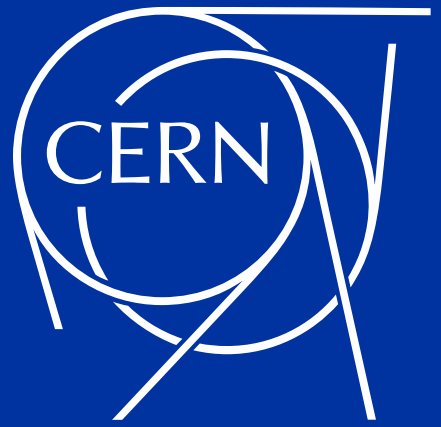

Proposal for Intensity Ramp-Up 2022

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217th MPP, November 19th, 2021

Outline

- **Motivation and general strategy**
- **Intensity ramp-ups in Run 2**
  - Re-cap of ramp-up 2018
  - Duration of ramp-ups
  - Issues discovered during ramp-ups
- **Proposal for intensity ramp-up 2022**
- **Reminder: ramp-up scenarios after stops of nominal operation**
- **Conclusions and outlook**

Intensity ramp-up: motivation and strategy

- **Step-wise increase of injected and stored beam energy after YETS and long shutdowns 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
- **Per intensity step: 3 fills, >20h stable beams**
- **Verify correct functioning of MP systems via checklists**
  - To be filled by system experts and checked by rMPP before advancing to the next intensity step
  - Systems covered: magnet powering, interlocks, RF, beam instrumentation, operation, orbit, feedbacks, injection, beam dumping system, heating of equipment

Re-cap of intensity ramp-up 2018

- **Intensity steps (~number of bunches):**

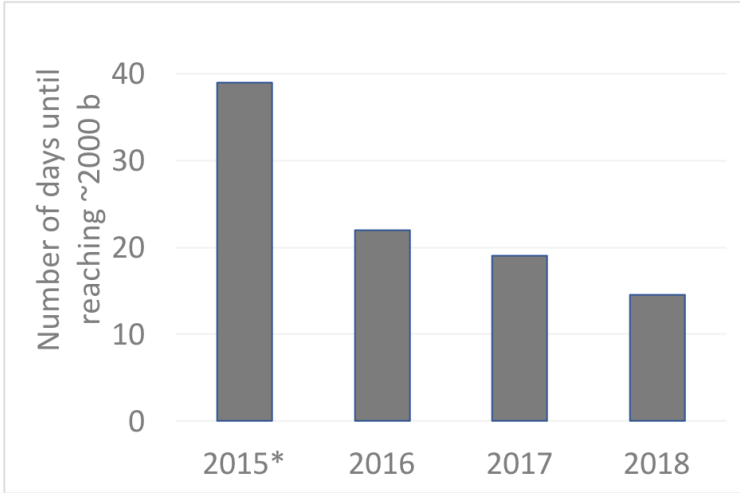
  3/12 - 75 - 300 - 600 - 900 - 1200 - 1800 - 2400 – 2550

Establish cycle
MP dominated
Intensity dominated

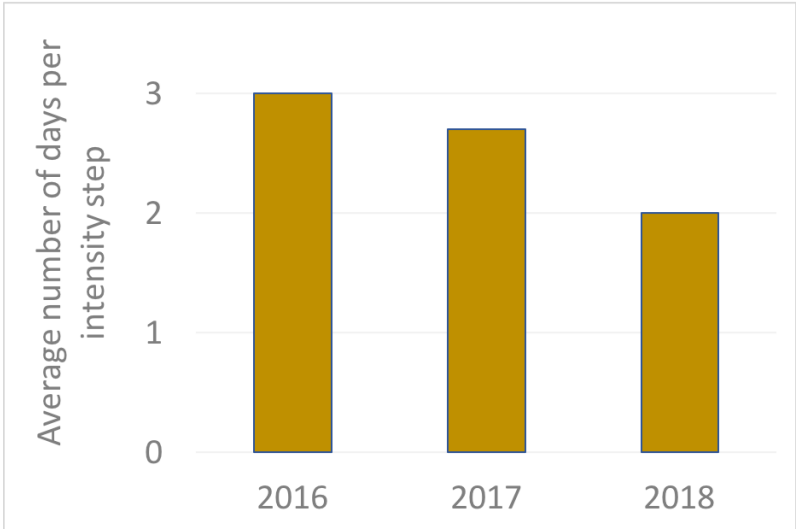
- **All high-energy beam dumps carefully checked and documented in 8 checklists on EDMS**

Durations of intensity ramp-ups in Run 2

- **2015: commissioning year**
  - Two ramp-ups (50 ns & 25 ns operation); intensity increase until end of proton run
- **2016/17/18: 7 steps to reach 2000+ bunches**
  - 2016 → 2018: reduction of ramp-up duration by 35%
  - The 14.5 days achieved in 2018 are close to the theoretical minimum
- **44 intensity-ramp-up and scrubbing checklists issued during Run 2**



*2015: up to 1825 b (25 ns)



See D. Wollmann, Evian'19

Issues discovered during intensity ramp-ups

- **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:**
  - QPS_OK flickering
  - MKD and MKB erratics
  - Un-physical BLM readings in PM

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

Proposal for intensity ramp-up 2022

- Continue successful strategy applied during Run 2
- Stepwise increase of stored energy and number of injected bunches:
  Use 3/12 - 75 - 300 - 600 - 900 - 1200 - 1800 - 2400 – 2700 bunches*

Establish cycle
MP dominated
Intensity dominated

- For each intensity step: monitor behavior during at least 3 fills and 20h stable beams, and validate via checklist
- Insertion of TOTEM/CT-PPS, AFP, ALFA roman pots to agreed settings after >2h in second fill and full third fill at each intensity step
- Keep bunch intensity to ~1.15e11 ppb during intensity ramp-up. Then, gently increase bunch intensity (e.g., in steps of 0.05e11) up to 1.4e11 ppb, depending on machine behaviour and available bunch intensity
- Use of beta* levelling already during the intensity ramp-up
- Scrubbing: Verify heating of critical elements before going to next intensity step. Intermediate scrubbing checklist after ~300 bunches (RF power, heating, …), final checklist at the end of scrubbing
- During the Run: issue Cruise Checklist every ~8 weeks (e.g., between TS) to check behaviour of MP systems

**exact number of bunches will depend on agreed filling schemes and beams*

Ramp-up scenarios after stops of nominal operation

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 600 bunches and min. 2 hours of stable beams*	One fill with 600 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 intensities	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**

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

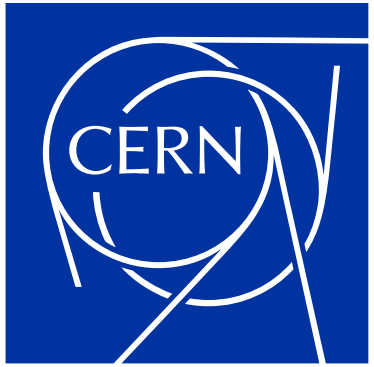
**E.g. triplet quench, warm up of triplet region, cryo stop in triplet region, …
Note: Fixed displays are available for WPS, pressure and thermal shield T covering ~1 week history, which should be used as indicators.

As approved in the LMC, 2018-03-28. No modifications proposed.

Conclusions and outlook

- **Intensity ramp-ups have been essential to identify and mitigate issues before physics production**
  - Ramp-up duration reduced by 35% from 2016 to 2018, indicating reduced number of issues
  - Checklists during intensity ramp-up and scrubbing have proven to be an important and useful tool to analyze and document the correct functionality and performance of the machine protection systems
- **Proposal for 2022 intensity ramp-up**
  - Based on successful strategy applied in Run 2
  - For each of the 8 intensity steps: 3 fills, >20h in stable beams, to be concluded by checklist
  - Keep bunch intensity at ~1.15e11 during ramp-up. Then, gradual increase of bunch intensity (e.g. steps of ~0.05e11) to 1.4e11
- **Checklist tasks to be reviewed for Run 3 (before FEB 2022)**
  - System experts will be contacted for their input
  - New web tool under preparation to replace the currently used shared spreadsheets

Thank you very much for your attention!



home.cern

Issues discovered during intensity ramp-ups

- Post Mortem / XPOC - missing data, data mis-aligned, missing files & synchronization, issues PM event builder stuck
- BIS timing mis-alignment
- Unbalanced rupture of the QPS internal quench loop
- Setup Beam Flag – glitches
- Beam Loss Monitors – communication issues BLM-SIS, un-physical readings in post-mortem data
- Direct BLMs (IP6) – connected to LBDS of wrong beam
- Collimators & Roman Pots – LVDT position drifts, LVDT/resolver faults
- Orbit Feedback – orbit jumps at optics changes, zeroing of reference, offsets due to BPM calibrations
- Dump Line – screen remaining in dump line, BTVDD images missing
- MKD and MKB erratics
- MKI – flashovers, MKI kicking last bunch of circulating beam
- Abort Gap Cleaning – in-sufficient cleaning, not functioning due to software issues / wrong parameters
- Radio Frequency – wrong low-level settings
- QPS_OK flickering
- Beam current change monitor – false dumps
- BIS – too much attenuation of signal in fibre (3 dumps)
- Earth fault in circuits (RB, RCS)
- QPS – single event upsets → dumps & communication issues
- UFO – 16L2 events causing beam dumps & quenches
- Collimators – un-physical temperature readings
- Injection – high losses and satellites leading to beam dumps
- TDI – vacuum issues and heating (2016)
- Insufficient cooling of a collimator
- Decrease of bunch length < 1ns in cycle
- Instabilities

Establish cycle/beam commissioning
MP dominated
Intensity dominated
Random

See checklists and D. Wollmann, Evian'19