BLM thresholds and beam losses for protons and ions

JAP23 Session 5 “LHC configuration and experiment specific”

06/12/2023

Sara Morales on behalf of SY-BI-BL and BLMWTG

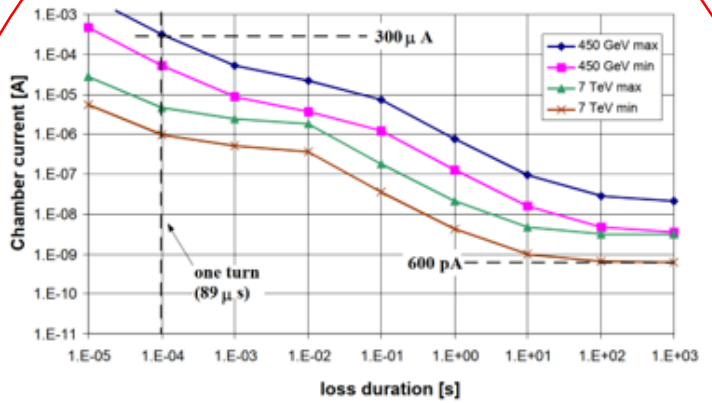
Special thanks to B.Salvachua, A.Lechner, colleagues from OP-LHC, Collimation, ABT and MPP

Outline of presentation

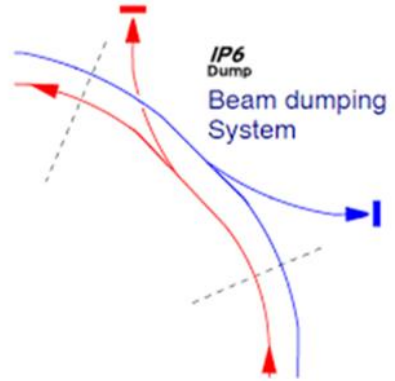
1. BLM thresholds and losses for protons in 2023
    - BLM threshold strategy for protons
    - Changes of BLM thresholds during the proton Run
    - Beam losses and margin to dump for various scenarios
        - Minimum beam lifetime and maximum beam power loss analysis
        - Beam dumps from beam losses
2. BLM thresholds and losses for ions in 2023
    - BLM threshold strategy for ions (changes on top of the proton BLM thresholds)
    - Changes of BLM thresholds during the ion Run
    - Beam losses and margin to dump for various scenarios
        - Minimum beam lifetime and maximum beam power loss analysis
        - Beam dumps from beam losses
    - Lessons learnt for next Ion Run

LHC BLM System

Continuous detection and monitoring of beam losses



Comparison of measured losses with predetermined thresholds



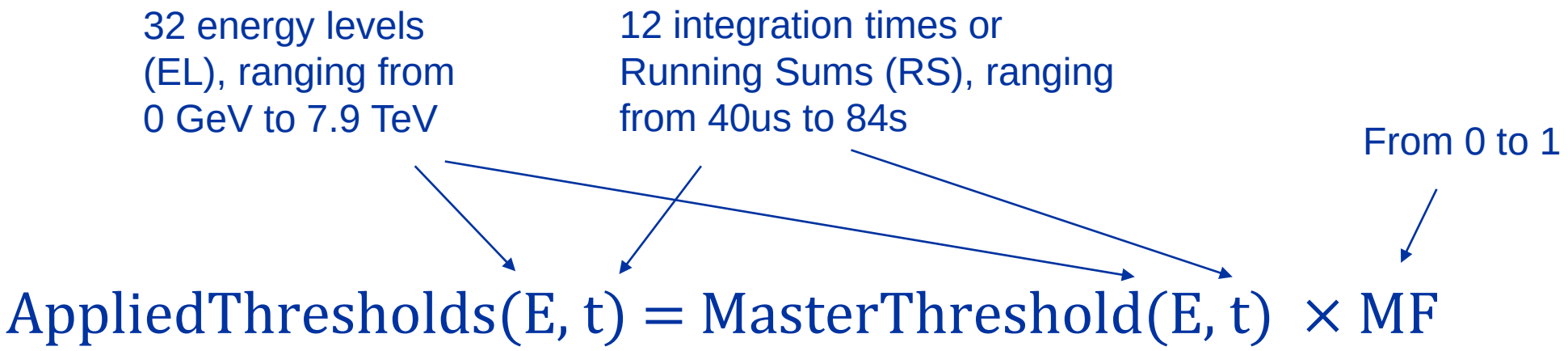
Beams extraction if losses above the thresholds

LHC -> ~ 4000 BLM detectors placed downstream the most likely loss locations

The main function of the BLM system is to protect actively the machine against energy deposition from beam losses

BLM thresholds

- Master thresholds selected according to different expected loss scenarios and damage/quench limits
- BLMs grouped in master thresholds families, each BLM with a different monitor factor (MF)



Each BLM thresholds family will have implemented values for each RS (12) and each EL (32), making it a total of 384 values

BLM thresholds strategy for protons

1. Cold magnets-> No changes with respect to 2022 -> Described in LHC-BLM-ECR-0073

- Dust particles (UFOs) dominant source of transient beam loss events in the LHC arcs and DS
- Best machine availability if UFO-induced BLM dumps are avoided and quenches tolerated

→ Master thresholds at 3x the quench level in short RS (40us – 2.5ms), and MF = 0.333

Thresholds reduced at selected arc/DS locations which are (possibly) affected by a hardware non-conformity: 2 magnets with one less quench heater and 35 magnets with a possible non-conform bypass diode

2. Collision debris -> Updated from measurements during the 2022 intensity ramp-up -> LHC-BLM-ECR-0074

- BLM threshold families in the experimental insertions (IR1/5/8) have increased thresholds in the long RS (0.08s - 84s) to avoid constant warnings due to the physics debris leaking from the experiments
- Increased thresholds only active at top energy
- These thresholds must remain below the warning level (30%) for a luminosity of $2.5 \times 10^{34} \mathrm{cm}^{-2} s^{-1}$ in ATLAS/CMS and $2.5 \times 10^{33} \mathrm{cm}^{-2} \mathrm{s}^{-1}$ in LHCb

BLM thresholds strategy for protons

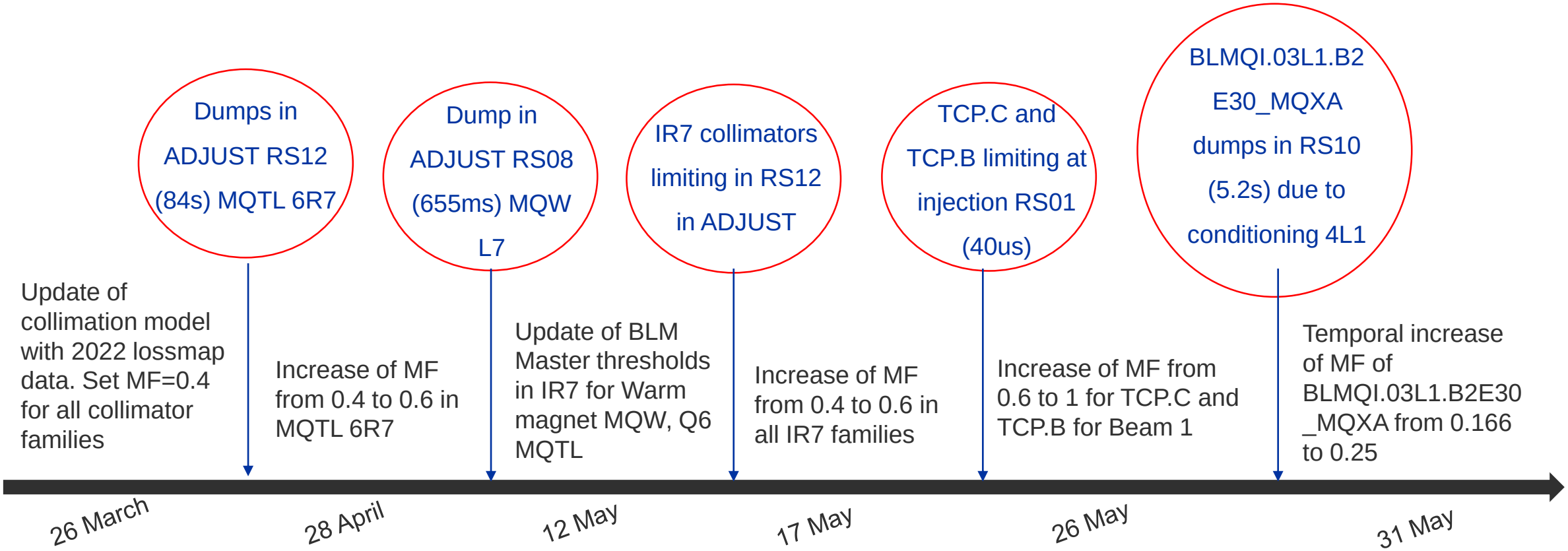
3. IR7 collimators and leakage -> New IR7 collimator threshold model applied in 2022 -> LHC-BLM-ECR-0072

- BLM thresholds adjusted to the damage limits in collimators from losses in the entire IR7 collimation system
    - BLM response (expected BLM signal per proton lost in the collimator system) from lossmaps
        - Updated values in 2023 from 2022 lossmaps -> LHC-BLM-ECR-0076
- Initial MF=0.4 for 2023 operation, was later changed to 0.6 (1.0 for TCP.B and TCP.C B1)
- IR7 warm and Q6 magnets are sensitive to IR7 collimation leakage
    - BLM thresholds aligned to the IR7 collimation BLM thresholds in the long RS (RS08-RS12) at the end of the ramp and at top energy -> LHC-BLM-ECR-0073 and LHC-BLM-ECR-0074

	Duration	Master thresholds	Applied thresholds (MF=0.4)	Applied thresholds (MF=0.6)
RS09	1.31 s	500 kW	200 kW	300 kW
RS10	5.24 s	500 kW	200 kW	300 kW
RS11	20.97 s	239 kW	96 kW	143 kW
RS12	83.89 s	100 kW	40 kW	60 kW

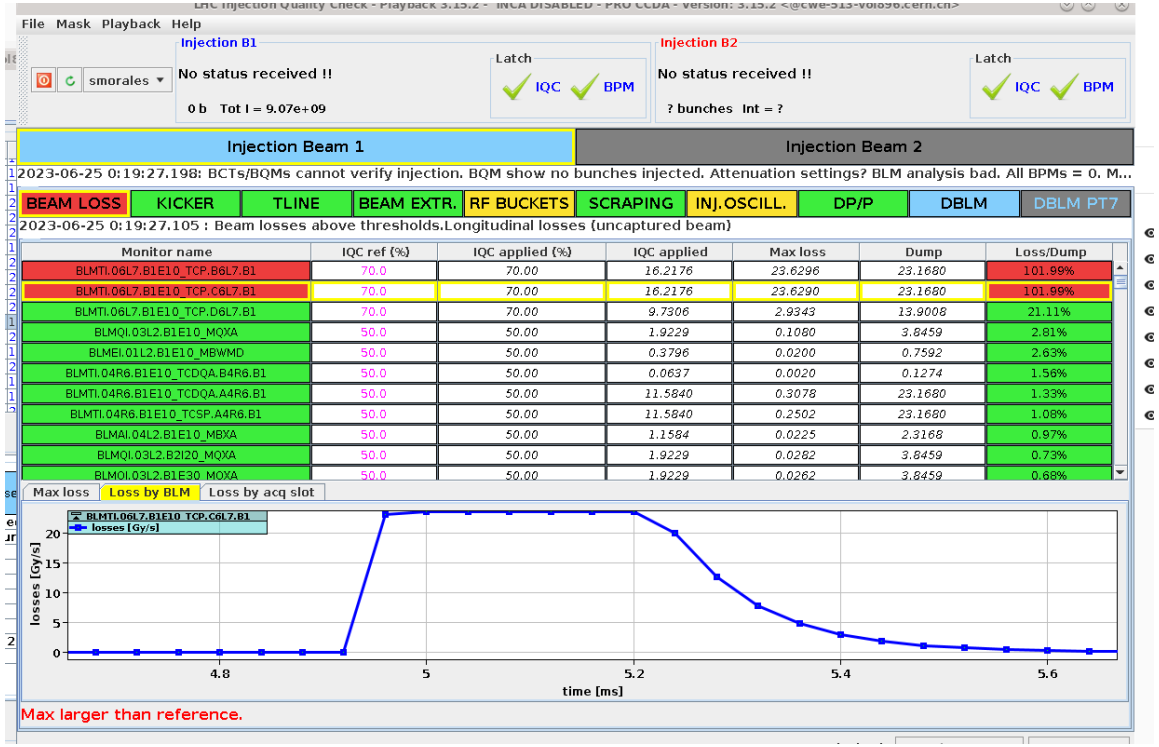
BLM thresholds strategy for protons

6. Changes during the Run

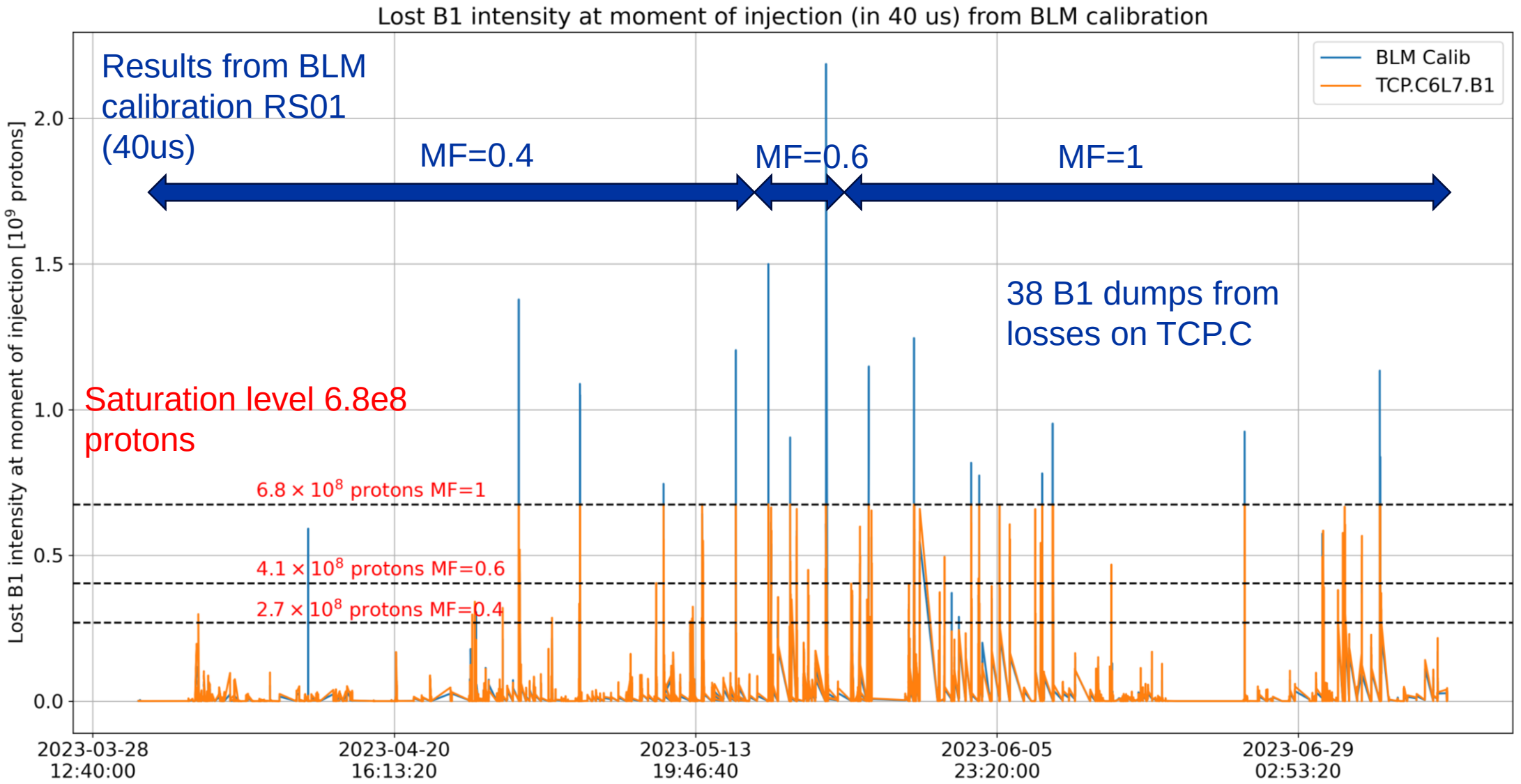


Protons: Beam losses and margin to dump during Injection

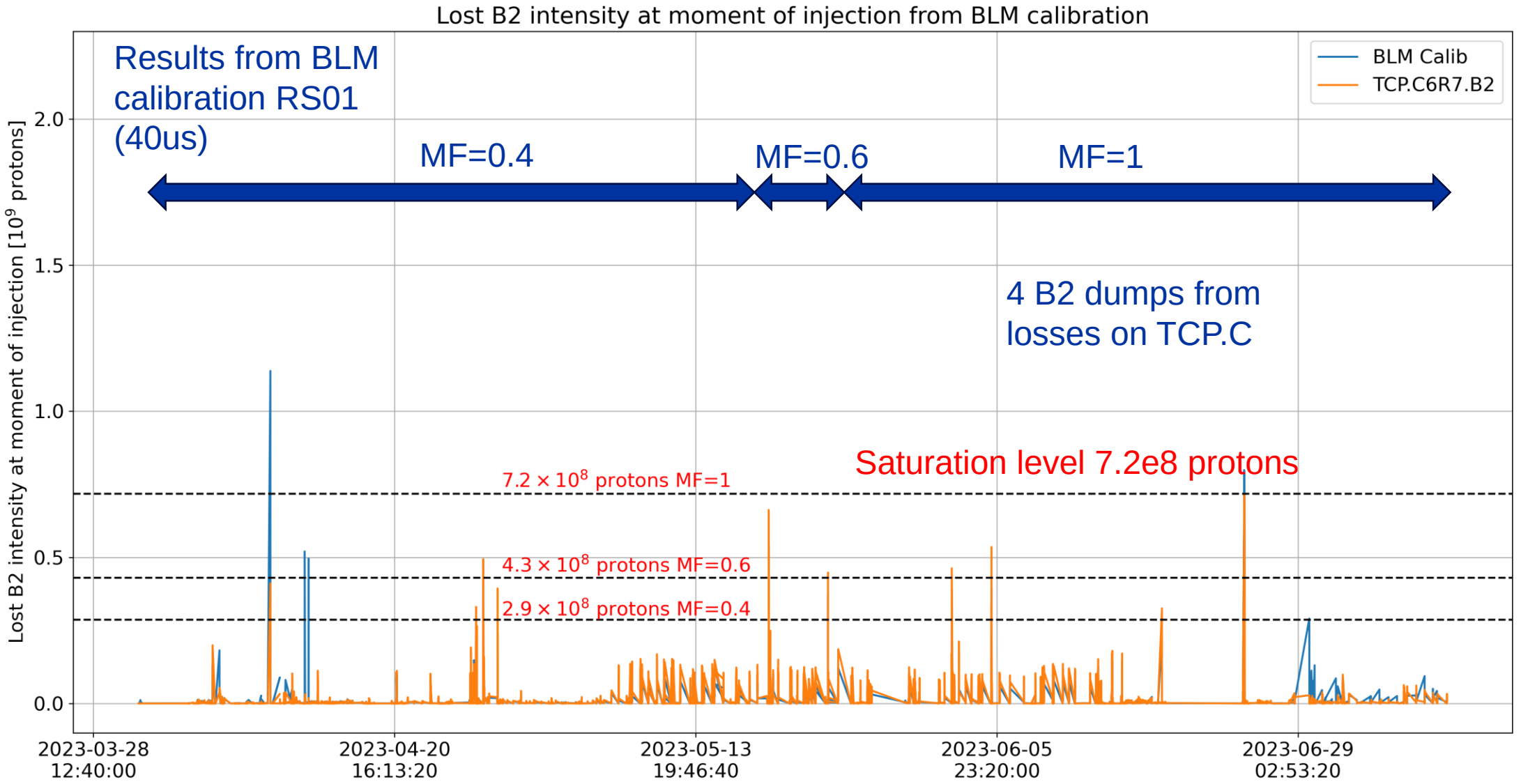
- Losses in IR7 dumping during injection (see talk by Y. Dutheil in JAPW Session 2) with 236b trains in B1
- Fast losses in RS01 (40us) reaching the BLM maximum electronics limit of 23 Gy/s at the B1 primary horizontal and skew collimator BLMs (TCP.C and TCP.B)
- Losses analyzed and studied correlation with multiple factors, see (see B.Salvachua in BLMTWG #97 and F.Velotti in LBOC #152)
- Simple calibration to obtain the number of lost protons at the moment of injection
- Known from BLM latency tests that a pilot lost at the TCPs reaches the BLM saturation limit



Protons: Beam losses and margin to dump during Injection



Protons: Beam losses and margin to dump during Injection

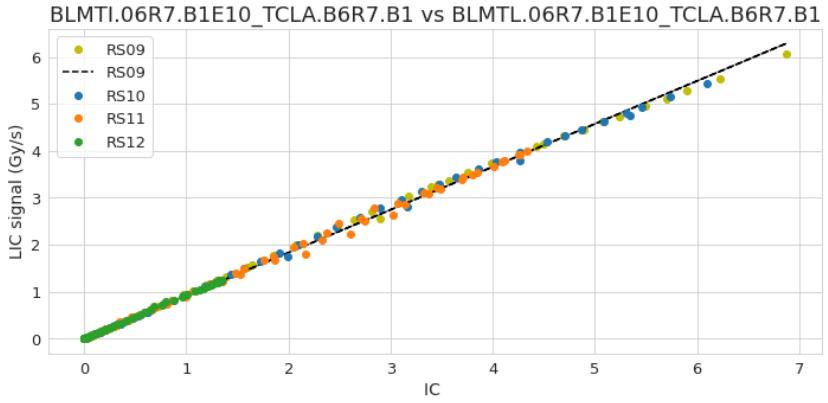


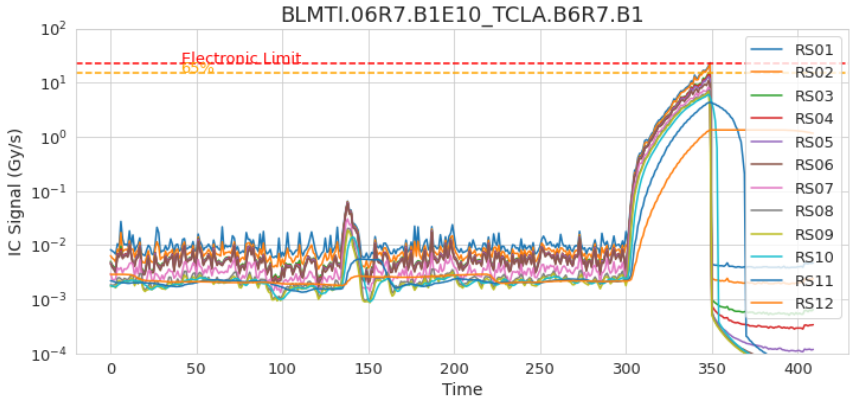
Protons: Beam losses and margin to dump during Injection

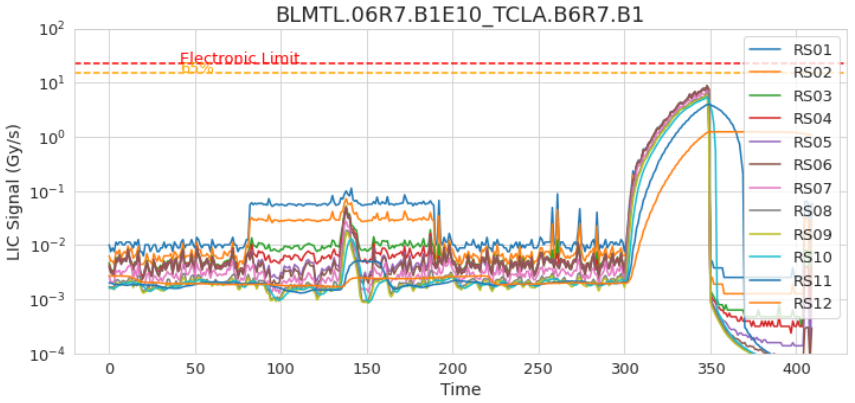
- Different options for mitigations:
  - Blindable BLMs in IR7
    - Blinding functionality not designed for IR7 BLMs
    - Current implementation would blind all BLMs in IR7 collimators -> Not acceptable risk
      - Modification of the functionality requires changes in LSA, FW, SW and GUIs -> not before LS3
    - Need to assess impact for combined fast failure scenarios
    - Blinding functionality will be commissioned for IP2/8 for IP2/8 injection regions in 2024
      - Common FW in all crates, i.e., will be available for IR7 if needed and approved

Protons: Beam losses and margin to dump during Injection

- Different options for mitigations:
  - Use of Little Ionization Chambers (LIC) detectors
    - Replace all SEM detectors by LIC -> Full deployment not before LS3, discussions ongoing
    - Interlock during injection or fast losses on LICs (less sensitive)
      - Would need to assess their stability first
      - First analysis shows linearity between IC and LIC BLM signals
    - Proposal to replace the SEMs at TCPs with LIC detectors monitoring Beam 1 during this EYETS (as is already the case for Beam 2 since LS1)





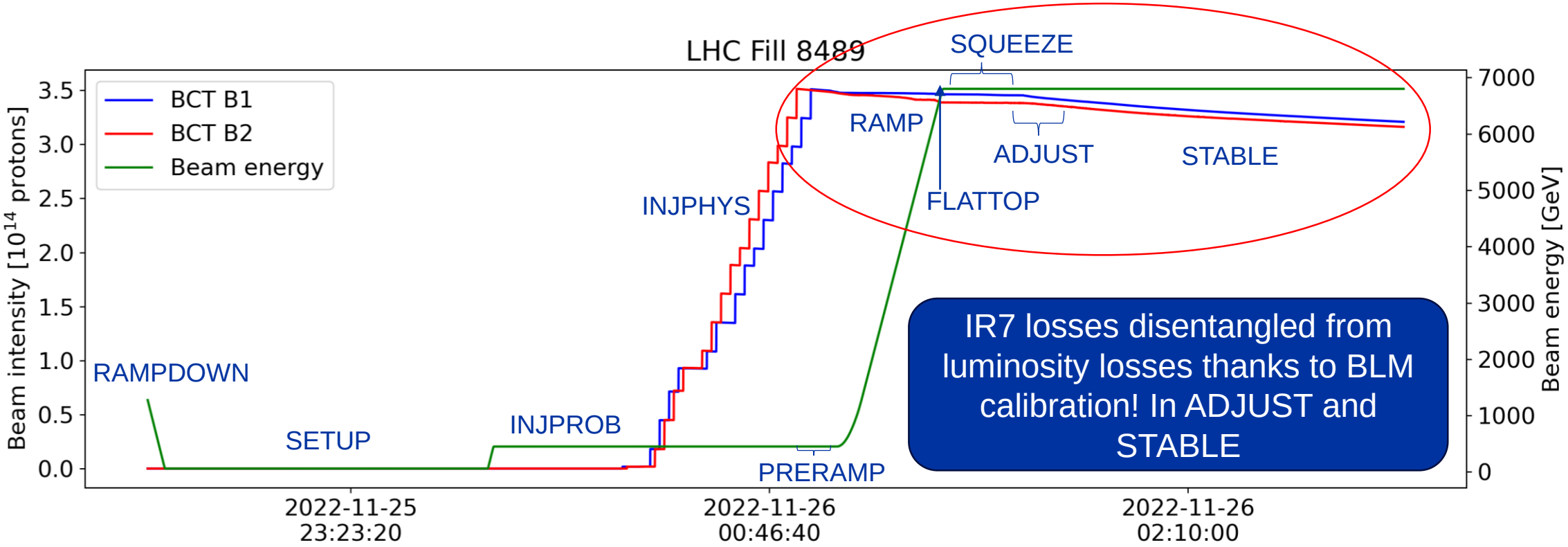


B.Salvachua in BLMTWG #97

Protons: Beam losses and margin to dump during Injection

- Different options for mitigations:
  - Add “displaced” BLMs to catch less loss showers
    - Enough with a factor ~2 to reach the same level as other limiting BLMs
    - Need FLUKA estimates of optimal new positions
    - Addition of extra BLMs in new optimal positions downstream of the TCPs
      - New BLMs will not be interlocked during commissioning
      - Allows comparison of response factors, and if response factors are the ones expected:
      - Change of database settings to become part of the protection BLMs
    - Preferred option
      - Currently investigating the availability of spare channels in the network and necessary cabling for possible installation during this EYETS

Protons: Beam losses and margin to dump



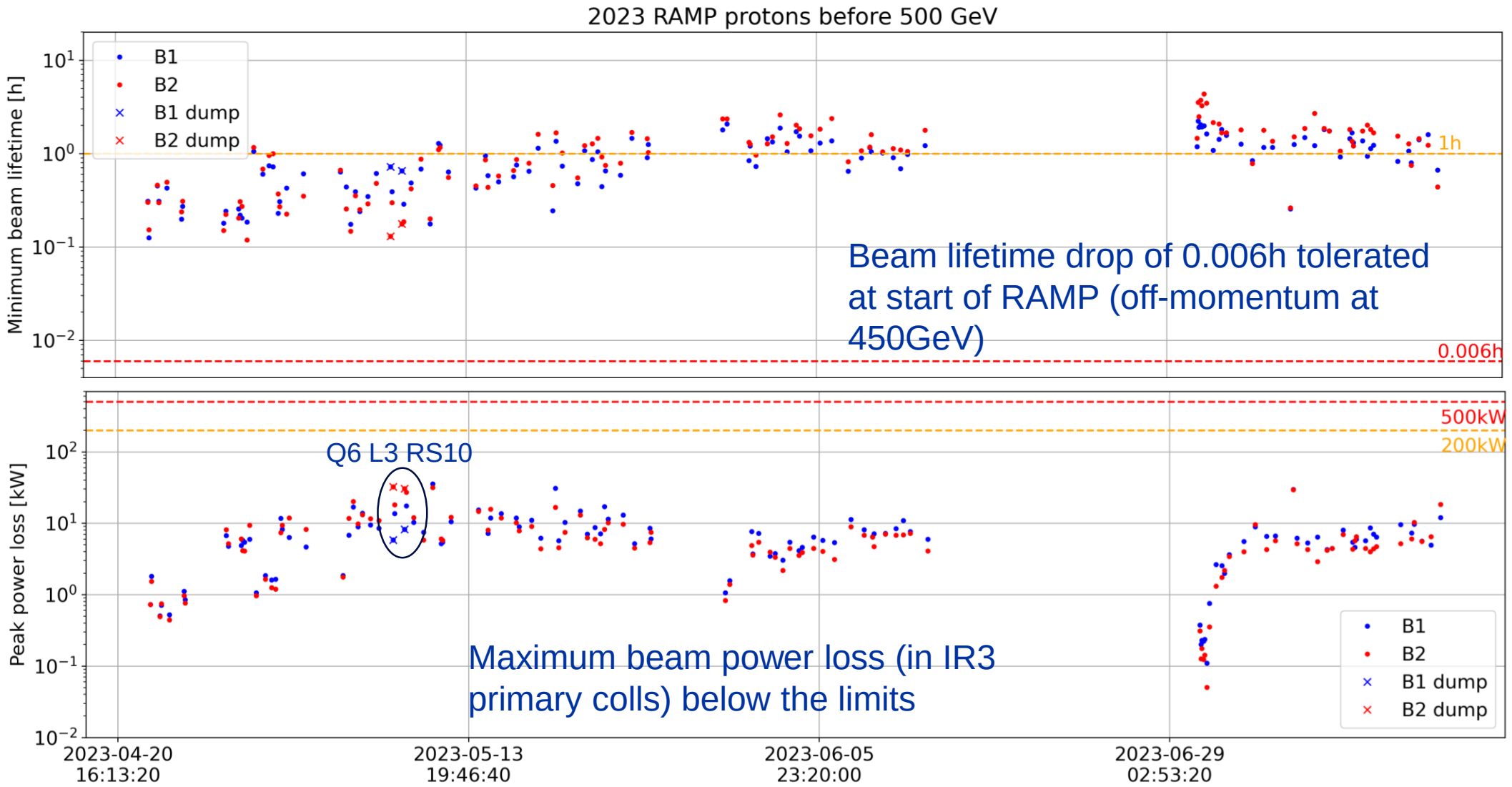
IR7 losses disentangled from luminosity losses thanks to BLM calibration! In ADJUST and STABLE

$$I = I_0 e^{\frac{-t}{\tau}} \rightarrow \tau = \frac{I}{dI/dt}$$

Beam lifetime and power loss analyzed across the cycle using BLM calibration with RS09 (1.3s)
Other RS studied when necessary

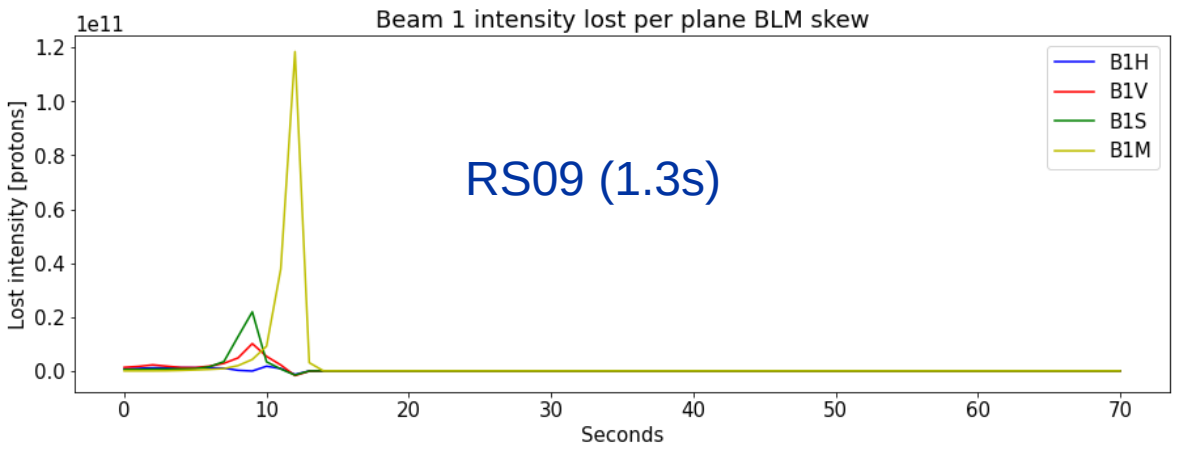
Protons: Beam losses and margin to dump during start of RAMP

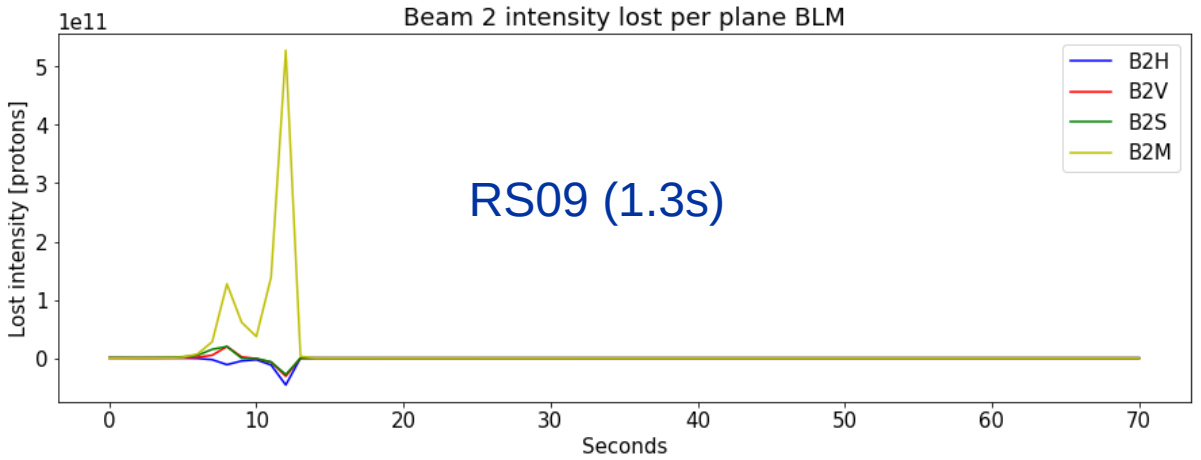
Mainly off-momentum losses in IR3 TCPs at start of RAMP, can be quantified with BLM calibration

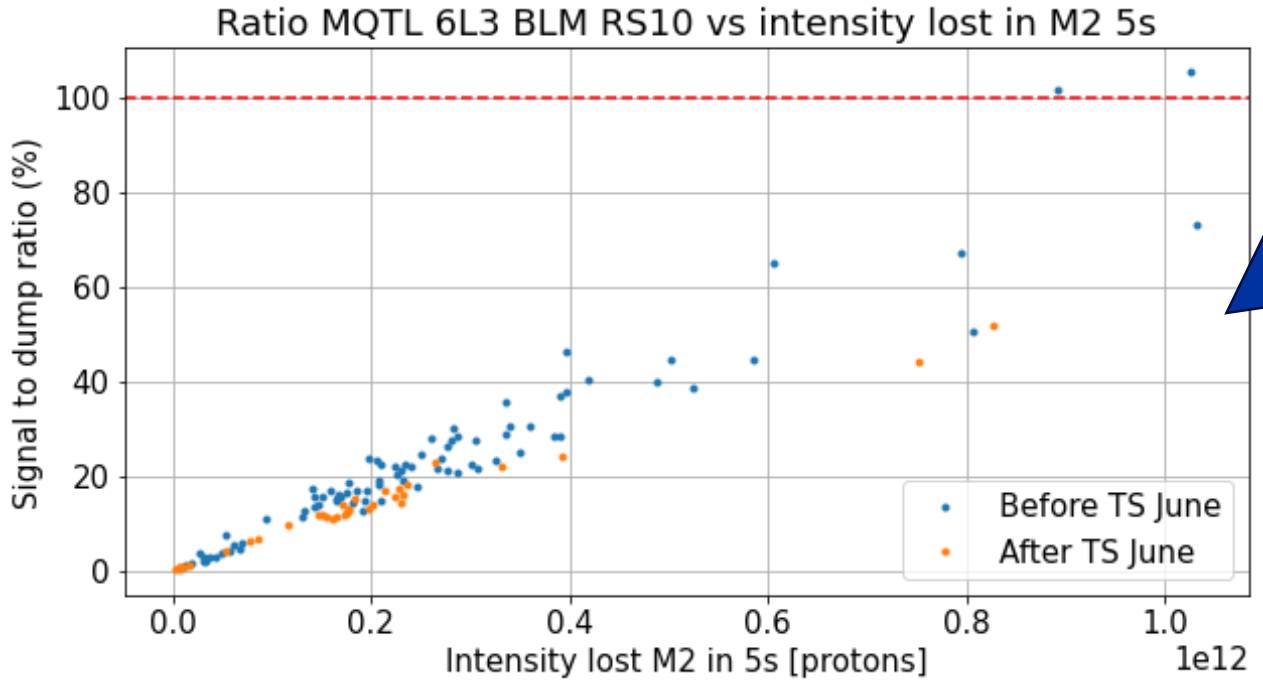


2 dumps in Q6 L3 in RS10 (5.2s) “after remaining a long time in injection”

Protons: Beam losses and margin to dump during start of RAMP





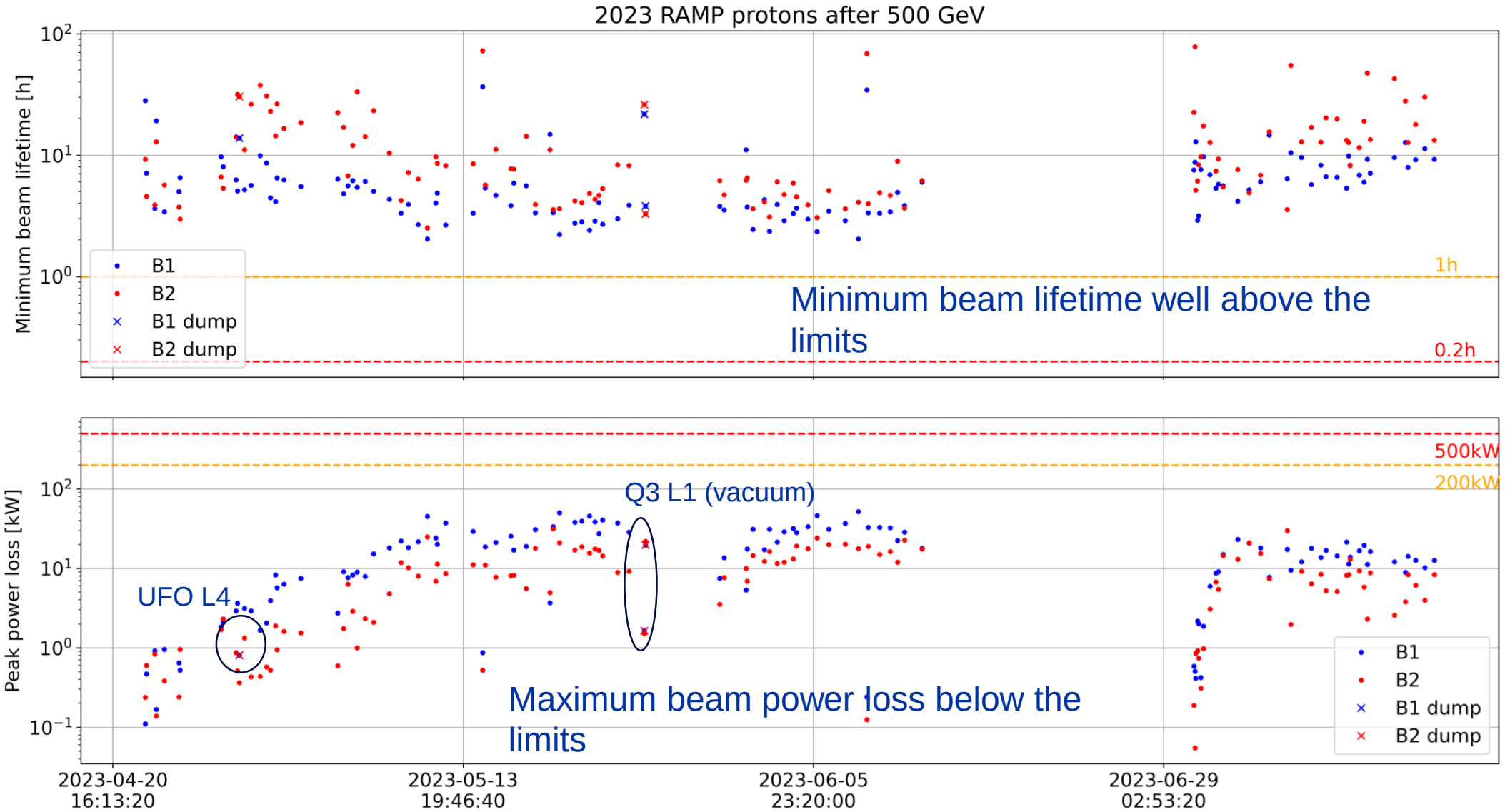


Signal to dump ratio of most limiting BLM vs off-momentum losses integrated 5s -> **Limit around 0.8-1e12 protons lost over 5s in IP3**

Main limitation in RS10 (5.2s) as off-momentum losses happen over several seconds

These losses also discussed in Birk's talk in this session

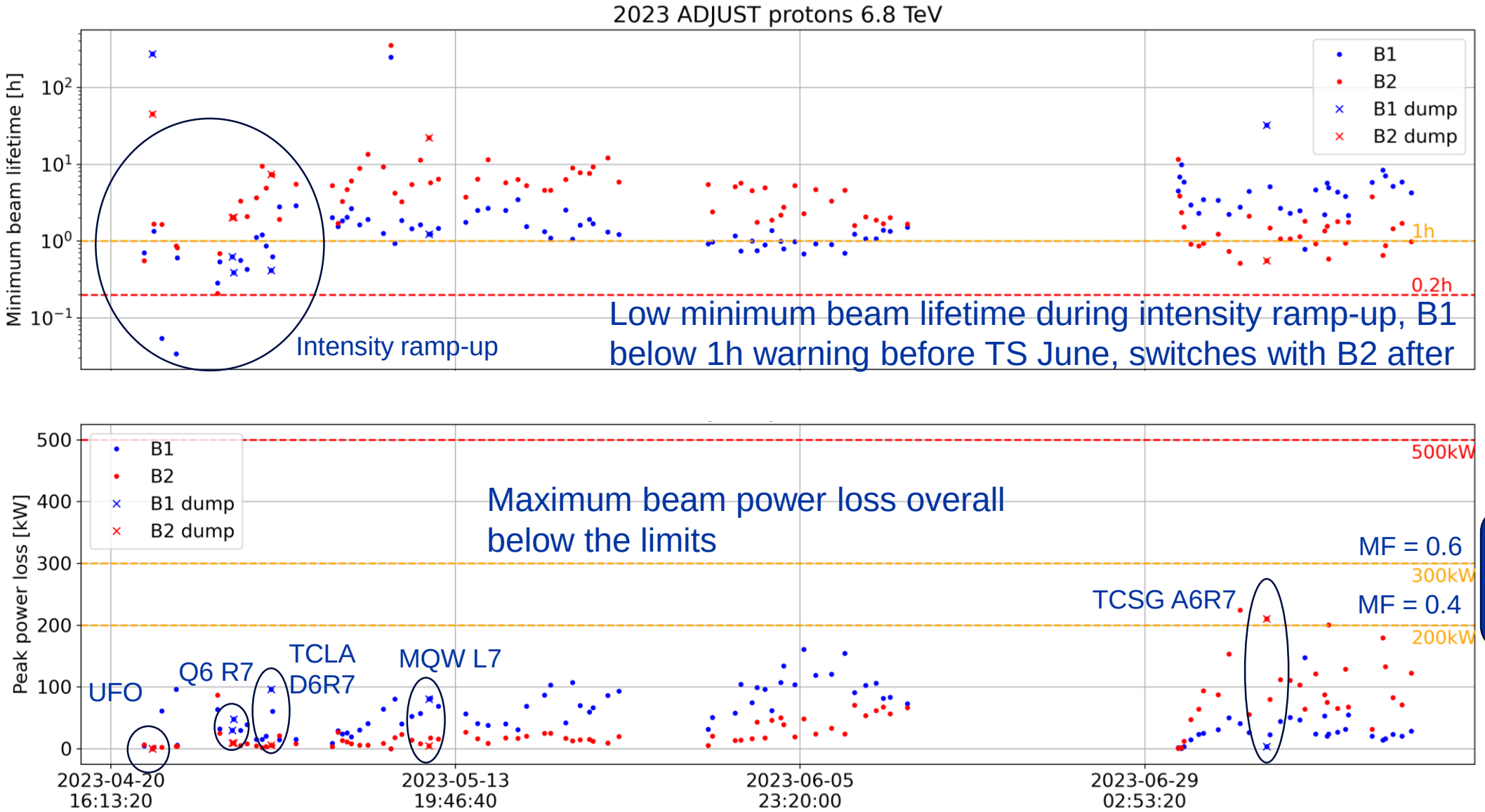
Protons: Beam losses and margin to dump during end of RAMP



1 dump due to UFO in L4

2 dumps in Q3 L1 RS10 (5.2s) due to losses during 4L1 conditioning, MF raised

Protons: Beam losses and margin to dump during ADJUST



1 dump due to UFO in R5

Protons: Beam losses and margin to dump during ADJUST

Fills	Date	BLM	BLM threshold then (Gy/s)	BLM threshold now (Gy/s)	RS	Losses in IR7 (kW)
8680	28-04-2023 20:18:18	BLMQI.06R7.B1E10_MQTL	0.00067	0.00089	RS12	12
8681	28-04-2023 22:30:41	BLMQI.06R7.B1E10_MQTL	0.00067	0.00089	RS12	17.5
8694	01-05-2023 10:52:43	BLMTI.06R7.B1E10_TCLA.D6R7.B1	0.0025	0.0038	RS12	31.7
8749	12-05-2023 01:21:35	BLMQI.05L7.B1E10_MQWA.D5L7	0.11	0.28	RS08	135.3
9040	07-07-2023 07:37:04	BLMTI.06R7.B2I10_TCSG.A6R7.B2	1.8	1.8	RS08	308.6

4 dumps at lower beam power loss than targeted (before main thresholds changes), last dump well aligned

BLM thresholds strategy for Pb ions

Changes applied on top of the existing proton BLM master thresholds in cases where there could be operational limitations -> All changes described in LHC-BLM-ECR-0079

1. IR7 collimators

- Crystal collimation used for operation with Pb ions for the first time
    - Completely different loss pattern in LSS7
    - Goal is to provide the necessary machine protection without limiting beam performance both when crystals are operating in optimal channeling (operational scenario) or in amorphous
- 2022 lossmaps at injection and top energy used as input to prepare the first proposal of BLM thresholds changes
- 2023 lossmaps with the final configurations not performed until the night of 26th to 27th of September
    - Verification of thresholds and changes implemented on the 28th of September

BLM thresholds strategy for Pb ions

Changes applied on top of the existing proton BLM master thresholds in cases where there could be operational limitations -> All changes described in LHC-BLM-ECR-0079

1. IR7 collimators

- The maximum beam power loss allowed for each scenario was:
    - Channeling: 50 kW
    - Amorphous: 15 kW
- At least 2 monitors per beam to cover H/V planes for the channeling case and 1 for amorphous case
- Different scale factors at top and injection, implemented as a step function at 2 TeV

2. Cold magnets -> Collimation leakage

- BLMs in the DS sensitive to collimation leakage
- Some BLMs in the DS showed signals above the thresholds during the 2015 quench test without quenching
    - Increase thresholds in these BLMs in the slow RS (RS08-RS10)

BLM thresholds strategy for Pb ions

Changes applied on top of the existing proton BLM master thresholds in cases where there could be operational limitations -> All changes described in LHC-BLM-ECR-0079

1. IR7 collimators and cold magnets -> MF strategy

- Same strategy followed for IR7 collimators and DS:
  - Collimators start with MF=0.4 -> 20kW in channeling
  - DS up to cell 13 start with MF=0.333 -> 35kW in channeling
  - Increase in steps of 10kW if needed
  - If a quench is observed, the MF will be reduced for the next fill

	Duration	Master thresholds Pb ions	Applied thresholds MF = 0.4	Applied thresholds MF = 0.6	Applied thresholds MF = 0.8
RS08-RS10	0.655 – 5.24 s	50 kW	20 kW	30 kW	40 kW
RS11	20.97 s	24 kW	9.6 kW	14.4 kW	19.2 kW
RS12	83.89 s	10 kW	4 kW	6 kW	8 kW

BLM thresholds strategy for Pb ions

Changes applied on top of the existing proton BLM master thresholds in cases where there could be operational limitations -> All changes described in LHC-BLM-ECR-0079

3. TCT collimators

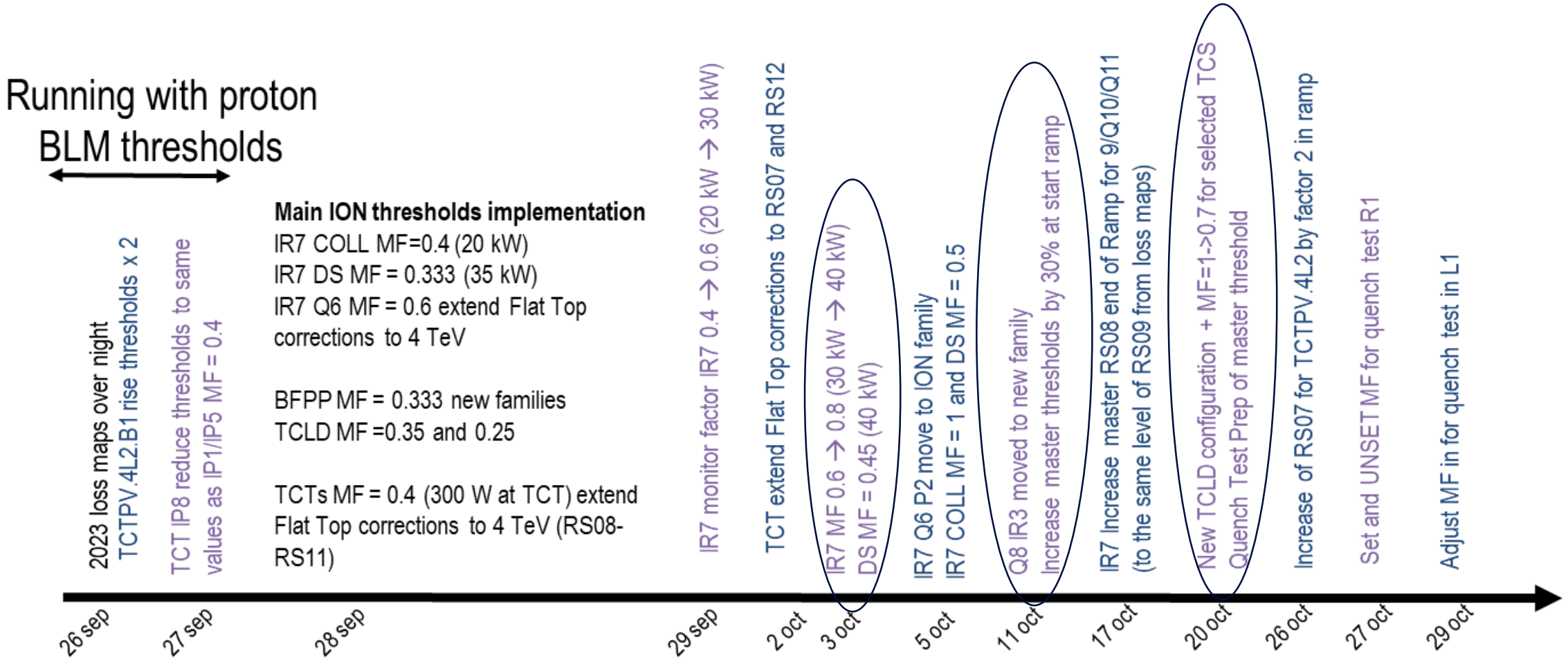
- Proton master thresholds would allow 500 W in RS12, considered to be above the damage limits
- Simulations still to be done to confirm, but decided to keep MF = 0.4 to allow 200 W on steady-state losses

4. BFPP luminosity losses

- Collision products that correspond to a variety of ions with different masses and charges, lost in the DS
- Deposited energy (proportional to instantaneous luminosity) could quench the DS magnets -> local orbit bumps to move the losses to an empty connection cryostat in all colliding IRs + TCLD collimator in IR2
- General philosophy to avoid BLM warning (30%) due to BFPP losses with peak luminosities of:
  - $6.4 \times 10^{27} \mathrm{cm}^{-2} s^{-1}$ in ATLAS/CMS/ALICE
  - $1 \times 10^{27} \mathrm{cm}^{-2} s^{-1}$ in LHCb

BLM thresholds strategy for Pb ions

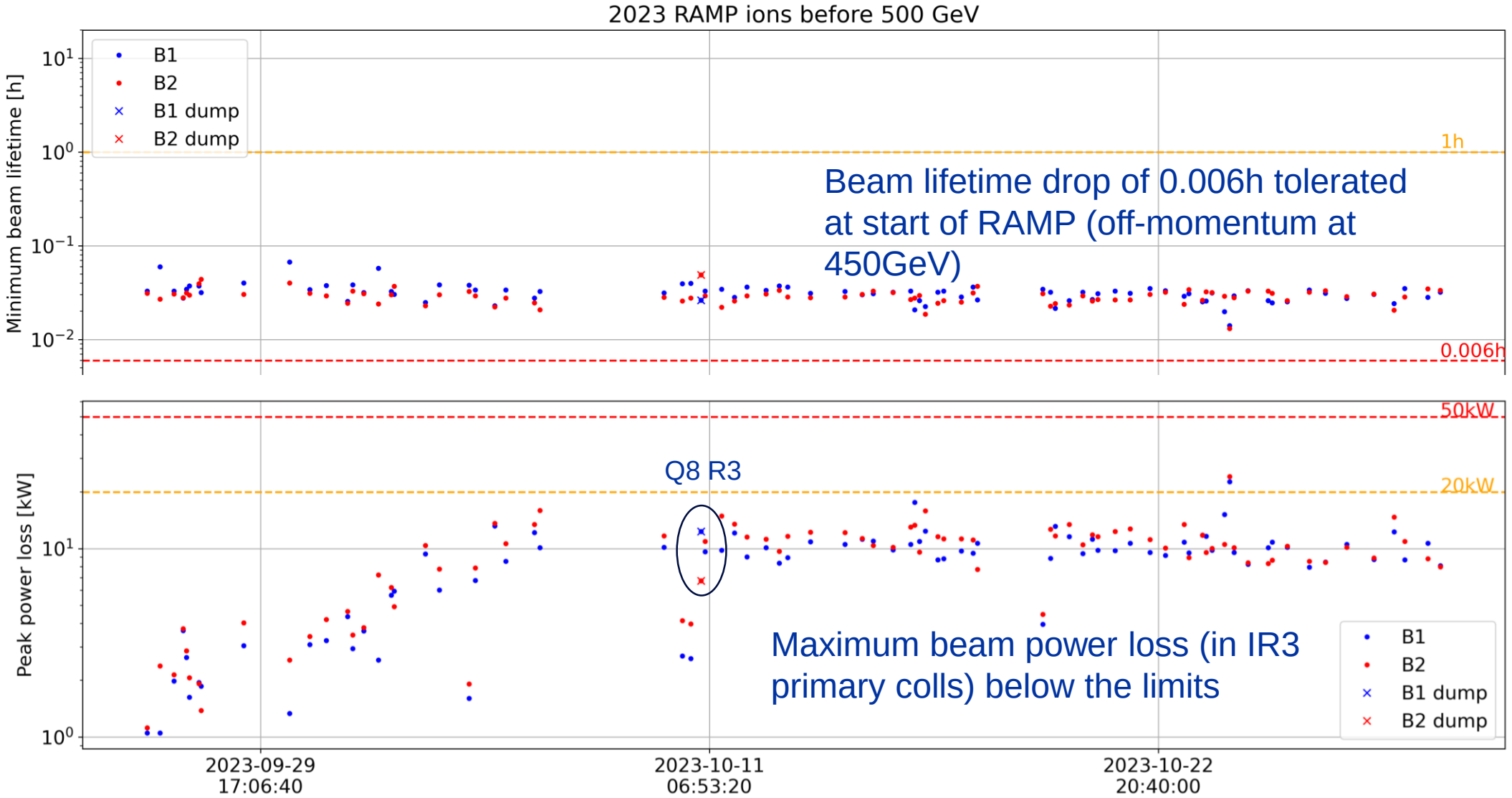
5. Changes during the Run



R.Bruce in LMC #475

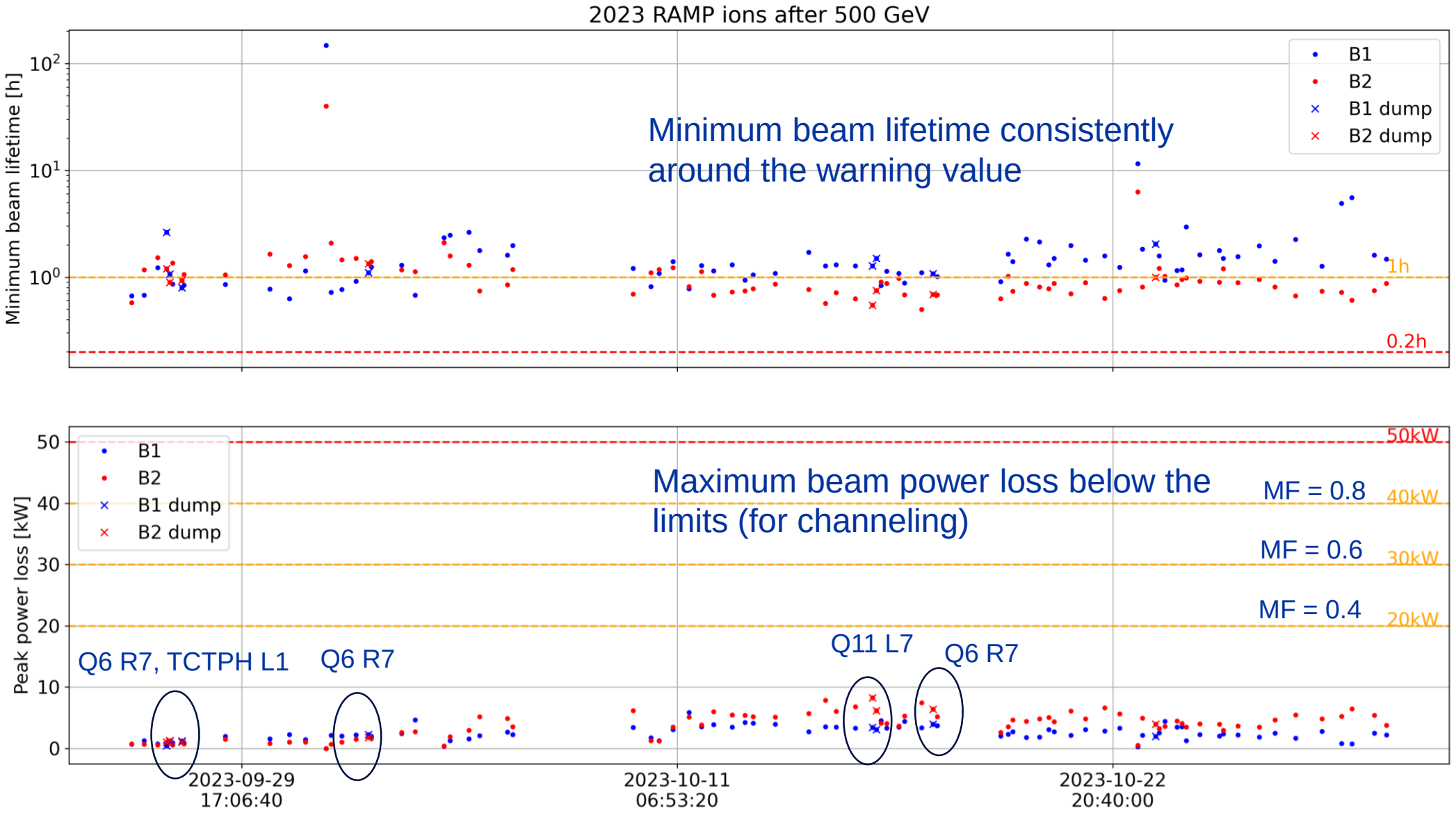
Pb ions: Beam losses and margin to dump during start of RAMP

From BCT, no BLM calibration for off-momentum losses at injection energy



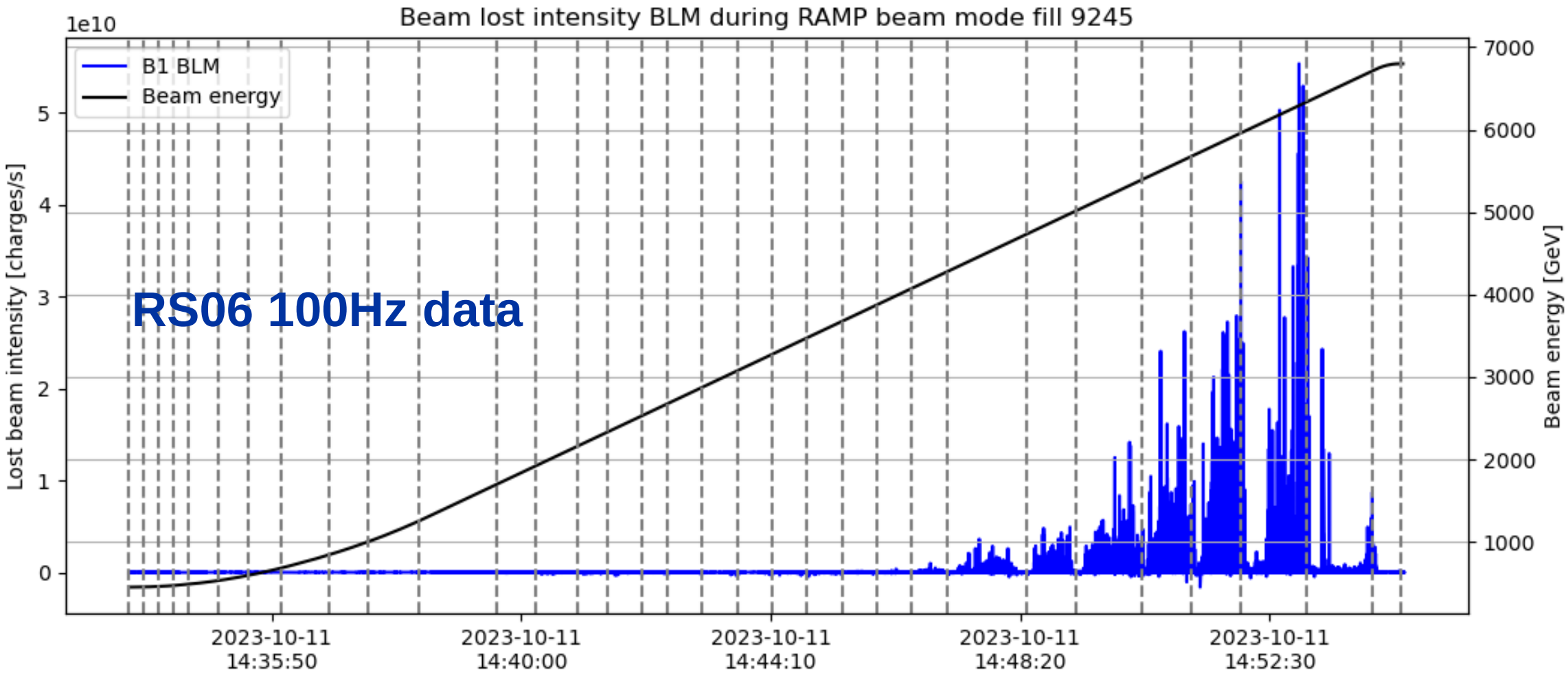
1 dump in Q8 R3 in RS09 (1.3s) -> Master thresholds raised

Pb ions: Beam losses and margin to dump during end of RAMP



8 beam dumps at different BLM and RS, 10Hz loss structure present in all, crystal seems to go out of channeling

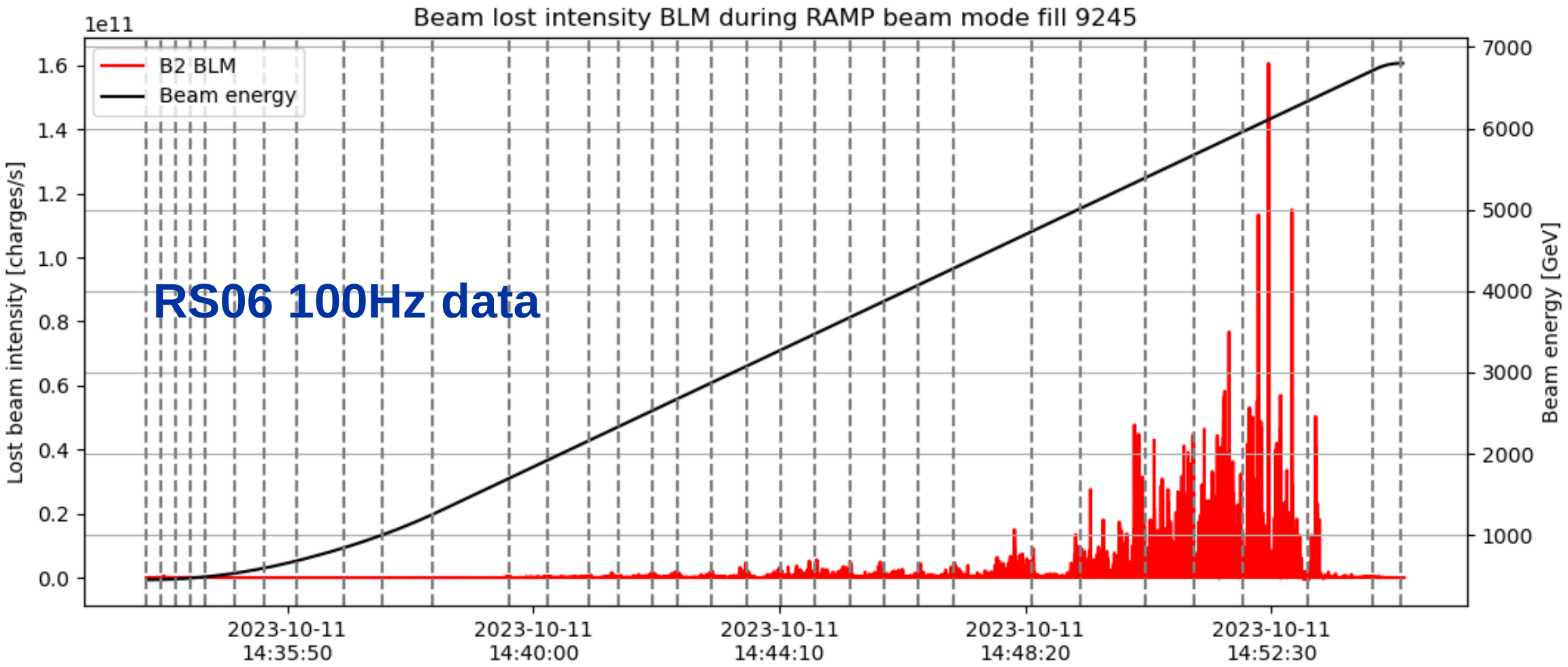
Pb ions: Beam losses and margin to dump during end of RAMP



Dashed lines: optics matched points

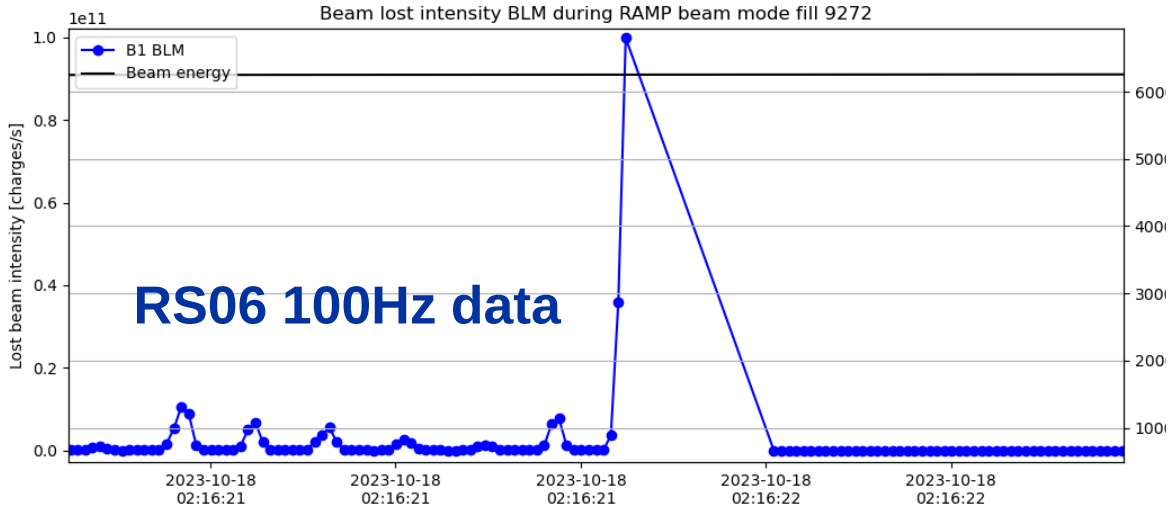
Lots of effort in understanding these 10Hz loss events, more information on LBOC #157 and #158

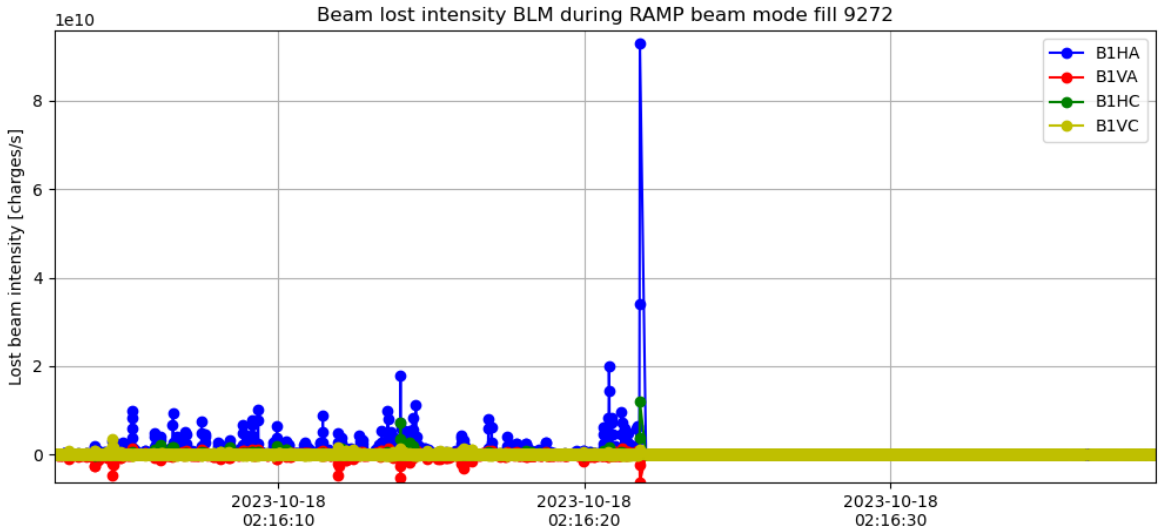
Pb ions: Beam losses and margin to dump during end of RAMP

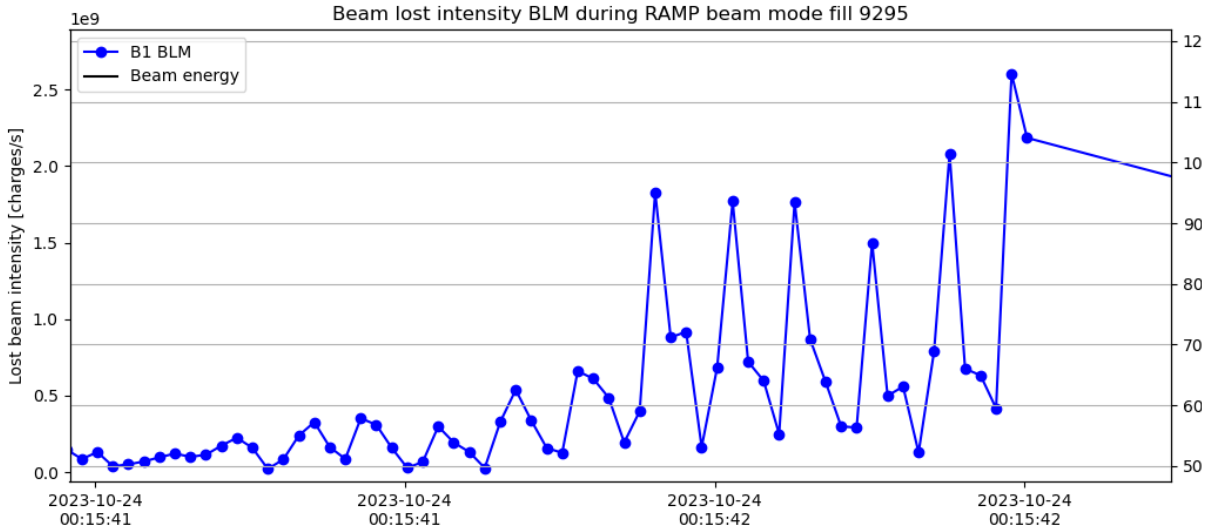


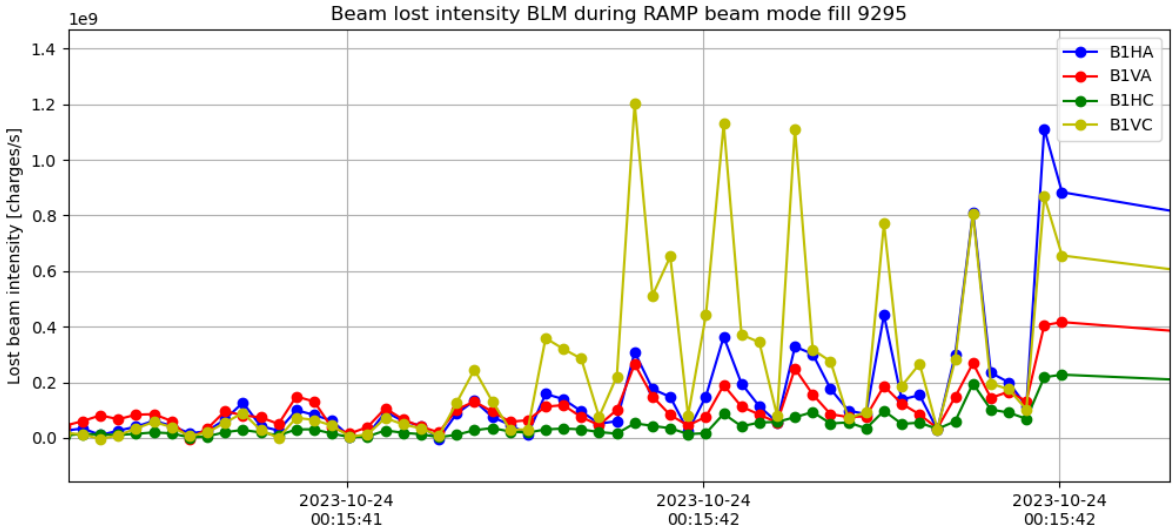
Lots of effort in understanding these 10Hz loss events, more information on LBOC #157 and #158

Pb ions: Beam losses and margin to dump during end of RAMP









Pb ions: Beam losses and margin to dump during end of RAMP

Fills	Date	BLM	BLM threshold then (Gy/s)	BLM threshold end (Gy/s)	RS	Losses IR7 (kW)	Energy (TeV)
9195	27-09-23 17:38:16	BLMQI.06R7.B1 E10_MQTL	0.00026 0.00018	0.014 0.014	RS10 RS11	0.20 10Hz AM	5.6
9196	27-09-23 19:42:17	BLMTI.04L1.B1I 10_TCTPH.4L1. B1	0.00044	0.0058	RS08	2 10Hz AM	6.3
9199	28-09-23 03:15:53	BLMTI.04L1.B1I 10_TCTPH.4L1. B1	0.00028	0.0058	RS09	1.2 10Hz AM	6.3
9219	03-10-23 02:16:10	BLMQI.06R7.B1 E20_MQTL	0.0011	0.0027	RS08	4.4 10Hz AM	6.3

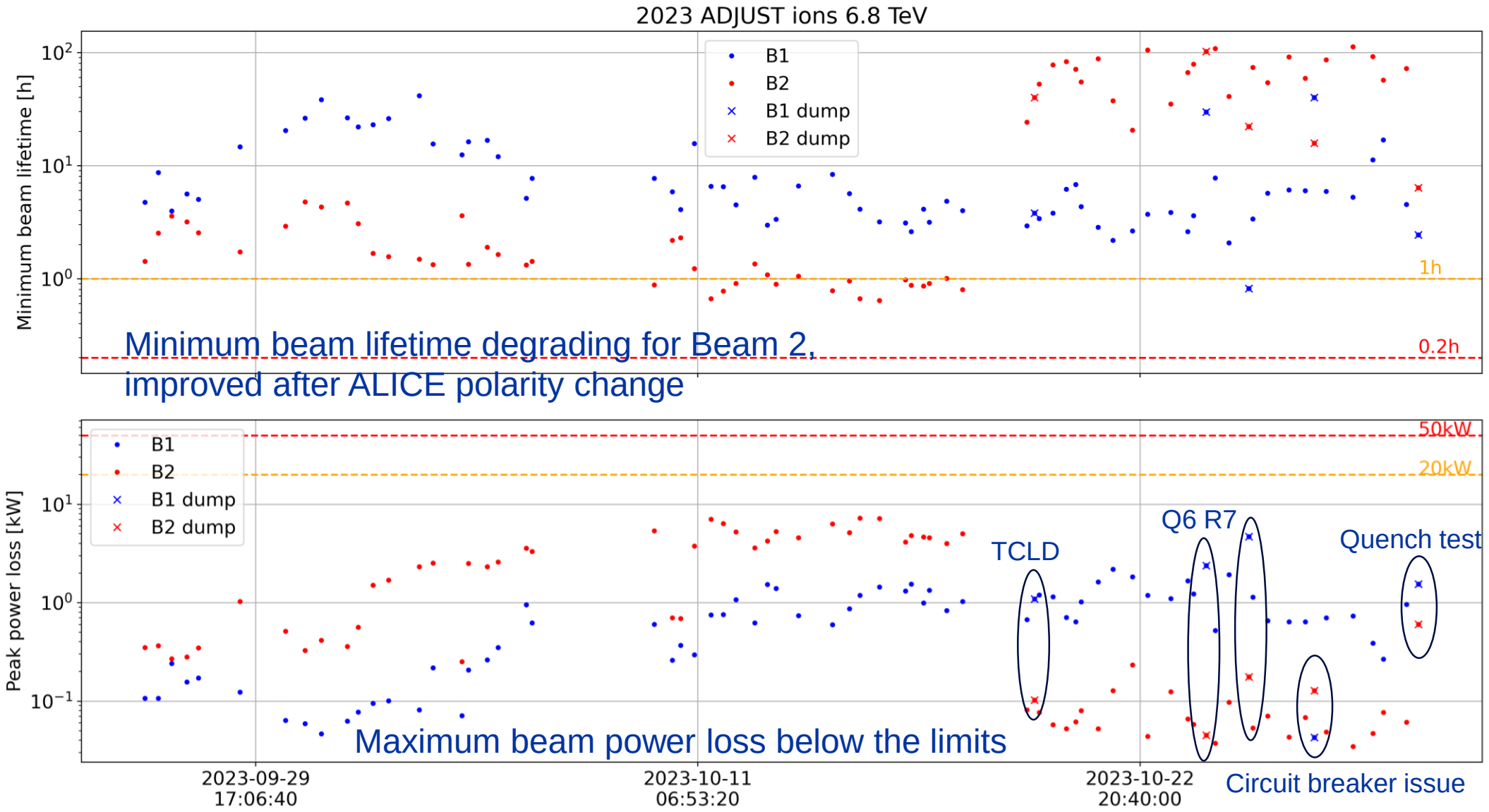
4 dumps at lower beam power loss than targeted (for channeling and amorphous), thresholds raised

Pb ions: Beam losses and margin to dump during end of RAMP

Fills	Date	BLM	BLM threshold then (Gy/s)	BLM threshold end (Gy/s)	RS	Losses IR7 (kW)	Energy (TeV)
9265	16-10-23 11:50:26	BLMQI.11L7.B2I 10_MQ	0.0051	0.0076	RS08	11.5 10Hz AM	6.2
9266	16-10-23 14:16:38	BLMQI.11L7.B2I 10_MQ	0.0060	0.0090	RS08	12.1 10Hz AM	6.0
9272	18-10-23 02:16:21	BLMQI.06R7.B1 E10_MQTL	0.11	0.11	RS06	99.3 10Hz AM	6.2
9295	24-10-23 00:15:42	BLMTI.04L2.B1 E10_TCTPV.4L 2.B1	0.0057	0.01	RS07	2 10Hz AM	6.7

3 dumps at targeted beam power loss for amorphous, some thresholds raised;
1 beam dump at lower beam power loss

Pb ions: Beam losses and margin to dump during ADJUST



3 beam dumps at RS06 (1ms), 10Hz loss structure present in all, crystal seems to go out of channeling

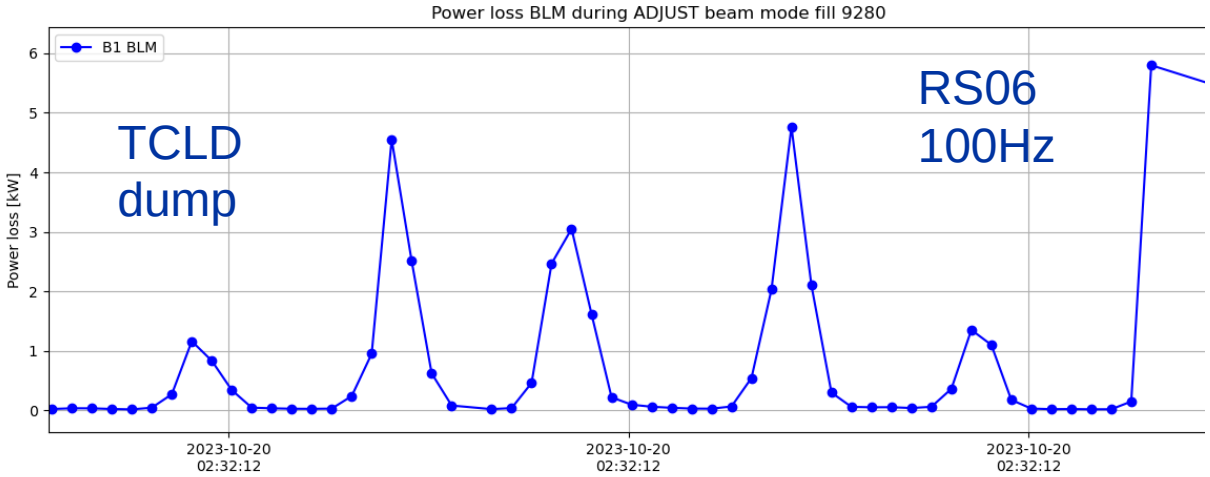
Pb ions: Beam losses and margin to dump during ADJUST

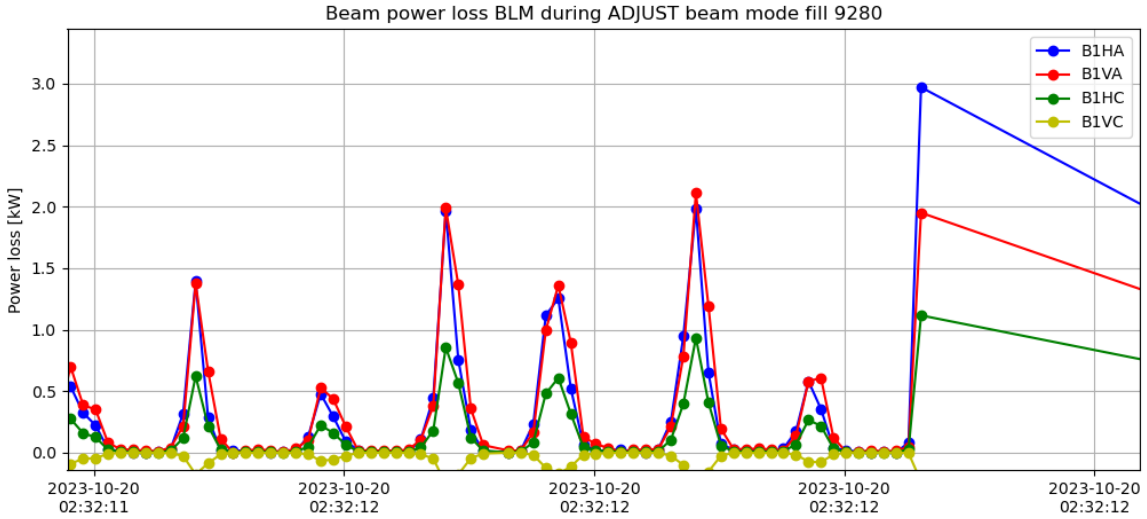
Fills	Date	BLM	BLM threshold (Gy/s)	RS	Losses in IR7 (kW)
9280	20-10-23 02:32:12	BLMTI.11R2.B1I10_TCLD.A11R2.B1	0.021	RS06	6 10Hz AM*
9299	24-10-23 14:17:57	BLMQI.06R7.B1E10_MQTL	0.10	RS06	145 10Hz TR*
9304	25-10-23 17:05:18	BLMQI.06R7.B1E10_MQTL	0.10	RS06	100 10Hz TR*

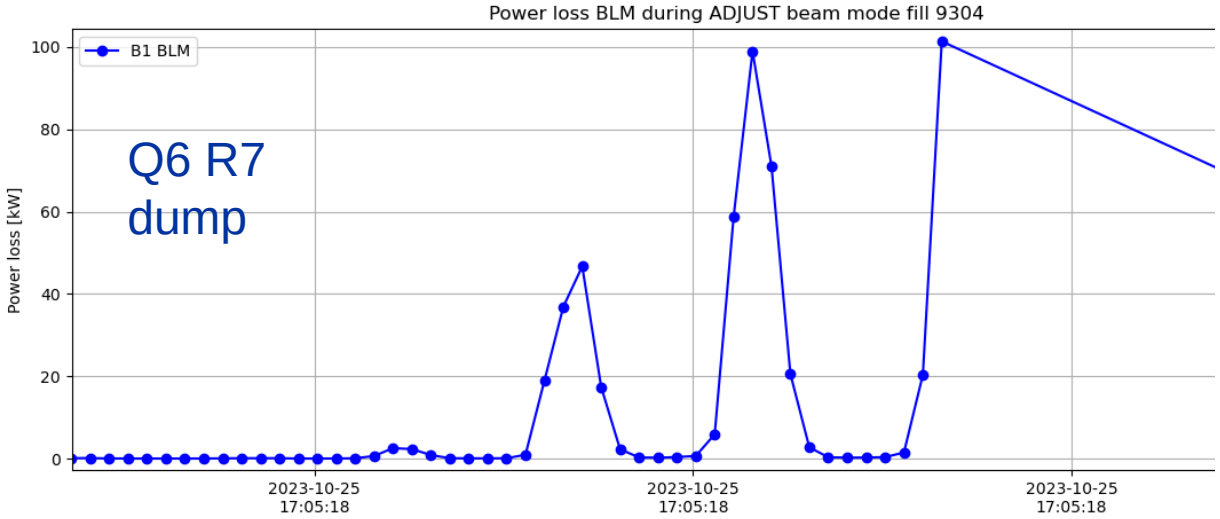
*Events studied by D.Mirarchi, presented on LBOC #158

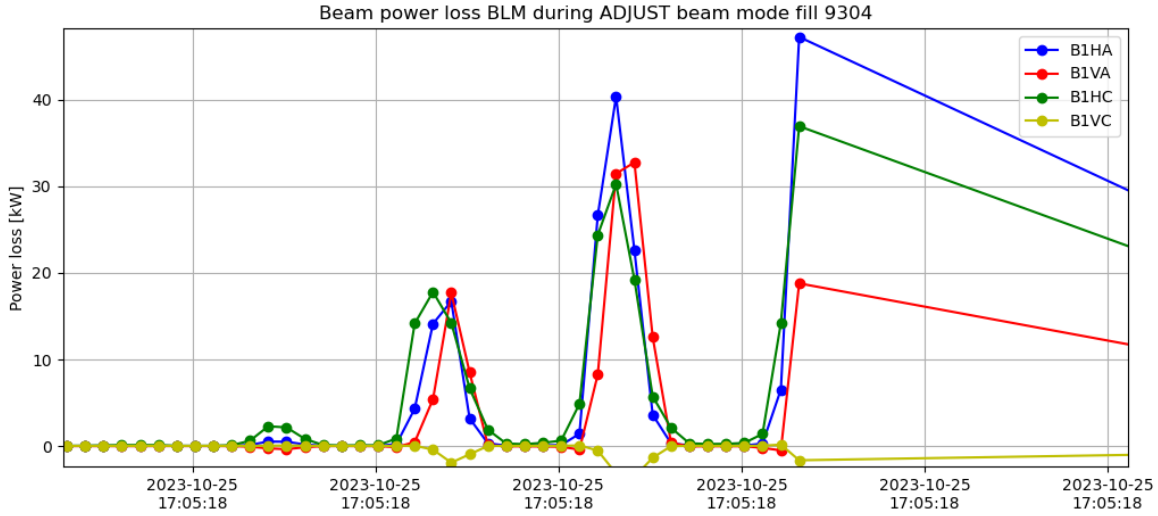
1 beam dump at a lower power loss but on the TCLD, settings changed;
2 beam dumps on Q6 R7 from violent 10Hz loss events
NO THRESHOLDS CHANGED

Pb ions: Beam losses and margin to dump during ADJUST

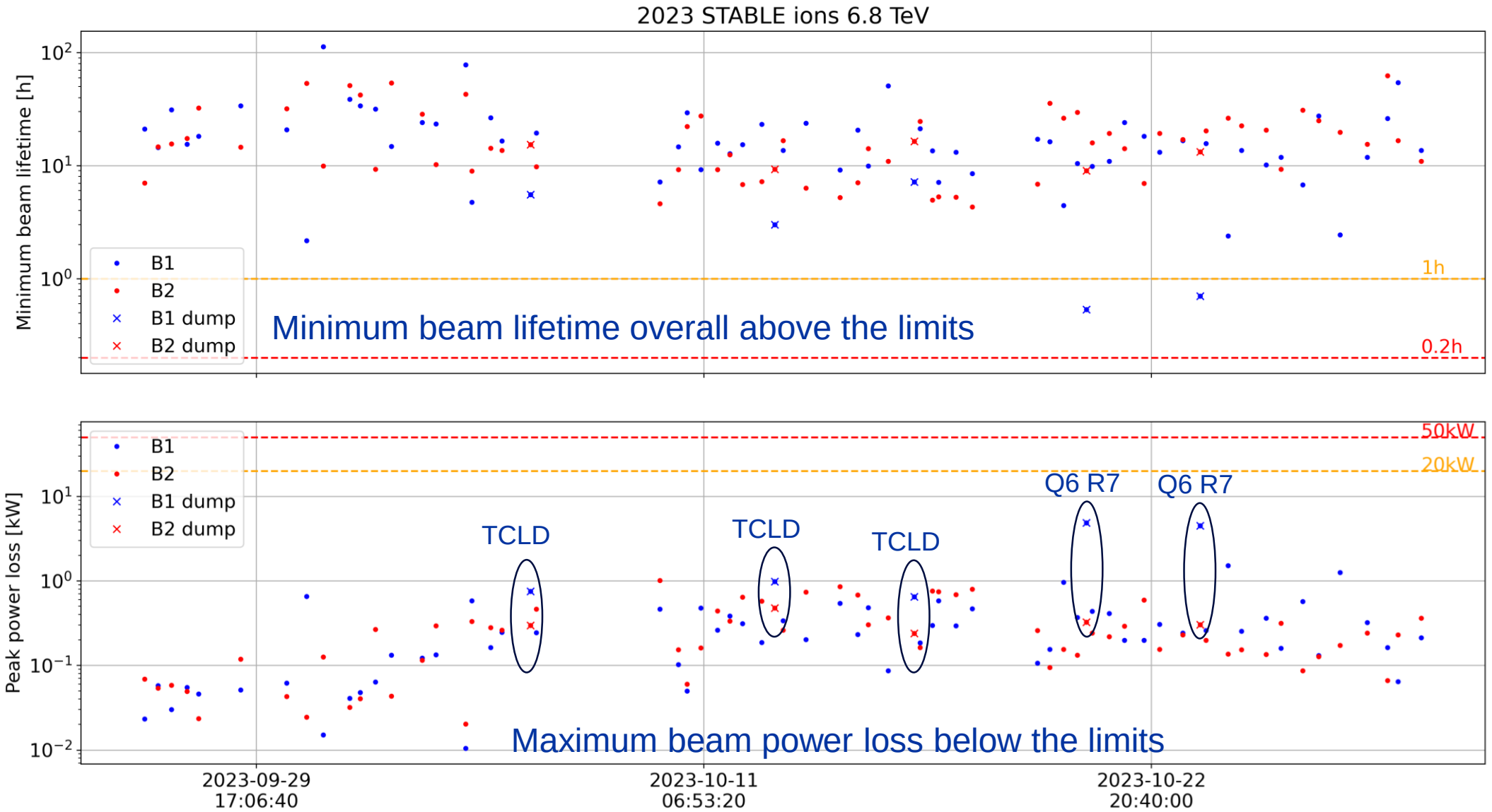








Pb ions: Beam losses and margin to dump during STABLE



5 beam dumps at RS06 (1ms), 10Hz loss structure present in all, crystal seems to go out of channeling

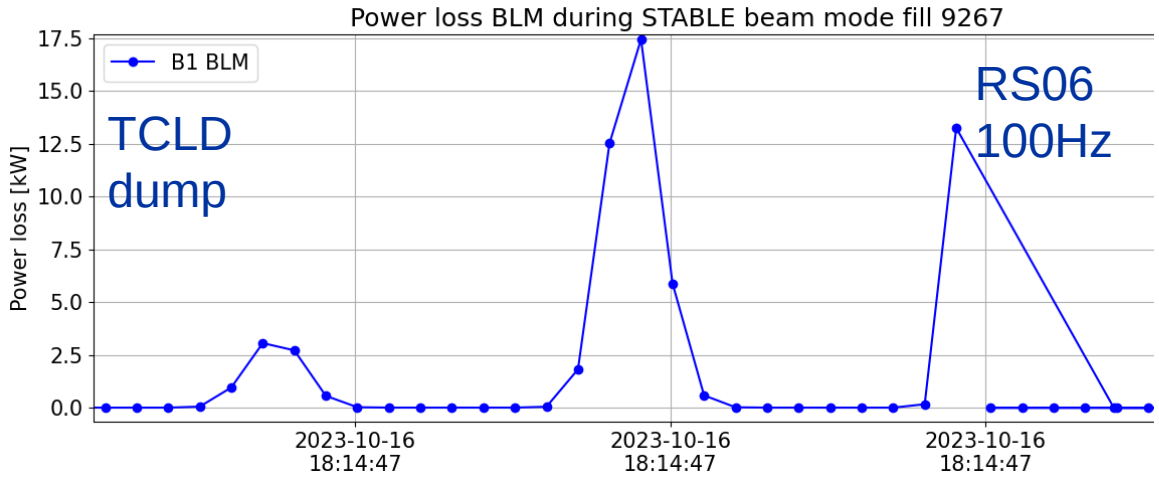
Pb ions: Beam losses and margin to dump during STABLE

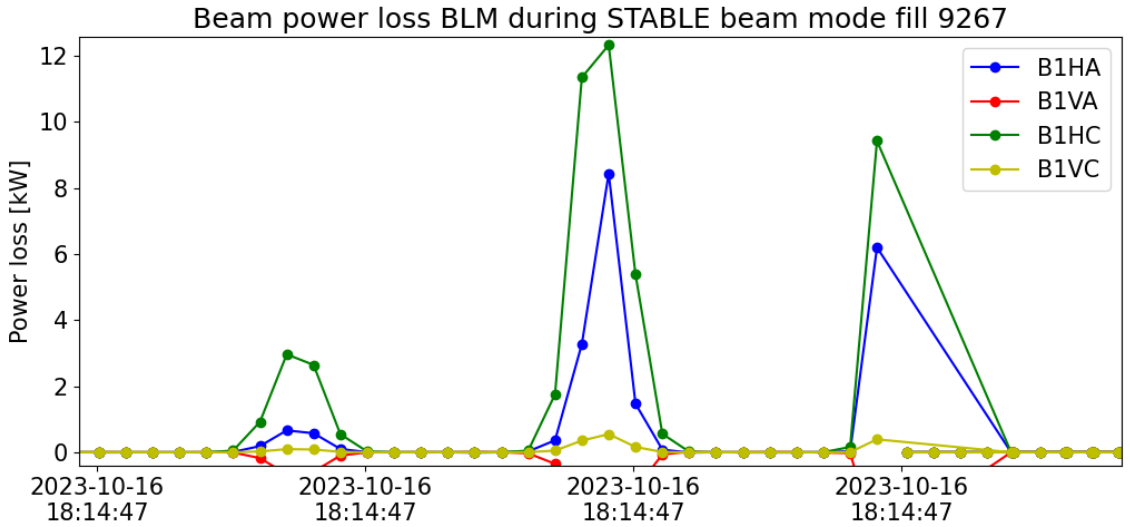
Fills	Date	BLM	BLM threshold (Gy/s)	RS	Losses in IR7 (kW)
9234	06-10-23 19:32:02	BLMTI.11R2.B1I10_TCLD.A11R2.B1	0.021	RS06	15 10Hz VR*
9251	13-10-23 05:10:16	BLMTI.11R2.B1I10_TCLD.A11R2.B1	0.021	RS06	10 10Hz AM*
9267	16-10-23 18:14:47	BLMTI.11R2.B1I10_TCLD.A11R2.B1	0.021	RS06	13.3 10Hz AM*
9284	21-10-23 05:31:02	BLMQI.06R7.B1E10_MQTL	0.101	RS06	15 10Hz TR*
9296	24-10-23 04:02:07	BLMQI.06R7.B1E10_MQTL	0.101	RS06	44.3 10Hz TR*

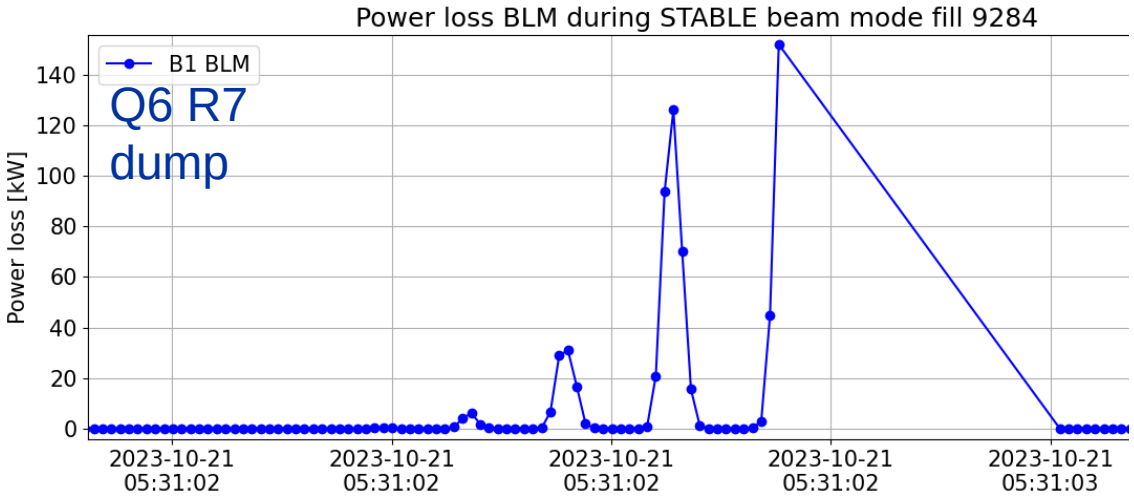
*Events studied by D.Mirarchi, presented on LBOC #158

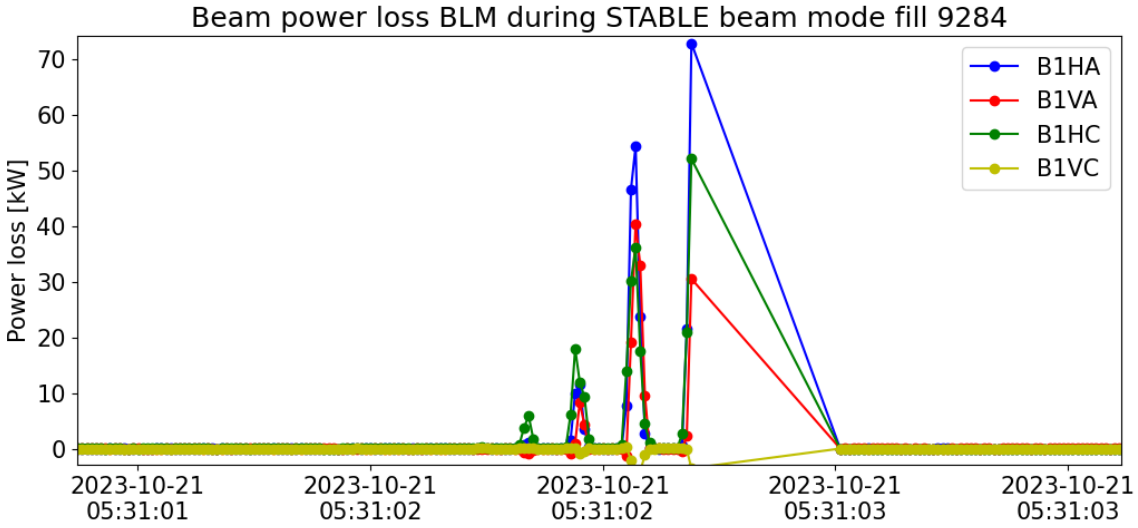
3 beam dumps on the TCLD at power losses comparable with amorphous, settings changed;
2 beam dumps on Q6 R7 from 10Hz loss events
NO THRESHOLDS CHANGED

Pb ions: Beam losses and margin to dump during STABLE









Lessons learnt for the next Ion Run

1. Operation with crystal was efficient but some improvement is needed in order to maintain the crystals in channeling, in particular during the energy RAMP -> See more in R.Cai's talk in this session
2. Crystal operation in channelling, amorphous or volume reflection has a big impact on BLM signal pattern
    - Additional margin for these cases is needed for next ion Run
3. Control of 10Hz losses will significantly improve
4. Loss maps as early as possible are essential, even if not in the full final configuration
    - First set of thresholds done with 2022 loss maps was important to advance the work

Summary

- Beam lifetime and beam power loss analyzed for the proton and ion 2023 Runs
- Proton Run:
  - Injection losses in particular of Beam 1 could pose a limitation for 2024 -> Several options to increase the margin of beam loss measurements in RS01 are under consideration.
  - Limitations in BLM thresholds during ADJUST understood and mitigated -> Running regularly with minimum beam lifetime of ~1h, equivalent to 100 kW maximum power loss on average, with peaks up to 230kW (300kW in RS08, 655ms)
- Ion Run:
  - New beam loss pattern in IR7 due to the novel crystal collimation operation -> Many BLM thresholds were needed to adapted for this new scenario, but overall, the strategy was correct
  - For next Run, we will study how to overcome the limitations found during the RAMP, when crystal channelling could not be maintained
  - ADJUST and STABLE beam lifetime drops dominated by 10Hz loss events

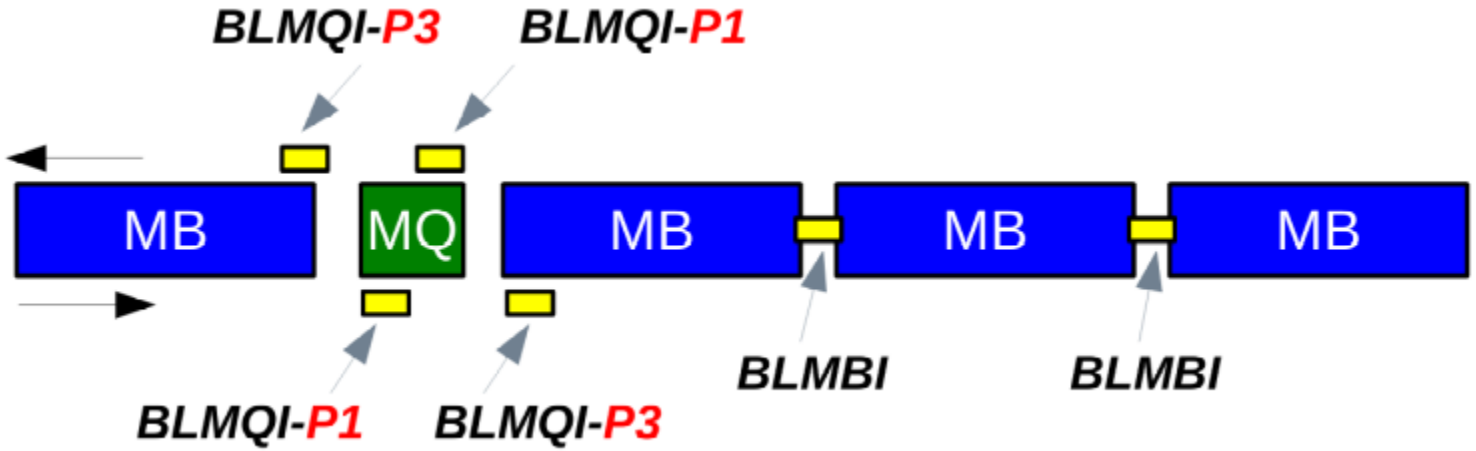
Backup slides

BLM thresholds strategy for protons

1. Cold magnets-> No changes with respect to 2022 -> Described in LHC-BLM-ECR-0073

- Dust particles (UFOs) dominant source of transient beam loss events in the LHC arcs and DS
- Best machine availability if UFO-induced BLM dumps are avoided and quenches tolerated

→ Master thresholds at 3x the quench level in short RS (40us – 2.5ms), and MF = 0.333



Standard BLM layout in a LHC arc half-cell

BLMQI-P1 = UFOs (MB)

BLMQI-P3 = Orbit bump (MQ)

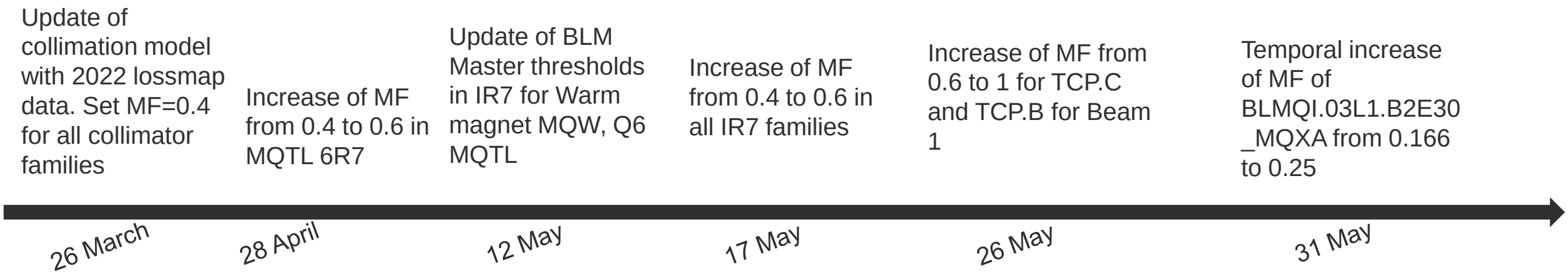
BLMBI = UFOs (MB)

Thresholds reduced at selected arc/DS locations which are (possibly) affected by a hardware non-conformity: 2 magnets with one less quench heater and 35 magnets with a possible non-conform bypass diode

BLM thresholds strategy for protons

6. Changes during the Run

- Rise of MF MQTL 6R7 after dumps in ADJUST RS12 (84s) before IR7 MQW, Q6 MQTL master thresholds update
- Rise of MF all IR7 families to give more margin to RS12 without changing the collimation model
- Rise of MF in B1 TCP.C and TCP.B to give more margin for injection losses RS01 (40us)
- Rise of MF in BLMQI.03L1.B2E30_MQXA to give more margin during conditioning to the high losses in 4L1

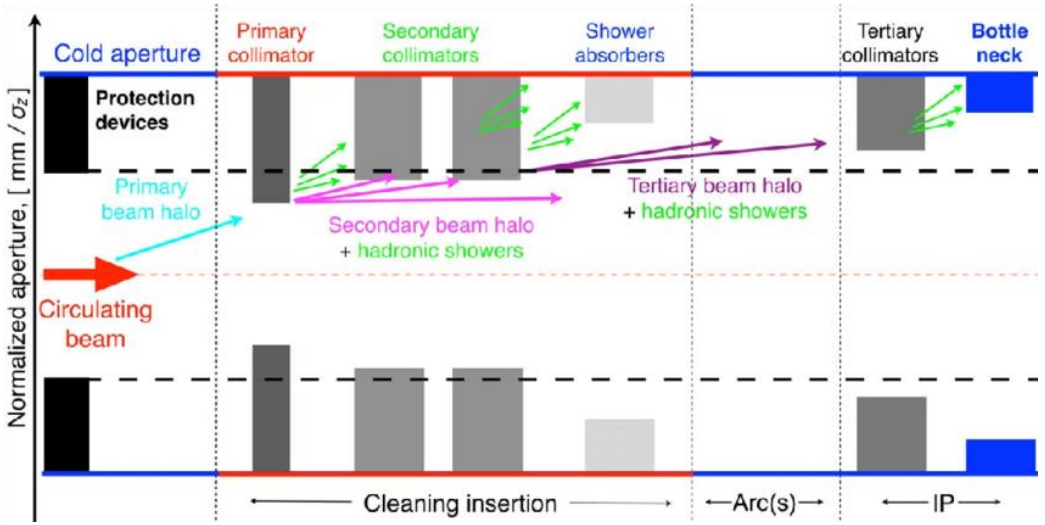


BLM thresholds strategy for protons

2. IR7 collimators -> New IR7 collimator threshold model applied in 2022 -> LHC-BLM-ECR-0072

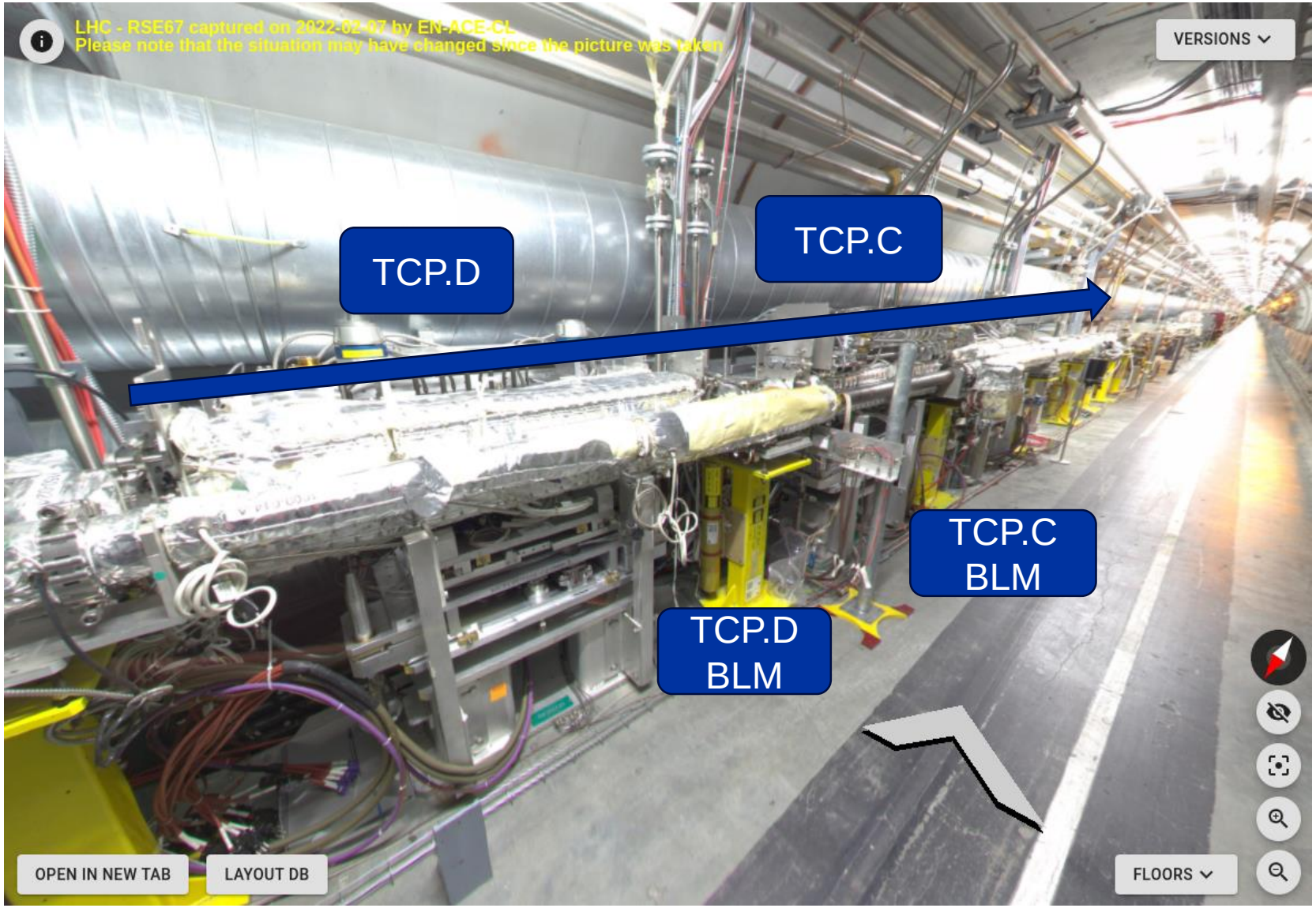
- BLM thresholds adjusted to the damage limits in collimators from losses in the entire IR7 collimation system
  - Damage limits from recent measurements and simulations at injection and top energy
  - Adjusted interpolation of proton loss rate for intermediate energies -> Same allowed power loss

Running Sum	Time Scale	Maximum Values	Max. Nb. Protons at 7 TeV	Max. Nb. Protons at 450 GeV
RS01 – RS06	40 μs – 0.01 s	125 kJ	1.1×10^{11} p	17.3×10^{11} p
RS07	0.08 s	500 kJ	4.5×10^{11} p	69.3×10^{11} p
RS08	0.6 s	500 kJ (833 kW)	4.5×10^{11} p	69.3×10^{11} p
RS09	1.3 s	500 kW	5.8×10^{11} p	90.2×10^{11} p
RS10	5.2 s	500 kW	23.2×10^{11} p	360.6×10^{11} p
RS11	20.9 s	5000 kJ	44.6×10^{11} p	693.6×10^{11} p
RS12	83 s	100 kW	74.0×10^{11} p	1151.3×10^{11} p

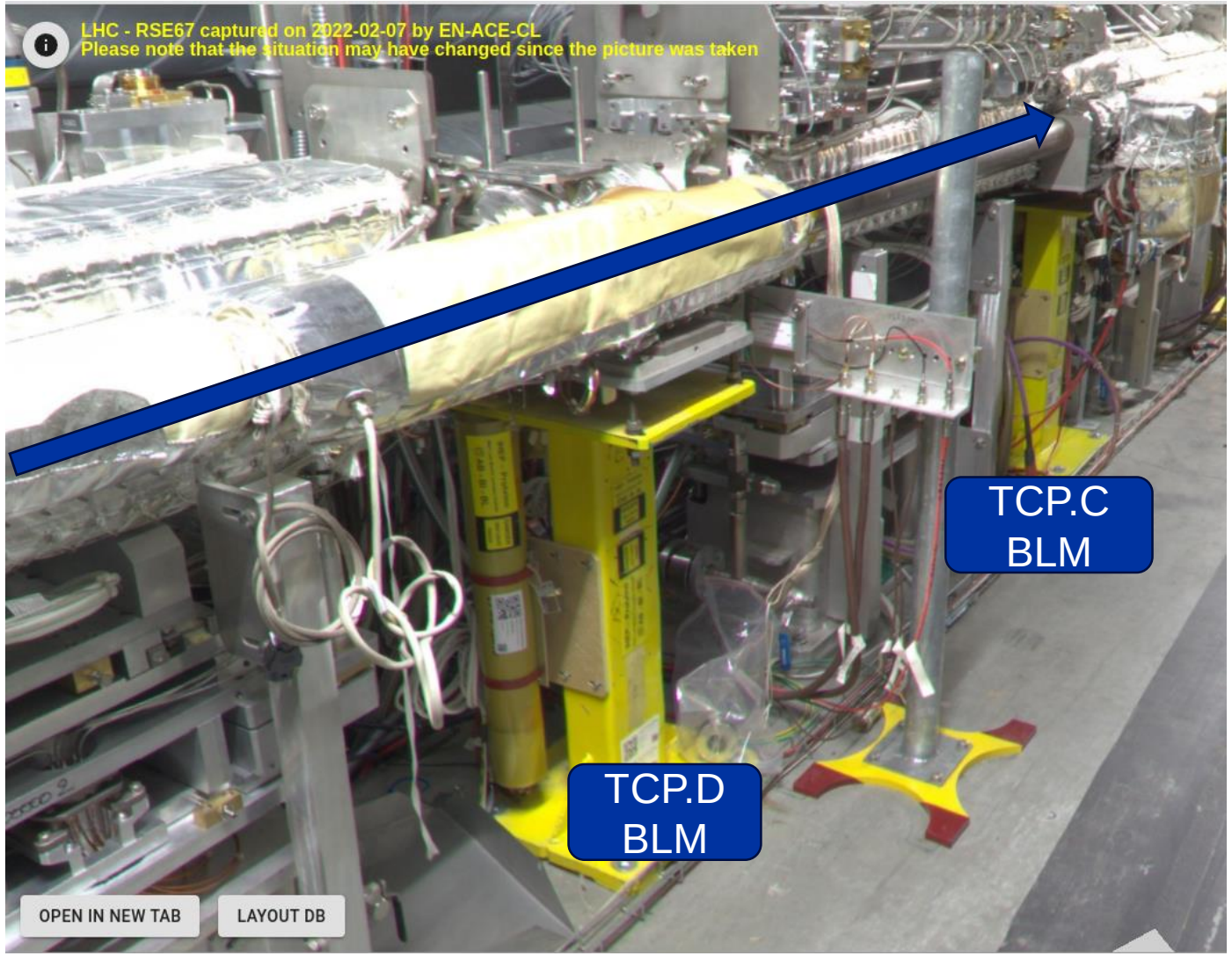


https://www.researchgate.net/figure/Key-elements-of-the-LHC-multistage-collimation-system-IP-interaction-point_fig12_306186620

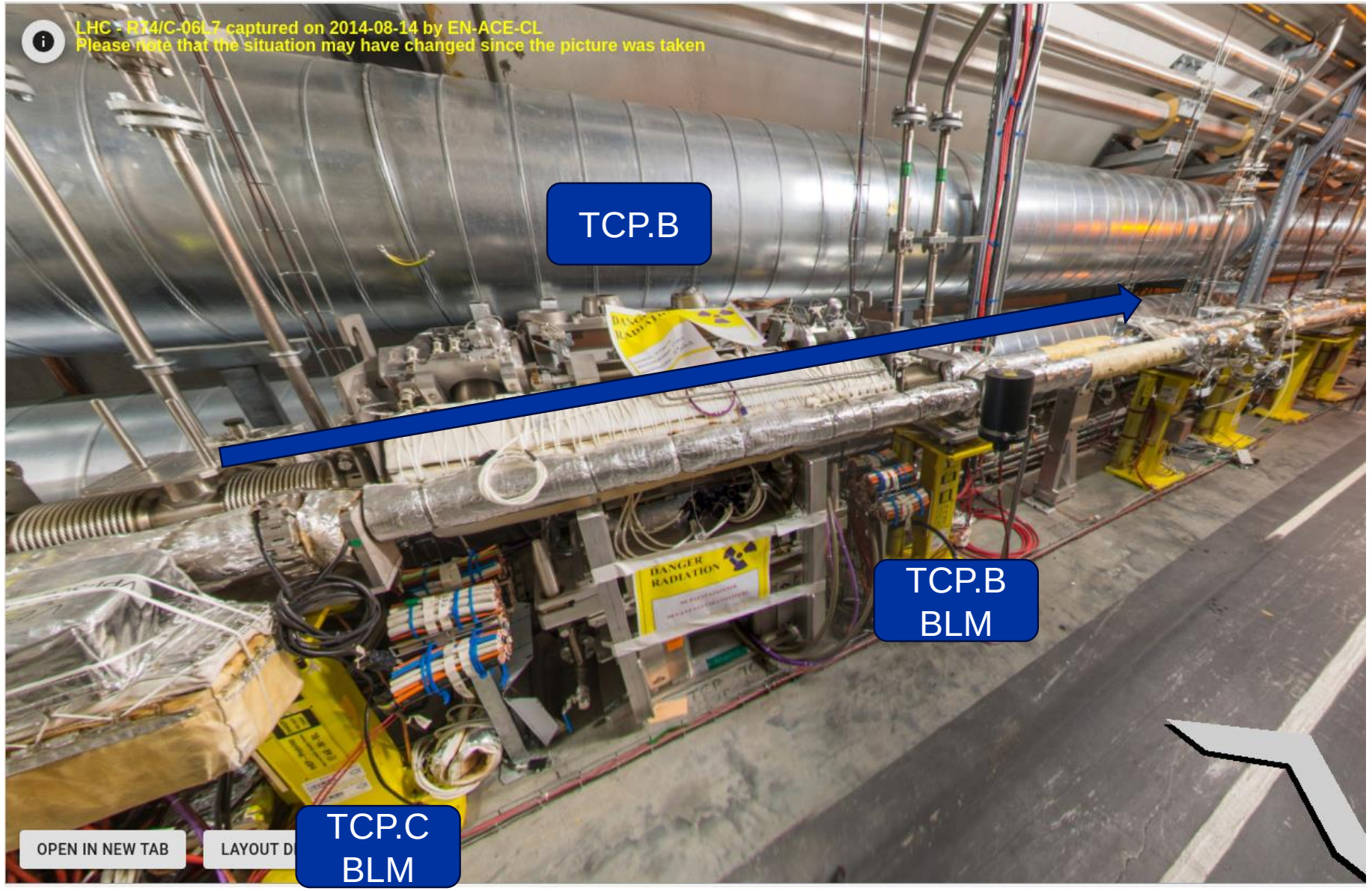
Protons: Beam losses and margin to dump during Injection



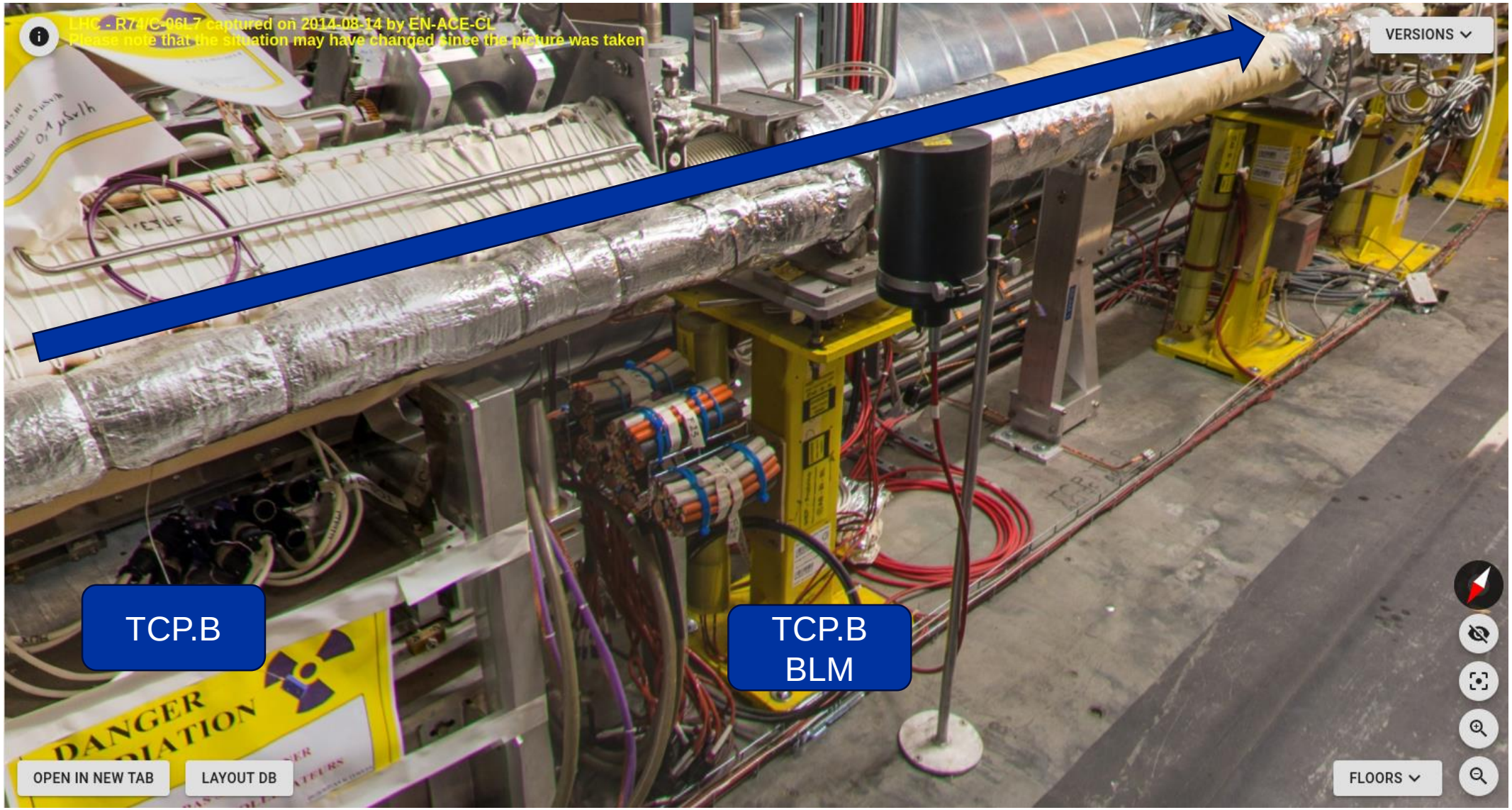
Protons: Beam losses and margin to dump during Injection



Protons: Beam losses and margin to dump during Injection



Protons: Beam losses and margin to dump during Injection



Protons: Beam losses and margin to dump during start of RAMP

Fills that dumped:
- 8735: Dumped 1490b due to losses at the beginning of the ramp (BLMQI.06L3.B2E10_MQTL, 5.2s RS) after remaining a long time at injection energy. Losses in R3, R7. Higher than usual losses in IR6 due to high AG population of 8.2e10 (B1) and 6.3e10 (B2). No relevant orbit changes.
- 8737: Dumped fill of 1800b due to losses at the beginning of the ramp due to debunched beam (BLMQI.06L3.B2E10_MQTL, 5.2s RS). Losses in R3, R7. Higher than usual losses in IR6 due to high AG population of 6.6e10 (B1) and 4.1e10 (B2). No relevant orbit changes. Similar event as on 08-MAY-2023 20h29.

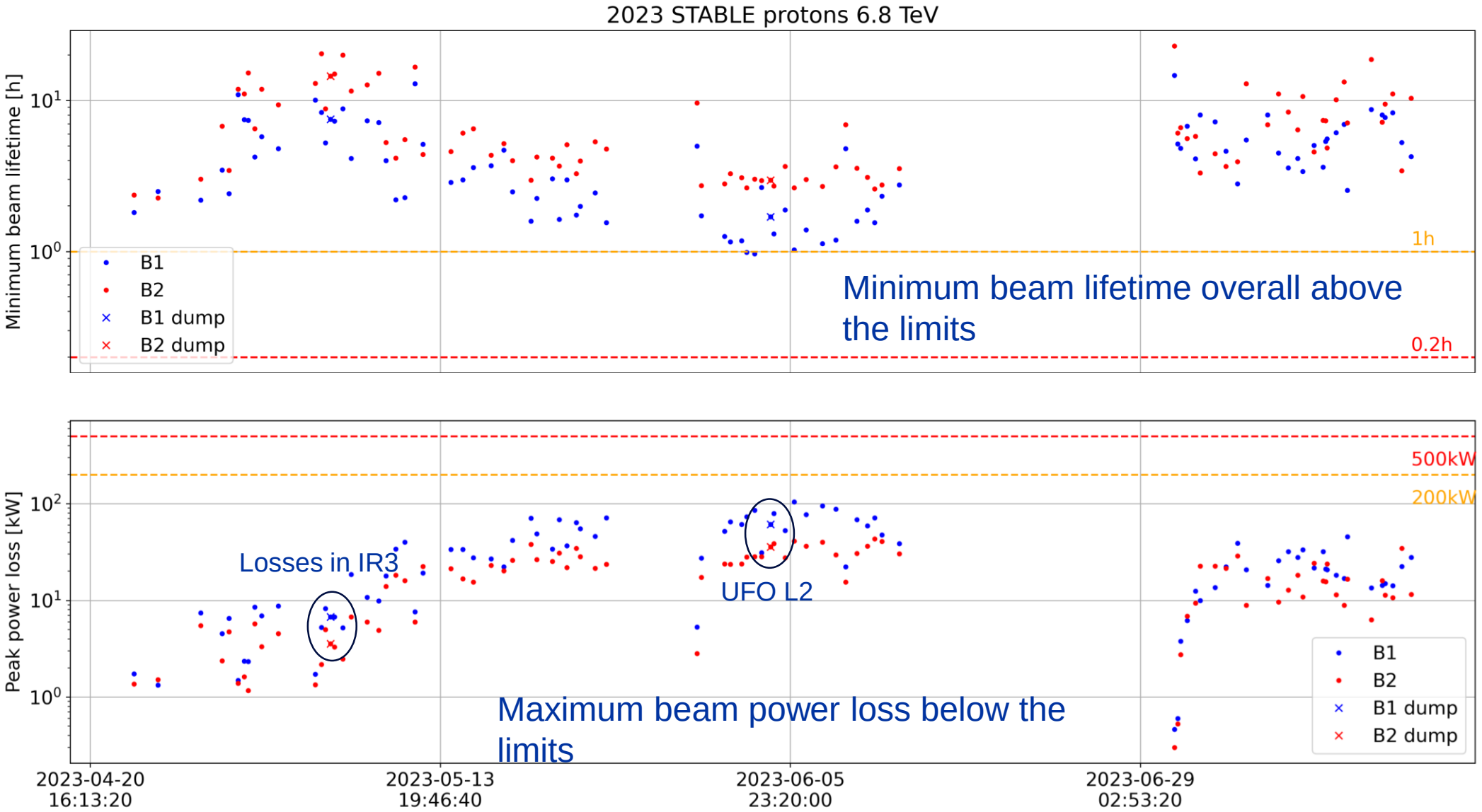
Protons: Beam losses and margin to dump during end of RAMP

8683 - Dumped during the ramp with 400b. UFO signature in 16/17L4. Losses in L4 as well as L5, IR6, L7 (Beam 1). Dumped on losses in RS04 at BLMAI.05R6.B1E10_DFBLB. Quench of MB A17L4. No visible orbit changes.
8828 - Dumped on losses during the ramp on BLMQI.03L1.B2E30_MQXA (5.2s RS). High vacuum activity in L1 before the dump. Asymmetric losses in IR7 (higher in R7). Usual AG losses in IR6. Orbit changes below <15 um (still in the ramp).
8829 - Dumped on losses in the ramp on BLMQI.03L1.B2E30_MQXA (5.2s RS). High vacuum activity in L1 before the dump. Asymmetric losses in IR7 (higher in R7). Usual AG losses in IR6. Orbit changes below <15 um (still in the ramp).

Protons: Beam losses and margin to dump during ADJUST

8643: Dump of 75b fill due to losses at TCL.6R5.B1 (RS01/02) caused by UFO when moving the TCL. High losses in R5 and asymmetric losses in IR7 (higher for L7). Otherwise clean dump. No relevant orbit changes.
8680: Issue in B1H with bad lifetimes leading to slow losses which dump in RS12. Clean dump
8681: Dump due to cleaning issue in B1H with slow losses in IR7 (RS12). Clean dump
8694: Dump of 900b physics fill due to losses at BLMTI.06R7.B1E10_TCLA.D6R7.B1 in RS12 when going into collisions (B1 lifetime issue). No relevant orbit change. Usual AG losses in IR6.
8749: Dump of 2400b physics fill due to beam losses in IR7 (lifetime dip) when going into collisions (BLMQI,05L7.B1E10.MQWA.D5L7, 655ms RS). Losses in L7, usual AG losses in IR6. Orbit changes < 10um RMS.
9040: Dumped on losses in IR7 when going into collisions (TCSG.A6R7.B2 - RS08). Losses in R7. Usual AG losses in IR6. No relevant orbit change.

Protons: Beam losses and margin to dump during STABLE



Protons: Beam losses and margin to dump during STABLE

Reasons to dump:
8728: Dump of ~1200b fill at beta*=39cm due to BLMs in IR3. No relevant orbit change. Clean dump with usual AG losses in IR6.
8872: Dumped on UFO-like losses in IR2, first detected by ALICE BCM. Losses in ~400us visible in IR2 before the dump. Highest losses on BLMEI.01L2.B1B10_BKGD_BCM. Usual AG losses in IR6. No relevant orbit changes.

BLM thresholds strategy for Pb ions

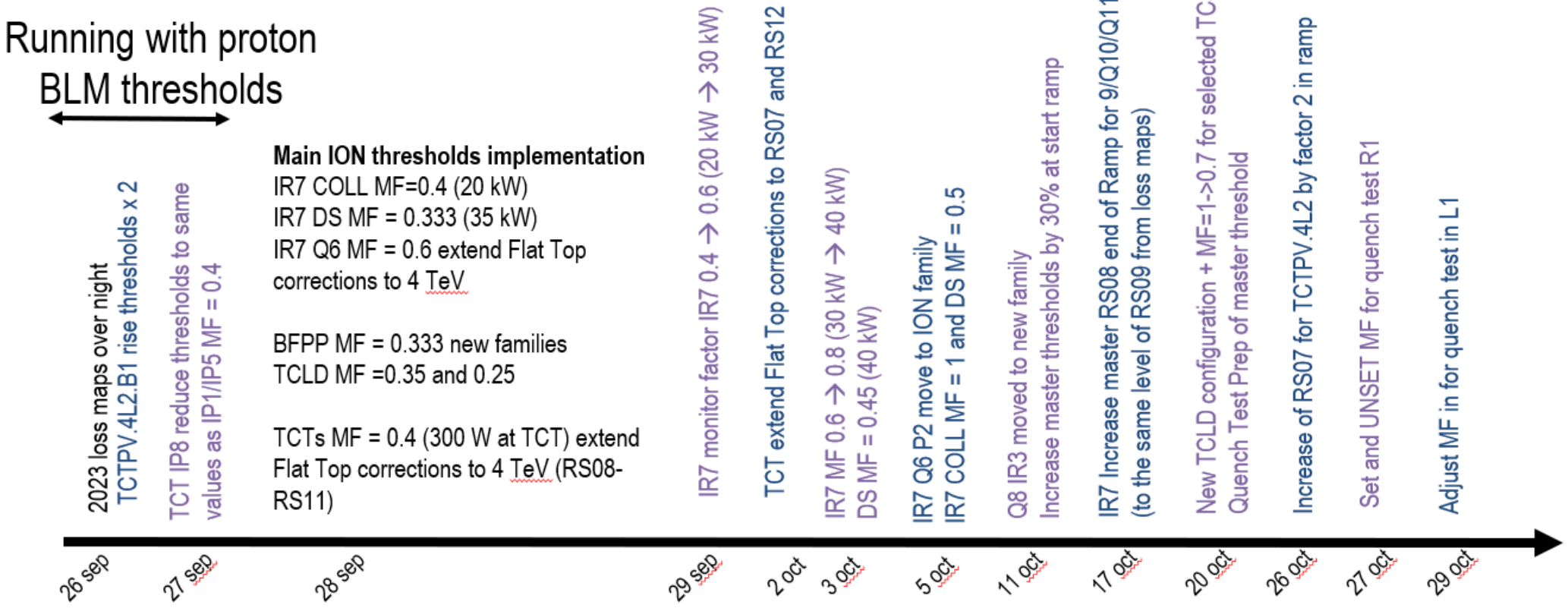
Changes applied on top of the existing proton BLM master thresholds in cases where there could be operational limitations -> All changes described in LHC-BLM-ECR-0079

Family	BLM	Factor 6.8 TeV	Factor 450 GeV	kW master channelling	kW master amorphous	kW master standard
Crystal in Channeling 4.75 sigma						
THRI_COLL_7_TCLA_LO_ION ** need but is at noise levels (only top energy)	BLMTI.06L7.B2I10_TCLA.D6L7.B2	2.5	0.133	+100 (17)	14 (+100)	+100
	BLMTI.06R7.B1E10_TCLA.D6R7.B1			+100 (+100)	14 (27)	+100
THRI_COLL_7_TCSPM_LO_ION_H_CH	**BLMTI.04L7.B1E10_TCSPM.B4L7.B1**	2.4	1.55	51 (21)	+100	+100
	BLMTI.04R7.B2I10_TCSPM.B4R7.B2			50 (45)	+100	+100
THRI_COLL_7_TCSPM_LO_ION_V_CH	**BLMTI.04L7.B1E10_TCSG.D4L7.B1**	0.45	1.55	50 (100)	+100	+100
	BLMTI.04R7.B2I10_TCSG.D4R7.B2			52 (51)	+100	+100
THRI_COLL_7_TCSG_LO_ION_H_CH	BLMTI.04L7.B1E10_TCSG.B4L7.B1	1.6	1.6	200 (26)	+100	+100
	BLMTI.04L7.B1E10_TCSG.A4L7.B1			50 (58)	+100	+100
	BLMTI.04R7.B1E10_TCSG.A4R7.B1			58 (184)	+100	+100
	BLMTI.04R7.B2I10_TCSG.A4R7.B2			50 (109)	+100	+100
THRI_COLL_7_TCSG_ME_ION_V_CH	**BLMTI.05L7.B1E10_TCSG.A5L7.B1**	0.5	0.023	57 (53)	+100	100
	BLMTI.05R7.B2I10_TCSG.A5R7.B2			50 (139)	+100	80
Crystal in Amorphous 4.75 sigma						
THRI_COLL_7_TCSG_ME_ION_V_AM	BLMTI.06L7.B2I10_TCSG.6L7.B2	0.005	0.12		31	
	BLMTI.06R7.B1E10_TCSG.6R7.B1				13	
THRI_COLL_7_**TCSPM**_LO_ION_H_AM	BLMTI.05L7.B2I10_**TCSG**.E5L7.B2	0.025	0.02	47 (54)	20	+100
	BLMTI.05R7.B1E10_**TCSG**.E5R7.B1			58 (337)	27	90
For the standard case we don't need to revert to proton families, just to move the monitors to these ones						
THRI_COLL_7_TCSG_ME_ION_H_STD	BLMTI.06L7.B2I10_TCSG.6L7.B2	0.05	0.05	-	-	24
	BLMTI.06R7.B1E10_TCSG.6R7.B1			-	-	31
THRI_COLL_7_TCSG_ME_ION_V_STD	BLMTI.05L7.B1E10_TCSG.A5L7.B1	0.13	0.13	-	-	26
	BLMTI.05R7.B2I10_TCSG.A5R7.B2			-	-	24

BLM thresholds strategy for Pb ions

5. Changes during the Run

- Fast losses at end of RAMP -> TCTs FT corrections extended, increased IR7 MF
- 10Hz events also observed at top energy, crystals going out of channeling
- Q8 IR3 thresholds increased by 30% at start of RAMP



Ions: Beam losses and margin to dump during start of RAMP

- Fill 9241: Dumped on losses just at the start of the ramp with 1240b in IR3 (BLMQI.08R3.B1I30_MQ, RS09). Likely unbunched beam. H orbit changes <30um RMS for B1/B2 (start of the ramp). High losses in IR3 and IR6.

Fills	Date	BLM	BLM threshold (Gy/s)	BLM threshold end (Gy/s)	RS	Losses IR3	Energy (TeV)
9241	27-09-23 17:38:16	BLMQI.08 R3.B1I30_ MQ	0.0039 0.006	0.005 0.0081	RS09 RS08	12kW 1.75e11 charges	450GeV

Ions: Beam losses and margin to dump during end of RAMP

- 9195: Fill with 395b dumped in the ramp due to losses above threshold for BLMQI.06R7.B1E10_MQTL (RS10/11). No relevant orbit changes. Moderate AG losses in IR6.
- 9196: Fill with 339b dumped on losses at BLMTI.04L1.B1I10_TCTPH.4L1.B1 (RS08). H Orbit changes <25um (still in the ramp). Relatively low AG losses in IR6.
- 9199: Fill with 283b dumped on losses at BLMTI.04L1.B1I10_TCTPH.4L1.B1 (RS09). H Orbit changes <20um (still in the ramp). Moderate AG losses in IR6.
- 9219: Dump of 675b fill in the ramp due to losses at BLMQI.06R7.B1E20_MQTL (RS08). Orbit change of ~20 um rms in B1H and B2H before dump. Strange excursions of ~200 um visible in BPM data in L6 for B2 H and V appearing 2 turns before the dump. Moderate AG losses in IR6.
- 9265: Dump on "10Hz losses" towards the end of the ramp. Losses triggered by BLM in 11L7.B2. Oscillatory pattern visible and also seen in IR3 and IR7. Pattern loosely visible on the BBQ data.
- 9266: 10Hz like losses during the ramp. Triggered on BLM in 11L7.B2. Pattern visible in IR3 and IR7 for B2. Otherwise, clean dump.

Ions: Beam losses and margin to dump during end of RAMP

- 9272: Dump on losses during the ramp (1240b) with 10Hz-like loss pattern (BLMQI.06R7.B1E10_MQTL, RS06). H orbit oscillations <10um RMS visible. Losses in IR7 and IR3. Relatively low AG losses in IR6.
- 9295: Dump of 1080b physics fill on beam losses (BLMTI.04L2.B1E10_TCTPV.4L2.B1, RS07) at the end of the ramp. Higher than usual losses in L7 and at TCTPV.L2.B1. Usual AG losses in IR6. Oscillating loss pattern before the dump (~20 Hz). Some orbit oscillation visible in H RMS orbit but with very low amplitude (5um RMS).

Ions: Beam losses and margin to dump during ADJUST

- 9280: Physics fill with 960b dumped on losses in ADJUST. TCLD.A11R2.B1 triggered in RS06. 10Hz loss pattern visible already 1s before the dump in IR7 and in R2. No obvious losses in IR3. Slightly higher than usual AG losses in IR6. H orbit oscillations <10um RMS for B1H and B2H.
- 9299: Physics fill with 960b dumped in Adjust due to losses in IR7. 10Hz loss pattern visible before the dump. Losses in IR7, IR3, and at TCTPV.4L2. H orbit increase up to 20 um (B1) and 10 um (B2) RMS before the dump.
- 9304: Physics fill with 960b dumped in Adjust due to losses in IR7. 10Hz loss pattern visible before the dump. Losses in IR7, IR3, and at TCTPH.4L1. H orbit oscillations of ~50um amplitude in B1 and ~20 um in B2 building up before the dump.

Ions: Beam losses and margin to dump during STABLE

- 9234: Physics fill with 1240b dumped on losses at BLMTI.11R2.B1I10_TCLD.A11R2.B1 (RS06). Losses at TCLD.R2 start to increase ~10ms before the dump. Smaller loss peak visible ~100ms before the dump. Losses also visible in IR7. Relatively high AG losses. Some H orbit movements visible but with amplitudes <20um.
- 9251: "10Hz dump" of 1240b ion fill. 10 Hz signature clearly visible in BLM signals. Dump on losses on TCLD.A11R2.B1. Clean dump.
- 9267: 10Hz event in stable beams. Dump triggered by losses on BLM TCLD.A11R2.B1. Pattern visible in IR3 and IR7 for B2. Orbit oscillations are visible. Otherwise, clean dump.
- 9284: Physics fill with 960b dumped due to losses in IR7 (Q6R7, RS06). 10Hz loss pattern visible before the dump. Losses in IR7 and IR3. Slightly higher AG losses. H orbit oscillations with ~40um amplitude RMS for B1H and ~15um for B2H. Same orbit oscillations in V but with much smaller amplitude (<5um).
- 9296: Physics fill with 1080b dumped due to losses in IR7 (Q6R7, RS06). 10Hz loss pattern visible before the dump. H orbit oscillations with ~35um amplitude RMS for B1H and ~10um for B2H. Losses in IR7 and IR3. Relatively low AG losses.