Electron lens for Landau damping

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➢ LHC experience with octupoles for Landau damping
  - 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 efficient 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 $\sim 2$ 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


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

- A small telescopic 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)
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


Short term DA
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 unknowns
Concerns for operation

➢ Only used operationally in RHIC for head-on beam-beam compensation (not for Landau damping)

➢ 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