Recent observations of collective effects at KEKB

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1. Effects of electron cloud in LER

2. Transverse coupled bunch instability in HER

1. Effects of electron cloud in LER

At KEKB LER a vertical beam blowup caused by an electron cloud (e-cloud) has been observed since the beginning of the operation.

The blowup is suppressed by solenoids installed around the ring at present operation condition.

However, if the machine is operated with shorter bunch spacing, a threshold bunch current of the blowup decreases.

⇨ The blowup is still an issue of the near-future luminosity upgrade.

Two measurements were performed in the latest operation period to consider measures to suppress the e-cloud further,

A) Measurement of the blowup and the tune shift by changing the strength of solenoid field,

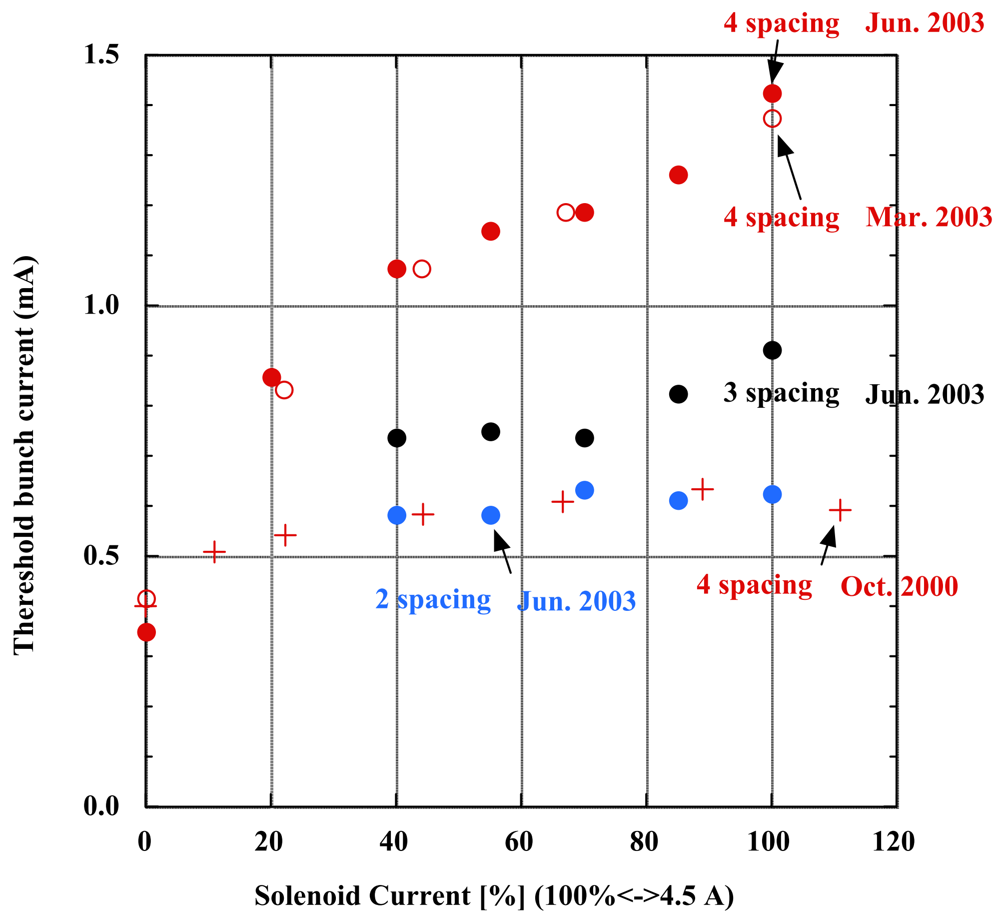
B) Measurement of the blowup and the tune shift by switching off the solenoid locally.

Furthermore we are recently trying a rather academic measurement,

C) Detecting a head-tail motion by the e-cloud by a streak camera (preliminary).

A) Field strength of solenoid vs. blowup or tune shift

a) Threshold current of the blowup



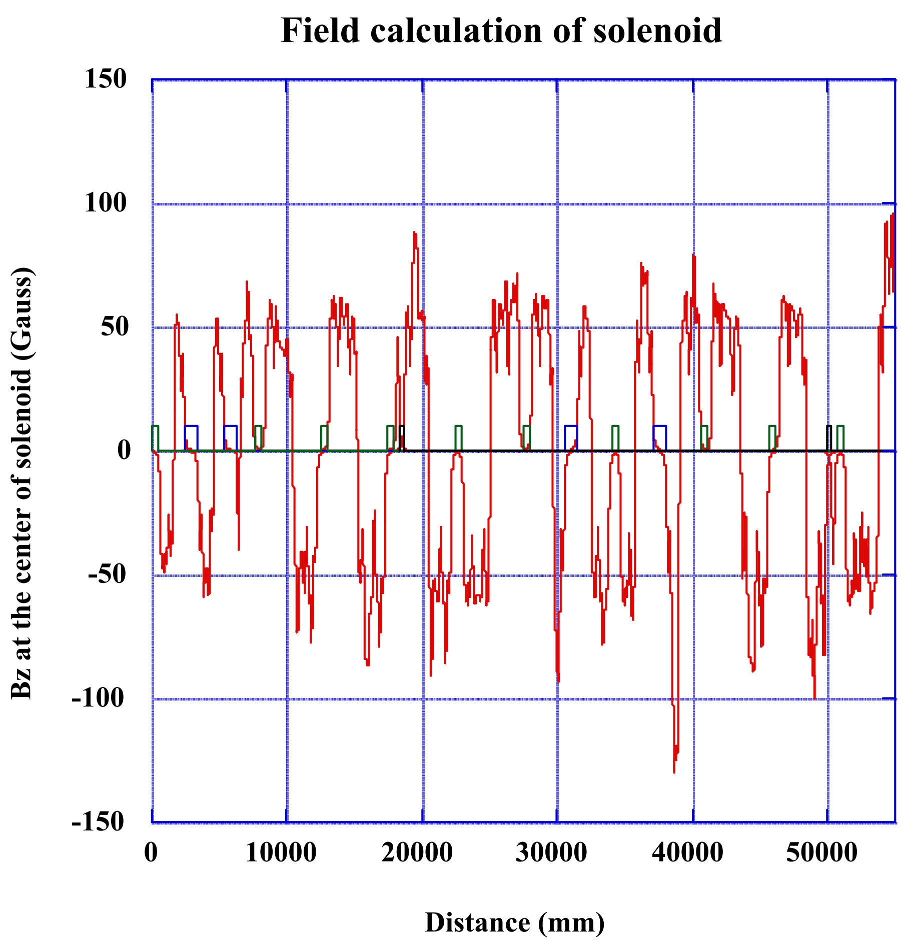
1) 3 and 4 bucket spacing : the threshold increases when the field strength increases.

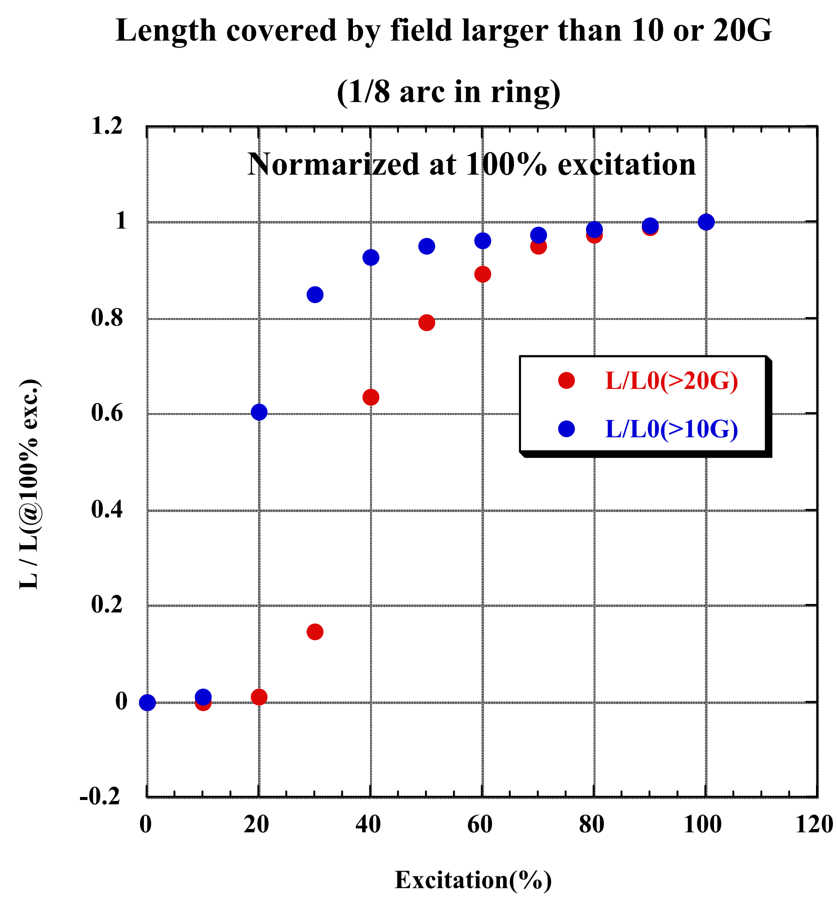
   2 spacing : the threshold saturates.

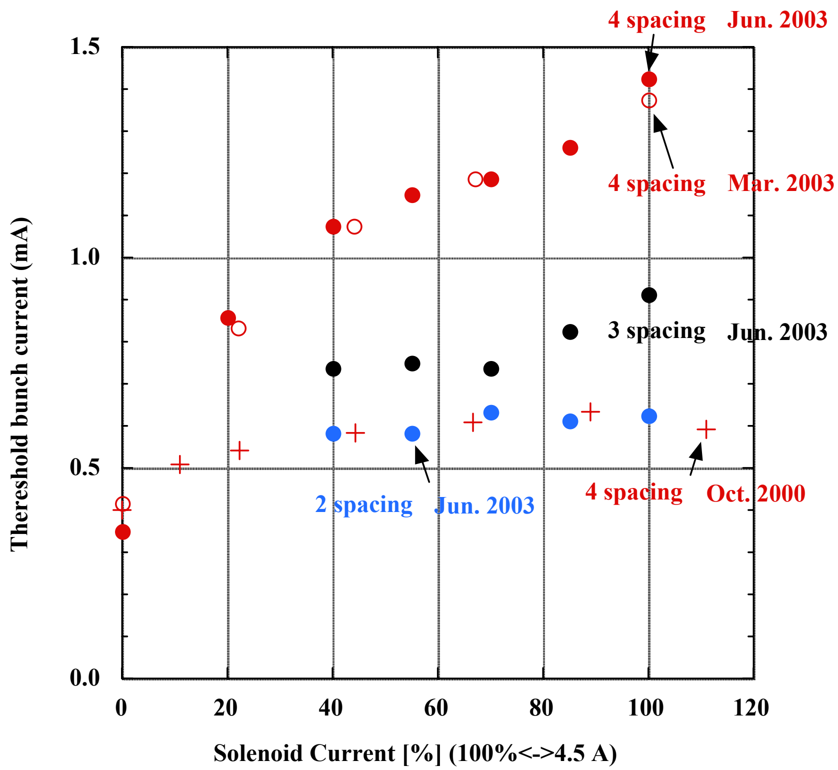
2) Assuming a present solenoid system, stronger field will be helpful in raising the threshold if bunch spacing is larger than/equal to 3 buckets.

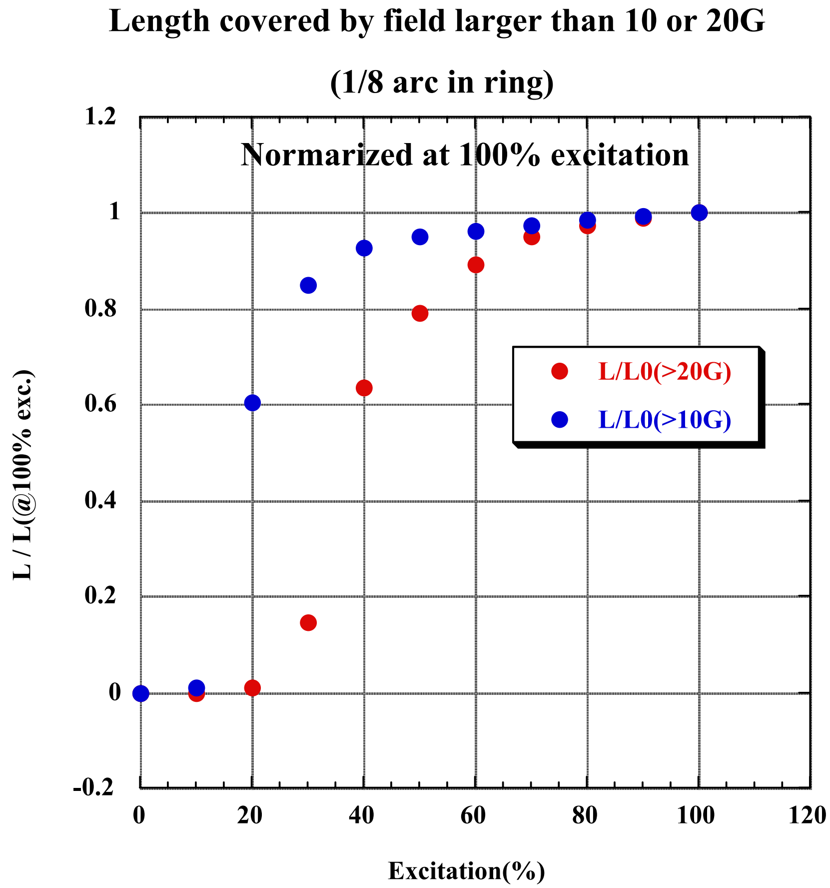
3) Why stronger field is better ?

Central field or fringe field ?









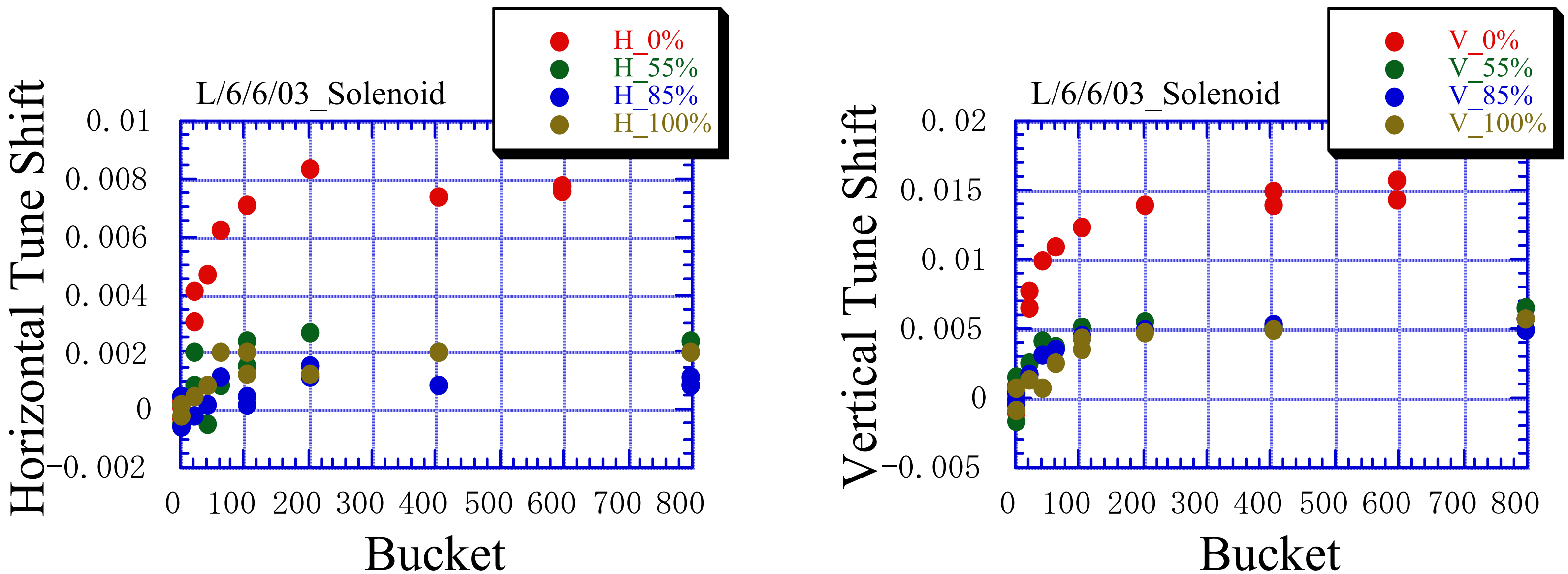
The increase of the threshold current at stronger solenoid field is not explained by the increase of fringe field in arc sections.

→ Stronger central field may be important.

b) Effect of solenoid field on the tune shift

Tune shift by e-cloud

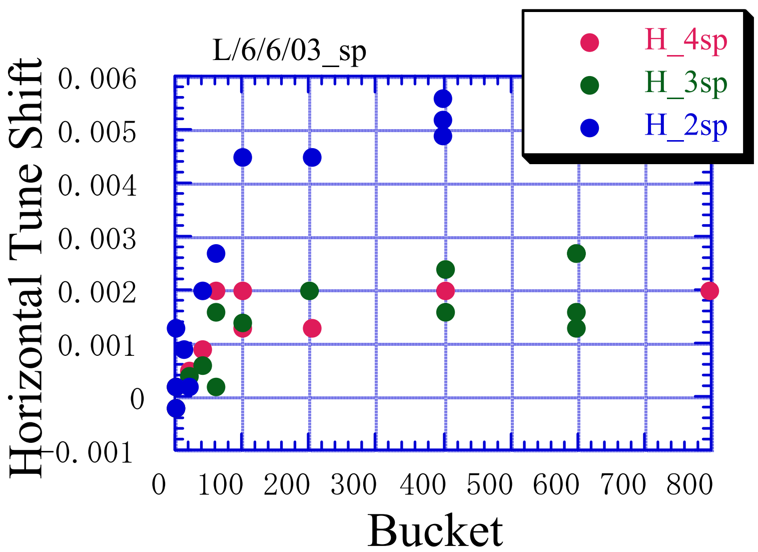
$$\Delta\nu_{x,y} = \frac{r_e}{2\gamma} \cdot \oint \rho \cdot \beta_{x,y} \cdot ds$$ K. Ohmi et al. (APAC01)

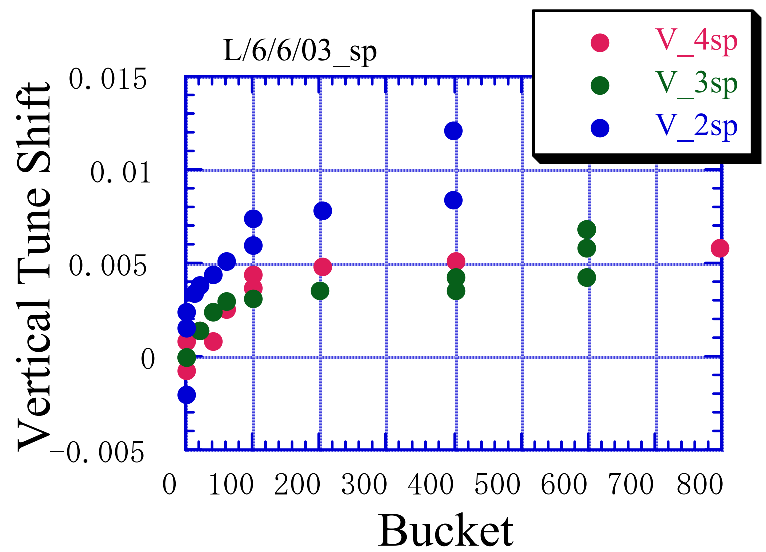


4 trains, 200 bunches/train, 4 bucket spacing, bunch current 0.58mA

50% of full excitation, i.e. about 25 G is enough to saturate the tune shift.

Bunch spacing





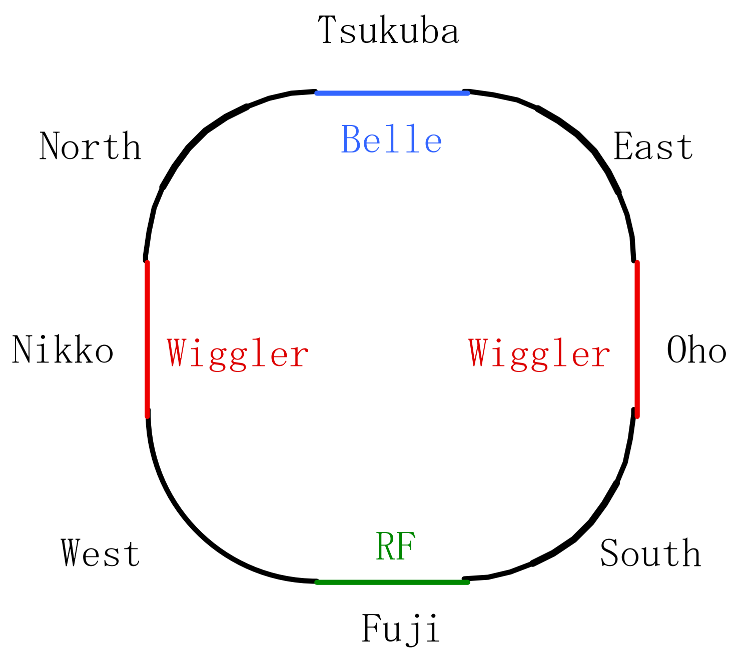
4 trains, 200 bunches/train, 2/3/4 bucket spacing, bunch current 0.5mA, with 100% solenoid

Large tune shift was observed in a fill pattern of 2 bucket spacing.

B) Location of solenoid vs. blowup or tune shift

Is there any difference in the effects of the solenoids in arc- and straight-sections ?

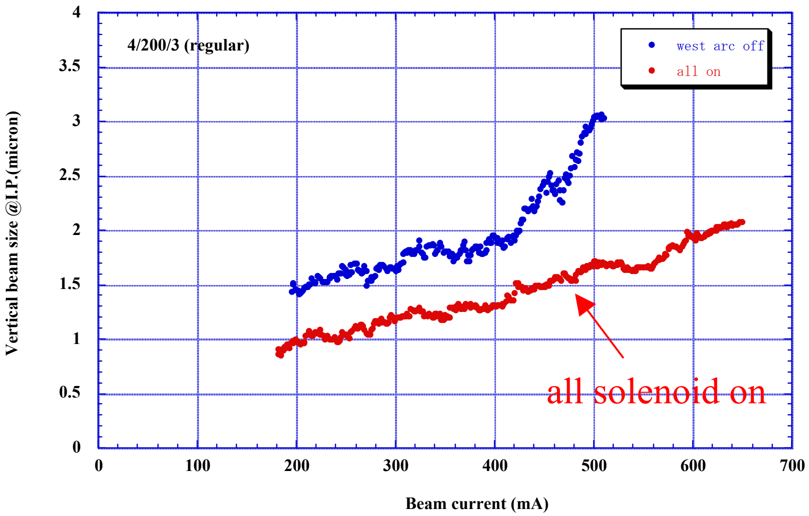
The blowup and the tune shift were measured by turning off the solenoid locally.



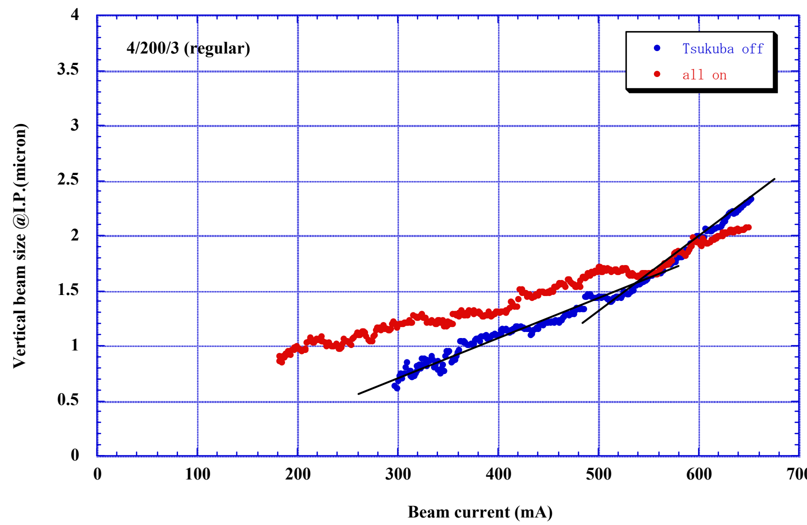
a) Blowup vs. location of e-cloud

4 trains, 200 bunches/train, 3 bucket spacing

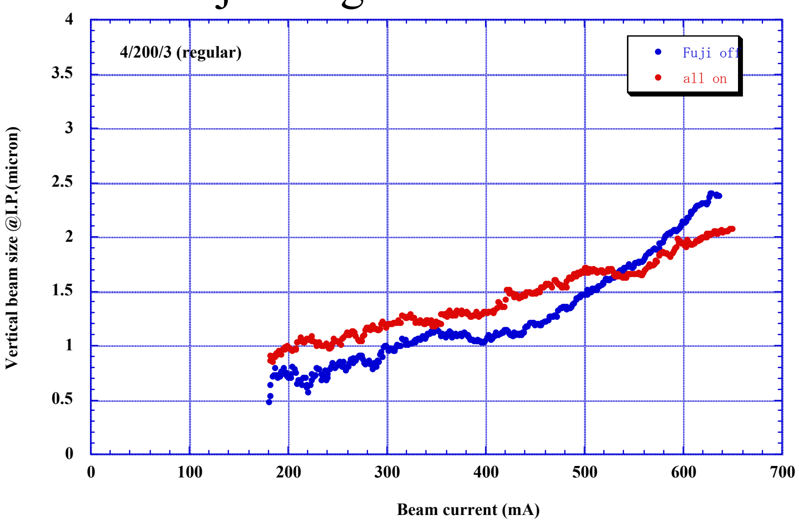
West arc off



Tsukuba straight section off



Fuji straight section off



1. The solenoids in the straight sections are effective on the blowup, even in Fuji straight section where no wiggler magnets are installed.

2. Effect of solenoids on the threshold current of the blowup

   1/4 arc > Fuji straight > Tsukuba straight

b) Tune shift vs. location of e-cloud $\Delta\nu_{x,y} = \frac{r_e}{2\gamma}\cdot\oint\rho\cdot\beta_{x,y}\cdot ds$ -- (1)

Measurement (4 trains, 200 bunches/train, 3 bucket spacing, bunch current 0.5 mA)

	Horizontal	Vertical
Arc solenoids off	0.006 (1)	0.006 (1)
Straight solenoids off	0.0035 (0.58)	0.008 (1.33)
Tsukuba straight off	0.001 (0.17)	0.003 (0.5)
All solenoids on	0.0015	0.005
Sum	0.011	0.019

Tune shifts in arc or straight sections are consistent with (1) except for the vertical tune shift in the straight sections, assuming a fixed cloud density .

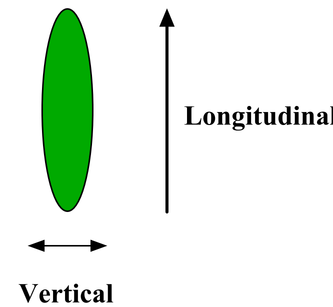
(The vertical tune shift in Tsukuba straight section is consistent with (1).)

Calculation of $\int_{drift}\beta_{x,y}\cdot ds$

	Horizontal (m^2)	Vertical (m^2)
Arc sec. total	24600 (1)	24500 (1)
Straight sec. total	14800 (0.60)	20300 (0.83)
Tsukuba straight sec.	4000 (0.16)	11000 (0.45)
Total	39400	44800

Large amount of e-cloud in high vertical beta sections in straight sections ???

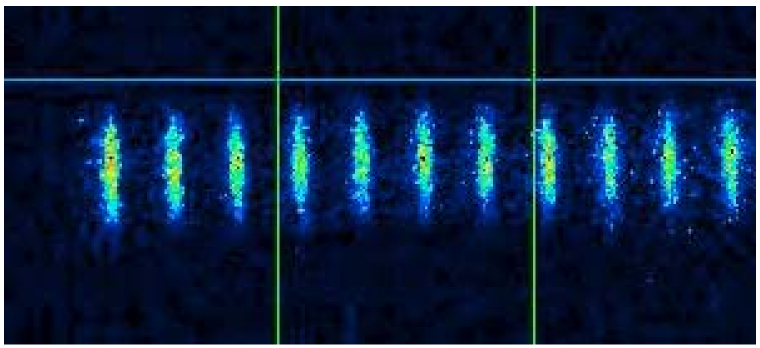
C) An attempt to detect a head-tail motion by the e-cloud by a streak camera (preliminary)



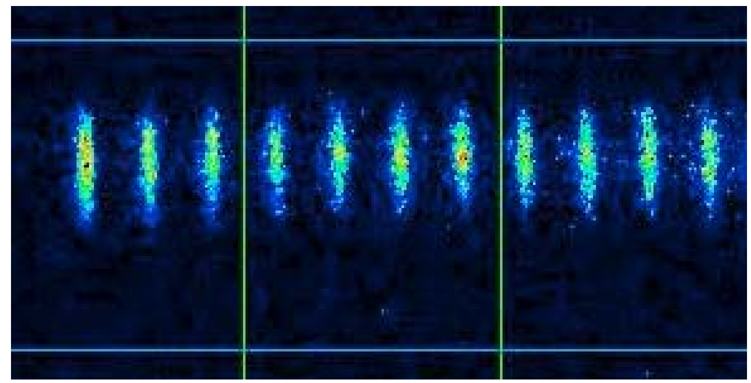
Solenoid on   1000 bunches, 4 bucket spacing

1000mA

Train head

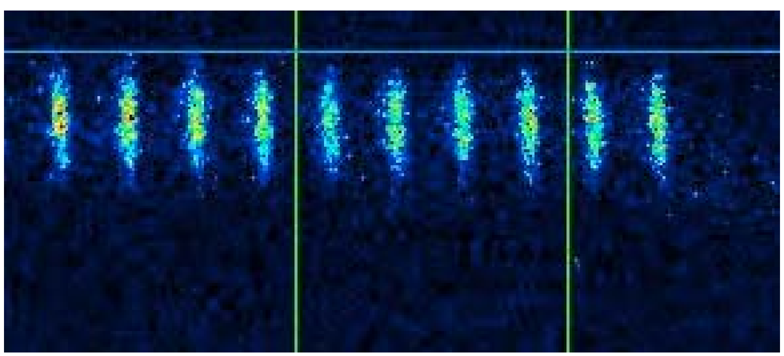


938mA

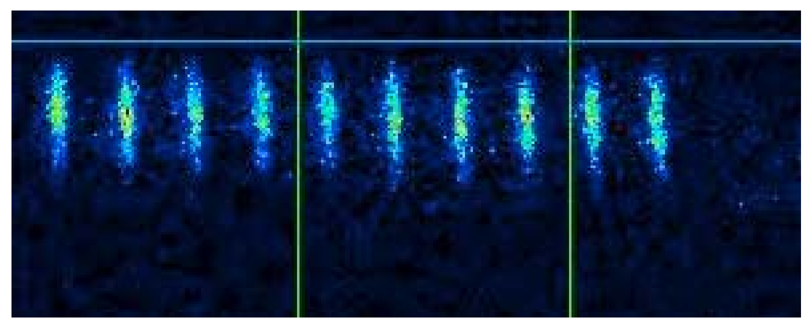


983mA

Tail



899mA

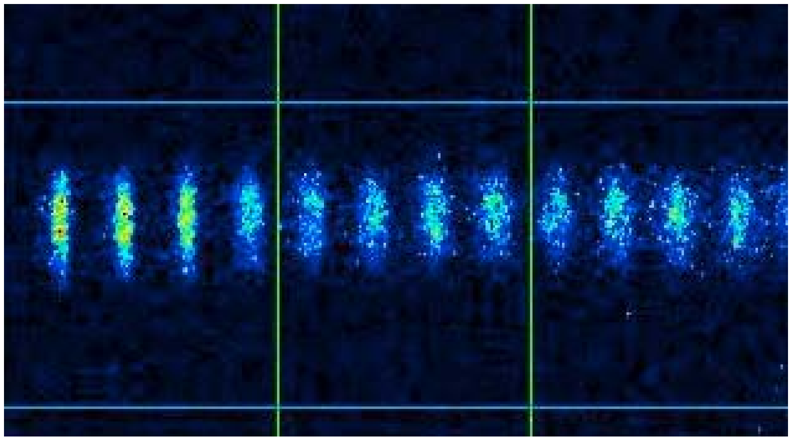


Solenoid off

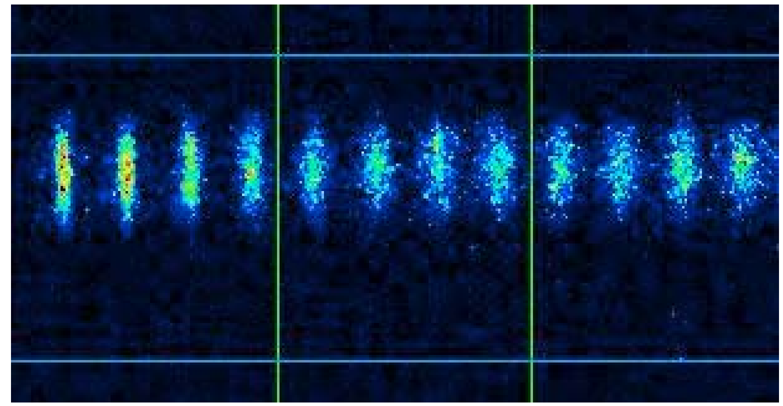
1000 bunches, 4 bucket spacing

Train head

893mA

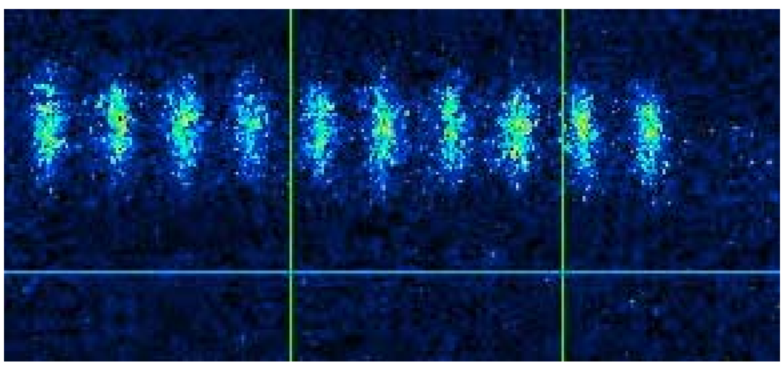


890mA

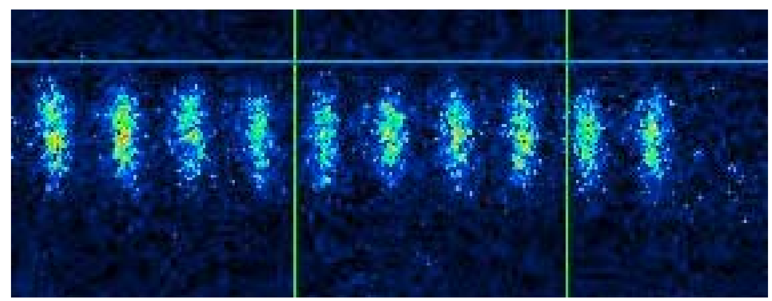


Tail

900mA



897mA



Vertical beam size starts to increase at 3 or 4th bunch.

A tilt of a bunch is not clearly observed.

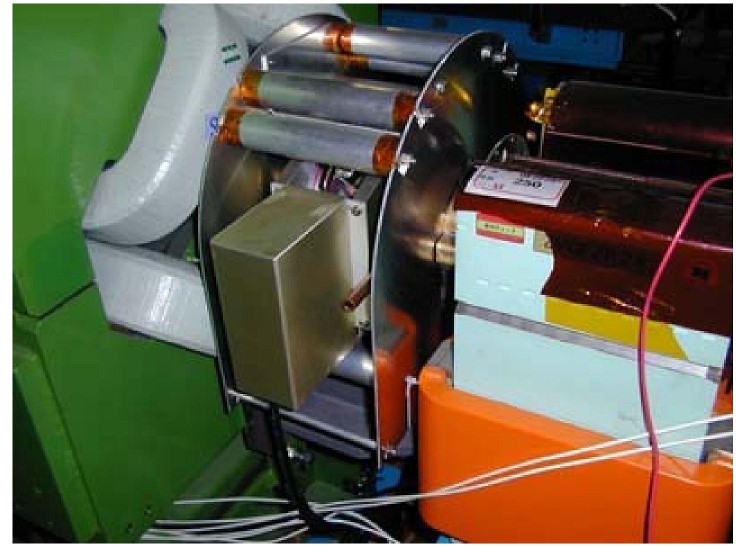
D) Others

a) Works in this summer

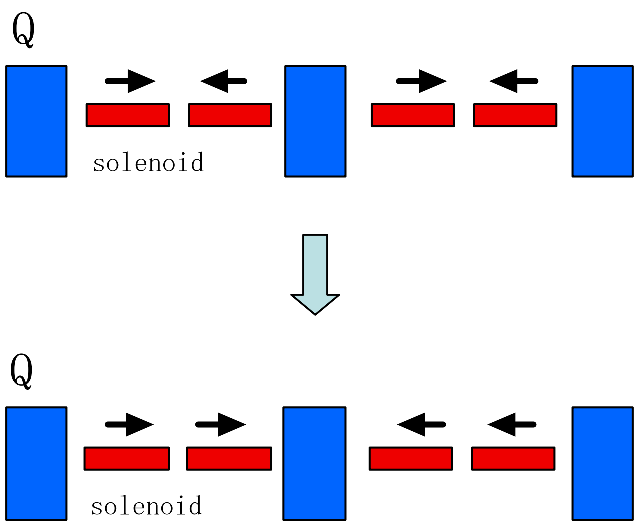
1. Addition of solenoids

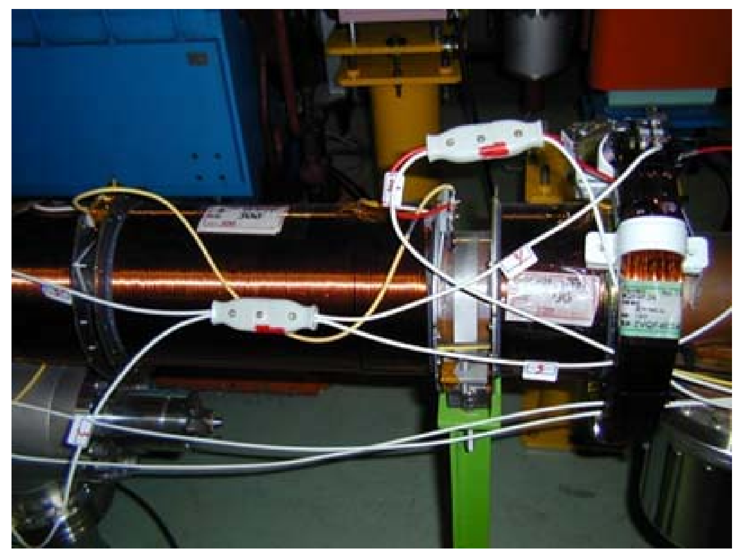
   1) 215 solenoids at straight sections

   2) 50 permanent magnets over BPM at Oho and Nikko straight sections



2. Changing the connection of the solenoid power cables to study the effect of polarity-changing-place.





b) Near future plans

1. Increase of solenoid field

   DC current : 4.5A ⇨ 10 A

   Temperature raise of solenoid coil: 100 ^{o}C

   (Life time of enamel wire will be OK.)

   New power supplies are required.

   ⇨ No decision yet.

2. Further solenoid winding in Fuji straight section (RF section)

3. Consideration of possibility to use electrodes to remove electrons inside magnets

Summary of observations of e-cloud effects

1. Increasing the solenoid field will improve the threshold of the blowup if bunch spacing is larger than/equal to 3 bucket spacing.

2. Substantial e-cloud is generated in straight sections according to the measurement of the blowup and the tune shift.

3. Suppression of e-cloud effects in 2 bucket spacing will be very difficult.

   Large tune shift was observed in 2 bucket spacing operation.

   Almost no effect was observed by increasing the solenoid field.

4. Clear vertical tilt along a bunch is not observed by the measurement of the streak camera.

2. Transverse coupled bunch instability in HER

In previous operation period, beam aborts accompanied by the horizontal oscillation sometime happened.

Tuning of the bunch-by-bunch feedback system looked to be OK.

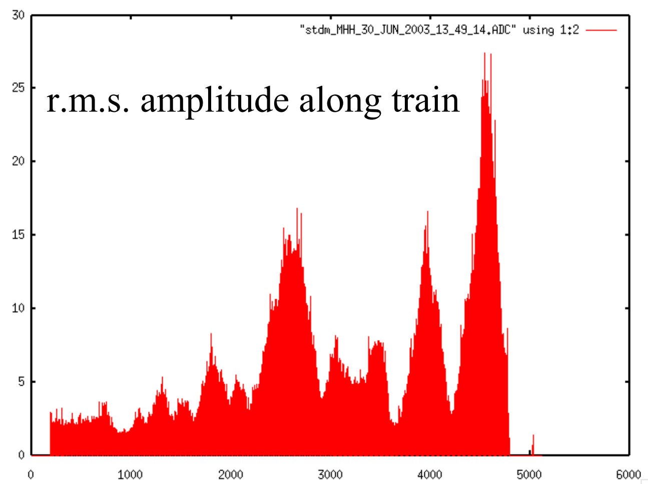
Vacuum pressure especially around I.P. was also OK.

Abnormal temperature rise of vacuum components was not observed.

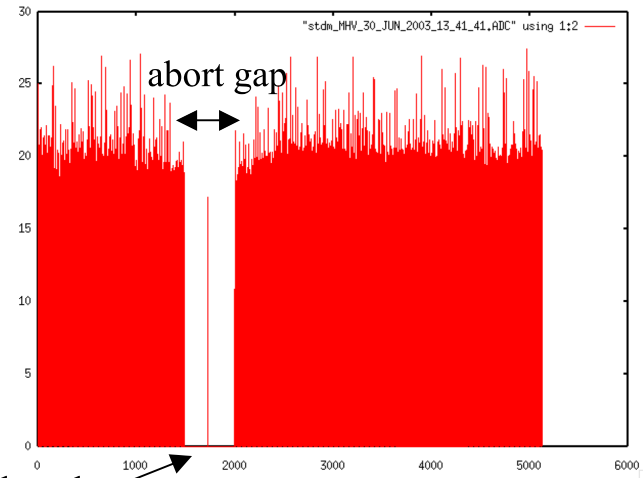
→ Beam oscillation was measured by a fast memory board after switching off the bunch-by-bunch feedback system.

1train, 1152 bunches/train, 4 bucket spacing, 600mA

Horizontal



Vertical

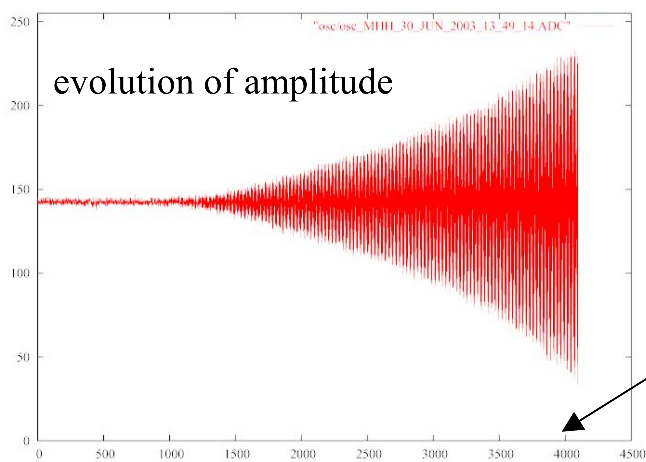


bunch

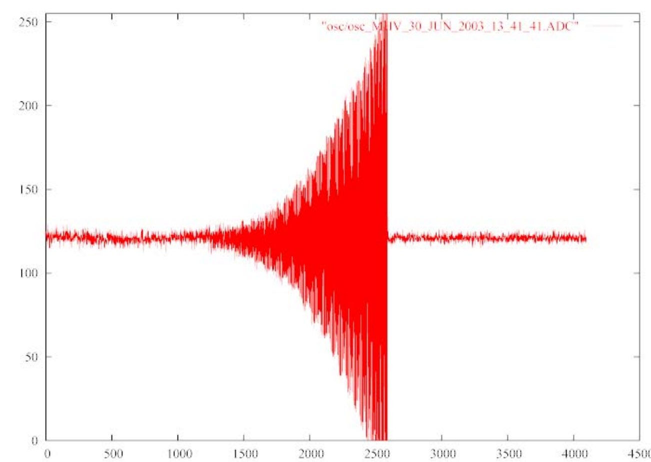
pilot bunch

Larger amplitude in tail-part

Almost uniform amplitude



4000 turn

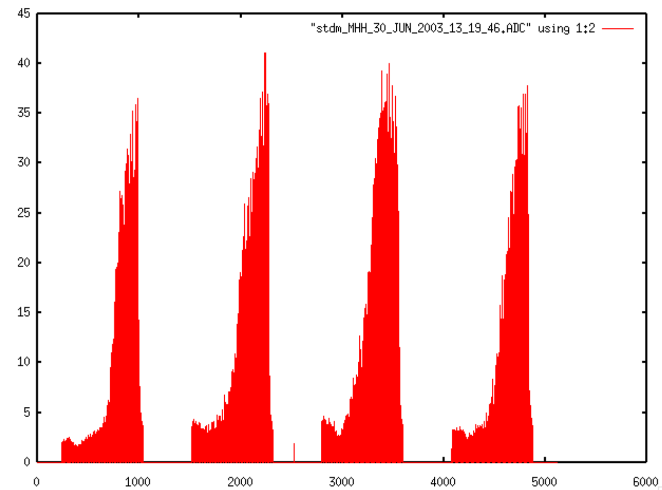


turn

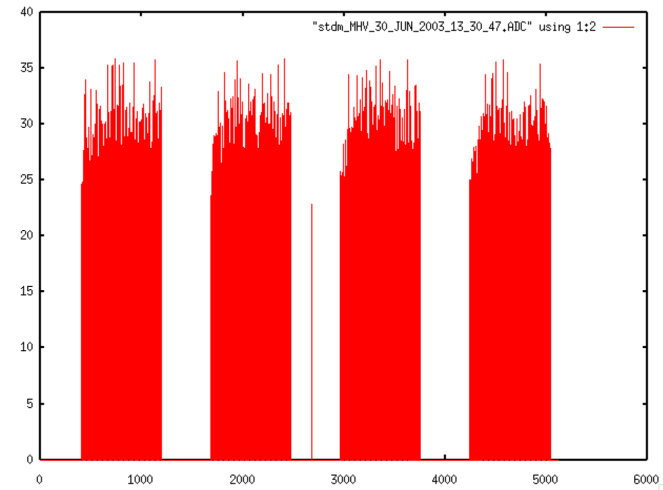
Horizontal growth rate < Vertical growth rate

4trains, 200 bunches/train, 4 bucket spacing, 600mA

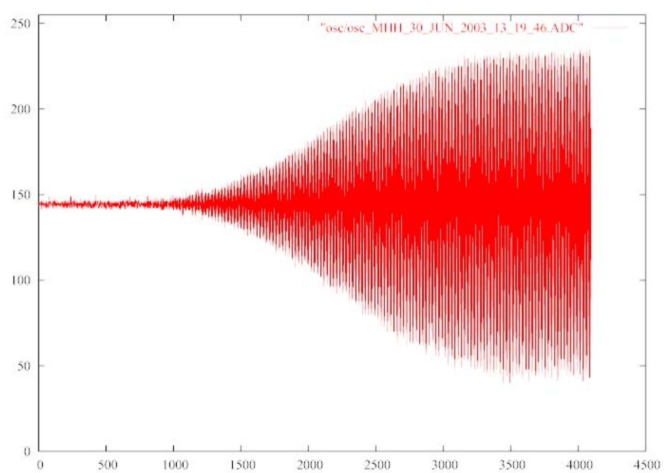
Horizontal	Vertical



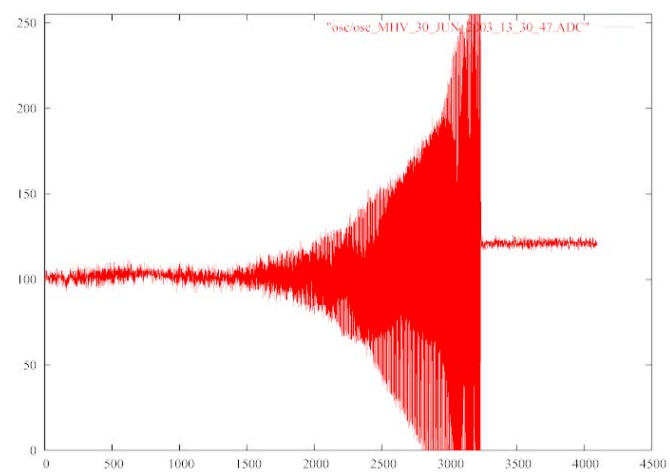
Larger amplitude in tail-part



Almost uniform amplitude



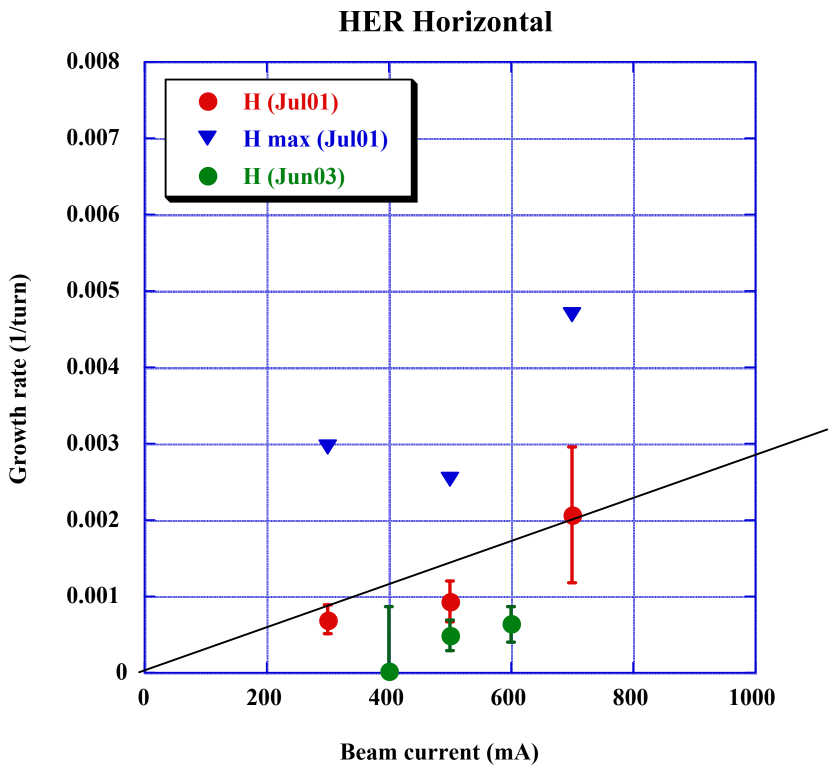
Saturation at large amplitude

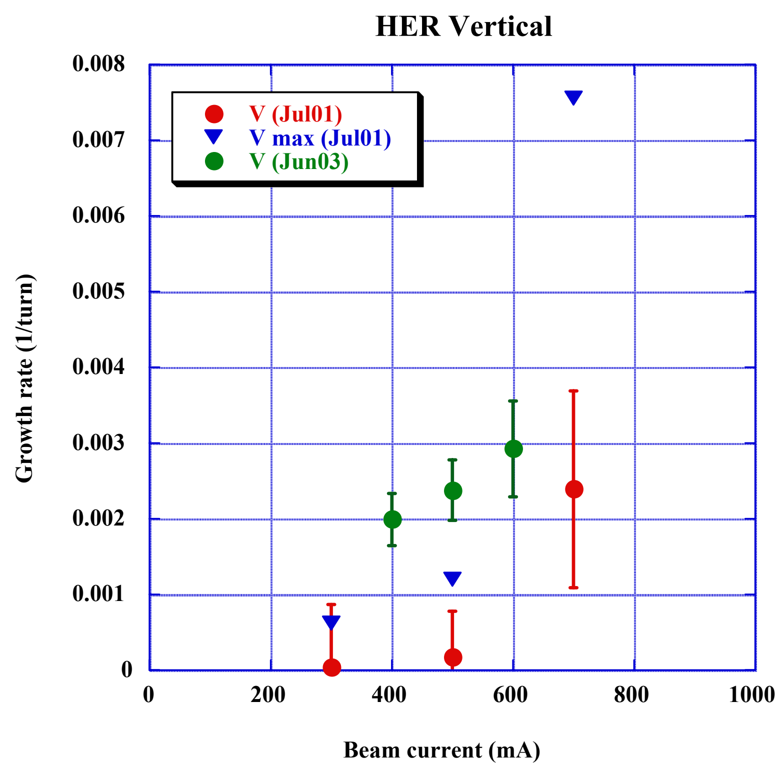


No saturation of amplitude

Growth rate

1 train, 1152 bunches, 4 bucket spacing

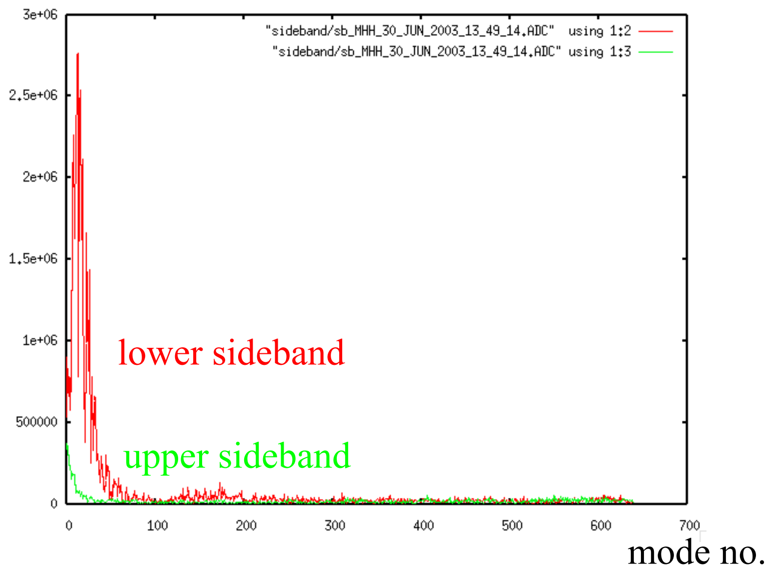




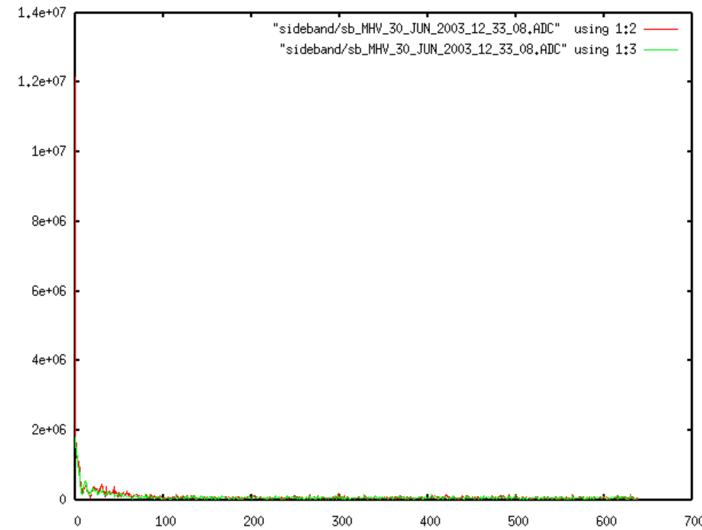
Growth rate : 0.002 (1/turn) or growth time : 5ms @700mA

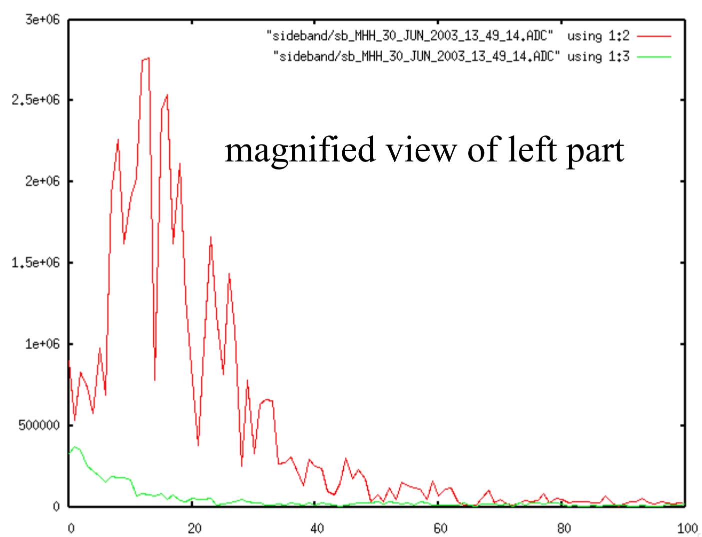
Oscillation mode 1 train, 1152 bunches, 4 bucket spacing, 600mA

Horizontal

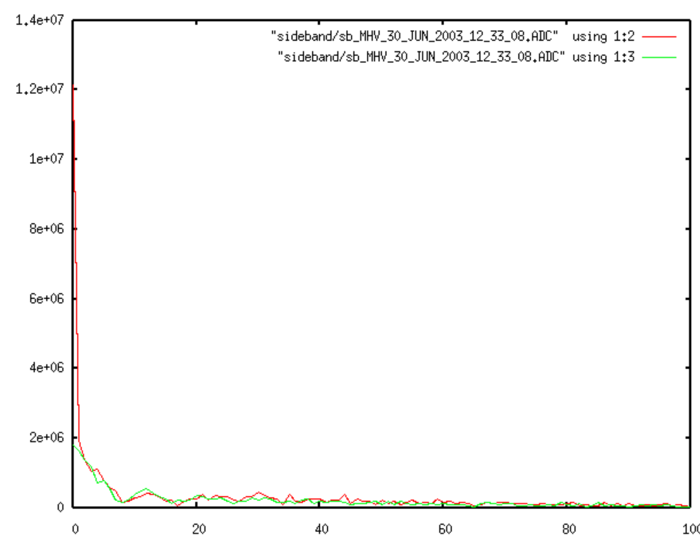


Vertical





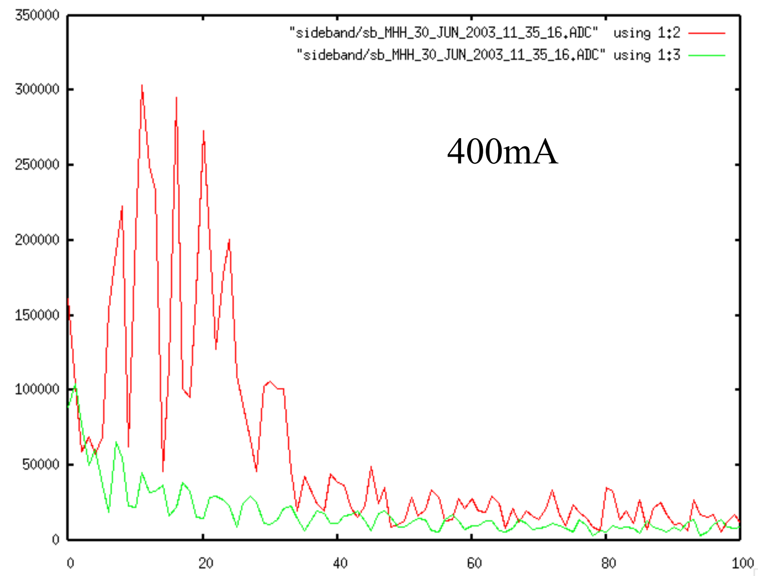
peak at about 10

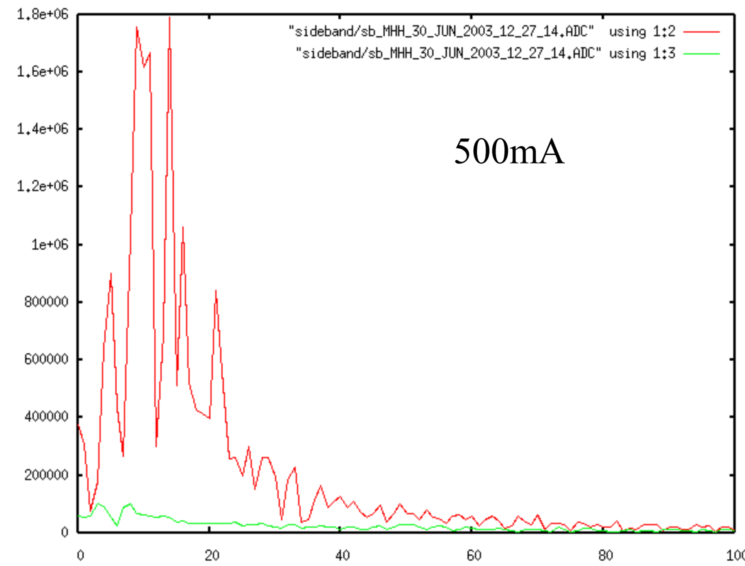


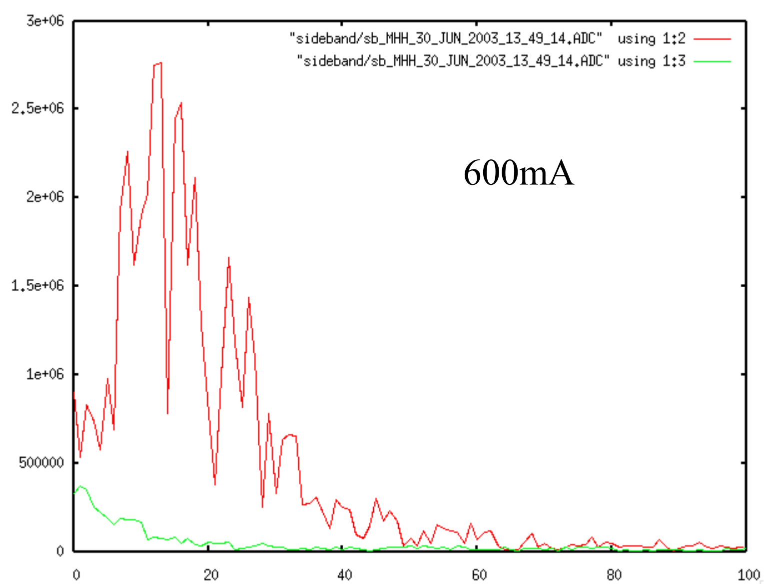
peak at 0

Beam current dependence of horizontal mode spectrum

1 train , 1152 bunches, 4 bucket spacing







Peak did not move much.

Features

Different characteristics of the horizontal and vertical oscillations.

a. Oscillation amplitude along train

Horizontal: train head < train tail, Vertical:uniform

b. Growth rate

Horizontal :0.0006 turn^{-1}(@600mA) < Vertical : 0.0029 turn^{-1}(@600mA)

c. Mode

Horizontal :broad peak at about mode 10, Vertical :peak at mode 0

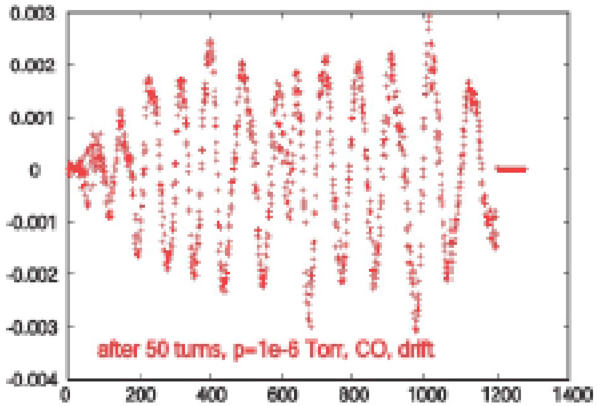
⇒ Sources of the instability may not be same in horizontal and vertical planes.

Simulation of horizontal instability (F. Zimmermann(PAC2003))

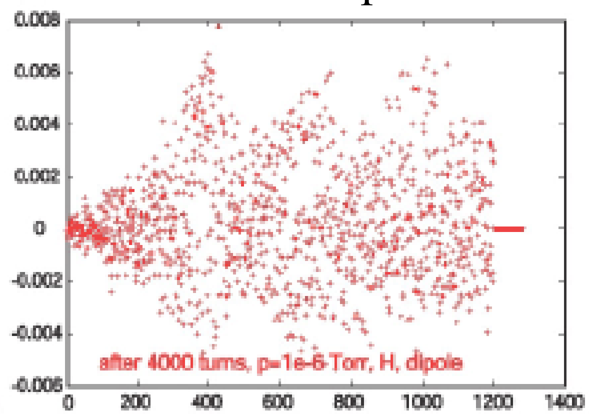
1. CO^+ without magnetic field
2. H^+ in a dipole field
3. Resistive wall
4. Electron cloud

Bunch position along train (1 train, 1200 bunches, 4 bucket spacing, 670mA)

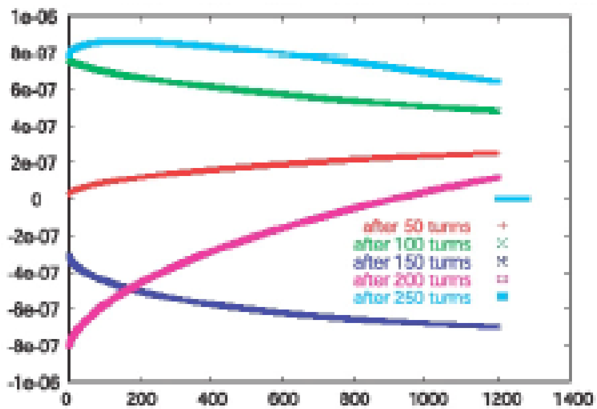
CO^+ without magnetic field



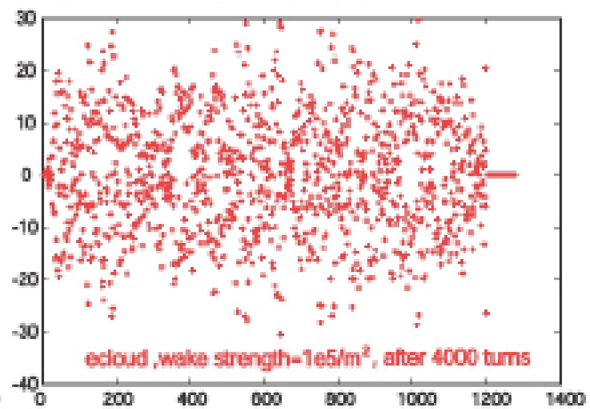
H^+ in a dipole field



Resistive wall



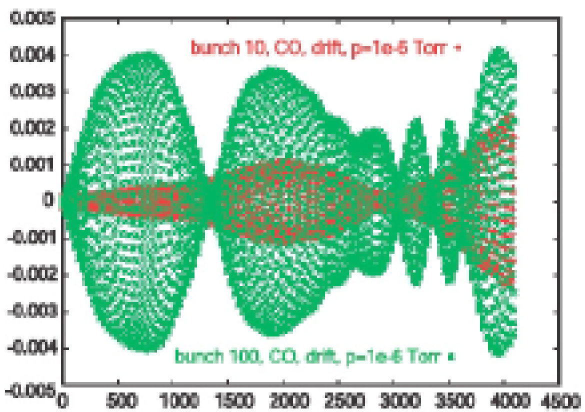
Electron cloud



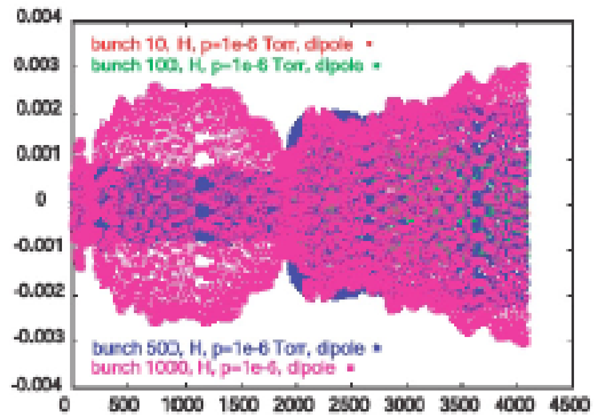
No amplitude growth along a train in resistive wall case.

Oscillation of a few bunches

CO^+ without magnetic field

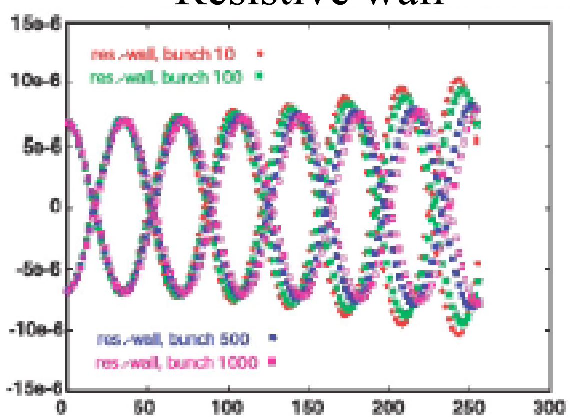


H $^+$ in a dipole field

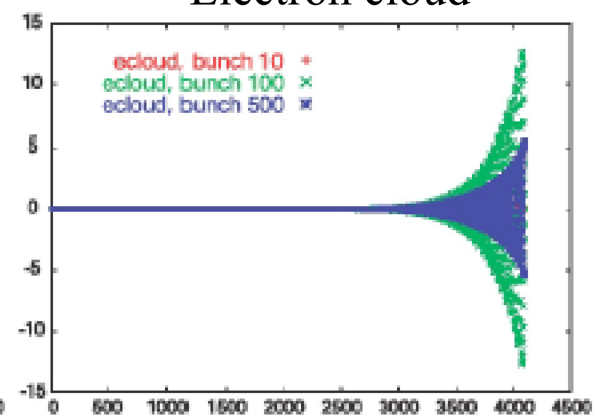


Saturation of oscillation in ion cases.

Resistive wall

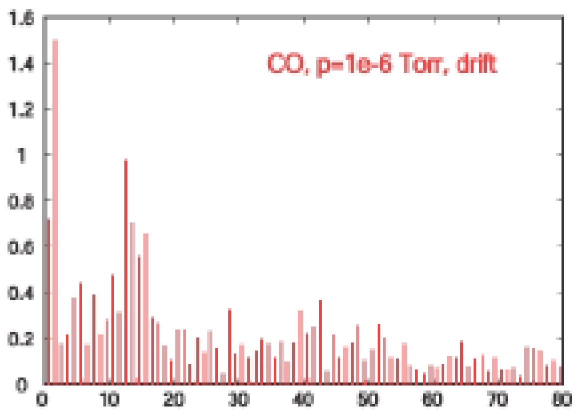


Electron cloud

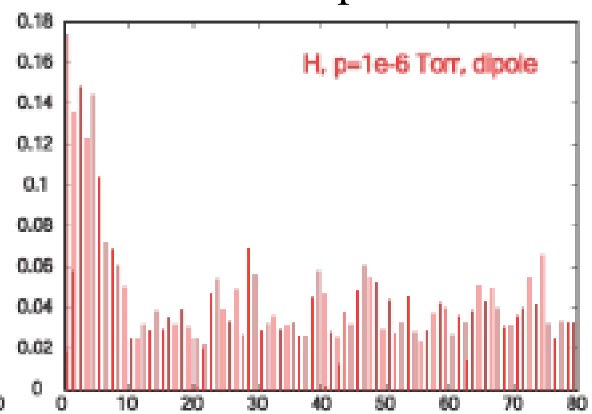


Mode spectra

CO^+ without magnetic field

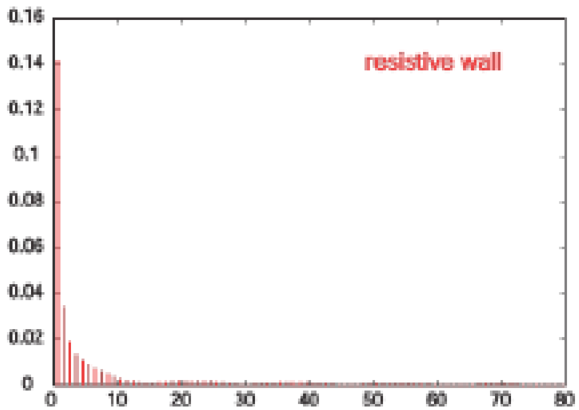


H^+ in a dipole field

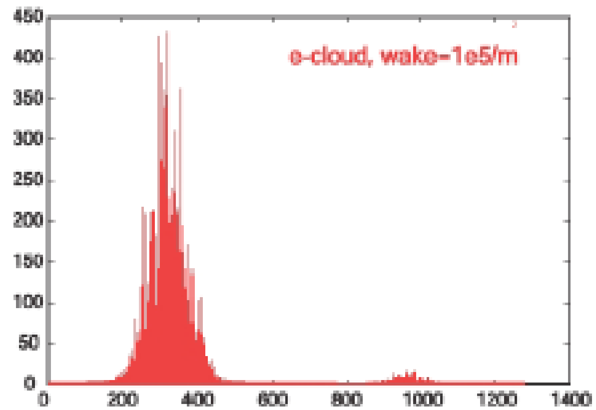


Peak appears near 10 in CO case.

Resistive wall



Electron cloud



Growth time

@beam current 670mA (observation : 2ms max.)

CO^{+} without magnetic field	1ms
H^{+} in a dipole field	4000ms
Resistive wall	5ms
Electron cloud	2ms

Comparison with observation

Results of the simulation assuming CO^+ ions is almost consistent with observations of the horizontal instability.

Peak of mode spectrum at about 10.

Saturation of oscillation amplitude.

Growing amplitude along the train.

Maximum growth time of order of 1 ms.

Expected future simulation work

Can the simulation explain the vertical instability ?

Why the peak of the mode spectrum does not move by changing the bunch current ?

Summary of observations of transverse coupled bunch instability in HER

1) Horizontal coupled bunch instability in HER sometime causes beam aborts which limit the beam current.

2) Observations are consistent with the results of the simulation which assumes the instability is caused by CO^+ ions.

3) A question remains why the instability was not cured by the bunch-by-bunch feedback system.

4) Vertical coupled bunch instability is also observed in HER. Features of the instability are different from those of the horizontal instability, which suggests the vertical instability is caused by a different source than that of the horizontal one.