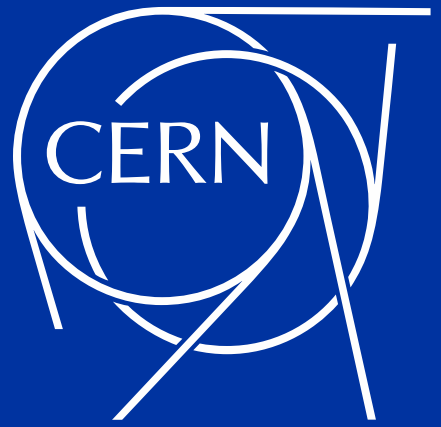


Effect of a high frequency BBR on the SPS TMCI from a BBR with PyHEADTAIL

Acknowledgments: N. Mounet, B. Salvant, C. Zannini

Sébastien Joly, Elias Métral

31/08/2020

Introduction

- **Within the framework of the study of the effects of space charge on the SPS TMCI, we looked at the effect of a high frequency broad-band resonator impedance on the TMCI from a broad-band resonator.**

- **A high frequency broad-band resonator impedance has some similarities with space charge and introduces negative tune shifts without any growth rate (for a high enough frequency).**

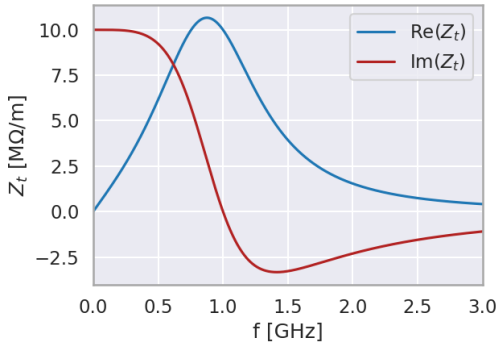
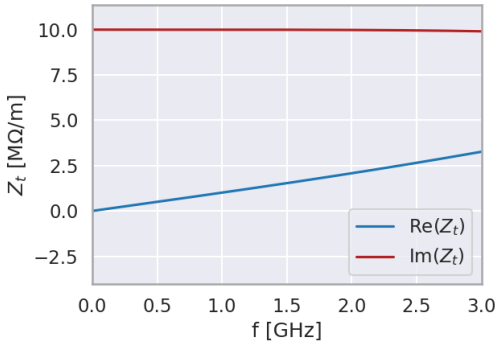
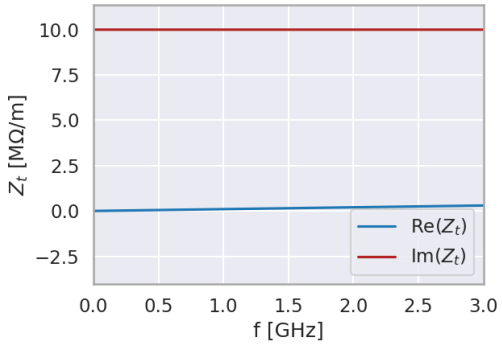
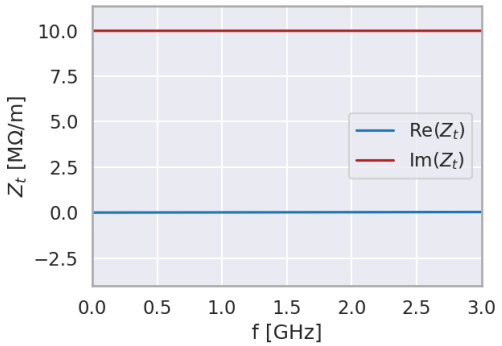
- **Investigating the impact of such an impedance could help us to understand better the different aspects of space charge on instabilities.**

SPS parameters

SPS Q26 optics at injection, single bunch PyHEADTAIL simulations

Parameters	$E_{kinetic}$ = 25.1 GeV
τ_b (full bunch length) [ns]	2.8
Q_s	$3.24*10^{-3}$
Q_x	26.13
Q_y	26.18
α_p	$1.92*10^{-3}$
γ_{tr}	22.8
n_{turns}	8192
$n_{macroparticles}$	500000
n_{slices}	5000

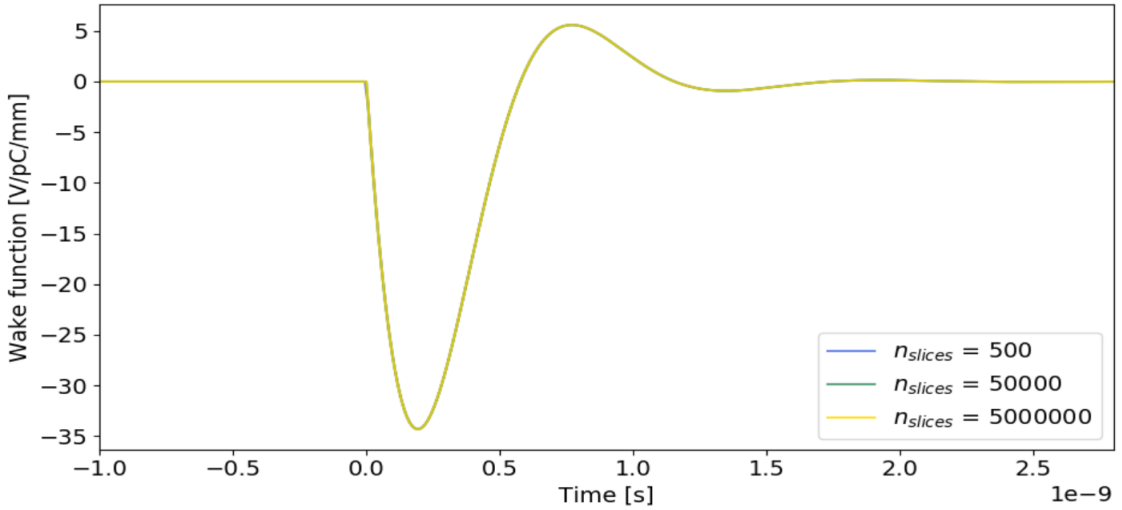
Resonators parameters

	Broad band resonator (BBR)	High frequency broad band resonator (hfBBR)		
R_t [MΩ/m]	10	0 → 100	0 → 100	0 → 100
Q	1	1	1	1
f_{res} [GHz]	1	10	100	1000
	R_t = 10 MΩ/m	**R_t = 10 MΩ/m**	**R_t = 10 MΩ/m**	**R_t = 10 MΩ/m**
Impedance plot				

Effect of n_{slices} on wake function (BBR and hfBBR cases)

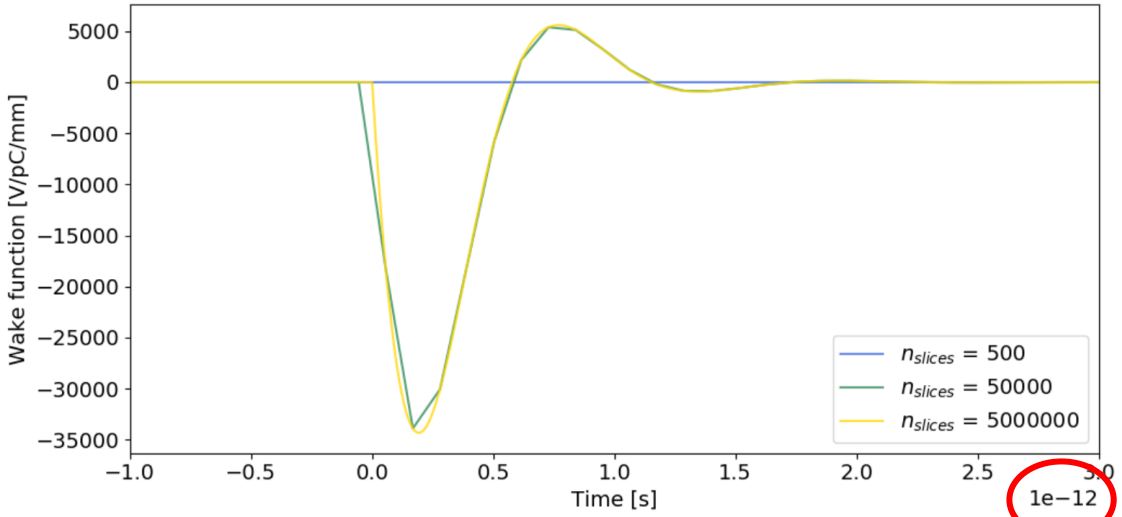
BBR wake function

- R_t = 10 [MΩ/m]
- Q = 1
- f_{res} = 1 GHz



hfBBR wake function

- R_t = 10 [MΩ/m]
- Q = 1
- f_{res} = 1000 GHz



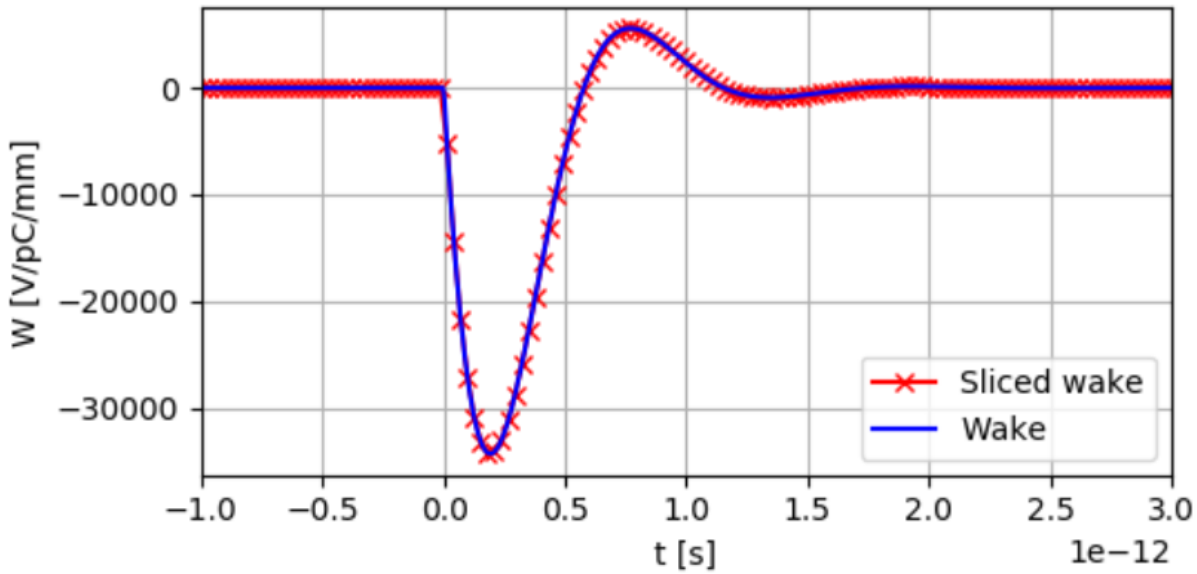
Wake function much shorter !

Effect of n_{slices} on wake function (BBR and hfBBR cases)

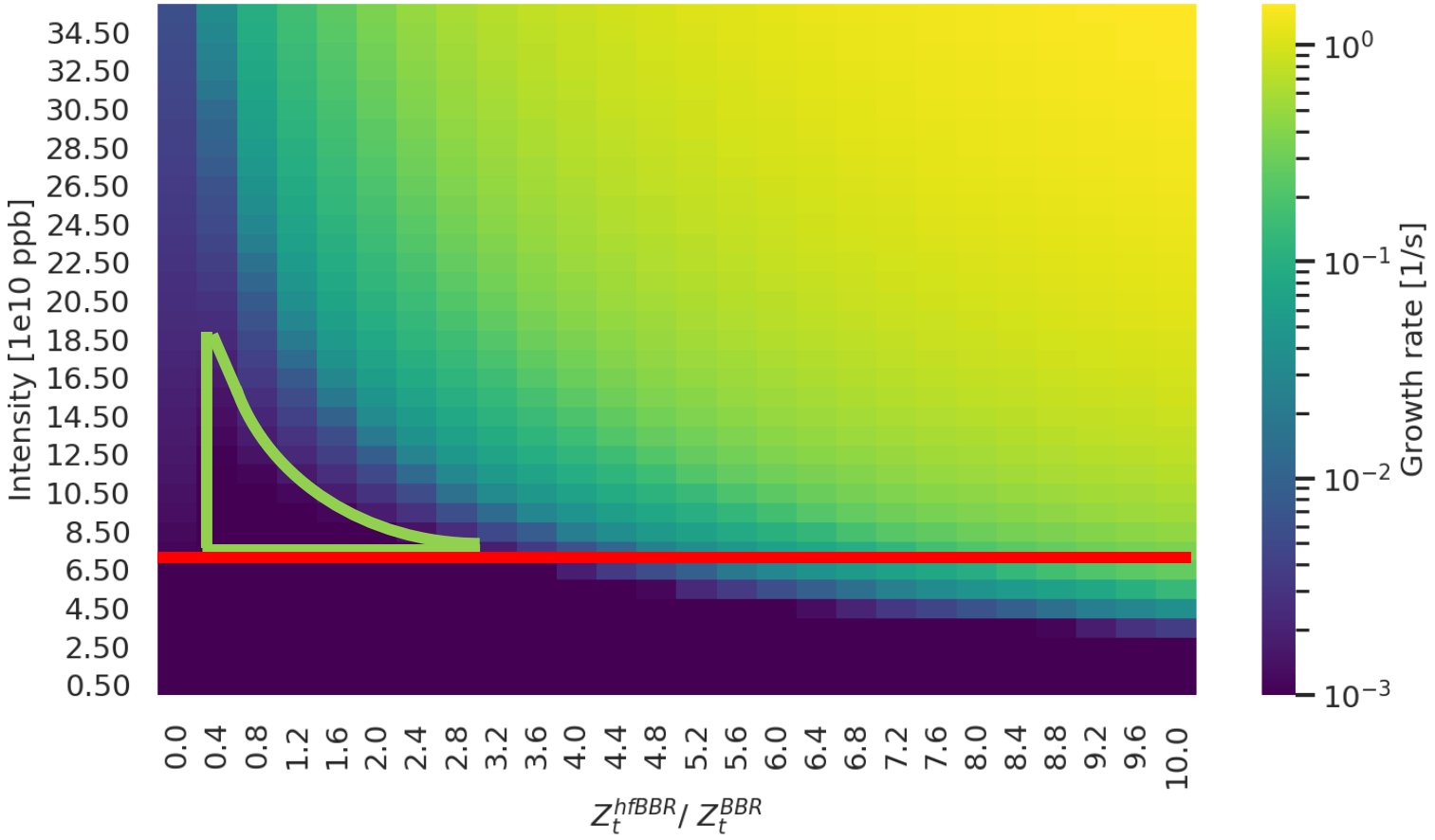
- Setting a number of slices up to 500000 allows accurate wake slicing to the cost of time consuming simulations
- Another option is to take advantage of the length of the wake. Rather than uniformly slice the wake from $-\sigma_z$ to σ_z we can slice from $-\sigma_z/100$ to $\sigma_z/100$
- We can use a limited number of slices (5000) and still accurately interpolate the wake
- We will use this way of slicing wakes for the rest of the study

hfBBR wake function

- R_t = 10 [MΩ/m]
- Q = 1
- f_{res} = 1000 GHz



Growth rate of a hfBBR (10 GHz) + BBR

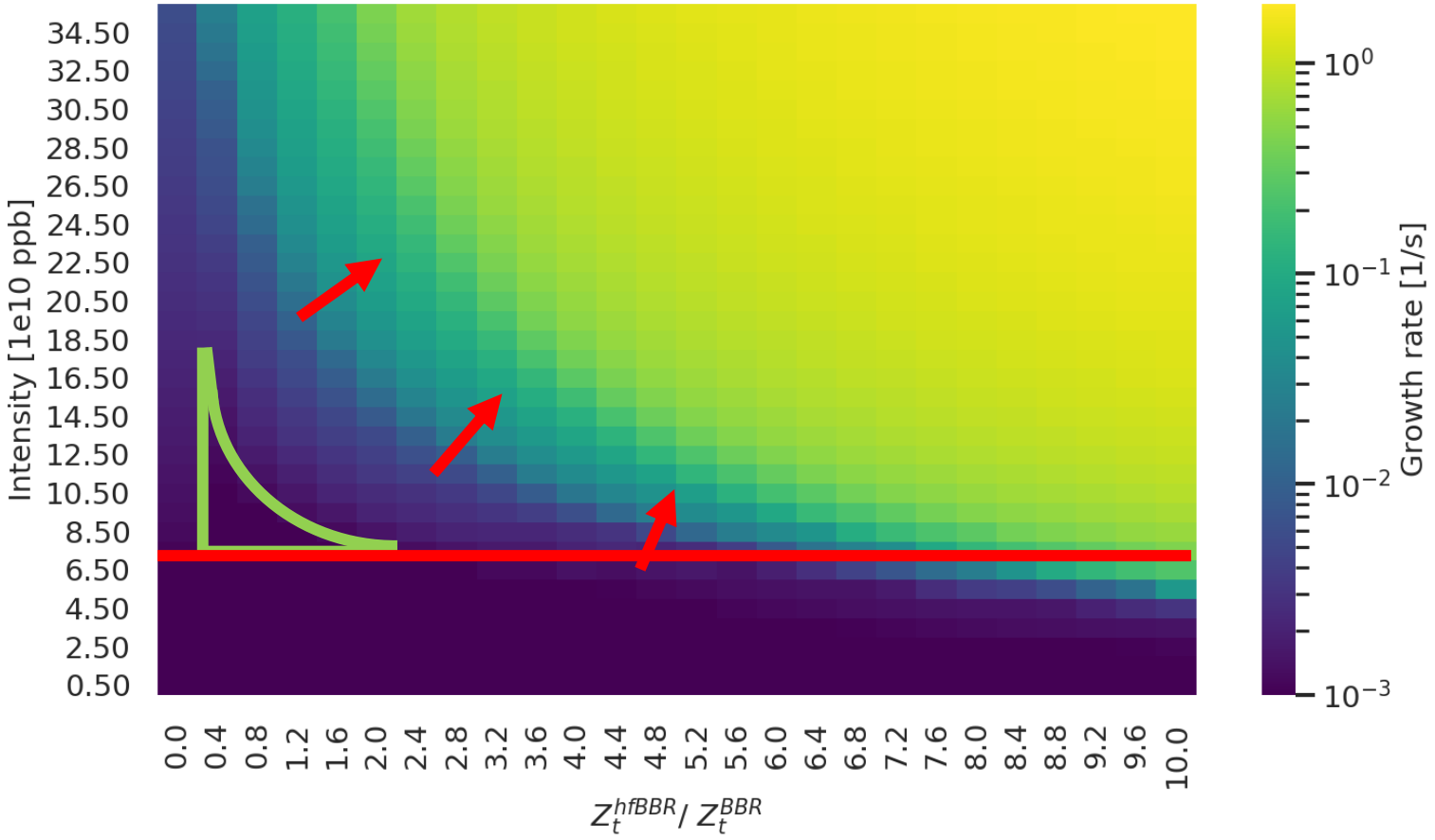


Region more stable than BBR only

SPS TMCI from a BBR threshold

- Beam becomes the most unstable at larger intensities and inductive impedances
- The area of the stable region becomes smaller as the frequency of the inductive impedance increases

Growth rate of a hfBBR (100 GHz) + BBR

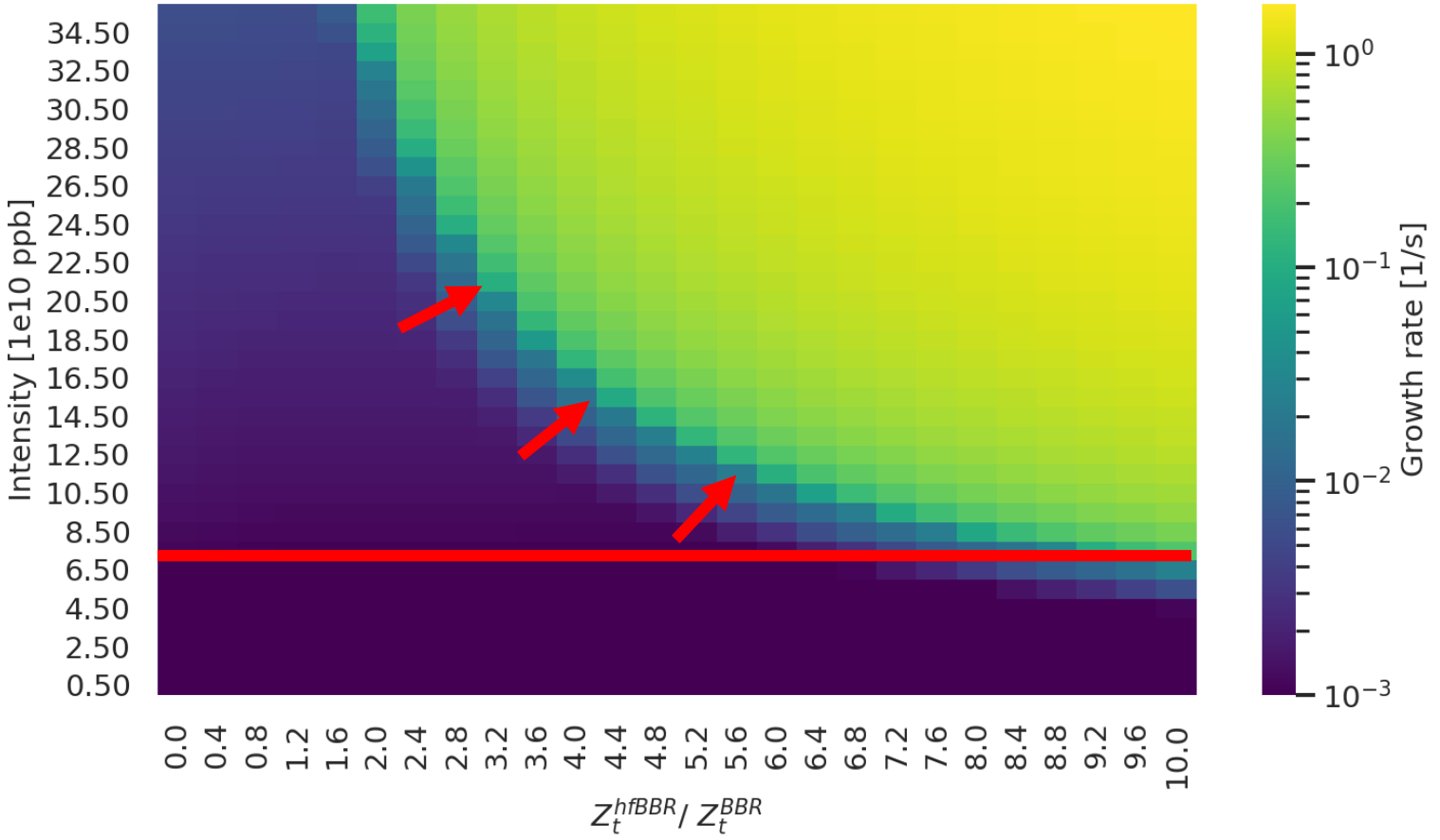


Region more stable than BBR only

SPS TMCI from a BBR threshold

- We observe a region where the effect of inductive impedance is beneficial leading to a beam more stable than the case BBR only
- We observe another region where the effect of inductive impedance is detrimental

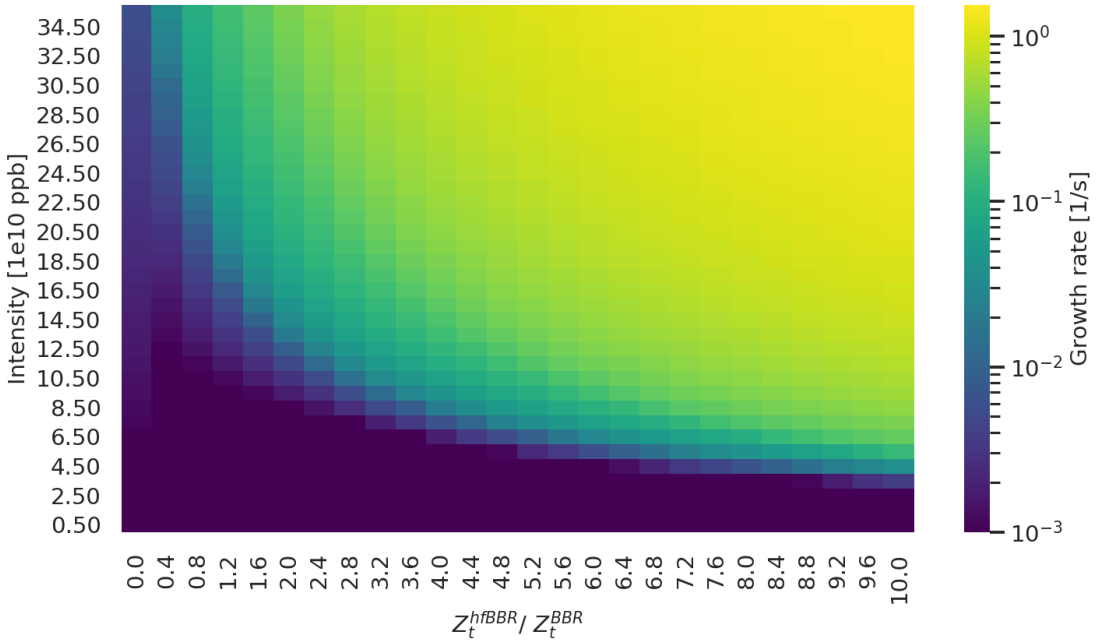
Growth rate of a hfBBR (1000 GHz) + BBR

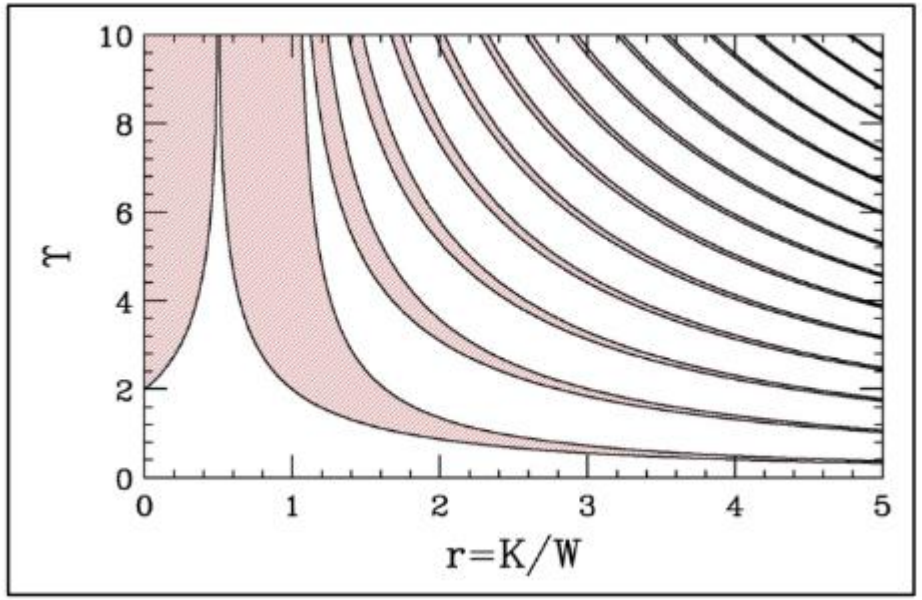


SPS TMCI from a BBR threshold

- **Beam becomes the most unstable at larger intensities and inductive impedances**
- **The stable region disappears after a certain frequency of the inductive impedance**

Similarities between the effect of a hfBBR and space charge





E. Métral, HSC section meeting, CERN, 18/05/2020

- **The effect of a hfBBR on the SPS TMCI from a BBR shares some similarities with the effect of space charge from 2-particle model from Chao-Chin-Blaskiewicz**

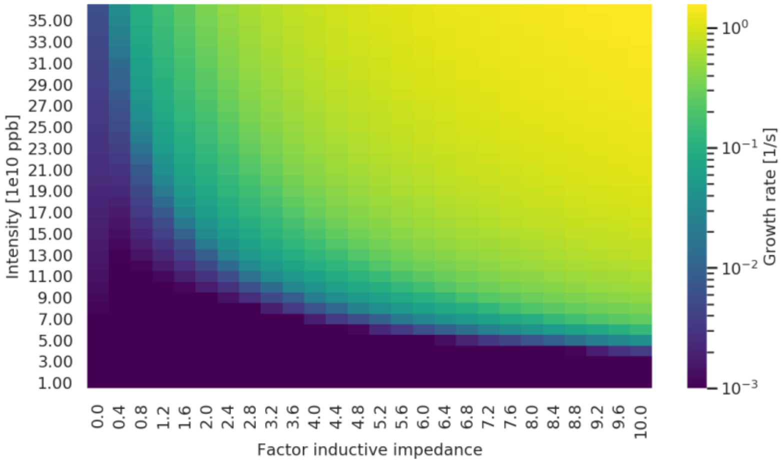
Conclusion

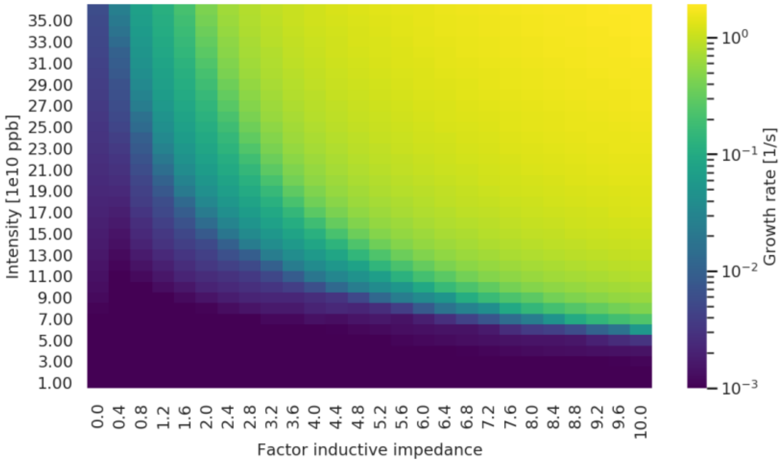
- **Adding a hfBBR impedance to a BBR impedance leads to two different effects :**
  - A beneficial effect with the presence of a stable region at small intensities and Z_t^{hfBBR}/Z_t^{BBR} (region more stable than BBR only)
  - A detrimental effect, leading to substantially more unstable beam outside of the stable region
- **Increasing the frequency of the hfBBR leads to two different effects :**
  - Reduction of the stable region area until it disappears at a high resonant frequency
  - Shift of the most unstable region to larger intensities and inductive impedances
  - TMCI intensity threshold lower than ~7.10^{10} ppb (BBR only case) for Z_t^{hfBBR}/Z_t^{BBR} high enough

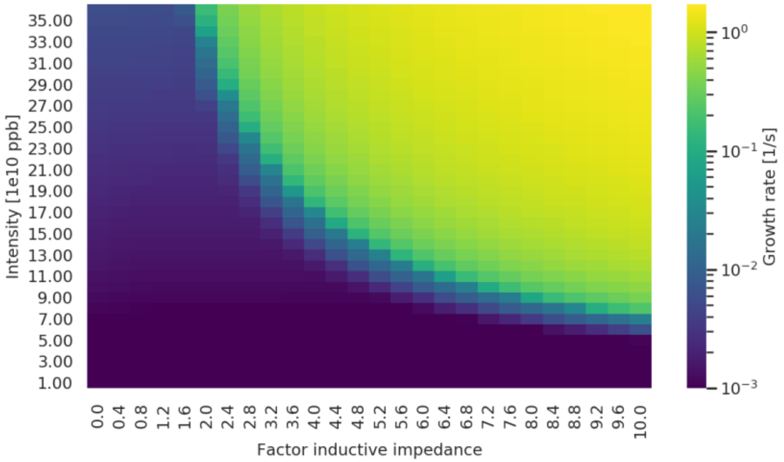
Outlook

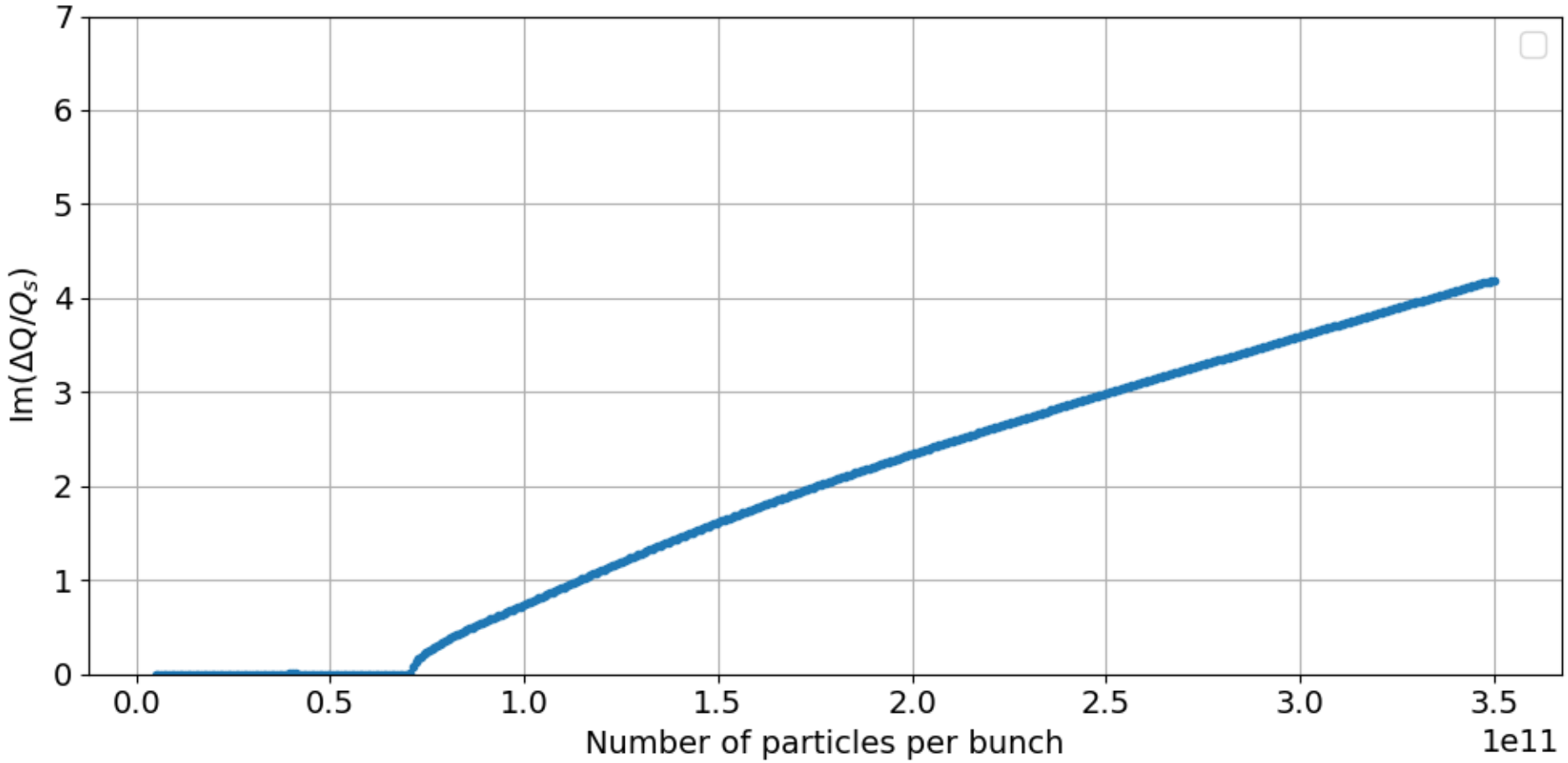
- **Check the results**
  - Check the convergence with the number of **turns**, **slices** and **macroparticles**
- **Look at intra-bunch motion**
- **How to introduce a hfBBR impedance in the SPS ?**
  - Investigate potential adverse effects from such an impedance
  - Use DELPHI again
  - Highlight most critical mode coupling with DELPHI

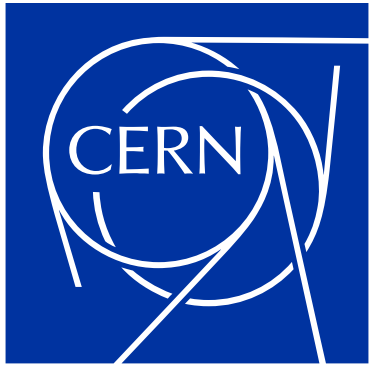
Backup slides


Intensity [1e10 ppb]
Factor inductive impedance
Growth rate [1/s]


Intensity [1e10 ppb]
Factor inductive impedance
Growth rate [1/s]


Intensity [1e10 ppb]
Factor inductive impedance
Growth rate [1/s]


7
6
5
4
3
2
1
0
Im(ΔQ/Q_s)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Number of particles per bunch
1e11



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