9th HL-LHC Collaboration Meeting, Fermilab, USA
14-16 October 2019

WP4
HOM Couplers, Field Antenna and Feedthroughs Status
(& FPC and Outer Tube)

eric.montesinos@cern.ch
on behalf of all persons involved

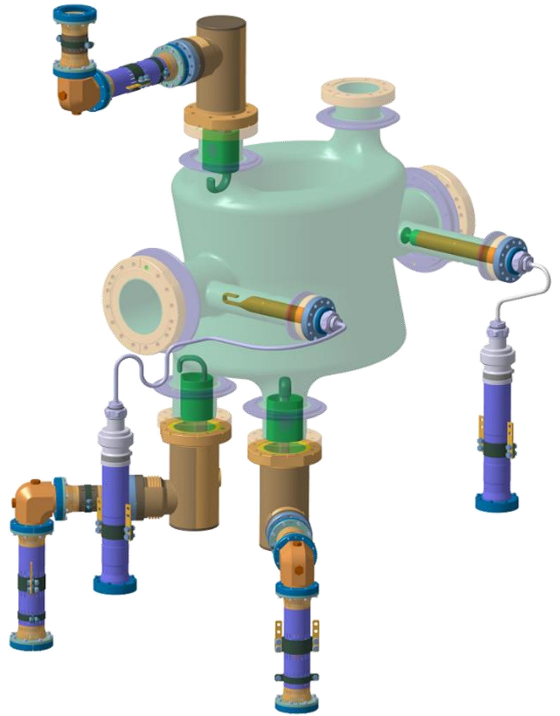
Preamble

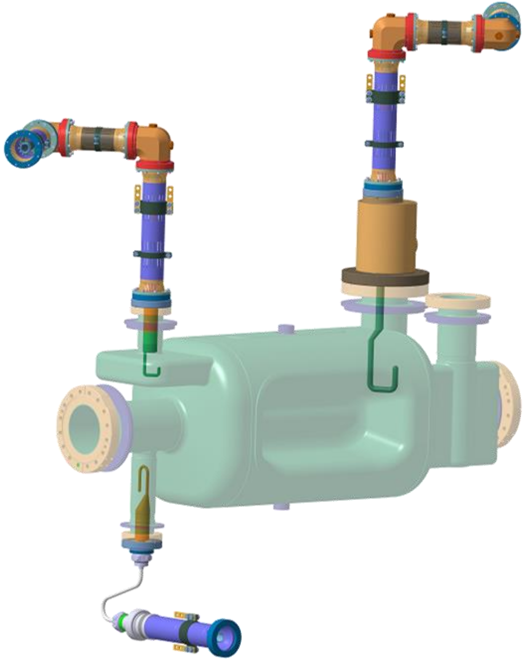
We have a (almost) weekly vidyo meeting with US-AUP colleagues

This presentation summarizes (almost all) what is discussed there

This is the view from the CERN side of it

HOM couplers, Field Antennas, RF power lines

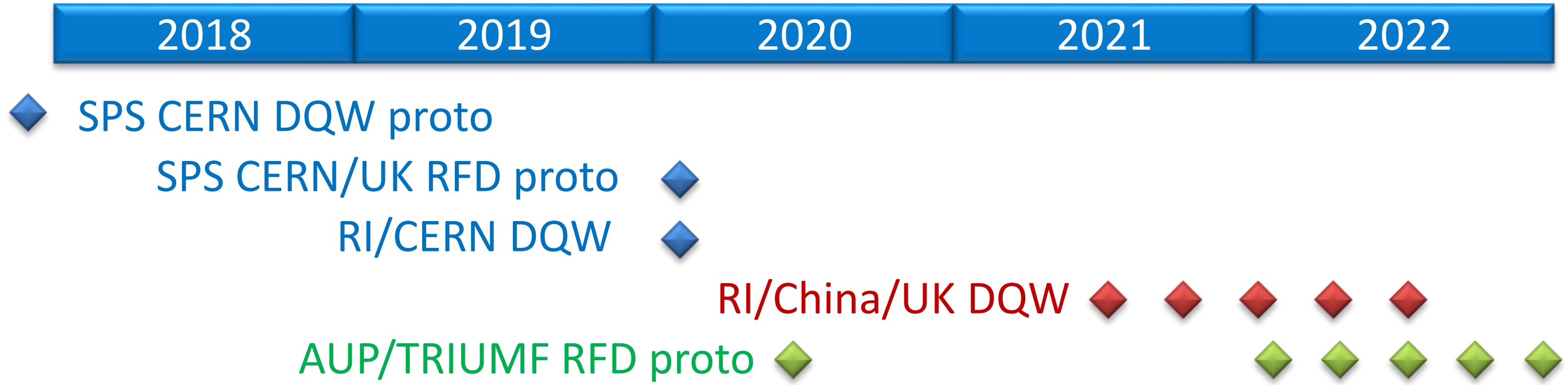




Schedule as per end 2018

To be provided by CERN

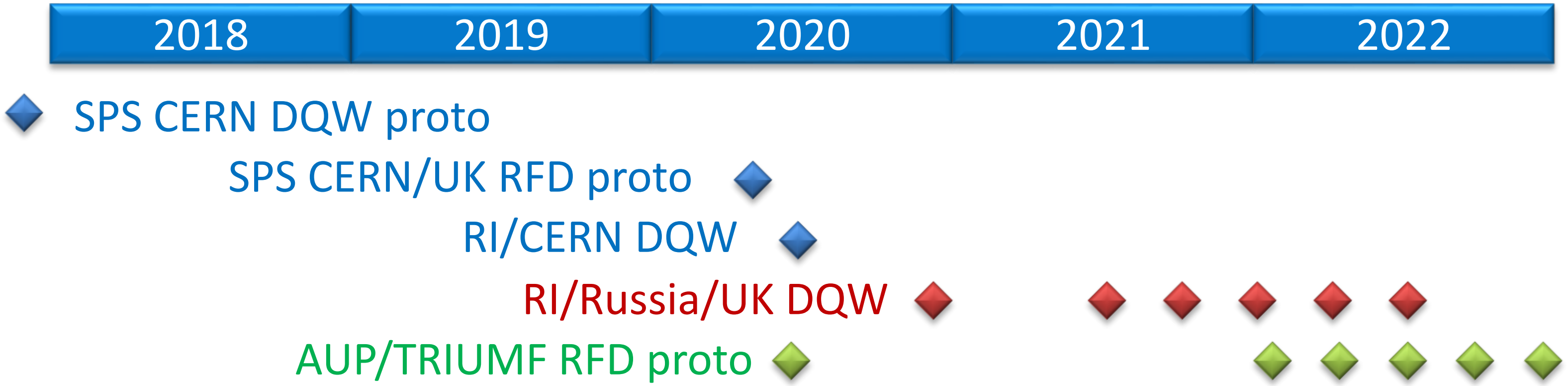
- Lines + Feedthroughs + Antennas + HOM couplers (blue)
- Lines (red)
- Lines (green)



Schedule as per September 2019

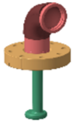
To be provided by CERN

- Lines + Feedthroughs + Antennas + HOM couplers (blue)
- Lines + all Feedthroughs (red)
- Lines (+ all Feedthroughs? to be decided) (green)



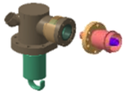
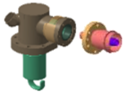
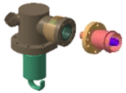
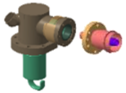
Schedule as per end 2018

2019	2020	2021	2022

3 RFD V — 2 (+1) x 

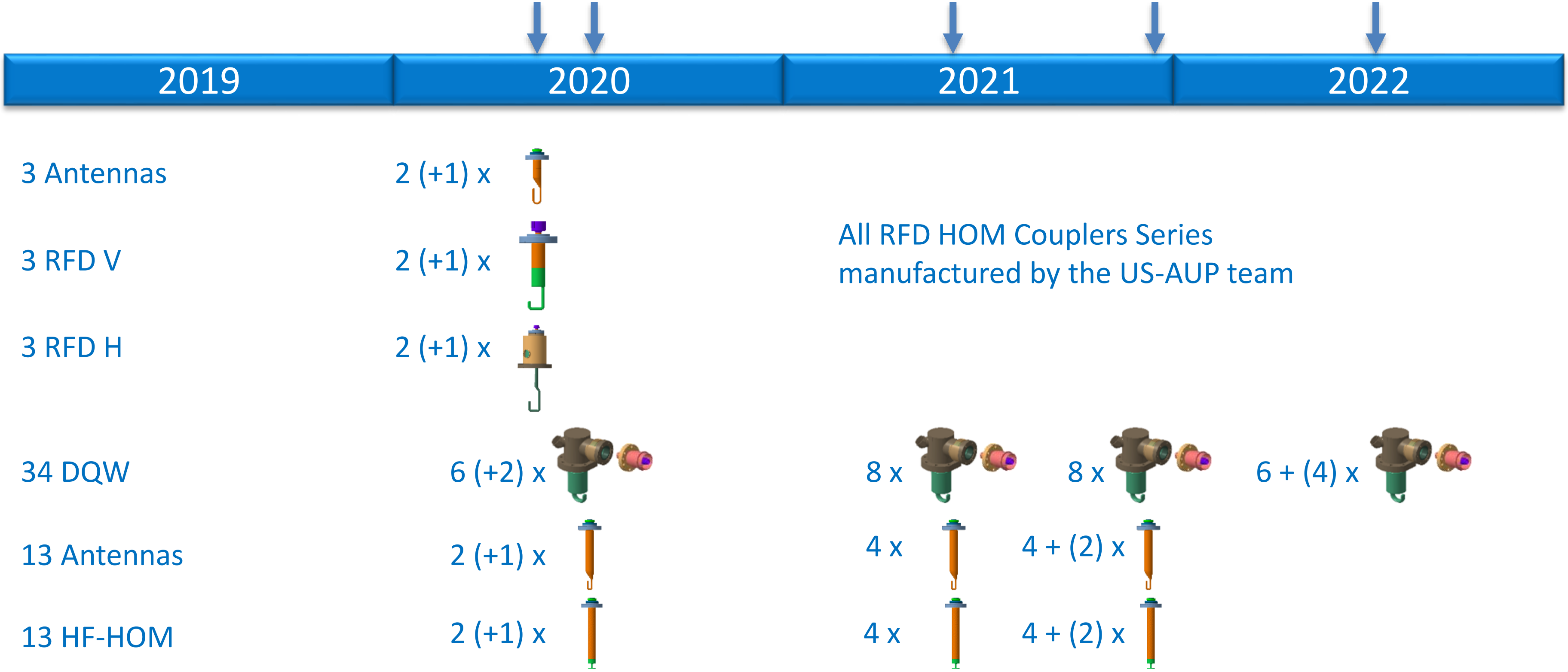
3 RFD H — 2 (+1) x 

All RFD HOM Couplers Series manufactured by the US-AUP team

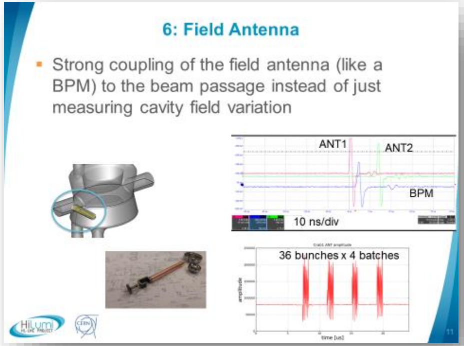
34 DQW — 6 (+2) x  — 8 x  — 8 x  — 6 + (4) x 

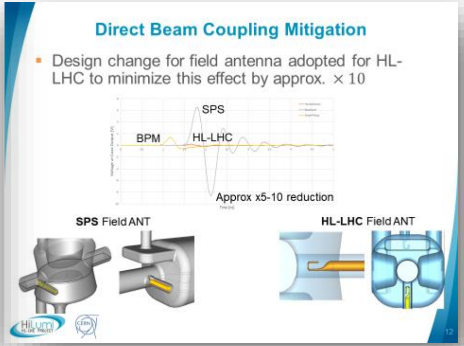
26 Antennas — 6 (+2) x  — 10 x  — 6 + (2) x 

Schedule as per September 2019



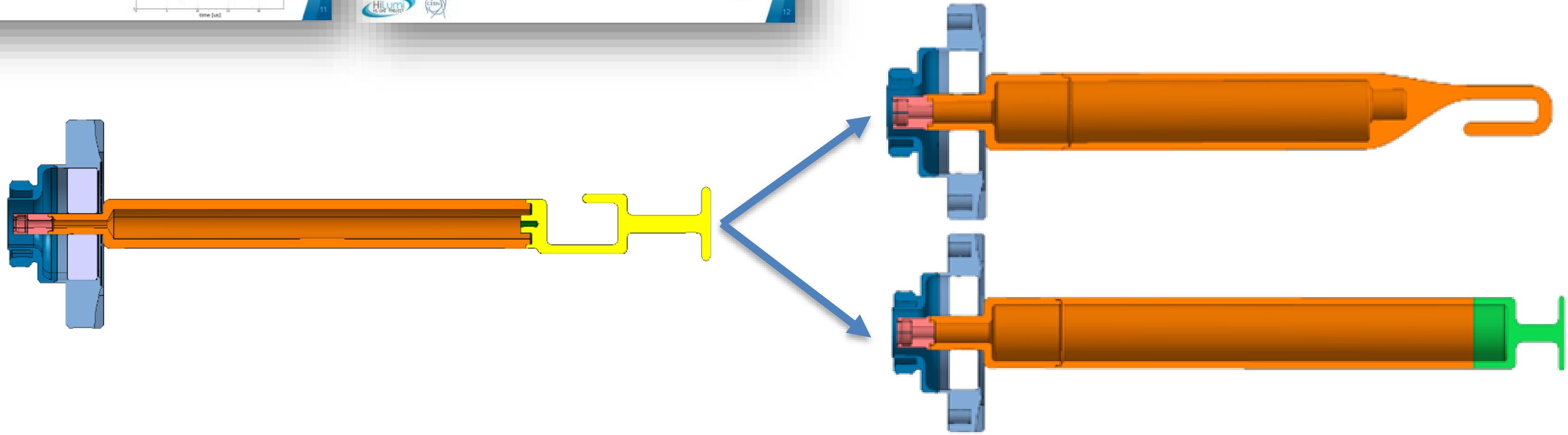
Field Antenna & HF HOM coupler



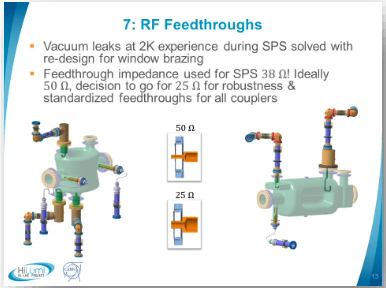


As Rama explained yesterday, we are 'concern #6'

To solve it we had to move from 'all in one Field Antenna & HF HOM' to one Field Antenna & one HF HOM coupler



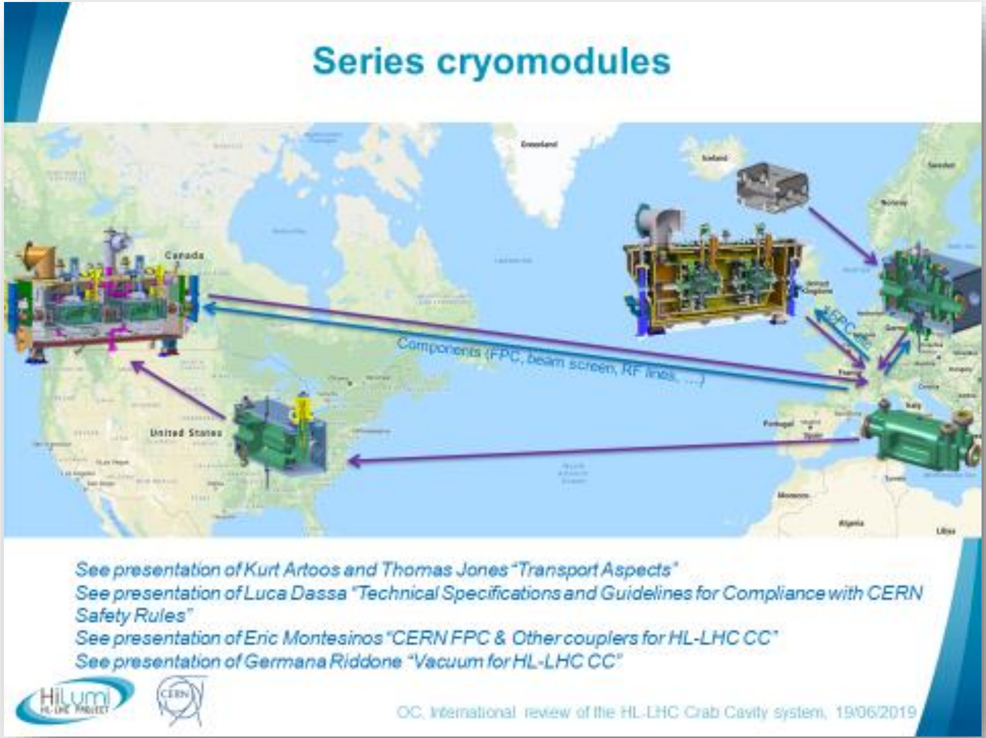
Feedthrough : 50 Ohm to 25 Ohm



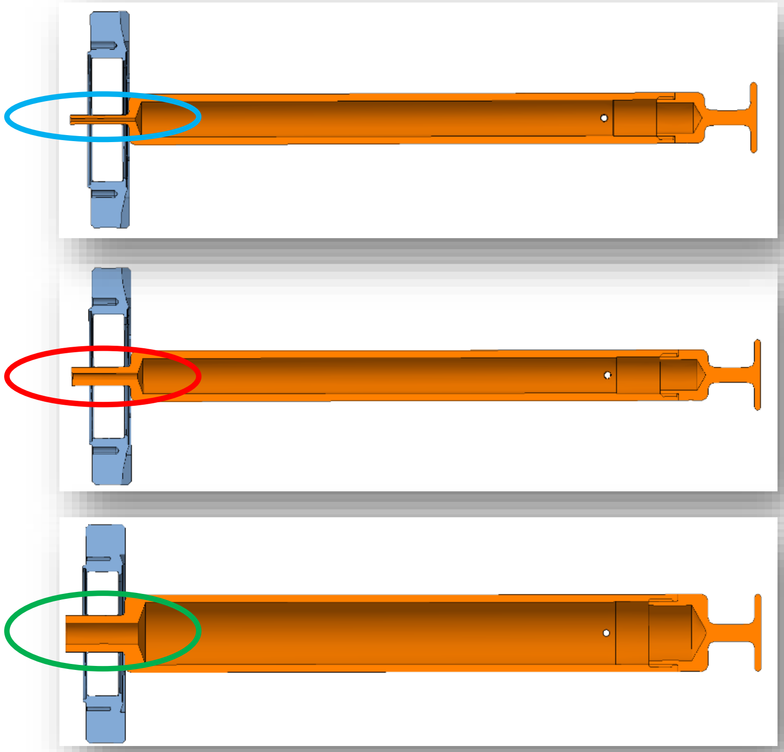
In addition to the coupling mitigation, we are also ‘concern #7’
I endorse it, as this is because of my fear of transportation

Transportation : 50 Ohm to 25 Ohm

With all the transportations we will have, we can reasonably expect some shocks



Transportation : 50 Ohm to 25 Ohm



Ideal design D39.7/d3.1 ; Z = 50 Ω

$$Z_{ceramic} = \frac{60}{\sqrt{\varepsilon_r}} \ln\left(\frac{D}{d}\right) \;;\; Z_{ceramic} \sim \; 20 \ln\left(\frac{D}{d}\right)$$

Crab SPS design D39.7/d6 ; Z = 38 Ω

In order to make it much more robust, Rama had the clever idea to propose 25 Ω

Crab design D40/d12 ; Z = 24 Ω

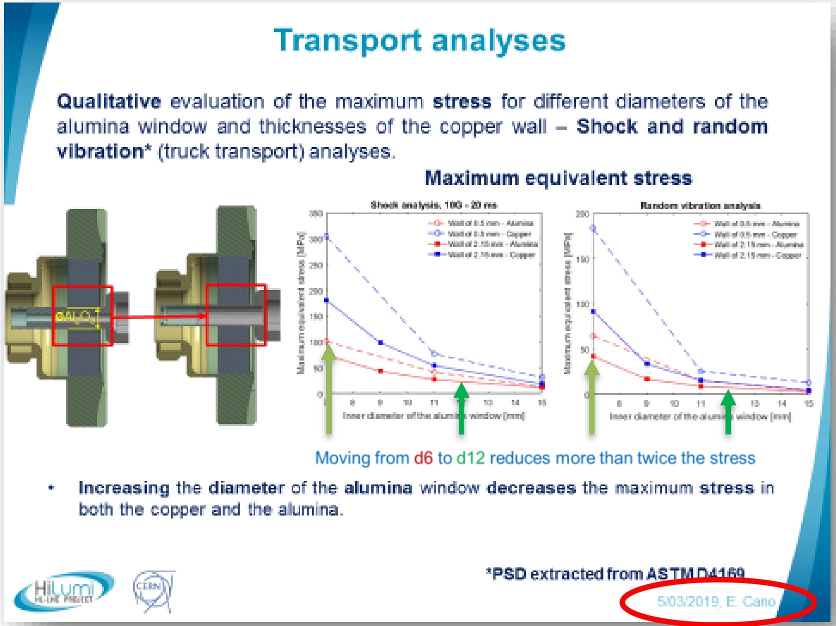
Transportation : 50 Ohm to 25 Ohm

Courtesy Eduardo, Ofelia and team

Moving from 50 Ω to 25 Ω is not an easy decision as it impacts a lot of modifications on all devices

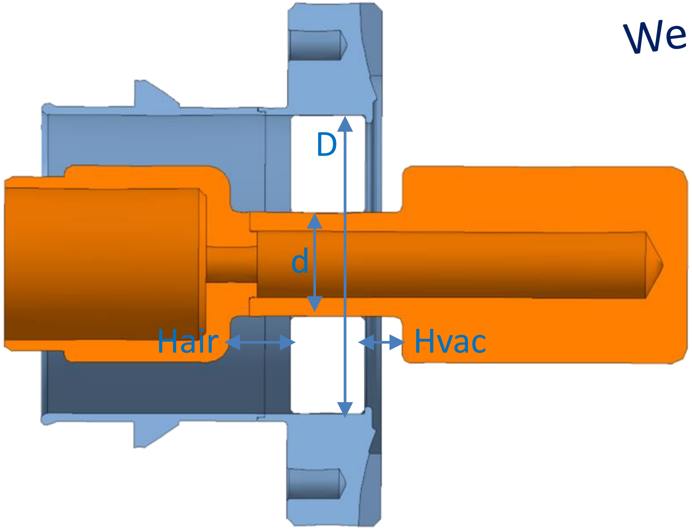
- Ceramic sizes
- Titanium flanges size
- Cavity flanges size

This was finally agreed by all actors, including US-AUP

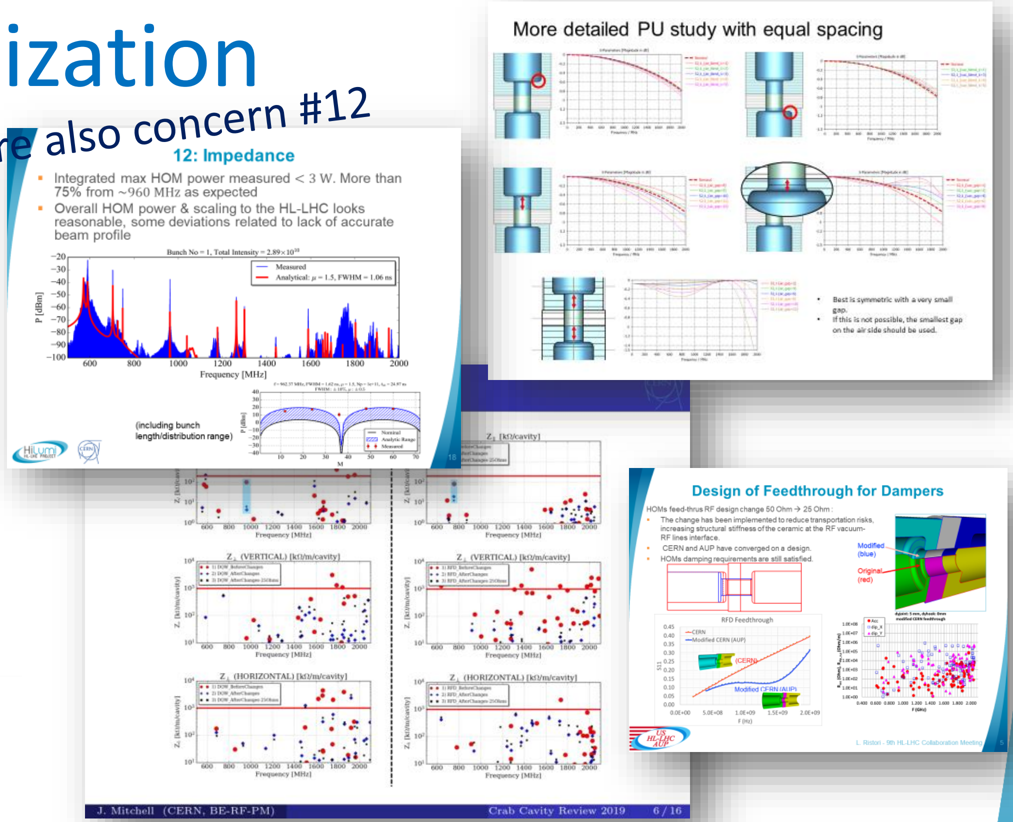


Eduardo did simulations showing that the stress in the ceramic is largely decreased with 25 Ω feedthroughs

Feedthroughs optimization



We are also concern #12



Devil is in the details, so everything is carefully adjusted in order to provide a wideband and robust 25 Ω feedthrough

D has been increased to 40.0 mm

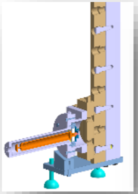
d has been slightly increased to 14.0 mm

Hair has been calculated taking into account fabrication constraints (EBW#1 and EBW#2) and RF optimization

Hvac has been calculated taking into account solidity with respect to transport and RF optimization

Zenghai and Jamie verified that this new impedance is still compatible with requirements, and RF optimization of the feedthrough was done taking it into account

Feedthroughs optimization

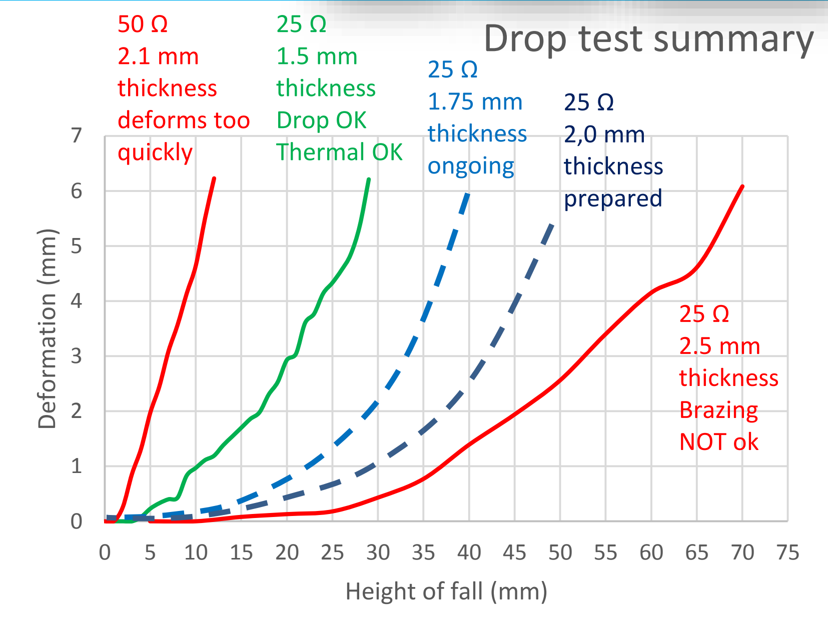


Thickness of the inner tube is a key parameters

- **1.5 mm is ok**
- 1.75 mm is being tested
- 2.0 mm is being prepared
- 2.5 mm failed, brazing was not ok

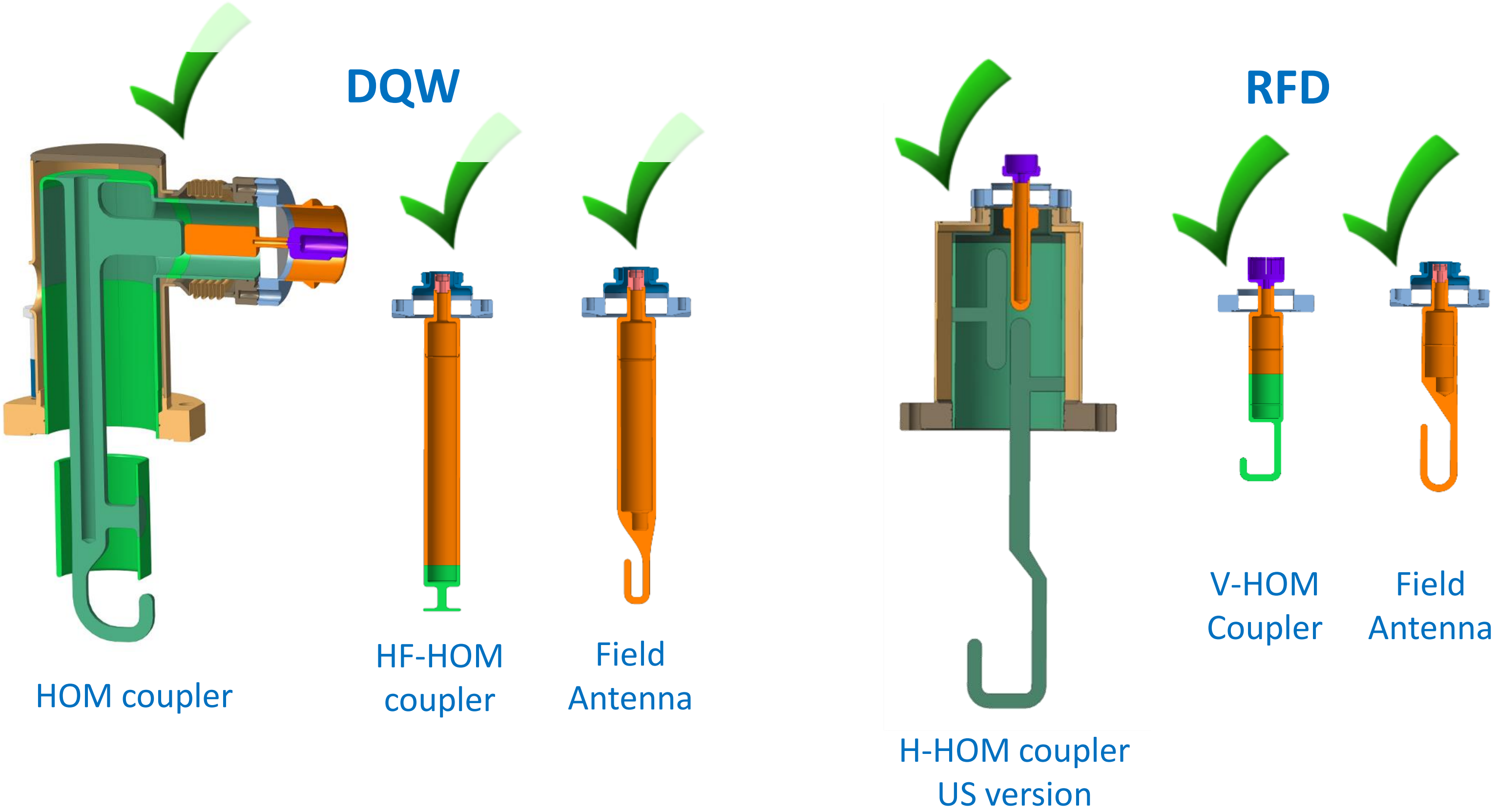
Thermal tests are performed before drop tests

1. Leak test
2. Keep the feedthrough under vacuum
3. Submerge the feedthrough slowly in liquid nitrogen
4. For ***120 seconds*** leave the piece
5. Slowly lift up the piece emptying any excess liquid
6. Submerge the feedthrough slowly in warm water
7. For ***120 seconds*** leave the piece
8. Slowly lift up the piece emptying any excess liquid
9. Repeat ***5 times*** steps 3 to 8
10. Leak test

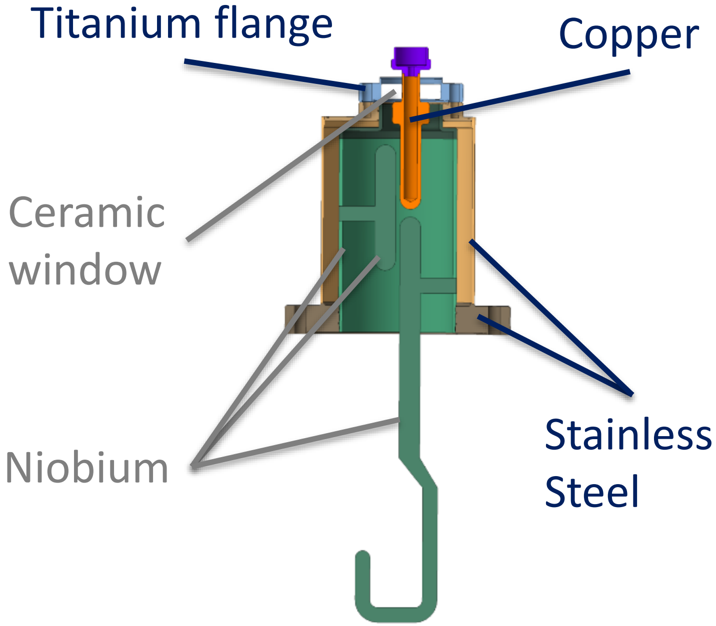


Frida and Sonia did drop tests that showed that moving to 25 Ω is not the only parameter, the thickness of the tube is also important and must not be to large

Design being finalized with a common feedthrough

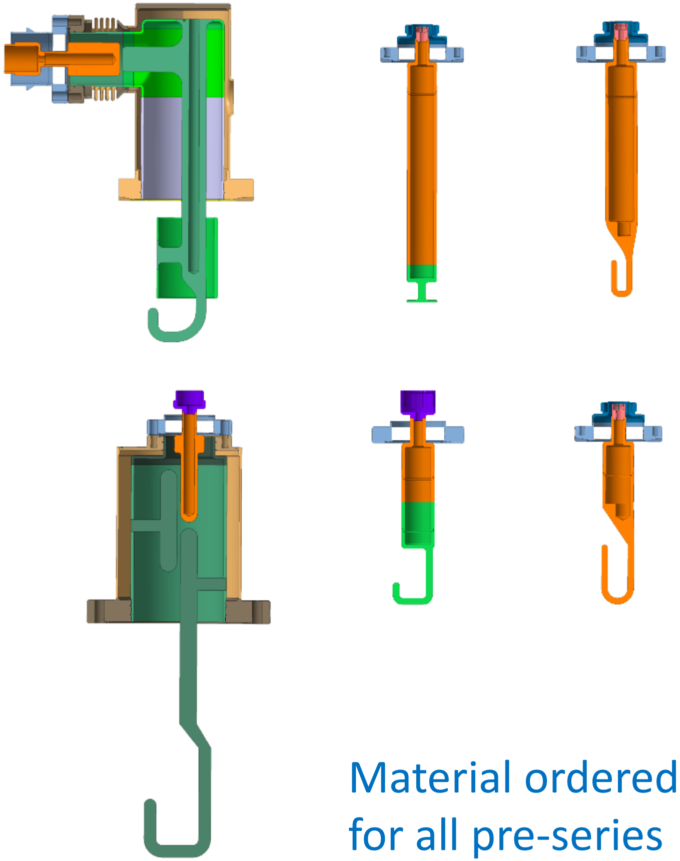


Raw material ordered



Material ordered and delivered

Material ordered not yet delivered



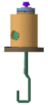
Material ordered for all pre-series

Schedule as per September 2019

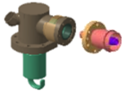
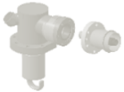
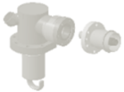
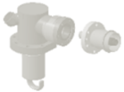
2019	2020	2021	2022

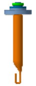
3 antennas — 2 (+1) x 

3 RFD V — 2 (+1) x 

3 RFD H $US_{version}$ — 2 (+1) x 

All RFD HOM Couplers Series manufactured by the US-AUP team

34 DQW — 6 (+2) x  — 8 x  — 8 x  — 6 + (4) x 

13 Antennas — 2 (+1) x  — 4 x  — 4 + (2) x 

13 HF-HOM — 2 (+1) x  — 4 x  — 4 + (2) x 

Collaboration with Russia being prepared

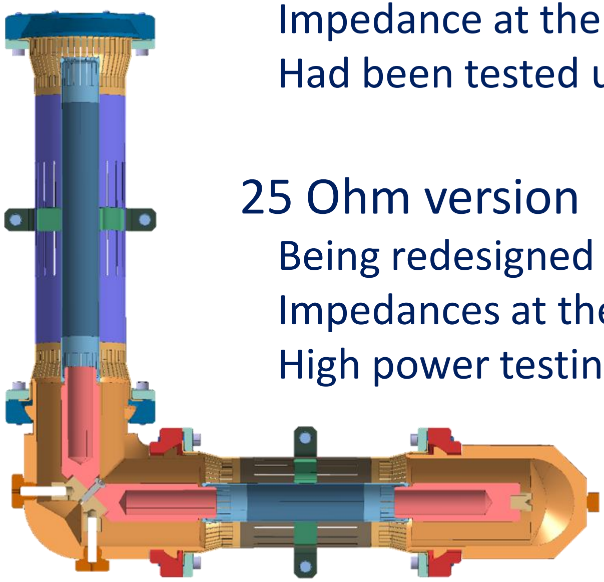
RF Power transmission lines

50 Ohm version

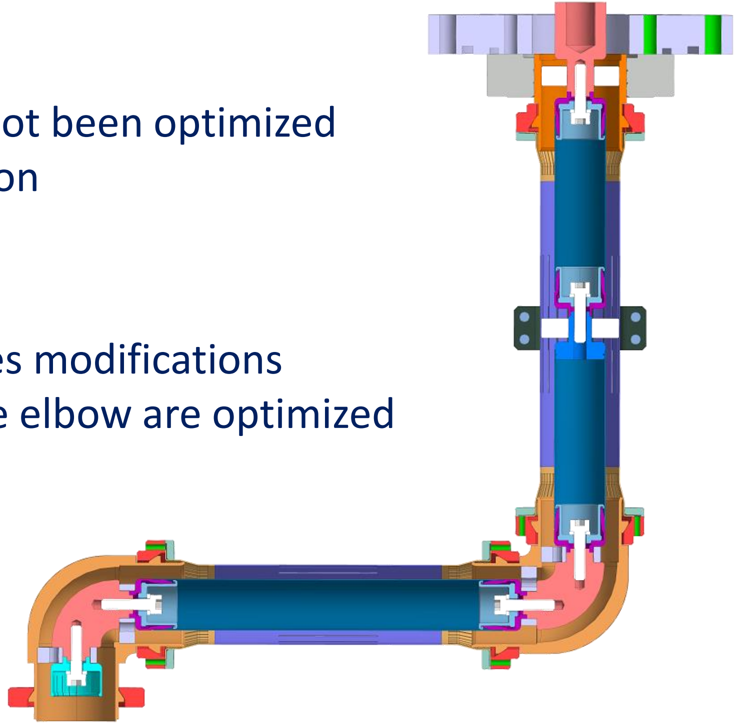
- Impedance at thermal anchor level had not been optimized
- Had been tested up to 16 kW full reflection

25 Ohm version

- Being redesigned for 25 Ohm, this induces modifications
- Impedances at thermal anchor and of the elbow are optimized
- High power testing being prepared



50 Ohm version, tested up to 16 kW CW under vacuum



25 Ohm version, must also sustains 4 kW full reflection, i.e. 16 kWp to do so, elbows are being redesigned

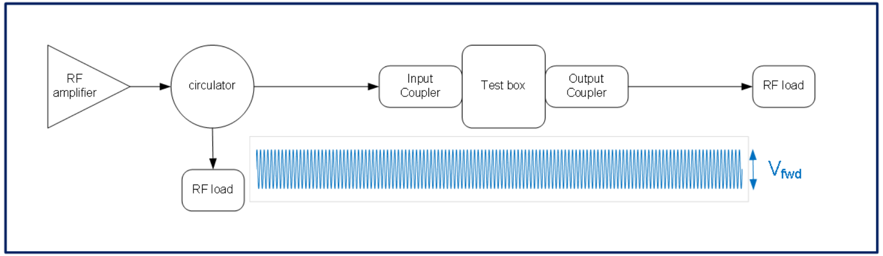
RF Power transmission lines

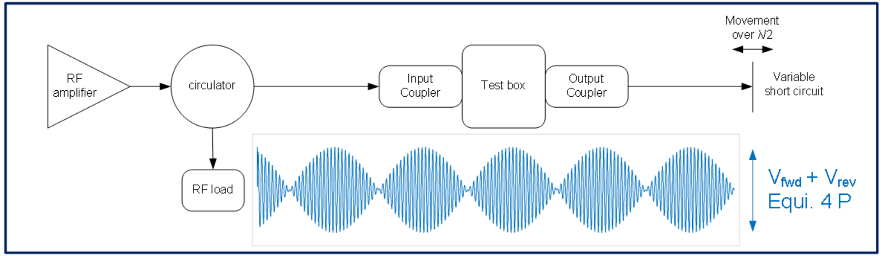
Power lines have to be powerful as if for any reason the load is removed or broken, they will locally be exposed to an equivalent of 4 times the power

This happened in 1996 with a SPS test of a LHC cavity

We had to open the cryomodule and to exchange the cables connecting the HOM couplers to external world

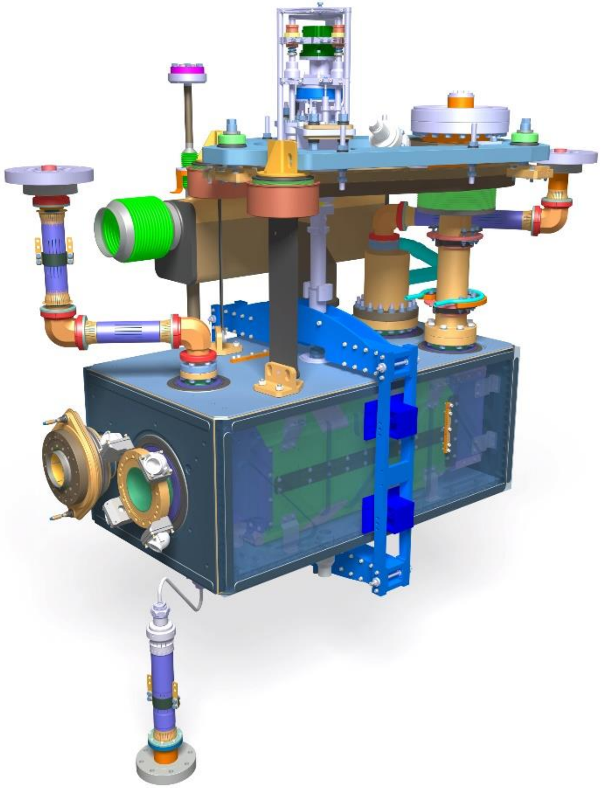
In addition, RF power lines are additional impedances mismatch added to the HOM impedance network, so they must be as well designed as possible

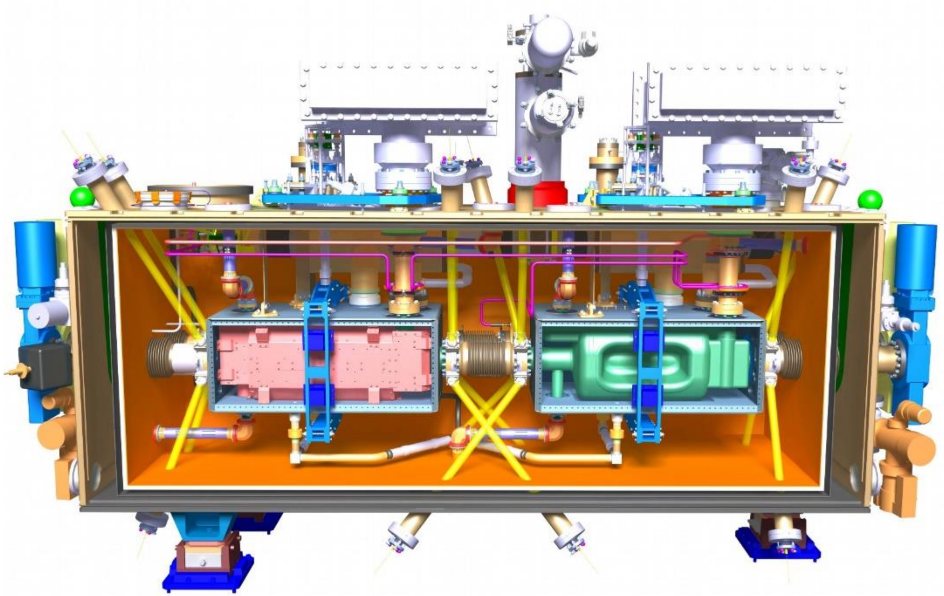




Usually we explain full reflection with an amplifier as a source and a load, here the source is the HOM coupler and the beam

RF Power transmission lines

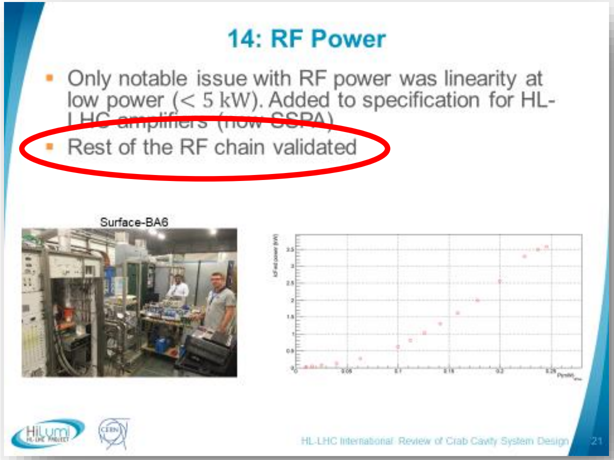




No one will agree that we ask to open the cryomodule to exchange a cable, reason why we are designing these ‘too big’ RF power lines

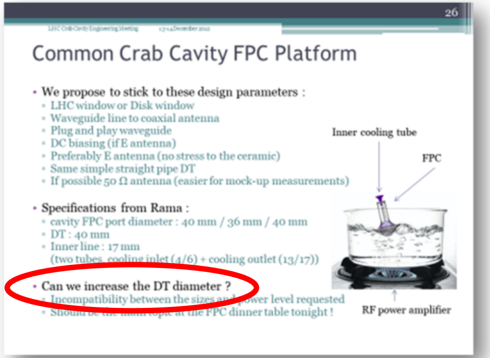
FPC

SPS Tests has demonstrated the good design of the FPC ‘ancillary’ (not a concern #14)



We are on track for the next two cryomodules to be equipped

2 RFD + 2 DQW FPC being prepared for RF processing on their test boxes



Do you remember that in December 2012 you asked to provide 100 kW CW through a 40/17 mm line ?

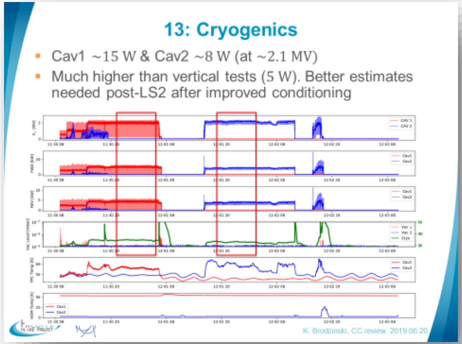
Fortunately we had a dinner at ‘Two Brothers’ and we agreed there a 62/27 mm line

We have been quite quick to design and construct the FPC

Please keep in mind that we are designing and producing quite a large number of these FPC, and this Crab one in an evolution of the SPL FPC

FPC Outer Tube

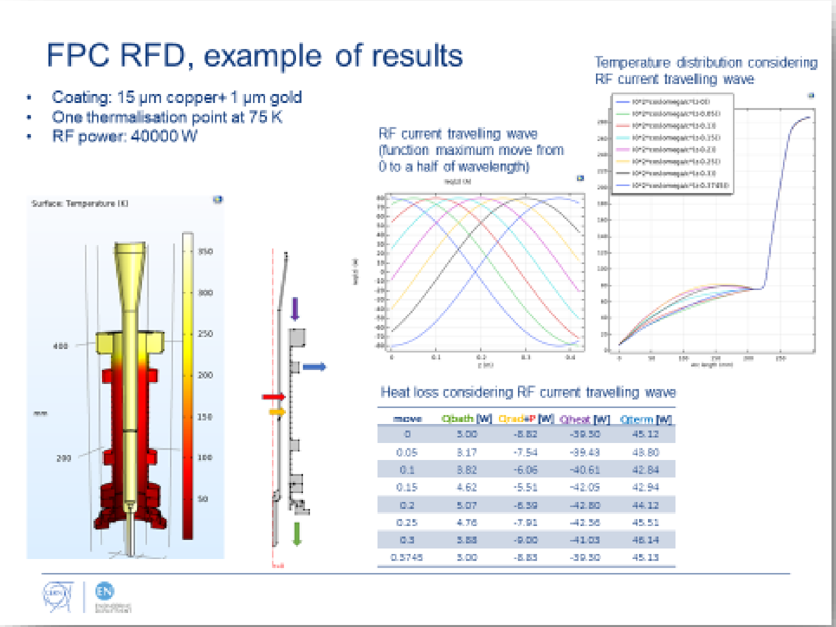
Perhaps linked to 'concern #13'



Being redesigned with two anchors positioned such that there is a monotonous thermal path

Feasibility of a gold-gold being studied (if not possible, will be gold-copper, as we did for the SPS test)

Courtesy Joanna, Ofelia and team



move	Qbath [W]	Qrad+P [W]	Qheat [W]	Qterm [W]
0	3.00	-8.82	-39.50	45.12
0.05	3.17	-7.54	-39.43	43.80
0.1	3.82	-6.06	-40.61	42.84
0.15	4.62	-5.51	-42.05	42.94
0.2	5.07	-8.39	-42.80	44.12
0.25	4.78	-7.91	-42.58	45.51
0.3	3.88	-9.00	-41.03	46.14
0.3748	3.00	-8.83	-39.50	45.13

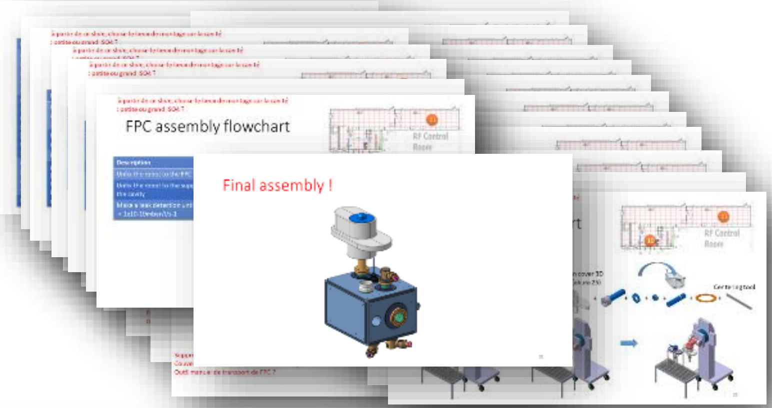
Assembly in clean room

Once the FPC have been RF processed, we assembled them in clean room

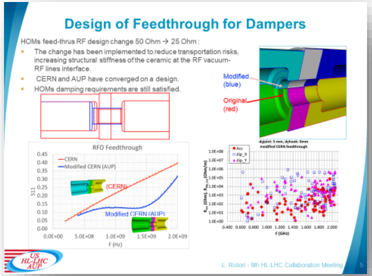
We will take advantage of the experience gain with the first DQW cryomodule

We upgraded our flip-book, and we are also upgrading our tooling

We also started to work on the test boxes we want to qualify the HOM couplers

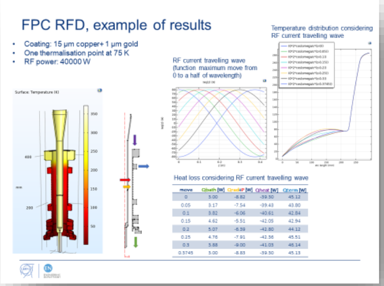


All difficulties we have to avoid/cure (impedances, transport,…)
not easily identifiable at a first glance



WP4 RF team
(CERN + US-AUP)

Nice (innocent)
HOM couplers



Still to be done

Complete the 3D and 2D drawings for DQW

Study how to qualify a 25 Ω system and build qualification tools

Order specific 25 Ω cables and loads

Prepare Clean Room assembling tooling (taking advantage of experience gained with DQW SPS test)

Ensure a correct Quality Management

Conclusion

We induced some delay due to the 25 Ohm design

We now have a solid feedthrough design that successfully passed thermal and drop tests (transport)

This design is common to all our couplers and antennas

We launched the production of the RFD couplers

DQW modifications to 25 Ohm are almost done and construction will be launched very soon

We stick to a delivery of RFD by end May 2020, and DQW by end July 2020

RF power lines modifications are being done

FPC are on track

Thanks once again to the management for the support

Thanks to all people involved doing a fantastic job !

We are eager to continue working on this exciting project