Measurements of incoherent emittance growth at CesrTA and KEKB

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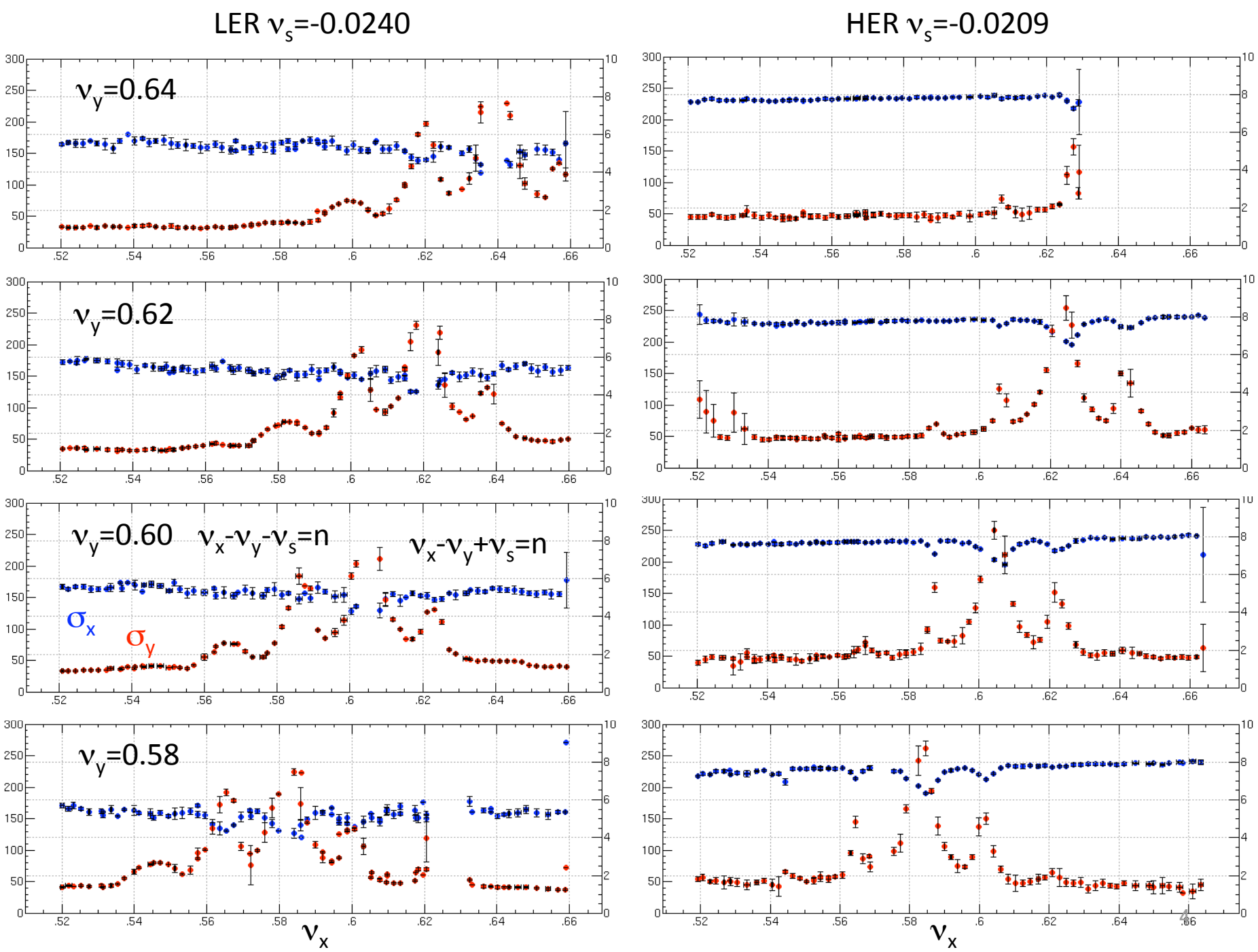
Incoherent emittance growth

- Studied and observed in beam-beam and space charge effects.
- Related to resonance and chaotic behaviors of beam particle motion.
- Beam-beam is localized interaction. All resonance harmonics exist.
- Electron cloud and space charge is not localized. Lattice structure, super period, cloud density distribution along s determines resonance harmonics. For the same tune shift as beam-beam, the incoherent effect due to electron cloud may be weaker than that due to beam-beam.

Measurement at KEKB

- Tune scan at 98 ns spacing; no electron cloud is supposed.
- 100 bunches, 80 mA
- Coupling resonance and its sidebands, ν_x-ν_y +kν_s=n (k=+-2) were seen.
- Coupling chromaticity induces the sidebands.


LER ν_s=-0.0240
HER ν_s=-0.0209
ν_y=0.64
ν_y=0.62
ν_y=0.60
ν_x-ν_y-ν_s=n
ν_x-ν_y+ν_s=n
σ_x
σ_y
ν_y=0.58
ν_x
ν_x

Beam size measurement with tune in multi-bunch operation

- Beam size was measured for changing fill pattern, which means changing electron density.
  - 100 bunches, 50 mA, single beam.
  - H. tune = 0.52
  - V. tune = 0.55, 0.56
- Sychro-beta sideband caused by electron cloud fast head-tail was seen at filling by 3 and 4.
- Synchro-beta sideband caused by electron cloud fast head-tail was not seen at filling by 6(12ns), 8(16ns), and 12(24ns), but emittance growth caused by coupling chromaticity resonance $\nu_x-\nu_y+2\nu_s=n$ disappear and weakened.
- Emittance growth far from the coupling the resonances was not seen.

Tune shift along the train

- Tune shift along the bunch train was measured (by T. Ieiri). 0.006, 0.004, 0.003 for 6 (12ns), 8(16ns) and 12(24ns) spacings, respectively.
- Beam size measurement was performed 0.002 step. A leak due to the tune shift (spread) is negligible.
- The tune spread of the resonance is wider ~0.01.

Beam Size vs. Fill Pattern

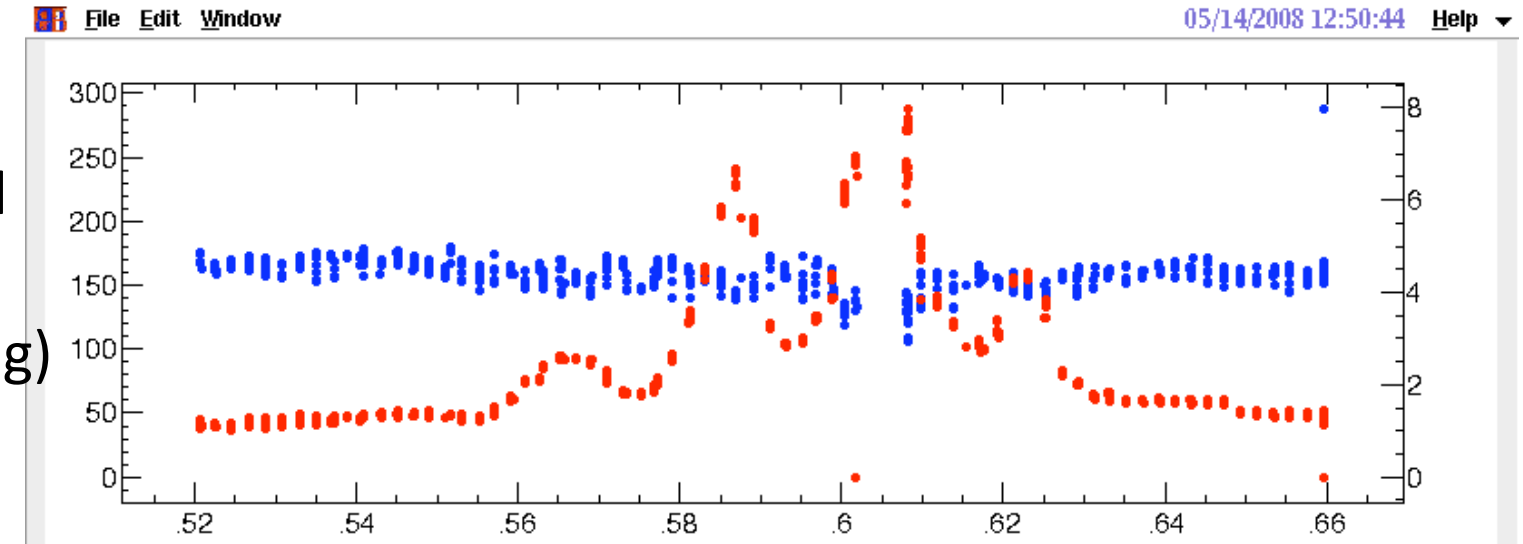
Bunches #	mA Total	mA /Bunch	Bucket Spacing	mA /Bucket	Head-Tail Sideband	σy (μm) @ νy = 0.55	σy (μm) @ νy = 0.56
100	50	0.5	3	0.167	◯進行方向振動	3.3	3.5
100	50	0.5	4	0.125	◯	2.3	2.5
100	50	0.5	5	0.100	?進行方向振動	1.7	
100	50	0.5	6	0.083	×	1.2	1.2
100	50	0.5	8	0.063	×	1.3	1.2
100	50	0.5	12	0.042	×	1.4	1.2
100	50	0.5	48	0.010	×	1.2	1.6

- Emittance growth seen at $\nu_x-\nu_y+2\nu_s=n$ ($\nu_y=0.56$) disappear narrower spacing than 24 ns.
- Emittance growth far from the coupling ($\nu_y=0.55$) the resonances was not seen.

H. Tune Scan (at ν_y=0.6)

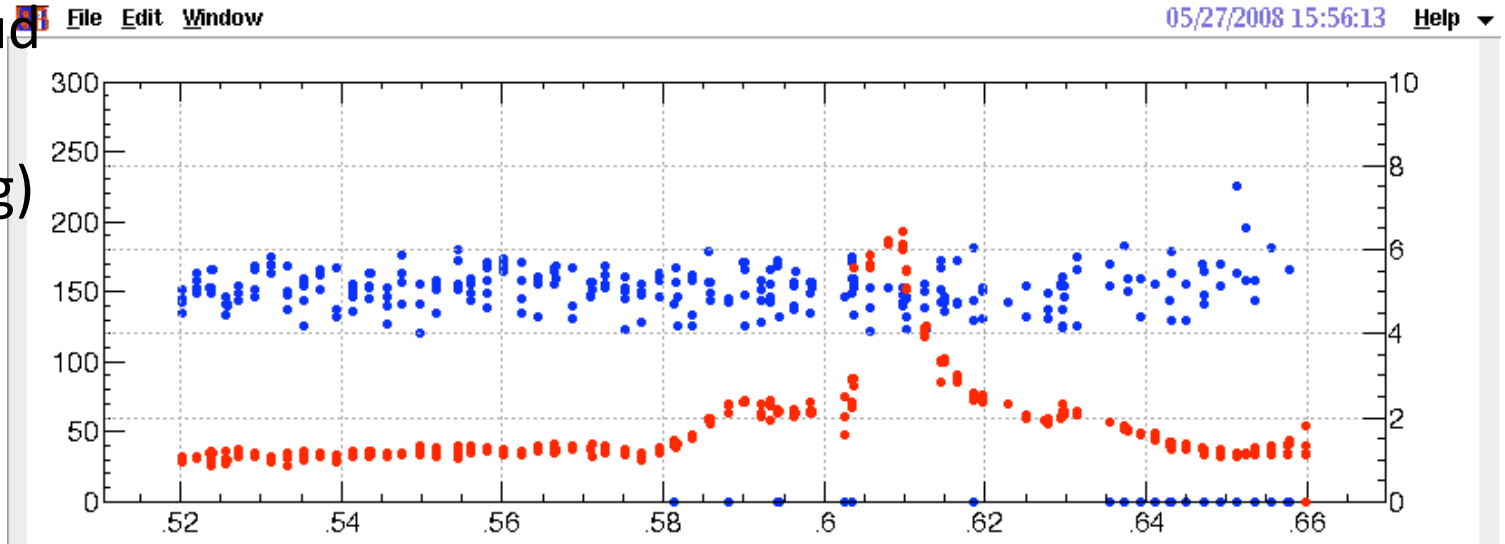
- No e-cloud (5/14)

  (98ns spacing)



- With e-cloud (5/27)

  (16ns spacing)



Summary for KEKB measurement

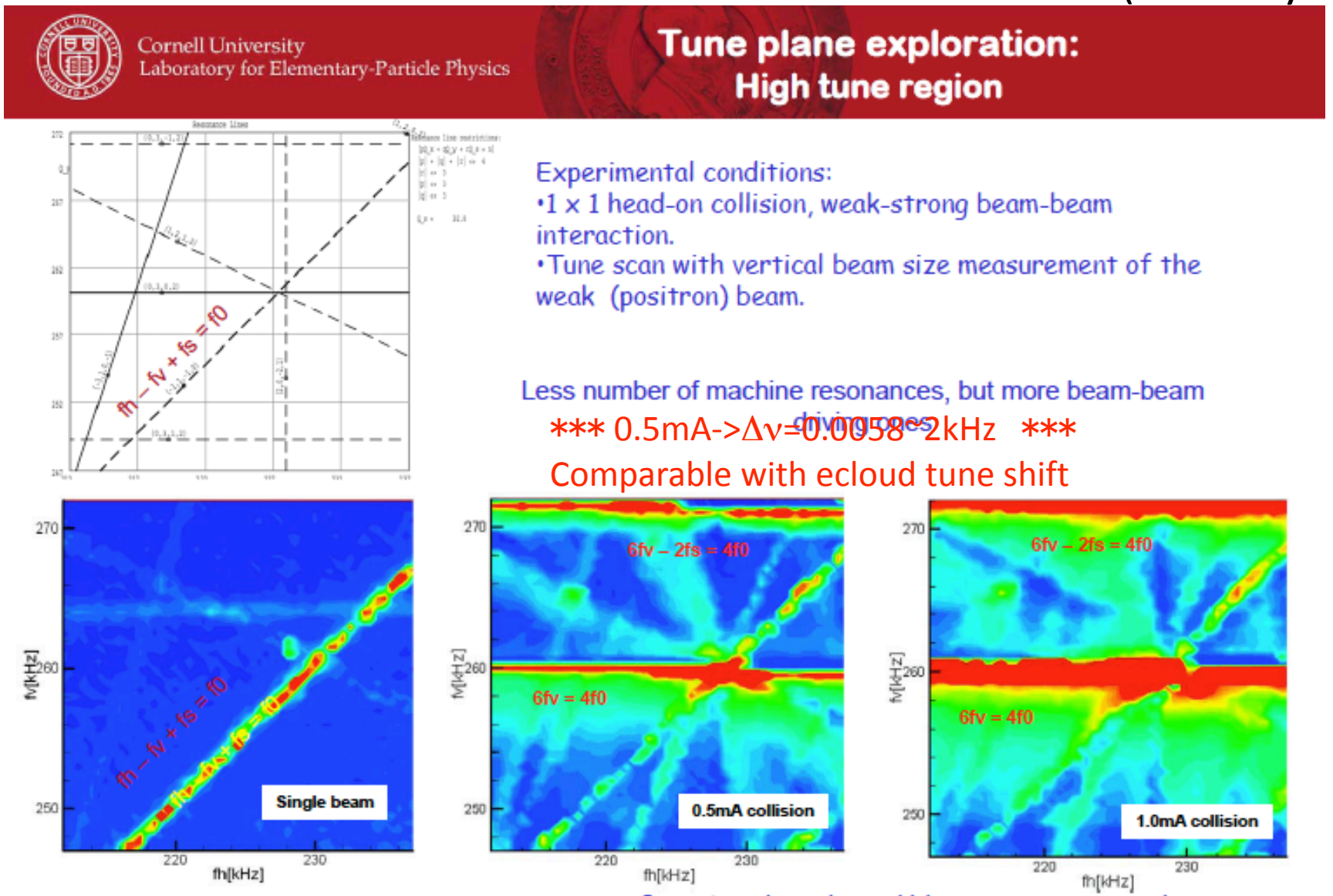
- The coherent electron cloud fast head-tail instability was dominant in KEKB: that was, emittance growth was not seen at operating point far from chromatic synchro-beta resonance below the threshold of the coherent instability.
- The chromatic synchro-beta was weakened by electron cloud rather than emittance growth.

CesrTA

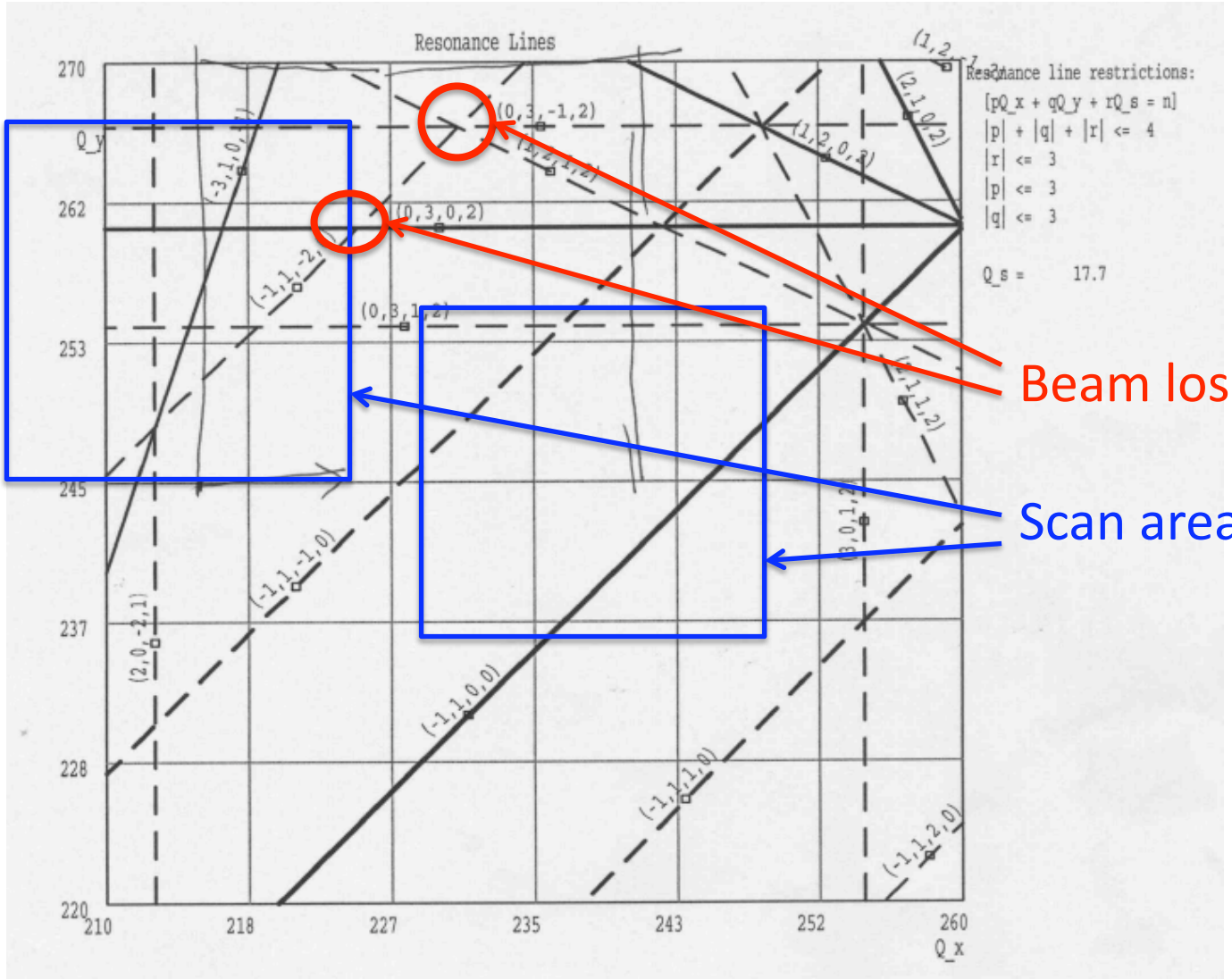
- Emittance growth due to beam-beam interaction has been measured by A. Temnykh et al.
- The same measurement was performed under the presence of electron cloud; multi-bunch with 14 ns spacing, on June 27-29, 2008.

- I stayed Cornell on the days. I apologize not to attend this workshop.

Measurement for CESR-c beam-beam (A.Temnykh)



Tune scan area



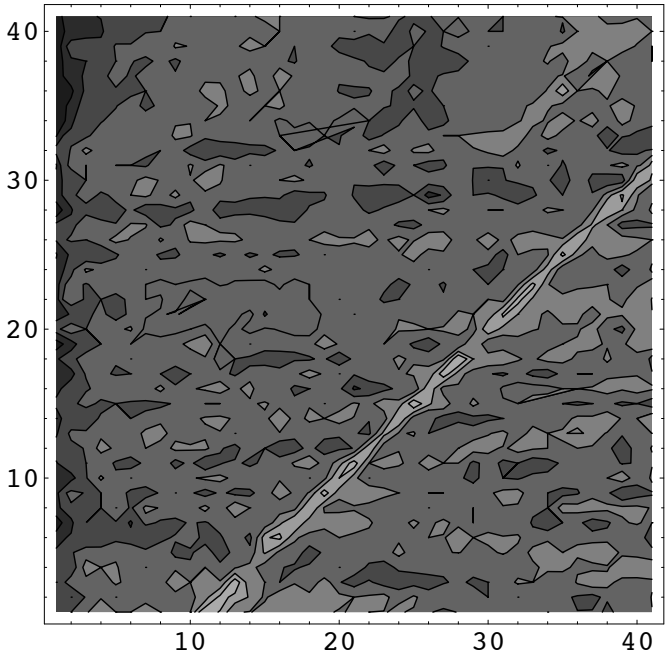
Single bunch 3 mA (as a reference)

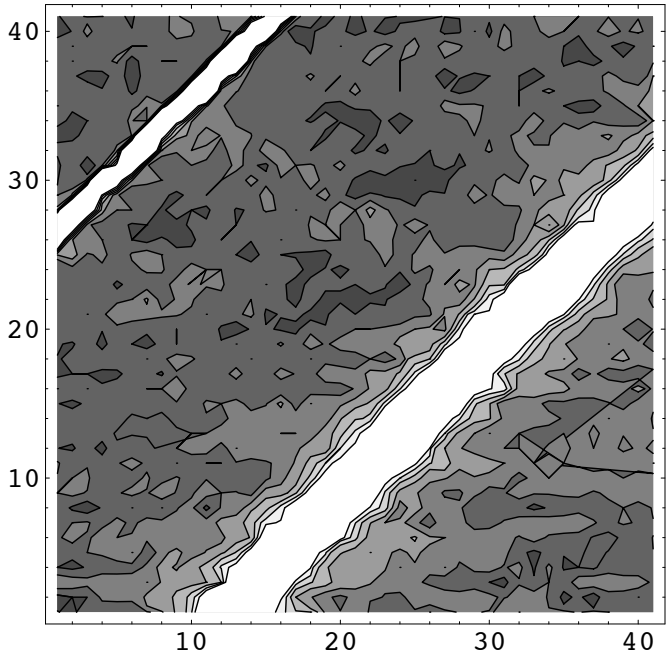
- Region I x=205-225 kHz, y=245-265 kHz, 0.5kHz step

  ν_x=0.525-0.577, ν_y=0.628-0.679, $\Delta\nu$=0.00128
- Region II x=230-250 kHz, y=236-256 kHz, 0.5kHz step

  ν_x=0.590-0.641, ν_y=0.605-0.656, $\Delta\nu$=0.00128

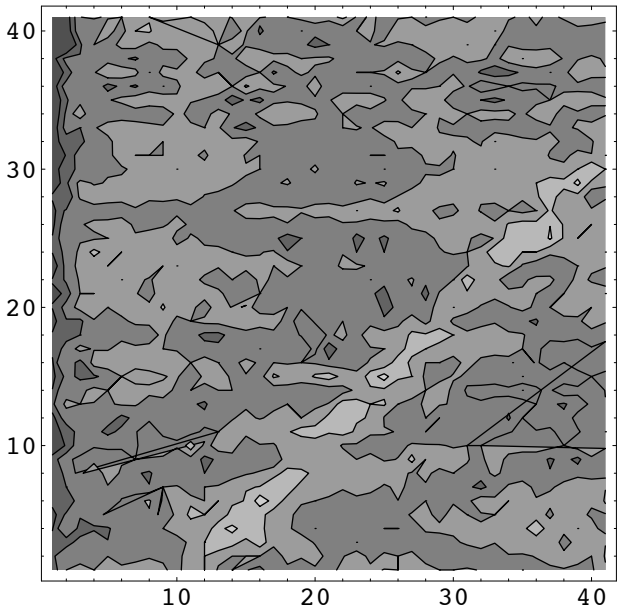
Beam loss near cross points of several resonances. The scan area is decided to avoid the loss area.

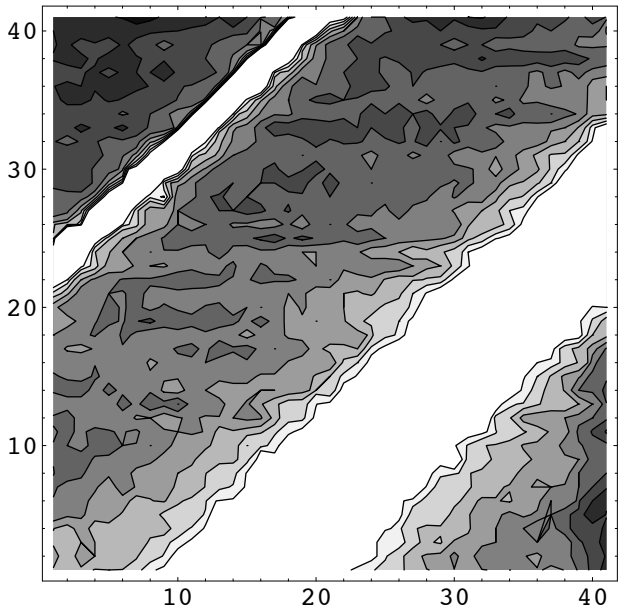




Multi-bunch operation

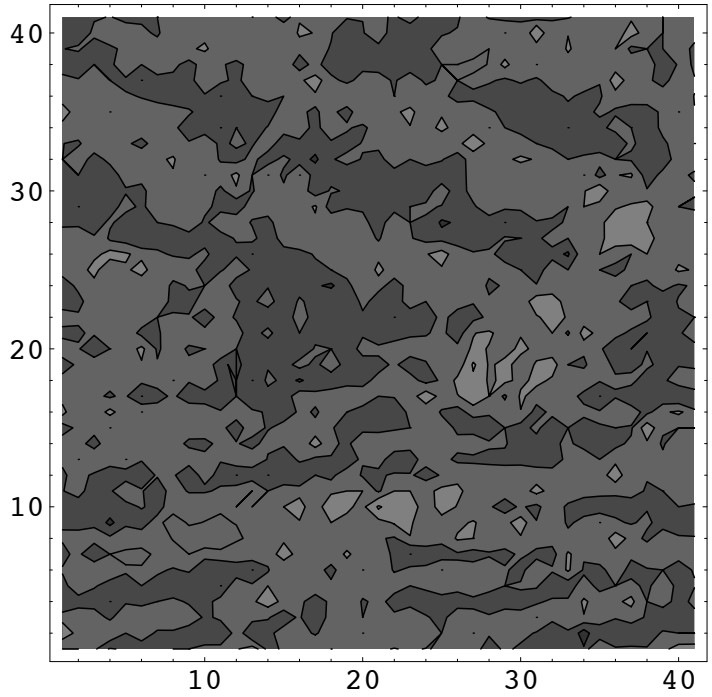
- 2.7mA x 10 bunches, 14ns

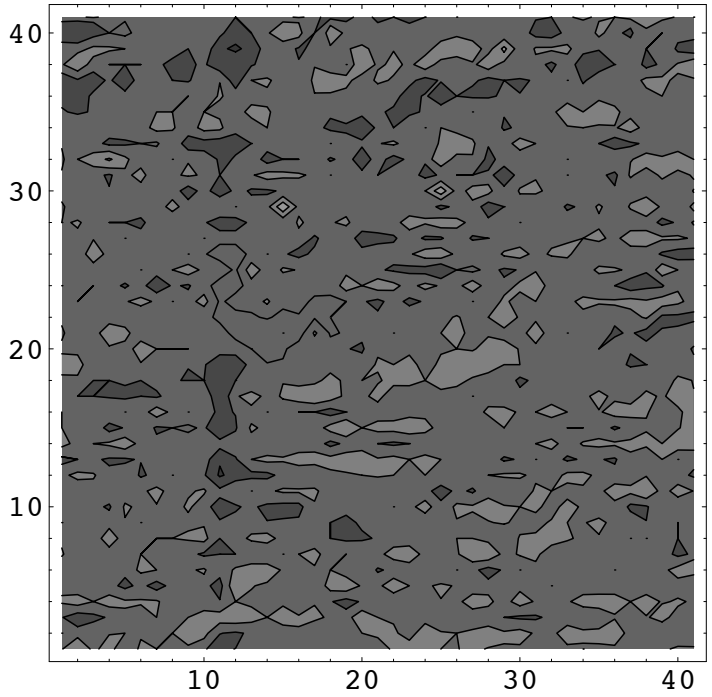




Higher current

- 47mA 70mA



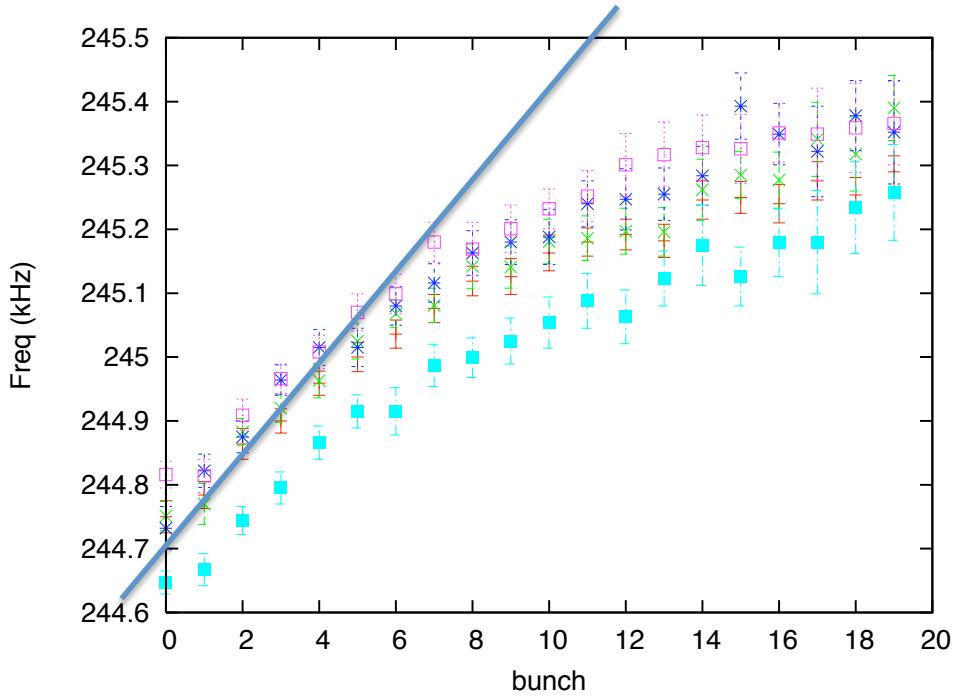


Results of the experiment

- No clear emittance growth relate to resonances were not seen, even very high current 7mA/bunchx10bunch, 14ns. While beam-beam interaction induced many resonances.
- The resonance line $\nu_x-\nu_y-2\nu_s=n$ is weakened as similar as KEKB.

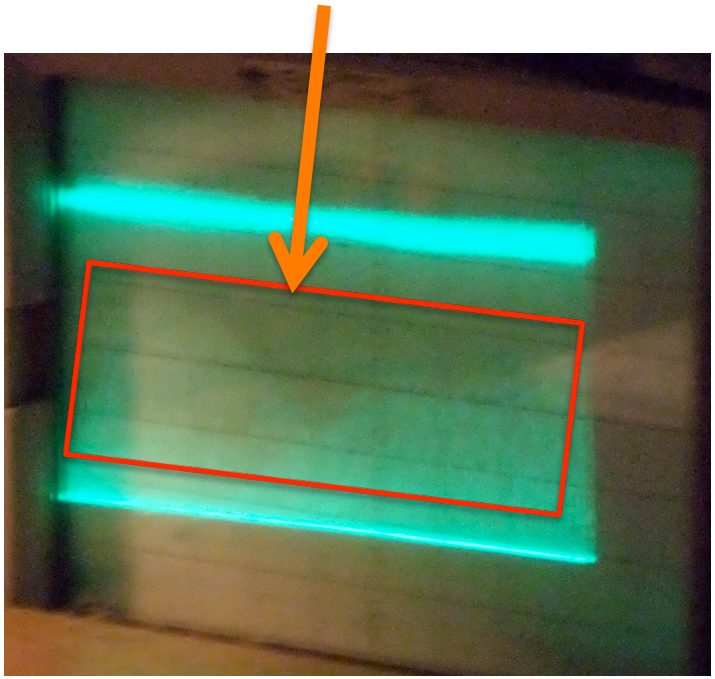
Tune shift in several operating points

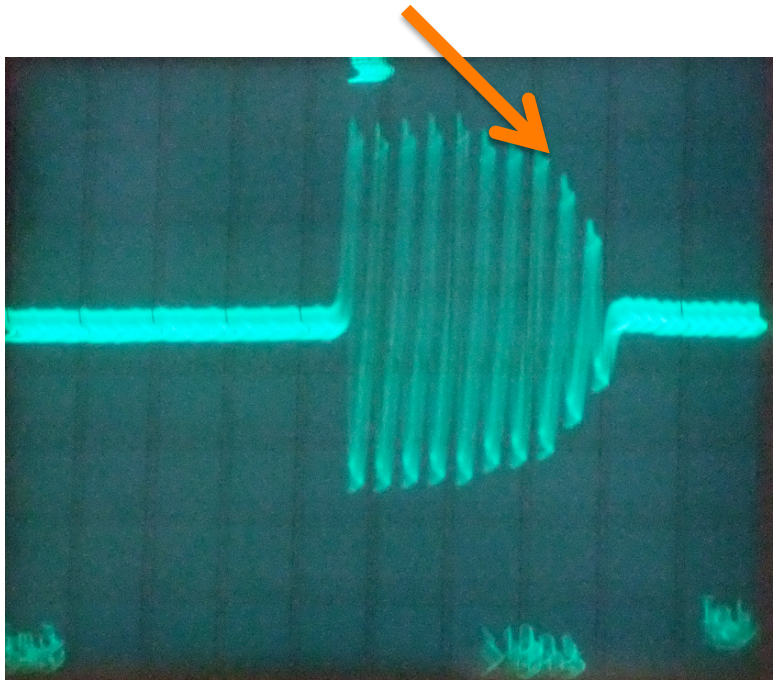
- Tune shift does not depend on the operating point. Maybe obvious.
- 0.75mAx20bunches, 14ns
- $\Delta\nu_y$=0.0002/bunch(=0.07-0.08kHz/bunch), saturate 10-20 bunches, $\Delta\nu_y$=0.002=0.7kHz.



Dipole oscillation

- Coherent motion due to coupled bunch instability is sometimes observed during the measurements.
- Coherent vertical dipole motion and beam loss at the tail part.





•Tunes can be measured without excitation. This means that self coherent motion exists.

•Control of coherent motion should be done. M. Tobiyama told me he could stop the motion by an investment of $50,000.

Further experiments

- Tune shift along the train is larger than the scan step. For 7mA/bunch, $\Delta\nu$~7kHz
- Bunch by bunch beam size measurement is necessary.
- Longer bunch train, saturation of tune shift, may be possible, but coupled bunch instability is more serious.

Summary

- No sign for incoherent emittance growth for the present.
- Control of coherent dipole oscillation is urgent business. It prevents detailed measurement for the beam size, because a smeared dipole motion gives emittance growth.
- We tried very high current, 70mA 10 bunches. Coherent fast head-tail instability may be observed in this condition as discussed another talk.