The European Circular Energy-Frontier Collider Study (EuroCirCol) project has received funding from the European Union's Horizon 2020 research and innovation programme under grant No 654305. The information herein only reflects the views of its authors and the European Commission is not responsible for any use that may be made of the information.

Update on Landau Damping

Vladimir Kornilov
GSI Helmholtzzentrum, Darmstadt, Germany

Oliver Boine-Frankenheim
TU Darmstadt, GSI Helmholtzzentrum, Darmstadt

EuroCirCol FCC-hh Task 2.4

Overview FCC Landau Octupoles

From FCC Week 2017 Berlin:

Blue: ΔQ_{coh} –Damping as in LHC.
3554 Octupoles.

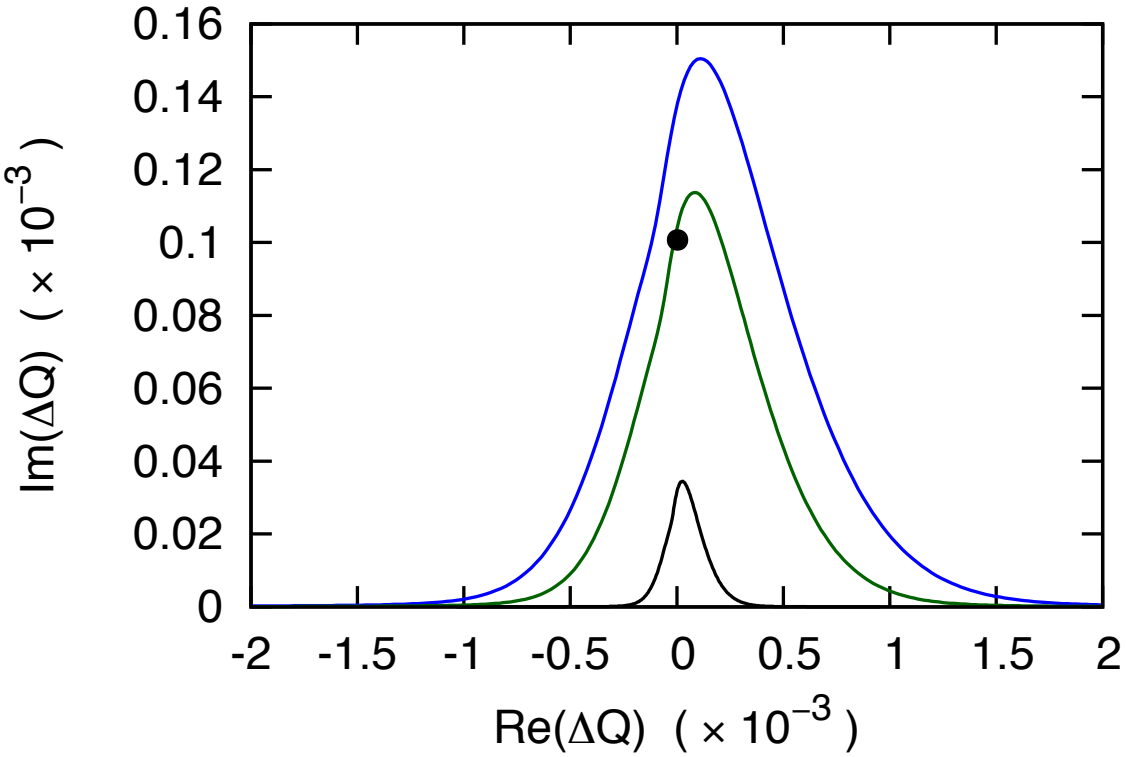
Green: enough damping for the (•) impedances.
2686 octupoles.

Black: $N_{MO} = N_{MQ} =$ **814**

LHC: 168 octupoles.

- LHC octupole magnets are assumed here
- $Z_{FCC}=Z_{LHC}$ (per length unit)

Reliable Technology & Physics for Landau Damping



Stability Diagram:
stable below the line,
unstable above the line.

Conclusions: talk FCC Week 2017

- Nearly 3600 LHC-octupoles are needed at FCC to ensure the transverse stability

- Stability of intra-bunch oscillations (k≥1 modes) due to octupoles corresponds to the 2D Landau damping DR.
  → the true Landau damping and
  higher tolerable impedances, or less octupoles

- RF Quadrupole provides stability only by
  factors ≈5−10 larger tune spreads
  → existence of Landau damping is not clear,
  it can be the instability drive modification (like ξ)

FCC Landau Octupoles

Example:

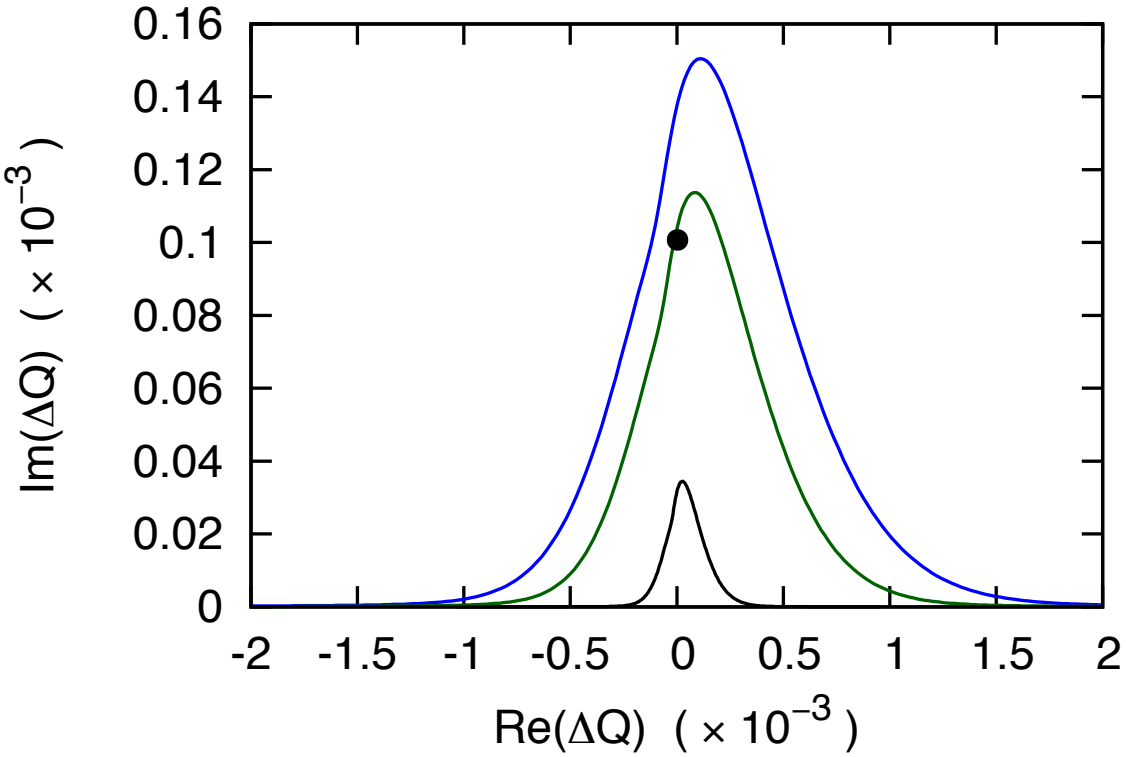
LHC octupole magnets:
$O_3=63.1\times10^3\ I_{oct}/550$
$L_m=0.32$m

Technologically possible:
$O_3=220\times10^3\ I_{oct}/550$
$L_m=0.64$m

↓

508 octupoles in FCC
(not 3600)

Reliable Technology & Physics
for Landau Damping



Stability Diagram:
stable below the line,
unstable above the line.

Discussion

- <u>Transverse Impedance per length unit at relevant frequencies</u>
  Different assumptions are around:
  $Z_{FCC}/Z_{LHC} = 1$
  $Z_{FCC}/Z_{LHC} = 2.5$
  $Z_{FCC}/Z_{LHC} = 6.5$
  proportionally changes the number of octupoles

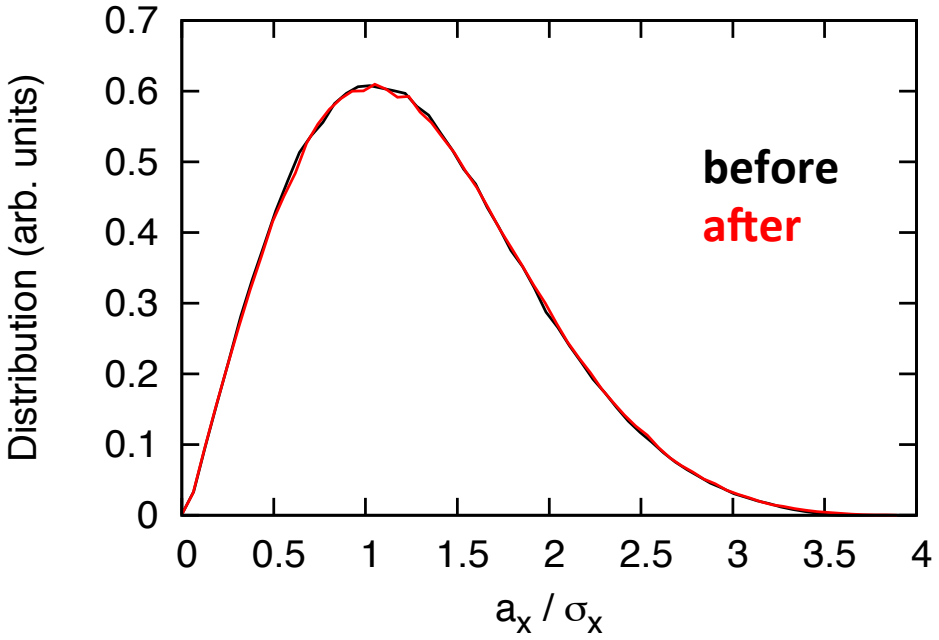
- Rely on Feedback for k=0 mode:
  higher order modes need weaker octupoles

- In addition to octupoles, other devices for Landau damping:
  RF Quadrupoles, Electron Lenses

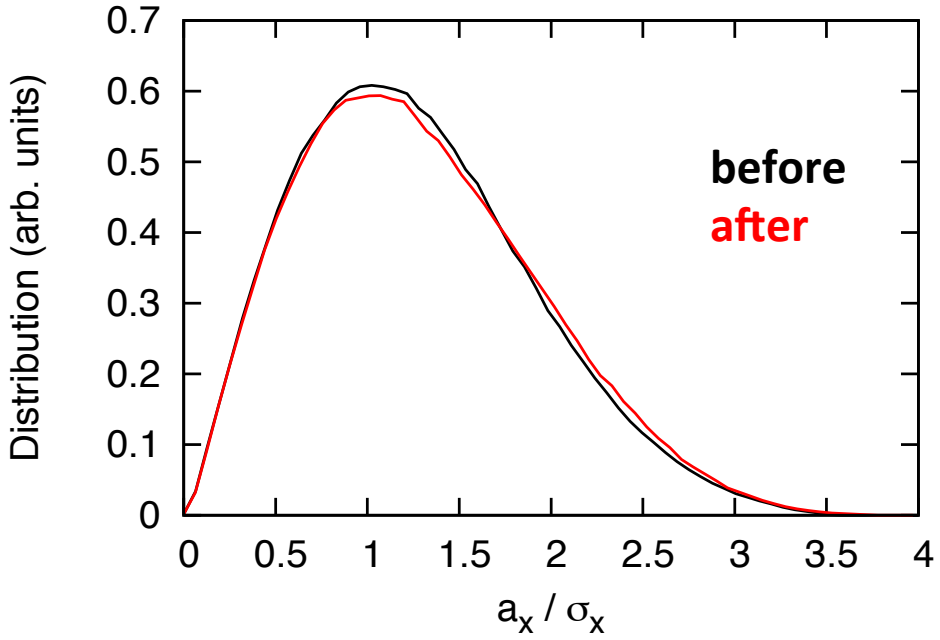
Simulations

Amplitude distribution **before** an **after**
decay of a perturbation (with an impedance) due to

RFQ



OCTUPOLES



Modifications of the amplitude distribution, and emittance blow-up

V.Kornilov, ICFA mini-Workshop on Impedances and Instabilities, Benevento, Italy, Sept 18-22, 2017
https://agenda.infn.it/conferenceDisplay.py?confId=12603

Landau Damping

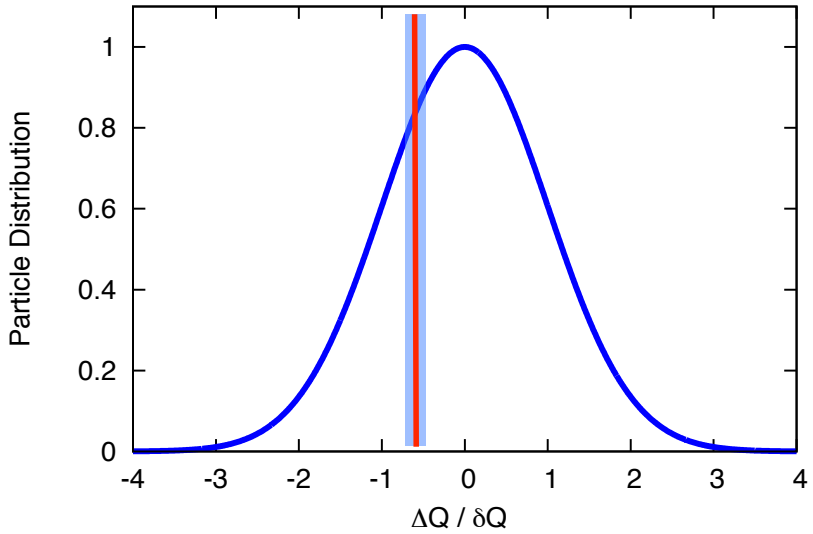
V.Kornilov, ICFA mini-Workshop on Impedances and Instabilities, Benevento, Italy, Sept 18-22, 2017
https://agenda.infn.it/conferenceDisplay.py?confId=12603

We know at least two examples where:

1. Head-tail modes and the chromaticity tune-spread
2. Nonlinear space-charge in coasting beams

- there is a **tune spread**
- the coherent frequency overlaps with the incoherent spectrum

still, there is **NO Landau Damping!**



a tune spread does not automatically means Landau Damping

Conclusions & Outlook

- An octupole scheme for FCC is under discussion, the footprint flexibility and the number of octupoles seems to be reasonable
- Re (Z) and Im(Z) need to be further sprecified
- RF Quadrupole provides stability. Existence of Landau damping is not clear
- Electron Lenses and RFQ should be further studies, theoretically and experimentally
- Feedback might be a part of the Landau damping consideration