Transverse Instabilities Studies for the SLS-2 Upgrade

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Many thanks to M. Aiba, G. Rumolo, A. Streun

Introduction

- Collective effects will be crucial for the SLS-2 upgrade
- Lattices considered have a very low and negative momentum compaction factor
- Narrow NEG coated pipes
- Vacuum chamber:
  - Round
  - Material: copper
  - Radius: 10 mm
  - NEG coated everywhere (1 μm assumed)

2 RF options: 500 and 100 MHz

- Check the matching in longitudinal plane
- $M=R_o\,|\eta|\,(\delta p/p_0)/(Q_s\,\sigma_z)$

- 1st RF scenario: 500 MHz
  - M=1.44 → not matched

- 2nd RF scenario: 100 MHz
  - M= 0.99 → matched → Simulations with 100 MHz parameters

Parameters for 100 MHz

E (GeV)	2.4
C (m)	288
α_p	-5.4×10^{-5}
ε_x^g (pm)	73
ε_y^g (pm)	5
ν_x / ν_y	39.4 / 13.17
ν_s	0.00037
σ_z (mm)*	7.4
γ	4700
V_{RF} (MV)	0.7
h	96
$\delta p/p_0$	0.0011

N_p	3.1×10^{10}
$\langle b_x \rangle$ (m)	6.65
$\langle b_y \rangle$ (m)	6.13
τ_x (ms)	5.58
τ_y (ms)	7.56

* Bunch length is without IBS/ 3HC. A 3HC will be considered to lengthen the bunch by a factor of 3

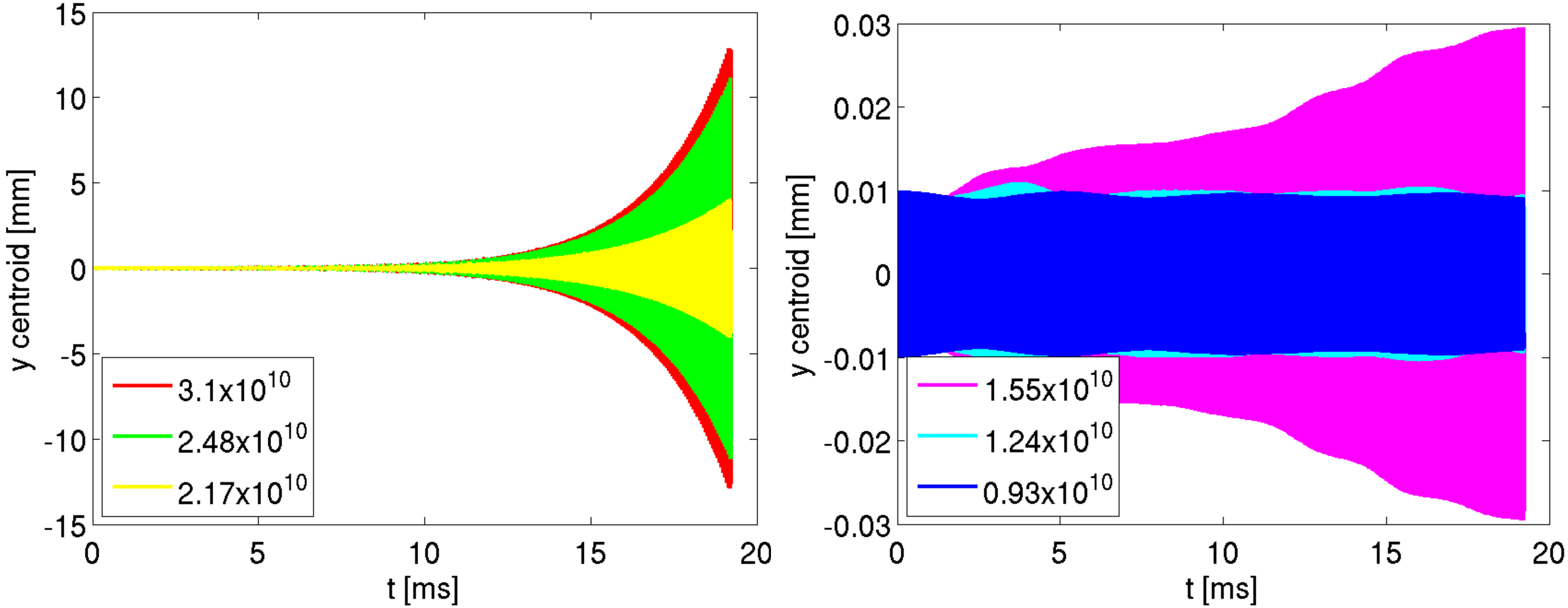
Resistive wall (ImpedanceWake2D code*)

Number of layers: 2
Layer 1 **inner radius in mm: 10**
Layer 1 DC resistivity (Ohm.m): 9.1e-7 → **NEG** (assumed **σ=1.1x10^{6} S/m**)
Layer 1 relaxation time for resistivity (ps): 0.
Layer 1 real part of dielectric constant: 1
Layer 1 magnetic susceptibility: 0
Layer 1 relaxation frequency of permeability (MHz): Infinity
Layer 1 **thickness** in **mm: 0.001**
Layer 2 DC resistivity (Ohm.m): 1.68e-8 → **Copper** (**σ=5.95x10^{7} S/m**)
Layer 2 relaxation time for resistivity (ps): 0.
Layer 2 real part of dielectric constant: 1
Layer 2 magnetic susceptibility: 0
Layer 2 relaxation frequency of permeability (MHz): Infinity
Layer 2 thickness in mm: Infinity

**N. Mounet, CERN-THESIS-2012-055*

HEADTAIL* simulations for RW: 0 chromaticity

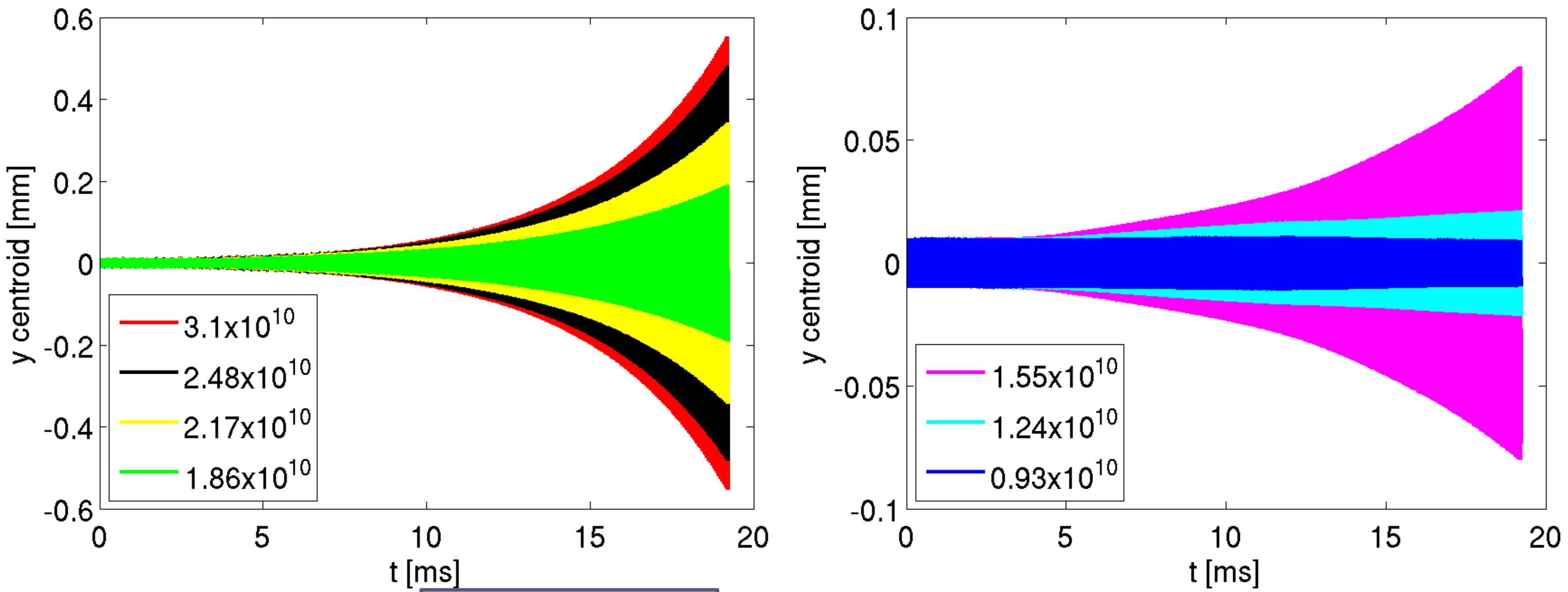
*G. Rumolo, F. Zimmermann, CERN-SL-Note-2002-036 (2002)



- Varying the bunch intensity (nominal value 3.1×10^{10})
- Already unstable just with the resistive wall
- Stable for $N_p < 1.24 \times 10^{10}$ (2.5 lower than the desired)

HEADTAIL simulations for RW: 0 chromaticity and 3HC (σ_z=22.2 mm, Q_s=1.2x10^{-4})

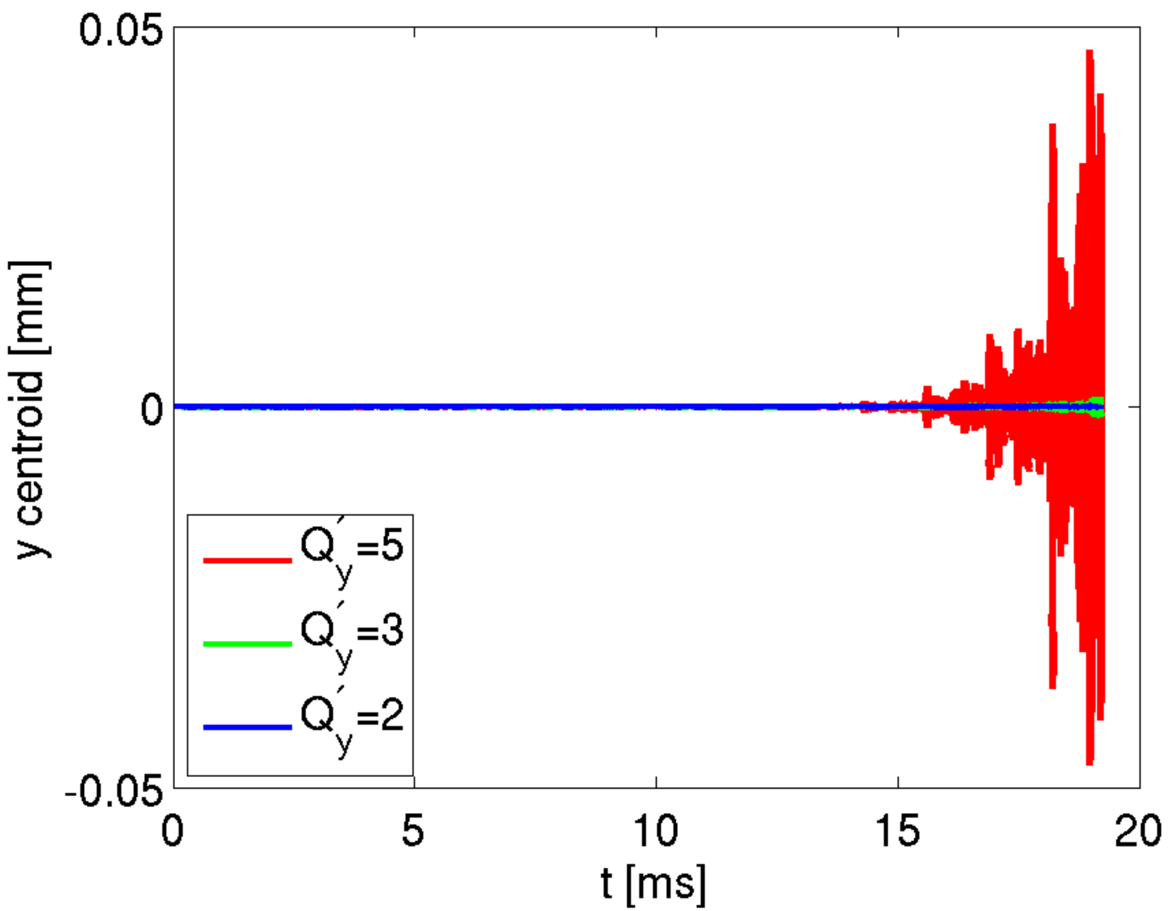
- Unstable with just the resistive wall



•Becomes stable for N_p < 0.93x10^{10} (even lower threshold than without the 3HC due to the smaller Q_s)

- Operation at 0 chromaticity is not an option (current 2.5 smaller to be stable ONLY with RW)

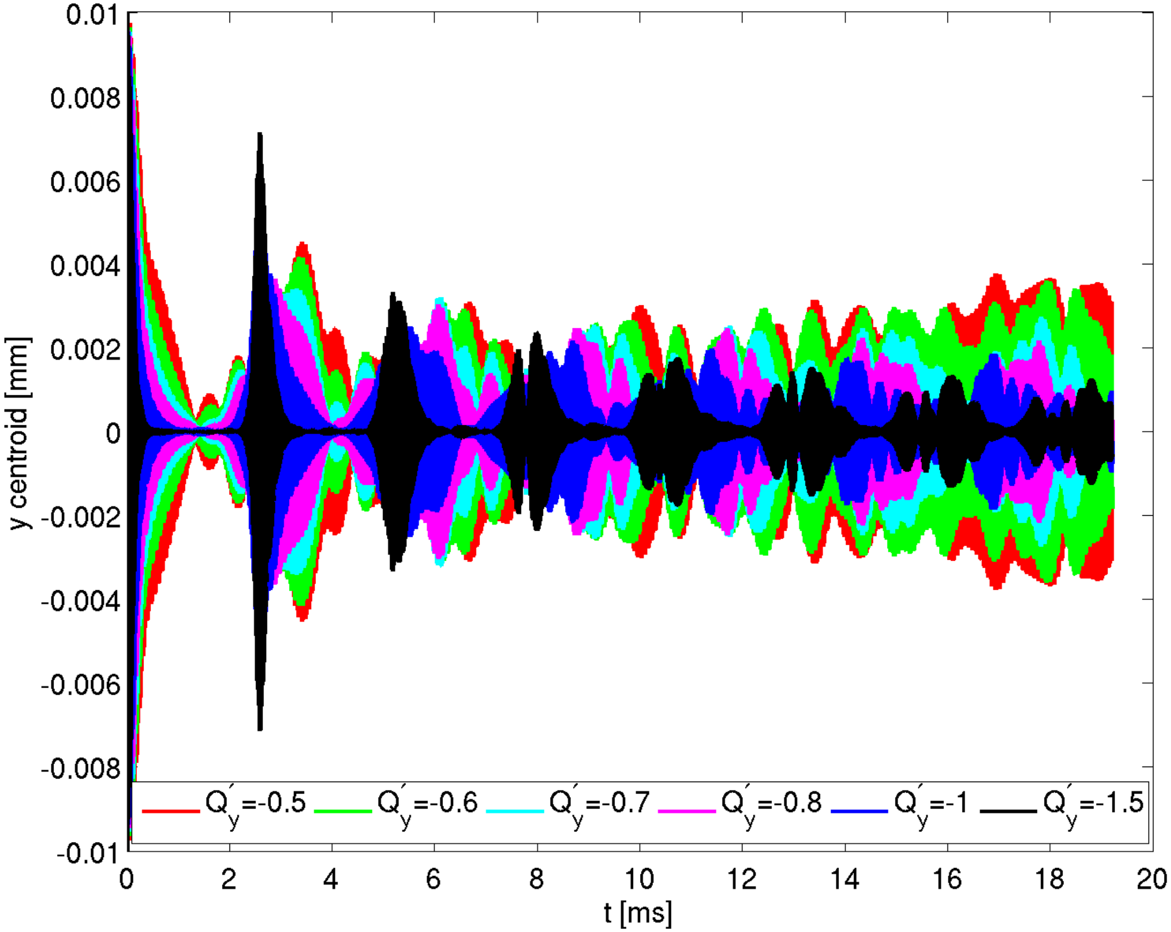
HEADTAIL simulations for RW: positive chromaticity



Q'y	Rise time [ms]
1	1.9
2	1.6
3	1.2
5	1

- Need to compare the rise time of the instability with the damping time, **τ_y=7.56 ms**
- Unstable for positive chromaticities

HEADTAIL simulations for RW: negative chromaticity



Q'y	**Rise time [ms]**
-0.5	13.6
-0.6	18.5

- Need to compare the rise time of the instability with the damping time, **τ_y=7.56 ms**
- Stable for negative chromaticities

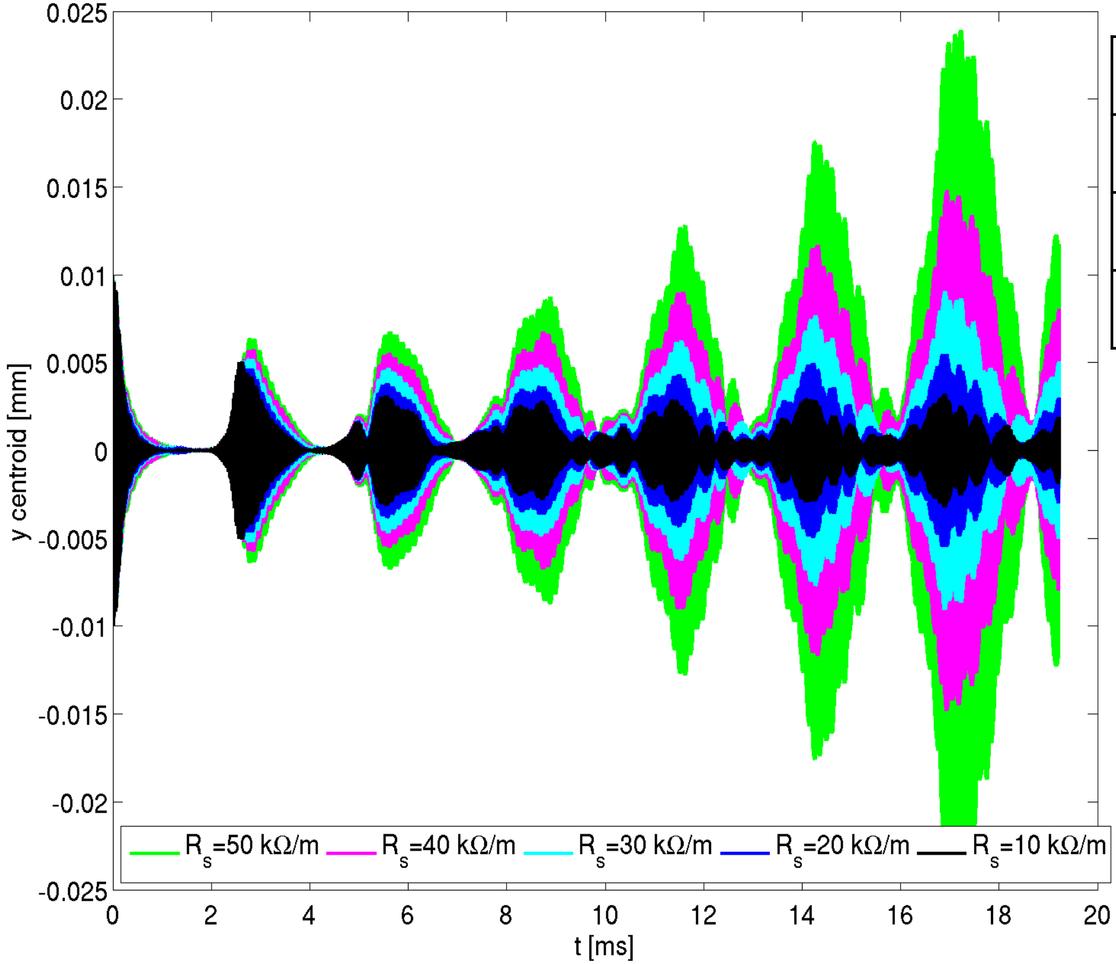
Broad-Band Resonator Parameters

- TM cut-off frequency: $\lambda=2\pi r/p_{mn}=2\pi*(10mm)/2.405$ → $f=c\backslash\lambda=11.5$ GHz
- TE cut-off frequency: $\lambda=2\pi r/p'_{mn}=2\pi*(10mm)/1.841$ → $f=c\backslash\lambda=8.8$ GHz

- **BBR: f_r= 8 GHz, Q=1**
- **R_s is the parameter to scan**

- Impedance Model: RW+BBR

Impedance Budget for Q'_y=-1 (RW+BBR)



Rs [kΩ/m]	Rise time [ms]
40	7.49 <7.56 = τ_y
50	6.4 < 7.56 = τ_y
100	3.1 < 7.56 = τ_y

Remaining transverse budget in y: <40 kΩ/m

Impedance Budget (RW+BBR)

Q'y	Rs [kΩ/m]	Rise time [ms]
-5	500	5.96
-6	500	7.67> 7.56 $= \tau_y$
-7	500	8 > 7.56 $= \tau_y$

- Slower instability than the damping mechanism
- Stable

- Operation with higher negative chromaticity than -6 will allow a budget of 0.5 MΩ/m

Conclusions

- Operation at 0 chromaticity: at least 2.5 lower bunch population to be stable (impedance model only RW)
- Negative chromaticity: The beam is stable with nominal parameters and only RW
- How negative? Depends on the total budget (RW+other elements+BBR)
- Need higher negative chromaticity than -6 to have 0.5 MΩ/m available
- Large tune footprint, limit dynamic aperture and Touschek lifetime