



# HL-LHC IT STRING and Series test of SC link

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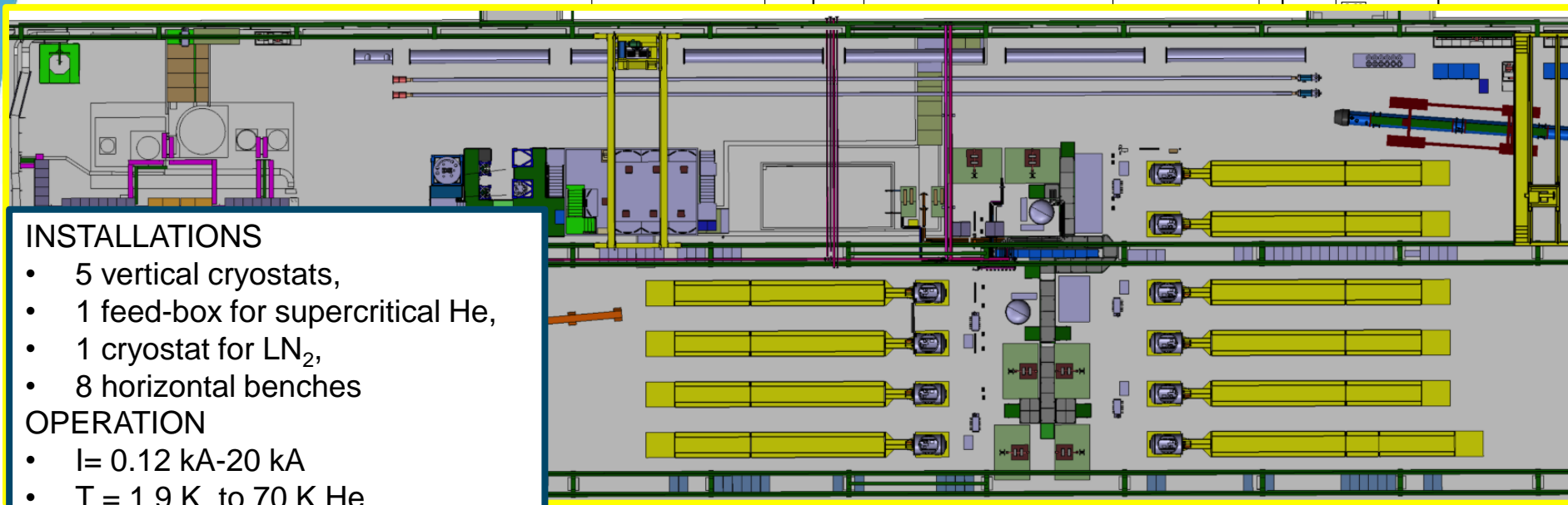


# Outline of the presentation

- Test stands today in Sm18
- Main facilities for tests in SM18
- Limitations and solutions in space
- Limitations and solutions in time
- Proposal for the STRING test
- Proposal for the SC LINK test
- Status of the work

# Magnet test stands layout @ CERN

## THE SUPERCONDUCTING MAGNET TEST STAND AT CERN in SM18



### INSTALLATIONS

- 5 vertical cryostats,
- 1 feed-box for supercritical He,
- 1 cryostat for LN<sub>2</sub>,
- 8 horizontal benches

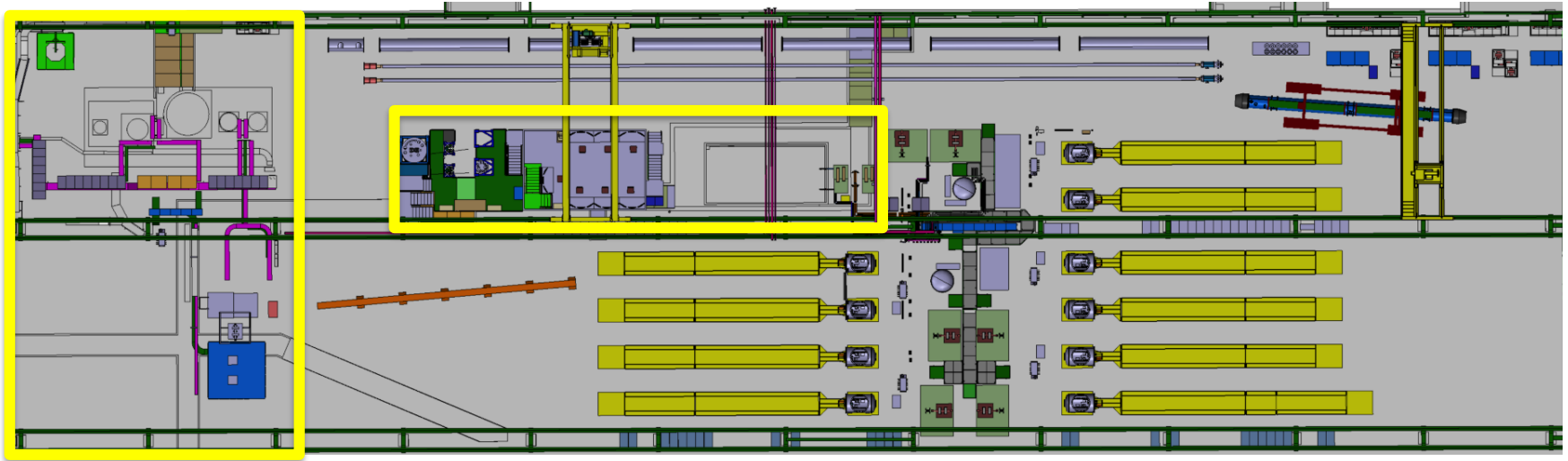
### OPERATION

- $I = 0.12 \text{ kA} - 20 \text{ kA}$
- $T = 1.9 \text{ K} \text{ to } 70 \text{ K He}$
- withstanding  $U = 1 \text{ kV} \text{ to } 3 \text{ kV}$

# Vertical test stand upgrade

Cluster G

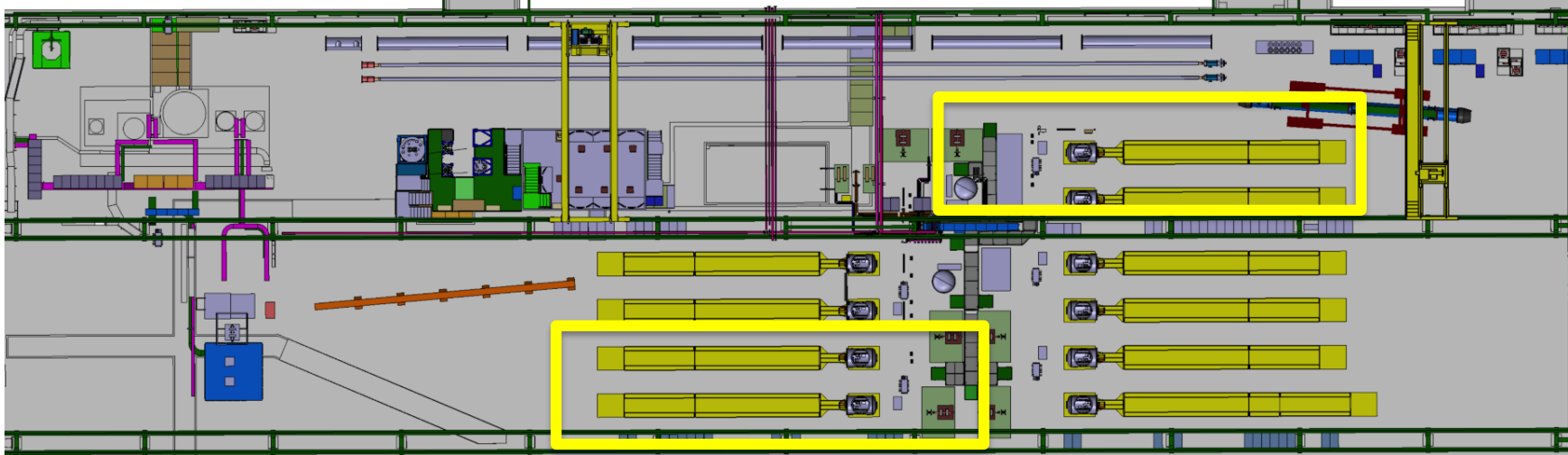
Cluster D



The vertical cryostats zone, called Cluster G is about  $400 \text{ m}^2$  . It is under upgrade with an extra space called Cluster D of  $150 \text{ m}^2$  . It will accommodate the test of **larger diameter** magnets @ **higher operating current** for HL LHC.

# Horizontal test bench upgrade

Cluster A

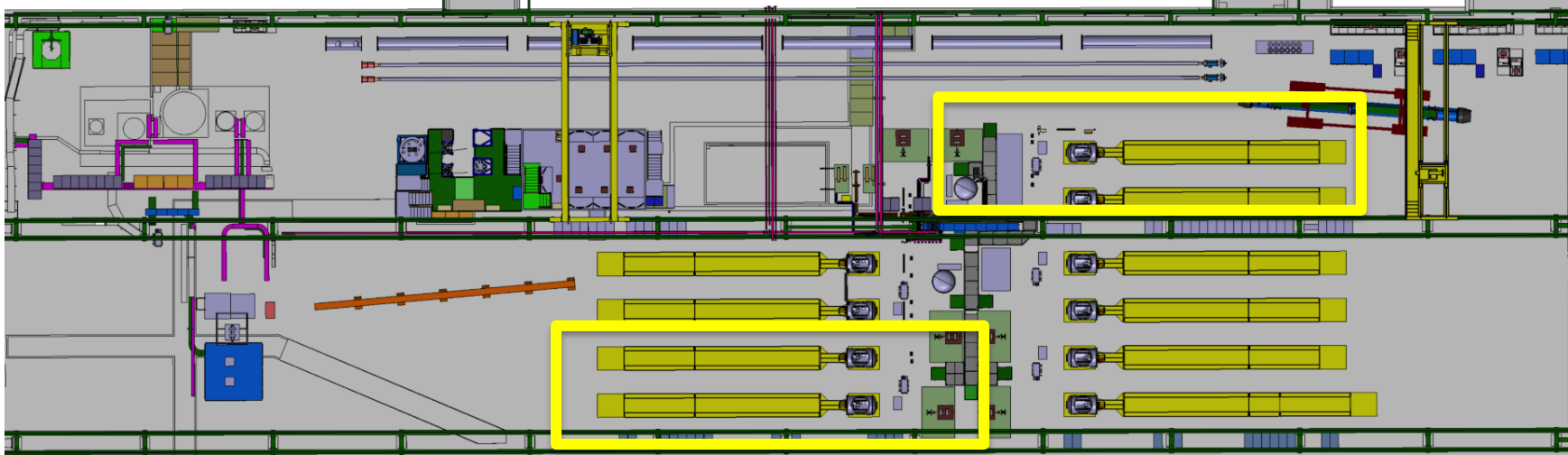


Cluster F

The horizontal test zone Cluster A to F excluding D is composed by 8 benches. They are equipped with 4 independent electrical circuits allowing to test magnets up to 15 kA @ 1.9 K. Two clusters are planned to be upgraded to 20 kA capacity.

# Horizontal test bench upgrade

## Cluster A



The UPGRADE is DRIVEN by HL-LHC needs: **Cluster F**

Target for prototype test:

$$90\% I_{ss} \leq 20 \text{ kA}$$

Target for series test :

$$108\% I_{nom} = 17.8 \text{ kA}$$

Magnet weight: 25 tonnes

Operating temperature: 4.2 K and 1.9 K

Max. Operating current: **20 kA, 2 x 2 kA**

Max. Pressure in the magnet in case of quench: 20 bars

Max. Test voltage: 3 kV

Cluster E will have the same characteristics. Foreseen later.

# Facilities Upgrade

UPGRADE DRIVEN BY The recommendation enabling to carry out the full test programme with no constraints

## CRYOGENIC COOLING PRODUCTION: + 35 g/s LHe

Needs essentially for HL-LHC IT STRING run in parallel with magnet testing

## DEMINERALISED WATER PRODUCTION: + 150 m<sup>3</sup>/h

Needs for demineralised water entirely coming from magnet operation

## HANDLING: 25 t and longer rope

Needs for overhead crane entirely coming from magnet operation

## nCONTROL ROOM

Needs to extend the small control room of the vertical . Test facility to be used also for horizontal benches and Sc link

For 2019

Operational

Operational

For mid 2016



# Conflict or synergy in space and time

Vertical test cryostat

SC link test stand (110m)

IT String (80 m)

Horizontal benches

Overlap with Vertical  
cryostats

Overlap Sc link test stand and STRING

The integration is driven by a possible synergy as following:  
Share time, cryogenic cooling and electrical powering systems between Sc link test stand and IT String

35 FRESCA2 with INSERT

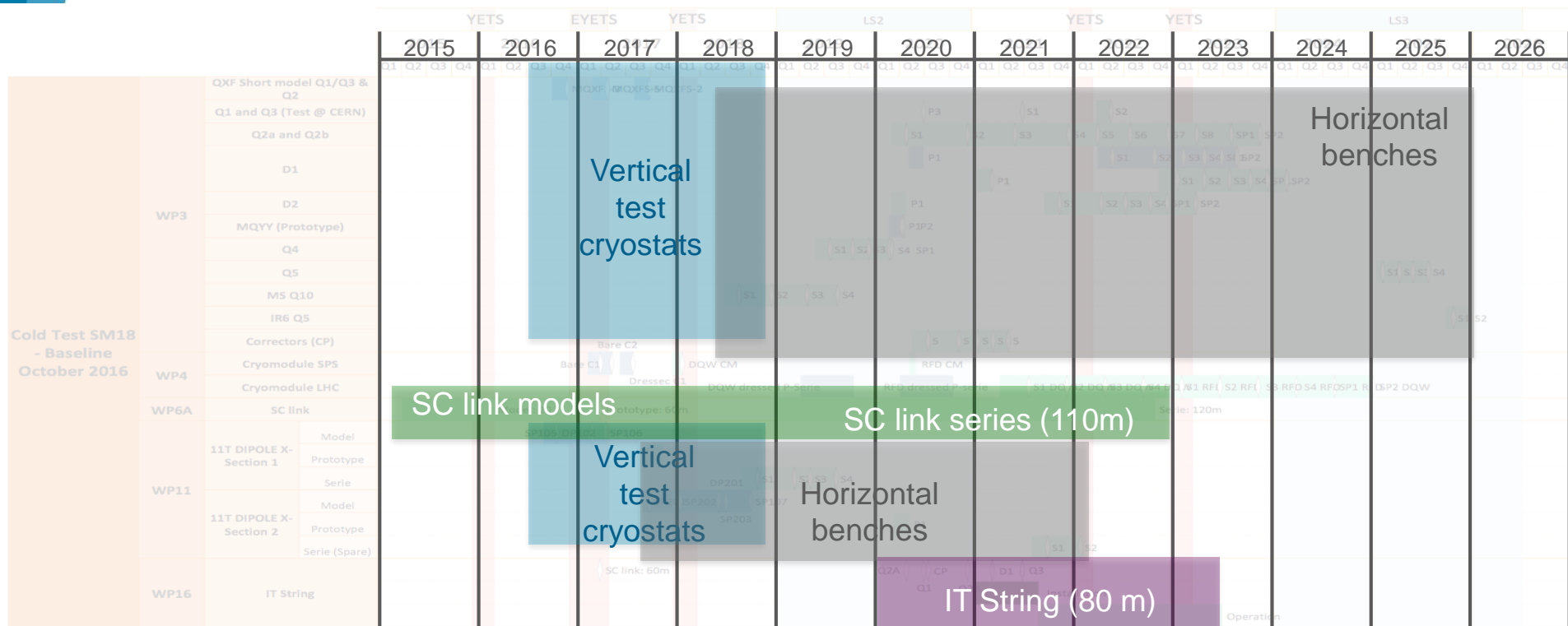
36 LHC Spare

FRESCA2 with INSERT  
LHC Spares

Task  
Task: IR STRING  
Task Start: Mon 01/06/20

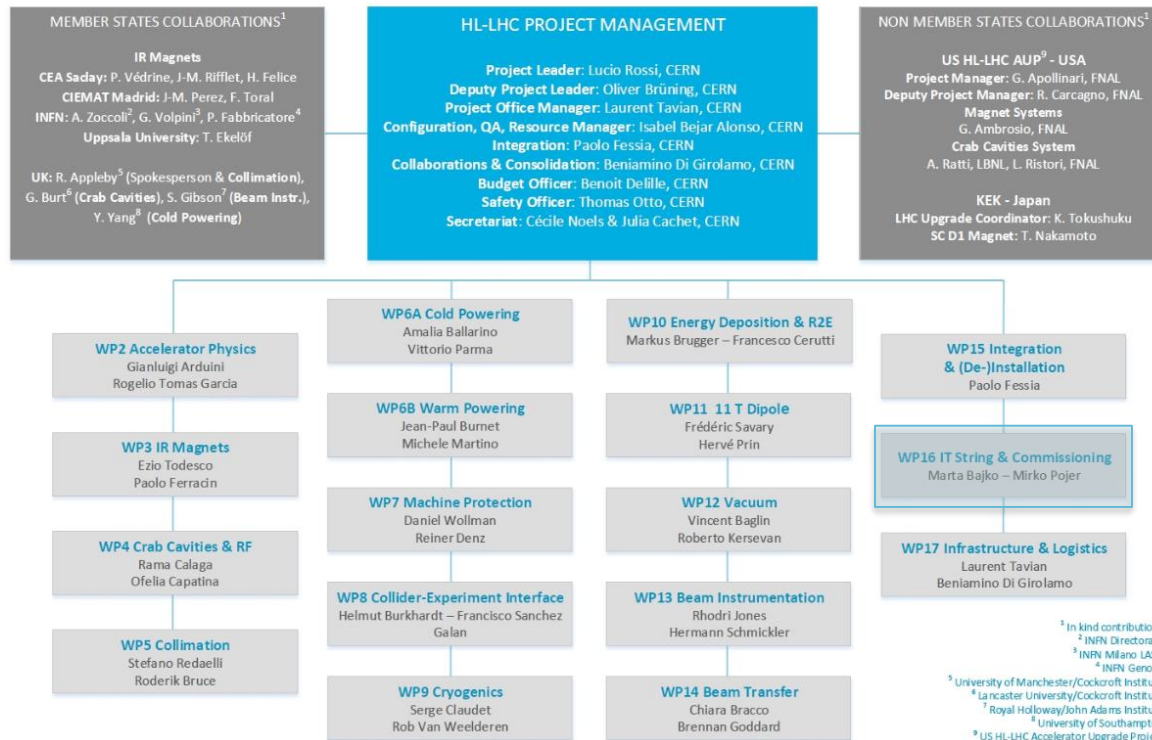


# Conflict/synergy between test stands/IT String ?



# The HL-LHC IT STRING in the organigram

## High Luminosity LHC Project



[...] **THE WP16** covers the coordination of the commissioning of the HL-LHC equipment as part of the accelerator system. [...] The first important system test will be the Inner Triplet (IT) STRING test.

The IT STRING should comprises all magnets with their cold and warm powering and associated cryogenics systems from Q1 to D1 magnets including DFX. [...] The IT STRING will have conditions as similar as possible to the operational ones and will constitute an integration and system test of the most critical part of the upgrade.

Ref. HL\_WP16 Conceptual specification : <https://edms.cern.ch/document/1586706/1>

Ref. HL\_WP16 IT STRING Mandate: <https://edms.cern.ch/document/1513780/1>

# The HL-LHC IT STRING SCOPE

## INTRODUCTION

In the HL-LHC configuration, the Inner Triplet (IT) region of IR1 and IR5 of the present LHC will be heavily modified. In particular the Q1-Q2-Q3-D1 magnets will be completely different from the present LHC magnets, mainly due to the new technology they are based. In particular the **D1** magnet will be **superconductor** instead of normal conductors as is today in the LHC. The IT quadrupoles (Q1-Q3) will use **Nb<sub>3</sub>Sn** superconductors instead of the **Nb-Ti** used by the present ones.

The powering of the magnets will be with **higher current** than the present LHC IR magnets and will be made via a **superconducting link**. The **protection** of the magnets based on Nb<sub>3</sub>Sn superconductor technology will be **different** from the present ones (ex. CliQ and new QH) due to its particulate characteristics at low and medium field and the **high magnetic energy stored** in the magnets in operational conditions.

In addition, the **aperture will be much larger**, the cold mass configuration will be completely different and the **corrector package** will be **substantially modified** as configuration and technology, too.

[...]

## MAIN GOAL

The HL LHC IT STRING will be a test stand to **STUDY and VALIDATE the COLLECTIVE BEHAVIOURE** of the different systems: magnets, magnet protection, cryogenics for magnets and superconducting link, magnet powering, vacuum, and interconnections between magnets and superconducting link, alignment.

Ref. HL-LHC IT STRING Scope <https://edms.cern.ch/document/1693312/1>

# Relevance for the HL-LHC IT STRING

The HL-LHC IT-String can provide relevant experience (same object as in the LHC), validation (“first time” test) and advanced operation information on:

- Magnet positioning, alignment, interconnection procedures (do not under-estimate)
- Mechanical behavior of the IT continuous cryostat (Q1 to DFX) and other components (DSH, DFH) under pressure, vacuum, cool-down, operation and warm-up
- Cryogenic behavior and operation under static and dynamic conditions
- Insulation and beam vacuum static (and dynamic) behavior
- Powering behavior of the system with Sc links, dynamic response (and associated field quality), interaction of circuits
- Cross talk between magnets in operation and during a quench, detection, propagation and protection of the complete superconducting circuit

These aspects, especially the **collective behavior**, can only be tested in a representative test, a so-called STRING

**GOALS** in parallel:    Develop methods, techniques  
Develop tooling  
Develop procedures    for  
definition of    Installations  
Test  
Operation    to    HWC and OP  
support    of HL-LHC

# ID Card of HL-LHC IT-String

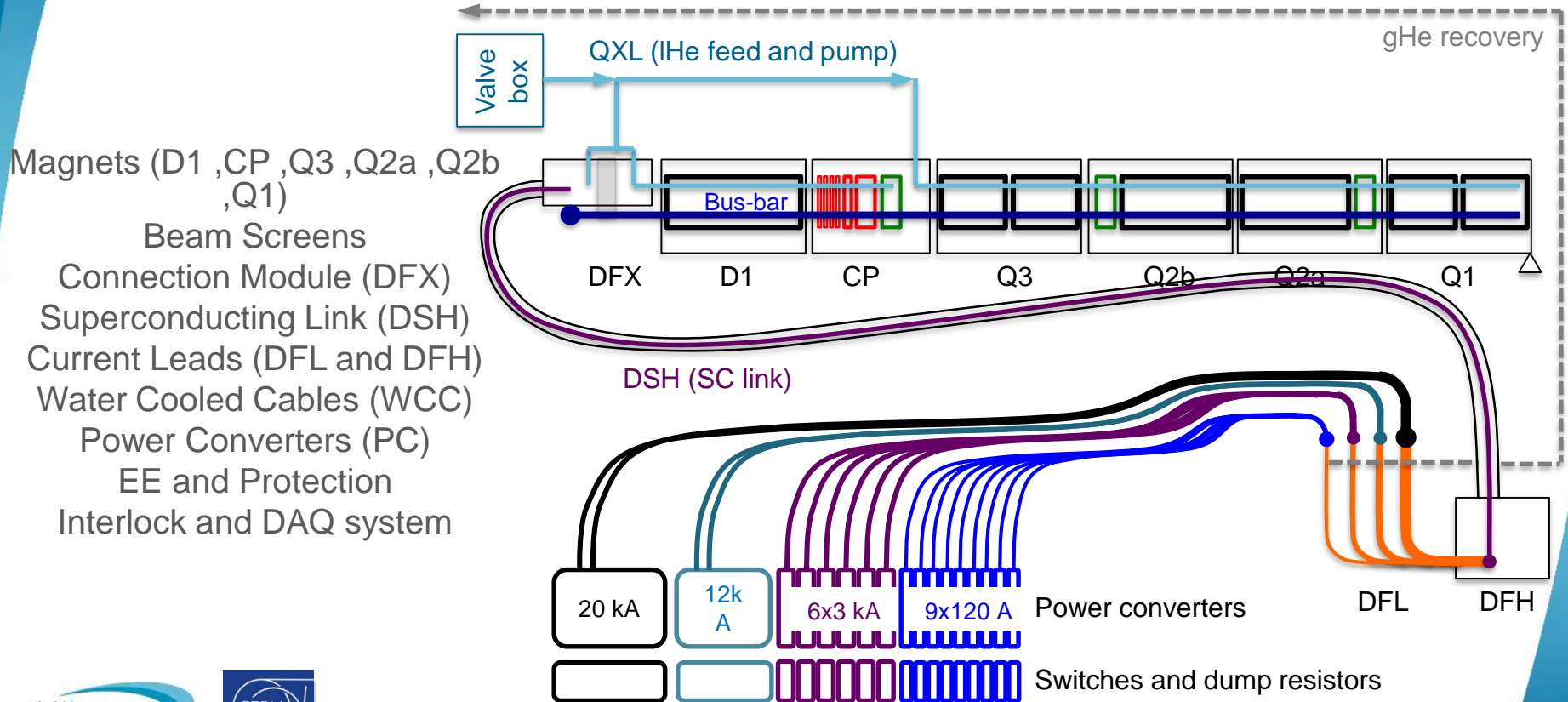
- Test Facility name: HL-LHC IT STRING
- Test Facility location: SM18 (b. 2173)
- Test date: 2020-2022
- Operational temperature: 1.9 K
- Operational current: 108%  $I_{\text{nominal}} = 18 \text{ kA}$
- Magnets: Q1, Q2a, Q2b, Q3, CP, D1
- Cold powering: SC link (60 m or 110 m) HTS leads DFH and DFX,
- Warm powering: 1 x PC 18 kA , 3 Trim Q1-Q3, 6 x 2 kA , 1 x 12 kA, 9 x 0.1 kA  
Water cooled cables
- Protection: CLIQ , QH and EE

[...] a **FULL INTEGRAL TEST** of the equipment from **Q1 till D1** including the **DFX** is foreseen in the HL-LHC project, in CONDITION AS SIMILAR AS POSSIBLE to the operational one.

The IT STRING of the HL-LHC will be composed by systems previously tested individually at least in nominal operational conditions.

HL\_WP16 Conceptual specification :  
<https://edms.cern.ch/document/1586706/1>

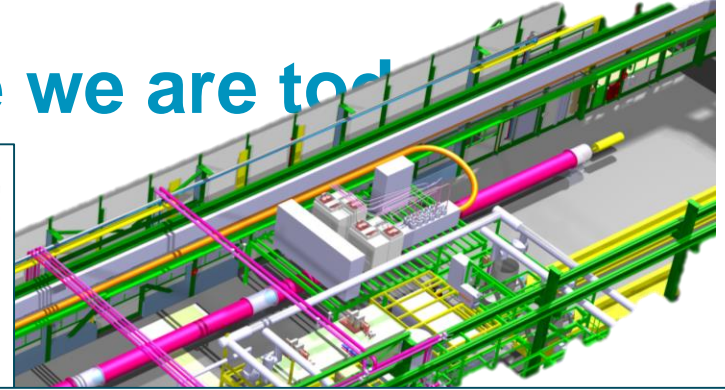
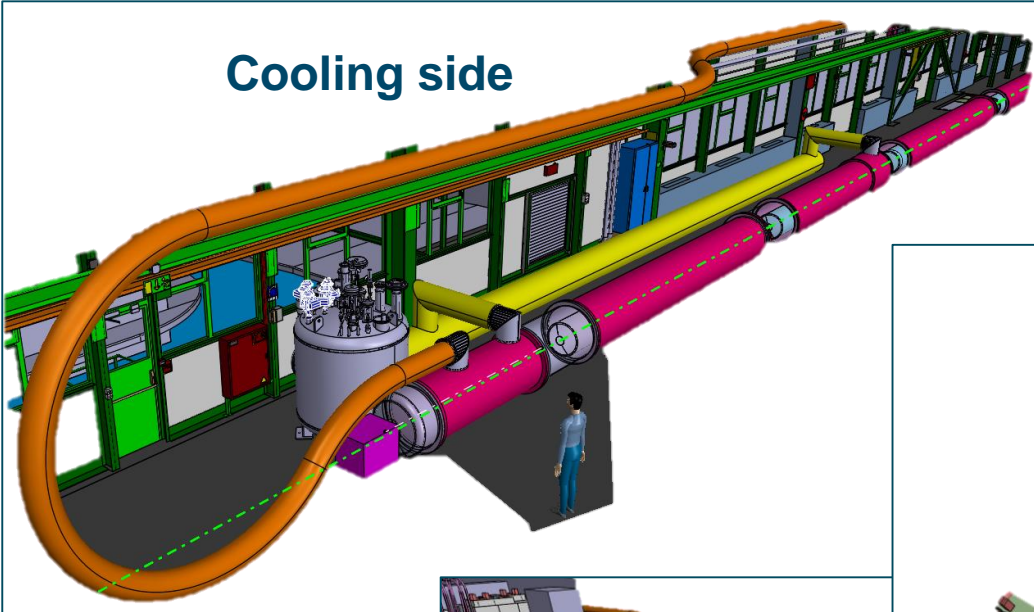
# Main components and schematics



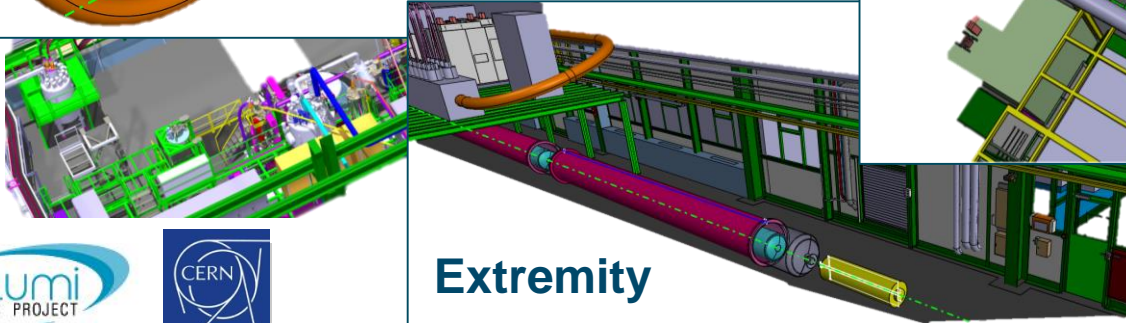
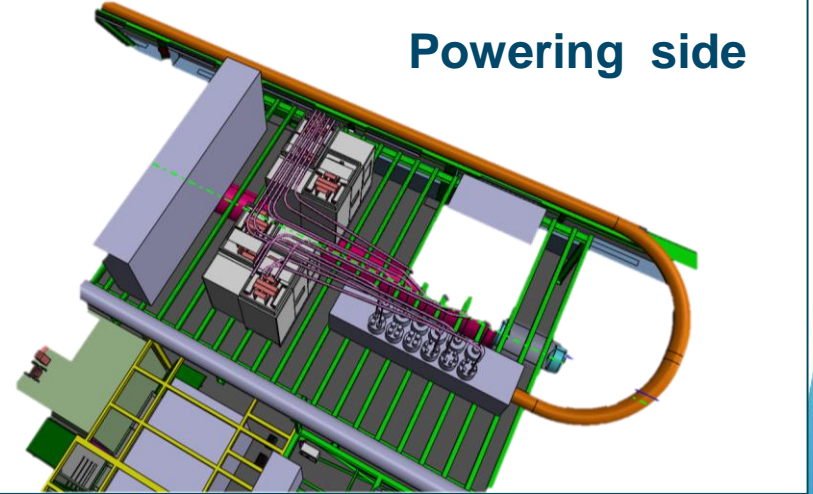


# Options in space: where we are today

Cooling side

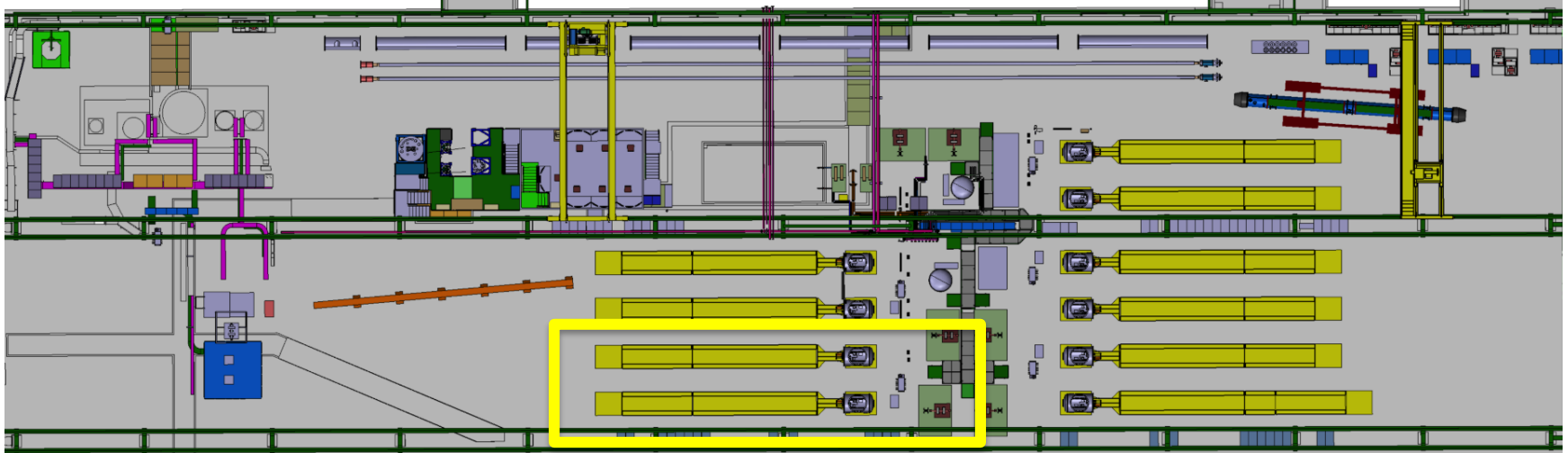


Powering side



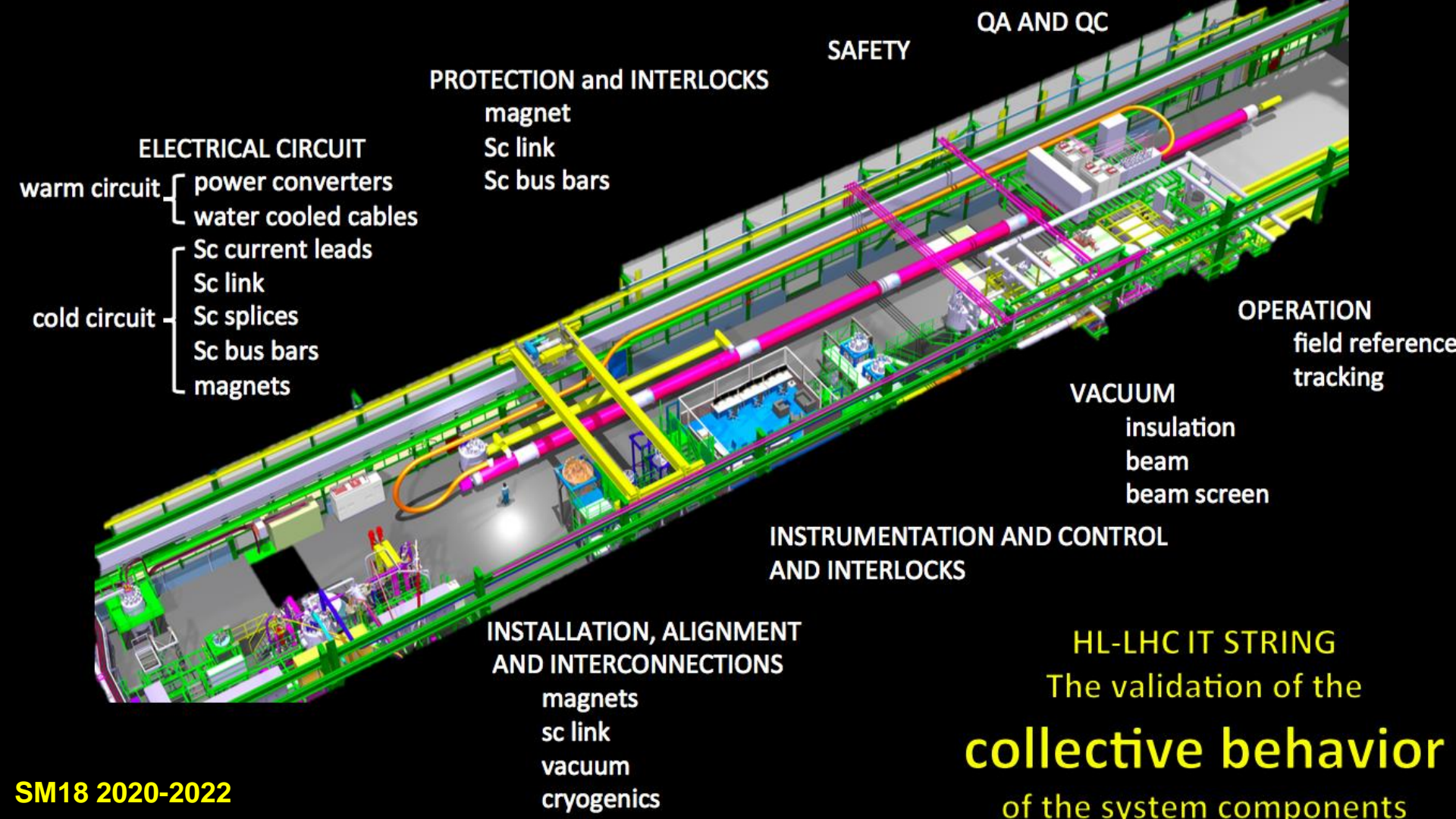
Extremity

# SC link series test



Cluster F





**HL-LHC IT STRING**  
The validation of the  
**collective behavior**  
of the system components