DE LA RECHERCHE À L'INDUSTRIE

CEA - Saclay

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27-28 JUNE 2017

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ESS POWER COUPLERS FOR THE ELLIPTICAL CAVITIES

-

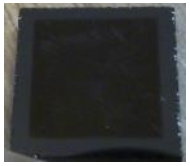
CHRISTIAN ARCAMBAL

OUTLINE

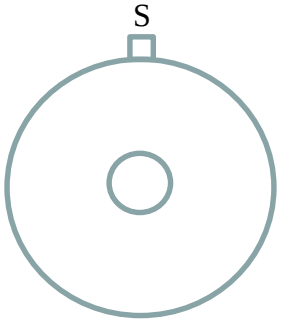
- Details of the manufacturing (prototype)
  - Window (TiN coating, electron beam welding)
  - Tube (realization of the cooling circuit, flange welding, copper coating)
  - Doorknob (high voltage insulation, RF gaskets, mechanical aspects)
- Coupler life cycle at CEA
- Conditioning of the 3 first pairs of couplers
- Overview of the production

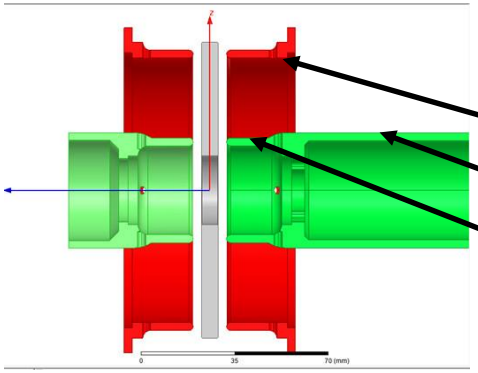
TIN PLATING (1/4)

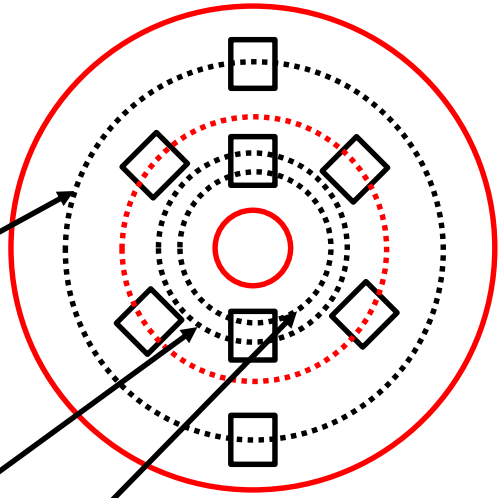
- Requirement: 10nm +/-5nm on the ceramic (vacuum side)
- 2 procedures of TiN coating:
  - Coating before brazing (on the whole surface of the ceramic)
  - Coating after brazing (areas hidden by the chokes)
- Magnetron sputtering deposition
- TiN coating controlled on vitreous carbon samples (10mm*10mm)
- Thickness and stoichiometric (Rutherford backscattering spectrometry) measurements



Sample on the border of the ceramic







Limit of the external choke

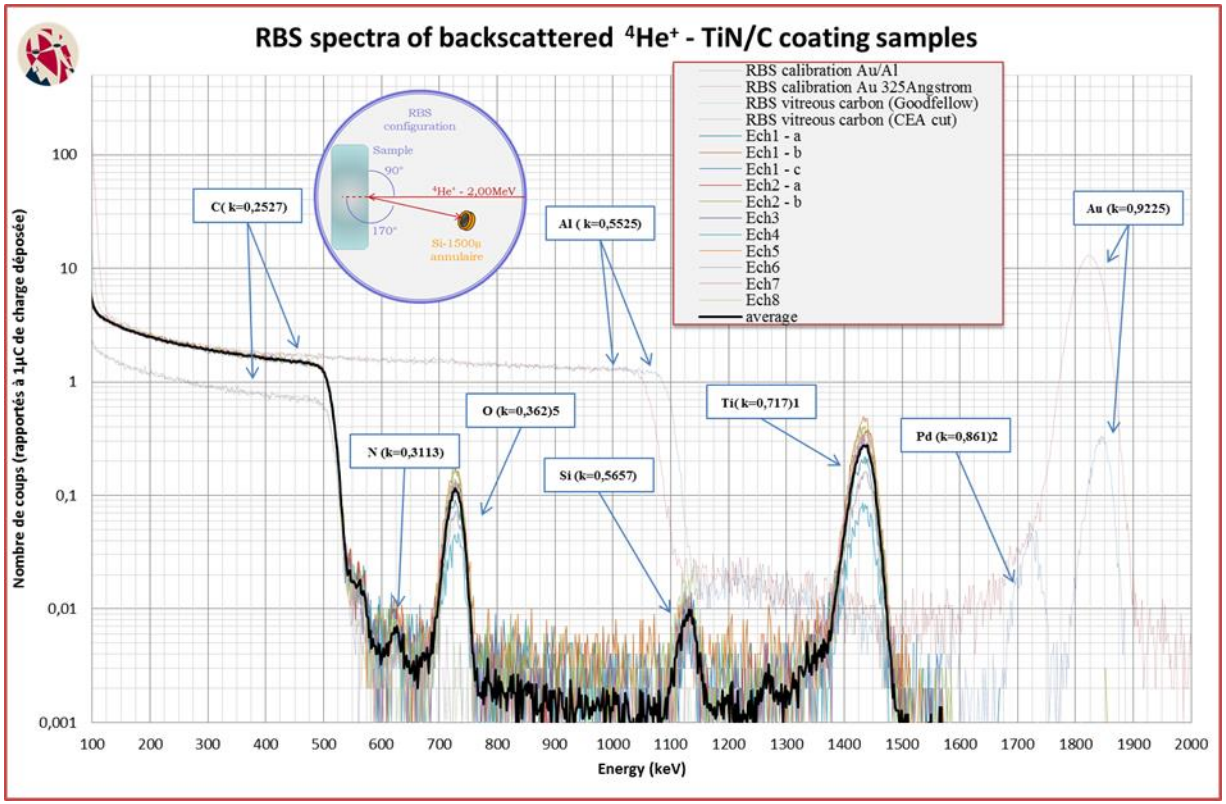
Limit of the internal conductor

Limit of the internal choke

TIN PLATING (2/4)

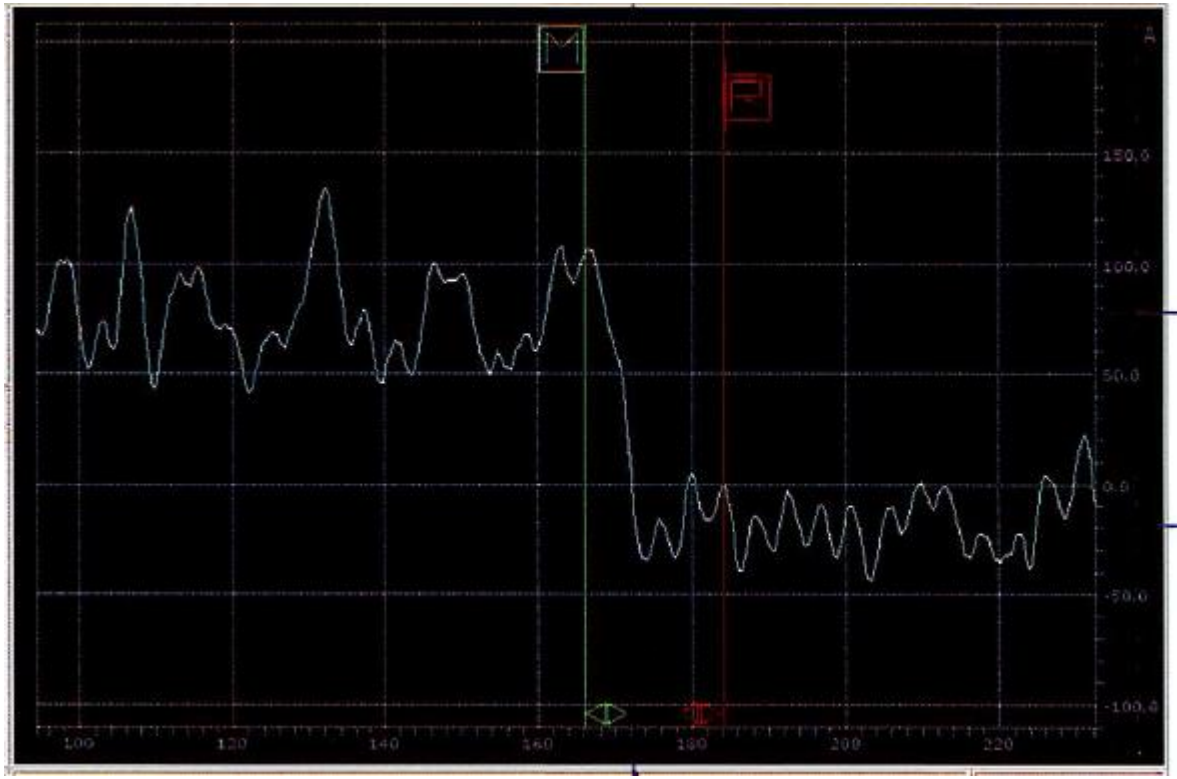
- Results obtained on samples (for plating before brazing)
  - Composition of TiN :

Ti:25.73%, **Si** :1 to 3%, **O**: 68.73%,**N** :5.55% ⇒ coating such as TiNxOy ,contamination with silicon, lack of nitrogen.

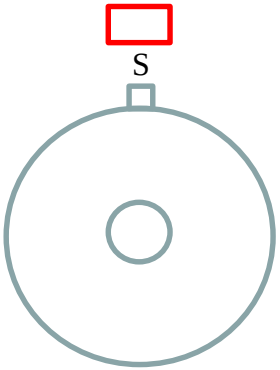


TIN PLATING (3/4)

- Thickness: measured with stylus profilometer (Dektak 6m), between 10.1 and 10.4nm on a white glass put above the sample



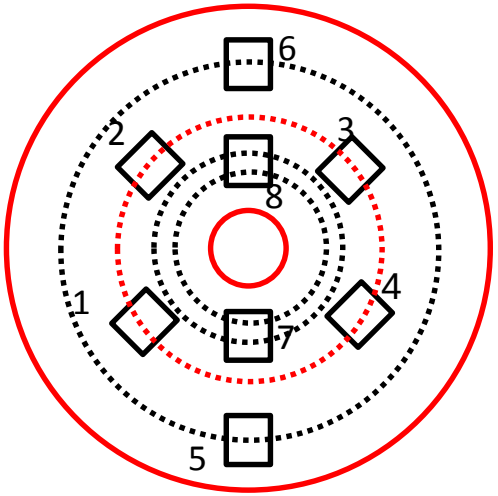
White glass



TIN PLATING (4/4)

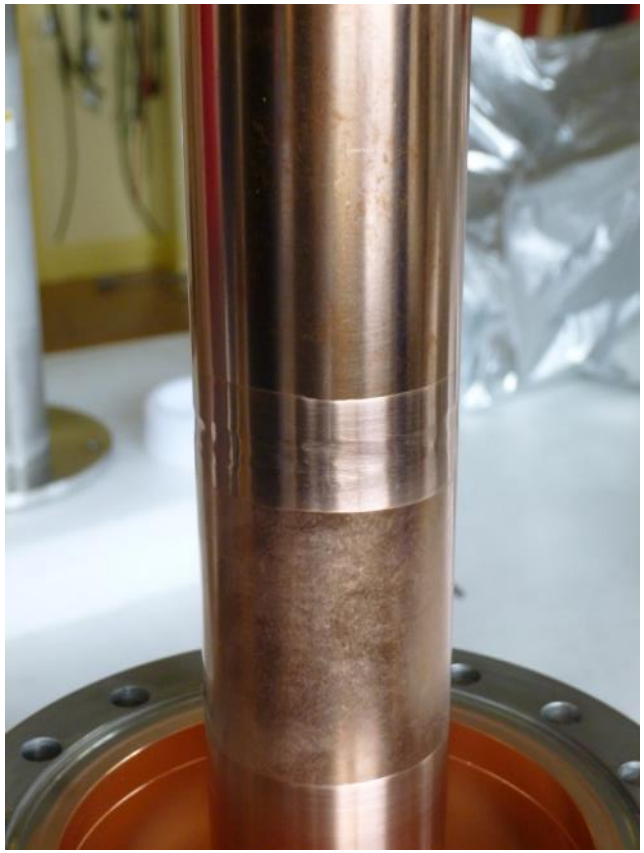
- Results obtained on samples:
  - Composition of TiN for plating after brazing
  - Estimation of the thickness by calculation

N°sample	thickness (nm)	% Ti	% N
1	5,310516384	0,50	0,50
1	5,113830592	0,55	0,45
1	4,720459008	0,54	0,46
5	**3,44200136**	**0,46**	**0,54**
5	**4,42543032**	**0,45**	**0,55**
5	**3,245315568**	**0,47**	**0,53**
5	**3,146972672**	**0,47**	**0,53**
6	3,44200136	0,49	0,51
6	2,95028688	0,49	0,51
6	3,540344256	0,41	0,59
6	5,113830592	0,42	0,58
7	**0,786743168**	**0,44**	**0,56**
7	**0,885086064**	**0,43**	**0,57**
7	**0,786743168**	**0,42**	**0,58**
7	**0,49171448**	**0,44**	**0,56**
8	1,770172128	0,43	0,57
8	2,163543712	0,42	0,58
8	0,49171448	0,47	0,53
8	1,770172128	0,43	0,57
8	1,770172128	0,43	0,57



ELECTRON BEAM WELDING ON THE ANTENNA (1/2)

- Electropolishing before welding on each part then manual polishing with scotch brite (#3000 non-woven polishing sheet)



ELECTRON BEAM WELDING ON THE ANTENNA (2/2)

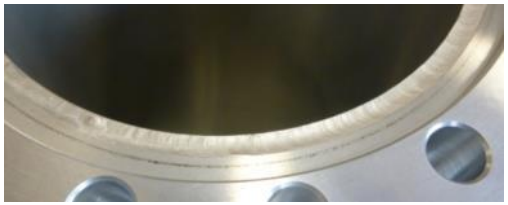
- From another manufacturer, not so smooth aspect

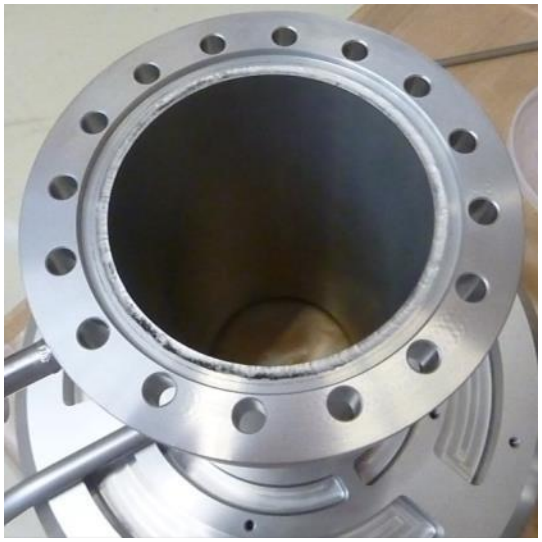
DOUBLE-WALL TUBE: COOLING CIRCUIT

- Cooling circuit composed of 3 helical channels
- Cooling circuit manufactured with the shrink-fitting method

WELDING ON THE TUBE

- Welding on the flange (cavity side)
- Welding on the flange (window side)



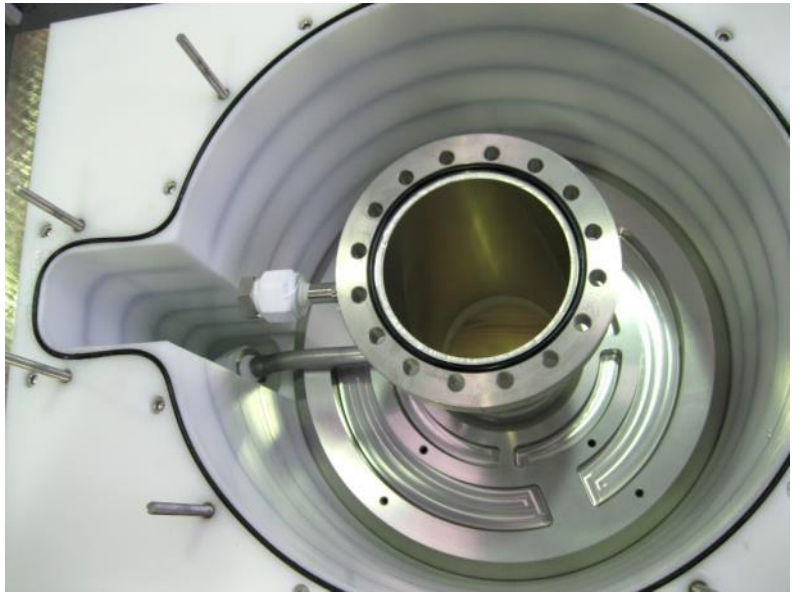


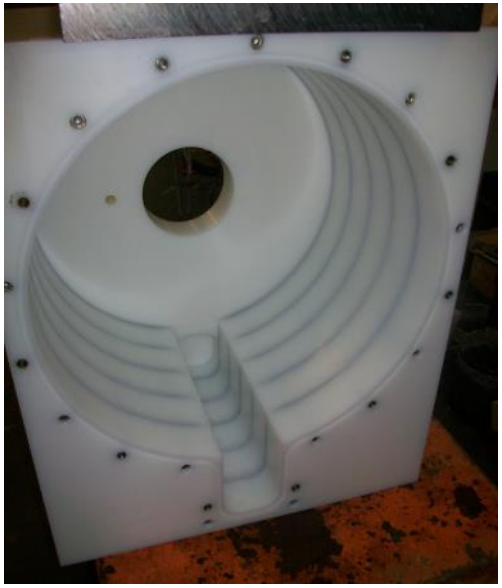
COPPER COATING (DOUBLE-WALL TUBE)-1

- Requirements: Copper coating with 10µm(-3/+2µm) thickness and RRR∈ [20;40] (threshold between RF and thermal aspects)
- electrolytic deposition
- Tubes from 2 manufacturers
- Validation of the coating on cylinder sample
- 1st manufacturer
  - Sample OK (use of resin to protect external face)

COPPER COATING (DOUBLE-WALL TUBE)-2

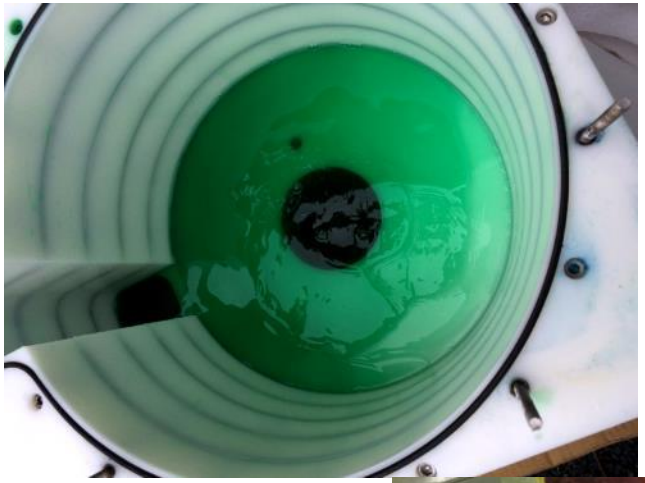
- Development of a protection tool

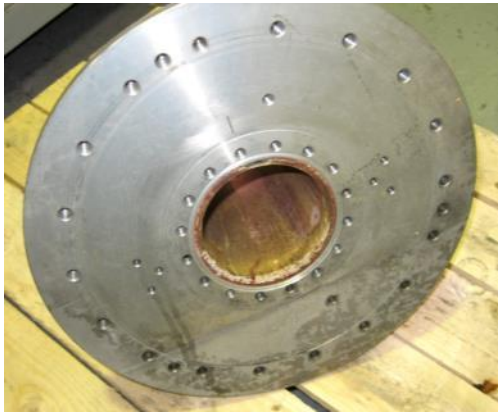


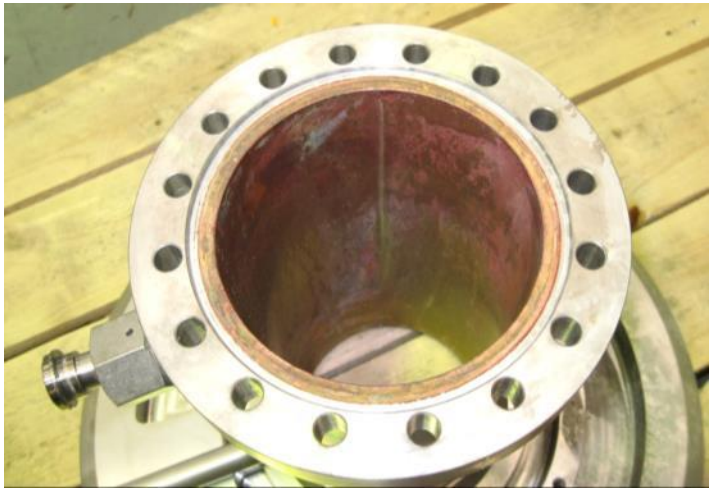


COPPER COATING (DOUBLE-WALL TUBE)-3

- Few tightness problems on the first tubes (coupler in contact with Wood's nickel)+copper deposit with lots of defaults

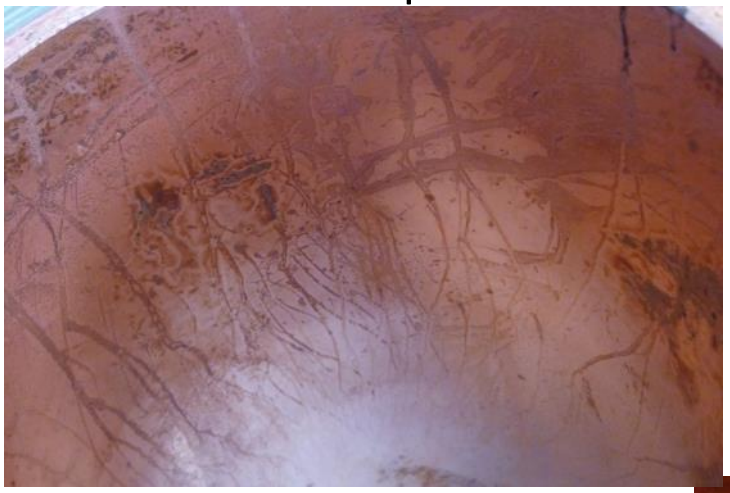






COPPER COATING (DOUBLE-WALL TUBE)-4

- When the protection tool works, copper deposit with lots of defaults



crack

peel

oxidation

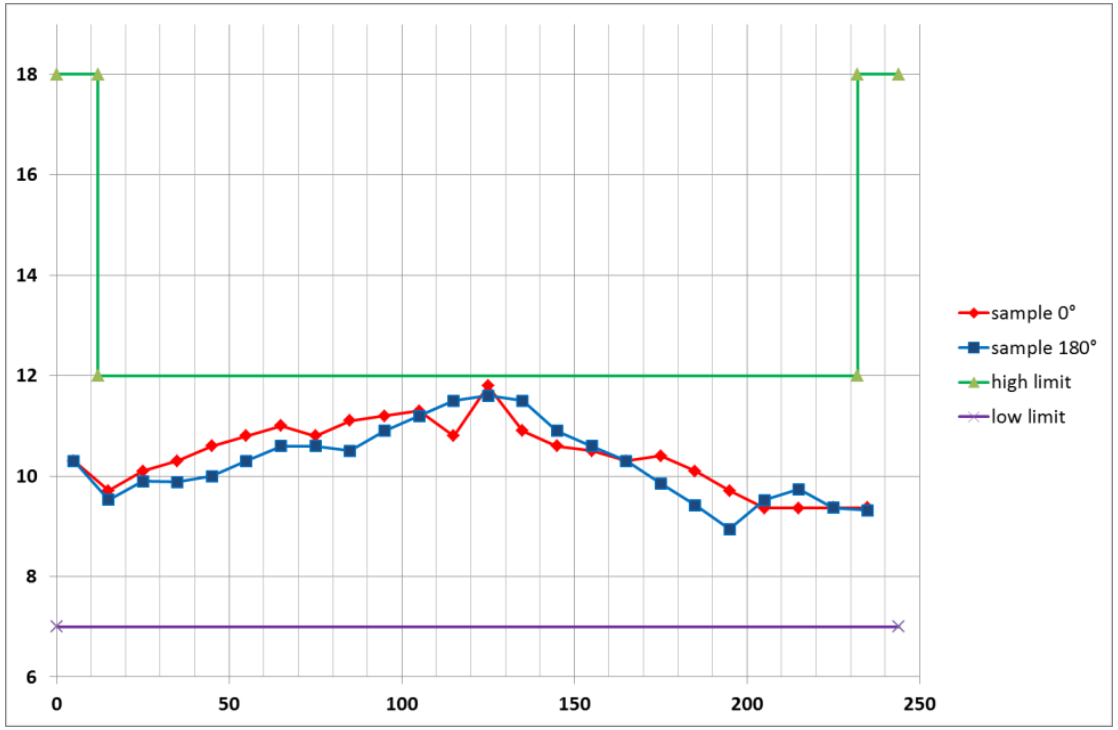
COPPER COATING (DOUBLE-WALL TUBE)-5

- Obligation to remove the copper deposit (use of nitric acid)

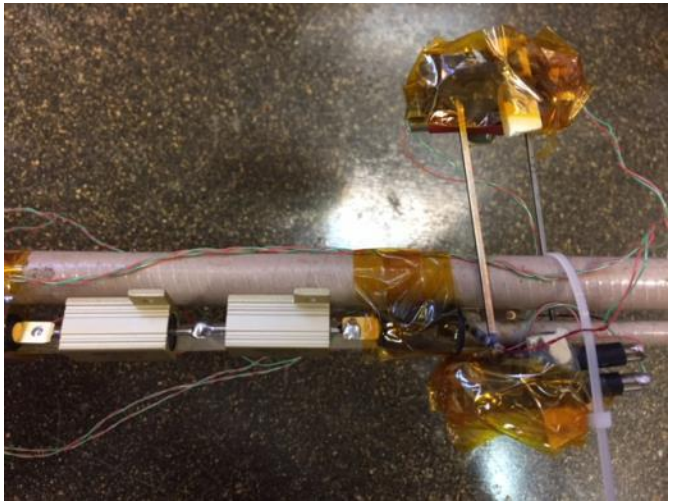
- New copper plating with another firm

RESULTS ON COPPER COATING-1

- Control of copper deposit

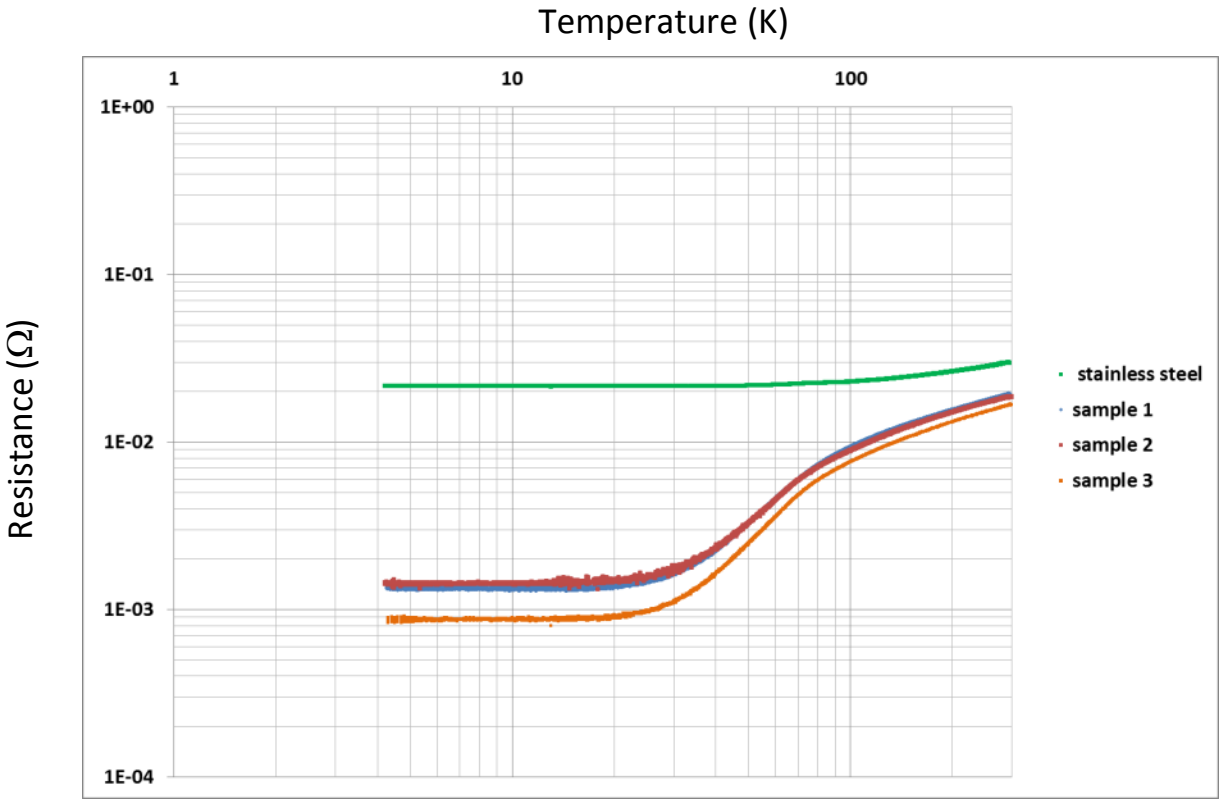


Copper plated samples



RESULTS ON COPPER COATING-2

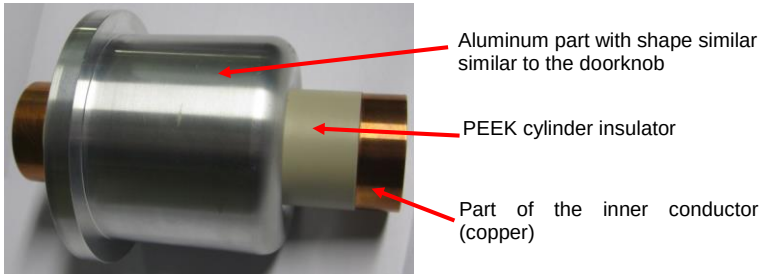
- RRR measurement (I-V measurement) on « rectangular » sample (2mm*1mm*100mm)

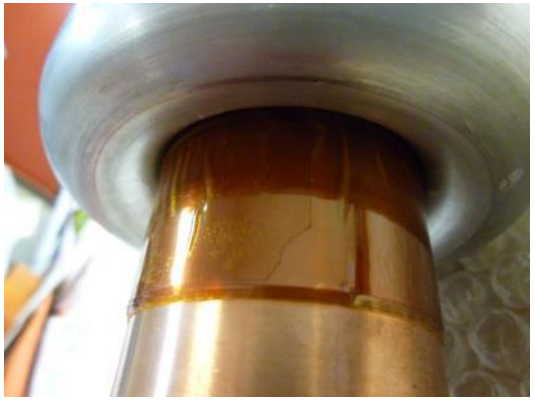


Measurement: RRR ∈ [30;39]

INSULATION-DOORKNOB TRANSITION-1

- First requirement: use of kapton to provide 10kV insulation
- Difficulty to obtain kapton cylinder with “high” diameter (43mm)
- 2 solutions:
  - Use of kapton adhesive
  - Change of material, PEEK (dielectric constant =3.3 (+/-10%) close to the kapton one and rather good insulation). Easy to be machined (cylinder obtained from solid material)
- Test on samples

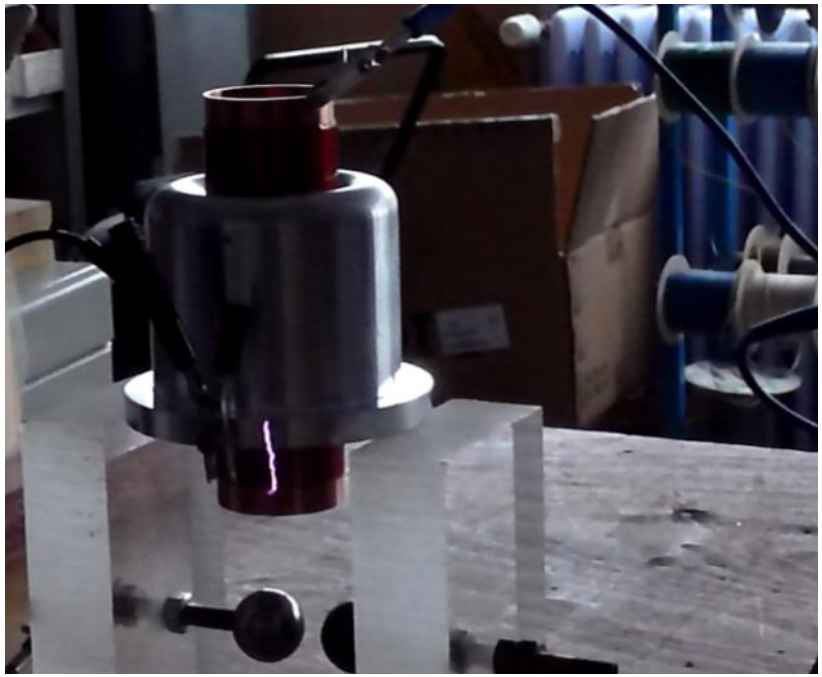


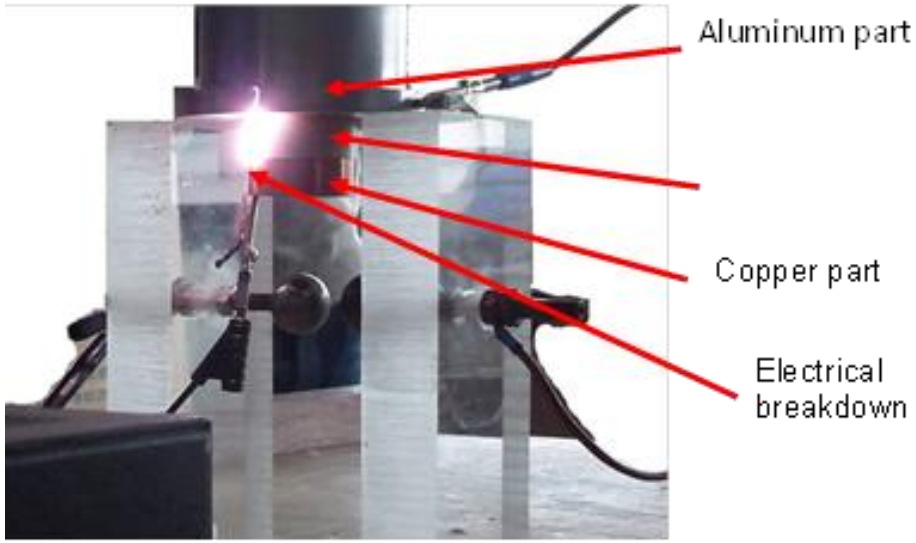


Solution not permanent (evolution of the adhesive, we can tear the adhesive, how to ensure no air between layers…)

INSULATION-DOORKNOB TRANSITION-2

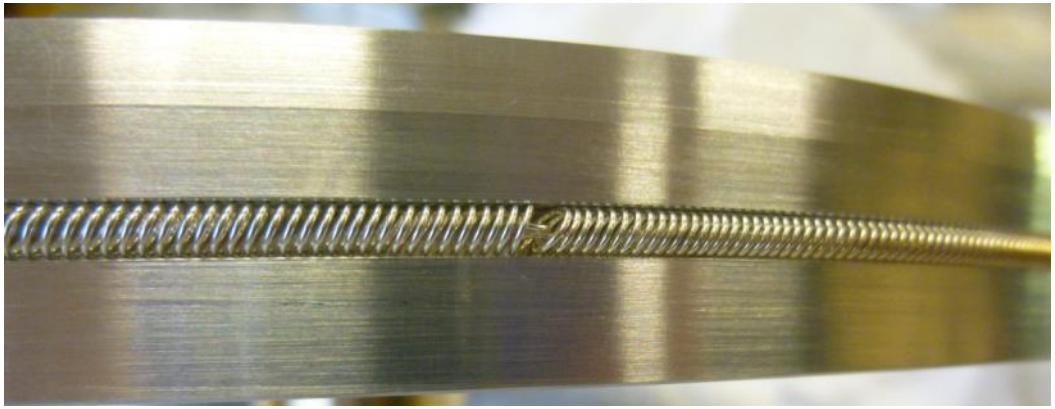
- breakdown voltage ≥18kV





RF GASKET (1/2)

- Bal Seal spring used as RF gasket
- Material: Beryllium copper Alloy 25 with silver plating
- 1st trials: the extremities of the spring are twisted to make hooks and then we link the hooks to close the gasket ⇒ when assembly and disassembly, risk of opening the gasket

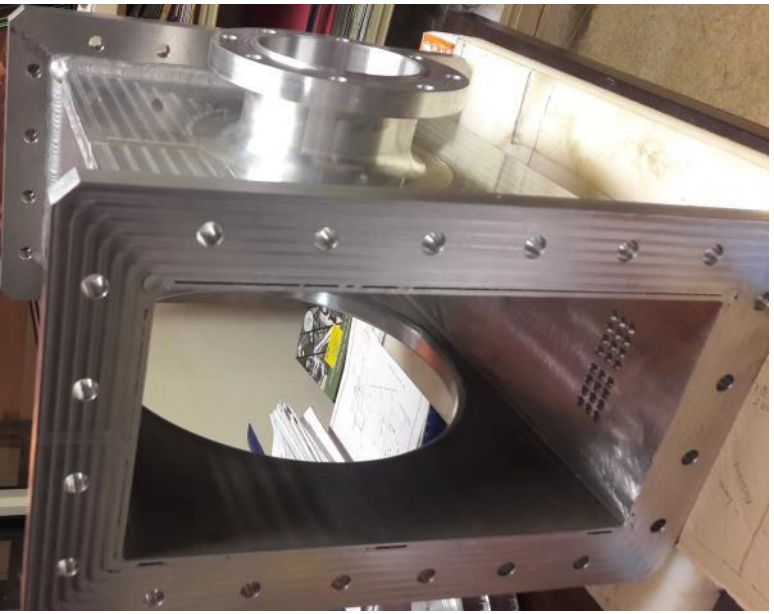


RF GASKET (2/2)

- 2nd trial (solution foreseen for the series):welding the gasket

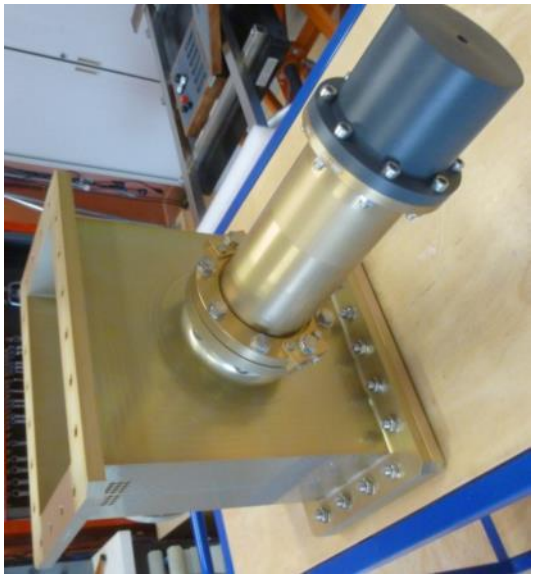
DOORKNOB BOX (1/2)

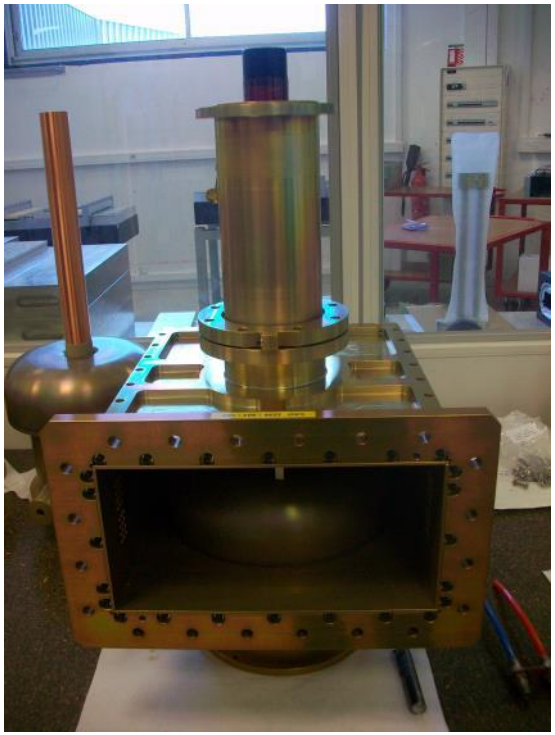
- Initial requirement: welding for the aluminum box (thin wall)
- Difficulty to obtain full penetration welds. After machining, some holes occur.

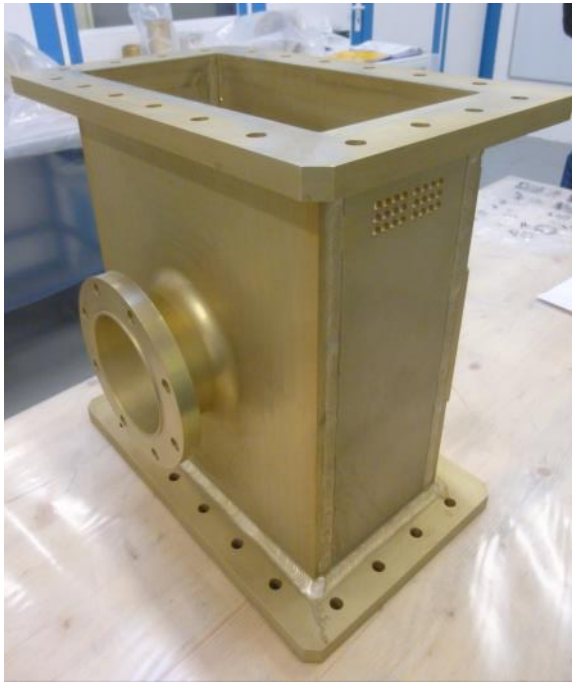


DOORKNOB BOX (2/2)

- 3 kinds of box
  - Welded box
  - Fully machined box
  - Screwed box

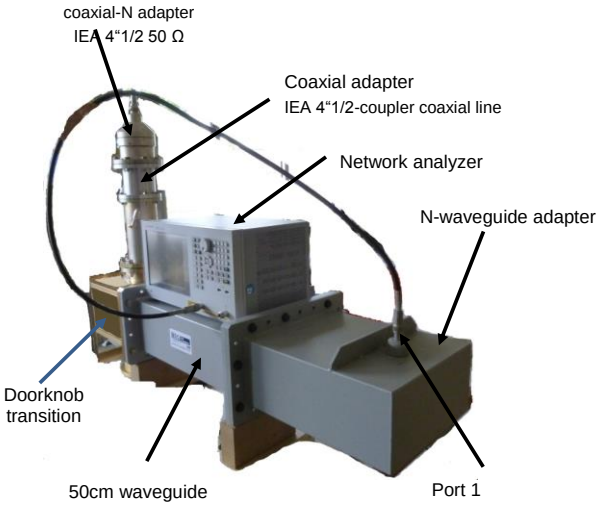


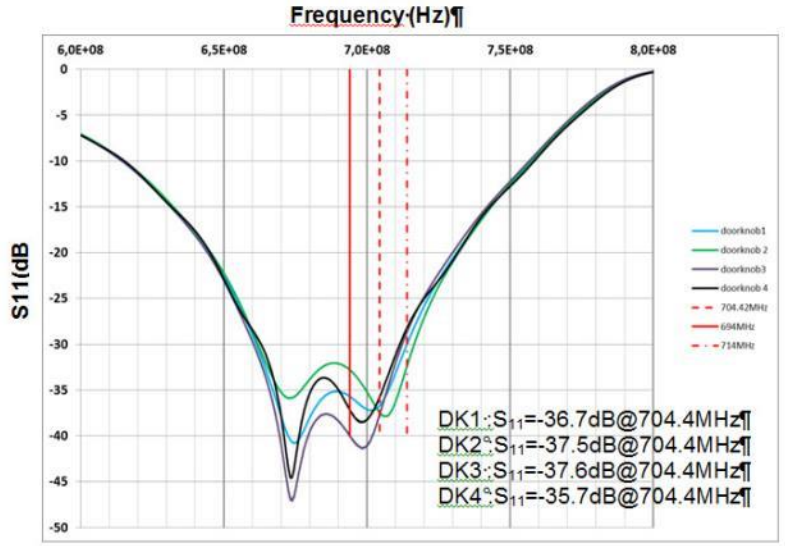




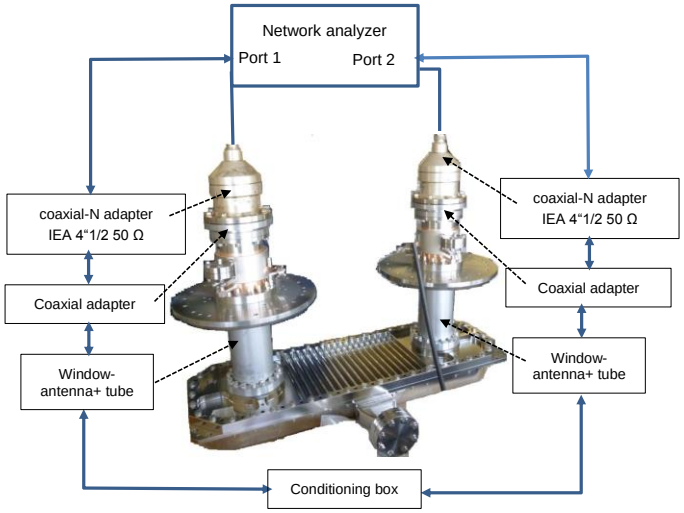
RF CHARACTERIZATION

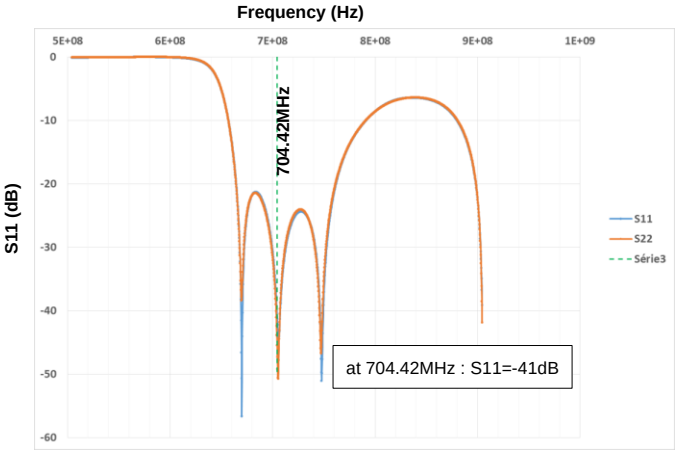
- Doorknob





- Couplers on the conditioning box



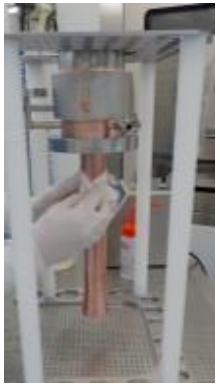


COUPLER LIFE CYCLE AT CEA (1/2)

- Cleaning of each part of the coupler

Tube in ultrasonic bath (Tickopur R33)

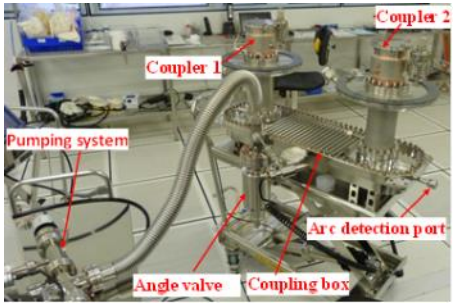
Coupling box in ultrasonic bath (TFD4)



Cleaning of the antenna with alcohol and RBS T310 if oxidation marks

- Assembly in cleanroom

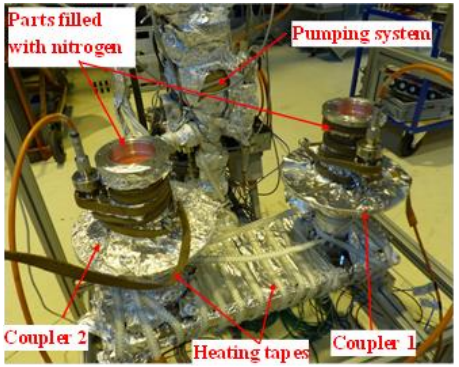
Assembly of the tube and window on the coupling box



Vacuum leak test

- Baking (couplers: 170°C for 72 to 120 hours]; pumping system: 120°C for 48 hours then 60°C)

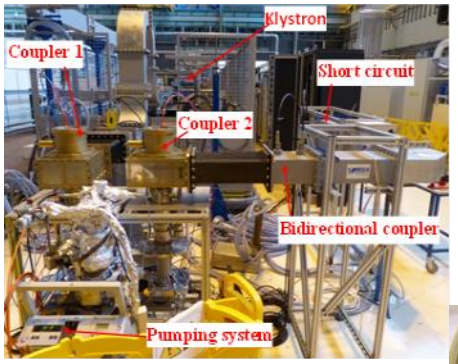
  silicon and fibre glass heating tapes for prototype, furnaces for series



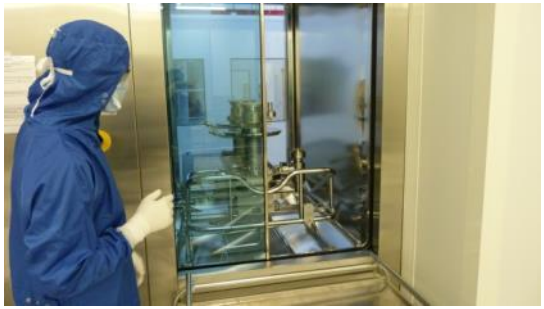
COUPLER LIFE CYCLE AT CEA (2/2)

- Conditioning of pairs of couplers (a)
- Cleaning before disassembly in cleanroom (b)
- Assembly on cavity (c)
- Conditioning on the cryomodule (d)

a



b

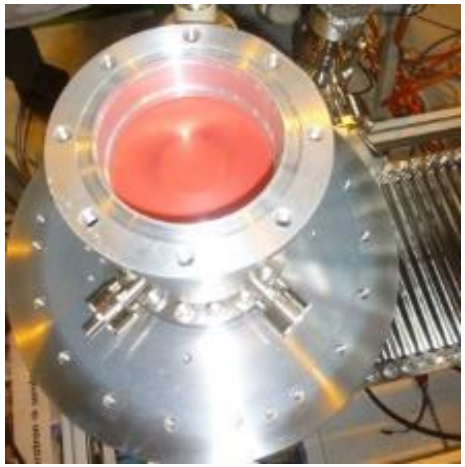


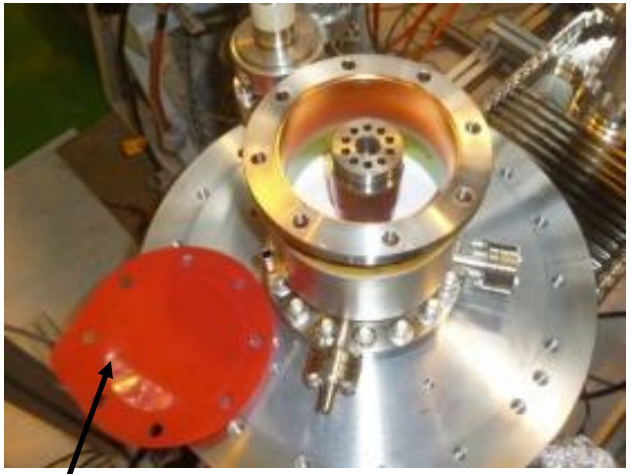
c

d

COPPER OF THE WINDOW (1/2)

- During baking, the air side of the window is put under nitrogen to avoid oxidation of the copper parts





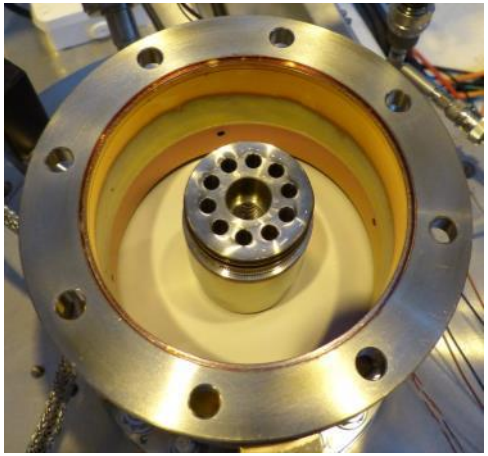
Silicone seal to cover the air part

COPPER OF THE WINDOW (2/2)

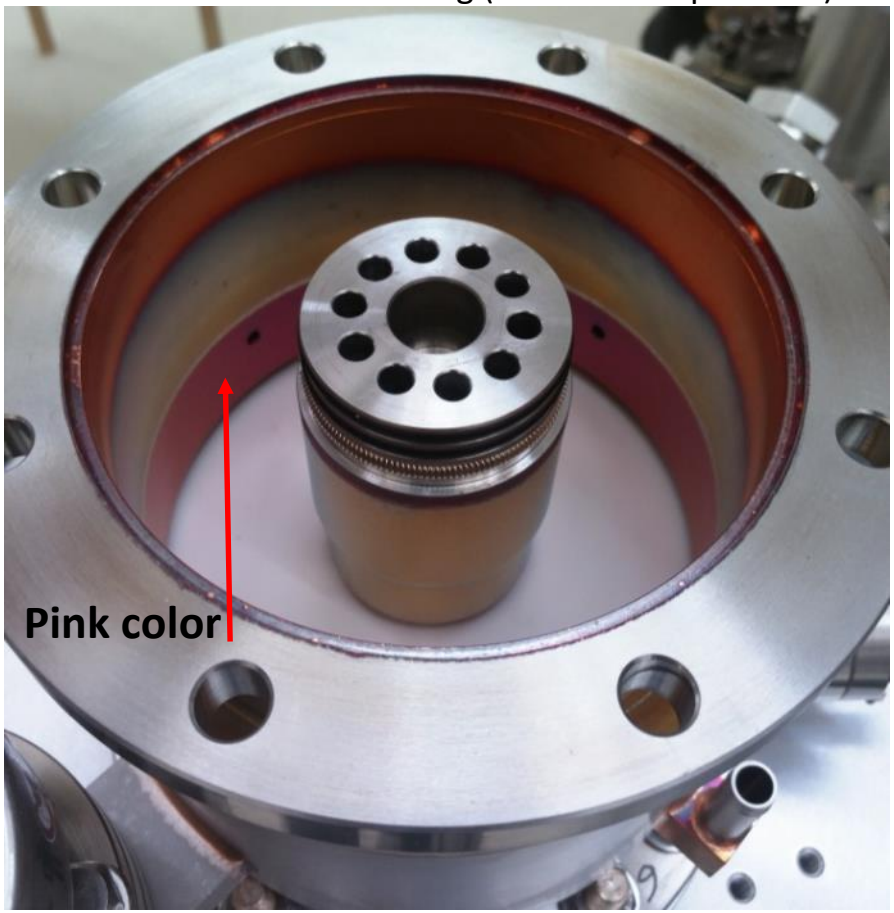
- Evolution of the copper (raw and coating) on the air side

Reception at CEA

After conditioning

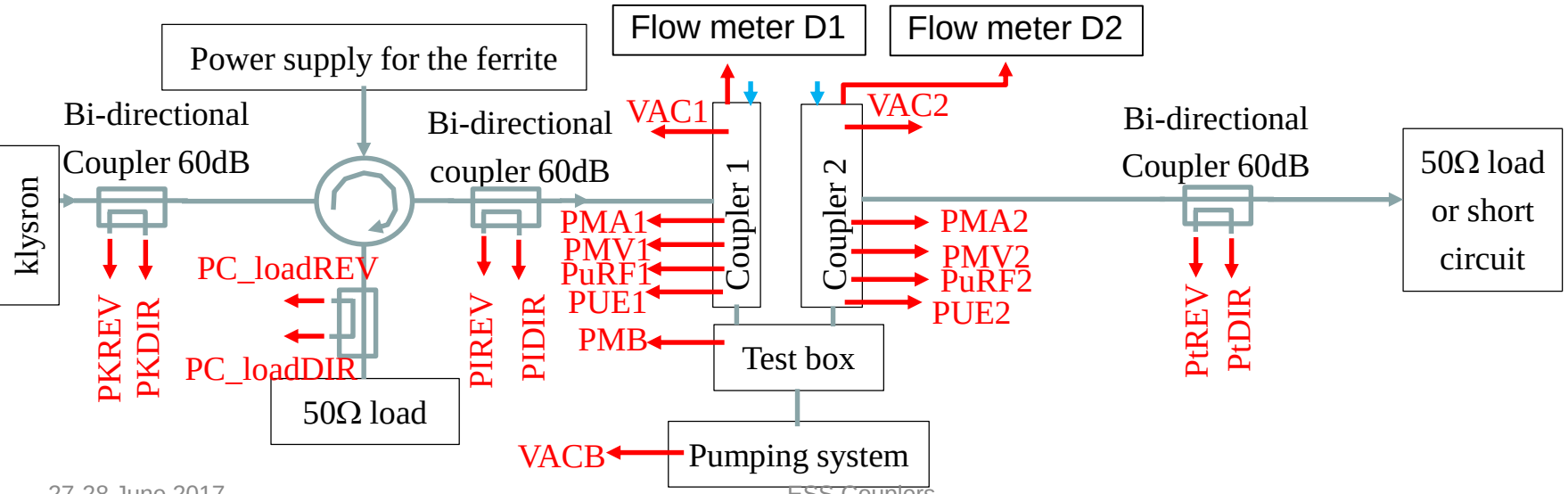


3 months after conditioning (ambient temperature)



MEASURED SIGNALS DURING HIGH POWER RF CONDITIONING

- 5 Photomultipliers (HAMAMATSU H10721-110):
  - Coupler1: 1PM vacuum side (PMV1) , 1PM air side (PMA1)
  - Coupler 2: 1PM vacuum side (PMV2) , 1PM air side (PMA2)
  - Box: 1PM (PMB)
- 2 electron pick-up / RF (coupler 1+coupler 2)
  - Coupling 80dB (10.4dBm for 1.1MW in TW, 16.4dBm in SW with Emax in front of pick-up antenna)
- 3 vacuum gauges:IKR070 with TPG300 controller from Pfeiffer (Coupler 1 (VAC1) & 2 (VAC2) + pumping system (VACB))
- 5 temperature probes (PT100): 2 for water cooling,1 for each coupler (set up on the window close to the ceramic), 1 for the test box
- 8 RF signals: Reverse and forward powers for each bidirectional coupler
- Security signals: 3 vacuum signals from the controllers, 2 water signals from flow meters (relays)

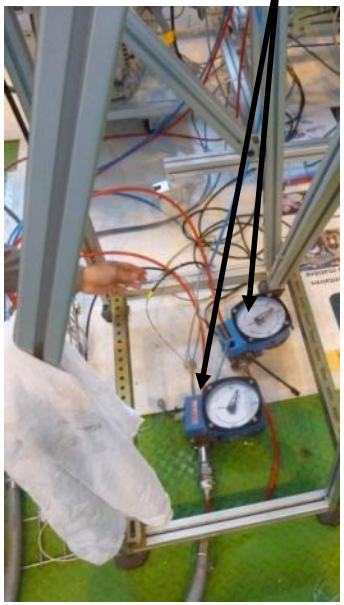


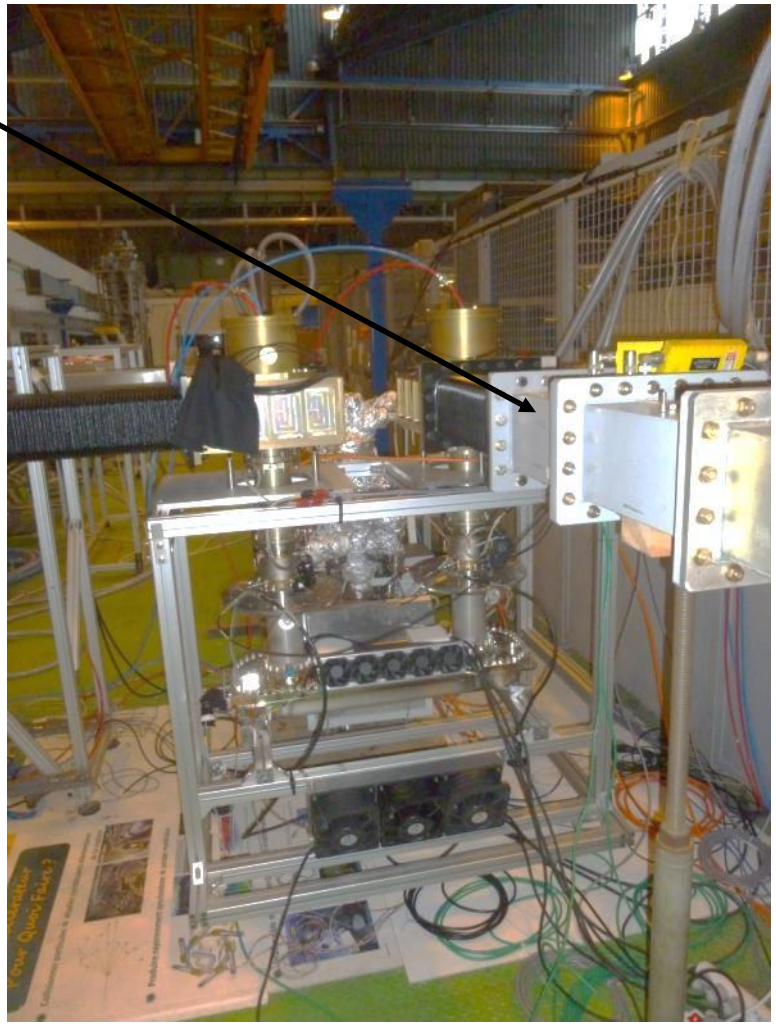
OVERVIEW OF THE CONDITIONING BENCH (1/2)

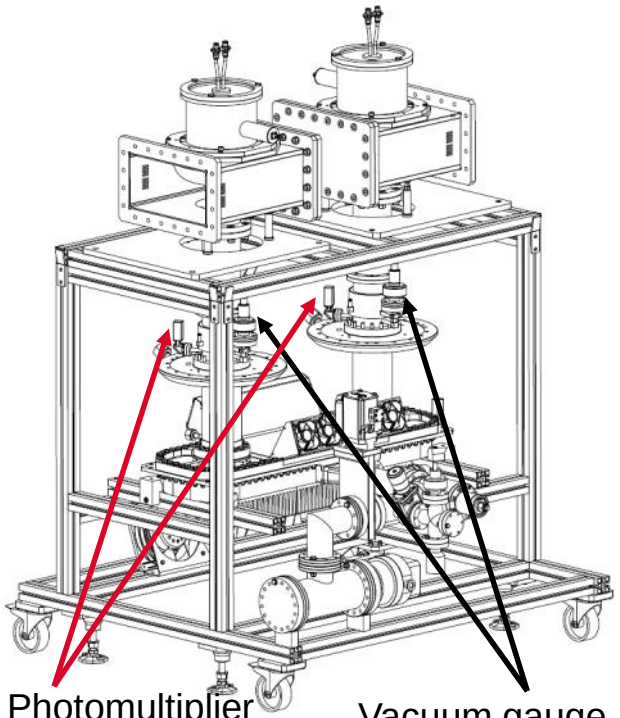
- Position of each diagnosis components

Bidirectional coupler (input Power :incident & reflected power)

Flow meter (ouptut water) &
Temperature probes (water)





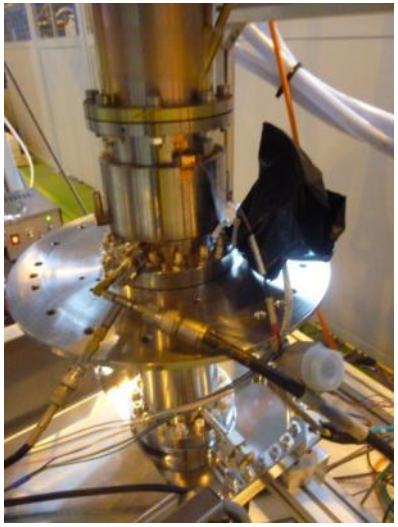


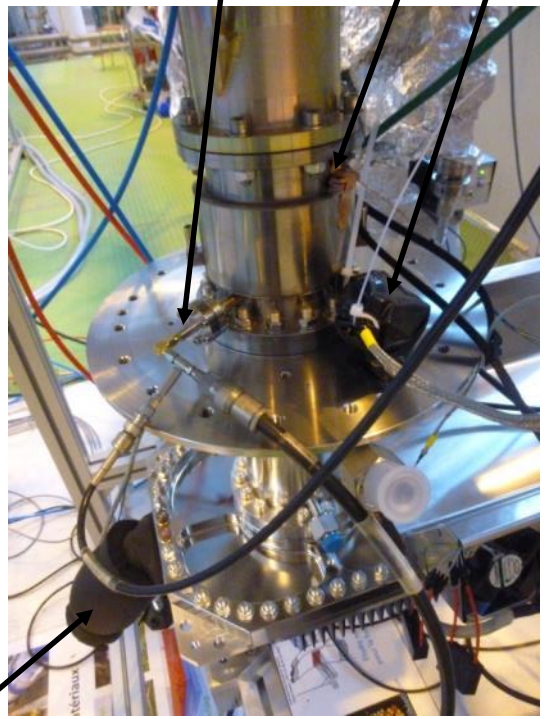
Photomultiplier (vacuum side)

Vacuum gauge

Pumping system

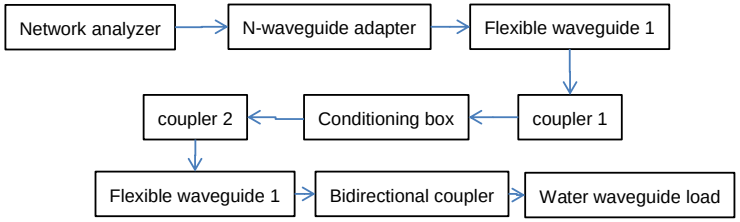
OVERVIEW OF THE CONDITIONING BENCH (2/2)

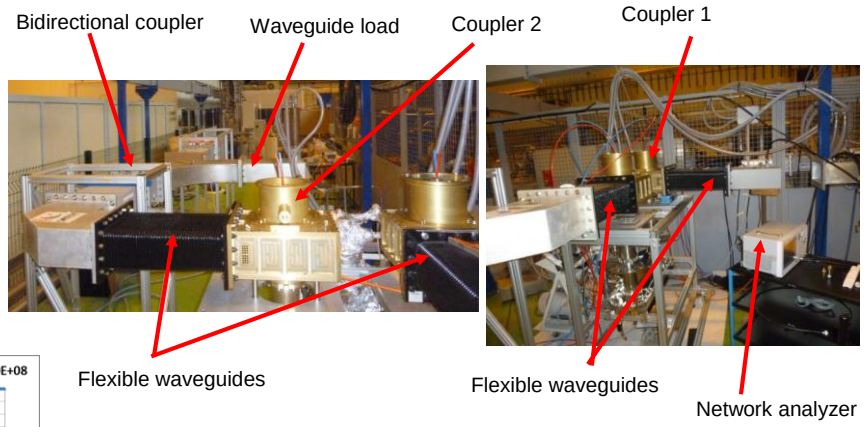


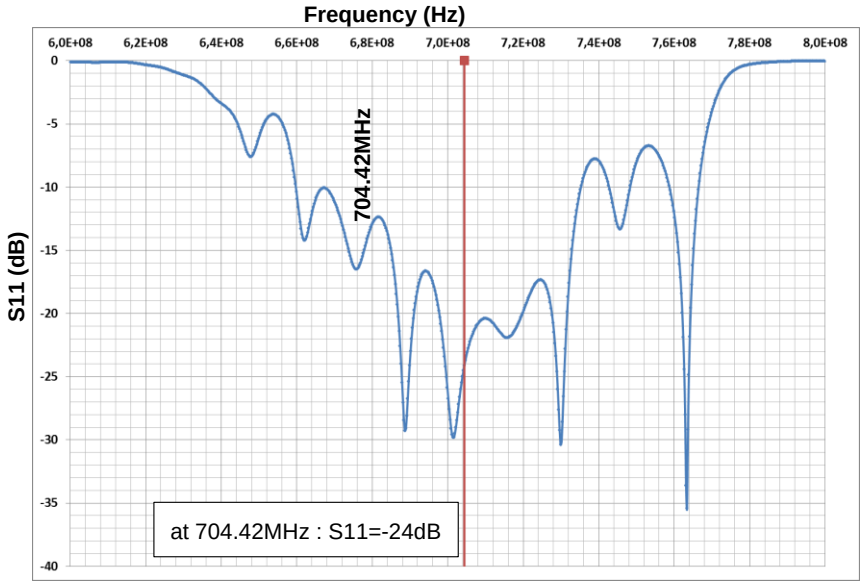


RF CHARACTERIZATION ON THE TEST STAND

- Measurement of the reflection coefficient of the pair of couplers with all the waveguide components (load 50Ω)

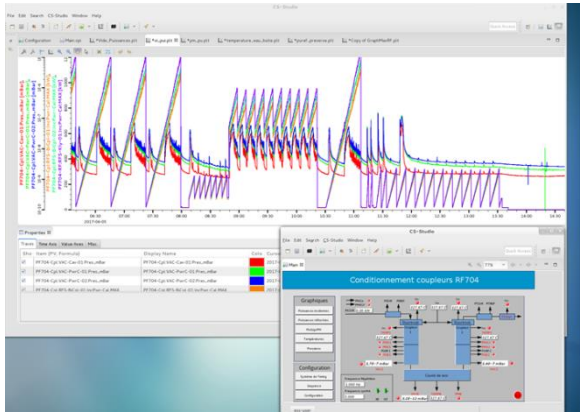






CONDITIONING

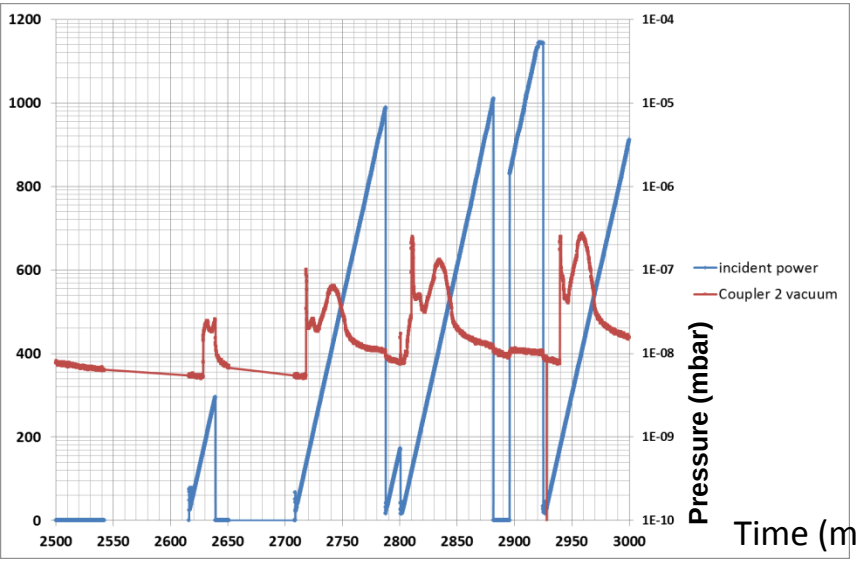
- Conditioning sequence in travelling waves (TW) : RF power ramp from 15kW to 1200kW (pulse width from 50µs to 3.6ms), repetition frequency: 1Hz then 14Hz
- Conditioning sequence in standing waves (SW): 2 positions of short circuit, RF power ramp from 15kW to 1200kW (pulse width from 50µs to 500µs, 1Hz), from 15kW to 300kW (pulse width: 500µs to 3.6ms, 14Hz)
- Conditioning test stand controlled with Labview then EPICS



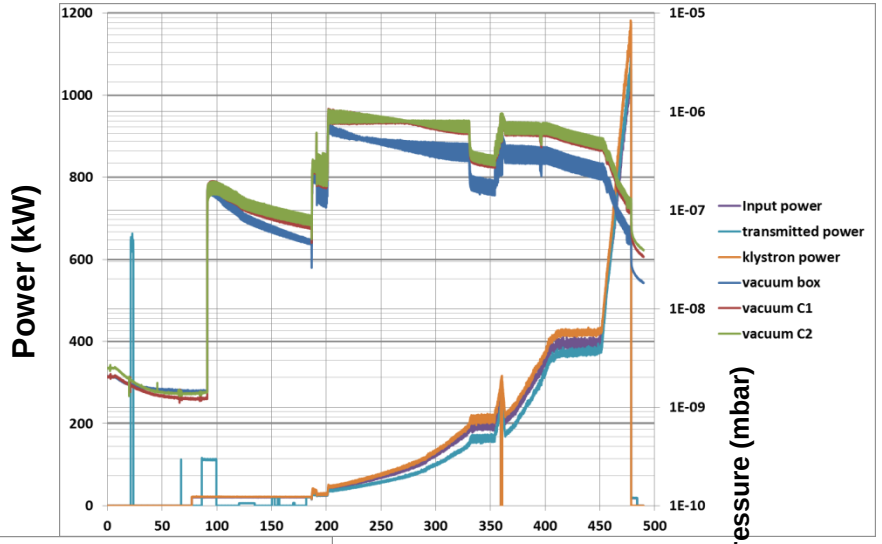
- RF time for the 3 first medium beta pairs of couplers: 82 hours, 88 hours and 106 hours

FIRST RF POWER RAMP

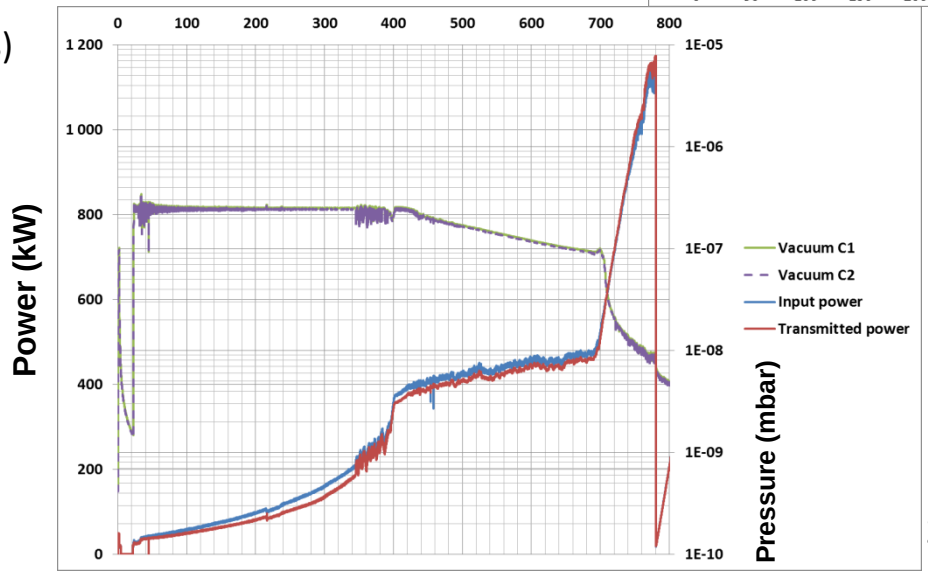
1st pair of coupleurs



3rd pair of coupleurs (coupling box re-used)



Time (minutes)

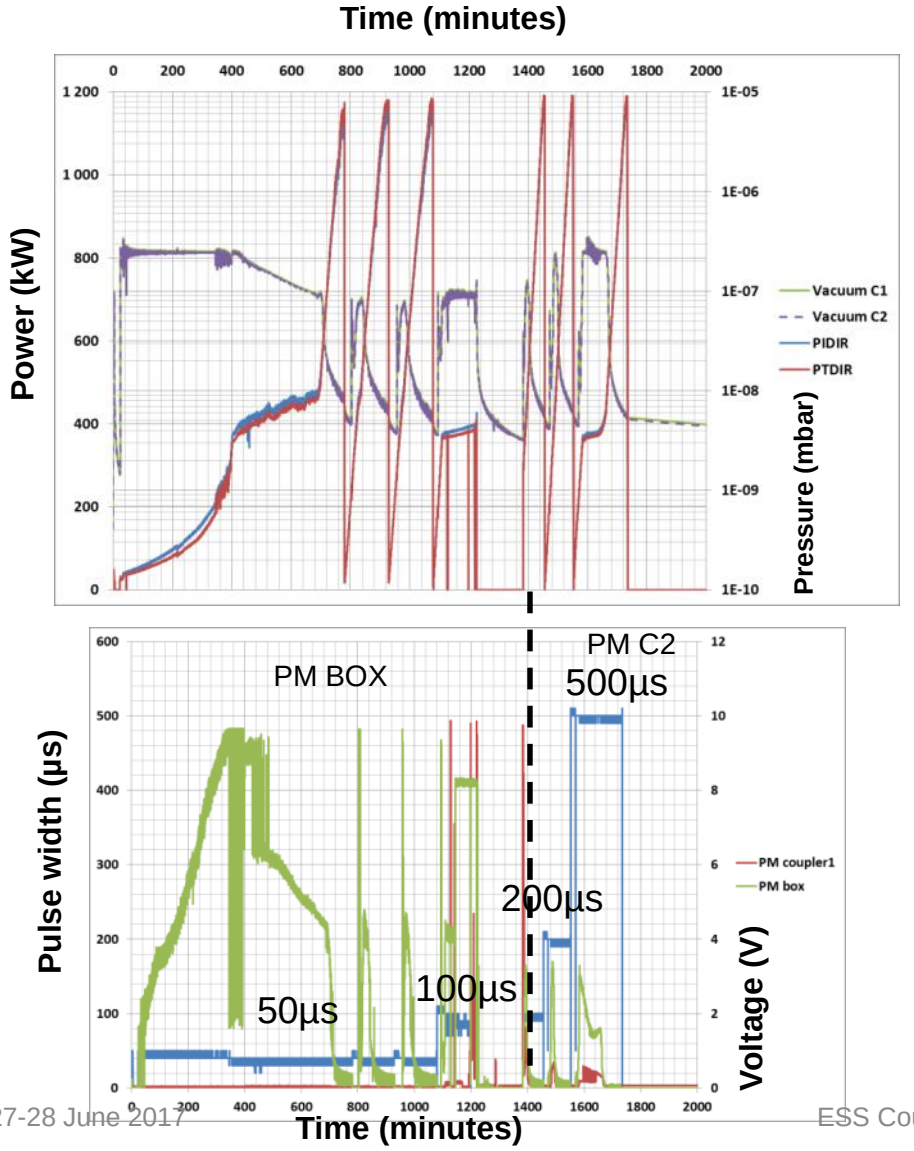


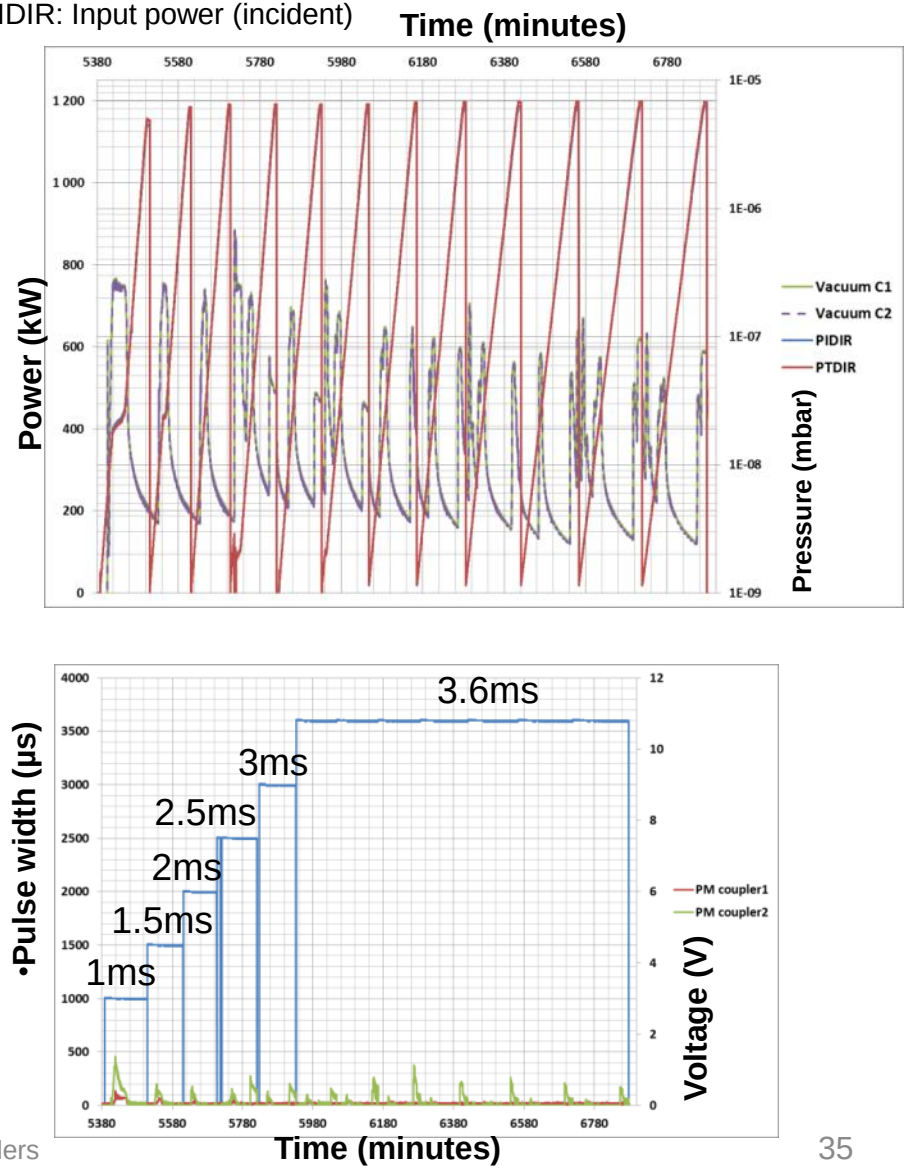
2nd pair of coupleurs

CONDITIONING-TRAVELLING WAVE (1/2)

- Results for repetition period=1.2second

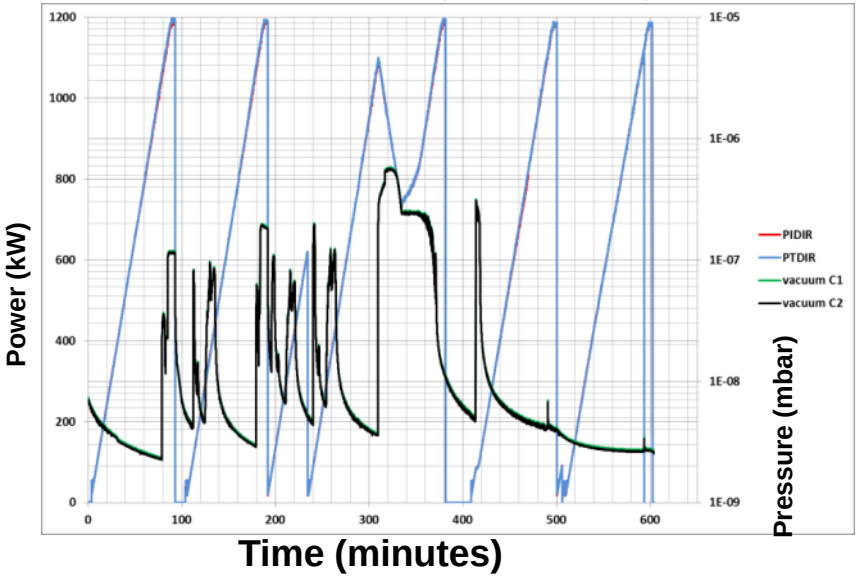
PTDIR: Output power (incident)
PIDIR: Input power (incident)



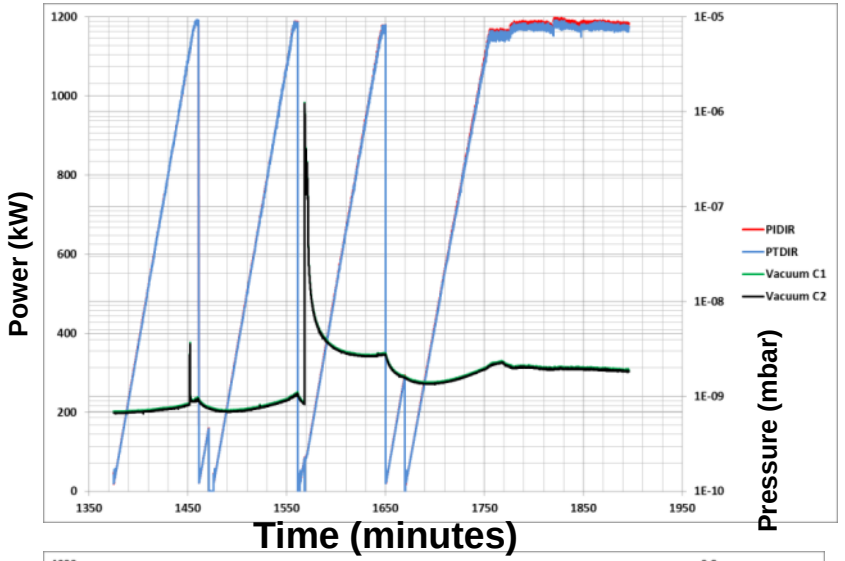


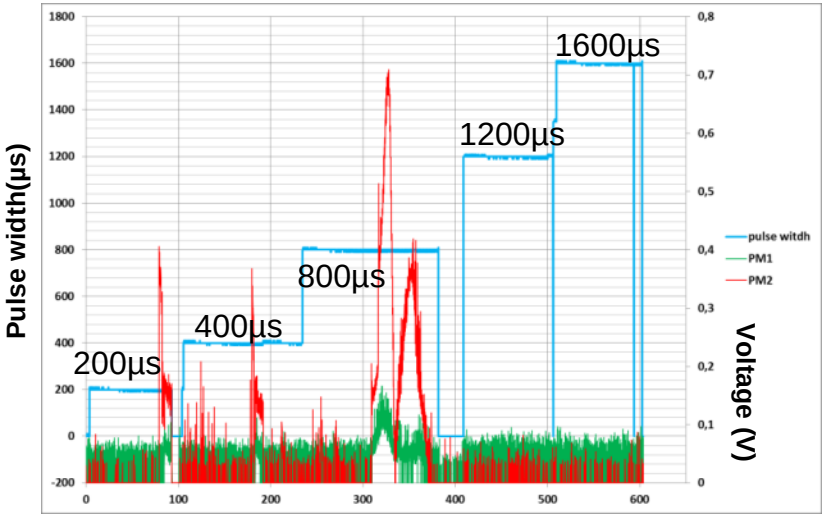
CONDITIONING-TRAVELLING WAVE (2/2)

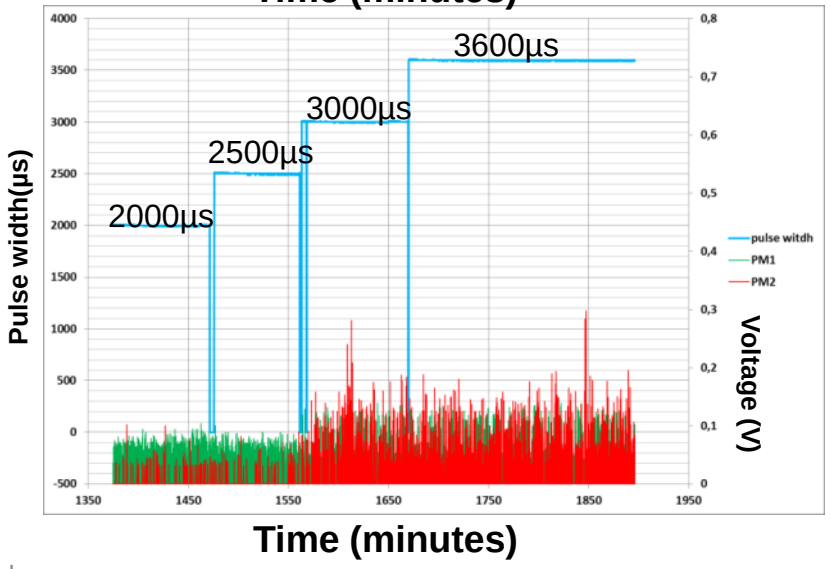
- Results for repetition period=72 ms



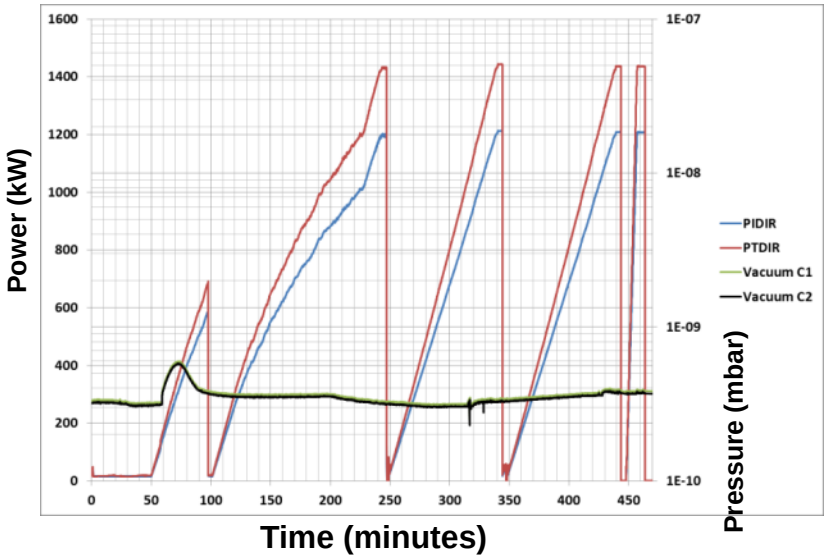
PTDIR: Output power (incident)
PIDIR: Input power (incident)

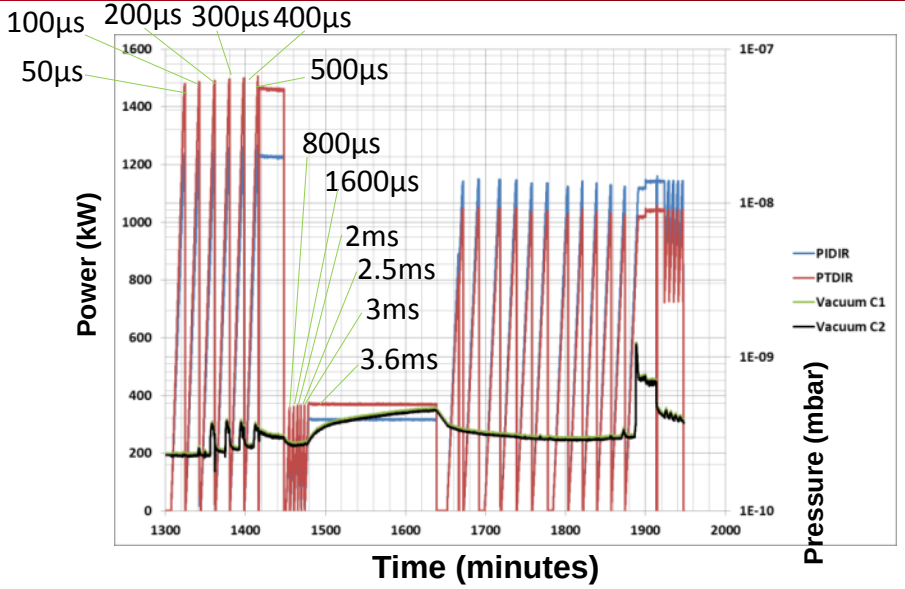


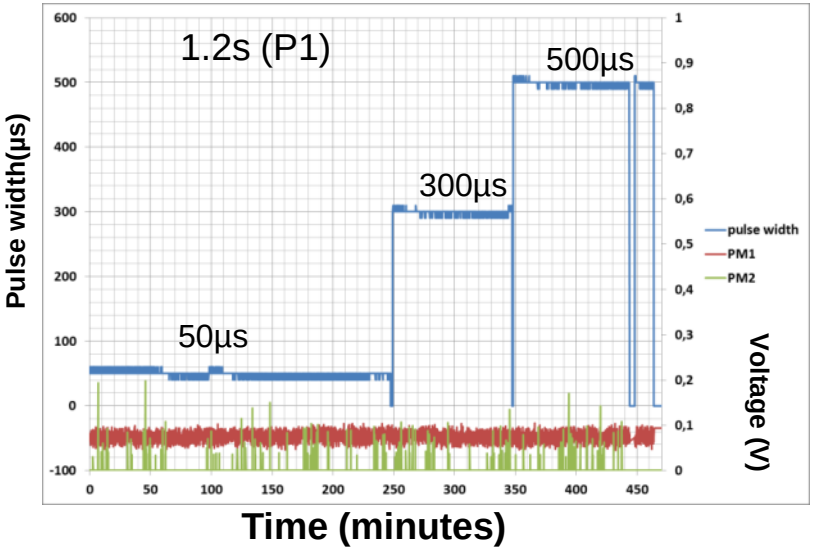


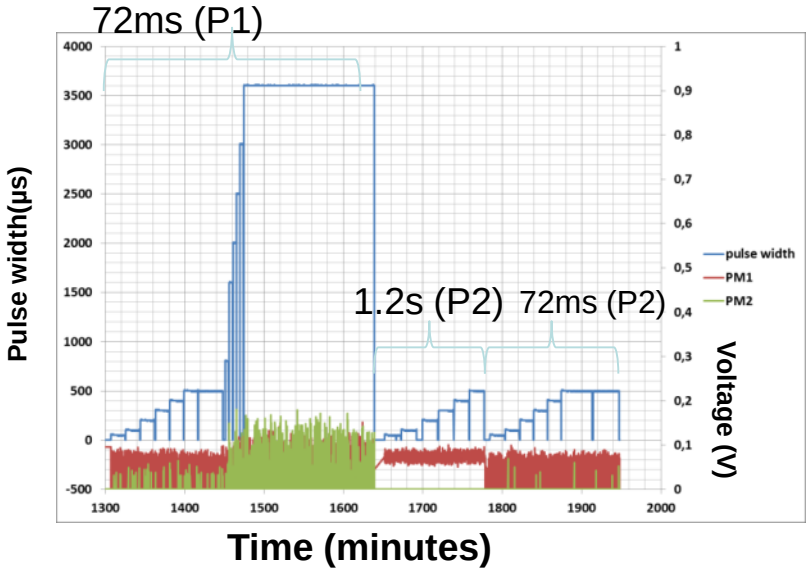


CONDITIONING-STANDING WAVE









TEMPERATURE DURING CONDITIONING

- Temperature of the water

  During the conditioning: for Φ=2.4l/min

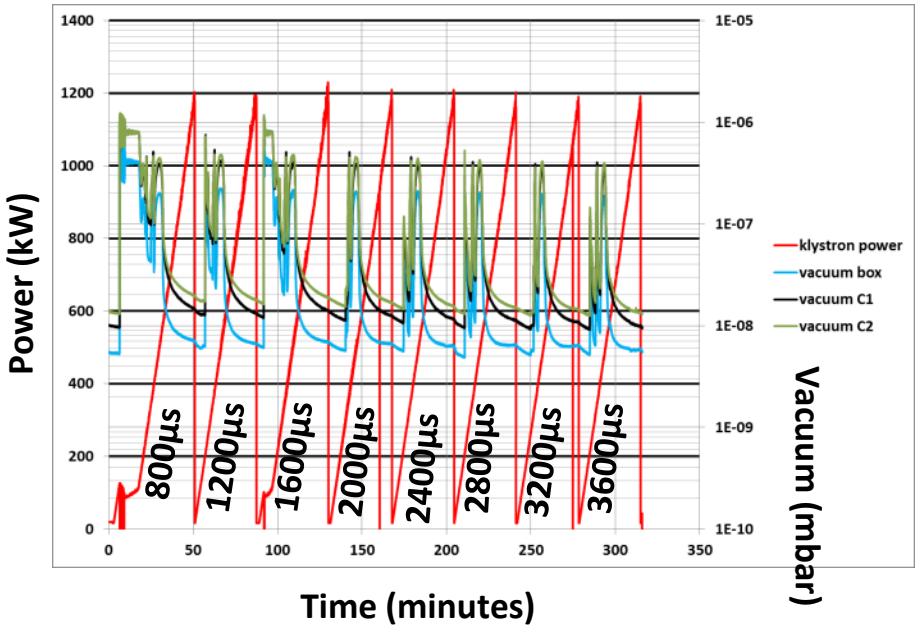
  T water input=25.6°C

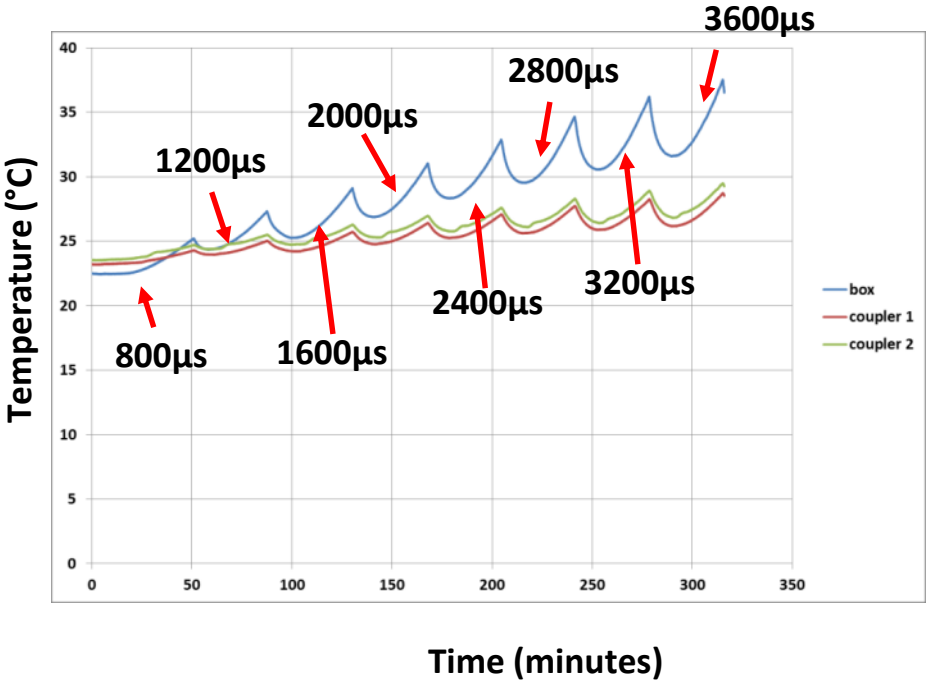
  T water output=26.2°C

Estimation of the water flow

Φ	ΔT
2 l/min	0.97°
2.5 l/min	0.78°
3 l/min	0.65°

- Temperature of the coupler (TW, 14Hz)





OVERVIEW OF THE COUPLER PRODUCTION

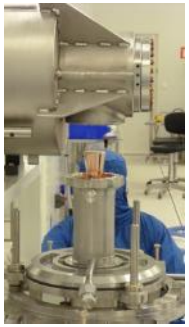
- Production of the 120 couplers (window, electron pick-up, double-wall tube, doorknob transition) performed by PMB.
- First couplers of the pre-series foreseen at the end of 2017

- Production of the coupling box performed by SDMS
- First boxes of the pre-series foreseen at the end of October 2017

- Delivery of a second klystron (1.5MW) : July 2017
- Development of a specific area with the possibility to perform the conditioning of 2 pairs in parallel

CONCLUSION

- Overview of the manufacturing for prototypes:
  - 6 medium beta double-wall tubes
  - 10 windows
  - 8 doorknob transitions
  - In progress, manufacturing of 6 high beta double-wall tubes (delivery in June 2017)
- Conditioning of 3 pairs of couplers with success (whose 4 couplers are now assembled in cavities)



- Production of series couplers and series coupling boxes in progress

Thank you

•27-28 June 2017

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