Recent results of new mbtrack

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Supplement
Optimum condition of double RF system

$$V(\phi) = V_{fc}\left\{\cos(\phi+\phi_{fc}) + k\cos(m\phi+\phi_{hc})\right\}$$

$$V(0) = U_{Loss}/e$$

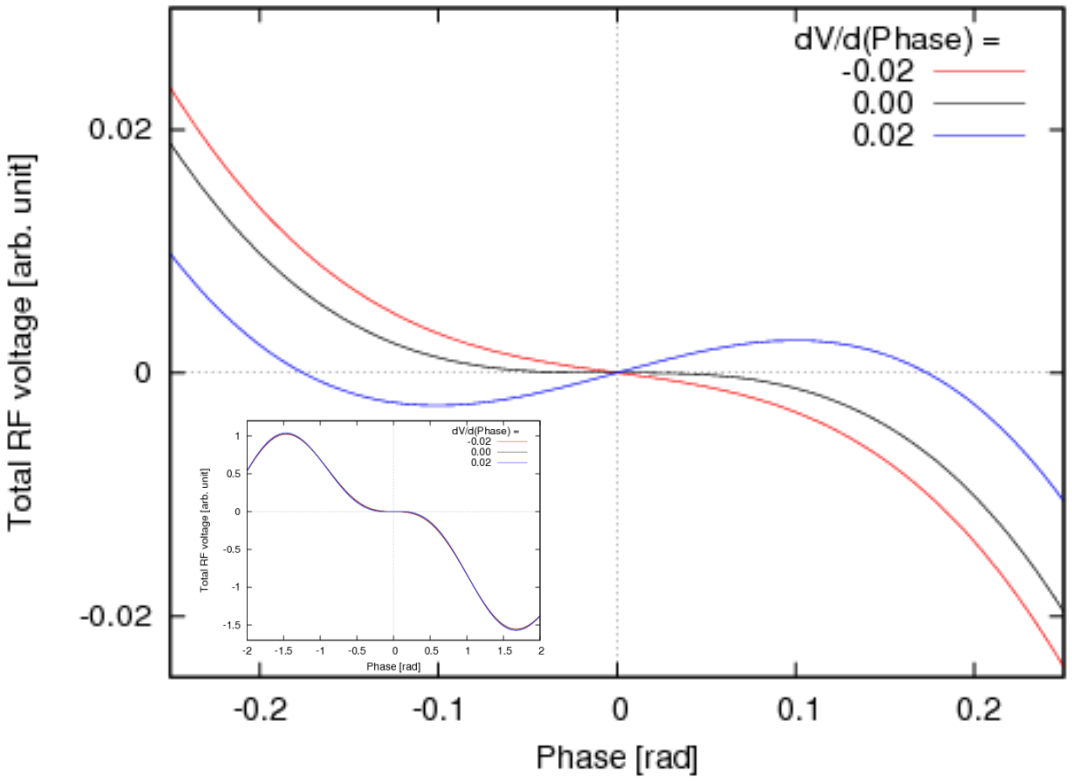
$$V'|_0 = \alpha, V''|_0 = 0$$

$$\cos\phi_{fc} = \frac{m^2}{m^2-1}\frac{U_{Loss}}{eV_{fc}}$$

$$\tan\phi_{hc} = m\frac{\alpha/eV_{fc} + \sin\phi_{fc}}{\cos\phi_{fc}}$$

$$k = -\frac{\cos\phi_{fc}}{m^2\cos\phi_{hc}}$$

V_{fc}: main voltage, m : harmonics
U_{loss} :radiation loss per turn
k: ratio of main and harmonic voltage
φ_{fc}:main RF phase
φ_{hc}: harmonic RF phase



Active harmonic cavity (ESRF)

Principal parameters of ESRF-EBS

RF freqency	f_{rf}	(MHz)	352,370
Harmonics number	h		992
Revolutoin frequency	f_{rev}	(MHz)	0,355
Main rf voltage	V_c	(MV)	6,6
Radiation loss per turn	U_o	(MeV/turn)	3,200

Parameters of Harmonic cavity

Shunt Impedance [MΩ]	Ra	5,8
Quality factor	Qo	20000
R/Q [Ohm], $R=Vc^2/Pc$	R/Q	290

*R/Q seems higher.

Tracking parameters for Harmonic cavities at stored currents of 200mA

Harmonic cavity voltage	k	0,286	0,286	0,286	0,286
Main cavity phase (cosine)	ϕ_s	56,9	56,9	56,9	56,9
Harmonic cavity phase (cosine)	ϕ_n	-102,24	-102,24	-102,24	-102,24
Number of harmonic cavities	Nhc	5	5	5	5
Cavity coupling factor	βhc	0,3483	1,000000	2,000000	5,000000
Total dissipation [kW]	Pc,hc	122,759	122,759	122,759	122,759
Beam loading power [kW]	Pb,hc	-80,0	-80,0	-80,0	-80,0
Total reflection power [kW]	Pr,hc	0,00	13,03	41,86	132,81
Total generator power [kW]	Pg,hc	42,8	55,8	84,6	175,6
Detuning frequency [kHz]	δfhc	75,103	75,103	75,1	112,7
K-value, fs≈√(K)	K	1,49	0,68	-0,42	-2,16

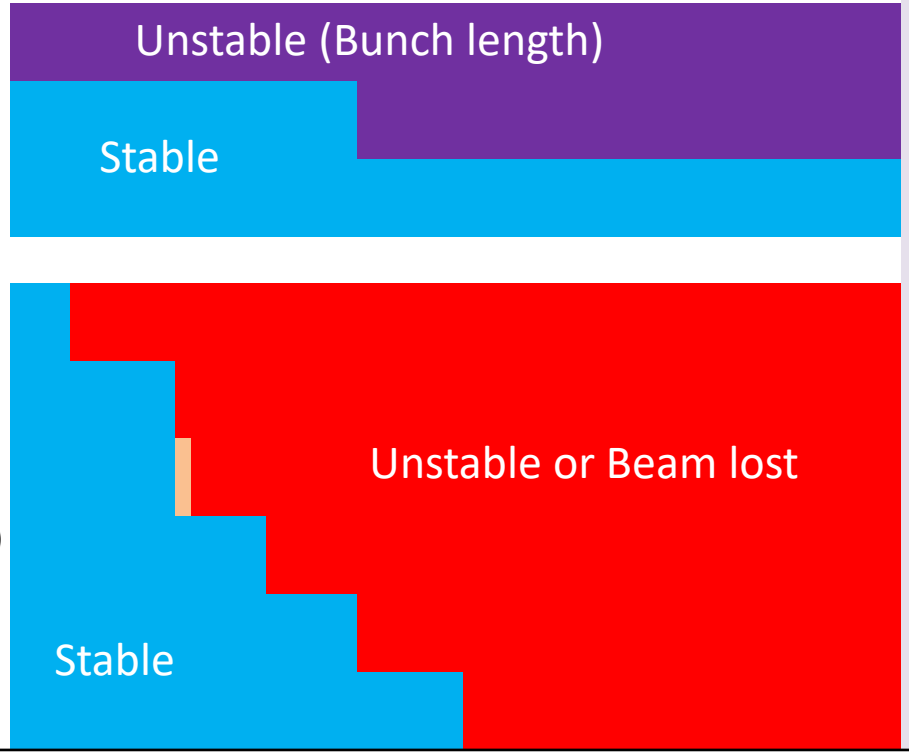
Optimum coupling

Active harmonic cavity (ESRF)

Filling : Uniform,7/8 fill Damping time: * ms
Stored current : 200mA
With Harmonic cavity

$$V(\phi) = V_{fc}\left\{\cos(\phi + \phi_{fc}) + k\cos(m\phi + \phi_{hc})\right\}$$
$$V(0) = U_{Loss} / e$$
$$V'|_0 = \alpha, V''|_0 = 0$$

Summary of the calculation results



Comment	Stable or not at each damping time	K*	CBI Growth time** [ms]		
			l=0 real	l=1 real	l=1 imag
Optimum (flat potential), uniform fill	Unstable (Bunch length)	1,50	-8,58	24,75	0,82
slope -0.01, uniform fill	Stable	1,80		24,57	0,82
slope -0.02, uniform fill	Stable	2,07		25,04	0,81
Coupling Beta = 5, 7/8 fill	Unstable or Beam lost	-2,16	-6,60	4,97	0,95
Coupling Beta = 2, 7/8 fill	Unstable or Beam lost	-0,42	-7,82	11,98	0,85
Coupling Beta = 1, 7/8 fill	Unstable or Beam lost	0,69	-8,57	16,96	0,83
Optimum tuning, (not flat) 7/8 fill	Unstable or Beam lost	1,50	-8,58	24,75	0,82
Coupling Beta = 0.1, 7/8 fill	Stable	1,67	-8,46	27,79	0,82
Coupling Beta = 0.2, 7/8 fill	Stable	1,78	-8,34	30,34	0,82

*f_s = sqrt(K) **Assuming with $\Omega_s \approx \omega_s$

Active harmonic cavity (ESRF)

Filling : Uniform,7/8 fill Damping time: * ms
Stored current : 200mA
With Harmonic cavity

$$V(\phi) = V_{fc}\left\{\cos(\phi + \phi_{fc}) + k\cos(m\phi + \phi_{hc})\right\}$$
$$V(0) = U_{Loss} / e$$
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Comment	Stable or not at each damping time (0,1 0,5 1,0 1,5 2,0 3,0 4.0 8,6ms)	K*	CBI Growth time** [ms]		
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Coupling Beta = 0.2, 7/8 fill	Stable	1,78	-8,34	30,34	0,82

Two different source of the instabilities?

1.(violet) RF flat potential (disappearance of focusing force)

2.(red) Harmonic Cavity(high-Q) impedances

Active harmonic cavity (ESRF)

Stored current : 200mA

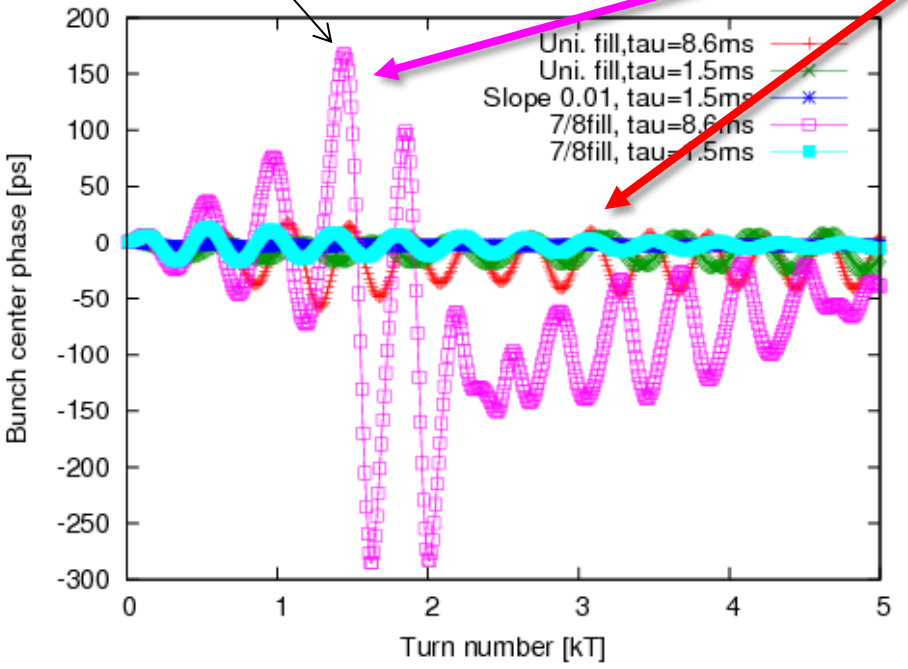
Summary of the calculation results

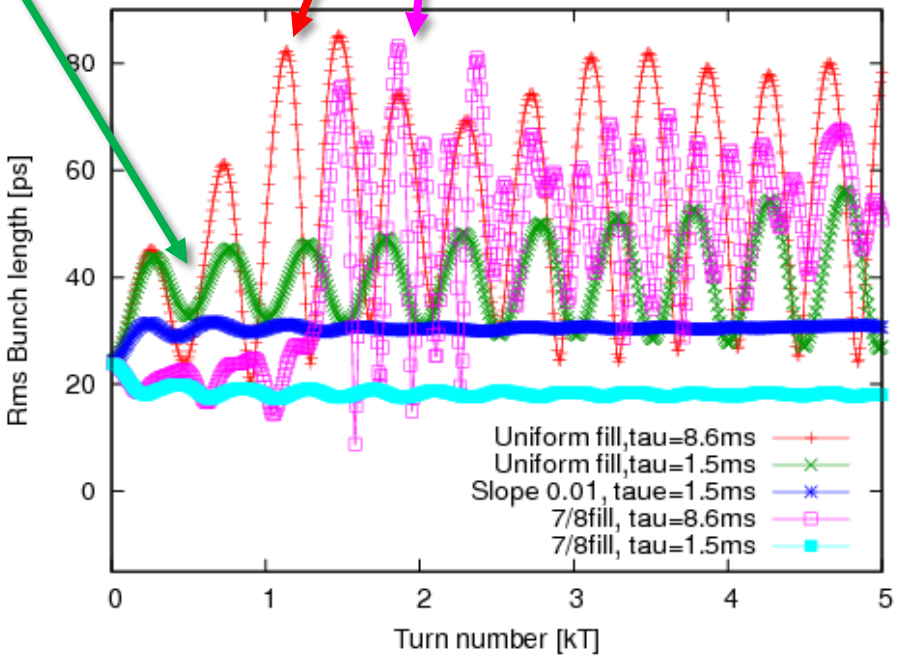
Comment	Stable or not at each damping time
	0,1 0,5 1,0 1,5 2,0 3,0 4.0 8,6ms
Optimum (flat potential), uniform fill	
slope -0.01, uniform fill	
slope -0.02, uniform fill	
Optimum tuning, (not flat) 7/8 fill	
Coupling Beta = 0.1, 7/8 fill	
Coupling Beta = 0.2, 7/8 fill	

Unstable bunch shape (bunch length)

Beam unstable (coherent motion)

Beam lost here





Active harmonic cavity (ESRF)

Stored current : 200mA

Summary of the calculation results

Comment	Stable or not at each damping time
	0,1 0,5 1,0 1,5 2,0 3,0 4.0 **8,6ms**
Optimum (flat potential), uniform fill	
slope -0.01, uniform fill	
slope -0.02, uniform fill	
Optimum tuning, (not flat) 7/8 fill	
Coupling Beta = 0.1, 7/8 fill	
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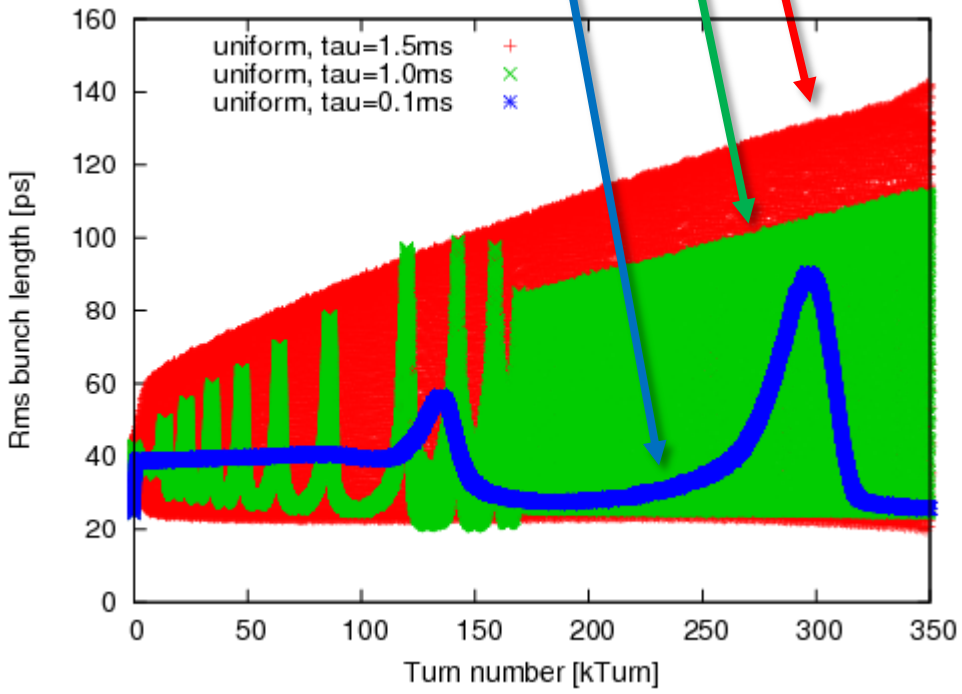

Typical tracking results
for the flat-potential induced instabilities
(unstable bunch shape)

Before the continuous unstable motion
(in case of Growth rate ≈ Damping rate),
Bunch length values are oscillated.

It looks like quadrupole mode.

Active harmonic cavity (ESRF)

Stored current : 200mA

Summary of the calculation results

Comment	Stable or not at each damping time
	0,1 0,5 1,0 1,5 2,0 3,0 4.0 8,6ms
Optimum (flat potential), uniform fill	
slope -0.01, uniform fill	
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Optimum tuning, (not flat) 7/8 fill	
Coupling Beta = 0.1, 7/8 fill	
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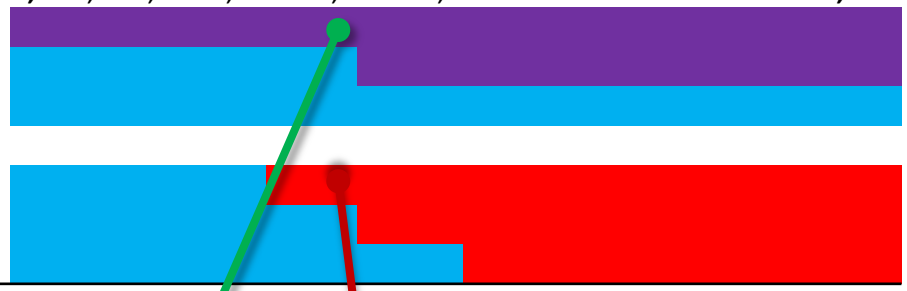
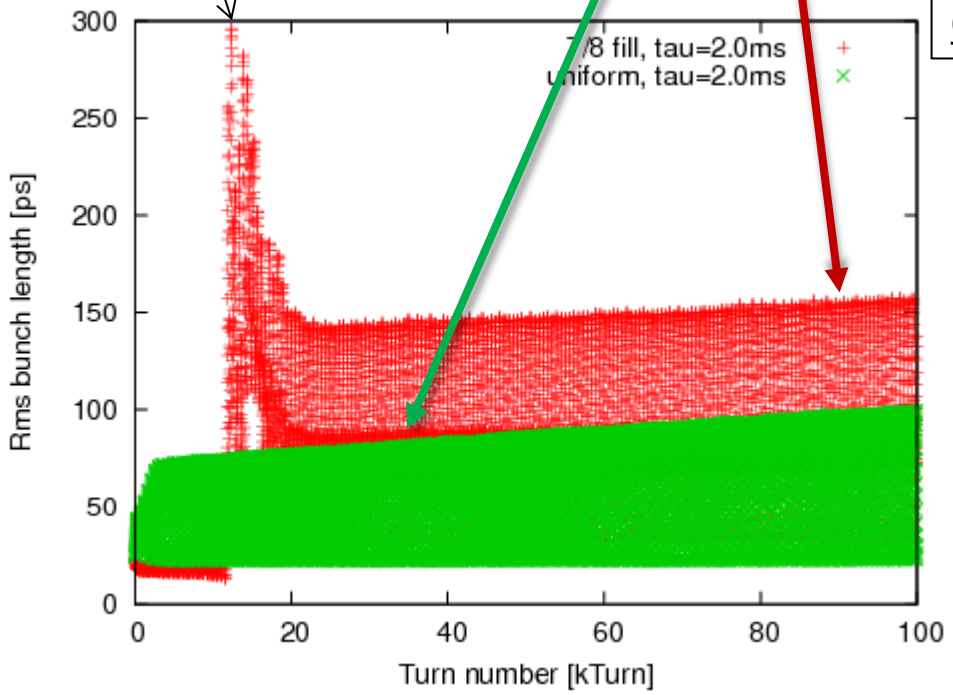
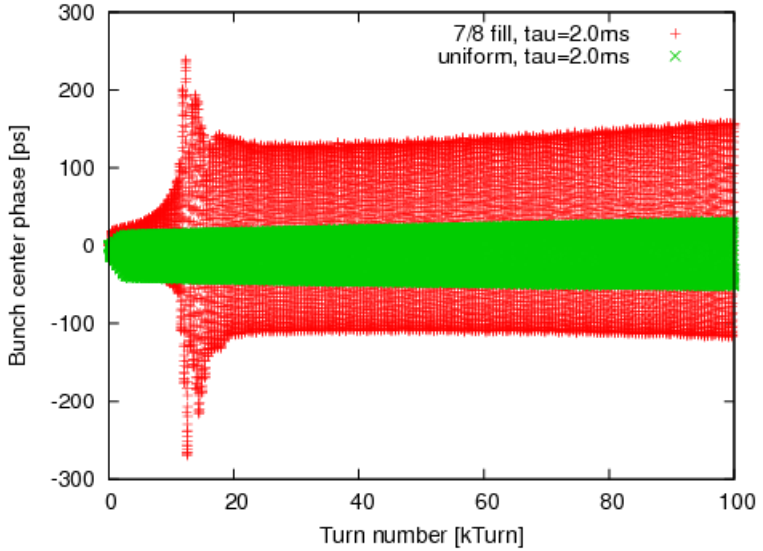


Beam lost here



Comparison of two different instabilities



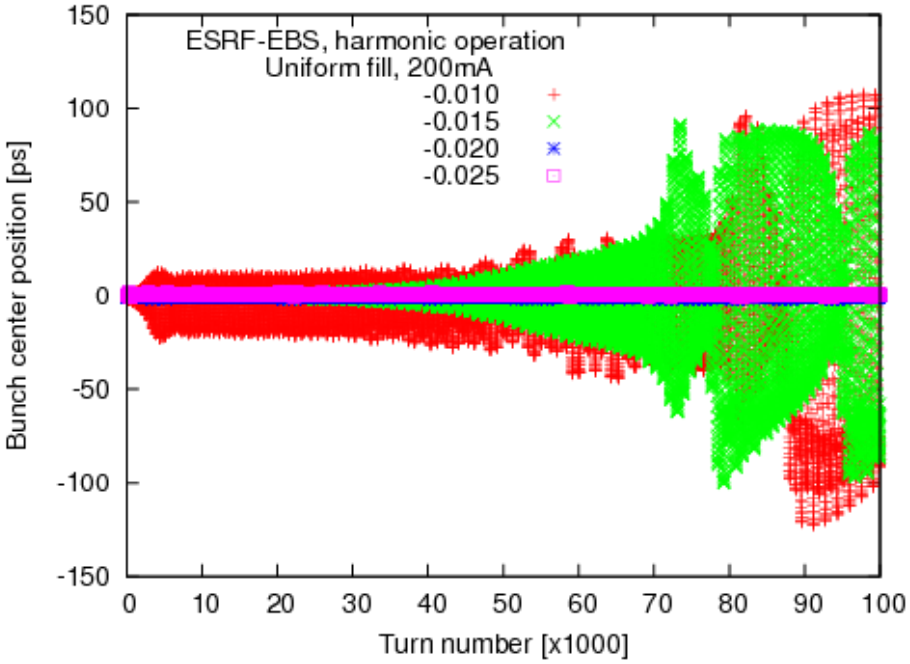
1.Instability in flat potential condition (ESRF, uniform)

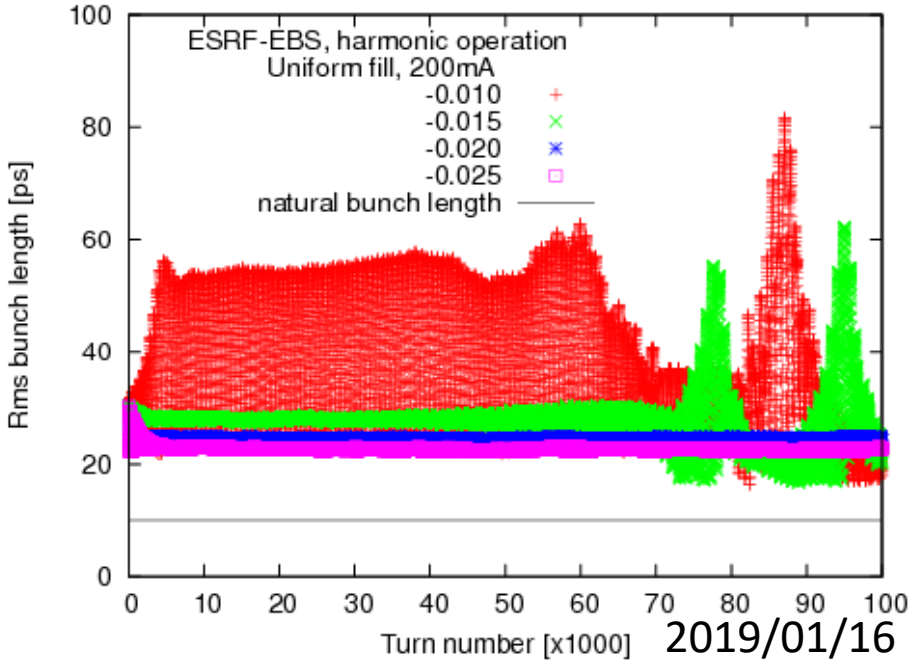
Comment	Stable or not at each damping time
	0,1 0,5 1,0 1,5 2,0 3,0 4.0 8,6ms
Optimum (flat pot.), uni. Fill	
slope -0.01, uni. Fill	
slope -0.02, uni. fill	

$$V(\phi) = V_{fc}\left\{\cos(\phi+\phi_{fc}) + k\cos(m\phi+\phi_{hc})\right\}$$
$$V(0) = U_{Loss}/e$$
$$V'|_0 = \alpha, V''|_0 = 0$$

- In the flat potential conditions, the beam shape is fluctuated(Red).
- Adding residual slopes to the rf potential, the beam becomes stable (Blue and Magenta).

Filling : Uniform Damping time: 8.6 ms
Stored current : 200mA





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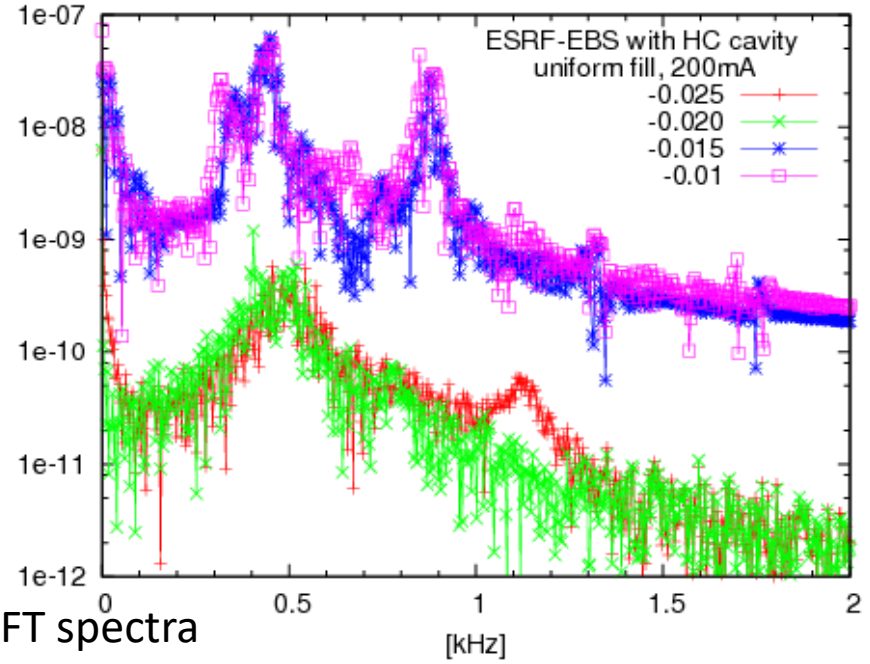
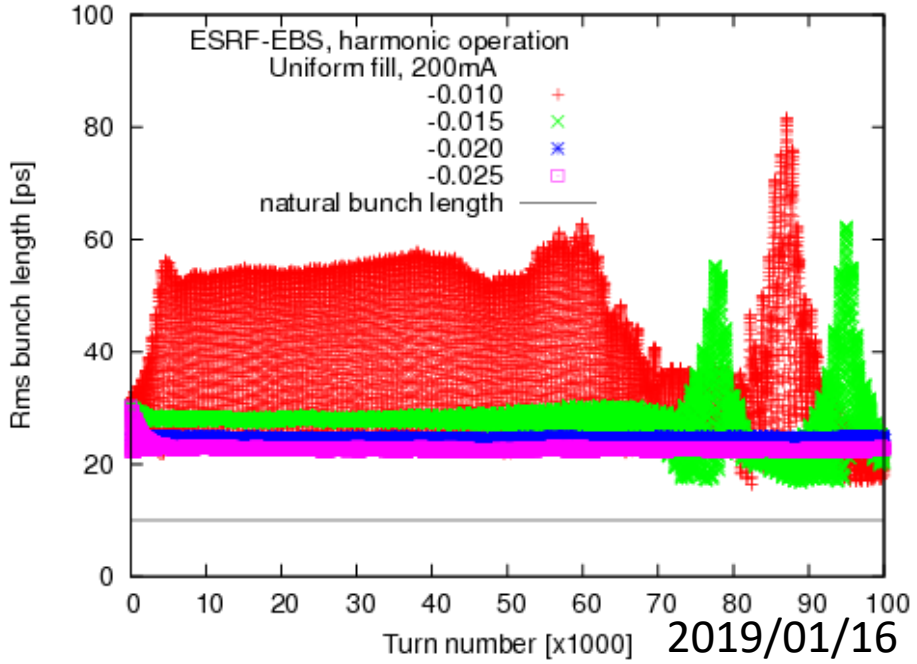
Stored current : 200mA



FFT spectra



2019/01/16

2. Instability due to cavity impedances cavity(?) (ESRF)

Summary of the calculation results

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What is the source of these instabilities?

a) Robinson instability?

$f_s \sim f_{rf}$ x sqrt [α **K'**], (K'<0 $\Leftrightarrow$ DC Robinson instability)

K' = $V_c \sin\phi_s + V_b \sin\psi + 3\,V_{c,3} \sin\phi_{s,3} + 3V_{b,3} \sin\psi$ (cosine-definition for ϕ_s & $\phi_{s,3}$)

b) l=1 mode instabilities (Venturini's paper)

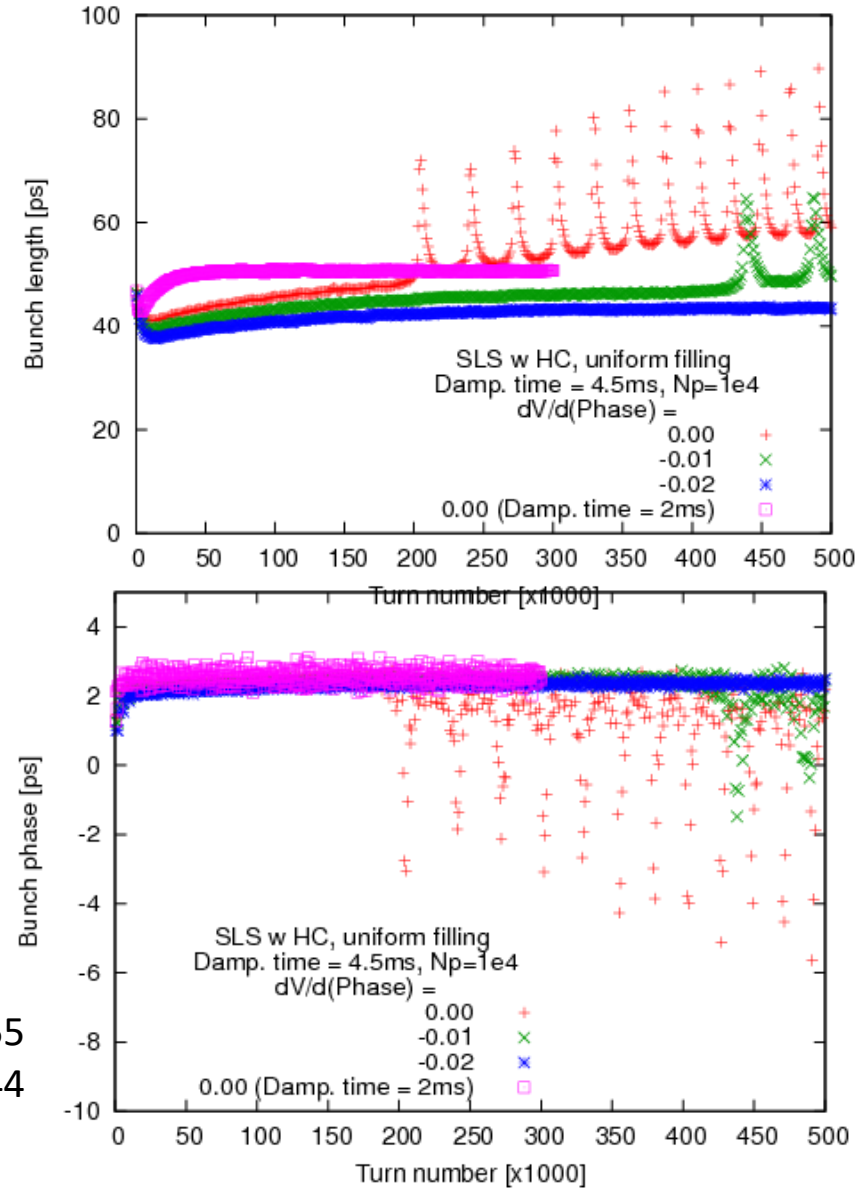
Passive harmonic cavity (SLS, uniform)

SLS parameter, Io = 320 mA
Damping time = 4,5 ms

Bunch length (Anal.) :
50,9 ps (x3,74)

[cavity_resonator_1]
m = 1.0
Rs = 13.6e6
Qzero = 40000.0
Qload = 9302
Vc = 2.0e6
syncPhase = 1.2680686
FBmode=1
FBGain=1
ForceWR = 1

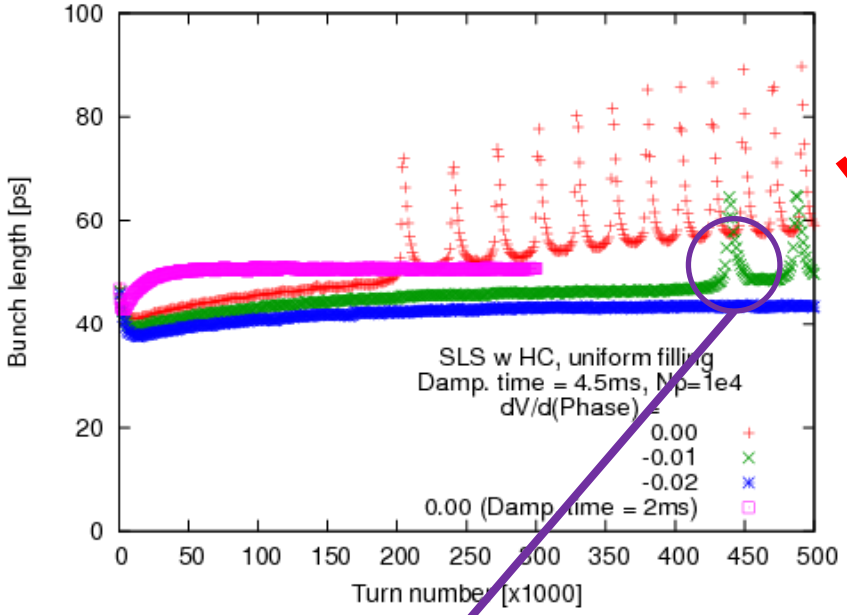
Flat potential
-> unstable beam?



[cavity_resonator_2]
m = 3.0
Rs = 1.7648e10
Qzero = 2.0e8, Qload = 109208.77
#optimum#Vc = 0.63979e6, syncPhase = -1.67453179
# slope -1% # Vc = 0.62653041e6, syncPhase = -1.6767355
# slope -2% # Vc = 0.61327345e6, syncPhase = -1.6790344
geneVolt = 0.0
FBmode = 2, FBgain = 0.1
ForceWR = 1

2018/11/22

Passive harmonic cavity (SLS, uniform)



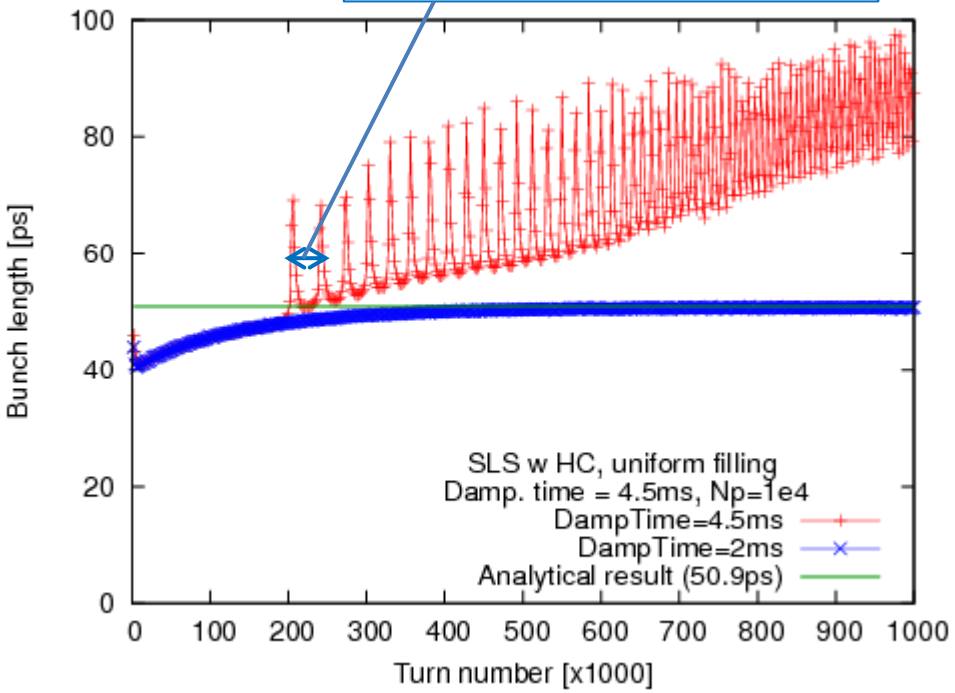
Bunch length (Anal.) : 50,9 ps (x3,74)

More turn

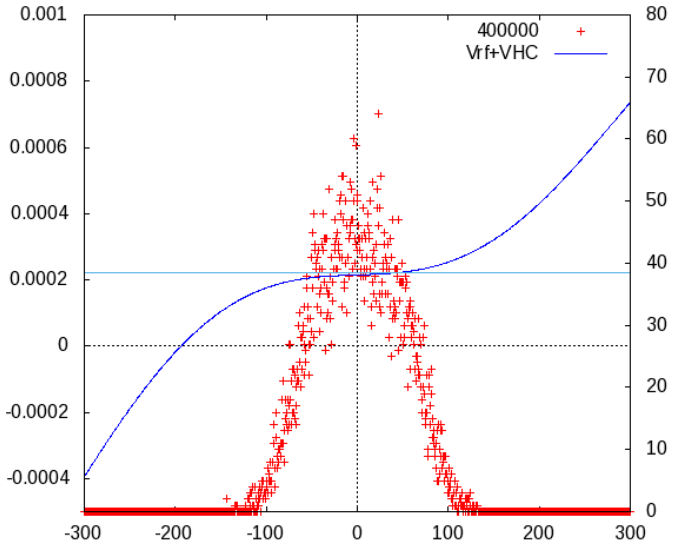
f_{s0}=6.6kHz

τ_{cav}=5.9us

36 turn (34.6us, 28.9kHz)



Bunch profiles



Quadratic mode?

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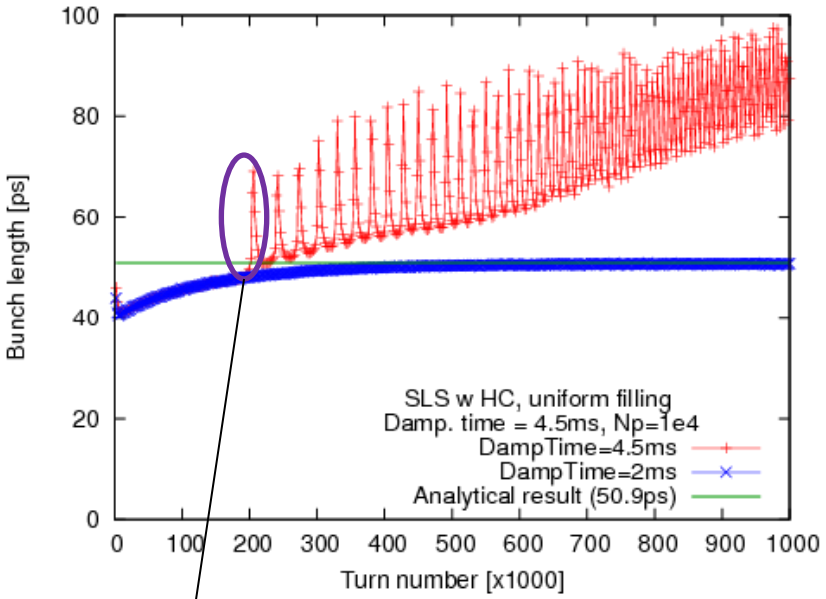
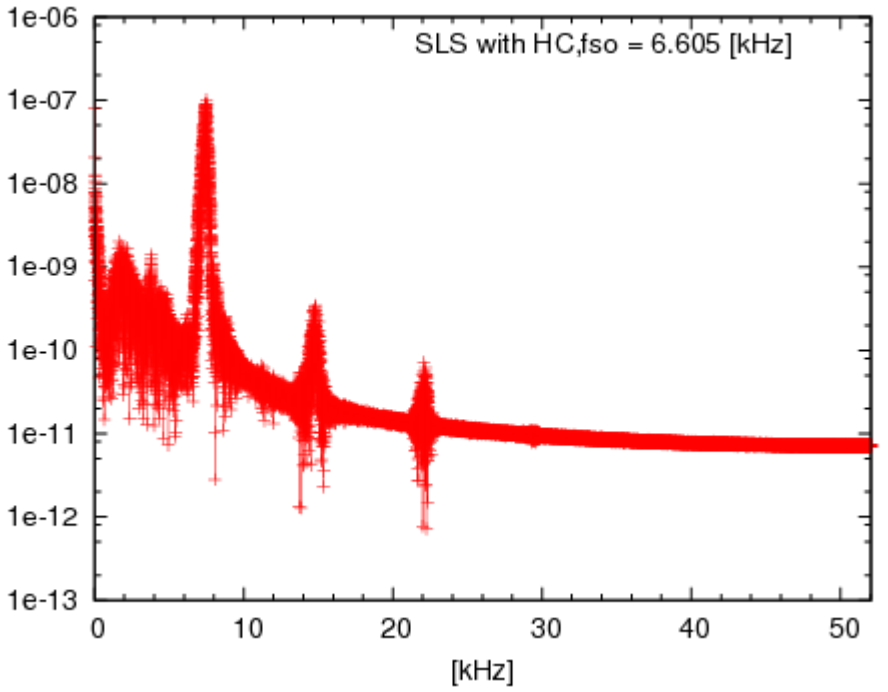
Passive harmonic cavity (SLS, uniform)



Growth rate = 38 [1/s] (26ms)
* with damp. time (4.5ms)

FFT

f_{s0}=6.6kHz
τ_{cav}=5.9us



2018/11/28