UFO BLM threshold strategy for Run 3 (arcs/DS)

A. Lechner
With valuable input from A. Apollonio

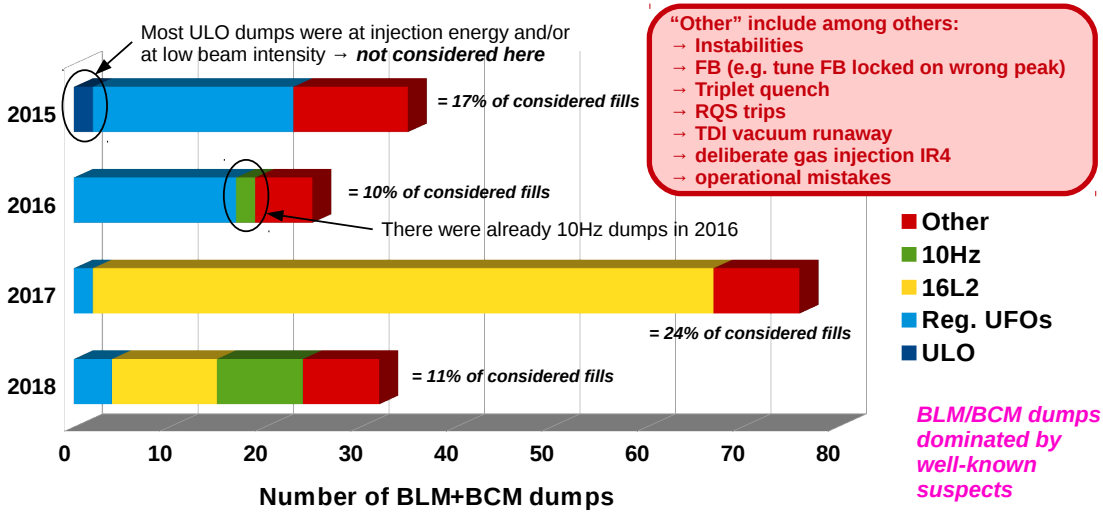
BLMTWG #87,

Oct 29$^{\mathrm{th}}$, 2021

Contents

Beam-induced BLM and BCM dumps in Run 2 - UFOs vs others

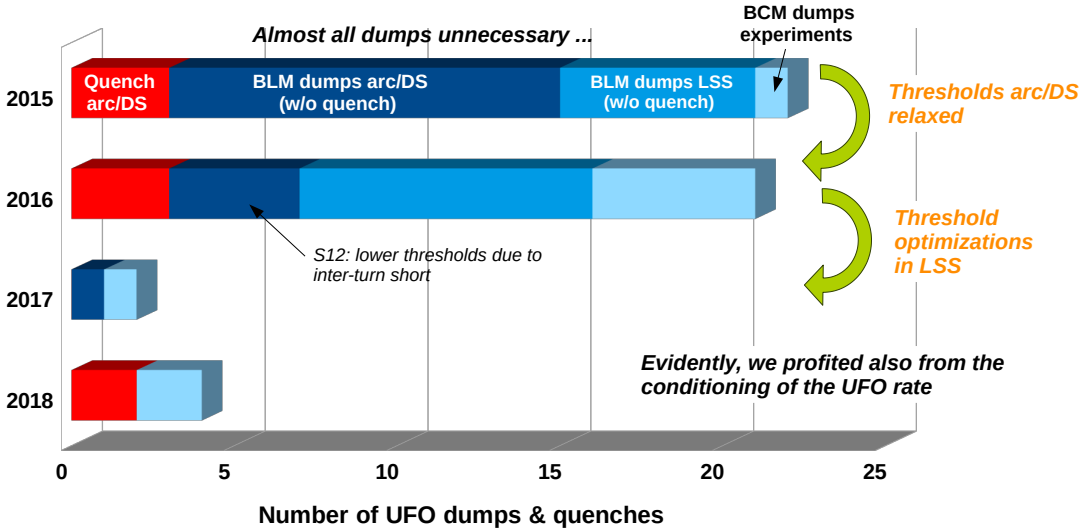
*Considered only fills with **E>450 GeV**, **I_{beam} > 3x10^{11} protons / >3.6x10^{9} Pb ions** (MDs excluded)*



"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

More details about UFO dumps and quenches in Run 2



UFOs in the arcs and dispersion suppressors - BLM threshold strategies

Avoiding quenches vs **avoiding unnecessary dumps**:

x0.3

Tight thresholds:

- Goal = prevent UFO quenches (yet faster UFOs can still quench magnets)
- At the cost of (many) unnecessary dumps

→ Applied in **S12** in the second half of **2016** (MB inter-turn short)

x3

Medium thresholds:

- Goal = prevent some UFO quenches
- At the cost of some unnecessary dumps

→ Applied in **2015** (in all arcs and dispersion suppressors)

Relaxed thresholds:

- Goal = avoid unnecessary dumps
- Quenches are tolerated

→ Applied in **2016-18** (in all arcs and dispersion suppressors, except S12 in 2016)

Run 2 was a mixture of different strategies → which one is the best for machine availability?

UFOs in the **arcs** and **dispersion suppressors** - BLM threshold strategies

Any impact of premature dumps on availability and hence on the number of fills is not reflected in this projection. Lower thresholds in S12 in 2016 are still account for in all cases.

If **tight settings** would have been applied the entire Run 2

	Quenches	Quench avoided	Unnecessary dumps
2015	0	4	58
2016	2	1	67
2017	0	0	19
2018	1	1	23
Total	3	6	173

555 hours lost

If **medium settings** would have been applied the entire Run 2

	Quenches	Quench avoided	Unnecessary dumps
2015	3	1	29
2016	3	0	34
2017	0	0	10
2018	2	0	12
Total	8	1	85

201 hours lost

If **relaxed settings** would have been applied the entire Run 2

	Quenches	Quench avoided	Unnecessary dumps
2015	3	1	17
2016	3	0	20
2017	0	0	6
2018	2	0	7
Total	8	1	50

126 hours lost

What we actually observed in **Run 2** in the arcs and DS

	Quenches	Quench avoided	Unnecessary dumps
2015	3	1	11
2016	3	0	4
2017	0	0	1
2018	2	0	0
Total	8	1	16

147 hours lost

Strategy only suitable if quenches shall be prevented for reasons other than machine availability

Assumption: Dump w/o quench = **3 hours lost**, Quench = **12 hours lost**

UFOs in the **arcs** and **dispersion suppressors** - BLM threshold strategies

Any impact of premature dumps on availability and hence on the number of fills is not reflected in this projection. Lower thresholds in S12 in 2016 are still account for in all cases.

If **tight settings** would have been applied the entire Run 2

	Quenches	Quench avoided	Unnecessary dumps
2015	0	4	58
2016	2	1	67
2017	0	0	19
2018	1	1	23
Total	3	6	173

555 hours lost

If **medium settings** would have been applied the entire Run 2

	Quenches	Quench avoided	Unnecessary dumps
2015	3	1	12
2016	3	0	11
2017	0	0	4
2018	2	0	7
Total	8	1	34

201 hours lost

If **relaxed settings** would have been applied the entire Run 2

126 hours lost

What we actually observed in **Run 2** in the arcs and DS

147 hours lost

Strategy not very effective in preventing quenches, while number of unnecessary dumps remains non-negligible

Assumption: Dump w/o quench = **3 hours lost**, Quench = **12 hours lost**

UFOs in the **arcs** and **dispersion suppressors** - BLM threshold strategies

Any impact of premature dumps on availability and hence on the number of fills is not reflected in this projection. Lower thresholds in S12 in 2016 are still account for in all cases.

	If **tight settings** would have been applied the entire Run 2			If **medium settings** would have been applied the entire Run 2			If **relaxed settings** would have been applied the entire Run 2			What we actually observed in **Run 2** in the arcs and DS		
	Quenches	Quench avoided	Unnecessary dumps	Quenches	Quench avoided	Unnecessary dumps	Quenches	Quench avoided	Unnecessary dumps	Quenches	Quench avoided	Unnecessary dumps
2015	0	4	58	3	1	12	4	0	1	3	1	12
2016	2	1	67	3	0	11	3	0	4	3	0	11
2017	0	0	19	0	0	4	0	0	1	0	0	4
2018	1	1	23	2	0	7	2	0	0	2	0	7
Total	3	6	173	8	1	34	9	0	6	8	1	34
	555 hours lost			**201** hours lost			**126** hours lost			**147** hours lost		

Best strategy for machine availability

Assumption: Dump w/o quench = **3 hours lost**, Quench = **12 hours lost**

UFOs in the **arcs** and **dispersion suppressors** - BLM threshold strategies

Any impact of premature dumps on availability and hence on the number of fills is not reflected in this projection. Lower thresholds in S12 in 2016 are still account for in all cases.

	If **tight settings** would have been applied the entire Run 2			If **medium settings** would have been applied the entire Run 2			If **relaxed settings** would have been applied the entire Run 2			What we actually observed in **Run 2** in the arcs and DS		
	Quenches	Quench avoided	Unnecessary dumps	Quenches	Quench avoided	Unnecessary dumps	Quenches	Quench avoided	Unnecessary dumps	Quenches	Quench avoided	Unnecessary dumps
2015	0	4	58	3	1	12	4	0	1	3	1	11
2016	2	1	67	3	0	11	3	0	4	3	0	4
2017	0	0	19	0	0	4	0	0	1	0	0	1
2018	1	1	23	2	0	7	2	0	0	2	0	0
Total	3	6	173	8	1	34	9	0	6	8	1	16
	555 hours lost			**201** hours lost			**126** hours lost			**147** hours lost		

Assumption: Dump w/o quench = **3 hours lost**, Quench = **12 hours lost**

Take-away messages from Run 2

UFOs in the arcs/dispersion suppressors:

- **Avoiding unnecessary dumps** while **tolerating quenches** was the best strategy for machine performance in Run 2

→ Strategy for Run 3 start-up to be discussed (see rest of presentation)

UFOs in the Long Straight Sections (LSS):

- Risk of UFO-induced quenches in the LSSs is small (and were indeed never observed)
- Threshold optimizations to avoid dumps were the key in Run 2

→ Will keep most optimizations in the LSSs from Run 2 (although some families will be revised, e.g. TCTs, TCLs)

UFO near the experiments:

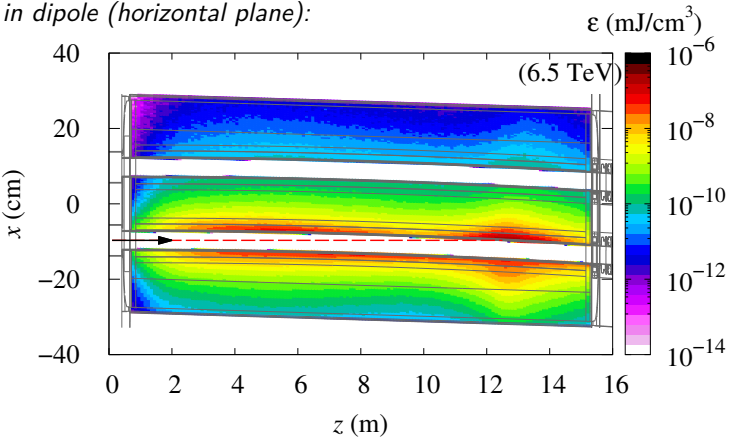
- BCMs often have lower thresholds than BLMs
- Discussions took place during Run 2 if there is margin to increase thresholds

→ Plan to have new discussions with experiments in 2022

Contents

Energy deposition by UFO-induced beam losses

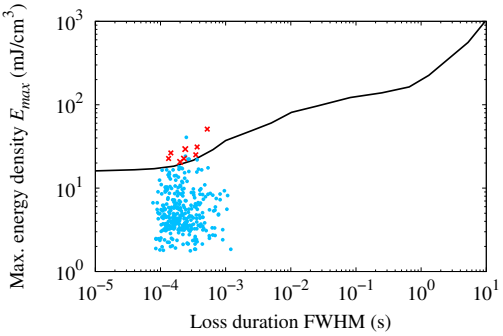
Energy density map in dipole (horizontal plane):

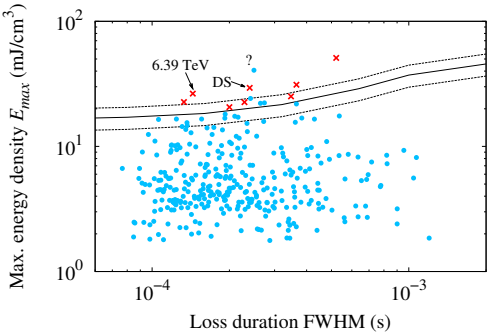


- Inelastic proton collisions in UFO $\rightarrow \gamma$'s (π^0 decay) and neutrons $\rightarrow$ hot spot after about 12 m
- **Quenches of MQs much less likely** since UFO must be at a specific location
- It is very unlikely that showers quench two magnets at the same time (and in fact was never observed)

Max. energy densities in MB coils for arc UFOs at 6.5 TeV (Run 2)

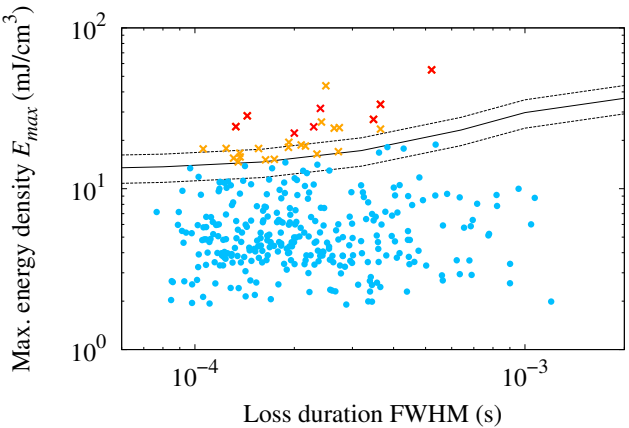
Largest UFO events in the arcs in Run 2 (energy deposition reconstructed with FLUKA):





- **Blue dots = no quench**, **red crosses = quench**
- Line = **MB quench level** as implemented in BLM threshold model (dashed lines +/- 20%)

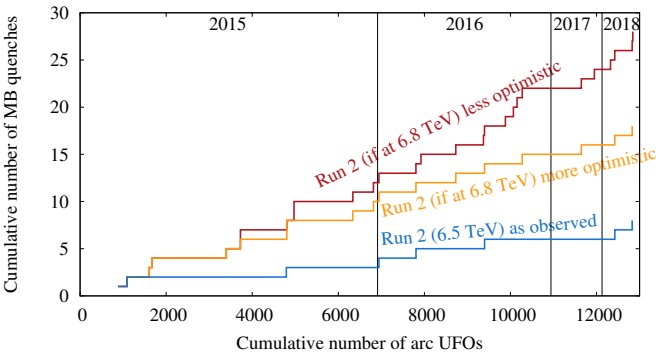
If we would have operated at 6.8 TeV in **Run 2** ...



- ... and assuming relaxed thresholds would have been applied throughout Run 2 ...
- then we could have potentially had **O(20+) quenches**

- Quench level 6.8 TeV vs 6.5 TeV: ↓ ∼**20%**
- Energy density per proton lost 6.8 TeV vs 6.5 TeV: ↑ ∼**7-8%**

If we would have operated at 6.8 TeV in Run 2 ...



- ... and assuming relaxed thresholds would have been applied throughout Run 2 ...
- then we could have potentially had **O(20+) quenches**
- Note: quenches can already occur with low intensities (e.g. in Run 2: 80b, 300b)

- Occurrence of a quench is statistical → proportional to the cumulative number of UFOs
- More UFOs are accumulated in the initial period → most quenches would have been in 2015+2016
- 2022: operational schedule is more like 2015 + a part of 2016
- *So if UFO rates fall back to 2015 values, one can expect a rocky start*

Contents

Possible BLM threshold strategies for the arcs/DSs for 2022

For discussion:

Scenario 1: if quenches can be tolerated in all sectors

- Relaxed thresholds could be applied from the beginning (best availability)
- If UFO rates are like in 2015, it is not excluded to have 10+ quenches in 2022

Scenario 2: if quenches in some magnets (or sectors?) shall be avoided*

- Tight tresholds could be applied selectively → if the number of magnets is limited (e.g. 100) then the impact should not be too severe
- At other locations, can still expect quenches like in scenario 1

Scenario 3: if quenches in all sectors shall be avoided*

- Tight tresholds could be applied for the initial period (e.g. for fills with <50-100 bunches)
- Once the UFO rate (hence the quench risk) is better known, the strategy can be adapted

* *Even with tight thresholds we cannot avoid all UFO-induced quenches (since some UFOs are too fast).*