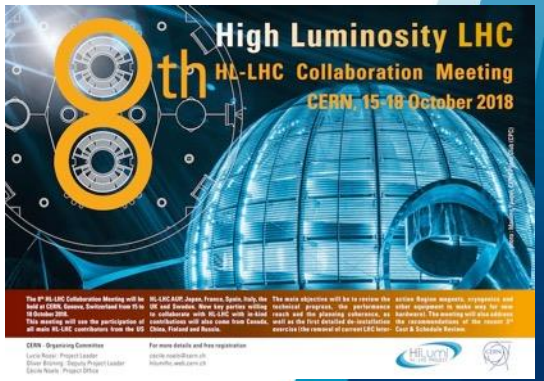
HL LHC IT STRING:
status, recent changing, pending actions

M. Bajko WP16



8th HL-LHC Collaboration Meeting @ CERN October 2018

CONTENT

- The HL-LHC STRING recent news : STRING day
- Motivations for HL-LHCSTRING test
- Layout and Components of the HL-LHC IT STRING
- Main steps
- Status of activities
- Conclusions

Internal review of the HL-LHC STRING

The main **objective** is to :

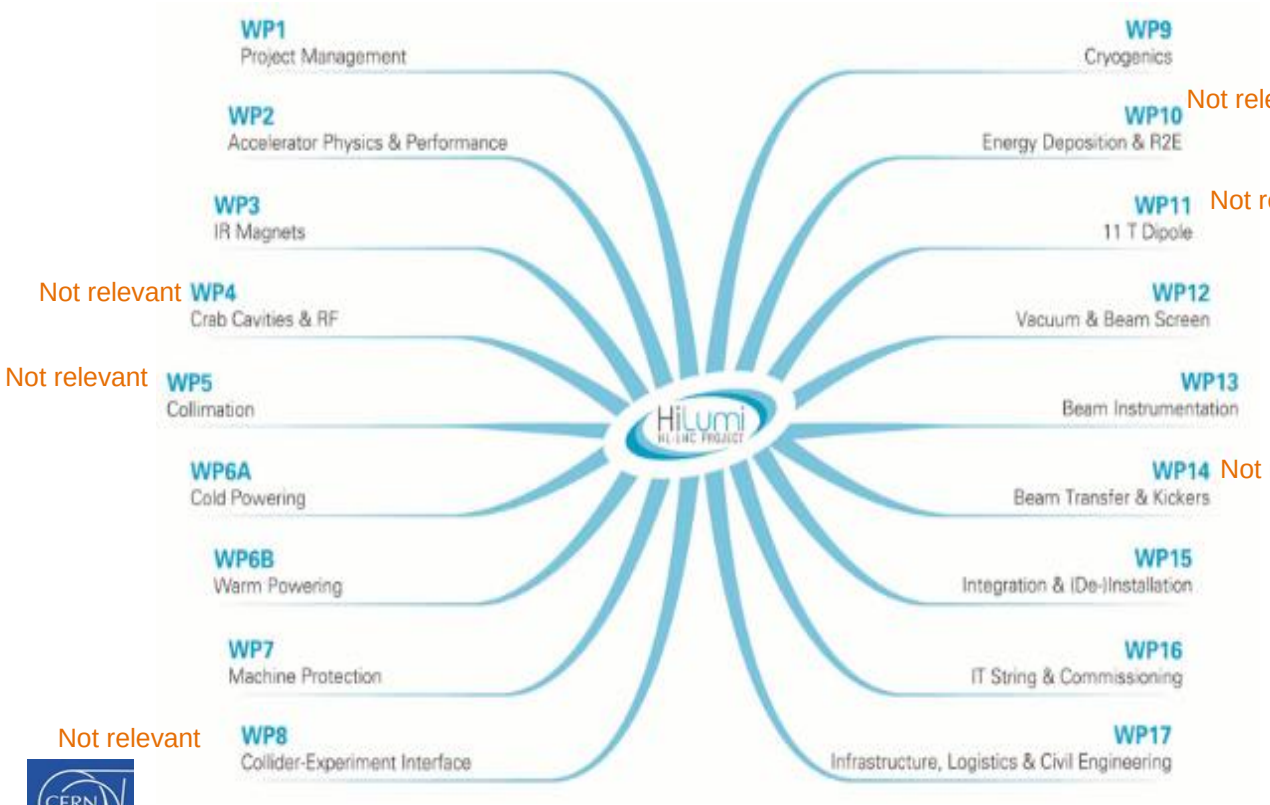
a. review the baseline configuration and the motivation of the associated test program of the HL-LHC IT STRING.
b. the evaluation of the advantage and/or the disadvantage of moving, if possible, measurements and tests to another configuration
c. assessment considered material and personnel resources.

With 16 talks (in a single day) we gave work for our review panel:
O. Bruning, J-M. Jimenez, P. Lebrun, L. Rossi, L. Tavian (Chair), A. Yamamoto.
And scientific secretary: S. Yammine

STRING Internal Review

1 Scope of the HL-LHC IT STRING Day	Speaker: Lucio Rossi
2 HL-LHC IT STRING baseline configuration	Speaker: Marta Bajko
3 LHC STRINGs experience	Speaker: Felix Rodriguez Mateos
4 Lessons learned from LHC, challenges for HL-LHC	Speaker: Arjan Verweij
5 HL-LHC IT Magnets for STRING	Speaker: Ezio Todesco
6 Cold powering system in the HL-LHC IT STRING	Speaker: Amalia Ballarino
7 Protection	Speaker: Reiner Denz
8 3D Integration, installation and interconnections.	Speaker: Delio Duarte Ramos
9 Alignment	Speaker: Helene Mainaud Durand
10 Cryogenics and installations for the HL IT STRING	Speaker: Antonio Perin
11 Vacuum systems for the HL-LHC IT STRING	Speaker: Paul Cruikshank
12 BPM test program - string test and alternatives	Speaker: Michal Krupa
13 Data analysis tools : configuration and advantages of early test	Speaker: Markus Zerlauth
14 HL-LHC IT commissioning and operation	Speaker: Mirko Pojer
15 Impact of faults/limitations on the performance of the HL-LHC	Speaker: Andrea Apollonio
16 Operation, Budget and Resources for the HL-LHC IT String	Speaker: Marta Bajko

The users of the HL-LHC IT STRING



Our strongest arguments for the tests

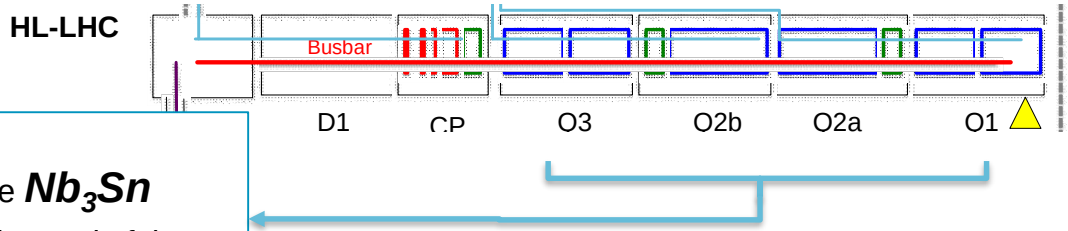
- Validation of the ***complete electrical circuit***, its protection and its different failure scenarios that has been simulated, but never before tested.

- Validation of the ***structure, the fully remote alignment system***, measurement of the target values with real loading conditions at cryogenic temperature, before and after quenching.

- ***Build up a team*** with expertise in all domains and make them working together ***for successful*** and possible the ***shortest LS3***.

The HL-LHC IT STRING MOTIVATION: Nb_3Sn

In the HL-LHC configuration, the Inner Triplet (IT) region of IR1 and IR5 of the present ***LHC will be heavily modified***.

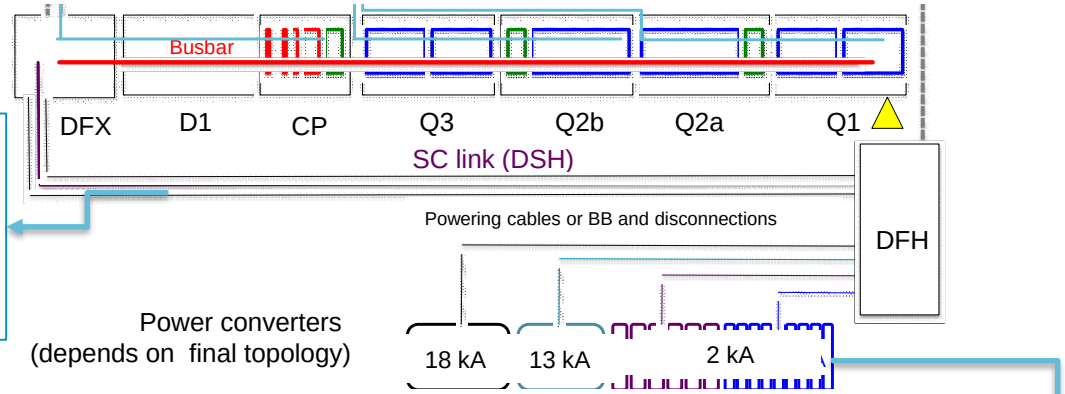


The IT quadrupoles:
Q1, Q2a,Q2b,Q3 will use ***Nb_3Sn*** **superconductor** instead of the **Nb-Ti** used by the present LHC ones.

The HL-LHC IT STRING MOTIVATION: MgB_2

In the HL-LHC configuration, the Inner Triplet (IT) region of IR1 and IR5 of the present ***LHC will be heavily modified***.

…and will be made via a ***HT Sc link using MgB_2 and new generation Sc current leads***



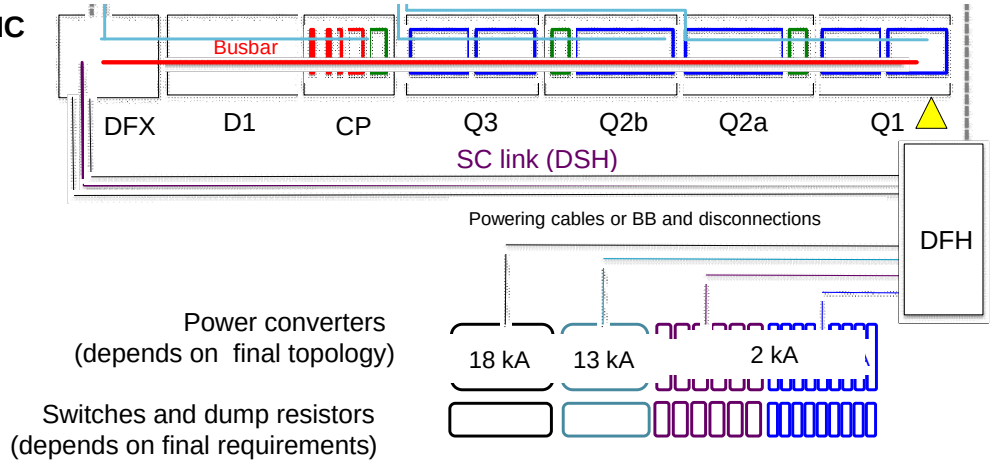
The powering of the magnets will be with ***higher current*** than the present LHC IR magnets

The HL-LHC IT STRING MOTIVATION: CLIQ

In the HL-LHC configuration, the Inner Triplet (IT) region of IR1 and IR5 of the present ***LHC will be heavily modified***.

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.

HL-LHC



Our strongest arguments for the tests

- Validation of the ***complete electrical circuit***, its protection and its different failure scenarios that has been simulated, but never before tested.

- Validation of the ***structure, the fully remote alignment system***, measurement of the target values with real loading conditions at cryogenic temperature, before and after quenching.

- ***Build up a team*** with expertise in all domains and make them working together ***for successful*** and possible the ***shortest LS3***.

Our strongest arguments for the tests

- Validation of the ***complete electrical circuit***, its protection and its different failure scenarios that has been simulated, but never before tested.

- Validation of the ***structure, the fully remote alignment system***, measurement of the target values with real loading conditions at cryogenic temperature, before and after quenching.

- ***Build up a team*** with expertise in all domains and make them working together ***for successful*** and possible the ***shortest LS3***.

The HL-LHC IT STRING GOAL

The HL-LHC IT STRING will serve as a test bed for matters or conditions that either :

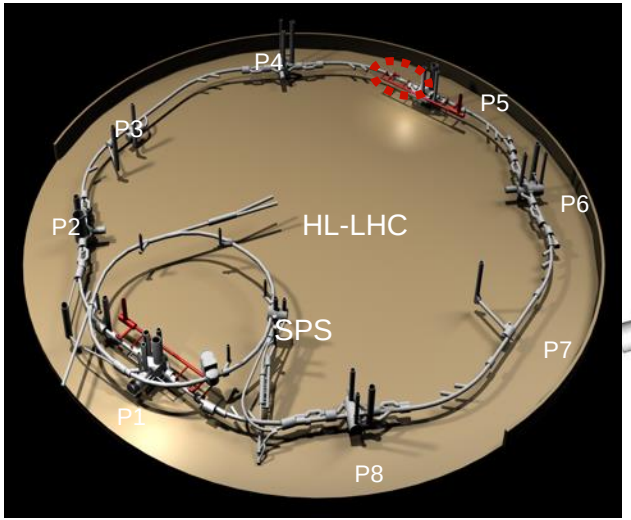
- **(a) cannot be tested as a part of the components acceptance and characterization program, or**
- **(b) depend on the response of the integrated system.**

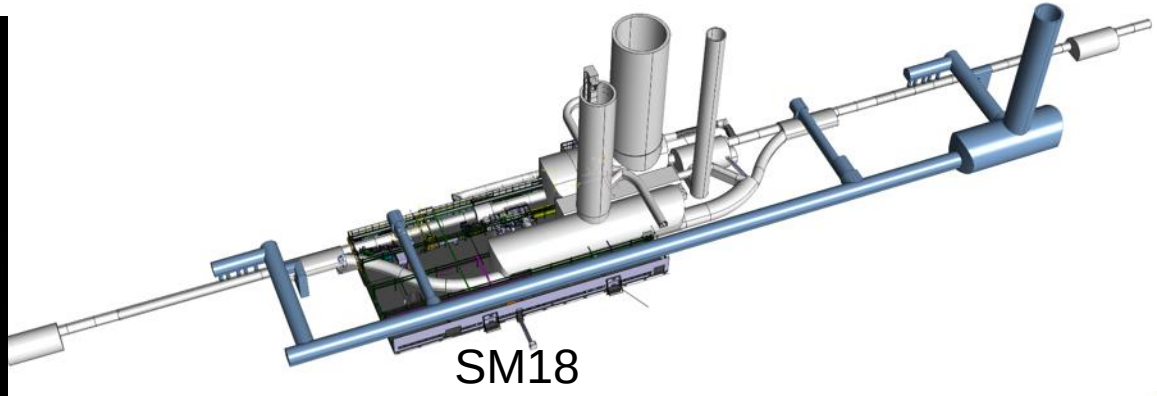
a.We do ***not*** pretend to ***do this***, due to the timing. The HL-LHC IT STRING is planned such that is ***too late*** to be used ***for qualification*** of the single components and « known un-knowns » are cured at the level of the design.

b. We ruther look after unforeseen failures and « un-known un-knowns » of the integrated system during its installation, operation and dismountling motivated by the use of **Nb_3Sn, MgB_2, CLIQ, Remote alignment**

Layout of 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*

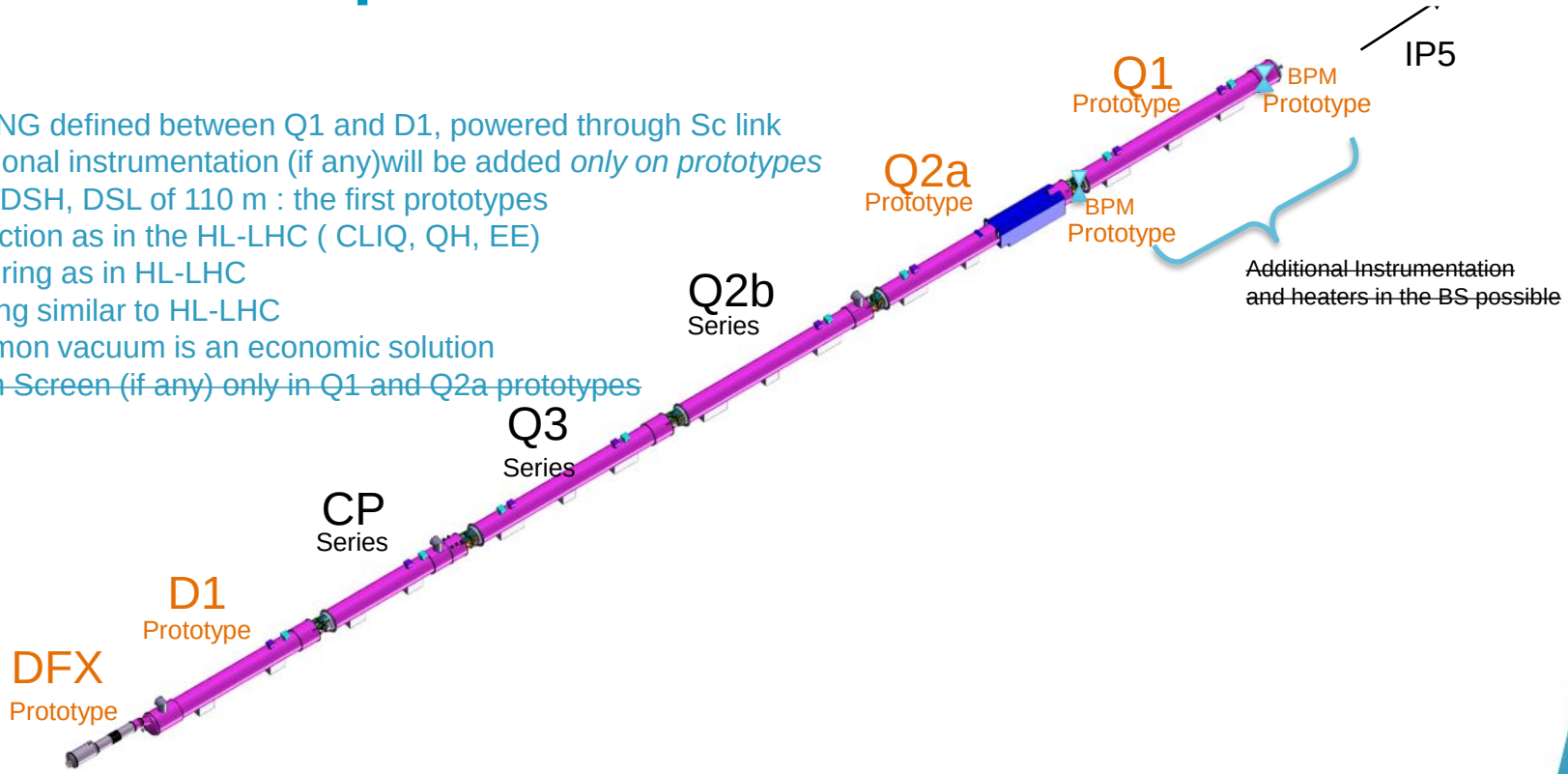




There is an essential difference as in HL LHC STRING we **do not reproduce the SLOPE** of the LHC tunnel.

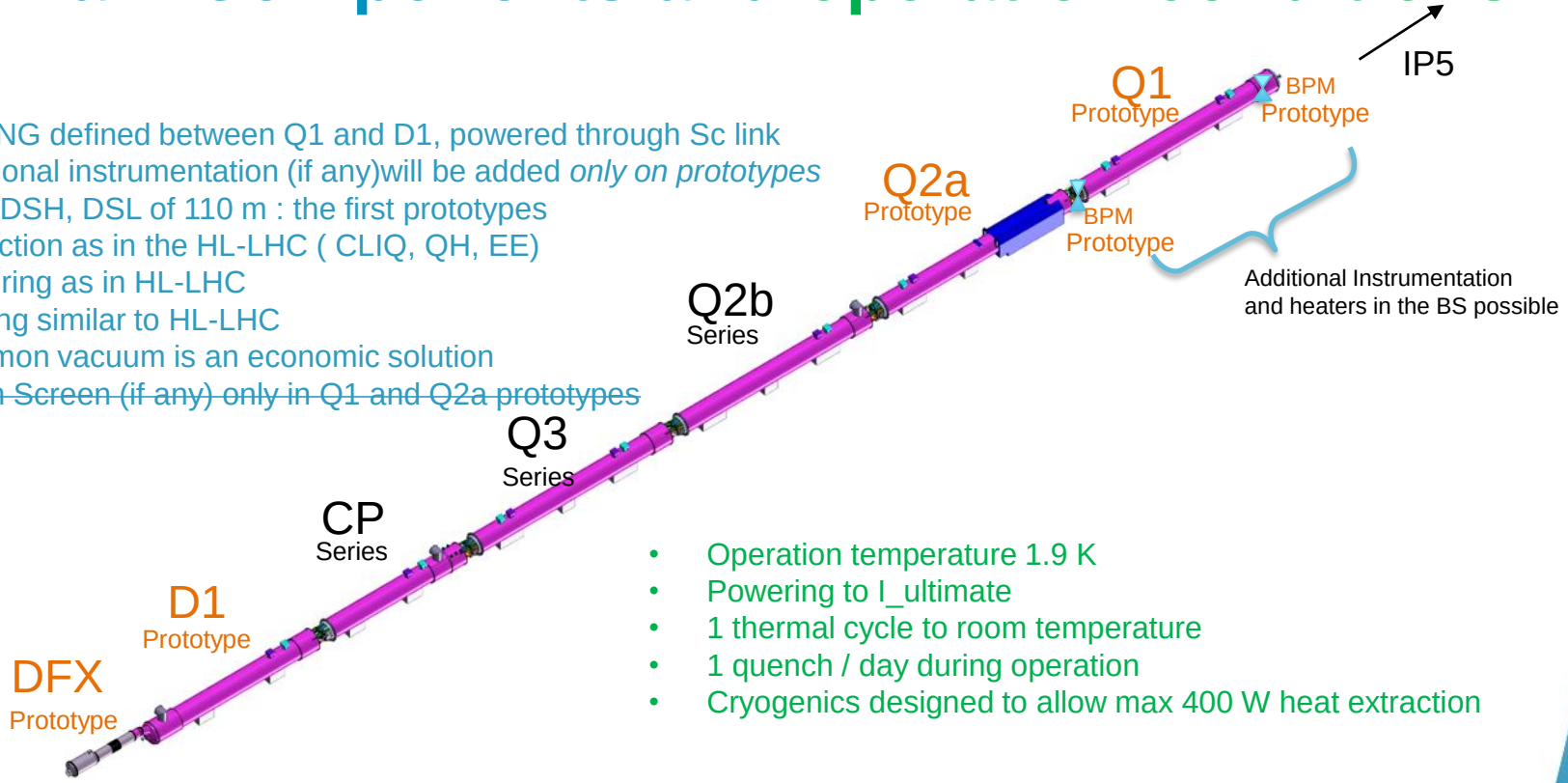
Main Components

- STRING defined between Q1 and D1, powered through Sc link
- Additional instrumentation (if any)will be added *only on prototypes*
- DXF, DSH, DSL of 110 m : the first prototypes
- Protection as in the HL-LHC (CLIQ, QH, EE)
- Powering as in HL-LHC
- Cooling similar to HL-LHC
- Common vacuum is an economic solution
- ~~Beam Screen (if any) only in Q1 and Q2a prototypes~~



Main Components and operation conditions

- STRING defined between Q1 and D1, powered through Sc link
- Additional instrumentation (if any)will be added *only on prototypes*
- DXF, DSH, DSL of 110 m : the first prototypes
- Protection as in the HL-LHC (CLIQ, QH, EE)
- Powering as in HL-LHC
- Cooling similar to HL-LHC
- Common vacuum is an economic solution
- ~~Beam Screen (if any) only in Q1 and Q2a prototypes~~

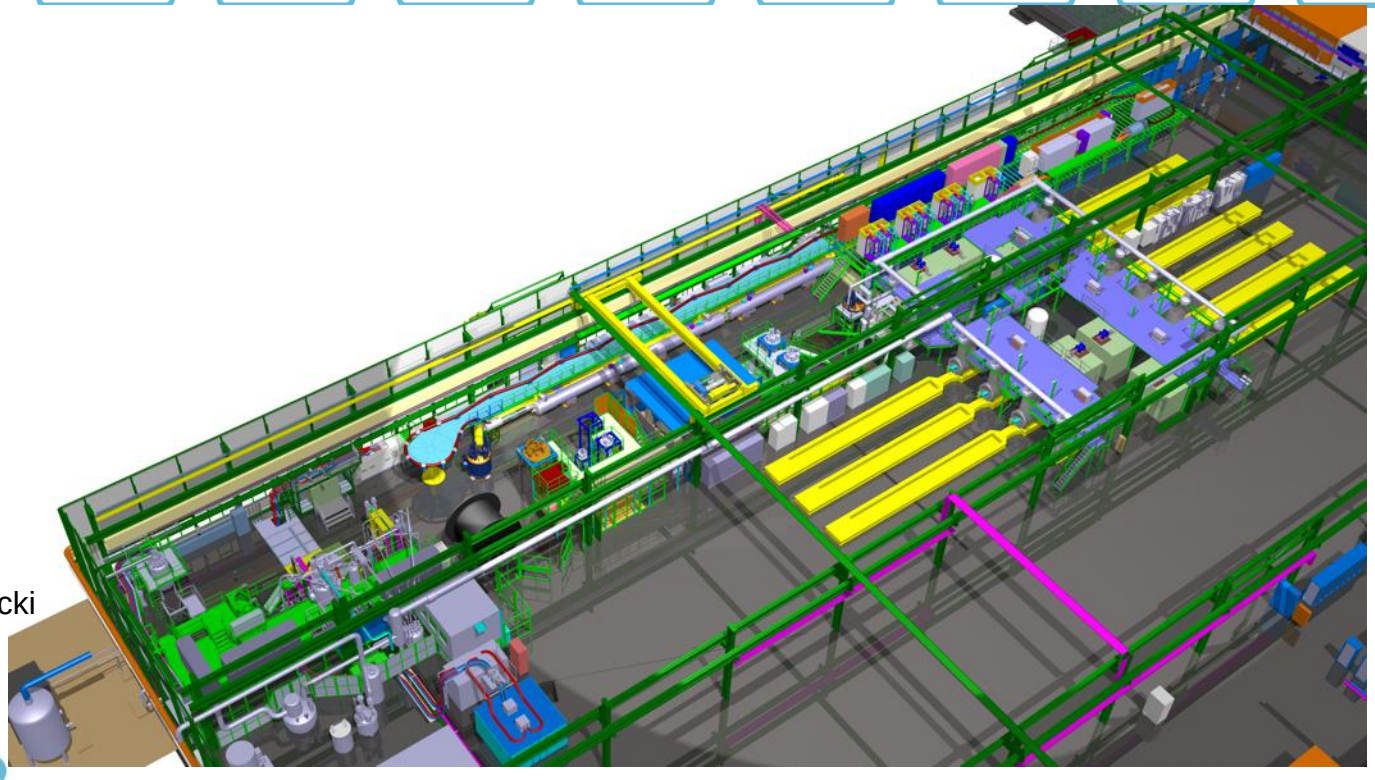


- Operation temperature 1.9 K
- Powering to I_ultimate
- 1 thermal cycle to room temperature
- 1 quench / day during operation
- Cryogenics designed to allow max 400 W heat extraction

All components are "like series" (prototypes) or series and are owned by the WP (ex. Magnets)
All infrastructure or components that can not be re-used in the HL-HC are owned by WP16 (ex. Cryogenics)

Main Steps of the HL-LHC IT STRING

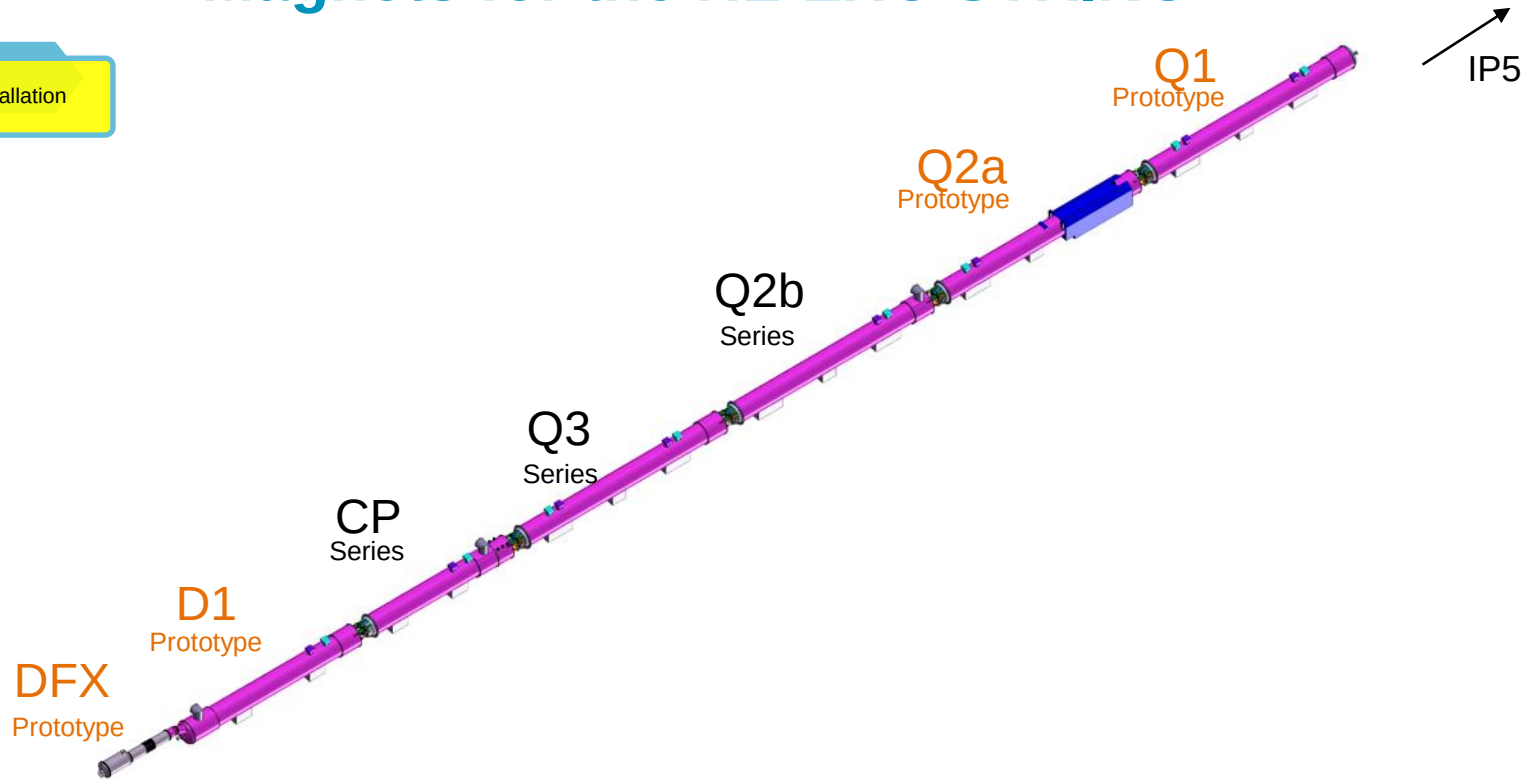
Installation | Inter-connection | Cooling | HWC | Exp @ Inom | Training to Iultimate | Thermal Cycle | HWC to Iultimate | Exp @ I ultimate | Warm up



Integration
by. A. Kosmicki

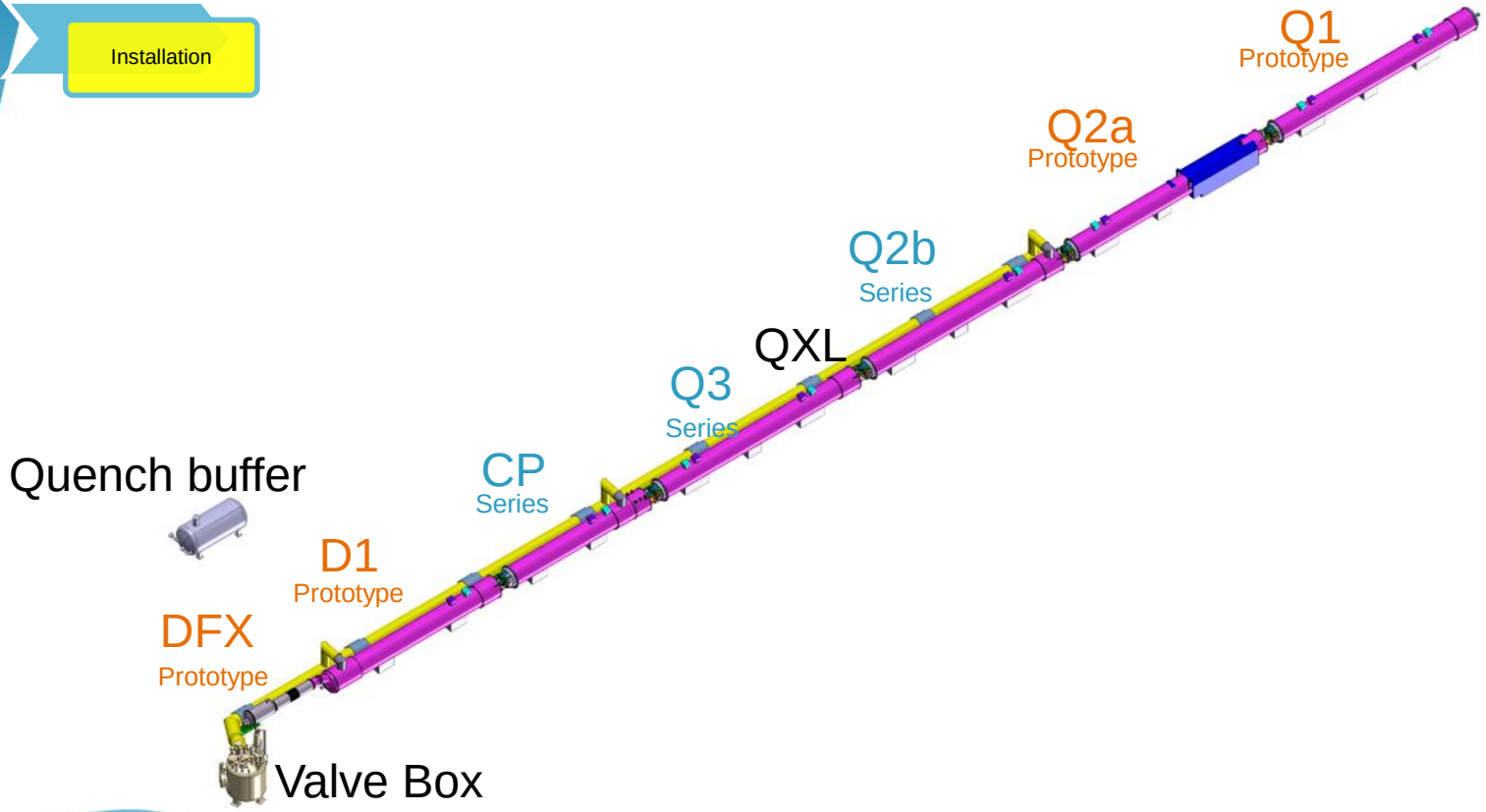
Magnets for the HL-LHC STRING

Installation



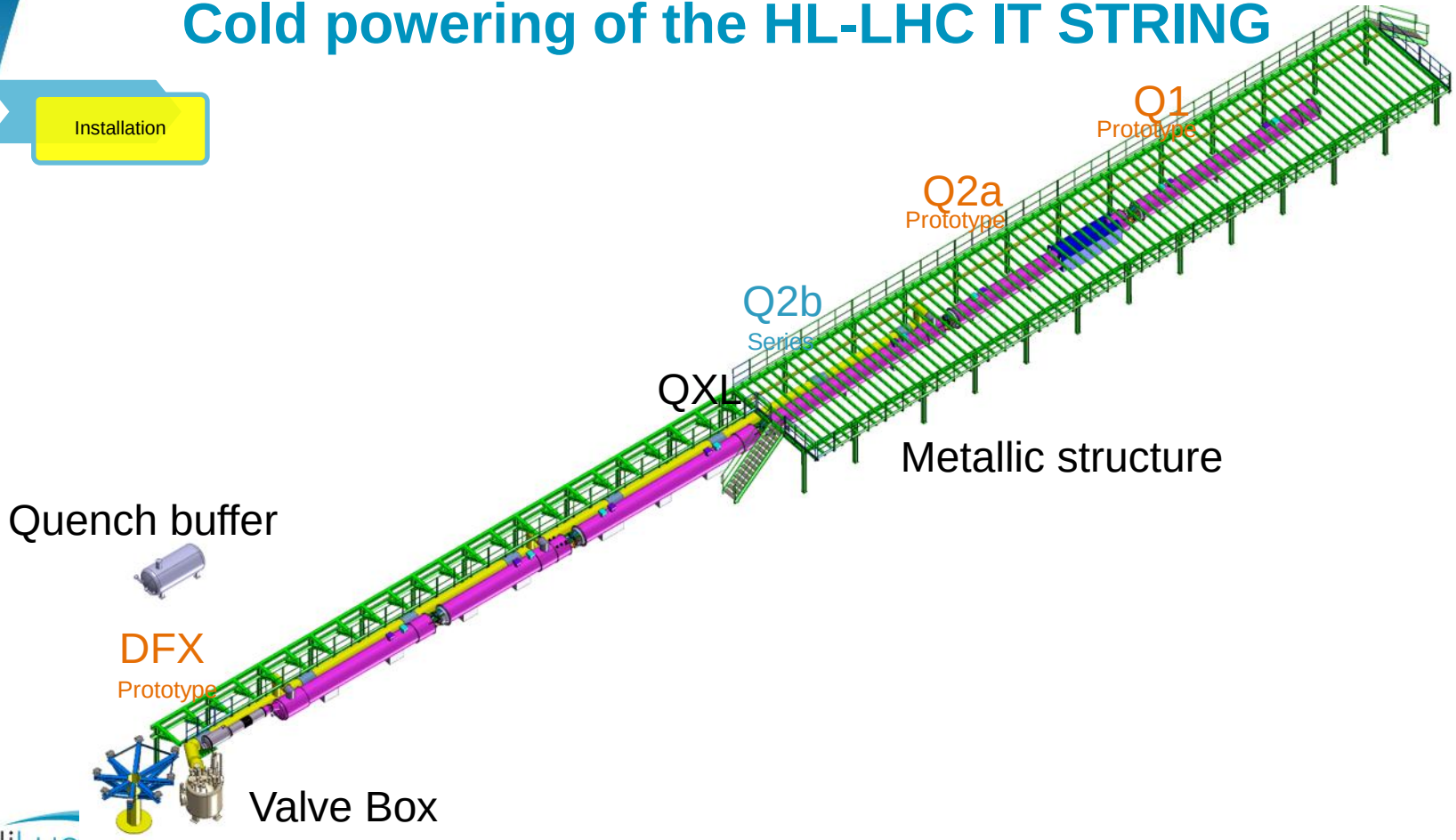
Cryogenics for the HL-LHC IT STRING

Installation



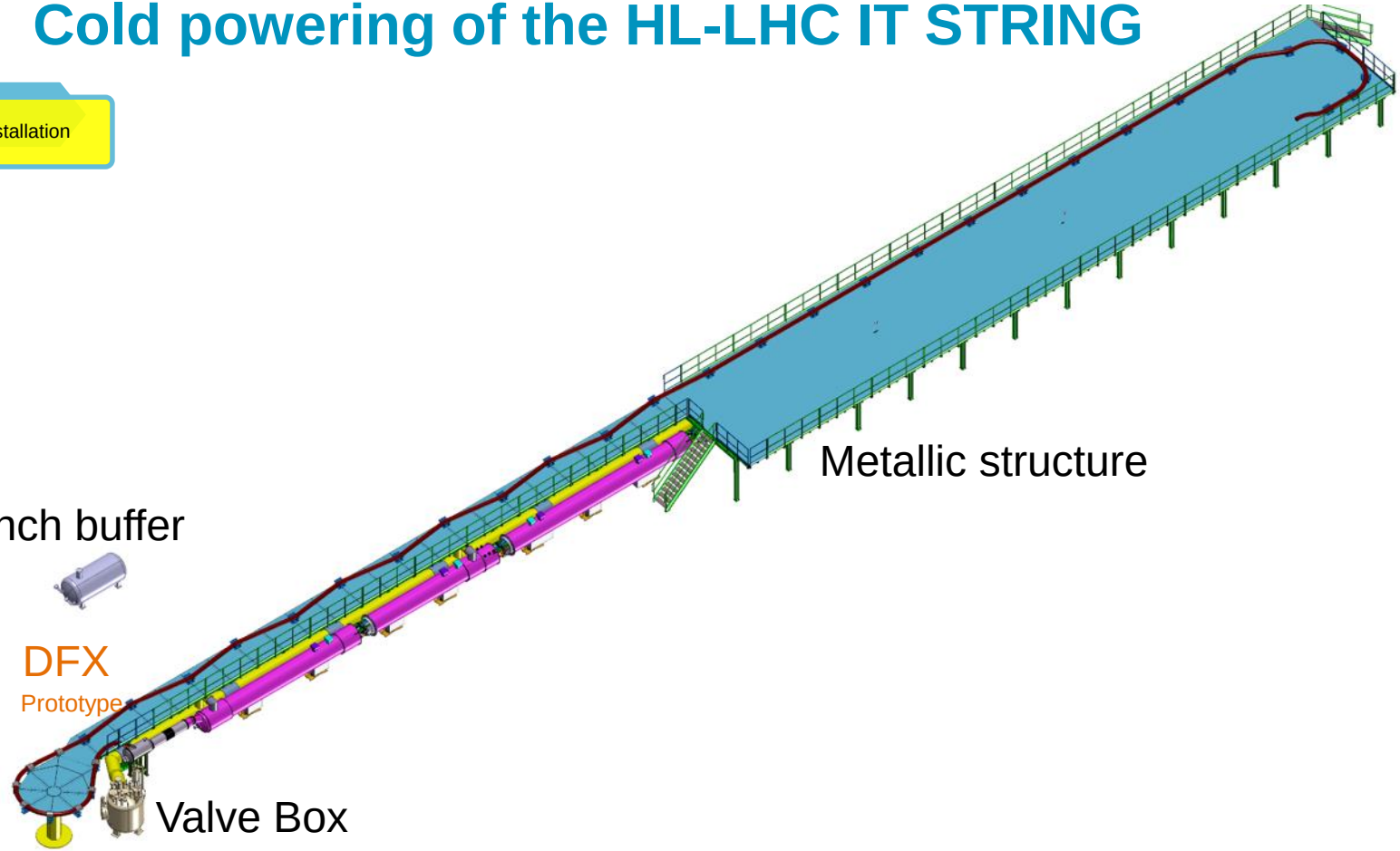
Cold powering of the HL-LHC IT STRING

Installation



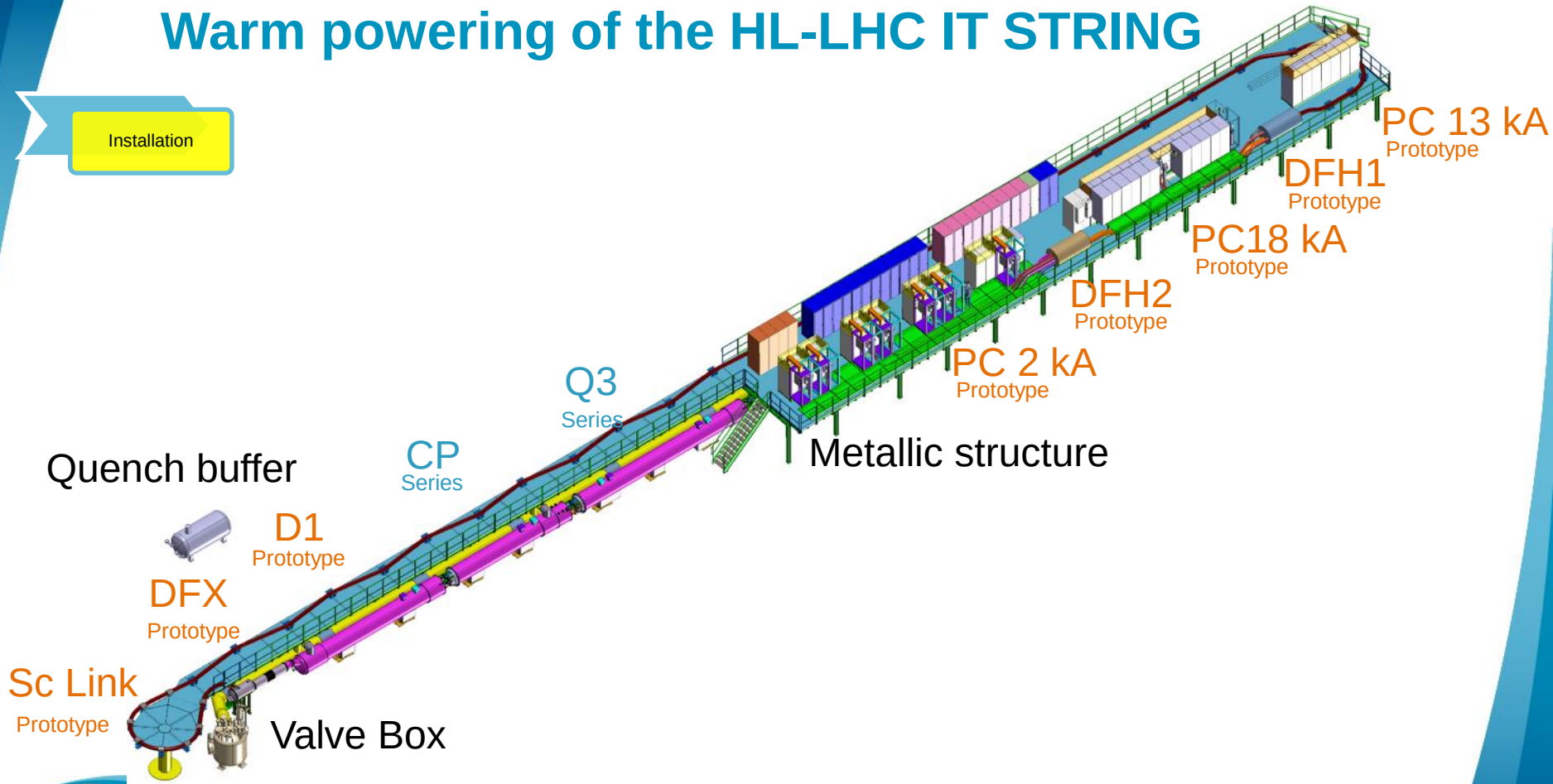
Cold powering of the HL-LHC IT STRING

Installation



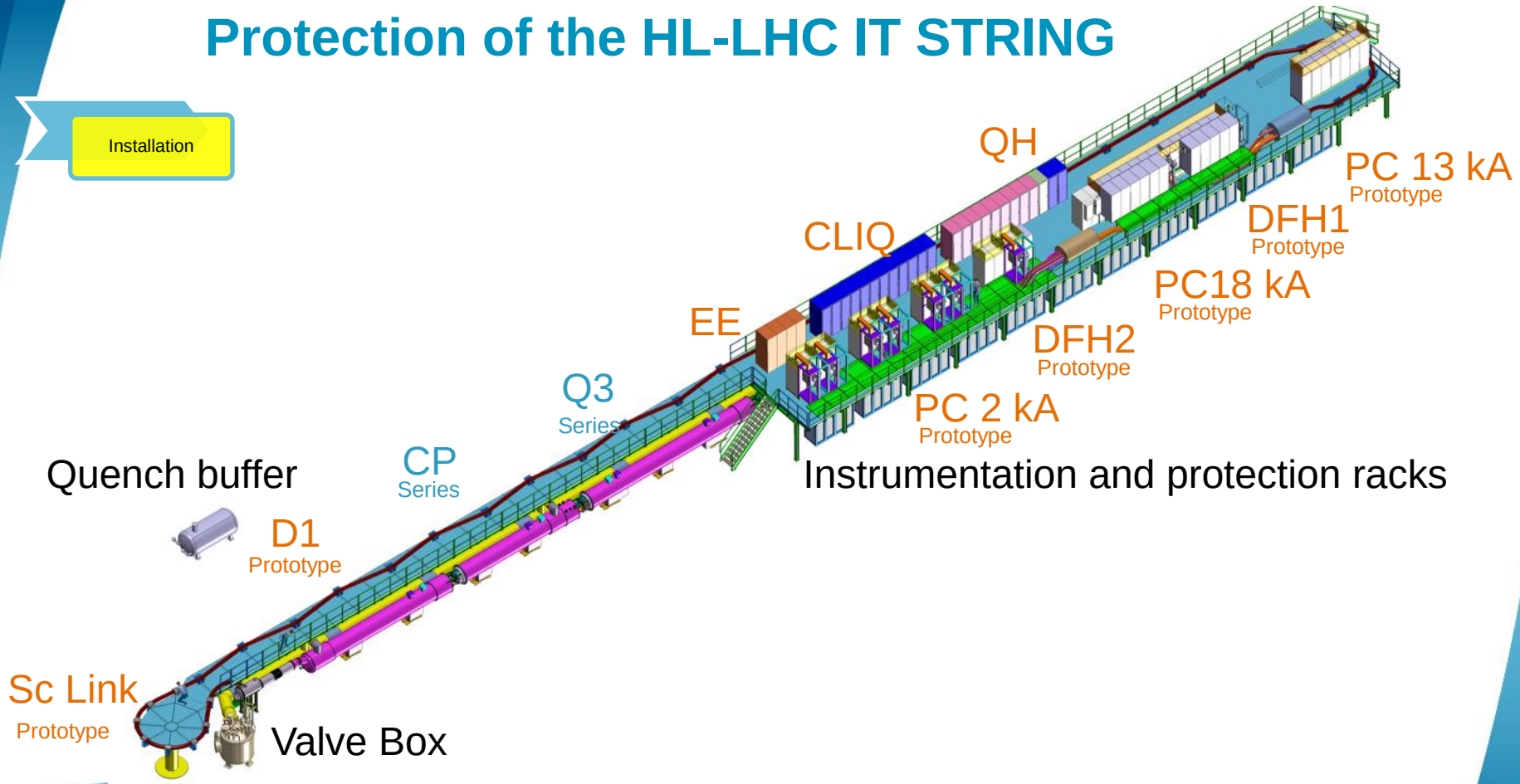
Warm powering of the HL-LHC IT STRING

Installation



Protection of the HL-LHC IT STRING

Installation



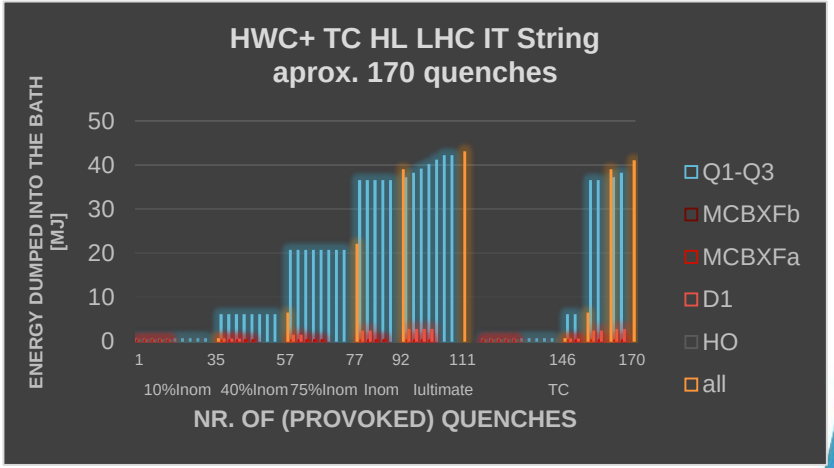
Test of the collective behaviour

This is a very important ***milestone*** as
from this stage we have electrical and hydraulical circuits
(not already and individually tested components!!)

From HWC to Experimental Program

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

Validation of the circuits and the protection systems powered as in HL-LHC (first time for converters, Sc link and magnets) up to ultimate operational mode,
a ***dry RUN for HL-LHC HWC***



Service infrastructure for the HL-LHC IT STRING

Installation

The SM18 upgrade was driven by the recommendation to be able to carry out the full test programme, including the IT STRING, withouth constraints

Completed

- DEMINERALISED WATER PRODUCTION: **+ 150 m³/h**

  NEEDED FOR DEMINERALISED WATER ENTIRELY COMING FROM MAGNET OPERATION
- HANDLING: **25 T and longer rope**

  NEEDED FOR OVERHEAD CRANE CHANGE ENTIRELY COMING FROM MAGNET OPERATION
- nCONTROL ROOM

  NEEDED TO EXTEND THE TOO SMALL CONTROL ROOM OF THE VERTICAL TEST FACILITY TO BE USED ALSO FOR HORIZONTAL BENCHES AND SC LINK

Foreseen to be completed for June 2019

- CRYOGENIC COOLING PRODUCTION: **+ 35 g/s LHe**

  NEEDED ESSENTIALLY FOR THE RUNNING OF THE HL LHC IR STRING IN PARALLEL WITH MAGNET TESTING
- PRIMARY WATER COOLING CAPACITY: **+736 m³/h**

  NEEDED FOR MAGNETS, CRYO AND RF
- CRYOGENIC PUMPING: **+6 g/s LHe**

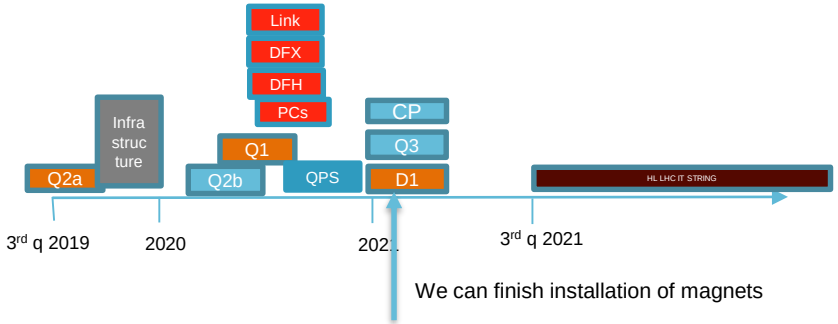
  NEEDED ESSENTIALLY FOR THE RUNNING OF THE HL LHC IR STRING IN PARALLEL WITH MAGNET TESTING
- POWERING FROM THE NETWORK: **3 MVA**

  NEEDED FOR NEW OR MODIFIED PCs FOR MAGNETS AND II STRING

Considerations for the PLANNING

The planning was build such that we ***start as earlier as possible***:
depending on the arrival of the main components

- The HL-LHC STRING will be run **continuously** in **one single phase** to avoid extra work and budget for building up a "SIMILAR system"
- Magnet installations con **not be earlier than Jan 2021,** the expected date of arrival of the latest magnet

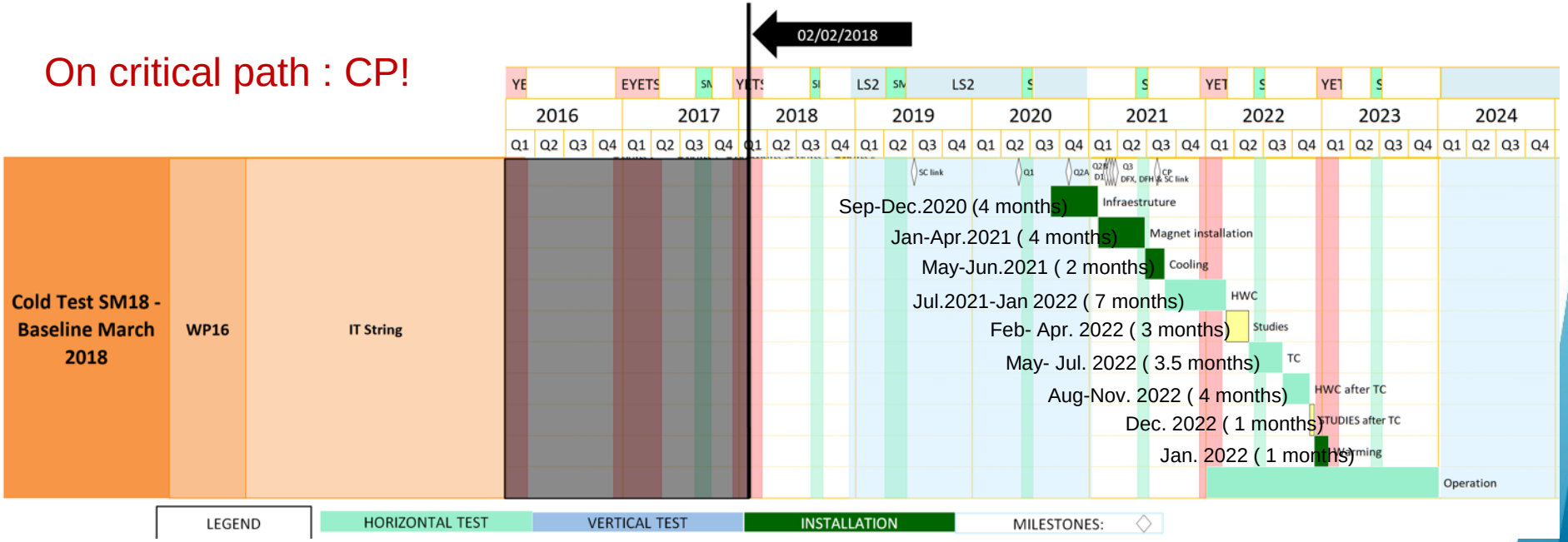


- Infrastructure is planned to be installed earlier: from September 2020
- The **minimum time** (from cooling to warming up including 1 TC) to run STRING (max.1 quench / day) is **30 months**
- The present planning allow us to bring the system to **ultimate performance before end 2022**.

Summary of the PLANNING

The HL-LHC Planning is integrated and Linked to the HL-LHC master planning.

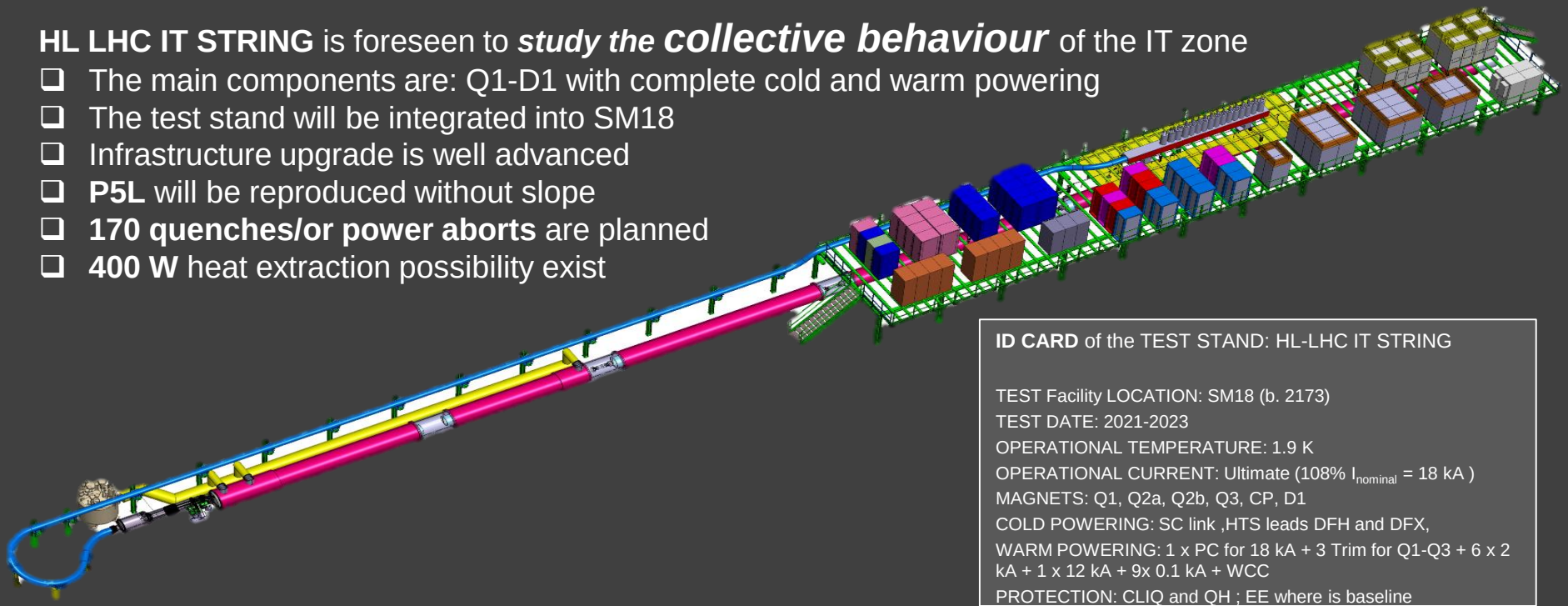
On critical path : CP!



The ID card of the HL-LHC IT STRING

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
- Infrastructure upgrade is well advanced
- **P5L** will be reproduced without slope
- **170 quenches/or power aborts** are planned
- **400 W** heat extraction possibility exist



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

Status of activities

- The tour of the WPs and groups has been done and we have a good understanding of their needs.
- Main components are defined and we are in the optimization of their use (ex. beam screen)
- Integration is well advanced, but still ongoing component design (ex. powering) does not allowed us to finalize it.
- The main steps are defined as it would be the main steps of the HL-LHC 1st HWC campaign.
- Service infrastructure is well advanced and allows the STRING operation with limited constrains in the SM18 (in parallel with RF and magnet testing).
- The cryogenic infrastructure of the STRING could be defined insuring with a given scenario (1 high energy quench/ day) the test in parallel of RF cavities, Magnets and Sc link systems.

Conclusions

- The HL LHC IT STRING is a test motivated by the new items or technologies wrt the LHC:ex. Nb_3Sn, MgB_2, CLIQ, FRA ect.
- The HL LHC IT STRING is **not** going to be used for the design or production **validation** of any of the **individual components** of the HL-LHC
- It is a ***dry run for the LS3*** of the IT zone and target to optimize the interventions and reduce time of LS3, looking for unexpected failure modes and unknown unknowns.
- It is an unique opportunity to operate the whole system on surface and ***demonstrate the ultimate operational condition before LS3***
- It is a great occasion to ***train*** a ***team*** of experts
- String will be in 1 run from 2021- 2022

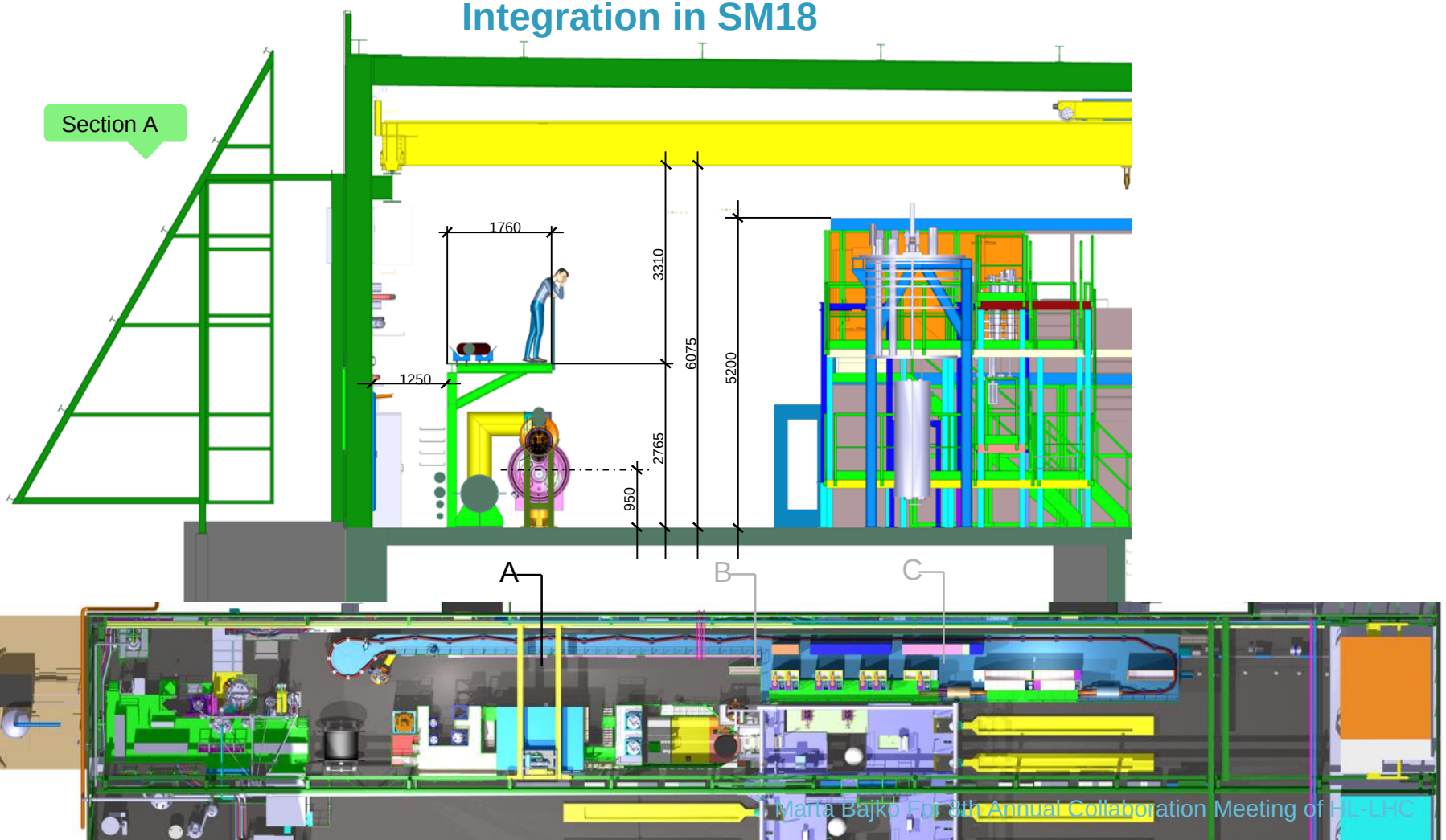
Thank you for your attention

and

Thank you for all collaborators but having contributed to the work

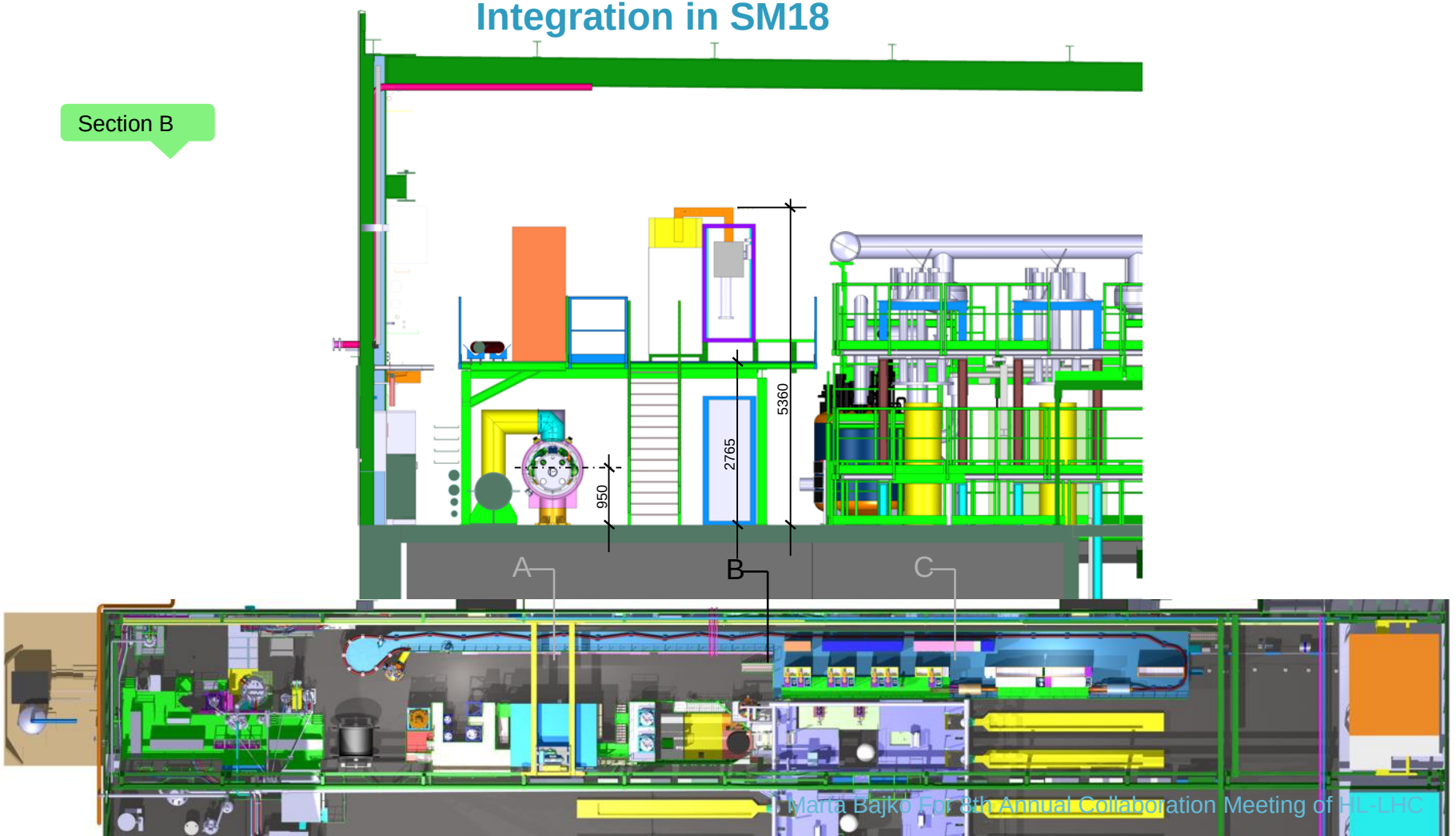
Gianluigi Arduini, Vincent Baglin, Amalia Ballarino, Luca Bottura, Serge Claudet, Michal Duda, Helene Mainaud Durand, Vittorio Parma, Serge Pelletier, Antonio Perin, Felix Rodriguez Mateos, Gerhard Schneider, Michal Krupa, Ezio Todesco, Rob Van Weelderen, Jean-Paul Burnet, Paolo Fessia, Reiner Denz, Jan Hansen, Germana Riddone, Paolo Ferracin, Herve Prin, Antoine Kosmicki, Thibaut Lefevre, Mirko Pojer, Markus Zerlauth, Delio Duarte Ramos, Andreas Herty, Michele Martino, Lucio Fiscarelli, Daniel Wollmann, Estrella Vergara Fernandez, Luca Sburlino, Jean-Claud Guillaume, Hugues Thiesen, Arjan Verweij, Samer Yammine, Massimo Giovannozzi, Paolo Fessia, Andrea Apollonio, Emmanuel Bigot, Arnaud Devred
for the many constructive discussions

Integration in SM18



Integration in SM18

Section B



Integration in SM18

Section C