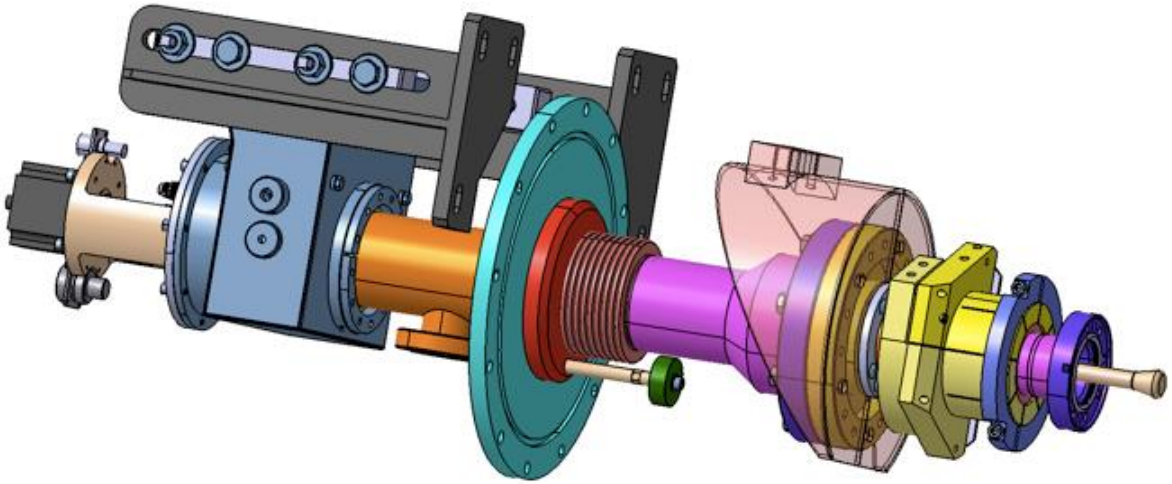
Issues faced during the XFEL mass production



Walid KAABI- LAL/CNRS

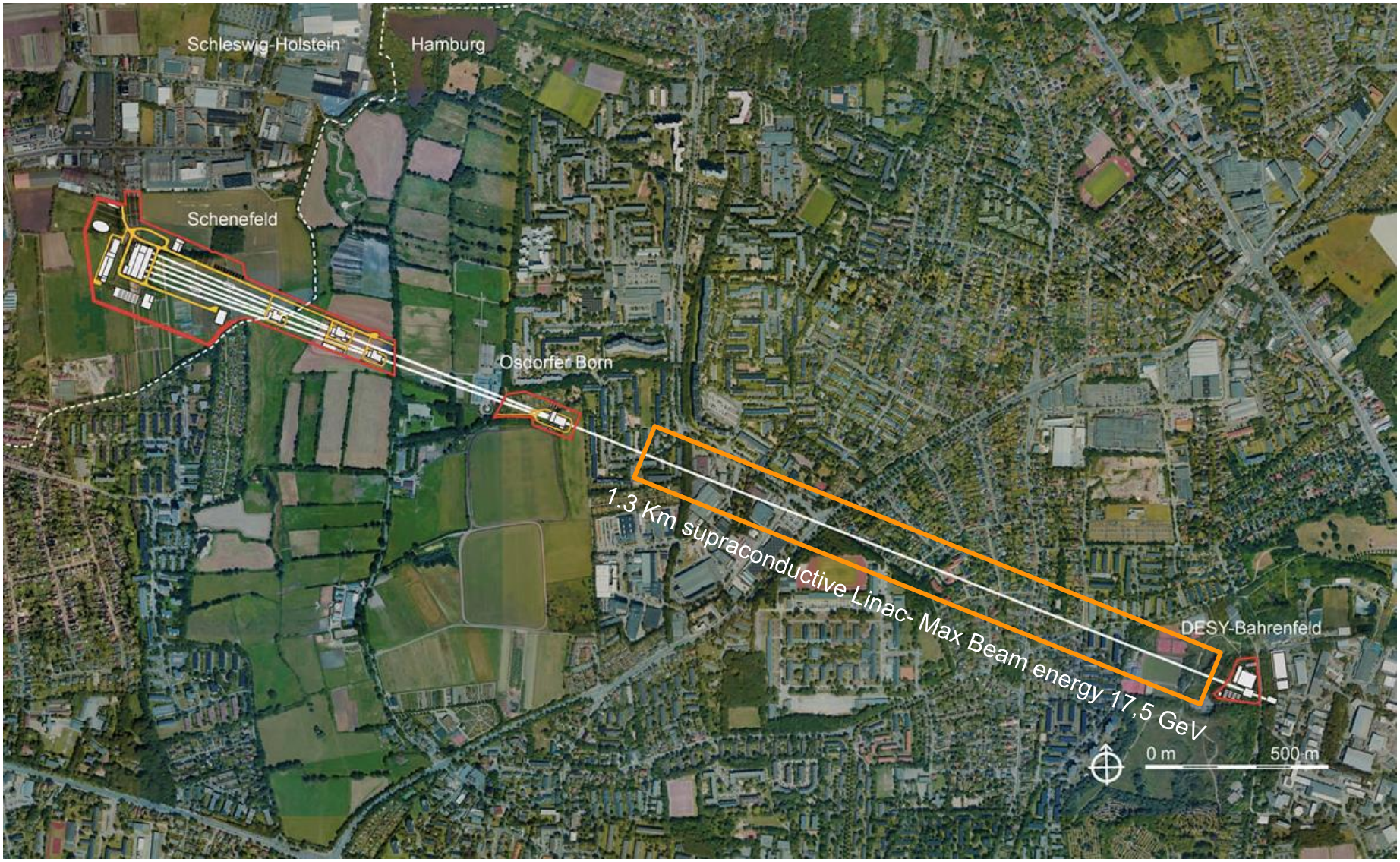
CERN, June 27th 2017

Outlines:

- Introduction
- Fabrication process
- RF conditioning at LAL
- Troubles on the track

European XFEL

Introduction:



Introduction:

Linac of 101 Cryomodules, equiped with 8 couplers each → Need of 808 Couplers 1,3 GHz.

Introduction:

800 power couplers 1.3 GHz are needed to equip **100 XFEL cryomodules**.

XFEL couplers are produced by 2 suppliers at 3 production sites:

- **Consortium Thales-RI** (Thonon les bains-France and Koln-Germany): **670** units.
- **CPI** (Beverly-Massachusetts-USA): **150** units.

Supported by DESY, LAL-Orsay has in charge:

- The **production monitoring** and the **quality control** at Thales-RI sites.
- The **RF conditioning** of all the couplers at Orsay and the weekly **delivery of 8 couplers/week** to IRFU-CEA (increased rate to **10 couplers/Week** since **January 2015**) .

Introduction:

Challenges:

- First experience in industrial monitoring at a such big scale,
- Successful know-how transfer to company: The clean room process & acceptance criteria,
- Rescaling the RF process at LAL to ensure the conditioning of 8 couplers per week,
- Respect of the overall project schedule.

Fabrication process:

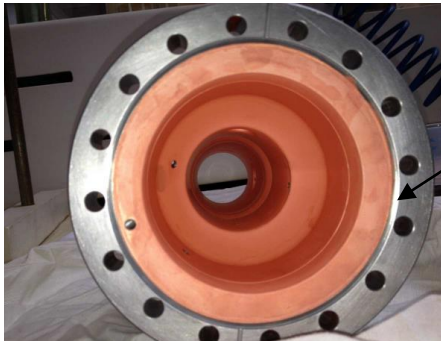
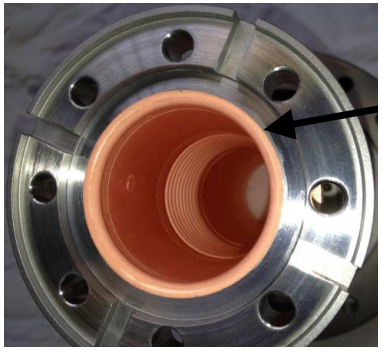
@ Thales-Thonon les bains production site:

- Step 1: Brazing of the inner and outer conductors:





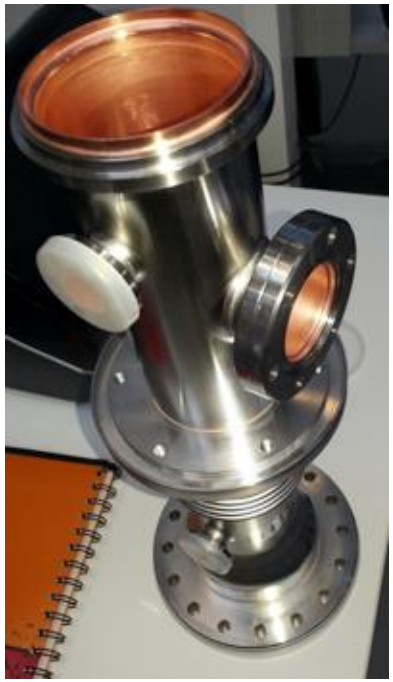

- Step 2: Copper plating of the inner surfaces:

Fabrication process:

Inspection & control of all the produced parts at Thales-Thonon site.

Double check during the reception at RI site under the same inspection criteria.

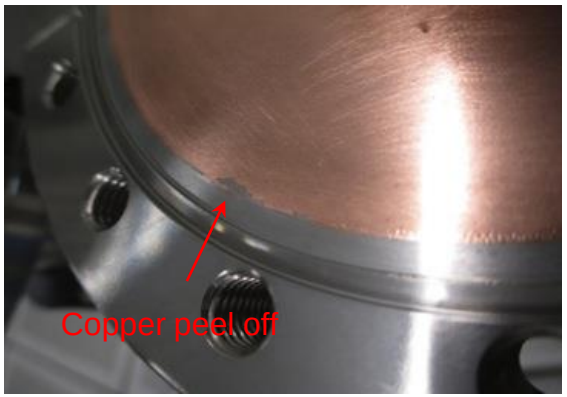


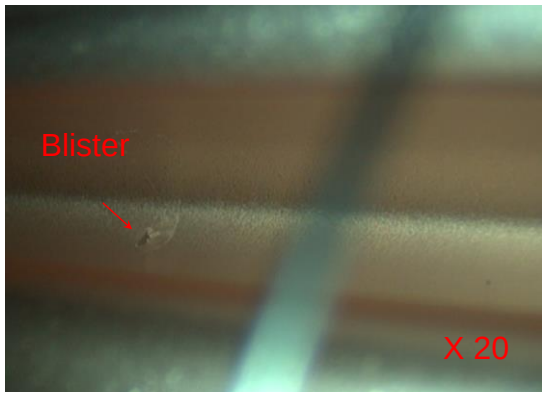
Warm Conductor

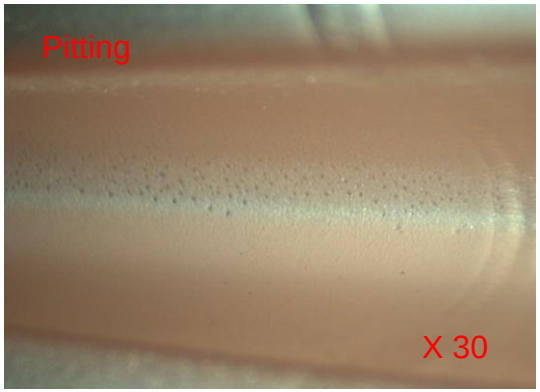
Cold conductor

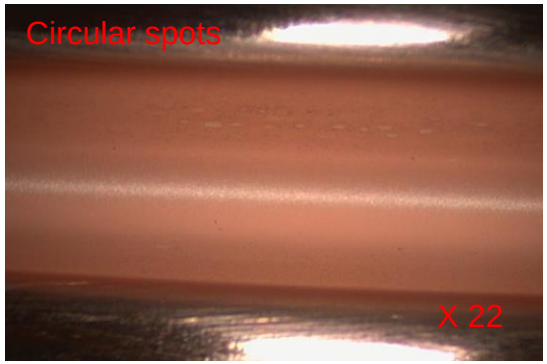
Fabrication process:

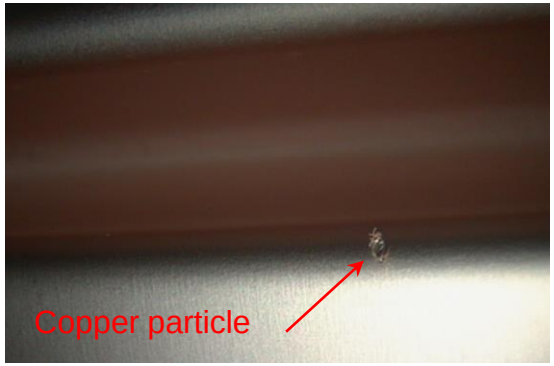
Examples of observed copper defects:





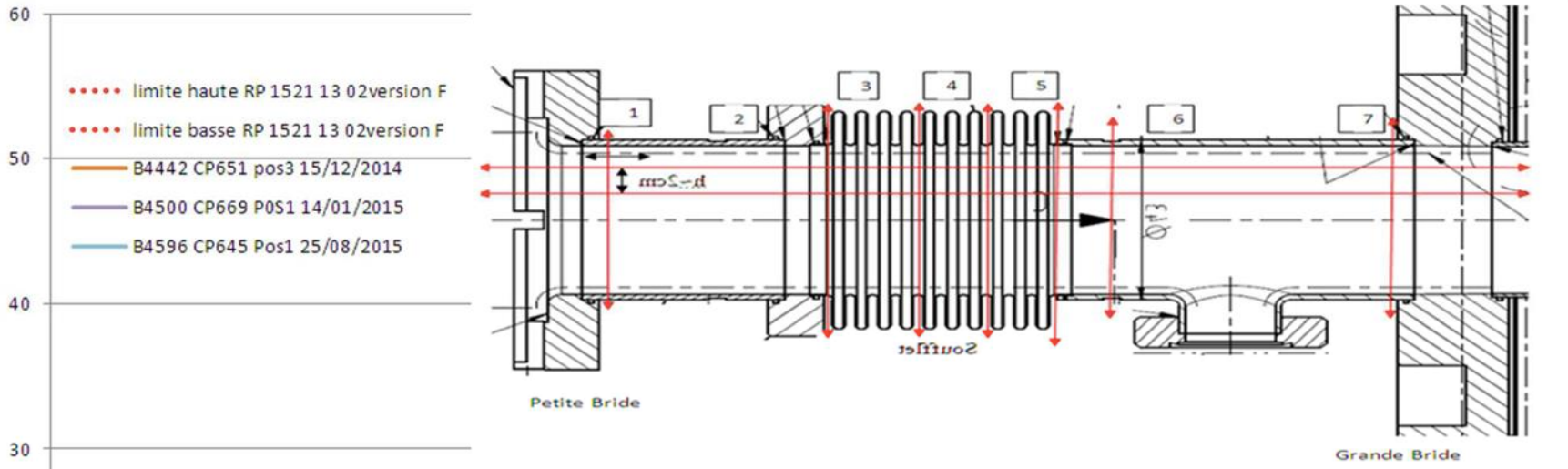




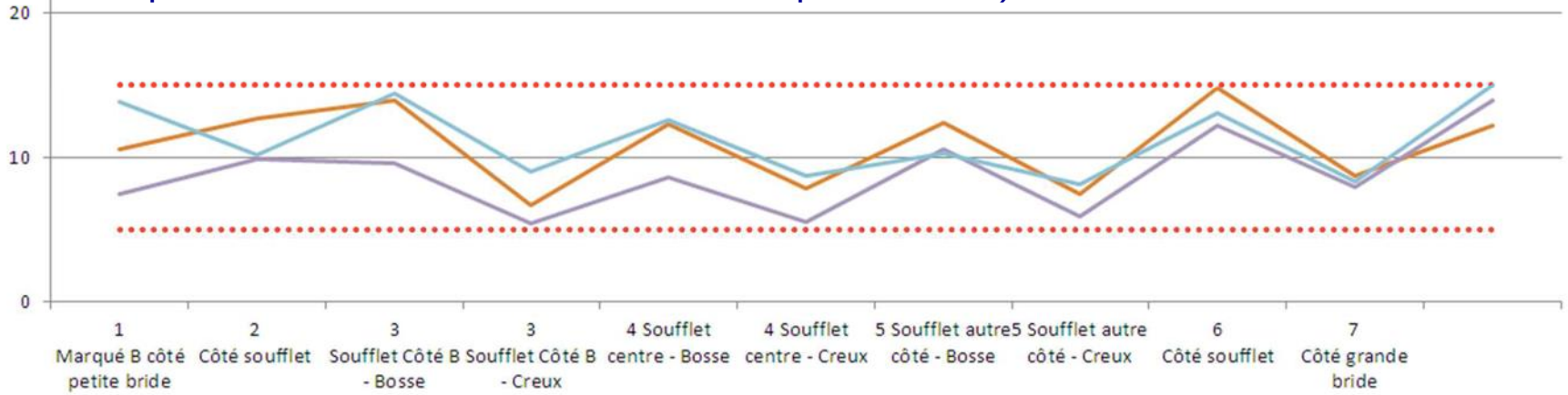


→ Qualitative & quantitative acceptance criteria definition: defects classified per types, dimensions et number. Agreement on corrective actions and validation tests.

Fabrication process:

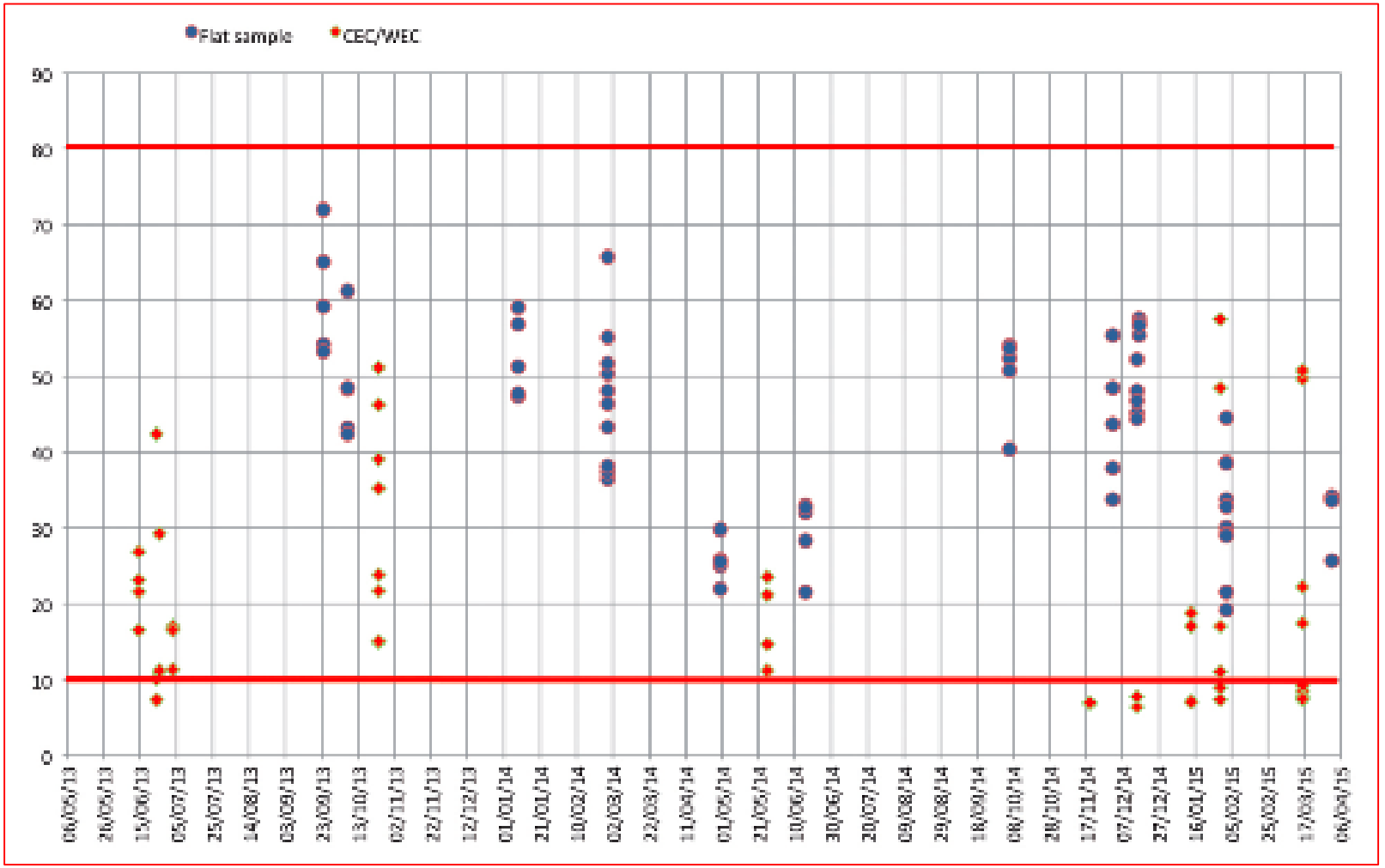


Copper thickness distribution in cold conductor (specif. 10µm ± 20% cylindrical parts & 10µm ± 30% in bellows→ relaxed to 10µm ± 50%):



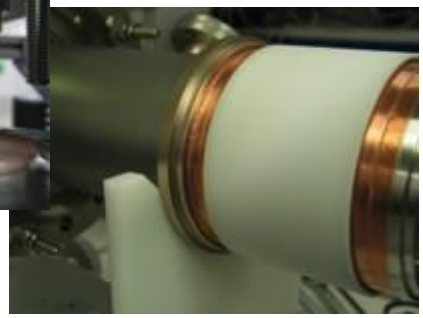
Fabrication process:

RRR measuremets (Specif. 10<RRR<80)



Fabrication process:

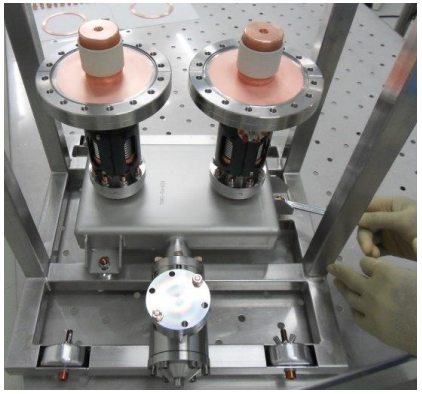
@ RI production site:

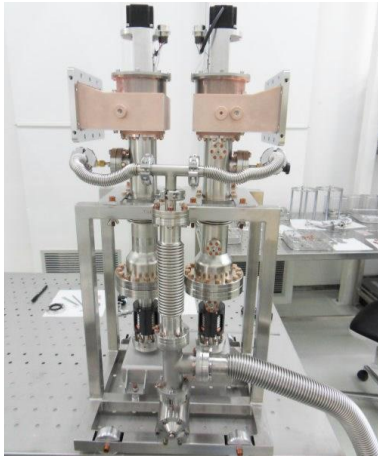


- TiN coating on ceramics
- ceramics EB welding of cold & warm parts

US degreasing of parts

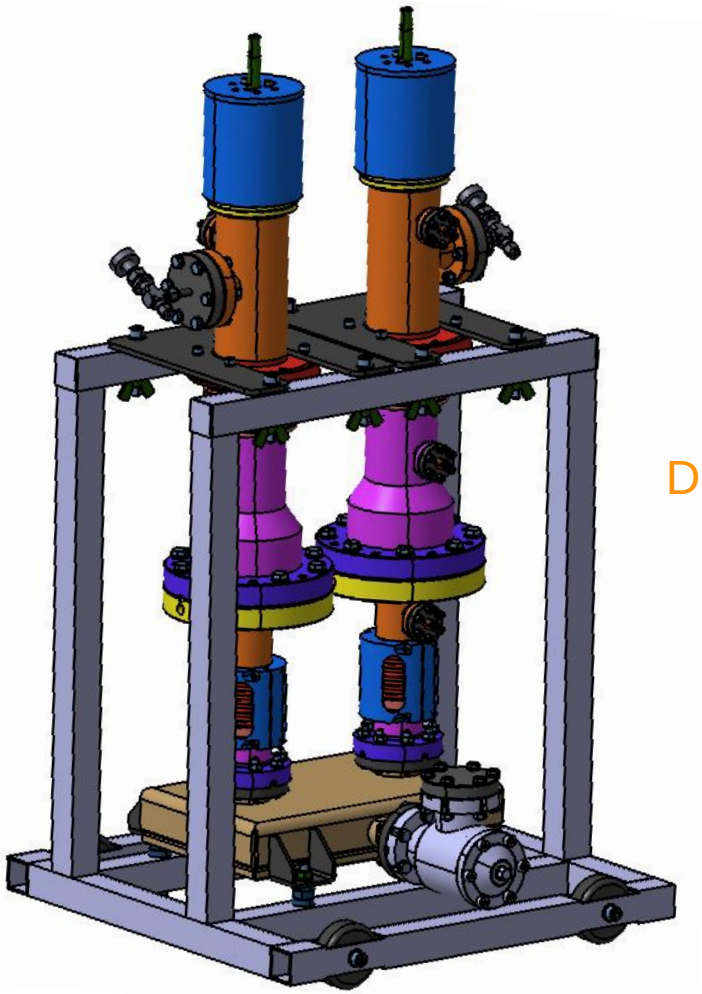
particle counting





coupler pair clean room assembly,
leak and actuator displacement test

Fabrication process:

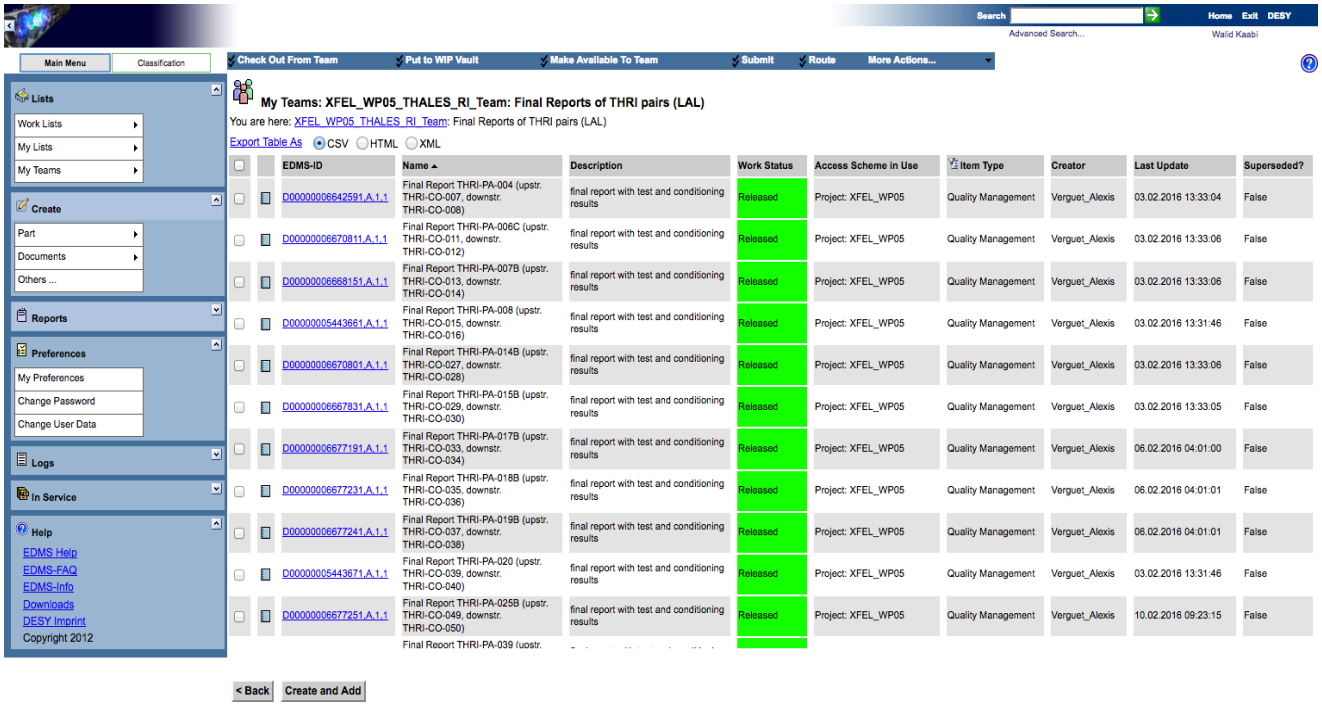


Delivery to LAL

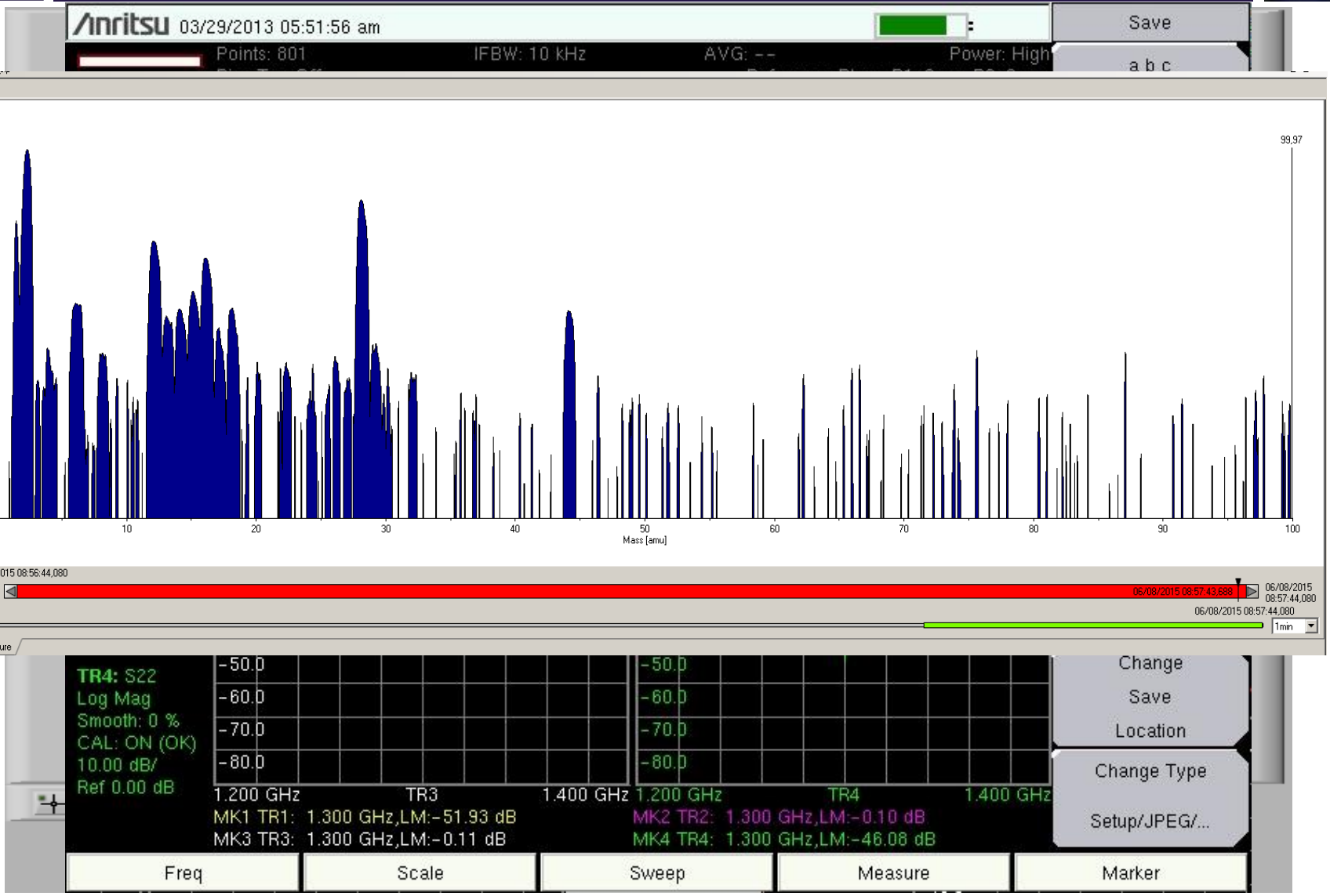
Fabrication process:

Dossier de fabrication des pièces

EDMS

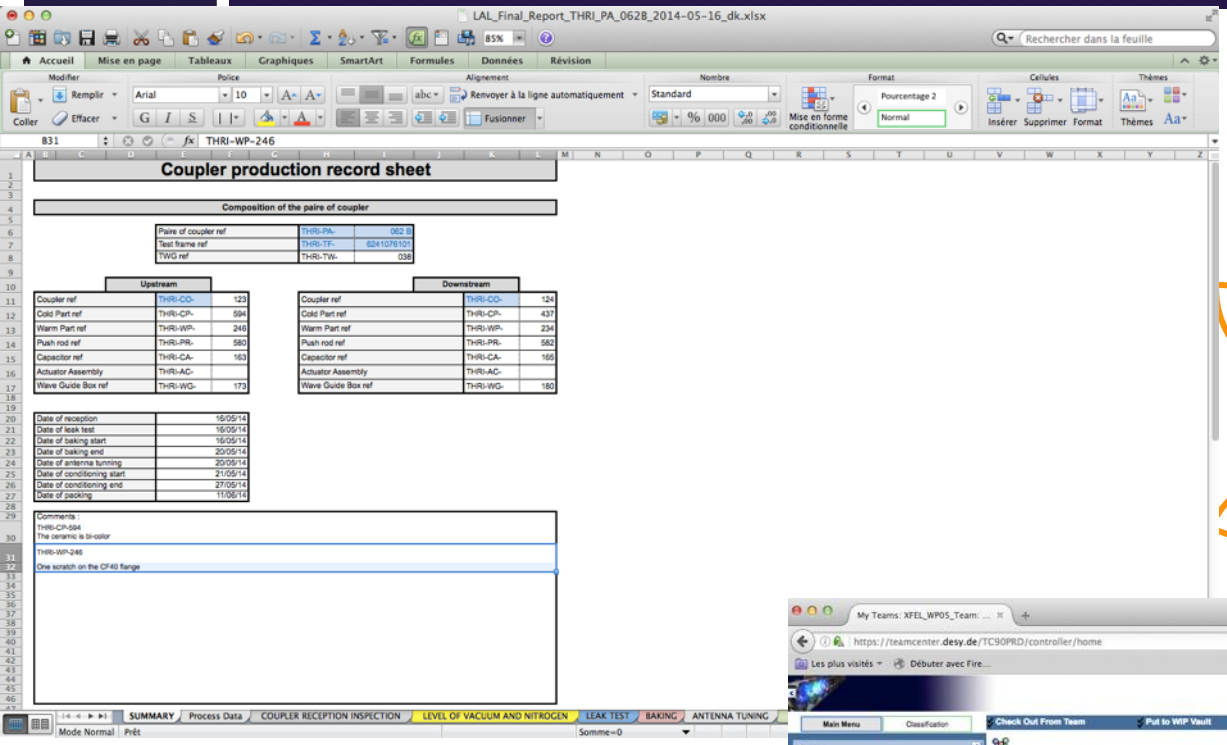


RF conditioning at LAL:



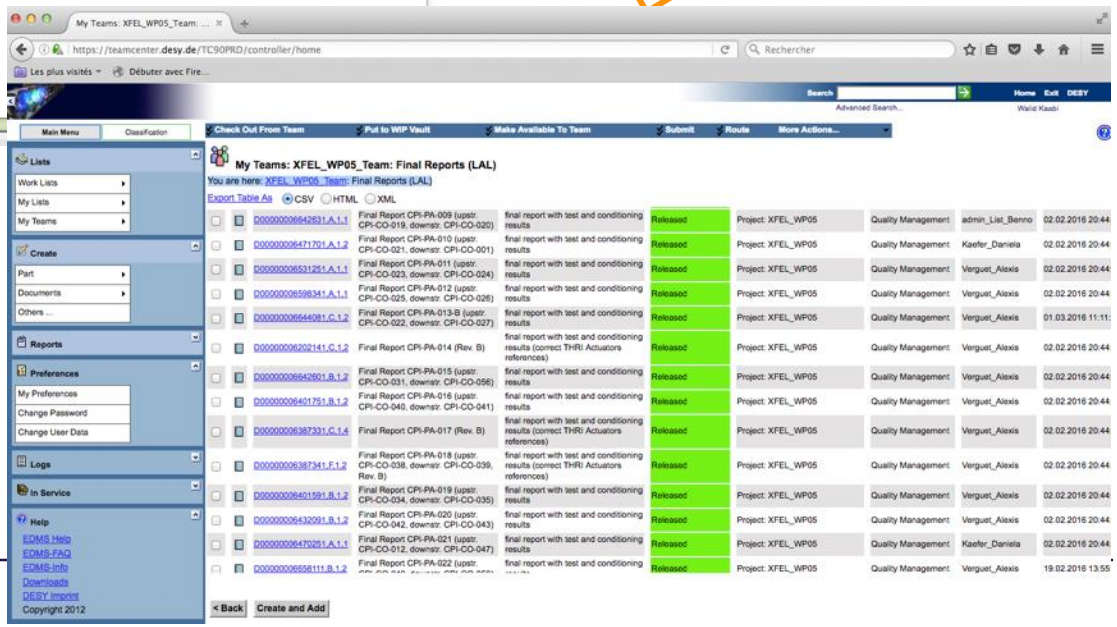
European XFEL

RF conditioning at LAL:



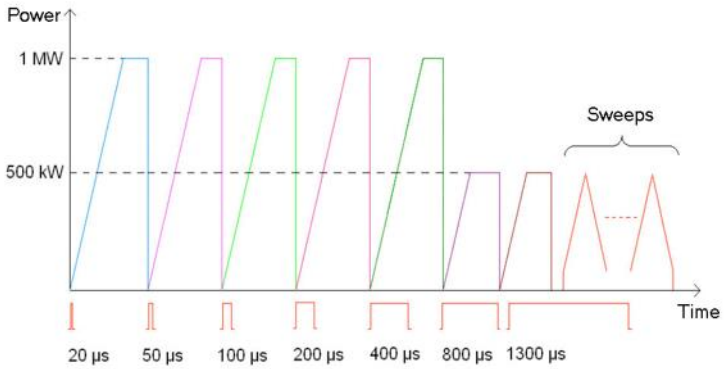
Rapport de Non-Conformité

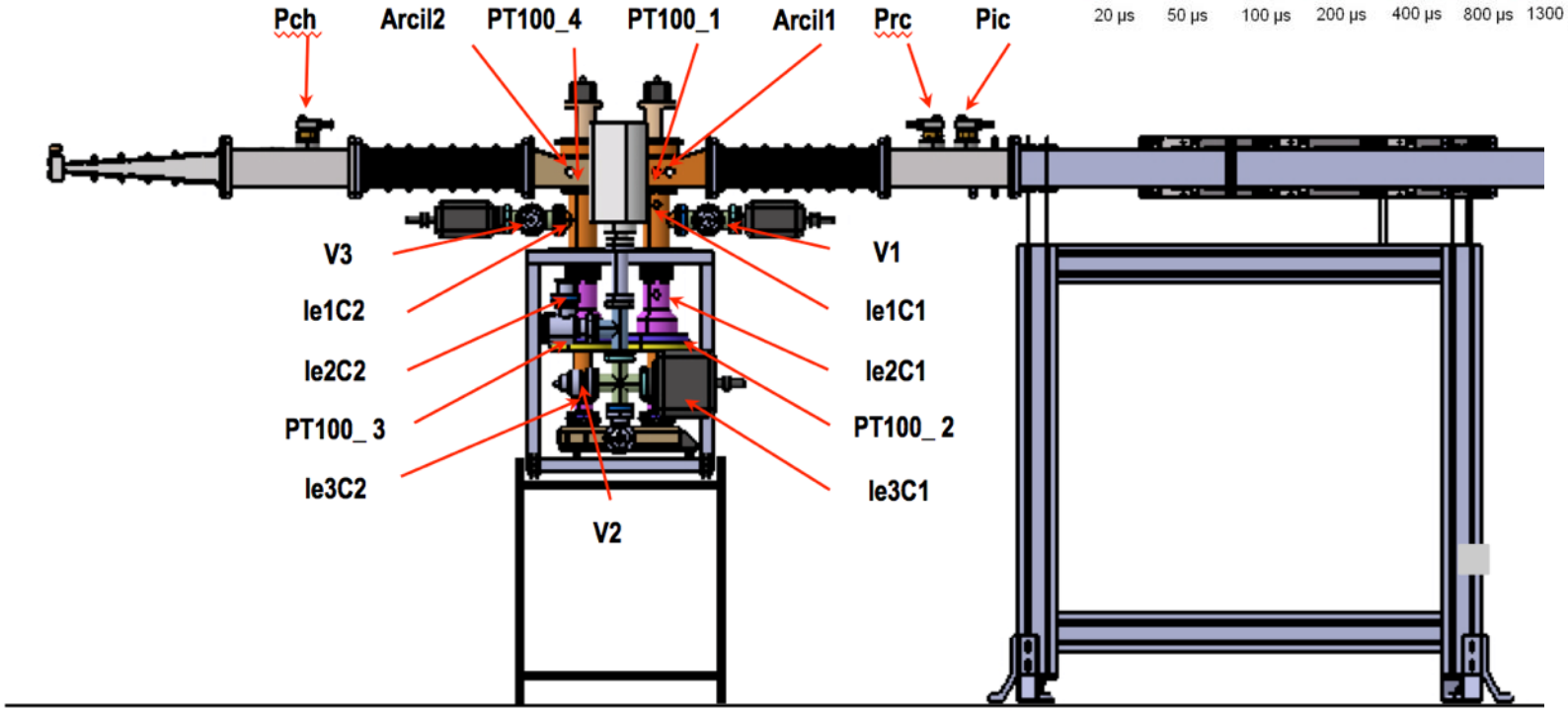
EDMS



RF conditioning at LAL:

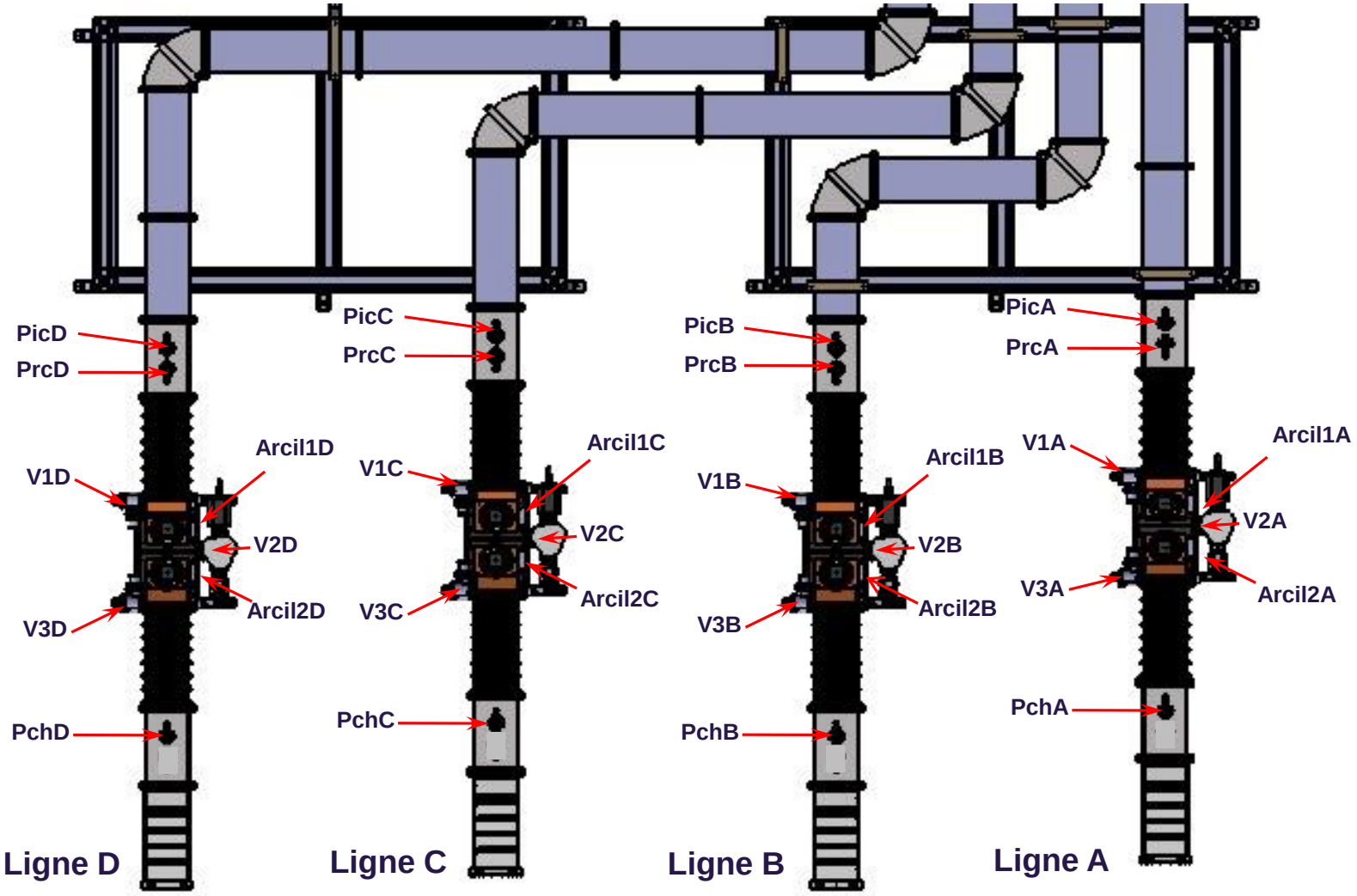
Vacuum	1st threshold (0.1 dB): SV1	6.10^{-7} mbar
	2nd threshold (0.4 dB): SV2	2.10^{-6} mbar
	Interlock: IL	5.10^{-6} mbar
e- current IL	8 mA	
Light IL	none	
Ceramic Temperature IL	60°c	
WG arc IL	If any	
Control loop duration(0.1 dB)	15 s	





RF conditioning at LAL:

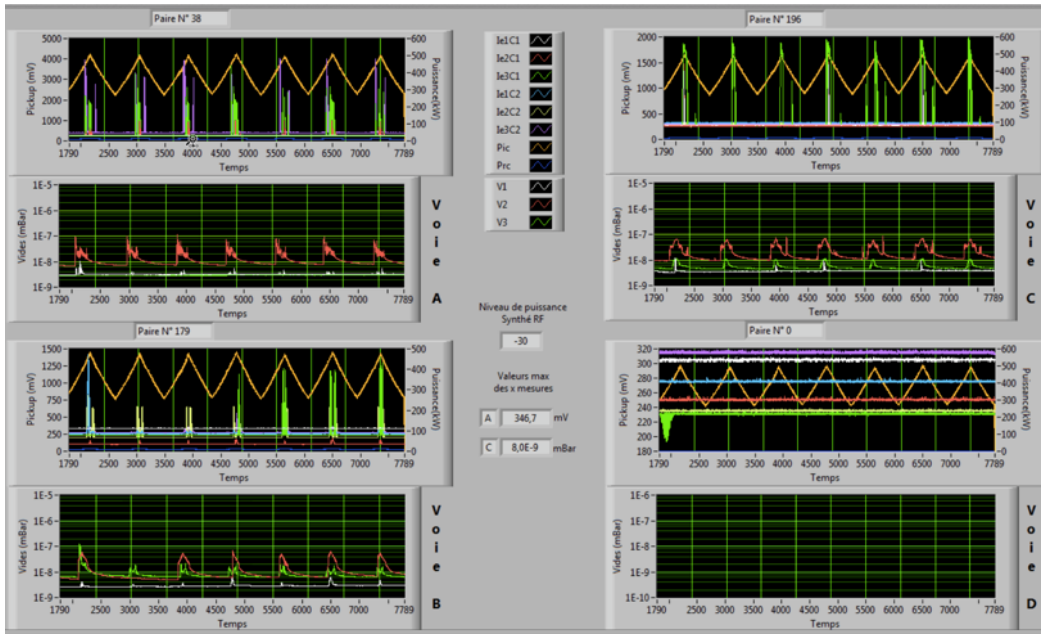
RF conditioning at LAL:



European XFEL

RF conditioning at LAL:

RF conditioning at LAL:

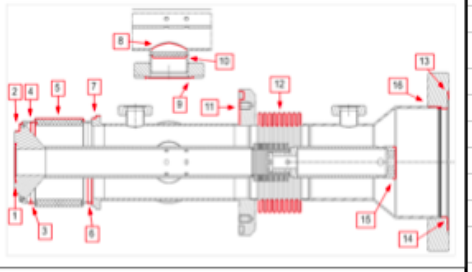


Shipment to IRFU-CEA

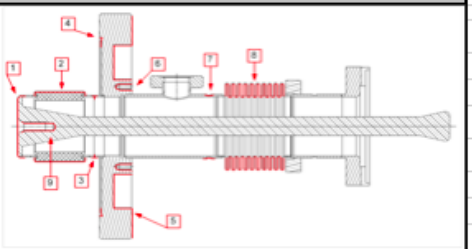
Coupler pair disassembly & final inspection

RF conditioning at LAL:

THRI-WP-246	CONTRÔLE DEMONTAGE PARTIE CHAUDE			27/05/14
	Point to check	Status Ok	Status Nok	Comments
1	Knife	Ok		Sharp edges, scrathes
2	Contact surface with the capacitor	Ok		Sharp edges, scrathes
3	Welding aspect (regularity, smoot et centering)	Ok		According to specification
4	Copper ring : centering, shape, smoothness	Ok		According to specification
5	ceramic coating and TiN deposite (color, spot, no splinter or particles)	Ok		Projection, decoloring, metalic scratches
6	Copper ring : centering, shape, smoothness	Ok		According to specification
7	RF surface with the WGB	Ok		Sharp edges, scrathes
8	Pumping flange (radius, regularity and smoothness)	Ok		Sharp edges, right angle
9	Knife, holes orientation		Nok	scratches
10	Rounded inner angle	Ok		Sharp edges
11	Roughness	Ok		Scratches
12	Outter bellows : deformation, penetration of the end seal	Ok		According to specification
13	Knife	Ok		Scratches
14	Limit of the copper deposit	Ok		According to specification
15	Contact	Ok		Sharp edges, scrathes
16	Solder joint: regularity, smoothness	Ok		According to specification
	(*)calculation : if result OK: value = 10	Ok		Remark(s):
	if result NOK: value = 0		Nok	One scratch on the CF40 flange
	total of points = sum = S	150		
	Total = line sum X 10= P	160		
	(NA no applicable)	N A		
	Final status	93,8%		



THRI-CP-594	CONTRÔLE DEMONTAGE PARTIE FROIDE			27/05/14
	Point to check	Status Ok	Status Nok	Comments
1	RF contact surface : smoothness, regularity of the chamfer	Ok		Sharp edges, scrathes
2	ceramic coating and TiN deposite (color, spot, no splinter or particles)		Nok	Projection, decoloring, metalic scratches
3	Welding aspect (regularity, smoot et centering)	Ok		According to specification
4	Knife	Ok		Arêtes vives, rayures
5	Orientation of the big flange and the cavity	Ok		According to specification
6	Correct orientation of the 6 M4 holes and of the 2 Ø3 holes	Ok		According to specification
7	Groove depth, axial position	Ok		According to specification
8	Bellows : deformation, penetration of the end seal	Ok		According to specification
9	La qualité du trou fileté	Ok		Presence of metalic particles
	(*)calculation : if result OK: value = 10	Ok		The ceramic is bi-color
	if result NOK: value = 0		Nok	
	total of points = sum = S	80		
	Total = line sum X 10= P	90		
	(NA no applicable)	N A		
	Final status	88,9%		

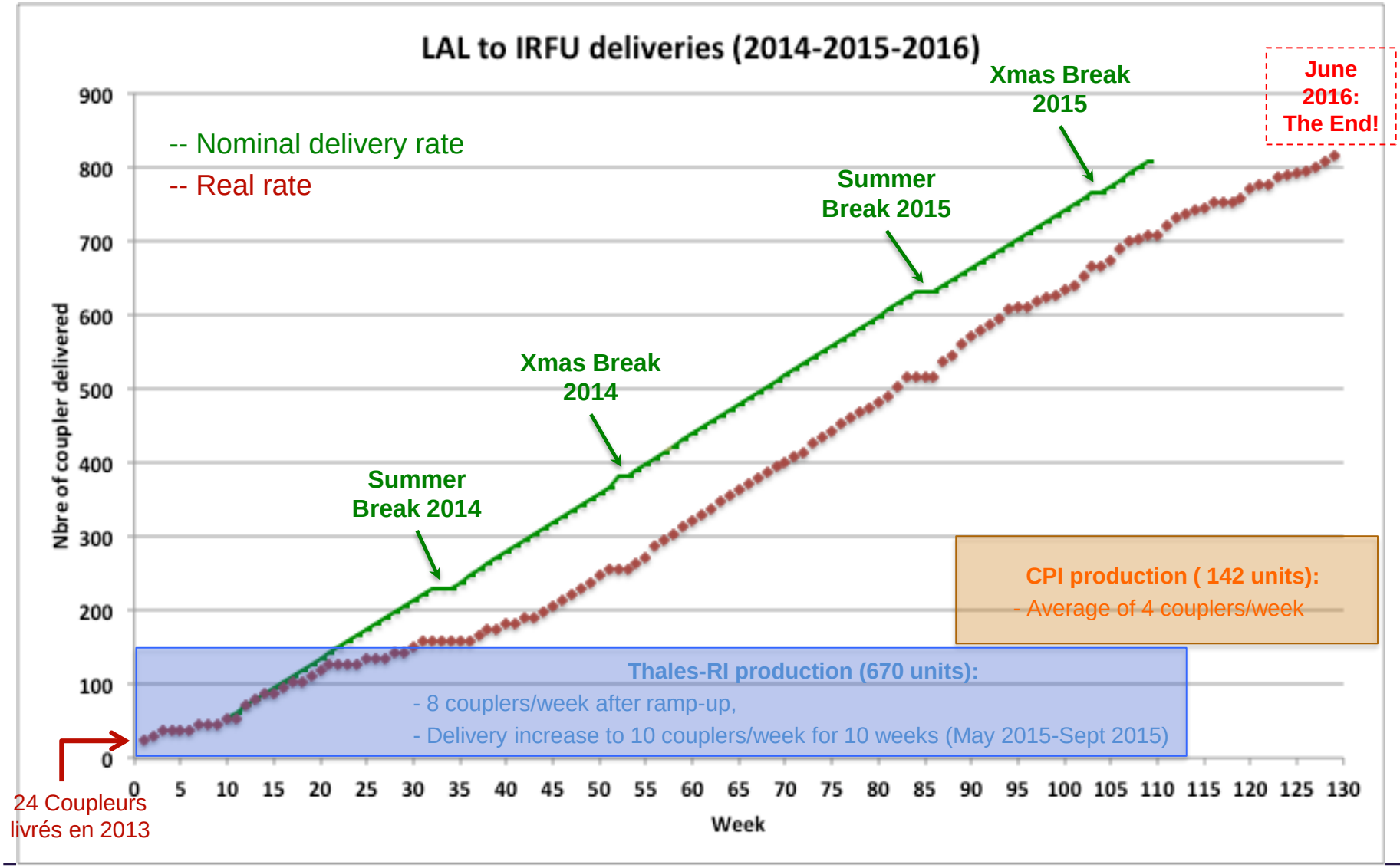


SUMMARY | Process Data | COUPLER RECEPTION INSPECTION | LEVEL OF VACUUM AND NITROGEN | LEAK TEST | BAKING

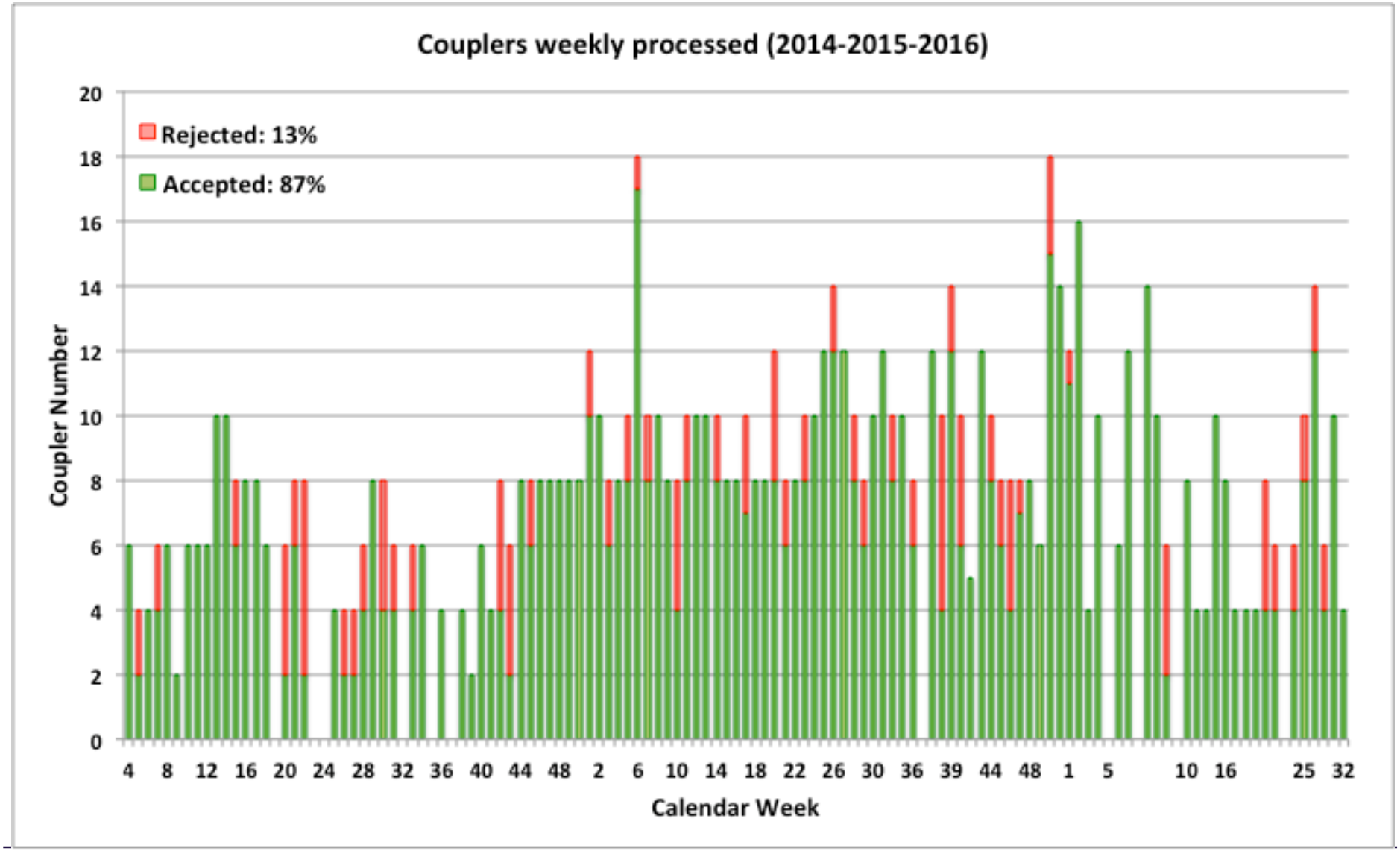
EDMS

Rapport de Non-Conformité

RF conditioning at LAL:

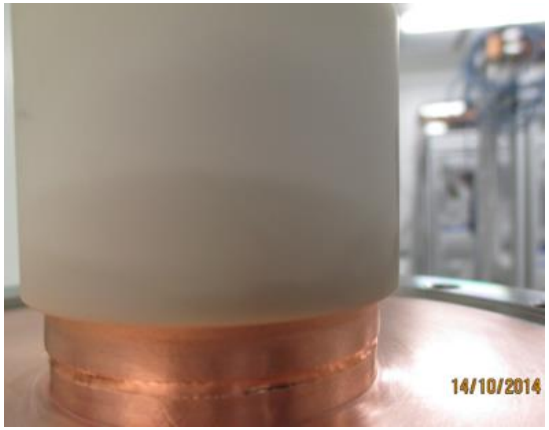


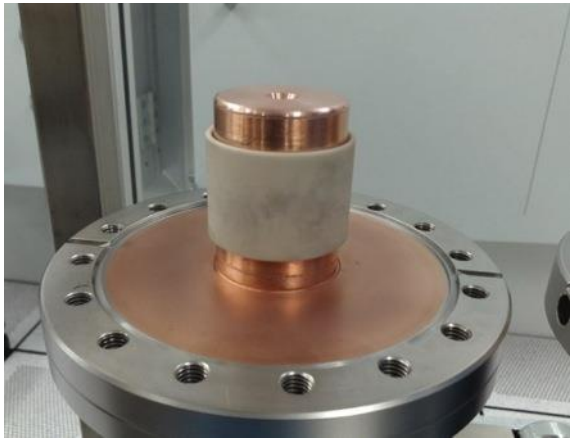
RF conditioning at LAL:

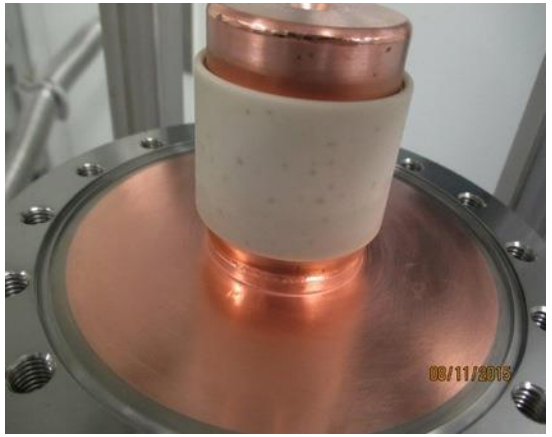


Troubles on the track: Dark layer on cold ceramic

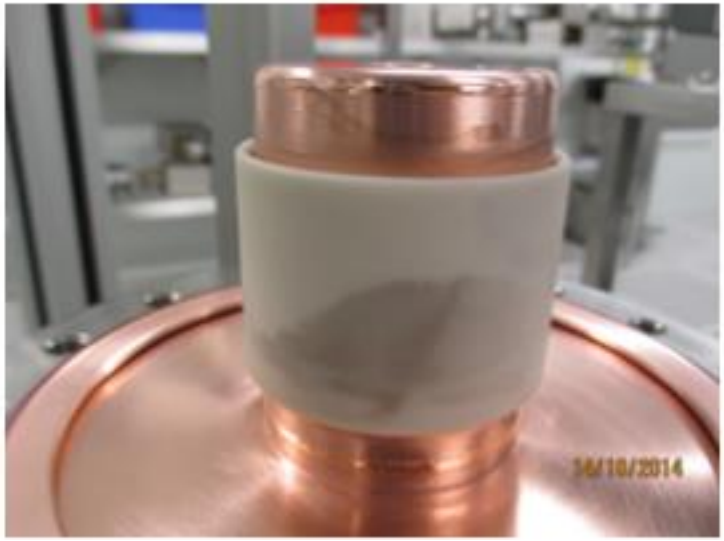
Main defect discovered during the final inspection: Dark layer in cold ceramic window





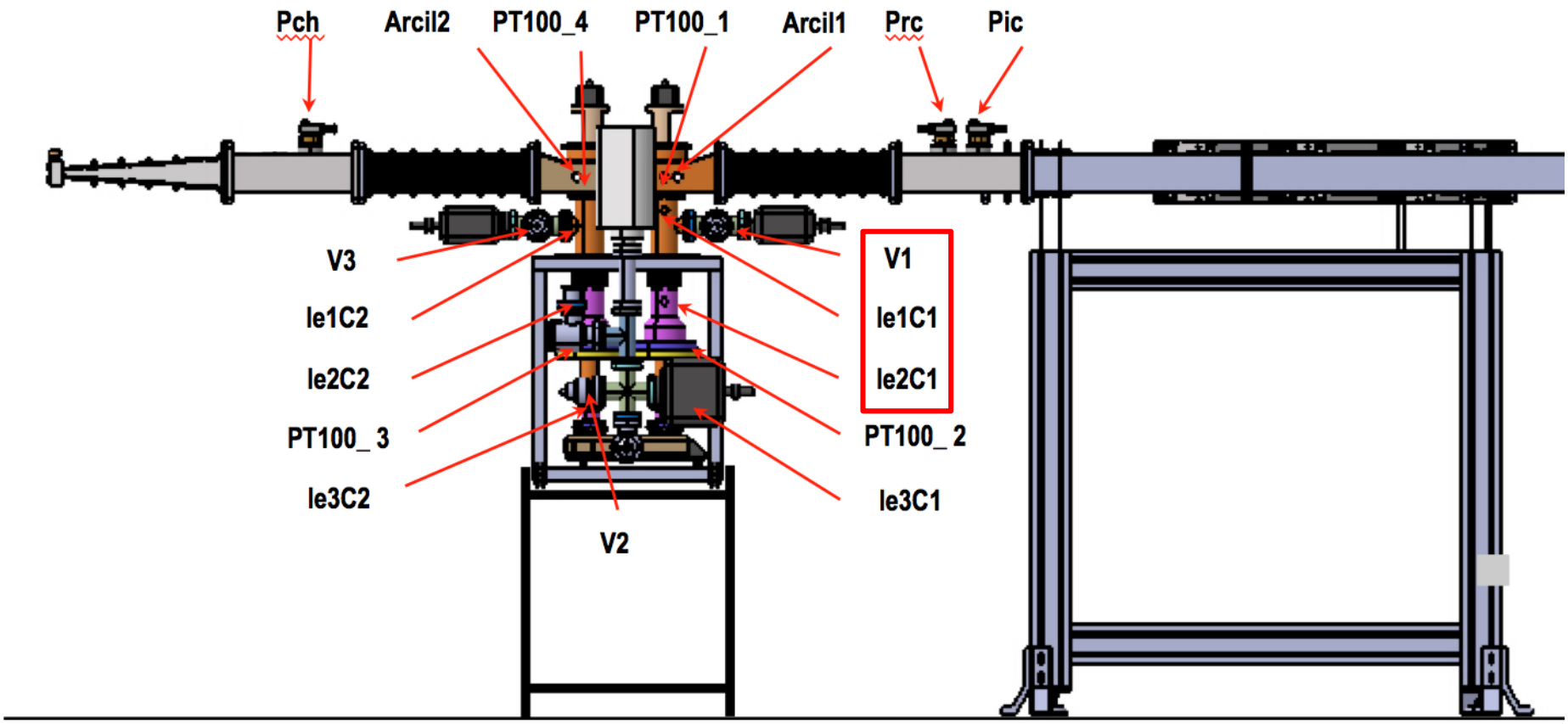


Troubles on the track: Dark layer on cold ceramic

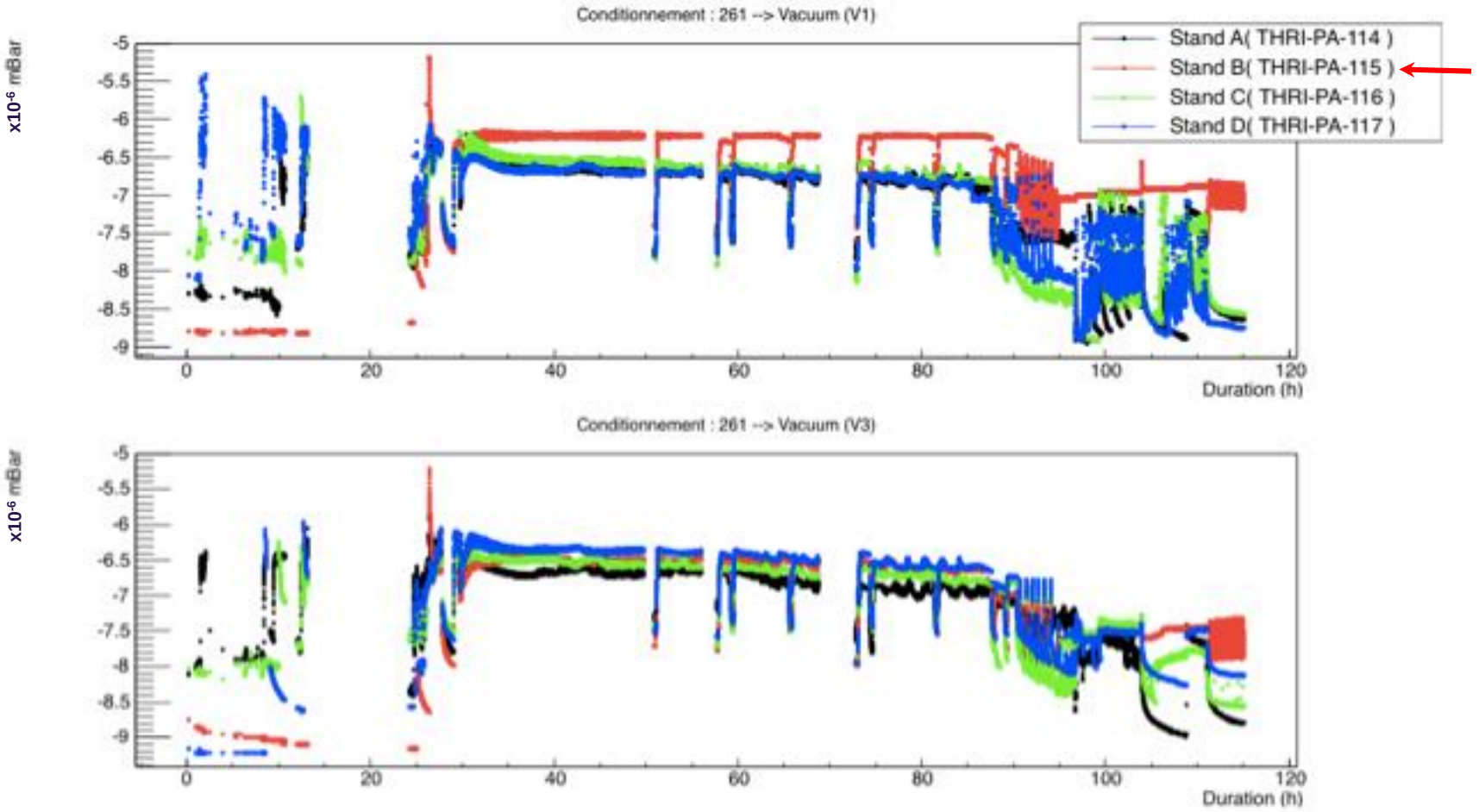


CP 331_Pair 115
Upstream coupler

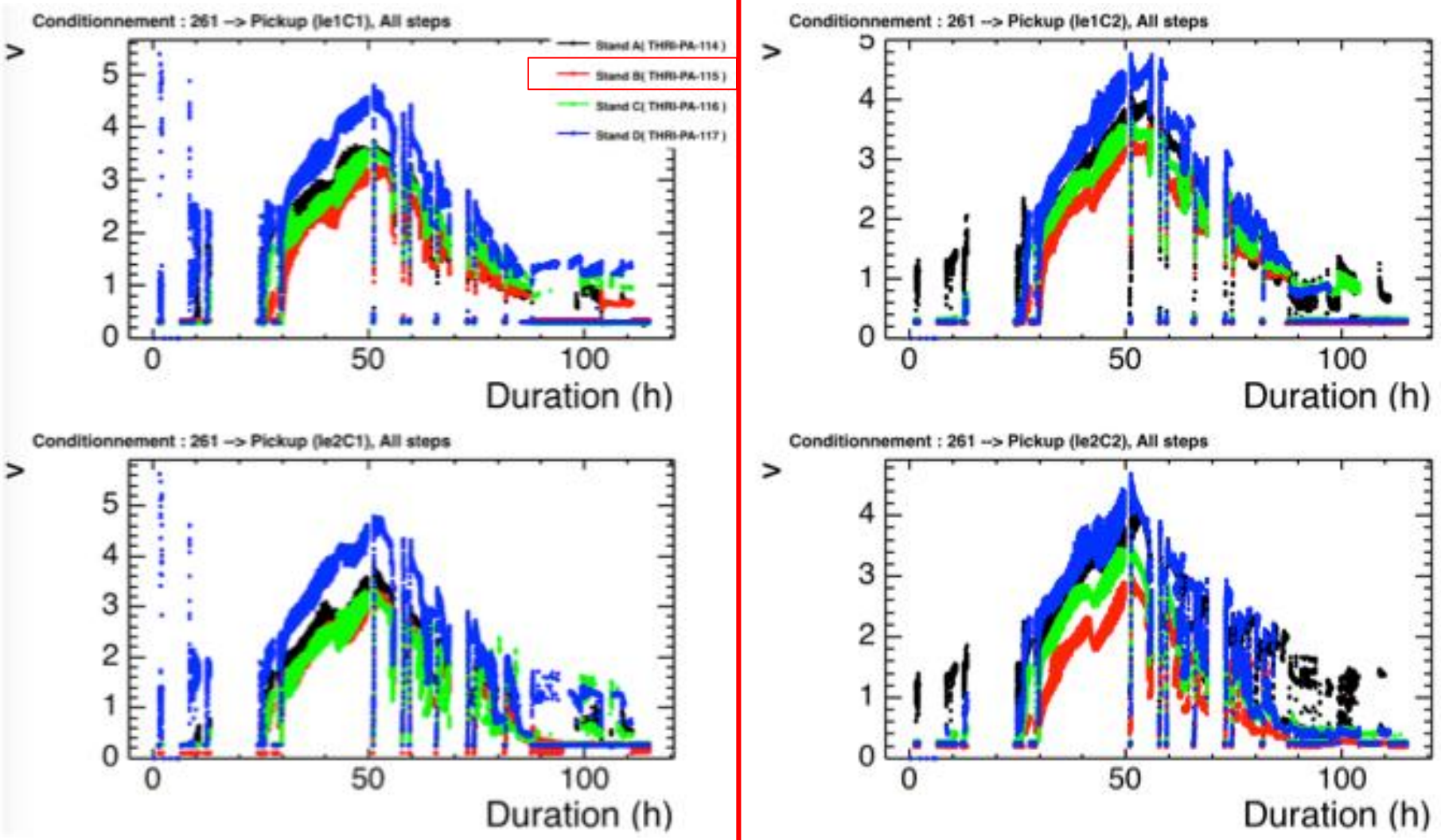
Troubles on the track: Dark layer on cold ceramic



Troubles on the track: Dark layer on cold ceramic

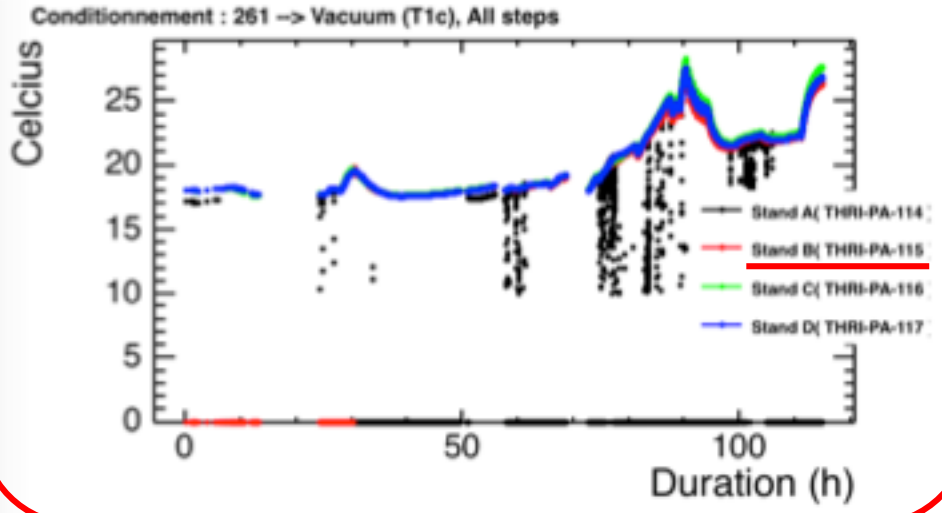


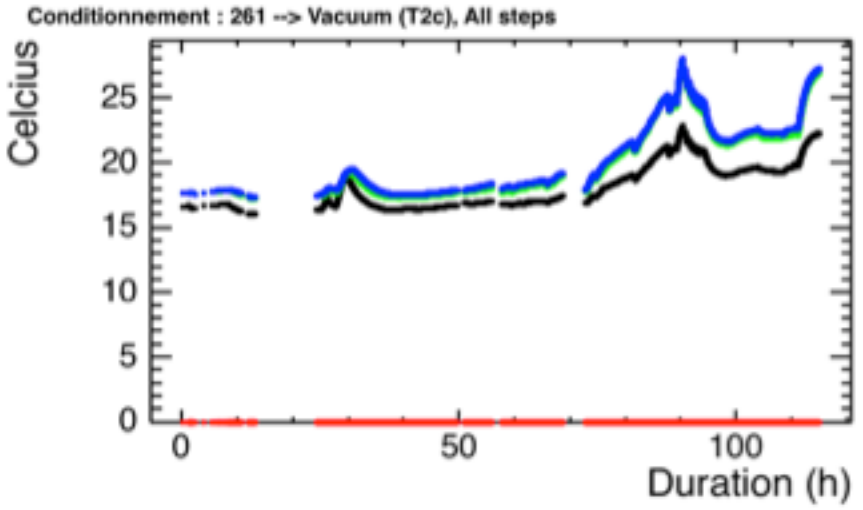
Troubles on the track: Dark layer on cold ceramic

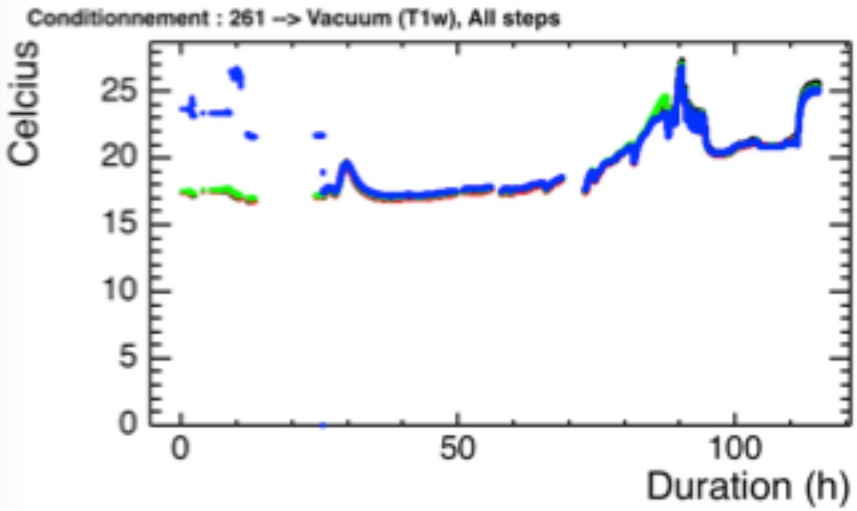


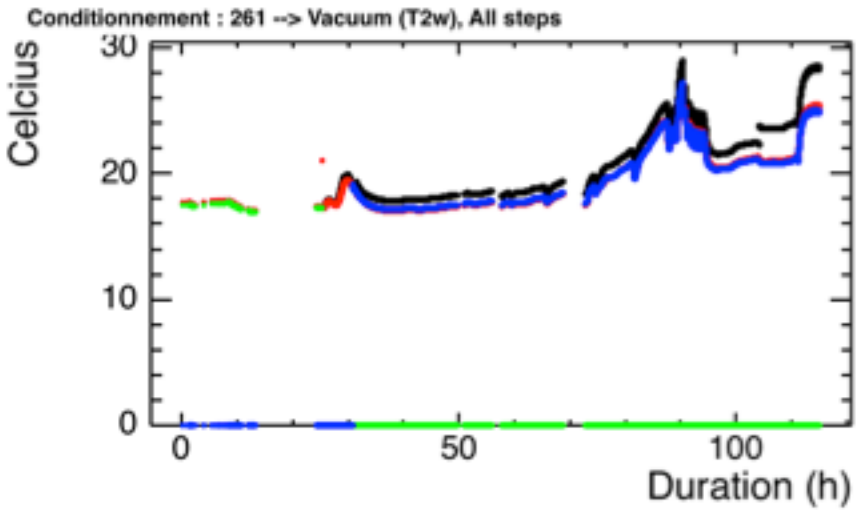
European XFEL

Troubles on the track: Dark layer on cold ceramic









Troubles on the track: Dark layer on cold ceramic

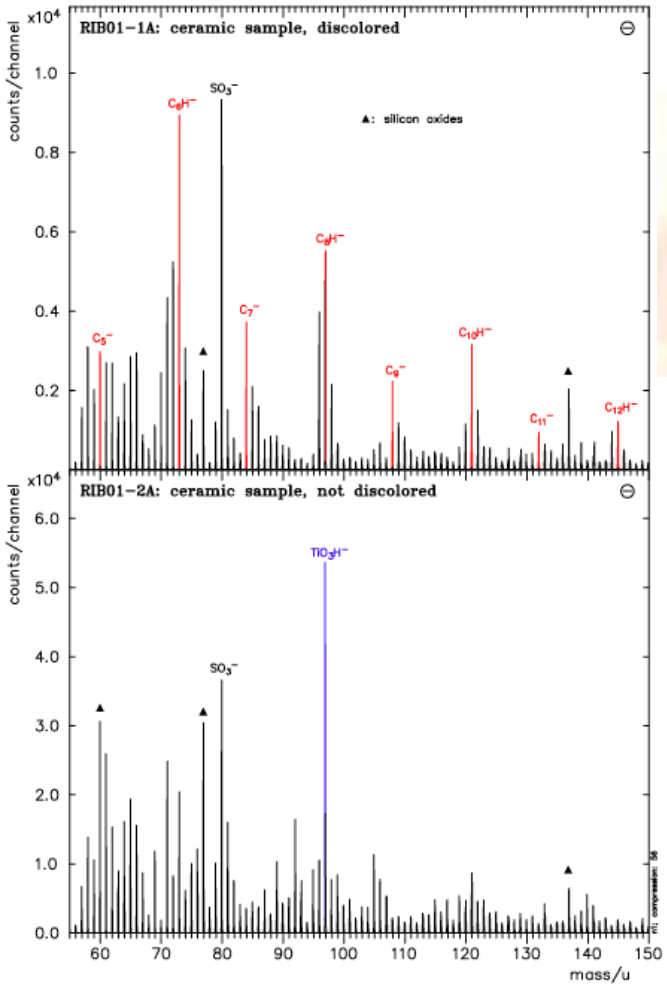
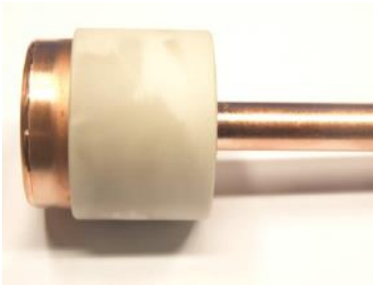
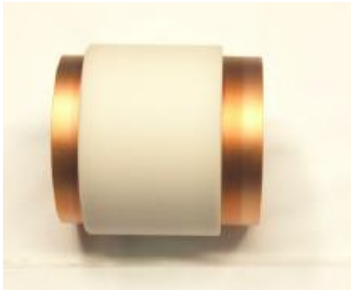


Figure 4: Details of the TOF-SIMS spectra of negative secondary ions





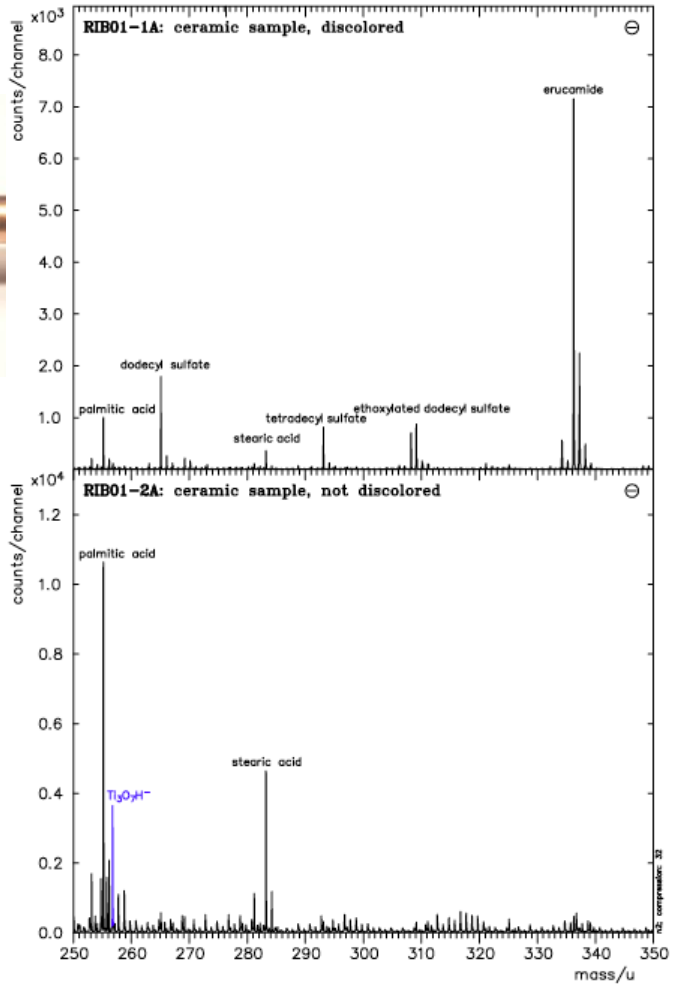


Figure 5: Details of the TOF-SIMS spectra of negative secondary ions

Troubles on the track: Dark layer on cold ceramic

OFG - Analytik
Oberflächen - Festkörper - Grenzflächen Analytik GmbH
• Mendelstr. 11 • 48149 Münster Tel: 0251 - 9801203, Fax: 0251 - 9801202

5. Results of the TOF-SIMS Analyses

5.1. Summary

The main results are[1,2]:

- In the spectra of sample 2 (not discolored) mass signals of **titanium**, **titanium oxides** and **silicon oxides** as well as mixed **silicon/titanium oxides** are distinctly observed (look at figures 4 and 5 on pages 8 and 9). Moreover **chlorine**, **higher fatty acids** (figure 5 on page 9) and the additive **4,4'-Bis(diethylamino)benzophenone** are detected with high signal intensities.
- In the spectra of both preparations **sodium**, **potassium**, **calcium** and **CN/CNO-** as well as **SO_x anions** are identified with high signal intensities.
- Only in the spectra of the discolored sample 1 the lubricant **erucamide** (figure 5 on page 9) and **soot-like carbon anions** (C_xH^-, figure 4 on page 8) as well as **alkylsulfates** (figure 5 on page 9) are clearly detected.

Further elements and compounds are detected mostly with low intensities, partly in the range of the detection limit. Table 1 gives a qualitative survey of the detected elements and compounds.

5.2. Comment

While in the spectra of the not discolored sample the ceramic material is distinctly observed, particularly erucamide and soot-like carbon anions are detected in the spectra of the discolored surface. The former compound can probably be attributed to the plastic wrapping of this sample (⟶ as-received condition). However the soot-like carbon anions (⟶ carbon black) can possibly be associated with the observed discoloration.

[1]The analyses were carried out according to procedure OFG-P1. The results were obtained by comparison with databases.
[2]Comments are set in italic text.

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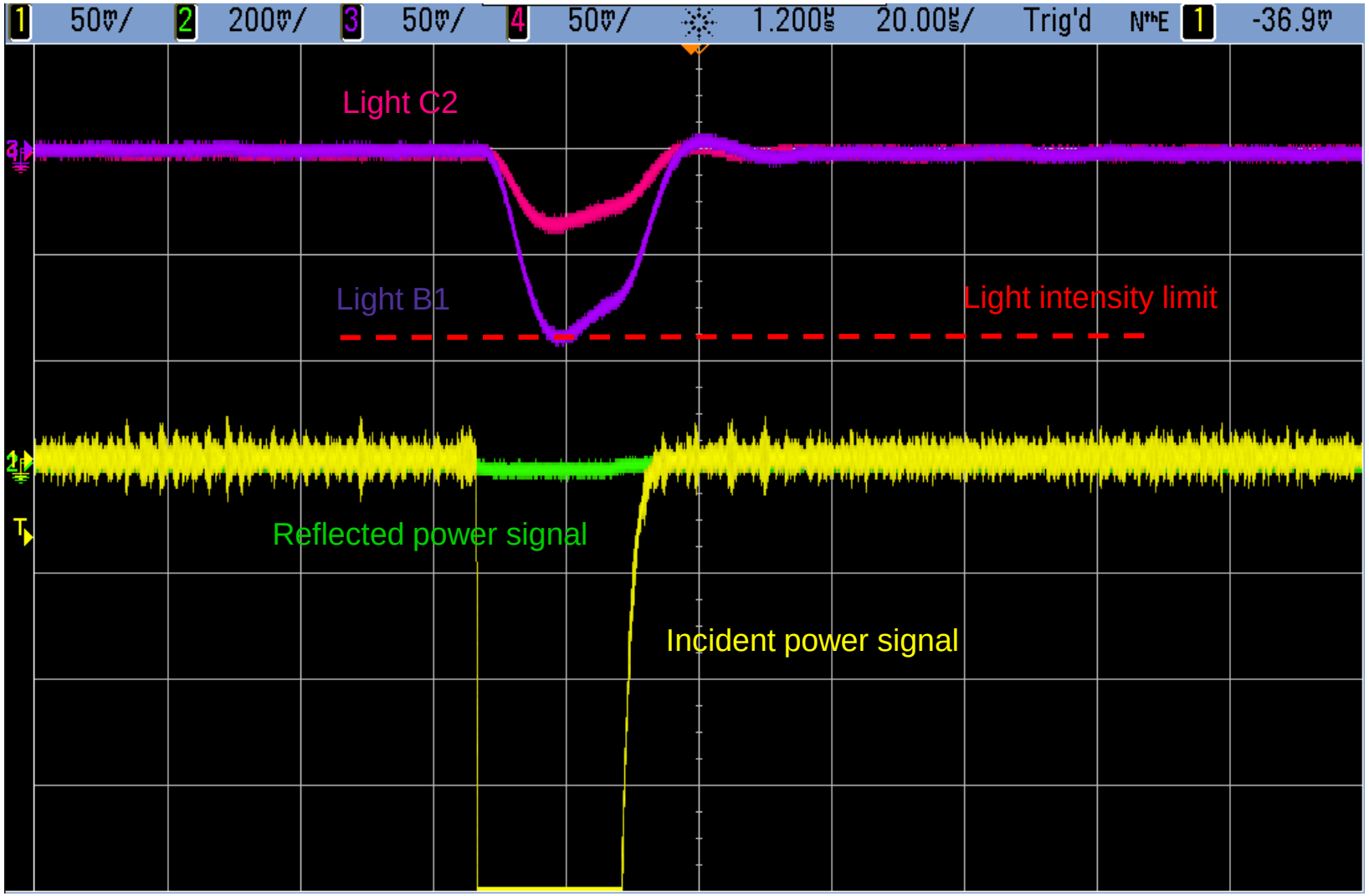
5.3. List of established elements / compounds

The specified elements / compounds are established with different intensities on the sample surfaces. Meaning of: — ⟶ not detected, □ ⟶ near the detection limit, ■ ⟶ very small intensity, ▬ ⟶ medium intensity and ▬ ⟶ very high intensity relative to basepeaks, substrate signals, signals of hydrocarbons or signals in comparable reference–spectra.

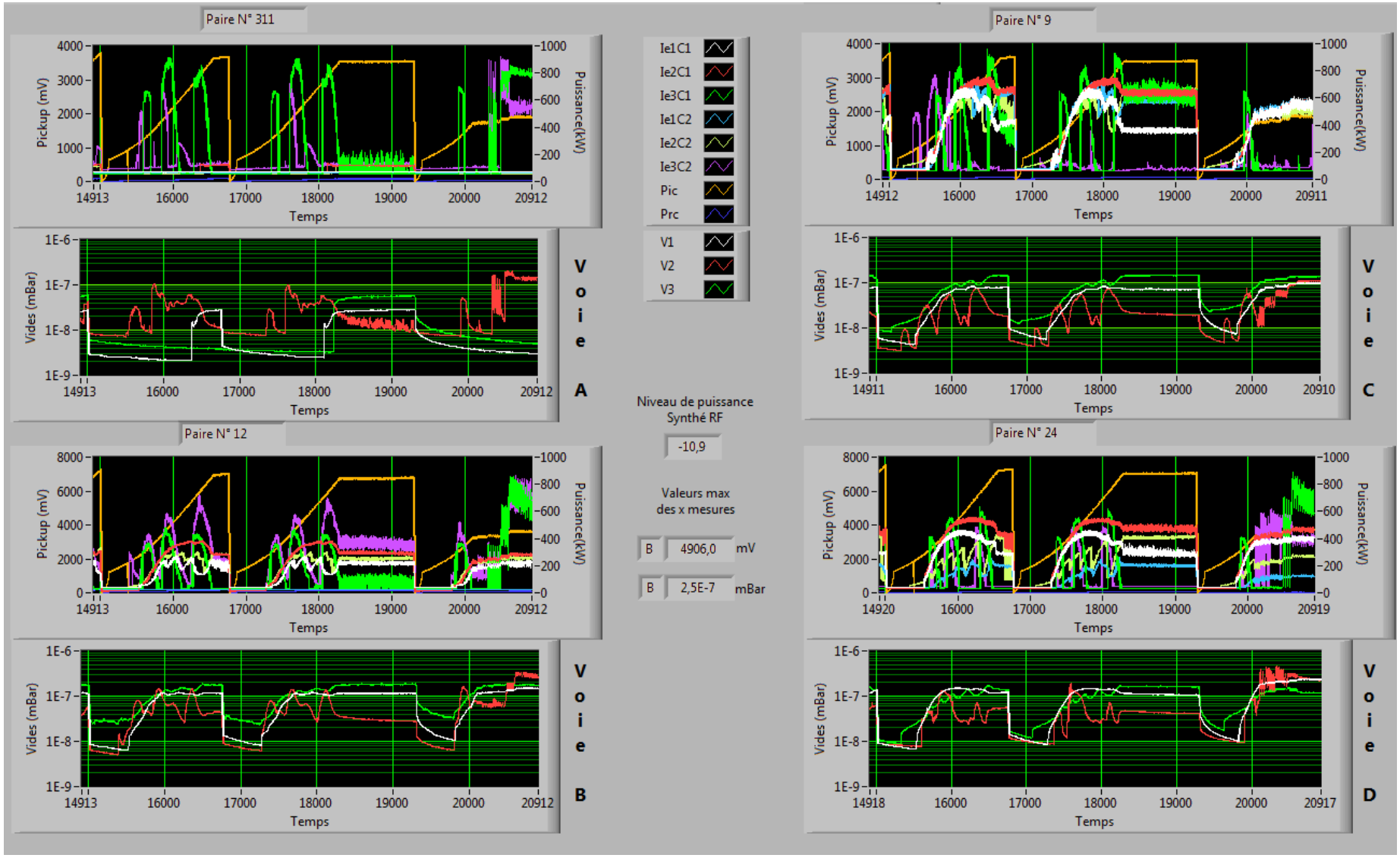
substance	prep. (RIB01-) 1A	2A				
additives:						
4,4'-Bis(Diethylamino)benzophenone	—	▬				
Irgafos 168	■	□				
alkaline/alkaline earth metals:						
calcium/calcium hydroxide	▬	▬				
potassium	▬	▬				
magnesium	□	■				
sodium	▬	▬				
sodium hydroxide	□	▬				
sodium sulfate	□	■				
anions (semispecific):						
CN^-/CNO^-	▬	▬				
NO_x^-	■	■				
PO_x^-	□	■				
SO_x^-	▬	▬				
half metals:						
silicon	■	■				
silicon oxides	■	▬				
silicon/titanium oxides	—	▬				
fatty acid amides:						
erucamide	▬	—				
diglycerides	□	—				
fatty acids:						
higher fatty acids	■	▬				
halogens:						
fluorine	■	■				
chlorine	■	▬				
metals / metal compounds:						
aluminium	■	■				
chrom	—	□				
copper	■	□				
mangan	□	□				
titanium/titanium dioxides	□	▬				
tin	—	□				
silicones:						
poly(dimethyl siloxane)	■	■				
anionic surfactants:						
alkylsulfates	■	□				
sulfur	□	□				
C_xH anions (⟶ soot/carbon black)	▬	—				

Table 1: Relative intensities of representative signal peaks for the investigated samples (Note: intensities within a single column are not comparable).

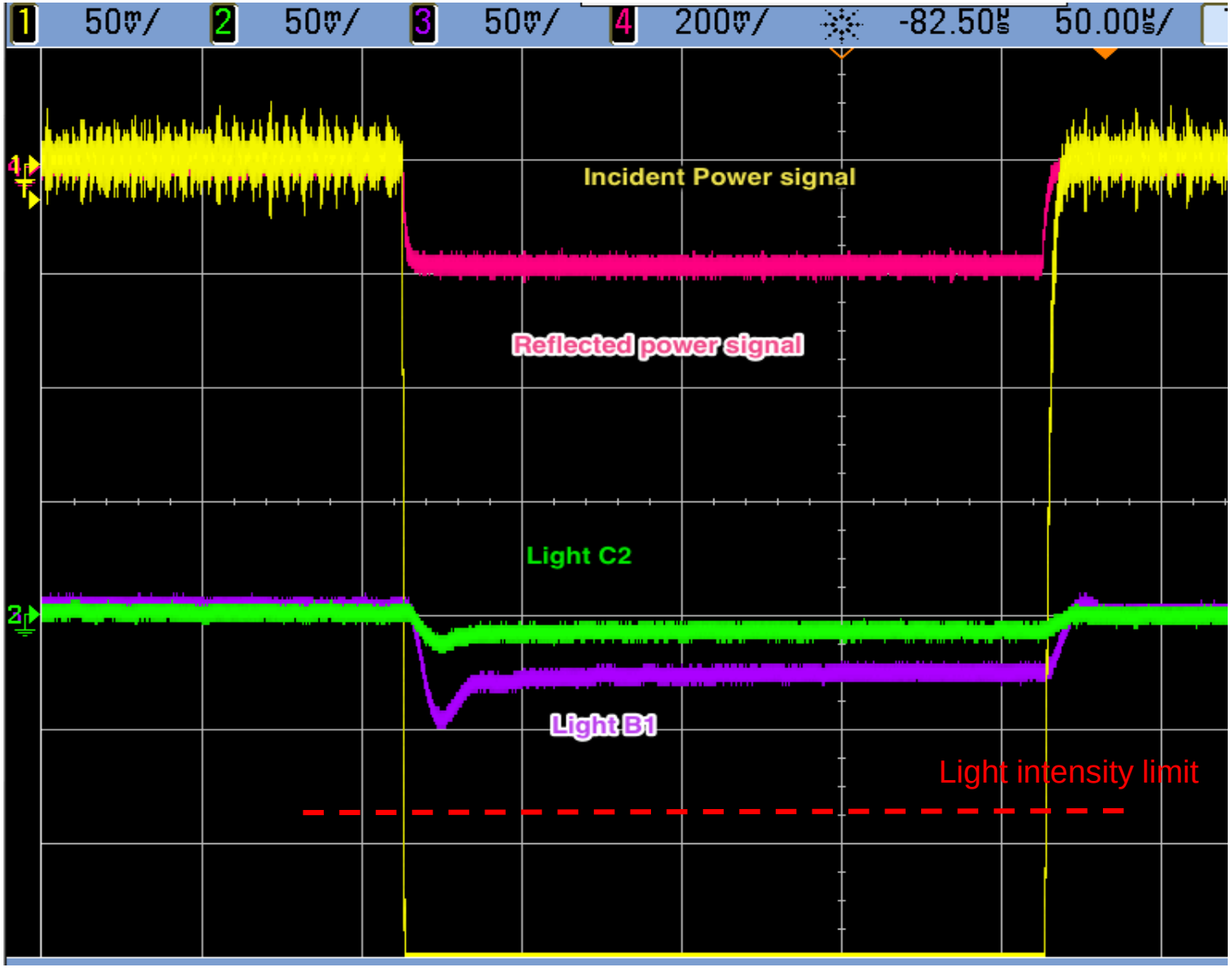
Troubles on the track: Light & arcing in the warm windows



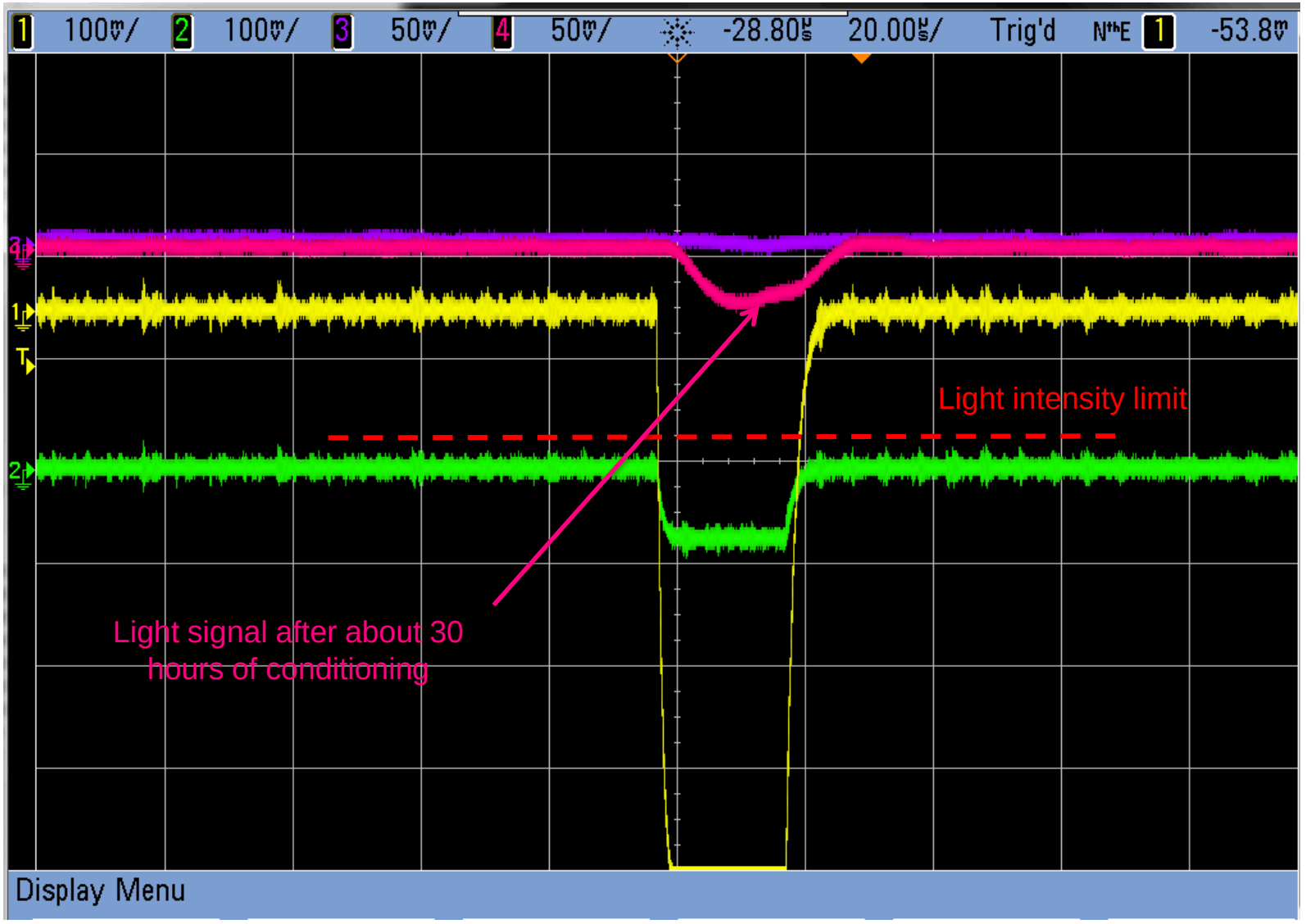
Troubles on the track: Light & arcing in the warm windows



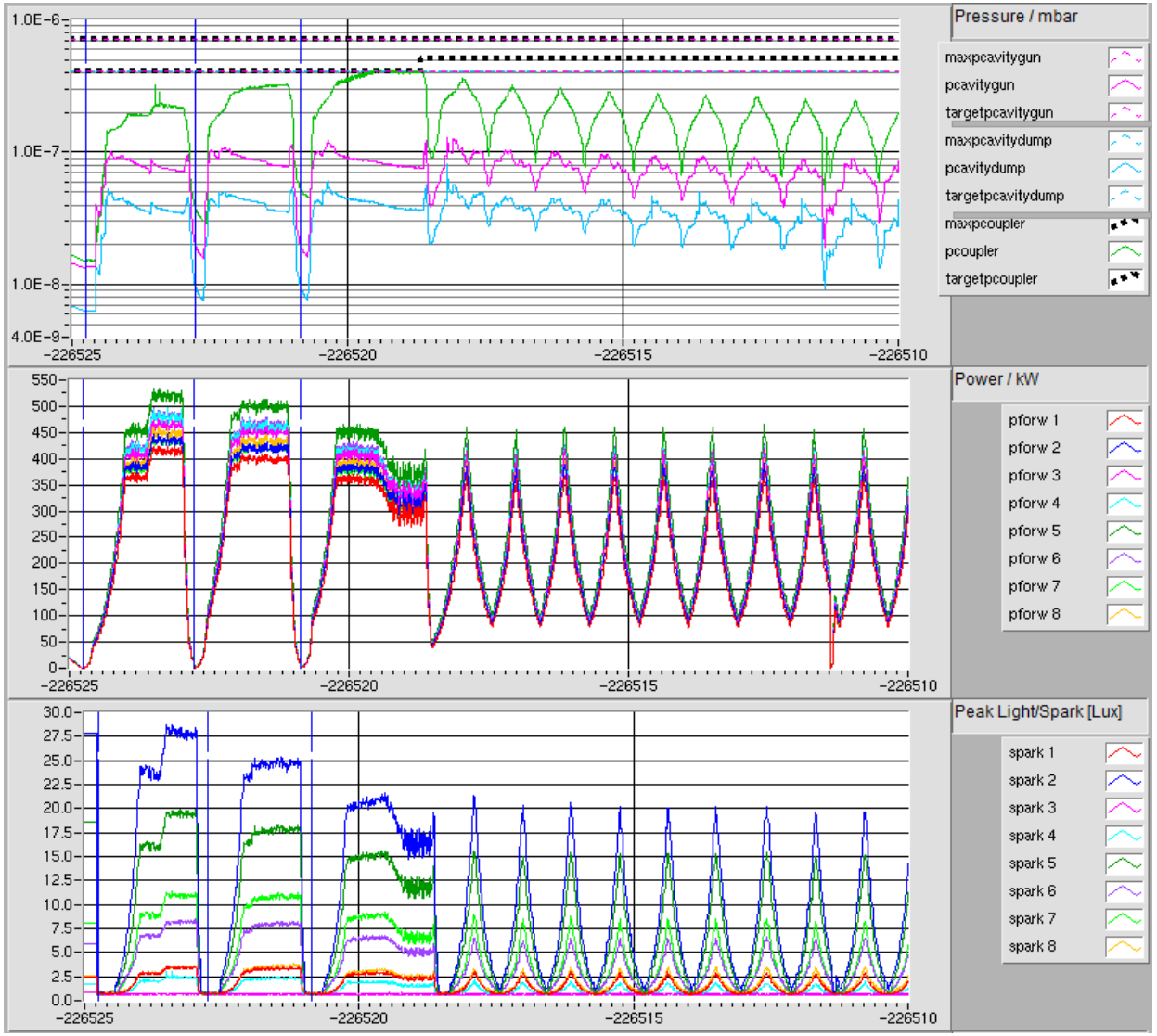
Troubles on the track: Light & arcing in the warm windows



Troubles on the track: Light & arcing in the warm windows



Troubles on the track: Light & arcing in the warm windows

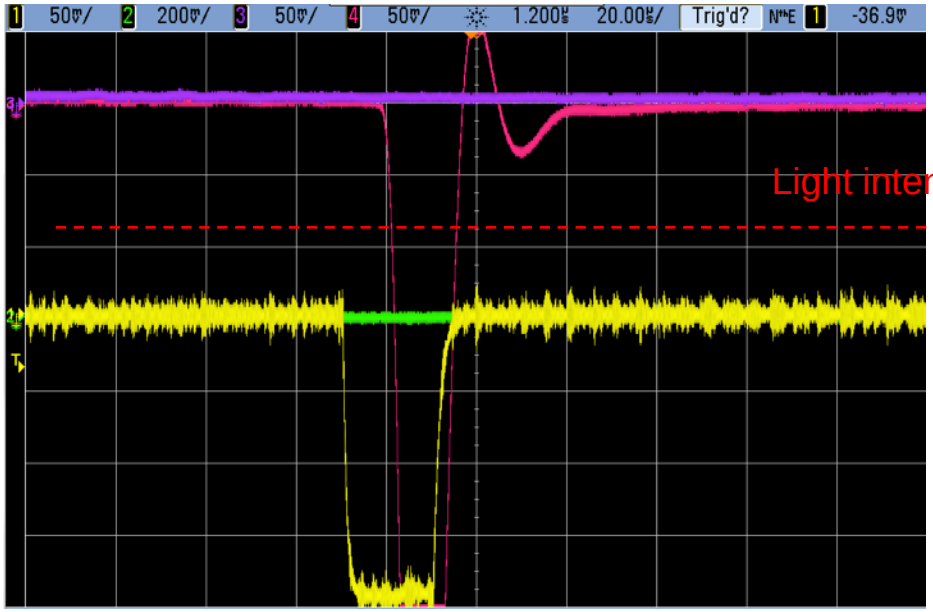


Module XM-1 couplers conditioning:

Light signal on spark sensors

Denis Kostin, MHF-sl, DESY

Troubles on the track: Light & arcing in the warm windows



Sudden increase of the light intensity causing arc interlock: generally occurs at low power (under 250 kW) at the shortest pulse (20us) → impossible to go further: the pair is removed from the test stand.

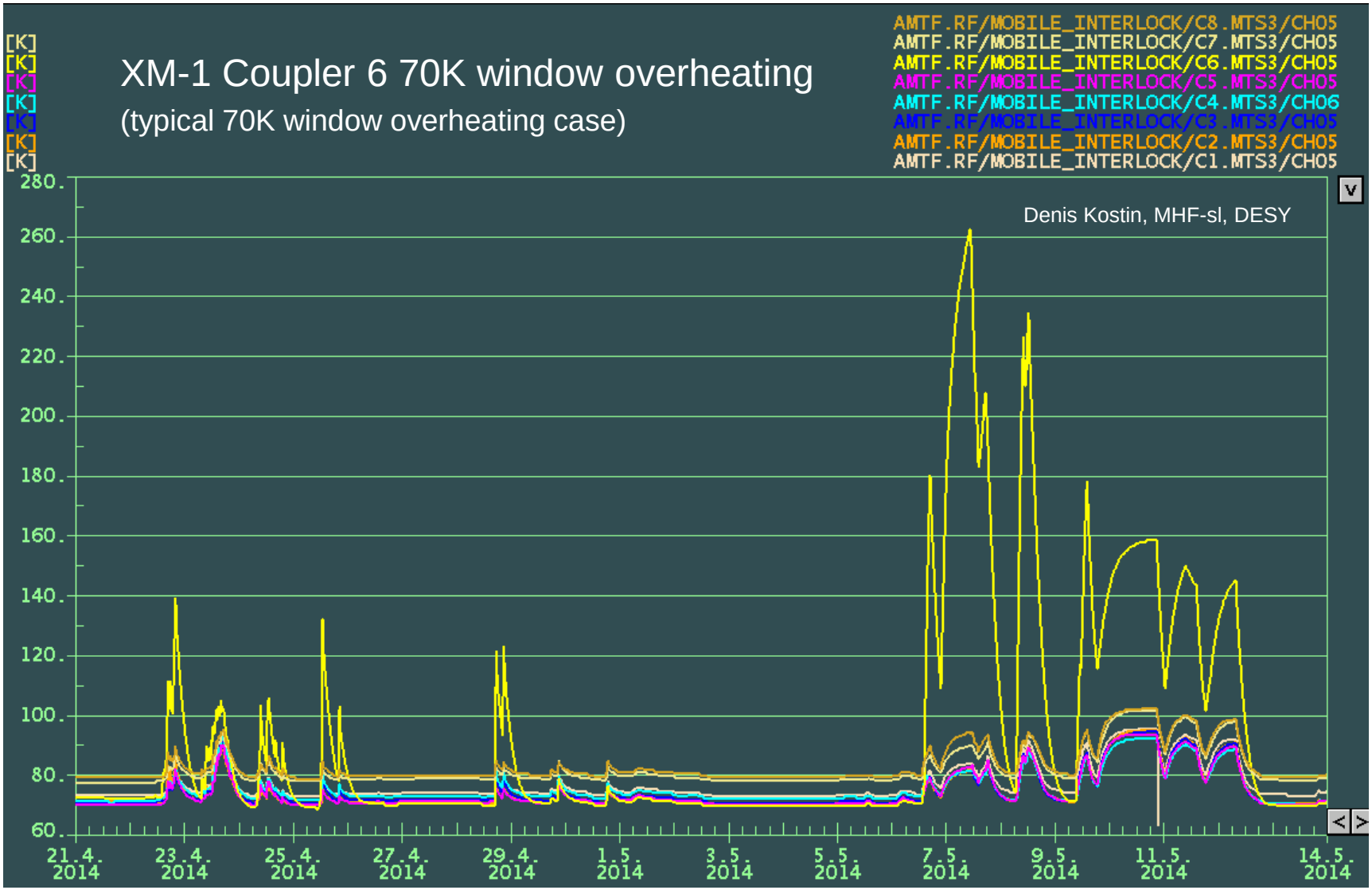
Troubles on the track: Light & arcing in the warm windows

European XFEL

Troubles on the track: Overheating during RF test

XM-1 Coupler 6 70K window overheating

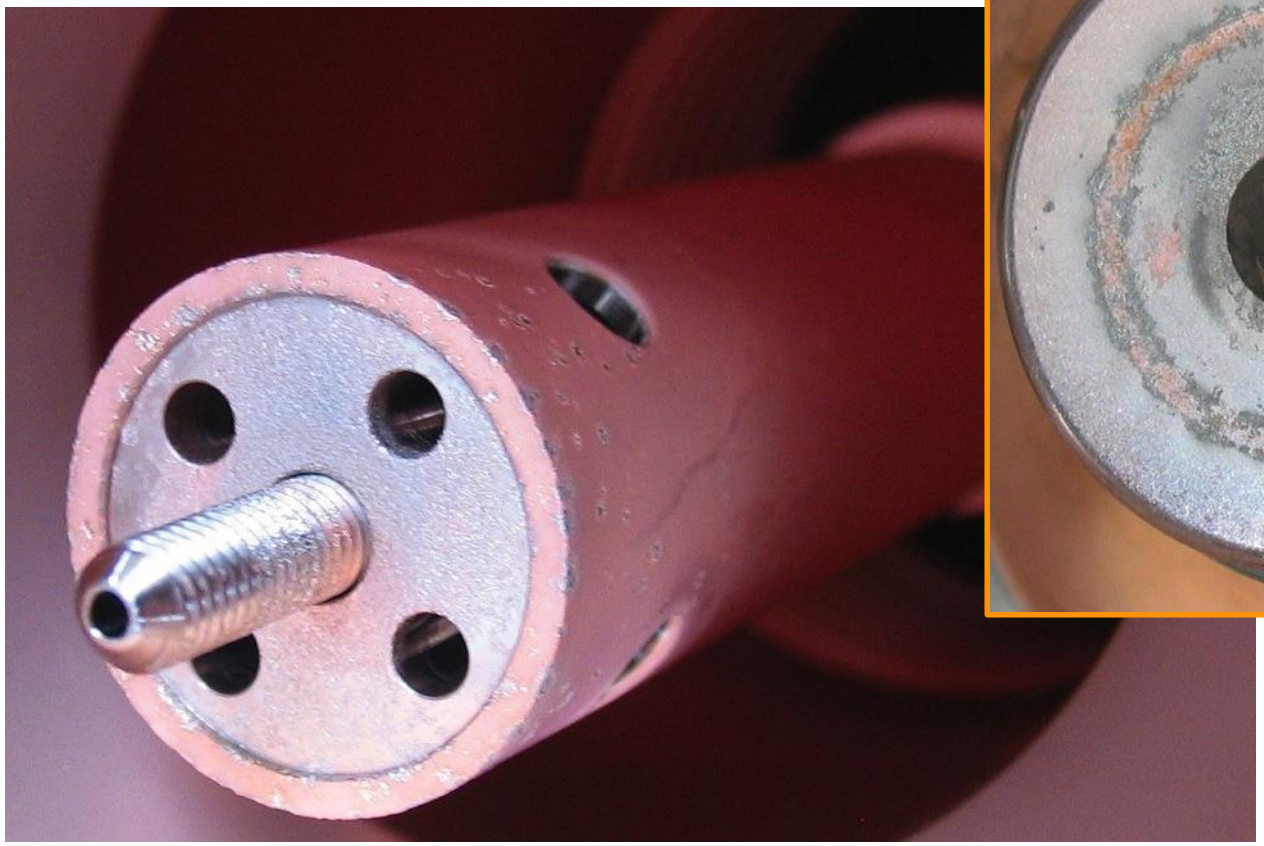
(typical 70K window overheating case)



Troubles on the track: Overheating during RF test

Coupler 70K window overheating due to loose connection between the WIC and the CP. Cold part must be grinded and cleaned. The WP must be changed.

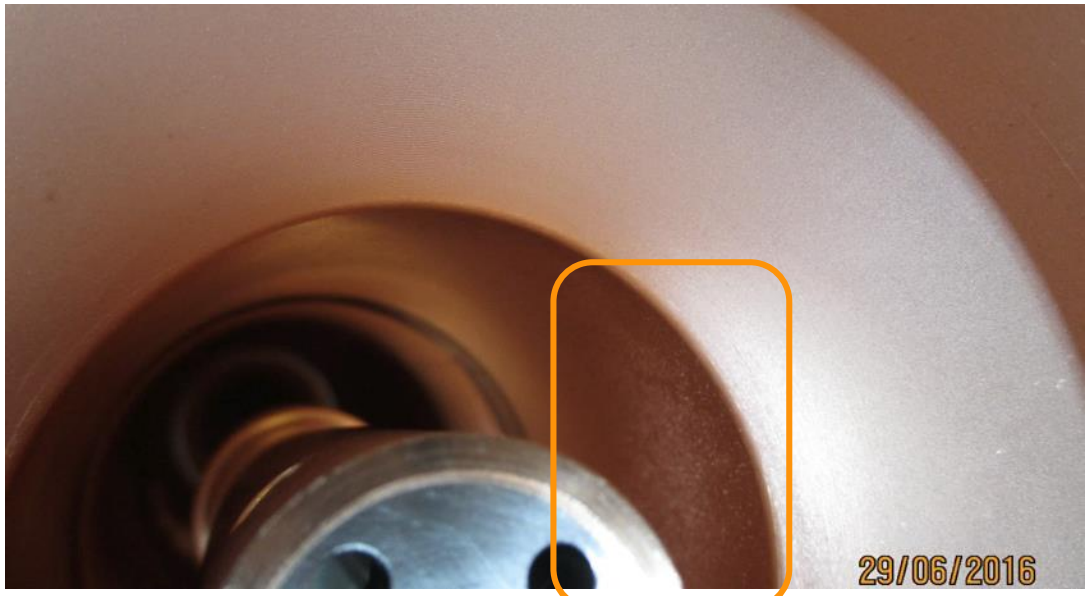
Re-conditioning takes long time: cleaning is difficult, no baking, no US-wash...

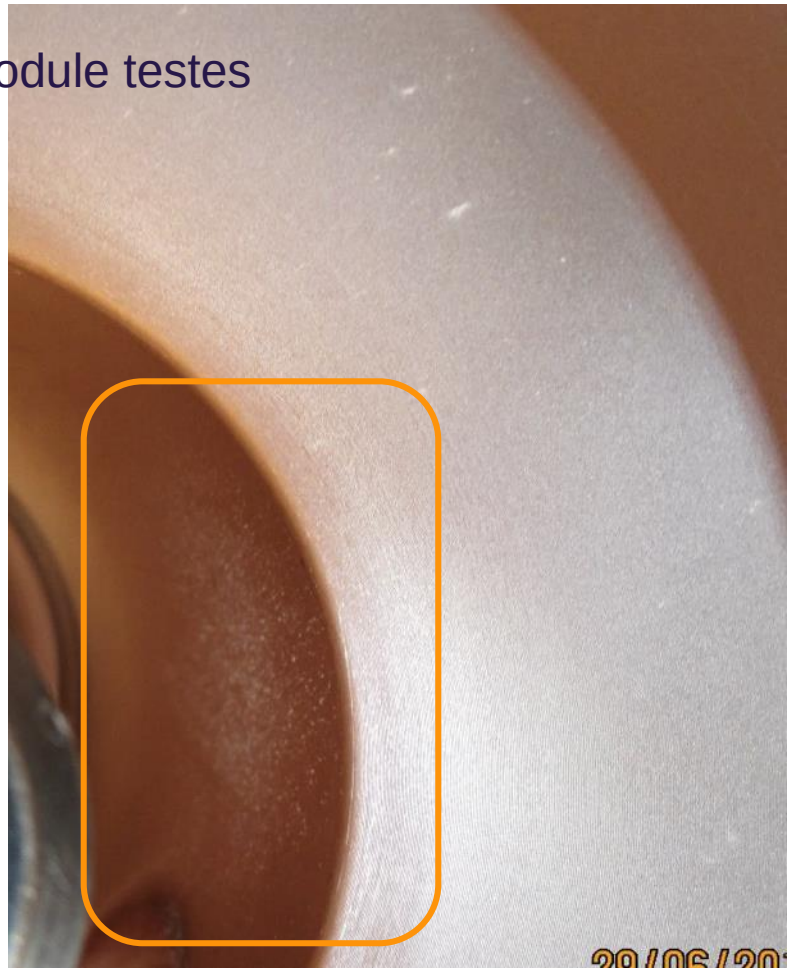


Denis Kostin, MHF-sl, DESY

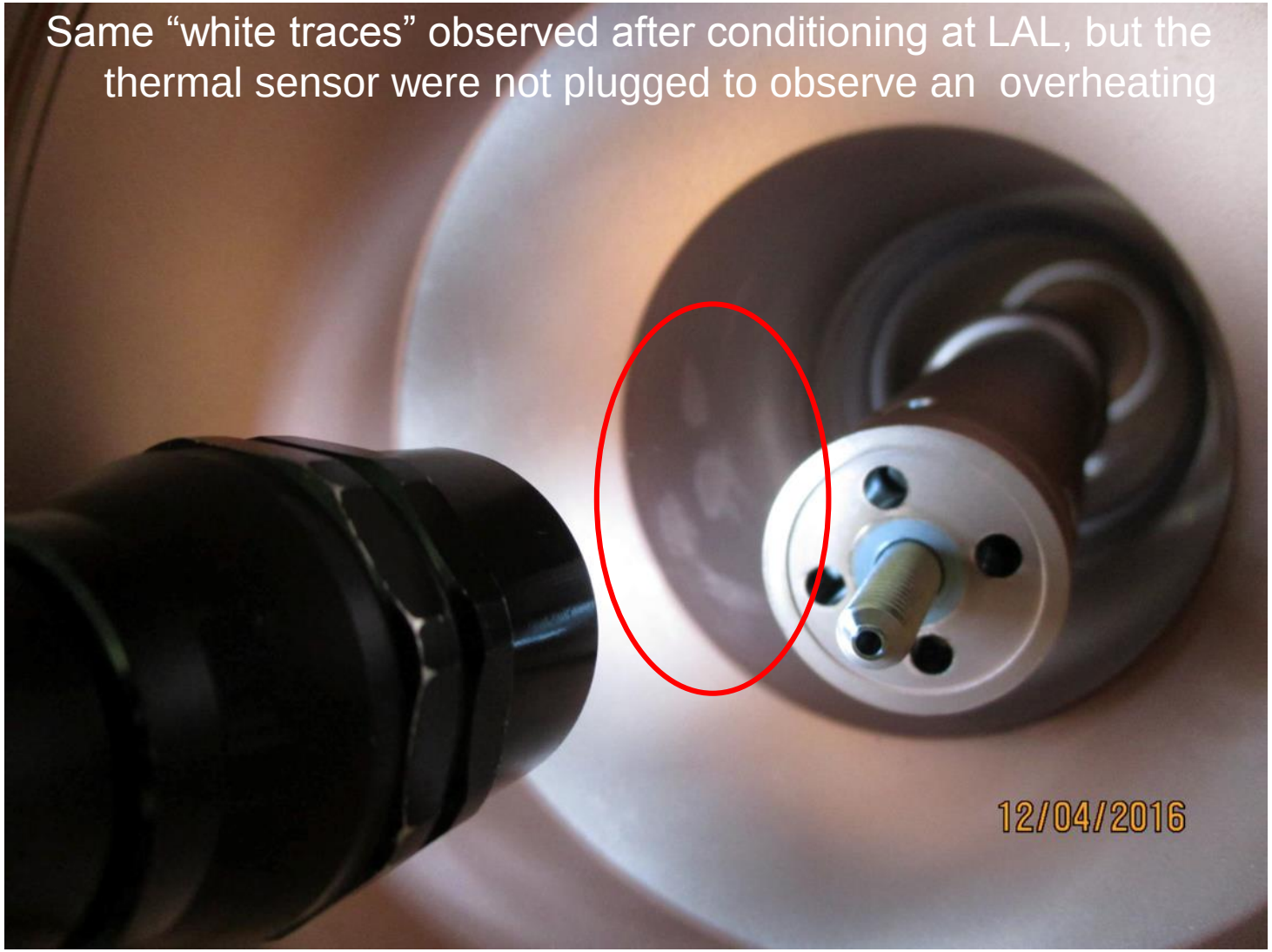
Troubles on the track: Overheating during RF test

WPs inspection after observed Overheating in module testes

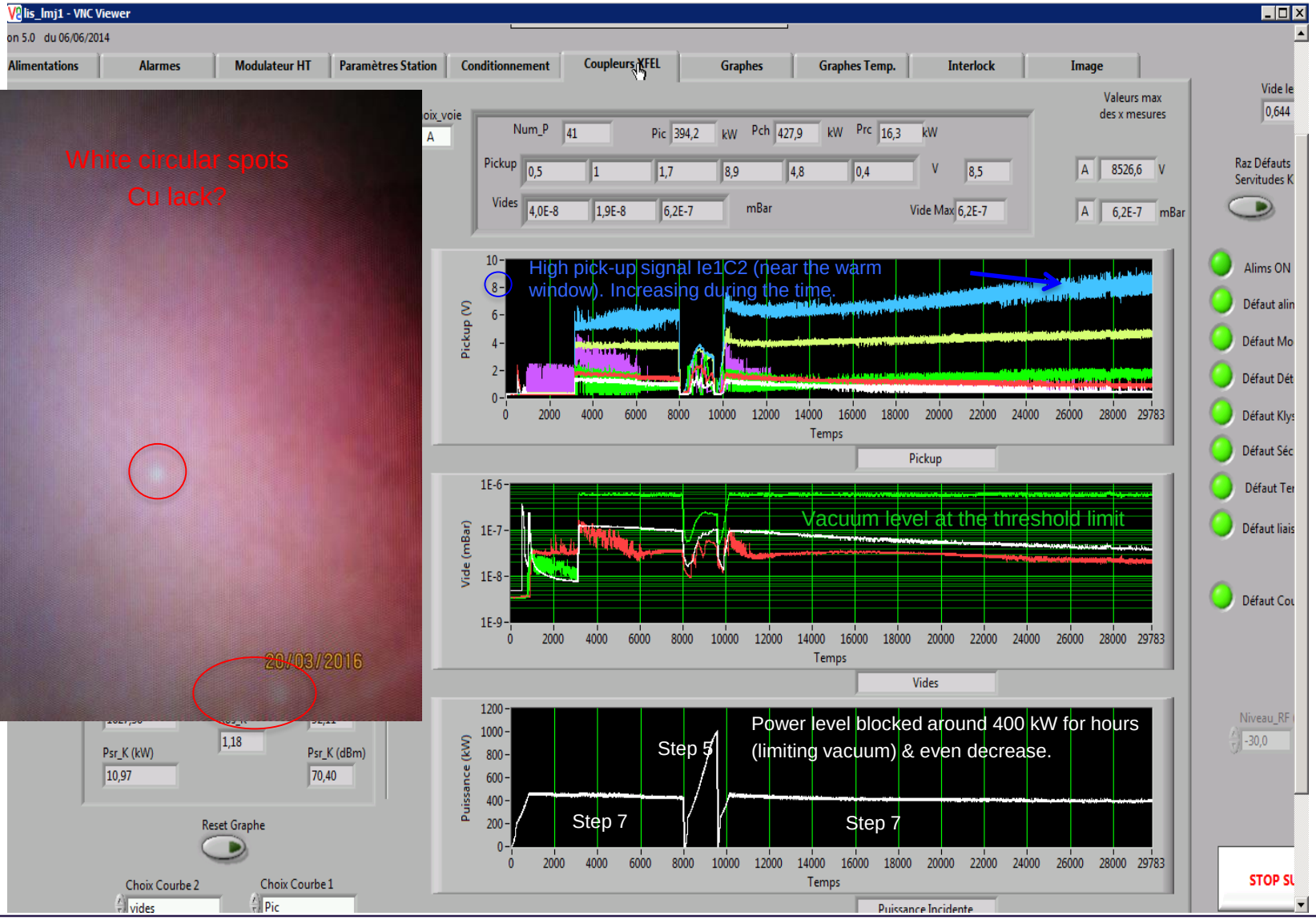




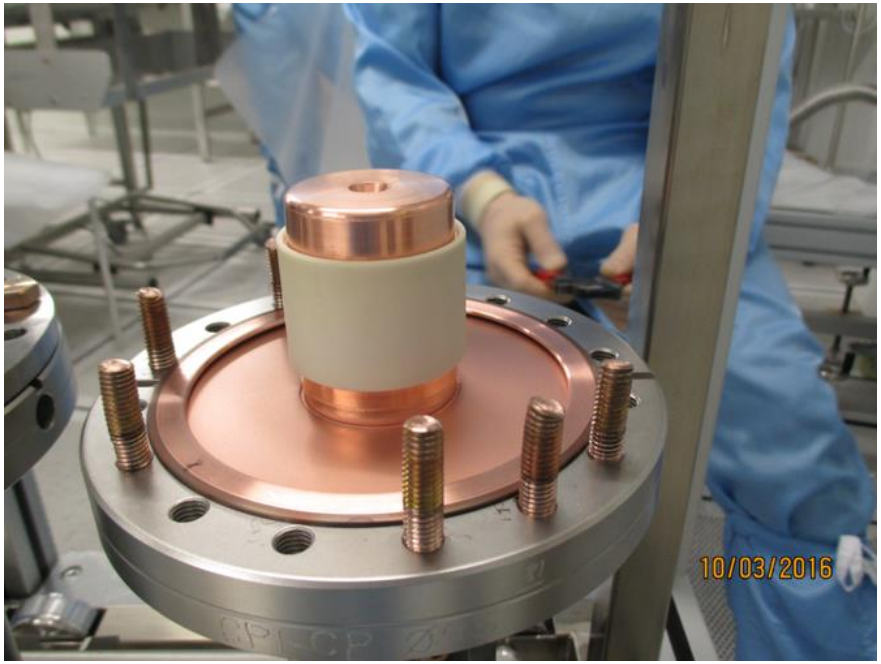
Troubles on the track: Overheating during RF test



Troubles on the track: Overheating during RF test



Troubles on the track: Other minor issue



First, we faced difficulties to remove the WP because of the tilted threaded rods, blocked in the flange.

Troubles on the track: Other minor issue

The 7 rods were then removed with a pliers, with the risk to heart the cold ceramic in case of bad handling, and to contaminate the parts with metallic particles.

Troubles on the track: Other minor issue

Once the rods removed, we started to rework the tapped holes. However, the quality of the original thread was so bad, that the tool was broken inside one hole.


Thanks for your attention.