DRAFT

High intensity MDs and operational experience

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- Milestones and plans
- Beam induced heating
- Injection losses (beam quality → Lotta)
- Losses in ADJUST
- Beam quality in collision
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- Conclusion

Milestones and plans

- Physcis with with **$1.6 \cdot 10^{11}$ p/b** → Limited by beam induced heating in non-conforming RF modules. Limitation lifted for operation next year by exchanging modules during the YETS
- Full cycle with 1 high intensity train (**36b, $1.8 \cdot 10^{11}$ p/b**) in MD. Limited by dump window until Run 4.
  → Next milestone : Physics with $1.8 \cdot 10^{11}$ p/b
- Injection of trains of 2x48b (tot 348b) with **$2.3 \cdot 10^{11}$ p/b** in MD, but not fully ready for operation (→ Birk)
  - → Next milestone : Beam quality preservation with $2.3 \cdot 10^{11}$ p/b (losses at start of the ramp). Injection of longer trains (HL-LHC baseline : 4x72b per injection) in MDs ($2.3 \cdot 10^{11}$ p/b) and potentially in operation ($1.8 \cdot 10^{11}$ p/b)

Beam induced heating

Beam Induced Heating: Overview

equipment	Problem	2011	2012	2015	2016
Vacuum modules	Damage		VMTSA removed		Spring on VMSI gone
TDI	Damage			Beam screen reinforced, non-conformity with hBN material	vacuum behavior with 55mm gap?
MKI	Delay			Beam screen upgrade and non conformity solved	ok
Collimators	Few dumps			Non conformity solved. TCTVB removed.	Several temperature probes perturbed by the beam → ok
Beam screen	Regulation at the limit	Q6R5 and TOTEM	Q6R5 and TOTEM	Upgrade of the valves +TOTEM ferrites baked out.	ok
ATLAS-ALFA	Risk of damage			New design + cooling	ok
BSRT	Deformation suspected			New design	ok
BGI	vacuum increase				BGI heats up

- **Some topics to follow up, but no limitation so far**

See B. Salvant, "Beam induced rf heating status", LMC No. 279

Damage
Limits operation
Worry that can limit operation
Should be fine

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L.Carver @ Evian 2016

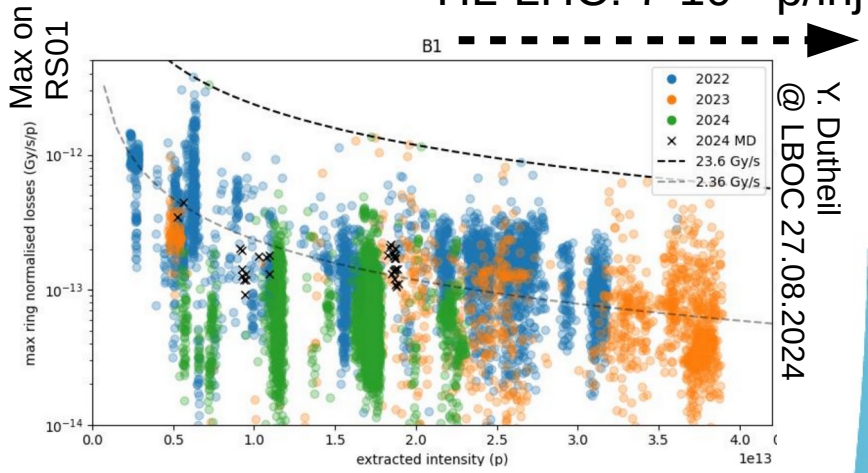
More examples by Benoit

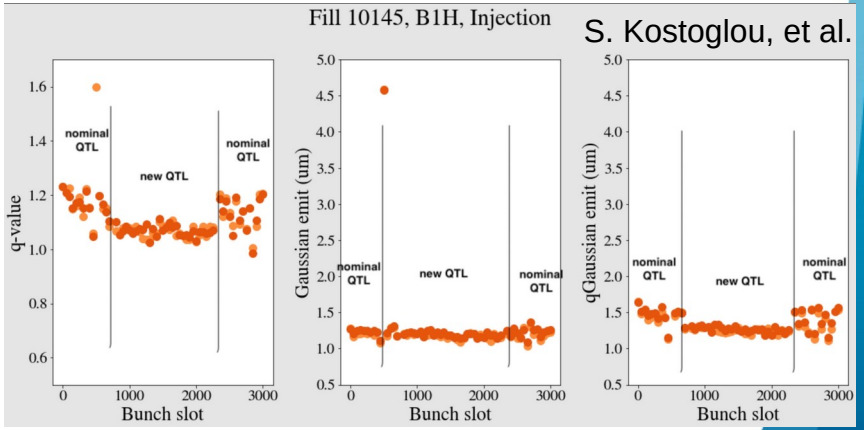
- No known limit to operate with $1.8 \cdot 10^{11}$ in 2025 thanks to the exchange of the warm modules.
- Critical to address unknown unknows asap

Injection losses

- Suffered from injection losses in 2022/23 (hybrid, 236b / inj)
  → Cause(s) not clearly identified (strong year-to-year and fill-to-fill fluctuations, beam-to-beam differences)
  → New Matching of the TL with updated transfer function for the quads could help the situation
- Current operation with short trains (108b / inj) offers large operational margin
  → Need tests in MD and in operation with longer trains at injection (hybrid scheme)

HL-LHC: $7 \cdot 10^{13}$ p/inj





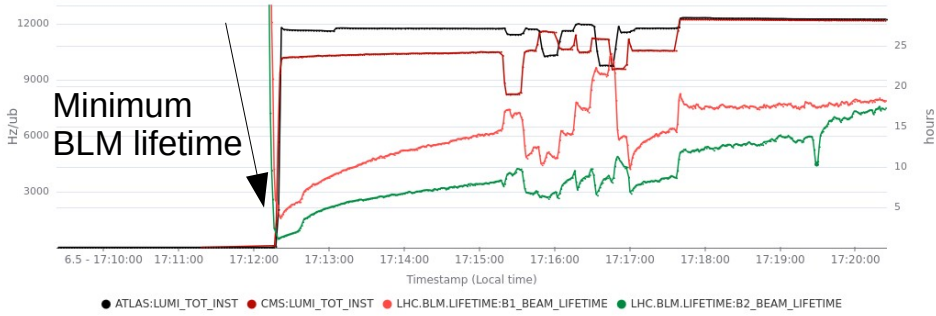
Losses in ADJUST

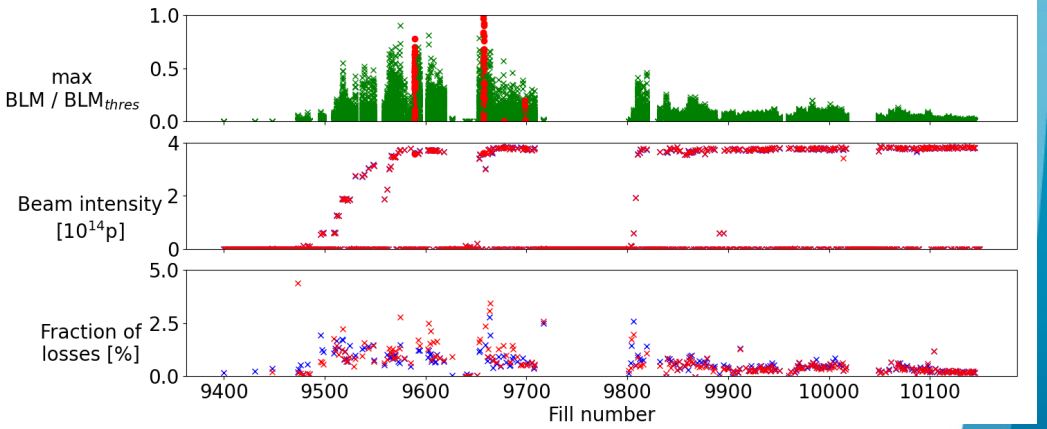
- Beam losses in ADJUST were close to dump levels

  → Clear correlation with tail population (see. S. Kostoglou)

- Chromaticity and octupole requirement are set by flat-top (w/o head-on) and the DA is limited only once in collision.

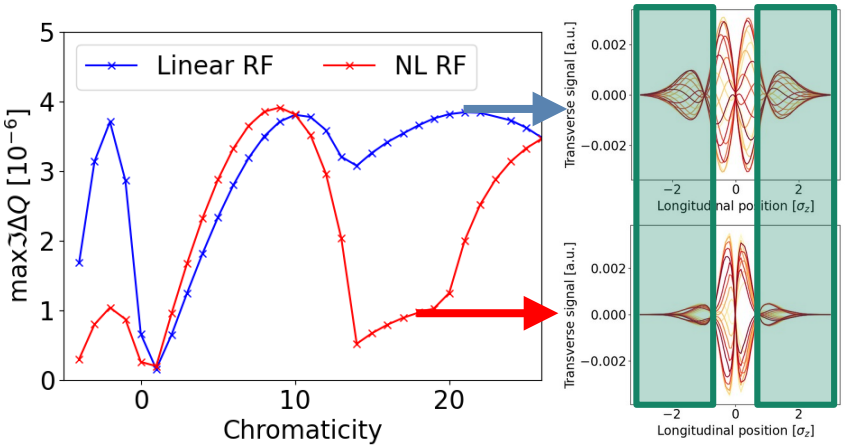
  → Need to quantify the link between the DA drop and the losses in ADJUST in MD

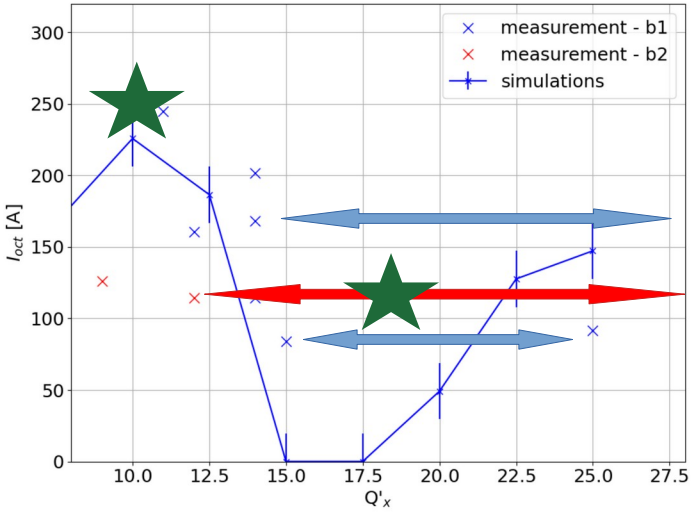




Stability requirement at flat top

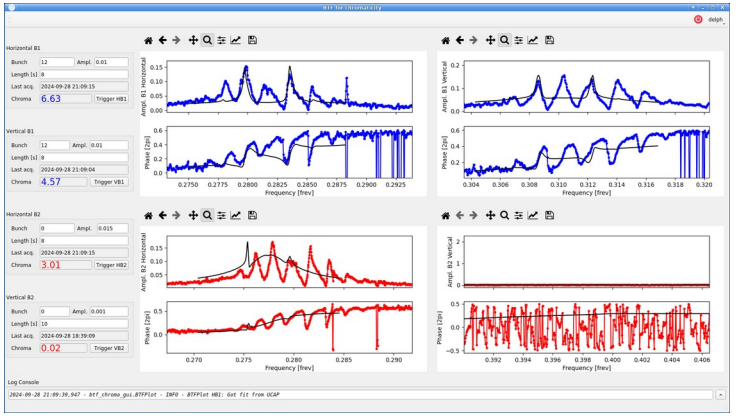
- The existence of a ‘sweet spot’ for chromaticities between 15 and 20 units was demonstrated experimentally
  - It is linked to the suppression of odd head-tail modes by the non-linearity of the RF
- Currently we operate with a singnficant margin in chromaticity (20 units), we could operate with a lower chromaticity (closer to the threshold) if the control is sufficient





Experience with BTF, AC-KFC and Schottky

- Tested new tools for chromaticity measurement in operational conditions at flat top, squeeze and collision (excitation on one bunch with full circulating beam)
  - No losses or emittance growth
  - Excellent signal, but post processing requires further improvement
- A new method based on ADT-AC dipole and head-tail measurement was tested a flat top but lead to beam degradation that needs to be understood
- Schottky statment

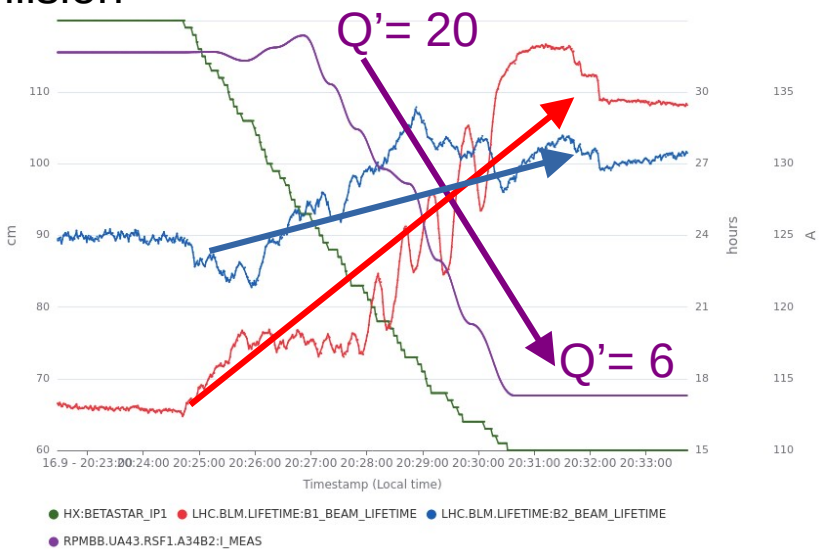


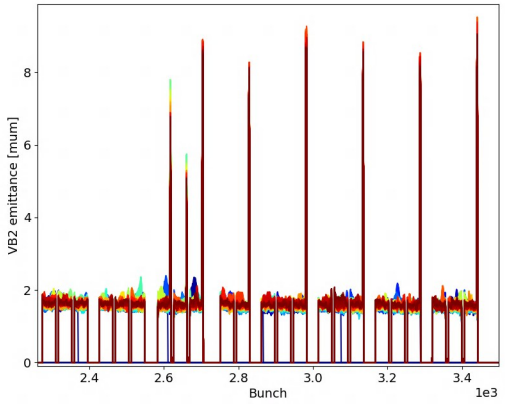
AC-KFC illustration from Kostas

Chromaticity and octupole requirement in collision

- Chromaticity and octupoles in collision are constrained by the stability of non-colliding bunches (same as flat top).
  - If needed their brightness could be reduced to allow for optimisation of the colliding bunches' quality preservation
- Chromaticity is also constrained by e-cloud instabilities with 'low' bunch intensities (~10^{11}p/b)
- In 2024 after TS, the chromaticity was reduced systematically during the fast part of **β*** leveling and kept low in collision (→ 6 units)

  → Few vertical instabilities with offset beams in either IP1 and 5. No Show-stopper, yet it shows that the e-cloud instability threshold is not far



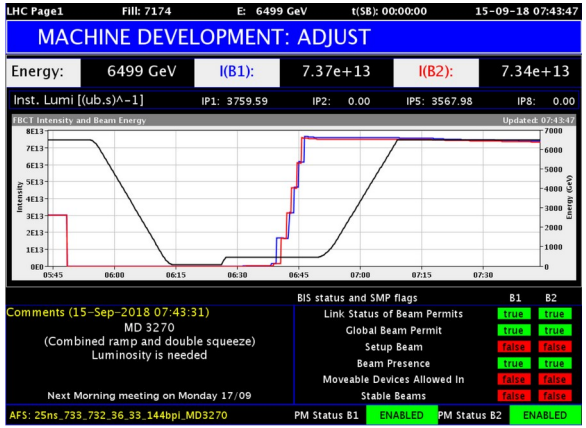


- Fill 10138
- 1.6 p/b
- 0.45cm
- Offset in CMS

Experience with negative polarity of the octupoles

- There is an interest to change the polarity of the octupole for the full cycle to optimise the DA in collision (See S. Kostoglou)
  - Over the years, a series of MDs were realised in this configuration, but we lack operational experience

    → Operating the LHC operation in 2025/26 with the negative would provide valuable experience without impact on the performance



Full cycle with negative polarity of the octupoles, 733b

S. Fartoukh, et al., CERN-ACC-2020-0028

Stability diagrams LHC 2025

Collective effects and collimation hierarchy

- Order of magnitude for beam-beam driven effects
- Reminder of past studies for HL

Summary