



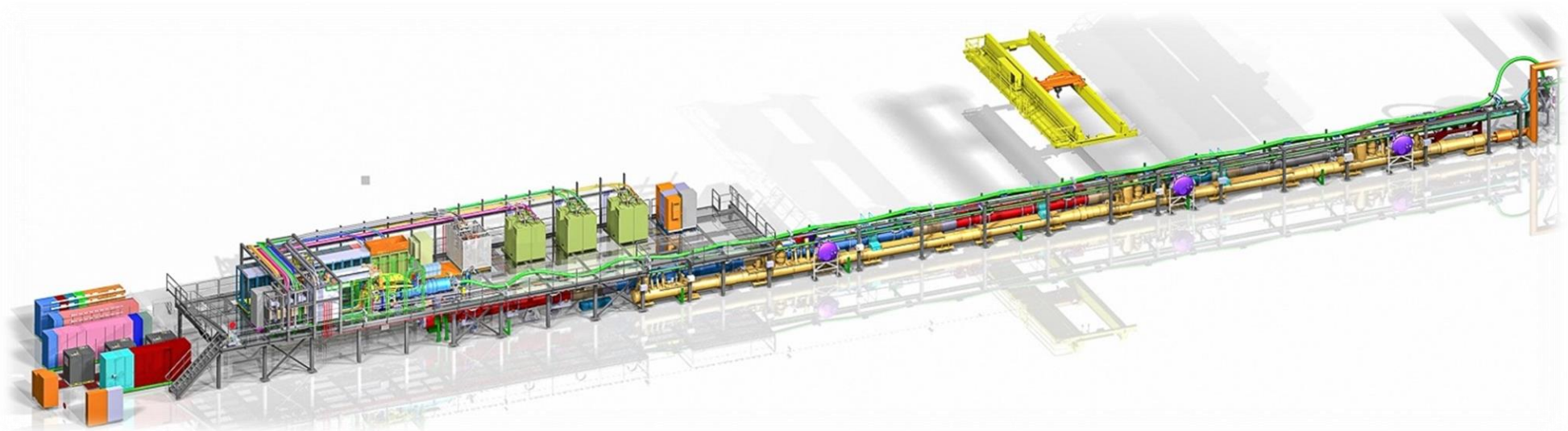
# HL-LHC IT String Quality Assurance & Control

N. Heredia García (TE-MPE-SF)

On behalf of WP16

# Scope of the talk

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



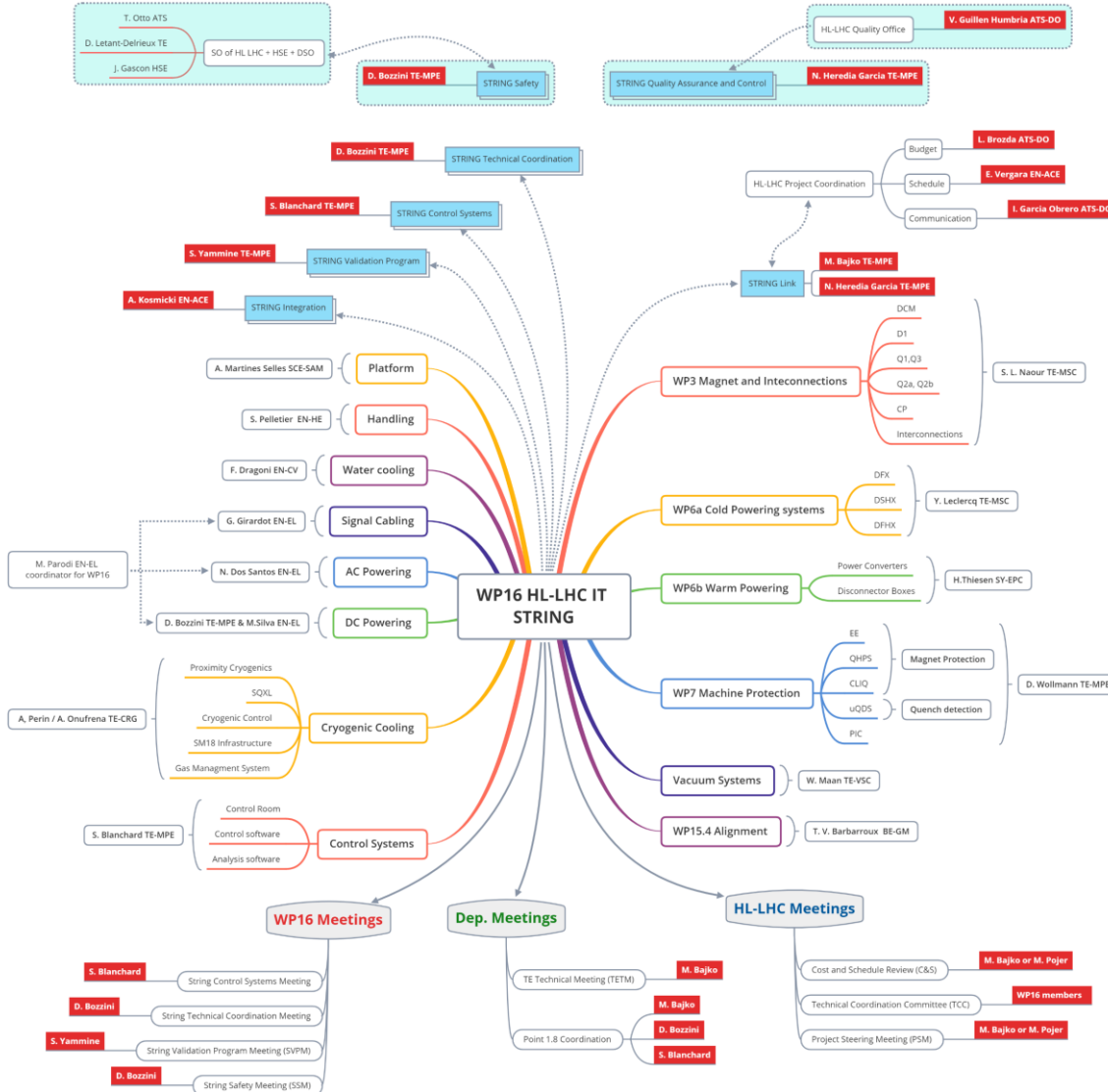
# Introduction

- 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](#).

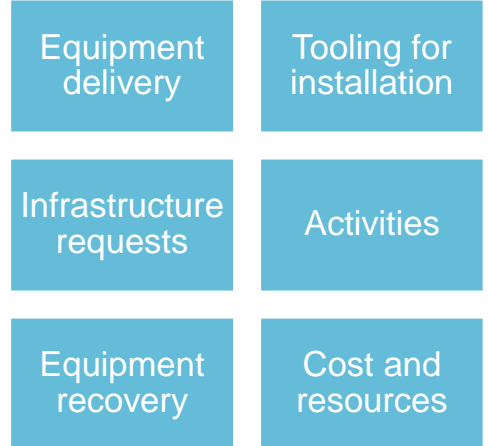
Phase	Goal	Description
Quality design	Plan quality management	Understand the specific needs and requirements of the project. It involves the definition of processes, tools and performance metrics.
Quality assurance	Manage quality	Ensure that the project meets the defined quality standards and requirements. 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



ENEA NO.	REV.	VALIDITY
CHANGE I.D.	LIB.	INDEX
REFERENCE: LHC-IMP-ES-0004		
<b>CONTRIBUTION DOCUMENT</b>		
<b>WP16: HL-LHC IT STRING &amp; HARDWARE COMMISSIONING</b>		
<b>SUMMARY OF TE-MSC CONTRIBUTION (MAGNETS) TO WP16 – IT STRING</b>		
<b>Abstract</b>		
This document summarises the contribution of TE-MSC group for the HL-LHC IT String. It relates 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.		
<b>TRACEABILITY</b>		
Prepared by:	S. La Rosa, N. Heredia Garcia	Date: 2024-03-16
Approved by:	N. Pico, N. Bourry, D. Duarte Ramos, E. Todesco and A. Balzano	Date: 2024-03-22
Authorised by:	A. Milani, J. Sathyan and M. Bako	Date: 2024-03-21
Description: All TE-MSC members, M. Zambelli		
Rev. No.	Date	Description of Changes (major changes only, minor changes in EDMS)
0.1	2023-03-16	First issue
0.2	2023-09-02	Update of the document
0.3	2023-10-10	Update of engineer responsible for the DCM

## Safety analysis

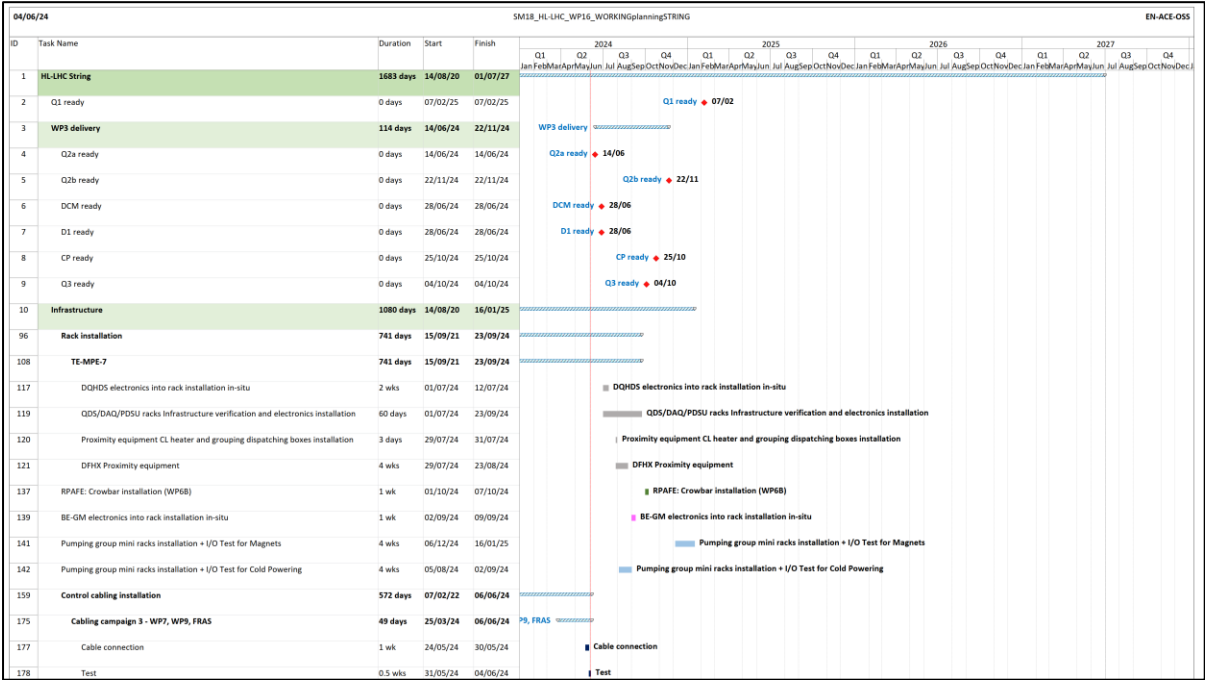
ENEA NO.	REV.	VALIDITY
CHANGE I.D.	LIB.	INDEX
REFERENCE: LHC-IMP-ES-0004		
<b>SAFETY DOCUMENT</b>		
<b>FMEA applied to test facility HL LHC IT STRING</b>		
<b>Failure Modes and Effects Analysis (FMEA)</b>		
<b>Test Stand HL LHC IT STRING</b>		
<b>Summary</b>		
This document is a Failure Modes and Effects Analysis - Safety (FMEA - Safety) of the various functions of the "HL LHC IT STRING" test bench located in building 213 (SM18). The study focuses on the detailed identification of all undesirable effects within the defined limits of the system under analysis. It also defines the measures to be implemented in order to improve the reliability and safety of the system. The present study is conducted by a working group involving a safety engineer and various individuals who worked on the design of the "HL LHC IT STRING". This method is applied to ensure the safety of personnel present at SM18 during the operational phases of the test bench.		
<b>Participants in the study:</b>		
<ul style="list-style-type: none"> <li>Emmanuel Bigot</li> <li>Marta Bajko</li> <li>Christian Gilmore</li> <li>Nora Girard</li> <li>Thomas Otto</li> <li>Samer Yammine</li> <li>Fabian Dhalaj</li> <li>Gabriella Rolandi</li> <li>Michèle Sisti</li> <li>Alain Antoine</li> <li>Yann Leclercq</li> <li>Felicitas Jenette</li> <li>De Luca Davide</li> </ul>	<ul style="list-style-type: none"> <li>Safety engineer</li> <li>Section leader</li> <li>Engineer (Section MSC-TE)</li> <li>HL-LHC Safety Support Officer</li> <li>DSO (Departmental Safety Officers)</li> <li>Warm powering system (EPC)</li> <li>Cryogenic System (TE-CRG)</li> <li>Cryogenic System (TE-CRG)</li> <li>Cryogenic System (TE-CRG)</li> <li>Powering Interlocks (PI)</li> <li>Magnets Cryostats &amp; Connections (MSC)</li> <li>Magnets Cryostats &amp; Connections (MSC)</li> <li>Water Cooled Cables (EN EL)</li> </ul>	

## Test plan

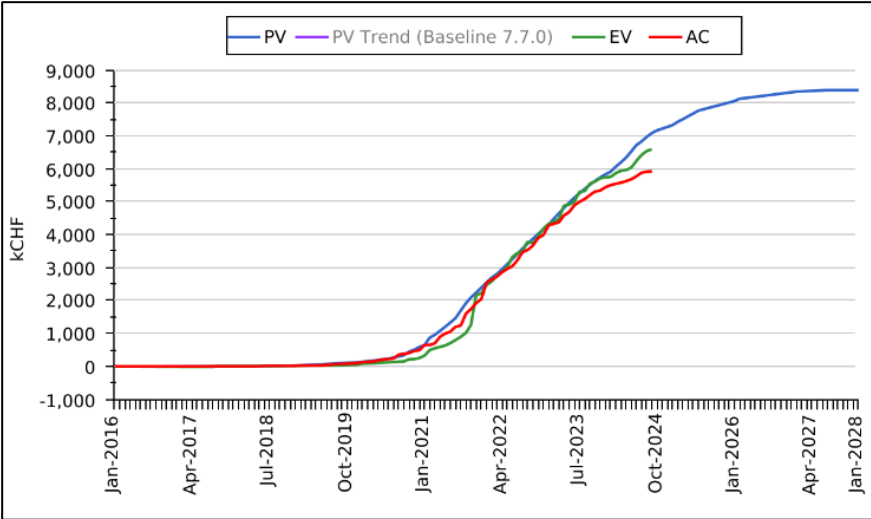
ENEA NO.	REV.	VALIDITY
CHANGE I.D.	LIB.	INDEX
REFERENCE: LHC-IMP-ES-0004		
<b>TEST PLAN</b>		
<b>HL-LHC INNER TRIPLET STRING</b>		
<b>HL-LHC IT STRING VALIDATION PROGRAM</b>		
<b>Abstract</b>		
The HL-LHC Inner Triplet (IT) String is a test stand, whose goal is to validate the collective behaviour of 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).		
<b>TRACEABILITY</b>		
Prepared by:	M. Bajko, N. Heredia Garcia, M. Pagan and S. Yammine	Date: 2022-03-05
Verified by:	M. Boharik, S. Blanchard, D. Bozzini, G. D'Angelo, G. Danilak, I. De Marco, R. Doria, J. Fisher, D. Girardin, M. Gamba, M. Garavito, K. Goude, M. Harty, S. Istantopol, W. Mann, M. Moser, A. Paris, E. Reavell, G. Roberts, S. Santilli, S. Santilli, G. Santilli, S. Thomas, A. Trossello and J. Zambelli	Date: 2022-02-21
Approved by:	V. Baglini, D. Spring, M. Sisti, A. Balzano, F. Chigiolini, S. Cusack, A. Denner, P. Ferras, B. Garabito, J. G. Gomez, B. Hestermann, M. Martin, A. Masi, V. Masettani, T. Ochi, M. Pagan, F. Rodriguez-Morales, I. Sorrento, A. Spentini, L. Taccetti, E. Todesco, B. Trossello, S. Yammine, D. Zambelli and M. Zambelli	Date: 2022-04-05
Description: F. Ferras, B. Garabito, J. G. Gomez, B. Hestermann, M. Martin, A. Masi, V. Masettani, T. Ochi, M. Pagan, F. Rodriguez-Morales, I. Sorrento and M. Zambelli		
Rev. No.	Date	Description of Changes (major changes only, minor changes in EDMS)
1.0	2022-04-27	Document released

# Quality design: Tools

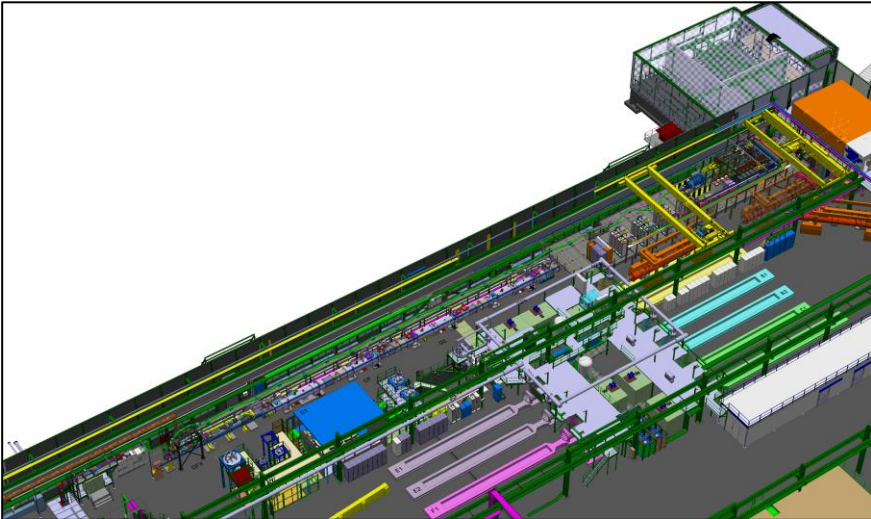
## Project planning



## Cost tracking



## Integration model

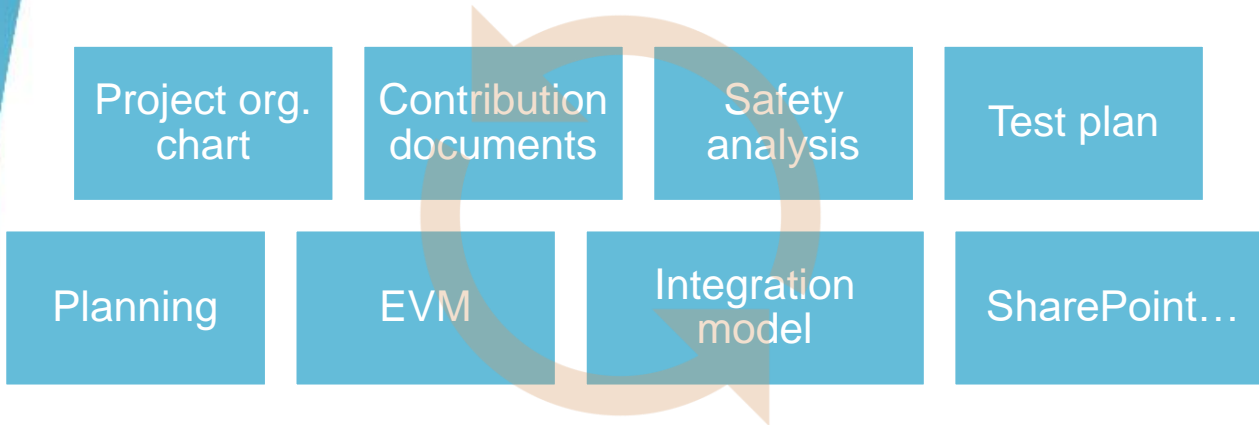


## Other tools



# Quality Assurance: Process

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



- 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*

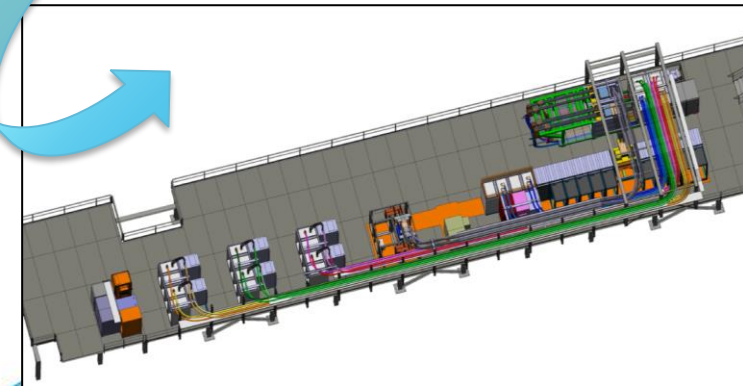
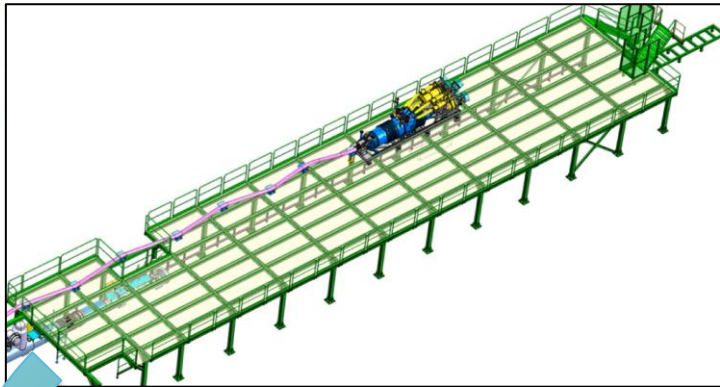
*Cost & Schedule Review*

*HL-LHC Annual Meeting*

# Quality Assurance: Examples

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

## Installation sequence

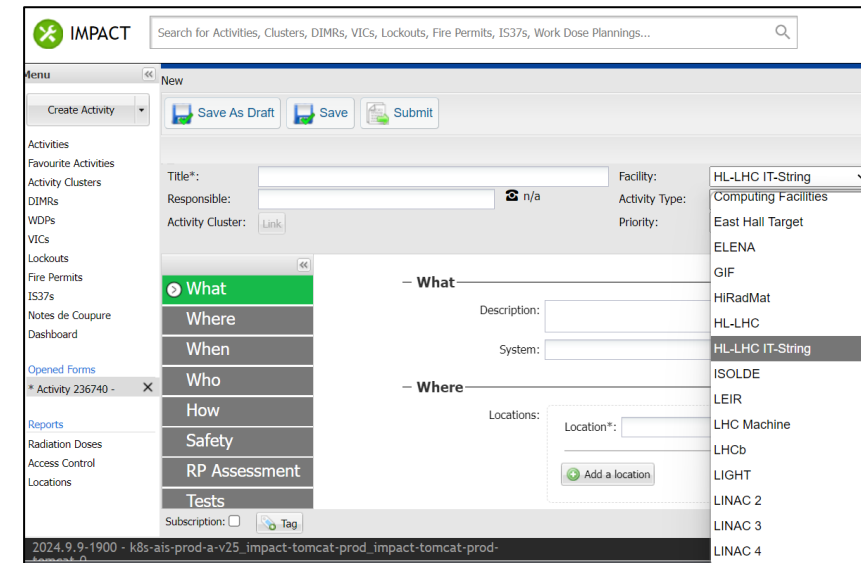


## Coordination

Sep-24 IT-STRING

	GROUND FLOOR AREA										MEZZANINE AREA				CR					
	RACKS	Q1	Q2a	Q2b	Q3	CP	D1	DCM	SOXL	DFX	DSH	DFHX	18 kA	14 kA	2 kA	EE	SF-HO	INT	EXT	
35																				
36																				
37																				
38																				
39																				

## Access

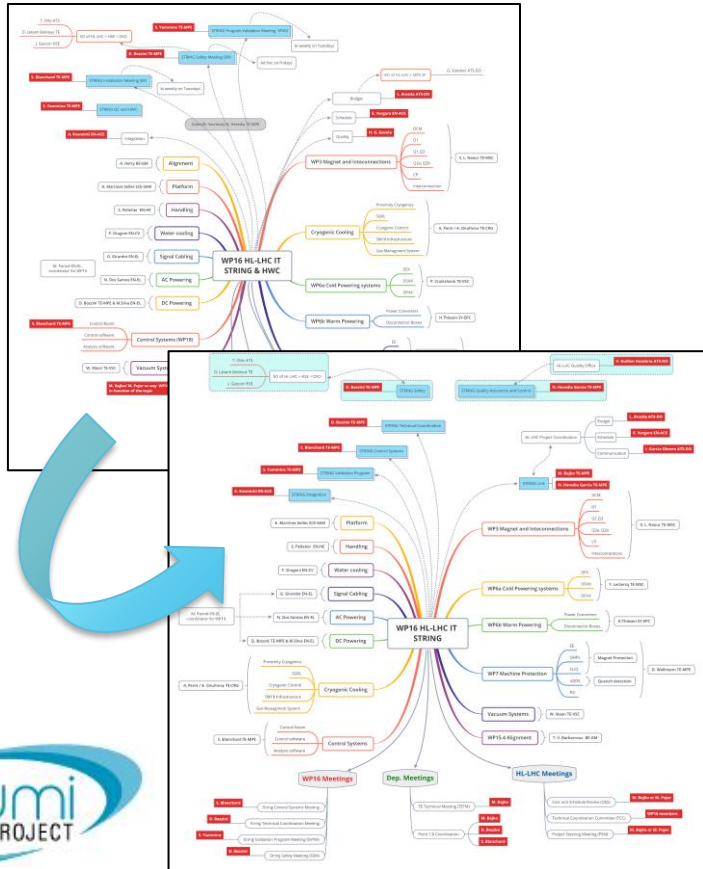


More info in "HL-LHC IT String Technical Coordination & Safety" by D. Bozzini

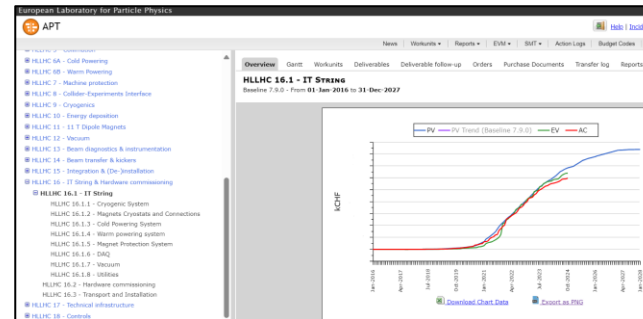
# Quality Assurance: Examples

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

## Roles and responsibilities

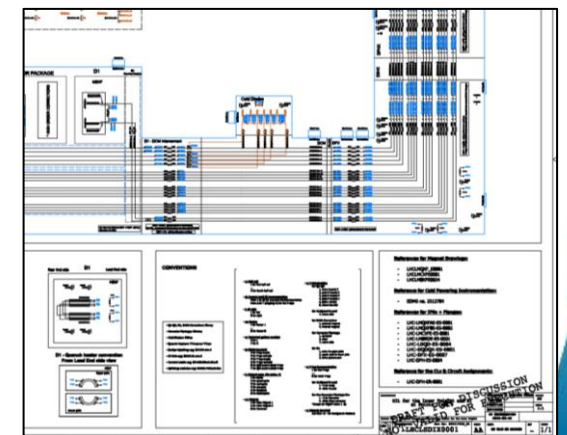
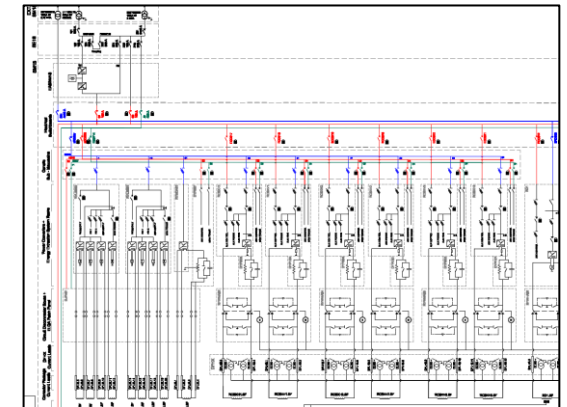


## Cost monitoring



The screenshot shows the 'CET Desktop' web application interface. The header includes the user's name 'JONSSON, Per Gunnar Mr.' and the date '01.04.2009'. Below the header, there is a navigation bar with tabs for 'Welcome', 'Contracts', 'Transactions and Orders', 'Summaries and Totals', 'CFUtK', 'Info and Misc', and 'My Stuff'. The main content area displays a 'Welcome to the CET Desktop' message and a list of 'Common Reports' including 'Transactions By Cost Centre', 'Team Transactions', 'Contract List', 'Contract Overview', 'Summaries/Pivot', 'Totals by Cost Centre', 'Monthly Totals', and 'Totals for Teams'. The interface is designed for project management and financial reporting.

## Operational drawings





# 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

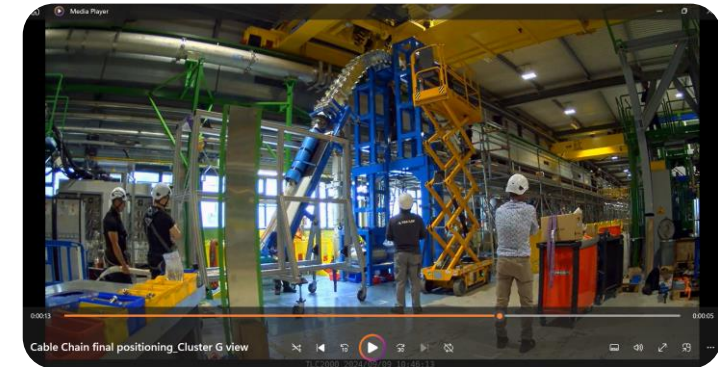
IFAST

EuPRAXIA

EASITrain

Knowledge Transfer

€1M innovation fund for sustainable accelerat...  
IFAST (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

**IT STRING: DESIGN AND PLANNING**

**THE IT STRING GOAL**

**SAFETY**

**ALIGNMENT SYSTEM**

**THE CIRCUIT AND PROTECTION**

**THE STRING VALIDATION PROGRAM**

**HANDING AND INSTALLATION**

**VACUUM SYSTEM**

**CONCLUSION**

## MT 28 (2023)

**HL-LHC IT STRING status and perspectives**

**STATUS**

**PERSPECTIVES**

## IPAC 24

**Hardware Commissioning of the HL-LHC Inner Triplet String Facility at CERN: Individual System and Short Circuit Tests**

**HL-LHC INNER TRIPLET STRING AT CERN**

**CRYOGENIC SYSTEM TESTS**

**INDIVIDUAL TESTS OF THE WARM POWERING SYSTEMS AND SHORT CIRCUIT TESTS**

## ASC 24

**TRANSFORMING CONCEPT INTO REALITY: OVERCOMING CHALLENGES IN THE HL-LHC IT STRING TEST STAND IMPLEMENTATION**

**Quality Assurance & Control in the HL-LHC IT String**

**QUALITY MANAGEMENT**

**QUALITY ASSURANCE**

**QUALITY CONTROL**



# 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

EDMS NO. 2102130 REV. 1.0 VALIDITY VALUO REFERENCE: LHC-XMS-EC-0002

**HL – LHC Engineering Change Request EXCLUSION OF THE BEAM SCREEN IN THE IT STRING**

**ECR DESCRIPTION**

WP Originator	WPSE	Process	Engineering, Integration
Equipment	LHCXMS	Baseline affected	Scope, Schedule, Cost
Drawing	Drawing(s) concerned	Date of issue	2022-02-03
Document	Document(s) concerned	CI responsible	M. Bujko
WP Affected	WP1, WP2, WP3	Reference Document	TDR version 1.0

**Detailed Description**

The cryosystems composing the HL-LHC IT STRING are D1, D2, D3, D4, D5, D6, D7, D8, D9, D10, D11, D12, D13, D14, D15, D16, D17, D18, D19, D20, D21, D22, D23, D24, D25, D26, D27, D28, D29, D30, D31, D32, D33, D34, D35, D36, D37, D38, D39, D40, D41, D42, D43, D44, D45, D46, D47, D48, D49, D50, D51, D52, D53, D54, D55, D56, D57, D58, D59, D60, D61, D62, D63, D64, D65, D66, D67, D68, D69, D70, D71, D72, D73, D74, D75, D76, D77, D78, D79, D80, D81, D82, D83, D84, D85, D86, D87, D88, D89, D90, D91, D92, D93, D94, D95, D96, D97, D98, D99, D100, D101, D102, D103, D104, D105, D106, D107, D108, D109, D110, D111, D112, D113, D114, D115, D116, D117, D118, D119, D120, D121, D122, D123, D124, D125, D126, D127, D128, D129, D130, D131, D132, D133, D134, D135, D136, D137, D138, D139, D140, D141, D142, D143, D144, D145, D146, D147, D148, D149, D150, D151, D152, D153, D154, D155, D156, D157, D158, D159, D160, D161, D162, D163, D164, D165, D166, D167, D168, D169, D170, D171, D172, D173, D174, D175, D176, 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**Reasons for change**

The reason for the change is the optimisation of the configuration, budget, and planning of the two main affected WPs, WP1 and WP2. Following the process, the beam screen presence in the STRING resulted not to be critical considering that the tests of the beam screens are being done on individual magnets and off line. As an example, the beam screen of the Q1 type magnets has been tested in the cryo lab for its thermal behaviour and in the model magnet (MDP54) in a vertical cryostat for its thermo-mechanical behaviour in the presence and use of the Q1 protection system.

**Impact on Cost, Schedule & Performance**

Page 1 of 3 Template EDMS No.: 1202829

Ex: [EDMS 2102130](#)

## SCR

EDMS NO. 2799934 REV. 1.0 VALIDITY VALUO REFERENCE: LHC-XMS-EC-0003

**HL – LHC Schedule Change Request Shift of Milestones in the HL-LHC IT String**

**SCR DESCRIPTION**

WP Originator	WP16	Baseline affected	Schedule
Equipment	IT String	Date of issue	2022-11-23
Drawing	-	CI responsible	M. Bujko
Document	WP16 planning	Reference Document	EDMS No. 2102130
WP Affected	WP1, WP6A, WP6B, WP7, WP13A, TE-CRS, EN-EL, TE-VSC, TE-MSC, TE-MFE and EN-HE	-	-

**Detailed Description**

The milestones of the HL-LHC IT String concerning its installation and operation are largely determined by the delivery of the major HL-LHC components by the different Work Packages. The critical path is today defined by the arrival of the last magnet, the interconnection process and the operational phase, all of which have to be executed sequentially. The subcritical item is today the delivery of the SC Link system for installation in the IT String. Table 1 summarises the major shifts in the HL-LHC IT String milestones occurred since the CBS Review 2021.

Milestone	Baseline 2 CBS Rev. 2021	Baseline 4 CBS Rev. 2022	Δt (months)
1. End of cryogenics commissioning without magnets	20/02/2023	31/10/2023	+ 8
2. End of power converters installation (including electronics)	12/05/2023	26/05/2023	+ 0.5
3. End of WP7 racks installation (including electronics)	26/05/2023	26/05/2023	+ 0
4. Delivery of SC Link system including (DPX and DPHX)	03/11/2022	03/07/2023	+ 8
5. Delivery of the last cryomagnet	05/05/2023	15/12/2023	+ 7.5
6. End of interconnections closure	14/09/2023	21/05/2024	+ 8
7. Start of first cool-down	24/11/2023	13/08/2024	+ 8.5
8. End of IT String program (start of the warming up)	30/03/2025	04/12/2025	+ 8.5

**Reasons for the request**

The main reasons inducing the changes exposed in Table 1 are provided hereafter:

- The end of the cryogenics commissioning without magnets is postponed by 8 months, to the end of October 2023. This is explained by the shift of the SM18 cryogenic shutdown. The CCU (Cold Compressor Unit) is to be installed in the shadow of the maintenance shutdown, as well as the handover of the SOG1 insulation vacuum from TE-CRS to TE-VSC. The cold test can only start once the shutdown is finished. Beginning of May 2023, as an estimated start date for this activity remains to be fully confirmed.

Page 1 of 5 Template EDMS No.: 1202715

Ex: [EDMS 2799934](#)

## DMR

EDMS NO. 2717815 REV. 1.0 VALIDITY VALUO REFERENCE: LHC-XMS-ED-0011

**HL-LHC: Decision Management APPROVAL OF AN ADDITIONAL THERMAL CYCLE WITH FULL POWERING TESTS IN THE HL-LHC IT STRING VALIDATION PROGRAM**

**Decision Description**

WP/Dep.	WP16, TE Department	Date of issue	2022-03-16
---------	---------------------	---------------	------------

**Facts**

The IT String Validation Program (SVP) can be initiated once verifications and measurements are possible on fully operational circuits. This implies that all the equipment has been inter-connected and as such do not represent individual components anymore but have become parts of the aforementioned circuits.

The HL-LHC IT String Validation Program is composed of 5 distinct phases that are to be completed in a sequential order:

1. Tests before cooling and 1° cool-down to LHe temperature
2. Powering tests before TC
3. TC 1° warm-up to 300 K followed by a 2° cool-down to 1.9 K
4. Powering tests after TC
5. 2° warm-up, final tests at room temperature and dismantling

These phases are performed at different steady state temperatures (Fig. 1). The time for transitioning from one phase to the next is also considered.

Page 1 of 5 Template EDMS No.: 1202710

Ex: [EDMS 2717815](#)

## NCR

EDMS NO. 3025021 REV. 1.0 VALIDITY VALUO REFERENCE: LHC-XMS-IQ-0002

**Nonconformity Report Cables trays for IT String WCC**

**NC Description**

Work Package	WP16	Equipment	Water Cooled Cables (WCC)
Collaboration Contact	EN-EL	Process	Visual Inspection
Team		Inspector	D. Bozzini, N. Heredia

**Introduction:**

The IT String includes 24 Water Cooled Cables (WCC) that connects electrically the power converters to the circuit disconnection breakers. The WCC are installed partially on metallic beams and on standard cable trays. The 3D isometric shows the position and routing of the WCC. Five Cable trays are necessary to support each four WCCs [1].

**Non-conformity:**

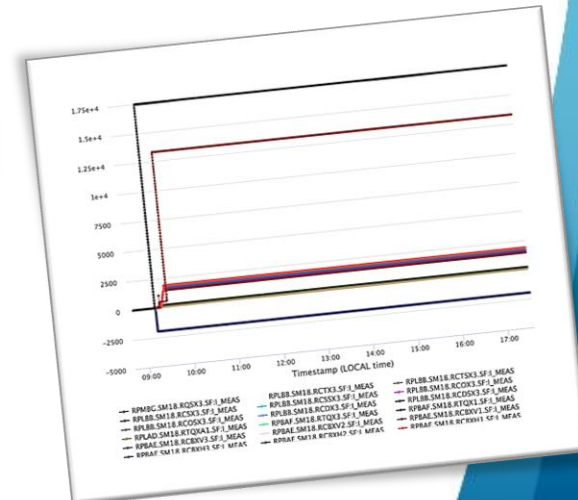
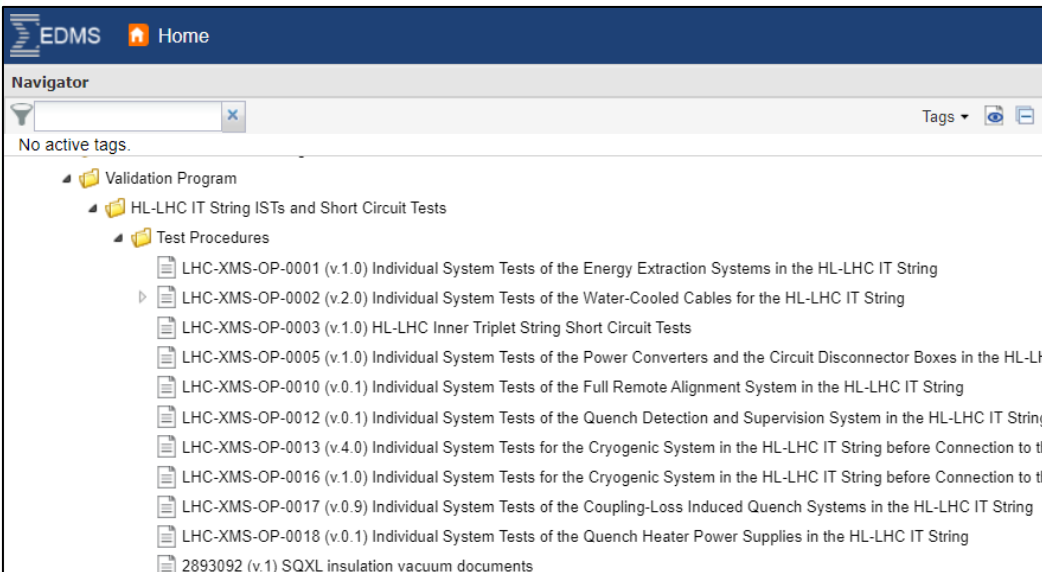
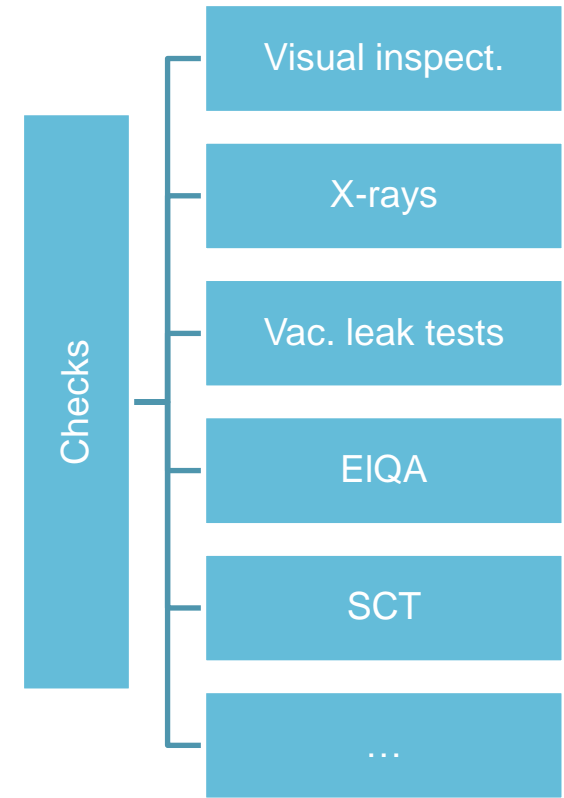
During the installation of the WCC on the cable trays it has been detected that in several points the cables trays where colliding. Visual inspections showed that the way of fixing the cables trays to the vertical beams of the metallic structure was plastically deformed. In some points the bolts and washers used to fix the cable tray to the vertical beam overstepped the U shape metallic profile. Figures 1 to 5 shows some of the non-conformity proofs.

Page 1 of 3 Template EDMS No.: 1202109

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.



# 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 structure is divided in several systems, and steps are defined for each of them.
- Steps are extracted from commissioning and operation procedures.

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

Main System data Installation & Commissioning Operation History Documents

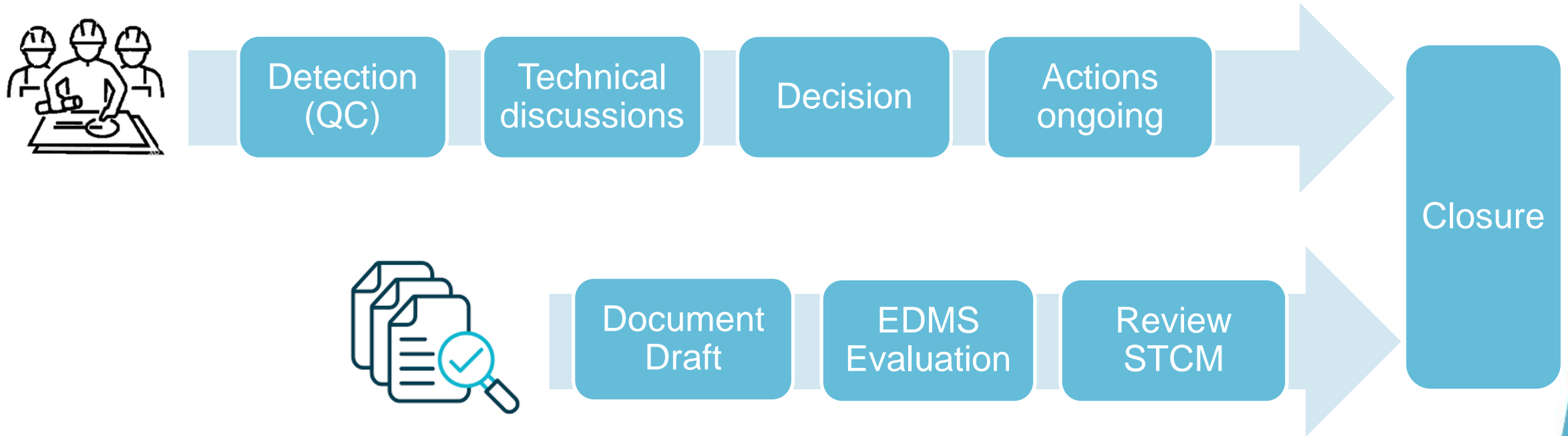
Actions: Create Job

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



# Non-conformities: Process

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



Feedback from IT String Day III:

- Addressing non-conformities: It's imperative to document these instances comprehensively, to prevent their recurrence in the HL-LHC tunnel installation ensuring a meticulous follow-up by the entire IT-String / HL-LHC project teams.

# Non-conformities: Template

- Information included in the non-conformity:



**HL-LHC Nonconformity Report**  
**Functional Range of Water Flow Switches for the Water-Cooled Cables in the 2kA Circuits**

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

NC Description			
<b>Work Package</b>	WP16	<b>Equipment</b>	Water flow switches, 2 kA water-cooled cables and 2 kA power converters
<b>Collaboration Teams</b>	EN-CV, EN-EL and 5Y-EPC	<b>Process</b>	IST & SCT
		<b>Inspectors</b>	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

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

two WCC in series, the nominal flow rate (4 – 6 l/min) is close to 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), if the powering during the Heat Run tests conducted on the 25<sup>th</sup> of February 2024 is depicted in Figure 3.

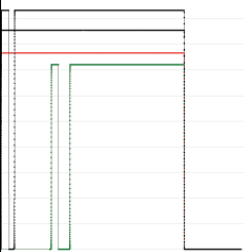


Figure 3: Current measurements registered in number for OC circuits H1 and V1 during Heat Run tests in the IT String [3]

those WCC are connected in series and necessitate a flow rate of 4 – 6 l/min of demineralized water [2]. This condition has led to faulty trips during the Heat Run tests as depicted in Figure 4.

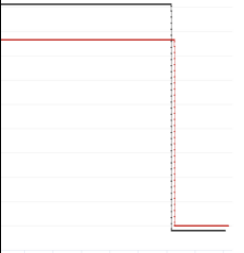


Figure 4: Current measurements registered in number for OC circuits H1 and V1 during Heat Run tests in the IT String [3]

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

**Information**

All the flowmeters installed in the IT String, despite the configuration of the hydraulic circuits while adjusting the nominal flow rate (4 – 6 l/min). This adjustment is deemed to have lower impact on series configuration.

To better align with the nominal flow rate of the water-cooled cables for the 2 kA circuits, given their configuration in the IT String [4]. Nevertheless, it is advisable to consider the various hydraulic circuits to be implemented.

Assignments for operation EDMS 2882278. The HL-LHC IT String EDMS 2744521. The cooling scheme EDMS 2953127.

Dr. F. Dragoni, J. Emonds-Ait, H. Garcia Gavela, V. Heredia, and M. Zerlauth.

**Critical (Impact 1,2 or 3)**

Return  Concession

**Date** 2024-02-05

**Responsible**

For the identification of the non-conformity. The test results are as follows:

No

**Date Closure** 2024-02-05

**Collaboration manager/WPE/WPL/PL**  
 M. Bajko, TE-MPE-SF

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# Non-conformities: Table

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

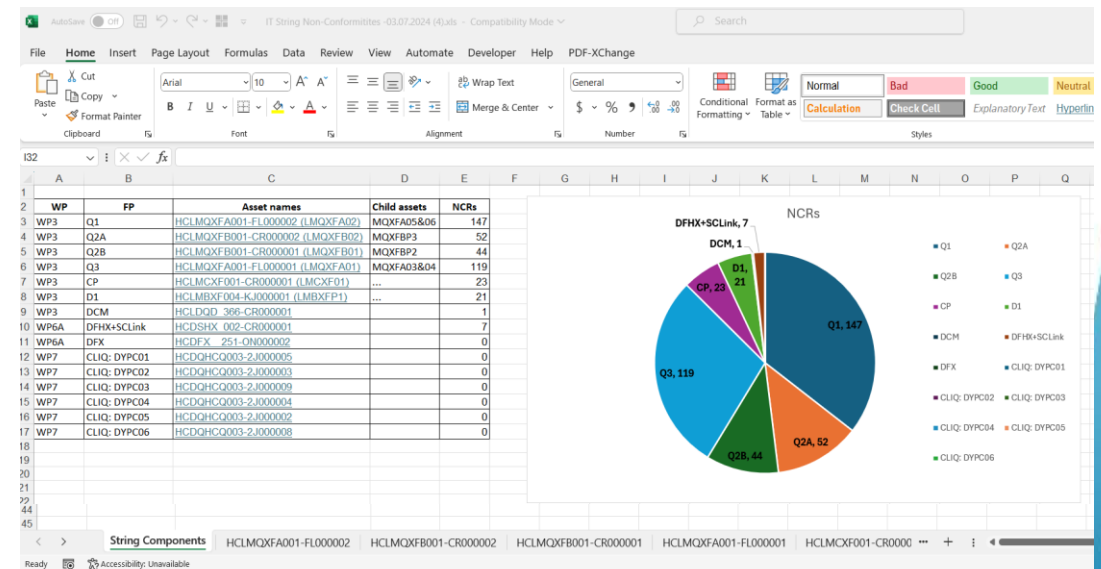
Ref.	NCR Description	Status	Ap. Date	EDMS	Criticality	Decision	Manag. team	Equipment	Detect. phase	Det. Year	Class
	NCR of TL02	1. To be Opened	TBD	TBD	Non-Critical	Repair	WP16	Cryogenics	Commissioning	2024	Mechanical
LHC-XMSAD-QN-0003	NCR of water-cooling plates for busbars	2. In Work	TBD	<a href="#">3162382</a>	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	<a href="#">3153667</a>	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	<a href="#">3045592</a>	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	<a href="#">3044384</a>	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	<a href="#">3075007</a>	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	<a href="#">3117788</a>	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	<a href="#">2804269</a>	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	<a href="#">3093233</a>	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	<a href="#">3045423</a>	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	<a href="#">3018444</a>	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	<a href="#">3025021</a>	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	<a href="#">2961669</a>	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	<a href="#">2961672</a>	Non-Critical	Repair	WP16	Cryogenics	Installation	2023	Mechanical
LHC-XMSAA-QN-0004	IT STRING - NCR - SQXL - DN100 Instrumentation Feedthroughs	4. Closed	22/03/2024	<a href="#">2961678</a>	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	<a href="#">2872779</a>	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.

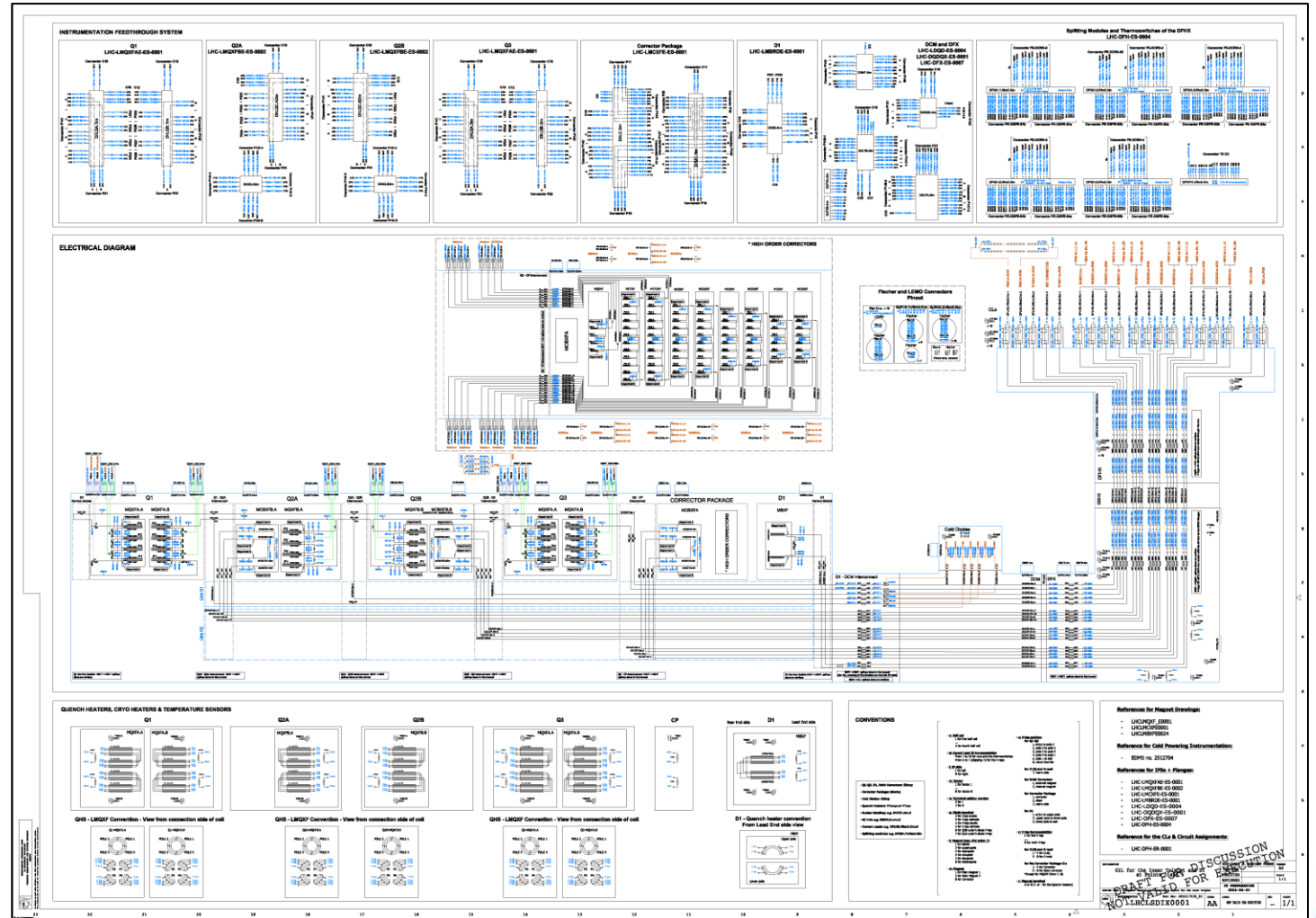
## Feedback from IT String Day III:

- Handling Non-Conformities: Identifying non-conformities for the String (out of all non-conformities traced across the project), crucial for HL-LHC, presents a challenge. Discussions focused on methods like tagging these issues in databases or Excel sheets. The focus is on comprehensive documentation and ensuring easy accessibility of these records for future reference is crucial.



# 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.

**HL-LHC Integration Meeting: Follow-up on “Lessons learned on IT String relevant for HL-LHC installation #1”, Lessons learned on IT String relevant for HL-LHC installation #2, HL-LHC upload of equipment to the Layout Database: UR15 UR55**

Friday Sep 13, 2024, 10:55 AM → 12:30 PM Europe/Zurich  
CERN

EDMS for presente...

Videconference HL-LHC Friday Integration meeting Join

10:55 AM → 11:25 AM	Follow-up on “Lessons learned on IT String relevant for HL-LHC installation #1”	30m
Speakers: Miguel Navarro Baeza (CERN), Darshana Kumari Ramrekha		
Follow-up on Lesso... Follow-up on Lesso...		
11:30 AM → 12:15 PM	Lessons learned on IT String relevant for HL-LHC installation #2	45m
Speakers: Davide Bozzini (CERN), Marta Bajko (CERN), Samer Yammine (CERN)		
Lessons_Learned... Lessons_Learned...		
12:15 PM → 12:30 PM	HL-LHC upload of equipment to the Layout Database: UR15 UR55	15m
Speaker: Miguel Navarro Baeza (CERN)		
HL-LHC_ApprovalLi... HL-LHC_ApprovalLi...		

**195th HL-LHC TCC**

Thursday May 23, 2024, 3:30 PM → 5:00 PM Europe/Zurich  
30/7-018 (CERN)

3:30 PM → 3:35 PM	HL-LHC Project announcements	5m
Speaker: Markus Zerlauth (CERN)		
3:35 PM → 3:40 PM	WP9 organization	5m
Speaker: Serge Clavier (CERN)		
3:40 PM → 3:45 PM	WP17 organization	5m
Speaker: Laurent Jean Tavian (CERN)		
3:45 PM → 3:55 PM	Mandate of EN-EL S3 Coordinator	10m
Speaker: Simao Pedro Costa Machado (CERN)		
4:00 PM → 4:20 PM	Progress report on IT String coordination, installation, and commissioning	20m
Speaker: Davide Bozzini (CERN)		

**192nd HL-LHC TCC**

Thursday Mar 14, 2024, 3:30 PM → 5:30 PM Europe/Zurich  
30/7-018 (CERN)

3:30 PM → 3:35 PM	HL-LHC Project announcements	5m
Speakers: Markus Zerlauth (CERN), Olivier Bruning (CERN)		
3:35 PM → 3:55 PM	Edge welded bellows – lessons learned and follow-up	20m
Speaker: Antonio Perillo-Mancione (CERN)		
4:05 PM → 4:25 PM	Position vs magnetic axis measurement for MQXF6	20m
Speakers: Di Carlo Pastore (CERN), Yusein Rade (CERN)		
4:35 PM → 4:55 PM	Summary of the of the warm powering IST and SCT campaign in the IT String	20m
Speaker: Samer Yammine (CERN)		

**HL-LHC IT String Day IV**

Friday Sep 27, 2024, 8:30 AM → 5:35 PM Europe/Zurich  
30/7-018 - Kjell Johnsen Auditorium (CERN)  
Markus Zerlauth (CERN)

10:40 AM → 12:20 PM Status / Lessons learned / Upcoming activities

10:40 AM	<b>Cryogenic cooling system (WP16/TE-CRG)</b>	20m
The presentation will address the following topics:		
<ul style="list-style-type: none"> <li>Overview of cryogenic system commissioning without magnets</li> <li>Status of the cryogenic system</li> <li>Outcomes of commissioning and lessons learnt</li> <li>Upcoming activities for preparation of commissioning with magnets</li> </ul>		
Speaker: Aleksandra Onufrena (CERN)		
11:05 AM	<b>Vacuum system (WP16/TE-VSC)</b>	20m
The presentation will address the following topics:		
<ul style="list-style-type: none"> <li>Vacuum leak tests and validation programs executed.</li> <li>Lessons learned during commissioning of SQL and Cold Powering System.</li> <li>Installation and interconnecting leak test tooling preparations.</li> <li>Upcoming activities.</li> </ul>		
Speaker: Willemjan Maan (CERN)		
11:30 AM	<b>Warm powering system (WP6A/SY-EPC)</b>	20m
The presentation will address the following topics:		
<ul style="list-style-type: none"> <li>Lessons learned from installation and commissioning.</li> <li>Upcoming activities.</li> </ul>		
Speaker: Hugues Thiesen (CERN)		
11:55 AM	<b>Cold powering system (WP6A/TE-MSD)</b>	20m
The presentation will address the following topics:		
<ul style="list-style-type: none"> <li>Performance of the Prototype Cold Powering system</li> <li>Completed installation activities and lessons learnt</li> <li>Upcoming activities and interfaces</li> </ul>		
Speaker: Yann Leclercq (CERN)		

# 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***

***Special thanks to all the collaborators for  
their efforts***