



DC cabling of the HL-LHC circuits and interlocking scheme

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12th HL-LHC Collaboration Meeting – Uppsala – 21/09/2022

Agenda

- Introduction
- Some WCC pictures
- Powering scheme evolution since 2016
 - Layout and quantities
 - Cooling schemes
 - Interlocks
- Next steps
- Conclusions

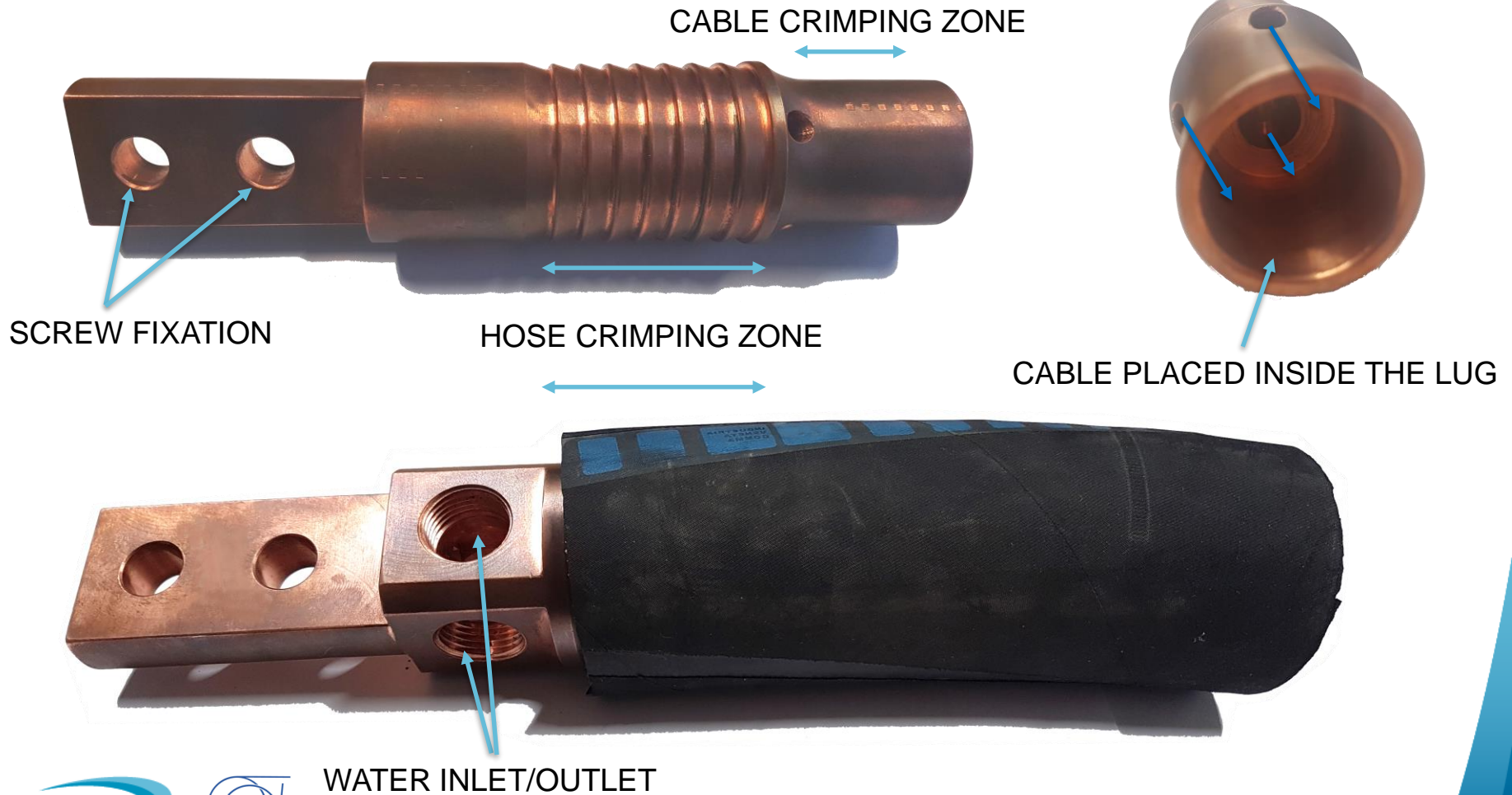
Introduction

- Two types of DC cables used for HL-LHC circuits
 - Air-cooled cables (ACC) → currents ≤ 600 A
 - Water-cooled cables (WCC) → currents > 600 A
- The installation in the IT string will allow to validate installation methodology, supports, cooling scheme and interlocks.

WCC technology overview

EXAMPLE: WCC LUG, 500 mm²

WATER IN/OUTFLOW MAINLY THROUGH OUTSIDE-HOLES BETWEEN LUG AND HOSE



WCC technology overview

CABLE BUNDLE CRIMPED ON THE LUG:
WCC WITHOUT SPRING (2000 mm²)



CABLE BUNDLE BRAISED ON THE LUG:
WCC WITH SPRING (2000 mm²)



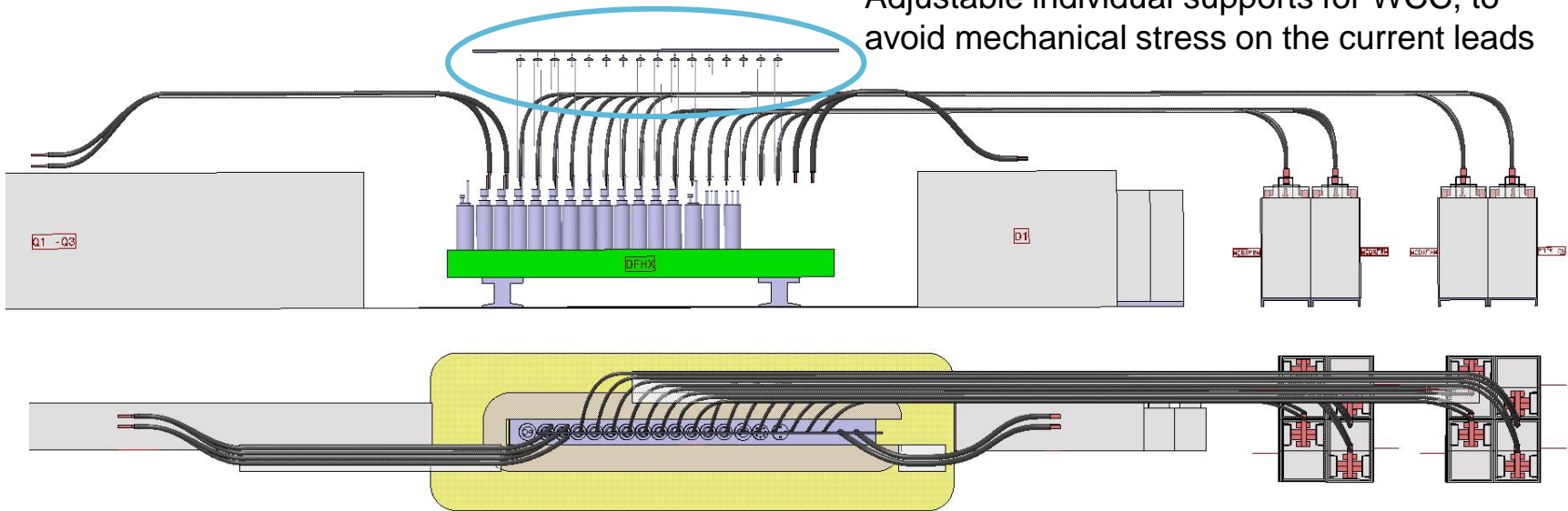
LHC WCC installation example: DFBA.L6



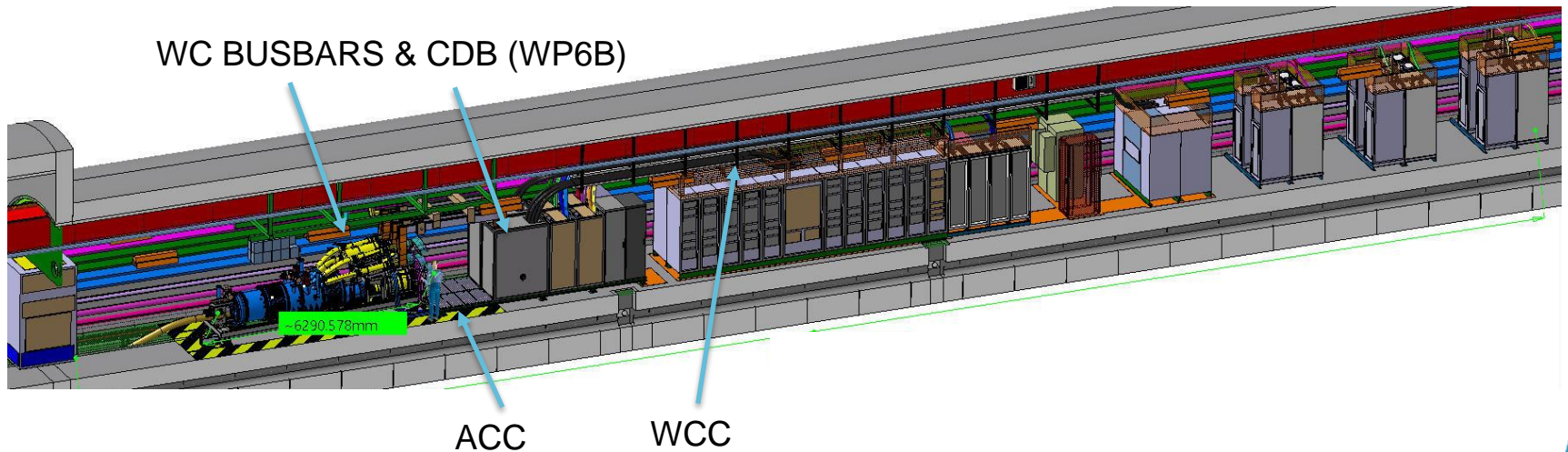
No longer the situation in HL-LHC: due to the introduction of CDBs no need for special supports, required to eliminate all mechanical stress exerted by the cable lugs on the current leads

Powering scheme evolution since 2016

Adjustable individual supports for WCC, to avoid mechanical stress on the current leads



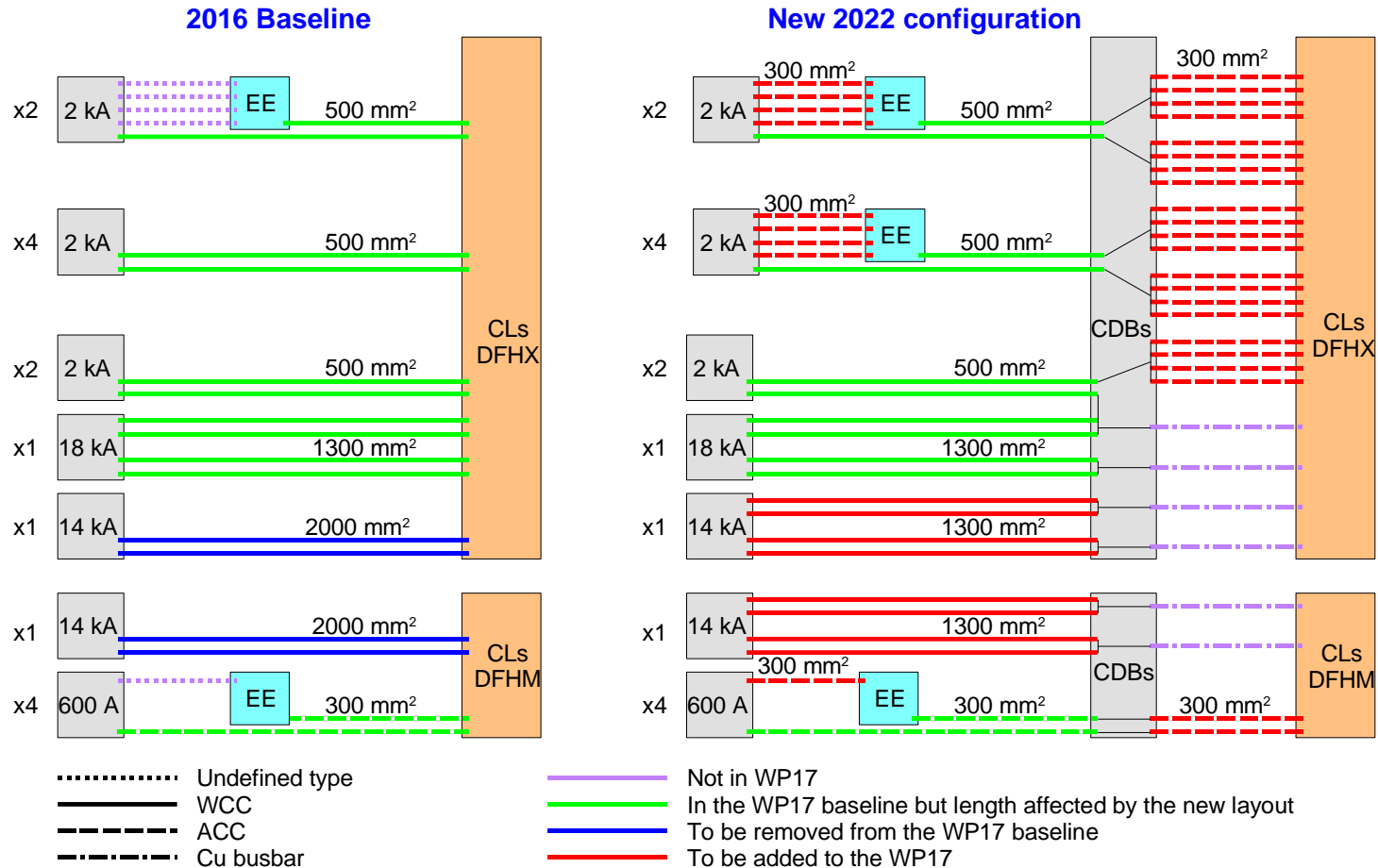
WC BUSBARS & CDB (WP6B)



Change of conceptual design of DGHX and DFHM, EDMS 2383175

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Layout, quantities and length

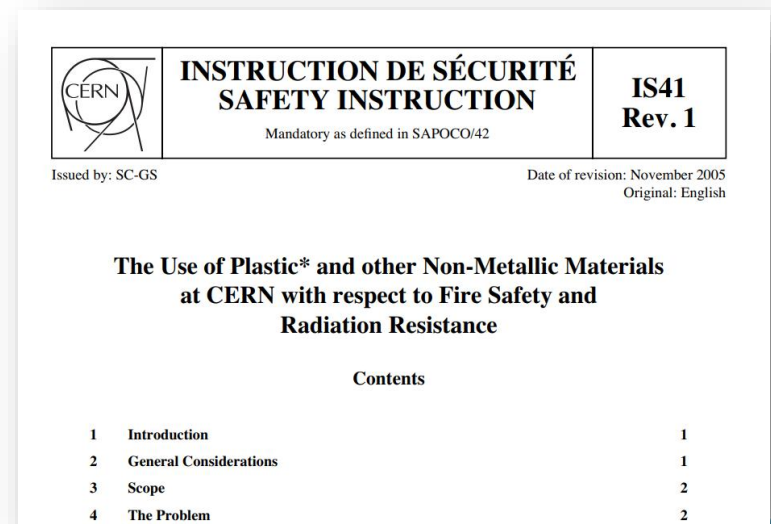


DC cables configuration per IP side, EDMS 2386350

Change from 2000mm² → 2x1300mm² (standardized CDB)
 Added ACC from CDBs for DFHX/DFHM
 Change of lengths, due to different integration

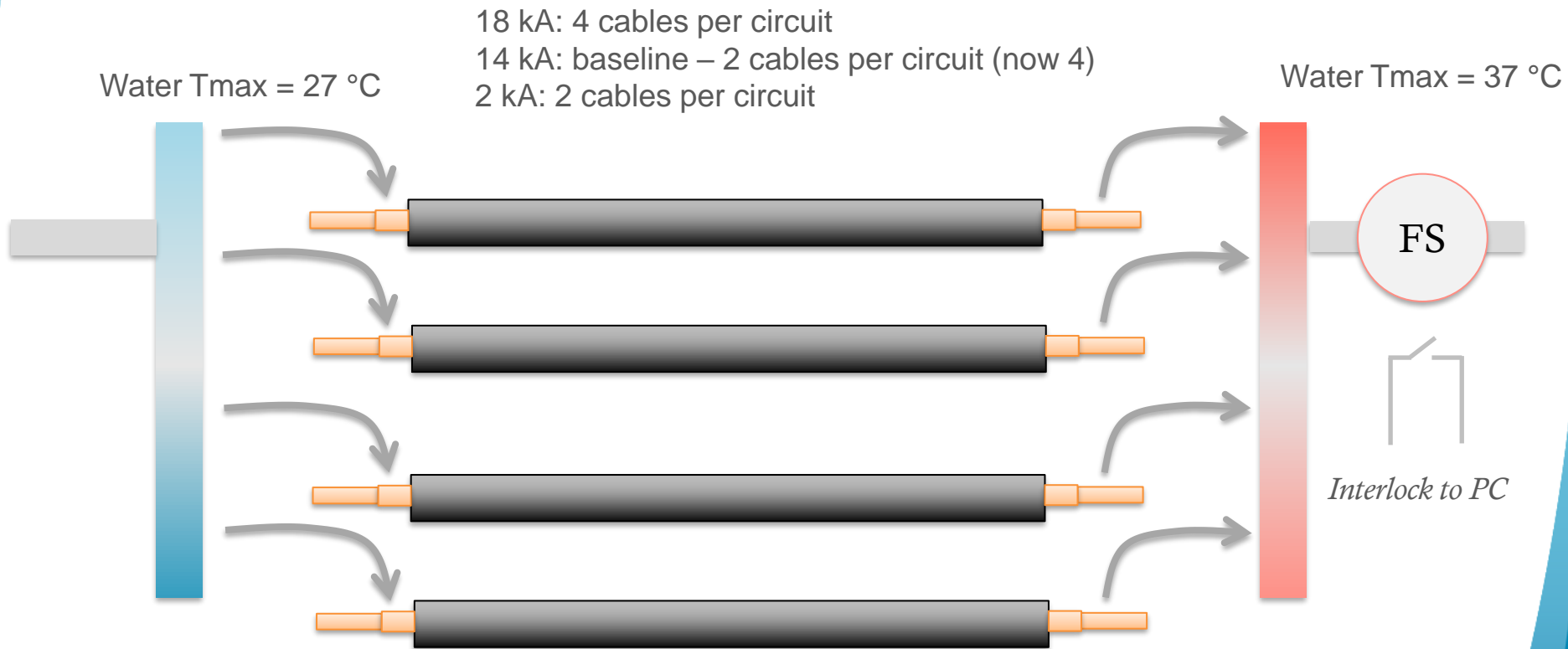
WCC characteristics

- Cable choice based on:
 - Maximum admissible density current: 8 A/mm^2
 - Equipment interfaces: 2 cables per polarity for RQX and RD1/2, 1 cable per polarity for the remaining circuits
- External hose must be compliant with IS41
 - To avoid premature aging and cracking (i.e. absence of chlorine, problem occurred in the past)



WCC cooling scheme 1/2

Baseline → use of WCC in parallel

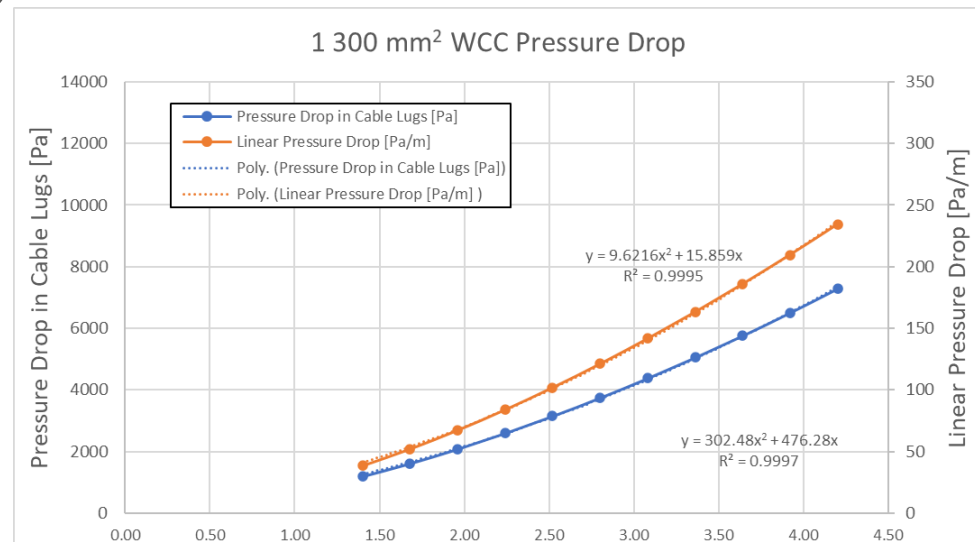


MCF #44, INDICO 1103524

WCC cooling scheme 2/2

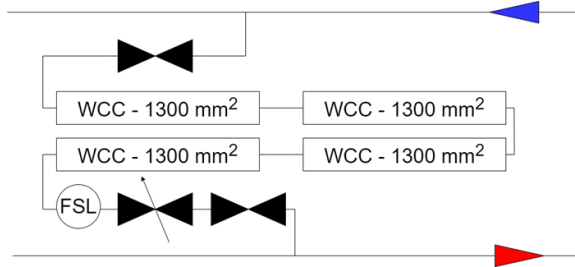
- Hydraulic circuits study conducted by EN-CV through CFD studies on 500 and 1300 mm² → possible to have 4 cables in series
- Experimental testing in SM18 already done on the 500 mm² confirmed the CFD simulations
- New proposed baseline (series) to be confirmed for the 1300 mm² in the IT String

Pressure drop on cable lug → an order of magnitude higher than pressure drop in a meter of WCC

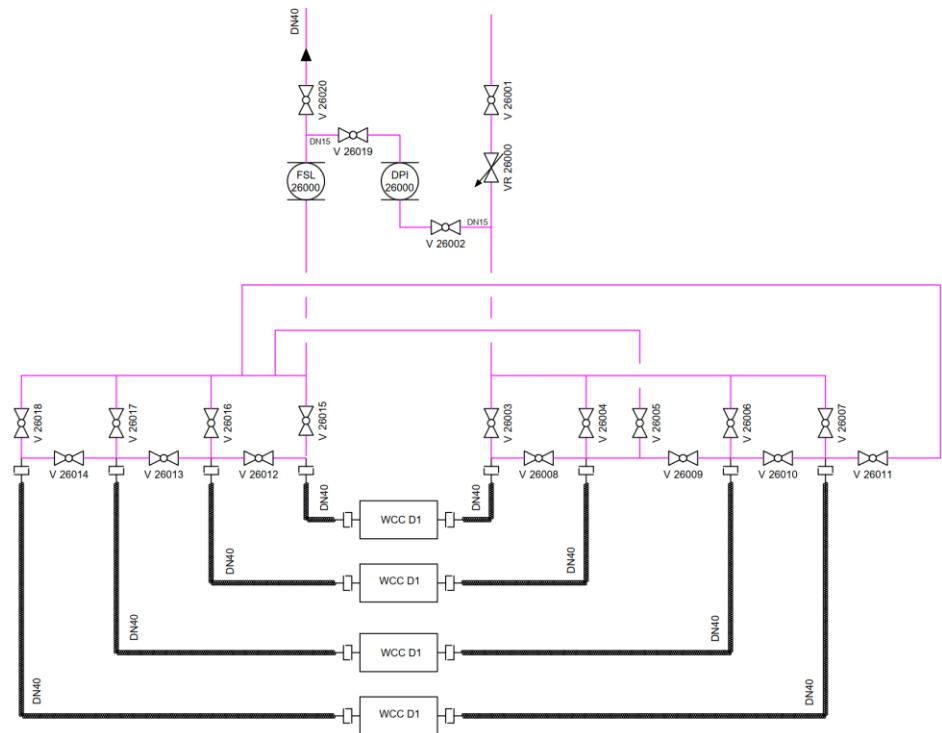
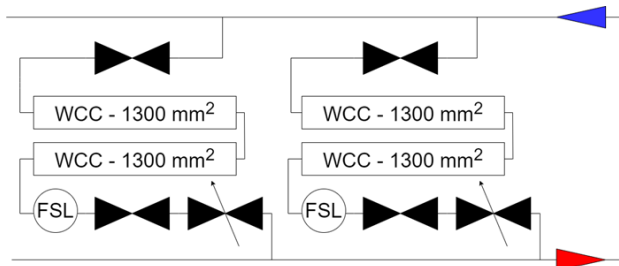


WCC cables: IT test bench

- Possibility of testing the following configurations:
 - 1 set of 4 WCC in parallel
 - 1 set of 4 WCC in series



- 2 sets of 2 WCC in series



WCC Cooling Meeting #6 – 23.05.2022

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WCC interlocks



- Each electrical circuit corresponds to one hydraulic circuit → interlock to a single PC
- The flow switch will be used as a trigger to stop power converters in case of inadequate water flow.
- The use of additional devices (e.g. thermal switches) for mitigating overheating risks was discarded according to a risk assessment analysis and water circuits configuration in series mode (to be fully validated during IT string commissioning).

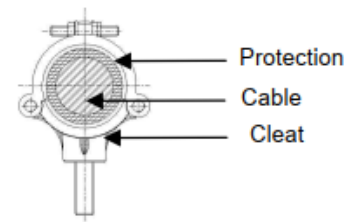
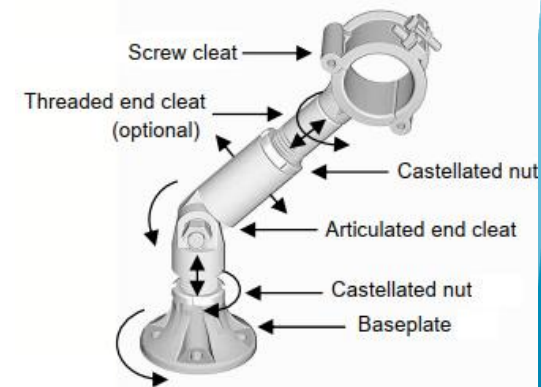
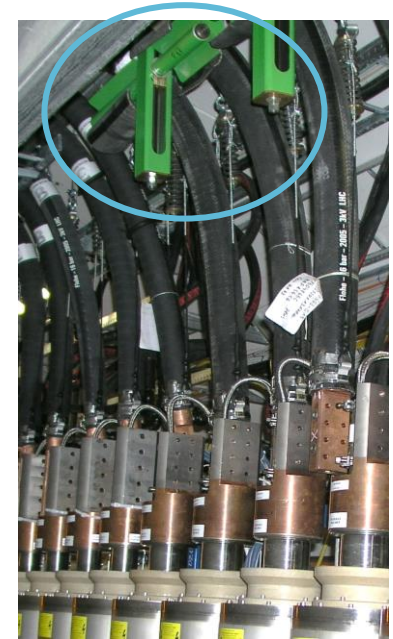
WCC supports

LHC supports

- Special supports were conceived to eliminate all mechanical stress exerted by the cable lugs on the current leads

HL-LHC supports

- No need of supports made specifically for the WCCs since the introduction of the CDB → cable lugs are no longer in contact with the current leads
- Supports are still necessary to reduce the mechanical load the cable exerts on itself and on its terminations → industry standard supports: articulated cable cleat with a protection



Next steps

- New WCC purchase contract expected to pass the March 2023 finance committee
- Provisory installation dates, to be discussed further:
 - LHC point 1: first half 2024
 - LHC point 5: second half 2024
- Pre installation requirements:
 - Finalization of UR integration
 - Power convertors, CDBs and DFHX mock-ups

Next steps



MOCK-UP DFB & POWER CONVERTERS (LHC INSTALLATION)

Conclusions

- Solid technology, reliability problems occurred in the past will be specifically addressed in the tender (i.e. hose cracking)
- Options about cooling scheme have been studied (flow simulation) and partially tested on site. Tests will continue in IT string before being deployed for HL-LHC.
- Interlocking scheme (flow switch) is sufficient for the series scheme, but further discussion could be held in the context of IT string installation at the MCF



Thanks to all EN-EL team working on DC cables (P. Orlandi, M. Silva Marreiros, S. Machado, A. Jacob...) and colleagues of EN-CV, WP15, WP6b, MCF...





Additional slides



RD1/RD2 WCC, from 2000 to 2x1300 mm²

Current Sharing Scheme

