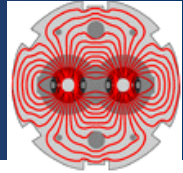
The first look on the quench test results

Mariusz Sapinski BE/BI

for all the people participating in quench tests
and now in analysis

LHC Machine Committee, 2013/03/27

Outlook



1. Beam induced quenches.
2. Quench tests 2013: planning and execution.
3. Steady-state dispersion suppressor test.
4. Steady-state with orbital bump test.
5. Influence of loss pattern.
6. Millisecond-timescale test.
7. Q6 test.

Beam induced quenches

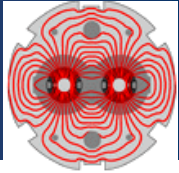


Table 1: List of beam-induced quenches

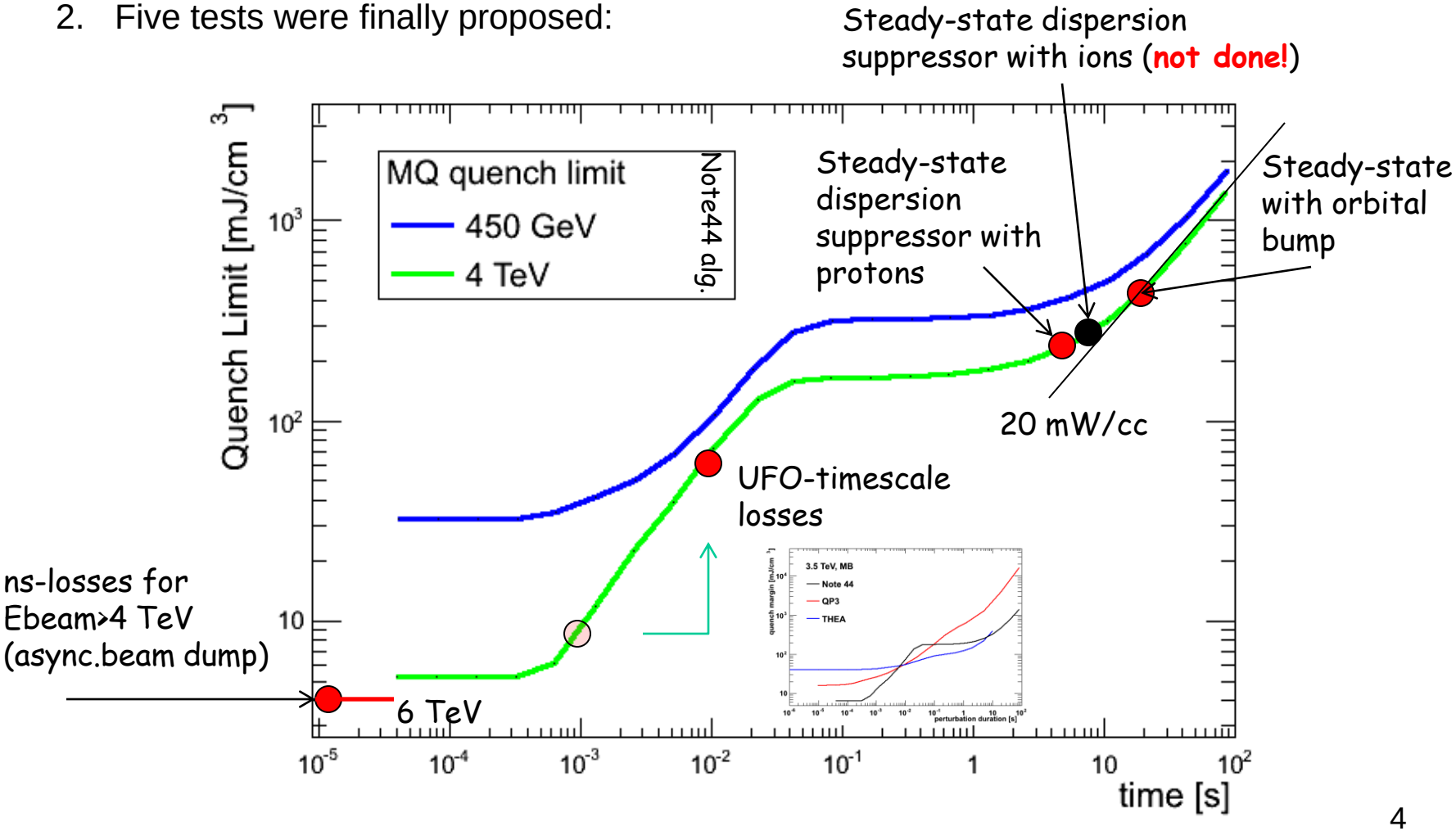
No	date	beam energy [TeV]	loss duration [s]	quenched magnet	location
1	2008.08.09	0.45	$\sim 10^{-9}$	MB	8L3
2	2008.09.07	0.45	$\sim 10^{-9}$	MB	10R2
3	2009.11.20	0.45	$\sim 10^{-9}$	MB	12L6
4	2009.12.04	0.45	$\sim 10^{-9}$	MB	15R2
5	2010.04.18	0.45	$\sim 10^{-9}$	MB+	20R1
6	2010.10.06	0.45	1	MQ	14R2
7	2010.10.06	0.45	1	MQ	14R2
8	2010.10.06	0.45	1	MB	14R2
9	2010.10.17	3.5	6	MQ	14R2
10	2010.11.01	3.5	$10 - 40^{-3}$	MBRB (4.5 K)	5L4
11	2011.04.17	0.45	ns	MB+	IP8
12	2011.07.04	0.45	ns	MB	14R2
13	2011.07.28	0.45	ns	MQXB+	IP2
14	2013.02.15	0.45 /6 TeV	10^{-9}	MQM (4.5 K)	6L8
15	2013.02.16	4.0	10^{-3}	MQ	12L6
16	2013.02.16	4.0	20	MQ	12L6

First quench test campaign

Second quench test campaign

Planning: cover various loss durations

1. During 2012 in frame of Quench Test Strategy WG various scenarios of quench tests were discussed.
2. Five tests were finally proposed:



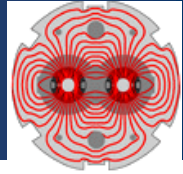
How it really was

One of the last versions of dynamic planning by Jan Uythoven

	start	stop	duration	task	
Thu	8:00	9:00	1:00	Dump, rampdown	
	9:00	13:00	4:00	Proton collimation, ramp 1 (ADT set-up) - done OK	Could be as early as 04:00
	13:00	14:00	1:00	Ramp down	ADT firmware change, if needed
	14:00	16:00	2:00	Proton collimation, ramp 2 (500 kW) - to be repeated	Max 1 train of 144
	16:00	17:00	1:00	Ramp down	Installation scope for Q6 test, takes 45 min
	17:00	19:00	2:00	Pre-cycle	
	19:00	21:00	2:00	Proton collimation, ramp 3 (500 kW, 2-3 sec)	Max 1 train of 144
	21:00	23:00	2:00	Ramp down, thresholds tuning, ADT firmware upgrade	
	23:00	1:00	2:00	Proton collimation, ramp 4 (750 kW)	Max 2 trains of 144
	1:00	2:00	1:00	Ramp down, recomputing thresholds	
	2:00	4:00	2:00	Proton collimation, ramp 5 (1 MW)	
	4:00	9:00	5:00	Quench recovery pre-cycle	Installation for fast losses, 2 hours ?
Fri	9:00	11:00	2:00	Q6 injection	BLMs changes not required
	11:00	14:00	3:00	Quench recovery and pre-cycle, another ACCESS if required	Installation, if not done, takes 2 hours
	14:00	20:00	6:00	ADT fast losses (large, so can take second ramp if required)	BLMs modified for ADT fast losses test
	20:00	1:00	5:00	Quench recovery and pre-cycle	
	1:00	4:00	3:00	Orbit bump steady state, 1 ramp	BLMs modified for Orbit bump test.
	4:00	8:00	4:00	Buffer for reality vs. optimism	
Sat	8:00	11:00	3:00	Buffer for limits IPQ	

Photo by Jaromir Ludwin

How it was



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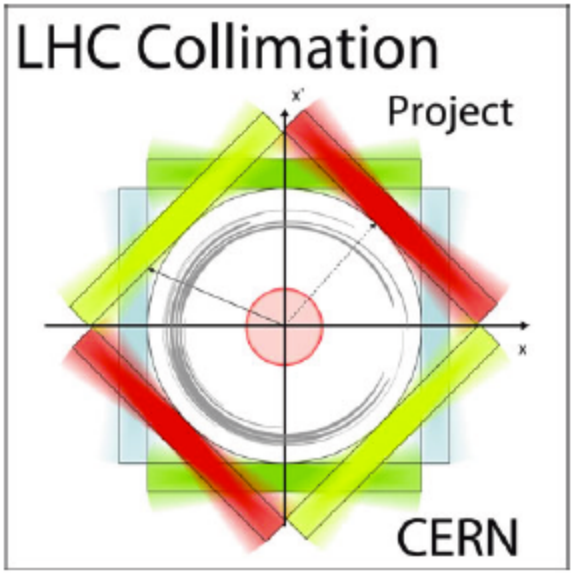
Special thanks to the people who were (sometimes always) there: Daniels (Valuch and Wollman), Bernd, Wolfgang (Hofle and Bartman), Tobias, Stefano, Belen, Agnieszka, Eduardo, Barbara, Rudiger, Markus, Matteo, Mateusz, Jaromir, Arjan , OP team and many others (also supporters)!

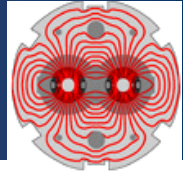
First results on proton collimation quench test



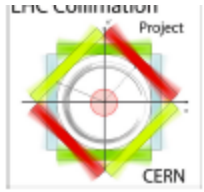
B.Salvachua, R.Bruce, S.Redaelli and D.Wollmann

Collimation Group: M.Cauchi, D.Deboy, L.Lari, D.Mirarchi, E.Quaranta and G.Valentino
MP team: R.Schmidt, M.Zerlauth
BLM team: E.Nebot, M.Sapinski, E.B.Holzer
ADT team: W.Hofle and D.Valuch
OP team: J.Wenninger, D.Jacquet

Collimation WG, 25th March 2013

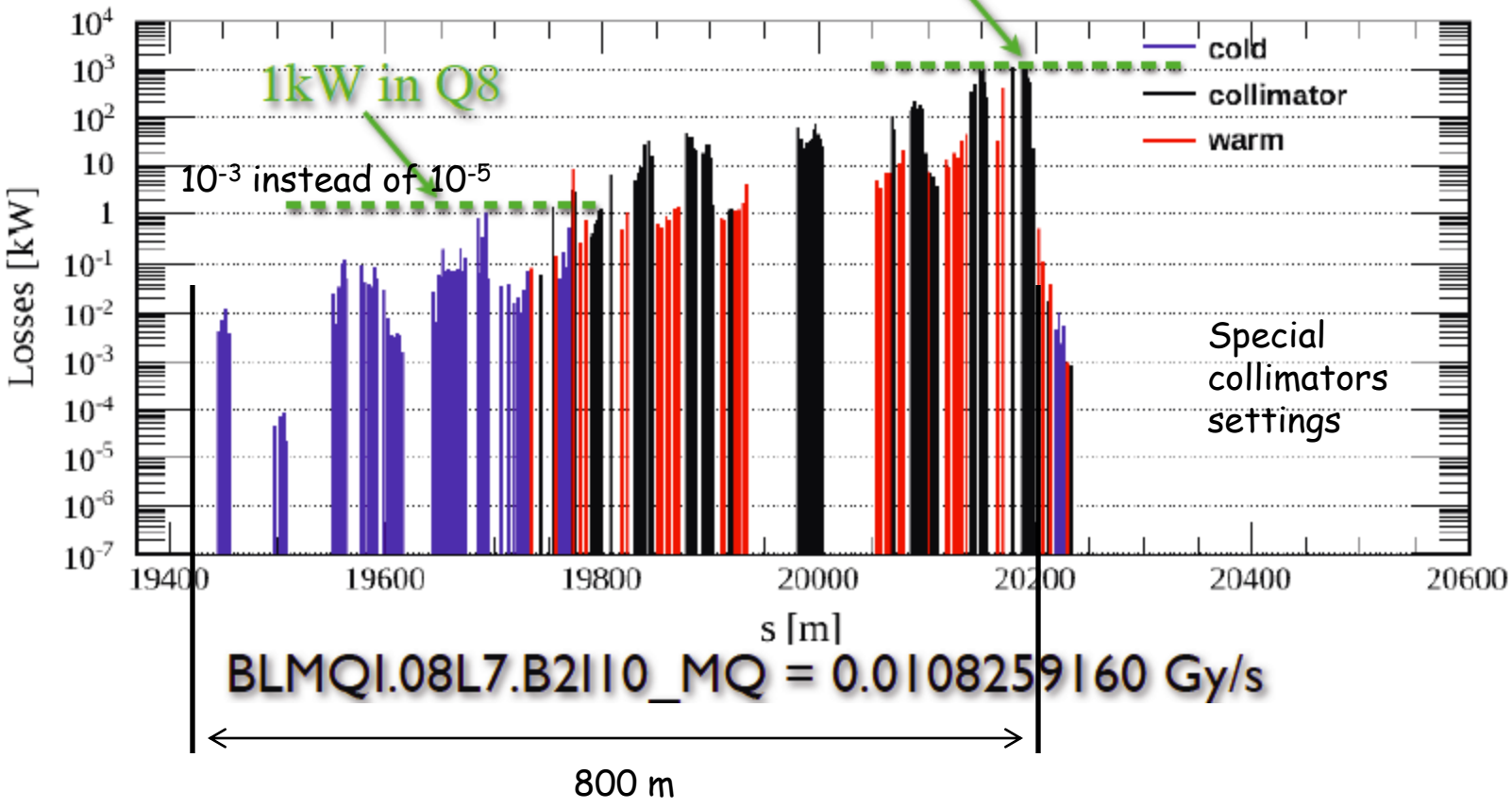


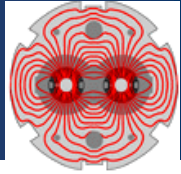
Losses in DS IR7



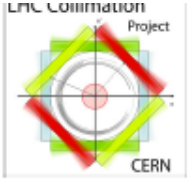
1.05MW in IR7!

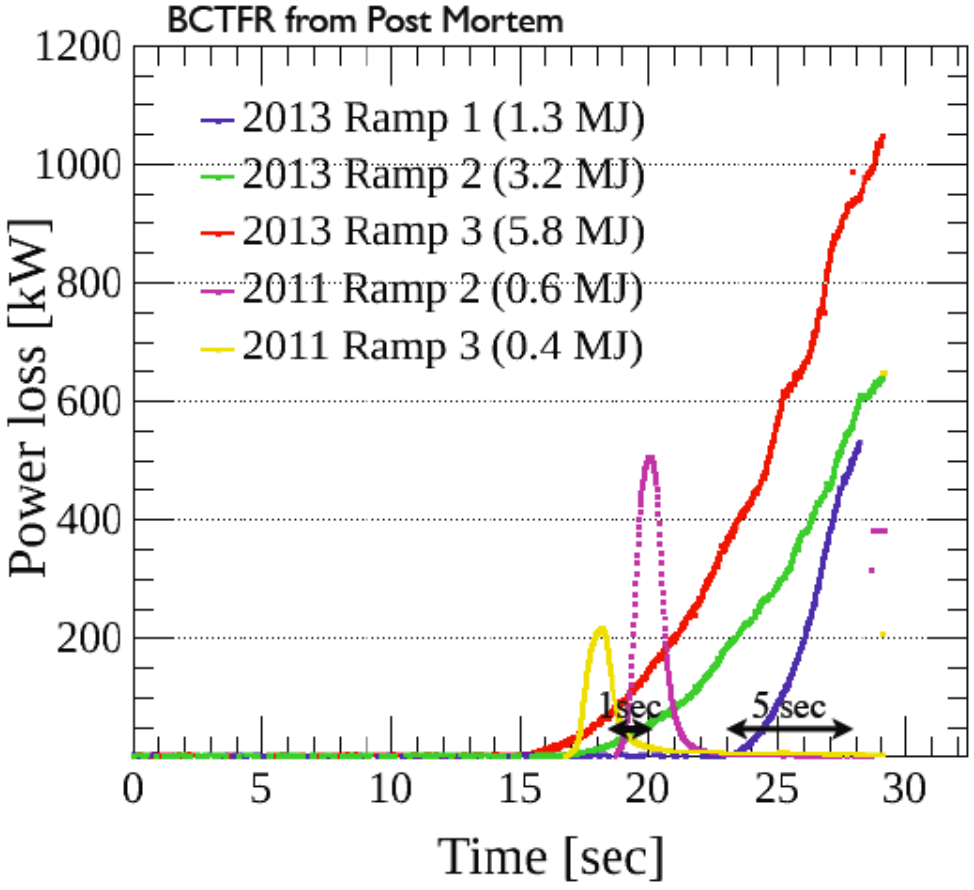
Last ramp (out of 3 for actual test)





Comparison to 2011 quench tests

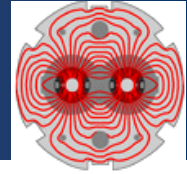




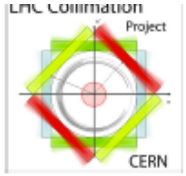
Better control of the blow-up with the ADT:

for the same peak loss rate (~500kW), in 2011 with the tune resonance mechanism the rise time was 1 second while for the ADT could be tuned to 5 seconds. This is important especial for the target power loss of 1MW, the TSI team requested to have a smooth increase of the losses

Ramp 1	520 kW
Ramp 2	650 kW
Ramp 3	1050 kW



Achieved quench limits



Thanks a lot to Eduardo for all the cross-checks!

BLM thresholds were changed during the test, the table bellow shows the measured losses in Q8 and the BLM threshold during the test

Ramp 3: ~1MW	RS09 = 1.3 s				RS10 = 5.2 s			
	BLM [Gy/]	Threshold [Gy/s]	Ratio Threshold to QL	BLM/ Thresh	BLM [Gy/]	Threshold [Gy/s]	Ratio Threshold to QL	BLM/ Thresh
BLMQI.08L7.B2I10_MQ	1.08E-02	0.035	7.5	**0.3**	8.42E-03	0.035	21	**0.24**
BLMQI.08L7.B2I20_MQ	3.81E-03	0.019	3	**0.2**	2.87E-03	6.90E-03	2.5	**0.42**

Taking now the assumed quench limit for each monitor the table bellow shows the achieved quench limit for RS over 1.3 sec and 5.2sec

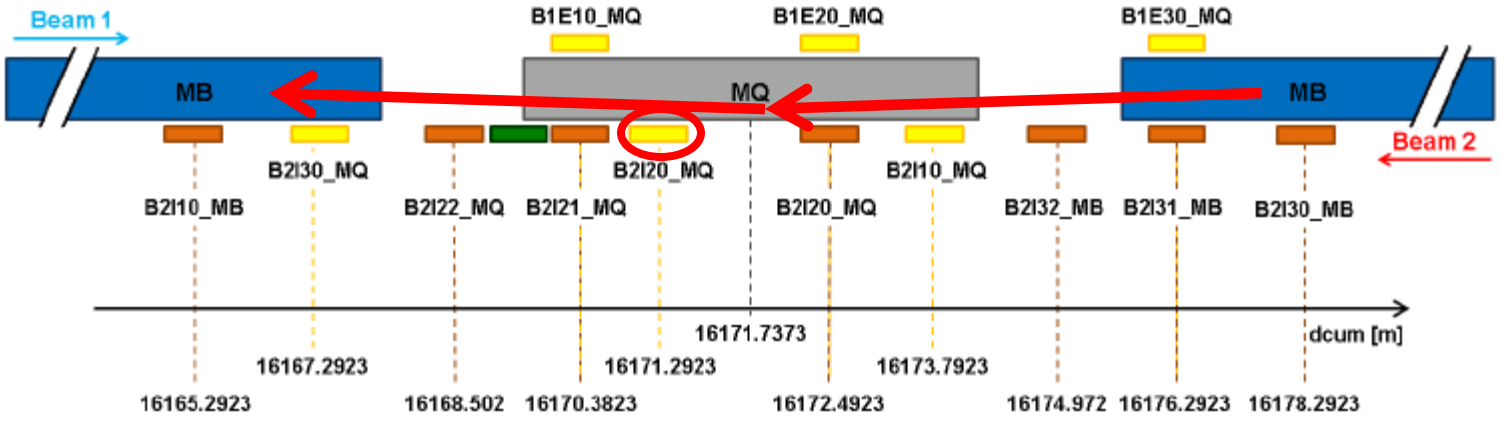
Ramp 3: ~1MW	RS09 = 1.3 s			RS10 = 5.2 s		
	BLM Measurement [Gy/]	Assumed Quench Limit [Gy/s]	Ratio BLM to Quench Limit	BLM Measurement [Gy/]	Assumed Quench Limit [Gy/s]	Ratio BLM to Quench Limit
BLMQI.08L7.B2I10_MQ	1.08E-02	4.65E-03	**2.3**	8.42E-03	1.67E-03	**5.1**
BLMQI.08L7.B2I20_MQ	3.81E-03	6.40E-03	**0.6**	2.87E-03	2.29E-03	**1.3**

No quench!

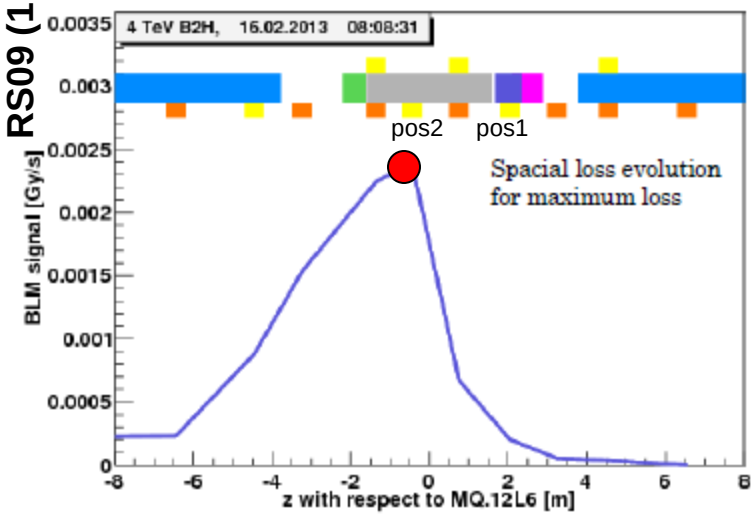
Collimation WG - 25th March - Belen Salvachua

Steady-state with orbital bump (and ADT)

Plots courtesy Agnieszka Preiebe



RS09 (1.3s)



RS10 (5.2s)

BLM	BLMQI.08L7.B2I20_MQ	BLMQI.12L6.B2I20_MQ
Signal	2.87 mGy/s	2.36 mGy/s
Threshold	2.29 mGy/s	
S/T	1.3	1.03
	no quench	**quench (as expected!)**

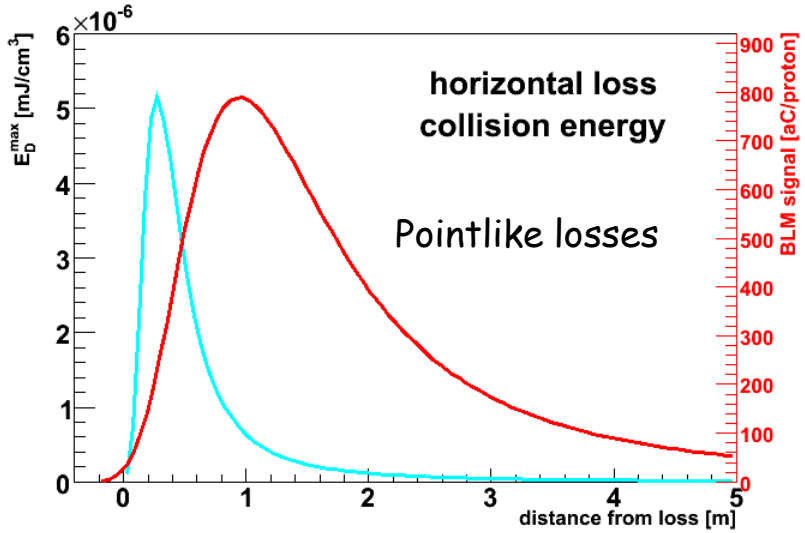
Loss scenario has an important impact on quench level as seen in BLMs.

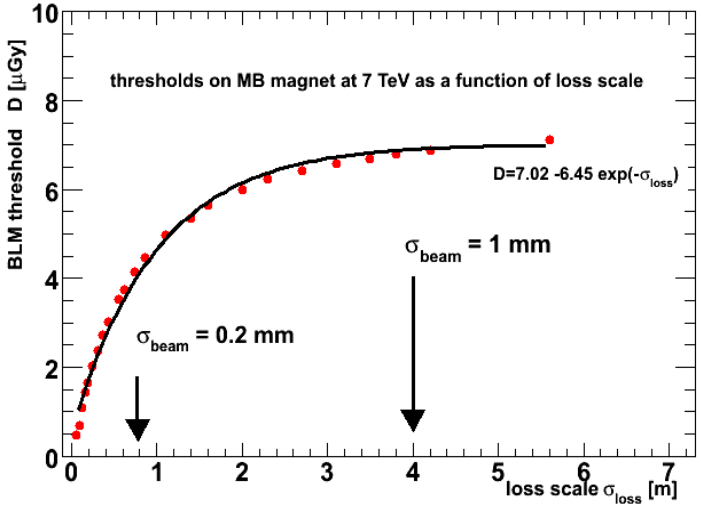
Why is that?

We will need FLUKA/Geant4 simulations to understand this in details

but…

CERN-LHC-Project-Note-422 (2009), MB case:



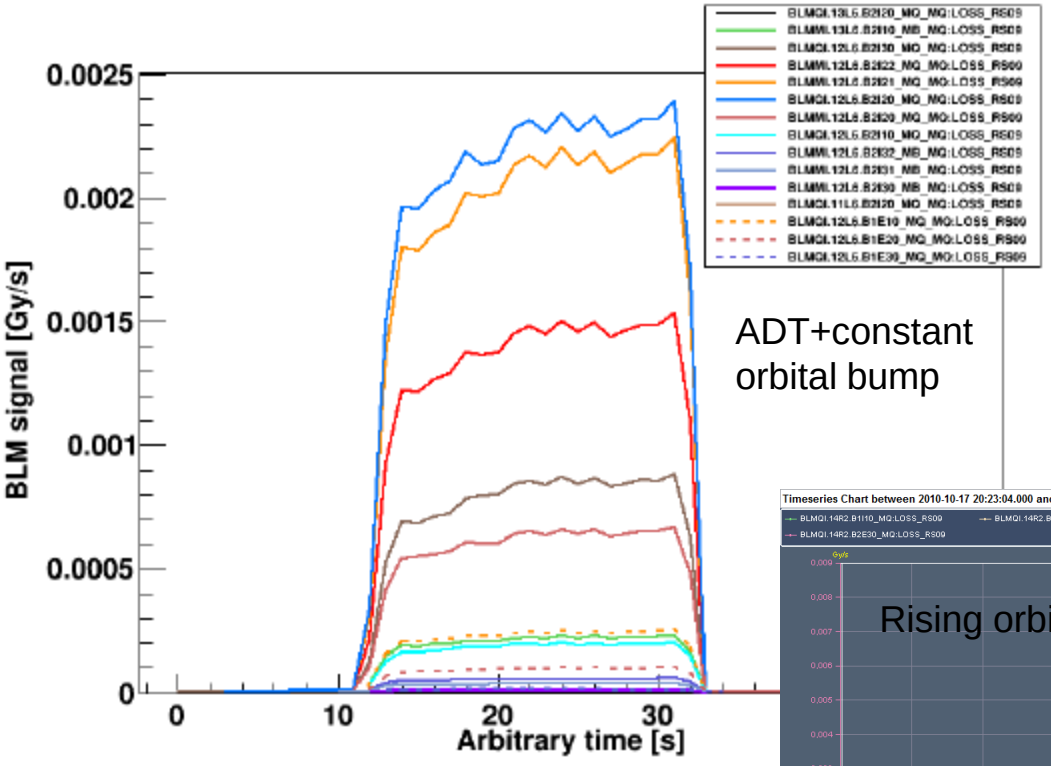


Threshold=QL*BLMsignal / E_{dep}^{coil}

When we smear the loss the amplitude of thinner distribution decreases faster than thicker one.

So more distributed losses lead to higher BLM signal at quench.

Steady-state with orbital bump (and ADT)

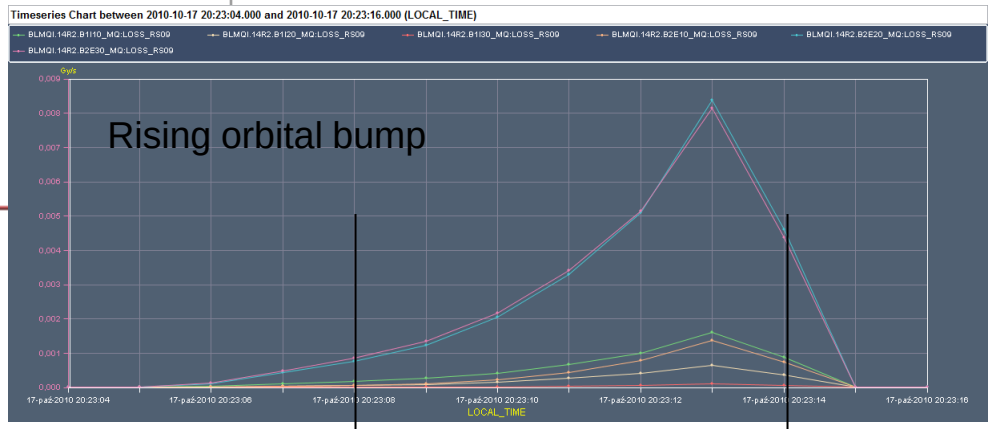


ADT+constant orbital bump

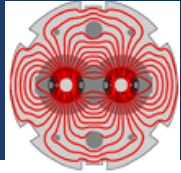
Plots courtesy Agnieszka Priebe

The loss rate obtained during this quench exercise was very flat and lasted about 20s!

For comparison, in 2010:



UFO-timescale quench test



It was a complex test, never done before:

- Inject and ramp 10 bunches (to have multiple attempts).
- Single bunch was first scraped by vertical blow to intensities < 10^9 p (special collimators setting).
- Horizontal orbital bump was created in Q12L6.
- Bunch was excited in horizontal plane by MKQ kick and then by ADT working in sign flip mode (anti-damping).
- If no quench – next bunch scraped less.

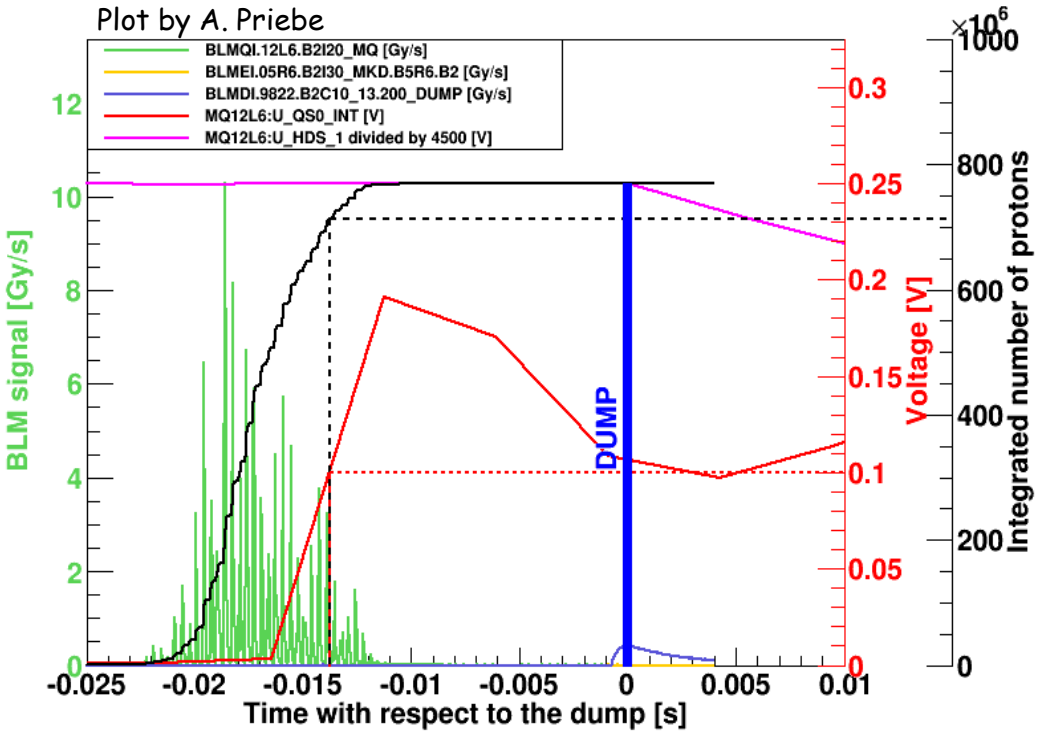
Scheme originally proposed by Wolfgang

Several challenges:

- for damper (ultra-low sensitivity mode: $5 \cdot 10^7$ p)
- instrumentation (measurement of intensity and emittance!)

But we were prepared (4 MDs).

UFO-timescale quench test



- $7.7 \cdot 10^8$ lost protons
- fraction lost when quench started
- duration: 10 ms (2-3 ms expected)

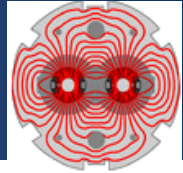
  UFO: shorter than 1 ms
- spiky loss structure

  UFOs are gaussian

RS	Signal (Gy/s)	S/Quech
40 µs	10.28	2.8
80 µs	7.61	2.3
320 µs	2.31	1.2
640 µs	1.99	2.1
2.56 ms	1.46	6.1
10.2 ms	0.73	12.0

For 2.56 ms (typical dump by UFO) signal is higher by factor 6 than expected. Potential increase of BLM thresholds on all cold magnets!

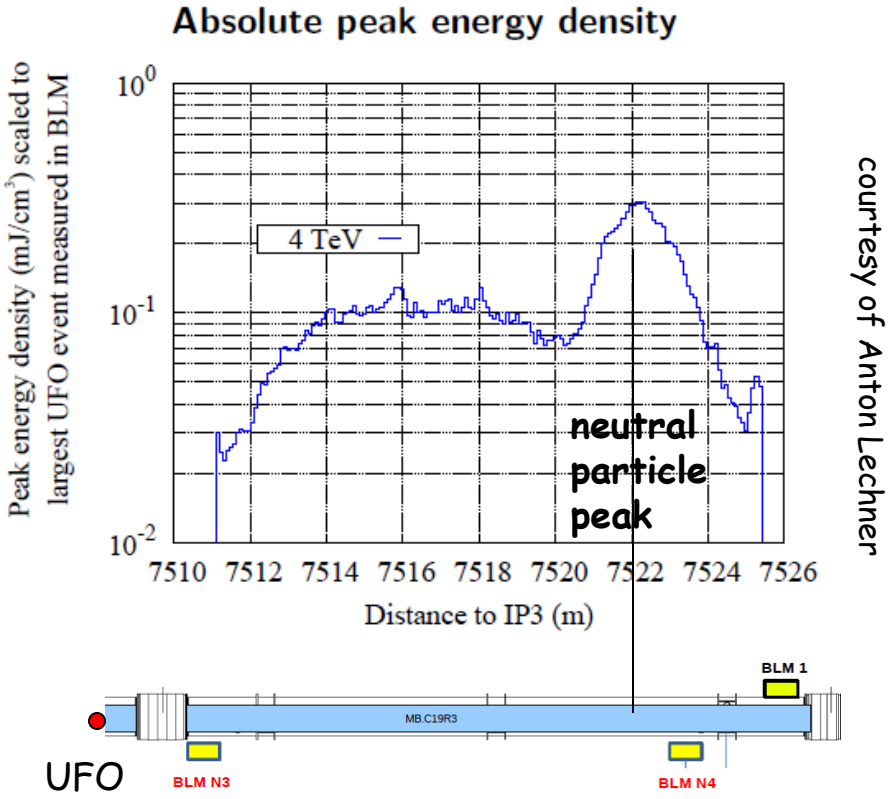
But we must be careful extrapolating to UFOs



• According to simulations (backed up by observations in especially equipped cell) maximum energy deposit is due to **neutral particle peak**.

• Ratio of BLMsignal/E_{dep} ^{coil} might be different than in our experiment.

• To make the analysis more challenging the loss pattern during quench test seems to move from turn to turn.



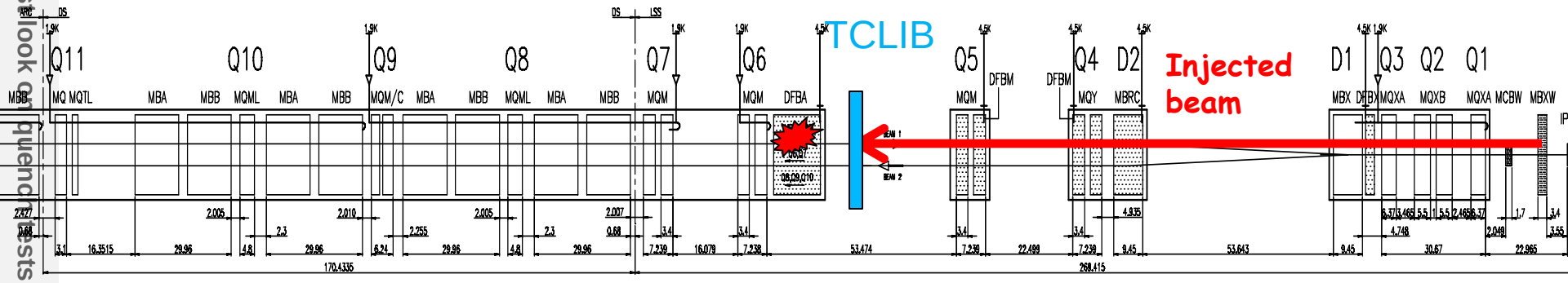
courtesy of Anton Lechner

• Special MAD-X simulations started to understand the time-dependent loss pattern (Vera Chetvertkova).

• FLUKA/Geant4 simulations also necessary

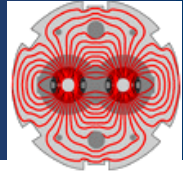
Q6 quench test

Slides by Chiara Bracco



- Emittance from SPS: **H ~0.5 μm, V ~ 0.5 μm ➔ impact parameter 4.5 σ** (full beam intercepted)
- **Pilot bunch 6-6.5e10p+** (probe beam limit increased to 1E11p+)
- Q6.L8 Current steps: 1000 A, 1500 A, 2000 A and **2500A (~ 6 TeV) ➔ Quench!**
- **Fluka studies ongoing, will give us very good quench limit at 6 TeV**

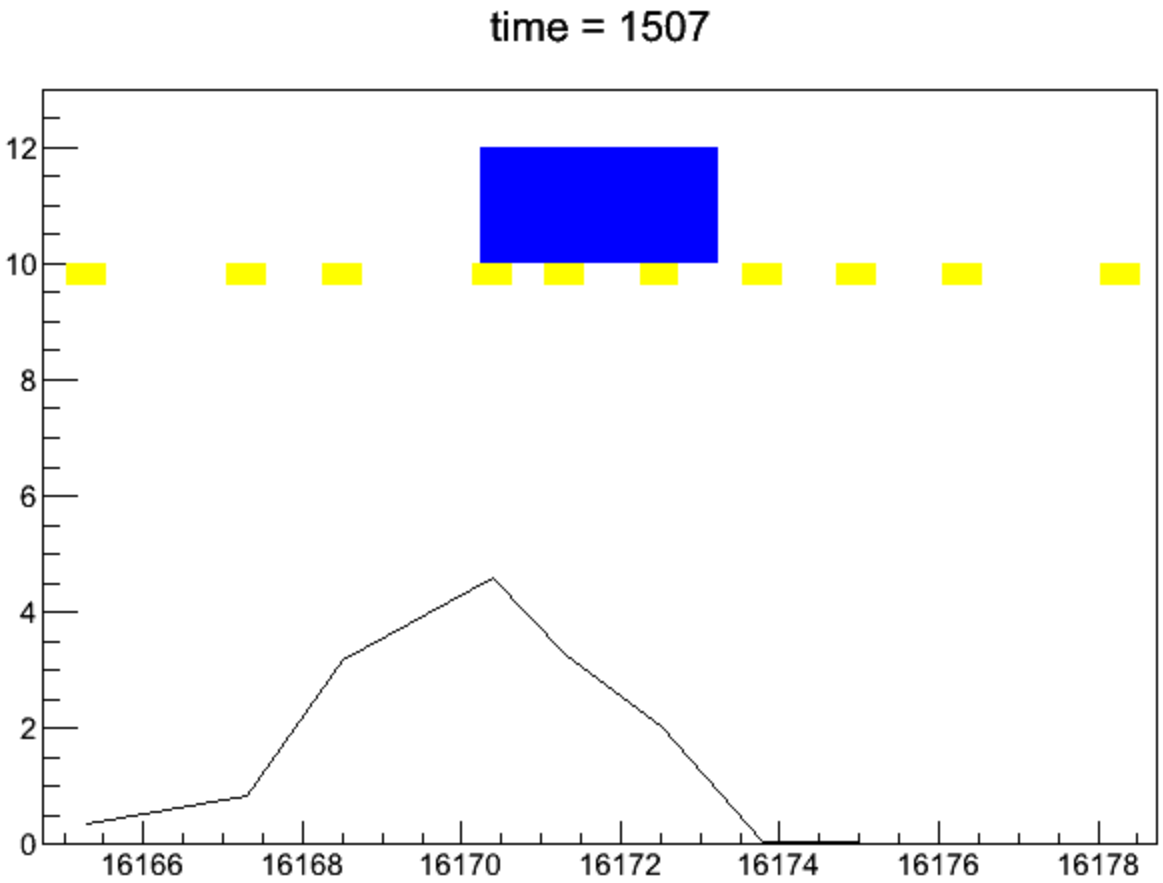
Conclusions



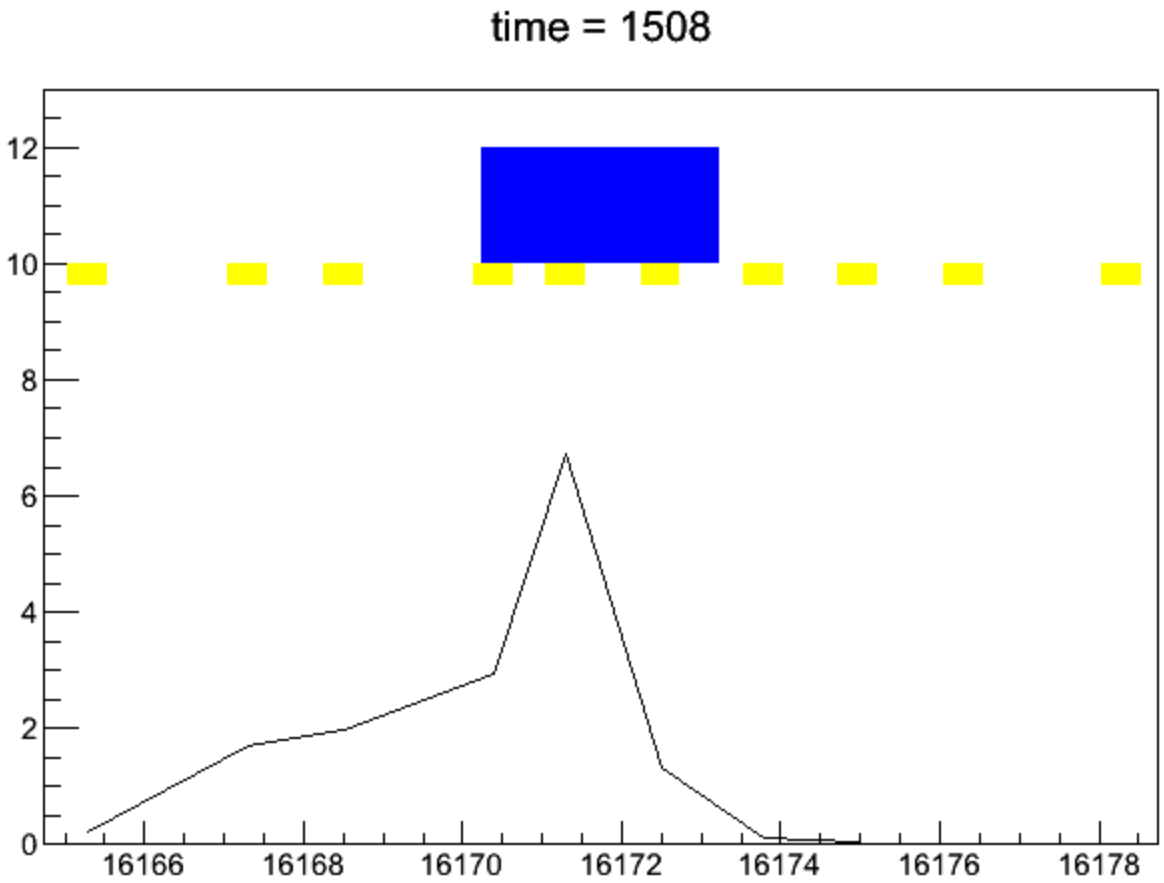
1. Quench Analysis WG has been established (April 9th – first meeting).
2. It will bring together:
    - FLUKA/Geant4 simulations
    - MAD-X/Sixtrack simulations
    - QP3 simulations
    - detailed data analysis
    - extrapolation to 7 TeV.
3. Significant dependence of BLM threshold on assumed loss scenario (possible increase of BLM thresholds in dispersion suppressor regions).
4. Larger than expected quench limit for UFO-timescale losses (possible increase of BLM thresholds on all cold magnets).

Extra slides

ADT loss shape



ADT loss shape



ADT loss shape