Electron Cloud Studies at CESR-c and CesrTA

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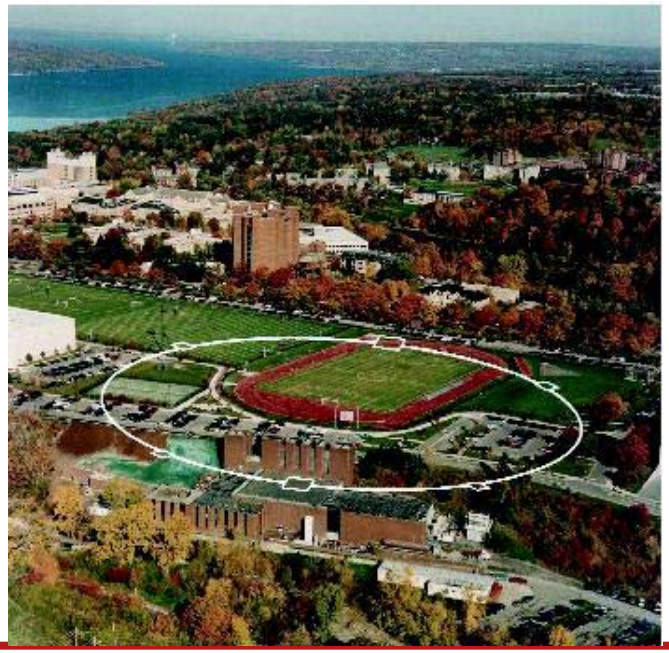


Outline

- CESR-c ⇨ CesrTA
  - Major focus on electron cloud measurements
- CESR-c Measurements
  - Instrumentation
  - Initial measurements
  - Experimental plans
- CesrTA Plans
  - Proposed ILC R&D program
  - Diagnostic wiggler chamber concept
- Conclusion
- Acknowledgments

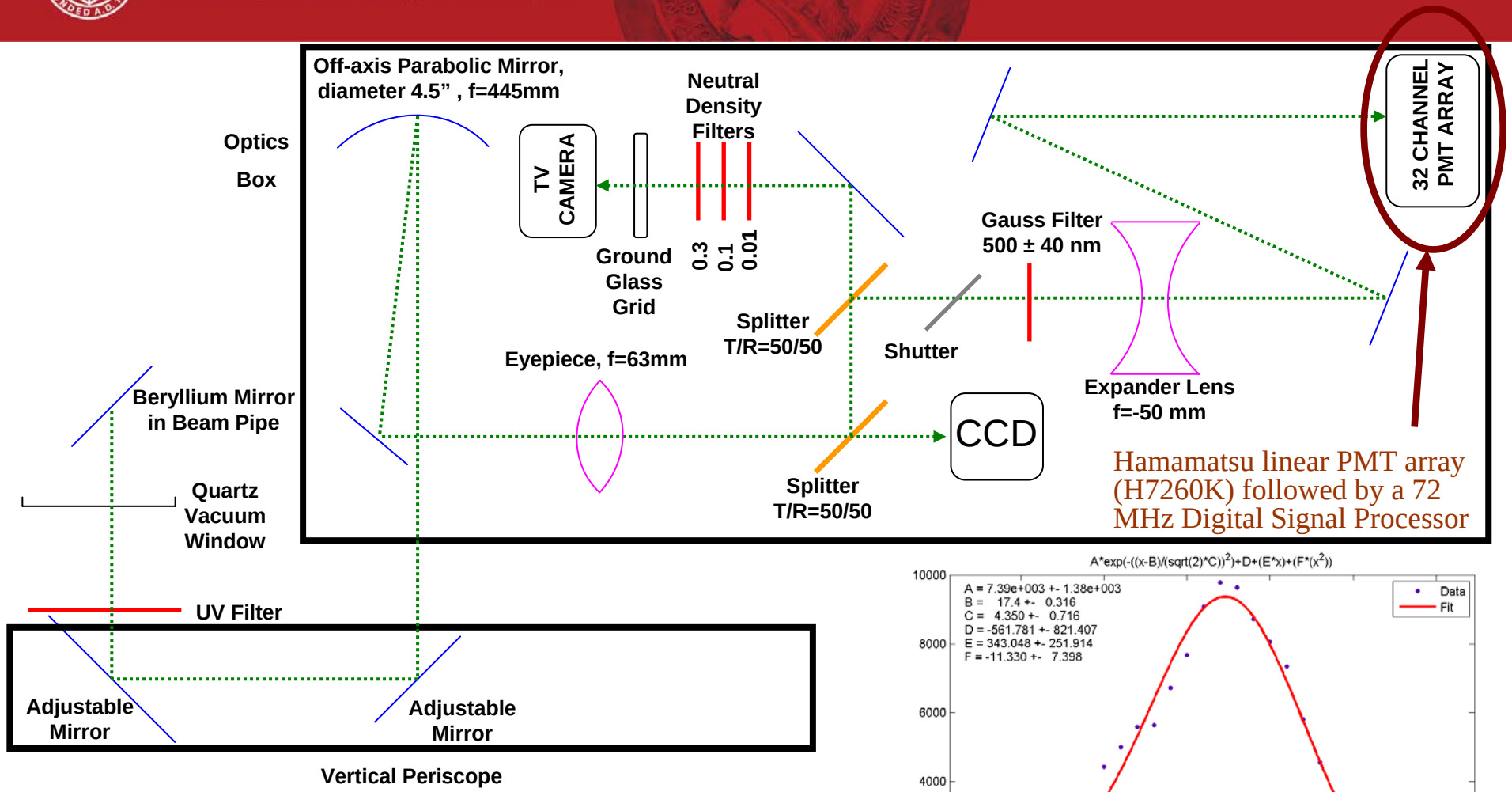
CESR-c ⇨ CesrTA

- CESR-c/CLEO-c HEP operations conclude March 31, 2008
- Propose to move CESR-c damping wigglers to zero dispersion regions to study ILC DR physics issues at ultralow emittance
  - 2 GeV baseline lattice with 12 damping wigglers
    - 2.25nm horizontal emittance
    - Goal is vertical emittance in 5-10pm range (in zero current limit)
    - Can presently operate with wigglers in the 1.5-2.5GeV range
    - Reconfigure so that one or more wigglers can operate at 5 GeV
    - Support operation at 4ns bunch spacings (comparable to 3.08ns of ILCDR)
  - Flexible operation with e^- and e^+ beams in same vacuum chamber
    - Detailed comparison of species
    - Study both electron cloud and ion effects
  - ILC DR wiggler design based on the CESR-c design
  - Provide 120 days of dedicated operation for damping rings experiments per year (flexible use for collaborators in the ILC DR community)

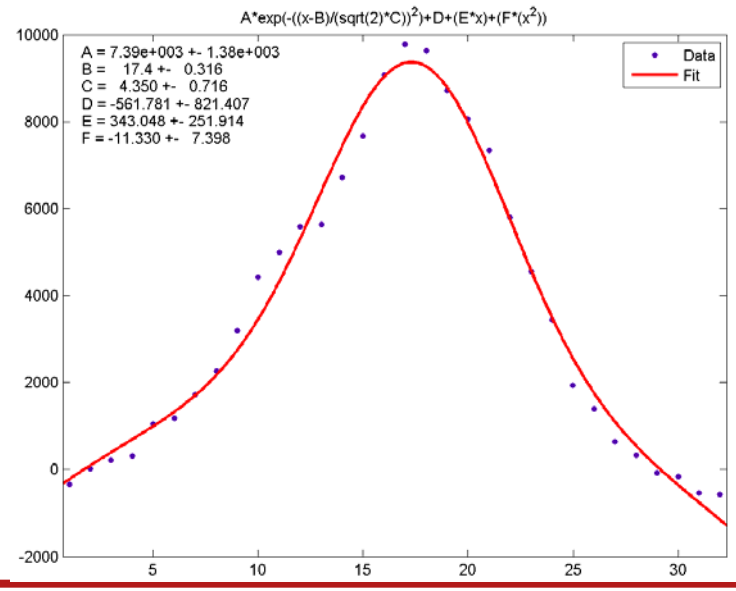
CESR-c Measurements

- Recent EC Measurements at CESR
  - Concerns about large e^+ emittance in HEP among other indicators
  - ILC DR interest
  - New instrumentation coming on line (CESR-c and ILC driven)
- Key CESR Parameters
  - Circumference: 768.44 m
  - Revolution frequency: 390.13 kHz
  - RF frequency: 499.76 MHz
  - Harmonic number: 1281
    - 1281/7 = 183 bunches
  - Spacing between bunches in train: 14 ns
  - Majority of the ring uses aluminum vacuum chambers
- Multibunch Instrumentation
  - 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
    - beam pinged for tune measurement

Beam Size Monitor

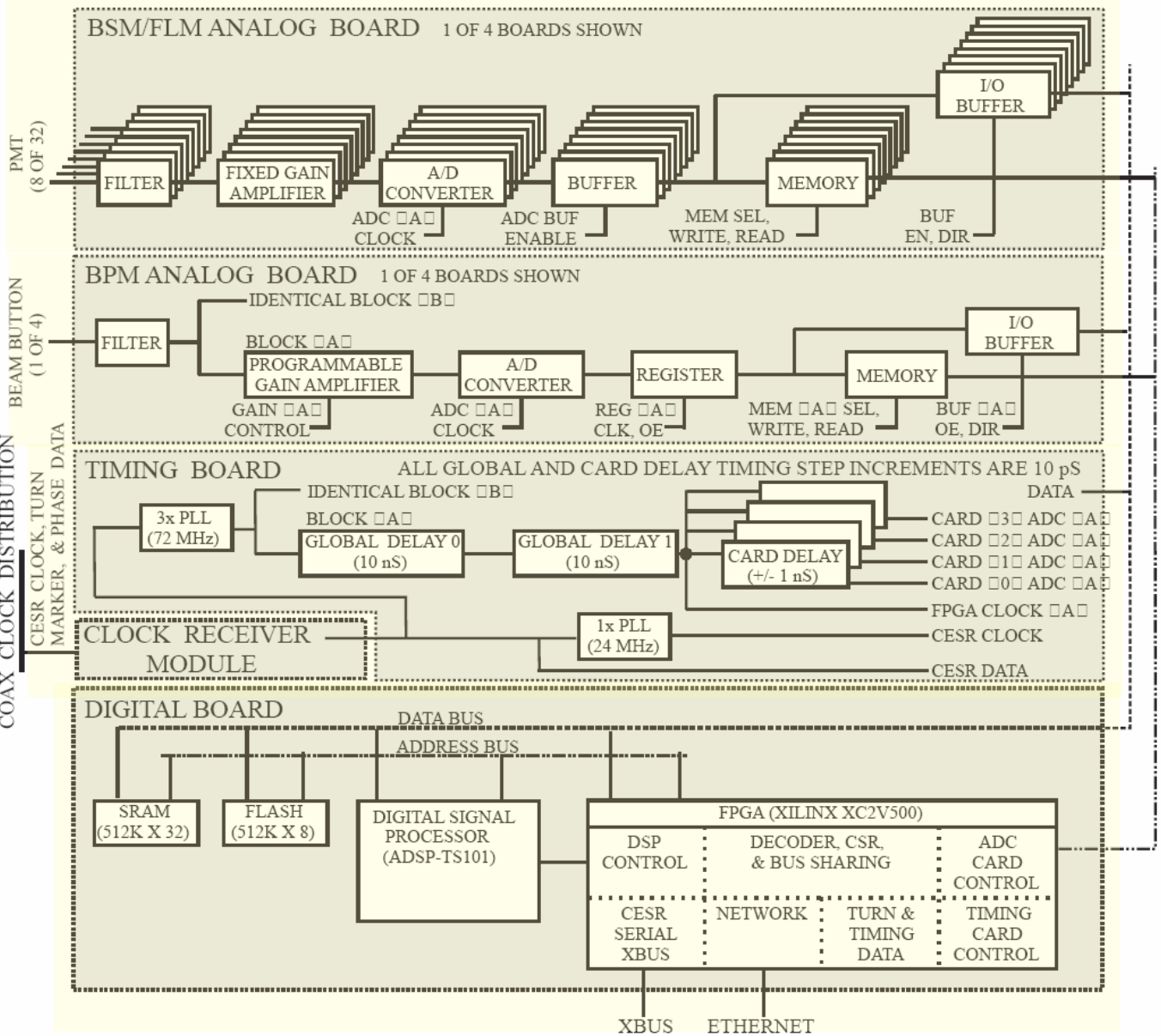


Hamamatsu linear PMT array (H7260K) followed by a 72 MHz Digital Signal Processor



Positron optics (electron optics similar)

Signal Processing and DAQ

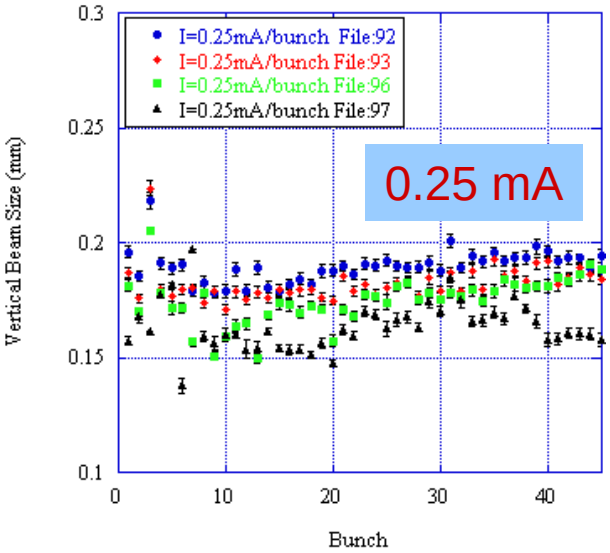


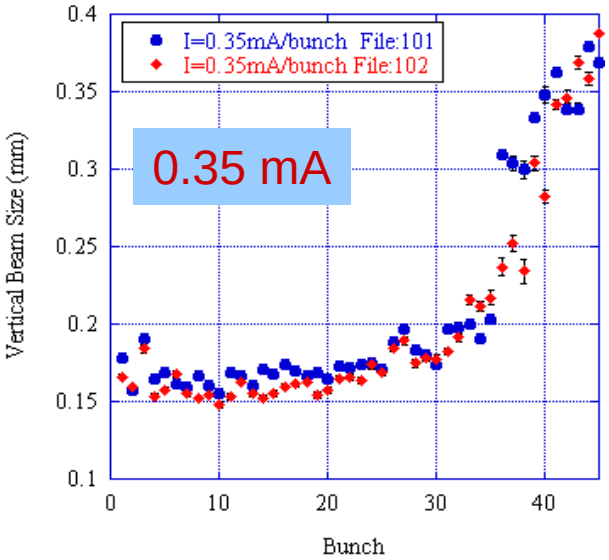
- DAQ is based on a 72 MHz Digital Signal Processor (DSP) capable of turn by turn and bunch by bunch data acquisition
- Similar architecture for BPM and BSM

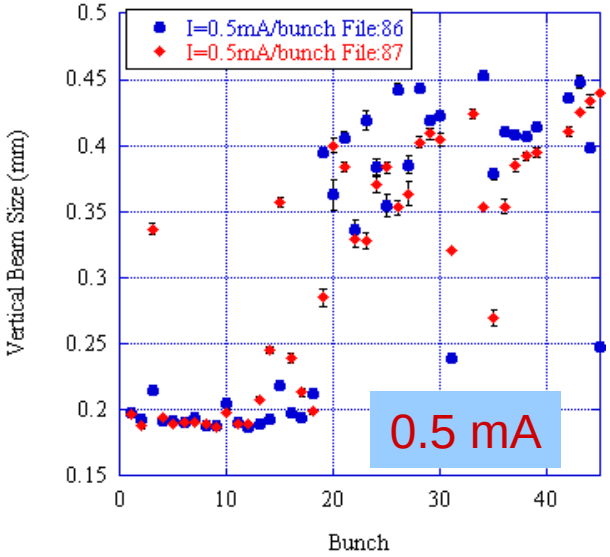
e+ Beam Size vs Bunch Current

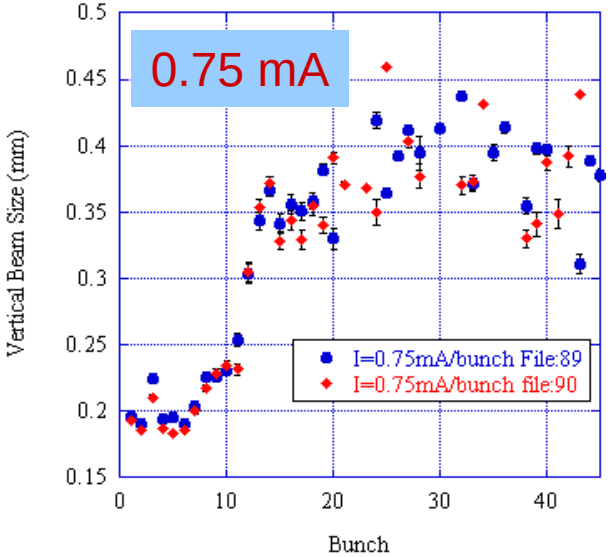
2 GeV vertical bunch-by-bunch beam size for 1x45 pattern, positrons

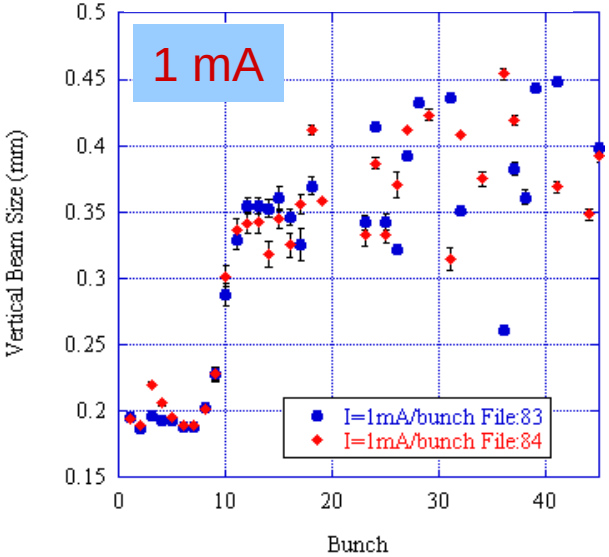
Advancing onset of beam instability as a function of increasing bunch current



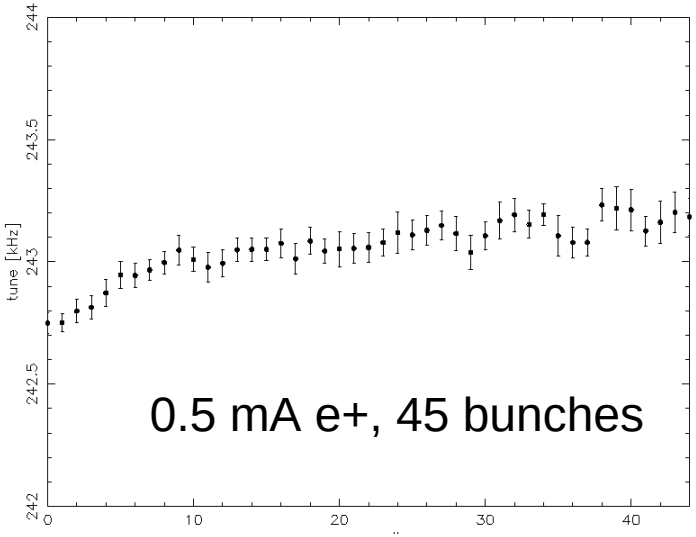








Multibunch Tune Measurements at 5.3 GeV

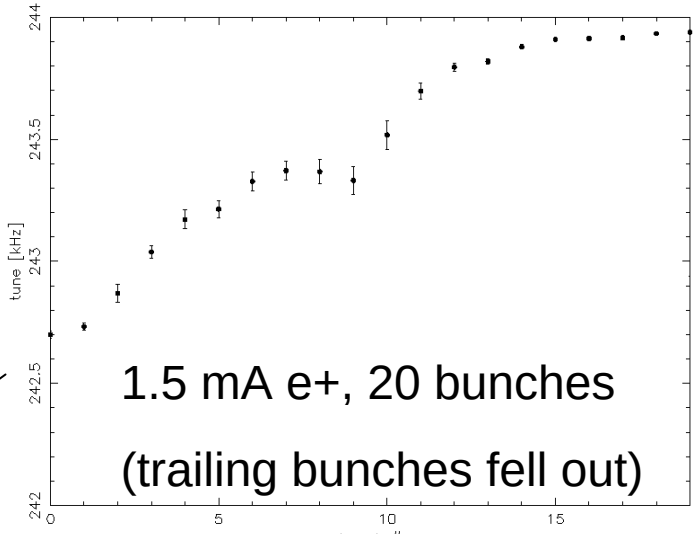


0.5 mA e+, 45 bunches

Bunch # (0-44)

5.3 GeV vertical tune for 1x45 pattern, positrons

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

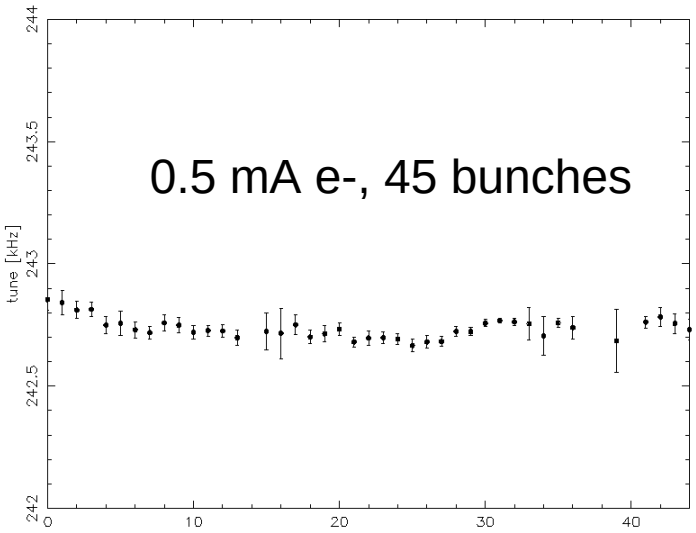


1.5 mA e+, 20 bunches

(trailing bunches fell out)

Bunch # (0-19)

2 kHz full scale

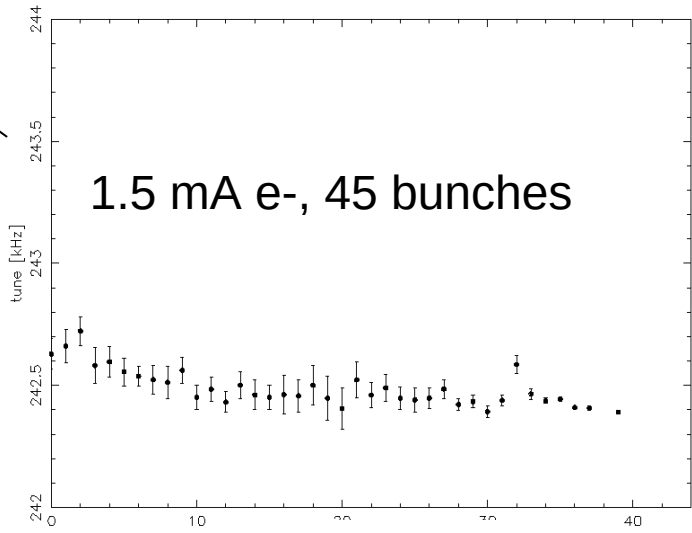


0.5 mA e-, 45 bunches

Bunch # (0-44)

5.3 GeV vertical tune for 1x45 pattern, electrons

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



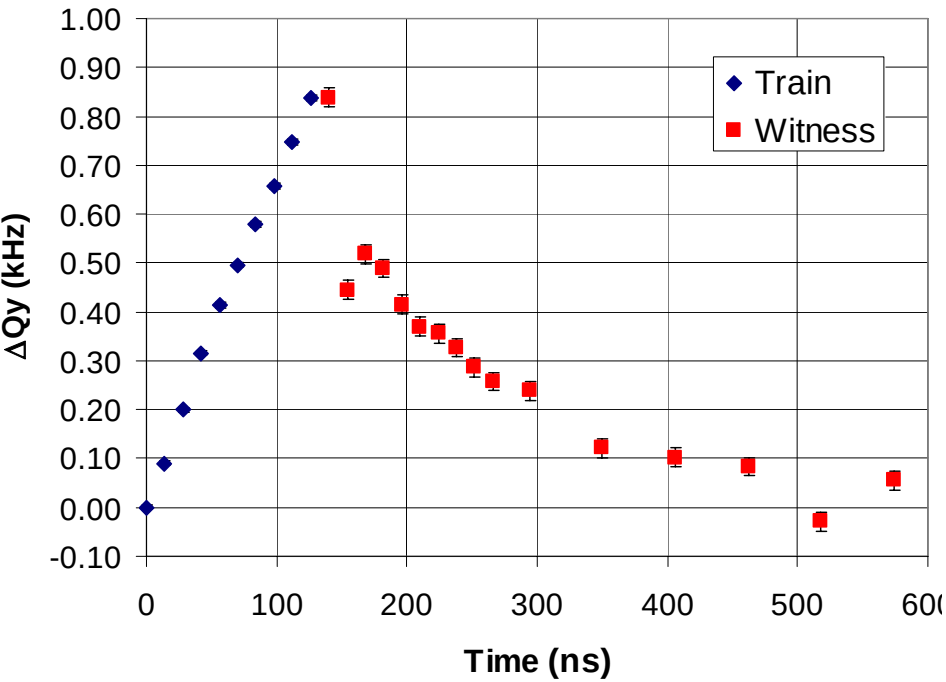
1.5 mA e-, 45 bunches

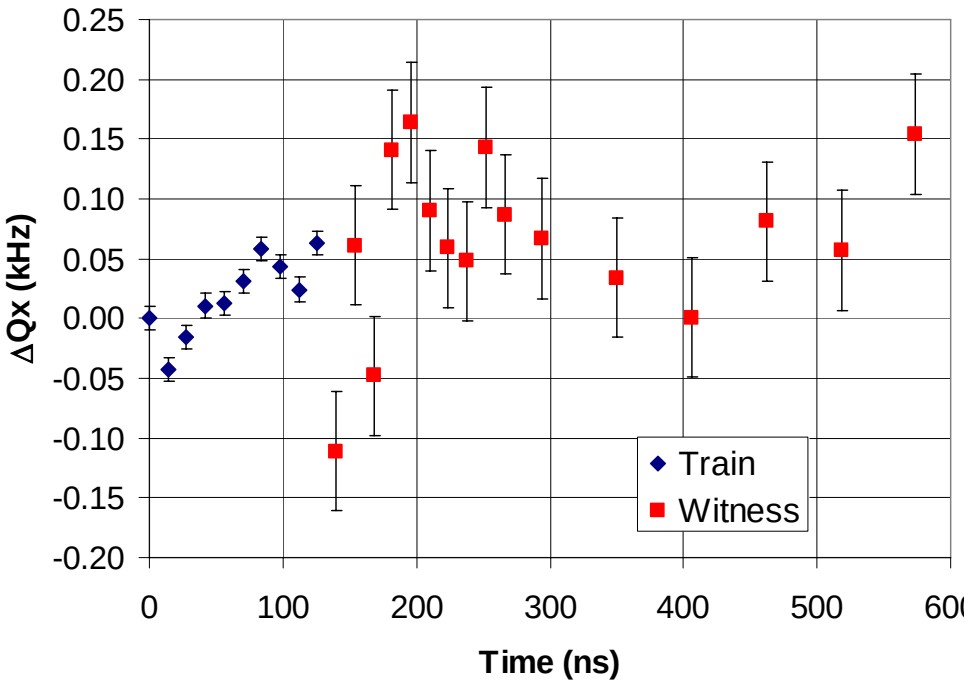
Bunch # (0-44)

Witness Bunch Studies – e^+ Vertical Tune Shift

- Initial train of 10 bunches ⇨ generate EC
- Measure tune shift and beamsize for witness bunches at various spacings

Positron Beam, 0.75 mA/bunch, 14 ns spacing, 1.9 GeV Operation





Error bars represent scatter observed during a sequence of measurements

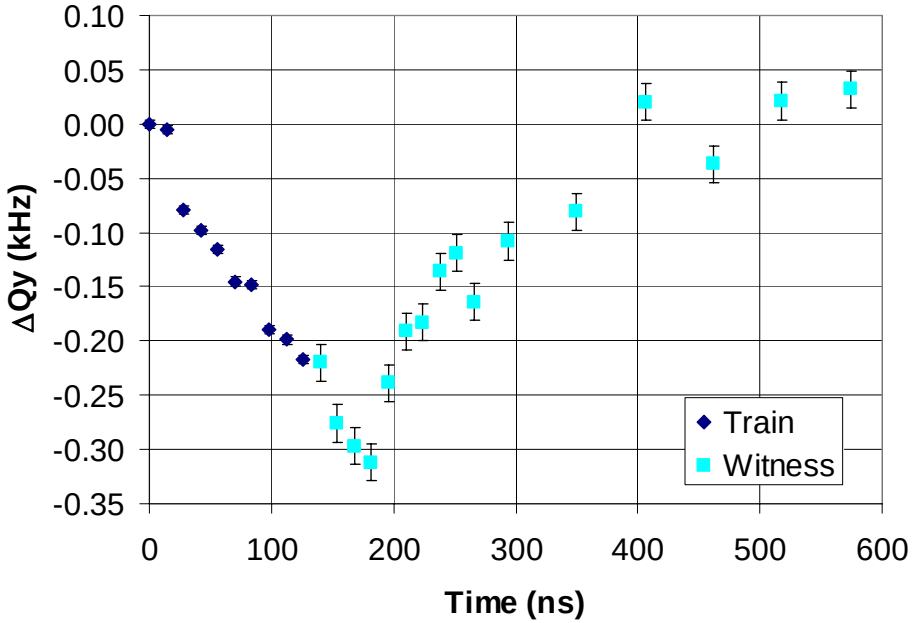
1 kHz ⇨ $\Delta\nu$=0.0026
$\rho_e \sim 1.5 \times 10^{11}\ m^{-3}$
Ohmi, etal, APAC01, p.445

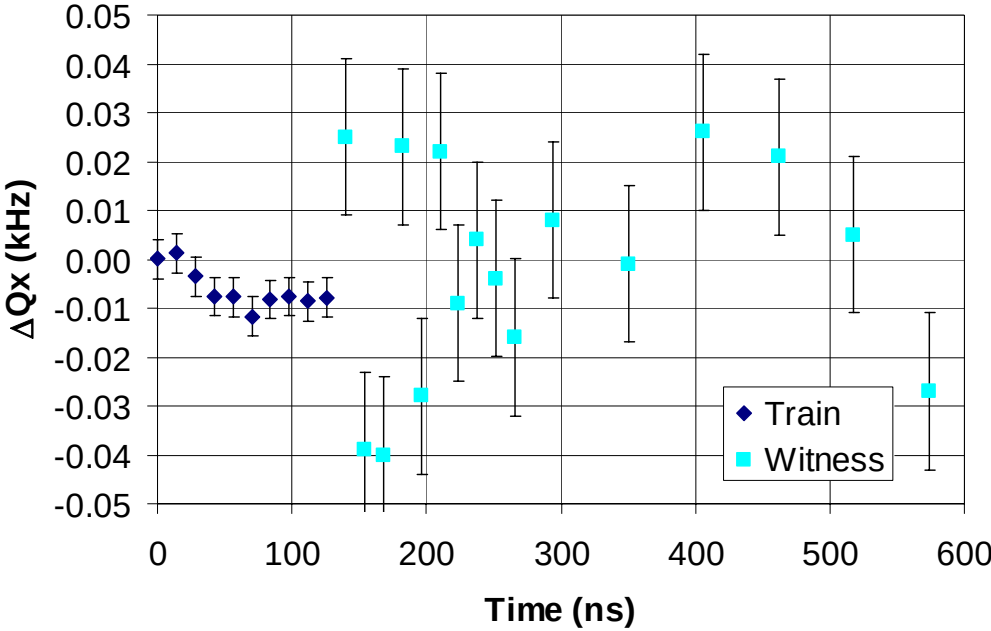
Preliminary Results

Witness Bunch Studies – e^- Vertical Tune Shift

- Same setup as for positrons
- Negative vertical tune shift and long decay consistent with EC

Electron Beam, 0.75 mA/bunch, 14 ns spacing, 1.9 GeV Operation



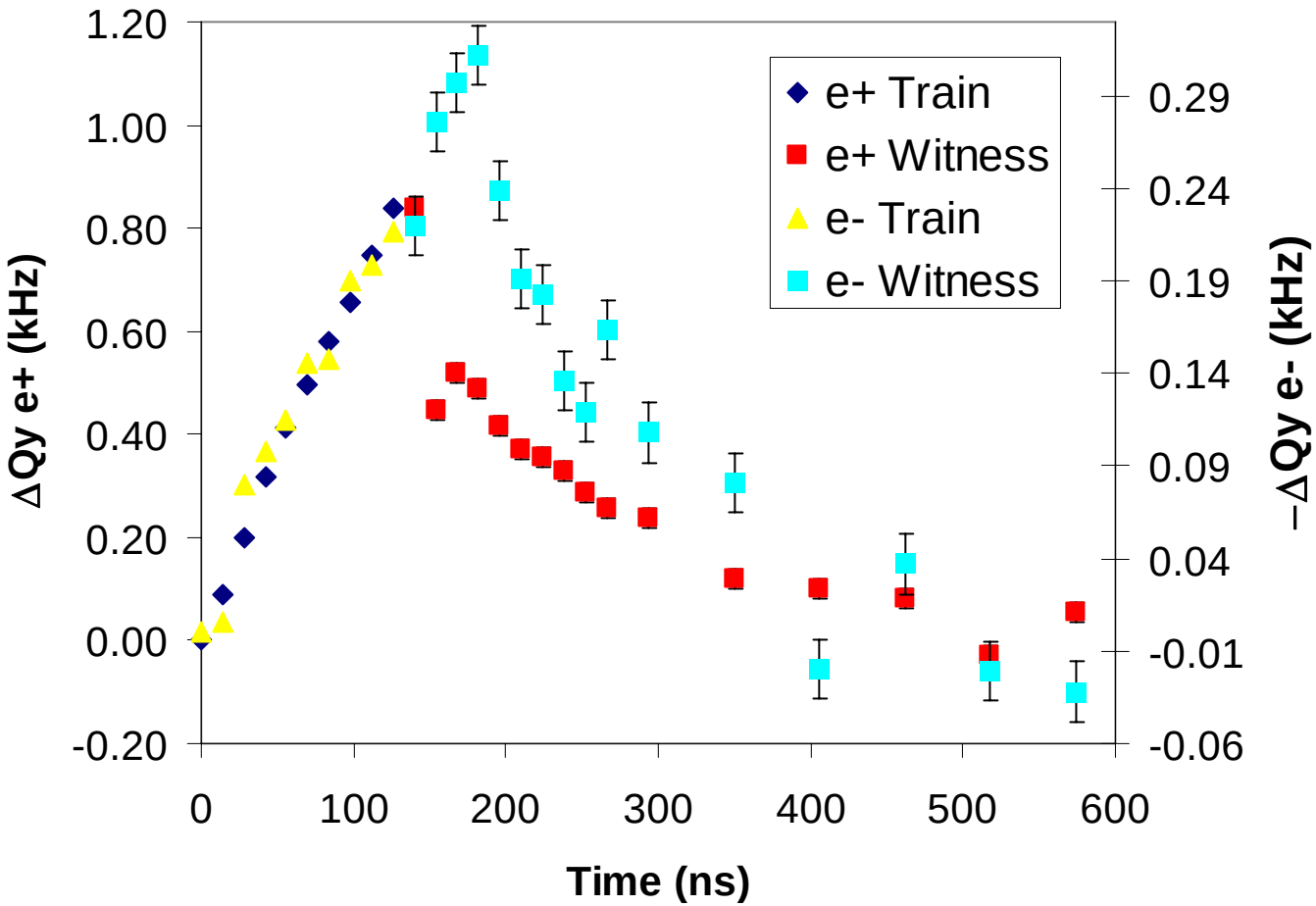


Negative vertical tune shift along train ⇨ consistent with EC
Magnitude of shift along train is ~1/4th of shift for positron beam
NOTE: Shift continues to grow for 1st 4 witness bunches!

Preliminary Results

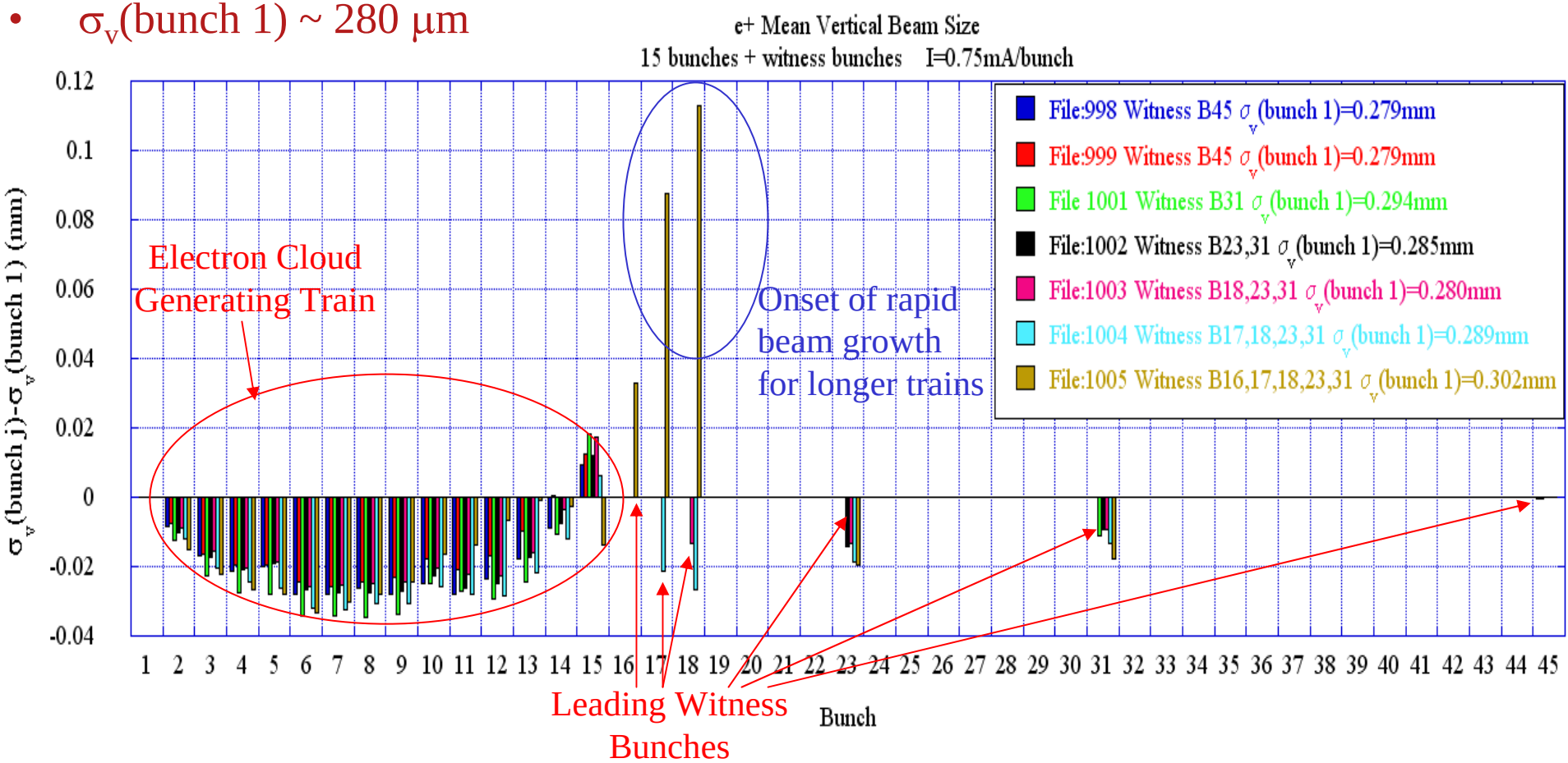
Witness Bunch Studies – Comparison of e-/e+ Tunes

- Magnitude of tune shift for electron beam is ~1/4th of shift observed for positron beam



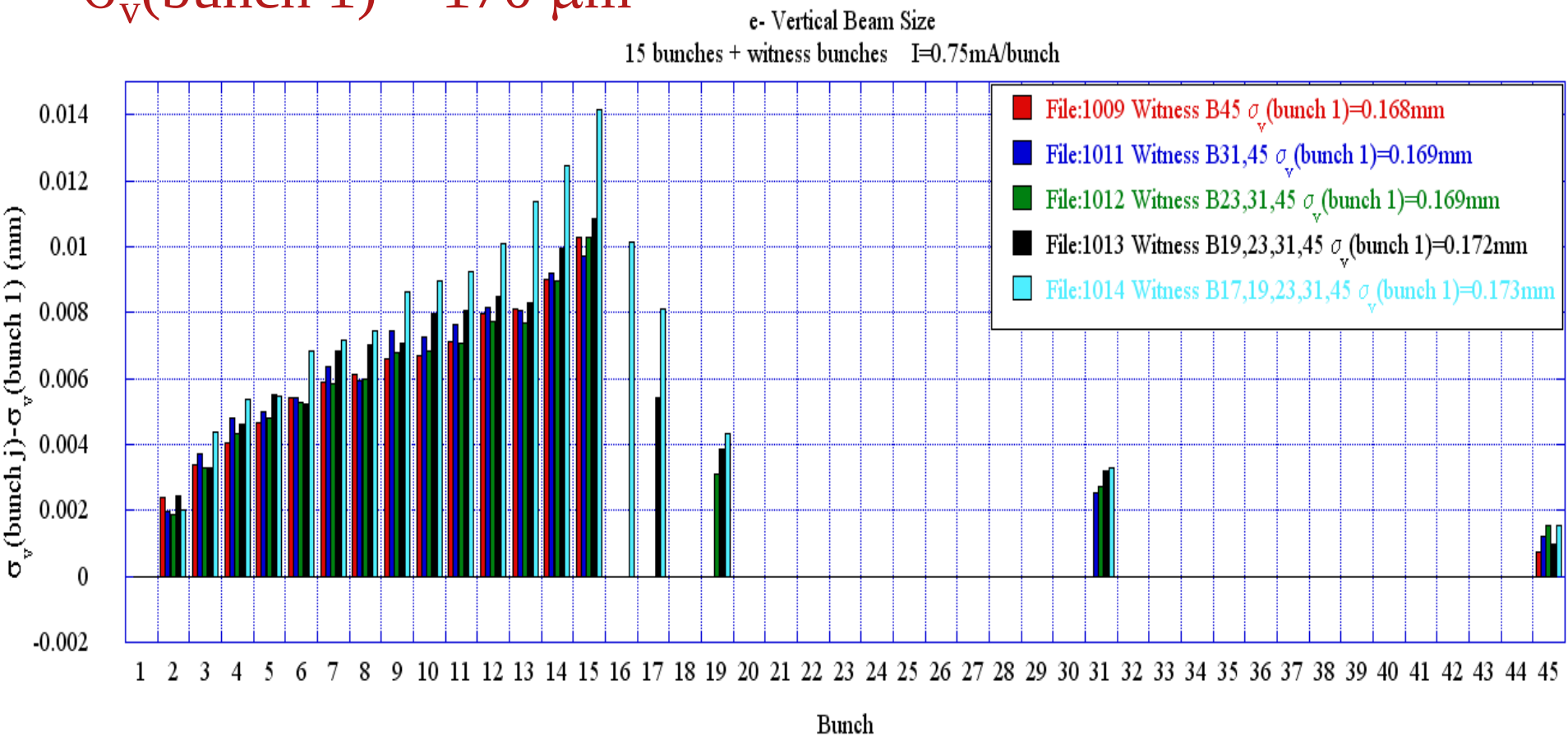
Witness Bunch Studies – e^+ Vertical Beamsize

- Initial train with 15 bunches
- Rapid growth observed with >15 consecutive bunches
- Witness bunches 17-31 fall in similar size range as in middle of train
- Witness bunch 45 beam size indistinguishable from bunch 1
- σ_v(bunch 1) ~ 280 μm



Witness Bunch Studies – e^- Vertical Beamsize

- ~6% growth down length of initial train
- Slow recovery for witness bunches to nearly bunch 1 size
- σ_v(bunch 1) ~ 170 μm



Electron Cloud (and Ion) Studies

- Electron Cloud Measurements Continue
- Collaborator Participation
  - Sept. 2006: M. Pivi
  - Jan. 2007:

    K. Harkay (ANL),

    J. Flanagan (KEKB)

    A. Molvik (LLNL)

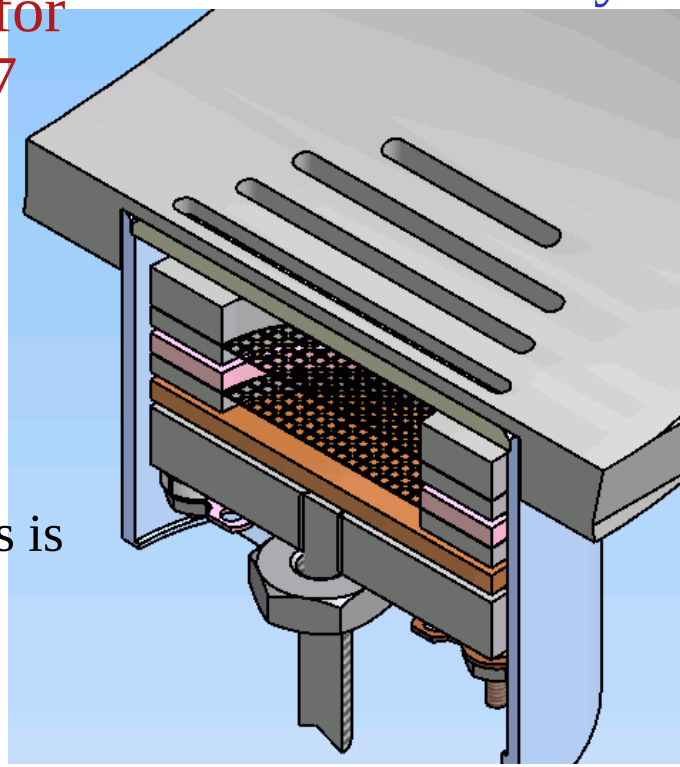
    R. Holtzapple &

    J. Kern (Alfred)

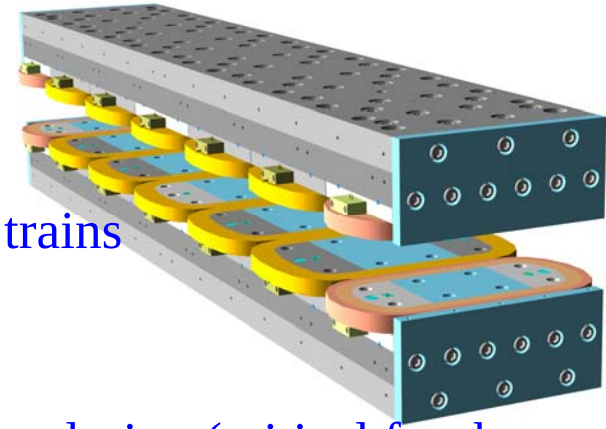
Experimental Plans Thru April 1, 2008

- 4ns transverse feedback
  - Implemented early this month
    - Presently able to fill a 21 bunch train at full ILC bunch current
    - Limitation is longitudinal feedback
  - Start looking at ILC-like bunch spacings
- Install L3 Retarding Field Analyzers (RFA) for electron cloud measurements during May `07 down
- Continue electron cloud and ion studies
  - Time for tests in lower emittance configuration?
- Prepare for wiggler vacuum chamber studies
  - Collaboration: SLAC, LBNL
  - Design and construction of new vacuum chambers is a critical path item
  - Segmented RFA for high field operation

L3 RFA Assembly



CesrTA Plans

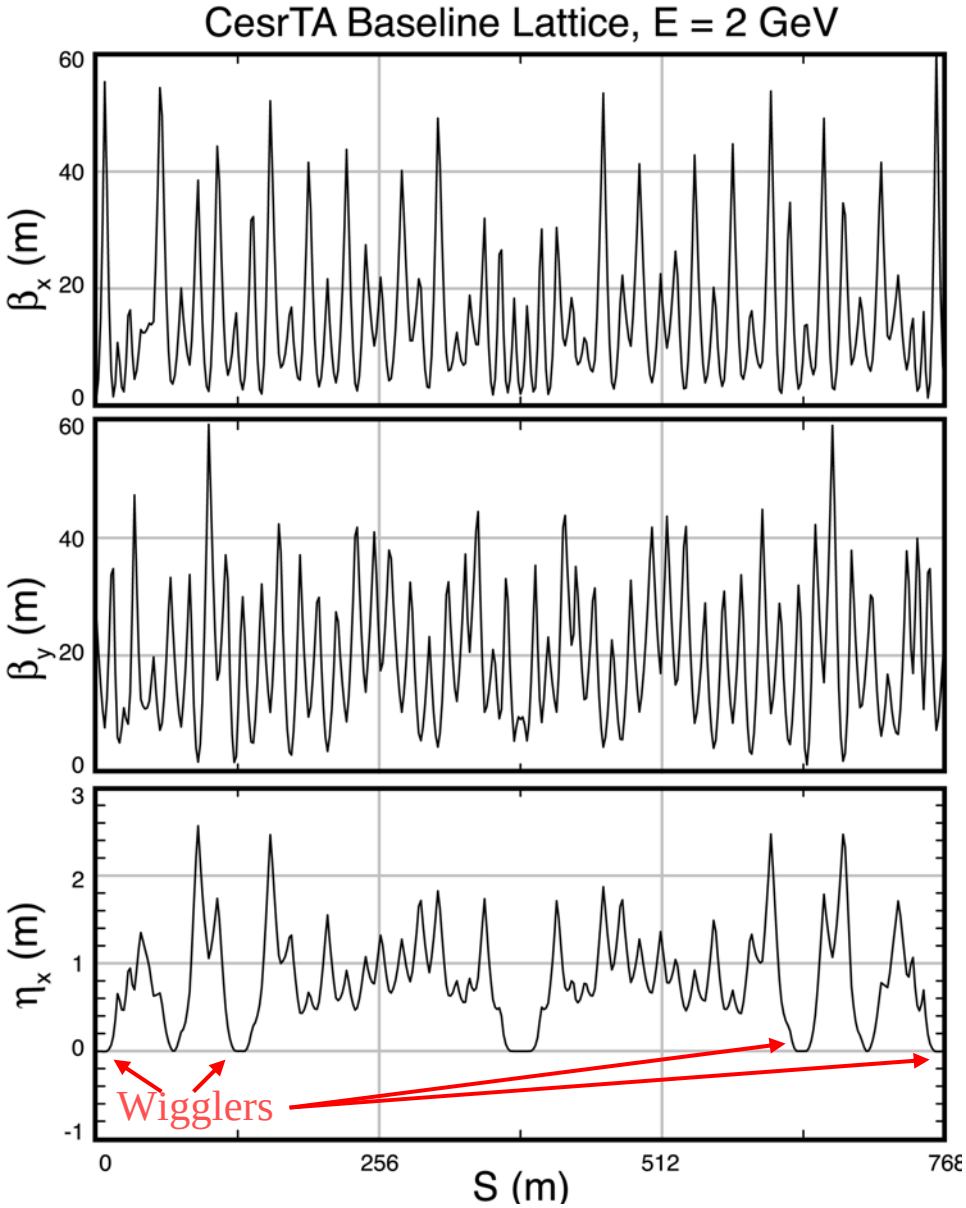


- Primary ILC EDR Goals
  - Electron cloud measurements
    - e^- cloud buildup in wigglers with ILC-like bunch trains
    - e^- cloud mitigation in wigglers
    - Instability thresholds
    - Validate the ILC DR wiggler and vacuum chamber design (critical for the single 6 km positron ring option)
    - Provide an experimental region with wigglers, dipoles, quadrupoles and drifts for general studies.
  - Ultra-low emittance operations and beam dynamics
    - Study emittance diluting effect of the e^- cloud on the e^+ beam
    - Make detailed comparisons between electrons and positrons
    - Look at fast-ion instability issues for electrons
    - Study alignment issues and emittance tuning methods
    - Develop fast emittance measurement techniques (including fast bunch-by-bunch X-ray camera)

Experimental Reach

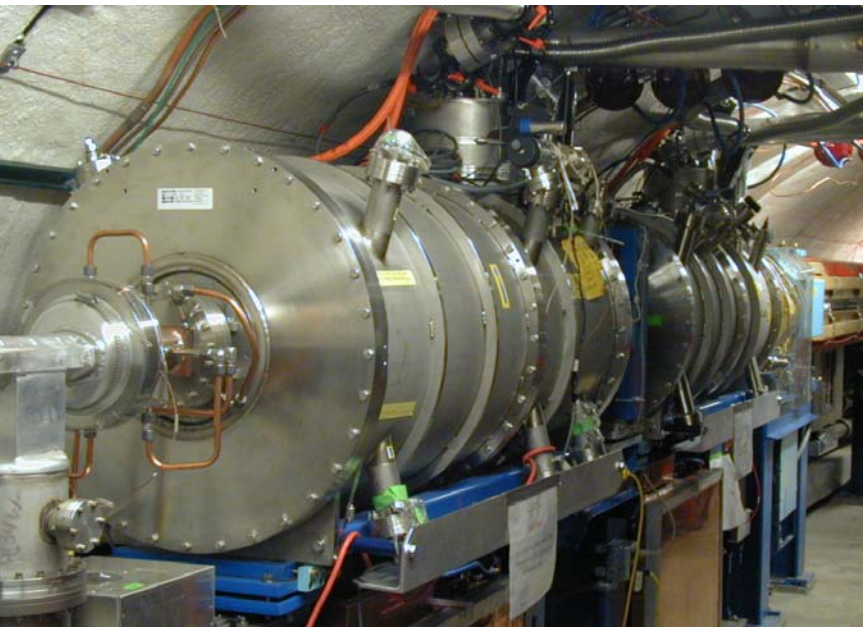
Baseline Lattice

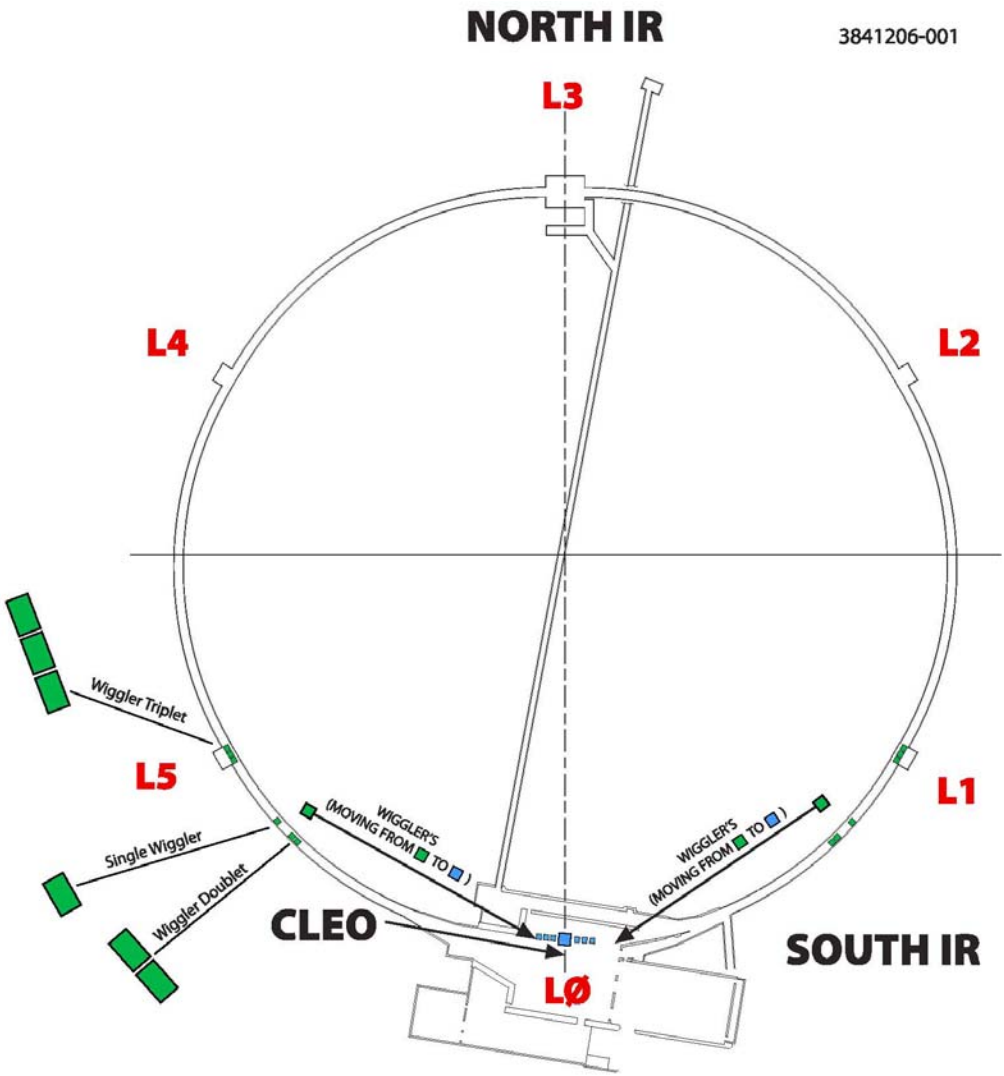
Parameter	Value
E	2.0 GeV
$N_{wiggler}$	12
B_{max}	2.1 T
ε_x	2.25 nm
Q_x	14.57
Q_y	9.62
Q_z	0.075
σ_E/E	8.6×10^{-4}
$\tau_{x,y}$	47 ms
σ_z (with V_{RF}=8.5MV)	9 mm
α_c	6.4×10^{-3}
$\tau_{Touschek}$(N_b=2x10^{10} & zero current ε_y=5pm)	~10 minutes



CESR Modifications

- Move 6 wigglers from the CESR arcs to the South IR (zero dispersion region)
  - Cryogenics support available
  - Zero dispersion regions can be created locally around the wigglers left in the arcs
- Make North IR available for insertion devices and instrumentation
- Instrumentation and feedback upgrade



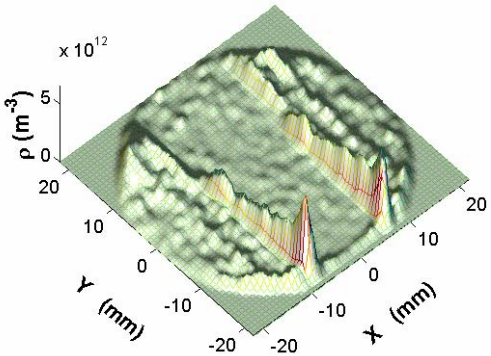


Suppressing Electron Cloud in Wigglers

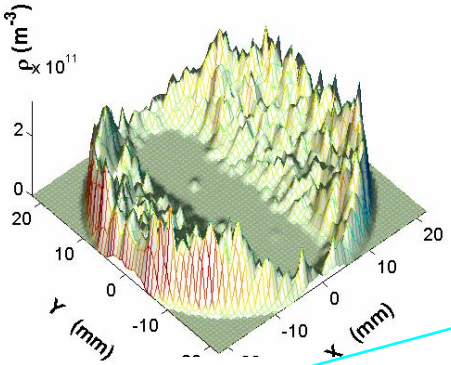
Design & test of impedance is under the way, test in PEPII Dipole & CESR Wiggler

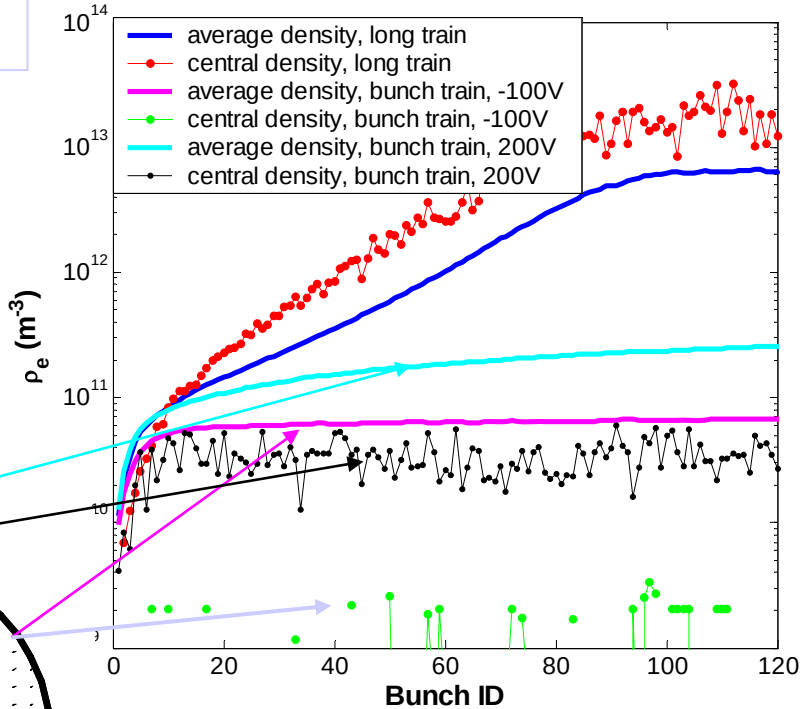
Submitted to PRSTAB

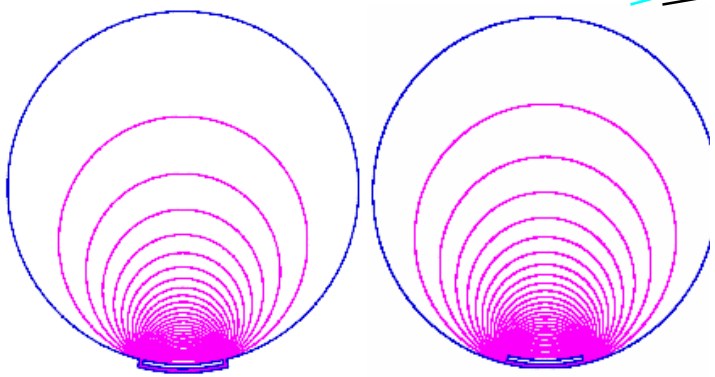
Strip-line type



Wire type







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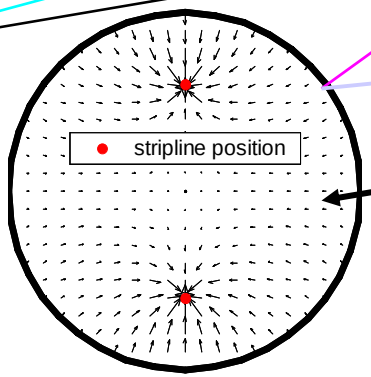


Wire type

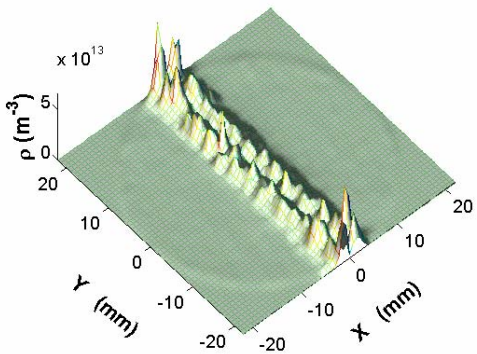
Suetsugu's talk

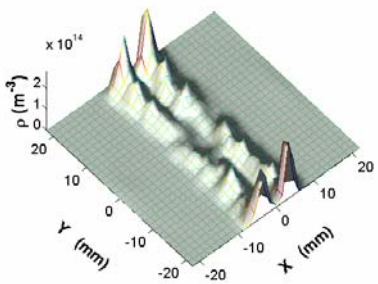
Calculation of the impedance (Cho, Lanfa)

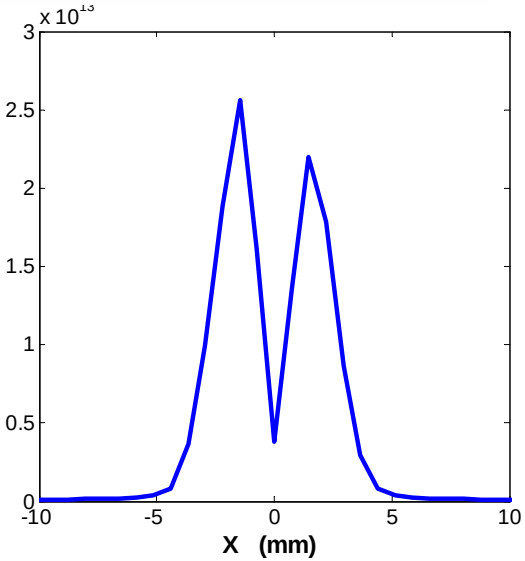
L. Wang
ILCDR06

Comparison with dipole

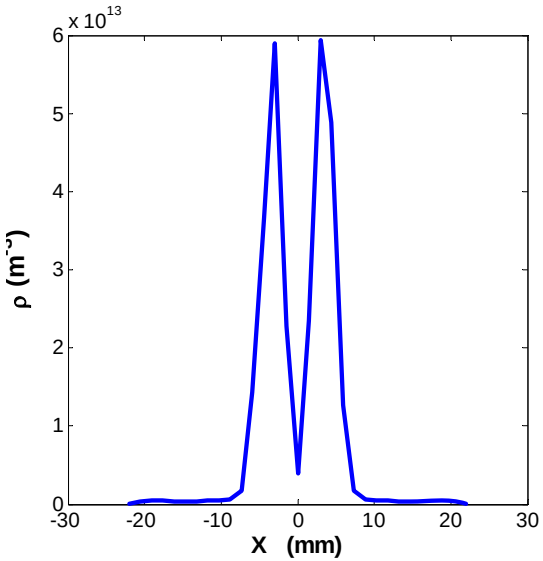
The multipacting strips of electron cloud in the wigglers is more close to the beam







Wiggler

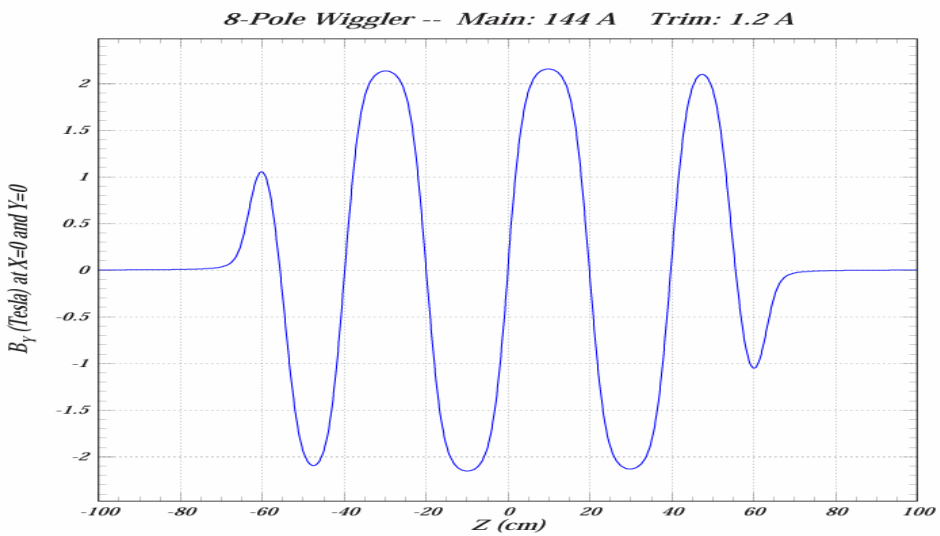


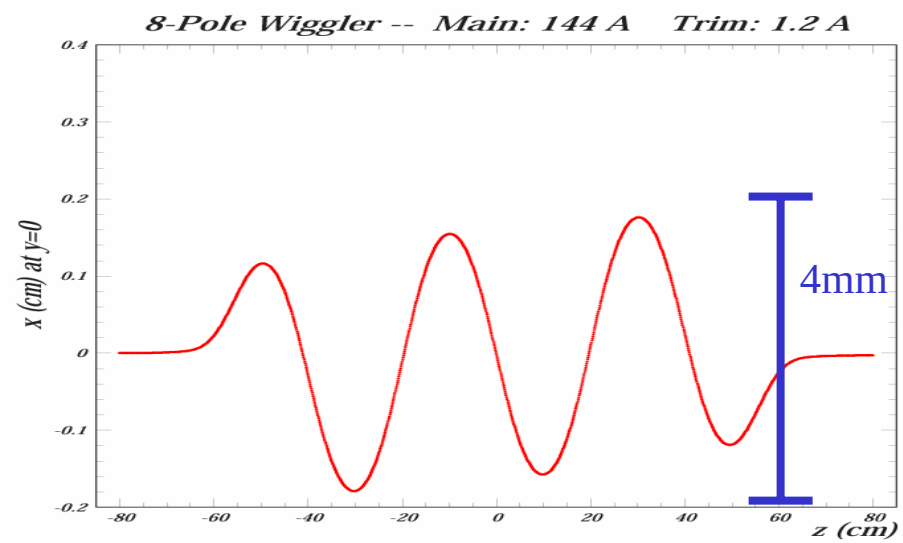
Dipole, B=0.194T

L. Wang, ILCDR06

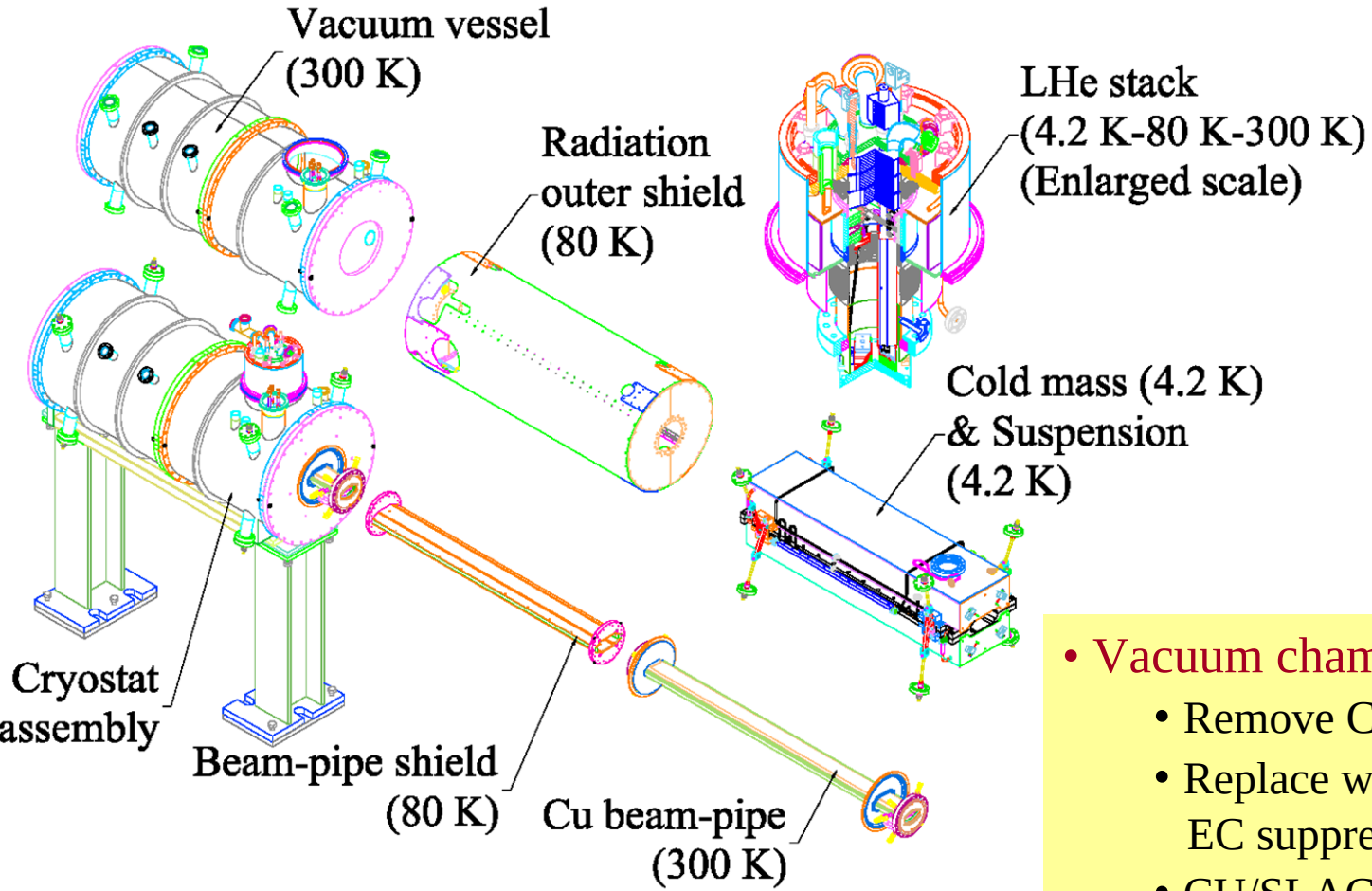
Wiggler Trajectory

- Note that CESR beam trajectory significant relative to stripe spacing at 2GeV
- Diagnostics
  - Ideally should be capable of roughly millimeter transverse resolution
  - Longitudinal segmentation to cleanly sample stripe





CESR-c Wiggler Modifications

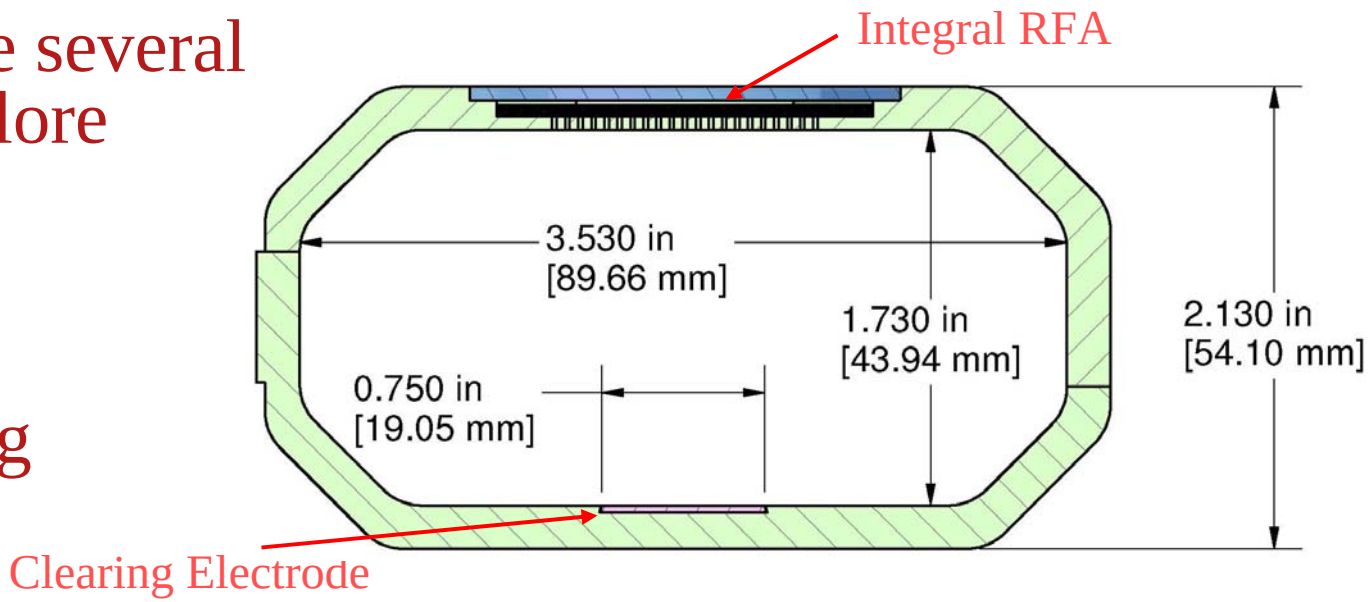


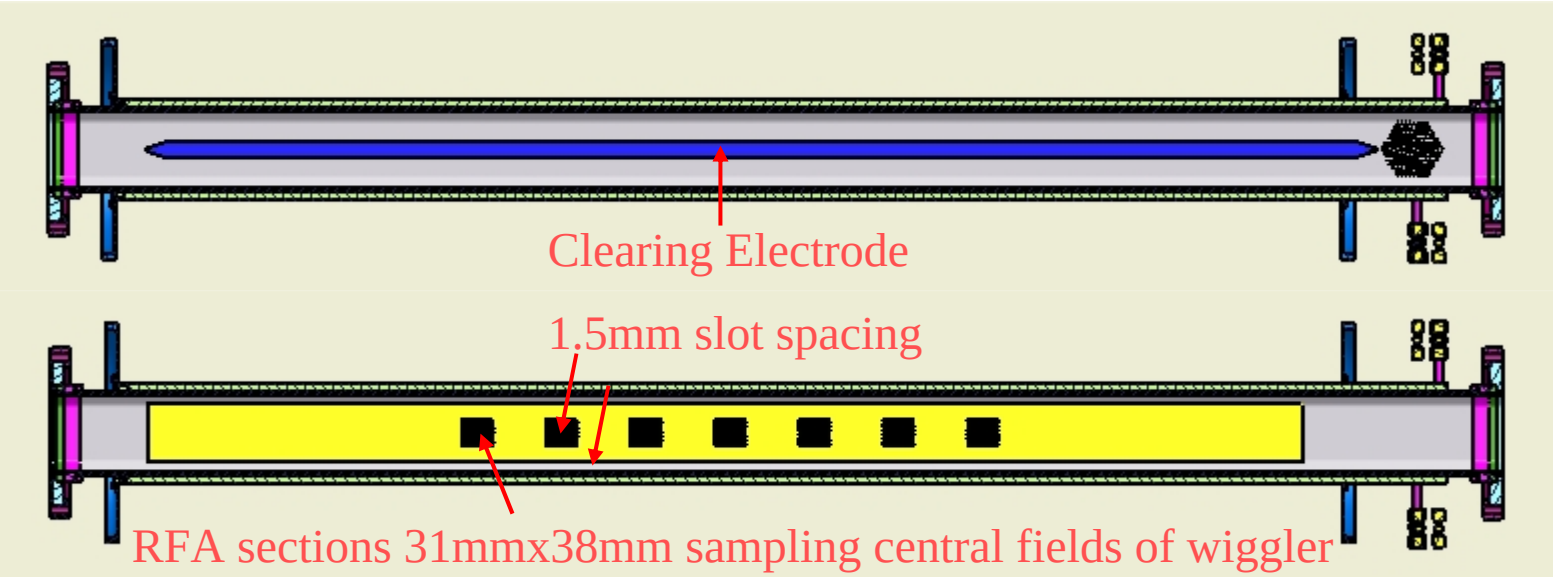
CESR vertical beam stay-clear: 50mm
ILC DR assumes 46mm diameter pipe

- Vacuum chamber tests in CesrTA
  - Remove Cu beam-pipe
  - Replace with beam-pipe having EC suppression and diagnostics
  - CU/SLAC/LBNL Collaboration
- Prototype ILC Wiggler and Vacuum Chamber
  - Cornell/LBNL Collaboration

Diagnostic Wiggler Chamber Concept

- Expect to make several variants to explore
  - Electrodes
  - Grooves
  - Coatings
- Modify existing extrusions

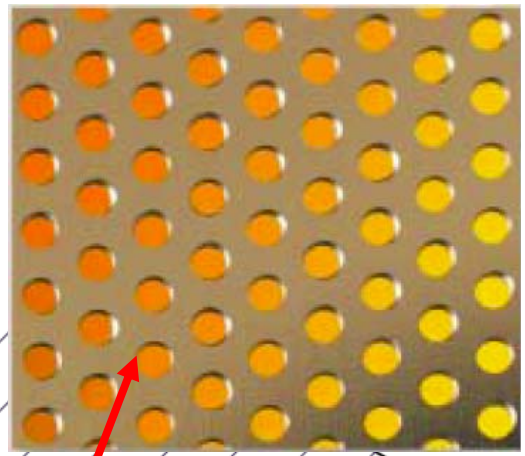


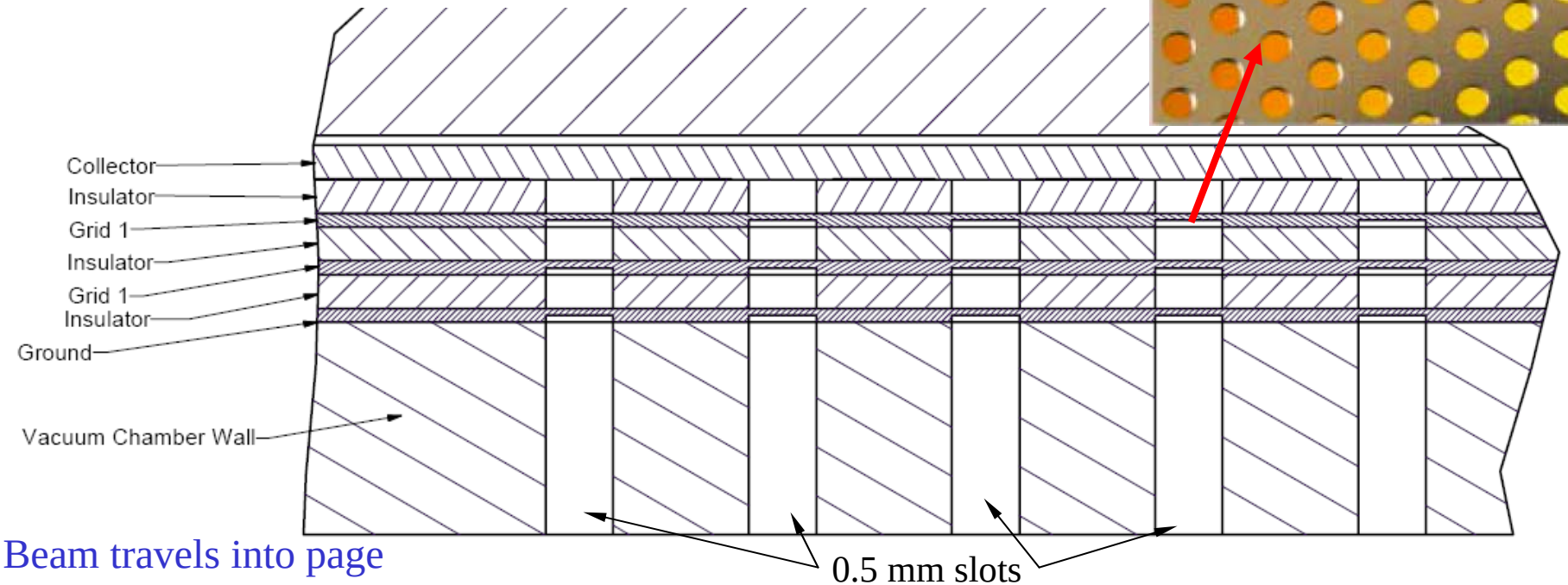


Wiggler Chamber Concept II

- Thin Retarding Field Analyzer Concept
  - Strip pickups - copper clad kapton (flex circuit), 0.010” thickness
  - Insulator layers – 0.010” kapton
  - 3 mesh layers
    - 0.002” mesh spot-welded to 0.002” SS
    - ~25% transparency
  - Slots – 33% transparency (too high?)
  - Build prototype and test this summer

InterNet, Inc.





Beam travels into page

Conclusion

- Initial measurements in CESR show evidence for electron cloud effects with both positrons and electrons
  - Work towards detailed comparison of data with simulations is starting
  - Will install first APS-style RFAs for direct measurement of cloud in roughly 2 months
  - Also setting up for measurements with 4ns bunch spacing
- CesrTA
  - Damping ring proposal has now been resubmitted as a joint DOE/NSF proposal
  - First dedicated run expected in mid-2008
  - Major focus on electron cloud growth and suppression in wigglers and characterization of EC with ultralow emittance beams
  - Preparation for wiggler chamber tests
  - Input and/or collaboration welcomed!

Acknowledgments

- CesrTA Development and CESR EC Machine Studies
  - J. Alexander
  - M. Billing
  - G. Codner
  - J. Crittenden
  - M. Ehrlichman (Minn)
  - M. Forster
  - D. Hartill
  - R. Helms
  - D. Rice
  - D. Rubin
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