BEAM INDUCED QUENCHES OF LHC MAGNETS

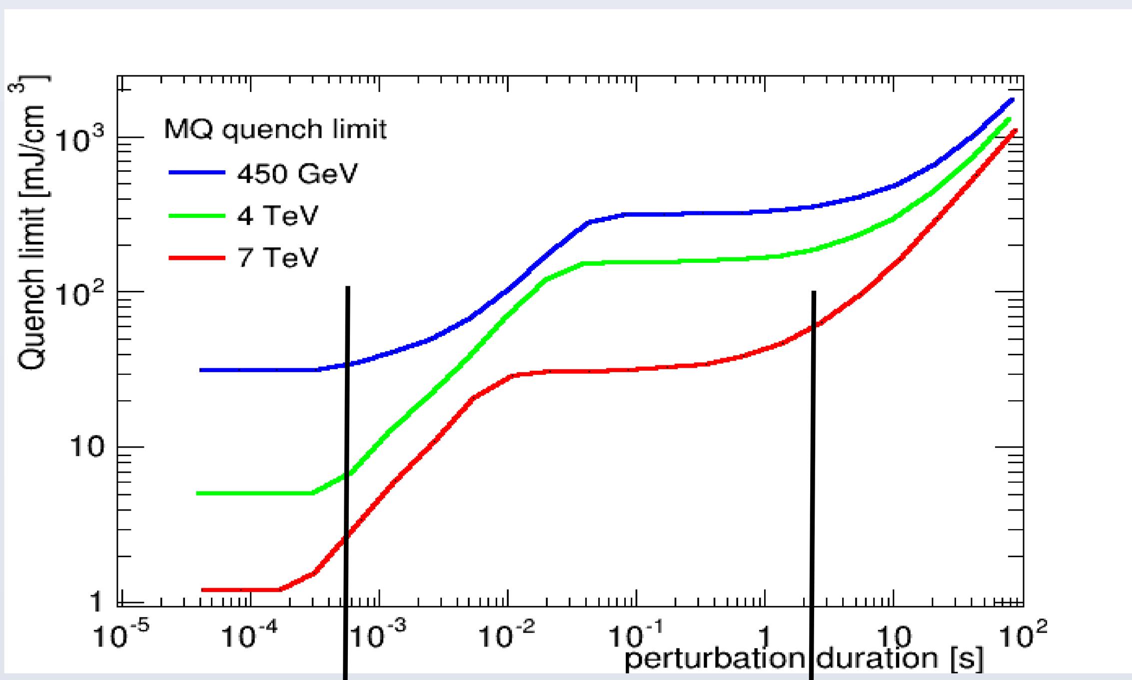
M. Sapinski, T. Baer, M. Bednarek, G. Bellodi, Ch. Bracco, R. Bruce, B. Dehning, W. Hofle, A. Lechner, E. Nebot Del Busto, A. Priebe, S. Redaelli, B. Salvachua, R. Schmidt, D. Valuch, A. Verweij, J. Wenninger, D. Wollmann, M. Zerlauth

CERN, Geneva, Switzerland

Abstract

In the years 2009-2013 LHC has been operated with the top beam energies of 3.5 TeV and 4 TeV instead of the nominal 7 TeV, with corresponding reduced currents in the superconducting magnets. To date only a small number of beam-induced quenches have occurred, with most of them being specially designed quench tests. During normal collider operation with stored beam there has not been a single beam induced quench. This excellent result is mainly explained by the fact that the cleaning of the beam halo worked very well and, in case of beam losses, the beam was dumped before any significant amount of energy was deposited in the magnets. However, conditions are expected to become much tougher after the long LHC shutdown, when the magnets will be working at near nominal currents in the presence of high energy and intensity beams. This paper summarizes the experience to date with beam-induced quenches. It describes the techniques used to generate controlled quench conditions which were used to study the limitations. Results are discussed along with their implication for LHC operation after the first Long Shutdown.

Quench limits



short — dry cable

intermediate — helium contribution

steady-state — heat transfer to cryogenic system

Numerical and phenomenological models [Note44, QP3, THEA] lead to different results, especially for intermediate duration losses. → Experiments needed!

List of beam-induced quenches

Table 1: List of beam-induced quenches

No	date	beam energy [TeV]	loss duration	quenched magnet	location	remark
1	2008.08.09	0.45	~ ns	MB	8L3	beam setup
2	2008.09.07	0.45	~ ns	MB	10R2	beam setup
3	2009.11.20	0.45	~ ns	MB	12L6	beam setup
4	2009.12.04	0.45	~ ns	MB	15R2	beam setup
5	2010.04.18	0.45	~ ns	MB+	20R1	wrong main quad current
6	2010.10.06	0.45	1s	MQ	14R2	quench test
7	2010.10.06	0.45	1s	MQ	14R2	quench test
8	2010.10.06	0.45	1s	MB	14R2	quench test
9	2010.10.17	3.5	6s	MQ	14R2	quench test
10	2010.11.01	3.5	10 – 40ms	MBRB (4.5 K)	5L4	quench test
11	2011.04.18	0.45	~ ns	MB+	IP8	kicker flashover
12	2011.07.04	0.45	~ ns	MB	14R2	test
13	2011.07.28	0.45	~ ns	MQXB+	IP2	injection oscillations
14	2012.04.15	0.45	~ ns	MB+	IP8	kicker flashover
15	2013.02.15	0.45/6	~ ns	MQM (4.5 K)	6L8	quench test
16	2013.02.15	4.0	5 – 10ms	MQ	12L6	quench test
17	2013.02.16	4.0	20s	MQ	12L6	quench test

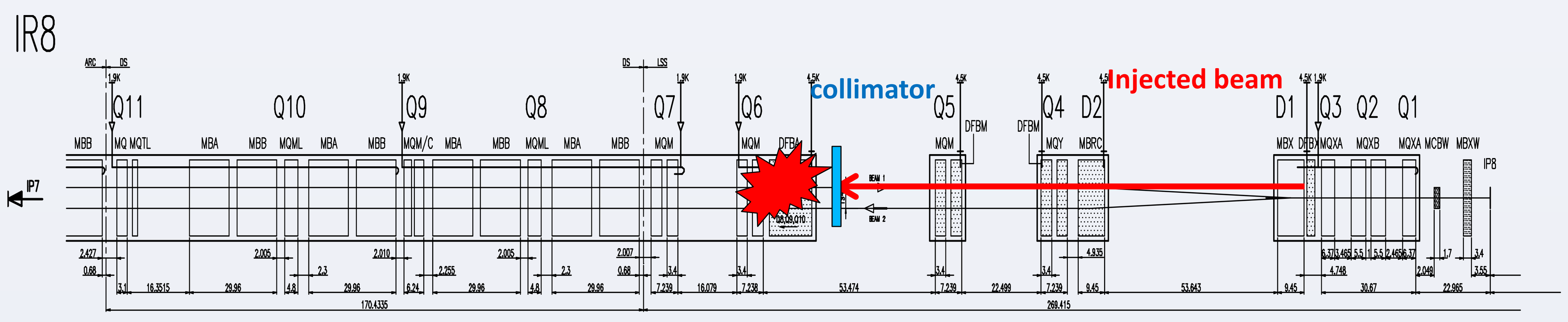
- Operational quenches: 5, 11, 13, 14 (all at injection)
- Beam setup quenches: 1-4
- Quench tests:
  - Campaign 2010: 6-10
  - Campaign 2013: 15-17

Data: Quench Protection System (QPS), Beam Loss Monitor system (BLM), Beam Position Monitors (BPM) and other systems.

Fast losses

Operational, beam setup [Note442] and quench tests (total 10 quenches).

In February 2013: quench test above 4 TeV beam energy:

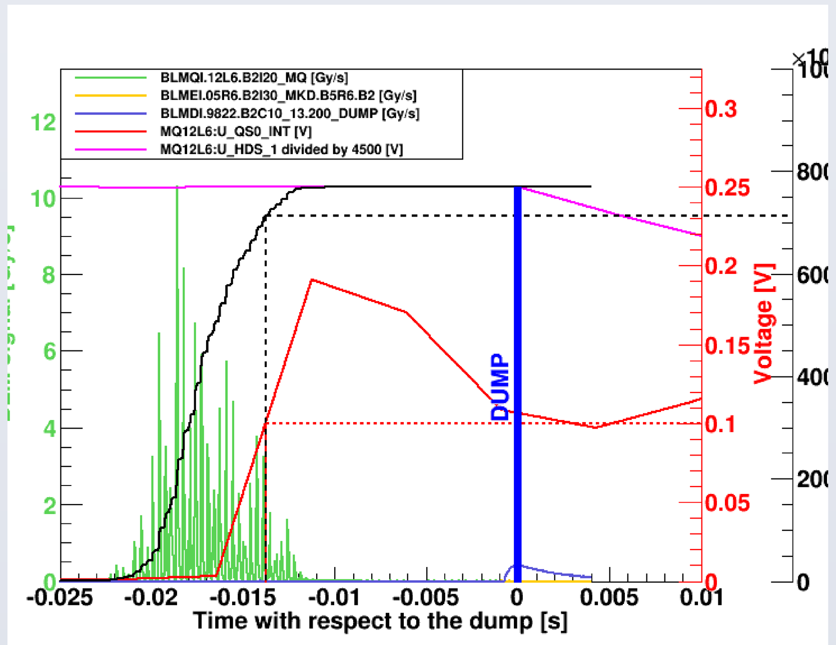


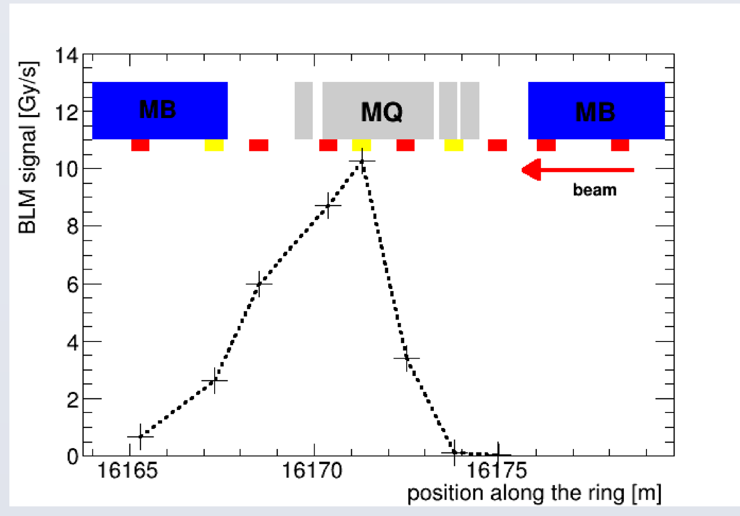
Quench with magnet current corresponding to 6 TeV beam energy. Important for estimation of number of quenching magnets in case of asynchronous dump.

Millisecond losses

Unidentified Falling Object (UFO) are beam losses presumably due to dust particles falling into the beam [UFO]. They can potentially quench the magnet with a loss in sub-millisecond timescale. Two experiments investigating quench limit has been performed: using wire scanner [WireScanner] and transverse damper excitation [ADT].

Magnet quenched with about $5 \cdot 10^8$ protons. This low intensity was a challenge for beam instrumentation. The loss duration until quench was about 5 ms.





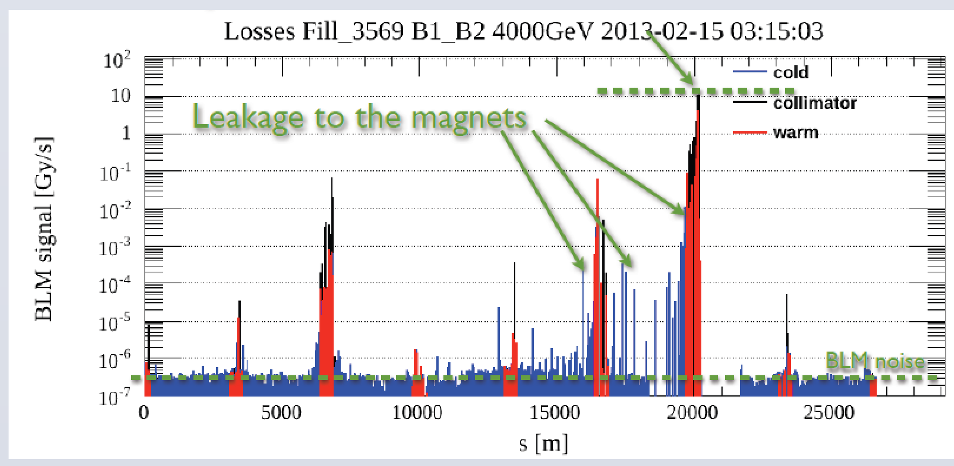
Steady-state losses

Particularly important, regular losses due to beam tails cleaning and luminosity.

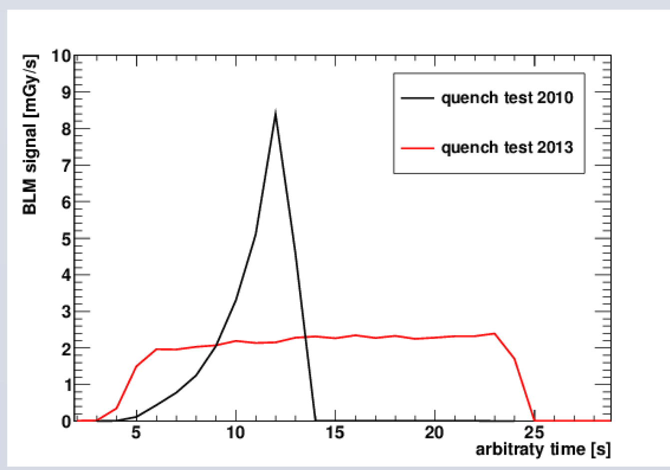
Two investigation techniques:

- enhanced collimation losses
- orbital bump with beam blowup

Enhanced collimation losses never gave quench even with 1 MW beam loss on the collimation system.



Orbital bump tests quenched magnets 5 times. Recently used together with ADT, which gives very good control of time structure of the loss. Tests show important dependence of BLM signal on the loss scale.



References

- [Note44] J.B. Jeanneret et al., *Beam Losses and Machine Protection*, LHC Project Report 044.
- [QP3] A. Verweij, *QP3 Users Manual*, CERN/EDMS 1150045
- [THEA] P.P. Granieri et al., *Stability Maps of the LHC Superconducting Magnets*, to be presented at the MT-23 conference, Boston, USA, 2013
- [Note422] M. Sapinski et al., *Simulation of Beam Loss in LHC MB Magnet and Quench threshold test*, CERN-LHC-Project-Note-422
- [UFO] T. Baer, PhD thesis (in preparation)
- [WireScanner] M. Sapinski et al., *LHC magnet quench with beam loss generated by wire scan*, Proceedings of IPAC11
- [ADT] M. Sapinski et al., *Generation of Millisecond Controlled Losses with Transverse Damper on LHC*, these proceedings
- [Steady2010] A. Preiebe et al., *Investigations of Quench Limits of the LHC Superconducting Magnets*, IEEE Transactions on Applied Superconductivity, Volume: PP, Issue: 99