CERN

EYETS Recovery

M.Solfaroli/M.Pojer
BE department
OP group

Thanks to: Cryo team, MP3, EPC, MPE, Fidel, OP, CO, MEF, A.Milanese

TRAINING CAMPAIGN

and a bit of EYETS recovery

~~EYETS Recovery~~

M.Solfaroli/M.Pojer

BE department
OP group

Thanks to: Cryo team, MP3, EPC, MPE, Fidel, OP, CO, MEF, A.Milanese

Outline

- Training campaign…data
- EYETS (in few words) & recovery
- 2017 operation, few ideas

The forecast

A TENTATIVE EXTRAPOLATION

Quench Behaviour Team

- So our best estimate with available data is 450 first quenches plus at most 150 second quenches
  - Estimate is rather linear in the 6.5-7 TeV range so for pushing the LHC today towards 7 TeV is about 50 quenches per 100 GeV, plus the second quench
  - If we consider case after a thermal cycle, we have to add the 170 quenches to go to 6.5 TeV

Best estimate for 7 TeV (first quench only)

sector	1000	2000	3000	total	done	to do
12	3	19	7	28	7	21
23	3	12	30	44	17	27
34	2	16	22	40	15	25
45	2	9	62	73	49	24
56	1	8	63	73	16	57
67	3	7	46	56	20	36
78	3	24	46	72	21	51
81	3	5	50	58	28	30
LHC	20	100	325	445	173	272

S34 → 25
S45 → 24
("virgin" magnets)

E.Todesco
LMC on 20/01/2016

E. Todesco

Still very modest knowledge (=high uncertainty) on the number of quenches needed to reach 7 TeV!

The method

TARGET = 12 kA
(7 TeV => 11850 A)

When

- 5^{th} to 14^{th} December

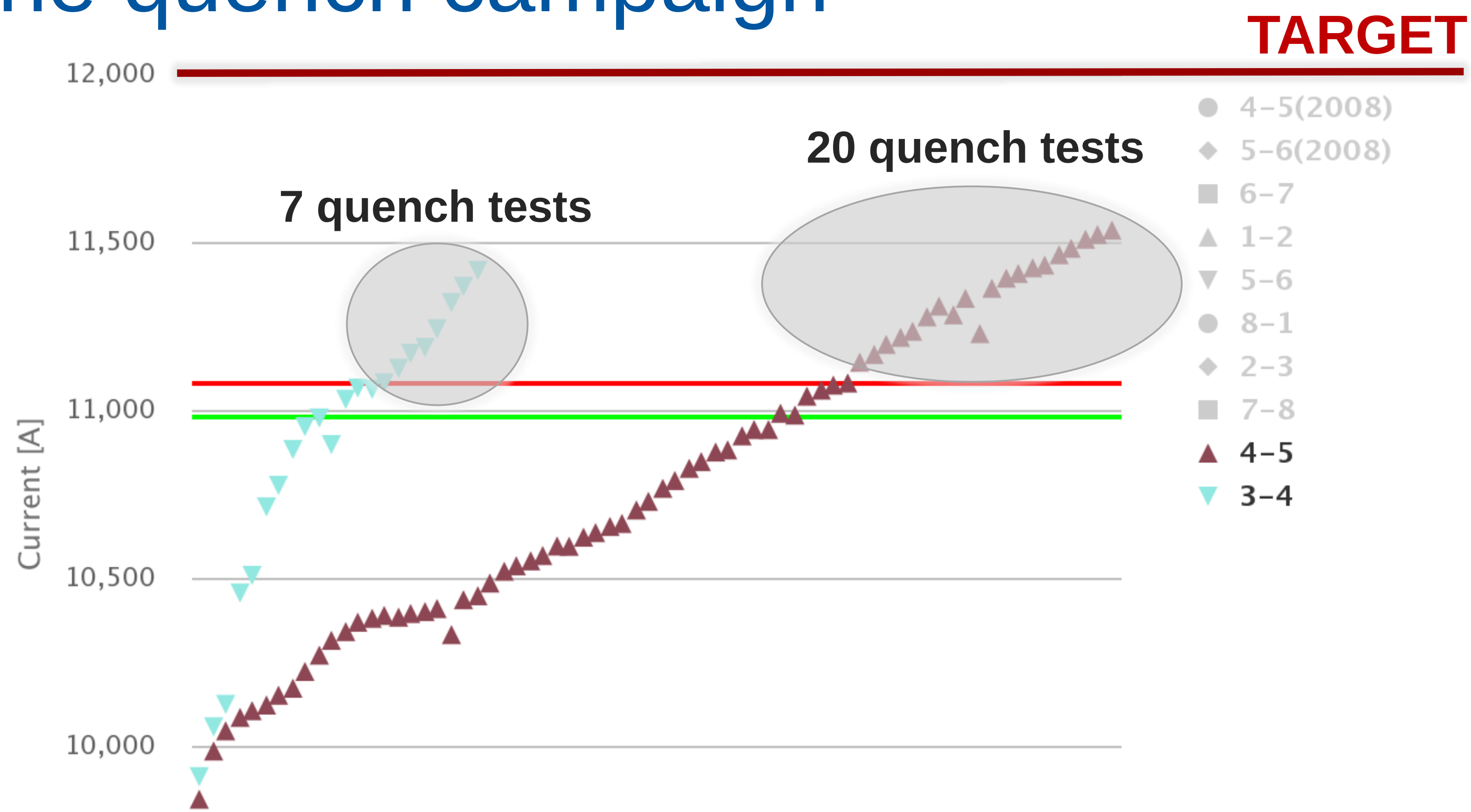
What is needed

- Nominal cryogenic conditions in the ARC34 and ARC45
- No PC condemnation
- PIC and QPS and technical services (EL, CV, VAC) as in operation
- Controls in their operational status
- Patrols maintained in point 2, 3, 4, 5 and 6

How

- Thanks to very efficient cryo recovery, we did **2-3 quenches/day**
- MP3 on shift from 7 till 23
- EPC, MPE and PIC piquet as in operation
- Test execution: OP in 2 shifts/day

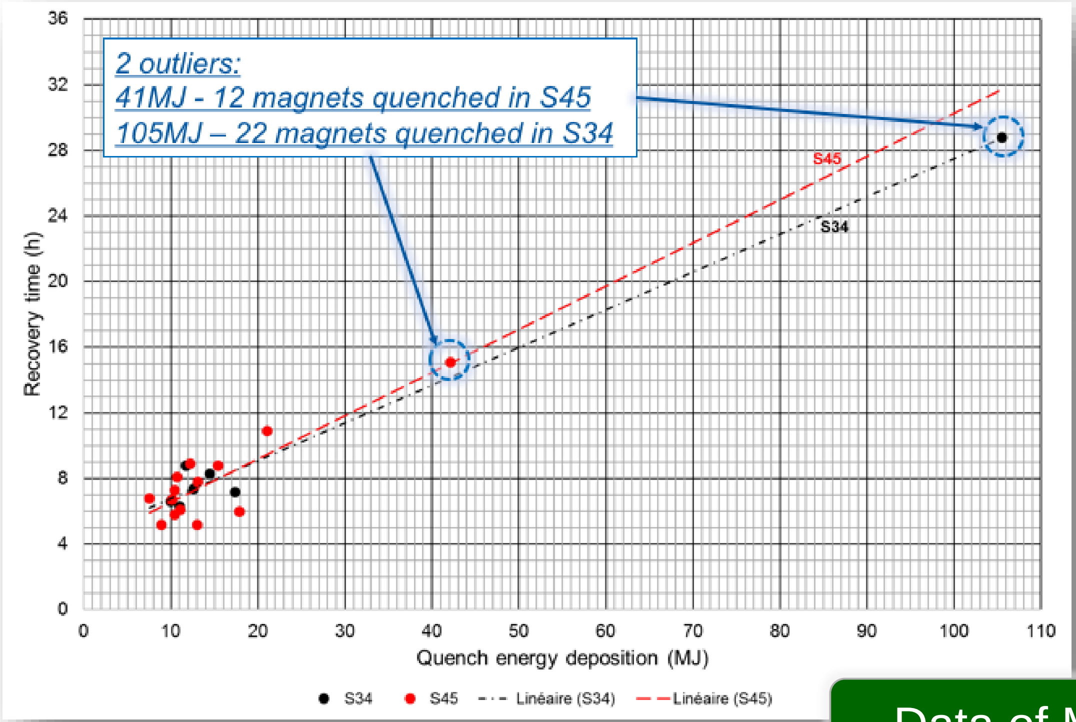
The quench campaign

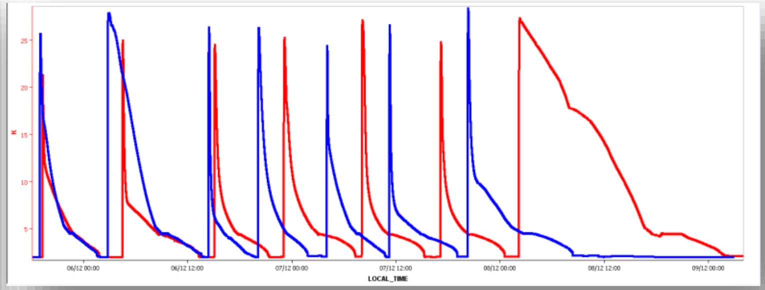


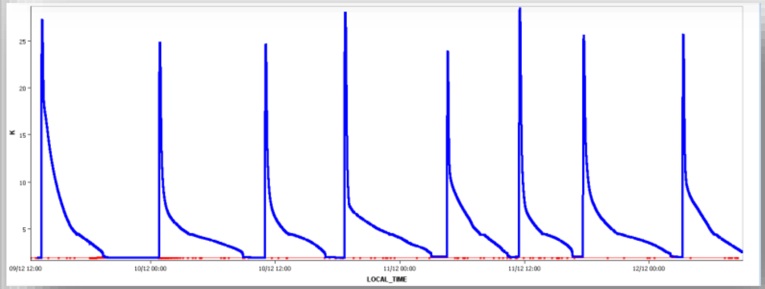
	Current	Energy [TeV]	# training tests	Avg step increase	# training quenches	# secondary quenches
S34	11415 A	6.74	7	48 A	8	43
S45	11535 A	6.82	20	23 A	24	76

The quench campaign (as seen by cryo)

	# training steps	E in the cryo system	Average E in the cryo system	Average recovery time
S34	7	76.7 MJ	12.8 MJ	7.4 hours
S45	16	161.3 MJ	12.4 MJ	7.2 hours



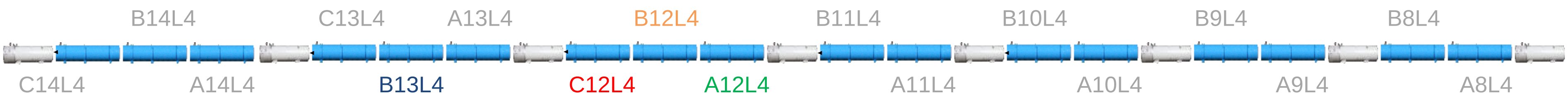


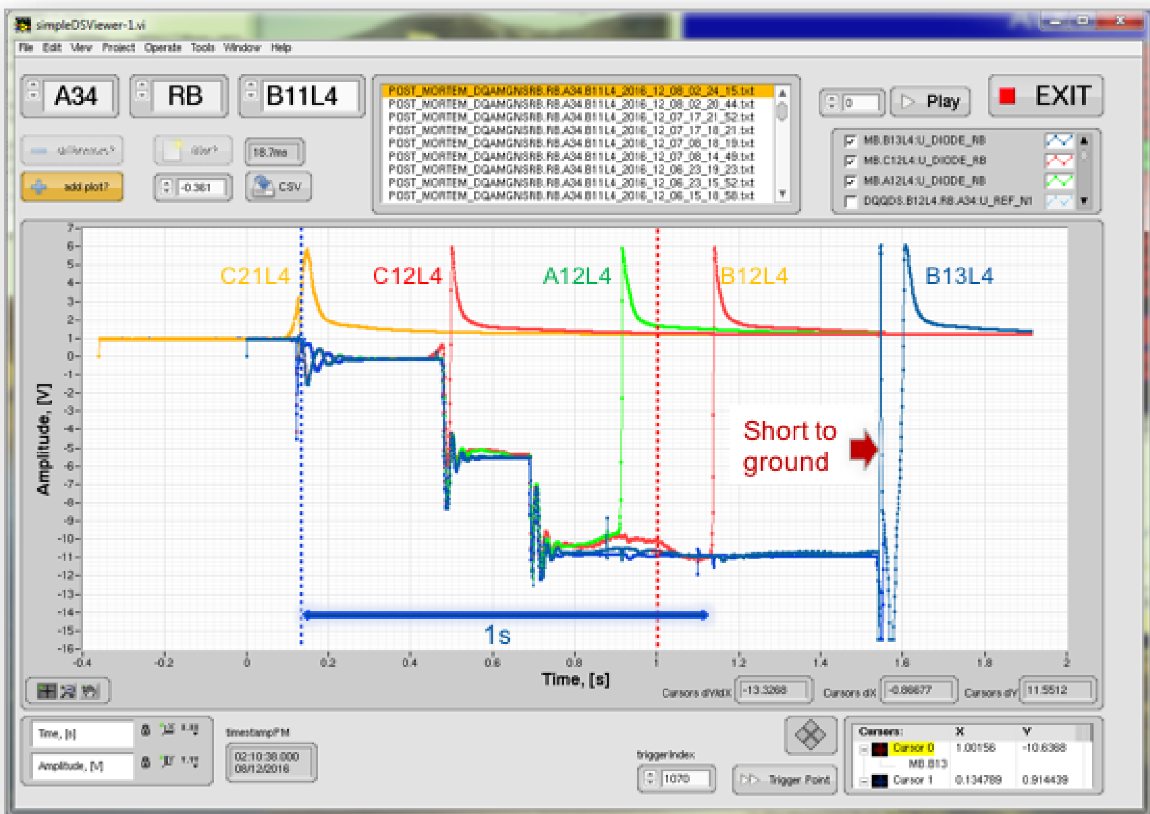


Data of Monday Dec 12th

L.Delprat

The quench campaign – RB.A34





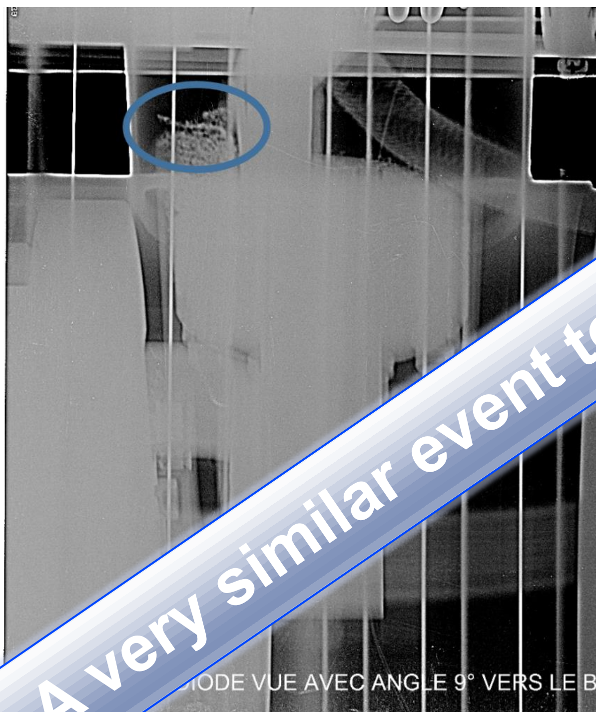
A short to ground appeared ~1.5s after the first magnet quench

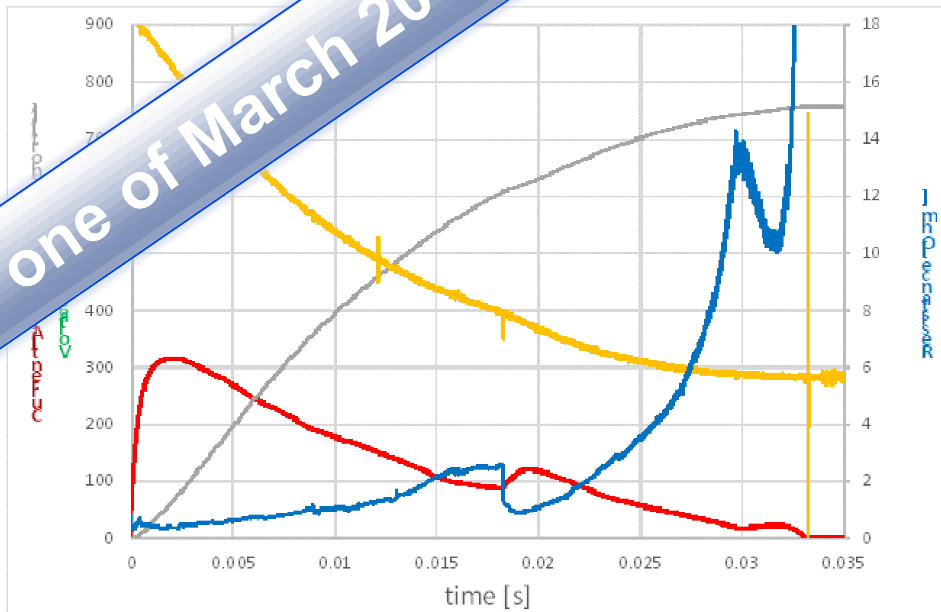
Courtesy of S.Le Naour

The quench campaign – RB.A34

- **ELQA measurements showed a permanent short-to-ground o… …ode lead of the cold diode of MB.C12L4, very likely at the half-… …nnection**
- **X-Rays show metallic debris on the half-moon of the … …d of C12L4**
- **Earth fault removed by means of a capacitive cu… …charge**

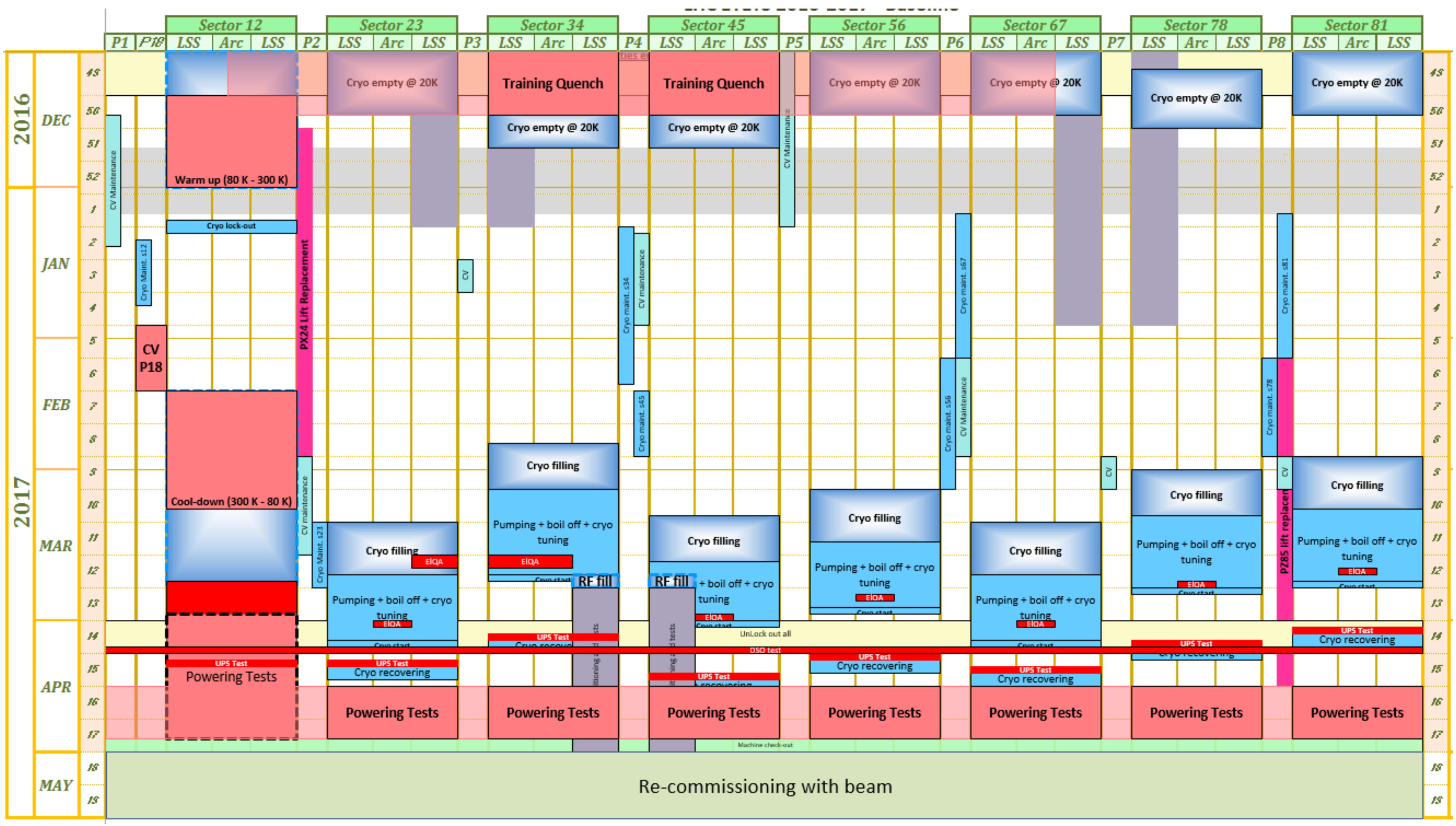
A very similar event to the one of March 2015 (magnet C19L4)





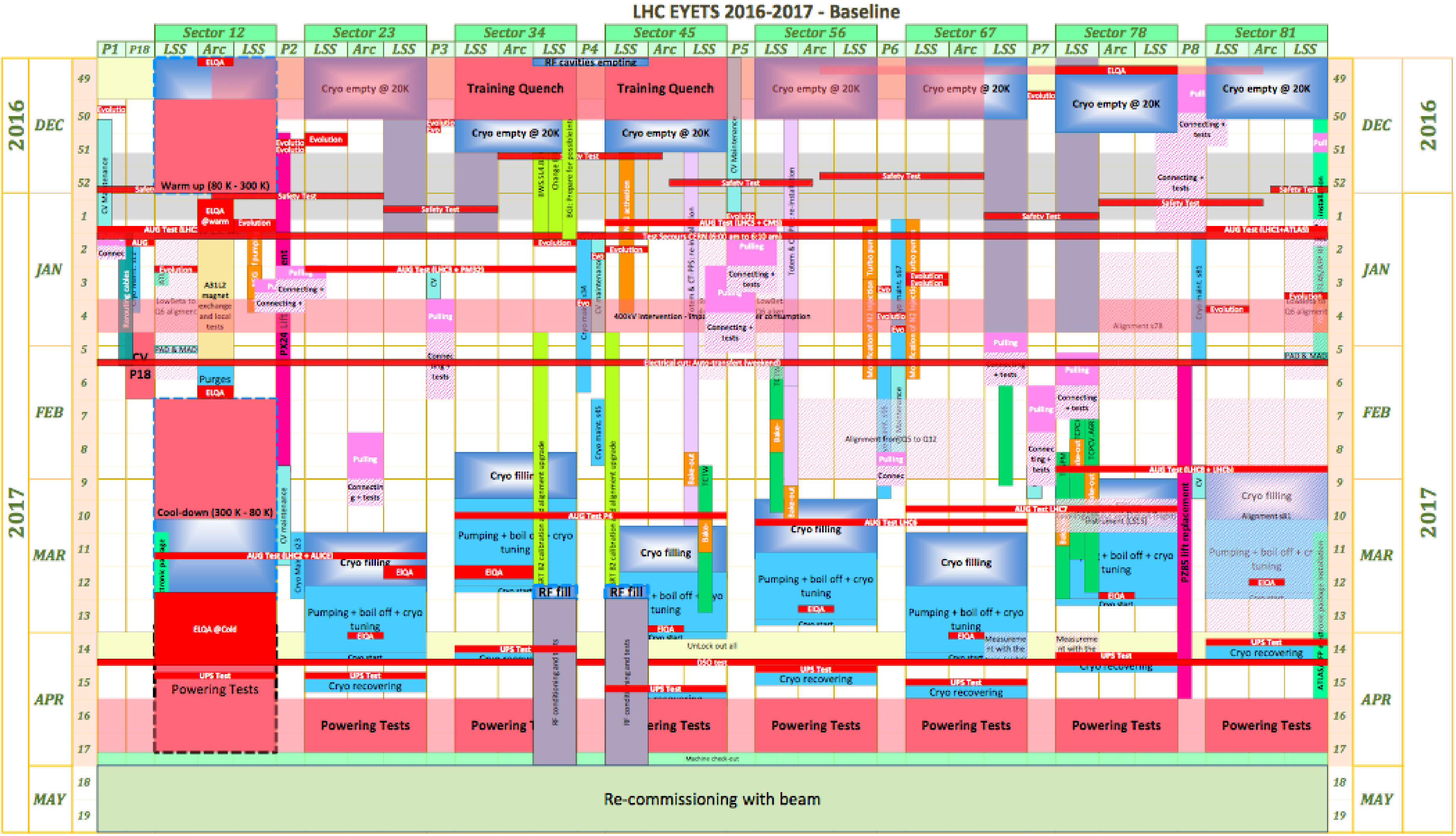
Orange: voltage over the capacitor of the Earth Fault Burner
Red: current through the short
Grey: energy dissipated in the short
Blue: calculated resistance of the short (=V_short/I_discharge)

Planning – the frame



Courtesy of M.Bernardini

Planning



Courtesy of M.Bernardini

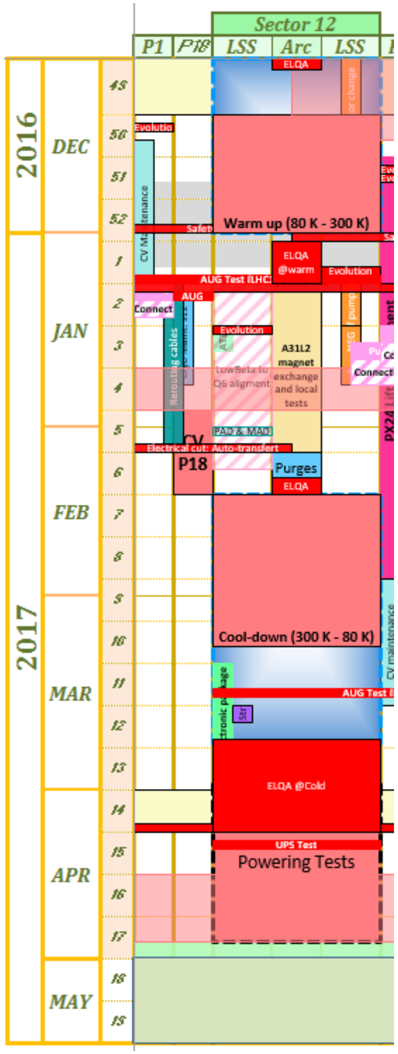
The critical path

A31L2 magnet exchange

- Sector 1-2 warm-up & related tests
- Magnet A31L2 exchange
- Sector 1-2 cool down & related tests

Vacuum openings & reconditioning

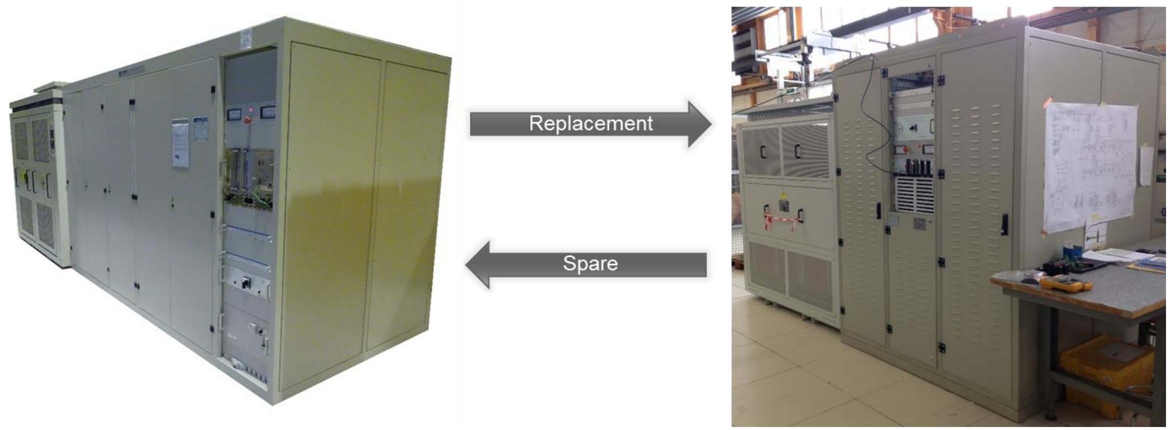
- 17 vacuum sectors will be opened (BE-BI, Collimators, Vacuum, …)



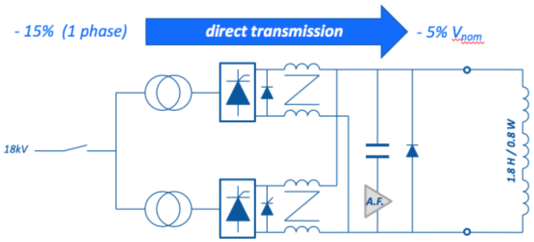
Courtesy of M.Bernardini

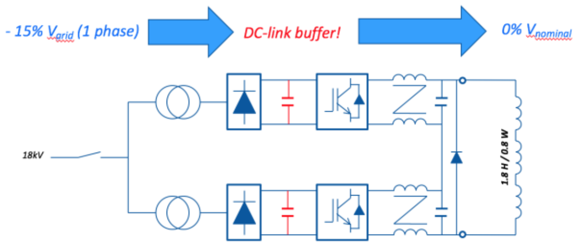
PC modifications – an example

- Exchange of **RD1 and RD34** (4 converters) to improve the response to electrical perturbation
- Deployment of **FGC-lite** to decrease the sensitivity to radiation



These modifications have a NON-negligible impact on the control system…





The EYETS

Solid baseline for 'each' YETS established last year

- Cryogenics qualification and readiness
- ElQA tests (baseline for the Main circuits + DSLC)
- Preparation of superconducting circuits
  - PC unlocking + check of cable water cooling interlocks
  - QHPS and QPS activation
- UPS tests (overhead for many users, but critical for machine safety)
- Extensive powering test campaign:
  - S12 full sector re-commissioning
  - Commissioning in the other sectors will be a repetition of 15/16 YETS campaign
  - Early debugging (3-4 days in advance) proved to be a big help!!

The powering tests (from Evian 2015)

- 60A
  - All tests 2200
- 80-120A
  - PIC2 600
  - PNO.d1 300
- 600A
  - PIC2 2000
  - PLI3.b1-SOF 200
  - PNO.d3 400
  - PNO.a3 400
- IPQs
  - PIC2 400
  - PNO.a7 80
  - All tests (excluding PNO.f4) for RQ4.L/R1
- IPDs
  - PIC2 80
  - PNO.a8 16
- ITs
  - PIC2 40
  - PNO.a9 8
- RQs
  - PIC2 100
  - PNO.b3 (4h) 16
- RBs
  - PIC2 48
  - PNO.b2 (4h) 8

Almost 7000 tests!!!

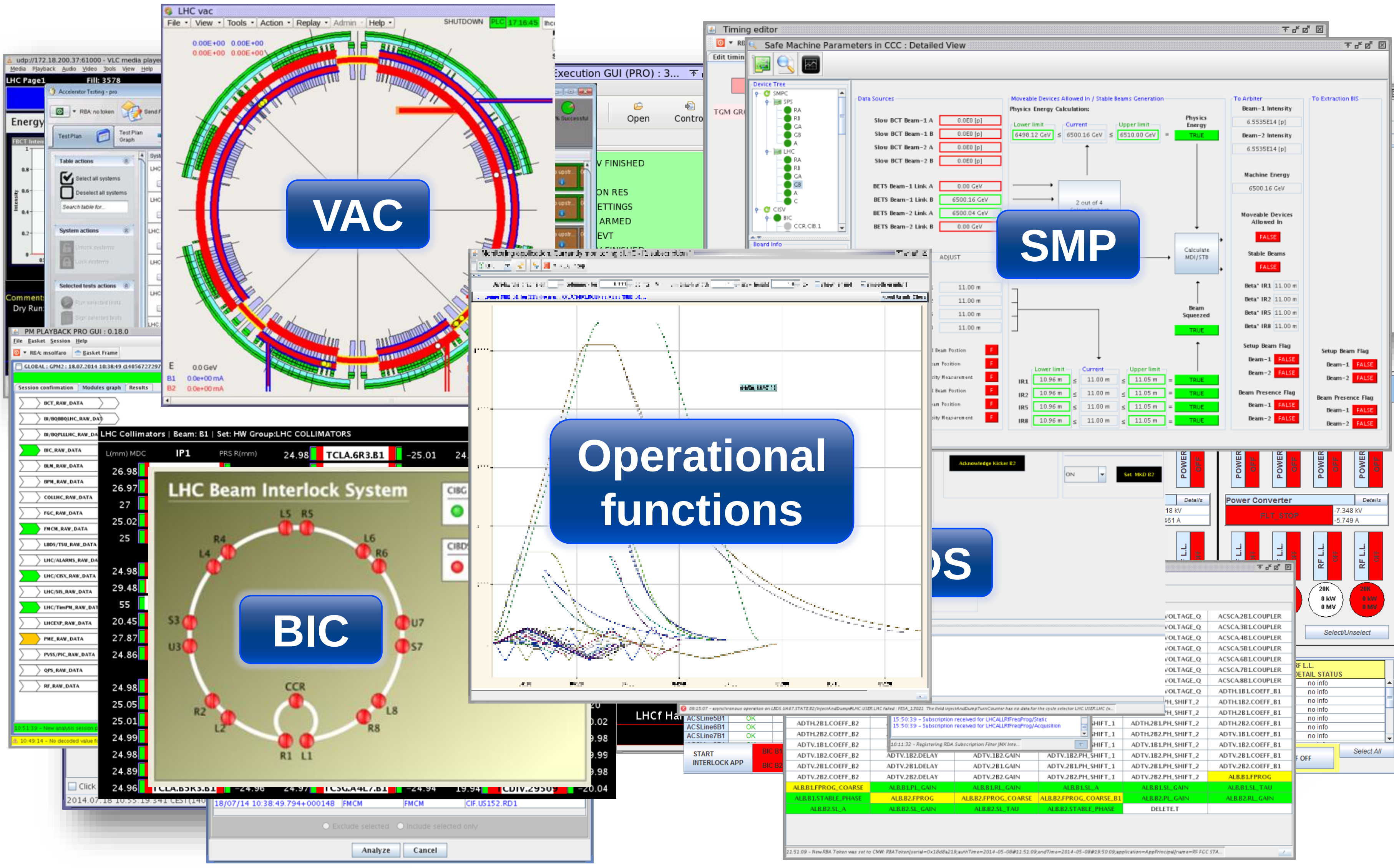
8592 test steps to be performed on the superconducting circuits

The challenges/worries

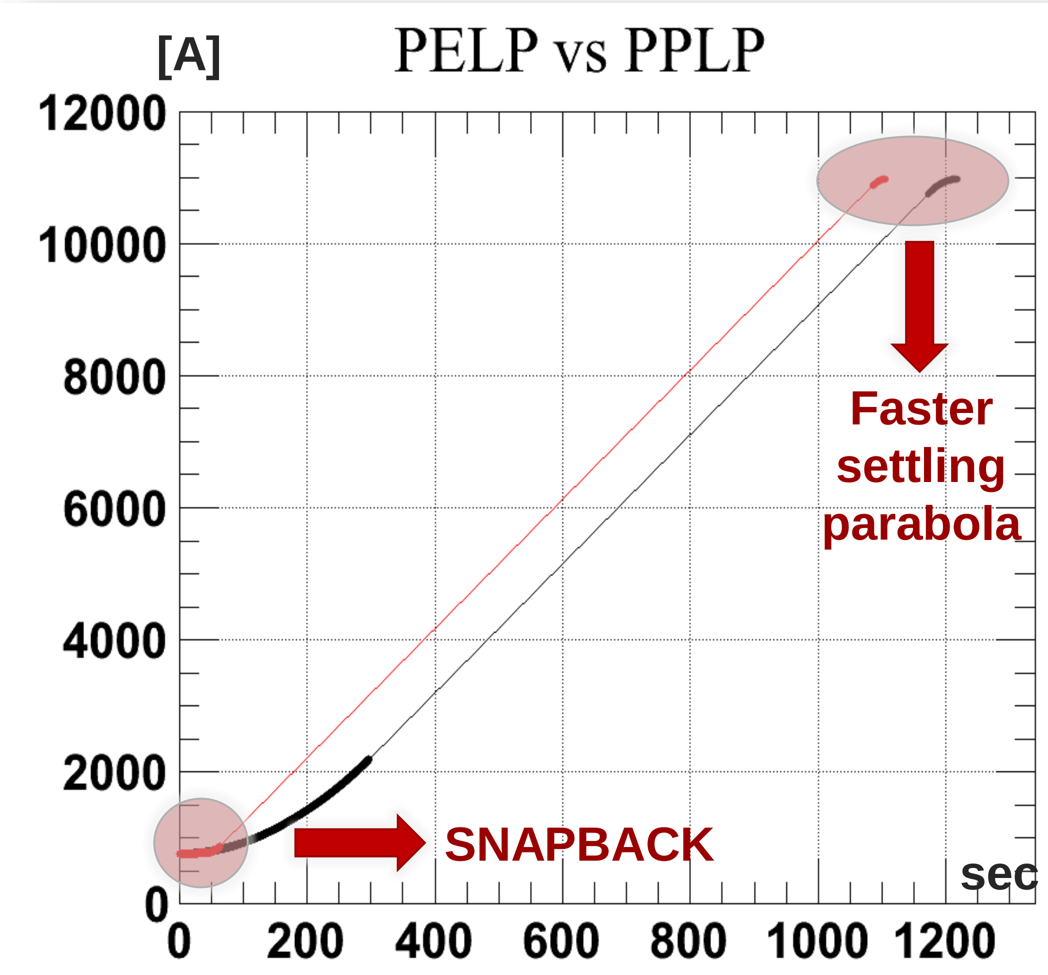
- 2015 powering tests experience:
  - A minimum of 3 weeks is MANDATORY (without overlap with machine check-out)
  - The last sector was commissioned in 4 weeks
- Powering tests will be done **during the last 2 weeks of April**
- **S12:**
  - 3 weeks (plus 1 in co-operation with ElQA) have been allocated
  - Re-commissioning = more than 2000 tests (+ possible re-training)
- **Other sectors:**
  - 2 weeks have been allocated
  - All sectors to be commissioned in parallel
  - ~6500 tests to be performed and analysed

No access during the powering tests!!!

Machine check-out – the usual



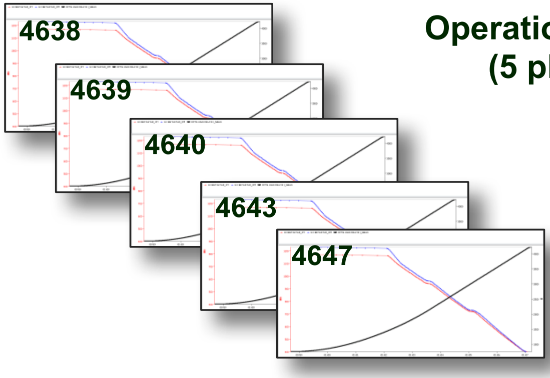
Operation 2016 – PPLP ramp (vs PELP)



- The PPLP ramp is **~10% shorter** than the PELP ramp (1100 sec vs 1210 sec)
- ~350 ramps in 2016 => it would result in **about 10 hours/year gain**
- The PPLP ramp has **still to be tested** with beam
- The proposal for 2017 is to **start with the PPLP ramp** (easy roll-back)

Operation 2016 – CRS

Combined Ramp&Squeeze with beam



Operational experience (5 physics fills)

2.51 TeV run

Optics	Energy (GeV)	Time (s)	Parabolic fraction
R2015a_A11mC11mA10mL10m_INJ	450	0	0.0
R2015a_A11mC11mA10mL10m_INJ	500	60	0.05
R2015a_A11mC11mA10mL10m_INJ	600	120	0.05
R2015a_A11mC11mA10mL10m_INJ	1000	200	0.08
R2015a_A900C900A10m_0.00950L900_0.00934	1200	290	0.1
R2015a_A700C700A10m_0.00950L800_0.00919	1300	380	0.1
R2015a_A400C400A10m_0.00950L700_0.00906	2450	500	0.1
R2015a_A400C400A10m_0.00950L700_0.00906	2510	530	0.1

Reasonable β* values:

- **3 m:** historical value where corrections started to be needed
- **1.2 m:** more aggressive scenario

Potential gain:

- β* = 3 m (352 sec/fill) **~19 hours/year**
- β* = 1.2 m (609 sec) **~33 hours/year**

LHC performance workshop - Chamonix 2016 – M.Solfaroli 19

The betatron squeeze was performed ~300 times in 2016, resulting in an overall gain of ~30 hours!!

Operation 2016 – CRS

Can we push it further??

YES

- From a mere setting point of view there is no limitations
- Optics measurements/corrections are not an issue anymore
- The proposal is to:
  - Keep a conservative approach while pushing further CRS
  - Maintain a good compromise between time gain and settings flexibility
  - Reasonable choices seem to be:
    - **1.2 m** (gain of 257 sec)
    - **1 m** (gain of 306 sec)
    - **80 cm** (gain of 405 sec)

Time gain calculated from the present optics configuration

MD to investigate very aggressive scenarios (up to 40 cm)

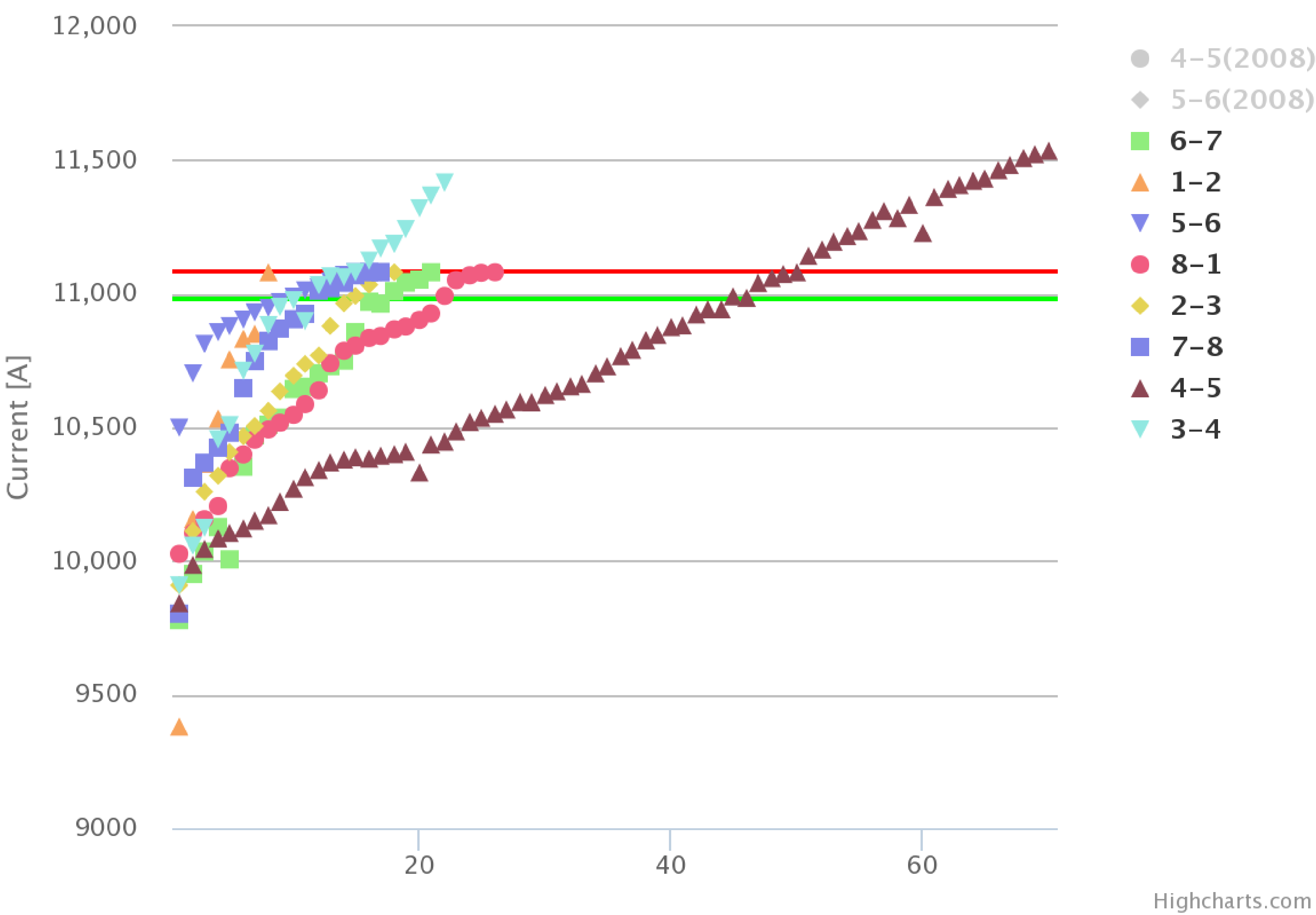
Conclusions

- The training campaign was extremely useful:
  - It showed a long way to 7 TeV:
    - Magnets re-quenching
    - Current steps seem to decrease at high(er) current
    - Quench on magnets from other manufacturers
  - It looks like we have established a method to remove faults in RBs (this might appear after quenches in the future)…still tests have to be done!
- The recovery from the EYETS will be challenging (many activities carried out)
- Some ideas are being considered to improve LHC operational efficiency in 2017

SPARE SLIDES

Circuit	I [A]	E [TeV]	Magnet	Previous quenches
RB.A34	11123	6.57	3401 (C14R3)	-
	11162	6.60	3155 (A17R3)	10124 A (2015)
	11186	6.61	3400 (C27L4)	-
	11241	6.64	2070 (B27L4)	-
	11319	6.69	3151 (A20L4)	10776 A (2015)
	11367	6.72	3089 (C20L4)	-
	11415	6.74	3399 (C21L4) 1127 (C12L4)	-

Circuit	I [A]	Eq. E[TeV]	Magnet	Previous quenches
RB.A45	11142	6.58	3196 (B31L5)	-
	11165	6.60	3180 (B27L5)	9789 A (2008), 10383 A (2015)
	11195	6.61	3202 (B8L5)	10635 A (2015)
	11216	6.63	3231 (C19L5)	-
	11234	6.64	3391 (A15L5)	9985 A (2015)
	11277	6.66	2132 (A14R4)	-
	11309	6.68	2162 (C20L5) 3190 (B21L5) 2135 (B24L5)	- 10408 A (2015) -
	11283	6.67	2159 (B23L5)	-
	11333	6.7	3191 (A27R4)	10274 A (2008)
	11227	6.63	3191 (A27R4)	10274 A (2008), 11333 (2016)
	11362	6.71	2156 (A13L5)	-
	11392	6.73	3238 (A34L5) 3213 (A33R4)	- 10314 A (2015)
	11406	6.74	2143 (A16L5)	-
	11423	6.75	3195 (A15R4)	-
	11431	6.75	3228 (B13R4)	-
	11462	6.77	3233 (C26R4)	10520 A (2015)
	11481	6.78	3217 (A26L5)	10395 A (2015)
	11508	6.80	3197 (A30L5)	9985 (2015)
	11522	6.81	3185 (A16R4)	-
	11535	6.82	3236 (A13R4) 2167 (B9R4)	- -



12,000
11,500
11,000
10,500
10,000
9500
9000
Current [A]
20
40
60
4-5(2008)
5-6(2008)
6-7
1-2
5-6
8-1
2-3
7-8
4-5
3-4
Highcharts.com