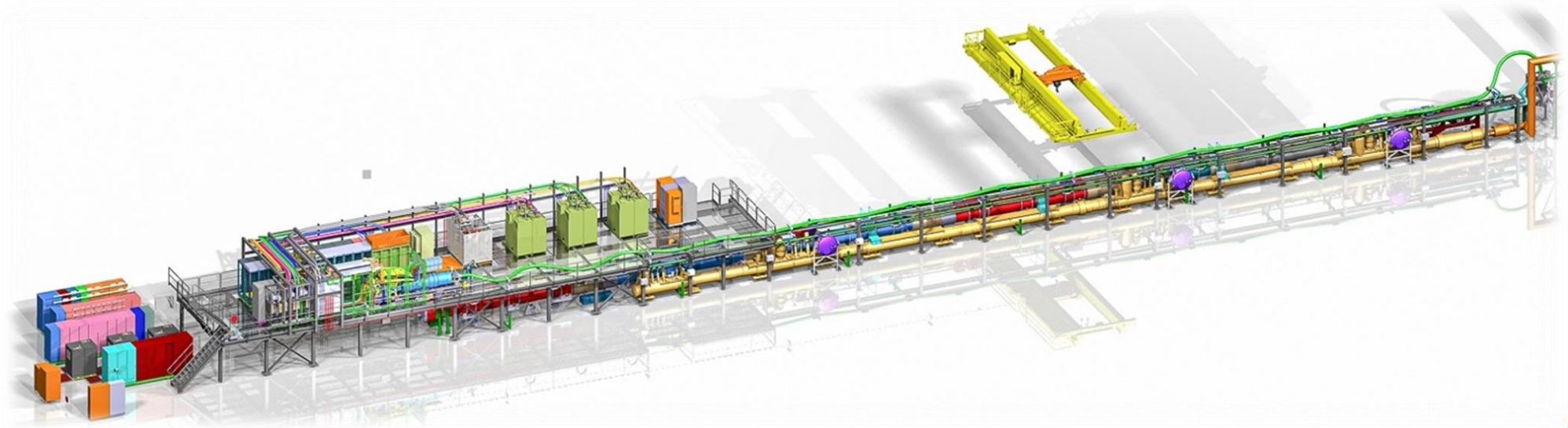
HL-LHC IT String Technical Coordination and Safety

HL-LHC IY String Day IV, Thursday 27 September 2024

D. Bozzini from TE-MPE-SF, on behalf of WP16 and IT String contributors



Content

- **IT String technical coordination**
  - How does it work and where do we stand
  - Short-term activity daily calendar
  - Organization of co-activities
  - Schedule and technical deviations from baseline
- **Lessons learned**
  - Dissemination of lesson learned
  - Relevant examples related to coordination
- **Safety**
  - During construction and commissioning
  - Operational safety
- **Concluding remarks**

IT String Technical Coordination

String Technical Coordination Meeting (STCM) – Structure and Interactions

[STCM SharePoint site]
[STCM in Indico]

Sources of inputs & channels for feedback

- PT18 Coordination meeting
- MCF Forum
- SVP
- QA/QC meeting
- SSM Safety meeting
- WPs which are present in IT String
- WP15 HL-LHC integration
- HL-LHC TCC meeting

On Tuesday, every two weeks

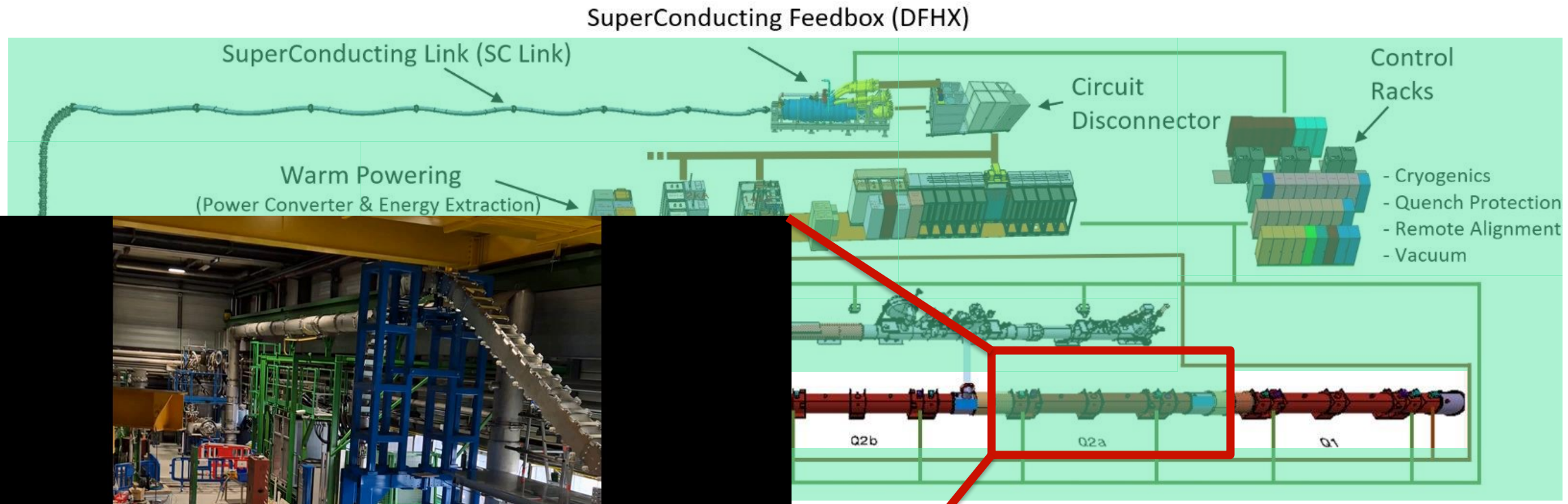
STCM

1. Master the state and **operate the IT String facility** in SM18
2. **Plan** short/mid term interventions
3. Technically **review feasibility of key activities** through ad-hoc meetings
4. **Grant working conditions** for successful feasibility of interventions
5. Identify and manage **co-activities**
6. Identify **non-conformities**
7. Grant operational **safety**

Ad-hoc technical meetings

- SC-Link installation
- Warm powering installation
- SQXL Installation and commissioning
- Magnets and interconnections
- CLIQ Installation
- FRAS Installation
- Cabling campaign execution
- More to come …..
- …… according to progress and needs

Main equipment installation – Overview

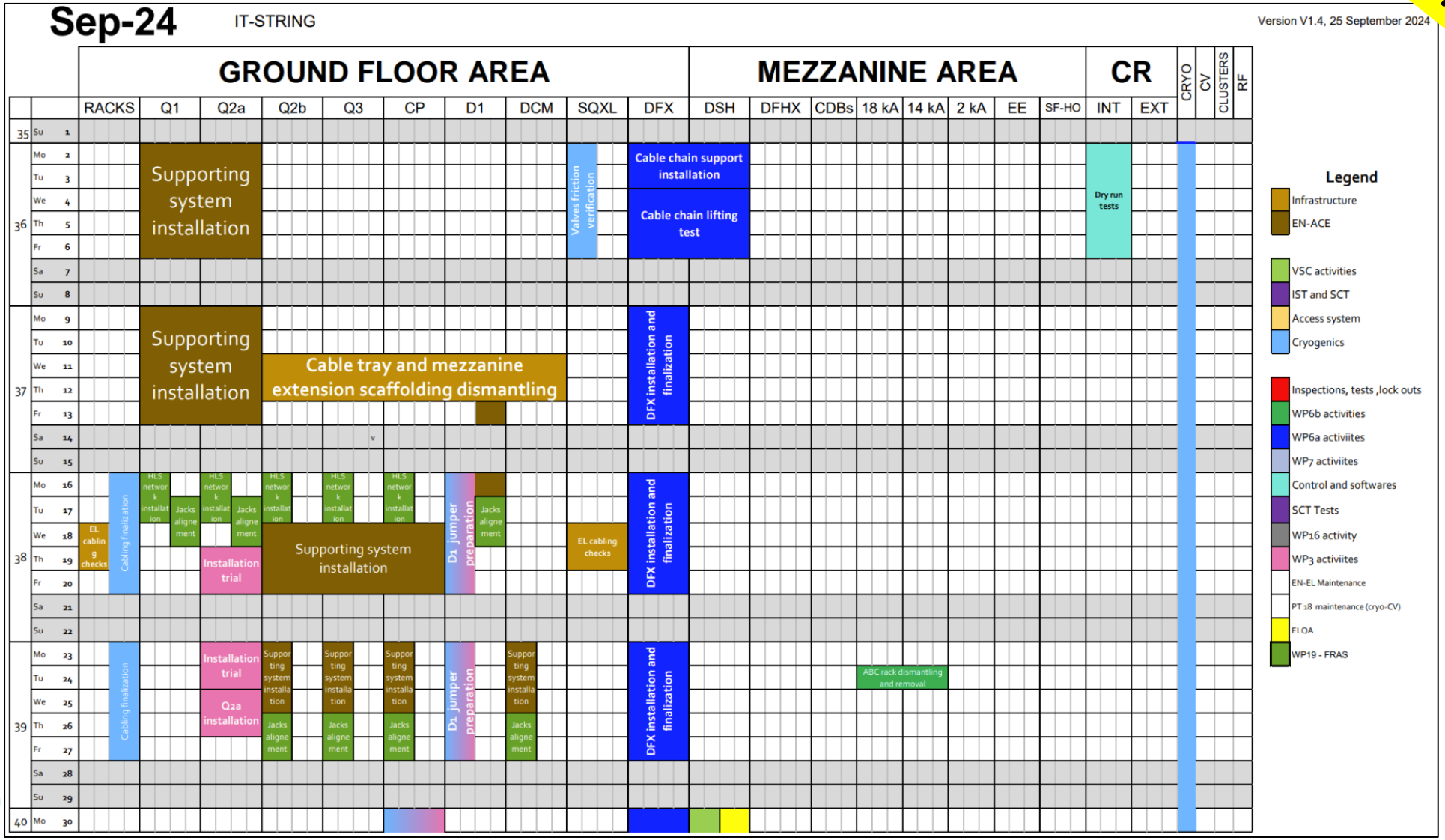


Breaking news:
First Q2a cryo-module successfully installed this Wednesday

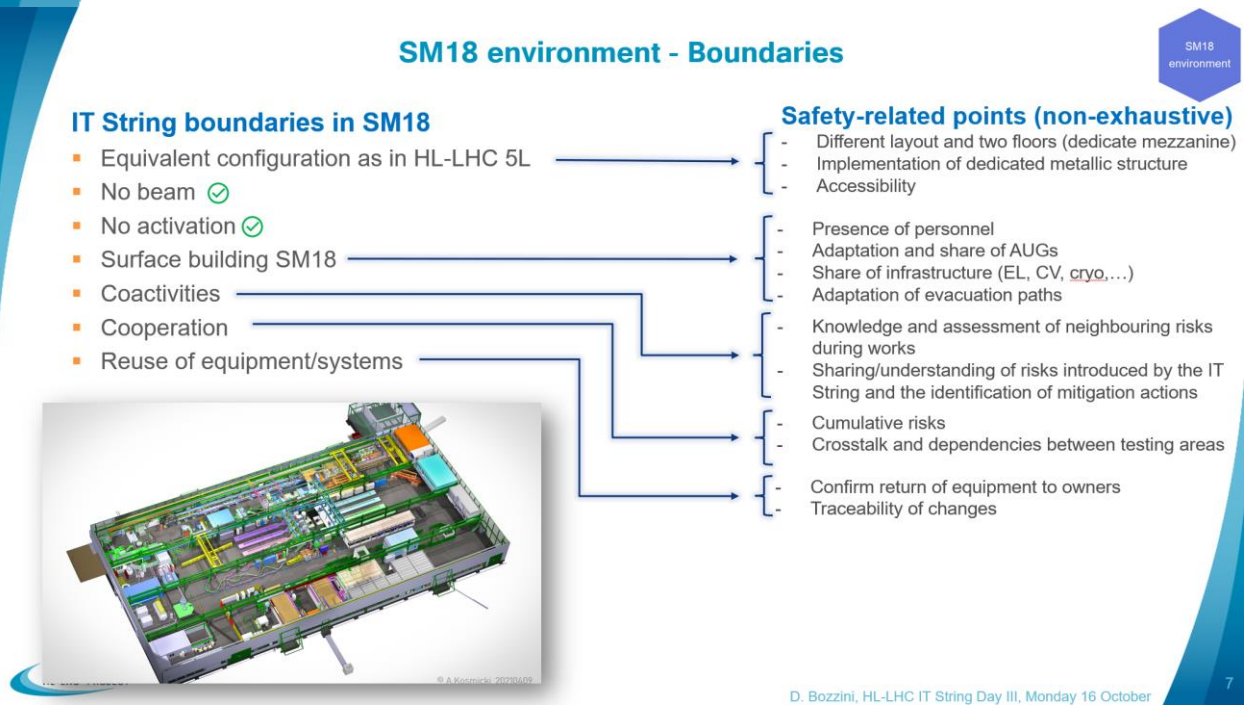
Short-term activity daily calendar

IT String day III recommendation

IT String daily calendar



Organization of co-activities

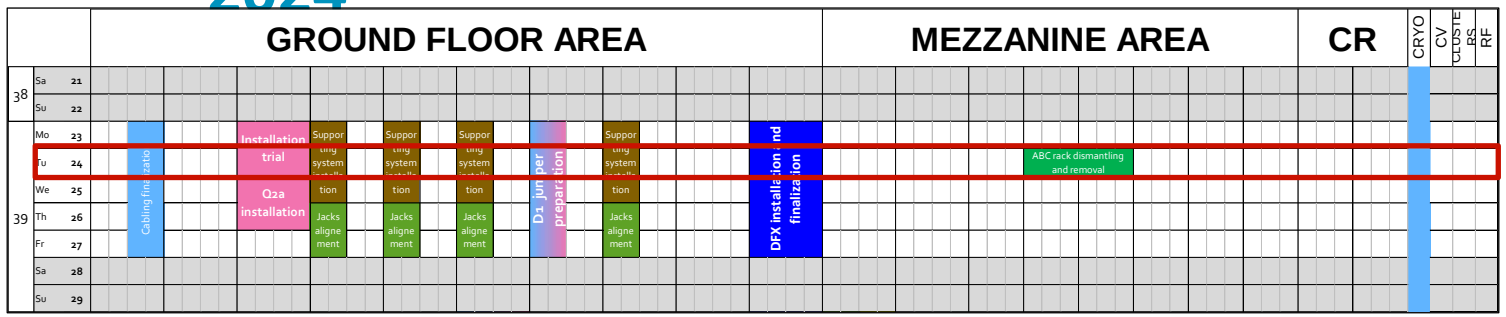


- **Short term calendar regularly updated**, shared and acknowledged by intervening teams
- **100 % physical presence on-site** of at least one IT String team member is a key aspect for the high level of co-activities we accept, and we deal with daily
- Shaking hands, taking the time do discuss with personnel on what and how they do their work and getting the different team members knowing each others **ease the co-habitation and the execution of the tasks**
- Continuous **In-situ safety awareness** of risks makes the intervening personnel more confident

Organization of co-activities – Example 24th of September 2024

Concurrent activities

- Cabling connectors in the rack area (up to 2 people)
- Transport and installation test trials for Q2a (up to 7 people)
- Installation of jacks (2 people)
- Dismantling and removal of rack from mezzanine (3 people)
- Opening of D1 jumper (up to 4 people)
- Magnet preparation by MSC collogues (Up to 3 people)
- ……



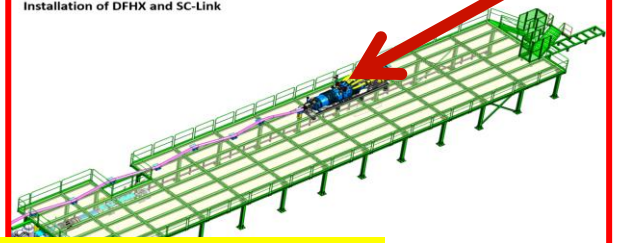
A big tank you to all intervening people for playing the safety game and respecting the rules

Schedule deviation from baseline - Sequence of installation change March 2022

Actual baseline

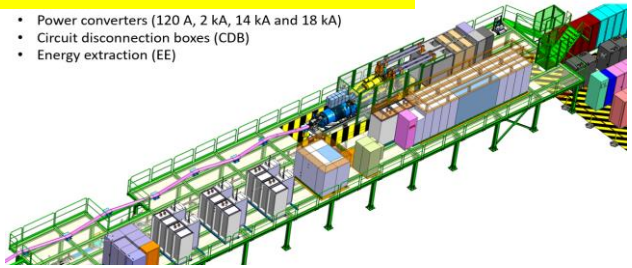
Installation of Sc-Link and DFHX took place on **23rd of August**

Installation of DFHX and SC-Link



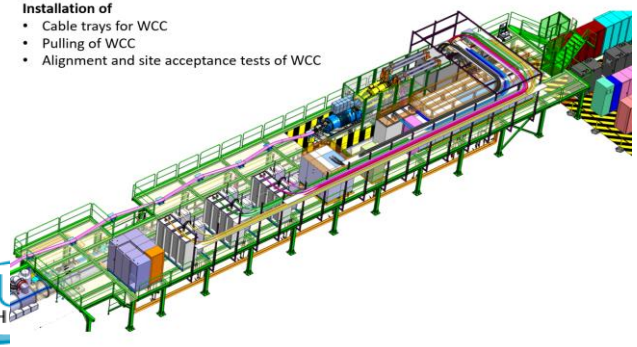
According to the 2020 baseline today we would be here

- Power converters (120 A, 2 kA, 14 kA and 18 kA)
- Circuit disconnection boxes (CDB)
- Energy extraction (EE)

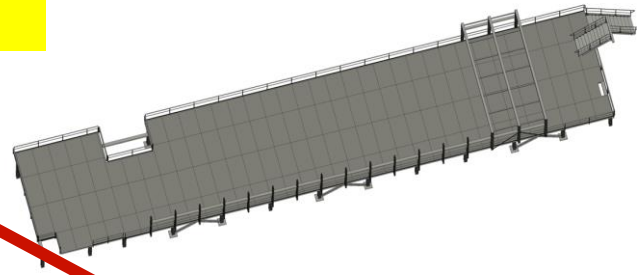


Installation of

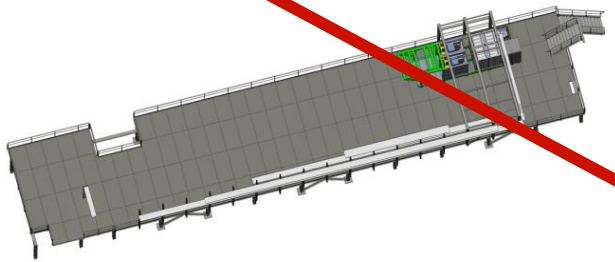
- Cable trays for WCC
- Pulling of WCC
- Alignment and site acceptance tests of WCC



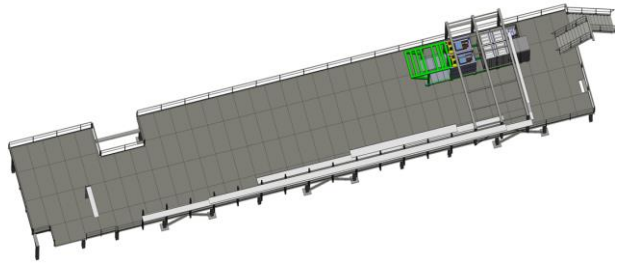
Situation as per today – March 2022



Installation of Circuit Disconnection Boxes (CDB)



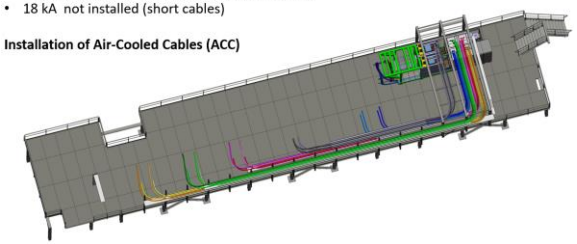
Installation of Circuit Disconnection Boxes (CDB)



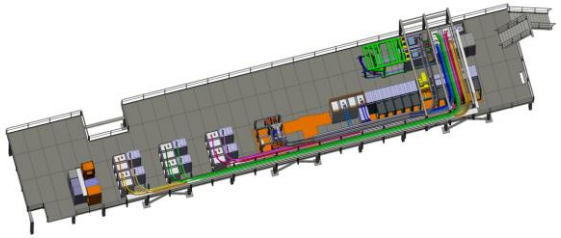
Installation of Water-Cooled cables (WCC)

- Definitive connection on CDB side
- "Parking position" on power converter (PC) side
- 18 kA not installed (short cables)

Installation of Air-Cooled Cables (ACC)

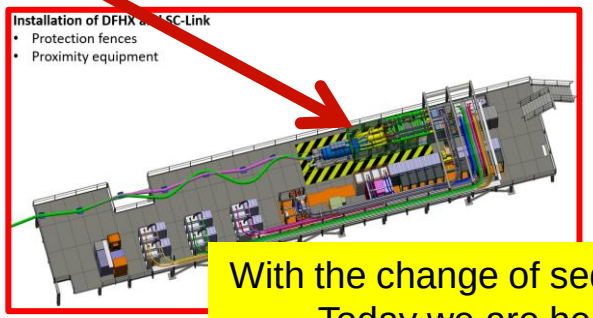


Installation of 18 kA power converter



Installation of DFHX and SC-Link

- Protection fences
- Proximity equipment



With the change of sequence Today we are here

Technical deviations from baseline

Status

- The baseline integration and the equipment/system design has been found not sufficiently detailed and/or mature
- Tanks to a series of STCM ad-hoc technical meetings with the concerned stakeholders, the required new designs and studies have been validated and implemented

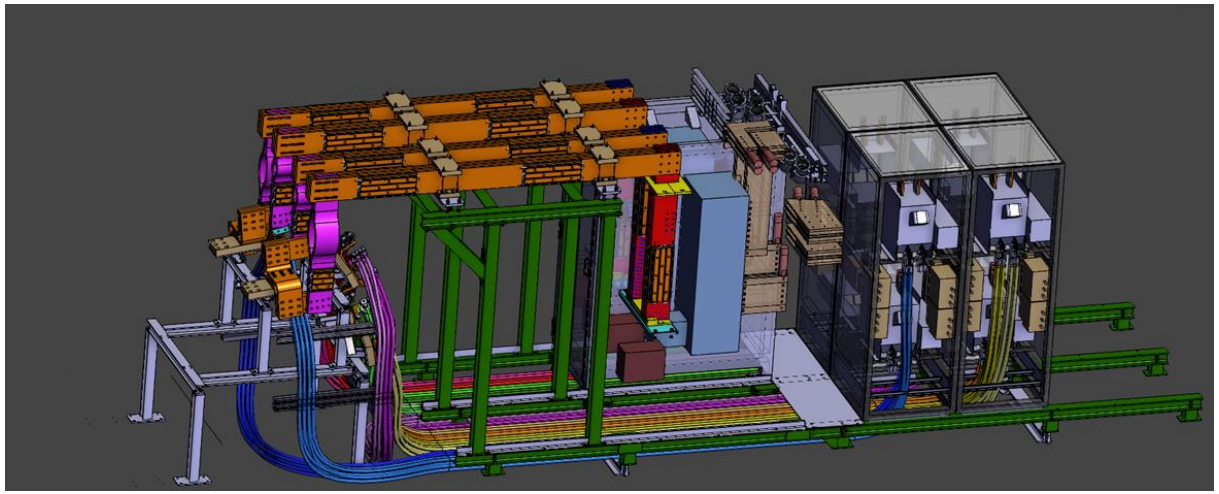
Here is a non-exhaustive list of technical deviations

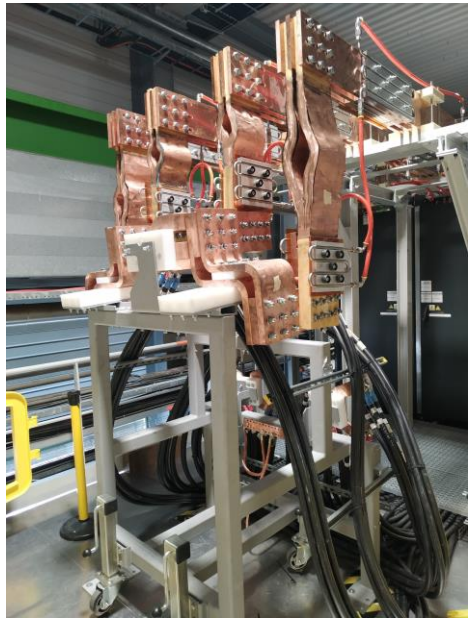
- Hardware for the execution of the Short Circuit Tests at the end of ACC and WCBB was not in the baseline ACC routing and connectivity to DFHX current leads
- DFHX current leads connections model
- Sequence of installation of cold powering on IT String
- ECR EMDS 2786783 ‘’Optimisation of the Current Measurement Scheme of the HL-LHC Inner Triplet Circuit’’
- WCC supporting system and connectivity to CDB, PC and EE
- Non conform 18 kA and 14 kA flexible bus bars
- Air cooled extra flexible cables for connection to DFHX current leads
- …….

Technical deviations from baseline – Example 1

Hardware for the execution of the Short Circuit Tests at the end of ACC and WCBB was not in the baseline ACC routing and connectivity to DFHX current leads

- WP16 took over the design and construction of a DFHX Current Lead Connections Model whose goals are:
  - to facilitate and optimize the installation of the DC warm connections (air cooled cables and bus bars)
  - to provide a support for the short circuit blocs required for the short circuit tests to avoid reworking the air-cooled cables after the arrival of the DFHX
- WP16 and MCF endorses the use of this approach for the HL-LHC





Technical deviations from baseline – Example 2

Cabling of 300mm2 copper cables

- Based on expertise gathered on DFHX test on cluster F2 the baseline solution with semi-rigid class 5 cables is not applicable. Cables are too stiff to connect to current leads

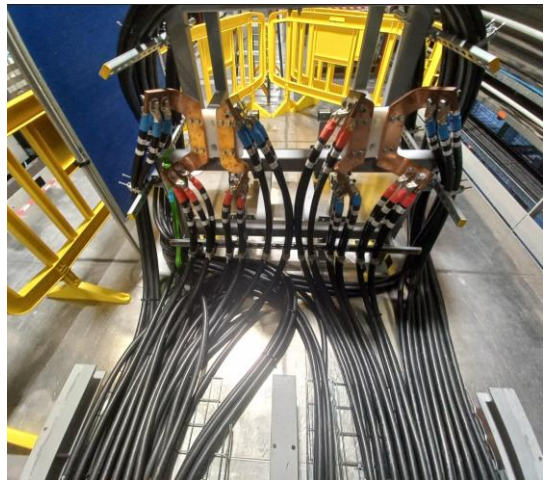
Actions taken

- Alternative solutions have been identified and studied
- The retained solution includes a last segment length of ultra-flexible class 6 cable
- A specific metallic structure to support the ultra-flexible cables has been designed and already installed on IT String
- Several assembly tests have been done on the IT String confirming the feasibility
- Ordering of material is ongoing with the aim of installing the ultra-flexible segments by end of October

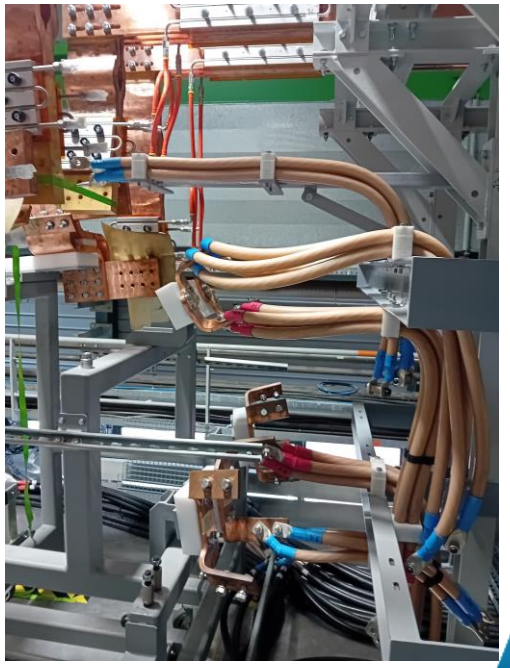
Outcome

- The proposed solution has been engineered on the IT String and has been endorsed as a valid solution for HL-LHC through MCF
- The proposed solution ease the connection of the ACC cables to the current leads

Semi-rigid class 5 cables



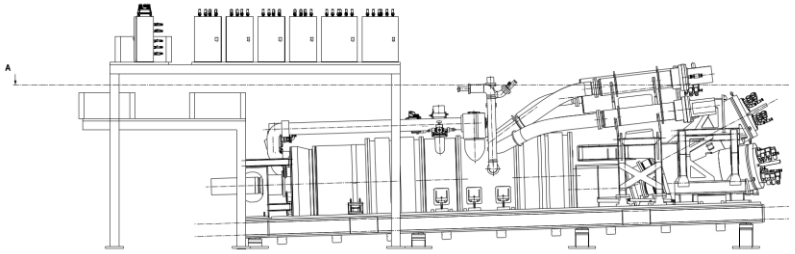
Ultra-flexible class 6 cables

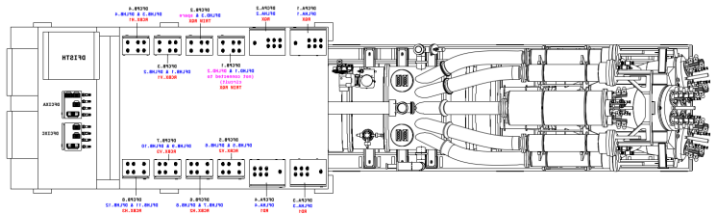


Technical deviations from baseline – Example 3

Sequence of installation of cold powering on IT String

- The baseline was insufficiently detailed as far as it concerns the installation sequence of the Sc-Link





Actions taken

- 15 ad-hoc technical meetings since November 2023 between WP6a and WP16 on Sc-Link installation with multiple reiterations before arriving to a robust installation sequence

Outcome

- Impressive progress on detailed integration studies (the majority are IT String specific)
- Final position of DFHX on mezzanine validated
- Finalization of proximity equipment and associated connectivity frozen
- Finalization of GMS position and associated gas recovery line routing
- Laying sequence of Sc-link documented and validated
- Finalization of DFX integration and supporting structure installed
- Sc-Link forming and Insertion sequence into DFX validated

Lessons Learned

Dissemination of lessons learned

- Lessons learned on IT String are disseminated to stakeholders and concerned bodies such as TCC, MCF, WP15 and groups such as EN-EL, SY-EPC, TE-MPE, …
- The goal of these talks is to report on lessons learned we consider useful in the framework of WP15 for the integration & installation of the HL-LHC in the machine
- Generic non-conformities are duly documented in EDMS. What we share are relevant lessons learned which are not systematically documented
- Six IT String lessons learned talks have been given since December 2023
  - IT String Lessons learned for EN-EL contribution, 1st December 2023
  - IT String Lessons learned for warm powering, 15th February 2024
  - Summary of the warm powering IST and SCT campaign in the IT String, 192nd TCC, 14th March 2024
  - Progress report on IT String coordination, installation, and commissioning, 195th TCC, 23rd May 2024
  - Lessons learned on IT String relevant for HL-LHC installation #1, HL-LHC Integration Meeting, 31st May 2024
  - Lessons learned on IT String relevant for HL-LHC installation #2, HL-LHC Integration Meeting, 13st September 2024

IT String day III recommendation

Relevant examples related to coordination: Example 1

Sequence of installation of cold powering on IT String

- Four transport and installation tests have been added to the baseline plan and successfully took place:
  - 25th of April - transport frame only
  - 3rd of May - frame + drum
  - 22nd of May – Sc-link positioning trial
  - 25th July - frame+ drum + DFHX dummy + unspooling
- An installation test of the cable chain has been planned before final installation
- 70 m^2 of additional scaffoldings had to be installed with a direct impact on the overall schedule and installation sequence of jacks and magnets

Lessons learned

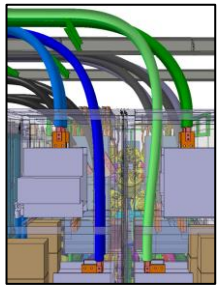
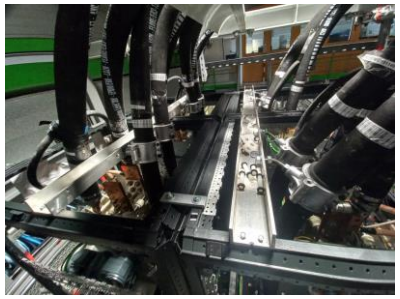
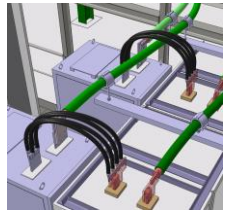
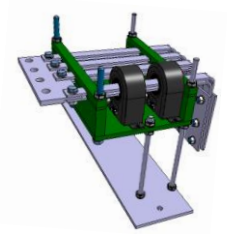
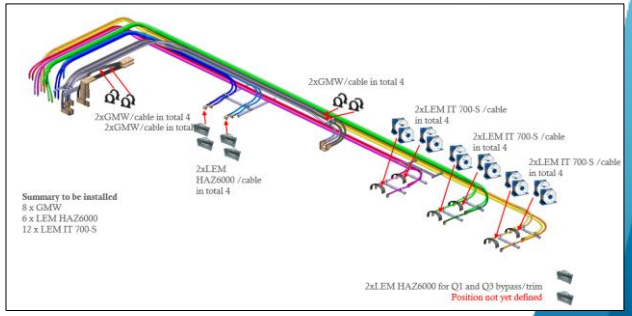
- Test trials have been essential for a successful transport and unspooling of the Sc-Link on the mezzanine
- The confidence and expertise that has been built up during the test trials allowed to do the most critical operation of the entire IT String project in four hours

Relevant examples related to coordination: Example 2

Warm powering interfaces

- From power converters to current leads the current passes through up to four different equipment owners' (WP6a, WP6b, WP7, WP17) part of three ATS departments
- The number of electrical interfaces between equipment owners is high and correspond to the same number of interfaces between equipment owner
  - 3 for 14 and 18 kA
  - 7 for 2 KA circuit equipped with EES
- Engineering design approaches (copper plates, supporting system, cooling pipes) are often different for the same functionality
- Typically, it is always the duty the counterpart to adapt. But which one?
- More than 12 technical meetings chaired by WP16 have been necessary to clarify and coordinate to technical requirements of multiple interfaces related to warm powering



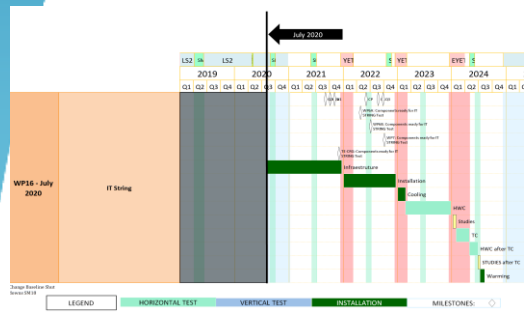






Lessons learned

- Harmonization of warm powering would be beneficial for both the technical solutions and the number of involved contributors

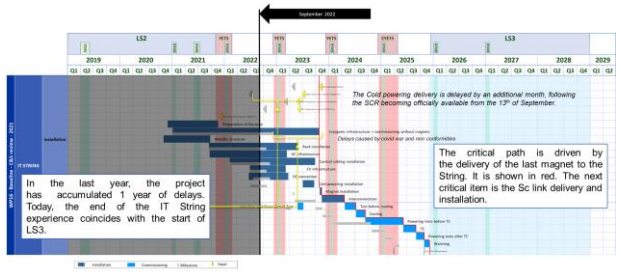
Relevant examples related to coordination: Example 3

Long term planning evolution



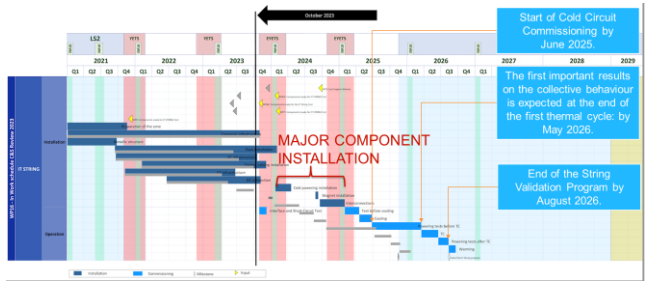
TCC 30 - July 2020

End of installation	Q4-2023
End of operation	Q3-2024



STRING day II - Sept 2022

End of installation	Q2-2024
End of operation	Q4-2025



STRING day III - Oct 2023

End of installation	Q1-2025
End of operation	Q3-2026

Today - September 2024

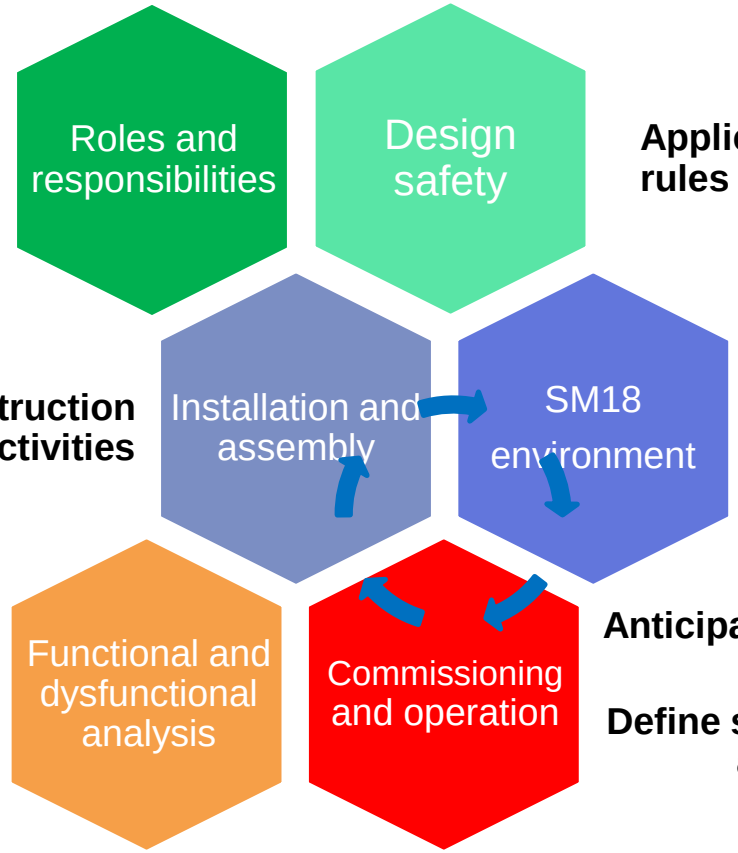
End of installation	Q3-2025
End of operation	Q1-2027

- Since July 2020 (baseline), the IT String cumulated 2.5 years of delay for reasons that are aknoledged at HL-LHC project level
- The lessons learned with those comparisons are:
  - to recognise that all IT String delays, on almost all installation activities, could be managed and absorbed in a transparent way and in the shadow of the overall delay of the HL-LHC project
  - Planning wise, the IT String ‘’executed schedule’’ cannot be considered as a reference case for the duration of similar activities to be done for the HL-LHC installation in the tunnel

Safety

IT String – Safety content sections

Six main safety sections covering the entire IT String life cycle



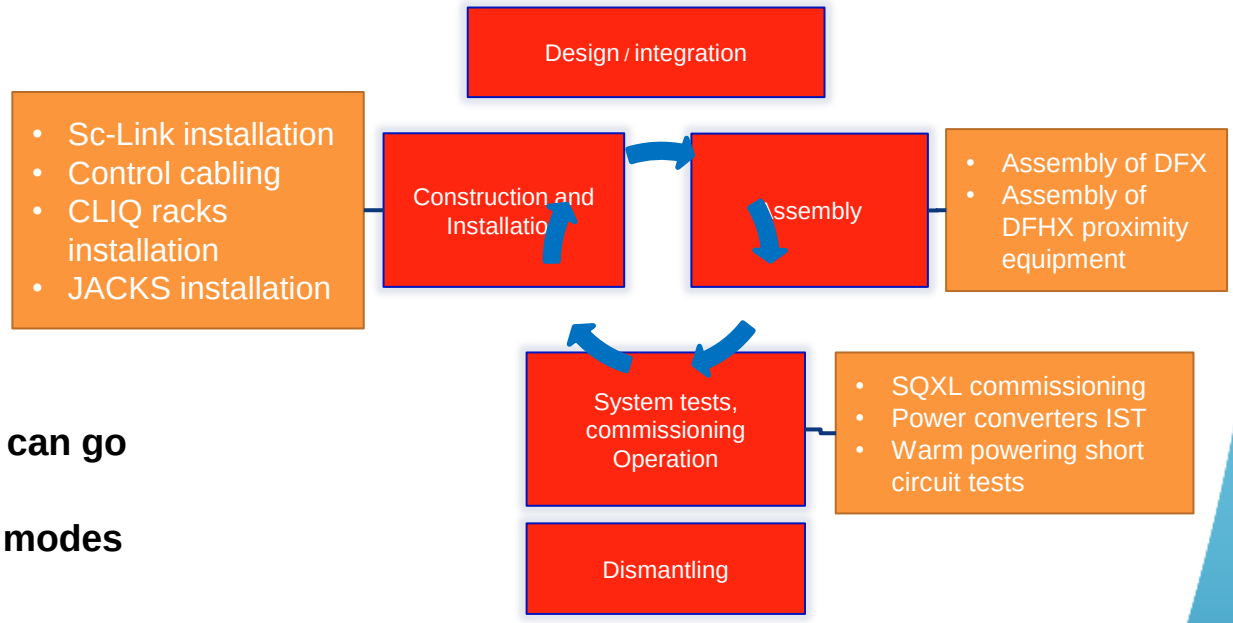
Applicable standards, norms, rules and regulations

On-site construction and coactivities

Anticipate/identify what can go wrong.

Define safe operational modes and procedures

Today's reality



IT String – Status of safety documentation for IT String

Design safety

Progress on SSA release schedule from HL-LHC Project safety officer

WP	Equipment/ Activity	Doctype	EDMS	Ver.	Q4 2023	Q1 - Q3 2024	Oct.2024	Nov.2024	Dec.2024
16	Test String in SM18	Master SSA	2568287	0.2	In Work	In Work	Eng Check	Under Approval	Released
16	Inner Triplet and Cold Powering in Test String	SSA	2575427	0.3	In Work	In Work	Eng Check	Under Approval	Released
16	Electrical Failure Modes of the Inner String Test Assembly in SM18	Risk Analysis	2478173	1.0	Released				
3	Inner triplet and cold powering	Master SSA	2567867	1.0	Released				
3	Inner Triplet Master	Master SSA	2575617	1.0	Released				
3	Q1-Q3 MQXFA	SSA	2115485	2.0	Released				
3	Q2a-Q2b (MQXFB)	SSA	2170722	1.0	Released				
3	D1 (MBXF)	SSA	2115625	1.0	Released				
3	Corrector Package CP	SSA	2575620	1.0	Released				
3	DCM D1-DFX Connection Module	SSA	2464501	1.0	Under Approval	Released			
6a	Cold Powering	Master SSA	2212619	1.2	Released				
6b	Safety of Power Converters (PC)	Master SSA	2618439	0.4	In Work	In Work	Eng Check	Under Approval	Released
9	IT Cryogenics for Test String	SSA	2366342	1.0	Released				
15.4	Full Remote Alignment System (FRAS)	SSA	2144080	1.0	Released				

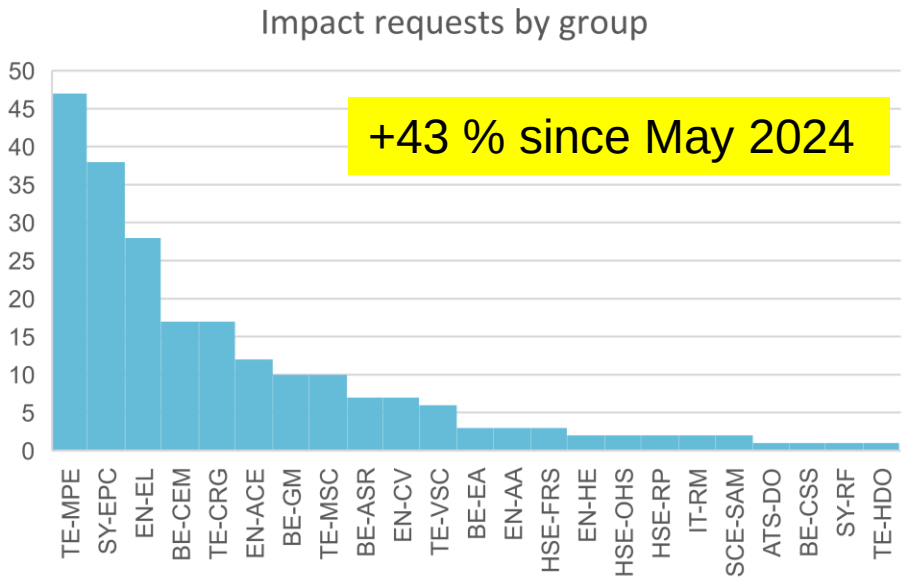
Courtesy of T. Otto

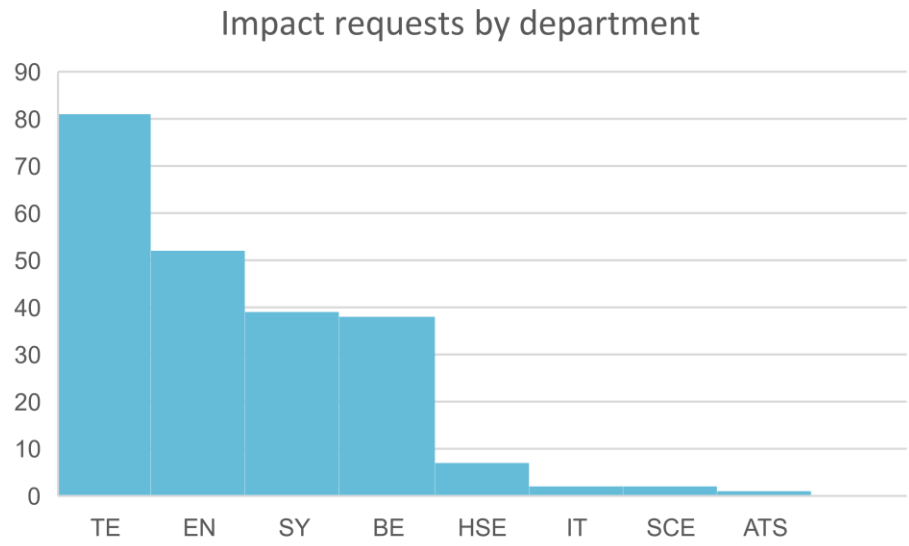
IT String Access - Impact tool - Visits

Who is working and visiting the IT String

- **222** Impact requests
- **23** Groups involved in-situ
- **8** Departments

- **23** Guided visits, +37 % since May 2024
- **11** Professional visits, +57% since May 2024





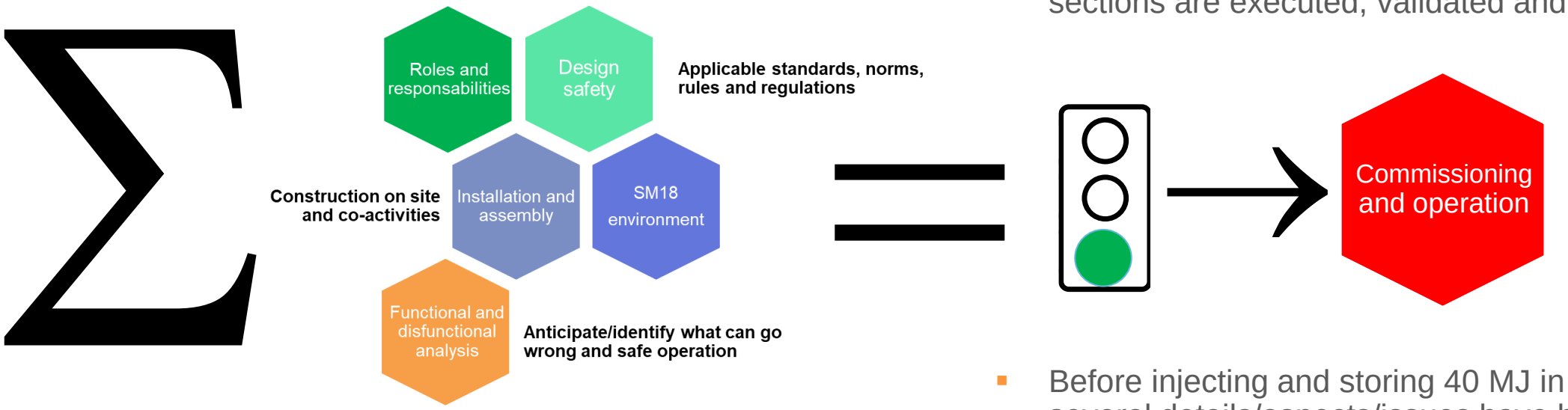
- High degree of adherence to Impact tool which contributes to a smooth coordination of multi-disciplinary activities
- VIC are triggered according to work description in Impact
- Increasing number of professional and guided visits

Operational safety

Commissioning and operation

Time to put power on infrastructure and current through the circuits

- Safe commissioning and operation of the IT String will depend on how the previous five safety sections are executed, validated and applied



- Before injecting and storing 40 MJ in the magnets, several details/aspects/issues have been finalized
- This work started in 2022 by WP16, MCF and concerned stakeholders
- Next slides will report on the progress and initiatives related to operational aspects

Operational safety

Commissioning and operation

As from January 2024 the IT String implemented the role of "chargé exploitation" responsible for the following mandate/tasks

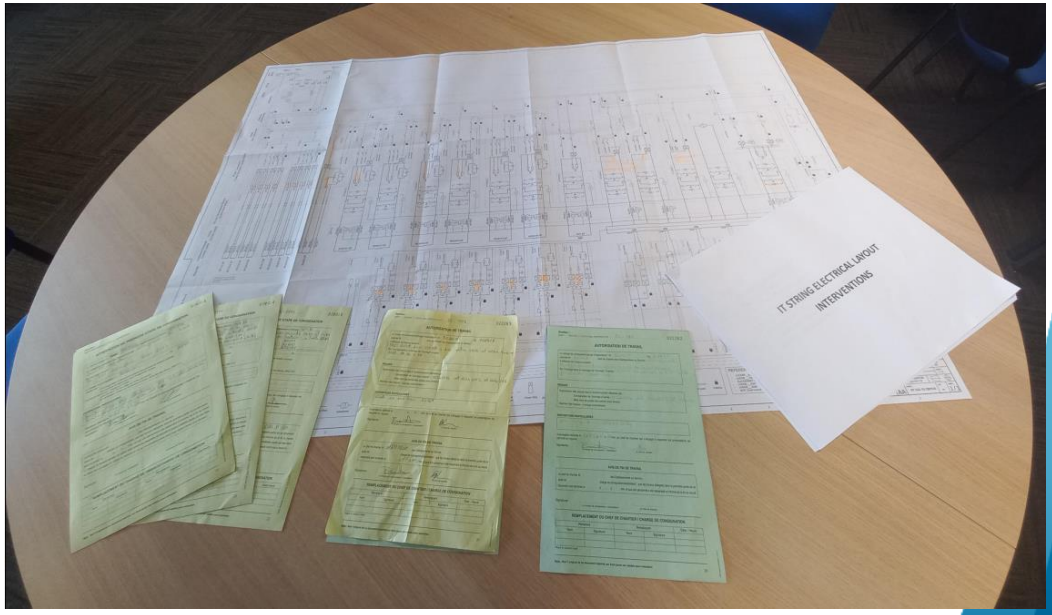
Define and implement access and control monitoring procedures	Plan and coordinate operational maneuvers	Issue all necessary authorizations, including access authorizations
Identify the person responsible for lockout/tagout procedures	Monitor the operations carried out and their progress	Monitor and plan the maintenance of the facility

Chargé exploitation : D. Bozzini and S. Yammine as alternate

Since January 2024

- 18 lock-out requests
- 21 work permits
- 5 electrical separation of networks

According to NF C 18 510



Operational drawing of electrical circuits

Commissioning and operation

Observation

- There are many drawings available, but we miss “the glue’’ between all of them for a global view of the electrical circuitry

Goal

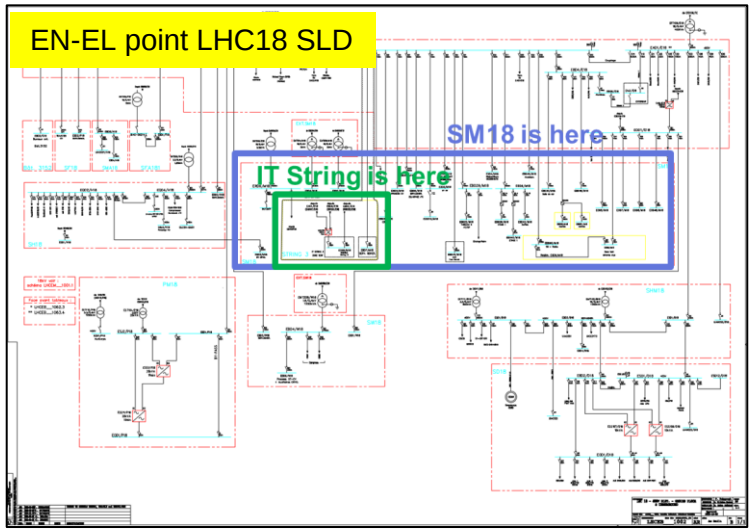
- Represent all electrical AC, DC circuits and internal sources of energy in a way that allows a safe electrical operation and a safe and efficient coordination of the interventions on IT String electrical infrastructure

Methodology

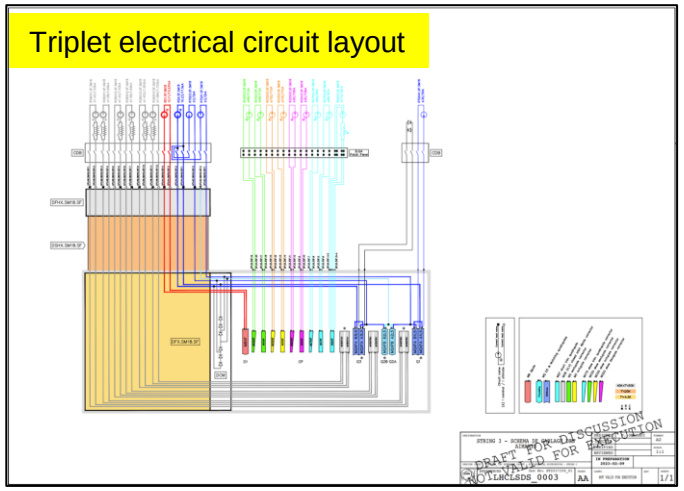
- Grouping of the different source and nature of electrical information into a single drawing/document
- Define layers that allow identifying relationships between electrical components and associated electrical sources
- Facilitate the identification of circuits that shall be lock-out according to the nature of the electrical intervention

This initiative also contributes to the ESP project

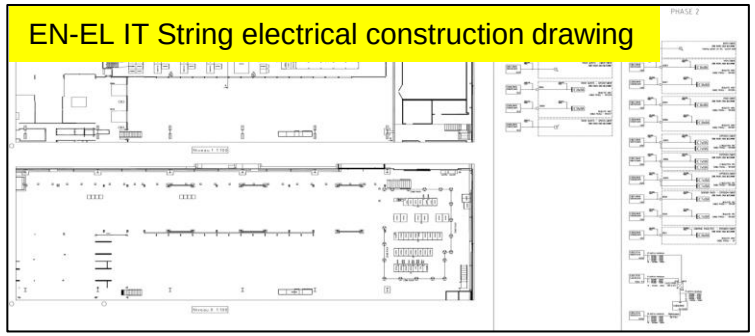
EN-EL point LHC18 SLD



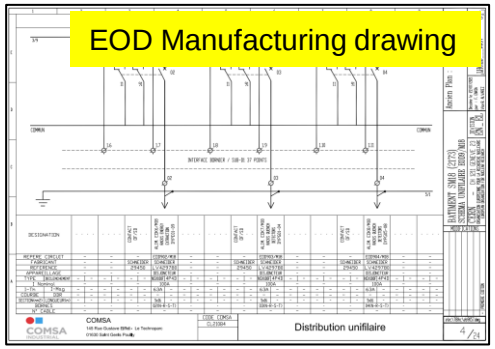
Triplet electrical circuit layout



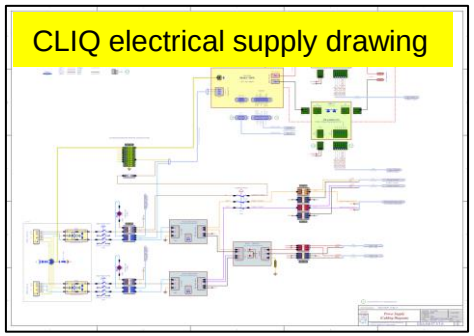
EN-EL IT String electrical construction drawing



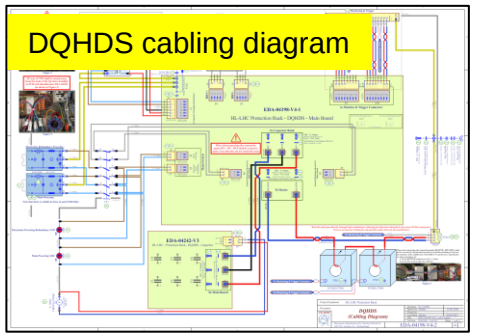
EOD Manufacturing drawing



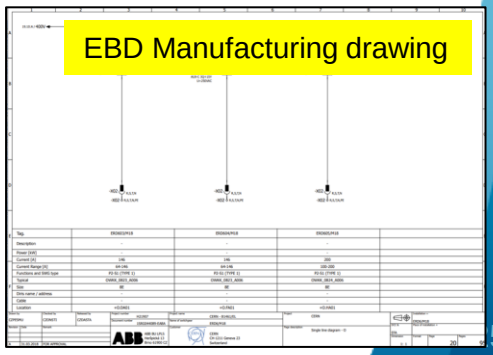
CLIQ electrical supply drawing



DQHDS cabling diagram



EBD Manufacturing drawing

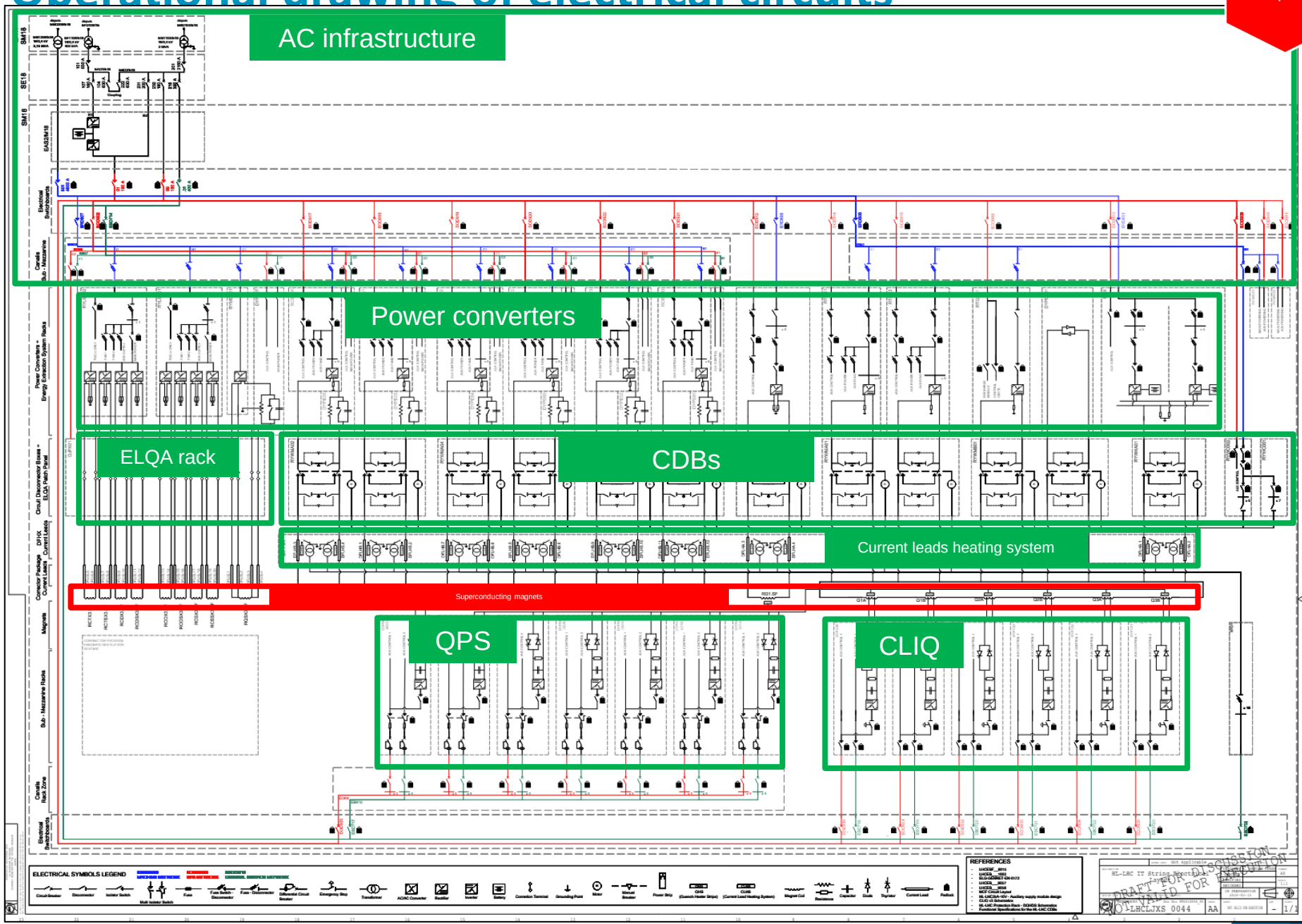


Operational drawing of electrical circuits

Commissioning and operation

Outcome

- A unique operational drawing showing:
  - All electrical elements (AC, DC, internal sources)
  - Clearly the electrical dependencies
  - The devices that can be locked out



Operational modes and procedures

- Electrical operation modes for the HL-LHC magnet circuits have been defined in the framework of MCF
- Four modes have been identified covering operation, testing and maintenance interventions
- Electrical operation procedures describing how to move between modes are under definition.
- The procedures will be part of a catalogue that can evolve according to the nature of the intervention and the ‘’habitation’’ of the intervening personnel

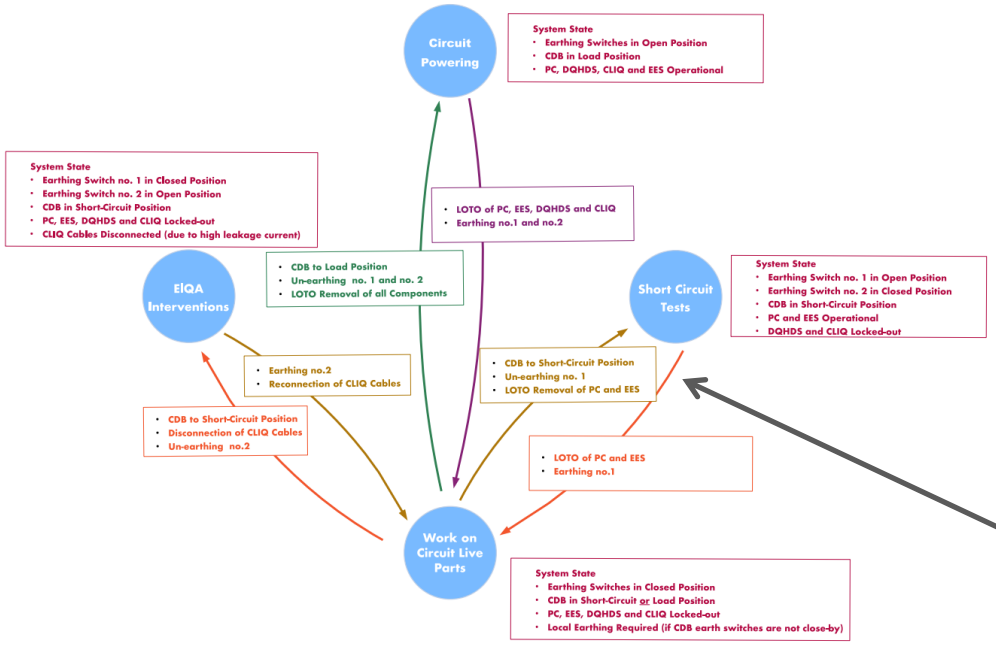
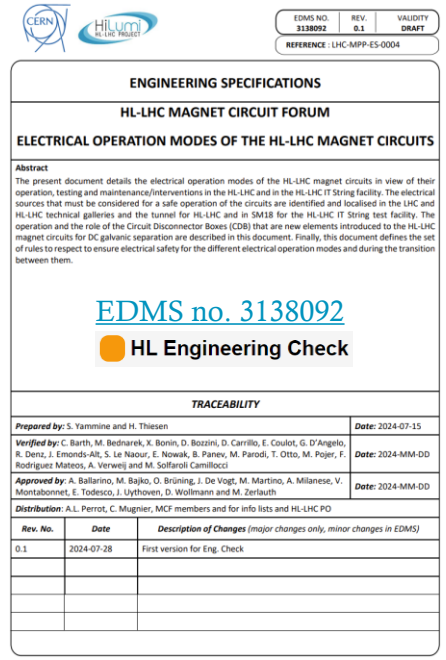


Figure 7 – Procedure overview of modification of the operation modes

Procedure nr. X

From ‘’SCT” to ‘’work on circuit live part”

- Nature of intervention
- Risk assessment
- Concerned circuit
- Concerned equipment
- Lock-outs points
- Who does what
- Work(s) authorization(s)
- Specific safety measures
- …..



EDMS NO. 3138092 | REV. 0.1 | VALIDITY DRAFT
REFERENCE : LHC-MPP-ES-0004

ENGINEERING SPECIFICATIONS

HL-LHC MAGNET CIRCUIT FORUM

ELECTRICAL OPERATION MODES OF THE HL-LHC MAGNET CIRCUITS

Abstract

The present document details the electrical operation modes of the HL-LHC magnet circuits in view of their operation, testing and maintenance/interventions in the HL-LHC and in the HL-LHC IT String facility. The electrical sources that must be considered for a safe operation of the circuits are identified and localised in the LHC and HL-LHC technical galleries and the tunnel for HL-LHC and in SM18 for the HL-LHC IT String test facility. The operation and the role of the Circuit Disconnector Boxes (CDB) that are new elements introduced to the HL-LHC magnet circuits for DC galvanic separation are described in this document. Finally, this document defines the set of rules to respect to ensure electrical safety for the different electrical operation modes and during the transition between them.

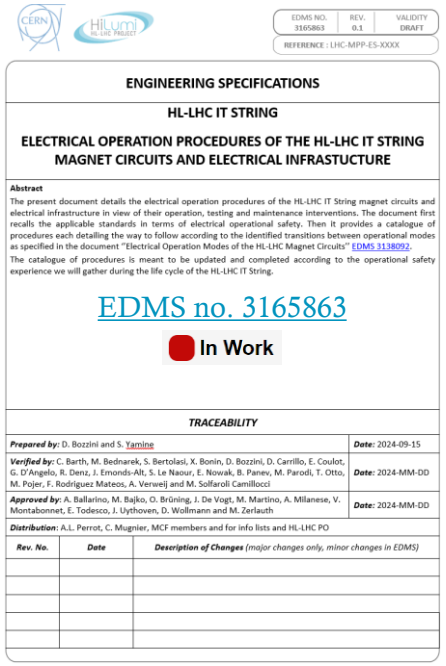
EDMS no. 3138092

HL Engineering Check

TRACEABILITY

Prepared by: S. Yammine and H. Thiesen	**Date:** 2024-07-15
Verified by: C. Barth, M. Bednarek, X. Bonin, D. Bozzini, D. Carrillo, E. Coulot, G. D'Angelo, R. Denz, J. Emonds-Alt, S. Le Naour, E. Nowak, B. Panev, M. Parodi, T. Otto, M. Pojer, F. Rodriguez Mateos, A. Verweij and M. Solfaroli Camillocci	**Date:** 2024-MM-DD
Approved by: A. Ballarino, M. Bajko, O. Brüning, J. De Vogt, M. Martino, A. Milanese, V. Montabonnet, E. Todesco, J. Uythoven, D. Wollmann and M. Zerlauth	**Date:** 2024-MM-DD
Distribution: A.L. Perrot, C. Mugnier, MCF members and for info lists and HL-LHC PO	

Rev. No.	Date	Description of Changes (major changes only, minor changes in EDMS)
0.1	2024-07-28	First version for Eng. Check



EDMS NO. 3165863 | REV. 0.1 | VALIDITY DRAFT
REFERENCE : LHC-MPP-ES-XXXX

ENGINEERING SPECIFICATIONS

HL-LHC IT STRING

ELECTRICAL OPERATION PROCEDURES OF THE HL-LHC IT STRING MAGNET CIRCUITS AND ELECTRICAL INFRASTUCTURE

Abstract

The present document details the electrical operation procedures of the HL-LHC IT String magnet circuits and electrical infrastructure in view of their operation, testing and maintenance interventions. The document first recalls the applicable standards in terms of electrical operational safety. Then it provides a catalogue of procedures each detailing the way to follow according to the identified transitions between operational modes as specified in the document "Electrical Operation Modes of the HL-LHC Magnet Circuits" EDMS 3138092.
The catalogue of procedures is meant to be updated and completed according to the operational safety experience we will gather during the life cycle of the HL-LHC IT String.

EDMS no. 3165863

In Work

TRACEABILITY

Prepared by: D. Bozzini and S. Yamine	**Date:** 2024-09-15
Verified by: C. Barth, M. Bednarek, S. Bertolasi, X. Bonin, D. Bozzini, D. Carrillo, E. Coulot, G. D'Angelo, R. Denz, J. Emonds-Alt, S. Le Naour, E. Nowak, B. Panev, M. Parodi, T. Otto, M. Pojer, F. Rodriguez Mateos, A. Verweij and M. Solfaroli Camillocci	**Date:** 2024-MM-DD
Approved by: A. Ballarino, M. Bajko, O. Brüning, J. De Vogt, M. Martino, A. Milanese, V. Montabonnet, E. Todesco, J. Uythoven, D. Wollmann and M. Zerlauth	**Date:** 2024-MM-DD
Distribution: A.L. Perrot, C. Mugnier, MCF members and for info lists and HL-LHC PO	

Rev. No.	Date	Description of Changes (major changes only, minor changes in EDMS)

Commissioning and operation

Concluding remarks

- Non negligible design deviations/changes from 2020 baseline have been implemented in IT String
- Trial tests on critical activities such as the transport and installation of the SC-link were not planned but resulted necessary for a successful and safe installation
- Sequence of IT String installation is regularly updated (every two weeks through the STCM coordination meeting) according to the evolution of the temporary infrastructure required for executing the works and on the equipment readiness and manpower availability
- Lessons learned are regularly shared with concerned groups, work packages and forums. WP16 is regularly invited by WP15 to contribute to the implementation of applicable changes for the HL-LHC
- Safety aspects are well established and applied. Participants are fully committed to work in a safe environment and with safe methods
- IT String provides the occasion to enhance aspects related to the operational safety of HL-LHC. It also gives the opportunity to actively contribute to the ATS Electrical Safety Project (ESP)

Thank you for your attention