BLM thresholds. Past experience and strategy after LS1

E. Nebot, T. Baer, G. Bellodi, C. Bracco, B. Dehning, J. Jowett, E.B. Holzer, A. Lechner,
B. Salvachua, S. Redaelli, A. Priebe, M. Sapinski, J. Wenninger, D. Wollmann,
C. Zamantzas, M. Zerlauth and R. Schmidt.

Outlook

- Threshold calculation reminder: Energy dependence? Time dependence? Loss scenario dependences?
- Thresholds in 2012: Evolution and motivation
- Thresholds for re-located BLMs in the ARCs
- Quench tests. What do we know/expect? How will it affect the threshold strategy?
- Potential limitations and threshold optimization:
  - Noise
  - Triplet magnets
  - Collimation
- Threshold strategy
- Summary and conclusions

BLM threshold calculation and definitions: reminder

- Master threshold (cold magnets)

Safety factor

Energy deposited in BLM

Energy deposited in magnetic coil

Quench margin

$$T(t,E) = 3 \times (E_{BLM}(E) / E_{COIL}(t,E) \times Q_L(t,E)) + \text{Corrections}$$

Monte Carlo (Geant4/FLUKA) dedicated measurements

Monte Carlo (Geant4/FLUKA)

Note 44/QP3

differences between predictions and measurements

- Applied threshold (dump threshold)

$$\mathbf{t(t,E_{beam}) = MF \times T(t,E_{beam})}$$

MF < 1 (Monitor Factor) is independent for each BLM and it gives flexibility.

Evolution during 2012

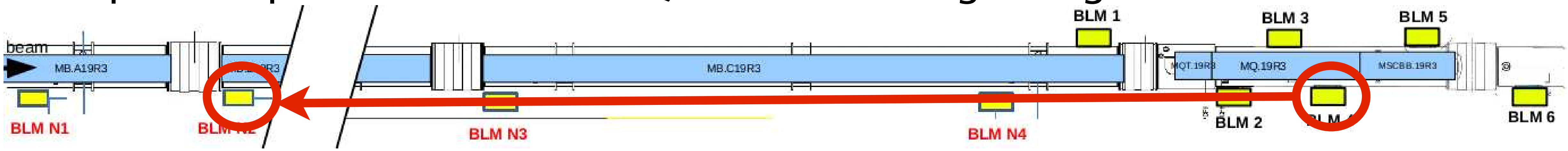
- Reduction in # threshold interventions of ~ factor 2 with respect to 2011
- Changes in 2012 dominated by systematic losses generated by beam instabilities

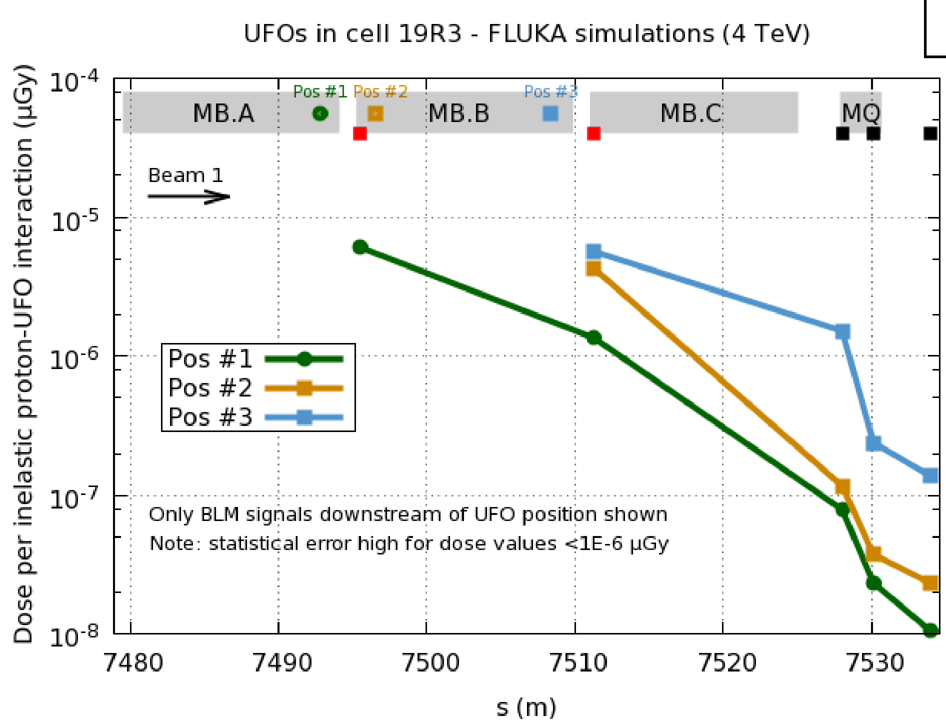
DATE	# of BLMs	LOCATION	Element	COMMENT
12/03/2012	15	L2 & R8	IR2/IR8	Start up. Installation of new BLMs
13/04/2012	48+2	IR3 & IR7/R7	MQW/TCLA	Instb squeeze and collision
19/04/2012	4	4L2, 4R8	MQ	MQY, UFOs
04/05/2012	2	L7	TCLAs	Instb squeeze and collision. MF 0.1 → 0.2
08/05/2012	4	4L6,5L6,4R6 and 5R6	MQY	Instb squeeze and collision. Leakage to IR6. MF 0.1 → 0.2
28/06/2012	41	IR3 & IR7	TCP, TCSG and TCLA	200 kW in IR7 (with margin for 500kW)
13/07/2012	48+24	IR3 & IR7/4,5L6 4,5R6	MQW/MQ	Instb squeeze and collision. MF = 0.5 →1, 0.1 →0.5
25/10/2012	1	6R5	RP	Left accidentally too low. MF 0.1 -> 0.3
08/11/2012	2	6R5, 6L5	RP	MF 0.3 → 1.0. Margin for RP
30/11/2012	18+12	IR3/IR3&IR7	TCP, TCSG and TCLA/MQ	200 kW in IR3 (with margin for 500kW)

COLLIMATORS WARM MAGNETS COLD MAGNETS

ARC BLM relocation I

- Proposed option. Move 2nd MQ BLM to the beginning of MB.B





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Proposed new BLM location based on signal gain

UFO Location	BLM MB.B	BLM MB.C
MB.A	80	13
MB.B beginning	--	50
MB.B end	--	7

- MQ BLM should be reduced by 50 in order to protect against UFOs at MB.B.

- OTHER OPTION. BLM located in the interconnect (vertically and ~ centered between B1 and B2) would cover all possible UFO locations (to be confirmed).

ARC BLM relocation II. Threshold estimation

- Comparison of thresholds for BLM at beginning of MQ and at beginning of MB.B BLM (other MB location requires new estimation of Q_{BLM})

Geant4 – (direct impact) distributed loss/FLUKA – (secondaries) point-like

Note 44/QP3

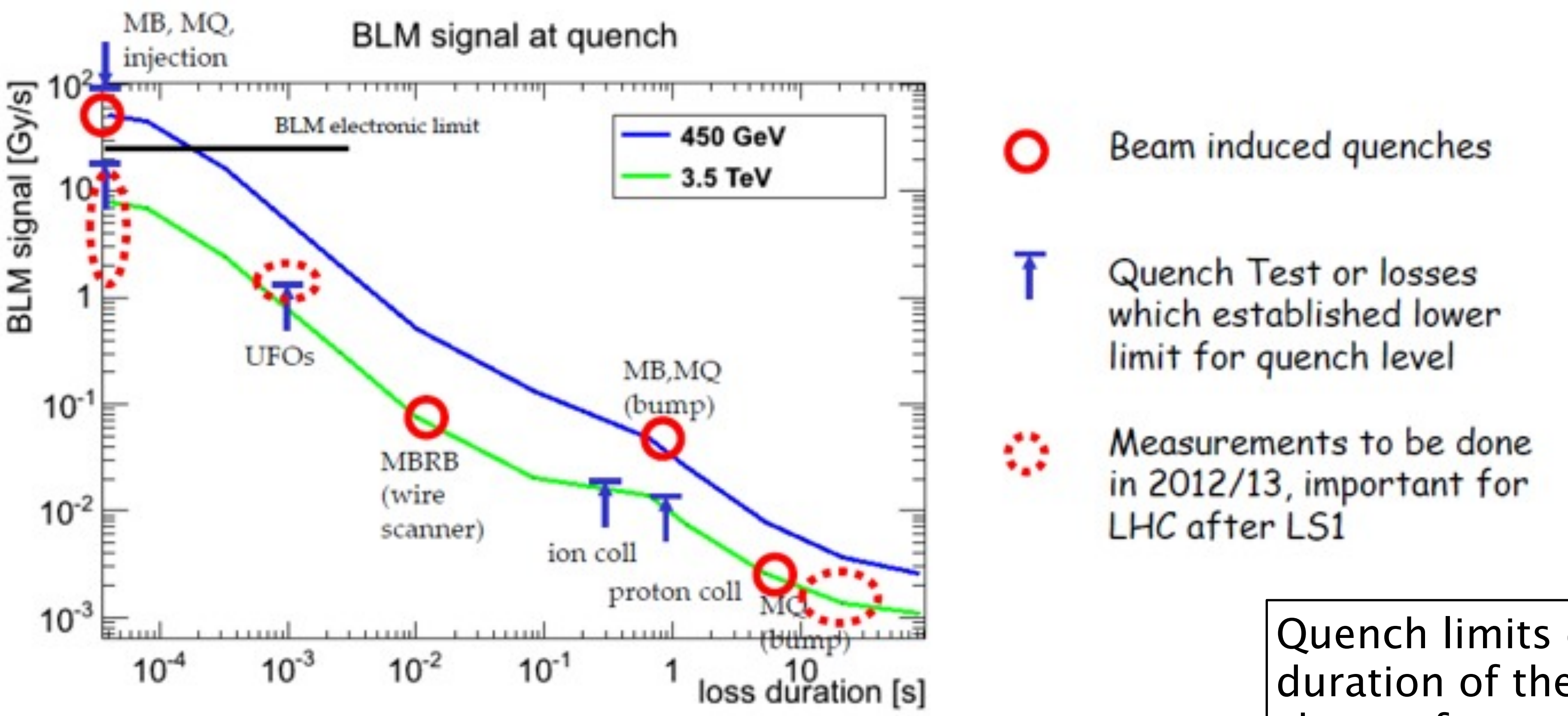
Magnet	Beam energy	E_{BLM} (Gy/p)	Ecoil (mJ/cm^3)	Q_L (mJ/cc)	Threshold (mGy)
MB	3.5 (TeV)	$2x\ 10^{-12}$	$5x\ 10^{-8}$	30	1.2
MQ		$1.1x\ 10^{-11}$	$3.2x10^{-7}$	**5x**6.2	1.14
MB	7 (TeV)	$4x\ 10^{-12}$	$2x\ 10^{-7}$	3	0.06
MQ		$2.2x\ 10^{-11}$	$6.6x\ 10^{-7}$	**5x**1.41	0.23

Agreement/Disagreement at 3.5 TeV/7TeV due to correction applied according to measurements in 2010

Factor 5 at 7TeV may not apply!

- To be tuned with Quench test results.

Quench tests I

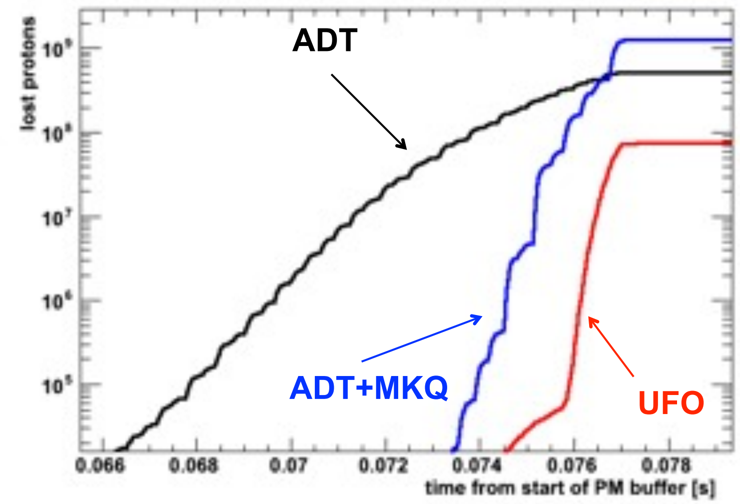


Quench limits depend on beam energy and duration of the loss. Plot shows the generic shape of quench limit in BLMs (Gy/s). It is obtained assuming proportionality between BLM signal and quench limits in coils (mJ/cm^3 or mW/cm^3).

- High priority test
  - ms scale. UFO-like losses
  - Steady-state in DS with collimation system (protons/ions)
- Other proposed test
  - Steady-state with orbital bump
  - Fast losses at injection (Q6L8)

Quench tests II

- ms scale. UFO
  - From QP3 (MB) Q_L =30 mJ/cm^3
  - From one UFO dump in the arc Q_L > 3.9 mJ/cm^3 (s) ~ 10% of expected quench margin (Tobias' presentation)
  - MQ Geant 4 simulations → quench expected for a few 10^8 lost protons
  - ➡ Large scale threshold modification (all cold magnets)



M.Sapinski et al., "UFO timescale quench test preparation", LSWG, 26.10.2012

- Steady-state with collimation system

PROTONS

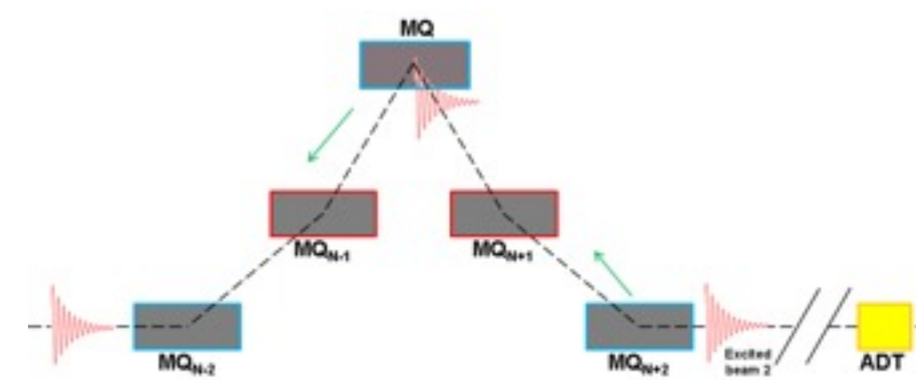
- Reached 500kW without quench
- Reached 70% of assumed quench limit
- Expected to quench for BLM signals ≳ 100% of quench limit
- ➡ Threshold modification at specific locations Q6, Q7, Q8 and Q9 in IR7.

IONs

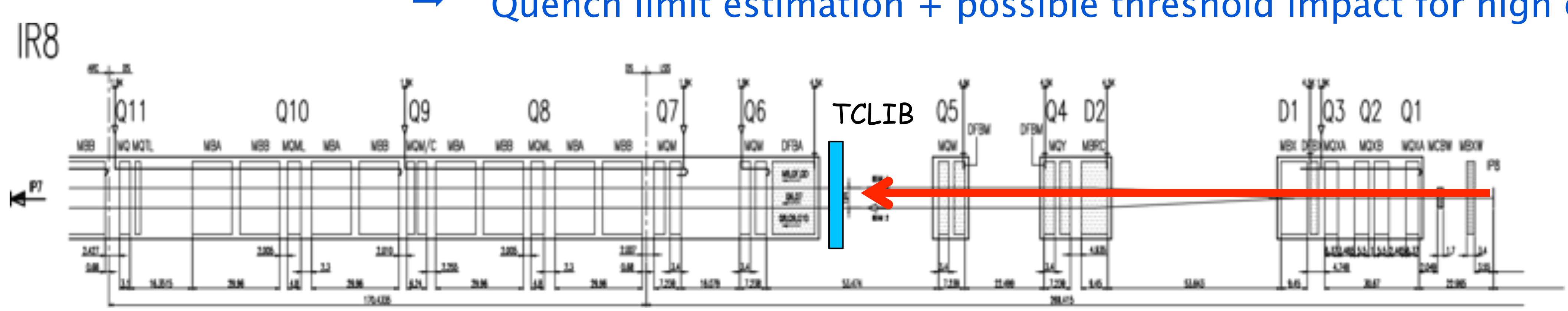
- Reached ~assumed quench limit in shorter time scale
- Need to foresee large scale threshold changes for future tests (global arc threshold raise)
- Expected to quench for BLM signals ≳ 100% of quench limit
- ➡ Threshold modifications like for protons as well and unforeseen location (determined only during test)

Quench tests III

- Steady-state with orbital bump
  - Achieved quench at 0.33% of quench margin for losses of ~5.3 s duration (3.5 TeV) → thresholds corrected.
  - Expected to reach losses in a longer scale (> 10 s) with ADT. Closer to steady-state limit (easier to draw conclusions).
  - Direct benchmark of our simulations. Easiest extraction of quench limit.
  - ➡ Thresholds. Possible impact in all cold magnets.



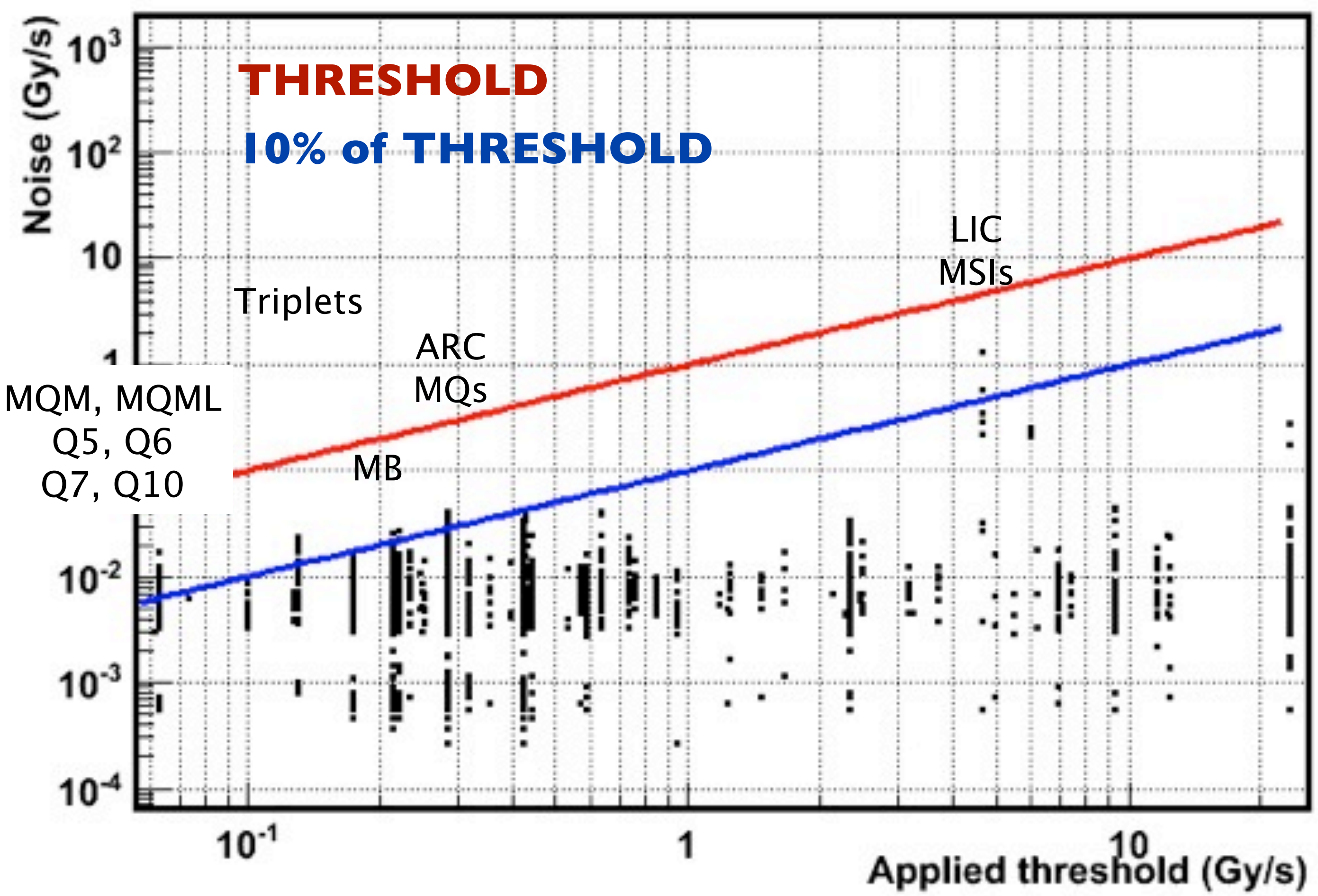
- Q6. Fast losses
  - Study of quench limit vs energy and consequences of async beam dump.
  - Not quench reached on previous test but thresholds uncorrected due to different loss scenario.
  - Only test with 4.5 K (Q6L8) magnet.
  - ➡ Quench limit estimation + possible threshold impact for high energy



Noise and 7 TeV thresholds

- Noise studies over 9 hours of no beam (Example TS 29/06 8 am → 5 pm)

OPERATIONAL MARGIN: NOISE < 0.1 APPLIED THRESHOLD

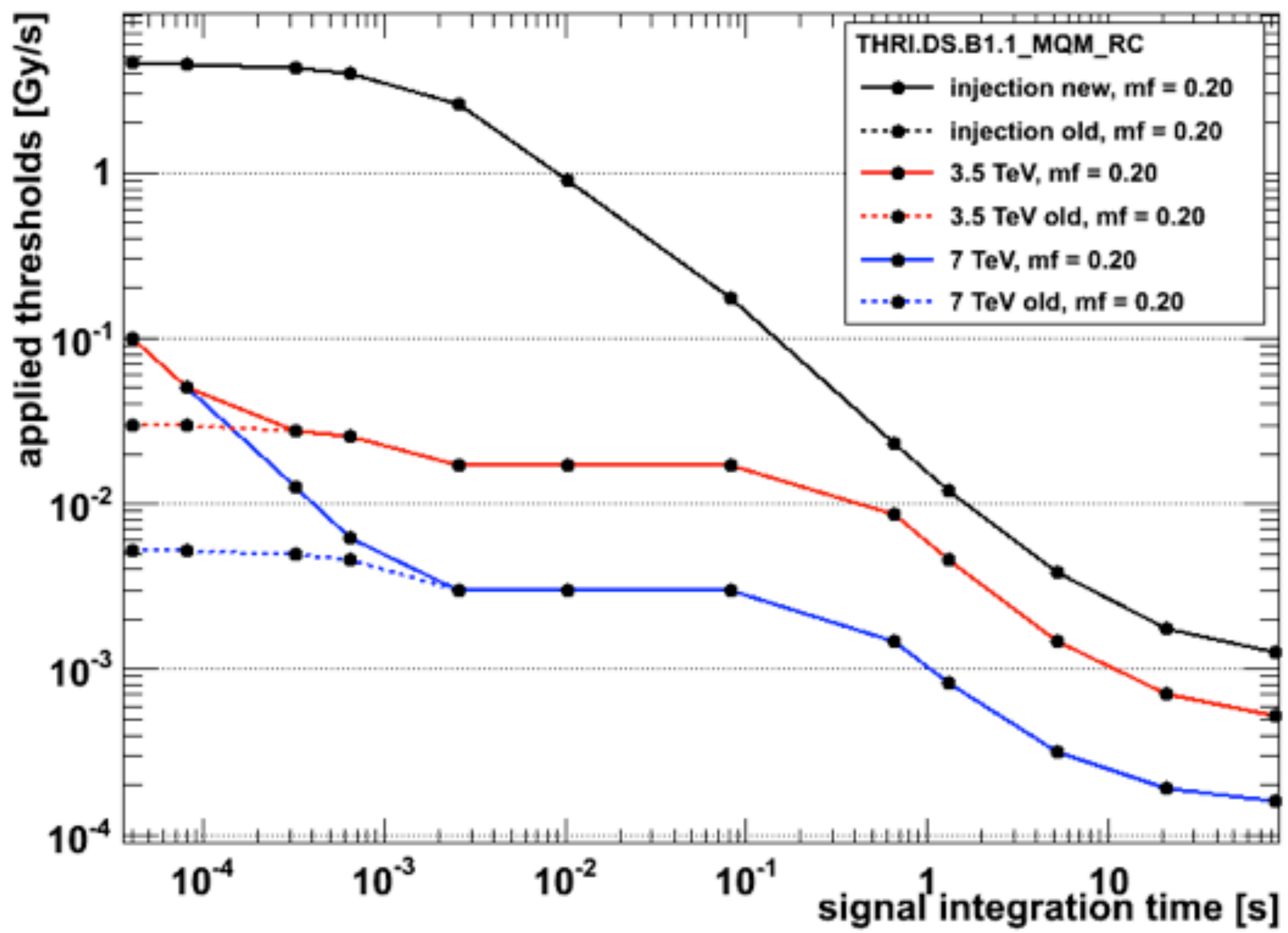


- ~40 monitors over the op margin
- No case with S/T > 0.5 observed
- New cabling (double copper shielding) introduced in during Xmas break
- More cabling to be installed during LS1 that should improve the situation

Noise and 7 TeV thresholds. Mitigation

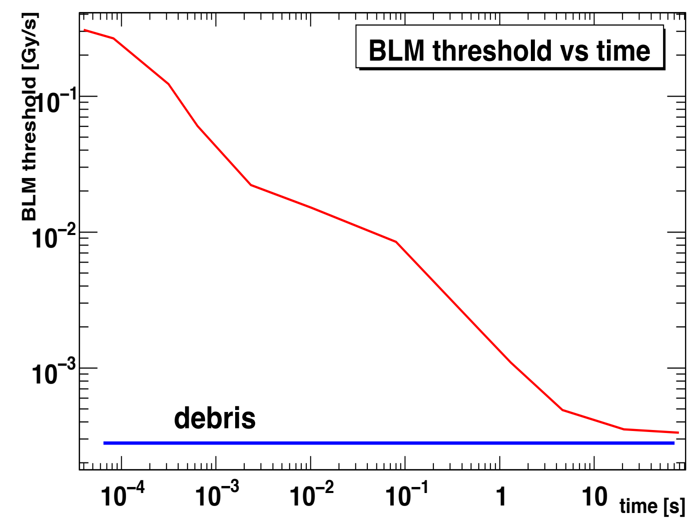
- Operational margin enforced by setting a minimum thresholds
- minimum threshold = 10xnoise ~ 6.0 μGy

APPLIED THRESHOLD MUST BE
BELOW QUENCH LIMIT
OR
BLM REDUNDANCY SHOULD EXIST



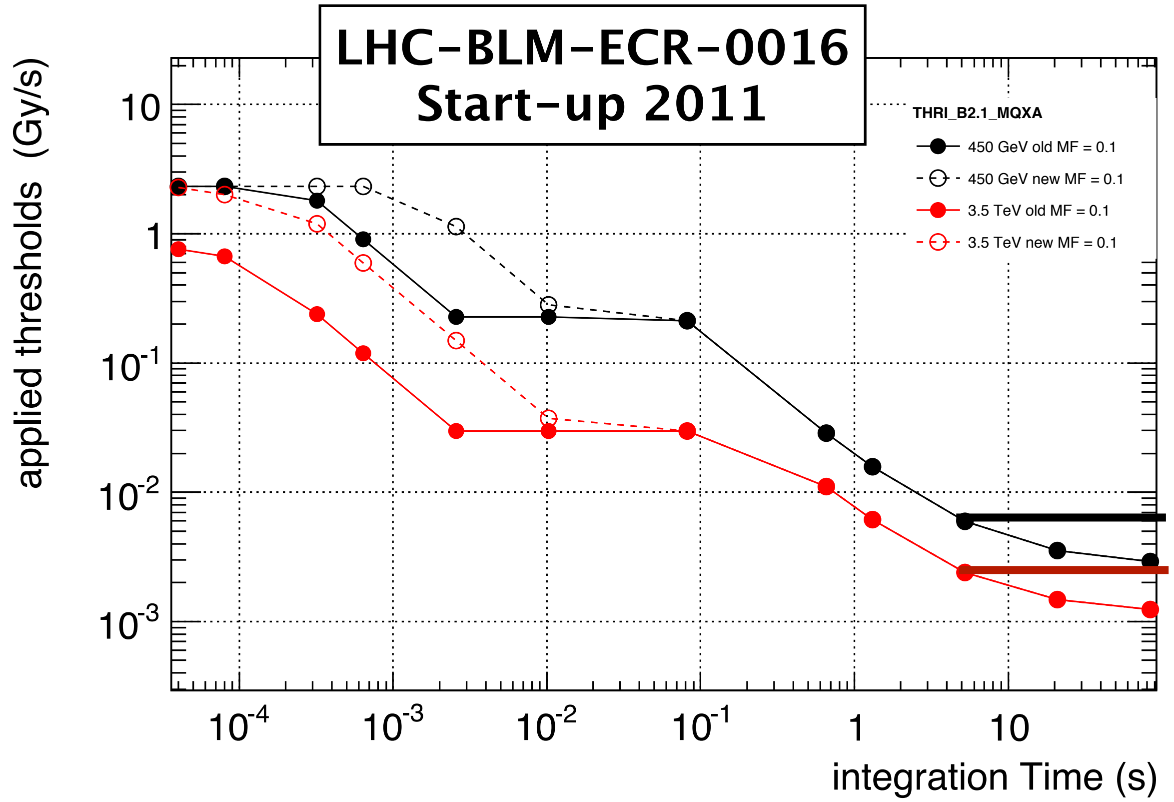
Triplets. Threshold estimation and history

INITIAL THRESHOLD SETTINGS:: FLUKA + Note 44. Edms 1049072
F.Cerutti, B. Dehning, C. Hoa, A. Meregheti, M. Sapinski and E. Wildner.



- Cases studied for steady-state triplet threshold:
  - Beam loss at TAS (E_{coil} (7 TeV)~2-3 10^{-9} mJ/cm^3)
  - Beam loss at triplet (E_{coil} (7 TeV) ~159 10^{-9} mJ/cm^3)
  - Particle debris (E_{coil} (7 TeV) ~ 5 x 10^{-9} mJ/cm^3)

- The thresholds for the steady-state case where increased in order to allow for luminosity induce losses.

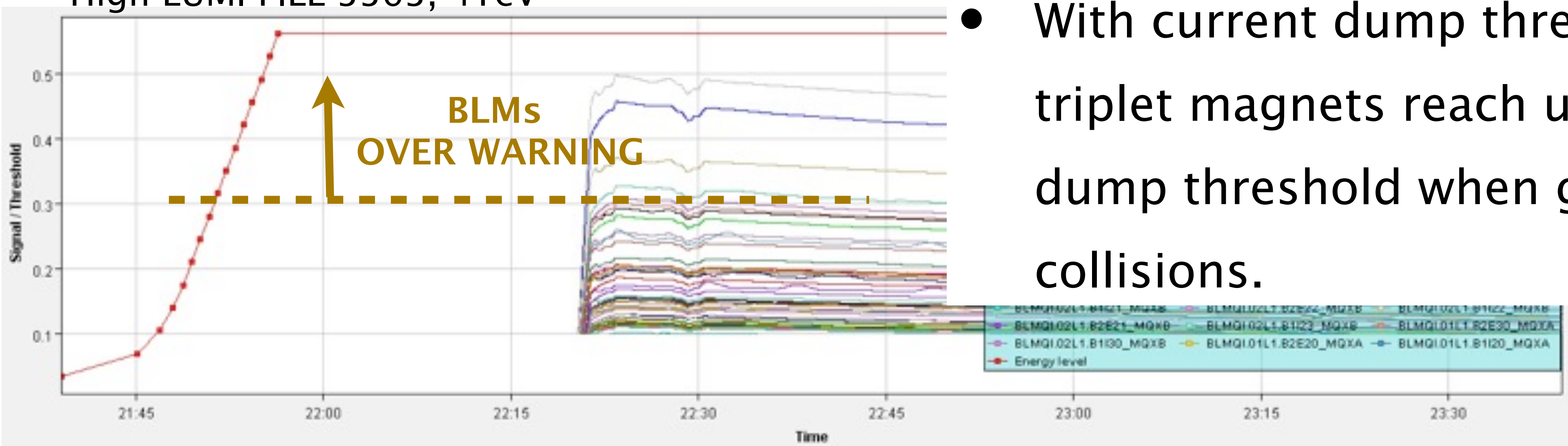


Steady state thresholds for cold magnets (except triplets) were decrease due to an overestimation of the quench margins (quench test with orbital bump in 2010)

Are we running unprotected against quench steady-state due to losses at triplets?

Triplets. Current situation

High LUMI FILL 3363, 4TeV



- With current dump thresholds, BLMs at triplet magnets reach up to ~50% of dump threshold when going into collisions.

- Consequences of beam energy increase (7 TeV):
  - BLM signal increase by a factor ~(1.0-3.3).
  - Threshold decrease by a factor ~ 4.5.

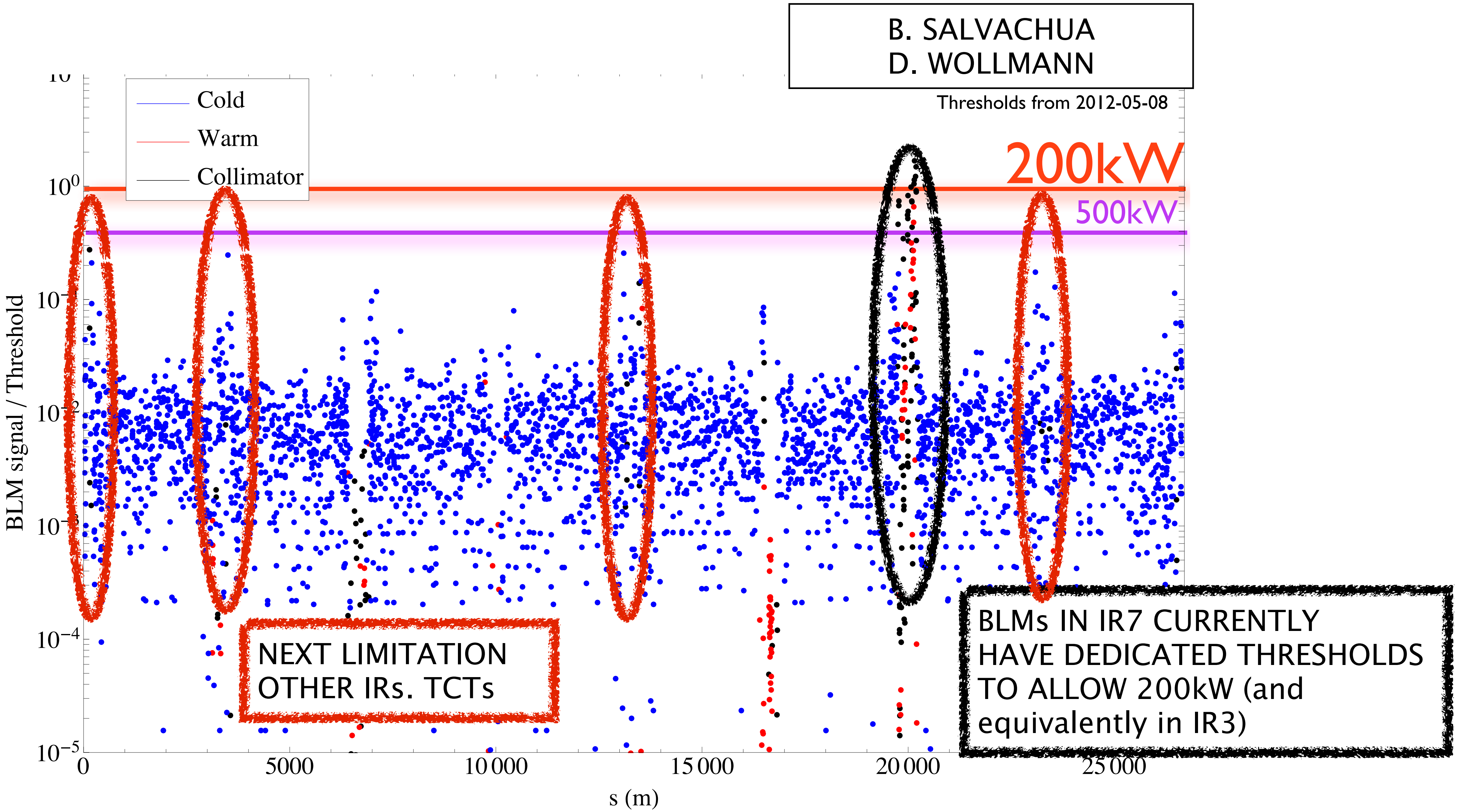
→ **S/T = (225-742)%!!!**
+ SCALING FACTOR DUE TO LUMINOSITY INCREASE

TO BE REVISITED

- Currently using very conservative values for steady-state quench margins:
  - MQ 24mW/cm^3 @450GeV and 5mW/cm^3 @7TeV (divided by 3 as measured in 2010).
  - Triplet 50mW/cm^3 @450GeV and 12mW/cm^3 @7TeV.
- Tuning according to loss scenario?
- More direct measurement of energy deposits in the coil. Investigating location of diamond detectors in the cold mass (not for LS1)

Optimization of collimation thresholds

- Originally very conservative thresholds set by collimator type.
- Dump thresholds to allow higher power loss estimated from loss maps



Threshold Strategy for after LS1

- A large campaign of BLM threshold changes is to be expected: All cold elements + small fraction of collimators.
- Systematic analysis of the several quench tests is required. We need to:
  - Measure BLM signals at quench.
  - Understand the particle loss distributions.
  - Estimate quench levels.
  - Extensive comparison of the accumulated data and quench calculation algorithms (QP3/Note 44).
- We can profit from the experience gained during operation 2010/2011/2012.
- Difficult to cover all possible limiting situations + relatively dramatic change on machine parameters = Expect some thresholds interventions during first few months after start-up.
- Can we improve predictability?

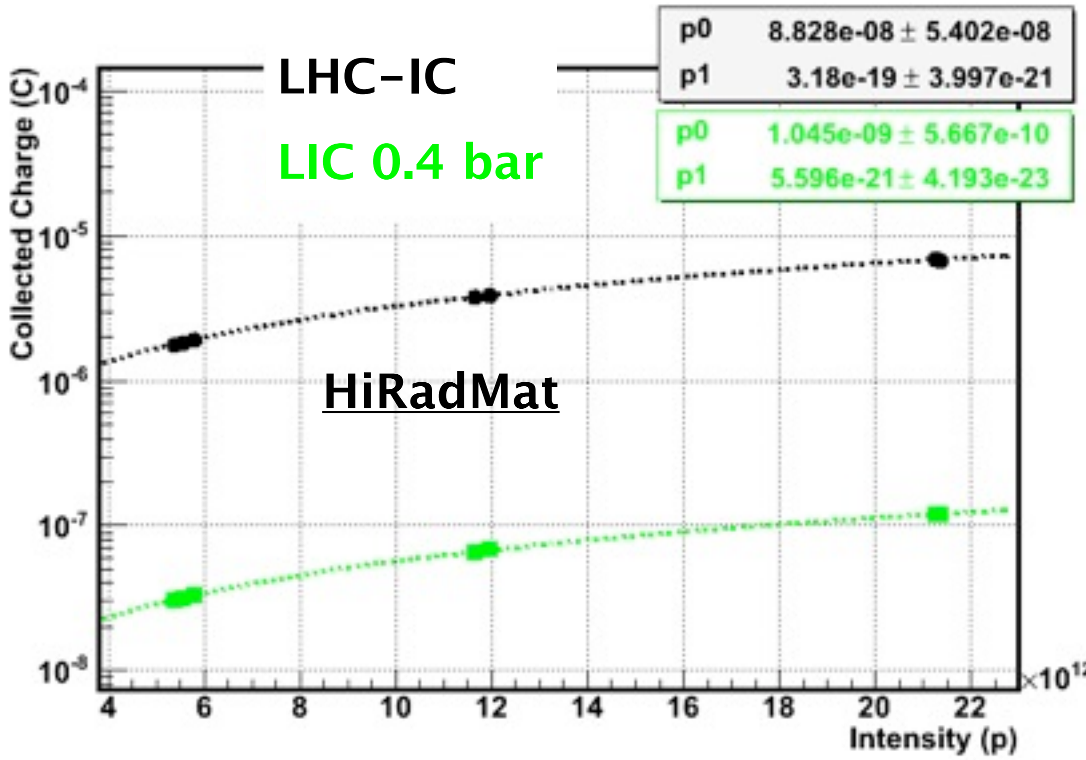
Summary and conclusions

- Significant reduction on threshold interventions respect to 2011 (as expected since we tune as we learn).
- Most of the BLM thresholds will be recalculated for after LS1 run.
- Identified limitations: Noise/triplets/collimation (leakage into TCTs)/more?
- Quench margin understanding mandatory for energy reach.

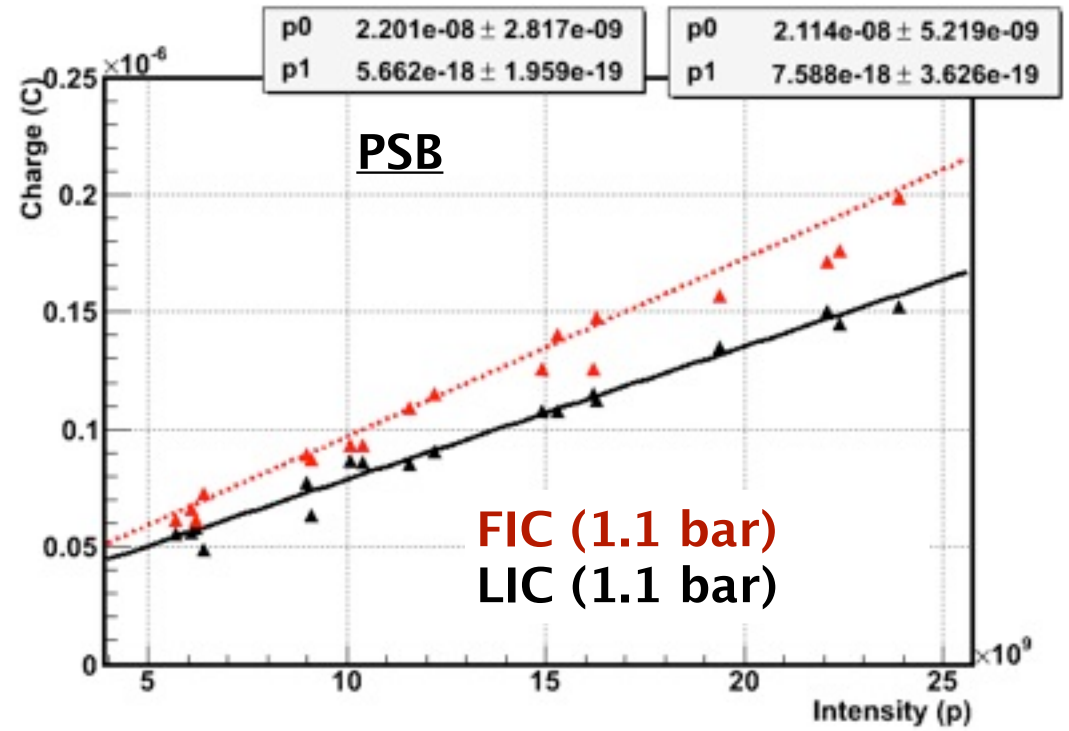
Thanks for your attention

Extra Slides

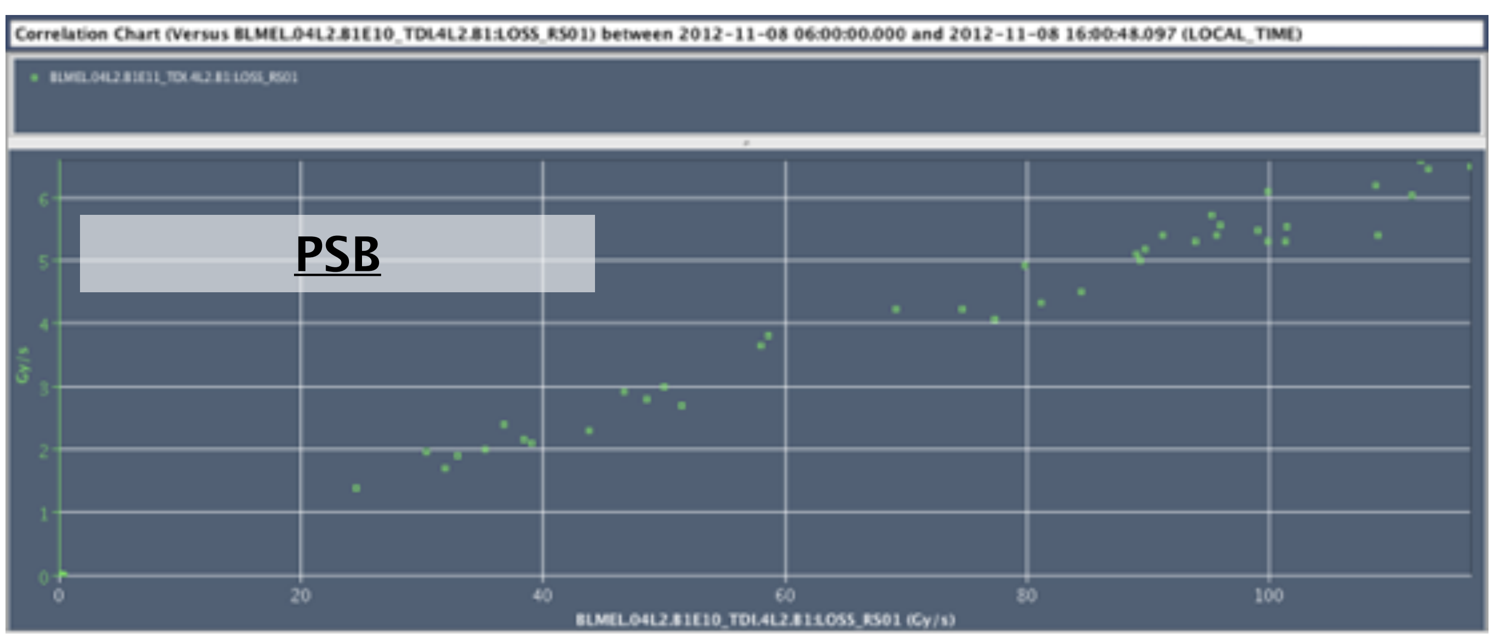
LIC new measurements



- Up to 144 bunches (~1.5x 10^{10}p)
- Linear dependence (up to 500 Gy/s in RS01).
- SIC/SLIC ~60 as previously measured.



- Single bunch (~60 ns, 0.5-2.0x 10^{10}p)
- No undesired effects for large charge densities



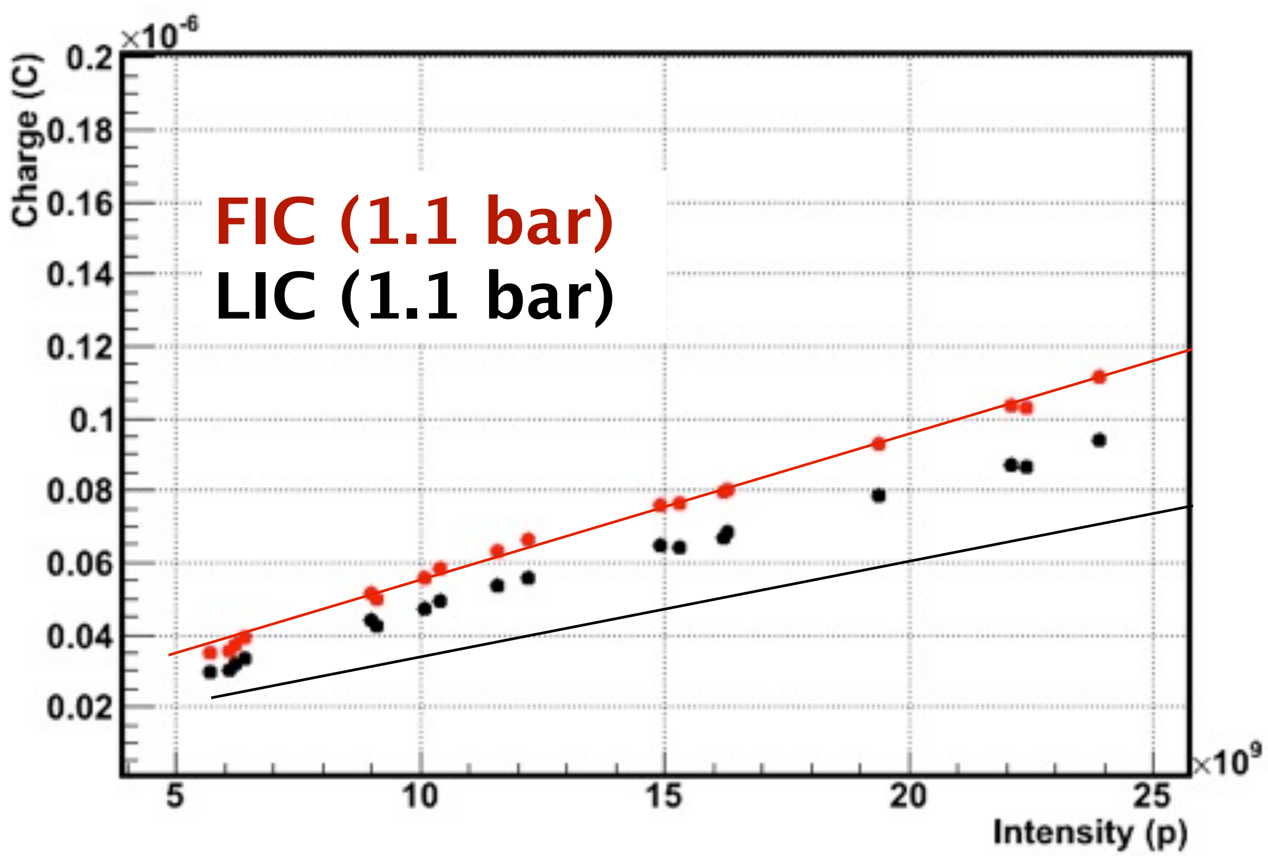
- Preliminary measurements at LHC show linear response of new (re-filled) chambers vs negihbouring monitors.

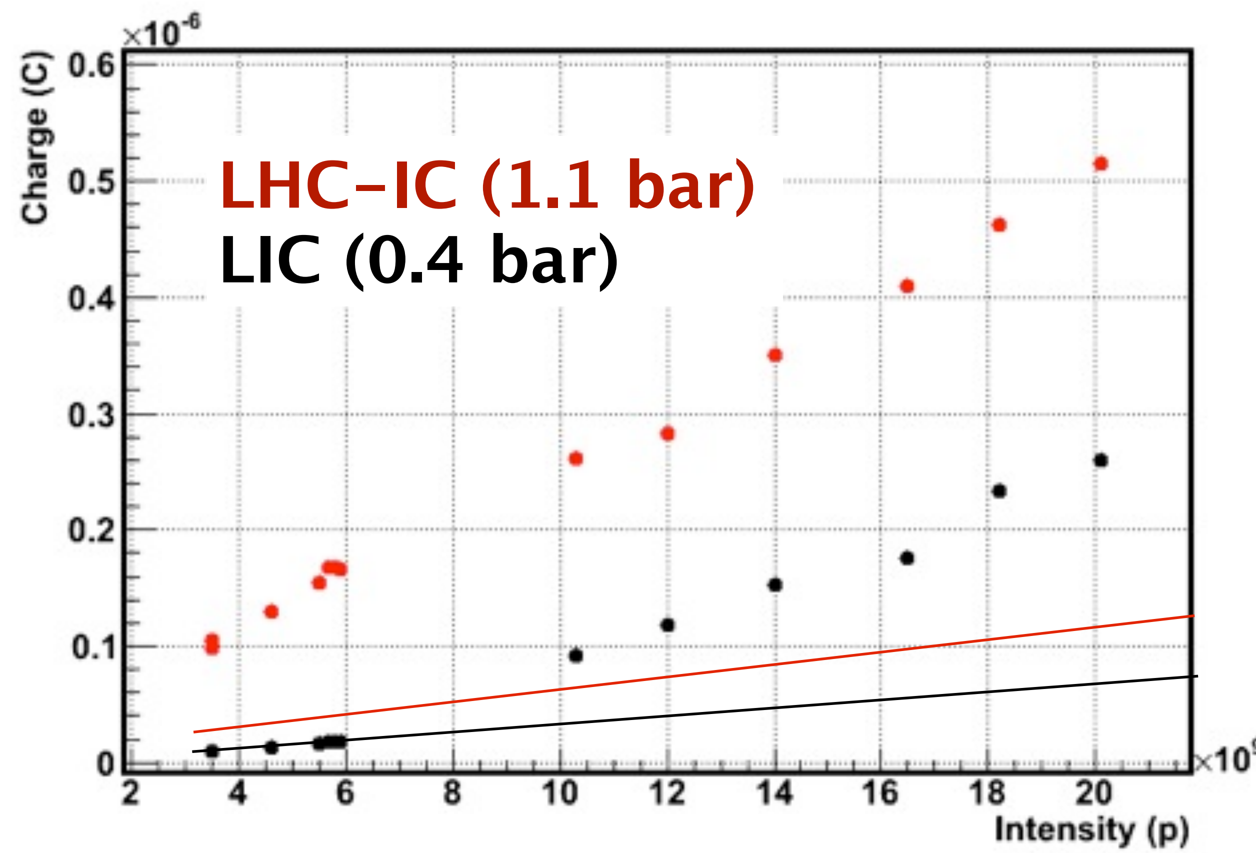
Intensity scan

Comparison with previous test

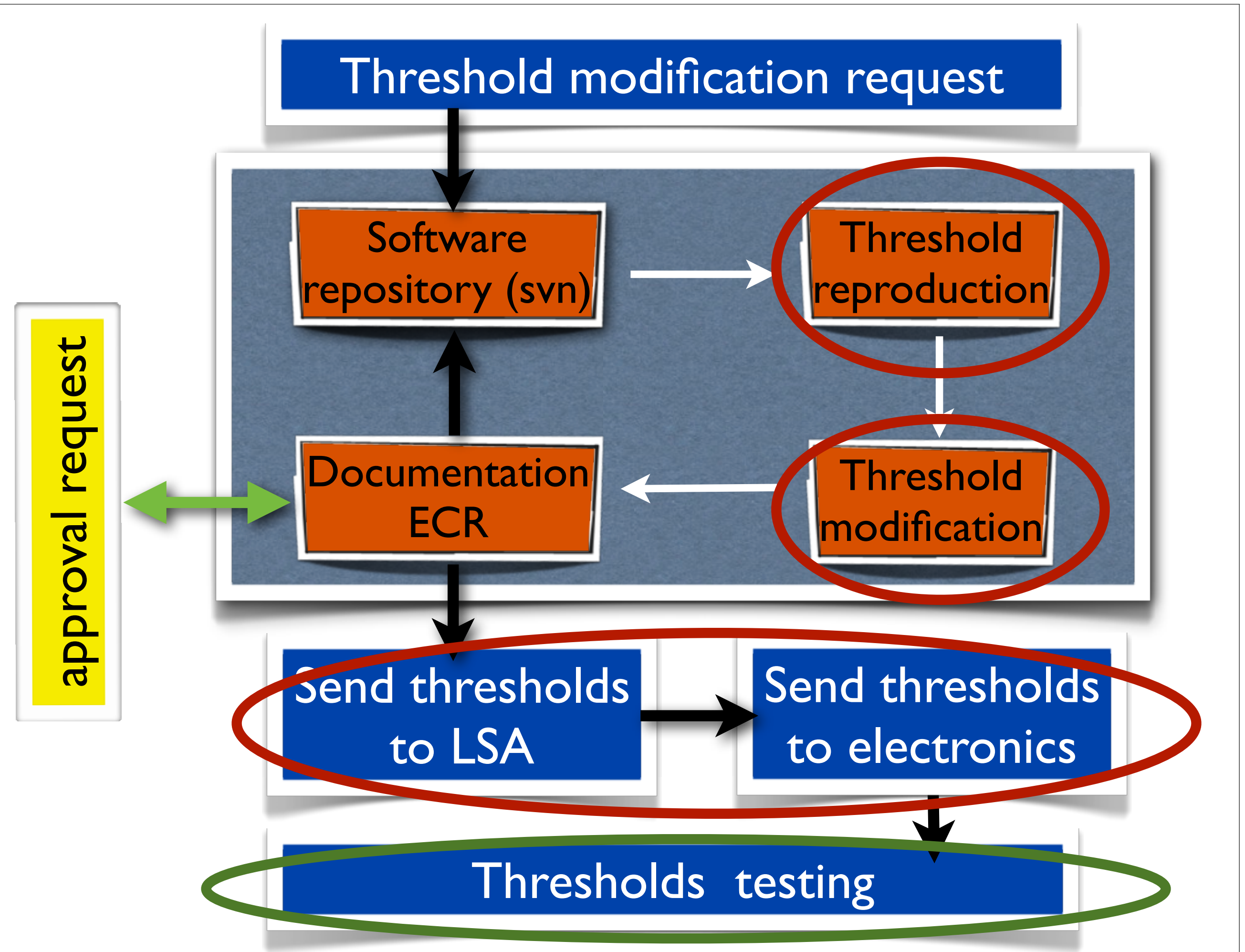
Integrated charge (1 μs)

Unexpected behaviour for LIC 0.4 bar for I > ~7.0 E+10





Deployment procedure



About 1.5 Million values highly critical for the proper functioning of the LHC need to be handled.

4000 (BLMs) x 12 (RS) x 32 (Eb)= 1.5E+6

A specific procedure is followed every time a new set of dump thresholds have to be introduced in the system

A set of tests are executed during the threshold deployment in order to minimize the probability of introducing wrong parameters into the system:

- During the manipulation process: threshold reproduction, modification and send to electronics.
- After the manipulation process: once the thresholds have been pushed to LSA and the electronics.

Signals at triplets and luminosity

- Correlation between BLM signal and instantaneous luminosity.

Triplets

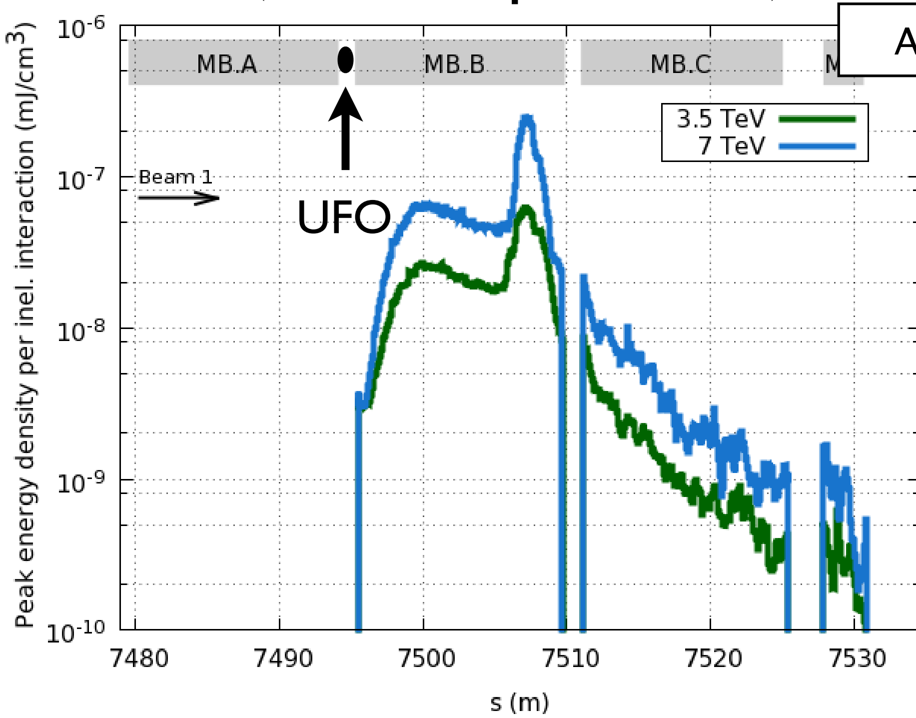
- Triplet thresholds? What at 7TeV and high Lumi.
  - Select 2-3 high lumi fills. See evolution of S/T over the beginning of the fills (when lumi is highest). Get S/T for the highest triplet monitors (see differences in thresholds between MQXA,MQXB and why?) and try to extrapolate. 1) measured signal to 7 TeV threshold. 2) extrapolated signal at 7TeV to current TeV threshold

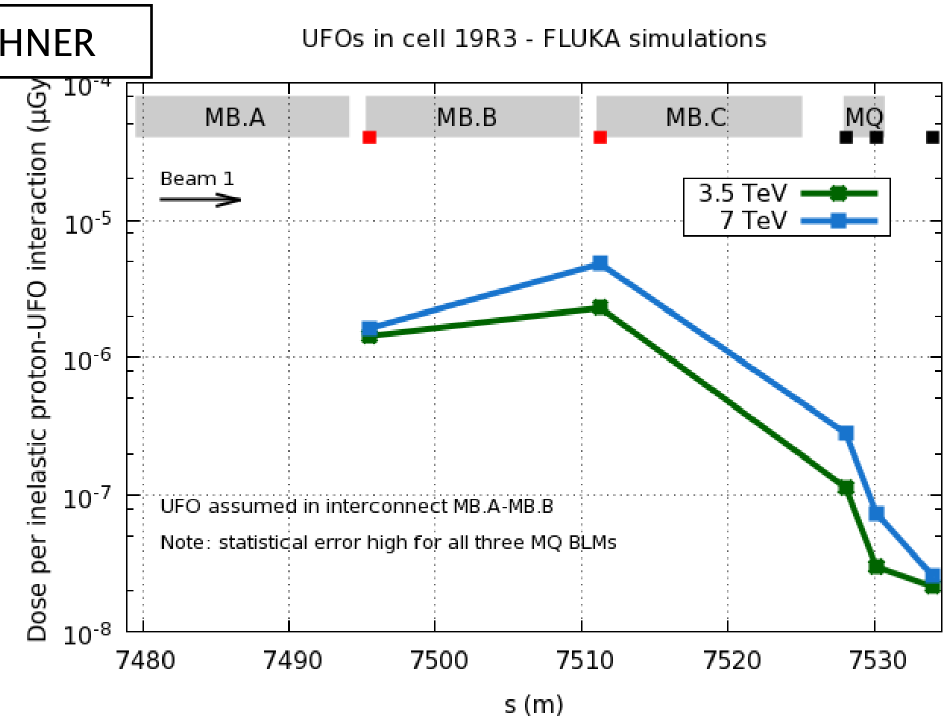
Fill	Date start	duration	Energy (TeV)	Peak Lumi (ATLAS)	norm emittance	beta*
3363	12/02/2012 20:54	11:36	4	6948	2.58	0.6
3231	10/27/2012 13:05	1:56	4	7320	2.39	0.6
3347	11/29/2012 23:30	9:50	4	7553	2.13	0.6
3207	10/21/2012 23:39	4:12	4	7611	2.52	0.6
2988	08/24/2012 04:07	7:29	4	7726	2.29	0.6
2256	10/26/2011 15:30	0:08	3.5	3648	---	1.0
2242	10/23/2011 09:02	10:25	3.5	3553	---	1.0
2219	10/16/2011 08:14	08:14	3.5	3502	---	1.0

ARC BLM relocation

- UFO in interconnect MB.A-MB.B. Large peak energy density deposited at the end of MB.B (neutral particles).

A. LECHNER

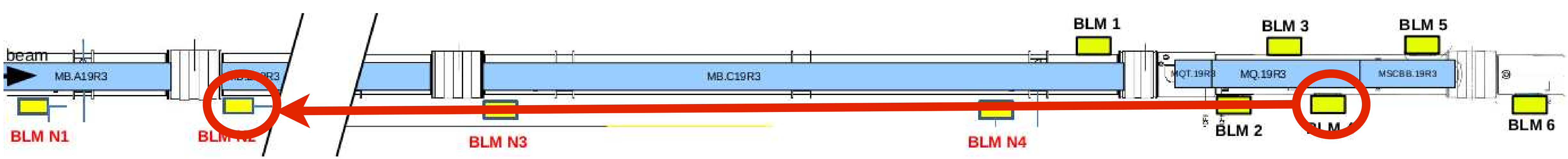




- Protection of MBs with current installation would require threshold decrease.
- Proposed new BLM location based on signal gain.

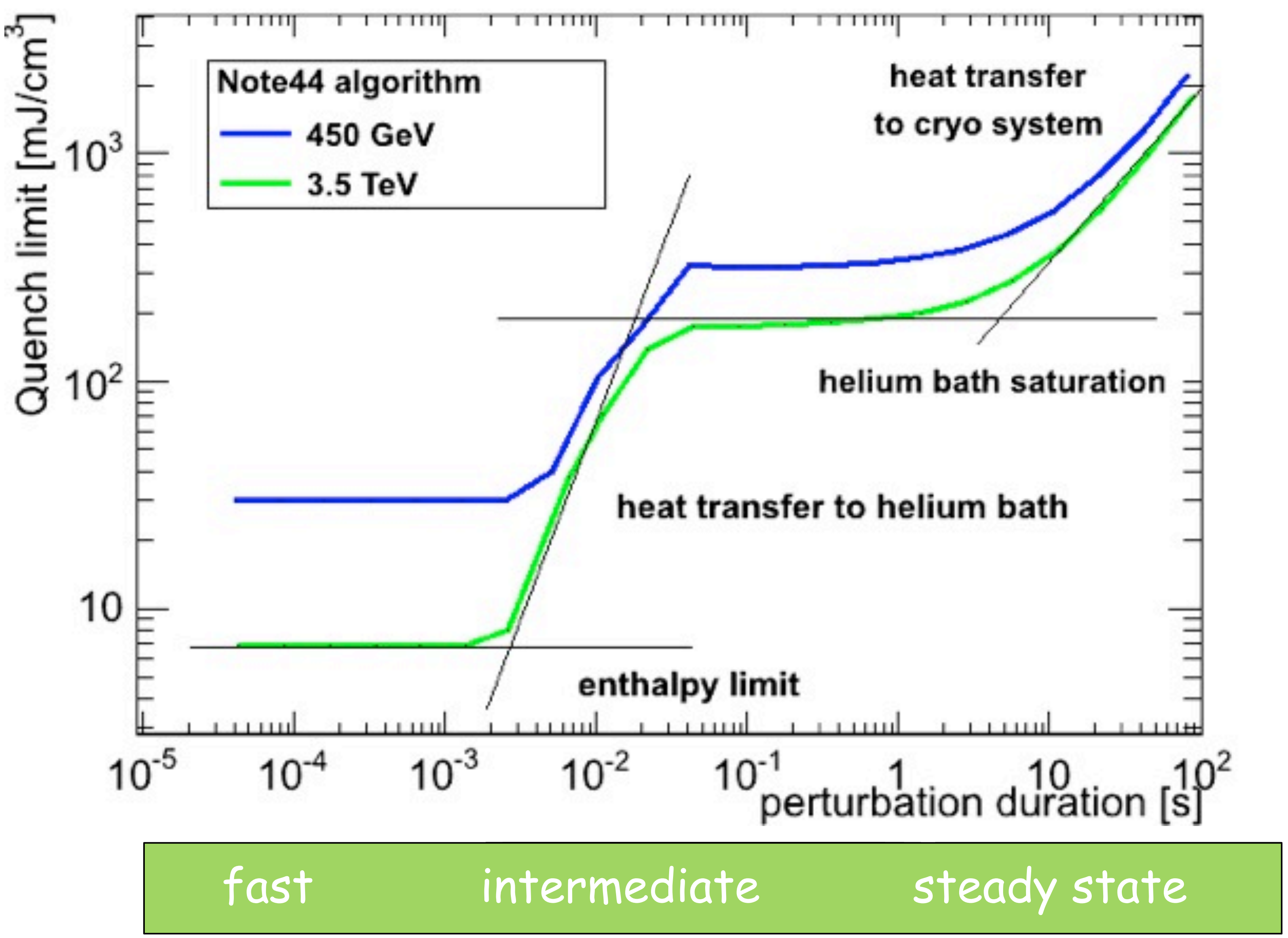
M. SAPINSKI

UFO location	BLM on MB.B	BLM on MB.C
MB.A	50	5
MB.B beginning	-	20
MB.B end	-	5



Time dependence

- Fast losses – easy enthalpy calculation.
- Steady state losses – models and measurements.
- Intermediate losses – difficult modeling.
- Different for 1.9 K and 4.5 K magnets.
- Different for various cables.



Quench levels

- ✓ Quench level for MQ @ 3.5 TeV