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

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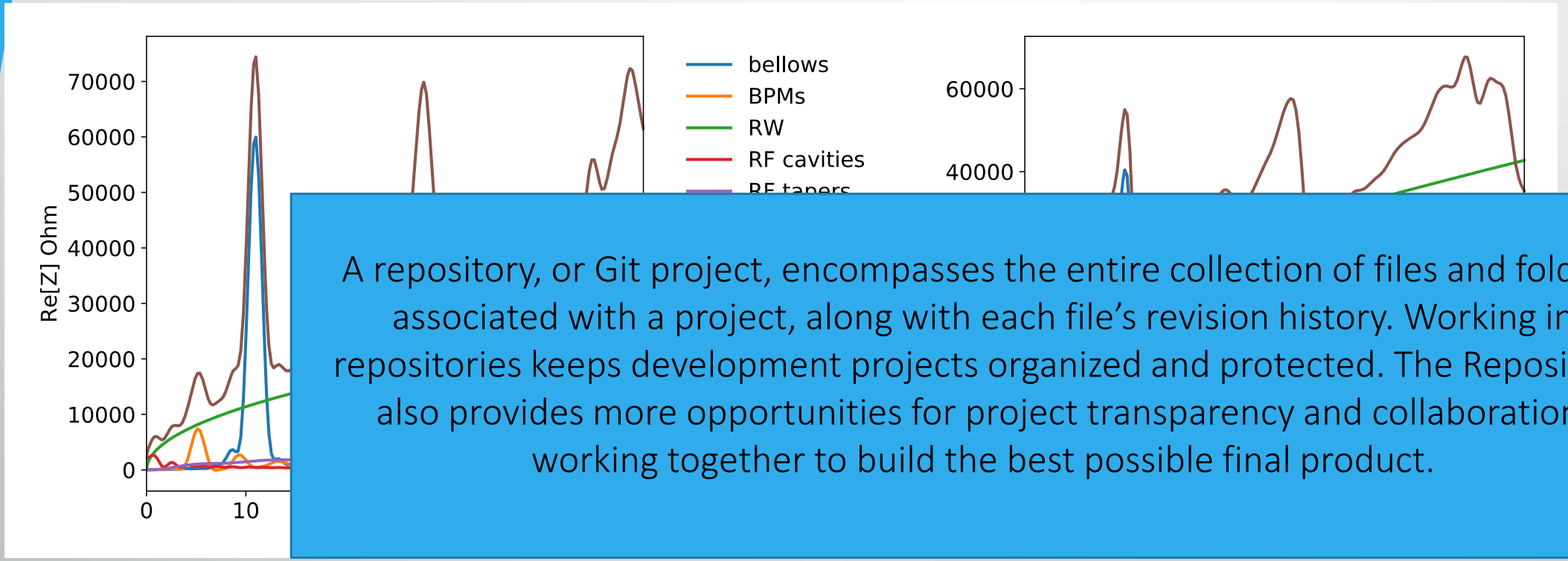
Collaborations: Y. Zhang

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

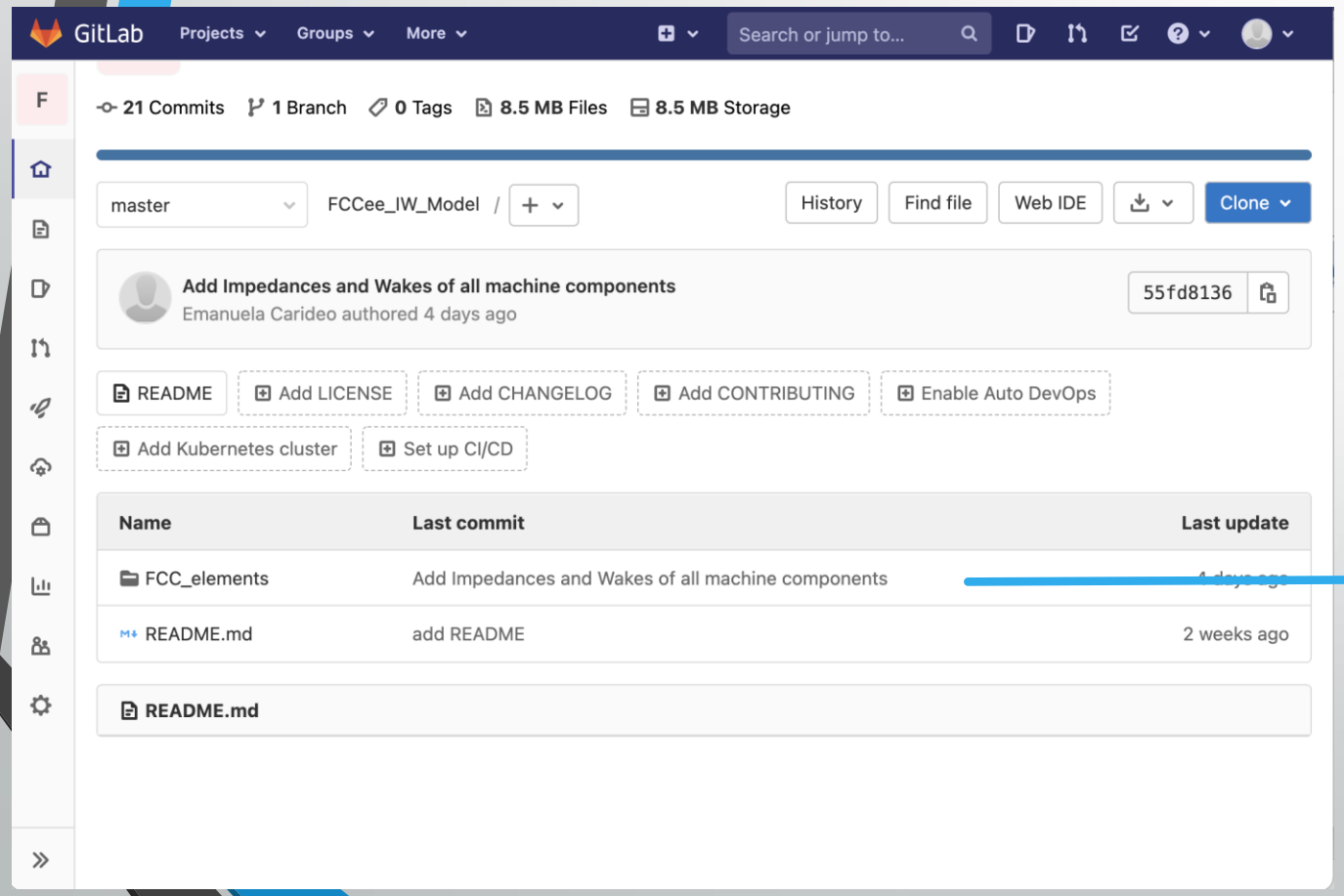


A repository, or Git project, encompasses the entire collection of files and folders associated with a project, along with each file's revision history. Working in repositories keeps development projects organized and protected. The Repository also provides more opportunities for project transparency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



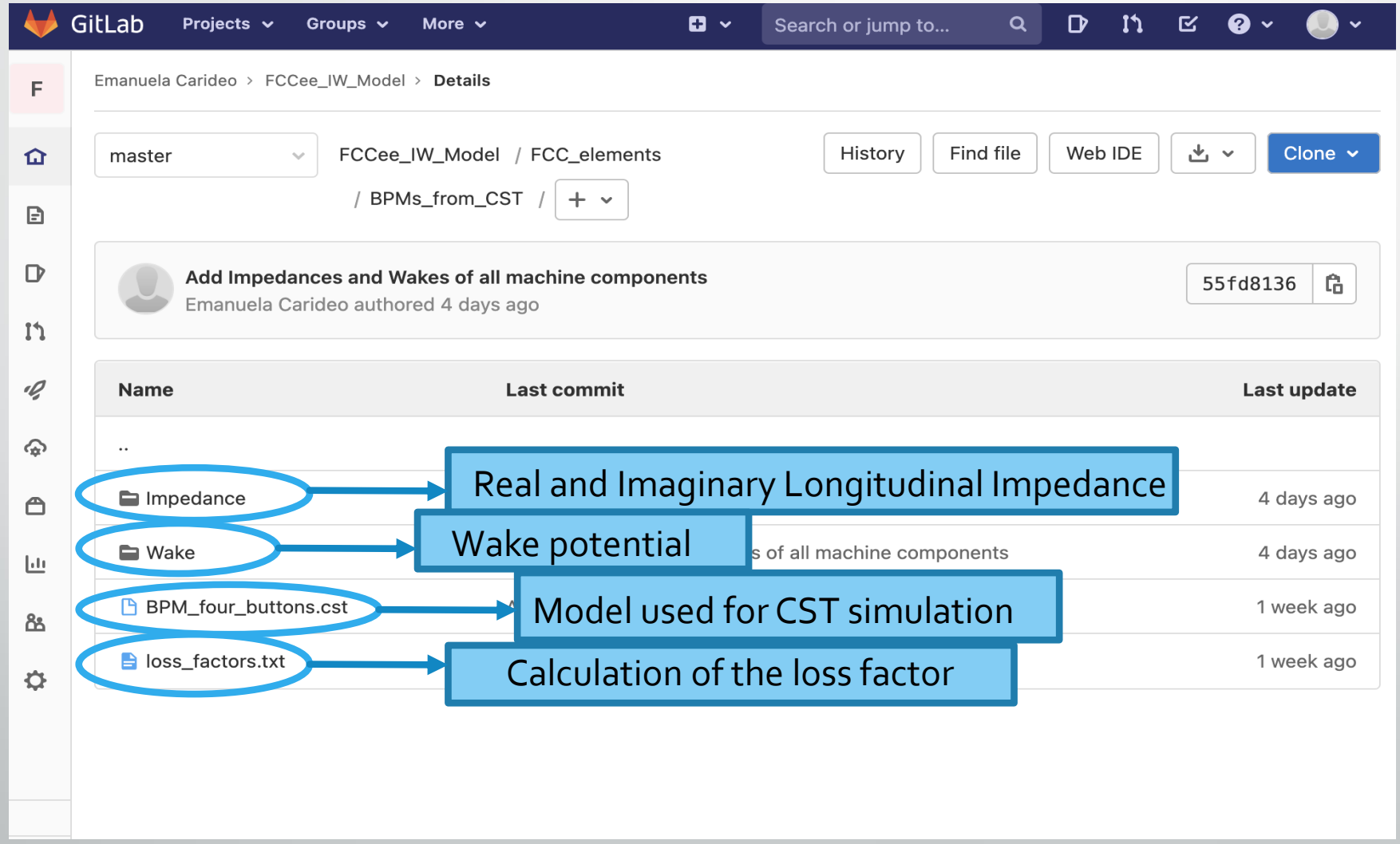
In this folder there are some of FCC-ee components

FCC-ee_IW_Model/FCC_elements/

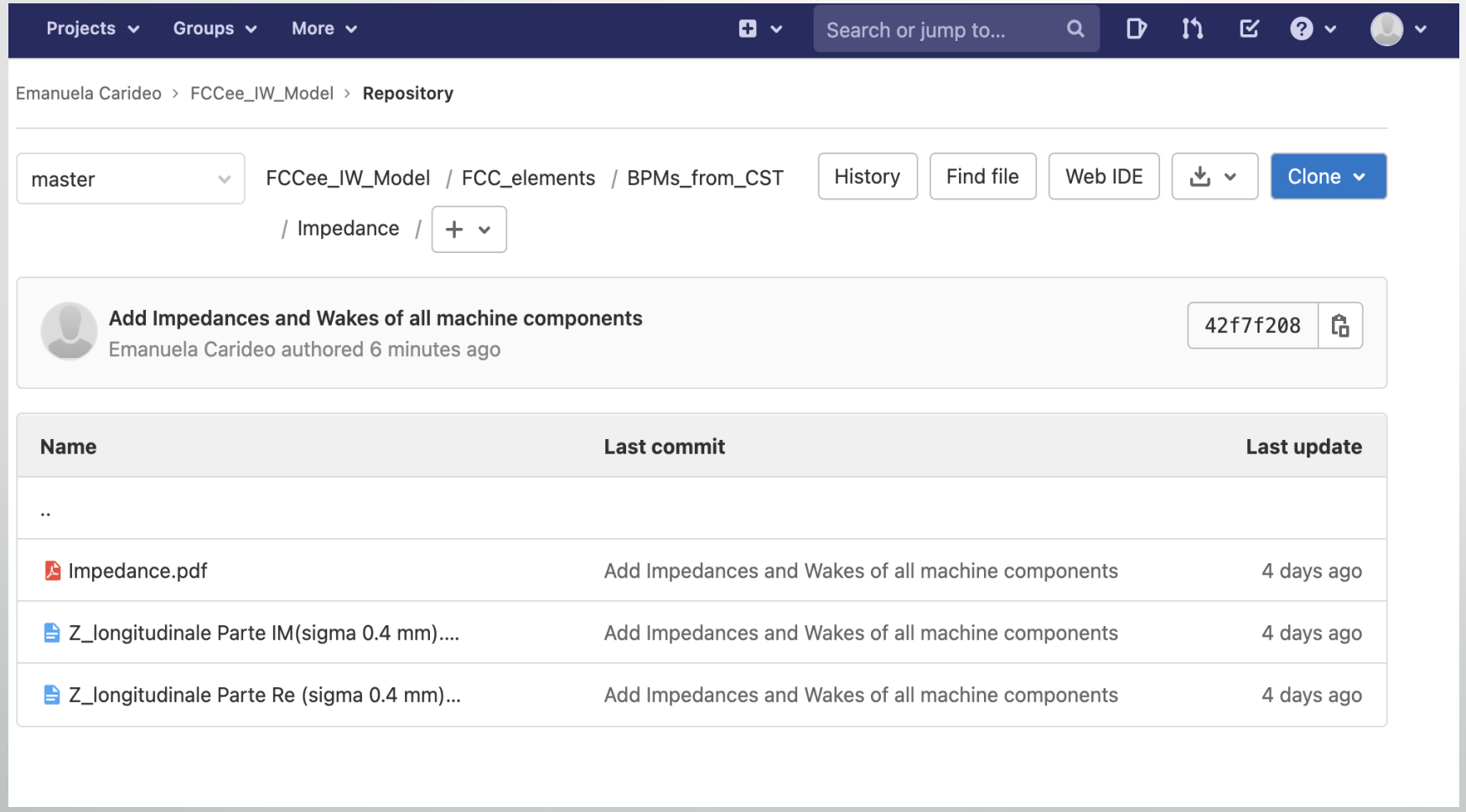
Name	Last commit
..	
BPMs_from_CST	Wake and Impedance for BPMs
Bellows_from_CST	Add Impedances and Wakes of all machine...
RF_Cavity_from_CST	Wakefield and impedance
RW_from_IW2D	Wakefield and impedance
Tapers_ABCI	
Total_FCCee_Impedance	

The total FCCee Impedance comes from all machine components

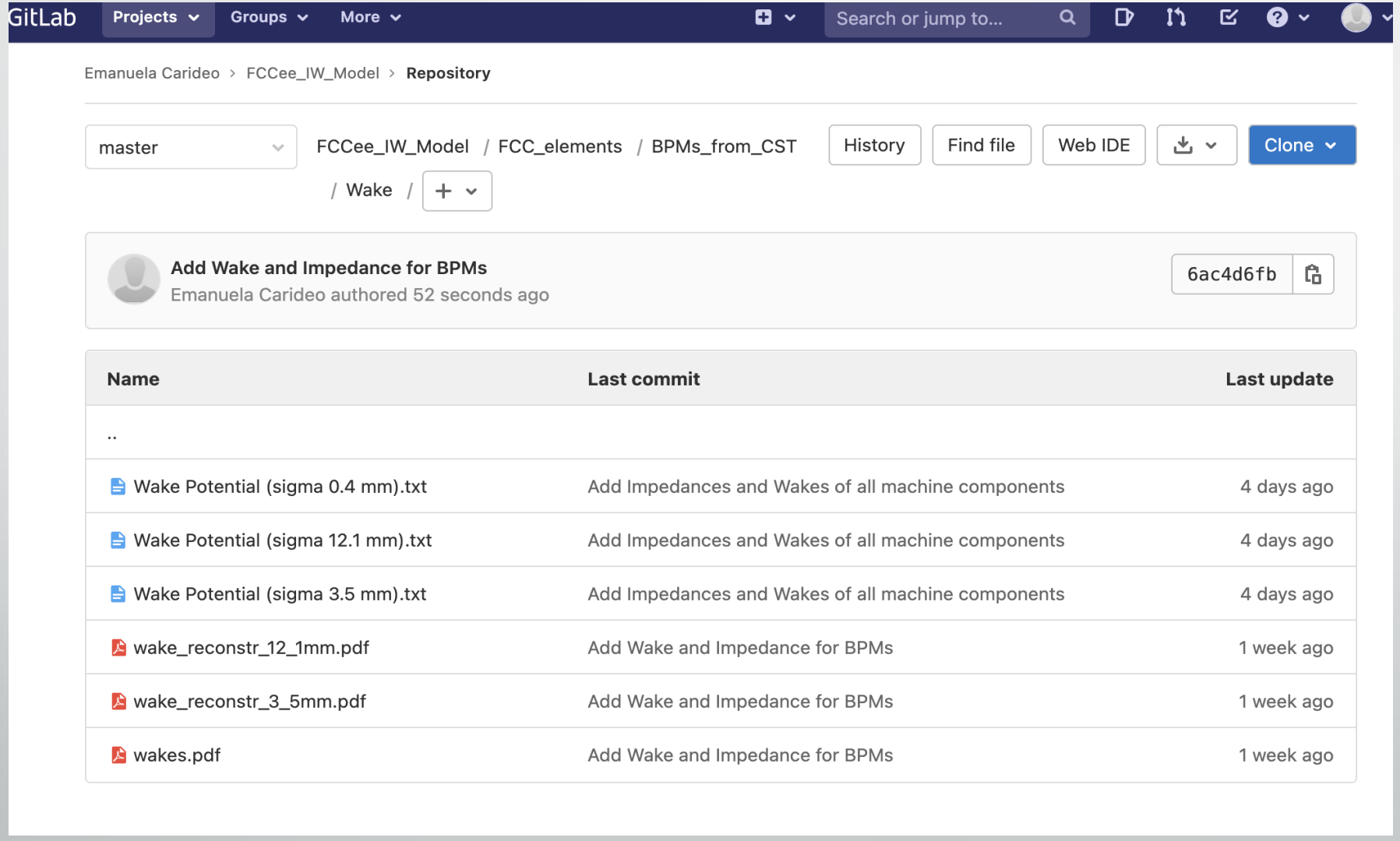
FCCee_IW_Model/FCC_elements/BPM_from_CST/



FCCee_IW_Model/FCC_elements/BPM_from_CST/Impedance



FCCee_IW_Model/FCC_elements/BPM_from_CST/Wake

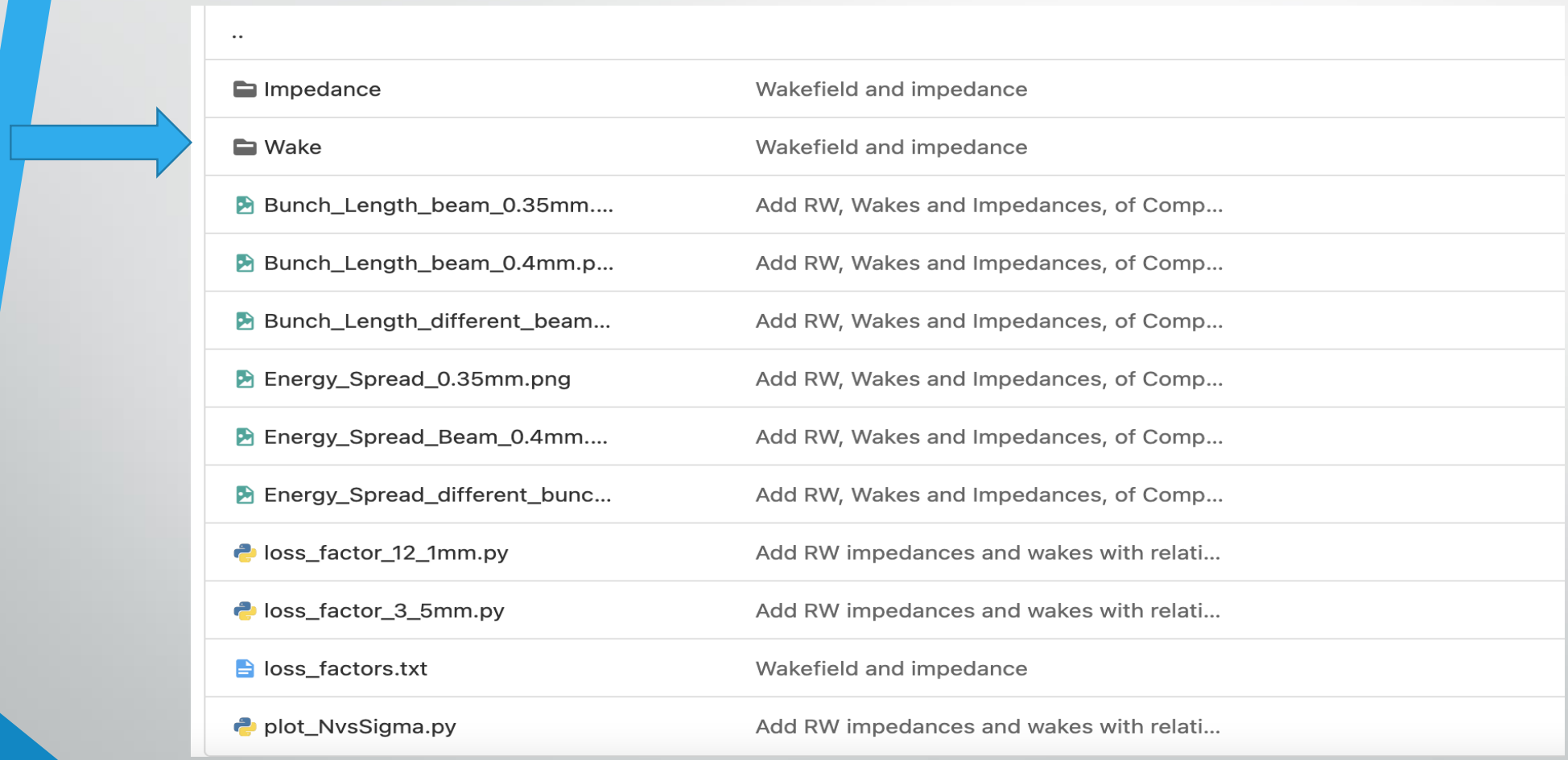


FCC-ee_IW_Model/FCC_elements/

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

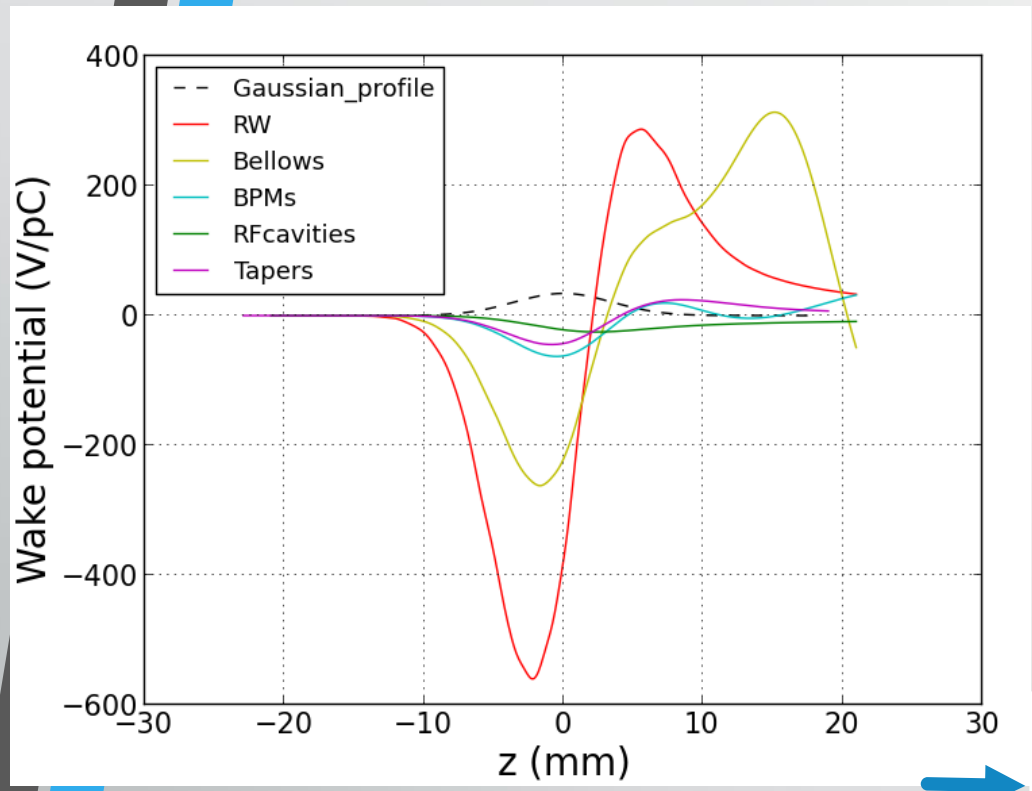


..	
Impedance	Wakefield and impedance
Wake	Wakefield and impedance
Bunch_Length_beam_0.35mm....	Add RW, Wakes and Impedances, of Comp...
Bunch_Length_beam_0.4mm.p...	Add RW, Wakes and Impedances, of Comp...
Bunch_Length_different_beam...	Add RW, Wakes and Impedances, of Comp...
Energy_Spread_0.35mm.png	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_reconstr_12_1mm.pdf	add Impedance and Wake of Resistive wall
wake_reconstr_3_5mm.pdf	add Impedance and Wake of Resistive wall

Impedance Sources: CST and IW2D simulations

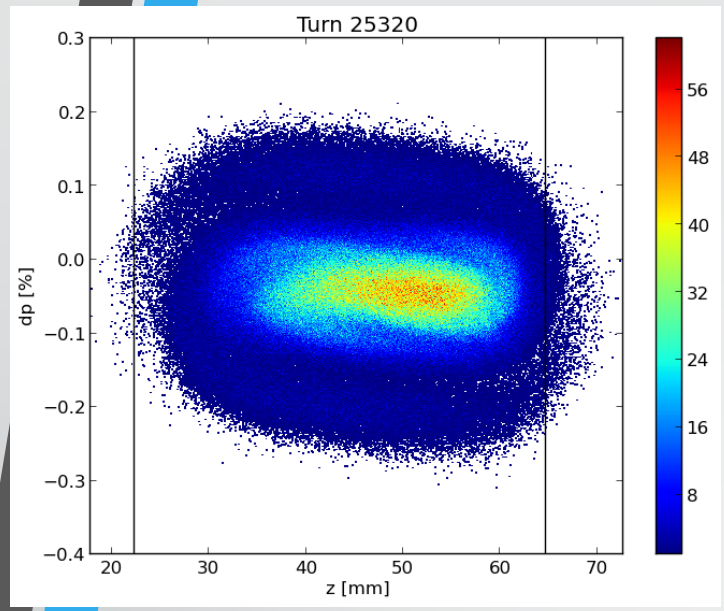


Longitudinal wake potentials for a Gaussian bunch with nominal bunch length σ_z = 3.5mm due to the main FCC-ee components, evaluated so far.

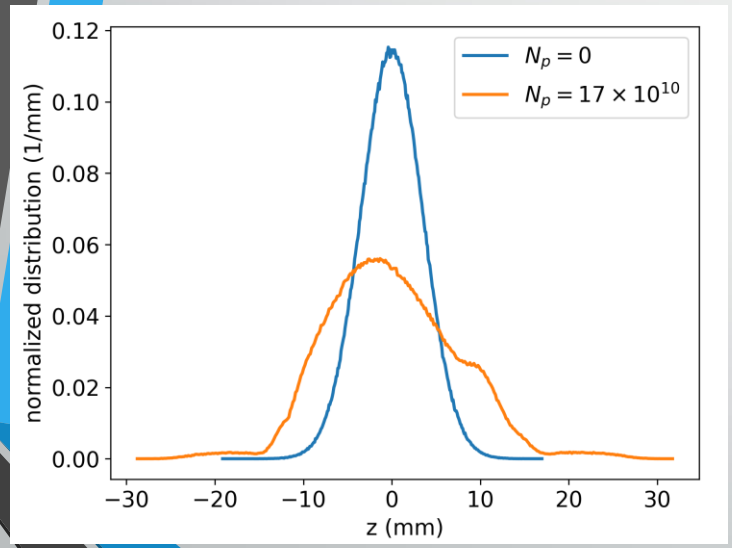
Loss factor and Power loss contribution of FCC-ee devices at nominal intensity and bunch length of 12.1 mm, in the lowest energy case of 45.6 GeV

Component	Number	K_{loss}(12.1mm)[V/pC]	$P_{loss}[MW]$
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

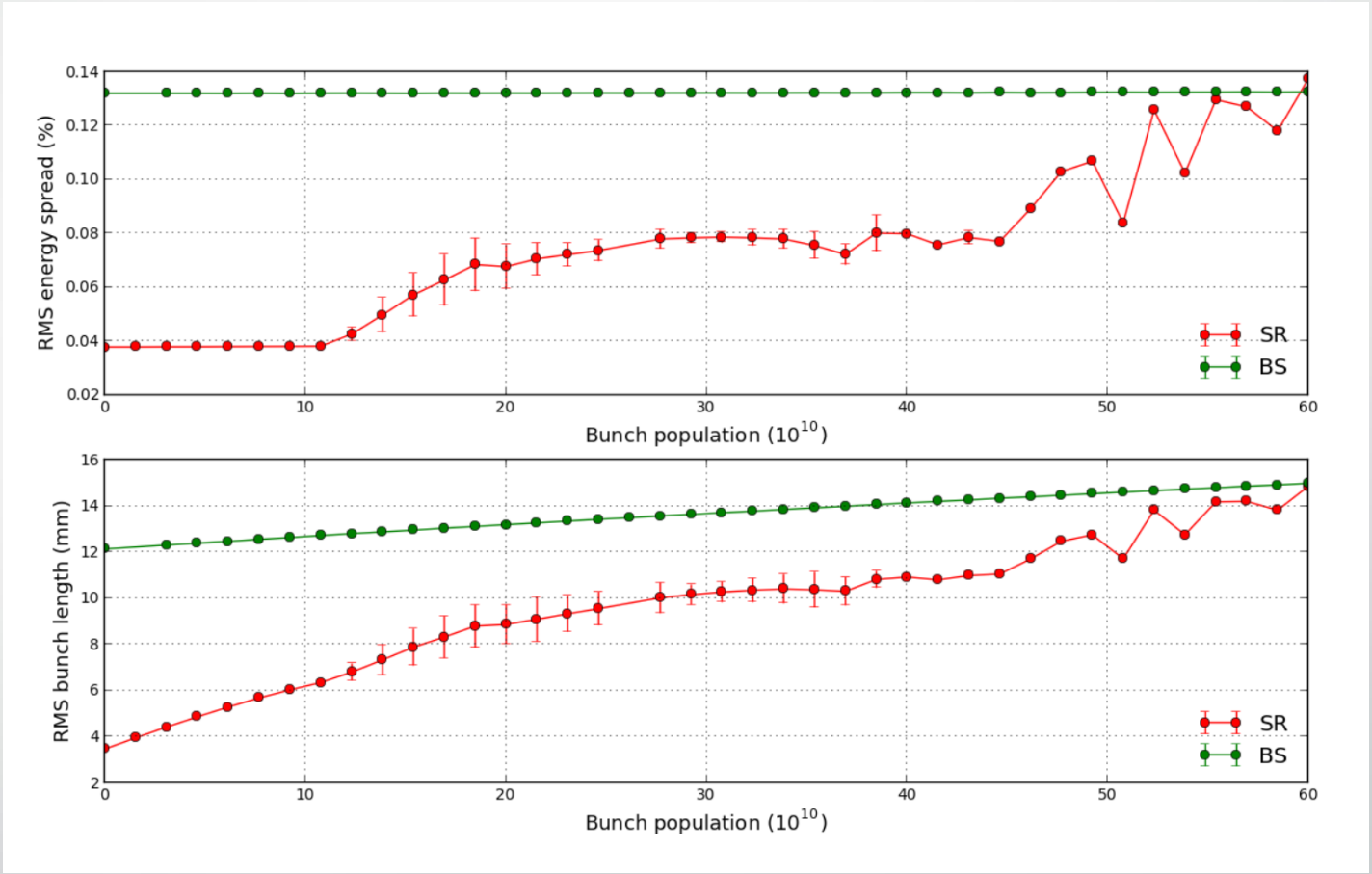
Longitudinal dynamics



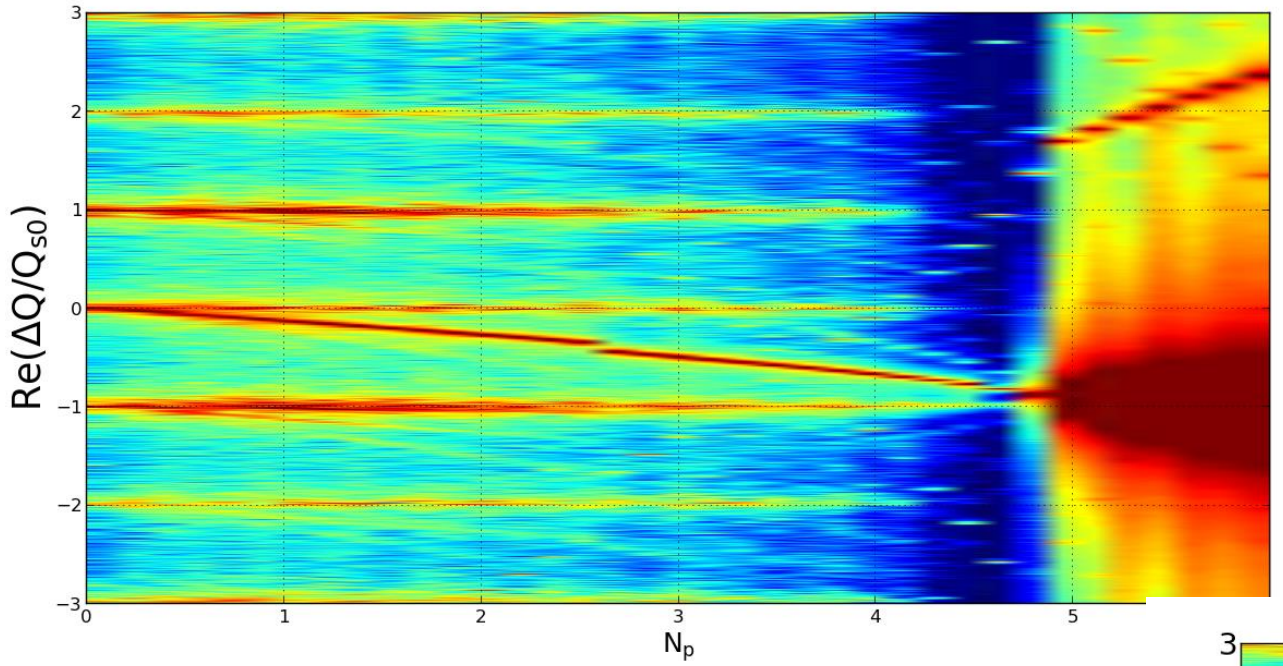
Longitudinal phase space



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



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.

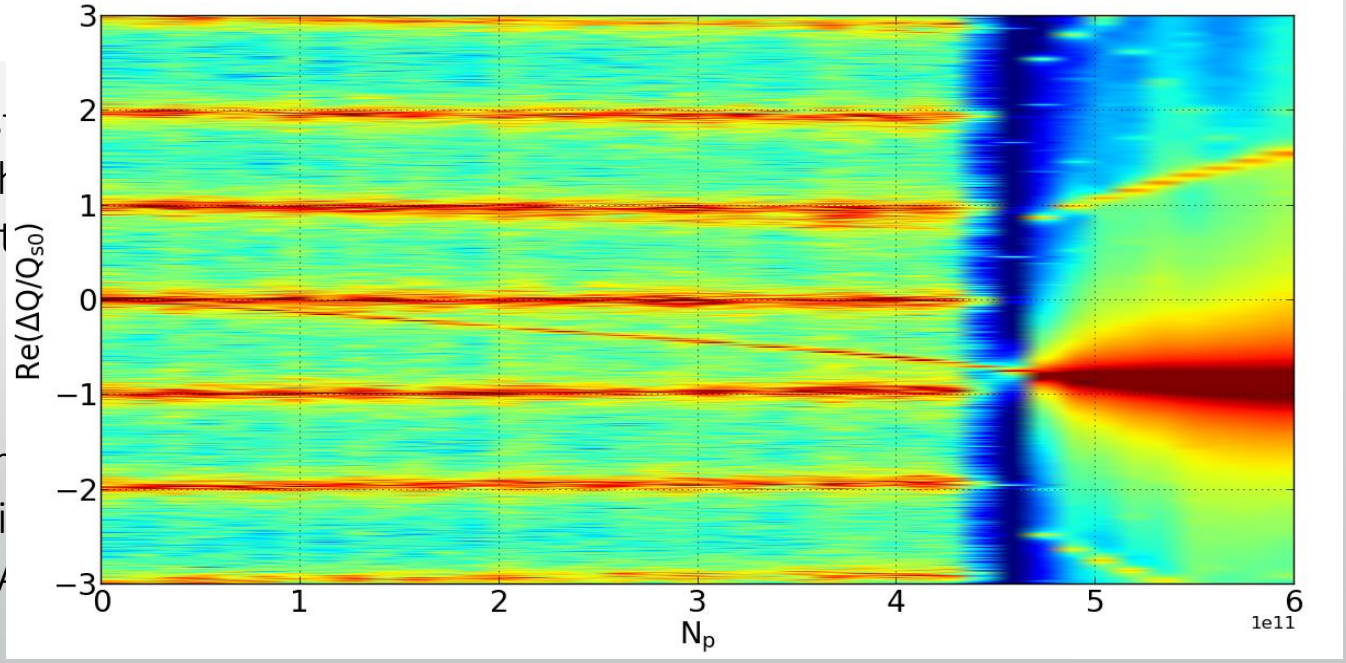


Transverse Dynamics

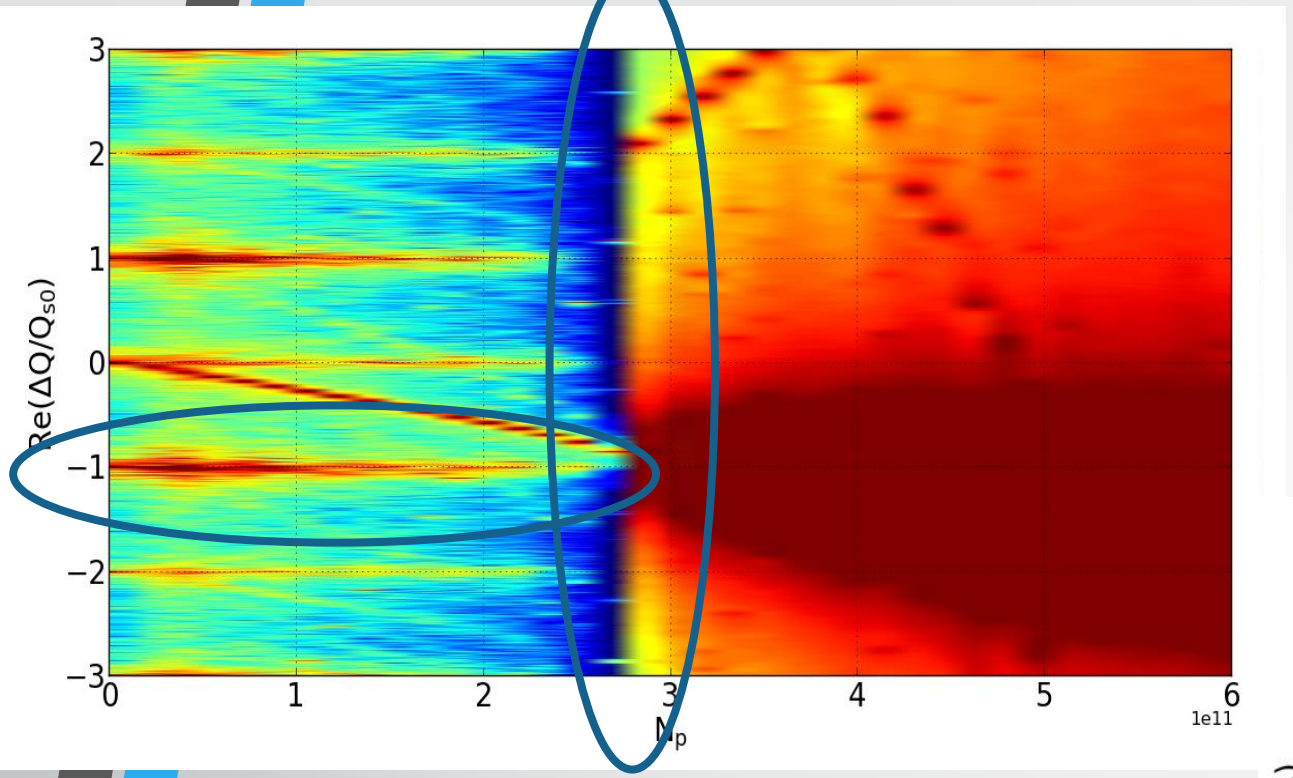
The TMCI occurs when the frequencies of two neighbouring coherent oscillation modes merge together. Above the transverse instability threshold the bunch is lost and this makes the TMCI very dangerous for the beam.

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

On the right, real part of the coherent tune sh
function of intensity considering the longi
resistive wall wakefield, by using PyHEA



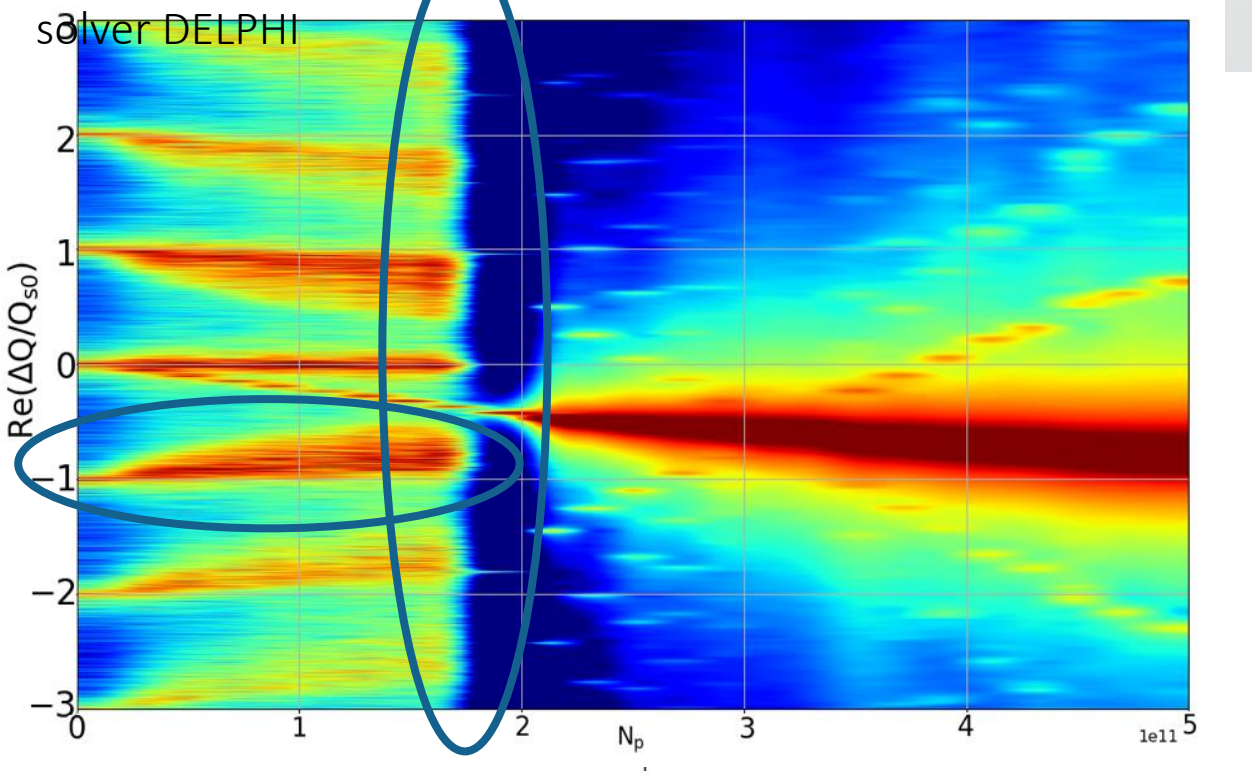
TMCI



Without longitudinal resistive wall wakefield

Real part of 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.

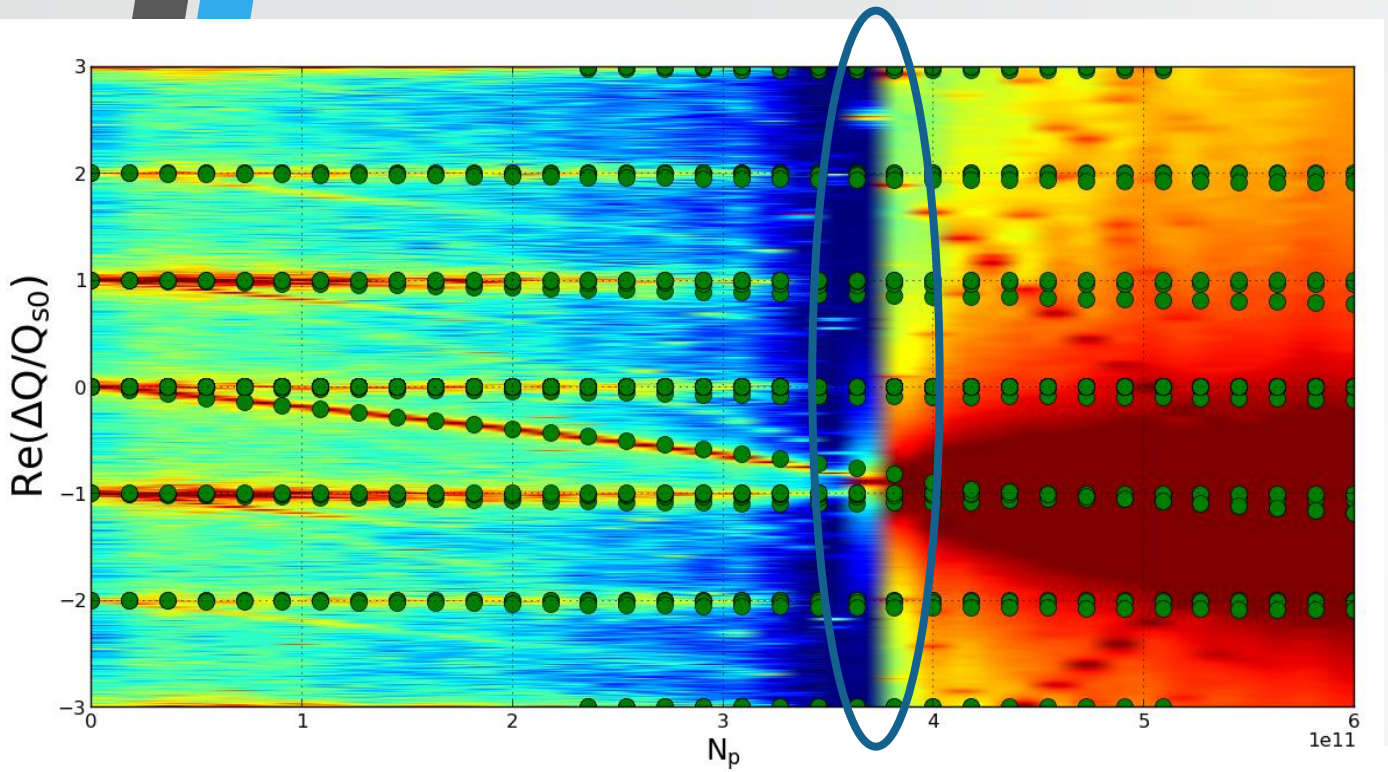
In addition to simulations with the tracking code, the TMCI threshold has been also evaluated with the analytic Vlasov solver DELPHI



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

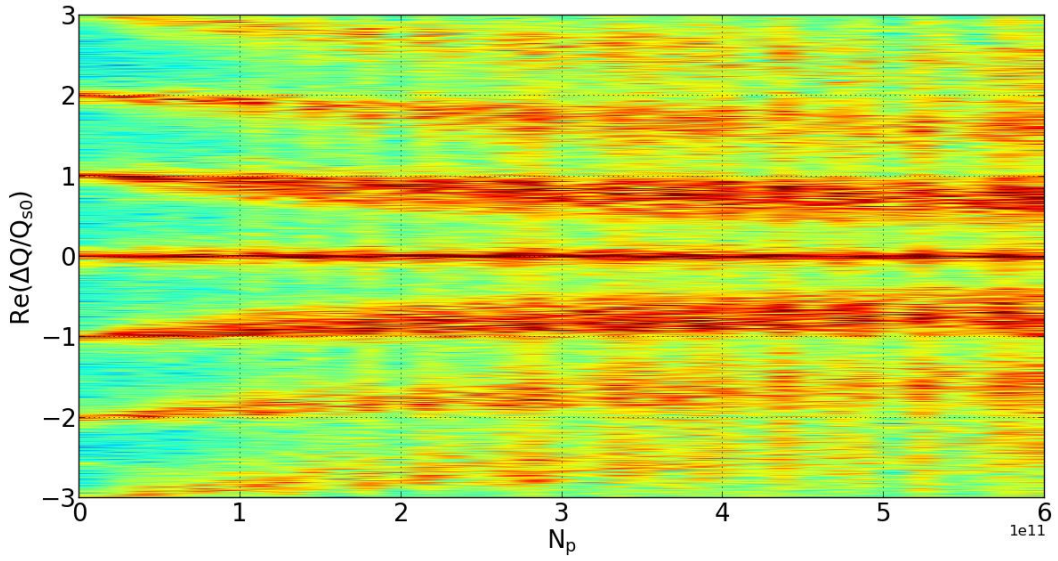
TMCI: Larger Momentum Compaction



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