



Machine protection aspects of Crab Cavity commissioning

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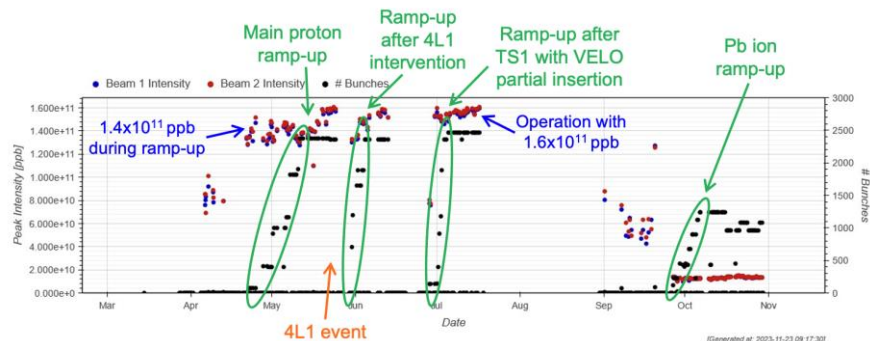
Special joint HiLumi LHC Work Package 2/4/7 meeting, 18.06.2024

• Outline

- Re-cap of intensity ramp-up after an LS
- Re-cap of checklist for the commissioning of machine protection systems
- MP commissioning procedure
- Specific MP tests to be performed

Re-cap intensity ramp-up after LS

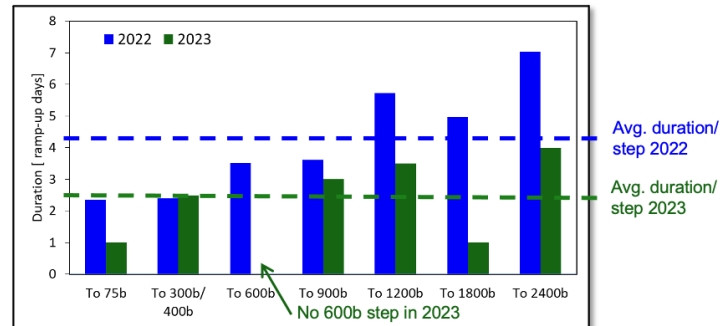
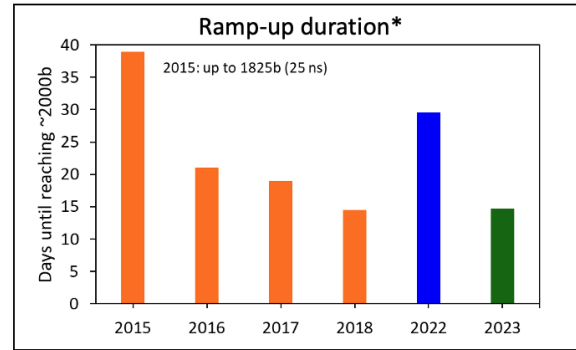
- Intensity steps 2024:
 - Use steps of 3/12 - 75 - 400 - 800 - 1200 - 1800 - 2400 - full machine
- At each step:
 - Monitor behaviour during >15h in stable beams with at least 2 fills that go through the full luminosity levelling process (reaching the smallest beta*) using the operational tool
 - Validate correct functioning of machine-protection systems via [checklist](#)
 - Before going from 12 to 75 bunches: verbal verification with all concerned teams and combined checklist for 3/12/75b fills after the 75b step
 - No simultaneous increase in the total number of bunches and the injected train length in the same fill.



Ramp-up duration 2023

- **Ramp-up time**
 - Reached 1200b in 10 ramp-up days*
 - Compared to 18 ramp-up days* in 2022
 - Reached full machine in ~15 ramp-up days*
 - Compared to ~30 ramp-up days* in 2022
 - Average duration per step decreased from 4.2d (2022) to 2.5d (2023)
- **Required time in SB for each intensity step**
 - In 2023, performed ≥ 2 fills with $>15h$ in SB
 - Compared to ≥ 3 fills with $>20h$ in SB for previous ramp-ups
 - De-facto duration of steps largely influenced by machine status and encountered issues

*Excludes time for scrubbing, commissioning left-overs, crossing-angle change (2023), long faults



March 27, 2024

C. Wiesner | Updates from MPP and intensity ramp-up proposal

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Courtesy [C. Wiesner, LMC #482 \(27.03.2024\)](#)

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Reminder: 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 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 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

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

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

LMC #460, 2023-04-05



March 08, 2024

C. Wiesner | Intensity ramp-up 2024

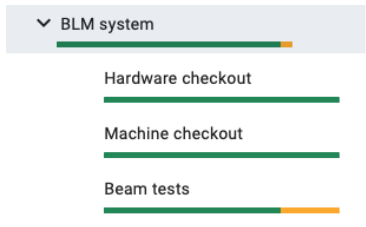
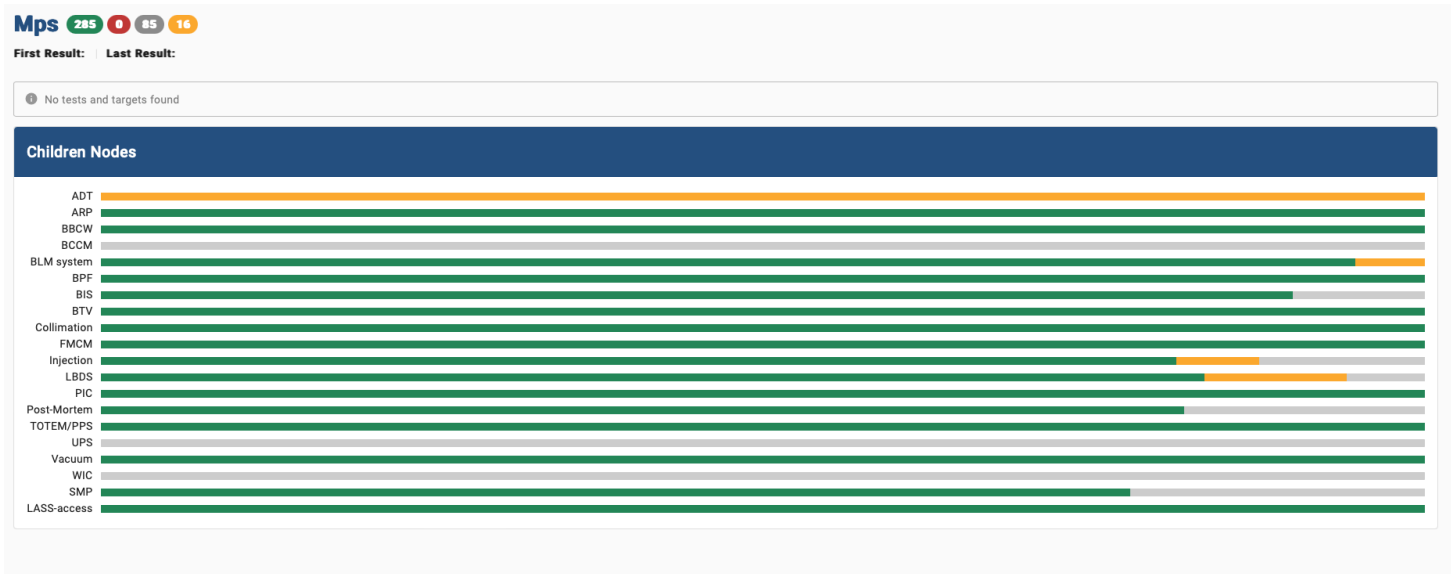
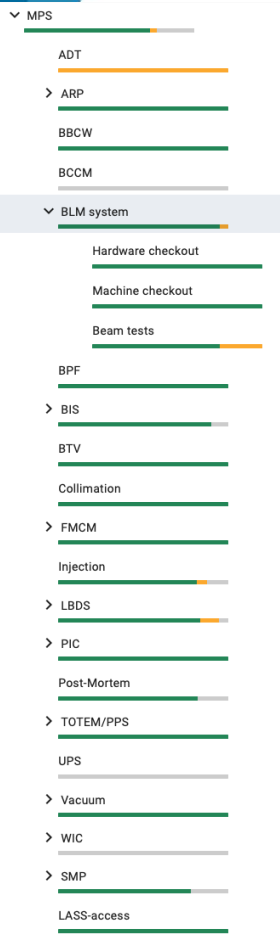
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Courtesy [C. Wiesner, 244th MPP \(08.03.2024\)](#)

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Re-cap: MP checklist for commissioning



- [Machine protection checklist](#) is based on MP commissioning procedures.
- Used for follow-up of progress during HWC and beam commissioning.



MP commissioning procedure

- Machine protection procedure for the commissioning of the crab cavities and their related interlocks:
 - Test to be performed without beam
 - Test to be performed with beam
 - Test to be performed after LS, YETS, TS or HW interventions
- Define which CC commissioning/validation steps can be done without beam, with pilots, INDIVs, trains? Which at injection energy and which at top energy? → potential impact on intensity ramp-up strategy.
- The procedure needs to be prepared by RF and approved by the MPP.
- The steps defined in the procedure will be added to the MP checklist.

Specific MP tests to be performed

- Validation and test of crab cavity interlocks (voltage and phase interlock) before first beam.
- MP test with low intensity beam (safe beam):
 - Switch off CC of one IP side (IP1/IP5) with interlock masked and with interlock unmasked at injection and top energy
 - Measure the delay from beginning of failure until the beam dump is triggered and beams are fully dumped.
 - Measure the impact on the circulating beam.
 - To be performed after each LS.
 - We could envisage to do this test once for each cavity separately.



Questions?

