



# The ELQA program for the Inner-Triplet String test in SM-18

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of the ELQA team*

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# Outline

- ELQA – Introduction
- ELQA plan post-LS2
- ELQA program on the IT String



# ELQA - introduction

- Test superconducting circuits and magnets (at warm, cold and during thermal transitions)
- Ensure readiness for powering
- Detect signs of faults, ageing, degradation
- The test results are assessed according to defined acceptance thresholds and also they are traced over time to find possible trends and signatures of faults that may develop
- The objective is to validate circuits for operation at high currents in a safe way

**Regularly performed starting from the LHC assembly phase (~2005) until today**

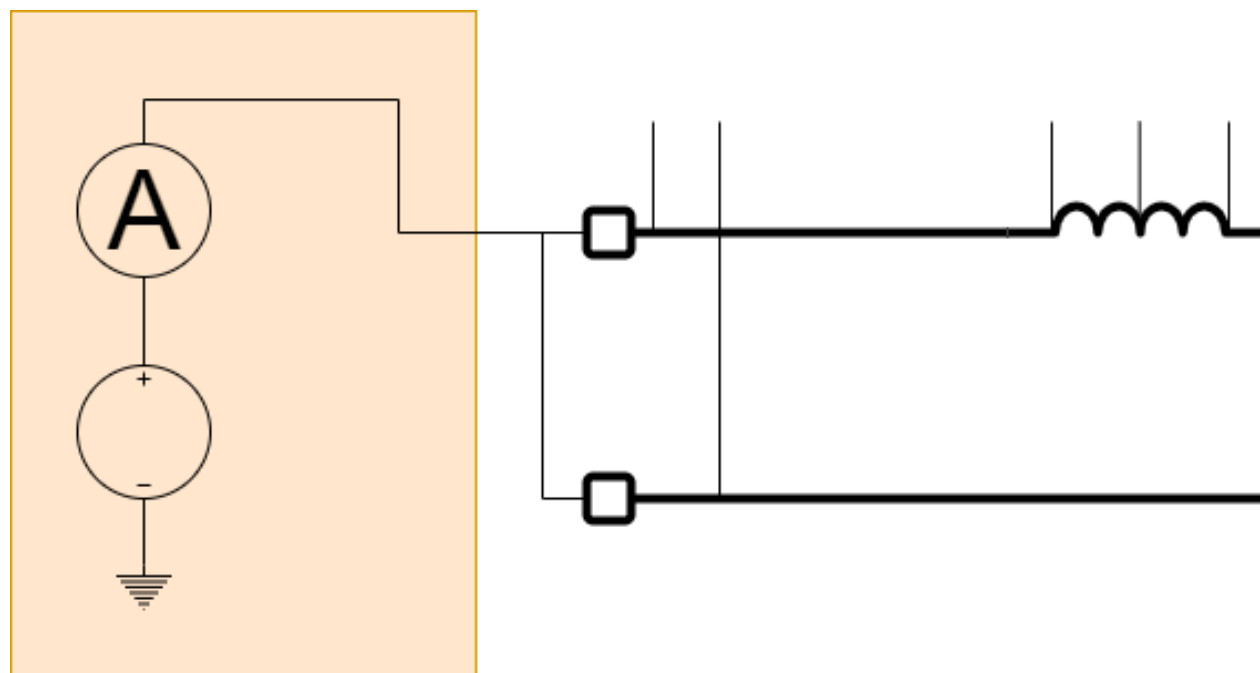


# ELQA „building blocks”

- HVQ – High Voltage Qualification
- TFM – Transfer Function Measurement
- IRC – Instrumentation Resistance Check
- ICC – Instrumentation Configuration Check
- TDR – Time Domain Reflectometry
- COC – Continuity of Conductor check
- QHR – Quench Heater Resistance measurement
- DVC – Diode opening Voltage Check
- TSQ – Temperature Sensor Qualification

# HVQ – High Voltage Qualification

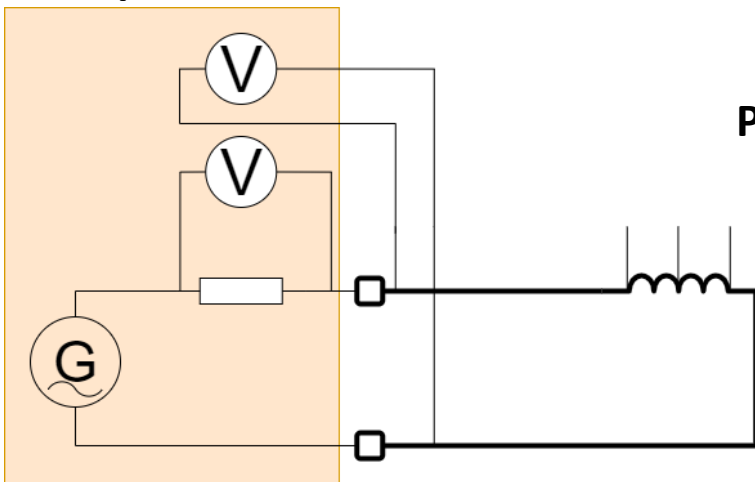
- Each circuit (part of a circuit, bus-bar, instrumentation wire or quench heater) is energized individually with respect to ground using a DC voltage source limited to a current of 2 mA
- During the test of a given circuit, all other circuits of the same electrical safety sub-sector are grounded
- Applied test voltages are defined for each component at each configuration and for warm and cold tests



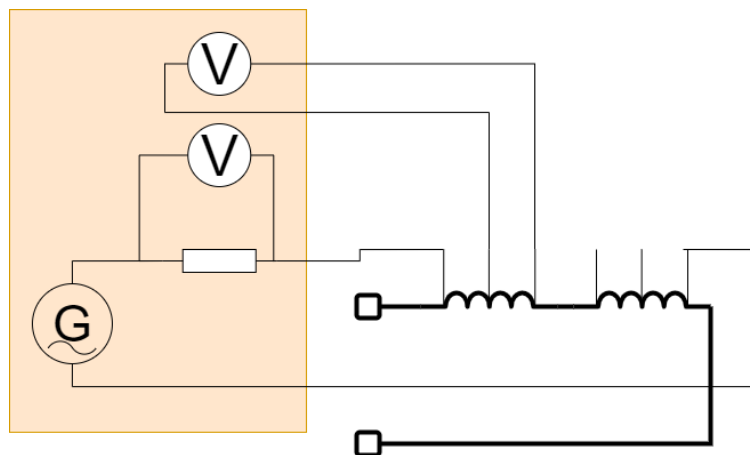
# TFM – Transfer Function Measurement

- This measurement determines the impedance as a function of frequency
- The results of these measurements are used to spot possible inter-turn shorts and detect other possible circuit anomalies
- The impedance is measured by applying a sinusoidal signal with maximum amplitude of 10 V and maximum current of 1 A
- Frequency range of 0.1 Hz - 100 kHz

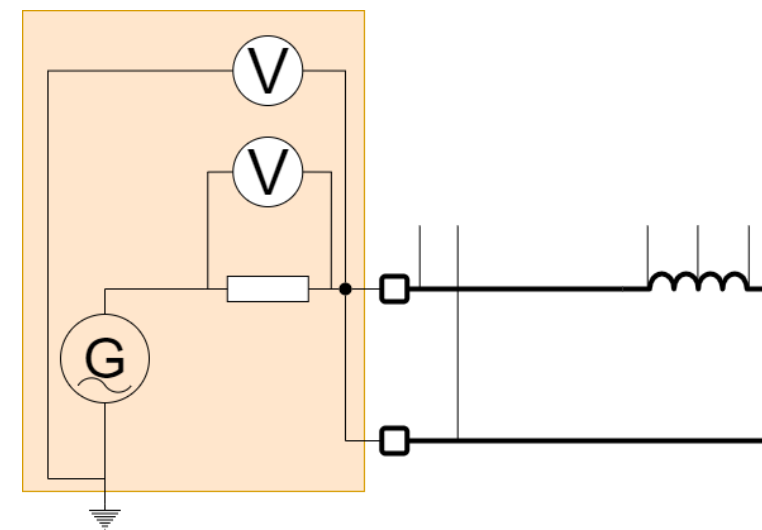
**Principle of TFM measurement**



**Principle of Local TFM measurement on the magnet (applied during MIC test)**



**Principle of TFM vs. GND measurement**

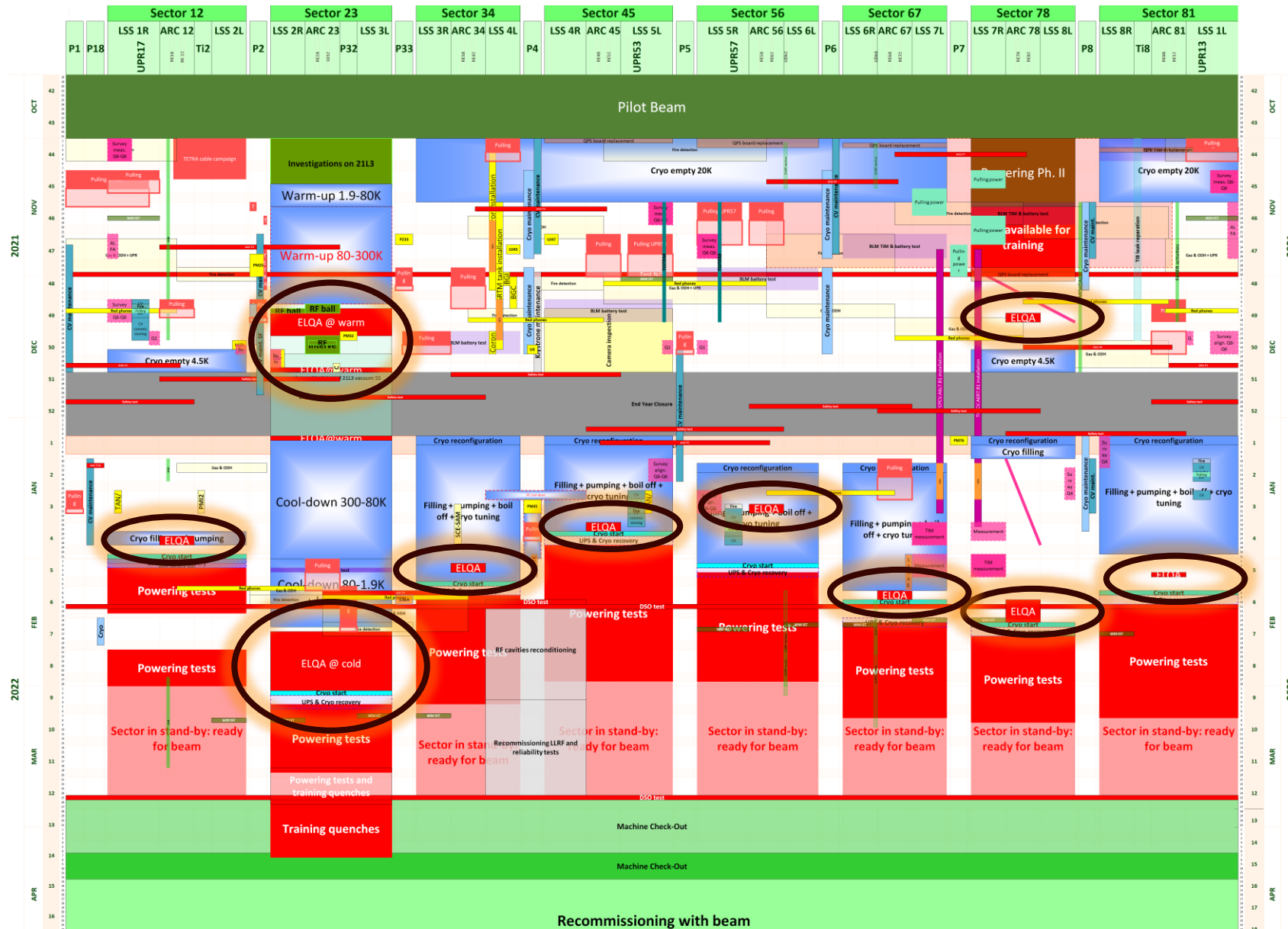


Detailed description of other tests is available in the test procedures:

- Regular ELQA in the LHC: [EDMS 788197](#)
- IT string procedures being finalised at the moment



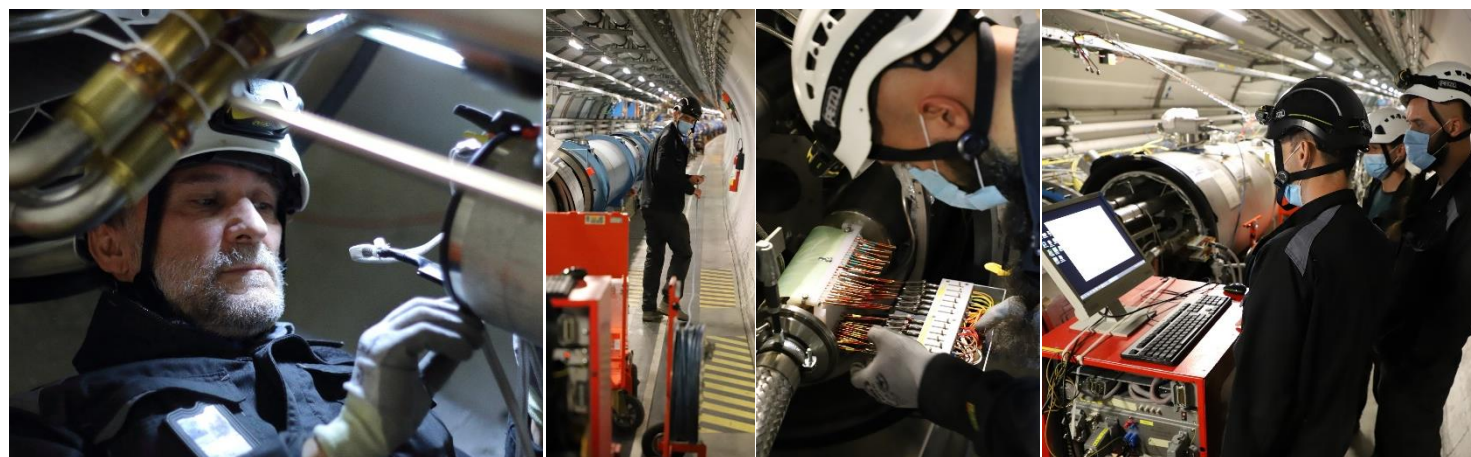
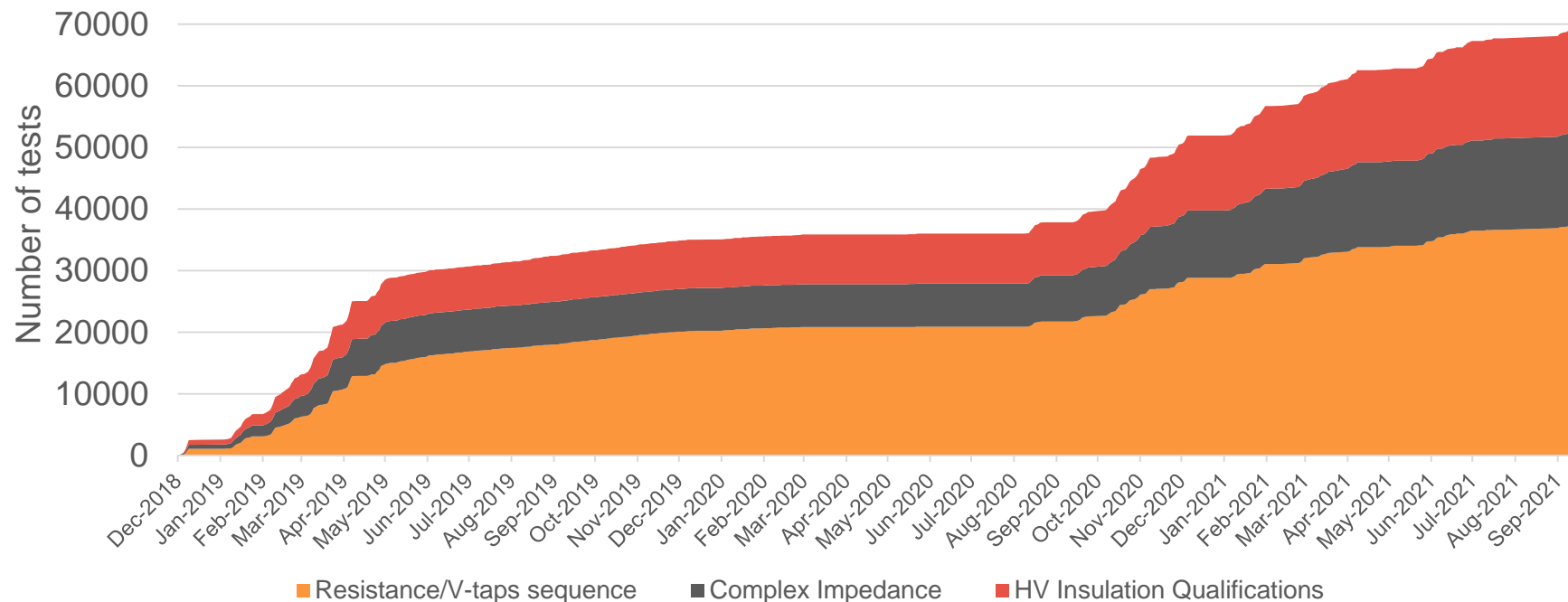
# Example: program of activities YETS 21/22





# Number of ELQA tests – LS2

Each test consists of several measurements. Results are stored and analysed.



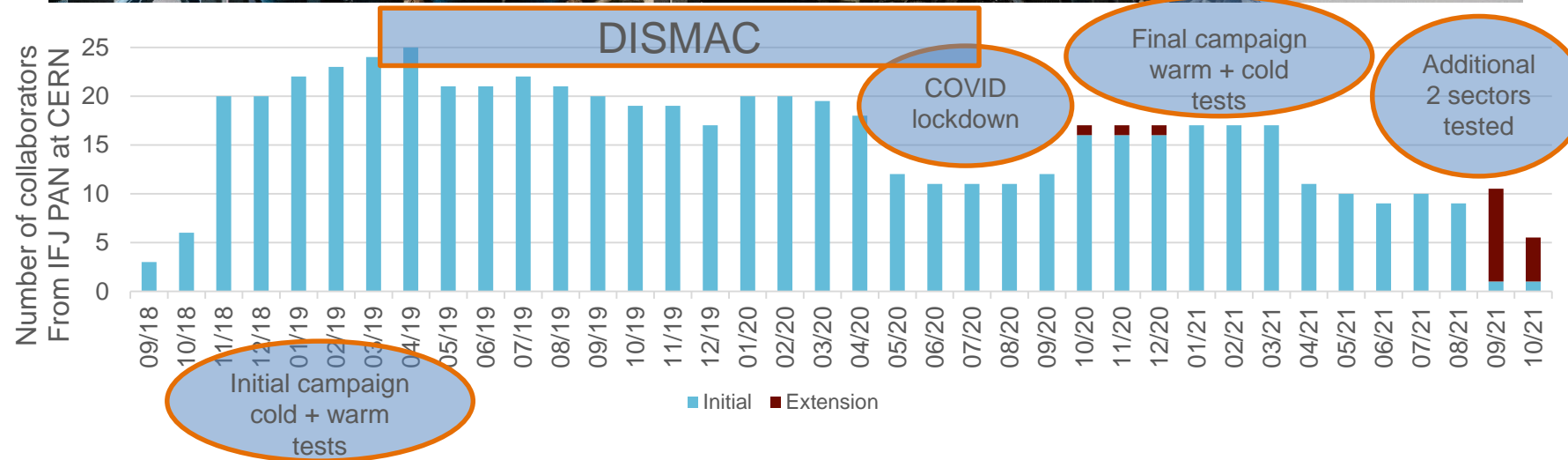
# The ELQA team – LS2



- Collaboration with Henryk Niewodniczanski Institute of Nuclear Physics Polish Academy of Sciences in Krakow
- ELQA experts at CERN (3 staff)

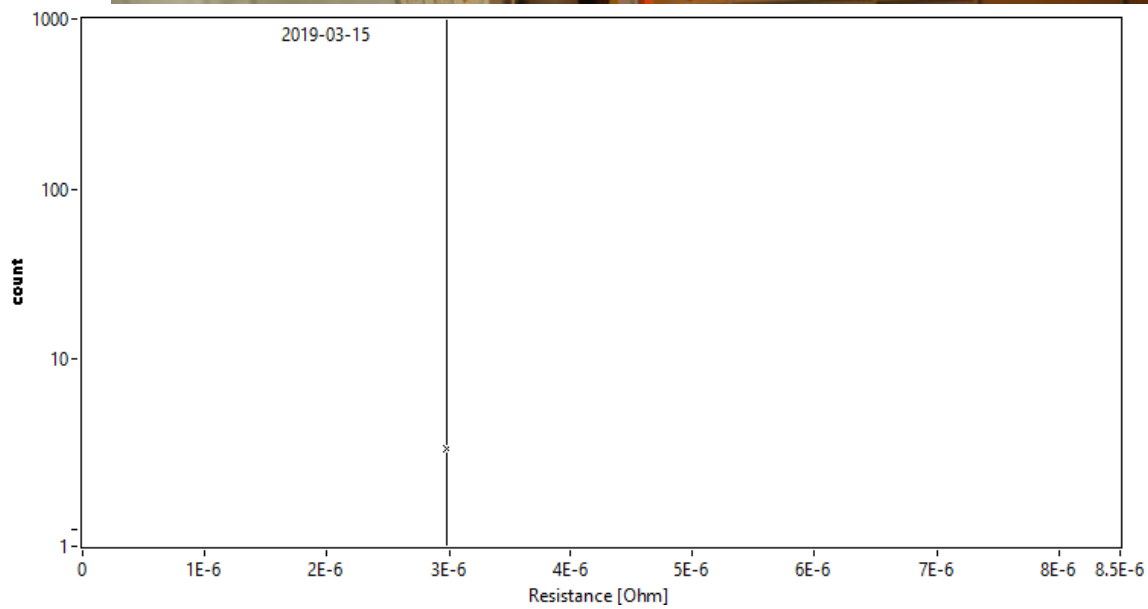
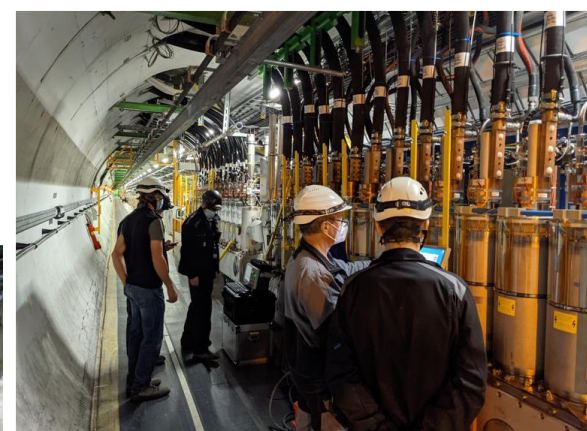
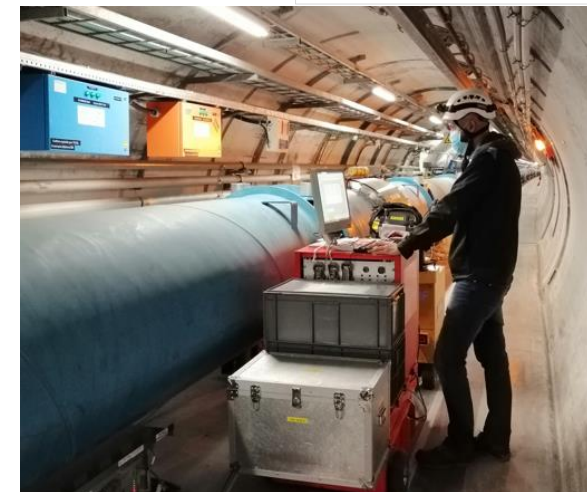


*Taken before the plague*





# ELQA in action – LS2

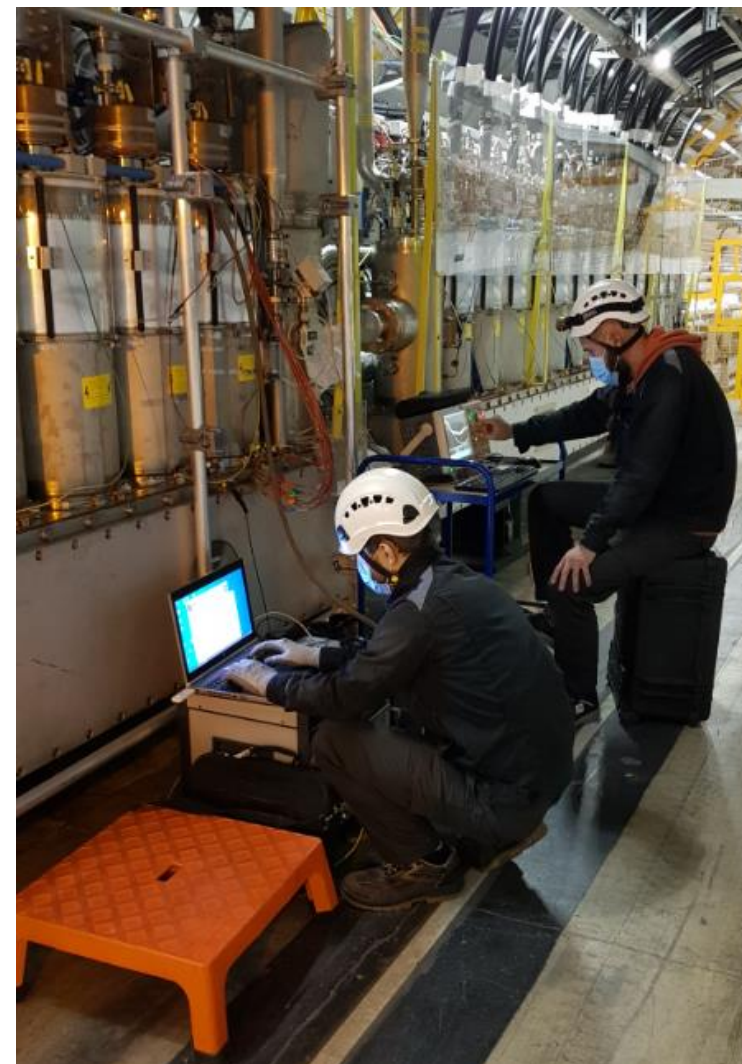
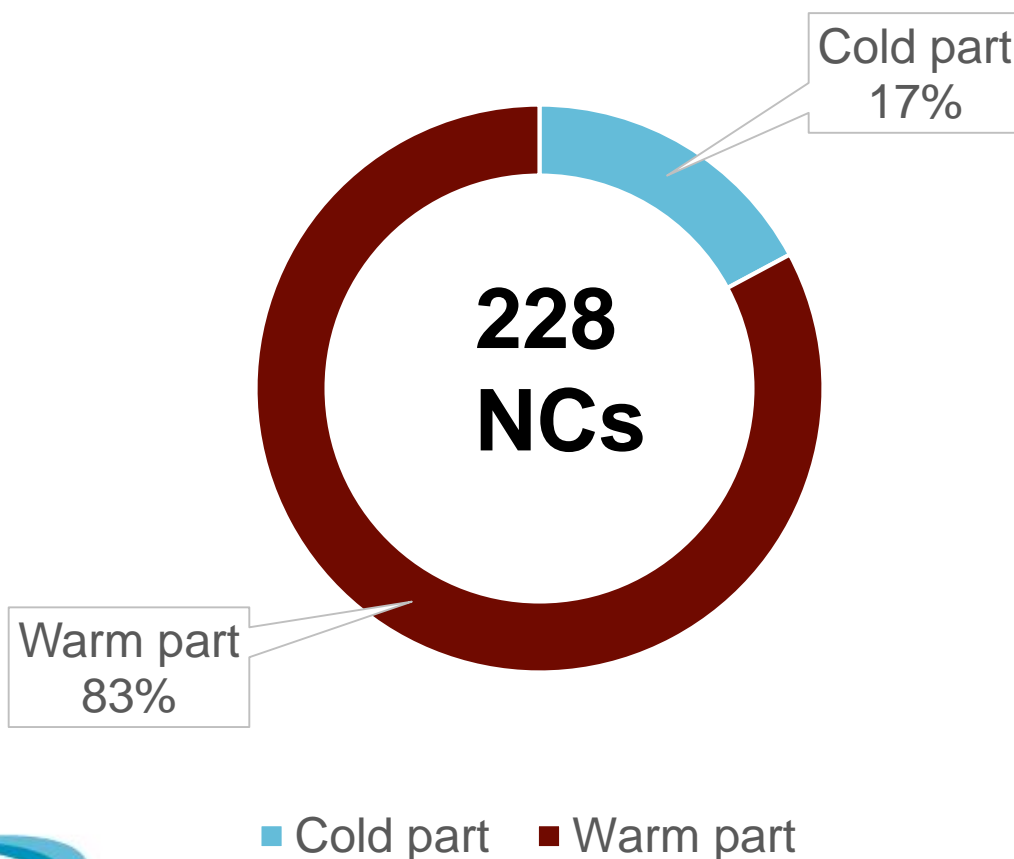




# Identified non-conformities during LS2

- Total number of NCs detected in LS2: **228**
- Similar number of NCs as in LS1

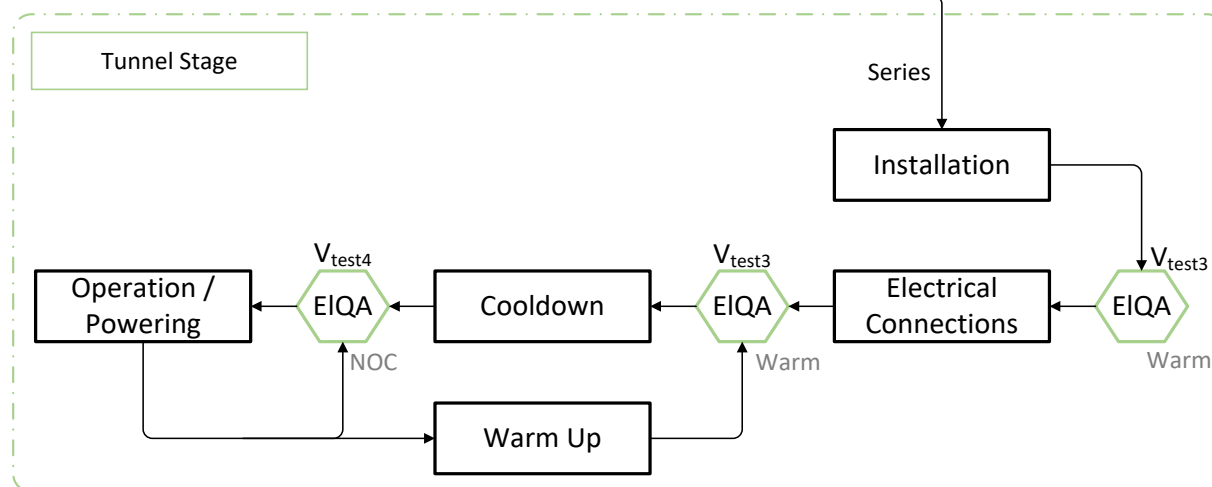
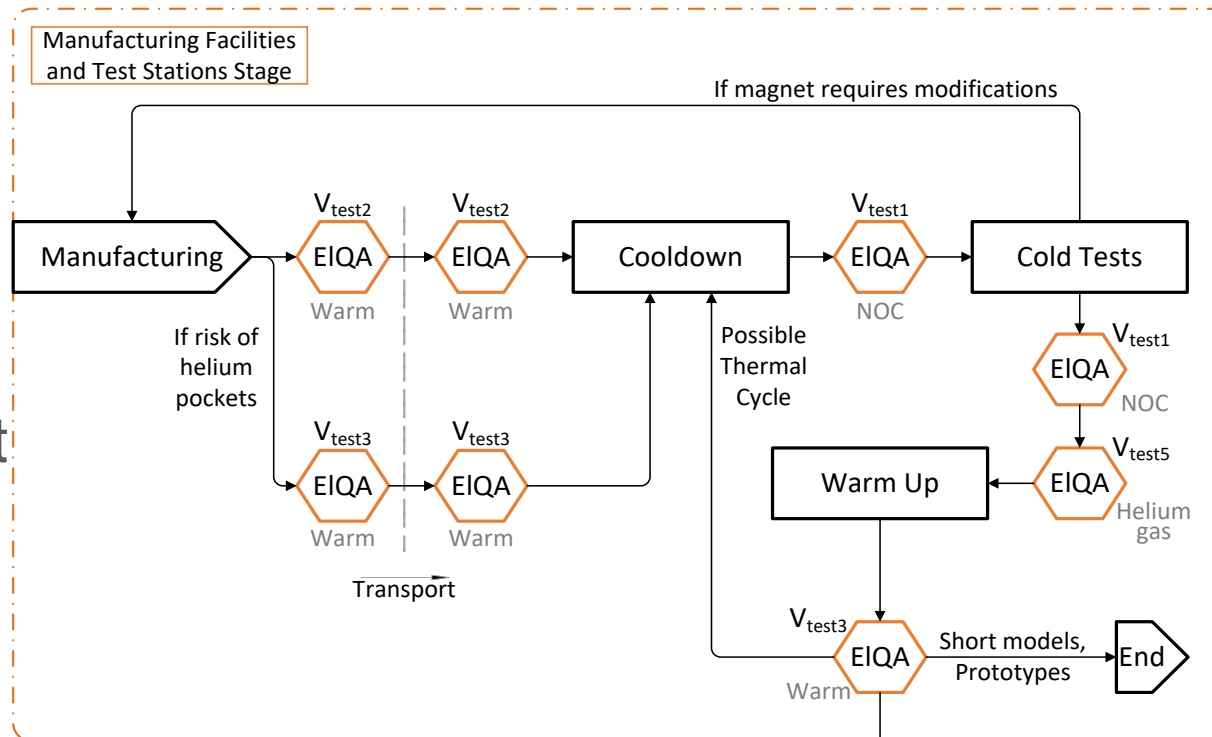
Last update: 06.10.2021





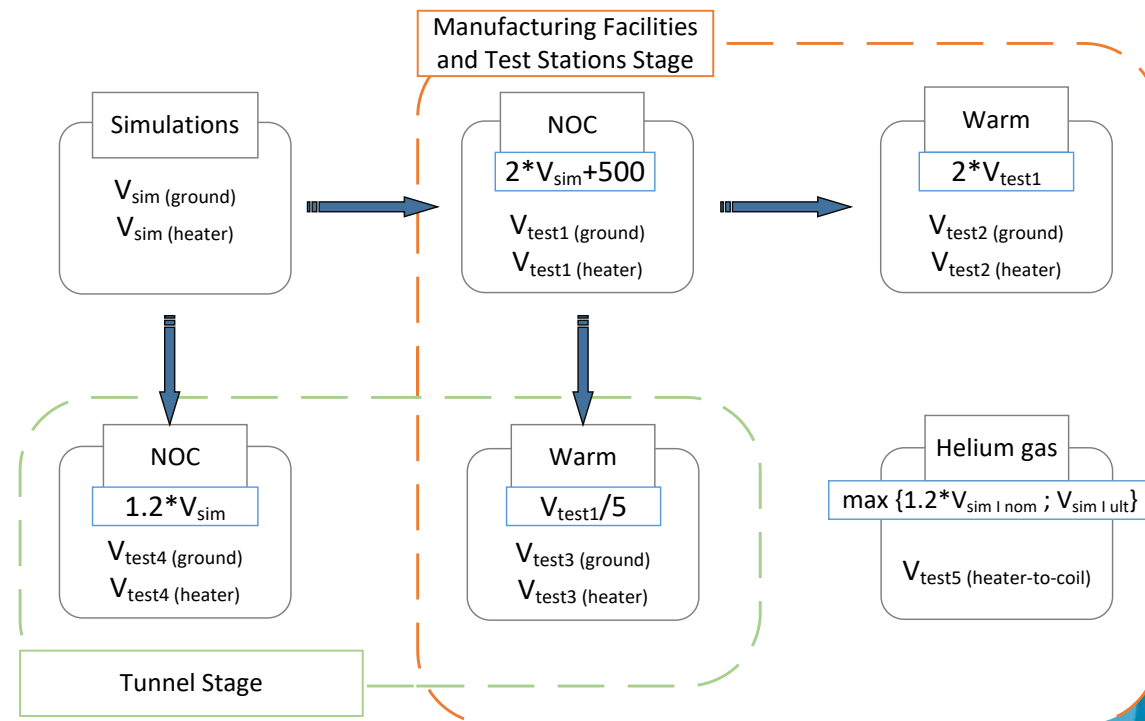
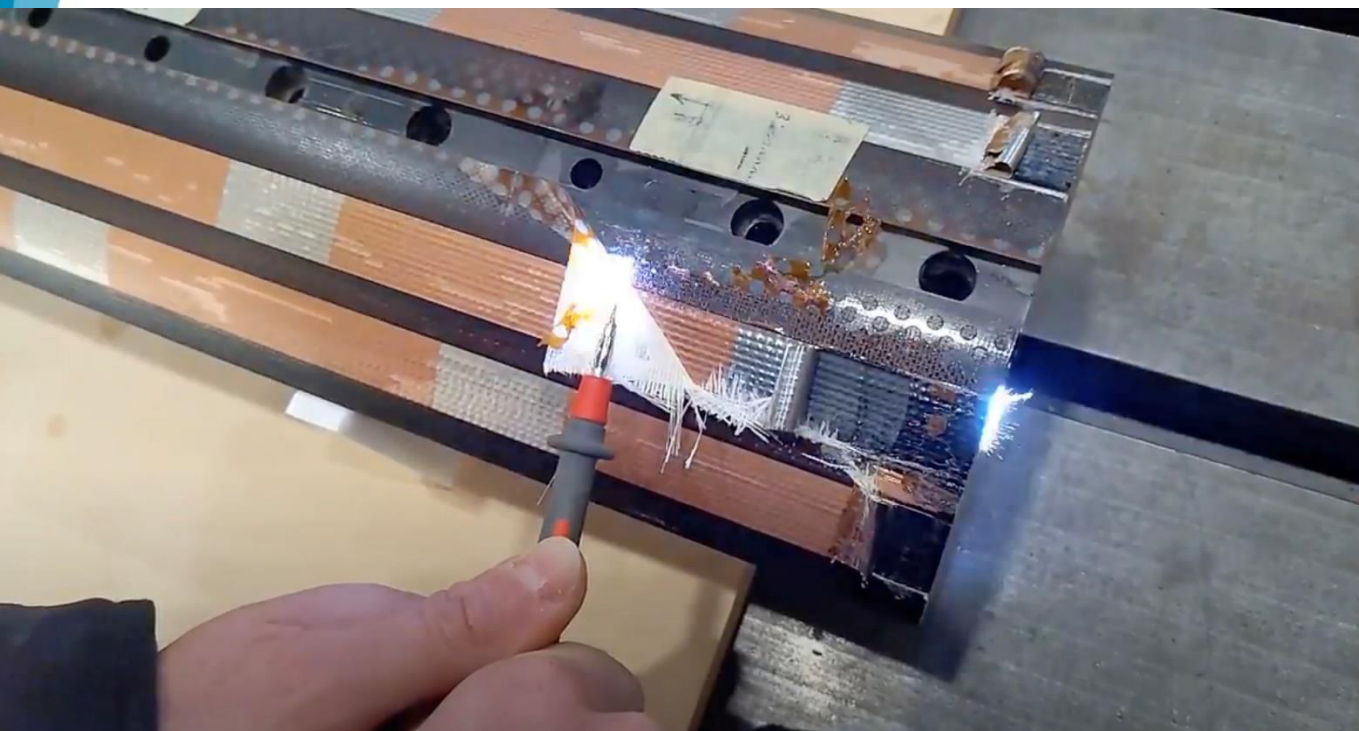
# ELQA steps in the construction of a magnet

- For HL magnets and components a set of „Electrical Design Criteria” documents was released
- All main manufacturing and test stages are taken into account
- HL-LHC magnets are often very sensitive and test voltage levels and conditions are strictly defined



# Definition of voltage levels

- Test voltage levels definition and validation is a topic for another presentation

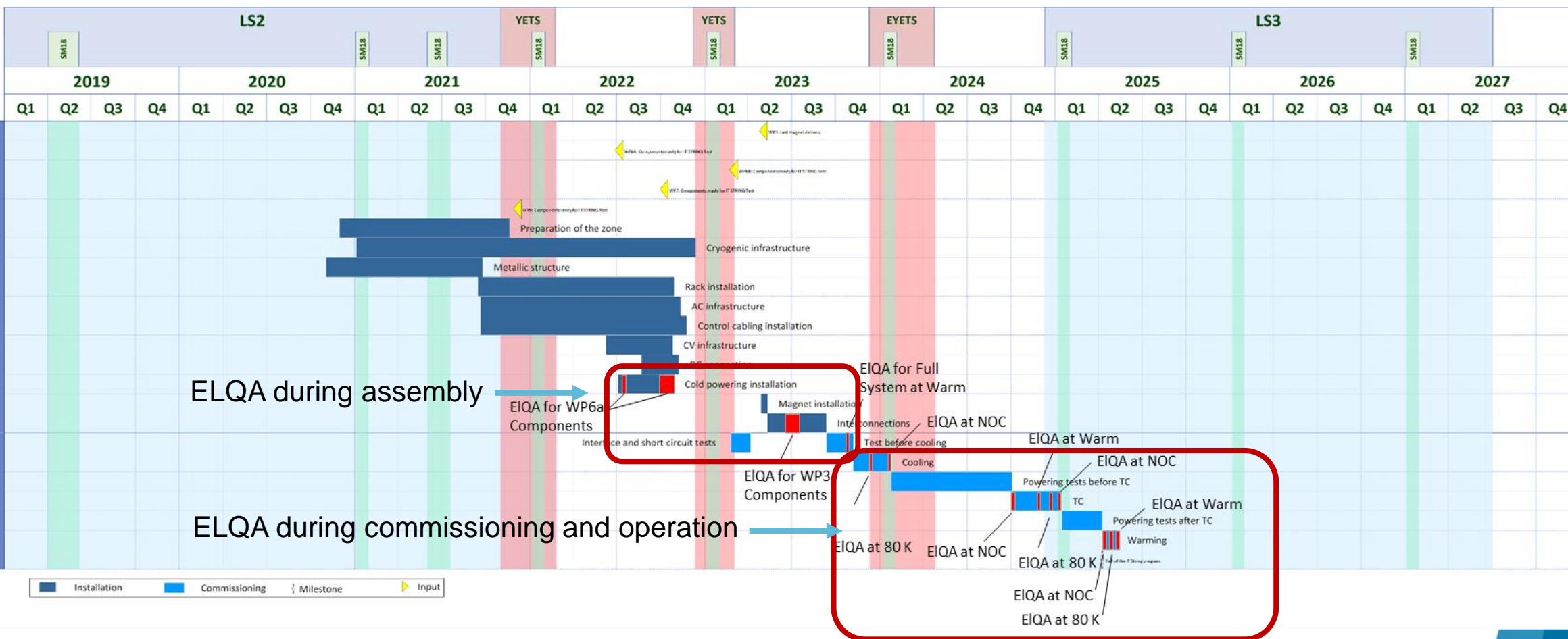


# ELQA plan post-LS2

	HL-LHC	LHC
Run 3	<ul style="list-style-type: none"> <li>• Development of new test benches to cover the needs of new HL-LHC magnets and installations</li> <li>• Follow-up of HL magnets and other cold powering assemblies (DCM, link, DFH, DFX etc.) design, manufacturing and related tests</li> <li>• Reception tests of those assemblies</li> <li>• Tests in IT string during               <ul style="list-style-type: none"> <li>○ Reception, installation, commissioning and operation</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Activities in the machine               <ul style="list-style-type: none"> <li>○ TSs</li> <li>○ YETS</li> <li>○ Operation</li> </ul> </li> <li>• Preparation for LS3               <ul style="list-style-type: none"> <li>○ Test systems maintenance and upgrades</li> </ul> </li> </ul>
LS3	<p>Tests during:</p> <ul style="list-style-type: none"> <li>• HL-LHC new magnets and cold powering components installation</li> <li>• Interconnection of new components</li> <li>• Installation of instrumentation cables</li> <li>• Commissioning of complete HL-LHC infrastructure</li> <li>• Special investigations and diagnostics</li> </ul>	<ul style="list-style-type: none"> <li>• Standard campaigns               <ul style="list-style-type: none"> <li>○ Large amount of work at the beginning and at the end of LS</li> </ul> </li> <li>• Special investigations</li> </ul>

# IT String planning

WP16 - Baseline - C&S review - 2021





# Tests for IT string/HL installations

- **Reception**
  - Take over components from WP3/WP6a
  - Reference for future tests
- **Assembly**
- **Commissioning**

# Reminder of acronyms ELQA „building blocks”

- HVQ – High Voltage Qualification
- TFM – Transfer Function Measurement
- IRC – Instrumentation Resistance Check
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# HL-LHC assembly

	MIC-0	PAQ-0	SLC	TP3	MIC-1	IT-PAQ	ITIV	ITIC
HVQ	✓	✓	✓	✓	✓	✓	✓	✓
TFM	✓		✓	✓	✓		✓	
IRC	✓		✓	✓	✓		✓	
ICC	✓	✓	✓	✓	✓	✓	✓	
TDR	✓		✓	✓	✓			✓
COC		✓	✓	✓		✓	✓	✓
QHR	✓				✓			
DVC	✓			✓	✓			
TSQ	✓		✓	✓	✓			

MIC-0 – Reference Magnet Instrumentation Check

PAQ-0 – Reference Partial Qualification

SLC – Superconducting Link Check

TP3 – Test Procedure 3

MIC-1 – Magnet Instrumentation Check – after transport

IT-PAQ – Inner Triplet Partial Qualification – after transport

ITIV – Inner Triplet Interconnection Verification

ITIC – Inner Triplet Instrumentation Check

# HL-LHC commissioning

	TP4-A	MIC-W	TP4-B	TP4-C	TP4-D +MIC-D	MIC-C	TP4-E
	At warm	At warm	After flushing	During cool-down/ warm-up	At 80 K	At cold	At cold
HVQ		✓	✓	✓	optional	✓	✓
TFM	✓	✓			optional	✓	✓
IRC	✓	✓			optional	✓	✓
ICC	✓	✓			optional	✓	✓
TDR		✓			optional		
COC							
QHR		✓			optional	✓	
DVC		✓				✓	
TSQ	✓	✓			optional	✓	✓

TP4-A – Test Procedure 4 type A

MIC-W – Magnet Instrumentation Check at warm

TP4-B – Test Procedure 4 type B

TP4-C – Test Procedure 4 type C

TP4-D – Test Procedure 4 type D

MIC-D – Magnet Instrumentation Check at 80 K

MIC-C – Magnet Instrumentation Check at cold

TP4-E – Test Procedure 4 type E



# IT String commissioning and operation

Test type	At warm	At warm after flushing	Cool-down 300 K to 80 K	At 80 K	Cool-down 80 K to 1.9 (4.5) K	At cold	At cold after powering	Warm-up	At warm	Cool-down	At cold	At cold after powering	Warm-up	At 80 K	Warm-up 80 K to 300 K	At warm
TP4-A	>								>							>
MIC-W	>								>							>
TP4-B		>							>							>
TP4-C			>		>			>		>			>		>	
TP4-D				>										>		
MIC-D				>										>		
MIC-C						>	>				>	>				
TP4-E						>	>				>	>				

# Other topics for future presentations related to this topic

- Maintenance of ELQA hardware after years of heavy operation
- Development of new ELQA systems for HL-LHC specific needs
- Test voltage levels definition and validation
- Analysis of test results obtained during ELQA
- Analysis of TFM (impedance measurements)
- Non conformities detected by ELQA
- Methods for diagnosing and localising faults in superconducting magnets

# Summary

- ELQA on HL-LHC installations (including the IT string test) will be performed by the LHC ELQA team (TE-MPE-PE)
- Reception tests of magnets and cold powering components will be performed by the ELQA team so that there is a reference for the tunnel qualification and that the experience with the new equipment is gained as early as possible
- ELQA test program on the IT String is defined and is being approved
- Development and implementation of new test bench functionalities needed for HL-LHC needs to start soon



Thank you for  
your attention!