Circuit Disconnector Boxes for HL-LHC

An Optimized Interface between Warm and Cold Powering

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With many valuable inputs from WP6a, WP6b, WP7, WP15, WP17 and MCF

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- Warm to Cold Transition in LHC
- Innovative Topology for SC Circuits Powering including Disconnectors
- HL-LHC Accessibility/Intervention Requirements for Powering Systems
- Circuit Disconnector Boxes as a Part of a Global Solution
- Conclusion

Warm to Cold Transition in LHC

Warm to Cold Transition in LHC

Courtesy of JC. Guillaume, L. Sburlino

Warm to Cold Transition in LHC

- Disconnection & Re-connection of water cooled cables in the LHC is:
  - Required in average once a year for high current circuits for ElQA tests
  - Time consuming & caution required during manipulation
  - Risky for current leads (fragile vs. heavy cables – above 800N damages the current leads)
  - Contact quality must be ensured
  - Presents additional risks on personnel
    - Ladder required in case of most DFBs
- Water-cooled cables are required to be maintained as a general remark (for instance insulation sheath replacement by expert industrials)

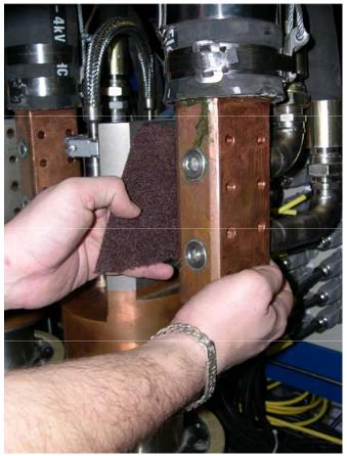
Warm to Cold Transition in LHC

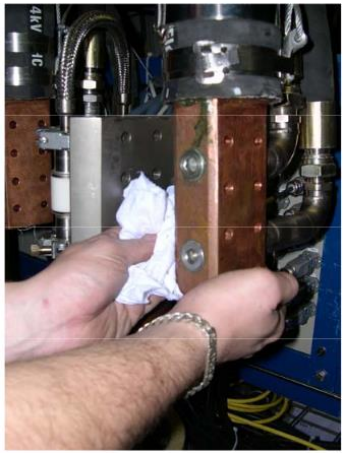
- Example: Connection of water cooled cables in the LHC

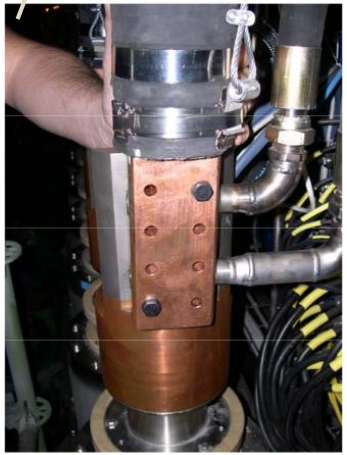
Surface Cleaning

Heavy cables positioning

Bolt torque tightening





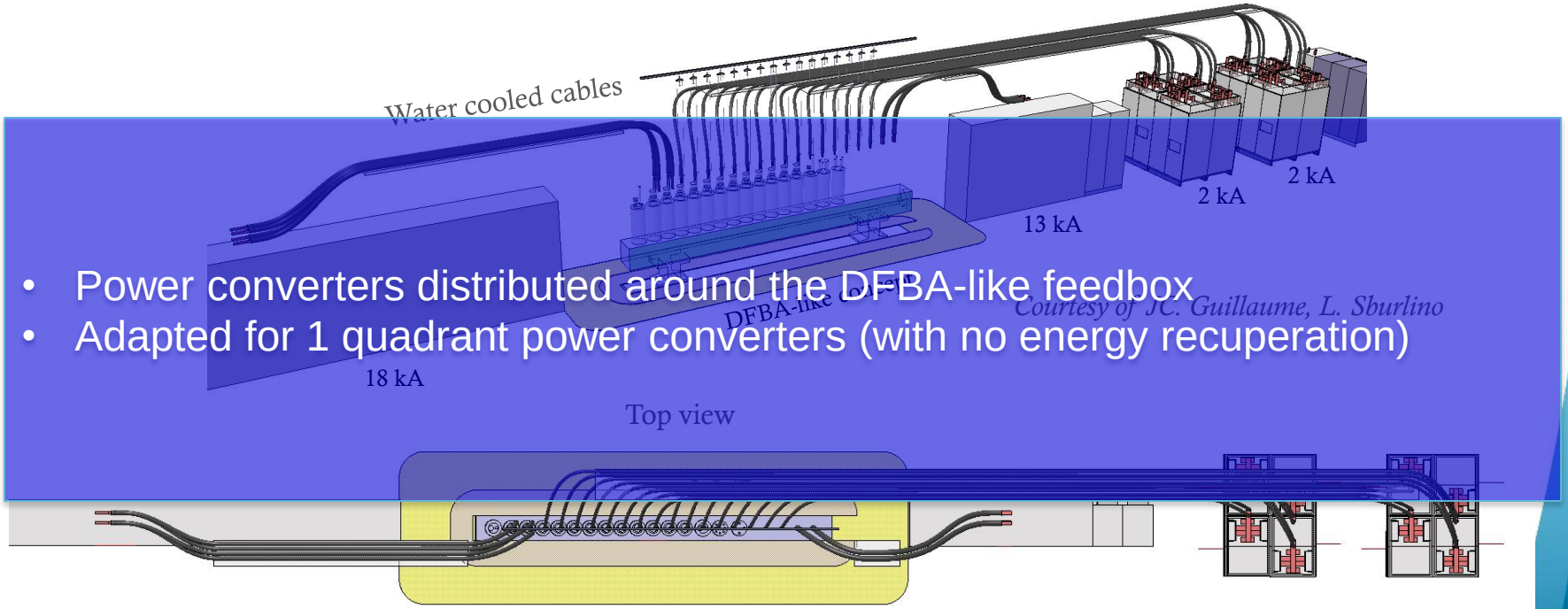


Courtesy of P. Denis (13 kA DC cables installation procedure EDMS 822785)

Innovative Topology for SC Circuits Powering including Circuit Disconnector Boxes

Innovative Topology for SC Circuits Powering

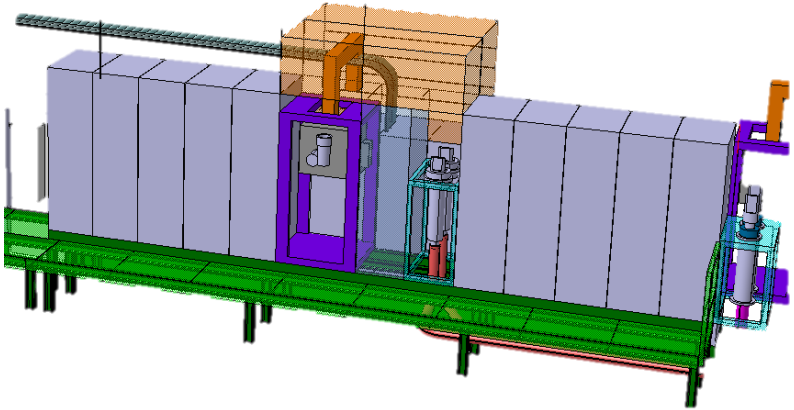
- LHC-based proposal (without disconnectors)



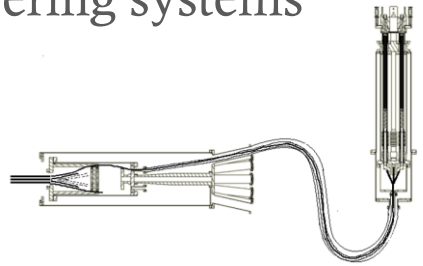
- Power converters distributed around the DFBA-like feedbox
- Adapted for 1 quadrant power converters (with no energy recuperation)

Innovative Topology for SC Circuits Powering

- Some of the novelties to the HL-LHC powering systems

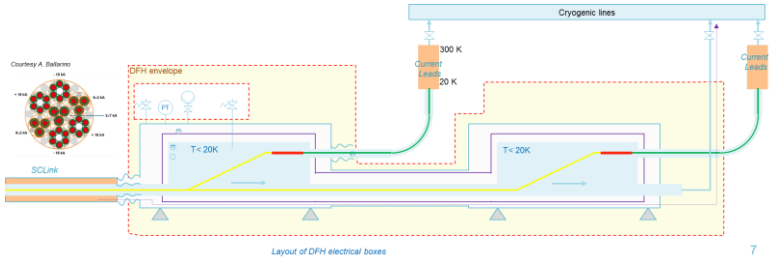


- Energy Storage System of the 18 kA PC
- Stores inductive energy
- Goal of 0 Joules consumption
- Energy dissipated in cables is “lost”



Flexible HTS between Leads and DFH

Courtesy of A. Ballarino and Y. Yang (WP6a)



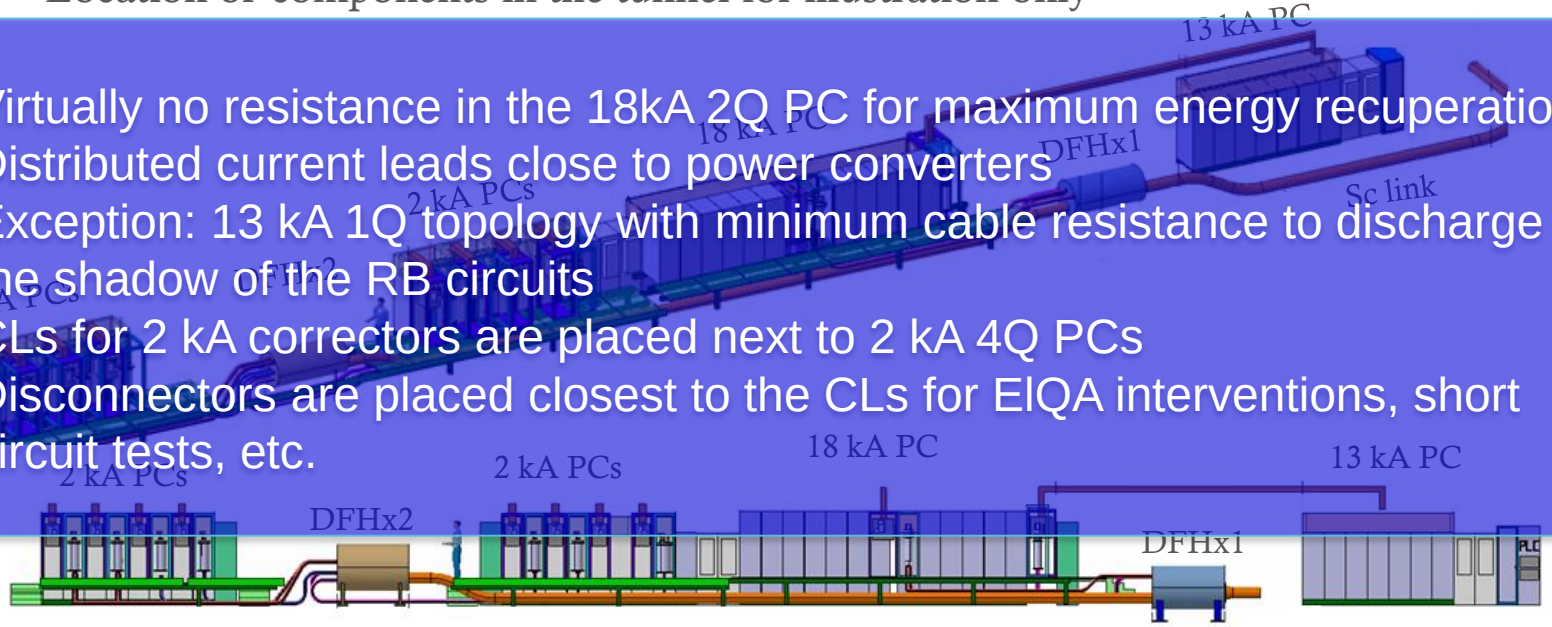
2 DFHx Systems for Less Congested Splicing

Courtesy of Y. Leclercq and A. Ballarino (WP6a)

Innovative Topology for SC Circuits Powering

- Proposed integration concept with circuit disconnector boxes
  - Location of components in the tunnel for illustration only

- Virtually no resistance in the 18kA 2Q PC for maximum energy recuperation
- Distributed current leads close to power converters
- Exception: 13 kA 1Q topology with minimum cable resistance to discharge in the shadow of the RB circuits
- CLs for 2 kA correctors are placed next to 2 kA 4Q PCs
- Disconnectors are placed closest to the CLs for ElQA interventions, short circuit tests, etc.



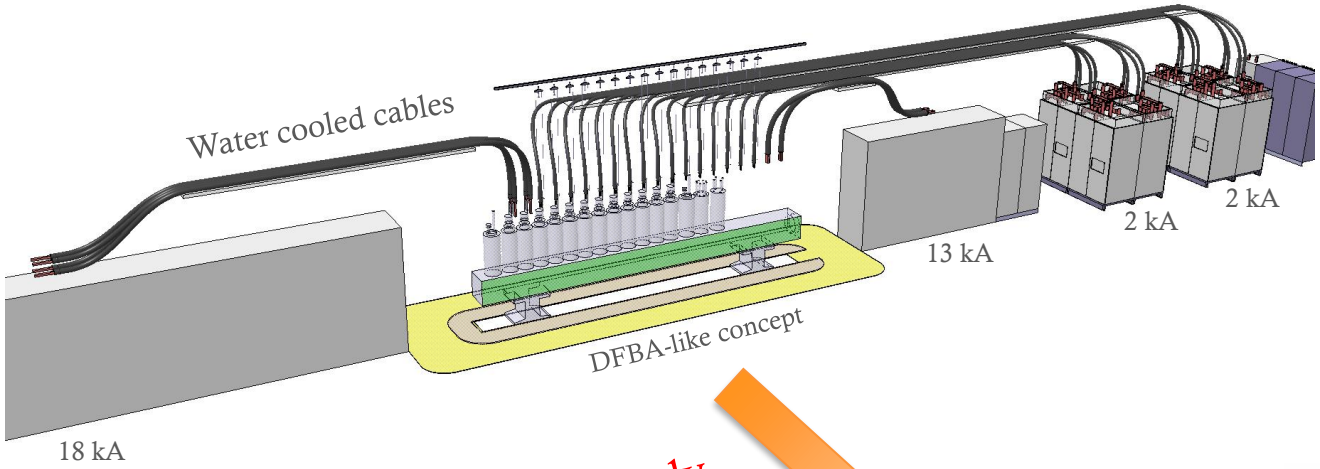
Optimization on-going (WP6a and WP6b)

Courtesy of S. Maridor

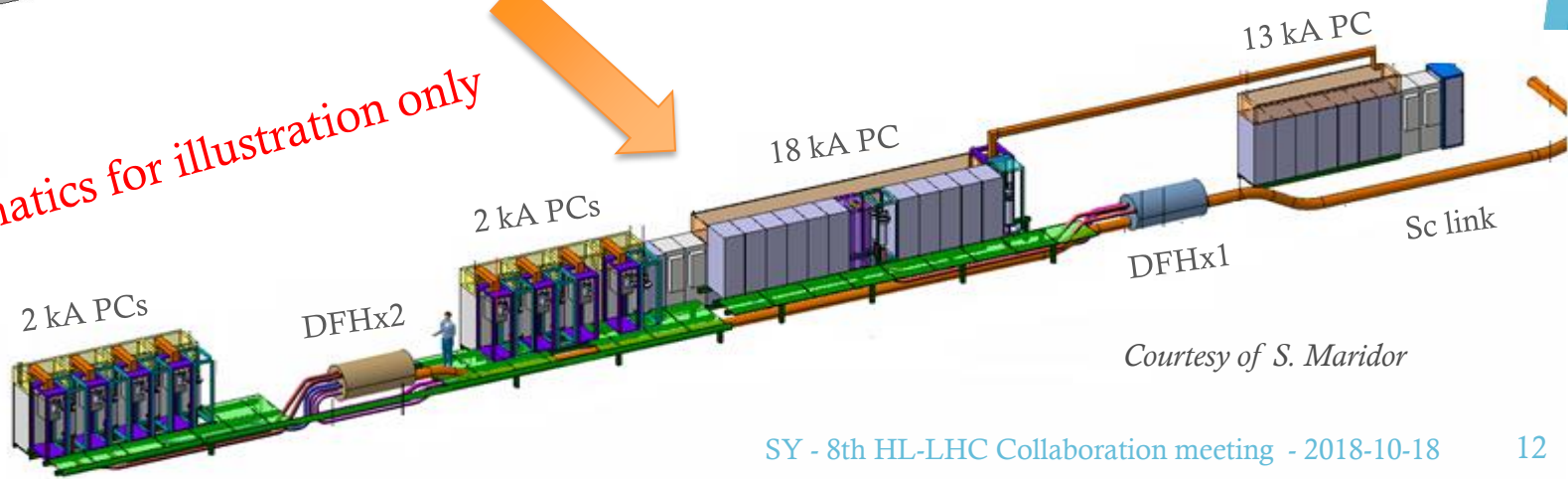
Innovative Topology for SC Circuits Powering

- Integration of the powering systems in HL-LHC, becomes
  - Close team effort due to a more integrated nature of the systems
  - Global system optimization
    - HTS and MgB_2 cable lengths
    - Water-cooled cables
    - System performance
    - Intervention
  - Exercise with an imposed envelope for services
    - Ventilation capability defined
    - Cooling capability defined
    - Civil engineering defined

Innovative Topology for SC Circuits Powering

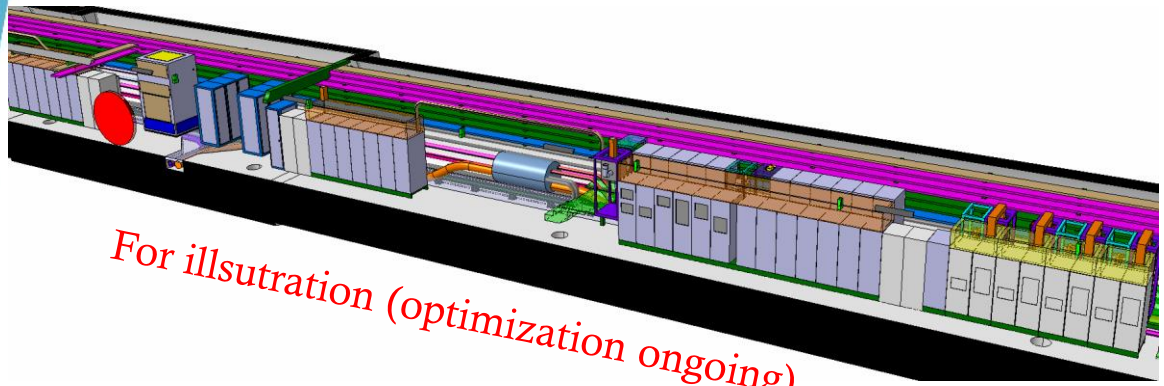


Schematics for illustration only

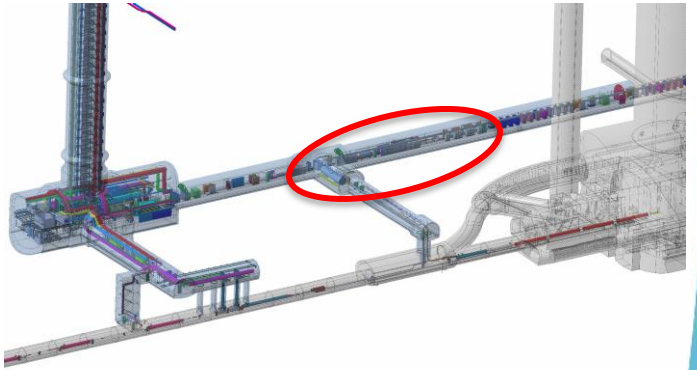


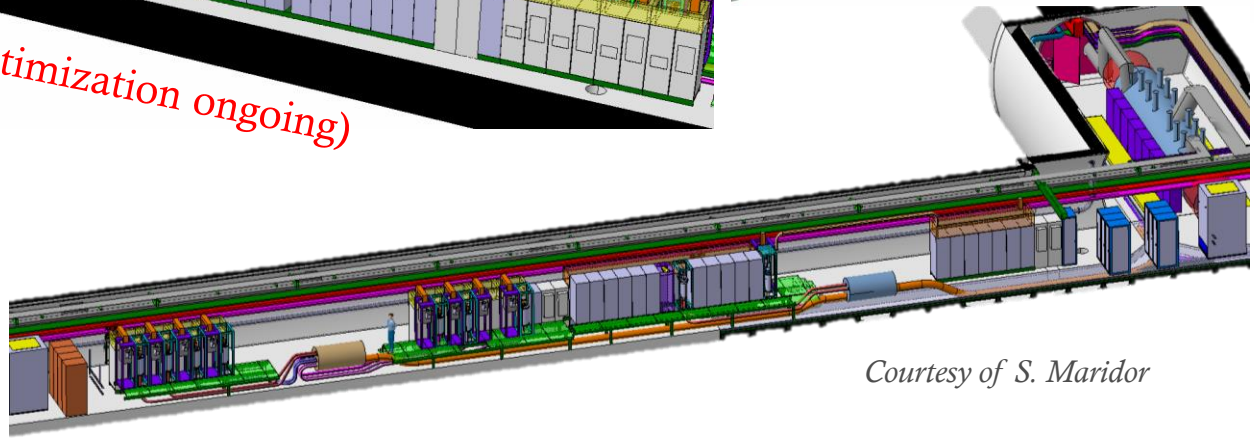
Courtesy of S. Maridor

Innovative Topology for SC Circuits Powering



For illsutration (optimization ongoing)





Courtesy of S. Maridor

HL-LHC Accessibility / Intervention Requirements for Powering Systems

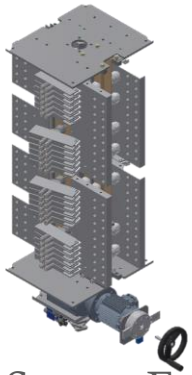
HL-LHC Accessibility/Intervention Requirements

- Provide solution to simplify the disconnection of warm & cold powering
  - Improve safety of people during intervention
  - Ensure galvanic insulation
    - 3 kV withstand level between poles and to ground with <1 µA leakage current
  - Reduce risks of damaging current leads
    - Due to mechanical strain (incorrect manipulation)
    - Due to hydraulic shocks (water hammer effect) when water is turned on/off
  - Maintain current leads contact quality without additional intervention
  - Reduce intervention time
  - Short circuit and grounding connections possibility (to maximize safety during intervention)
- Accessible technical galleries during operation
  - Electrically protected equipment (IP2X)

Circuit Disconnector Boxes as a Part of a Global Solution

Circuit Disconnector Boxes

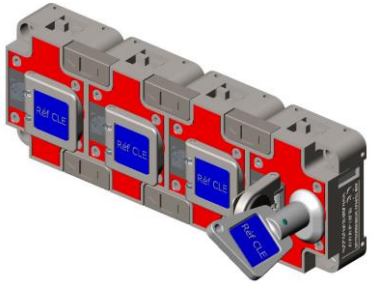
- Present TE-EPC disconnector concept relies on:
  - Switchable fingers type for 18 & 13 kA circuits
  - Rotative position type for ≤ 2 kA circuits
  - PLC to communicate state of the disconnectors and ensure correct manipulation
  - Panel key controller to control access and to ensure correct manipulation



18 kA System Example

2 kA System Example

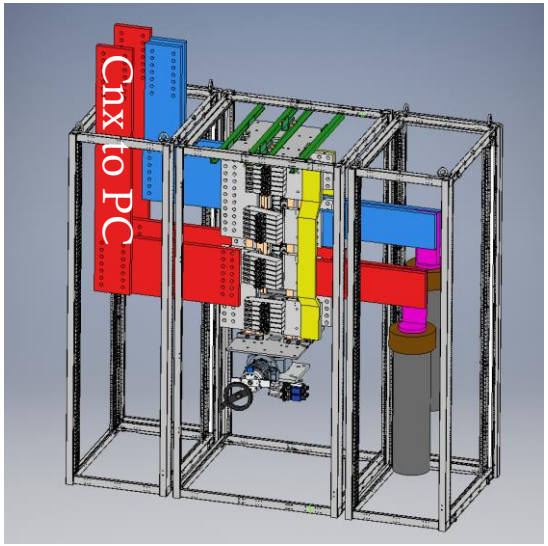
PLC System



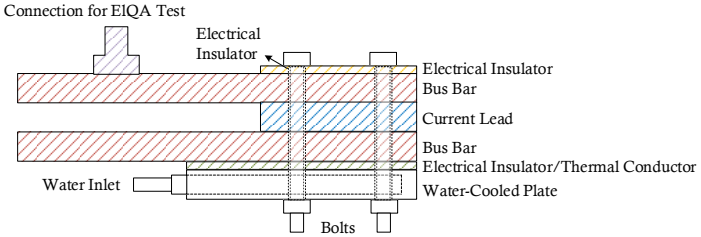
Panel Key Controller

Circuit Disconnector Boxes

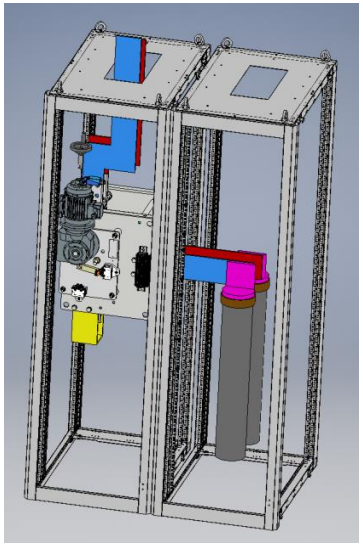
- Some conceptual sketches for HL-LHC



18 kA System



18 kA Current Leads Interfaces

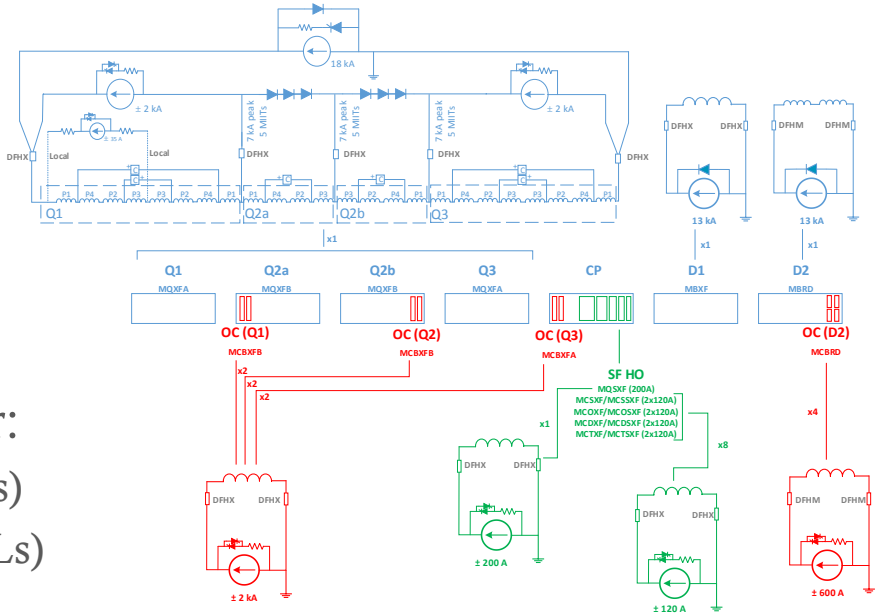


2 kA System

Further information on operation of the powering systems
S. Yammine Tuesday PM

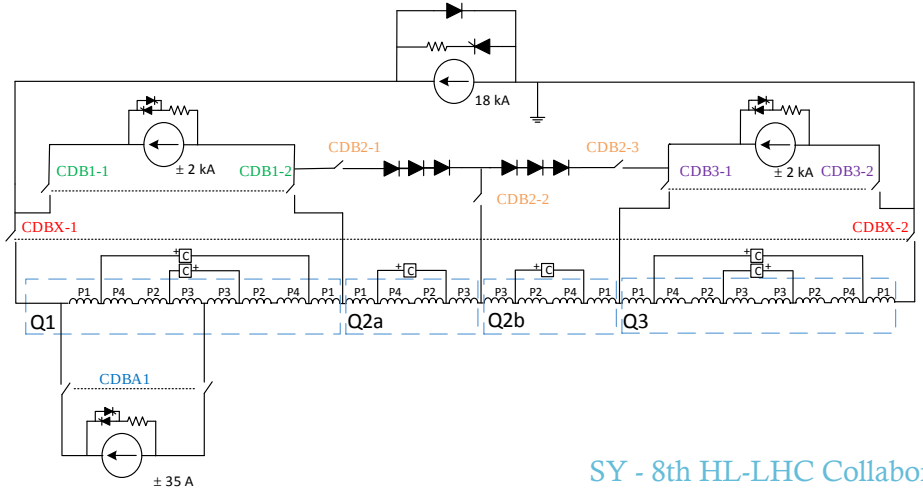
Circuit Disconnector Boxes

- Considered for circuits in the URs
  - 1x18 kA circuit
  - 2x13 kA circuits
  - 8x2 kA circuits
  - 4x0.6 kA circuits
  - 1x0.035 kA circuit
- CDBs are not considered (so far) for:
  - 1x0.2 kA circuit (could be moved to ULs)
  - 8x0.12 kA circuit (could be moved to ULs)



Circuit Disconnector Boxes

- HL-LHC inner triplet main circuit with disconnectors
  - Four electrically connected powering circuits with five disconnectors
  - Six connected CLIQ systems that introduce new electrical risk during intervention
  - Discussions are ongoing to be able to intervene on PCs without CLIQ discharge
  - In general, disconnectors and PLC ensure that the circuit is safe and the procedures are respected to significantly reduce risk while intervening



Conclusion

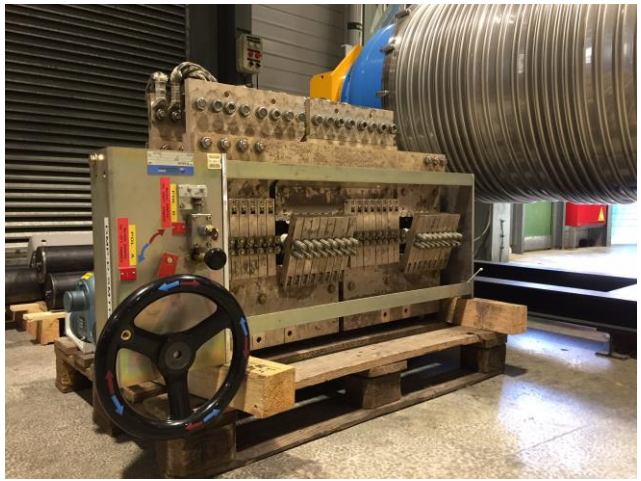
Conclusion

- Novel approach proposed for the powering of the SC circuits
  - Disconnectors are in the heart of the approach
  - Major improvement from LHC for which these aspects were overlooked in the design
  - Reduction of WCCs that need to be maintained regularly
- Disconnectors improve conditions for intervention on the equipment
  - Safer operation around the current leads
  - Safer and easier ElQA intervention
  - Safer operation on the inner triplet main circuits (with CLIQ)
- Services and civil engineering are defined and the systems should cope
- Optimization ongoing between WP6a, WP6b and WP17 to optimize systems cost and enhance performance and operation. The aim is to find a global cost neutral solution wrt baseline (Δ WP6a + Δ WP6b + Δ WP17 $\approx$ 0) that enhances safety and quality of intervention.

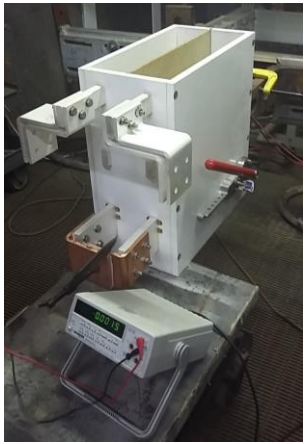
Thank you for your attention

Circuit Disconnector Boxes

- TE-EPC already have a wide experience with this type of disconnectors
  - SM18 (16 kA)
  - POPS-B (3 kA/7.2 kV)
  - Several more examples (LHCb, SPS Mains, 163 for Fresca 2, etc.)



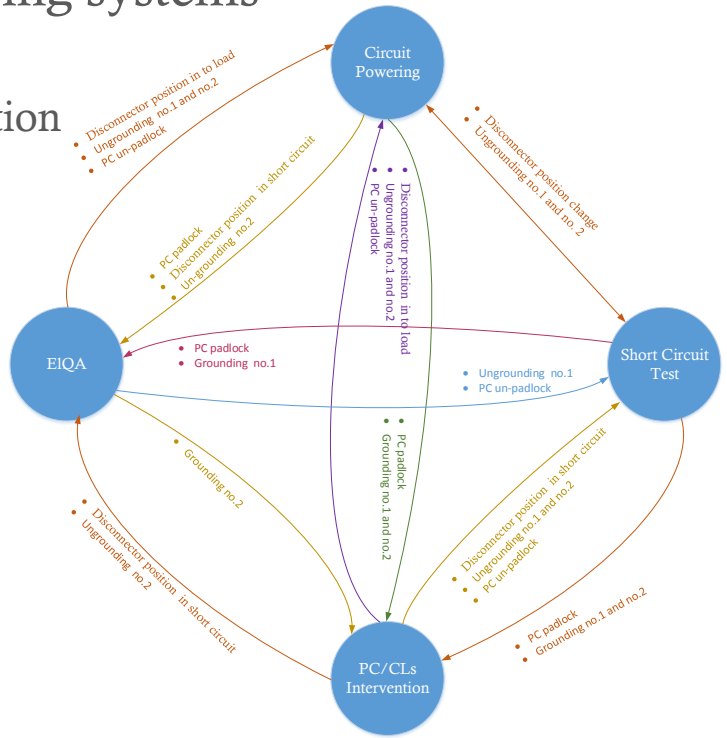
SM18



POPS-B

Operation of the Circuit Disconnector Boxes

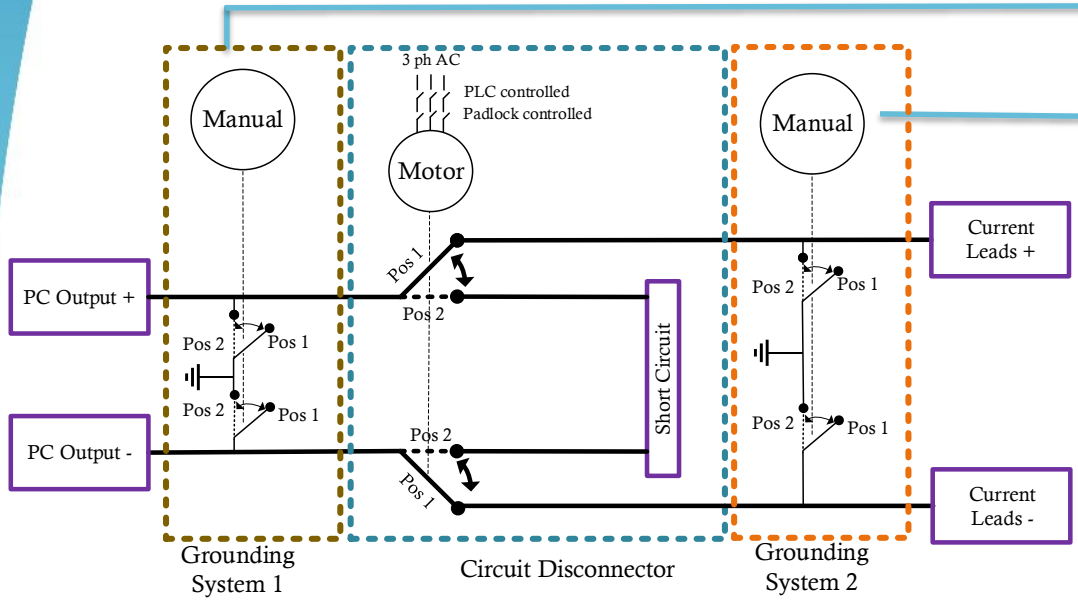
- Four configurations of the powering systems
  - System in powering configuration
  - Power converter in short circuit position
  - Power converter intervention
  - Current leads intervention
  - ElQA



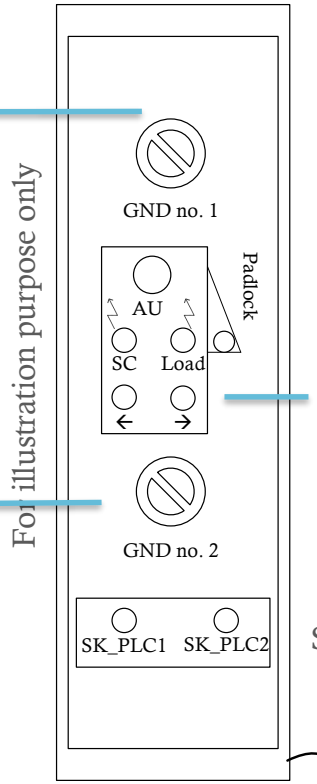
State Machine for Configurations (Under Discussion)

Operation of the Circuit Disconnector Boxes

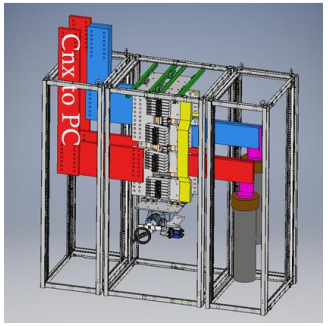
- Electric scheme of the disconnector



Proposal (to be finalized at WP6b/MCF)



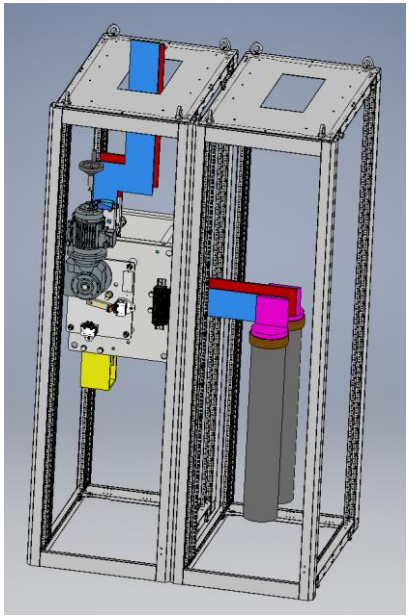
Disconnector Rack Front Panel



System at SM18

Operation of the Circuit Disconnector Boxes

- Proposal of sequence for disconnector position inversion sequence
  - Ensured by first line intervention team (TE-EPC)
  - Padlock of power converter
  - Grounding of DC circuit
  - PLC liberation of key when conditions are met
  - Disconnector position change verified by PLC
  - Key returned to panel key controller



Operation of the Circuit Disconnector Boxes

- PLC verifies the correct conditions for disconnector manipulation
  - Current in the circuit is zero
  - DCCT is operational
  - Power converter is OFF
  - PC output and CLs are grounded

- PLC ensures security on two levels when conditions are not met
  - De-energizes the motor AC connection
  - Blocks the access of the key for padlock
  - Key transported from PLC rack to the CDB rack for intervention
  - Only people with the correct procedure could intervene