Electron Cloud and Ion Experimental Program

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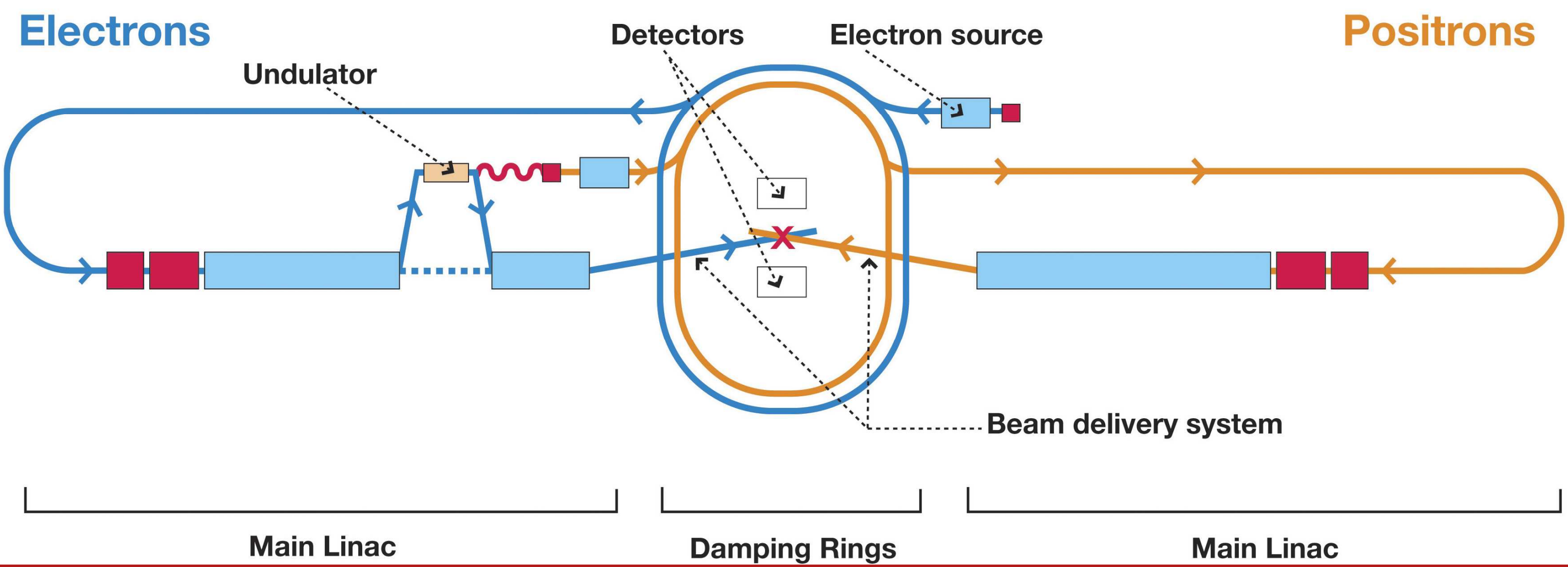
Outline

- Key Issues for the Damping Rings
- Electron Cloud
  - Present Understanding
  - Extrapolation to the DR Regime
  - ▶▷▶ **CesrTA Experimental Goals** ◀◁◀
- Experimental Plans
  - Electron Cloud Growth Studies
    - Chambers for Study
    - Techniques
  - Beam Dynamics Studies (EC and Ions)
    - Methods
    - Instrumentation
- Milestones for the ILC EDR
- Program Comments and Conclusion

ILC DR Key Issues

- Reference Design Report – 2007
  - Central damping ring complex
  - Single positron damping ring
    - For an ~6 km ring, electron cloud mitigation is a serious issue
- Engineering Design Phase
  - Engineering Design Report ➪ 2010
  - Damping Rings R&D required as well as engineering design work

Beam energy	5 GeV
Circumference	6695 m
RF frequency	650 MHz
Harmonic number	14516
Injected (normalised) positron emittance	0.01 m
Equilibrium (normalised) emittance	5 μm × 20 nm
Extracted energy spread	<0.15%
Average current	400 mA
Maximum particles per bunch	2×10^{10}
Bunch length (rms)	9 mm
Minimum bunch separation	3.08 ns

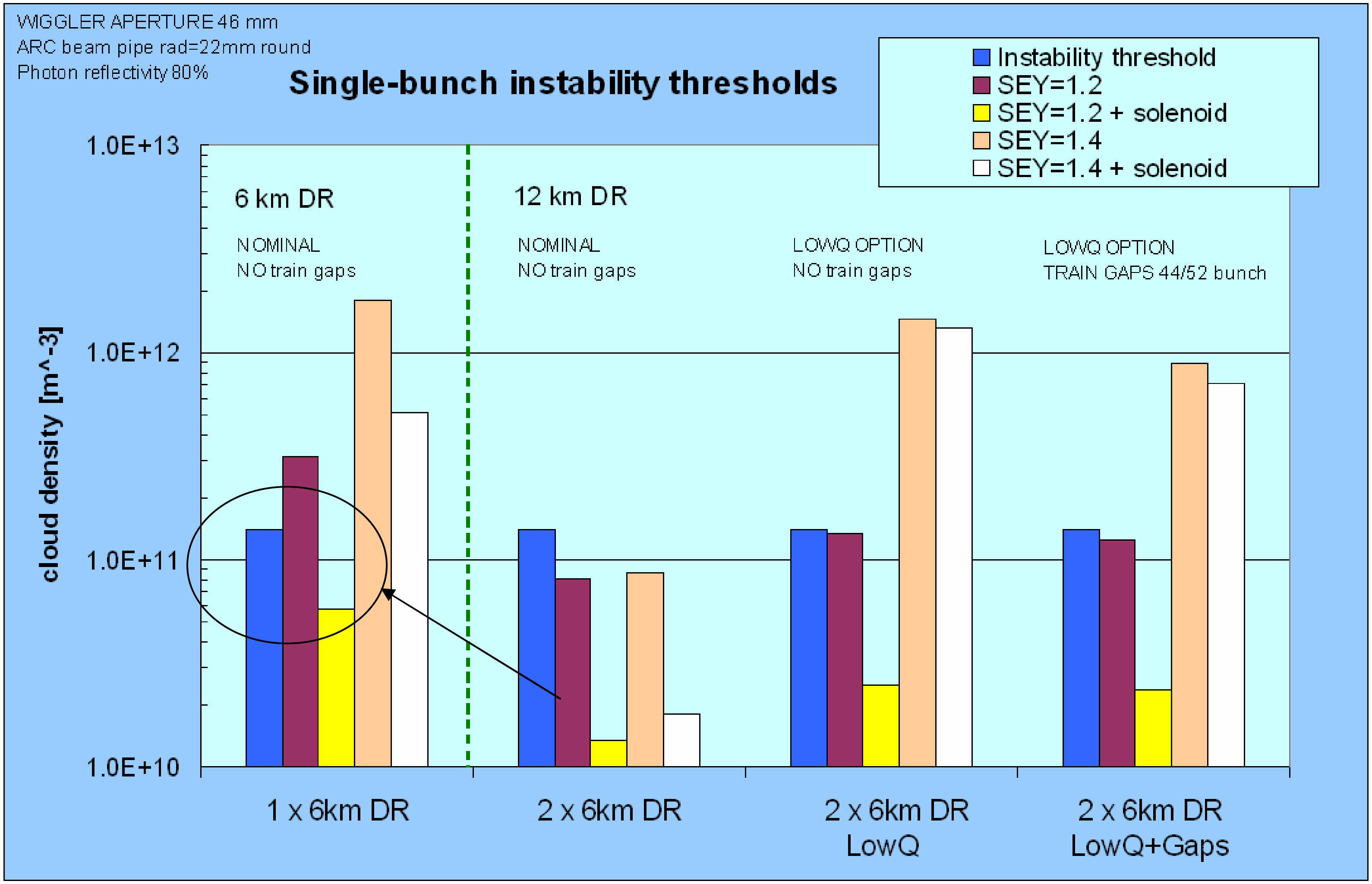


ILC Damping Rings R&D Task Force
Very High Priorities

- Lattice design for baseline positron ring
- Lattice design for baseline electron ring
- Demonstrate < 2 pm vertical emittance
- Characterize single bunch impedance-driven instabilities
- Characterize electron cloud build-up
- Develop electron cloud suppression techniques
- Develop modelling tools for electron cloud instabilities
- Determine electron cloud instability thresholds
- Characterize ion effects
- Specify techniques for suppressing ion effects
- Develop a fast high-power pulser

Moving to a Single Positron DR

M. Pivi
ILCDR06



Cloud density near (r=1mm) beam (m^{-3}) before bunch passage, values are taken at a cloud equilibrium density. Solenoids decrease the cloud density in DRIFT regions, where they are only effective. Compare options LowQ and LowQ+train gaps. All cases wiggler aperture 46mm.

Our Present Understanding

- The data most relevant to our understanding of the EC in the ILC damping rings comes mainly from the positron rings of the B-Factories

	ILC DR	KEK B LER	PEP II LER
E (GeV)	5	3.5	3.1
t_{bunch} (ns)	3.1	7	4.5
N_{bunch}	2×10^{10}	7.3×10^{10}	7×10^{10}
ε_x (nm)	0.5	18	31
ε_y (pm)	2	400	1400

Extrapolations to the ILC DR

- Two key extrapolations exist
  1. Bulk of positron studies based on measurements with beams with significantly larger emittance
     - Horizontal emittances 10's of times larger than ILC spec
     - Vertical emittances 100's of times larger than ILC spec
  2. B factories have been limited by EC in drift regions
     - Success of mitigation techniques in drifts already included for the ILC simulations
     - Primary focus of concern for the positron damping ring is on the EC build-up in the dipole and wiggler regions
     - Suitable mitigation techniques for dipole and wiggler regions must be verified

CesrTA Goals I

- Electron Cloud Growth Studies
  - Provide a "laboratory" for the study of EC growth
    - Particularly in regions of greatest concern for DR : wigglers and dipoles
    - Provide suitable diagnostics to characterize the growth in all key regions
  - Characterize the performance of mitigation techniques in dipoles, quadrupoles and wigglers
  - Explore a parameter regime that approximates the ILC DR
    - Bunch train configuration
      - Bunch charge, length, spacing, emittance
      - Inter-train gaps
    - Energy
    - Investigate parameter dependence (eg, adjust wiggler fields to vary primary versus secondary electron contributions)

⇨ Detailed data with which to benchmark ILC simulations

⇨ Demonstrate suitable vacuum chamber technologies

CesrTA Goals II

- Electron Cloud Induced Instability and Emittance Dilution
  - Characterize the impact of the cloud on witness bunches/trains trailing an initial EC-generating train
    - Provide sufficient local diagnostics to characterize EC growth and decay in all representative chambers
    - Control EC density and distribution around ring by witness bunch delay and/or intensity of generating train
    - Explore a range of witness bunch parameters (emittance, charge, energy etc)
    - Species-dependent studies in same chamber
      - Distinguish impedance effects
      - Will study the Fast Ion Instability with the electron beam to ensure a complete understanding of the relevant beam dynamics
  - Dipole chambers dominate CESR ring
    - ILC simulations indicate dipole regions will have the highest EC density

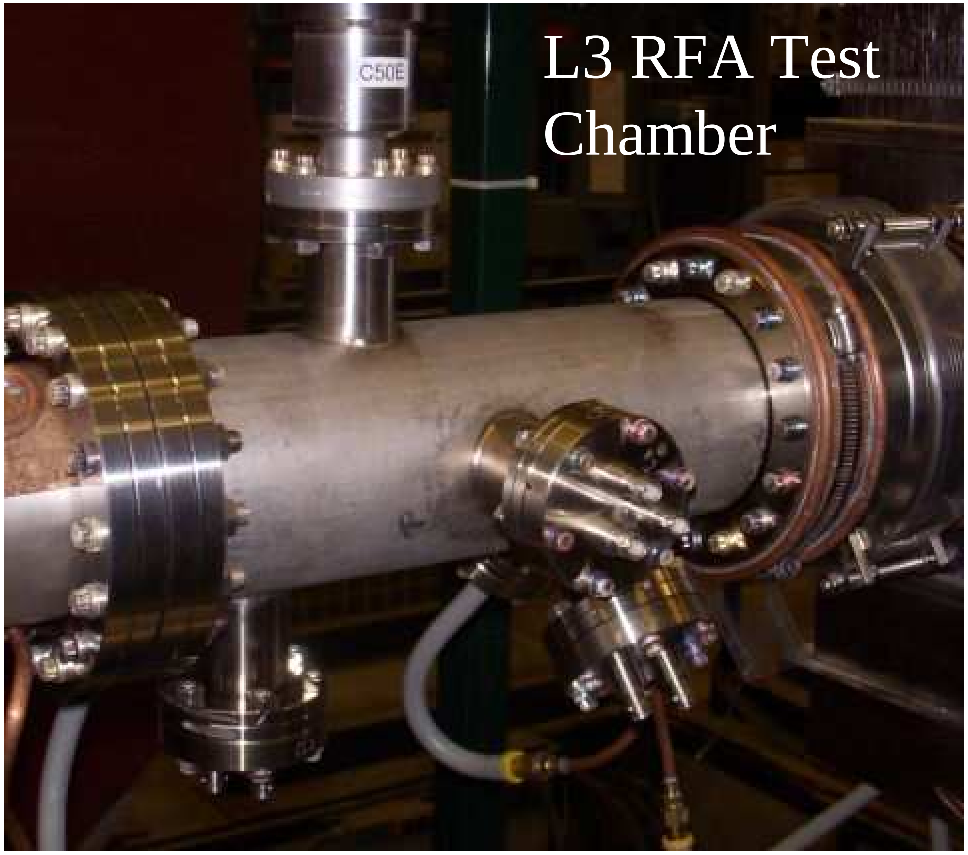
⇨ Detailed data with which to benchmark ILC simulations

CesrTA EC Program Summary

- CesrTA will provide:
  - Detailed local EC growth measurements with which to benchmark the relevant simulation codes
  - Detailed studies of EC mitigation in critical vacuum chambers
    - Includes testing of true ILC prototype chambers by the end of the program
  - Beam dynamics measurements over significant parameter ranges to verify key inputs to the instability modeling codes and to benchmark their performance
- The goal of our program is to demonstrate key EC mitigation technologies, measure instabilities and emittance growth, and validate EC simulations in a regime approaching that of the ILC DR on a timescale consistent with the EDR.

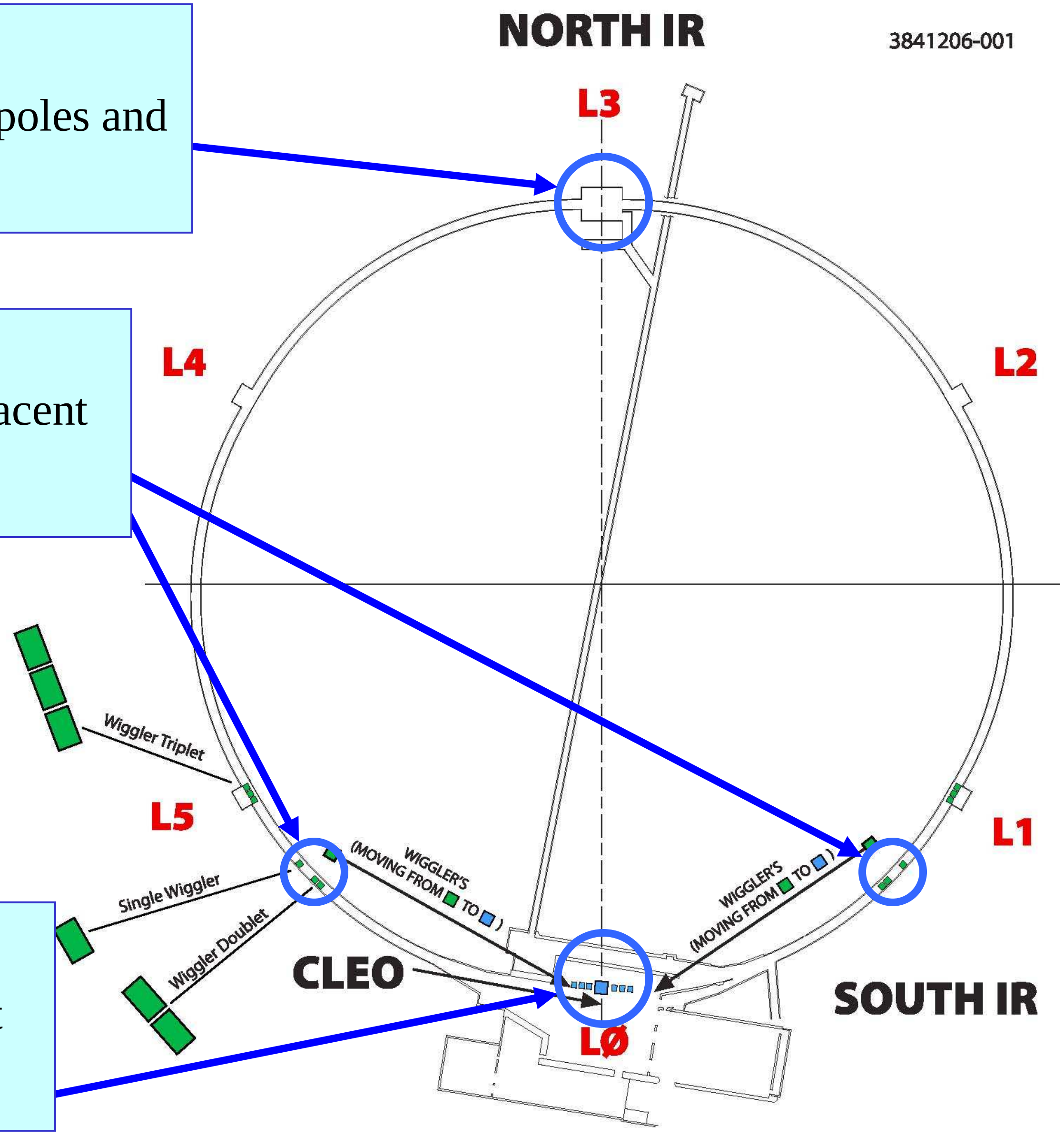
EC Growth Studies

- Install chambers with EC growth diagnostics and mitigation
  - Goal is to have implemented diagnostics in each representative chamber type by mid-2009
    - Retarding Field Analyzers with extra bias grid for ion measurements
  - Wiggler chambers in L0 straight w/mitigation
  - Dipole chambers in arcs w/mitigation
  - Quadrupole chambers w/mitigation
    - L0 and L3 straights
  - Drifts
    - Diagnostics adjacent to test chambers
    - Solenoids
  - Some components provided by collaborators (eg, wiggler vacuum chambers supplied by LBNL)



Components of the EC Growth Plan

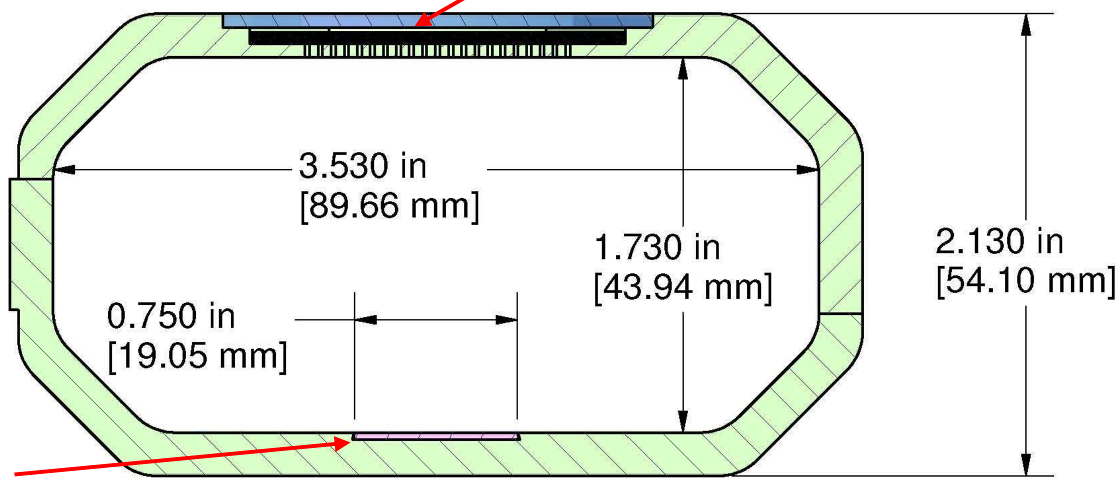
- L3 Straight
  – Instrument large bore quadrupoles and adjacent drifts
- Arcs where wigglers removed
  – Instrumented dipoles and adjacent drifts
- Pressure bump capabilities planned for each instrumented region
  – Impact on ECE and FII
- L0 Straight
  – Instrumented wiggler straight and adjacent sections



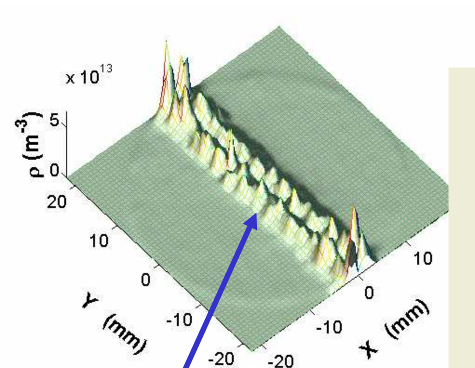
Diagnostic Wiggler Chamber Concept

- Expect to make several variants to explore
  - Coatings
  - Electrodes
  - Grooves
- Modify existing extrusions
- Validate RFA concept by December 2007

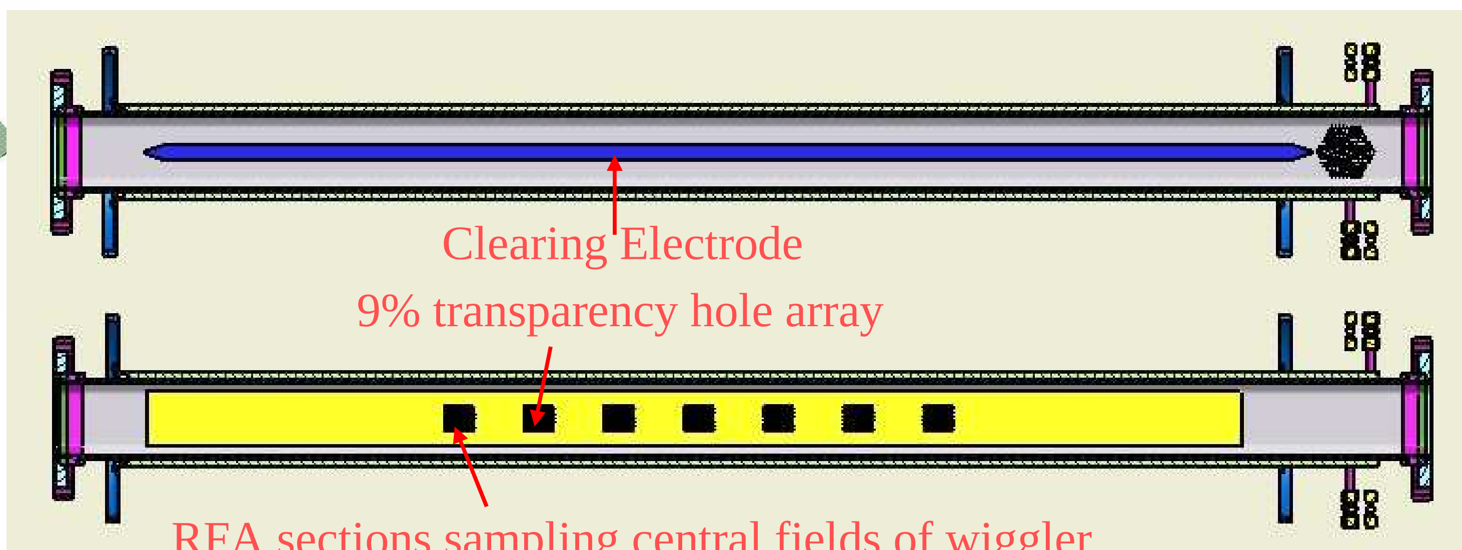
Integral RFA



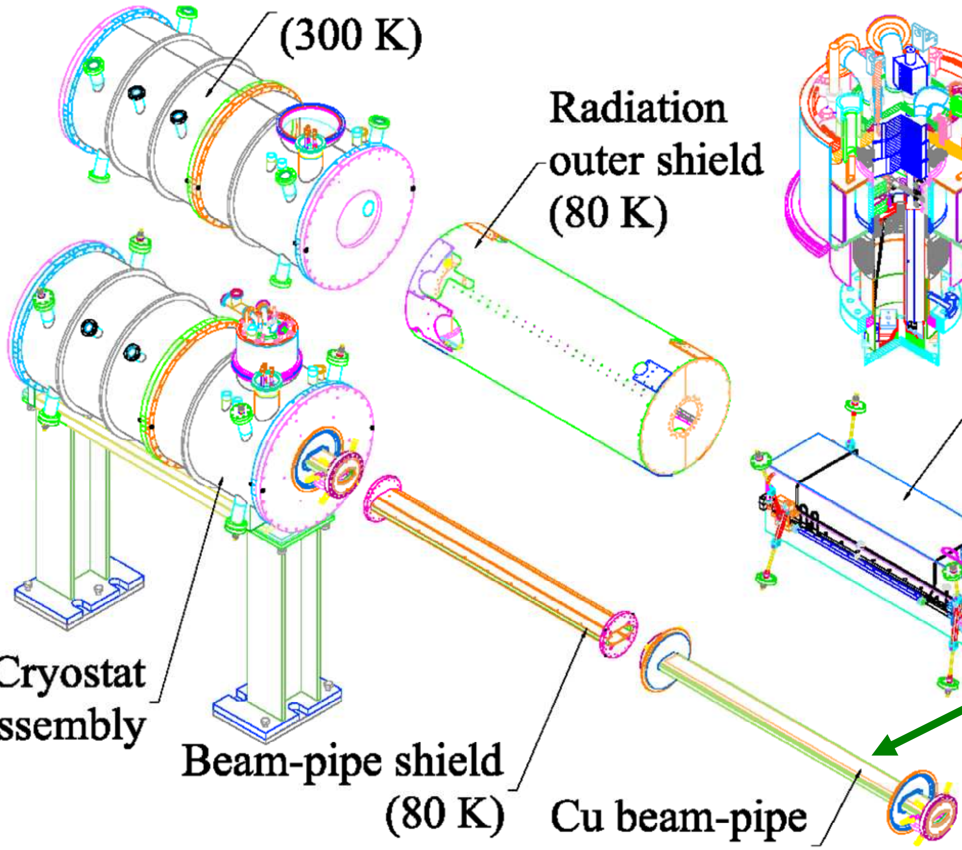
Clearing Electrode



Multipacting stripe in wiggler
L. Wang
ILCDR06



CesrTA Vacuum Chambers



CESR-c Wiggler Chambers
- Vertical beam stay-clear: 50mm
- ILC DR assumes 46mm dia. pipe

CesrTA Wiggler Modifications
- Remove Cu beam-pipe
  - Replace with beam-pipe having EC suppression and diagnostics

- Vacuum chambers for tests in CesrTA
  - Cornell collaborating closely with SLAC & LBNL
- Prototype ILC Wiggler and Vacuum Chamber
  - Cornell/LBNL Collaboration

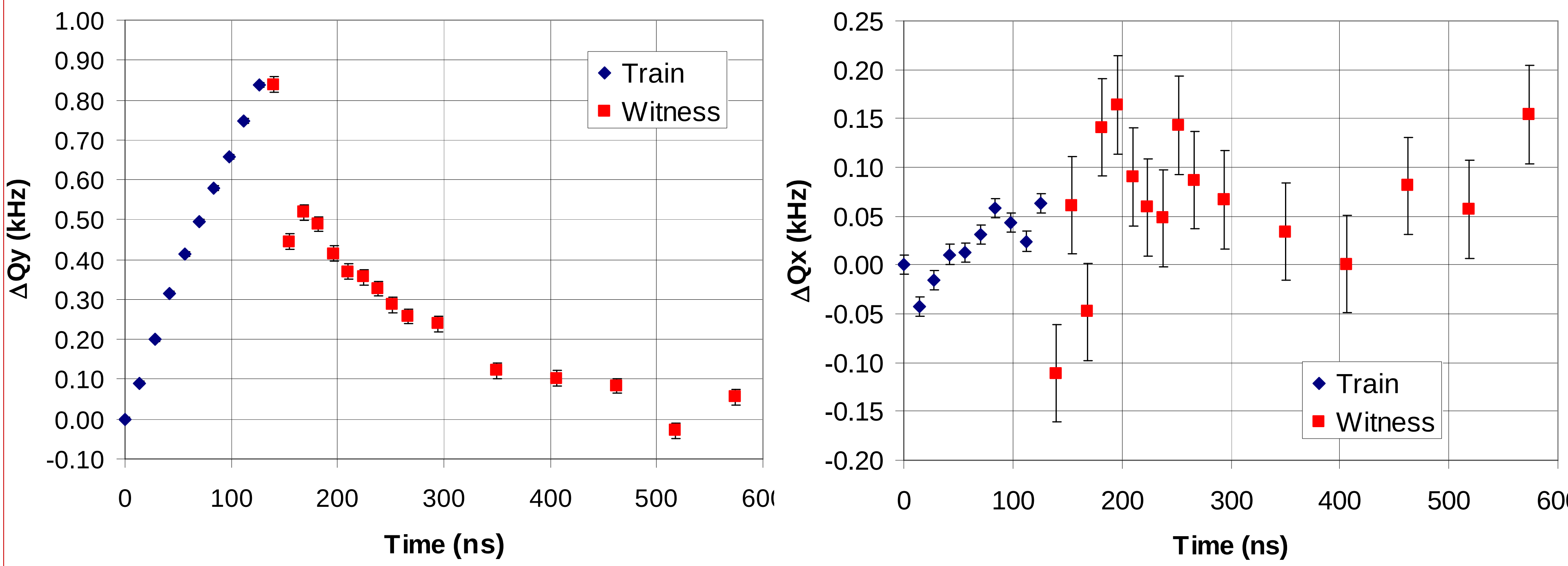
Beam Dynamics Studies

- Prerequisites
  - Instrumentation to characterize bunch trains at ultra low emittance
    - Multibunch detectors and readouts
    - High resolution beam profile monitors
    - See following instrumentation talks for details
  - Ring operation at ultra low emittance
    - See ultra low emittance talk for details
- Instability Studies
  - Focus on witness bunch studies where EC density controlled by intensity of leading train and delay to witness bunches
  - Detailed study of instability thresholds and emittance growth versus the witness bunch-train parameters
  - Detailed electron-positron comparisons to help distinguish the dynamics and to evaluate EC impact on the electron beam
  - Characterize fast ion effects for the electron beam as part of this program
    - Measurements of instabilities and emittance growth along electron bunch trains
    - Explore the dependence on emittance, bunch charge and spacing, train gaps and vacuum pressure

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
- Bunch-by-bunch, turn-by-turn beam position monitor

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



Error bars represent scatter observed during a sequence of measurements

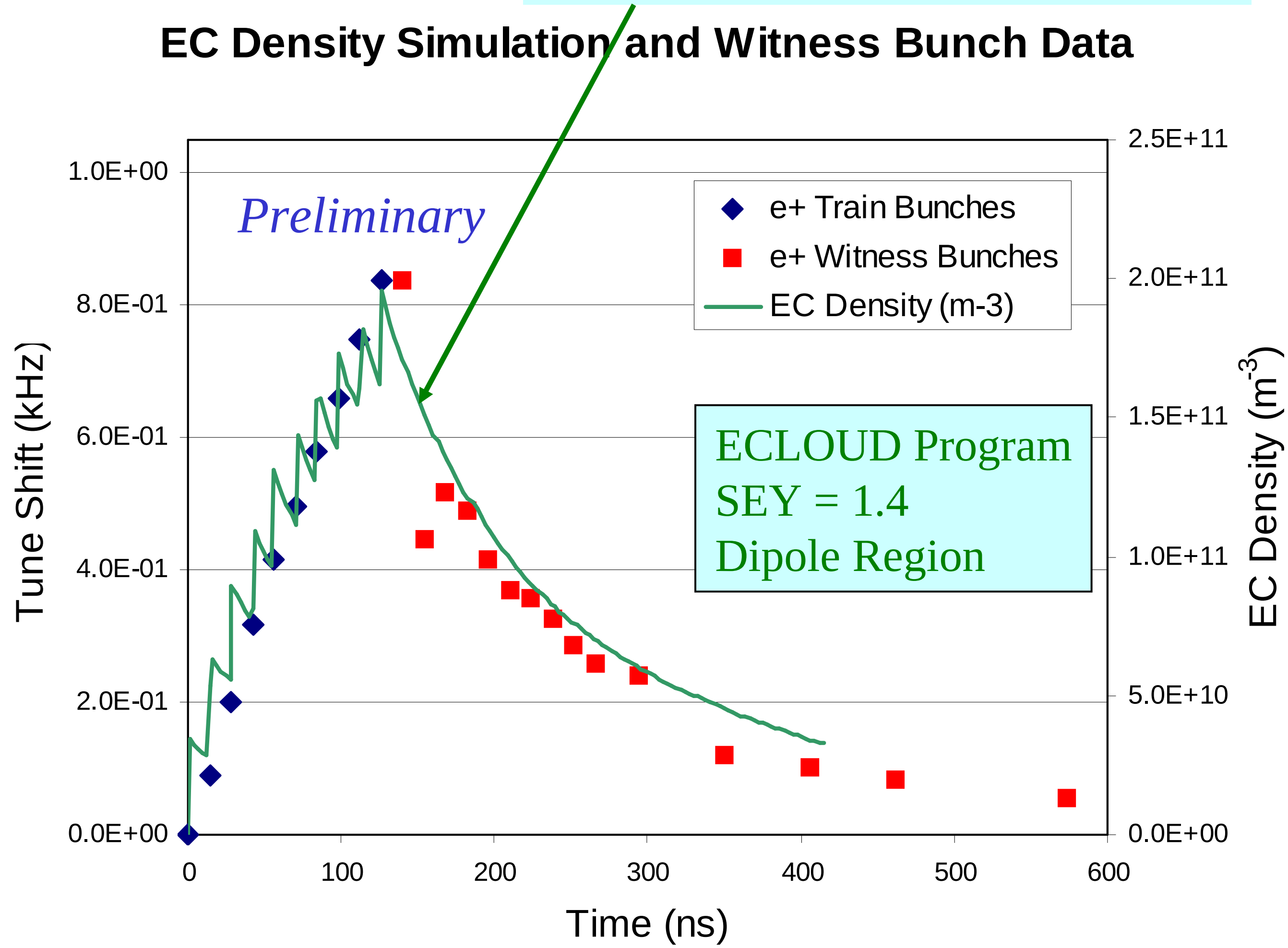
1 kHz ➪ $\Delta\nu$=0.0026
$\rho_e \sim 1.5 \times 10^{11}\ m^{-3}$
Ohmi, etal, APAC01, p.445

Preliminary

Data and Simulation

- Initial comparisons for CESR
  - Growth modeling for dipole chambers
  - Initial level of agreement is promising
- Ongoing Effort
  - Model full ring and explore parameter space
  - Measurement of emittance and bunch spacing dependencies this Fall

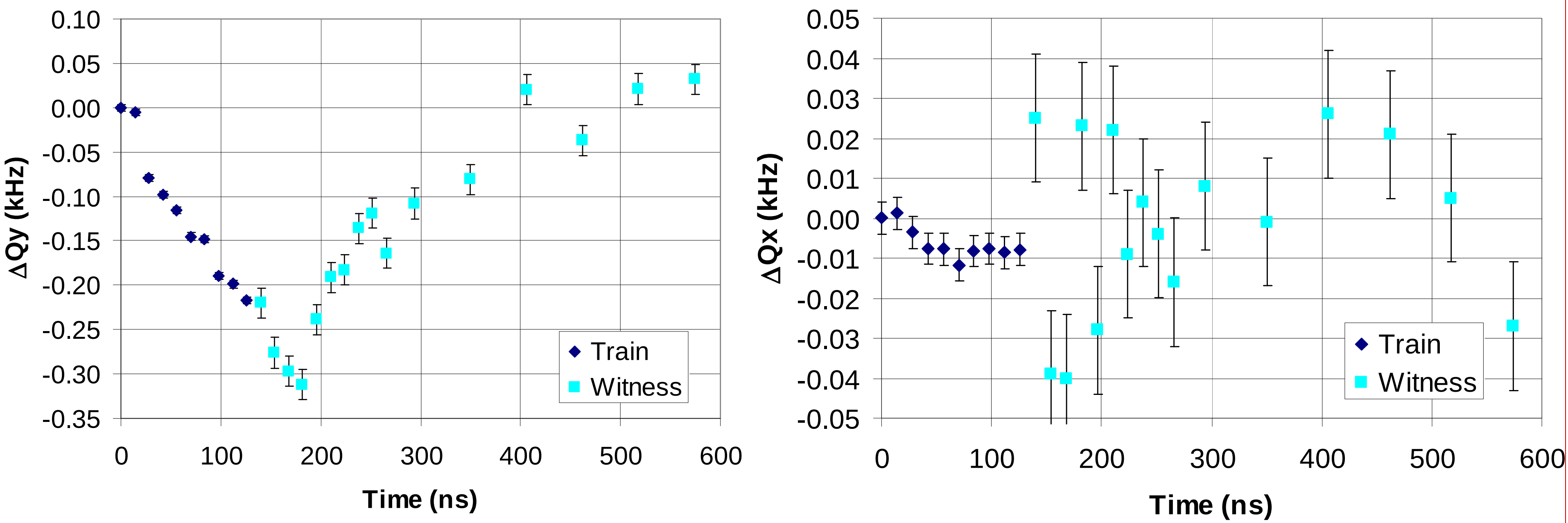
Overlay simulated EC density on vertical tune shift data



Witness Bunch Studies – e^- Vertical Tune Shift

- Same setup as for positrons
- Negative vertical tune shift and long decay consistent with EC
  - Implications for the electron DR?

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

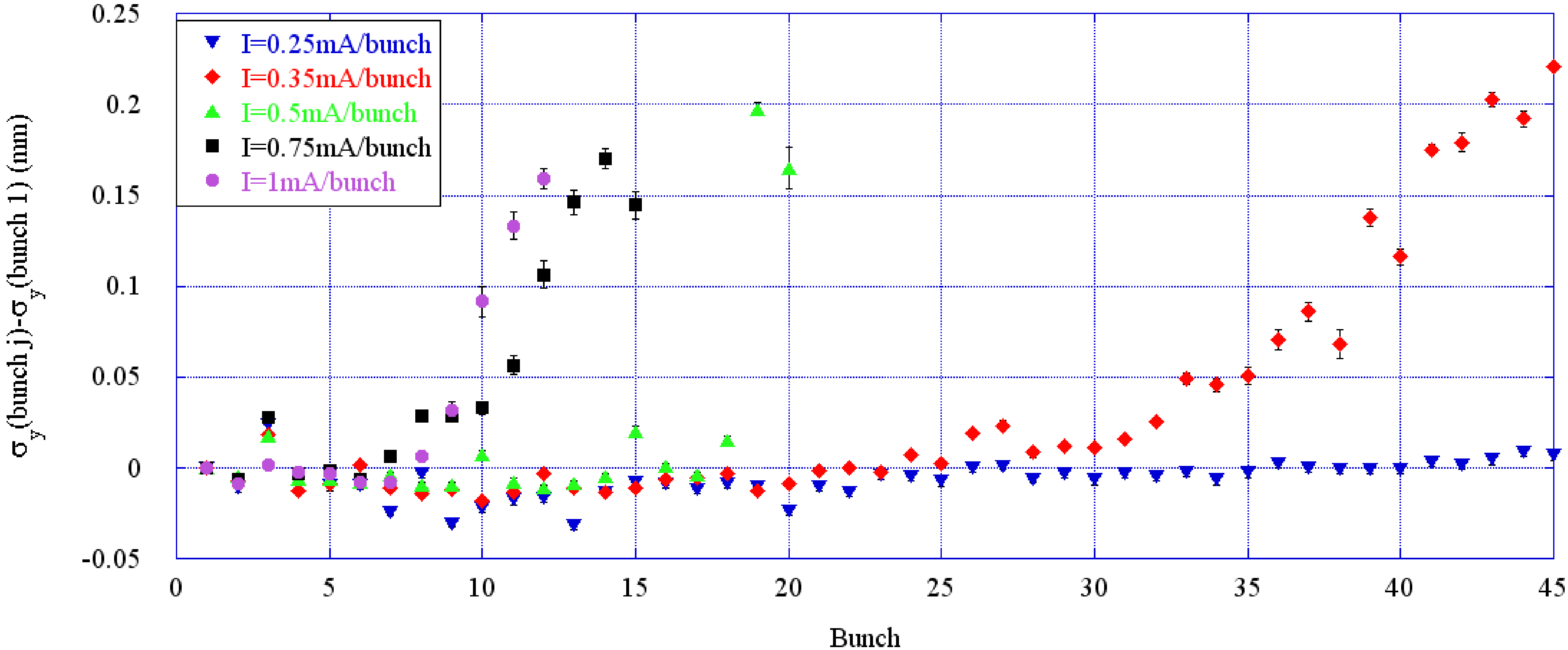


Negative vertical tune shift along train ⇨ consistent with EC
Magnitude of shift along train is ~1/4th of shift for positron beam
NOTE: Shift continues to grow for 1st 4 witness bunches!

Preliminary Results

EC Induced Instability

- Vertical beam size along 45 bunch e+ trains (2 GeV, 14 ns bunch spacing)
  - Range of bunch currents
  - 200 50-turn averages collected for each point
- Observe onset of instability moving forward in train with increasing bunch current – consistent with EC



Milestones

- Project milestones will be covered in detail in a later talk
- Brief Overview
  - 2008-2009
    - Major focus on EC growth and suppression in wiggler, dipole and quadrupole chambers
  - 2009-2011
    - Beam dynamics studies with electrons and positrons (EC and FII) as progressively lower emittances obtained (note: preliminary work already underway)
  - 2010-2011
    - Tests with ILC prototype chambers
- Evaluations for the ILC EDR available in 2010

Dealing with Challenges and Risks

- Experimental program is designed to deal with discoveries and changes in direction through the course of the R&D
  - Schedule allows for re-evaluation of key physics issues and technologies as the program proceeds
    - Course corrections are expected along the way
    - This makes the program robust against short term technical and/or physics surprises
  - Technology down-selects can be employed as data is obtained to optimize the program along the way
  - Program relies heavily on support from collaborators
- Key technical drivers for the program are:
  - Electron Cloud Growth Studies
    - Chamber construction
    - Implementation of diagnostics
  - Beam Dynamics Studies
    - Issues affecting our ability to achieve ultra low emittance (see later talks)
    - Issues affecting our implementation of high resolution emittance diagnostics (see later talks)
- Key assets
  - A well-understood machine
  - An experienced accelerator staff
  - A highly expert group of collaborators

Collaborators

- Program relies heavily on collaborator participation and input (see letters of support)
  - Will require a plan for coordination (see Project Mgmt Talk)
- Ongoing Collaborator Participation
  - Sept. 2006: M. Pivi
  - Jan. 2007:
    K. Harkay (ANL),
    J. Flanagan (KEKB),
    A. Molvik (LLNL)
    R. Holtzapple &
    J. Kern (Alfred)

Conclusion

- CESR offers
  - Damping wigglers meeting the ILC specification
  - Flexible energy and emittance range for experimental studies
  - Experimental studies with electrons and positrons in the identical environment
  - Experienced staff and well-developed tools
- The CesrTA program provides
  - Detailed studies of electron cloud growth and validation of mitigation techniques in time for the ILC EDR
  - Beam dynamics results on electron cloud and fast ion instabilities in time for the ILC EDR
  - Assurance that the ILC DR design is feasible by benchmarking our simulations with data in the relevant parameter regime