Layouts for the HL-LHC Quench Detection Instrumentation

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HL-LHC Magnet Circuit Instrumentation Day 2023

Content

- Recall from the HL-LHC Instrumentation Review 2020
- Layouts for the HL-LHC Quench Detection Instrumentation and Signals
- Overview of the Instrumentation Routing
- Conclusions

Recall from the HL-LHC Instrumentation Review 2020

Extract from the Pannel Report (EDMS 2431168)

Rec. No.	Extract from Panel Review	Comment
R1	Clarify the level of quench heater redundancy for the D1 magnet (i.e. number of quench heaters necessary for nominal operation in tunnel)	Out of Scope of the Day
R2	Connection method of (redundant) V-taps should be clearly defined, documented and coherently applied for all circuit parts	See talk by Herve,Yann, Christian
R3	A coherent documentation of the overall circuit instrumentation must be established, shared and approved between all WPs (including all protection as well as monitoring needs)	Covered by this talk
R4	CLIQ leads and (identical) k-mod leads are to be included in the protection baseline (through monitoring during discharge/powering)	Covered by this talk
R5	The responsibilities for proximity equipment must be clarified and synergies exploited between the involved WPs. The development of 'ELQA measurement ports' is supported.	Covered by this talk + see talk by Jens in the afternoon
R6	The IFS systems are to be considered and optimised as a global, integrated system, including flanges, connections on both warm and cold sides as well as cabling and ancillaries	see talk by Giorgio

Extract from the Pannel Report (EDMS 2431168)

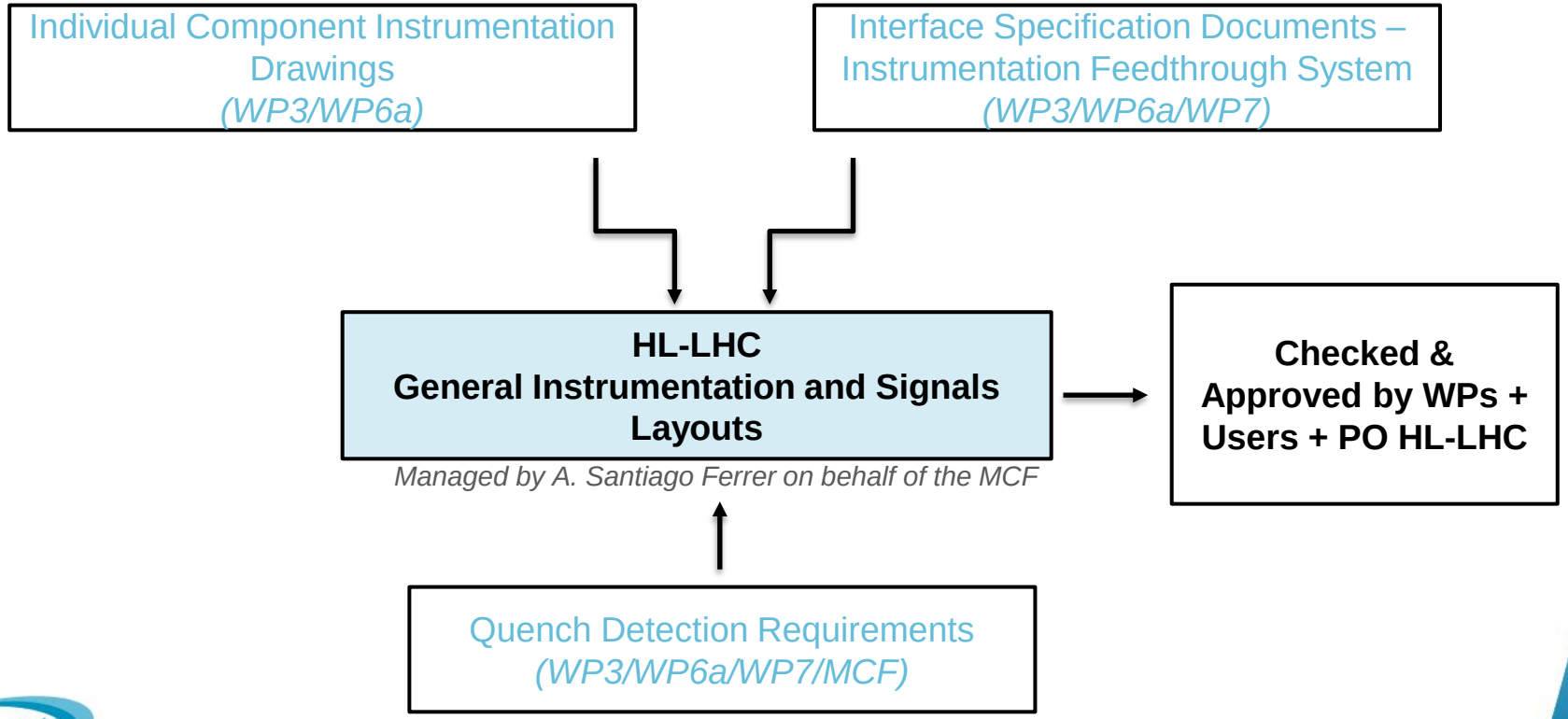
Rec. No.	Extract from Panel Review	Comment
R7	The detailed design of the instrumentation interconnection box should be addressed rapidly as one of the complex and important items to be integrated.	See talk by Giorgio on IFS + Talk of Jens on QDS Patch Panel + Talk of Chrisitan on Splitting Modules
R8	The use of a standard IFS solution for the V-taps (in particular on DFX/M and DFHX/M) should be investigated. The use of the LEMO connector type for temperature sensors on current leads should be reconsidered.	See talk by Giorgio on IFS + Talk of Chrisitan on cold powering instrumentaiton
R9	Based on new instrumentation baseline endorsed by the review panel, conduct a final optimization of cover flange types, aiming as well at reducing the number of spare feed-throughs.	See talk by Giorgio on IFS
R10	A thorough QA process along with the setup of a dedicated test program and planning is mandatory to assure the quality of HL-LHC flanges to match at least that of the LHC flanges.	See talk by Herve
R11	The D2 and MCBRD currently foresees redundant V-taps for splice monitoring. The same strategy as for all other circuits should be applied for series (redundant for protection, single for monitoring).	Covered by this talk

Extract from the Pannel Report (EDMS 2431168)

Rec. No.	Extract from Panel Review	Comment
R12	Internal magnet splices do not require to be monitored individually. External splices of main circuits (IT, D1, D2) should be monitored as they can be repaired in situ	Covered by this talk
R13	Monitoring of all splices in the superconducting link is justified due to the novel materials and possibility of in-situ repair. It is recommended to reduce to single monitoring V-taps.	Covered by this talk
R14	Series magnets shall contain only nominal instrumentation. Additional sensors that may still remain from test setups should be terminated suitably with test and operation requirements	Covered by Herve's talk
R15	Establish and approve an agreed project baseline and protection scheme (including CRYO/SW interlocks) for the machine, among WP6a, WP7 and WP9, aiming at a considerable optimisation of necessary instrumentation	Covered by this talk + talk by Marco + talk by Christian
R16	Review and document rationale behind modified choice of instrumentation wires for QH and cryo-heater in view of capillary integration	See Herve's talk
R17	Clarify and document QA procedures for acceptance of instrumentation wires, as they were not presented during the review	See Herve's talk + Christian's talk

Layouts for the HL-LHC Quench Detection Instrumentation and Signals

Circuit Instrumentation and Signal Layouts Workflow



Overview of the General Instrumentation Layouts

R3

R15

- Proposed to provide a full picture of the HL-LHC magnet and cold powering instrumentation
- Support for a wide-range of users (ElQA team, IFS box design and intervention, magnet & cold powering builders, circuit operators or circuit analysis)

In Engineering Check

GIL for the Inner Triplet & D1 at Points 1 and 5:	**GIL for the Matching Section at Points 1 and 5:**	**Quech Detection Signal Representation for the Inner Triplet, D1 & D2 magnets:**
LHCLSDIX0001	LHCLSDIM0001	LHCLSDIQ0001

R3: A coherent documentation of the overall circuit instrumentation must be established, shared and approved between all WPs (including all protection as well as monitoring needs)

R15: Establish and approve an agreed project baseline and protection scheme (including CRYO/SW interlocks) for the machine, among WP6a, WP7 and WP9, aiming at a considerable optimisation of necessary instrumentation

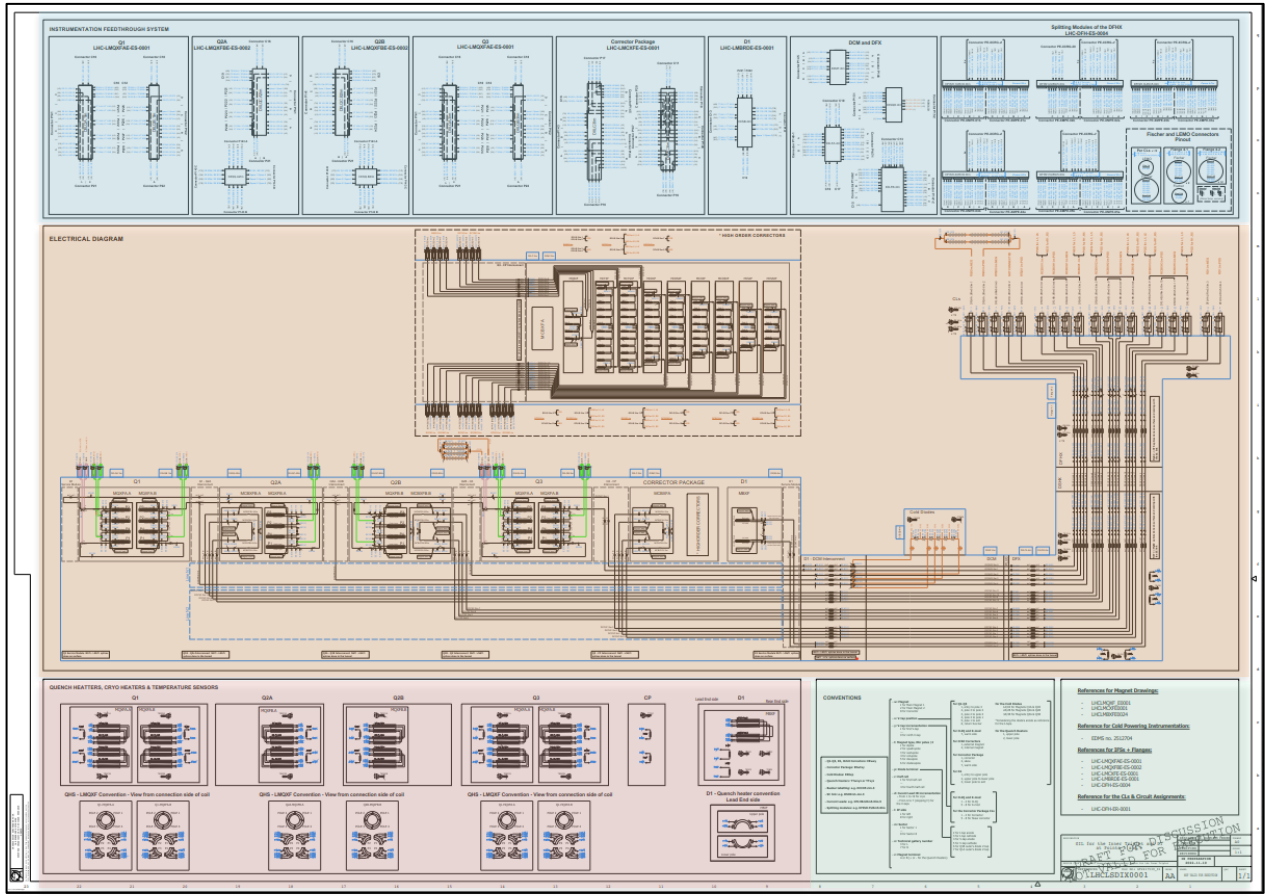
Layout 1 - Inner Triplet and D1 at Points 1 and 5

R3

IFSs
+
DFH Splitting Modules
Routing

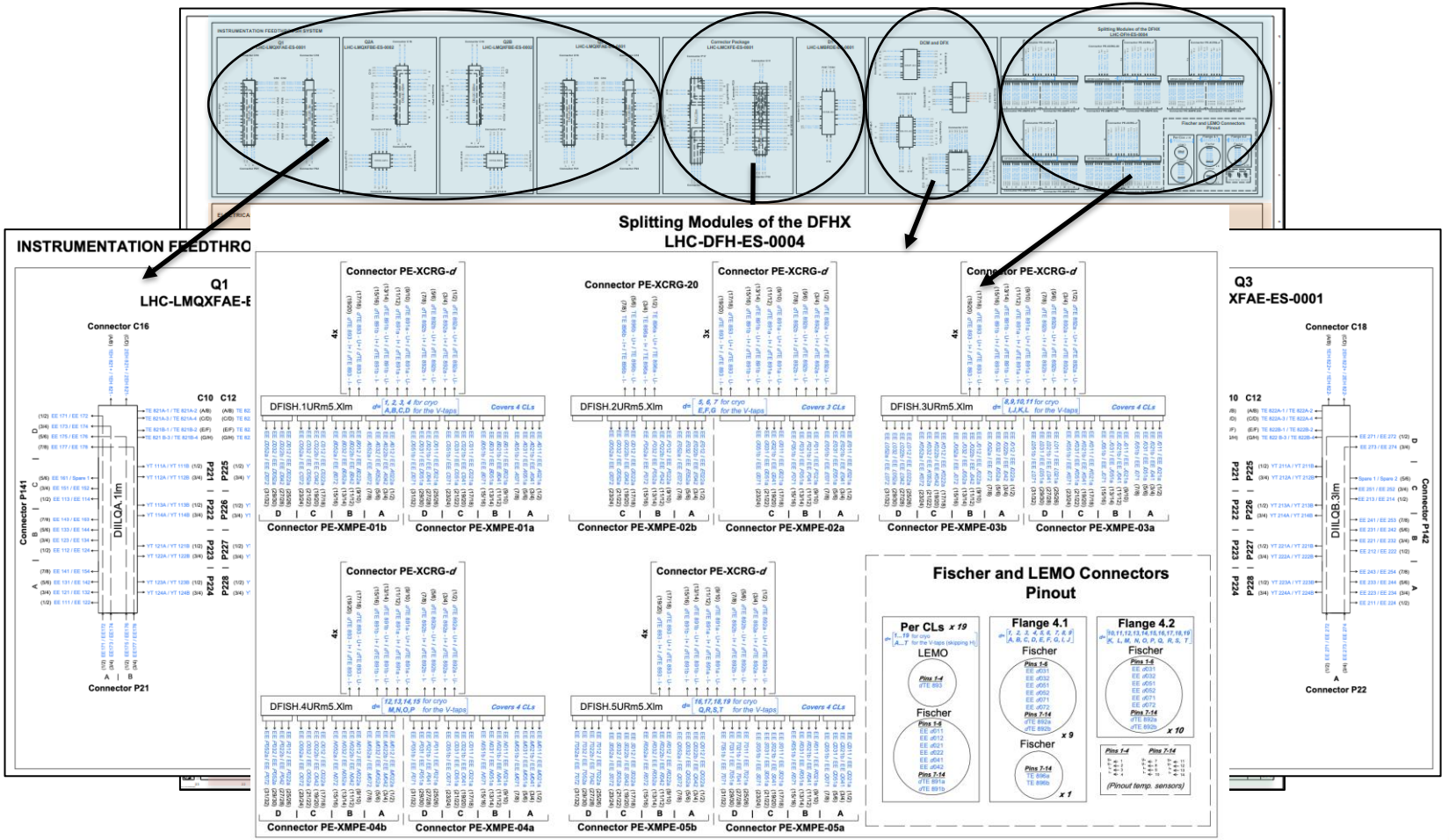
Magnets
+
Cold Powering
+
Instrumentation
V-taps
+
Polarities

QHs
Cryo Heaters
Temp. Sensors

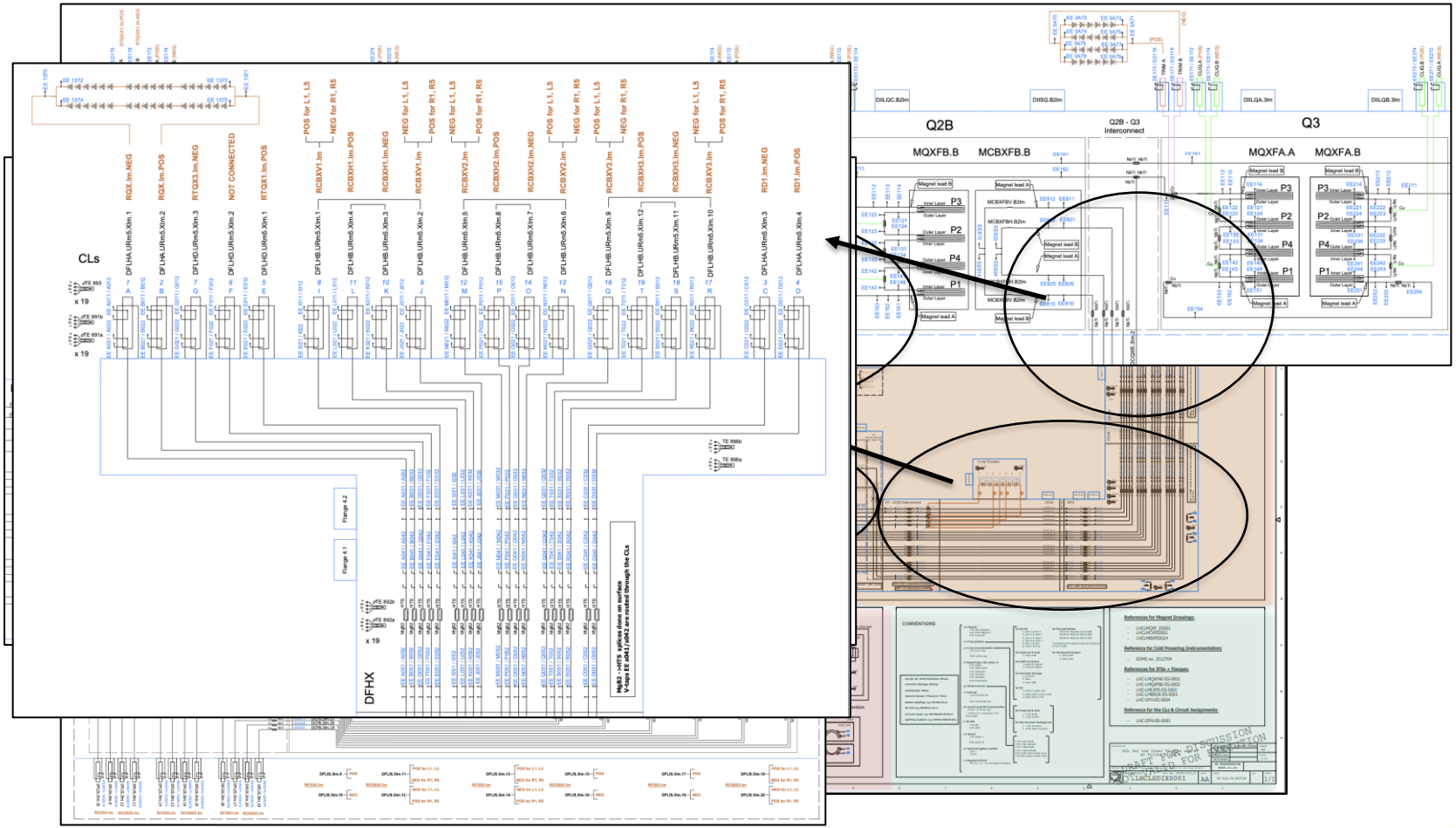


References
+
Conventions

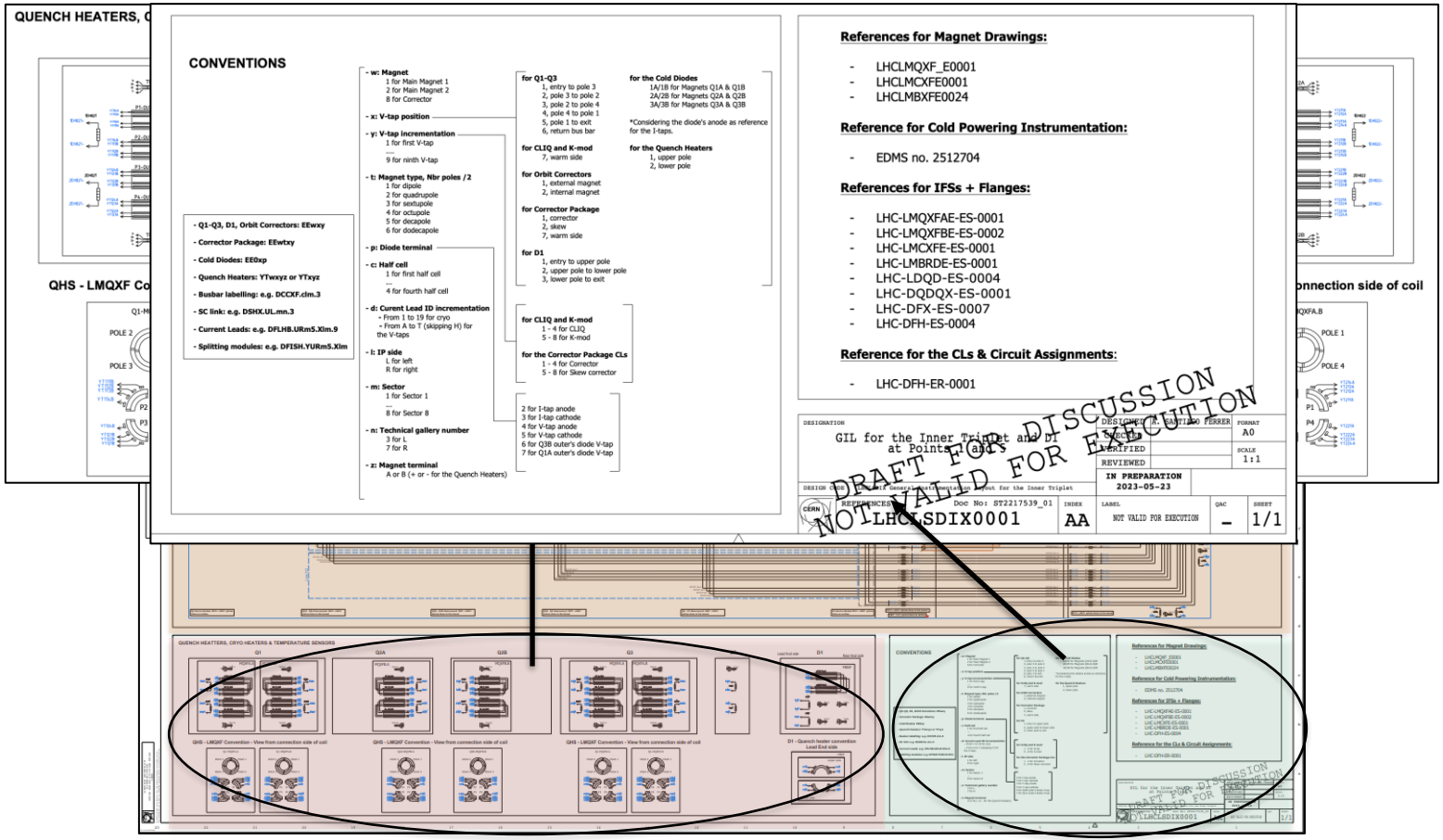
Layout 1 – Zoom on the different components



Layout 1 – Zoom on the different components



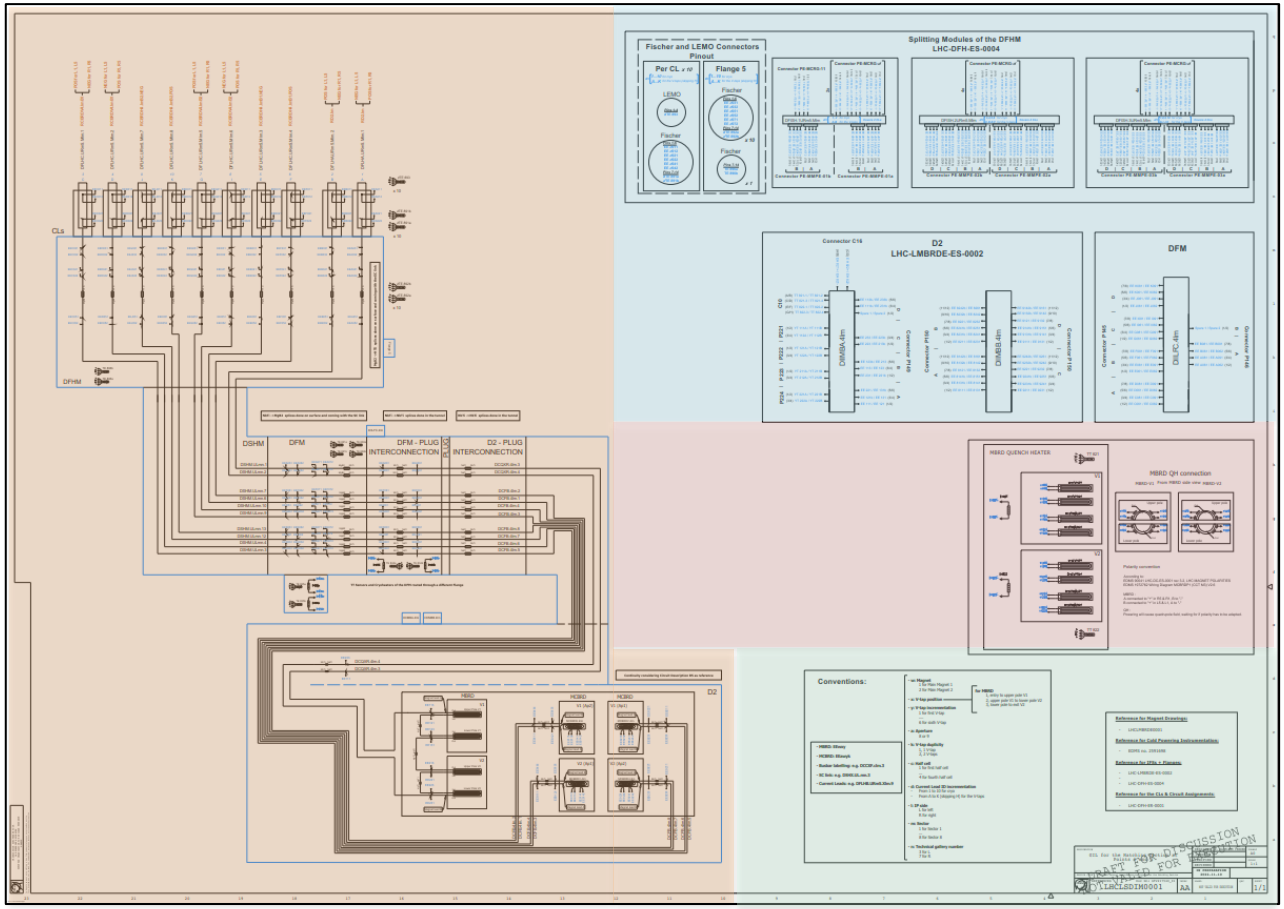
Layout 1 – Zoom on the different components



Layout 2 - Matching Section at Points 1 and 5

R3

Magnets
+
Cold Powering
+
Instrumentation
V-taps
+
Polarities



IFSs
+
DFH Splitting
Modules
Routing

QHs
Cryo Heaters
Temp. Sensors

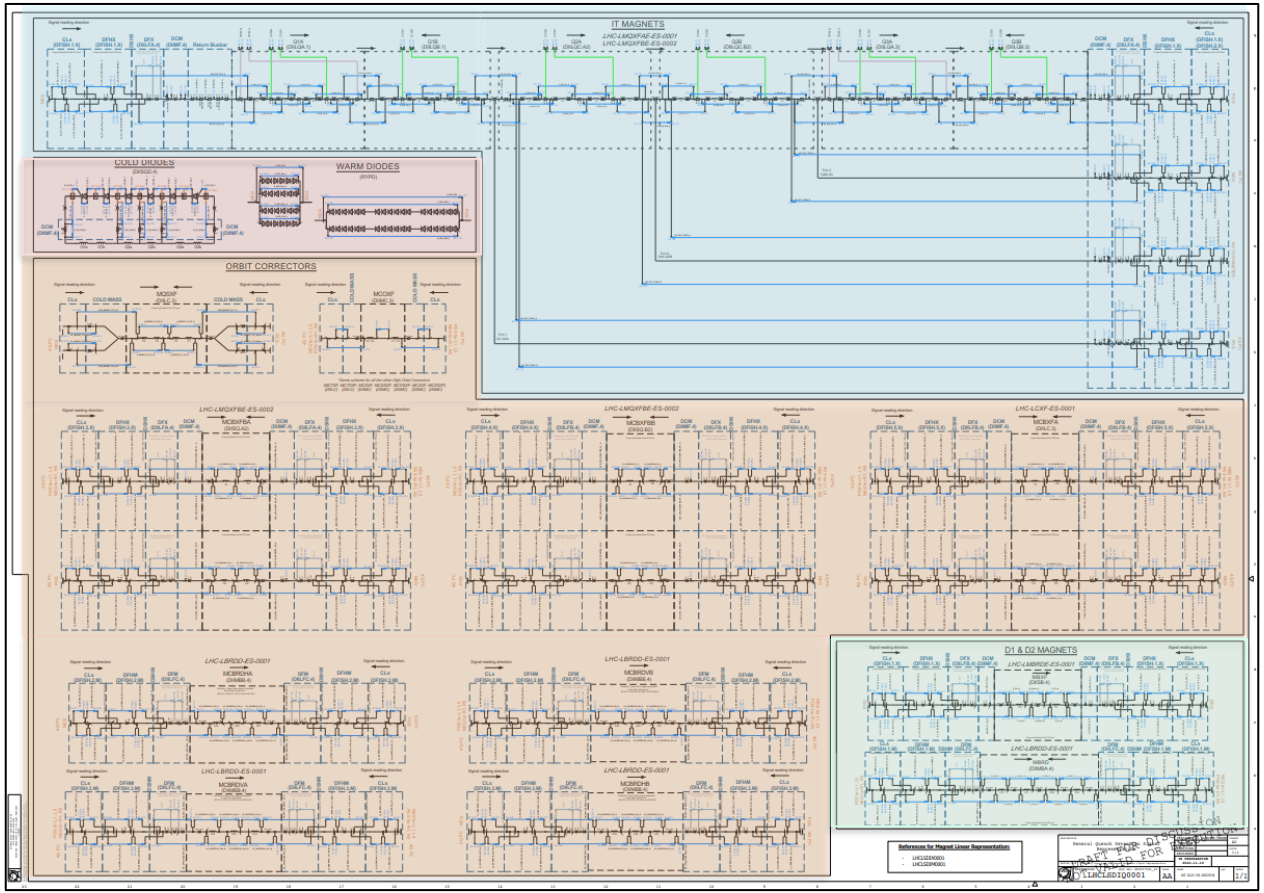
References
+
Conventions

Layout 3 - Quench Detection Signal Representation

R3

R15

Cold / Warm Diodes



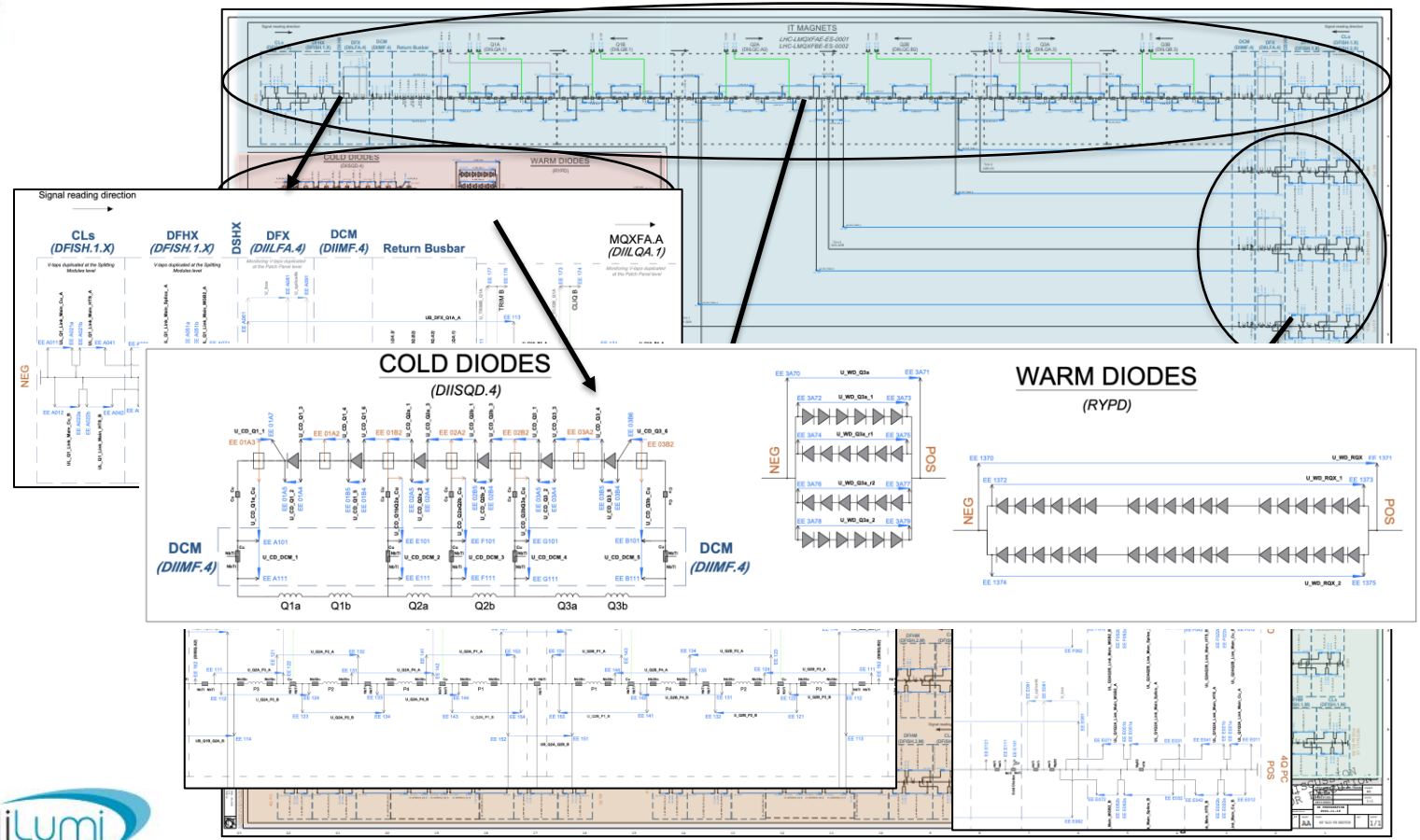
IT Magnets

Corrector Magnets

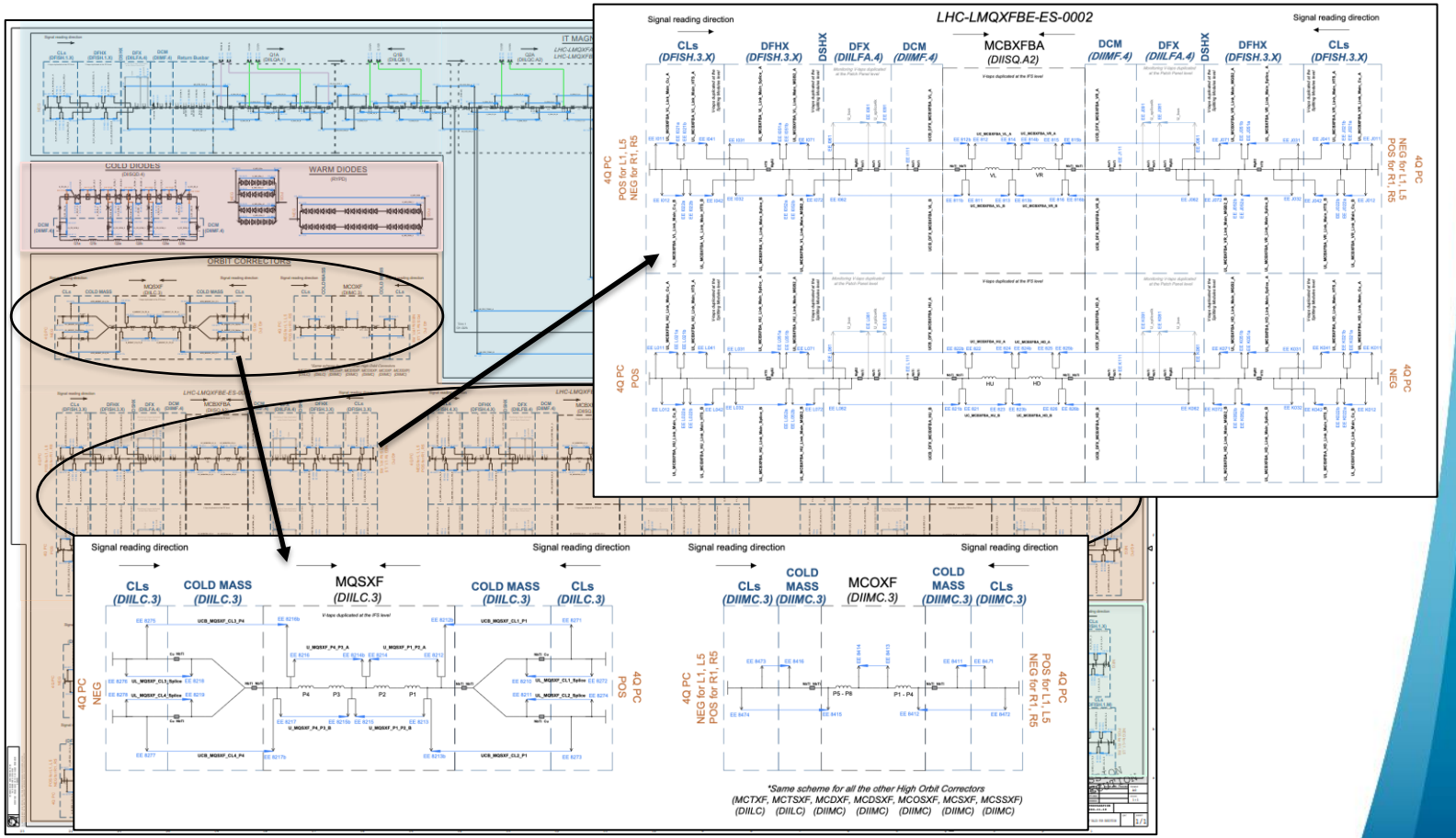
D1 & D2 Magnets

HL-LHC General Quench Detection Signal Representation

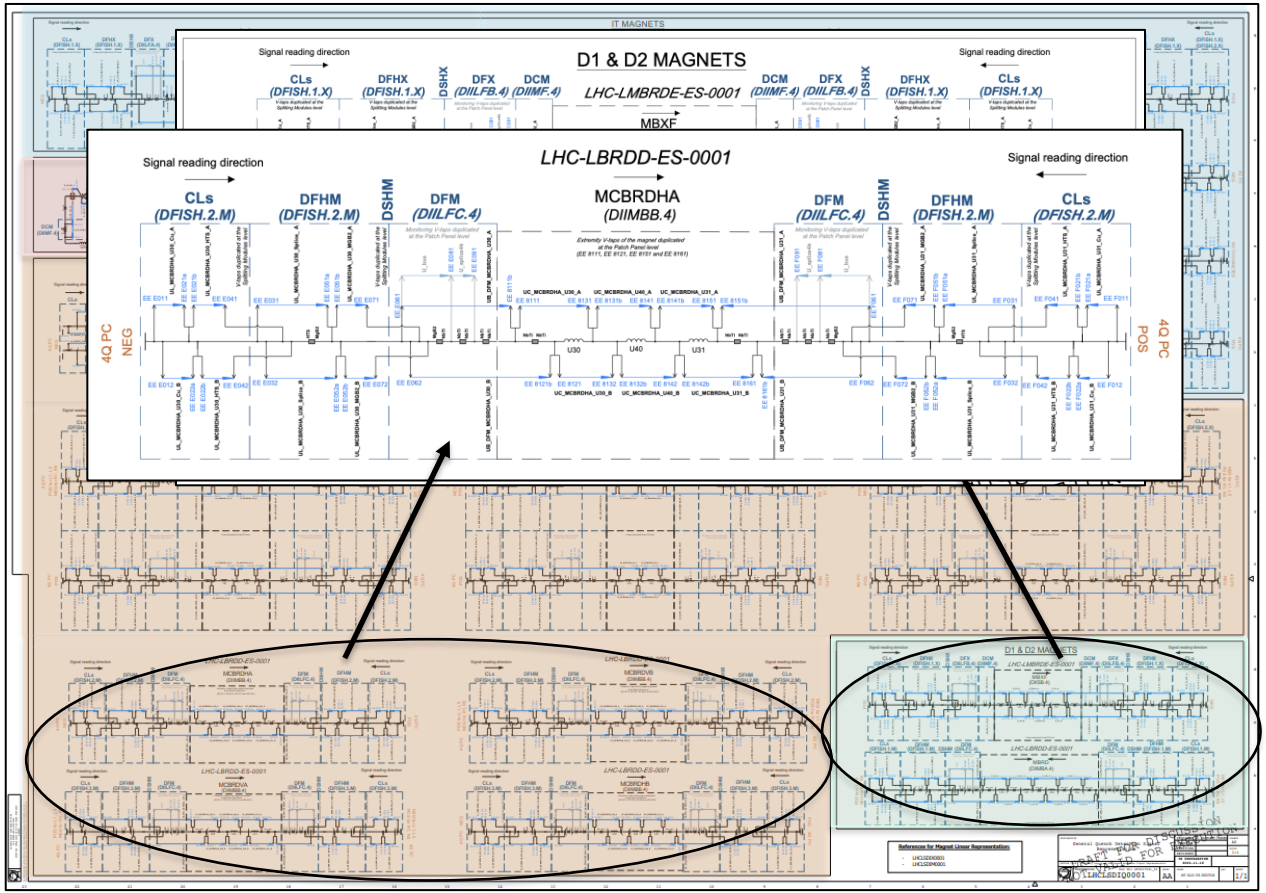
Layout 3 - Zoom on the different components



Layout 3 - Zoom on the different components



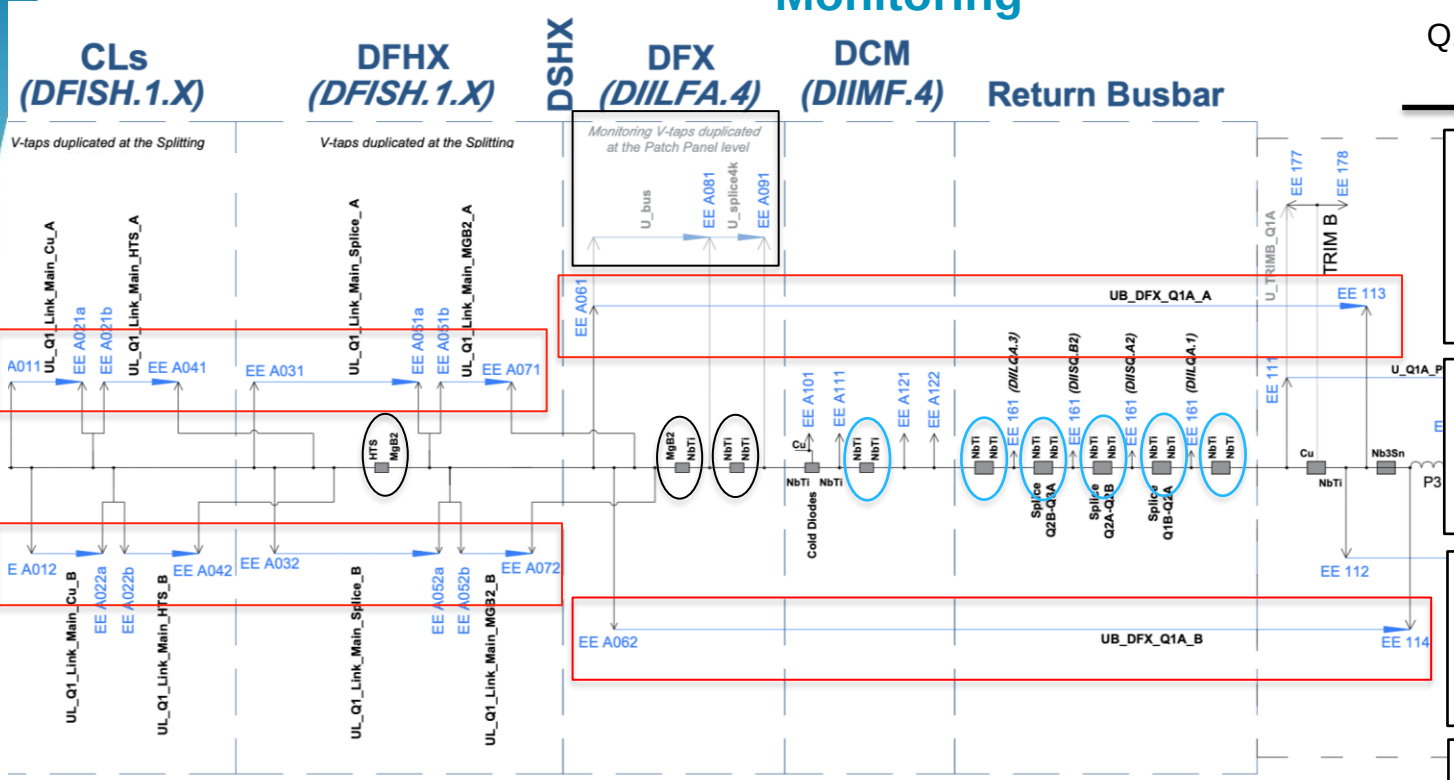
Layout 3 - Zoom on the different components



Answered Recommendations in the Layouts – Protection and Monitoring

R12

R13



The protection of the **CLs, HTS, MgB_2** and the **HTS-MgB_2 splices** is done with **redundant signals**

Protection of the bus bar from the **DFX/M to the Magnet** done with **redundant signals**

MgB_2-NbTi splice and the **NbTi-NbTi splice** in the **DFX** monitored by a **non-redundant signal**

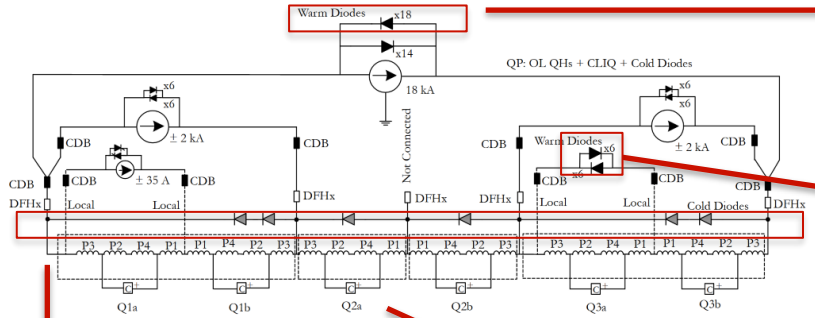
High current splices (IT, D1, D2) can be diagnosed offline by the ElQA on the QDS Patch Panel

R12: External splices of main circuits (IT, D1, D2) should be monitored as they can be repaired in situ

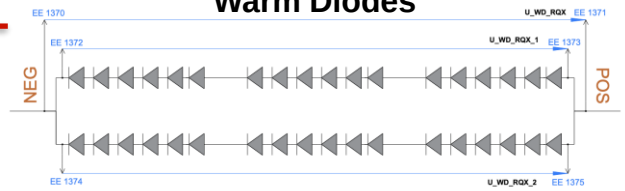
R13: Monitoring of all splices in the superconducting link is justified due to the novel materials and possibility of in-situ repair. It is recommended to reduce to single monitoring V-taps

Monitoring Signals for CLIQ, K-mod, Cold Diodes and Warm Diodes

R4

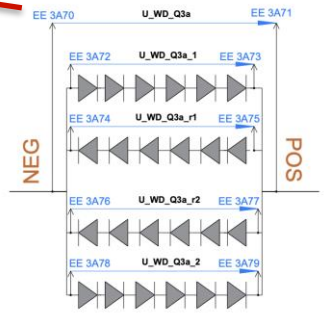


Warm Diodes



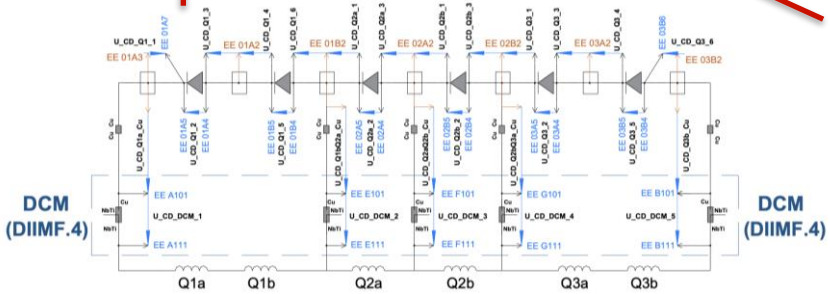
(optimized for 3 signals)

Warm Diodes



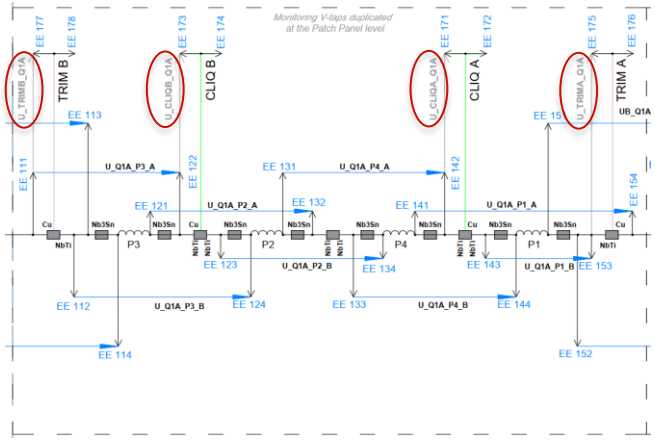
(optimized for 5 signals)

Cold Diodes
(28 signal readings)



Maximum signal configuration chosen as a baseline
(can be optimized after the IT String test)

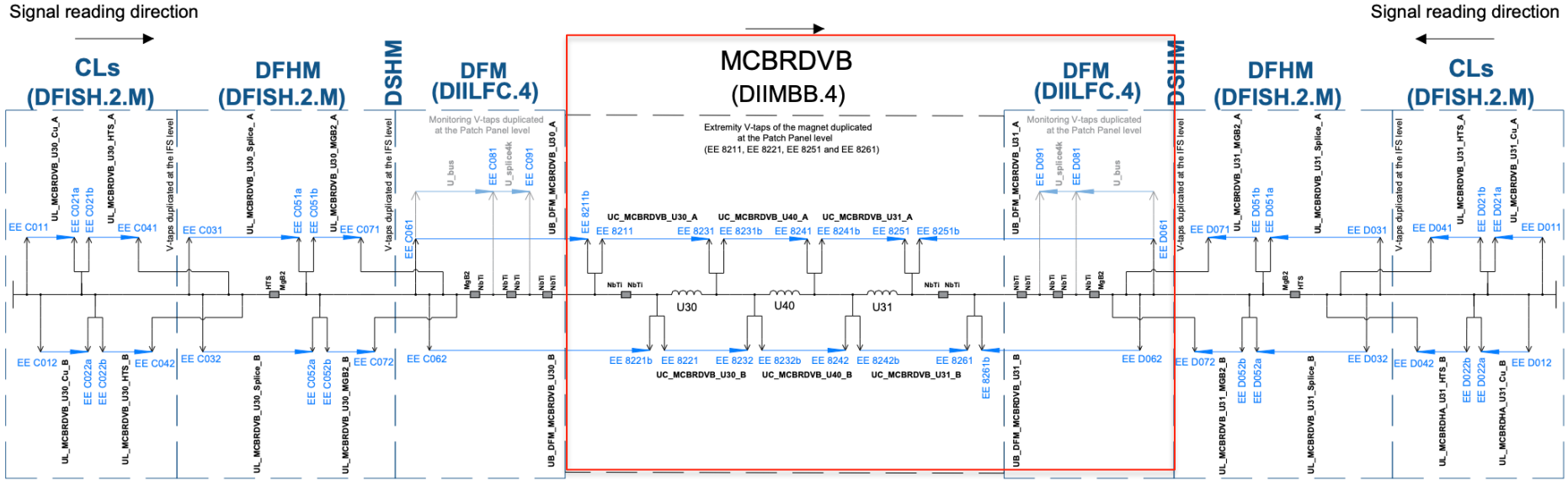
CLIQ and k-mod



R4: CLIQ leads and (identical) k-mod leads are to be included in the protection baseline (through monitoring during discharge/powering)

Protection and Monitoring of the D2 Correctors

R11



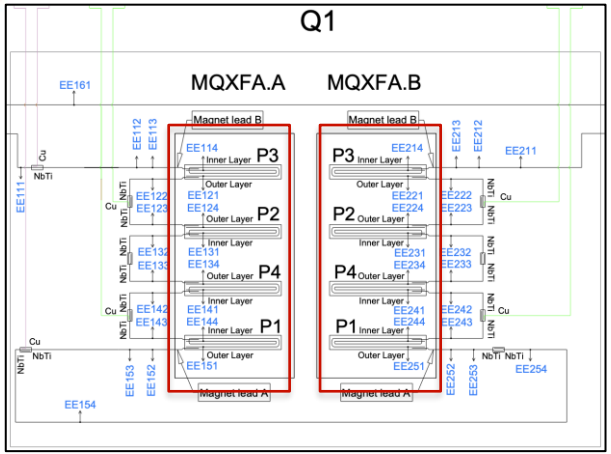
Example for MCBRD circuits

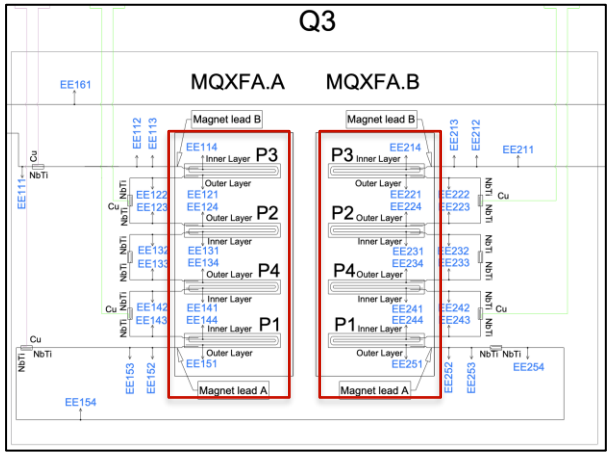
Remark: The HL-LHC convention of of the signal reading is from the current leads to the magnet mid-point as baseline. except for D2 correctors as it was possible to introduce V-taps to measure 30 %, 40 % and 30 % of coil voltage (CCT magnet)

R11: The D2 and MCBRD currently foresees redundant V-taps for splice monitoring. The same strategy as for all other circuits should be applied for series **(redundant for protection, single for monitoring)**

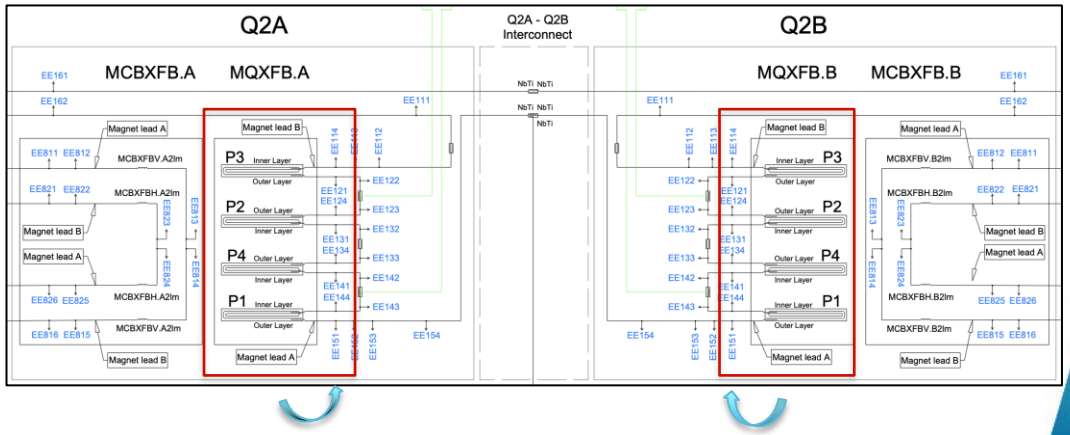
NB_3Sn Splices for the MQXFB magnets

R12





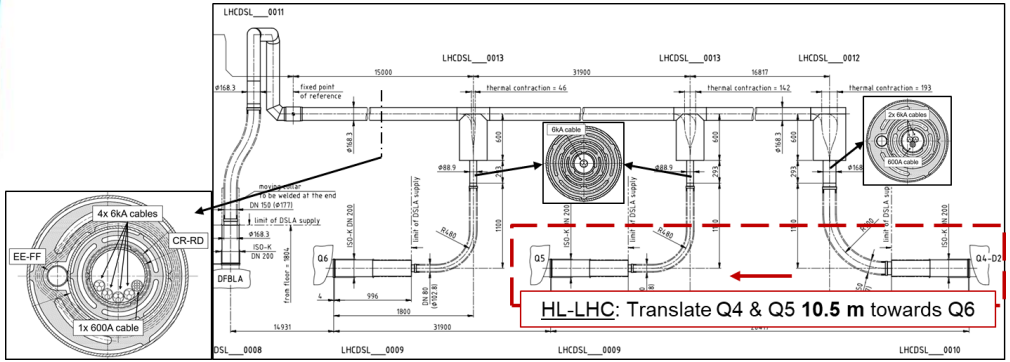
- In September 2020, the HL-LHC Instrumentation review (indico 948311) recommended not to monitor internal splices in the tunnel
- In spring of 2021, MQXFBP2 was tested, and it was demonstrated the capability to measure two Nb_3Sn-NbTi internal splices using only the external splices → WP3 took the decision of **removing internal V-taps in MQXFB (Q2a/Q2b).** To fulfill de requirements for detection, the internal V-taps will be replaced by external V-taps in the pole-to-pole interconnection region. This **change is not implemented in MQXFA (Q1/Q3)**



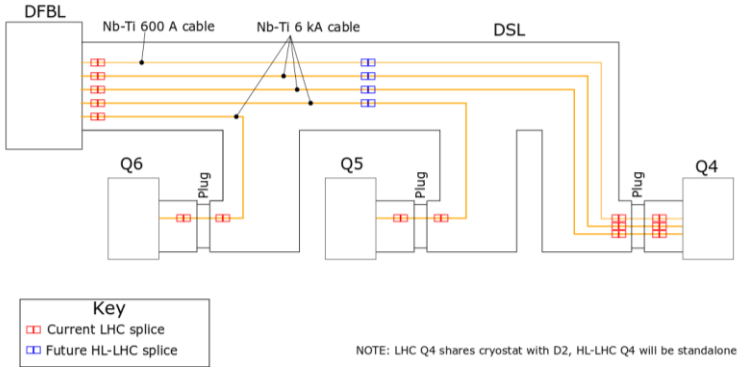
R12: Internal magnet splices do not require to be monitored individually

DSL Refurbishment for the HL-LHC

- DSL will be refurbished for the HL-LHC to translate Q4 and Q5 to the non-IP side:
  - Sleeves connections, ≈12.3 m apart
- Installation of new connection (splice) box:
  - New splices (for 6 kA and 600 A bus bars) with the expertise from TE-MSC team
- New Splices will be protected in the chain with the other splices/bus bars
- No additional V-taps or IFS are required



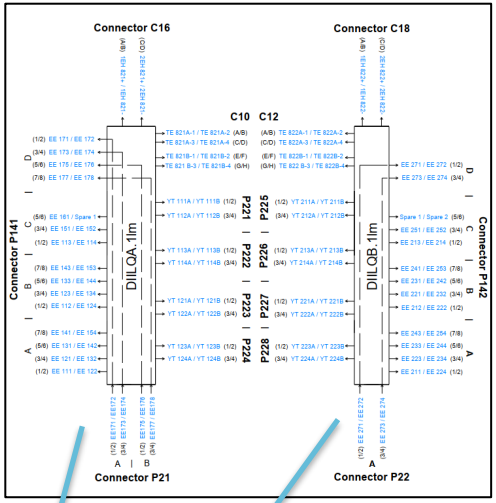
Courtesy of A. Lees, G. Casula – MCF no. 98



Overview on the Instrumentation Routing

Magnet, DCM and DFX/M V-taps Routing

More details in Giorgio's talk

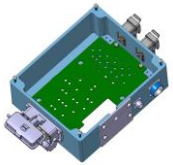


Routing done using the HL-LHC standard IFS boxes (S, L and M type) for magnets, DCM and DFX/M

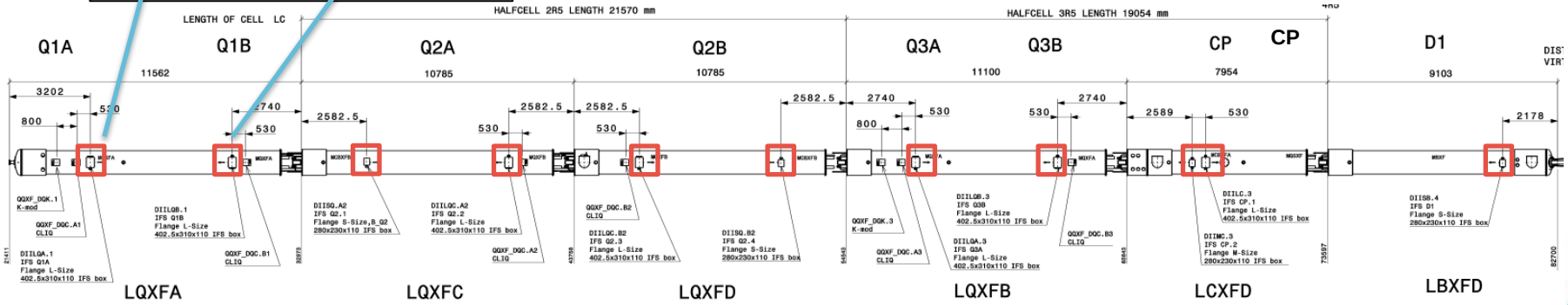
Connectors from all the IFS boxes routed to the QDS

QDS Input Patch Panel

uQDS



CRG Electronics



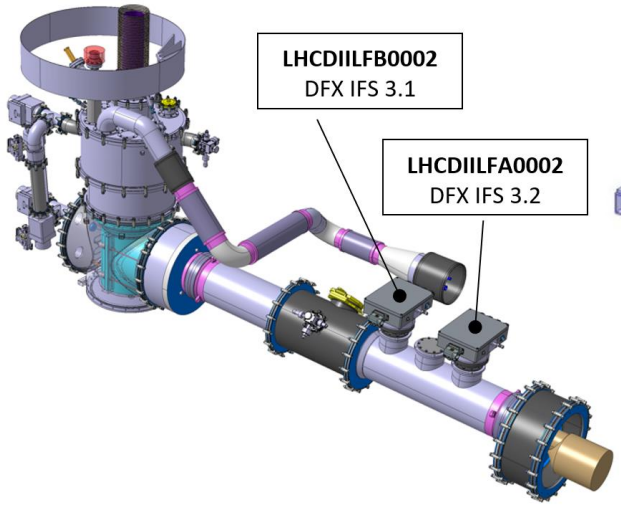
IFS for DFX/M and Splitting Modules of the DFHX/M

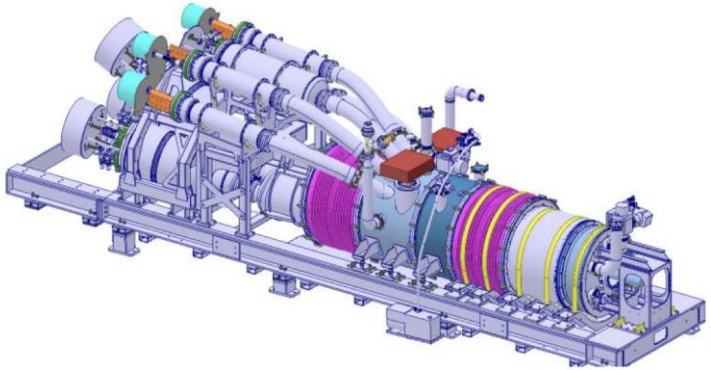
R8

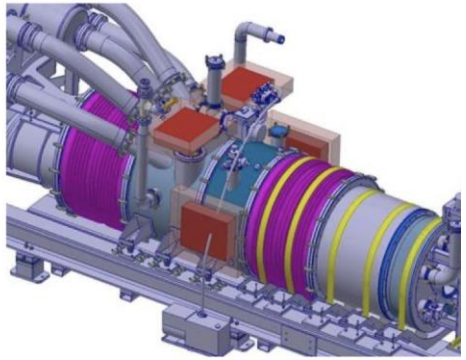
Engineering Specification: IFS Design for DFHX and DFHM

The solution of using the HL-LHC standard flanges requires space not compatible with the transport requirement. In addition, the routing of cables and potential access for inspection would not be granted.

A solution gathering signals with the same potential on common connectors is more compact and compliant with the available space







Integration study considering the 2 and 4 L-type IFS solutions for the DFHX

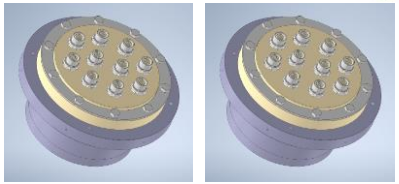
More details in Christian's talk

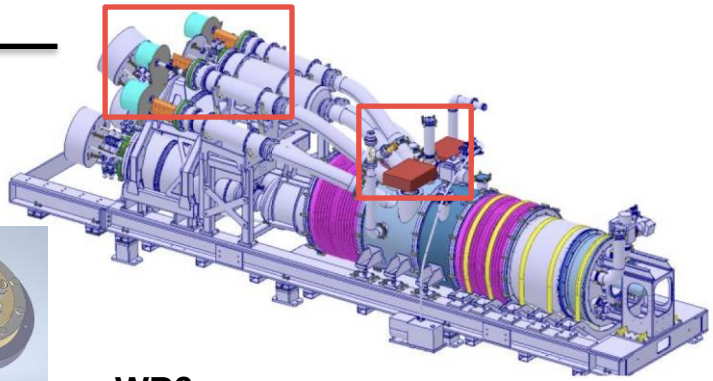
R8: The use of a standard IFS solution for the V-taps (in particular on DFX/M and DFHX/M) should be investigated. The use of the LEMO connector type for temperature sensors on current leads should be reconsidered

Splitting Modules of the DFHX/M

Splitting Modules (DFHX)
1 unit for the 18 kA leads
1 unit for the Trim leads
3 units for the correctors

V-taps and Temp sensors from flanges + CLs





WP6a

More details in Christian's talk

WP7

QDS Input Patch Panel

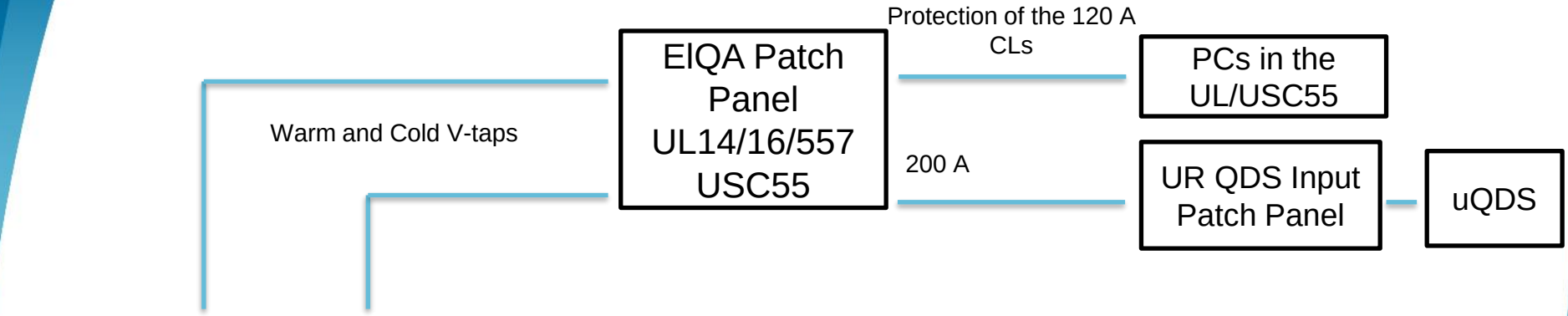
uQDS

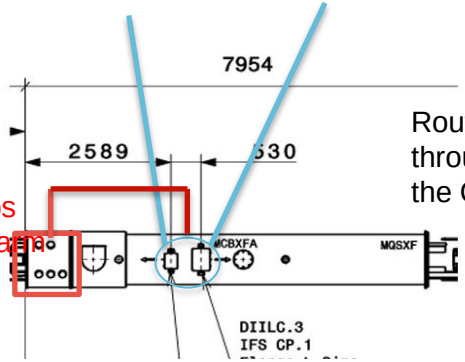
WP9

CRG Electronics

R5: The responsibilities for proximity equipment must be clarified and synergies exploited between the involved WPs. The development of 'ELQA measurement ports' is supported.

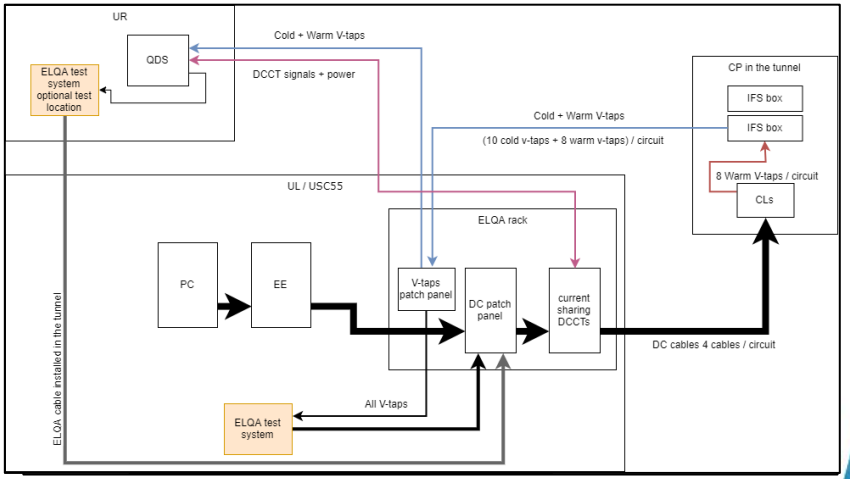
IFS Routing for the Corrector Package





40 V-taps From Warm

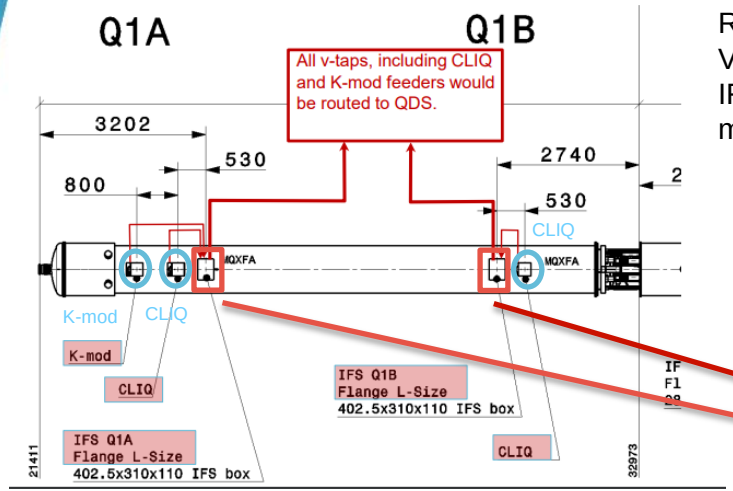
Routing of the Warm V-taps through the two IFS boxes of the CP



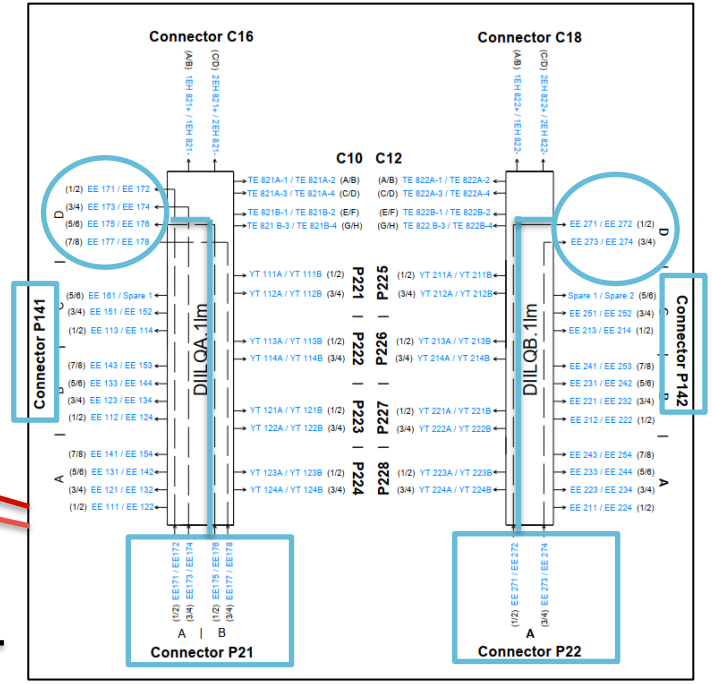
HL-LHC ECR WP7

IFS Routing for Warm V-taps for CLIQ and k-mod feeders

R4



Routing of the Warm V-taps through the IFS boxes of the IT magnets



Monitoring signals for CLIQ and k-mod included in the QDS Protection Scheme

UR QDS Input Patch Panel

The V-taps on the CLIQ and k-mod feeders go inside the IFS box through a connector and they are rerouted internally

R4: CLIQ leads and (identical) k-mod leads are to be included in the protection baseline (through monitoring during discharge/powering)

Conclusions

- Three instrumentation layouts have been proposed to reply to the recommendations in the Instrumentation Review 2020.

- Support for a wide-range of users (ElQA team, IFS box design and intervention, magnet & cold powering builders, circuit operators or circuit analysis)

- Routing of the instrumentation inside the helium environment has been introduced highlighting the different configurations for the HL-LHC

HiLumi
HL-LHC PROJECT

Thank you for your attention