Powering Tests - machine status coming out of LS1

Matteo Solfaroli & Mirko Pojer
on behalf of all teams involved
(TE-MPE, TE-EPC, TE-MSC, EN-EL, EN-CV, EN-ICE, EN-MEF, BE-CO, BE-OP)

outline

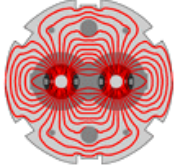
LS1 Changes

Short Circuit Tests

Powering Tests

Conclusions

LS1 Changes – PC 1/2



MAINTENANCE & CONSOLIDATION

…for availability and/or performance increase

- ✓ General maintenance of all PCs (cleaning, connection tightening, water leak check,…)
- ✓ Water cooling circuits consolidation:
  - Change of all flexible on internal water cooling circuits of IPQ and IPD PCs
  - Change of defective 600 A PCs to water cooling connections
- ✓ Change of electrolytic capacitor in the power supply feeding the 60 A PC electronics
- ✓ Change of rectifier diodes in the output modules of 1-quadrant PCs (RQs, IPD, IPQ)
- ✓ Software updates

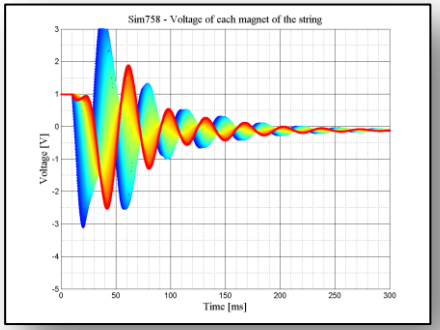
- ✓ Calibration campaign of all PCs – Transparent unless some PCs have drifted away (not expected) but it can be anticipated and compensated

LS1 Changes – PC 2/2

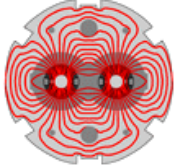
SPECIAL INTERVENTIONS

…for improvements and/or correction

- ✓ Consolidation of 600 A power supply units to stand high radiation level
- ✓ Change of the DCCT on RD4.L4 and RD4.R4 to increase (6250 A vs 5520 A) the maximum current in order to cope with optics at >6 TeV (implementation of the remaining part of the ECR 938922 “Change of magnet and commissioning parameters for various LHC circuits”)
- ✓ Installation of an additional DC cable for RQ4.L5 and RQ4.R5 to cancel the limitation of the PC (ECR 1377232 “Electrical circuit change for high beta optics in IR1 and IR5 of the LHC”) - PC to be recalibrated
- ✓ Replacement of the WCC of RQX.L5 circuit with higher cross-section cables to increase di/dt – SCT
- ✓ R2E PCs relocation in IP1, IP5 and IP7 (warm magnets) - SCT
- ✓ Installation of a Free Wheel Thyristor on the output of RB PCs to reduce the 30 Hz voltage oscillations (ERC 1387235) – the thyristor has been installed in all RB PCs and will be connected and tested in the first sector; a decision will then be taken



LS1 Changes – QPS 1/2



FUNCTIONALLY EQUIVALENT INTERVENTIONS

- ✓ R2E consolidation
  - Relocation of IT quench protection racks in IP1 and IP5 (re-cabling)
  - Upgrade of the 600 A protection system in IP1, IP5 and IP7 to cure SEUs
  - Upgrade of the IPQ/D protection system
  - Firmware updates
- ✓ Automatic check of the LSA parameters (SET possibility)
- ✓ Connection of nQPS to PM
- ✓ Recording of both A and B cards
- ✓ FESA3

INTERVENTION WITH IMPACT ON AVAILABILITY

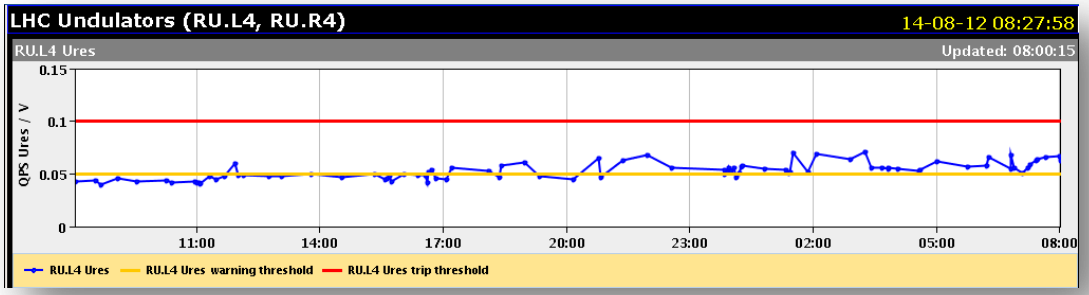
- ✓ "Yellow rack" update
  - Enhanced supervision of the quench heater discharge (linked to QPS OK)
  - Implementation of full redundancy of powering of the detector system. If short MTBF this could affect availability (linked to the QPS OK, no BD)
  - Remote power cycle installation
- ✓ Installation of earth voltage measurement system on nQPS (many components added)
- ✓ Disp Supp IPQ instrumentation re-cabled to reduce EMC

For details see R. Denz @LMC#181

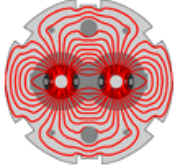
LS1 Changes – QPS 2/2

SPECIAL CASES

- ✓ No change on 600 A IT correctors (RCBXs) to avoid simultaneous powering. A software protection could be implemented
- ✓ RQTD/F protection system vs feedback requirements. The stability problem could become an issue at higher current, as the design thresholds for the protection system have to be re-established
- ✓ RU.R4 – The magnet has not been changed and the required protection does not allow a change on operational parameters (~1.5h of ramp). Nevertheless, tests have been performed on the spare in SM18 and an upgrade of the protection electronic should result in less drifting (reset at each TS)



LS1 Changes – QPS/EE



"All interventions have been done to:

- Cope with high(er) energy and luminosity
- Reduce the system downtime (thus the accesses needed)
- Increase availability and reliability of the system

BUT…all instrumentation cables have been touched and many components added. The system is **brand-new** and has to be carefully commissioned!"

Quoted by R.Denz

EE system

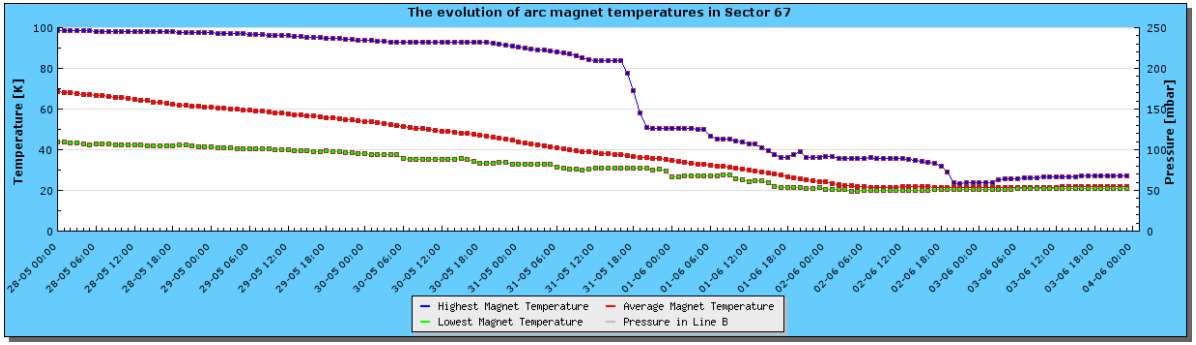
- ✓ Maintenance on the 13 kA EE:
  - Circuit breaker contact cleaning
  - New relays
- ✓ Addition of snubbers on the Main Quads
- ✓ Change of time constant to designed value (104 s for RBs and 29 s for RQs)
- ✓ Major maintenance campaign on the 600 A EE systems

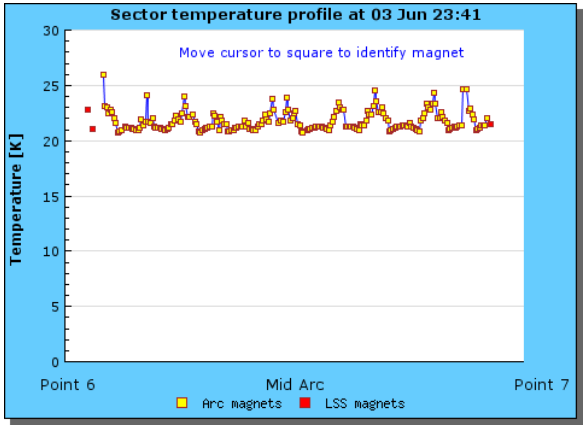
LS1 Changes - cryo

- ✓ Major overhauling of compressors and motors
- ✓ R2E consolidation at IP4
- ✓ DFBA consolidations
- ✓ QRL compensator bellow repairs
- ✓ Beam screen cooling, diagnostics and heating (installation of additional T sensors to disentangle heat load in the dipoles and in the quadrupoles) to follow more precisely the scrubbing evolution
- ✓ New isolated electronics for current lead temperature
- ✓ DFBX current lead cooling control

For details see L. Tavian @LMC#180

…sector 67 is already on its way!





LS1 Changes – other systems

PIC

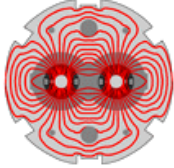
- ✓ Relocation of several racks due to R2E
- ✓ Change of the matrix of auxiliary and essential circuits embedded in the PIC
- ✓ Additional PLC installed in the CCR to improve dependability in the transmission of the access status to the SIS for the powering to access protection (slow power abort in case of access during powering phase 2) – tests foreseen for next week

For details see I. Romera

Electrical distribution

- ✓ New WCC cables pulled in some points and sheaths changed in many locations - SCT
- ✓ New UPS, with full redundancy - tests being organized by V. Chareyre and I. Romera

LS1 Changes – circuits



- ✓ **RCBH31.R7B1**: Condemned (resistive coil)
- ✓ **RCOSX3.L1**: circuit open
- ✓ **RCOSX3.L2 + RCOX3.L2 + RCSSX3.L2**: circuits open after beam impact – potential limitation for ions operation at very low beta*
- ✓ **RCBYH4.R8B1**: I_{PNO} limited at 50 A if used at 0.67 A/s
- ✓ **RCBYV5.L4B2**: I_{PNO} limited at 50 A if used at 0.67 A/s
- ✓ **RCBYHS4.L5B1**: I_{PNO} limited at 50 A if used at 0.67 A/s
- ✓ **RCSSX3.L1**: maximum current reduced to 60 A (nominal 100 A)
- ✓ **RCBYHS5.R8B1**: I_{PNO} limited at 20 A if used at 0.6 A/s (the limit can probably be increased to 40 A if used up to 0.3 A/s)
- ✓ **RQTF.A81B1**: 4 magnets bypassed – back in service
- ✓ All **RCOs** circuits are now operational, but have an issue with the Fischer connector that need to be fixed to use them at current higher than 30 A:
  - ✓ **RCO.A78B2 and RCO.A81B2**: 2 magnets bypassed
  - ✓ **RCBCH6.L2B2 vs RCO.A12B2**: Fischer connector changed
- ✓ **RQ5.R2**: maximum current reduced to 4100 A (nominal 4300 A) due to slow training
- ✓ **RD3.L4**: maximum current reduced to 5600 A (nominal 5850 A) due to slow training – the present current value allows an energy of 6.74 TeV

A full and detailed list (MP3 website): https://twiki.cern.ch/twiki/bin/view/MP3/SummaryIssues

outline

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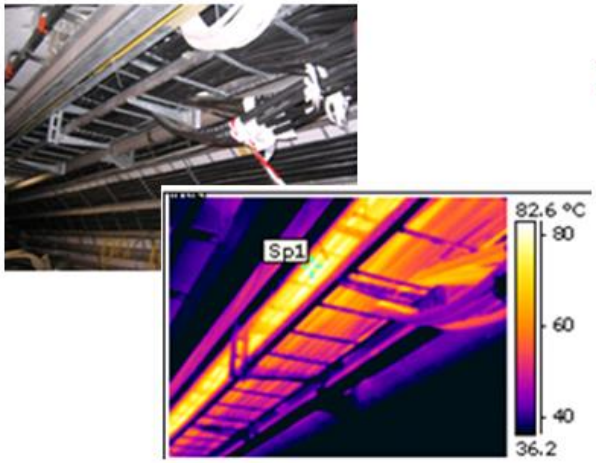
Short Circuit Tests

Un exemple: les tests en court circuit

- Ils sont faits pour valider:
  - Câbles DC
  - Convertisseurs de puissance
  - System de protection de quench et extraction d'énergie
  - Distribution électrique
  - Ventilation
  - Distribution d'eau



- Un exemple des problèmes rencontrés et solutions adoptées:
  - Charge de chaleur extrême (jusqu'à 95° C) sur les câbles 600A de la UJ33 => re-routage des chemins de câbles
  - Ventilation en dehors des paramètres spécifiés => installation des unités de ventilation supplémentaires dans toutes les UA

18th October 2012 **18.10.2012** M.Solfaroli

Short Circuit Tests - why

- Change of the WCC sheaths (UA47, UA63, UA67, UA83, UA87, RA32)
- Replacement of the WCC (IT main circuit in IP5L)
- Power converters and/or PIC racks relocation, due to the LHC availability improvement in the frame of R2E project (IT circuits of IP1L/R and IP5R)
- Modification of the EE system of the 13 kA circuits (**all points**)
- Maintenance/upgrade of the 600 A EE systems (**all points**)

CERN CH-1211 Geneva 23 Switzerland

EDMS NO.	REV.	VALIDITY
464458	2.0	RELEASED

LHC

REFERENCE: LHC-R-HCP-0001

Date: 2014-04-23

HARDWARE COMMISSIONING PROCEDURE

The Power Converters Connected to the DC Cables in Short Circuit

ABSTRACT:

The tests are meant to **validate the normal conducting part of the electrical circuits** powering superconducting magnets, extending from the 18 kV and 400 V feed and including the water-cooled cables before their connection to the DFB. After this, the validation of the water and air-cooling infrastructure will be carried-out by means of a heat run with the circuits powered at ultimate current.

For LS1, special test procedures and configuration will be applied.

PREPARED BY:	CHECKED BY:	APPROVED BY:
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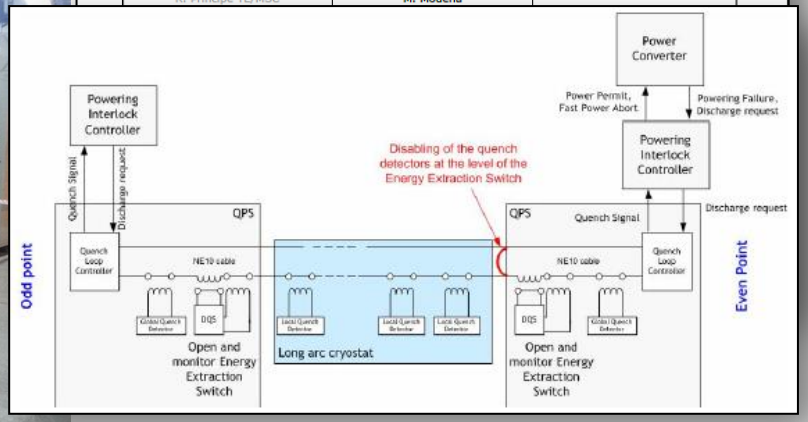
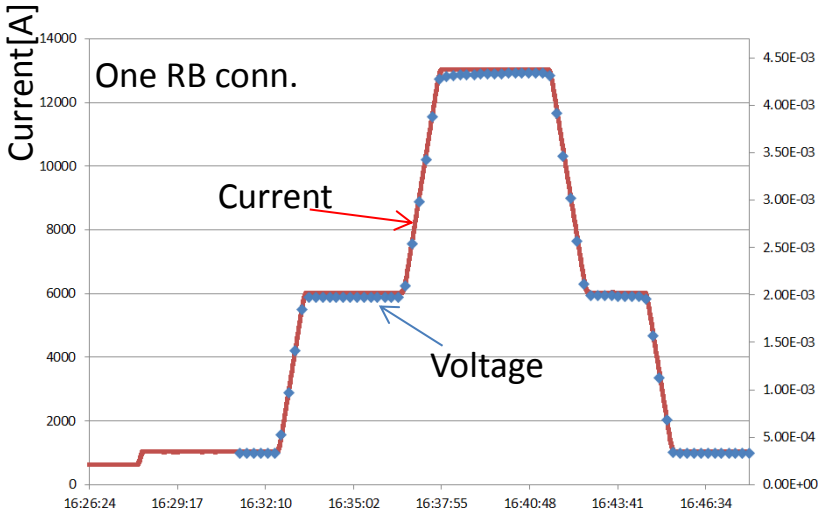
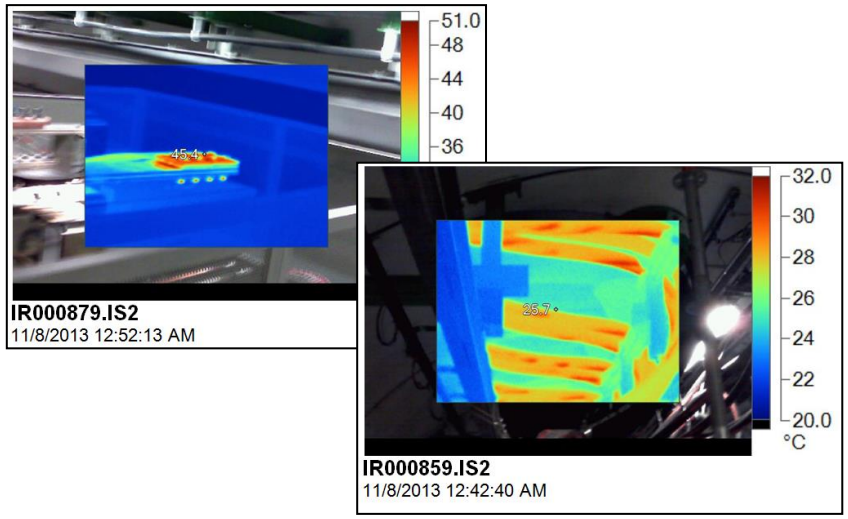


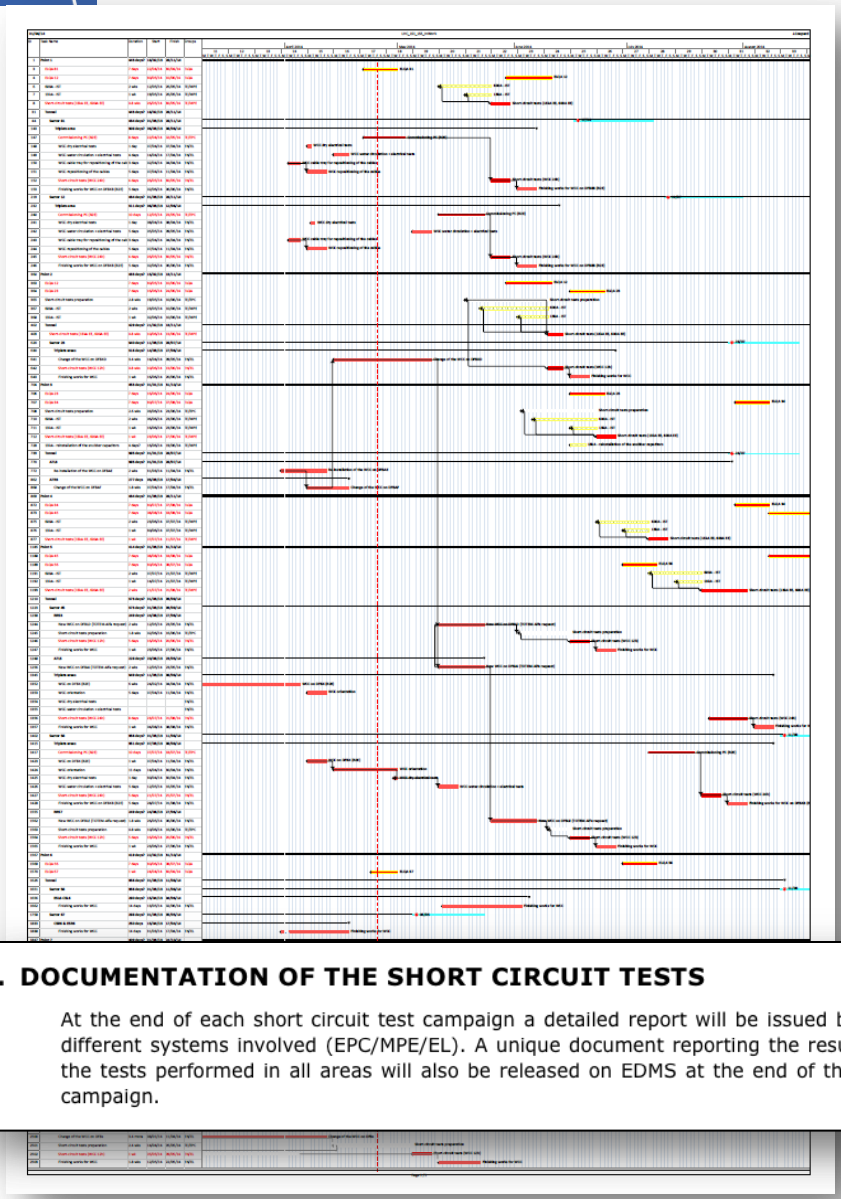
Short Circuit Tests - what

- 13 kA circuits:
  - HV qualification (WCC and EE system)
  - EE system IST
  - Interlock signals verification:
    - Water cable cooling
    - FPA @different current levels
  - Conical connection R verification
  - Heat run (12h or 24h)
- 6 kA
  - Heat run
- 600 A EE verification
  - in order to avoid the cable-DFB disconnection a short circuit is made via installation of 3.5 m long 120 mm^2 cables between EE and PC
  - Heat run of 600 A in UA67 to validate the status after the flood occurred





Short Circuit Tests - outlook



7. DOCUMENTATION OF THE SHORT CIRCUIT TESTS

At the end of each short circuit test campaign a detailed report will be issued by the different systems involved (EPC/MPE/EL). A unique document reporting the results of the tests performed in all areas will also be released on EDMS at the end of the LS1 campaign.

Test Done:

✓ UA47 + UA63 + UA67 + RR73 + RR77 + UL14 + RR13 + UL16 + RR17:

SUCCESSFULLY COMPLETED!

Some encountered (solved!) problems

- Wrong water interlock cabling
- Some lose conical connections (re-tightened)
- Hole in the WCC of RQX.L1
- Earth fault due to contact between water connector and ground
- Special configuration used for 600 A in RR13+RR17, as the installation of short circuit between is not possible

outline

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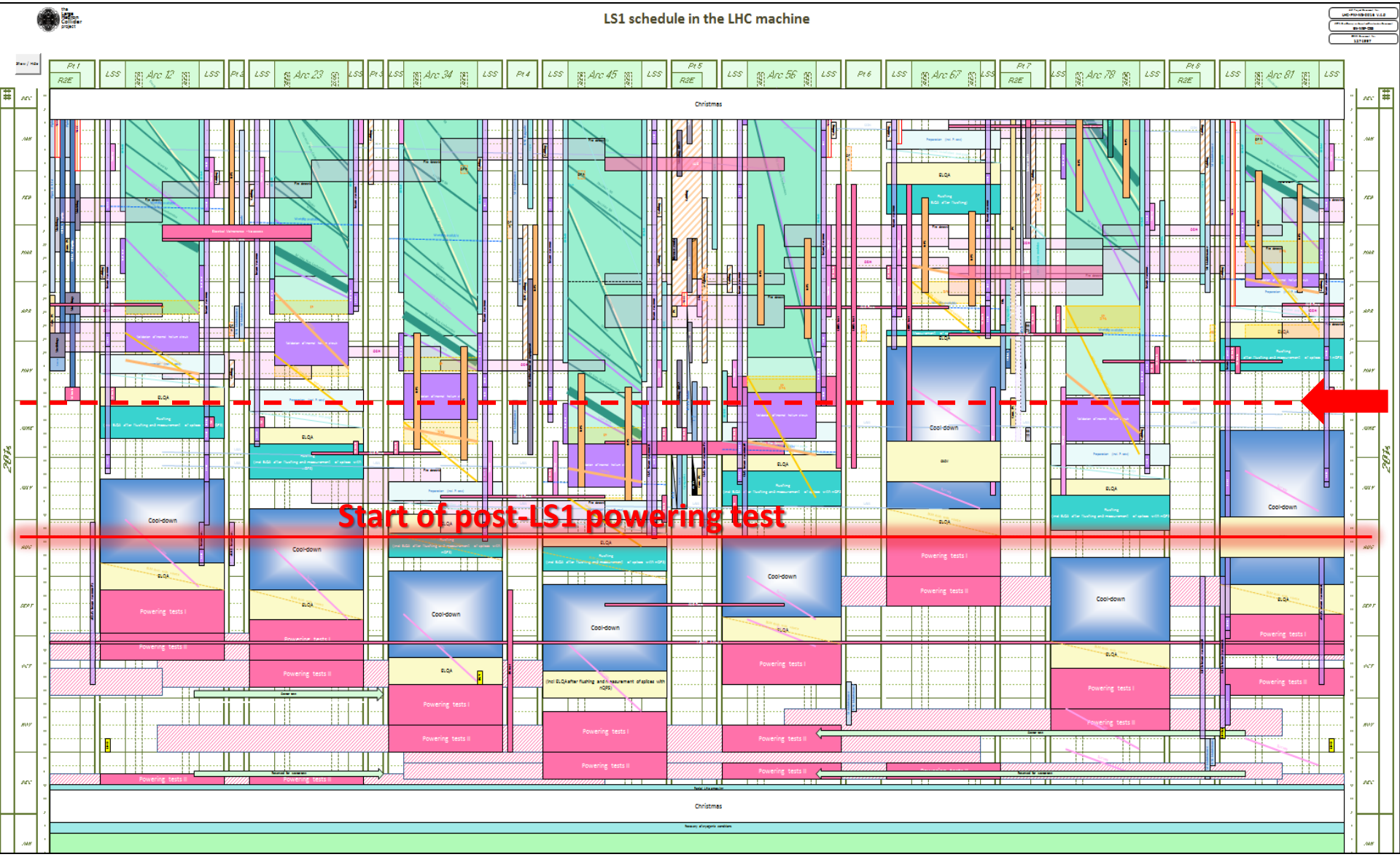
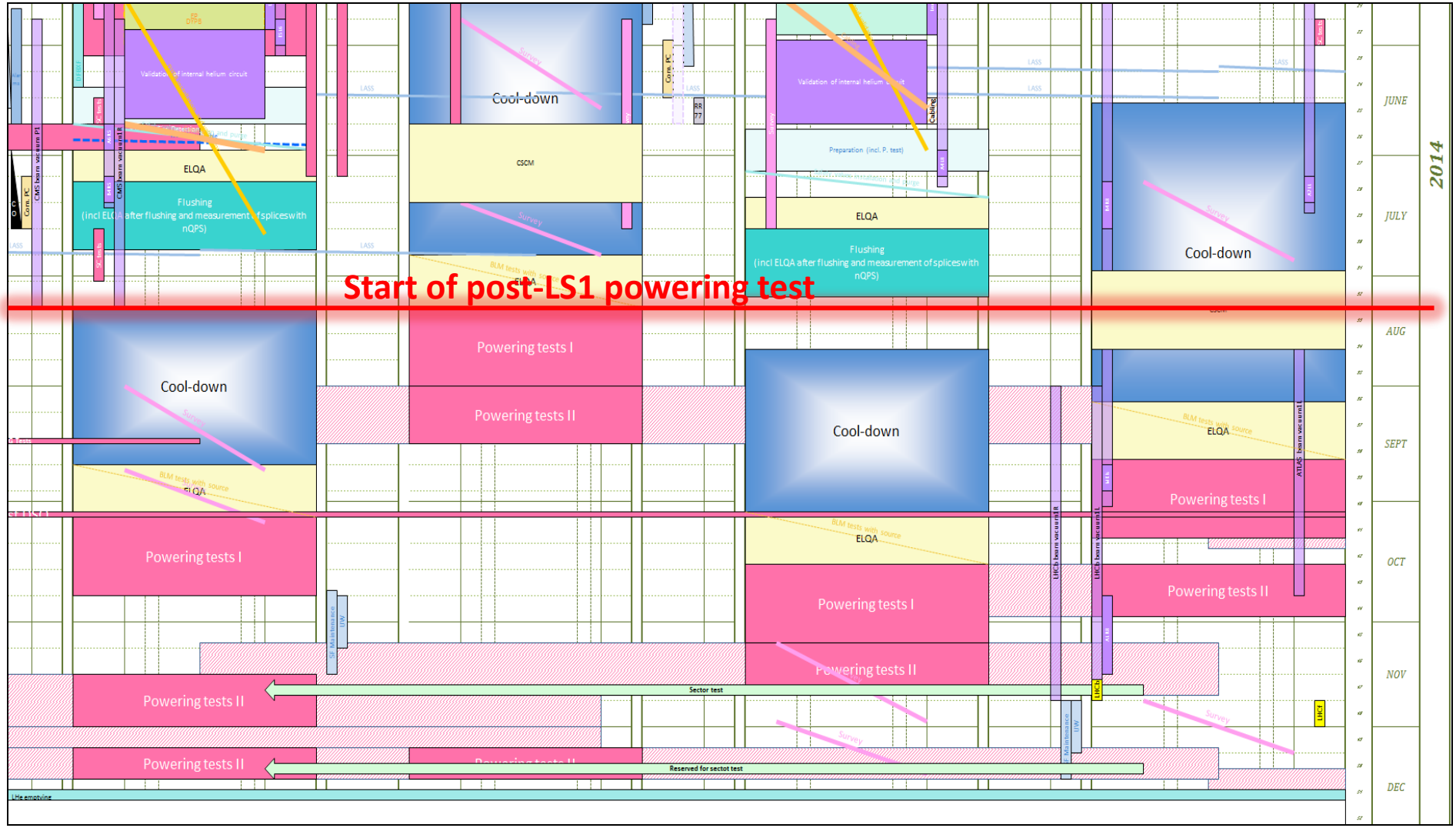
Powering Tests - planning



Powering Tests - planning

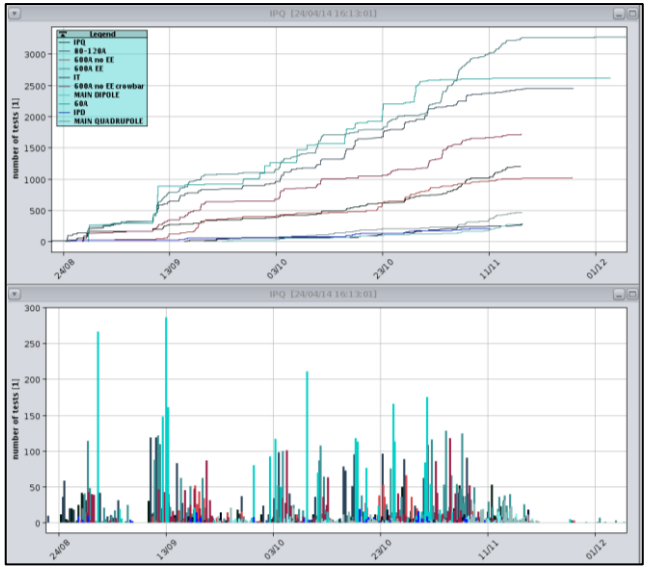


Powering Tests – overview

Almost 1600 circuits

- 24 Main circuits
  - 8 RBs + 16 RQs
- 8 ITs
- 94 Individually Powered 4-6 kA circuits
  - 78 IPQs
  - 16 IPDs
- 410 x 600 A circuits:
  - 202 with EE
  - 208 w/o EE
- 284 x 80-120A circuits
- 752 x 60 A circuits

A total of **more than 10.000 powering test steps** in less than 4 months!!

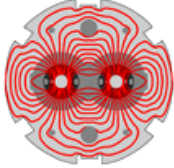


Cumulative number of powering test steps performed between August and December 2009 (divided per circuit type)

In 2009 the LHC was commissioned in a similar amount of time after the incident repair also with a new QPS system.

Nevertheless, the other systems had not undertaken massive changes (3 sectors not even warmed up) and the main circuits were only commissioned for 3.5 TeV

Powering Tests - overview



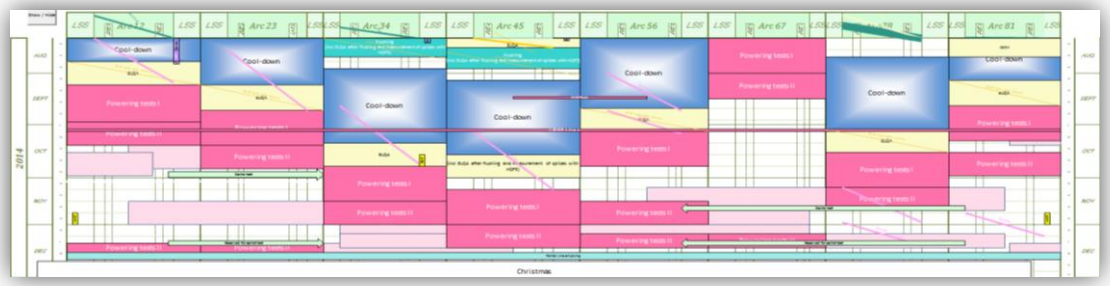
- Powering tests will start in August (many people on holydays)
- Cohabitation with other LS1 activities (mainly ElQA, geometers and BLM testing)
  - Phase I and Phase II are completely separated to allow maximum flexibility
  - 3 weeks for Phase I powering (most of debugging) and 2 weeks for Phase II
  - Might be obliged to test outside normal working hours
- Possible interference between CSCM in Sector 81 and Powering Tests in Sector 67 (CSCM requires support of many experts, QPS mainly)
- Sector 67 will be the test bench, after which 7 sectors have to be commissioned in 3 months!

Definition of powering phases

LHC-MPP-ES-0002, EDMS 1001985: "Access and powering conditions for the superconducting circuits in LHC"

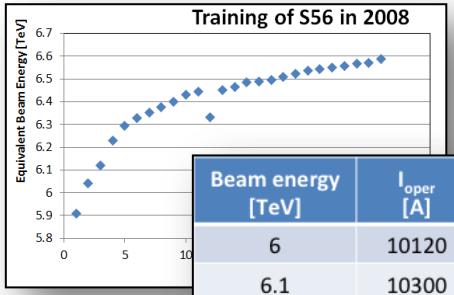
Phase I is defined as when "the current in a sector is limited to a value with negligible risk of massive accidental helium release due to powering". Access limitations only in the sector under powering.
Phase II is beyond this limit. Strong access implications.

Powering Tests - overview



Circuit type	Δ [A]
RB	100 A
RQ	100 A
IT main	100 A
IPQ	50-100 A
IPD	50-100 A
600 A	10-20 A
80-120 A	5 A
60 A	5 A

- Training strategy for the 13 kA circuits:
  - defined maximum number of quenches at a first stage to reduce commissioning time and minimize risk of failures
  - According to the results of all sectors, an extension of the training could be needed (additional week on mid-December allocated)
- **Only one sector will be (partially!!) trained before Chamonix**
- Careful tuning of the tests needed to ensure readiness for sector test



Beam energy [TeV]	I_{oper} [A]	$I_{max,HWC}$ [A]	Exp. nr. of training quenches during HWC
6	10120	10220	5-10
6.1	10300	10400	10-20
6.2	10470	10570	20-30
6.3	10640	10740	30-40
6.4	10810	10910	50-80
6.5	10980	11080	90-130
6.6	11160	11260	>150
6.7	11330	11430	>300

A. Verweij @LMC#177

Powering Tests - organization

"The team is responsible for the general organization and execution of the powering tests, interface to coordination and other teams, as well as with other teams preparing beam operation"

Organization and coordination

3 March 2014

EDMS NO. 1358404

MEMORANDUM

To: Odd Andreassen, Jean-Christophe Garnier, Mirko Pojer, Rüdiger Schmidt, Andrzej Siemko, Matteo Solfaroli, Arjan Verweij, Jörg Wenninger, Gerard Willering

From: Frédérick Bordry

Distribution: Paul Collier, José Miguel Jiménez, Roberto Saban, BE group leaders, EN group leaders, TE group leaders, Benoit Delille

Subject: **Organisation of the commissioning of the LHC Superconducting Magnet Circuits**

MP3 is responsible to:

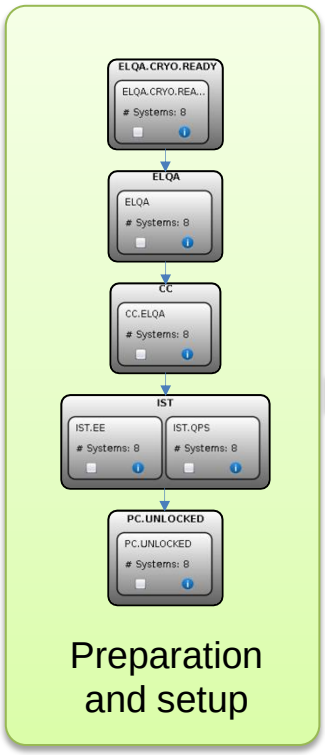
- "define the procedure and the criteria for test analysis"
- "identify, track and document exceptions"
- "give recommendation for future operation"

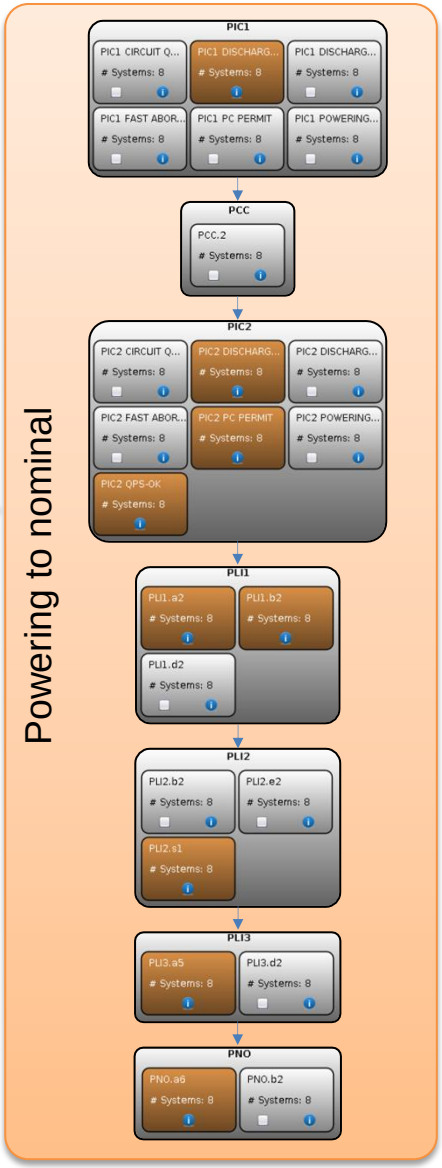
Automation

"The team will ensure that tools are available for the follow-up of all phases […] assume responsibility for providing the sequences and provide tools for automatic testing of circuits and analysis of test steps"

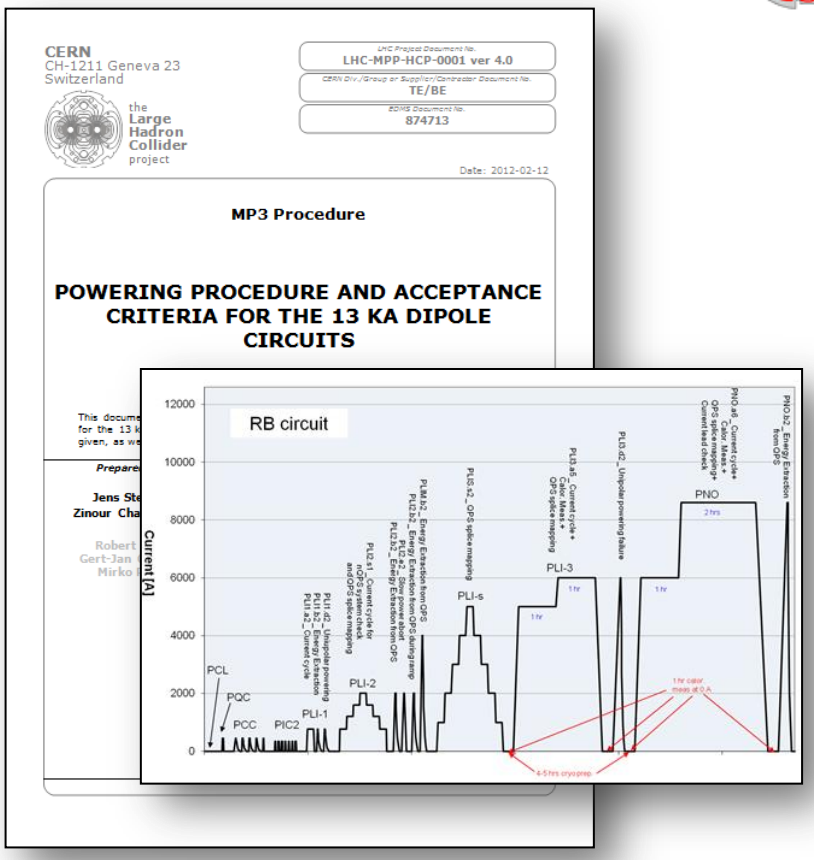
MP3

Powering Tests - tools





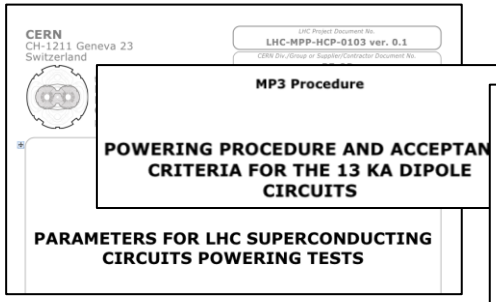
Example of the testing flowchart for the RB circuits



Big effort from MP3 to review and optimize all powering procedures

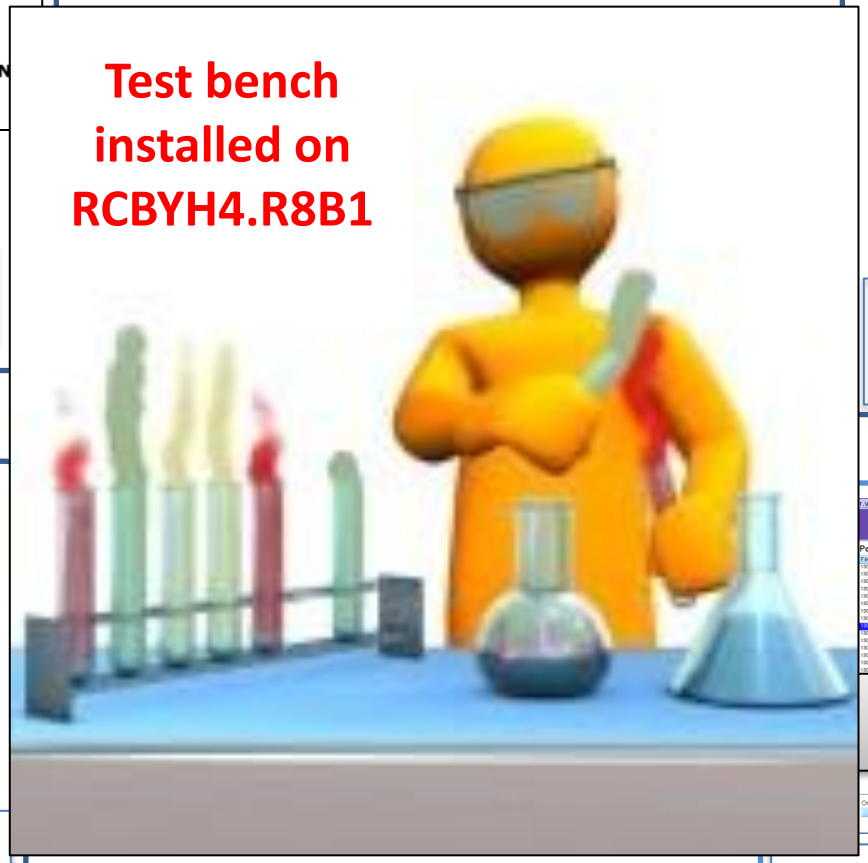
Revision process to be completed by the end of June

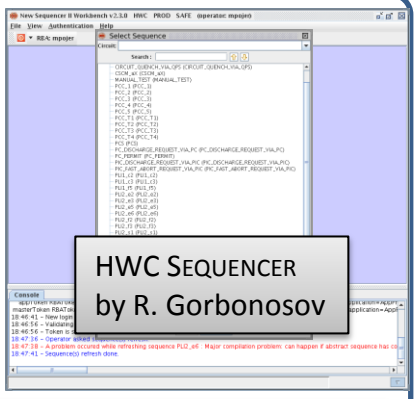
Powering Tests - tools



New procedures and parameter document

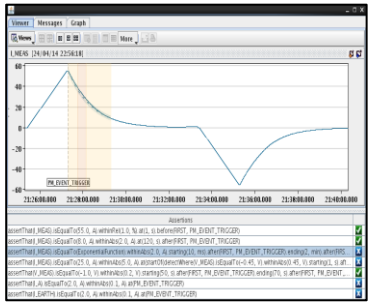
Test bench installed on RCBYH4.R8B1



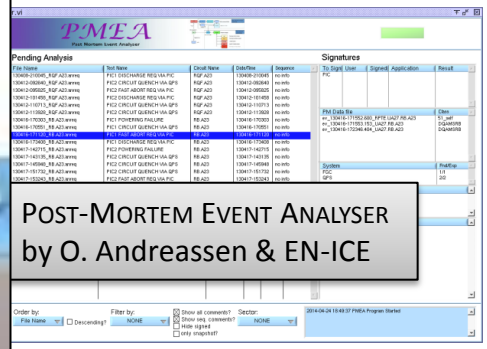


HWC SEQUENCER by R. Gorbonosov

Sequences code and LSA parameters have to be updated and tested



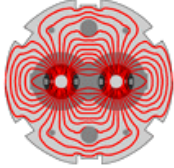
Analysis modules that can be automatically executed by the framework. 60 A circuits are completely automated. More tests will possibly follow.



POST-MORTEM EVENT ANALYSER by O. Andreassen & EN-ICE

Maintenance and adaptations have been done to make it compatible with the new ACCTEST framework introduced in LS1. All PCC and PIC tests are automated.

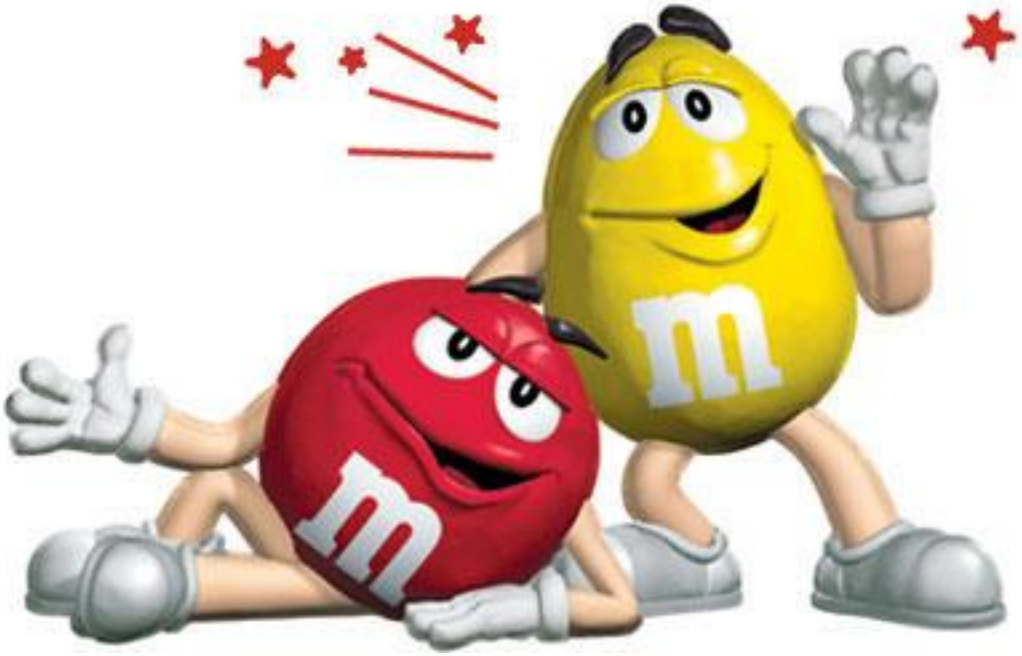
Conclusions



- ✓ LHC preparation has seriously started a long time ago!
- ✓ Besides general maintenance, many changes have been applied with the goal of increasing availability/reliability/performance. This will have an impact on the powering tests as well as on the machine efficiency
- ✓ The SCT campaign is successfully proceeding fast:
  - ✓ Solved the initial teething problems, the well defined *modus operandi* allows the tests to proceed quickly and efficiently
  - ✓ The problems encountered (and solved) show the importance of this campaign
  - ✓ The limited time doesn't leave much time to cope with possible errors
- ✓ The ongoing preparation of powering tests campaign is crucial for its success:
  - ✓ Powering procedures are being finalized
  - ✓ A test bench has been prepared to verify the functionality of all SW infrastructure
  - ✓ The individual tests of the systems (IST) are being prepared
  - ✓ A close coordination and problem follow-up is needed to ensure readiness of all systems

Conclusions

…as a result of LS1 changes all systems have to be carefully tested and some of them have to be considered as brand-new…**A LOT OF WORK!!**



THANK YOU!