Effect of chromaticity on the destabilizing effect of the transverse damper

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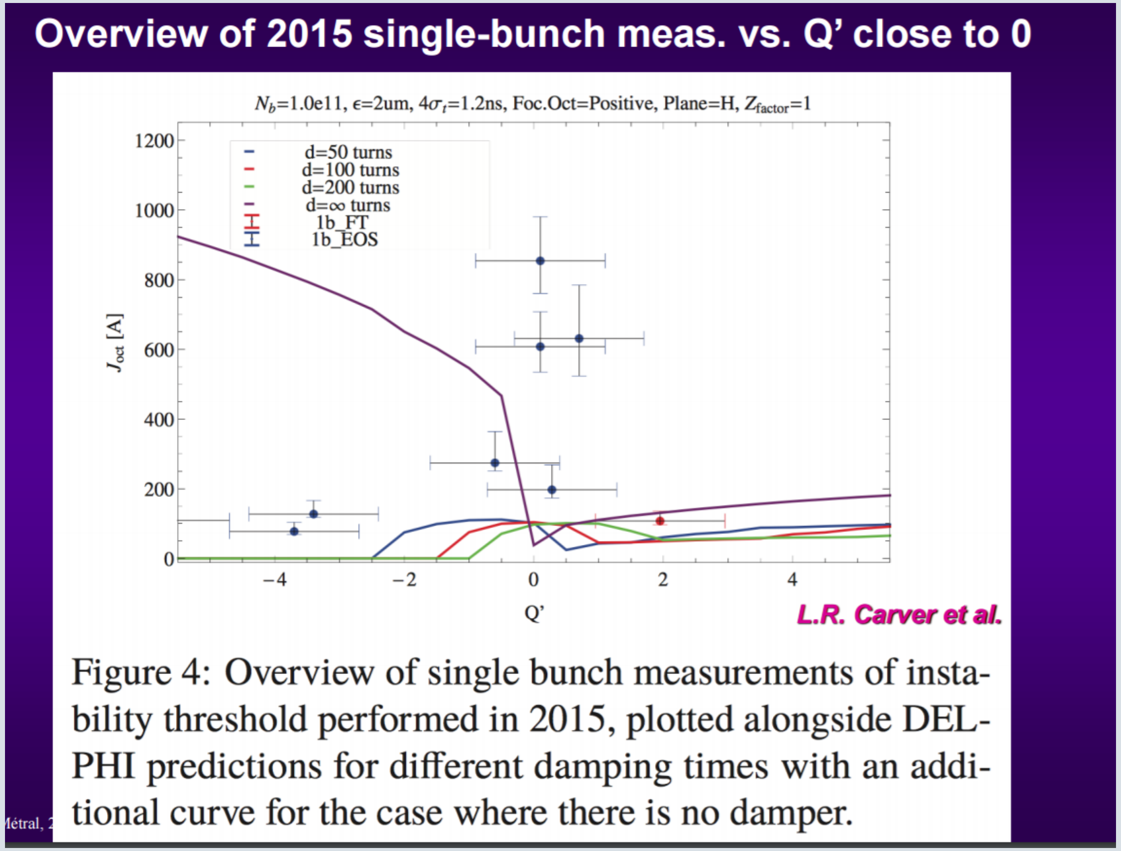
MANY THANKS TO D. AMORIM, N. BIANCACCI, X. BUFFAT

26.02.18

Destabilizing effect of resistive transverse damper



Overview of 2015 single-bunch meas. vs. Q' close to 0

L.R. Carver et al.

Figure 4: Overview of single bunch measurements of instability threshold performed in 2015, plotted alongside DELPHI predictions for different damping times with an additional curve for the case where there is no damper.

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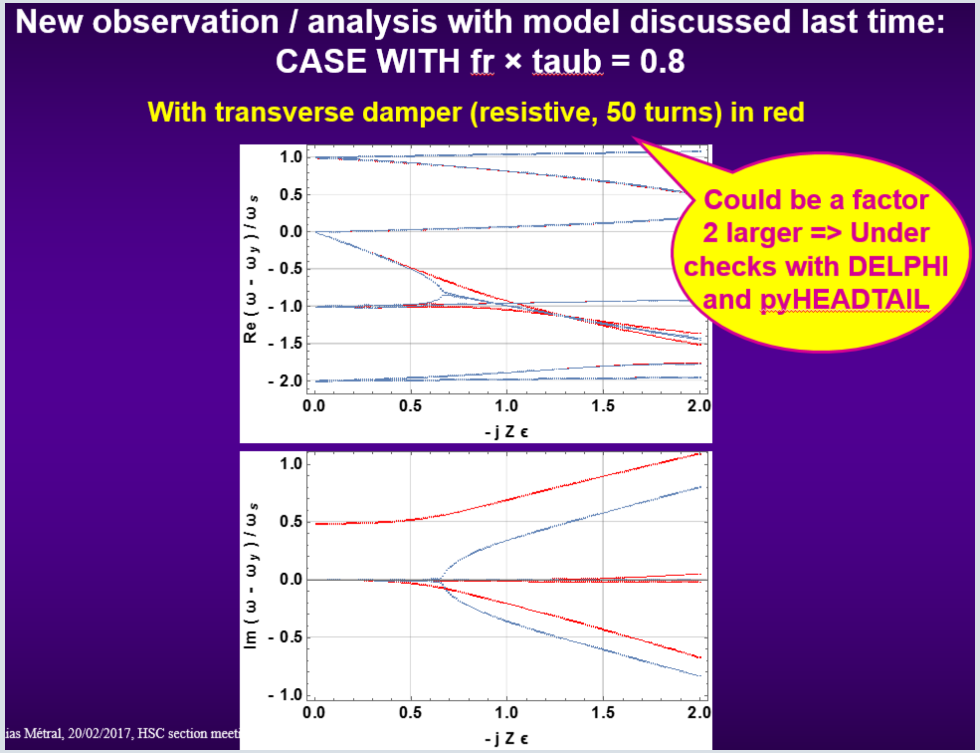


New observation / analysis with model discussed last time: CASE WITH fr × taub = 0.8

With transverse damper (resistive, 50 turns) in red

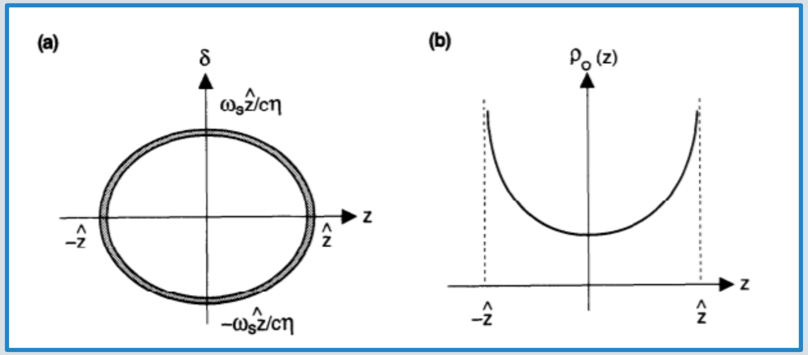
Could be a factor 2 larger => Under checks with DELPHI and pyHEADTAIL

ias Métral, 20/02/2017, HSC section meeti

E. Metral et al., Destabilizing effect of the resistive transverse damper, APB-HSC meeting, 20.02.17

E. Metral, La Sapienza University, Rome, Italy, May 23-26, 2017

A simple air-bag model contains all relevant physics

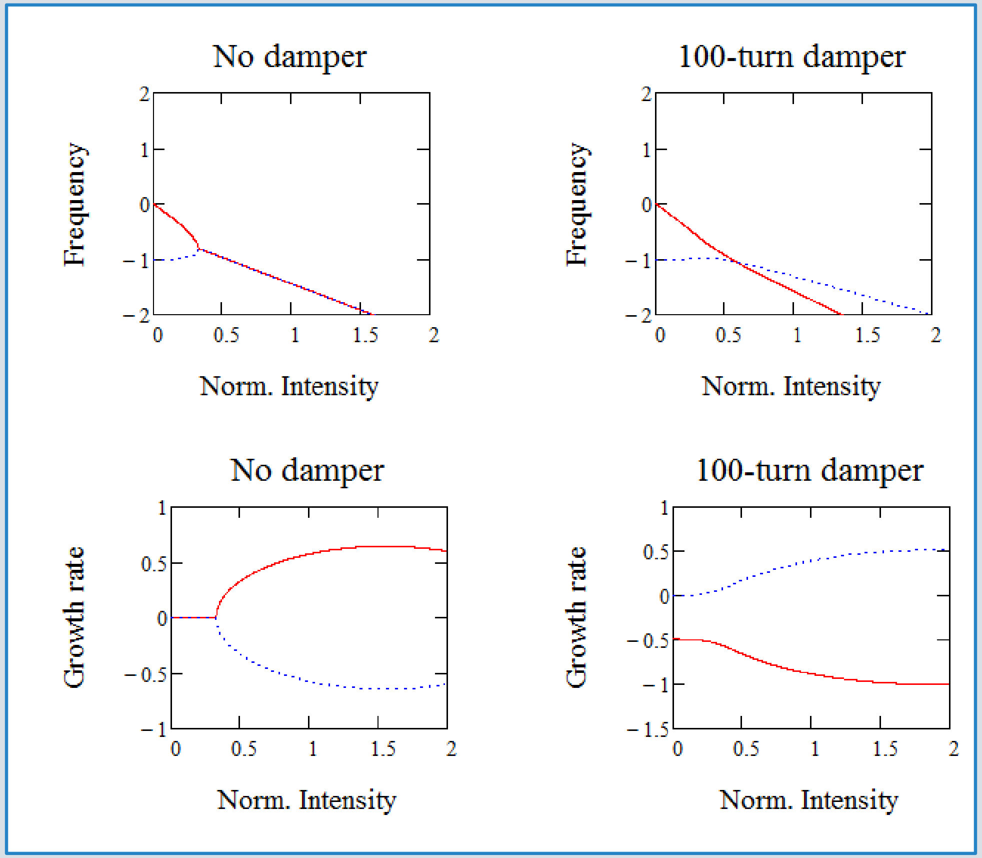


Dynamics is described by a real matrix (no damper, *Q'* = 0)

$$M = \begin{bmatrix} \cdots & & & & & & \\ \cdots & & & & & & \\ & 2+I & R & I & R & I & \\ & R & 1+I & R & I & R & \\ & I & R & I & R & I & \\ & R & I & R & -1+I & R & \\ & I & R & I & R & -2+I & \\ & & & & & & \cdots \\ & & & & & & \cdots \end{bmatrix}.$$

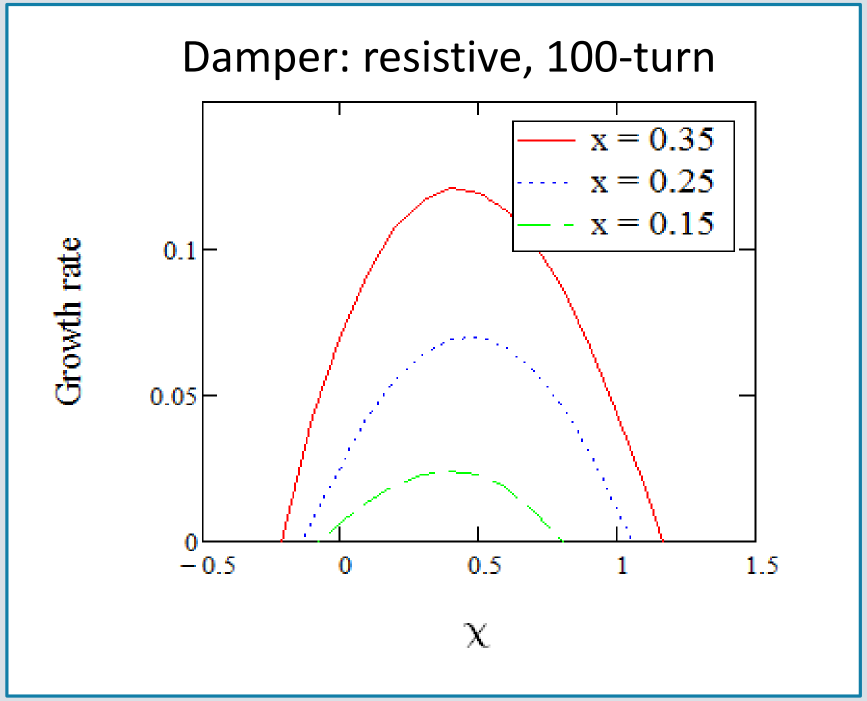
Im Z

Re Z



S. Antipov, et. al, 'Destabilizing effect of transverse damper and air-bag beam', HSC Meeting, 26.06.17

The maximum growth rate may be at Q’ ≠ 0



Damper gain: $$g = \frac{f_0}{n_{turns}\omega_s}$$

Norm. Intensity: $$x = \frac{R_s N_b q_e^2}{Z_0 E_0 \tau_b \omega_s}$$

Head-tail phase: $$\chi = \frac{\xi \omega_0 \tau}{\eta}$$

Simplified model, only two azimuthal modes

What is the relevant chromaticity range of the effect?

S. Antipov, et. al, ‘Destabilizing effect of transverse damper and air-bag beam’, HSC Meeting, 26.06.17

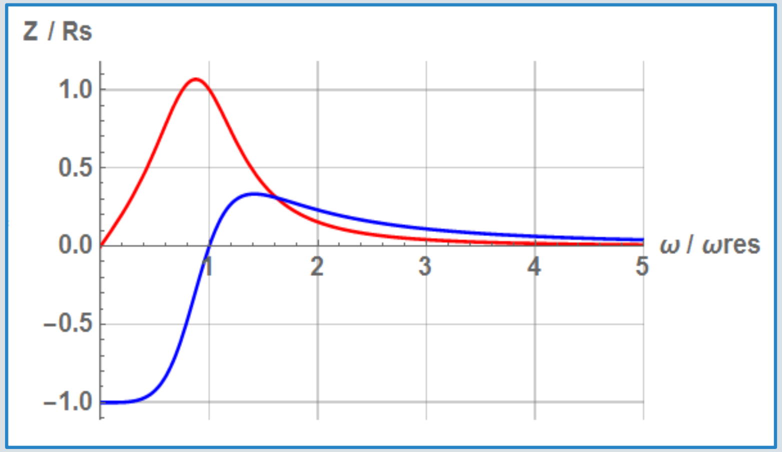
SPS ‘toy’ model

Energy: $E_0 = 26$ GeV

Bunch length: $\tau_b = 0.8$ ns

Tunes: $Q_x = 26.13$, $Q_y = 26.18$, $Q_s = 7.3*10^{-3}$

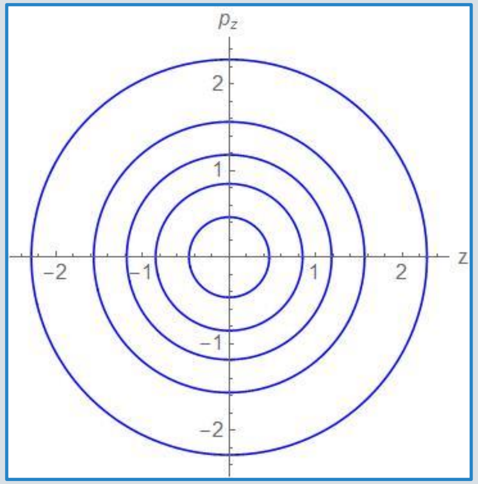
Impedance: Broadband resonator model
$Q = 1$, $f_r = 1$ GHz, $R_s = 10$ MΩ/m



Longitudinal bunch distribution: Gaussian

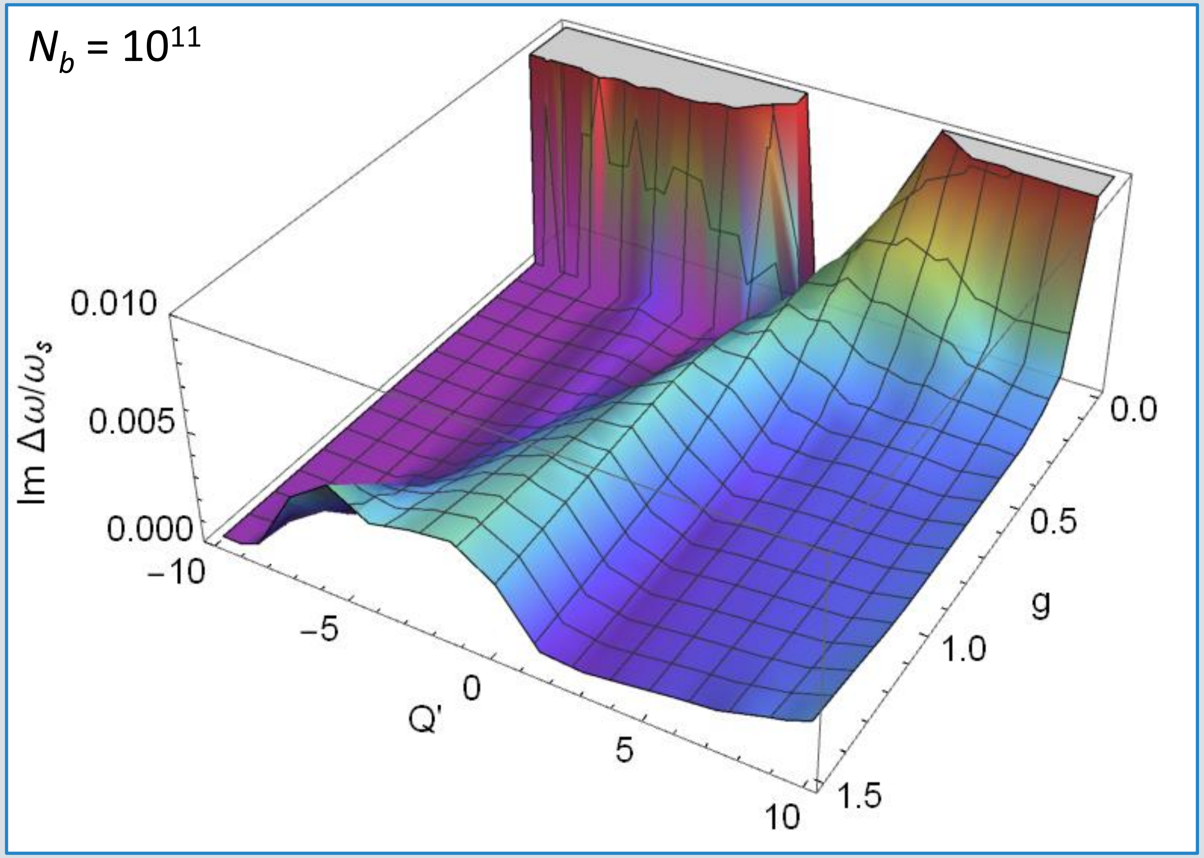
Azimuthal modes: $l = -10 \ldots +10$

Radial modes: 5



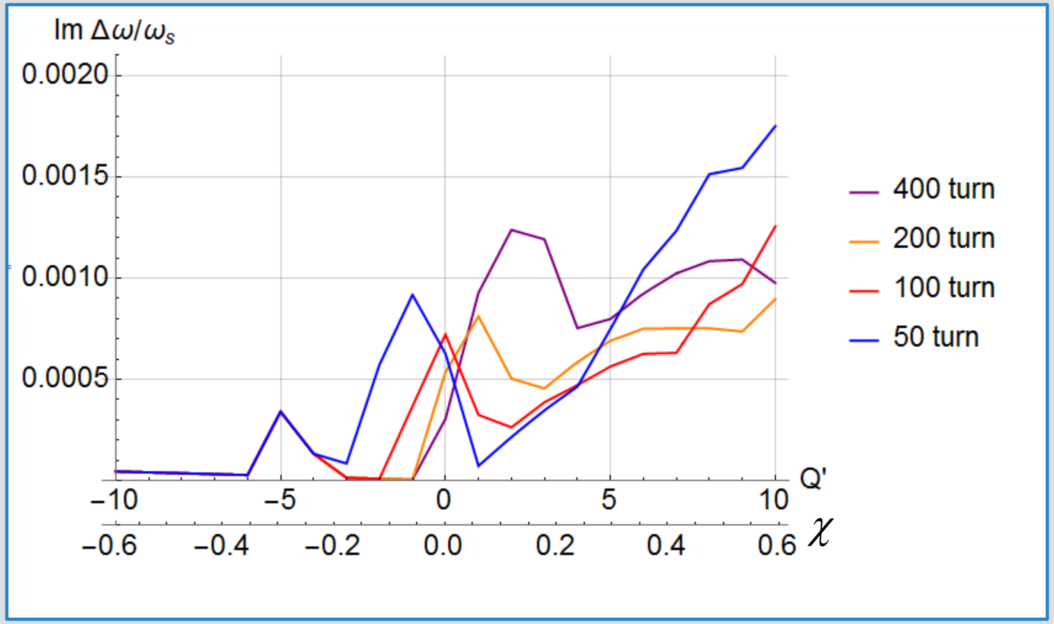
‘Worst’ chromaticity depends on damper settings

The maximum of the growth rate shifts toward negative Q’ for greater damping strengths

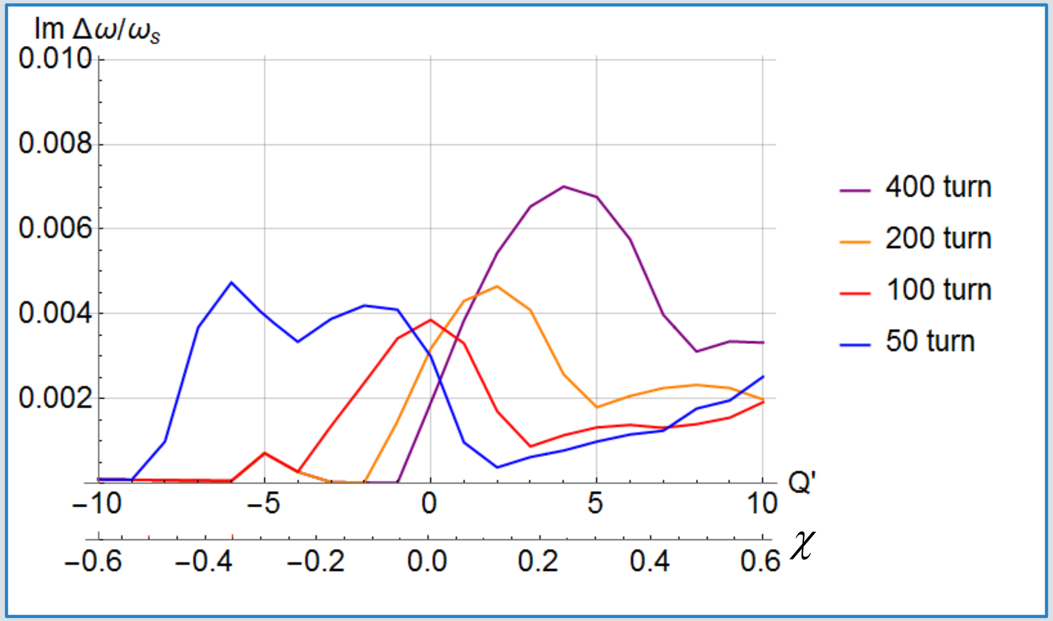


Higher intensity – larger width of the coupling

LOWER BUNCH INTENSITY, 1x10^{11} PPB



HIGHER BUNCH INTENSITY, 2x10^{11} PPB



Being checked in DELPHI by D. Amorim

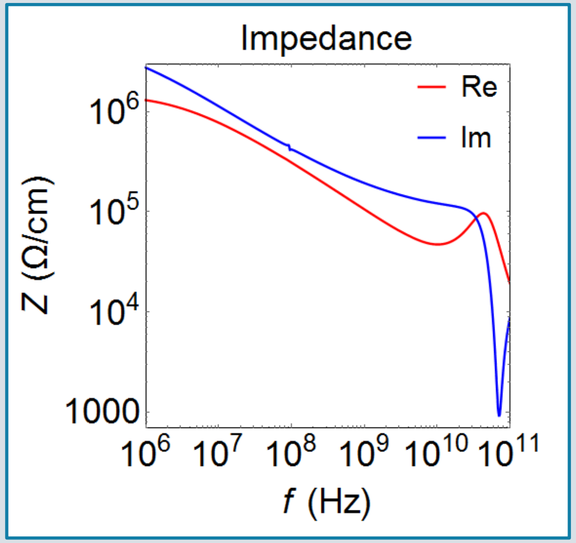
LHC Model

Flat-top, E = 6.5 TeV

2017 collimator settings:

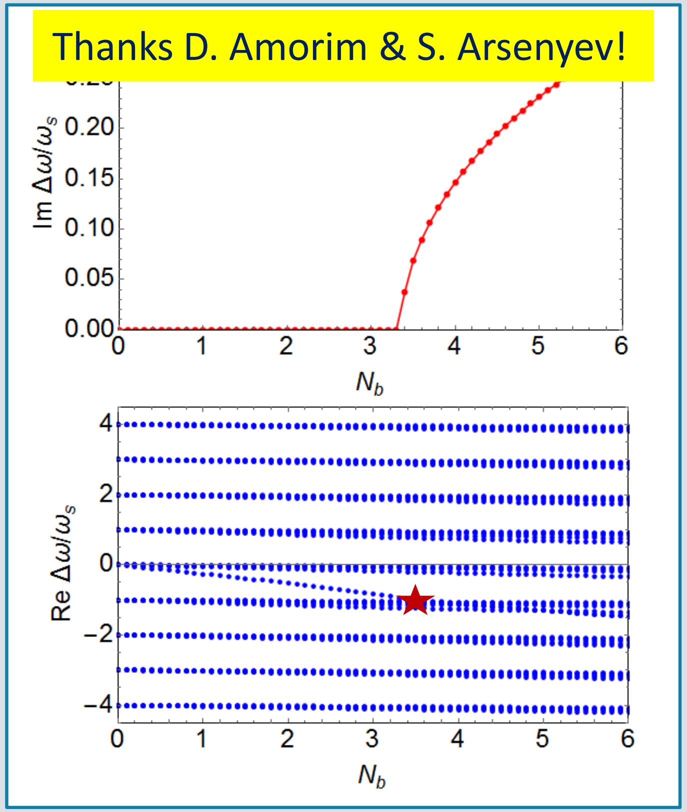
- Primaries 5.0 σ
- Secondaries 6.5 σ

Single-bunch, Gaussian profile

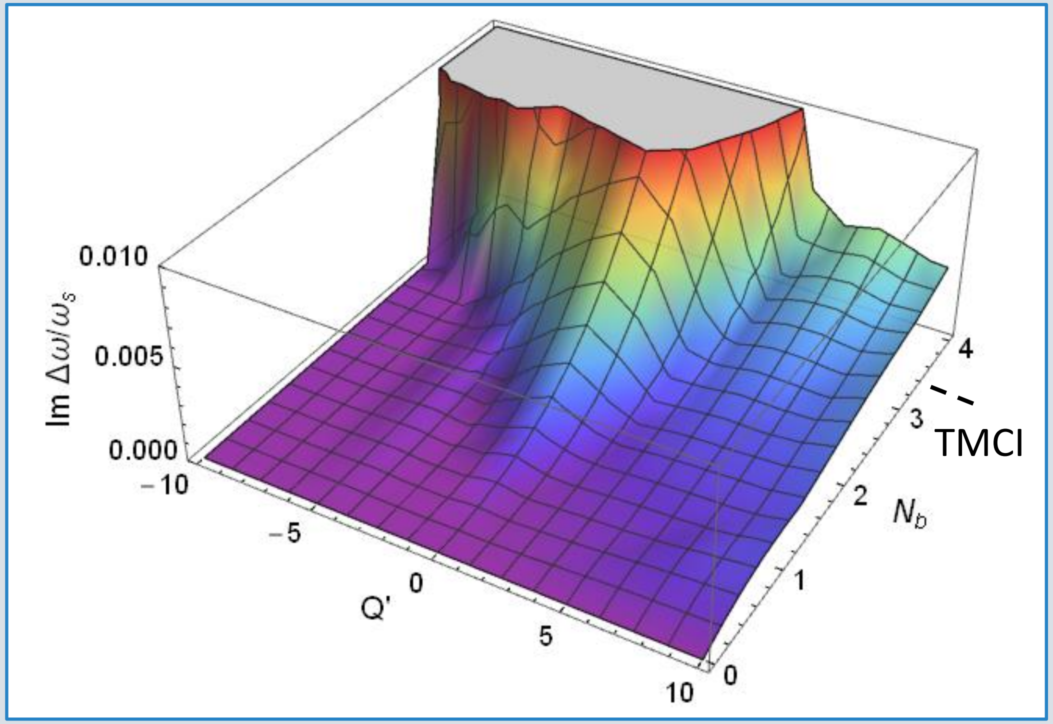


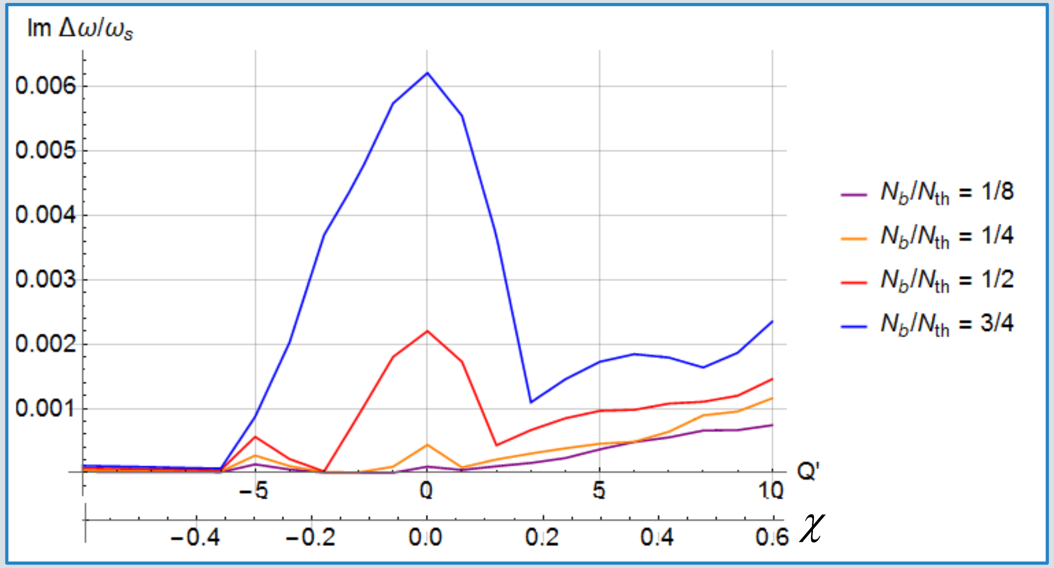
Azimuthal modes 0 and -1 couple at 3.4x10^{11} p

- Q’ = 0, no damper

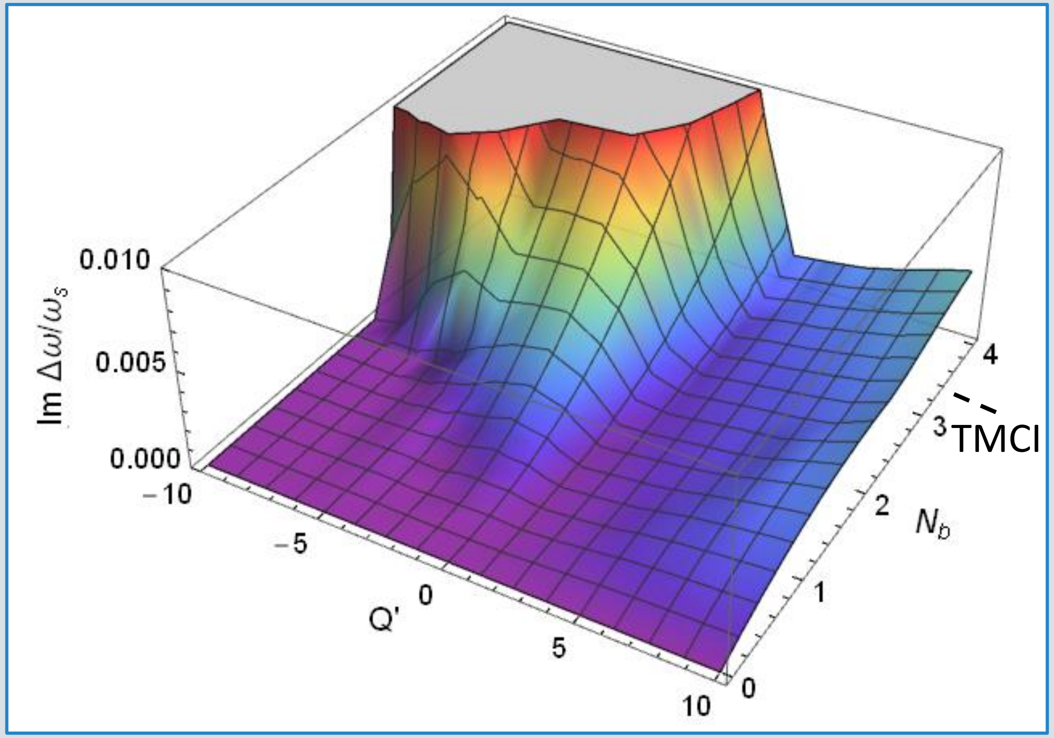

Thanks D. Amorim & S. Arsenyev!

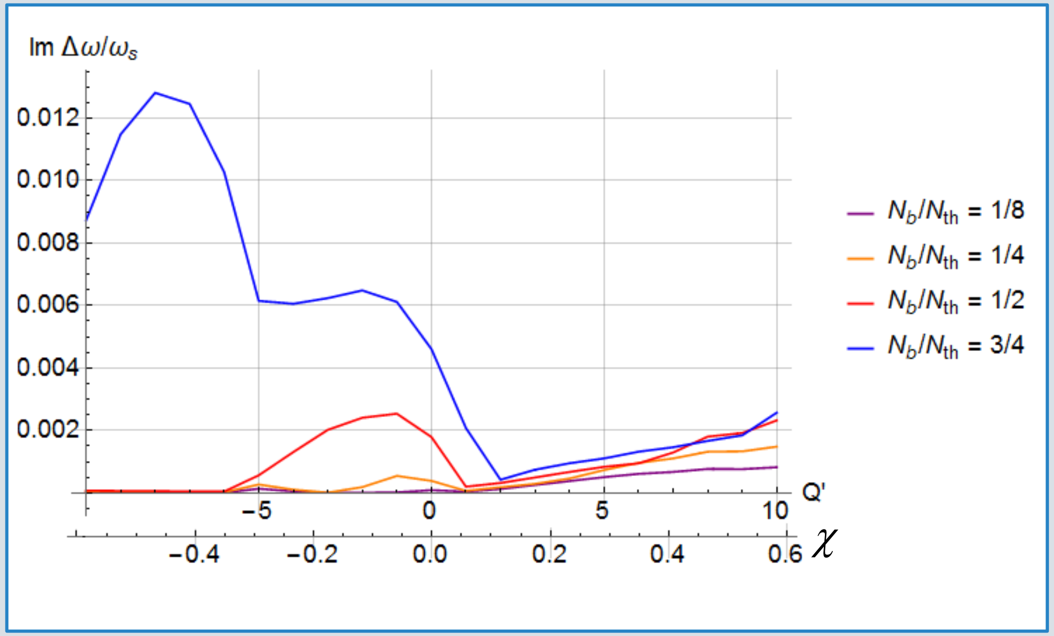
For a 100-turn damper gain the maximum is exactly at Q' = 0



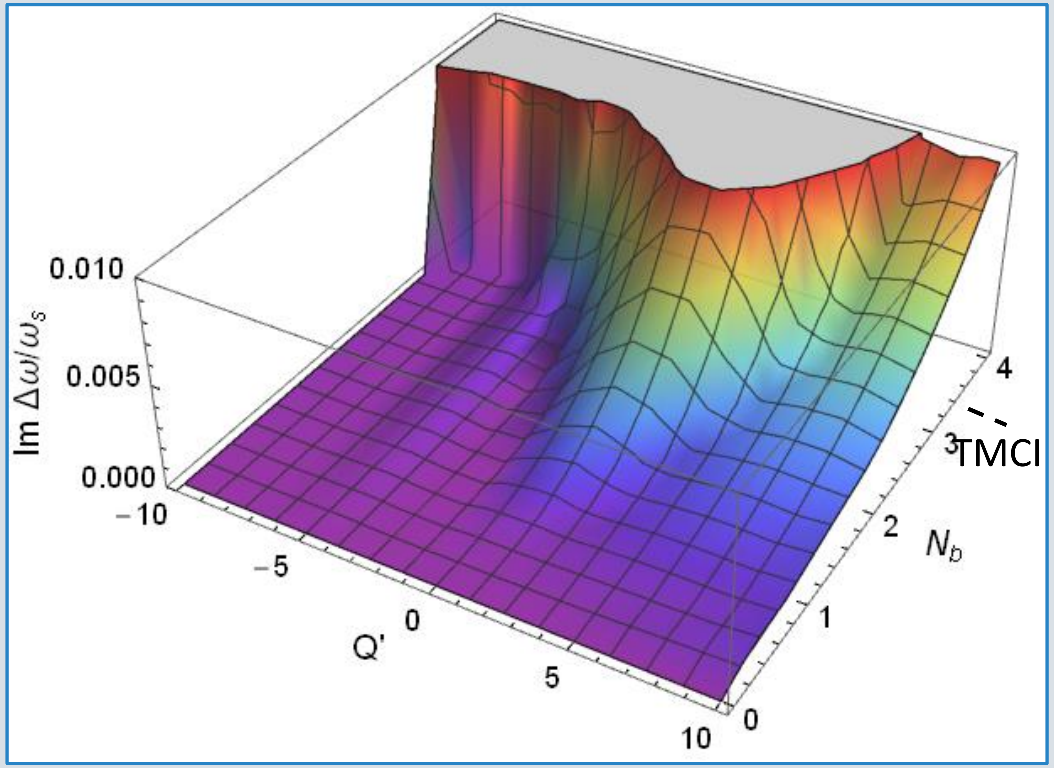


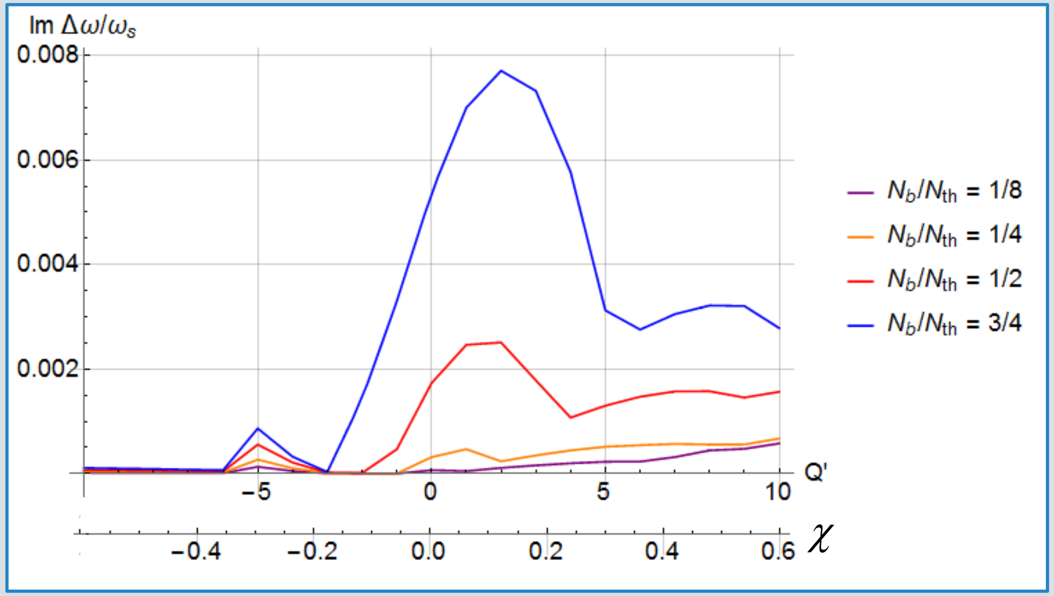
Stronger damper (50 turns): Maximum growth rate at negative Q’



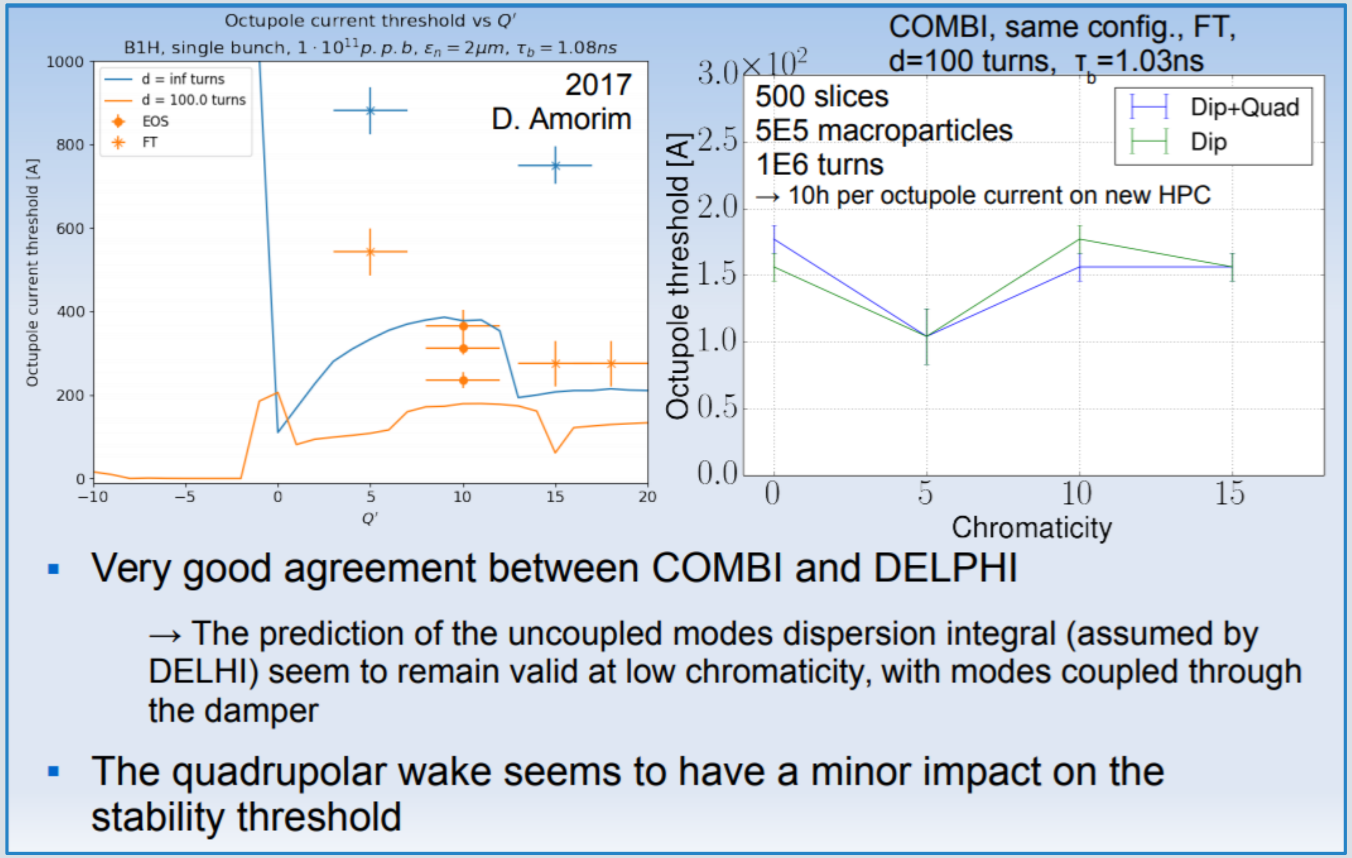


Intensity scan (200 turns): Maximum growth rate at positive Q’





One can still estimate the octupole threshold treating the modes as independent



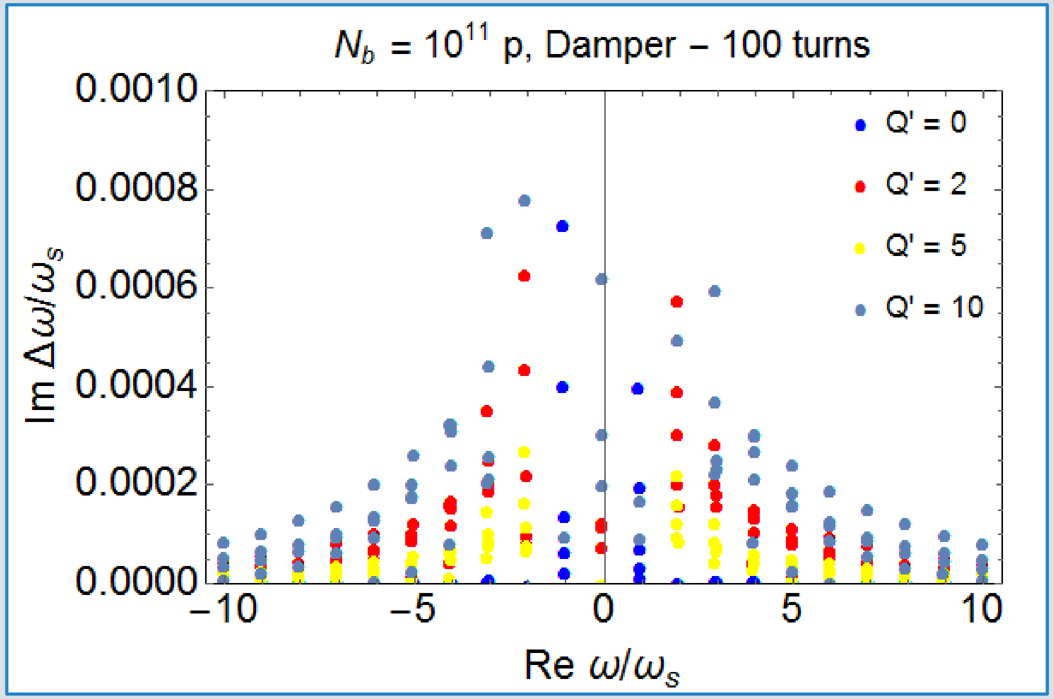
- Very good agreement between COMBI and DELPHI

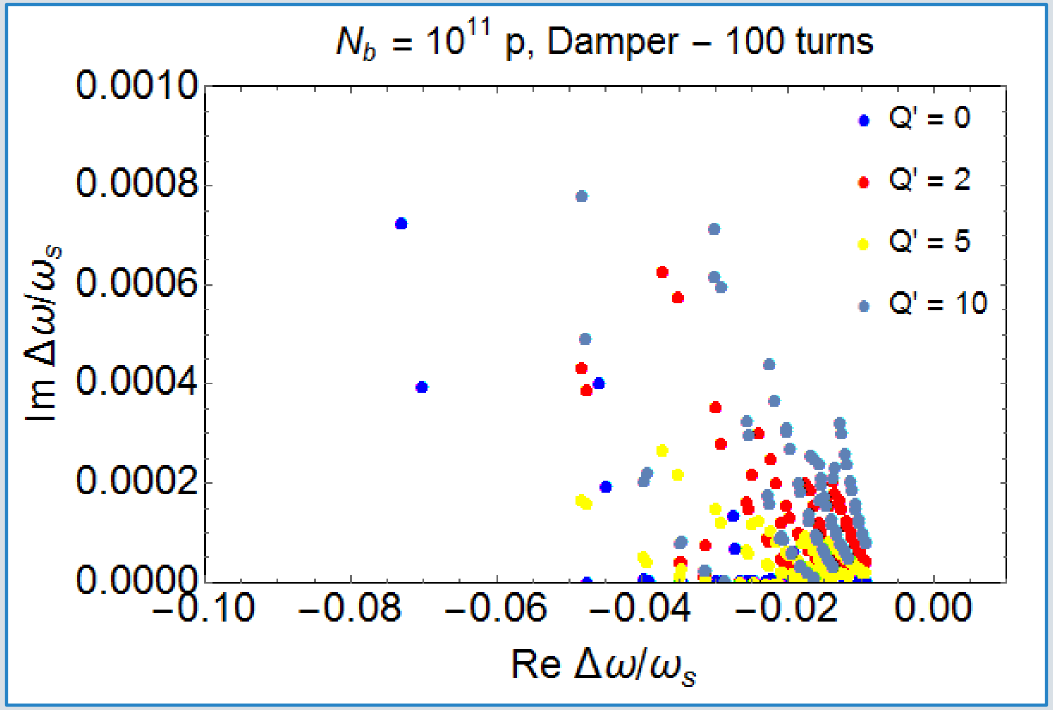
  → The prediction of the uncoupled modes dispersion integral (assumed by DELHI) seem to remain valid at low chromaticity, with modes coupled through the damper

- The quadrupolar wake seems to have a minor impact on the stability threshold

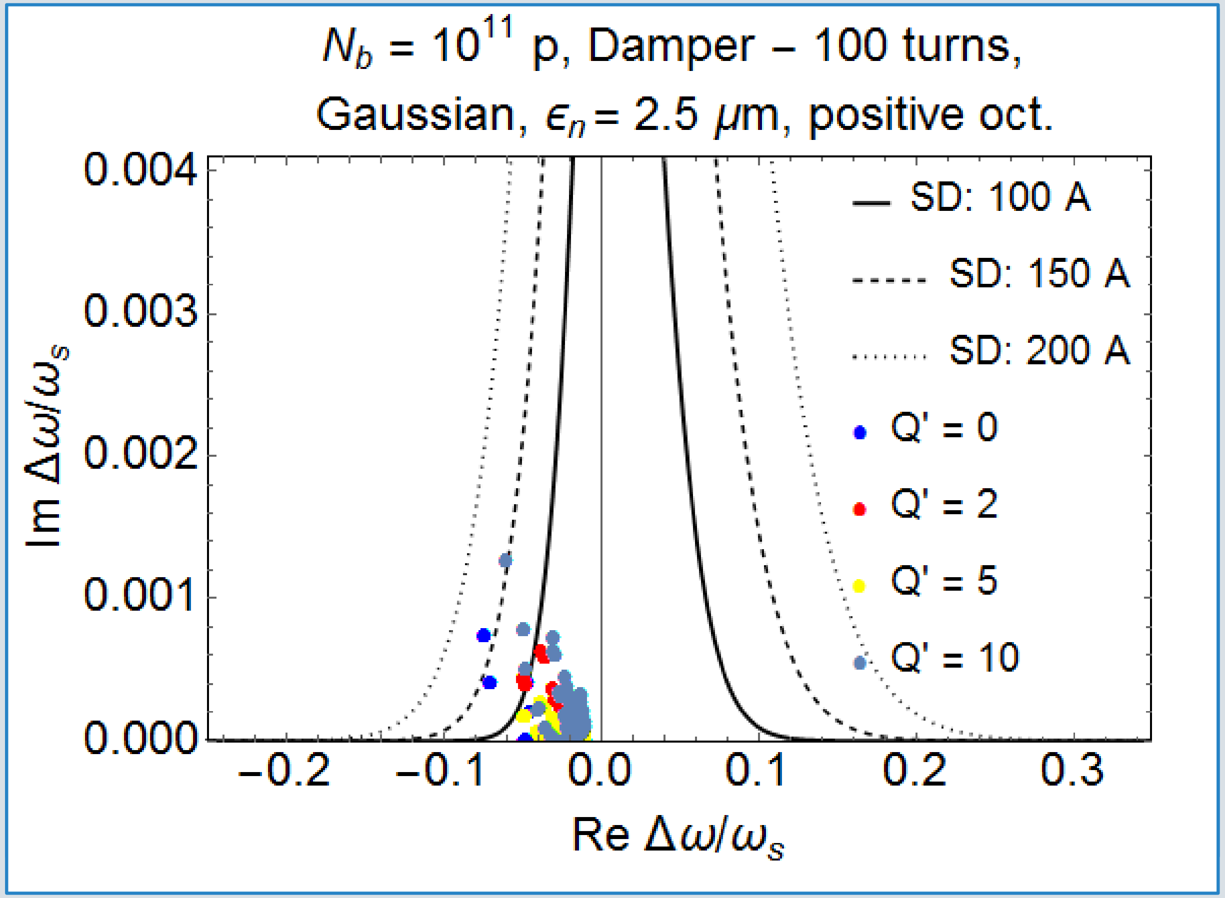
X. Buffat, ‘Few simulations of octupole thresholds with damper and quadrupolar wakes’, HSC Meeting, 15.01.18

The modes at low Q’ have a larger real shift





Larger octupole current required at low Q’ despite similar growth rate



Conclusion

Resistive damper leads to mode coupling and causes an instability at Q’ = 0

A simple airbag model predicts that the effect may be the strongest an a small but non-zero chromaticity

NHT simulation qualitatively confirms this prediction

- Both for a ‘toy’ SPS model and a real LHC impedance
- Position of the maximum depends on the damper gain
- Width increases as the bunch intensity approaches the TMCI threshold

In the presence of the effect, at low Q’ the most unstable head-tail modes have larger real tune shifts than the ones at high Q’

- Up to 2 times greater octupole current may be required to stabilize, depending on the exact settings and the shape of the stability diagram