BLM threshold changes for the 2024 heavy ion run

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Machine Protection Panel, 04/11/2024

Introduction

- **Heavy ion operation in the LHC requires significant BLM threshold changes, mainly due to:**
  - Betatron halo losses in IR7 (→ crystal collimation)
  - Fragment leakage to other locations (e.g. TCTs)
  - BFPP losses
- **The 2023 Pb run was challenging from the beam loss perspective (→ first times with crystals!)**
  - Needed to carry out 15+ threshold changes during the run due to recurring beam dumps
  - All the BLM threshold changes were documented in the *LHC-BLM-ECR-0079* - EDMS link
- **Thresholds for the 2024 Pb run:**
  - Starting point are the 2023 thresholds, but updated with 2024 loss maps
  - In addition, propose several changes, which should reduce the risk of premature dumps

2023 Pb run:

- **18 BLM dumps** in physics fills (9 in ramp, 9 at top energy)
- Mostly at **Q6R7** (7x), **TCLDs** (4x) and **TCTs** (4x)
- Almost all dumps were **"10 Hz" dumps**, often on top of other losses

1	Event Timestamp	Beam Mode	Beam Energy [MeV]	Fill Number	Stable Beam	BLM
2	27-SEP-2023 17.38.16.	RAMP	5642280	9195	0	Q6R7
3	27-SEP-2023 19.42.16.	RAMP	6328320	9196	0	TCTPH.4L1
4	28-SEP-2023 03.15.52.	RAMP	6312840	9199	0	TCTPH.4L1
5	01-OCT-2023 20.36.49.	ADJUST	6799200	9214	0	multiple
6	03-OCT-2023 02.16.09.	RAMP	6331920	9219	0	Q6R7
7	06-OCT-2023 19.32.01.	STABLE BEAMS	6799320	9234	0.285	TCLD.A11R2
8	11-OCT-2023 01.41.23.	RAMP	450480	9241	0	Q8R3
9	13-OCT-2023 05.10.15.	STABLE BEAMS	6799320	9251	2.37	TCLD.A11R2
10	16-OCT-2023 11.50.25.	RAMP	6145080	9265	0	11L7
11	16-OCT-2023 14.16.37.	RAMP	5969640	9266	0	11L7
12	16-OCT-2023 18.14.46.	STABLE BEAMS	6799320	9267	0.694	TCLD.A11R2
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14	20-OCT-2023 02.32.11.	ADJUST	6799320	9280	0	TCLD.A11R2
15	21-OCT-2023 05.31.01.	STABLE BEAMS	6799320	9284	1.12	Q6R7
16	24-OCT-2023 00.15.41.	RAMP	6714360	9295	0	TCTPV.4L2
17	24-OCT-2023 04.02.06.	STABLE BEAMS	6799320	9296	1.05	Q6R7
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19	24-OCT-2023 17.10.32.	FLAT TOP	6799320	9300	0	TCTPV.4L2
20	25-OCT-2023 17.05.17.	ADJUST	6799200	9304	0	Q6R7

List of BLM dumps in 2023 Pb run

Recap of 2023 BLM thresholds strategy

- **Quench risk for losses in IR7 (crystal collimation)**
  - Non-negligible uncertainty of allowed power loss without quenching → estimated to be roughly between 30-50 kW for slow losses in channeling (about 4x lower for amorphous)
- **IR7 BLM thresholds (collimators, Q6) in 2023:**
  - Decided to set master thresholds to **50-60 kW** for RS08-RS10 (0.5-5 s) channeling, and 4x lower for amorphous
  - Started with **MF=0.4**, but increased up to **MF=1.0** due to warnings and dumps (10 Hz losses)
- **IR7 DS magnet thresholds:**
  - Master thresholds were adjusted to 3x signal@quench measured during previous quench test (slow losses)
  - Started with **MF=0.333**, but then increased to **MF=0.45**


Losses in IR7: thresholds strategy for 2023 Pb run

- Propose adaptive BLM threshold strategy to optimize performance and avoid unnecessary dumps on losses → increase thresholds in steps (via Monitor Factor) in case of availability limitations
- **Any increase to be decided jointly by BLMTWG, MPP, collimation team and OP.**
- If a quench occurs, settings will be reverted to the previous one, avoiding further quenches (note: no magnets with possibly non-conform diodes are concerned), gives also valuable info about quench level

Master thresholds set to a power loss of 60 kW at collimators (for 10 sec), and slightly lower power loss at DS magnets

Propose to use initially a Monitor Factor (MF) of 0.4 for IR7 collimators and DS magnets

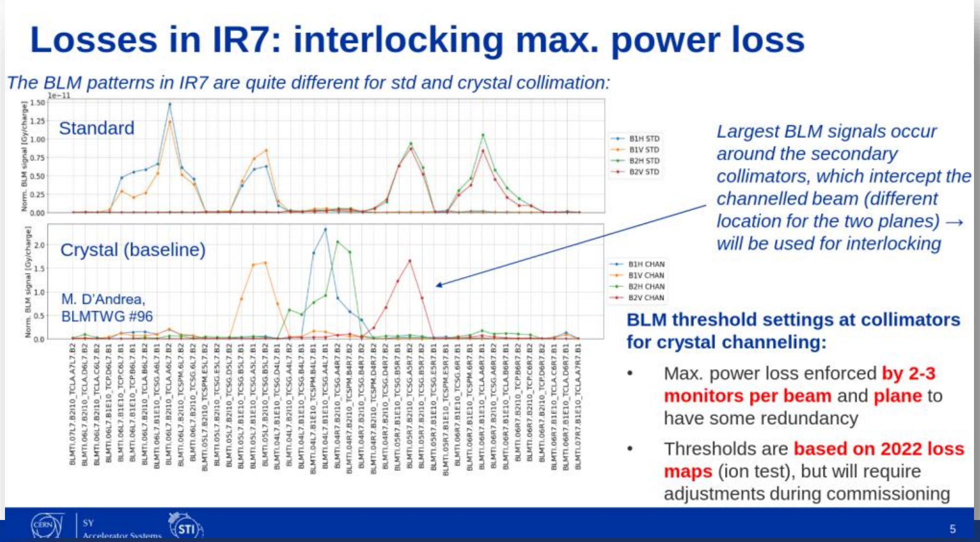
In case of premature dumps w/o quench, allow for a MF increase in steps of 0.2

	Duration	Proton run 2023		Proposal for Pb run 2023 (with crystals)				
		Master	Applied (MF=0.6)	Master	Applied (MF = 0.4)	Applied (MF=0.6)	Applied (MF=0.8)	Applied (MF=1.0)
RS08	0.655 s	500 kW	300 kW	60 kW	24 kW	36 kW	48 kW	60 kW
RS09	1.31 s	500 kW	300 kW	60 kW	24 kW	36 kW	48 kW	60 kW
RS10	5.24 s	500 kW	300 kW	60 kW	24 kW	36 kW	48 kW	60 kW
RS11	20.97 s	239 kW	143 kW	29 kW	12 kW	17 kW	23 kW	29 kW
RS12	83.89 s	100 kW	60 kW	12 kW	5 kW	7 kW	10 kW	12 kW

Allowed power loss by BLM thresholds at IR7 collimators

Initial

Possible steps


Losses in IR7: interlocking max. power loss

The BLM patterns in IR7 are quite different for std and crystal collimation:

Largest BLM signals occur around the secondary collimators, which intercept the channelled beam (different location for the two planes) → will be used for interlocking

BLM threshold settings at collimators for crystal channeling:

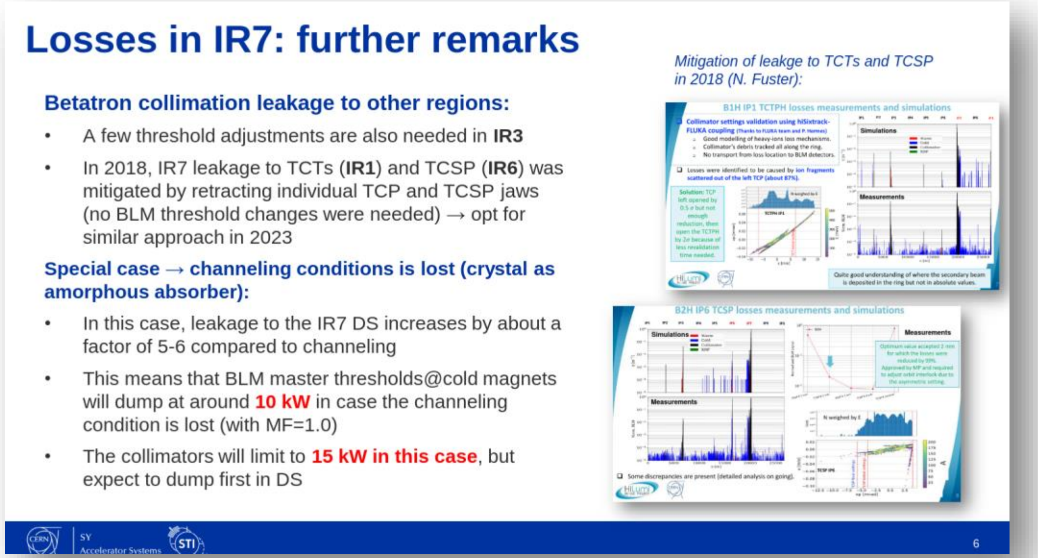
- Max. power loss enforced **by 2-3 monitors per beam** and **plane** to have some redundancy
- Thresholds are **based on 2022 loss maps** (ion test), but will require adjustments during commissioning

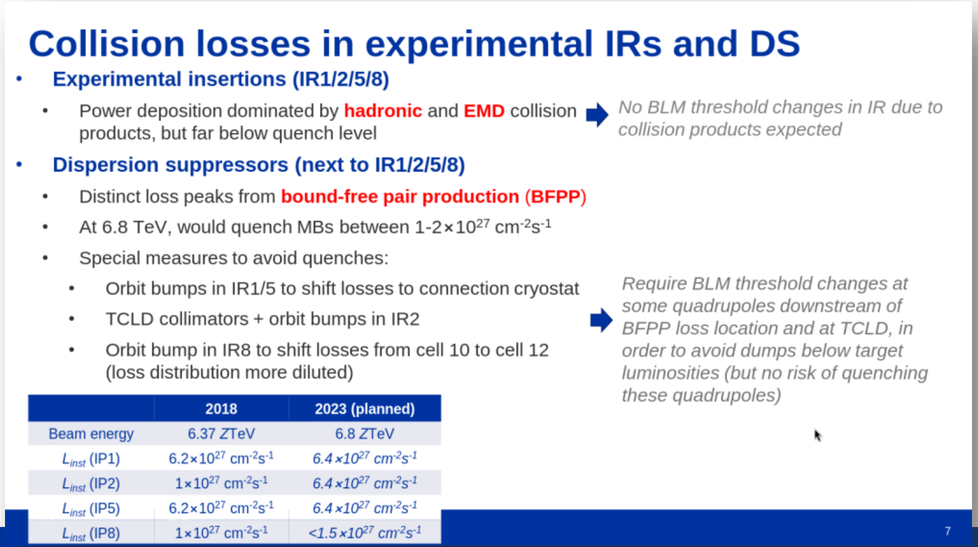
Note: the 2023 strategy included the possibility of a DS magnet quench → in case a quench would have occurred, we would have reduced the MFs to avoid a second quench

Recap of 2023 BLM thresholds strategy

- **Betatron collimation leakage to other regions**
  - Did not expect major threshold changes due to fragment leakage to other regions
  - But this turned out to be wrong → almost half of the dumps were due to fragment leakage to TCTs/TCLD (again fast losses, i.e., 10 Hz events)
  - Required multiple master threshold changes during run
- **Collisional losses:**
  - Thresholds set to avoid BLM warnings due to collisional losses (mainly BFPP ions)
  - Everything worked as expected

Summary of main issues encountered in 2023:
- Lost channeling conditions (often in amorphous or volume reflection)
- Fast losses (10 Hz) were eventually more limiting than slow losses → hit bottlenecks at Q6, TCLDs and TCTs





	2018	2023 (planned)
Beam energy	6.37 ZTeV	6.8 ZTeV
L_{inst} (IP1)	6.2×10^{27} cm^{-2}s^{-1}	6.4×10^{27} cm^{-2}s^{-1}
L_{inst} (IP2)	1×10^{27} cm^{-2}s^{-1}	6.4×10^{27} cm^{-2}s^{-1}
L_{inst} (IP5)	6.2×10^{27} cm^{-2}s^{-1}	6.4×10^{27} cm^{-2}s^{-1}
L_{inst} (IP8)	1×10^{27} cm^{-2}s^{-1}	$<1.5\times10^{27}$ cm^{-2}s^{-1}

Main changes of thresholds wrt 2023 Pb run

- **Starting point are the final 2023 ion run thresholds, updated with new loss maps**
- **In addition, we propose a few changes compared to 2023:**
  - Crystal collimation: **include volume reflection** in the IR7 threshold settings (besides channeling and amorphous regimes)
  - **IR7 DS thresholds:** align the master thresholds with the power loss allowed in the collimation system since the past quench tests were not representative for fast losses (10 Hz losses) → simulations suggest that we will still remain well below the quench level for fast losses
  - **Revisit Q6 thresholds** in IR7 → performed shower simulations to understand the actual power deposition for Pb losses
  - **Revisit TCT and TCLD thresholds** in intermediate and long running sums → simulation campaign in order optimize settings while remaining in a safe operational regime

Outline

- TCT/TCLD thresholds in IR1/2/5/8
- Special case: Q6 thresholds in IR7
- Collimator and DS thresholds in IR7
- BFPP thresholds in IR1/2/5/8
- Summary

2023 Pb run: “10 Hz” dumps on TCLD/TCT BLMs

Fast losses on the TCTs/TCLDs (“10 Hz” events) **caused 8 beam dumps:**

2023 (Pb)	TCLDs	TCTs
# dumps	3x in STABLE, 1x in ADJUST	3x in RAMP, 1x in FLATTOP
RS	All in RS06 (10ms)	RS07-9 (82ms -1.2s)

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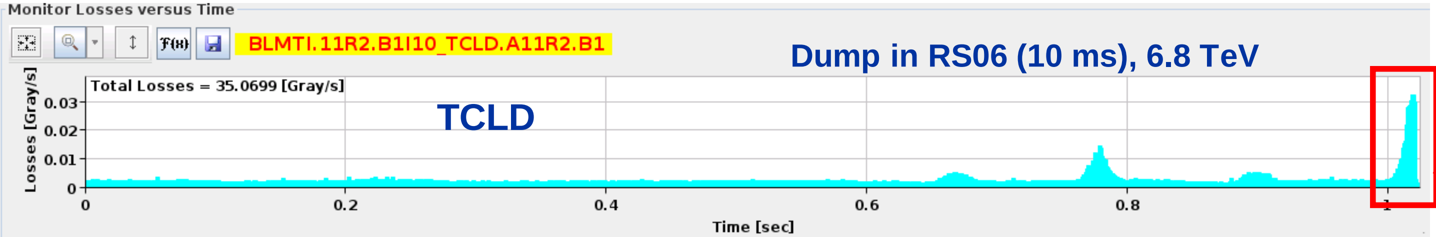
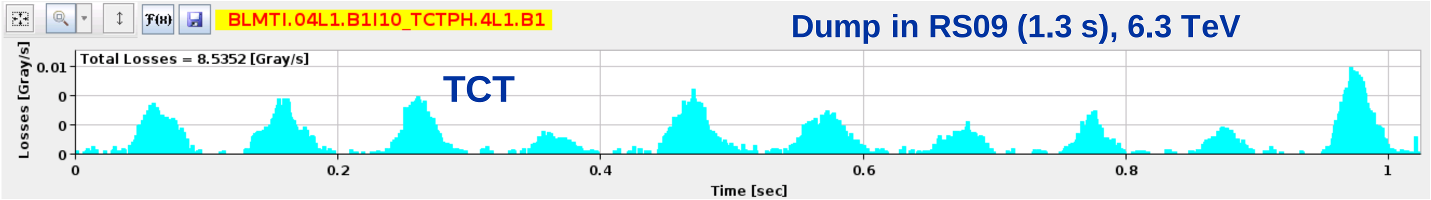
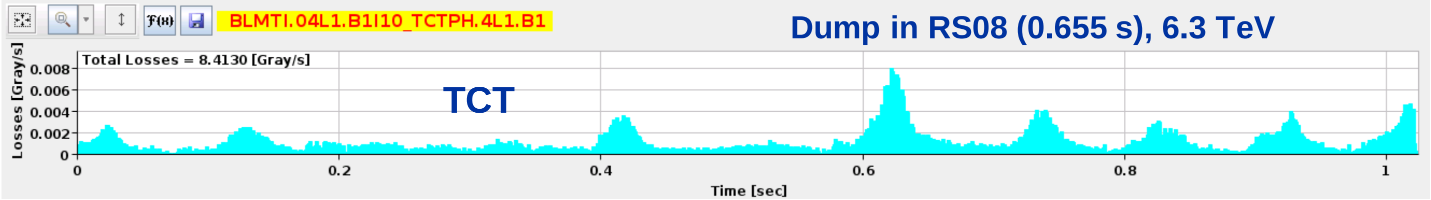
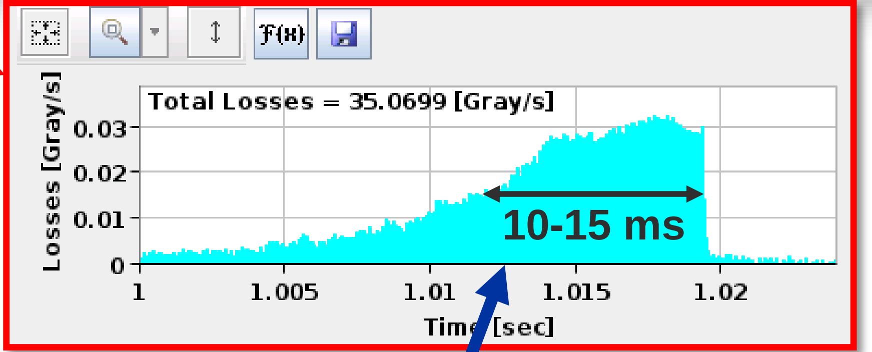
Typical time profiles in the last second before dump:





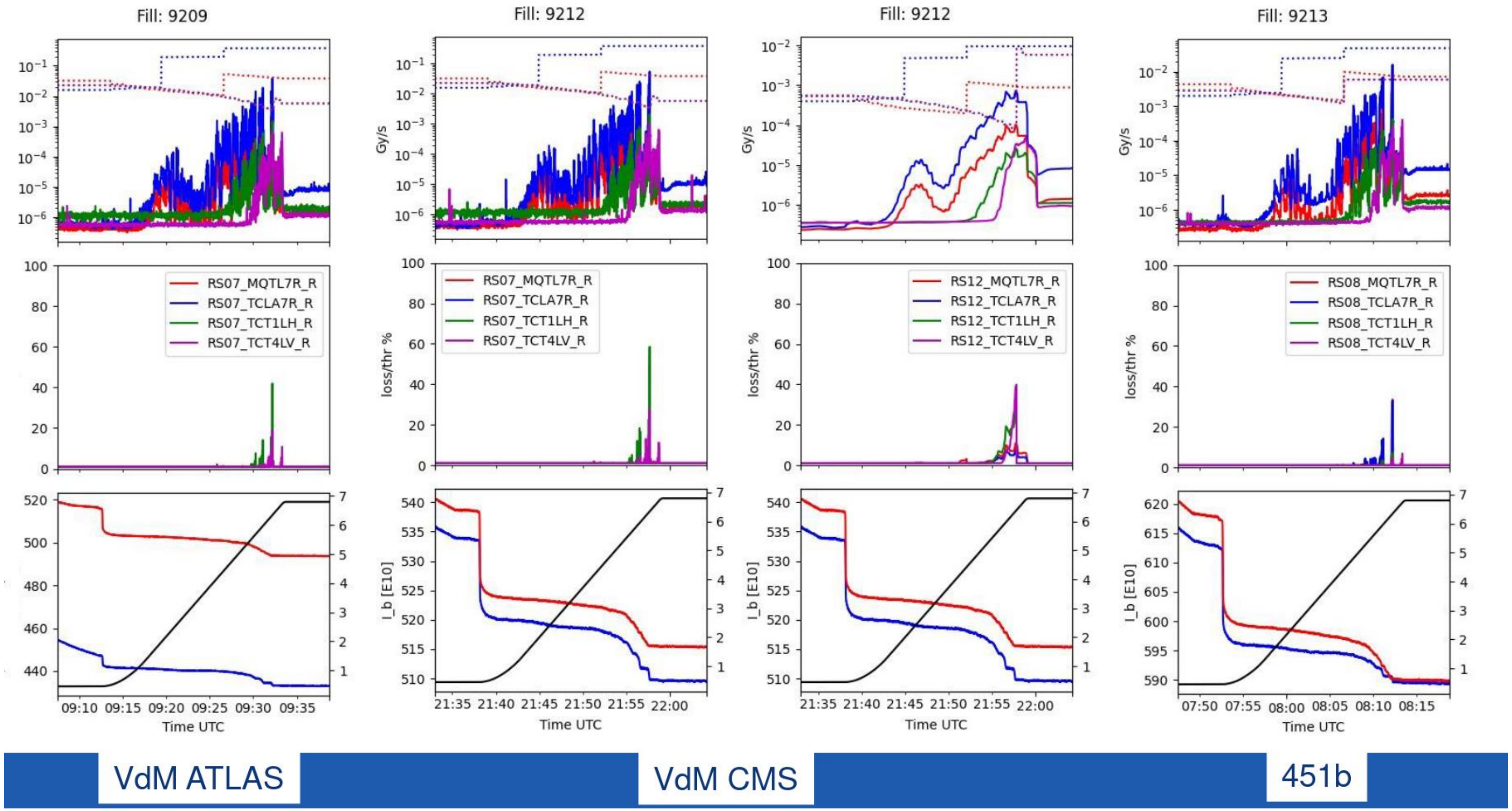




- Loss spikes are about 10-20ms long
- Explains dumps in RS06 (10ms)
- But can also accumulate multiple spikes over longer periods and dump in longer RS

2023 Pb run: TCT BLM warnings during ramp

Besides the 10 Hz dumps, regularly reached **BLM warning levels on TCT BLMs** due to slow losses towards the end of the ramp (5+ TeV), in **RS07-12 (0.082 s - 82 s)**



TCT BLMs in 400+b fills:

- 60% in RS07
- 40% in RS12

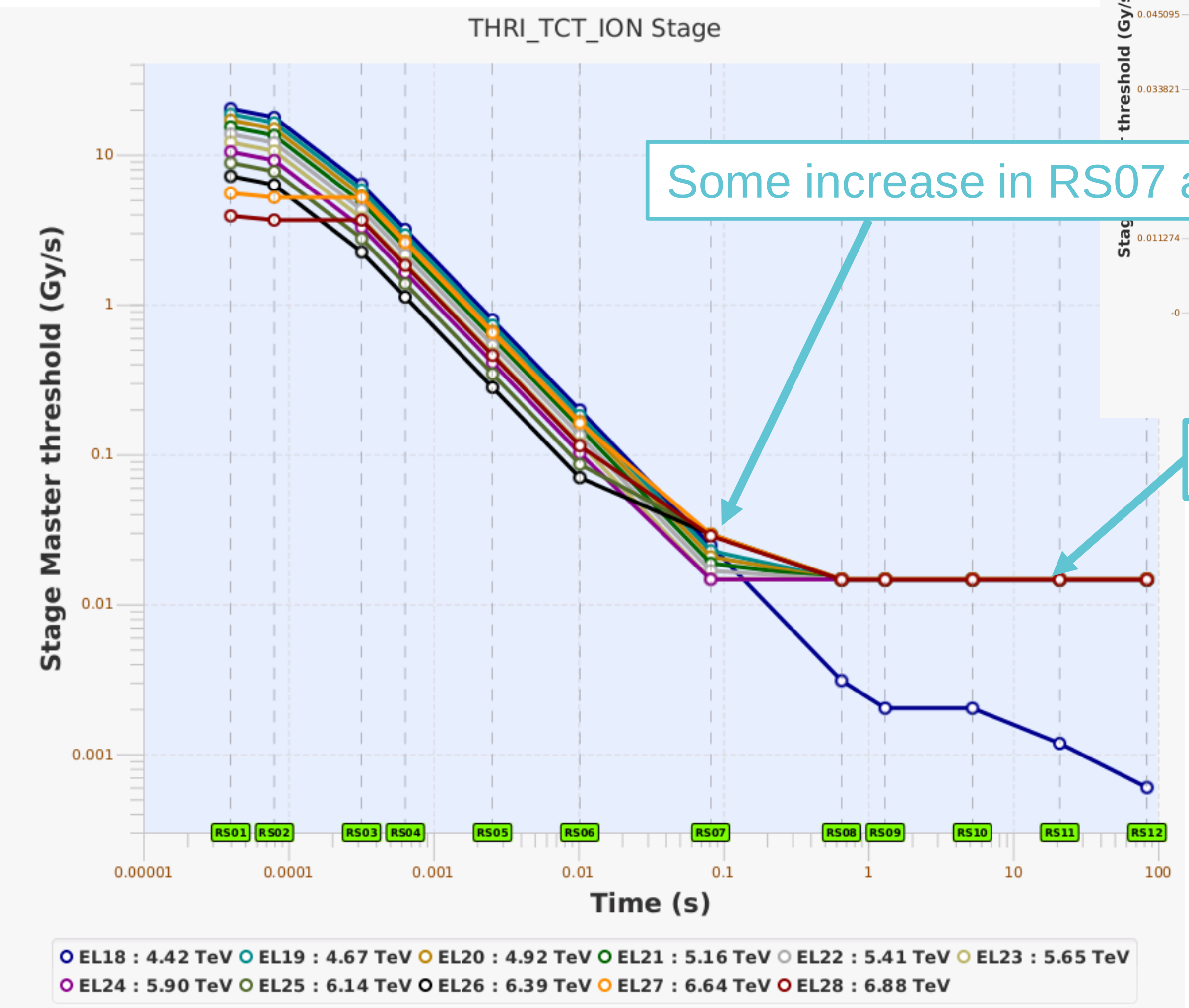
Always in the ramp (5+TeV)

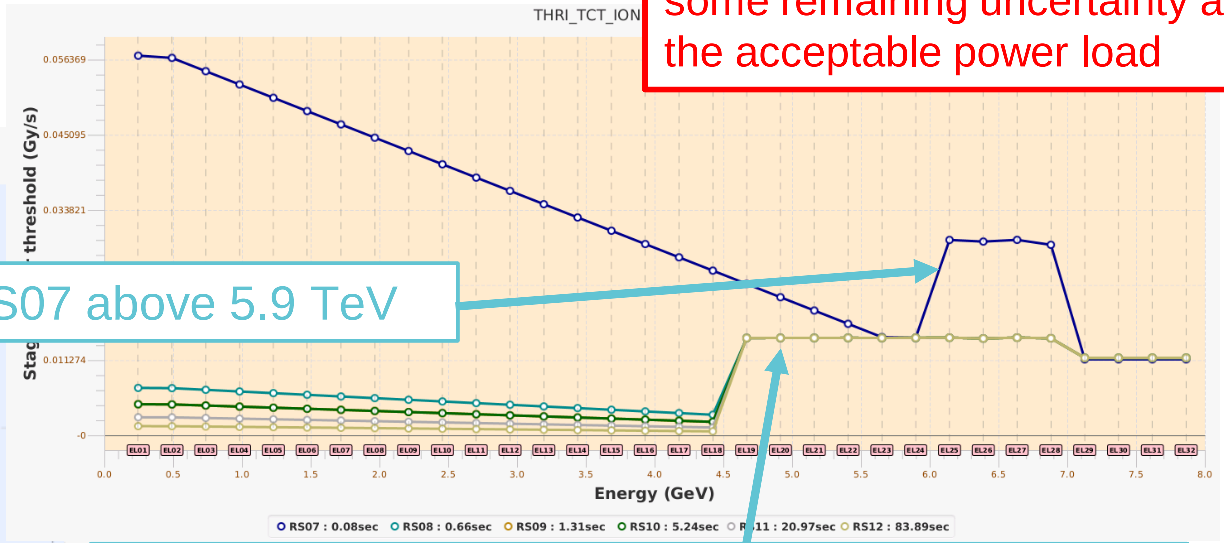
From E. Bravin

2023 Pb run: TCT master thresholds

2023: kept the Monitor Factor at 0.4
→ prudent approach since there was some remaining uncertainty about the acceptable power load

Final 2023 master threshold curves:



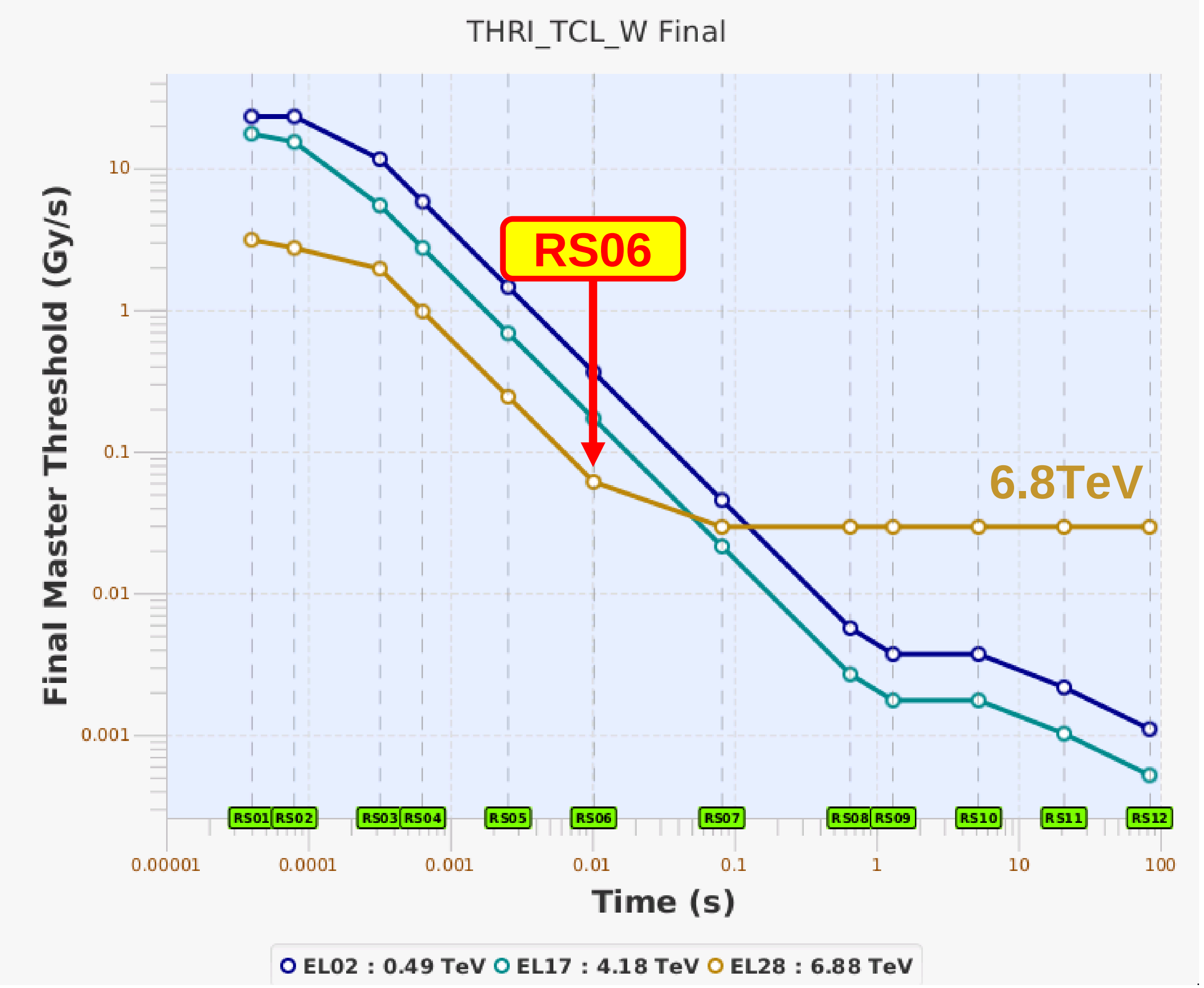


Some increase in RS07 above 5.9 TeV

Flat profile for RS08+ for energies above 4.4 TeV

- Dedicated **THRI_TCT_ION** BLM threshold family was created, based on the THRI_TCT proton family
- In 2023 Pb run, all TCT BLMs without filters (14) were assigned to this family (i.e., all except R8)
- Performed multiple changes of master thresholds **during** the 2023 run to avoid too many recurring beam dumps
- Nevertheless, remained prudent with the

2023 Pb run: TCLD BLM thresholds



- **TCLD collimators in 11L2/11R2 (60 cm W-alloy)**
  - Used for the first time in Pb run 2023
  - Intercept BFPP and (a fraction of) EMD ions from IP2 (about 150 W for L=6x10^{27}cm^{-2}s^{-1})
- **TCLD BLM thresholds in 2023**
  - Were added in the **TCL_W** BLM thr. family, i.e. in the same BLM family as W TCLs in IR1/5
  - The MFs were adjusted such that BFPP ions do not generate warnings (MF=0.25 in 11L2 and 0.35 in 11R2)
  - Despite 10 Hz dumps, did not change master thresholds (neither increased MF) due to some remaining uncertainty about the acceptable power load

TCT/TCLD thresholds: preparatory work for 2024

- ***Can we increase the TCT/TCLD thresholds for 2024 to provide more op. margin?***
- **A key question after the 2023 Pb run was the acceptable power load in TCT/TCLD jaws:**
  - How much power deposition can we allow for in the intermediate RS06/07 (**0.01-0.1s**)?
  - In the longer running sums (RS08-12), can we allow for higher power deposition than in the original TCT design specifications (**2 kW** for **10s**, **400 W** for **steady state**)?
- **Performed an extensive simulation campaign (for TCTs → also applicable for TCLD)**
  - Tracking (BE/ABP) + energy deposition (SY/STI) + thermo-mechanical (EN/MME)
  - Simulated different loss scenarios (Pb halo leakage from IR7 and accidental Pb beam scraping)
  - Calculated BLM response for different TCT/TCLD BLM positions

For details see:

- https://indico.cern.ch/event/1468337/
- https://indico.cern.ch/event/1469754/
- https://indico.cern.ch/event/1471526/

Thanks for Volodymyr, Natalia, Andrej, Bjorn, Roderik, Luisa, Federico!

TCT/TCLD: thermo-mechanical studies

From Luisa, Federico

Fragment leakage scenario:

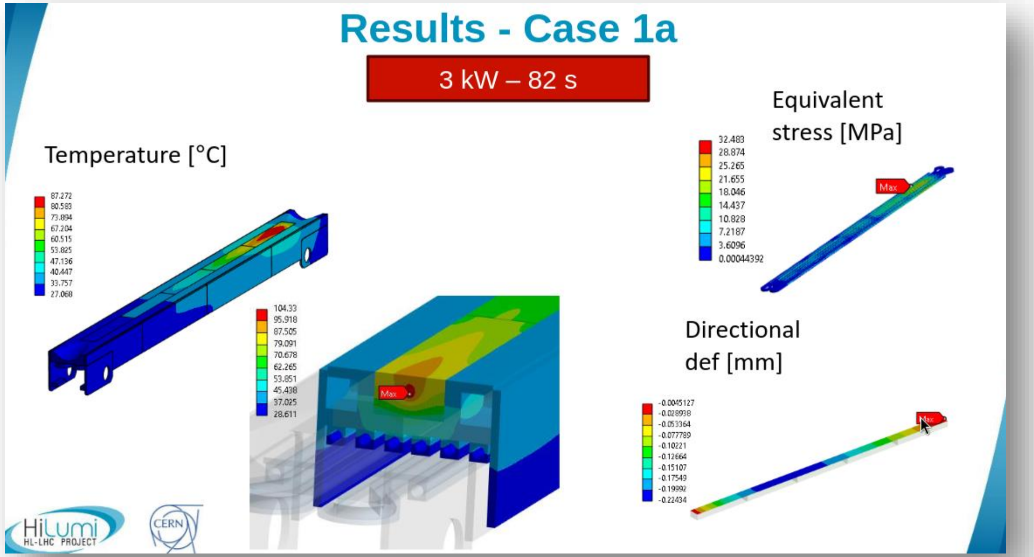
Reminder:
- Yield stress CuNi pipes = 120 MPa
- Yield stress Inermet180 = 640 MPa

Deposited Power [kW]	Time [s]	Tmax jaw [°C]	T probe [°C]		Max deflection jaw [um]	Max stress [MPa]	
						Pipes	Blocks
20	10 e-2	47.3	27.0	27.0	133	22.1	18.0
6	82 e-3	47.9	27.0	27.0	133	22.1	21.5
3	82	105.5	31.9	44.6	220	32.5	65

Scraping scenario:

Deposited Power [kW]	Time [s]	Tmax jaw [°C]	T probe [°C]		Max deflection jaw [um]	Max stress [MPa]	
						Pipes	Blocks
9	10 e-2	60.3	27.0	27.0	130	24.5	58.8
3	10 e-2	38.1	27.0	27.0			

Fragment leakage scenario:



- Max. temperature and stresses found acceptable
- Jaw deflection also considered OK

Based on these studies, we propose a master threshold increase for TCTs and TCLDs (see next page) while maintaining a certain safety margin to account for simulation uncertainties, different impact conditions etc.

TCTs/TCLDs: proposed master thresholds for 2024

TCTs: Use again **THRI_TCT_ION** BLM threshold family, **but with a factor of 3 increase in RS06-12 in EL19-28 (>4.4 TeV)**

	Final 2023 master threshold		Proposed 2024 master threshold	Power deposition in impacted jaw 2024 master thr. (halo)	Power deposition in impacted jaw 2024 master thr. (scraping)
RS06 (10 ms)	0.11431 Gy/s		0.34293 Gy/s	20 kW	4.3 kW
RS07 (82 ms)	0.02859 Gy/s	3x	0.08577 Gy/s	5 kW	1.1 kW
RS08-12 (0.6s-82s)	0.01457 Gy/s		0.04371 Gy/s	2.5 kW	0.5 kW

BLM response different from halo scenario!!

TCLDs: Derive new BLM threshold family **THRI_TCLD_W** from **THRI_TCL_W**, **increase RS06-12 according to the table below (for EL28/6.8 TeV only since the TCLD is retracted before)**

	Present master threshold		Possible new master threshold	Deposited power in impacted jaw at new master threshold
RS06 (10 ms)	0.06096 Gy/s	4x	0.24384 Gy/s	18 kW
RS07 (82 ms)	0.02935 Gy/s	2.5x	0.073375 Gy/s	5.5 kW
RS08-12 (0.6s-82s)	0.02935 Gy/s	1.5x	0.044025 Gy/s	3.3 kW

TCTs/TCLDs: proposed Monitor Factors (MFs)

- Propose to start with similar MFs as at the end of 2023 (effectively we would start with higher applied thresholds due to Master threshold increase
- Contrary to 2023, we know that the MF can be increased to 1 if needed while still operating in the safe regime for the collimators

	2023 Pb run (final)	2024 Pb start (proposal)
TCTs (except R8)	Max 0.4	0.4*
TCLDs	Max 0.35	0.4**

This would mean:

*Start with 3x higher thresholds in RS06-12 (EL19-28) due to master threshold increase

**Start with 1.5-4x higher thresholds in RS-12 (EL28) due to master threshold increase

Outline

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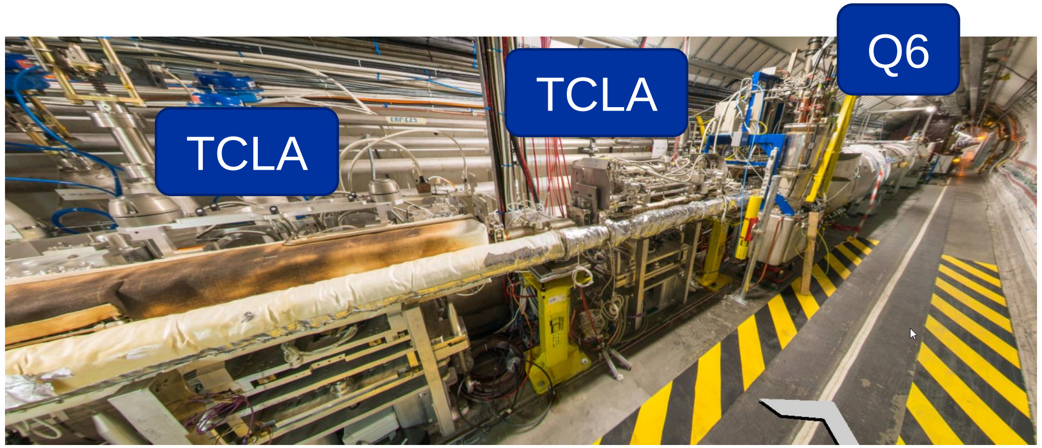
Context about the Q6 in IR7

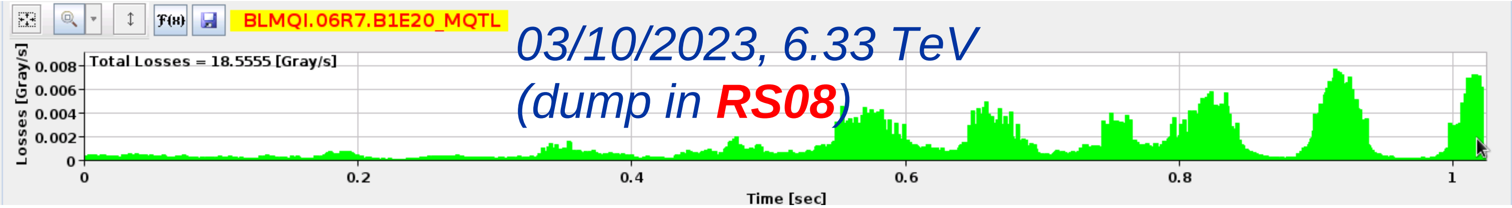
Q6 is just a few meters downstream of two TCLAs

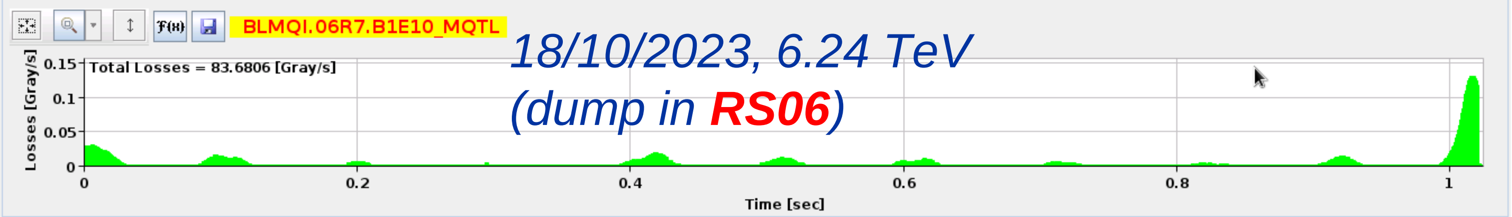


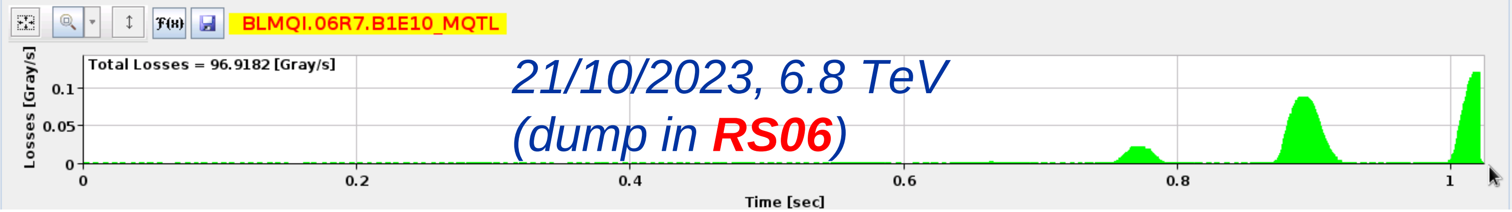
- The SC Q6 magnets in IR7 (**MQTLH**, **4.5K**) are exposed to showers from TCLAs
- Operational experience showed that the Q6 BLM thresholds **pose a performance bottleneck** for certain loss conditions, in particular for fast losses in Pb operation (2023 experience)
- The Q6 BLM **master threshold model** is **ignorant of collimation losses** → assumes direct beam losses on the Q6 aperture (implemented in LS1), which is a very unlikely scenario since the Q6 is right next to the TCLAs which would intercept the beam first
- As a consequence, several **ad-hoc corrections** had to be applied on top of the model to avoid premature dumps (→ several corrections in the 2023 Pb run)
- *It is important to understand the **actual** quench margin we have for the Q6 **for Pb collimation losses** → how much can we increase the thresholds to remove any bottleneck?*

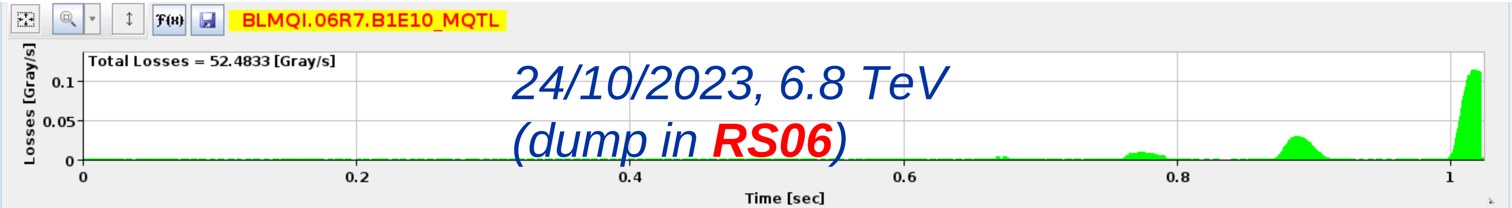
2023 Pb run: “10 Hz” dumps on Q6 BLMs

Fast losses in IR7 (“10 Hz” events) **caused 7 beam dumps on the Q6R7 magnet:**









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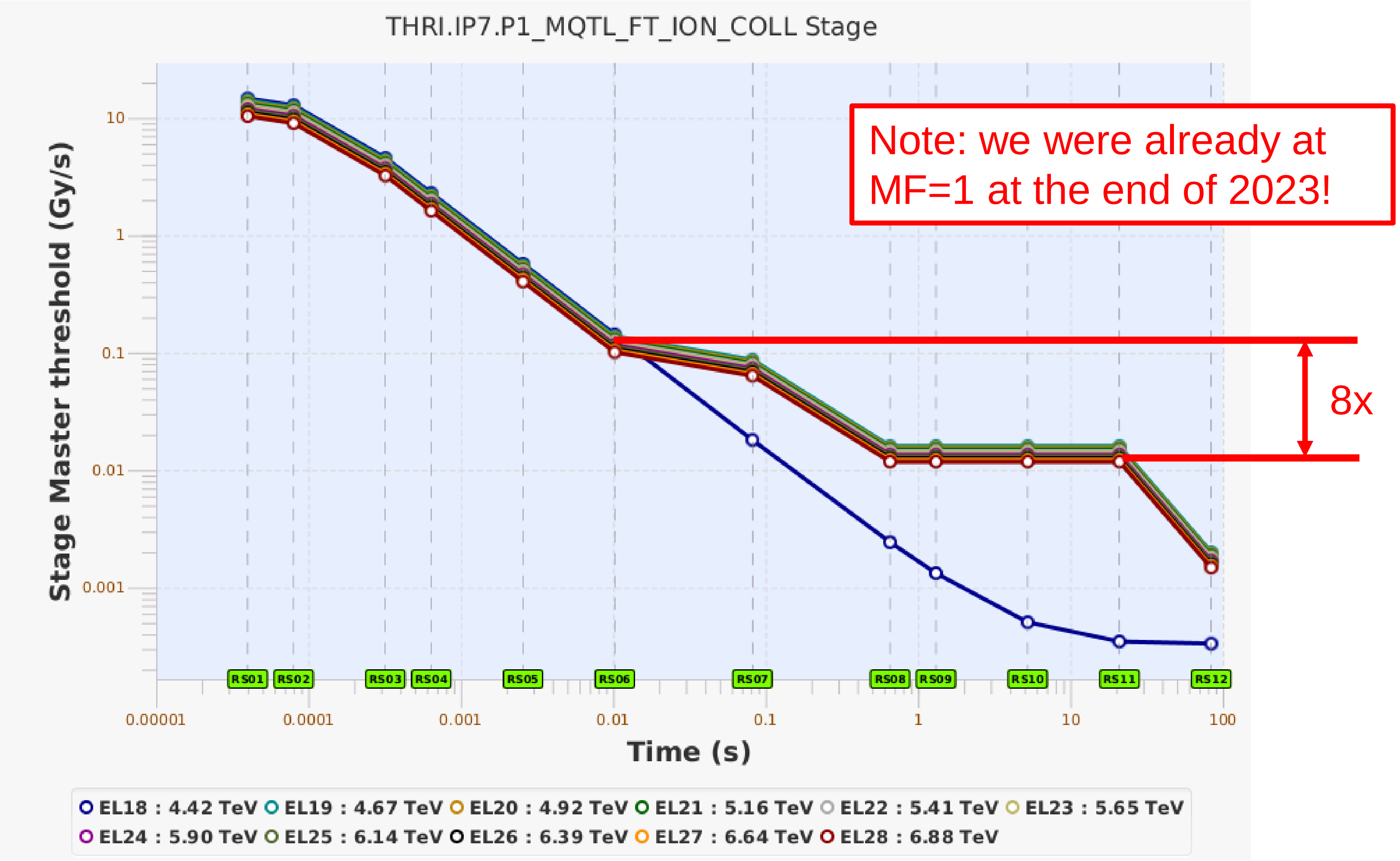
17	24-OCT-2023 04.02.06.	STABLE BEAMS	6799320	9296	1.05	Q6R7
18	24-OCT-2023 14.17.56.	ADJUST	6799320	9299	0	Q6R7
19	24-OCT-2023 17.10.32.	FLAT TOP	6799320	9300	0	TCTPV.4L2
20	25-OCT-2023 17.05.17.	ADJUST	6799200	9304	0	Q6R7

2023 (Pb)	At Q6R7
# dumps	**3x in RAMP, 2x in STABLE, 2x in ADJUST**
RS	**5x RS06 (10ms), 1x RS08 (0.655s) 1x RS10/11 (5-20s)**

2023 Pb run: why did we dump first on the Q6?



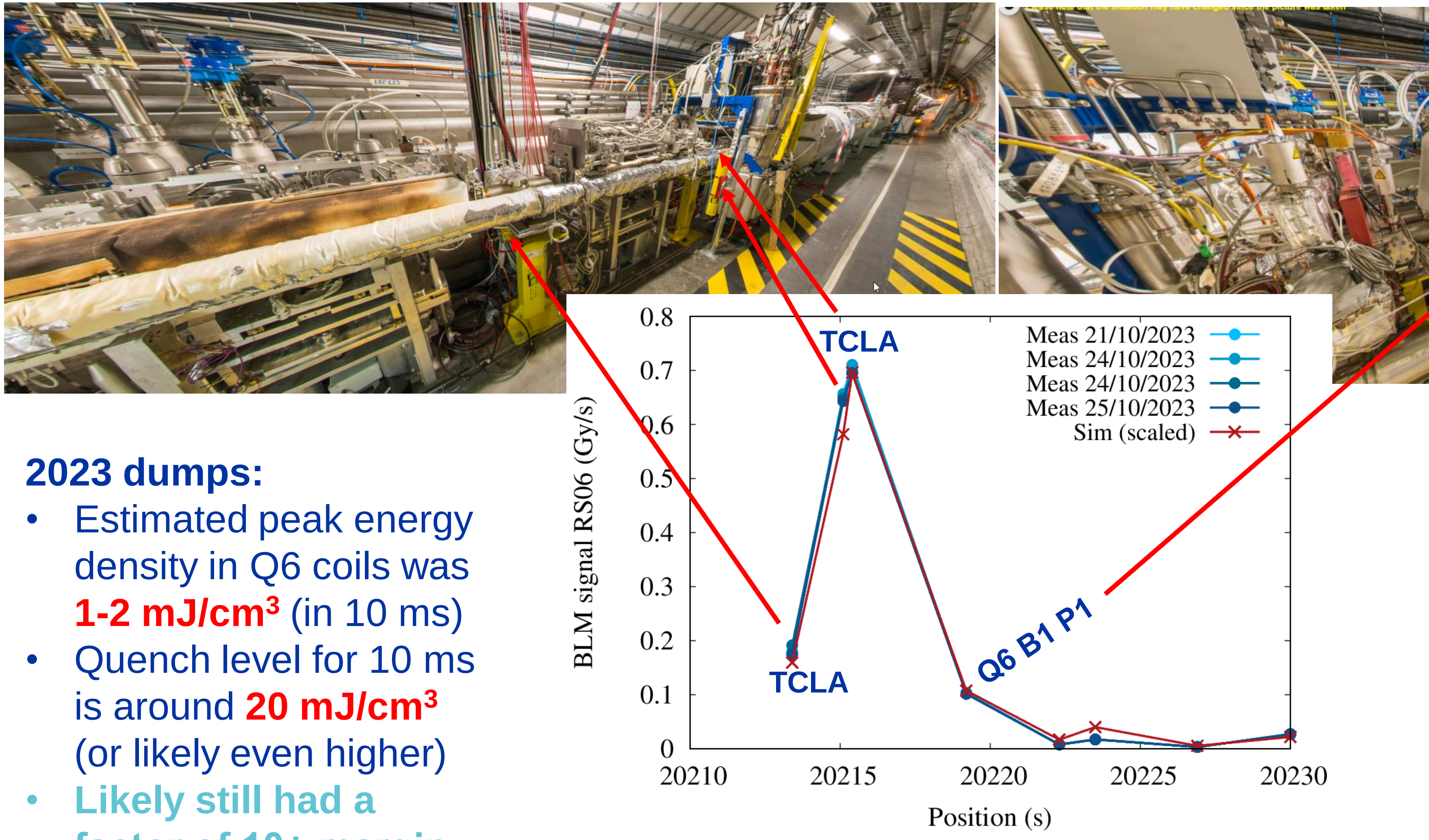
2023 Pb thresholds for Q6

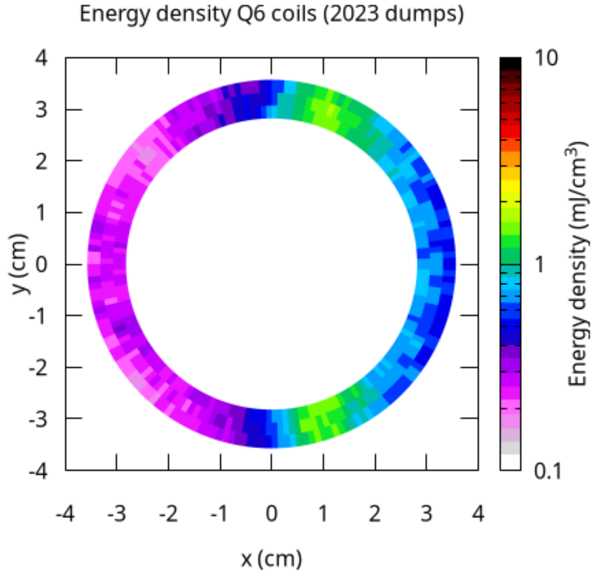
- For RS08-11, the Q6 thresholds were aligned to the loss maps ("50-60kW" level like the collimators)
- For short loss duration (RS06), the master thresholds were still based on the assumption of direct beam losses on the aperture (more conservative)

But:

- For collimators, RS06 is 24x higher than RS08-11
- For the Q6, RS06 is "only" 8x higher than RS08-11→ Q6 was the bottleneck for 10ms losses

2023 Pb run: how much quench margin for the Q6?



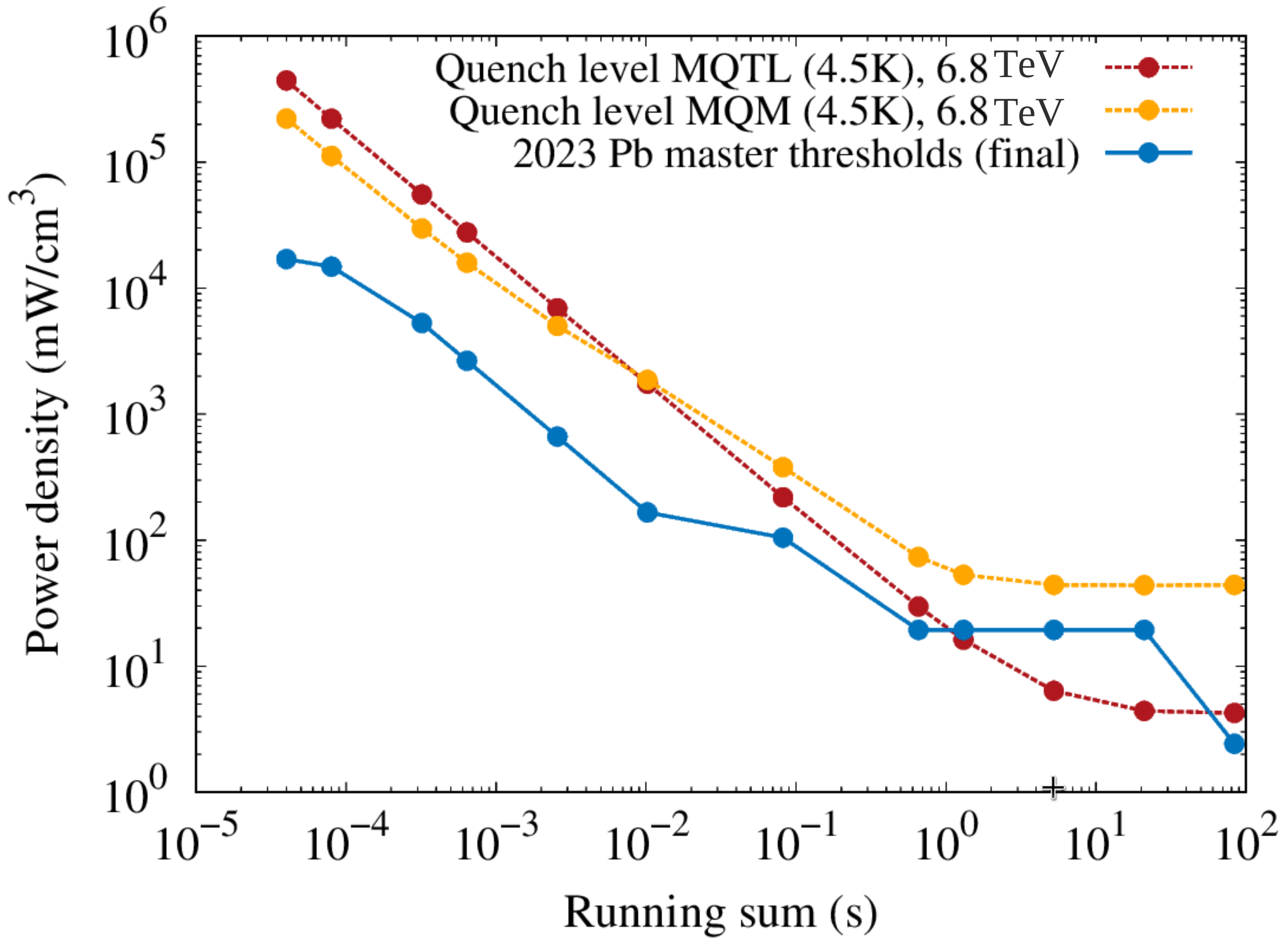


2023 dumps:

- Estimated peak energy density in Q6 coils was **1-2 mJ/cm³** (in 10 ms)
- Quench level for 10 ms is around **20 mJ/cm³** (or likely even higher)
- **Likely still had a factor of 10+ margin…**

Simulation reproduces BLM signal pattern quite well!

2023 Pb run: how much quench margin for the Q6?

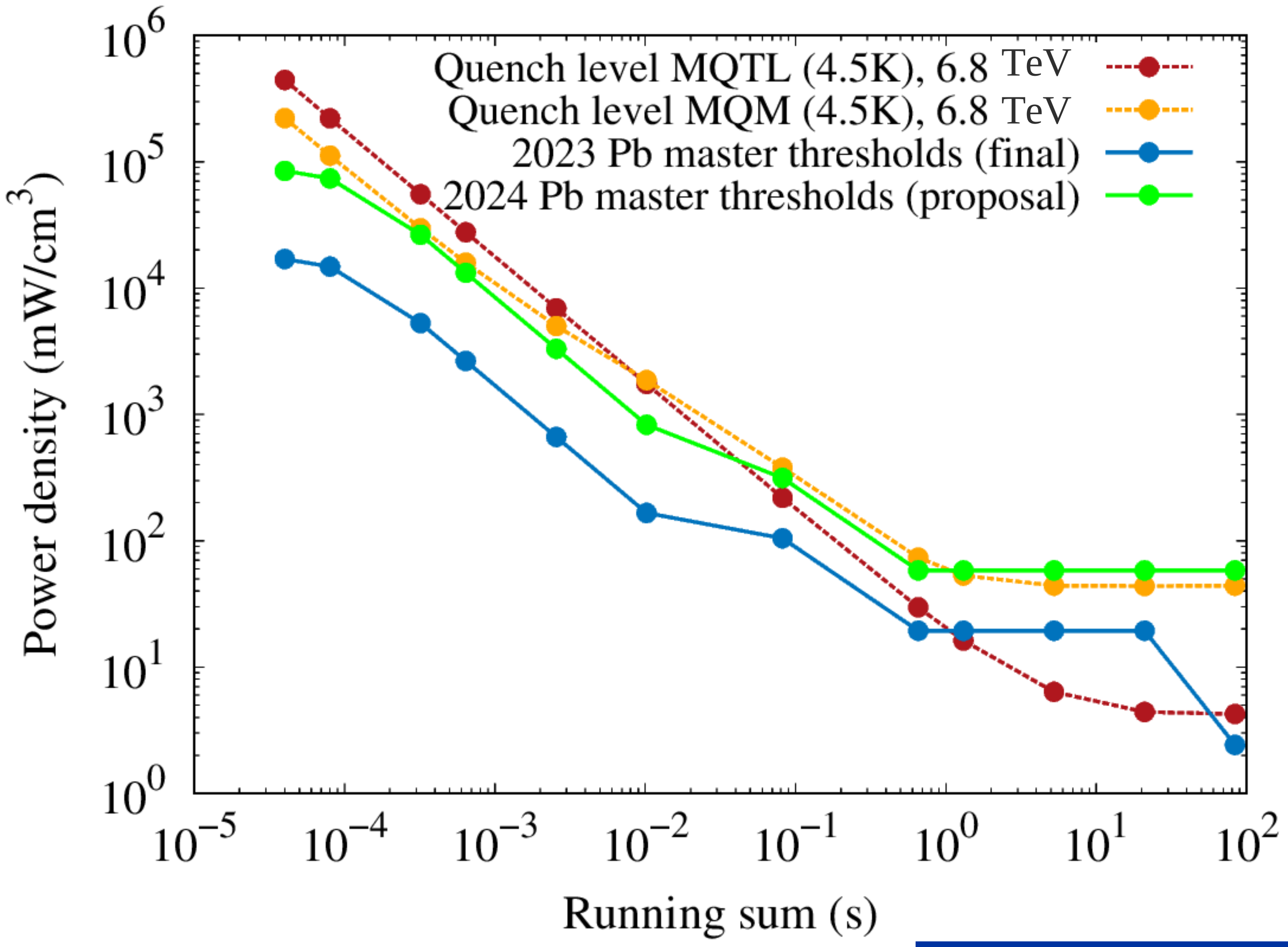


The figure compares:

- **Blue curve:** the **power density in Q6 coils** we allow for with the present Q6 master thresholds (family THRI.IP7.P1_MQTL_FT_ION_COLL)
- **Red curve:** the **assumed quench levels of the MQTL (4.5K)** – **look very conservative for long RS (lower than for all other magnets…)**
- **Yellow curve:** the **assumed quench levels of the MQM (4.5K)**

Note: for convenience the quench level is expressed in terms of power density for all loss durations

Q6R7/Q6L7: proposed master thresholds for 2024



Proposed approach:

- Consider Pb collimation leakage instead direct Pb losses on Q6 aperture
- For longer loss durations, consider MQM quench levels as the reference (MQTL quench levels appear too low)

Based on 2023 Q6 BLM families (P1 and P2), propose master thresh. increase:

	Increase factor
RS01-06 (40 us -10 ms)	5x
RS07-11 (82 ms-20s)	3x
RS12 (82s)	24x*

**Align RS12 to RS07-11*

Monitor Factor	2023 Pb run (final)	2024 Pb start (proposal)
Q6	1.0	0.4? 0.6?

Sig-thr ratio for Q6 dump events in 2023 (RS06)

Even if we increase the Q6, other BLMs might not be far behind (factor 2-3x) as 2023 experience showed → need also to look closer at RS06/07 thresholds for IR7 collimators and DS magnets

24/10/2023	Signal RS06	Threshold RS06	Ratio
BLMQI.06R7.B1E10_MQTL	0.10354	0.100999	1.02516
BLMTI.05R7.B1E10_TCSG.E5R7.B1	0.19745	0.37926	0.52062
BLM2I.11R7.B1E24_MBB_MBB	0.0403276	0.096694	0.417066
BLMTI.06R7.B1E10_TCLA.C6R7.B1	0.17595	0.466921	0.37683
BLMTI.06R7.B1E10_TCLA.D6R7.B1	0.710402	1.94547	0.365158
BLM2I.11R7.B1E23_MBB_MBB	0.0334288	0.096694	0.345719
BLM2I.11R7.B1E23_MBA_MBA	0.0204838	0.096694	0.211842

25/10/2023	Signal RS06	Threshold RS06	Ratio
BLMQI.06R7.B1E10_MQTL	0.101743	0.100999	1.00737
BLMTI.05R7.B1E10_TCSG.E5R7.B1	0.210411	0.37926	0.554793
BLM2I.11R7.B1E24_MBB_MBB	0.038002	0.096694	0.393017
BLMTI.06R7.B1E10_TCLA.C6R7.B1	0.175218	0.466921	0.375262
BLMTI.06R7.B1E10_TCLA.D6R7.B1	0.69501	1.94547	0.357246
BLM2I.11R7.B1E23_MBB_MBB	0.034451	0.096694	0.356292
BLM2I.11R7.B1E23_MBA_MBA	0.020152	0.096694	0.208413

21/10/2023	Signal RS06	Threshold RS06	Ratio
BLMQI.06R7.B1E10_MQTL	0.101734	0.100999	1.00728
BLMTI.05R7.B1E10_TCSG.E5R7.B1	0.196181	0.37926	0.517273
BLM2I.11R7.B1E24_MBB_MBB	0.0384597	0.096694	0.397748
BLMTI.06R7.B1E10_TCLA.C6R7.B1	0.180442	0.466921	0.38645
BLMTI.06R7.B1E10_TCLA.D6R7.B1	0.699435	1.94547	0.35952
BLM2I.11R7.B1E23_MBB_MBB	0.0320483	0.096694	0.331442
BLM2I.11R7.B1E23_MBA_MBA	0.0195399	0.096694	0.20208

24/10/2023	Signal RS06	Threshold RS06	Ratio
BLMQI.06R7.B1E10_MQTL	0.101628	0.100999	1.00623
BLMTI.05R7.B1E10_TCSG.E5R7.B1	0.173381	0.37926	0.457155
BLMTI.06R7.B1E10_TCLA.C6R7.B1	0.191589	0.466921	0.410324
BLM2I.11R7.B1E23_MBB_MBB	0.0346923	0.096694	0.358785
BLMTI.06R7.B1E10_TCLA.D6R7.B1	0.695351	1.94547	0.357421
BLM2I.11R7.B1E24_MBB_MBB	0.0335472	0.096694	0.346944

Tables include all BLMs, which exceeded 20% of thresholds in RS06

- *TCSG.E5R7 was about a factor 2 behind*
- *Some DS magnets were a factor of 2.5 behind*
- *TCLAs just upstream of Q6 were about a factor of 3 behind*

Outline

- TCT/TCLD thresholds in IR1/2/5/8
- Special case: Q6 thresholds in IR7
- Collimator and DS thresholds in IR7
- BFPP thresholds in IR1/2/5/8
- Summary

BLM thresholds strategy for IR7 collimators

- **Similar approach as in 2023**
  - Use certain collimator BLMs to interlock to defined target power loss values for different crystal regimes
  - New in 2024: consider as well Volume Reflection (VF) in addition to CH and AM
  - BLM response derived from latest loss maps
- **Target power loss values for 2024 (for master thresholds)**
  - Same as in 2023
  - Discussed possibility to increase RS06 (RS07) target power loss by 2x (1.5x) to leave more margin for possible 10 Hz events → need more discussions before concluding

RS	Duration	kW channeling	kW amorphous/VR?
RS01	40 us	375000	93750
RS02	80 us	187500	46875
RS03	320 us	46875	11719
RS04	640 us	23438	5859
RS05	2.56 ms	5859	1465
RS06	10.24 ms	1465	366
RS07	81.92 ms	732	183
RS08	655 ms	91	23
RS09	1.3 s	60	15
RS10	5.2 s	60	15
RS11	21 s	29	7
RS12	84 s	24	6

Considerations for the IR7 DS thresholds

- **Reminder: master threshold model for DS magnets**
  - The model assumes direct beam losses in the DS but is ignorant of collimation losses
  - For cold magnets, the master thresholds are typically set to 3x quench level → with MF=0.333 we are more or less aligned with the quench level (there are exceptions!)
  - For IR7 collimation leakage, we typically need corrections on top to avoid premature dumps
- **Threshold settings in the 2023 Pb run:**
  - The strategy was to align the applied thresholds (with MF=0.333) to the signals@quench measured in previous collimation quench tests
- ***However, this approach has a few shortcomings:***
  - The previous quench tests were executed by generating slow losses, hence measured signals are not representative for fast losses (10 Hz events!)
  - The DS loss pattern measured in previous quench tests (w/o crystals) is not entirely representative for crystal collimation and the present collimation hierarchy
  - As a consequence, the DS is not necessarily aligned with the power loss allowed in IR7

IR7 DS: proposed master thresholds for 2024

- **Proposed approach:**
  - In addition to the 2023 Pb thresholds, the proposal is to **allow in the DS master thresholds** the **same target power loss** values as the **collimators** → loss maps show that this requires few changes for RS07, but not for longer running sums
  - For fast losses (RS06-07, 0.01-0.1s) we expect to remain quite below quench level
  - In the longer RS10-11, the master threshold possibly allow to go higher than the quench level (this was already the case in 2023)

	Assumed quench level at 6.8 TeV	Estimated allowed Pb beam power loss at 6.8 TeV in IR7 without quenching (when in channeling*)	Proposed RI7 power loss for master thresholds (collimators and DS) (when in channeling*)
RS06 (10 ms)	60-90 mJ/cm3	10-16 MW for 10 ms	1.5 MW for 10 ms
RS07 (82 ms)	110-130 mJ/cm3	2.5-3 MW for 80 ms	0.7 MW for 80 ms
RS10-11 (few sec)	15-20 mW/cm3	30-50 kW for seconds	60 kW for seconds

*About 4 times lower for amorphous and VR (as indicated by measurements)

IR7: possible monitor factors for the start-up

For discussion:

	2023 Pb run (final)	2024 Pb start (for discussion)
IR7 collimators	Max 1.0	0.4? 0.6?
IR7 Q6	Max 1.0	0.4? 0.6?
IR7 DS magnets	Max 0.45	0.333?

Depending on the operational needs, Monitor Factor increases during the run shall be agreed by BLMTWG, MPP, OP, collimation team and involved equipment groups (magnets, collimators)

Outline

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BFPP thresholds in IR1/2/5/6

- The **same measures as in 2023** will be applied to cope with **BFPP losses**:
  - Orbit bumps in DS next to IR1/5 to shift BFPP losses to connection cryostat
  - Orbit bumps in DS next to IR2 to intercept BFPP ions with TCLDs
  - Orbit bumps in DS next to IR8 to shift BFPP losses to cell 12
- New bump amplitudes were already established one week ago and the measured loss patterns look similar as in 2023
- Propose to **start with same master thresholds* and monitor factors*** for BFPP losses as in 2023 and adjust on the fly if needed

* For the TCLDs, we will use the higher thresholds as proposed earlier in this presentation

Outline

- TCT/TCLD thresholds in IR1/2/5/8
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Summary

- **Compared to the BLM threshold strategy for the 2023 Pb run, we propose a few changes for the 2024 Pb run**
  - The goal is to avoid premature beam dumps and to **avoid the need of too many changes during the run which is always more risky**
  - The changes are well supported by simulation studies
- **The main changes include (besides updates wrt new loss maps):**
  - Increase the master thresholds for TCTs and TCLDs
  - Increase the master thresholds for the Q6
  - Adapt the IR7 DS thresholds better to fast losses
- **Note: like in 2023, we BLM threshold strategy does not fully exclude the risk of a quench (in the IR7 DS, less likely for IR7 Q6)**
  - In case of a quench, would reduce settings to avoid a second quench

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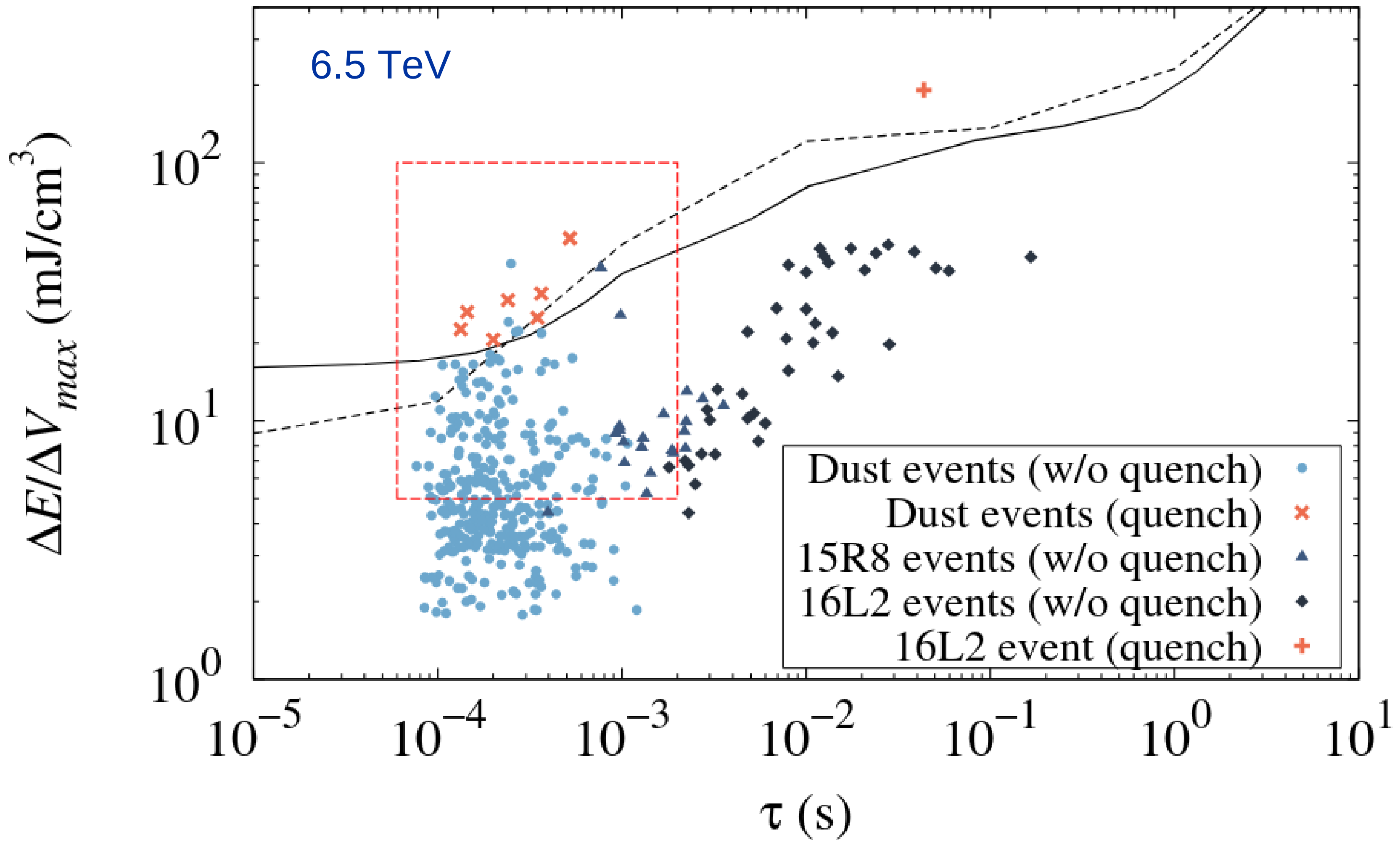
Estimated MB quench levels for fast losses



Dashed and solid line: QL calculations by L. Bottura et al. and B. Auchmann et al.

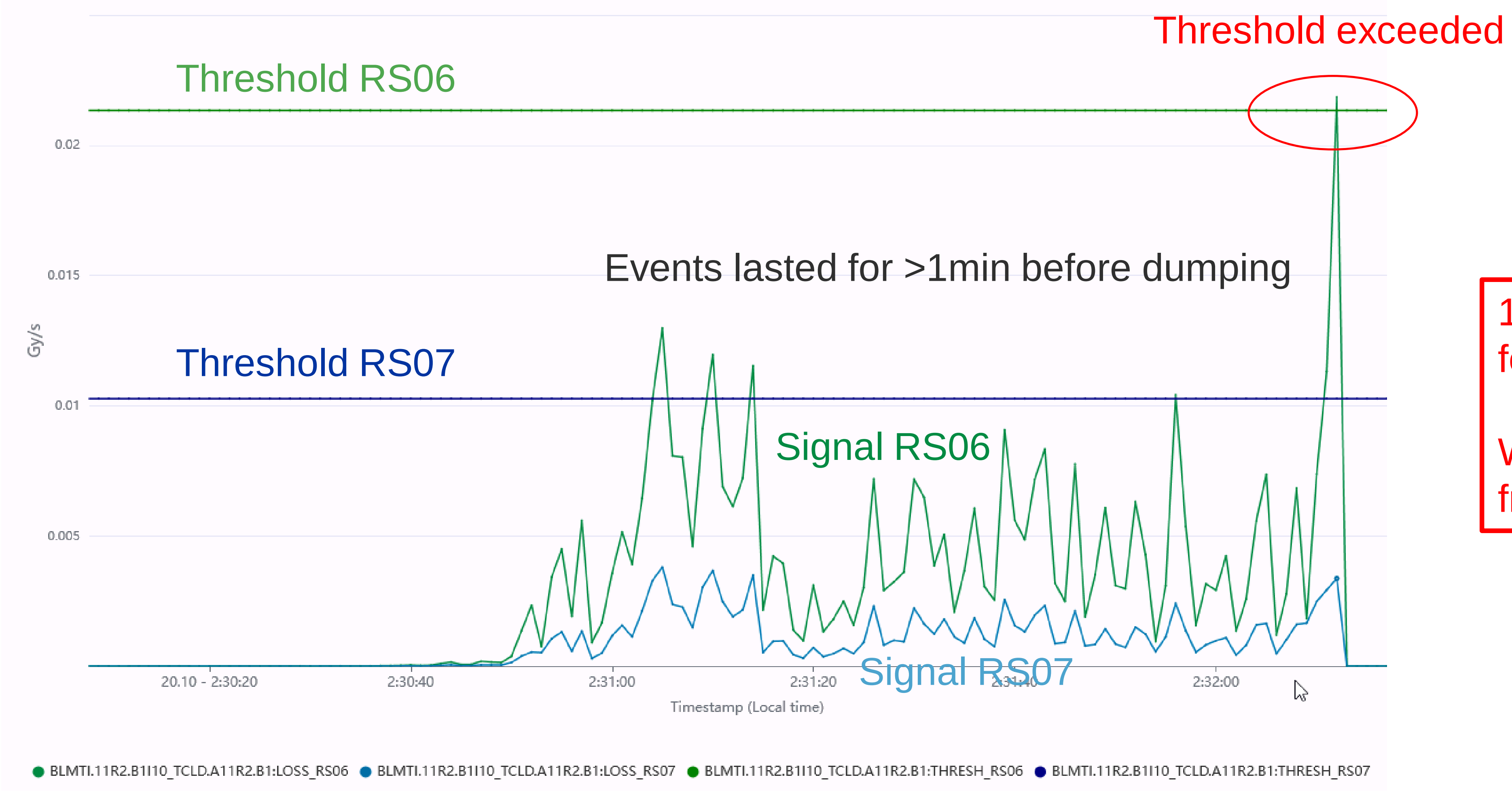
For **10 ms (RS06)**, the quench level is estimated to be around **70-100 mJ/cm^3** (6.5 TeV)

For **80 ms (RS07)**, the quench level is estimated to be around **120-150 mJ/cm^3** (6.5 TeV)

Expect 10% lower quench level for 6.8 TeV

“10 Hz” dumps on TCLD BLMs in 2023 Pb run

Example of BLM signals in the last minutes before dump on TCLD BLM:



10 Hz losses lasted for >1min

Would we recover from these events?