Proposal for 2023 Intensity Ramp-Up

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Outline

- **Intensity ramp-up in 2022**

- **Proposal for 2023 intensity ramp-up**

- **Update for ramp-up scenarios after stops of nominal operation**

- **Conclusions**

Introduction and intensity ramp-up 2022

- **Intensity ramp-up based on step-wise increase of injected and stored beam energy after YETS/LS to:**

  - establish operational cycle

  - identify and mitigate issues in machine-protection-relevant systems that are remaining after individual system tests and hardware commissioning

  - identify issues related to stored beam intensity and other beam related parameters and establish mitigation measures

- **Ramp-up 2022:**

  - Steps of 3/12 - 75 - 300 - 600 - 900 - 1200 - 1800 - 2400 bunches performed, whereas 2700b step was dropped

  - Bunch intensity kept at ~1.15×10^{11} ppb during intensity ramp-up. Then, gradually pushed to ~1.4×10^{11} ppb

  - For each step, monitored behavior during at least 3 fills and 20h stable beams, and validated correct functioning of machine-protection systems via checklist

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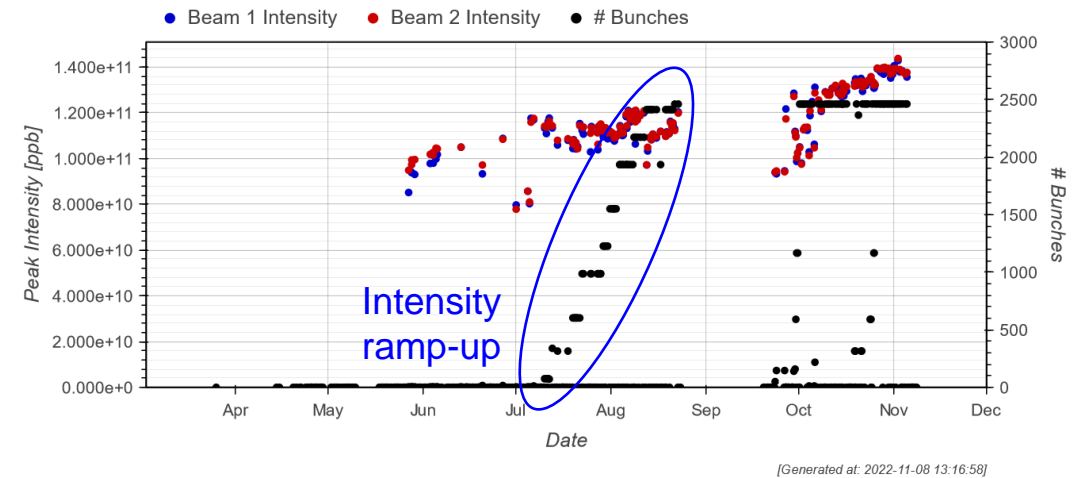
For more details see LMC, 9.11.2022, 217th MPP and 10th "Evian" workshop

Observations during 2022 intensity ramp-up

- **No beam-induced damage occurred** during intensity ramp-up and the following high-intensity operation

- Important number of issues that (would have) degraded the protection functionality were found and followed up

- **Issues distributed over all intensity steps**

Step / period	# of issues	Issues observed (examples)	Checklist (EDMS)
Scrubbing beyond 500 bunches	9	- Intermittent issues with BQM and FBCT that prevented IQC from confirming that an injection took place - Issue with AG cleaning due to problem in SIS-ADT link - Unexpected high beam losses at TCLIA	#2748476
From 3/12b to 75b	5	- Issue with creation of PM event causing XPOC to latch - BLMLHC FESA server exiting due to low memory	#2756305
From 75b to 300b	8	- Redundancy lost between one BLM card in the tunnel to the surface at point 1 - BLMLHC FESA server exiting due to low memory	#2756853
From 300b to 600b	7	- LVDT reading of TCTPV.4R1.B2 drifting and reaching the dump limit - Update of BETS TCDQ thresholds - Change of BLM thresholds (IR7)	#2761348
From 600b to 900b	8	- Miscalibration of BSRA B2 by factor 4 - Change of BLM thresholds (IR5)	#2766212
From 900b to 1200b	9	- Large LVDT offsets observed at several collimators - Intermittently missing BBQ data in PM event - Change of BLM thresholds (IR7/IR5)	#2768054
From 1200b to 1800b	8	- Dumps on TCLIA temperature probe leading to threshold adaption - Sporadic missing of BLM data in XPOC and PM - Change of BLM thresholds (IR7)	#2768971
From 1800b to 2400b	8	- Sporadic missing of BLM data in XPOC and PM - Change of BLM thresholds (IR1/2/5)	#2771221

See also LMC, 9.11.2022

Ramp-up duration 2022: break-down
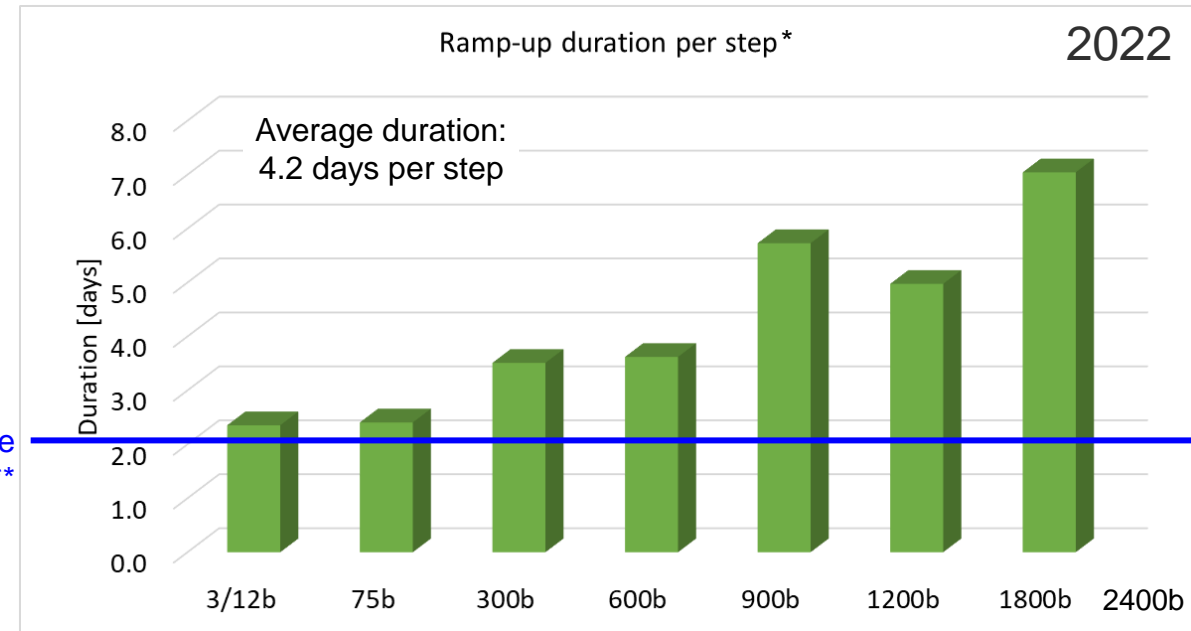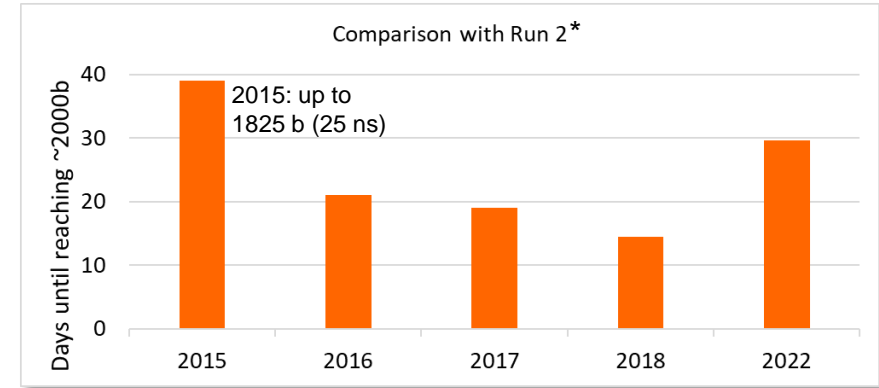
- **Duration**

  - Reached 1200 bunches in ~18 ramp-up days*

  - Reached 2400 bunches in <30 ramp-up days*

  - Efficient performance considering that machine came out of a Long Shutdown

  - First two ramp-up steps completed in 2.4 days each, i.e. close to the minimum achievable duration of 2.1 days**

  - Following steps marked by UFOs, diverse faults, commissioning left-overs, BBCW validation, …

- **Validation and approval**

  - Delay between end of last fill and sending out checklist typically 1-3 hours

  - Delay between end of last fill and approval typically 8-10 hours

  - → Great thanks to all the involved system experts for their commitment and anticipation!

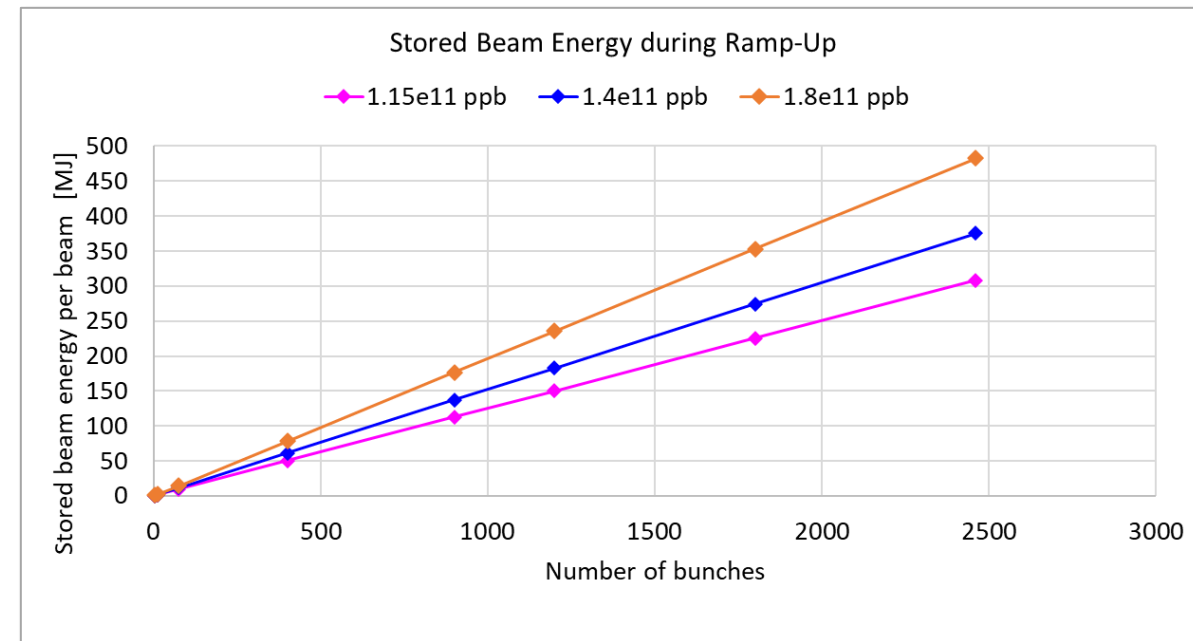*Excludes time for scrubbing, commissioning left-overs, BBCW validation fills

**Assuming 60% availability, 3h turn-around time, and 10h to fill and validate the checklist

Comparison with Run 2*

2015: up to 1825 b (25 ns)

Days until reaching ~2000b

Ramp-up duration per step*   2022

Average duration: 4.2 days per step

Minimum achievable time per step: 2.1d**

What is new in 2023?

- **Extended range of luminosity levelling**

  - To be fully performed during ramp-up fills using the operational tool

- **Mixed (BCMS/8b4e) filling scheme foreseen**

  - Maximum number of bunches limited to ~2400 bunches (i.e. no 2700-bunch step foreseen)

- **Bunch intensity**

  - Intensity of ~1.4×10^{11} ppb established in 2022
  - Plan to reach 1.8×10^{11} ppb during 2023, corresponding to almost 500 MJ of stored energy per beam

Stored Beam Energy during Ramp-Up

— 1.15e11 ppb — 1.4e11 ppb — 1.8e11 ppb

Stored beam energy per beam [MJ] vs Number of bunches

Proposal for 2023 intensity ramp-up (1/2)

- **Intensity steps:**
  - Use steps of 3/12 - 75 -   400   - 900 - 1200 - 1800 – 2400* bunches
  - Compared to 3/12 - 75 - 300 - 600 - 900 - 1200 - 1800 - 2400 bunches in 2022

- **For each step:**
  - Monitor behavior during >15h in stable beams with at least 2 fills that go through the full luminosity levelling process (reaching the smallest beta*) using the operational tool
  - Validate correct functioning of machine-protection systems via <u>checklists</u>
  - TOTEM/CT-PPS, AFP, ALFA roman pots to be inserted to agreed settings before the first levelling step for all fills at each intensity step
  - No simultaneous increase in the total number of bunches and the injected train length in the same fill

> Reduces *theoretically* minimum achievable ramp-up duration per step from 2.1d to 1.6d and total duration from ~15d to ~10d.**

exact number of bunches will depend on agreed filling schemes

**Assuming 60% availability, 3h turn-around time, and 10h to fill and validate the checklist

Proposal for 2023 intensity ramp-up (2/2)

- **Bunch intensity**
  - Start with bunch intensities established in 2022 (~1.4e11 ppb at LHC, 1.5e11 ppb from SPS)
  - Option to gradually increase the bunch intensity after having reached at least 1200 bunches depending on the machines' status

- **Scrubbing:**
  - Verify heating of critical elements before going to next intensity step. Intermediate scrubbing checklist after ~500 bunches, final checklist at the end of scrubbing

- **During the Run**
  - Issue Cruise Checklists covering ~8 weeks (e.g. between TS) to check behaviour of machine-protection systems

Ramp-up scenarios after stops of nominal operation

- For consistency, propose to replace the 600-bunch with a 400-bunch fill

Stop >48 h with massive HW + SW interventions	Stop >48 h without massive HW + SW interventions	Triplet events with non-reversible position changes**
One fill with either pilot bunches or max. 2-3 nominal bunches into SB (cycle revalidation, etc.)	One fill with 2-3 nominal bunches into SB (cycle revalidation, etc.)	One fill with 2-3 nominal bunches into SB (re-adjust orbit in IP)
One fill with ~50 bunches and about 1-2 hours of stable beams		
One fill with *400* bunches and min. 2 hours of stable beams*	One fill with *400* bunches and min. 2 hours of stable beams*	
If > 2000 bunches have been reached, one fill with about half max. number of bunches and about 5 hours of stable beams		
Back to pre-stop intensities	Back to pre-stop intensies	Back to pre-stop intensity
In total, 3-4 fills for ramp-up	**In total, 2 fills for ramp-up**	**In total, 1 fill for ramp-up**

Note: All fills need to go through the full luminosity levelling.

*known intensity step to disentangle wrong settings, de-conditioning, etc. from intensity dominated effects at full intensity

See LMC, 2018-03-28

**E.g. triplet quench, warm up of triplet region, cryo stop in triplet region, …

Conclusions

- **Intensity ramp-up 2022 accomplished in a safe and efficient manner**

    - Reached 1200b in 18 ramp-up days

    - No beam-induced damage occurred

- **Proposal for 2023 intensity ramp-up**

    - Based on successful strategy used in 2022 and in Run 2

    - Intensity steps of 3/12 - 75 - 400 - 900 - 1200 - 1800 - 2400 bunches

    - For each step: >15h in SB with $\geq$2 fills that go through the full luminosity levelling, to be validated via checklist

    - Start ramp-up with bunch intensity of 1.4×10^{11} ppb

Thank you very much for your attention!

Issues encountered during 2022 intensity ramp-up

- Examples:
  - Unexpected high beam losses at TDIS*
  - Unexpected high beam losses at TCLIA**
  - Issue with creation of PM event causing XPOC to latch
  - Sporadic missing of BLM data in XPOC and PM
  - Intermittently missing BBQ data in PM event
  - BLMLHC FESA server exiting due to low memory
  - Need to adapt BLM thresholds
  - Miscalibration of BSRA B2 by factor 4

- Intermittent issues with BQM and FBCT that prevented IQC from confirming that an injection took place
- One MKI2 main switch showing higher erratic rate
- Dumps on TCLIA temperature probe leading to threshold adaption
- LVDT reading of TCTPV.4R1.B2 drifting and reaching the dump limit
- Difficulties in using the QFB due to working point with high Q' and octupoles

*See D. Wollmann, LMC,#450, 12.10.2022
** See C. Bracco, LBOC #142, 1.11.2022

See checklists for details

Note that the 2022 ramp-up could profit from issues found and solved during the beam test in Oct 2021, in particular the aperture restriction in 21L3.

Issues discovered during ramp-ups (Run 2) - Selection

- **Establish cycle/beam commissioning:**
  - PM/XPOC: data missing or misaligned
  - BIS timing mis-aligned
  - Direct dump BLMs (IR6) – connected to LBDS of wrong beam

- **MP dominated:**
  - Orbit feedback: offsets due to BPM calibrations
  - UFO – 16L2 events causing beam dumps & quenches
  - Abort Gap cleaning not properly functioning
  - Screen unintentionally left in dumpline

- **Intensity dominated:**
  - TDI – vacuum issues and heating
  - Insufficient cooling of a collimator
  - Instabilities

- **Random occurrence:**
  - MKD and MKB erratics
  - Un-physical BLM readings in PM
  - PM event builder stuck

For full list: see D. Wollmann, Evian'19 and checklists for intensity ramp-up