Measurements of electron cloud effect in KEKB

K. Ohmi (KEK)

Thanks to

J. Flanagan, H. Fukuma, Y. Funakoshi, H. Ikeda, K. Kanazawa, S. Kato, Y. Suetsugu, M. Tobiyama, S. Uehara, S. Win

- Electron measurement
- Instability measurement

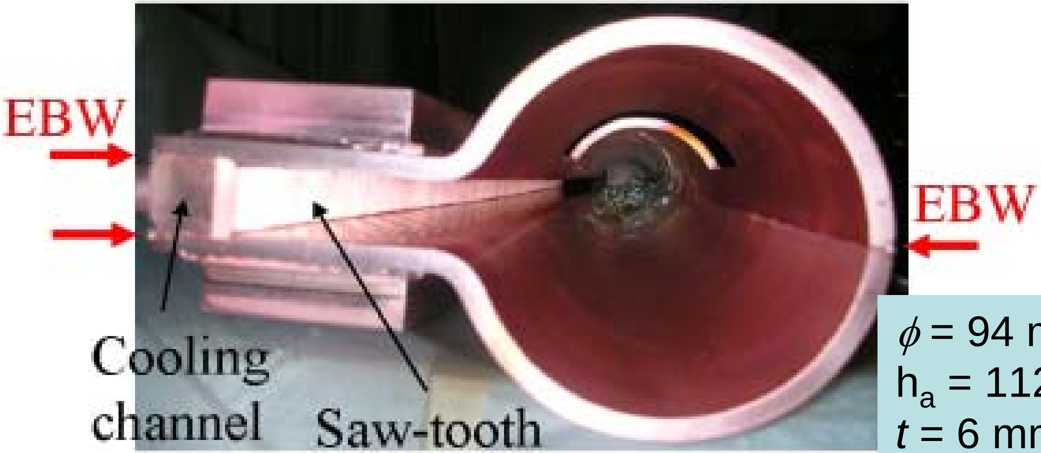
Electron cloud measurement in KEKB (Suetsugu et al.)

- Manufacturing a test antechamber.
- Measurement of electron cloud in the antechamber at KEKB.
- Measurement of electron cloud for various surface condition. Estimation of secondary emission rate.
- Comparison with simulation developed by Suetsugu.

Manufacturing of Antechamber

- Manufacturing
  - Two test ducts LER, Material: OFC, Total length=5.2 m
- Two manufacturing methods:
  - Pressing (Formed from a copper plate, and welded by EB)
  - Drawing (Cold drawing from a copper pipe)
- Saw-tooth like surface, or rough surface (beads blast) at side
  - to reduce photoelectrons and the reflection

[Pressing]



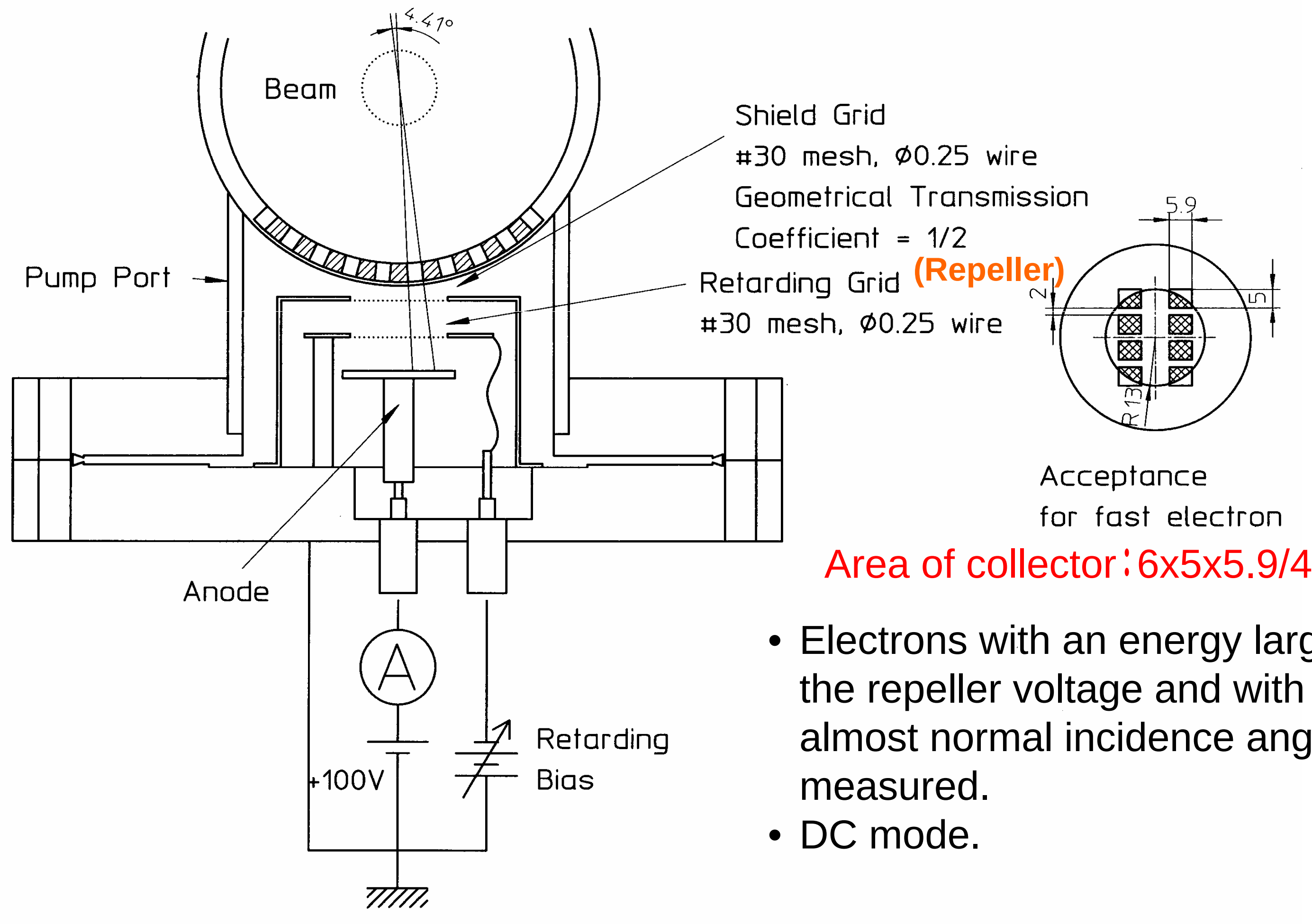
ϕ = 94 mm
h_a = 112 mm
t = 6 mm

[Drawing]

Y.Suetsugu et al., NIM-PR-A,Vol.538, 2005,p206-217

Measurement of electron cloud

- Electron Monitor (by K.Kanazawa)



Area of collector：6x5x5.9/4~40 mm^2

- Electrons with an energy larger than the repeller voltage and with an almost normal incidence angle are measured.
- DC mode.

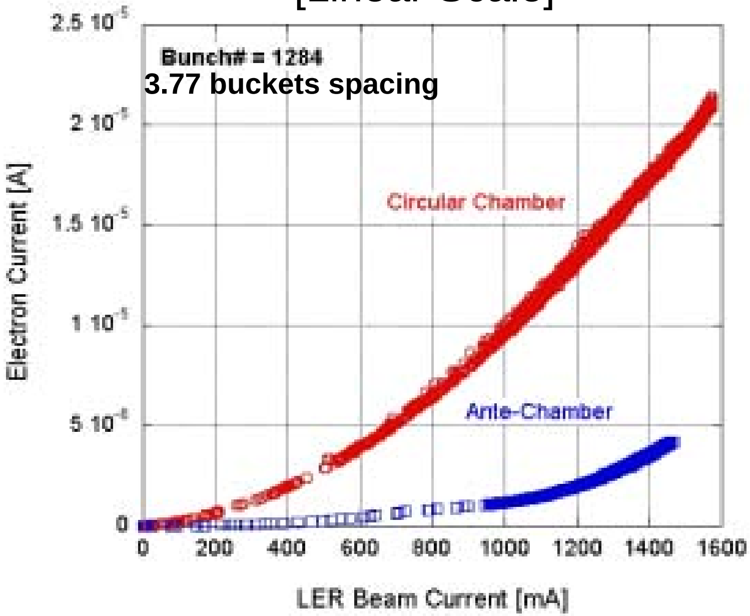
Measurement result

- Result: electron currents
  - Photoelectrons decreased by factors at high current ($I_b \geq$1 000 mA).
  - The reduction was by orders at low current ($I_b \leq$ 100mA).
  - Multipactoring seems to become important at higher current.
- Effective, but combination with solenoid field, and an inner surface with a low SEY will be required at higher current.

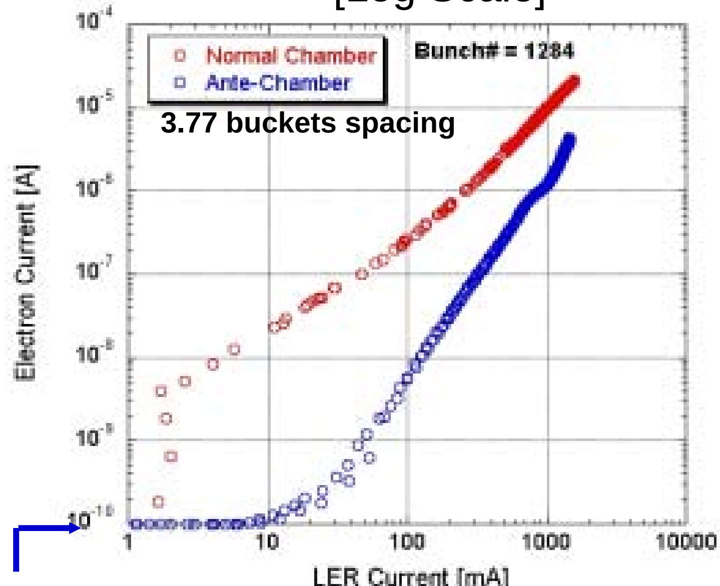
(Secondary Electron Yield)

Repeller Voltage = -30 V

[Linear Scale]



[Log Scale]

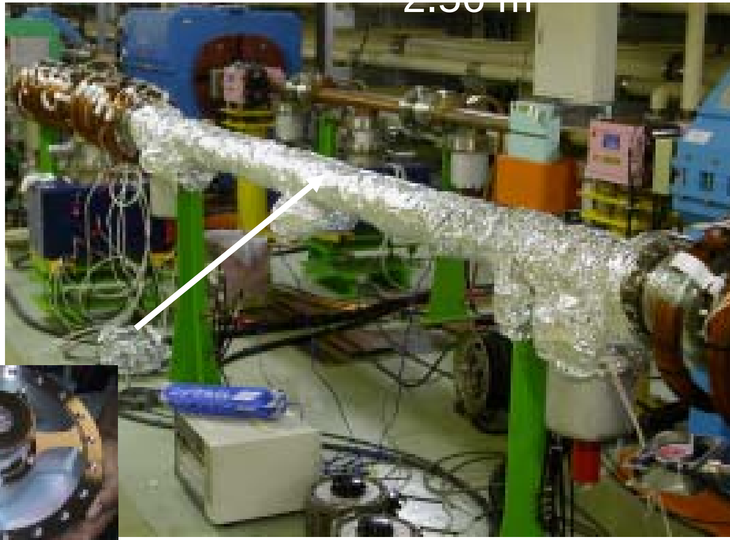


Limit of measurement

NEG, TiN Coated Duct (cylindrical)

- NEG (TiZrV)、TiN were prepared and installed in LER
  - OFC、ϕ94mm(LER standard), Total length=2.56m
- Measured were electron currents from the beam channel, pressures and temperatures during operation.
- Points of the beam test:
- First measurement in a high current e^+ machine
  - Included are effects of SR (photoelectrons), beam field, space charge
  - Detailed surface analysis *in situ.* is impossible now (a future issue)
- Installed place：
  - 5.4m downstream side of a B mag.
  - Photons: 6×10^{14} photons/s/mA/m

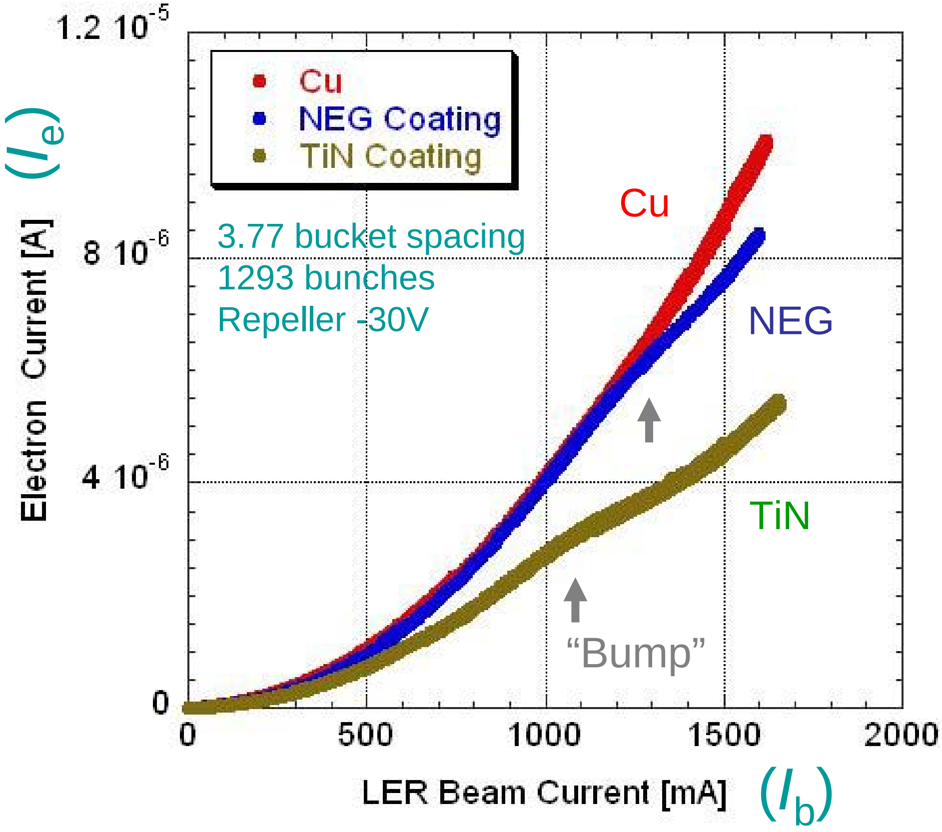
[Test chamber in the tunnel]



[Electron Monitor]

Measurement of electron cloud in the coated chambers

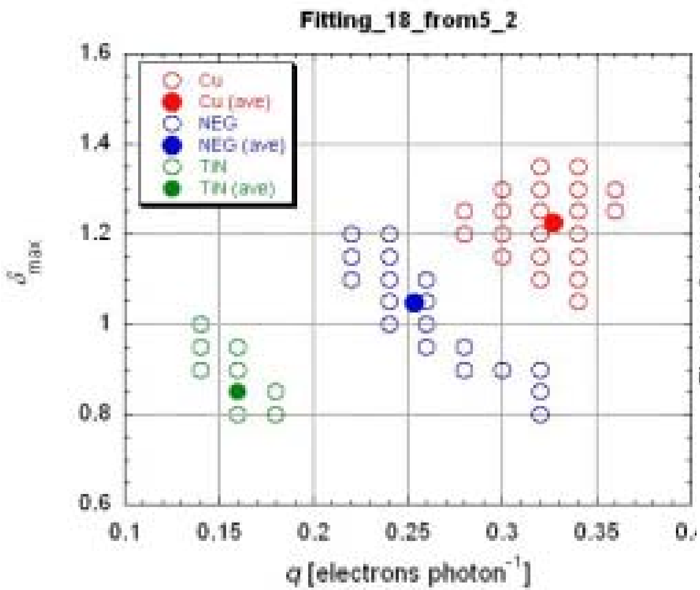
- Measured electron current (I_e) vs. beam current (I_b)

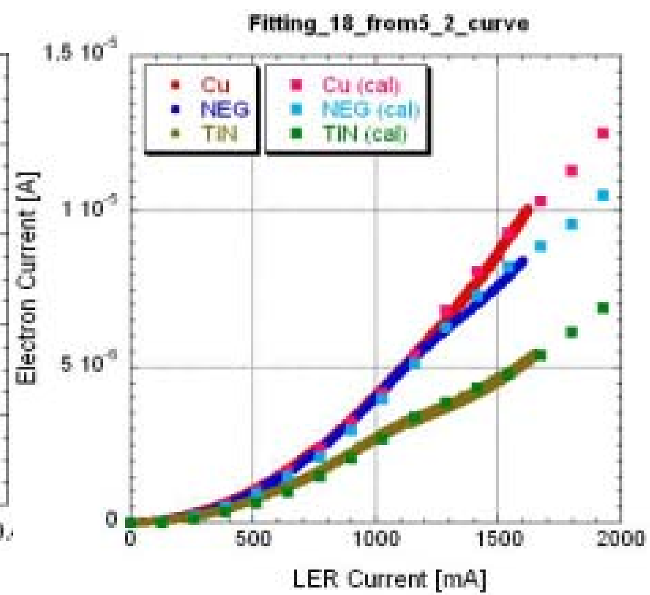


- Measured after the electron dose >10mC/mm^2.
- I_e for NEG coating is almost same as that of Cu, except for high current.
- I_e for TiN coating is clearly lower than those for Cu and NEG.
- TiN seems better from the view point of low electrons in the beam duct.
- Some structures ("Bump") can be seen for NEG and TiN.

Simulation of Electron Current

- Curve fitting
  - Curve fitting by scanning *q* (0.1≤*q* ≤ 0.4) and *d* (0.8 ≤ *d* ≤ 2.0).
  - Constraints : *q* [Cu]=0.3~0.4, *q* [Cu] : *q* [NEG] : *q* [TiN]=1:~0.8:~0.55





	q	δ_{max}
Cu	0.30-0.35	1.1-1.35
NEG	0.24-0.3	0.9-1.2
TiN	0.14-0.17	0.8-1.0

- TiN coating seems better from view points of low SEY and small *q*.
- δ_{max} of NEG should be lower than Cu, but not so clear due to the high *q*.
- The δ_{max} of Cu, NEG and TiN is near to those after electron bombardment.

Measurement of secondary efficiency (Kato et al.)

- Measurement with sample materials
- Conditioning of chamber is related to carbon graphitization of the surface.
- δ_{2max} (as is received) > 2 is indepedent of metal species (contaminated by C, H_2O, molecules…).
- After conditioning, electron bombardment, δ_{2max} ~1.0-1.2 for copper and TiN coated chamber (carbon graphitization).
- Then ion sputter cleaning results δ_{2max} ~1.4 for copper and δ_{2max} ~0.9 for TiN (pure material surface).

Surface analysis

- CO, H_2O and their molecules was observed on the surface as is receive.
- Strong C-1S signal was observed after electron bombardment in a high quality vacuum.
- N and Ti for TiN and copper signals were observed after ion sputtering.

Conclusion

- Secondary efficiency in electron (positron) rings can be expected to be low δ_{2max} ~1-1.2.

Measurement of instabilities

- Coupled bunch instability
- Single bunch instability

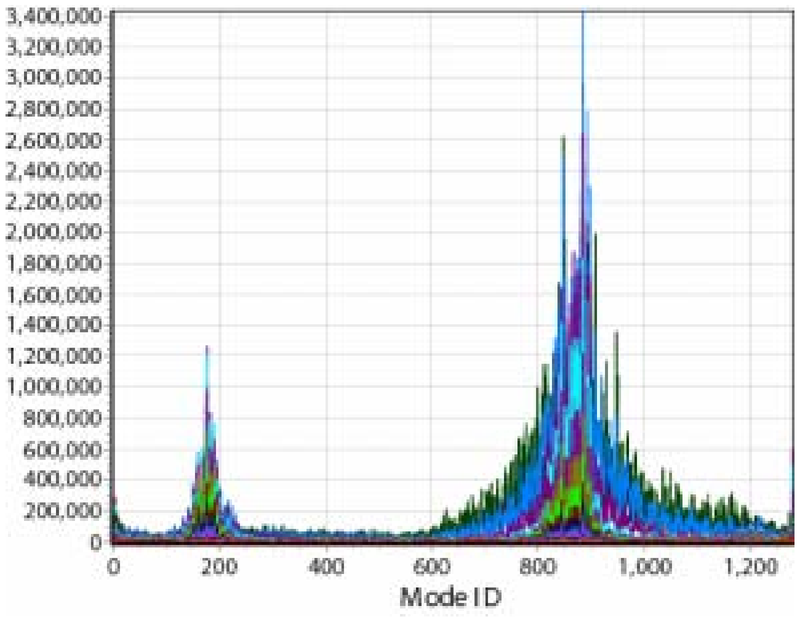
Cured by solenoid magnets which cover 95% of magnet free space.

- Other effect? For example incoherent emittance growth.

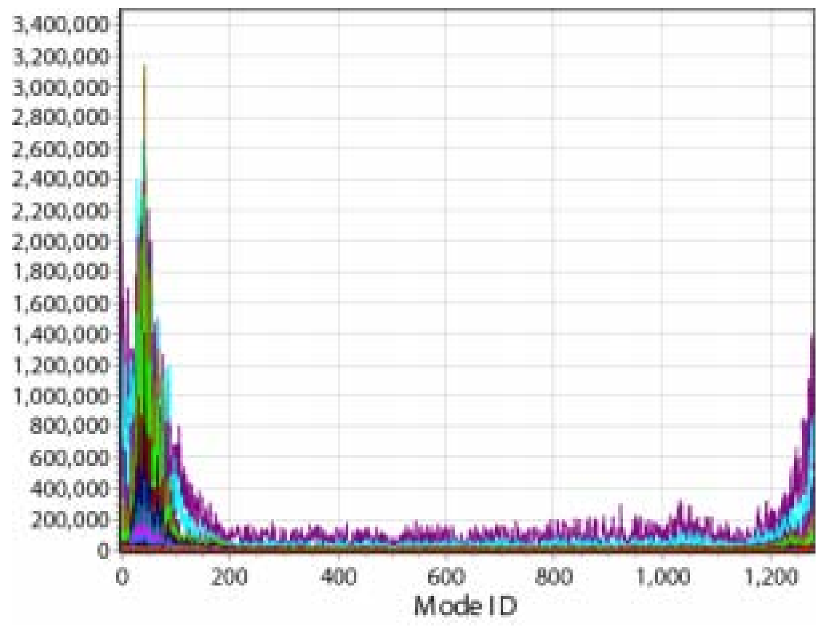
Coupled bunch instability

- Fast amplitude growth which causes beam loss has been observed.
- The mode spectrum of the instability depends on excitation of solenoid magnets.

Solenoid off

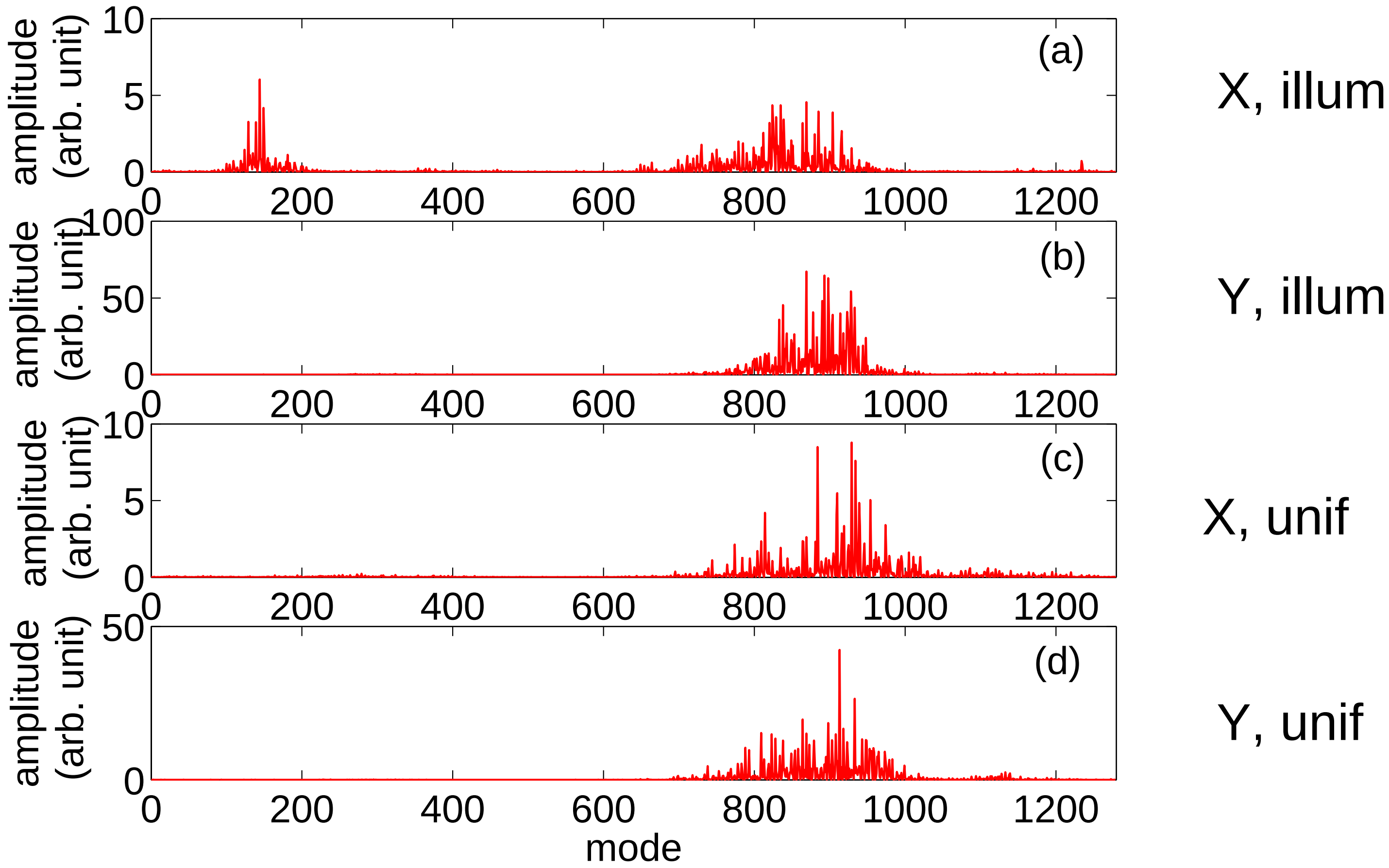


on (measurement)

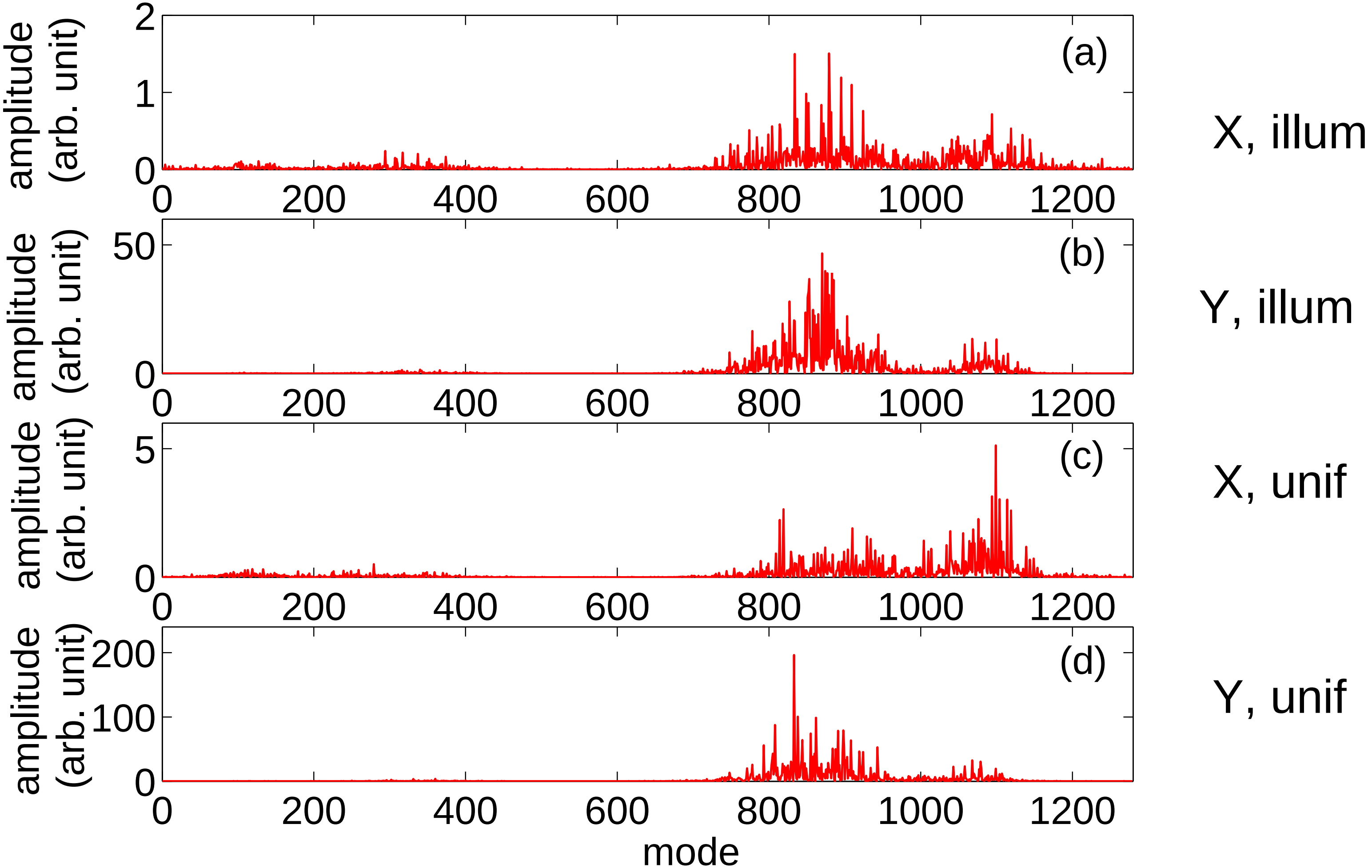


Mode spectra by simulation

- Drift without solenoid, δ_{2max}=1.0

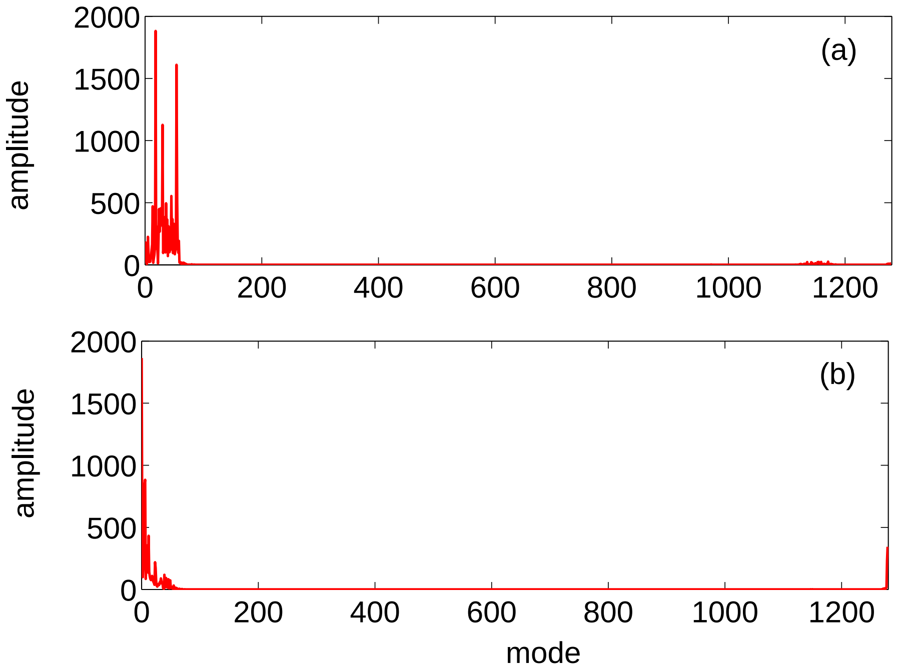


- Drift without solenoid, δ_{2max}=1.5

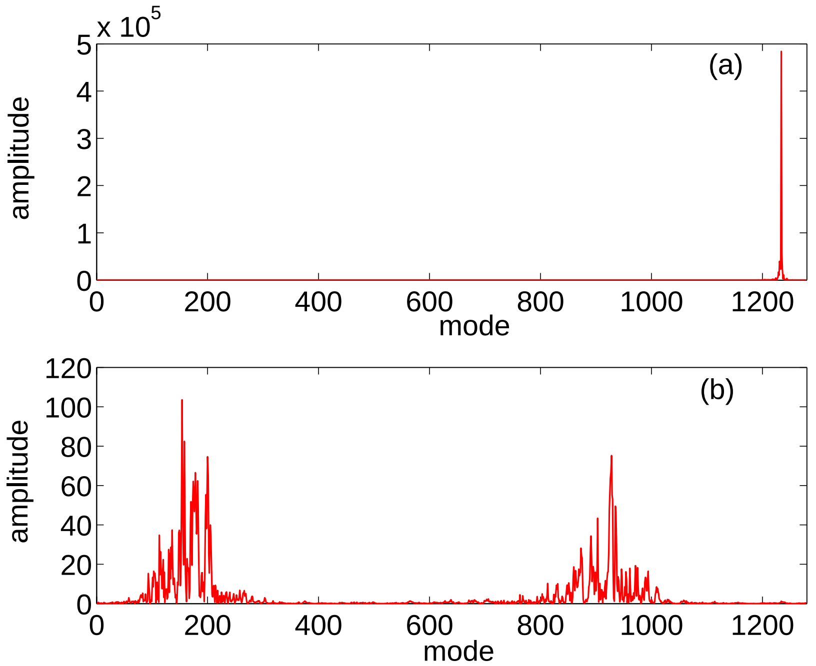


Spectrum in magnets (simulation)

Solenoid



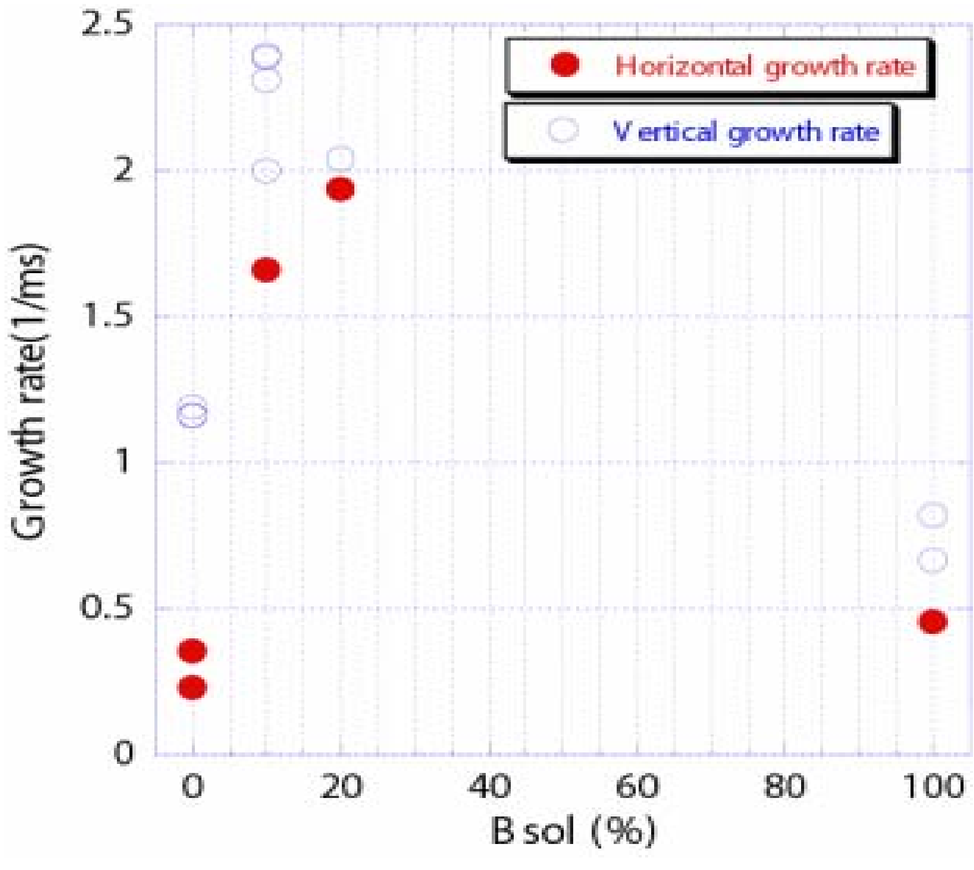
Bending magnet



x: upper y:lower

Growth rate for solenoid strength

- 600 mA 100%~50 G



Result from the mode spectra

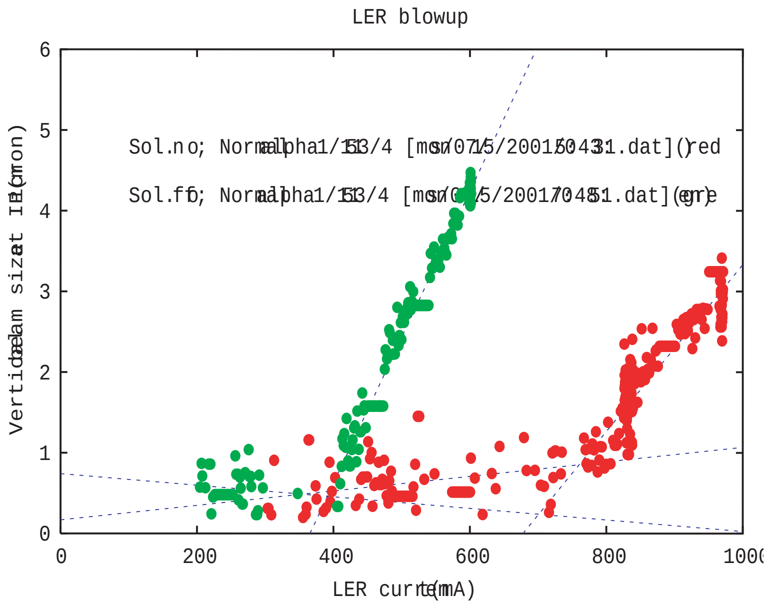
- Measured spectra without solenoid is close to simulation result of δ_{2max}=1.0 rather than that of δ_{2max}=1.5.
- The spectra can be explained by the simulation for drift space with/without solenoid. There was no effect of bending and other magnets.
- Frequency for solenoid spectra is a little faster than the simulation.
- Growth enhancement for weak solenoid field (a few G) is not understood.

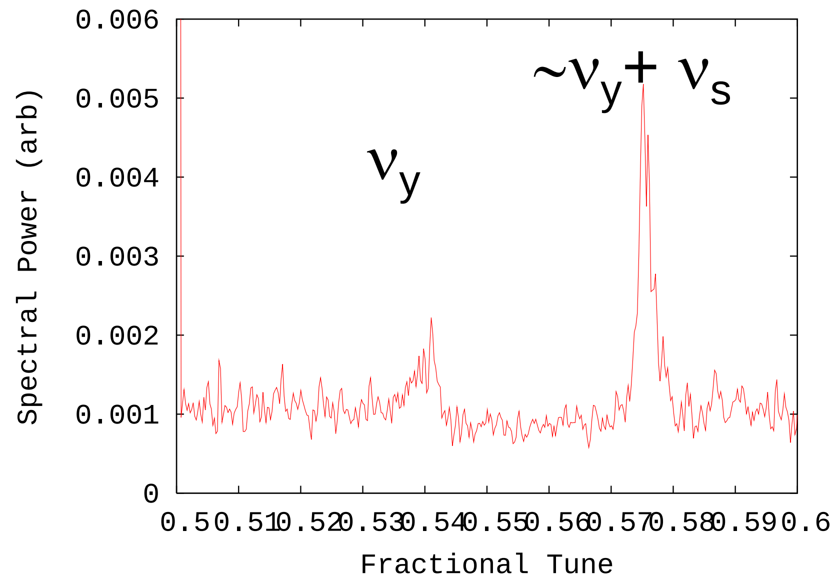
Single bunch instability due to electron cloud

- Beam size blowup has been observed above a threshold current (~400 mA).
- Synchro-betatron sideband, $\sim\nu_y+\nu_s$, has been observed above the threshold.
- The threshold of emittance growth and sideband appearance synchronize on/off of the solenoid magnets.
- Luminosity degradation occur simulteneously.

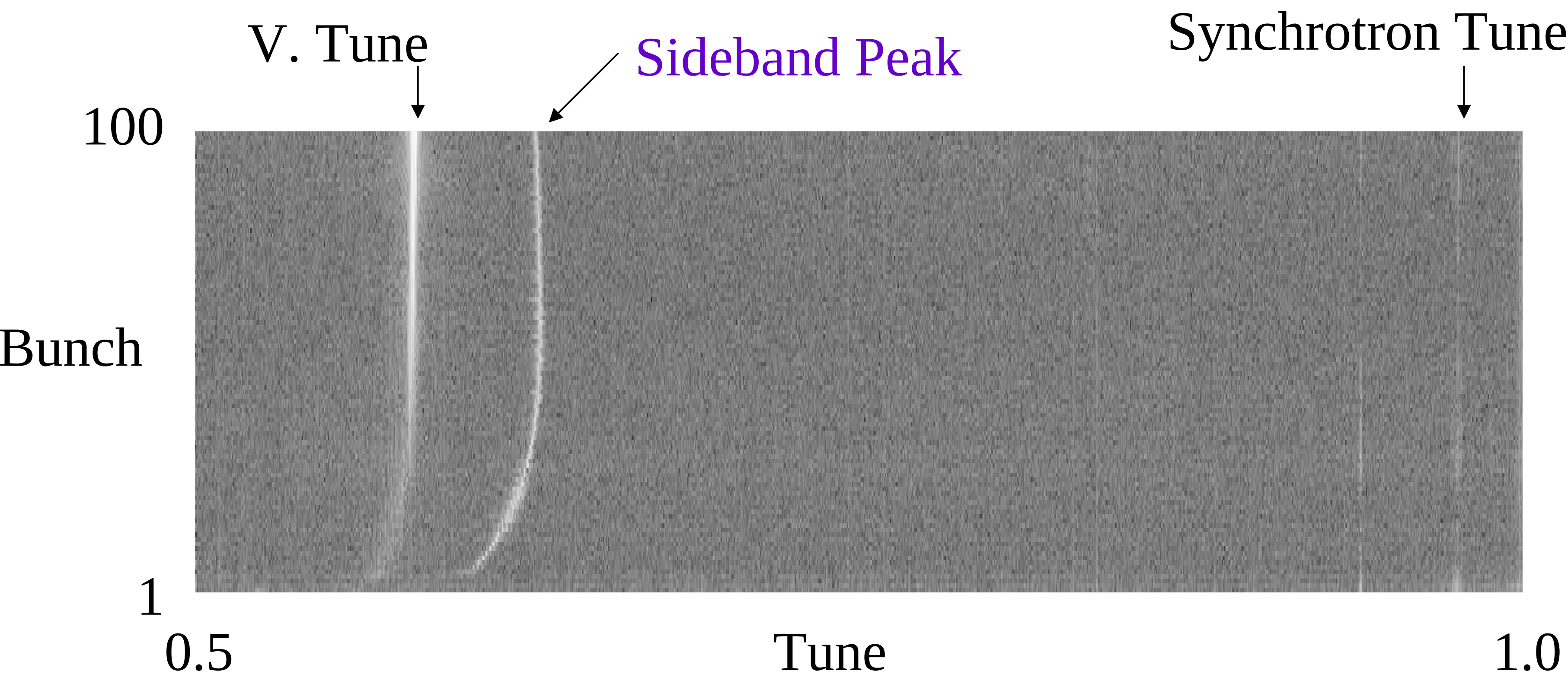
Measurements of the single bunch instability

- Beam size blow-up
- Synchro-beta sideband





Fourier power spectrum of BPM data



LER single beam, 4 trains, 100 bunches per train, 4 rf bucket spacing

Solenoids off: beam size increased from 60 μm ->283 μm at 400 mA

Vertical feedback gain lowered

– This brings out the vertical tune without external excitation

What the measurement tell us

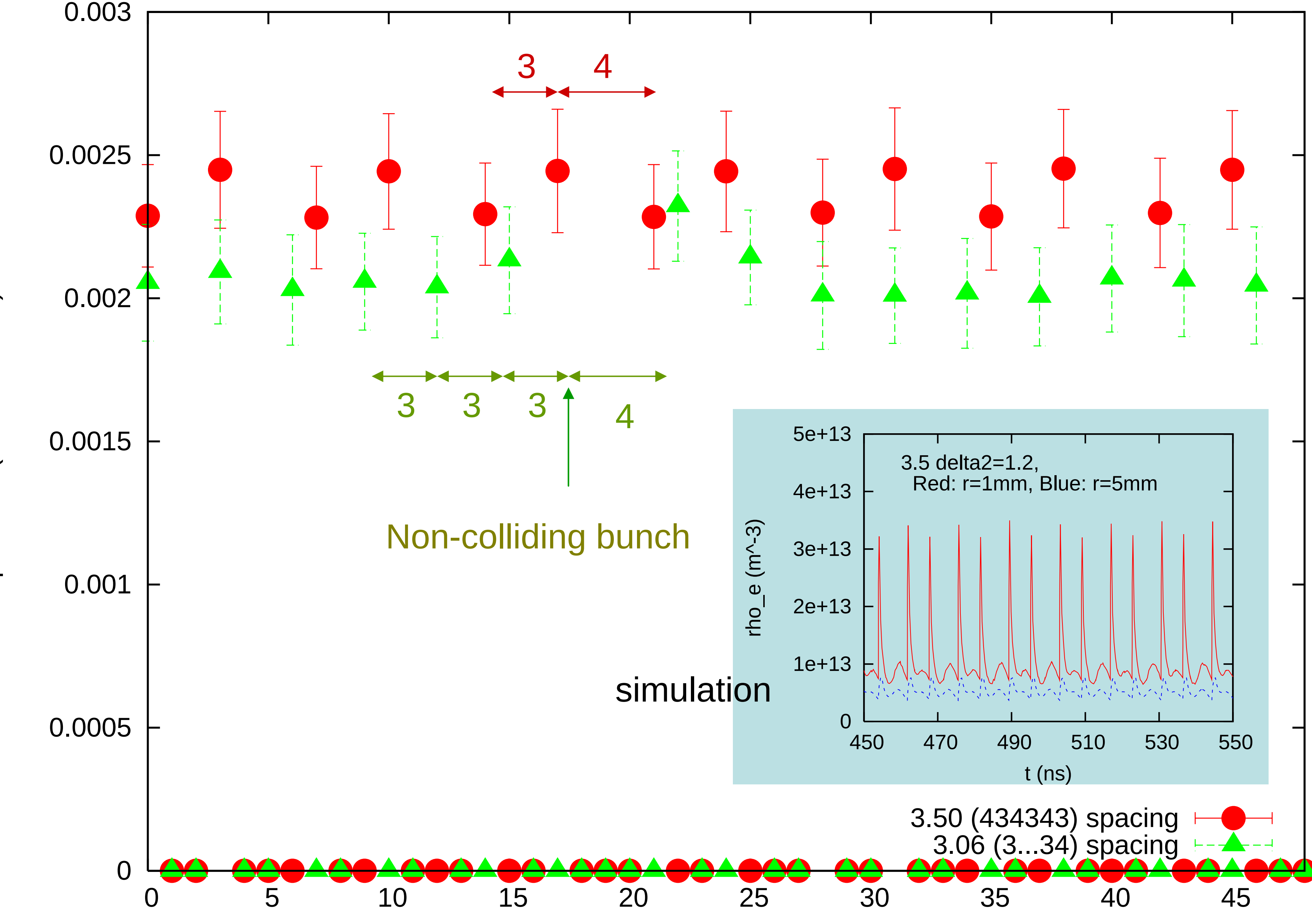
- Synchro-betatron sideband which indicated head-tail instability was observed.
- The threshold was consistent with simulations.
- The sideband appear near $\sim\nu_y+\nu_s$, while simulation gives $\sim\nu_y-\nu_s$, like ordinary strong head-tail instability.

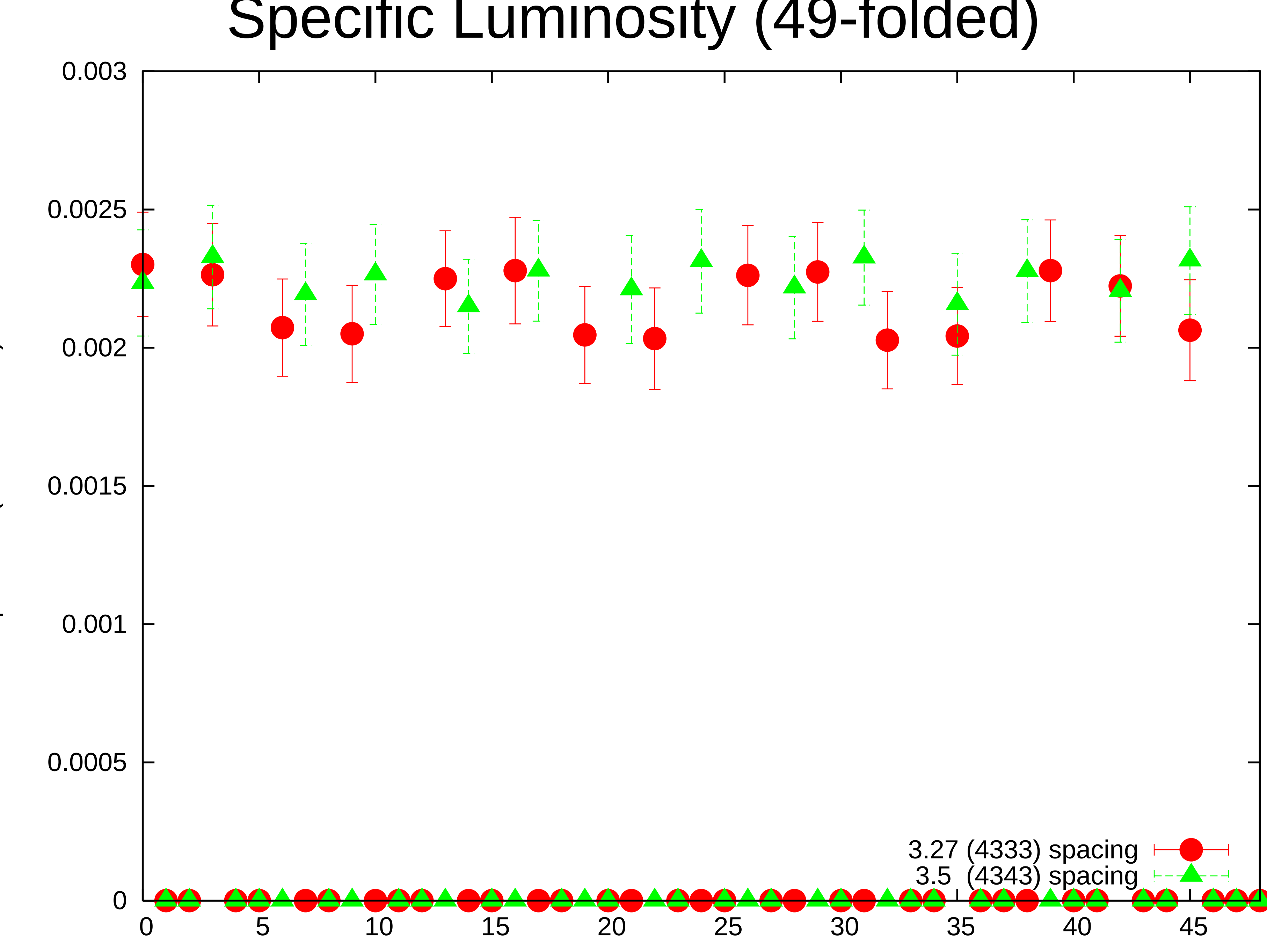
Future problem 1

Filling pattern and specific luminosity

- Various filling patterns are examined to get higher luminosity.
- To keep colliding condition, only a small part of train (300/5120 bucket) is filled with various pattern. The beam study was done parallel with physics run.

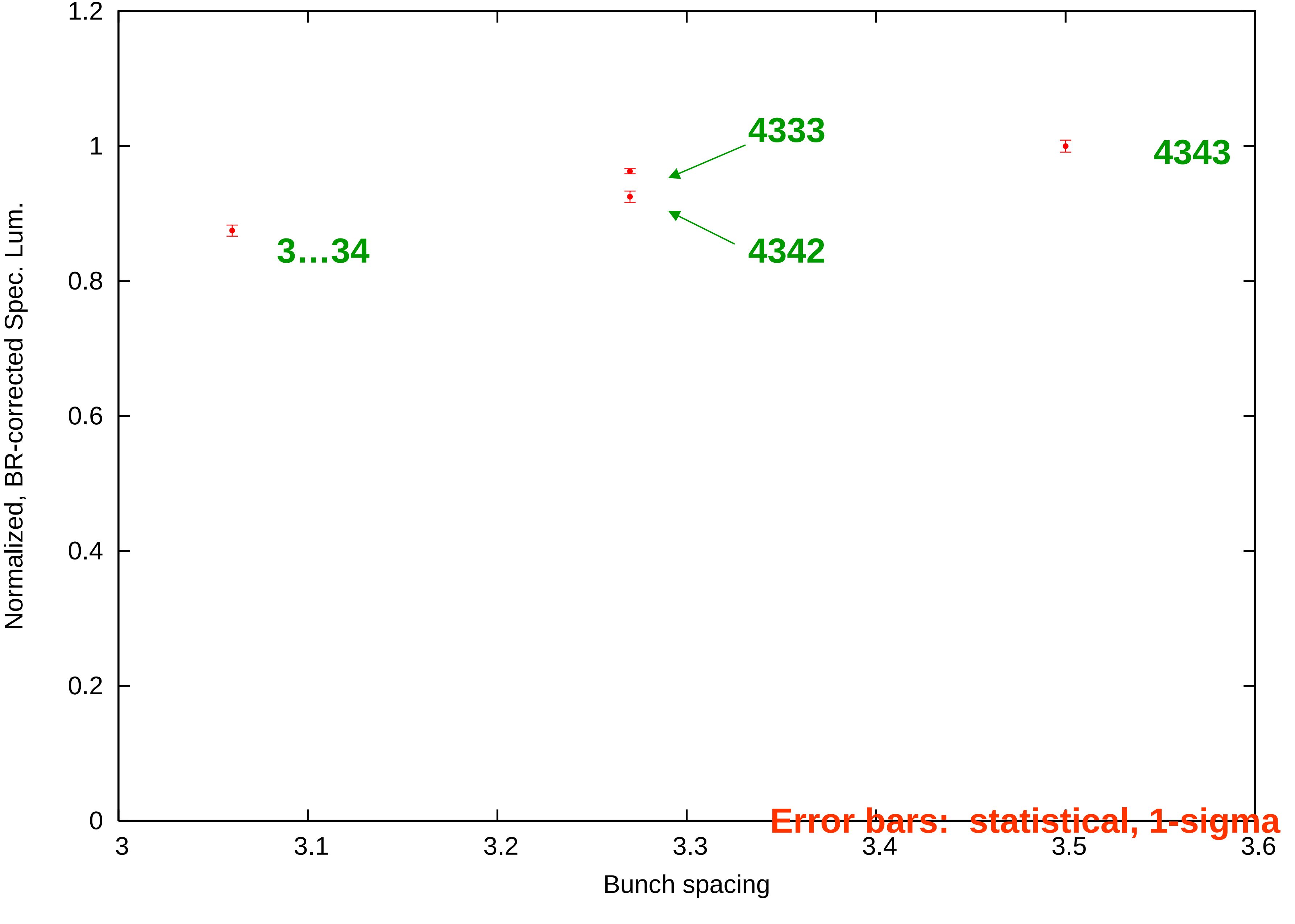
Specific Luminosity (49-folded)



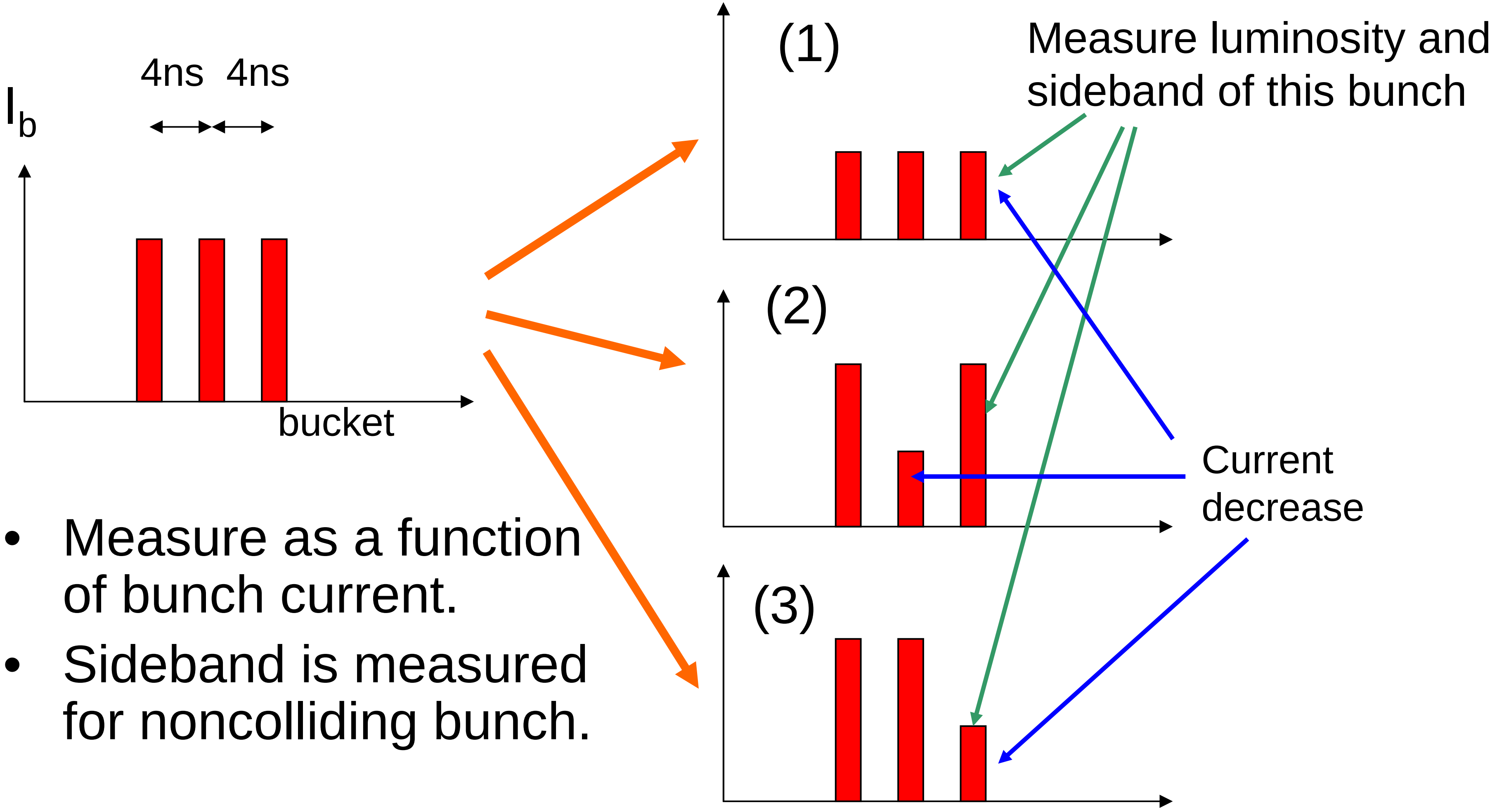


Specific Luminosity (49-folded)
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
0
5
10
15
20
25
30
35
40
45
3.27 (4333) spacing
3.5 (4343) spacing

Bunch Spacing vs Spec. Lum.



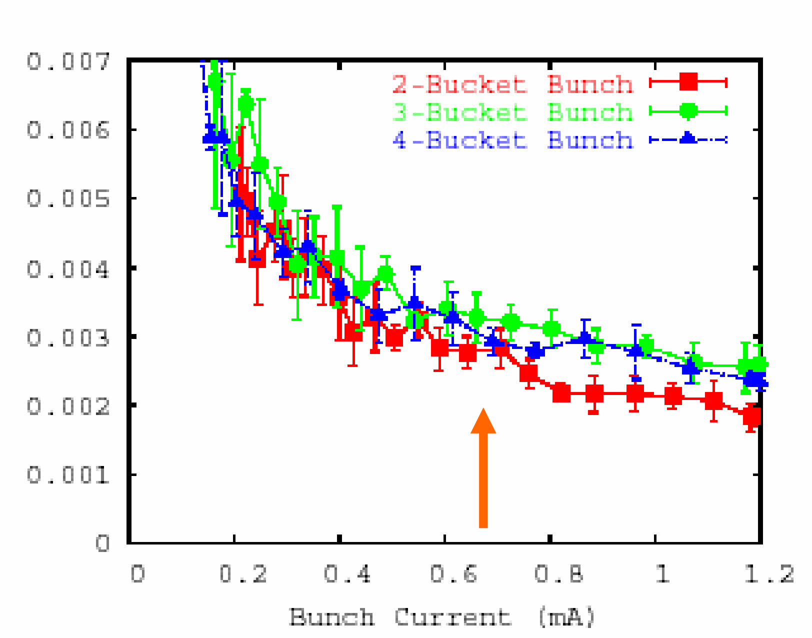
Luminosity-bunch current-sideband experiment

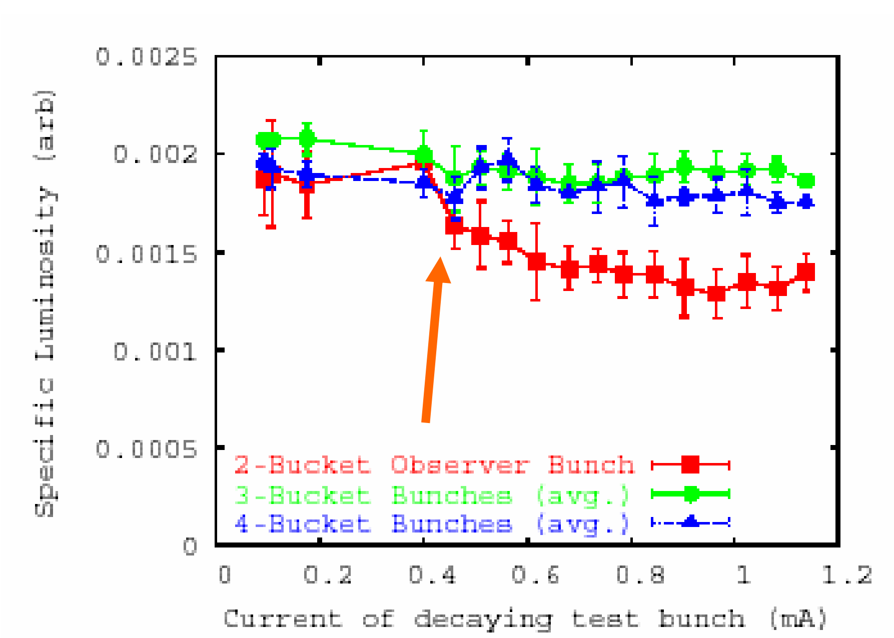


- Measure as a function of bunch current.
- Sideband is measured for noncolliding bunch.

- Luminosity degradation coincided with sideband appearance.

Type (1) (2)





Specific luminosity for 4ns spacing is lower below threshold?

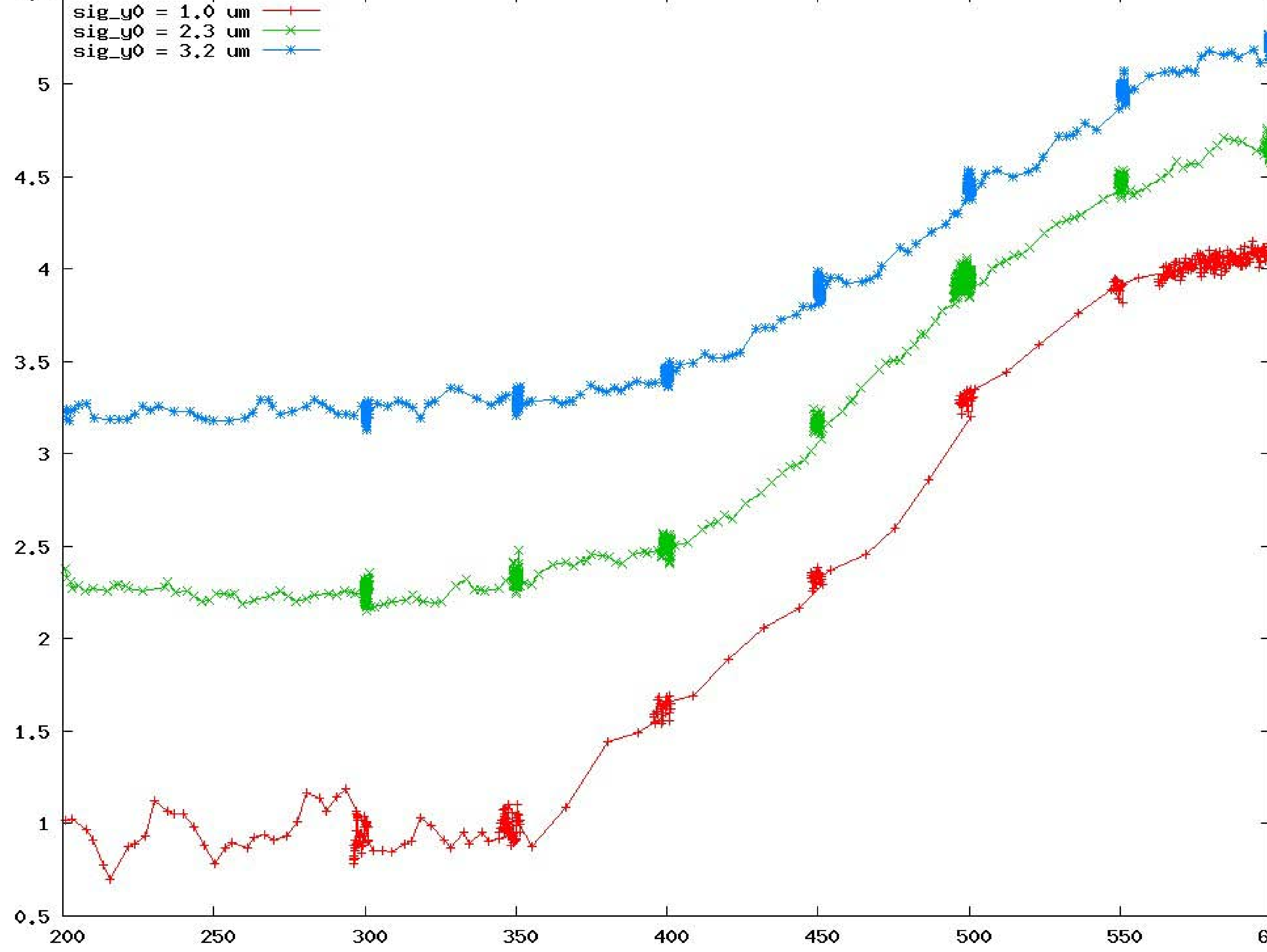
Is there another effect, incoherent effect?

Future problem 2

Emittance dependence

- The emittance of Damping ring is very small compare than KEKB.
- It is important to understand how the single bunch instability depend on emittance.

- Measurement results no clear emittance dependence.



sig_y0 = 1.0 um
sig_y0 = 2.3 um
sig_y0 = 3.2 um
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
200
250
300
350
400
450
500
550

Can we understood this behavior?

- Threshold

$$\rho_{e,th} = \frac{2\gamma\nu_s\,\omega_e\sigma_z/c}{\sqrt{3}KQr_0\beta L}$$

Q=min(Q_{nl}, $\omega_e\sigma_z$/c)

$$\omega_e = \sqrt{\frac{\lambda_p r_e c^2}{\sigma_y(\sigma_x+\sigma_y)}}$$

- ω_e of numerator is cancelled by ω_e in Q so perfectly?

  Future problem 3

- Maybe true, since $\omega_e\sigma_z$/c=2.5 for KEKB.

Summary

- Test antechamber was suppressed electron cloud with 1% level for low current (<100 mA), while the suppression was 10% at high current (>1A).
- Secondary efficiency seems to be ~1.1-1.2 in the measurements of KEKB installed chamber and samples.
- Spectra of coupled bunch instability showed the low secondary efficiency.
- Experiments for single bunch instability are consistent with strong head-tail model for threshold, while several problems remain.