

# Transverse beam stability studies in the presence of 2 RF systems – a status report

**9th HiLumi WP2 Task 2.4 meeting**  
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# Overview

- Overview
- Expected impact of double harmonic RF on transverse stability
- Simulation method
- Results
- Conclusions & outlook

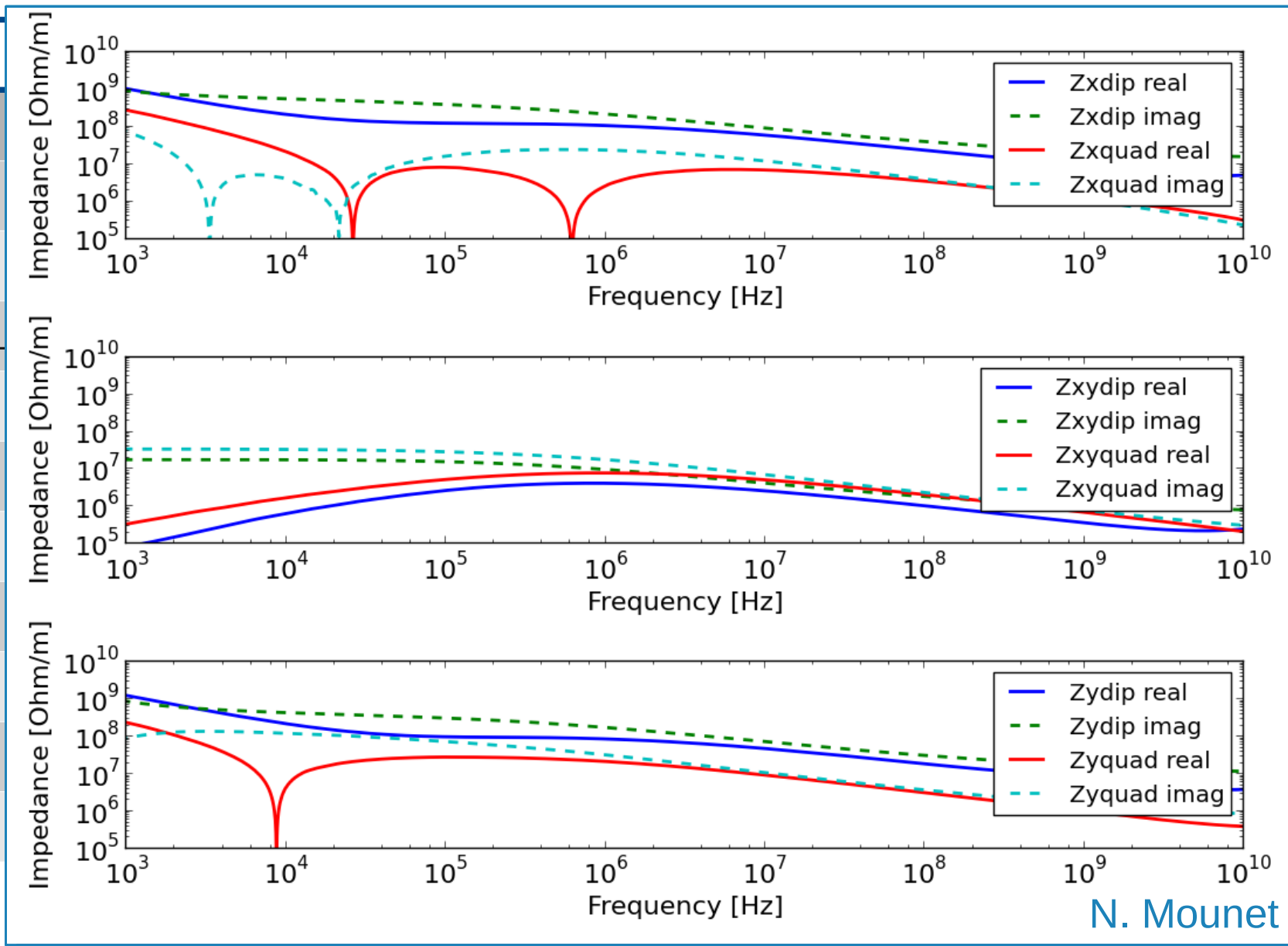
# Overview

- A harmonic RF system can be used to shape the longitudinal phase space and incoherent synchrotron tune spectrum
- Both the longitudinal phase space profile and the incoherent synchrotron tune spectrum have an influence on the transverse beam stability
- We will investigate TMCI thresholds:
  - HL-LHC impedance model (N. Mounet)
  - 400 MHz + 800 MHz double harmonic RF system in shortening and lengthening mode

# Parameters

	Single RF	Shortening	Lengthening
Energy [TeV]	7		
$\beta_x, \beta_y$ [m]	65.98, 71.53		
$\varepsilon_x, \varepsilon_y$ [normalized $\mu\text{m}$ ]	2, 2		
$Q_x, Q_y$	64.31, 59.32		
$4 \sigma_z$ [ns]	1	?	?
$\varepsilon_z$ [eV s]	2.47	?	?
$Q_s$	0.00204		
$V_{400}$ [MV]	16	16	16
$V_{800}$ [MV]	0	8	8
$\Delta\phi$	0	0	$\pi$

# Parameters



$\epsilon_X, \epsilon_Y$

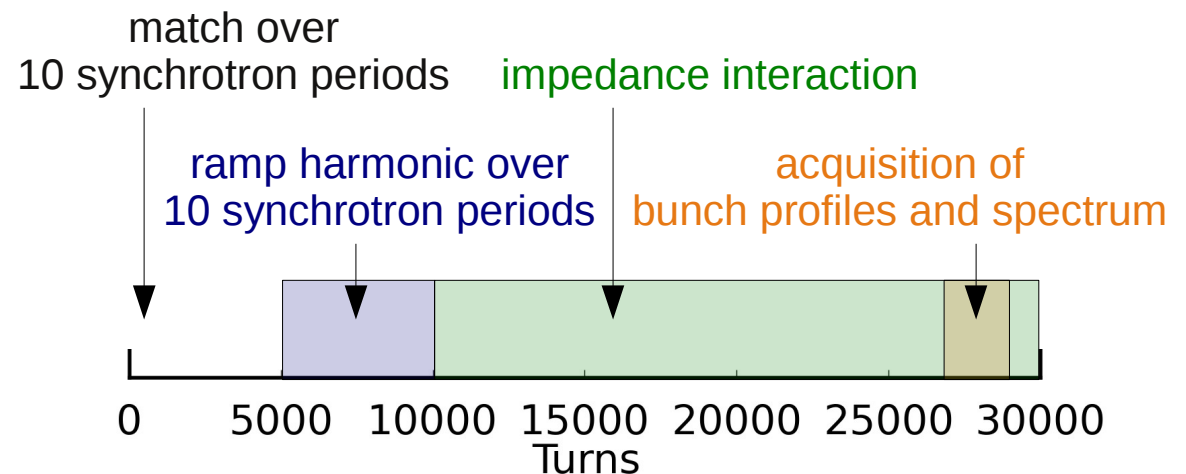
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N. Mounet

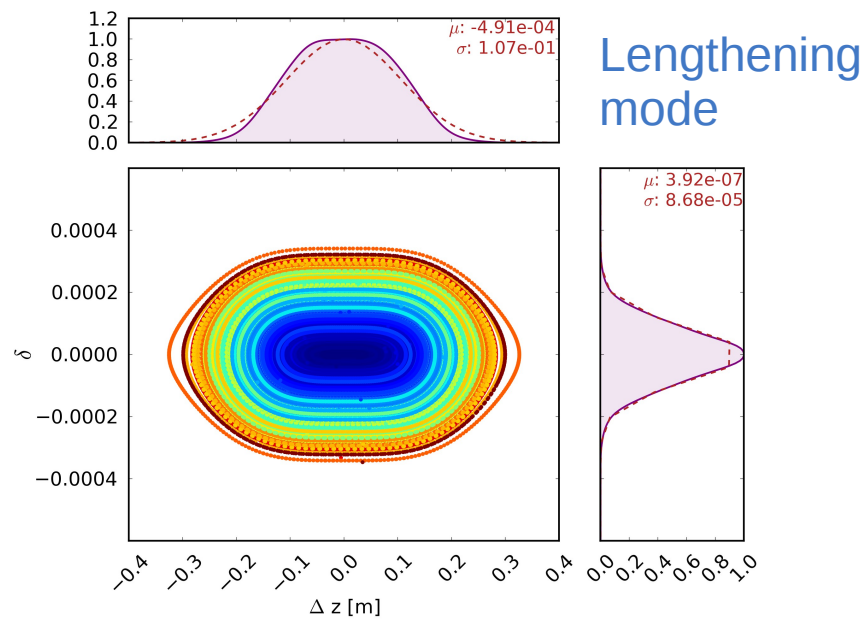
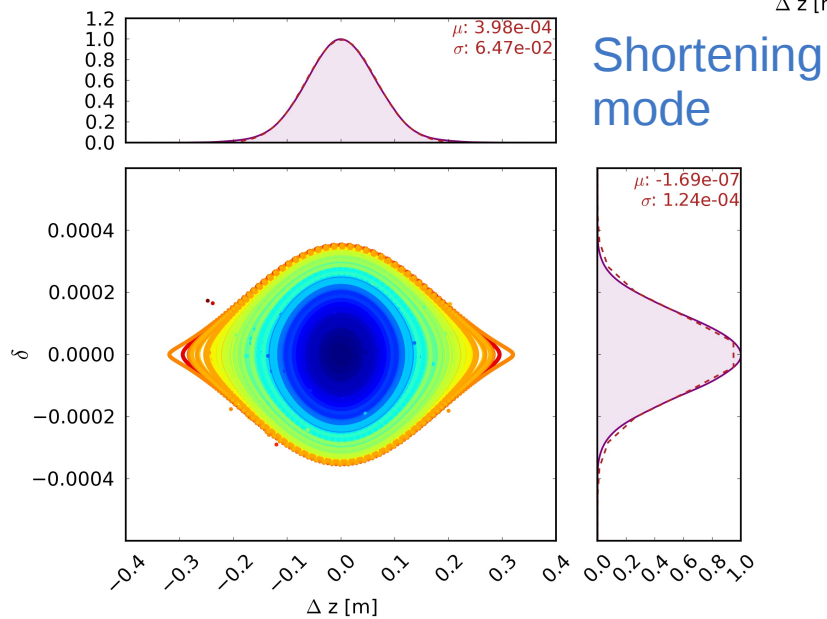
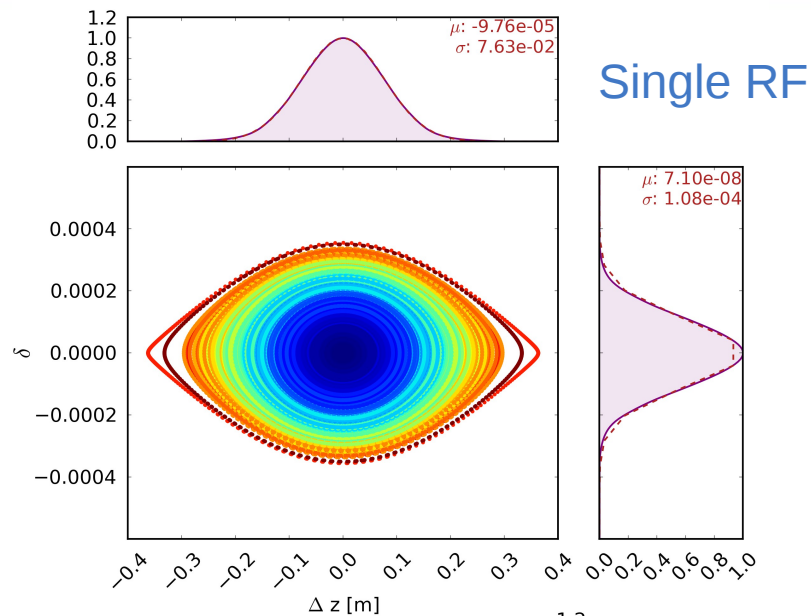


# Simulation method

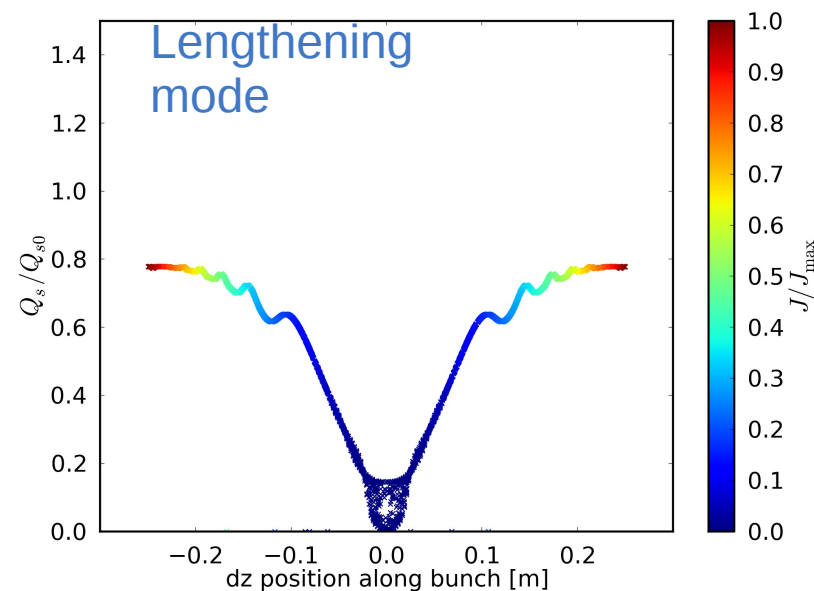
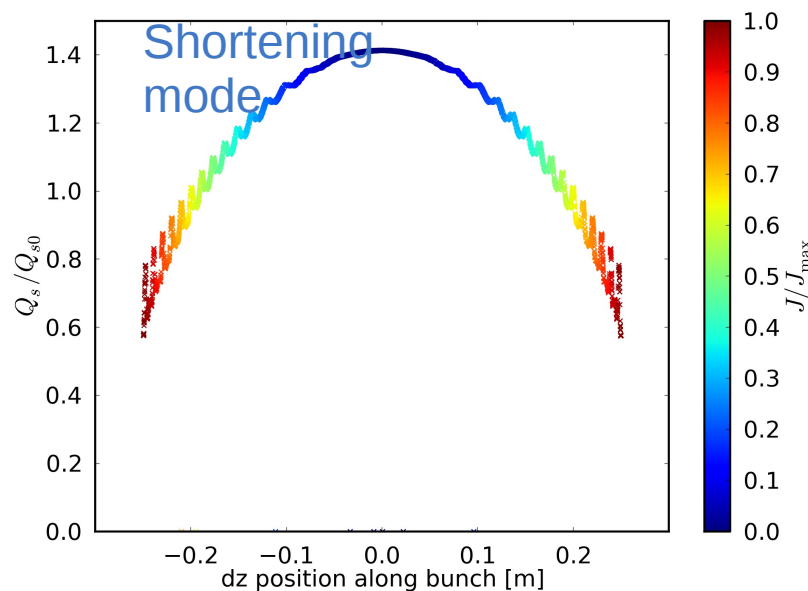
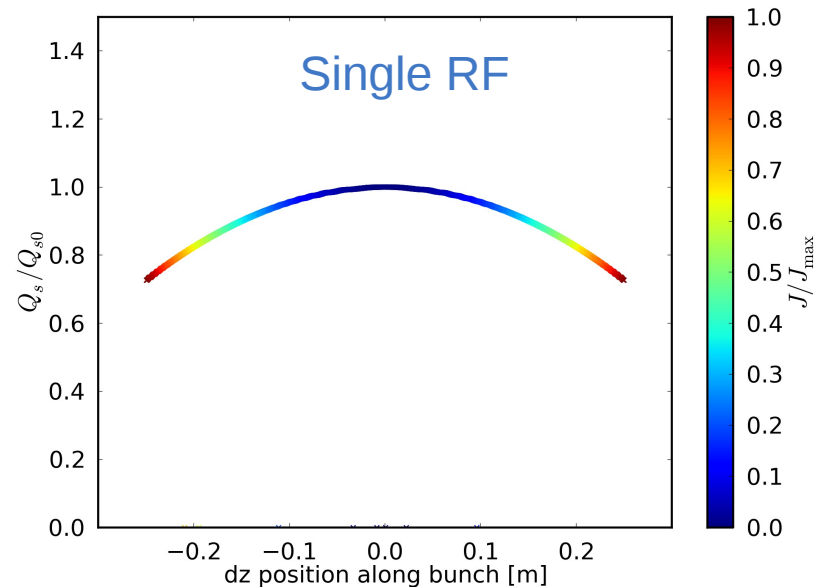
- HL-LHC impedance model → waketable
- Sychrotron motion → double RF system:
  - Match nonlinear bucket over 5000 turns
  - Ramp 2<sup>nd</sup> harmonic over 5000 turns
  - Turn on impedance after 10000 turns
- Analysis:
  - Emittance
  - Rise times
  - Tune spectra



# Longitudinal phase space portraits



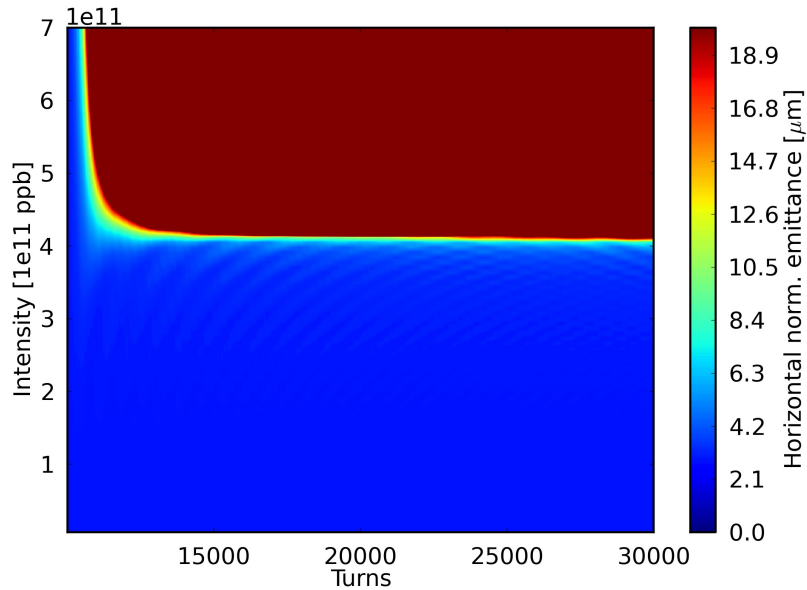
# Incoherent synchrotron tunes





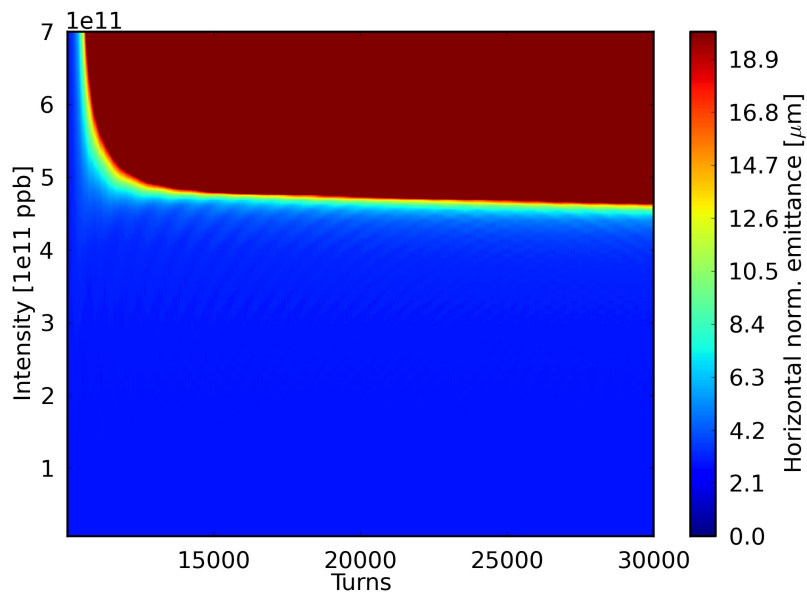
# TMCI thresholds

Single RF

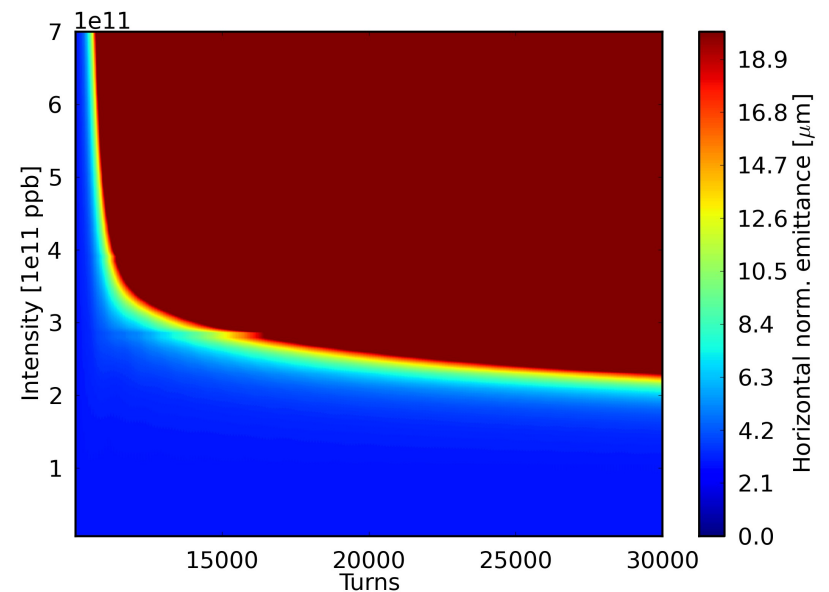


- Instability thresholds:
  - Single: 4.1e11
  - Shortening: 4.8e11 (+ 20%)
  - Lengthening: 3.0e11 (- 25%)

Shortening

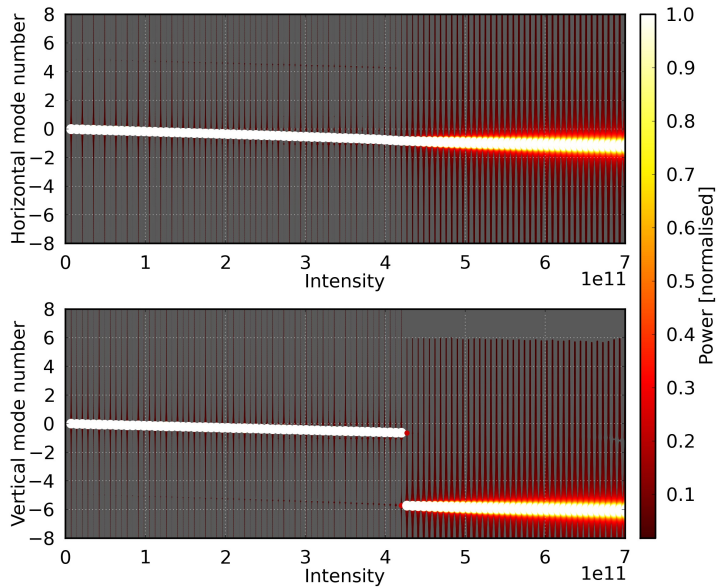


Lengthening



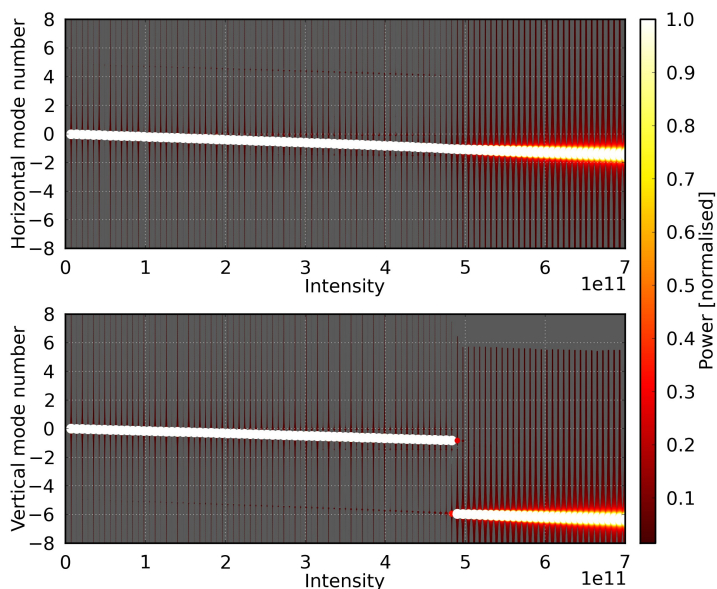
# TMCI thresholds

Single RF

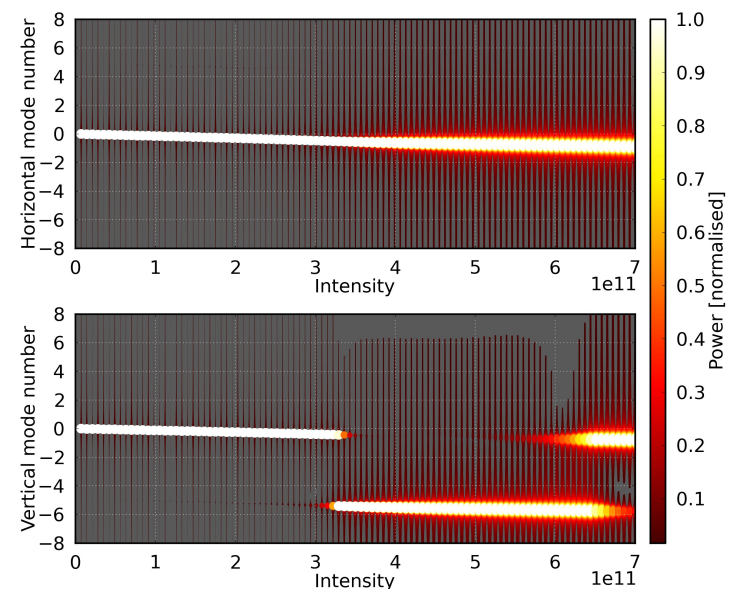


- Instability thresholds:
  - Single: 4.1e11
  - Shortening: 4.8e11 (+ 20%)
  - Lengthening: 3.0e11 (- 25%)
- TMCI modes 0 & -1

Shortening

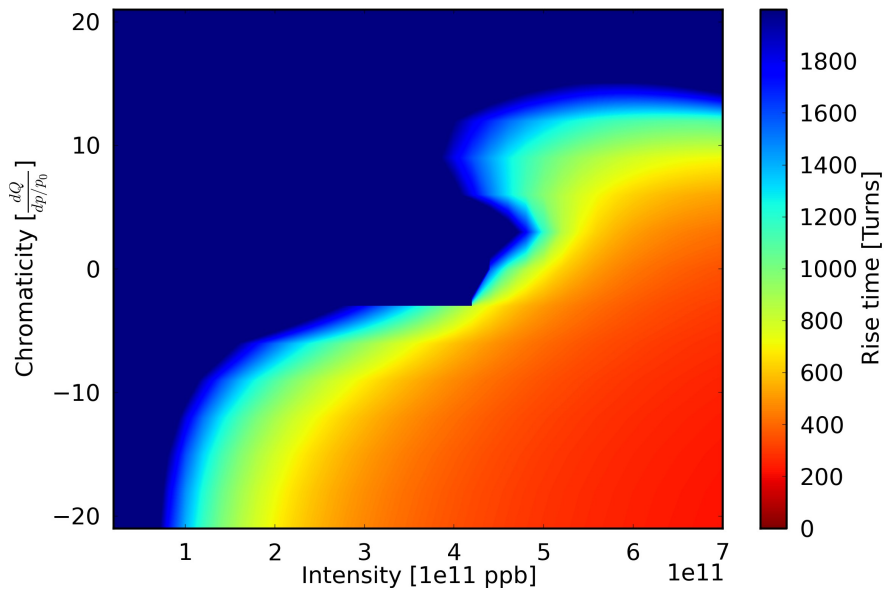


Lengthening

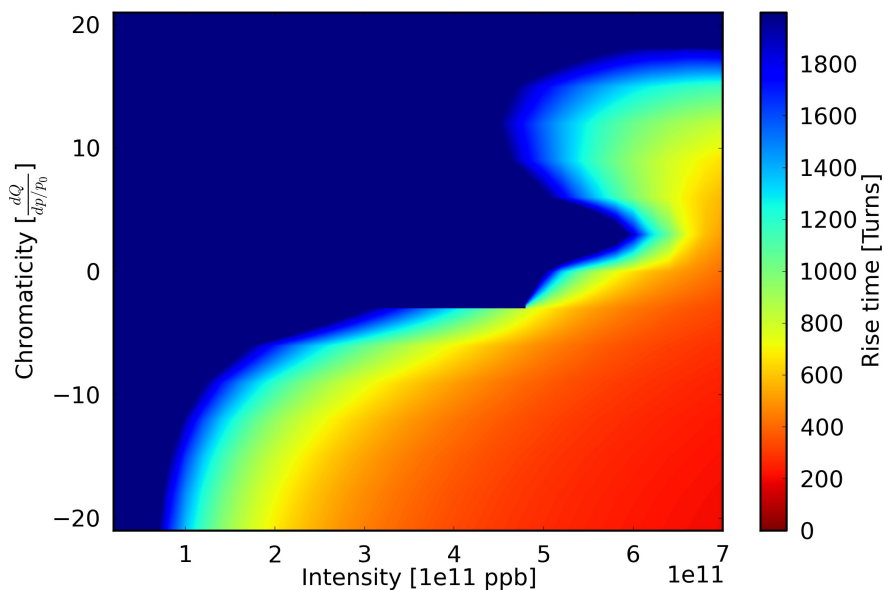


# The impact of chromaticity

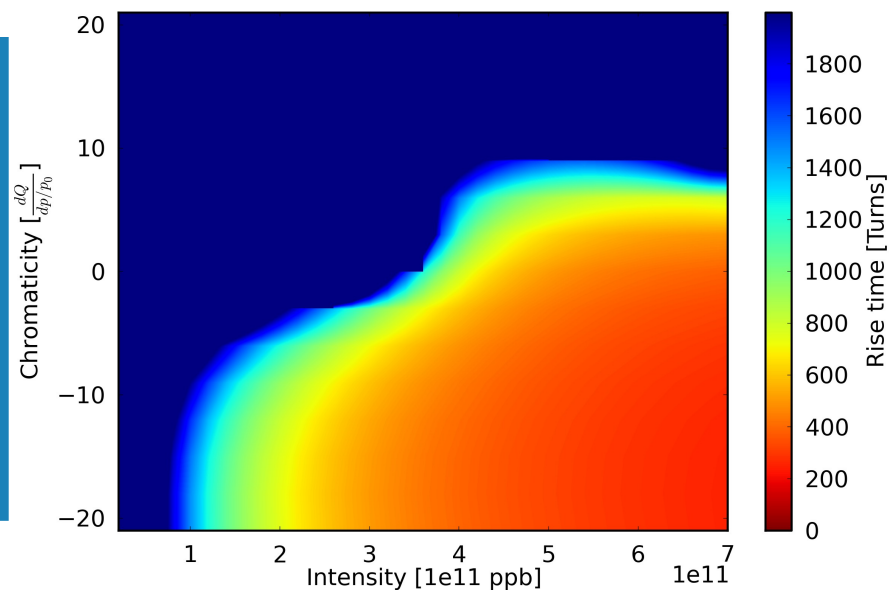
Single RF



Shortening

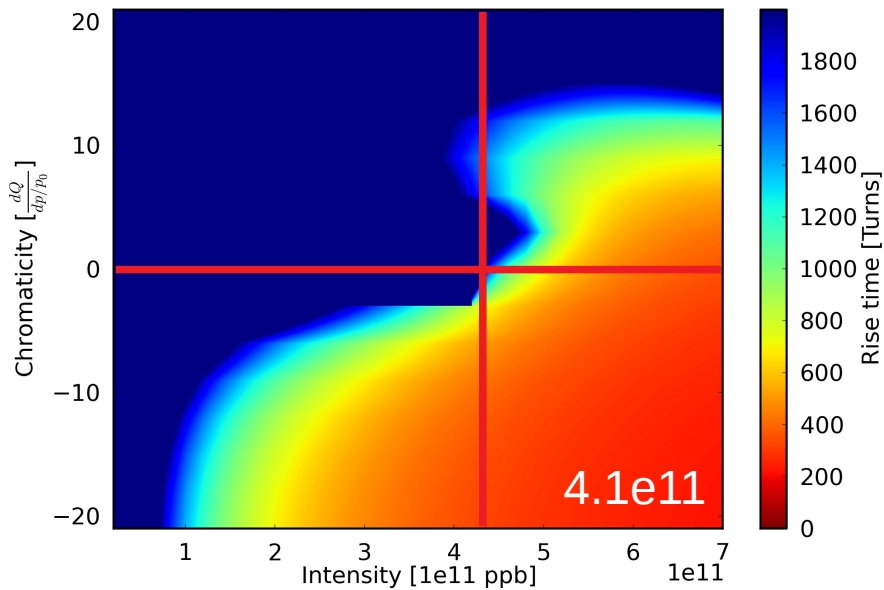


Lengthening



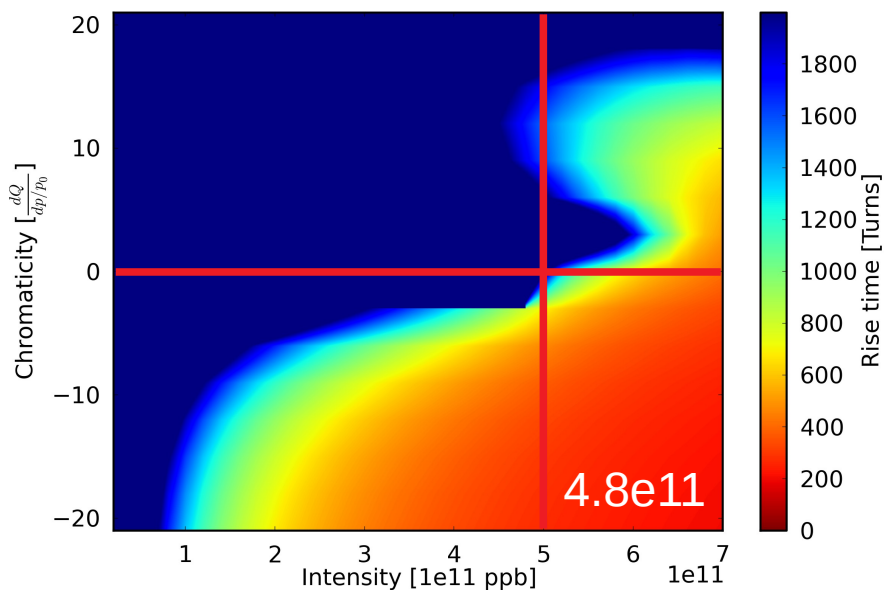
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Single RF

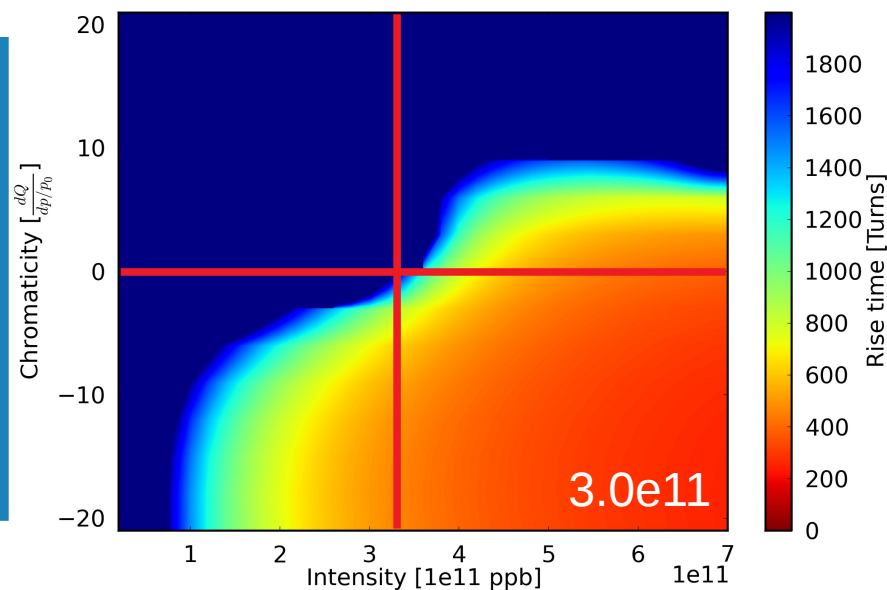


• Thresholds as seen before

Shortening

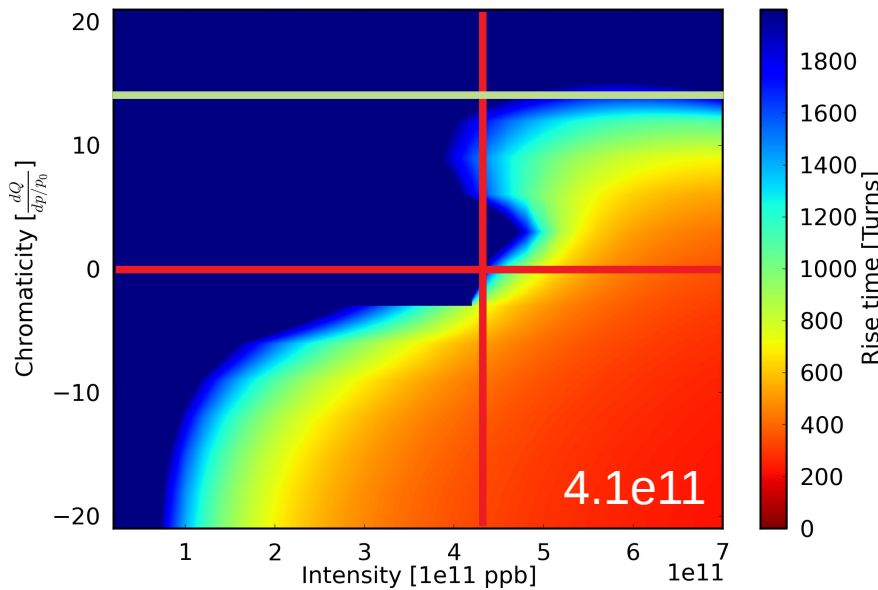


Lengthening



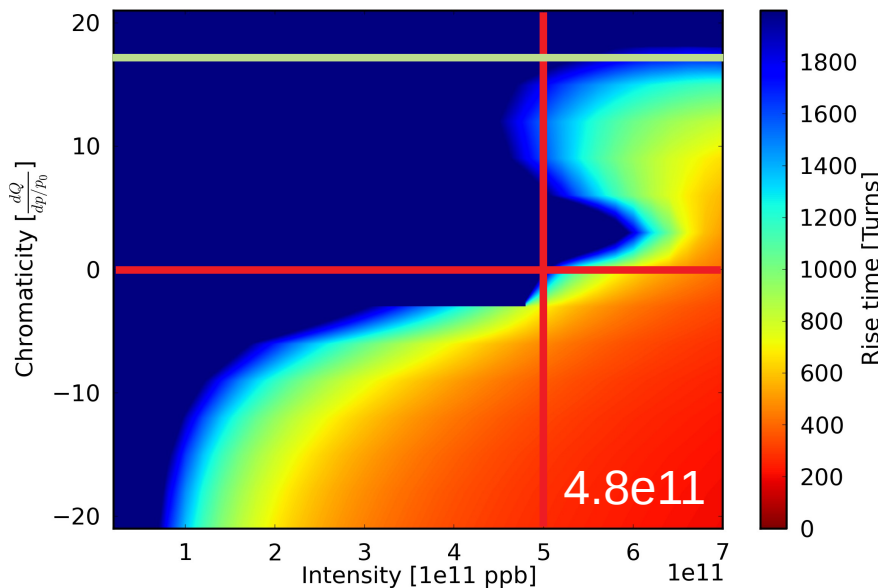
# The impact of chromaticity

Single RF

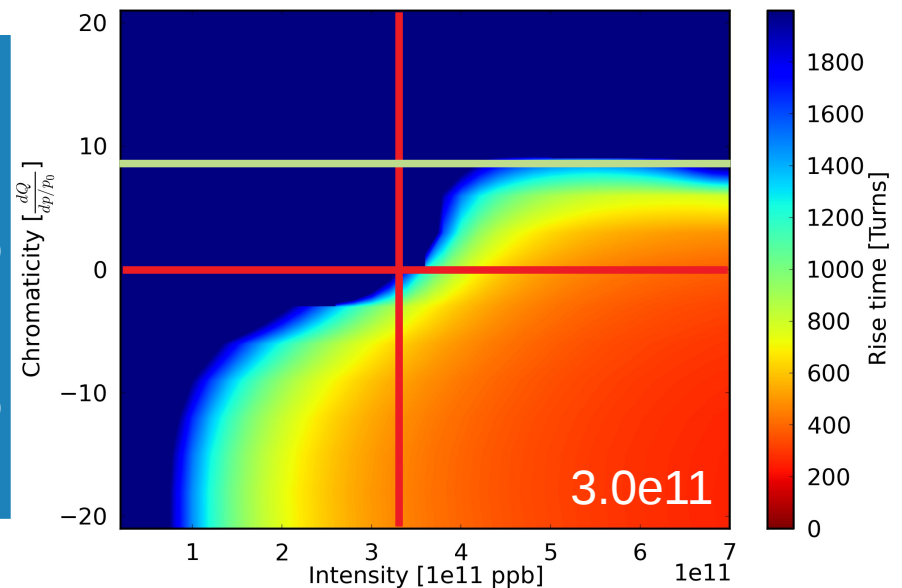


- Thresholds as seen before
- Positive chromaticity stabilises the beam much earlier in bunch lengthening mode

Shortening



Lengthening



# Conclusions & outlook

- Established a methodology to study multiple harmonic RF systems
- Concluded on TMCI threshold using the HL-LHC impedance model and a double harmonic RF system in shortening and lengthening mode
- Further refinements needed for the numerical treatment
- Include phase errors and the ideal transverse damper

	Threshold	Chromaticity to stabilise
Single RF	4.1e11	14
Shortening	4.8e11	18
Lengthening	3.0e11	9