Cornell University
Laboratory for Elementary-Particle Physics

Plans for Utilizing CESR as a Test Accelerator for ILC Damping Rings R&D

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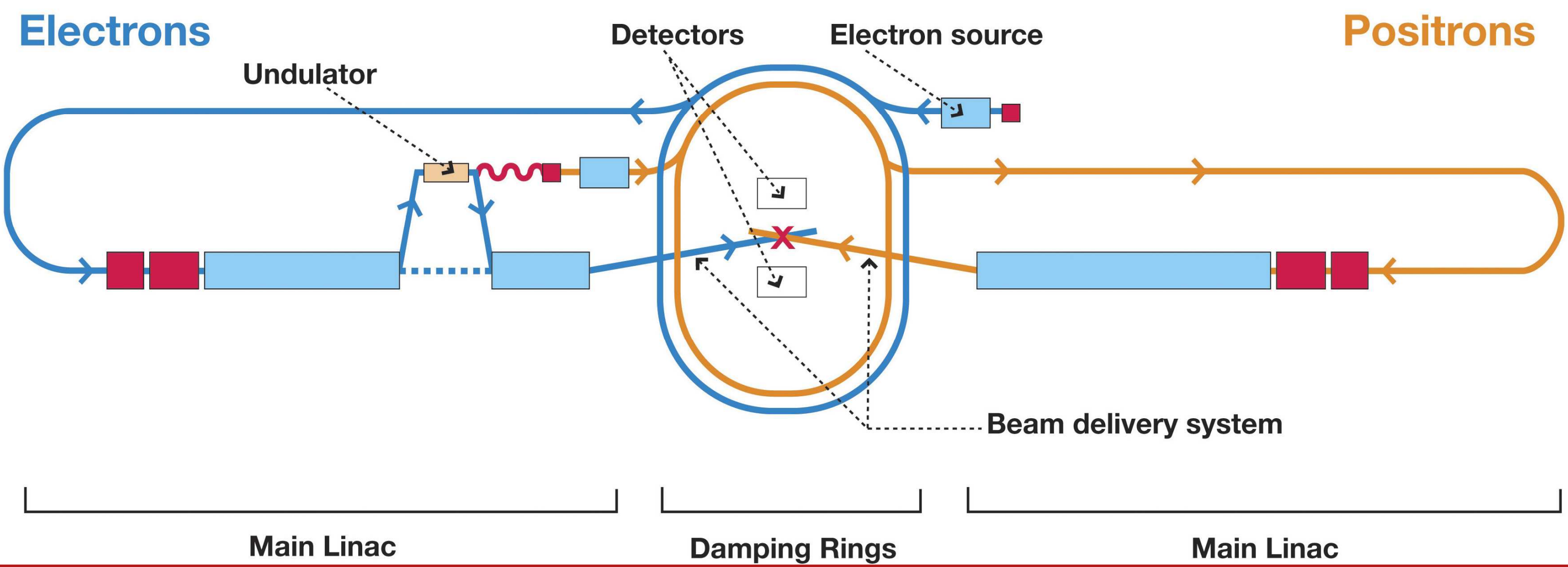
Outline

- ILC Damping Rings R&D Priorities for the Engineering Design Report
- CESR as a Vehicle for Damping Rings R&D
  - CESR Availability
  - CesrTA Concept and Goals
  - CESR ⇨ CesrTA Conversion
  - CesrTA Parameters
  - ILC Research at CESR – Ongoing and Planned
- Conclusion

ILC Damping Rings

- 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
Extracted (normalised) emittance	8 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

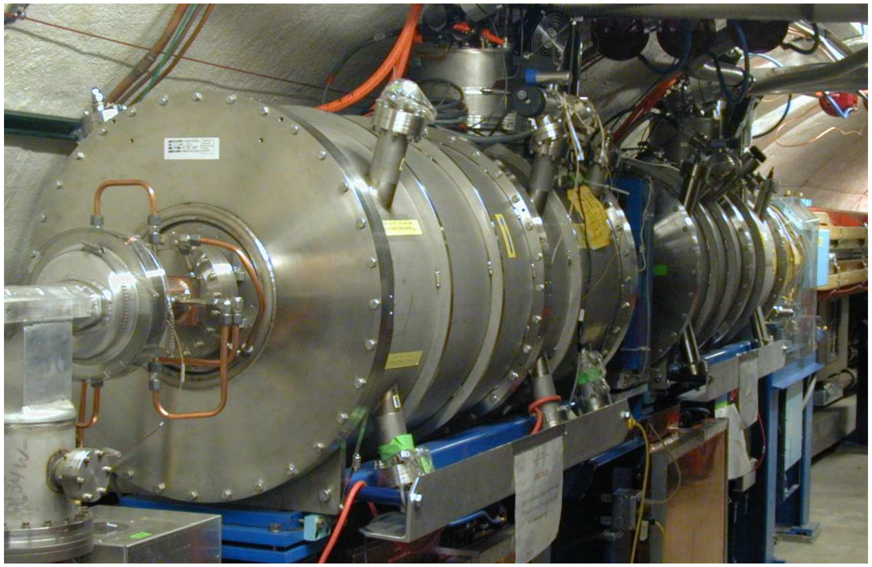
- Lattice design for baseline positron ring
- Lattice design for baseline electron ring
- Demonstrate < 2 pm vertical emittance
- Characterize single bunch impedance-driven instabilities
- Characterize electron cloud build-up
- Develop electron cloud suppression techniques
- Develop modelling tools for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

CesrTA Concept and Goals

- CESR
  - Nearly 3 decades of colliding beam physics at Wilson Laboratory will conclude on March 31, 2008
  - It may be possible after the conclusion of HEP to carry out a program of ILC damping rings R&D ⇨ CesrTA
- CesrTA Goals:
  - Support critical damping rings R&D on a timescale compatible with EDR completion in 2010
  - Provide sufficient amounts of dedicated running time to facilitate key damping ring experiments
  - Provide an R&D program complementary to work going on elsewhere (*eg*, at KEK-ATF)

Unique Features of CesrTA

- Offers:
  - An operating wiggler-dominated storage ring
  - R&D with the CESR-c damping wigglers
    - Baseline technology choice for the ILC DR
    - High-field, large-aperture wigglers with exceptional field quality
  - Flexible operation with positrons and electrons in the same ring
  - Flexible energy range
    - 1.5 GeV – 5.5 GeV
  - Dedicated experimental runs for ILC R&D starting in 2008

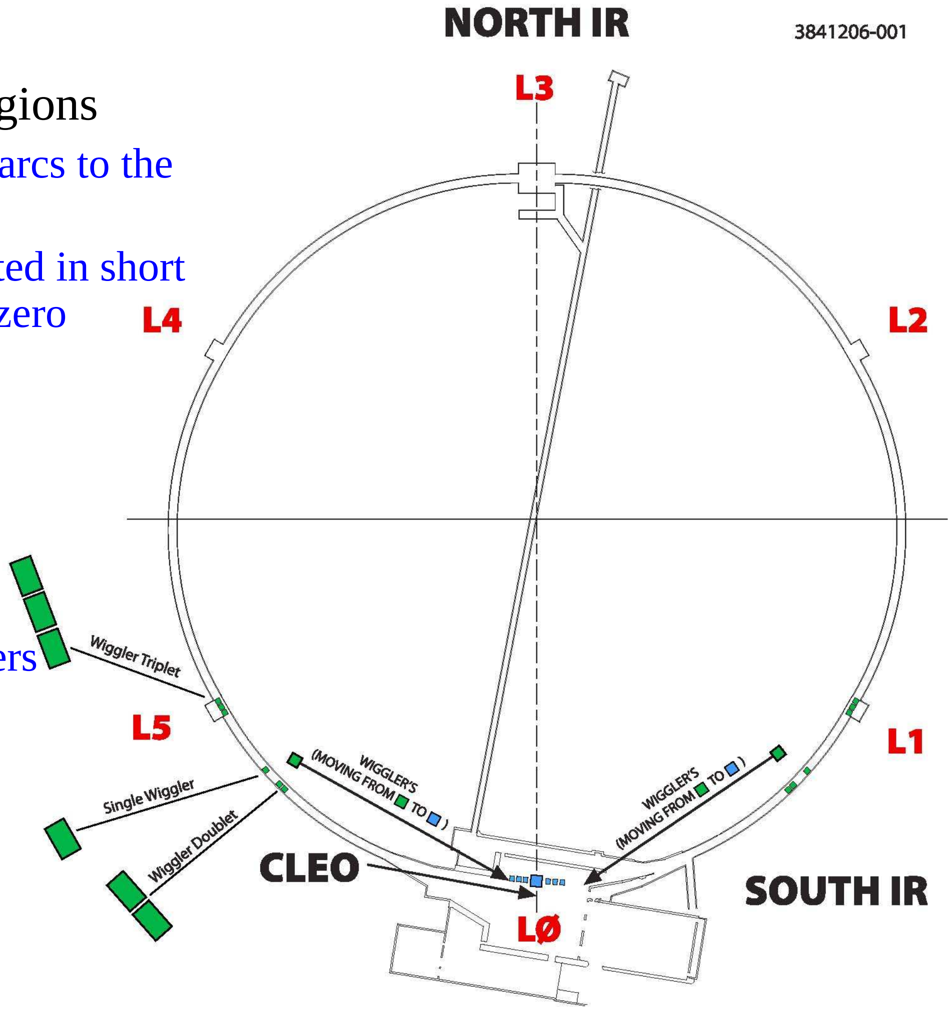


CesrTA Experimental Reach

- A number of *High* and *Very High* priority R&D items, as specified by the damping rings R&D task force, can be addressed with CesrTA
  - Electron Cloud (EC) for the Positron DR
    - Study cloud growth in quadrupoles, dipoles, and wigglers
    - Study cloud suppression in quadrupoles, dipoles, and wigglers
    - Study instability thresholds and emittance growth
    - The decision to employ a single positron damping ring has increased the significance of these issues
  - Ion Effects for the Electron DR
    - Study instability thresholds and emittance growth with ILC-like trains
    - Evaluate suppression methods
  - Ultra Low Emittance Operation
    - Evaluate:
      - Alignment and survey issues
      - Beam-based alignment techniques
      - Optics correction techniques
      - Ultra low emittance measurement and tuning
    - Demonstrate ultra low emittance operation with positron beams
  - System and Component Testing
    - For example: ILC prototype wiggler, injection/extraction kickers, etc

CESR ⇨ CesrTA Conversion

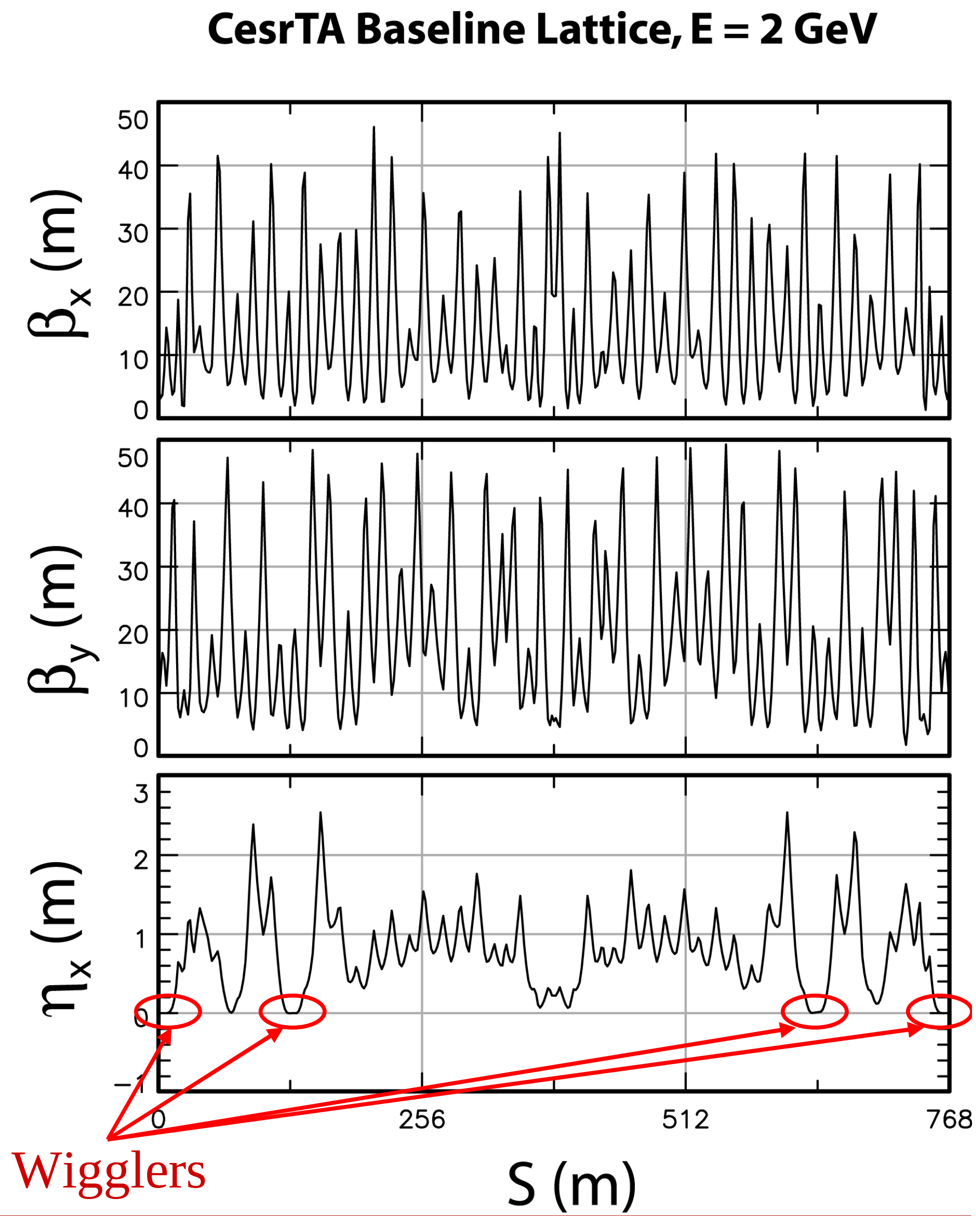
- Proposed CESR modifications:
  - Place all wigglers in zero dispersion regions
    - 6 wigglers must move from the CESR arcs to the L0 interaction straight
    - Remaining 6 wigglers are already located in short straights which can be configured for zero dispersion
  - Eliminate the CLEO IR optics
  - Modify the vacuum system…
    - For wiggler move
    - For EC growth diagnostics
    - For EC suppression in selected chambers
    - For flexible installation of test devices
  - Upgrade instrumentation to…
    - Achieve and measure ultra low emittance beams
    - Characterize dynamics of ILC-like bunch trains
  - Upgrade feedback system for 4 ns bunch train operation



CesrTA Parameters

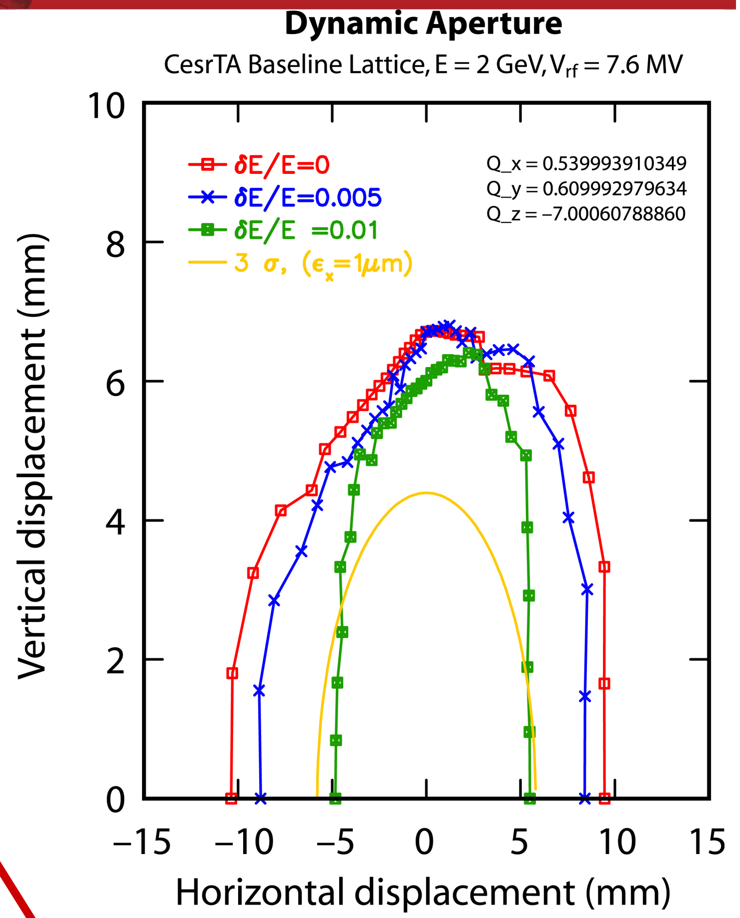
Baseline Lattice

Parameter	Value
E	2.0 GeV
$N_{wiggler}$	12
B_{max}	1.9 T
ε_x (geometric)	2.3 nm
ε_y (geometric) Target	5–10 pm
$\tau_{x,y}$	56 ms
σ_E/E	8.1 x 10^{-4}
Q_x	14.54
Q_v	9.61
Q_z	0.070
Total RF Voltage	7.6 MV
σ_z	8.9 mm
α_p	6.2 x 10^{-3}
$\tau_{Touschek}$	>10 minutes
Bunch Spacing	4 ns



Lattice Evaluation

- Dynamic aperture
  - 1 damping time
  - Injected beam fully coupled
    - $\varepsilon_x = 1\ \mu m$
    - $\varepsilon_y = 500\ nm$
- Have explored alignment sensitivity and low emittance correction algorithms for various assumptions ⇨ results consistent with achieving our vertical emittance target of 5–10 pm

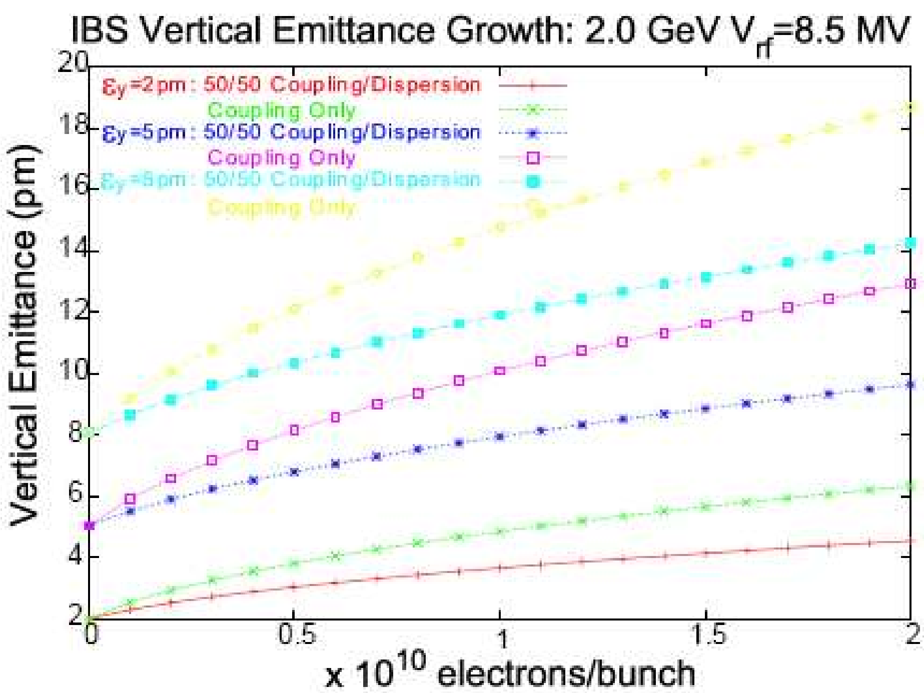


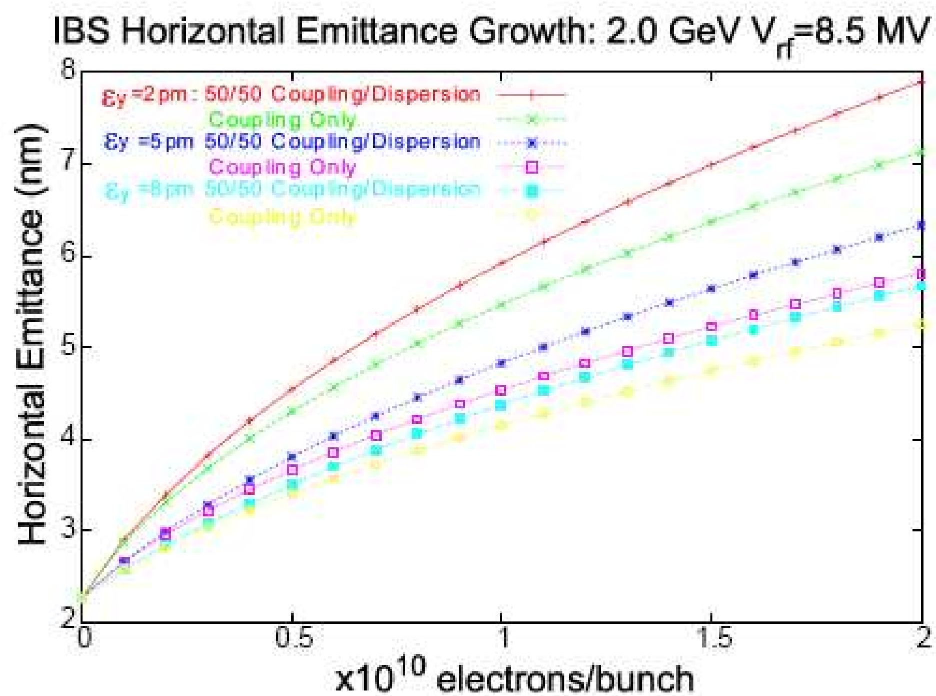
Element Misalignment	Nominal	Worst Case
Quad/Bend/Wiggler Offset	150 μm	300 μm
Sextupole Offset	300 μm	600 μm
Rotation (all elements)	1 mrad	2 mrad
Quad Focusing	4×10^{-4}	4×10^{-4}
Beam Position Monitor Errors		
Absolute (orbit error)	10 μm	50 μm
Relative (dispersion error)	2 μm	10 μm
Rotation	1 mrad	2mrad

Vertical Emittance		
Alignment/BPM Errors	**Mean**	**95% C.L.**
Nominal	2.0 pm	4.7 pm
Worst Case	6.5 pm	11.3 pm

IBS Evaluation (2 GeV Lattice)

- Transverse emittance growth for different contributions of coupling and dispersion to the vertical emittance
  - Baseline lattice
  - Compare different corrected optics assumptions
  - ~9 mm bunch length
- IBS effects will be significant
  - Energy flexibility of CESR and γ^{4} IBS dependence offers a flexible way to study, control and understand IBS contributions to emittance relative to other physics under consideration



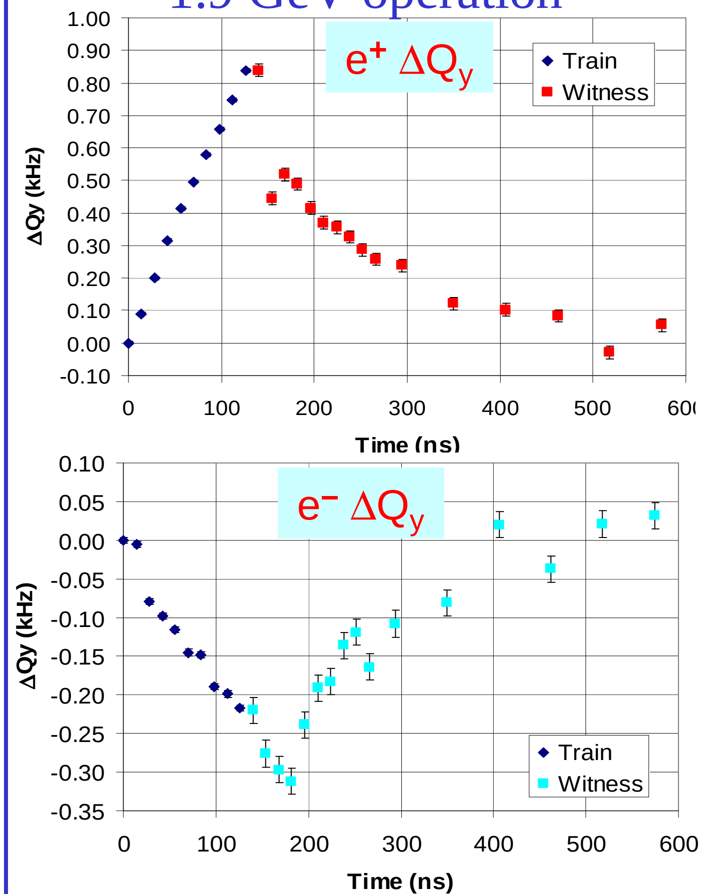


Ongoing R&D Using CESR

- Multi-bunch turn-by-turn instrumentation has been commissioned in CESR
  - Beam position and vertical beam profile measurements
  - See posters THPAN087 and FRPM047 for beam profile measurement details
- Example: Witness Bunch Studies
  - Initial train of 10 bunches to generate EC
  - Witness bunches placed at varying distances behind train
  - Vertical tune shift for both beams consistent with presence of EC (observed horizontal tune shifts are much smaller in magnitude)
  - Positron tune shift: 1 kHz ⇨ $\Delta\nu$=0.0026

    $\rho_e \sim 1.5 \times 10^{11}\ m^{-3}$ (model of Ohmi, et al., APAC01, p. 445)
  - Electron tune shift
    - Magnitude of shift along train is ~1/4th of shift for positron beam
    - NOTE: Shift continues to grow for 1st 4 witness bunches!

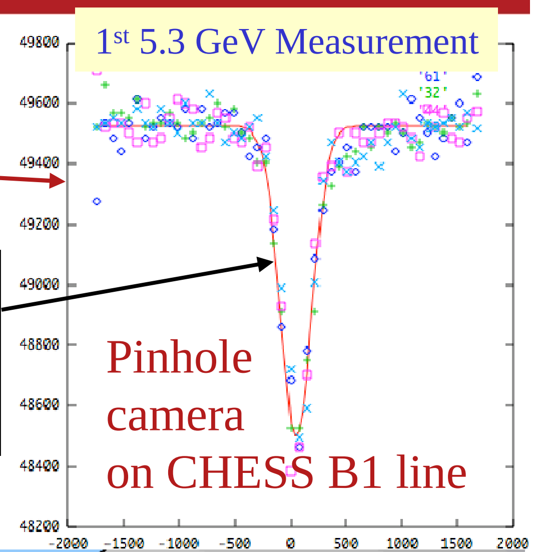
0.75 mA/bunch, 14 ns spacing
1.9 GeV operation

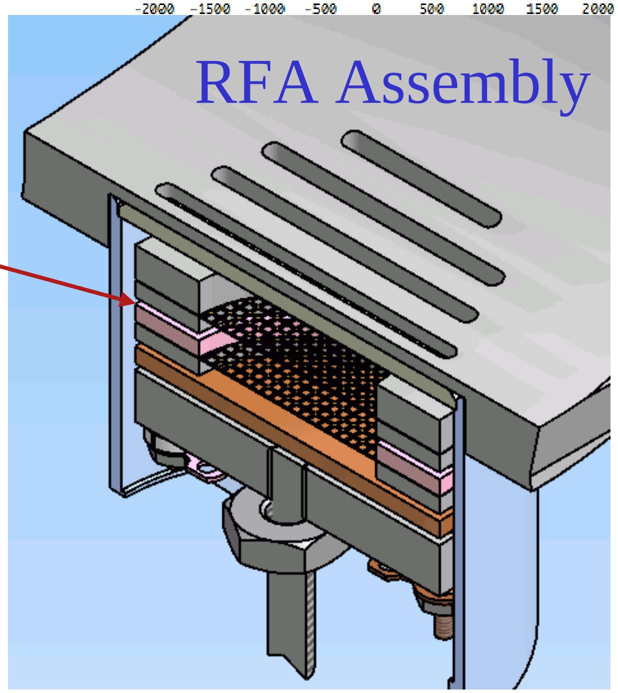


Preliminary Results

Preparation for CesrTA

- Transverse feedback recently upgraded for 4 ns operation
- Work on fast x-ray beam profile monitor
  - Fast GaAs diode arrays (<50 ps rise- and fall-time)
  - Targeting a multi-bunch turn-by-turn detector with ~1 μm resolution
- Preparatory machine studies program
  - Electron cloud and fast ion studies
  - Start exploration of low emittance operations
    - CESR-c (existing machine layout) optics have been designed: $\varepsilon_x \sim 6.5$ nm
    - Early work on beam-based alignment
- First Retarding Field Analyzers (RFA) based on an APS design installed in L3 straight
- Development work for wiggler vacuum chambers
  - Collaboration: LBNL, SLAC
  - EC collector design underway (prototype this summer)
  - Will test various EC mitigation techniques
- General infrastructure preparation
  - Feedback
  - Vacuum
  - Other…





CesrTA Experimental Program

- Schedule:
  - Primary conversion down in mid-2008
  - 2 CesrTA experimental runs scheduled for 2008
  - 2009 onwards:
    - 3 CesrTA experimental runs/yr totaling ~1/3rd of each year
    - 3 High Energy Synchrotron Source (CHESS) runs/yr totaling ~1/3rd of each year
    - Remainder of year scheduled as down and commissioning time for hardware installation and experimental setup
    - Provides flexible scheduling of experiments for collaborators

- Experimental Focus Recap:
  - EC Growth and Mitigation Studies – particularly in the damping wigglers
    - Bunch trains similar to those in the ILC DR
  - Ultra Low Emittance Operation
    - Validation of correction algorithms
    - Measuring, tuning for, and maintaining ultra low emittance
  - Beam Dynamics Studies
    - Detailed inter-species comparisons (distinguish EC, ion and wake field effects)
    - Characterize emittance growth in ultra low emittance beams (EC, ion effects, IBS,…)
    - Demonstrate ultra low emittance operation with a positron beam
  - Test and Demonstrate Key Damping Ring Technologies
    - Wiggler vacuum chambers, optimized ILC wiggler, diagnostics, …

Conclusions & Acknowledgments

- CesrTA conceptual design work is ongoing
  - Program offers unique features for critical ILC damping ring R&D
  - Simulations indicate that the emittance reach is suitable for a range of damping ring beam dynamics studies
  - The experimental schedule will allow timely results for ILC damping ring R&D!

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