HL-LHC Project

O. Brüning
On behalf of the
HL-LHC Project

LHC in the Geneva Basin and its Experiments

LHC (Large Hadron Collider): Magnet Technology

14 TeV proton-proton accelerator-collider built in the LEP tunnel ➔ requires ca. 9T magnets!!!

➔ 200000 times the earth magnetic field!!

➔ Requires Superconducting magnet technology

Ca. 20 years magnet development!!!

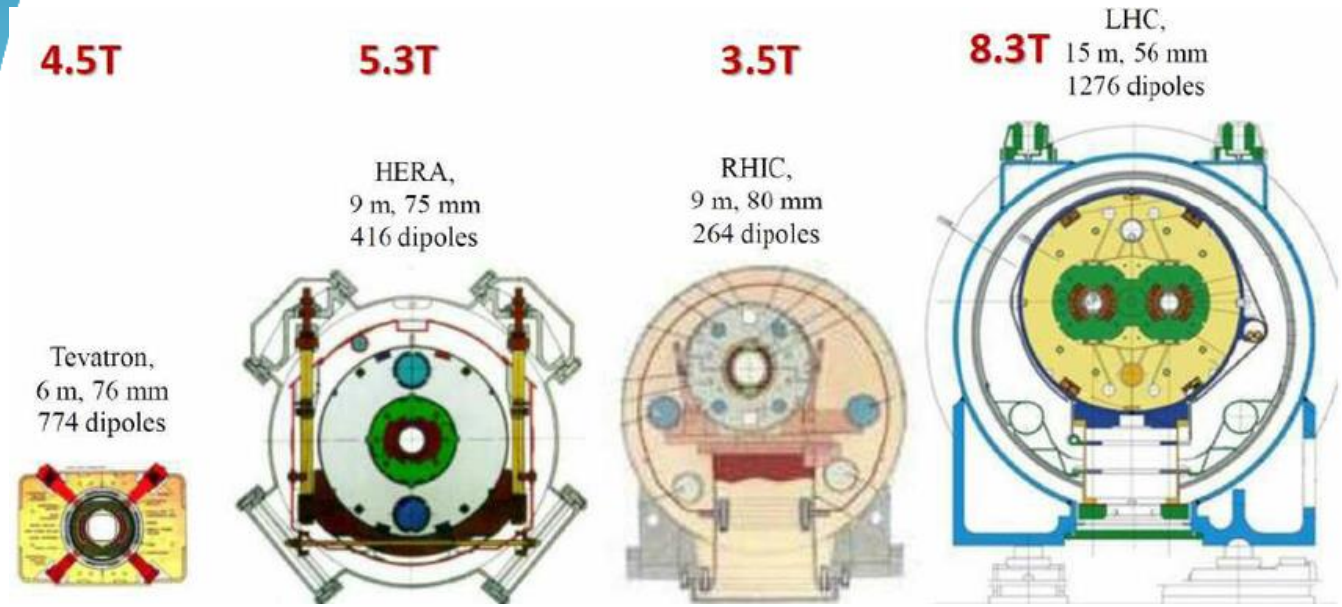
1983 : First studies for the LHC project
1988 : First magnet model (feasibility)
1994 : Approval by the CERN Council
1996-1999 : Series production industrialisation
1998 : Declaration of Public Utility & Start of civil engineering
1998-2000 : Placement of main production contracts
2004 : Start of the LHC installation
2005-2007 : Magnets Installation in the tunnel
2006-2008 : Hardware commissioning
2008-2009 : Beam commissioning and repair

As of 2010: Physics exploitation

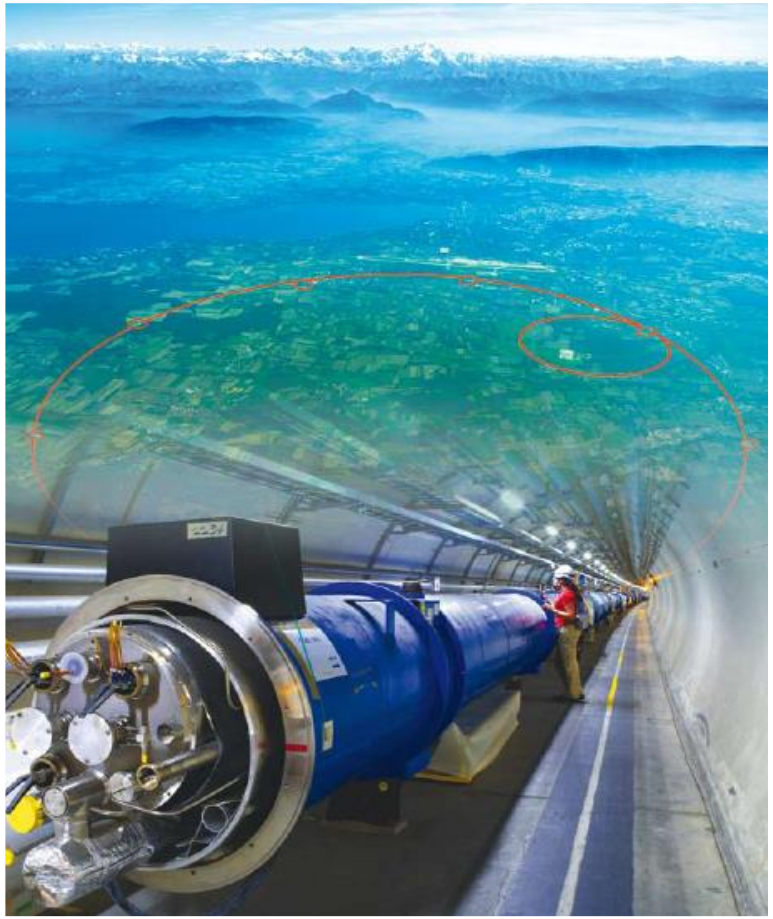
Ca. 30 years machine development!!!

➔ Significant Time scale extending well beyond that of a physicist career!!!

LHC (Large Hadron Collider): Magnet Technology



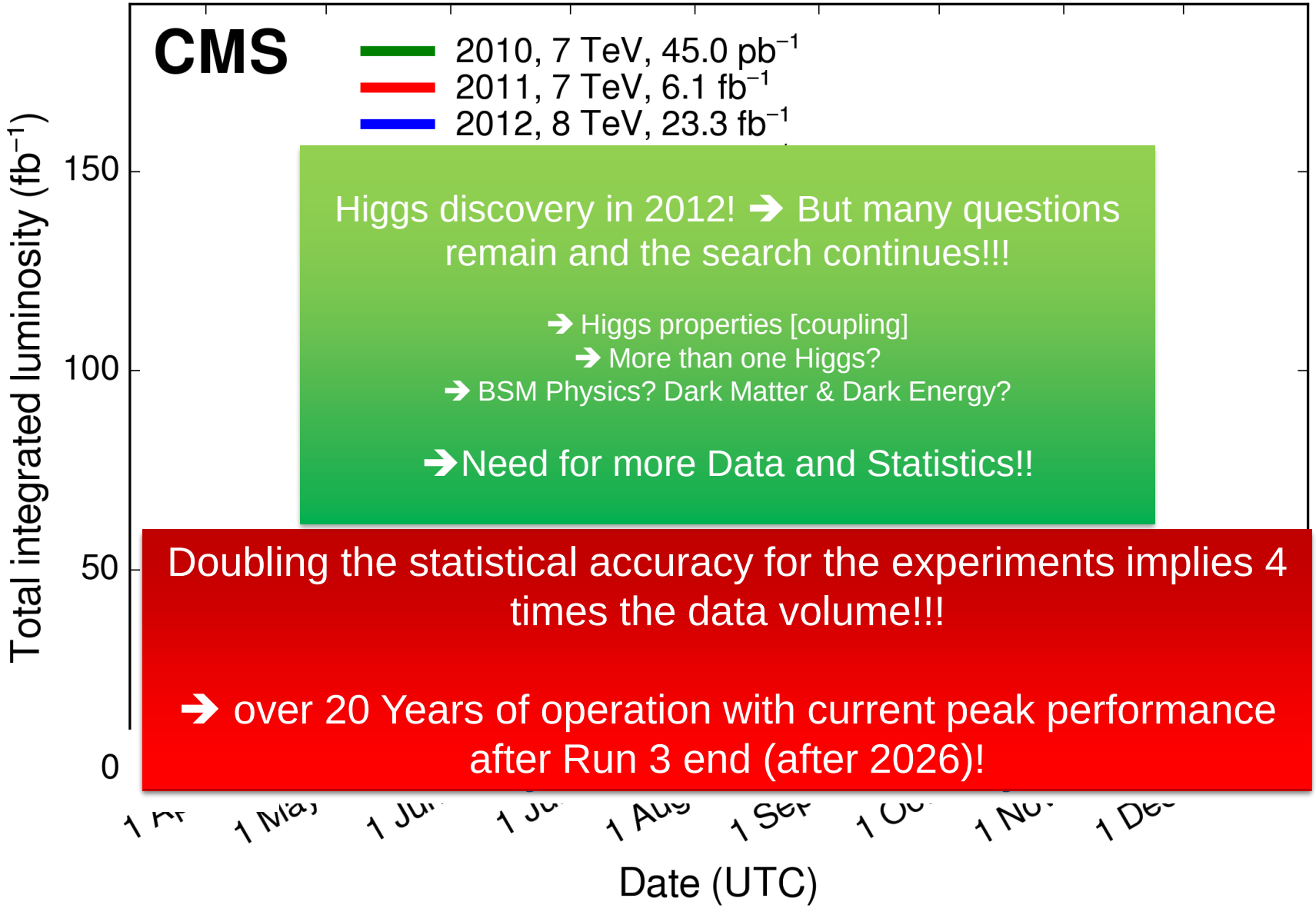
1983 1991 2000 2010



➔ The LHC dipole magnets mark the culmination of 30 years of superconducting magnet technology development!

➔ Requiring 1.9K [-271 degrees Celsius] operating temperature

LHC Performance



Higgs discovery in 2012! ➔ But many questions remain and the search continues!!!

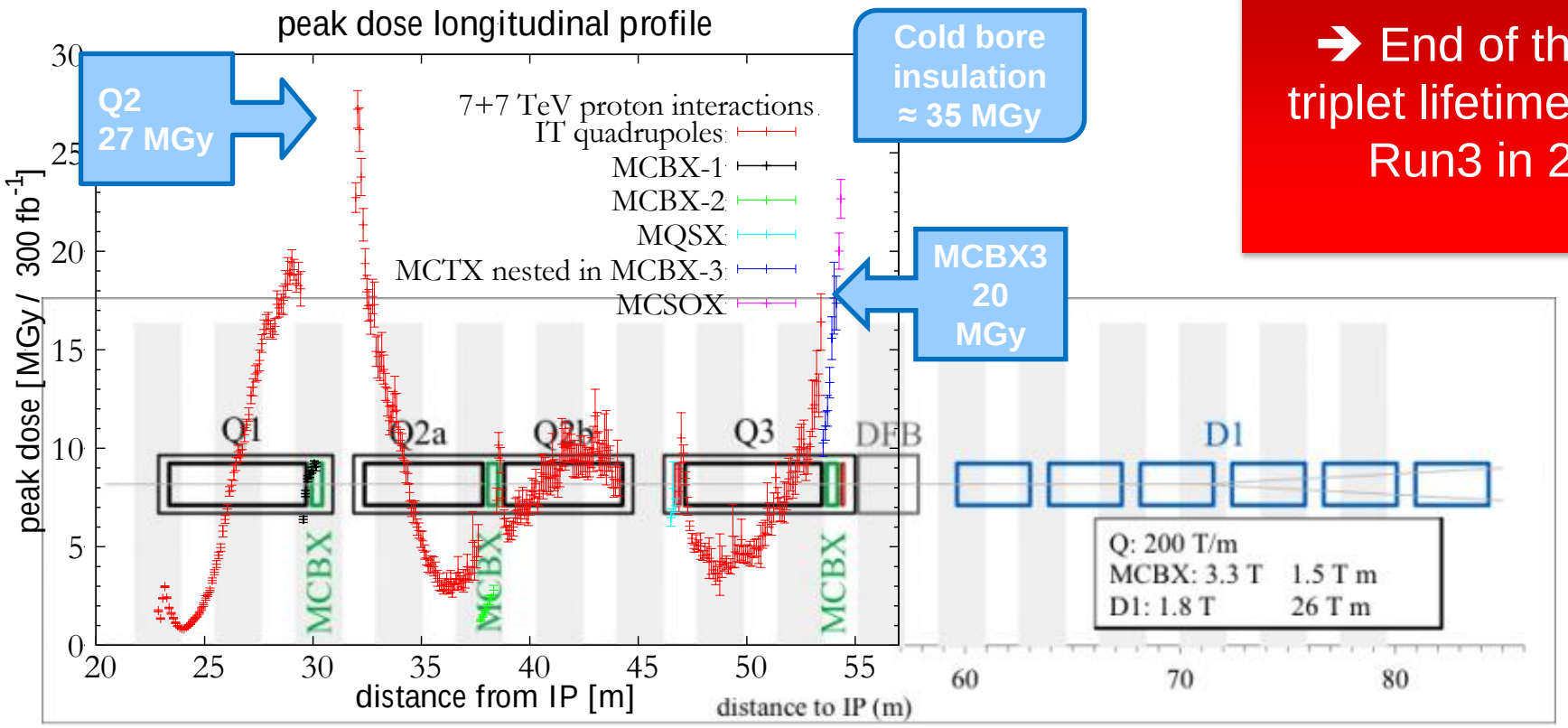
➔ Higgs properties [coupling]
➔ More than one Higgs?
➔ BSM Physics? Dark Matter & Dark Energy?

➔Need for more Data and Statistics!!

Doubling the statistical accuracy for the experiments implies 4 times the data volume!!!

➔ over 20 Years of operation with current peak performance after Run 3 end (after 2026)!

LHC Lifetime Limitation:
Debris from the IP & Radiation damage to magnets!



➔ End of the LHC triplet lifetime by End Run3 in 2026

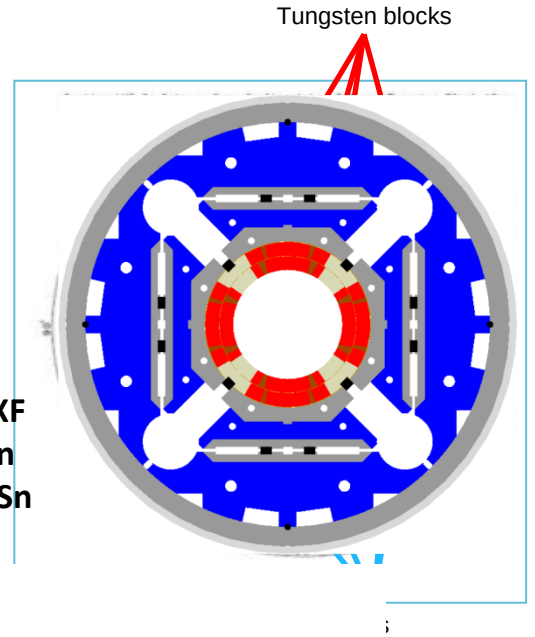
➔ **HL-LHC goal: 10 times the LHC data Volume within 10 years of operation**

HL-LHC technical bottleneck: Radiation damage to triplet magnets

Need to replace existing triplet magnets with radiation hard system such that the new magnet coils receive a similar radiation dose @ 10 times higher integrated luminosity!!!!!

➔ Shielding!

- Requires larger aperture!
- New magnet technology!



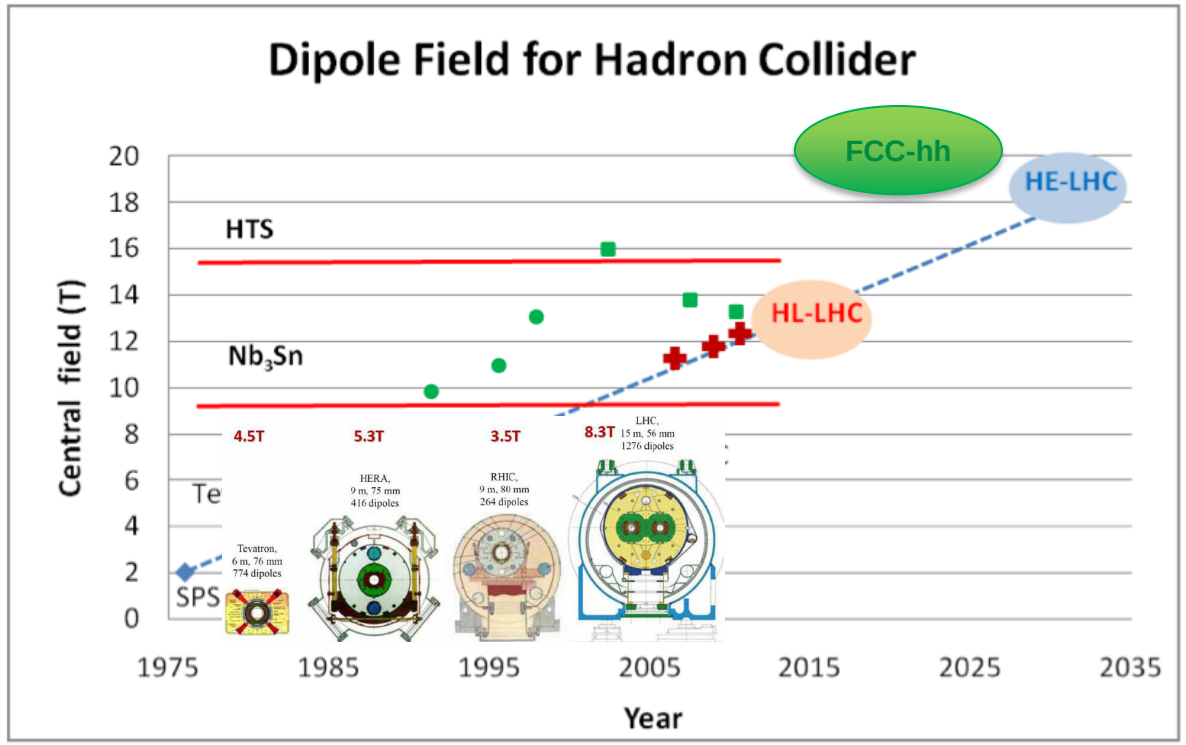
US-LARP MQXF magnet design Based on Nb_3Sn technology

- 70mm at 210 T/m ➔150mm diameter 140 T/m ➔ Longer magnets

  8T peak field at coils ➔ 12T field at coils (Nb_3Sn)!!! ➔ New Superconductor

High Field SC Magnets

Magnet development requires substantial R&D effort!!!



Ca. 30 years of NbTi magnet R&D leading up to the LHC dipole magnets!

Transition from NbTi to Nb_3Sn: required similar length of R&D!

HL-LHC led the R&D for 11-15T magnets based on Nb_3Sn technology:

➔ Started in early 2000

➔15-20 years R&D program

➔ Ready for installation by 2025

➔ Ready for operation by 2029

➔ ca. 30 years of development!!!

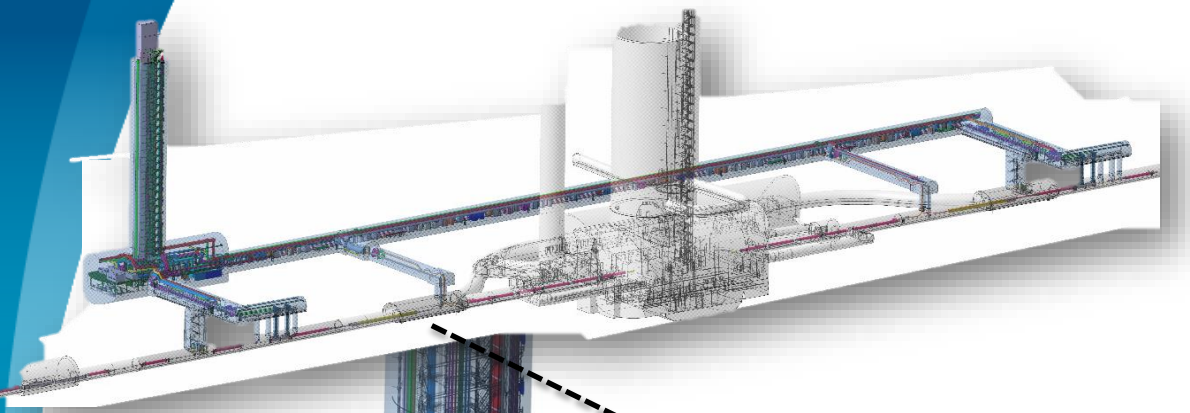
Technology Landmarks

Separation / Recombination dipole magnets: D1 & D2

Need to overcome several limitations in the existing LHC machine!!!

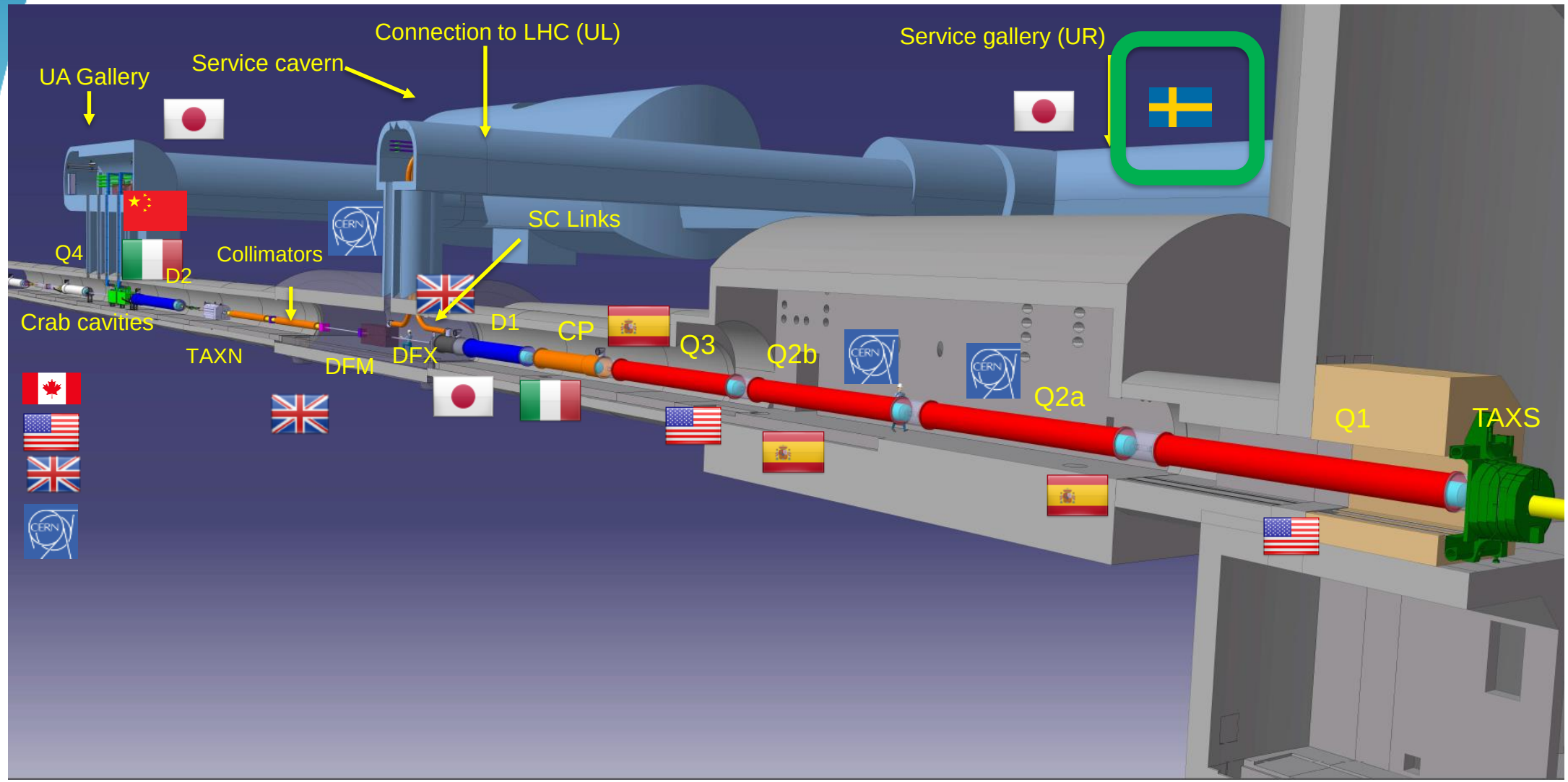
Ca. 1BCHF CtC Project

Civil Engineering:

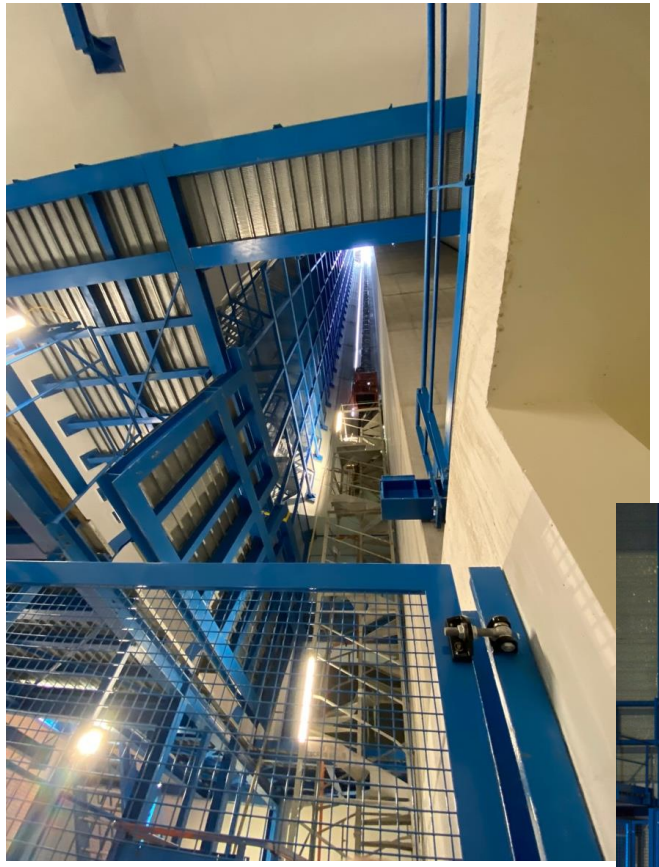


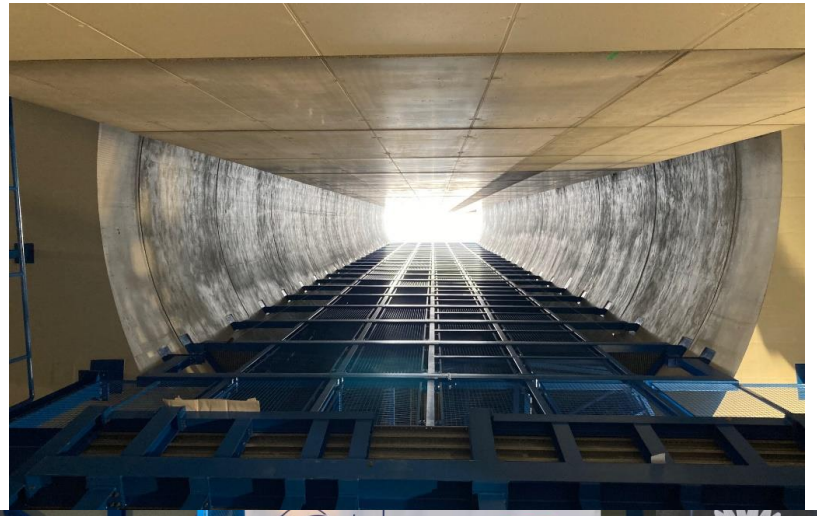
Underground Civil Engineering Excavation work completed!

The Insertion Region (up to Q4)

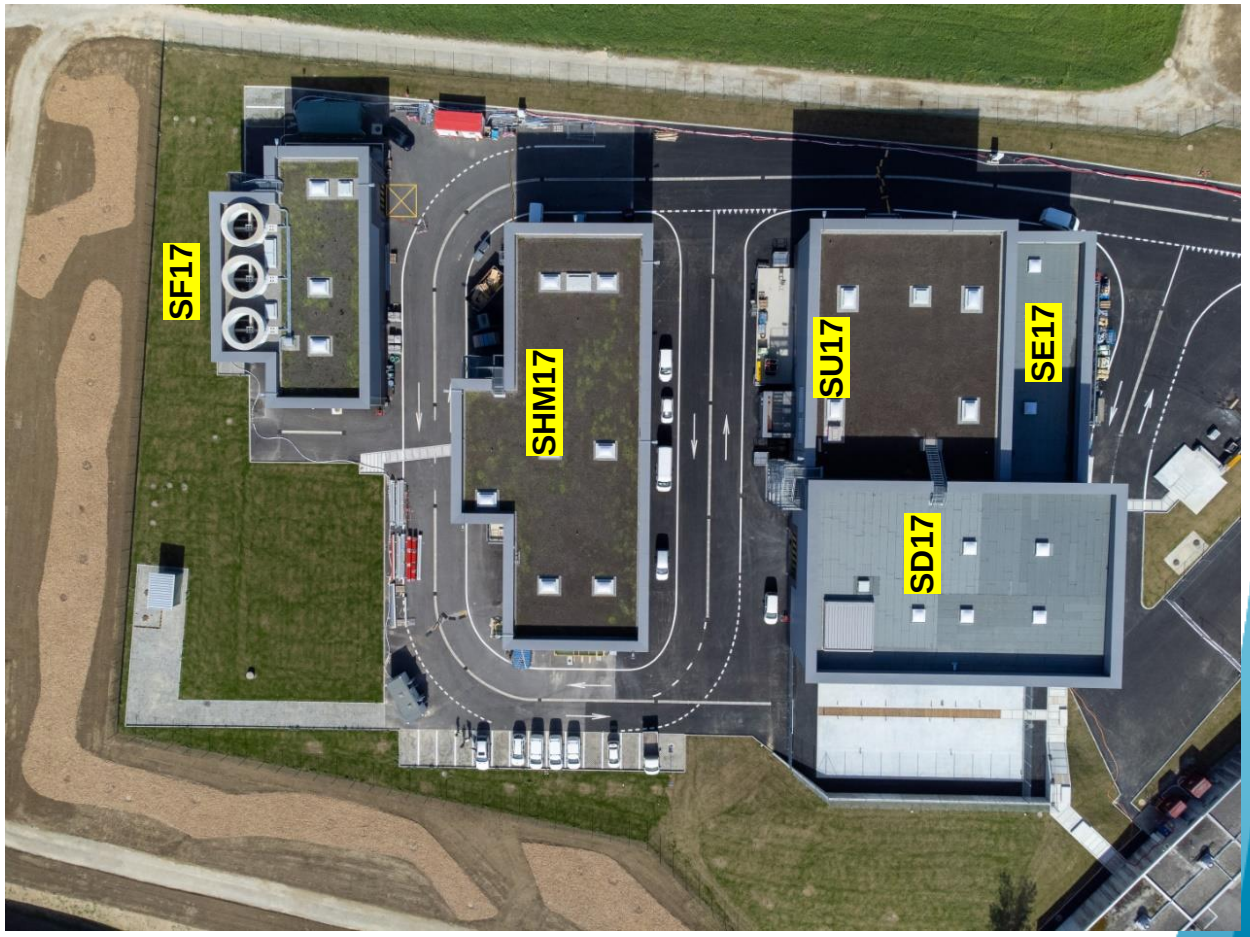


Completion of CE on January 20th 2023



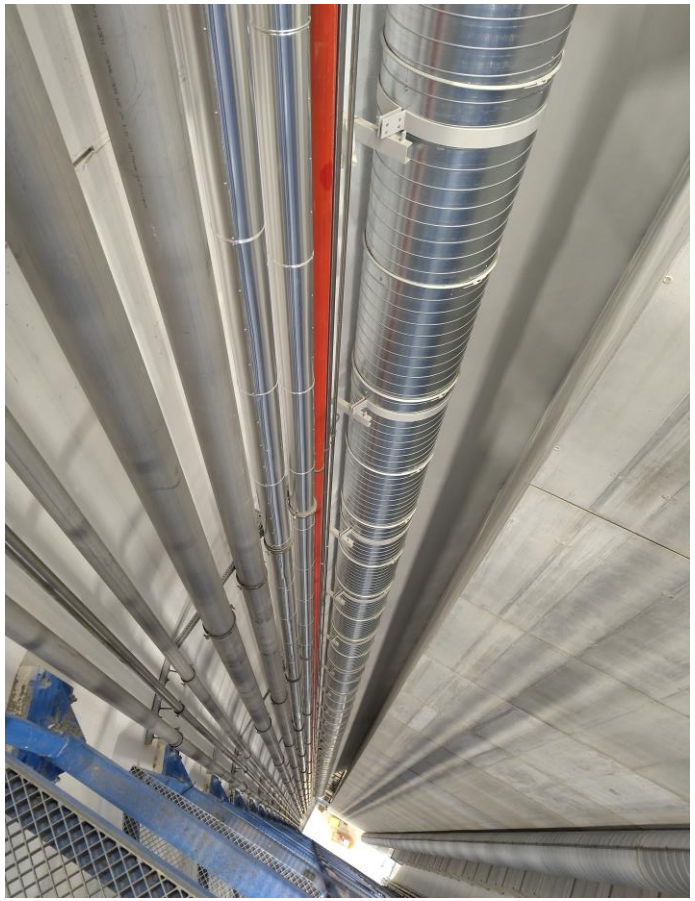


Completion of the civil engineering works: Surface Buildings finished in 2023

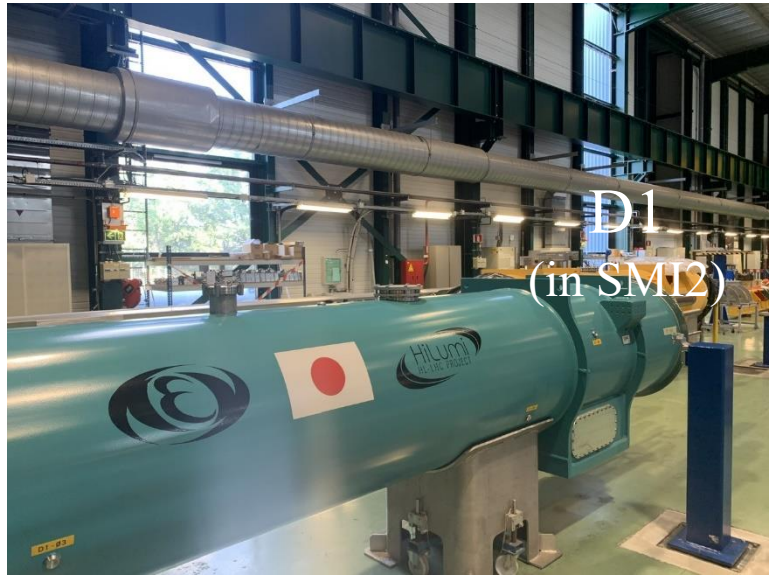


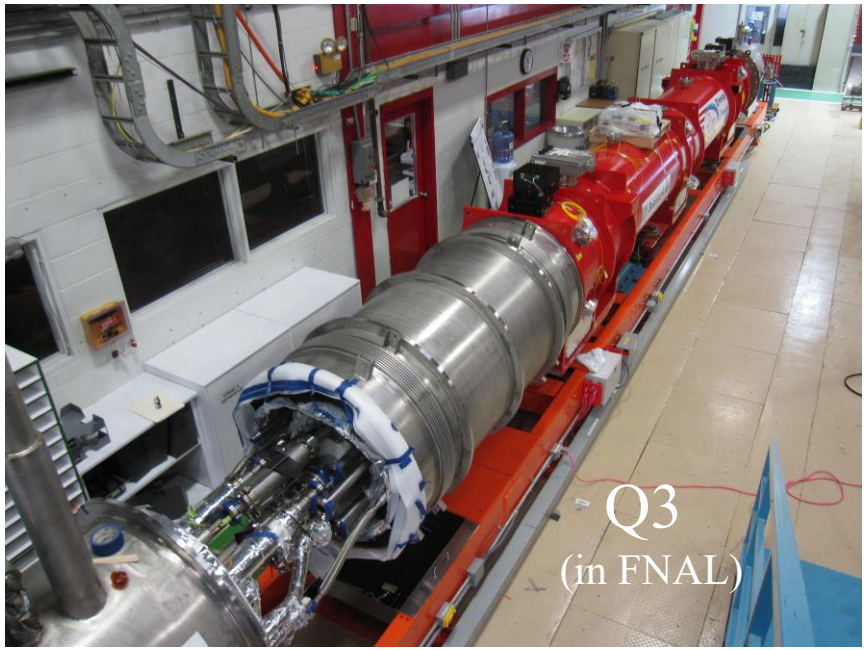
Example Point 1

Status of infrastrucuture installations at P5

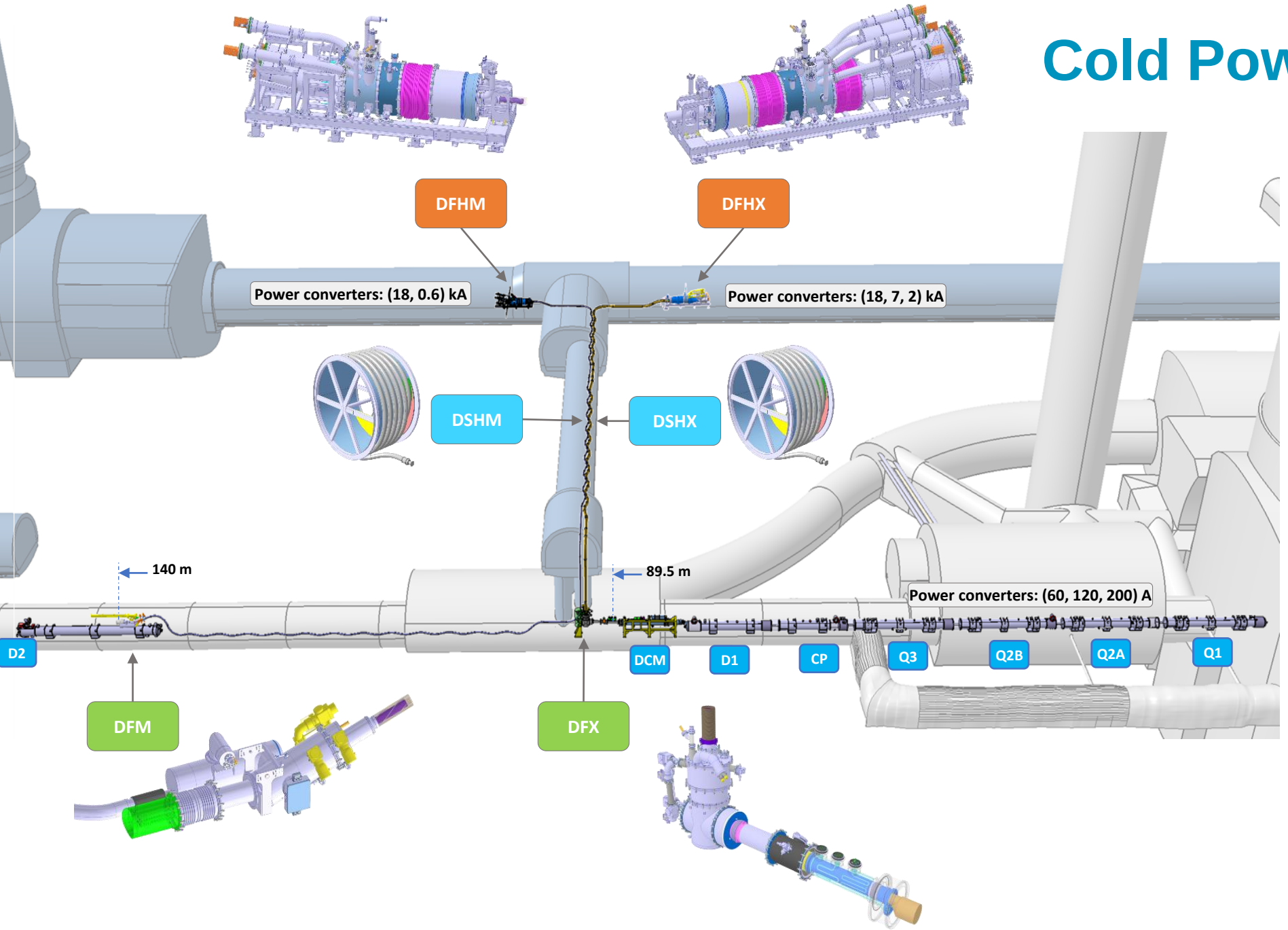


NEW MAGNETS ARE GETTING READY: Fully in Series Production



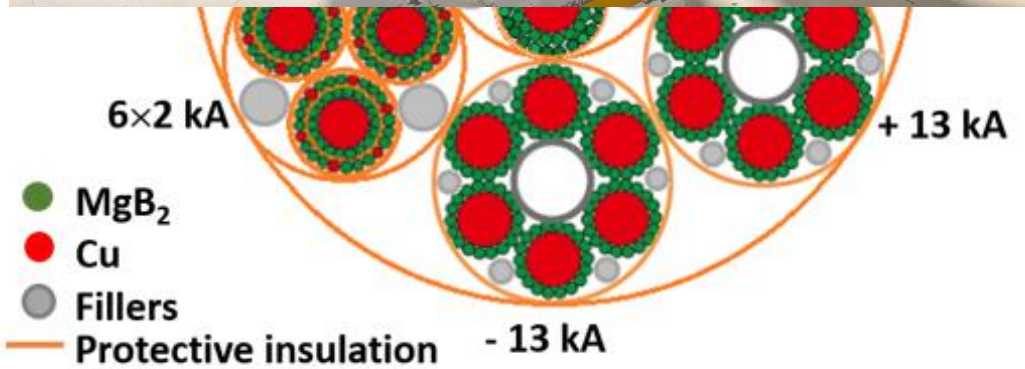


Cold Powering System

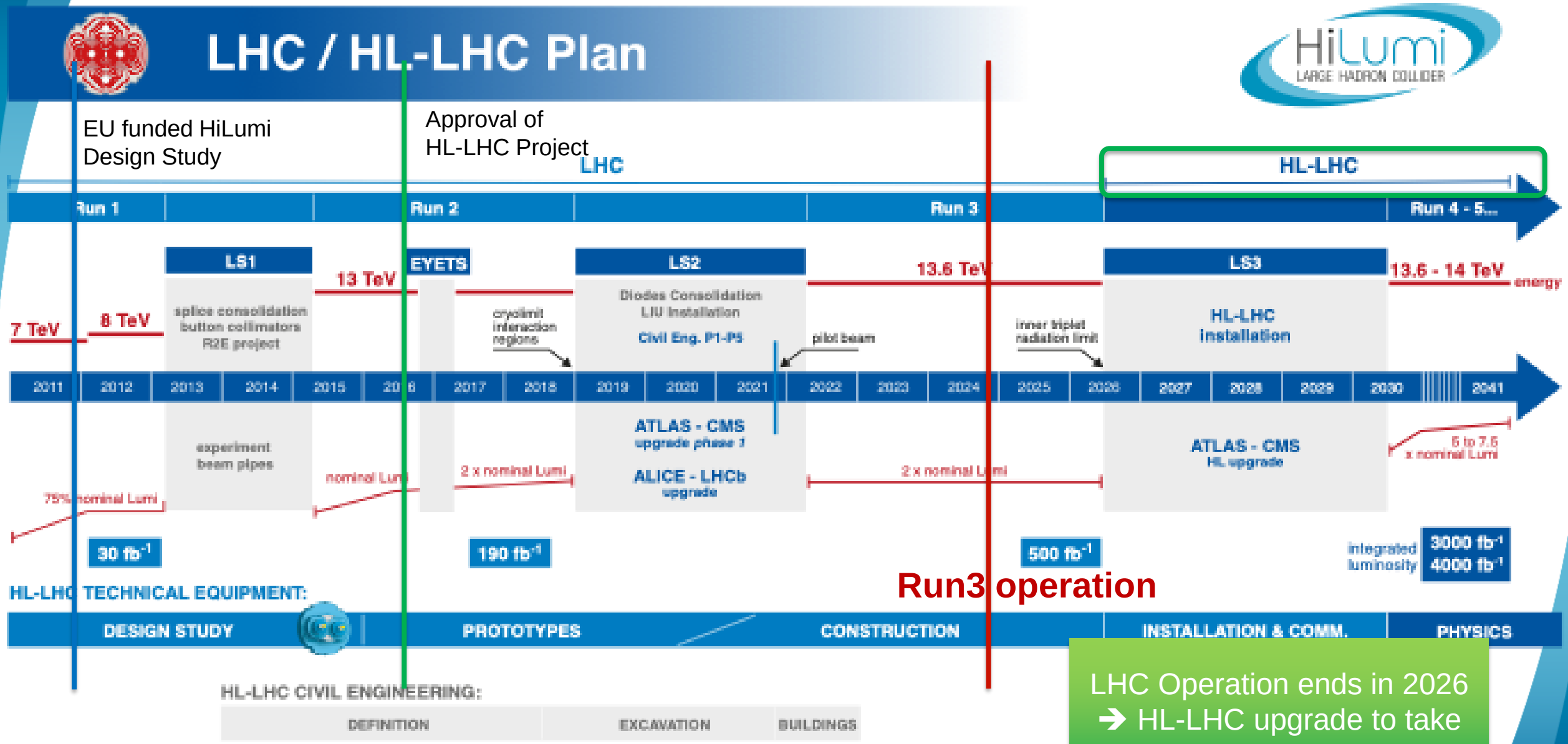


MgB_2 Superconductor an

The flexible, double-wall, corrugated cryostat comprises 19 twisted together to form a compact bundle. These 19 supe current of about 120 kA at ~20 K.



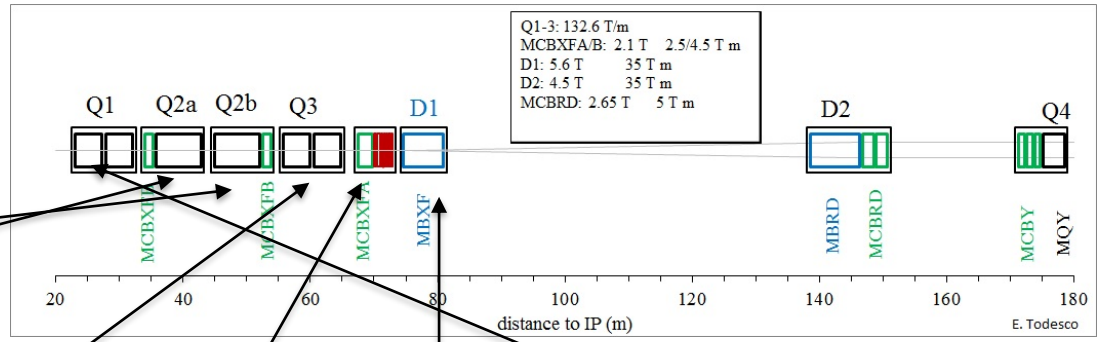
LHC / HL-LHC Plan



Run3 operation

LHC Operation ends in 2026
➔ HL-LHC upgrade to take over as of 2030 after LS3

Magnet Validation for IT-String



Completed testing at FNAL;
Expected @ CERN by January 2025

Q2a cold mass installation

Sc Link INSTALLATION IN THE IT STRING

-LHC Summary

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Second Edition

Editors
Oliver Brüning and **Lucio Rossi**

World Scientific

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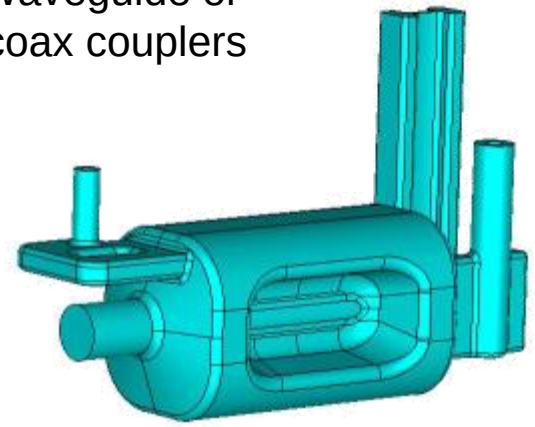
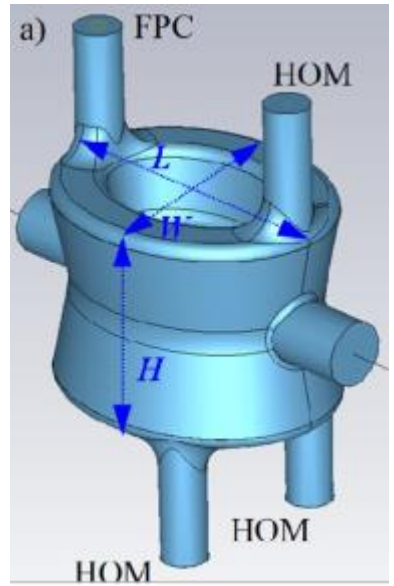
HL-LHC cavity designs

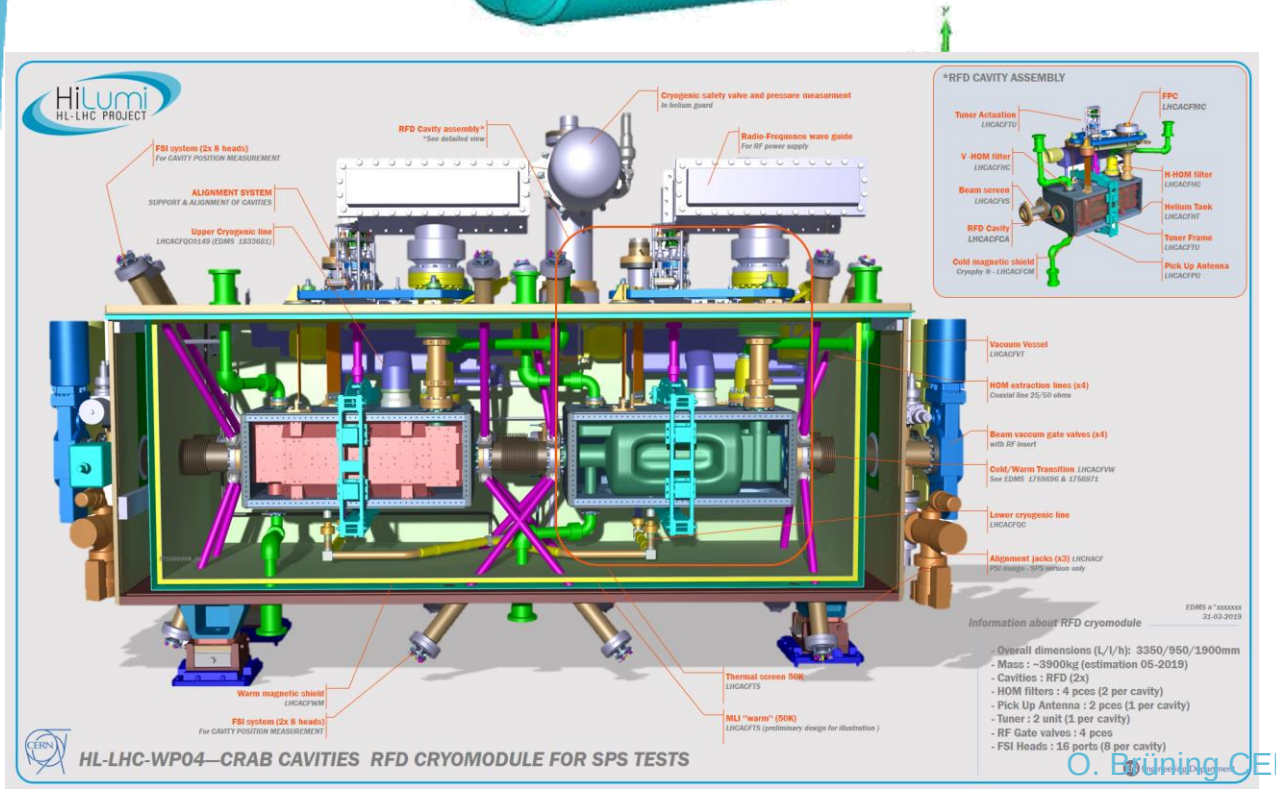
RF Dipole: Waveguide or waveguide-coax couplers



2 Designs with Different Coupler concepts and for crossings in the vertical and horizontal planes



Double ¼-wave: Coaxial couplers with hook-type antenna

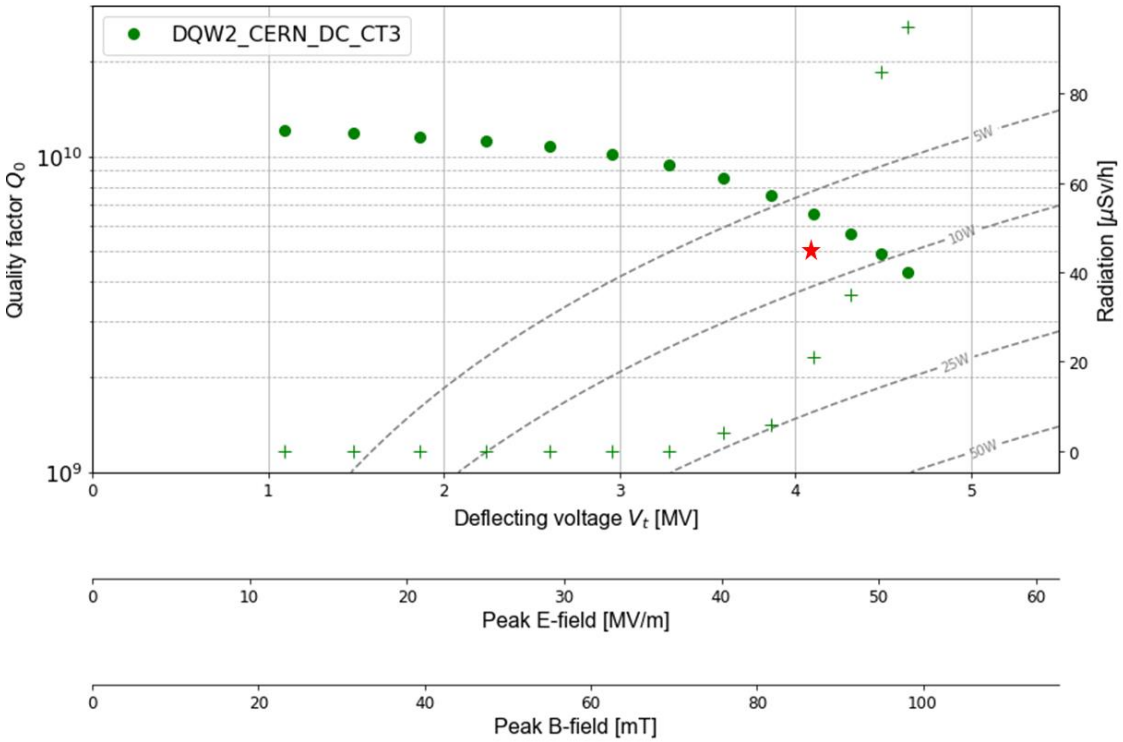


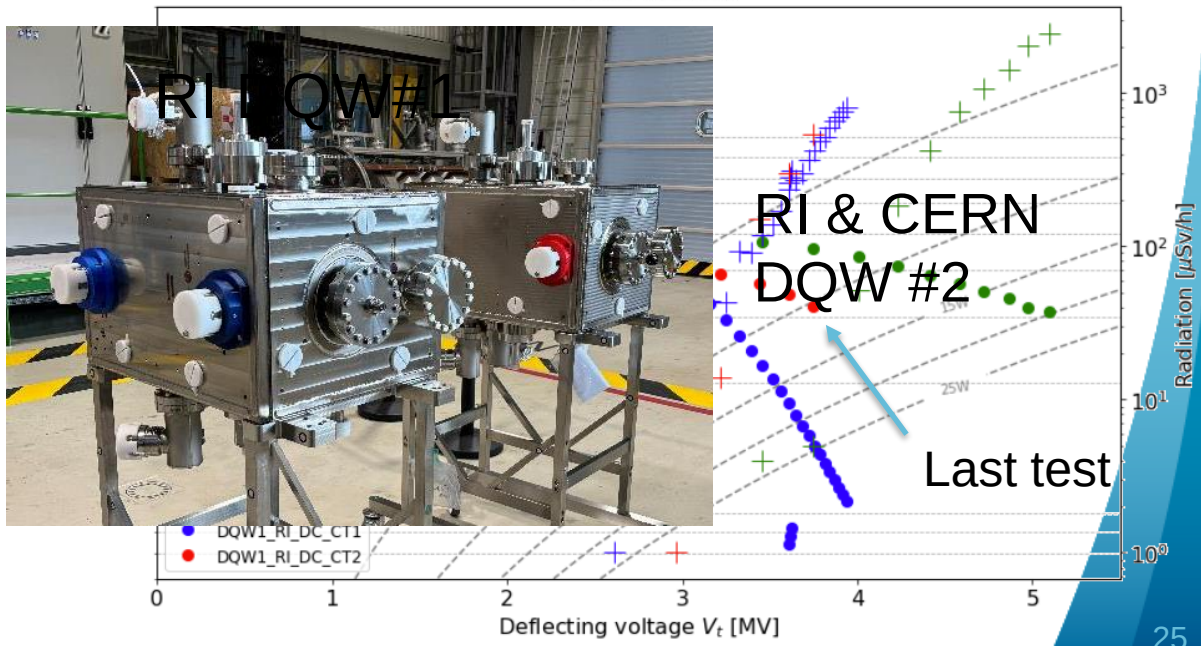
Present baseline: 4 cavities / IP / side ➔ 16 total

Present baseline: 2 cavities within one common cryostat

Industrial DQW Series Cavities

- CERN #2 & RI #2 cavities qualified (~4.7 MV)
  - Will be used for next string assembly and are already in the UK for assembly
- The RI #1 re-tested, but limited to 3.75 MV (NCR)
- The RI #3 required repair, testing @ CERN still planned for 2024

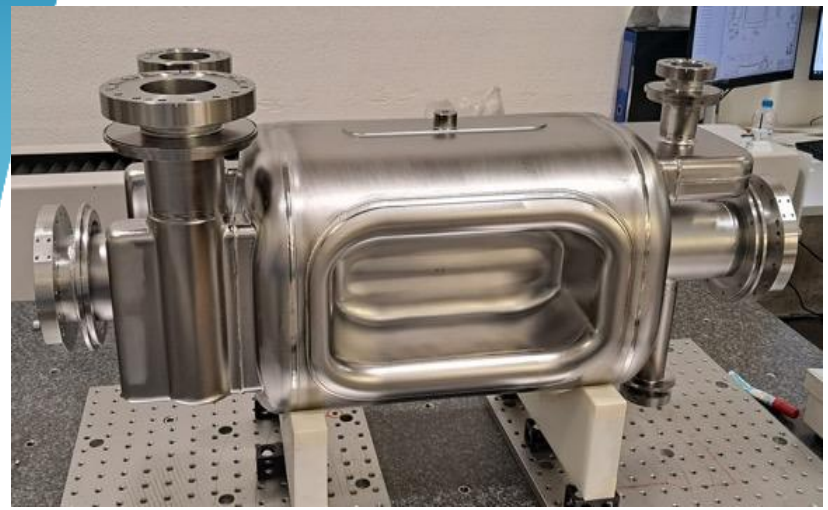




See Rama Calaga on Monday for more details

RFD cryomodule assembled in UK and being tested in M7 bunker (SM18-CERN) in 2024 before installation in SPS in YETS 2024 / 2025

Crab Cavity series production well underway



RF

One of the two
suffered from fi

See Leonardo Risori on Monday for more details

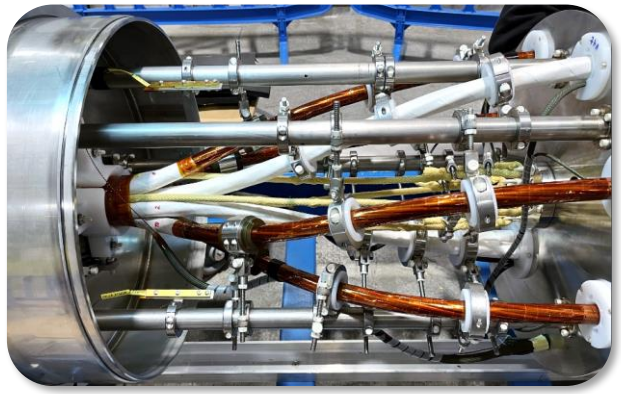
Zanon
RESEARCH & INNOVATION SRL

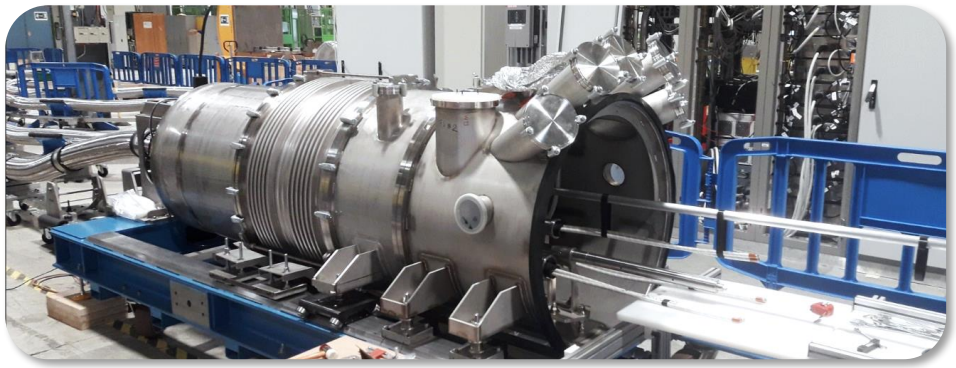
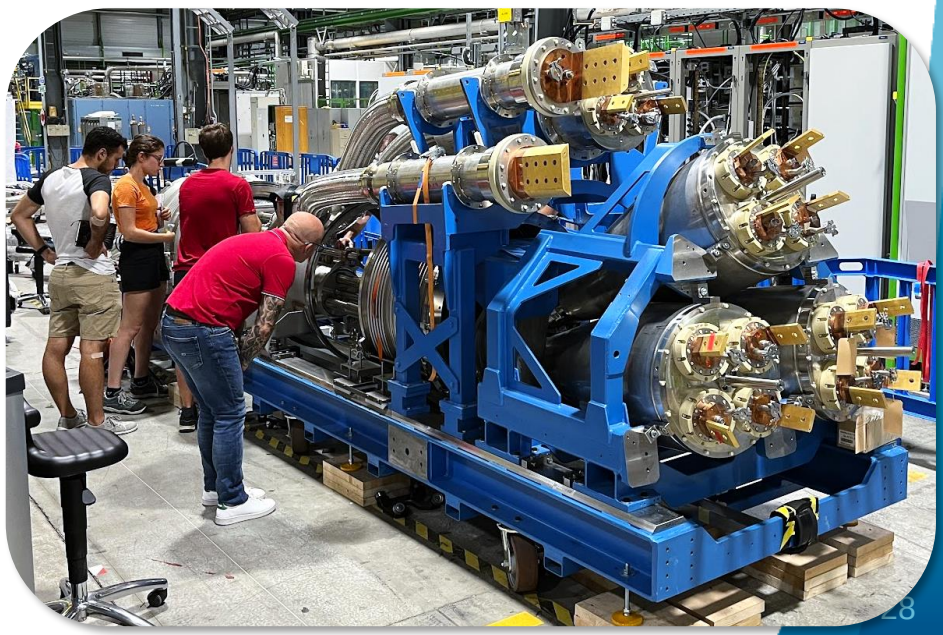
FIRST TWO PRODUCTION RFD CRAB CAVITIES WELDED!

Nov 27, 2023 | News





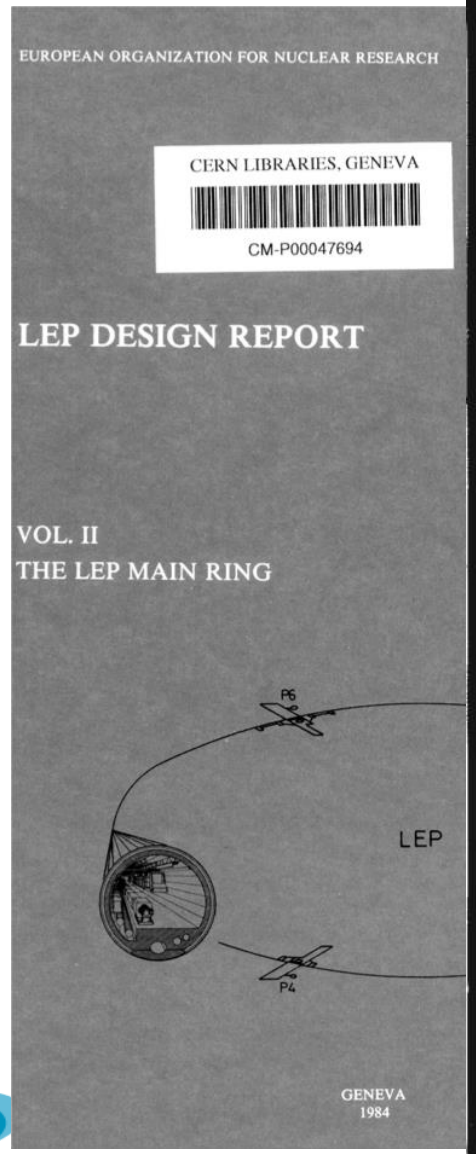




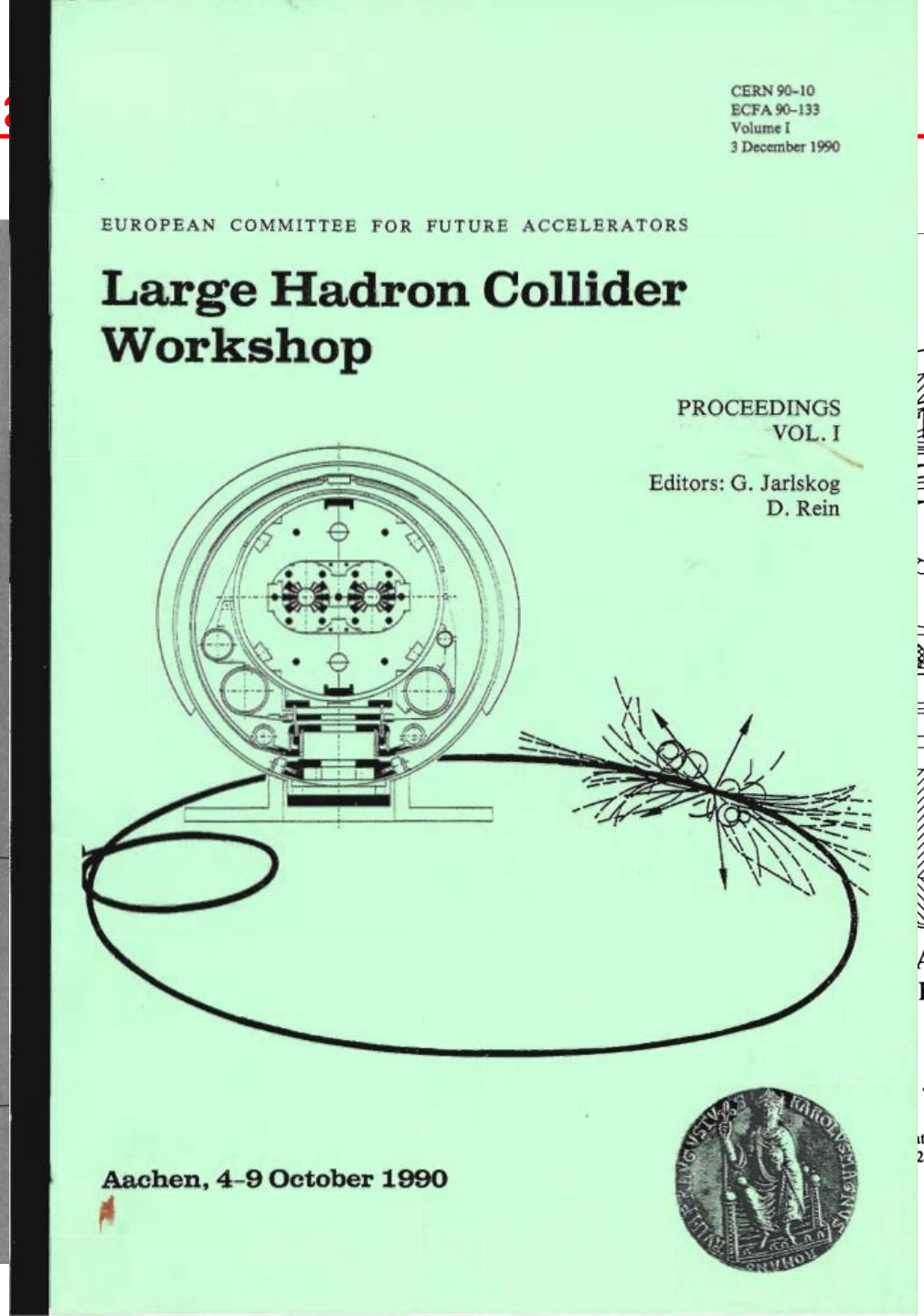
SC-Link-DFHX assembly in pictures

LHC: was alre

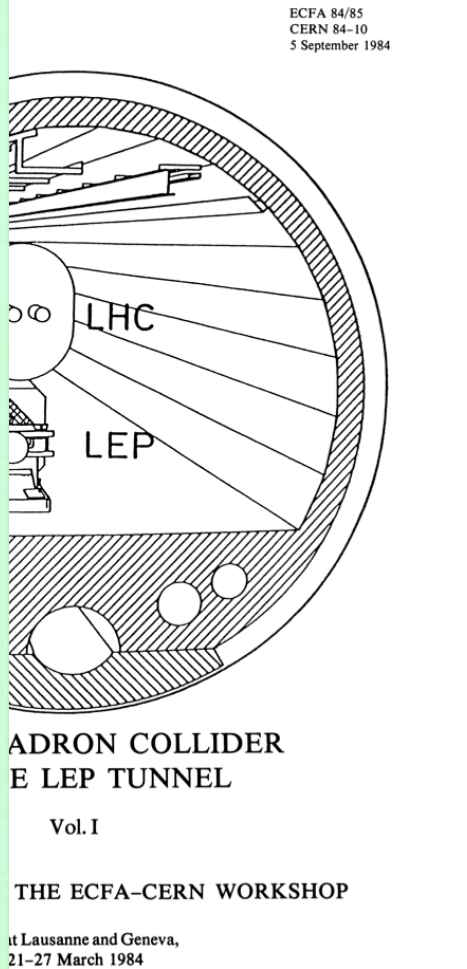
Start of LEP

LEP Design Report 1984





Lausanne ECFA-CERN Workshop 1984



HiLumi HL-LHC PROJECT