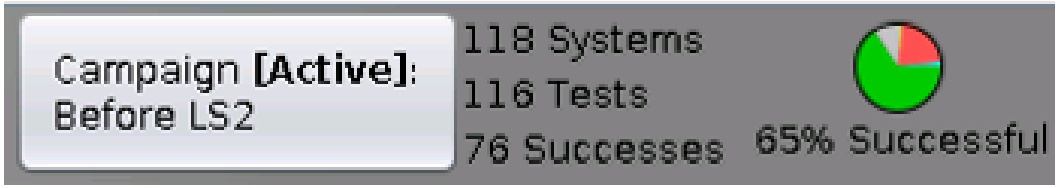

CERN

Experience from LHC Powering Tests Campaign "Before LS2"



Outline

- What was planned (*M&M)*
- Trainings on main dipoles
- Heater provoked quenches on selected MBs
- Trainings on main quadrupoles
- Series of FPAs on the RB and RQD/F circuits
- ~~Findings: couplings, high diode lead resistances, …~~
- Concluding remarks (*M&M)*

Zinour Charifoulline, on behalf of MP3

Planning of powering to 7 TeV

- **Dipole training** for RB.A12
- **Quadrupole training** for all RQD/F
- **IPQs & IPDs training** to 7 TeV equivalent current
- **IT IP1/5** to 7 TeV equivalent current

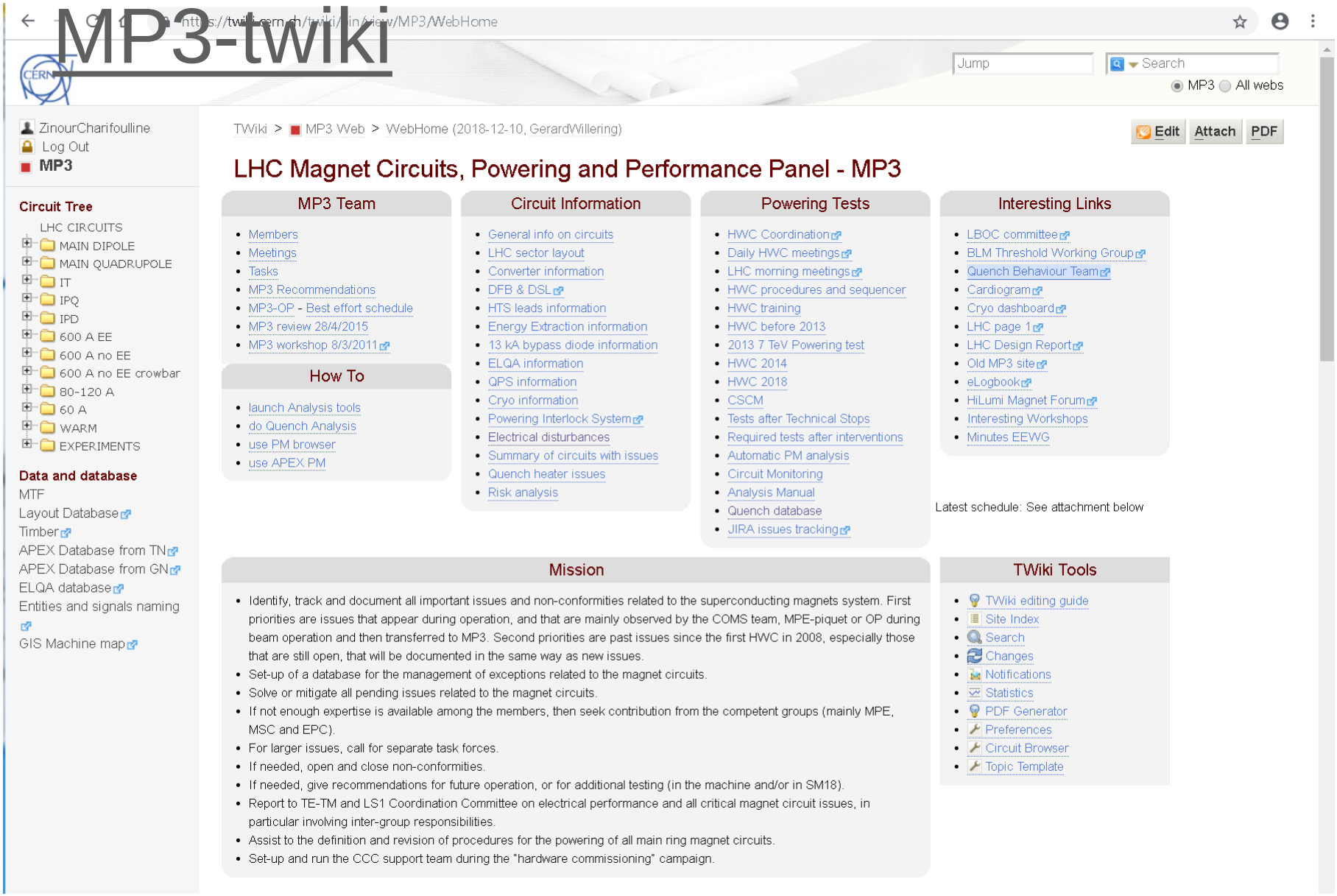
} + margin

- **600A**
  - Test of few circuits with suspected reduced performance
  - Check of increased performance for octupoles and sextupoles
- **Special tests:**
  - Series of FPA on the RBs
  - Series of FPA on the RQD/F
  - Few provoked quenches on selected RBs
  - Investigation on problematic circuits (RCO/RCS)
  - Check of new di/dt sensor on some circuits

Dense planning, made challenging by the electrical power cut (almost 3 days lost!)

Mirko Pojer, LMC, 12/12/2018

MP3-twiki


https://twiki.cern.ch/twiki/bin/view/MP3/WebHome
Jump
Search
MP3
All webs
ZinourCharifoulline
Log Out
MP3
Circuit Tree
LHC CIRCUITS
MAIN DIPOLE
MAIN QUADRUPOLE
IT
IPQ
IPD
600 A EE
600 A no EE
600 A no EE crowbar
80-120 A
60 A
WARM
EXPERIMENTS
Data and database
MTF
Layout Database
Timber
APEX Database from TN
APEX Database from GN
ELQA database
Entities and signals naming
GIS Machine map
TWiki > MP3 Web > WebHome (2018-12-10, GerardWillering)
Edit
Attach
PDF
LHC Magnet Circuits, Powering and Performance Panel - MP3
MP3 Team
Members
Meetings
Tasks
MP3 Recommendations
MP3-OP - Best effort schedule
MP3 review 28/4/2015
MP3 workshop 8/3/2011
How To
launch Analysis tools
do Quench Analysis
use PM browser
use APEX PM
Circuit Information
General info on circuits
LHC sector layout
Converter information
DFB & DSL
HTS leads information
Energy Extraction information
13 kA bypass diode information
ELQA information
QPS information
Cryo information
Powering Interlock System
Electrical disturbances
Summary of circuits with issues
Quench heater issues
Risk analysis
Powering Tests
HWC Coordination
Daily HWC meetings
LHC morning meetings
HWC procedures and sequencer
HWC training
HWC before 2013
2013 7 TeV Powering test
HWC 2014
HWC 2018
CSCM
Tests after Technical Stops
Required tests after interventions
Automatic PM analysis
Circuit Monitoring
Analysis Manual
Quench database
JIRA issues tracking
Interesting Links
LBOC committee
BLM Threshold Working Group
Quench Behaviour Team
Cardiogram
Cryo dashboard
LHC page 1
LHC Design Report
Old MP3 site
eLogbook
HiLumi Magnet Forum
Interesting Workshops
Minutes EEWG
Latest schedule: See attachment below
Mission
Identify, track and document all important issues and non-conformities related to the superconducting magnets system. First priorities are issues that appear during operation, and that are mainly observed by the COMS team, MPE-piquet or OP during beam operation and then transferred to MP3. Second priorities are past issues since the first HWC in 2008, especially those that are still open, that will be documented in the same way as new issues.
Set-up of a database for the management of exceptions related to the magnet circuits.
Solve or mitigate all pending issues related to the magnet circuits.
If not enough expertise is available among the members, then seek contribution from the competent groups (mainly MPE, MSC and EPC).
For larger issues, call for separate task forces.
If needed, open and close non-conformities.
If needed, give recommendations for future operation, or for additional testing (in the machine and/or in SM18).
Report to TE-TM and LS1 Coordination Committee on electrical performance and all critical magnet circuit issues, in particular involving inter-group responsibilities.
Assist to the definition and revision of procedures for the powering of all main ring magnet circuits.
Set-up and run the CCC support team during the "hardware commissioning" campaign.
TWiki Tools
TWiki editing guide
Site Index
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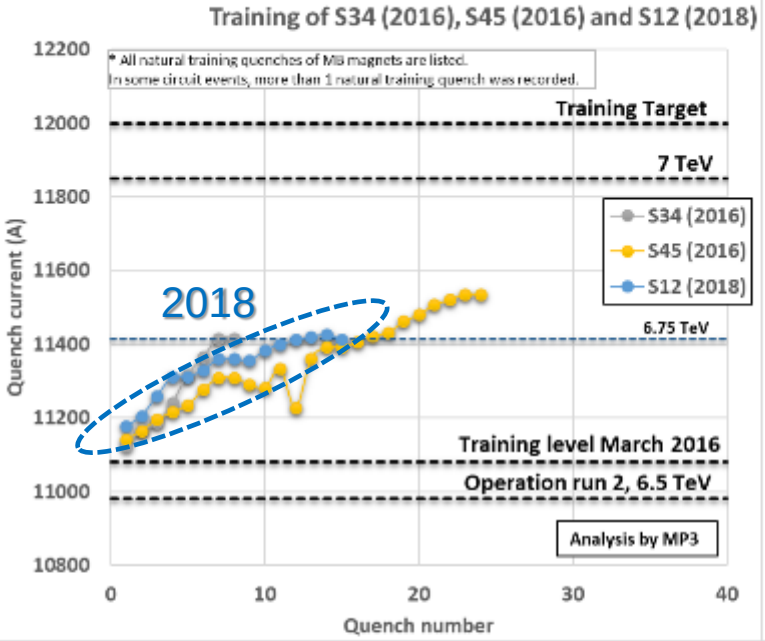
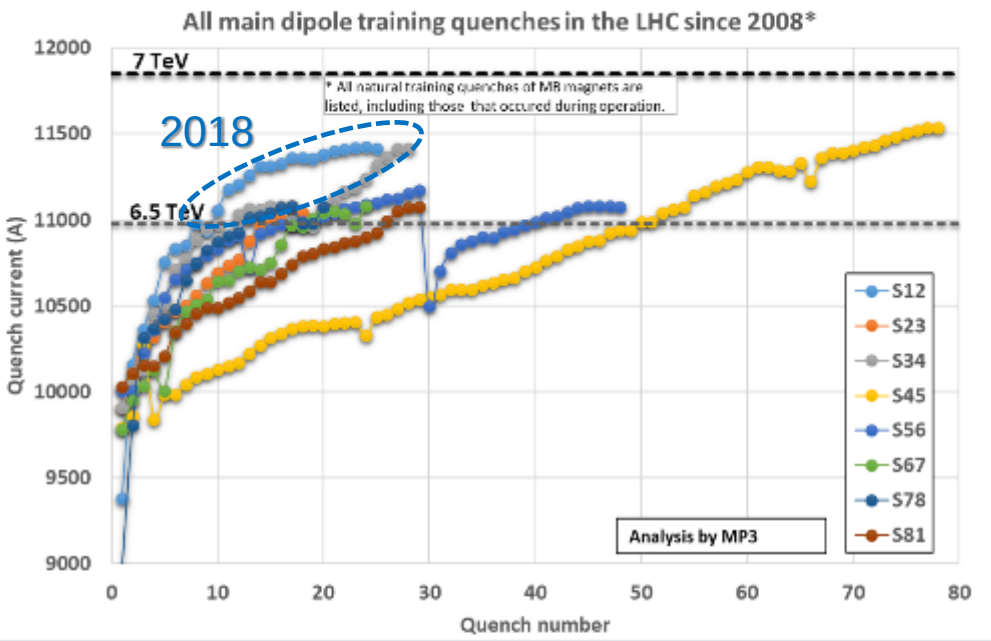
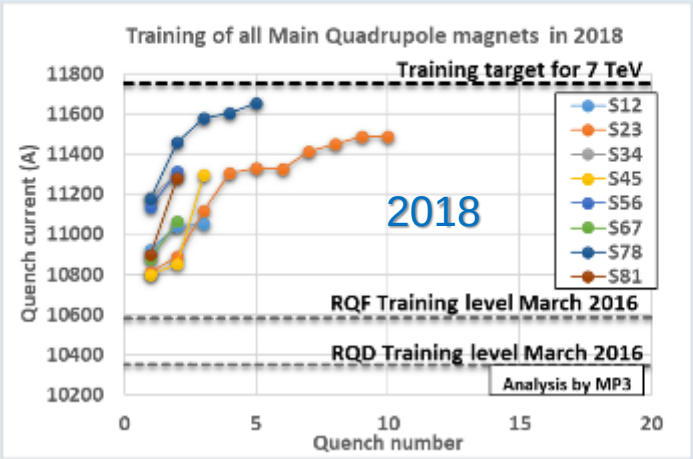
Topic Template

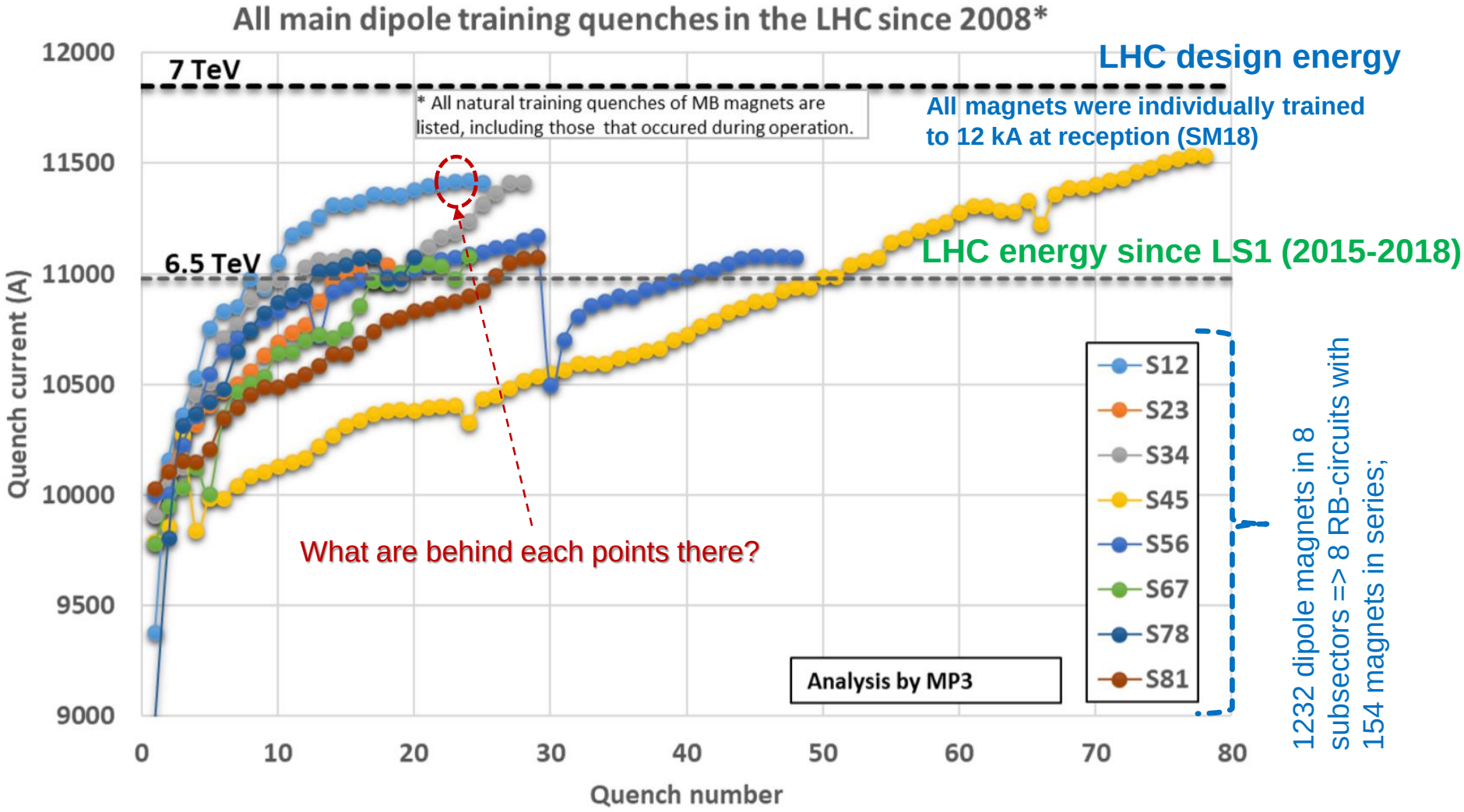
Main Magnet Training above 6.5 TeV
Updated 12-12-2018 12:00

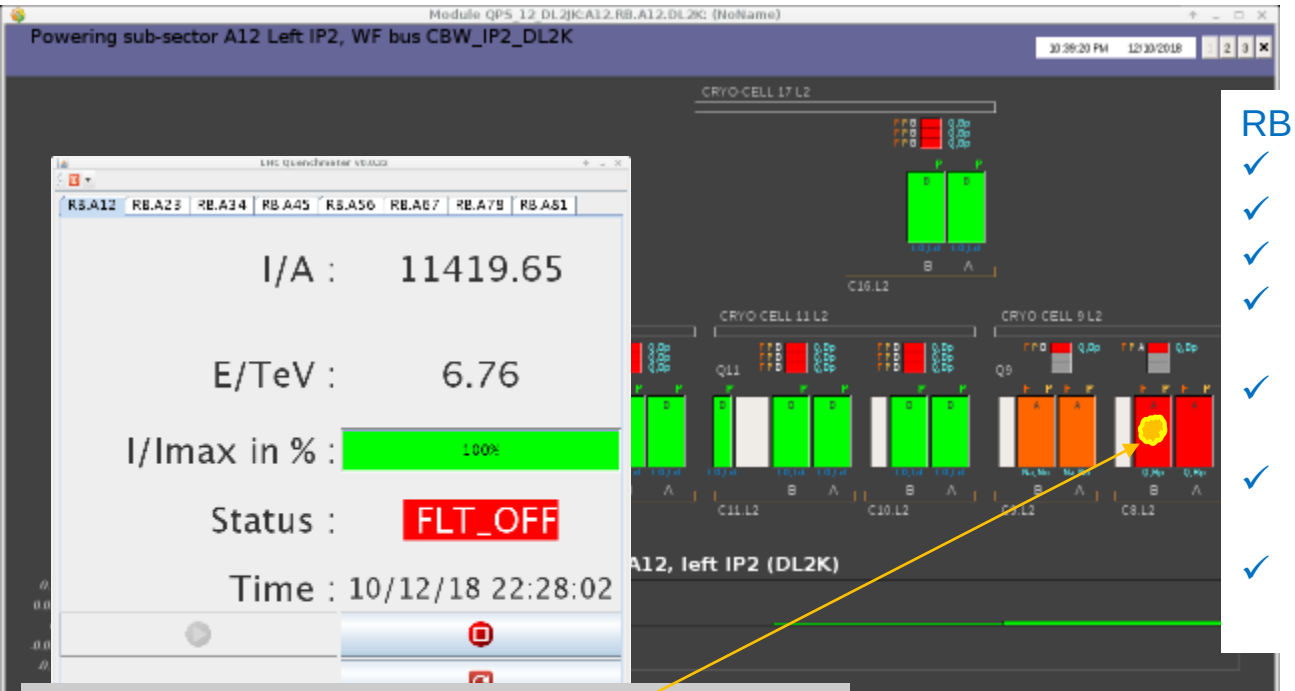




- ✓ All MB-quenches in the LHC since 2008;
- ✓ Individual plots represent 8 RB-circuits;
- ✓ MQ-quenches started since this campaign;

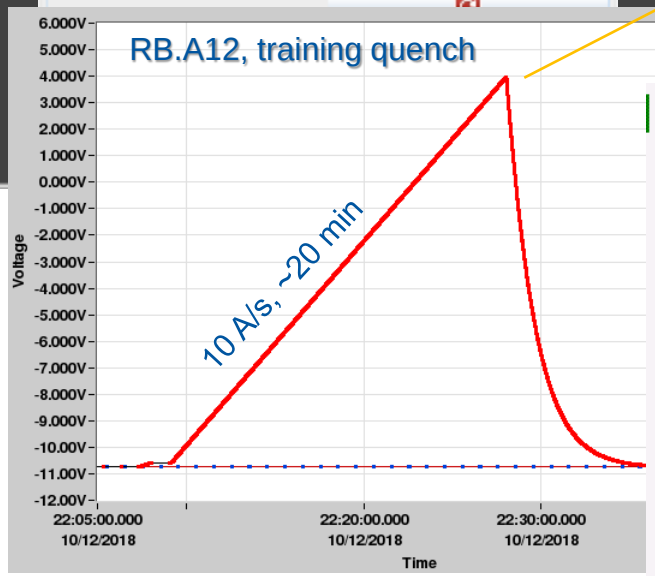


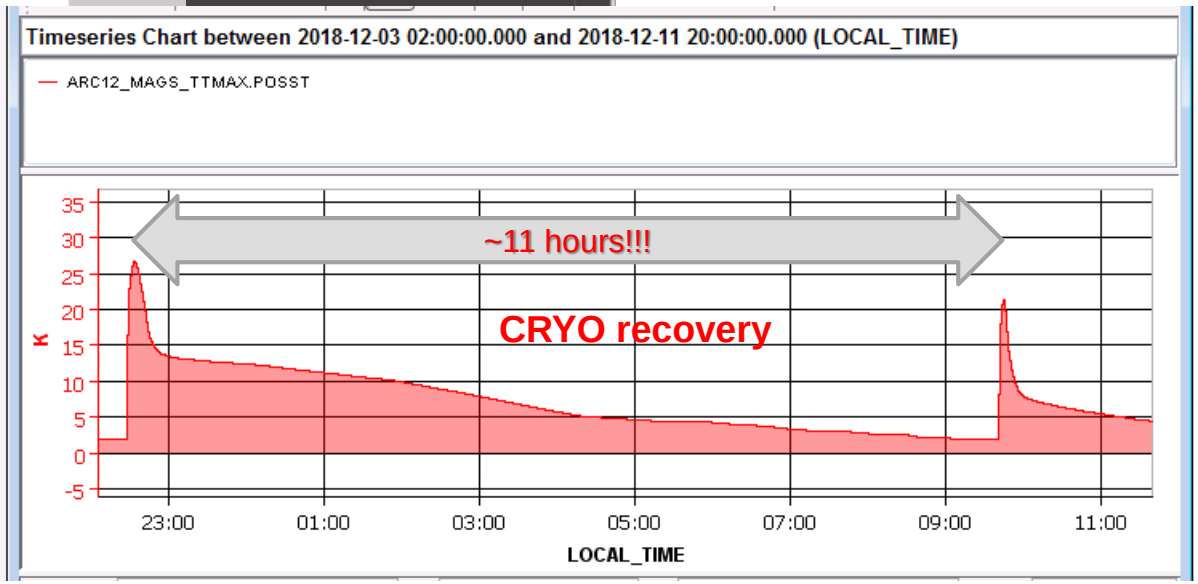

All main dipole training quenches in the LHC since 2008*
7 TeV
6.5 TeV
* All natural training quenches of MB magnets are listed, including those that occured during operation.
LHC design energy
All magnets were individually trained to 12 kA at reception (SM18)
LHC energy since LS1 (2015-2018)
What are behind each points there?
Analysis by MP3
S12
S23
S34
S45
S56
S67
S78
S81
1232 dipole magnets in 8 subsectors => 8 RB-circuits with 154 magnets in series;
Quench current (A)
Quench number
12000
11500
11000
10500
10000
9500
9000
0
10
20
30
40
50
60
70
80

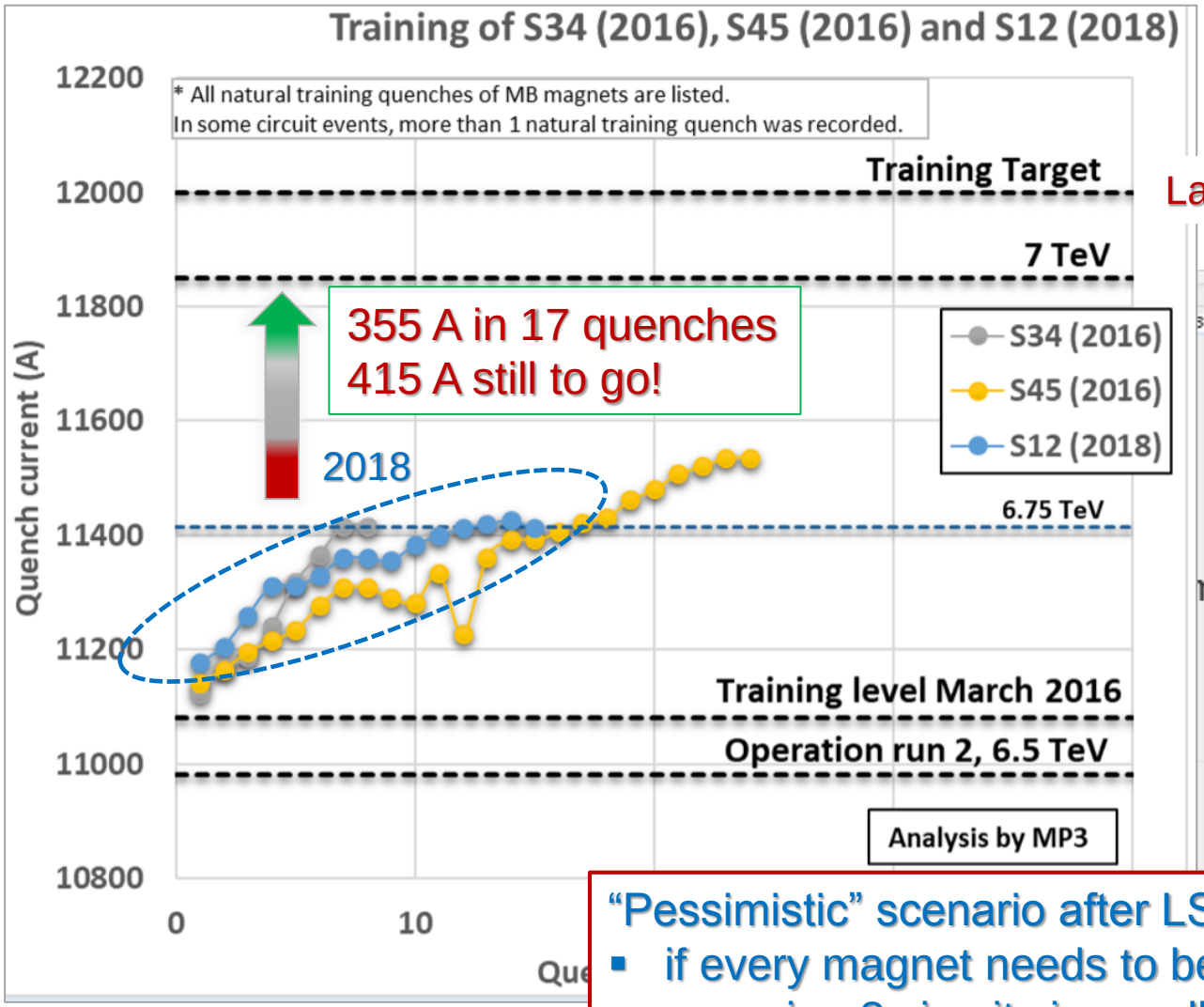


RB.A12, 154 MBs, Single Training Run:

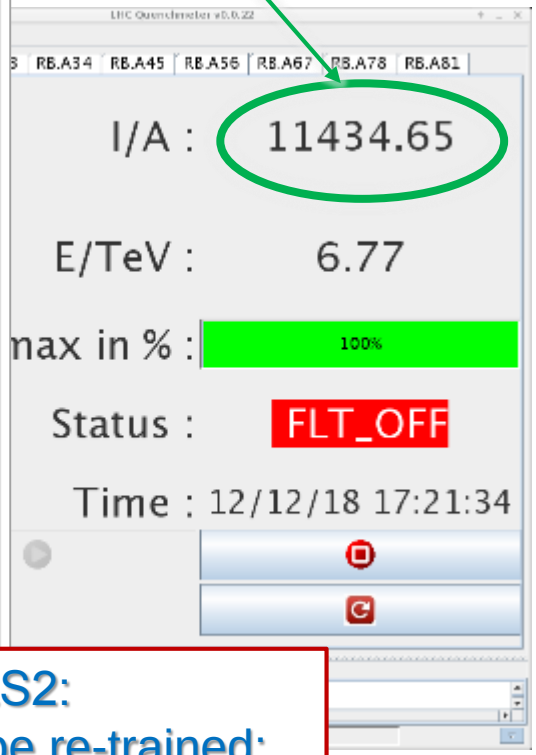
- ✓ Powering Test (PNO.b2);
- ✓ ~20 minutes of ramp up;
- ✓ 1 natural quench (training);
- ✓ 1-3 fast quenches due to EM coupling;
- ✓ 2-4 magnets will quench due to the heat propagation;
- ✓ so, 1 training out of 4-10 quenches in total;
- ✓ which ends up with about 6-12 hours of CRYO recovery;







Last training quench so far

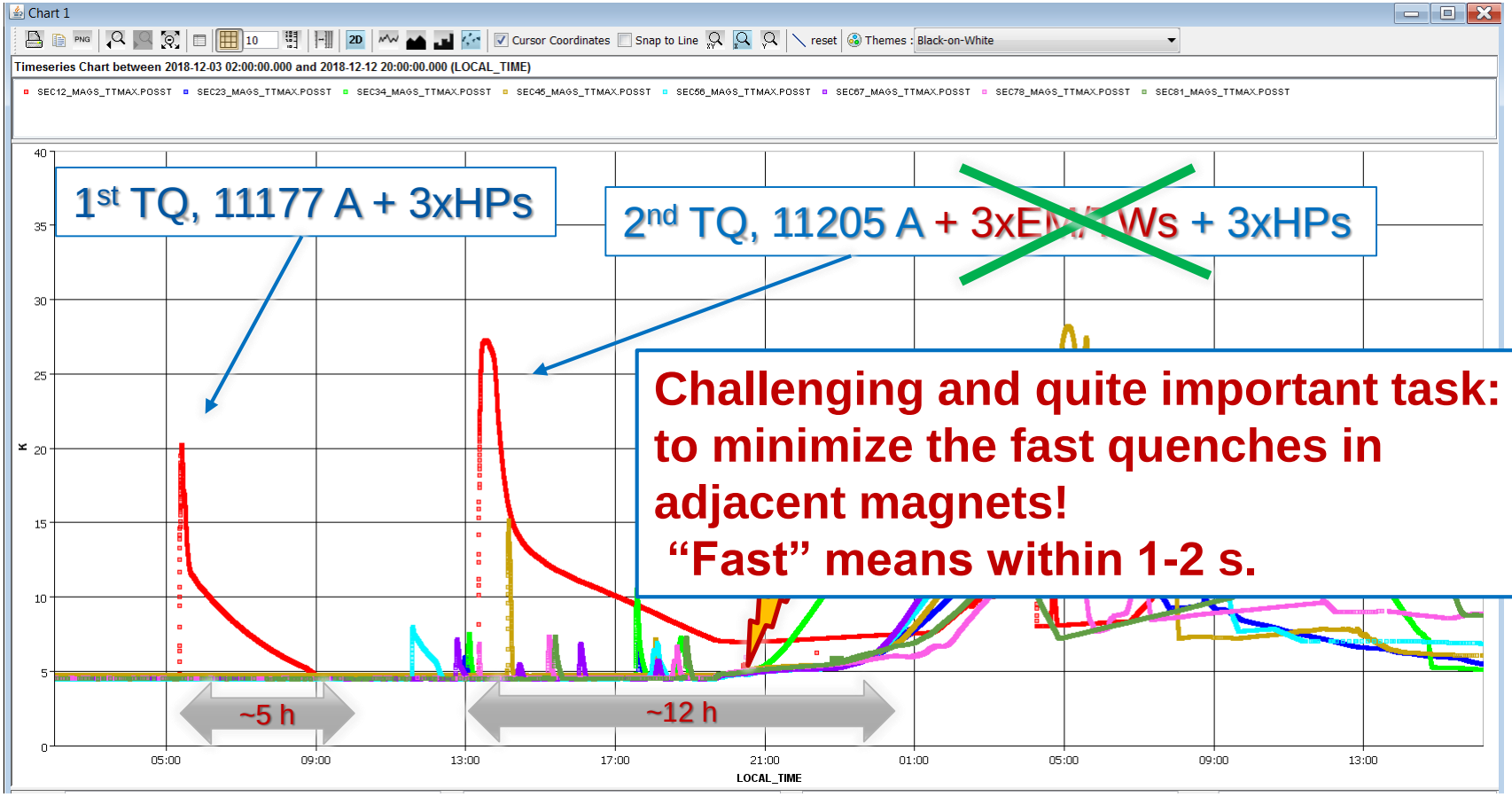


"Pessimistic" scenario after LS2:

- if every magnet needs to be re-trained;
- powering 8 circuits in parallel;
- 154 x 10 hours / 24 ≈ 60 days;

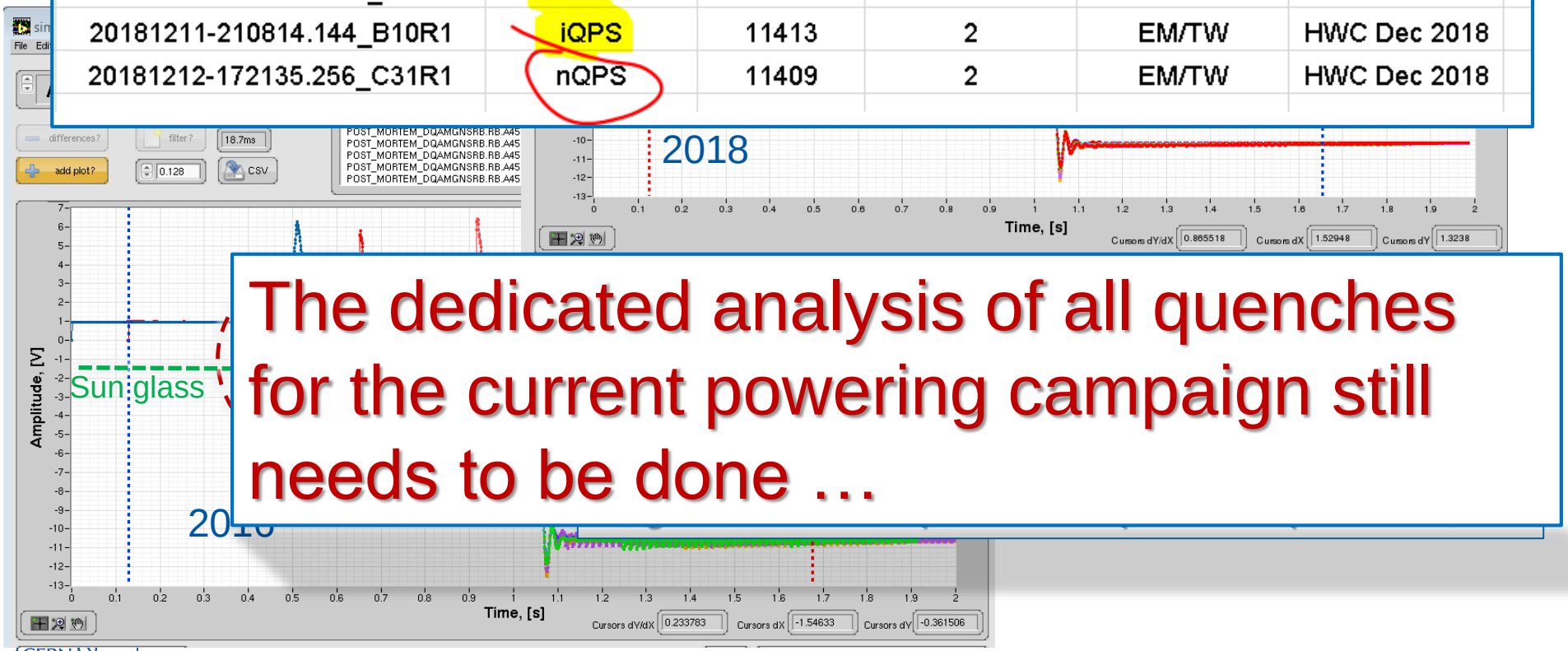
A bit long but not infinite …

CRYO recovery time:
Multiple High Current Quenches vs Power Cut

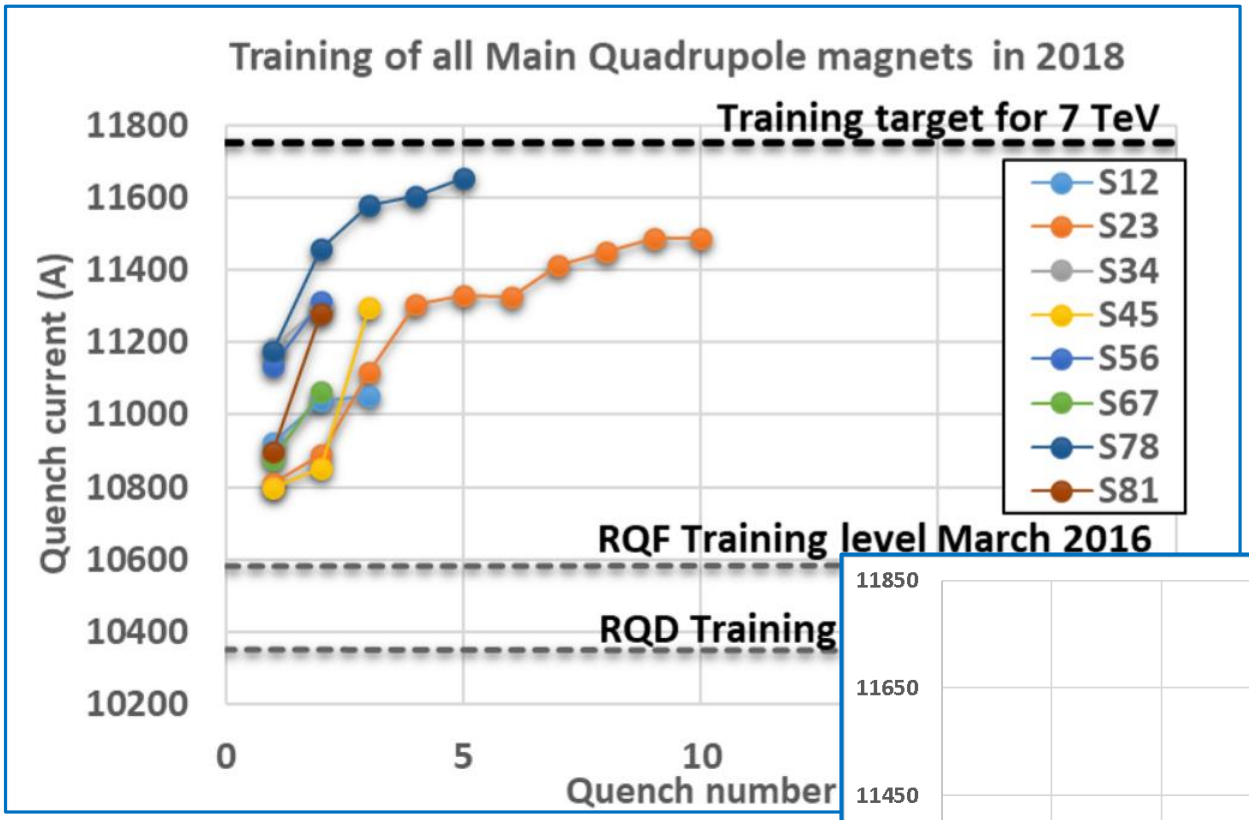


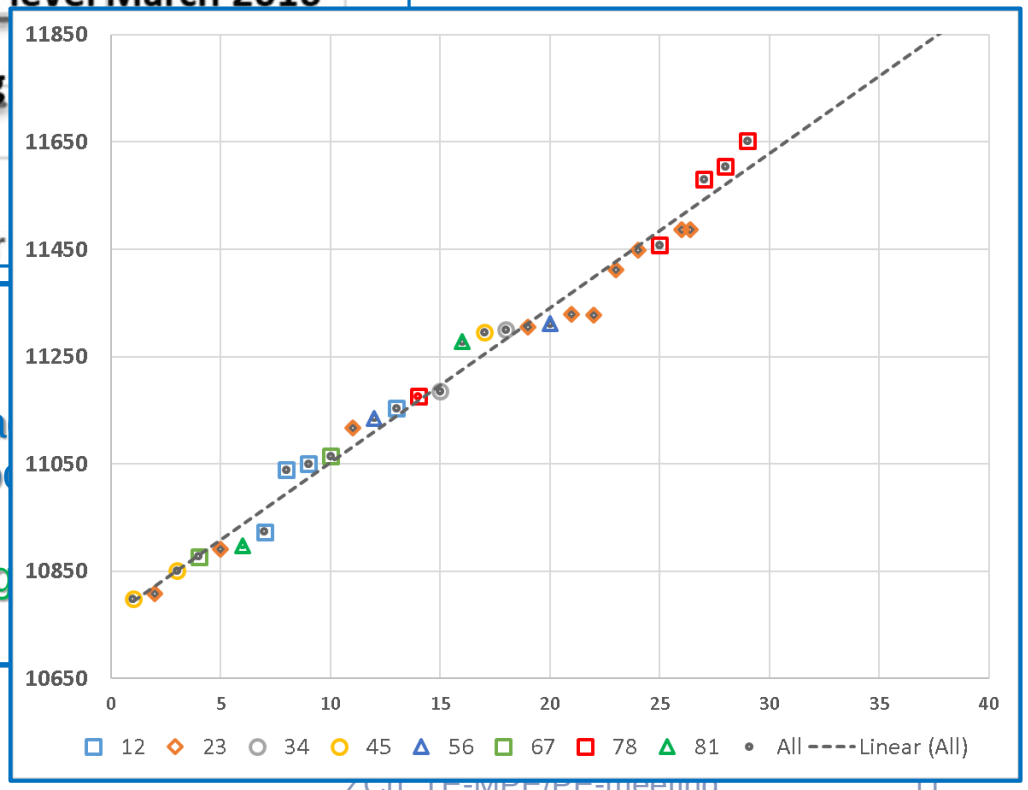
Special test: HP quench in C27L5

QPS PM file	iQPS or nQPS	I_q	Nr in Q event	Type of Q	Period
170423-132901.334_B25R1	iQPS	11055	2	EM/TW	
20181203-132042.627_B19L2	iQPS	11205	2	EM/TW	HWC Dec 2018
20181206-190239.603_A10L2	iQPS	11259	2	EM/TW	HWC Dec 2018
20181208-161744.182_B16R1	iQPS	11356	2	EM/TW	HWC Dec 2018
20181209-062054.729_A26R1	iQPS	11383	2	EM/TW	HWC Dec 2018
20181209-165309.417_C22R1	iQPS	11400	2	EM/TW	HWC Dec 2018
20181210-063122.824_B20R1	iQPS	11412	2	EM/TW	HWC Dec 2018
20181210-222802.411_A9L2	iQPS	11420	2	EM/TW	HWC Dec 2018
20181211-210814.144_B10R1	iQPS	11413	2	EM/TW	HWC Dec 2018
20181212-172135.256_C31R1	nQPS	11409	2	EM/TW	HWC Dec 2018



The dedicated analysis of all quenches for the current powering campaign still needs to be done …





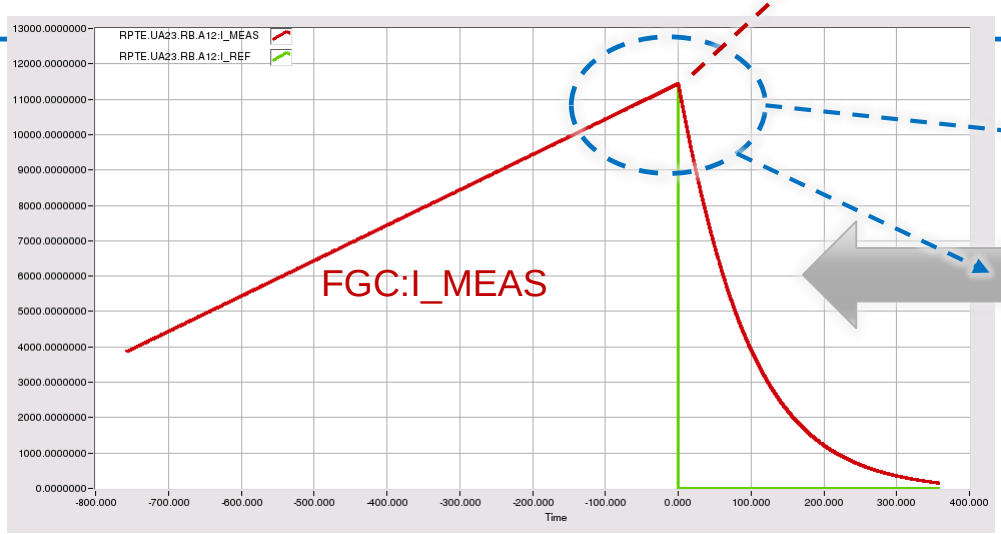
8 RQD/RQF-circuits are trained in parallel:

- ✓ much less stored energy in a single ma
- ✓ only one magnet is quenching for the p
- ✓ short CRYO recovery time (~1h);
- ✓ can be done in a shadow of RB-training

Series of special FPAs on the RB and RQD/F

FPA tests performed in Dec 2018 where all nQPS DS and iQPS DL buffers are read. Delays EE: 100 ms and 600 ms

Sector	2 kA	4 kA	5 kA	6 kA	8 kA	10 kA
S12						
S23	181207-205921.000	181210-014943.879	181210-033636.840	181208-190223.160		181210-044922.340
S34						
S45	181208-180936.880			181208-193410.520	181210-054606.740	181208-211807.820 181209-123227.780
S56						
S67						
S78	181208-124704.840			181208-160205.180		
S81						



2s nQPS DS buffer

8s iQPS DL buffer

Concluding remarks

- Despite the long training of RB.A12 and some time lost, there are many positive aspects of this campaign.
- **Most of the high current circuits were successfully commissioned to the target value**
  - RD3.L4 went to target without quench (was stopped to 6.9 TeV during the training before LS1)
  - RQ5.R1 went to target with 2 quenches (this was suspected to be a ”long-trainer”)
  - RQ5.R5 went to target with 2 quenches (also suspected to be a ”long-trainer”)
  - Some IPQs (RQ5.R6, RQ5.L6, RQ7s@IP5) reached ultimate current with al limited number of quenches (very important for HL-LHC)
  - RQ5.L8 (replaced in LS1 and never trained in the tunnel) reached nominal current with 3 quenches
  - Few 600 A circuits proved that no degradation can be observed in time
  - Octupoles and sextupoles were successfully tested to larger di/dt or/and ramp rate to allow faster operation functions in Run III
- **Quench propagation studies** were done to prove the effectiveness of new QDS thresholds which allow reducing the number of secondary quenches during training
- Fast power aborts were also performed to allow characterizing the RB, RQD/RQF circuits

Mirko Pojer, LMC, 12/12/2018

Thanks!

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The transfer of current from quenching dipoles and quadrupoles into the cold bypass diode