



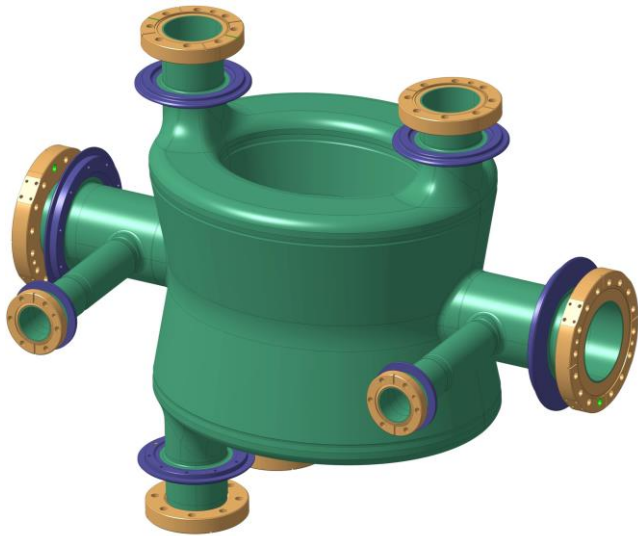
HL-LHC WP4 Cavities and cryomodules strategy and status

Ofelia Capatina (CERN) on behalf of the
WP4 collaboration members

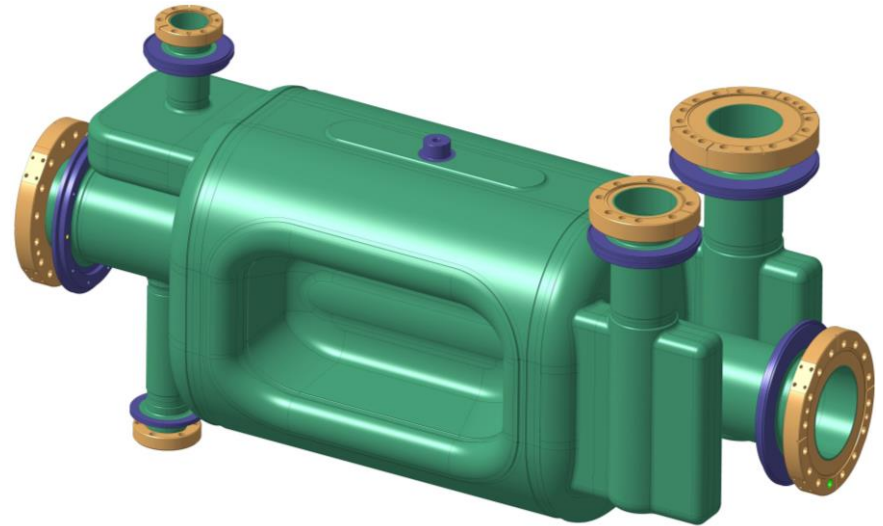


HL-LHC Crab Cavity types

- Superconducting compact RF crab cavities will be used at ATLAS and CMS.
- Two types of cavities required (vertical, horizontal)
- Cryomodule composed of 2 identical cavities



Double Quarter Wave (DQW) cavity –
Vertical – to be used in Point 5 (CMS)



RF Dipole cavity – Horizontal – to be used in
Point 1 (ATLAS)

CERN locations

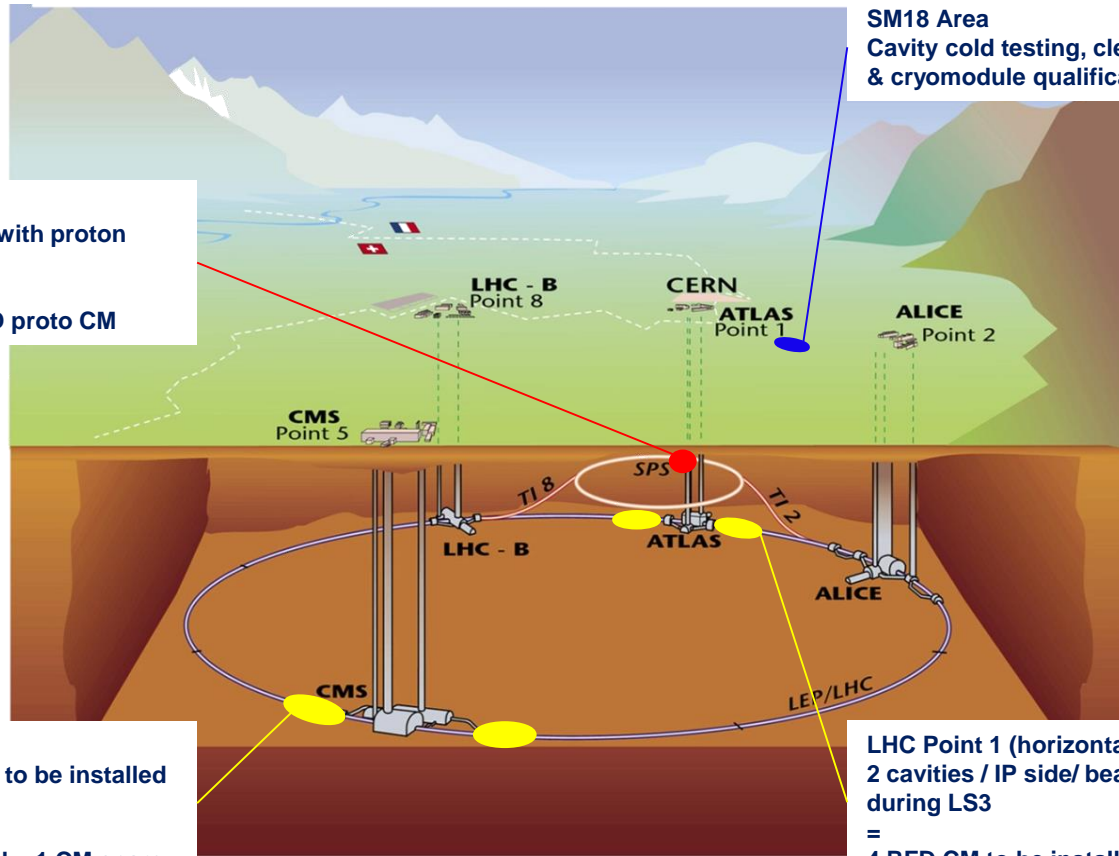
SPS BA6
Test Prototype Modules with proton beam

1 DQW proto CM + 1 RFD proto CM

LHC Point 5 (vertical)
2 cavities / IP side/ beam to be installed during LS3

=
4 DQW CM to be installed + 1 CM spare

SM18 Area
Cavity cold testing, clean room facilities & cryomodule qualification

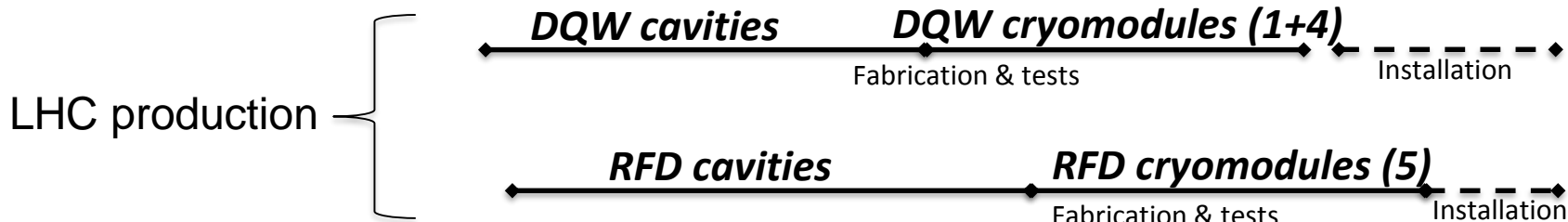
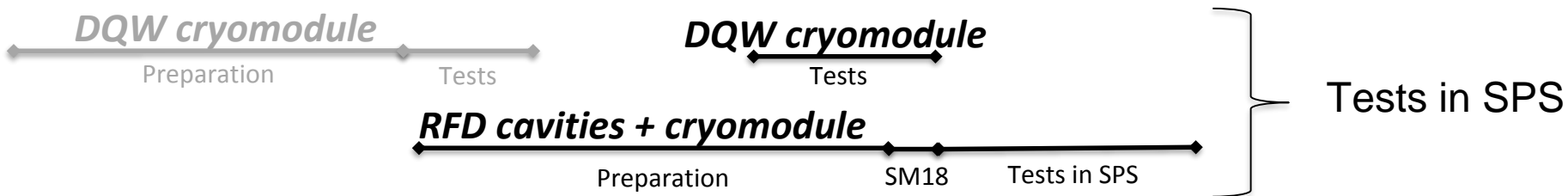


LHC Point 1 (horizontal)
2 cavities / IP side/ beam to be installed during LS3

=
4 RFD CM to be installed + 1 CM spare

Crab cavities & cryomodules general plans

- 2 cryomodules for SPS tests
 - 1 cryomodule with 2 identical cavities (type «vertical» - DQW)
 - Tests in SPS in 2018 and 2021
 - 1 cryomodule with 2 identical cavities (type «horizontal» - RFD)
 - Tests in SPS in 2022
- 8 cryomodules (4 of each type) for installation in LHC during LS3
 - + 2 spares (1 of each type)



Crab cavities & cryomodules

today ↓



Design & developments



DQW cavities (2) + CM (1)

Fabrication Tests

DQW cryomodule (1)

Tests



RFD cavities (2) + cryomodule (1)



SM18

Tests in SPS

Tests in SPS

DQW dressed cavities (2+9) DQW cryomodules (1+4)

Fabrication & tests

Installation



LHC production

RFD dressed cavities (2+2+10) RFD cryomodules (5)

Fabrication & tests

Installation



Crab cavities & cryomodules

today ↓



Design & developments

A green-bordered box containing the text 'Design & developments' and the flags of the United States, the United Kingdom, and the CERN logo.

DQW cavities (2) + CM (1)

A horizontal timeline for 'DQW cavities (2) + CM (1)'. It shows a 'Fabrication' phase followed by a 'Tests' phase. The CERN logo is positioned below the timeline.

DQW cryomodule (1)

A horizontal timeline for 'DQW cryomodule (1)'. It shows a 'Tests' phase. The CERN logo and the flag of the United Kingdom are positioned below the timeline.

RFD cavities (2) + cryomodule (1)

A horizontal timeline for 'RFD cavities (2) + cryomodule (1)'. It shows a 'Tests in SPS' phase. The CERN logo and the flag of the United Kingdom are positioned below the timeline. The label 'SM18' is placed near the end of the timeline.

Tests in SPS

LHC production

DQW dressed cavities (2+9) DQW cryomodules (1+4)

A horizontal timeline for 'DQW dressed cavities (2+9) DQW cryomodules (1+4)'. It shows 'Fabrication & tests' and 'Installation' phases. The CERN logo, the flag of Russia, and the flag of the United Kingdom are positioned below the timeline.

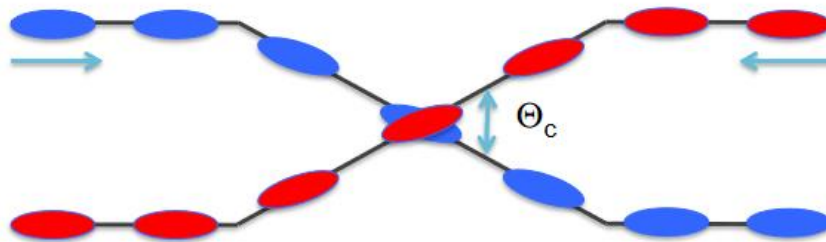
RFD dressed cavities (2+2+10) RFD cryomodules (5)

A horizontal timeline for 'RFD dressed cavities (2+2+10) RFD cryomodules (5)'. It shows 'Fabrication & tests' and 'Installation' phases. The flag of the United States and the flag of Canada are positioned below the timeline.

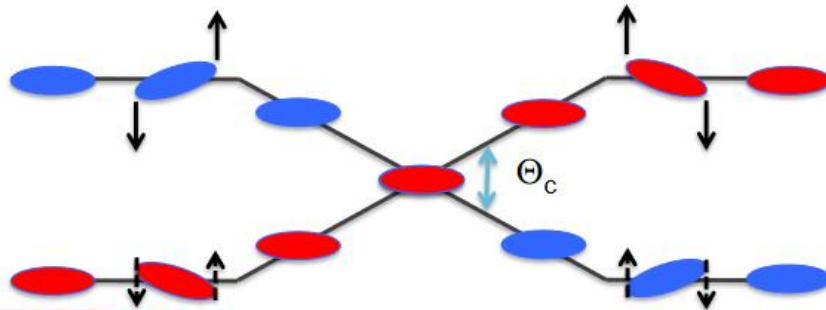
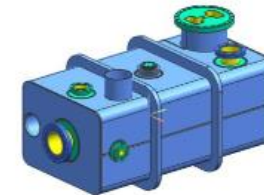
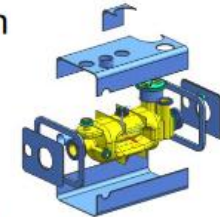


LARP “before HiLumi Project” (cont.)

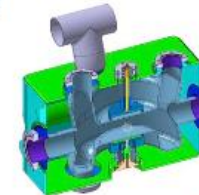
- Larger Crossing angle ($\sim 300 \mu\text{rad}$ in HL-LHC vs. $\sim 150 \mu\text{rad}$ in LHC) calls for a correction of individual bunches orientation



RFD Option

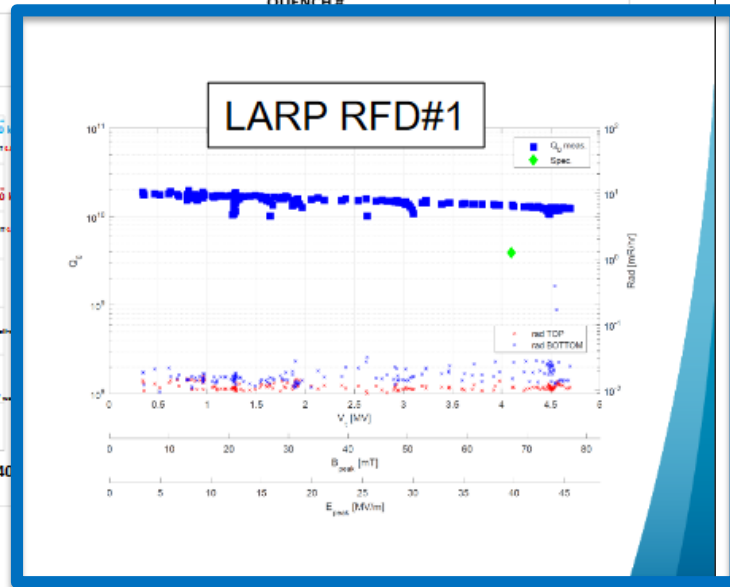
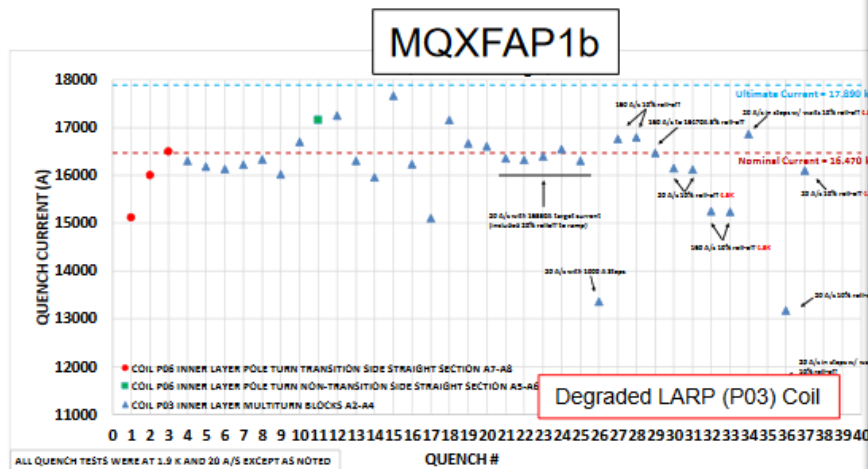
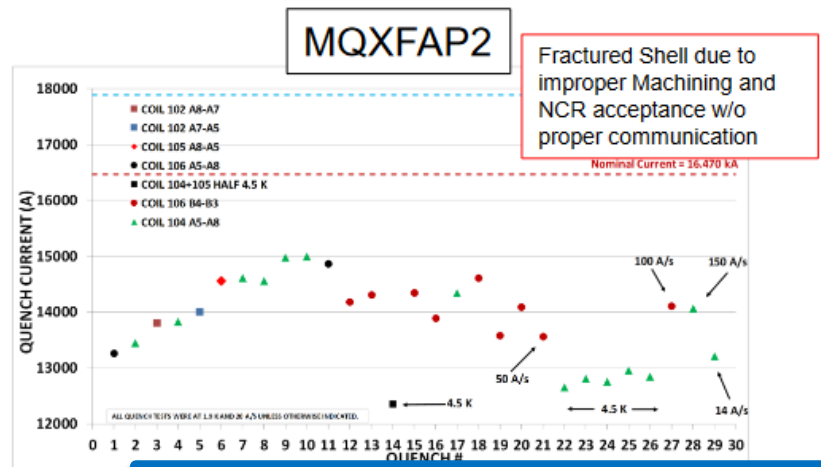
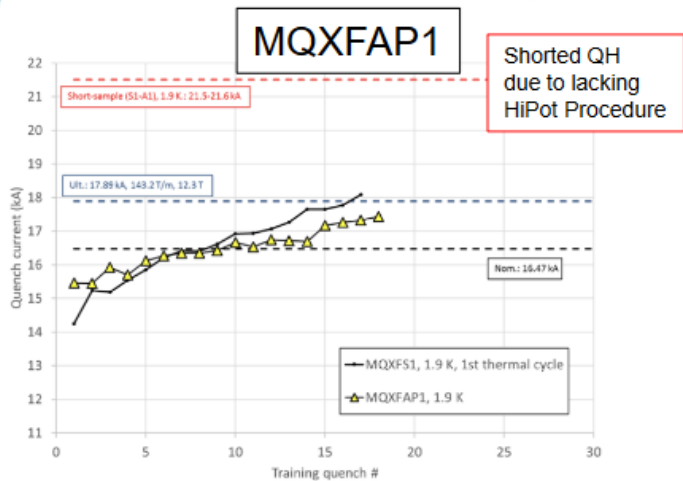


DQW Option



Presentation of Giorgio Apollinari “Status of US contribution to HiLumi (past and present)”

AUP Prototypes Technical Status (cont.)



Presentation of Giorgio Apollinari "Status of US contribution to Hilumi (past and present)"

See also presentations of Silvia Verdu and Paolo Berutti tomorrow



Crab cavities & cryomodules

today ↓



Design & developments



DQW cavities (2) + CM (1)

Fabrication Tests

DQW cryomodule (1)

Tests



RFD cavities (2) + cryomodule (1)



SM18

Tests in SPS

Tests in SPS

DQW dressed cavities (2+9) DQW cryomodules (1+4)

Fabrication & tests

Installation



LHC production

RFD dressed cavities (2+2+10) RFD cryomodules (5)

Fabrication & tests

Installation



DQW Cavities and cryomodule for tests in SPS

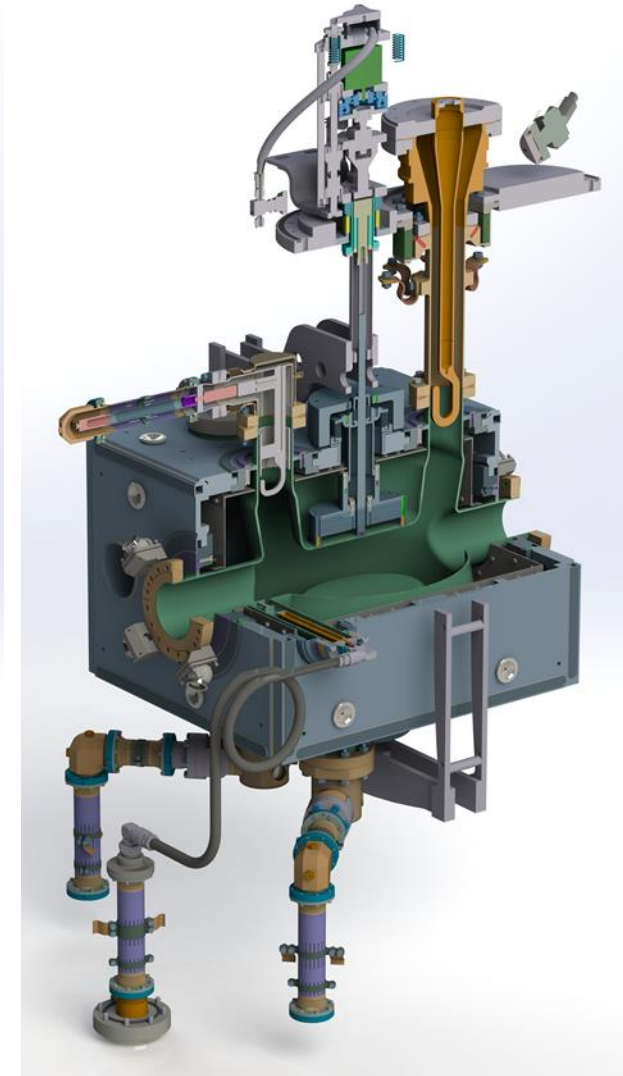
- Cavities (x2) + ancillaries built at CERN in a "crash program"
- Cold magnetic shield built in UK
- Cryomodule design in close collaboration CERN - UK
- Cryomodule (x1) built at CERN
- Design compatible with LHC but missing some features (second beam pipe,...)
- Tests with protons in SPS during 2018 will continue after LS2 until end 2021

DQW Cavity for tests in SPS

Bare DQW cavity



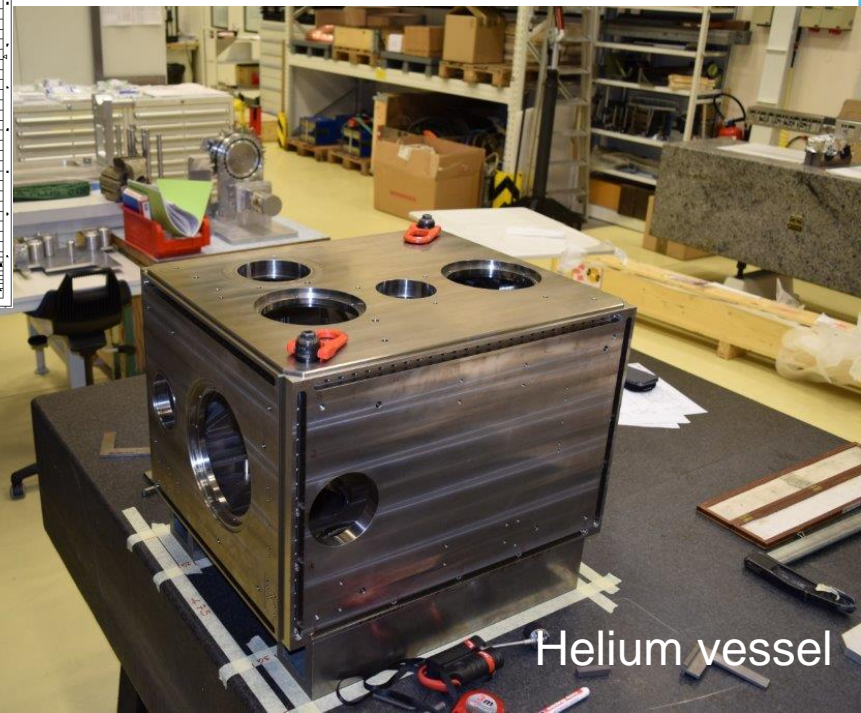
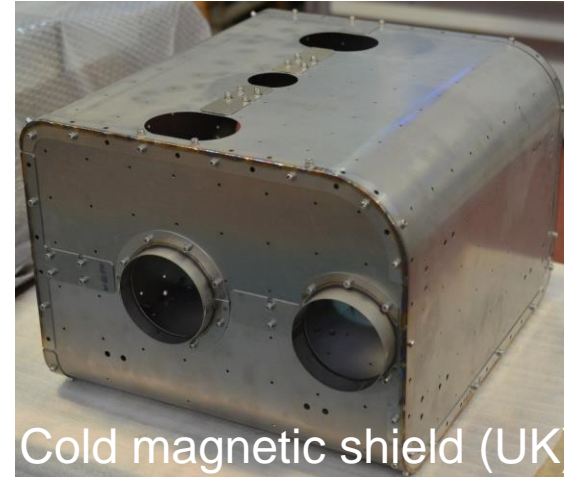
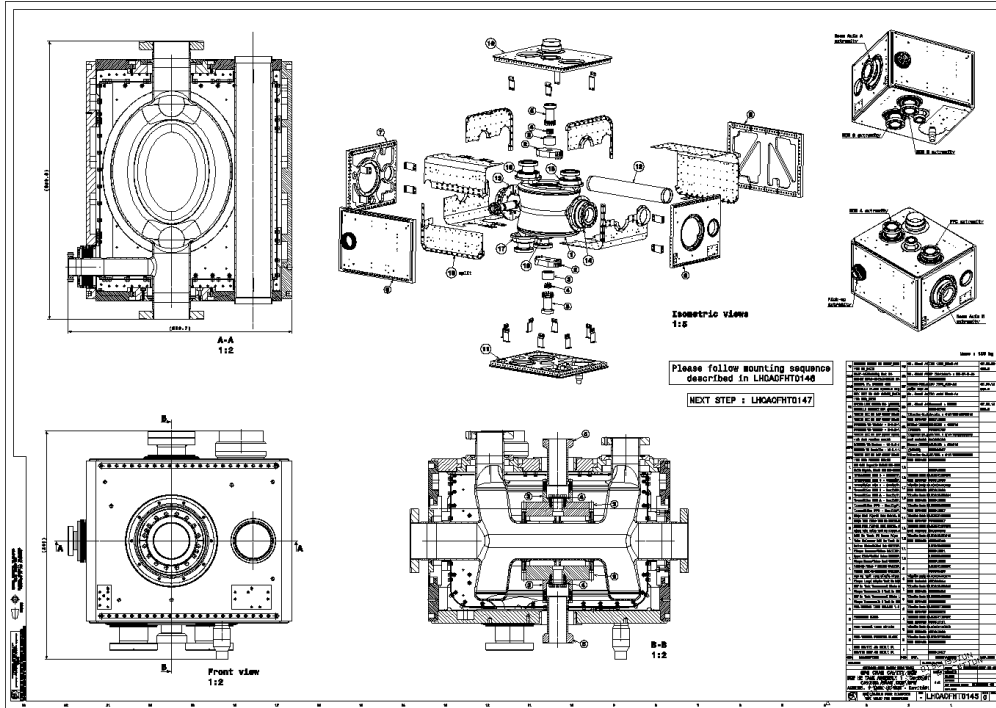
Dressed DQW cavity



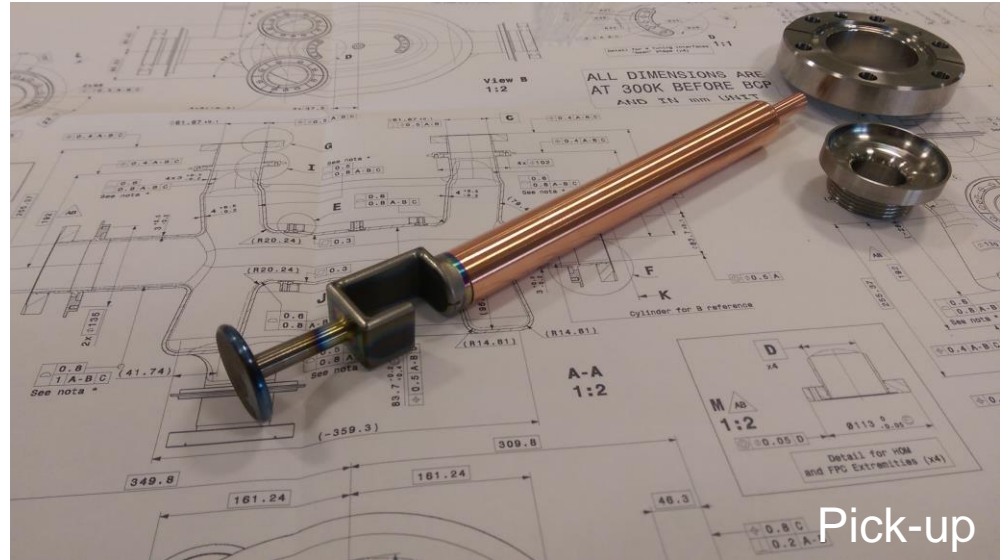
DQW cavity for tests in SPS



DQW Helium vessel & cold magnetic shield for tests in SPS



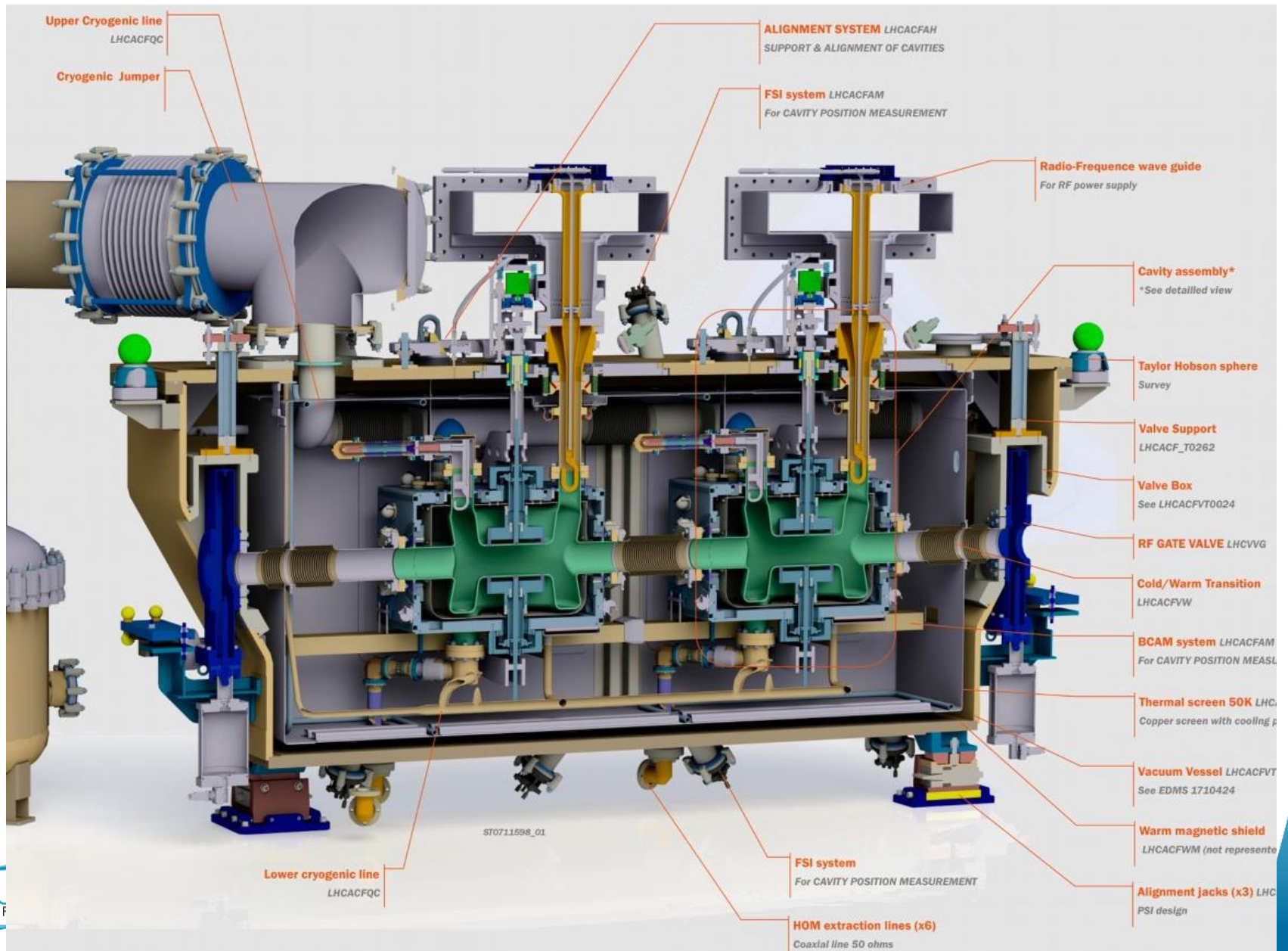
DQW HOMS & Pick-up for tests in SPS



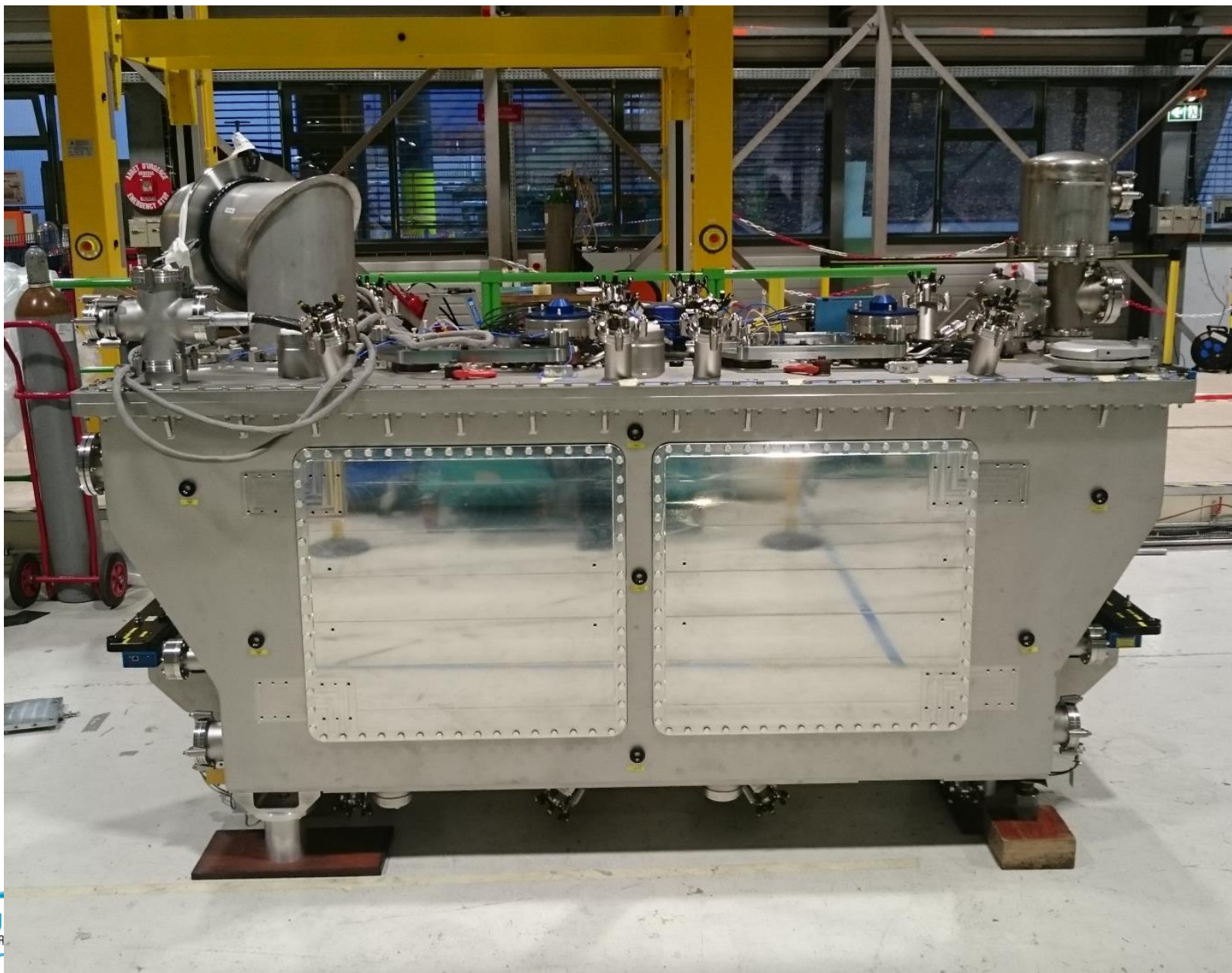
DQW dressed cavities for tests in SPS



DQW Cryomodule for tests in SPS built at CERN



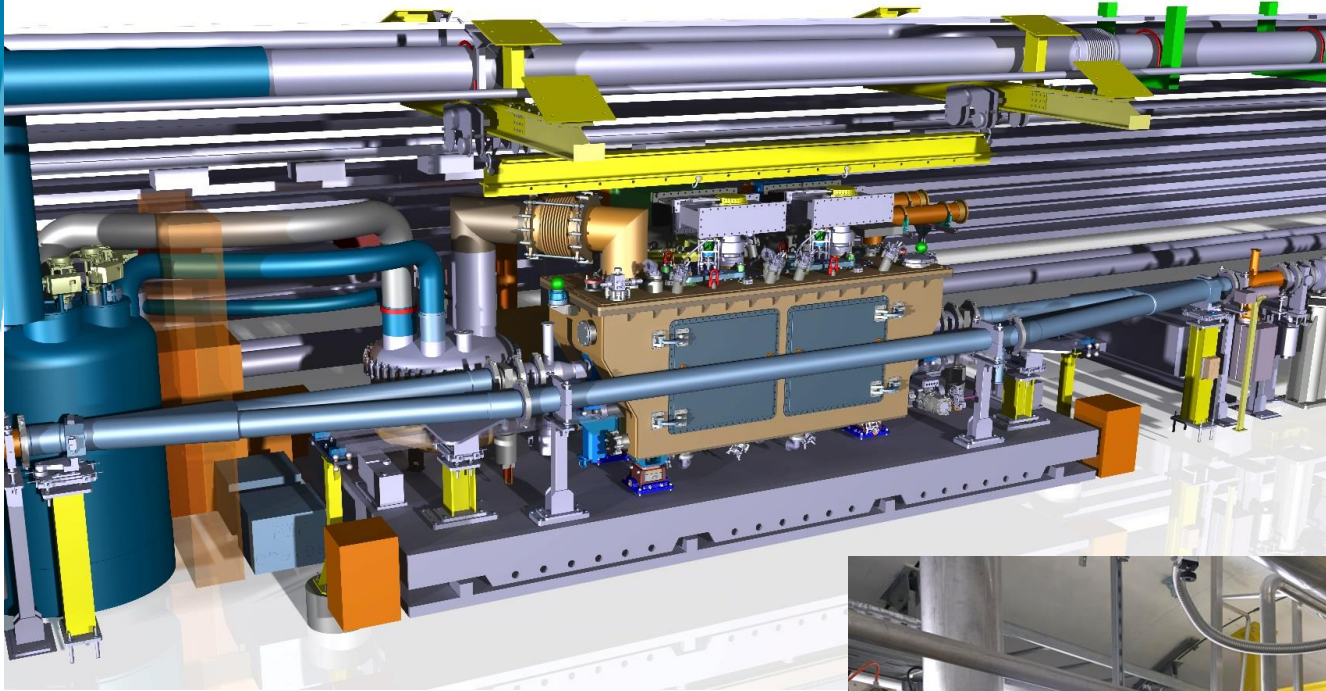
DQW Cryomodule for tests in SPS



DQW Cryomodule for tests in SPS cold tested in SM18 bunker



DQW Cryomodule for tests in SPS BA6



*See presentation of Rama Calaga
“SPS crab cavity tests: lesson
learnt in view of final design”*



Crab cavities & cryomodules

today ↓



Design & developments



DQW cavities (2) + CM (1)

Fabrication Tests

DQW cryomodule (1)

Tests



RFD cavities (2) + cryomodule (1)

SM18 Tests in SPS

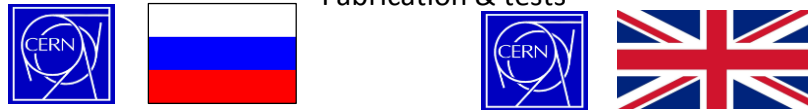
Tests in SPS



DQW dressed cavities (2+9) DQW cryomodules (1+4)

Fabrication & tests

Installation

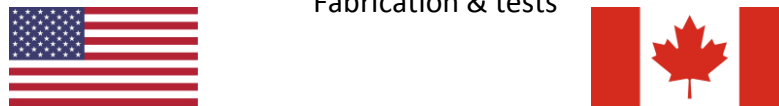


LHC production

RFD dressed cavities (2+2+10) RFD cryomodules (5)

Fabrication & tests

Installation

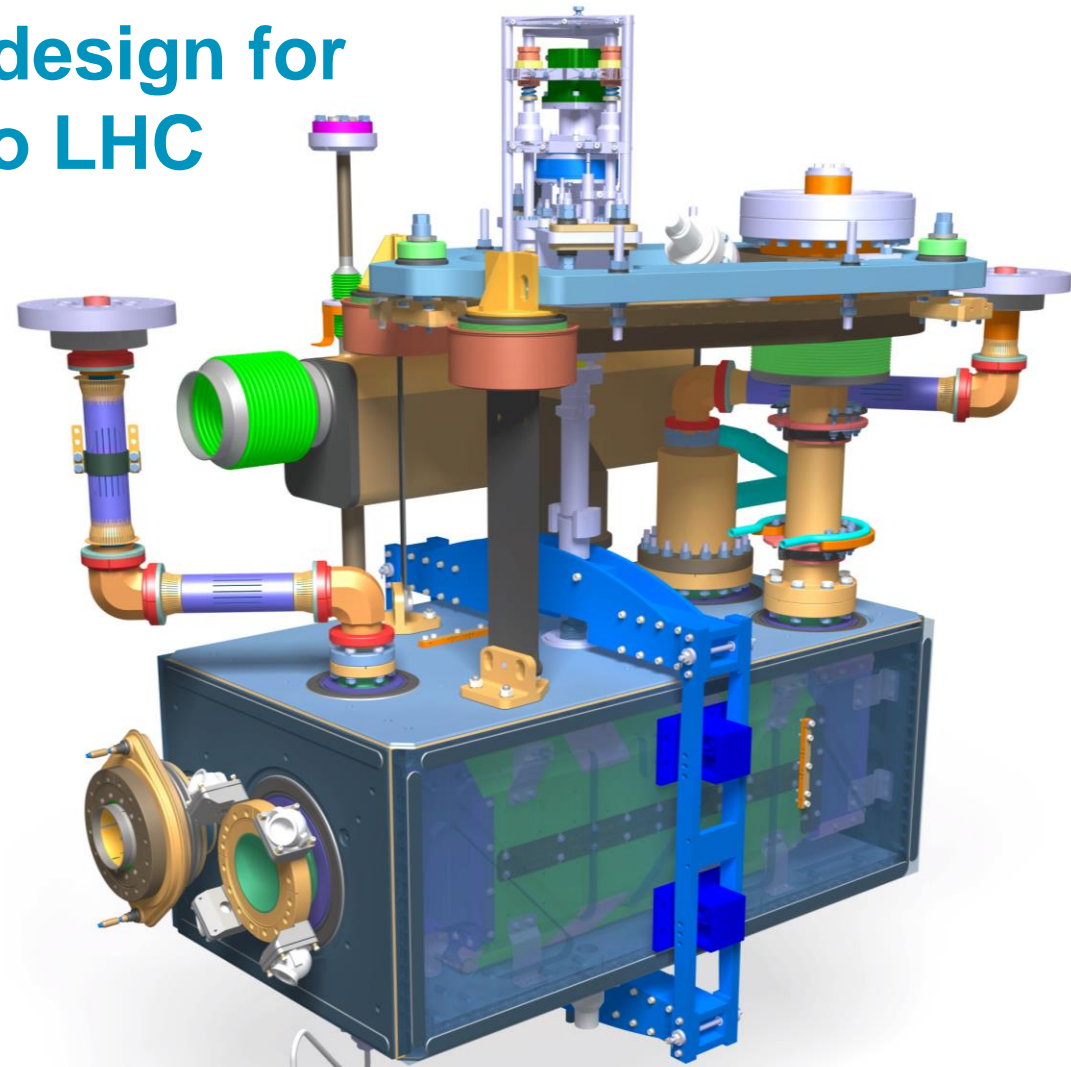
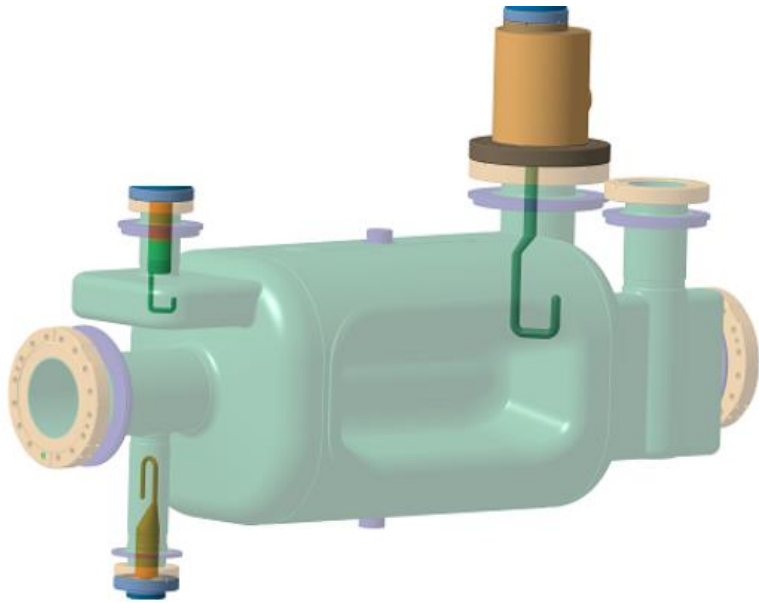


RFD Cavities and cryomodule for tests in SPS

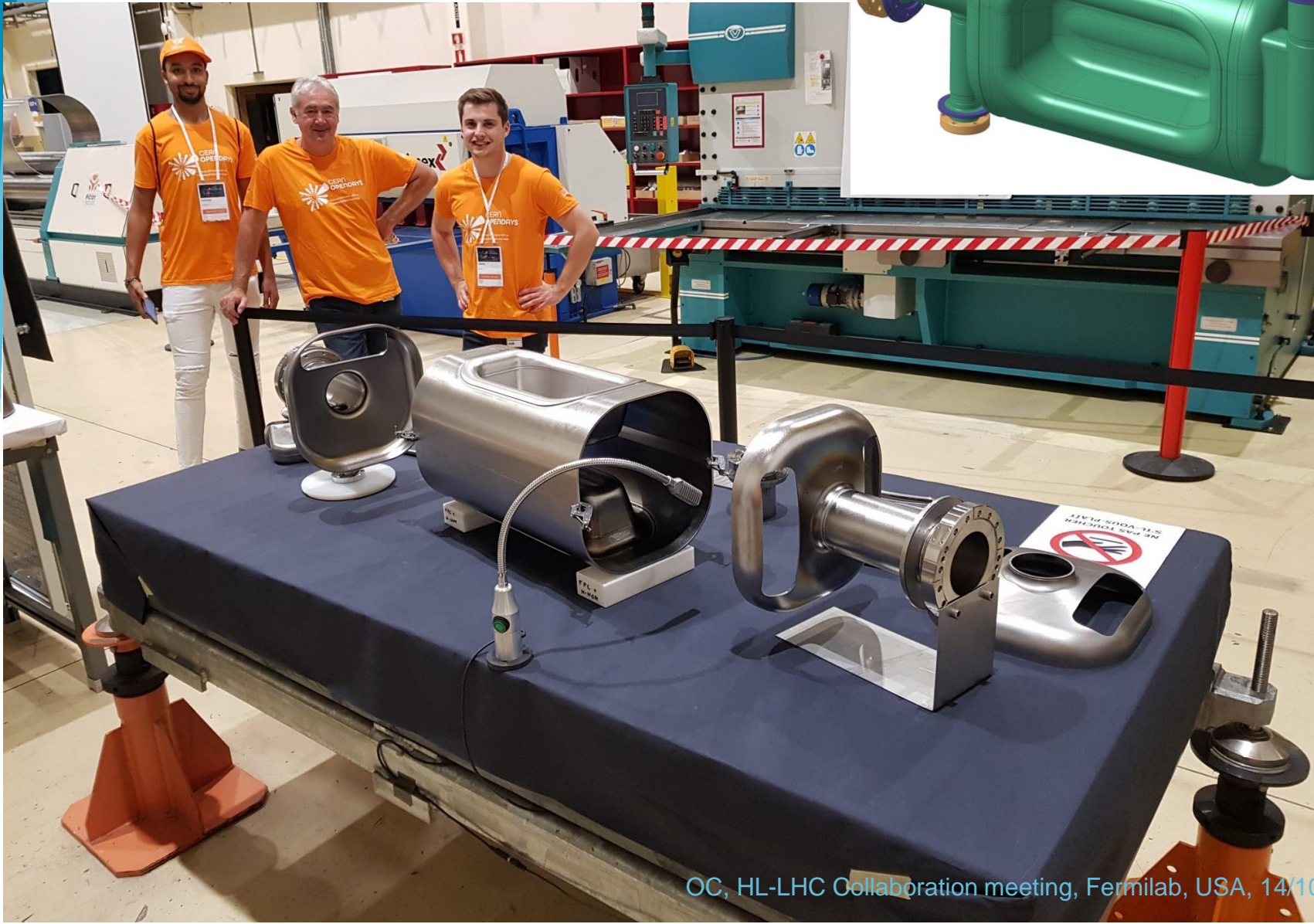
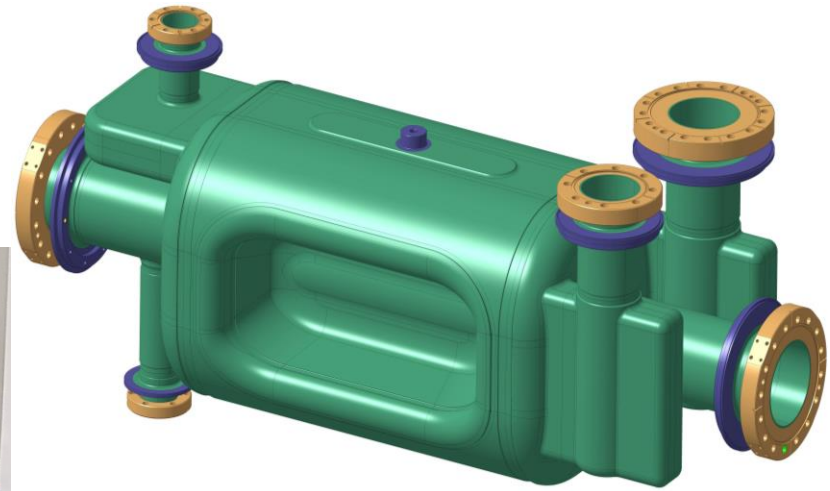
- Cavity design updated after DQW tests with beam in SPS
- Cavities (x2) + ancillaries construction ongoing at CERN. See presentation of Eric Montesinos tomorrow
- Cold magnetic shields built in UK
- Dressed cavities fully validated will be sent to UK by Oct 2020

- Cryomodule design in close collaboration CERN - UK (collaboration agreement already in place)
- Design identical to cryomodule for LHC
- Cryomodule (x1) to be assembled in UK, with some components from CERN (detailed responsibilities split fully agreed)
- Cryomodule assembled in UK will be sent to CERN by Aug 2021
- Tests at 2K in SM18, then installation in SPS by end 2021

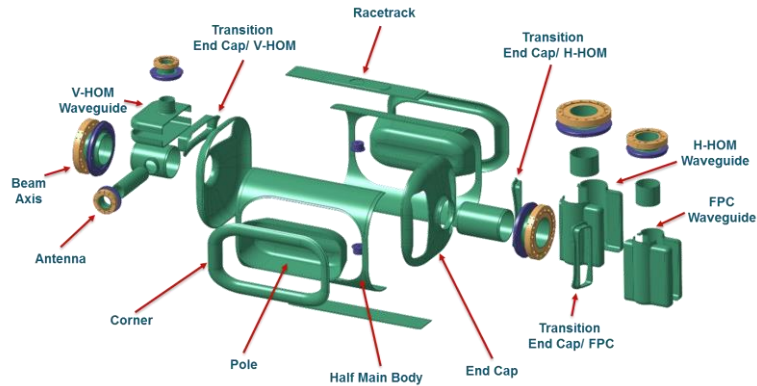
RFD dressed cavity design for SPS tests identical to LHC



RFD cavity for tests in SPS (CERN manufacturing)



RFD cavities for tests in SPS (CERN manufacturing)

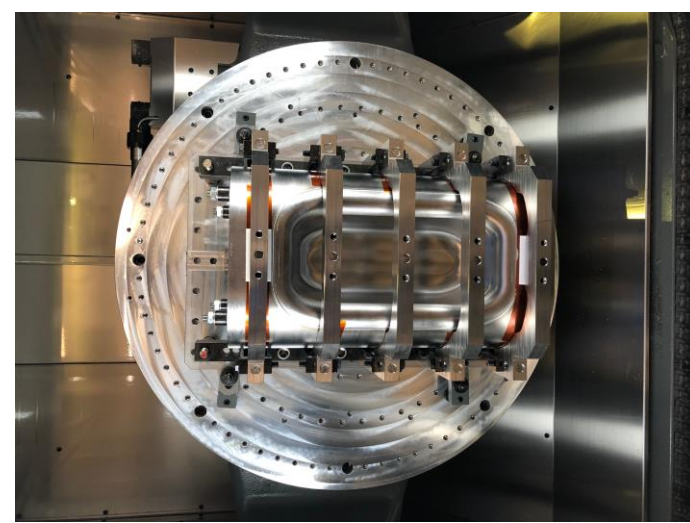


RFD cavities production at CERN on track for finishing before end of 2019

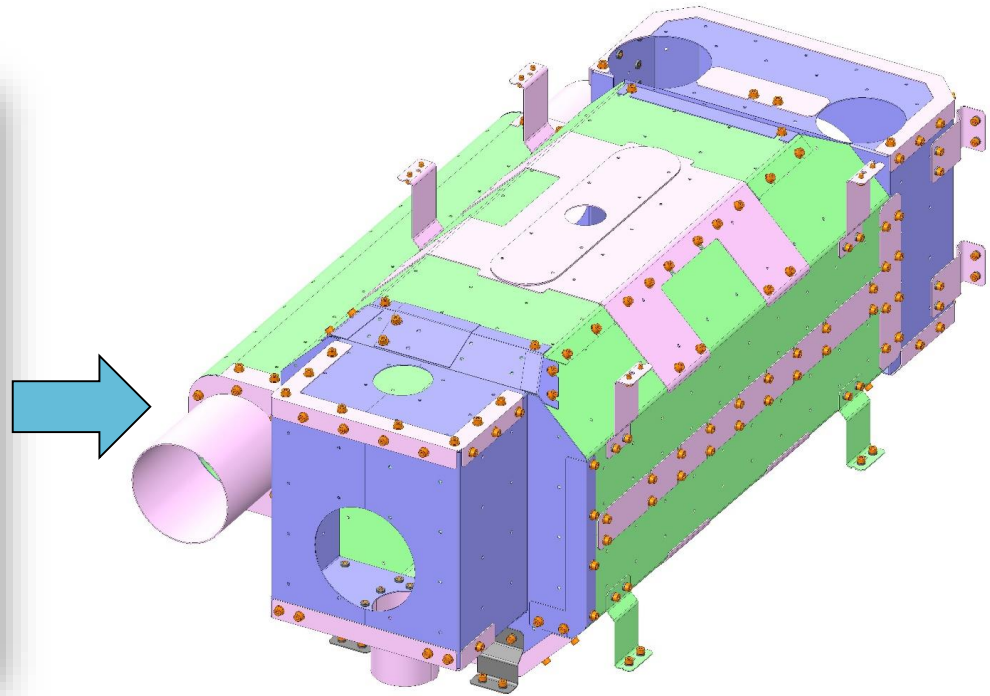
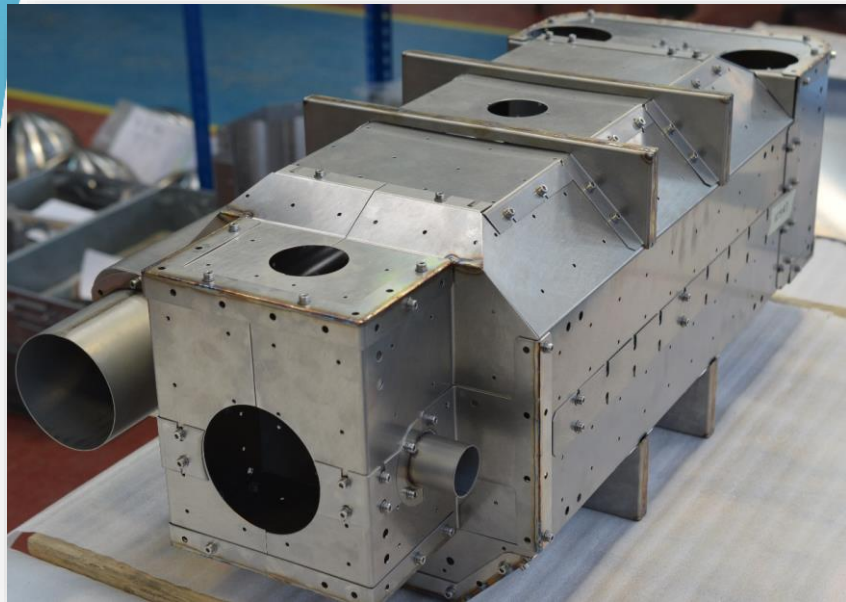
Changes to field antenna port implemented from SPS experience



RFD cavities for tests in SPS (CERN manufacturing)

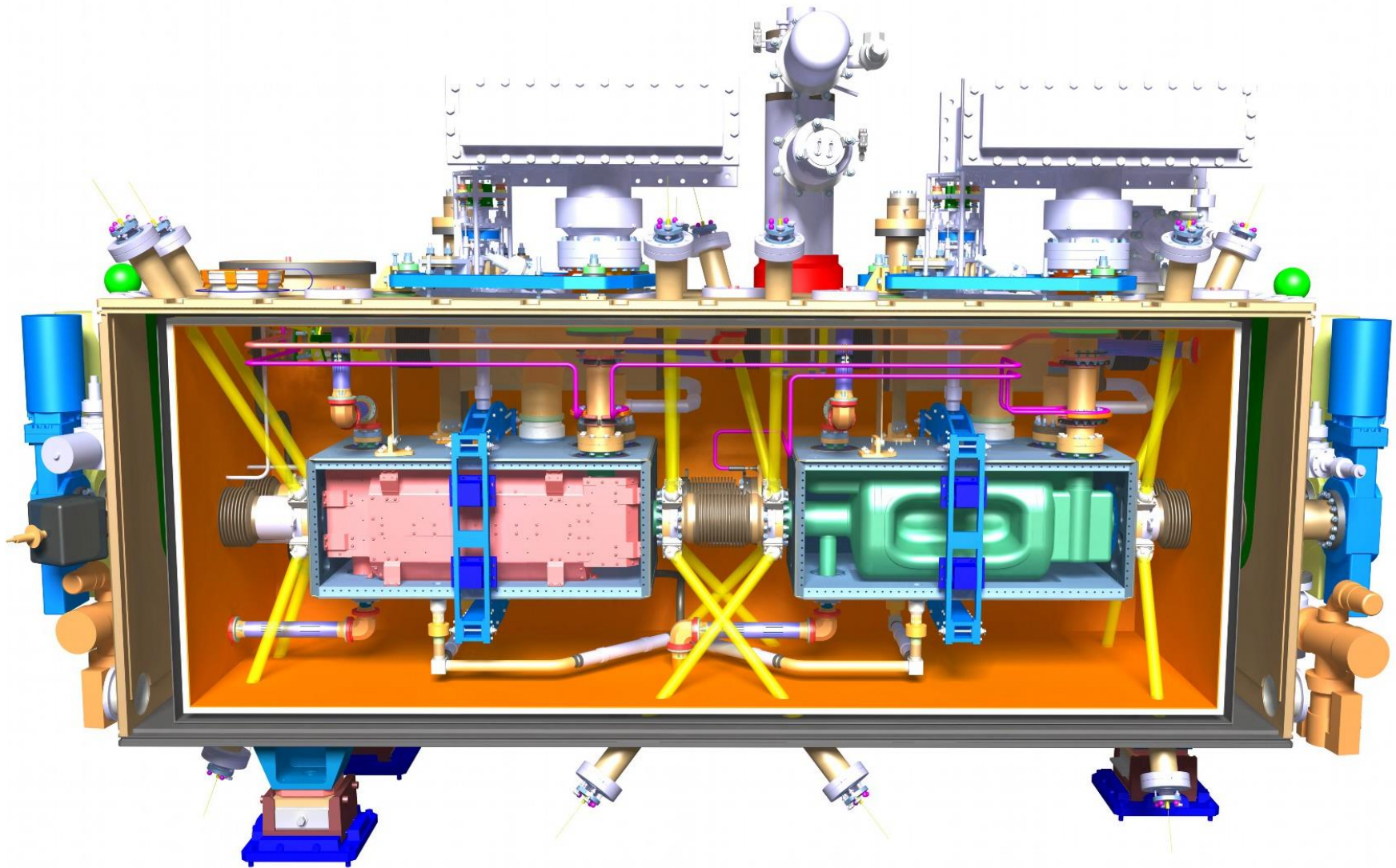


RFD Cavities cold magnetic shield for tests in SPS



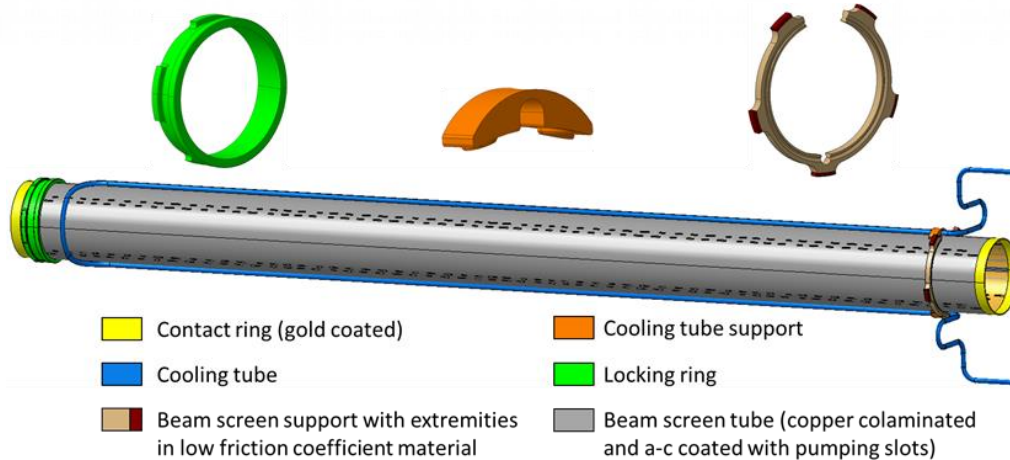
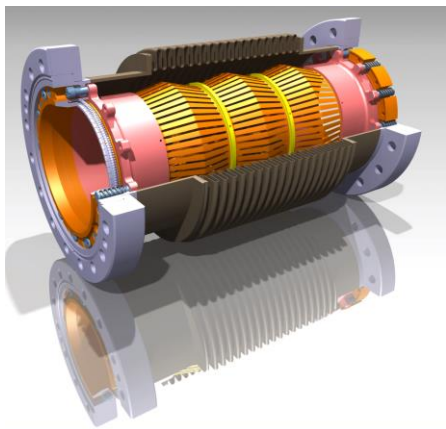
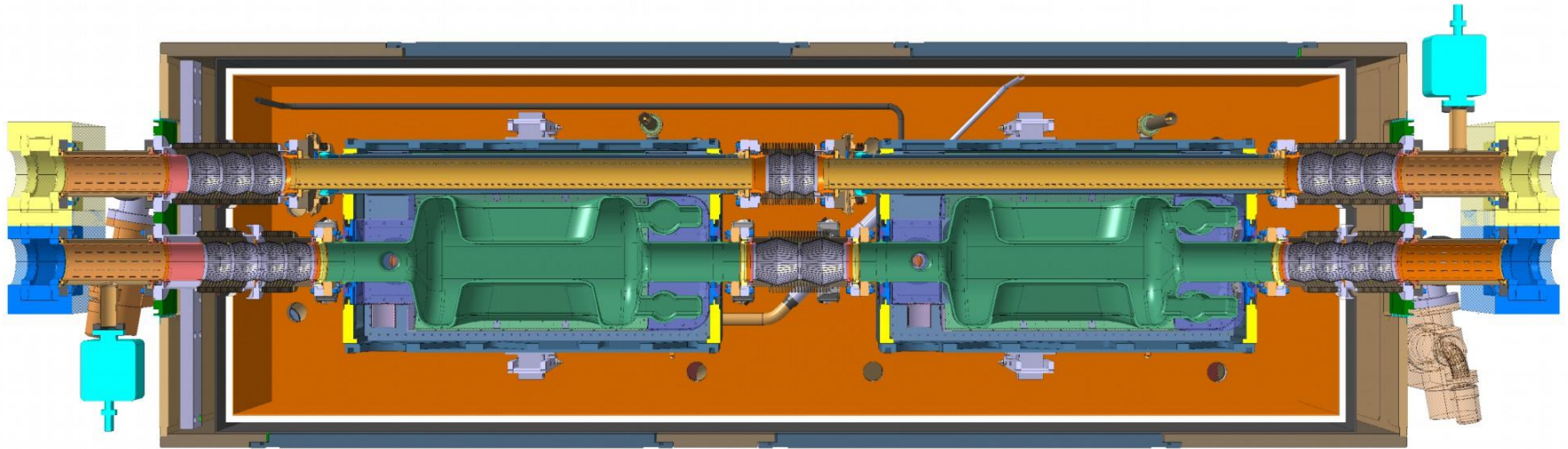
Modification of RFD cold magnetic shields being finalised by UK

RFD Cryomodule for tests in SPS identical to LHC cryomodule



RFD Cryomodule for tests in SPS identical to LHC cryomodule

Design update including second beam pipe with beam screen, RF shielded bellows, ...



Courtesy of Germana Riddone

Crab cavities & cryomodules

today ↓



Design & developments



DQW cavities (2) + CM (1)

Fabrication Tests

DQW cryomodule (1)

Tests



RFD cavities (2) + cryomodule (1)



SM18

Tests in SPS

Tests in SPS

DQW dressed cavities (2+9) DQW cryomodules (1+4)

Fabrication & tests

Installation



LHC production

RFD dressed cavities (2+2+10) RFD cryomodules (5)

Fabrication & tests

Installation



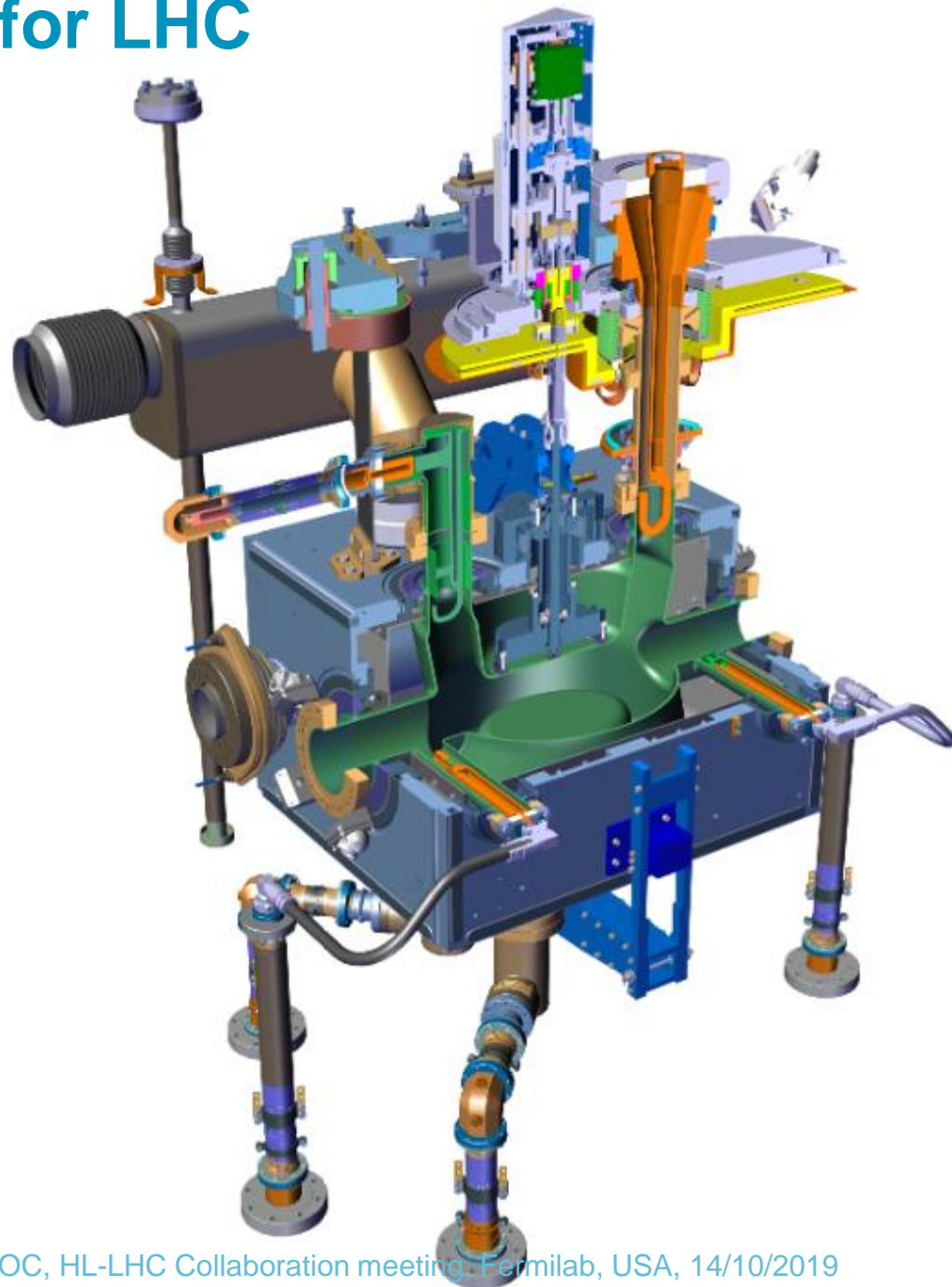
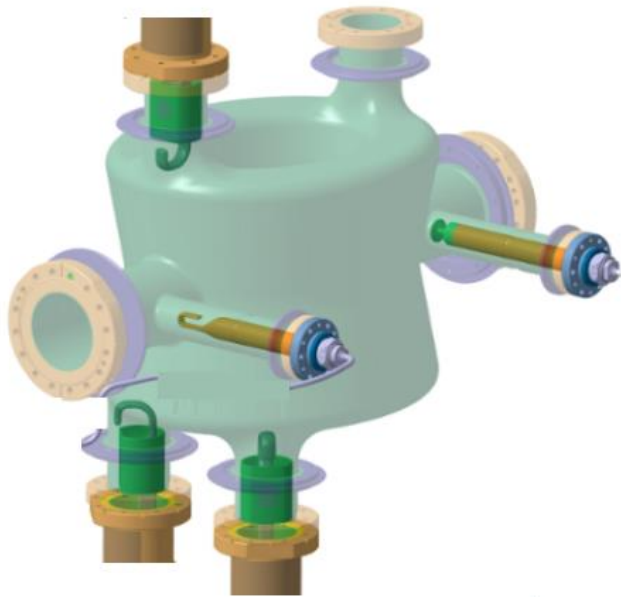
DQW Cavities for installation in LHC

- Cavities design updated after SPS tests with beam
- Cavities (2 pre-series + 9 series) equipped with cold magnetic shield and helium vessel being manufactured under CERN contract with Industry (RI, DE)
- CERN passed to Industry all the lessons learnt during the construction at CERN
- See presentation by Nuria Valverde tomorrow
- HOMs and pick-up antennas to be built by Russia collaboration, collaboration agreement under preparation.
- See presentation of Eric Montesinos tomorrow

DQW Cryomodules for installation in LHC

- Cryomodule design to be updated with missing features for LHC (second beam pipe, corresponding cooling circuit, RF shielded bellows,...)
- First series cryomodule will be built at CERN
- Following cryomodules (x4) will be built in UK
 - Dressed cavities from CERN
 - Some cryomodule components from CERN (detailed responsibilities split agreed, still to be formalised)
- Collaboration agreement to be finalised
- See presentation by Thomas Jones tomorrow

DQW dressed cavity for LHC



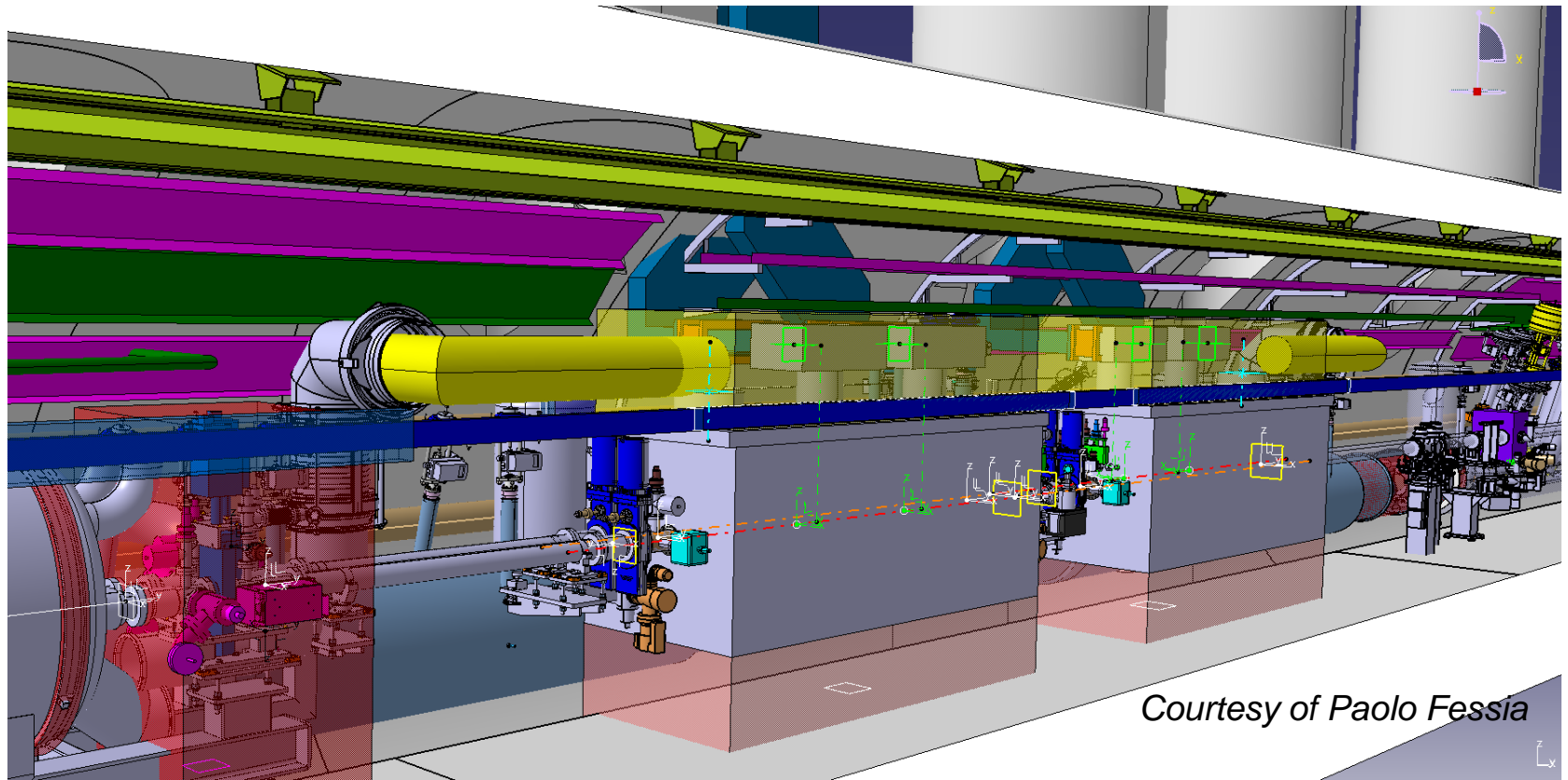
Industrial Production (RI) of DQW cavities for LHC

Design modification from SPS experience implemented in RI production
RI production progressing well



*See presentation tomorrow
by Nuria Valverde
“DQW RI production”*

Crab cryomodule in LHC environment



Courtesy of Paolo Fessia

The design update for integration in the LHC also takes into account placement of cryogenics + interchangeability between Point 1 and 5 + independent warm-up + remote alignment

Crab cavities & cryomodules

today ↓



Design & developments



DQW cavities (2) + CM (1)

Fabrication Tests

DQW cryomodule (1)

Tests



RFD cavities (2) + cryomodule (1)



SM18

Tests in SPS

Tests in SPS

DQW dressed cavities (2+9) DQW cryomodules (1+4)

Fabrication & tests

Installation



LHC production

RFD dressed cavities (2+2+10) RFD cryomodules (5)

Fabrication & tests

Installation



RFD Cavities for installation in LHC

- Cavities and cryomodule design identical to SPS tests
- Dressed cavities by US-AUP (deliverable x10)
- Collaboration agreement already in place
- Prototype bare cavities (x2) construction ongoing by US-AUP in industry (Zanon, IT)
- Pass to Industry all the lessons learnt during the construction at CERN
- See presentations by
 - Leonardo Ristori this afternoon
 - Manuele Narduzzi tomorrow
 - Naeem Huque tomorrow

RFD Cryomodules for installation in LHC

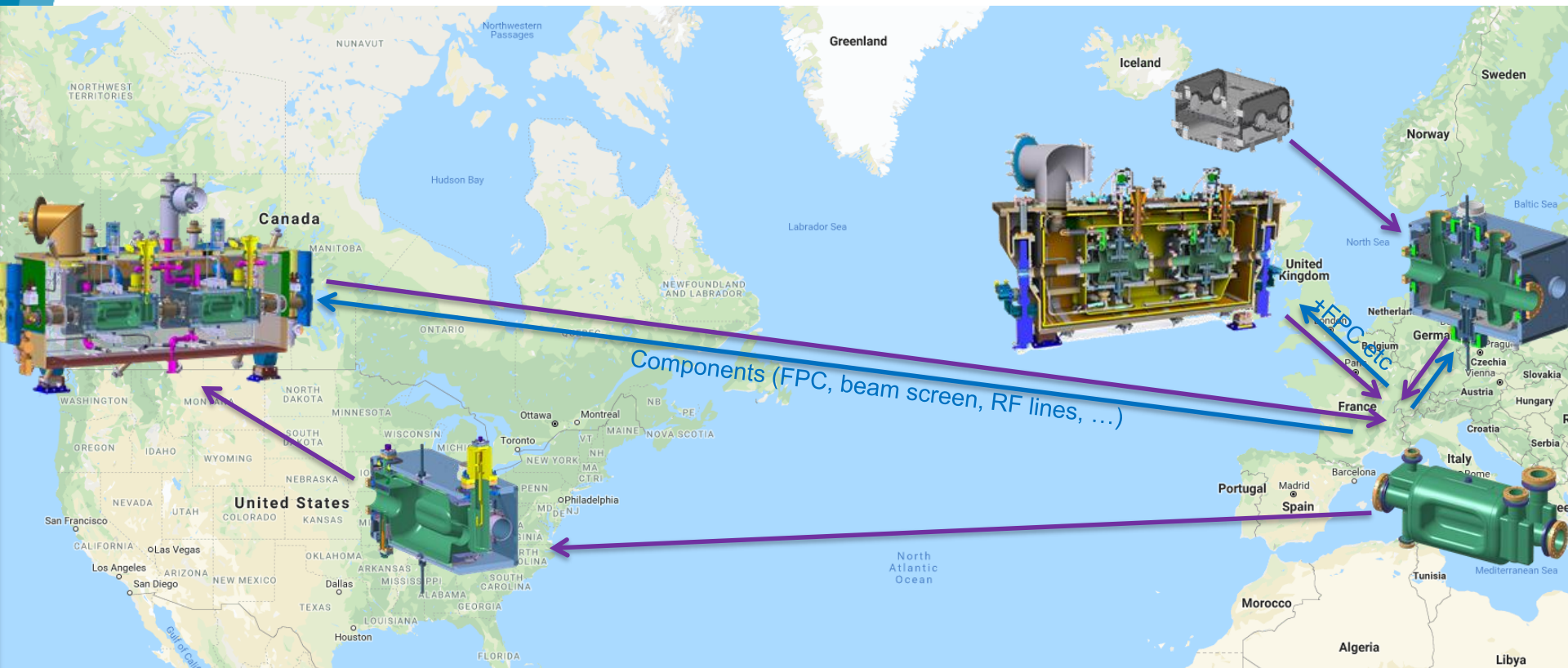
- Cryomodules (x5) to be built in Canada
 - Dressed cavities from US-AUP
 - Some cryomodule components from CERN (responsibilities split discussed, still to be formalised)
- Budget secured in Canada, collaboration agreement to be finalised
- See presentation by Robert Laxdal tomorrow

Engineering Specifications developed with collaborators

| Name | ID code | <u>Engineering Specification</u> <u>[EDMS nr]</u> | <u>Guideline for compl. with CERN Saf. Reg. [EDMS nr]</u> |
|---|----------------------------|--|---|
| | | <ul style="list-style-type: none"> to catch the HL-LHC needs (functional and technical requirements) to comply with ESRs List of required documentation Author: CERN-WP4 + Collaborating Entities | <ul style="list-style-type: none"> refers to the corresponding Eng. Spec demonstration of compliance, ESR by ESR intended for CERN int. use and for HSE, available for consultation Author: CERN-WP4 |
| Full Cryomodule | ACFGA | 2043014 | 2043016 |
| Dressed cavities, HOMs couplers, Pick-up antennas, Cold magnetic shield | ACFDC, ACFHC, ACFPU, ACFCM | <u>1389669</u> | 2058183 |
| Cryogenic circuits | ACFQC | 2093032 | 2101920 |
| Thermal shield | ACFTS | 2101922 | 2101923 |
| MLI | ACFTS | 2144140 | Not needed |
| Vacuum vessel | ACFVT | 2101924 | 2101925 |
| Warm Magnetic shield | ACFWM | 2101926 | Not needed |
| Instrumentation | ACFIS | 2145054 | Not needed |
| Sector Valves (beam line) | TBC | 2101929 | 2101930 |
| Plug-in modules for Cold-Warm transition + Intercavity Chamber | TBC | 2101931 | 2101932 |
| Fundamental Power Coupler | ACFMC | 2101934 | 2101936 |
| Tuning system | ACFTU | 2101938 | 2101939 |
| Safety protecting devices | ACFGA | 2101940 | 2101943 |
| Beam screen | TBC | 2101950 | 2101951 |
| Others (Alignment monitoring system, Support and alignment system, RF internal lines) | ACFAM, ACFAH, ACFRL | Not needed or not present | Not needed or not present |

• Released
• Draft available for feedback
• Int. discussion at CERN
• Not available

World-wide collaboration - Transport aspects being addressed in detail



See presentation of Thomas Jones "UK1 RFD cryomodule status and transport aspects"
See presentation of Robert Laxdal "RFD Canada status & transport aspects"

Summary

- Tests in SPS
 - DQW SPS cryomodule
 - First crab cryomodule manufactured from scratch and **successfully operated** during one year in the SPS - big achievement considering the important number of newly developed complex components and no time contingency
 - Tests in SPS with beam **triggered cavities modifications**, and some other components design modifications for next generation
 - RFD SPS cryomodule
 - Cavities manufacturing at CERN well advanced, on track for delivery to UK by Oct-2020 in the frame of UK1
 - Cryomodule design updated **identical to LHC**
- Cavities and cryomodule series production
 - DQW and RFD (US-AUP) **cavities production launched** (RI and Zanon) including cavities modifications. Russia collaboration for DQW HOMs being finalised.
 - CERN has manufactured both types of cavities, and it is able now to ensure a backup role if needed. The **lessons learned from CERN manufacturing** are **shared with industry** and implemented in the industrial production.
 - **Strategy defined** for the production of **series cryomodules** in the frame of the collaboration with Canada, UK and US
 - Canada and UK2 cryomodules **collaboration agreements being finalised**
 - Includes manufacturing at CERN of critical components as well as the first series cryomodule

Crabs are made by very committed people. Thanks to all colleagues of the world-wide collaboration !

