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Proposal for post-LS1 thresholds in the arcs

Overview

- BLM Thresholds Formula
- Pre LS1 thresholds and corrections based on operational experience.
- Strategy for a threshold update in the arcs.
- Case study of BLMs in position 1 on MQ.
- Roadmap for new thresholds in DS and SS, and beyond.

BLM Thresholds

- Current from the ionization chamber is integrated over 12 different time intervals (running sums) ranging from 40 µs to 84 s.
- Thresholds are set for 12 running sums and 32 energy levels.

BLM Threshold Formula

- The assumed signal at quench is composed of three input factors:

$$\mathrm{BLMSignal@Quench}(E,t) = \frac{\mathrm{BLMResponse}(E,t) * \mathrm{QuenchLevel}(E,t)}{\mathrm{EnergyDeposit}(E,t)}$$

$$\mathrm{Gy} = \frac{\mathrm{Gy/p} * \mathrm{mJ/cm^3}}{\mathrm{mJ/(cm^3 p)}}$$

- The MasterThreshold is a multiple of the BLMSignal@Quench.

$$\mathrm{MasterThreshold}(E,t) = N * \mathrm{BLMSignal@Quench}(E,t) * \mathrm{AdHoc}(t)$$

- The AppliedThreshold is set with the MonitorFactor [0…1].

$$\mathrm{AppliedThreshold}(E,t) = \mathrm{MonitorFactor} * \mathrm{MasterThreshold}(E,t)$$

- The factor *N* shall ensure safety from damage while providing flexibility and room to correct for uncertainties via the MonitorFactor. Pre LS1 *N* = 3.

BLMs pre LS1

- Thresholds set for orbit-bump scenario in MQs.
- BLMResponse and EnergyDeposition based on C. Kurfürst diploma thesis.
- QuenchLevels based on Report 44 and D. Bocian studies.

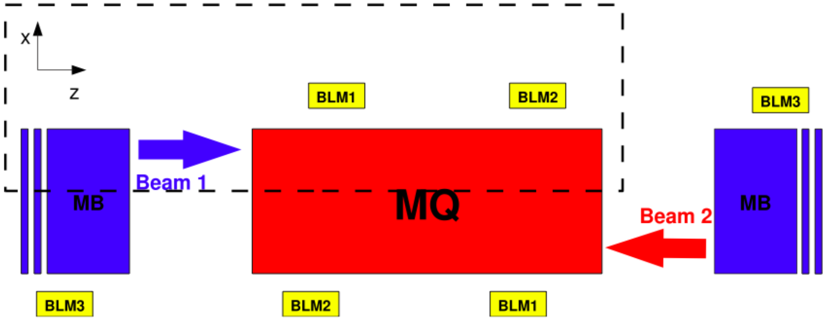
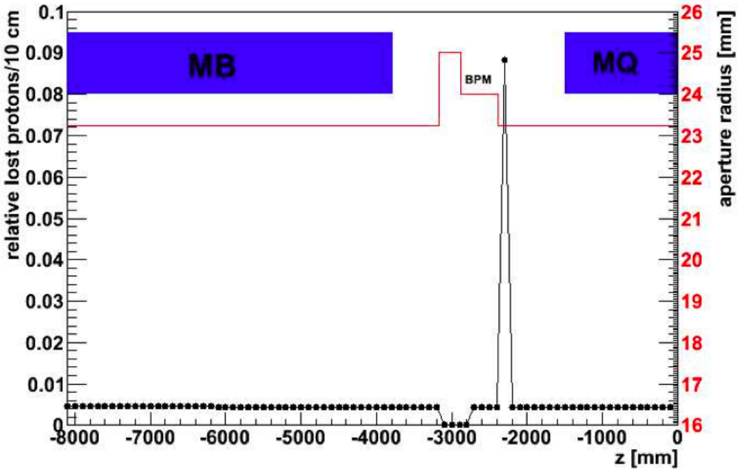


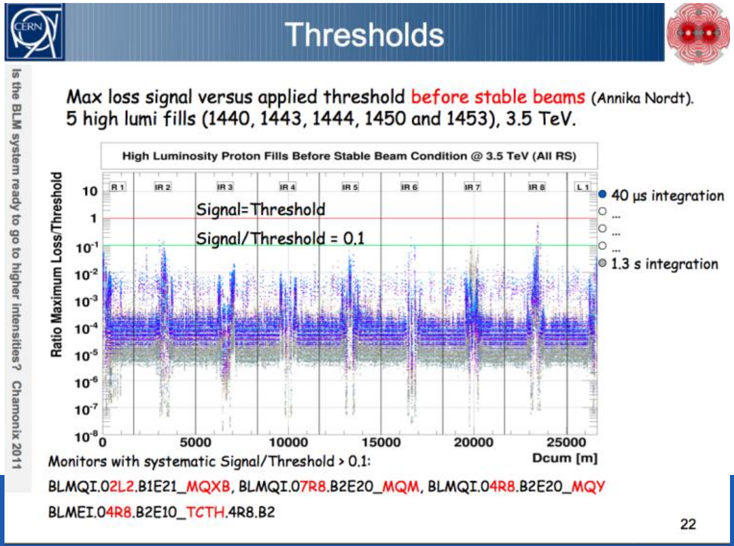
Figure 5.15: Map of the BLM positions for both beam lines. MQ designates the superconducting coil and not the entire cold mass with corrector magnets. The region inside the dashed line corresponds to the overview of the interconnection given in figure 5.2.

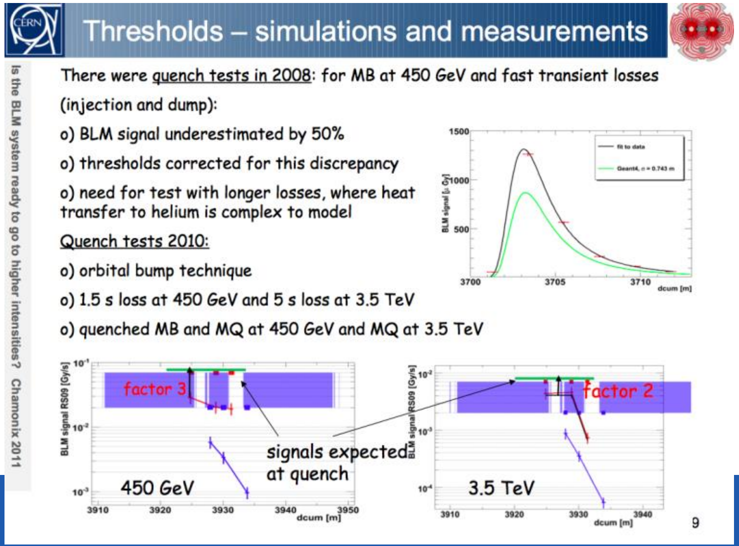


C. Kurfürst, Diploma Thesis, Quench Protection of the LHC Quadrupole Magnets.

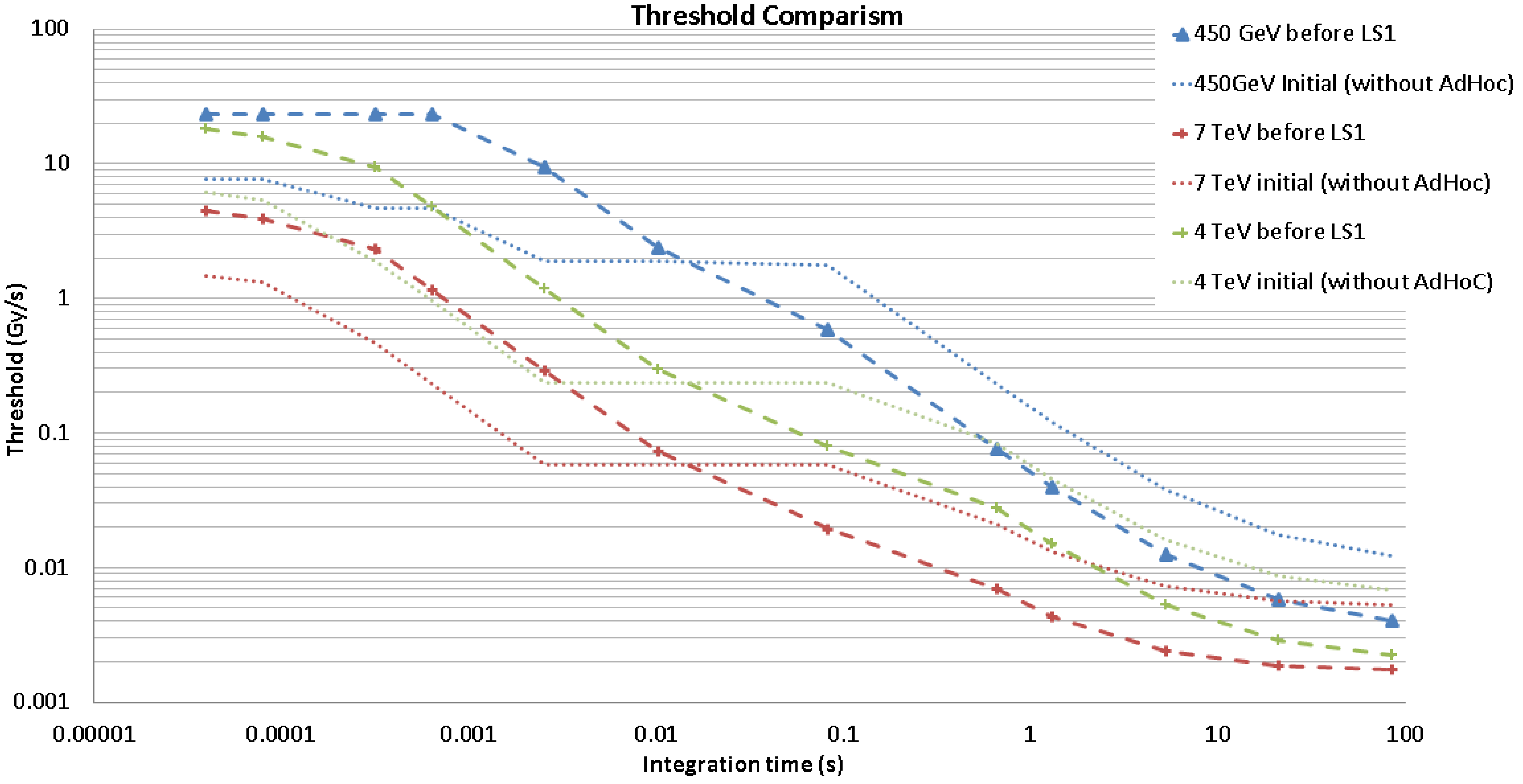
MasterThreshold AdHoc Corrections

- Max. BLM signals shortly before stable beams @ 3.5 TeV
  - BLM thresholds increased by factor 3 in short running sums.
- UFO events without quench.
  - BLM thresholds increased by factor of 5 in ms-range.
- Dynamic orbit-bump QT.
  - BLM thresholds reduced by factor 1/3 in long running sums.
- All corrections were used for all magnet types and around the ring.





MasterThreshold AdHoc Corrections



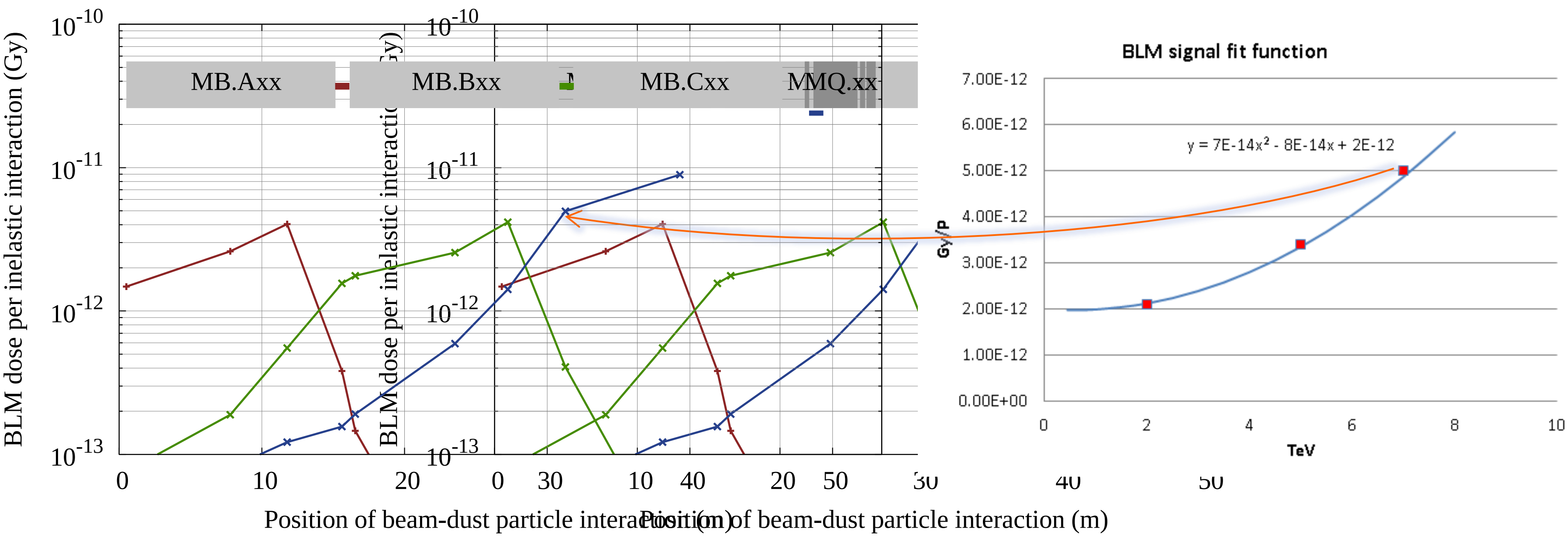
Post LS1 Arc Strategy Proposal

- What are the relevant scenarios in the arc?
  - The most likely scenario is U.F.O. for intermediate-duration running sums.
  - The orbit bump scenario is extremely unlikely in any running sum.
  - A gas leak, albeit unlikely, could be of interest for long running sums. (Scenario is related to the U.F.O., but with fixed loss origin in the interconnects.)
- Problem: No likely loss scenarios for very short and very long running sums.
- Therefore we propose 3 options for the arcs:
  1. Use U.F.O. scenario throughout.
  2. Use U.F.O. scenario up to RS07 (0.08 s) and gas-leak scenario above.
  3. Use U.F.O. scenario up to RS09 (1.3 s) and keep thresholds constant above (effectively discarding long running sums).
- In what follows we discuss option 1.

$$\mathrm{BLMSignal@Quench}(E,t) = \frac{\mathrm{BLMResponse}(E,t) * \mathrm{QuenchLevel}(E,t)}{\mathrm{EnergyDeposit}(E,t)}$$

U.F.O. BLMResponse

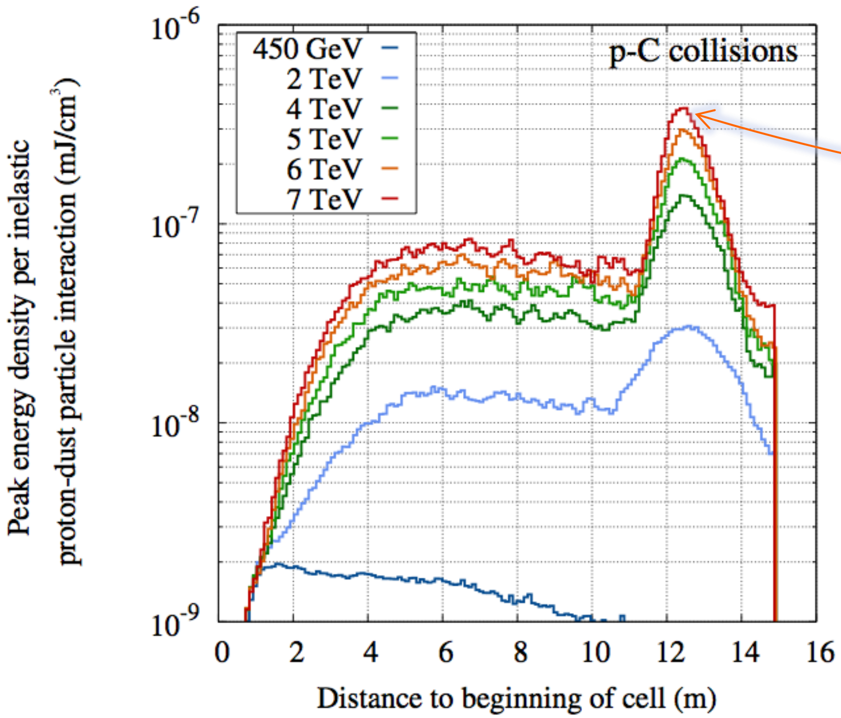
- BLMs moved from MQ position 2 above MB-MB interconnects.
- FLUKA study of collision proton/carbon by A. Lechner.
- Sensitivity of BLMResponse w.r.t. U.F.O. location and beam energy:



$$\text{BLMSignal@Quench}(E,t) = \frac{\text{BLMResponse}(E,t) * \text{QuenchLevel}(E,t)}{\text{EnergyDeposit}(E,t)}$$

U.F.O. EnergyDeposit

- Energy deposition for p-C collsion at the beginning of an MB.
- Maximum due to neutral particles and sagitta in the MB.



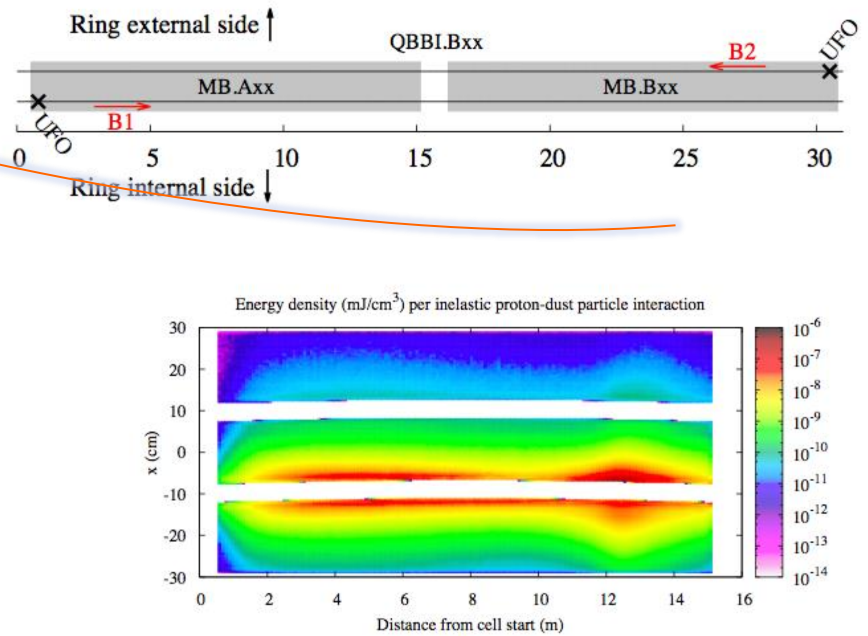
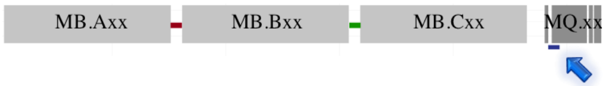
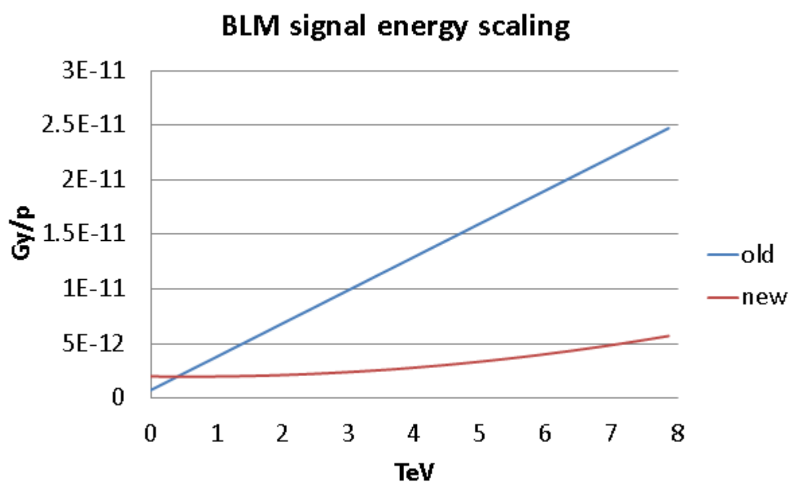


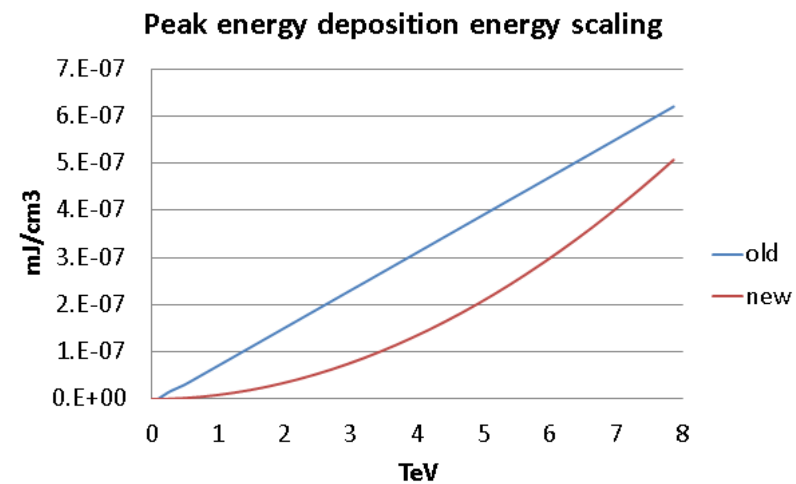
Figure: Energy density in the horizontal plane of MB.Axx due to beam-dust particle interactions in B1 (internal beam).

$$\mathrm{BLMSignal@Quench}(E,t) = \frac{\mathrm{BLMResponse}(E,t) * \mathrm{QuenchLevel}(E,t)}{\mathrm{EnergyDeposit}(E,t)}$$

BLMResponse/EnergyDeposit: old and new





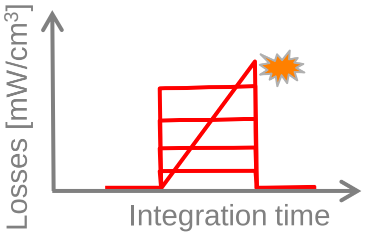


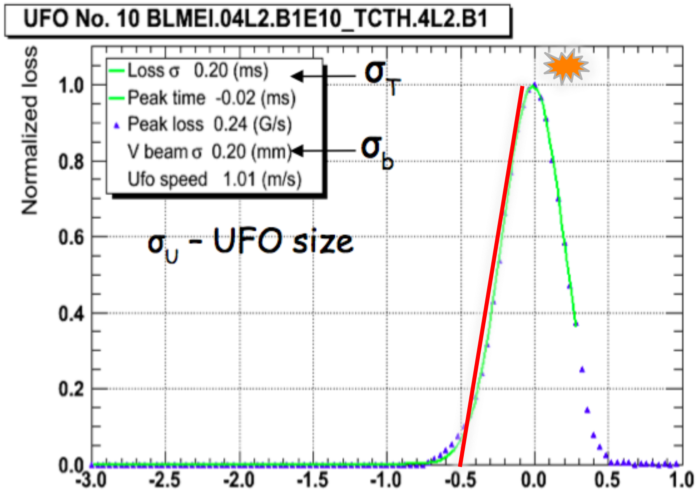
- BLMResponse: Much less signal at high energies.
- EnergyDeposit old/new ratio is very large at injection!
  (No neutral peak.)
- At high energies new BLMResponse/EnergyDeposit is smaller.
- At low energies new BLMResponse/EnergyDeposit is a lot larger.

$$\text{BLMSignal@Quench}(E,t) = \frac{\text{BLMResponse}(E,t) * \text{QuenchLevel}(E,t)}{\text{EnergyDeposit}(E,t)}$$

Quench Level

- The QP3 program (A. Verweij) computes quench levels for each running sum, assuming a loss pattern over time, and scales the losses iteratively until a quench just occurs.
- U.F.O. time distribution is usually Gaussian, but BLMs would trigger at peak or shortly after.
- The linearly rising loss pattern are used.
- This reduces the quech level by ~2.

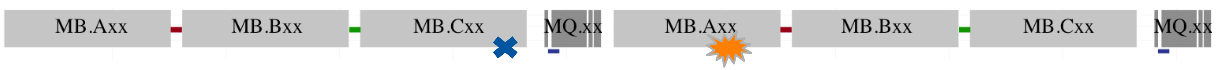


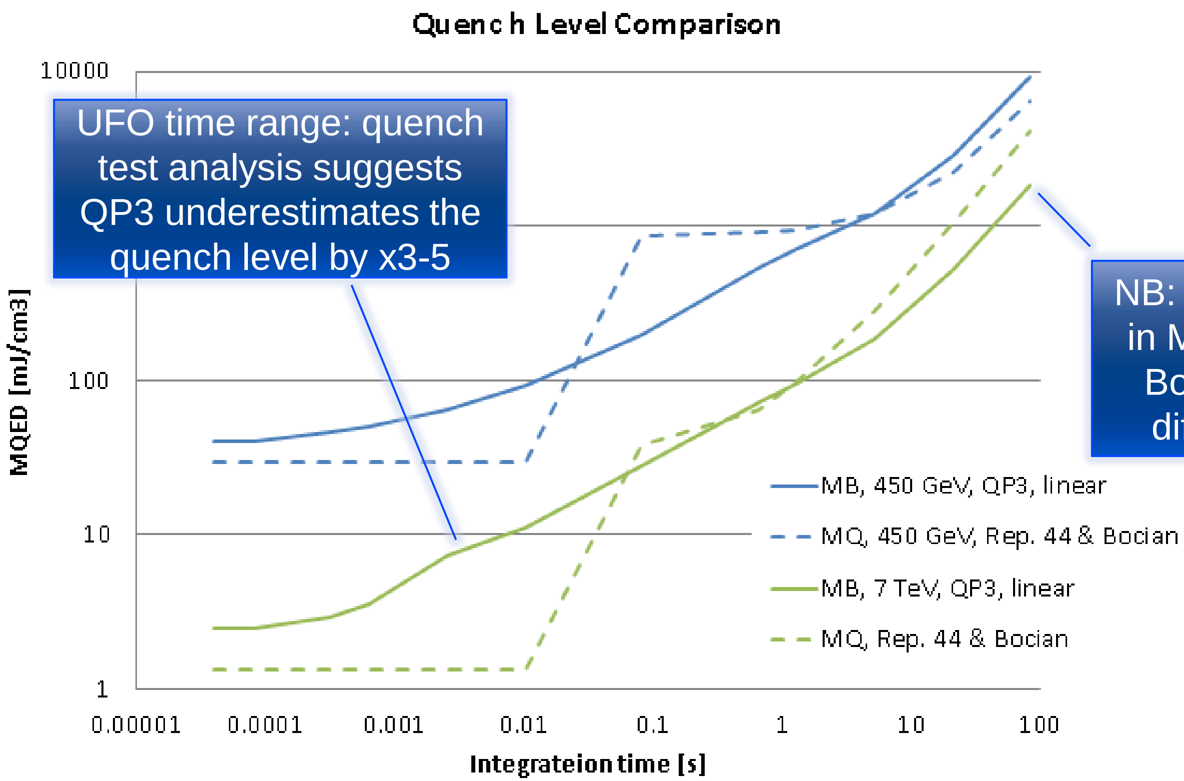


$$\text{BLMSignal@Quench}(E,t) = \frac{\text{BLMResponse}(E,t) * \text{QuenchLevel}(E,t)}{\text{EnergyDeposit}(E,t)}$$

Quench Level

- In the U.F.O. scenario, all BLMs are protecting MBs!



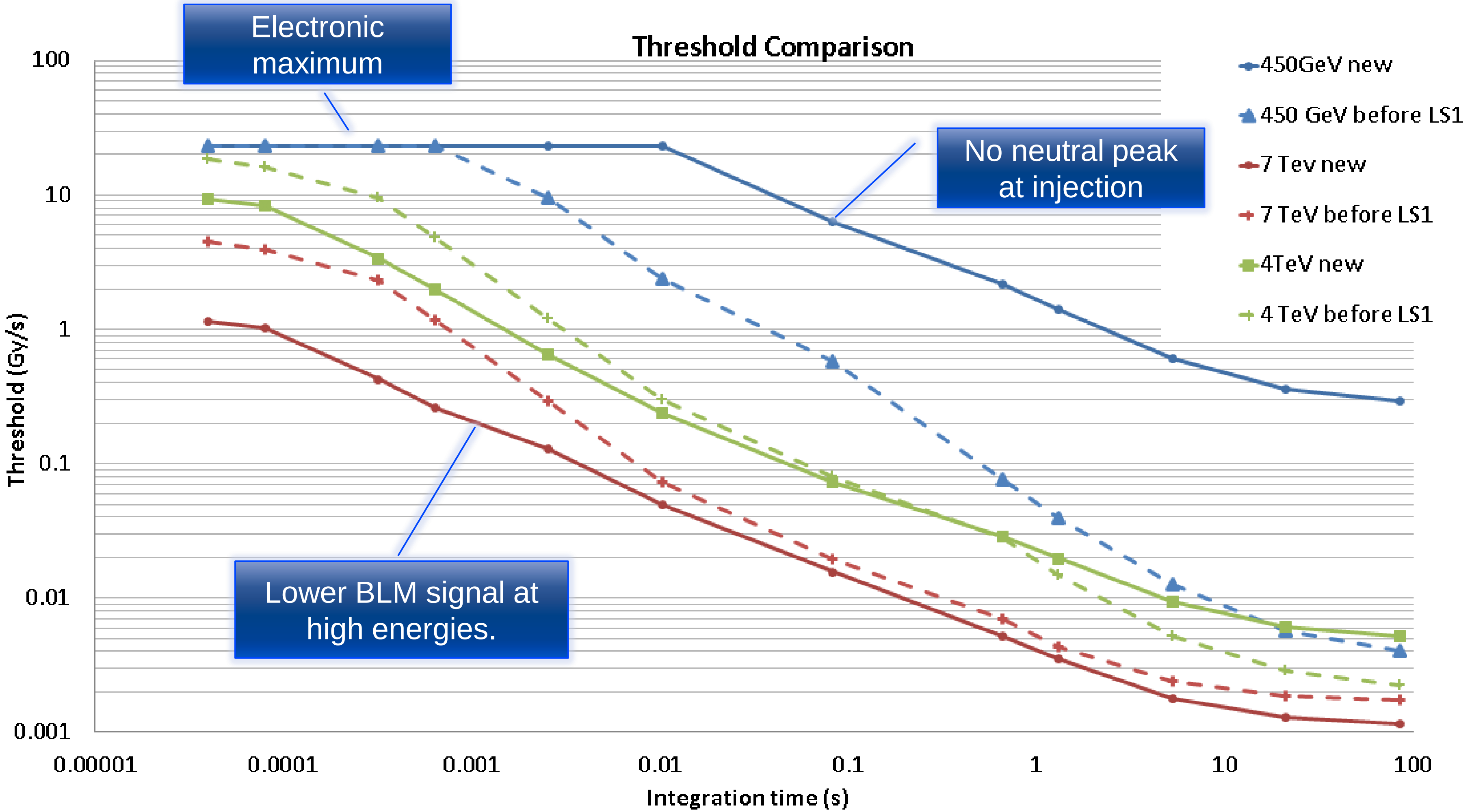


UFO time range: quench test analysis suggests QP3 underestimates the quench level by x3-5

NB: QP3 QL for rect. Pulse in MQ would be 2x above Bocian. New QL are for different loss scenario!

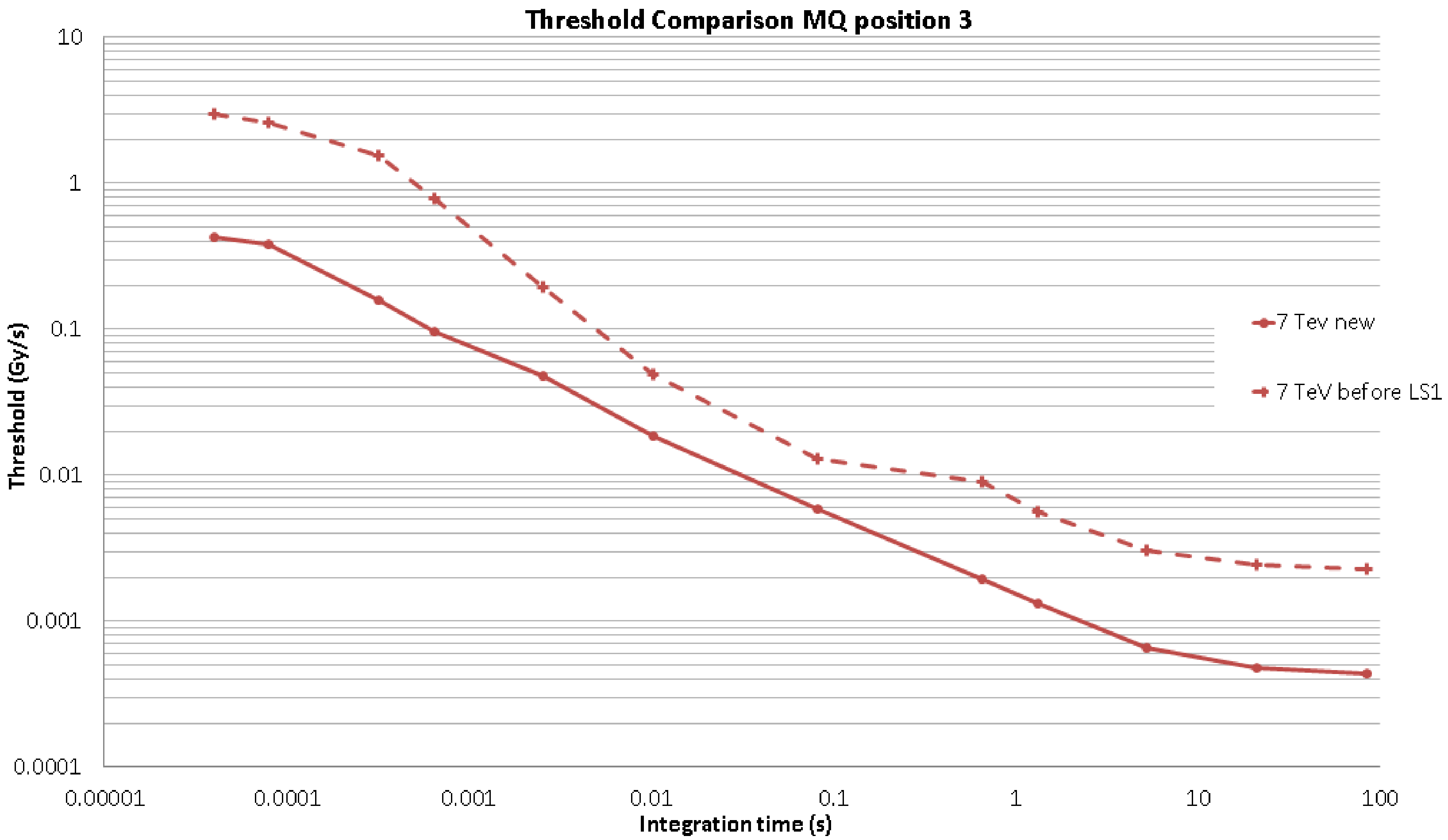
$$\mathrm{MasterThreshold}(E,t) = N * \mathrm{BLMSignal@Quench}(E,t) * \mathrm{AdHoc}(t)$$

MasterThresholds (*N*=3) on MQ Position 1.



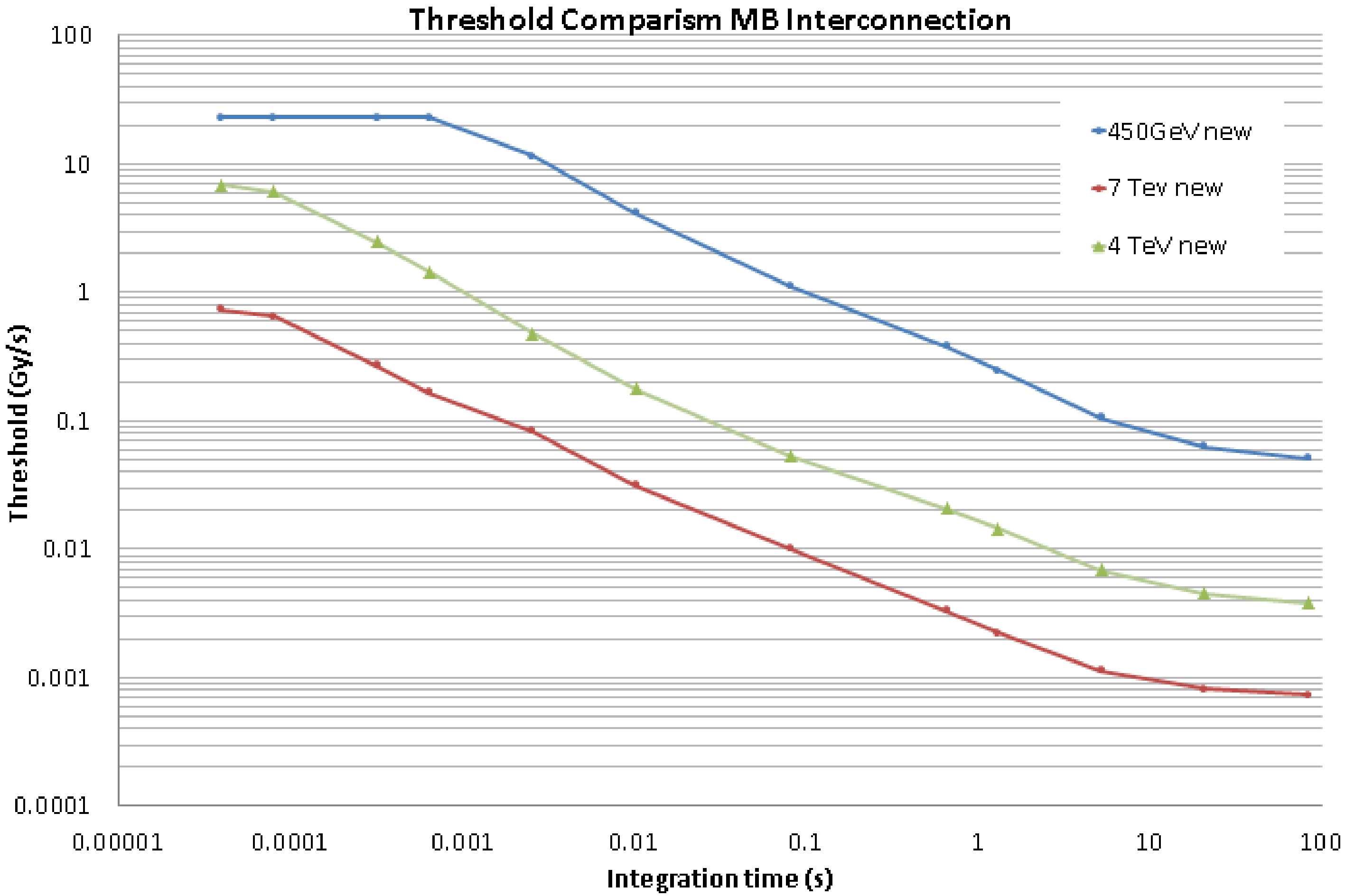
$$\text{MasterThreshold}(E,t) = N * \text{BLMSignal@Quench}(E,t) * \text{AdHoc}(t)$$

MasterThresholds (*N*=3) MQ Position 3



$$\mathrm{MasterThreshold}(E,t) = N * \mathrm{BLMSignal@Quench}(E,t) * \mathrm{AdHoc}(t)$$

MasterThresholds (*N*=3) above MB-MB interconnects



$$\mathrm{MasterThreshold}(E,t) = N * \mathrm{BLMSignal@Quench}(E,t) * \mathrm{AdHoc}(t)$$

“AdHoc” Corrections and Monitor Factor

- Short running sums:
  - Redo analysis of loss distribution before stable beams; increase thresholds in RS01-02 where necessary.
- U.F.O. time range:
  - Factor x 3-5 for QP3 underestimation in all magnets wound from Rutherford-type cable operated at 1.9 K.
- Long RSs:
  - Cross-check with collimation loss maps, extrapolated to 200(500) kW.

- Default Monitor Factor / Which *N* should be choose?
  - Low enough to protect from damage.
  - High enough to allow for timely adjustments, e.g., in case of new relevant loss scenario.
  - Proposal: *N* = 10 (instead of 3 pre LS1).

DS and SS strategy

1. Define thresholds as in the arcs
   - with accurate quench levels for all magnet types (in particular potted MQTs).
2. Perform extrapolation of pre-LS1 proton loss maps to 500 kW.
   - Apply AdHoc factor to long running sums to allow for (with MonitorFactor = 1) 500 kW impacting power on primary collimators.
3. With 2015 beam and new collimation settings, extrapolate first loss maps and repeat the exercise.
4. Repeat the exercise to allow for Pb-Pb operation.

Beyond Cryo-Magnets in Arcs, DS, SS

- Collimator BLMs: Joint CWG, BLMTWG meeting in Aug. 14.
  - Review of threshold corrections since 2008.
  - Review of family compositions.
  - Review and update of Ralph’s tables of maximum allowable proton loss rates.
  - Review and update of the BLM signal / lost proton models.
- IT BLMs, first step:
  - Review of initial scenario and corrections since 2008.
- Warm magnets, first step:
  - Review max. allowable proton loss rates and corresponding BLM signals.
  - Take into account new masks.
- LIBD, next step:
  - Has been studied during LS1.
  - Discussion responsible team will follow.

Summary

- Proposal to base BLM thresholds for the protection of cryo magnets in arc, DS, and SS on entirely new scenario (U.F.O., …).
- AdHoc corrections
  - for U.F.O. time-scale
  - to allow for
    - losses before stable beams
    - to allow for 500 kW impacting power on primary collimators
    - ion runs.
- Further steps needed in coming months to review all BLM families around the ring!

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