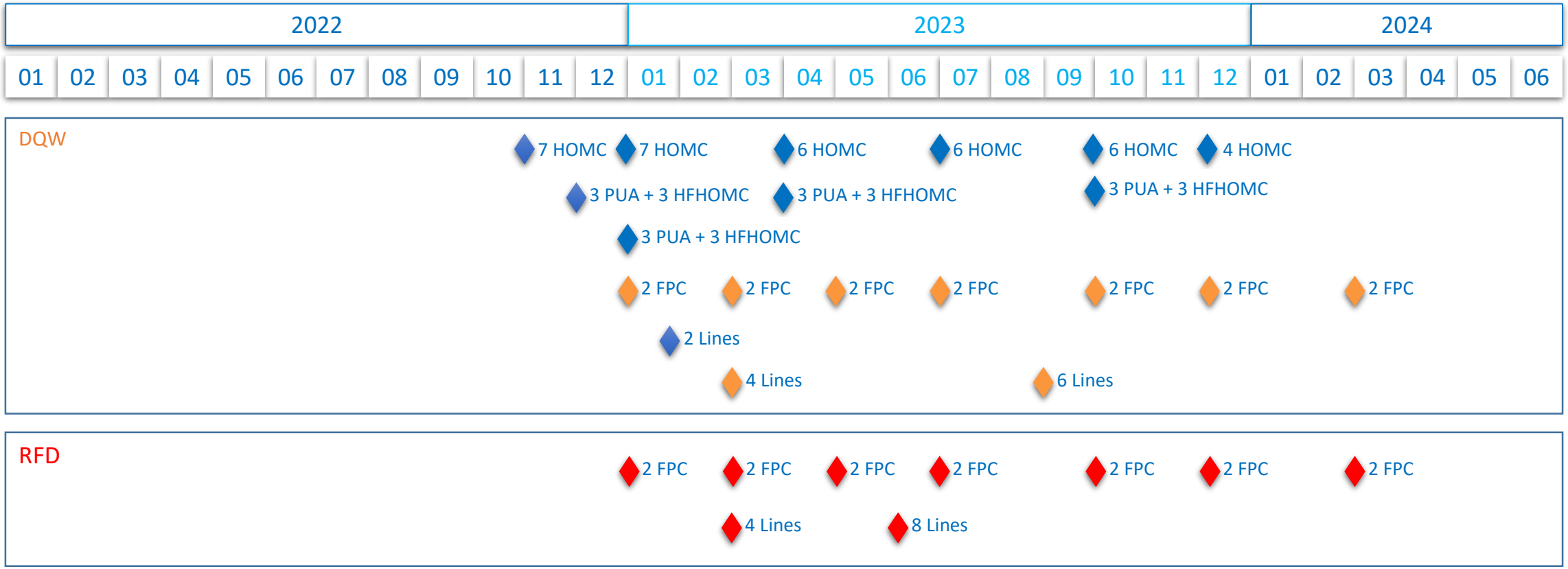
DQW Couplers fabrication & status

eric.montesinos@cern.ch, on behalf of all colleagues involved, a huge thanks to all of them

12th HL-LHC Collaboration Meeting, Uppsala, Sweden, 19-22 September 2022

Couplers master schedule (Sept 2022)

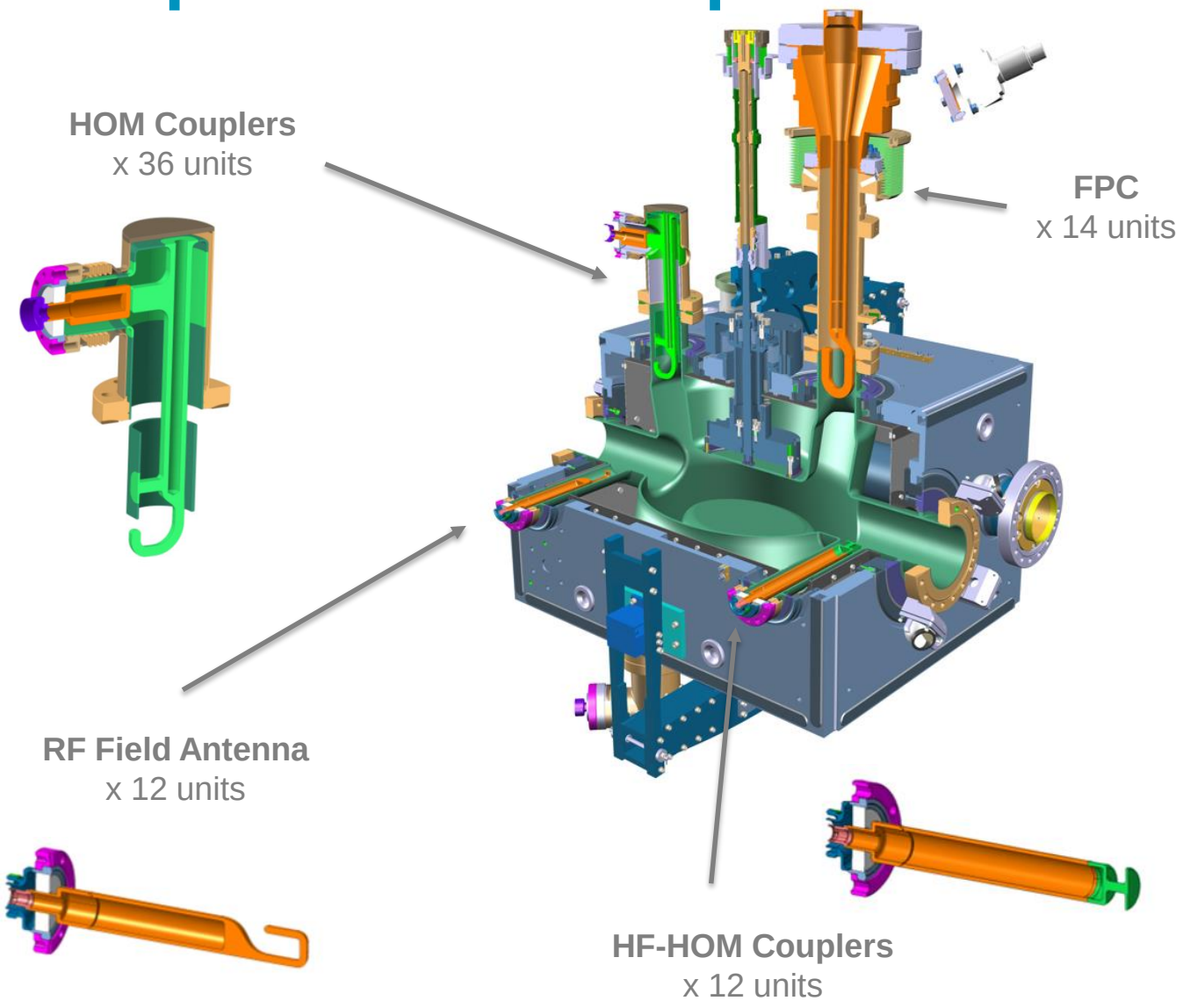
- Delivered CERN
- Delivered UK
- Delivered Canada



DQW couplers production scope

HOM Couplers, Feedthroughs, Field Antennas HF-HOM and FPC for **all LHC-series DQW crab cavities** are being manufactured at CERN Main Workshop,
i.e. quantities for 8 cavities including spares

Beautiful items, at the state of the art, and even beyond that…

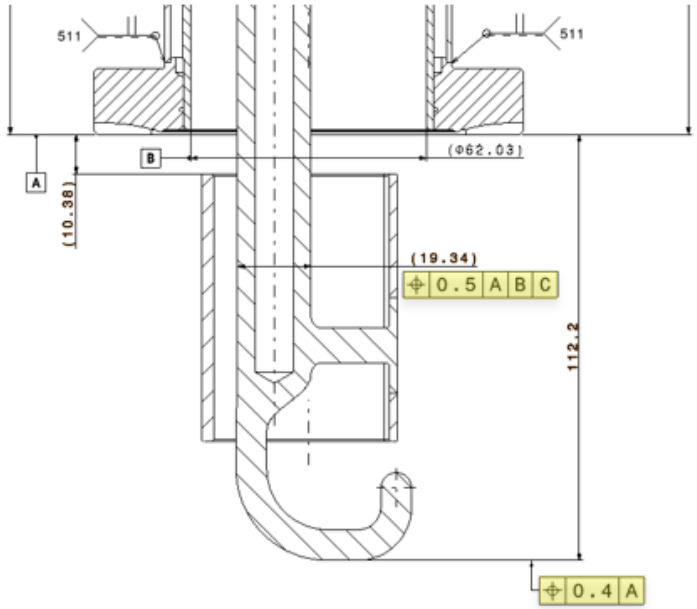


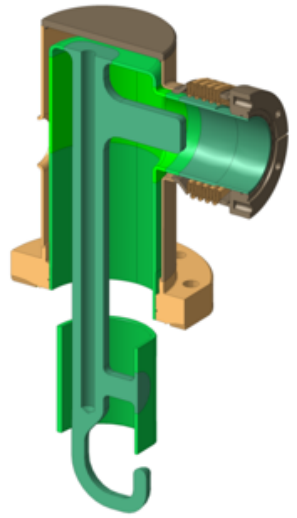
Design Specificities & Challenges

SRF performance highly dependant on geometry and surface quality
- Final tolerances in few tens of millimetres after many assembly steps
- Machined and welded RF surfaces, specific parameters

RF ancillaries are made of specific and expensive materials
- Extra-pure niobium, OFE copper, titanium grade 23 (TA6V ELI), stainless steel 316LN

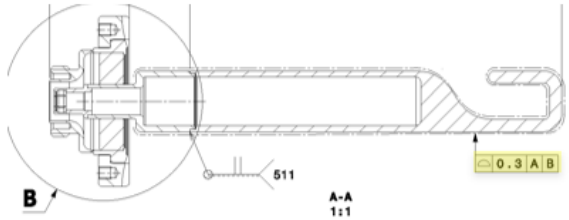
Fabrication process definition & follow-up
- Complex intertwining of techniques with high added-value subcomponents
- Multiple activities and actors in parallel in different groups
- Advanced follow-up to fulfil HL-LHC quality standards
- PED-related normative, MTF steps, traceability





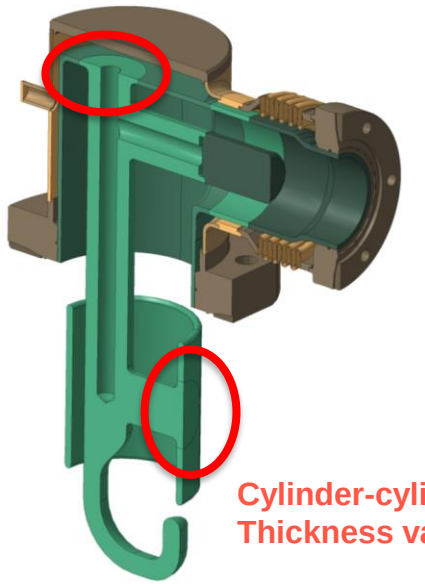
DQW HOM Coupler

DQW RF Antenna

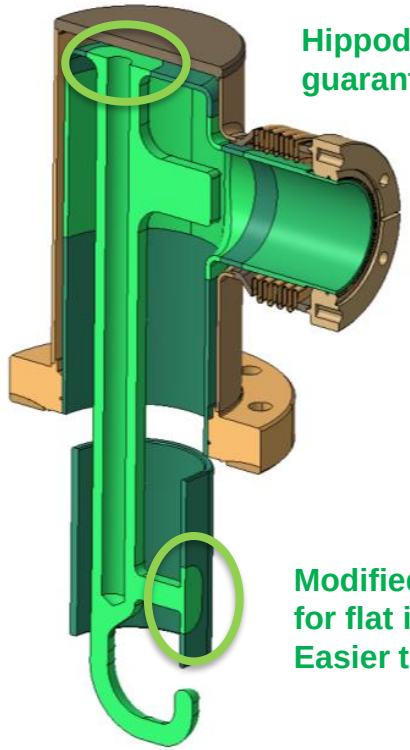


From Prototypes to Series Production

Many lessons learned thanks to DQW & RFD prototypes programmes
Design changes and geometry optimization have been implemented to ease assembly processes



SPS-DQW HOM Coupler



LHC-DQW HOM Coupler

Raw material procurement

316LN stainless steel, OFE copper

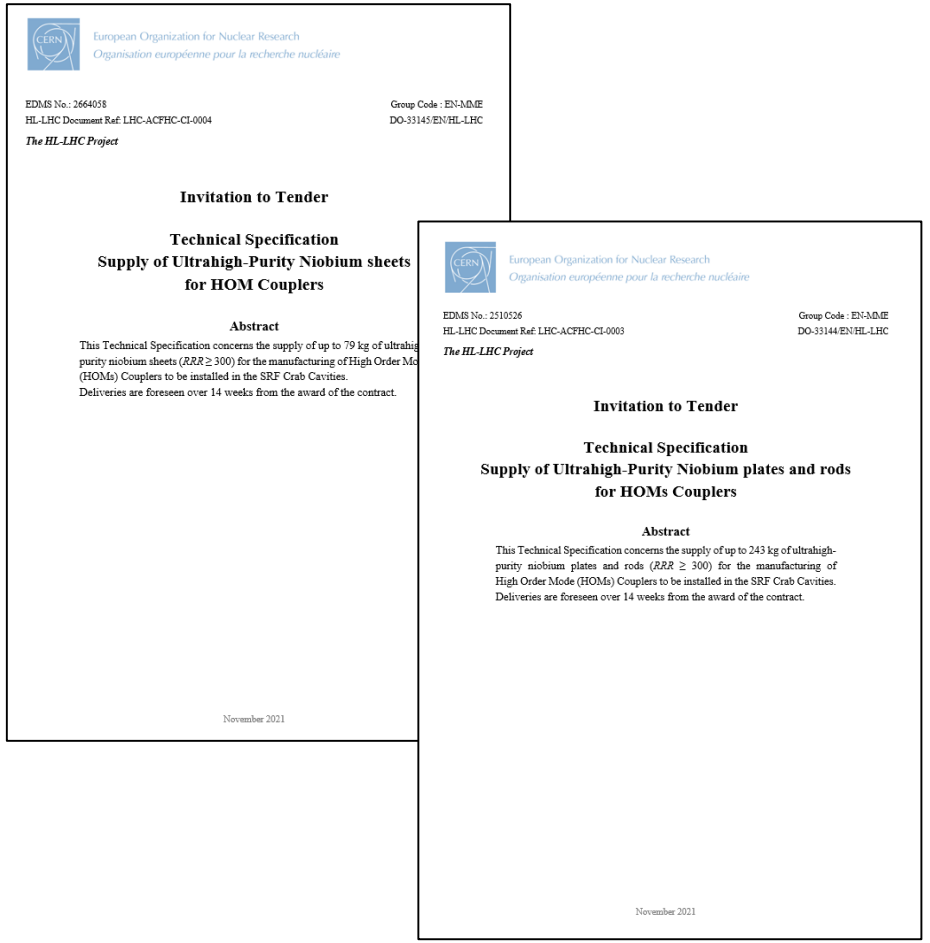
- CERN “standard” materials, no shortages expected as of today (procurement anticipated, thanks to MME colleagues)

Titanium Grade 23

- Received and available for remaining production

RRR300 Niobium

- 320 kg of ordered in 2021 (rods, plates, sheets)
- Delivery partially delayed due to many circumstances until Q4-2022, but should not impact delivery of “pre-series” DQW-HOM couplers (for 4 cavities)



European Organization for Nuclear Research
Organisation européenne pour la recherche nucléaire

EDMS No.: 2664058 Group Code : EN-MME
HL-LHC Document Ref: LHC-ACFHC-CI-0004 DO-33145/EN/HL-LHC
The HL-LHC Project

Invitation to Tender

Technical Specification
Supply of Ultrahigh-Purity Niobium sheets for HOM Couplers

Abstract

This Technical Specification concerns the supply of up to 79 kg of ultrahig purity niobium sheets (*RRR* ≥ 300) for the manufacturing of High Order Mo (HOMs) Couplers to be installed in the SRF Crab Cavities.
Deliveries are foreseen over 14 weeks from the award of the contract.

November 2021

European Organization for Nuclear Research
Organisation européenne pour la recherche nucléaire

EDMS No.: 2510526 Group Code : EN-MME
HL-LHC Document Ref: LHC-ACFHC-CI-0003 DO-33144/EN/HL-LHC
The HL-LHC Project

Invitation to Tender

Technical Specification
Supply of Ultrahigh-Purity Niobium plates and rods for HOMs Couplers

Abstract

This Technical Specification concerns the supply of up to 243 kg of ultrahigh-purity niobium plates and rods (*RRR* ≥ 300) for the manufacturing of High Order Mode (HOMs) Couplers to be installed in the SRF Crab Cavities.
Deliveries are foreseen over 14 weeks from the award of the contract.

November 2021

RF Field Antennas status

Bulk-machined OFE copper hook welded to a “standard” 25 Ω RF brazed feedthrough

Brazed feedthrough with EBW RF clamp

EB weld tooling for last weld

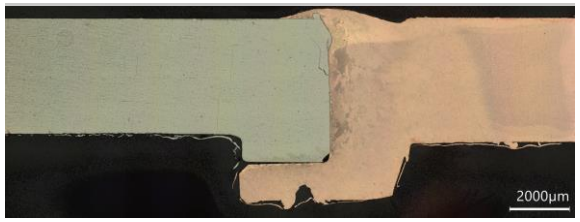
Final assembly

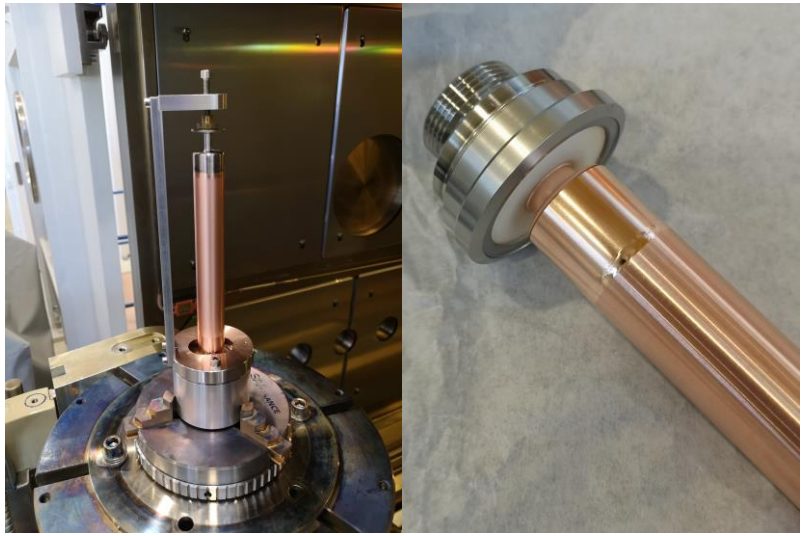
3 x Field Antennas fully assembled, metrology ongoing, remaining 9 x units under last assembly phases

HF-HOM couplers status

New process for Niobium-Copper welds fully qualified

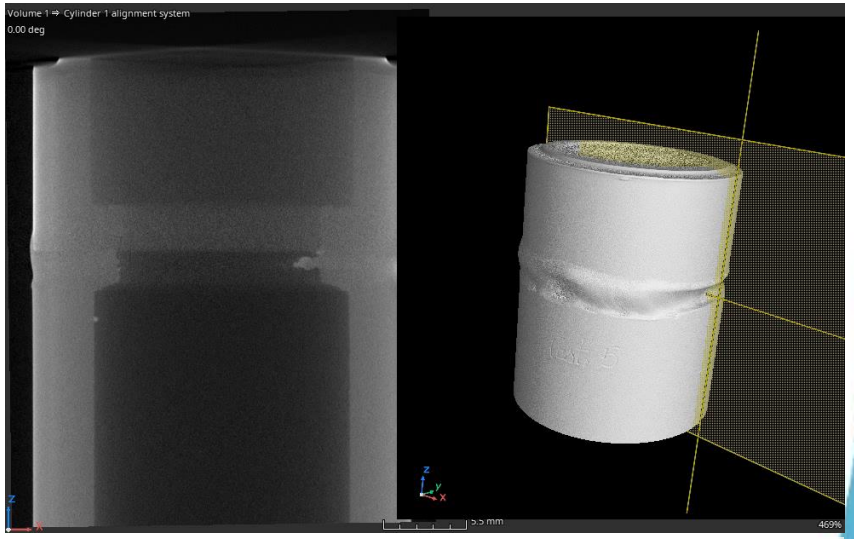
Macrograph





Final EB weld

Metrology before final assembly



X-rays µ-computed tomography

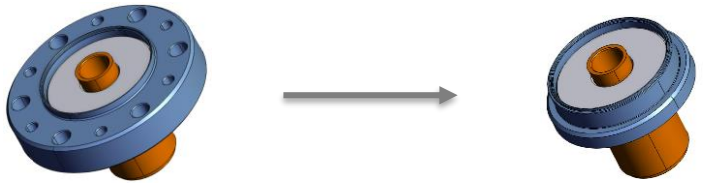
3 x HF-HOM couplers fully assembled, metrology ongoing, remaining 9 x units under last assembly phases

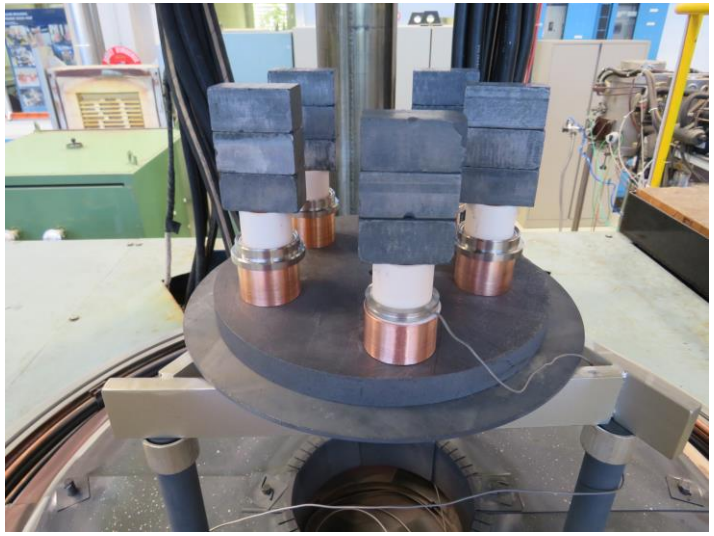
Feedthroughs status

Robust design fully qualified for series production

Fixed flange (too high strains)

Rotatable flange (much less strains)





Vacuum brazing

Vacuum brazed

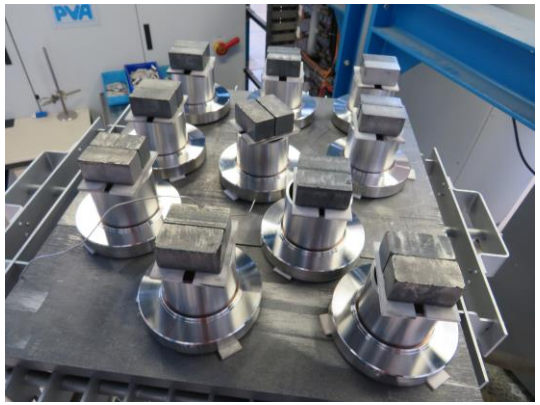
EB weld of RF clamp

6 x HOM feedthroughs fully assembled, metrology ongoing, remaining 9 x first set under last assembly phases

Production of 21 x second set already started

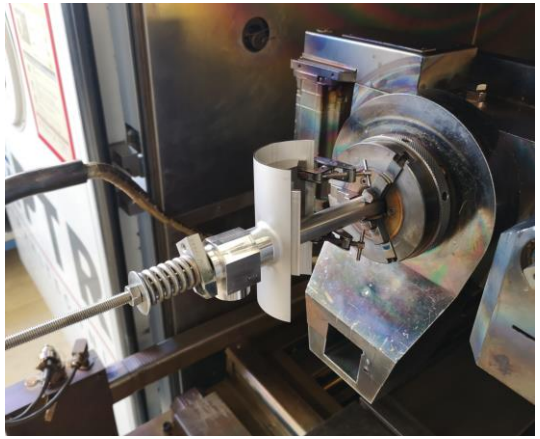
HOM couplers status

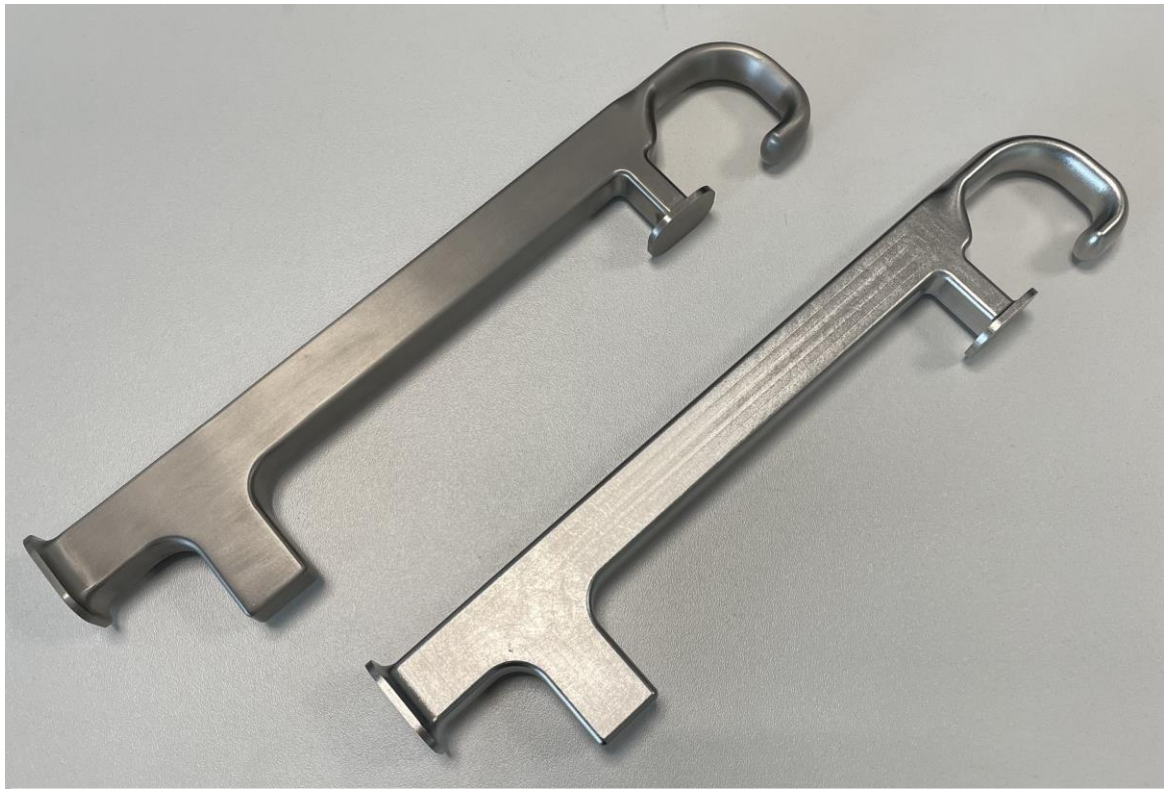
Recent developments for hook machining & drilling (200 mm in Nb!), 15+ electron-beam welding steps



Vacuum brazing St. Steel to Nb

Stainless Steel jacket welding



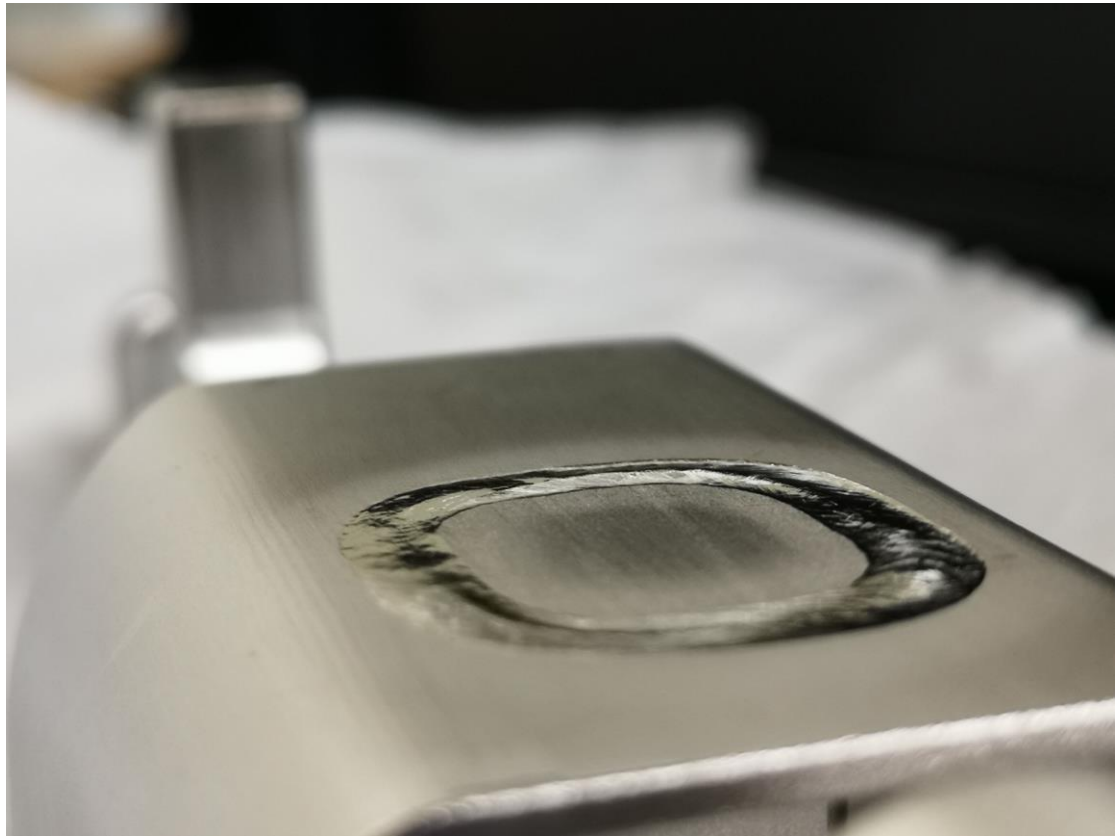


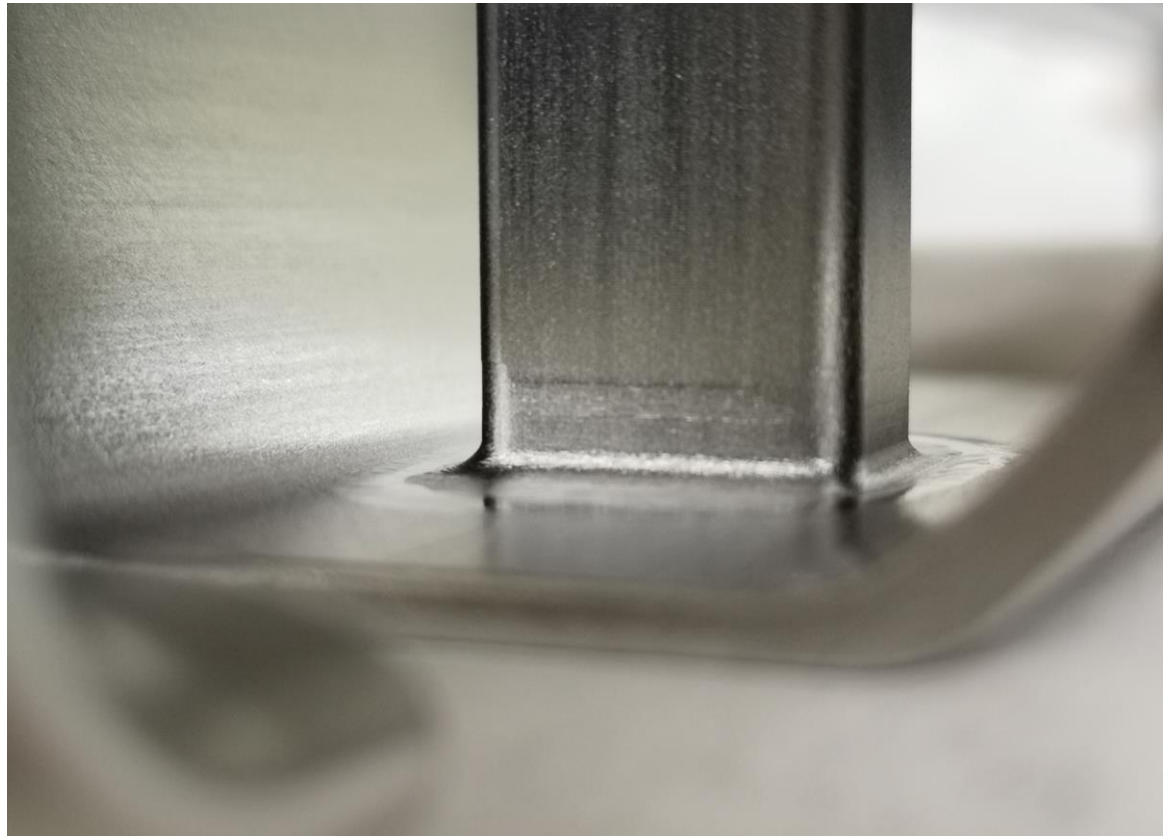
Nb machined Hooks (before and after BCP)

Nb Body with brazed 316LN flange

EB Weld Hook to Nb Collar

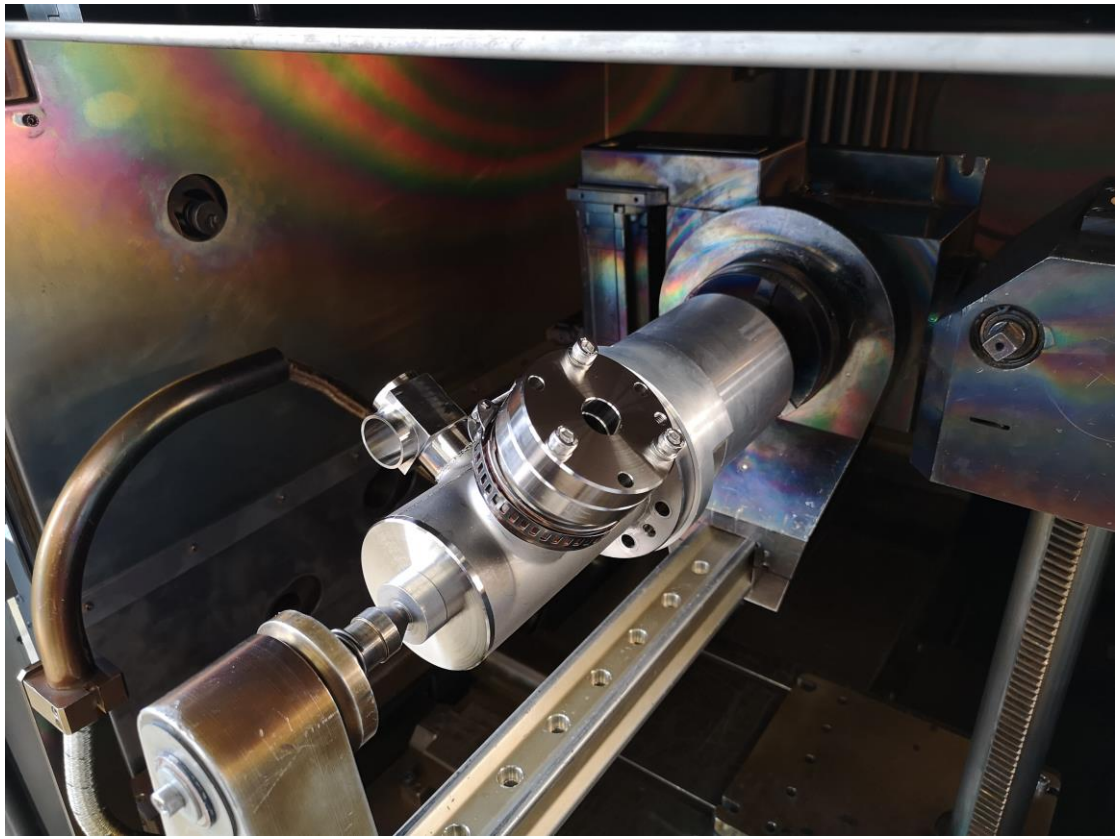
HOM couplers status



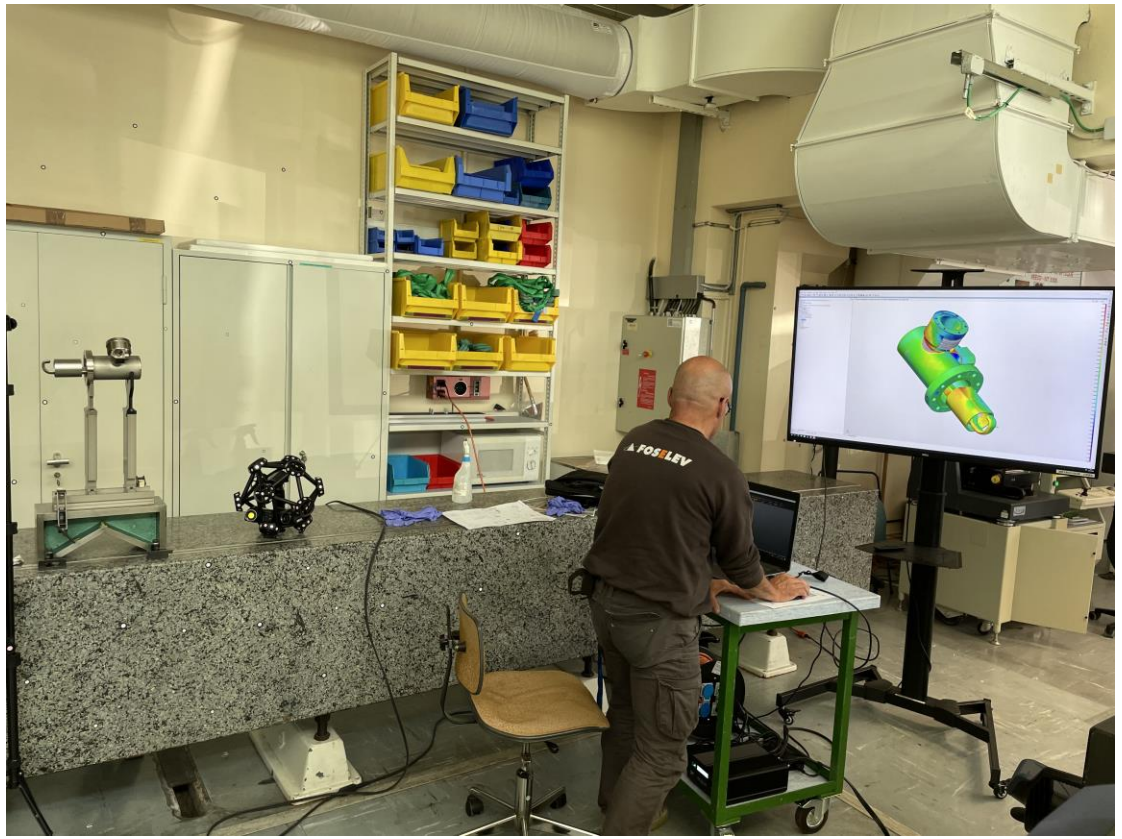


Hook weld of the highest quality

HOM couplers status

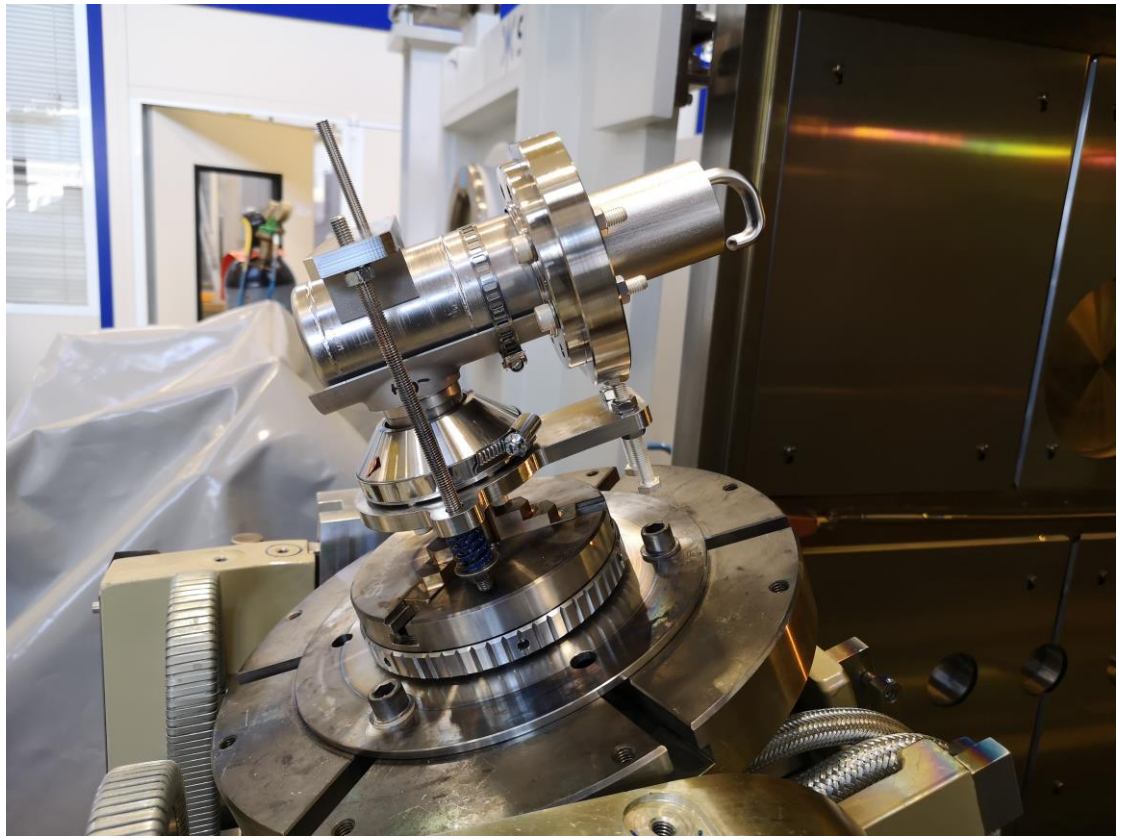


Final EB weld to close helium vessel

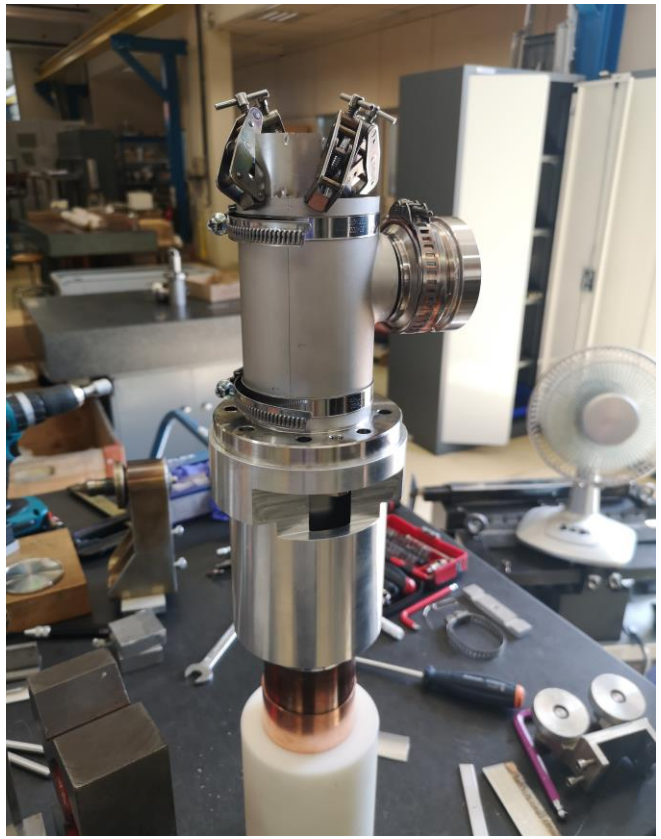


3D-scan of final assembly

HOM couplers status



EB weld of DN40 extremity



Welding tool for helium vessel assembly

HOM couplers

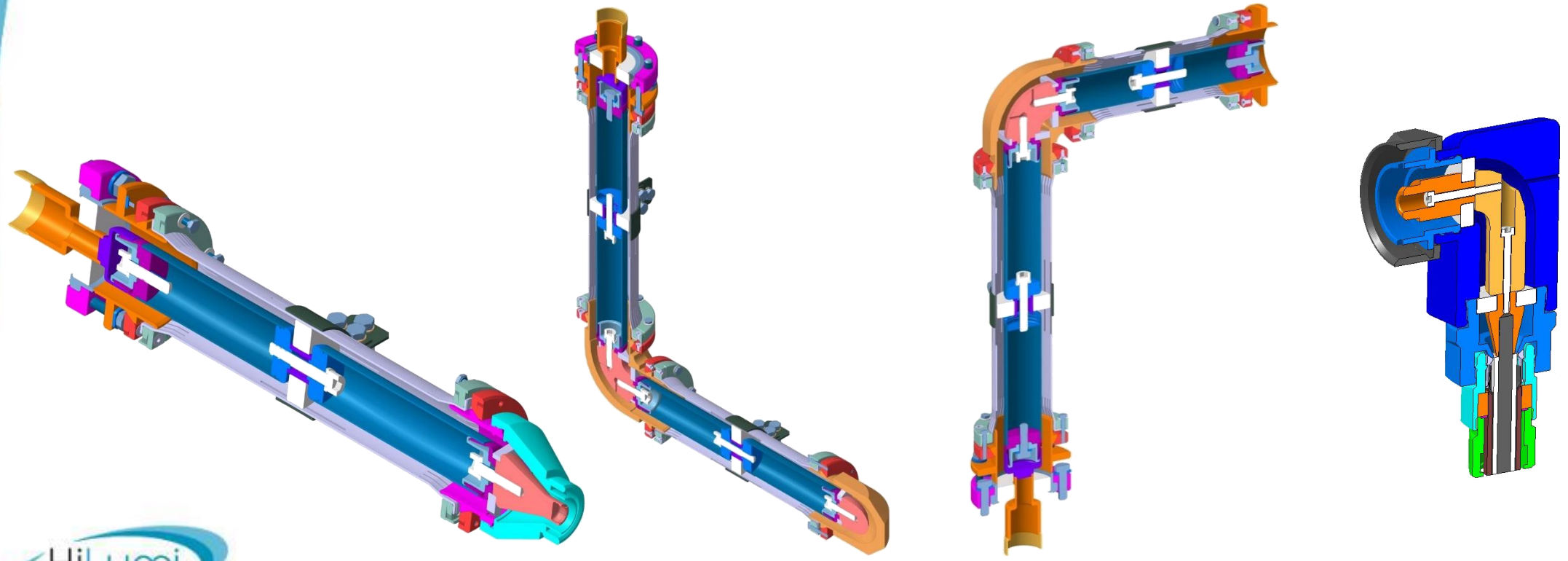
8 x HOM couplers fully assembled and ready for installation,
remaining 7 x first set under last assembly phases
Production of 21 x second set already started

RF lines status

We simplified the external tube from 3 parts to 1 part

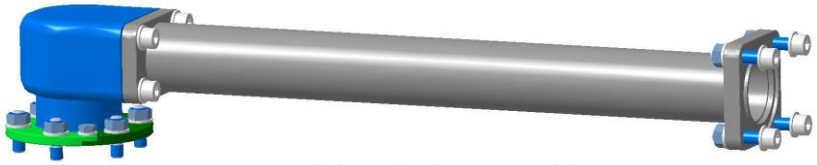
We also improved the conductivity of the line without changing the thermal transmission by the application of a copper coating on the internal side of the external line and the external side of the internal line

The new 25 Ω 90 degrees elbow, connecting the cables to couplers are machined in copper, bronze, and Shapal, then surface treated with silver-plating, these are small parts with hard-to-machine internal shapes and fine tolerances

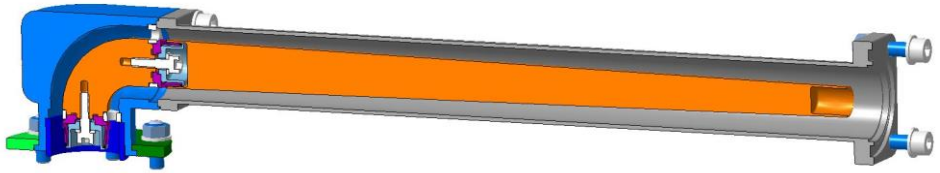


Cryomodule exit line status

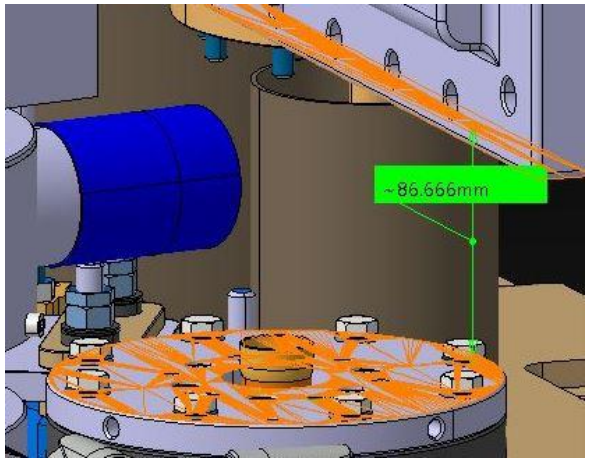
In order to connect the “air-side” to the Feedthrough of the internal RF lines we need to change the impedance from 25 Ω to 50 Ω, same challenges, machined in copper, bronze, stainless steel, and Shapal and then surface treated with silver-plating , and hard-to-machine internal shapes and fine tolerances



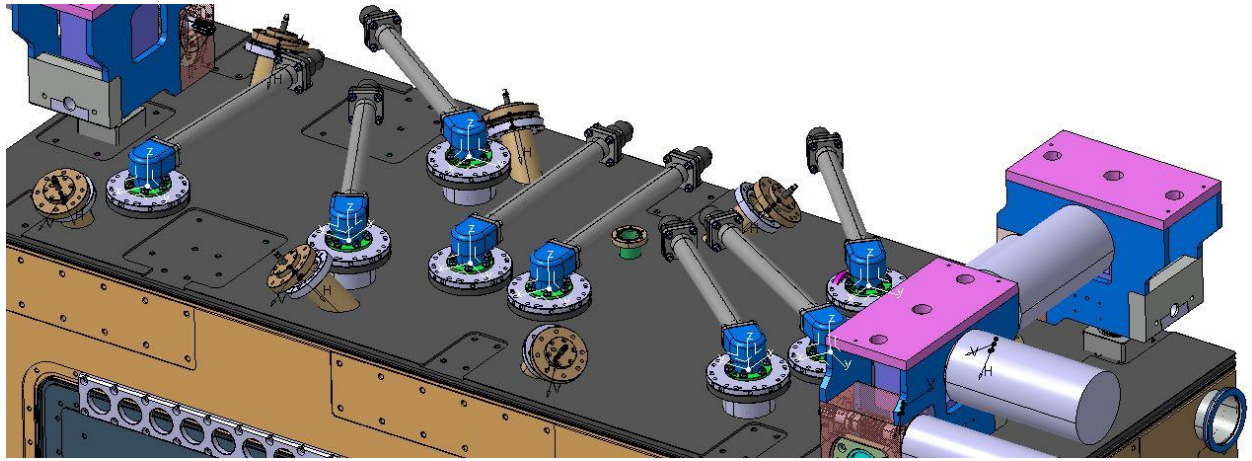
Cryomodule Exit Line assembly



Cryomodule Exit Line assembly cross-section

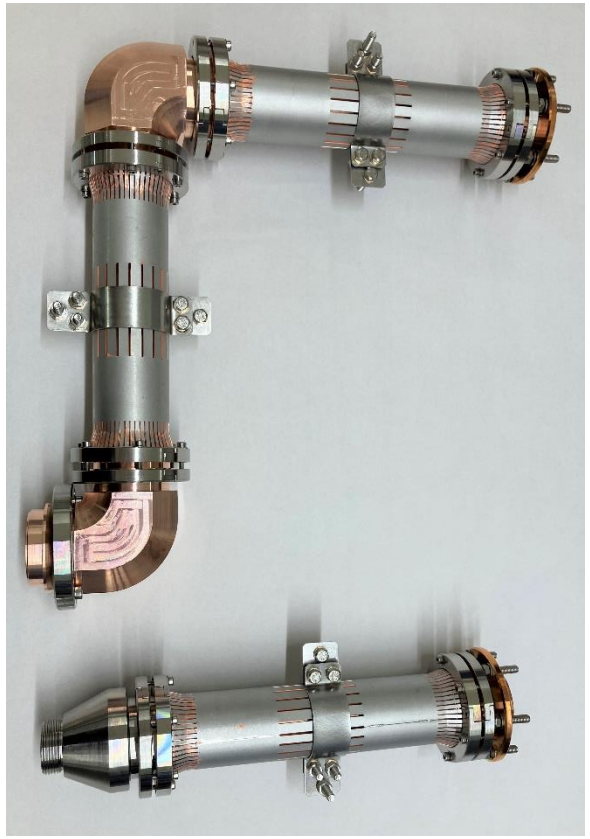


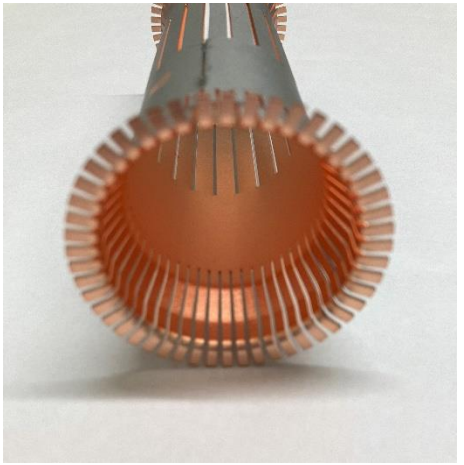
Limited space (86.6mm)



Bottom side DQW (8 lines)

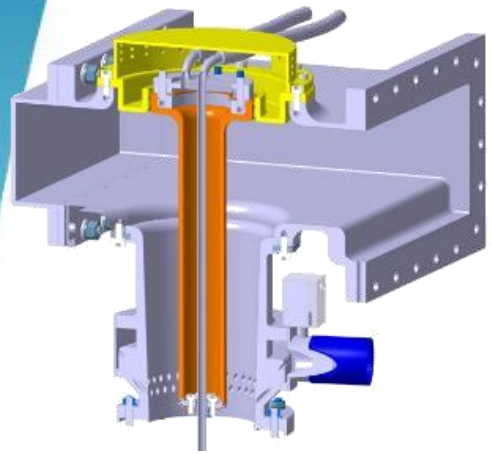
RF lines status



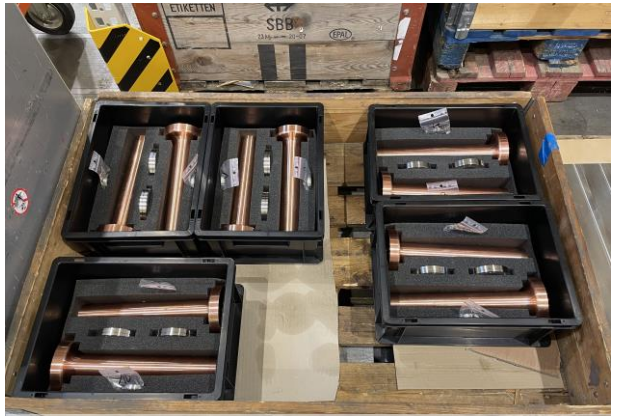


6 x DQW lines fully assembled and ready for installation,
remaining 6 x DQW lines under last assembly phases

Fundamental Power Coupler (FPC)

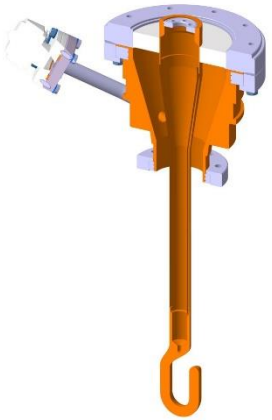


Vacuum brazing of FPC main vacuum bodies

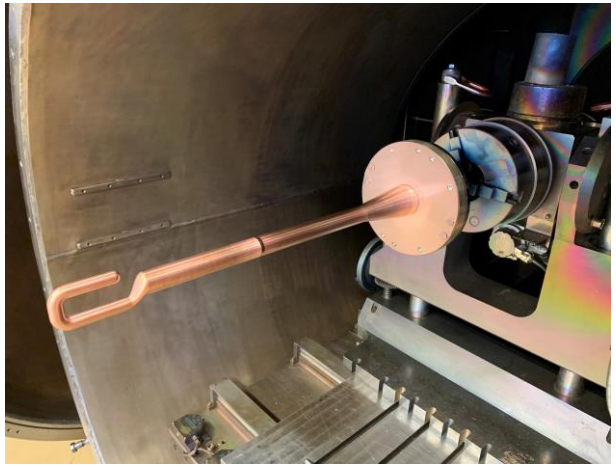


Water cooled inner antennas

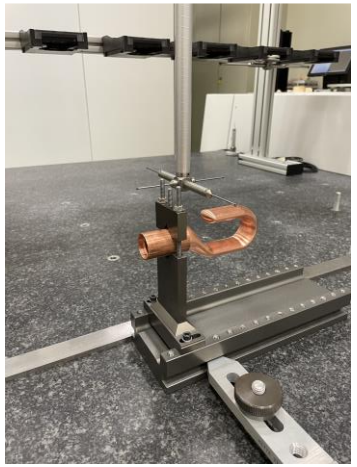
DQW & RFD air side



Final EB weld of FPC coupler's antenna



Metrology of DQW hooks



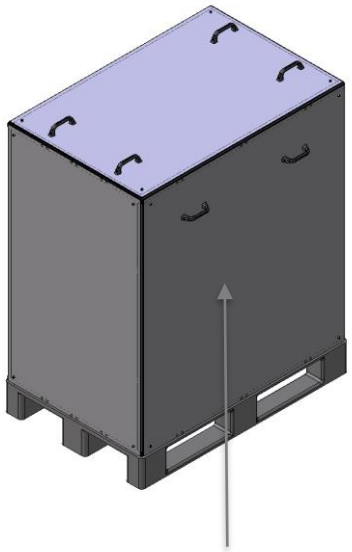
DQW FPC antenna

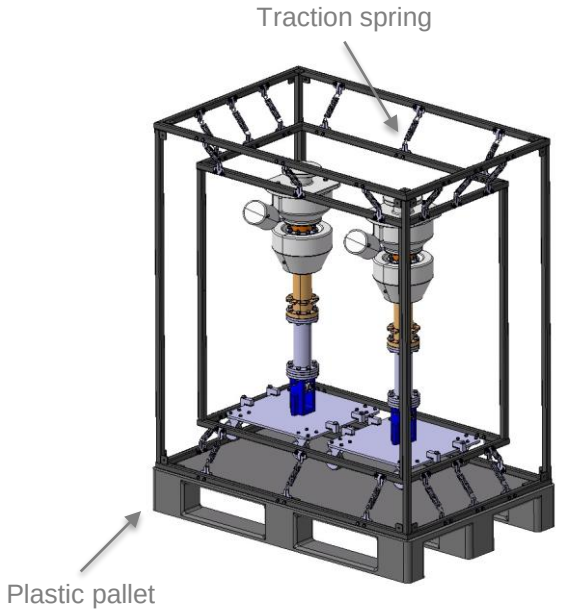
5 x DQW and 5 x RFD couplers ready for assembly and then RF conditioning

Remaining 9 x and 9 x couplers under last assembly phases

Metallic transport boxes

The transport box of the FPC (no wood) has been designed to reduce the vibration given to the FPC vacuum chamber by having some traction springs that absorbs the force from all directions

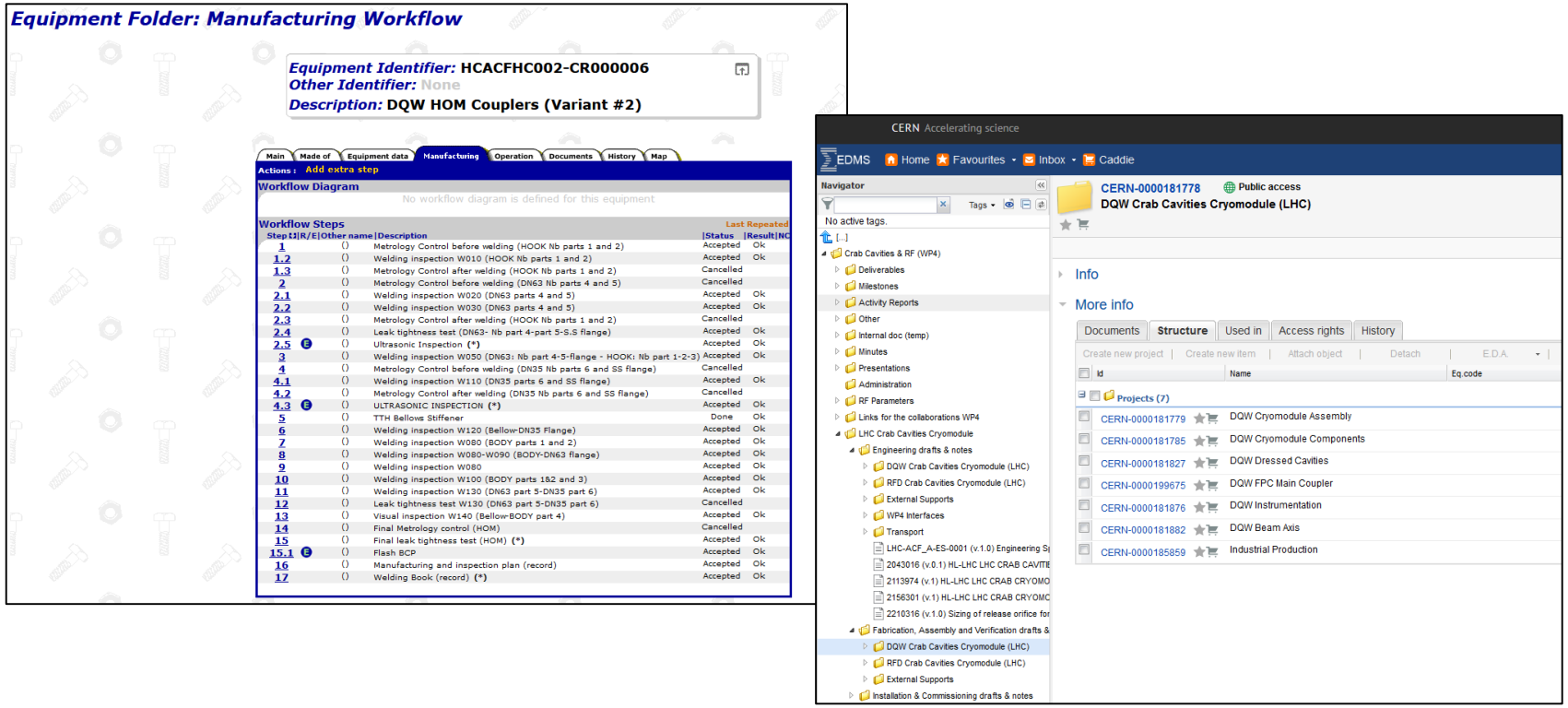




Quality & Documentation

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! (especially in case of difficulties)



Lessons learned

Many techniques intertwined

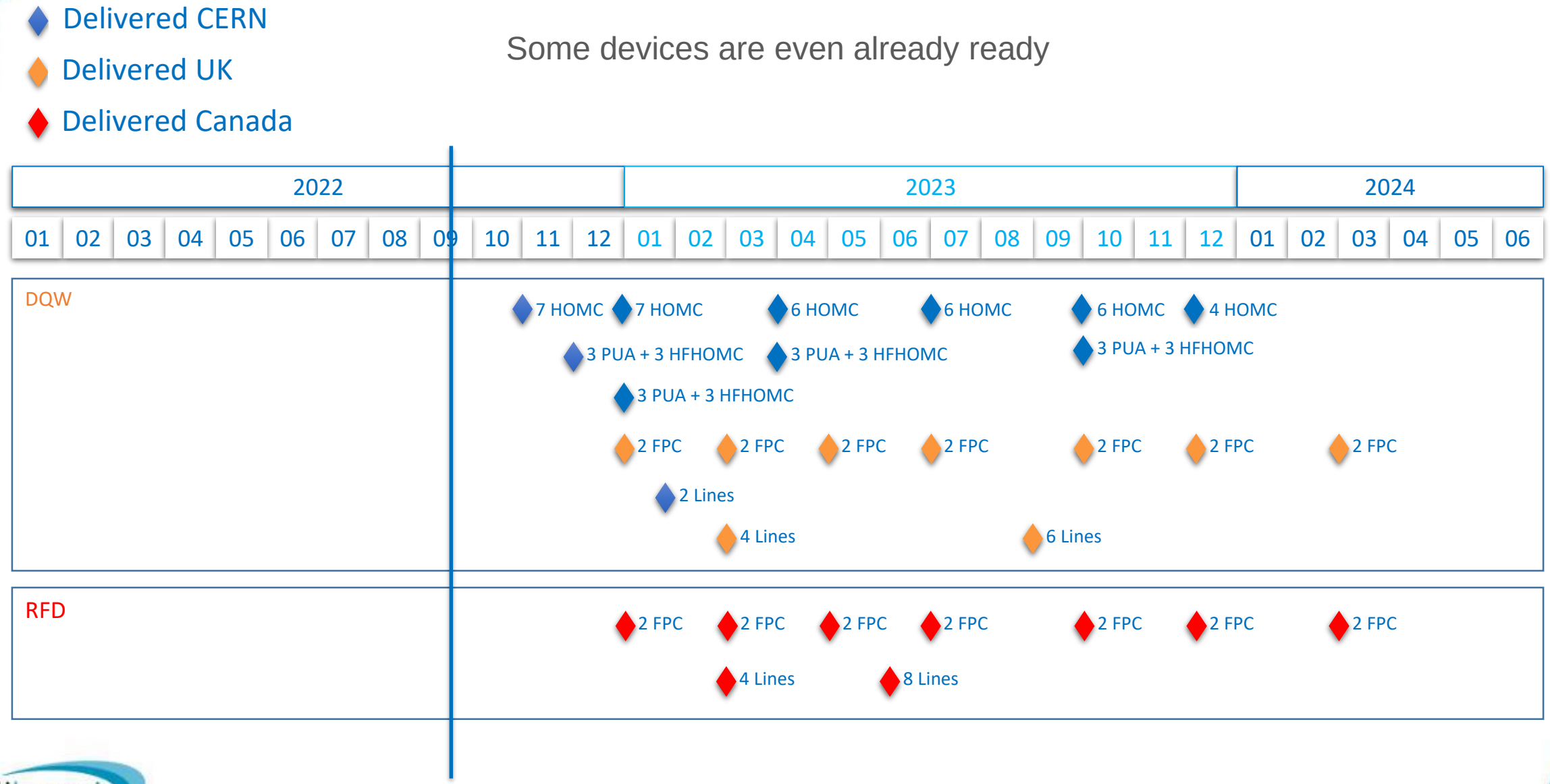
- advanced coordination and follow-up for fabrication, but also for all related services, such as NDT, metrology, chemistry, …

Fragile and high added-value components require specific processes for handling and storage, especially for series production

Additional constraints for logistics, packaging, transport… to be tackled as soon as possible

Conclusion: we are on track!

Some devices are even already ready



RF power stations (RFPS)

Given the international situation, we decided to go for IOT stations, our first baseline

- Shortage of solid state devices
- Obsolescence is too quick with transistors, especially LDMOS
- Thales, our IOT provider, agreed to guaranty 10 years of production

We still have to work out the linearity at low power, we plan 3 directional couplers spaced $\lambda/6$ to get rid of directivity with reflection, …

We are working an option to have IOT stations provided by an In-Kind from Japan

All RF power lines, circulators and loads, and waveguides would also be covered by this In-Kind

More news to come soon…

They did not know it was impossible… so they did it
[Mark Twain]

Thanks to Rama and Ofelia (WP4 leaders), to RF management, to SY management and to HL-LHC management for supporting us all along despite the difficulties encountered

Special thank to Sebastien, (Said, now MME Group Leader), Marco (taking over after Said) and Simon for managing this project

Thanks to all SY-RF-AC team and to all MME colleagues involved

We are not at the state of the art level, we are defining the new state of the art in many domains!

(I am so proud working with such fantastic teams, thank you very much)