INTERPLAY BETWEEN SPACE CHARGE, INTRA-BEAM SCATTERING AND SYNCHROTRON RADIATION EFFECTS

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Abstract

The objective of this research is to study the interplay of synchrotron radiation, intra-beam scattering and space charge in the vicinity of excited resonances. In this respect, two modules were developed to simulate intra-beam scattering and synchrotron radiation effects and plugged into pyORBIT to be used together with its space charge module. Different regimes of synchrotron motion were used to study the response of the beam to a lattice resonance when space charge, intra-beam scattering and synchrotron radiation are present.

Introduction

MOTIVATION

In ultra-low emittance rings, such as the *Compact Linear Collider Damping Rings (CLIC DRs*) that need to deliver beam emittances under strict requirements, the performance can be limited by:

- Magnet non-linearities and errors.
- Interplay with incoherent effects such as *Intra-Beam Scattering (**IBS**)* and *Space Charge (**SC**)*.

GOAL

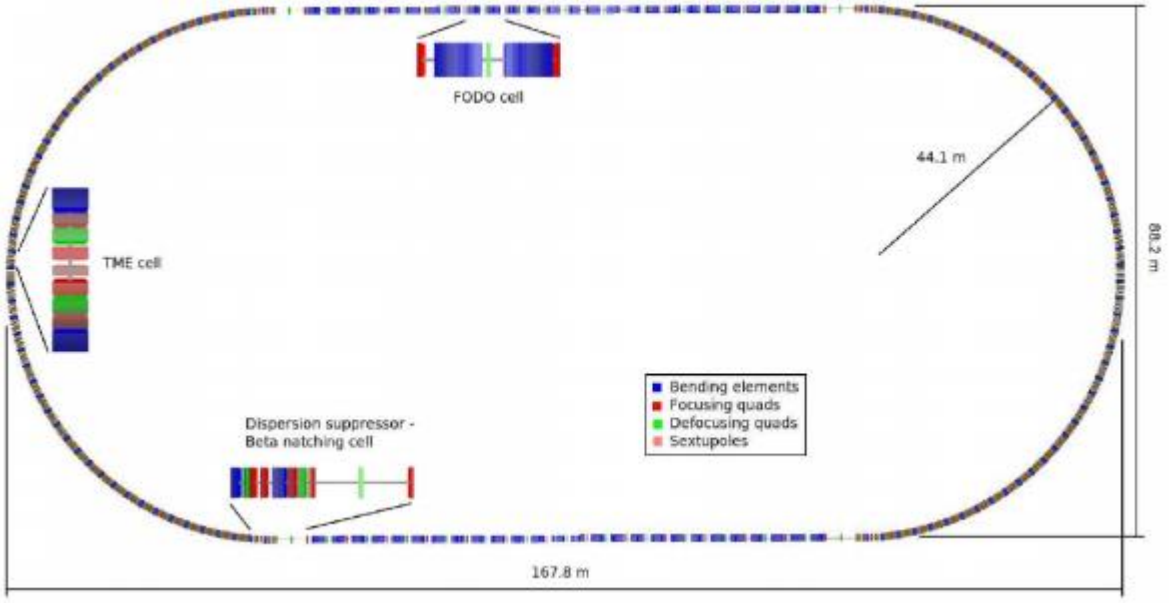
- Study the interplay of *SC* and *IBS* in the vicinity of an excited, vertical resonance.
- Examine if *SR* damping can help preserve the vertical emittance by compensating these two effects and their potential interplay.

The CLIC DRs

THE CLIC DR CONCEPTUAL DESIGN

The CLIC main DRs are part of the CLIC injector complex.

- Receive the beam with large transverse emittances and damp them down by two orders of magnitude within a repetition rate of $50Hz$.
- Final emittance steady state need to comply with strict extraction requirements and is defined by *SR*, Quantum Excitation *(QE)* and *IBS* effects.

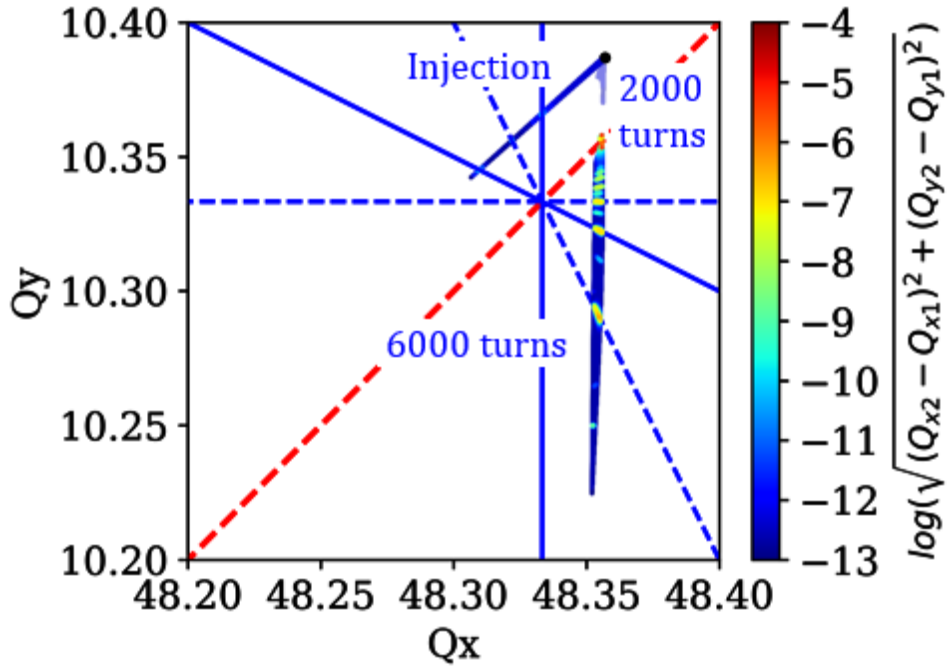


Space Charge Studies

TUNE FOOTPRINT EVOLUTION

To verify that the *SC* induced tune shift indeed becomes critical for the beam parameters close to equilibrium, tune footprints were evaluated for on-momentum particles.

- Large transverse emittances: particles experience large amplitude detuning.
- Small transverse emittances: SC induced tune spread becomes dominant.



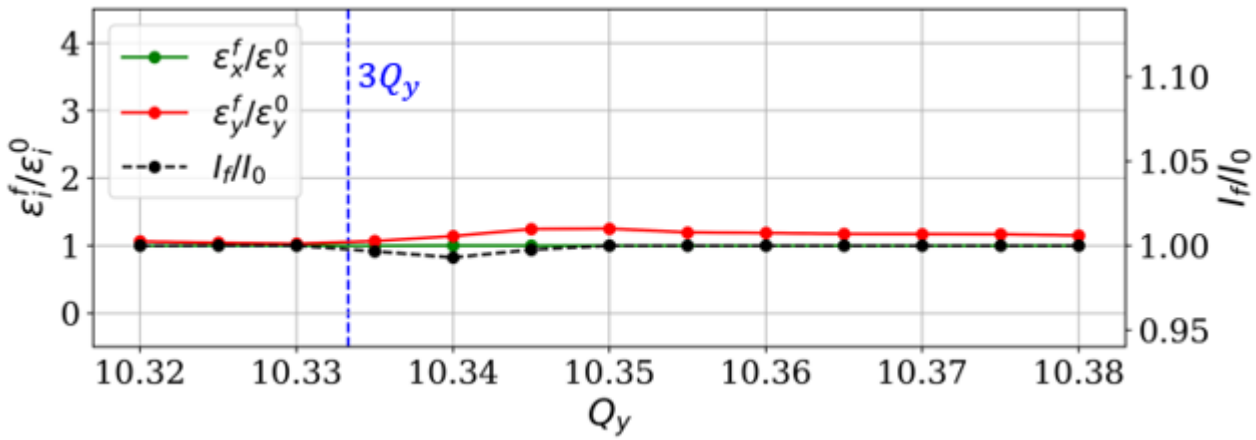
Space Charge Studies

TUNE SCANS

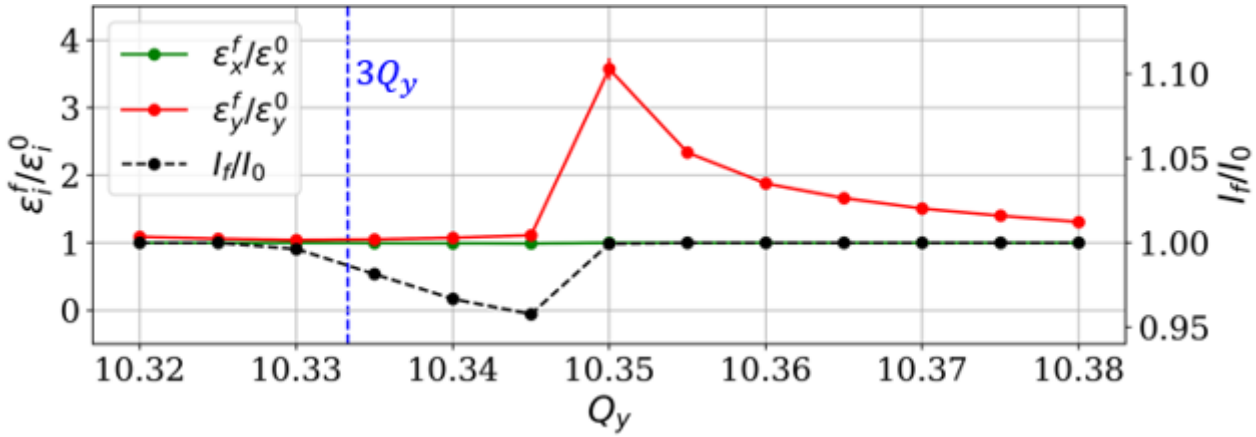
Two skew sextupoles were added as errors to excite the $3Q_y = 31$ resonance.

- Nominal case: weak response due to the fast synchrotron motion.
- Slower synchrotron motion: the vertical emittance growth for working points above the resonance is clearly pronounced.

$T_s \approx 150\ Turns$ (nominal)



$T_s \approx 1500\ Turns$

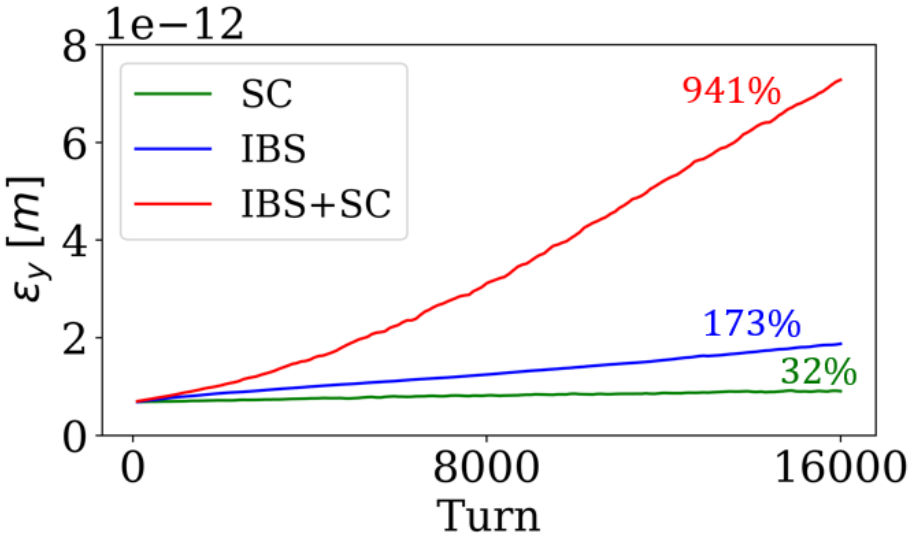


Space Charge Studies with IBS and SR

INTERPLAY OF *SC* AND *IBS*

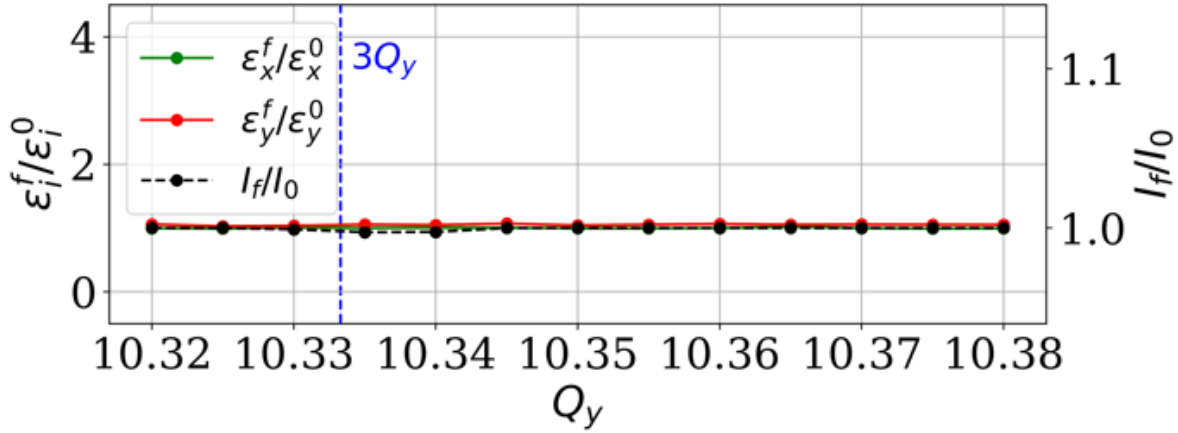
The working point $Q_y = 10.35$ is presented, which was most affected by the resonance.

- the interplay of these two effects clearly results in enhanced particle diffusion.

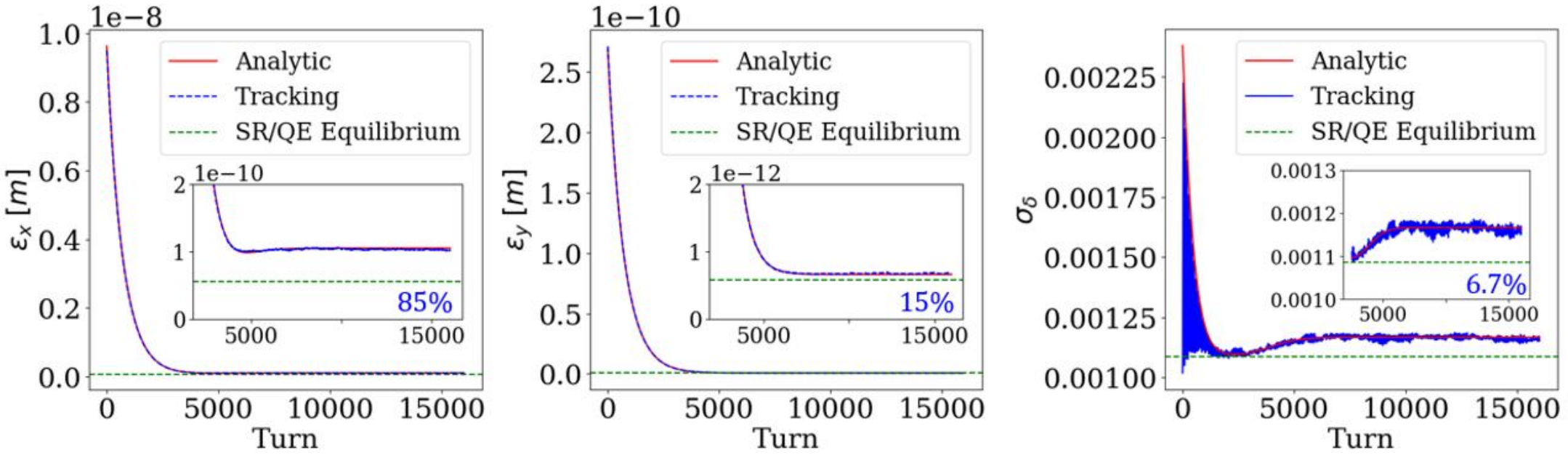


INTERPLAY OF *SC*, *IBS* AND *SR*

- SR mostly cancels the vertical blow-up.
- The residual blow-up remains always below 5% and particle losses below 1%.



CLIC DRs full cycle



Emittance evolution for the nominal cycle, without imperfections:

- Agreement between Analytical calculations (IBS, SR) and Tracking simulation (IBS, SC, SR).
- SC does not affect the final steady state.

Summary and Future Work

SUMMARY

- The beam degradation due to resonance crossing induced by SC is relatively weak due to the fast synchrotron motion.
- Considering IBS seems to strongly enhance the emittance growth.
- The strong damping from SR counteracts the final beam degradation.
- The operational scenario of the CLIC DR without imperfections did not reveal a strong impact of SC effects on the final steady state.

FUTURE WORK

- Address the impact of lattice imperfections including coupled resonances.