HL LHC IT STRING TEST

M. Bajko CERN

On behalf of the string team

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- The HL LHC STRING in the organisation
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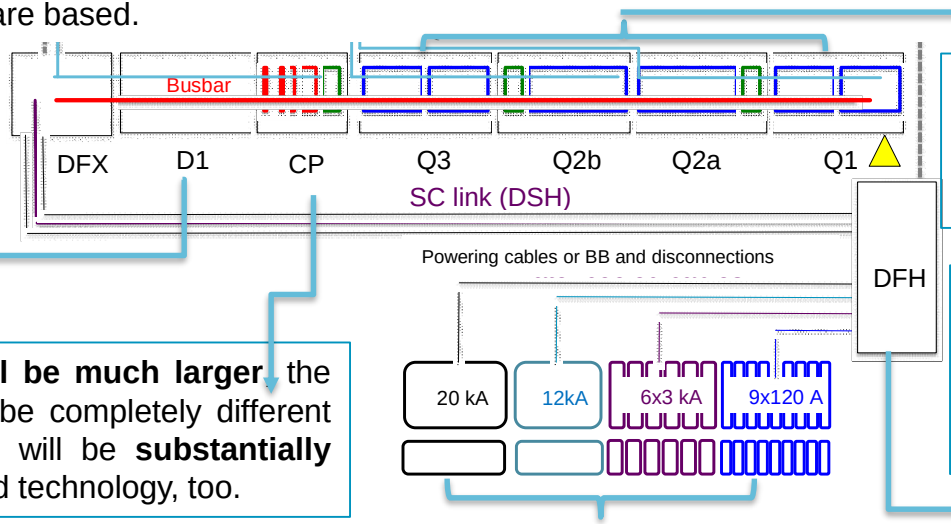
The HL-LHC IT STRING MOTIVATION 1

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.

HL-LHC

D1 magnet will be **superconductor** instead of normal conductors as is today in the LHC.



The IT quadrupoles (Q1-Q3) will use **Nb_3Sn** instead of the **Nb-Ti** used by the present ones.

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.

The powering of the magnets will be with **higher current** than the present LHC IR magnets

and will be made via a **superconducting link and new generation superconducting current leads**

The **protection** of the magnets based on Nb_3Sn 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 (1.2 MJ/m, 2-4 x higher than in LHC)** in the magnets in operational conditions.

The HL-LHC IT STRING MOTIVATION 2

The main motivation is to represent, as far as reasonably achievable in a surface assembly, the various operation modes and make of the HL LHC IT STRING 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

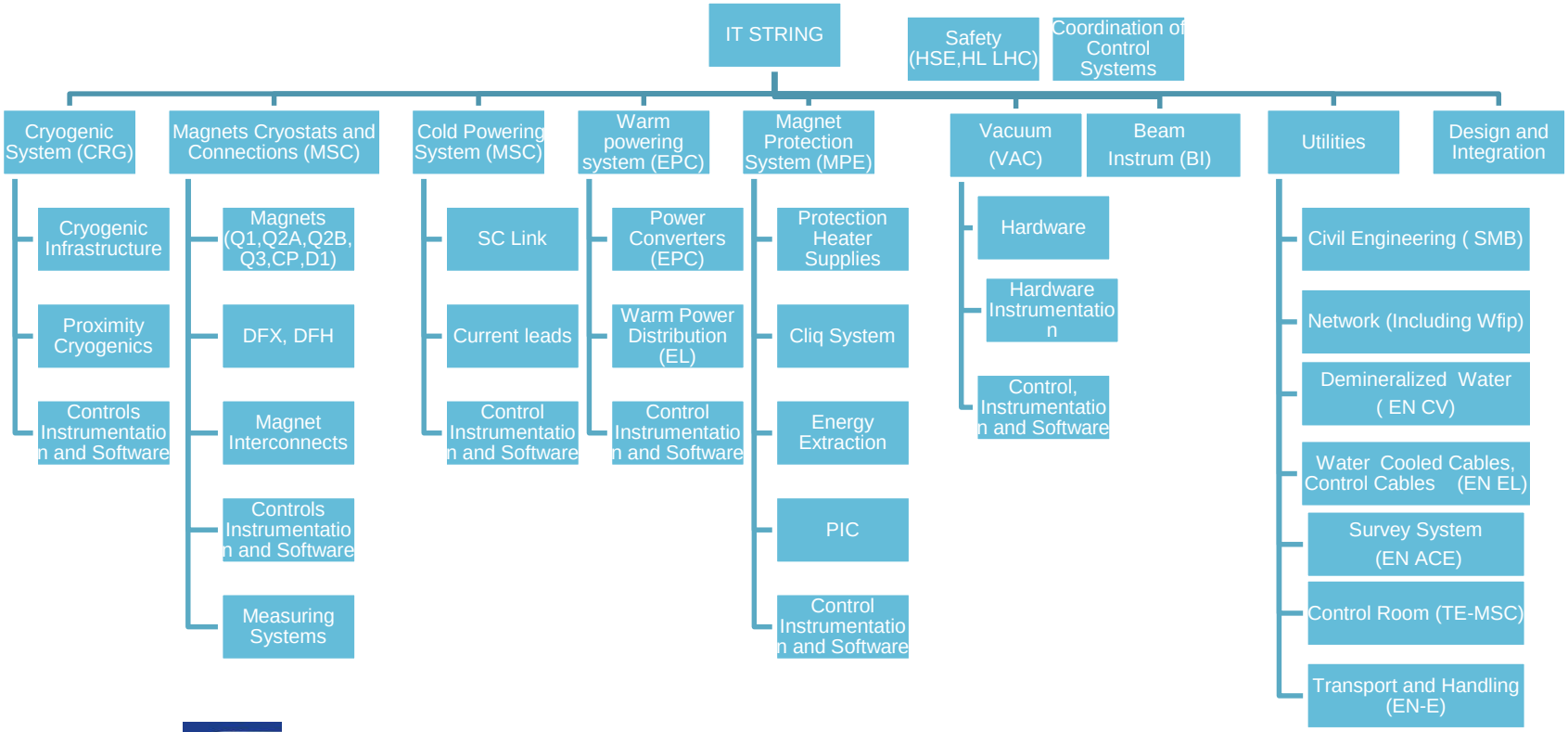
- **The HiLumi String will serve as a test bed for matters or conditions that either :**
  - **(a) cannot be tested as a part of the components acceptance and characterization program, or**
  - **(b) depend on the response of the integrated system.**

The HL LHC IT STRING in the organigram

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

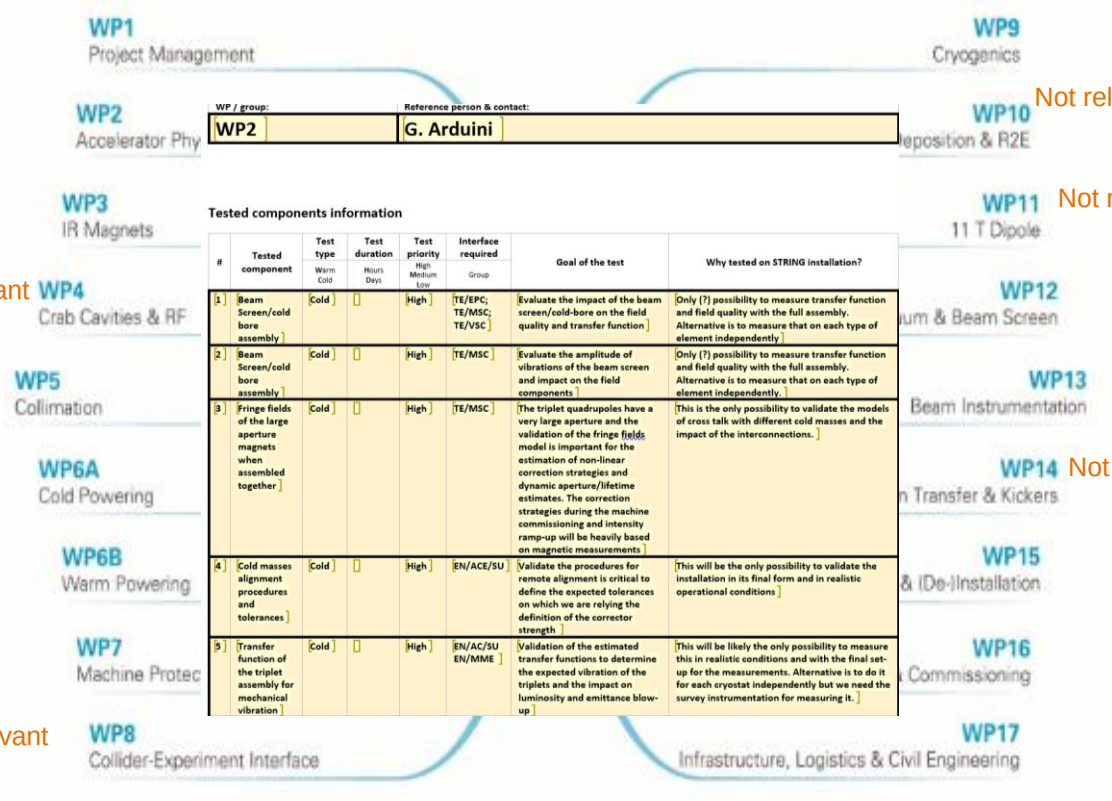
HL_WP16 Conceptual specification : https://edms.cern.ch/document/1586706/1

Organization for Construction of the STRING



https://edms.cern.ch/document/1690890/1.0

Preparing the STRING experimental program

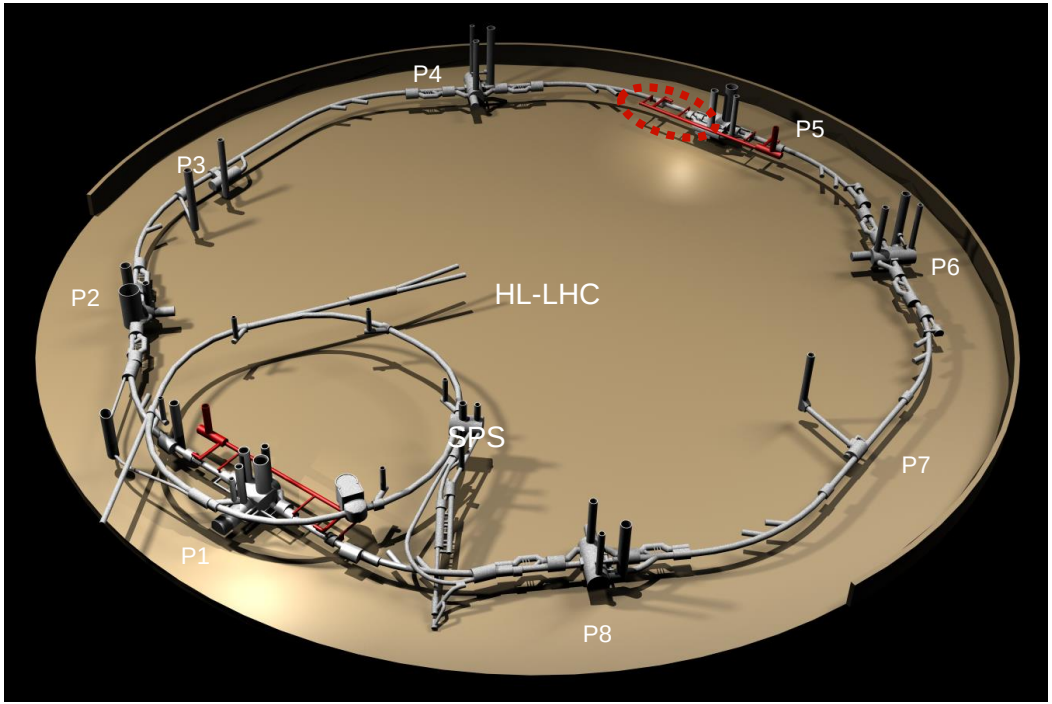


WP / group:	Reference person & contact:
WP2	G. Arduini

Tested components information

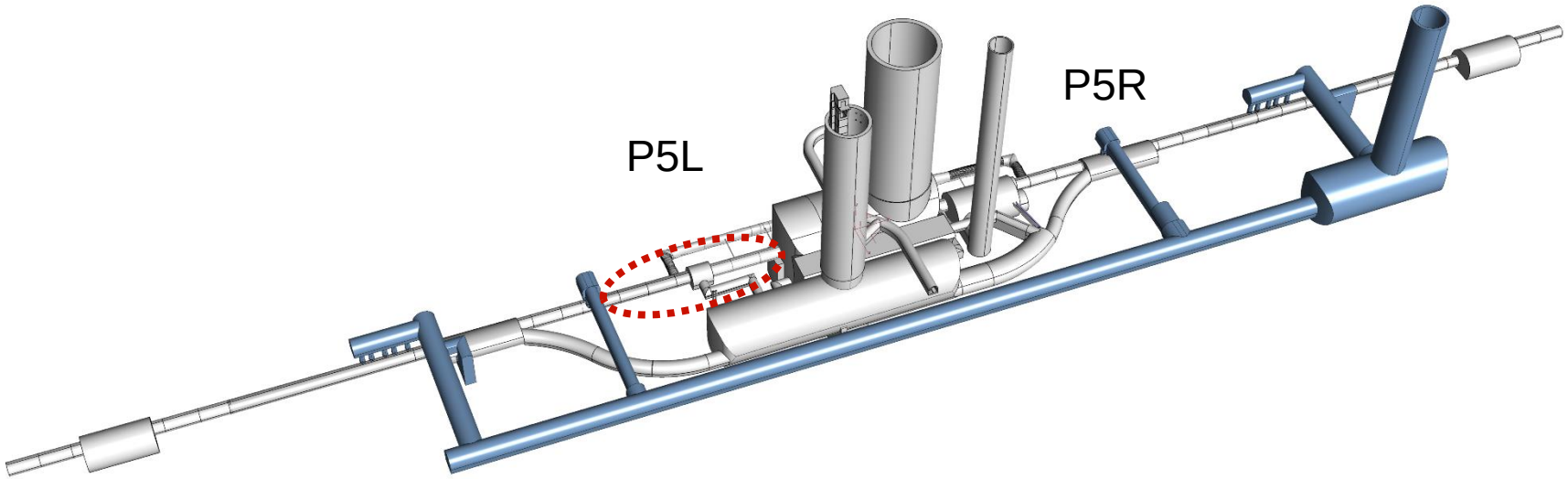
#	Tested component	Test type (Warm / Cold)	Test duration (Hours / Days)	Test priority (High / Medium / Low)	Interface required (Group)	Goal of the test	Why tested on STRING installation?
1	Beam Screen/cold bore assembly	Cold		High	TE/EPC; TE/MSC; TE/VSC	Evaluate the impact of the beam screen/cold-bore on the field quality and transfer function	Only (?) possibility to measure transfer function and field quality with the full assembly. Alternative is to measure that on each type of element independently
2	Beam Screen/cold bore assembly	Cold		High	TE/MSC	Evaluate the amplitude of vibrations of the beam screen and impact on the field components	Only (?) possibility to measure transfer function and field quality with the full assembly. Alternative is to measure that on each type of element independently.
3	Fringe fields of the large aperture magnets when assembled together	Cold		High	TE/MSC	The triplet quadrupoles have a very large aperture and the validation of the fringe fields model is important for the estimation of non-linear correction strategies and dynamic aperture/lifetime estimates. The correction strategies during the machine commissioning and intensity ramp-up will be heavily based on magnetic measurements	This is the only possibility to validate the models of cross talk with different cold masses and the impact of the interconnections.
4	Cold masses alignment procedures and tolerances	Cold		High	EN/ACE/SU	Validate the procedures for remote alignment is critical to define the expected tolerances on which we are relying the definition of the corrector strength	This will be the only possibility to validate the installation in its final form and in realistic operational conditions
5	Transfer function of the triplet assembly for mechanical vibration	Cold		High	EN/AC/SU EN/MME	Validation of the estimated transfer functions to determine the expected vibration of the triplets and the impact on luminosity and emittance blow-up	This will be likely the only possibility to measure this in realistic conditions and with the final set-up for the measurements. Alternative is to do it for each cryostat independently but we need the survey instrumentation for measuring it.

Which configuration for the HL LHC IT STRING?



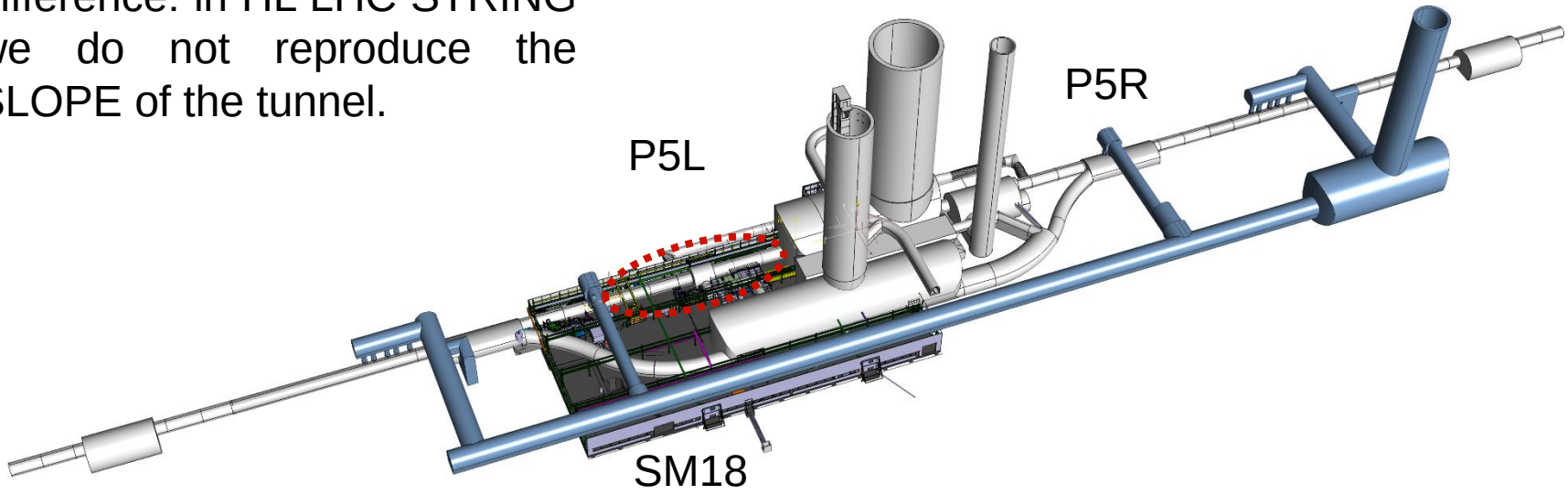
P5L *is the most complicated and coherent set up with the Sm18 installations and the tunnel is the smallest . We plan to reproduce the space allowed in that place of the tunnel for the interventions*

HL LHC IT STRING: P5L



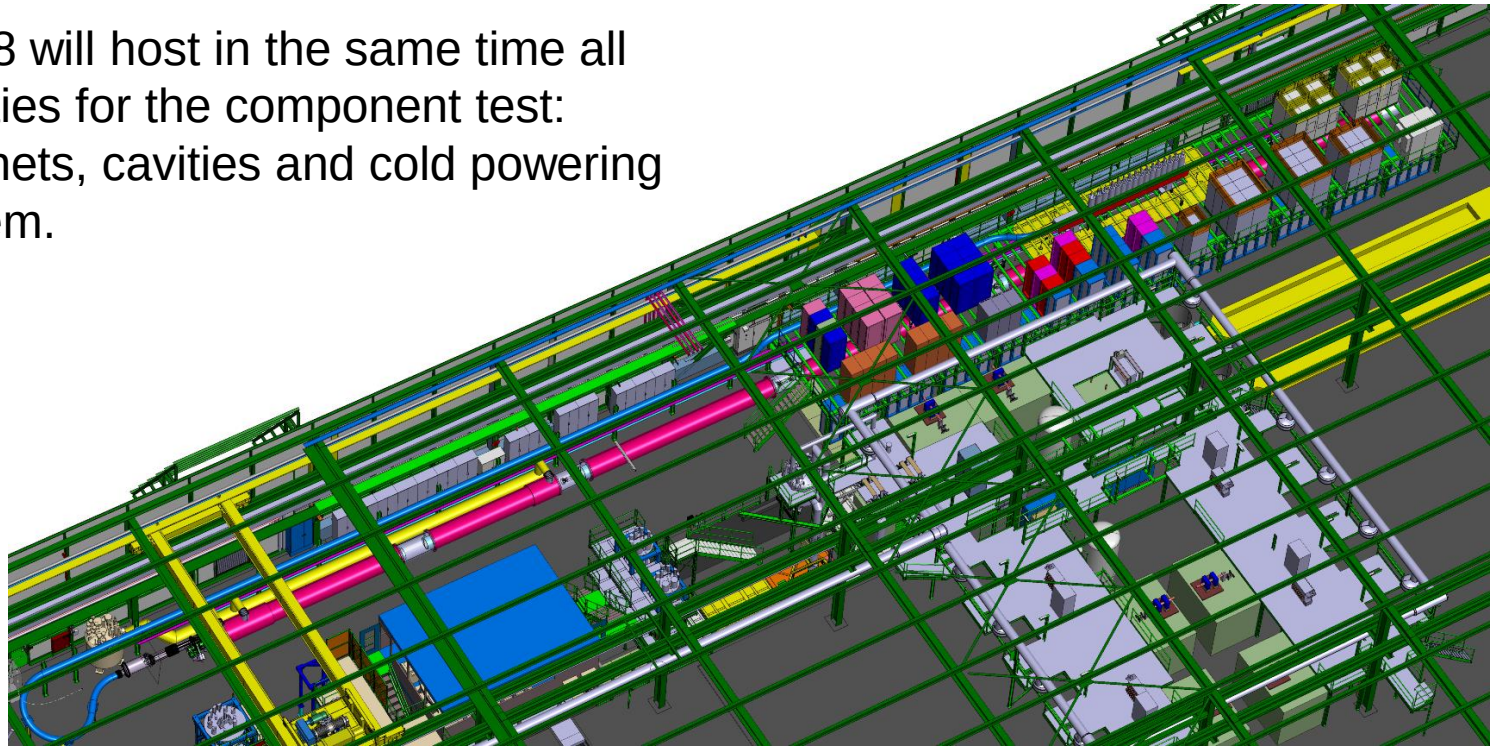
HL LHC IT STRING: P5L wrt to SM18

There is an essential difference: in HL LHC STRING we do not reproduce the SLOPE of the tunnel.



Integration in SM18

SM18 will host in the same time all facilities for the component test: magnets, cavities and cold powering system.



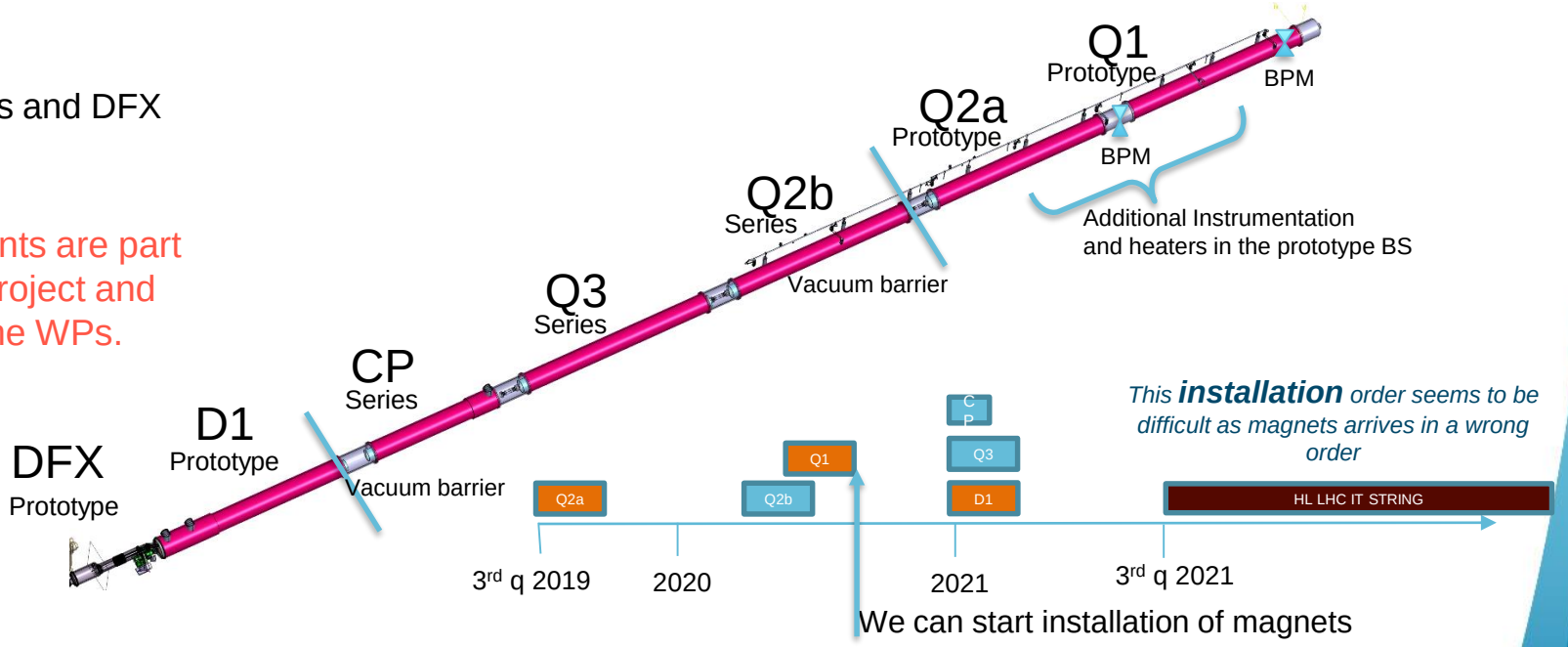
Which components are we going to use?

IP5

Installation | Inter-connection | Cooling | HWC | Exp @ Inom | Training to Iultimate | Thermal Cycle | HWC to Inom | Exp @ I nominal | Warm up

The magnets and DFX

All components are part of HL LHC project and belongs to the WPs.



This is a layout under discussions as we were asked to minimize the cost and more specifically the one related to the beam screens

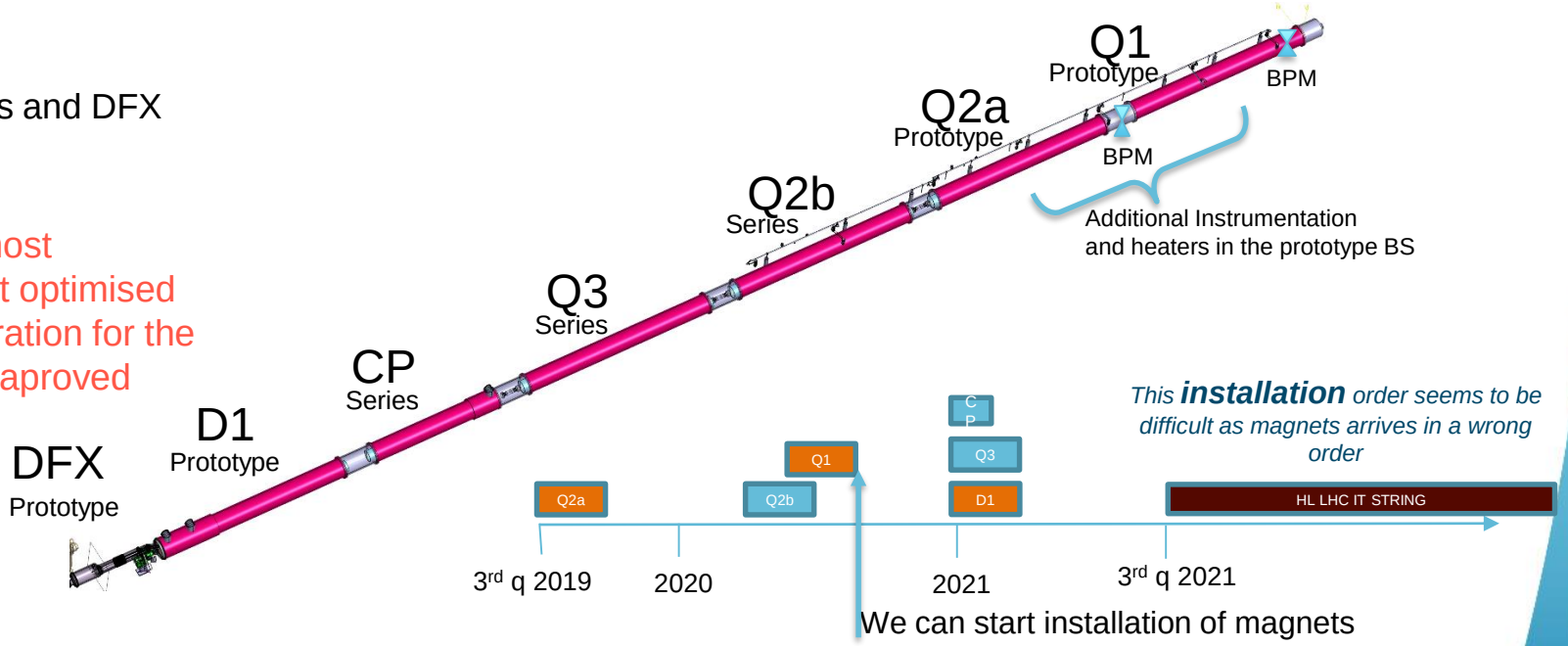
Which components are we going to use?

IP5

Installation | Inter-connection | Cooling | HWC | Exp @ Inom | Training to Iultimate | Thermal Cycle | HWC to Inom | Exp @ I nominal | Warm up

The magnets and DFX

This is the most adequate but optimised cost configuration for the moment not aproved



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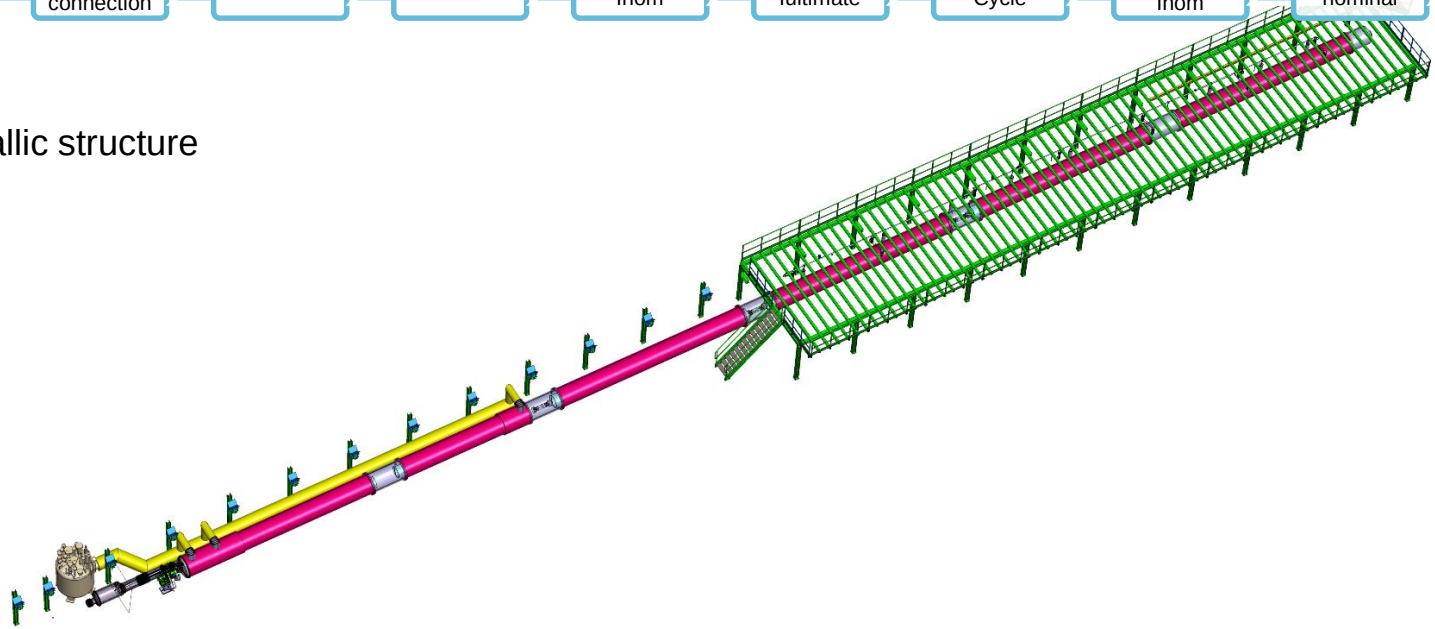
Test infrastructure for HL LHC IT STRING

Installation | Inter-connection | Cooling | HWC | Exp @ Inom | Training to Iultimate | Thermal Cycle | HWC to Inom | Exp @ I nominal | Warm up

The metallic structure



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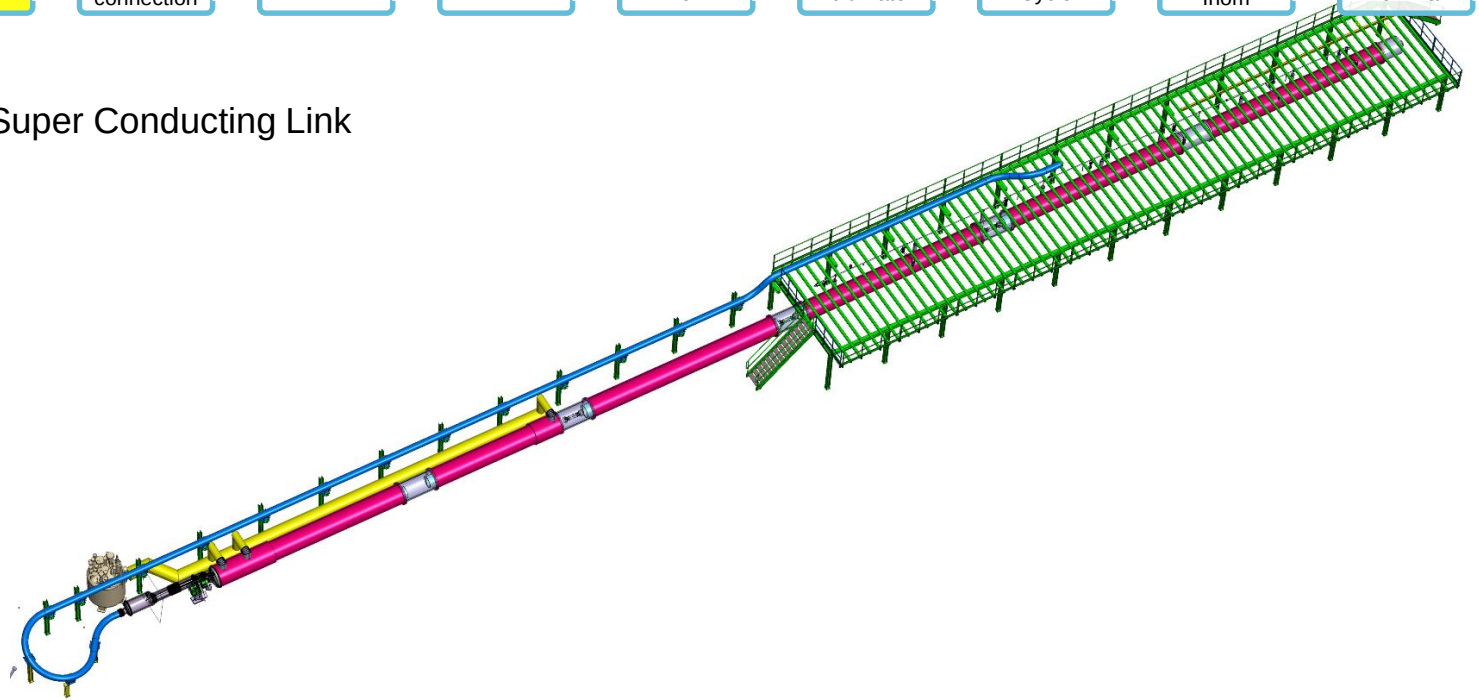
The Super Conducting Link



Test infrastructure for HL LHC IT STRING

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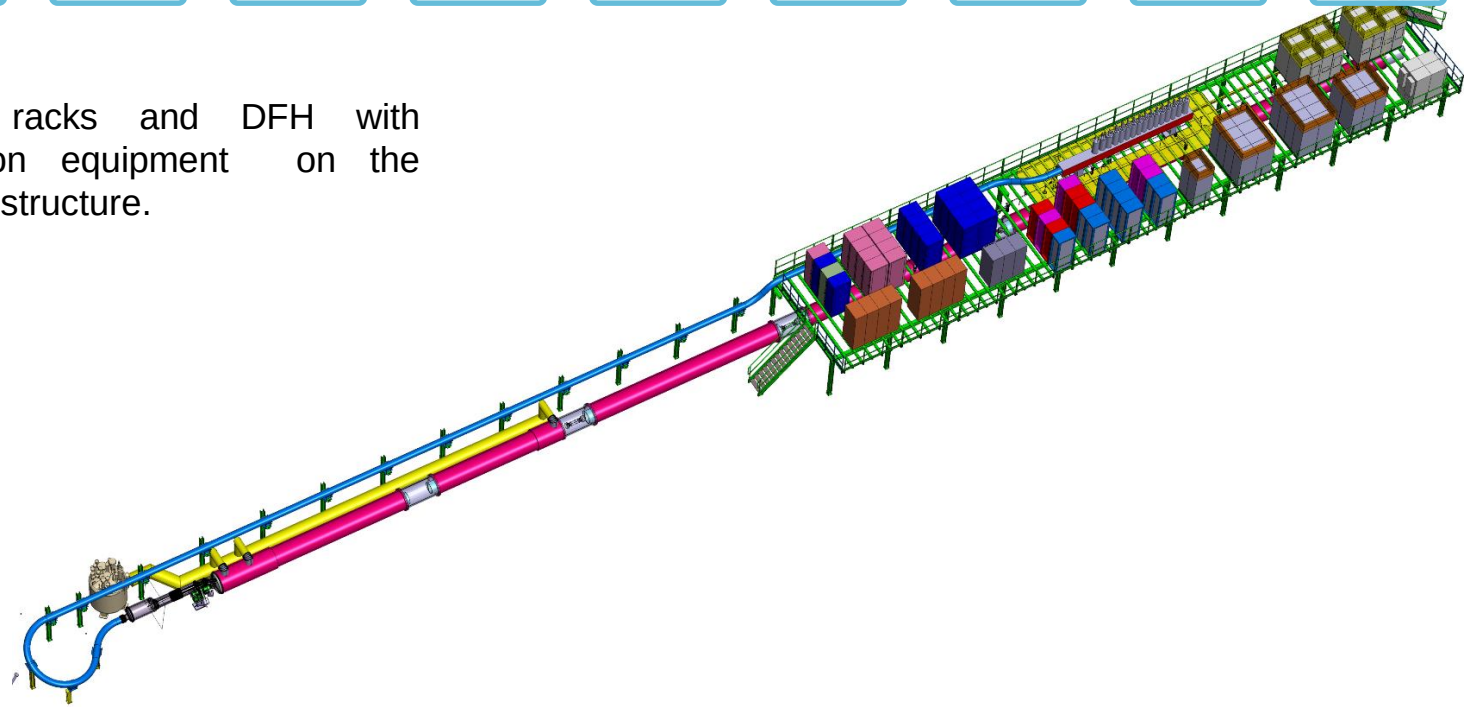
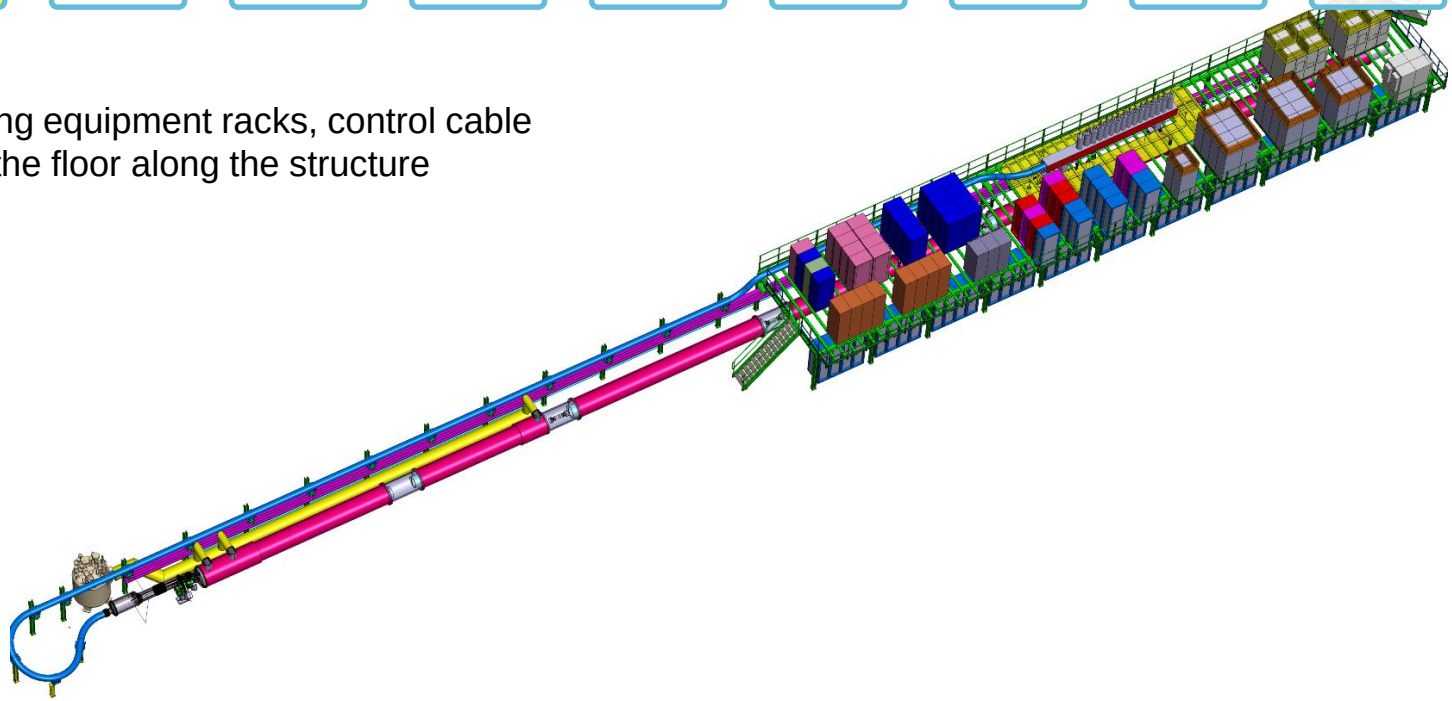
Power racks and DFH with protection equipment on the metallic structure.



Test infrastructure for HL LHC IT STRING

Installation | Inter-connection | Cooling | HWC | Exp @ Inom | Training to Iultimate | Thermal Cycle | HWC to Inom | Exp @ I nominal | Warm up

Measuring equipment racks, control cable trays in the floor along the structure



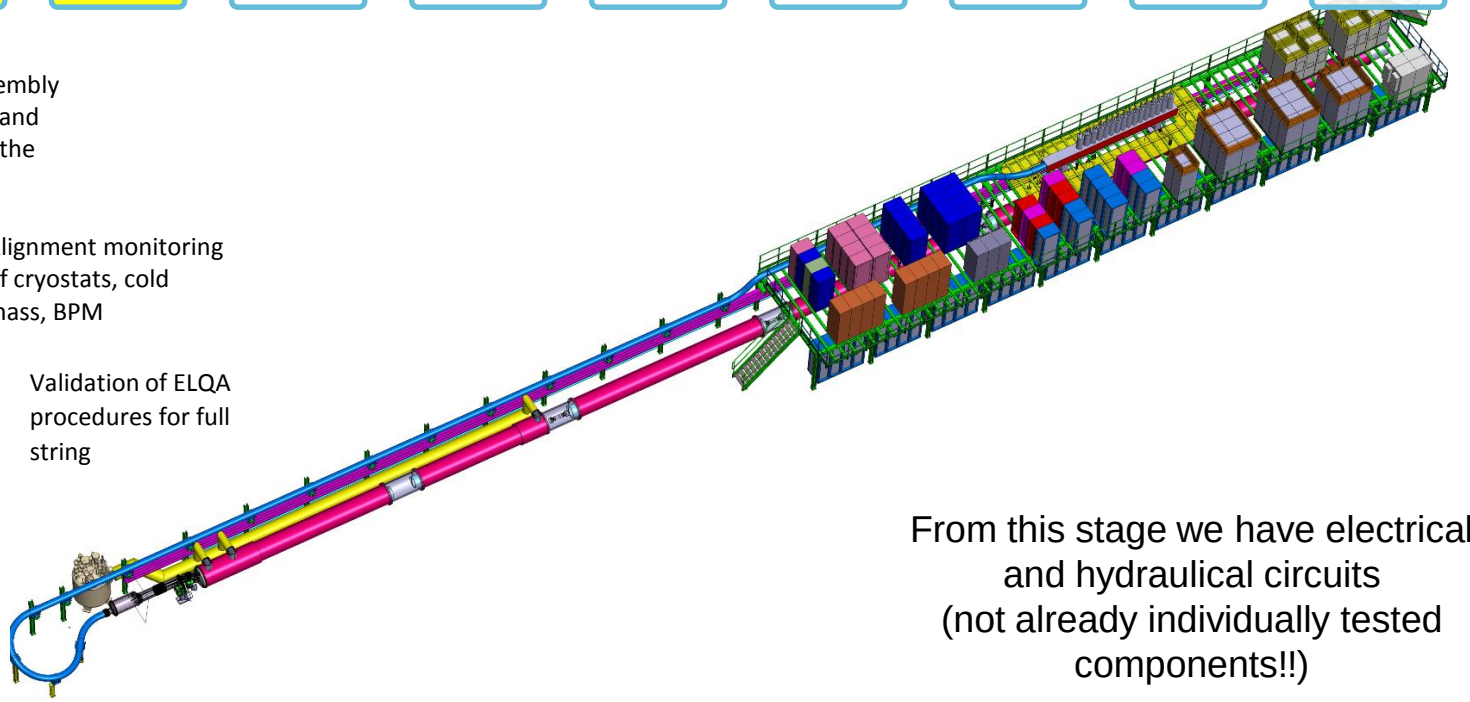
Test of the collective behaviour

Installation | Inter-connection | Cooling | HWC | Exp @ Inom | Training to Iultimate | Thermal Cycle | HWC to Inom | Exp @ I nominal | Warm up

Test of assembly procedure and tooling for the installation

Alignment monitoring of cryostats, cold mass, BPM

Validation of ELQA procedures for full string



From this stage we have electrical and hydraulical circuits (not already individually tested components!!)

Test of the collective behaviour

Installation | Inter-connection | Cooling | HWC | Exp @ Inom | Training to Iultimate | Thermal Cycle | HWC to Inom | Exp @ I nominal | Warm up

Pump down time

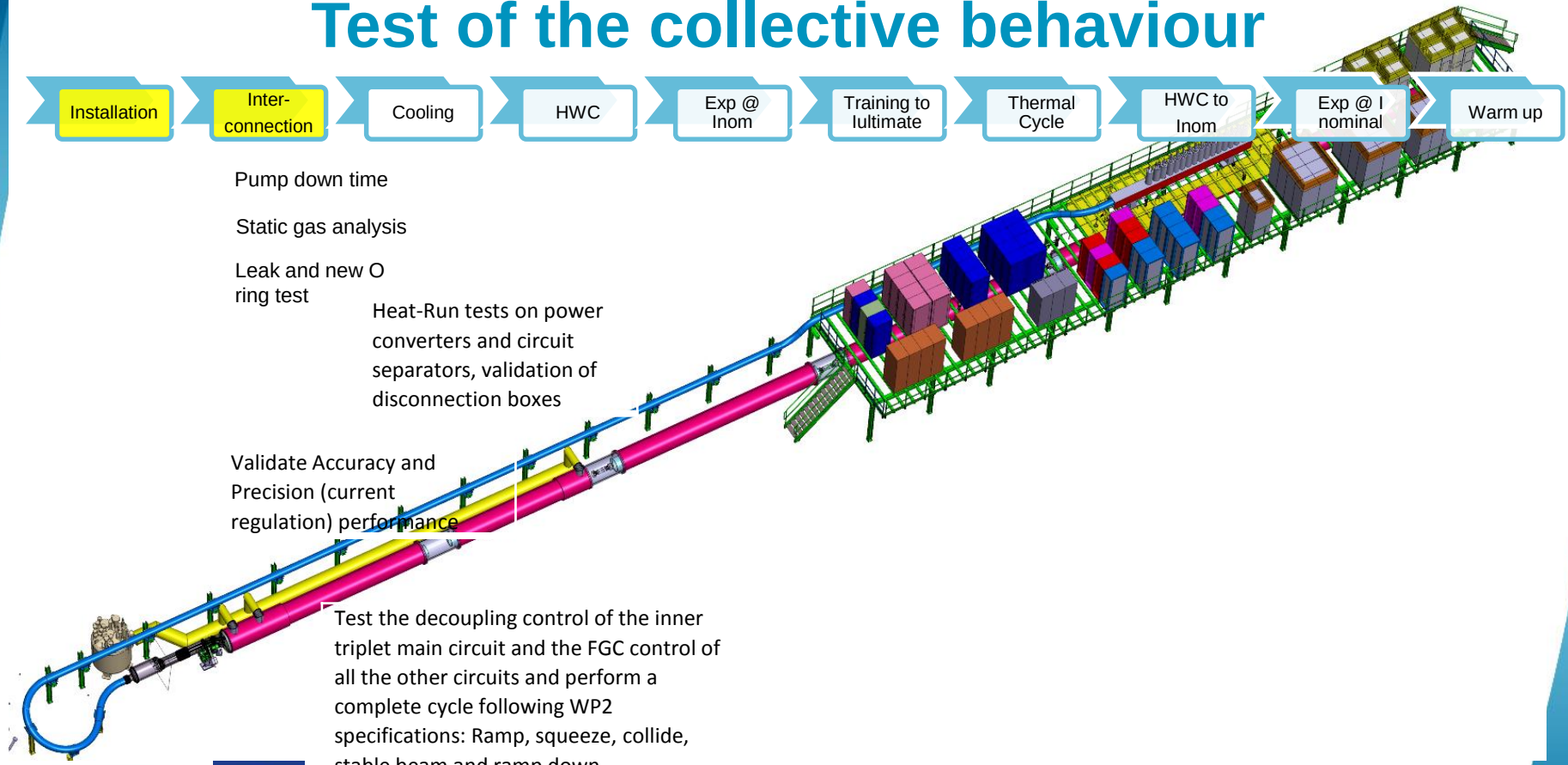
Static gas analysis

Leak and new O ring test

Heat-Run tests on power converters and circuit separators, validation of disconnection boxes

Validate Accuracy and Precision (current regulation) performance

Test the decoupling control of the inner triplet main circuit and the FGC control of all the other circuits and perform a complete cycle following WP2 specifications: Ramp, squeeze, collide, stable beam and ramp down.



Test of the collective behaviour

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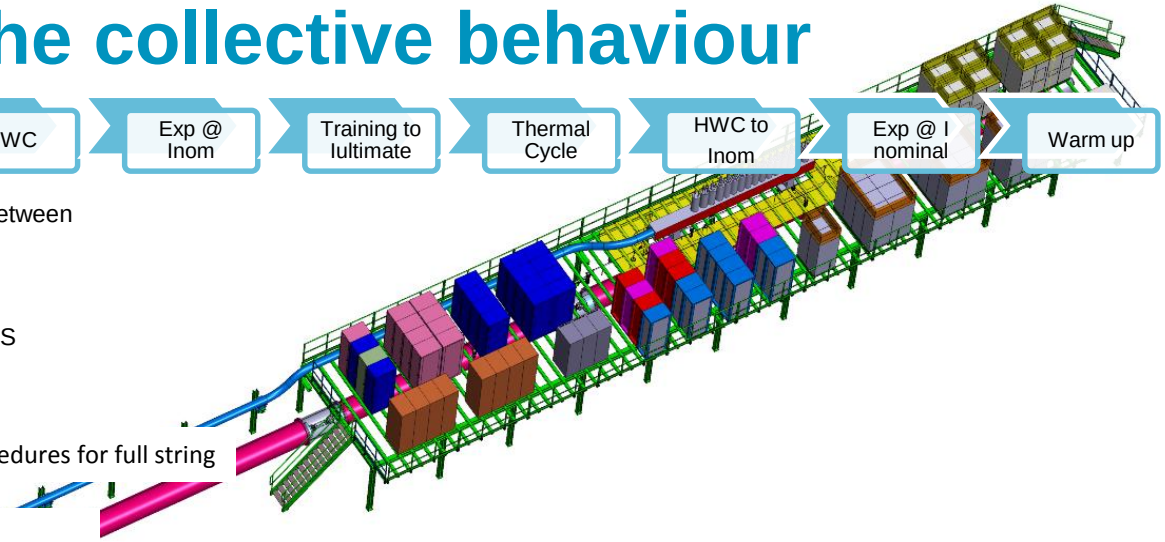


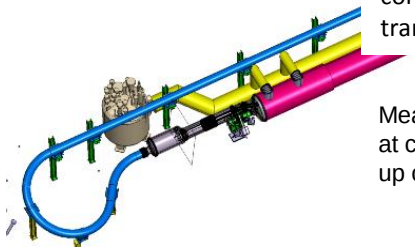
Thermal contraction between BS screen and CB

Flow induced vibration on BS

Behaviour of RF fingers

Validation of ELQA procedures for full string

Determine the control characteristics of the HL-LHC string in various operational conditions. Particularly during transients.



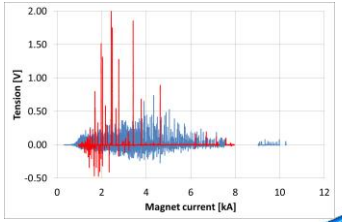
Measurements of the displacements at cold, during cool down and warm-up of components including BPM

Hardware commissioning

Installation → Inter-connection → Cooling → HWC → Exp @ Inom → Training to Iultimate → Thermal Cycle → HWC to Inom → Exp @ I nominal → Warm up

Test functionality of the circuit protection elements against over currents and HV during quenches

Validation of interlock loops and quench loops.

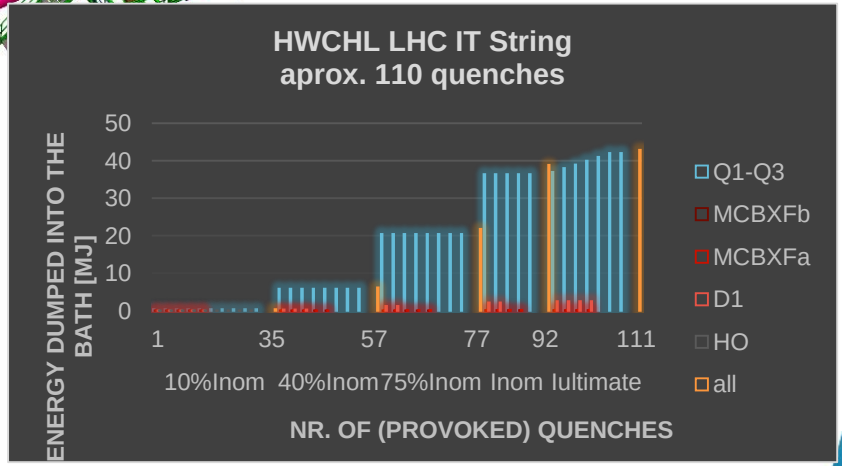


Validation of final versions of quench detection system (QDS)

Validation of EE systems for IT corrector magnets (600A, 2kA)

Validation of ELQA procedures for full string

Determine the thermohydraulic behaviour of the string during quenches. Study the cooldown after quenches.



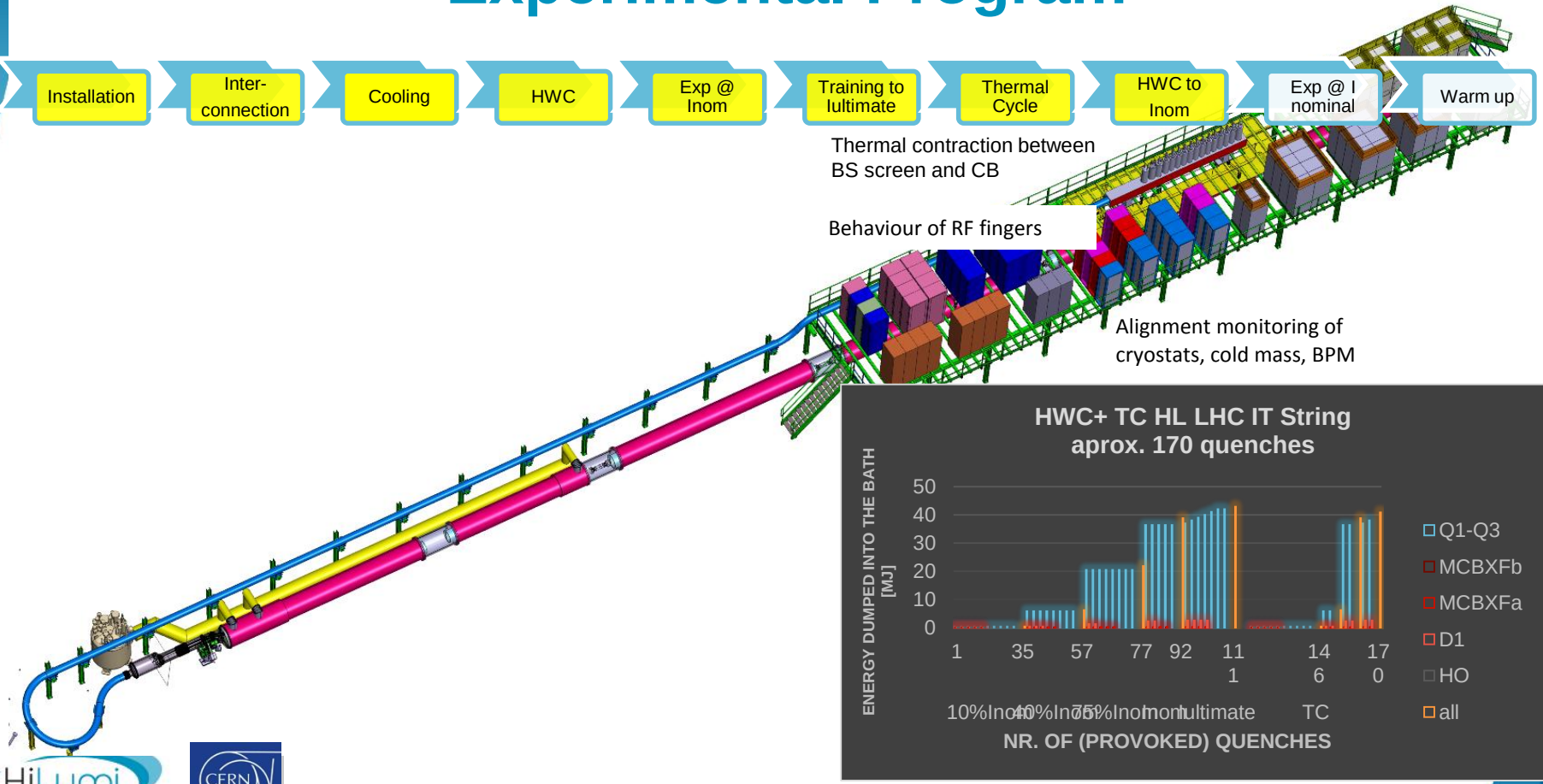
Experimental Program

Installation → Inter-connection → Cooling → HWC → Exp @ Inom → Training to Iultimate → Thermal Cycle → HWC to Inom → Exp @ I nominal → Warm up

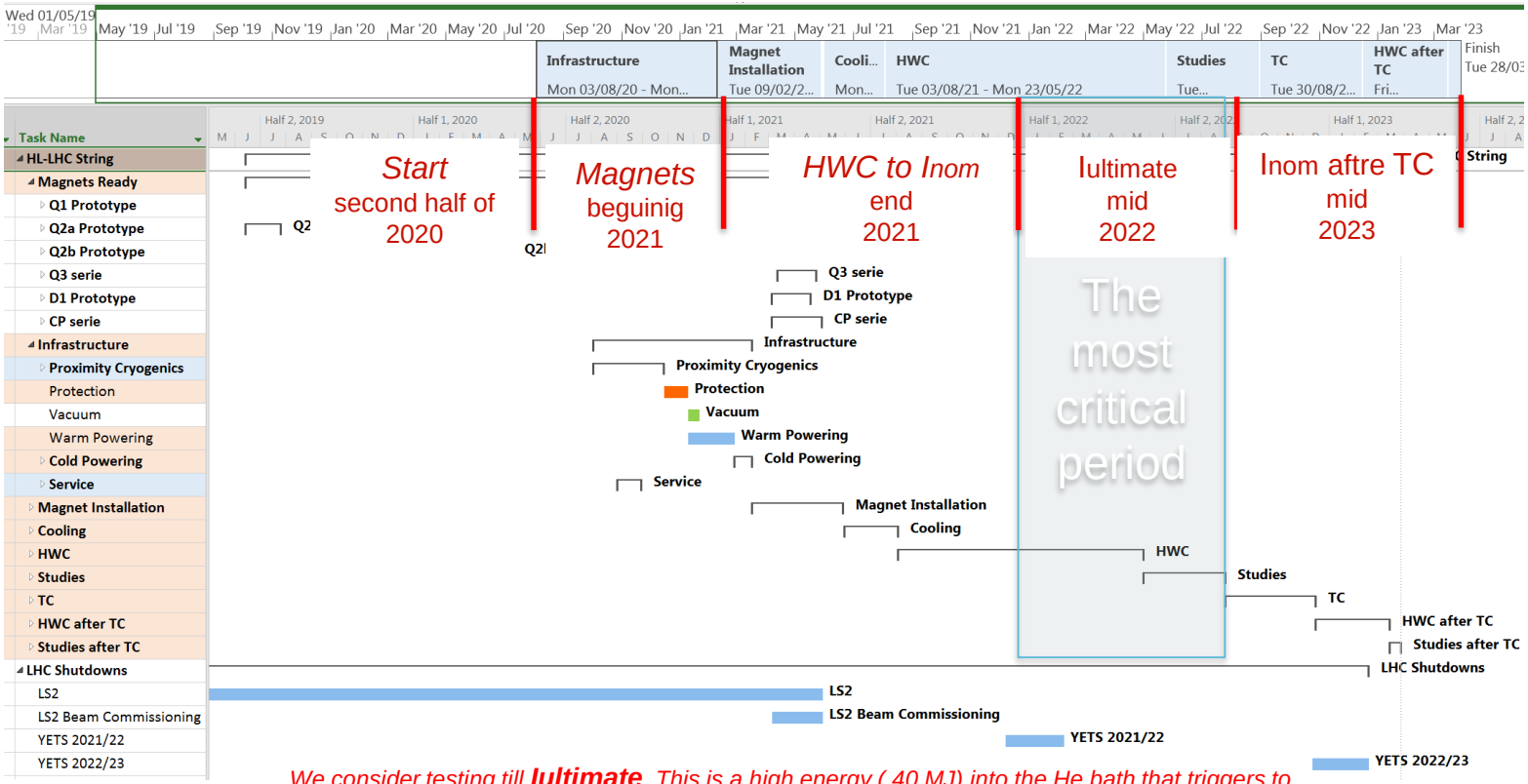
Thermal contraction between BS screen and CB

Behaviour of RF fingers

Alignment monitoring of cryostats, cold mass, BPM



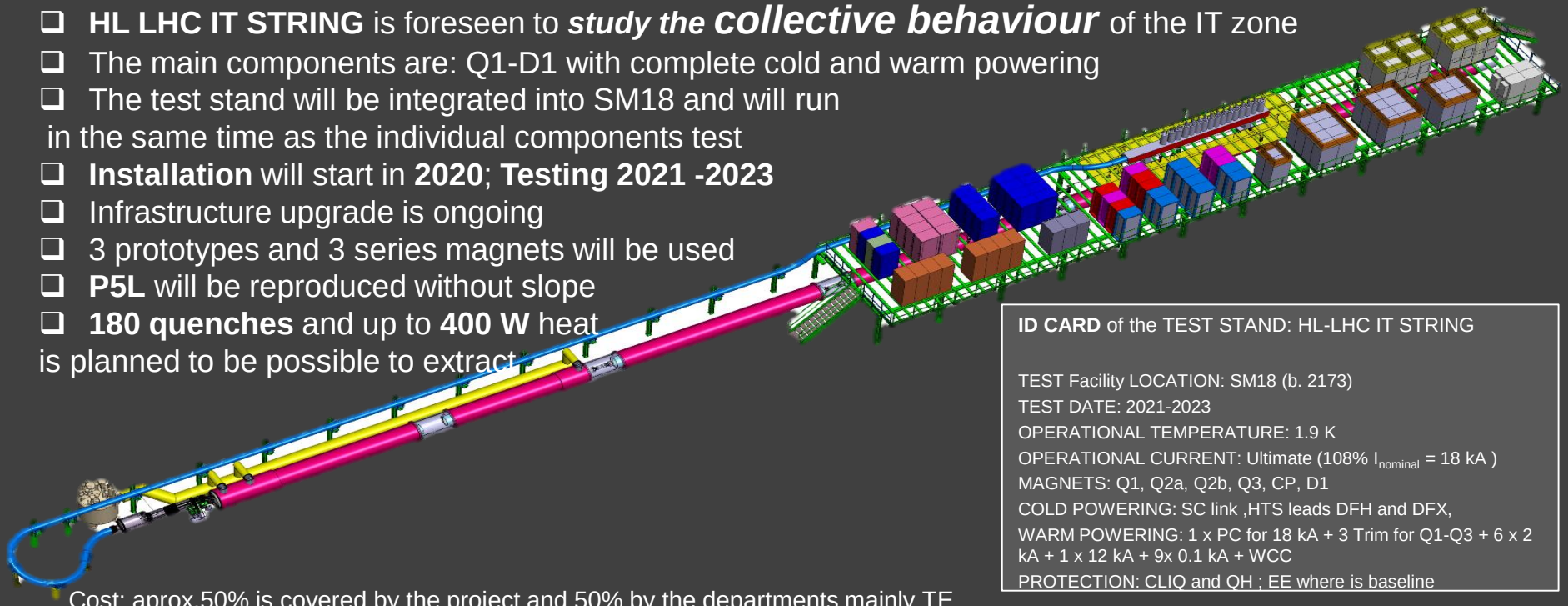
Planning



*We consider testing till **Iultimate**. This is a high energy (40 MJ) into the He bath that triggers to the review of the consumption and He distribution in the SM18 users. We consider that each medium or high current quench **is recovered in 12h**. This is still to be verified with the presently planned infrastructure and magnet + cavity test plan.*

Summary

- **HL LHC IT STRING** is foreseen to ***study the collective behaviour*** of the IT zone
- The main components are: Q1-D1 with complete cold and warm powering
- The test stand will be integrated into SM18 and will run in the same time as the individual components test
- **Installation** will start in **2020**; **Testing 2021 -2023**
- Infrastructure upgrade is ongoing
- 3 prototypes and 3 series magnets will be used
- **P5L** will be reproduced without slope
- **180 quenches** and up to **400 W** heat is planned to be possible to extract



ID CARD of the TEST STAND: HL-LHC IT STRING

TEST Facility LOCATION: SM18 (b. 2173)
TEST DATE: 2021-2023
OPERATIONAL TEMPERATURE: 1.9 K
OPERATIONAL CURRENT: Ultimate (108% $I_{nominal}$ = 18 kA)
MAGNETS: Q1, Q2a, Q2b, Q3, CP, D1
COLD POWERING: SC link ,HTS leads DFH and DFX,
WARM POWERING: 1 x PC for 18 kA + 3 Trim for Q1-Q3 + 6 x 2 kA + 1 x 12 kA + 9x 0.1 kA + WCC
PROTECTION: CLIQ and QH ; EE where is baseline

Cost: aprox.50% is covered by the project and 50% by the departments mainly TE