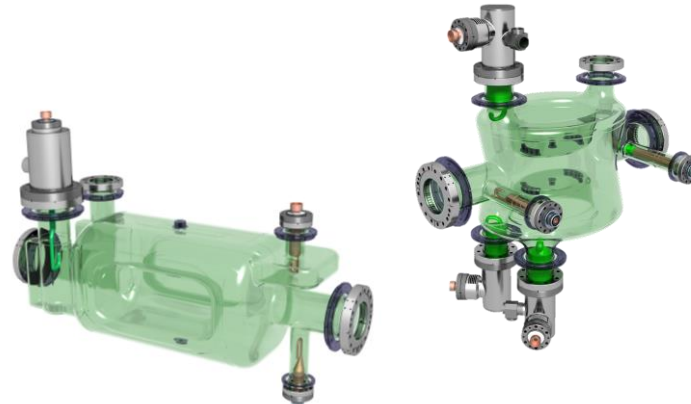




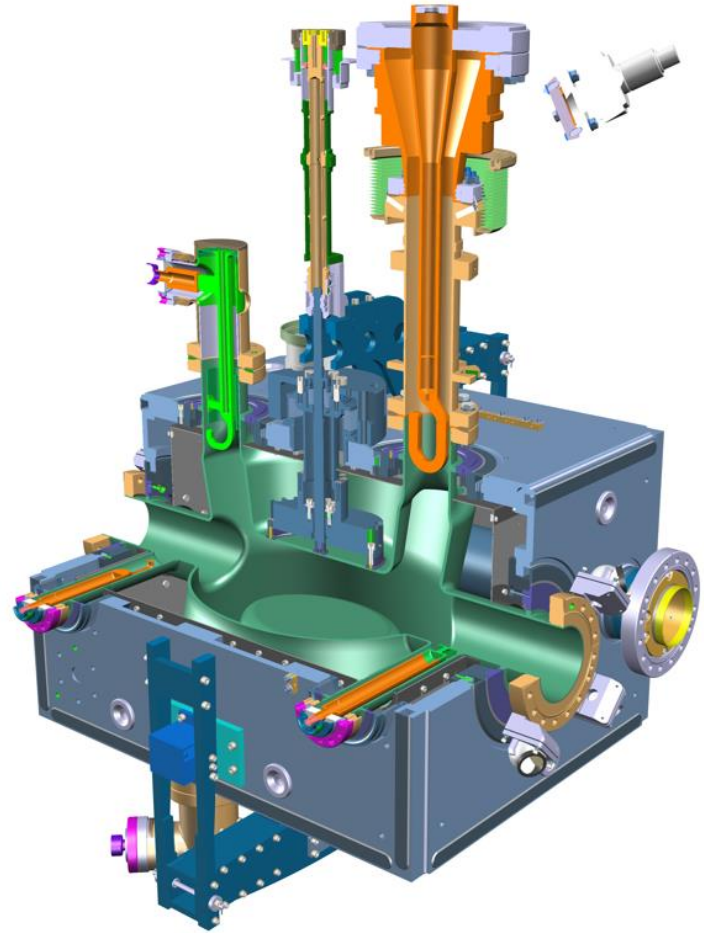
HL-LHC Crab Cavities: DQW & RFD HOM couplers fabrication challenges

Simon Barrière, CERN
on behalf of the HL-WP4 team



Outline

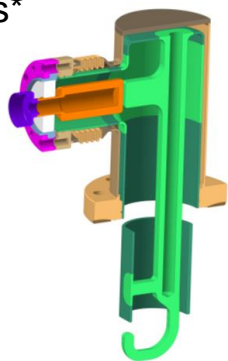
- Scope of Production
- Manufacturing Status
- Latest Challenges & Lessons Learned



Production Scope: DQW series

- HOM Couplers, HOM Feedthroughs, HF-HOM Couplers and Field Antennas for LHC-series DQW Crab Cavities are being produced at CERN Main Workshop

HOM Coupler + Feedthrough
x 36 units*



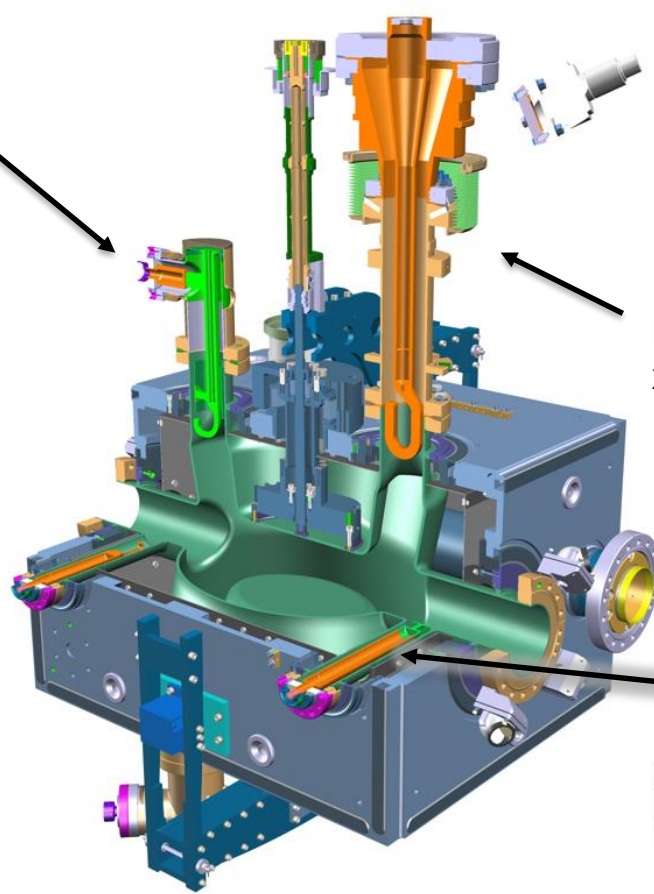
Fundamental Power Coupler
x 14 units*



RF Field Antenna
x 12 units*



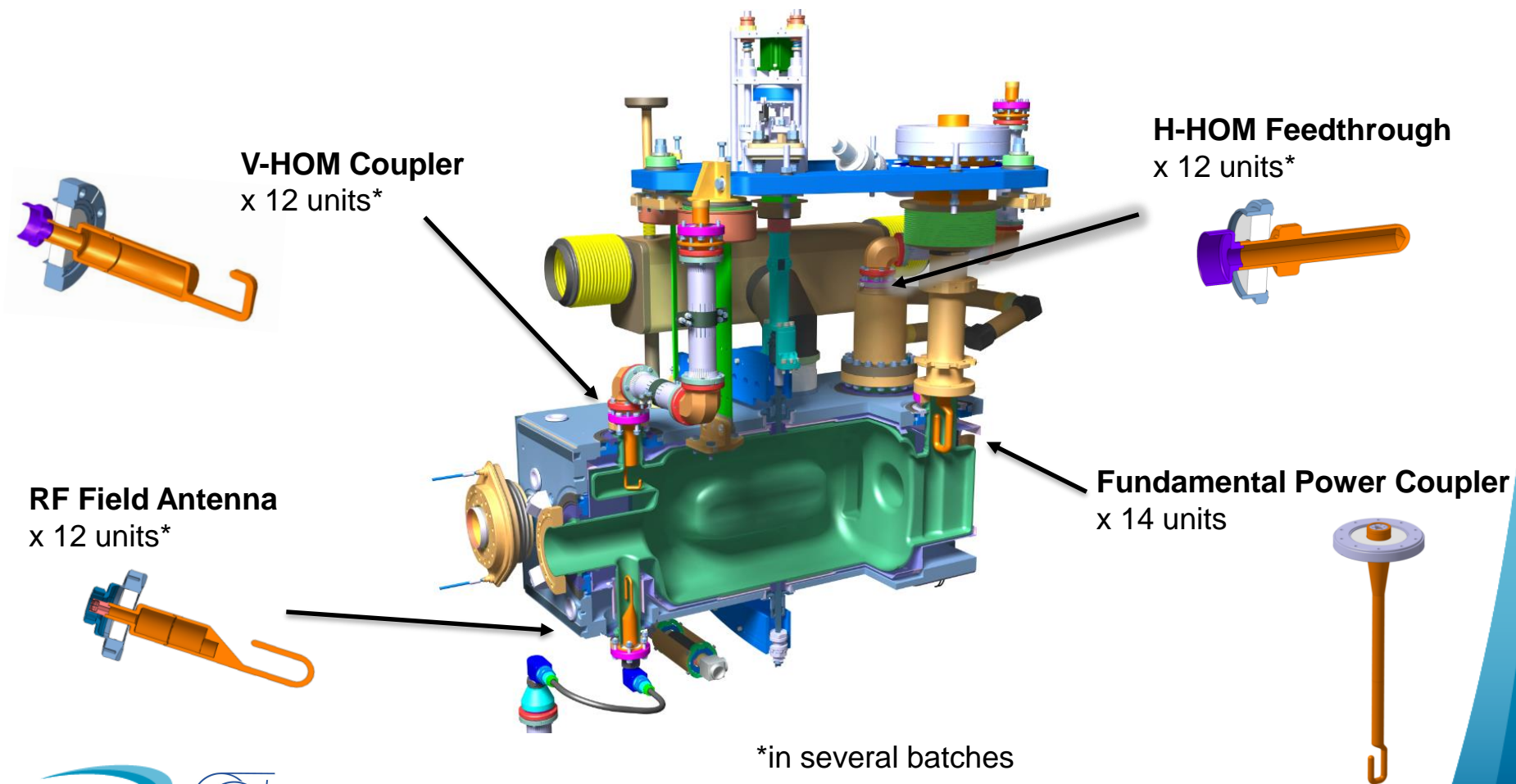
HF-HOM Coupler
x 12 units*



*initial scope, quantities for 8 cavities including spares

Production Scope: RFD series

- **June 2024: Request from US-AUP to produce at CERN:**
 - V-HOM Couplers, H-HOM Feedthroughs and Field Antennas for LHC RFD Crab Cavities
- **H-HOM Coupler still under US-AUP scope (see presentation by N. Huque)**



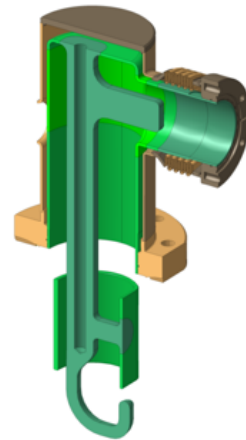
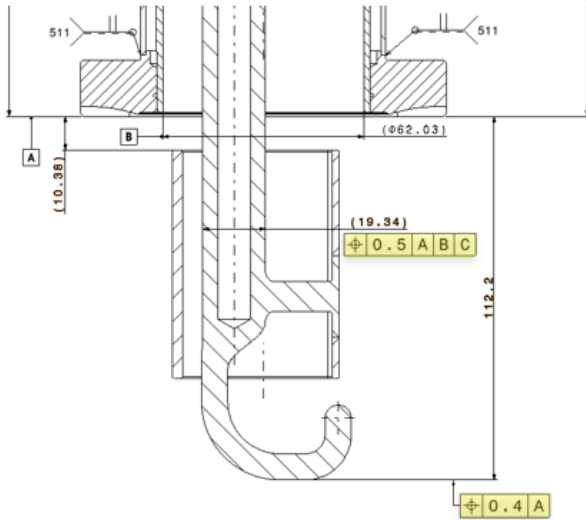
Why are these Objects a Manufacturing Challenge?

Specific (and expensive!) materials

- Extra-pure niobium, OFE copper, titanium grade 23 (TA6V ELI), stainless steel 316LN

(S)RF performance highly dependent on geometry and surface quality

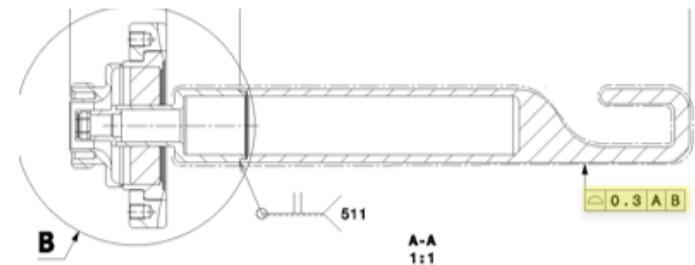
- Final tolerances in **few tenths of millimetres** after many assembly (welding!) steps
- Machined and welded RF surfaces = specific parameters



DQW HOM Coupler



DQW RF Antenna



Multi-Technology components with pressure joints

- ~13 technologies involved and intertwined
- Multiple activities and actors in parallel in different groups
- Advanced follow-up to fulfil HL-LHC quality standards (*PED-related normative, MTF steps, traceability*)

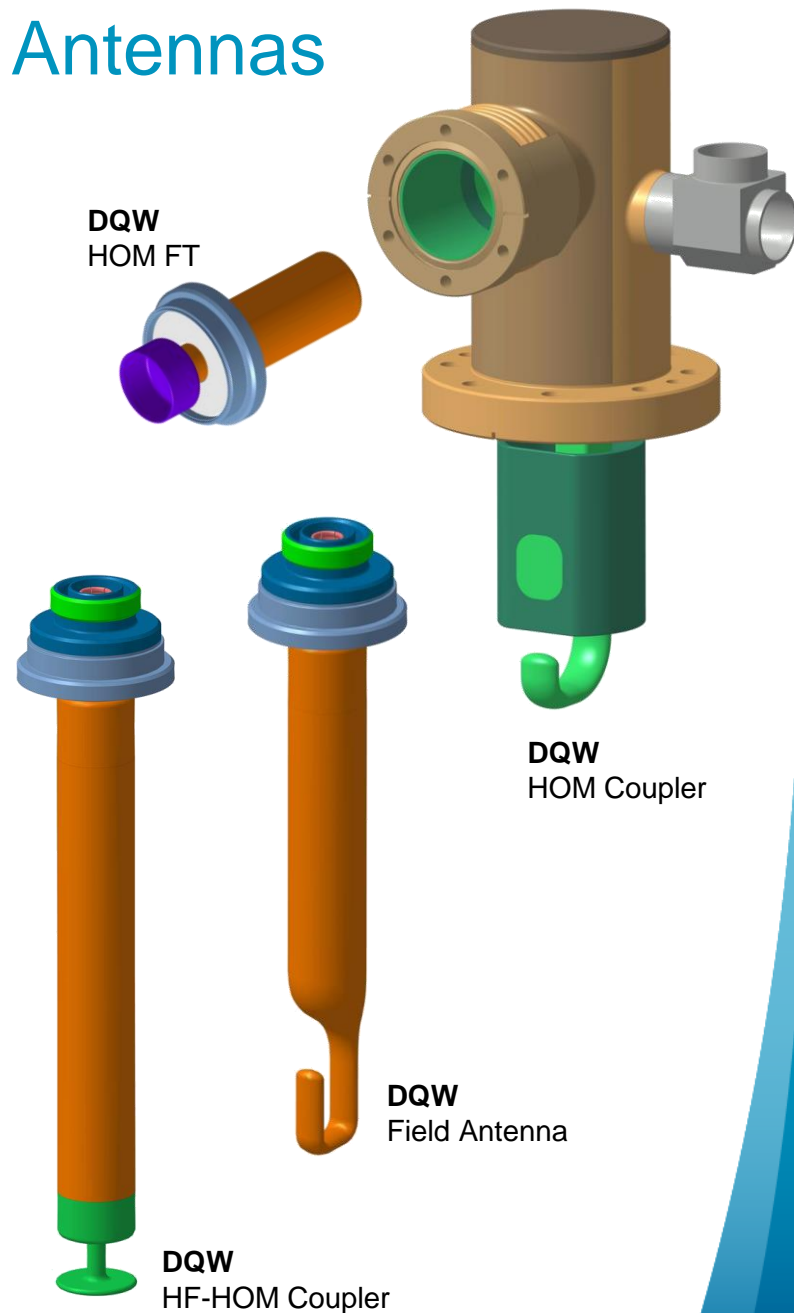
Manufacturing Status

- HOM Couplers & Antennas

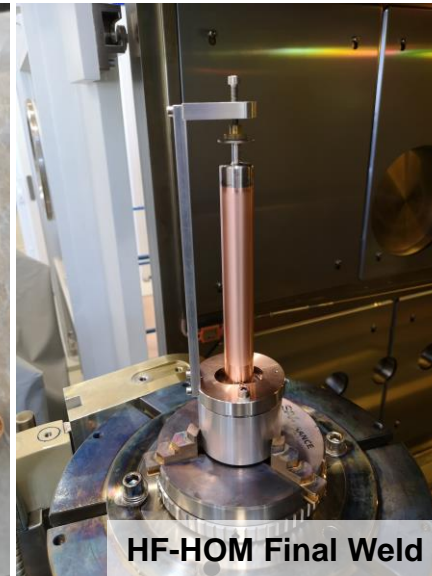
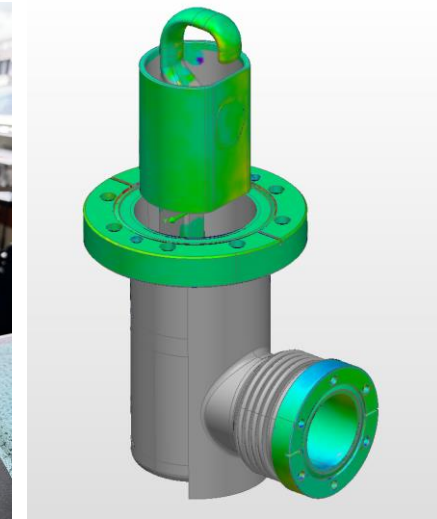
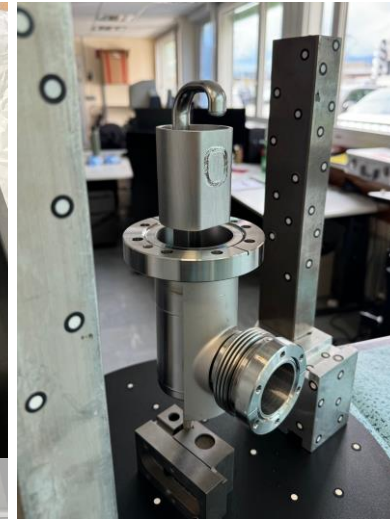
DQW – HOMC and Antennas

Pieces	Qty requested	Qty produced at CERN
HOM Coupler	36	15 done 1 not conform 21 ongoing
HOM Feedthrough	36 + 12*	20 done 16 ongoing 12*
HF-HOM Coupler	12 + 4*	12 done 4*
Field Antenna	12 + 4*	12 done 4*

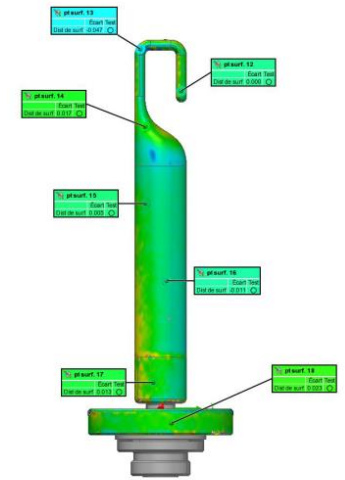
* : additional quantities to be produced following last PSM in Sept 2024 (spares)



DQW – HOMC and Antennas



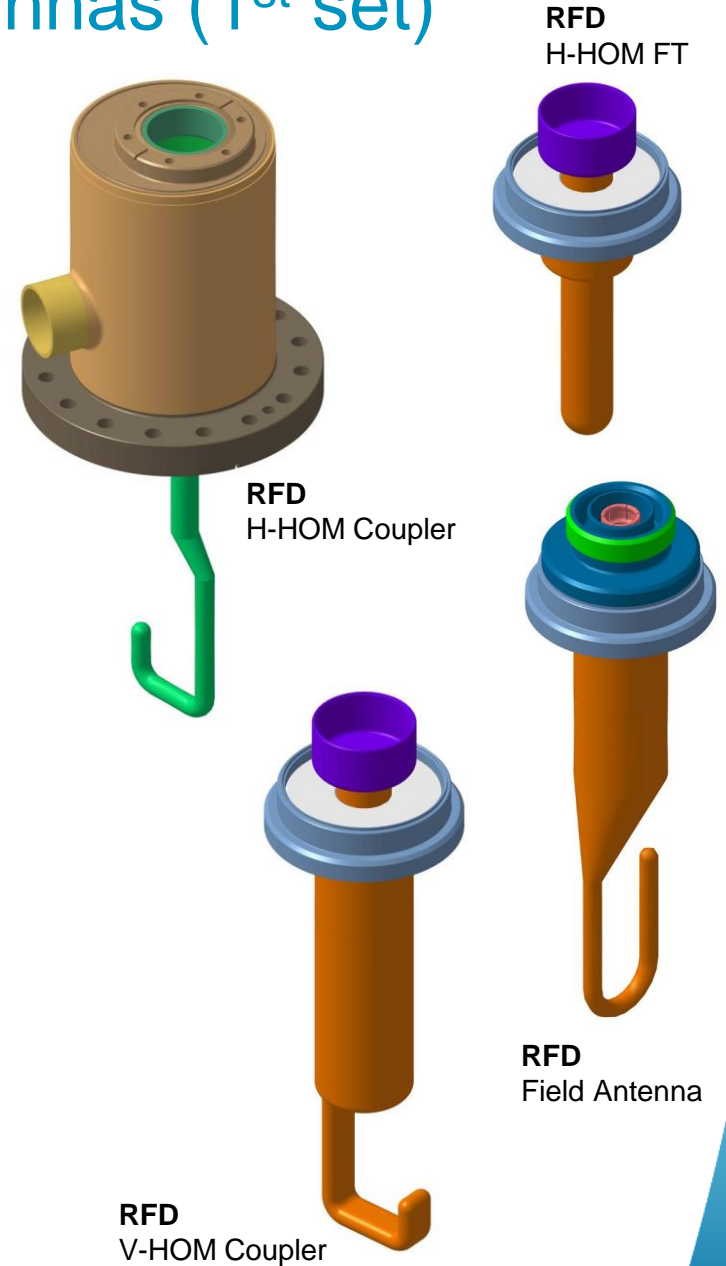
Metrologies (3D Scans)



RFD – HOMC and Antennas (1st set)

Pieces	Qty requested	Qty produced at CERN
H-HOM Coupler	2**	2** shipped
H-HOM Feedthrough	2** + 4	2** + 4 shipped
V-HOM Coupler	2** + 4	2** + 4 shipped
Field Antenna	2** + 4	2** + 4 shipped

** : prototypes built at CERN for RFD-SPS cryomodule



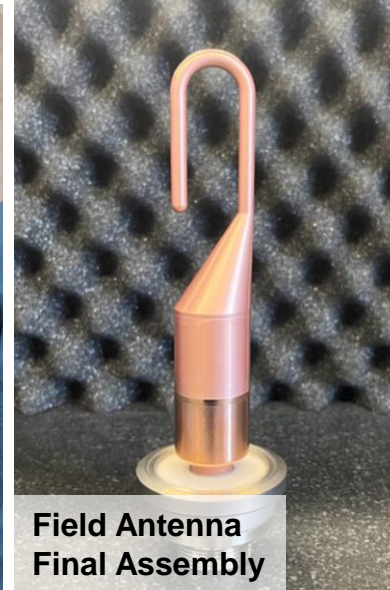
RFD – HOMC and Antennas (1st set)



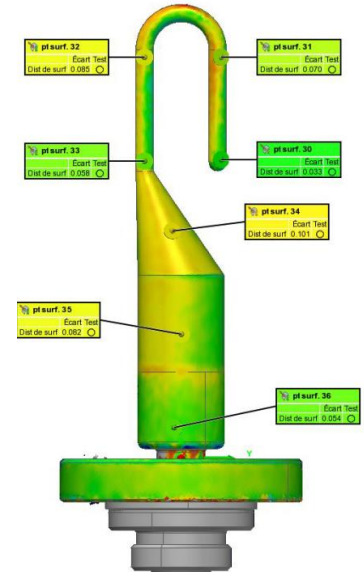
H-HOM Feedthrough brazed



RF Clamp
EB weld



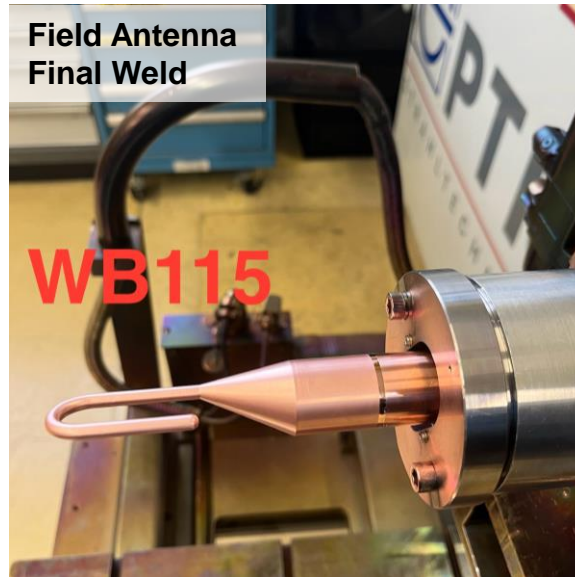
Field Antenna
Final Assembly



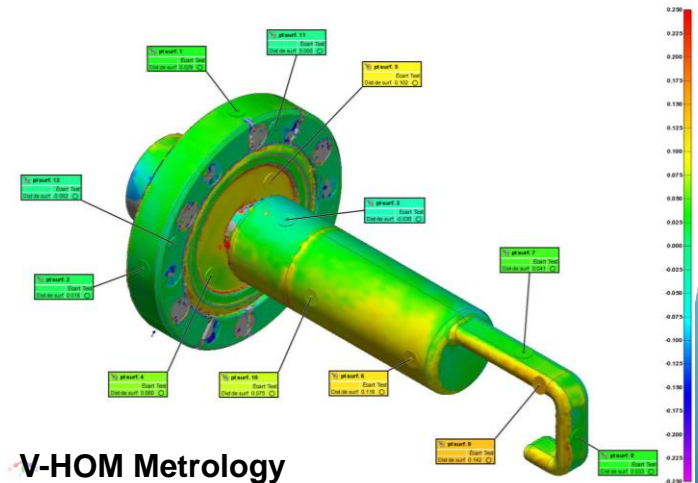
Field Antenna
Metrology



V-HOM Final
Assembly



Field Antenna
Final Weld

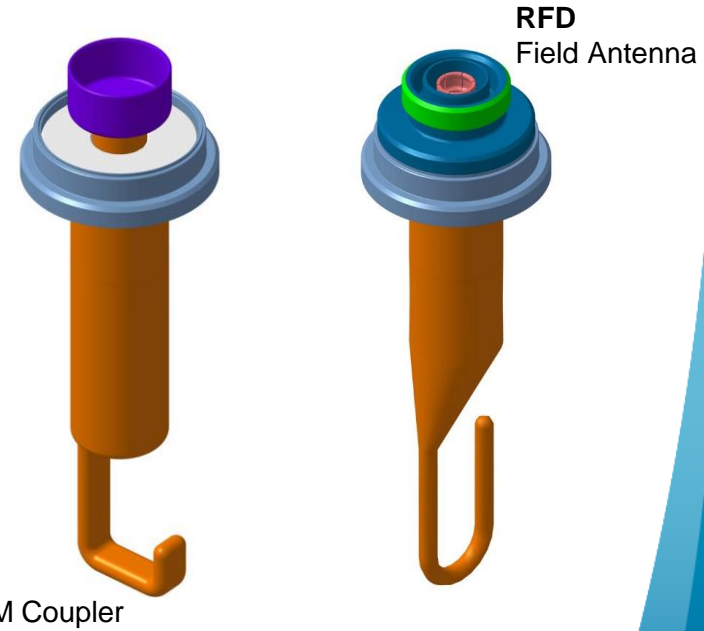
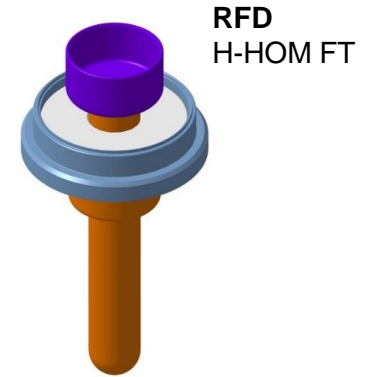


V-HOM Metrology

RFD – HOMC and Antennas (2nd set)

Pieces	Qty requested	Qty produced at CERN
H-HOM Feedthrough	8	8 ongoing
V-HOM Coupler	8	8 ongoing
Field Antenna	8	8 ongoing

All raw materials received including ceramics, brazing and machining ongoing

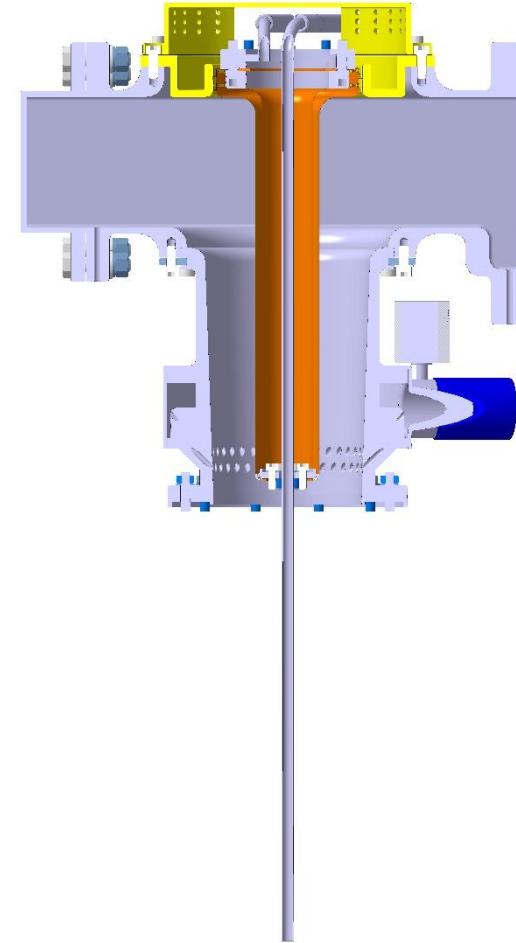


Manufacturing Status

- FPC

DQW & RFD – FPC Air Side

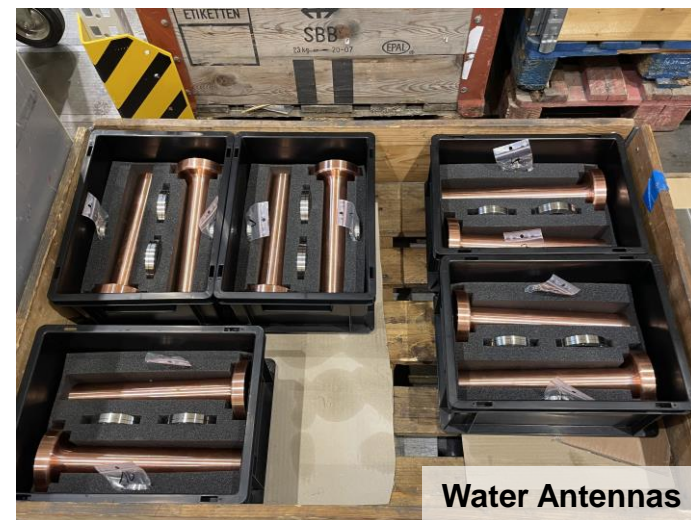
Pieces	Qty requested	Qty produced at CERN
Water Antenna	28	28 done
Water Flanges In/Out	30	30 done
Transmission Line (wevaguide, body)	30	30 done



DQW & RFD – FPC Air Side



Aluminum Waveguides



Water Antennas

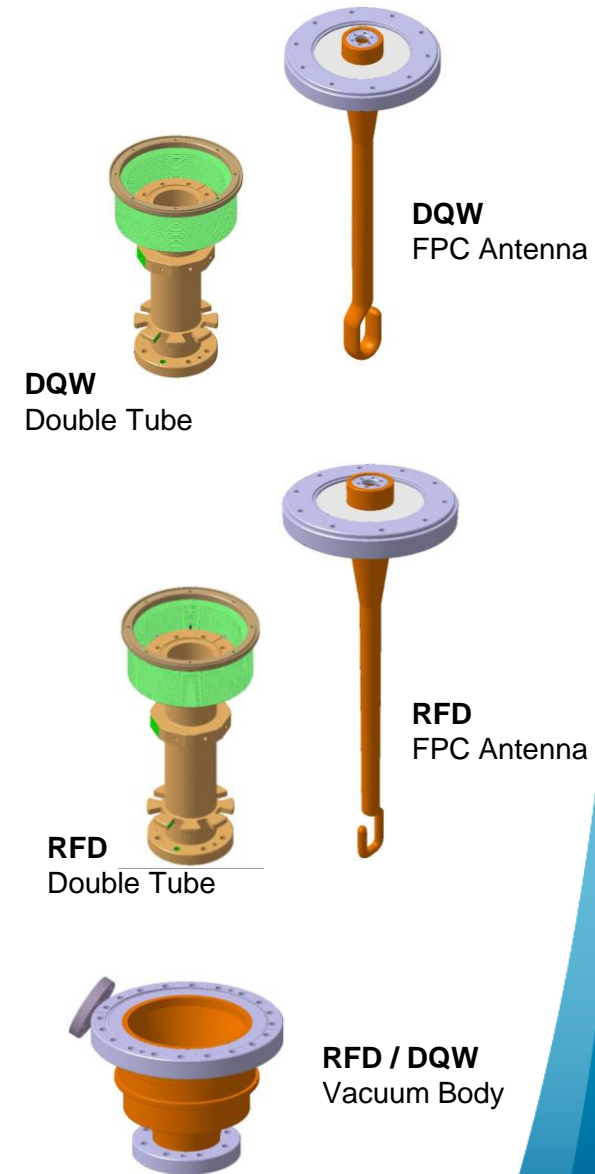


Central Body and Cooling Collars

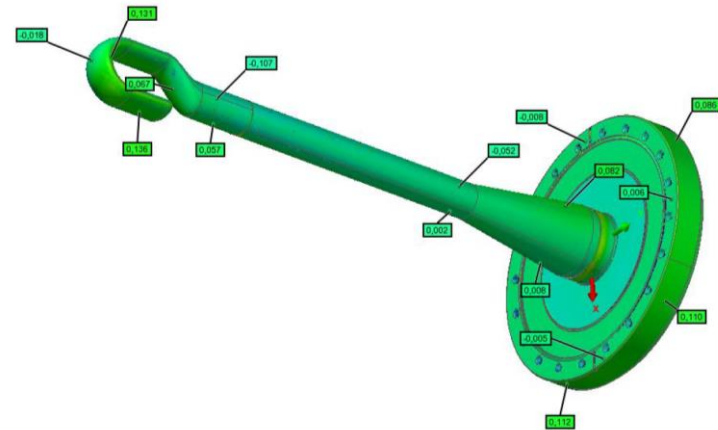
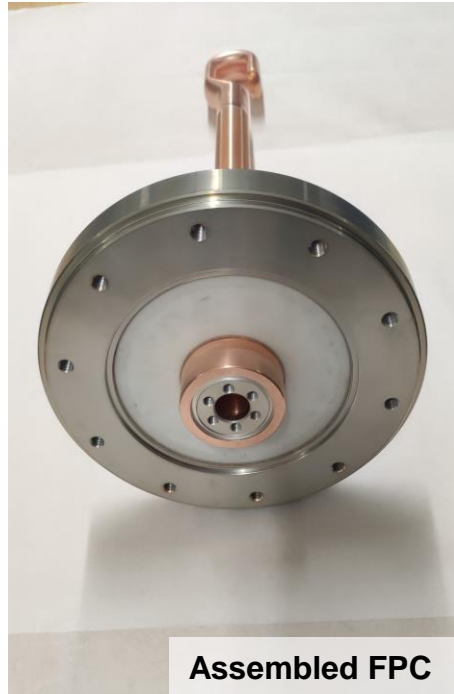
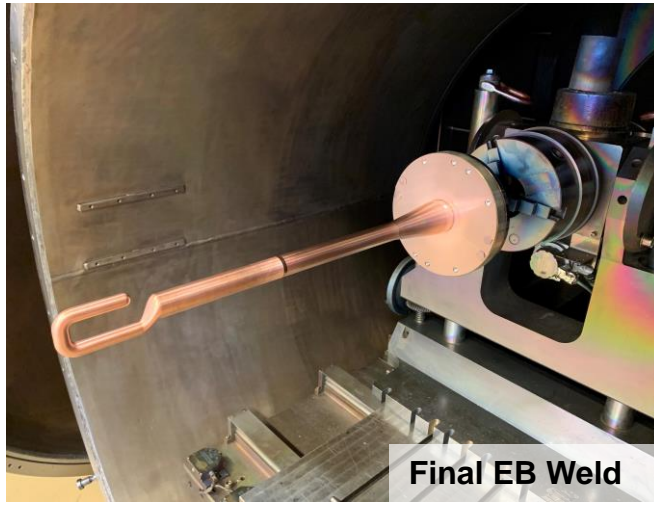
DQW & RFD – FPC Antenna

Pieces	Qty requested	Qty produced at CERN
DQW Antenna	14	6 done 8 ongoing
DQW Double Tube	14	8 done 6 ongoing
RFD Antenna	14	8 done 6 ongoing
RFD Double Tube	14	8 done 6 ongoing
Vacuum Body	28	28 done

All missing assemblies are at very latest steps of production



DQW & RFD – FPC Antenna

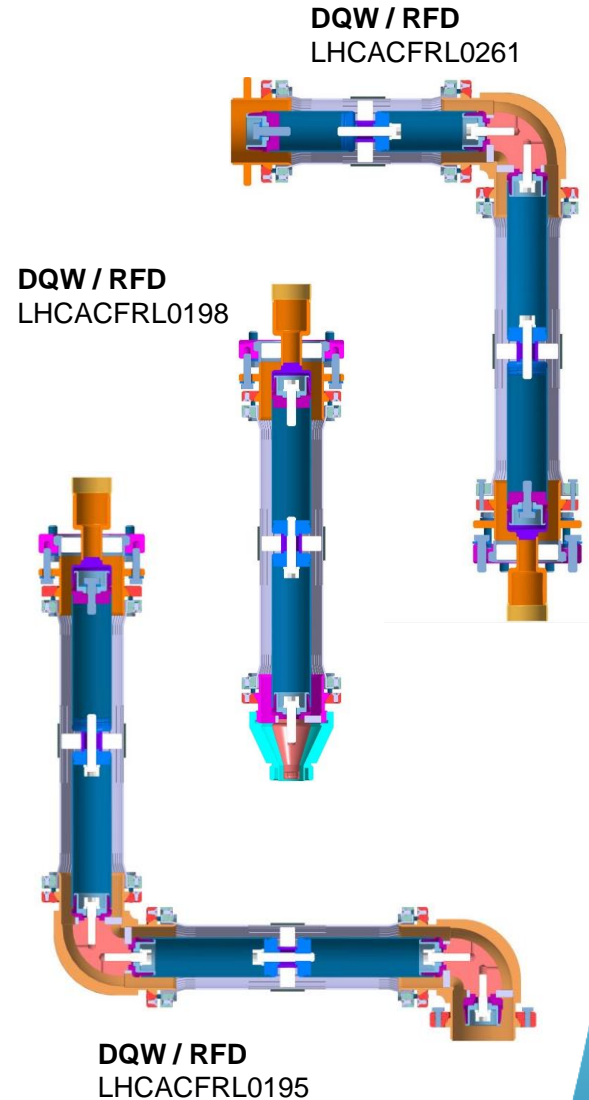


Manufacturing Status

- Coaxial Lines

DQW & RFD – Coaxial RF Internal Lines

Pieces	Qty requested	Qty produced at CERN
LHCACFRL0195 x2 for 1 CM RFD x1 for 1 CM DQW	36	36 ongoing
LHCACFRL0198 x1 for 1 CM RFD x2 for 1 CM DQW	36	36 ongoing
LHCACFRL0261 x2 for 1 CM DQW	24	24 ongoing

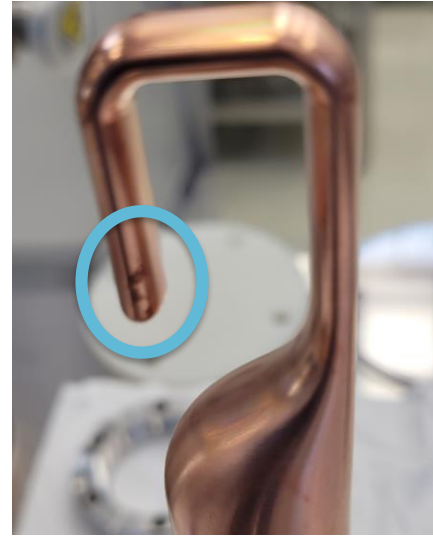


All pieces needed for 2x DQW cryomodules and 2x RFD cryomodules will be ready in Dec 2024

Latest Challenges

Stains

We have been chasing stains (and their origin) the past few months
We have upgraded our procedures with more visual checks, systematic replacement of gloves after touching other objects, extended care and protections for transport



Fingerprints (!)
Old gloves
Chemistry
Drying
Long storage
...



Most of the traces appear after the cleanroom processing

We are questioning ourselves if this is really a problem for RF

Scratches

Mostly caused by insufficient care during handling & transport between all fabrication steps

New standardized process using silk paper + foam reduces the risk

Visual control between all critical steps



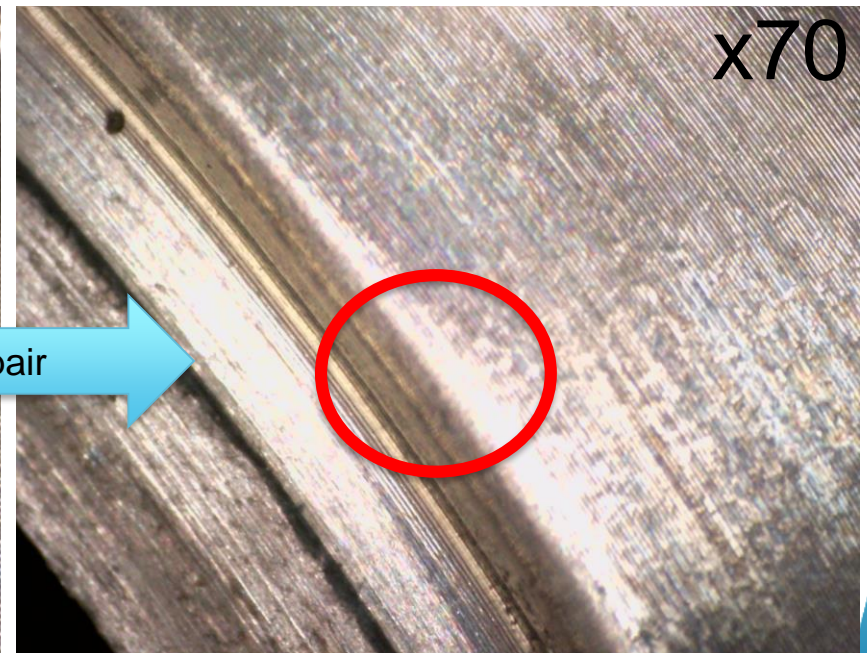
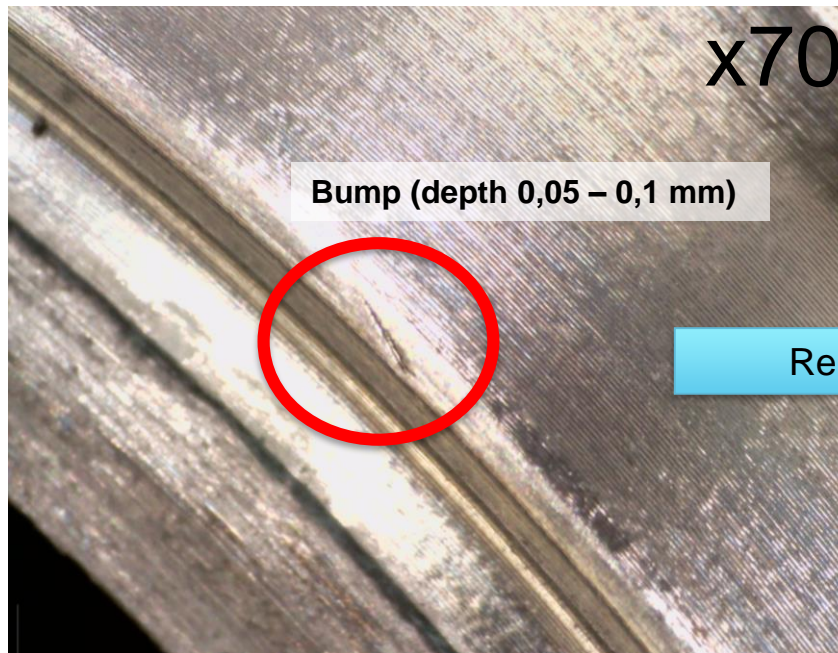
Repair is possible:

When identified after final steps, polishing process defined for removal (polishing stone grit 8000 with isopropyl alcohol)



Devil is in the Details

- Stainless steel and titanium knives are key element to ensure light tightness in operation and for validation tests at 2 K.
- Cold leaks (at 2 K with superfluid helium) are impossible to locate at warm \longrightarrow root cause very difficult to assess
- **All knives are inspected, defects or bumps systematically removed**



Knives repair

- Polishing stone grit 8000 with isopropyl alcohol
- Abrasive blocks with different grits



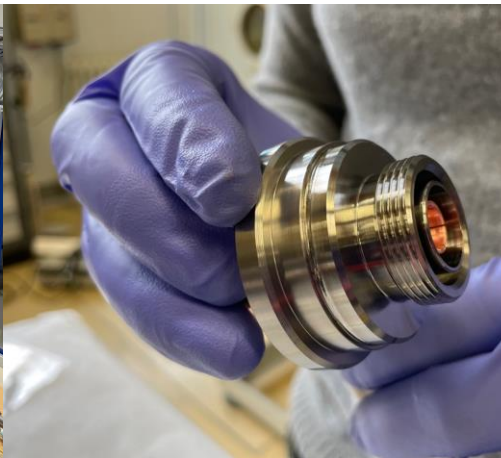
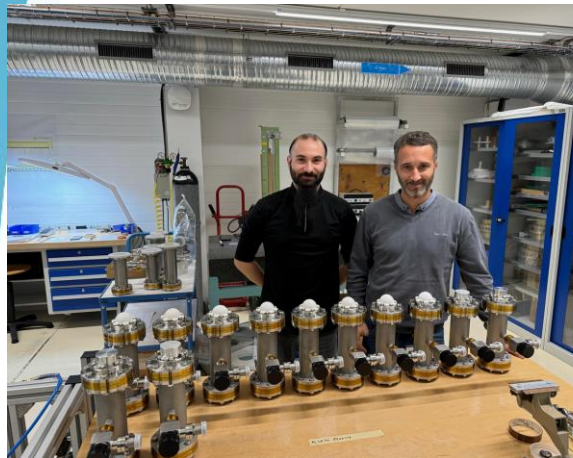
Conclusions & Lessons Learned

- Fabrication of RF couplers & antennas in CERN scope is currently on track
- **Level of attention and care should remain the same in prototyping phase and series production, until the last object is built.** While many eyes are put on prototypes (= low quantity of items), keeping the same level of attention in series production has proven to be challenging
- Manufacturing **and delivery** of high-quality (S)RF couplers requires extended care on all handling and transport operations
- Understand criteria linked to **chemistry processes on multi-material objects** is of paramount importance: is beautiful the best?



Many thanks to all the colleagues involved in the production of such beautiful objects!

**Special thanks to the EN-MME Manufacturing Team,
and Sébastien, Francesco, Nuria & Eric (SY-RF)**

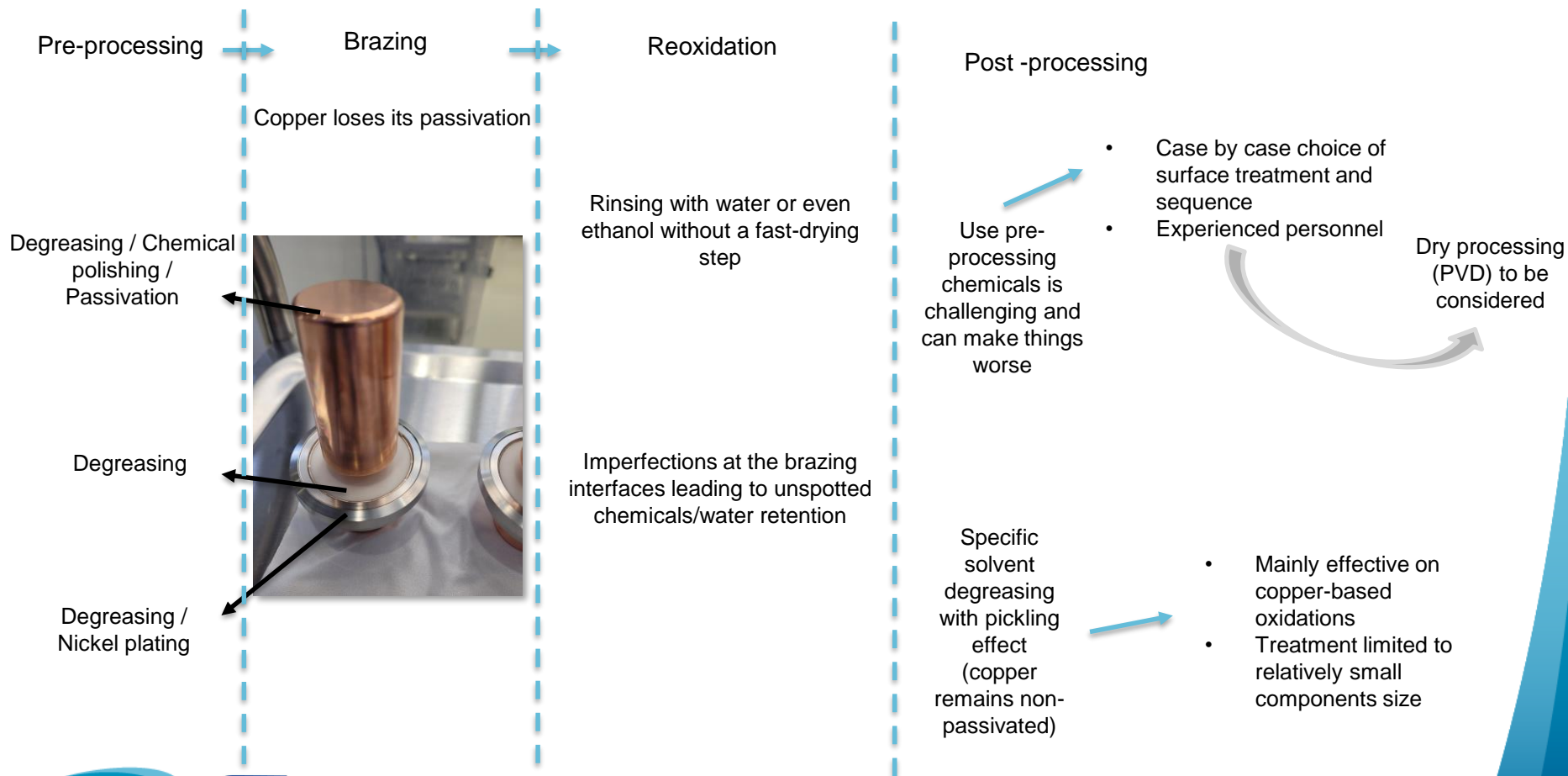




Spare slides

Surface treatment of assembled heterogenous materials is a challenge

Courtesy
Leonel Ferreira
(CERN)



Quality & Documentation

TRAVELLER HOM COUPLERS & FEEDTHROUGHS						N°WB - __
	CDD Number / Numéro CDD	Bld./ Lieu	Collaborator / Responsable	Signature	Date	Comments / Observations
Ceamic order number		112			__/__/20__	
Visual inspection of ceramic discs		112			__/__/20__	
Degreasing		107			__/__/20__	
Metalization / Mo/Mn 20-45 µm + Ni 5-10 µm					__/__/20__	
Visual inspection of ceramic discs		112			__/__/20__	
Metrology		AP			__/__/20__	
Machining Titanium flange (rough)		AP			__/__/20__	
Machining Copper part (finishing)		AP			__/__/20__	
Thermal stress relief treatment		107			__/__/20__	
Machining final Titanium flange (finishing)		AP			__/__/20__	
Etching flange + tube before brazing		107			__/__/20__	
Visual control before brazing		112			__/__/20__	
Vacuum brazing		112			__/__/20__	
Visual control after brazing		112			__/__/20__	
Ceramic n° engraving		112			__/__/20__	
Leak test		864			__/__/20__	
Sandblasting of ceramic		864			__/__/20__	
Metrology of antenna's height		AP			__/__/20__	
EB Welding of back pieces		AP			__/__/20__	
Visual control						
Metrology		100			__/__/20__	
Inspection finale SY-RF		864			__/__/20__	
Leak test / Contrôle d'étanchéité		864			__/__/20__	

Quality & Documentation

- Strong commitment from WP4 teams to fulfil HL-LHC quality standards
 - *MTF, EDMS, Non-Conformities Reports... but also technical documentation*
- 90+ assets to be followed-up, from materials traceability to all inspections and controls up to last steps. **Challenging but of paramount importance!**

Equipment Folder: Manufacturing Workflow

Equipment Identifier: HCACFHC002-CR000006
Other Identifier: None
Description: DQW HOM Couplers (Variant #2)

Main Made of Equipment data Manufacturing Operation Documents History Map

Actions: Add extra step

Workflow Diagram

No workflow diagram is defined for this equipment

Step	Id	Description	Status	Result	NC
1	0	Metrology Control before welding (HOOK Nb parts 1 and 2)	Accepted	Ok	
1.2	0	Welding inspection W10 (HOOK Nb parts 1 and 2)	Accepted	Ok	
1.3	0	Metrology Control after welding (HOOK Nb parts 1 and 2)	Cancelled		
2	0	Metrology Control before welding (DN63 Nb parts 4 and 5)	Cancelled		
2.1	0	Welding inspection W020 (DN63 parts 4 and 5)	Accepted	Ok	
2.2	0	Welding inspection W020 (DN63 parts 4 and 5)	Accepted	Ok	
2.3	0	Metrology Control after welding (HOOK Nb parts 1 and 2)	Cancelled		
2.4	0	Leak tightness test (DN63- Nb part 4-part 5-S.S flange)	Accepted	Ok	
2.5	0	Ultrasonic Inspection (*)	Accepted	Ok	
3	0	Welding inspection W050 (DN63: Nb part 4-5-flange - HOOK: Nb part 1-2-3)	Accepted	Ok	
4	0	Metrology Control before welding (DN35 Nb parts 6 and SS flange)	Cancelled		
4.1	0	Welding inspection W110 (DN35 parts 6 and SS flange)	Accepted	Ok	
4.2	0	Metrology Control after welding (DN35 Nb parts 6 and SS flange)	Cancelled		
4.3	0	ULTRASONIC INSPECTION (*)	Accepted	Ok	
5	0	TTH Bellows Stiffener	Done	Ok	
6	0	Welding inspection W120 (Bellow-DN35 Flange)	Accepted	Ok	
7	0	Welding inspection W080 (BODY parts 1 and 2)	Accepted	Ok	
8	0	Welding inspection W080-W090 (BODY-DN63 flange)	Accepted	Ok	
9	0	Welding inspection W080	Accepted	Ok	
10	0	Welding inspection W100 (BODY parts 182 and 3)	Accepted	Ok	
11	0	Welding inspection W130 (DN63 part 5-DN35 part 6)	Accepted	Ok	
12	0	Leak tightness test W130 (DN63 part 5-DN35 part 6)	Cancelled		
13	0	Visual inspection W140 (Bellow-BODY part 4)	Accepted	Ok	
14	0	Final Metrology control (HOM)	Cancelled		
15	0	Final leak tightness test (HOM) (*)	Accepted	Ok	
15.1	0	Flash BCP	Accepted	Ok	
16	0	Manufacturing and inspection plan (record)	Accepted	Ok	
17	0	Welding Book (record) (*)	Accepted	Ok	

CERN Accelerating science

EDMS Home Favourites Inbox Caddie

Navigator

CERN-0000181778 Public access
DQW Crab Cavities Cryomodule (LHC)

No active tags.

Crab Cavities & RF (WP4)

- Deliverables
- Milestones
- Activity Reports
- Other
- Internal doc (temp)
- Minutes
- Presentations
- Administration
- RF Parameters
- Links for the collaborations WP4
- LHC Crab Cavities Cryomodule
 - Engineering drafts & notes
 - DQW Crab Cavities Cryomodule (LHC)
 - RFD Crab Cavities Cryomodule (LHC)
 - External Supports
 - WP4 Interfaces
 - Transport
 - LHC-ACF_AE-ES-0001 (v.1.0) Engineering S
 - 2043016 (v.0.1) HL-LHC LHC CRAB CAVITE
 - 2113974 (v.1) HL-LHC LHC CRAB CRYOMO
 - 2156301 (v.1) HL-LHC LHC CRAB CRYOMC
 - 2210316 (v.1.0) Sizing of release orifice for
 - Fabrication, Assembly and Verification drafts & notes
 - DQW Crab Cavities Cryomodule (LHC)
 - RFD Crab Cavities Cryomodule (LHC)
 - External Supports
 - Installation & Commissioning drafts & notes