BLM thresholds - summary of Run 2 and first outlook to Run 3

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On behalf of the BLMTWG

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Reminder:

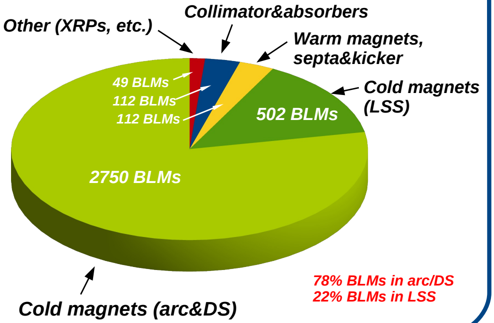
Applied Thresholds** (E,t) = **Master Thresholds** (E,t) **x Monitor Factor

12 Running Sums (40 µs – 84 s)

The same for all BLMs in a family (Master Thresholds)

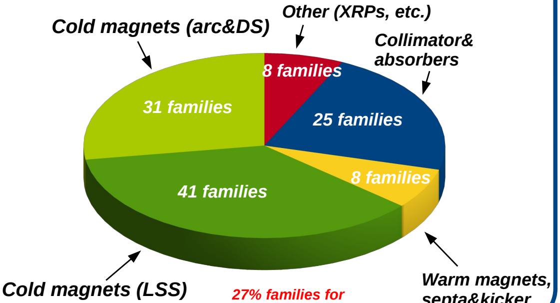
Can be different for BLMs in a family (Monitor Factor)

Number of BLMs in BIS (2018): 3525



78% BLMs in arc/DS
22% BLMs in LSS

Number of BLM families (2018): 113

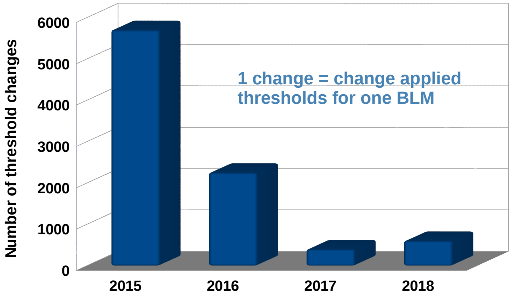


27% families for arc/DS
73% families for LSS

Run 2 BLM threshold changes in a nutshell

Number of threshold changes in Run 2 (p & Pb):

(numbers are approximative and do not include short temporary changes, e.g. RP alignment)



→ ***had about 70 BLMTWG meetings (including dedicated UFO meetings)***

→ ***changes documented in 36 ECRs***

Some key changes:

New threshold model for magnets in 2015

In 2015+16, many empirical corrections for UFOs to improve availability

Special loss cases requiring locally a tighter quench protection (ULO, interturn short in 31L2, 16L2, reducing risk of symmetric quenches in Q10,...)

Regular corrections (1-2 x per year) for collimation losses and collision debris (otherwise could not have reached design loss rates / desired luminosities)

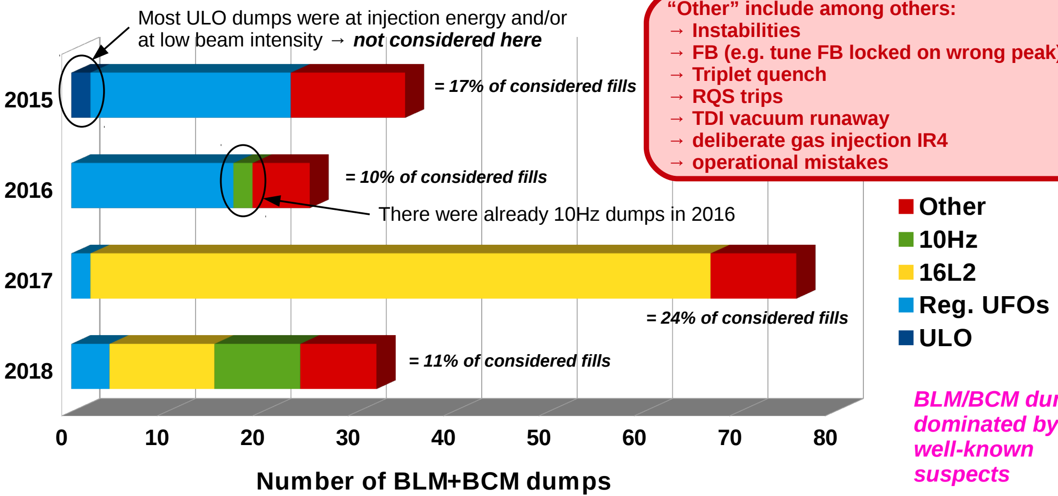
Special settings for Pb runs

Contents

Beam-induced BLM and BCM dumps in Run 2 - by year/source of losses

*Considered only fills with **E>450 GeV**, I_{beam} **> 3x10^{11} protons / >3.6x10^{9} Pb ions** (MDs excluded)*

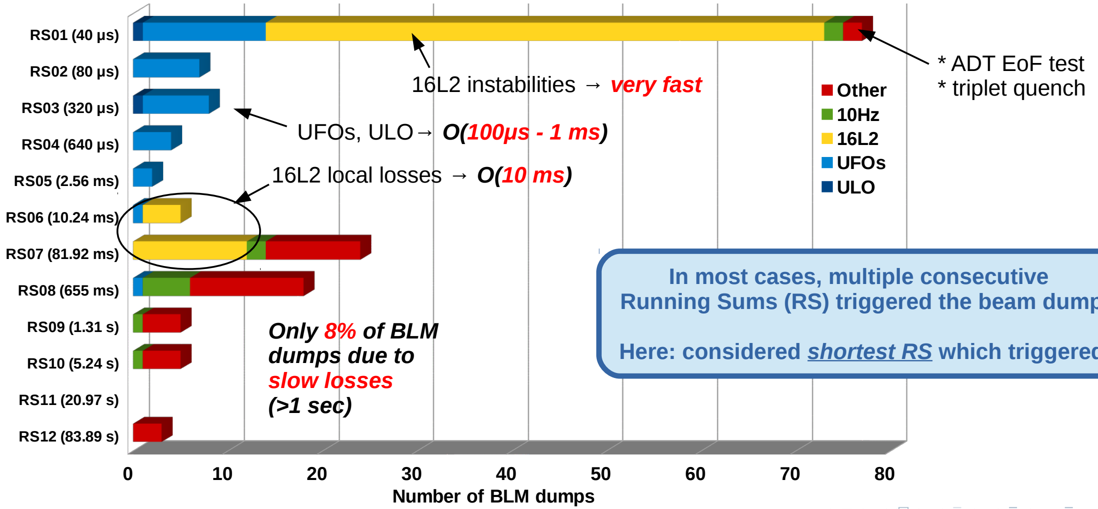
"Other" include among others:
- → Instabilities
- → FB (e.g. tune FB locked on wrong peak)
- → Triplet quench
- → RQS trips
- → TDI vacuum runaway
- → deliberate gas injection IR4
- → operational mistakes



BLM/BCM dumps dominated by well-known suspects

Beam-induced BLM dumps in Run 2 - by Running Sum

*Considered only fills with **E>450 GeV**, **I_{beam} > $3x10^{11}$ protons** / **>$3.6x10^{9}$ Pb ions** (MDs excluded)*

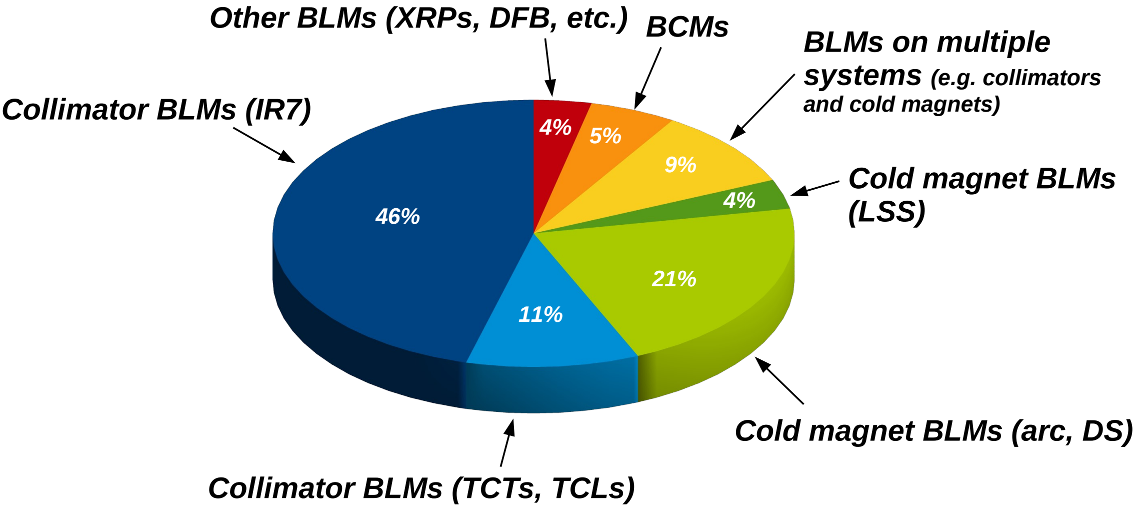


In most cases, multiple consecutive Running Sums (RS) triggered the beam dump

Here: considered *shortest RS* which triggered

Beam-induced BLM and BCM dumps in Run 2 - by equipment

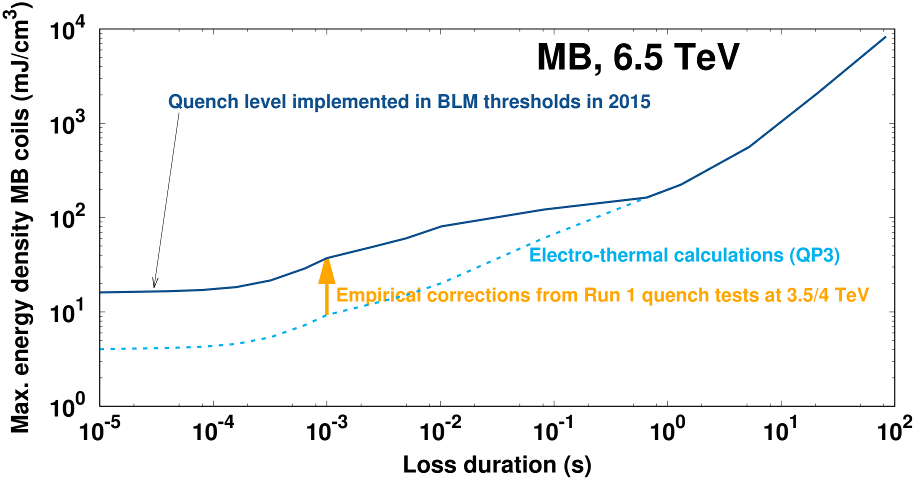
Considered only fills with ***E>450 GeV***, ***I_{beam} > 3x10^{11} protons*** **/** ***>3.6x10^{9} Pb ions*** *(MDs excluded)*



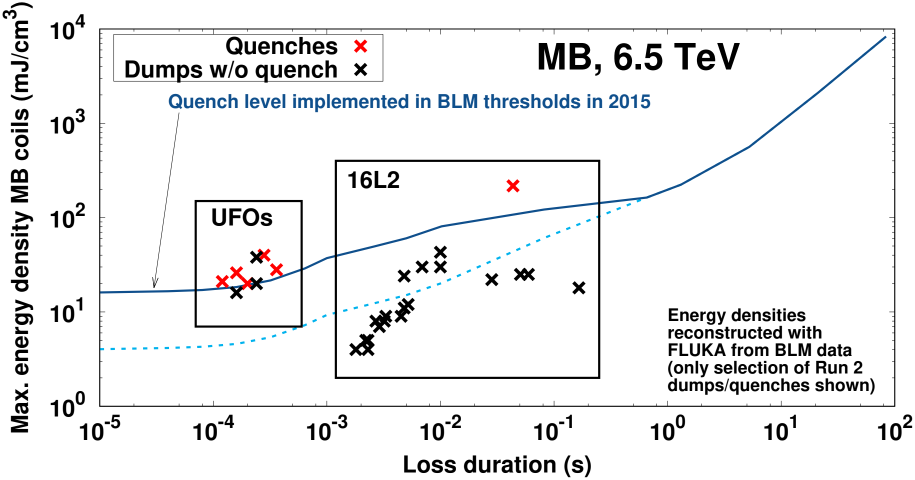
Contents

BLM thresholds at cold magnets - lessons from Run 2 (1/2)

Lesson #1: ***quench levels (MB) implemented in LS1 confirmed by events@6.5TeV***



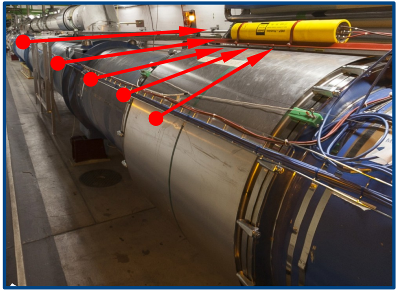
***<u>Lesson #1:</u>* quench levels (MB) implemented in LS1 confirmed by events@6.5TeV**



Lesson #2: *preventing UFO quenches comes at the cost of unnecessary dumps*

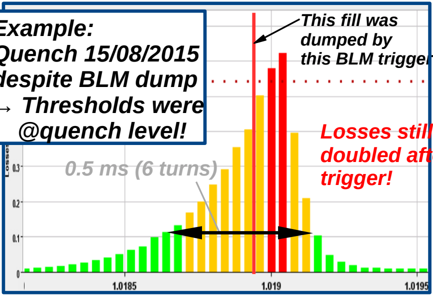
Why?

1) To prevent quenches, thresholds need cover full magnet length → UFOs close to BLM can trigger a dump even if they are not dangerous



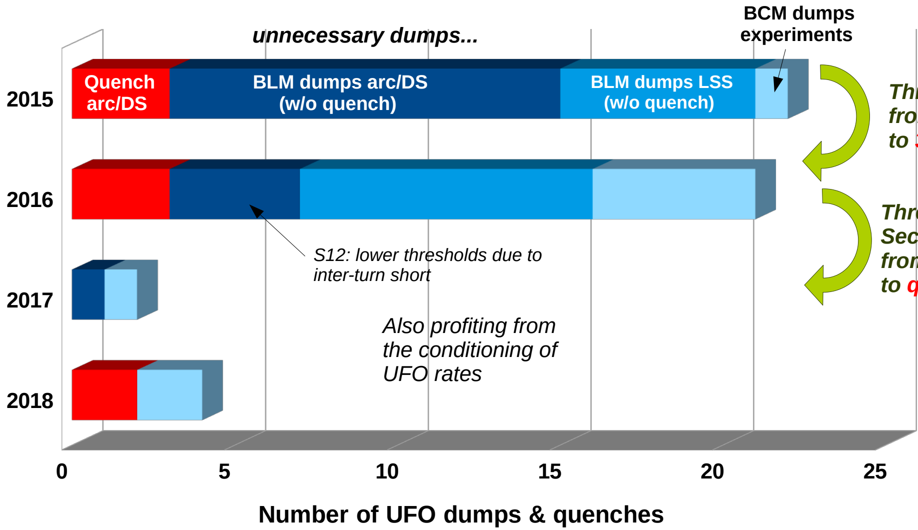
2) To prevent quenches, threshold need to be set lower than quench level (by about a factor of 3) since beam is not instantly gone → provokes even more unnecessary dumps

Example: Quench 15/08/2015 despite BLM dump → Thresholds were @quench level!



Conclusion: *for availability it is better to avoid unnecessary dumps and tolerate quenches*

BLM threshold strategy for cold magnets - Run 2 experience (UFOs)



Thresholds arc/DS: from quench level to 3 x quench level

Thresholds Matching Section quadrupoles: from quench level/3 to quench level

BLM threshold strategy for cold magnets (UFOs) - first outlook for Run 3

- **Proposal for Run 3 start-up → keep 2018 strategy (avoid unnecessary dumps, tolerate quenches)**
- **UFO quench risk will depend on energy in 2021 (is about 2-4 higher at 7 TeV than at 6.5 TeV)**
- **Deconditioning: if we fall back to 2015 rates, can expect O(5-10) quenches in 2021 if *E*=7 TeV**

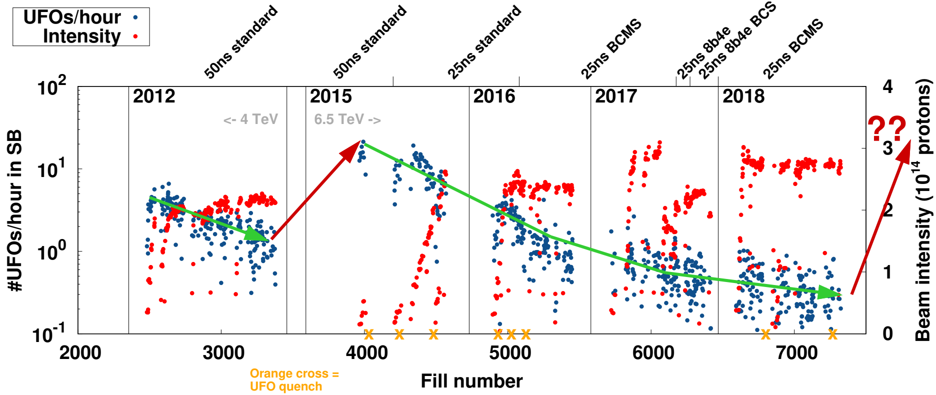


Figure includes only cells ≥12, and considers only fills with ≥1 h in STABLE and with >100b per beam, only BLMs common to Run 1 and Run 2. Different RS04 detection thresholds used to account for different beam energies (4 TeV: 1×10^{-4} Gy/s, 6.5 TeV: 2×10^{-4} Gy/s).

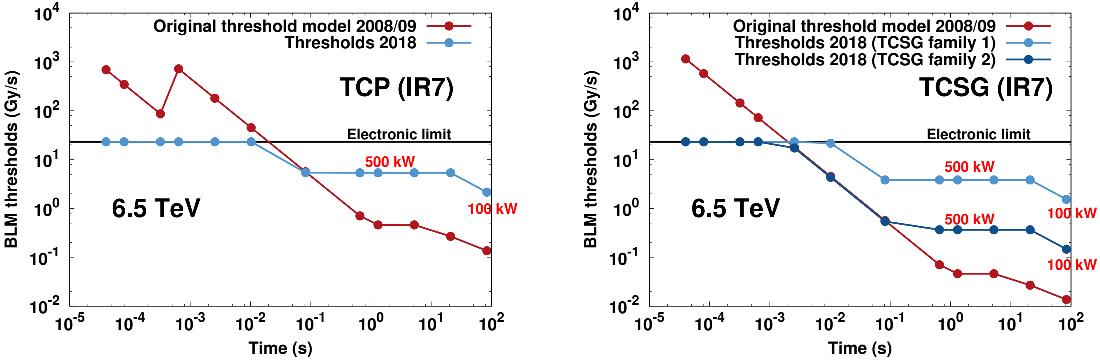
BLM threshold model for collimators - Run 1&2 experience

- **Original model (from 2008/09) did not consider cross-talk, collision debris etc. → needed many empirical corrections throughout the years**

  ⇒ to **align thresholds to design loss rates in IR7**

  ⇒ to **avoid premature dumps from pp debris** (TCLs, TCTs)

For example:



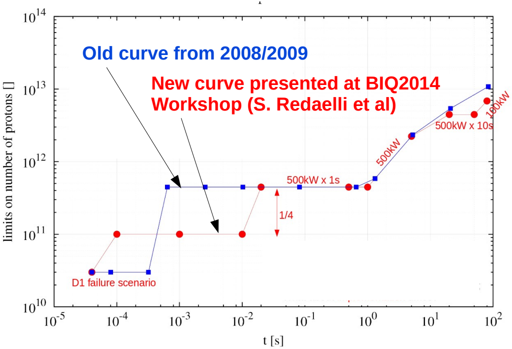
Note that for short loss durations, model would be quite higher than electronic limit

BLM threshold model for collimators - updates for Run 3

- **Operational experience (i.e. empirical corrections) from Run 2 → a good basis for Run 3, but need to establish threshold model parameters for MoGR collimators (some have a coating)**
  - FLUKA simulations of energy deposition/BLM response needed (incl. energy deposition in coating)
- **At the same time, plan to remove multiple shortcomings in original model**
  - New energy/material-dependent BLM response
  - New proton loss rates
  - New scaling factors for TCLAs/TCTs/TCLs

→ *in practice this means limited changes for existing thresholds (will be in the shadow of empirical corrections and electronic limit)*

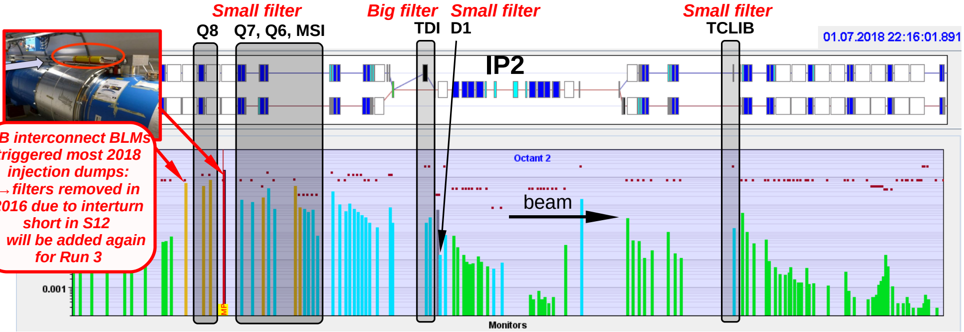
- **Other plans: harmonize BLM positions at TCLs, TCTs (better prediction of response)**



Losses in injection regions - Run 2 experience

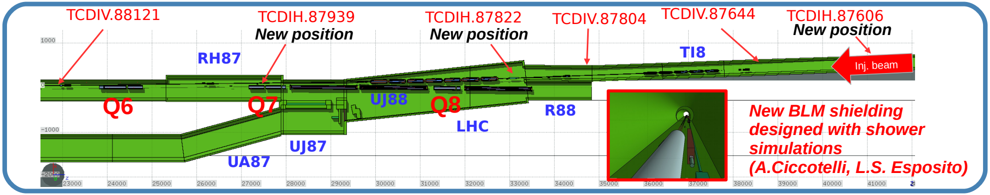
- In Run 2, injection losses were handled with BLM filters (**21 BLMs with filters in IR2, 28 in IR8**) + special BLM families for injection regions
- Mainly small filters (**factor 20 reduction in RS01**), few big filters on TDIs (**factor 180 reduction**)
- In **2018** (**2017**), **87%** (**97%**) of injections were below 20% of dump thresholds *(F. Velotti, Evian19)*

Typical transverse loss event in 2018 (impact on TCDIs → cross talk to LHC BLMs):



BLM thresholds in injection regions - outlook to Run 3

- **Significant changes in Run 3**
  - New transfer line collimators TCDILs (will be longer: 2.1 m instead of 1.2 m)
  - New TCDIL positions in TI8 (+new BLM shielding)
  - More bunches/injection (288), higher bunch intensity than in Run 2



- **Baseline for Run 3 start-up: still handle injection losses with BLM filters**
  - Shower simulations for new TI8 layout (*A. Ciccotelli, L.S. Esposito, BLMTWG #71*) indicate that this **should in principle be feasible** (need to review BLM families ahead of Run 3)
  - In case , use injection inhibit (aka **blindable BLMs**) as a **fallback solution** - suggest that the system should be commissioned early
  - Alternative to blindable: use big filters for selected BLMs on SC magnets? (for discussion...)

Contents

Summary & conclusions

- **BLM thresholds for superconducting magnets:**
  - Threshold model (quench levels) **proved to be accurate**
  - Optimized strategy for UFOs throughout Run 2 → **plan to retain strategy for Run 3 start-up** (avoid unnecessary dumps, tolerate quenches)
  - **No major changes planned in LS2**, but still some work ahead (e.g. 11T magnets, review triplet threshold model, extend FT corrections to 7 TeV, ...)
- **BLM thresholds for collimators:**
  - Thresholds are **now largely based on operational experience** (in particular wrt cross-talk)
  - For Run 3, need to define **threshold model parameters for MoGR collimators** (e.g. BLM response)
  - Will also **update parameters in original collimator threshold model**
  - Empirical corrections (for cross-talk) from Run 2 form a good basis for Run 3
- **BLM thresholds for injection regions:**
  - Baseline for **Run 3 start-up** is to **rely on BLM filters as in Run 2**
  - **Blindable system** only as **fallback solution**, but should be commissioned
- **Not all topics were discussed, e.g. Pb thresholds, thresholds for warm magnets, septa, ...**