Impact of known NCs on machine operation

M. Giovannozzi

- MP3 NCs
- Beam screen orientation (sawtooth)
- SSS activities in LS1 and LS2

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MP3 NCs: ITs

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.
- Hopefully, LS1 consolidation will enable solving a long standing issue with MCBX, i.e., interlock should be based on $I^2_{MCBXH}+I^2_{MCBXV} < 550^2$ A
- RCBXV3.L8: in general MCBX are critical magnets and any effort should be made to have them operational!

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 DFB 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.

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.

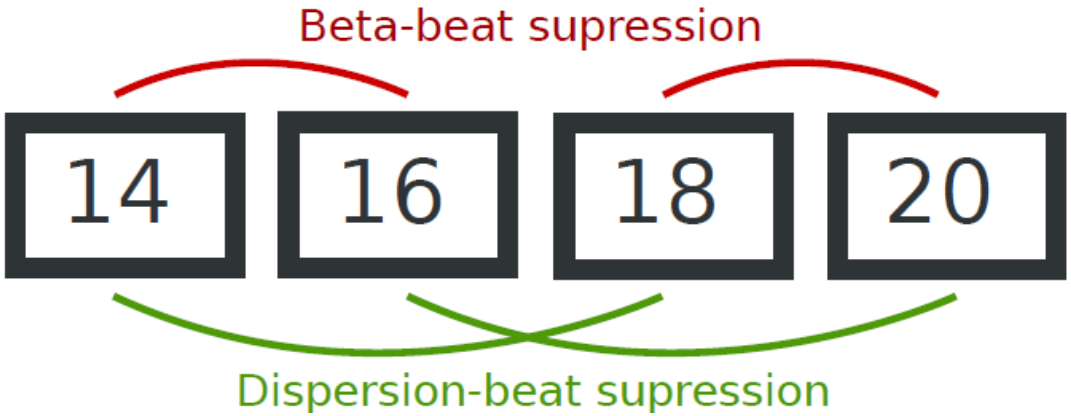
MP3 NCs: 600 A circuits - I

- Weak MQTLIs (already known from the MEB times):
  - No limitation for LHC operation even at 7 TeV.
- New weak MQTLIs (MQTL11.R5)
  - Current limited to 450 A: 277 A are required. No limitation for LHC operation even at 7 TeV. **However, this is a crucial element for CMS optics.**
- Quenches at flat top affecting:
  - MQSs -> coupling correction
  - MQTs -> tune feedback and machine optics (IR6 and IR5)
  - RCSs -> chromaticity
  - ROs -> instabilities

  } Not much to do…
- Short to ground of MQT.18.L1.B1 in circuit RQTF.A81.B1. Recommendation given:
  - to bypass 4 MQT magnets in SSSs 14.L1, 16.L1, 18.L1, and 20.L1 via a short-cut in the circuit in the interconnection at location 20R8,
  - to add the repair information to the non-conformity 1285058 and attach it physically to the two modified interconnections,
  - to update the electrical layout-database accordingly,
  - to include the changes in LSA and propagate them to the tune feedback system

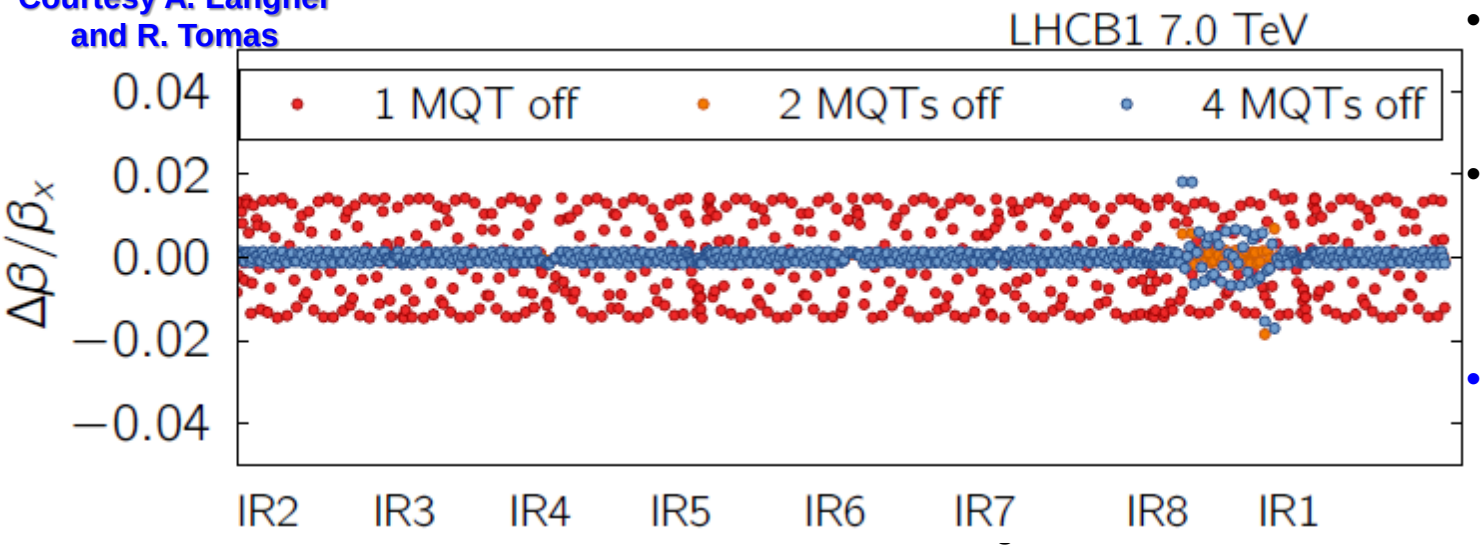
MP3 NCs: 600 A circuits - II

- Four magnets have to be removed to keep under control both beta- and dispersion-beating.



- Simulations performed to assess impact on LHC optics

Courtesy A. Langner and R. Tomas



- Global beta-beat is negligible if 4 MQTs are switched off.
- Only around these MQT positions a larger beta-beat is observed.
- 2% peak beta-beating is generated in arc 81, only.

MP3 NCs: 60-80-120 A circuits

- RCBH31.R7.B1: corrector 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).
- RCBCH6.L2B2: was used and can be used up to nominal performance as long as RCO.A12B2 is condemned.

MP3 NCs: RCO circuits - I

- From injection up to 3-4 TeV b_4 average is 0.05 units, while at top energy it is 0.25 units.
- Specifications for the b_4 of the dipoles (LHC report 501) is $b_{4U} < 0.4$ units. At top energy, the MCOs (at 100 A) cannot correct more than 0.13 units of b_4 in the dipoles.
- At top energy the total integrated strength of the MCOs (at 100 A) corresponds to about 24% of the total integrated strength of the Landau octupoles, i.e., MOF (or MOD).
- In terms of detuning and non-linear chromaticity:
  - MCOs contribute up to **8.5%** and **24%**, for the **detuning** and the **cross-term**, respectively.
  - MCOs contribute between 8.5% and 24% to the second order chromaticity depending on the plane.

Impact of optics functions

MP3 NCs: RCO circuits - II

- In 2015 the injected beams will have a larger emittance than during Run I, hence enhancing all amplitude-dependent effects, beyond what was the case during Run I.
- Based on the previous figures:
  - The use of MCOs at injection might be questionable as:
    - Because of the smaller-than-specified b_4 in the dipoles, thus forcing to work at very low excitation fields, but they can be used also to compensate other effects, e.g., non-perfect b_5 correction and related feed down effects.
  - The use of MCOs at top energy is less questionable as:
    - Thanks to the reduced b_4 at top energy almost half of the b_4 could be corrected.
    - The total integrated strength of the MCOs and their impact on detuning with amplitude or non-linear chromaticity is a non-negligible fraction of that of a single MO family, hence constituting an interesting safety margin for machine operation.
- Therefore, it is proposed to keep in operation all MCOs, possibly set up via beam measurements at injection and then ramped up to flat top. Of course, the analysis of the repairing actions should be properly taken into account for the final decision.

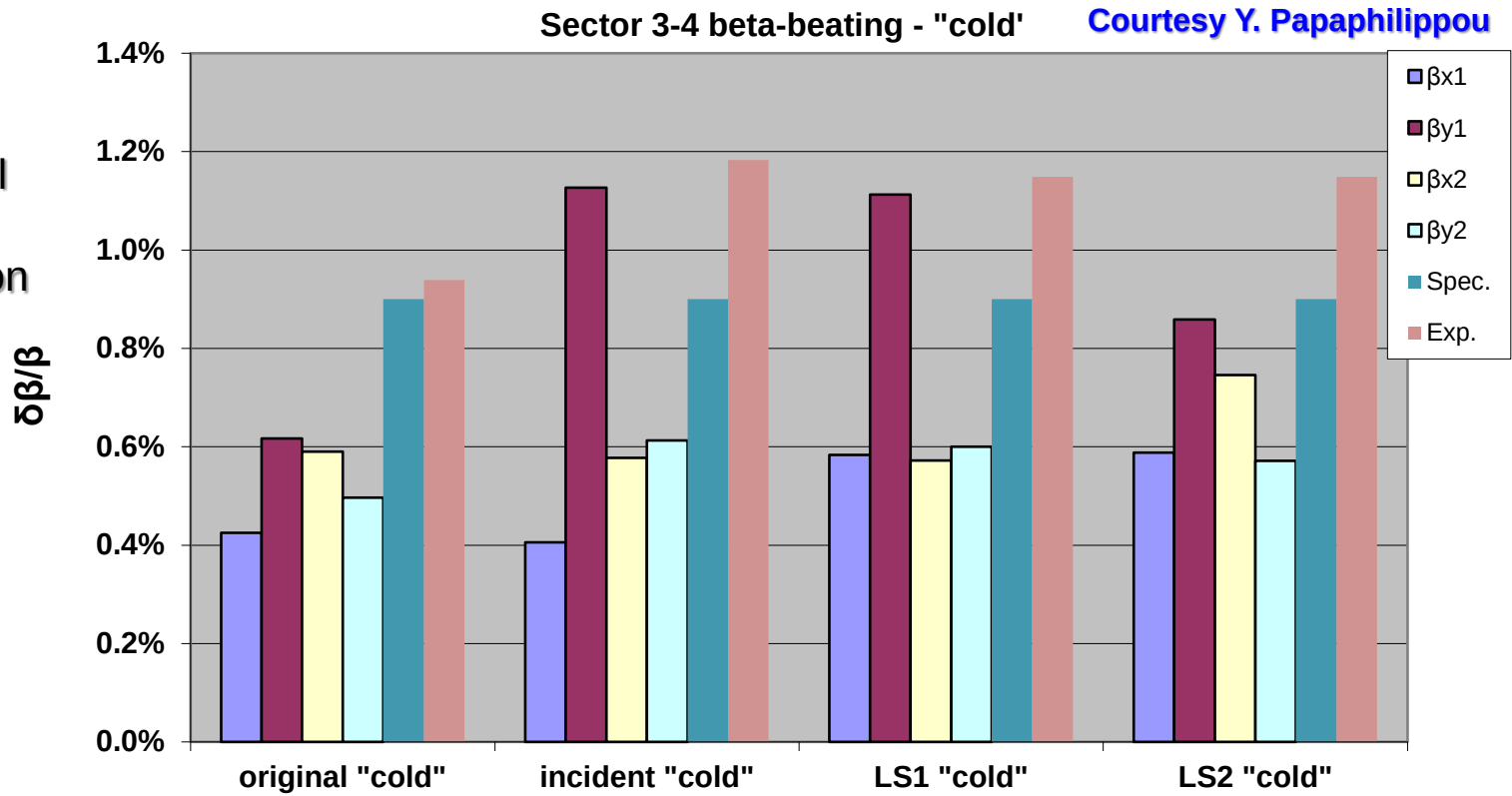
Beam screen orientation (sawtooth)

- Introduced in the machine at the time of magnet replacement following 2008 incident.
- Guideline has been to minimise the number of wrongly-oriented beam screens/half cell.
- Impact on beam operation already analysed in the past and found negligible.
- During LS1 two dipoles with wrongly-oriented beam screen were removed in order to have no more that one wrong beam screen/half cell in the LHC ring.

SSS activities in LS1 and LS2 - I

- After LS1 (restoring MQS circuit in 3-4):
  - **SSS055 (Q27R3)** to be replaced by **SSS233**
  - **SSS243 (Q23R3)** to be replaced by **SSS230**
- After LS2 (restoring beta-beating and MO circuit):
  - **SSS369 (Q28R3)** (with MQS) to be replaced by **SSS198** (with MO)
  - **SSS279 (Q32R3)** (with MQT) to be replaced by **SSS200** (with MO)

- Sorting efficiency reduced after incident for vertical beating of beam1 (above specification of 0.9%) and reduced after LS2
- Slight increase of beta-beating for both beams after LS1 and LS2, but still within specs



Conclusions

- MP3-related NCs should not limit LHC performance (apart, maybe, for the observed quenches at top energy).
- It is proposed to keep in operation the RCO circuits for the sake of having additional margins. Of course, this request should be balanced against considerations on the repairing activities.
- The situation of wrongly-oriented beam screens (sawtooth) has been further improved during LS1.
- The replacement of SSS during LS1 has allowed to put back a missing MQS circuit in sector 3-4 as a consequence of the 2008 incident. A further reduction of beta-beating has been prepared by an appropriate choice of the replacing SSS, to be completed in LS2.