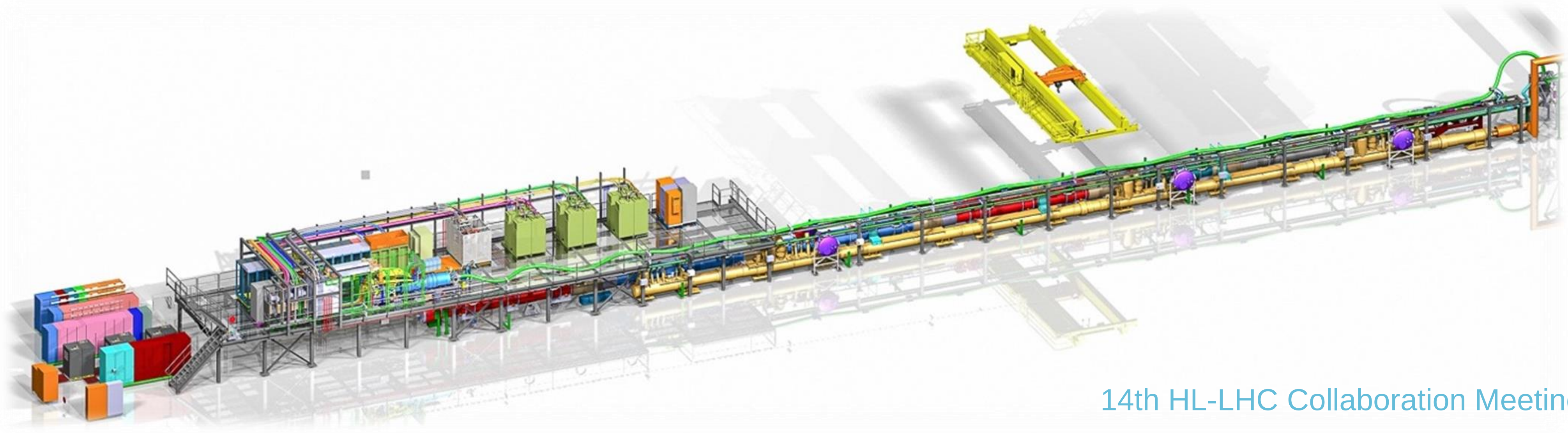
HL-LHC IT String Quality Assurance & Control

N. Heredia García (TE-MPE-SF)
On behalf of WP16

14th HL-LHC Collaboration Meeting, Genoa, 7-10 October 2024

Scope of the talk

- Introduction
- Quality design
- Quality assurance
- Quality control
- Non-conformities
- Lessons learned
- Conclusions



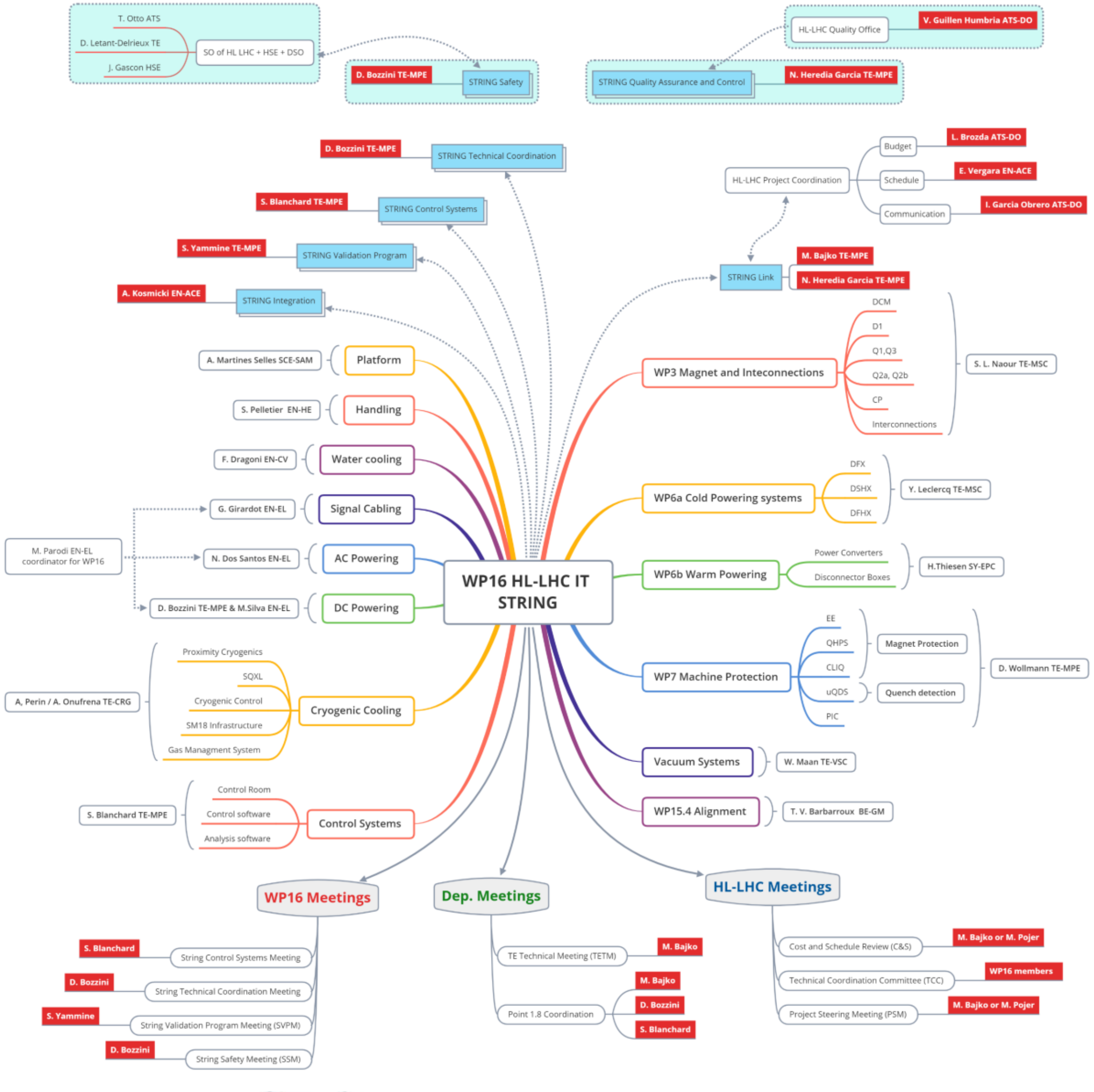
Introduction

- Careful consideration of quality management driven by the diverse components, constraints and required stakeholders.
- Three phases of quality management have been considered, defined by PMI.
- the IT String follows the quality standards and processes established for the HL-LHC project within the quality plan.

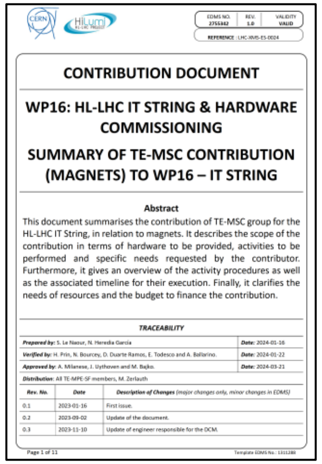
Phase	Goal	Description
Quality design	Plan quality management	Understand the specific needs and requirements of the project. It involves the definition of processes, tools and performance metrics.
Quality assurance	Manage quality	Ensure that the project meets the defined quality standards and requirements. It involves regular reviews, and continuous improvement.
Quality control	Monitor, record and control quality	Validation of the system to ensure a qualified output. It involves testing and corrective actions.

Quality design: Requirements & Expectations

Project organization chart



Scope baseline



CONTRIBUTION DOCUMENT

WP16: HL-LHC IT STRING & HARDWARE COMMISSIONING

SUMMARY OF TE-MSC CONTRIBUTION (MAGNETS) TO WP16 – IT STRING

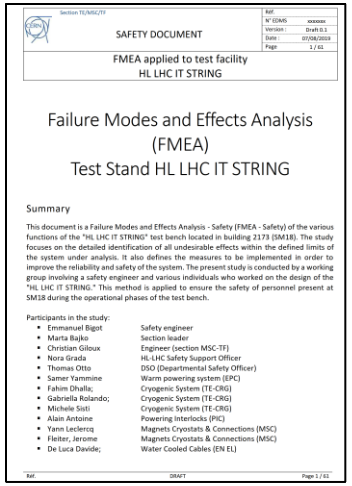
Abstract

This document summarises the contribution of TE-MSC group for the HL-LHC IT String, in relation to magnets. It describes the scope of the contribution in terms of hardware to be provided, activities to be performed and specific needs requested by the contributor. Furthermore, it gives an overview of the activity procedures as well as the associated timeline for their execution. Finally, it clarifies the needs of resources and the budget to finance the contribution.

TRACEABILITY

- Equipment delivery
- Tooling for installation
- Infrastructure requests
- Activities
- Equipment recovery
- Cost and resources

Safety analysis



SAFETY DOCUMENT

FMEA applied to test facility HL LHC IT STRING

Failure Modes and Effects Analysis (FMEA) Test Stand HL LHC IT STRING

Summary

Test plan

TEST PLAN

HL-LHC INNER TRIPLET STRING

HL-LHC IT STRING VALIDATION PROGRAM

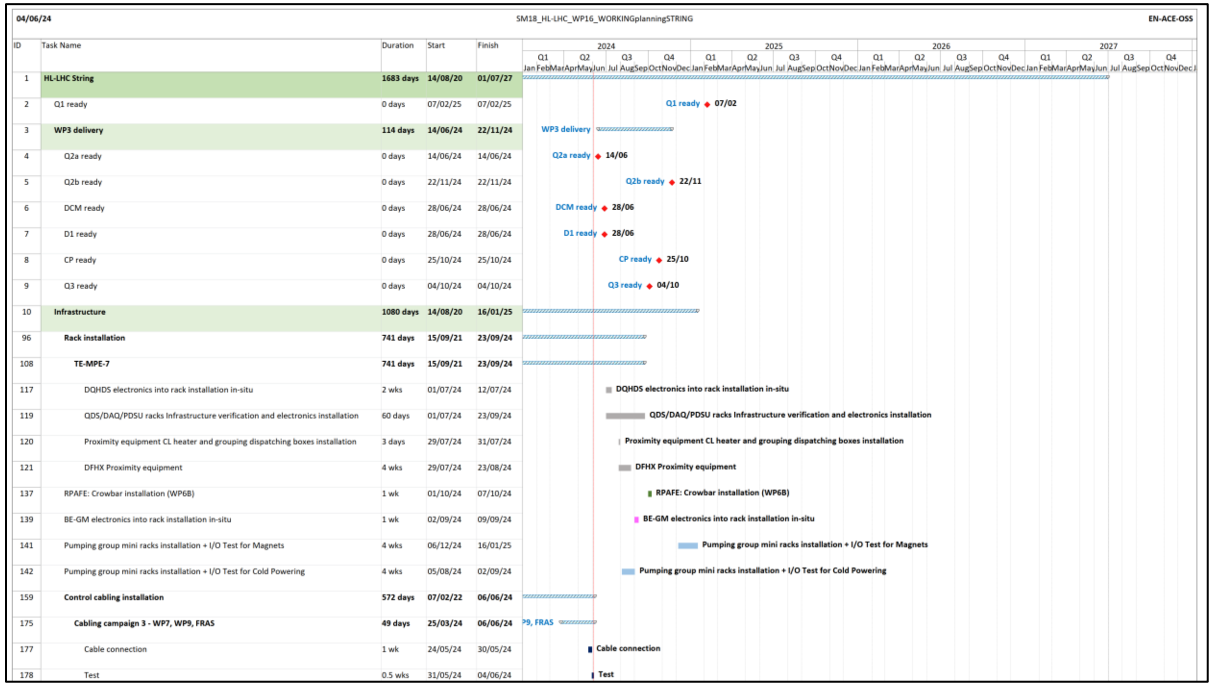
Abstract

The HL-LHC Inner Triplet (IT) String is a test stand, whose goal is to validate the collective behaviour of the cooling, powering and protection of the IT magnets and circuits in conditions as similar as possible to their later operation in the LHC. This document will be concerned with classifying the tests requested by the different WPs involved in the HL-LHC IT String. It will also show a proposed test sequence, as well as a time estimation of the different tests that make up the HL-LHC IT String Validation Program (SVP).

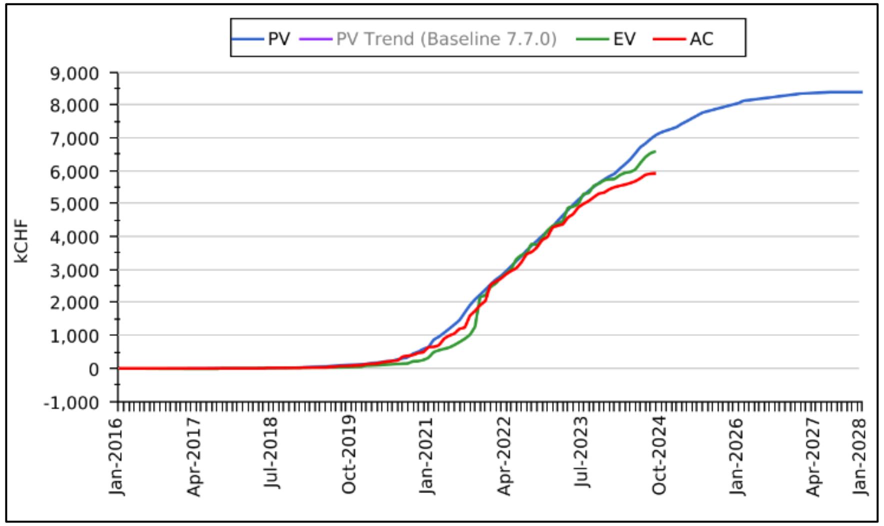
TRACEABILITY

Quality design: Tools

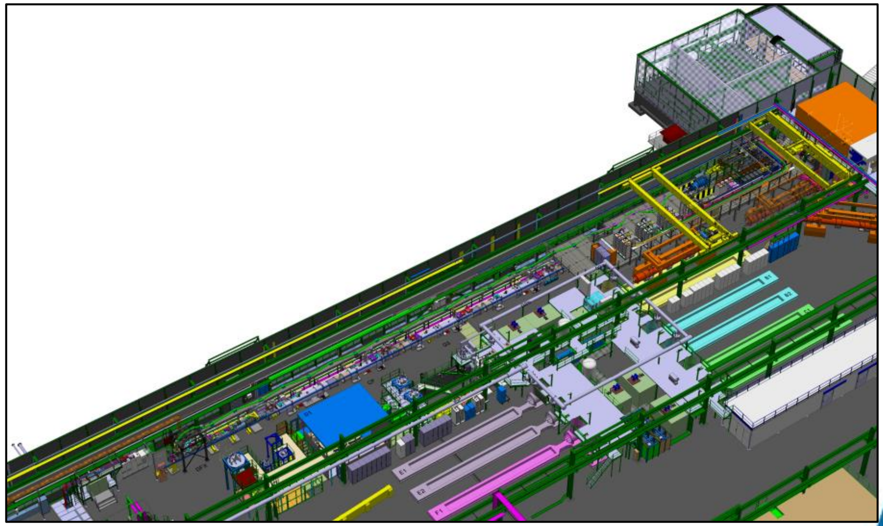
Project planning



Cost tracking



Integration model



Other tools

EDMS

Quality Assurance: Process

- The tools developed during the quality design phase have been continually updated.

Project org. chart | Contribution documents | Safety analysis | Test plan

Planning | EVM | Integration model | SharePoint…

- The IT String coordination team has organized/participated in multiple meetings to present project updates, discuss next steps, address non-conformities, provide lessons learned…

String Technical Coordination Meeting

String Validation Program Meeting

String Controls Meeting

String Quality Meeting

String Day

Project Steering Meeting

Technical Coordination Committee

Cost & Schedule Review

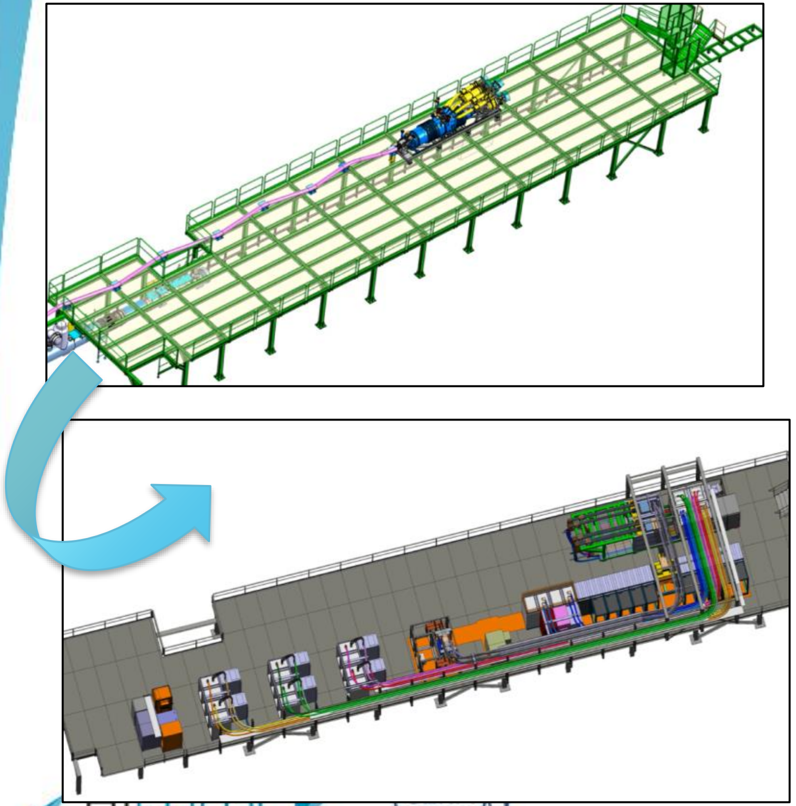
HL-LHC Annual Meeting

HiLumi HL-LHC PROJECT CERN

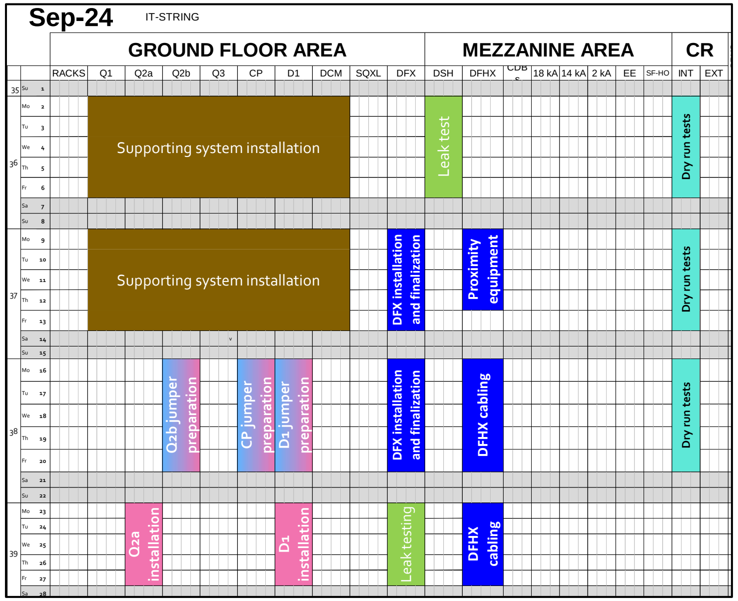
Quality Assurance: Examples

- To enhance project execution, various changes, measures, and tools have been implemented, reflecting engagement to continuous improvement:

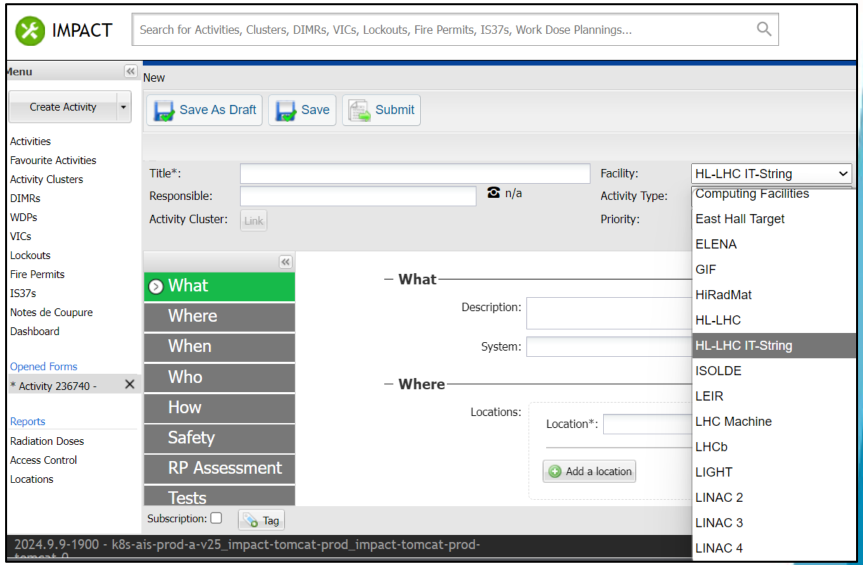
Installation sequence



Coordination



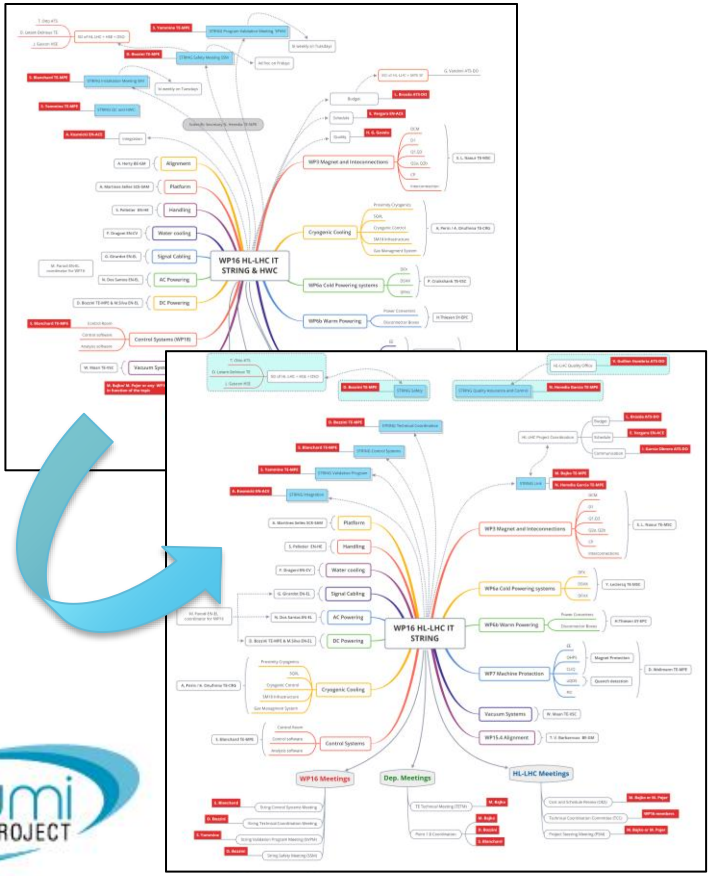
Access



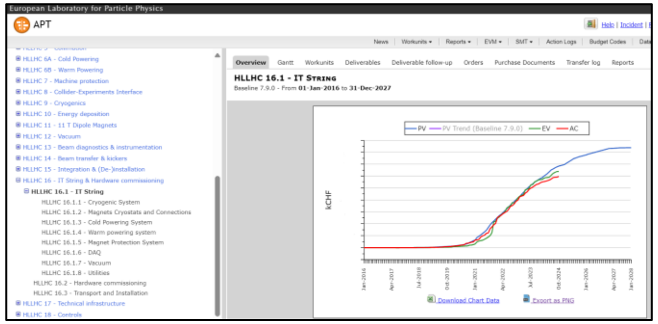
Quality Assurance: Examples

- To enhance project execution, various changes, measures, and tools have been implemented, reflecting engagement to continuous improvement:

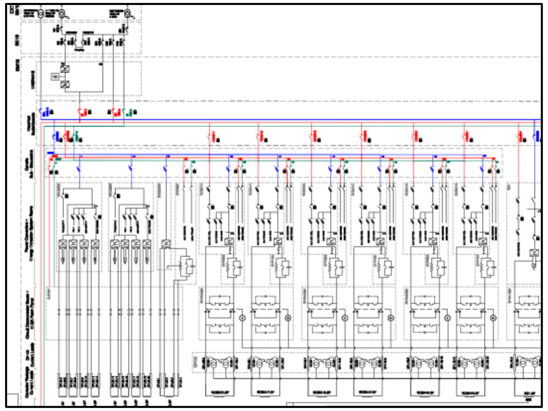
Roles and responsibilities

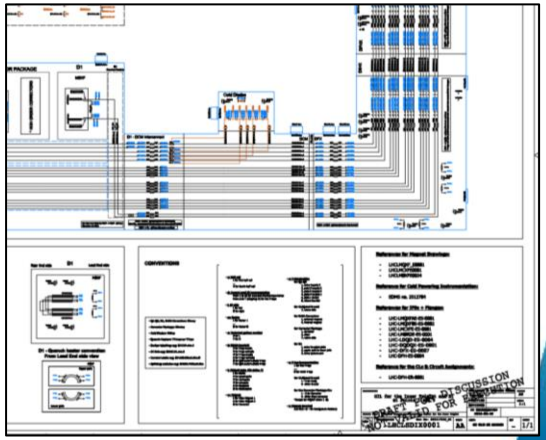


Cost monitoring



Operational drawings



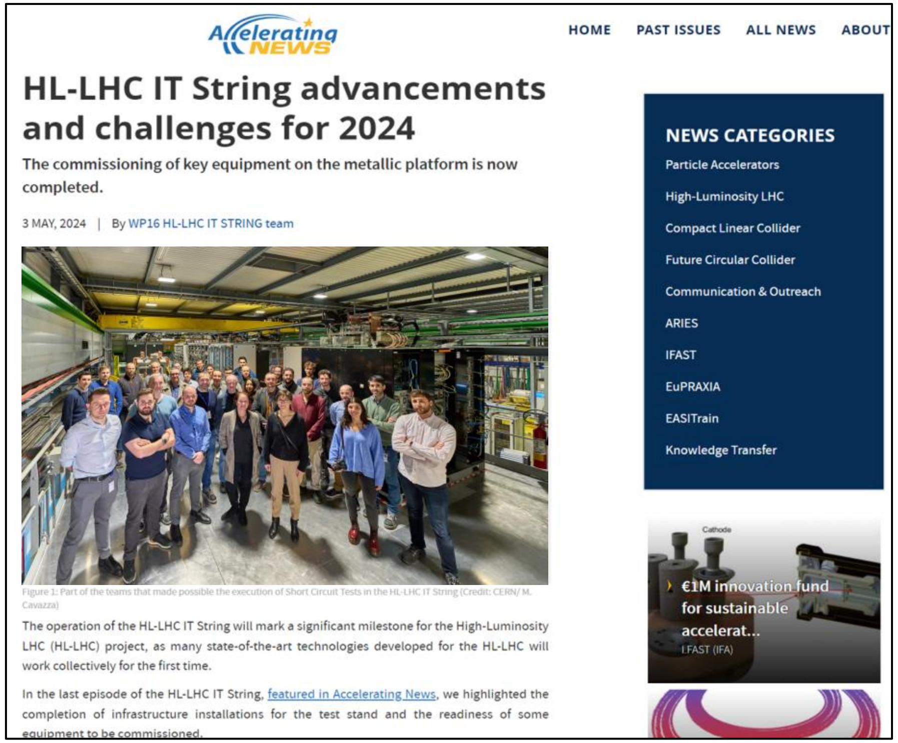


HiLumi HL-LHC PROJECT

Quality Assurance: Examples

- To enhance project execution, various changes, measures, and tools have been implemented, reflecting engagement to continuous improvement:

Communication strategy



Accelerating NEWS

HOME PAST ISSUES ALL NEWS ABOUT

HL-LHC IT String advancements and challenges for 2024

The commissioning of key equipment on the metallic platform is now completed.

3 MAY, 2024 | By WP16 HL-LHC IT STRING team

Figure 1: Part of the teams that made possible the execution of Short Circuit Tests in the HL-LHC IT String (Credit: CERN/ M. Cavazza)

The operation of the HL-LHC IT String will mark a significant milestone for the High-Luminosity LHC (HL-LHC) project, as many state-of-the-art technologies developed for the HL-LHC will work collectively for the first time.

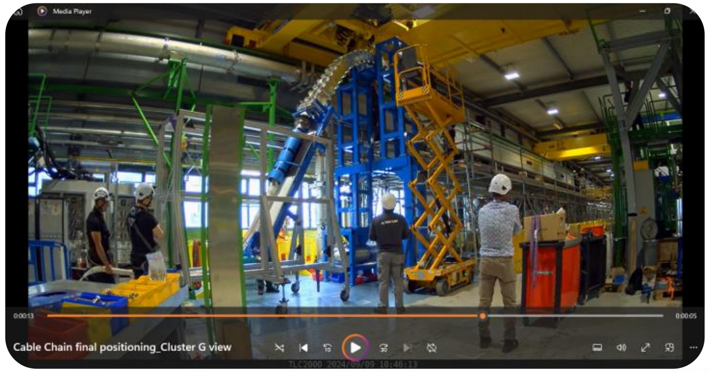
In the last episode of the HL-LHC IT String, featured in Accelerating News, we highlighted the completion of infrastructure installations for the test stand and the readiness of some equipment to be commissioned.

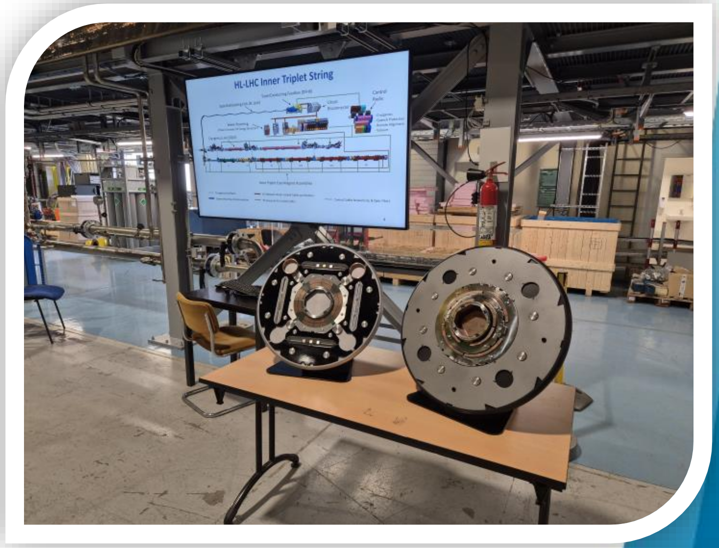
NEWS CATEGORIES

- Particle Accelerators
- High-Luminosity LHC
- Compact Linear Collider
- Future Circular Collider
- Communication & Outreach
- ARIES
- IFAST
- EuPRAXIA
- EASITrain
- Knowledge Transfer

€1M innovation fund for sustainable accelerat...

I.FAST (IFA)



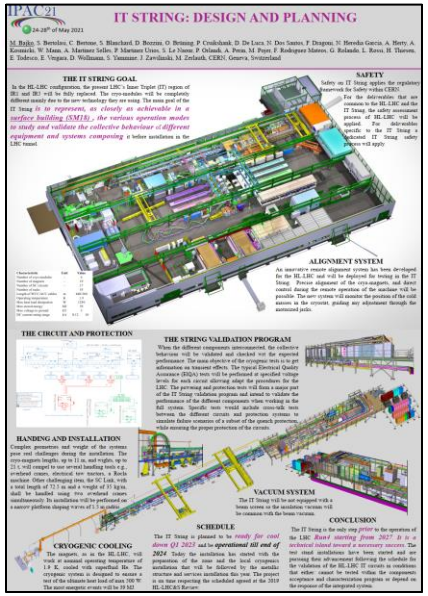


Quality Assurance: Examples

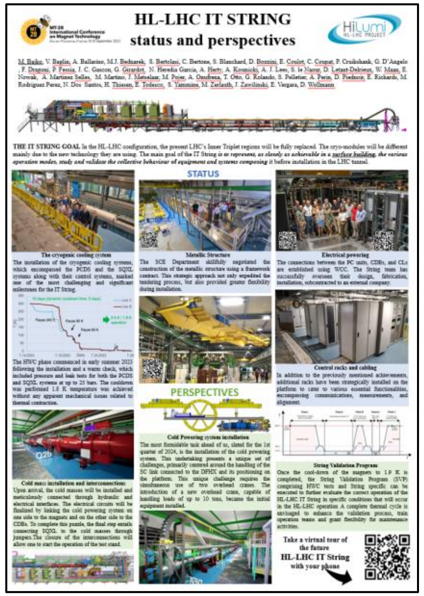
- To enhance project execution, various changes, measures, and tools have been implemented, reflecting engagement to continuous improvement:

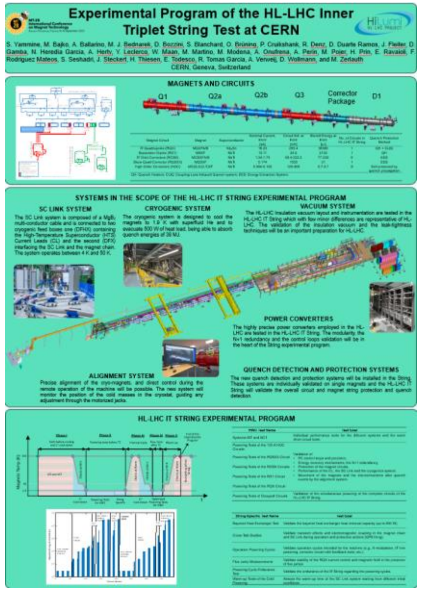
Communication strategy

IPAC 21

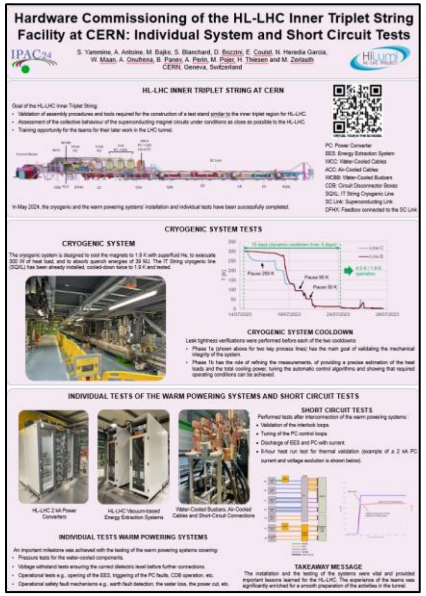


MT 28 (2023)

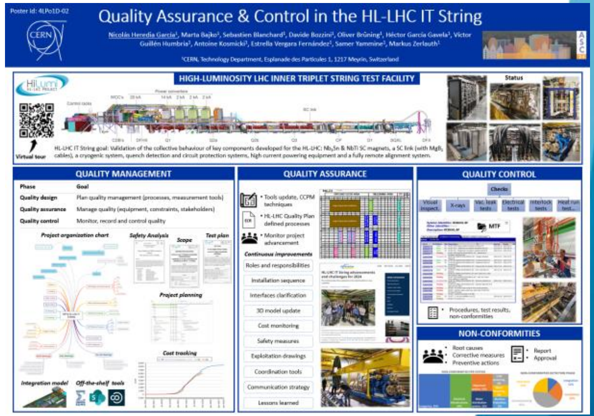




IPAC 24



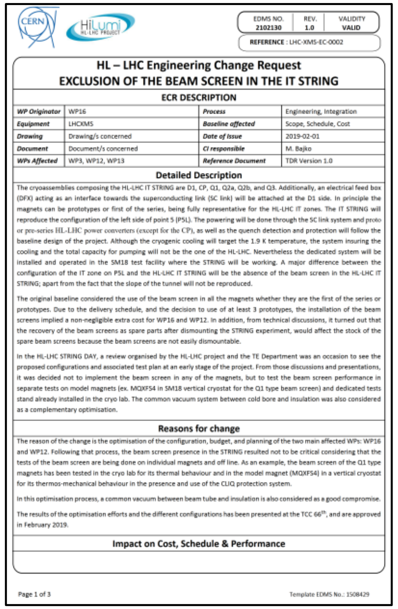
ASC 24



Quality Assurance: HL-LHC

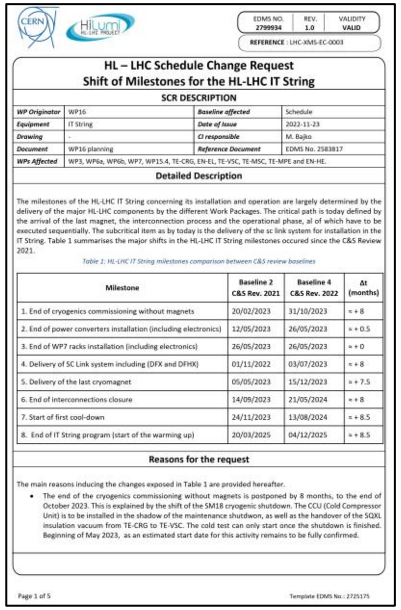
- The IT String has adhered to HL-LHC processes for requesting and documenting deviations and/or changes with regards to the baseline scenario during project execution, including:

ECR



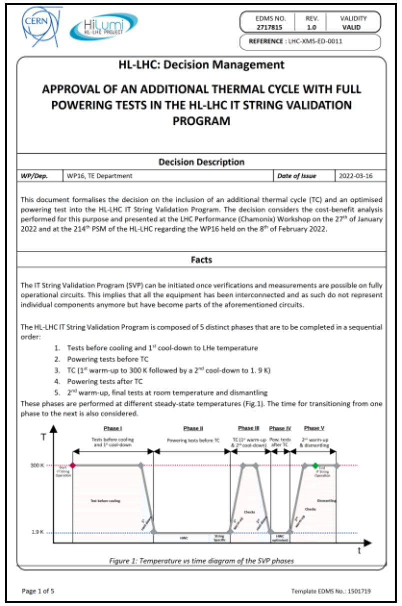
Ex: [EDMS 2102130]

SCR



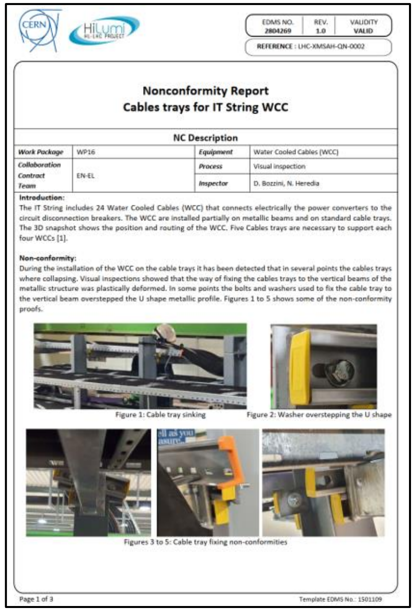
Ex: [EDMS 2799934]

DMR



Ex: [EDMS 2717815]

NCR

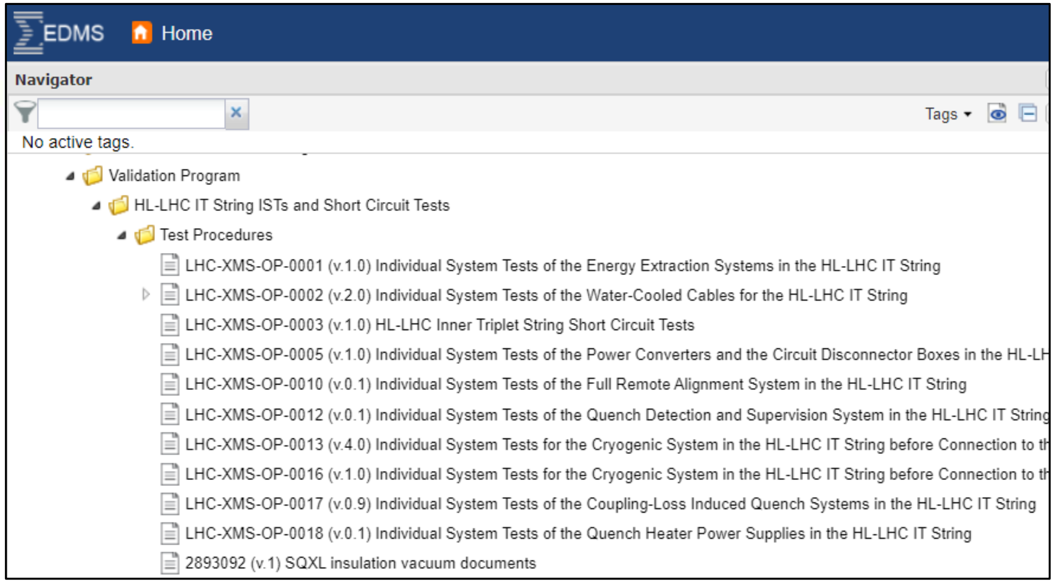


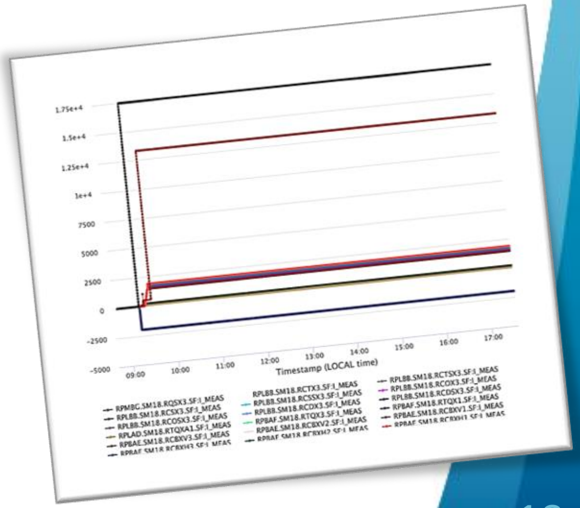
Ex: [EDMS 3025021]

Quality Control: Process

- Quality control tests are managed by the equipment owner.
- The String coordination team:
  - Ensure proper conditions for the execution of the tests.
  - Follow up the activities on-site.
  - Check that the test results are documented.
- Tests procedures are defined as part of the String Validation Program.

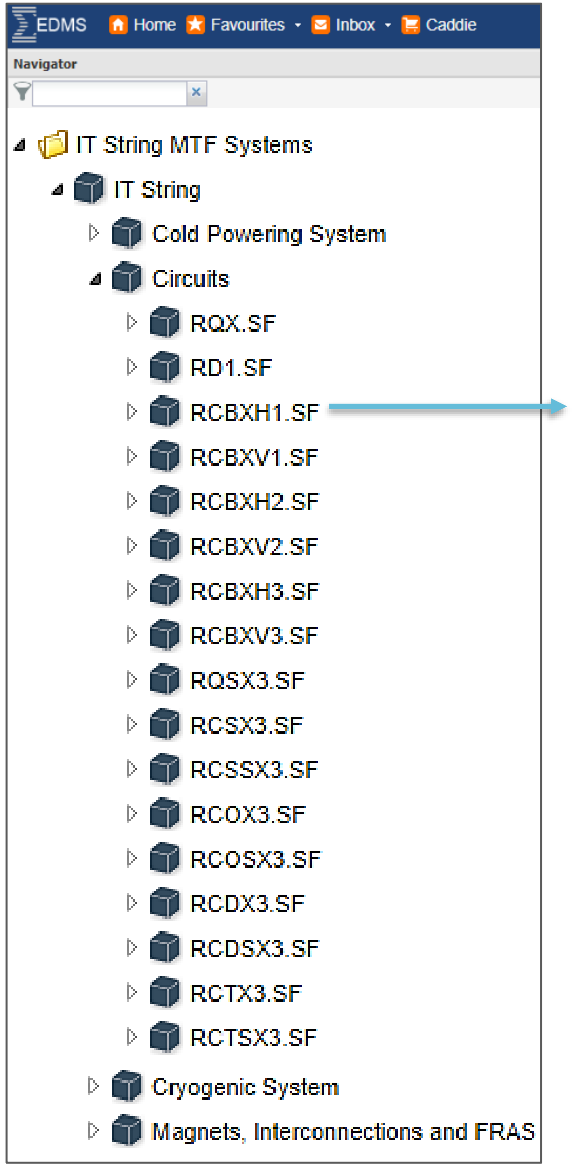
Checks
- Visual inspect.
- X-rays
- Vac. leak tests
- ElQA
- SCT
- …

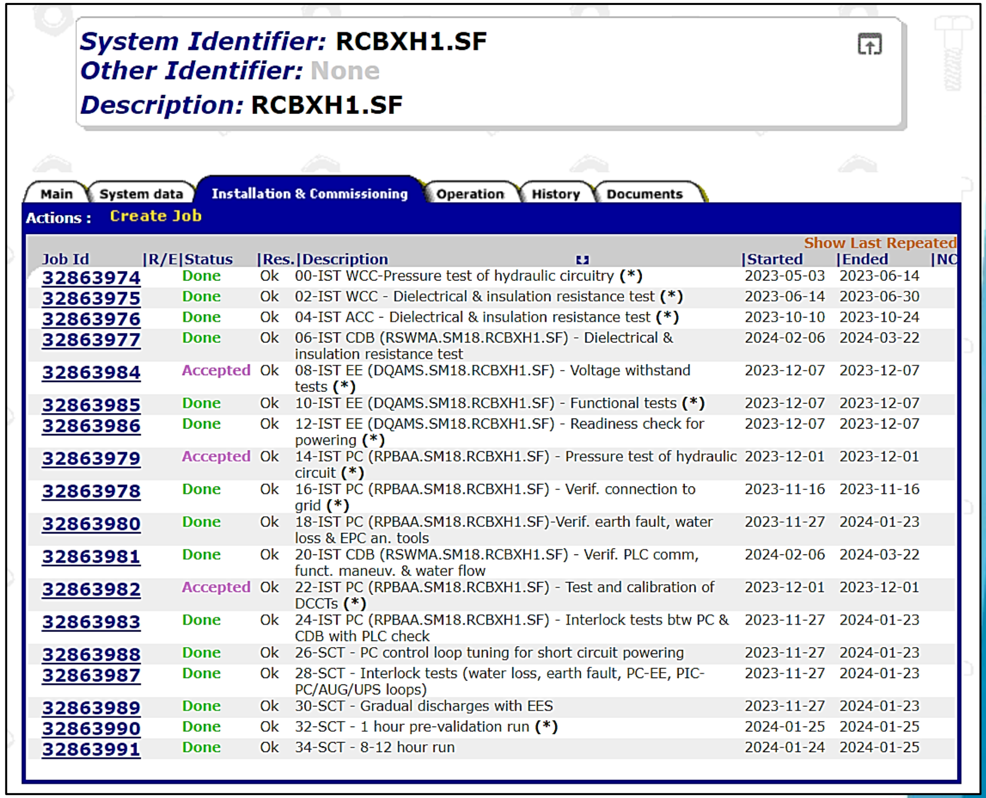




Quality control: MTF

- For the follow up of the quality checks WP16 proposed a MTF structure that was agreed with the HL-LHC Quality Office.
- The Manufacturing and Test Folder (MTF) is used at CERN to register manufacturing and quality control steps, it is imbricated in EDMS.
- The structure is divided in several systems, and steps are defined for each of them.
- Steps are extracted from test procedures.




System Identifier: RCBXH1.SF
Other Identifier: None
Description: RCBXH1.SF

Main | System data | Installation & Commissioning | Operation | History | Documents

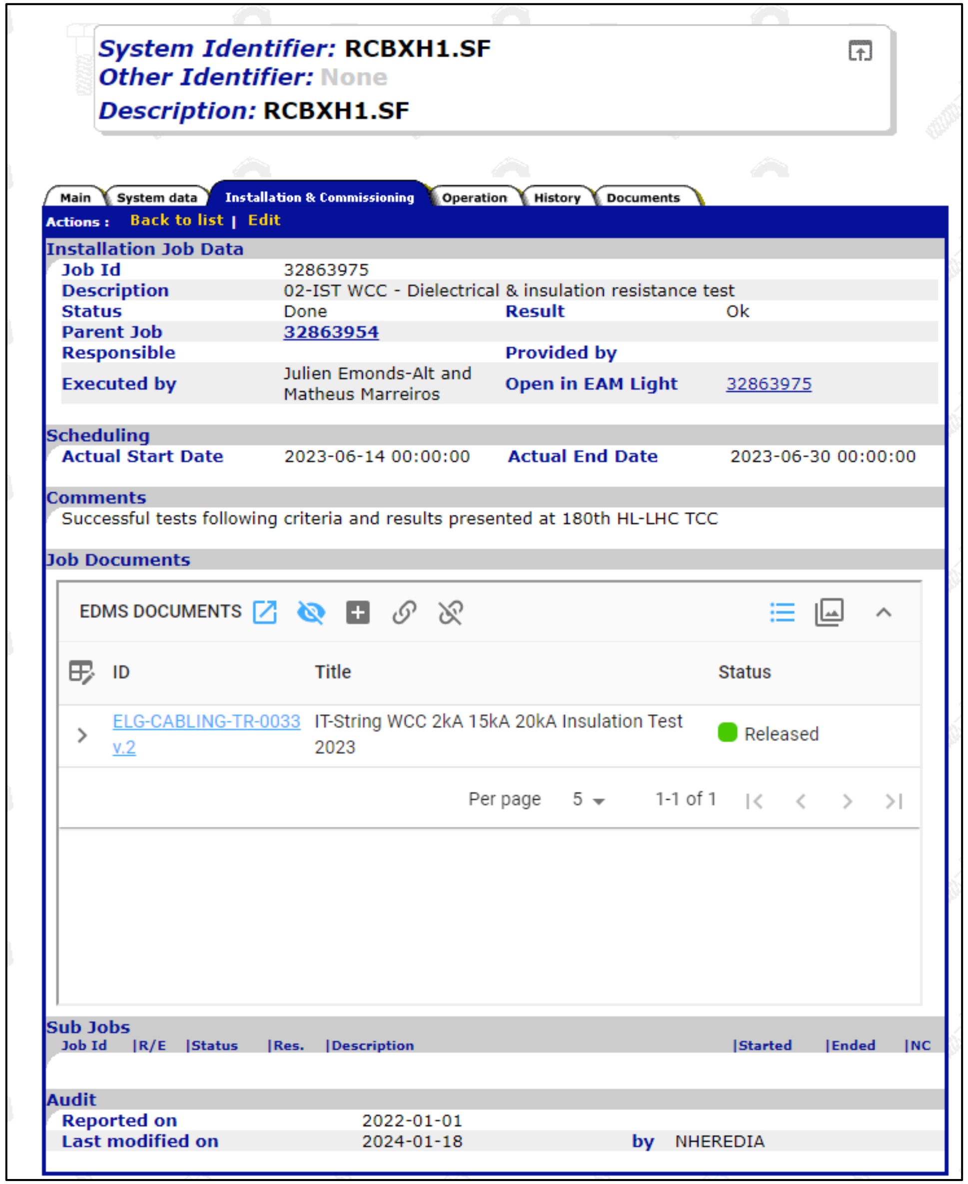
Actions : Create Job

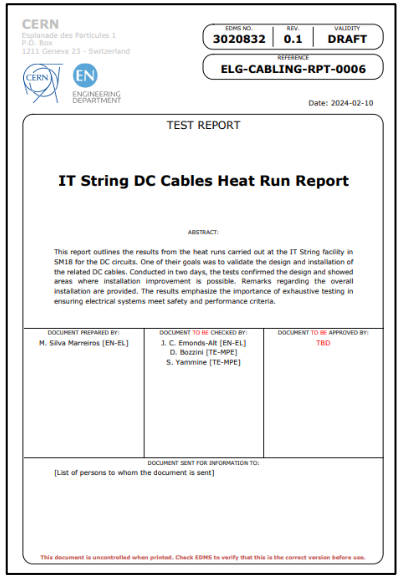
Show Last Repeated

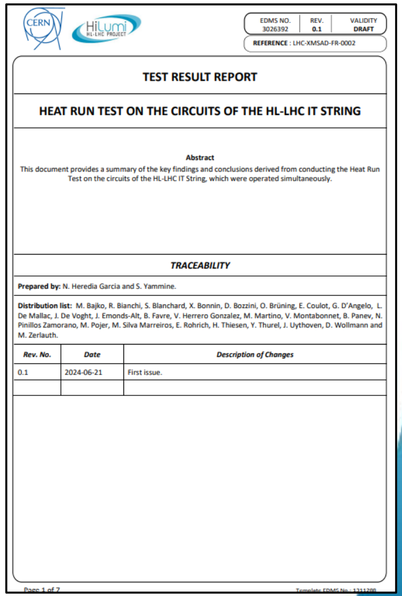
Job Id	R/E	Status	Res.	Description	Started	Ended	NC
32863974		Done	Ok	00-IST WCC-Pressure test of hydraulic circuitry (*)	2023-05-03	2023-06-14	
32863975		Done	Ok	02-IST WCC - Dielectrical & insulation resistance test (*)	2023-06-14	2023-06-30	
32863976		Done	Ok	04-IST ACC - Dielectrical & insulation resistance test (*)	2023-10-10	2023-10-24	
32863977		Done	Ok	06-IST CDB (RSWMA.SM18.RCBXH1.SF) - Dielectrical & insulation resistance test	2024-02-06	2024-03-22	
32863984		Accepted	Ok	08-IST EE (DQAMS.SM18.RCBXH1.SF) - Voltage withstand tests (*)	2023-12-07	2023-12-07	
32863985		Done	Ok	10-IST EE (DQAMS.SM18.RCBXH1.SF) - Functional tests (*)	2023-12-07	2023-12-07	
32863986		Done	Ok	12-IST EE (DQAMS.SM18.RCBXH1.SF) - Readiness check for powering (*)	2023-12-07	2023-12-07	
32863979		Accepted	Ok	14-IST PC (RPBAA.SM18.RCBXH1.SF) - Pressure test of hydraulic circuit (*)	2023-12-01	2023-12-01	
32863978		Done	Ok	16-IST PC (RPBAA.SM18.RCBXH1.SF) - Verif. connection to grid (*)	2023-11-16	2023-11-16	
32863980		Done	Ok	18-IST PC (RPBAA.SM18.RCBXH1.SF)-Verif. earth fault, water loss & EPC an. tools	2023-11-27	2024-01-23	
32863981		Done	Ok	20-IST CDB (RSWMA.SM18.RCBXH1.SF) - Verif. PLC comm, funct. maneuv. & water flow	2024-02-06	2024-03-22	
32863982		Accepted	Ok	22-IST PC (RPBAA.SM18.RCBXH1.SF) - Test and calibration of DCCTs (*)	2023-12-01	2023-12-01	
32863983		Done	Ok	24-IST PC (RPBAA.SM18.RCBXH1.SF) - Interlock tests btw PC & CDB with PLC check	2023-11-27	2024-01-23	
32863988		Done	Ok	26-SCT - PC control loop tuning for short circuit powering	2023-11-27	2024-01-23	
32863987		Done	Ok	28-SCT - Interlock tests (water loss, earth fault, PC-EE, PIC-PC/AUG/UPS loops)	2023-11-27	2024-01-23	
32863989		Done	Ok	30-SCT - Gradual discharges with EES	2023-11-27	2024-01-23	
32863990		Done	Ok	32-SCT - 1 hour pre-validation run (*)	2024-01-25	2024-01-25	
32863991		Done	Ok	34-SCT - 8-12 hour run	2024-01-24	2024-01-25	

Quality control: Steps

- Information included in a MTF step:
  - Description
  - Status
  - Executor
  - Activity start date
  - Activity end date
  - EDMS docs.: Test result reports, confirmation emails, non-conformities

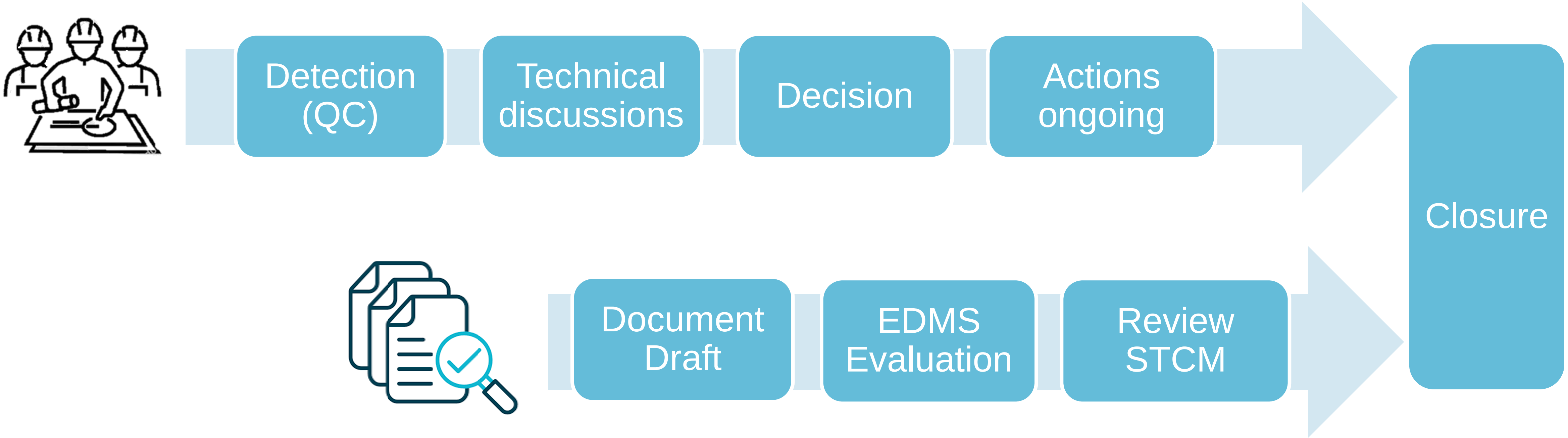






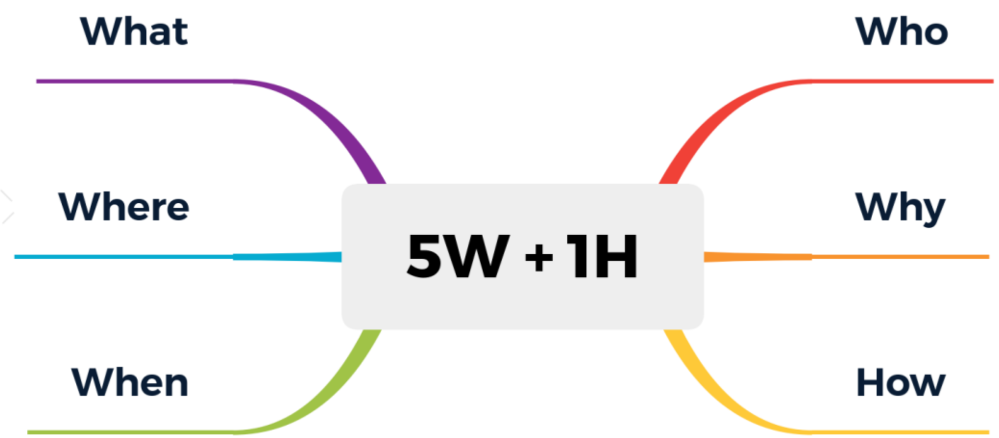
Non-conformities: Process

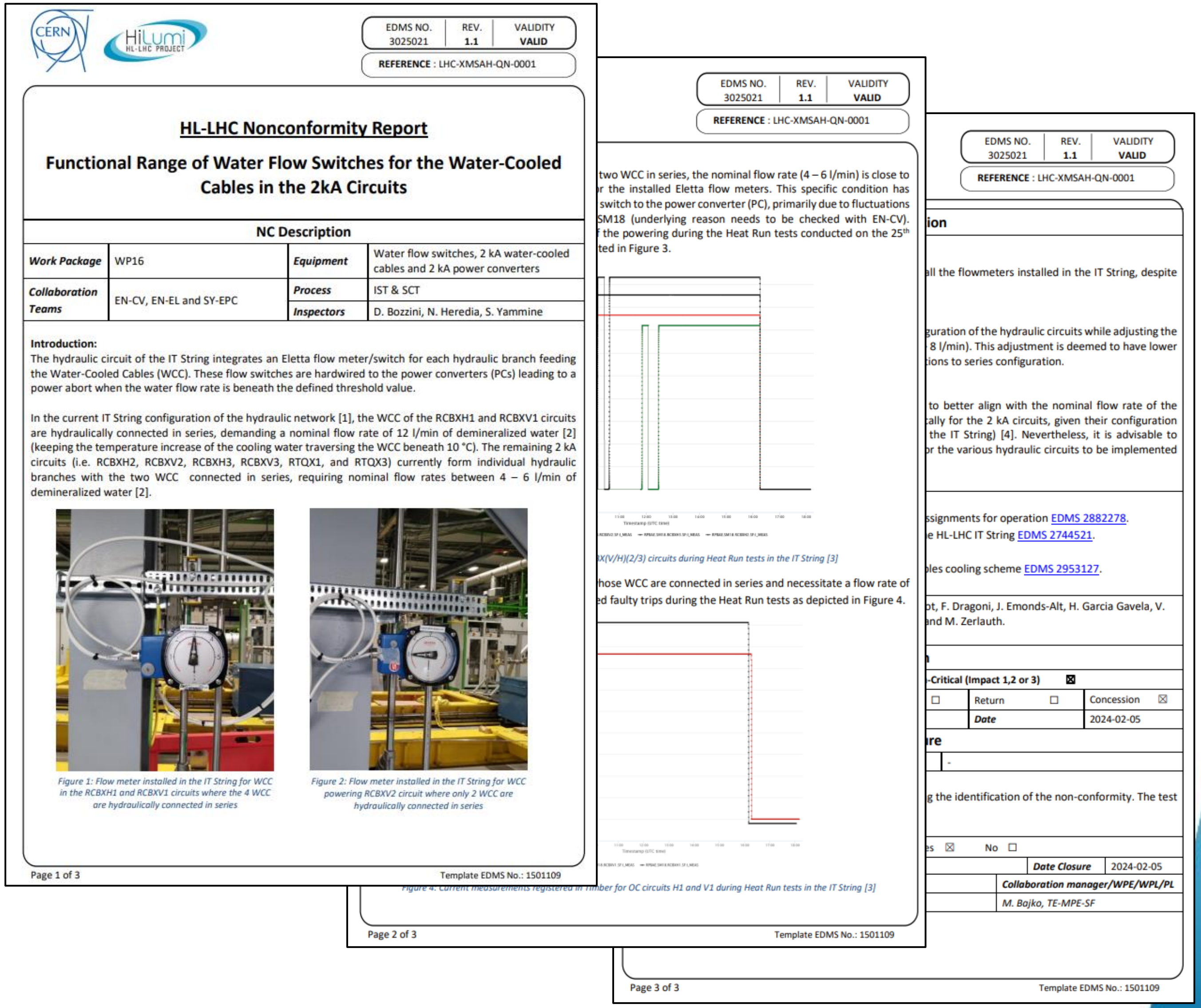
- HL-LHC process in place (https://edms.cern.ch/document/1499015):



Non-conformities: Template

- Information included in the non-conformity:





EDMS NO. 3025021 | REV. 1.1 | VALIDITY VALID
REFERENCE : LHC-XMSAH-QN-0001

HL-LHC Nonconformity Report

Functional Range of Water Flow Switches for the Water-Cooled Cables in the 2kA Circuits

NC Description			
Work Package	WP16	*Equipment*	Water flow switches, 2 kA water-cooled cables and 2 kA power converters
Collaboration Teams	EN-CV, EN-EL and SY-EPC	*Process*	IST & SCT
		Inspectors	D. Bozzini, N. Heredia, S. Yammine

Introduction:
The hydraulic circuit of the IT String integrates an Eletta flow meter/switch for each hydraulic branch feeding the Water-Cooled Cables (WCC). These flow switches are hardwired to the power converters (PCs) leading to a power abort when the water flow rate is beneath the defined threshold value.

In the current IT String configuration of the hydraulic network [1], the WCC of the RCBXH1 and RCBXV1 circuits are hydraulically connected in series, demanding a nominal flow rate of 12 l/min of demineralized water [2] (keeping the temperature increase of the cooling water traversing the WCC beneath 10 °C). The remaining 2 kA circuits (i.e. RCBXH2, RCBXV2, RCBXH3, RCBXV3, RTQX1, and RTQX3) currently form individual hydraulic branches with the two WCC connected in series, requiring nominal flow rates between 4 – 6 l/min of demineralized water [2].

Figure 1: Flow meter installed in the IT String for WCC in the RCBXH1 and RCBXV1 circuits where the 4 WCC are hydraulically connected in series

Figure 2: Flow meter installed in the IT String for WCC powering RCBXV2 circuit where only 2 WCC are hydraulically connected in series

Page 1 of 3 Template EDMS No.: 1501109

two WCC in series, the nominal flow rate (4 – 6 l/min) is close to … r the installed Eletta flow meters. This specific condition has … switch to the power converter (PC), primarily due to fluctuations … SM18 (underlying reason needs to be checked with EN-CV). … f the powering during the Heat Run tests conducted on the 25th … ted in Figure 3.

…X(V/H)(2/3) circuits during Heat Run tests in the IT String [3]

…hose WCC are connected in series and necessitate a flow rate of … ed faulty trips during the Heat Run tests as depicted in Figure 4.

Figure 4: Current measurements registered in Timber for OC circuits H1 and V1 during Heat Run tests in the IT String [3]

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…ll the flowmeters installed in the IT String, despite …

…guration of the hydraulic circuits while adjusting the … 8 l/min). This adjustment is deemed to have lower … ions to series configuration.

… to better align with the nominal flow rate of the … ally for the 2 kA circuits, given their configuration … the IT String) [4]. Nevertheless, it is advisable to … r the various hydraulic circuits to be implemented

…ssignments for operation EDMS 2882278.
…e HL-LHC IT String EDMS 2744521.
…les cooling scheme EDMS 2953127.

…t, F. Dragoni, J. Emonds-Alt, H. Garcia Gavela, V. … nd M. Zerlauth.

…-Critical (Impact 1,2 or 3) ☒

☐ Return ☐ Concession ☒
Date 2024-02-05

…g the identification of the non-conformity. The test …

…s ☒ No ☐

Date Closure 2024-02-05
Collaboration manager/WPE/WPL/PL
M. Bajko, TE-MPE-SF

Page 3 of 3 Template EDMS No.: 1501109

Non-conformities: Table

- Table of non-conformities to keep track of documentation status. Reviewed at the String Technical Coordination Meeting.

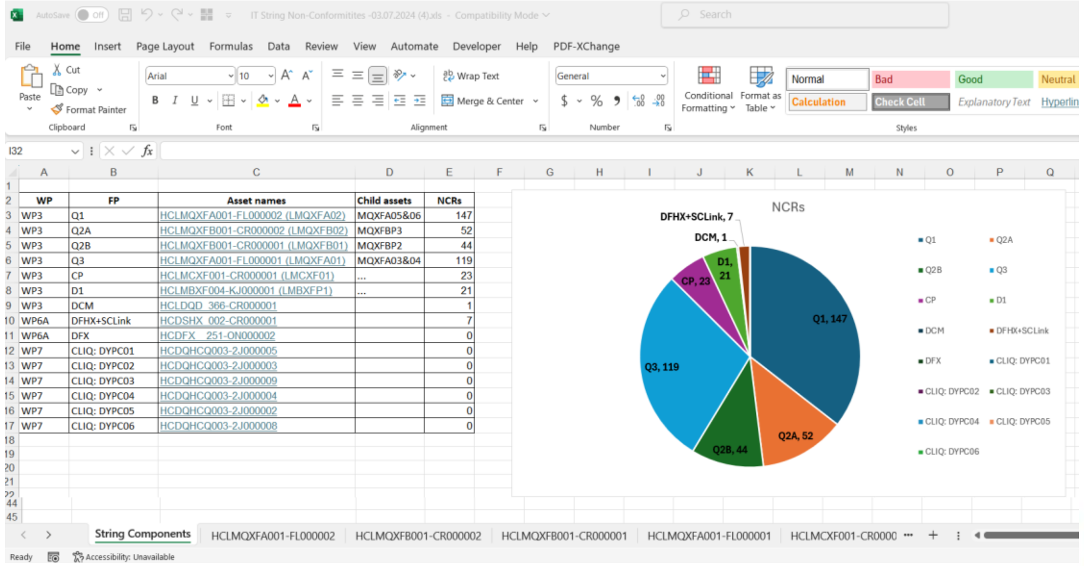
Ref.	NCR Description	Status	Ap. Date	EDMS	Criticality	Decision	Manag. team	Equipment	Detect. phase	Det. Year	Class
	NCR of TL02	1. To be Opened	TBD	TBD	Non-Critical	Repair	WP16	Cryogenics	Commissioning	2024	Mechanical
LHC-XMSAD-QN-0003	NCR of water-cooling plates for busbars	2. In Work	TBD	3162382	Non-Critical	Repair	WP16	Warm powering	Commissioning	2024	Manufacturing
LHC-XMSA-QN-0002	NCR - Integration conflict between alignment system and SQXL	2. In Work	TBD	3153667	Non-Critical	Repair	WP16	FRAS	Integration	2024	Integration
LHC-XMSAH-QN-0003	NCR - Acceptance criteria for WCC High Voltage Tests in the HL-LHC IT String	2. In Work	TBD	3045592	Non-Critical	Concession	WP16	Electrical infrastructure	Commissioning	2023	Electrical
LHC-XMSAA-QN-0001	NCR - Excessive Heat Load Detected in Line C within TL01	2. In Work	TBD	3044384	Non-Critical	Repair	WP16	Cryogenics	Operation	2023	Mechanical
LHC-XMSAA-QN-0005	NCR - Leak tightness of the SQXL main volume envelope	2. In Work	TBD	3075007	Non-Critical	Repair	WP16	Cryogenics	Commissioning	2024	Vacuum
LHC-XMSAH-QN-0004	NCR - WCC weight distribution plates at the extremities of the cable trays	4. Closed	15/07/2024	3117788	Non-Critical	Repair	WP16	Electrical infrastructure	Installation	2024	Mechanical
LHC-XMSAH-QN-0002	Non-conformity of cables trays supporting system for WCC	4. Closed with Warnings	15/07/2024	2804269	Non-Critical	Repair	WP16	Electrical infrastructure	Operation	2022	Mechanical
LHC-XMSA-QN-0001	NCR - Conflict between cable trays and ROCLA in the racks zone	4. Closed	07/06/2024	3093233	Non-Critical	Repair	WP16	Electrical infrastructure	Operation	2024	Transport
LHC-XMSAC-QN-0001	Flexible busbars manufacturing for the IT String	4. Closed	13/05/2024	3045423	Non-Critical	Repair	WP16	Cold powering	Installation	2023	Manufact. & instal.
LHC-XMSAD-QN-0001	Cable convention for connecting water flow switches to 14 and 18 kA PC	4. Closed	29/04/2024	3018444	Non-Critical	Repair	WP16	Water distribution system	Commissioning	2024	Electrical
LHC-XMSAH-QN-0001	NCR - Water Flow Switches Functional Range for the Water-Cooled Cables on the 2kA Circuits	4. Closed	29/04/2024	3025021	Non-Critical	Concession	WP16	Water distribution system	Operation	2024	Other
LHC-XMSAA-QN-0002	IT STRING - NCR - SQXL - Shape of service modules	4. Closed	22/03/2024	2961669	Non-Critical	Concession	WP16	Cryogenics	Installation	2022	Mechanical
LHC-XMSAA-QN-0003	IT STRING - NCR - SQXL - Pipe element vacuum vessel reinforcement	4. Closed	22/03/2024	2961672	Non-Critical	Repair	WP16	Cryogenics	Installation	2023	Mechanical
LHC-XMSAA-QN-0004	IT STRING - NCR - SQXL - DN100 Instrumentation Feedthroughs	4. Closed	22/03/2024	2961678	Non-Critical	Repair	WP16	Cryogenics	Commissioning	2023	Manufact. & instal.
LHC-XMS-QN-0001	Non-conformity SM18 floor for jack shims Q3	4. Closed	02/04/2024	2872779	Non-Critical	Concession	WP16	FRAS	Integration	2023	Integration

Non-conformities: Quality Meetings

- A series of meeting have been launched with the HL-LHC Quality Office. Assets codes of the equipment coming to the IT String are been identified.

- Using the asset codes, non-conformities have been extracted using Pentaho tool and some of them reviewed. Also, assets will be attached to the String MTF structure to have full traceability of their installation.

- On a weekly basis, the HL-LHC Quality Office informs WP16 via email about the status of open non-conformities in the HL-LHC project.



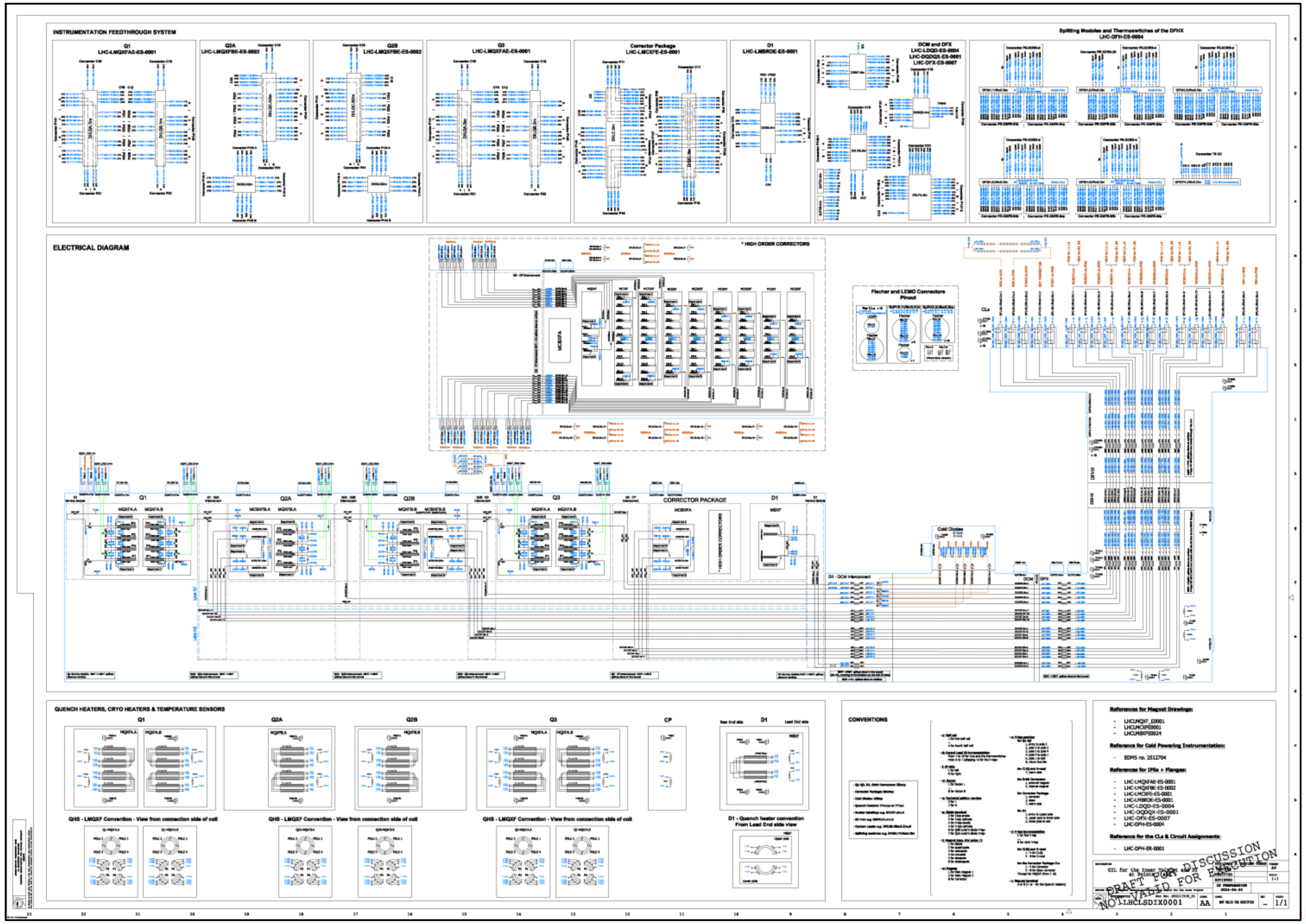
WP	FP	Asset names	Child assets	NCRs
WP3	Q1	HCLMQXFA001-FL000002 (LMQXFA02)	MQXFA05&06	147
WP3	Q2A	HCLMQXFB001-CR000002 (LMQXFB02)	MQXFBP3	52
WP3	Q2B	HCLMQXFB001-CR000001 (LMQXFB01)	MQXFBP2	44
WP3	Q3	HCLMQXFA001-FL000001 (LMQXFA01)	MQXFA03&04	119
WP3	CP	HCLMCXF001-CR000001 (LMCXF01)	...	23
WP3	D1	HCLMBXF004-KJ000001 (LMBXFP1)	...	21
WP3	DCM	HCLDQD 366-CR000001		1
WP6A	DFHX+SCLink	HCDSHX 002-CR000001		7
WP6A	DFX	HCDFX 251-ON000002		0
WP7	CLIQ: DYPC01	HCDQHCQ003-2J000005		0
WP7	CLIQ: DYPC02	HCDQHCQ003-2J000003		0
WP7	CLIQ: DYPC03	HCDQHCQ003-2J000009		0
WP7	CLIQ: DYPC04	HCDQHCQ003-2J000004		0
WP7	CLIQ: DYPC05	HCDQHCQ003-2J000002		0
WP7	CLIQ: DYPC06	HCDQHCQ003-2J000008		0

Non-conformities: Quality Meetings

- For the equipment non-conformities tagged as “electrical”, an exercise is being initiated in the coordination team to integrate them as part of the general instrumentation layout drawing.

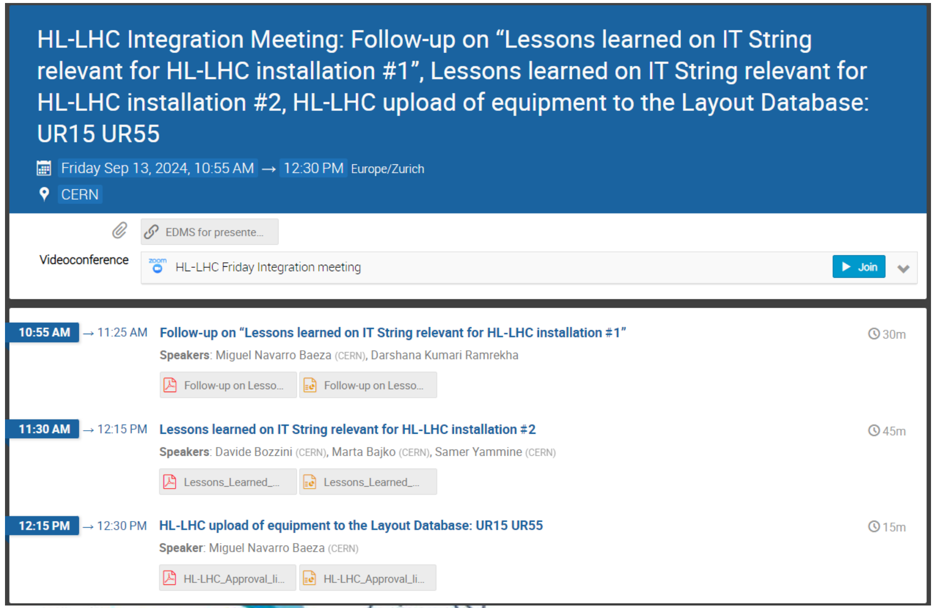
- Deviations from the baseline will also be signaled in this “As-built” drawing.

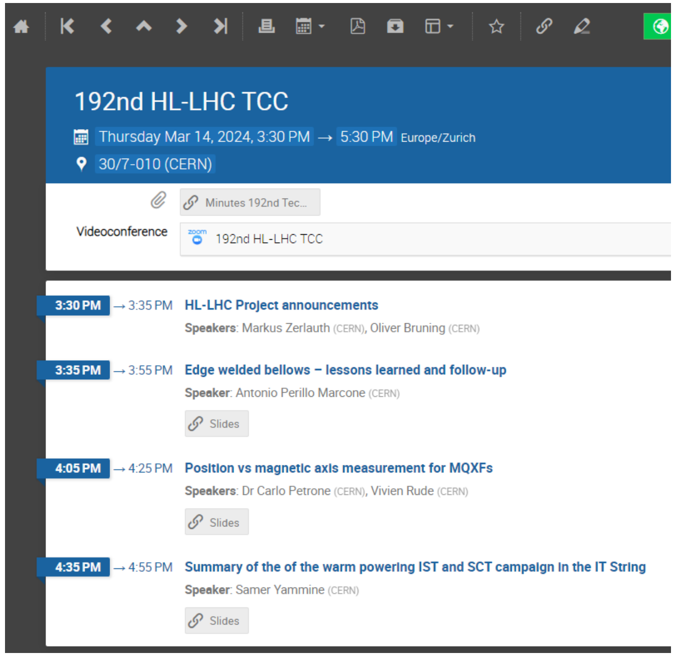
- This drawing will help to analyse the test results.

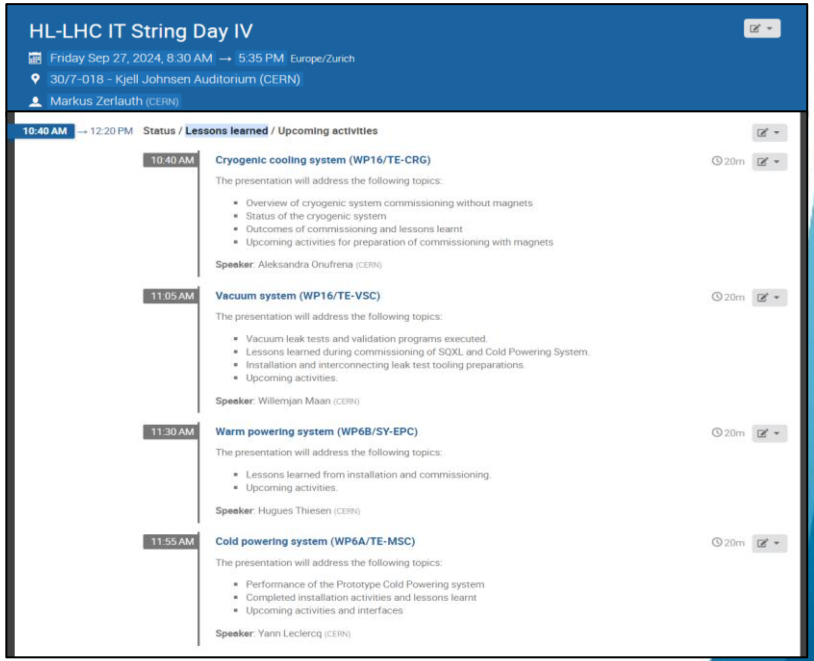


Lessons Learned

- Lessons learned have been transmitted to the HL-LHC project in different forums (WP15 integration meeting, TCC, String Day).
- Non-conformity reports contain a chapter dedicated to lessons learned.
- Working meetings have been organised with the intervening teams after completing an installation to discuss areas of improvement.
- A document of lessons learned will be drafted to gather all the feedback communicated.







Conclusions

- Sound quality processes are in place in the IT String, with improvements in various aspects.
- Effective collaboration and support from the HL-LHC quality office to deal with quality subjects.
- Intervening teams are committed to quality, and they count with experience in quality assurance/control methods.
- WP16 discovered non-conformities up to now are not critical and corrective measurement have been successfully implemented.
- A meeting dedicated to quality is launched to review, among others, equipment non-conformities potentially affecting the IT String.
- Lessons learned from the IT String experience have been gathered and communicated.

Thank you for your attention