



**High
Luminosity
LHC**

LHC NCs that might have an impact on HL-LHC operation/performance

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Thanks to R. De Maria, A. Verweij, G. Willering



Circuit	Comments
60 A	2 condemned circuits
80-120 A	4 circuits with reduced I_{PNO}
600 A	1 condemned circuit 6 circuits with less magnets 27 RQTL, 2 RU, and 15 RCD circuits with reduced I_{PNO}
IPQ	2 circuits with 4-lead powering
Triplets	4 condemned correctors 1 corrector with reduced IPNO Some constraints for powering of RCBXH/V-RCSX3-RCTX3
RQD/F	-
RB	-

This is certainly an improvement for operation!



Some of the NCs date back to 2009, while others have been found out in LS1.
Optics configurations have been adapted (or can be adapted) to these NCs.

MP3 NCs: 60-80-120 A circuits

Colour code:

- Black -> Run I NCs
- Orange -> from LS1
- RCBH31.R7.B1, RCBV26.R5.B1: correctors condemned. Not too serious, but orbit bump in the region should be monitored as there are strong MOs close by and feed down effects might be relevant (already confirmed to be the case in 2012).
- RCO.A78.B2, RCO.A81.B2: in each circuit 2 out of 77 magnets are bypassed. This has a marginal impact on performance as
 - b4 component in MBs is smaller-than-anticipated
 - RCO strength can be adjusted to compensate for missing magnets.

MP3 NCs: 60-80-120 A circuits

Circuit	Comments
RCBYH4.R8B1	I_{PNO} limited at 50 A if used at 0.67 A/s. $I_{\text{DELTA}}=0$ A.
RCBYHS4.L5B1	I_{PNO} limited at 50 A if used at 0.67 A/s. $I_{\text{DELTA}}=0$ A.
RCBYHS5.R8B1	I_{PNO} limited at 40 A with 0.3 A/s. $I_{\text{DELTA}}=0$ A. (was 20 A with 0.6 A/s during Run-1)
RCBYV5.L4B2	I_{PNO} limited at 50 A if used at 0.67 A/s. $I_{\text{DELTA}}=0$ A.

A. Verweij, LMC 13/5/2015

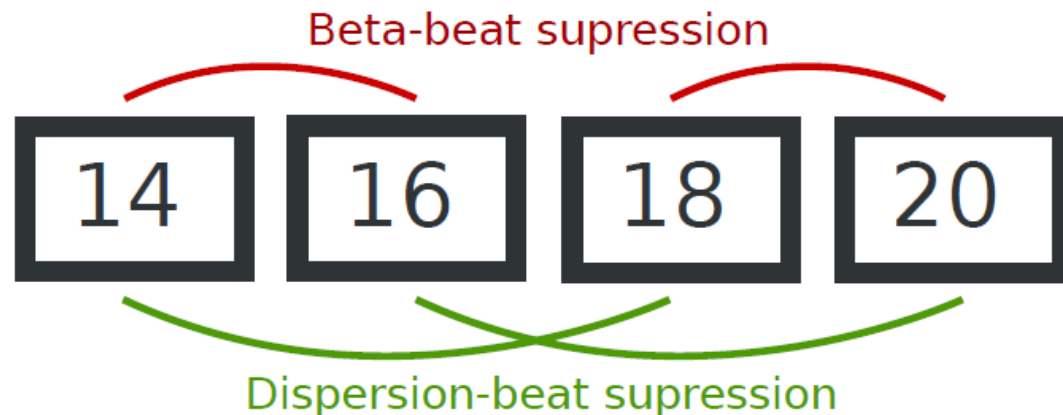
- **RCBYH4.R8B1, RCBYHS5.R8B1:** impact on crossing angle for LHCb. The strength is limiting the crossing angle at top energy with injection optics -> reduced angle to 230 μrad . Increased to nominal value (250 μrad) during squeeze. No side issues.
- **RCBYHS4.L5B1, RCBYV5.L4B2:** no impact on performance.

MP3 NCs: 600 A circuits - I

- Weak MQTLIs (already known from the MEB times):
 - No limitation for LHC operation even at 7 TeV.
- New weak MQTLIs (**MQTL9.L7.B1**)
 - Current limited to 300 A: No limitation for LHC operation even at 7 TeV.
- Short to ground of **MQT.18.L1.B1** in circuit RQTF.A81.B1
 - Bypassed 4 MQT magnets in SSSs 14.L1, 16.L1, 18.L1, and 20.L1.
 - 2 % peak beta-beating is generated in Arc 81, only.

Check strength
evolution with time:
relevant for HL-LHC

Courtesy A. Langner and
R. Tomas



MP3 NCs: 600 A circuits - II

- **ROD.A34B1, ROF.A34B2:** in each circuit 2 out of 13 magnets missing (in Q28R3 and Q32R3). Minimum loss of Landau octupole strength. **The circuit will be recovered in LS2.**
- **RCS.A34B2:** 3 out of 154 magnets bypassed. Not a problem for overall correction of b3 in sector 3-4.
- **RSS.A34B1:** Circuit condemned. Not used during Run I and considered not essential for Run II.
- **ROD.A56B1:** limited to 450 A (all others brought to 590 A). Overall strength available is more than nominal.
- **RCD.%:** I_PNO reduced to 450 A (except RCD.A78B1/2). More than enough for compensating b5 (apart from sector 7-8).
- **All RSD/F:** Acceleration reduced (0.25 to 0.15 A/s²).
- **RU.R4:** ramp rate reduced to 0.08 A/s (acc.=0.0025 A/s²).

MP3 NCs: 600 A circuits - III

- **RCS.A78B2**: very recent NC. For LHC an alternative solution has been proposed (distribute the strength of the circuit to the other RCSs). Impact on HL-LHC optics performance should be assessed.

MP3 NCs: IPQs

Circuit	Specific magnet	Description	NC	Action	Resolved
RQ4.L1	Q4.L1	Quench in bus of DFBLA with coupling to RD2.L1	-	Analysed and understood	Yes
RQ4.L2	Q4.L2	Unbalanced forces in the busbar	850864	Analysed	No
RQ4.L8	Q4.L8	Unbalanced forces in the busbar	850864	Analysed	No
RQ4.L8	Q4.L8	Defective quench heater	832580 1020189	Used with 7 in stead of 8 heaters	Yes*
RQ4.R2	Q4.R2	High joint resistance	-	Lifting of the DFBMB	Yes
RQ5.L8	Q5.L8	Problem in one of its correctors	-	Magnet replaced during LS1	Yes
RQ5.R1	Q5.R1	2 quenches without heater firing	-	Analysed and understood	Yes
RQ5.R2	Q5.R2	Many training quenches	-	I_NOM reduced from 4310 to 4100 A	Yes*

- Maximum strength required for RQ5.R2 occurs near the beginning of the squeeze and corresponds to 3205 A at 7 TeV: **the reduction of I_NOM is not a limitation for LHC operation.**

MP3 NCs: ITs

From LMC 2/4/2014

Circuit	Specific magnet	Description	NC	Action	Resolved
RQX.R1	Q1	Faulty electrical insulation of QH vs GND	1017174	Change of the heater voltage and capacitance of the redundant quench heater power supply	Yes
RCBX%	MCBX	Nested H and V magnets. Current lead cooling problem	1027950,1027951	Modification lead cooling during LS1	Yes (after LS1)
RCBXV3.L8	MCBXV	Quenches at flat-top			No
RCOSX3.L1	(MCOSX)	Circuit open	948545	Will not be repaired. Circuit condemned	No
RCOSX3.L2	(MCOSX)	Circuit open after beam impact	1203477	Will not be repaired. Circuit condemned	No
RCOX3.L2	(MCOX)	Circuit open after beam impact	1203478	Will not be repaired. Circuit condemned	No
RCSSX3.L2	(MCSSX)	Circuit open after beam impact	1203479	Will not be repaired. Circuit condemned	No
RCSSX3.L1	(MCSSX)	Circuit trips at 62.9 A	1053719	I_NOM reduced from 100 to 60 A	Yes*

- Correctors circuits not used so far.
- Possibly needed only at small beta* (i.e., for IR2 only in ion operation).
- NCs already considered and **are not believed to be a limitation for LHC**.
- **RCBXH/V.%**: The H and V magnets are individually commissioned with $I_{PNO}=540$ A, except RCBXH1.L5 (490 A). For combined powering they are commissioned to

$$I_H^2 + I_V^2 < 400^2 \text{ A}^2.$$

In Run II the crossing and separation bumps are generated using all MCBXs to overcome strength limitations.

MP3 NCs: IPDs

Circuit	Specific magnet	Description	NC	Action	Resolved
RD1.R8	D1	One quench heater failed HV test	1118353	Operates with one heater	Yes*
RD2.L1	D2	Quench in bus of DFBLA with coupling to RQ4.L1	-	Analysed and understood	Yes
RD2.L2	D2	Unbalanced forces in the busbar	850864	Analysed	No
RD2.L8	D2	Unbalanced forces in the busbar	850864	Analysed	No
RD2.R8	D2	Quench in bus not being in LHe	-	Lowering of the DEB link	Yes
RD3.L4	D3	Slow trainer	-	I_nom reduced from 5850 to 5600 A	Yes*

- Operational current for D3 at 7 TeV is 5850 A.
- No limitation expected at 6.5 TeV.

Conclusions (for LHC)

- MP3-related NCs should not limit LHC performance.
- Mitigation measures have been found and implemented in the optics configuration (e.g., optimisation of bump shapes/strength requirements).
- Some MP3-related NCs will be fixed in LS2
 - Missing octupole circuit in sector 3-4
 - Restoring of original beta-beating optimisation from MEB slot assignment
- The situation of the weak MQTLs should be carefully monitored to ensure the long-term machine performance.

Conclusions (for HL-LHC)

- **RCBYH4.R8B1, RCBYHS5.R8B1**: limit to IR8 crossing scheme.
- **RCBYHS4.L5B1**: this assembly should be moved to a Q5 in IP1/5 and its strength is essential.
- **MQT.18.L1.B1**: short to ground.
- **ROD.A56B1**: limited to 450 A.
- **All RSD/F**: Acceleration reduced (0.25 to 0.15 A/s²).
- **RCS.A78B2**: circuit condemned.
- **RSS.A34B1**: circuit condemned.

These circuits are important enough to suggest that further checks should be performed to assess their status, and in case plan for repairing actions.

These circuits are important, but additional studies should be carried out to assess the actual impact on machine performance. The outcome of such studies would indicate whether repairing actions would be needed.