LHC Status Report

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Outline

● Highlights from June to September
● Focus:
  ○ Quenches
  ○ UFOs
  ○ Heatload
  ○ Late August incident
● Conclusions & next steps
Highlights from June to September
Highlights: scrubbing

- Beam-induced electron bombardment ("scrubbing") lowers Secondary Emission Yield (SEY)
- ~ 8 days of dedicated scrubbing
  - Machine generally well conditioned
- As beam quality was preserved, further dedicated scrubbing was not needed
  - LHC continued scrubbing during physics fills
- S78 showed good conditioning but still quite high heatload
  - Limitation for cryo cooling capacity

e-cloud impacts significantly the beam quality, heatload and vacuum pressure

L.Mether LMC #444 - 2022 Scrubbing Run Outcome - https://indico.cern.ch/event/1180238/
Highlights: media event

- After ~ 11 weeks of commissioning
- First Stable Beams energy record 13.6 TeV on 5th July
  - Cryo managed to recover just in time from a rather heavy quench in the morning!!
- Very successful event as reported by media service

Many thanks to the media service and experiments for the organization and collaboration in the event!
Highlights: intensity ramp-up

- Intensity ramp-up proceeded smoothly
  - 75b 10/07 $\rightarrow$ ~ 2400b 12/08
  - Limited to 2400b due to heatload limitation in S78 (step 2700b missing)

- Machine protection checklist approved before each step
Highlights: physics production

- Physics production well on track…
  - … before August incident
  - B* levelling on IP1 and IP5
  - Separation levelling on IP2 and IP8

- LHC is flexible about levelling strategies
Focus
Quenches

- Since June we experienced **14 quenches**
  - 13 training quenches + 1 UFO induced quench
- Machine is well trained at 6.8 TeV
  - Training at nominal current + operational margin (100A)
- Profited from the current beam stop to “train” the machine a bit more
  - 5 quenches
  - Likely saved a significant downtime during operation!!
- No indication quenches will be a limiting factor
  - Some quenches are to be expected

A quench involves a quite significant mechanical stress for the affected magnets. The most time consuming activity is the recovery of the nominal cryo conditions. Depending on the number of quenching magnets, a quench event results in 8+ hours recovery.

![RB training quenches graph](image)
Unidentified Falling Objects are particles (mostly dust) that “fall” into the beam causing secondary particle emissions leading to inevitable losses in the machine.
UFOs

- 23 beam dump events so far (1 quench)
  - Predominantly in regions where magnets were exchanged in LS2
- UFOs conditioning is going really well
  - BLM thresholds optimized in the ring
  - Trade-off between quenches and premature dumps
- **Not expected to be a limiting factor**
Heatload

- Heatload in the machine generally conditioned very well during scrubbing

- Heatload of S78 is the current limitation for increasing intensity in the machine
  - Max cryo cooling capacity reached with 2400b and ~1.2e11 ppb
  - Heatload is expected to decrease with time as the machine conditioning improves

- Mitigation scenarios are:
  - 8b4e filling scheme, heatload free but at the cost of lower total intensity
  - Hybrid 8b4e and 25ns filling scheme, compromise between heatload and intensity

- No decision has been officially taken yet

L.Mether LMC #444 - 2022 Scrubbing Run Outcome - https://indico.cern.ch/event/1180238/
23rd August incident

- ~ 18:00 lost communication SF4 cooling water flow PLC
  - Cryo compressor stopped in P4
  - RF cryo went in safe mode → controlled He release
- ~ 22:00 cryo system back online, start of recovery
- Fast response time of all involved teams!

- RF cavities pressure release disks ruptured
  - Cold He release lowered the burst disk rupture threshold
  - Disks replaced during the night by RF and Fire Brigade
  - Warm up to 300K is needed due to contaminated atmosphere in the RF cryo module

- Expected downtime ~4 weeks
23rd August incident: mitigations

- SF4 cooling tower controls
  - PLC consolidations project underway EDMS 2256896
  - Incident cause under investigation with PLC manufacturer
  - Reliability being addressed but is only one mechanism to cause a loss of cryo cooling

- Immediate measures (RF burst disk task force)
  - Safety valves recalibrated to open at a slightly lower pressure
  - He release mechanism modified to ensure that burst disks are not cooled down significantly during He release
  - Should improve margin between safety valve opening and burst disk rupture → lab results showed no cooling of the burst disks

- Longer term solutions being studied by a dedicated task force with the aim of implementation during the YETS
Conclusions & next steps

- All systems commissioned
- Smooth intensity ramp-up
- Physics target for 2022 within reach!
- Very good performance increase
  - Peak lumi close to 2018!!
- Availability ~ 70% (commissioning year)
- Stable Beams time positive trend
  - ~ 34% overall → ~ 41% in August

- Next steps are under careful consideration
  - Present limitation is heatload of S78
  - Significant impact of RF cryomodule issue

- News will be presented in the next days, starting with LMC this afternoon
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Big thanks to all involved teams, injector complex and experiments for the demonstrated flexibility and performance delivery!
Backup
Cryo event on Friday 18th March 2022

- 11h10: Failure of the "PRM card" in the PLC driving the P4 cryo distribution box (QUI)
  - PRM card = Profibus communication card of the PLC
  - Failure of the Profibus network related to this PLC (all QUI valves driven in Profibus)
  - All the QUI valves related to sectors 34 & 45 closed (fail-safe position) ➔ loss of cryo distributions towards S34+45, including RF

- 11h25: RF cavities reached 1.5 bar ➔ degraded mode. Successful helium recovery to QRL/WRL, prevent ODH alarm level 3 (O₂<18%) & evacuations thanks to prompt cryo operator actions.

- 11h35: RF cavities reached 1.8 bar ➔ safety valves start to release helium

- 12h00: remote start/stop of QUI PLC by BE-ICS
  - Profibus network still in error

- 12h24: 24V local reset on the PRM card by TE-CRG by request of BE-ICS
  - Profibus network recovered, all QUI valves were accessible again via the cryo control system
  - Smooth restart to depressurize QRL lines and start the helium recovery by refrigerators

- 13h05: RF safety valves closed below 1.7 bar

- 13h45: replacement of the PRM card by BE-ICS
  - Replacement done by prevention and to perform a post-analysis in the lab

- 14h00: Rupture of the burst disk of RF cryomodule B1 in L4 whereas pressure was stable @ 1.6 bar / 40K
  - Isolation of the 2 RF cryomodules in L4 to avoid air pollution in the rest of the cryo system
  - Cryo lock out of RF cryomodules (TE-CRG) and replacement of the burst disk during the evening (SY-RF)

- 16h: setup of standby 20 K in the 2 x RF cryomodules in R4 at 1.3 bar.

- Sunday at 3h: Cryo conditions recovered in S34 & S45 (except RF)
Normalized heatload 2022