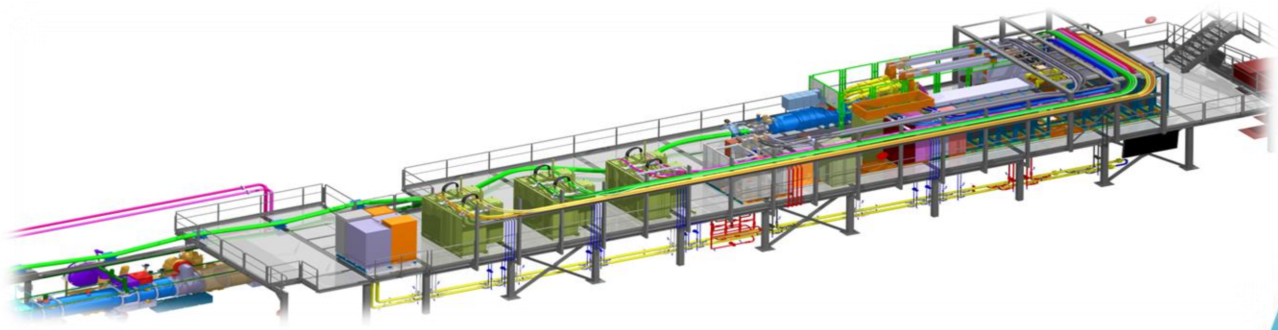
Experience with WP6B equipment operation in the HL-LHC IT String



H. Thiesen – CERN

With the contribution of WP6B&WP16 teams and SY-EPC group

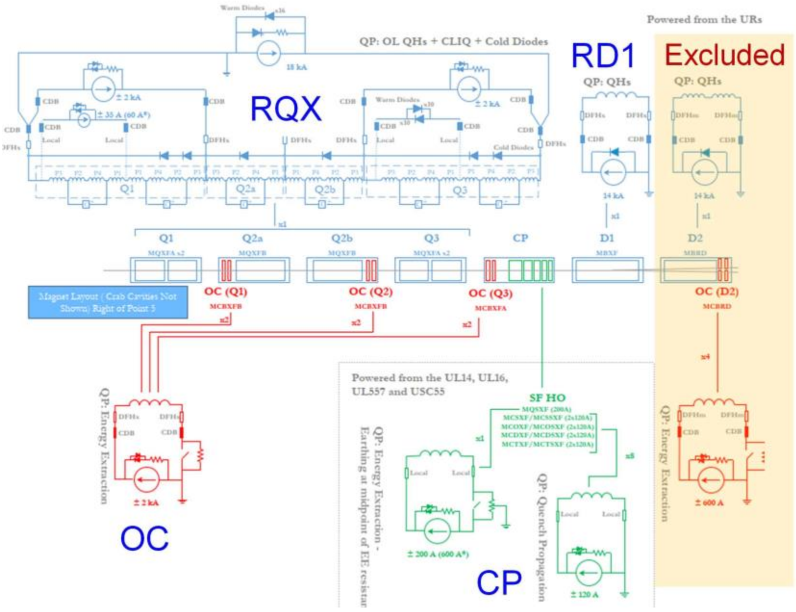
14th HL-LHC Collaboration Meeting, Genoa (Italy), 7-10 October 2024

Outline

- Warm Powering System of HL-LHC String
- Feedback of Integration & Installation
- Experience of IST and SCT
- Electrical Safety Aspect
- Powering of the Magnets
- Summary

Warm Powering System of HL-LHC String

- HL-LHC String as been designed as the 5th IP side of HL-LHC project
  - String is identical (or close) to IP side with same electrical circuits (w/o RD2 and its 600A correctors)



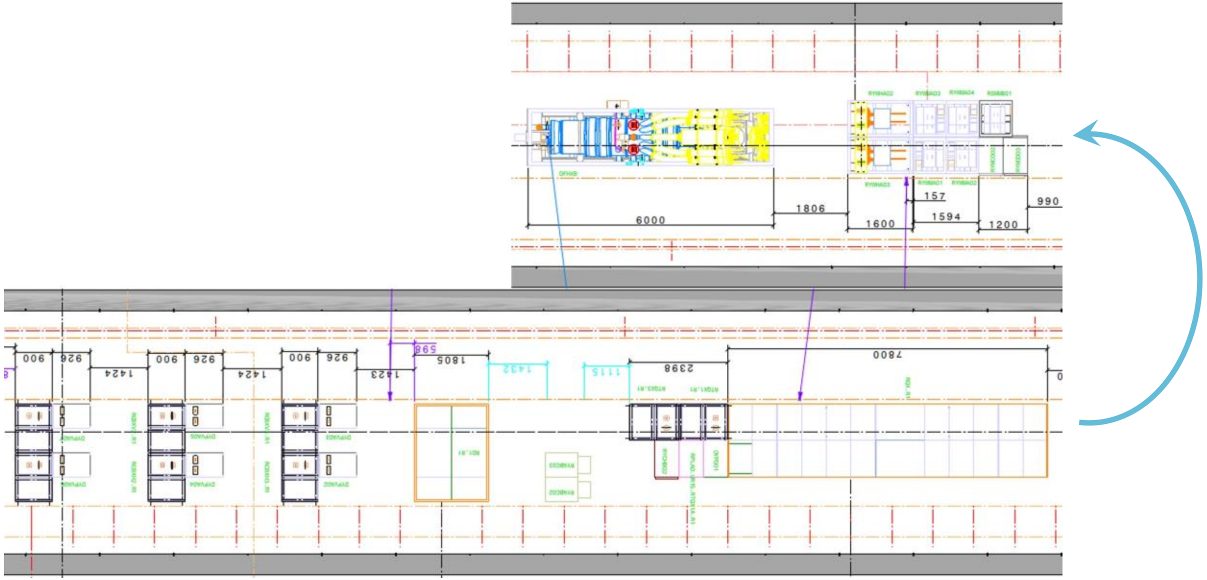
Warm Powering System of HL-LHC String

- HL-LHC String as been designed as the 5th IP side of HL-LHC project
  - Same electrical parameters

	Circuits for HiLumi	Magnet Type	PC Type	Nb of circuits	Total number of circuits	I_nominal (7 TeV) [kA]	I_ultimate [kA]	L per circuit at nominal current [mH]	R per circuit [mΩ] (machine)	R per circuit [mΩ] (String)
Inner Triplet	Triplet Q1, Q2a, Q2b, Q3	MQXFA / MQFXB	HCRPAFE	1	4 (IR1/5)	16.23	17.5	255.4	0.15	0.06
	Trim Q1	-	HCRPBAB	1	4 (IR1/5)	2	2	69	1.35	1.14
	Trim Q1a	-	HCRPLAD	1	4 (IR1/5)	0.035	0.035	34.5	226.16	234.82
	Trim Q3	-	HCRPBAB	1	4 (IR1/5)	2	2	69	1.2	1.13
	Orbit correctors Q1/2 - Horizontal/Inner	MCBXFB	HCRPBAA	2	8 (IR1/5)	1.74	1.864	58.4	2.37	2.39
	Orbit correctors Q1/2 - Vertical/Outer	MCBXFB	HCRPBAA	2	8 (IR1/5)	1.43	1.532	124.8	2.42	2.335
	Orbit correctors Q3 - Horizontal/Inner	MCBXFA	HCRPBAA	1	4 (IR1/5)	1.593	1.709	107.1	1.99	2.04
	Orbit correctors Q3 - Vertical/Outer	MCBXFA	HCRPBAA	1	4 (IR1/5)	1.34	1.441	232.3	1.98	2.12
	Superferric, order 2	MQSXF	HCRPMBG	1	4 (IR1/5)	0.174	0.197	1530	14.31	11.28
	Superferric, order 3, normal and skew	MCSXF / MCSSXF	HCRPLBC	2	8 (IR1/5)	0.099	0.112	213	54	38.16
	Superferric, order 4, normal and skew	MCOXF / MCOSXF	HCRPLBC	2	8 (IR1/5)	0.102	0.115	220	54	39.6
	Superferric, order 5, normal and skew	MCDXF / MCDSXF	HCRPLBC	2	8 (IR1/5)	0.092	0.106	120	54	39.6
	Superferric, order 6	MCTXF	HCRPLBC	1	4 (IR1/5)	0.085	0.097	805	54	41.04
	Superferric, order 6, skew	MCTSXF	HCRPLBC	1	4 (IR1/5)	0.084	0.094	177	54	41.04
D1	Separation dipole D1	MBXF	HCRPAFF	1	4 (IR1/5)	12.11	13.231	24.84	0.31	0.28

Warm Powering System of HL-LHC String

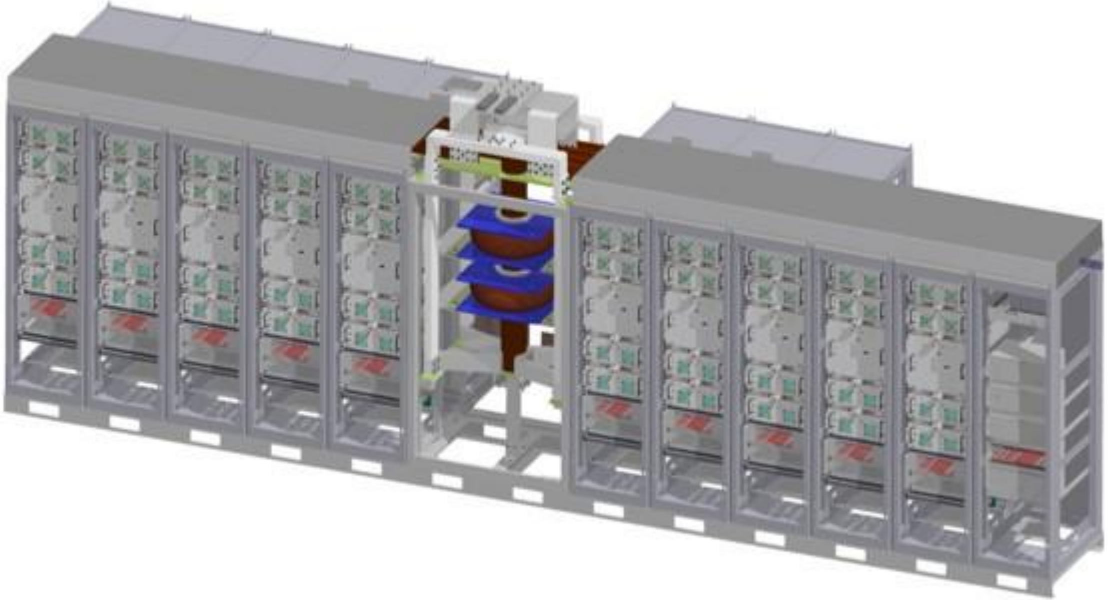
- HL-LHC String as been designed as the 5th IP side of HL-LHC project
  - Same integration



String integration versus machine integration

Warm Powering System of HL-LHC String

- HL-LHC String as been designed as the 5th IP side of HL-LHC project
  - Machine equipment is used

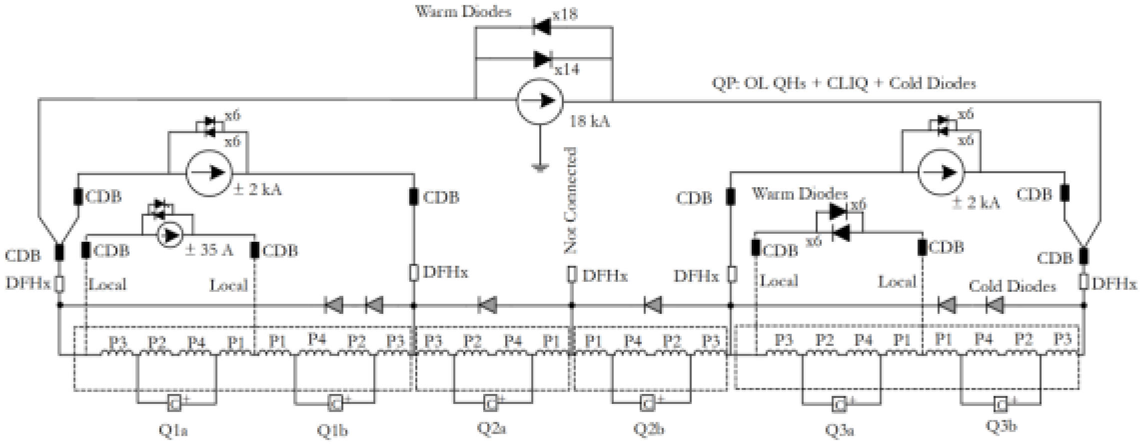


18kA Power Converter of RQX circuit

Warm Powering System of HL-LHC String

- HL-LHC String as been designed as the 5th IP side of HL-LHC project
  - Advantages: experience of String can be directly used for the machine

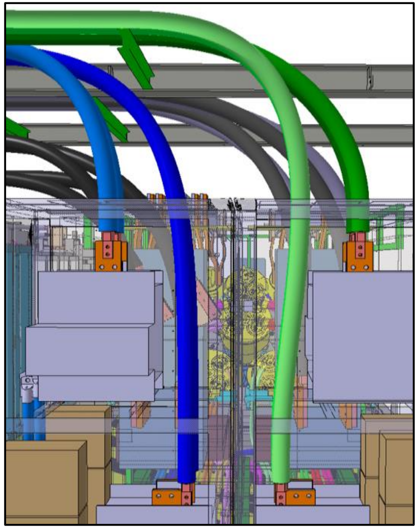
IT Main Circuit:

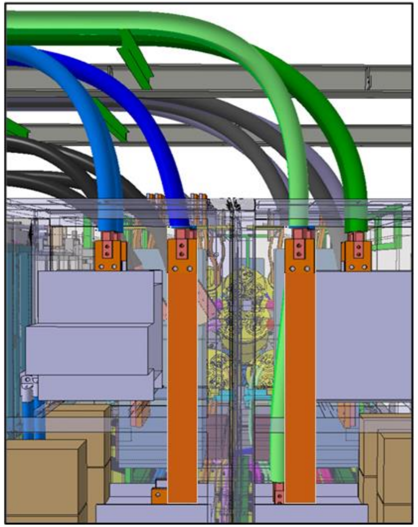


Current control with matrix decoupling loop

Warm Powering System of HL-LHC String

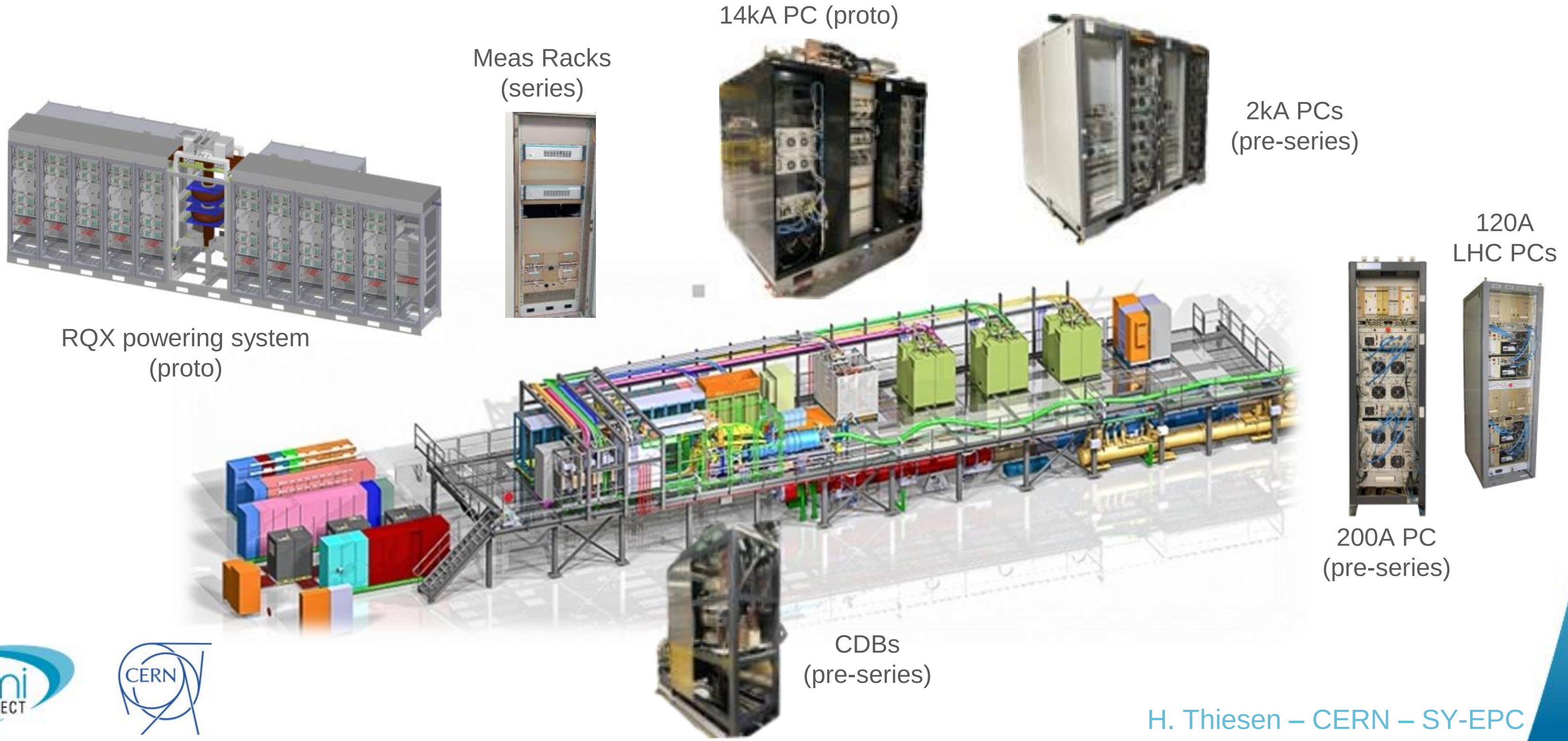
- HL-LHC String as been designed as the 5th IP side of HL-LHC project
  - Drawbacks:
    - Not major redesign possible
    - Upgrade of the equipment between HL-LHC String and last IP side (6 to 8 months)


String & machine integration


Proposal integration

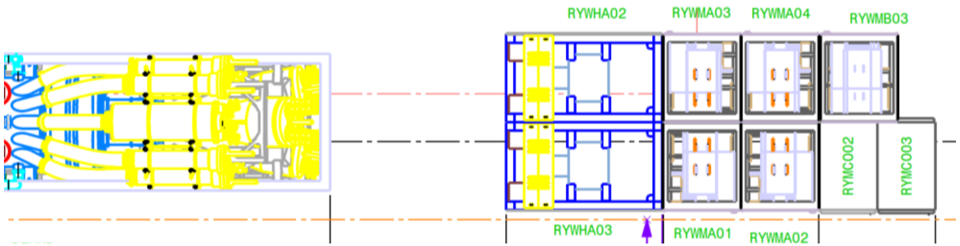
Integration & Installation

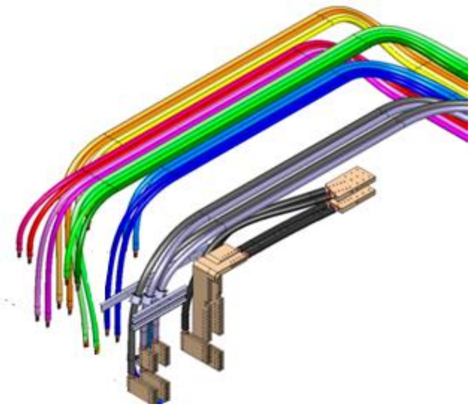
- Equipment installed in the HL-LHC String

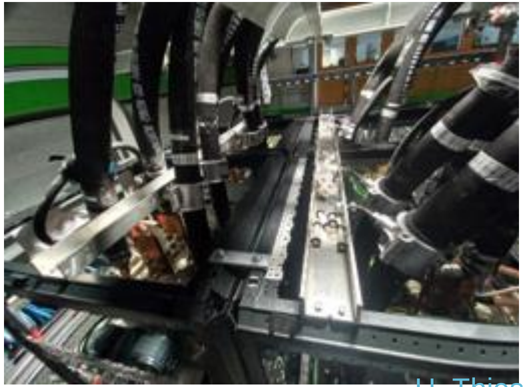


Feedback of Integration & Installation

- Feedback of integration
  - Integration of HL-LHC has shown issue for the machine installation and operation







Feedback of Integration & Installation

- Feedback of integration
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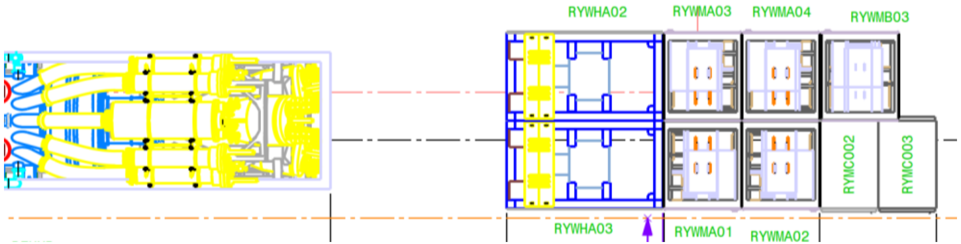
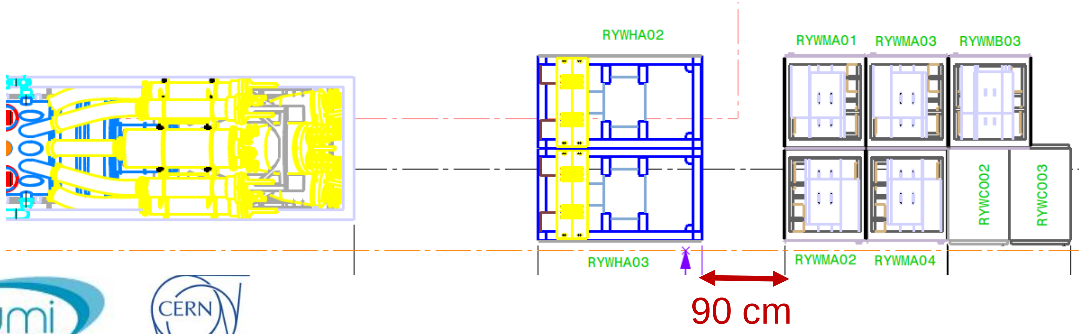


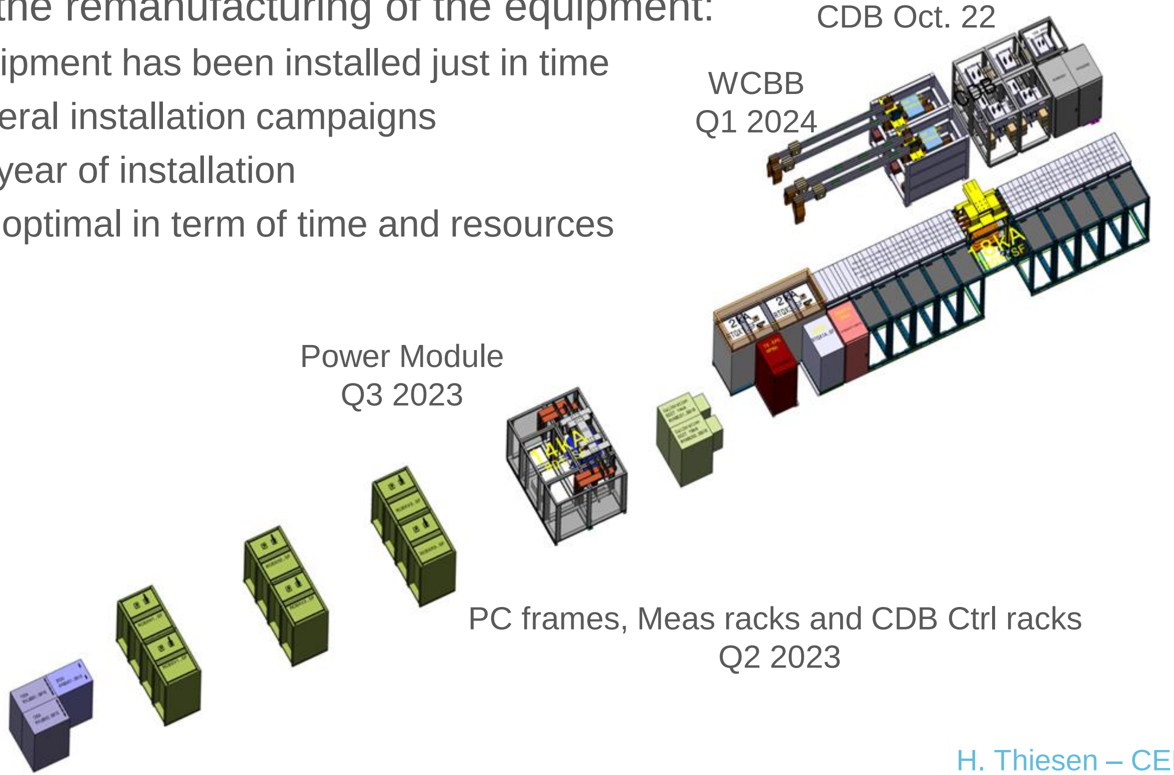
Initial UR integration



Final UR integration
With HL-LHC String Feedback
(ECR LHC-RP-EC-0014)

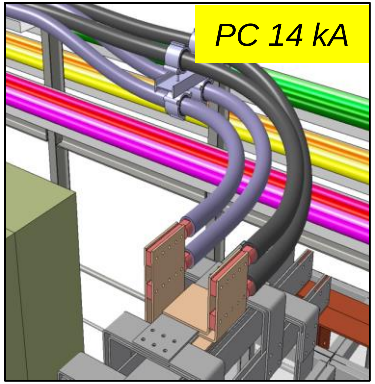
Feedback of Integration & Installation

- Feedback of installation
  - To limit the remanufacturing of the equipment:
    - Equipment has been installed just in time
    - Several installation campaigns
    - 1.5 year of installation
    - Not optimal in term of time and resources



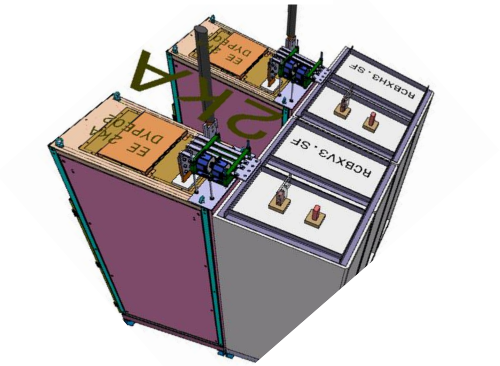
Feedback of Integration & Installation

- Feedback of installation
  - Mechanical interfaces have been defined during HL-LHC String installation
    - Better machine integration
  - HL-LHC String was a good training exercise
    - Gain of time and resources during LS3 (critical period)
    - 2 months are planned per IP side (1.5 year for String)



Optimization of the interface between PCs and WCCs

Final int. with Current sensor



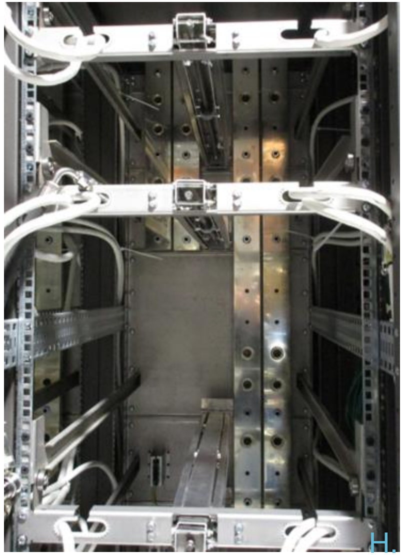
Optimization of the interface between PCs and EES

Individual System Tests and Short Circuit Tests

- 1st phase of powering
  - Before to power the magnets, the power converters have been tested
    - Alone to validate the interface with the HL-LHC String infrastructure (IST)
      - Water Colling System
      - AC distribution (normal and UPS)
      - Communication system….
      - Test procedure EDMS 2767662
    - With the other systems to validate the warm parts of the HL-LHC String (SCT)
      - PIC
      - EES
      - WCC
      - String Control Room…
      - Test procedure EDMS 2744522

Individual System Tests and Short Circuit Tests

- IST
  - First time that PCs and CDBs are operating in a machine infrastructure
  - Several issues have been identified
    - Mechanical issue to plug the power modules inside 18kA power converter – Redesign of internal DC busbar



Individual System Tests and Short Circuit Tests

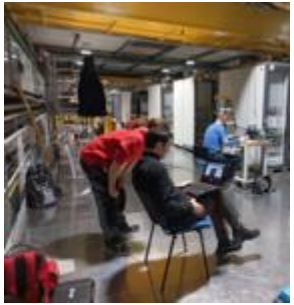
- IST
  - First time that PCs, CDBs are operating in a machine infrastructure
  - Several issues have been identified
    - Water distribution of 2kA power converters was not compliant with CV specification – Redesign of internal water distribution and removing several quickfit connectors

Individual System Tests and Short Circuit Tests

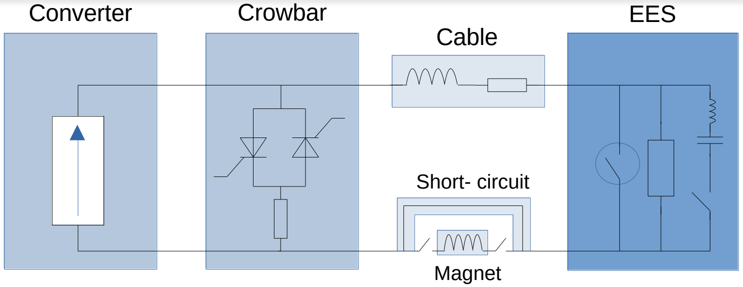
- IST
  - First time that PCs, CDBs are operating in a machine infrastructure
  - Several issues have been identified
    - Electrical insulation weakness of WCP – redesign of WCP and review of assembly procedure

Individual System Tests and Short Circuit Tests

- SCT
  - First time that PCs, CDBs are operating with the other warm systems, mainly EES, PIC and WCC
  - Several issues has been identified or confirmed
    - Over voltage generated by EES capacitor during the opening – 0.4 mH inductor added for the 200A circuit

EES discharge tests with SY-EPC and TE-MPE

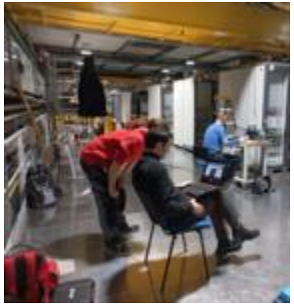


Accepted converter output voltage within ± 63 V

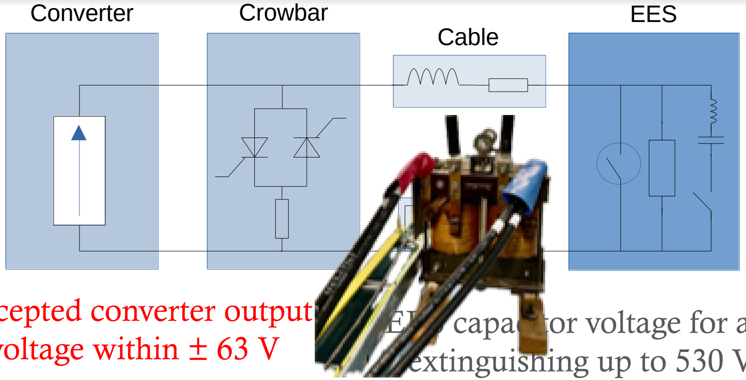
EES capacitor voltage for arc extinguishing up to 530 V

Individual System Tests and Short Circuit Tests

- SCT
  - First time that PCs, CDBs are operating with the other warm systems, mainly EES, PIC and WCC
  - Several issues has been identified or confirmed
    - Over voltage generated by EES capacitor during the opening – 0.4 mH inductor added for the 200A circuit



EES discharge tests with SY-EPC and TE-MPE

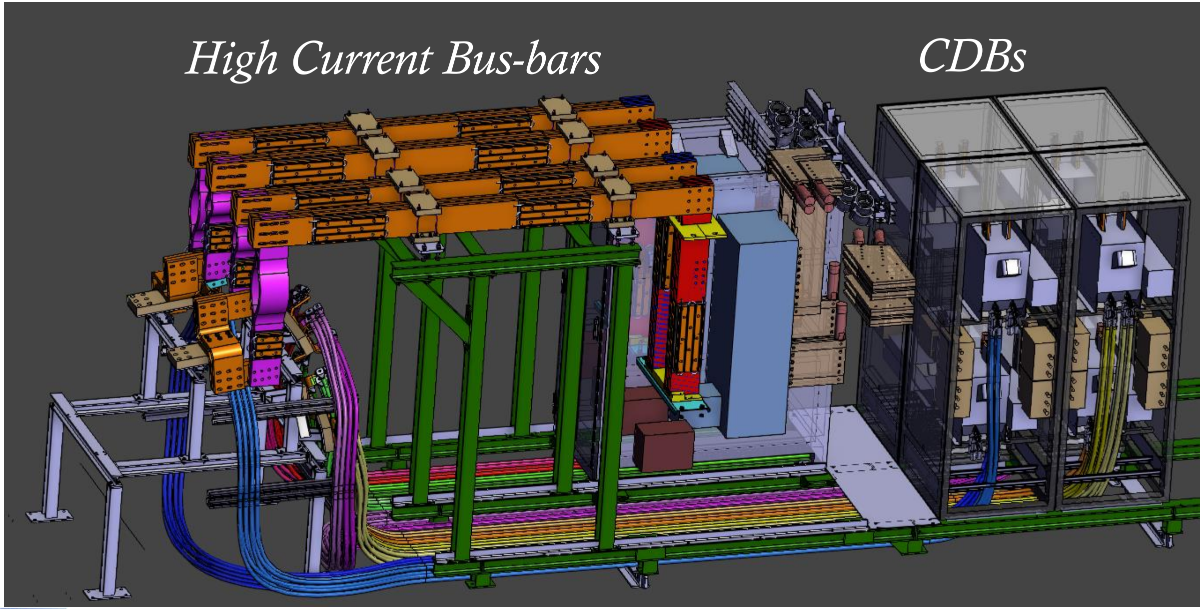


Accepted converter output voltage within ± 63 V

E[illegible] capa[illegible]tor voltage for arc extinguishing up to 530 V

Individual System Tests and Short Circuit Tests

- SCT
  - A unique opportunity to validated CDBs and WCBB in real conditions

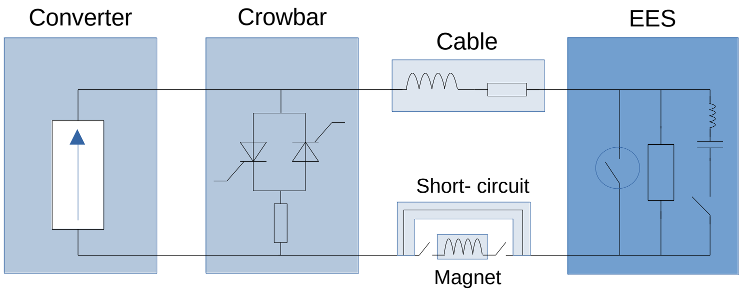


Electrical Safety Aspect

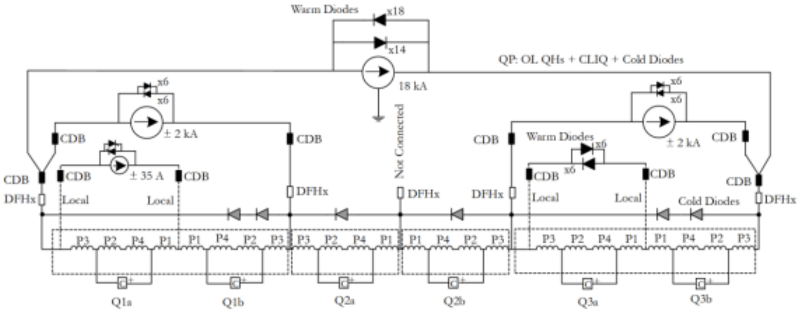
- Electrical Hazards
  - During intervention, electrical hazards are eliminated by the *consignation* of the circuit
  - In the LHC, electrical hazards are generated by power converter (electrical source) and the superconducting magnet (stored energy)
  - Electrical hazards are eliminated by
    - *Consignation* of the power converter
    - Checking the Zero Current in the circuit

Electrical Safety Aspect

- Electrical Hazards
  - In the HL-LHC circuits, electrical hazards are generated by
    - power converter (electrical source)
    - superconducting magnet (stored energy)
    - Charged capacitors of EES (2kA, 600A and 200A circuits)
    - Charged capacitors of CLIQ (RQX circuits)



IT Main Circuit:



Electrical Safety Aspect

- Electrical Hazards
  - New procedures have been defined to mitigate theses new hazards as *Electrical Operation Modes of HL-LHC Magnet Circuits*

EDMS NO.	REV.	VALIDITY
3138092	**0.1**	**DRAFT**

REFERENCE : LHC-MPP-ES-0004

ENGINEERING SPECIFICATIONS

HL-LHC MAGNET CIRCUIT FORUM

ELECTRICAL OPERATION MODES OF THE HL-LHC MAGNET CIRCUITS

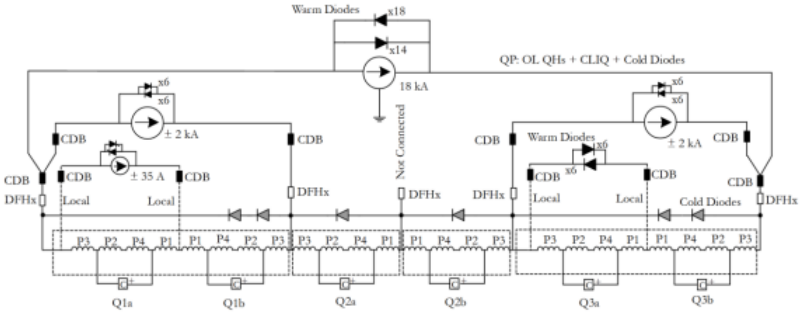
Abstract

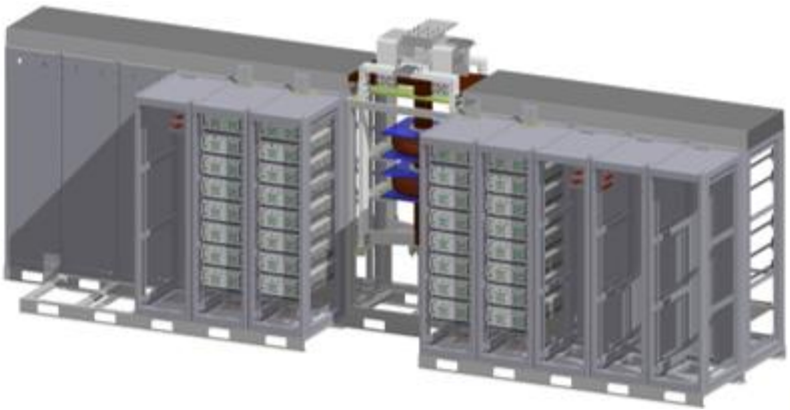
The present document details the electrical operation modes of the HL-LHC magnet circuits in view of their operation, testing and maintenance/interventions in the HL-LHC and in the HL-LHC IT String facility. The electrical sources that must be considered for a safe operation of the circuits are identified 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.

Powering of the Magnets

- Finalization of the installation
  - As mentioned before, equipment is installed when needed. Today, several parts are missing because not needed for the 1st powering campaign (IST and SCT)
    - 18kA power converter crowbar

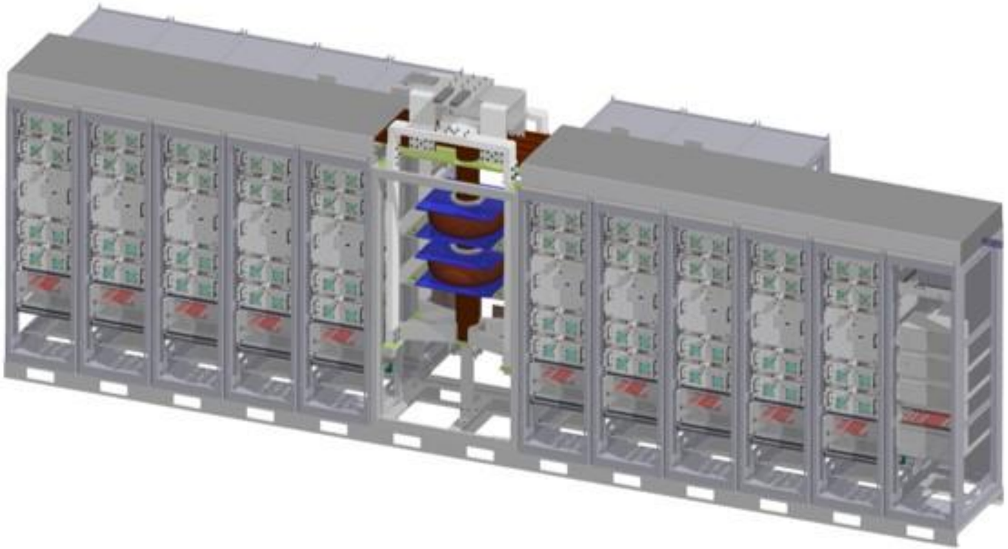
IT Main Circuit:





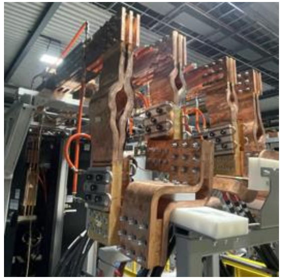
Powering of the Magnets

- Finalization of the installation
  - As mentioned before, equipment is installed when needed. Today, several parts are missing because not needed for the 1st powering campaign (IST and SCT)
    - Second DCCT and external ADC for 18kA, 14kA and 2kA power converters

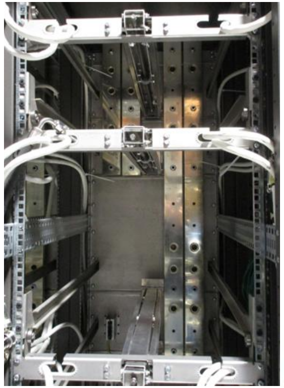


Powering of the Magnets

- Finalization of the installation
  - Some equipment upgrades are needed
    - Upgrades of WCBBs & WPCs and 18kA power converter




Insulation of WCBB&WPC

Internal BB of 18kA PC

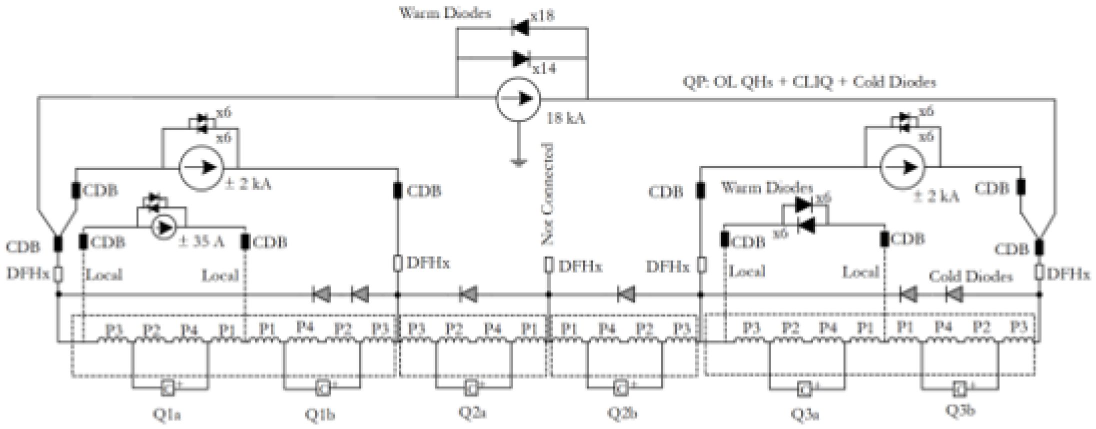
Powering of the Magnets

- Finalization of the installation
  - Final installation will be done in Q2-2025
  - Recommissioning of warm powering systems in July 2025

Powering of the Magnets

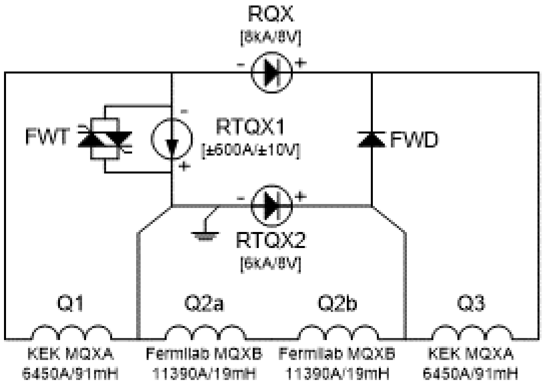
- Main challenges of the powering of the Magnets
  - Control of the RQX circuit

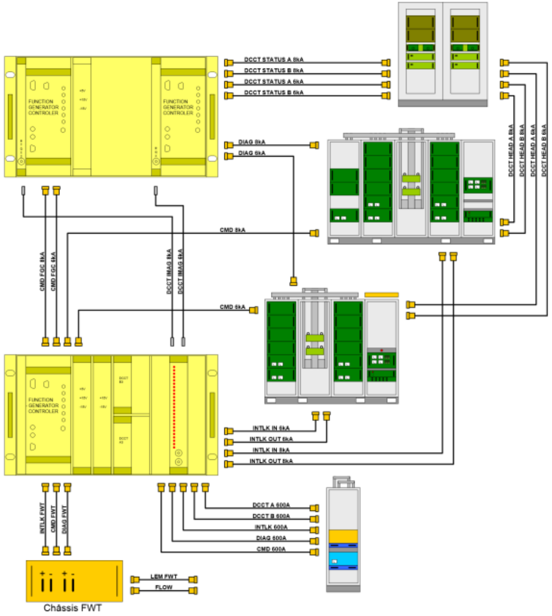
IT Main Circuit:



Powering of the Magnets

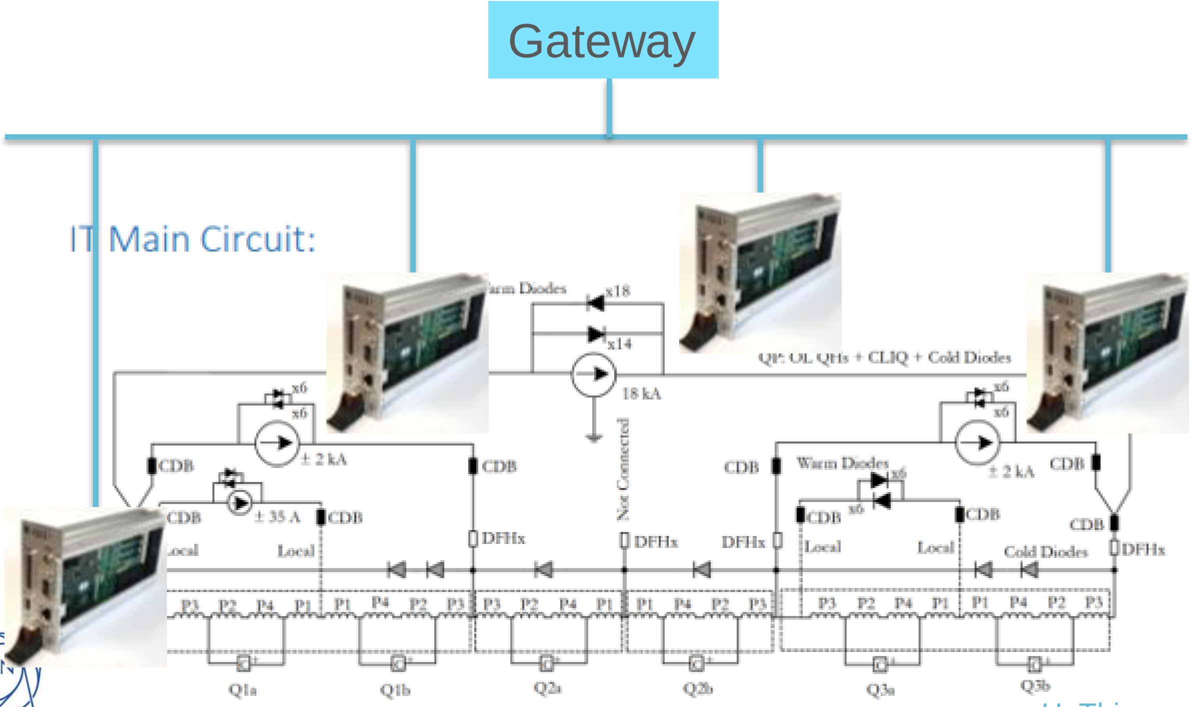
- Main challenges of the powering of the Magnets
  - LHC: Analog and Logic control





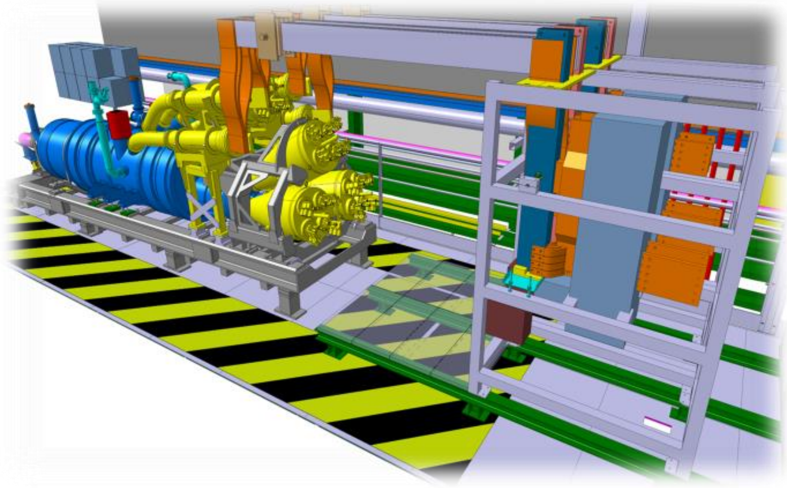
Powering of the Magnets

- Main challenges of the powering of the Magnets
  - HL-LHC: Digital and FGC intercommunication



Powering of the Magnets

- Main challenges of the powering of the Magnets
  - Final validation of the WCBB and DFHX interface (thermal aspect)



Summary

- Today we have a better integration of the IP side with the definition of the interfaces between PCs & CDBs and the WCCs & EESs
- Several Issues have been identified
  - Water distribution of 2kA PCs
  - Internal BB of 18kA PC
  - WCBB and WCP insulation weakness
- Installation cookbook (or the good practices for efficient installation) has been created
- 2 main challenges for the powering of the magnets
  - Current loop of RQX circuit with decoupling matrix
  - Final validation of the WCBB

Thank you