Impedance consideration

EMANUELA CARIDEO

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FCCIS – The Future Circular Collider Innovation Study. This INFRADEV Research and Innovation Action project receives funding from the European Union's H2020 Framework Programme under grant agreement no. 951754. The information herein only reflects the views of its authors and the European Commission is not responsible for any use that may be made of the information.

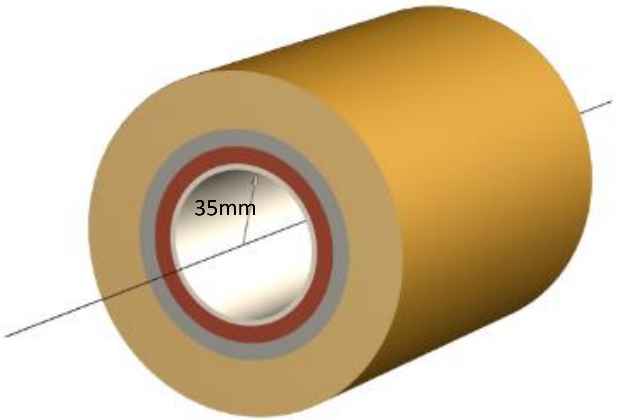
FCC-ee main parameters

Beam energy	[GeV]	45.6	80	120	182.5
Layout		PA31-1.0			
# of IPs		4			
Circumference	[km]	91.174117		91.174107	
Bending radius of arc dipole	[km]	9.937			
Energy loss / turn	[GeV]	0.0391	0.370	1.869	10.0
SR power / beam	[MW]	50			
Beam current	[mA]	1280	135	26.7	5.00
Bunches / beam		10000	880	248	40
Bunch population	$[10^{11}]$	2.43	2.91	2.04	2.37
Horizontal emittance ε_x	[nm]	0.71	2.16	0.64	1.49
Vertical emittance ε_y	[pm]	1.42	4.32	1.29	2.98
Arc cell		Long 90/90		90/90	
Momentum compaction α_p	$[10^{-6}]$	28.5		7.33	
Arc sextupole families		75		146	
$\beta^*_{x/y}$	[mm]	100 / 0.8	200 / 1.0	300 / 1.0	1000 / 1.6
Transverse tunes/IP $Q_{x/y}$		53.563 / 53.600		100.565 / 98.595	
Energy spread (SR/BS) σ_δ	[%]	0.038 / 0.132	0.069 / 0.154	0.103 / 0.185	0.157 / 0.221
Bunch length (SR/BS) σ_z	[mm]	4.38 / 15.4	3.55 / 8.01	3.34 / 6.00	1.95 / 2.75
RF voltage 400/800 MHz	[GV]	0.120 / 0	1.0 / 0	2.08 / 0	2.5 / 8.8
Harmonic number for 400 MHz		121648			
RF freuqeuncy (400 MHz)	MHz	399.994581		399.994627	
Synchrotron tune Q_s		0.0370	0.0801	0.0328	0.0826
Long. damping time	[turns]	1168	217	64.5	18.5
RF acceptance	[%]	1.6	3.4	1.9	3.0
Energy acceptance (DA)	[%]	±1.3	±1.3	±1.7	-2.8 +2.5
Beam-beam ξ_x/ξ_y [a]		0.0023 / 0.135	0.011 / 0.125	0.014 / 0.131	0.093 / 0.140
Luminosity / IP	$[10^{34}/\mathrm{cm}^2\mathrm{s}]$	182	19.4	7.26	1.25
Lifetime (q + BS + lattice)	[sec]	840	–	< 1065	< 4062
Lifetime (lum)	[sec]	1129	1070	596	744

[a] incl. hourglass.

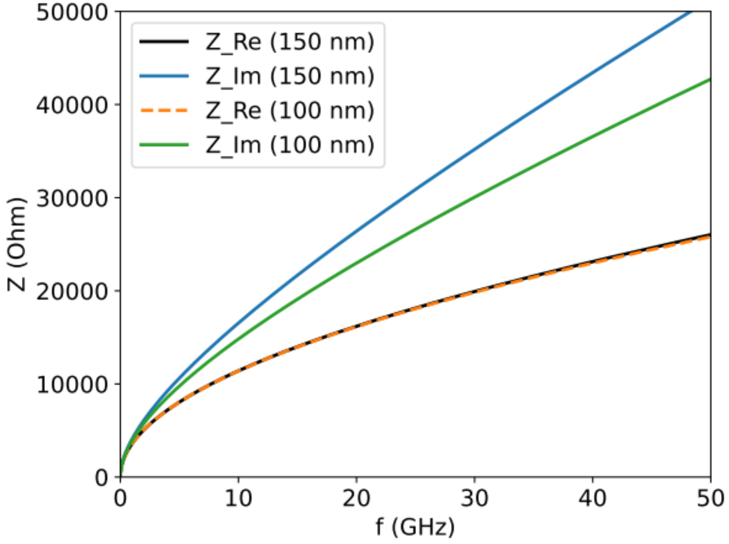
K. Oide, Oct. 17, 2022

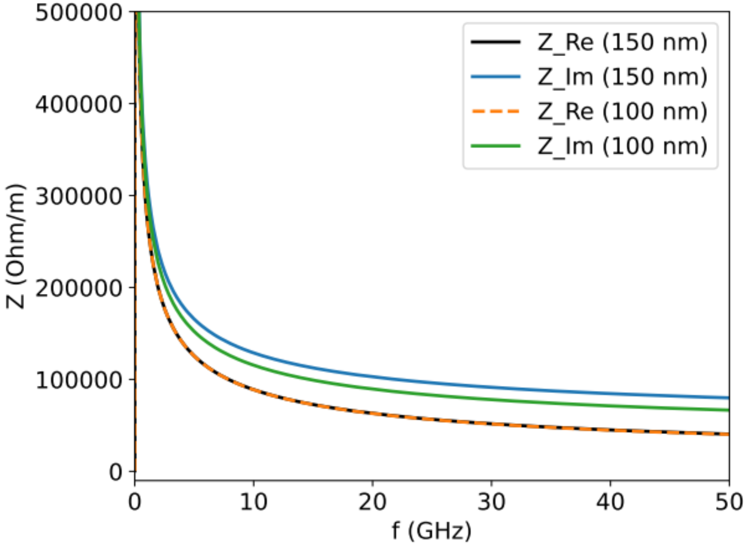
Main impedance sources: Resistive wall



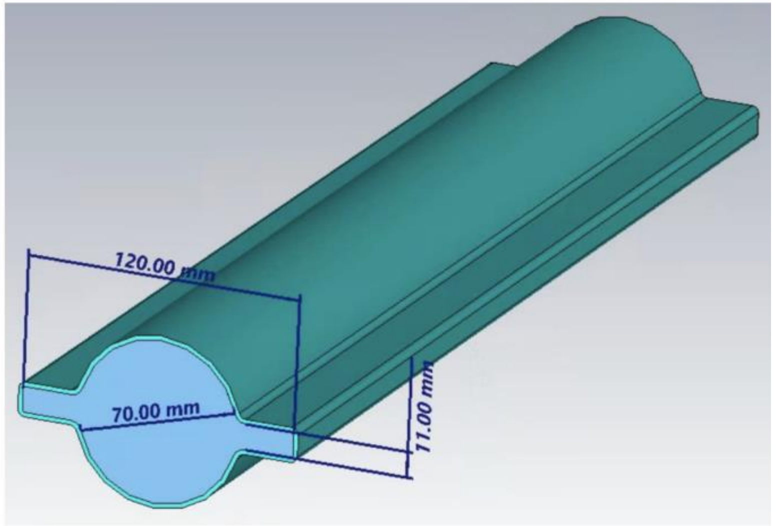
IRON	$\Delta = \infty$	$\rho = 6.89 \cdot 10^{-7}\Omega m$
DIELECTRIC	$\Delta = 6\ mm$	$\rho = 10^{-15}\Omega m$
COPPER	$\Delta = 2\ mm$	$\rho = 1.66 \cdot 10^{-8}\Omega m$
NEG	$\Delta = 150\ nm$	$\rho = 10^{-6}\Omega m$

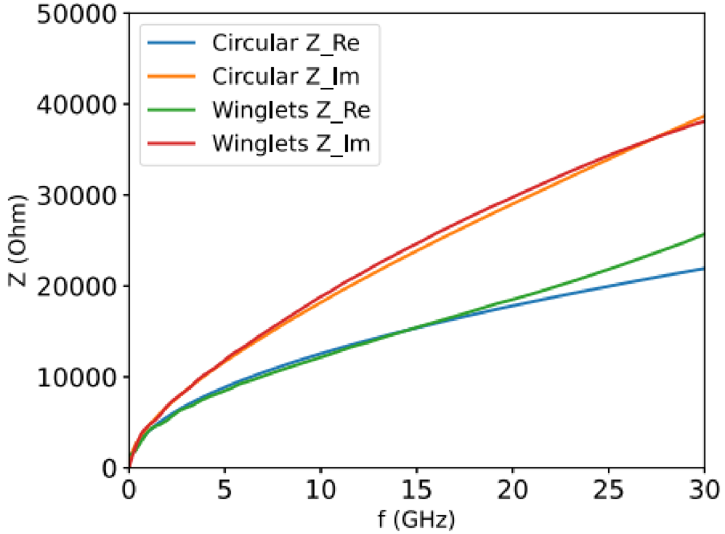
- The interaction of the beam with the environment can produce **wakefields** (**impedances** in the frequency domain) that induce **instabilities**
- By increasing the machine length the contribution of the RW impedance assumes more and more importance with respect to other elements
- NEG coating is needed to mitigate the electron cloud build-up in the positron machine and for pumping reasons in both rings.

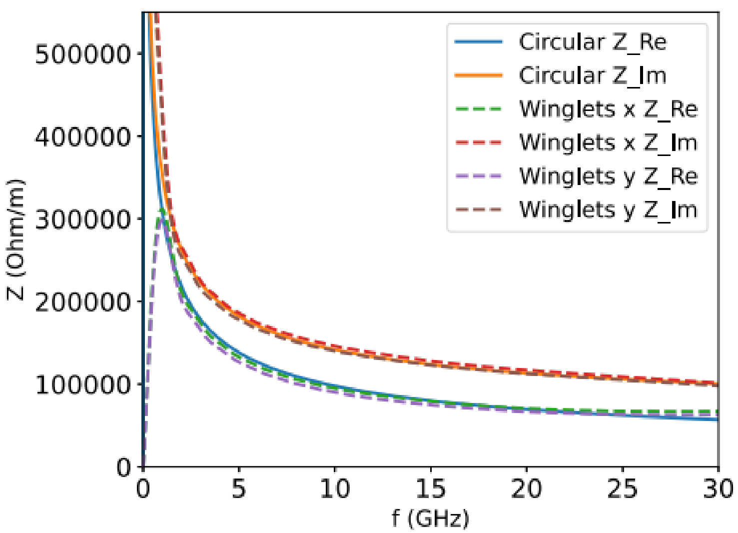




More realistic model:
We estimated a factor 1.1 for winglets contribution





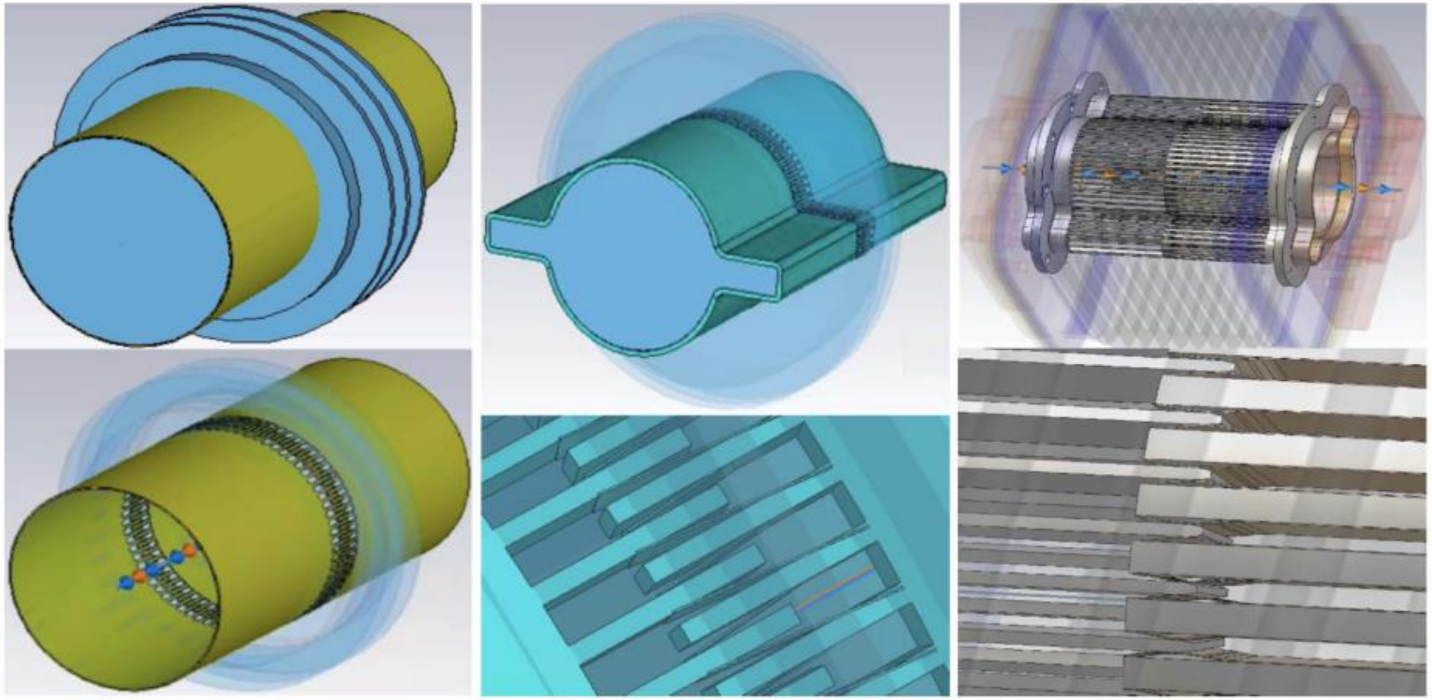


Resistive wall longitudinal and transverse impedance for FCC-ee obtained with CST by considering the winglets realistic model with a single infinite layer of material having a conductivity of $\sigma_c = 10^5$ S/m re-scaled with the surface impedance of a double layer and compared with the results of IW2D with four layers for a circular pipe, and multiplied by a factor 1.1

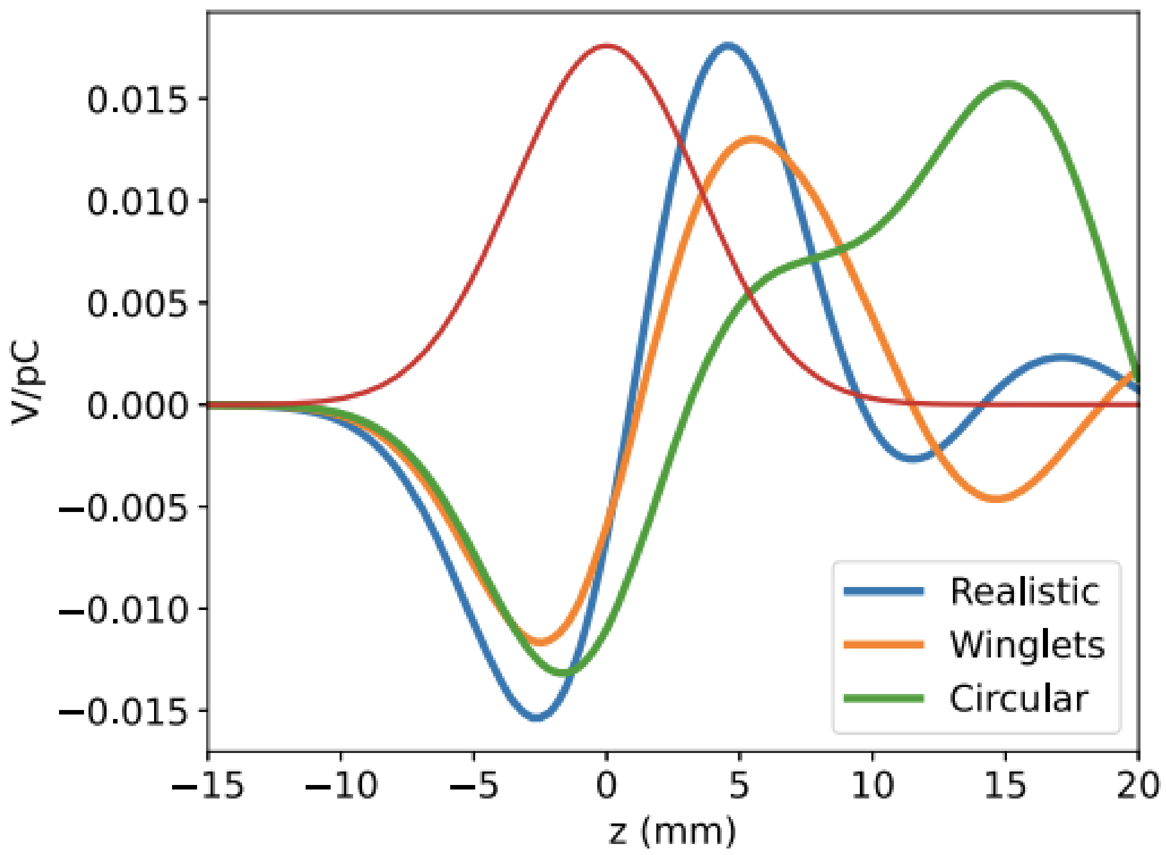
Main impedance sources: Bellows

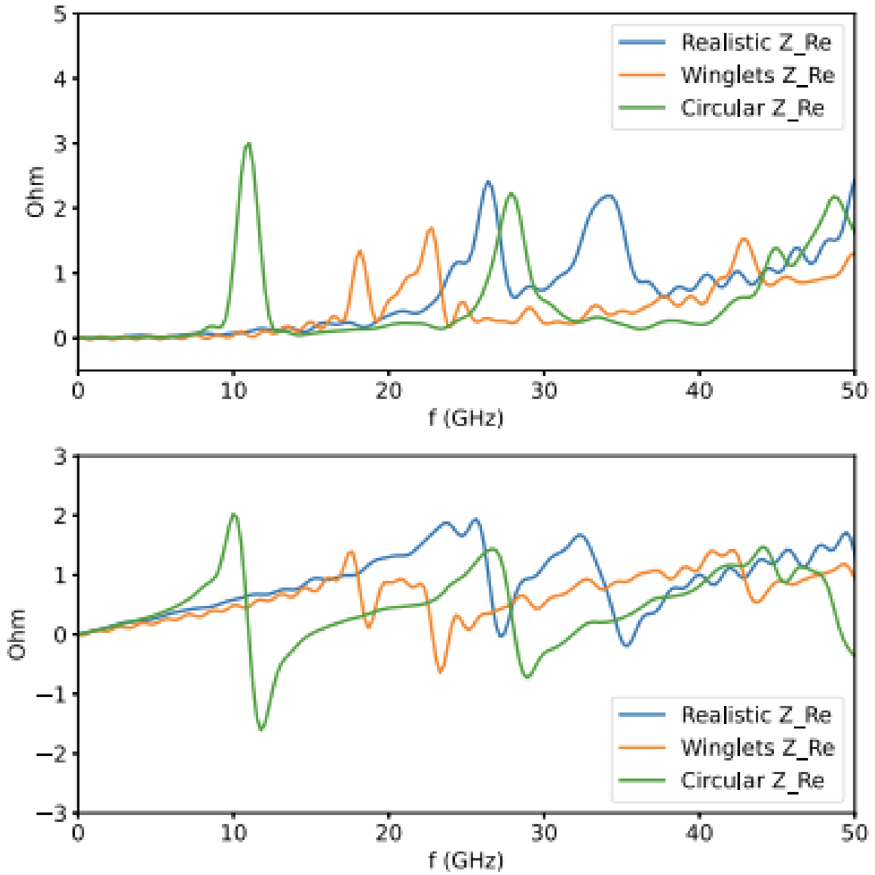
They represent the second highest impedance source so far. We have used an upper pessimistic estimate of 20000 bellows

Simulated models of FCC-ee beam vacuum chamber including bellows. On the left there is a simplified model with circular geometry, in the centre a simplified model with winglets, on the right the realistic model

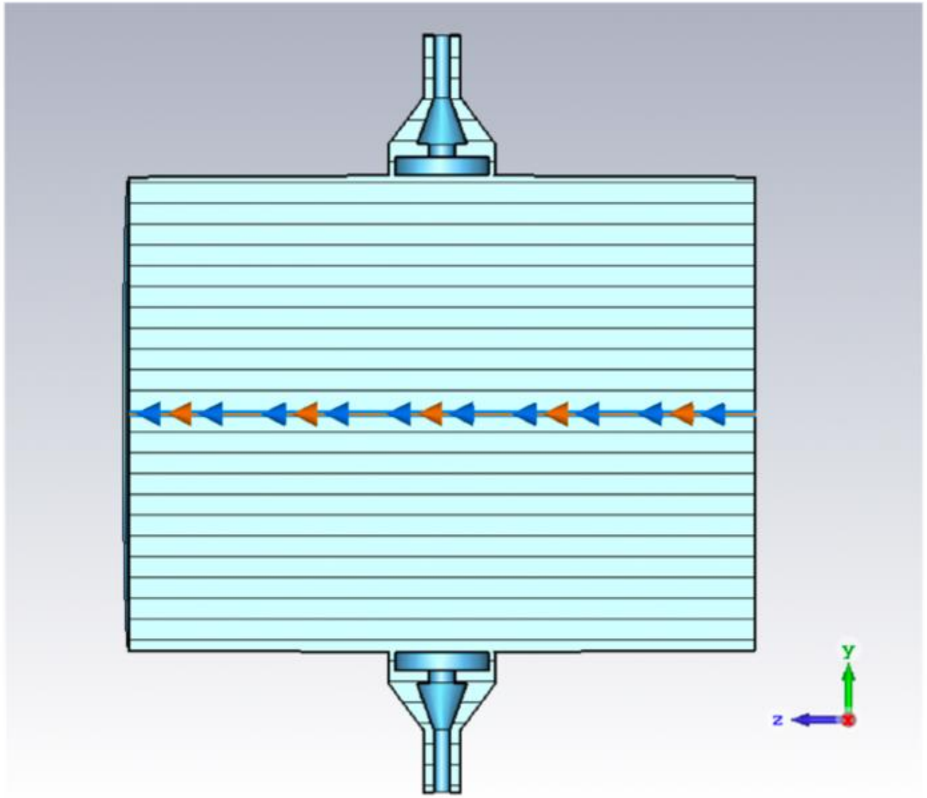


Longitudinal wake potential and impedance for the three studied models of the bellow





Beam Position Monitors : #4000



CST perspective view of the four-button BPM

The button has a diameter of 15 mm and a thickness of 3 mm

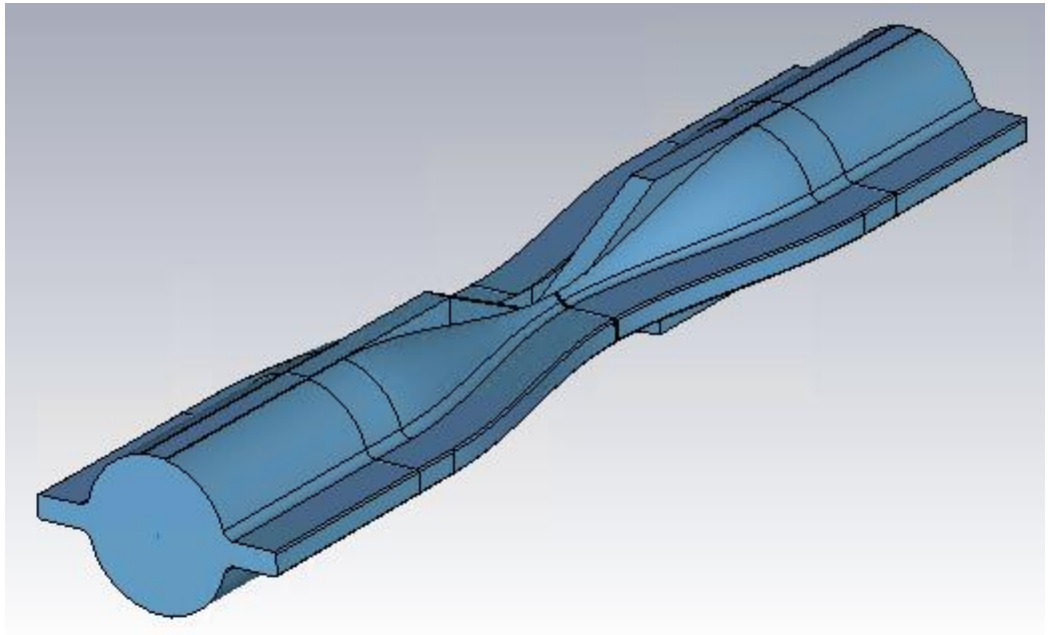
In order to push the higher order modes trapped in the BPM structure to higher frequencies a BPM design with a conical button, similar to the one used in SIRIUS

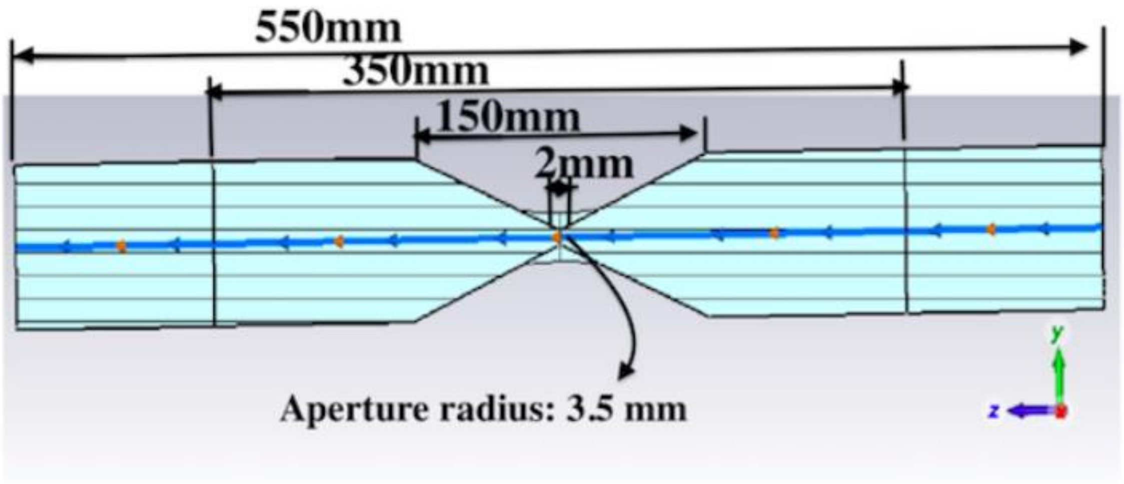
BPMs will be installed directly on the beam pipe with a rotation angle of 45°

Collimators

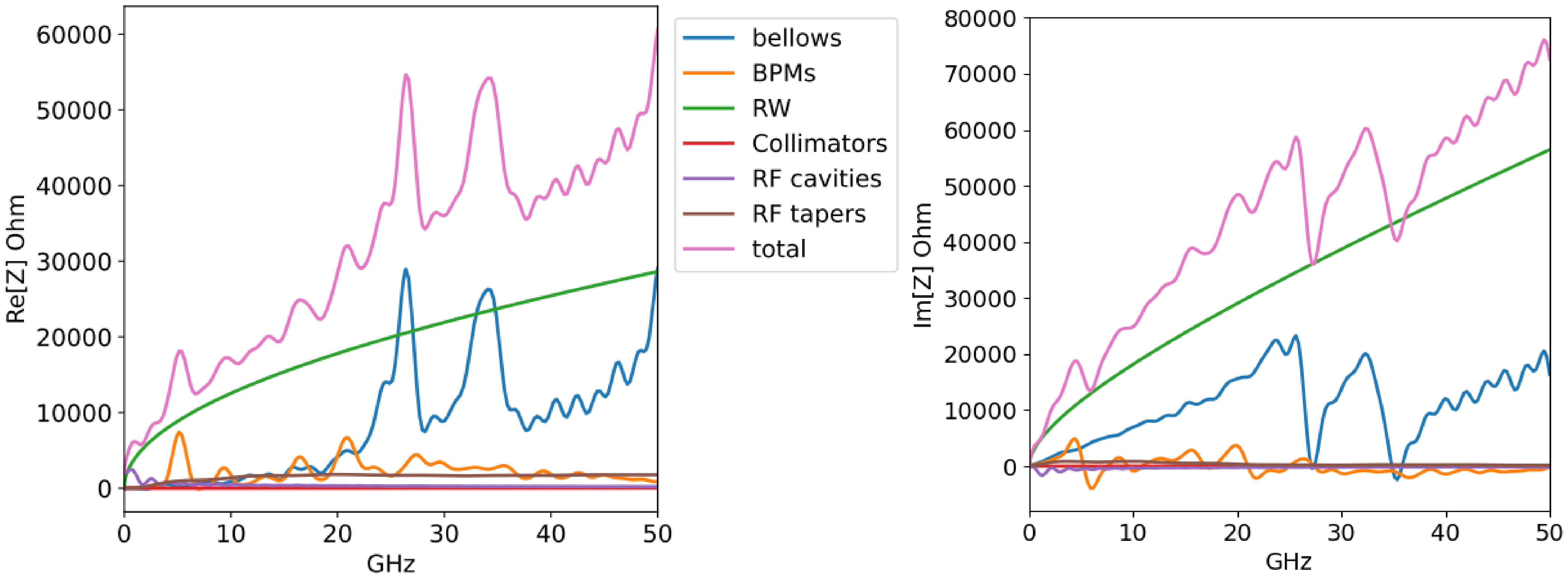
This type of collimators, for now, is made of Tungsten, and they can be much shorter.

We investigated the SuperKEKB model. A similar model, in particular for the taper, can also be used to evaluate the geometrical contribution to the impedance of the betatron and off-momentum collimators.

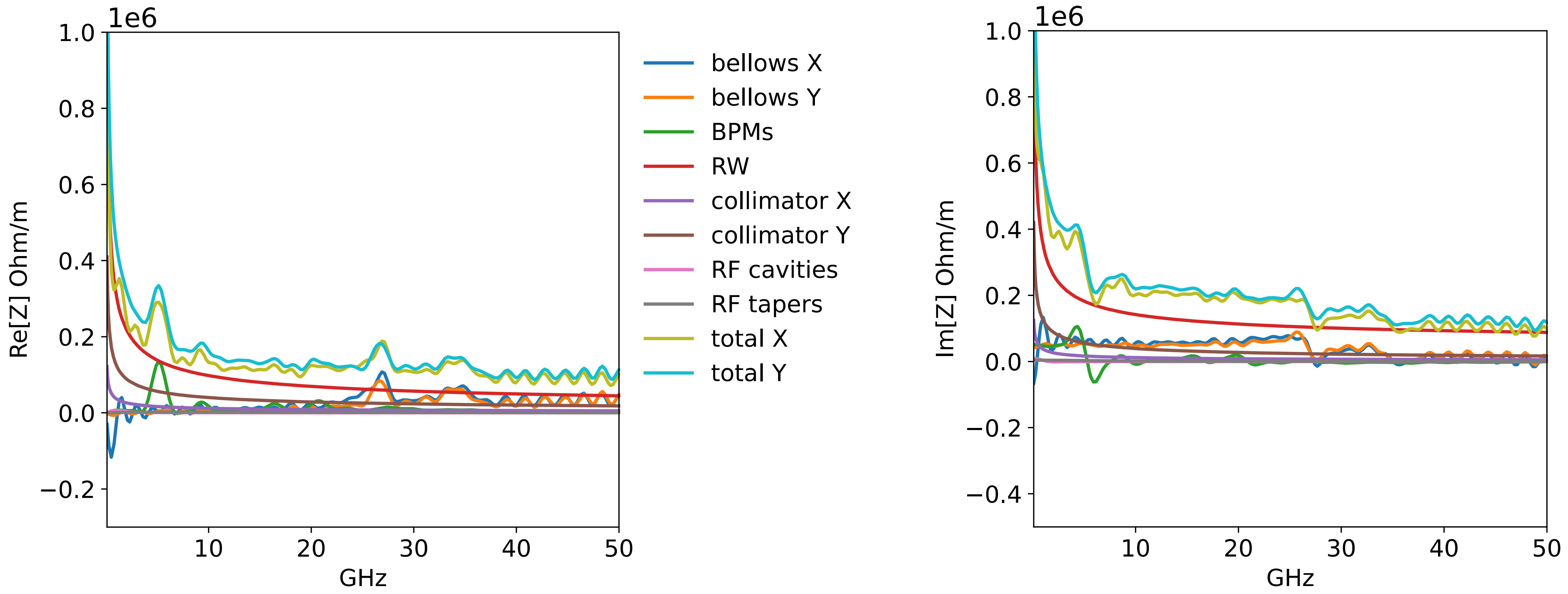




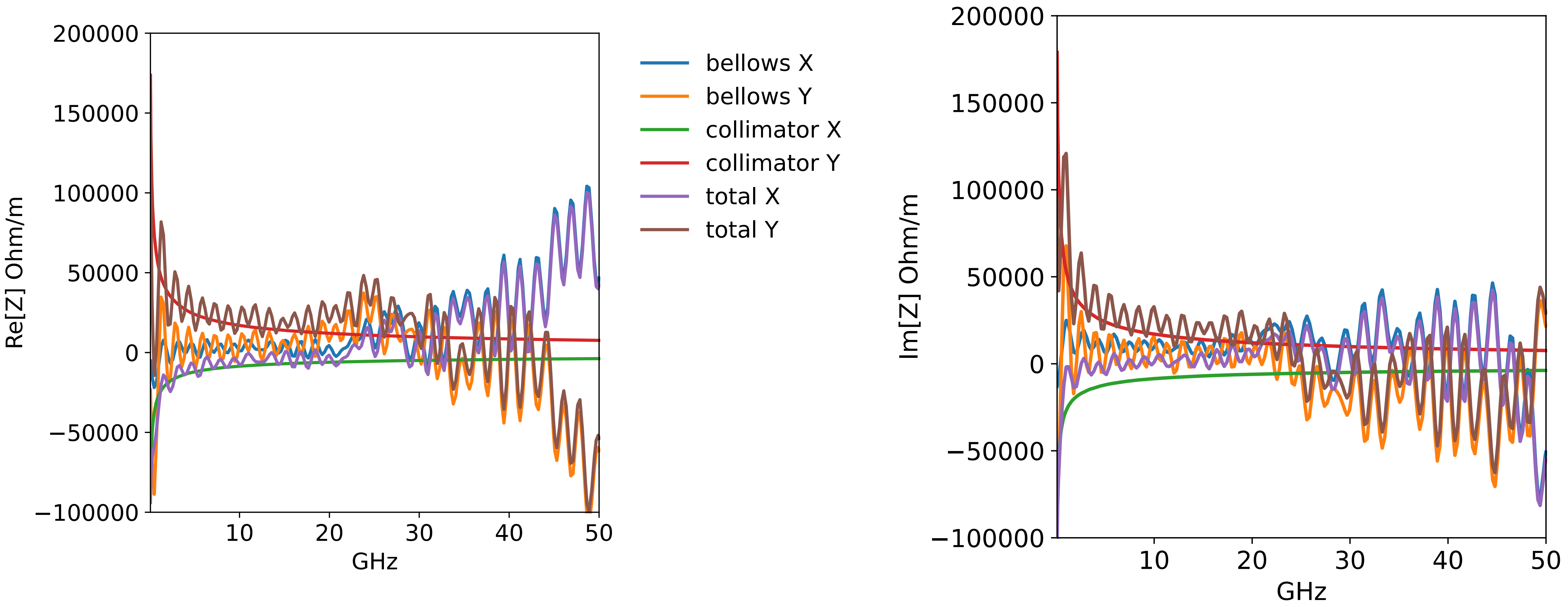
Total impedance: Longitudinal



Total impedance: Transverse Dipolar

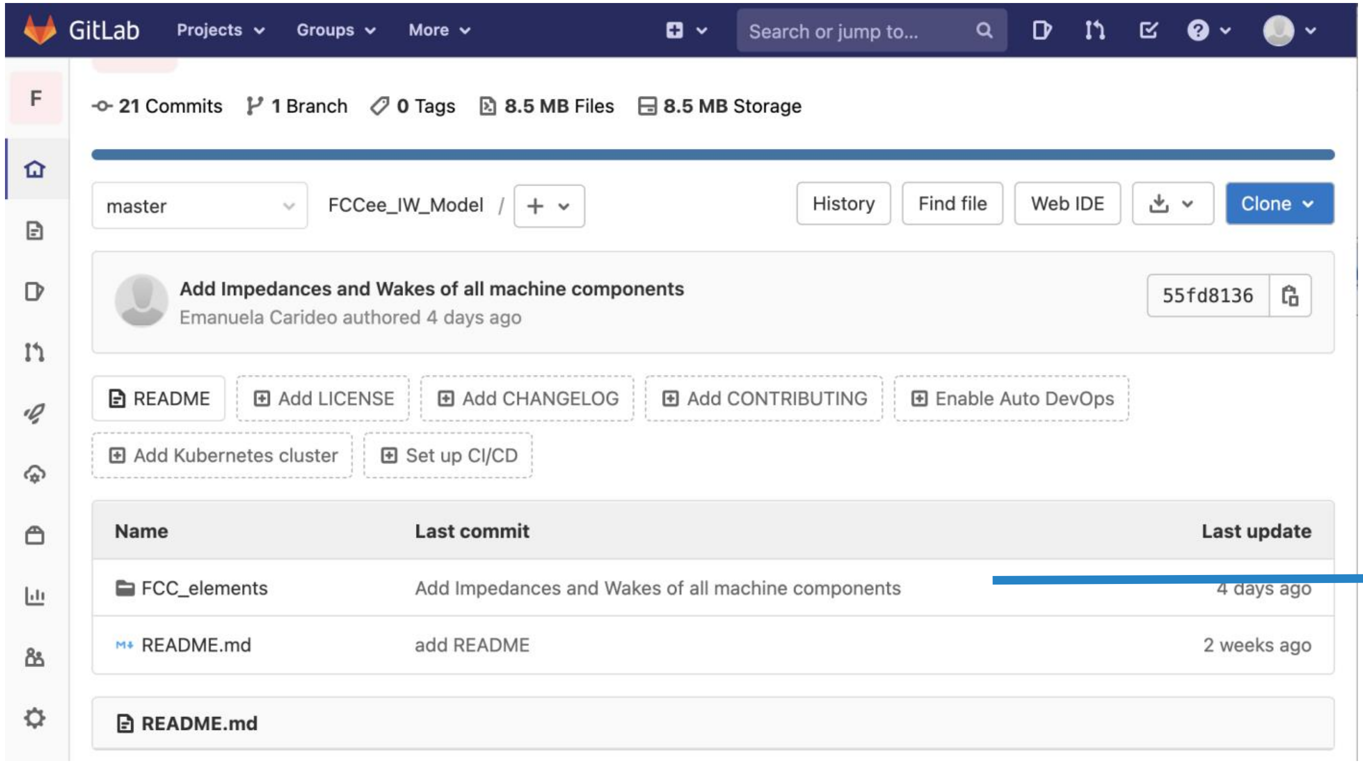


Total impedance: transverse quadrupolar



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

A repository, or Git project, encompasses the entire collection of files and folders associated with a project. Working in repositories keeps development projects organized and organized and protected.

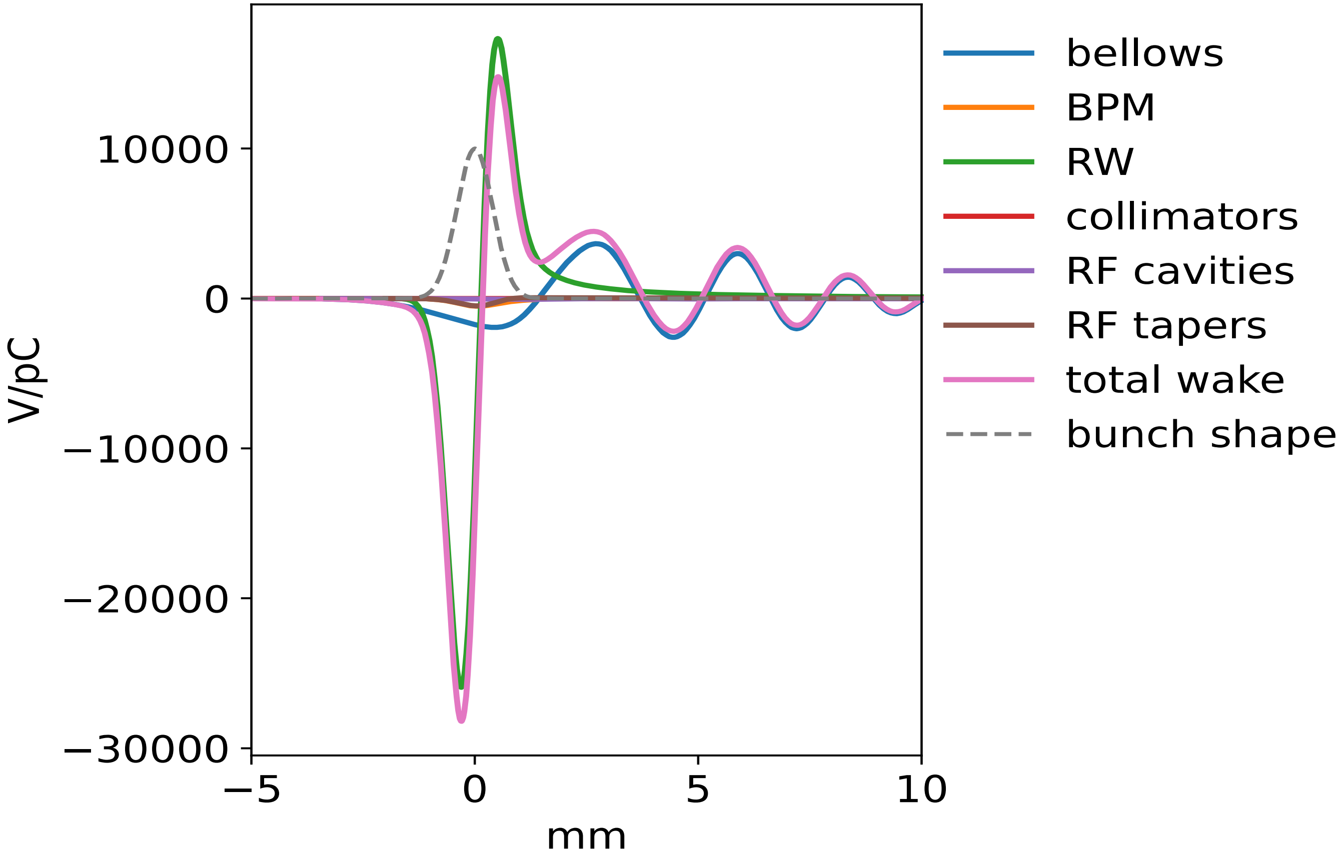


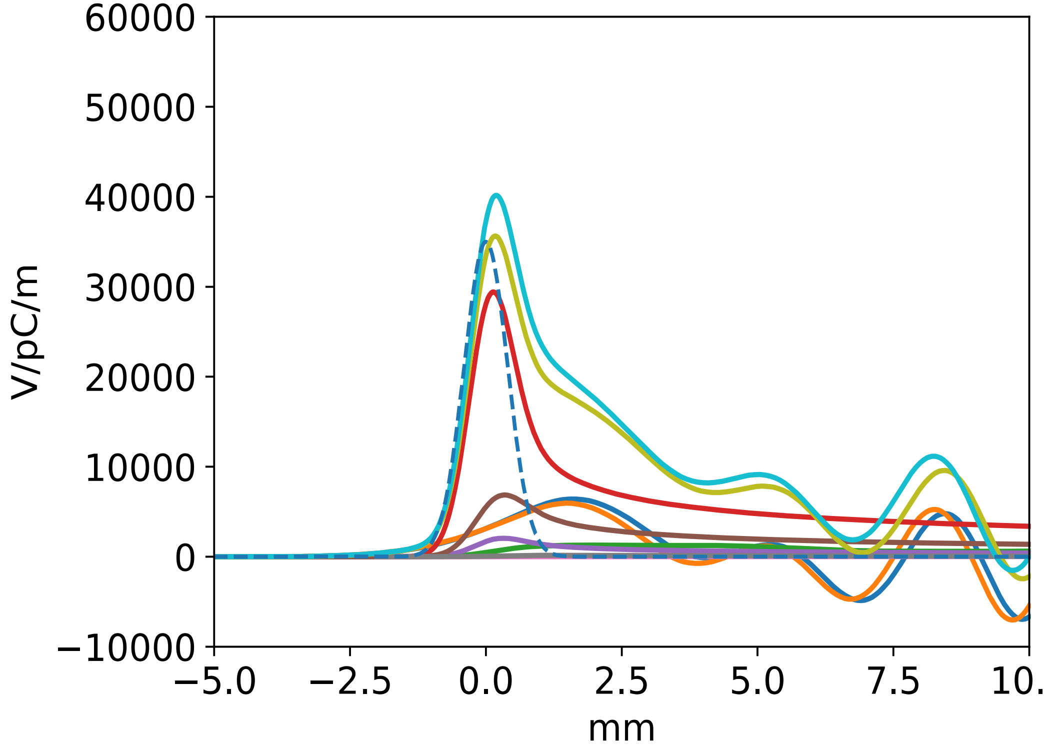
The Repository also provides more opportunities for project transparency and collaboration, working together to build the best possible final product.

How is it developed?

In this folder there are some of FCC-ee components and for each machine components the calculated impedance and wake

Wake potential of 0.4 mm Gaussian bunch due to the main FCC-ee components, evaluated so far

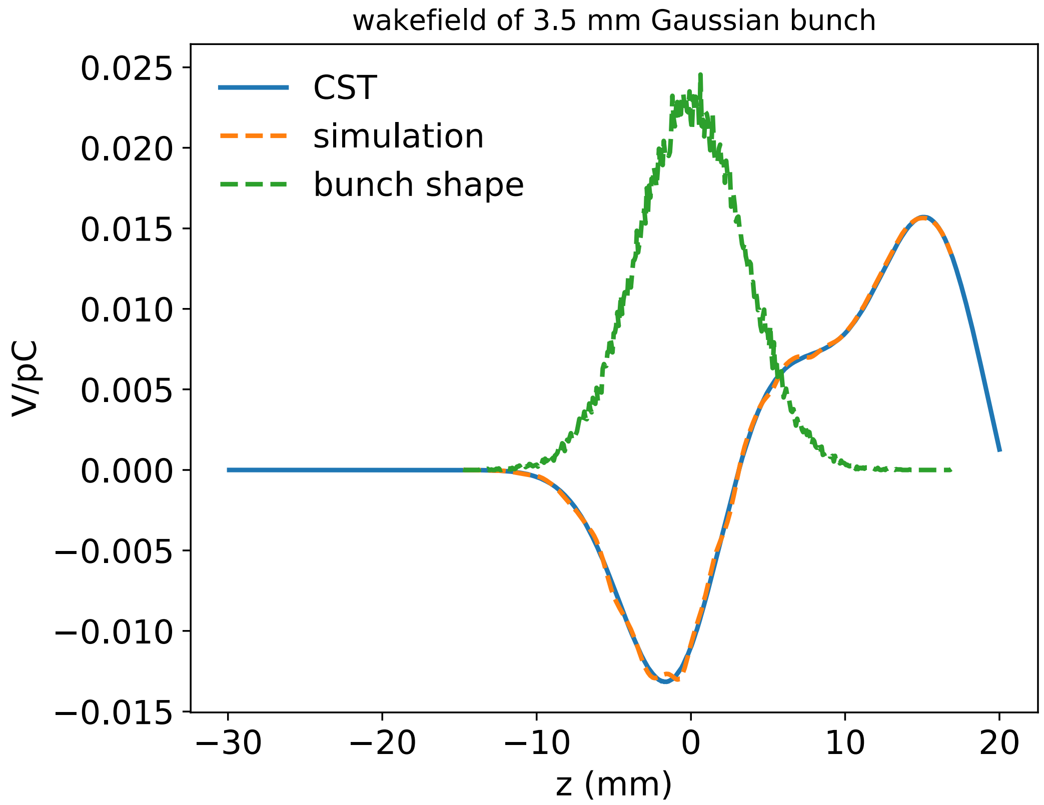


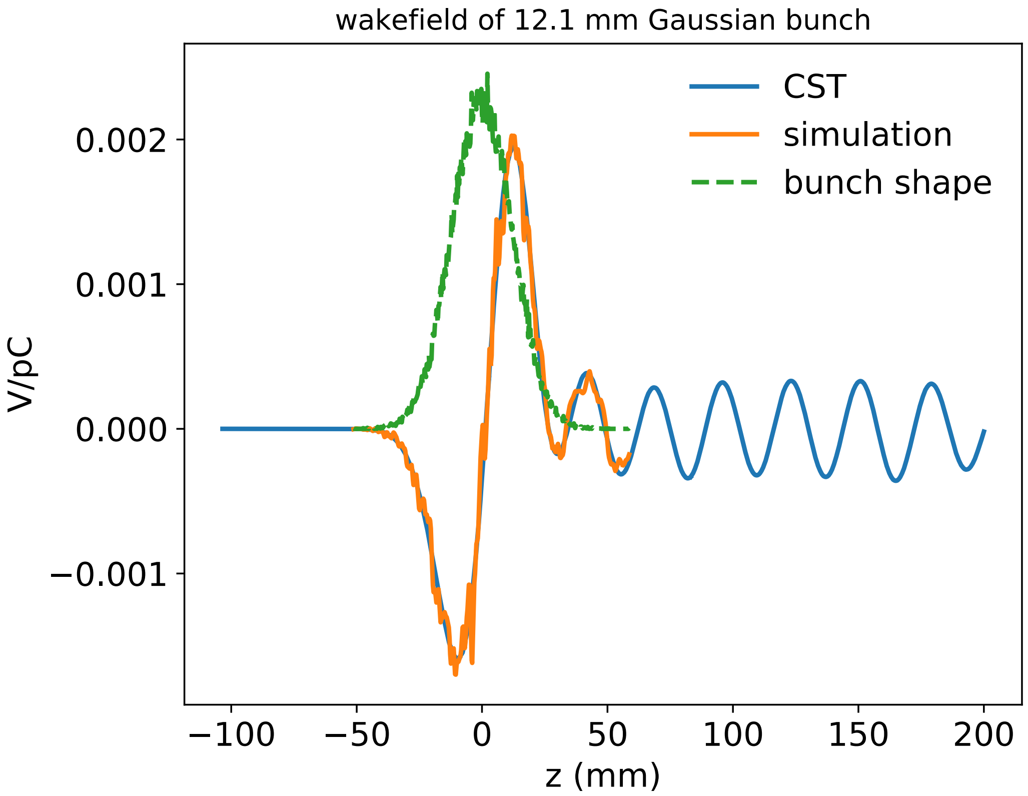


How did we do these simulations?

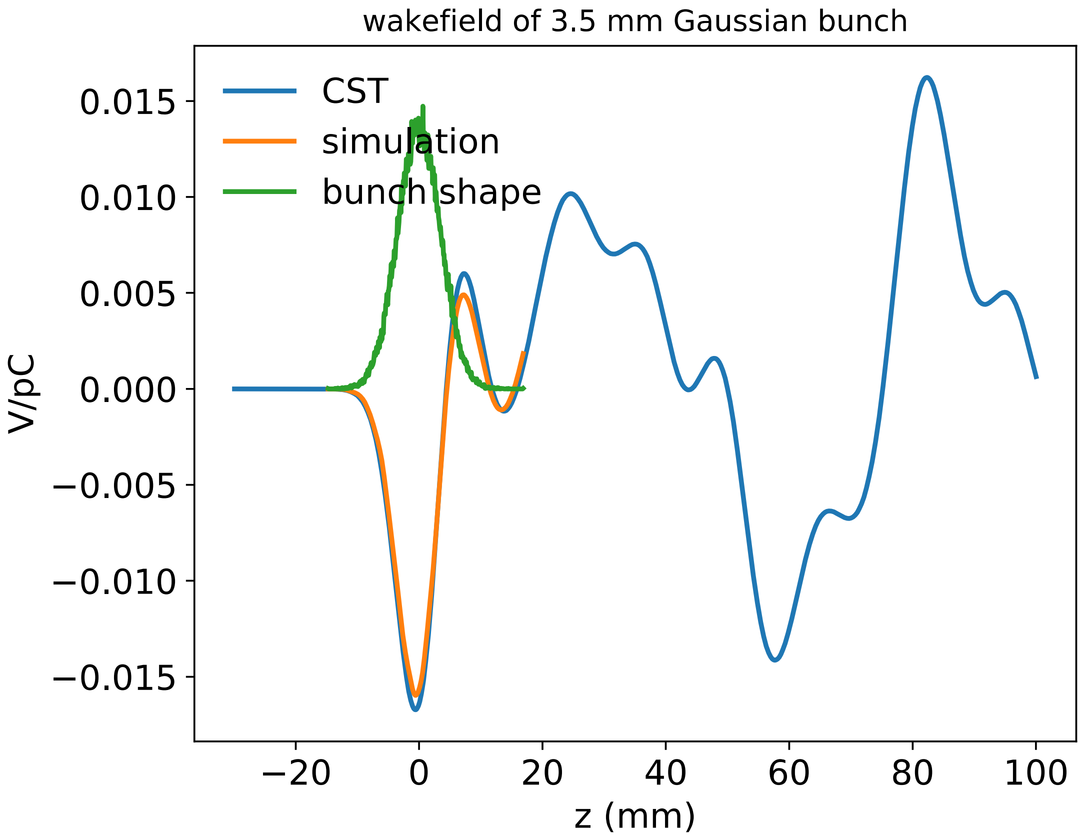
Method to calculate the Wake Potential by software simulation: Comparison of the wake potential of 3.5 mm bunch length between PyHT and CST - Bellows

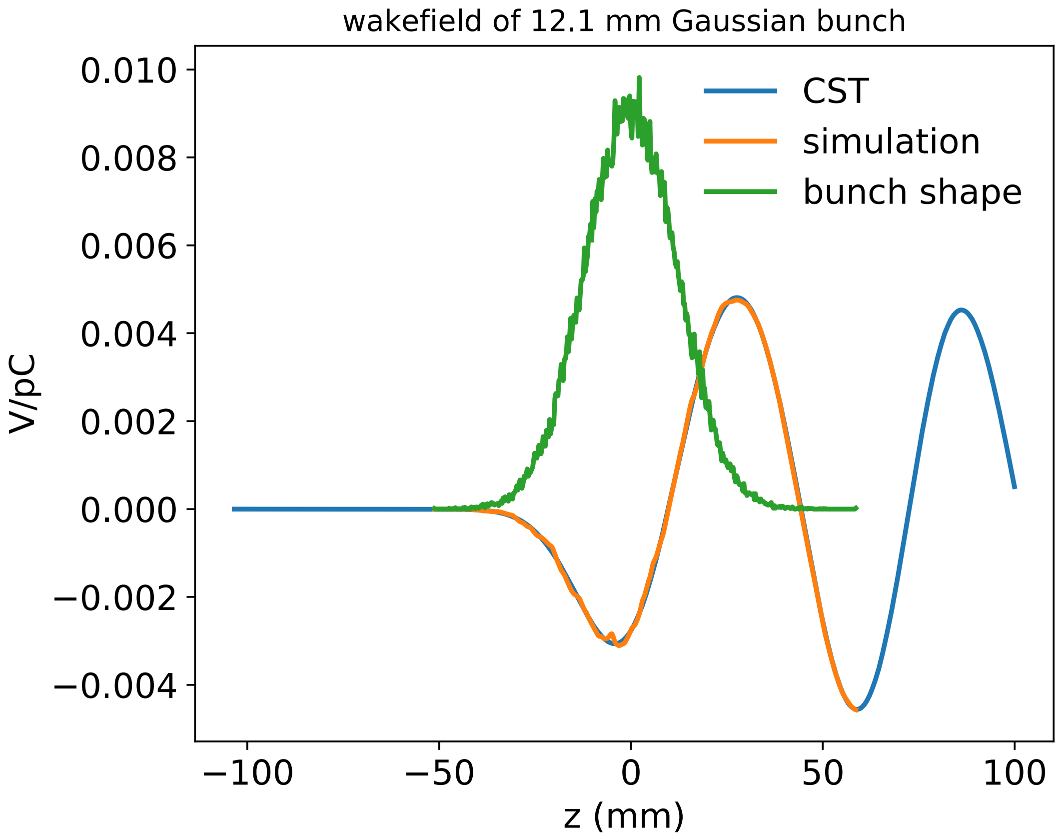
Wake potential for a Bellow of a 3.5 mm Gaussian bunch obtained directly by CST (blue curve) and with the convolution by using the wake potential of 0.4 mm Gaussian bunch (orange dots).



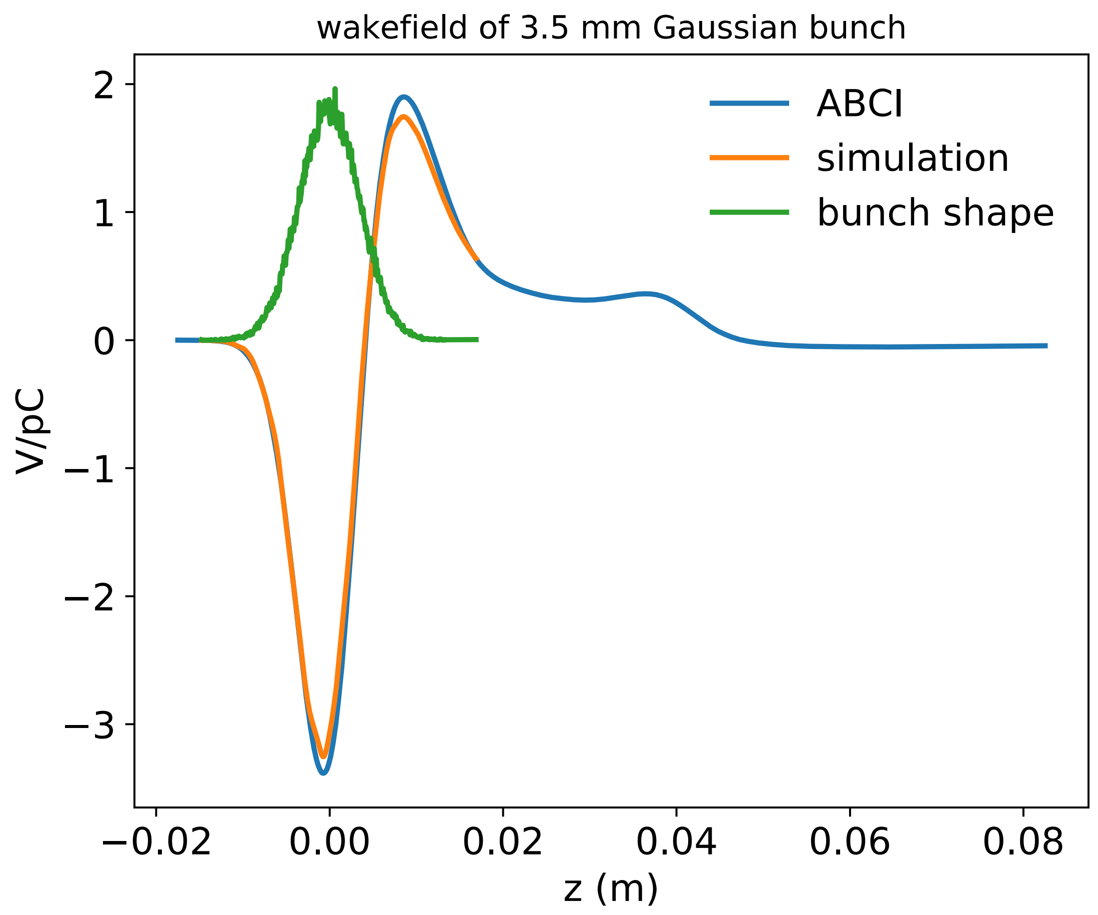


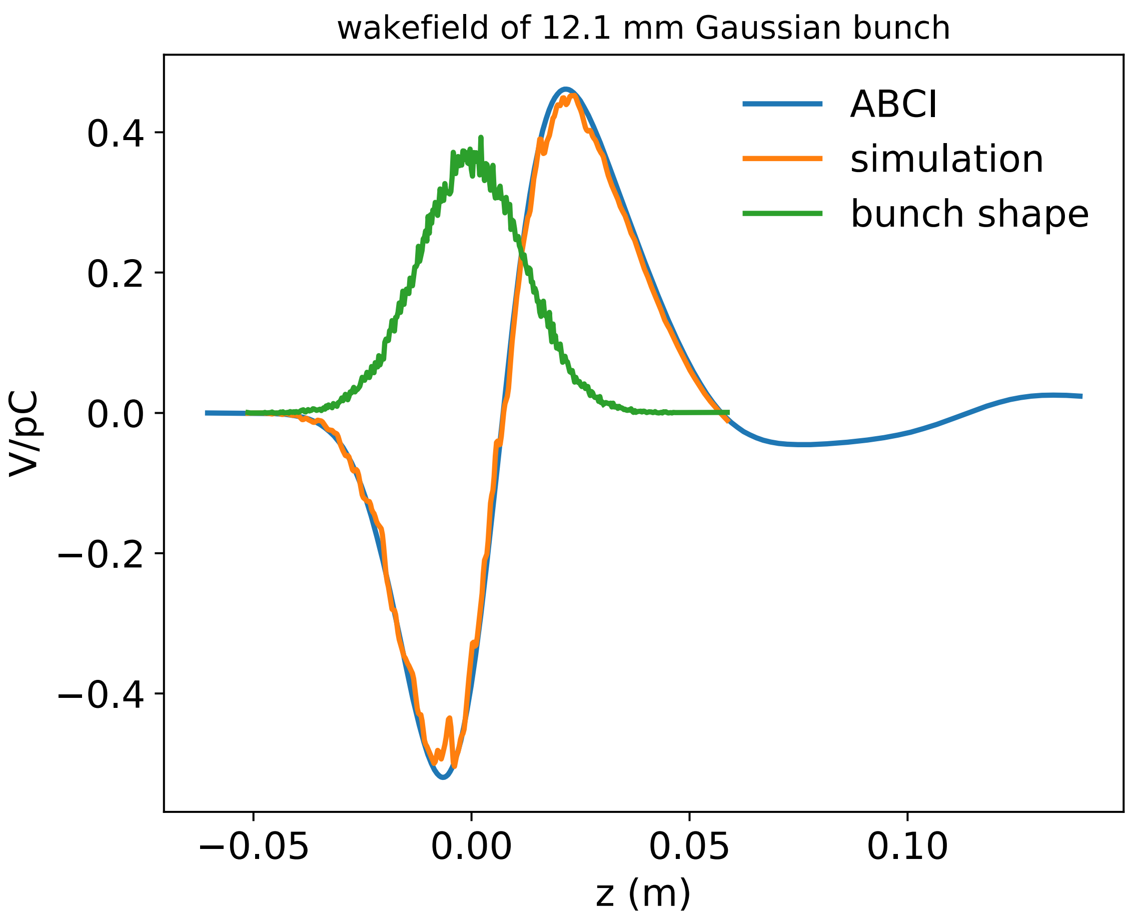
Method to calculate the Wake Potential by software simulation: BPMs



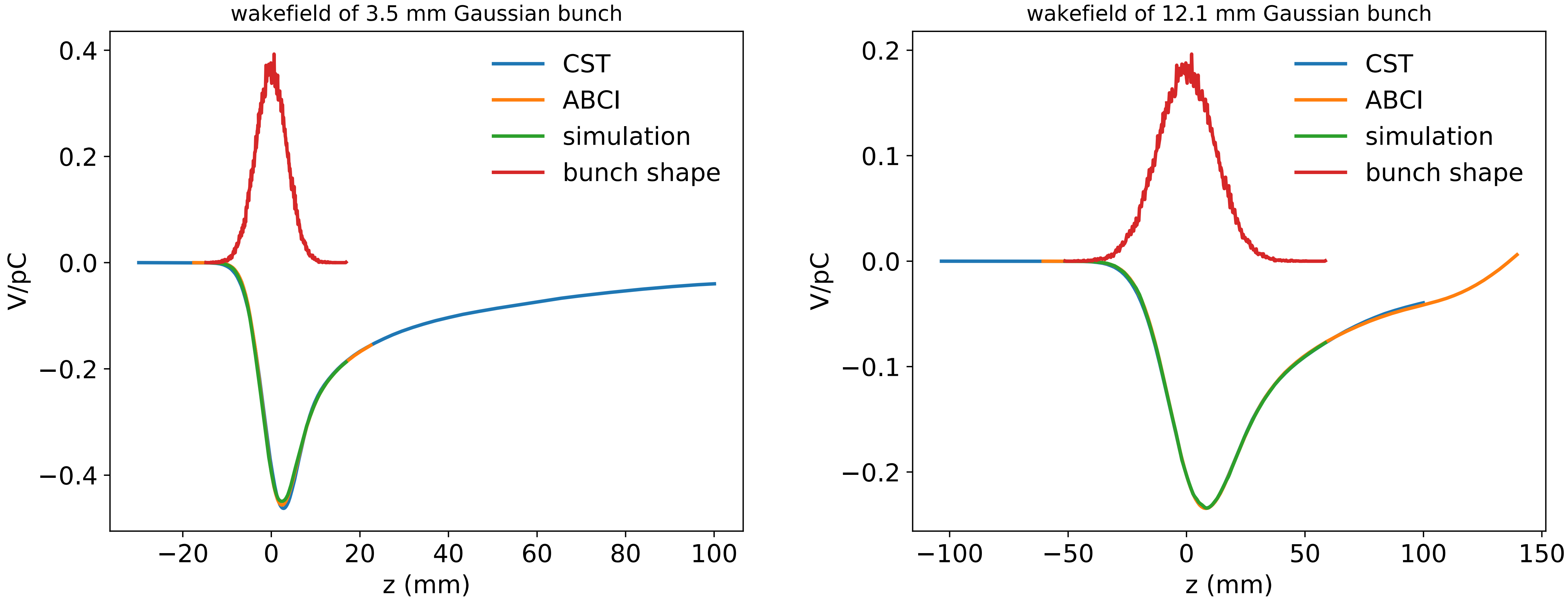


Method to calculate the Wake Potential by software simulation: Tapers

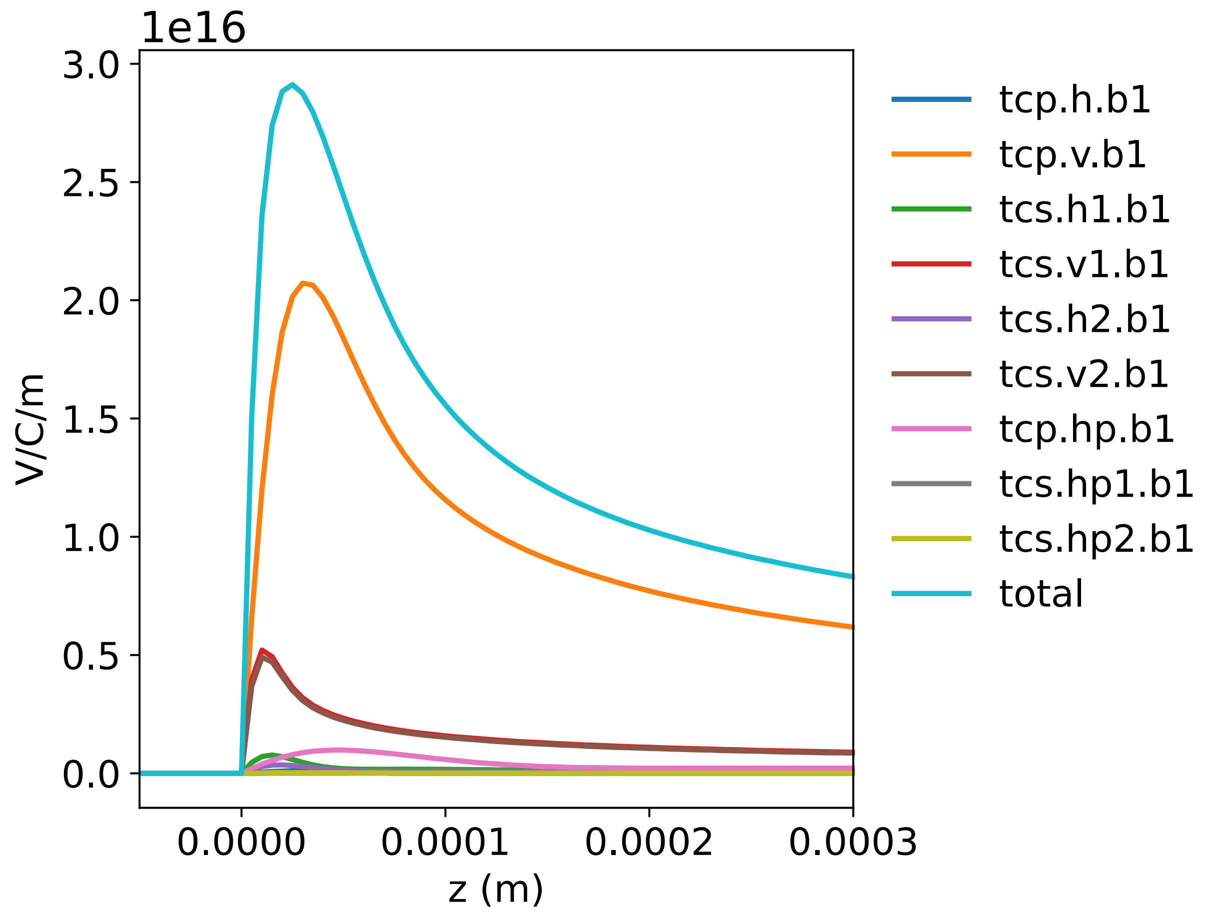




Method to calculate the Wake Potential by software simulation: RF Cavities

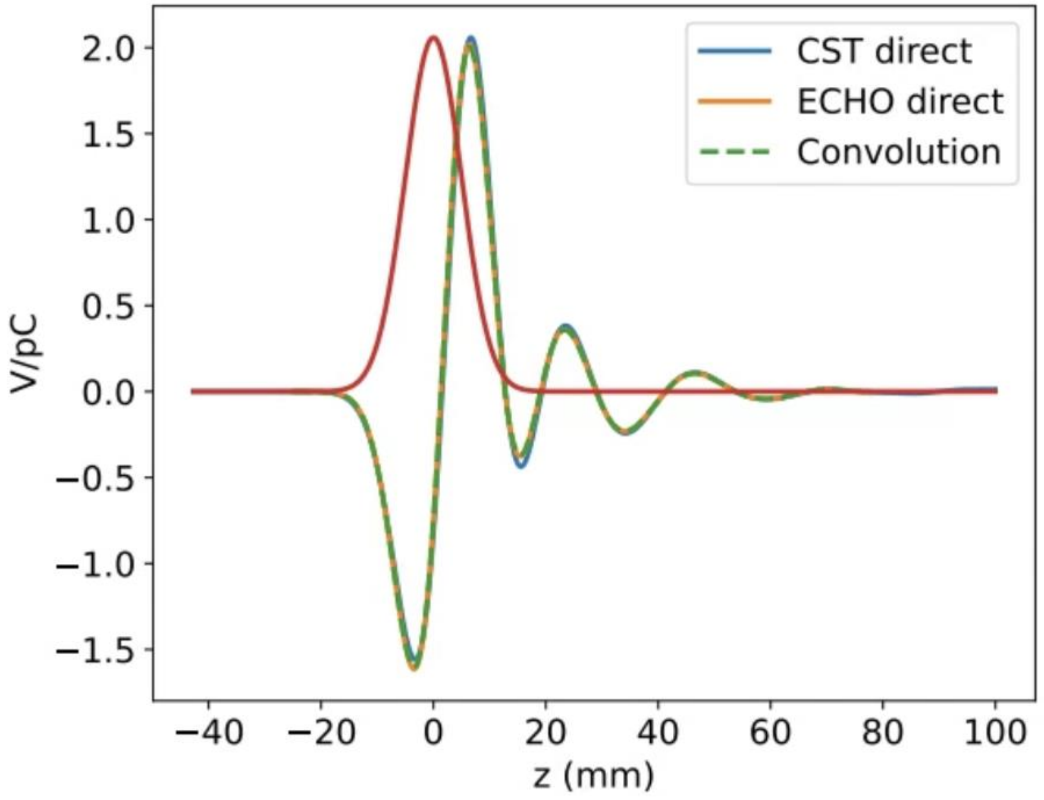


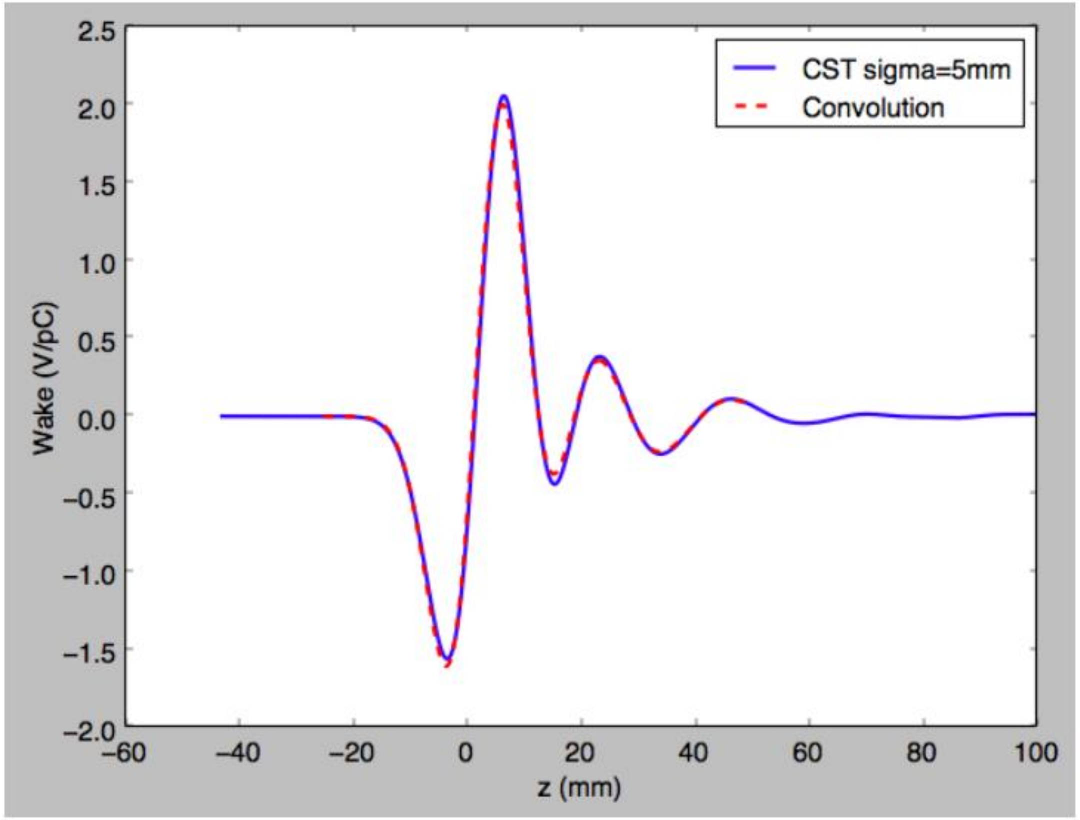
Collimator RW contributions: Dipolar wake y



Geometrical impedance for collimators: still work in progress

geometric longitudinal wakefield of a 5 mm Gaussian bunch





Important questions for future plans

Continue the work for the evaluation, reduction and optimization of the impedances of the main machine elements (e. g. collimators system), and also for implementing the FCC-ee repository.

Is there a CAD design to use for the impedance evaluation of BPMs?

We estimated a number of 4000 BPMs. Should we change this estimation?

Are there other devices to evaluate for the beam instrumentation? Is there any design?

Thanks for your attention!