

# HL-LHC Status

O. Brüning  
On behalf of the  
HL-LHC Project



# Reminder of the HL-LHC Goals

From FP7 HiLumi LHC Design Study application in 2010

The main objective of HiLumi LHC Design Study is to extend the LHC lifetime by **another decade** and to determine a hardware configuration and a set of beam parameters that will allow the LHC to reach the following targets:

A peak luminosity of  $L_{\text{peak}} = 5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$  with levelling, allowing:

An  $L_{\text{int}} \sim 4000 \text{ fb}^{-1}$  goal of  
An  $L_{\text{int}} \sim 4000 \text{ fb}^{-1}$  goal of  
This  $L_{\text{int}} \sim 4000 \text{ fb}^{-1}$  goal of  
first  $L_{\text{int}} \sim 4000 \text{ fb}^{-1}$  goal of

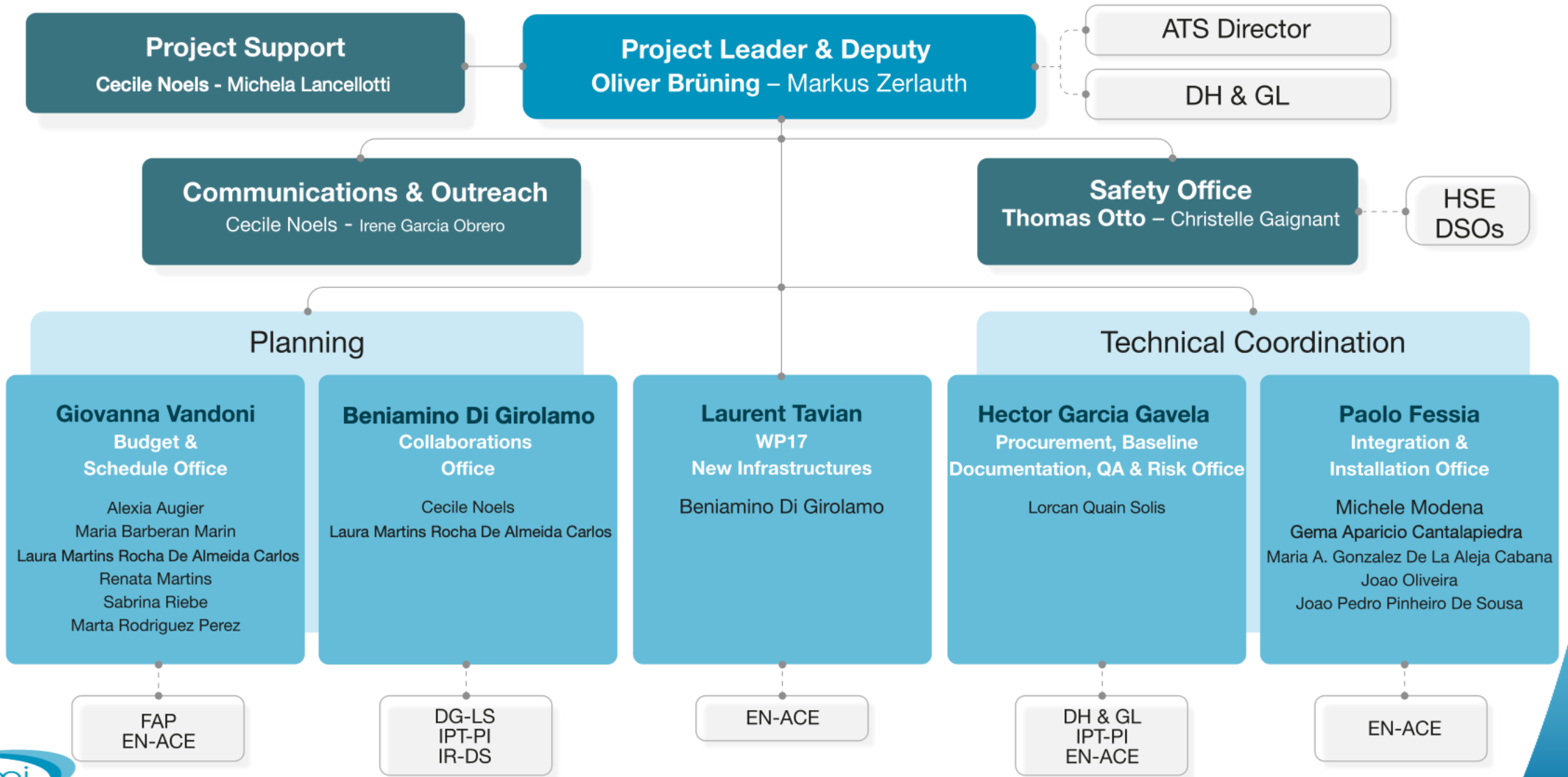
Transition from Design to Prototype Validation

→ Completion of Prototype tests and Start of Series production for many components!!!

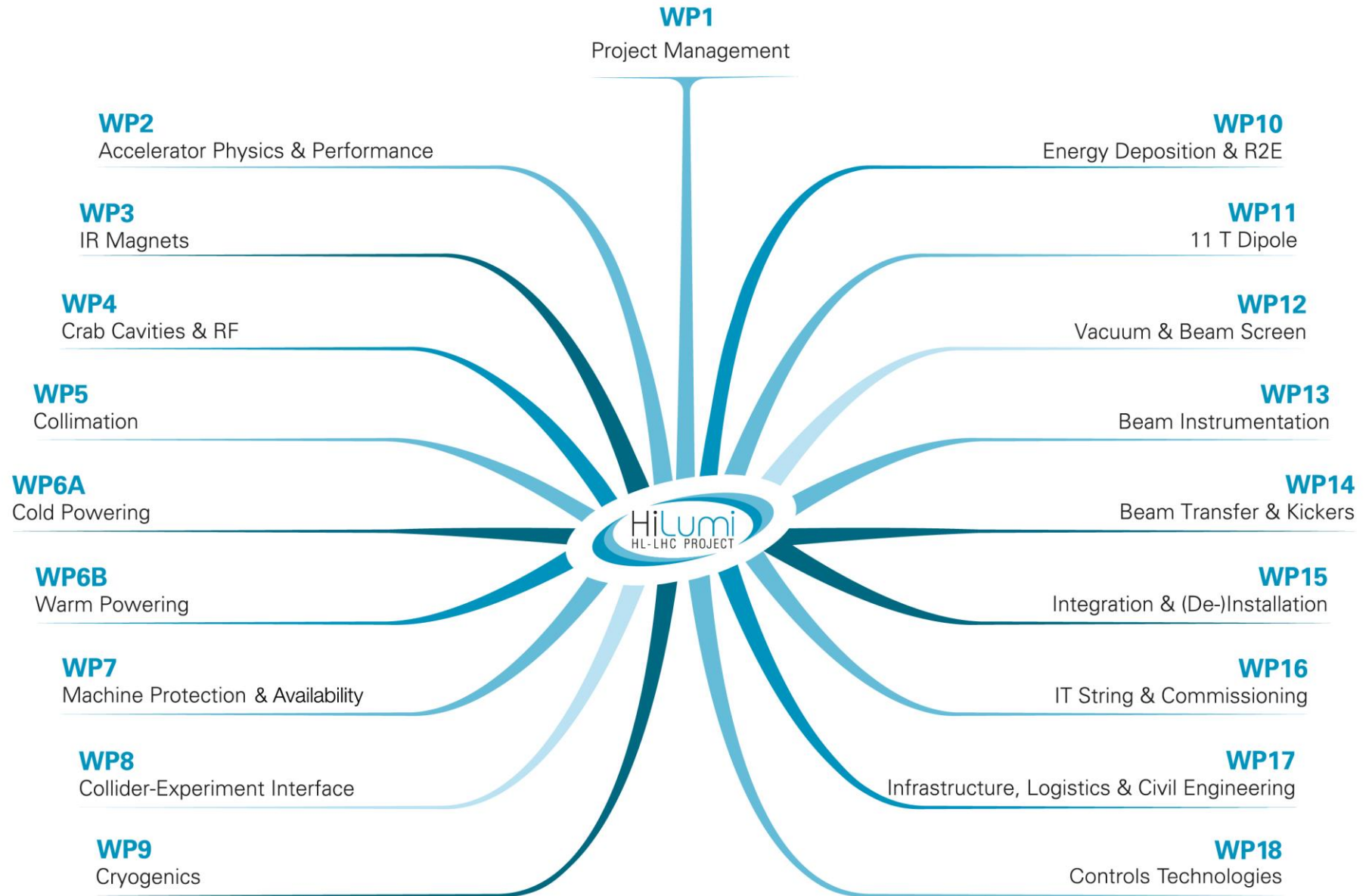
**Ultimate** performance established 2015-2016. With same hardware and same beam parameters, by using **engineering margins**:

$L_{\text{peak ult}} \cong 7.5 \cdot 10^{34} \text{ cm}^{-2}\text{s}^{-1}$  and **Ultimate Integrated**  $L_{\text{int ult}} \sim 4000 \text{ fb}^{-1}$   
LHC should not be the limit, would Physics require more than nominal

# HL-LHC PROJECT OFFICE



# Project Work Package Structure remains unchanged:



High-Luminosity  
Large Hadron Collider (HL-LHC)  
Technical design report

Editors:

**I. Béjar Alonso**  
**O. Brüning**  
**P. Fessia**  
**M. Lamont**  
**L. Rossi**  
**L. Tavian**  
**M. Zerlauth**



# TDR V1.0

## The last version of the TDR Including the added scope - 2020

V0.1 Published in electronic version for the October 2016  
Cost & Schedule review

[EDMS: 1723851](#)

and as CERN Yellow Book in **October 2017**

**New Updated Version 1.0 published in electronic version  
in 2020:**

<https://e-publishing.cern.ch/index.php/CYRM/issue/view/127>

Published as CERN Yellow Book in **2021**

Hardcopy versions available from HL-LHC Project Office

# Covid-19 Work Interruptions @ CERN in 2020

Practically all facilities were closed for ca. 3 month

→ Total delay including restart and slow down of activities of the order of 6 months

- Number of people on sites includes CERN's personnel as well as contractors.
- **Personnel involved in LS2, accelerator and detector upgrades, urgent site and building work came back to site gradually as of 18 May.**
- **The rest of personnel started coming back gradually as of 2<sup>nd</sup> week of June.**

Current situation @ CERN:

## COVID-19: WHAT'S NEW THIS WEEK COVID-19 : ACTUALITÉS DE LA SEMAINE



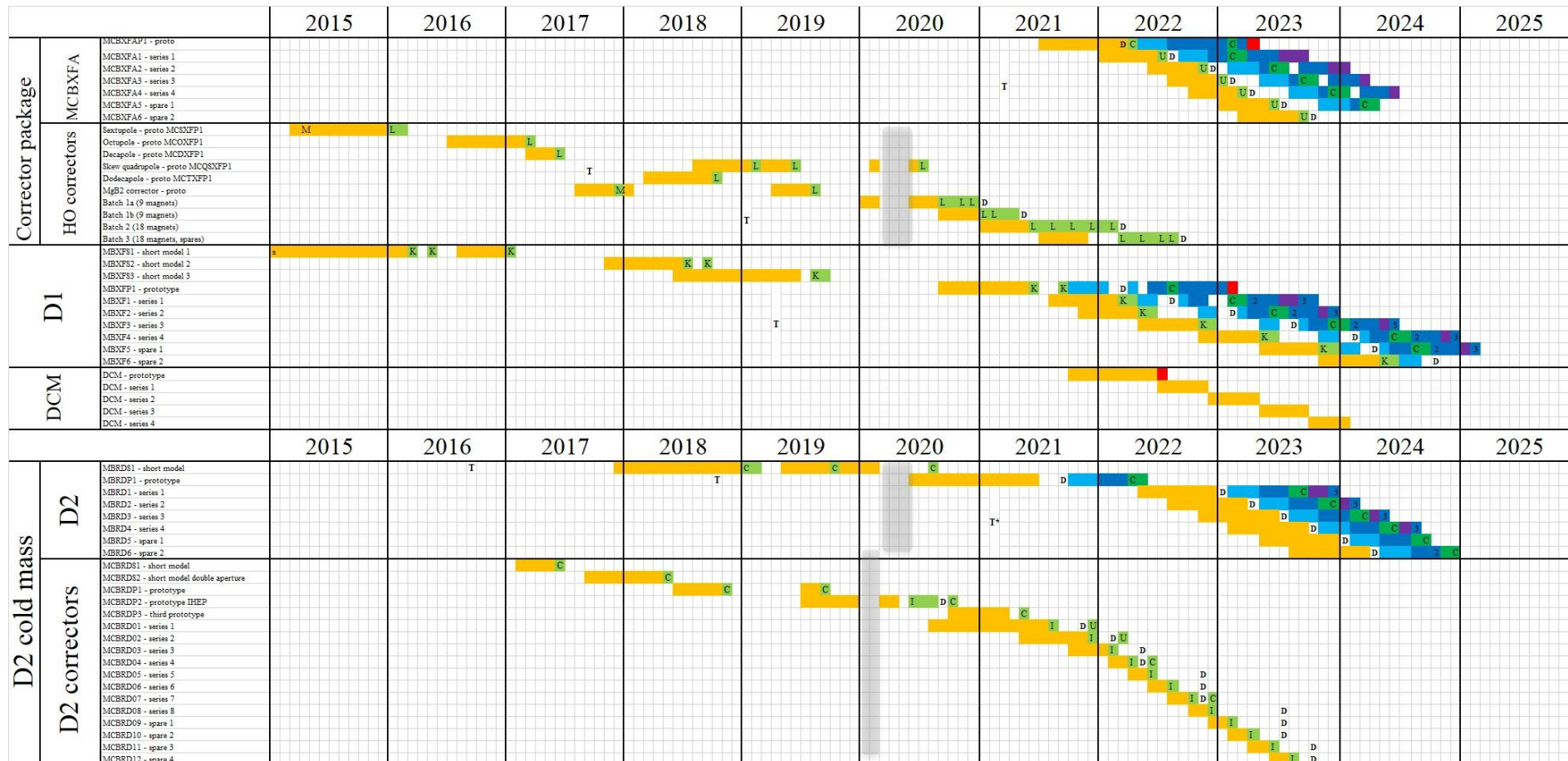
### CERN'S CURRENT COVID-19 LEVEL

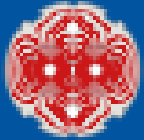


# COVID-19 impact WP3

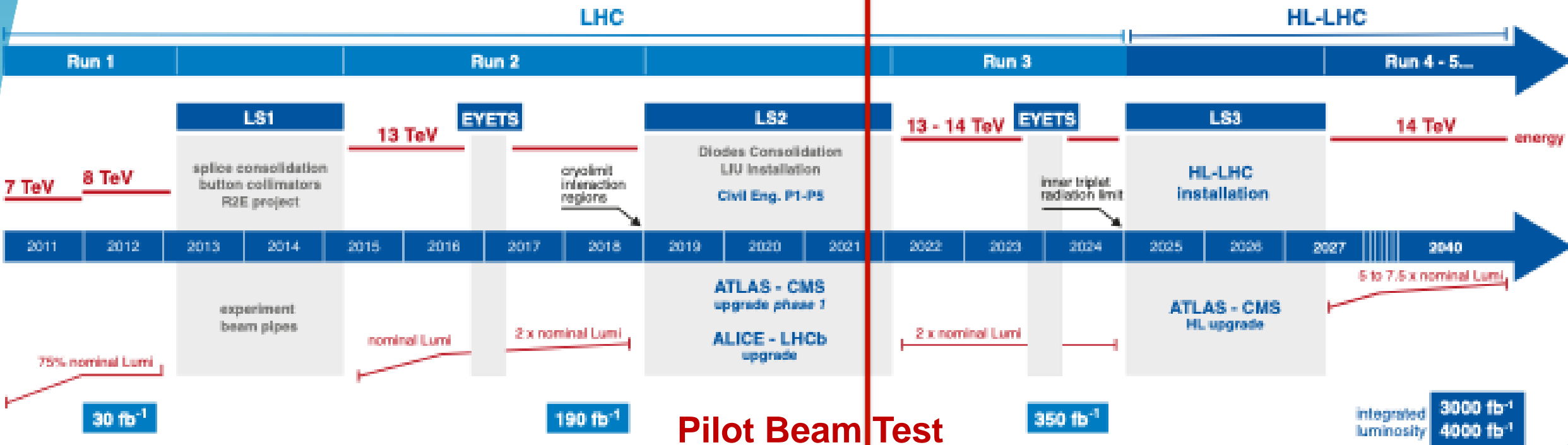
Ezio Todesco

- Practically all facilities of CERN and Collaborators closed for order of 3 months
- Total delay including restart and slow down of activities order of 6 months**





# LHC / HL-LHC Plan



## HL-LHC TECHNICAL EQUIPMENT:

**LS2 extended and hardware commissioning extended to end 2021; Run3 start only in 2022!**  
**Beam Energy for Run3 fixed @ 6.8 TeV**  
**Long EYETS 2023-24 to be confirmed in 2022**  
**HL-LHC keeps the construction schedule unchanged where possible to keep the momentum!**  
**➔ But shifts the start of the IT String operation to 2024**





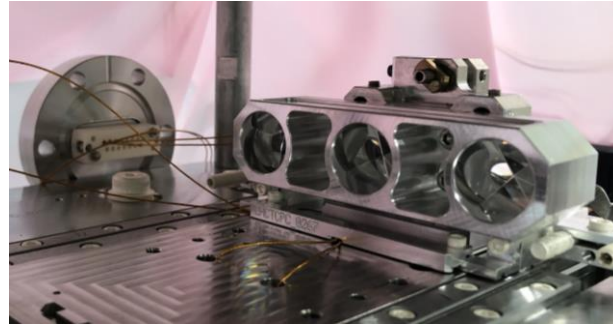
# Timeline: Main Milestones in 2021

- November 2020: AUP CD3 approval by DOE ✓
- **January 2021: Decision to defer 11T installation to after LS2 → activation of Crystal coll. option**
- **March 2021: □ Test of MQXF02 @ CERN → limited in one coil close to nominal ✓**
- April 2021: □ Successful test of MQXF05 @ BNL ✓
- April 2021: Collaring of 2 apertures for D2 prototype
- June 2021: □ Successful test of MQXF06 @ BNL ✓
- **July 2021: Successful test of D1 prototype at KEK → reached nominal performance ✓**
- July 2021: Review of the SM18 test facility infrastructure @ CERN
- **August 2021: □ Test of MQXF07 @ BNL → limited in one coil close to nominal ✓**
- August 2021: Revised schedule for IT String test @ CERN → main exploitation now during 2024
- August 2021: design finetuning and successful cold test @ CERN of MCBXF01 ✓
- August 2021: Completion of D2 prototype assembly
- **August 2021: RFD1 was tested - 4MV @ 5 10<sup>9</sup> ✓**
- August 2021: Completion of the JTT and VT supports for the Detector Machine Interface

# Crystal collimation

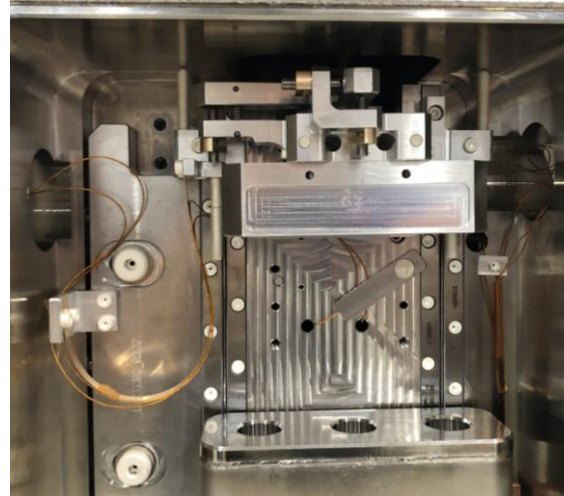
Two crystal primary collimator (TCPC) assemblies completed at CERN, in time for the installation in the YETS21/22 → 2 more units planned for YETS22/23

*Full TCPC assembly ready for impedance measurements.*

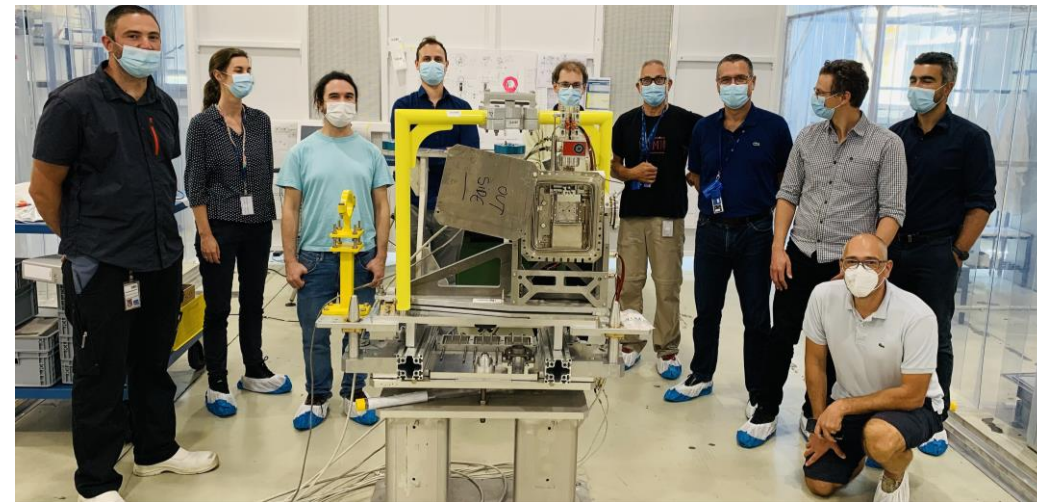


*Retro-reflectors of interferometer*

*Bent crystals of excellent quality produced by PNPI and INFN-Fe being tested with SPS beams — the two best ones will be mounted mid Oct. in the TCPCs*



*Internal mechanical components*



*Team photo during a visit in Sep. (Courtesy M. Calviani)*

O. Brüning, 16<sup>th</sup> CERN-KEK Committee, October 7<sup>th</sup> 2021

# Q2 MQXFB Prototype Tests @ CERN

- Performance limitations of second prototype: limited @ 7TeV in one coil
  - Re-evaluation of all mechanical tolerances → slightly out of spec coil deformation → higher than expected stress on coil after Stainless Steel assembly
  - Change of the procedures of the coil production and stainless steel assembly under study
  - Decision to test lower pre-stress on a short magnet - **successful test in August 2021** - No impact on magnet performance
  - 3<sup>rd</sup> Prototype test planned for January 2022



# MQXFA Magnet Construction in the US: Q1 and Q3

- All magnets tested vertically and without Stainless Steel shell!
- MQXFA03 & 04 tested successfully.
  - *Deliverable* Magnets for one assembly
- MQXFA05 & 06 tested successfully.
  - *Deliverable* Magnets for second assembly
- ➔ Sufficient magnets for assembling Q1 & Q3 for the IT String @ CERN!!!
- MQXFA07 tested and showed weakness in one coil ➔ will be disassembled
- MQXFA08 under assembly at LBNL

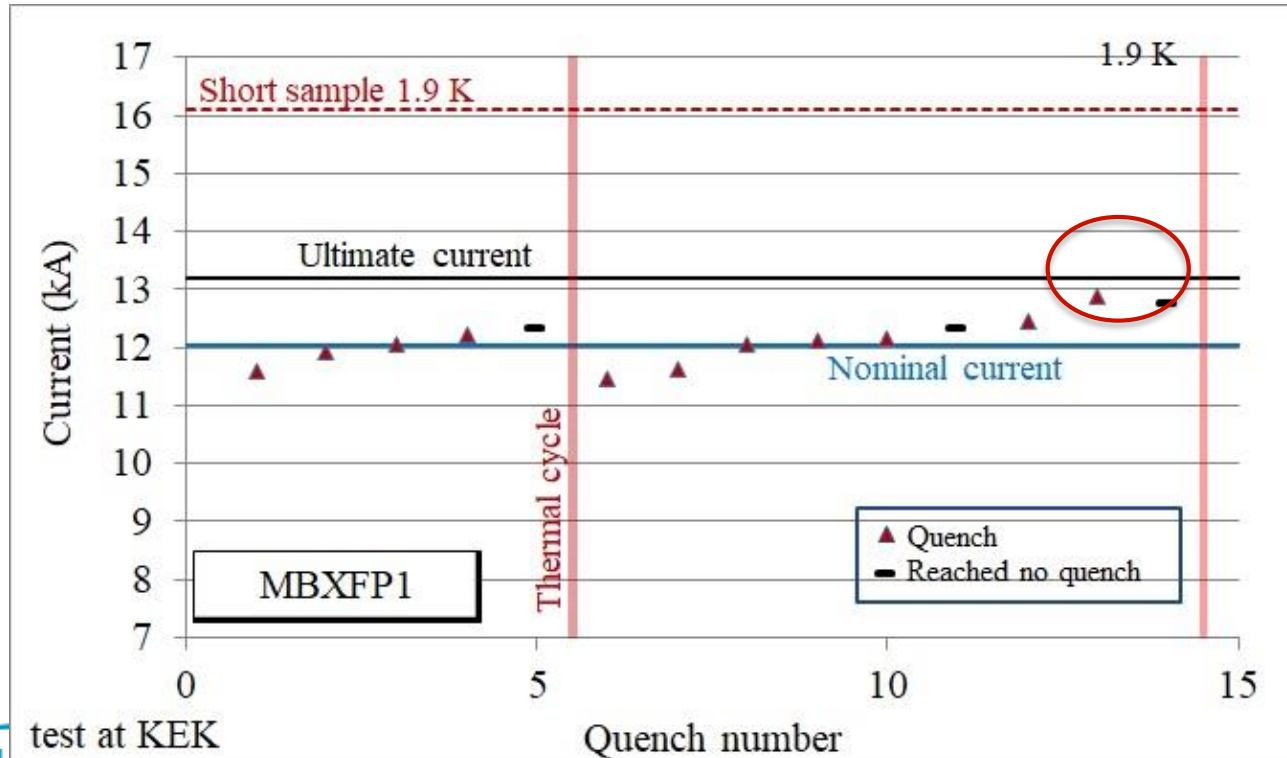
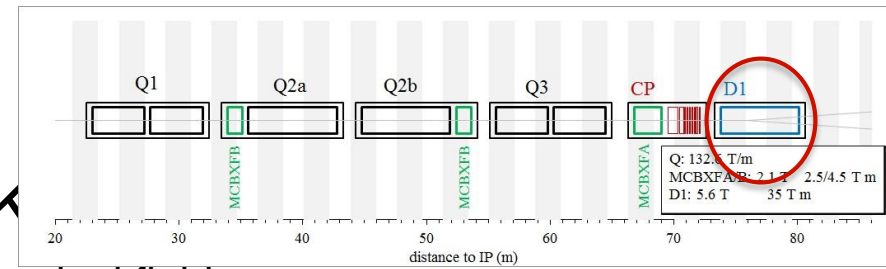




# Separation dipole

## June/August 2021: test of the prototype in KEK

- 7m-long magnet manufactured in Hitachi, based on KEK design, 5.6 T nominal field
- First run: **nominal current (7 TeV operation) reached**
- Second run: trained towards ultimate (7.5 TeV operation), test stopped due to limitations in test station**
- Good validation of the design, no visible show-stoppers!**



test at KEK

# CERN-RFD Tests & Status

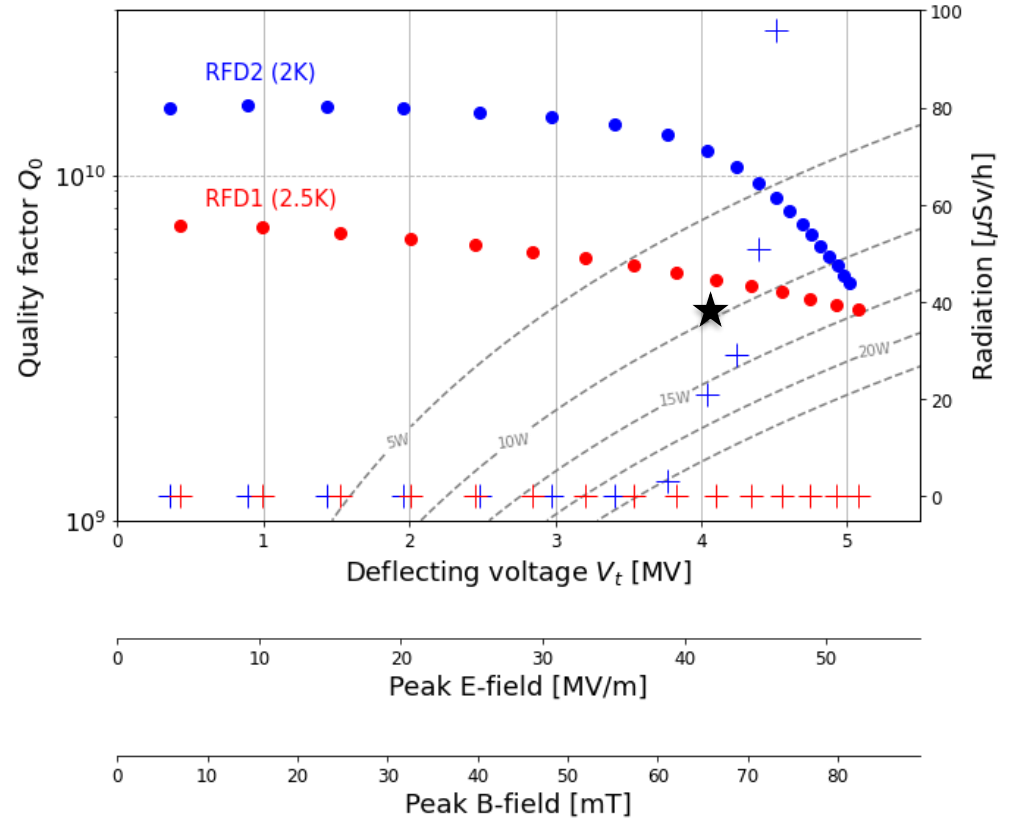
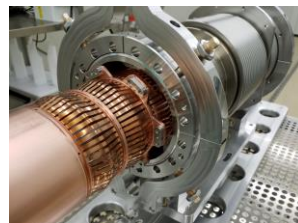
CERN-RFD2



Transport Preparations to UK



Couplers & Vacuum Modules



Getting ready for shipment to the UK for Cryomodule assembly after overcoming initial vacuum leaks

# Timeline: Main Milestones in 2021

- September 2021: Completion of D2 prototype magnet
- September 2021: D2 corrector magnet reached required performance: change from prototype to series production ✓
- **September 2021: First Crab Cavities from industry [RI and Zanon] arrived at CERN and reached nominal field ✓**
- September 2021: Successful Testing of nested orbit corrector design iteration ✓
- October 2021: Shipment of RFD cavities from CERN for SPS tests to the UK ✓
- October 2021: all LS2 collimator installations finished in time during LS2
- **October 2021: Completion of new Underground caverns and galleries**
- November 2021: HO corrector manufacturing and assembly completed
- November 2021: 5<sup>th</sup> Cost & Schedule Review
- Fall 2021: September 2021: Assembly of first US cold mass containing MQXFA03 and 04
- **YETS 21/22: Installation of new generation of Crystal Collimators**

# Crab Cavities Production:

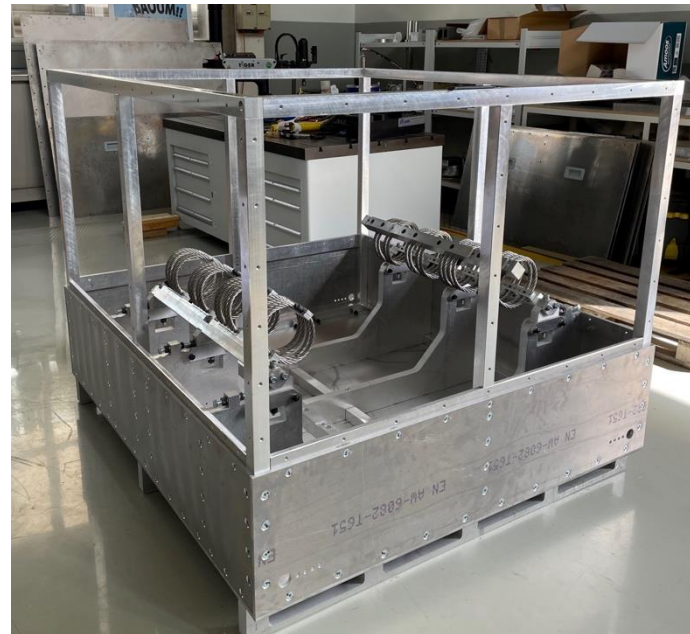


First industrial series cavities at CERN  
DQW (Research Instruments)



CERN RF Dipole cavity  
RFD2 final assembly of  
beam screen before shipping  
to the UK for cryostating &  
transport frame

→ RFD2 left CERN for UK in  
September 2021

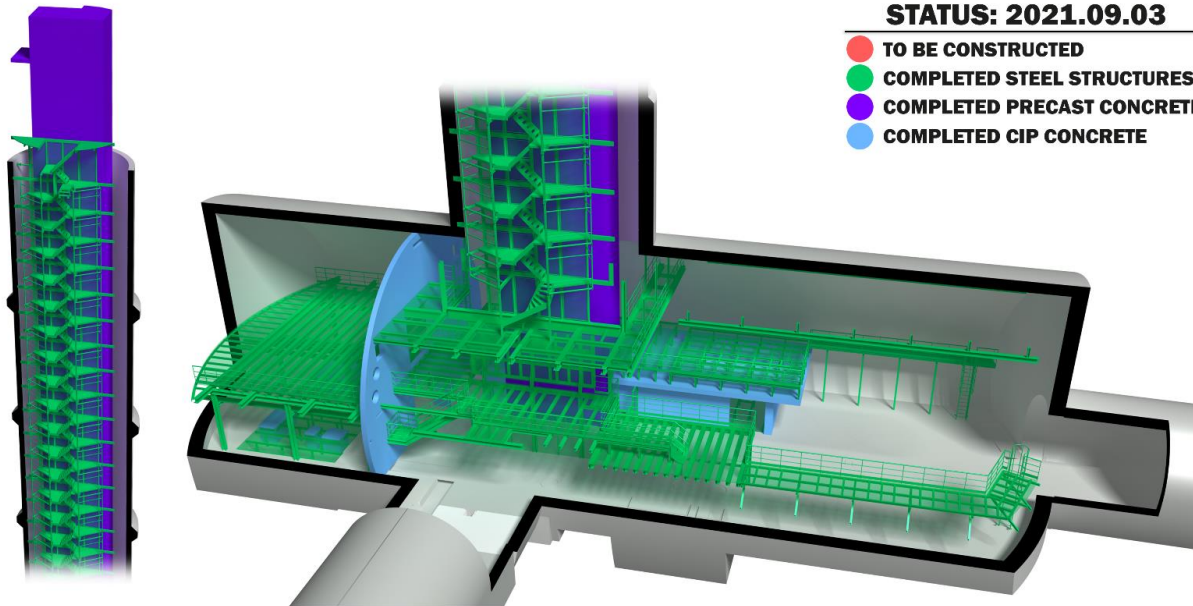




# HL-LHC civil engineering status (Point 1)

Overall progress: **71%**

## Underground

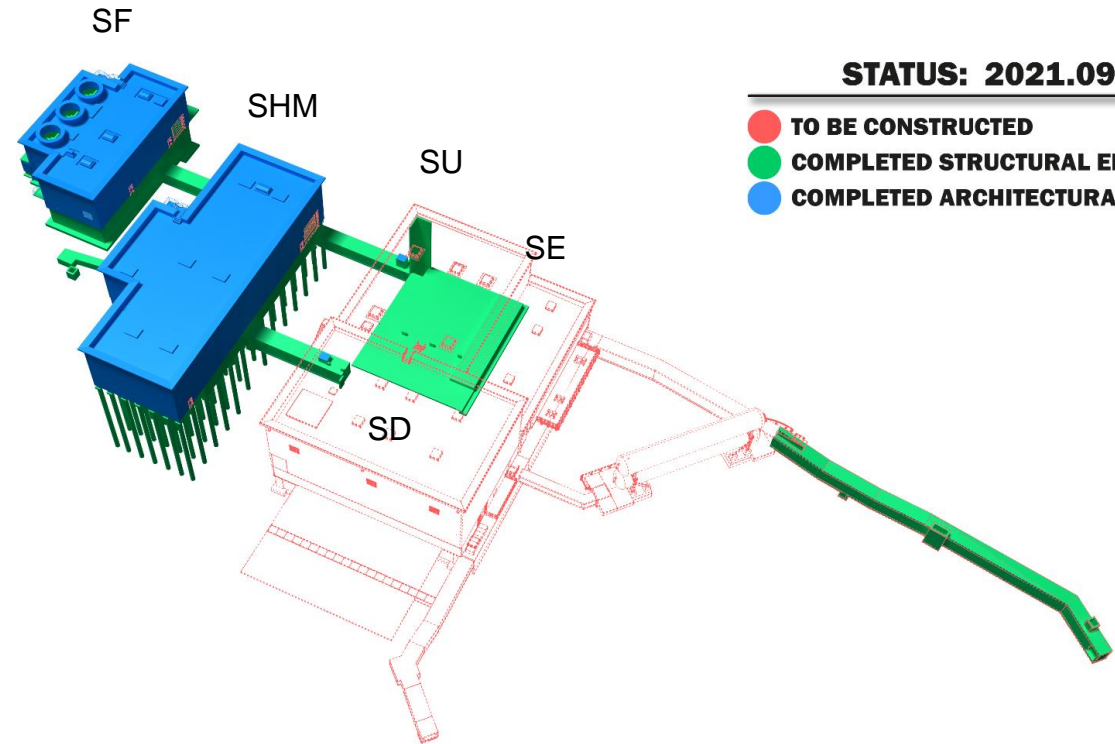


**STATUS: 2021.09.03**

- TO BE CONSTRUCTED
- COMPLETED STEEL STRUCTURES
- COMPLETED PRECAST CONCRETE
- COMPLETED CIP CONCRETE

**Expected completion by October 2021  
(including + ~1 month due to Covid-19)**

## Surface



**STATUS: 2021.09.03**

- TO BE CONSTRUCTED
- COMPLETED STRUCTURAL ELEMENTS
- COMPLETED ARCHITECTURAL FINISHES

**Expected completion by September 2022  
(Including + ~1 month due to Covid-19)**

# HL-LHC civil engineering status (Point 1)



PM17 shaft equipped with concrete modules and metallic structures

US/UW17 cavern with metallic structures for technical infrastructure



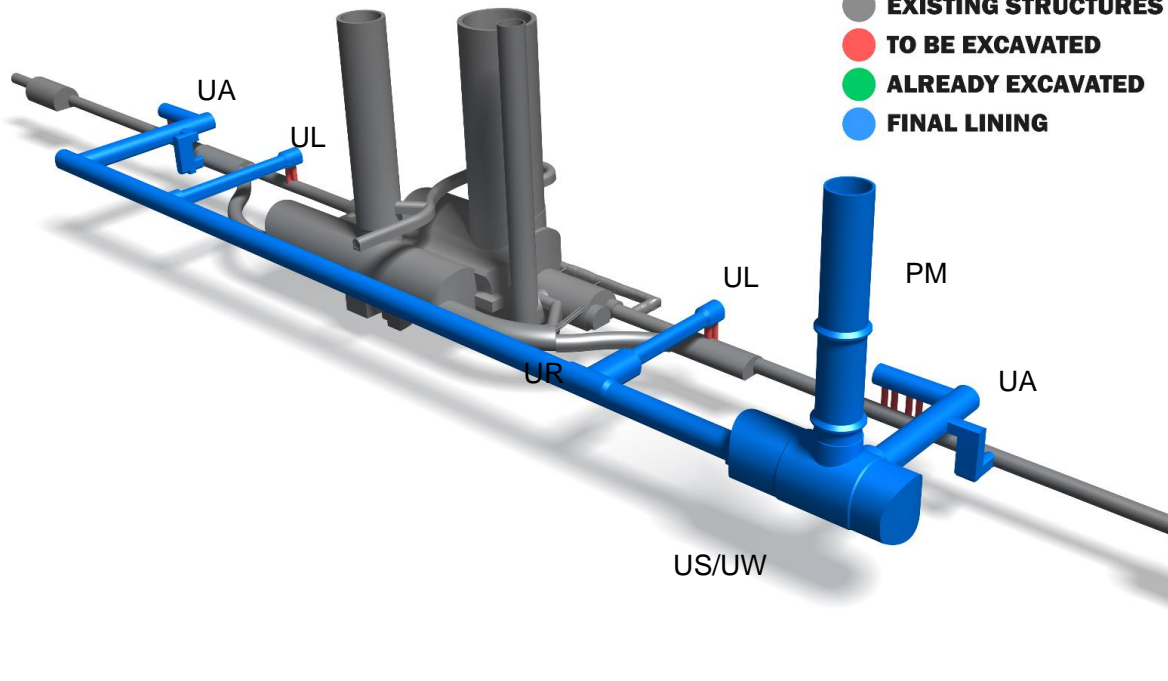
# HL-LHC civil engineering status (Point 5)

Overall progress: **64%**

## Underground

**STATUS: 2021.09.03**

- EXISTING STRUCTURES
- TO BE EXCAVATED
- ALREADY EXCAVATED
- FINAL LINING

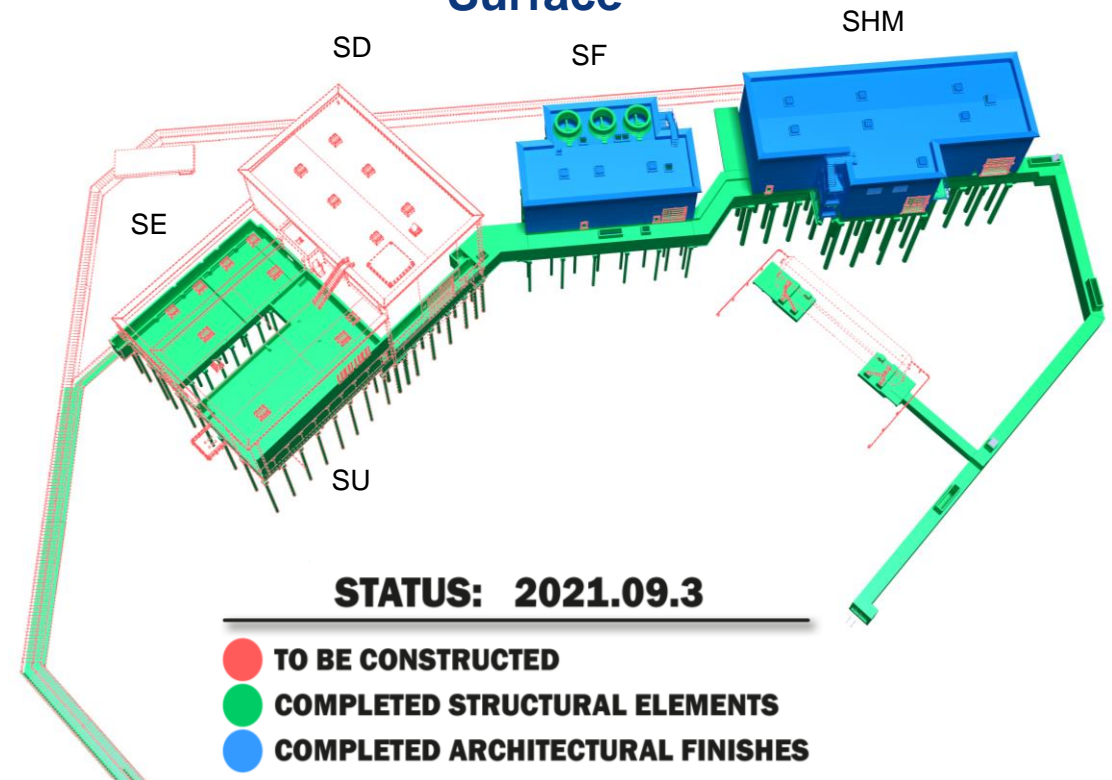


**Expected completion by Feb 2022**  
**(including + ~2 months of delay with 1.5**  
**months due to Covid-19)**

## Surface

**STATUS: 2021.09.3**

- TO BE CONSTRUCTED
- COMPLETED STRUCTURAL ELEMENTS
- COMPLETED ARCHITECTURAL FINISHES



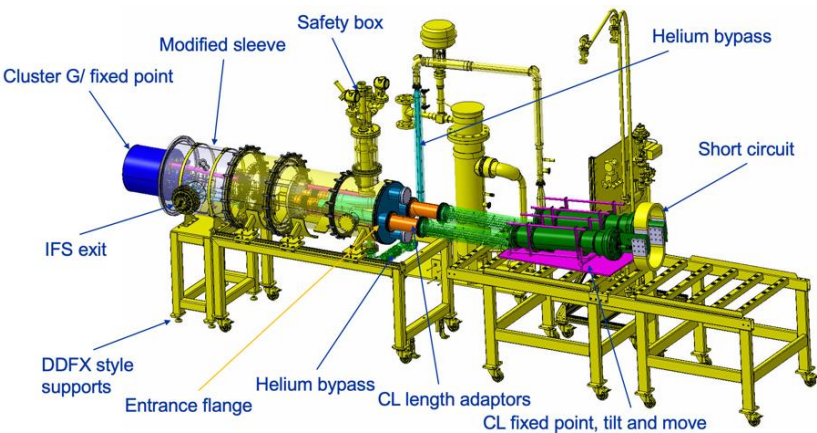
**Expected completion by November 2022**  
**(including + ~2 months due to Covid-19)**

# SM18 upgrade project – Scrutiny outcome

- Important upgrade of CERN’s SM18 test facility is required to allow for the testing of (pre-)series magnets, current leads and cold powering systems (sc links and feedboxes) for the HL-LHC project
- Scrutiny group request, assure conformity with needs beyond
- Detailed report of technical choices, quality assurance

Updated schedule for magnet availability for IT String Test!

→ Updated Schedule for IT String Test



HTS current lead testing

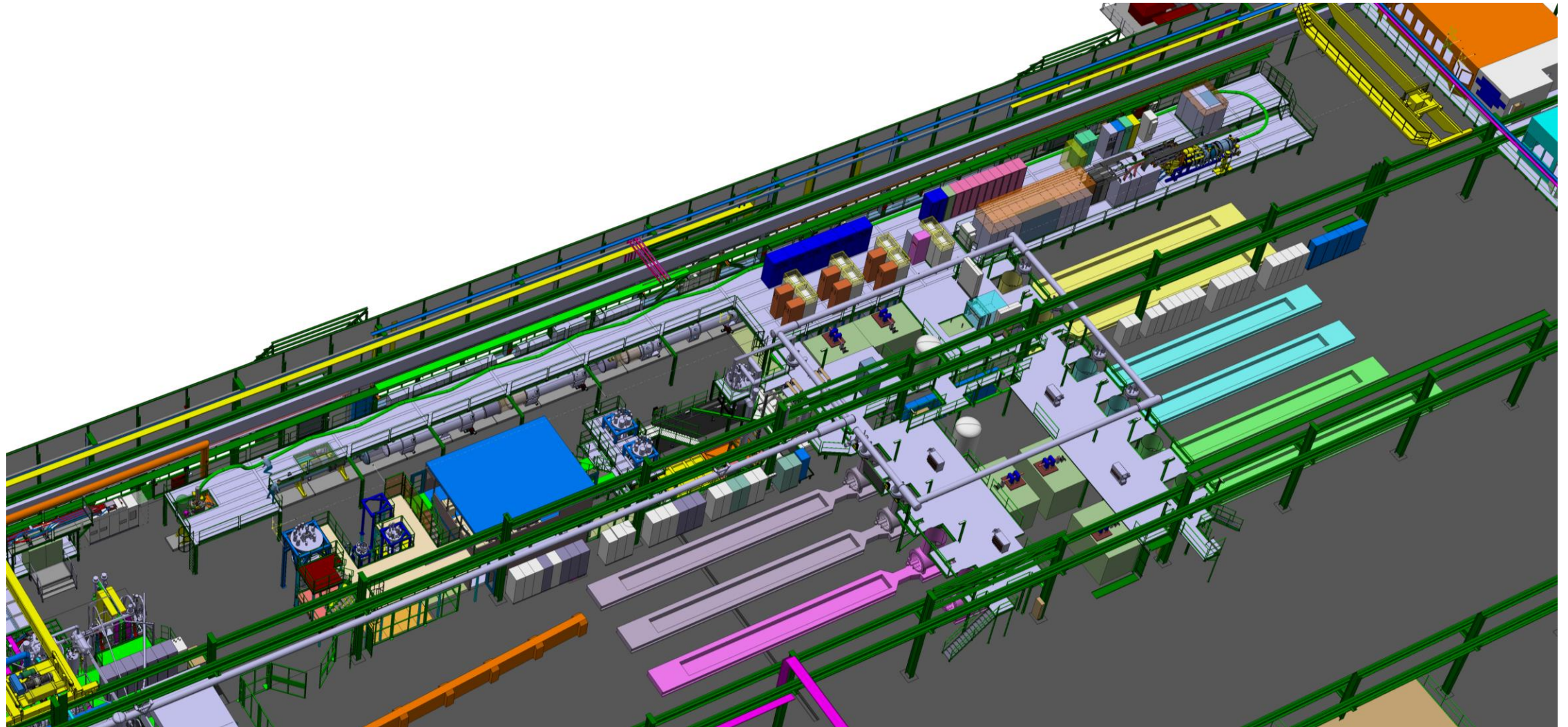


Test station for sc link and feedboxes



Magnet test benches

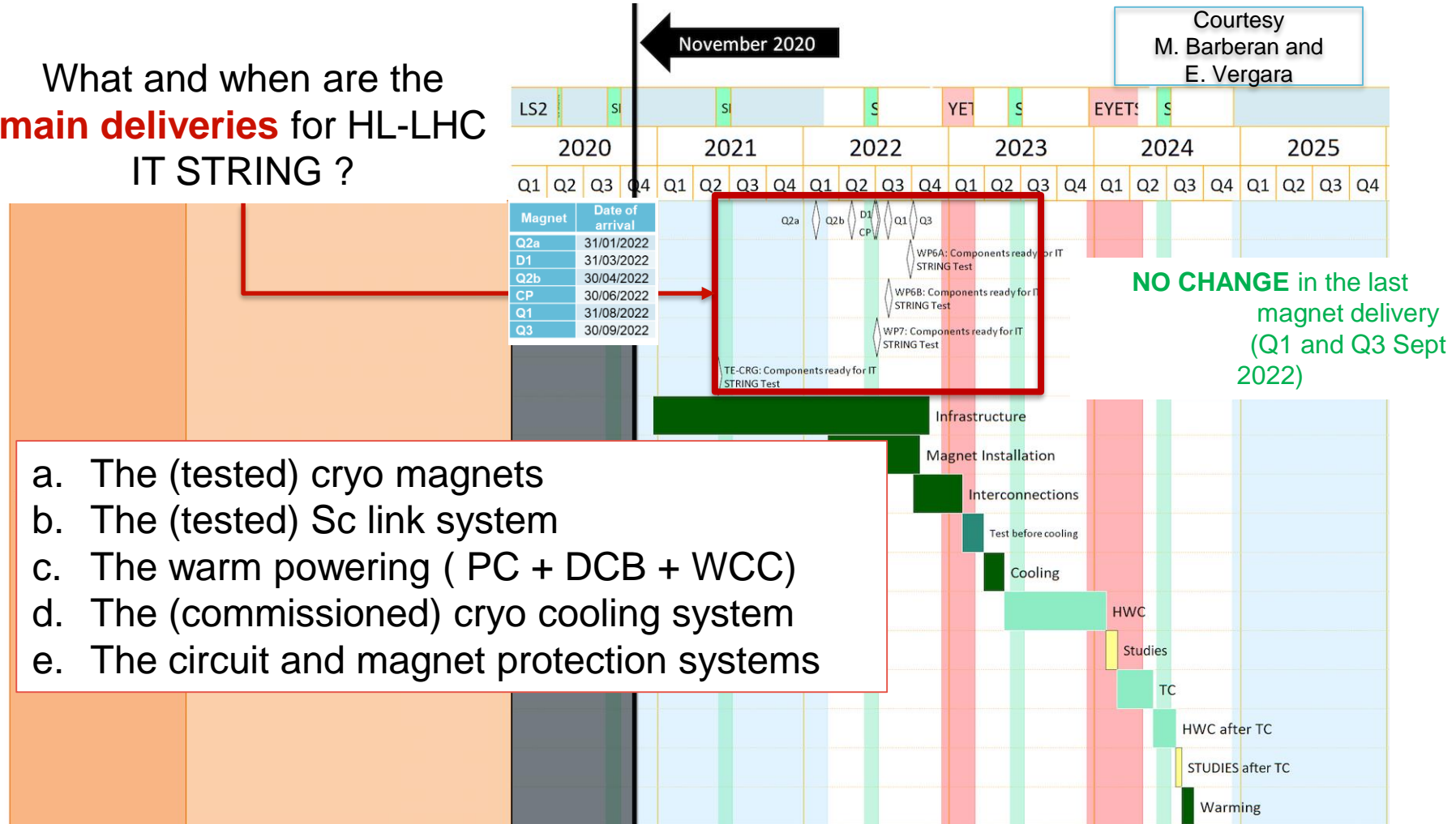
# IT String Installation in SM18: Q1 up to D1 inclusive!



# Master schedule changes in 2020: explanation

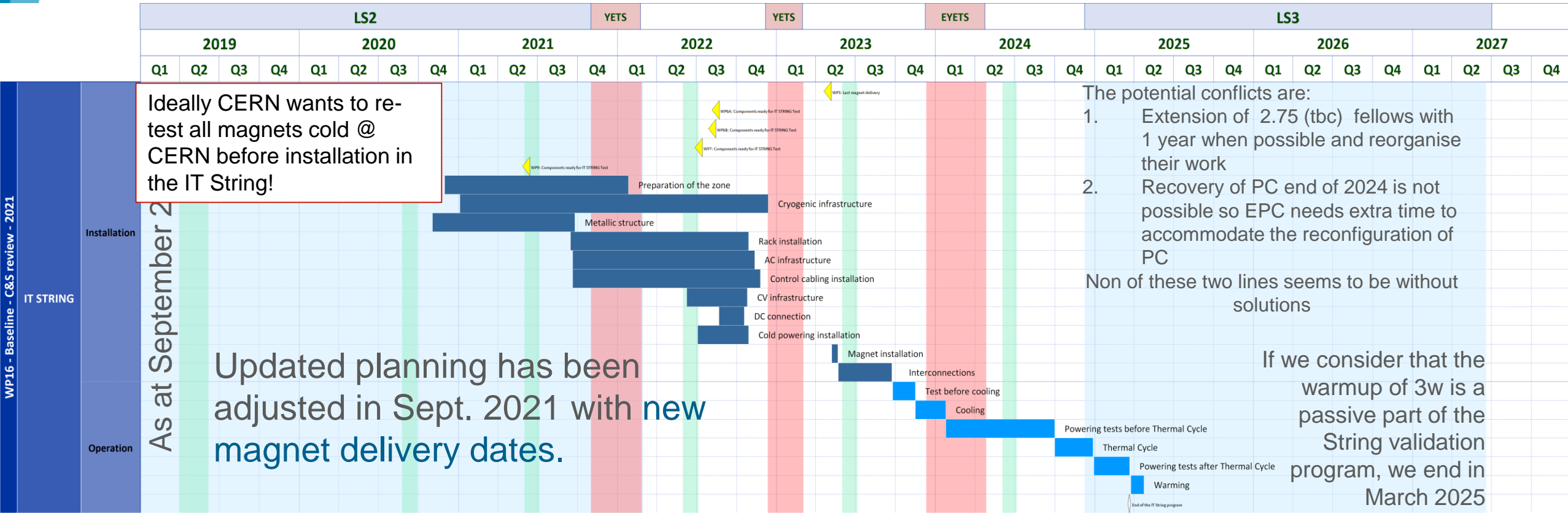
The HL-LHC IT STRING planning as integrated in the masterplan in **Nov 2020**.

What and when are the **main deliveries** for HL-LHC IT STRING ?



# New IT String Schedule

End of IT STRING test: End 2024 → April 2025 with re-testing after Thermal Cycle



This is 1 year shift in the STRING planning wrt C&S2019. Delay to be applied only from the date of magnet deliveries

# Upcoming Events

## HL-LHC Annual Meeting in October 2021: Virtual via Zoom

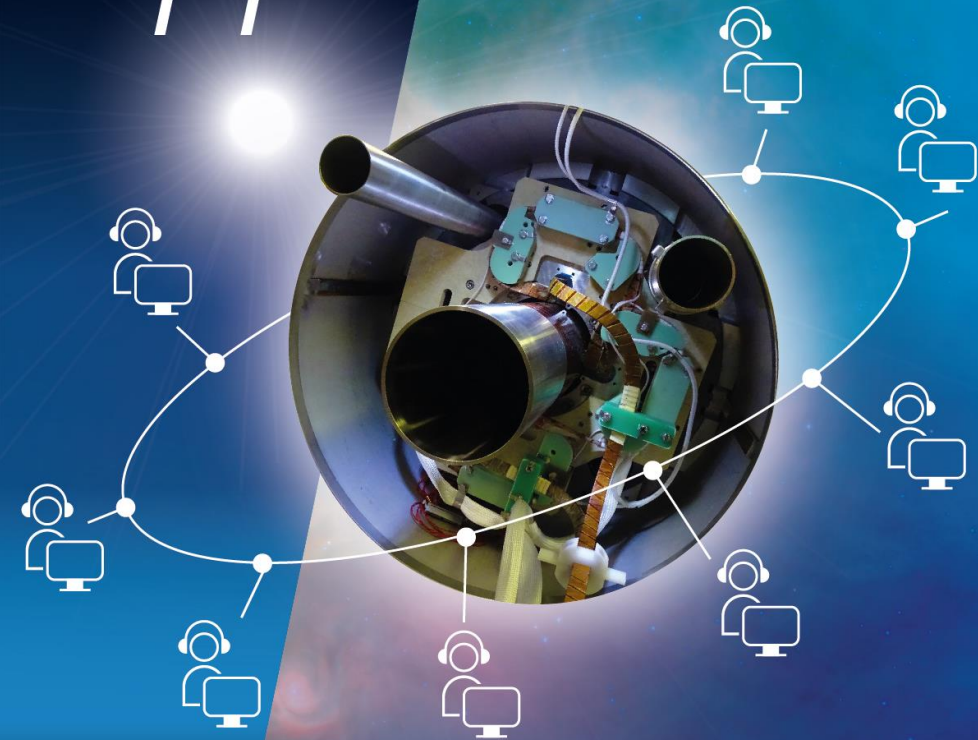
<https://indico.cern.ch/event/1079026/>

## Cost & Schedule Review in November 2021

# HIGH LUMINOSITY LHC / HL-LHC

# 11<sup>th</sup>

HL-LHC Collaboration Meeting  
CERN, 19 > 22 October 2021



The 11<sup>th</sup> HL-LHC Collaboration Meeting will be held in digital format and will take place from 19 to 22 October 2021. This format was chosen after consultations with all collaboration partners and tries to address the preferences of all HL-LHC collaborators given the persisting travel restrictions and limitations for social gatherings due to COVID-19.

Based on the traditional programme with plenary and work package parallel sessions, this meeting will serve as a technical update forum for the 5th Cost and Schedule Review, which is scheduled for 8-10 November 2021.

The main objectives will be to update all HiLumi collaborators on the results of key HL-LHC prototype tests, to highlight the progress made in the last year when all work still had to adapt to pandemic restrictions, and to update all collaborators on the latest schedule changes.

This year, all HL-LHC collaborators will be invited to follow the presentations 100% remotely. Participation in the meeting is by invitation only, and registration is mandatory and without fee.

### CERN - Organizing Committee

- Oliver Brüning Project leader
- Markus Zerlauth Deputy Project leader
- Cécile Noels Project Office

For more details and registration

[www.siteweb-hilumi.ch](http://www.siteweb-hilumi.ch)



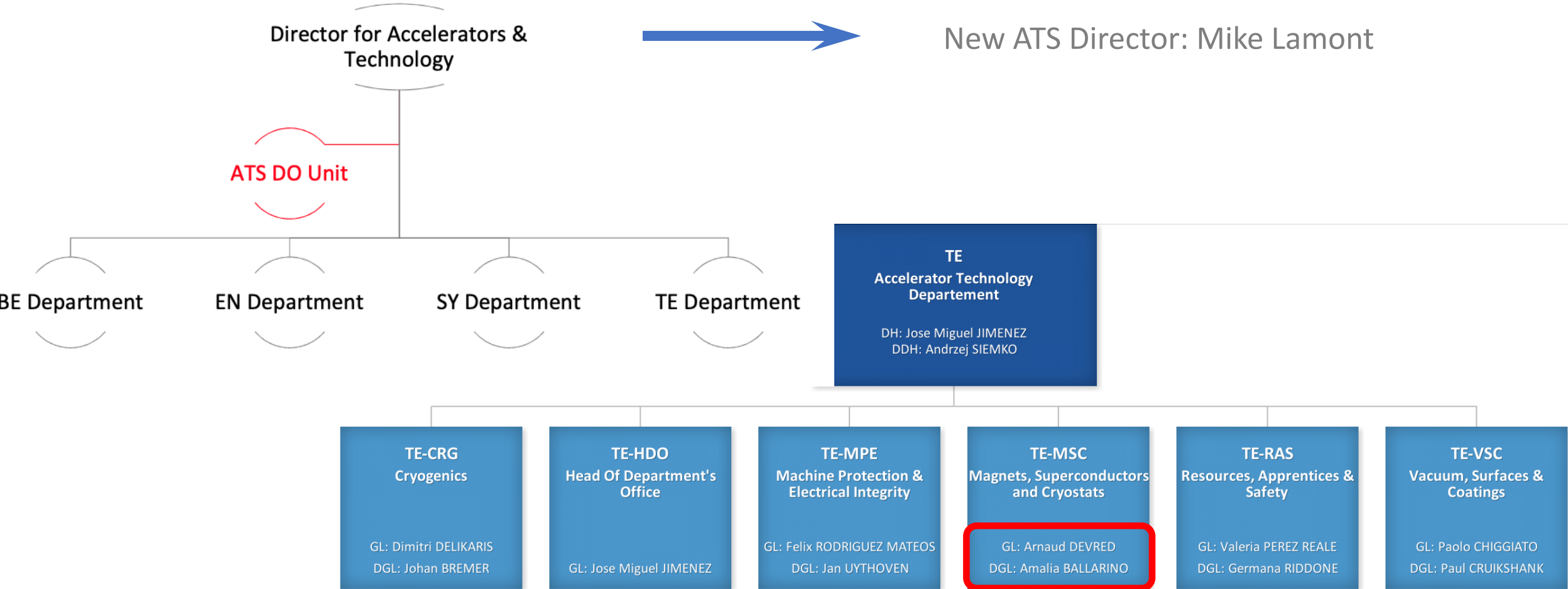
O. Brüning, 16<sup>th</sup> CERN-KEK Committee, October 7<sup>th</sup> 2021







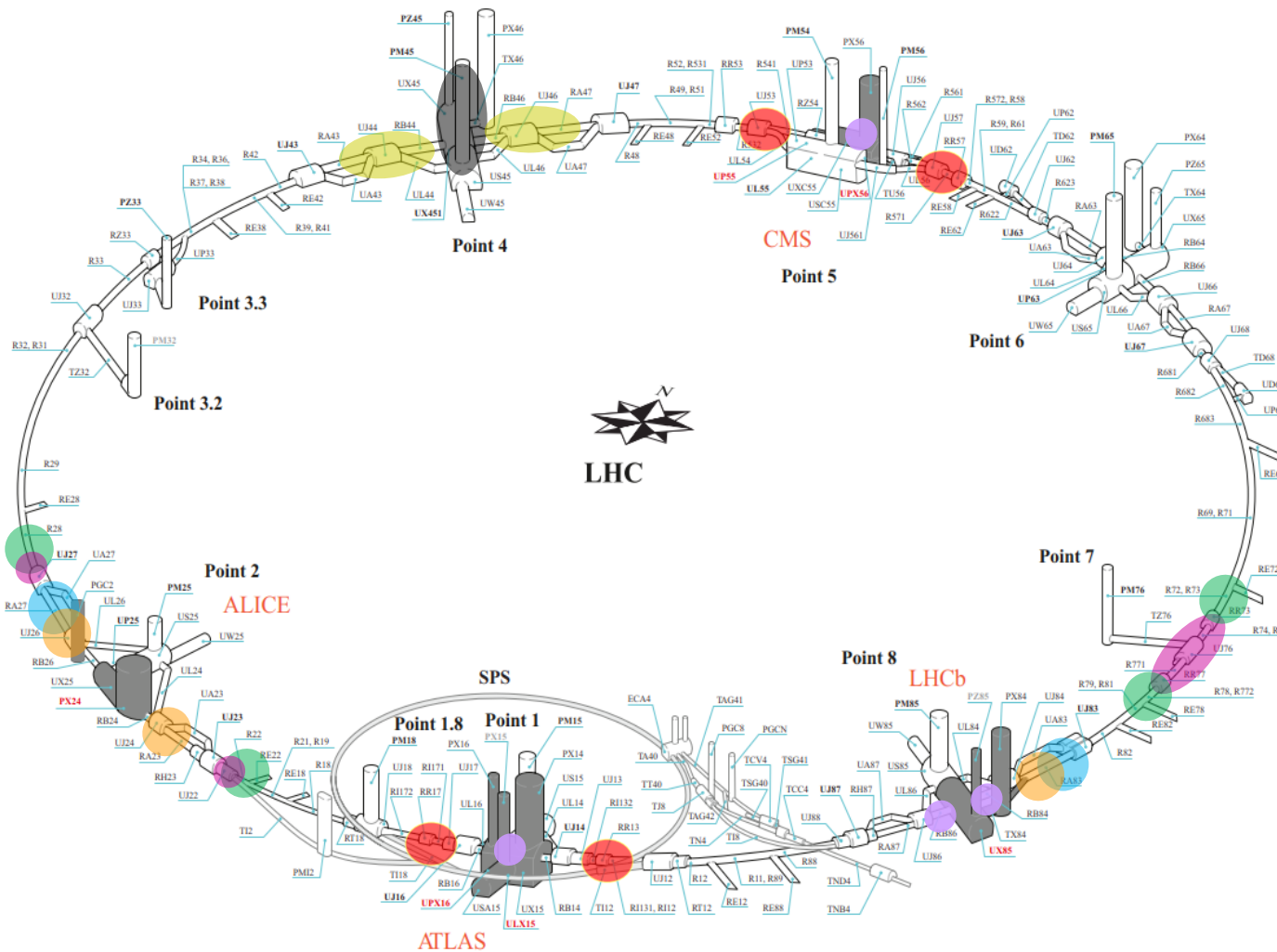
# Change of Management @ CERN → New Project Structure



# Key Japan Contributions to HL-LHC

- D1 superconducting Dipole: Advancing well with Hitachi → Prototype successfully tested!
- Additional Contributions previously discussed with KEK:
  - Quench Heater Power supplies
  - **Coronagraph Optical Components**
  - Coronagraph Intensified Cameras
  - Streak Cameras Prototypes
  - Streak Cameras Series
  - **Options:**
  - Cryogenic One Cold Compressor
  - Cryogenic Warm Compressors
  - ~~Mo Coated Graphite~~

# Termination of HL-LHC LS2 activities



## WP5 - Collimation

- 8 Target Secondary Collimators TCSPM in LSS7
- 2 Dispersion Suppression Collimators TCLD in LSS7 (11T) - postponed
- 2 Dispersion Suppression Collimators TCLD LSS2 (CC)

## WP8 - Collider & Experiment Interface

- TANB both sides LSS8
- ATLAS forward shielding modification and JTT installation
- CMS forward shielding modification and VAX support installation

## WP9 - Cryogenics

- Cryogenics upgrade of refrigerator & cold Box

## WP11 – 11T DS Dipole

- 11T in A9R7 & A9L7 - postponed
- CC in C11R2 & C11L2

## WP12 – Beam Vacuum

- In-situ aC-coating Q5 at P8
- In-situ aC-coating Q6 at P8 and Q5-Q6 at P2 postponed

## WP13 – Beam Diagnostics

- Wide-Band transverse pick-up BPW prototype at LSS4L - postponed
- Beam Gas Curtain BGC prototype at LSS4L
- BSRT (adding halo cleaning) at LSS4L/R

## WP14 – Beam Transfer & Kickers

- Injection Dump TDIS at P2L & P8R
- Cooled MKI at P2 - postponed
- Displacement of TCLIA in LSS2R (C4R2)

## WP17 - Infrastructure Logistics and Civil Engineering

- UPR connections and general services installation at P1 & P5

# Summary of HL-LHC Equipment Installation

- 1 EYETS 2016
- 2 YETS 2017
- 3 LS2
- 4 YETS 2021

**WP13: BWS**  
**WP13: Fluorescence Measurement Test Chamber Installation (BGC)**

**WP5: 2 TCTW wire collimators**  
**WP17: UPR cables rerouting**

**WP8: CMS forward shielding modification & VAX support installation**  
**WP17: UPR connections and general services**

**WP13: Remove of BRANA and replace by the new BRAND prototype (left IP)**  
**WP17: New mechanical ventilation in the UA/UPRs and in the tunnel area new cabling campaign**

**WP5: 2 Dispersion Suppression Collimators TCLD**  
**WP11: CC in C11R2 & C11L2**  
**WP12: In-situ aC-coating Q5-Q6 (postponed)**  
**WP14: Injection Dump TDIS, Cooled MKI (postponed) & Displacement of TCLIA**

**WP9: Cryogenics upgrade of refrigerator & Cold Box**  
**WP13: Wide-Band transverse pick-up BPW (postponed), Beam Gas Curtain BGC prototype & BSRT (adding halo cleaning)**

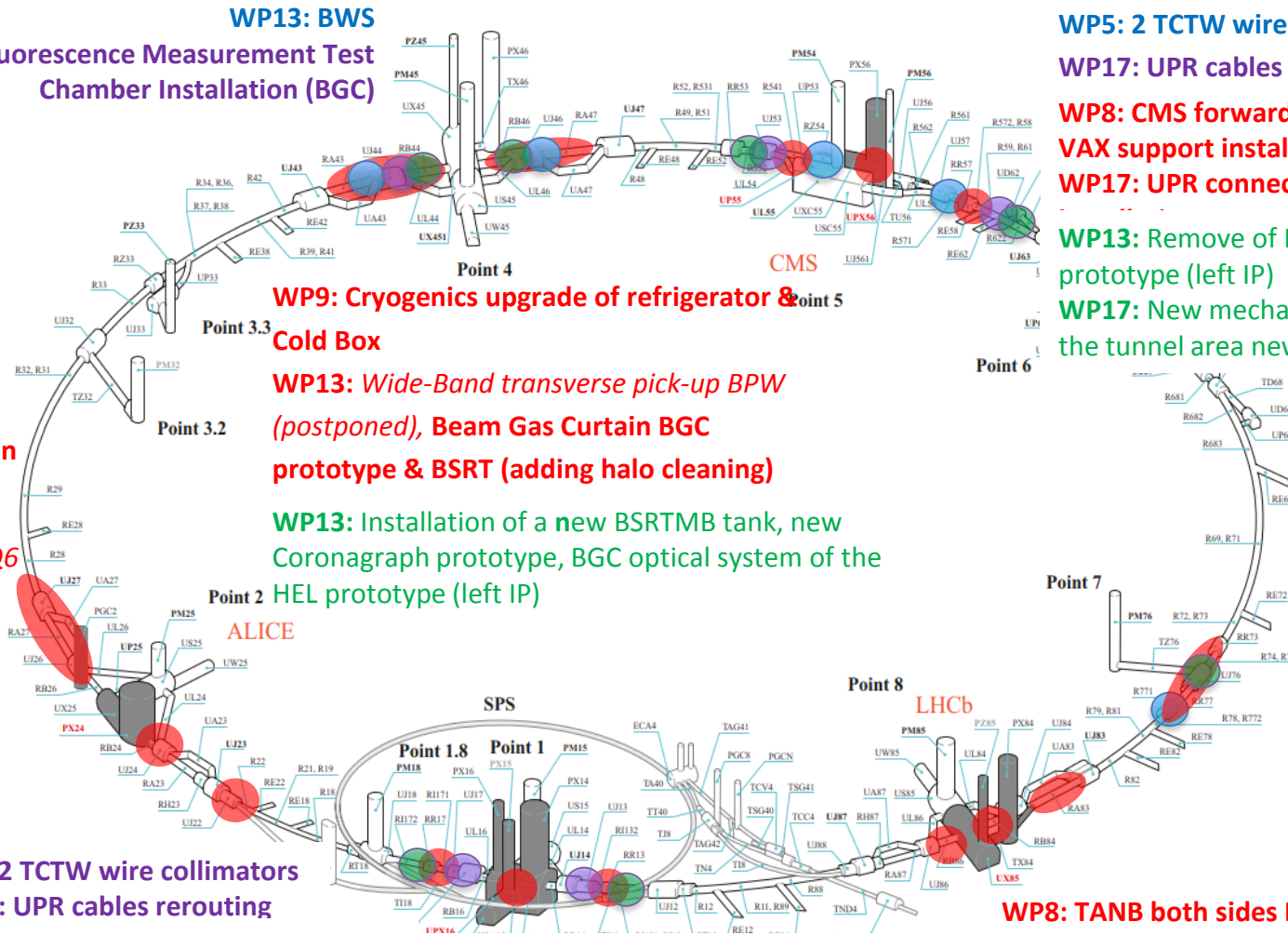
**WP13: Installation of a new BSRTMB tank, new Coronagraph prototype, BGC optical system of the HEL prototype (left IP)**

**WP5: 1 TCSPM secondary proto collimator**  
**WP5: 8 Target Secondary Collimators TCSPM & 2 Dispersion Suppression Collimators TCLD (postponed)**  
**WP11: 11T in C9R7 & C9L7 (postponed)**  
**WP5: 2 TCPC crystal collimators**

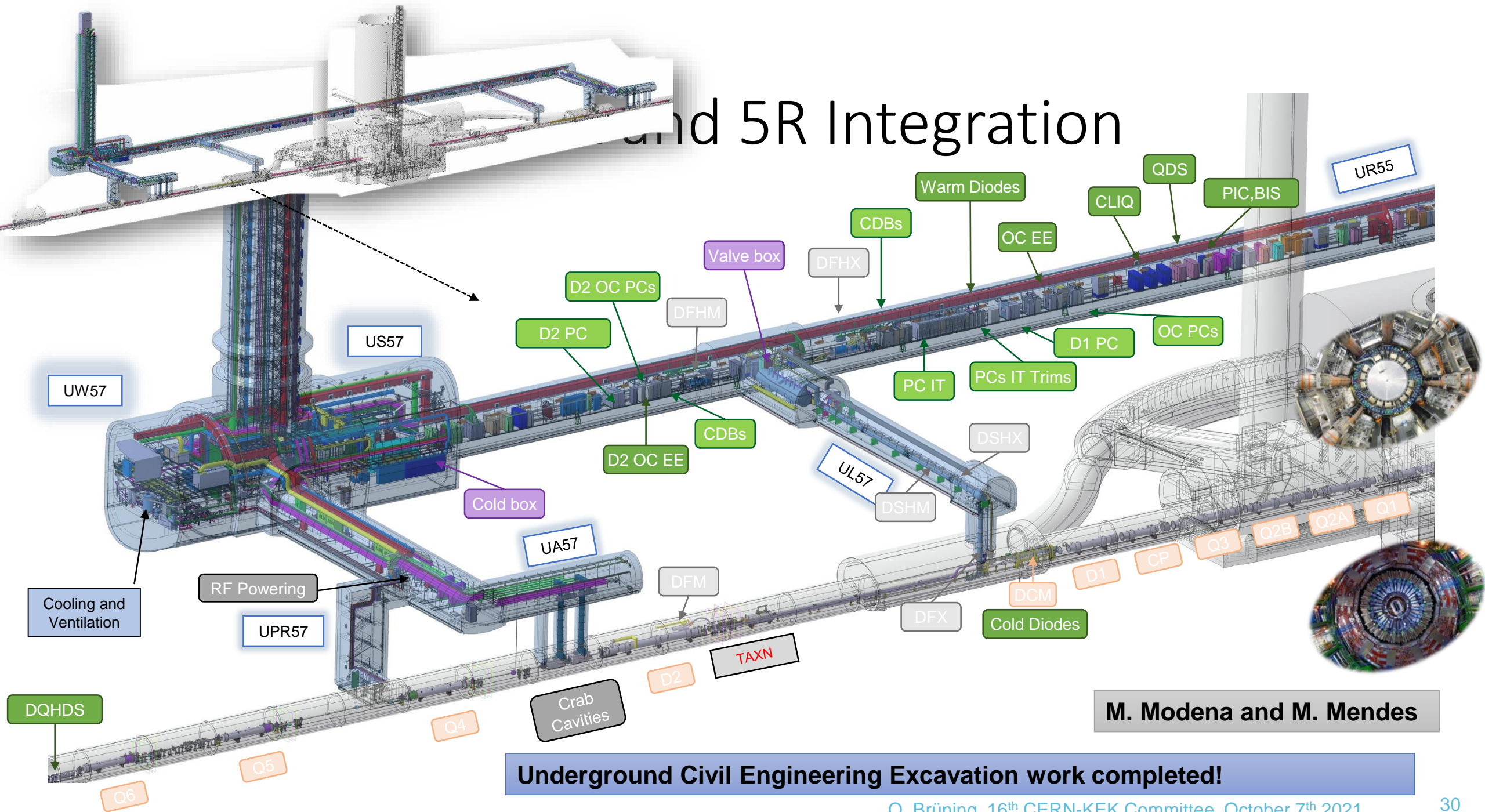
**WP5: 2 TCTW wire collimators**  
**WP17: UPR cables rerouting**  
**WP8: ATLAS forward shielding modification and JTT installation**  
**WP17: UPR connections and general services installation**

**WP13: Remove of BRANA and replace by the new BRAND prototype (right IP)**  
**WP17: New mechanical ventilation in the UA/UPRs and in the tunnel area new cabling campaign**

**WP8: TANB both sides LSS8**  
**WP12: In-situ aC-coating Q5-Q6 (postponed)**  
**WP14: Injection Dump TDIS**



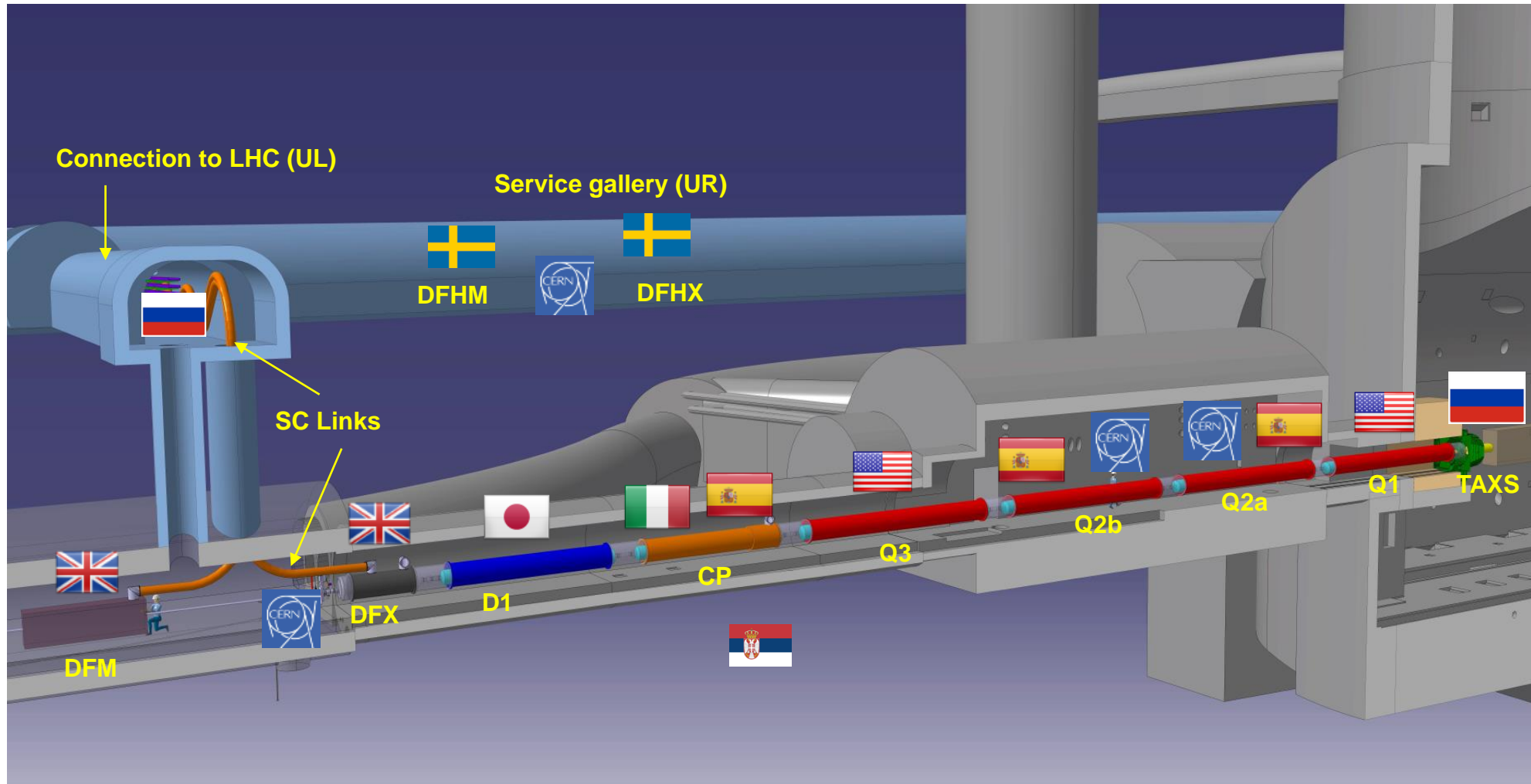
# and 5R Integration



M. Modena and M. Mendes

**Underground Civil Engineering Excavation work completed!**

# Truly International Collaboration



# The MS region with in-kind contributions

