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Collective effects for single-beam in FCC-ee and Impedance database

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Collaborations: Y. Zhang

Outline

- Wakefields and impedances evaluated so far: FCC-ee Wake & Impedance Repository
- Longitudinal single beam instabilities: MI analysis
- Transverse single beam instabilities : TMCI mode analysis

Real and imaginary impedance of some machine devices



A repository, or Git project, encompasses the entire collection of files and folders associated with a project, along with each file's revision history. Working in repositories keeps development projects organized and protected. The Repository also provides more opportunities for project transparency and collaboration, working together to build the best possible final product.

Wake and impedance repository for FCC-ee: https://gitlab.cern.ch/ecarideo/FCCee_IW_Model

How is it developed?

Link : https://gitlab.cern.ch/ecarideo/FCCee_IW_Model

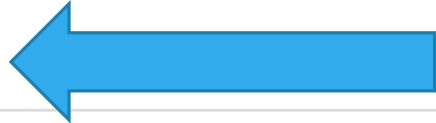
The screenshot shows the GitLab interface for the repository 'FCCee_IW_Model'. The top navigation bar includes 'GitLab', 'Projects', 'Groups', and 'More'. Below the navigation bar, the repository name 'FCCee_IW_Model' is displayed along with statistics: 21 Commits, 1 Branch, 0 Tags, 8.5 MB Files, and 8.5 MB Storage. The current branch is 'master'. A commit titled 'Add Impedances and Wakes of all machine components' by Emanuela Carideo is highlighted, with a commit ID of 55fd8136. Below the commit information, there are several buttons for adding project files and settings, such as 'Add LICENSE', 'Add CHANGELOG', 'Add CONTRIBUTING', 'Enable Auto DevOps', 'Add Kubernetes cluster', and 'Set up CI/CD'. A table lists the repository's files and their commit history:

Name	Last commit	Last update
FCC_elements	Add Impedances and Wakes of all machine components	1 days ago
README.md	add README	2 weeks ago
README.md		

In this folder there are some of FCC-ee components

FCC-ee_IW_Model/FCC_elements/

Name	Last commit
..	
📁 BPMs_from_CST	Wake and Impedance for BPMs
📁 Bellows_from_CST	Add Impedances and Wakes of all machine...
📁 RF_Cavity_from_CST	Wakefield and impedance
📁 RW_from_IW2D	Wakefield and impedance
📁 Tapers_ABCI	Wakefield and impedance
📁 Total_FCCee_Impedance	



The total FCCee Impedance comes from all machine components

FCCee_IW_Model/FCC_elements/BPM_from_CST/

GitLab Projects Groups More Search or jump to...

Emanuela Carideo > FCCee_IW_Model > Details

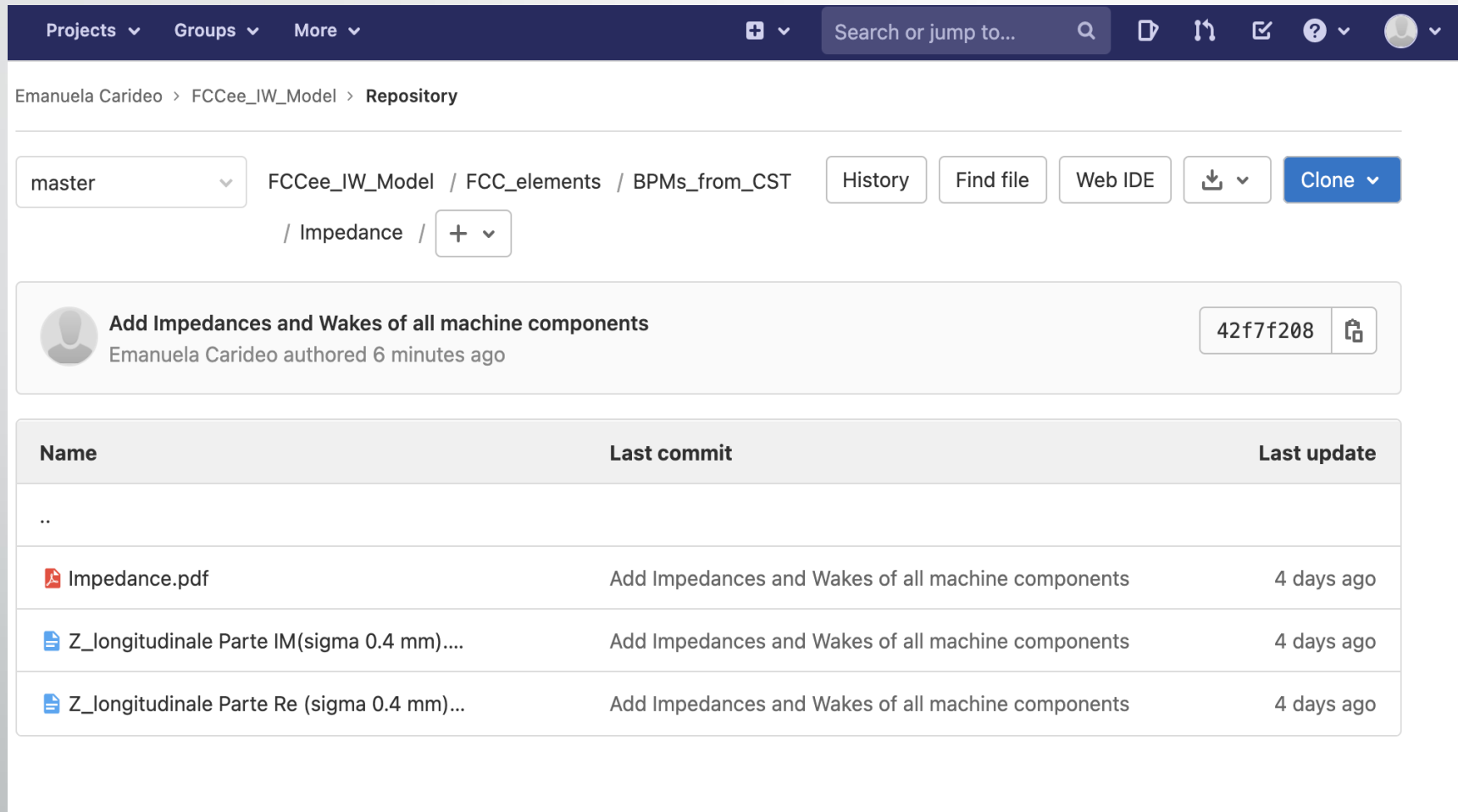
master FCCee_IW_Model / FCC_elements History Find file Web IDE Clone

/ BPMs_from_CST / +

Add Impedances and Wakes of all machine components
Emanuela Carideo authored 4 days ago 55fd8136

Name	Last commit	Last update
..		
Impedance	Real and Imaginary Longitudinal Impedance	4 days ago
Wake	Wake potential s of all machine components	4 days ago
BPM_four_buttons.cst	Model used for CST simulation	1 week ago
loss_factors.txt	Calculation of the loss factor	1 week ago

FCCee_IW_Model/FCC_elements/BPM_from_CST/ Impedance







Projects ▾ Groups ▾ More ▾ + ▾ Search or jump to... 🔍 📄 ↺ 📄 ? ▾ 👤 ▾

Emanuela Carideo > FCCee_IW_Model > Repository

master ▾ FCCee_IW_Model / FCC_elements / BPMs_from_CST History Find file Web IDE 📄 ▾ Clone ▾

/ Impedance / + ▾

 **Add Impedances and Wakes of all machine components** 42f7f208 📄
Emanuela Carideo authored 6 minutes ago

Name	Last commit	Last update
..		
 Impedance.pdf	Add Impedances and Wakes of all machine components	4 days ago
 Z_longitudinale Parte IM(sigma 0.4 mm)....	Add Impedances and Wakes of all machine components	4 days ago
 Z_longitudinale Parte Re (sigma 0.4 mm)...	Add Impedances and Wakes of all machine components	4 days ago

FCCee_IW_Model/FCC_elements/BPM_from_CST/Wake

The screenshot shows a GitLab repository page for the path `FCCee_IW_Model / FCC_elements / BPMs_from_CST / Wake`. The current branch is `master`. A commit titled "Add Wake and Impedance for BPMs" by Emanuel Carideo is shown, with commit hash `6ac4d6fb`. Below the commit, a table lists files in the directory:


Name	Last commit	Last update
..		
Wake Potential (sigma 0.4 mm).txt	Add Impedances and Wakes of all machine components	4 days ago
Wake Potential (sigma 12.1 mm).txt	Add Impedances and Wakes of all machine components	4 days ago
Wake Potential (sigma 3.5 mm).txt	Add Impedances and Wakes of all machine components	4 days ago
wake_reconstr_12_1mm.pdf	Add Wake and Impedance for BPMs	1 week ago
wake_reconstr_3_5mm.pdf	Add Wake and Impedance for BPMs	1 week ago
wakes.pdf	Add Wake and Impedance for BPMs	1 week ago

FCC-ee_IW_Model/FCC_elements/

Name	Last commit
..	
📁 BPMs_from_CST	Add Wake and Impedance for BPMs
📁 Bellows_from_CST	
📁 RF_Cavity_from_CST	
📁 RW_from_IW2D	
📁 Tapers_ABCI	Wakefield and impedance
📁 Total_FCCee_Impedance	Wakefield and impedance


The same procedure for the other folders















FCC-ee_IW_Model/FCC_elements/RW_from_IW2D



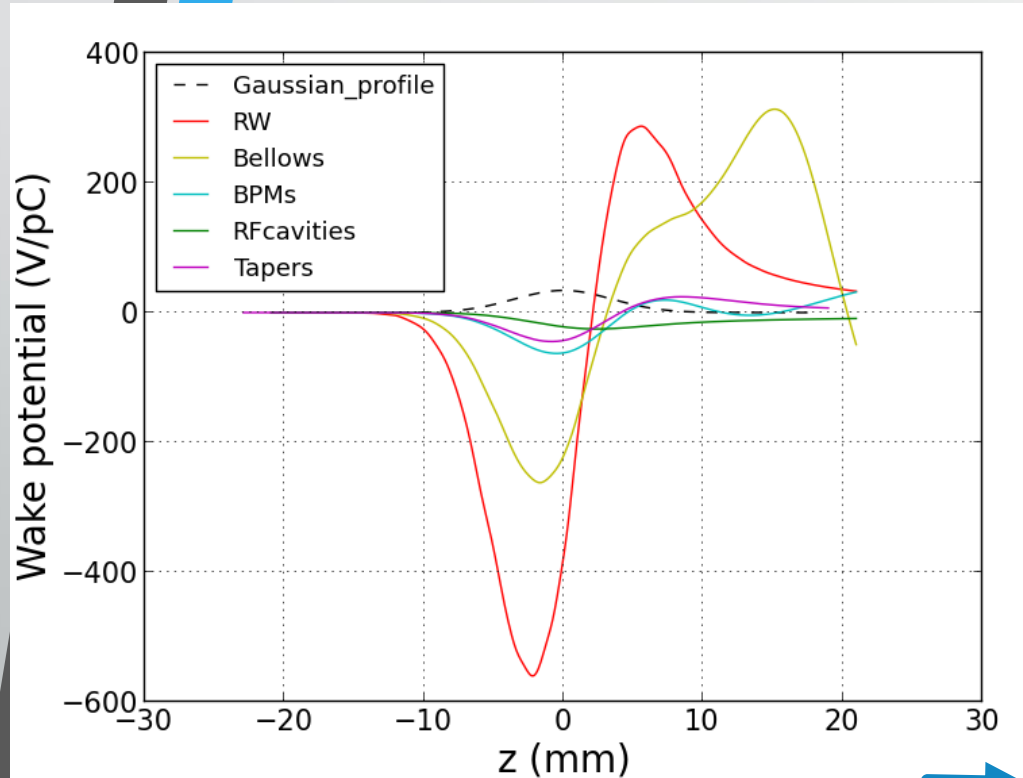
..	
Impedance	Wakefield and impedance
Wake	Wakefield and impedance
Bunch_Length_beam_0.35mm....	Add RW, Wakes and Impedances, of Comp...
Bunch_Length_beam_0.4mm.p...	Add RW, Wakes and Impedances, of Comp...
Bunch_Length_different_beam...	Add RW, Wakes and Impedances, of Comp...
Energy_Spread_0.35mm.png	Add RW, Wakes and Impedances, of Comp...
Energy_Spread_Beam_0.4mm....	Add RW, Wakes and Impedances, of Comp...
Energy_Spread_different_bunc...	Add RW, Wakes and Impedances, of Comp...
loss_factor_12_1mm.py	Add RW impedances and wakes with relati...
loss_factor_3_5mm.py	Add RW impedances and wakes with relati...
loss_factors.txt	Wakefield and impedance
plot_NvsSigma.py	Add RW impedances and wakes with relati...

FCC-ee_IW_Model/FCC_elements/RW_from_IW2D/ Wake



 HTLauncher.py	Wakefield and impedance
 MAIN_FILE.py	Wakefield and impedance
 Wake Potential (sigma 0.4 mm...	Add Impedances and Wakes of all machi...
 Wake Potential (sigma 12.1 m...	Add Impedances and Wakes of all machi...
 Wake Potential (sigma 3.5 mm...	Add Impedances and Wakes of all machi...
 Wake_Bunch_length_0.4mm.p...	Add RW, Wakes and Impedances, of Com...
 WlongWFCC_4layers35.00mm...	Add RW impedances and wakes with rela...
 WxdipWFCC_4layers35.00mm...	Add RW impedances and wakes with rela...
 WxquadWFCC_4layers35.00m...	Add RW impedances and wakes with rela...
 WydipWFCC_4layers35.00mm...	Add RW impedances and wakes with rela...
 WyquadWFCC_4layers35.00m...	Add RW impedances and wakes with rela...
 verify_wake.py	Wakefield and impedance
 wake_reonstr_12_1mm.pdf	add Impedance and Wake of Resistive wall
 wake_reonstr_3_5mm.pdf	add Impedance and Wake of Resistive wall

Impedance Sources: CST and IW2D simulations



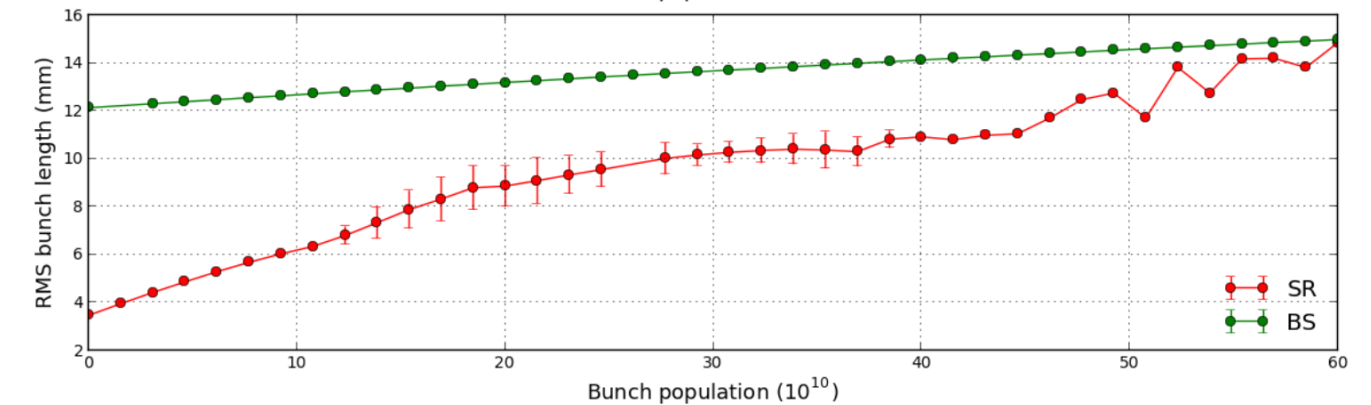
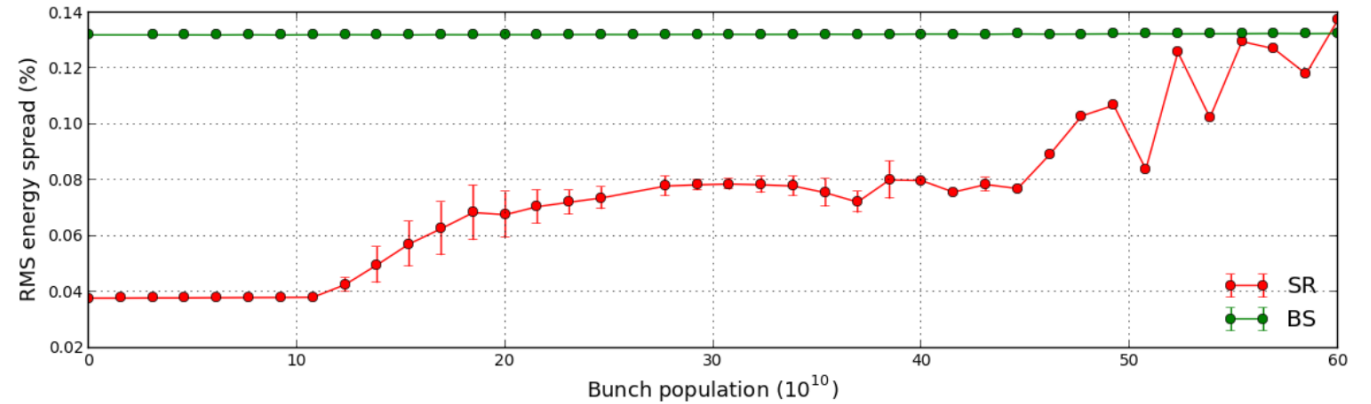
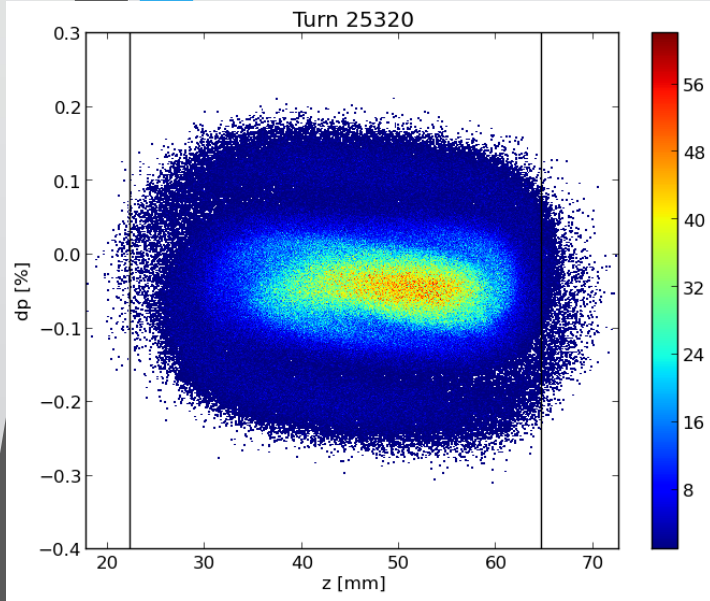
Longitudinal wake potentials for a Gaussian bunch with nominal bunch length $\sigma_z = 3.5\text{mm}$ due to the main FCC-ee components, evaluated so far.

Loss factor and Power loss contribution of FCC-ee devices at nominal intensity and bunch length of 12.1 mm, in the lowest energy case of 45.6 GeV

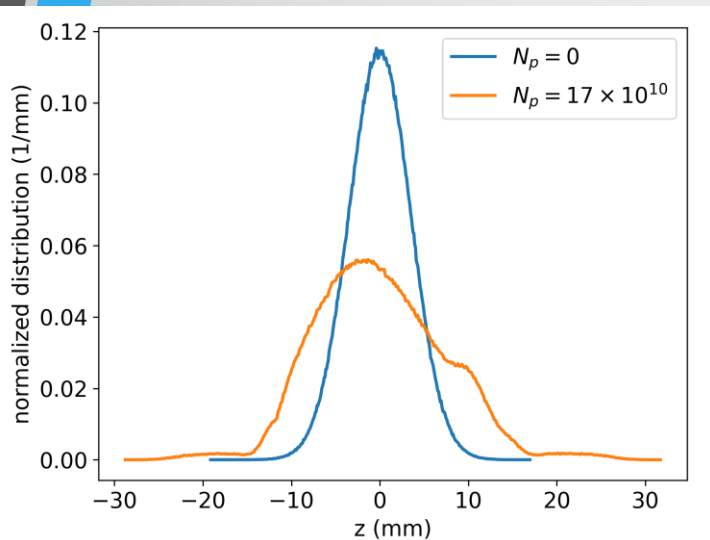
Component	Number	$K_{\text{loss}}(12.1\text{mm})[\text{V/pC}]$	$P_{\text{loss}}[\text{MW}]$
Resistive Wall	97.75 km	33.1	1.21
RF cavities	52	8.76	0.334
BPMs	4000	4.81	0.180
Bellows	20000	23.95	0.880
RF double tapers	13	2.33	0.088

Longitudinal dynamics

Longitudinal phase space



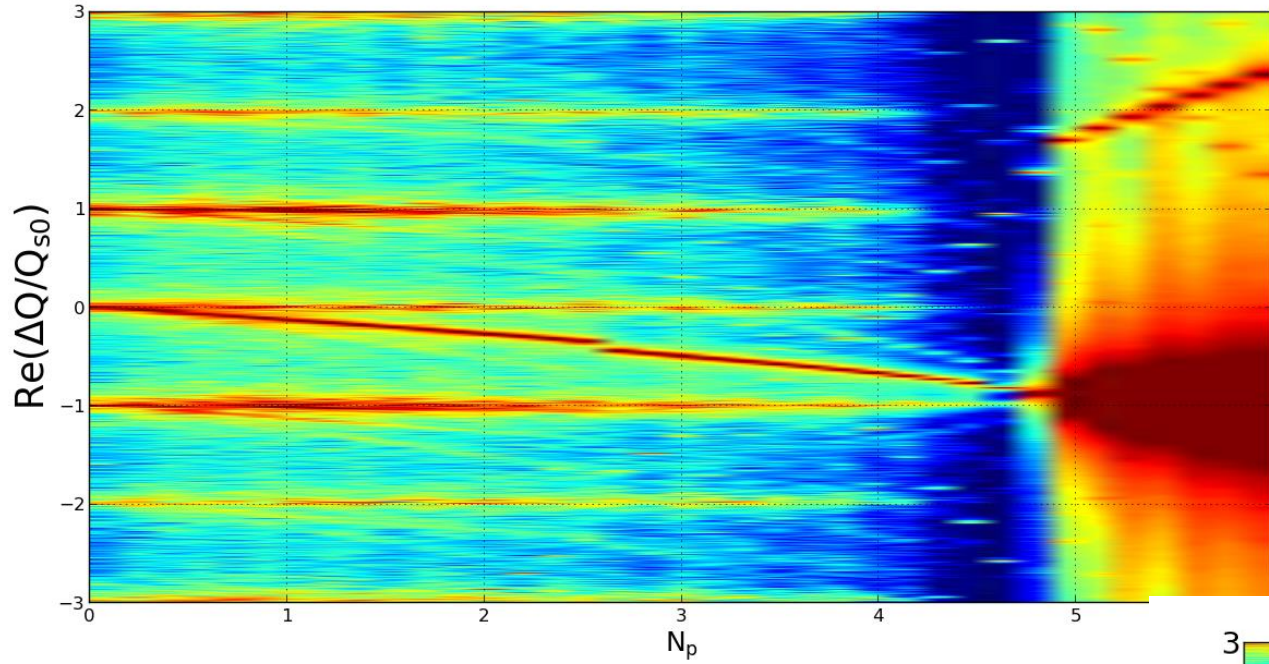
Bunch length (bottom) and RMS energy spread (top) as a function of bunch population in the case with (BS) and without (SR) beamstrahlung, which is considered here independent of the longitudinal impedance.



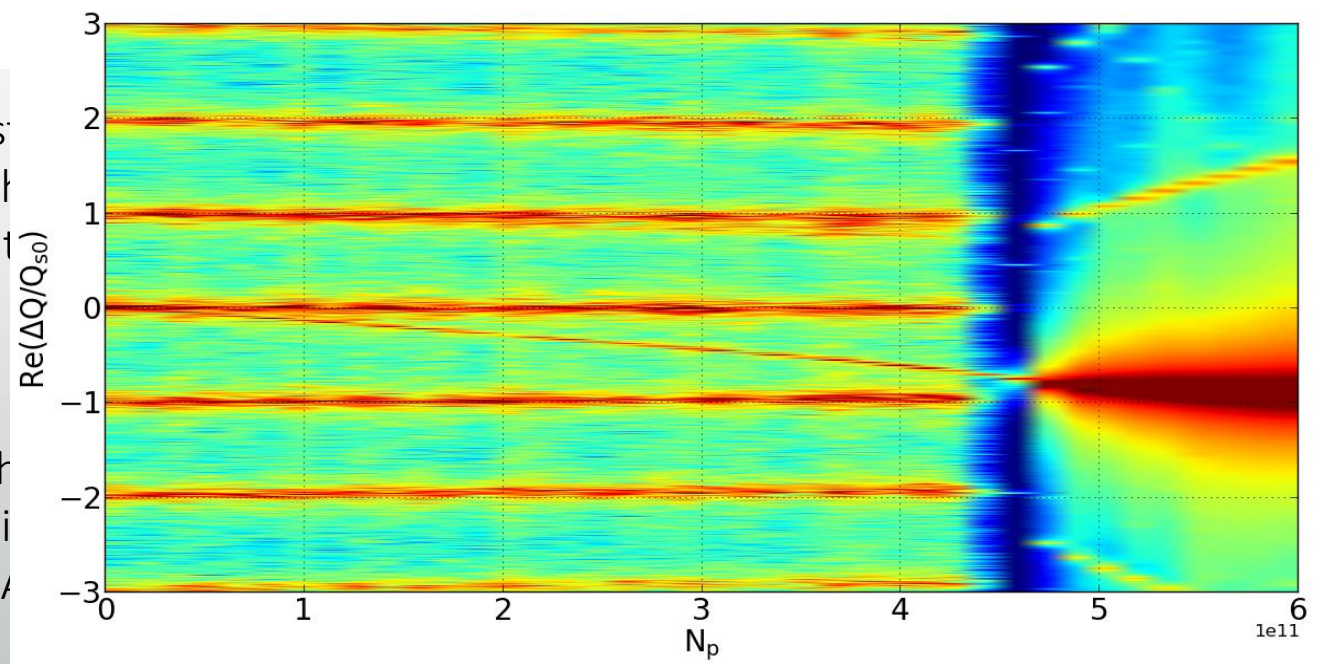
Bunch shape distortion at nominal intensity from the original Gaussian one.

Transverse Dynamics

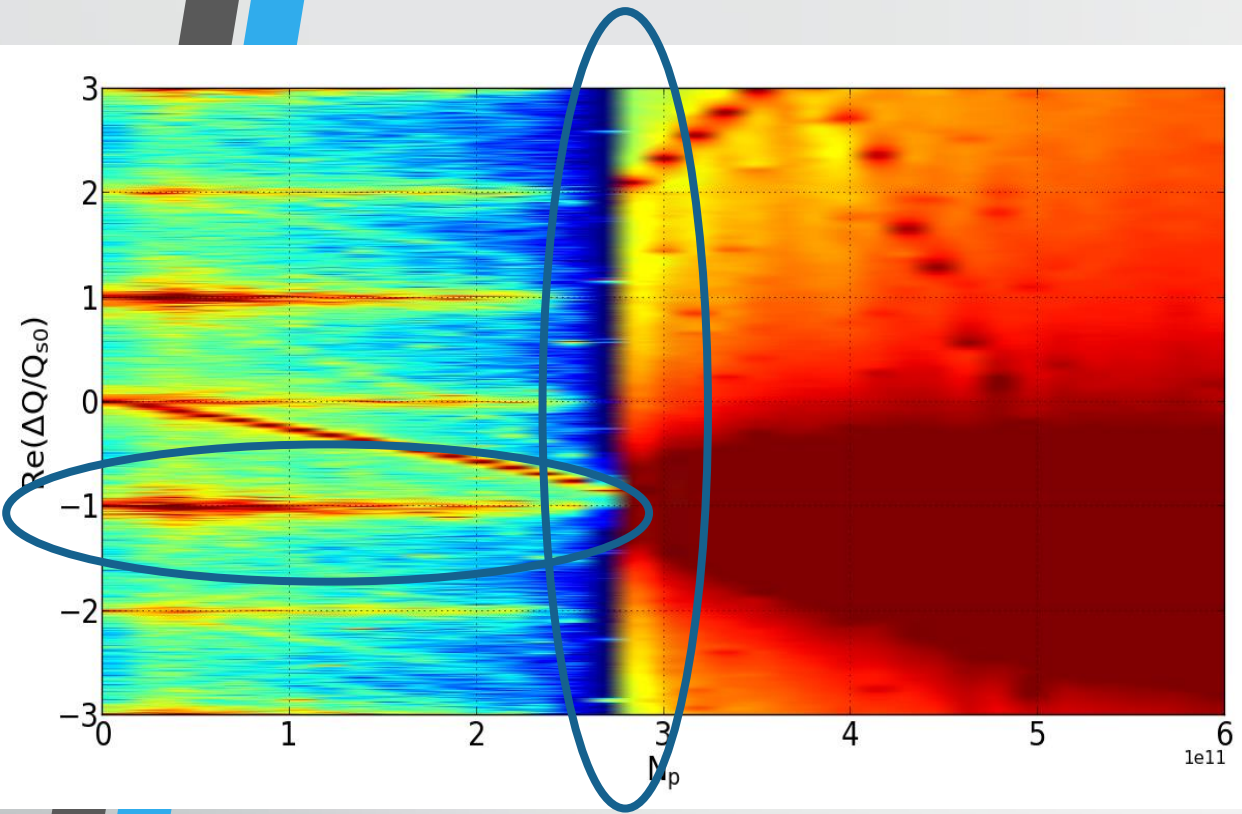
The TMCI occurs when the frequencies of two neighbouring coherent oscillation modes merge together. Above the transverse instability threshold the bunch is lost and this makes the TMCI very dangerous for the beam.



On the top, real part of the frequency shift of the first coherent oscillation modes as a function of the bunch population with beamstrahlung, by considering only the RW impedance produced by a NEG film with 100 nm thickness given by IW2D.

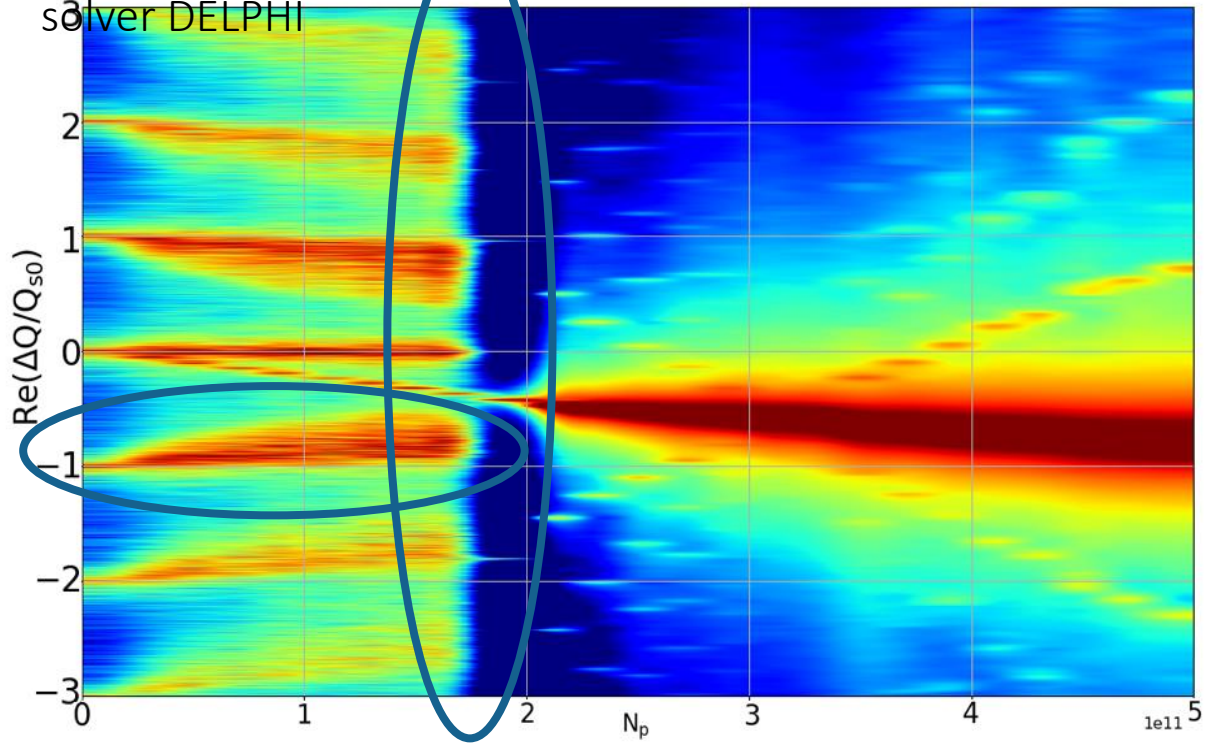


On the right, real part of the coherent tune shift as a function of intensity considering the longitudinal resistive wall wakefield, by using PyHEADTAIL.



Without the frequency shift of the first coherent oscillation modes as a function of the bunch population without beamstrahlung (nominal bunch length), by considering only the RW impedance produced by a NEG film with 100 nm thickness given by IW2D.

In addition to simulations with the tracking code, the TMCI threshold has been also evaluated with the analytic Vlasov solver DELPHI

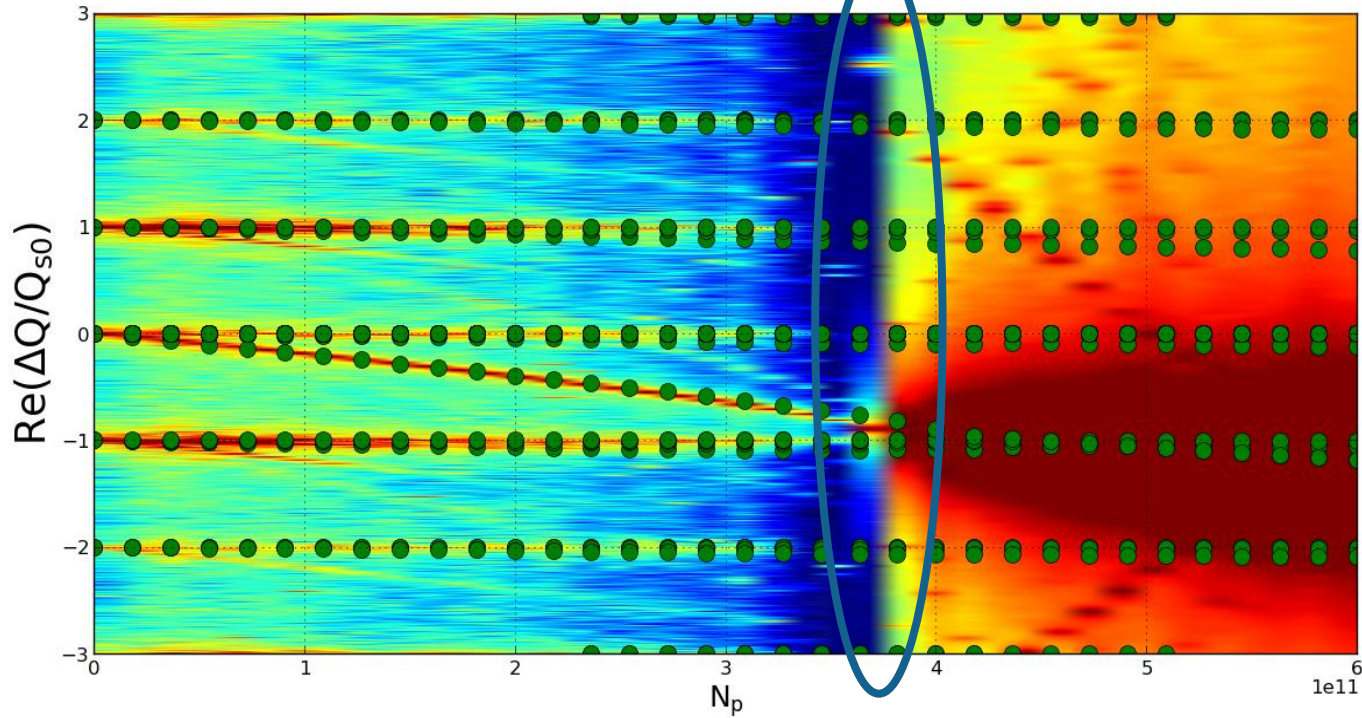


On the right, real part of the coherent tune shift as a function of intensity considering the longitudinal resistive wall wakefield for a bunch length of 3.5mm, by using PyHEADTAIL.

Considering the longitudinal resistive wall wakefield

TMCI:

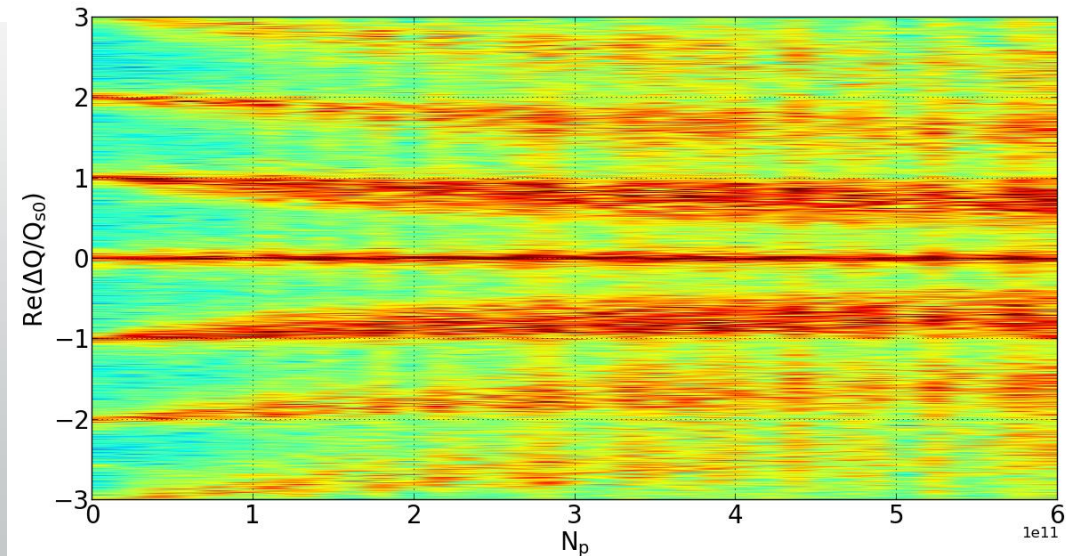
Larger Momentum Compaction



α_p [10^{-5}]	1.48	2.5
σ_{z0} [mm]	3.5	4.5

Trasverse RW with higher Momentum compaction considering the nominal bunch length of 3.5 mm. Also in this case we analyzed the TMCI using both methods: PyHT and DELPHI

Real part of the coherent tune shift as a function of intensity considering the longitudinal RW with higher Momentum compaction for a bunch length of 3.5mm, by using PyHEADTAIL.



Future plan

- Continue the work for the evaluation, reduction and optimization of the impedances of the main machine elements (e. g. flanges, collimators), and also implementing the FCC-ee repository
- Update of some impedance sources (e. g. bellows, RW, RF tapers) with more realistic models (for now we neglected the perturbation introduced by the lateral winglets used to place synchrotron radiation absorbers)
- Evaluate the transverse wakefields and impedances and perform PyHEADTAIL simulations in addition to RW
- Future investigations about the reduction of the TMCI threshold due to the longitudinal wake are required, as well as possible mitigation solutions: continuing the study on the larger momentum compaction



Thanks for your attention!

Bunch length and energy spread for considered cases

- The transverse impedance almost does not affect the longitudinal dynamics

