Arbitrary filling patterns in NHT

S. ANTIPOV

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MANY THANKS N. BIANCACCI, G. IADAROLA, C. ZANNINI

NHT assumes equidistant bunches

Eigenvalue problem:

RF well Imp Damp CB

$$\frac{\Delta\omega}{\omega_s}X = SX - iZX - igFX + CX,$$

Flat wake approximation:

$$C^{\mu}_{lm\alpha\beta} = W^{\mu}F_{lm\alpha\beta}$$

$$F = \frac{i^{m-l}}{n_r}J_l(\chi_\alpha)J_m(\chi_\beta)$$

Equdistant bunches:

$$W^{\mu} = 2\pi\kappa\sum_{k=1}^{\infty}W(-ks_0)\exp(2\pi i\nu_{k\mu}) \qquad \mu = 0, \ldots M-1,$$

$$\nu_{k\mu} = k(\mu+\nu)/M$$

?

Need to solve for couple-bunch eigenmodes:

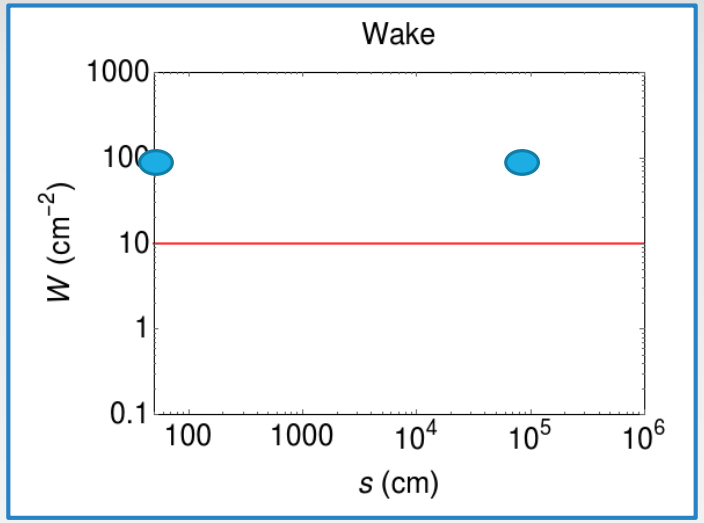
$$w^{\mu}Y^{\mu} = (W - igG)Y^{\mu}$$

- Addding up conventional and damper wakes
- Ideal feedback – last term is a diagonal matrix and can be taken out

$$W^{\mu} - ig \rightarrow w^{\mu}$$

Benchmarking on 2 bunches: Constant wake - OK

SINGLE TURN COSTANT WAKE

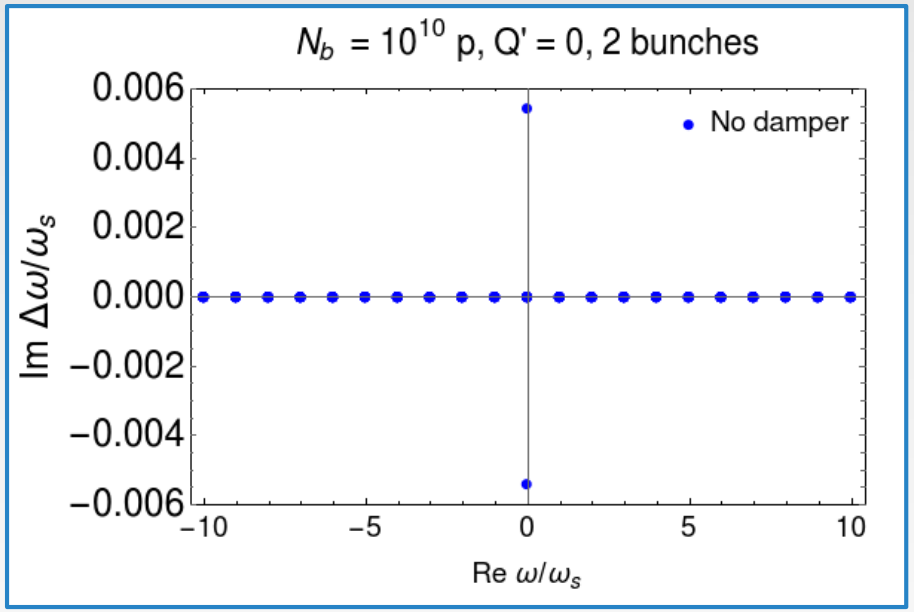


$$\begin{pmatrix} 0 & W_0 e^{-i\phi_{12}} \\ W_0 e^{-i\phi_{21}} & 0 \end{pmatrix} \rightarrow \Delta\omega/\omega_s = \pm 2\pi\kappa W_0 e^{\pi i Q}$$

see for example A. Chao Eq. (5.25)

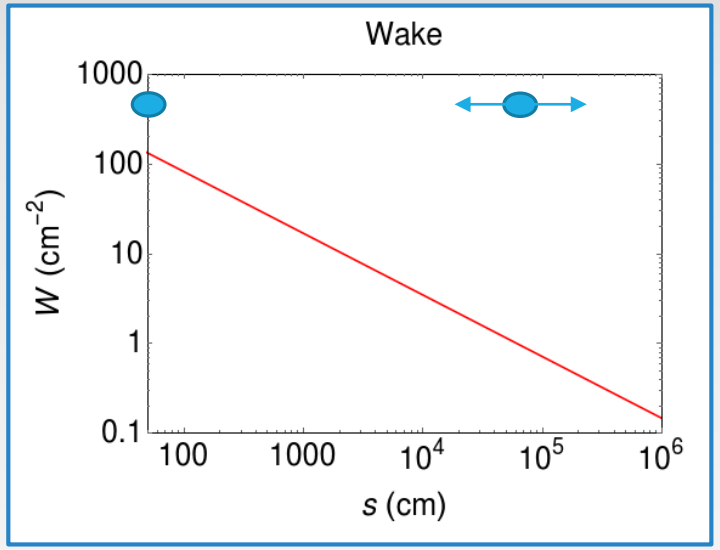
MATCHES THE EXACT SOLUTION

0.0054 vs 0.0054



Benchmarking on 2 bunches: Realistic wakes - OK

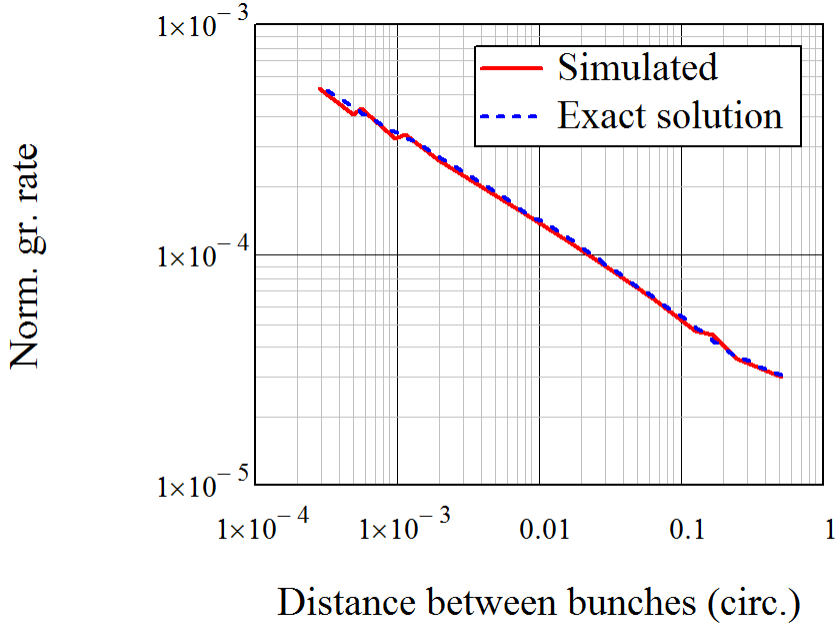
MULTITURN RESITIVE WALL



$$2\pi\kappa \begin{pmatrix} W_{11} & W_{12} \\ W_{21} & W_{22} \end{pmatrix}$$

$$W_{ij} = \sum_{k=1}^{\infty} W(s_i - s_j + kC) \exp[-i\phi_{ij} - 2\pi i k Q]$$

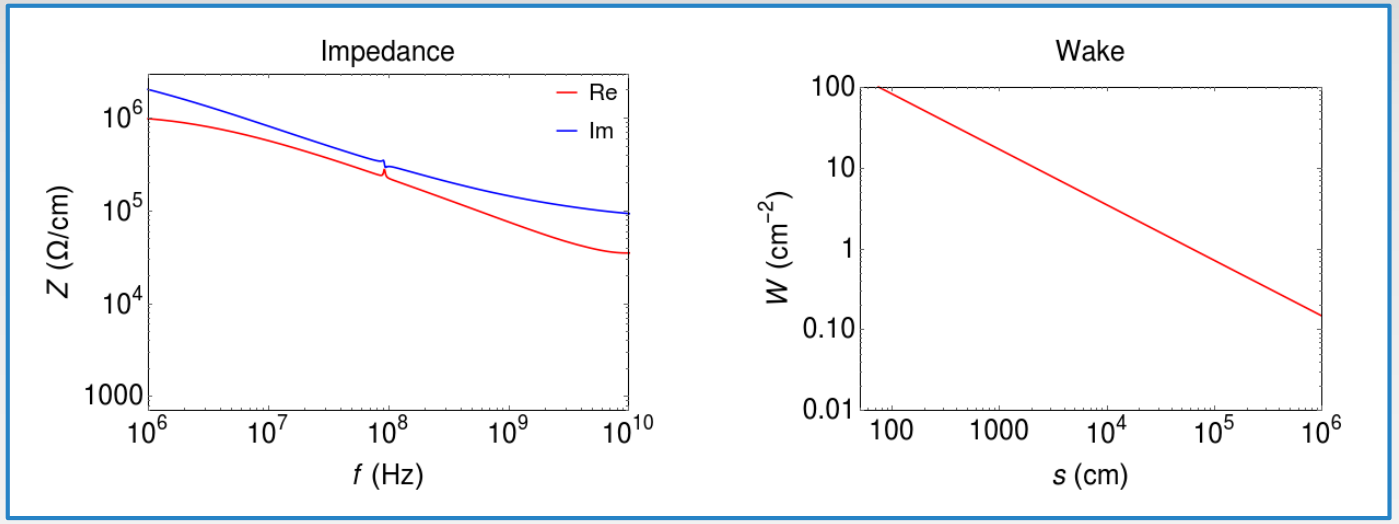
MATCHES THE EXACT SOLUTION



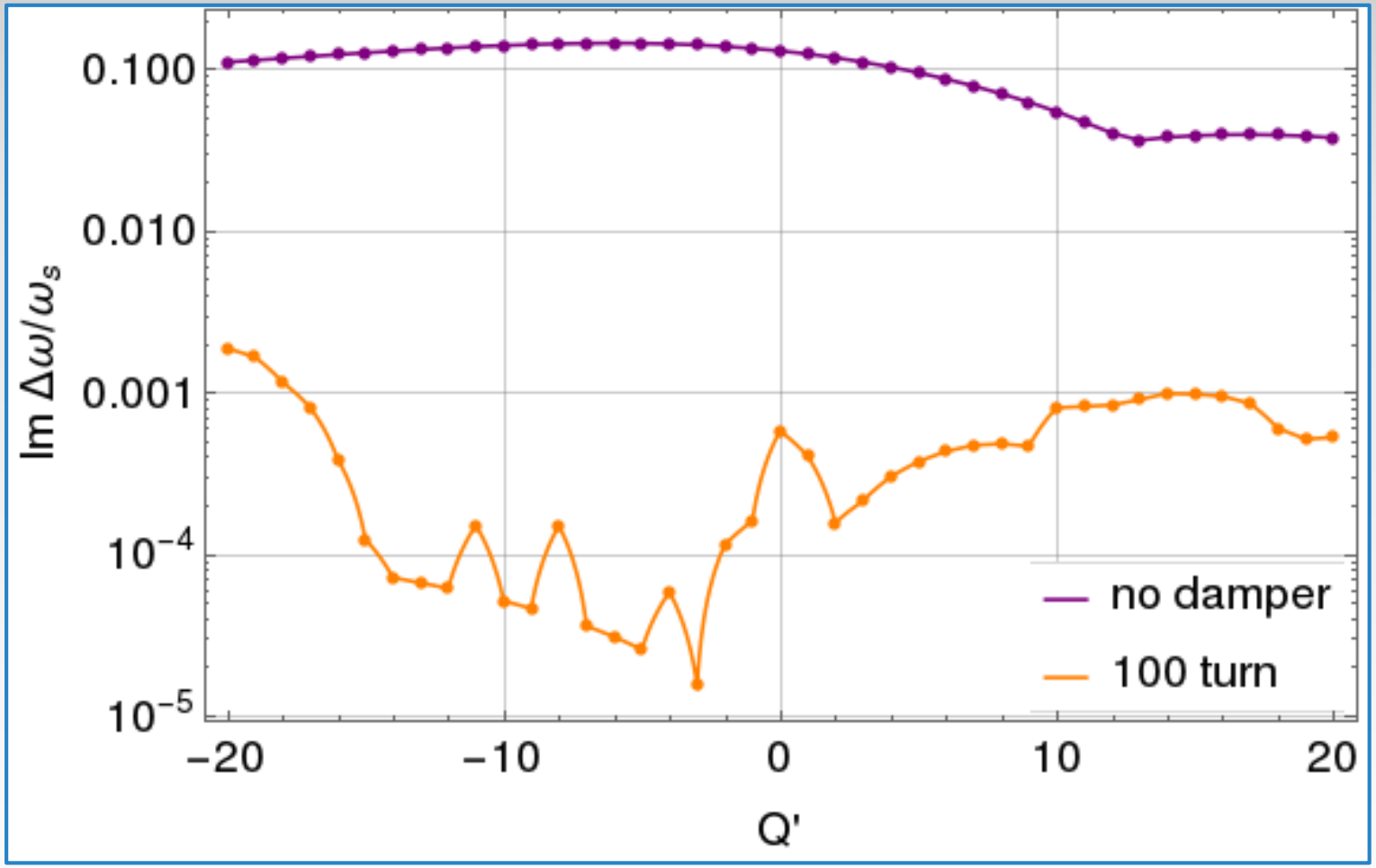
LHC benchmark: Equidistant bunches

E	6.5 TeV
Q_x	62.31
Q_s	0.002
Q’	-20… +20
σ_s, rms	7.5 cm
N_b	1 x10^{11} pbb
N bunches	3564
Spacing	25 ns
Damper	100 turn

2015 Wake and impedance model

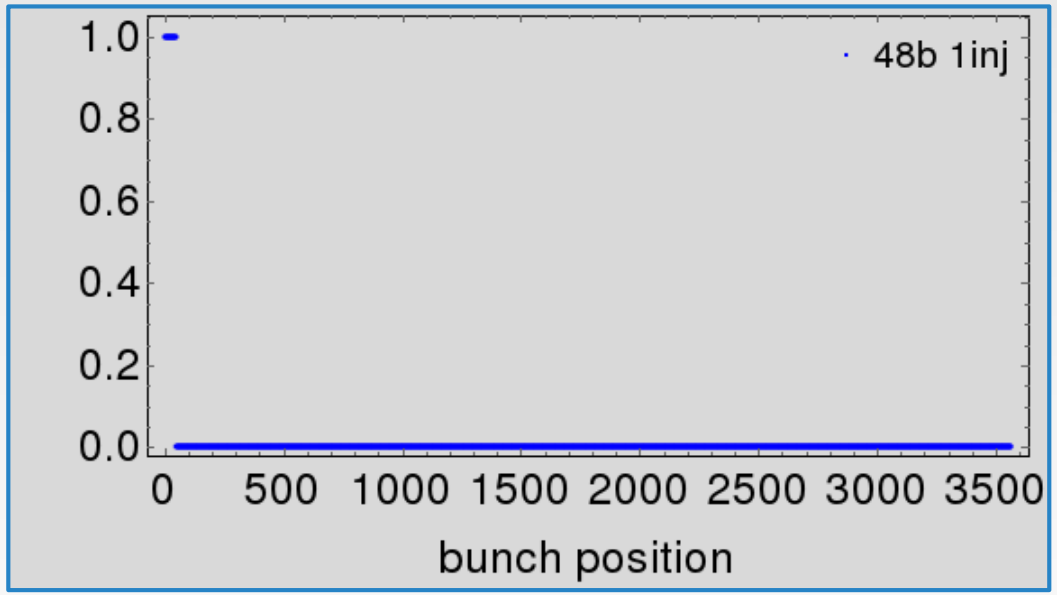


LHC benchmark: Equidistant bunches - OK

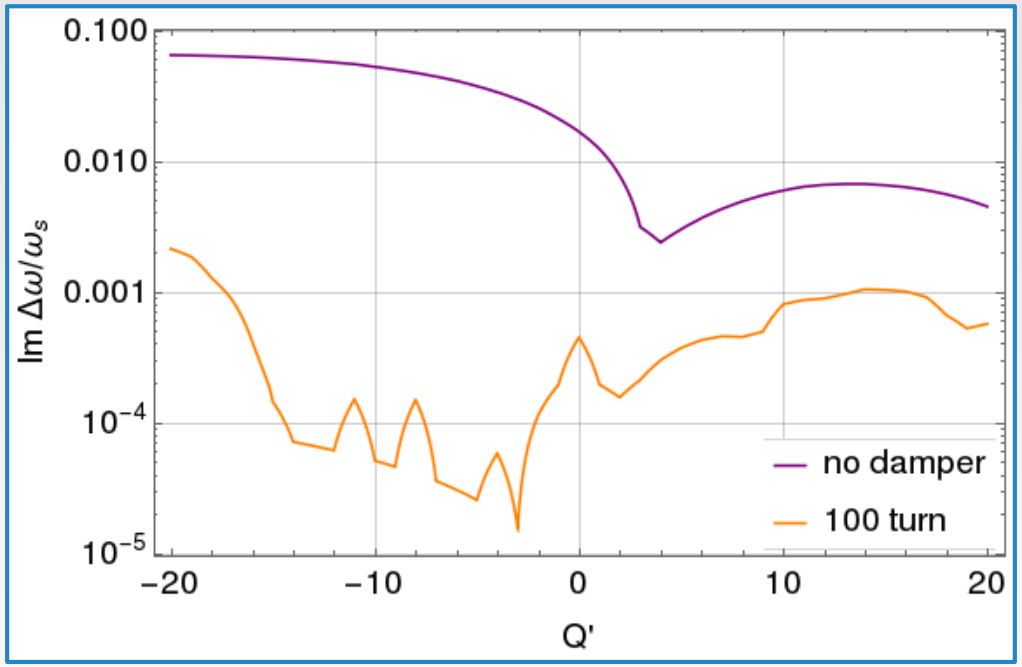


LHC: Increasing number of bunches

FILLING SCHEME



GROWTH RATE



LHC: Increasing number of bunches

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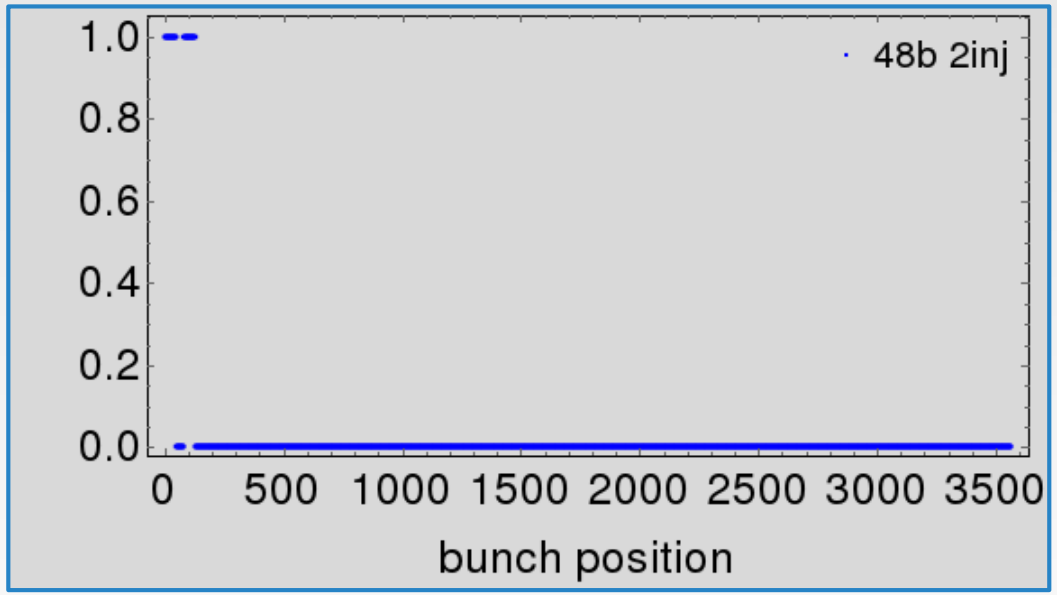

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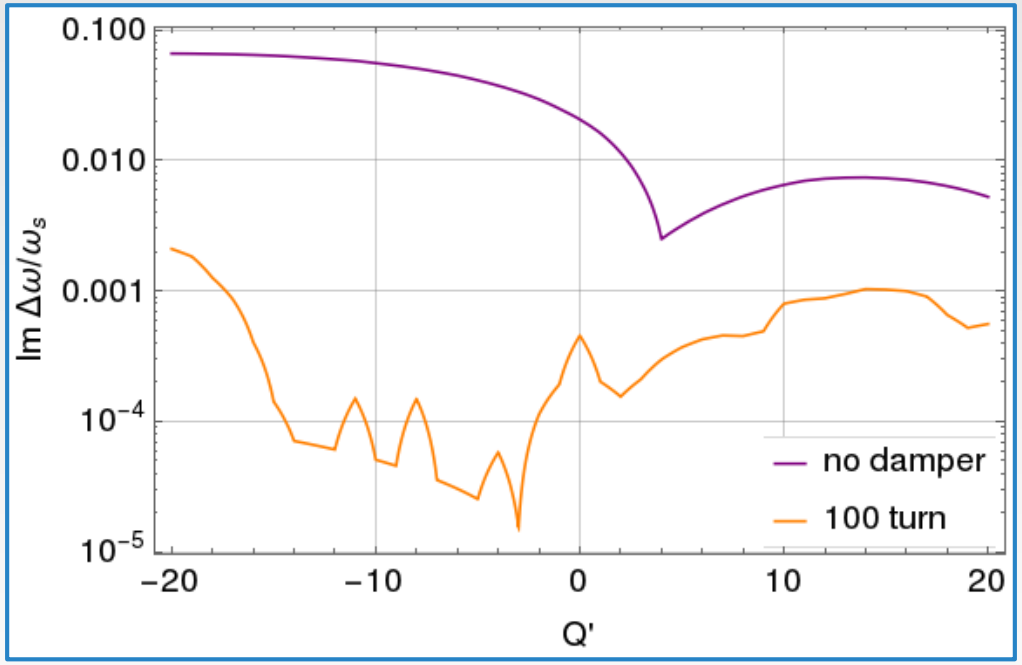

LHC: Increasing number of bunches

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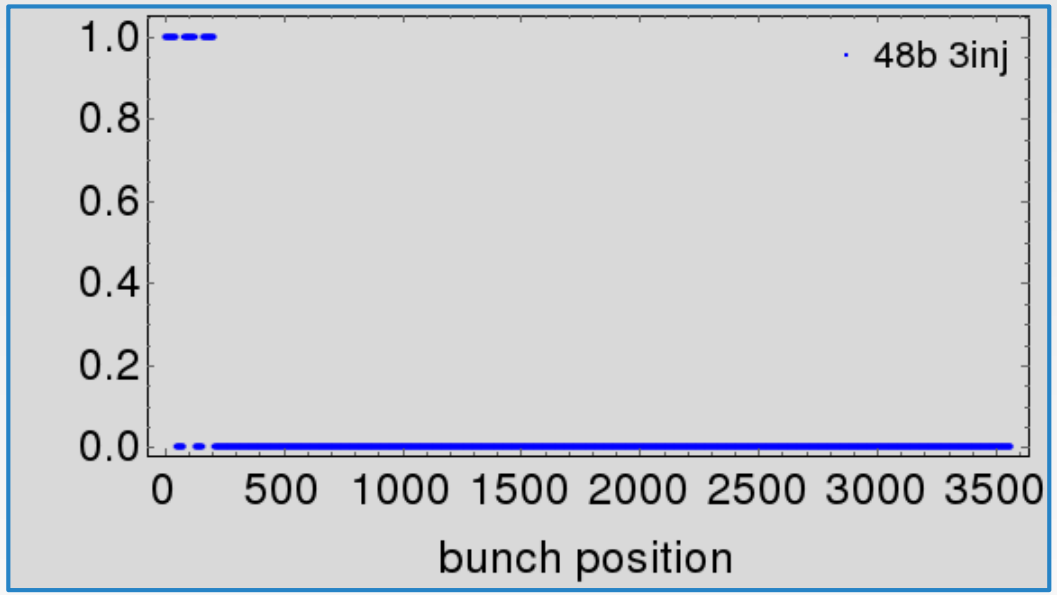

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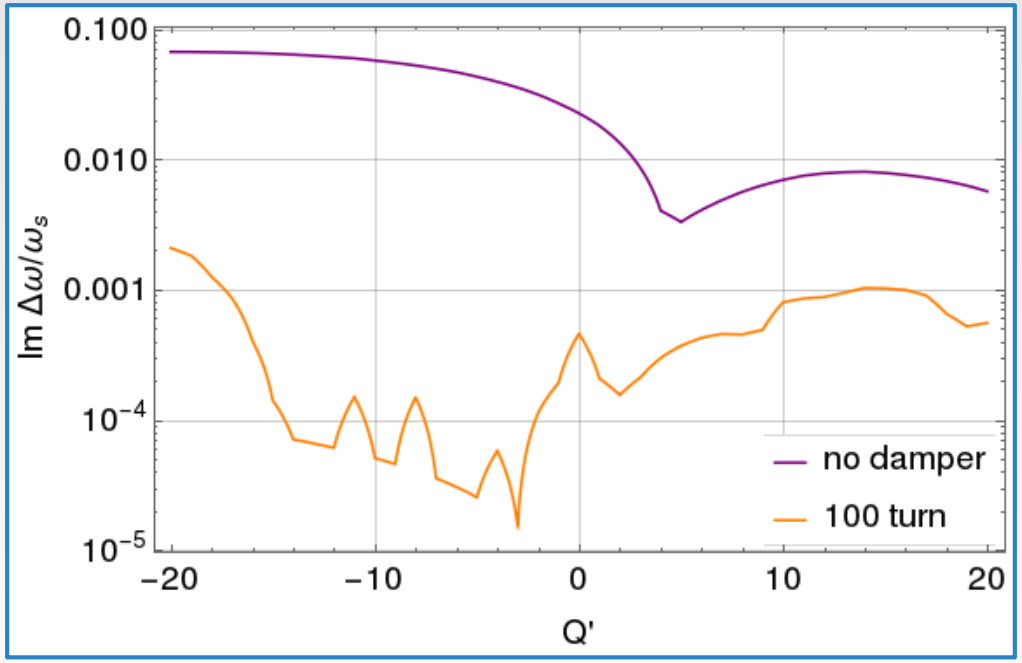

LHC: Increasing number of bunches

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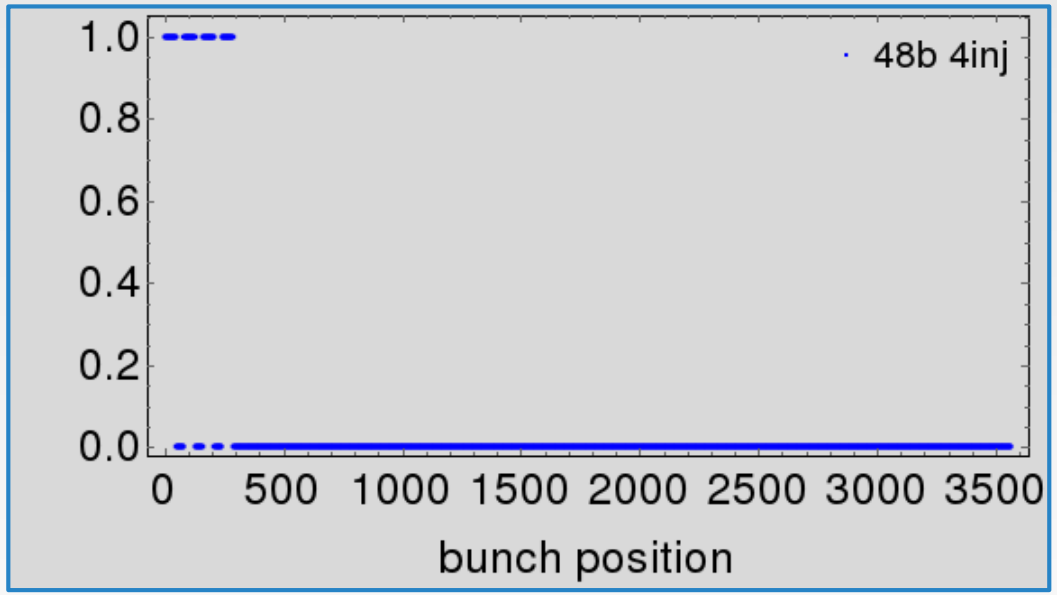

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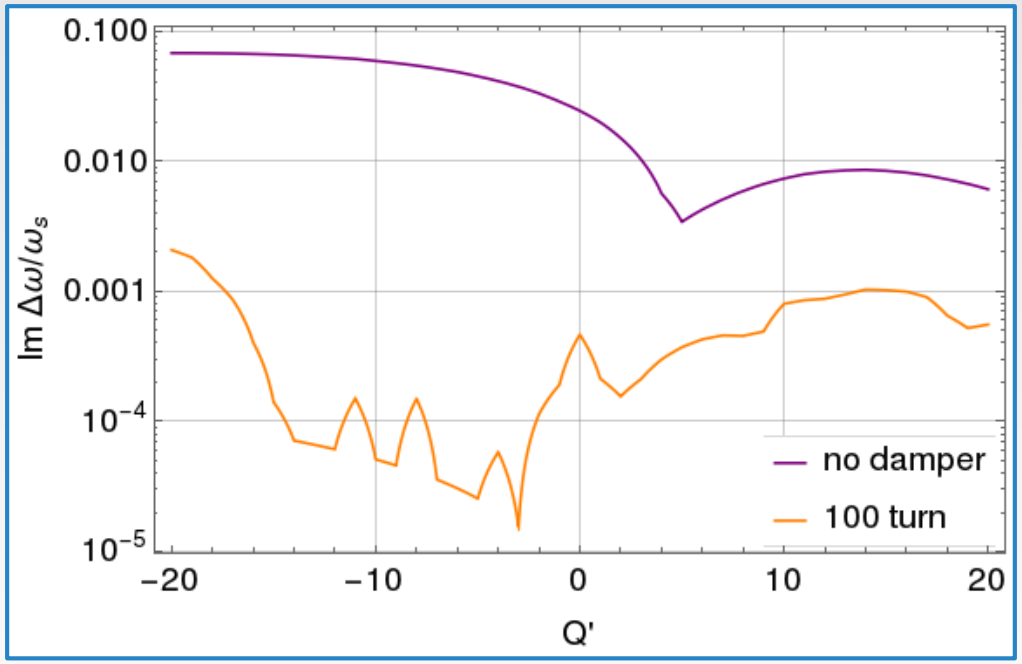

LHC: Increasing number of bunches

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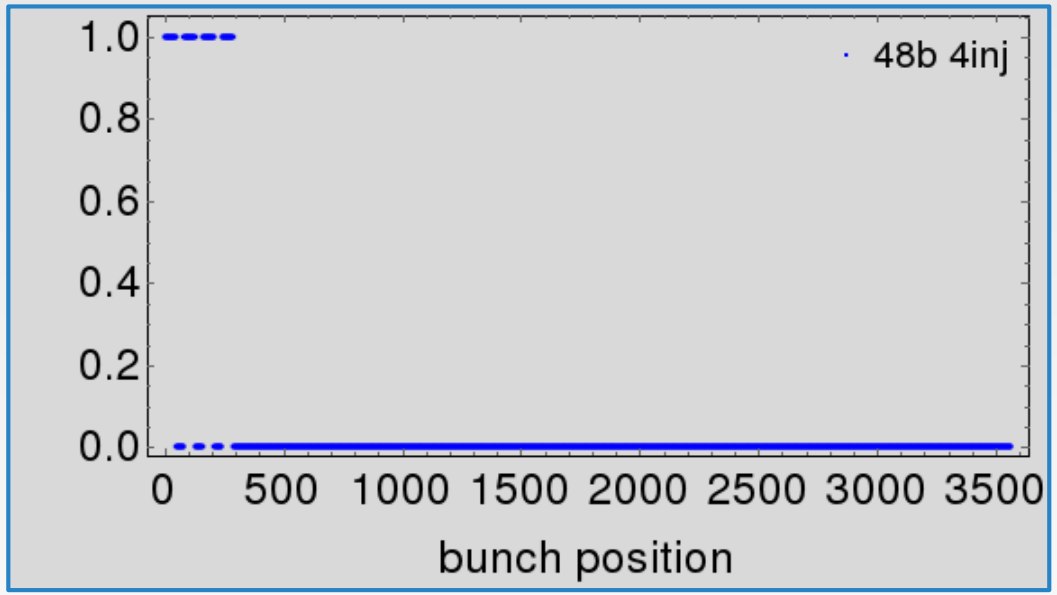

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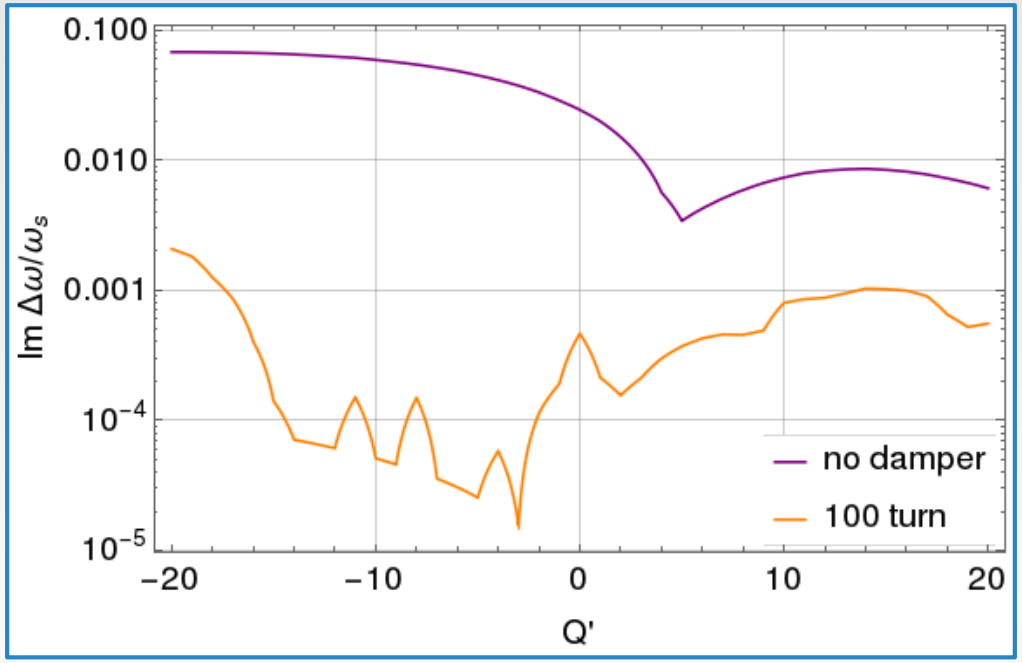
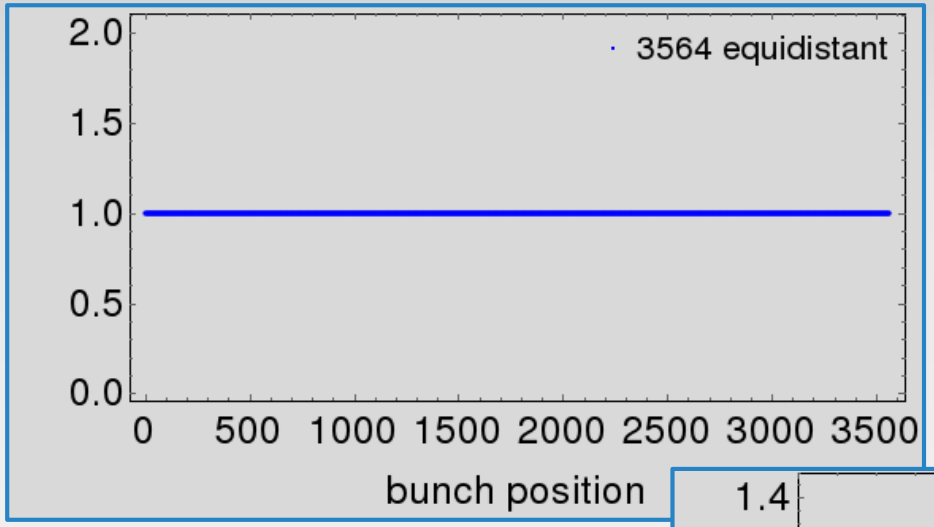
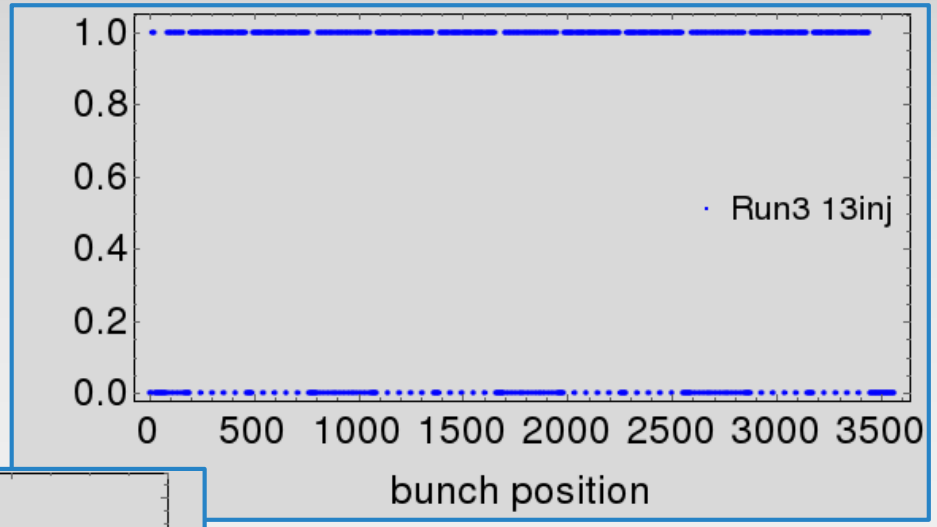
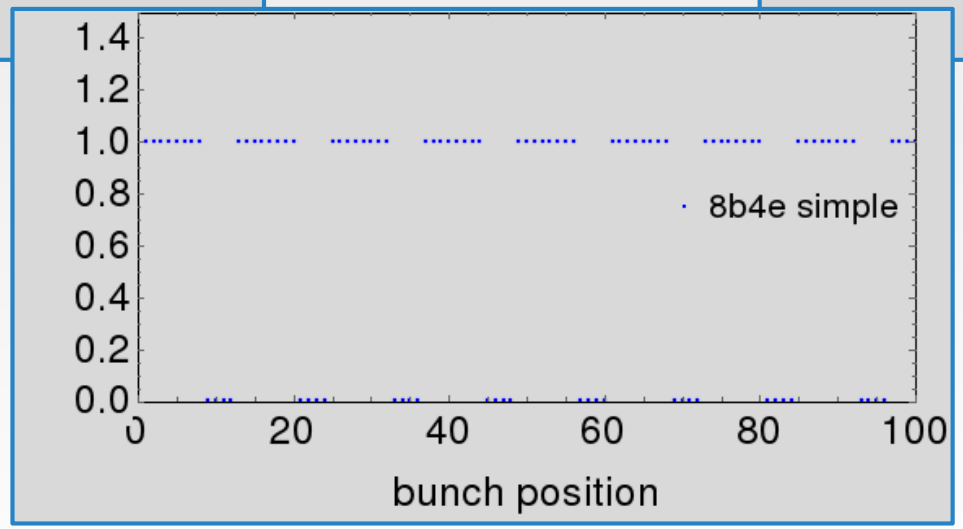


No big difference as long as the transverse feedback is on

LHC: Comparing filling schemes



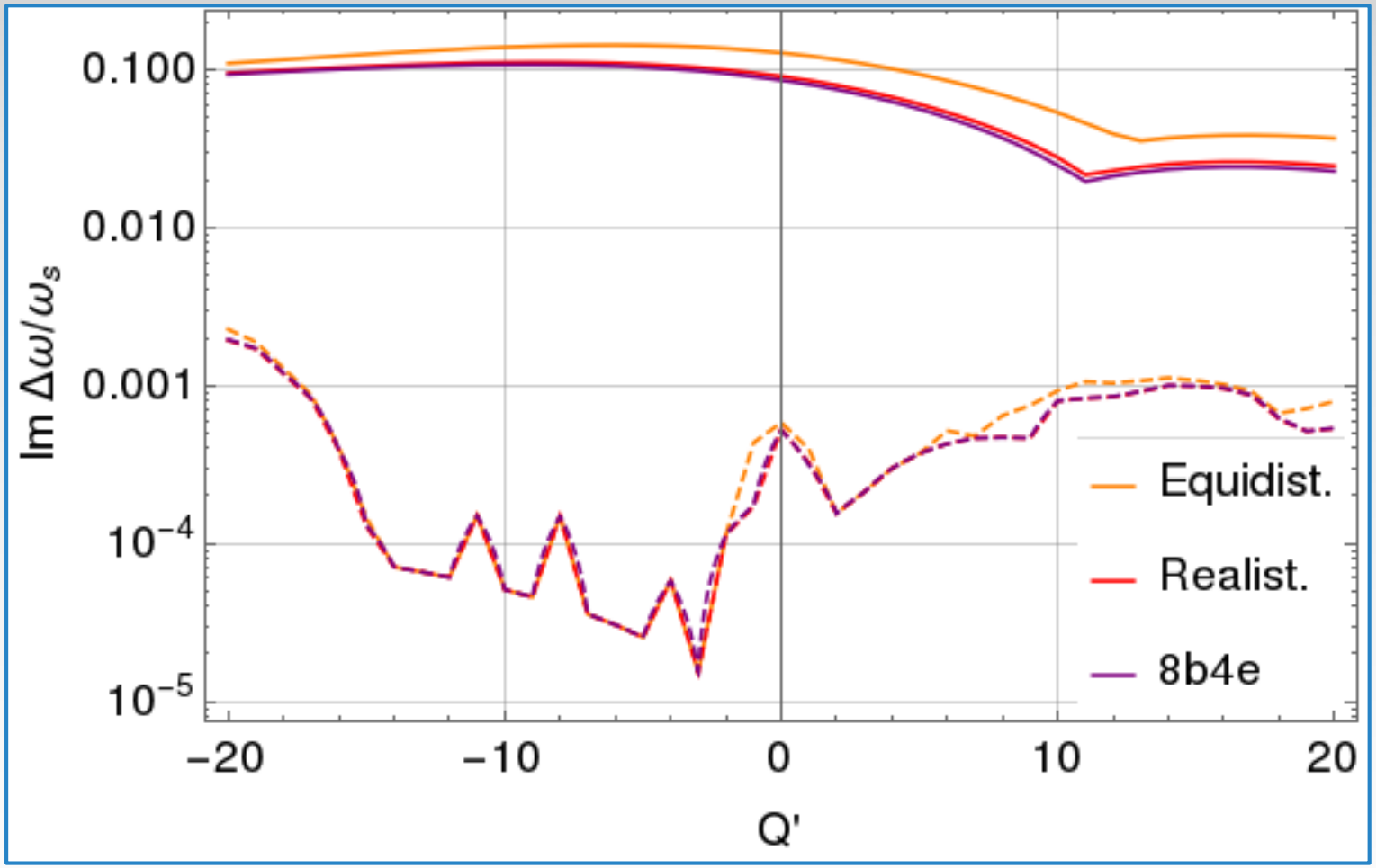




Thanks Gianni for providing the filling scheme!

1-10 sec per filling scheme

No significant difference for different fillings schemes in LHC with damper



Conclusion

NHT has a capability of simulating any filling patterns

- Assuming flat CB wakes

No significant difference in growth rates observed for LHC

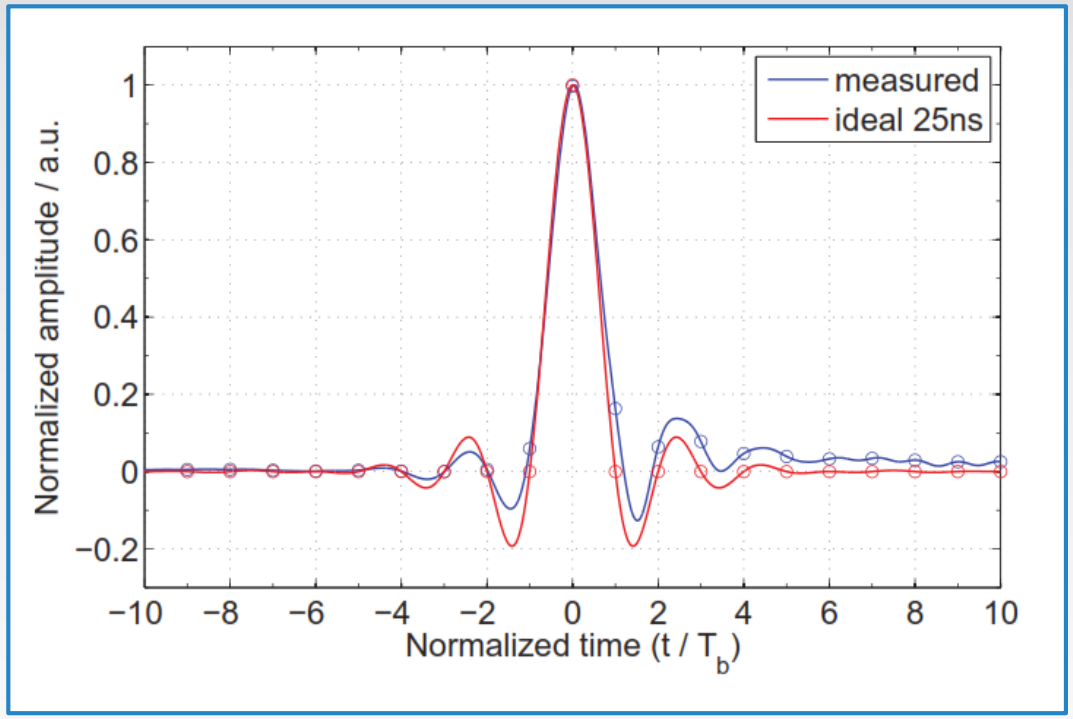
- Might be more critical when being close to intensity threshold (see backup)

Work in progress – add a realistic damper

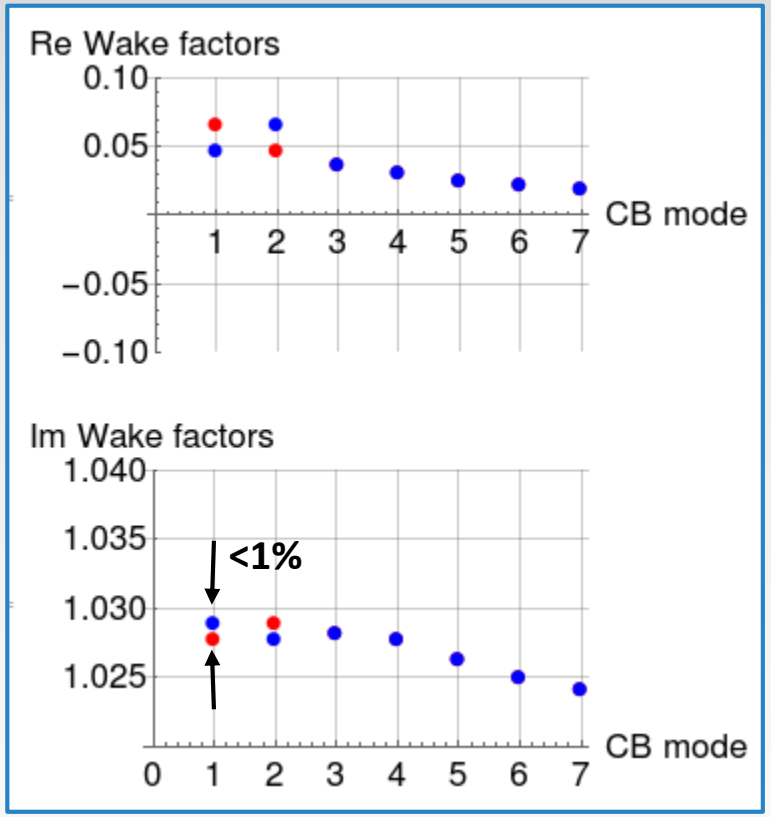
- In contact with W. Hoffle and D. Valuch

LHC: Realistic vs ideal feedback

Feedback kick leacks into
the bunches behind and in the front



W. Hofle *et al., IPAC'13*

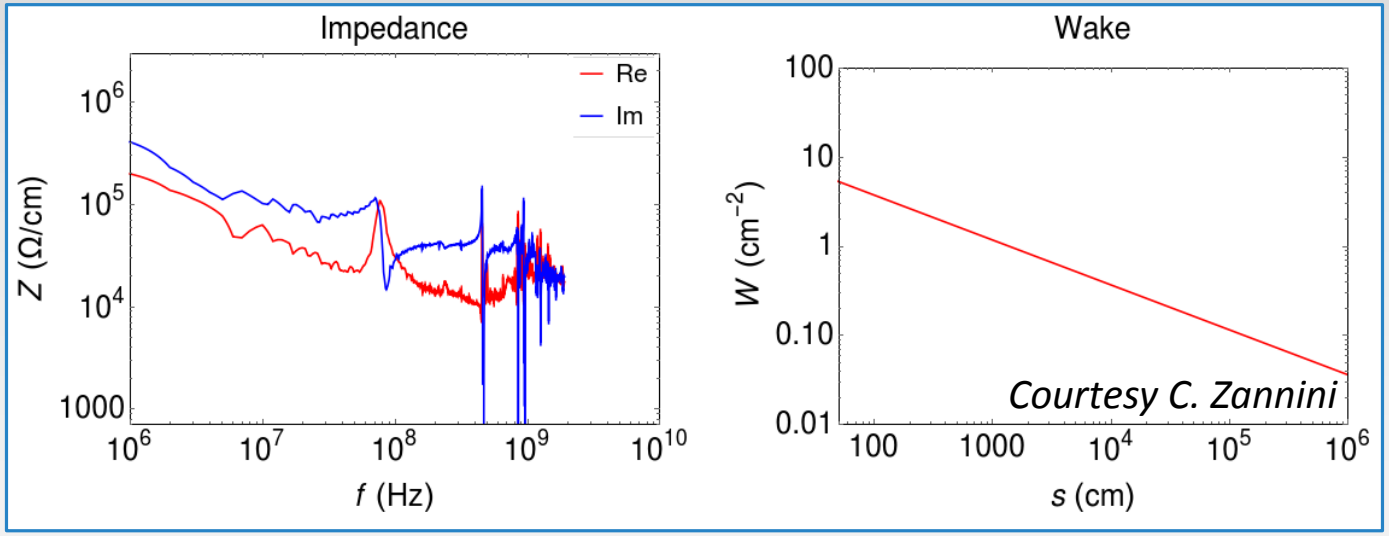


SPS: Study parameters

E	25 GeV
Q_x	**20**.13
Q_s	0.016875
Q’	4
σ_s, rms	22.5 cm
N_b	0-4 x10^{11} pbb
N bunches	1, 48, 2x48, 3x48, 4x48
Spacing	25 ns, 200 ns
Damper	30 turn

Q20 Impedance

RW wake

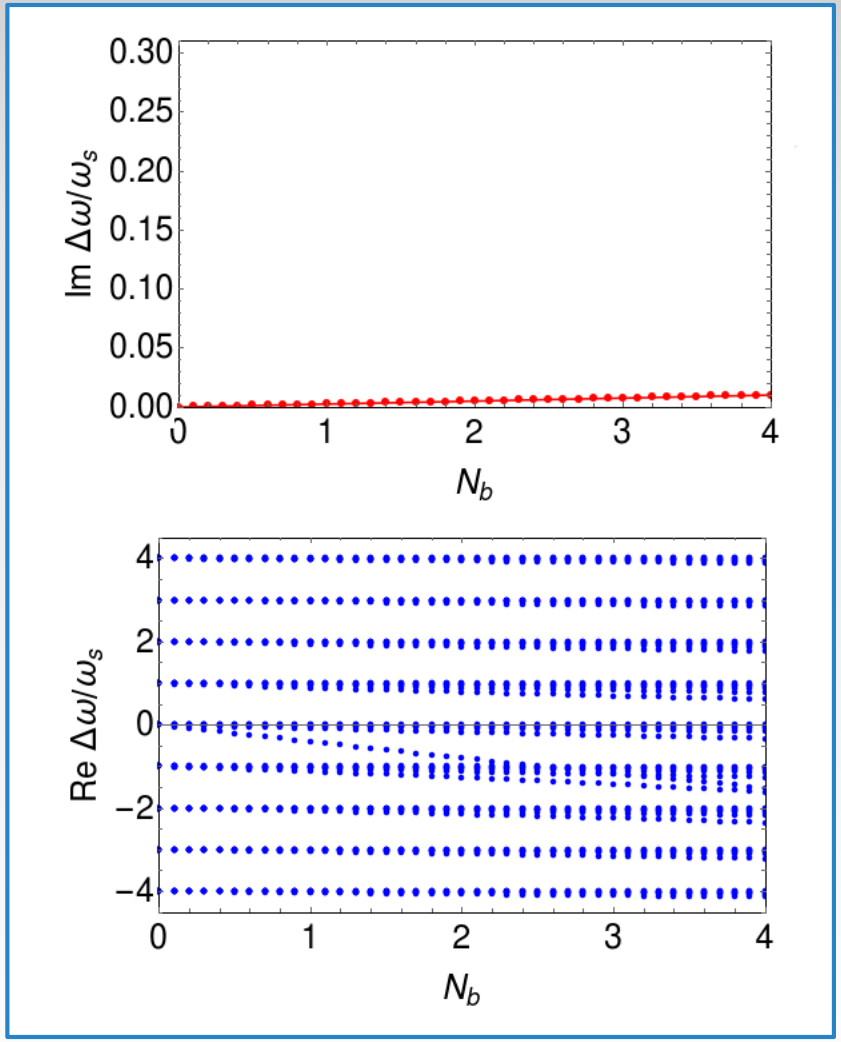


SPS: No coupling at Q'= 4
Destabilizing effect of transverse feedback

1 bunch

Q' = 4

Damper on



SPS: CB seems to bring back the coupling

48 bunches

Q’ = 4

Damper on