MIRKO POJER

WHICH SYSTEMS (EXCEPT MAIN CIRCUITS) SHOULD BE COMMISSIONED/TESTED FOR 7 TEV OPERATION BEFORE THE LONG SHUTDOWN?

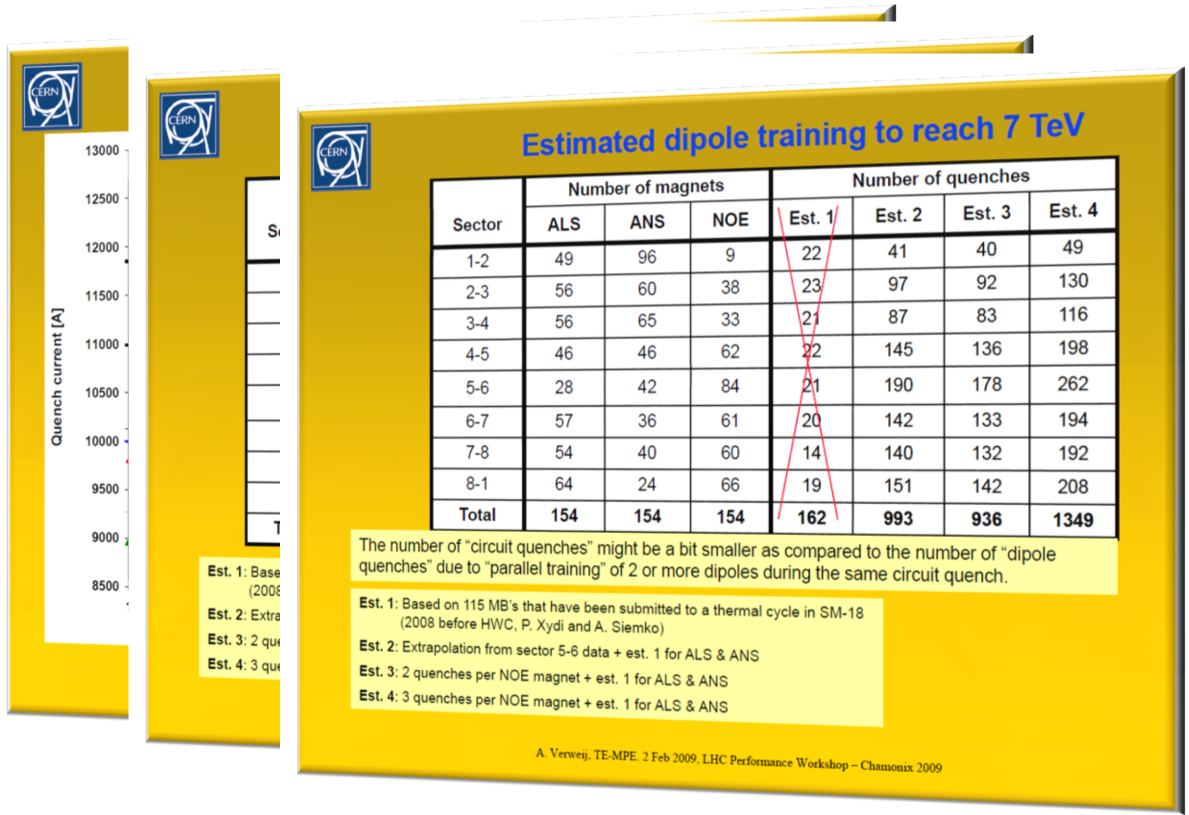
Session 02 Shutdown 2012 (Part 1) – Chamonix 2011

Acknowledgements: N. Catalan Lasheras, R. Schmidt, M. Solfaroli, W. Venturini,
S. Claudet, Y. Thurel, R. Denz, G-J. Coelingh, K. Dahlerup-Petersen,
B. Dehning, M. Sapinski, R. Assmann, B. Goddard, J. Uythoven,…

OUTLINE

- Status of machine commissioning in 2008
- Status of machine commissioning in 2010
  - Non-conformities and strategy for re-test
    - Training
    - Splices, shorts and open circuits
    - QPS, cryogenics and other
  - Other specific tests
- What else can we test with beam?
- An attempt of time estimate
- Conclusions

- Even after the 2012(13) consolidation, the 7 TeV will not be close at hand



Estimated dipole training to reach 7 TeV

Sector	Number of magnets			Number of quenches			
	ALS	ANS	NOE	Est. 1	Est. 2	Est. 3	Est. 4
1-2	49	96	9	22	41	40	49
2-3	56	60	38	23	97	92	130
3-4	56	65	33	21	87	83	116
4-5	46	46	62	22	145	136	198
5-6	28	42	84	21	190	178	262
6-7	57	36	61	20	142	133	194
7-8	54	40	60	14	140	132	192
8-1	64	24	66	19	151	142	208
Total	154	154	154	162	993	936	1349

The number of "circuit quenches" might be a bit smaller as compared to the number of "dipole quenches" due to "parallel training" of 2 or more dipoles during the same circuit quench.

Est. 1: Based on 115 MB's that have been submitted to a thermal cycle in SM-18 (2008 before HWC, P. Xydi and A. Siemko)
Est. 2: Extrapolation from sector 5-6 data + est. 1 for ALS & ANS
Est. 3: 2 quenches per NOE magnet + est. 1 for ALS & ANS
Est. 4: 3 quenches per NOE magnet + est. 1 for ALS & ANS

A. Verweij, TE-MPE, 2 Feb 2009, LHC Performance Workshop – Chamonix 2009

From A. Verweij
Chamonix '09

- We will have certainly to critically review the values of current needed for the correctors for the operation at 7 TeV, after this year run:
  - some correctors were already used last year to much lower current values than those to which they were commissioned
  - we don't really know what is needed and we'll only know during operation, i.e. at low β^*

Status of commissioning in 2008 (sector 34 excluded)

- At the end of 2008, all circuits were commissioned to 7 TeV equivalent current, except:
  - Main circuits were commissioned to 5.5 TeV
    - RB.A78 was stopped to less than 5 TeV due to training below 9.3 kA
    - RB.A56 was commissioned to 6.6 TeV
    - RQD/F.A56 were commissioned to 7 TeV
  - RQX.L5, commissioned to less than 5 TeV, due to change in nominal current
  - IPDs
    - I_nom was changed for RD3.R4 and RD4.R4 after commissioning, which then resulted in less than 7 TeV (6.6 and 6.3 TeV, respectively)
    - **RD2.R8 quenched 4 times (5816, 5788, 5856 and 5854 A) at less than 6.8 TeV**
  - 80-120 A not commissioned for 7 TeV
    - RCBYHS4.L5B1 had a hardware problem and was limited to half the energy
    - RCBYHS5.R8B1 had a ramp-down quench after attaining the nominal
    - RCBYH4.R8B1 had a ramp-down quench after attaining the nomina[l]
  - (IPQs all fine for 7 TeV)

Weak magnets

We were almost there

Training was the normality, not only for RBs

STATUS OF COMMISSIONING IN 2008 (SECTOR 34 EXCLUDED)

- At the end of 2008, all circuits were commissioned to 7 TeV equivalent current, except:
  - 600 A were “jeopardized”, due to the reduction of I_nom and to the change of specs.

Sector 12		Sector 23		Sector 45		Sector 56		Sector 67		Sector 78		Sector 81	
RCS.A12B2	5	RCO.A23B1	<5	RQS.A45B1	<5	RCO.A56B1	<5	RQTD.A67B1	5	RCD.A78B1	5	RCO.A81B1	-
RQS.L2B1	<5	RCO.A23B2	<5	RQTF.A45B2	7	RCO.A56B2	<5	RQTD.A67B2	5	RCD.A78B2	5	RCO.A81B2	-
RQT13.R1B1	7	RQS.R2B2	7	RSS.A45B1	<5	RCS.A56B1	5	RQTF.A67B1	5	RCO.A78B2	-	RQS.R8B2	7
RQTD.A12B1	5	RQT12.L3B1	5	RU.R4	<7	RCS.A56B2	5	RQTF.A67B2	5	RCS.A78B1	5		
RQTD.A12B2	5	RQT12.L3B2	5	RCBXV2.L5	<5	ROD.A56B1	<5	RQTL9.L7B1	5	RCS.A78B2	5		
RQTF.A12B1	5	RQT13.L3B1	5	RCBXV3.L5	<5	ROD.A56B2	<5	RQTL9.L7B2	5	RQS.L8B1	7		
RQTF.A12B2	5	RQT13.L3B2	5	RQT13.L5B1	<5	ROF.A56B1	<5	RSD1.A67B1	5	RQTD.A78B1	5		
RSD1.A12B1	5	RQTD.A23B1	5	RQTL11.L5B1	<5	ROF.A56B2	<5	RSD1.A67B2	5	RQTD.A78B2	5		
RSD1.A12B2	5	RQTD.A23B2	5	RQTL11.L5B2	<5	RQT12.L6B1	<5	RSD2.A67B1	5	RQTF.A78B1	5		
RSD2.A12B1	5	RQTF.A23B1	5	RQTL11.R4B1	<5	RQT12.L6B2	<5	RSD2.A67B2	5	RQTF.A78B2	5		
RSD2.A12B2	5	RQTF.A23B2	5	RQTL11.R4B2	<5	RQT12.R5B1	<5	RSF1.A67B1	5	RQTL11.R7B1	5		
RSF1.A12B1	5	RQTL11.L3B1	5			RQT13.L6B1	<5	RSF1.A67B2	5	RQTL11.R7B2	5		
RSF1.A12B2	5	RQTL11.L3B2	5			RQT13.L6B2	<5	RSF2.A67B1	5	RQTL7.R7B1	5		
RSF2.A12B1	5	RQTL8.L3B1	5			RQT13.R5B1	<5	RSF2.A67B2	5	RQTL7.R7B2	5		
RSF2.A12B2	5	RQTL8.L3B2	5			RQT13.R5B2	<5	RSS.A67B1	5	RQTL8.R7B2	<5		
RSS.A12B1	5	RSD1.A23B1	5			RQTL11.L6B1	5	RSS.A67B2	5	RQTL9.R7B1	5		
RSS.A12B2	5	RSD1.A23B2	5			RQTL11.L6B2	5	RCO.A67B1	<5	RQTL9.R7B2	5		
		RSD2.A23B1	5			RQTL11.R5B1	5	RCO.A67B2	<5	RSD1.A78B1	5		
		RSD2.A23B2	5			RQTL11.R5B2	5	RQT12.L7B1	5	RSD1.A78B2	5		
		RSF1.A23B1	5			RSD1.A56B1	5	RQT12.L7B2	5	RSD2.A78B1	5		
		RSF1.A23B2	5			RSD1.A56B2	5	RQT12.R6B1	5	RSD2.A78B2	5		
		RSF2.A23B1	5			RSD2.A56B1	5	RQT12.R6B2	5	RSF1.A78B1	5		
		RSF2.A23B2	5			RSD2.A56B2	5	RQT13.L7B1	5	RSF1.A78B2	5		
		RSS.A23B1	5										
		RSS.A23B2	5										

Non-conformities
- DC contactor
- QPS
- Splice

Complete test up to 7 TeV of the missing 600 A circuits

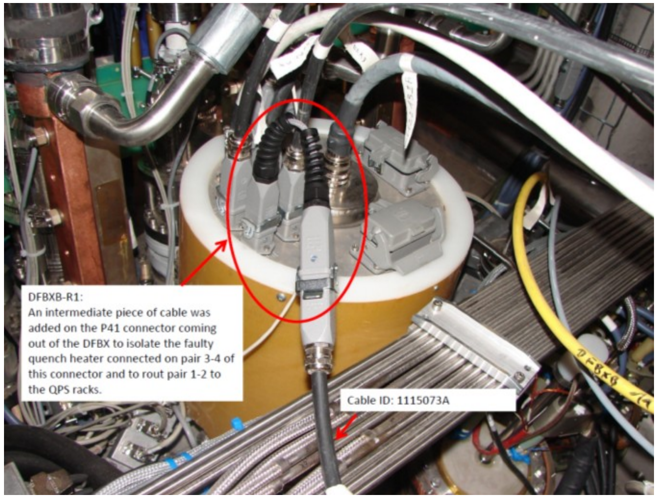
+

RD3.R4, RD3.R4, RD2.R8 and RQX.L5

Status of Re-commissioning in 2010 (sector 34 included)

- At the end of 2010, all circuits were commissioned to 3.5 TeV equivalent current, with the following non-conformities on the high current circuits:

  - RB.A78 - NC 1060444 - the circuit was ElQA tested up to 1.6 kV instead of 1.9 kV due to weak insulation on magnet B30.R7 – 4 TeV limited
  - RQ4.L8 – NC 1020189 - Quench heater YT313 of SSS607 (Q4L8) was found too resistive, and badly insulated during the MIC-C campaign 2009 (37 Ohm instead of 11 Ohm). Known problem, NC was already opened to report this problem (cf. NC 832580).
  - RQX.R1 - NC 1017174 - QH YT1121 of magnet Q1 is showing a weak electrical insulation to coil and/or ground (Breakdown at 1100 Volts) – 3.5 TeV limited



See N. Catalan Lasheras, in session 4

2010 RE-COMMISSIONING: NONCONFORMITIES - 2

- Training (2-quenches rule was introduced to shorten commissioning)

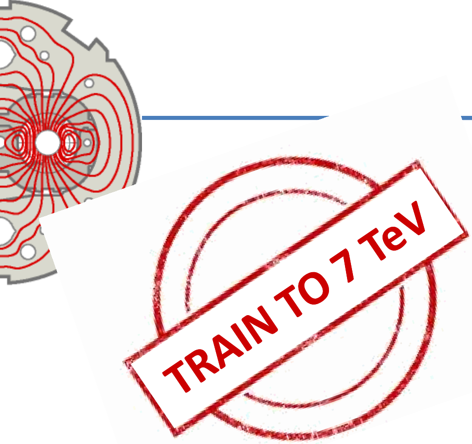
600 A

- RCD.A45B1 - NC 1035252 - quenched twice (at 300 and 391 A); limited to 400 A
- RCD.A56B2 - NC 1026728 - quenched twice (at 479 and 496 A); limited to 450 A
- RCD.A81B1 - NC 1043522 - quenched twice (at 351 and 484 A); limited to 450 A
- RQTL11.L2B2 - NC 1020622 - quenched (544.85 A); limited to 500 A
- ✗ RQTL11.R5B1 - NC 1027448 - quenched twice (at 501 and 492 A); limited to 450 A
- ✗ RQTL11.R5B2 - NC 1027413 - quenched twice (at 550 and 533 A); limited
- ✗ RQTL11.L6B1 - NC 1026809 - long training (353, 292, 340, 350,
- ✗ RQTL11.L6B2 - NC 1026747 - long training (267, 348, 384, 354,
- RQTL8.L7B1 - NC 1046464 - quenched twice (at 240 and 257 A); l
- RQTL9.R3B2 - NC 1046992 - quenched at 359, 399.9 and 396.1 A;
- ✗ RQT13.L5B1 - NC 1060679 - this magnet shows a strange behavior; ... 400 A

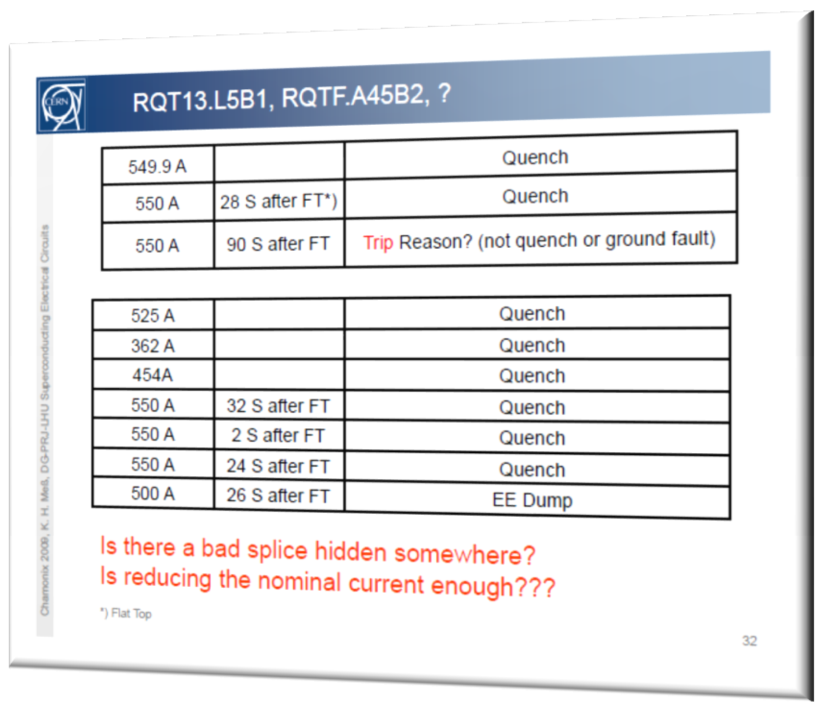
80-120 A

- RCBCV5.R5B2 - NC 1029792 - quenched twice (at 69.4 and 76.9 A); li ... to 72A
- RCBCH7.R3B1 - NC 1046994 - quenched twice (at 98 and 95 A); limited to 80 A
- ✗ RCBYH4.R8B1 - NC 1051795 - quenched at 55.6 A; limited to 50 A
- RCBYV5.L4B2 - NC 1049055 – 3 quenches w.o. training (63.3, 65.7 a
- RCSSX3.L1 - NC 1053719 - the circuit trips when it reaches 62.9 proven 4 times (circ
- ✗ RCBYHS5.R8B1 - NC 1063839 - circuit quenches when coming dov zero; the control of the current also shows high instability (see EDMS 10.
- ✗ RCBYHS4.L5B1 - NC 1053709 - circuit can not handle di/dt : weak m ... 2008 (see MP3 meeting 4/11); tested with reduced I_PN ... A and OK so new I_PNO defined at 50 A

✗ **Not powered to 7 TeV in 2008**



- Power the circuits up to 7 TeV equivalent current
- In case of quench, power again; repeat up to *n* quenches (number to be defined with MP3 and experts)
- If the circuit cannot reach 7 TeV, then diagnostics have to be carried out to identify the problem; in case of a serious problem, a decision must be taken
  - lowering the nominal current
    - in agreement with the reviewed machine parameters
    - if there is the possibility of a new optics
  - performin
  - we could ... ng
    circuit wit ... 8



RQT13.L5B1, RQTF.A45B2, ?

549.9 A		Quench
550 A	28 S after FT*)	Quench
550 A	90 S after FT	Trip Reason? (not quench or ground fault)

525 A		Quench
362 A		Quench
454A		Quench
550 A	32 S after FT	Quench
550 A	2 S after FT	Quench
550 A	24 S after FT	Quench
500 A	26 S after FT	EE Dump

Is there a bad splice hidden somewhere?
Is reducing the nominal current enough???

*) Flat Top

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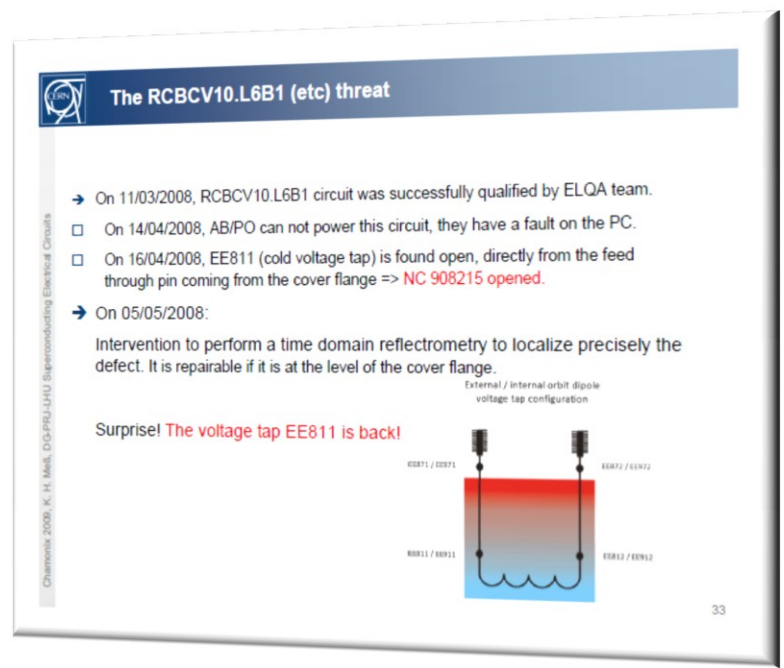
From K.H. Meß Chamonix '09

Splices, shorts and open circuits (already known and well documented)

- RCBCHS5.L8B1 - NC 831927 - superconducting circuit shows high resistance (around 22 mΩ) on the cold side at 4.5 K; replaced by warm magnet installed in the vicinity
- RCO.A81B2 - NC 955048 - CL1, CL2 and coil resistance too high
- RCOSX3.L1 - NC 948545 - circuit found open below the cold v_taps of the 120 A current leads; this circuit is isolated from ground and from the other circuits

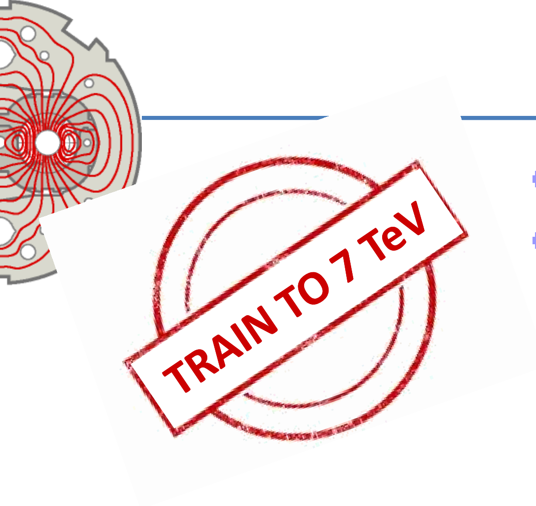
From K.H. Meß Chamonix '09



Splices, shorts and open circuits (investigations to be carried on)

- RCO.A78B2 - NC 1029807 - the circuit "quenched" always (three times) while ramping up the current from 55 A; possible splice problem
- RQT12.R7B1 - NC 1027412 - high splice resistance after PNO test
- RQTL10.R7B1 - NC 1026729 - magnet resistance slightly outside limits (202nΩ per splice) and increasing from last year
- RCBCH6.L2B2 - NC 1020424 - cold part of the circuit appears too resistive (about 10 mΩ)
- RCBCV6.L2B1 - NC 1020423 - cold part of the circuit appears too resistive (about 10 mΩ)
- RCBCH7.L2B1 - NC 1084848 - slightly high resistance measured (3.04mΩ instead of 3mΩ)
  RCBCV7.L2B2 - NC 1084849 - slightly high resistance measured (3.04mΩ instead of 3mΩ)
- RCBH31.R7B1 - NC 1017094 - the Hi current lead resistance (DFLDS.31R7.2) is too high (1.14e-3 Ω) and coil seems to be too resistive

QUALITY EIQA TESTS CONTROL



STRATEGY PROPOSAL

- Power the circuits up to 7 TeV equivalent current
- In case of quench, power again; repeat up to *n* quenches (number to be defined with MP3 and experts)
- If the circuit cannot reach 7 TeV, then diagnostics have to be carried out to identify the problem; in case of a serious problem, a decision must be taken

- ElQA to perform dedicated diagnostics:
  - (narrowing) fault localization to provide extremely useful information to the people in charge of carrying out the repair
  - transfer functions on 120 A circuits to understand strange behaviors
- Specific powering cycles (i.e. with modified parameters)
- Heat deposition measurements with the help of Cryogenics

2010 RE-COMMISSIONING: NONCONFORMITIES - 5

QPS (direct and indirect)

- RCBXH3.L5 - QPS hardware problem
- RQ6.L7B1 - NC 1053720 - di/dt reduced because of trips (from 1.5 to 1.2 A/s)
- RSD/F-1/2 - NC 1053713 - frequent trips during cycles likely due to acceleration rate when approaching 400A; this has been reduced to 0.15 A/s^2 [nominal was 0.25]
- RCBX - NC 1027941 - new RCBXH/RCBXV protection to be set to limit $I_H^2 + I_V^2 < 550^2$

See also J. Steckert, in session 4

Cryogenics

- RCBXH1/V1 - NC 1046463 - ramp rate and acceleration limited to 4.5 A/s and 0.25 A/s^2
- RQSX3 - NC 1027961 - the cooling of low-beta vapor cooled corrector magnet current leads can become instable at current higher than 400 A; therefore, the lead voltage drop measurements can reach 160 mV, which triggers the QPS trip

See O. Pirotte, later in this session

Other

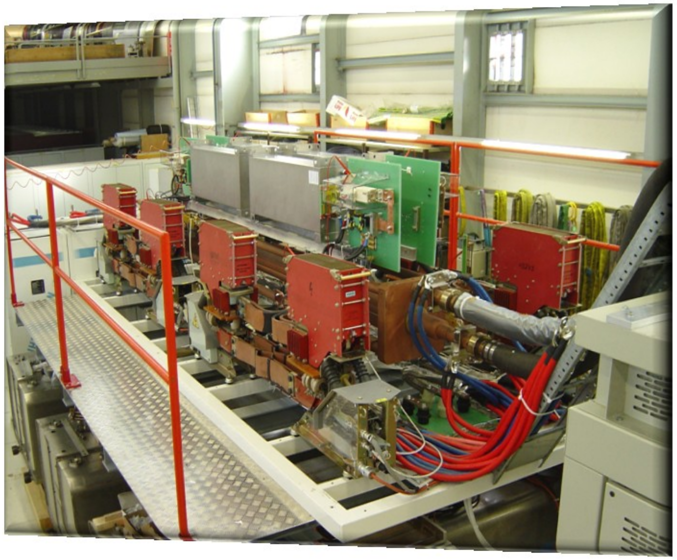
- RCBH31.R4B2 - NC 1053210 - resistance of the cold part is seen a reading from the FGC

OTHER SPECIFIC TESTS

- ElQA tests are presently executed with a “reduced” voltage on the RQD/F and the 600 A circuits: the actual value does not take into account the simultaneous powering of circuits routing through the same line → a re-test to higher voltage level is needed (i.e. 480 V instead of 240 V for RQD/F).

See N. Catalan Lasheras, in session 4

- If not done in this technical stop (see the outcome of this workshop), testing all the snubber capacitors is essential, to check whether there is some sector behaving strangely (unforeseen quenches, strange signals developed,…)

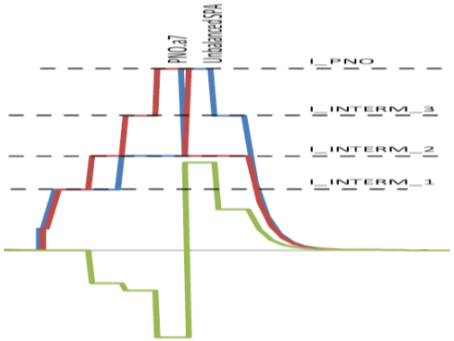


Snubber capacitors at test hall
Courtesy of Knud Dahlerup-Petersen

- The energy extraction for the main circuits will have to be modified with consequences on the n-QPS, which will have to be verified
- Dedicated powering of few 600 A circuits where we might get problems with quench detection settings if going to higher energy (e.g. trim quads, IT correctors ...)
- Test the n-QPS for IPQ configuration (installation, re-commissioning of the circuit plus specific tests) and the earth voltage measurement system for the Mains

OTHER SPECIFIC TESTS continued

- If not completed between this technical stop and those planned during this year, carry on with the validation of the splices inside the individually-powered quadrupoles (10 in DS region -6LR and 1R- plus all SAMs) and dipoles



- Test of mutual coupling between circuits in the same DFB

- Heat run with the whole machine (apart Mains) powered to 7 TeV equivalent current plus the Mains to 3.5 TeV

- Test of the operational cycle with all circuits powered to 7 TeV equivalent current (except the Mains as above), including the squeeze to nominal β^*

- Cryogenics:
  - Quench lines between QUI and helium tank in all even points
  - (quench lines at odd points and IT correctors cooling problems)

- Vacuum:
  - leak detection before ventilation of insulation vacuum *See V. Baglin, later in this session*

What else can we test with beam?

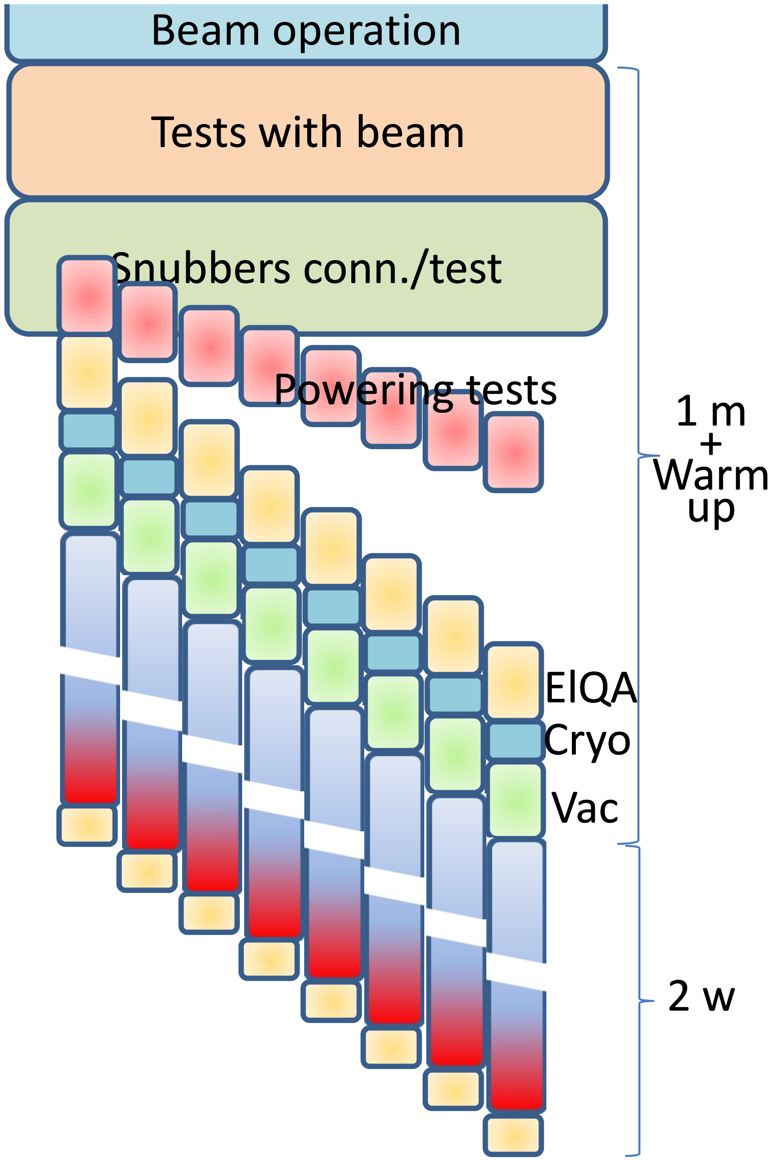
- Wire scanner/quench tests (Bernd, Mariusz)
  - proton beam at injection, 900 bunches, wire speeds 1 - 0.3 m/s - this is to break the wire and test why we had breaking at different conditions in SPS and in LHC.
  - ion beam at injection, 150 nominal bunches, wire speeds, 1-0.2 m/s - this is to break the wire with ions and see if it agrees with models.
  - quench test, 900 bunches at top energy - this is to repeat the test from last year with a quench provoked in 1-5 ms scale instead of 30 ms. It is the only way we know now to provide a data about quench level for the losses in ms timescale.
- BLMs
  - the change of threshold for high energy may result in the noise
- CODs (Yves)
  - Can we try and compensate the loss of one with real time trims on the others?

What else can we test with beam?

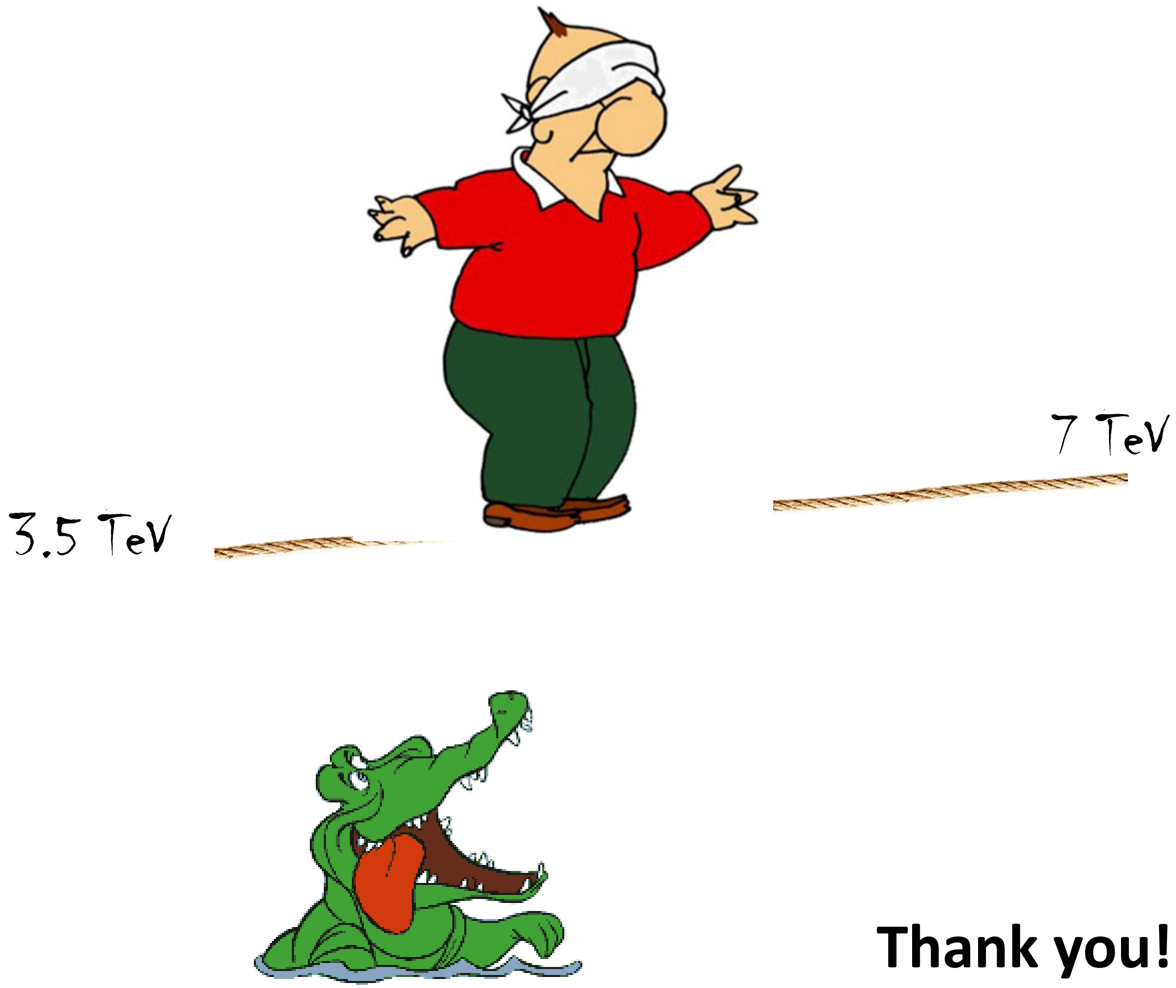
- Collimators (Ralph)
  - Stability and impedance with closed collimators (nominal gaps).
  - Combined betatron and momentum cleaning in IR3.
- Injection and dump (Brennan, Jan)
  - injecting full intensity trains of 288b
  - squeezing to 0.5 m beta* and checking the protection hierarchy there
  - quench tests with beam at different loss time scales
  - deliberate asynchronous dump tests with high intensity and also with 25ns
    - asynch dump of all MKDs synchronous, but asynchronous to the abort gap
    - a real pre-trigger with 1 or 2 MKDs being asynchronous to the other MKDs and also synchronous to the abort gap
  - full power cut with beam
  - with small intensity beam force a power abort of the dipoles in one octant but not dump the beam and see where it ends up (could be part of a study to install another big TCDQ like absorber in the machine)

AN ATTEMPT OF TIME ESTIMATE

- min 1 week of dedicated tests with beam
- 1 week for snubbers connection and validation, plus energy extraction reconfiguration and HV test
- 1 week for Powering tests:
  - Define priority (for example in sector 78 a magnet must be replaced)
  - Start with low radiation points for snubber installation
- Massive ElQA campaign (about 4 days per sector+2 days at warm):
  - Qualification to nominal voltage
  - Test all non-conform circuits
- Cryogenics verifications (2 days)
- Vacuum leak tests (4 days per sector)



- Before going into the long shutdown, all limits will have to be highlighted
- The main points of the proposed strategy:
  - Try and push everything (Mains excluded) to 7 TeV before the shutdown
  - Heat runs and nominal powering cycles will be performed with all circuits (Mains excluded) up to 7 TeV currents
  - Many special tests will be performed to exclude or to cope with anomalies
  - A massive ElQA campaign will be carried out
- RD2.R8 is most probably the (second) most important problem in the machine:
  - What if we cannot reach 7 TeV?
  - If we reach 7 TeV, this magnet will be a special observed during the heat run
- Special setups with beam can be figured out, which can even be (moderately) destructive
- Many other systems will have to be tested, but most of them (warm magnets, LBDS, …) can be tested at any time.



Thank you!