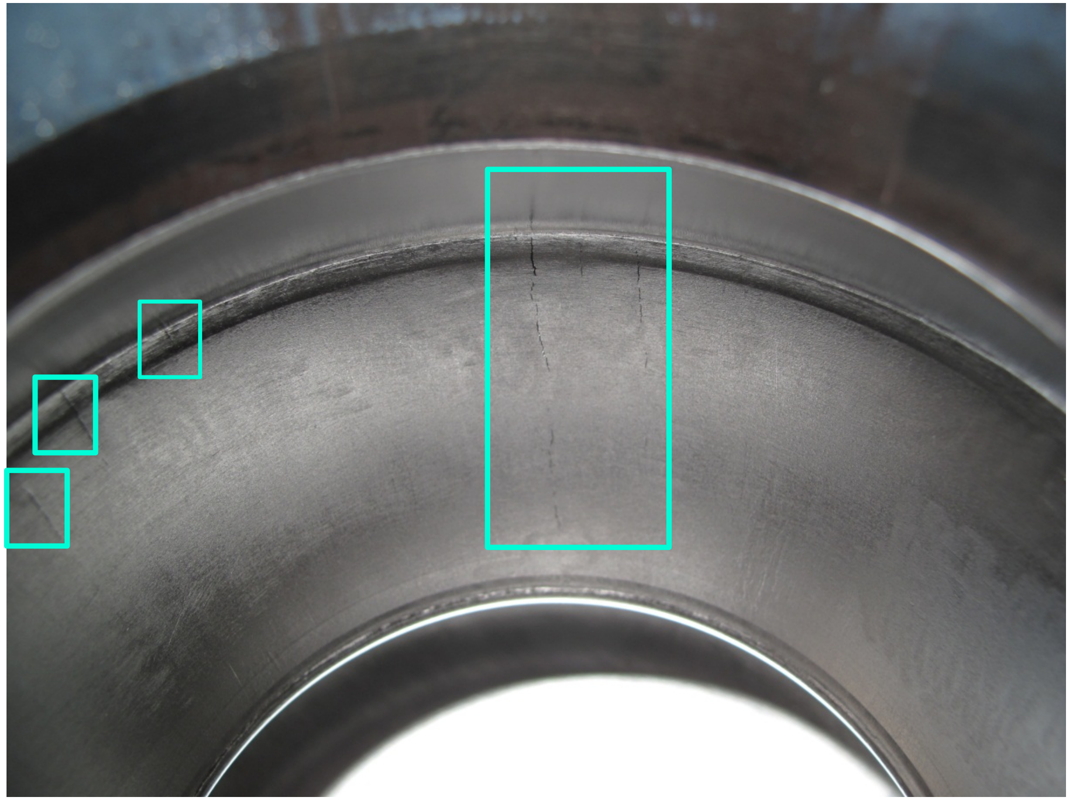


Courtesy of L. Ferreira

Niobium cavity-Monocell from RI

Material defects made evident after EP



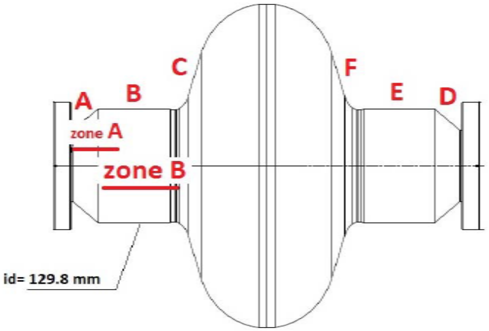


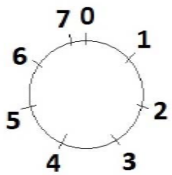
Niobium cavity-Monocell from RI

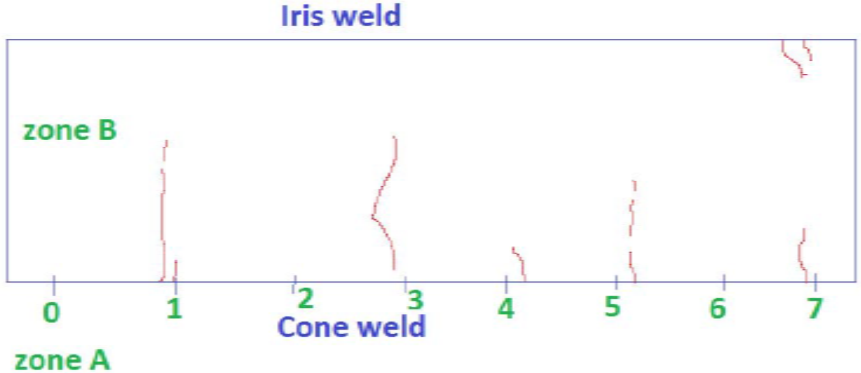
Full inspection of the monocell:

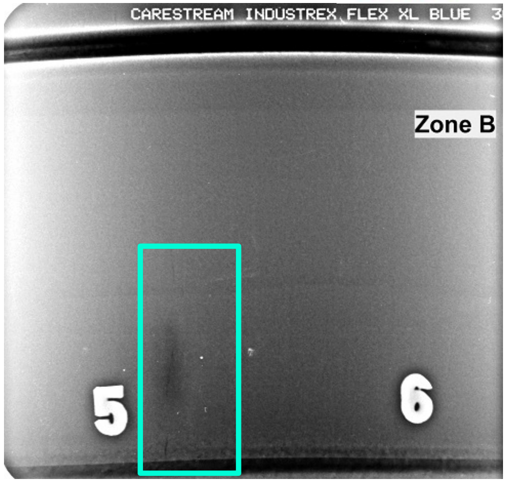
- Radiographic examination

We found cracks only in one beam tube





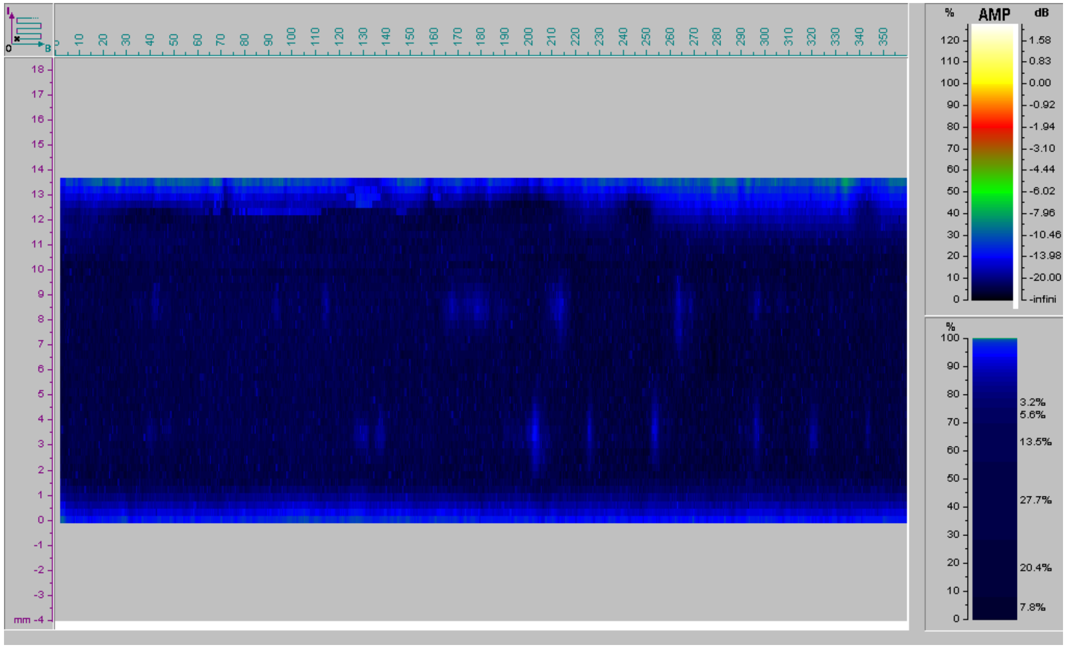




Niobium cavity-Monocell from RI

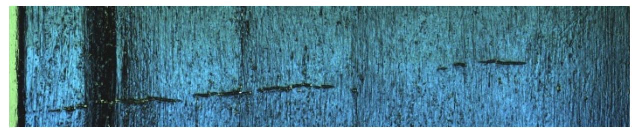
- Ultrasonic examination:

Brazing between niobium tube and SS flanges. They fulfilled the requirements.



Niobium cavity-Monocell from RI

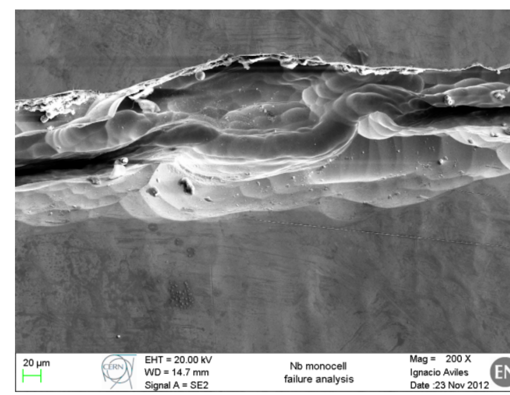
- Optical inspection :



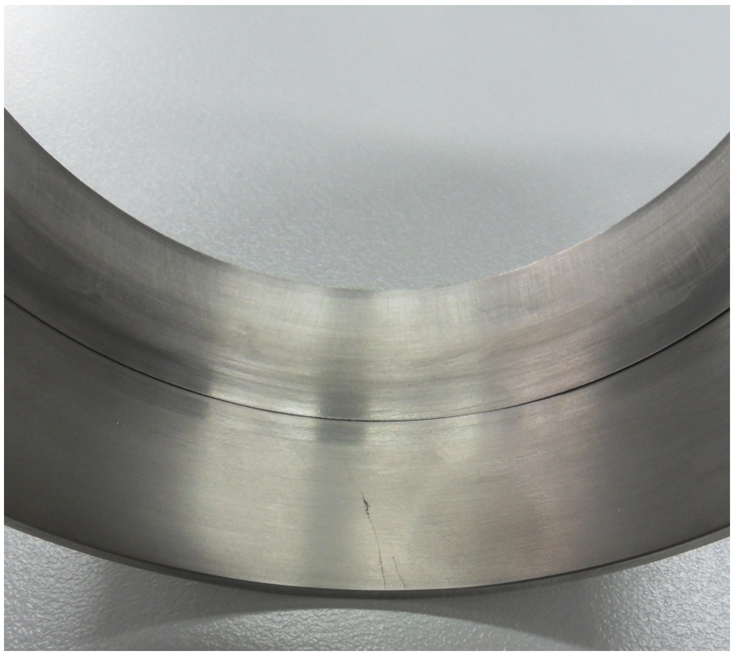
Courtesy of J.K. Chambrillon

- Destructive examination:

Cutting the monocell to inspect the cracks and study their origin



Niobium cavity-Niobium tube

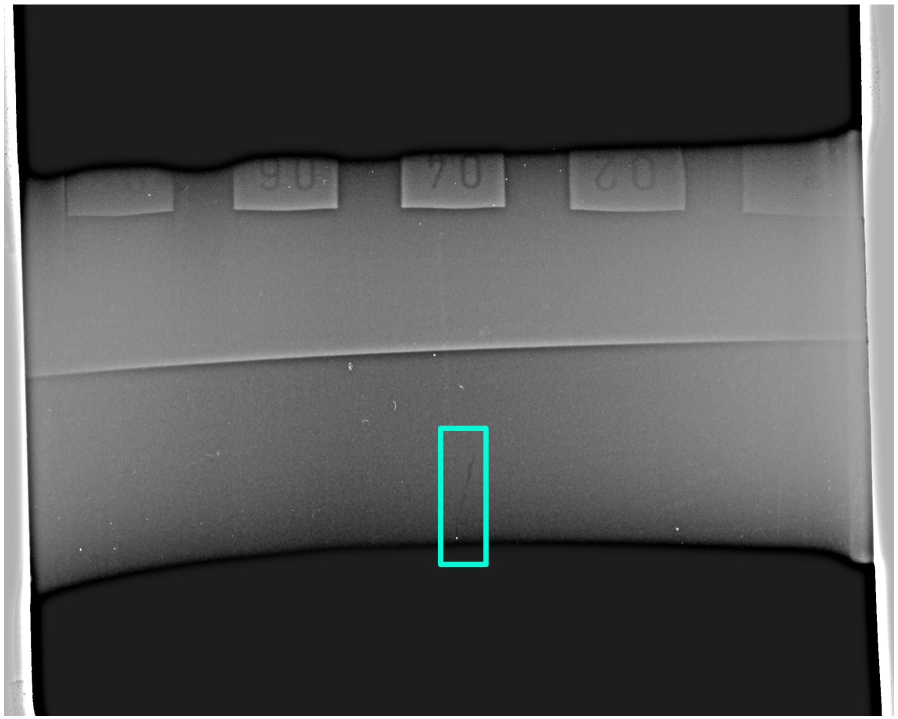


During fabrication at RI it was detected a material discontinuity.

Non destructive and destructive testing were carried out to asses the origin of the defect.

Niobium cavity-Niobium tube

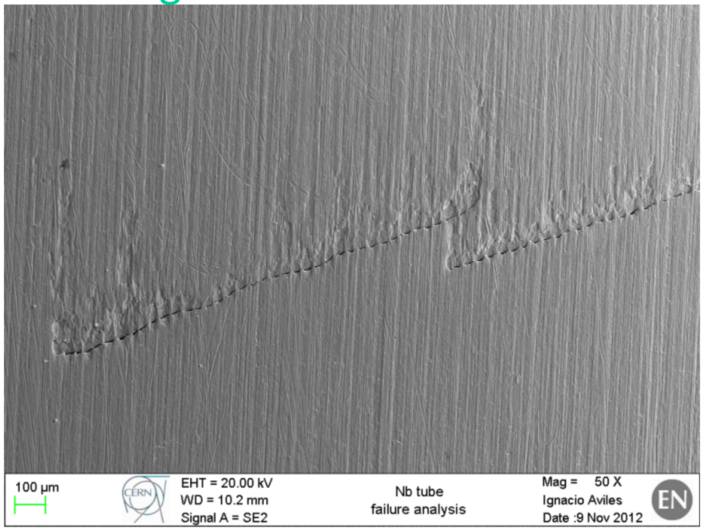
Radiographic examination

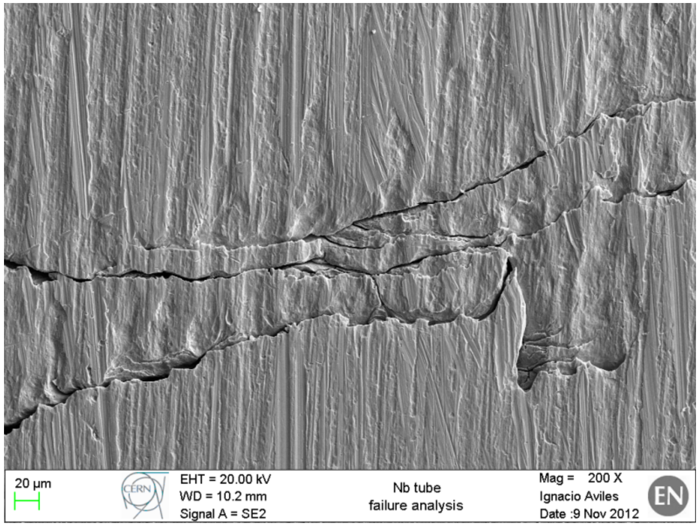


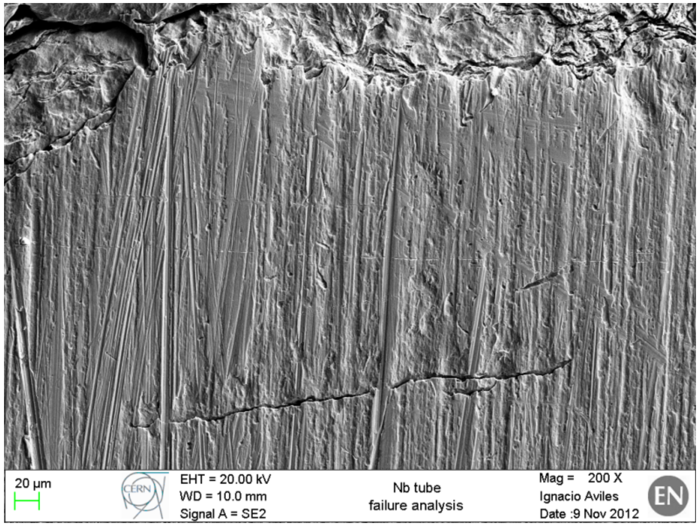
Penetrant testing

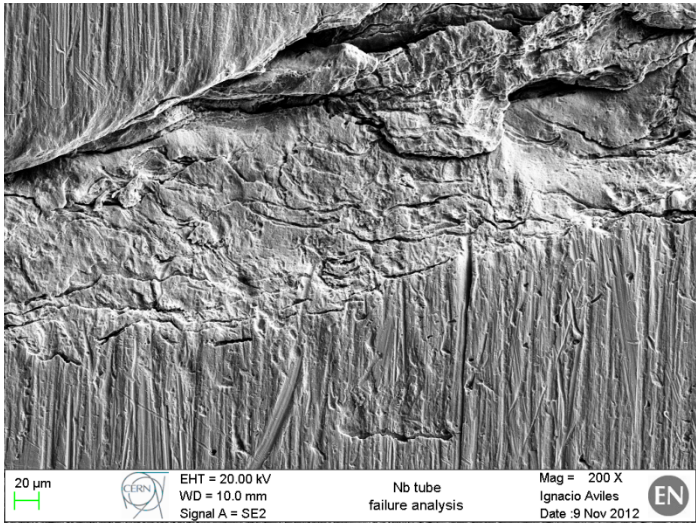
Niobium cavity-Niobium tube

SEM images of the defect



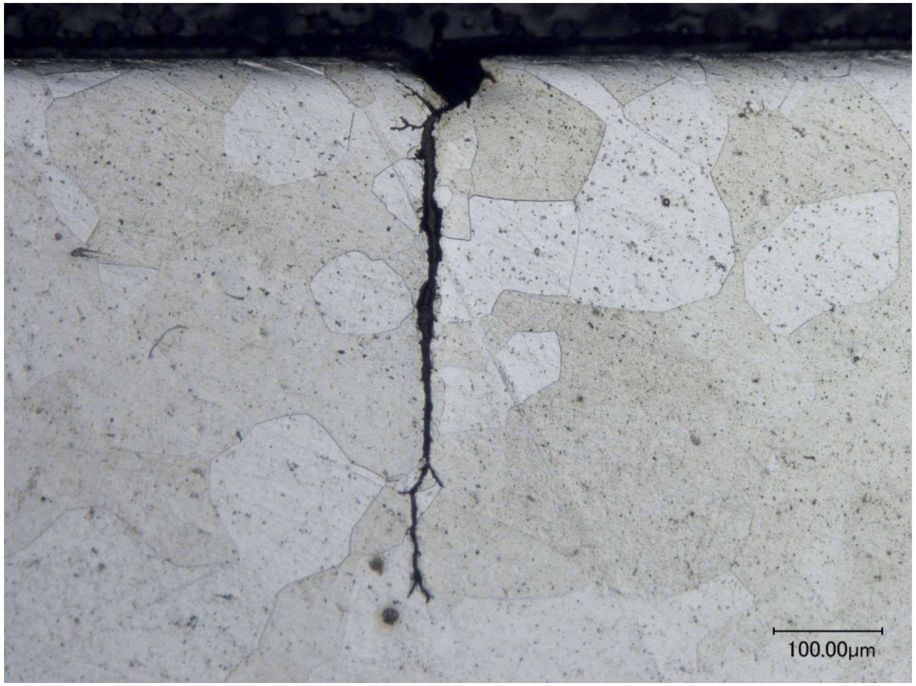


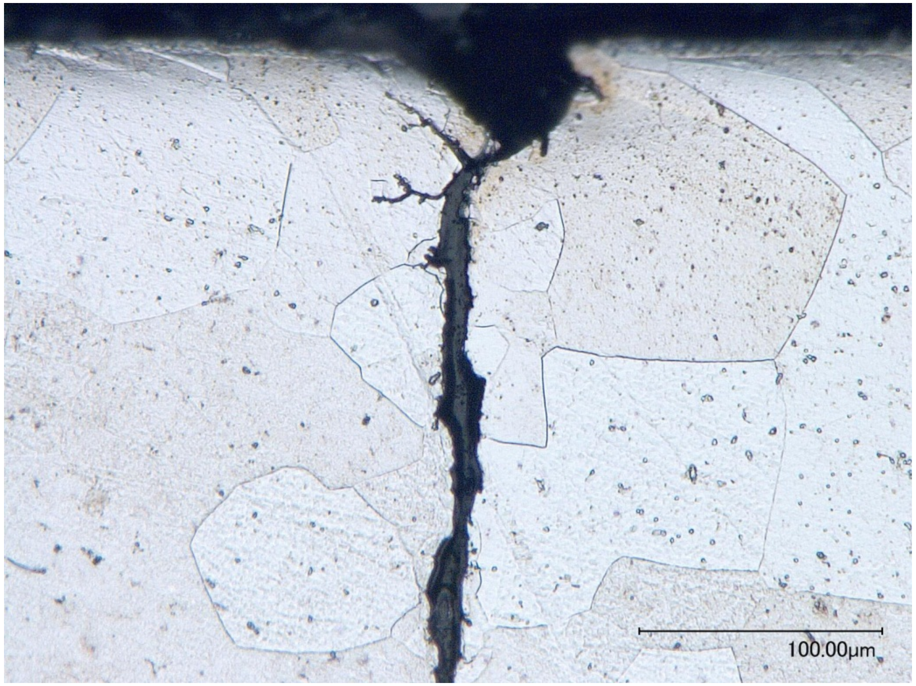




Niobium cavity-Niobium tube

Metallography of the cross section



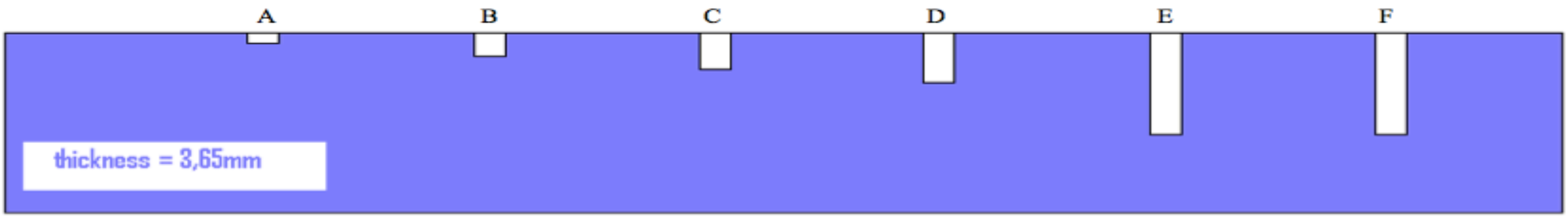


Evaluation of the defect’s origin still on going

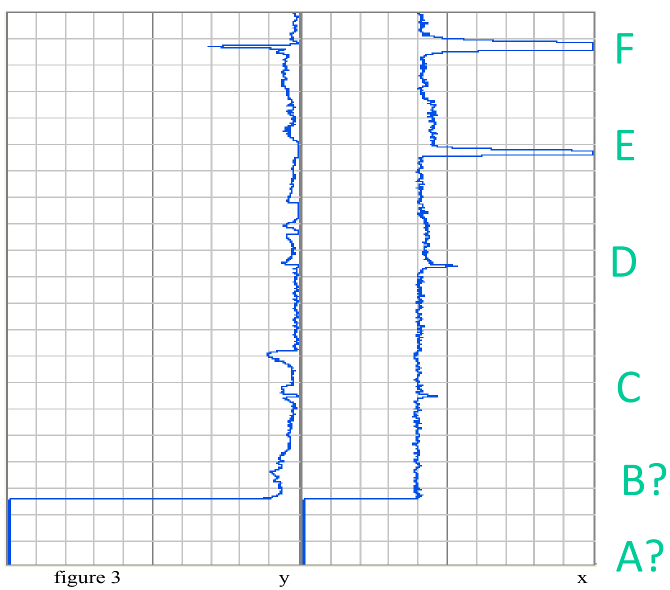
Niobium cavity-Material studies

Eddy current feasibility

groove dimensions: length x width A-E = 3 x 0,5mm F = 10 x 0,5mm



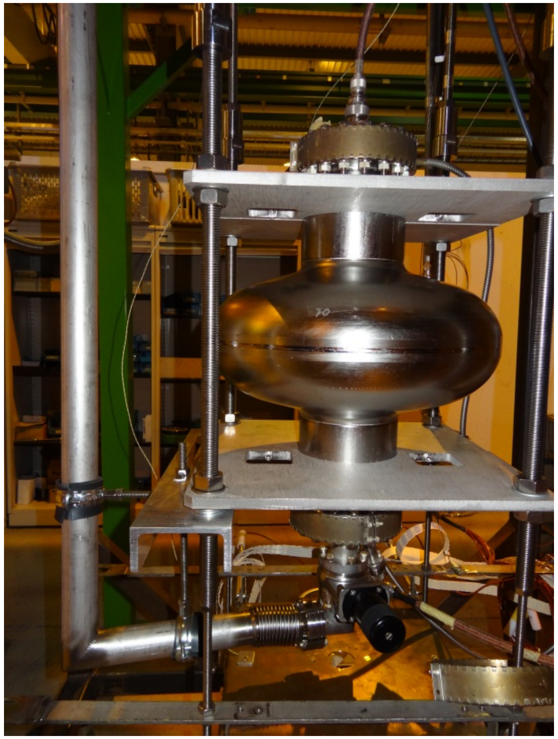
	A	B	C	D	E	F
groove depth	0,25	0,50	0,75	1,00	2,00	2,00
material thickness left	3,40	3,15	2,90	2,65	1,65	1,65



Sub-surface defects are detected up to C (3mm bellow surface)

Niobium cavity-Monocell from RI

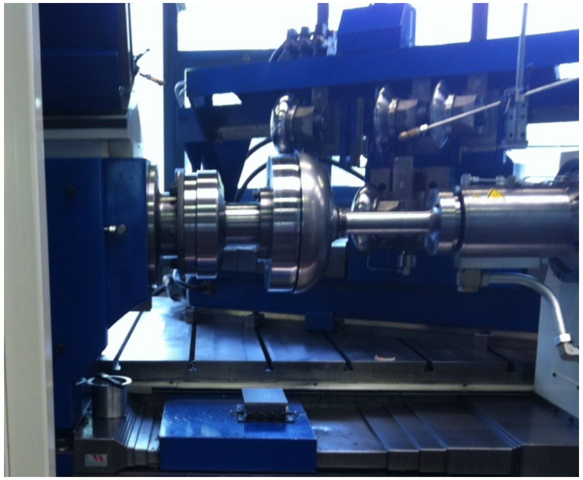
Before cutting the monocell a cold RF test (2 K) was done and even with the defects the results were encouraging.



Courtesy of M. Therasse

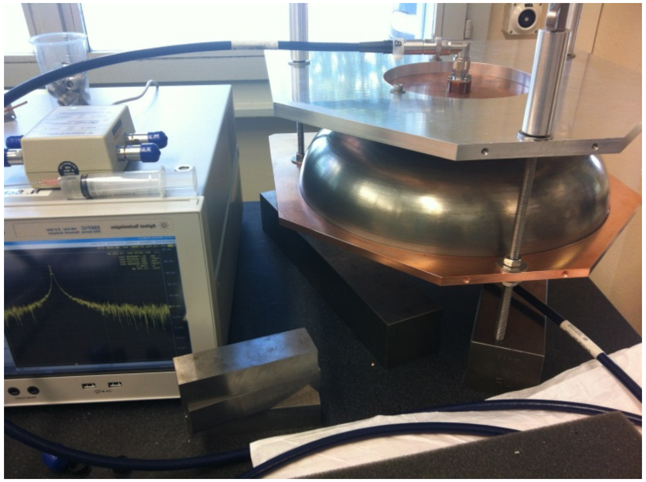
Niobium cavity at CERN

Spinning of 2 half-cells and 1 beam tube at HEGGLI for testing



Dimensional control by CMM

RF measurements.



Niobium cavity at CERN

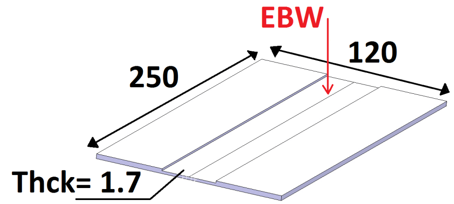
New EB welding machine at CERN (11 m^3);

- SS vacuum chamber;
- Vacumm level $1x10^{-5}$ mbar up to 10^{-7} mbar (cryo. pump)→ Adecuate for high RRR niobium welds.

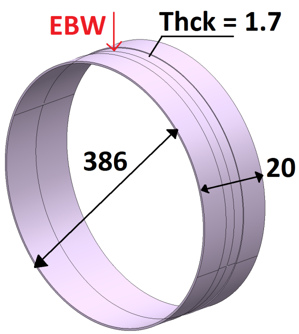
Niobium cavity at CERN

Foreseen welding tests for optimization of parameters:

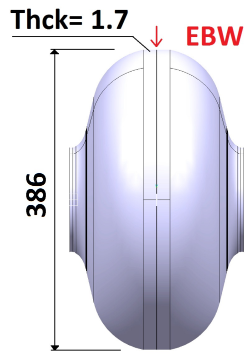
- ❖ 10 linear welding tests



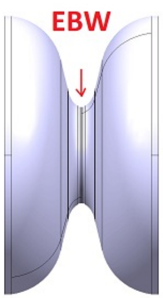
- ❖ 4 circular welding tests – (same diameter as HC)



- ❖ 3 circular welding tests at the Equator

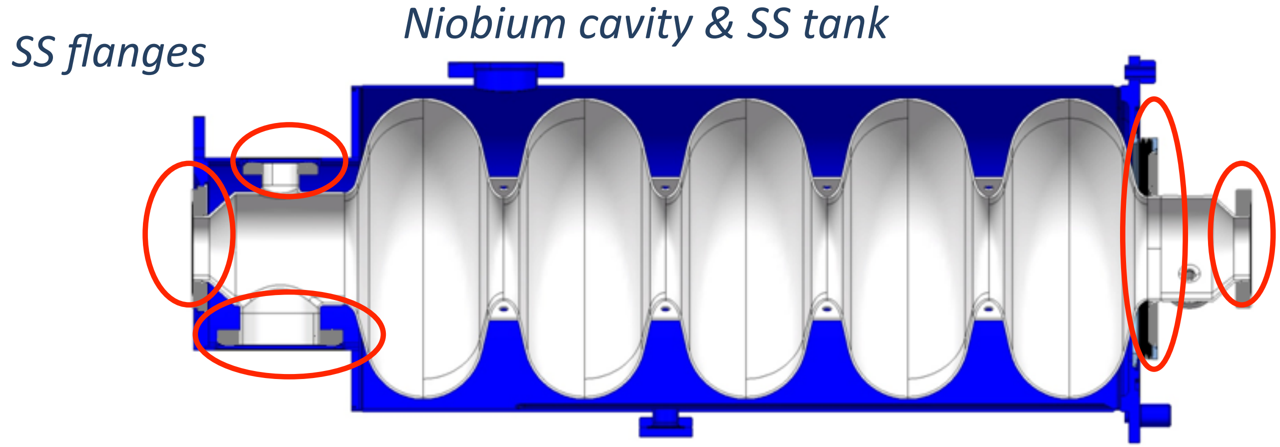


- ❖ 3 circular welding tests at the iris



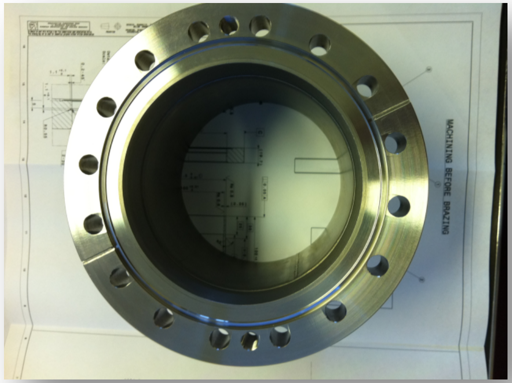
- ❖ 3 welding tests- Stifenning ring+ HC

R&D- Brazing



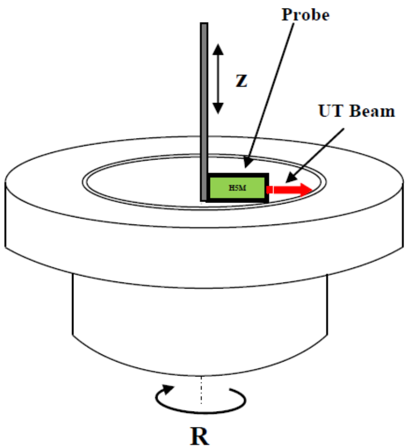
Brazing Nb / SS 316 LN is a key technology
Developed at CERN in 1987

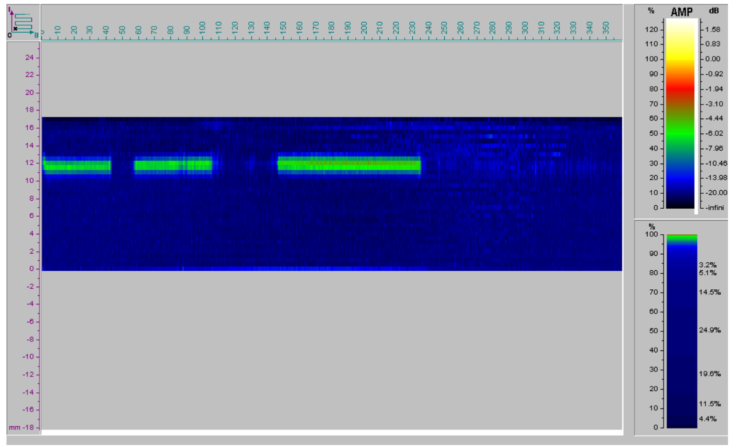
Test I- Nb tube + SS flange DN100



R&D- Brazing

Ultrasonic examination (by immersion) of the brazed area





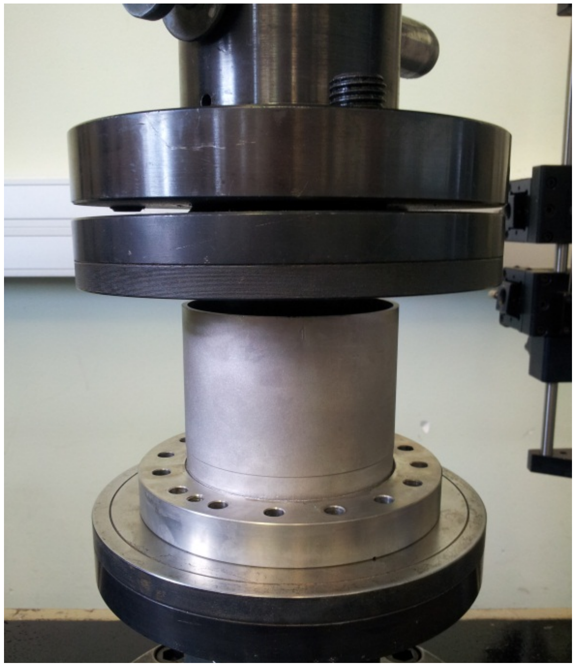
Leak test

Thermal shock liquid N2 (x5)

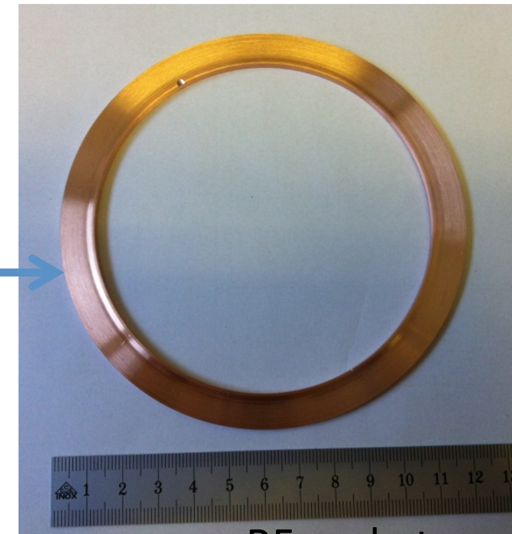
- Ultrasonic examination
- Leak test
- Thermal shock liquid N_2 (x5)
- Ultrasonic examination
- Leak test
- Electropolishing
- HT (600°C/24h)
- Electropolishing
- Leak test
- Ultrasonic examination
- Thermal shock liquid N_2 (x5)
- Ultrasonic examination
- Leak test
- Shear test
- Leak test
- Ultrasonic examination
- Assembly test
- Metallographic examination
- Fractography
- SEM assesment + EDS

R&D- Brazing

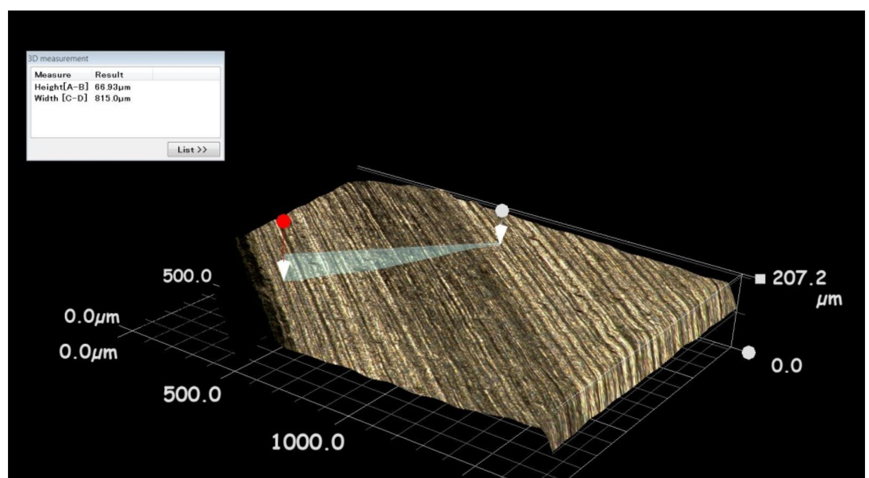
Shear test (3 tons)



Assembly test

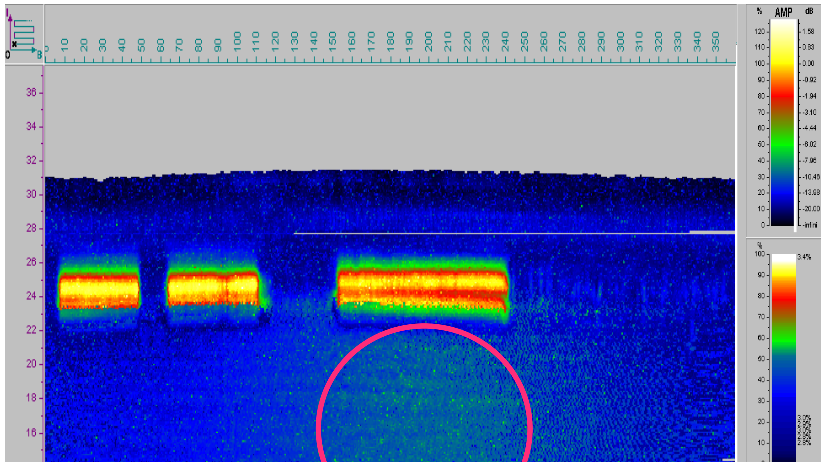


RF gasket



R&D- Brazing

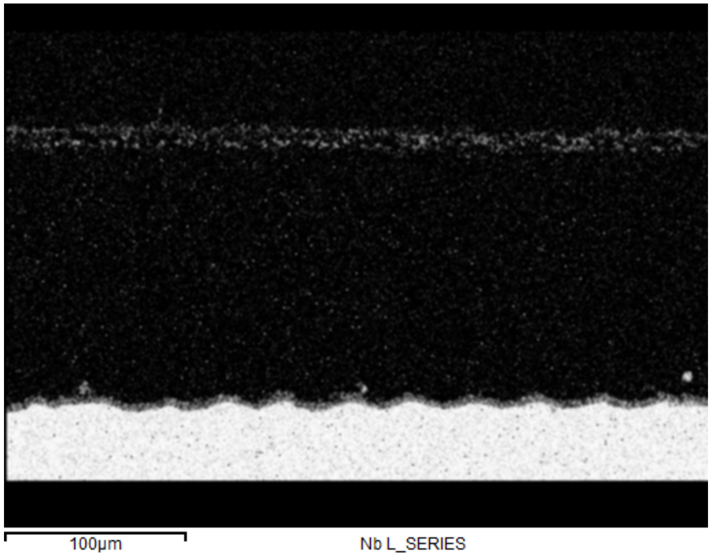
Ultrasonic examination (by immersion) after tests

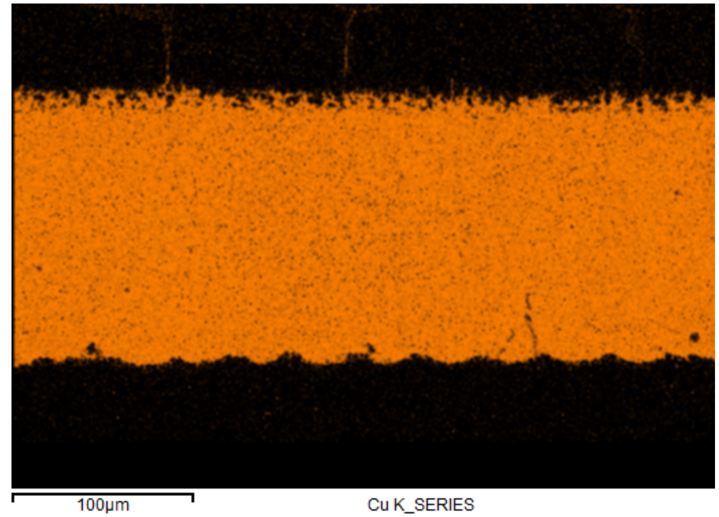


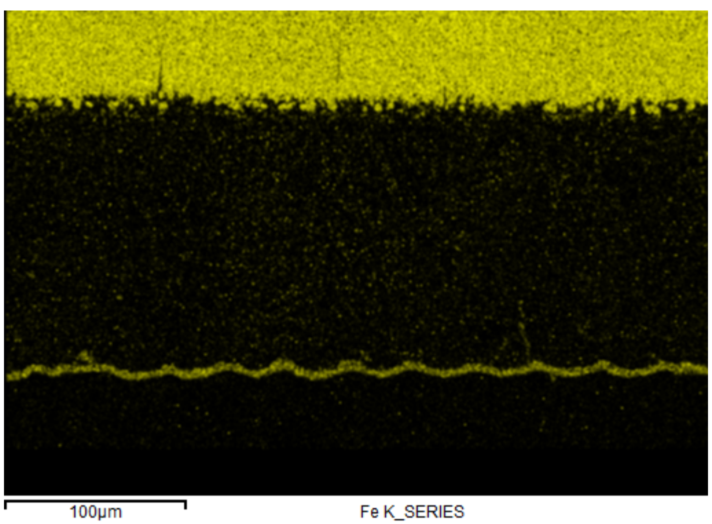
Metallographic examination

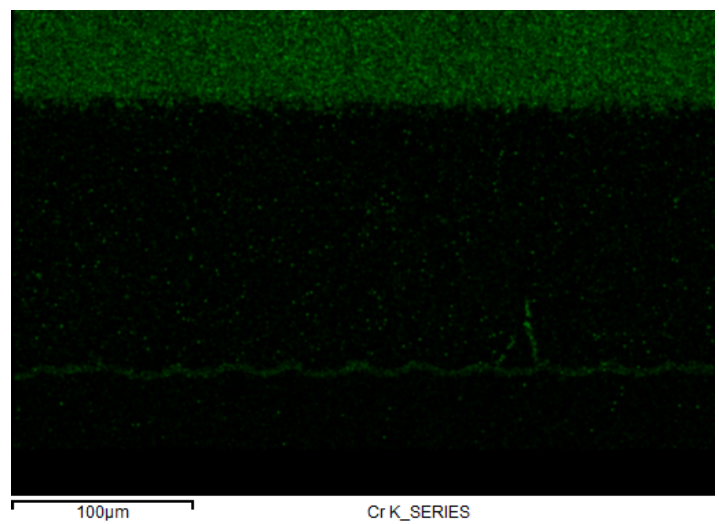
R&D- Brazing

EDS analysis









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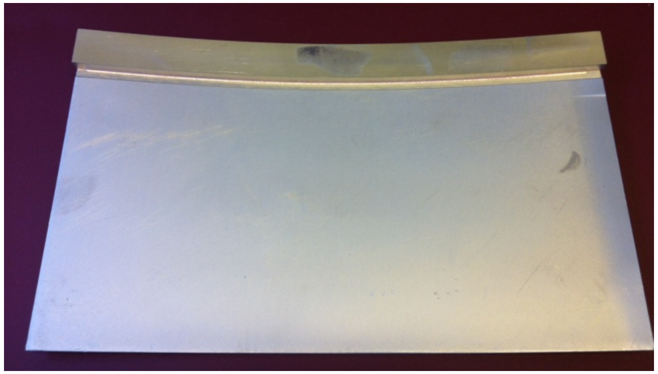
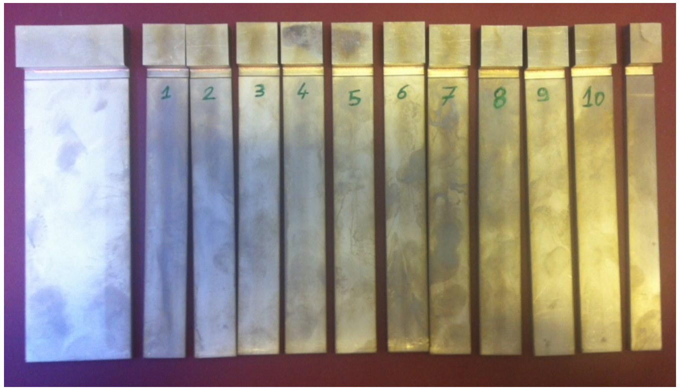
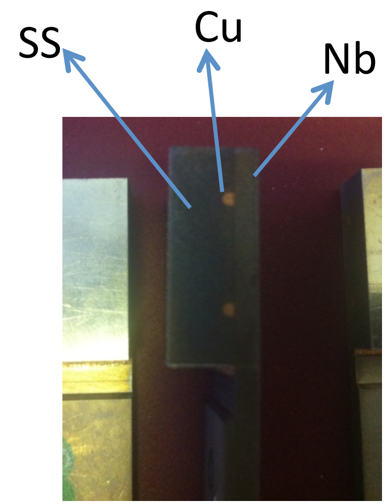
R&D- Brazing

Test II- Effect of the chemical etching on the brazed joint







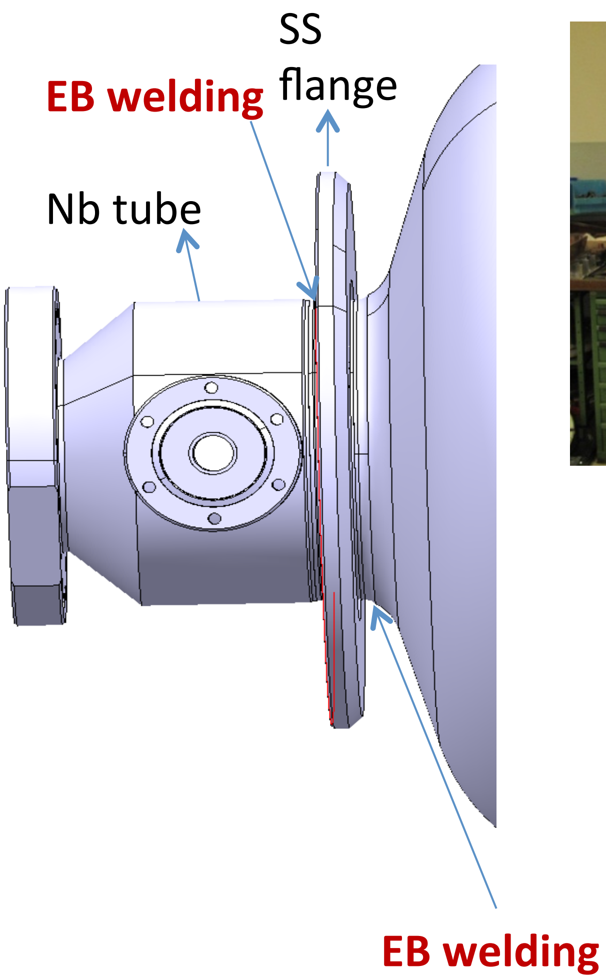
The bath removed ~ 300 µm of Cu
The bath attacks more the Nb than the SS

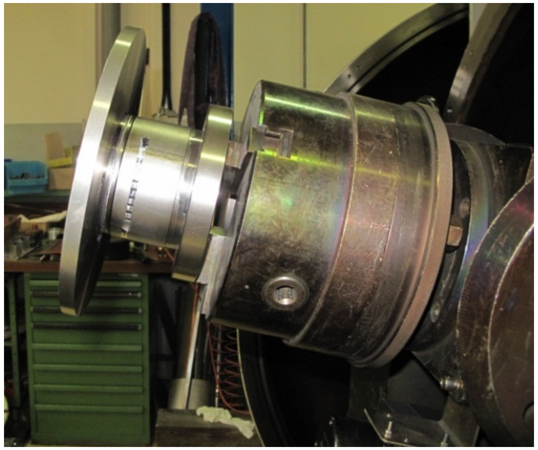
→ Full results in presention
I. Aviles and N. Valverde
SLHiPP2

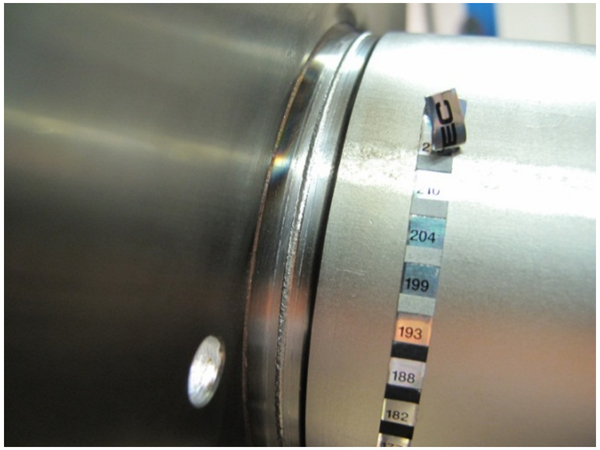
It was decided to mask the brazed joint with a polymer

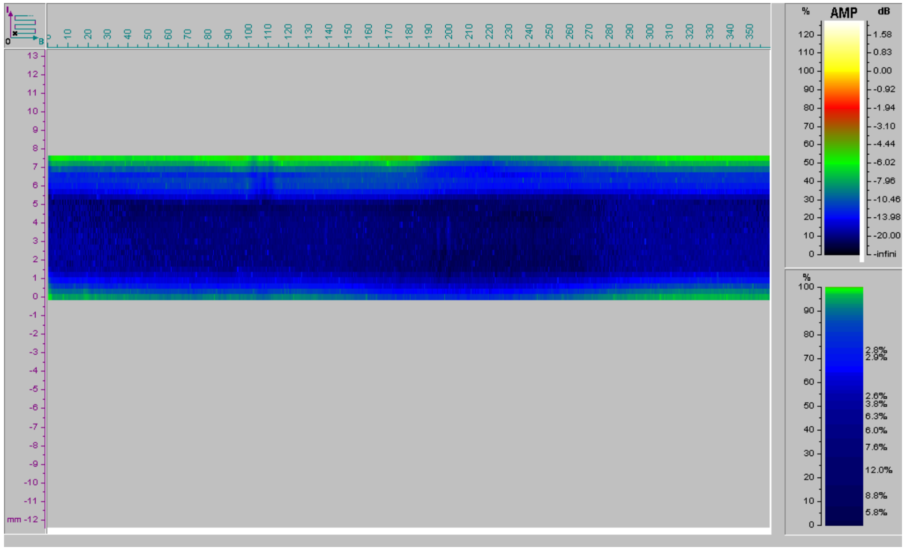
R&D- Brazing

Test III- Effect of EB weld close to the brazed joint





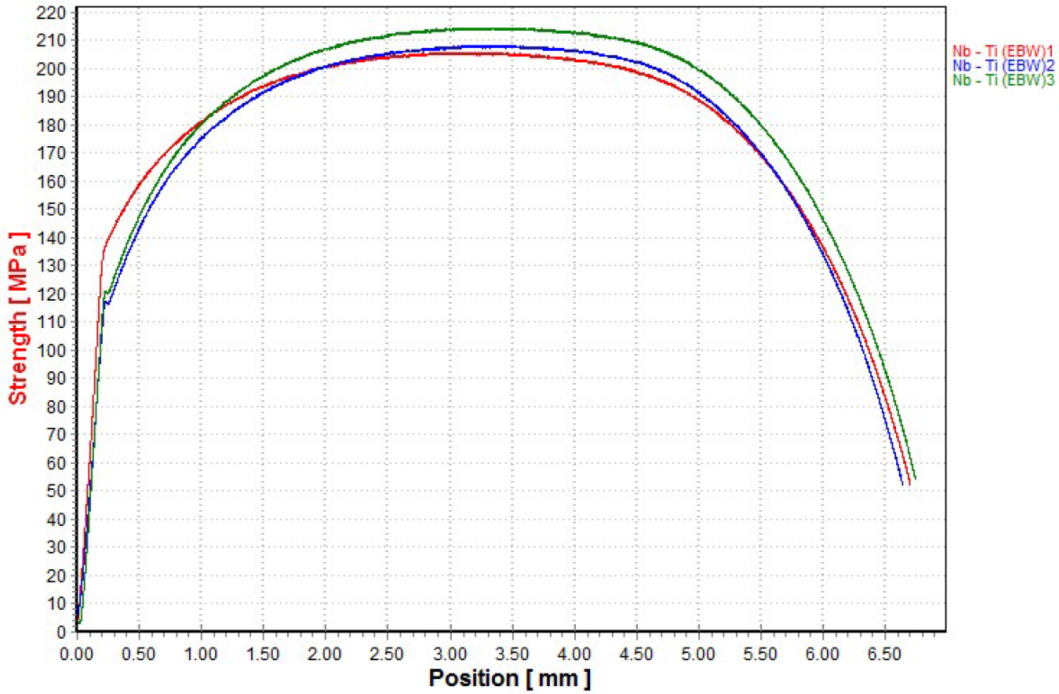


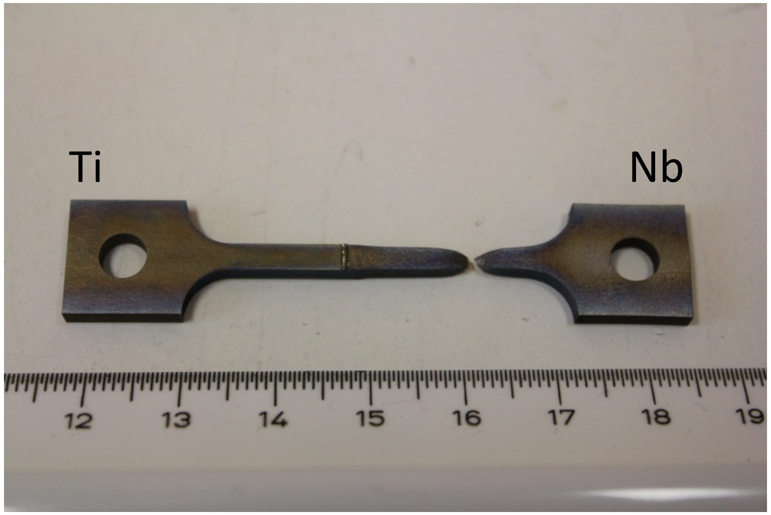


R&D- Nb/Ti weld

Nb – Ti(V) EBW with improved welding parameters

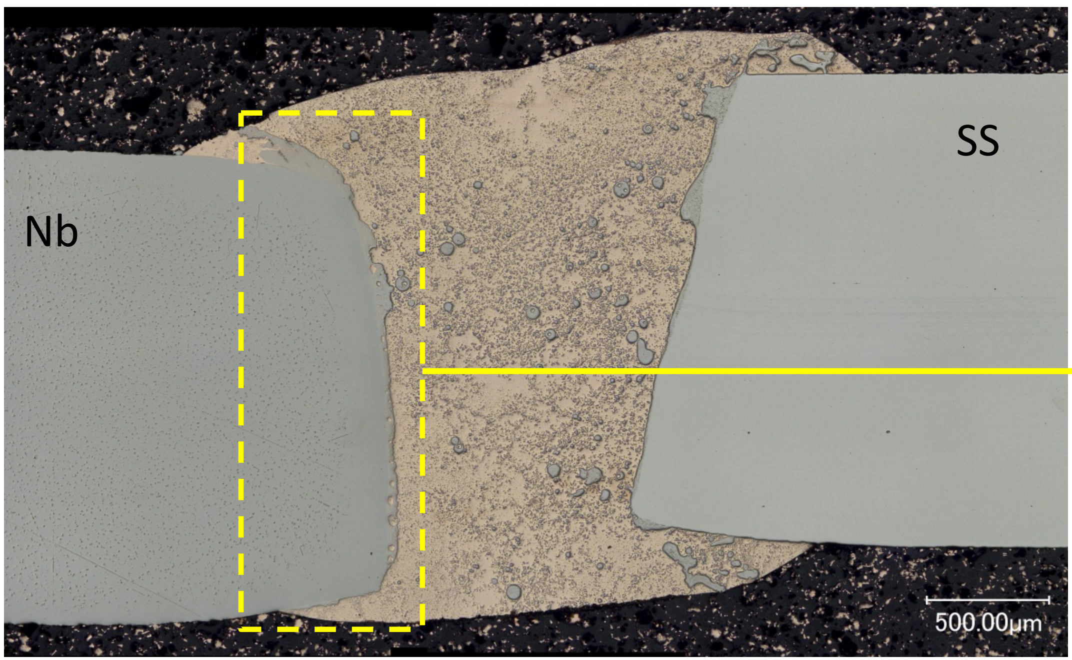
Heat treatment: 24 hours @ 600 °C

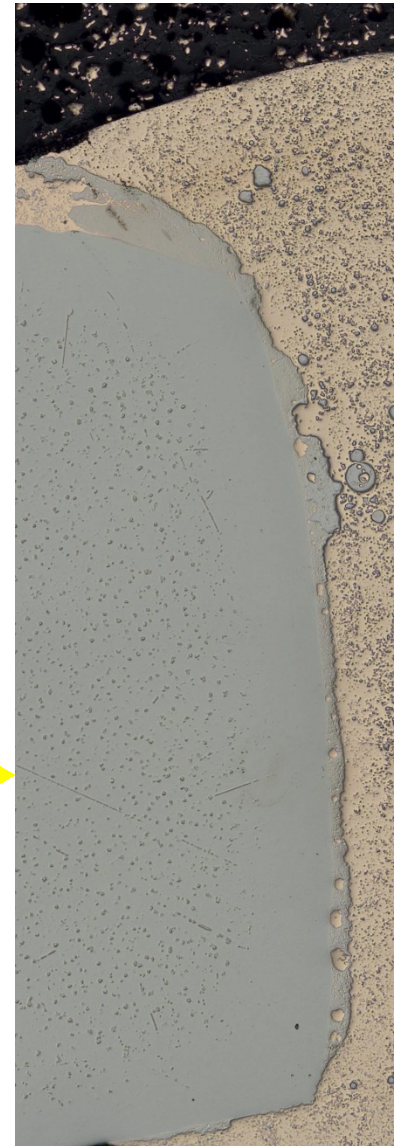




R&D- Nb/SS weld

Nb / SS(316LN) EBW with
Cu -OFE plate between the two metals

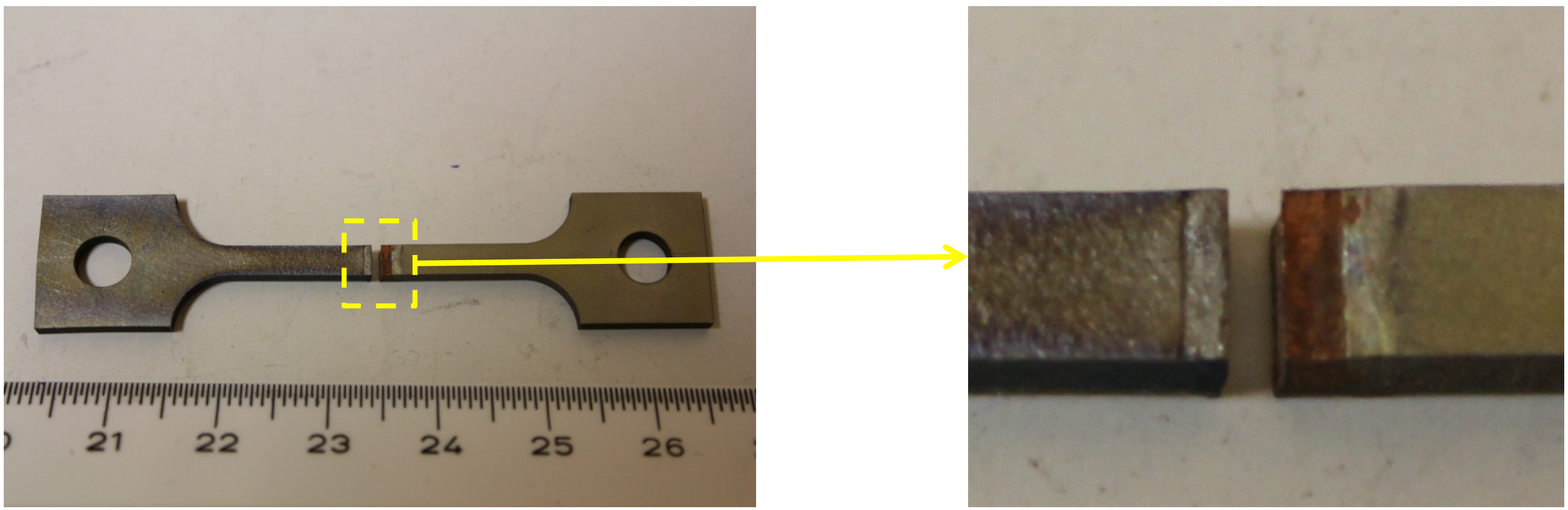




R&D- Nb/SS weld

Brittle fracture

Interface Nb - Cu



New metals will be tested to be used between Nb and SS

Conclusions

Copper cavity – 2 cavities fabricated successfully and very useful for the development of the RF measurements.

Niobium cavity- 4 cavities under fabrication at RI. Manufacturing in stand-by until is better understood the origin of the monocell's defects.

Niobium cavity at CERN- to obtain expertise in the manufacturing processes.

R&D-

Brazing: It has been proved that is a functional solution for the niobium/SS interfaces for superconducting cavities

Conclusions

Nb/Ti weld- first tests results point out that could be a suitable solution for niobium/titanium interfaces

Nb/SS weld- first atempt was not satisfactory. New solutions are under study

Thanks for your attention!!

We would like to thank the people who help us in our work:

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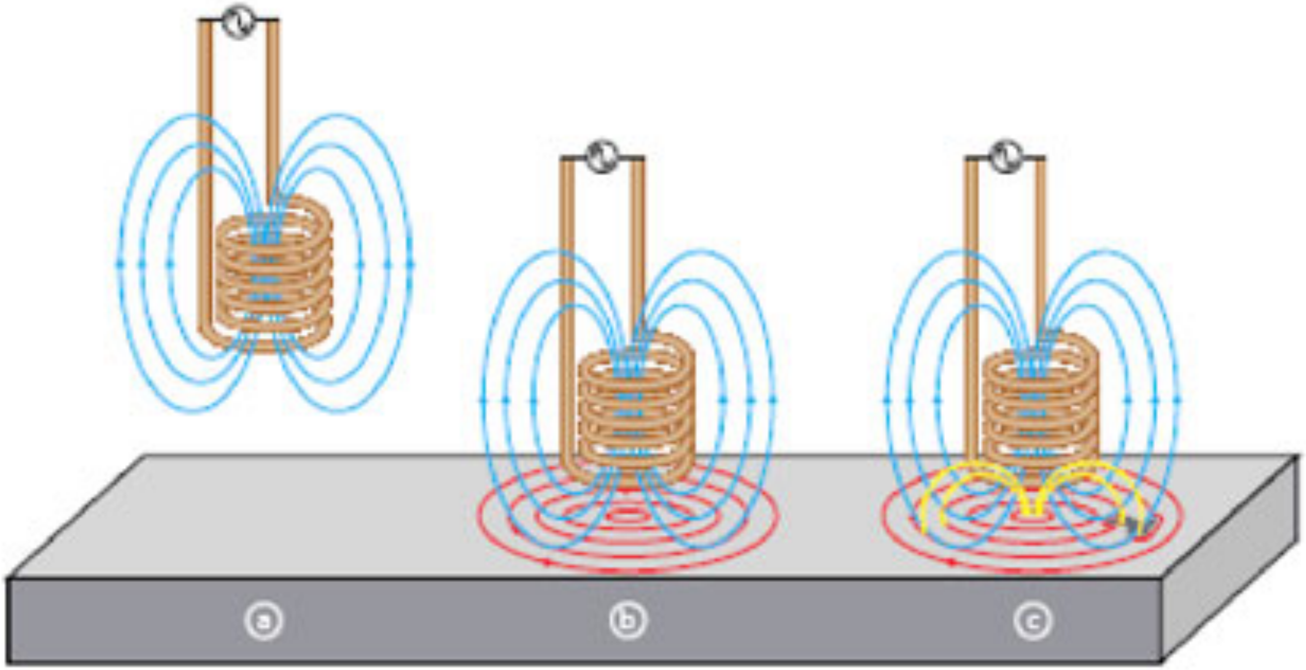
Extra slides



a—The alternating current flowing through the coil at a chosen frequency generates a magnetic field around the coil.

b—When the coil is placed close to an electrically conductive material, eddy current is induced in the material.

c—If a flaw in the conductive material disturbs the eddy current circulation, the magnetic coupling with the probe is changed and a defect signal can be read by measuring the coil impedance variation.