INFN

SAPIENZA UNIVERSITÀ DI ROMA

DIPARTIMENTO DI SCIENZE DI BASE E APPLICATE PER L'INGEGNERIA

FUTURE CIRCULAR COLLIDER Innovation Study

Update on FCC-ee collective effects
2nd FCC@LNF

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Parameters (for mid-term review)

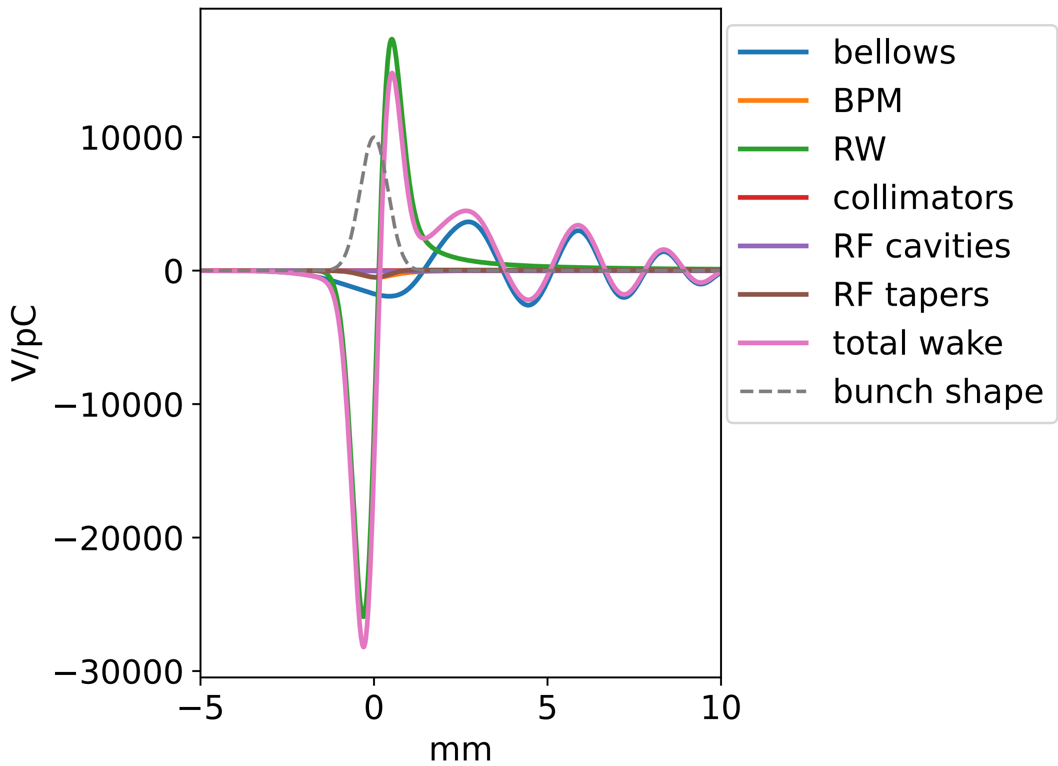
Note the lower synchrotron tune (0.029 with respect to 0.037) and the lower single bunch intensity (1.5e10 with respect to 2.6e10)

Table 1: FCC-ee collider parameters for Z as of Apr. 20, 2023.

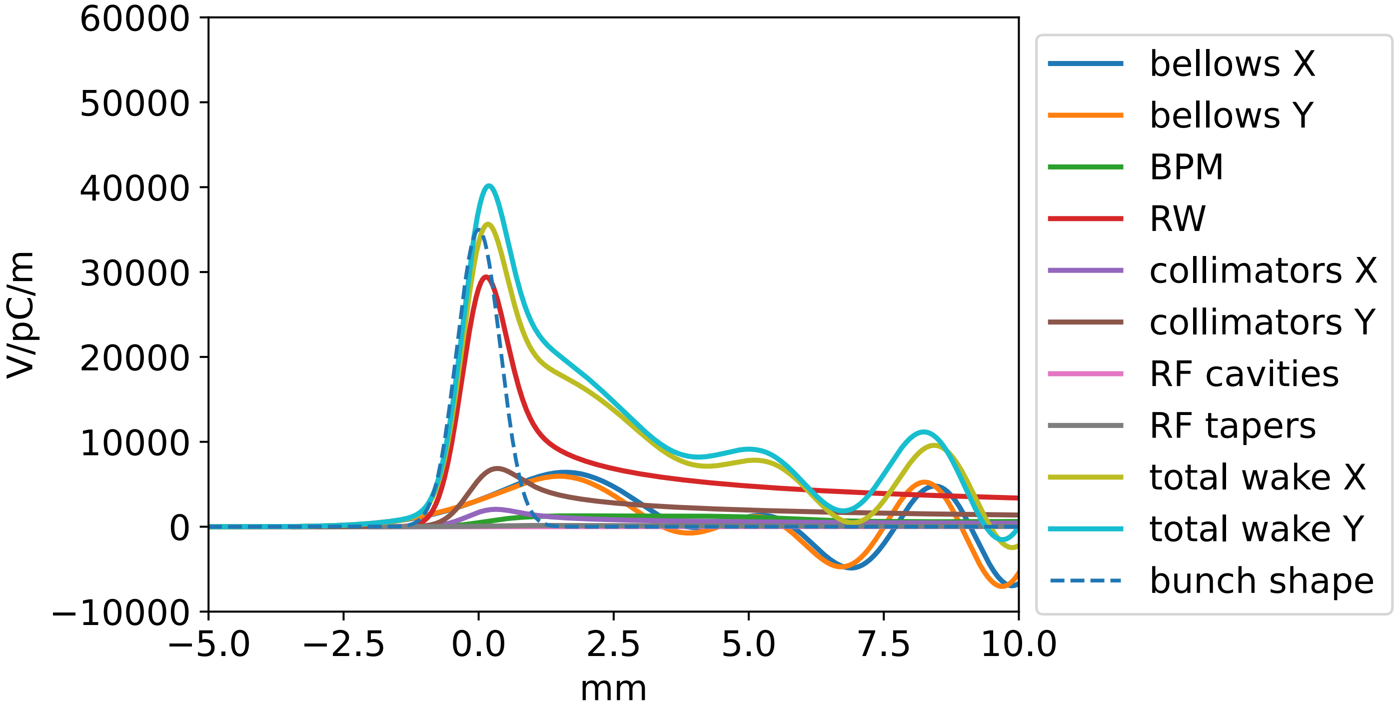
Beam energy	[GeV]	45.6	
Version		Apr. 20	Feb. 07
Layout		PA31-3.0	
# of IPs		4	
Circumference	[km]	90.658816	
Bending radius of arc dipole	[km]	9.936	
Energy loss / turn	[GeV]	0.0394	
SR power / beam	[MW]	50	
Beam current	[mA]	1270	
Colliding bunches / beam		15880	9200
Colliding bunch population	[10^{11}]	1.51	2.60
Horizontal emittance at collision ε_x	[nm]	0.71	
Vertical emittance at collision ε_y	[pm]	1.4	
Lattice vertical emittance $\varepsilon_{y,\text{lattice}}$	[pm]	0.75	< 0.3
Arc cell		Long 90/90	
Momentum compaction α_p	[10^{-6}]	28.6	
Arc sextupole families		75	
$\beta^*_{x/y}$	[mm]	110 / 0.7	100 / 0.8
Transverse tunes $Q_{x/y}$		214.158 / 214.200	214.260 / 214.380
Chromaticities $Q'_{x/y}$		0 / +5	0 / 0
Energy spread (SR/BS) σ_δ	[%]	0.039 / 0.089	0.039 / 0.143
Bunch length (SR/BS) σ_z	[mm]	5.60 / 12.7	4.37 / 15.9
RF voltage 400/800 MHz	[GV]	0.079 / 0	0.120 / 0
Harmonic number for 400 MHz		121200	
RF freuqeuncy (400 MHz)	MHz	400.786684	
Synchrotron tune Q_s		0.0288	0.0370
Long. damping time	[turns]	1158	
RF acceptance	[%]	1.05	1.6
Energy acceptance (DA)	[%]	±1.0	
Beam crossing angle at IP	[mrad]	±15	
Crab waist ratio	[%]	70	97
Beam-beam ξ_x/ξ_y [a]		0.0023 / 0.096	0.0023 / 0.139
Lifetime (q + BS + lattice)	[sec]	15000	20
Lifetime (lum) [b]	[sec]	1340	1010
Luminosity / IP	[$10^{34}/\text{cm}^2\text{s}$]	140	186

[a] incl. hourglass.
[b] only the energy acceptance is taken into account for the cross section

Longitudinal wake potential of a 0.4 mm Gaussian bunch used as Green function in beam dynamics simulations

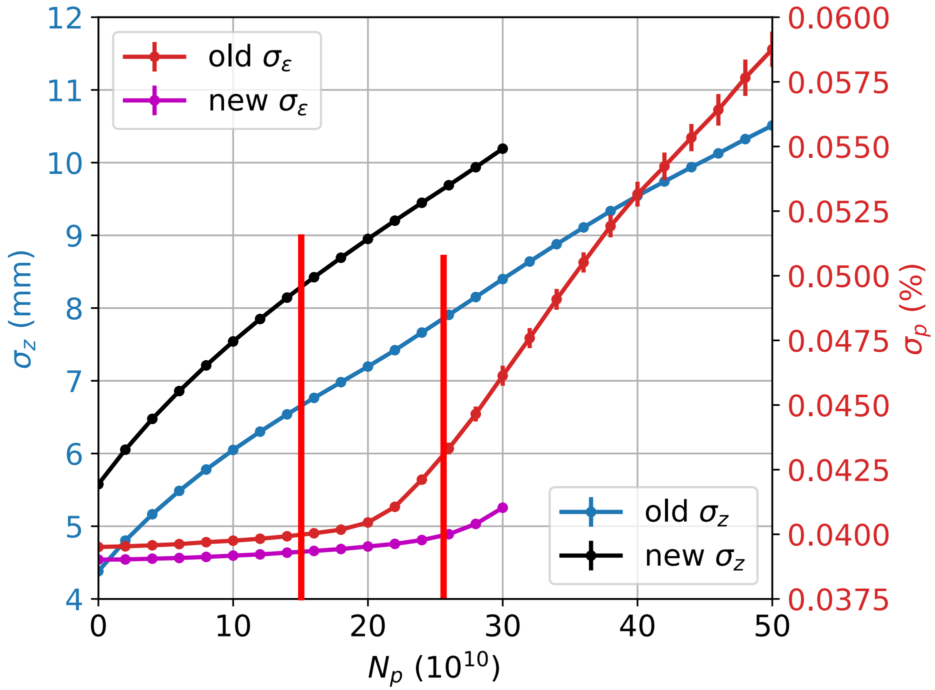


Transverse dipolar wake potential of a 0.4 mm Gaussian bunch used as Green function in beam dynamics simulations

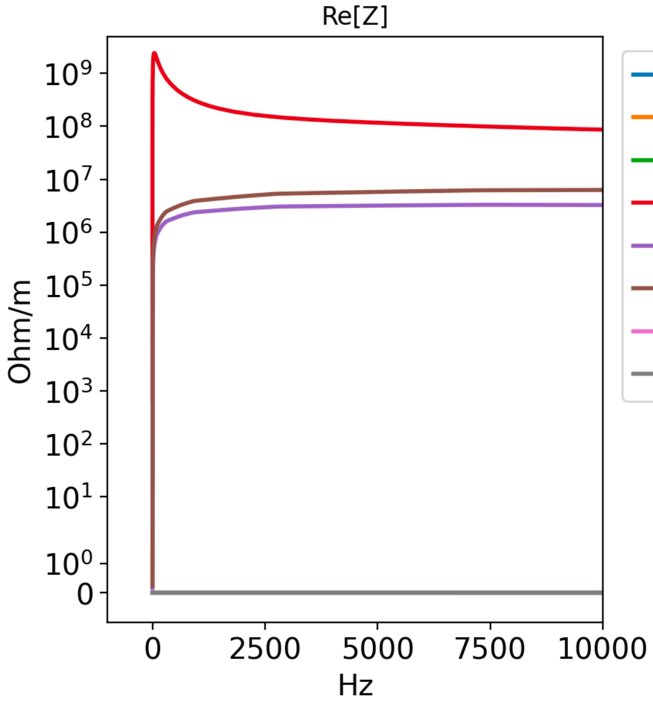


In beam dynamics simulations we have also included the quadrupolar wake potential of the short bunch.

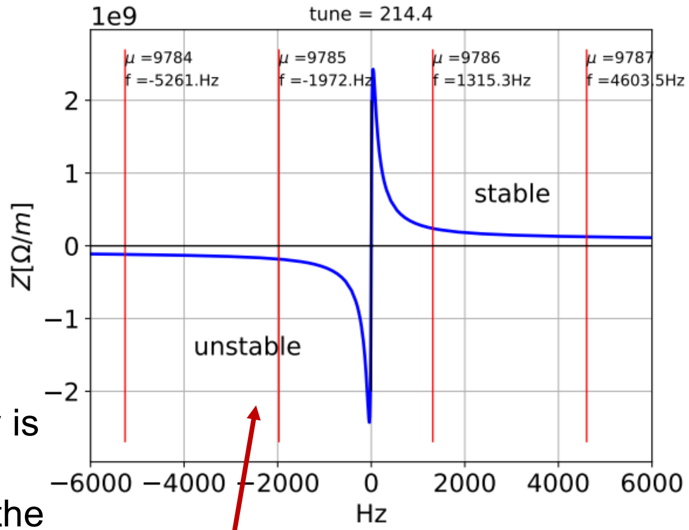
Single bunch collective effects in the longitudinal plane



Transverse coupled bunch instability and feedback system



The TCBI is evaluated by considering the lowest azimuthal intra-bunch mode (rigid dipolar oscillations) and Gaussian bunches. The instability is due to the coupling of the multi-bunch coherent frequencies with the real part of the dipolar coupling impedance at the lowest frequencies.

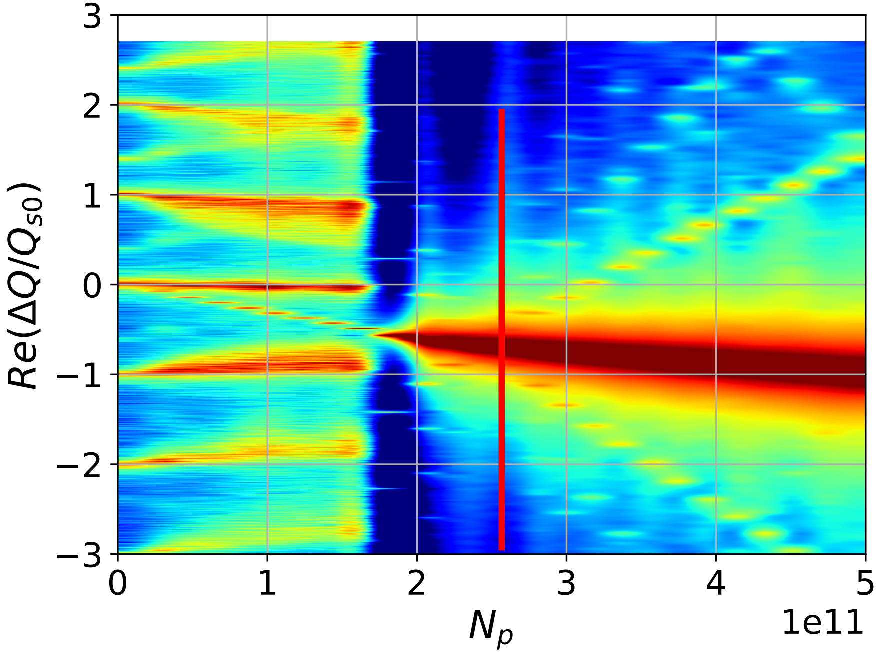


The most dangerous mode is that closest to the origin (with negative frequency)

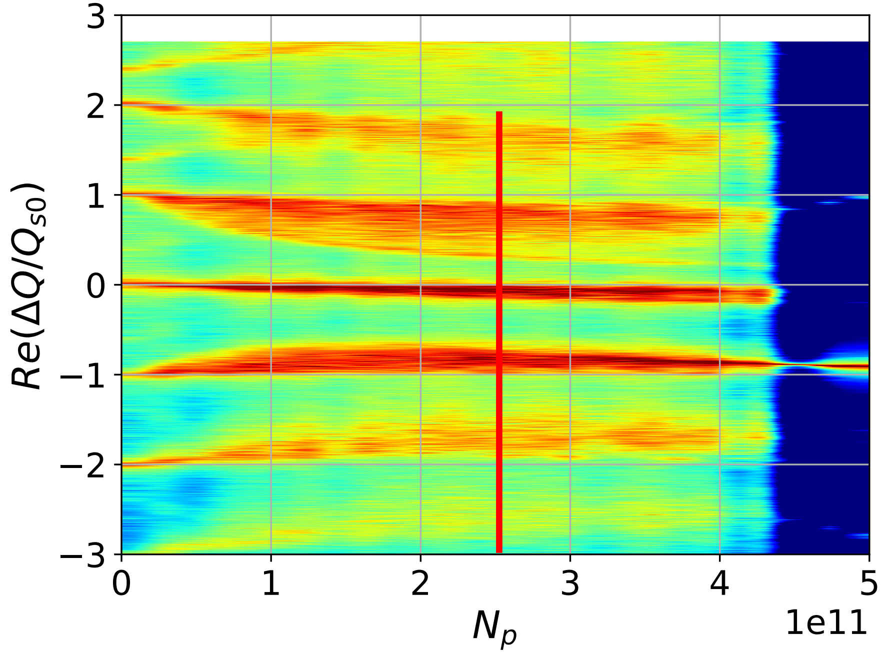
From the real part of the transverse impedance at low frequency we see that only the RW contribution due to the beam pipe is important. Collimators do not seem to contribute much at such low frequencies

Single bunch collective effects in the transverse plane: old parameters

no feedback

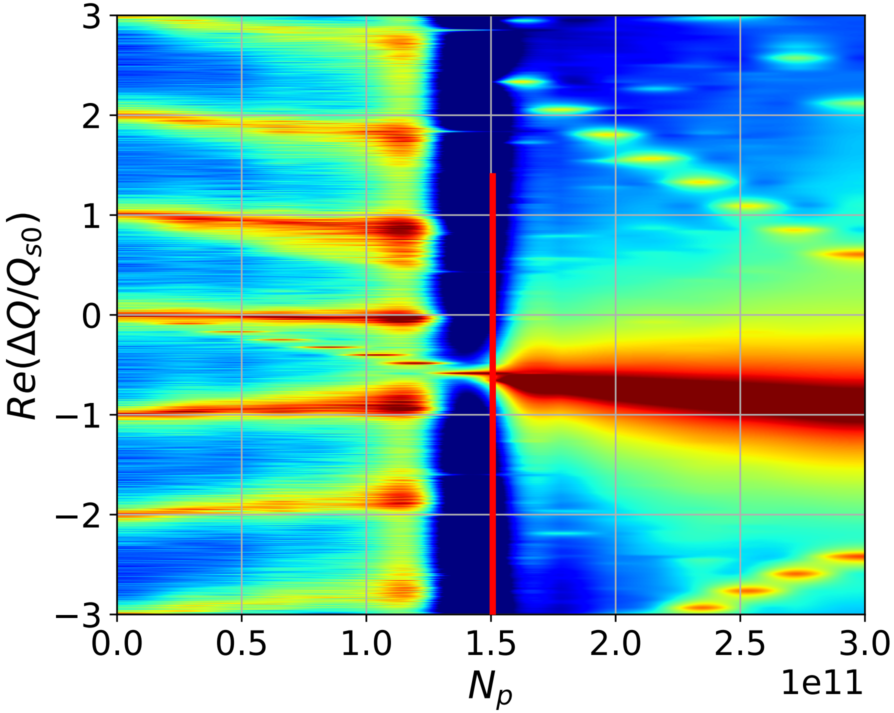


with feedback

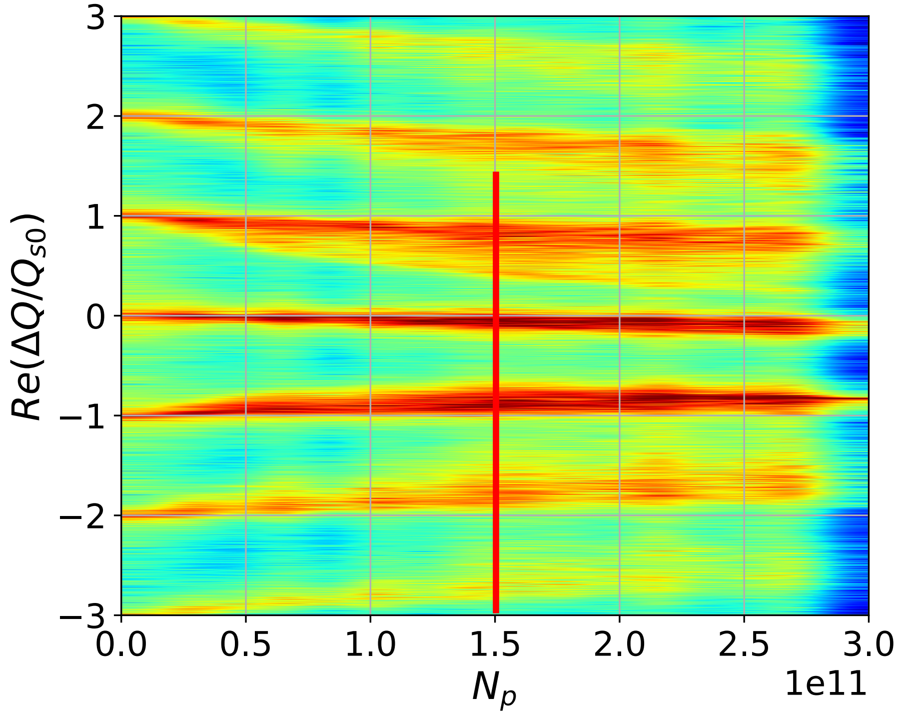


Single bunch collective effects in the transverse plane: new parameters

no feedback

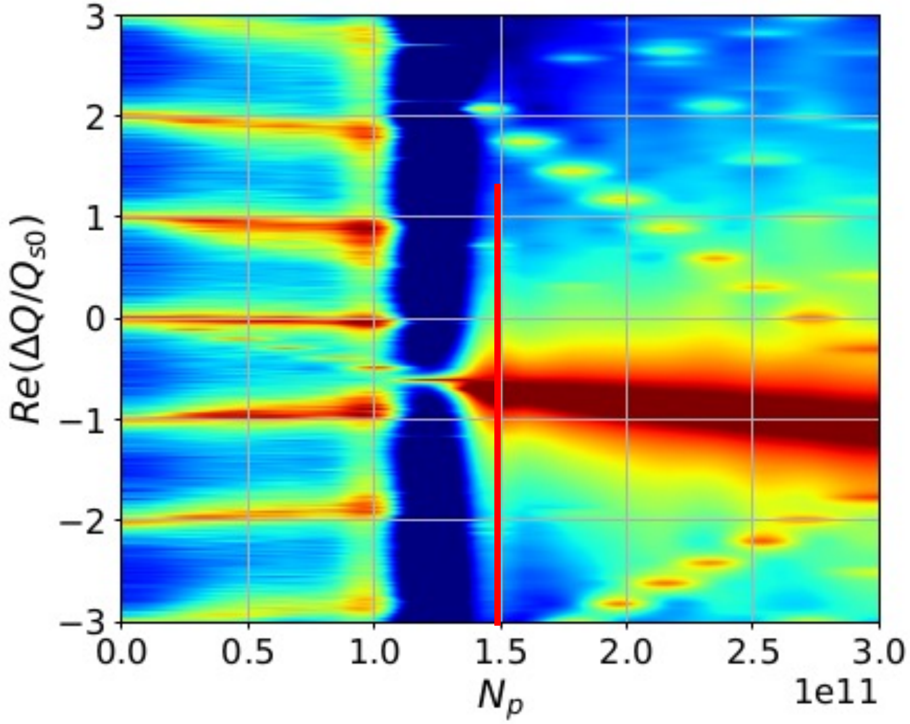


with feedback

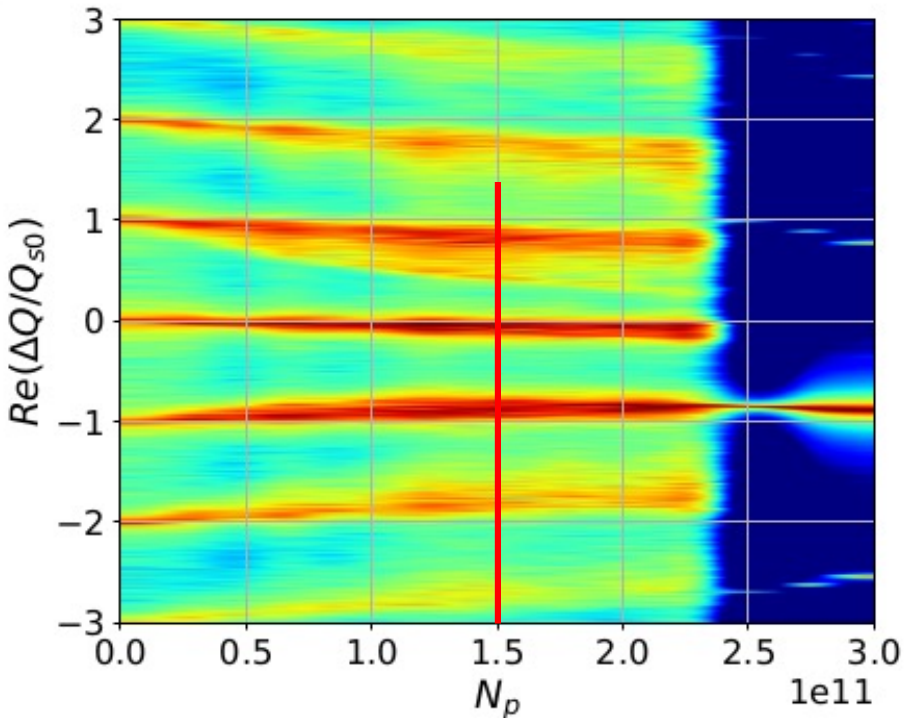


Single bunch collective effects in the transverse plane: new parameters and reduced beam pipe (from 35 mm to 30 mm of radius)

no feedback



with feedback



Beam beam

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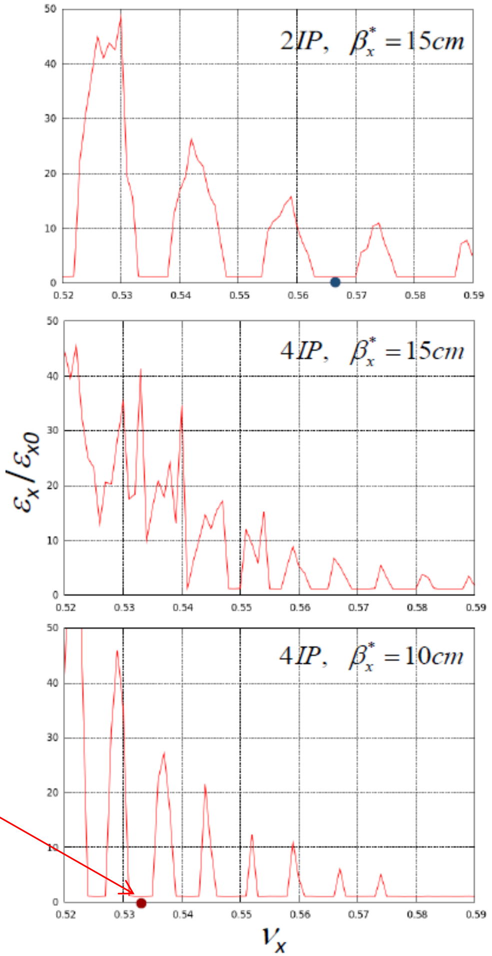
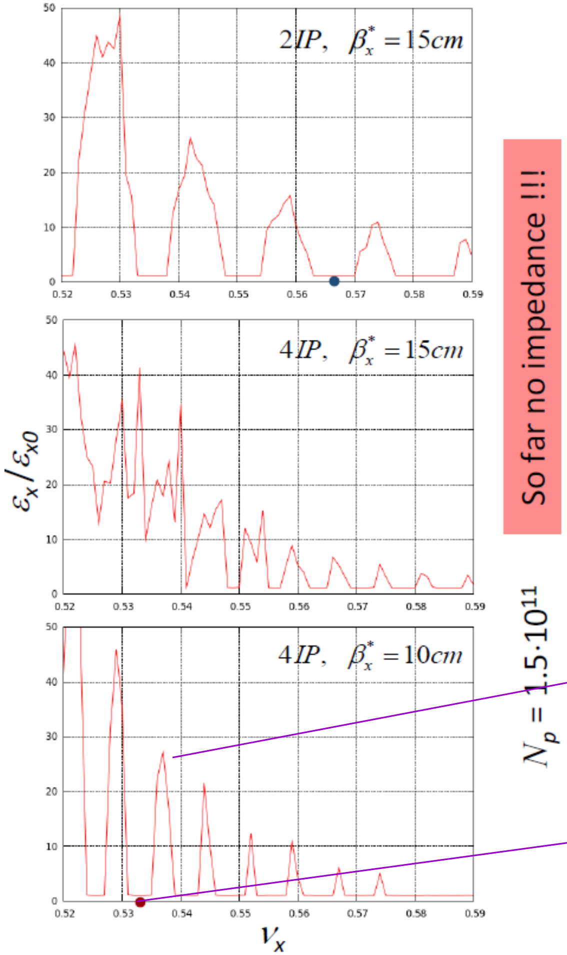
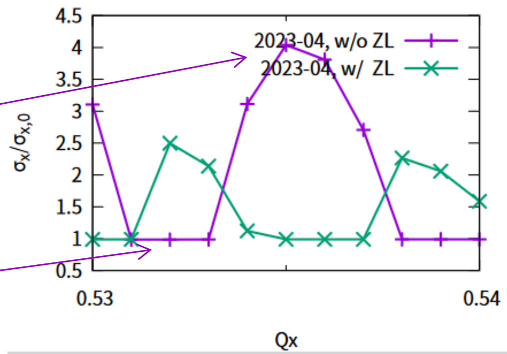


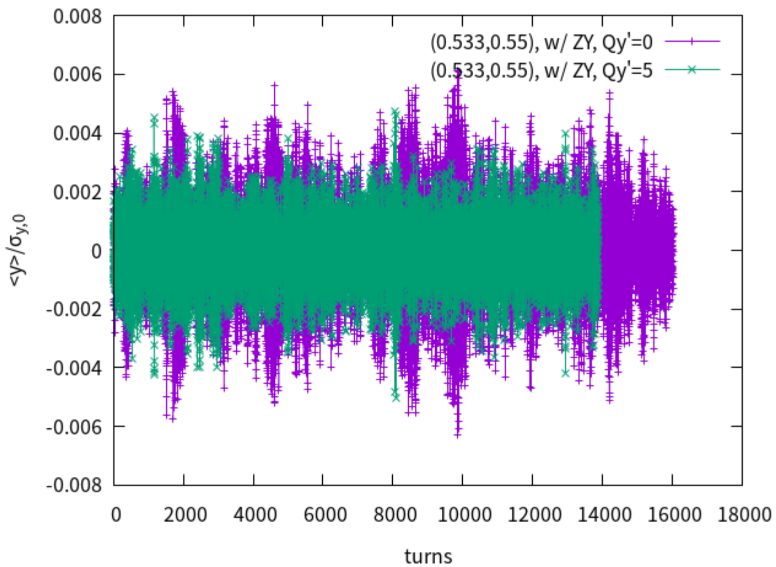
So far no impedance !!!

$N_p = 1.5 \cdot 10^{11}$

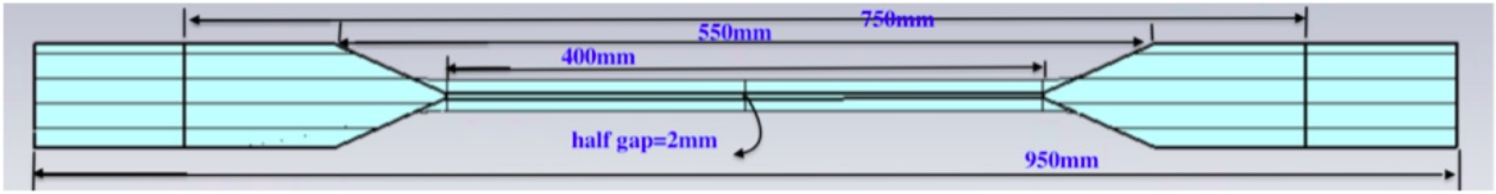
Beam beam (preliminary)

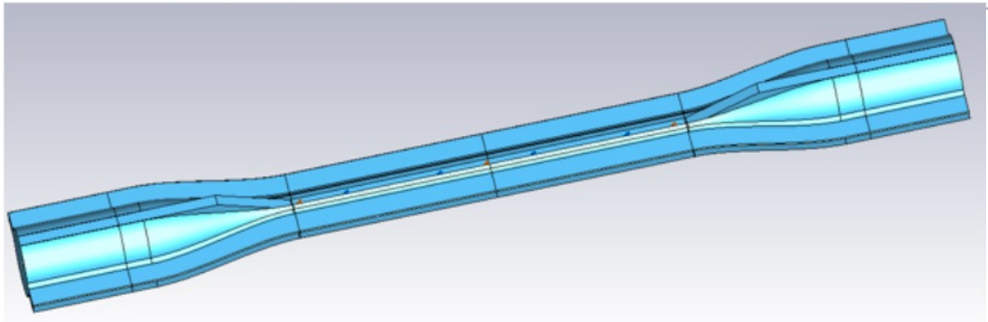






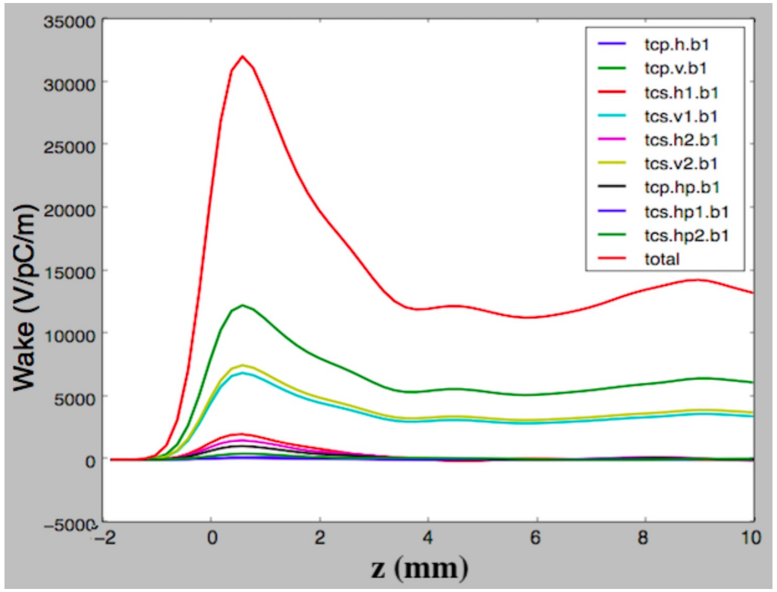
Geometrical wakefield of collimators

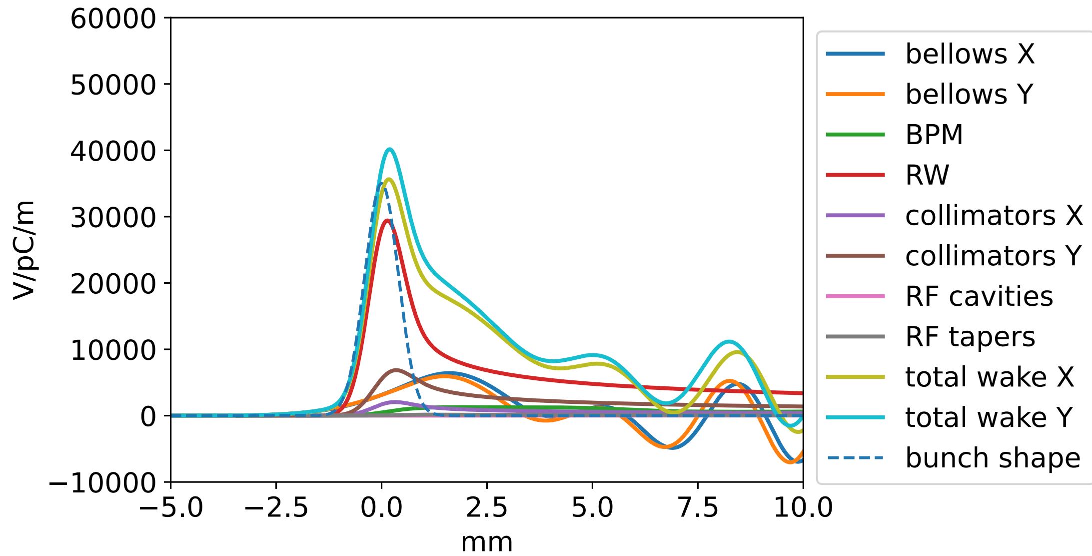




name	type	length [m]	nsigma	half-gap [m]	material
tcp.h.b1	primary	0.4	11.0	0.005504	MoGR
tcp.v.b1	primary	0.4	65.0	0.002332	MoGR
tcs.h1.b1	secondary	0.3	13.0	0.004162	Mo
tcs.v1.b1	secondary	0.3	75.5	0.00203	Mo
tcs.h2.b1	secondary	0.3	13.0	0.005956	Mo
tcs.v2.b1	secondary	0.3	75.5	0.002116	Mo
tcp.hp.b1	primary	0.4	29.0	0.005755	MoGR
tcs.hp1.b1	secondary	0.3	32.0	0.01649	Mo
tcs.hp2.b1	secondary	0.3	32.0	0.011597	Mo

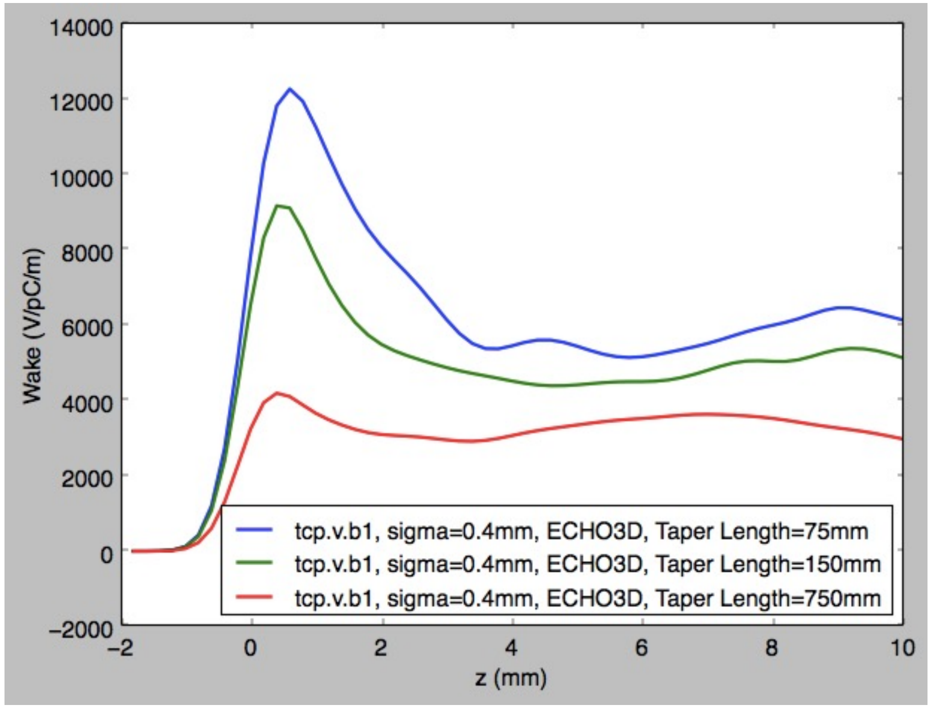
Work in progress: geometrical wakefield due to collimators





Work in progress: geometrical wakefield due to collimators

How to mitigate this geometrical contribution?



Work in progress: geometrical wakefield due to collimators