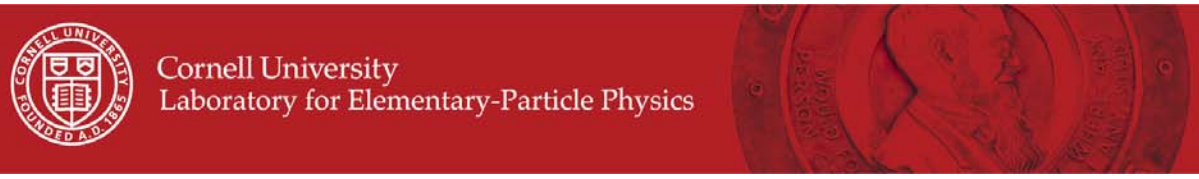
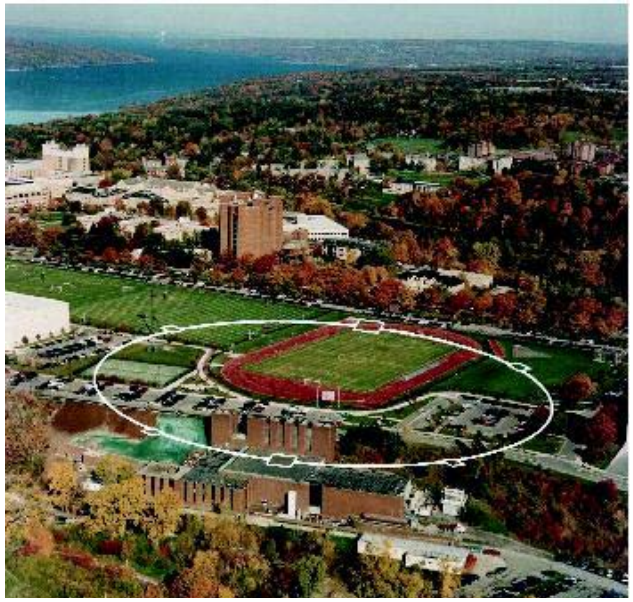


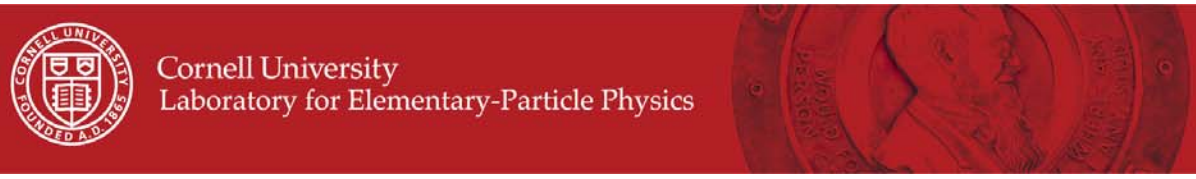
Recent electron cloud studies at CESR

David Rice

Cornell University

Laboratory for Elementary-Particle Physics





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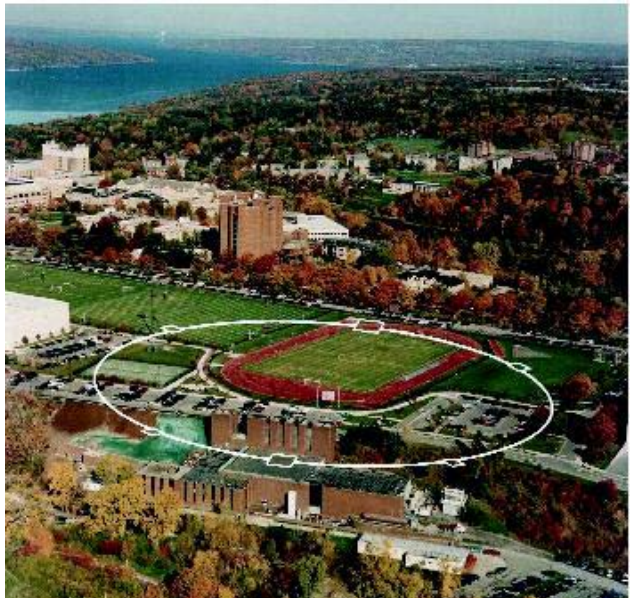


A special thanks to Eugene Tanke and Jerry Codner for preparation of these slides.

Presentation Outline

- Measurements Performed at CESR
- Key Beam Diagnostics used
- Electron Cloud Experiments
- Other Phenomena

Measurements made at CESR

- Investigation of possible electron cloud effects
  - Look for vertical tune shift for positrons (coherent)
  - Look for positron beam size blow up (incoherent)
  - Check effects for electrons
- Other phenomena
  - Onset of instability in vertical beam size and vertical position
  - Tune split (betatron sideband) vertical and horizontal
  - Other effects on positrons and electrons

Machine conditions at CESR

- Machine conditions
  - electrostatic separators always off
  - bunch patterns
    - one long train of 45 bunches, 14 ns spacing
    - widely separated (280 ns) trains of 5 bunches (14 ns spacing) used in operation
  - bunch currents
    - 0.25 to 1.5 mA per bunch in 45 bunch trains, 14 ns spacing
    - 1.0 to 8.0 mA per bunch in widely separated bunch trains
  - beam energy: high (5.3 GeV) and low (~ 2 GeV)
  - 12 wigglers on versus 6 wigglers on (low energy only)
  - Transverse feedback on and off
  - With and without low field solenoid in 15 meter straight section

Next topic

- Measurements Performed at CESR
- Key Beam Diagnostics used
- Electron Cloud Experiments
- Other Phenomena

Key beam diagnostics used (1)

- BSM (Beam Size Monitor)
  - shuttered, 32 channel linear PMT array looking at synchrotron light
  - one sample per channel per bunch on each turn
  - separate DAQ for each species samples up to 183 bunches
  - optics accommodate linear CCD array and TV camera

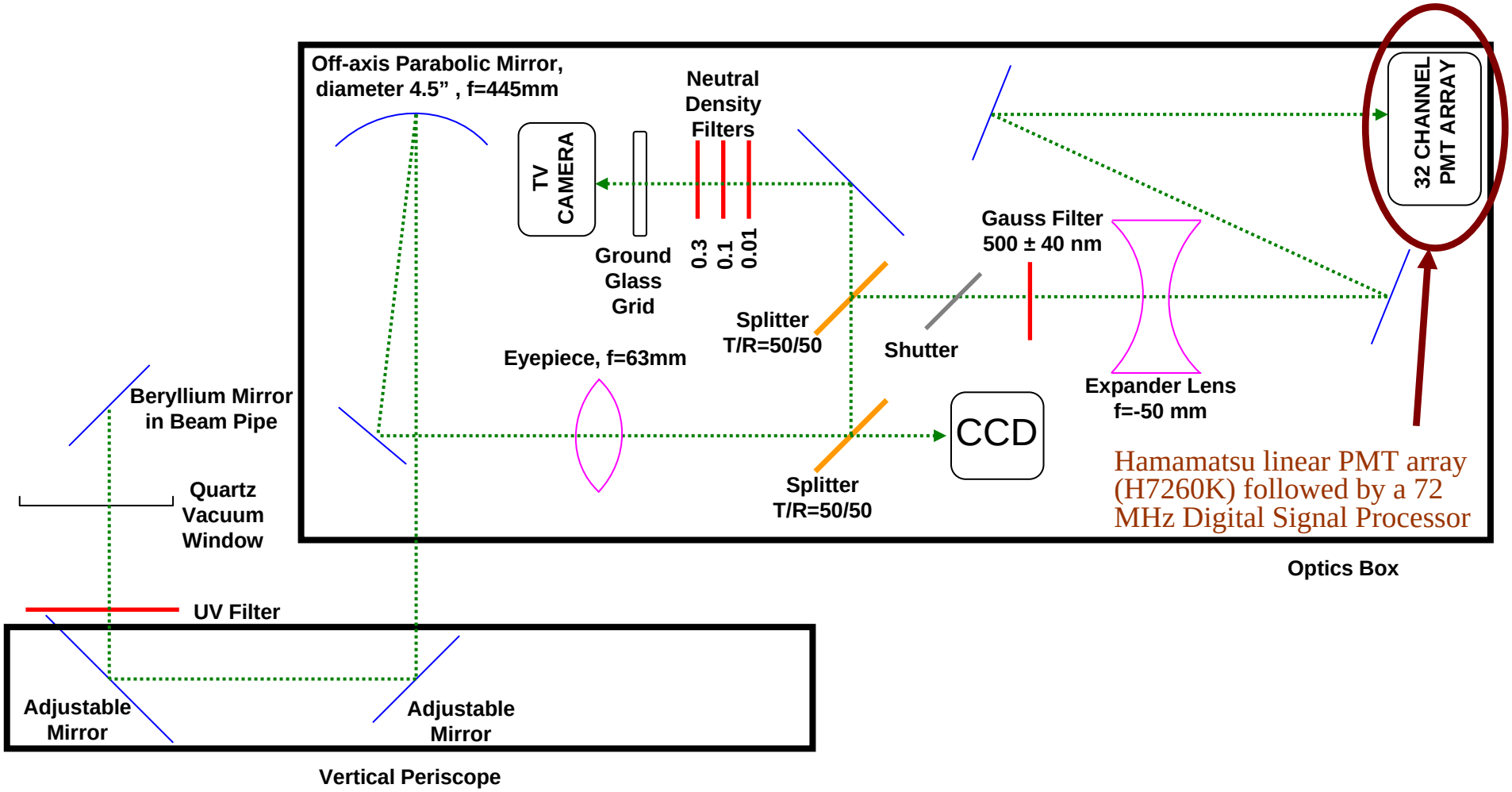
- BPM (Beam Position Monitor)
  - uses four beam buttons, four channels per beam
  - one sample per channel per bunch per species on each turn
  - one DAQ samples up to 183 bunches per species

- Major Differences
  - BPM is 2 beams per DAQ, 8 channels total (8k turns for 45 bunches)
  - BSM is 1 beam per DAQ, 32 channels
  - BSM requires much more data to be transferred
  - BSM requires much more sophisticated and CPU intensive analysis

Key beam diagnostics used (2) : Optics

BSM synchrotron light optics line for positrons

(optics line for electrons is similar)



Key beam diagnostics used (1)

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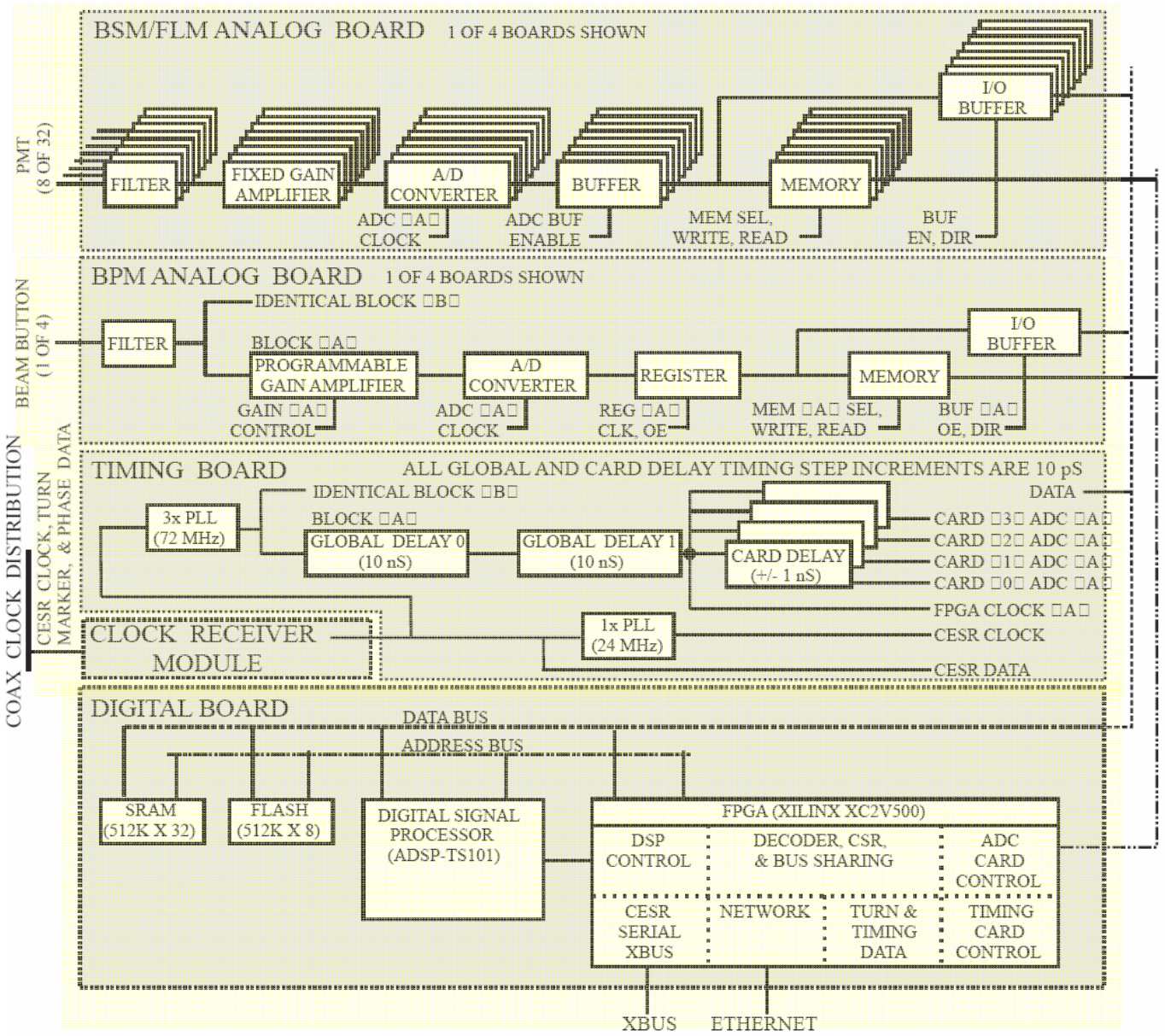
Key beam diagnostics used (3): DAQ



- DAQ is based on a 72 MHz Digital Signal Processor (DSP) capable of turn by turn and bunch by bunch data acquisition
- Similar architecture for BPM and BSM

Beam Diagnostics Time Line

- Beam diagnostics used in EC experiments evolved during 2006.
- Initial diagnostics were **turn-by-turn beam position measurements** for each bunch and **measurements of vertical beam size** averaged over all bunches.
- Turn-by-turn vertical beam size measurements for each bunch were added for electrons in June and for positrons in August.

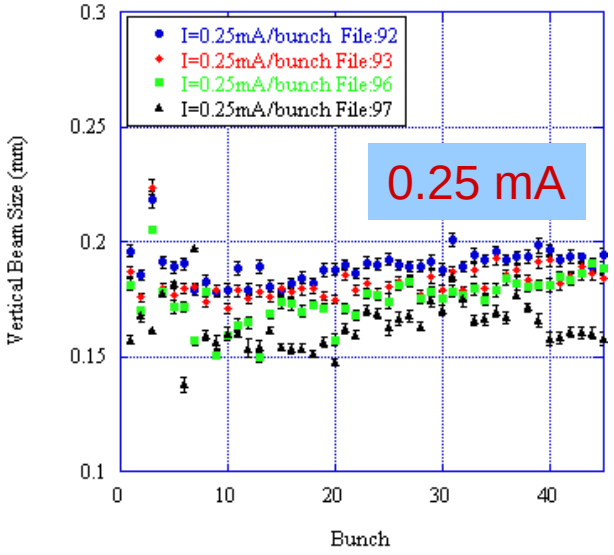
Next topic

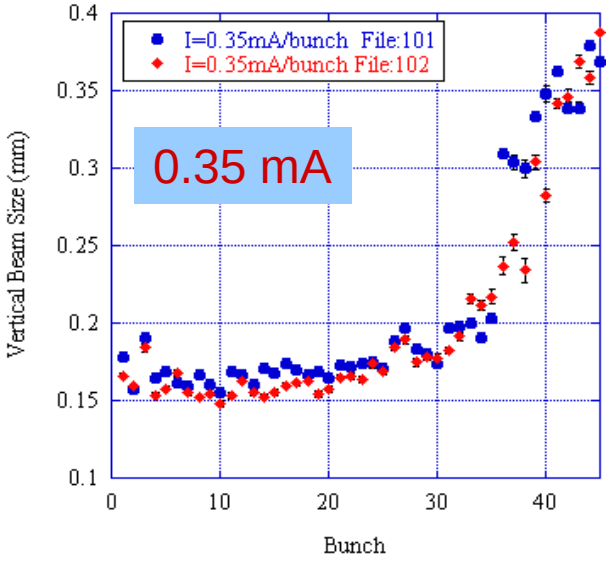
- Measurements Performed at CESR
- Key Beam Diagnostics used
- Electron Cloud Experiments
- Other Phenomena

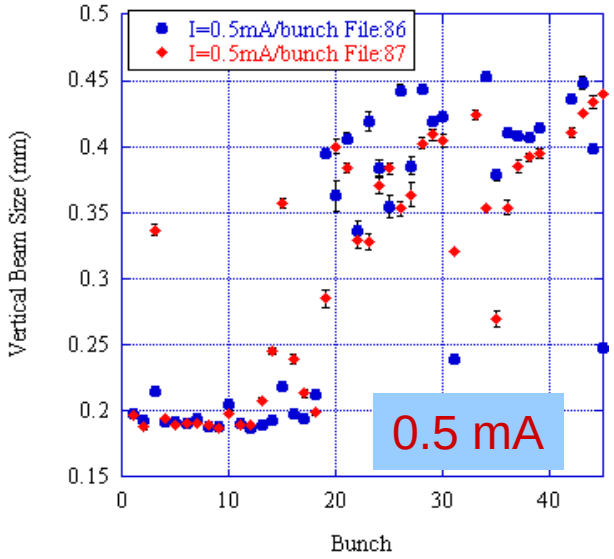
Evidence of e+ beam size blow up found

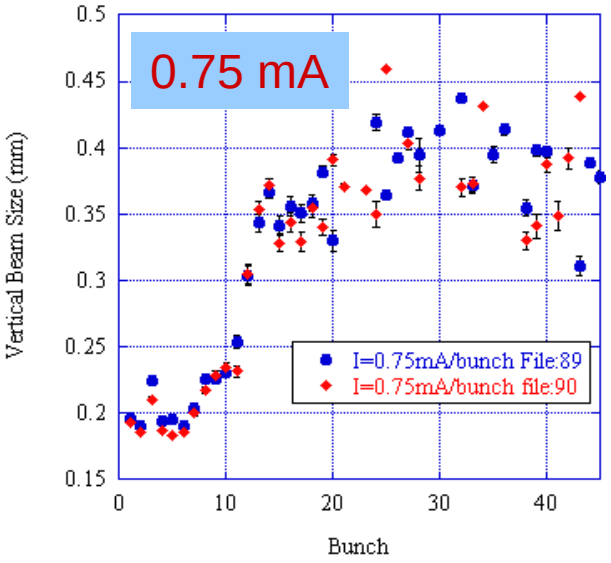
2 GeV vertical beam size for 1x45 pattern, positrons

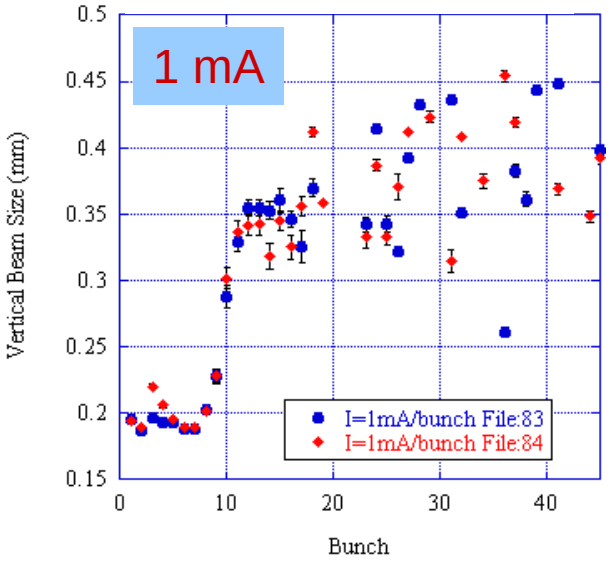
Notice advancing onset of beam size blow up as a function of bunch current





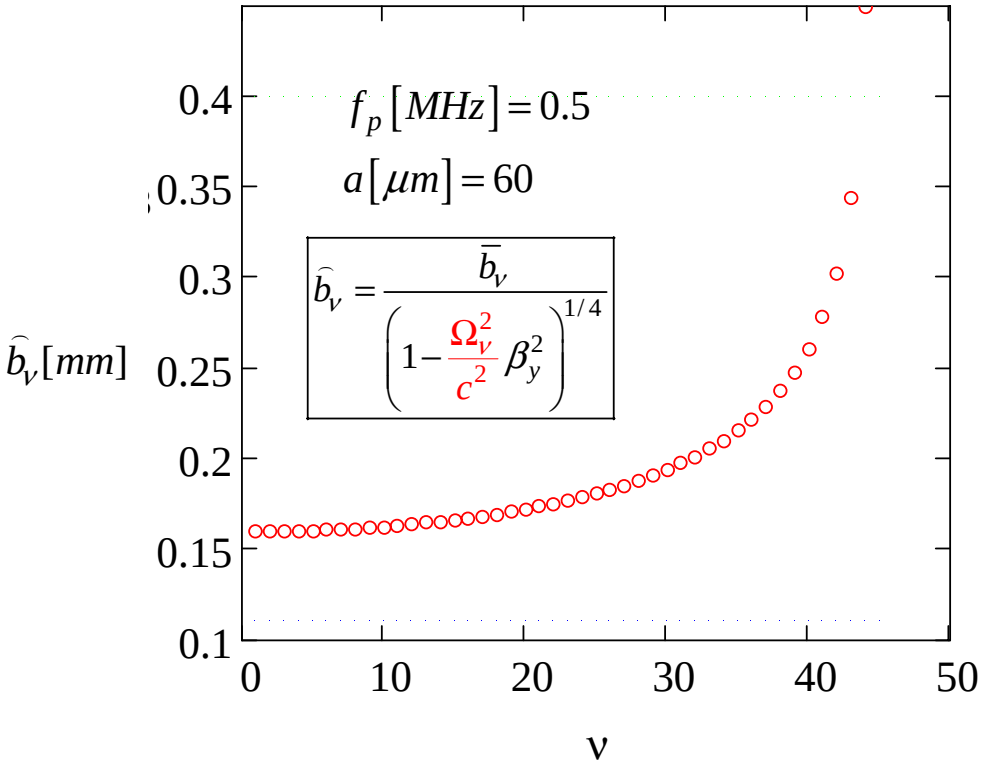


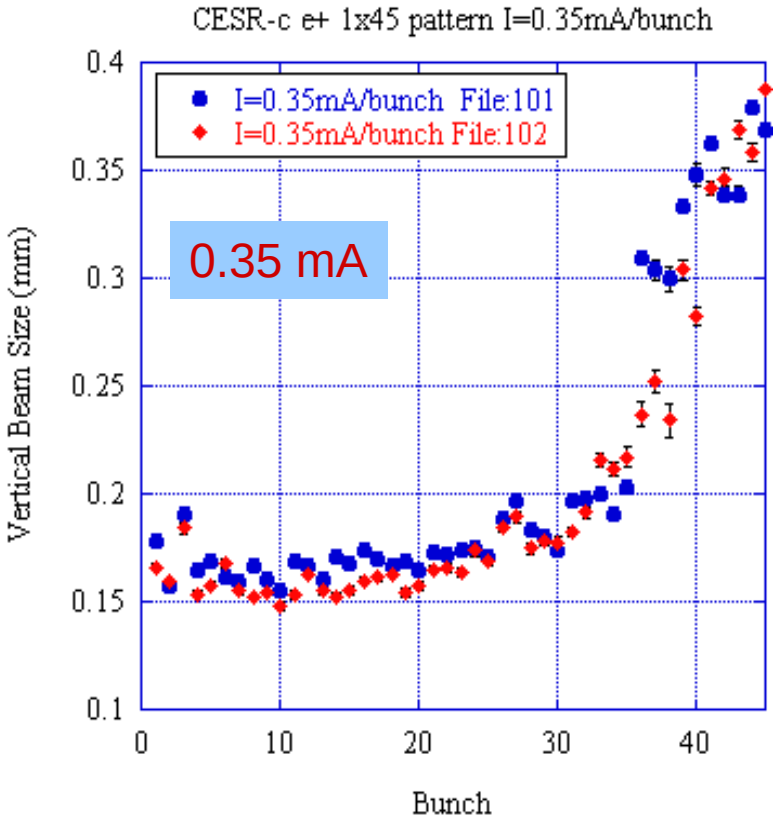




Theory and measurement of instability onset

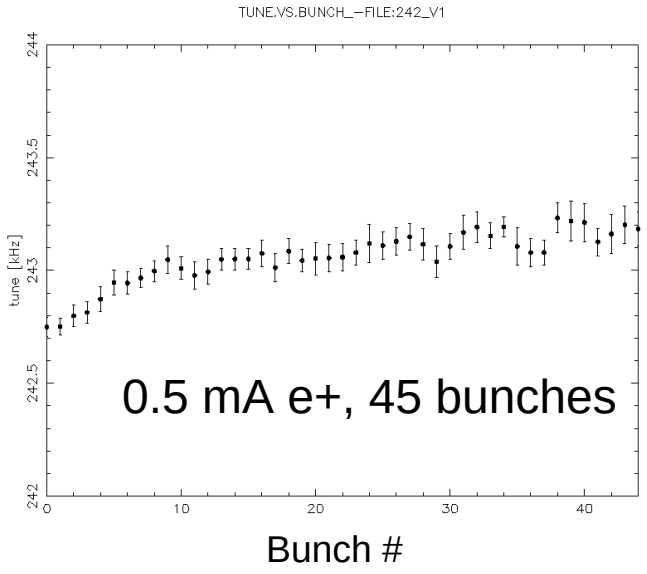
Qualitative comparison: if the transverse eigen-frequency becomes comparable with the corresponding betatron frequency (xc), then the transverse motion becomes unstable. Need to take into account the horizontal motion as well.

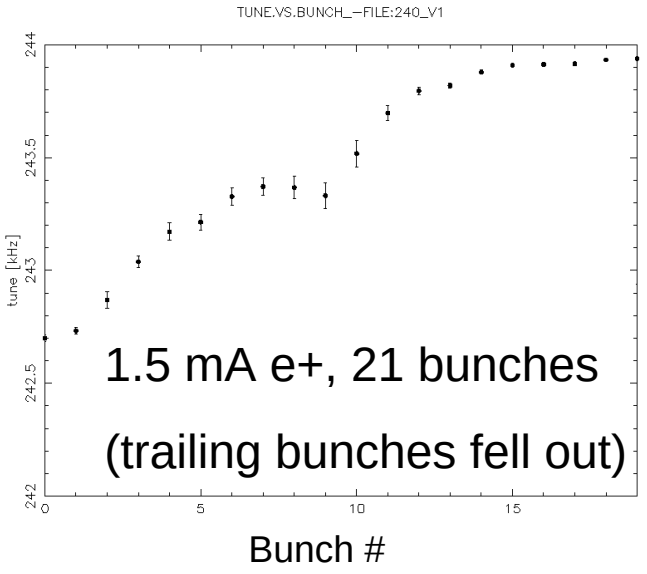




Details were presented in Levi Schachter's talk

Evidence of tune shift for positrons found

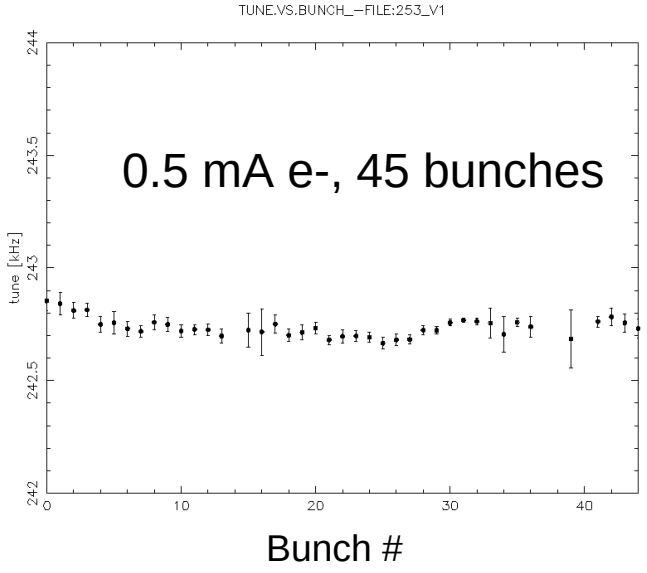




5.3 GeV vertical tune for 1x45 pattern, positrons

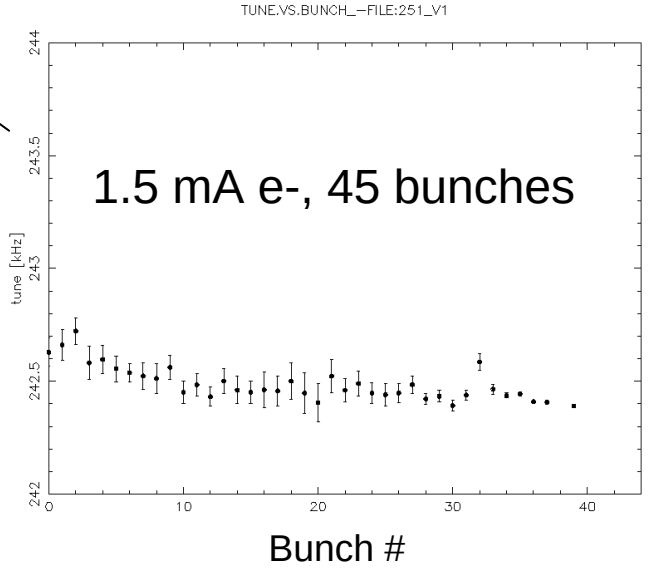
(2 kHz $\Delta f \sim 0.005\ \Delta Q$)

2 kHz full scale



5.3 GeV vertical tune for 1x45 pattern, electrons

e- tune change is much smaller than for e+ (but there is an effect)



Predictions of e- density (J. Crittenden, 3/9/2006)

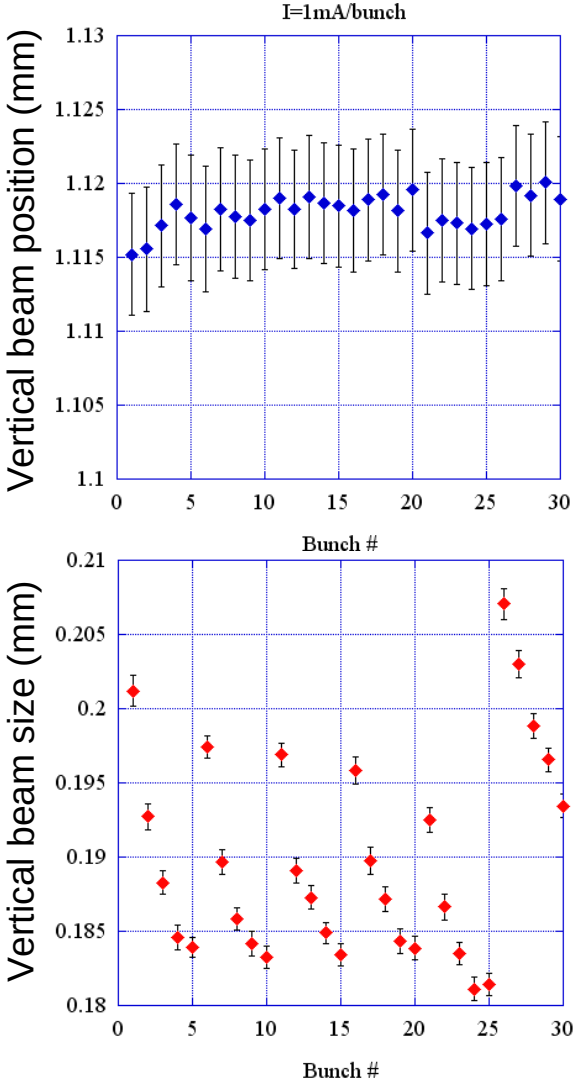
- Electron densities modeled with ECLOUD and compared with measured tune shift in 45 bunch e+ train
- Assume simple tune shift model (Ohmi et al., APAC2001, p.445-447):

$$\Delta Q_{x,y} \approx \frac{r_e}{2\gamma}\left\langle \beta_{x,y} \right\rangle \rho_e \; L$$

- Calculate e- densities in drifts (19%), bends (62%) and quads (9%) at 5.3 GeV.
- Average density of 4E11/m^3 produces 1 kHz (0.0025) tune shift with <ß>=30 m

Observations with 6t x 5b pattern, e+

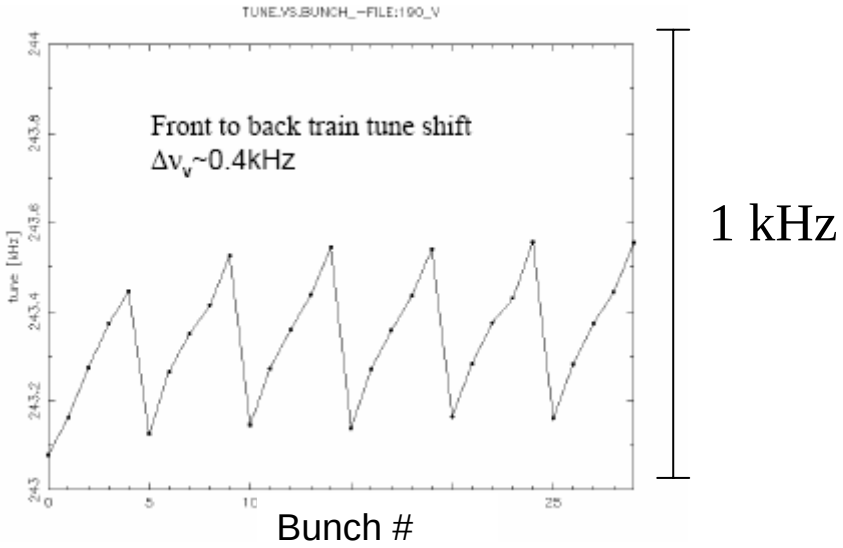
5.3 GeV vertical tune for 6 trains x 5 bunch pattern, positrons



(trains start at bunches 6,11,16, 21 and 26)

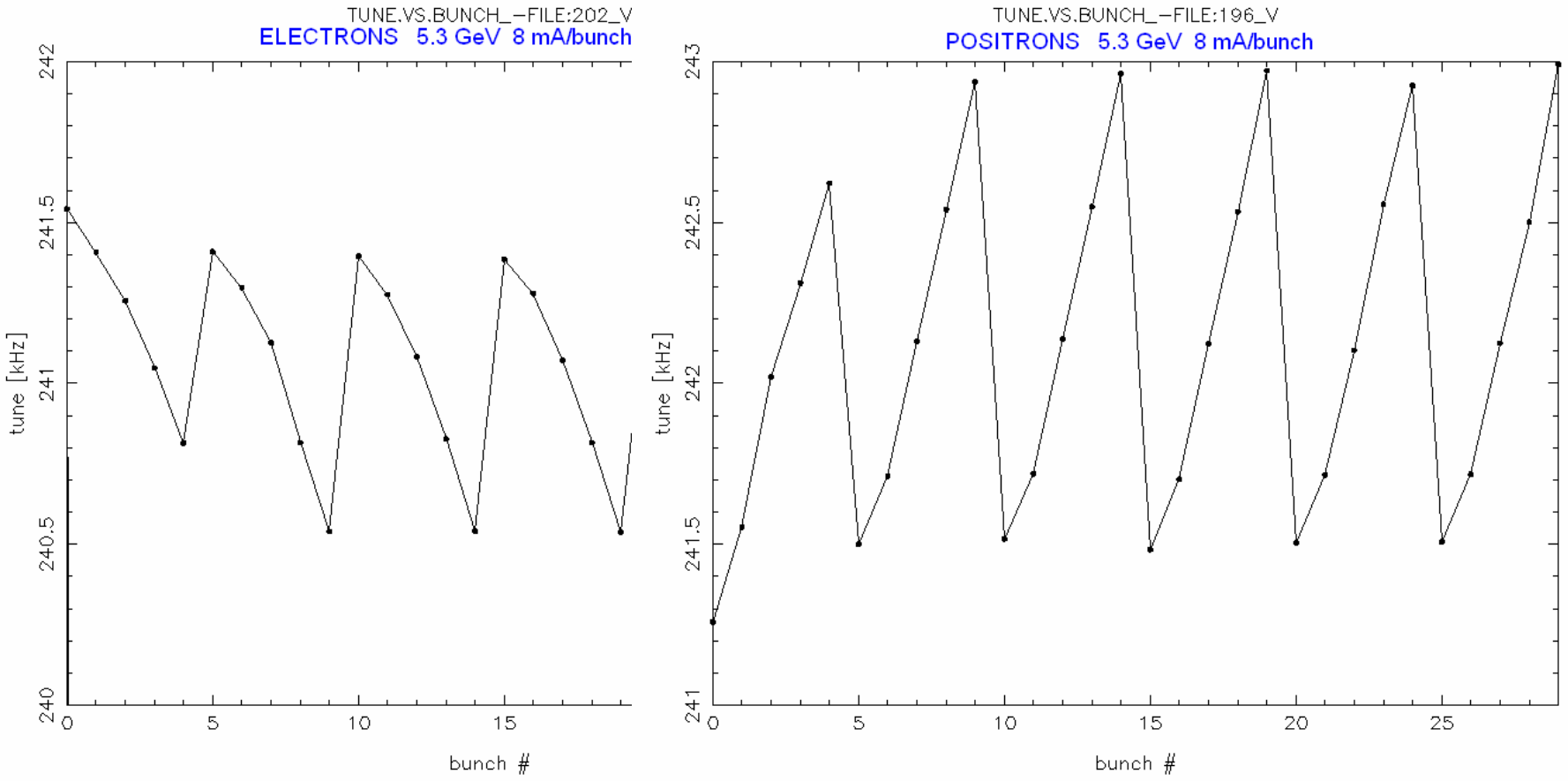
- **Positive tune shift from first to fifth bunch in a train is 0.4 kHz**
- **See difference from first train to trailing trains of 0.1 kHz**
- **Beam size has bunch dependence**

vertical tune vs. bunch, I = 1 mA

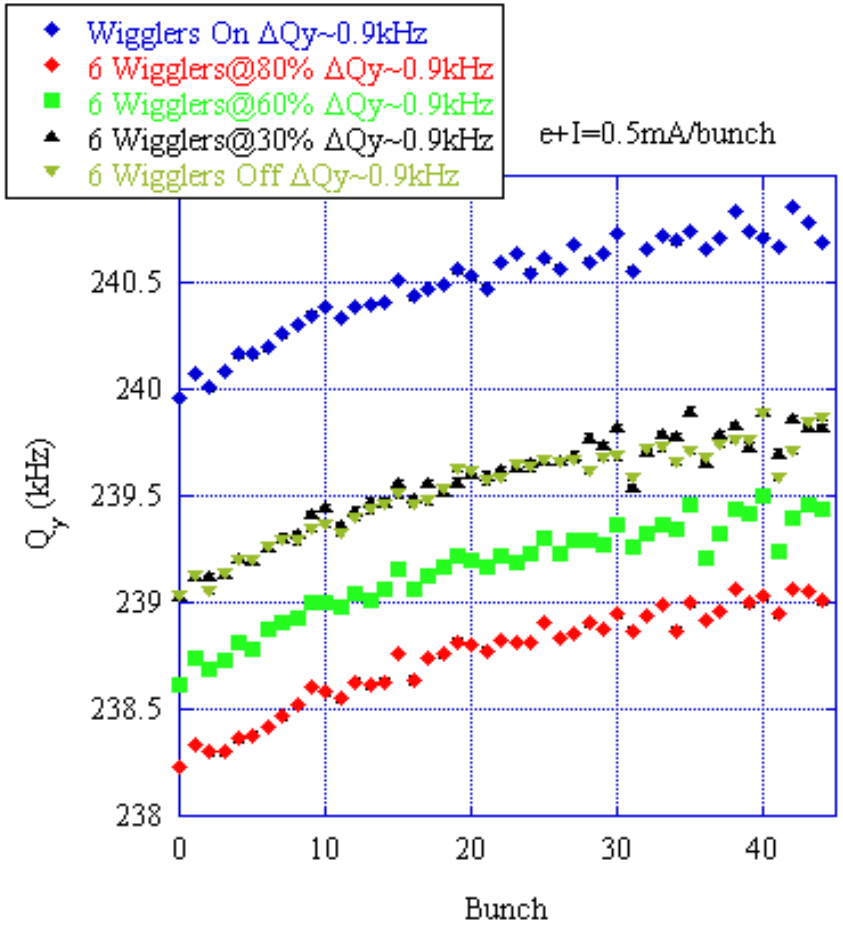


Observations with 6t x 5b pattern, e-

5.3 GeV vertical tune for 6 trains x 5 bunch pattern electrons, 8 mA per bunch



Impact of wigglers on electron cloud effects, e+



- Started with all 12 wigglers on and subsequently ramped down 6 wigglers with stored beam
- Notice no significant change in vertical tune vs. bunch (adjacent plot); **E cloud in CESR is not dominated by the wigglers**
- A rough estimate of photon flux from wigglers, using ECLOUD, predicts average electron densities of 3E12 for ~12 m by each of 2 wiggler clusters. We might expect 0.25 kHz change in tune shift from first to last bunch.

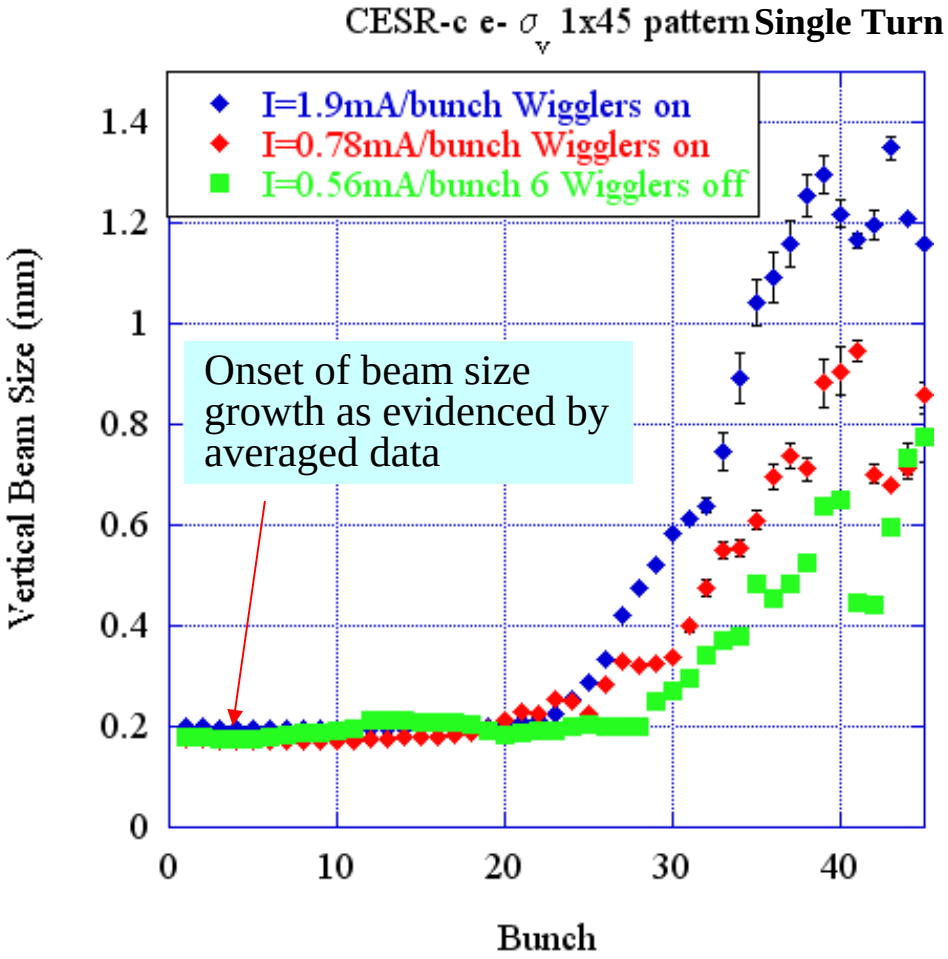
Next topic

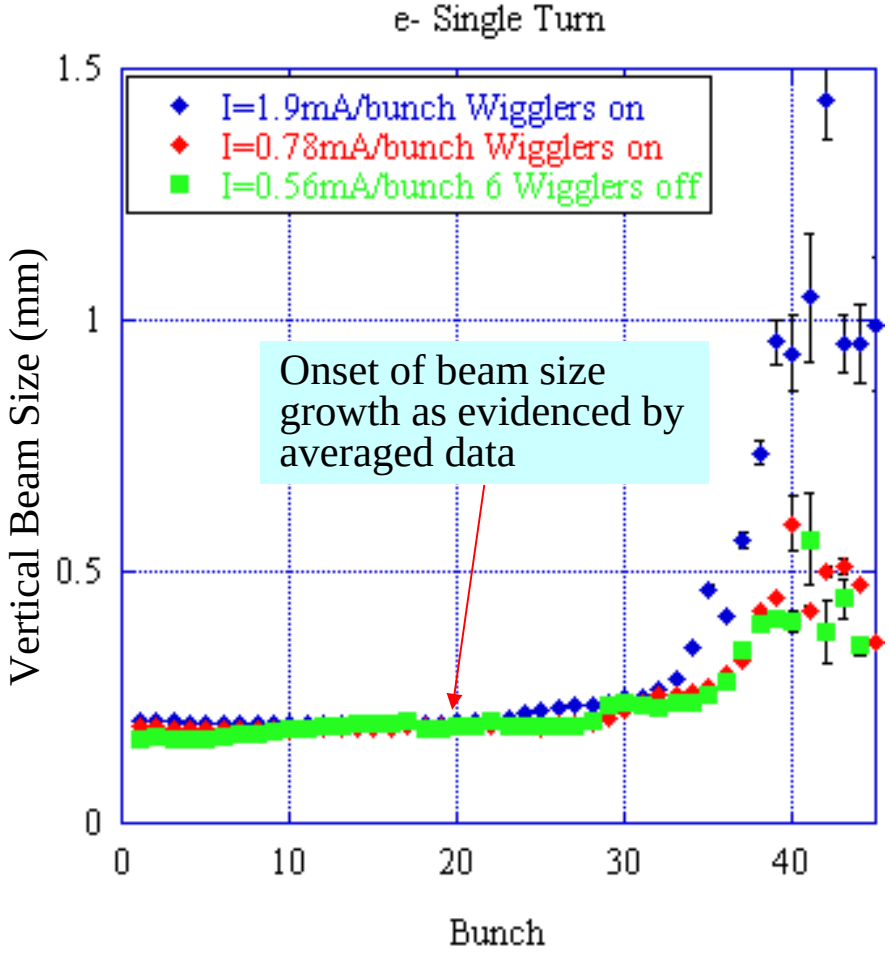
- Measurements Performed at CESR
- Key Beam Diagnostics used
- Electron Cloud Experiments
- Other Phenomena

Impact of vacuum processing after a leak repair in June 2006 Electrons

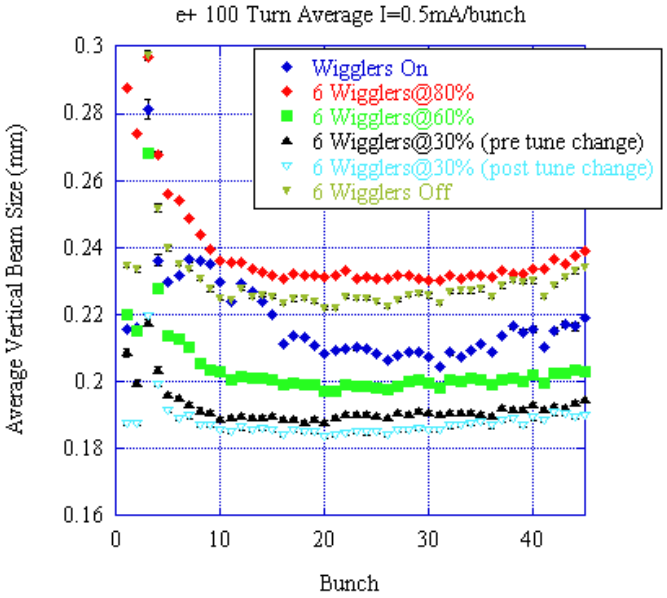
July 2006

August 2006



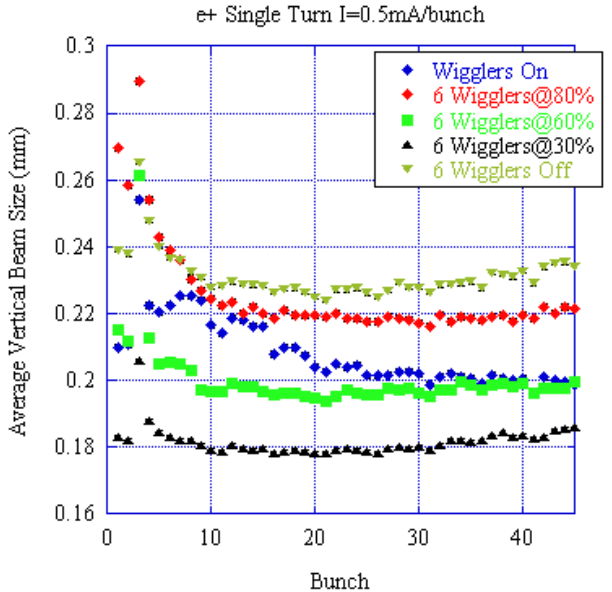


Compare 12 vs. 6 wigglers on, e+

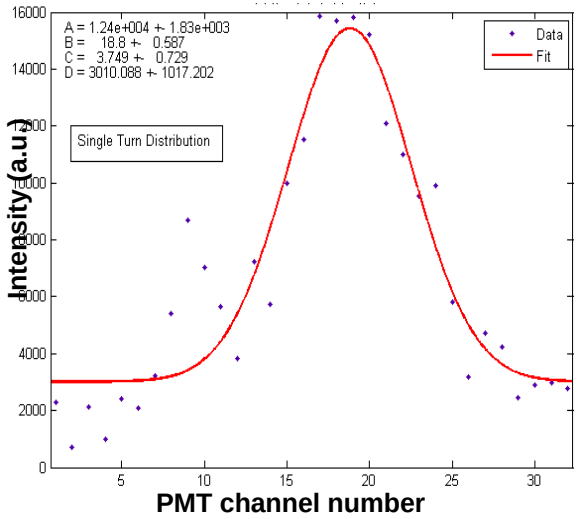


2 GeV positrons,
0.5 mA/bunch for
1x45 Pattern

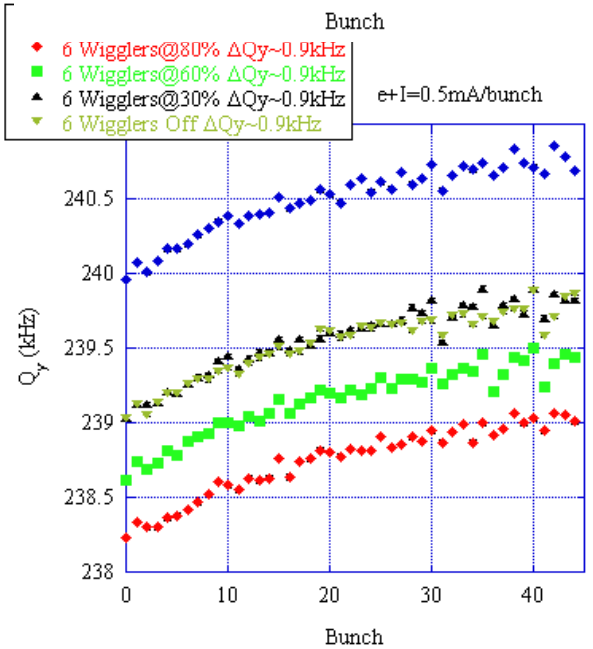
Vertical Beam Size for 100 turn averaged data (left) and single turn data (right)



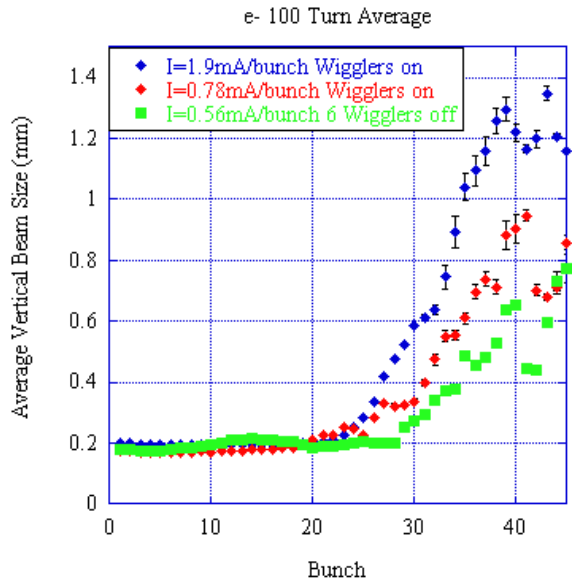
Single Turn Distribution (dots) and Gaussian fit (red line)



- Started with all 12 wigglers on and subsequently ramped down 6 wigglers with stored beam, compensating for the 0.1 vertical tune shift per wiggler with local quadrupole changes.

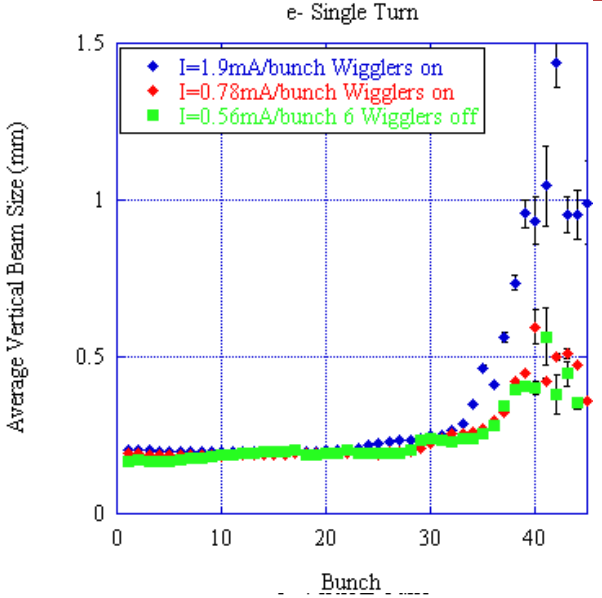


Compare 12 vs. 6 wigglers on, e-

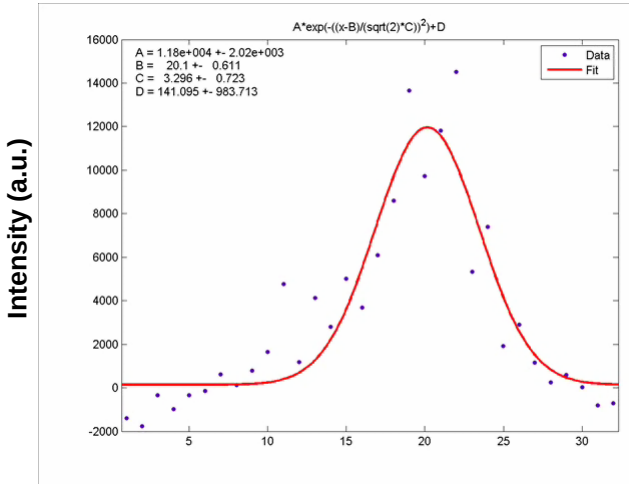


2 GeV electrons, at 3 bunch currents 1x45 Pattern

100-turn averaged beam sizes (left) as compared to single turn beam sizes blown up by centroid motion (see movie at left bottom)



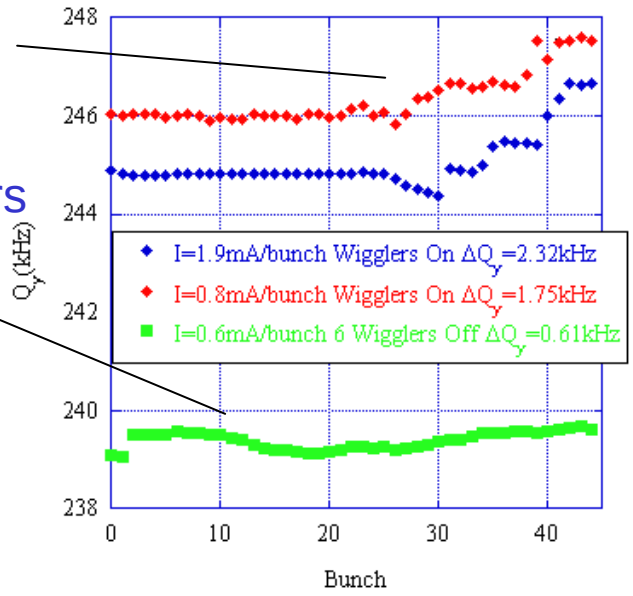
Distribution on PMT for bunch 30, bunch current 0.5 mA



ΔQy ~ 2kHz w/ 12 wigglers
I = 0.8 and 0.9 mA/bunch

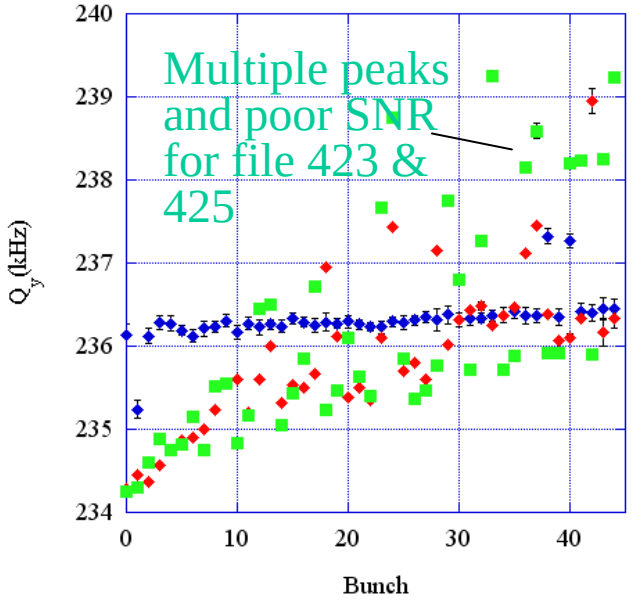
ΔQy ~ 0.6 kHz w/ 6 wigglers
I = 0.6 mA/bunch

(could be due to current difference)

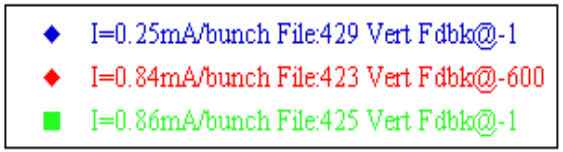


24-Aug-2006 data

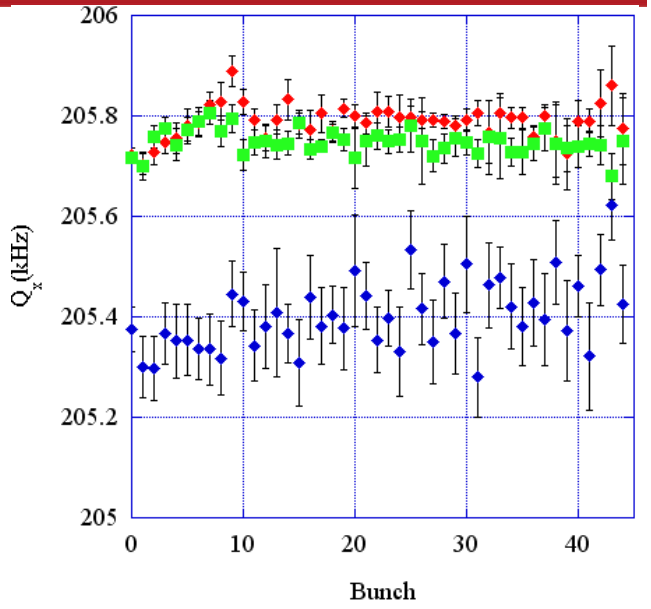
Transverse feedback, 12 wigglers, e+

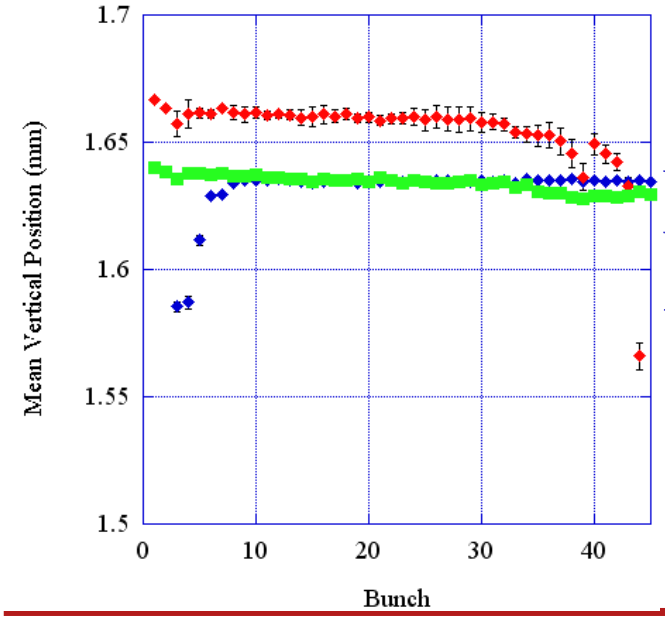


2 GeV tunes, position and beam size for 1x45 pattern, positrons

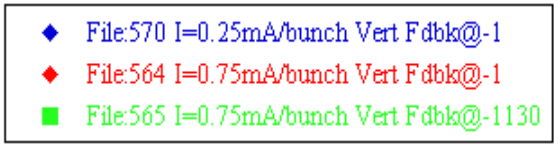


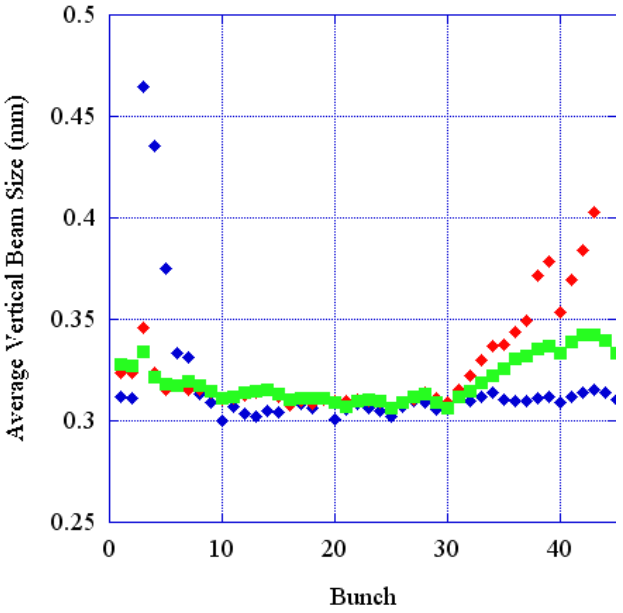
ΔQy ~ 4kHz
@ I = 0.86mA/bunch



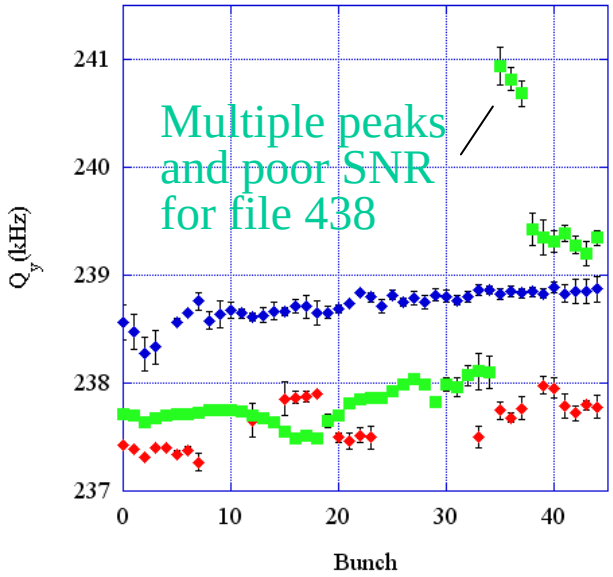


Vertical bunch by bunch feedback reduces the coherent motion of the beam and reduces the beam size at the end of the train

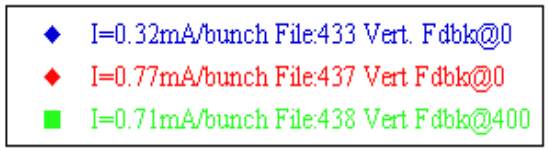




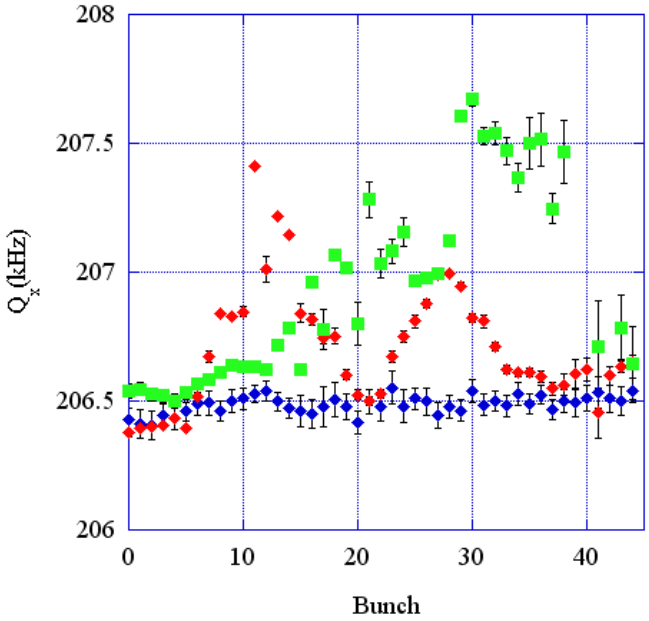
Transverse feedback. 12 wigglers, e-

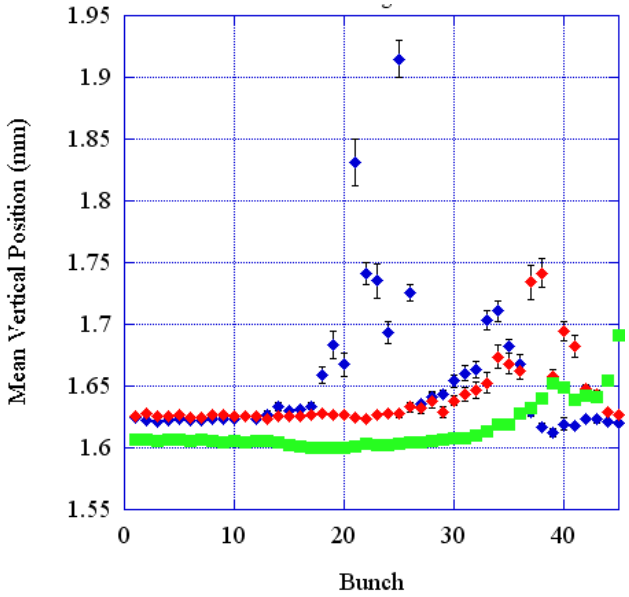


2 GeV tunes, position and beam size for 1x45 pattern, electrons

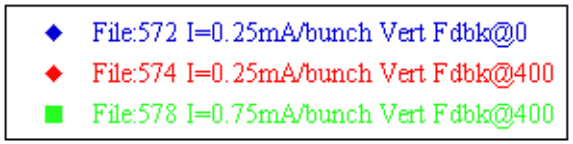


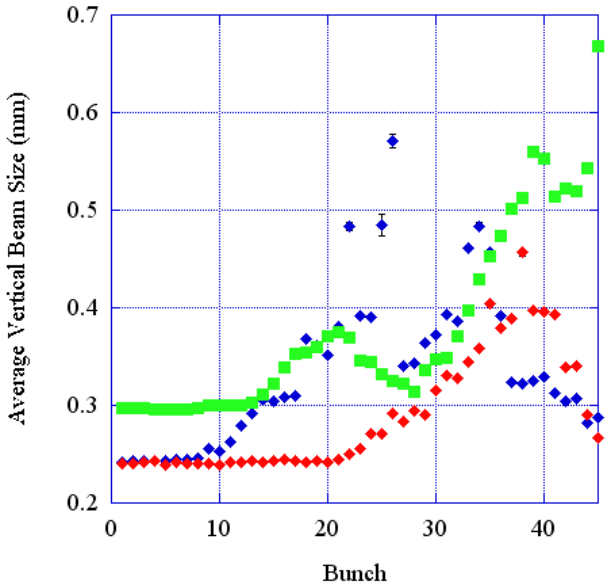
ΔQy ~ 0.25 kHz
@ I = ~0.7 mA/bunch





Vertical bunch by bunch feedback reduces the coherent motion of the beam and reduces the beam size at the end of the train





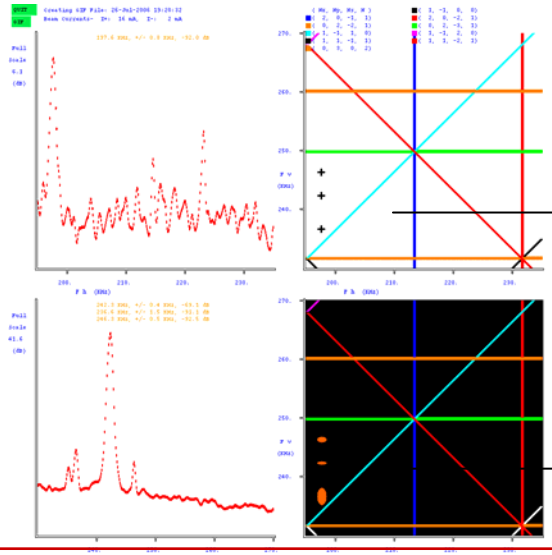
Tune split: 2 GeV, e+ example, 1t x 45b

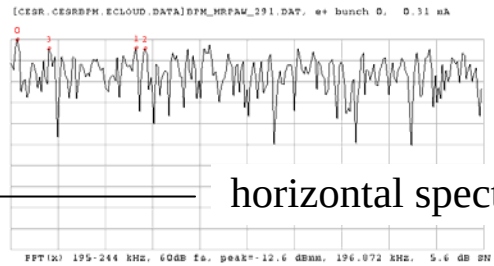
all bunches, spectrum analyzer

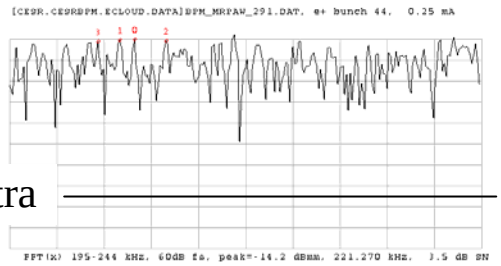
bunch 1, BPM FFT data

bunch 45, BPM FFT data

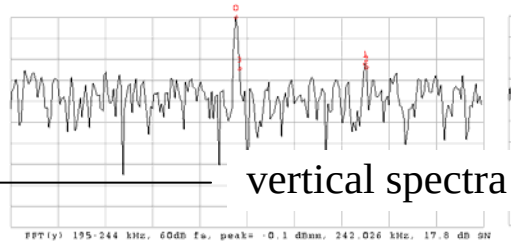
0.3 mA per bunch

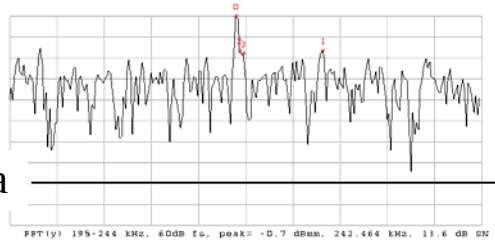






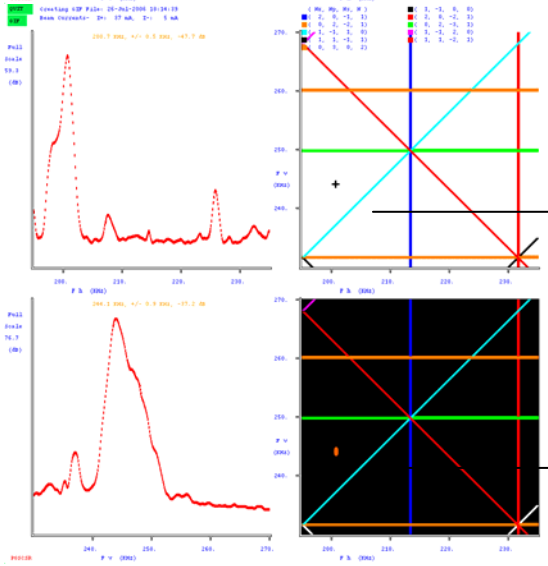
horizontal spectra

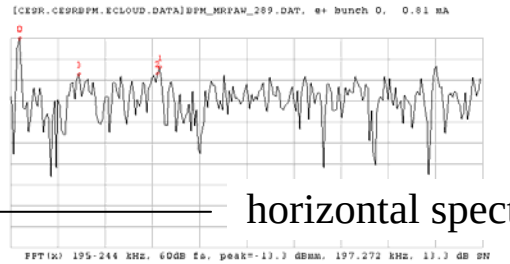


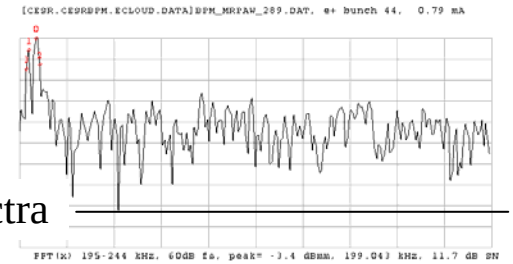


vertical spectra

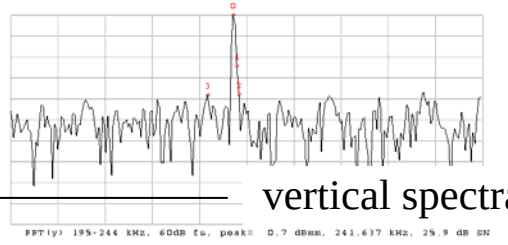
0.8 mA per bunch

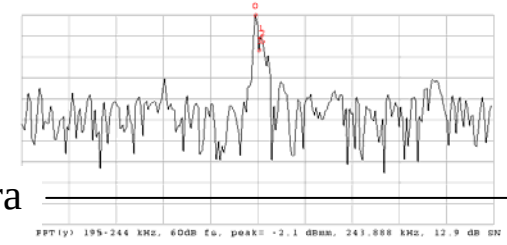






horizontal spectra





vertical spectra

Summary & Conclusions

- Effects seen: Electron cloud
  - See clear evidence in tune versus bunch for positrons vs. electrons
  - See clear evidence in beam size versus bunch
- No effects seen: 12 vs. 6 wigglers, solenoids
  - 6 of 12 wigglers turned off, 3 in each straight section, W & E
  - Low current solenoid in straight section, < 2% of storage ring
- Other phenomena
  - Electron beam size blow up and instability (ions?)
  - Tune split, betratron sideband require explanation (KEK help)
  - Vertical tune vs. bunch dependence for electrons
- Next
  - Explore different bunch spacings
  - Distinguish impedance, ion effects from ECE
  - Compare with calculations

Acknowledgements

M. Billing, G. Codner, J. Crittenden, M. Forster, M. Palmer, D. Rice, E. Tanke (Cornell)

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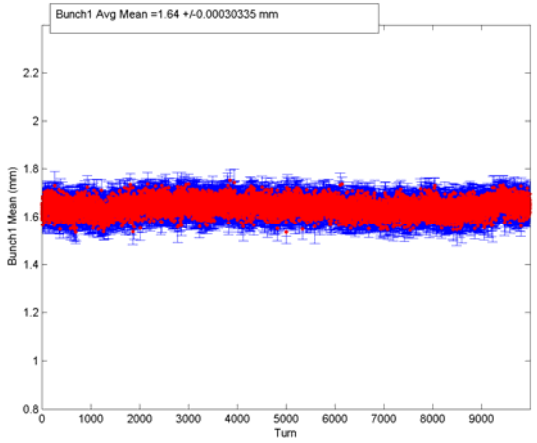
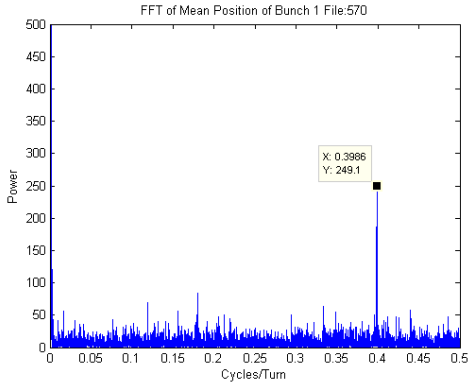
B. Cerio (Colgate University)

M. Watkins (CMU)

Bunch 1 , e+ at 0.25 mA



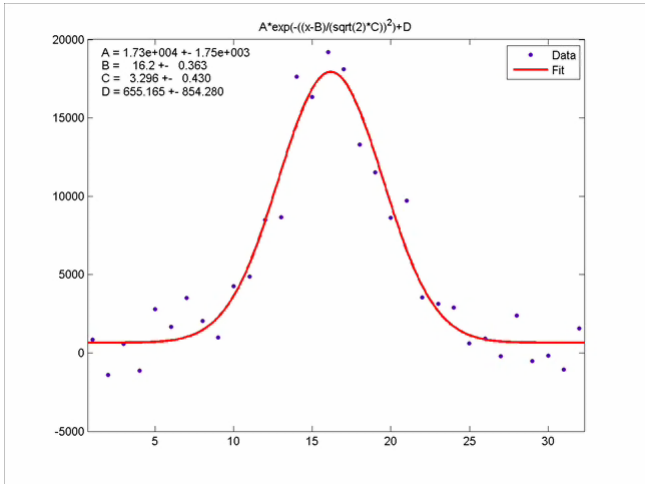


FFT

F_{cesr} =390.406kHz

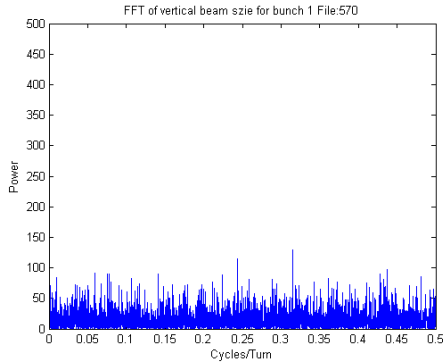
$F_{oscillation}$ =390.406 kHz×0.3986=155.6 kHz or

$F_{oscillation}$ =(1-0.3986)×390.406=234.8 kHz

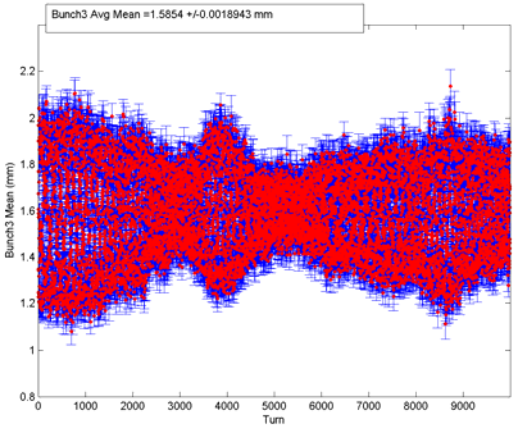


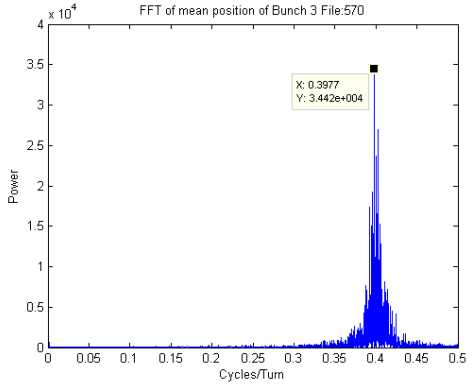
e+
Bunch 1
I=0.25m
A/bunch
12
Wigglers
On
File 570

e+ Bunch 1
I=0.25mA/b
unch
12 Wigglers
On
File 570

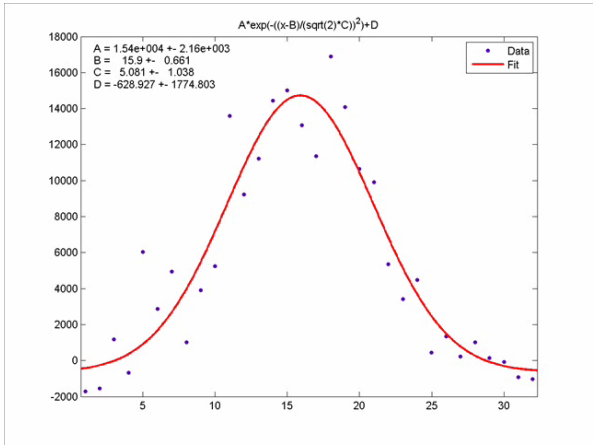


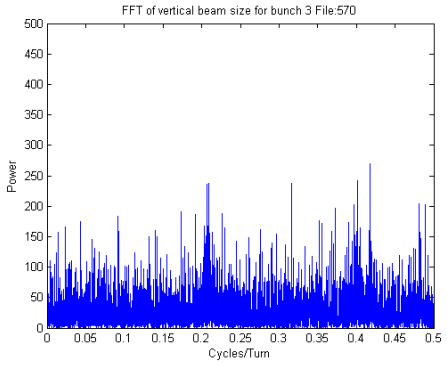
Bunch 3 , e+ at 0.25 mA



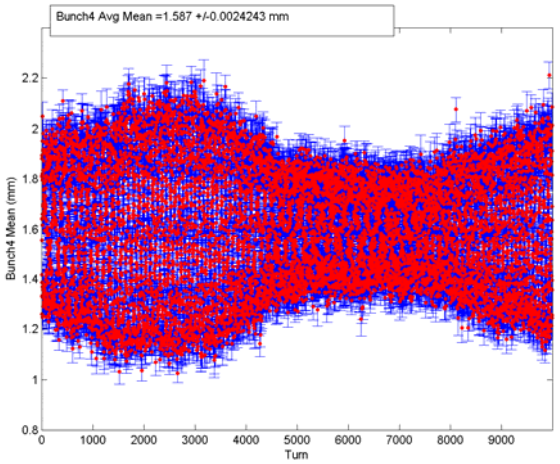


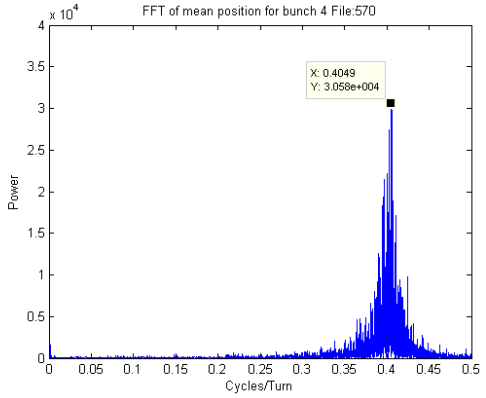
e+ Bunch 3
I=0.25mA/bu
nch
12 Wigglers
On
File 570



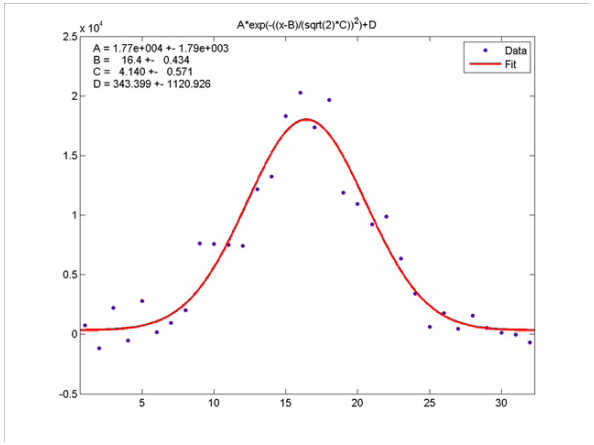


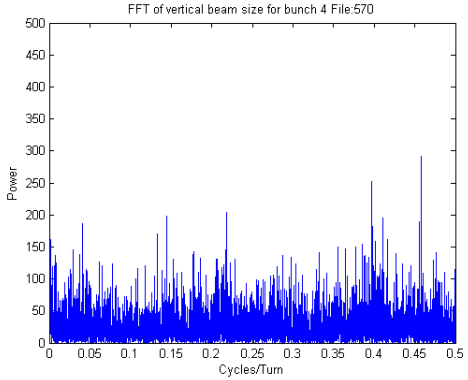
Bunch 4 , e+ at 0.25 mA



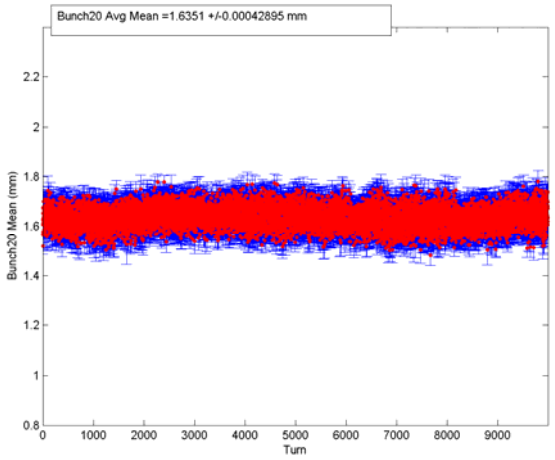


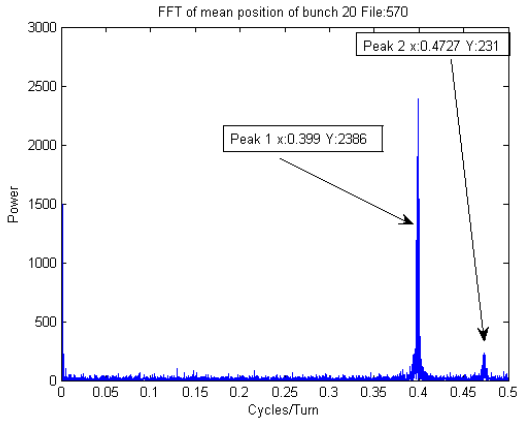
e+ Bunch 4
I=0.25mA/b
unch
12 Wigglers
On
File 570





Bunch 20 , e+ at 0.25 mA





e+ Bunch 20
I=0.25mA/bu
nch
12 Wigglers
On
File 570