Electron Cloud Studies at CESR-c and CesrTA

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Accelerator-Based Sciences and Education

Outline

- Introduction
- 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

Introduction

- 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
- 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

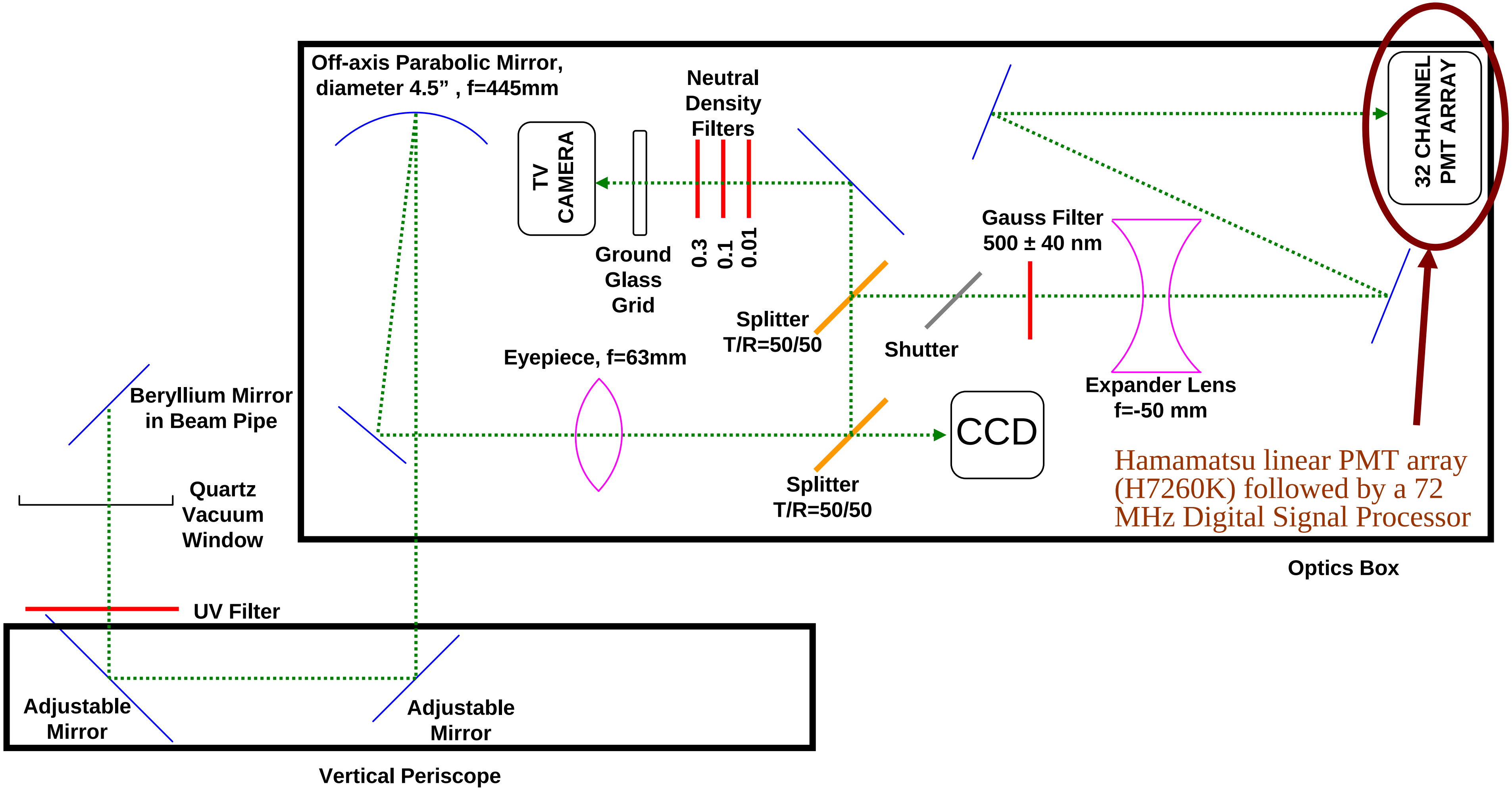
CESR-c ⇨ CesrTA

- 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
  - Provide 120 days of dedicated operation for damping rings experiments per year (flexible use for collaborators in the ILC DR community)

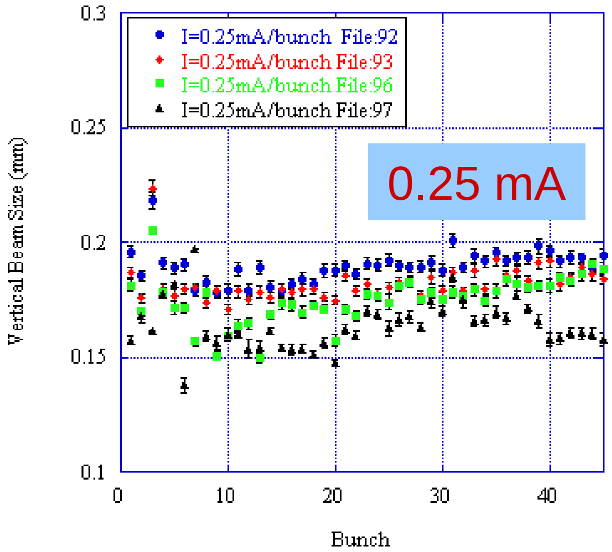
Beam Size Monitor

BSM synchrotron light optics line for positrons

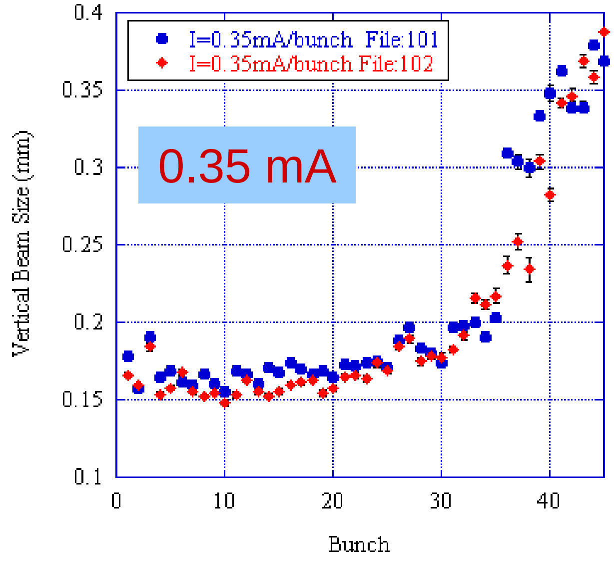
(optics line for electrons is similar)



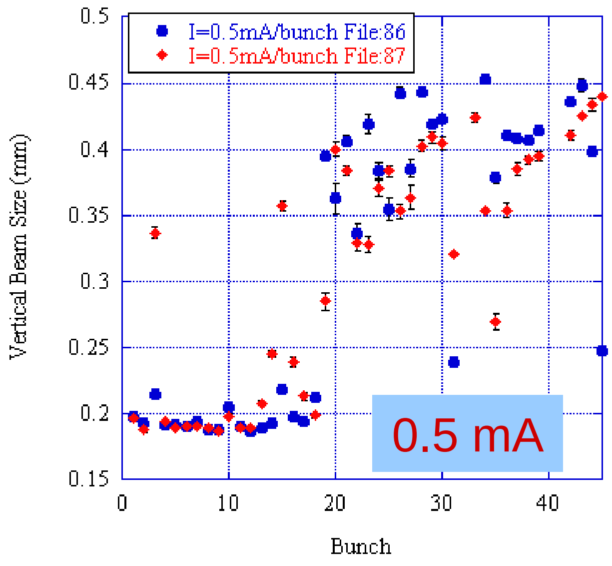
e+ Beam Size vs Bunch Current

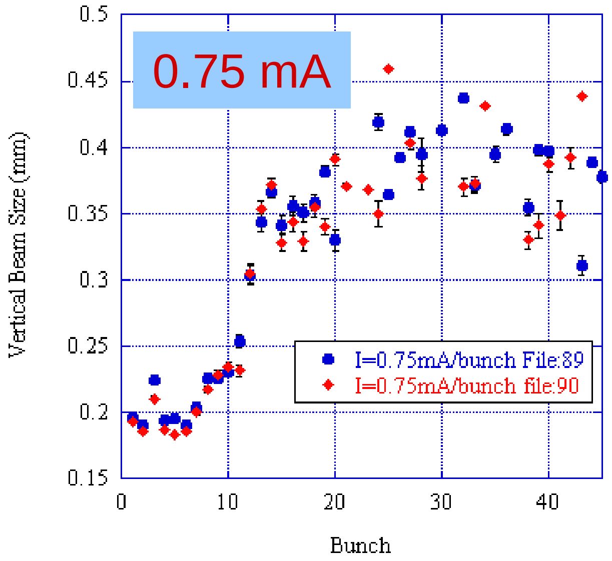


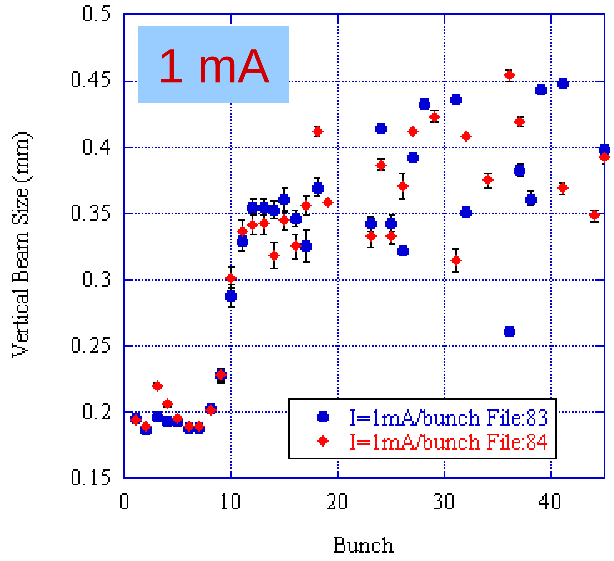
2 GeV vertical bunch-by-bunch beam size for 1x45 pattern, positrons



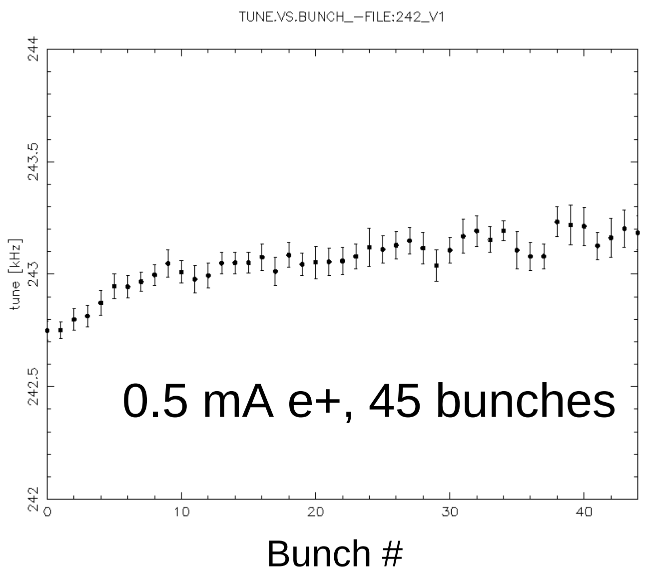
Advancing onset of beam instability as a function of increasing bunch current





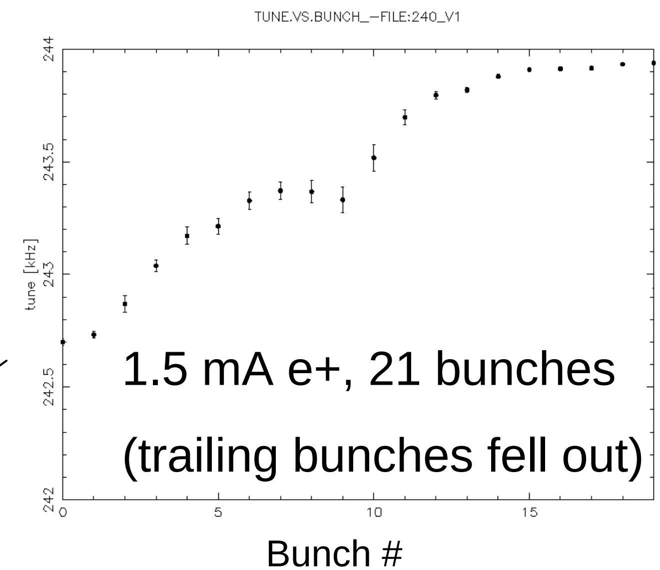


Multibunch Tune Measurements at 5.3 GeV

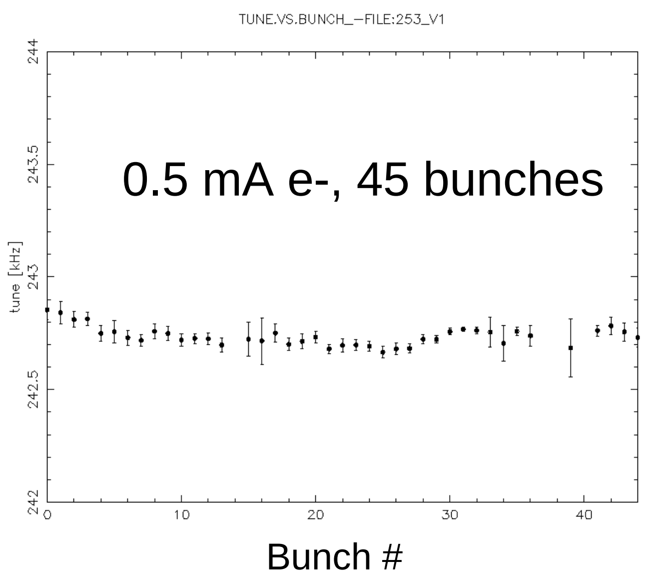


5.3 GeV vertical tune for 1x45 pattern, positrons

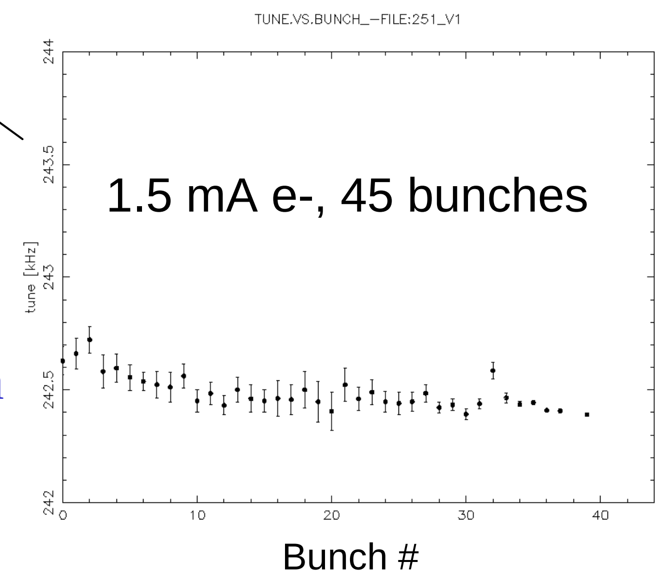
(2 kHz Δf ~ 0.005 ΔQ)



2 kHz full scale



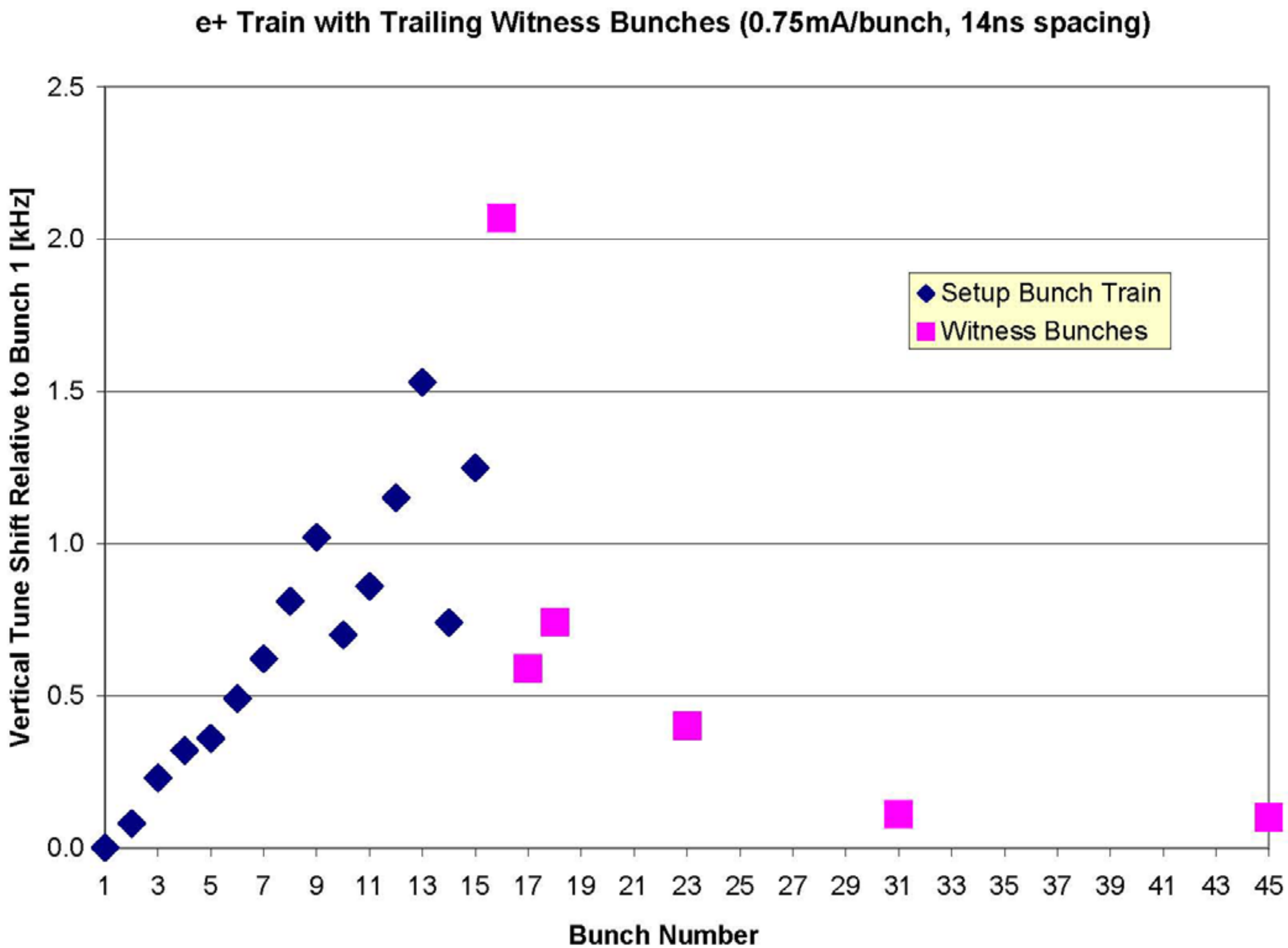
5.3 GeV vertical tune for 1x45 pattern, electrons



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

Witness Bunch Studies – e^+ Vertical Tune Shift

- Initial train of 15 bunches ⇨ generate EC
- Measure tune shift and beamsize for witness bunches at various spacings

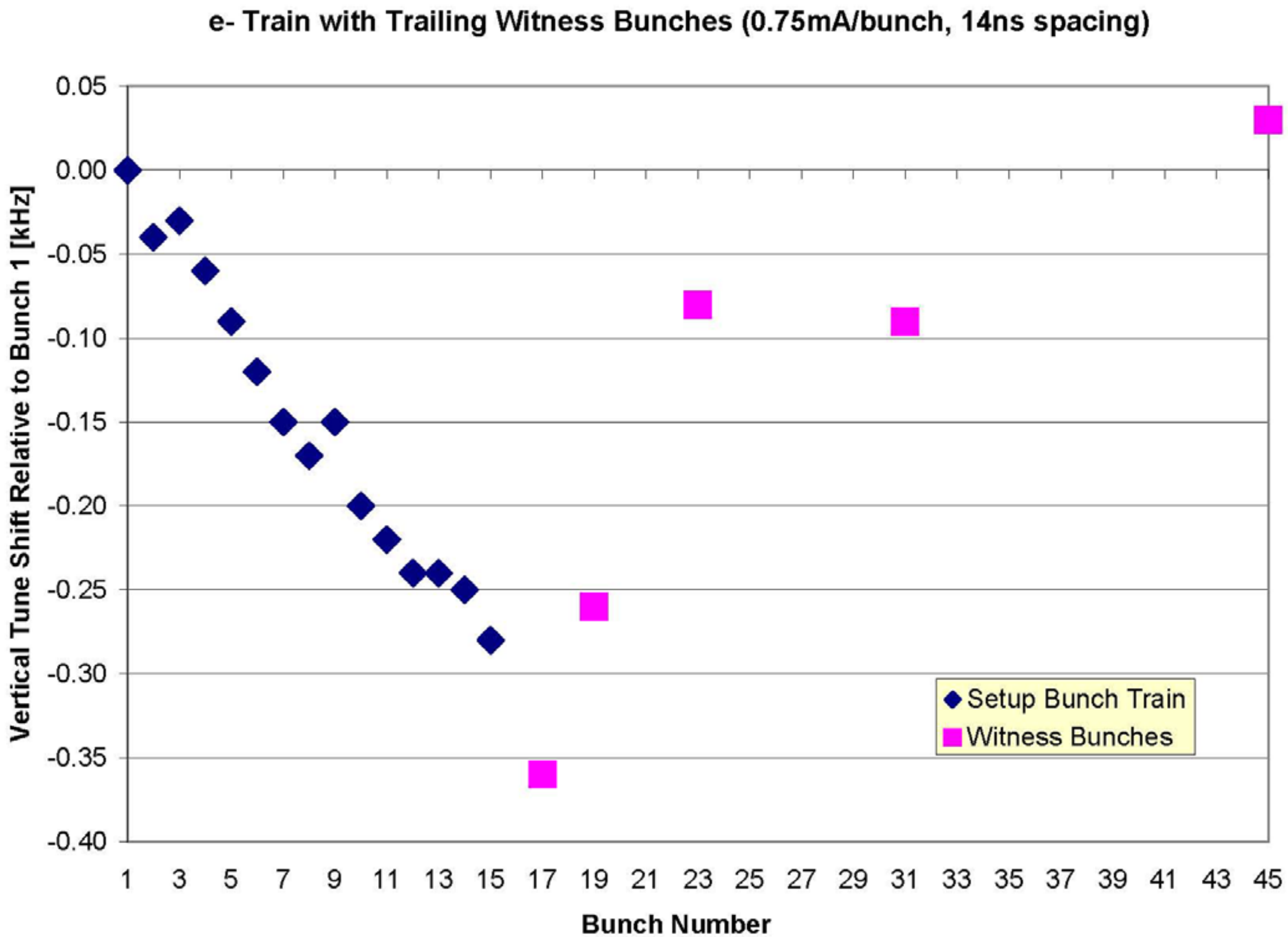


1 kHz ⇨ $\Delta\nu$=0.0026
$\rho_e \sim 1.5 \times 10^{11}$ m^{-3}
Ohmi, etal, APAC01, p.445

1.9 GeV Operation

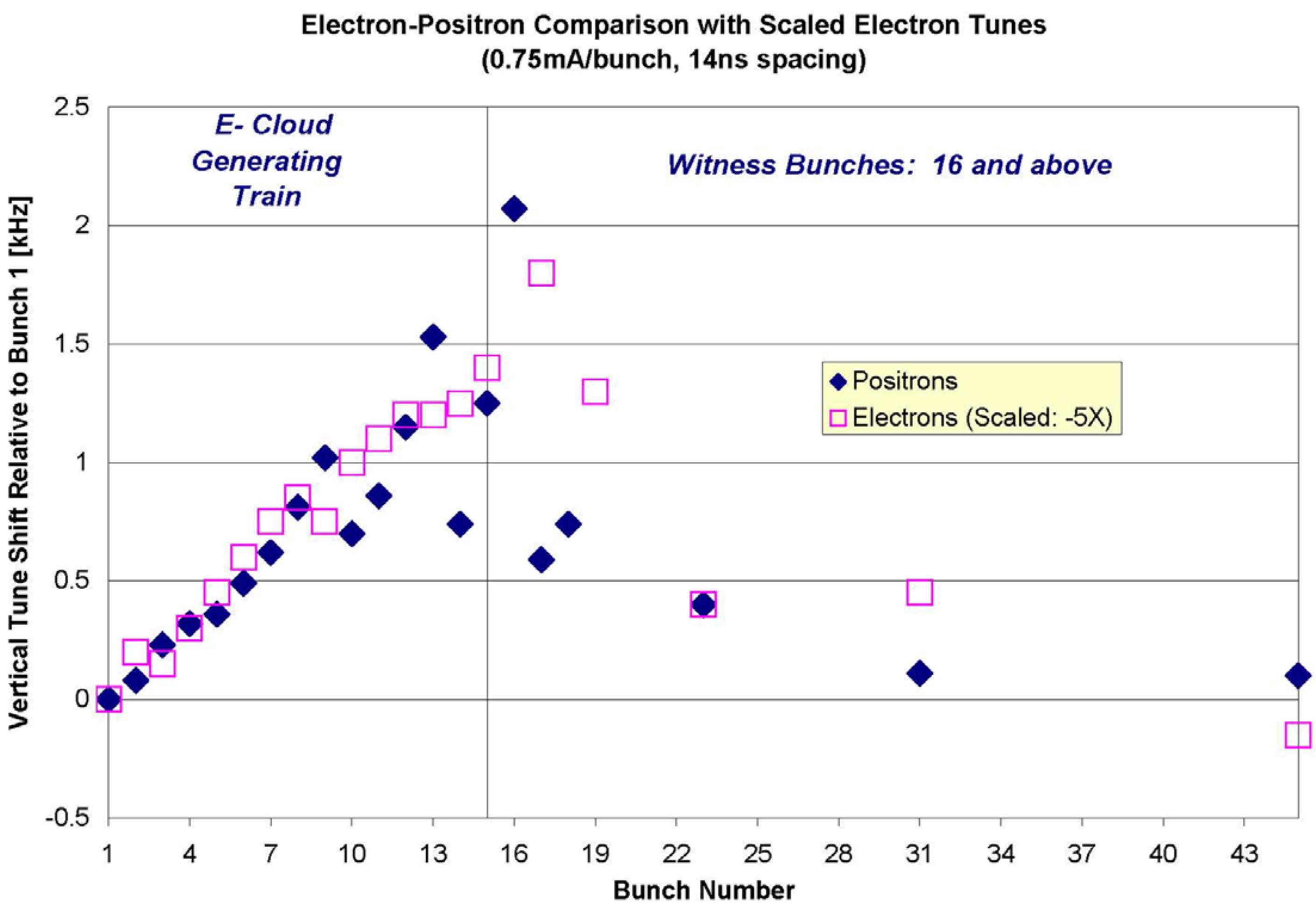
Witness Bunch Studies – e^- Vertical Tune Shift

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



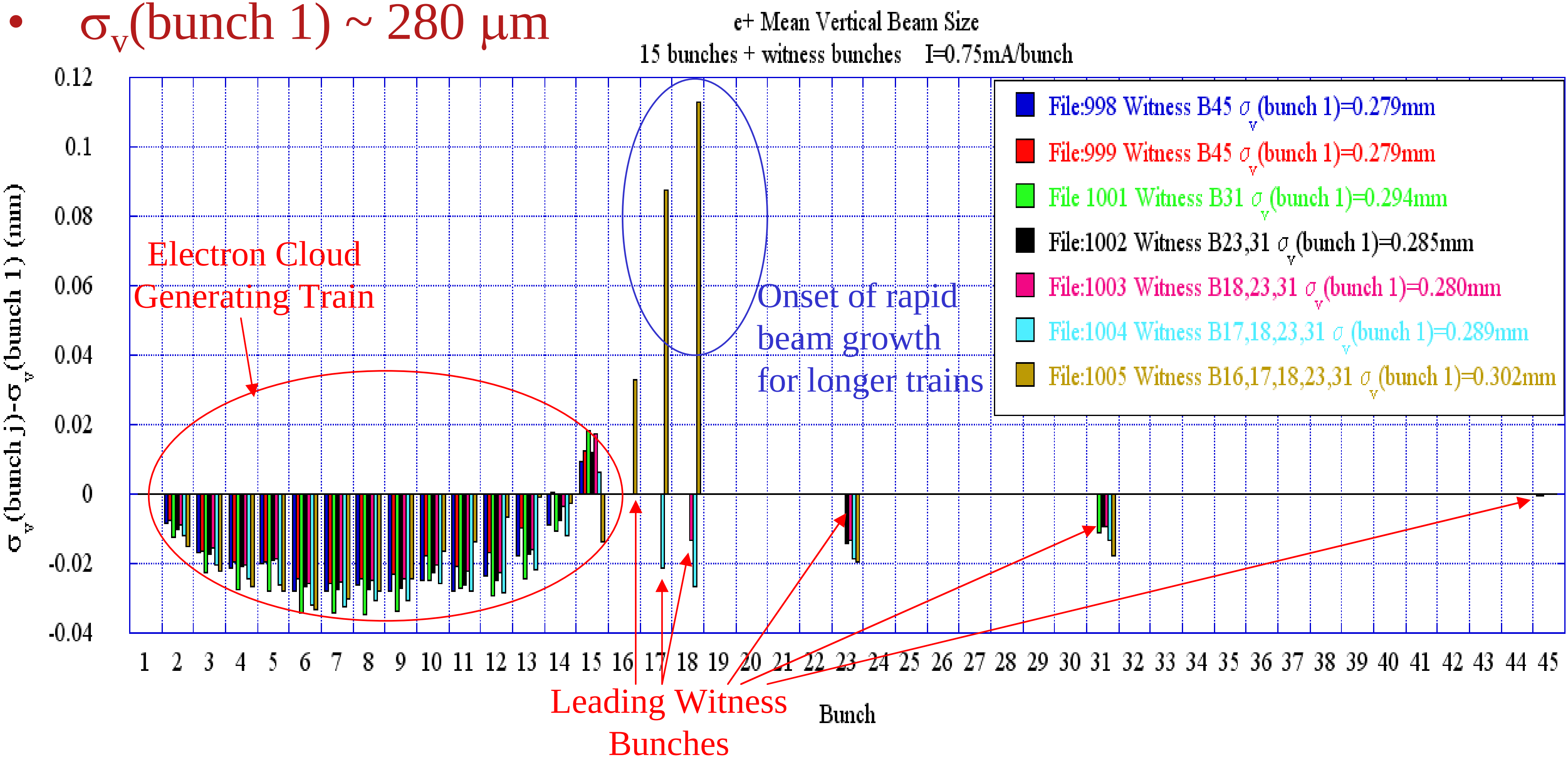
Witness Bunch Studies – Comparison of e-/e+ Tunes

- Magnitude of tune shift for electron beam is ~1/5 of shift observed for positron beam



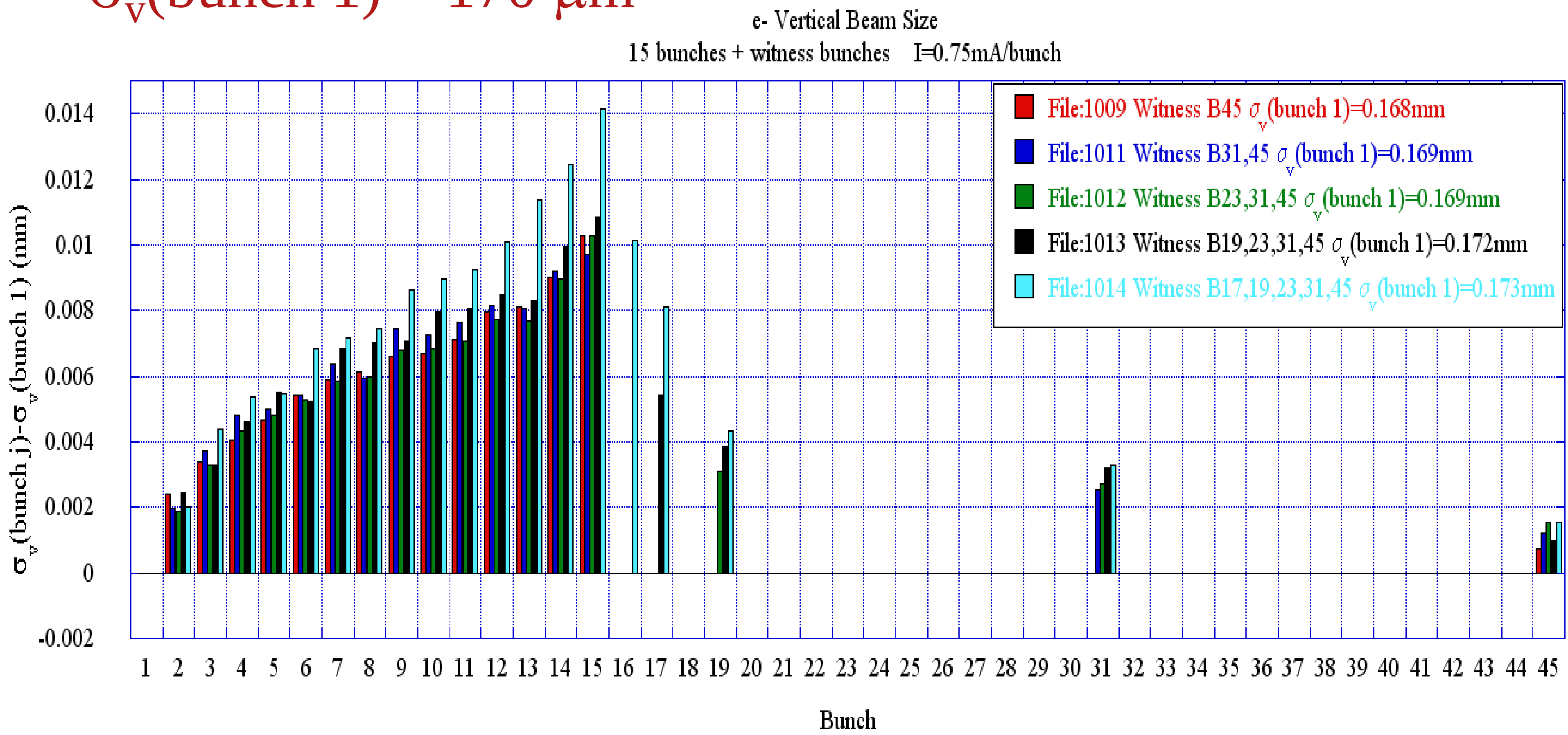
Witness Bunch Studies – e^+ Vertical Beamsize

- 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

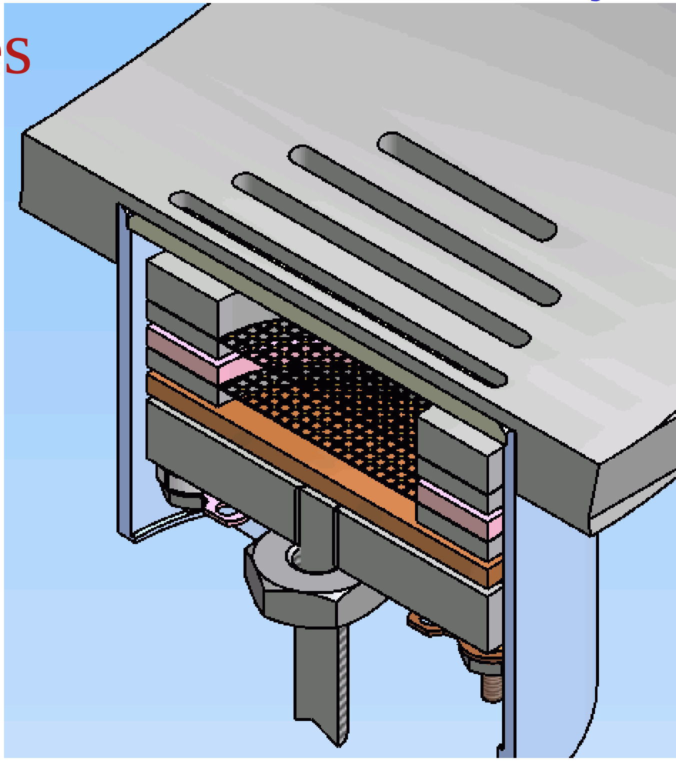


- Electron Cloud and Ion Studies Continue
- Collaborator Participation
  - Sept. 2006: M. Pivi
  - Jan. 2007:
    K. Harkay (ANL),
    J. Flanagan (KEKB)
    A. Molvik (LLNL)
    R. Holtzapple &
    J. Kern (Alfred)

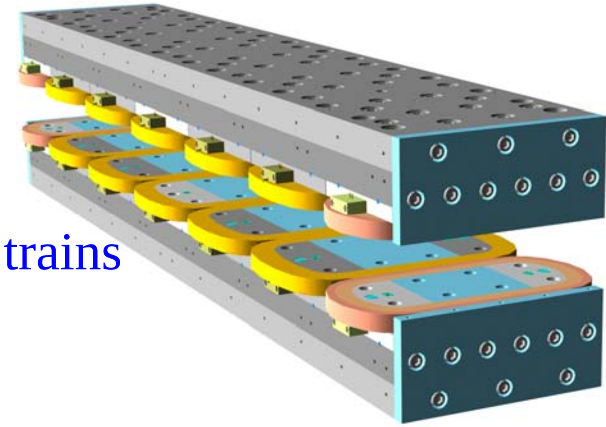
Experimental Plans Thru April 1, 2008

- Implement 4ns transverse 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

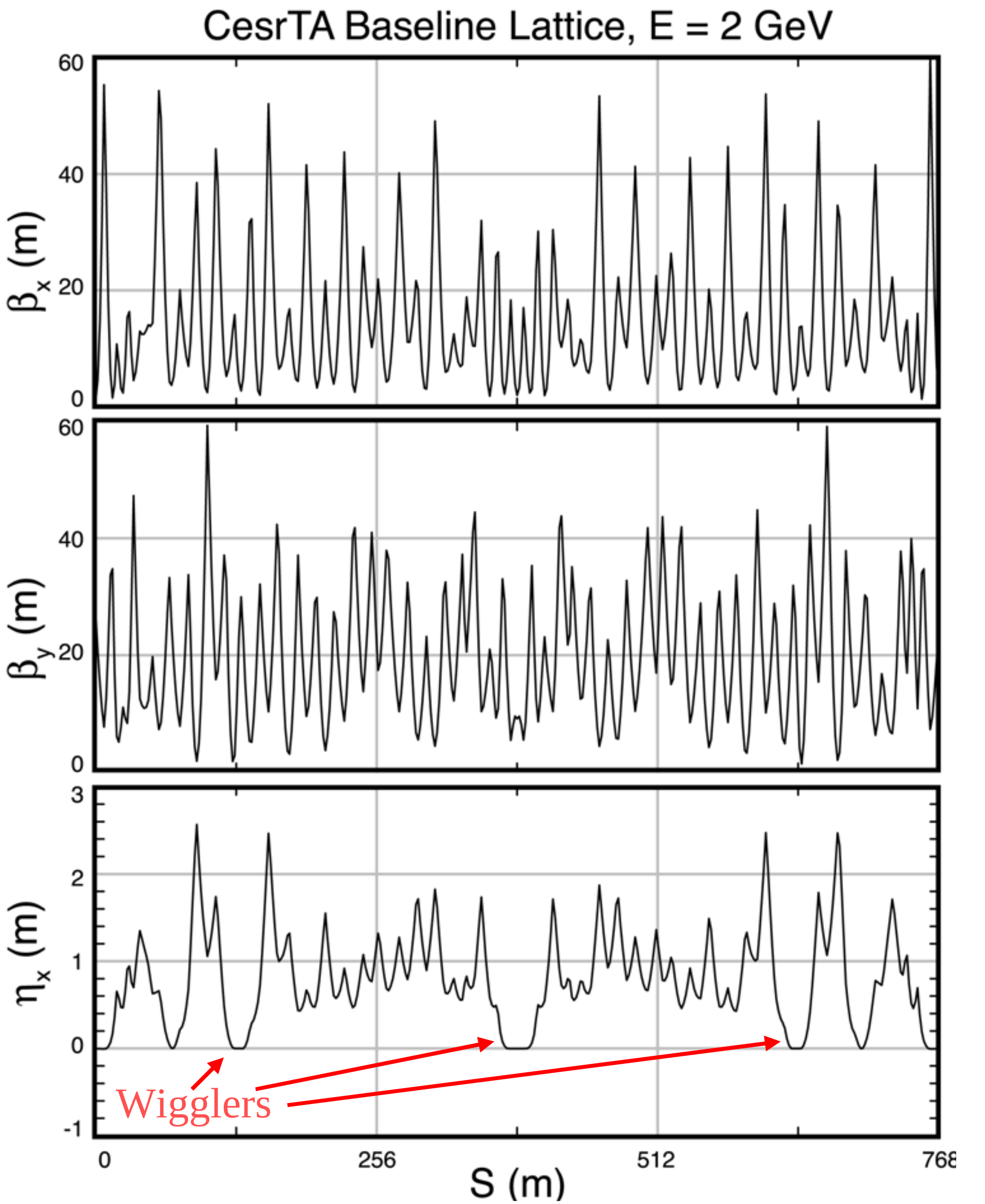


- Primary ILC EDR Goals
  - Electron cloud measurements
    - e^- cloud buildup in wigglers with ILC-like bunch trains
    - e^- cloud mitigation in wigglers
    - Instability thresholds
    - Validate the ILC DR wiggler and vacuum chamber design (critical for the single 6 km positron ring option)
  - Ultra-low emittance operations and beam dynamics
    - Study emittance diluting effect of the e^- cloud on the e^+ beam
    - Detailed comparisons between electrons and positrons
    - Also look at fast-ion instability issues for electrons
    - Study alignment issues and emittance tuning methods
    - Emittance measurement techniques (including fast bunch-by-bunch X-ray camera)

Experimental Reach

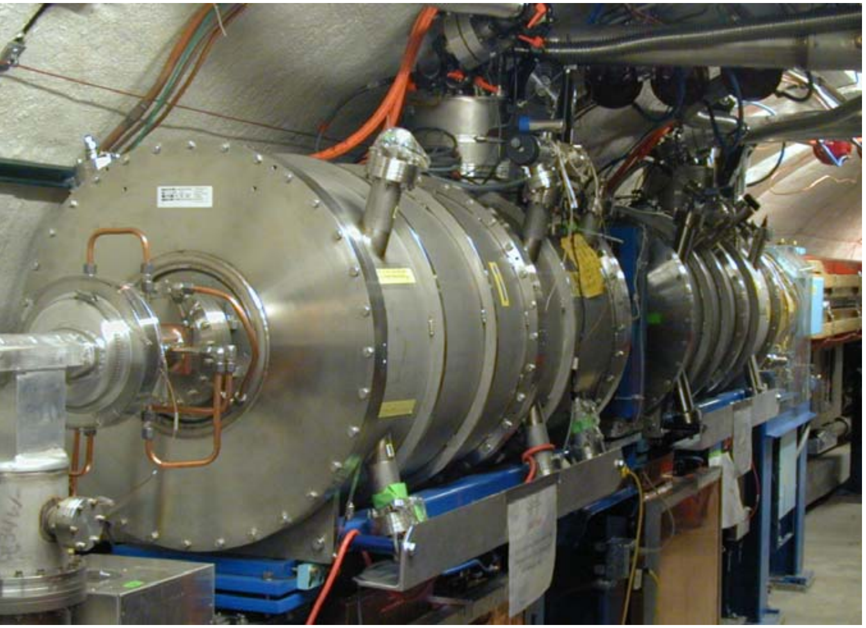
Baseline Lattice

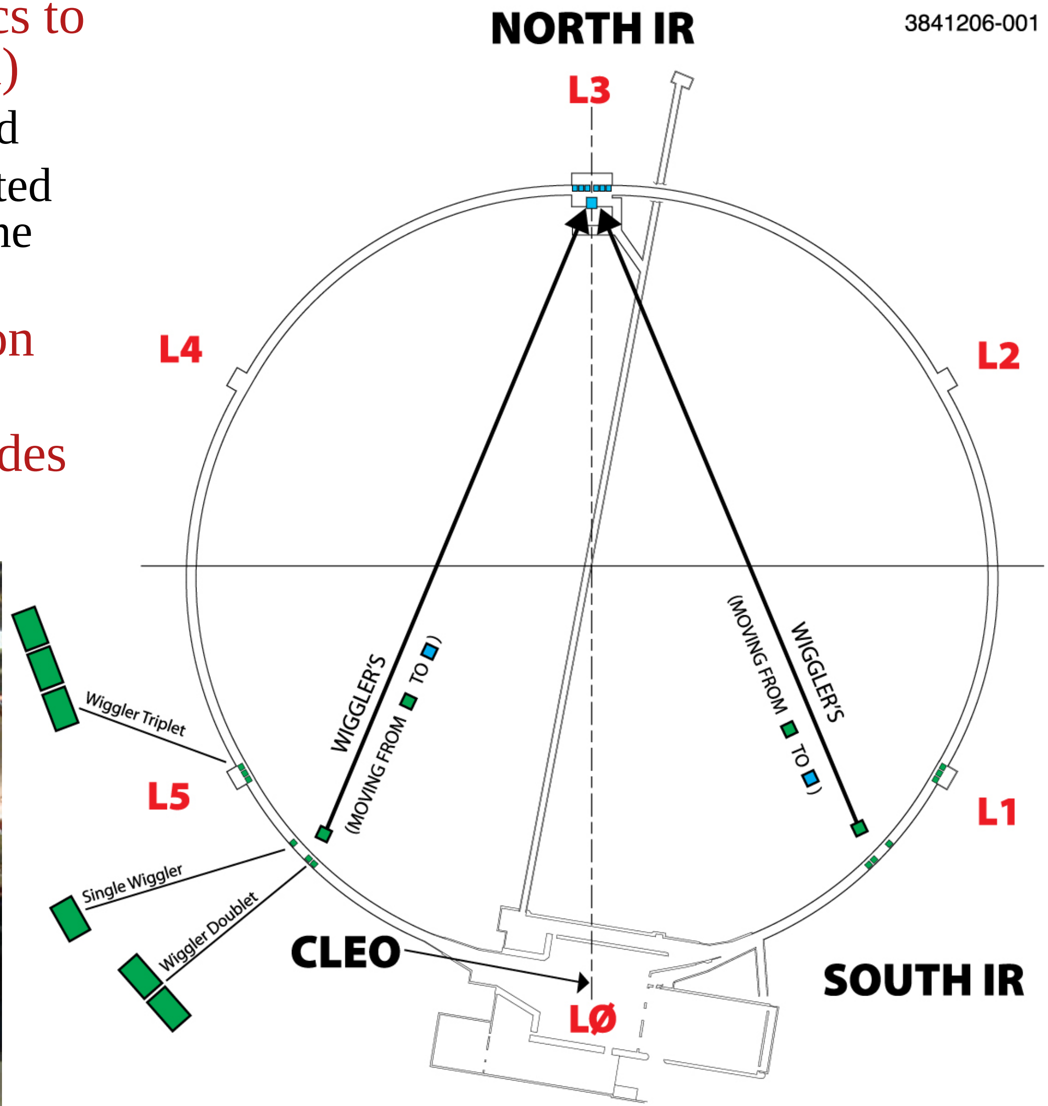
Parameter	Value
E	2.0 GeV
$N_{wiggler}$	12
B_{max}	2.1 T
ε_x	2.25 nm
Q_x	14.59
Q_y	9.63
Q_z	0.098
σ_E/E	8.6 x 10^{-4}
$\tau_{x,y}$	47 ms
σ_z (with V_{RF}=15MV)	6.8 mm
α_c	6.4 x 10^{-3}
$\tau_{Touschek}$(N_b=2x10^{10} & ε_y=5pm)	7 minutes



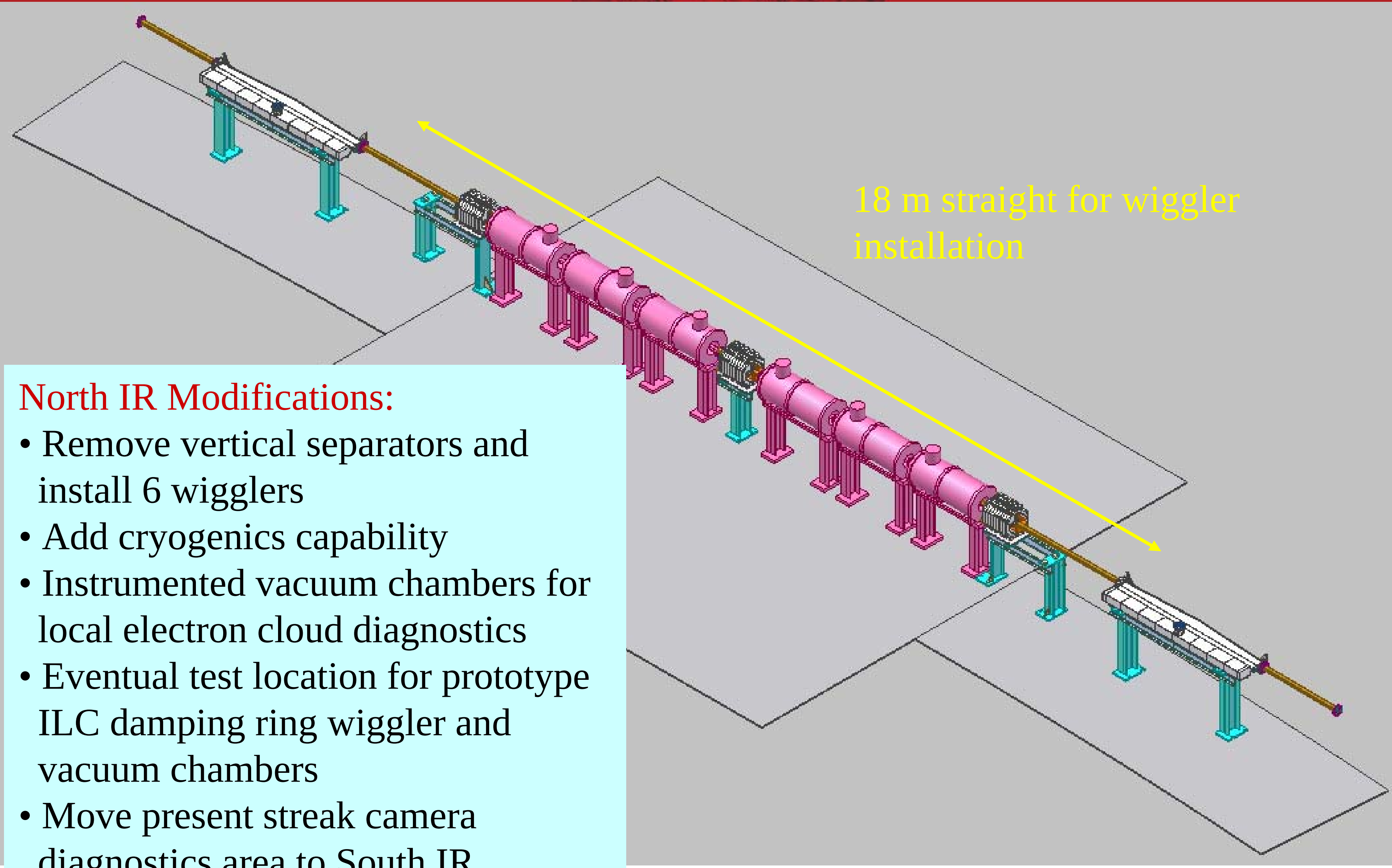
CESR Modifications

- Move 6 wigglers from the CESR arcs to the North IR (zero dispersion region)
  - New cryogenic transfer line required
  - Zero dispersion regions can be created locally around the wigglers left in the arcs
- Make South IR available for insertion devices and instrumentation
- Instrumentation and feedback upgrades





The North IR



North IR Modifications:

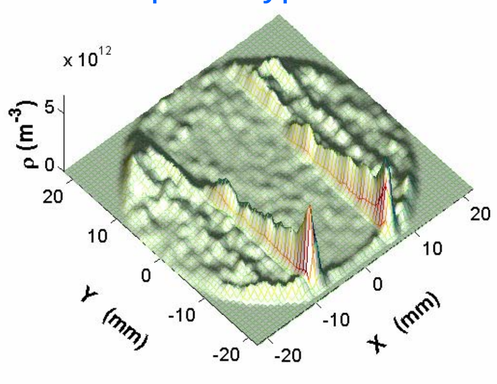
- Remove vertical separators and install 6 wigglers
- Add cryogenics capability
- Instrumented vacuum chambers for local electron cloud diagnostics
- Eventual test location for prototype ILC damping ring wiggler and vacuum chambers
- Move present streak camera diagnostics area to South IR

Suppressing Electron Cloud in Wigglers

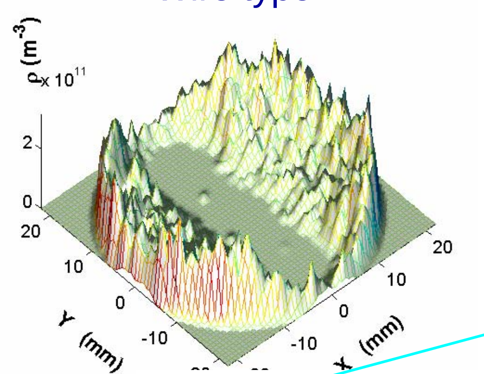
Design & test of impedance is under the way, test in PEPII Dipole & CESR Wiggler

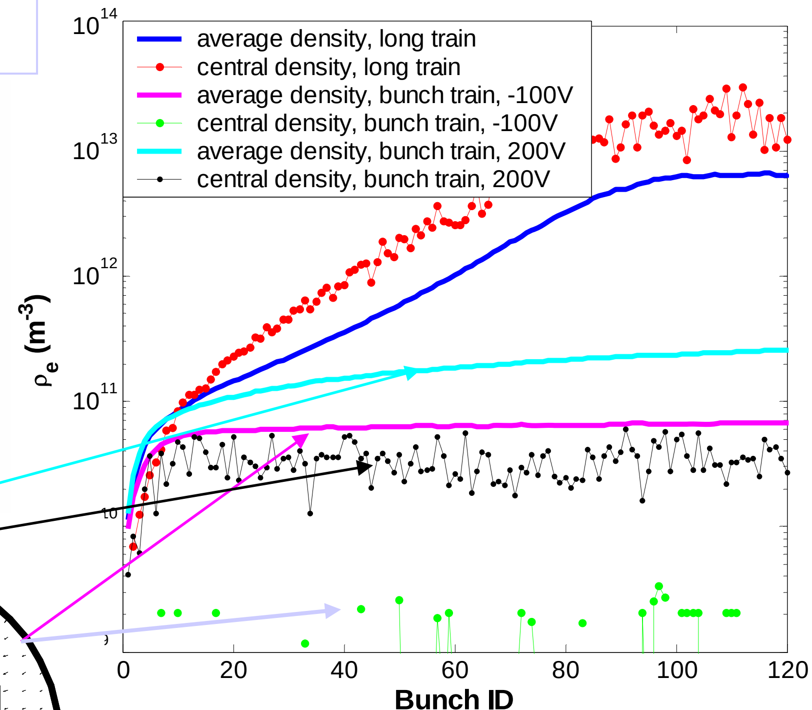
Submitted to PRSTAB

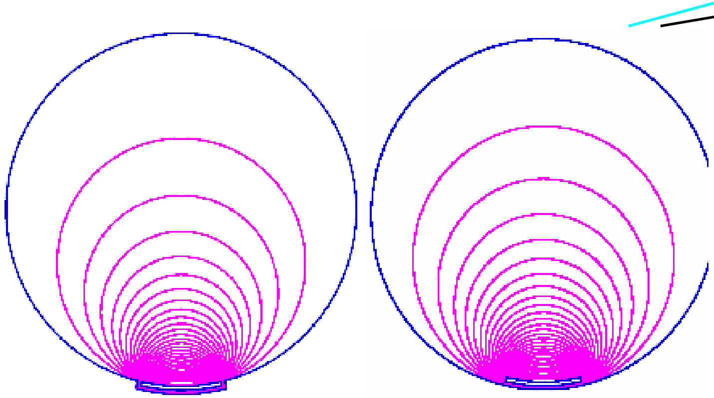
Strip-line type



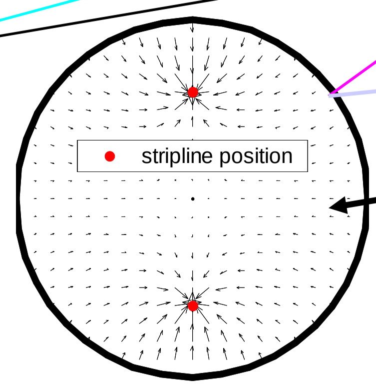
Wire type







Strip-line type



Wire type

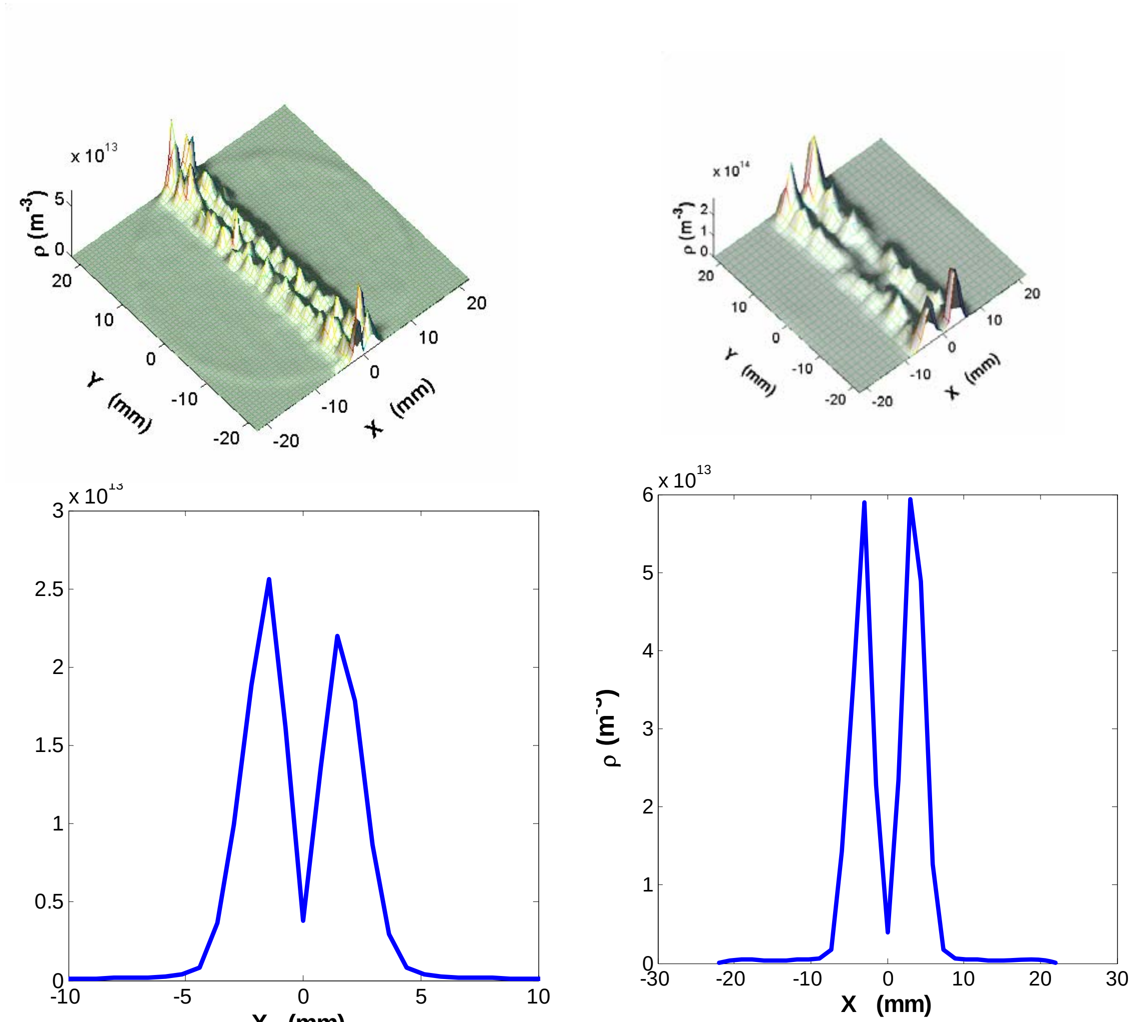
Suetsugu's talk

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



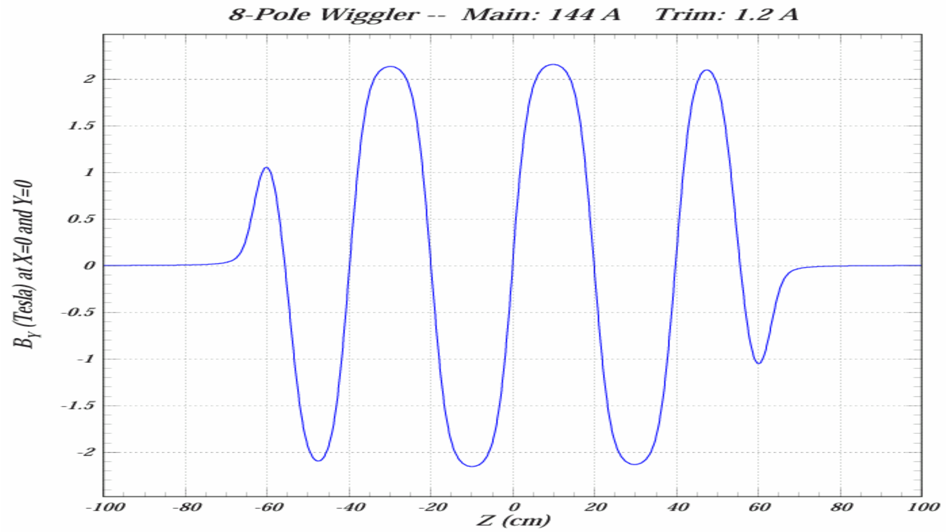
Wiggler

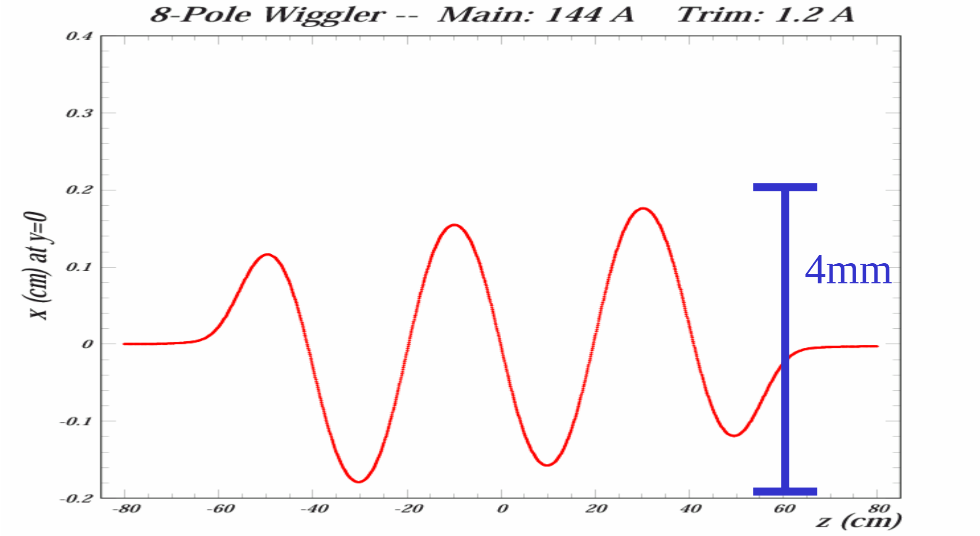
Dipole, B=0.194T

L. Wang, ILCDR06

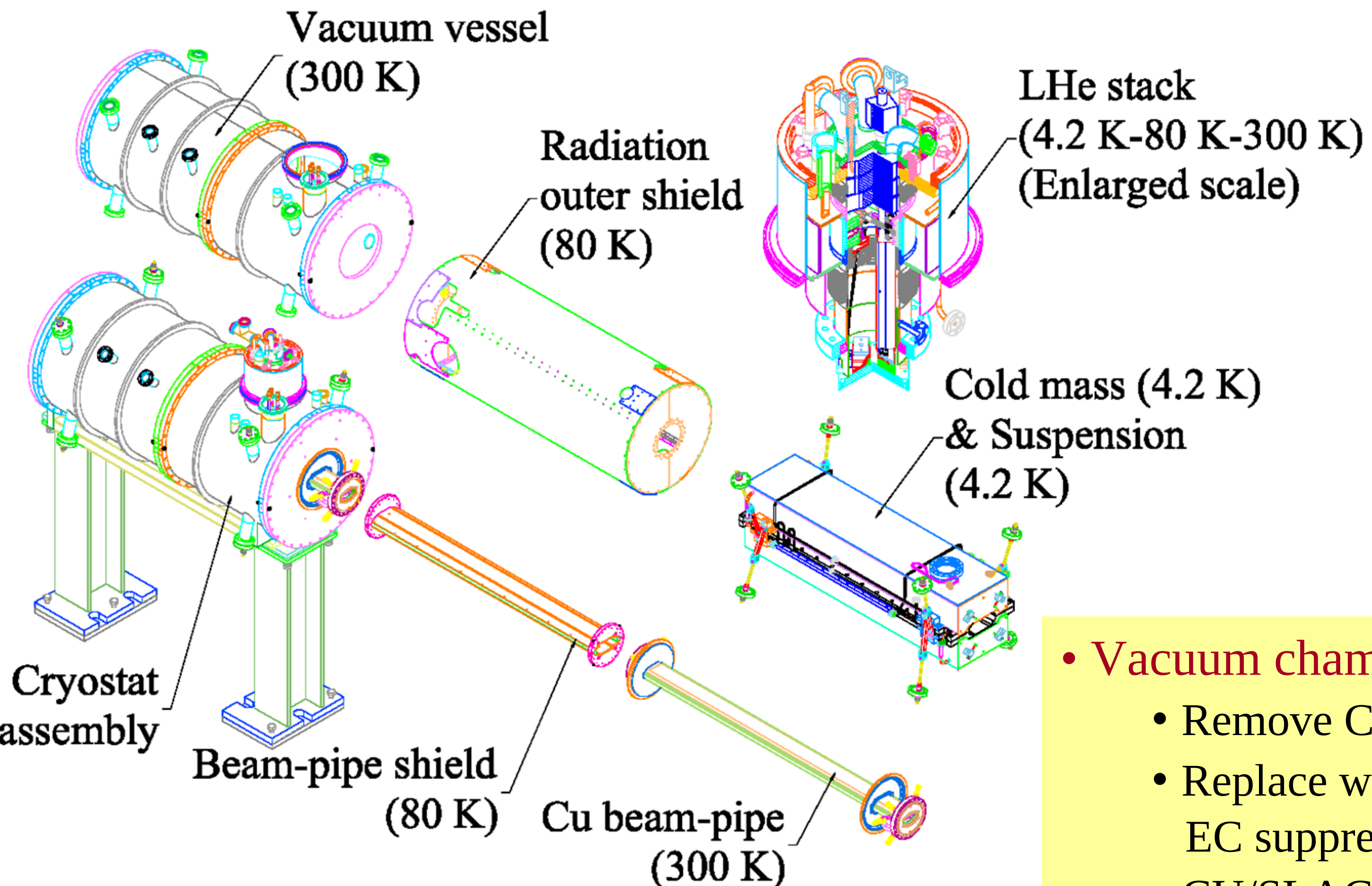
Wiggler Trajectory

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





CESR-c Wiggler Modifications

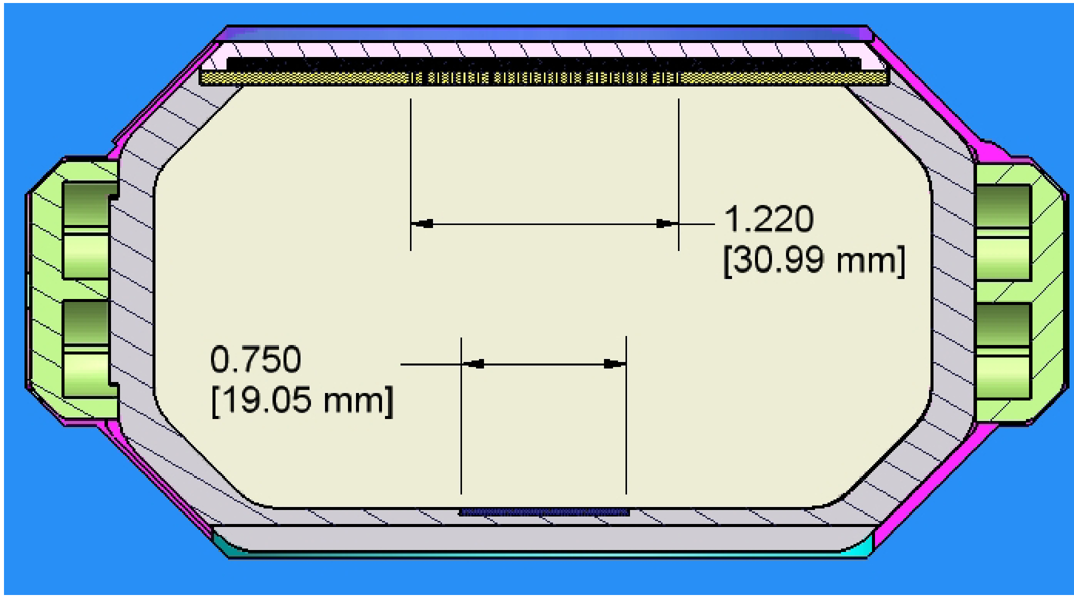


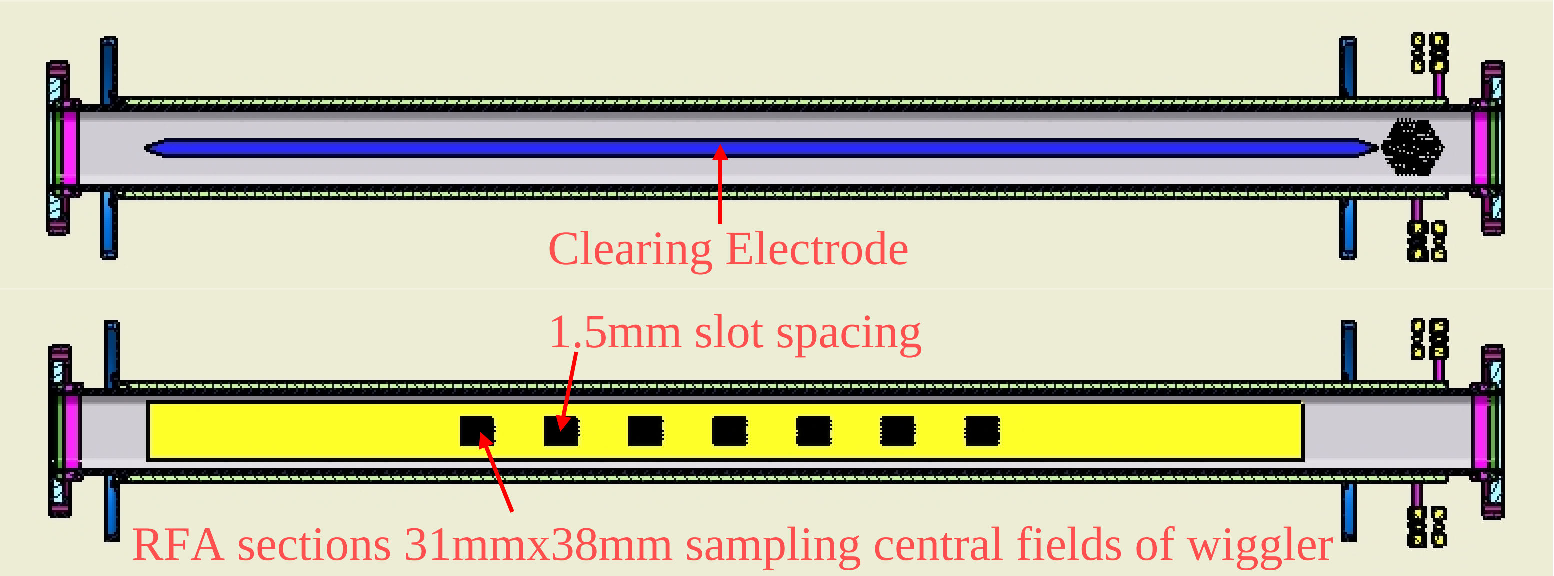
CESR vertical beam stay-clear: 50mm
ILC DR assumes 46mm diameter pipe

- 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
- Preserve >45mm vertical aperture

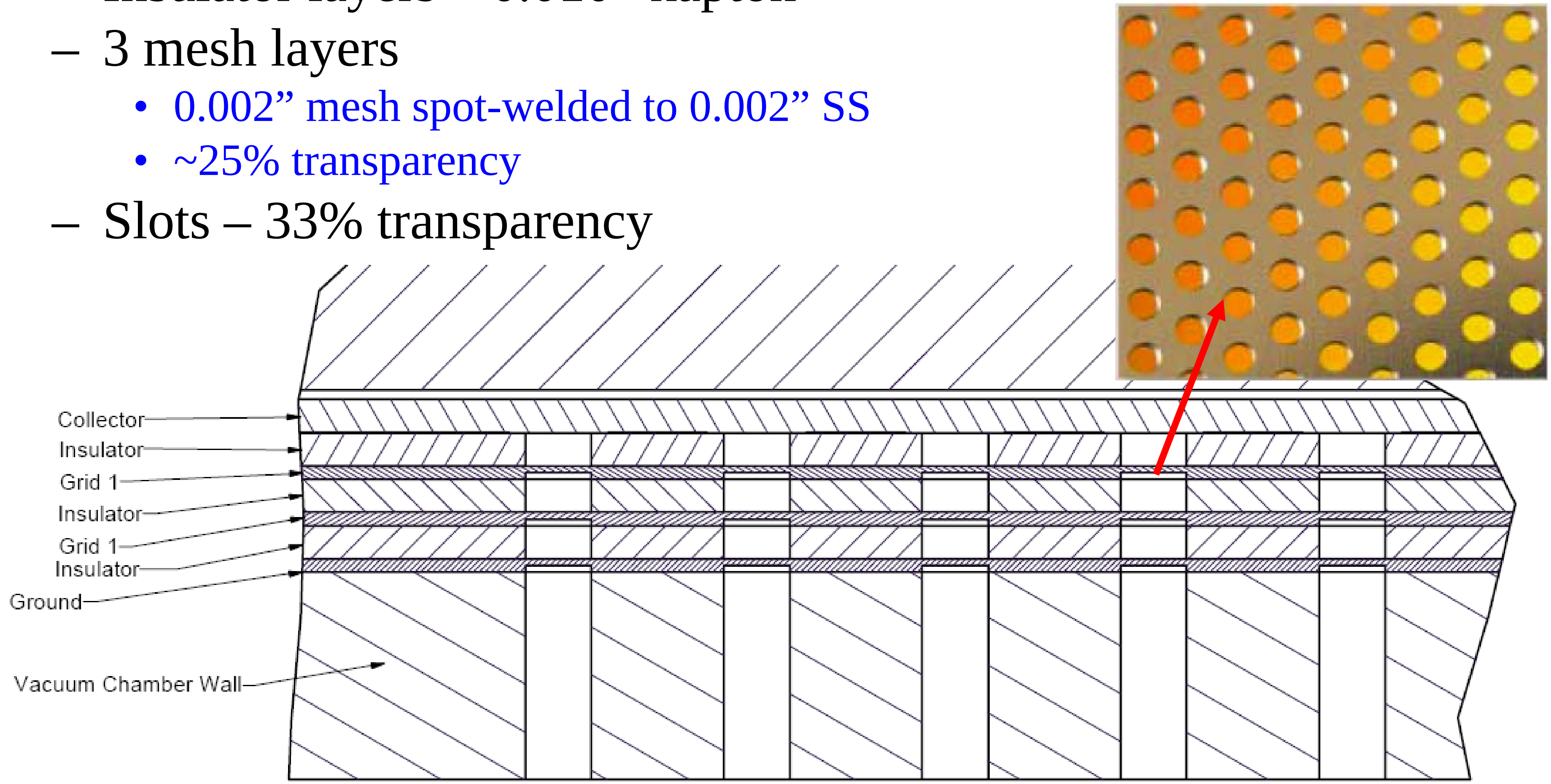




Wiggler Chamber Concept II

- 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

InterNet, Inc.



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 RFAs for direct measurement of cloud in roughly 2 months
- CesrTA
  - Proposal recently submitted to NSF
  - 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
  - Input and/or collaboration welcomed!

Acknowledgments

- CesrTA Studies and CESR EC Machine Studies
  - J. Alexander
  - M. Billing
  - G. Codner
  - J. Crittenden
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  - R. Helms
  - D. Rice
  - D. Rubin
  - D. Sagan
  - L. Schachter
  - J. Shanks (REU)
  - E. Tanke
  - M. Tigner
  - J. Urban
- Collaborators participating in recent CESR machine studies
  - J. Flanagan (KEKB)
  - K. Harkay (ANL)
  - R. Holtzapple (Alfred)
  - A. Molvik (LLNL)
  - M. Pivi (SLAC)