Transition Studies

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Intro

- Single bunch transverse instability and related beam losses have been a known effect at the transition in previous RHIC runs (with bunch spacing 216ns and more). Remedies developed during the machine operation included:
  - Using arc octupoles to introduce tune spread
  - Fine adjustment of chromaticity crossing 0 just before the transition
- Studies, which are presented in this talk, concentrated on measurements with bunch spacing 108ns (120 bunch pattern). Results demonstrate that in this bunch pattern the electron cloud and electron-ion interaction become the essential ingredient of beam dynamics at the transition region.
- Observations include:
  - Bunch-train dependence of loss, emittance
  - Trailing-edge phenomena

e-cloud parameter regime (2005)

- Single beam (blue), up to 41 bunches, 3-bucket, 108 ns spacing
- Cu, 5×10^9 per bunch; varying RF voltage and octupole strength

Table 1: RHIC parameters during year 2005 *e*-I study.

Ring revolution period	12.79	μs
Aperture, IR (2/6/8/10, 4/12)	7, 12	cm
Aperture (arc, triplet)	7, 13	cm
Beam species	Cu^{29+}	
Energy, injection - top	9.8 - 100	GeV/u
Transition energy, γ_T	22.9	
Bunch intensity	5×10^9	
Bunch center spacing	108	ns
Bunch length at transition, full	~ 5	ns
Electron bounce frequency	~ 400	MHz
Peak bunch potential	~ 1.6	kV
e^- energy gain upon acceleration	~ 300	V

Beam loss vs. bunch sequence

- Effect first noted during 120 bunch pattern studies by Wolfram and Ubaldo.
- Measured in details during consequent transition studies.
- Puzzle: why the first-bunch beam loss is much higher than nominal, 216 ns spacing case (where the loss is at less than 5%)?

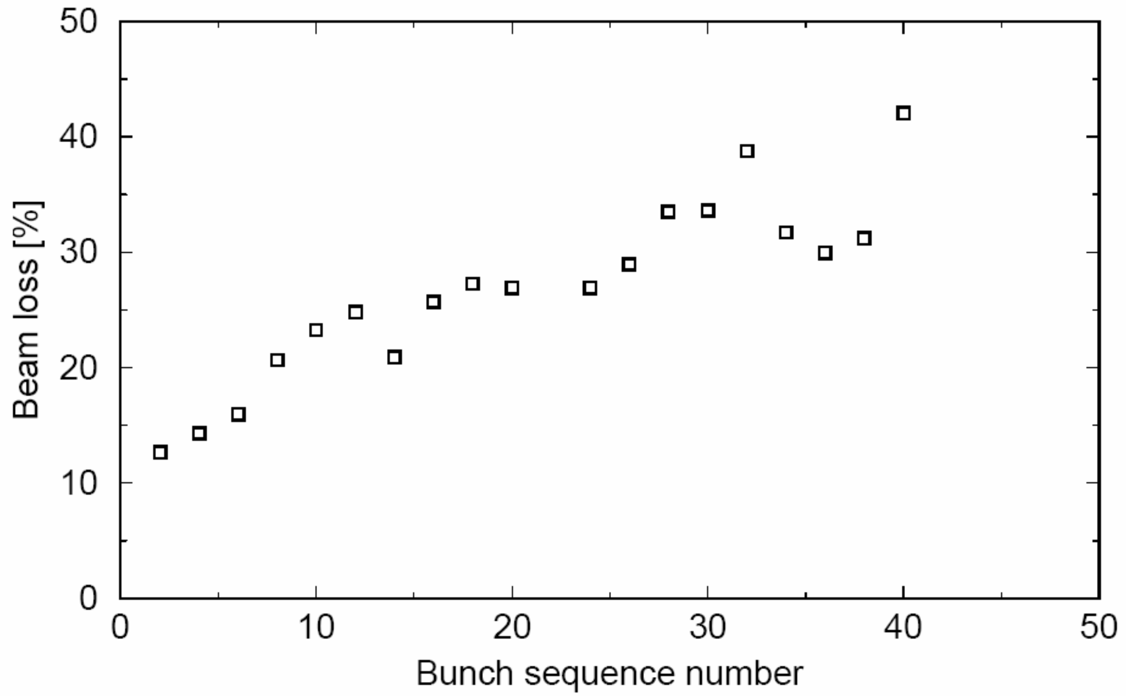

Figure 3: Beam loss at transition as a function of bunch sequence number with V_{rf}=200 kV and $b_{oct} = -3$ unit.

Instability observation

- Loss occurs about 10 ms after transition for about 100 ms.
- Transverse instability is seen by coherence monitor.

WCM data

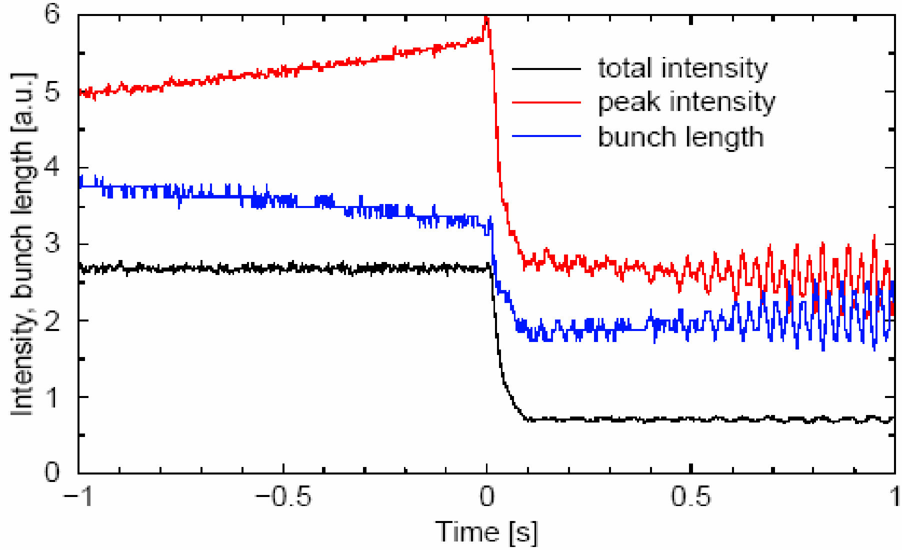

Figure 2: Beam loss and bunch size variation of bunch #40 at transition with $V_{rf} = 300$ kV and $b_{oct} = -3$ unit.

Coherence monitor data

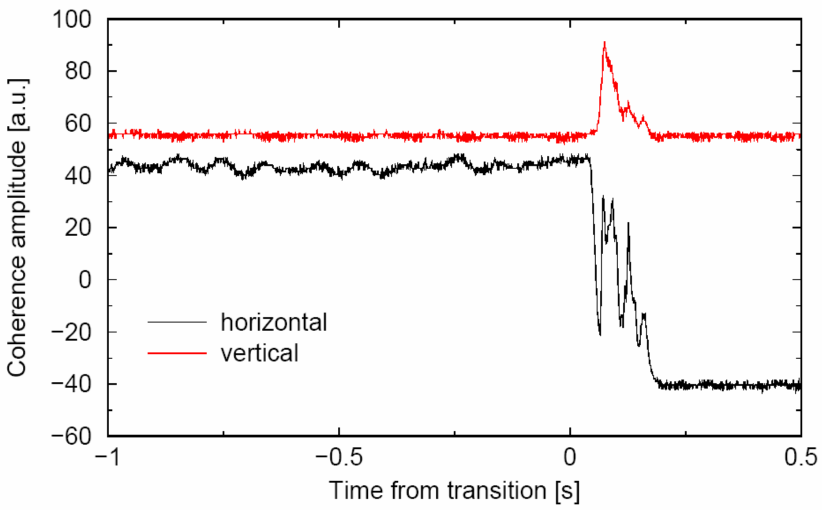

Figure 5: Coherence signal of bunch #40 from the turn-by-turn BPM data. The horizontal instability signal is within a step caused by the orbit shift due to γ_T-jump.

Beam loss at the bunch trailing edge

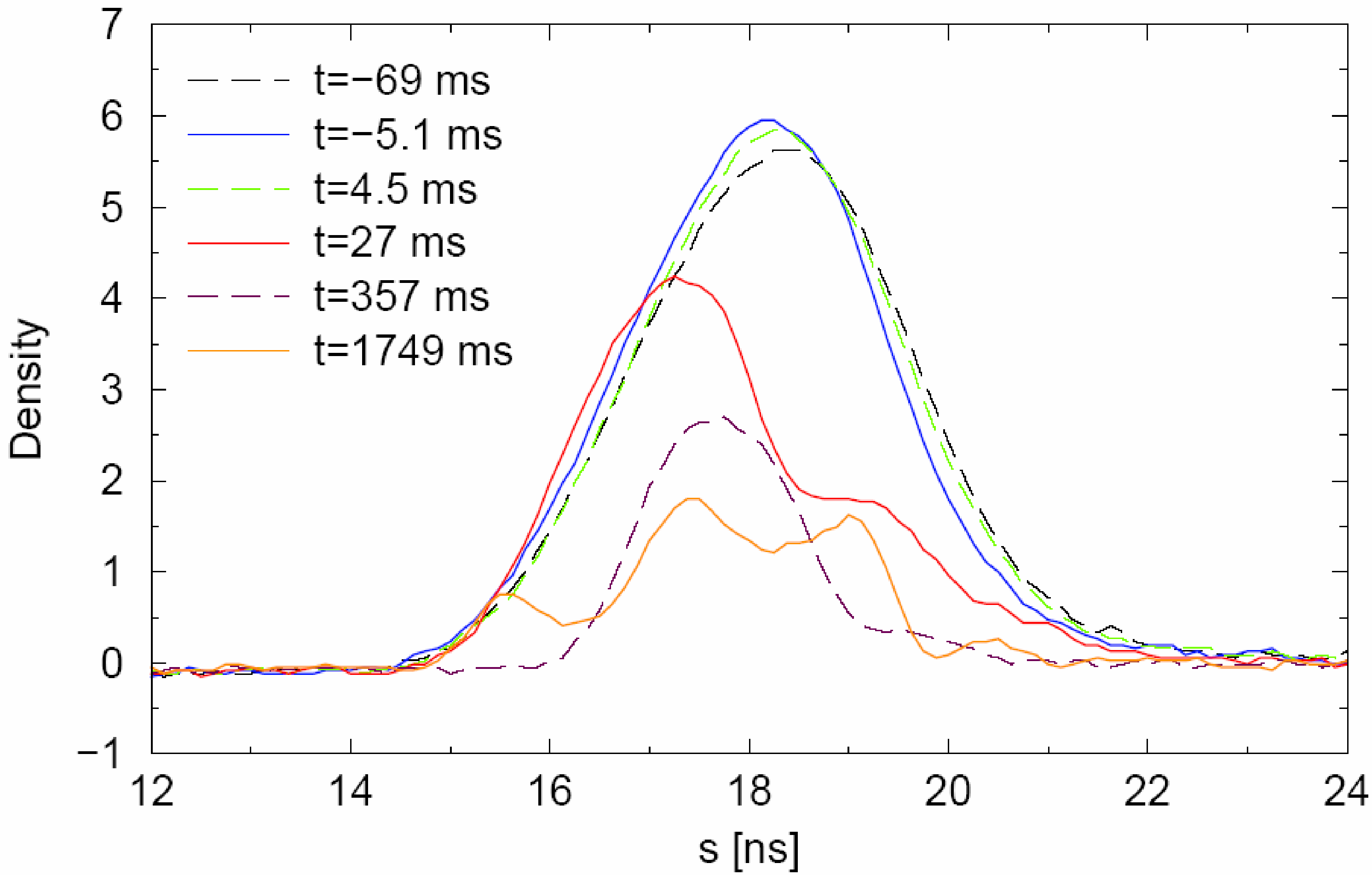

Figure 9: Evolution of the longitudinal profile upon the beam loss near γ_T with V_{rf}=300 kV and $b_{oct} = -4$ unit.

Transverse emittance growth

- When beam loss is relatively moderate, emittance growth shows bunch train dependence
- It is difficult for IPM to work near transition (electron? Loss/pressure/background?)

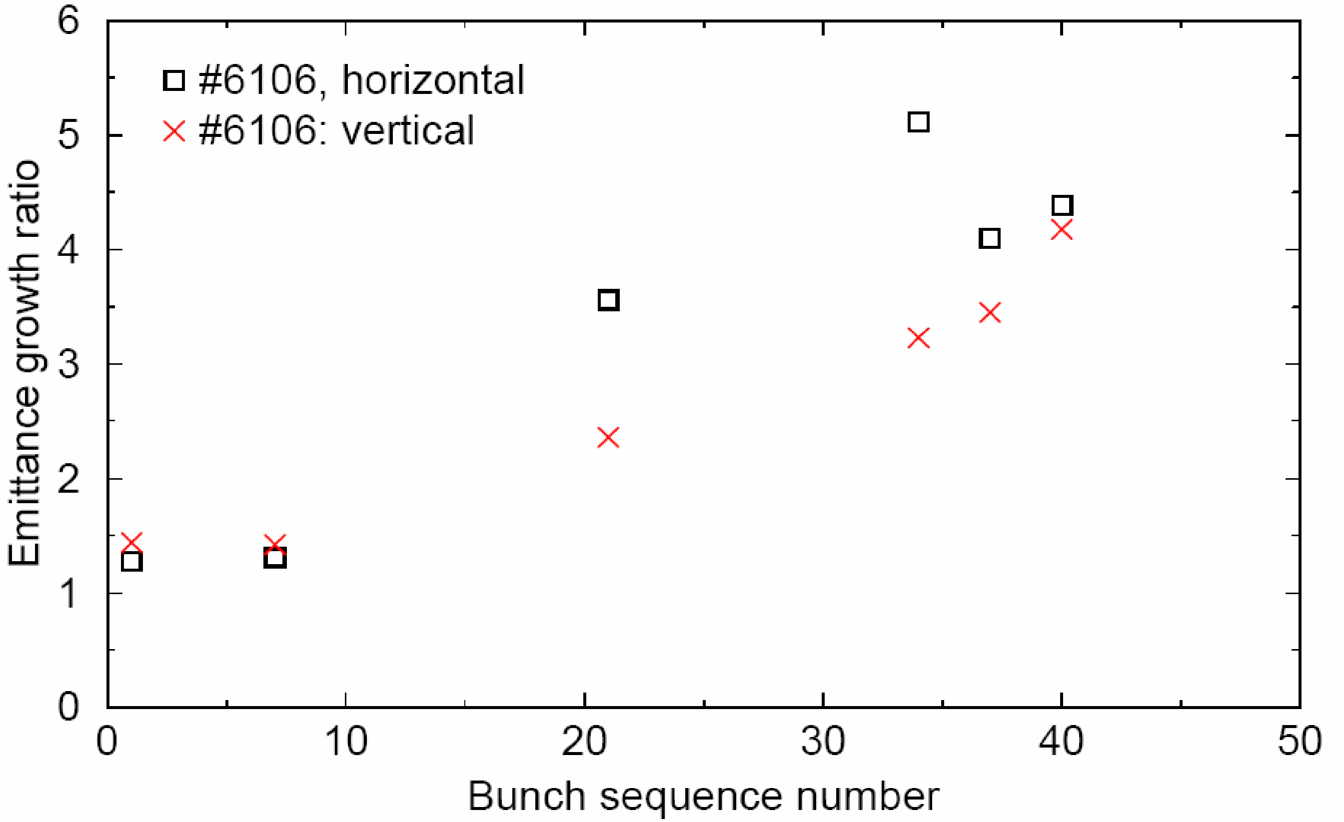

Figure 8: Bunch train dependence of the beam emittance growths at γ_T with V_{rf}=100 kV and $b_{oct} = -4$ unit.

Octupole dependence (weak)

- Higher octupole strength: lower loss, lower coherence

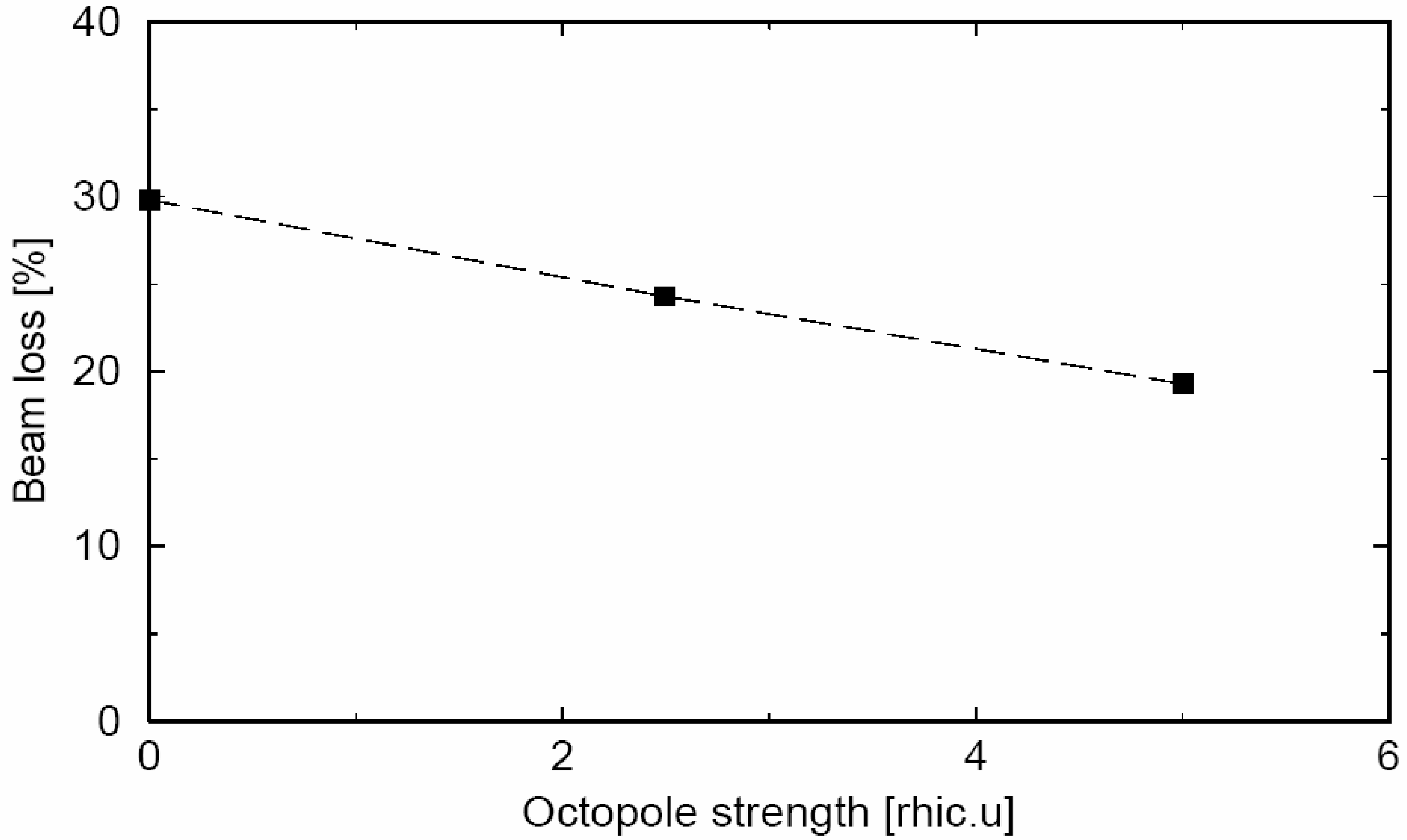

Figure 7: Average beam loss at transition as a function of the octupole magnet strength $|b_{oct}|$ with $V_{rf} = 200$ kV.

RF voltage dependence (strong)

- Lower RF voltage: no coherence; lower beam loss; lower e-flux
- RF manipulation can possible cure the problem!

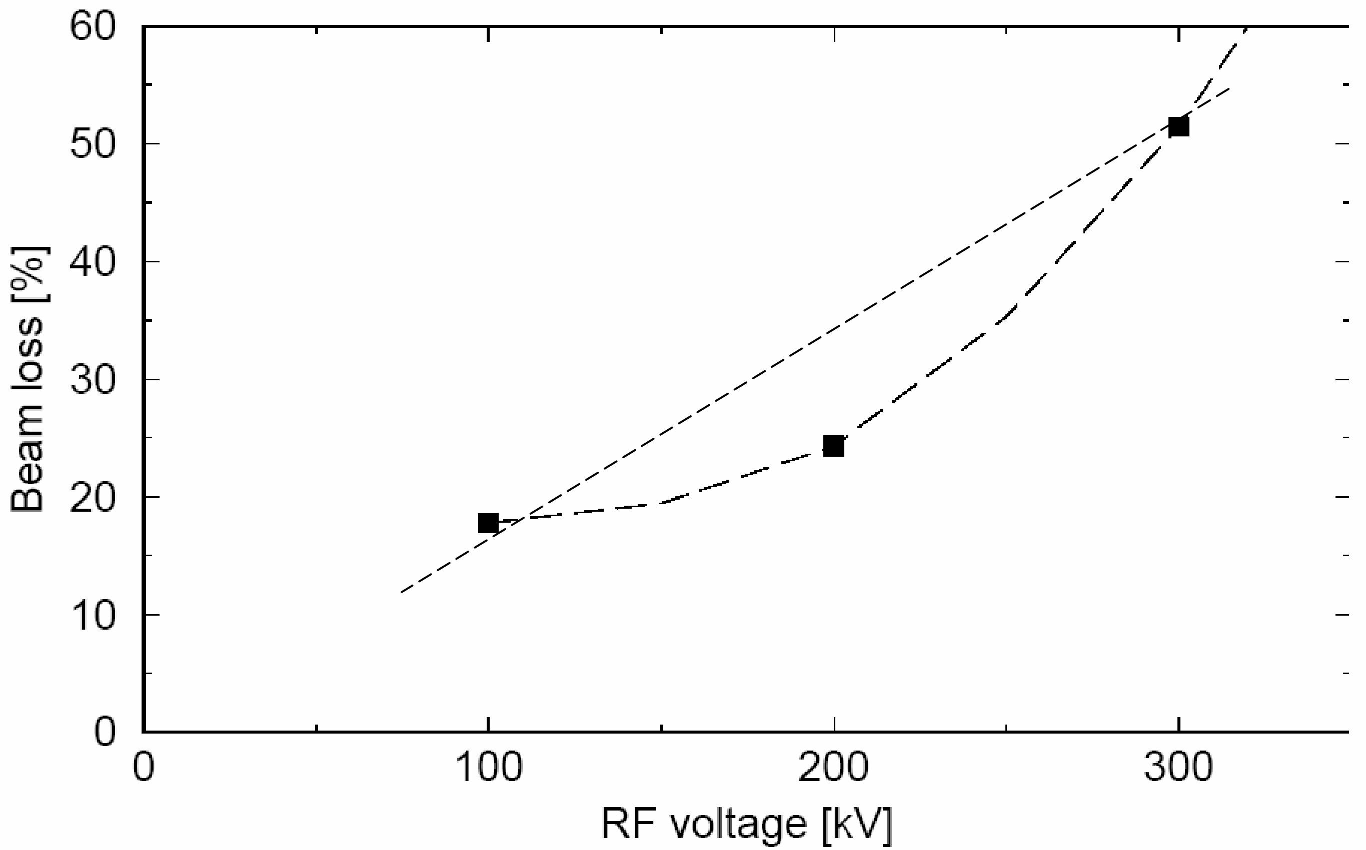

Figure 4: Average beam loss at transition as a function of the RF voltage with $b_{oct} = -3$ unit.

Is it electron?

- Measured electron flux that correlates to pressure and bunch-train dependence of beam loss
- Bunch-train dependence of beam loss, emittance growth, instability growth
- Trailing-edge beam loss

➢ A definitive measurement would be tune shift along the bunch train

  ➢ Previously measured at injection

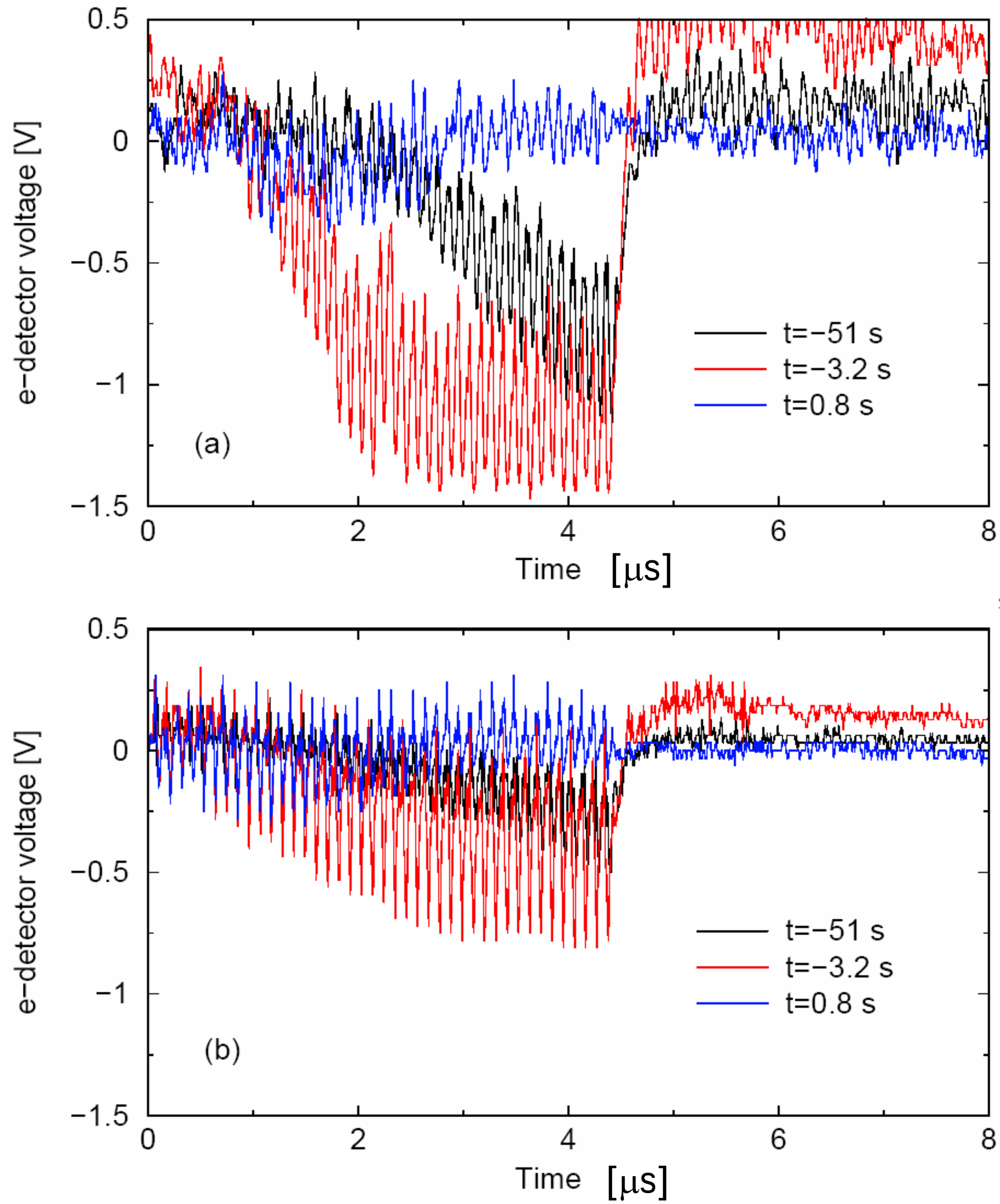

Figure 10: e-flux measured in the (a) horizontal and (b) vertical directions near γ_T. An ac-coupled amplifier is used with a low-frequency cut-off of about 300 kHz. The grid is not biased. The collector is biased at 50 - 100 V positive.

Conclusion

- Electron cloud is a serious obstacle on RHIC's upgrade path
- More simulation is needed especially on electron-ion interaction and vacuum pressure rise (2/3 of the work to be done: electron generation, vacuum pressure rise, and e-I interaction)
- More beam study is needed to resolve open questions

- For more details and result discussions:

1. J.Wei et al., "Observation of Electron-Ion Effects at RHIC Transition", PAC05
2. J.Wei presentation at RHIC Retreat 05