Combined effect of beam-beam interaction and longitudinal beam coupling impeance

Self-consistent simulations of beam-beam interaction in future e^+e^- circular colliders including beamstrahlung and longitudinal coupling impedance

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Combined influence of beamstrahlung and coupling impedance on beam energy spread and length in future lepton colliders

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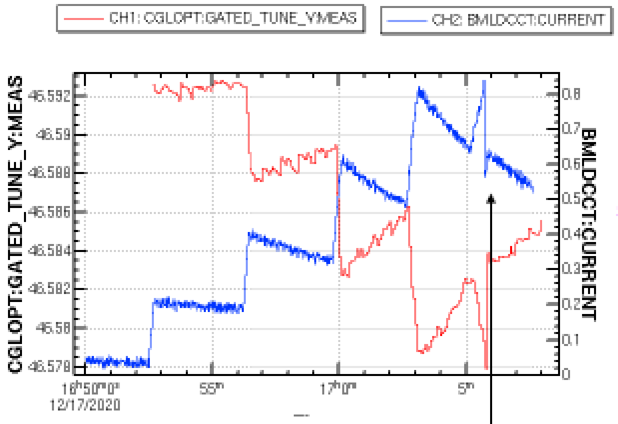
Other Factors Affecting Luminosity

1. Electron cloud (beam size blow up, tune spread)
2. Lattice Nonlinearities
3. Ions of residual gas (incoherent effects, trapped ions, fast ions)
4. Wake fields (single and multibunch effects)
5. Gap transients (different bunch synchronous phases)
6. Feedback noise (and also in other devices)
7. Low lifetime (not enough time for fine tuning)
8. Space charge effects
9. Touschek scattering
10. Other effects

Presented at IPAC2010

Single Bunch Tune Shift and TMCI in LER (2020c)

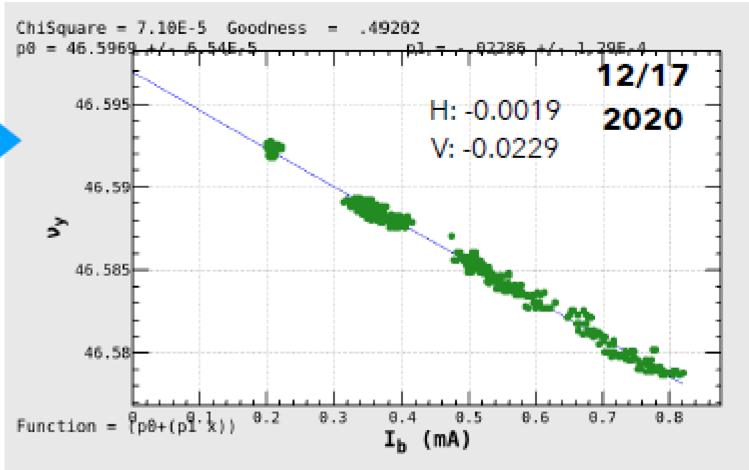
vert. tune



single bunch current

Tune shift is same as synchrotron tune

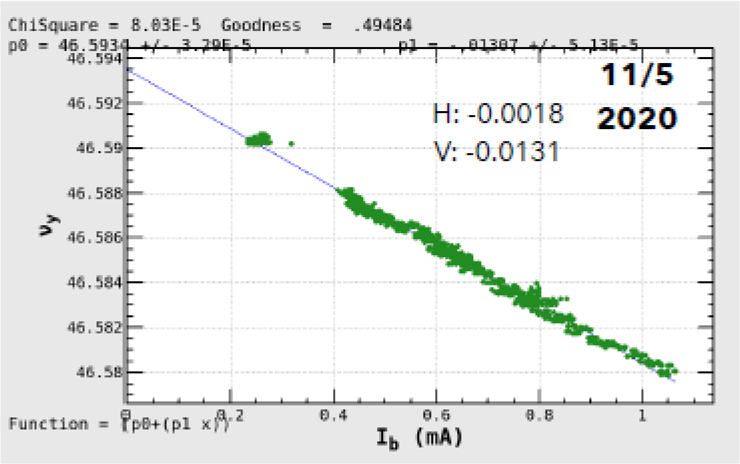
$\nu_s = -0.0235$



Beam current can not be stored larger than 0.8 mA/bunch.

2020	11/5	12/17
D02V1 (mm)	1.52 / 1.2 (1.36)	1.68 / 1.2 (1.44)
D03V1 (mm)	2.0 / 1.98 (1.99)	0.68 / 1.38 (1.03)
D06V1 (mm)	3.2 / 3.2 (3.2)	2.7 / 1.2 (1.95)
D06V2 (mm)	2.2 / 1.9 (2.05)	2.28 / 1.85 (2.07)

← carbon head



From the talk of Y.Ohnishi, "Status of SuperKEKB", IAS Program on High Energy Physics 2021, Hong Kong, 19 January 2021

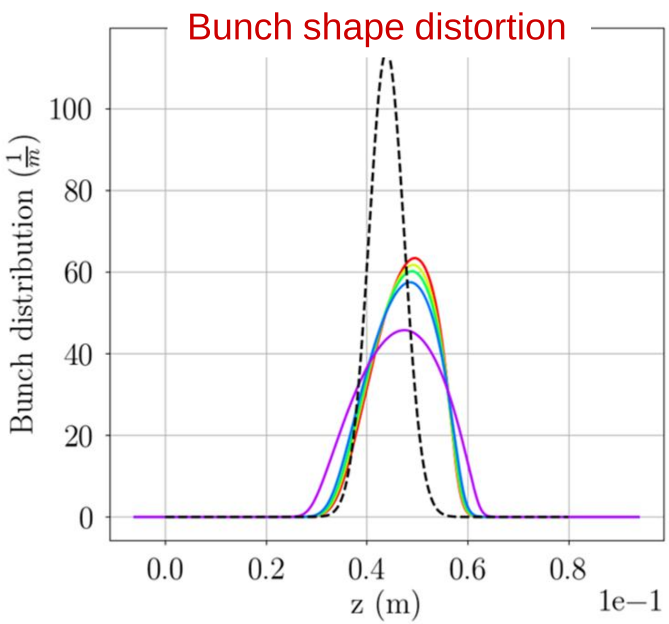
Why have we started with the longitudinal impedance?

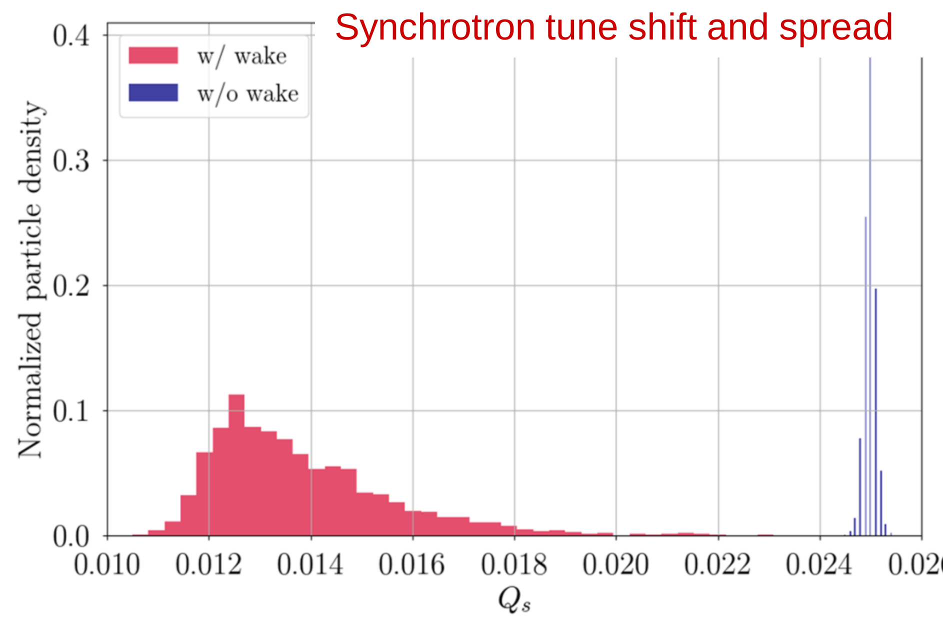
1. In the collision scheme with Crab Waist and Large Piwinski Angle the luminosity and tune shifts strongly depend on the bunch length

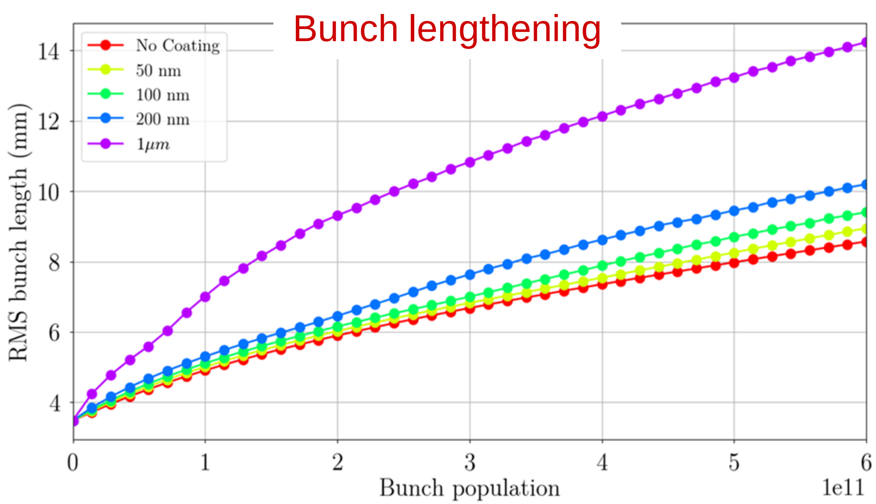
$$L \propto \frac{N\xi_y}{\beta_y^*}, \quad \xi_y \propto \frac{N\sqrt{\beta_y/\varepsilon_y}}{\sigma_z\theta}, \quad \xi_x \propto \frac{N}{(\sigma_z\theta)^2}$$

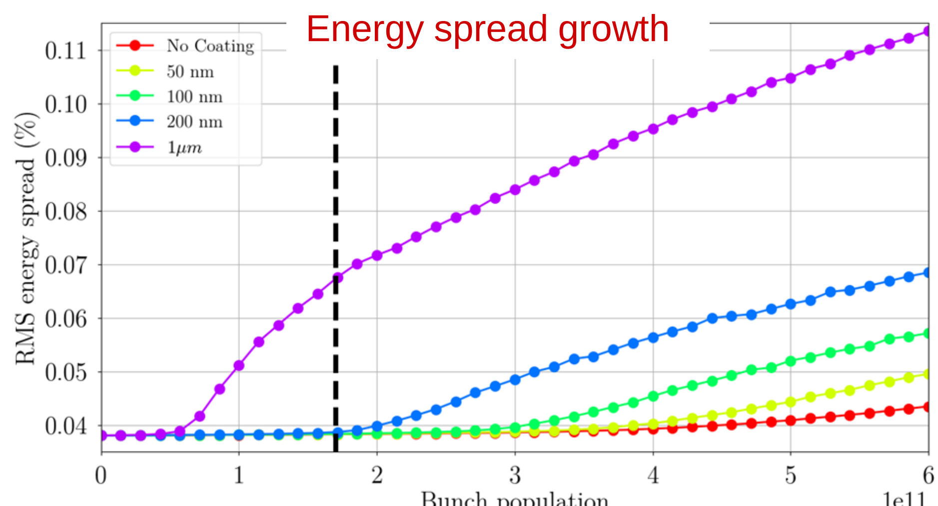
2. For the future circular colliders with extreme beam parameters in collision several new effects become important such as beamstrahlung, coherent X-Z instability and 3D flip-flop. The longitudinal beam dynamics plays an essential role for these effects.

Single bunch longitudinal dynamics









M.Migliorati, E.Belli and M.Zobov,
Phys.Rev.Accel.Beams 21 (2018) 041001

Interplay between beam-beam interaction, beamstrahlung and longitudinal impedance

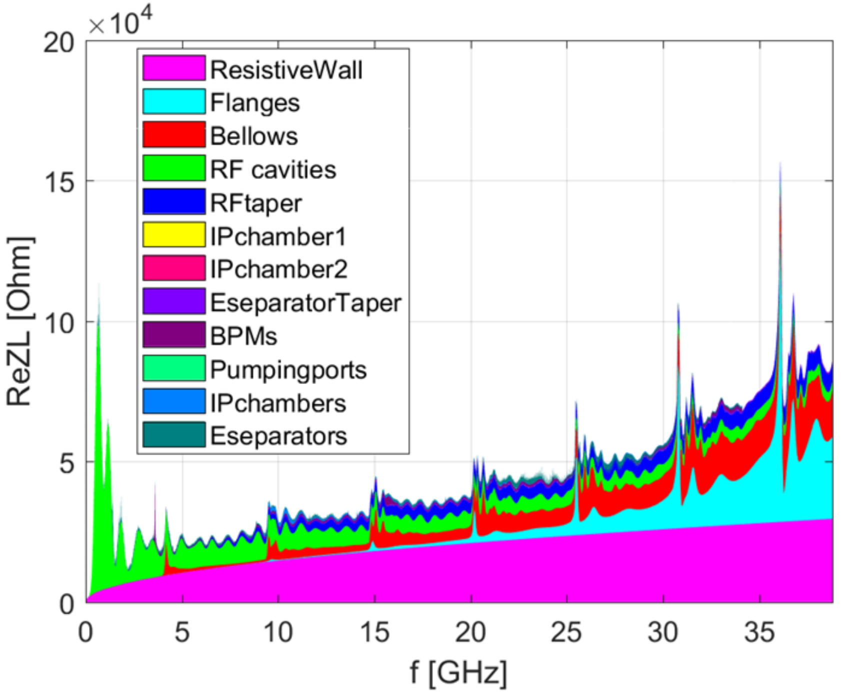
X-Z Instability

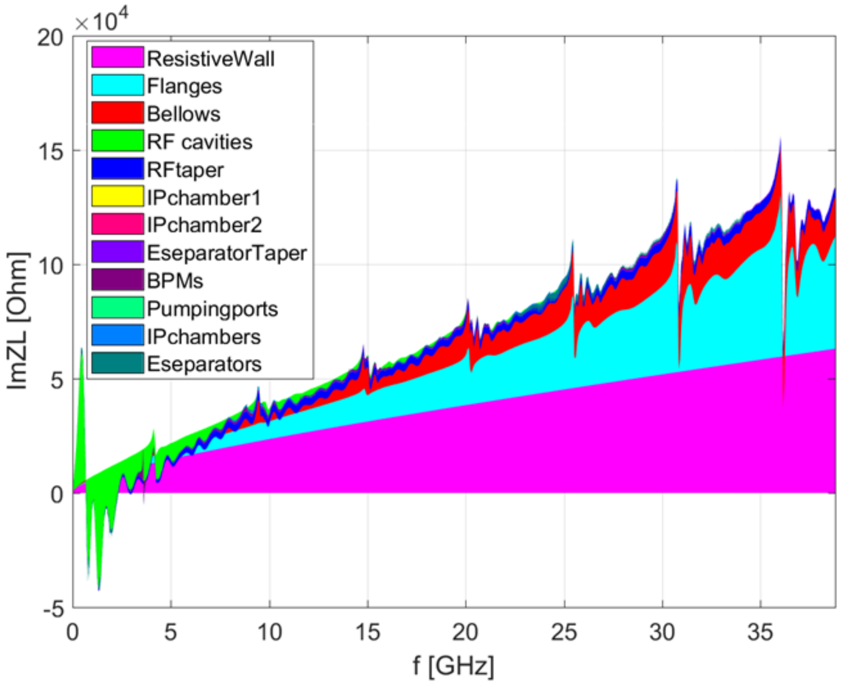
1. Tune shift of stable tune areas due to the impedance related synchrotron frequency reduction
2. Reduction of sizes of the stable tune areas
3. Smaller beam blowup presumably due to the synchrotron frequency spread induced by the impedance

In Stable Areas

1. Longer bunch length
2. Smaller energy spread than that due to beamstrahlunh alone
3. Eventual damping of the microwave instability due to longer bunches and overall higher energy spread

CEPC Beam Coupling Impedance





Horizontal size blowup tune scan (CEPC)

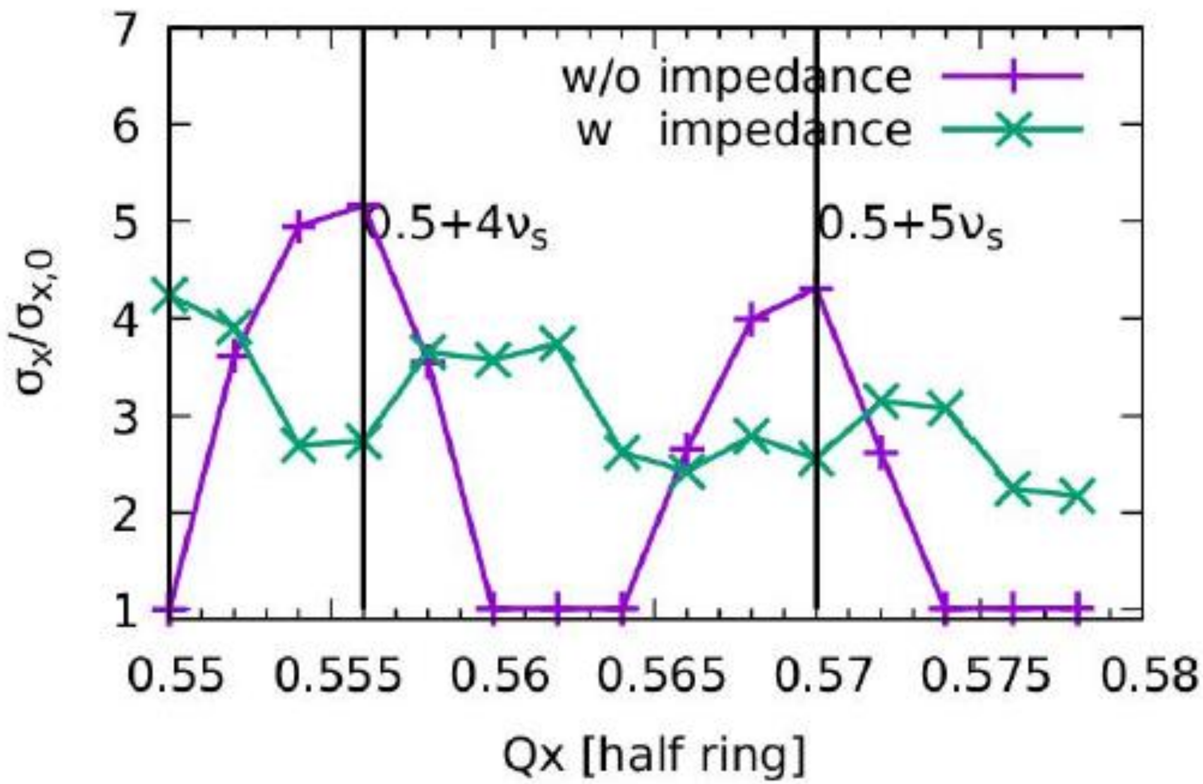


Figure 13: Horizontal beam size blow up in collision obtained by simulation with and without impedance.

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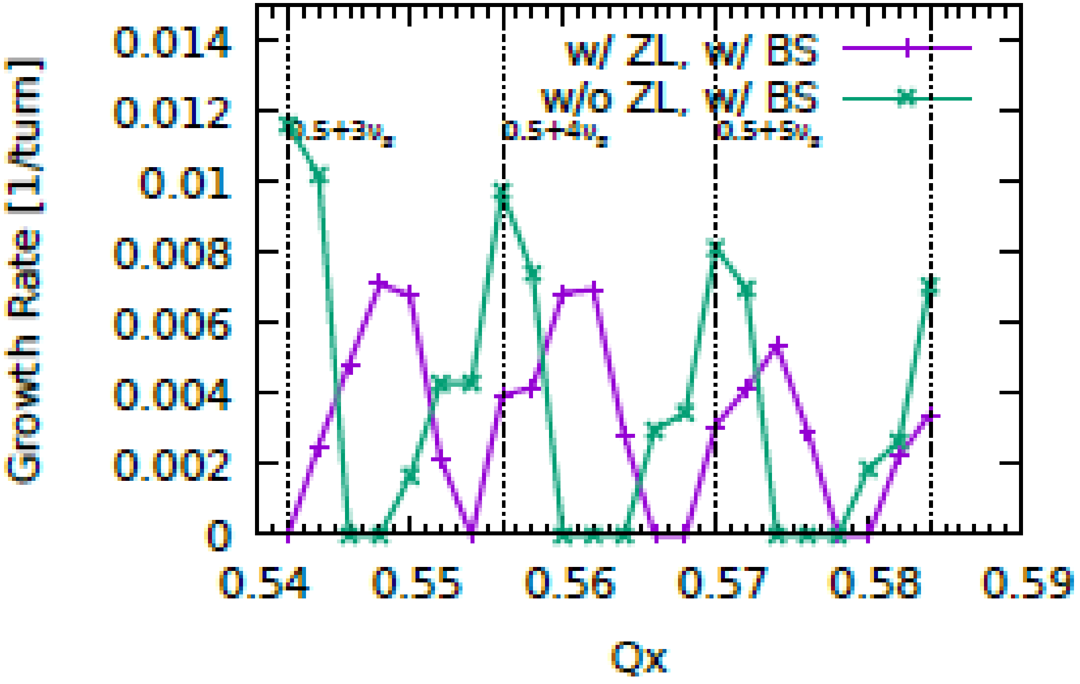
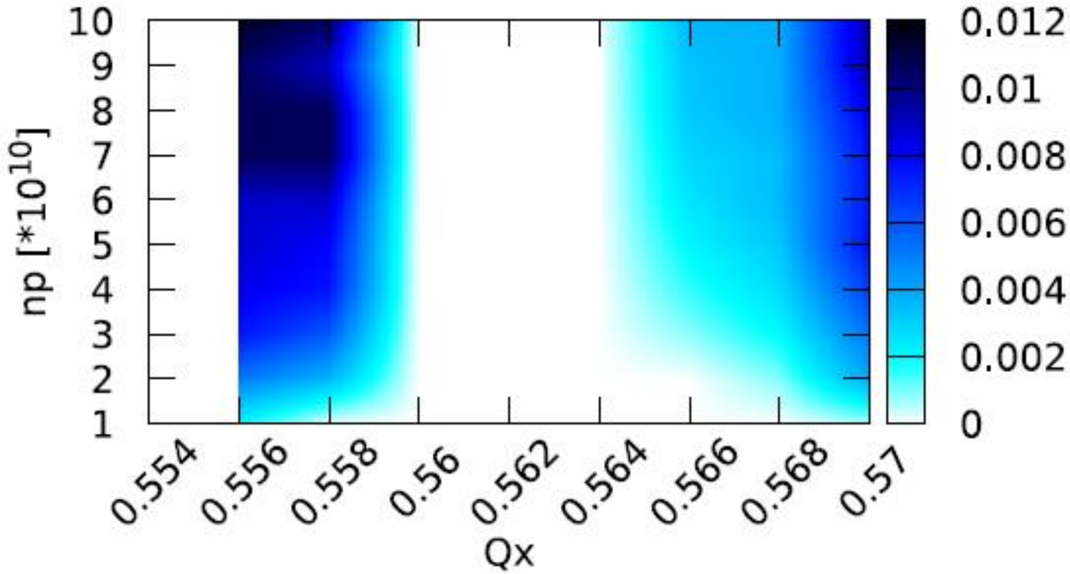
After the horizontal beta function reduction from 0.2 m down to 0.15 m

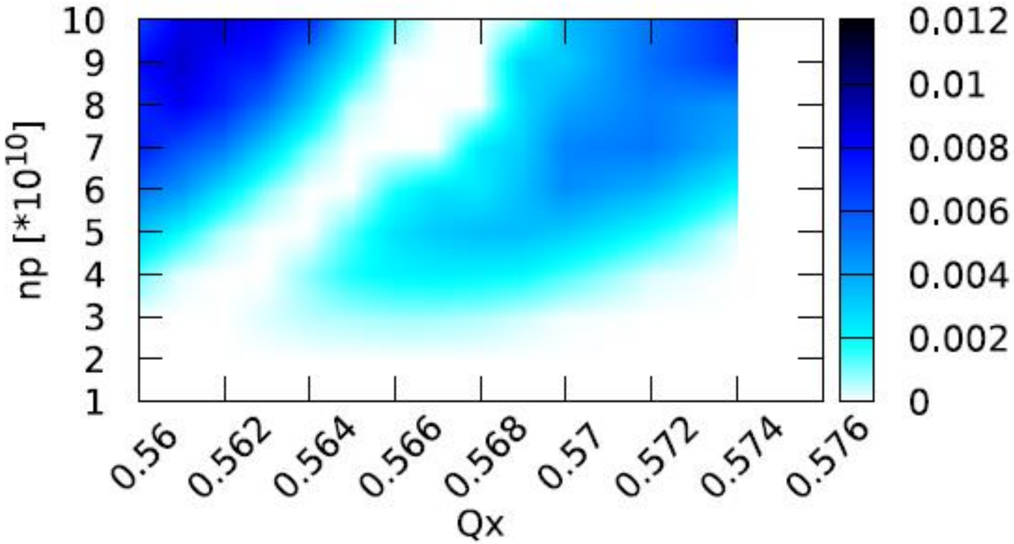


By including the impedance stable areas become narrower and are shifted in frequency

X-Z instability tune scan with and without beam coupling impedance (CEPC)

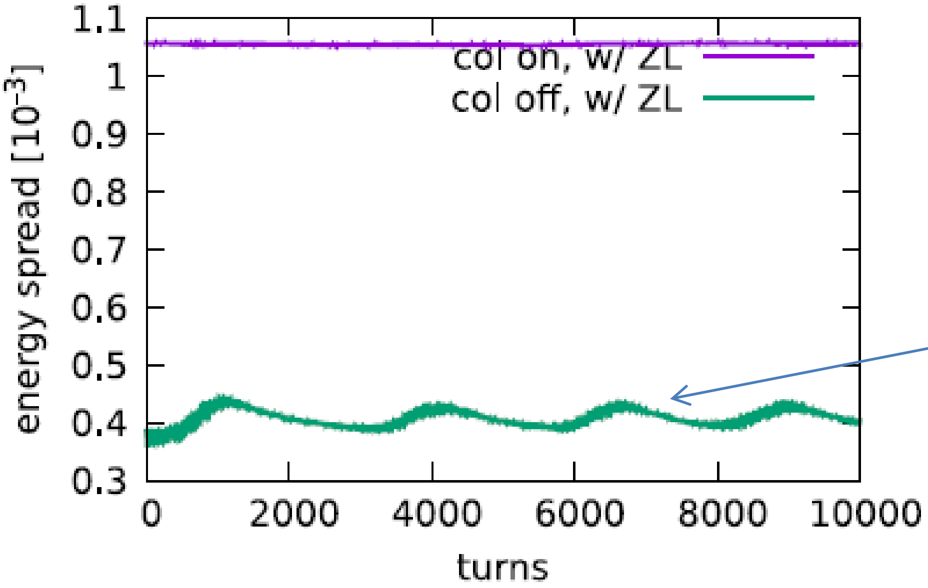


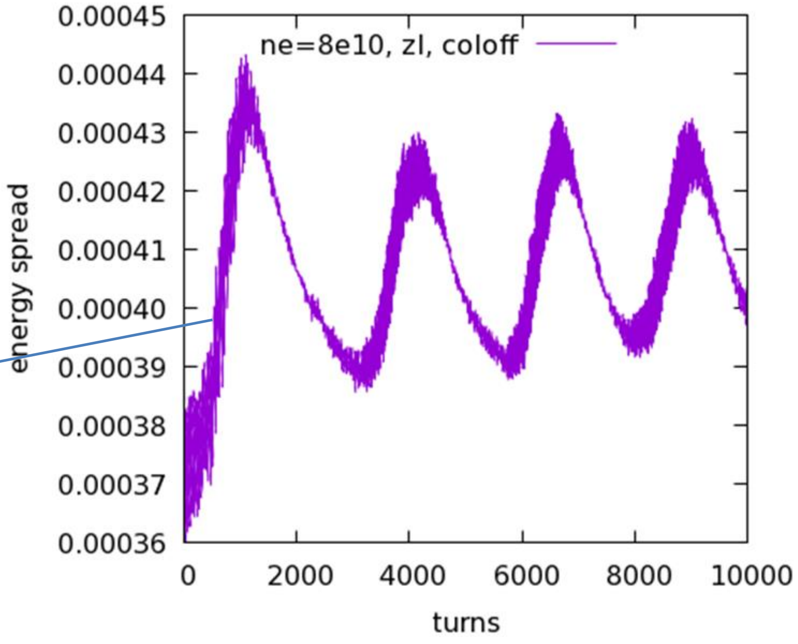
Without impedance



With impedance

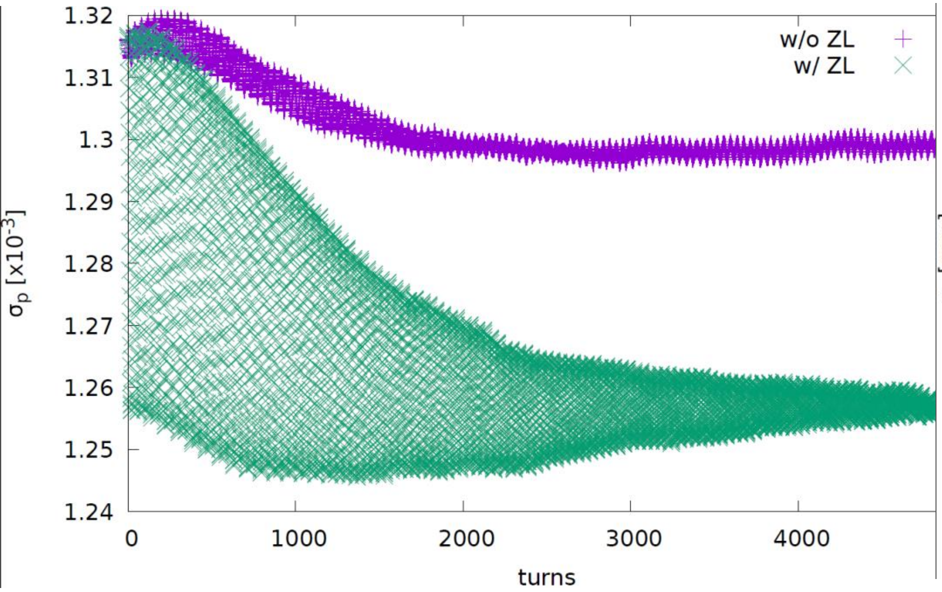
Microwave instability suppression in collision (CEPC example)



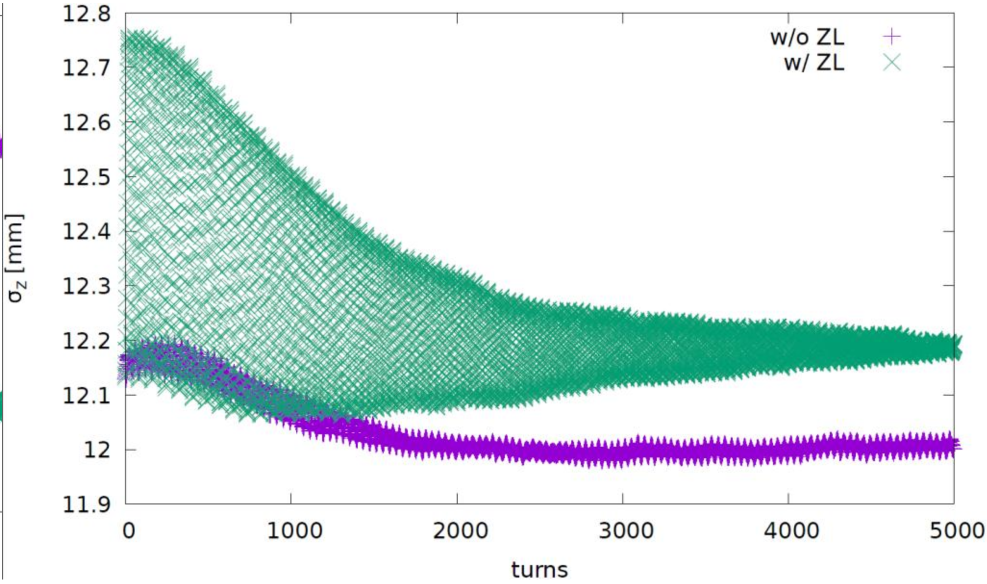


Combined effect of beamstrahlung and longitudinal impedance in stable tune areas

Energy spread



Bunch length



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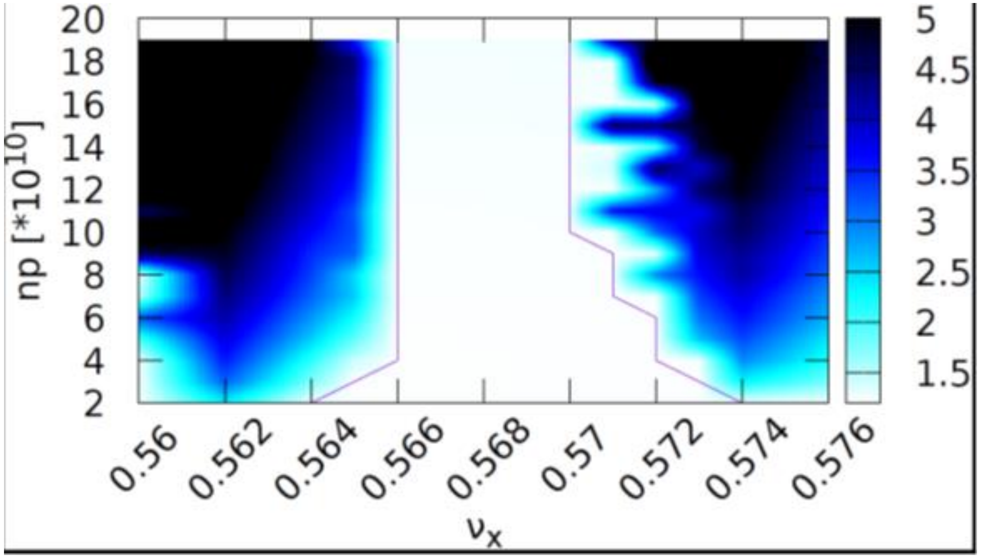
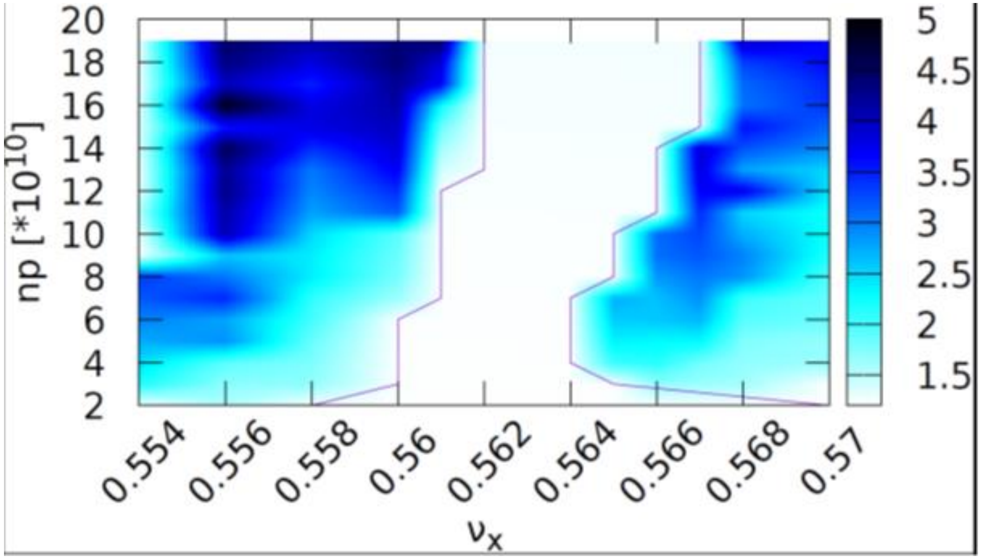
X-Z instability tune scan with and without beam coupling impedance (FCC-ee)



Without impedance



With only RW mpedance

Some Conclusions

The beam coupling impedance can have a substantial impact on the choice of beam parameters and the final collider performance.

The principal effects are summarized on Slide 6.

The work is in progress in order to evaluate the combined effect of the beam-beam interaction and the impedance in FCC-ee by using the updated impedance model (M.Migliorati, R. Kersevan, Y.Zhang et al.)