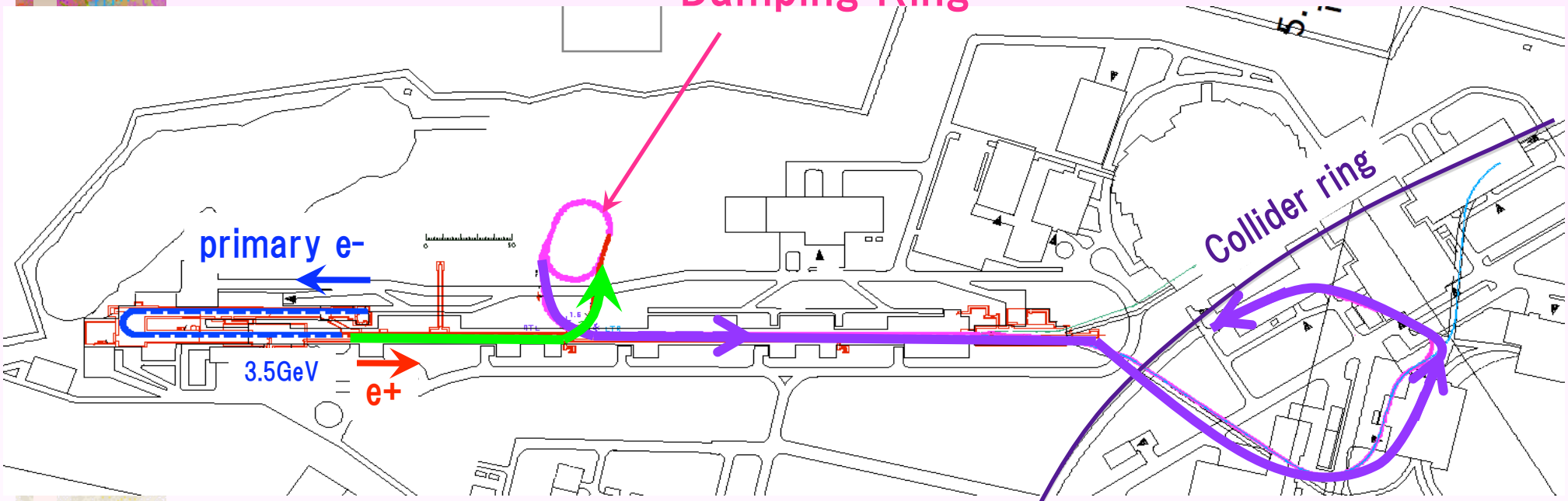
CSR in Damping Ring

2012/2/21

The 17th KEKB Accelerator Review Committee

H.Ikeda

Damping Ring of SuperKEKB



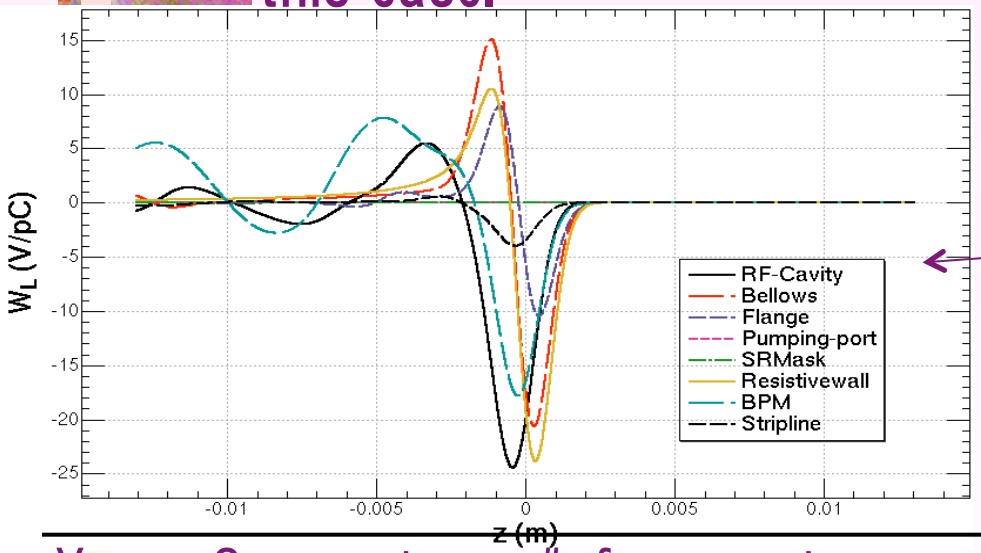
The SuperKEKB DR is now under construction. DR is necessary to inject the low emittance positron beam to the LER, which has very small acceptance in both of transverse and longitudinal planes. Beam instability is important to design the DR since the bunch current is relatively high. Since it was found that the instability due to CSR severely damages the beam performance for shorter bunch-length and lower momentum compaction, we tried to found the good shape of beam pipe for suppression of the instability.

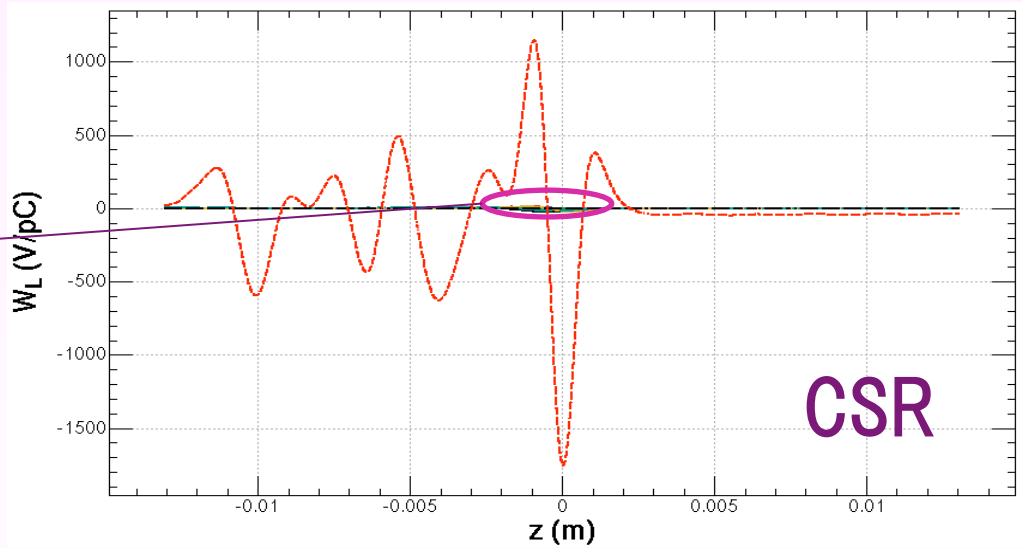
DR Parameter

Parameter		unit
Energy	1.1	GeV
No. of bunch trains/ bunches per train	2/2	
Maximum bunch charge	8	nC
Circumference	135.5	m
Maximum stored current*	70.8	mA
Energy loss per turn	0.091	MV
Horizontal damping time	10.9	ms
Injected-beam emittance	1700	nm
Equilibrium emittance(h/v)	41.4/2.07	nm
Coupling	5	%
Emittance at extraction(h/v)	42.5/3.15	nm
Energy band-width of injected beam	±1.5	%
Energy spread	0.055	%
Bunch length	6.53	mm
Synchrotron tune	.02569	
Momentum compaction factor	0.0141	
Number of normal cells	32	
Cavity voltage for 1.5 % bucket-height	1.4	MV
RF frequency	509	MHz

Wake potential

- Longitudinal wake potential per turn has been estimated for each vacuum component, RF cavity and resistive-wall with 0.5mm bunch length (< 1/10 of the natural bunch length).
- The CSR wake is 100 times higher than the other components in this case.





Vacuum Component	# of component
RF Cavity	2
Bellows	88
Flange	176
SR Mask	176
Resistive wall	135.5[m]
BPM	82
Strip line	1

(T.Abe, K.Shibata, M.Tobiyama)

Calculation of CSR and Tracking

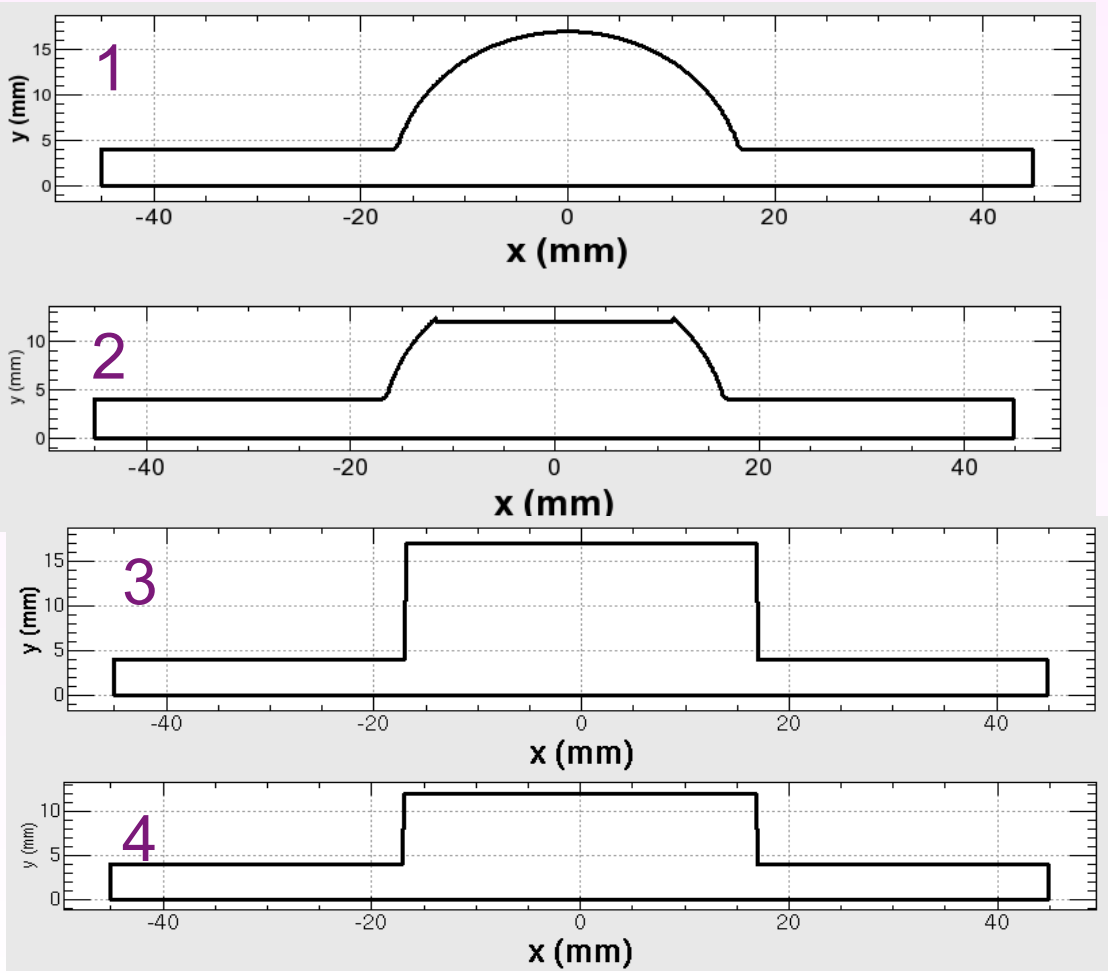
- The cross section of DR beam pipe is decided based on the CSR instability.
- The wake potential by CSR is calculated by two independent codes and the results agree for rectangular cross section chambers. Following results are using numerical calculation by Oide's code which is implemented to SAD.
- The tracking simulation was made for Gaussian beam and the tracking used up to 5,000,000 macro particles to confirm the convergence in the number of particles.

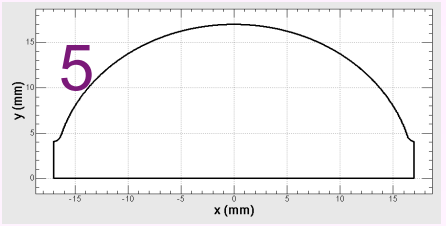
Bend	Length[m]	Bending angle	# of elements
B1	.74248	.27679	32
B2	.28654	.09687	38
B3	.39208	.12460	6
B4	.47935	.15218	2

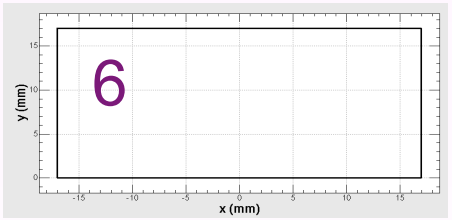
Parameters of dipole magnets

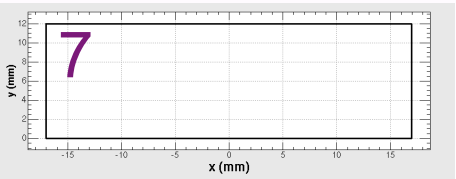
Calculation of CSR due to Chamber shape

The wake potentials by CSR are calculated for 7 types cross section.



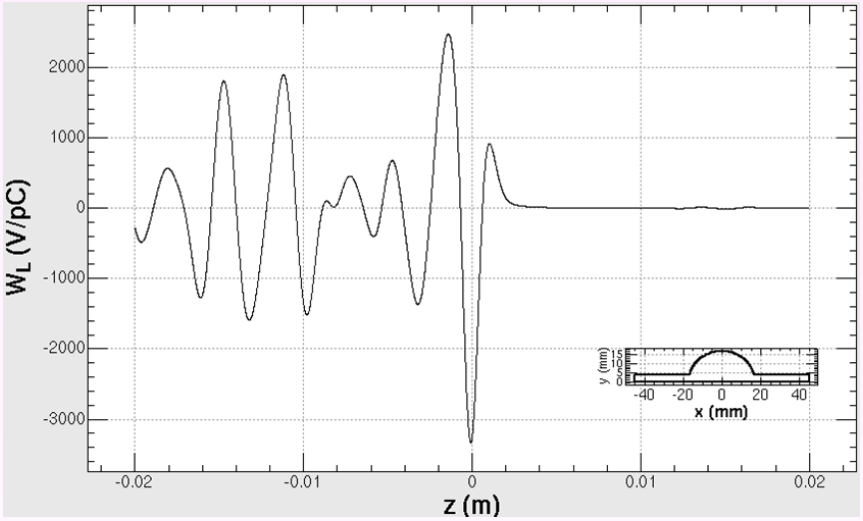


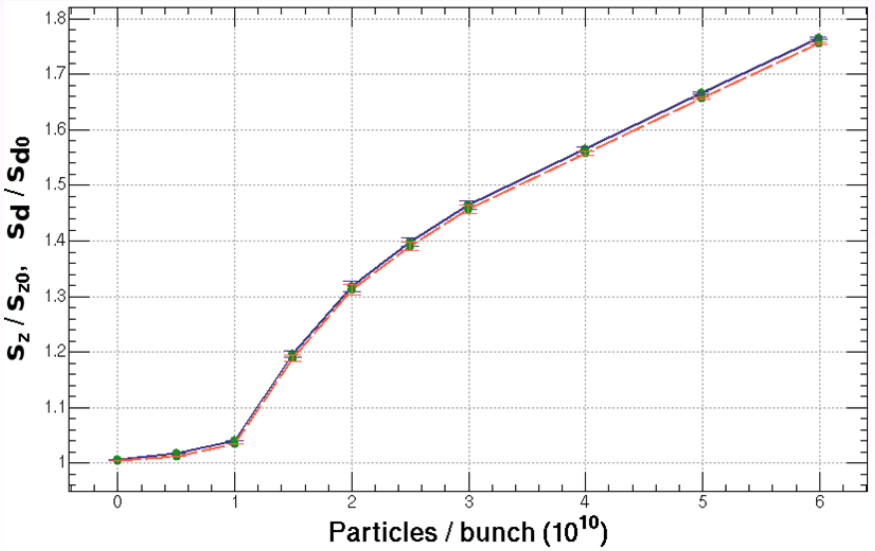




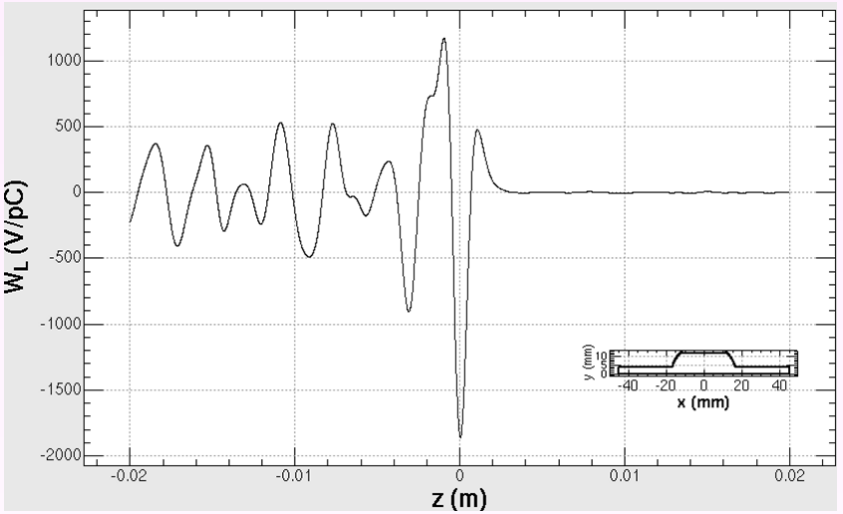
Calculation of CSR and Tracking [1]

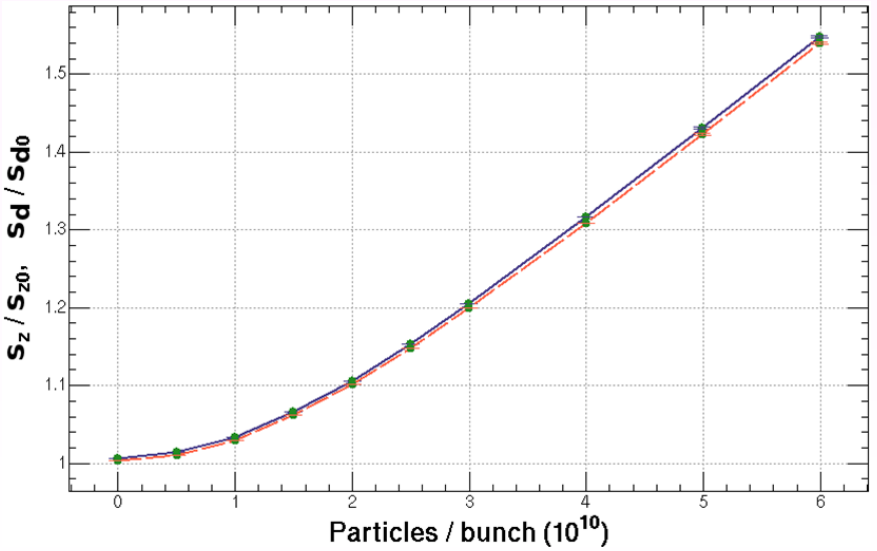
Antechamber 34 ϕ





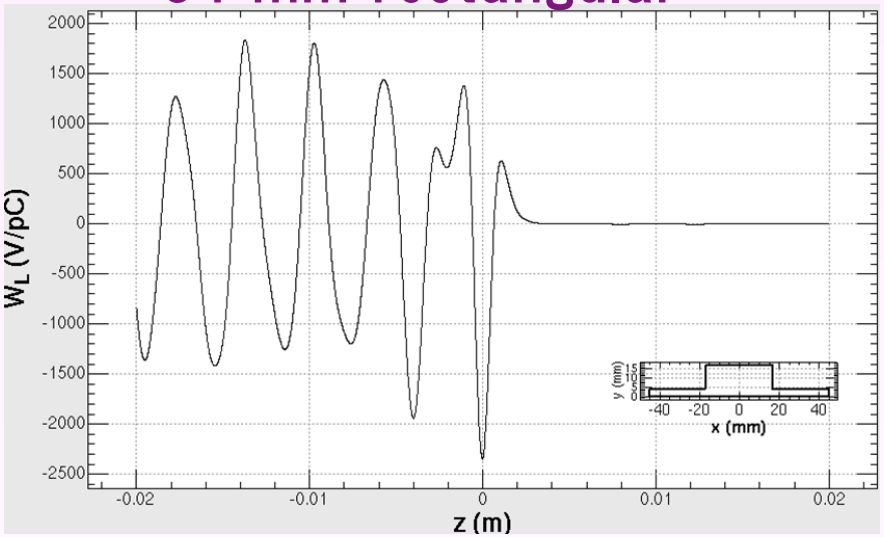
Antechamber 24 mm

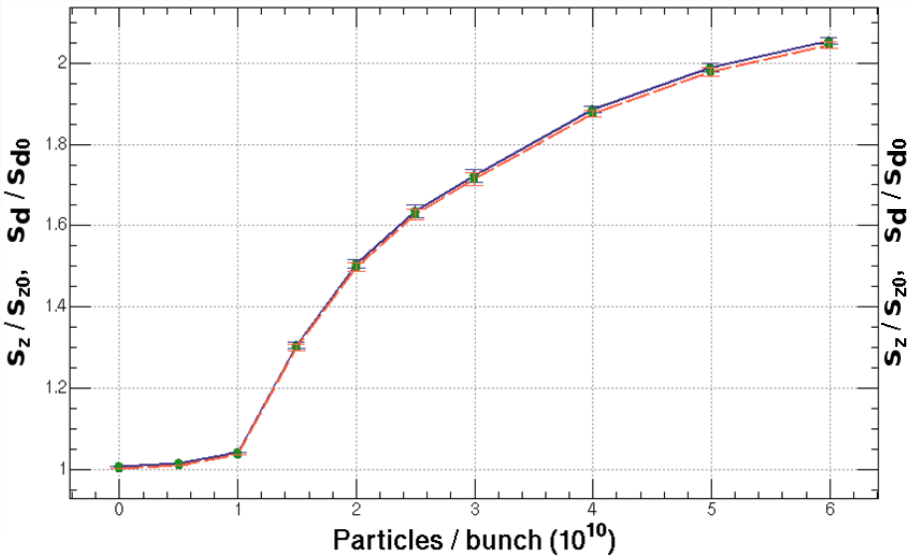




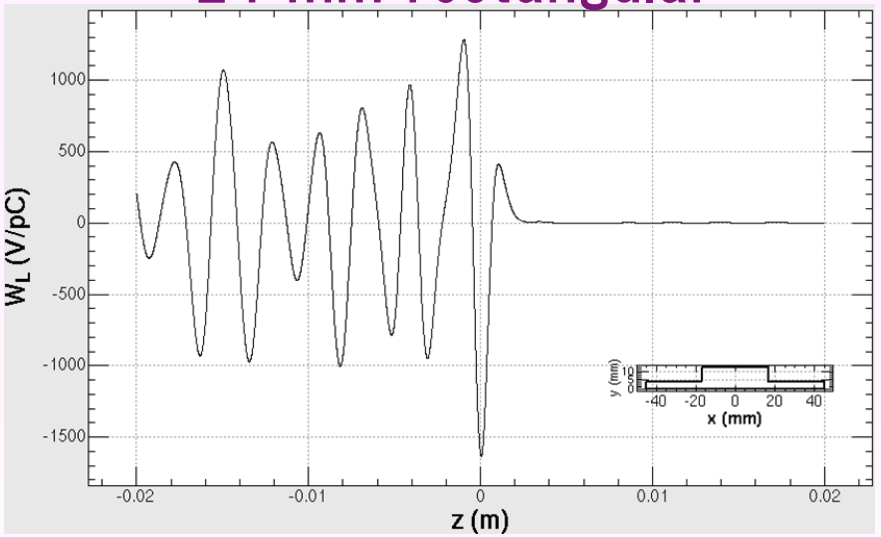
Calculation of CSR and Tracking [2]

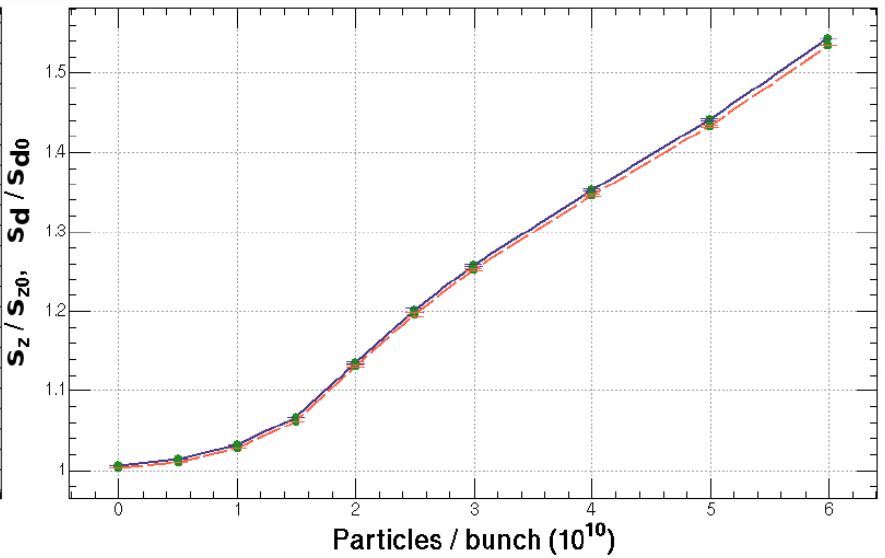
Antechamber
34 mm rectangular





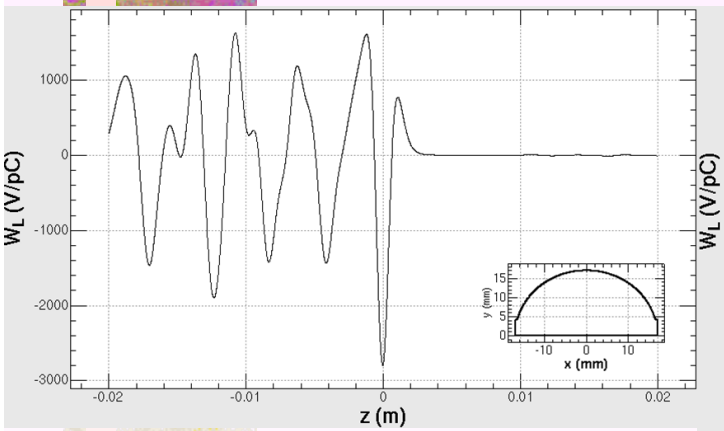
Antechamber
24 mm rectangular

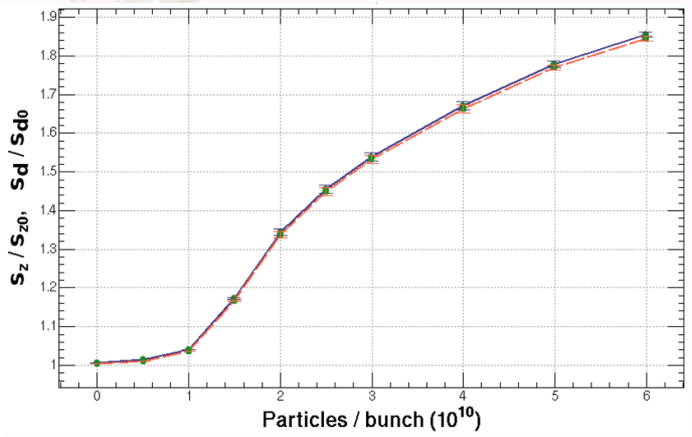




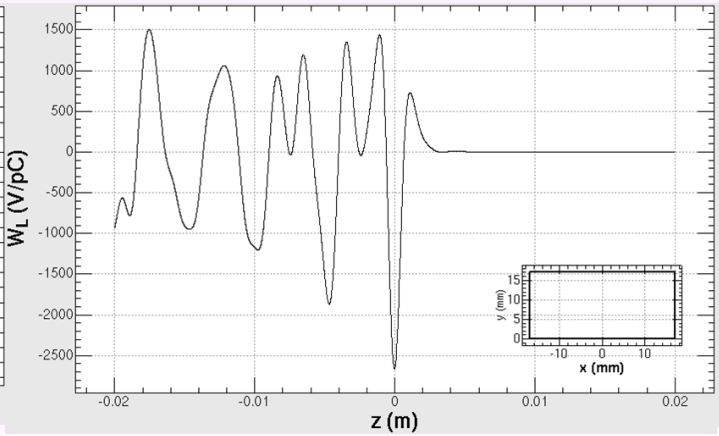
Calculation of CSR and Tracking [3]

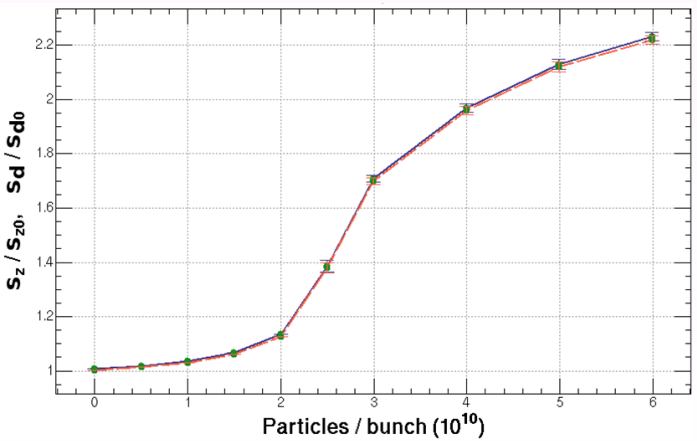
Normal chamber 34 ϕ



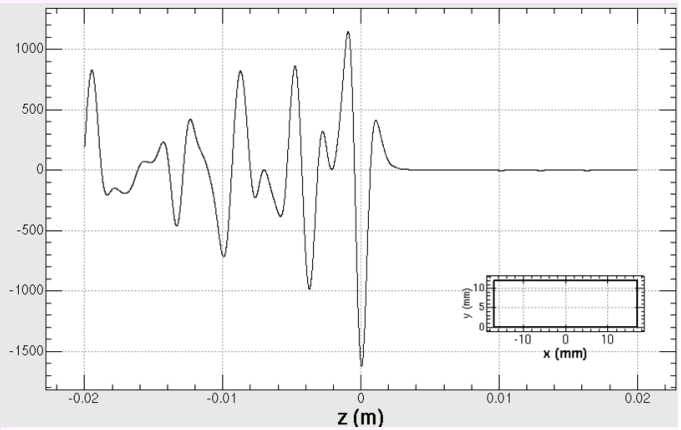


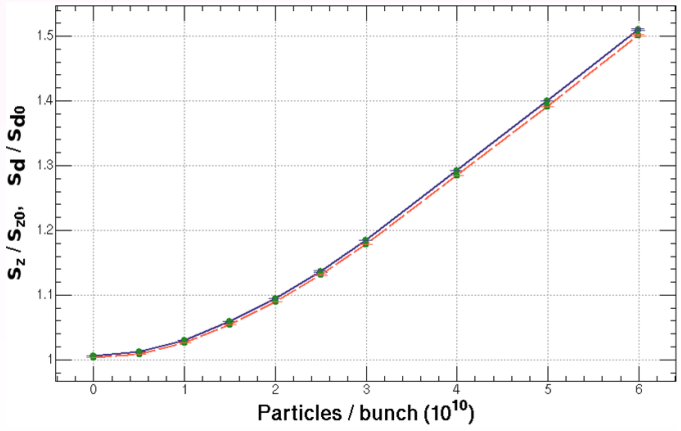
34 mm rectangular





24 mm rectangular





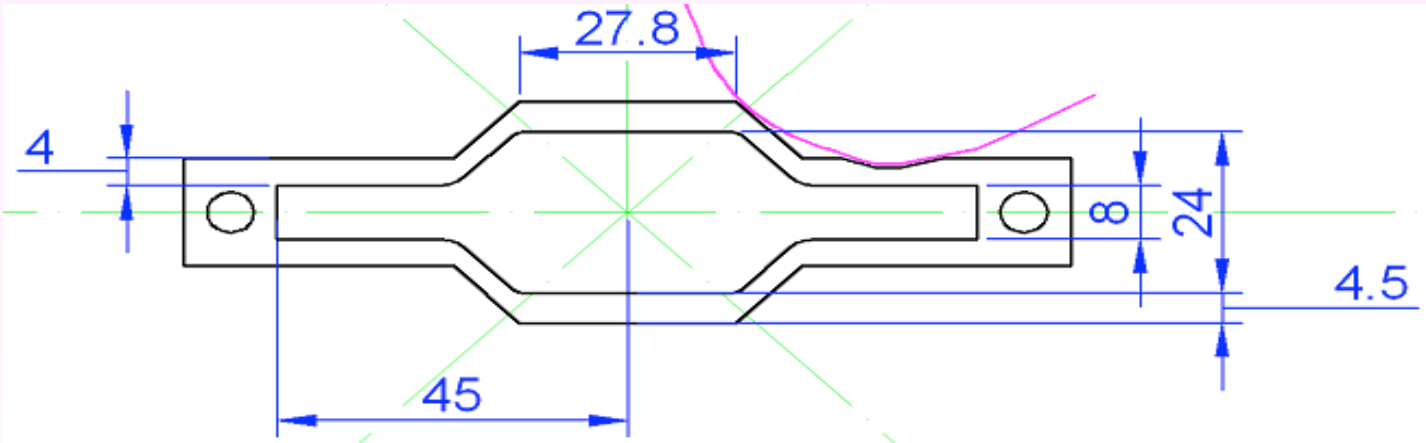
Calculation of CSR and Tracking [summary]

Cross section of beam pipe	$\sigma_\Delta/\sigma_{\Delta 0}$		σ_z/σ_{z0}	
	4nC	8nC	4nC	8nC
(1) Antechamber 34 ϕ	39%	65%	40%	66%
(2) Antechamber 24 mm	15%	43%	15%	43%
(3) Antechamber 34 mm rectangular	63%	98%	63%	98%
(4) Antechamber 24 mm rectangular	20%	44%	20%	44%
(5) Normal chamber 34 ϕ	45%	77%	45%	78%
(6) 34 mm rectangular	39%	115%	39%	115%
(7) 24 mm rectangular	14%	39%	14%	40%

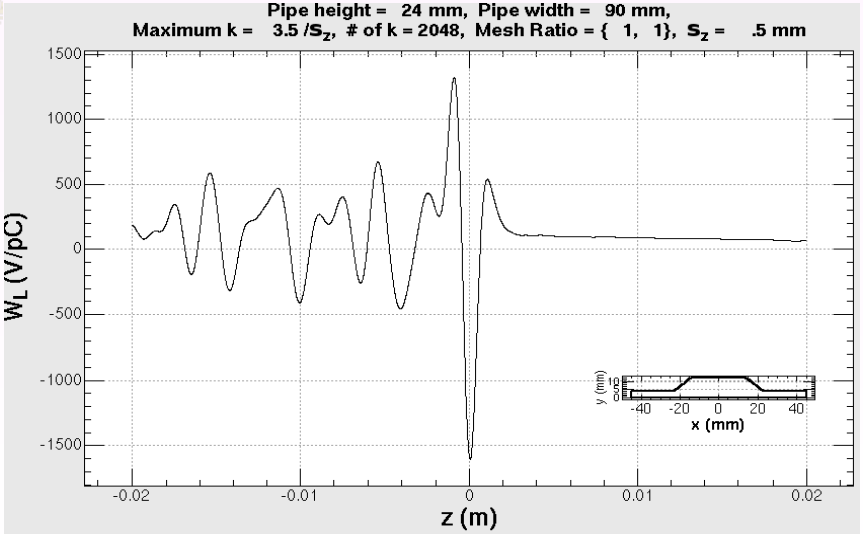
- We chose a design with antechamber for the DR beam pipe to reduce the instability caused by the wake field of vacuum components.
- The antechamber with smaller pipe height shows better situation.

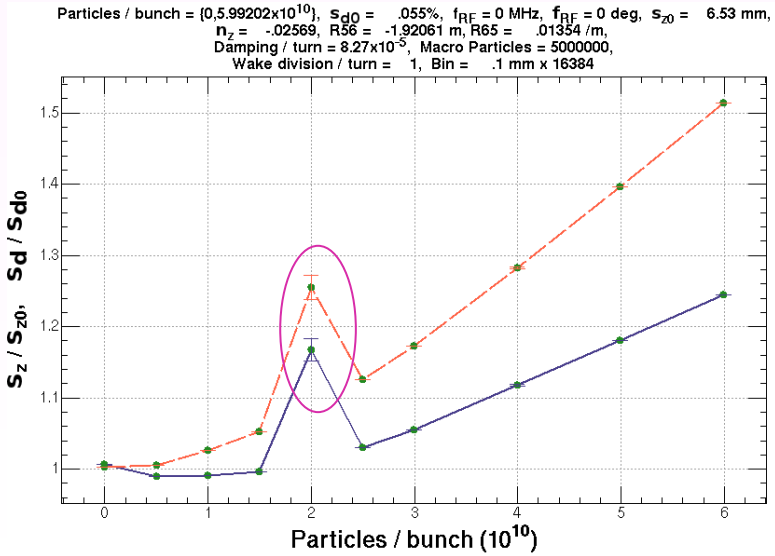
Design of beam pipe

- We designed the actual cross section of the beam pipe, considering the easiness of the production and the tracking simulation was made.



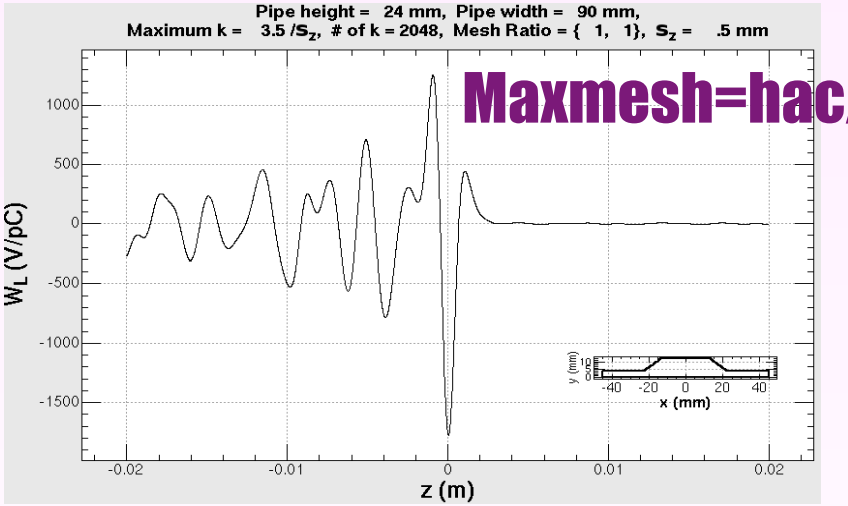
(K.Shibata)

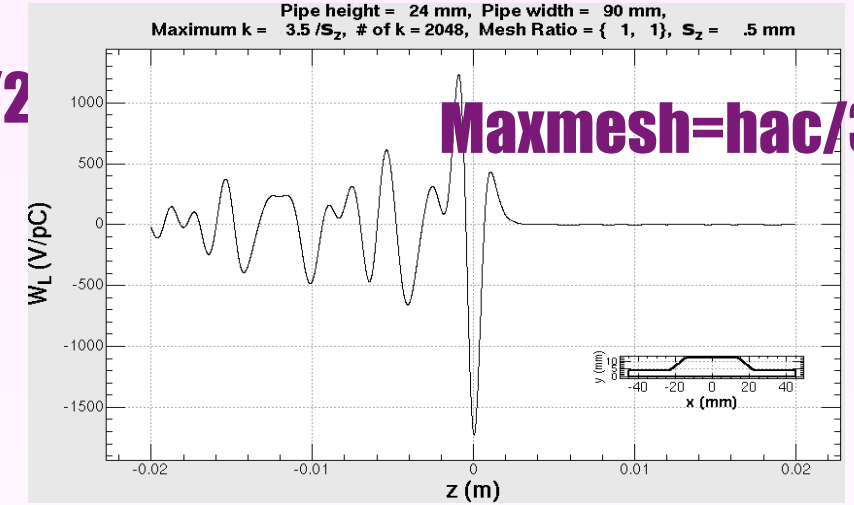


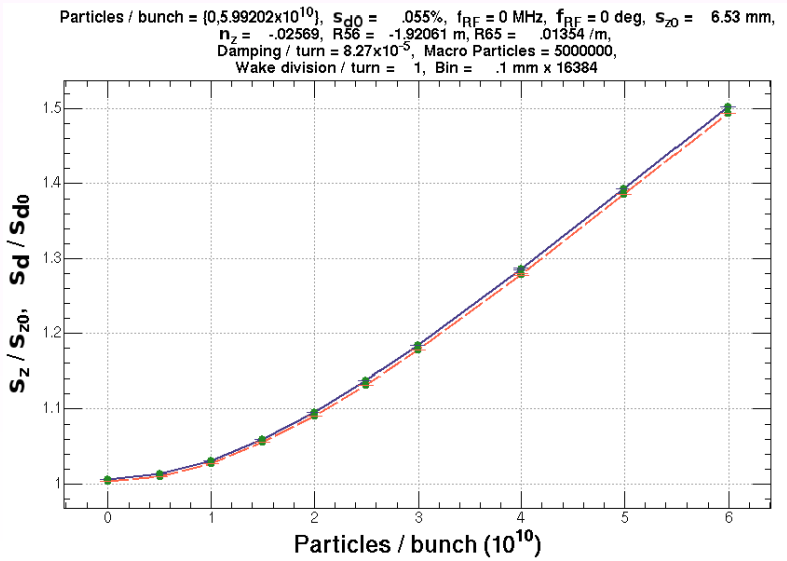


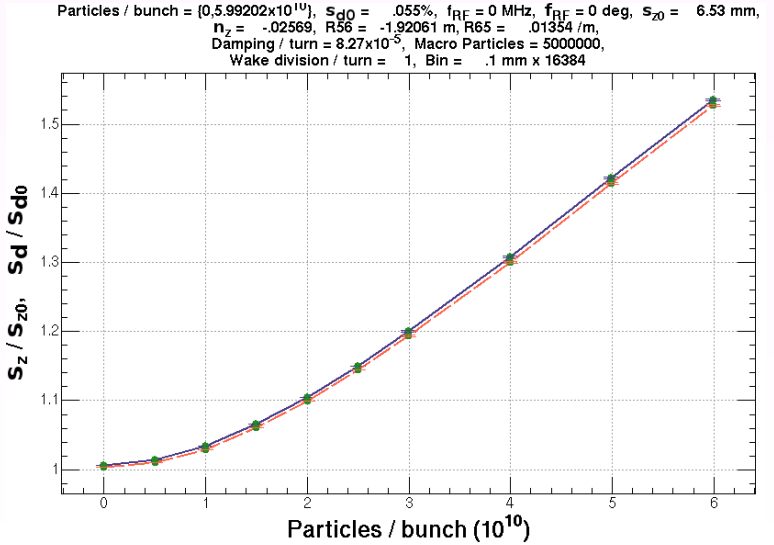
Calculation of CSR and Tracking :Change the mesh size

- Change the mesh size in order to check the calculation are converged.

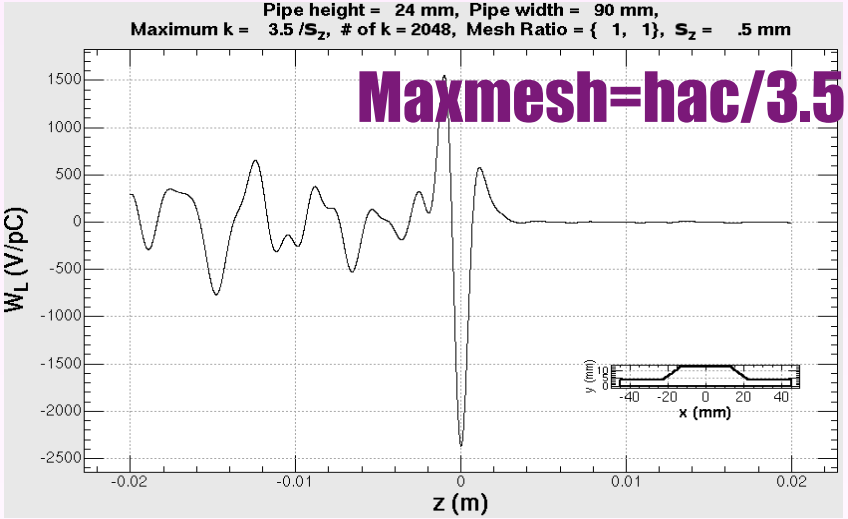


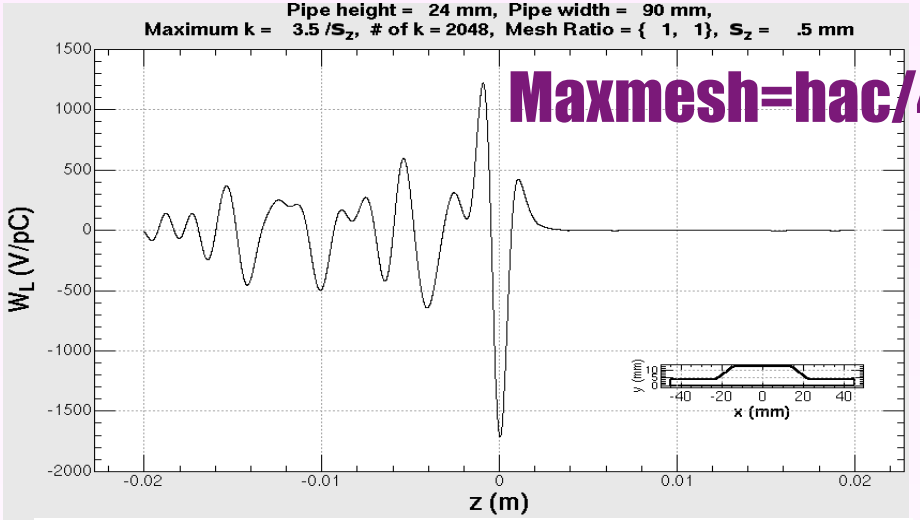


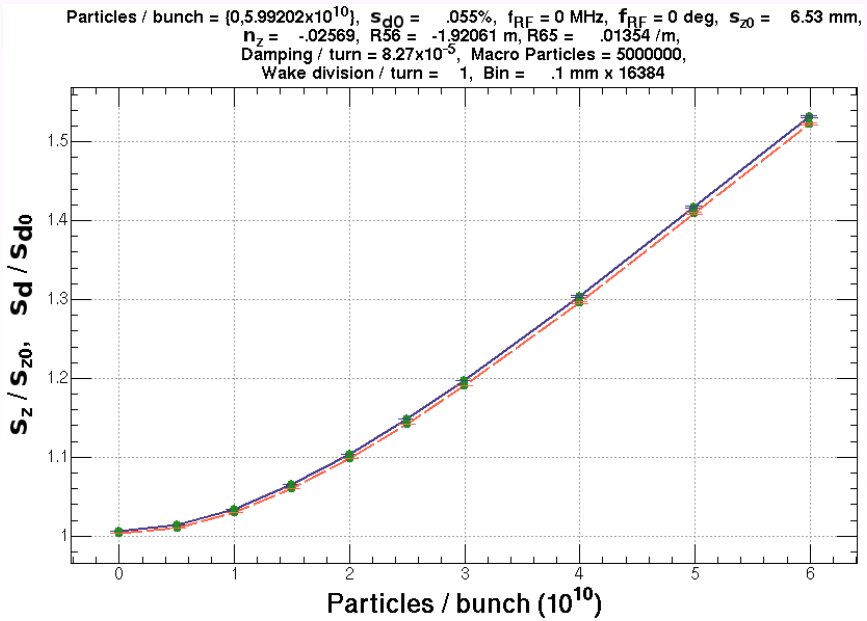


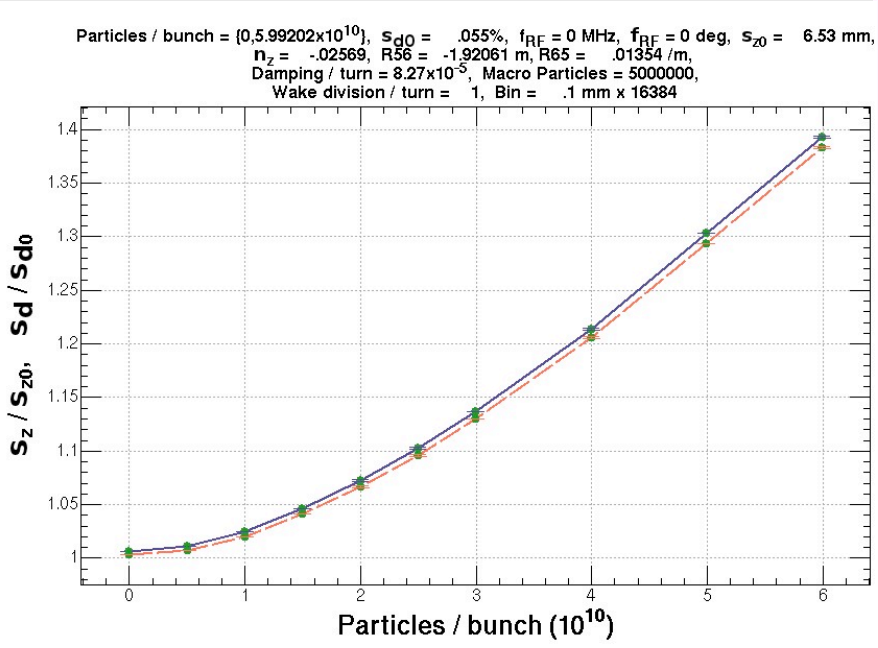


Calculation of CSR and Tracking :Change the mesh size

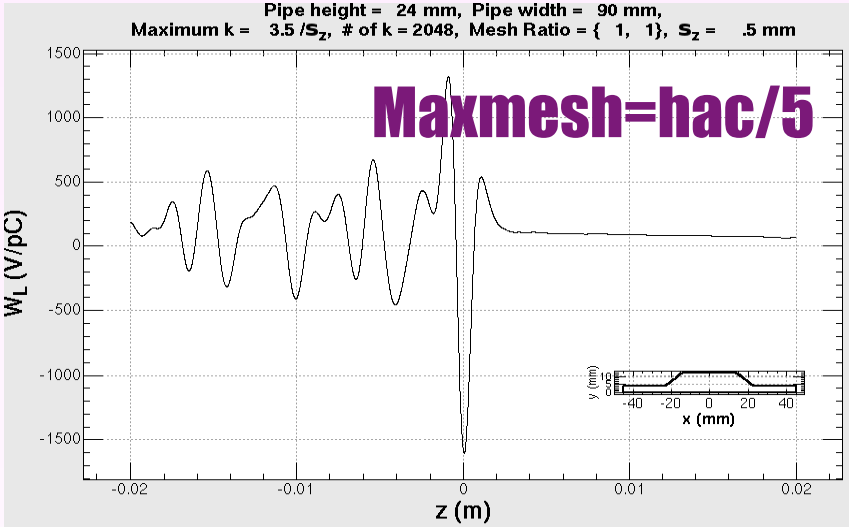


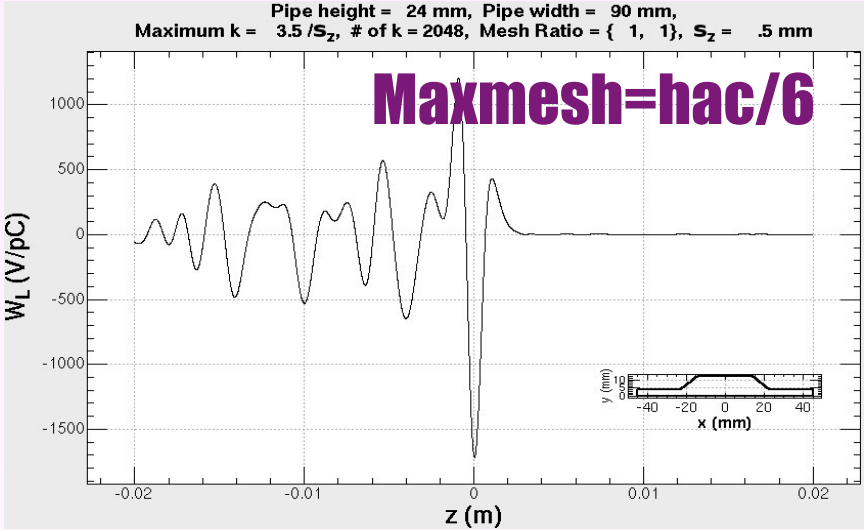


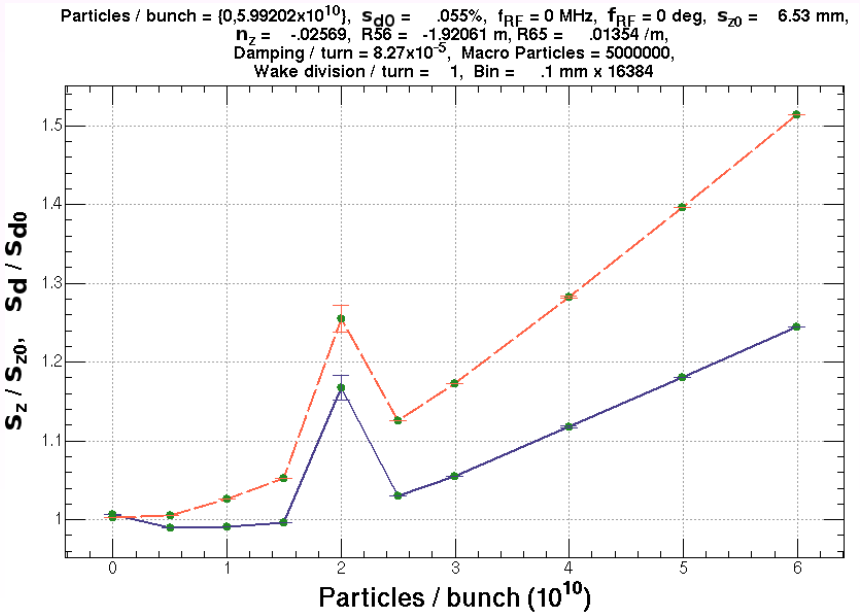


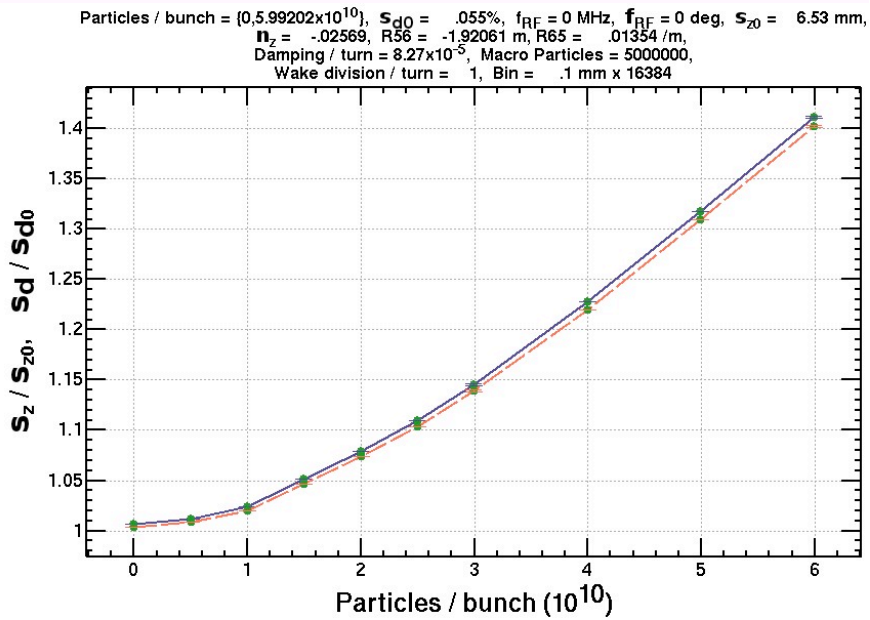


Calculation of CSR and Tracking :Change the mesh size

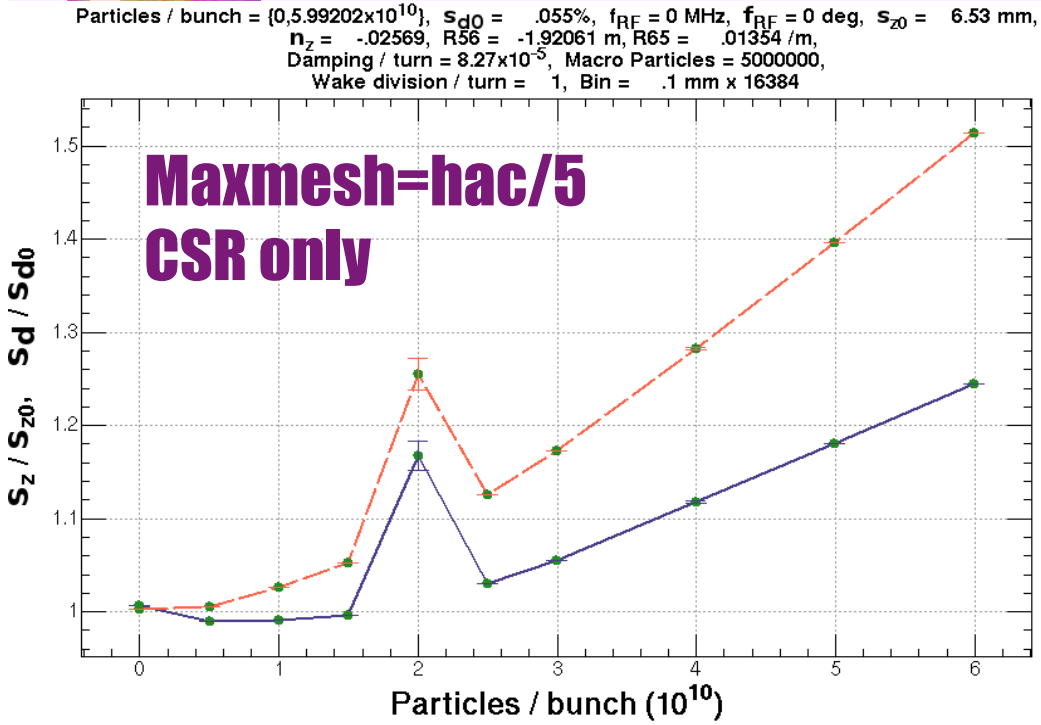


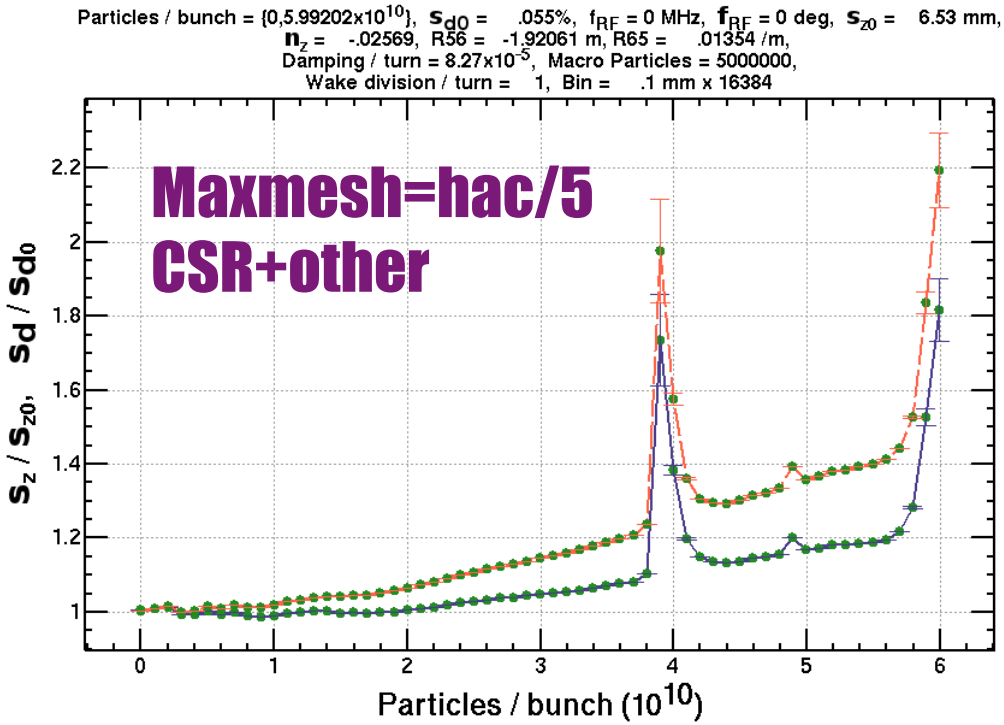






Calculation of CSR and Tracking :Add other components wake

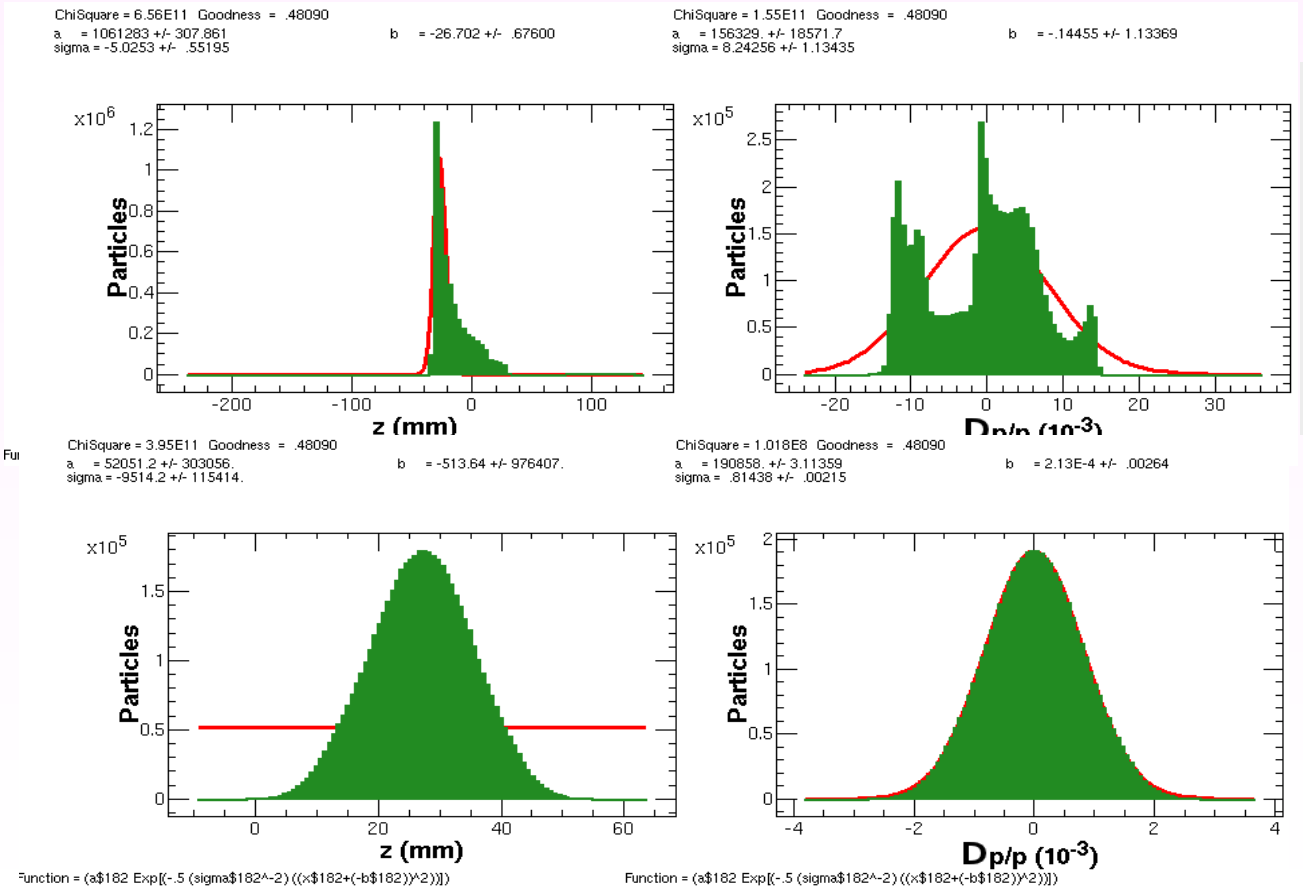


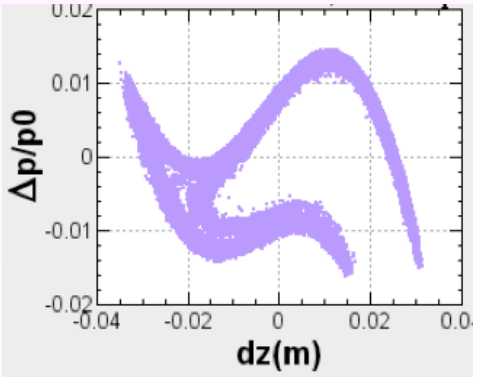


In the case of the wake potentials by other vacuum components are added, the peak position is changed.

Calculation of CSR and Tracking :Linac beam

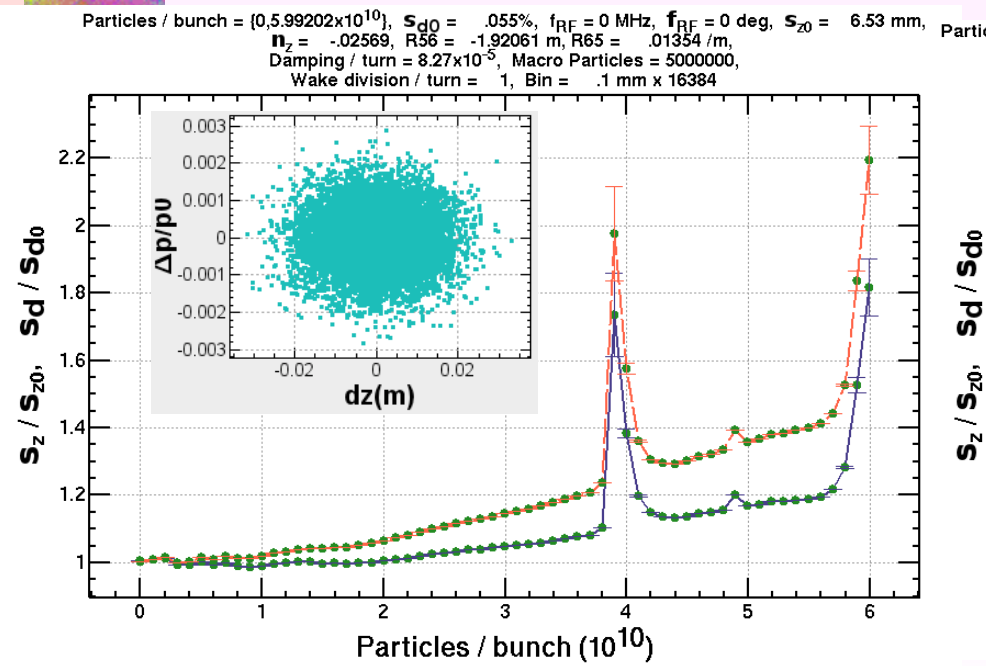
. We also checked the tracking result by using the beam from linac before damping instead of damped Gaussian beam.

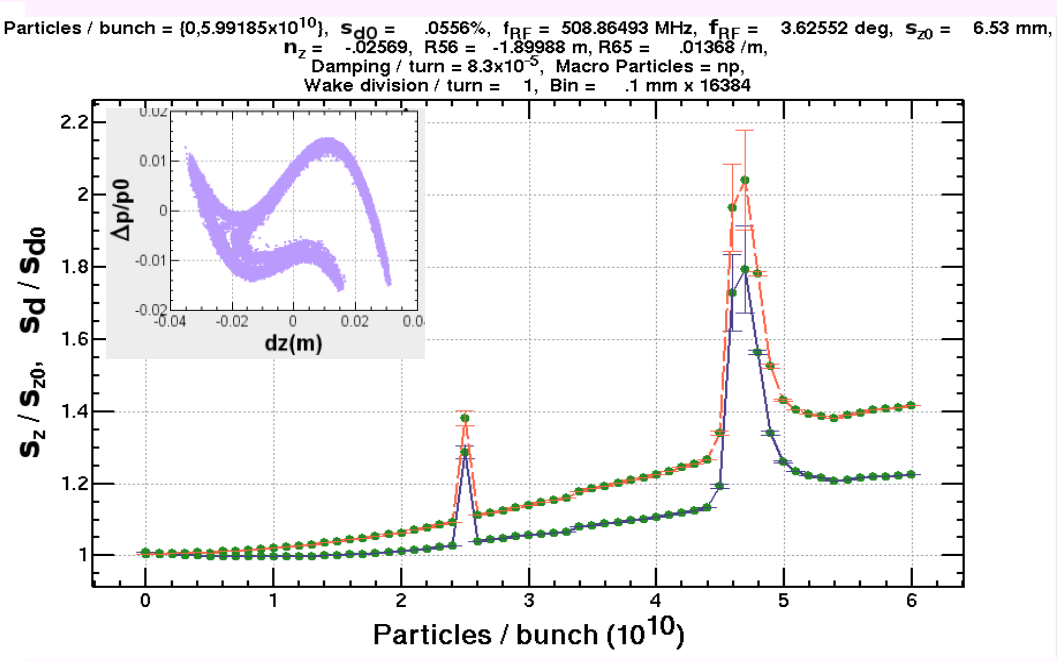




(Kamitani, N.Iida

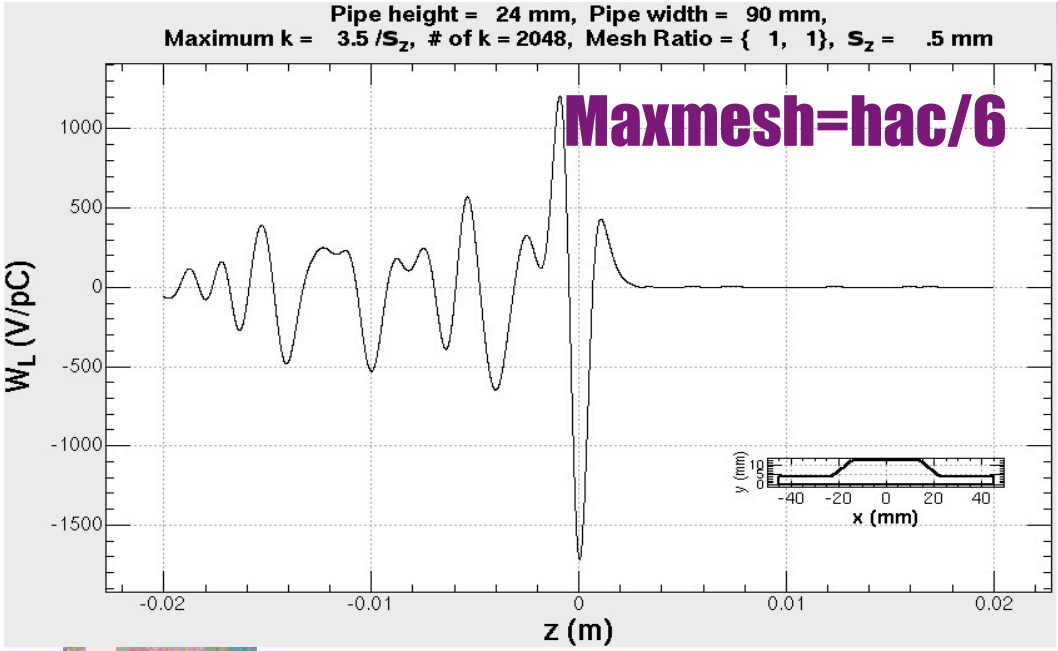
Calculation of CSR and Tracking :Gaussian and Linac beam

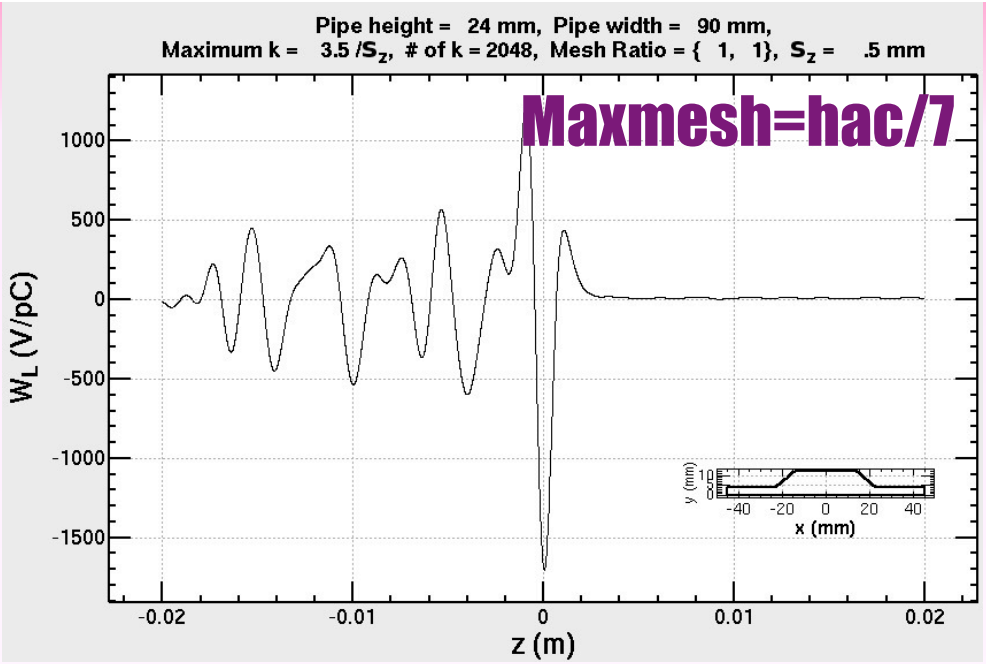


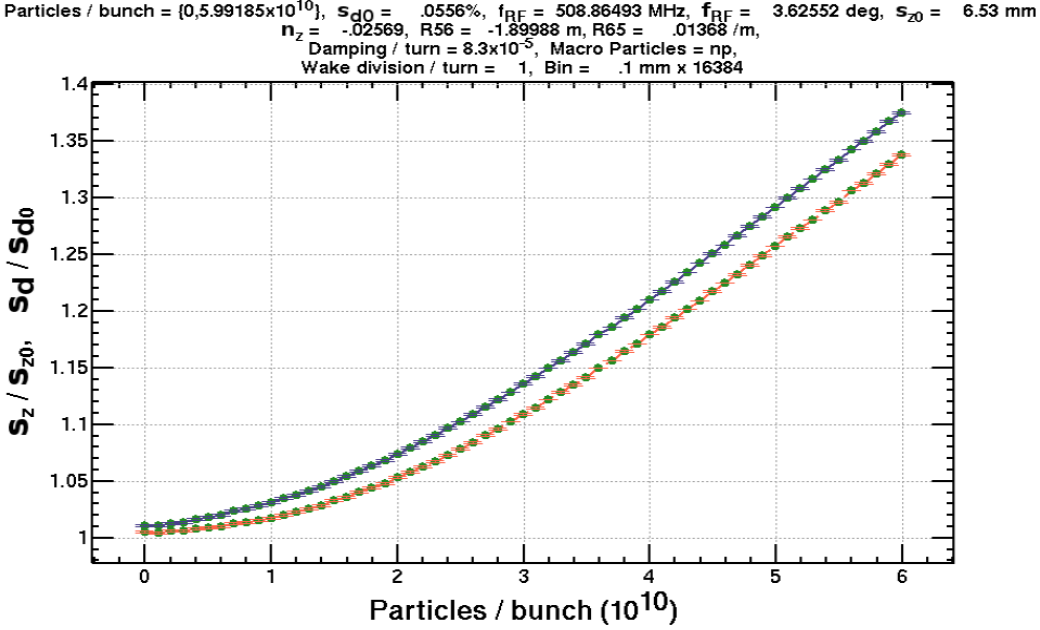


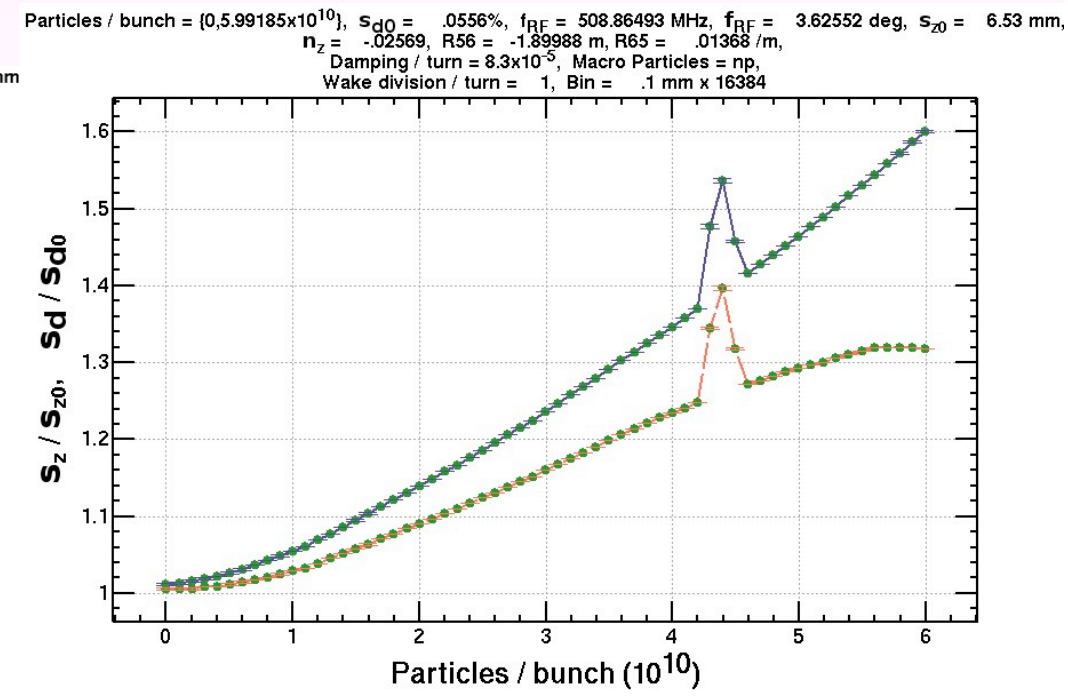
Maxmesh=hac/5

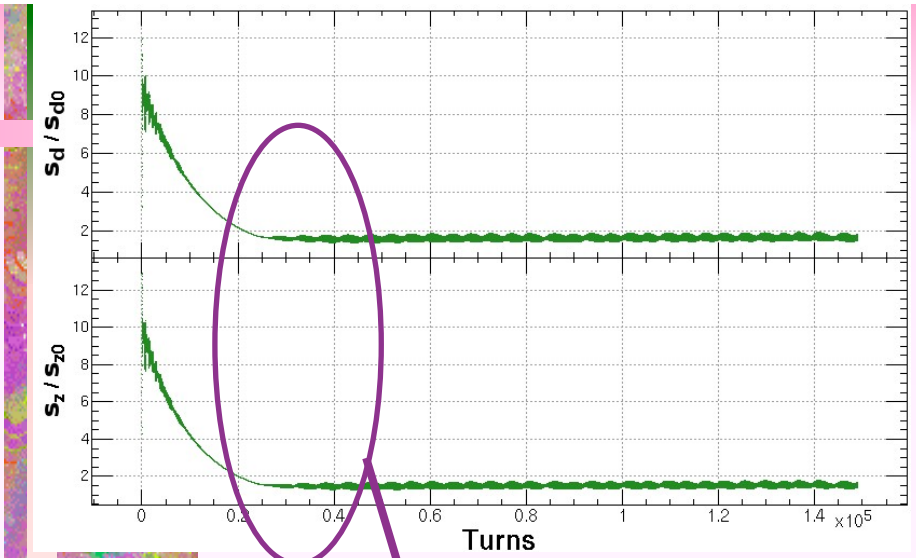
The beam from linac damps to somewhat different state compared to the case starting from the damped beam.

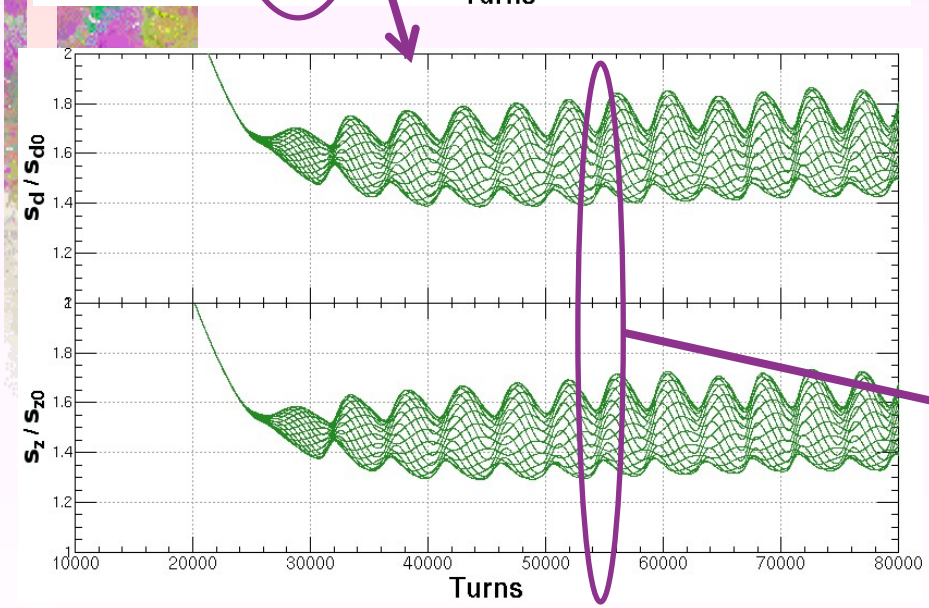

Pipe height = 24 mm, Pipe width = 90 mm,
Maximum k = 3.5 /S_z, # of k = 2048, Mesh Ratio = { 1, 1}, S_z = .5 mm
Maxmesh=hac/6
W_L (V/pC)
z (m)
y (mm)
x (mm)

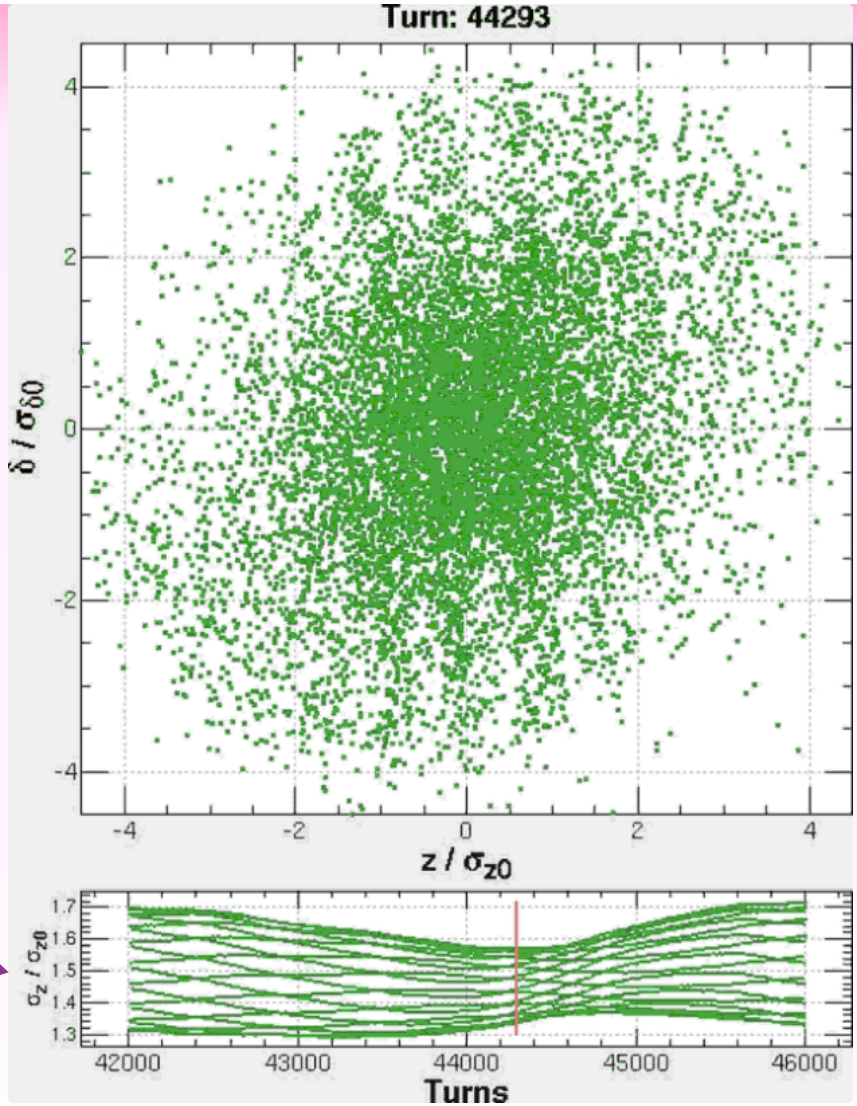

Pipe height = 24 mm, Pipe width = 90 mm,
Maximum k = 3.5 /S_z, # of k = 2048, Mesh Ratio = { 1, 1}, S_z = .5 mm
Maxmesh=hac/7
W_L (V/pC)
z (m)
y (mm)
x (mm)


Particles / bunch = {0,5.99185x10^{10}}, S_{d0} = .0556%, f_{RF} = 508.86493 MHz, f_{RF} = 3.62552 deg, S_{z0} = 6.53 mm
n_z = -.02569, R56 = -1.89988 m, R65 = .01368 /m,
Damping / turn = 8.3x10^{-5}, Macro Particles = np,
Wake division / turn = 1, Bin = .1 mm x 16384
S_z / S_{z0}, S_d / S_{d0}
Particles / bunch (10^{10})


Particles / bunch = {0,5.99185x10^{10}}, S_{d0} = .0556%, f_{RF} = 508.86493 MHz, f_{RF} = 3.62552 deg, S_{z0} = 6.53 mm,
n_z = -.02569, R56 = -1.89988 m, R65 = .01368 /m,
Damping / turn = 8.3x10^{-5}, Macro Particles = np,
Wake division / turn = 1, Bin = .1 mm x 16384
S_z / S_{z0}, S_d / S_{d0}
Particles / bunch (10^{10})







An instability with high frequency mode causes the oscillation of bunch length and energy spread. The emittance fluctuates greatly at the same time. The cycle of emittance change is 10 times of the synchrotron oscillation. This is thought a sort of saw tooth instability.

Summary

- We calculated the longitudinal microwave instability effect for SuperKEKB DR.
- The longitudinal wake is dominated by the CSR wake field and the effect is tolerance level except some peak of energy spread and bunch length.
- The hexangular antechamber has been proposed as beam pipe based on the calculation result.
- The mechanism of the instability at some bunch current is under consideration.
- We already started the R&D of prototype, including monitor chamber. Fabrication of chambers is scheduled in the JFY 2012.