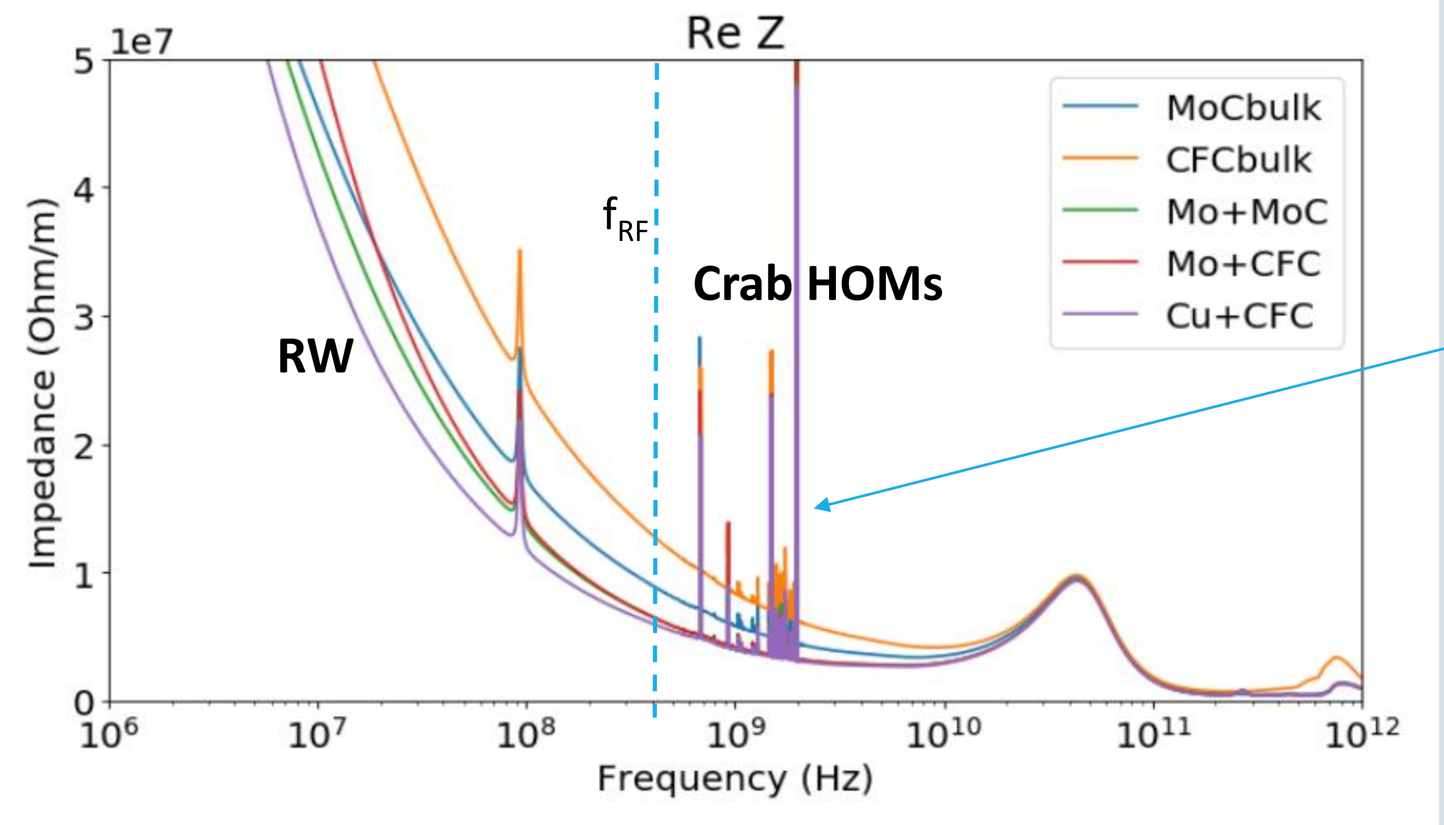
Effect of Crab Cavity HOMs on the Couple-Bunch Stability of HL-LHC

S. ANTIPOV

MANY THANKS TO A. BUROV (FNAL), N. BIANCACCI, E. METRAL

9/11/17

Some crab HOMs have a high shunt impedance. They can drive a couple-bunch instability

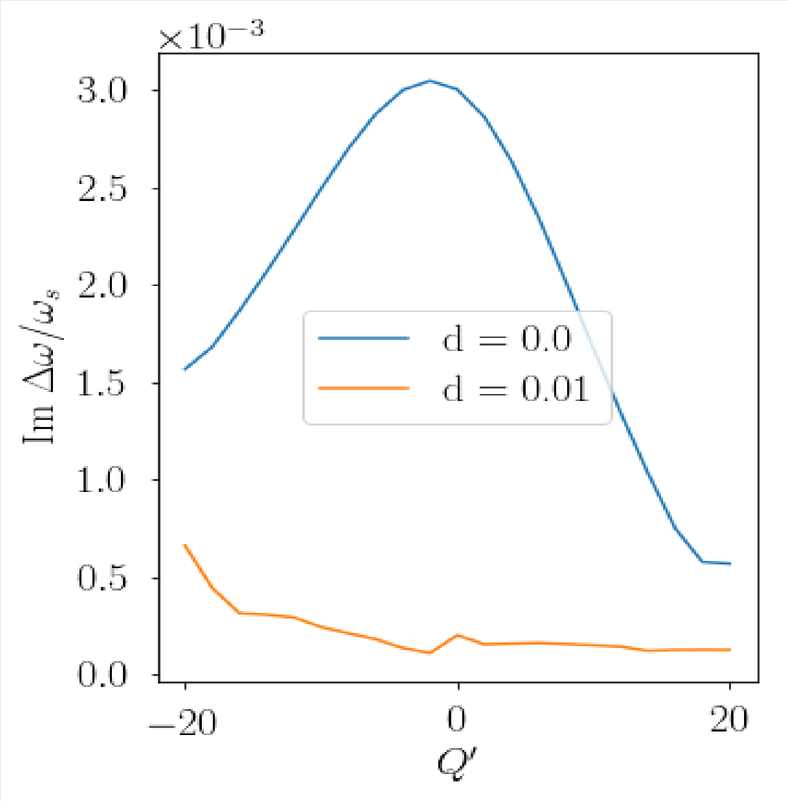


DQW design:

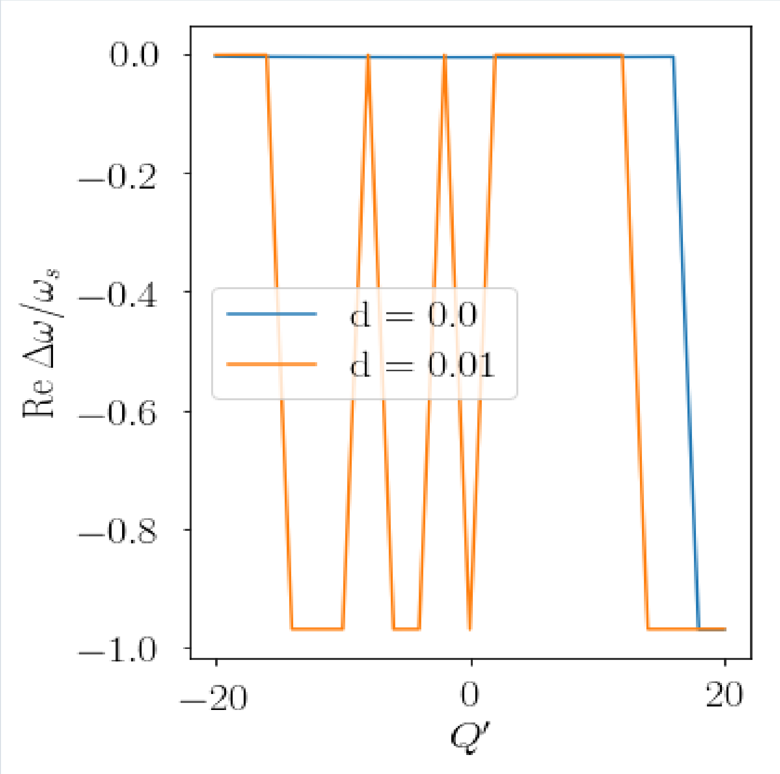
- R_s = 2.7 MΩ/m
- f = 1.96 GHz
- Q = 31000

DELPHI shows that the *l* = 0 mode is the most critical
Impedance model – 1 HOM, no RW, low intensity

Growth rate



Tune shift

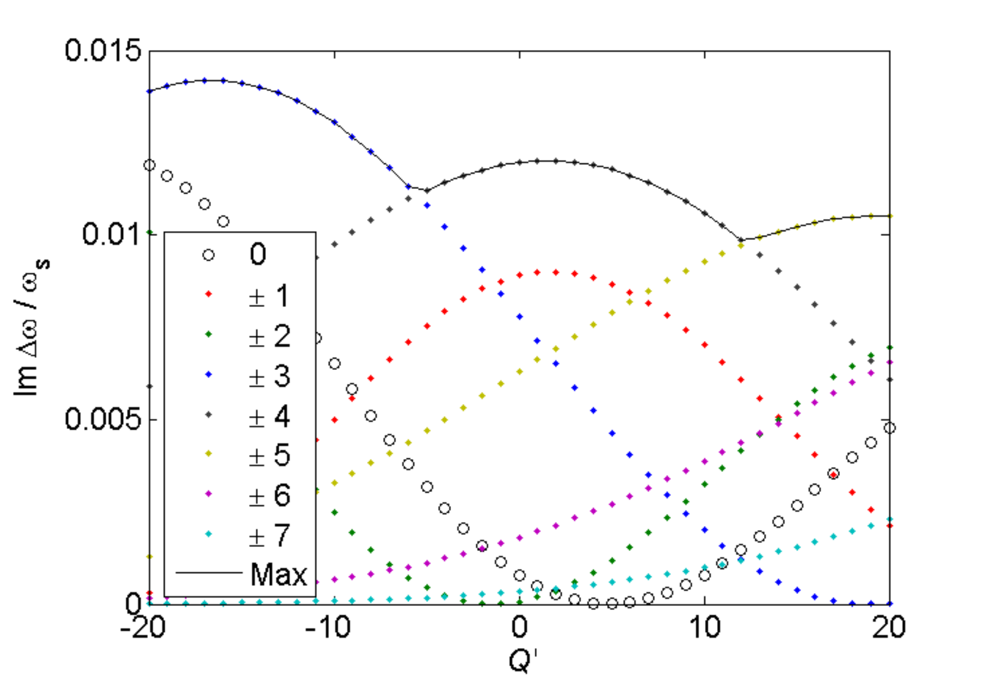


The most unstable couple-bunch mode excites many azimuthal intra-bunch modes

Low intensity:

$$\Omega^{l} - \omega_{\beta} - l\omega_{s} \approx -i\frac{MN_{b}r_{0}c}{2\gamma T_{0}^{2}\omega_{\beta}}\sum_{p} Z(\omega')J_{l}^{2}(\omega'\tau - \chi)$$

$$\omega' = \left(pM + \mu\right)\omega_{0} + \Omega$$

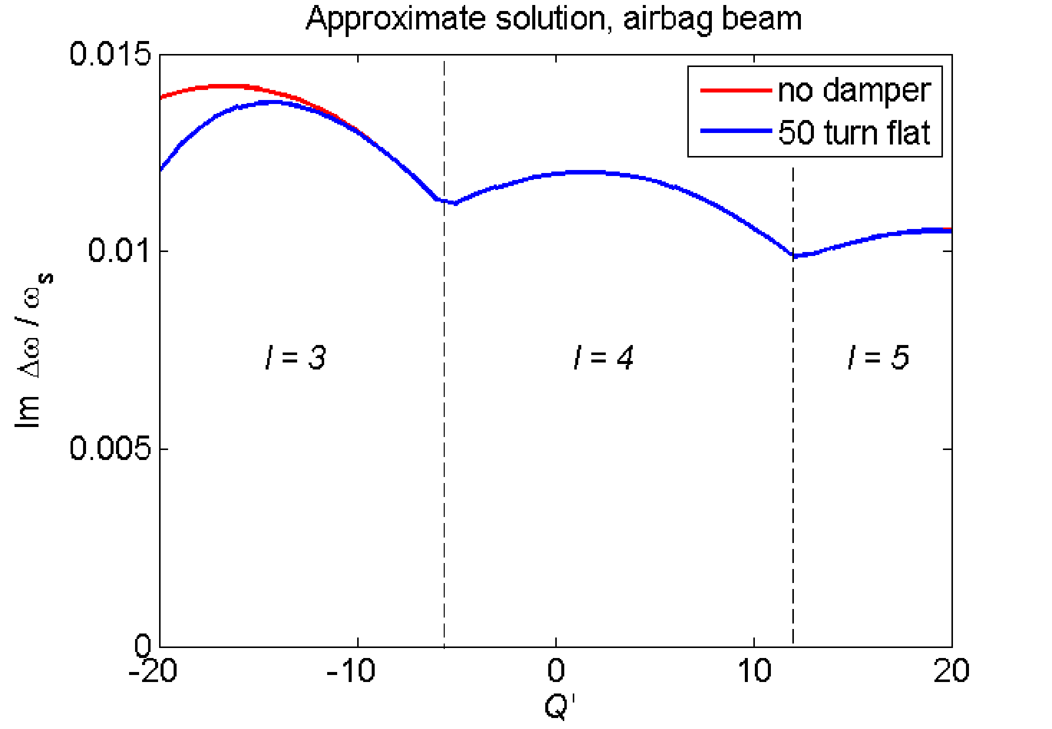


Neither chromaticity, nor flat damper can help

Flat damper:

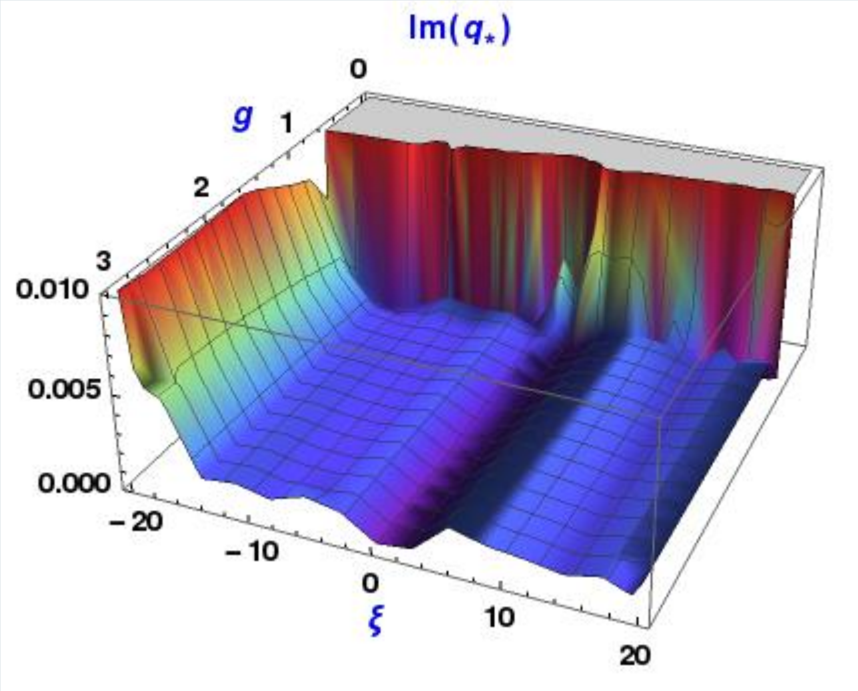
$$\Omega^{l} - \omega_{\beta} - l\omega_{s} \approx -i\frac{MN_{b}r_{0}c}{2\gamma T_{0}^{2}\omega_{\beta}}\sum_{p} Z(\omega')J_{l}^{2}(\omega'\tau - \chi) - igJ_{l}^{2}(\chi)$$

$$Z_{damp}(\omega) \propto \delta(\omega)$$

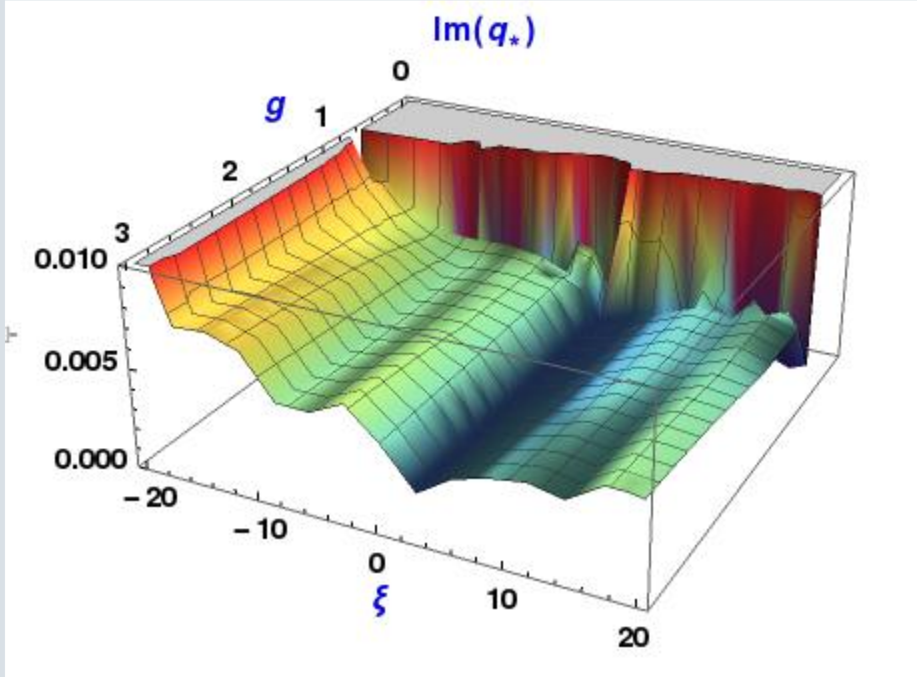


Crab HOMs significantly increase the instability growth rate for HL-LHC

WITHOUT THE CRABS

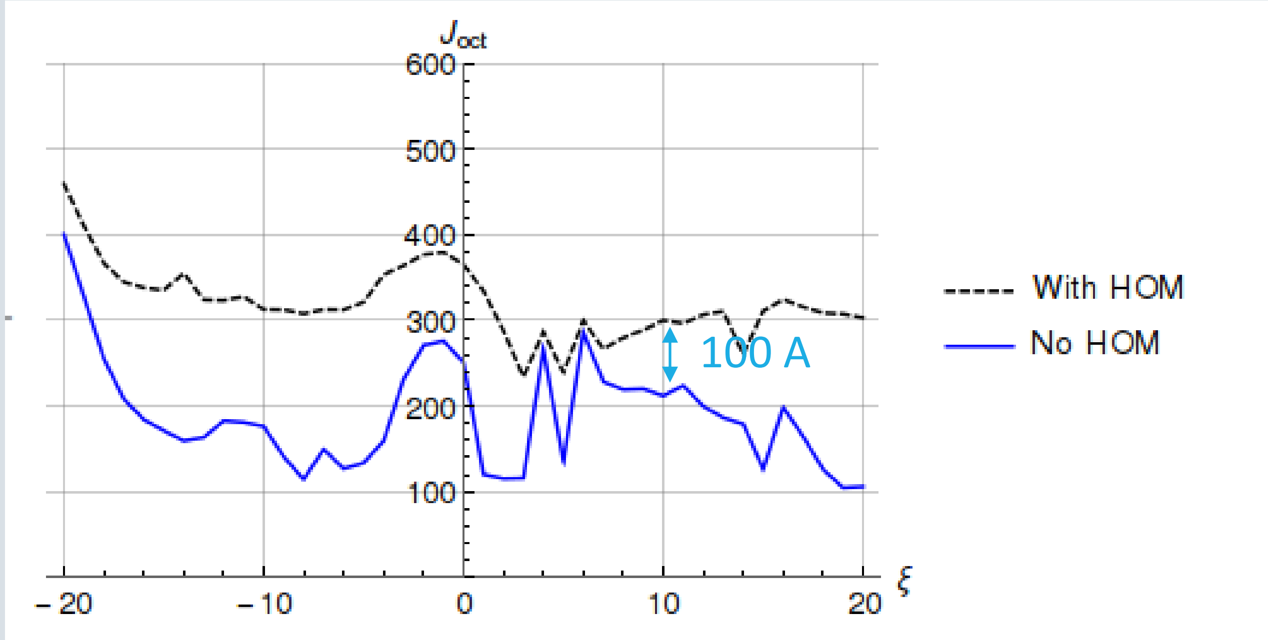


WITH 1 DOMINANT CRAB HOM



Need large additional octupole current to stabilize

ε_n = 2.0 μm, β^* = 15 cm, negative oct., Gaussian,
Mo+MoGr coating in IR7



Summary

High-impedance HOMs can drive a CB instability in HL-LHC

They excite multiple azimuthal intra-bunch modes
- Thanks to their high frequency
- Flat resistive damper and Q' are inefficient

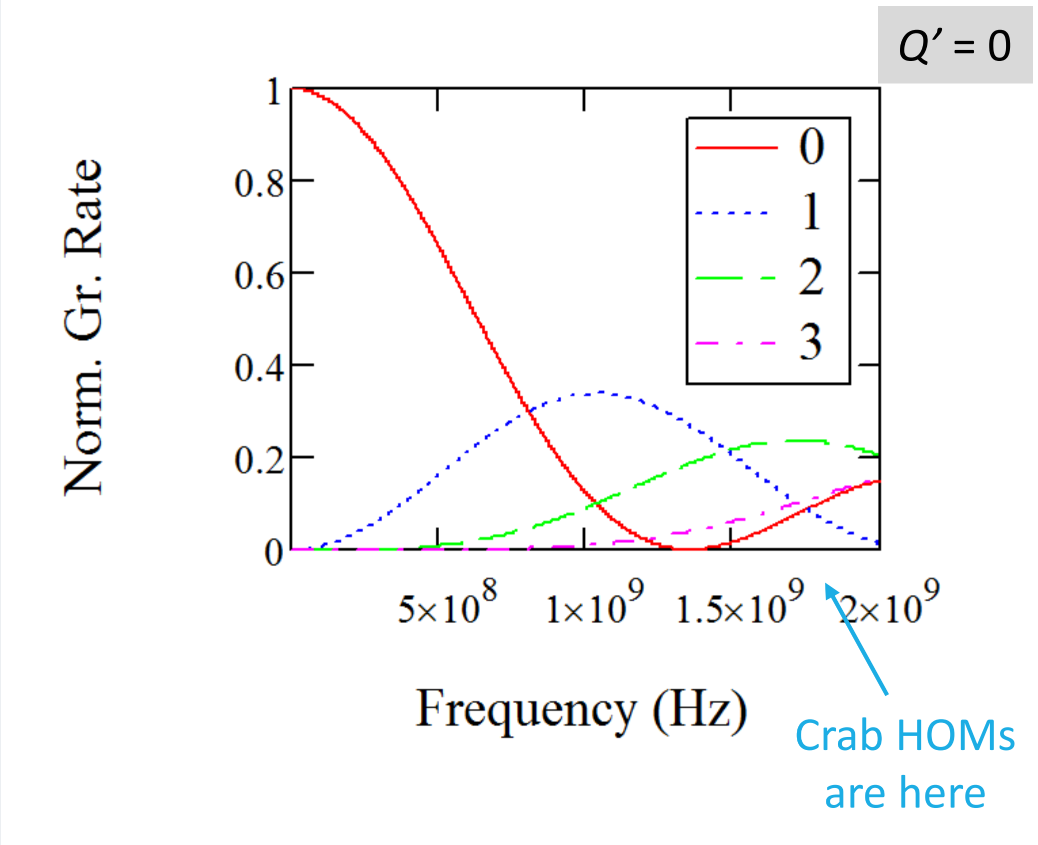
Might need additional octupole current ~ **100 A**

Possible ways to mitigate:
- Reducing mode impedance with new HOM couplers?
- Extra tune spread with an electron lens?
- Wideband feedback?
- Going to collision at a higher β^*

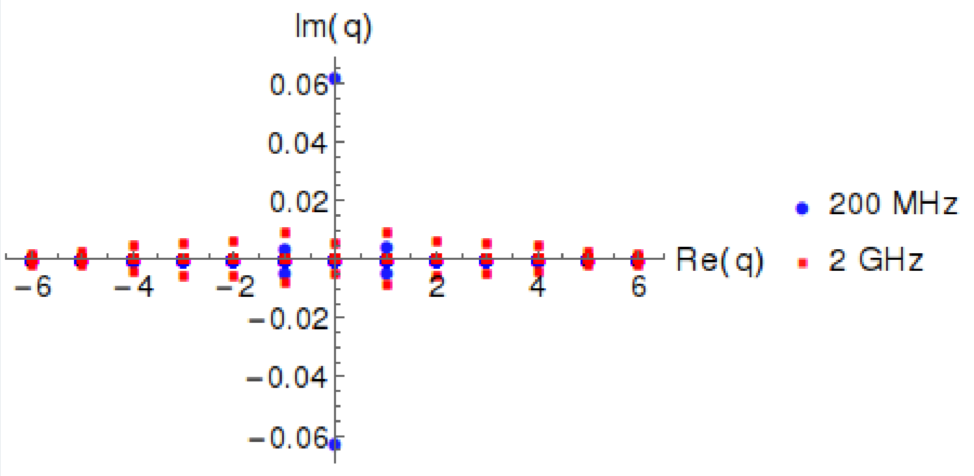
Thank you

BACK-UP SLIDES

At large frequencies many azimuthal modes excited; at lower frequencies – only the low-*l* ones

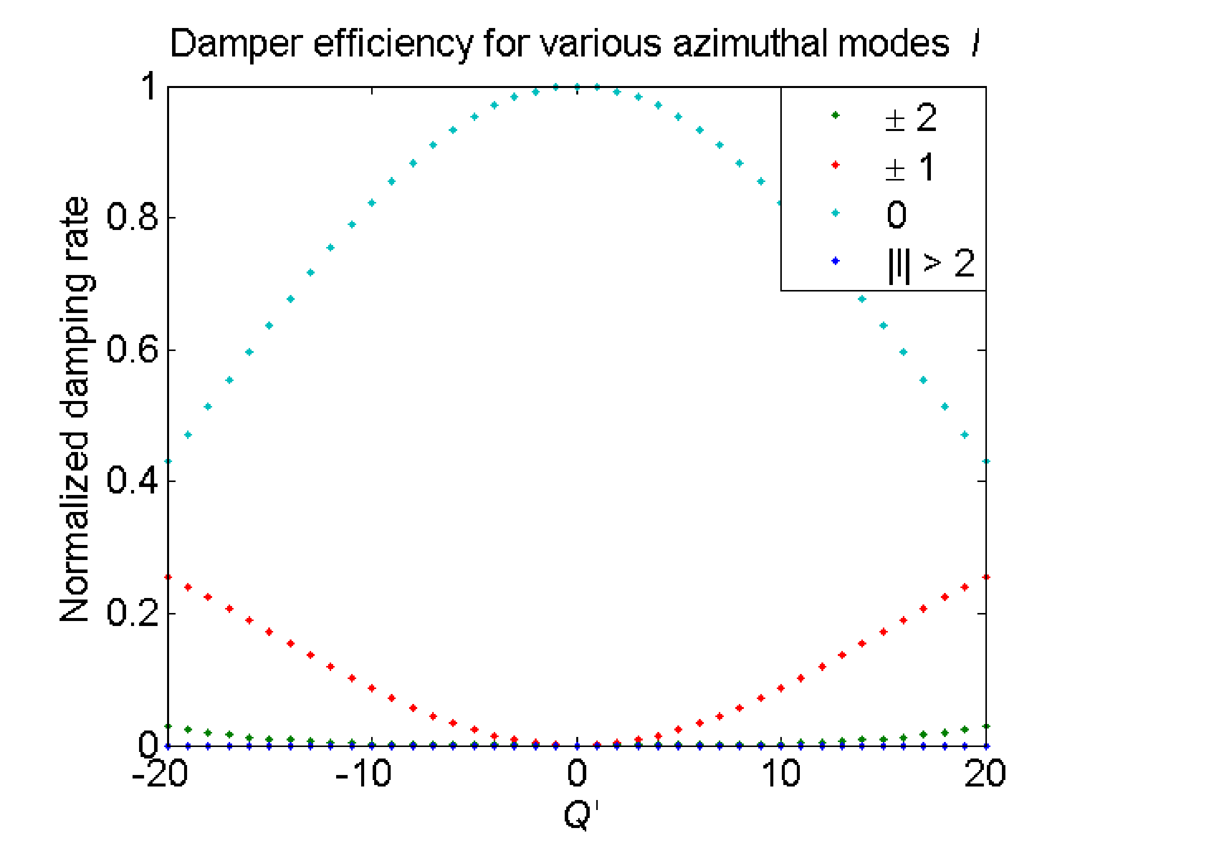


NHT Simulation: 2.3×10^{11} ppb, 1 HOM, Q′ = 0



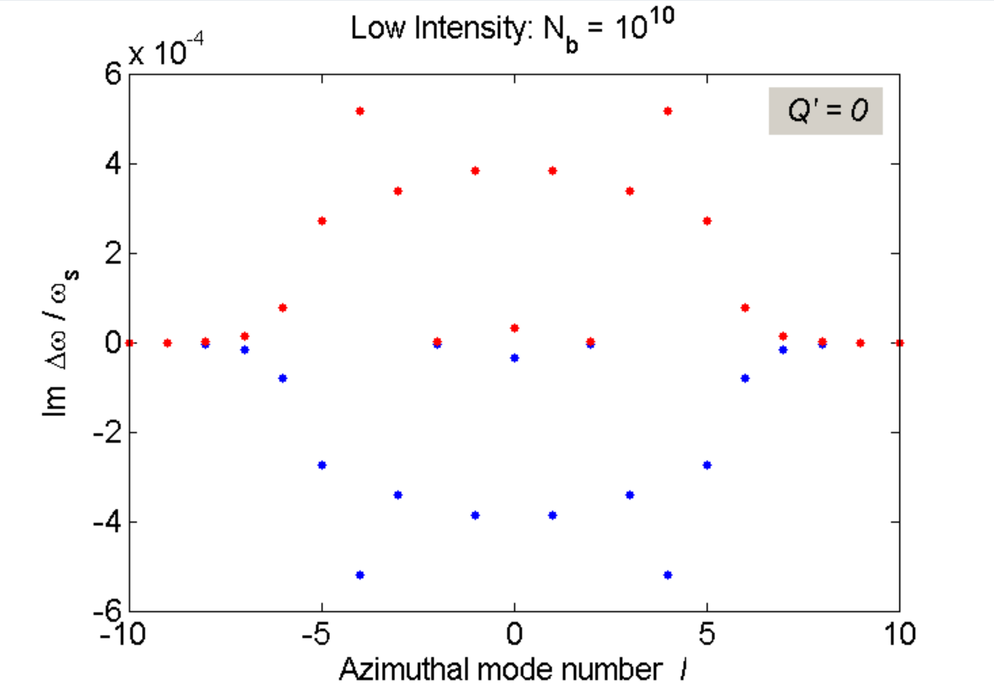
Comparison made keeping *f/Q* = *const*

Damper is not efficient for high azimuthal mode numbers

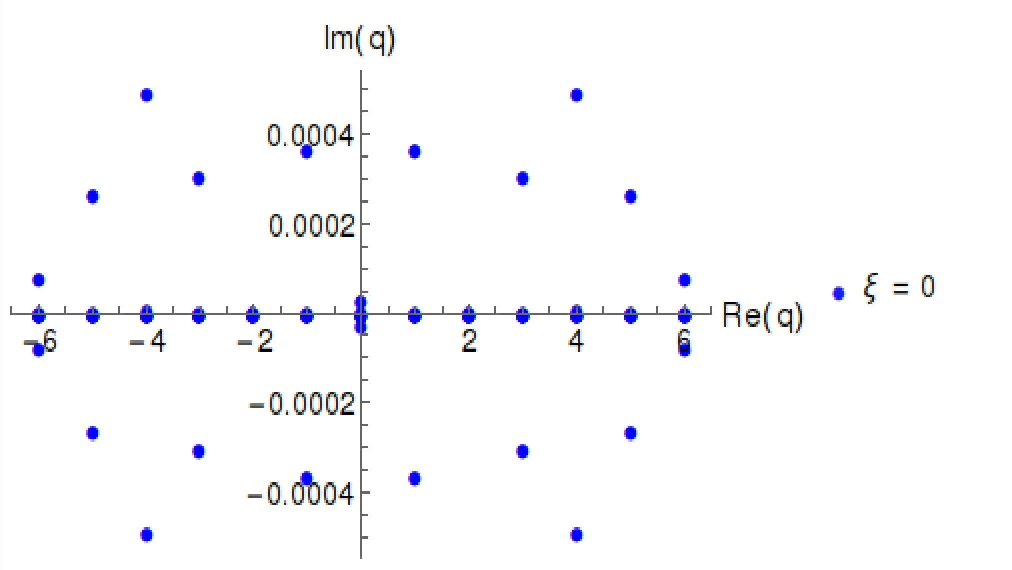


NHT agrees well with the approximate solution at low intensities: Q' = 0, no damper

APPROXIMATE FORMULA

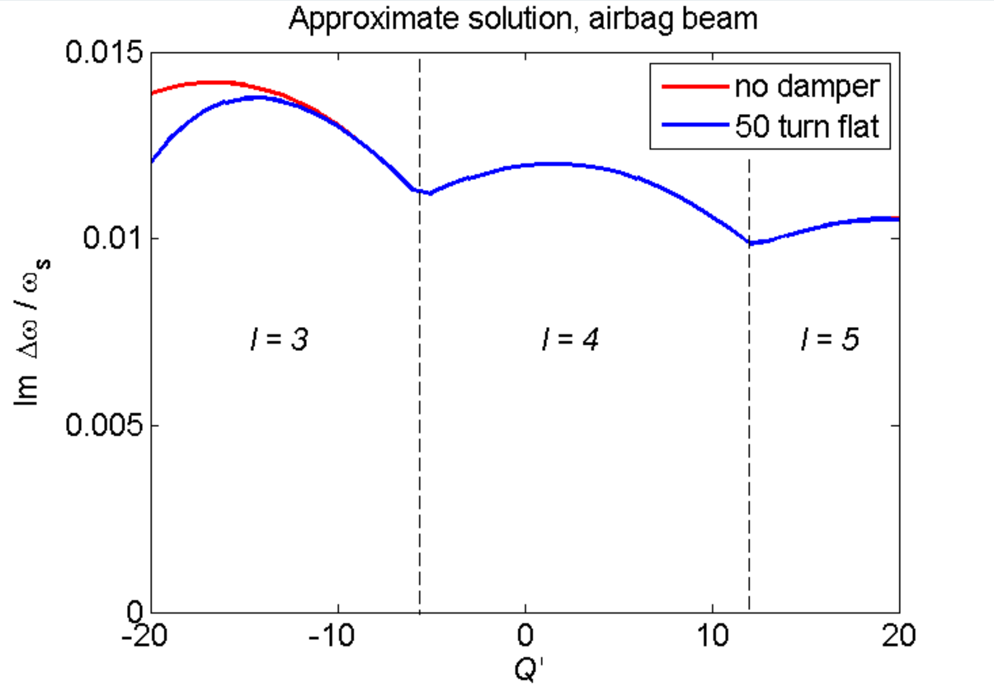


NHT: 5 RADIAL RINGS

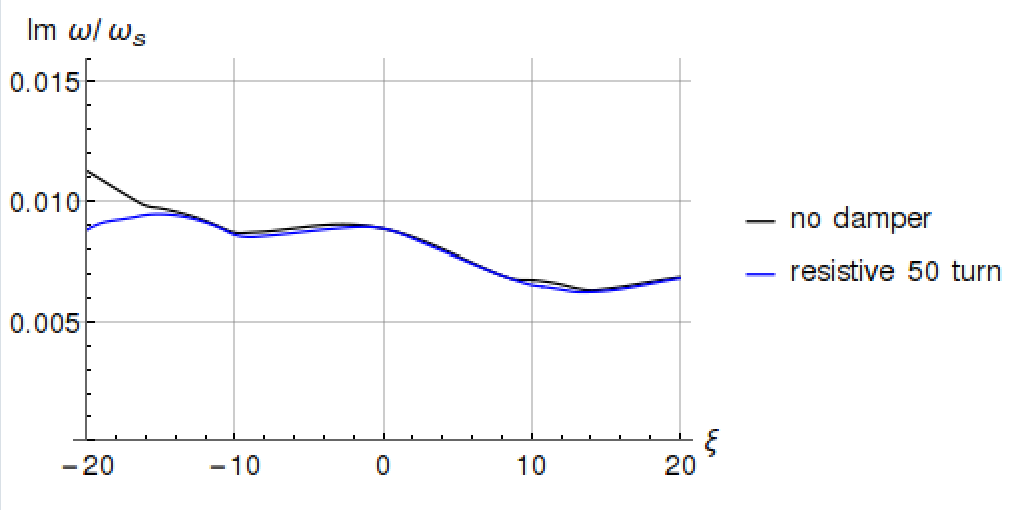


NHT agrees qualitatively with the approximate solution at higher intensities: 2.3x10^{11} ppb

APPROXIMATE FORMULA



NHT: 5 RADIAL RINGS



DELPHI shows that the *l* = 0 mode is the most critical

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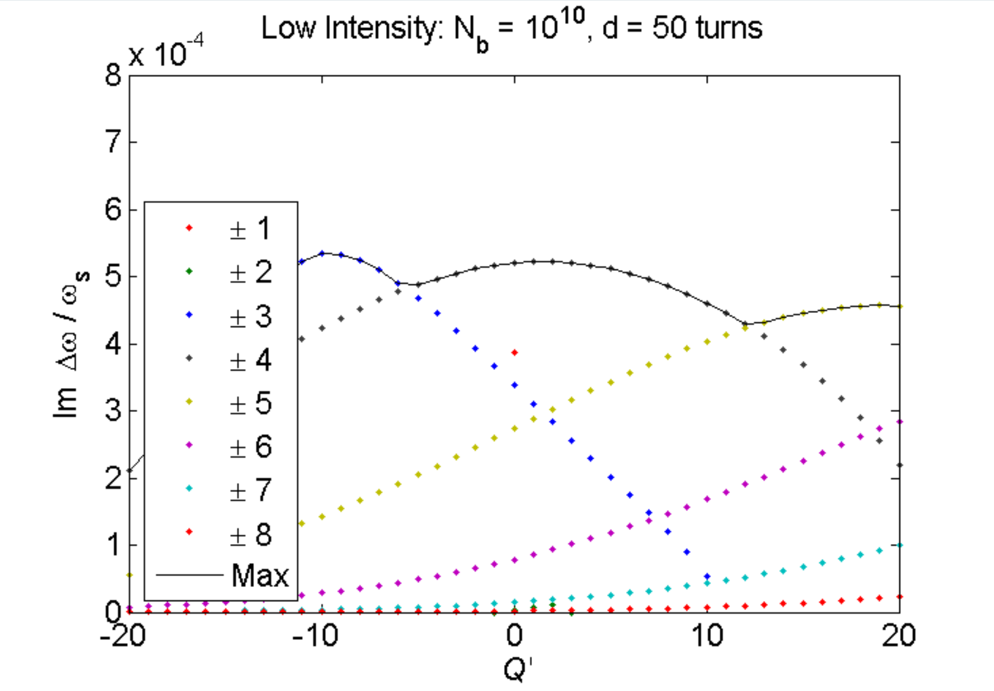
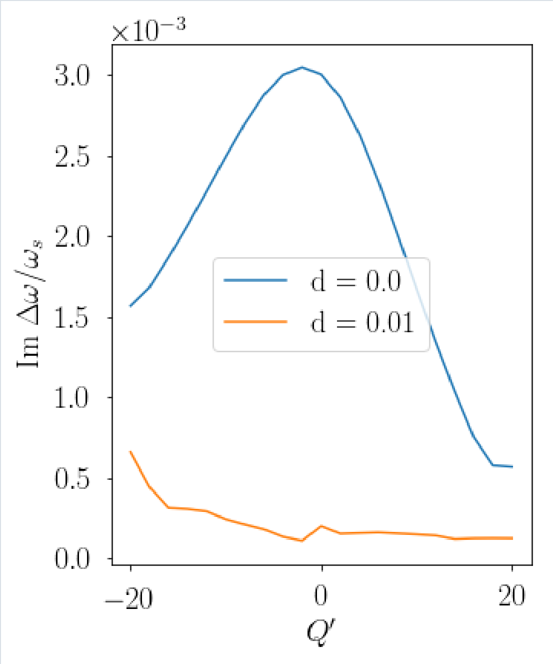


DELPHI

Growth rate



Tune shift