Damping Ring Activities at Cornell

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Accelerator-Based Sciences and Education

ILC2007

Global Design Effort

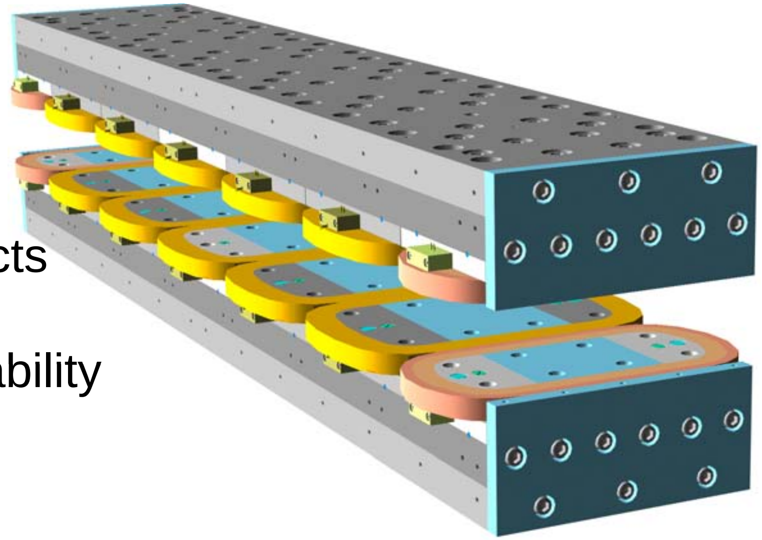
Outline

- Overview of the Cornell Program
  - **Recent efforts**
  - **Goals for EDR phase**
- Review Highlights of Recent Activities
  - **Wiggler optimization**
  - **Bypass line options to relax kicker requirements**
  - **Electron cloud studies**
  - **CesrTA design and planning**
  - **Diagnostics development**
- Conclusion

Cornell Program

- Recent efforts
  - **Beam dynamics efforts**
    - Dynamic aperture studies
      - Wigglers and multipole errors
    - Optimized wiggler parameters
    - Electron cloud and ion studies
    - Alternative lattice design to ease kicker requirements
  - **Engineering efforts**
    - Magnets
      - Wiggler, magnet specifications, DR magnet power supply system
    - Fast kicker tests
    - Diagnostics development
      - Multi-bunch turn-by-turn diagnostics
      - X-ray beam size monitor
  - **Test Facility efforts**
    - CesrTA development
- EDR plans
  - **Primary focus is to support DR R&D via the CesrTA program**

Wiggler Optimization

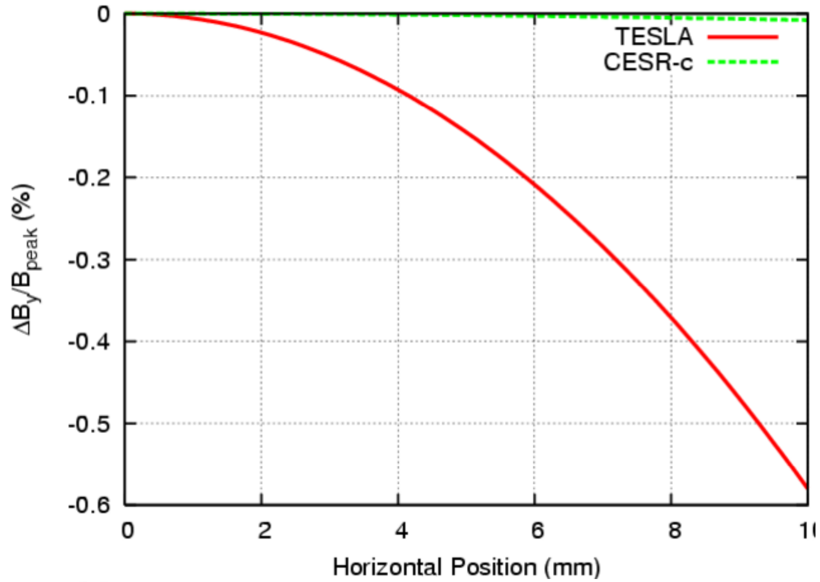


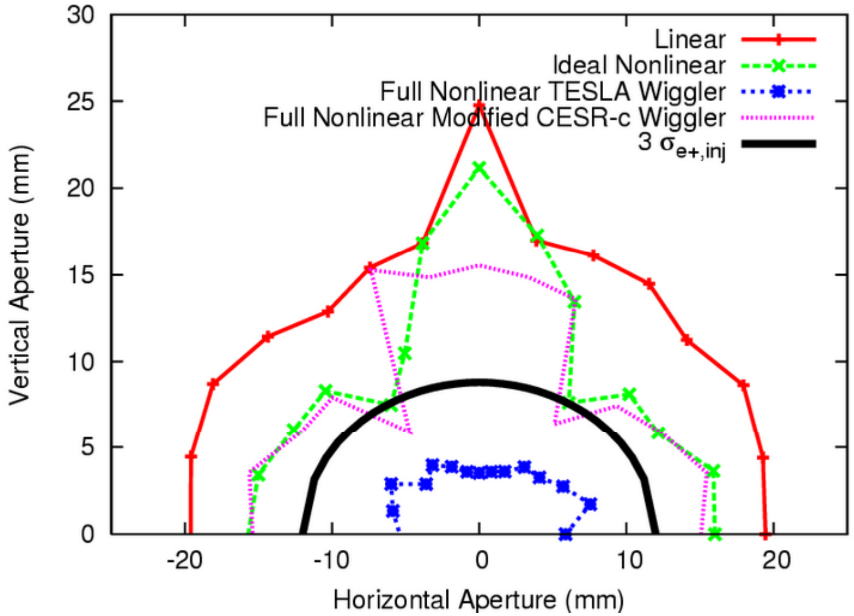
- Basic Requirements
  - **Large Physical Aperture**
    - Acceptance for injected e+ beam
    - Improved thresholds for collective effects
      - Electron cloud
      - Resistive wall coupled bunch instability
  - **Dynamic Aperture**
    - Field quality
    - Wiggler nonlinearities
- Work Towards a Final Design
  - **Superferric Wiggler Physics Optimization**
    - No. Poles
    - Period
    - Gap
    - Width
    - Peak Field
  - **Engineering Issues and Optimization**
    - Expected Cost Impact

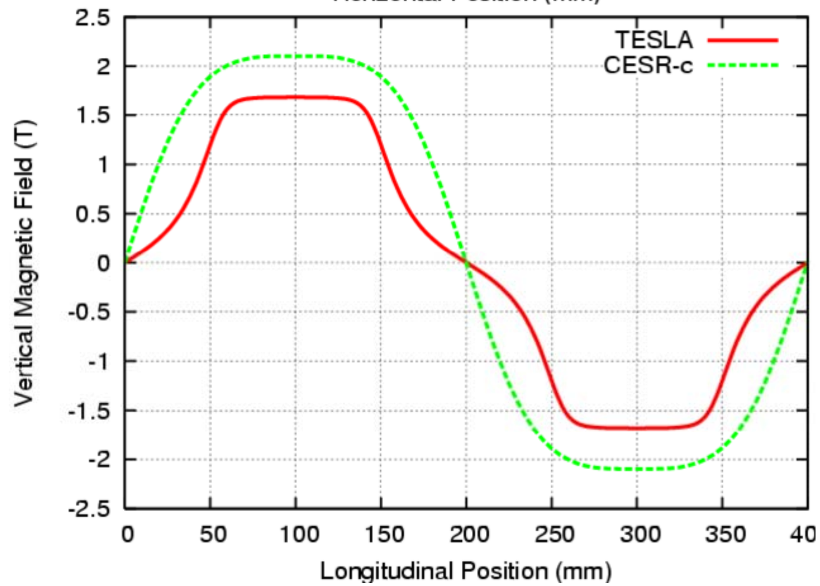
Wiggler Comparison

J. Urban

	TESLA	CESR-c	Modified CESR-c
Period	400 mm	400 mm	400 mm
$B_{y,peak}$	1.67 T	2.1 T	**1.67 T**
Gap	25 mm	76 mm	76 mm
Width	60 mm	238 mm	238 mm
Poles	14	8	**14**
Periods	7	4	**7**
Length	2.5 m	1.3 m	2.5 m







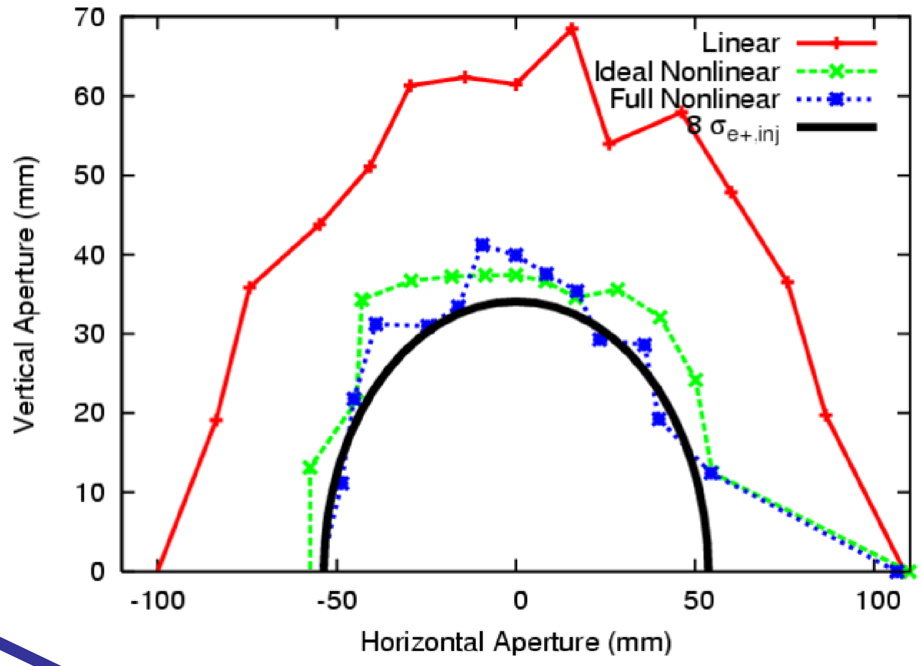
Optimized Wiggler

- Superferric ILC-Optimized CESR-c Wiggler
  - **12 poles**
  - **Period = 32 cm**
  - **Length = 1.68 m**
  - **$B_{y,peak}$ = 1.95 T**
  - **Gap = 86 mm**
  - **Width = 238 mm**
  - **I = 141 A**

  τ_{damp} = 26.4 ms

  $\varepsilon_{x,rad}$ = 0.56 nm·rad

  σ_{δ} = 0.13 %



Misses nominal target (25 ms)

Engineering Impact

- Cryogenics Modifications
  - **Indirect cooling for cold mass**
  - **Switch to cold He gas for cooling thermal shields**
  - **42% of manpower for inner cryostat and stack assembly ⇨ significant cost reduction expected**
- Shorter Unit
  - **Simplified and more robust yoke assembly**
  - **Significant cost reduction**
    - 14 % fewer poles
    - 30% reduction in length
- Larger aperture
  - **Relaxed constraints on warm vacuum chamber interface with cryostat**
- Initial estimate of cost savings: ~25%
- Wiggler Information:

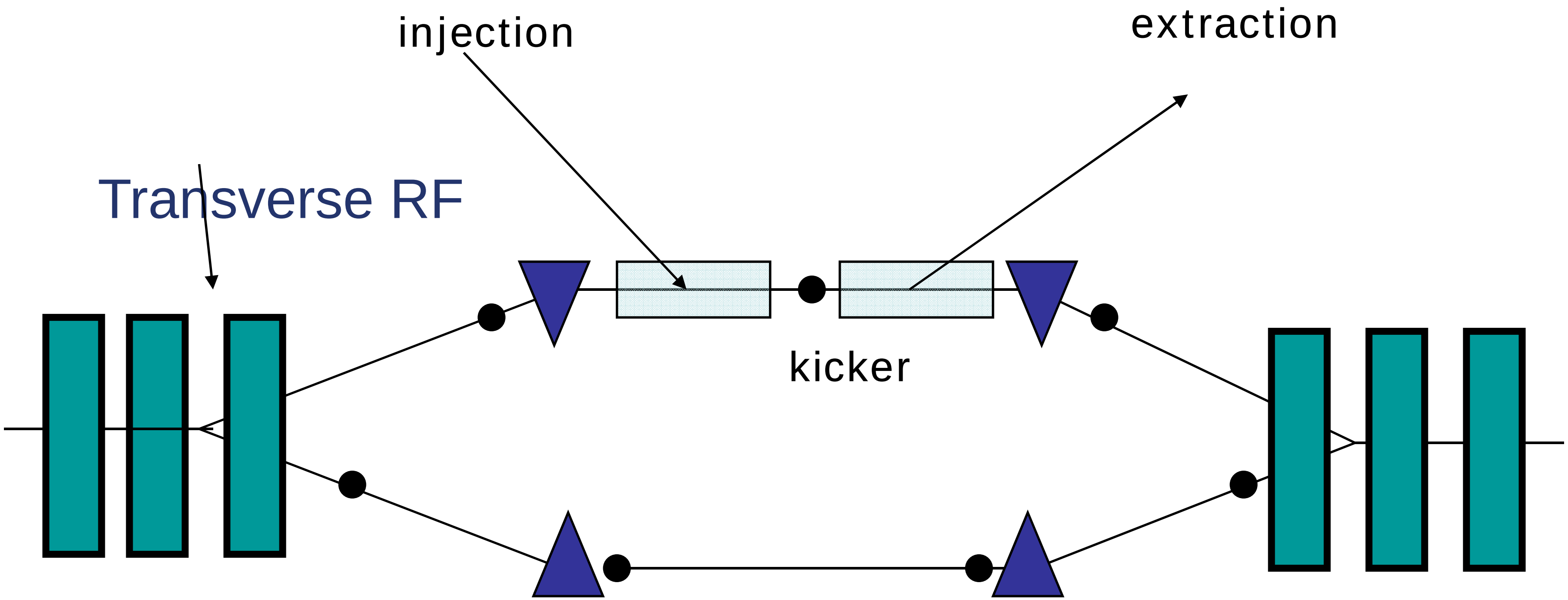
https://wiki.lepp.cornell.edu/ilc/bin/view/Public/CesrTA/WigglerInfo

Bunch Separation with RF Deflectors

R. Helms, D. Rubin

In the event that an injection/extraction kicker with pulse width of ~6ns is not practical…

⇨ we can increase effective bunch spacing with RF separation



Separation with Transverse RF

Timing

$\Delta t = nT_{RF}$ (Δt = bunch spacing)

$N = T_{rev}/T_{RF}$

$\Delta t = (m+1/2)T_{TR}$ (opposite kick for consecutive bunches)

$T_{rev}/T_{TR} = (M+1/2)$ (opposite kick for the same bunch on consecutive turns)

$T_{TR} = [n/(m+1/2)]\ T_{RF}$

$n=2,\ m=1$ ⇨ $T_{TR}=(4/3)T_{RF}$

$f_{RF}=650MHz$

$f_{TR}=487.5MHz$

$N=14402$

$M=10801$

Train spacing

⇨ 337ns Linac bunch spacing

Extraction from tail of train:

$t_{rise}\sim 6ns,\ t_{fall}>49ns$

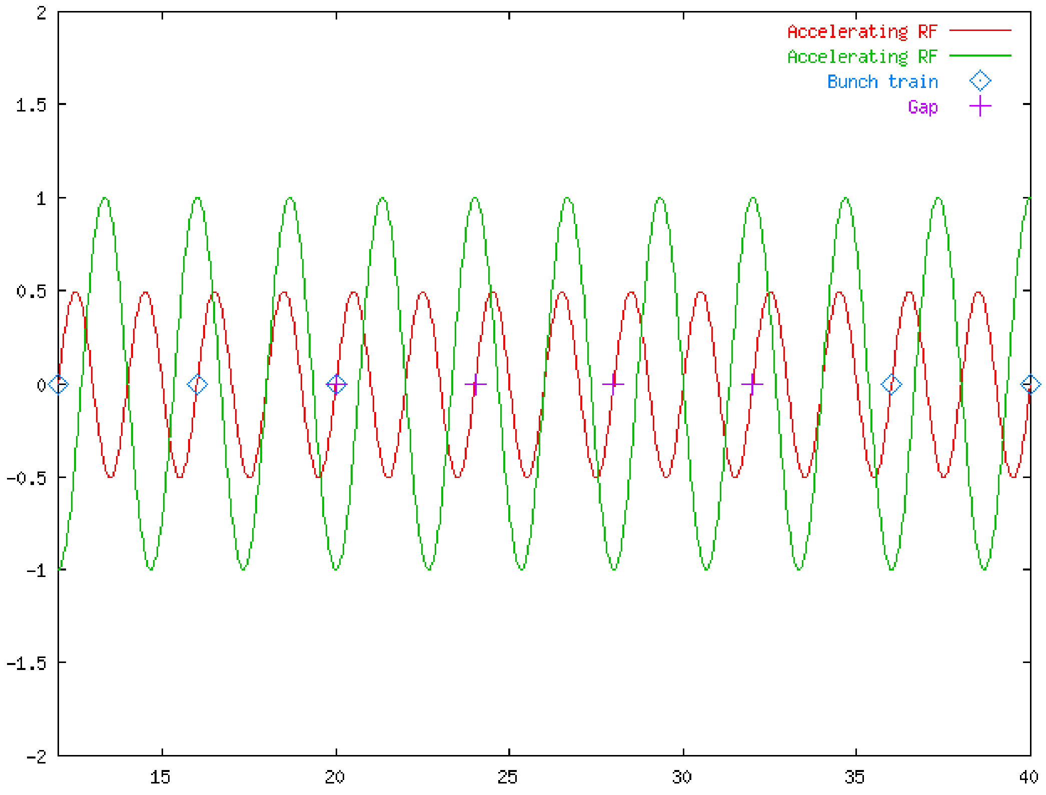
- Injection at head of train:

$t_{fall}\sim 6ns,\ t_{rise}>49ns$

Kick Amplitude

Require ~0.9 mrad kick

⇨ *eg*, 3 KEKB Crab cavities

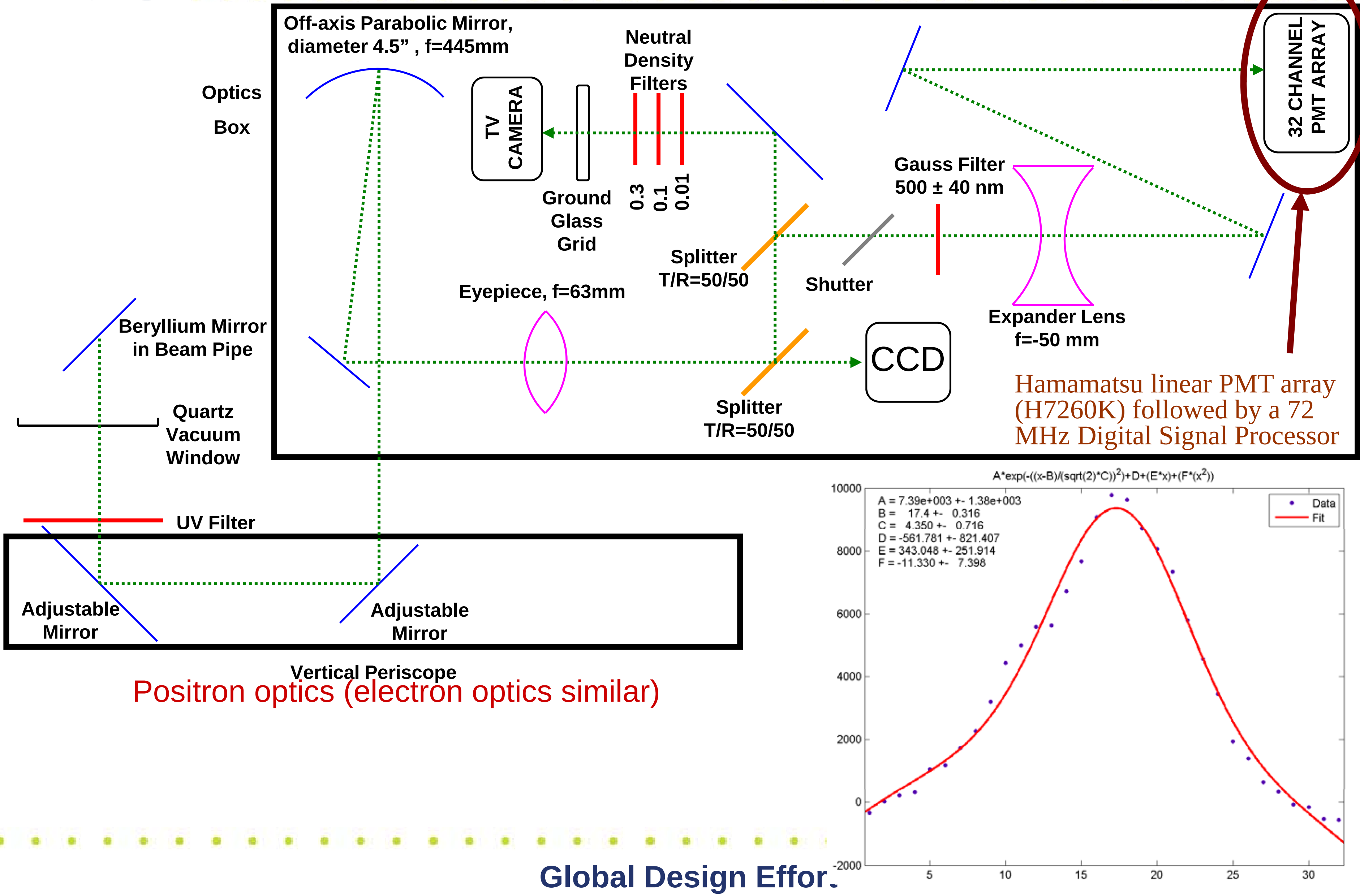


Electron Cloud Measurements

- 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**

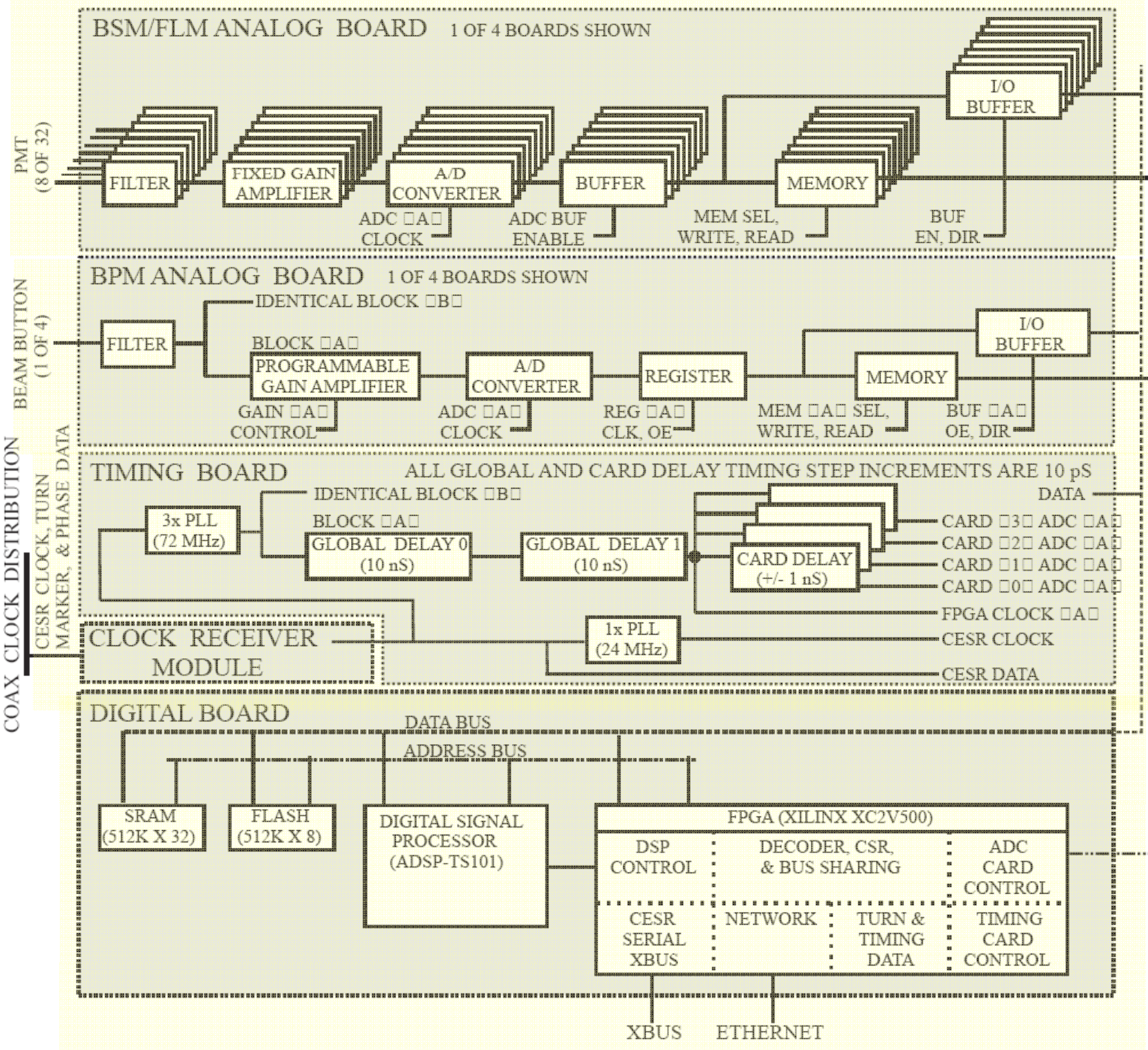
- Multibunch Instrumentation
  - **BSM (Beam Size Monitor) shuttered, 32 channel linear PMT array looking at synchrotron light from dipole**
    - one sample per channel per bunch on each turn
    - separate DAQ for each species samples up to 183 bunches
    - optics accommodate linear CCD array and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



Positron optics (electron optics similar)

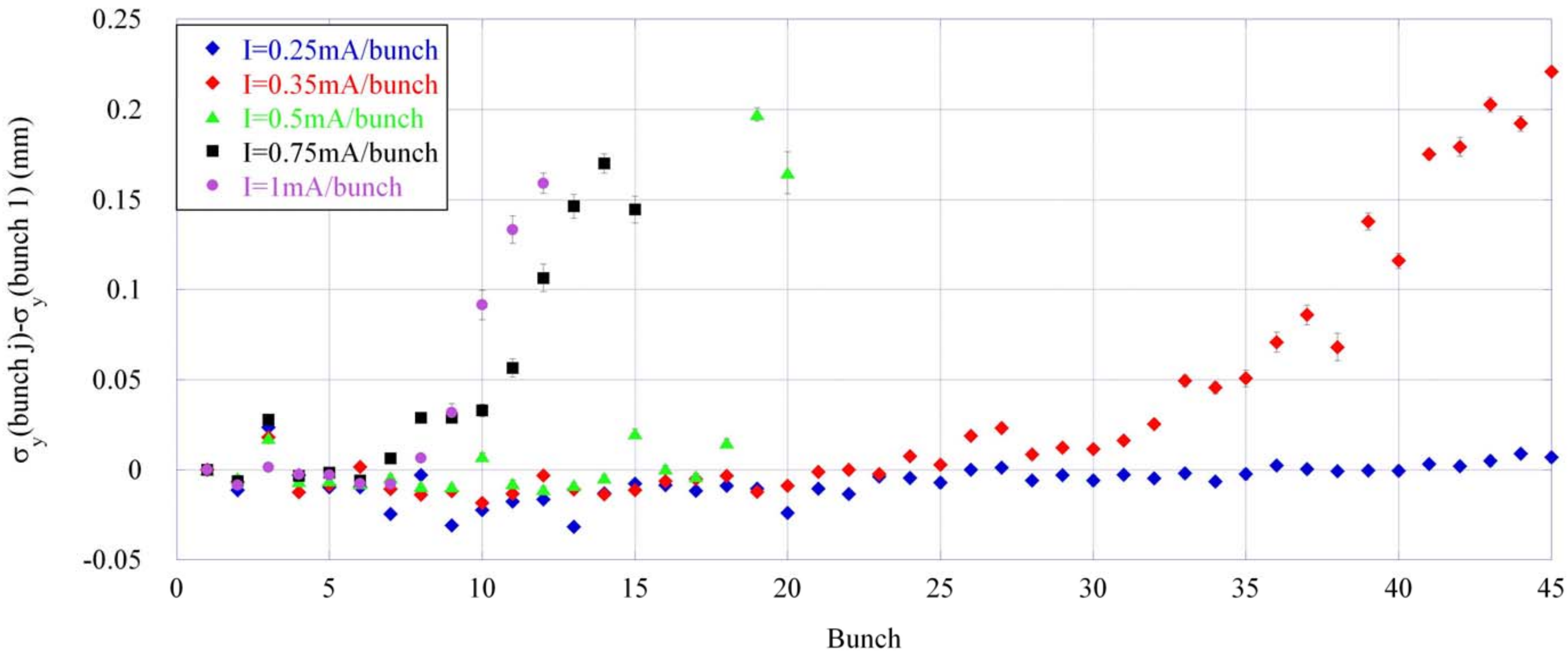
Signal Processing and DAQ



- DAQ for 14 ns bunch spacings is based on a 72 MHz Digitizer Module capable of turn-by-turn and bunch-by-bunch data acquisition
- Each module equipped with an on-board digitial signal process for local data processing capability
- Similar architecture for BPM and BSM

EC Induced Instability

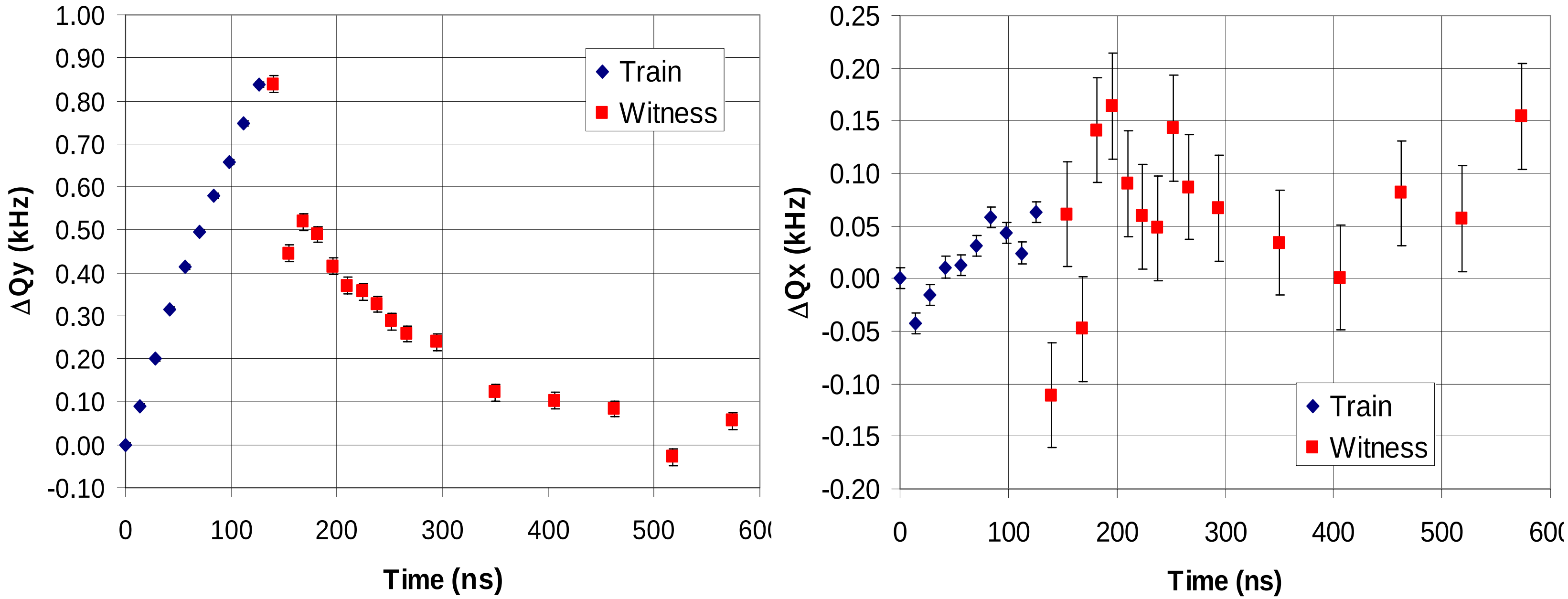
- Bunch-by-bunch beam size
  - **2 GeV**
  - **45 bunch positron train**
  - **Each point ⇨200 50-turn averages (sensitive to centroid motion and incoherent growth)**
- Advancing onset of instability with increasing bunch current



Witness Bunch Studies – e^+ Tune Shifts

- 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

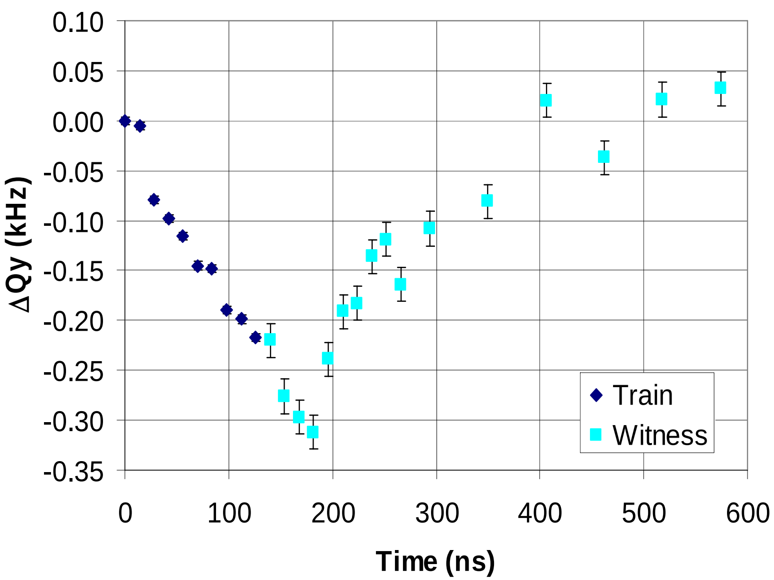
1 kHz ⇨ $\Delta\nu = 0.0026$
$\rho_e \sim 1.5 \times 10^{11}\ m^{-3}$
Ohmi, etal, APAC01, p.445

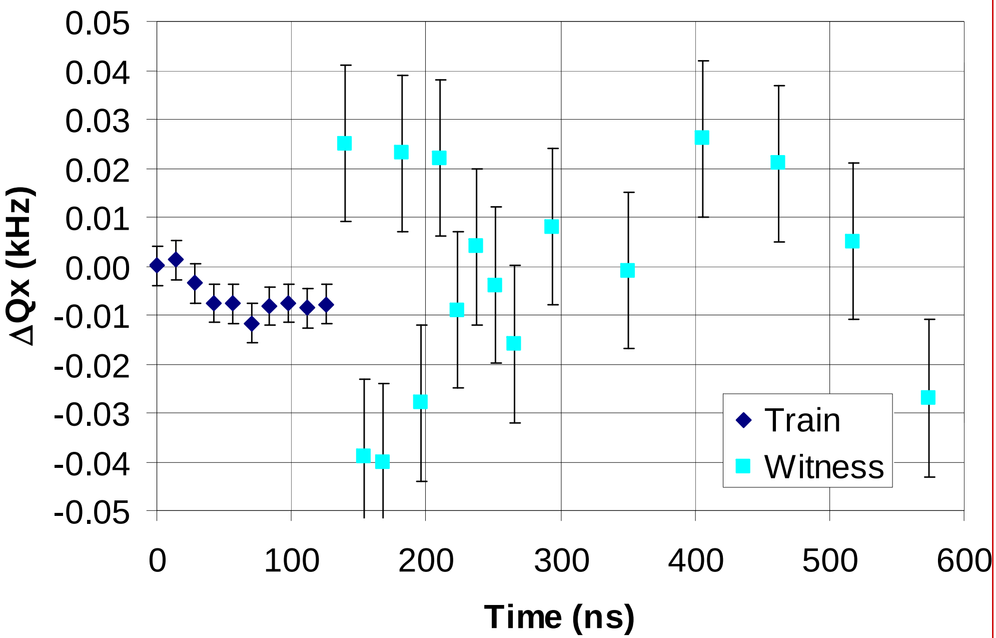
Preliminary Results

Witness Bunch Studies – e^- 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



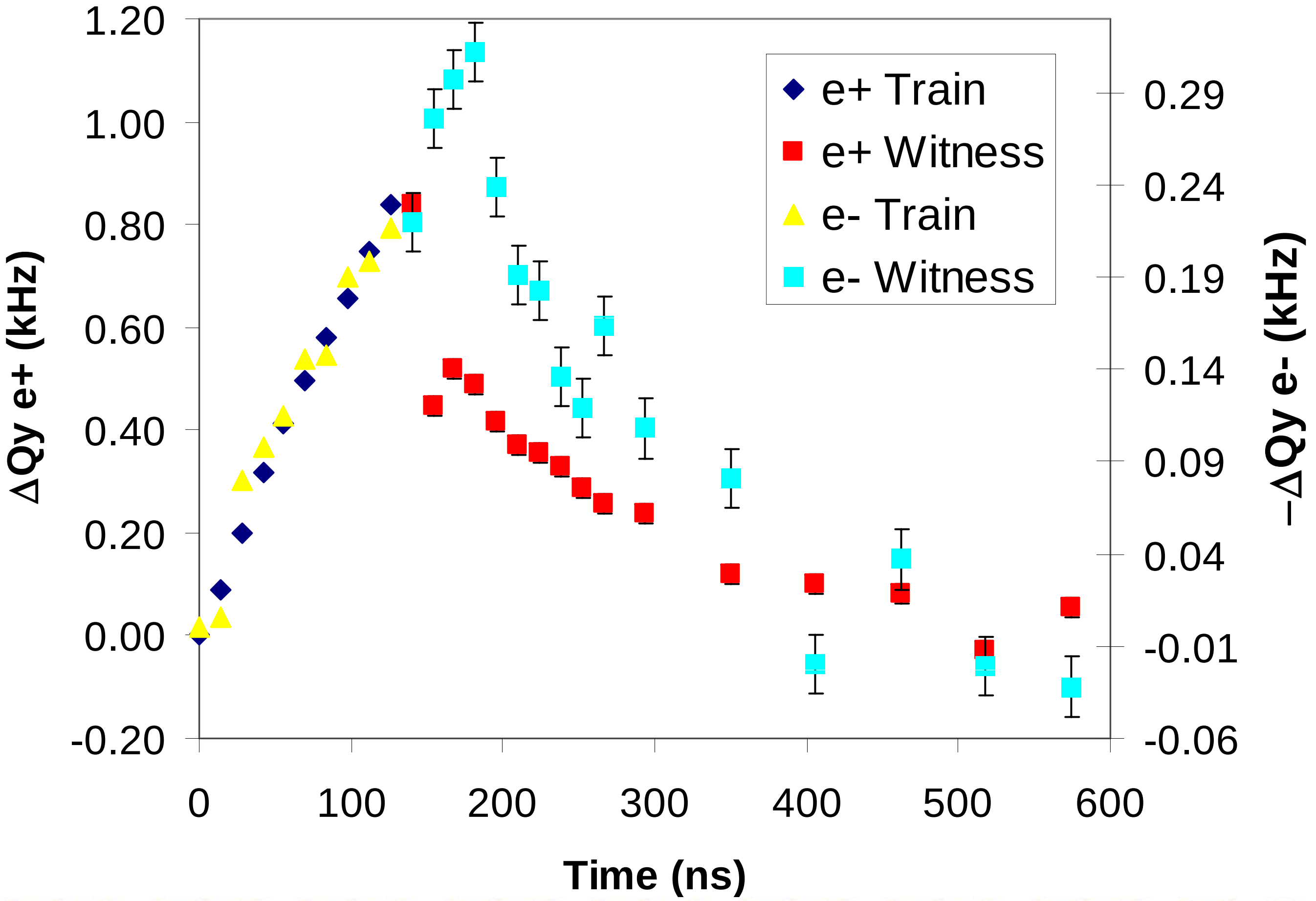


Negative vertical tune shift along train ⇨ consistent with EC
Magnitude of shift along train is ~1/4th of shift for positron beam
NOTE: Shift continues to grow for 1st 4 witness bunches!

Preliminary Results

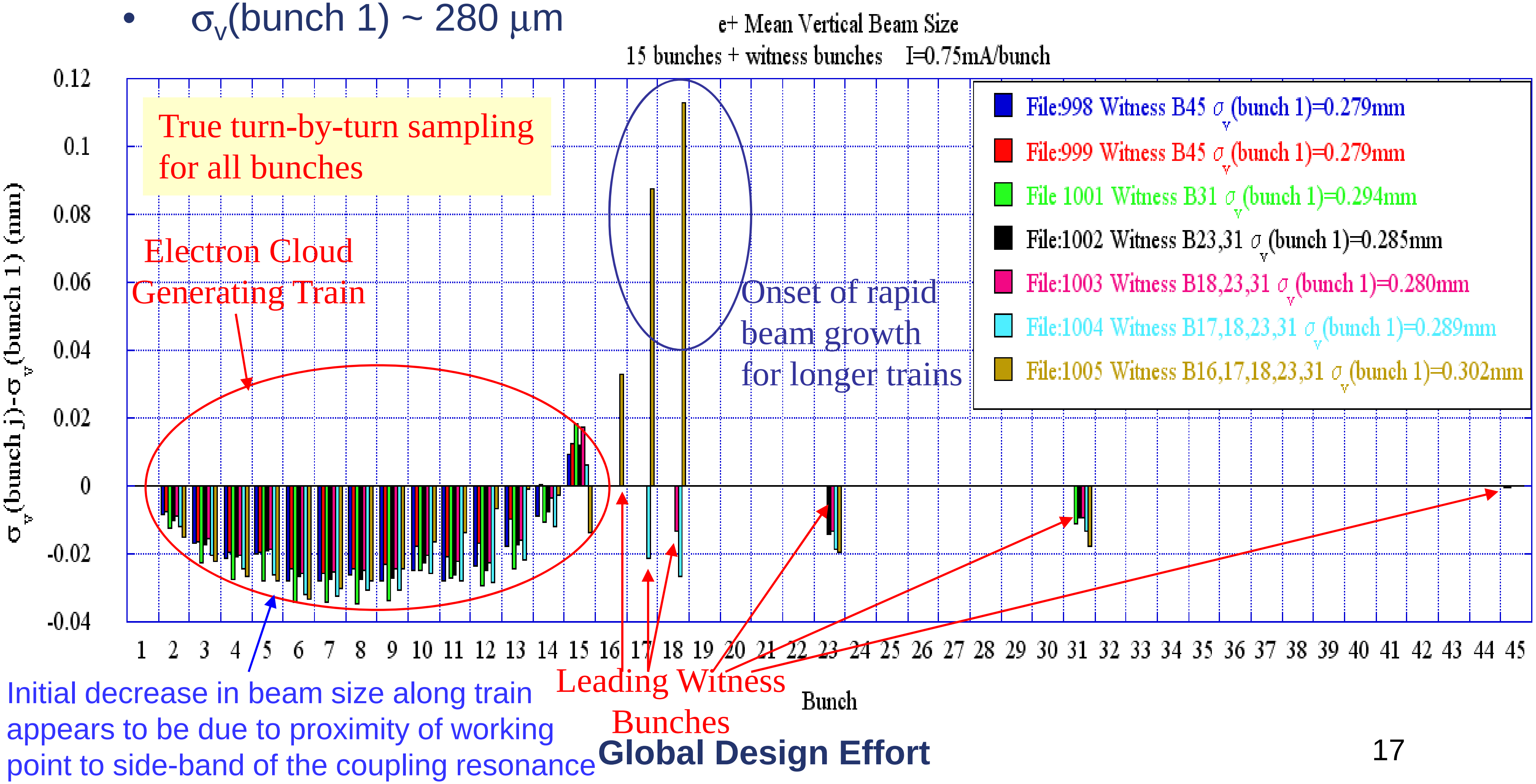
Witness Bunch Studies – Comparison of e- & e+

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



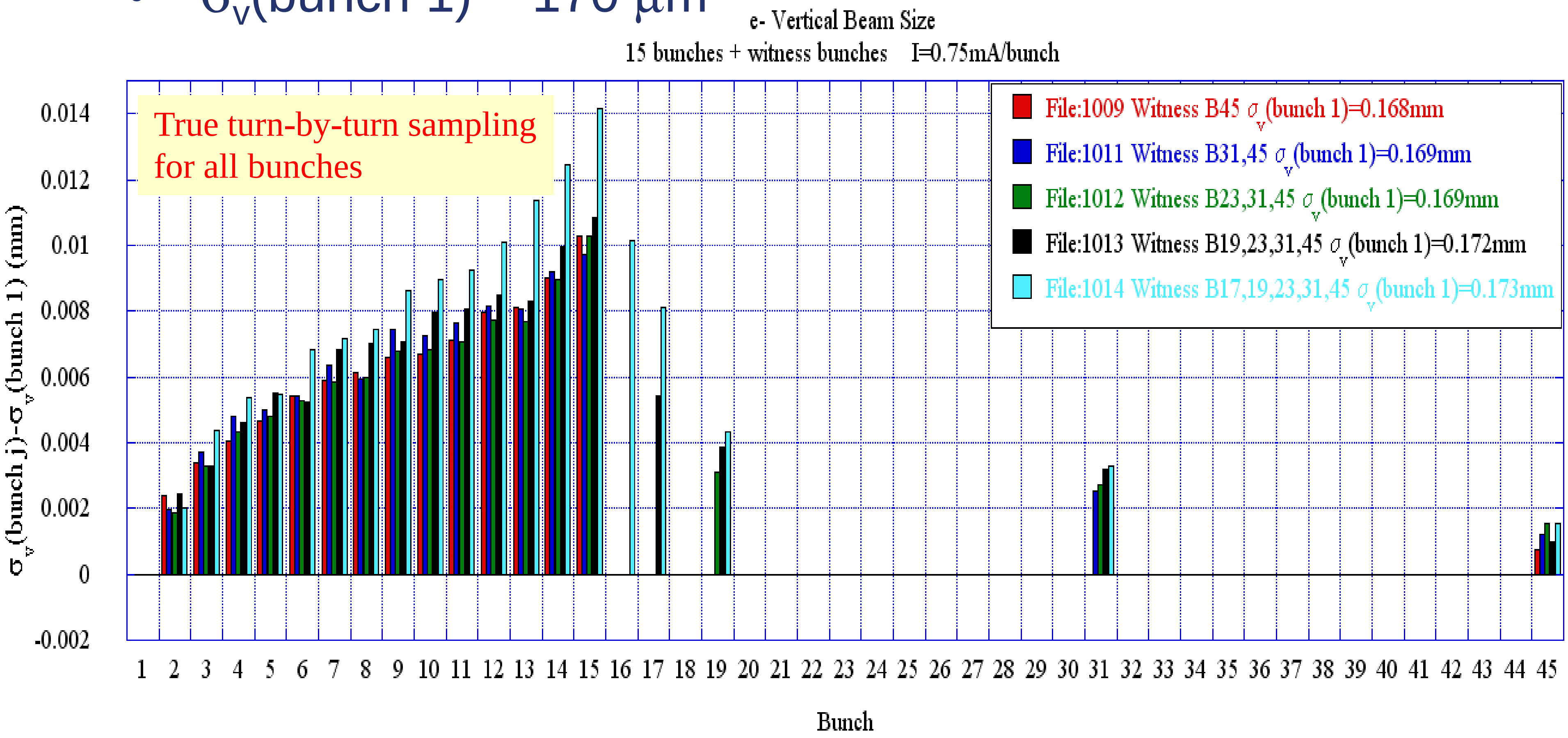
Witness Bunch Studies – e$^+$ Vertical Beamsize

- 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



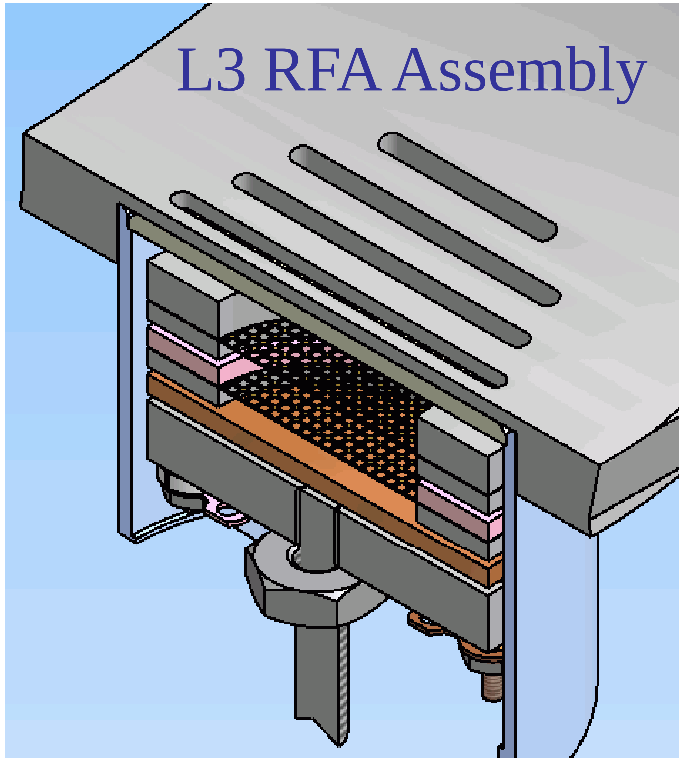
Witness Bunch Studies – e$^-$ Vertical Beamsize

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



Experimental Plans Thru April 1, 2008

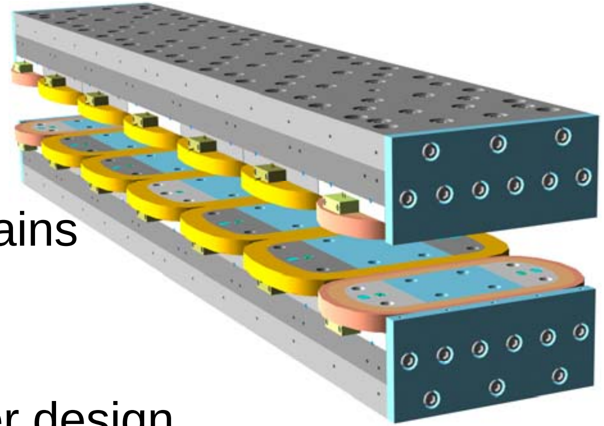
- 4ns transverse feedback
  - **Implemented in April '07**
  - **Start looking at ILC-like bunch spacings**
- 3 Retarding Field Analyzers (RFA) for electron cloud measurements just installed in L3 straight during May '07 shutdown
- Continue electron cloud and ion studies
  - **Time for tests in lower 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**



CESR-c ⇨ CesrTA

- CESR-c/CLEO-c HEP operations conclude March 31, 2008
- 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**
    - 2.25 nm horizontal emittance
    - Goal is vertical emittance in 5-10 pm range (in zero current limit)
    - Can presently operate with wigglers in the 1.5-2.5 GeV range
    - Reconfigure so that one or more wigglers can operate at 5 GeV
    - Support operation at 4 ns bunch spacings (comparable to 3.08 ns 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)**

CesrTA Plans

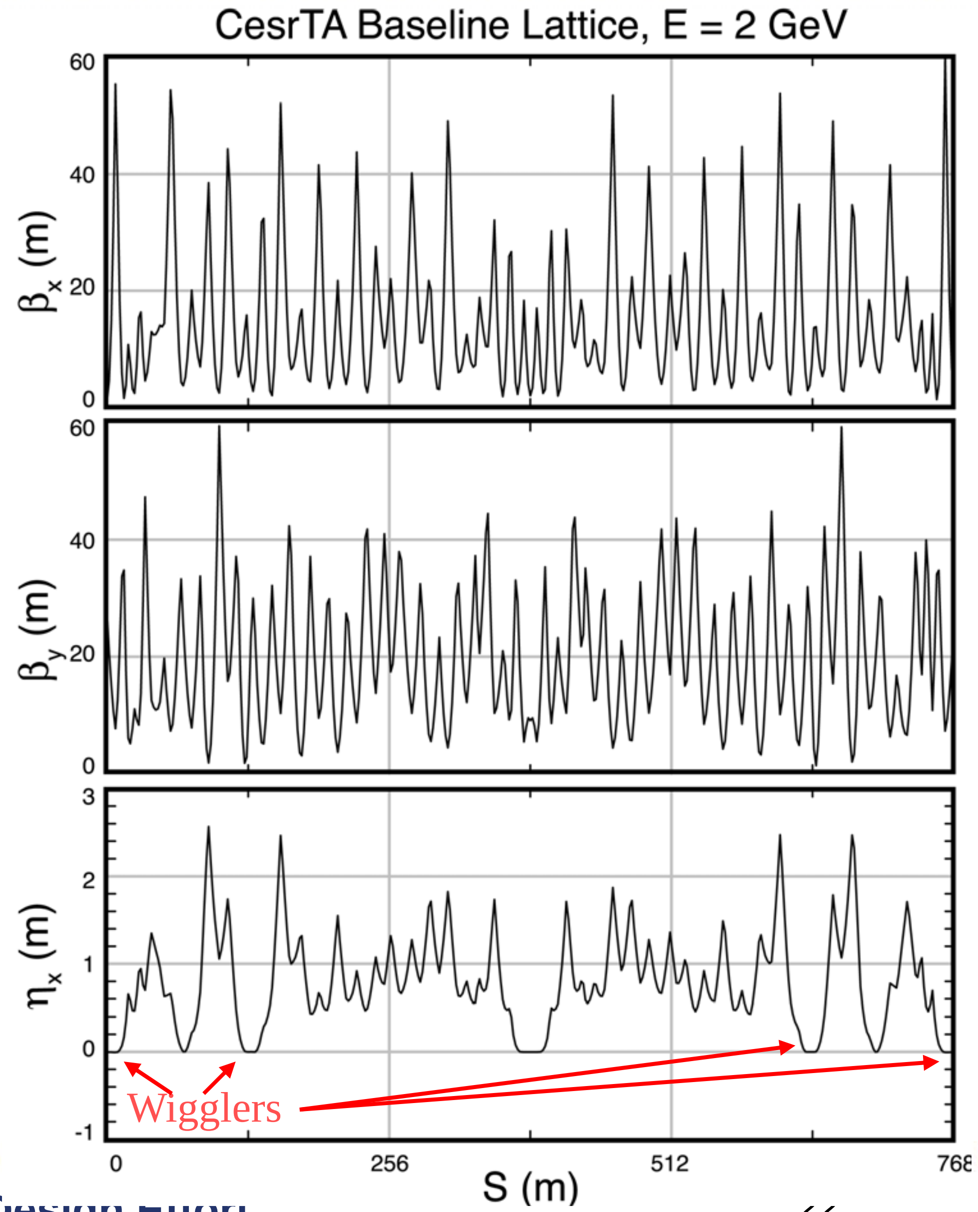


- Primary ILC EDR Goals
  - **Electron cloud measurements**
    - e^- cloud buildup in wigglers with ILC-like bunch trains
    - e^- cloud mitigation in wigglers
    - Instability thresholds
    - Validate the ILC DR wiggler and vacuum chamber design (critical for the single 6 km positron ring option)
    - 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

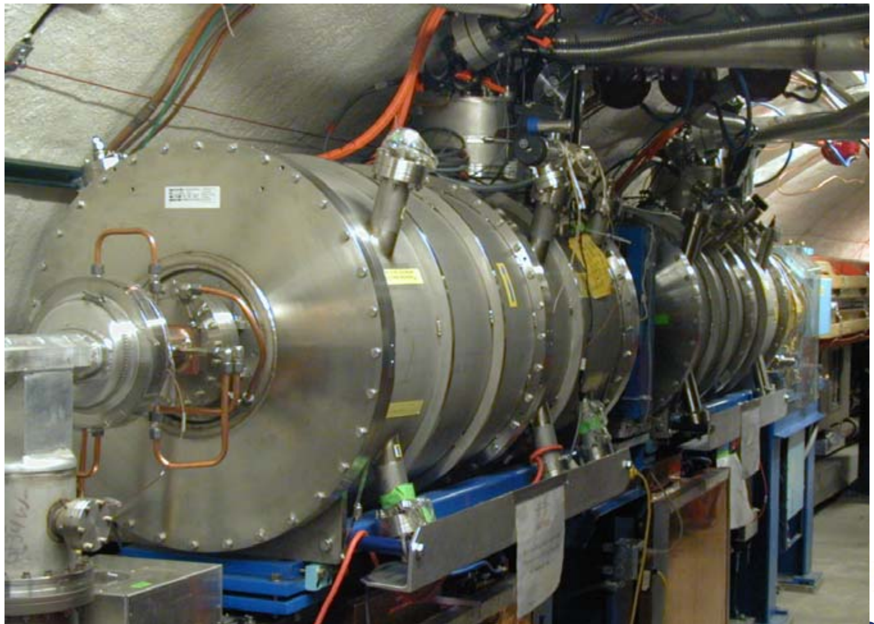
Baseline Lattice

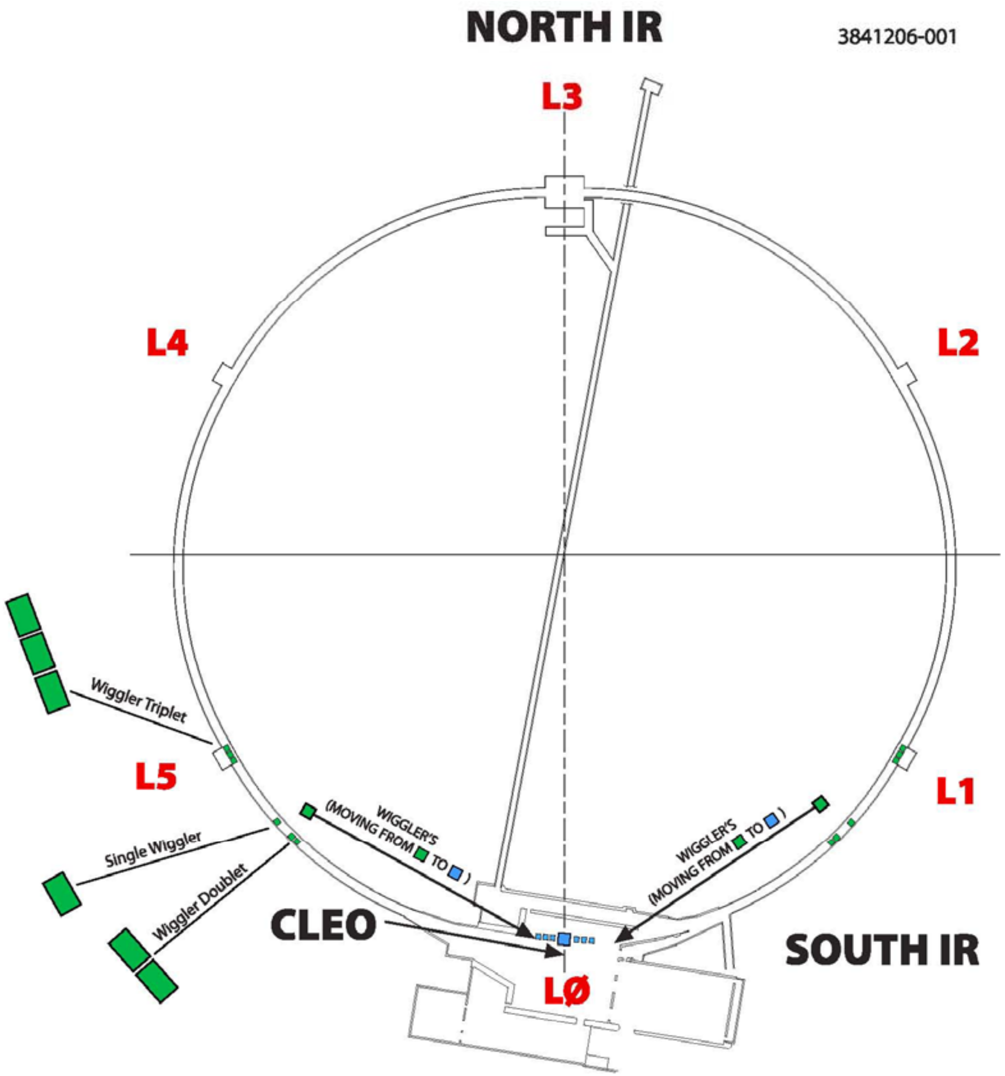
Parameter	Value
E	2.0 GeV
$N_{wiggler}$	12
B_{max}	2.1 T
ε_x	2.25 nm
Q_x	14.57
Q_y	9.62
Q_z	0.075
σ_E/E	8.6 x 10^{-4}
$\tau_{x,y}$	47 ms
σ_z (with V_{RF}=8.5MV)	9 mm
α_c	6.4 x 10^{-3}
$\tau_{Touschek}$(N_b=2x10^{10} & zero current ε_y=5pm)	~10 minutes



CESR Modifications

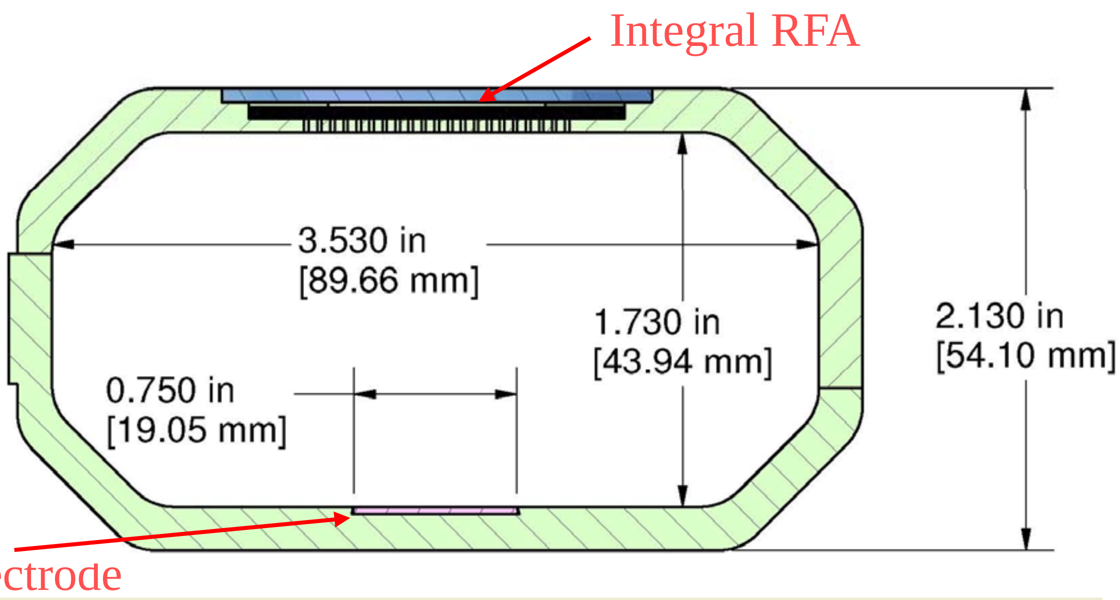
- Move 6 wigglers from the CESR arcs to the South IR (zero dispersion region)
  - **Cryogenics support available**
  - **Zero dispersion regions can l created locally around the wigglers left in the arcs**
- Make North IR available for insertion devices and instrumentation
- Instrumentation and feedback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

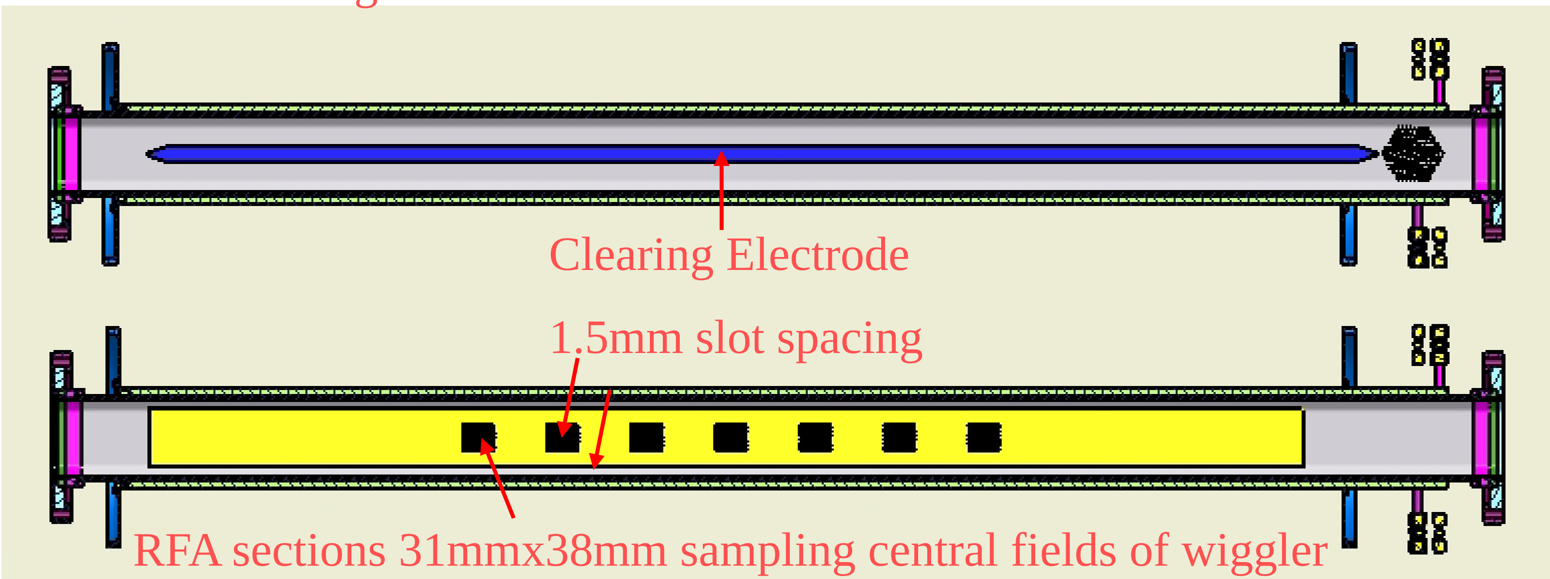




Diagnostic Wiggler Chamber Concept

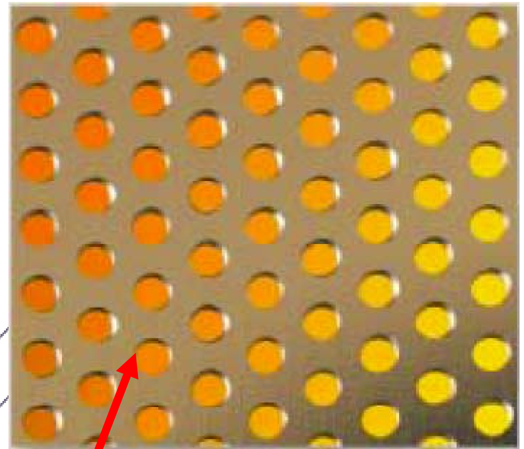
- Expect to make several variants to explore
  - **Electrodes**
  - **Grooves**
  - **Coatings**
- Modify existing extrusions

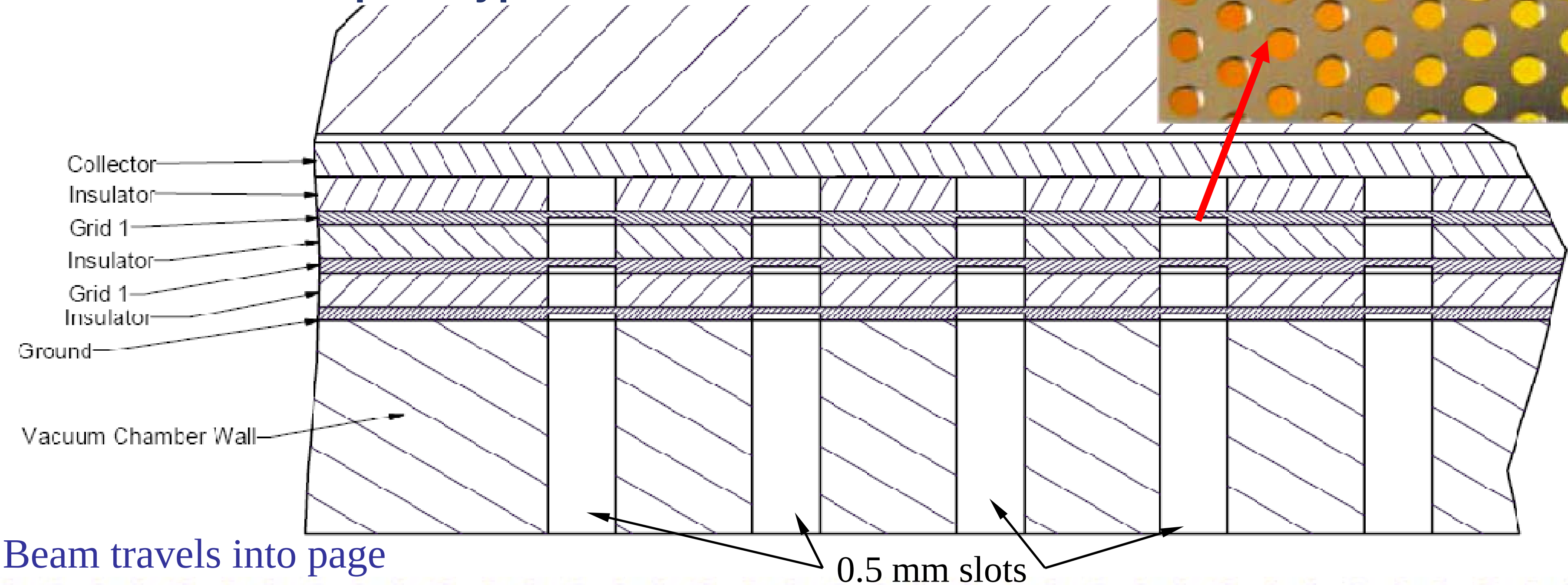




Wiggler Chamber Concept II

- 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**





Diagnostics Development

- Techniques for ultralow emittance
  - **Targeting real time techniques for correcting and tuning machine ⇨ achieve and *maintain* ultralow emittance**
    - Fast vertical dispersion measurement techniques
      - Turn-by-turn BPMs with induced energy oscillation
      - Normalize to measured horizontal dispersion
    - Bunch-by-bunch and turn-by-turn X-ray beam size monitor
      - Typical CesrTA Beam Sizes
        - » Vertical: σ_y~10-12 μm
        - » Horizontal: σ_x ~ 80 μm (at a zero dispersion point)
      - Fast X-ray imaging system (Alexander)
        - » Core diagnostic for CesrTA – high resolution and bunch-by-bunch capability
        - » Plan for integrating systems into CHESS lines
        - » First pinhole camera tests were successful! (see next slide)

GaAs Detector for X-ray Imaging

First bunch-by-bunch beam size data in CHESS conditions ⇨

Significant CHESS support

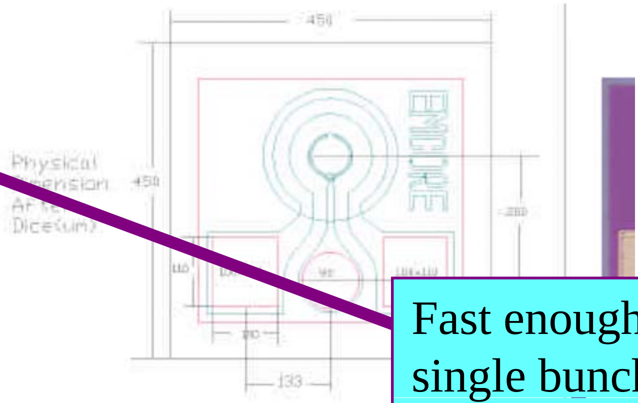
10 Gbps GaAs PIN Photodiode*

Product Description

EMCORE's 10 Gbps Gallium Arsenide (GaAs) PIN photodiode is designed for multimode fiber EMCORE's own state-of-the-art MOCVD wafer foundry and device fabrication facility guarantees fabrication source of package ready die to meet the growing needs of fiber optic component ma device performance and robust operation makes this the superior device for high speed multimode applications.

Features

- Data rates of 10 Gb/s
- Excellent responsivity
- Large aperture size
- Low capacitance
- Low dark current

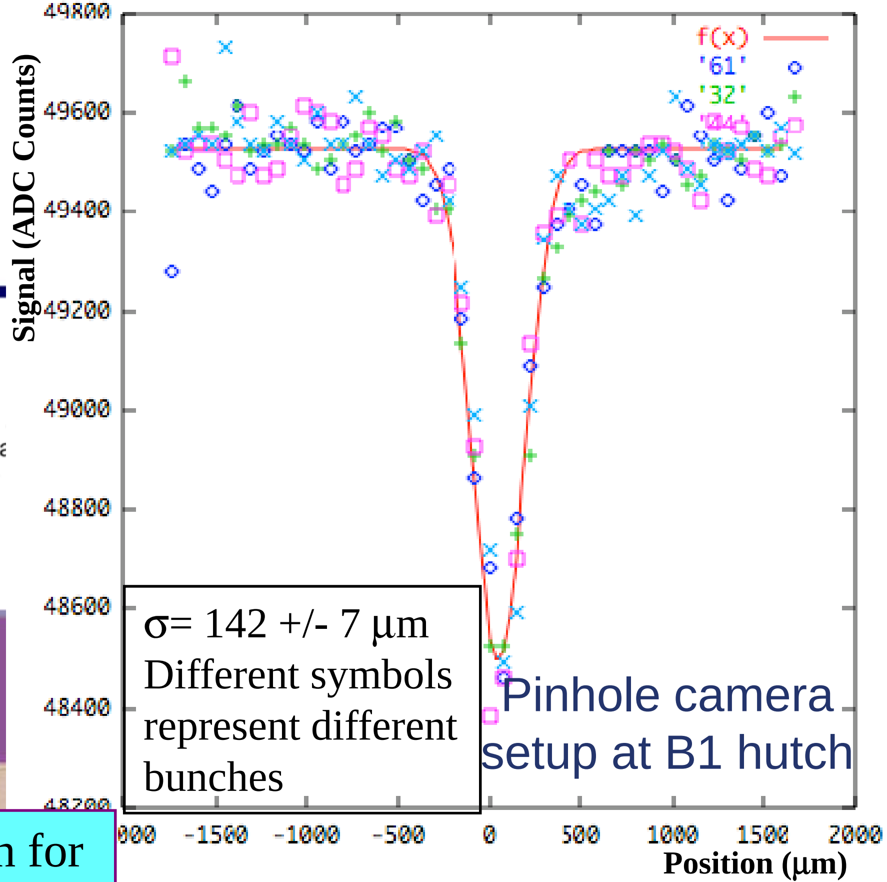


Fast enough for single bunch resolution

Product Specifications

Electro-Optical Characteristics (T = 30°C)

	Conditions	Min.	Typical	Max.	Unit
Speed	-1.6 V		8.5		GHz
Responsivity	3 to -26 dBm, 850 nm Epoxy coated, n=1.6		.5		A/W
Active Area (aperture)	-		60		µm
Rise/Fall Time	20% / 80%, -1.6 V bias		30/35		ps
Dark Current	-1.6 V, -70 dBm		<.2	1	nA
Capacitance	-1.6 V, 1 MHz		.28		pF
Reverse Breakdown	1 µA	20	50		V
Reflectivity	Epoxy coated, n=1.6			1	%



NEW: GaAs arrays from Hamamatsu

- 1x512 linear array
- 25 µm pitch
- 1st sample has recently arrived

CesrTA Beamsize Monitor Concept

- Simple optics
  - **High transmission**
  - **2 keV operation (works for both 2 GeV and 5 GeV)**
  - **Hundreds (2 GeV) to thousands (5 GeV) of photons per bunch passage**
- Explore other detector possibilities (*eg*, InSb arrays)
- Collaboration with CHESS colleagues for optics and device development as well as integration with existing Xray lines

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**
  - **First APS-style RFAs for direct measurement of cloud have just been installed (first beam in 2 weeks)**
  - **Also setting up for measurements with 4ns bunch spacing**
- CesrTA
  - **Damping ring proposal has now been submitted 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 collaboration welcomed!**

Acknowledgments

- CesrTA Development and CESR EC Machine Studies
  - **J. Alexander**
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  - **D. Hartill**
  - **R. Helms**
  - **D. Rice**
  - **D. Rubin**
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  - **R. Holtzapple (Alfred)**
  - **A. Molvik (LLNL)**
  - **M. Pivi (SLAC)**