CERN

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Status of BLM thresholds for Run 2

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With slides from M. Albert and G. Papotti, as well as B. Kolad and M. Sobieszek

Overview

1. Where do we stand?
2. Cold-magnet threshold strategy update.
3. Arc and DS thresholds.
4. Status of the UFO Buster.

Where do we stand with tools and thresholds?

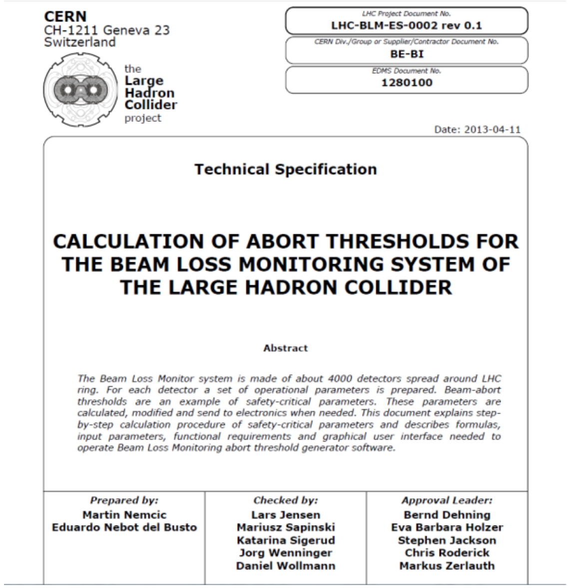
New tools

New tool for generation/history tracking, etc:

- New User Interface
- Threshold-generating algorithms implemented directly in ELSA (no more external C++ code)

Status overview:

- Prototype in testing phase.
- Old thresholds, based on Report-44 quench levels, can be produced.
- New thresholds, based on QP3 quench levels, need to be implemented. Should be ready for testing in the next weeks.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the Large Hadron Collider project

LHC Project Document No.
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CERN Div./Group or Supplier/Contractor Document No.
BE-BI

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1280100

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Technical Specification

CALCULATION OF ABORT THRESHOLDS FOR THE BEAM LOSS MONITORING SYSTEM OF THE LARGE HADRON COLLIDER

Abstract

The Beam Loss Monitor system is made of about 4000 detectors spread around LHC ring. For each detector a set of operational parameters is prepared. Beam-abort thresholds are an example of safety-critical parameters. These parameters are calculated, modified and send to electronics when needed. This document explains step-by-step calculation procedure of safety-critical parameters and describes formulas, input parameters, functional requirements and graphical user interface needed to operate Beam Loss Monitoring abort threshold generator software.

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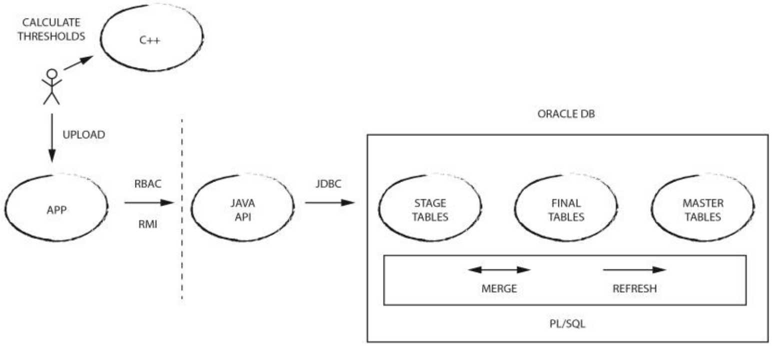
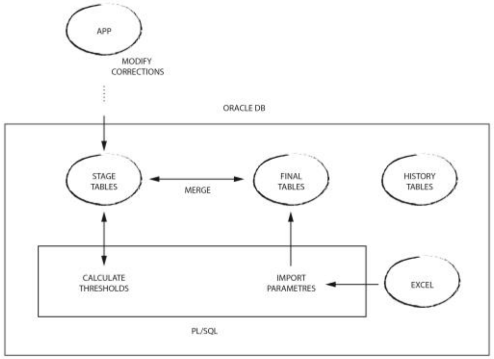




New thresholds

Goals of the update campaign:

- UFO thresholds in the arcs (new locations).
- Implementation of knowledge gained from quench tests and Run 1.
- Uniform methodology (FLUKA/MAD-X/QP3) that was successfully applied to quench-test analysis.
- High level of documentation.

Status overview (in order of readiness):

- Arc and DS thresholds **ready** (UFOs!)
- IPQs, IPDs, proposal **ready** (orbit bumps/UFOs)
- ITs under **preparation**. Finished in 1-2 weeks
- Warm magnets under **preparation**. (V. Raginel, L. Skordis)
- Collimation under **preparation**. (S. Redaelli, L. Skordis)
- Injection regions. **Likely to start up with old thresholds** (B. Holzer)
- Special locations (Roman pots) **Likely to start up with old thresholds.**
- Horizontal DS-MB BLMs. Will be studied in time for ion operation. **Set to maximum at startup.** (J. Jowett)

Priorities

By default, where no new thresholds are provided, we will start, for the time being, with the old thresholds.

1. **Arcs and DS**. Imperative for efficient learning curve with UFOs. Startup without safety factors at the assumed quench level.
2. **Collimators**. May require adjustment to the generator-software. Will be implemented as soon as available and possible.
3. **IPQ, IPD**. Thresholds less accurate due to spread of BLM locations and limited FLUKA resources. We have learned that they are hard to quench for UFOs. Startup with old thresholds is not a problem. Threshold increases for UFOs, if needed, can be done without further analysis work.
4. **Warm magnets** (MQWs). Thresholds will be implemented as soon as available.
5. **Injection regions**. Injection analysis was done by W. Bartmann based on old thresholds. Analysis needs to be redone after a threshold update. Will be done as soon as resources are available. Injection thresholds will be the same with or without update!
6. **Special** (Roman pots) Difficult scenario for simulation. Requires further discussion. Possibly set empirically.
7. **Ion**-operation specific BLMs will follow at a later time.

Cold-magnet threshold strategy

Several points have evolved w.r.t. 2014 presentations at MPP, BLMTWG, BIQ-Workshop, Chamonix.

BLM Threshold Formula

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

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

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

The $\mathrm{MasterThreshold}$ is a multiple of the $\mathrm{BLMSignal@Quench}$.

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

The $\mathrm{AppliedThreshold}$ is set with the $\mathrm{MonitorFactor}$ (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 for corrections via the $\mathrm{MonitorFactor}$.

- 2009 Startup for cold magnets: N = 3, $\mathrm{MonitorFactor}$ = 0.1.

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

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

N and MonitorFactor

The N factor is hard-coded to equal 3 in the new tool and cannot be used for convenience.

The MonitorFactor will be set to 0.33 in the arc and DS sections, and to 0.1 elsewhere (comment of J.P. Tock at Chamonix on the availability of spares).

MPP 14/06/26

Default Monitor Factor / Which *N* should be choose?

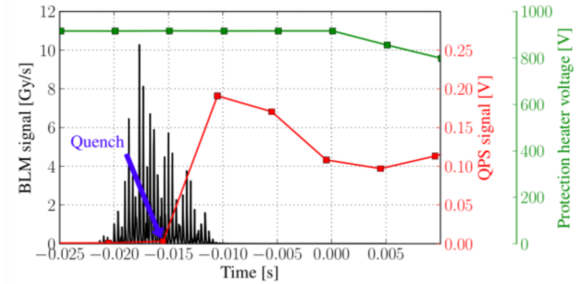
- Low enough to protect from damage.
- High enough to allow for timely adjustments, e.g., in case of new relevant loss scenario.
- Proposal: *N* = 10 (instead of 3 pre LS1).

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

AdHoc corrections

AdHoc accounts for missing features/inaccuracies in the numerical models.

The electro-thermal model underestimated the quench level for the intermediate-loss orbit-bump quench test at 1.9 K (ADT).



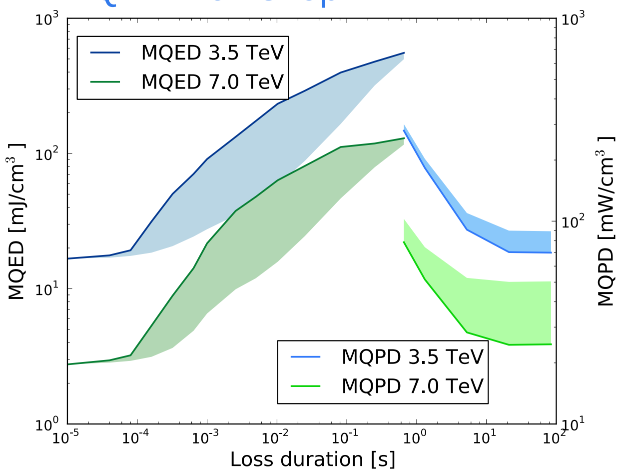
This might be due to the spiky sub-structure of the losses, in which case the factor should apply also to faster RSs.

The only faster quench test produced single-turn losses.

For all magnets at 1.9 K we correct the quench levels!

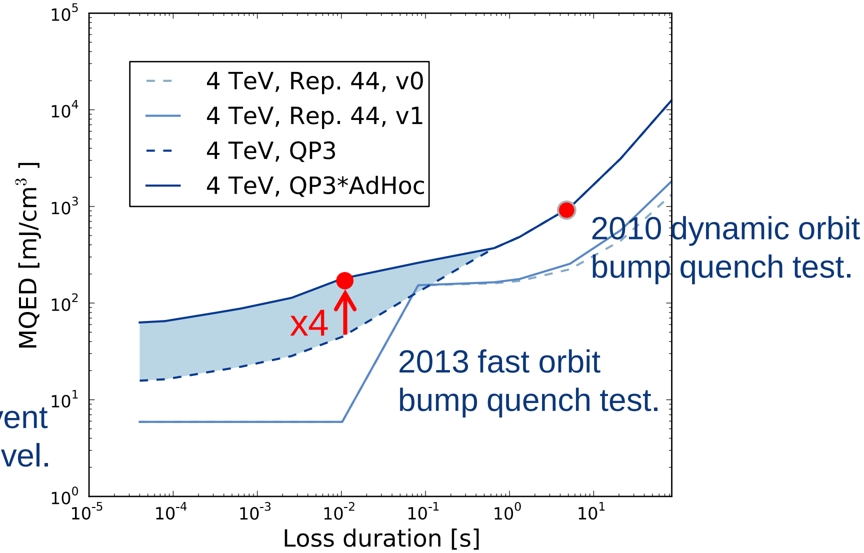
In the arcs his may lead to a few beam-induced quenches until we get the factors right.

BIQ14 Workshop



2008 strong-kick event validated quench level.

Chamonix 14



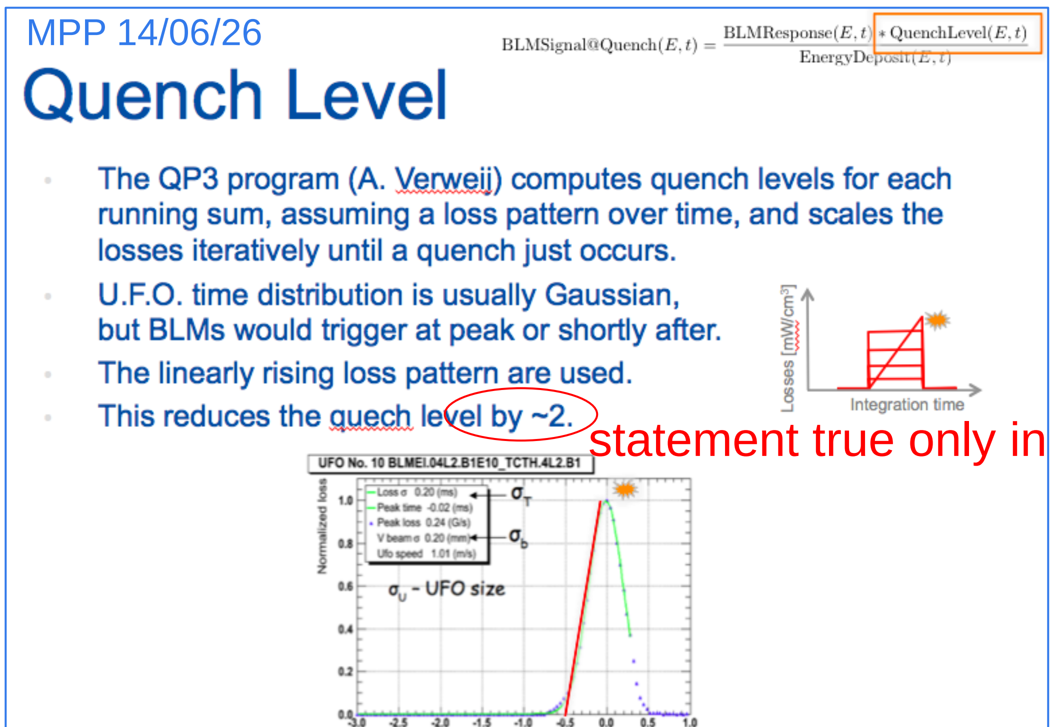
$$\text{BLMSignal@Quench}(E,t) = \frac{\text{BLMResponse}(E,t) * \text{QuenchLevel}(E,t)}{\text{EnergyDeposit}(E,t)}$$

Temporal loss profile

At MPP 14/06/26 we proposed to use linearly rising losses in all RSs for the definition of quench levels.

However, the impact of this choice in the short-intermediate RSs is small, whereas it is large in the long RSs.

We have, therefore, opted for the constant loss pulses.



statement true only in long RSs!

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

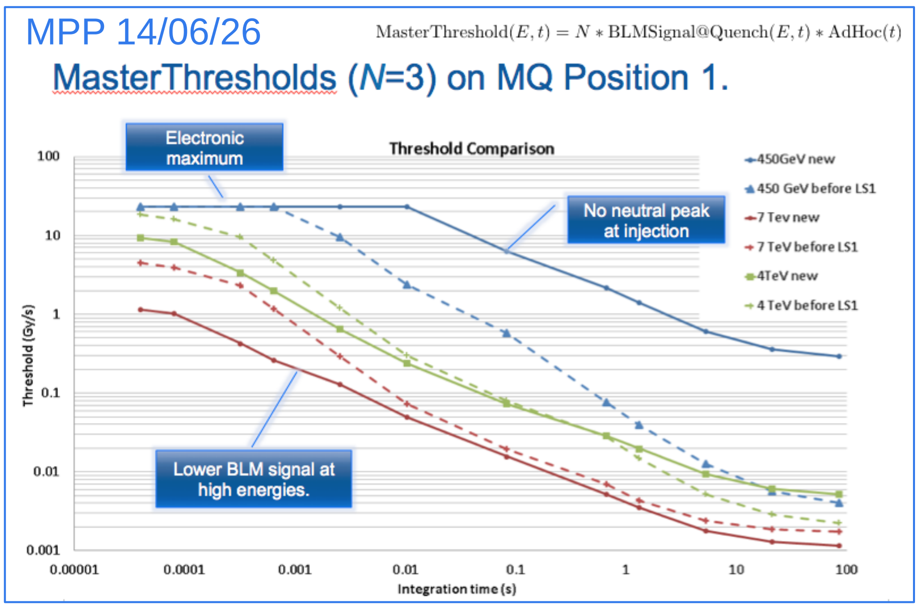
Multiple loss scenarios

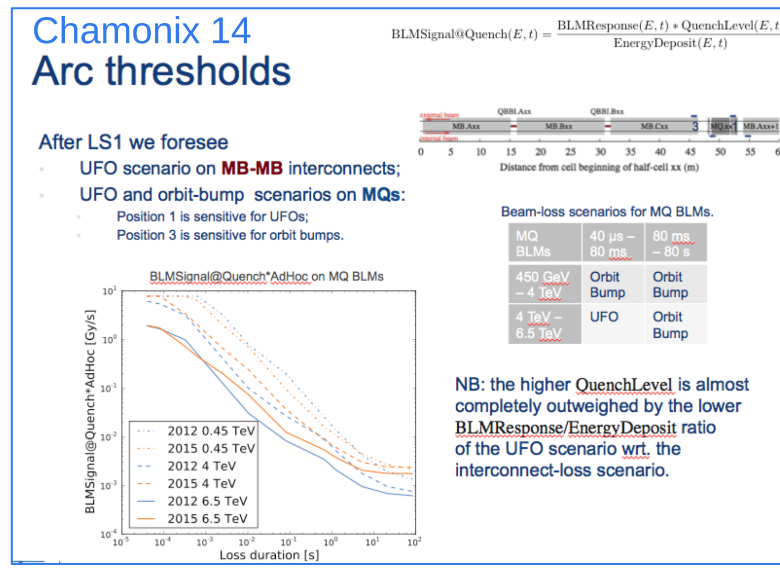
Initial studies showed a drastic increase in low-energy thresholds on MQ Position-1 if only the UFO scenario was used.

As a remedy it was planned to use multiple scenarios (orbit bump at low energy and long RSs, UFO everywhere else).

This solution is technically not feasible with the new tool for the time being.

Additional UFO simulations at low energies have improved the situation (see following slides).





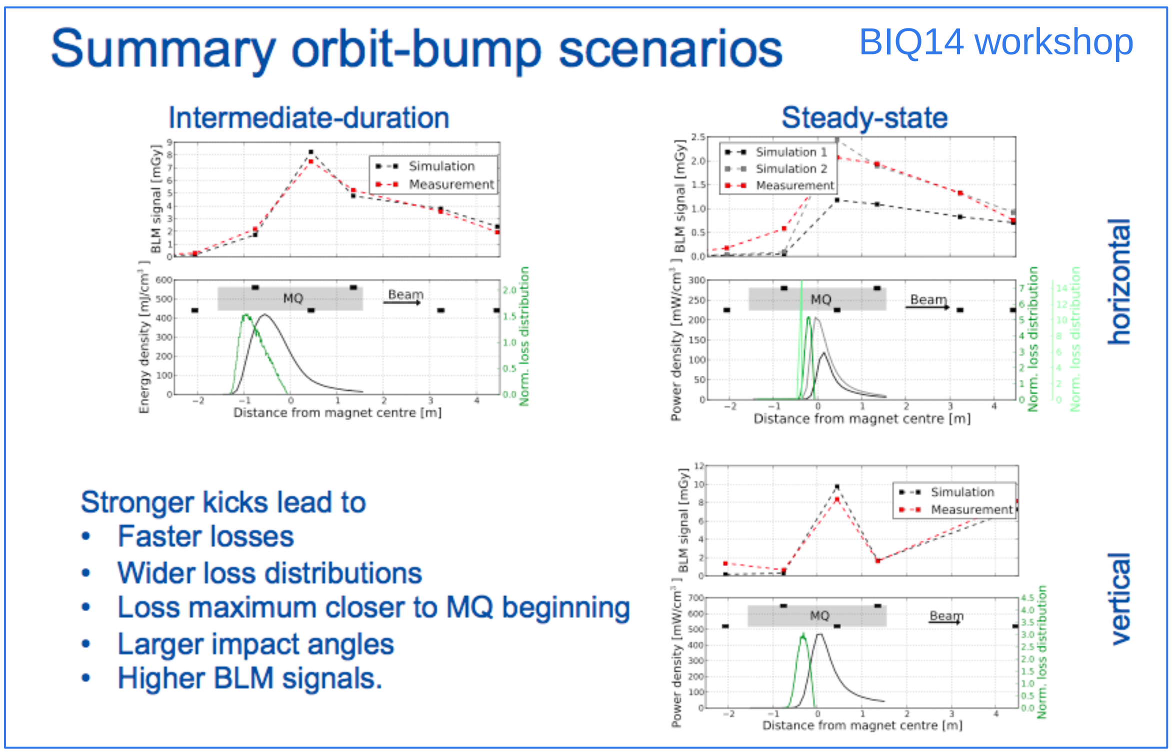
$$\text{BLMSignal@Quench}(E,t) = \frac{\text{BLMResponse}(E,t) * \text{QuenchLevel}(E,t)}{\text{EnergyDeposit}(E,t)}$$

Which orbit bump?

No ONE orbit-bump scenario can accurately predict all RSs. Loss distribution depends on loss duration.

For orbit-bump-type losses we select the vertical orbit-bump scenario of the 2010 dynamic-orbit-bump quench tests (DOB).

Applied in MQ position 3, IPQs, Q1/3, MQW.

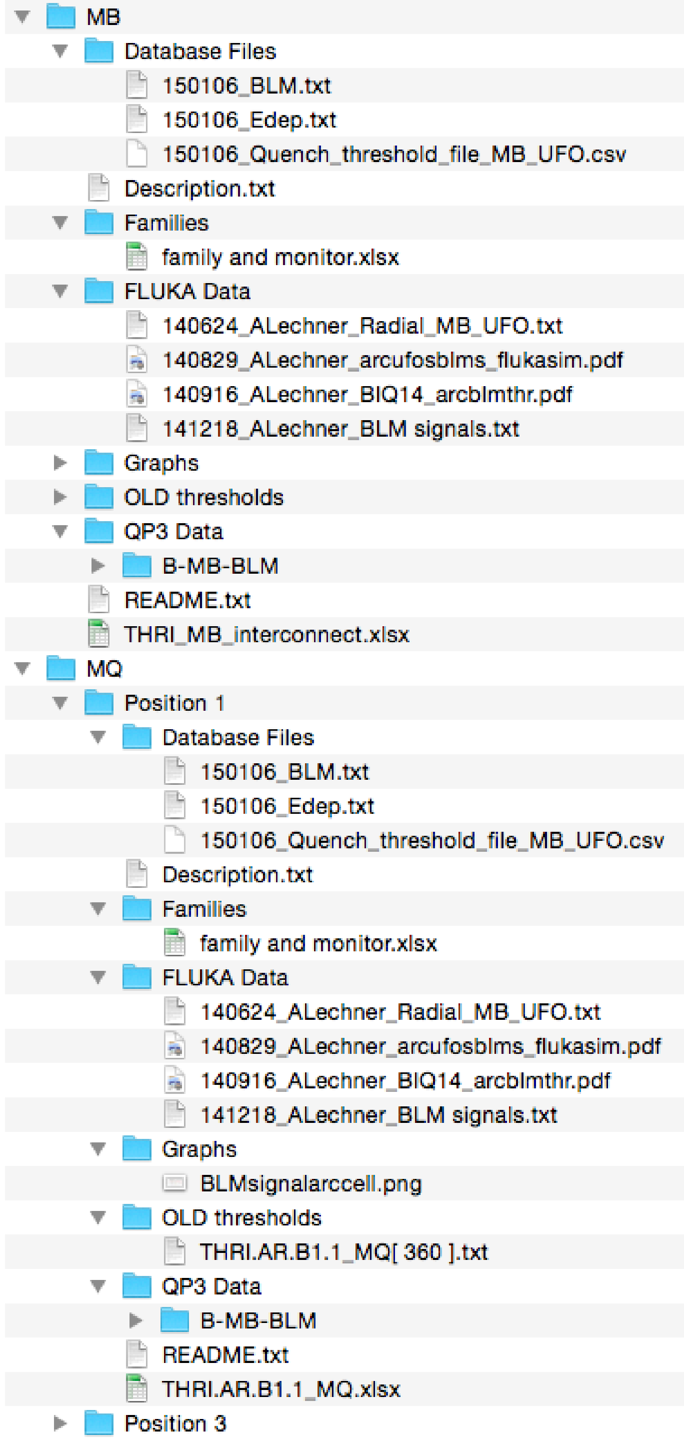


Documentation

All data concerning Run 2 thresholds will be stored on the BLMTWG website for reference.

Work in progress.

BIQ proceedings will be used to layout the full rationale.



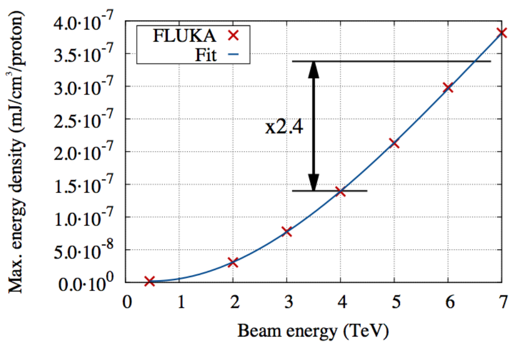
Arc and DS Loss Scenarios and Thresholds

UFOs and orbit bumps

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

Arc-UFO loss scenario

BLMs on top of MB-MB interconnects, as well as those on the MQ position 1 are set for the UFO scenario with MB quench levels.



FLUKA EnergyDeposit

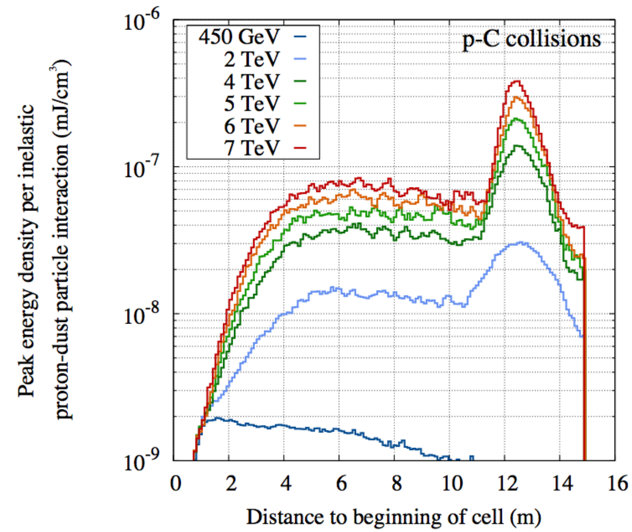
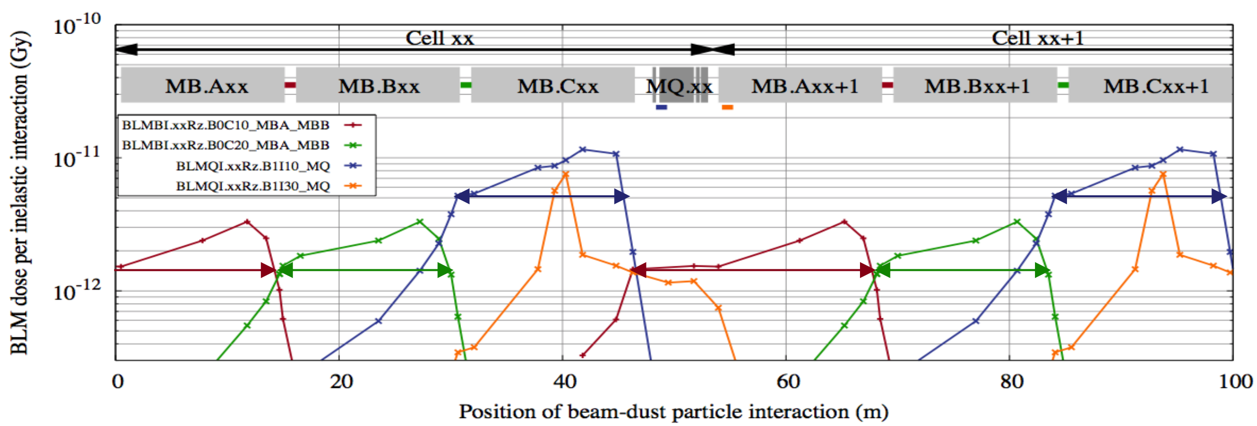


Figure: Peak energy density in MB coils per proton–dust particle interaction for different beam energies. The dust particle is assumed to be composed of carbon.

FLUKA BLMResponse

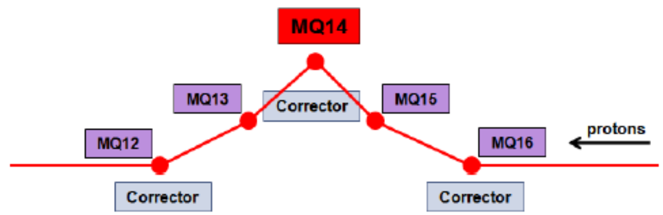


$$\mathrm{BLMSignal@Quench}(E,t) = \frac{\mathrm{BLMResponse}(E,t) * \mathrm{QuenchLevel}(E,t)}{\mathrm{EnergyDeposit}(E,t)}$$

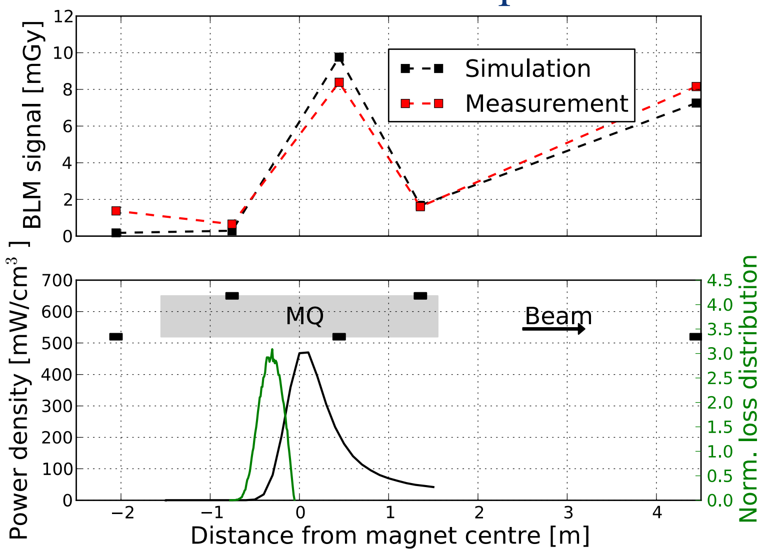
DOB loss scenario (Arc, DS, IPQs, Q1/3)

BLMs in the quadrupole position 3* are set for the dynamic-orbit-bump (DOB) scenario with quad quench levels.

*… position formerly known as position 3.

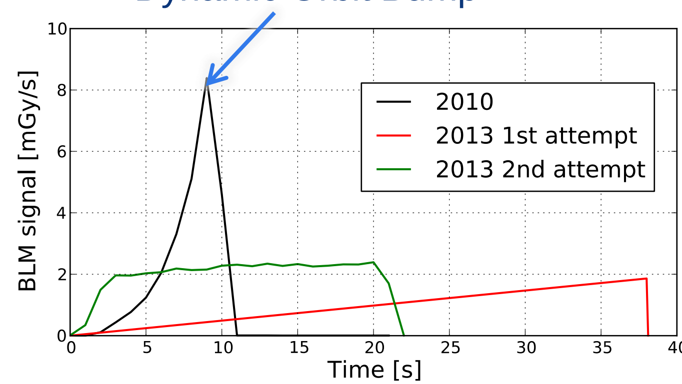


FLUKA BLMResponse

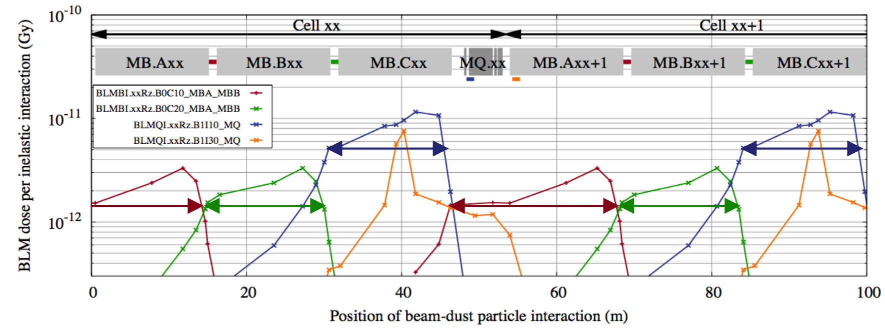


FLUKA EnergyDeposit

Dynamic Orbit Bump



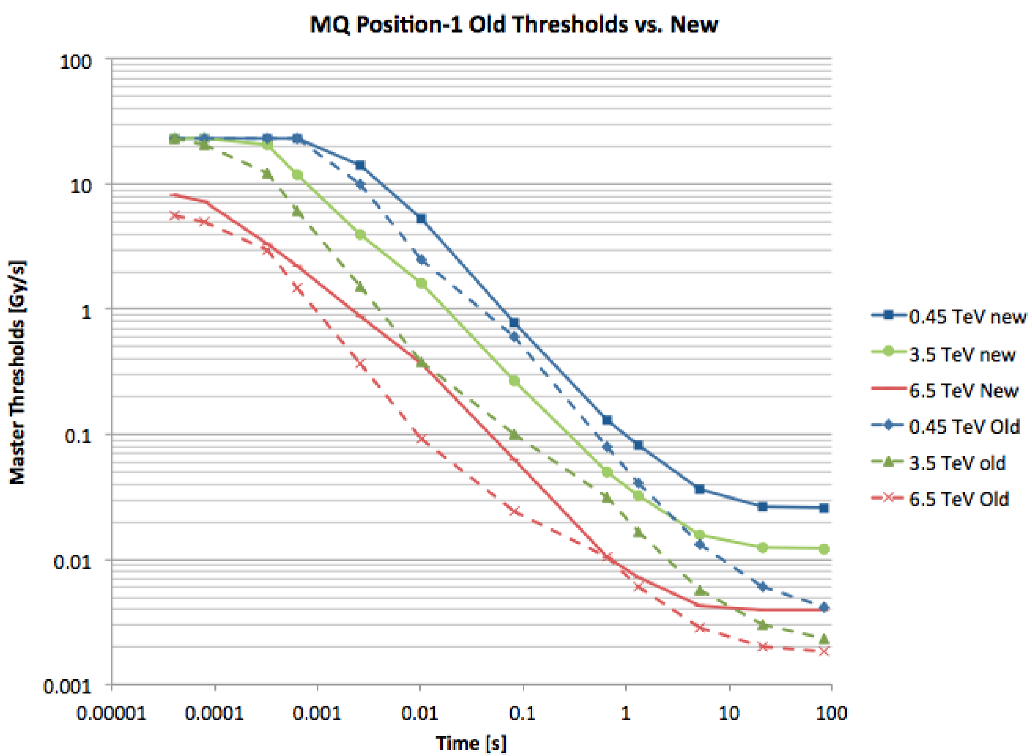
MQ Position-1 Thresholds



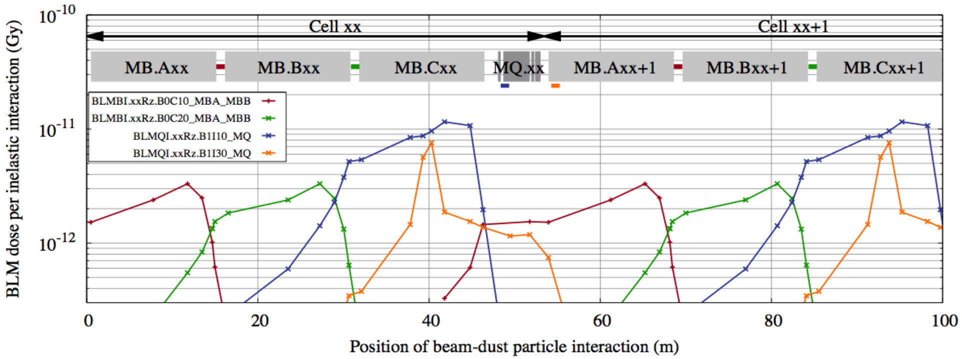
UFO.

Old Thresholds:

- Energy Deposit and BLM Response: C. Kurfürst “TWISS” scenario (Losses at interconnect).
- Quench Level: Note 44 / D. Bocian parameters.



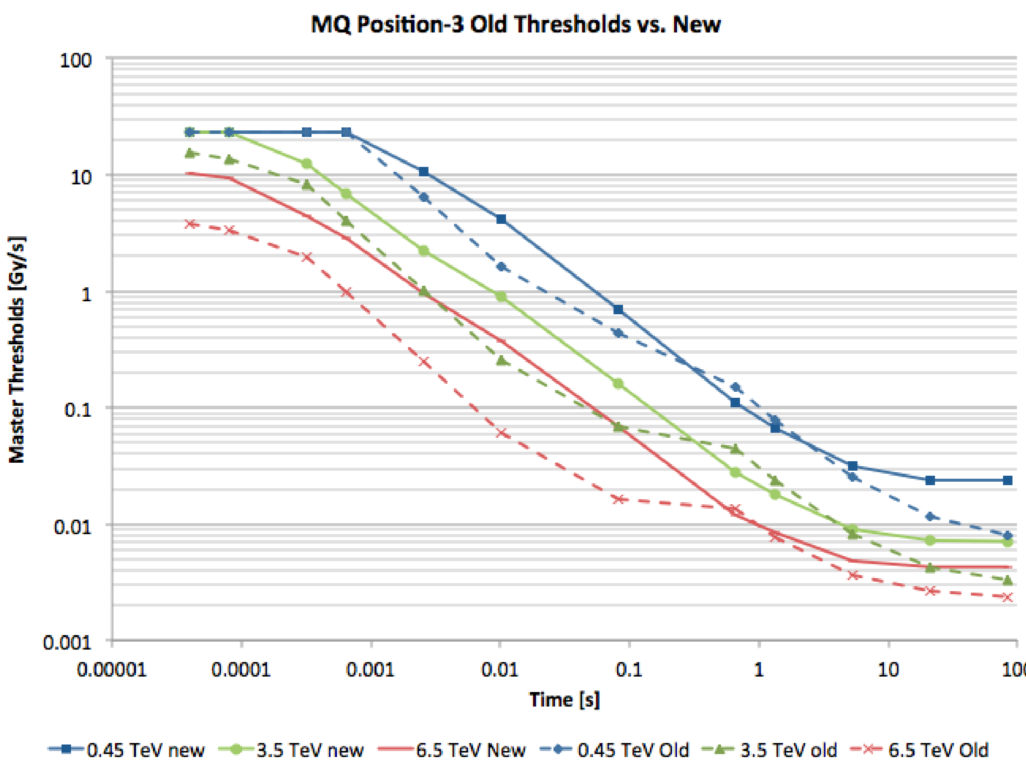
MQ Position-3 Thresholds



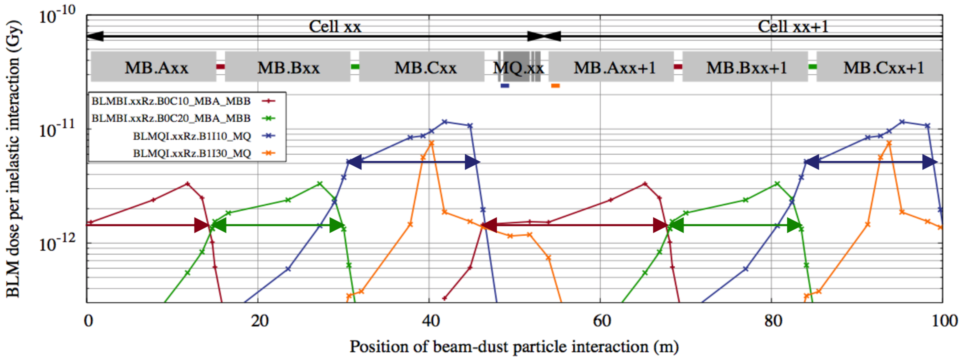
Dynamic orbit bump.

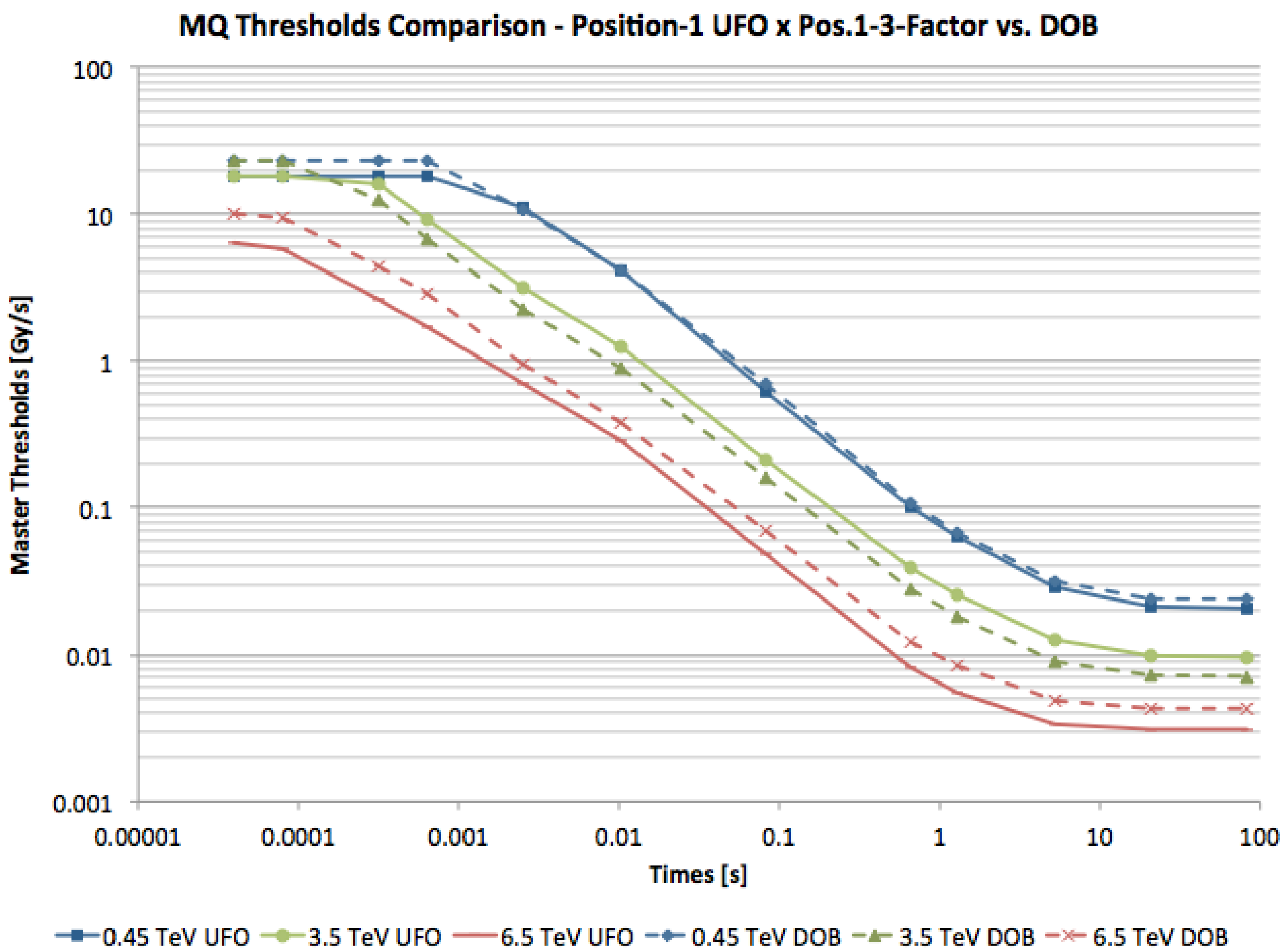
Old thresholds:

- Energy Deposit: Note 422 MB (Strong-kick event)
- BLM Response: C. Kurfürst “TWISS” scenario (Losses at interconnect).
- Quench Level: Note 44 / D. Bocian parameters.



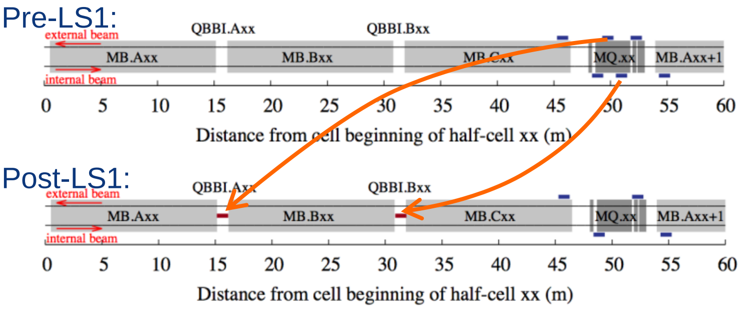
MQ Position-3
DOB vs. UFO

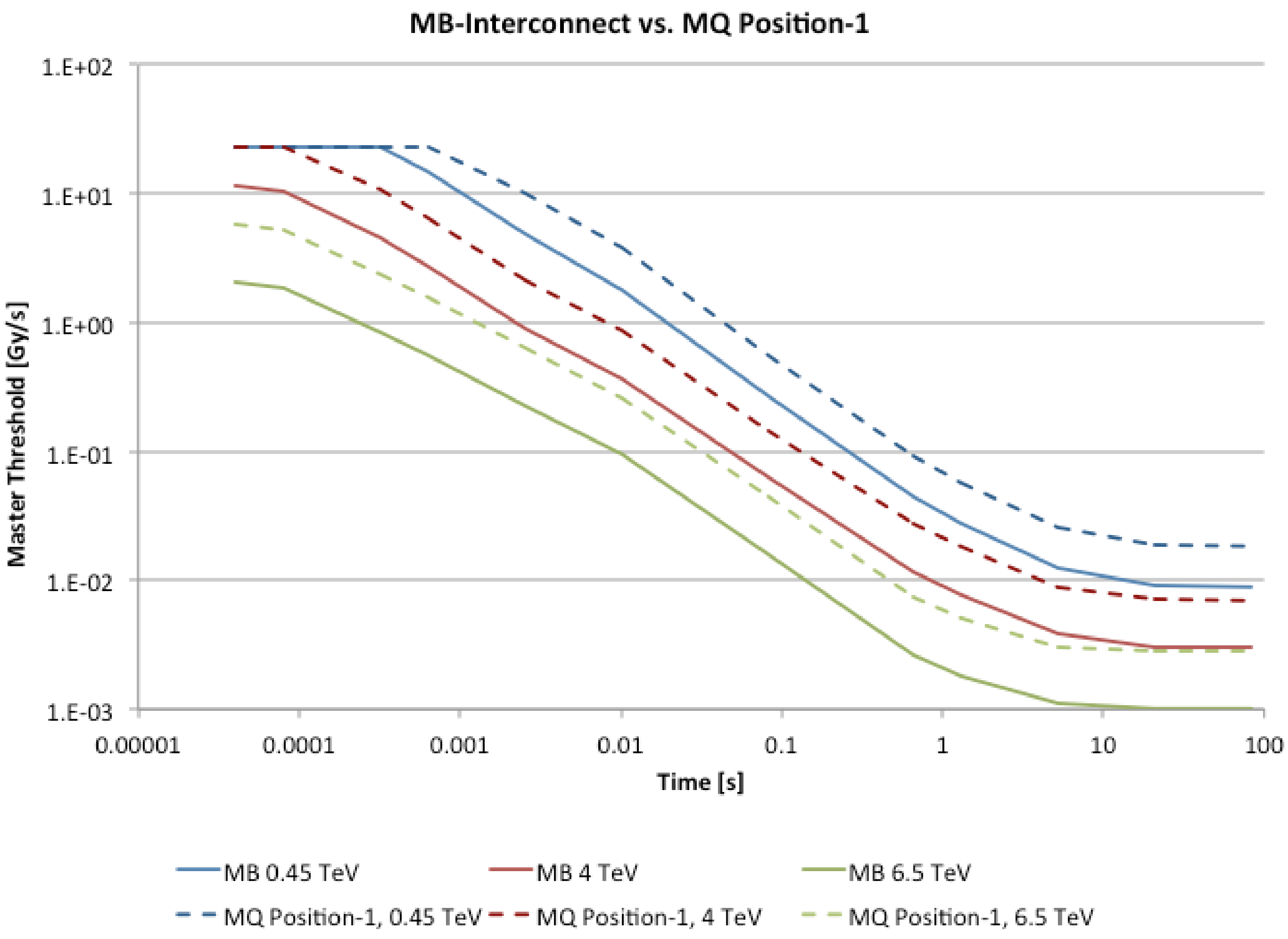




MB-MB Interconnect Thresholds

UFO.



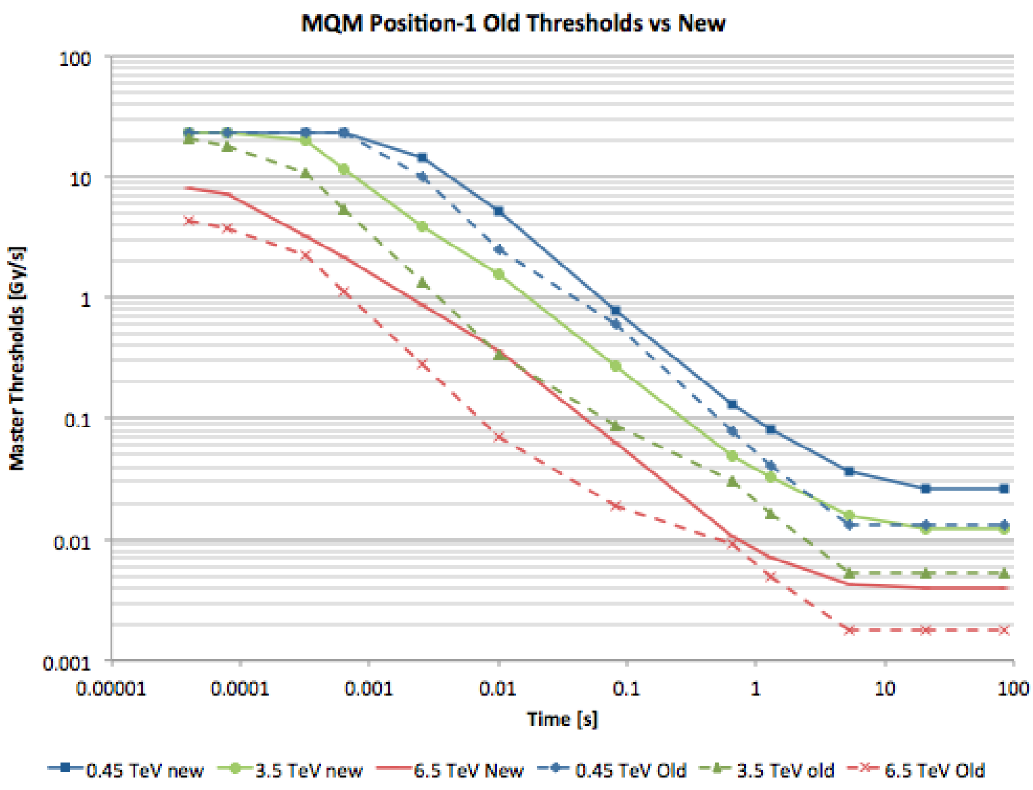


MQM 1.9 K Position-1 Old vs. New

UFO.

Old thresholds:

- Energy Deposit and BLM Response: C. Kurfürst "TWISS" scenario (Losses at interconnect).
- Quench Level: MQM Note 44 / D. Bocian parameters.

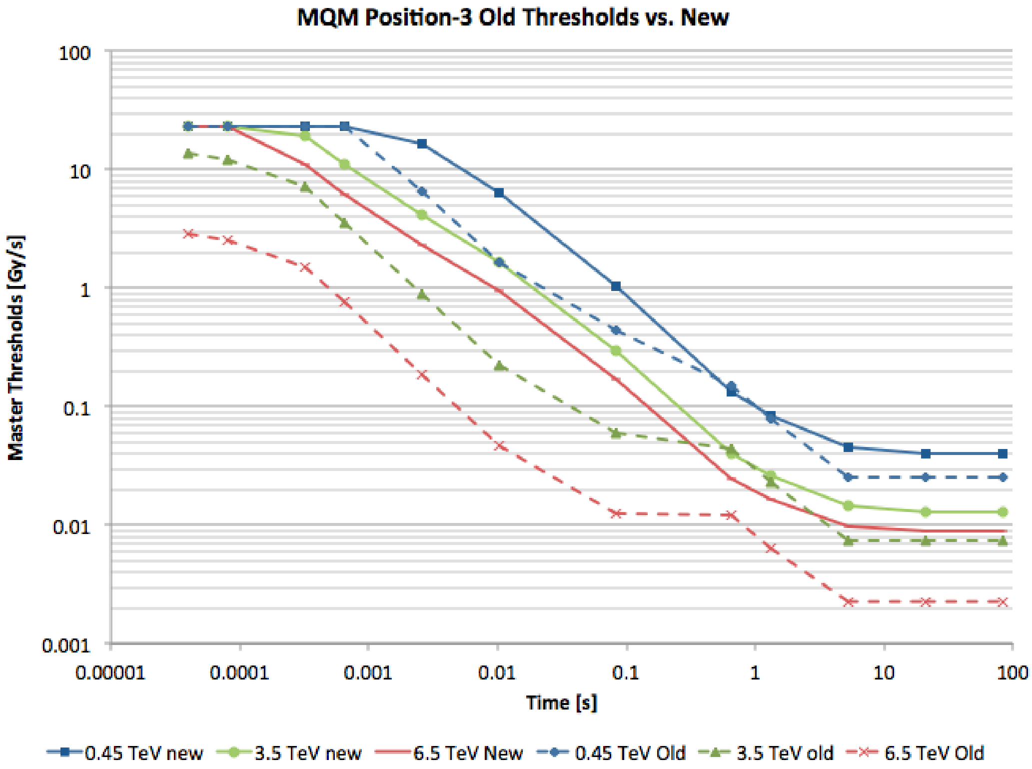


MQM 1.9 K Position-3 Old vs. New

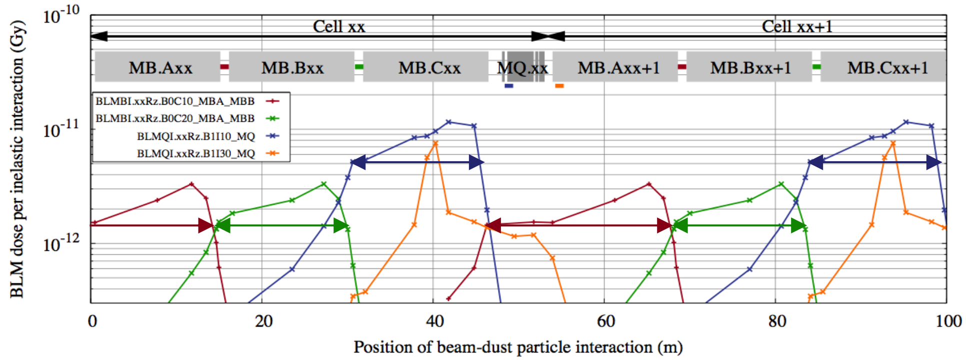
Dynamic orbit bump.

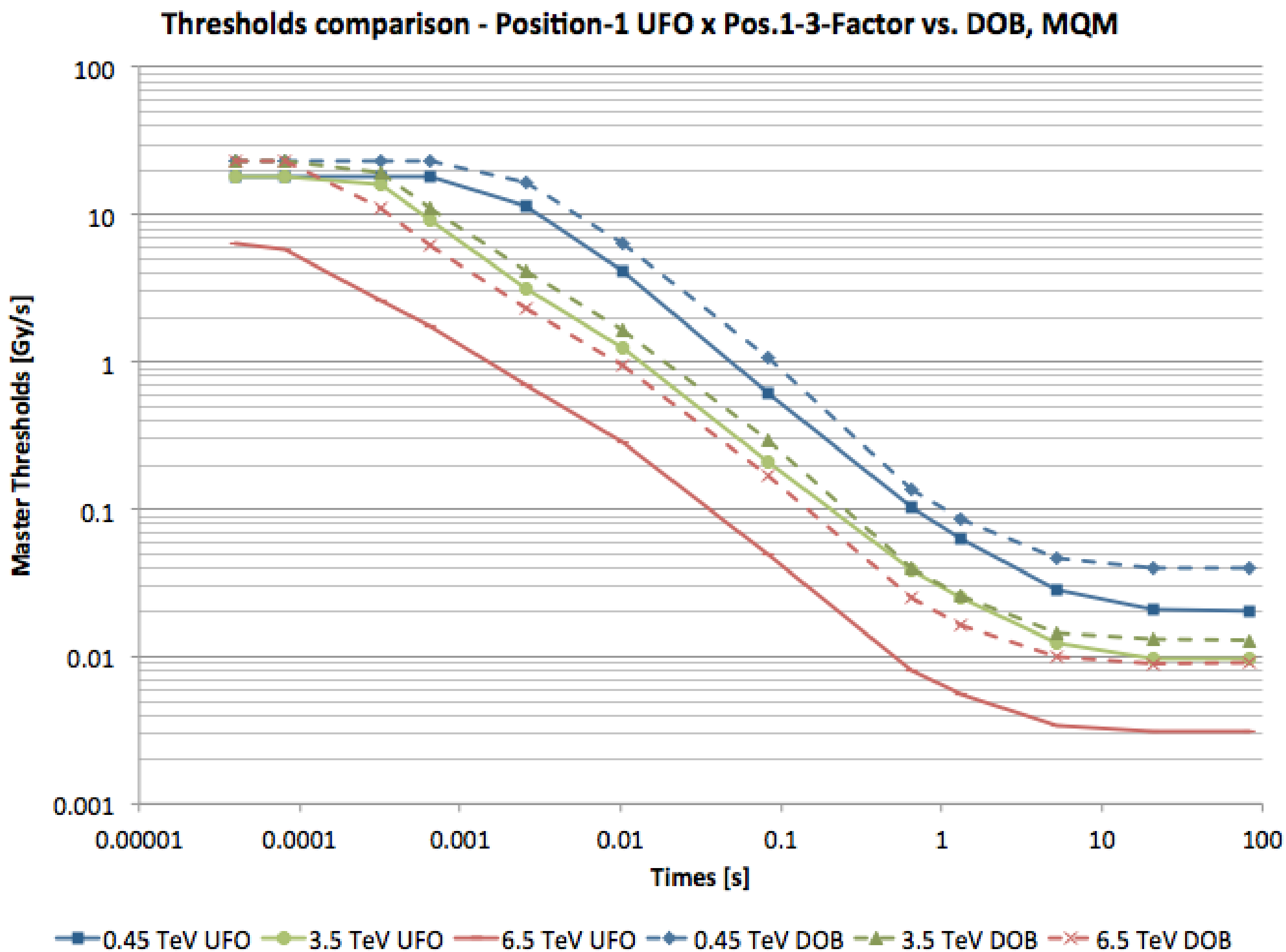
Old thresholds:

- Energy Deposit: Note 422 MB (Strong-kick event)
- BLM Response: C. Kurfürst “TWISS” scenario (Losses at interconnect).
- Quench Level: MQM Note 44 / D. Bocian parameters.



MQM Position-3
DOB vs. UFO





Future tasks

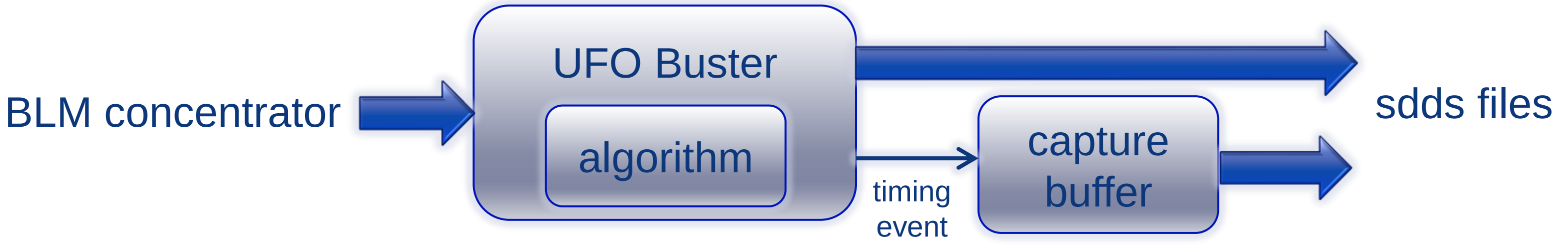
1. Finish the threshold-generation tool.
2. Finish thresholds.
    1. Finish cold magnets.
    2. MQW thresholds.
    3. Collimation thresholds.
    4. Injection settings.
    5. XRP thresholds.
    6. DS horizontal MB BLMs.
3. Fix families and family naming.
4. Validation of deployed thresholds vs. Excel/old thresholds.
5. Pre-startup threshold cross-checks with Run 1 operational data.
6. Thresholds vs. noise.

UFO Buster status

Presented content by G. Papotti and M. Albert

UFO Detection

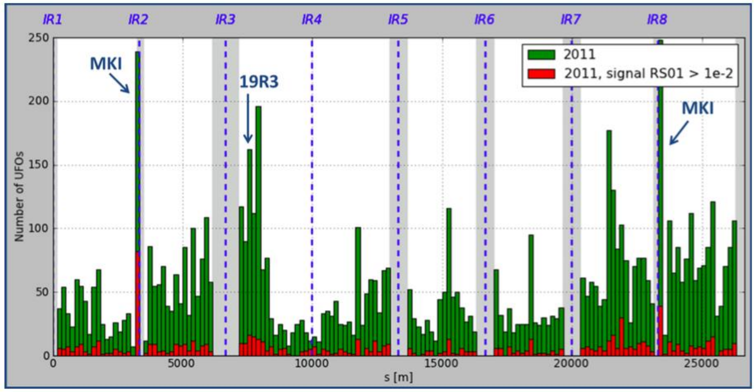
- online detection by “UFO buster”
  - inherited by M. Albert (BE-OP-LHC)
  - java code running on a virtual machine
  - algorithm decides when a UFO is detected
    - takes input from BLM concentrator
    - algorithm: 2 BLMs within 40 m to detect >1e-4 Gy/s in RS 4 (640 us)
      - plus noise filter on all BLMs on RS2/RS1 and RS3/RS2, remove wire scans and injection
      - Will need to be adapted for the arcs and DS!
  - outputs
    - sdds files including fill data, BLM monitor names, settings, max reading of all running sum per second
    - capture buffer data saved by triggering timing event
  - CCC GUI based on same code

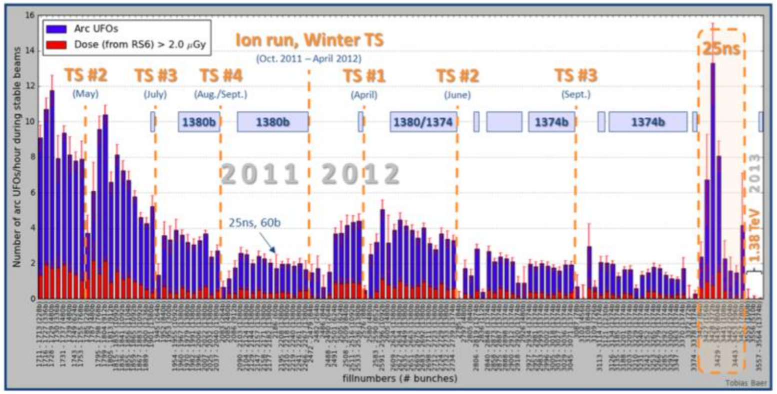


UFO Analysis

- Tobias's legacy in Python
  - inherited by G. Papotti (BE-OP-LHC)
  - import sdds data into python data structure
  - filter further
    - additional cuts to avoid false triggers
    - filter based on energy, location, dose, for specific analysis
  - plot
    - examples: arc UFO rates, spatial UFO distribution, …

  - Will need to adapt the detection algorithm to the new run. Try to predict based on the UFO model, to be refined with first data.





Short and long-term plans

- UFO buster
  - already adapted to LS1 code changes, JUnitTests working, BLM name changes being applied
  - move UFO kernel from virtual machine to server
  - up and running with first beam
    - use initial period with single bunches to verify data flow
  - expect first real UFOs with 50 ns ramp-up
    - verify detection algorithm, or optimize it
- longer term
  - improve integration in infrastructure
    - save data into proper database (e.g. Post Mortem)
    - move part of analysis into Post Mortem

Summary

Big steps towards increased consistency.

Much work ahead for the next 2 months!

Thanks for your attention!

Extra Slides

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

SS heat-transfer models MB, MQ

Based on steady-state orbit-bump quench test (ADT) analysis we select the more conservative empirical model for MB and MQ.

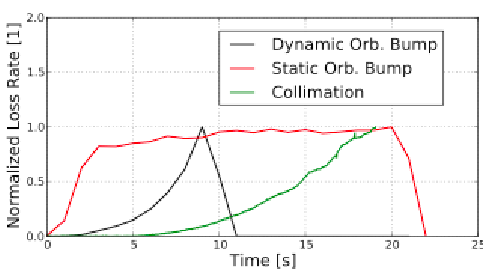
The model still gives much higher estimates than previously used.

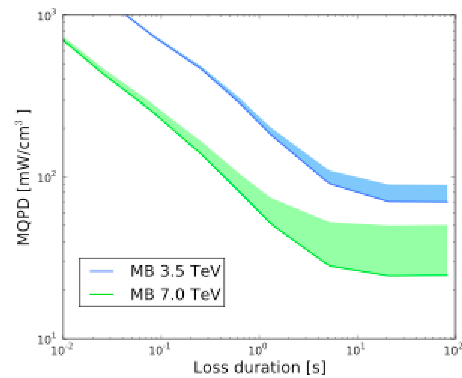
Steady-state losses (5 s – infty)

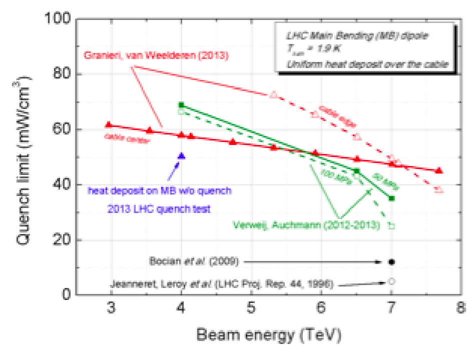
BIQ14 workshop

- Uncertainties due to "fish-bone" are more important at higher energies.
- Definitive validation not possible at 4 TeV.
- Based on static-orbit bump QT results we use the more conservative assumption.
- More input in tomorrow's morning session!

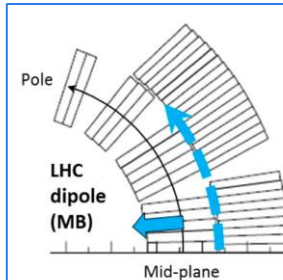
Test	Energy [TeV]	Type	Ramp time [s]	MQPD [mW/cm³]	FLUKA [mW/cm³]
Dyn. Orbit Bump	3.5	MQ	6	180 +35	208
Collimation	4	MB	15	115 +25	n/a
Static Orbit Bump	4	MQ	infty	70 +18	41 +33







Courtesy P.P. Granieri

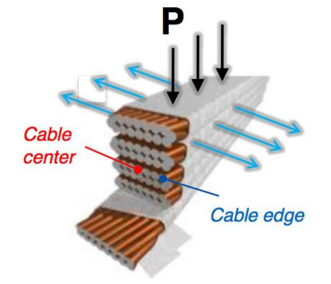


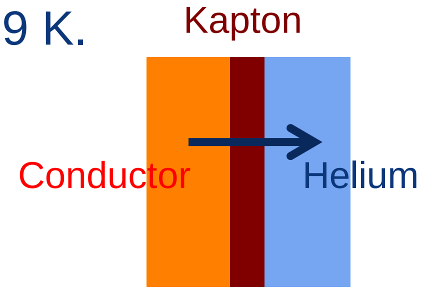
$$\mathrm{BLMSignal@Quench}(E,t) = \frac{\mathrm{BLMResponse}(E,t) * \boxed{\mathrm{QuenchLevel}(E,t)}}{\mathrm{EnergyDeposit}(E,t)}$$

PSS heat-transfer models IPQs, ITs

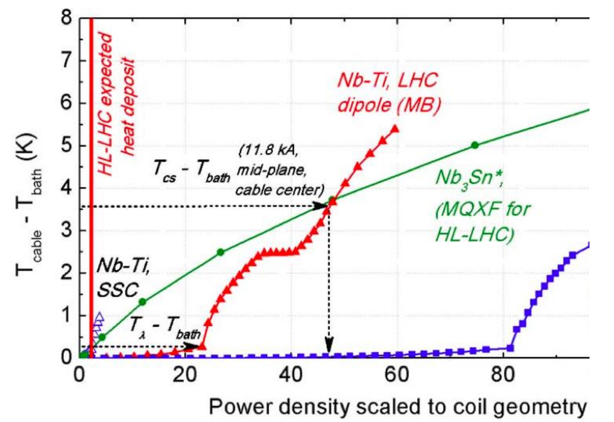
In an attempt to be consistent with below literature we propose:

- MQXA and MQXB get conservative bulk-insulation model.
- MQM at 1.9 K get the MB/MQ empirical model.
- At 4.5 K (MQM, MQY, MQTL) the bulk-insulation model is used.
- MQTL would get the bulk-insulation mode even at 1.9 K.





Bulk-insulation model



Empirical model

R. Ostojic, Insertion Magnets and Beam Heat Loads, at workshop "Beam generated heat deposition and quench levels for LHC magnets", 3-4 March 2005

I. Novitski and A. V. Zlobin. Thermal analysis of SC quadrupoles in accelerator interaction regions. IEEE Transactions On Applied Superconductivity, 17(2):1059–1062, June 2007.

L. Chiesa, S. Feher, J. Kerby, M. Lamm, I. Novitski, D. Orris, J. P. Ozelis, T. J. Peterson, M. Tartaglia, and A. V. Zlobin. Thermal studies of a high gradient quadrupole magnet cooled with pressurized, stagnant superfluid. IEEE Transactions on Applied Superconductivity, 11(1):1625–1628, March 2001.

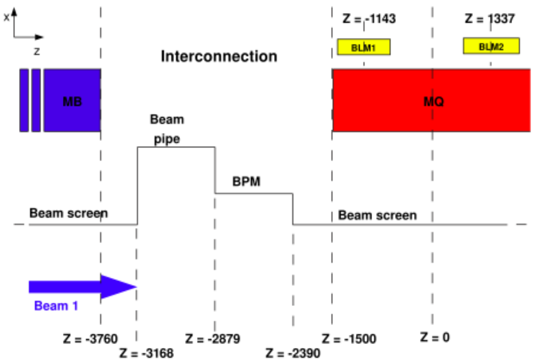
N. Kimura, A. Yamamoto, T. Shintomi, and A. Terashima. Heat transfer characteristics of Rutherford- type superconducting cables in pressurized He II. IEEE Transactions on Applied Superconductivity, 9(2):1097–1100, June 1999.

CERN

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

Old scenarios: TWISS and Note-422

TWISS scenario: Ch. Kurfürst, losses on the MB-MQ interconnect.



Note-422: 2008 strong-kick event. Pilot-bunch kicked into a dipole.

LHC Project Note 422

July 15, 2009

Energy deposition in LHC MB magnet and quench threshold test with beam.

Bernd Dehning, Agnieszka Priebe, Mariusz Sapinski *
CERN CH-1211 Geneva 23, Switzerland

SS Loss Scenarios and Thresholds

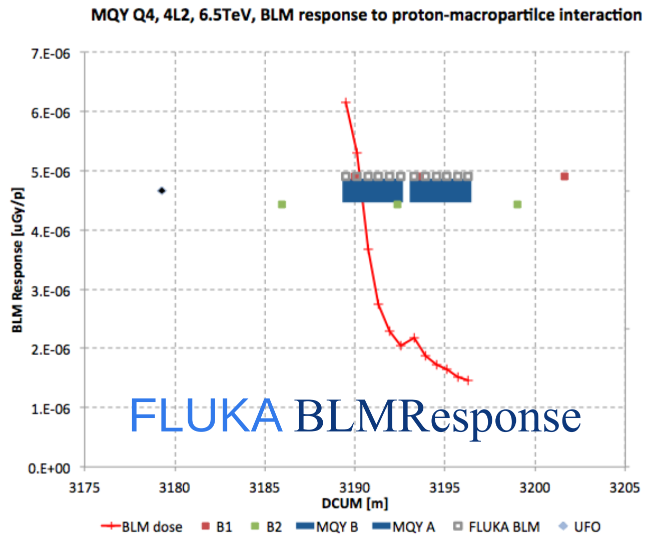
UFOs and orbit bumps.

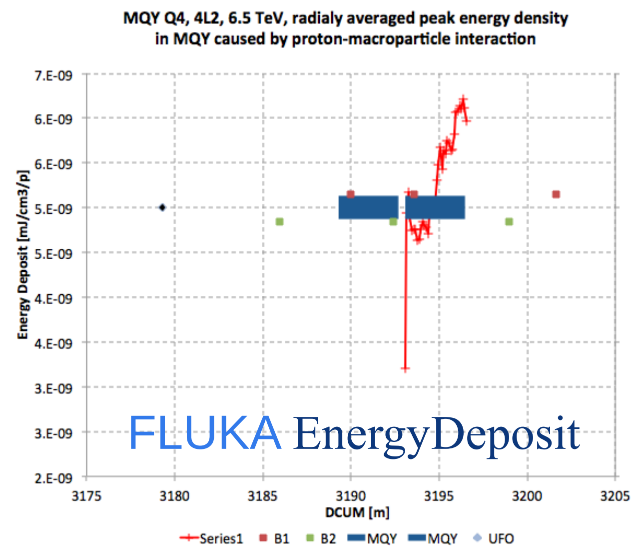
Large uncertainties on BLM locations.

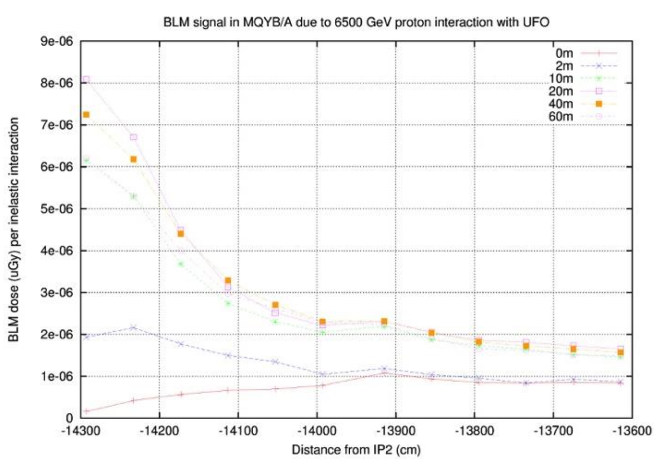
$$\text{BLMSignal@Quench}(E,t) = \frac{\text{BLMResponse}(E,t) * \text{QuenchLevel}(E,t)}{\text{EnergyDeposit}(E,t)}$$

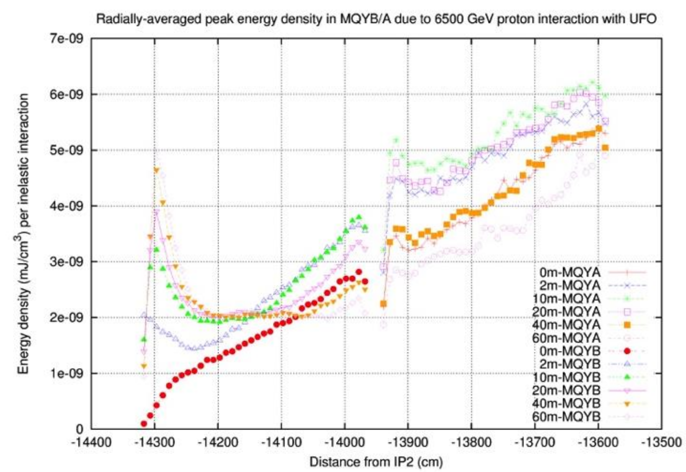
MQY UFO

UFOs are simulated in different locations upstream of the MQY. Thresholds are computed for the **10-m-location**, which is a likely scenario for MKI UFOs.





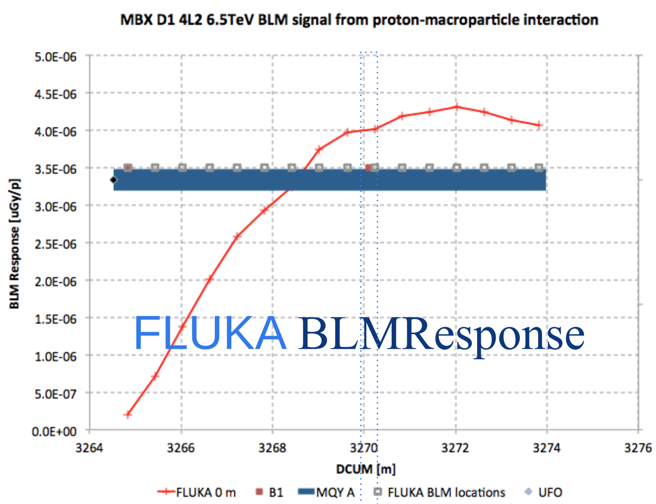


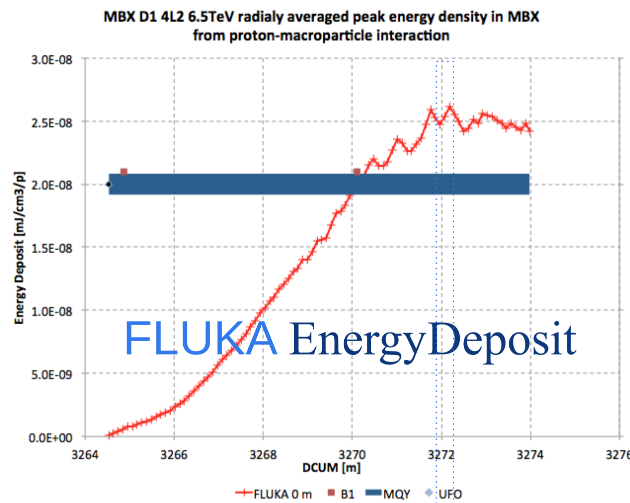


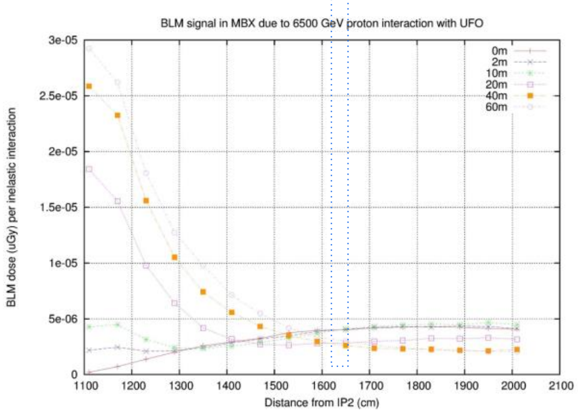
$$\text{BLMSignal@Quench}(E,t) = \frac{\text{BLMResponse}(E,t) * \text{QuenchLevel}(E,t)}{\text{EnergyDeposit}(E,t)}$$

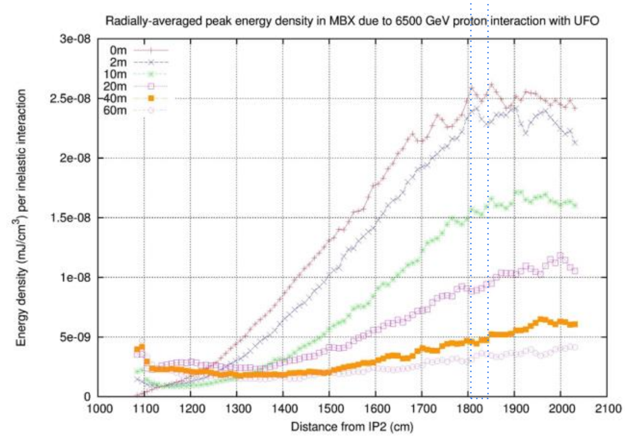
MBX (MBRC) UFO

UFOs are simulated in different locations upstream of the MQY. Thresholds are computed for the **0-m-location**, as otherwise they would be exceedingly large.







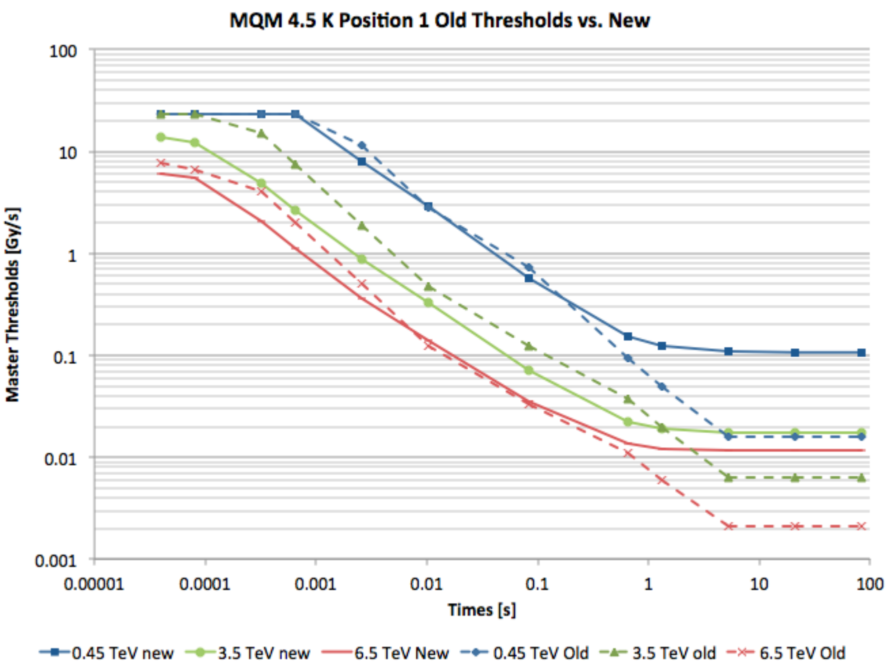


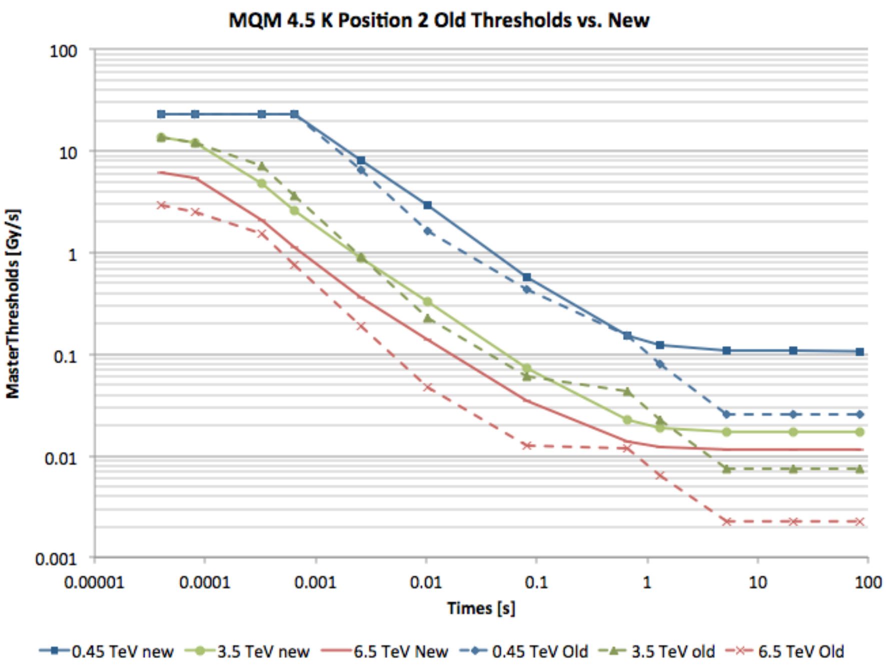
MQM 4.5 K Positions 1,2

DOB. Pos. 1 and 2 thresholds identical (Position 1 sees little signal from DOB)

Old thresholds:

- Energy Deposit and BLM Response: C. Kurfürst “TWISS” scenario (Losses at interconnect).
- Quench Level: MQM Note 44 / 4.5 K strand enthalpy and 1.9 K steady-state limit.



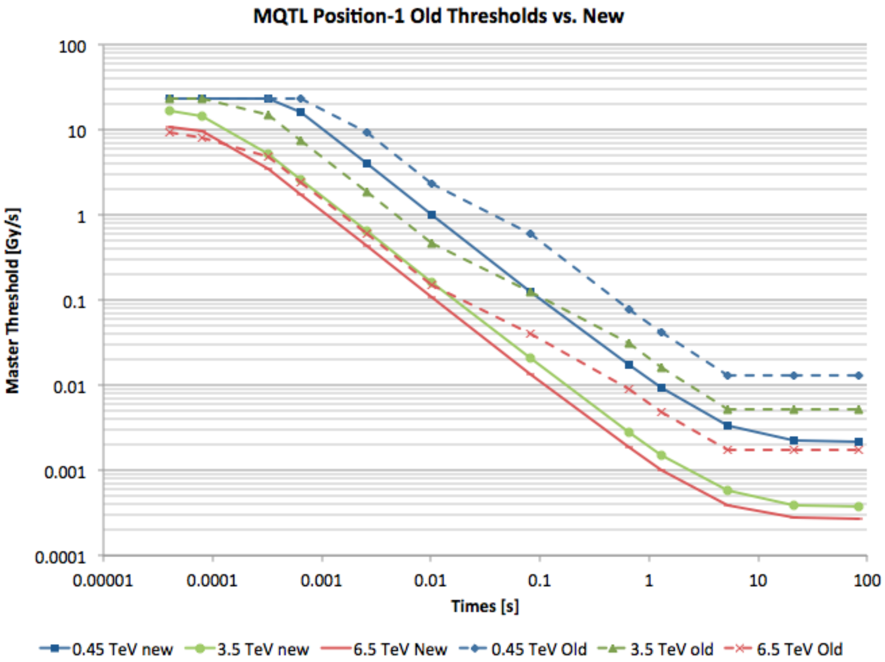


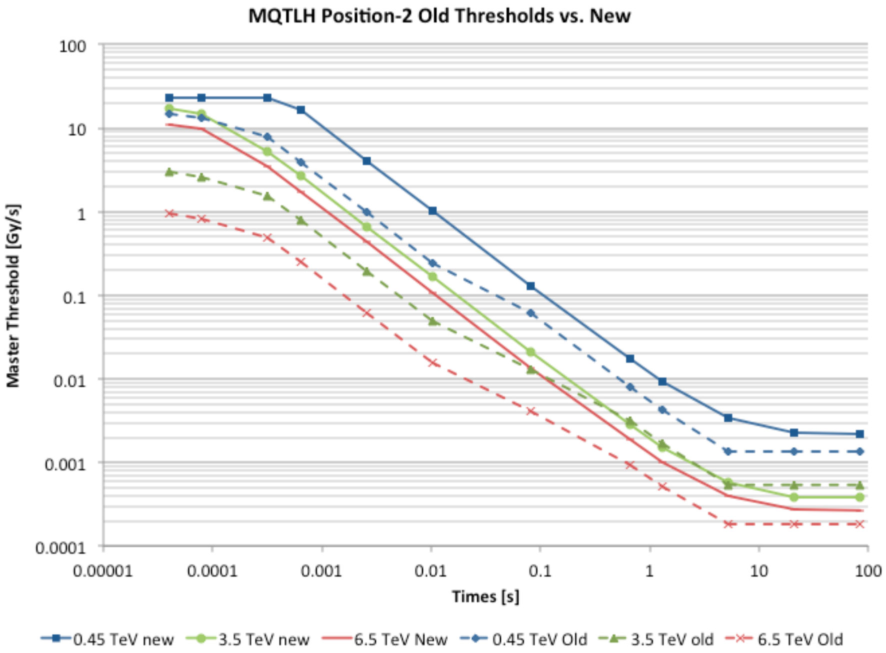
MQTL 4.5 K Positions 1,2

DOB. Pos. 1 and 2 thresholds identical (Position 1 sees little signal from DOB)

Old thresholds:

- Energy Deposit and BLM Response: C. Kurfürst "TWISS" scenario (Losses at interconnect).
- Quench Level: MQY Note 44 with D. Bocian values.

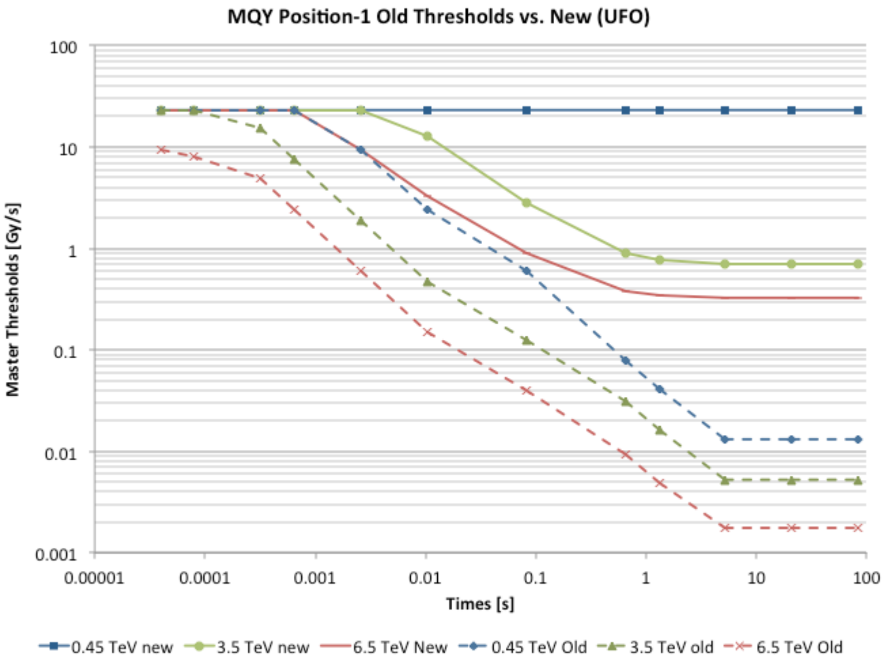


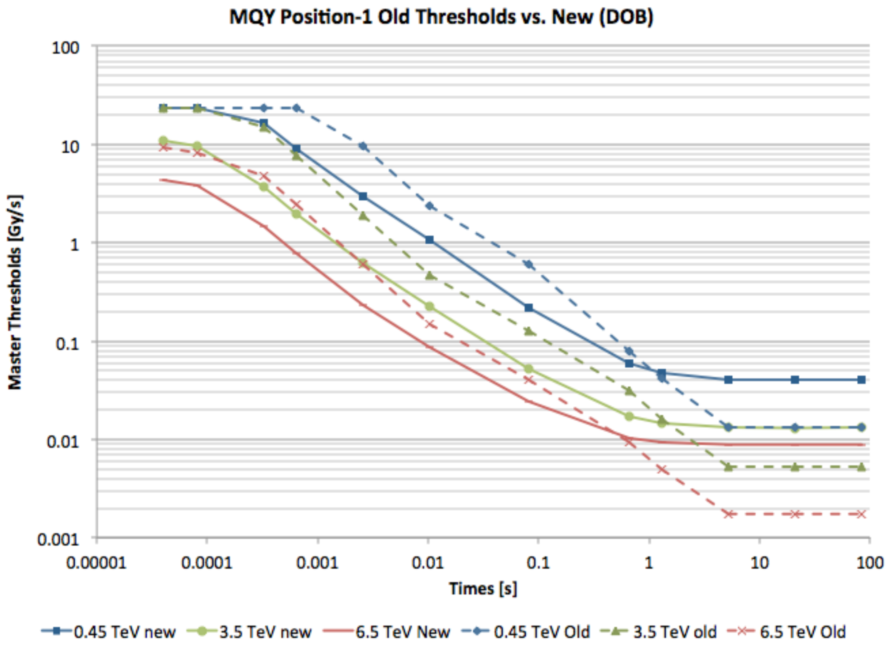


MQY 4.5 K Position 1

UFO vs. DOB.

Proposition: Use DOB with AdHoc factors (see next slide).



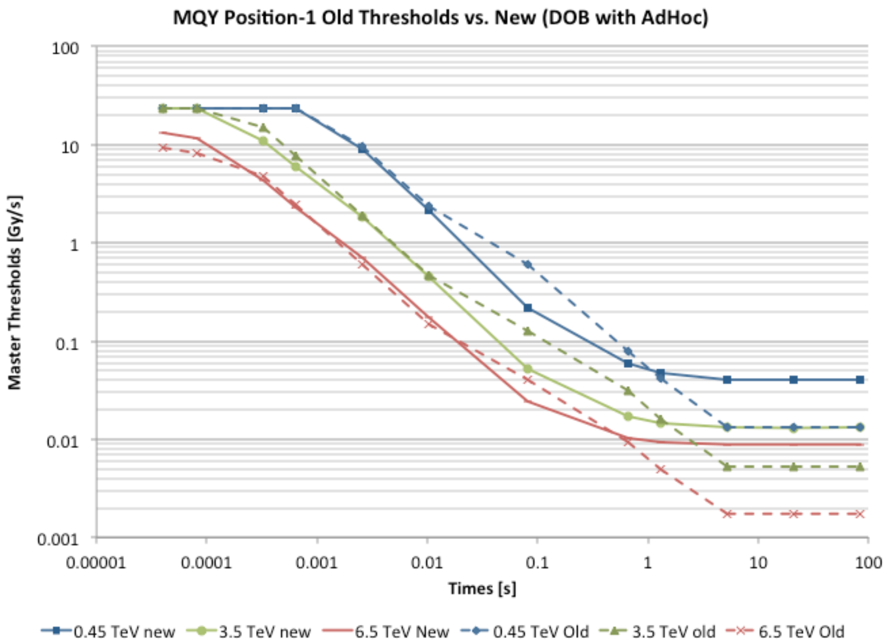


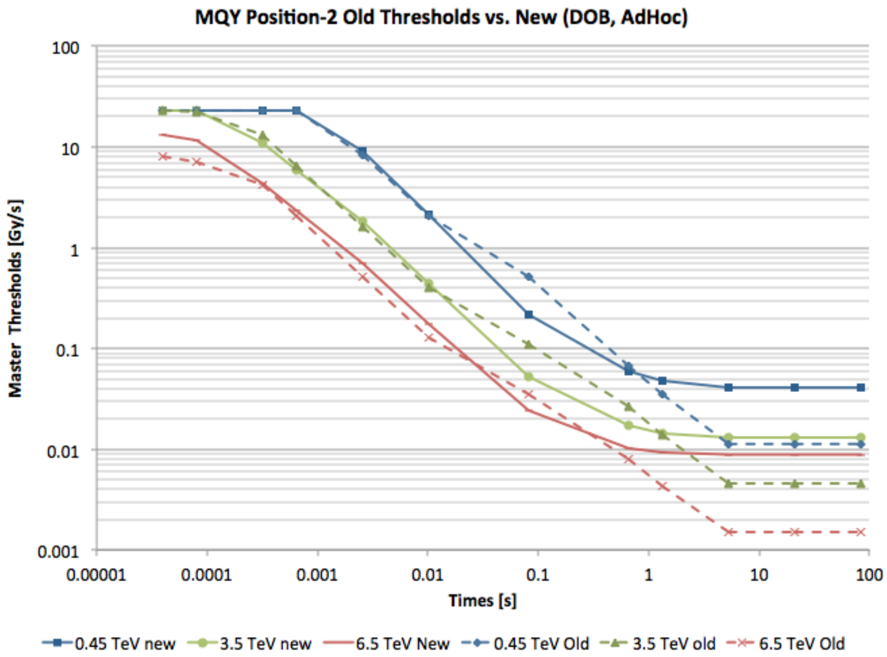
MQY 4.5 K Positions 1,2

DOB with AdHoc factors. Note that there should be room for a further increase in AdHoc factors to accommodate MKI UFOs.

Old thresholds:

- Energy Deposit and BLM Response: C. Kurfürst "TWISS" scenario (Losses at interconnect).
- Quench Level: MQY Note 44 / D. Bocian parameters.



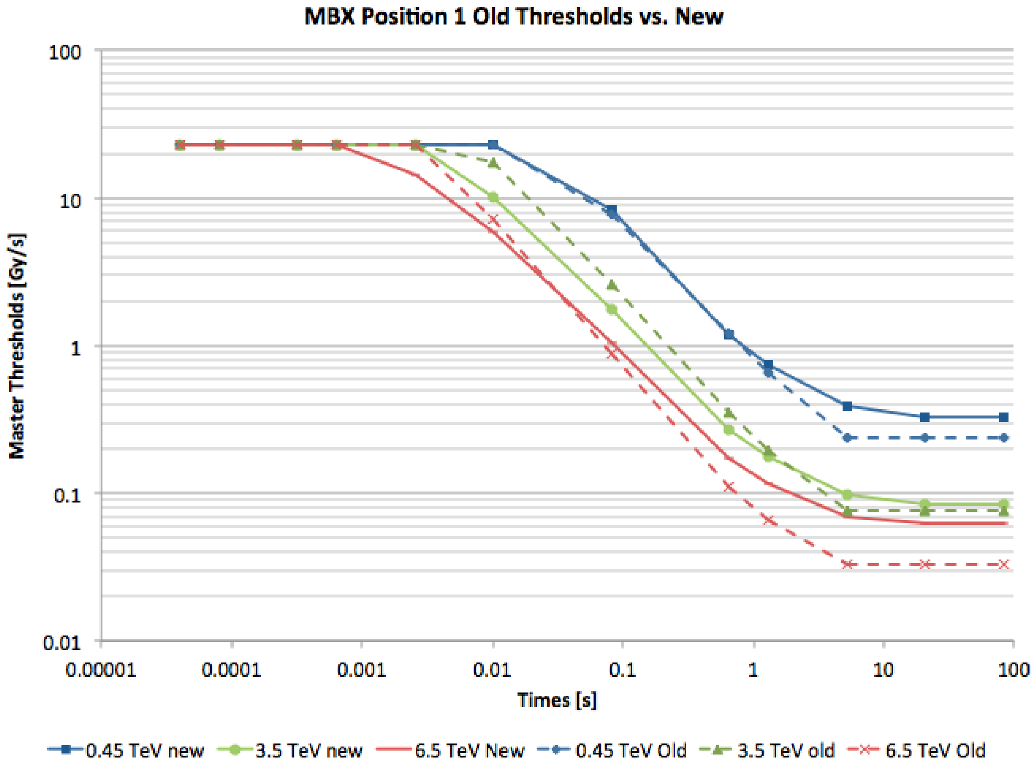


MBX 1.9 K Positions 1,2

UFO location selected as to reproduce roughly old thresholds!

Old thresholds:

- Energy Deposit: Position 1: Note 422 MB (Strong-kick event), Position 2: C. Kurfürst “TWISS” scenario (Losses at interconnect)
- BLM Response: C. Kurfürst “TWISS” scenario (Losses at interconnect).
- Quench Level: MBX = 2x MB.



MBRC 4.5 K Positions 1,2

UFO location selected as to reproduce roughly old thresholds!

Old thresholds:

- Energy Deposit and BLM Response: C. Kurfürst “TWISS” scenario (Losses at interconnect).
- Quench Level: MQM 4.5 K Note 44 / D. Bocian parameters.