Electron lens for Landau damping

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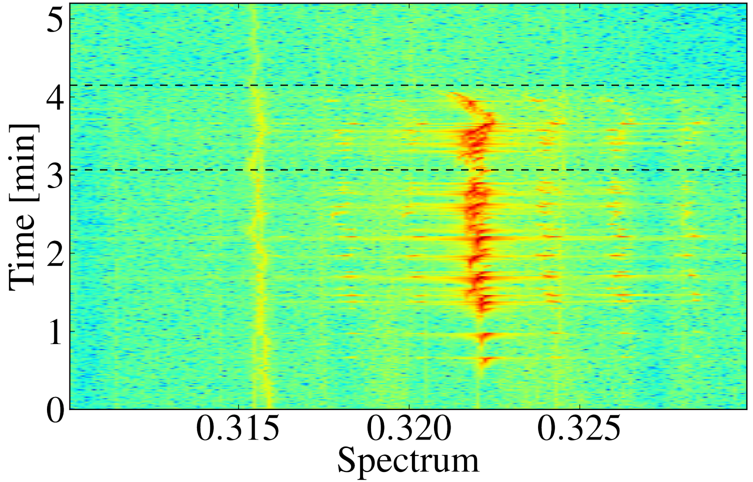
  - HL-LHC requirements
- Electron lens potential and concerns
  - Orbit stability
  - Noise (current jitter)
- Summary

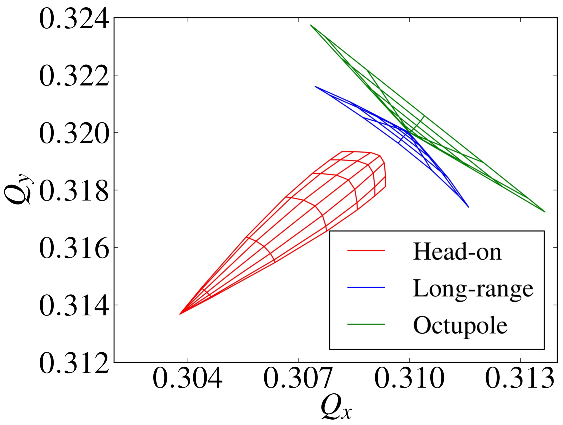
LHC experience with octupoles – Run I

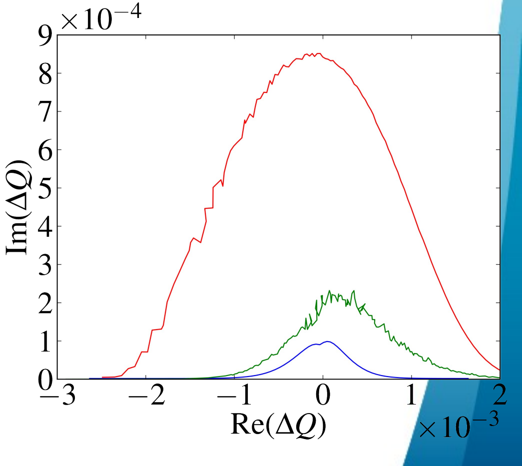
- During operation in 2012, it became clear that operation with octupoles for Landau damping needed to be re-visited

  → Interplay with beam-beam effects, lattice non-linearities and linear coupling



- Already then, the benefits of the head-on tune spread was considered as potential solution to relax the brightness limitation
- Thanks to its effect on the core, the head-on / electron lens induced tune spread spread is more effcient at providing Landau damping

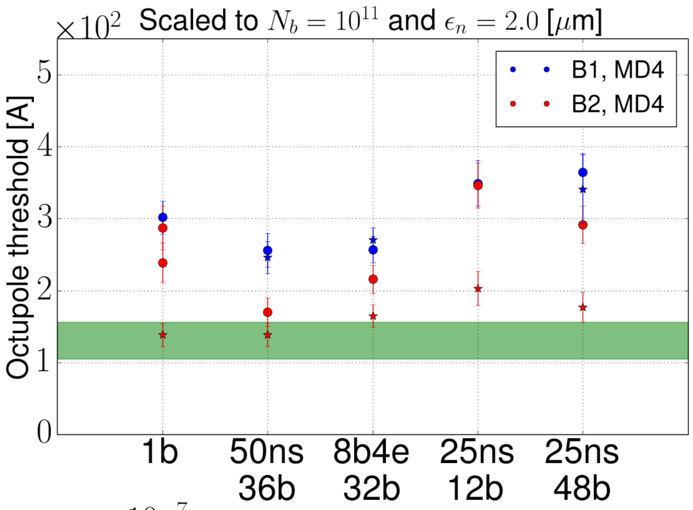


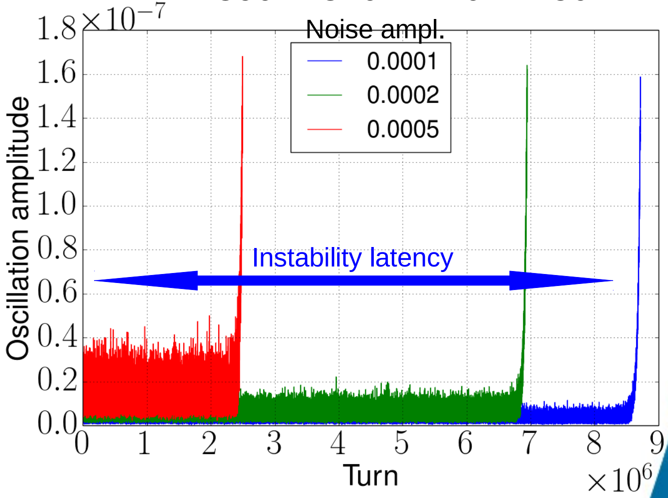


X. Buffat, et al., Squeeze with colliding beams, Evian 2012

LHC experience with octupoles – Run II

- Tight control of the machine linear and non-linear optics reduced the discrepancy with the model to a factor ~ 2 at flat top
- The effect of noise/external excitations is suspected to play a role in this factor, due to the long latencies observed (up to 45 minutes)

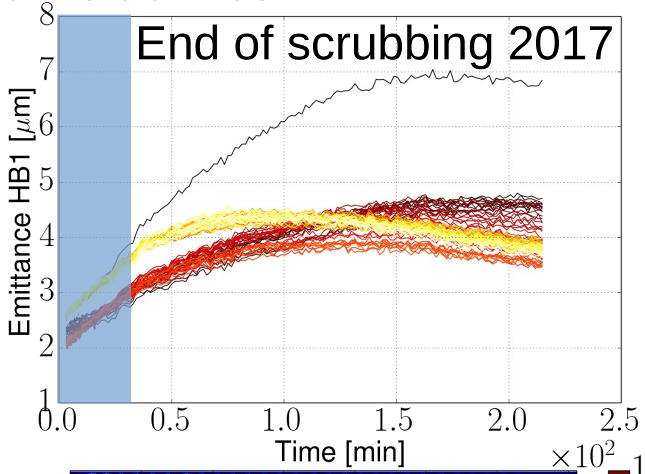


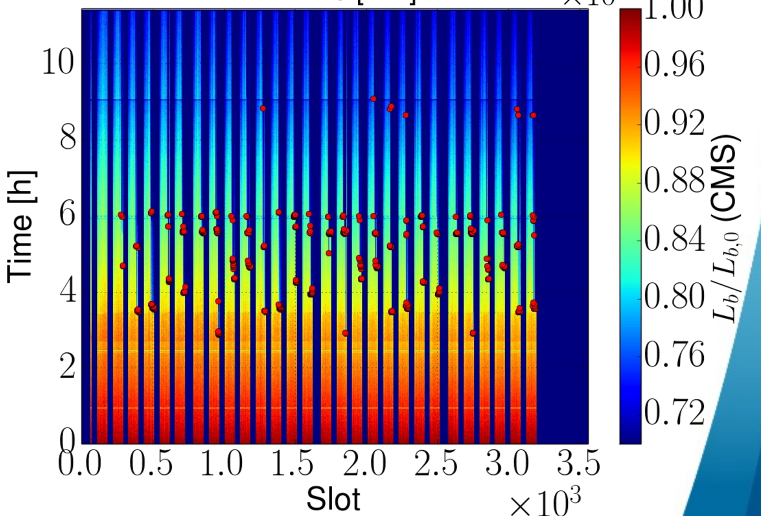


LHC experience with octupoles – Electron cloud instabilities

- A strong octupole current is needed at injection to stabilise e-cloud instabilities
- The head-on tune spread was not sufficient to stabilise the e- cloud instability at top energy
  (see A. Romano, et al., Electron cloud instabilities triggered by low bunch intensity at the Large Hadron Collider, Phys. Rev. Accel. Beams, 2018)

→ The capacity of the e-lens to outperform the octupoles against electron cloud instabilities at injection is not granted

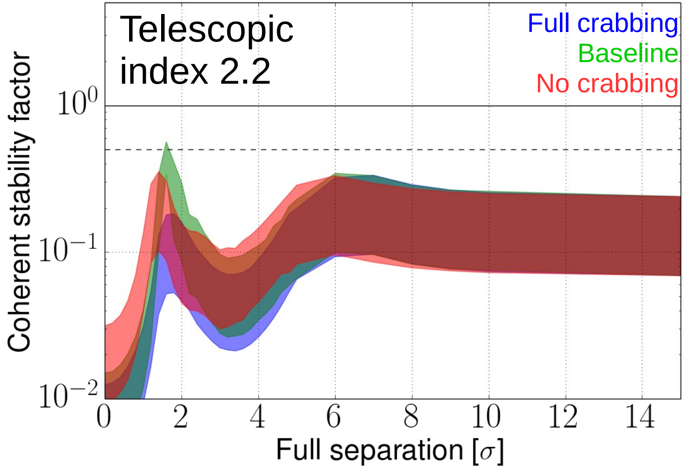




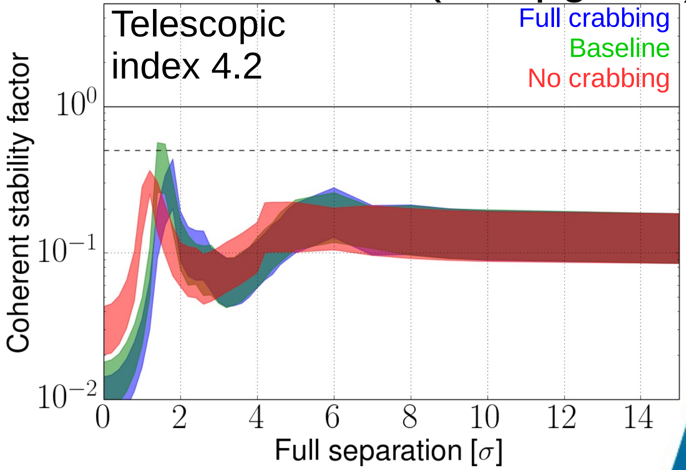
HL-LHC requirement

- A small telesopic squeeze is needed already at flat top to recover the stability margins of a factor 2, including the low impedance collimator upgrade (Ultimate BCMS scenario)
  - A Gaussian distribution cut at 3 sigma is considered for Landau damping
- The ultimate BCMS scenario without collimator upgrade would rely on a large telescopic index
  - Limits of the RATS still need to be estimated (optics)

Low impedance collimator upgrade

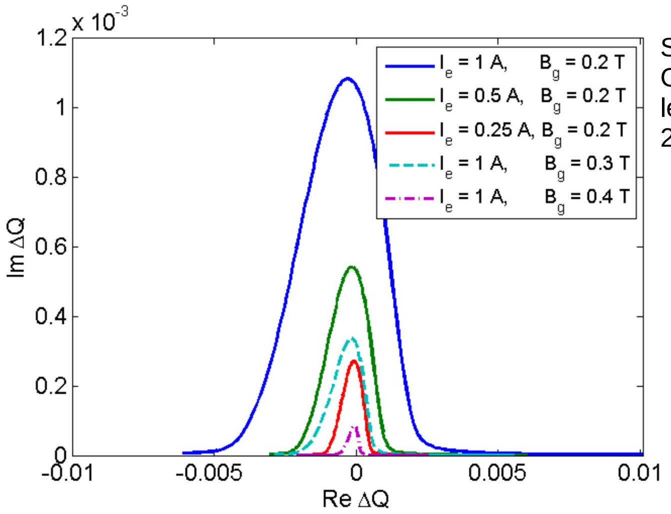


CFC collimators (no upgrade)

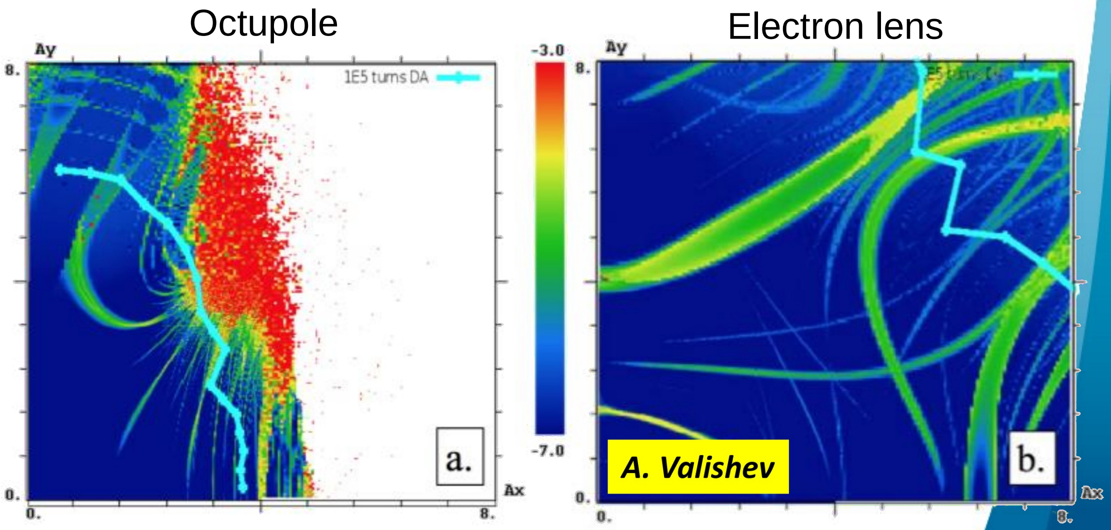


Gaussian e-lens potential

- Large and efficient tune spread, due its large impact on the beam core and its reduced impact on dynamic aperture w.r.t. octupole magnets
  - ~10 times larger stability diagram than maximum octupole current (without RATS) achievable for reasonable electron beam parameters
  - Potential to improve even further the efficiency by using more advanced electron beam profiles



S. Antipov, et al., Stability diagram with a Gaussian electron lens in HL-LHC, HSC meeting 09 Oct 2017



Short term DA
V. Shiltsev, et al., Phys. Rev. Lett. 119, 134802 (2017)

E-lens potential

- Mostly interesting at the design stage (e.g. HE-LHC / FCC-hh) to consider as a replacement for octupole magnets, thanks in particular to the favourable scaling with the energy

- Here we focus on the HL-LHC project :

  → Replace the low impedance collimator upgrade, in particular if the capability of the RATS is limited (studies needed)

  → Stabilise the electron cloud instability at injection with a reduced impact on the beam lifetime (studies needed)

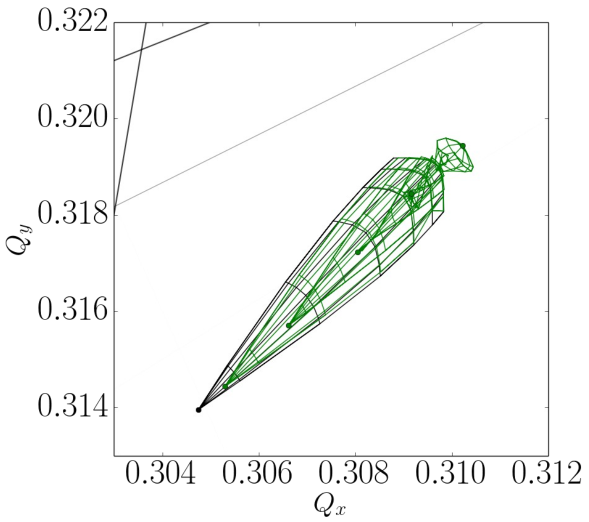
  → Adjust the current to the needs of individual bunches (non-colliding bunches)

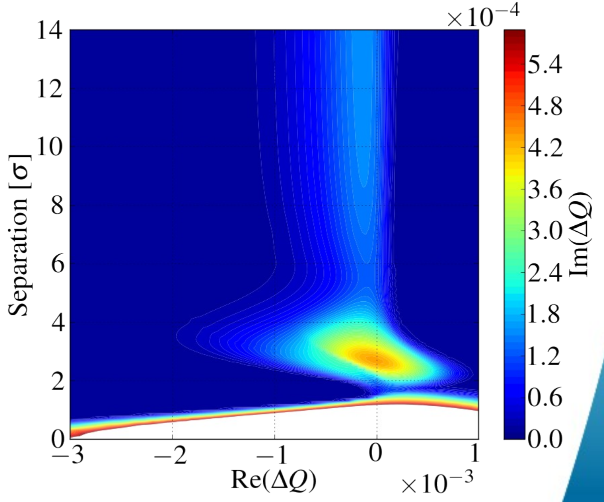
  → Reduce dependence on the tail distribution

  → Provide large margins (X10) for unkowns

Concerns for operation

- Only used operationally in RHIC for head-on beam-beam compensation (not for Landau damping)
  - Observed noise induced losses and emittance growth (current jitter) W. Fischer et al, Phys. Rev. Accel. Beams 20, 091001
- Need to avoid loss of Landau damping with offset at the electron lens (similar to head-on collision, tolerances to be defined)
  - Orbit jitter (machine variations and PACMAN effects)
- Bringing the beams into collision
  - Landau damping when the changing the tune shift sign to be studied





Summary

- An e-lens has a large potential to relax brightness limitations due to collective instabilities in high energy machine, possibly higher than usual octupole magnets
- The HL-LHC baseline (nominal and ultimate) does not *need* an electron lens for Landau damping, however there is a potential to :
  - Improve the beam stability at injection, and consequently the preservation of the beam quality
  - Improve the beam stability at flat top, possibly removing the need for a low impedance collimator upgrade and RATS
- In both cases detailed studies are needed to estimate the limits of the scheme