

Cornell University
Laboratory for Elementary-Particle Physics



CesrTA Low Emittance and Electron Cloud R&D

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Accelerator-Based Sciences and Education

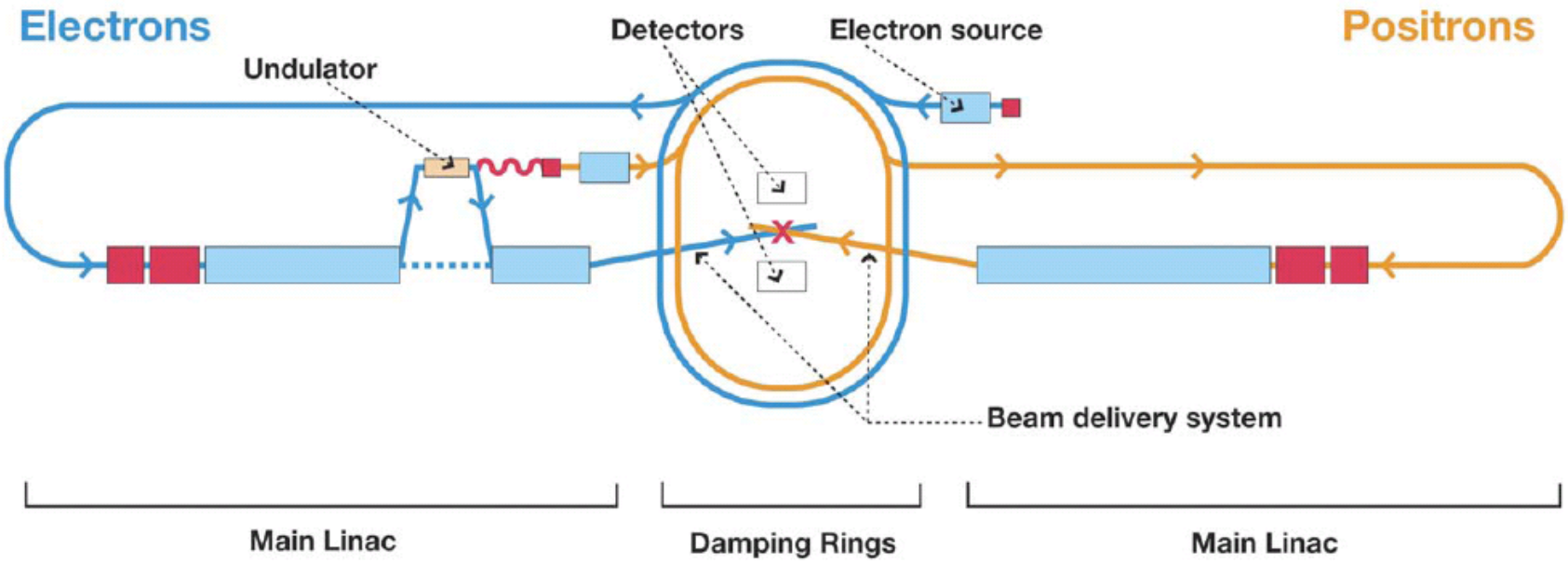








- 11km SC linacs operating at 31.5 MV/m for 500 GeV
- Centralized injector
  - Circular damping rings for electrons and positrons
  - Undulator-based positron source
- Single IR with 14 mrad crossing angle



ILC Damping Rings

- Beam Parameters
  - 2625 bunches/ RF pulse
  - Pulse rate - 5.0Hz
  - Pulse length ~ 0.8 ms (240 km)
  - Bunch spacing in linac ~ 300ns
  - Particles/bunch - $2X10^{10}$
  - Beam emittance ~ ε_x= 0.8nm, ε_y = 2pm (at 5GeV)
- Damping rings

  (1 for electrons, 1 for positrons)
  - E_{beam} = 5 GeV
  - ~ 6 km circumference (20 μs revolution period)

  → 3ns bunch spacing

  It is anticipated that the electron cloud will limits positron current/emittance

  Viability of the design depends on development of suitable

  - electron cloud mitigation and
  - low emittance tuning techniques

Electron Cloud

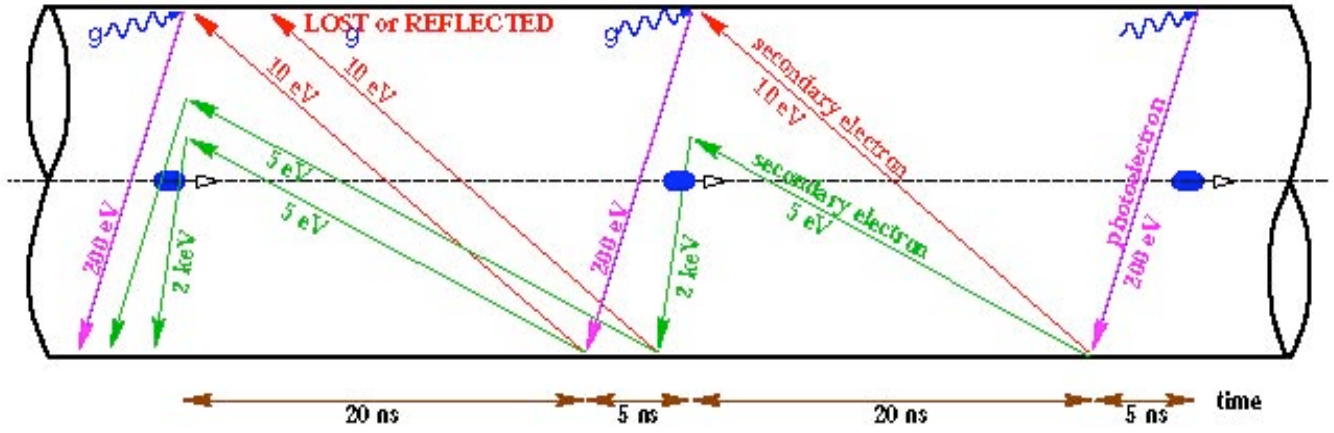
What is the electron cloud?

– Synchrotron radiation from the circulating positrons, strikes the walls of the vacuum chamber and photoelectrons are emitted

–An electron cloud evolves and is trapped in the path of the beam by the beam potential and the magnetic fields of dipoles, quadrupoles, and especially wigglers

– Focusing of e-cloud on circulating bunches shifts tune and dilutes beam emittance

– E-Cloud couples transverse motion of one e+ bunch to the next, eventually destabilizing the bunch train



schematic of e- cloud build up in the arc beam pipe, due to **photoemission** and **secondary emission**

[Courtesy F. Ruggiero]

CesrTA Objective

Provide a laboratory for the study of electron cloud phenomena in a parameter regime that approximates ILC damping rings to measure

- Dependence of e-cloud growth on
  - Beam current, bunch spacing, beam size
  - Magnetic field
  - Vacuum chamber geometry and chemistry
  - Beam energy
- Mitigation techniques (coatings, clearing electrodes, grooves, etc.)
- Enable measurement of instabilities and other current dependent effects in the ultra low emittance regime for both electrons and positrons

  Such as dependencies of
  - Vertical emittance and instability threshold on density of electron cloud
  - Cloud build up on bunch size
  - Emittance dilution on bunch charge (intrabeam scattering)

CesrTA Objective

Develop strategies for systematically tuning vertical emittance

- Rapid survey
- Efficient beam based alignment and correction algorithms

- Demonstrate ability to reproducibly achieve our target of < 20 pm (geometric)
  - In CesrTA this corresponds to a vertical beam size of about ~ 20microns

Low Emittance Tuning

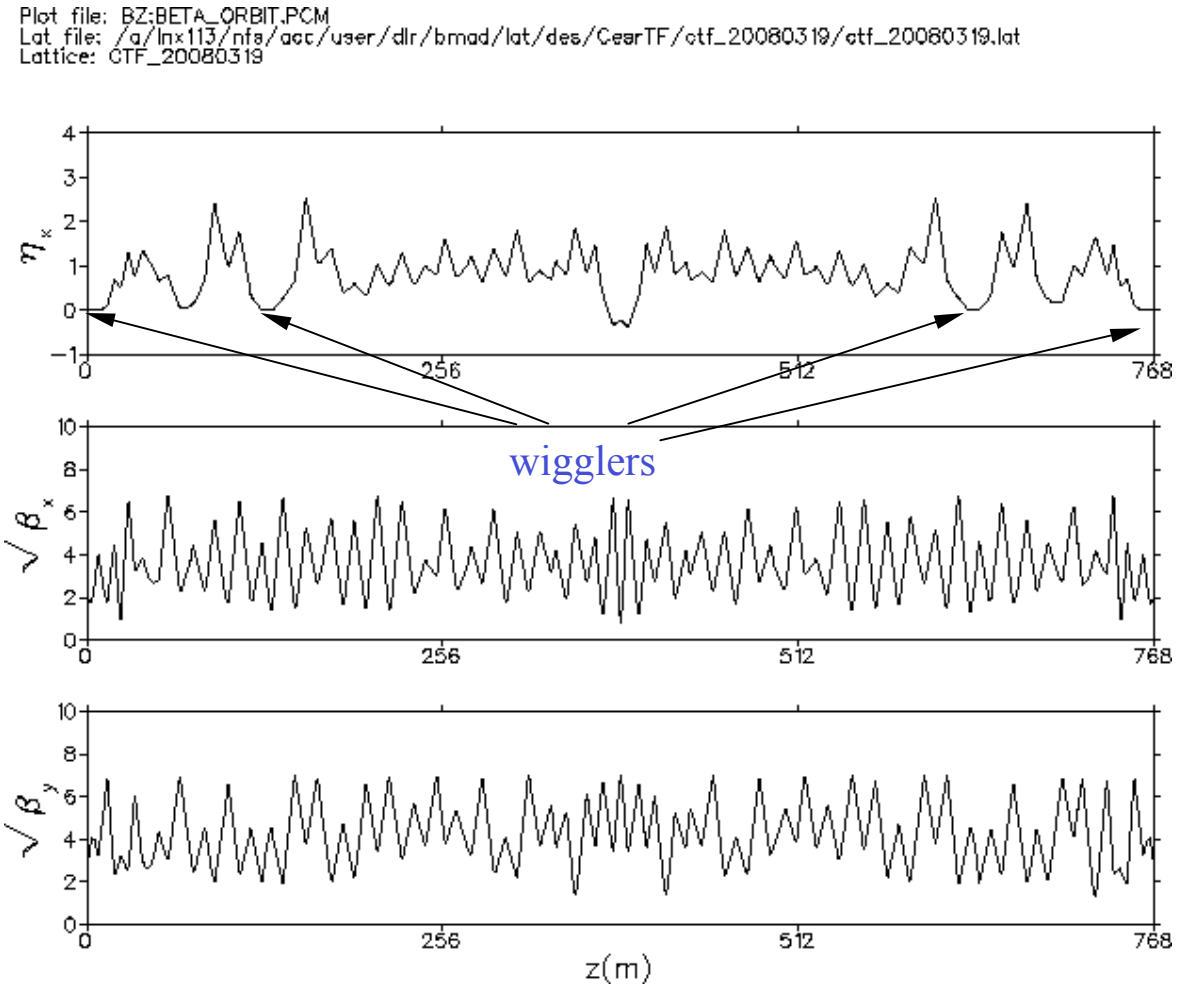
Outline

- CesrTA optics
  - Horizontal emittance in a wiggler dominated ring
  - Sensitivity of horizontal emittance to optical and alignment errors
- Contribution to vertical emittance from dispersion and coupling
  - Dependence of vertical emittance on misalignments of guide field elements
- Beam based alignment
  - Alignment and survey
  - Dependence on BPM resolution
  - Beam position monitor upgrade
- Beam size monitors
- Intensity dependent effects
- First experiments with low emittance optics

Low Emittance Optics

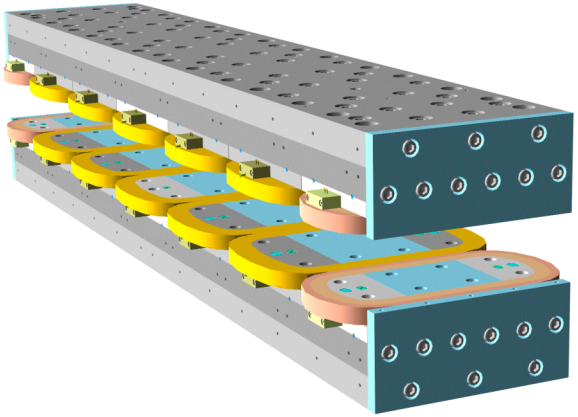
Parameter	Value
E	2.0 GeV
$N_{wiggler}$	12
B_{max} (wigglers)	1.9 T
ε_x (geometric)	2.3 nm
ε_y (geometric) Target	20 pm
$\tau_{x,y}$	56 ms
σ_E/E	8.1×10^{-4}
Q_z	0.070
Total RF Voltage	7.6 MV
σ_z	8.9 mm
α_p	6.2×10^{-3}

Wiggler dominated:
90% of synchrotron radiated power in wigglers

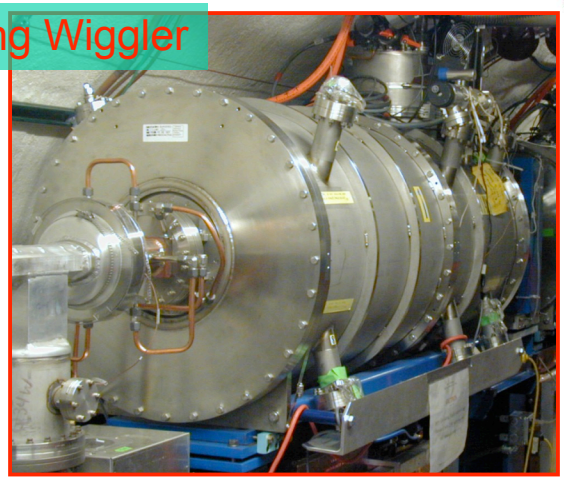


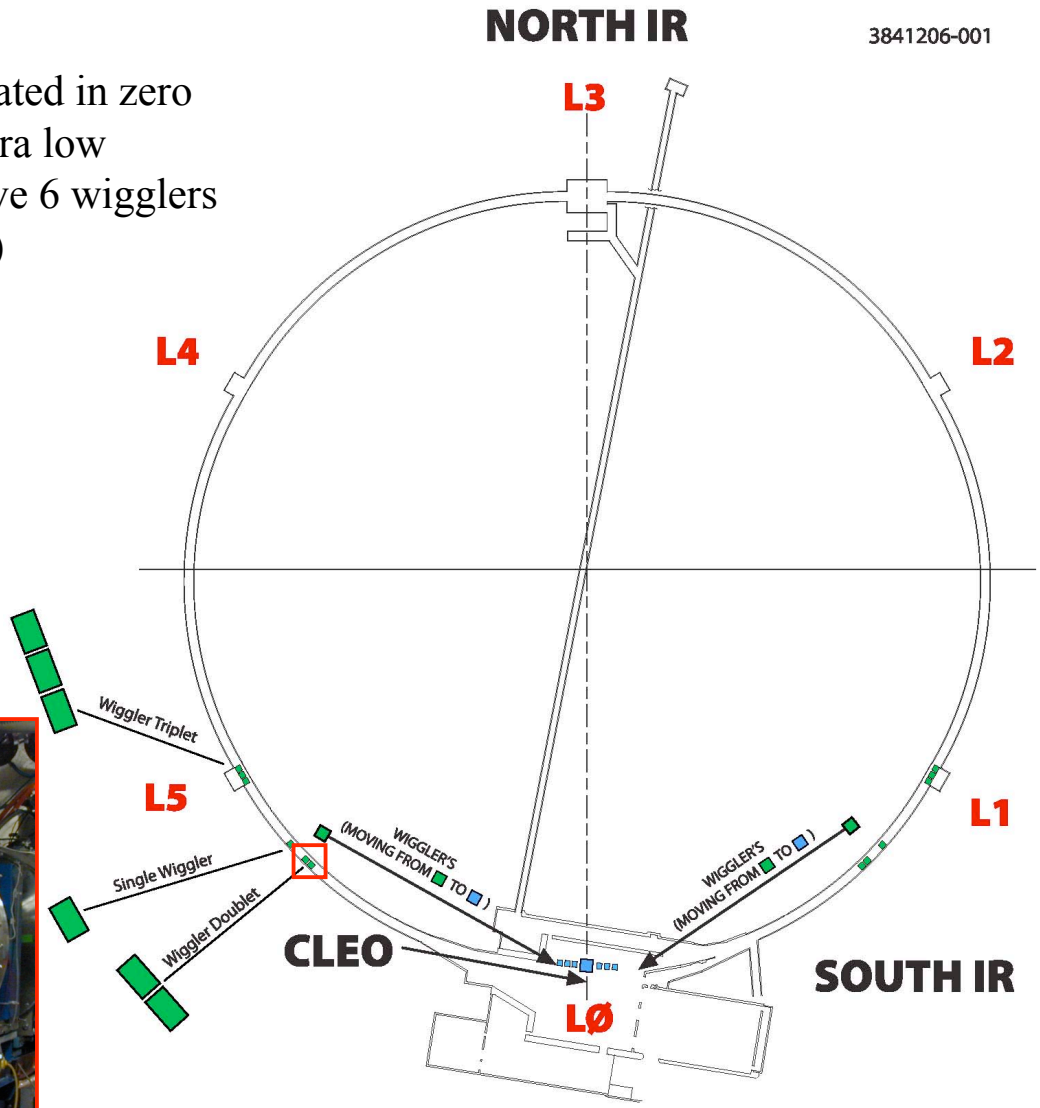
Low Emittance Optics

- CesrTA Configuration:
  - 12 damping wigglers located in zero dispersion regions for ultra low emittance operation (move 6 wigglers from machine arcs to L0)

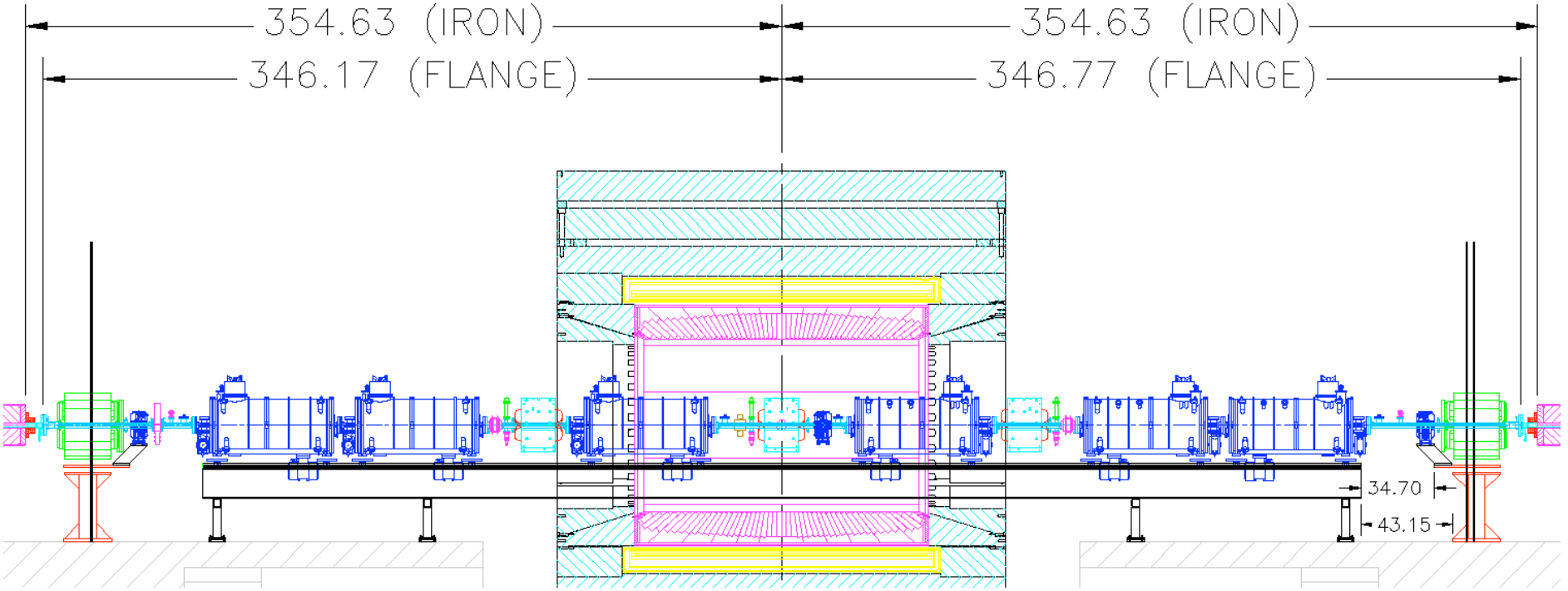


CESR-c Damping Wiggler





L0 Wiggler Region



MAIN COMPONENT POSITIONS

- L0 wiggler experimental region design work well underway
  - Installation during July down
  - Heavily instrumented throughout with vacuum diagnostics
- Note: Part of CLEO will remain in place
  - At present unable to remove full detector
  - Time savings

Low Emittance Optics

Emittance scaling with energy and tune

$\varepsilon \sim E^2/Q_h^3 \rightarrow$ 9 (nm) at Q_h=14.52, E=2GeV

Emittance scaling with wigglers

$$\varepsilon_x = C_q \frac{\gamma^2 I_5}{J_x I_2}, \qquad I_2 = \oint \rho^{-2} ds, \qquad I_5 = \oint \frac{H}{|\rho|^3} ds$$

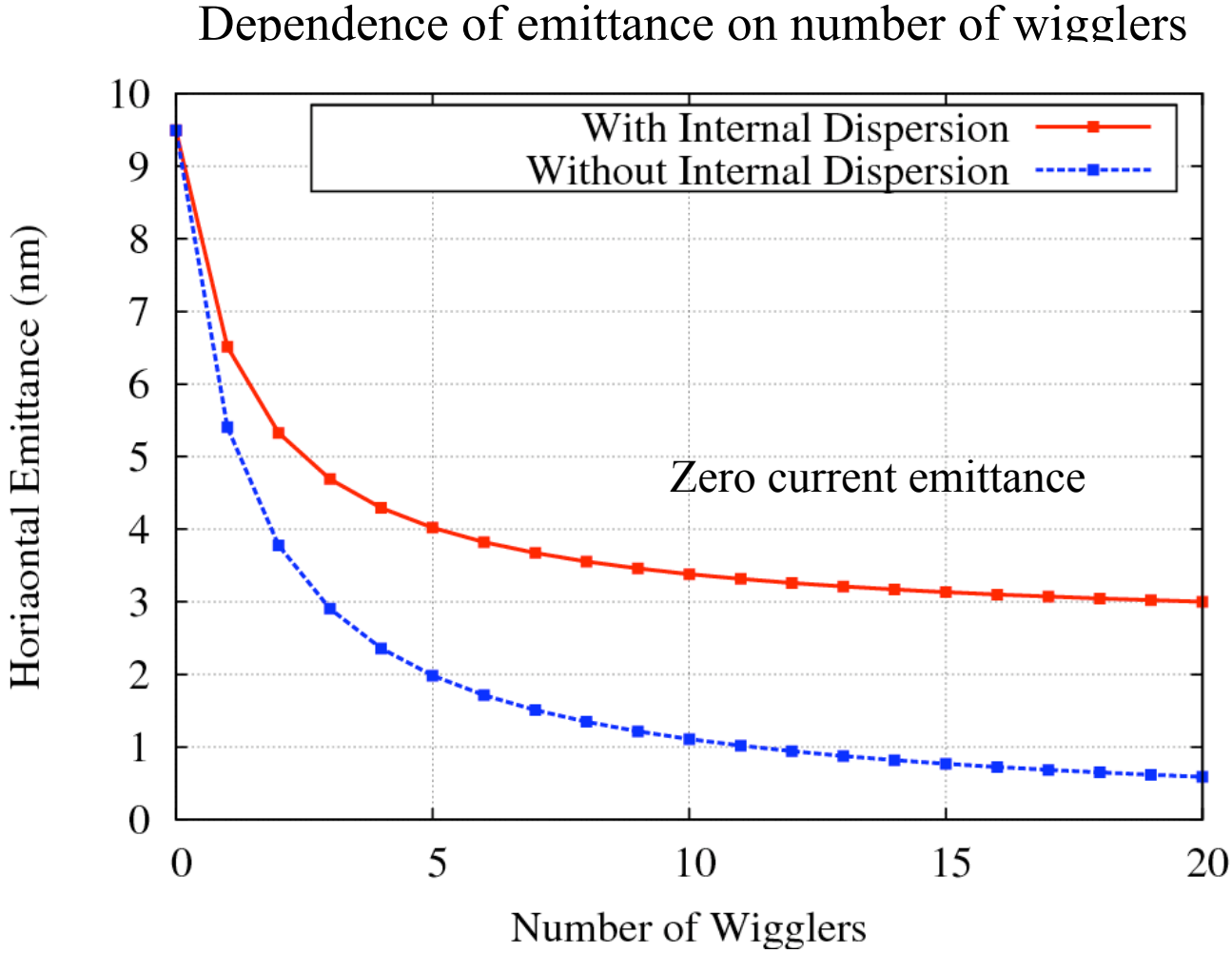
HEP configuration - taylor *H* in wigglers to increase emittance
Damping ring configuration - minimize *H* in wigglers

12, 2.1T wigglers in CESR at 2GeV/beam increases I_2 X 10

In the limit where I_2(arc)<<I_2(wiggler), and I_5(arc) → 0, and $\eta=\eta' =0$ at start and end of wigglers,
The contribution of a single wiggler period is:

$$\Delta I_5 \approx \frac{4\beta_x}{15 k_p^3 \rho_w^5}, \qquad \Delta I_2 = \frac{\pi}{2 k_p \rho_w^2}, \qquad \varepsilon_x \approx C_q \frac{\gamma^2}{J_x} \frac{8\beta_x}{15\pi k_p^2 \rho_w^3}$$

Wiggler Emittance



In CesrTA - 90% of the synchrotron radiation generated by wigglers

Minimum horizontal emittance

Can we achieve the theoretical horizontal emittance?
How does it depend on optical errors/ alignment errors?

Correct focusing errors - using well developed beam based method

1. Measure betatron phase and coupling
2. Fit to the data with each quad k a degree of freedom
   - Quad power supplies are all independent. Each one can be adjusted so that measured phase matches design
3. On iteration, residual rms phase error corresponds to 0.04% rms quad error.

→ residual dispersion in wigglers is much less than internally generated dispersion

- We find that contribution to horizontal emittance due to optical errors is neglible.
- Furthermore we determine by direct calculation that the effect of

of misalignment errors on horizontal dispersion (and emittance) is negligble

We expect to achieve the design horizontal emittance (~2.3nm)

Sources of vertical emittance

- Contribution to vertical emittance from dispersion

$$\varepsilon_y = 2J_\varepsilon \frac{\langle \eta_y^2 \rangle}{\langle \beta_y \rangle} \sigma_\delta^2$$

Dispersion is generated from misaligned magnets

- Displaced quadrupoles (introduce vertical kicks)
- Vertical offsets in sextupoles (couples horizontal dispersion to vertical)
- Tilted quadrupoles (couples η_x to η_y)
- Tilted bends (generating vertical kicks)

- Contribution to vertical emittance from coupling

Horizontal emittance can be coupled directly to vertical through tilted quadrupoles

$$\varepsilon_y = \langle \overline{C}_{21}^2 + \overline{C}_{22}^2 \rangle \varepsilon_x$$

Beam Based Alignment

1. Model ring
   - Magnet misalignments
   - Magnet field errors
   - Beam position monitor offsets and tilts
   - BPM resolution [absolute & differential]
2. "Measure"
   - Orbit
   - Dispersion
   - Betatron phase
   - Transverse coupling
3. Fit - (using dipole and skew quad correctors)
   - Fit "measured" betatron phase to ideal model using ring quadrupoles
   - Fit "measured" orbit to ideal model using dipole correctors
   - Fit "measured" dispersion to ideal model using dipole correctors
   - Fit "measured" transverse coupling to ideal model using skew correctors

(Thanks to Rich Helms)

Misalignments

For CesrTA optics:

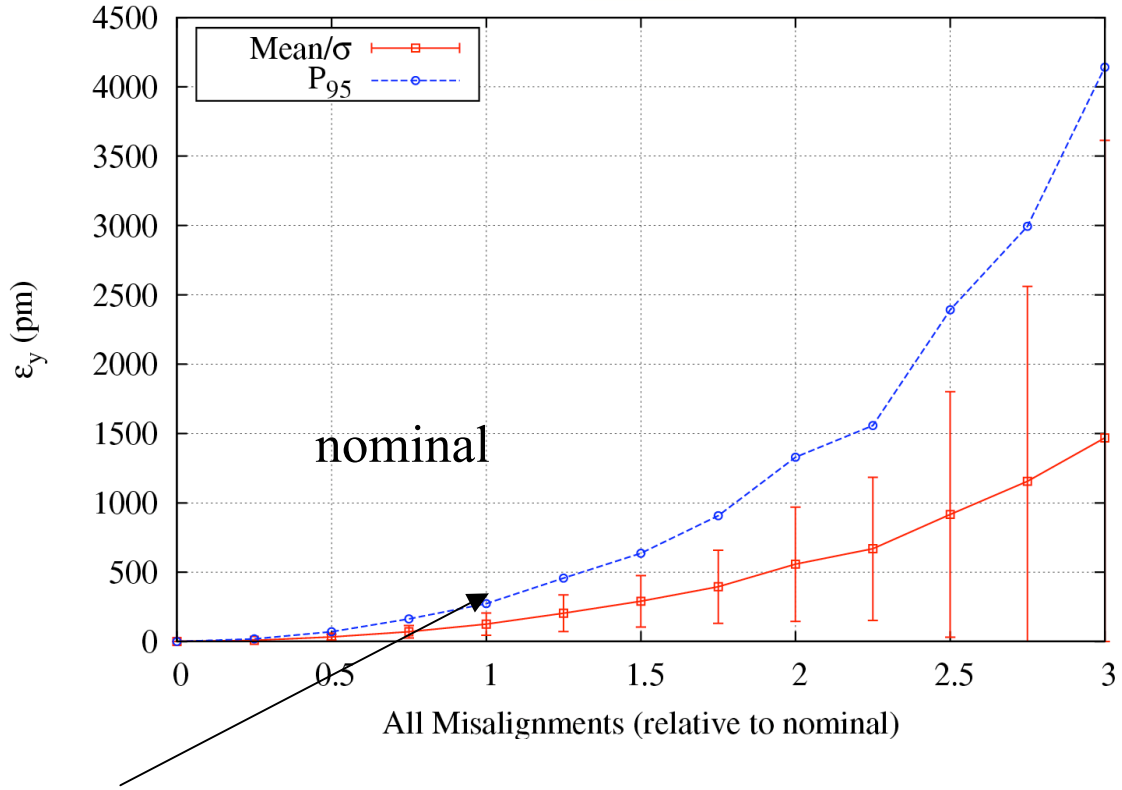
Use gaussian distribution of alignment errors to create

"N" machine models

and compute emittance of each

Element type	Alignment parameter	Nominal value
quadrupole	vert. offset	150μm
sextupole	vert. offset	300μm
bend	roll	100μrad
wiggler	vert. offset	150μm
quadrupole	roll	100μrad
wiggler	roll	100μrad
sextuple	roll	100μrad
quadrupole	horiz. offset	150μm
sextupole	horiz. offset	300μm
wiggler	horiz. offset	150μm

Dependence of vertical emittance on misalignments



Element type	Alignment parameter	Nominal value
quadrupole	vert. offset	150μm
sextupole	vert. offset	300μm
bend	roll	100μrad
wiggler	vert. offset	150μm
quadrupole	roll	100μrad
wiggler	roll	100μrad
sextuple	roll	100μrad
quadrupole	horiz. offset	150μm
sextupole	horiz. offset	300μm
wiggler	horiz. offset	150μm

For nominal misalignment of all elements, $\varepsilon_v < 270$pm for 95% of seeds

Misalignment tolerance

Contribution to vertical emittance at nominal misalignment for various elements

Element type	Alignment parameter	Nominal value	Vertical emittance
quadrupole	vert. offset	150μm	114pm
sextupole	vert. offset	300μm	8.3pm
bend	roll	100μrad	2.3pm
wiggler	vert. offset	150μm	1.4pm
quadrupole	roll	100μrad	1pm
wiggler	roll	100μrad	<< 0.01pm
sextuple	roll	100μrad	
quadrupole	horiz. offset	150μm	
sextupole	horiz. offset	300μm	
wiggler	horiz. offset	150μm	

Target emittance is < 20 pm

Beam Based Alignment

- Beam base alignment algorithms and tuning strategies (simulation results)
  - Beam based alignment of BPMs (depends on independent quad power supplies)
    - $\Delta Y < 50\mu m$
  - Measure and correct
    - β-phase → design horizontal emittance
    - Orbit → reduce displacement in quadrupoles (source of vertical dispersion)
    - Vertical dispersion → minimize vertical dispersion
    - Transverse coupling → minimize coupling of horizontal to vertical emittance
  - Minimize β-phase error with quadrupoles
  - Minimize orbit error with vertical steering correctors
  - Minimize vertical dispersion with vertical steering correctors
  - Minimize coupling with skew quads

One parameter correction

- CESR correctors and beam position monitors
  - BPM adjacent to every quadrupole (100 of each)
  - Vertical steering adjacent to all of the vertically focusing quadrupole
  - 14 skew quads - mostly near interaction region

- The single parameter is the ratio of the weights
- Three steps (weight ratio optimized for minimum emittance at each step)
  - Measure and correct vertical orbit with vertical steerings

    minimize $\Sigma_i \, (w_{c1}[\mathrm{kick}_i]^2 + w_o \, [\Delta y_i]^2)$
  - Measure and correct vertical dispersion with vertical steering

    minimize $\Sigma_i \, (w_{c2}[\mathrm{kick}_i]^2 + w_\eta [\Delta \eta_i]^2)$
  - Measure and correct coupling with skew quads

    minimize $\Sigma_i \, (w_{sq}[k_i]^2 + w_c [C_i]^2)$

Tuning vertical emittance

Evaluate 6 cases

2 sets of misalignments:

1. *Nominal* and *2.* Twice nominal (*Worse*)

X 3 sets of BPM resolutions:

1. No resolution error, 2. *Nominal*, and 3.*Worse* (5-10 X nominal)

	Parameter	Nominal	Worse
Element Misalignment	Quad/Bend/Wiggler Offset [μm]	150	300
	Sextupole Offset [μm]	300	600
	Rotation (all elements)[μrad]	100	200
	Quad Focusing[%]	0.04	0.04
BPM Errors	Absolute (orbit error) [μm]	10	100
	Relative (dispersion error*)[μm]	2	10
	Rotation[mrad]	1	2

$\sigma_y = 109\mu m$
May 07 survey

$\sigma(one\ turn) \sim 27\mu m$
$\sigma(N_{turn}\ average) \sim 27\mu m/\sqrt{N}$

*The actual error in the dispersion measurement is equal to the differential resolution divided by the assumed energy adjustment of 0.001

Low emittance tuning

Vertical emittance (pm) after one parameter correction:

Alignment	BPM Errors	Mean	1 σ	90%	95%
Nominal	None	1.6	1.1	3.2	4.0
"	Nominal	2.0	1.4	4.4	4.7
"	Worse	2.8	1.6	4.8	5.6
2 x Nominal	None	7.7	5.9	15	20
"	Nominal	8.0	6.7	15	21
"	Worse	11	7.4	20	26

With *nominal* magnet alignment,
we achieve emittance of 5-10pm for 95% of seeds
with *nominal* and *worse* BPM resolution

With 2 X nominal magnet alignment yields emittance near our 20pm target

Two parameter correction

Consider a two parameter algorithm

1. Measure orbit and dispersion. Minimize $\Sigma_i\, w_{c2}[kick_i]^2 + w_{o2}\,[\Delta y_i]^2 + w_{\eta 1}[\Delta\eta_i]^2$
2. Measure dispersion and coupling. Minimize $\Sigma_i\, w_{sq}[k_i]^2 + w_{\eta 2}[\Delta\eta_i]^2 + w_c[C_i]^2$

The two parameters are the ratio of the weights. The ratios are re-optimized in each step

Vertical emittance (pm) after one and two parameter correction:

Alignment	BPM Errors	Correction Type	Mean	1 σ	90%	95%
2 x Nominal	Worse	1 parameter	11	7.4	20	26
"	"	2 parameter	6.5	6.7	9.6	11.3

2 X nominal survey alignment, 10μm relative and 100μm absolute BPM resolution

- 2 parameter algorithm yields tuned emittance very < 20pm for 95% of seeds

Instrumentation - new equipment

Digital level and laser tracker

Network of survey monuments

→Complete survey in a couple of weeks

Magnet mounting fixtures that permit precision adjustment

- beam based alignment

BPM resolution

Relative BPM resolution critical to measurement of vertical dispersion

Dispersion depends on differential orbit measurement
$\eta_v = [y(\delta/2) - y(-\delta/2)]/\ \delta$ $\quad\quad$ $\delta \sim 1/1000$
In CesrTA optics dependence of emittance on vertical dispersion is

$$\varepsilon_v \sim 1.5 \text{ X } 10^{-8} \langle \eta^2 \rangle$$

Emittance scales with square of relative BPM error
(and the energy offset δ used to measure dispersion)

σ(single pass) ~ 27μm
σ(N turn average) ~ 27μm/√N

Note:
σ(*nominal*) ~ 2μm
Achieve emittance target if
$\sigma < 10\mu m$

Beam Position Monitor System

- Presently (and for June 08 run) have a mixed dedicated digital system with twelve stations and a coaxial relay switched analog to digital system with ninety stations.
  - Digital system stores up to 10 K turns of bunch by bunch positions with a typical single pass resolution of ~ 30 microns.
  - From the multi-turn data, individual bunch betatron tunes can be easily determined to < 10 Hz.
  - (Upgraded digital system will be fully implemented within the next year)

Meanwhile we work with digital/analog hybrid

AC dispersion measurement

Traditional dispersion measurement

- Measure orbit
- Change ring energy ($\delta E/E = (\delta f_{rf}/f_{rf})/\alpha_p$)
- Measure again. $\eta_x = \Delta x/(\delta E/E)$

AC dispersion

Note that dispersion is z-x and z-y coupling

Use transverse coupling formalism to analyze dispersion

$T=VUV^{-1}$ (T is 4X4 full turn transport, U is block diagonal)

$$V = \begin{pmatrix} \gamma I & C \\ -C^{+} & \gamma I \end{pmatrix} \qquad \bar{C} = G_b^{-1} C G_a \qquad G = \begin{pmatrix} \sqrt{\beta_a} & 0 \\ -\alpha/\sqrt{\beta_a} & 1/\sqrt{\beta_a} \end{pmatrix}$$

$$\bar{C}_{12} = \frac{y_{amp}}{x_{amp}} \sin(\varphi_y - \varphi_x) \qquad \bar{C}_{22} = \frac{y_{amp}}{x_{amp}} \cos(\varphi_y - \varphi_x)$$

AC dispersion measurement

To measure x-y coupling

Drive beam at horizontal (a-mode) frequency

Measure x and y amplitude and phase at each BPM

$$\bar{C}_{12} = \frac{y_{amp}}{x_{amp}} \sin(\varphi_y - \varphi_x) \qquad \bar{C}_{22} = \frac{y_{amp}}{x_{amp}} \cos(\varphi_y - \varphi_x)$$

In the limit $Q_s \rightarrow 0$

$C_{12}(z\text{-}x) = \eta_{x,}$ $C_{22}(z\text{-}x) = \eta'_x$

$C_{12}(z\text{-}y) = \eta_{y,}$ $C_{22}(z\text{-}y) = \eta'_y$

Drive beam at synchrotron tune (z-mode)

Measure x, y (and z) amplitude and phase at each BPM

$$\bar{C}_{12} = \frac{x_{amp}}{z_{amp}} \sin(\varphi_x - \varphi_z)$$ Is the horizontal dispersion (η_x)

$$\bar{C}_{12} = \frac{y_{amp}}{z_{amp}} \sin(\varphi_y - \varphi_z)$$ Is the vertical dispersion (η_y)

AC dispersion measurement

We measure x_{amp} and ϕ_x, y_{amp} and ϕ_y

But we are unable to measure z_{amp} and ϕ_z with sufficient resolution

Longitudinal parameters come from the design lattice

$z_{amp} = \sqrt{(\varepsilon_z \beta_z)}$, $13m < \beta_z < 14.6m$ (CesrTA optics)

$\rightarrow$ z_{amp} is very nearly constant - there is an overall unknown scale (A)

$0 < \phi_z < 36°$.

We compute ϕ_z from the design optics at each BPM

- there is an overall unknown phase offset (ϕ_0)

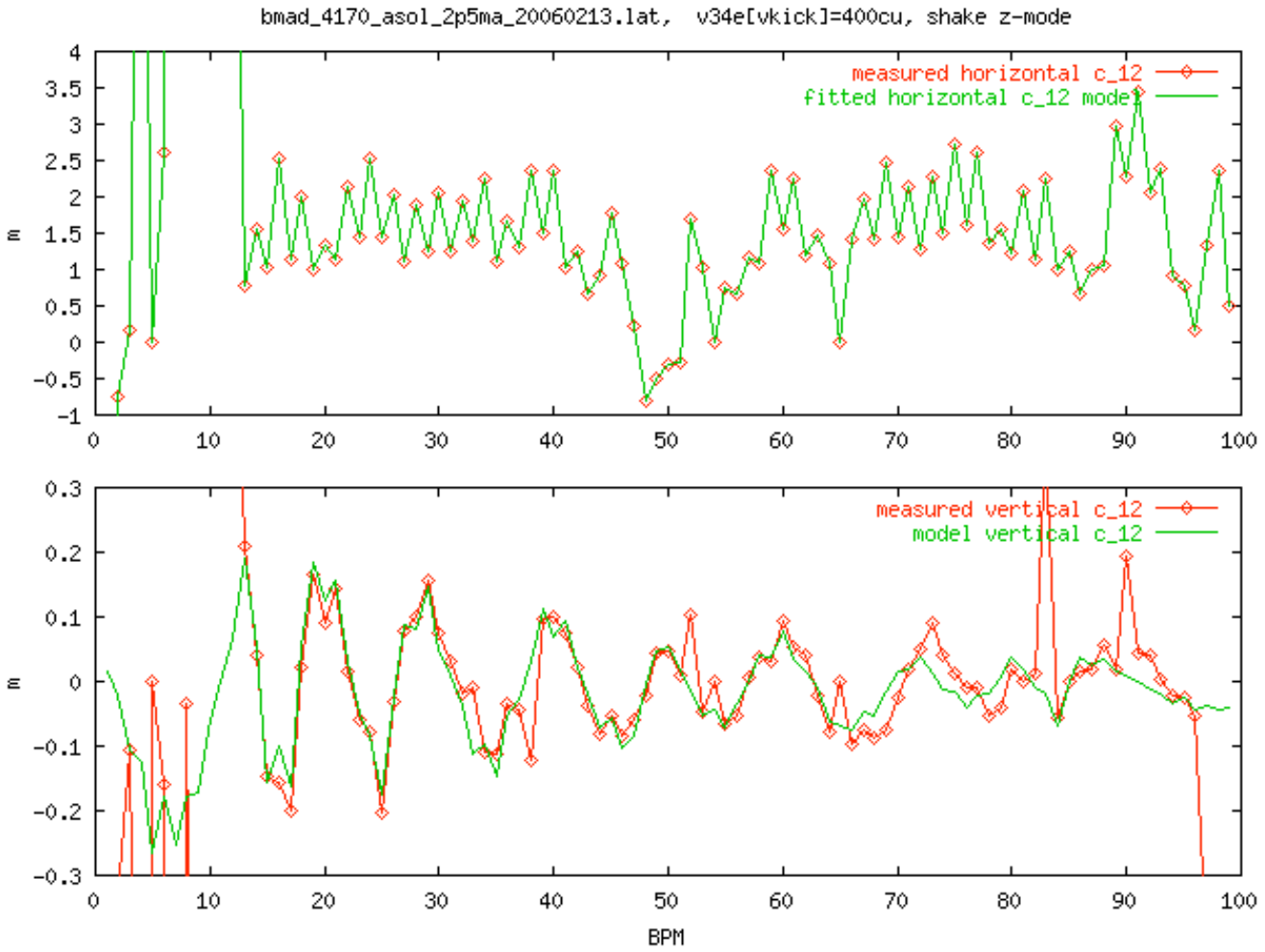
- Determine A, ϕ_0 by fitting x - data to model horizontal C_{12}

- Then use fitted parameters to determine vertical C_{12}

AC dispersion measurement

Horizontal data
Fit to model C_{12} with A and φ_0

Vertical data
(using A, φ_0 from fit)
model



Vertical dispersion is due to a kick from a vertical dipole corrector

(No data from detectors 1-12, 98-100)

AC Dispersion

- ## Summary

Dispersion is coupling of longitudinal and transverse motion

Measurement
-Drive synchrotron oscillation by modulating RF at synch tune
-Measure vertical & horizontal amplitudes and phases of signal at synch tune at BPMs

Then
$\{\eta_v/\beta_v\} = (y_{amp}/z_{amp}) \sin(\varphi_y - \varphi_z)$
$\{\eta_h/\beta_h\} = (x_{amp}/z_{amp}) \sin(\varphi_h - \varphi_z)$

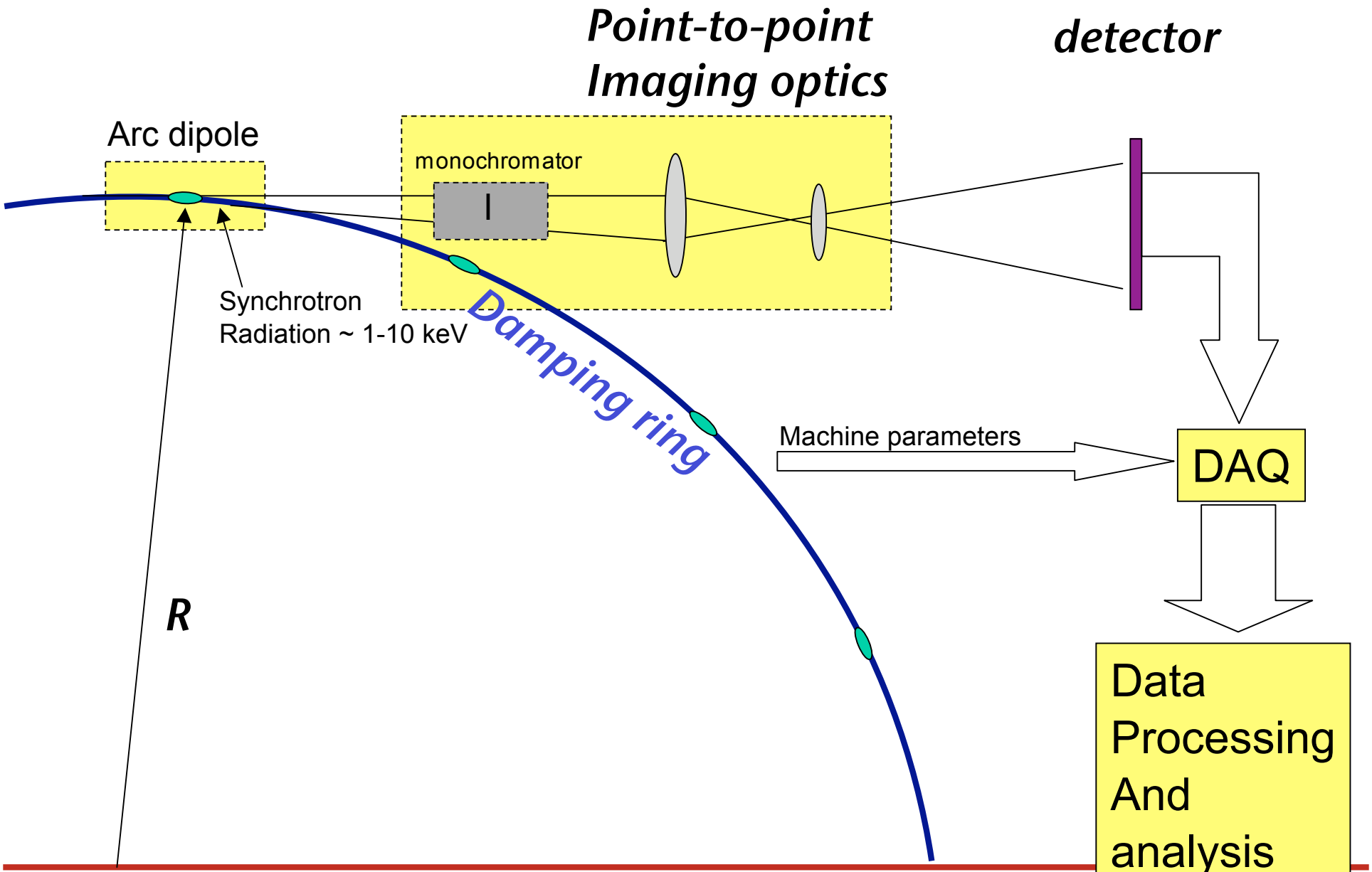
Advantages:

1. Faster (30k turns) (RF frequency does not change)
2. Better signal to noise -
   filter all but signal at synch tune

Beam Size Measurements

- Conventional visible synchrotron light imaging system for light from arc dipoles for both electrons and positrons with a vertical beam size resolution of ~ 140 microns.
- 32 element linear photomultiplier array enables multi-turn bunch by bunch vertical beam size measurements using the same electronics as the digital beam position monitor system.
- A double slit interferometer system using the same 32 element linear photomultiplier array. Anticipated resolution
  - ~ 100 micron single pass bunch by bunch vertical beam size resolution
  - 50 micron multi-pass bunch by bunch vertical beam size resolution
- X-ray beam size monitor
  - Bunch by bunch 2-3 μm resolution
  - One each for electrons and positrons

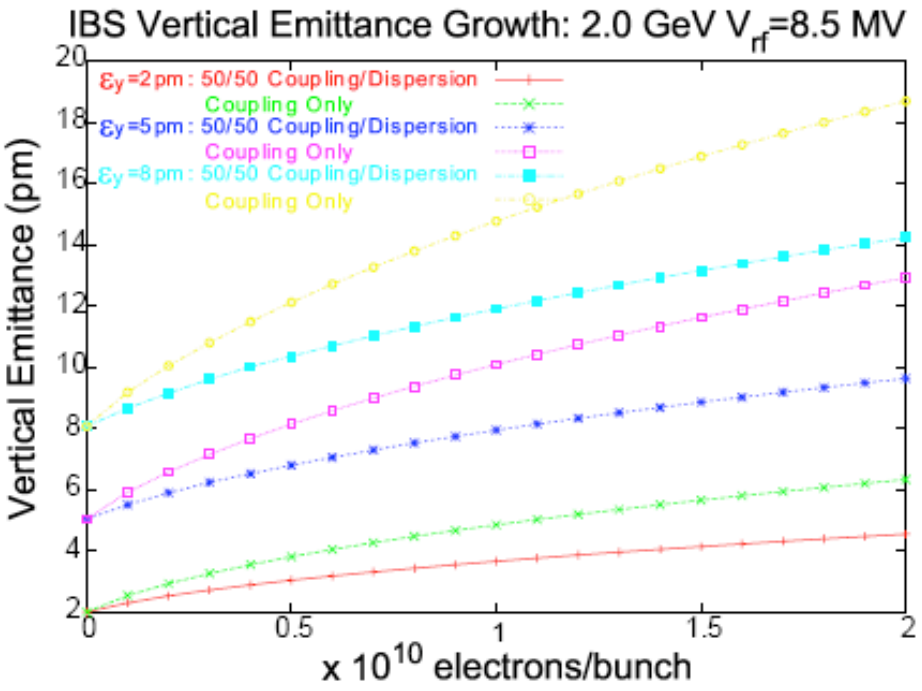
X ray beam size monitor



Intensity dependent effects

- Emittance
  - Intrabeam scattering

Depends on amplitude and source (dispersion or coupling) of vertical emittance



IBS has strong energy dependence ($\sim\gamma^{-4}$)
Flexibility of CESR optics to operate from1.5-5GeV will allow us to distinguish IBS from other emittance diluting effects.

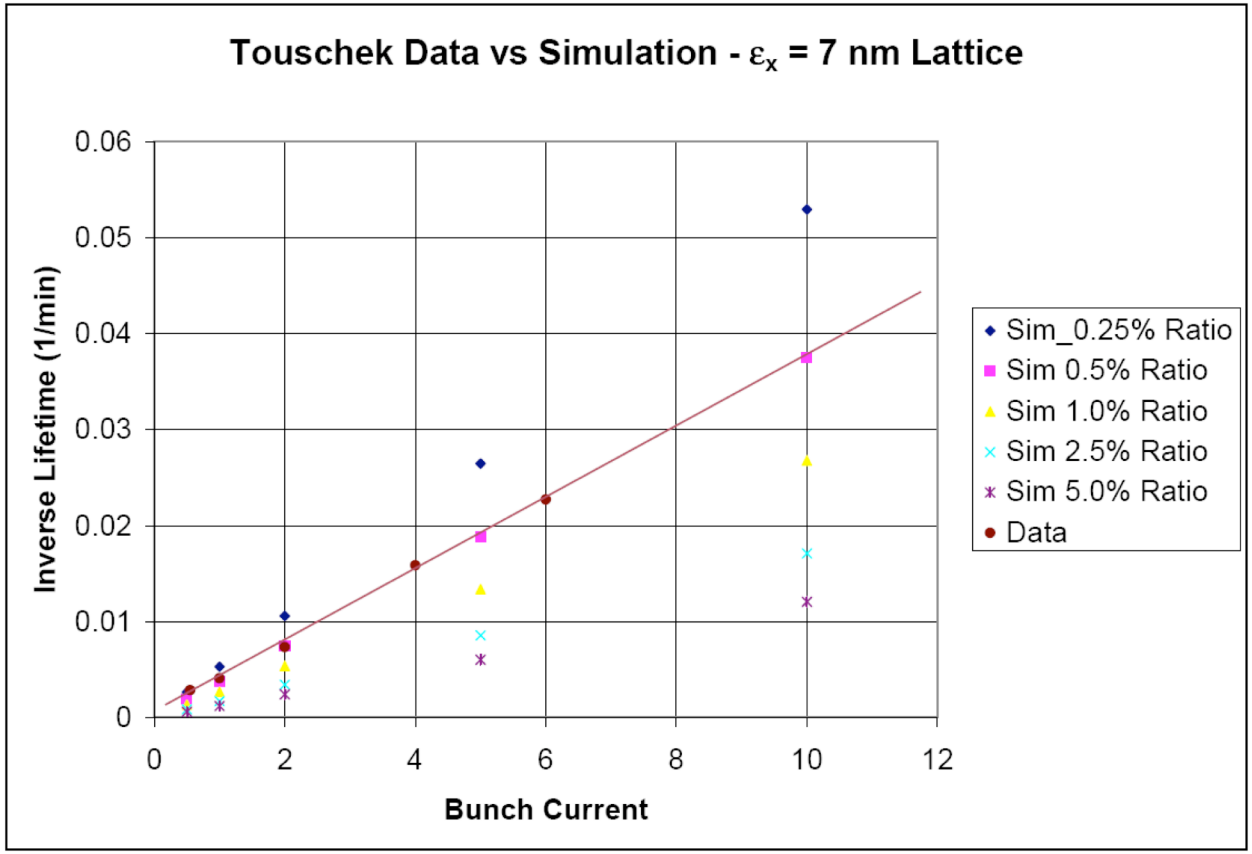
Lifetime

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	8.1×10^{-4}
Q_z	0.070
Total RF Voltage	7.6 MV
σ_z	8.9 mm
α_p	6.2×10^{-3}
$N_{particles}$/bunch	2×10^{10}
$\tau_{Touschek}$	>10 minutes
Bunch Spacing	4 ns

At emittance as low as 5-10pm and 2×10^{10} particles/bunch $\tau_{Touschek}$ decreases to ~10 minutes.

Low Emittance Tests

- CESR-c Low Emittance Lattice with CLEO solenoid on (likely lattice for CesrTA Run 1)
  - 6 wigglers (in L1/L5 straights) at 0 dispersion
  - Without suitable emittance measurement capability, measure Touschek lifetime versus bunch current and compare with simulation for vertical beam size dominated by emittance coupling



Electron cloud measurement

Tune shift

- Electron cloud focuses positron bunch, defocuses electron bunch
- Bunch by bunch tune shift scales with cloud density
- Relative size of vertical and horizontal tune shifts related to distribution of electrons
- Witness bunch measurements
  - Cloud decay time
  - Time dependence of cloud distribution

Bunch size

- Nonlinear focusing can dilute emittance
- Electron cloud couples bunch to bunch, head to tail

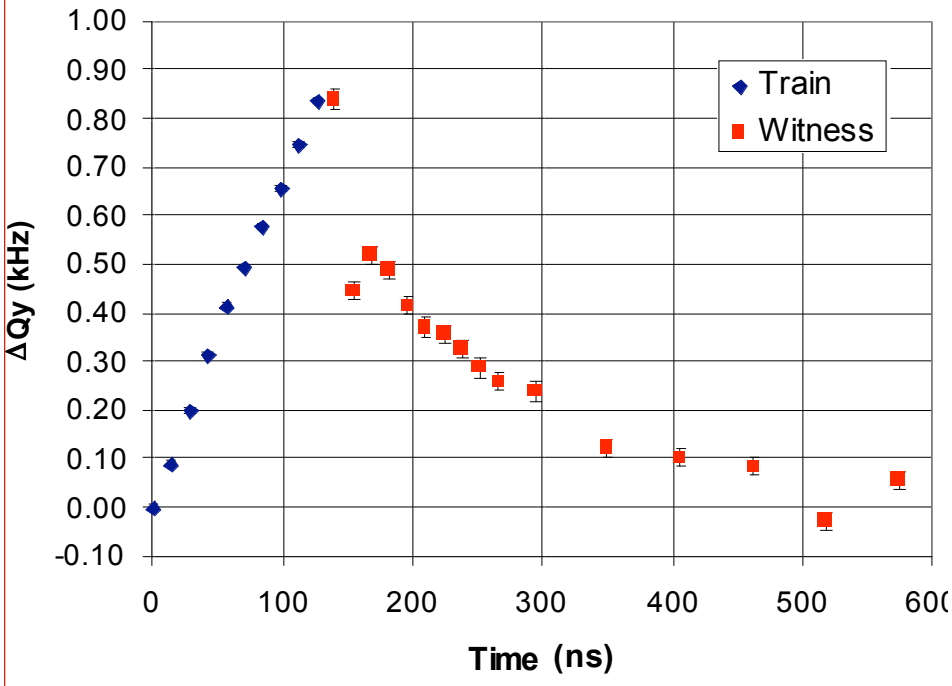
Retarding field analyzer (RFA)

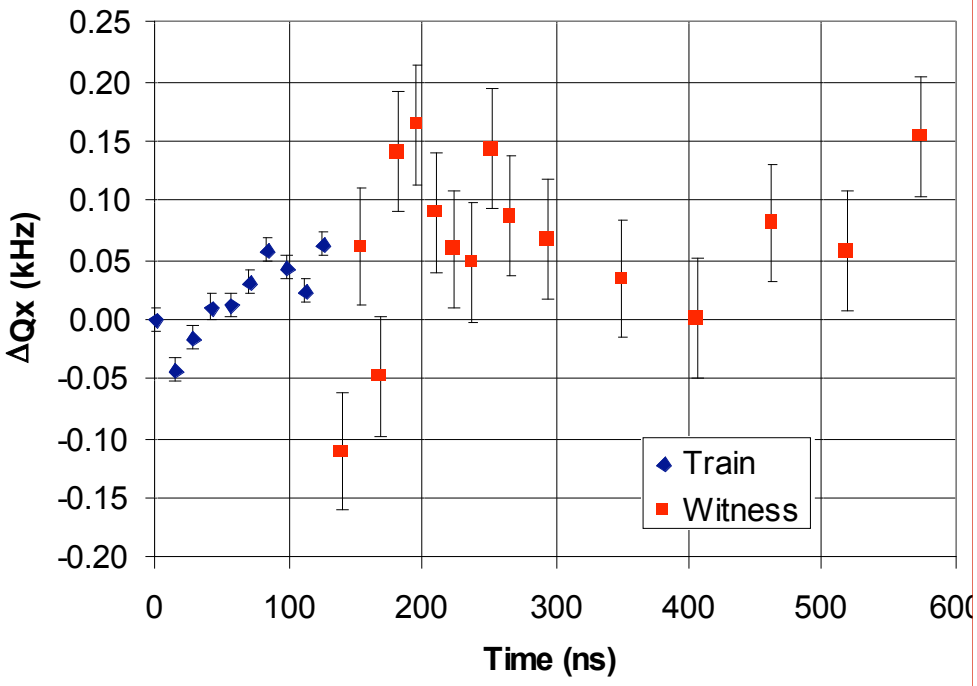
- Measure local electron cloud density and energy spectrum
- Segmentation gives measure of cloud distribution

Witness Bunch Studies – e^+ 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

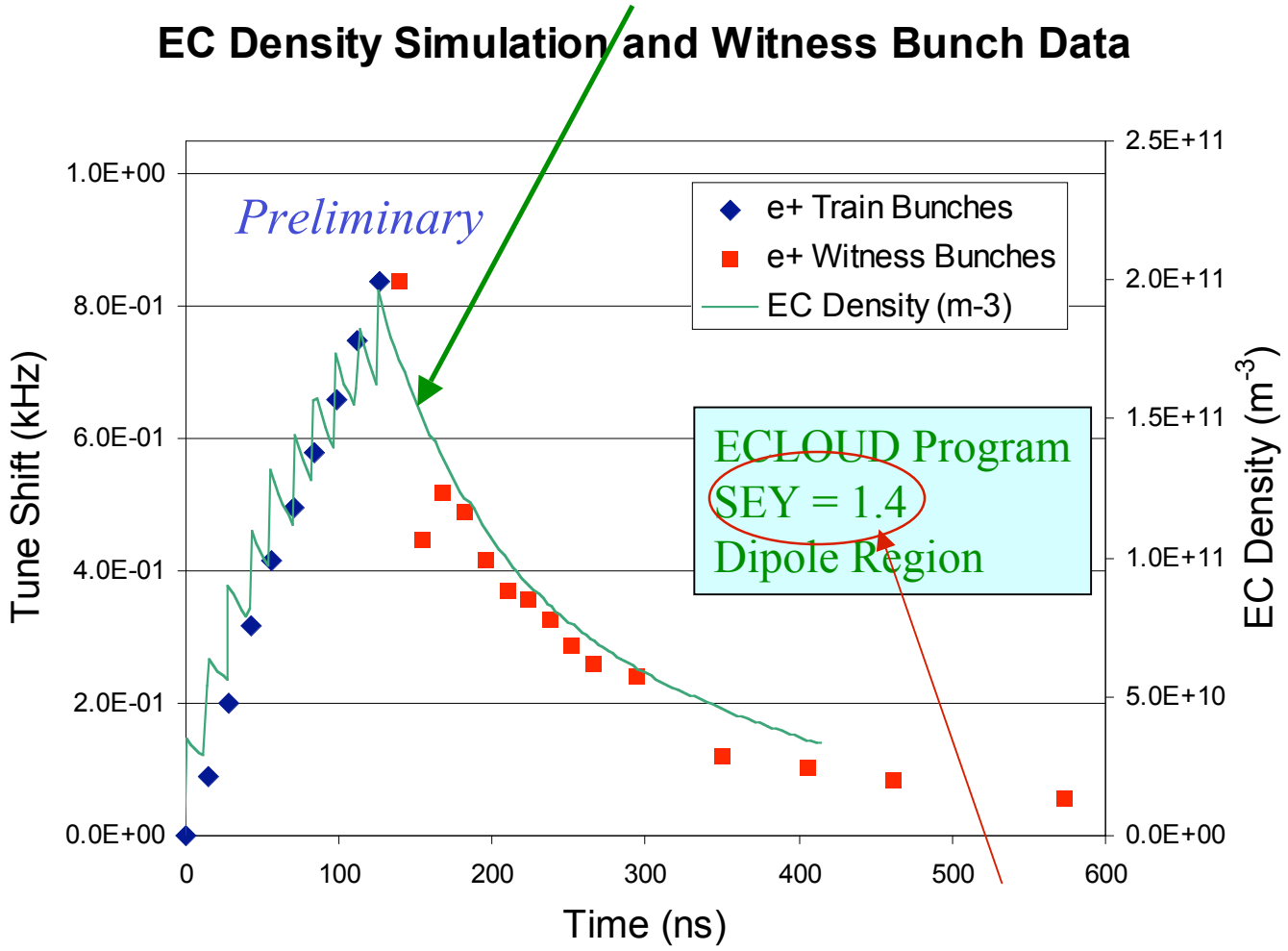
(Δf=1kHz→ΔQ=2.5E-3)

Preliminary

Data and Simulation

- Initial comparisons for CESR
  - Growth modeling for dipole chambers

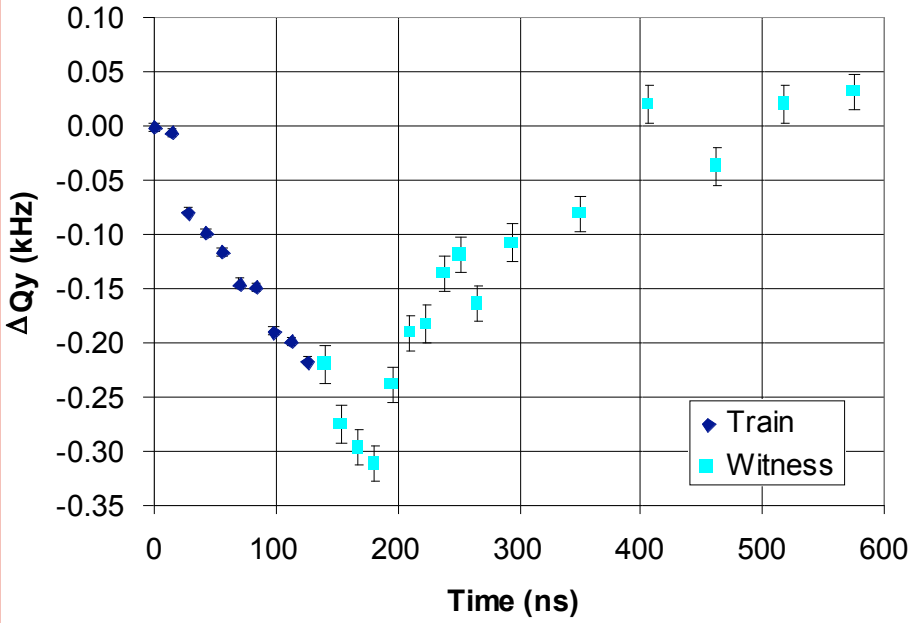
Overlay simulated EC density on vertical tune shift data

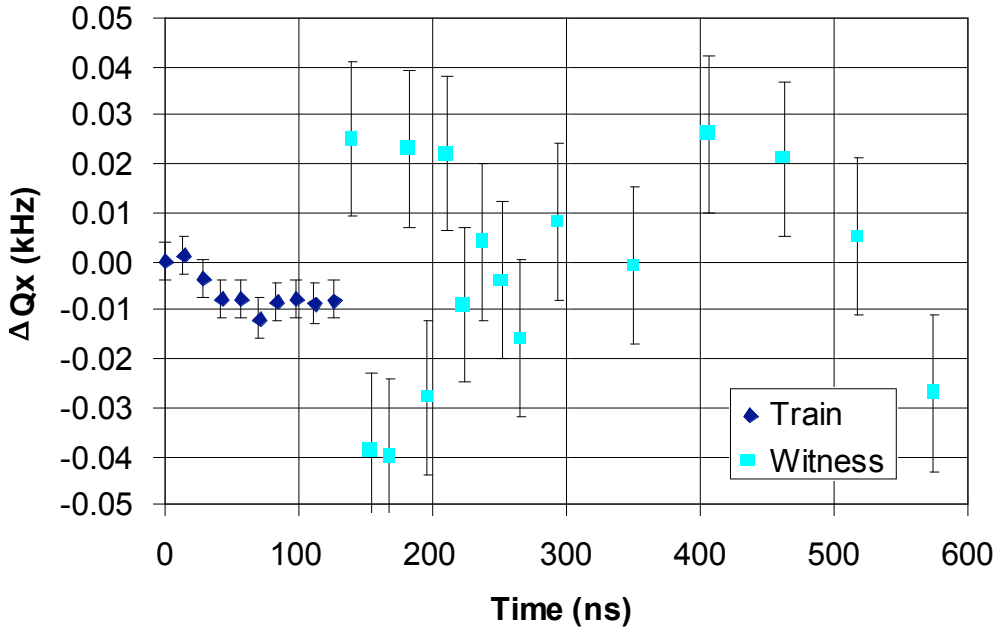


Witness Bunch Studies – e^- Vertical Tune Shift

- 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



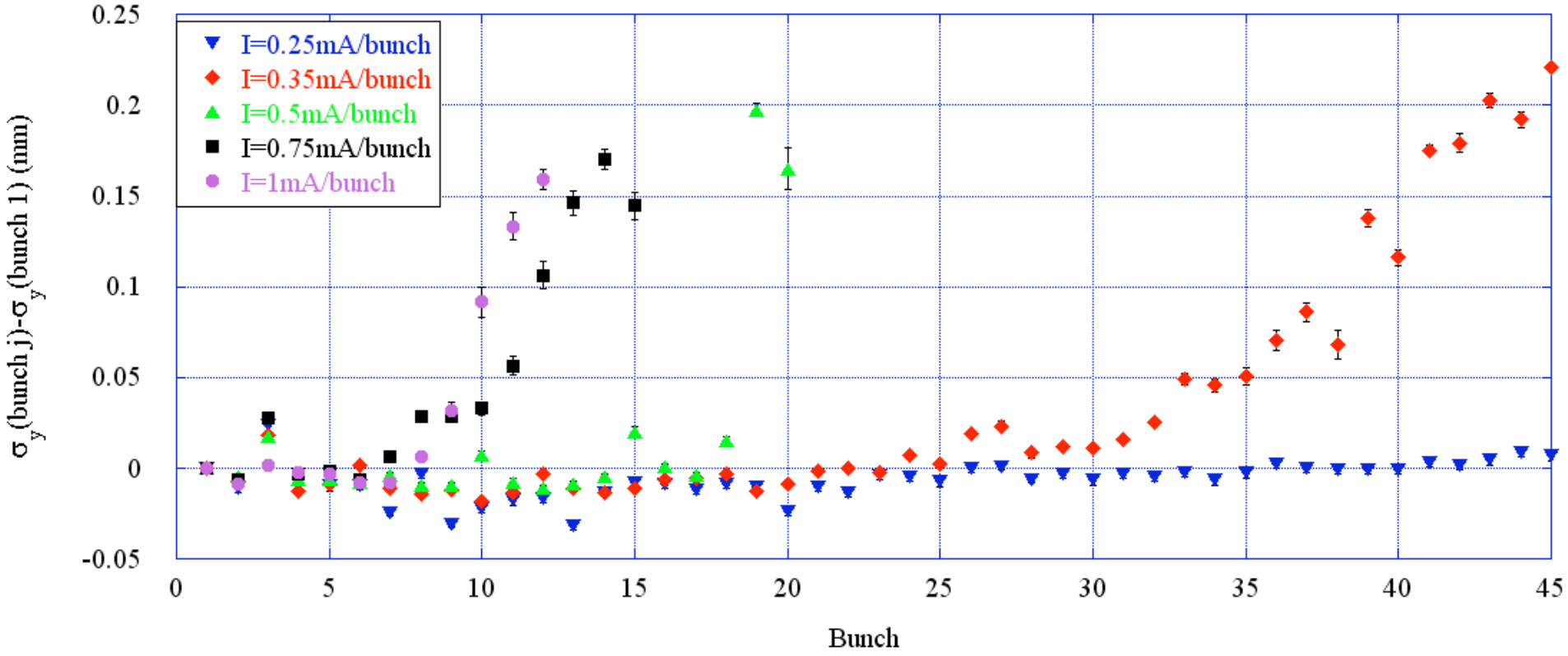


Negative vertical tune shift along train ⇨ consistent with EC
Magnitude of shift along train is ~1/4th of shift for positron beam
NOTE: Shift continues to grow for 1st 4 witness bunches!

Preliminary Results

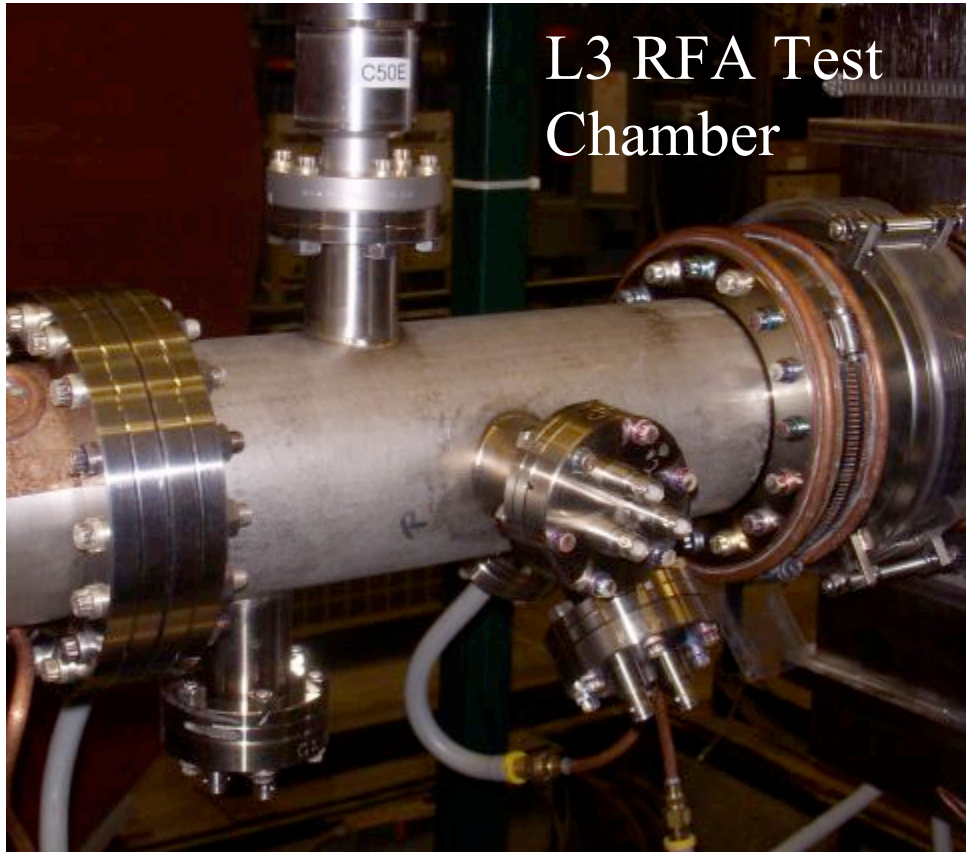
EC Induced Instability

- 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



EC Growth Studies

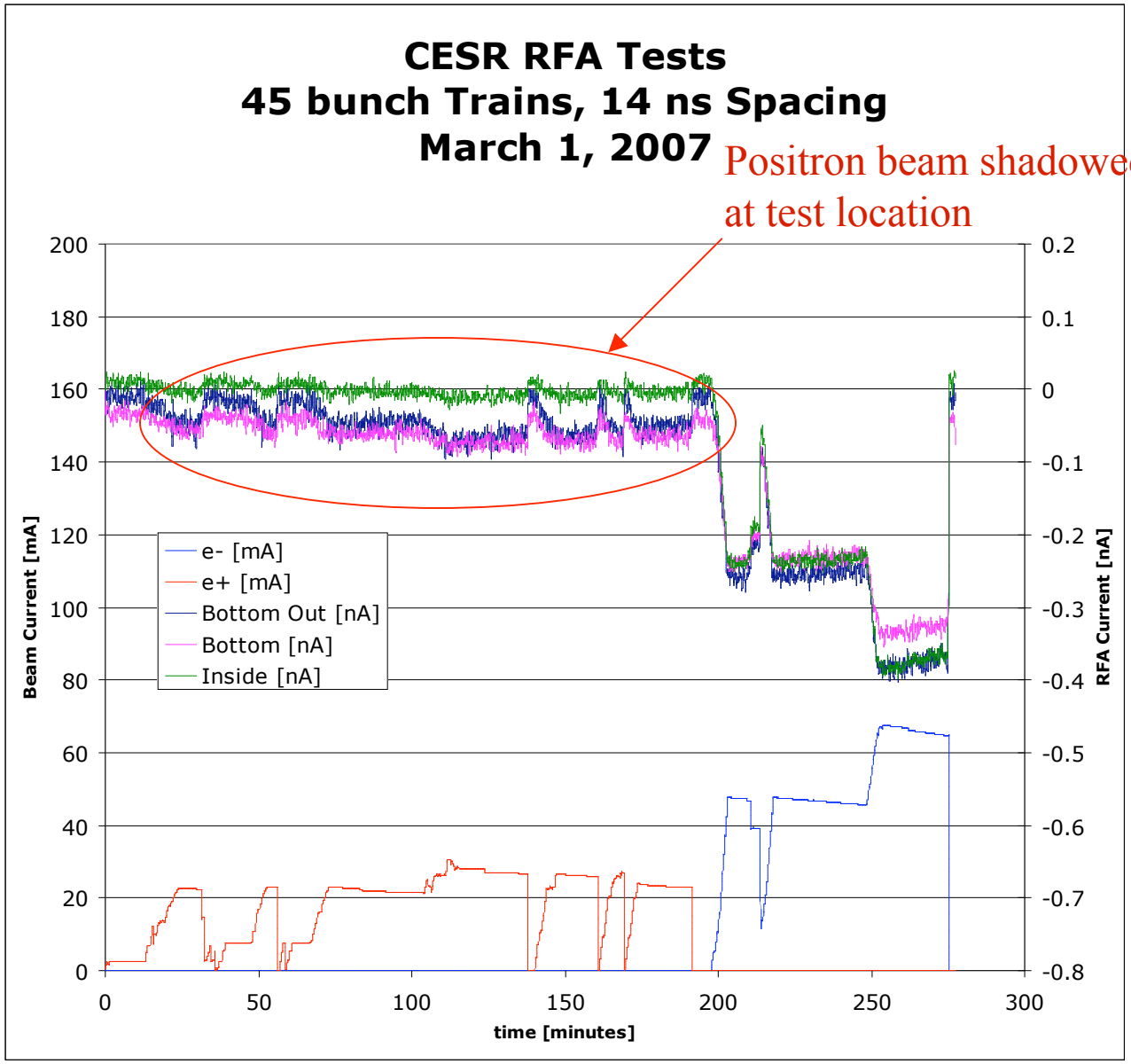
- Install chambers with EC growth diagnostics and mitigation
  - Goal is to have implemented diagnostics in each representative chamber type by mid-2009
    - Heavy reliance on segmented Retarding Field Analyzers
  - Wiggler chambers in L0 straight w/mitigation
  - Dipole chambers in arcs w/mitigation
  - Quadrupole chambers w/mitigation
    - L0 and L3 straights
  - Drifts
    - Diagnostics adjacent to test chambers
    - Solenoids
  - Some components to be provided by collaborators



L3 RFA Test Chamber

Retarding Field Analyzers

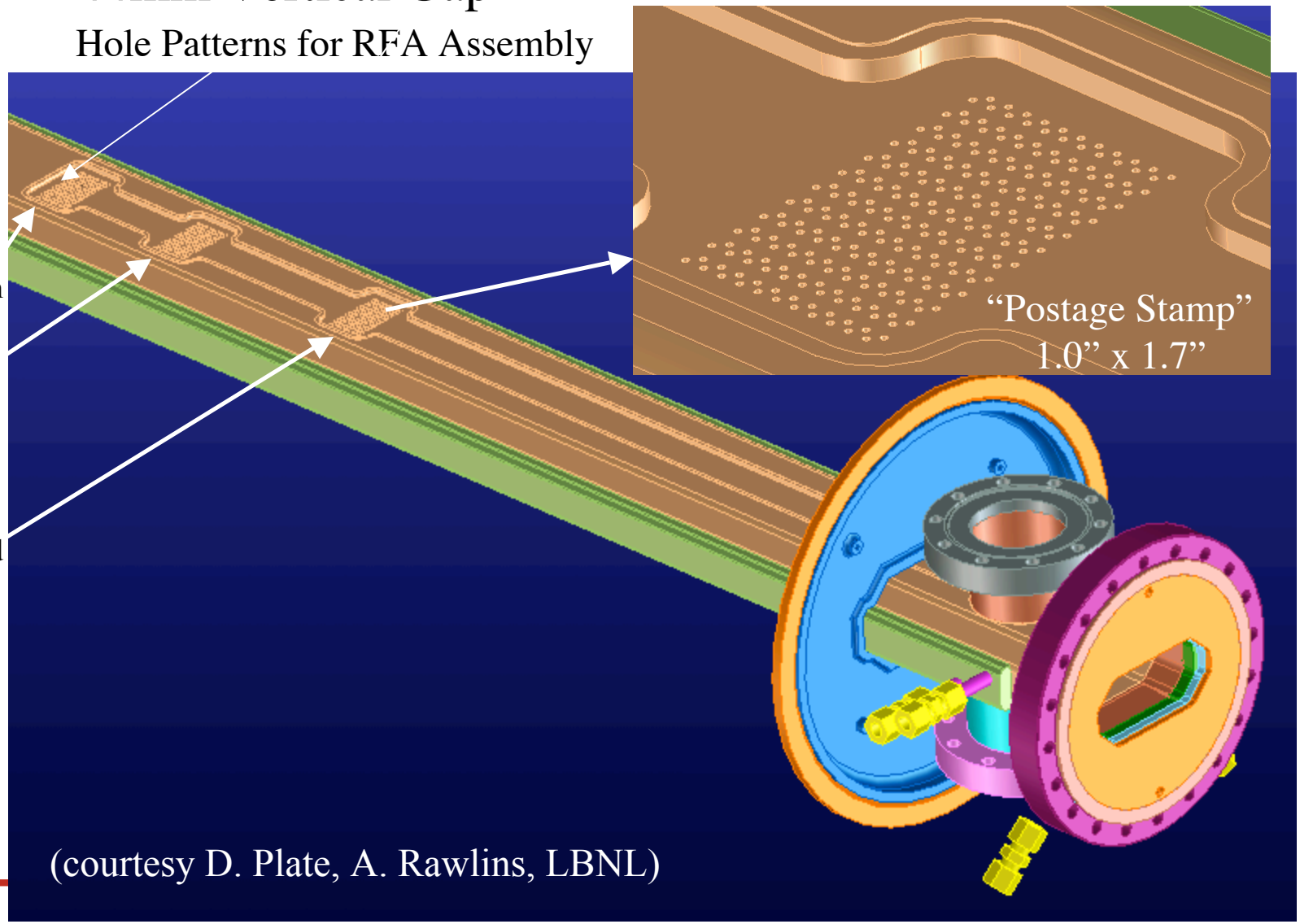
- Upgraded readout electronics for large channel count RFAs are in production
- Thin RFA structure performing well



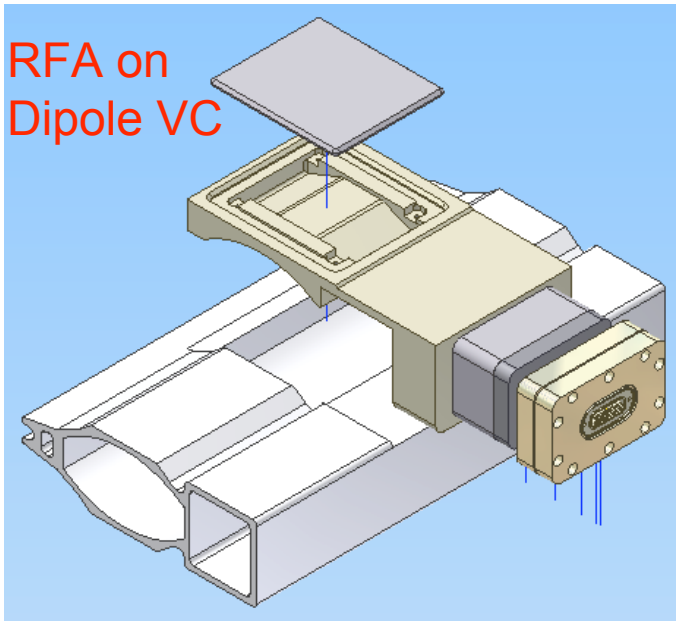
Wiggler Vacuum Chamber Design

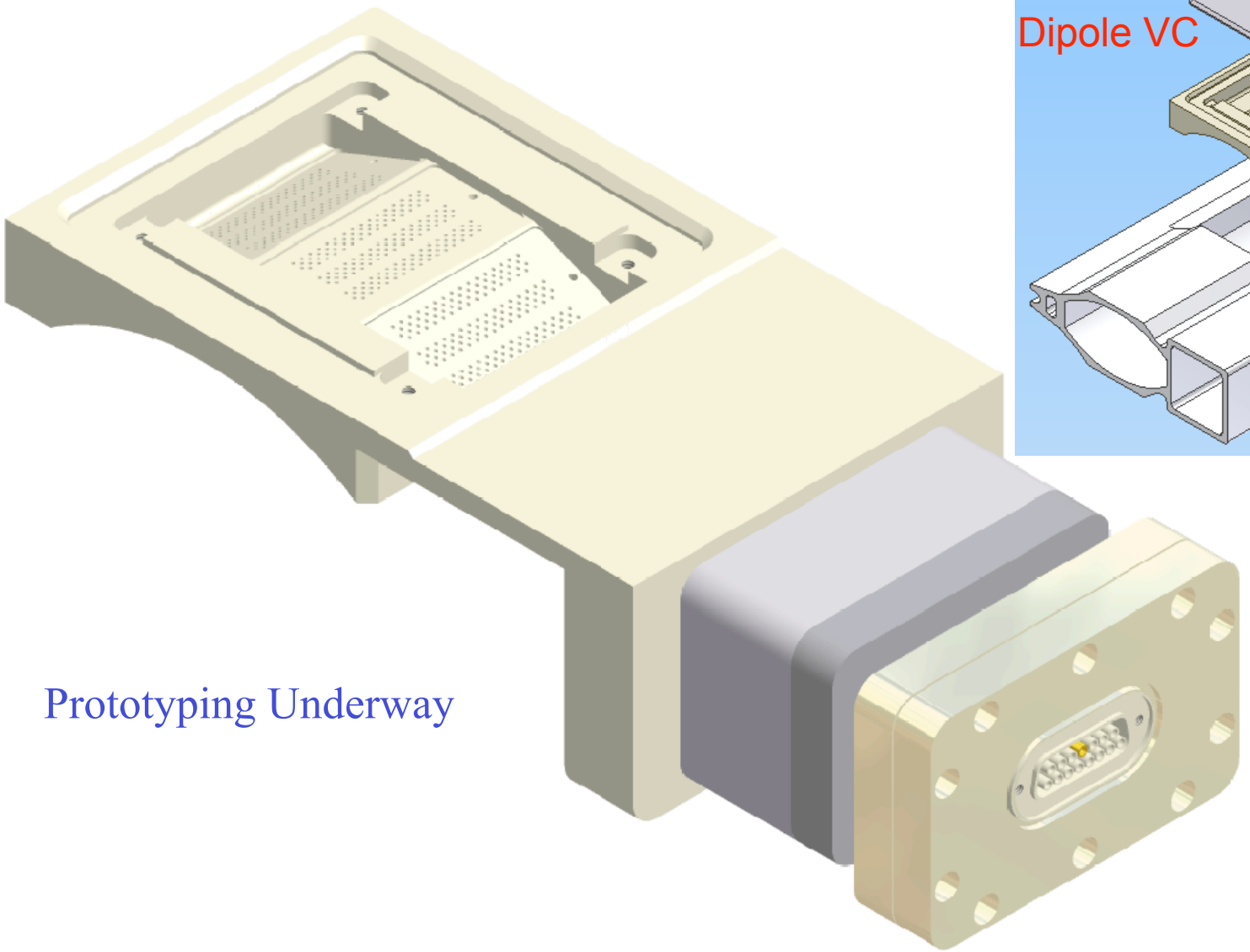
CesrTA Electron Cloud Test Chamber 1 Assembly, 44mm Vertical Gap

Hole Patterns for RFA Assembly



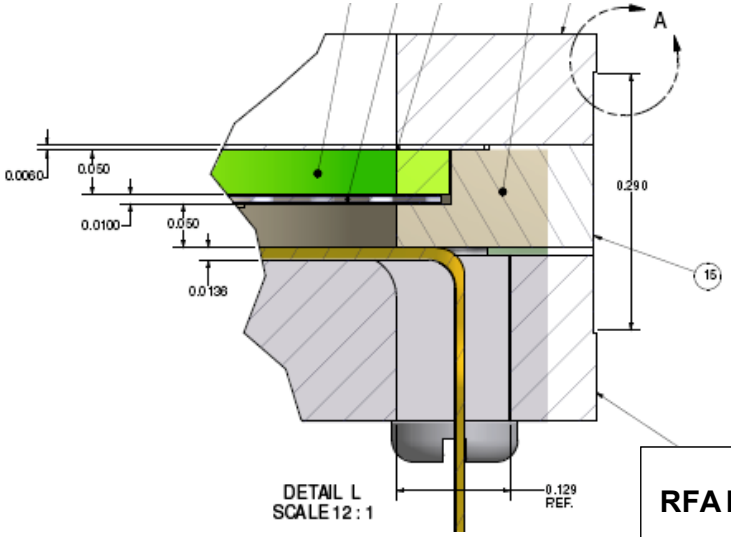
CESR Dipole Chamber RFA

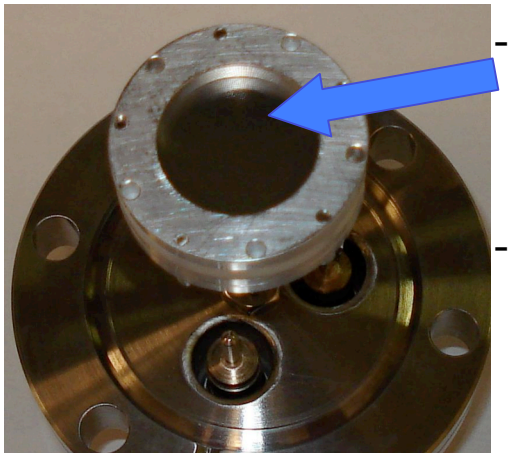




Prototyping Underway

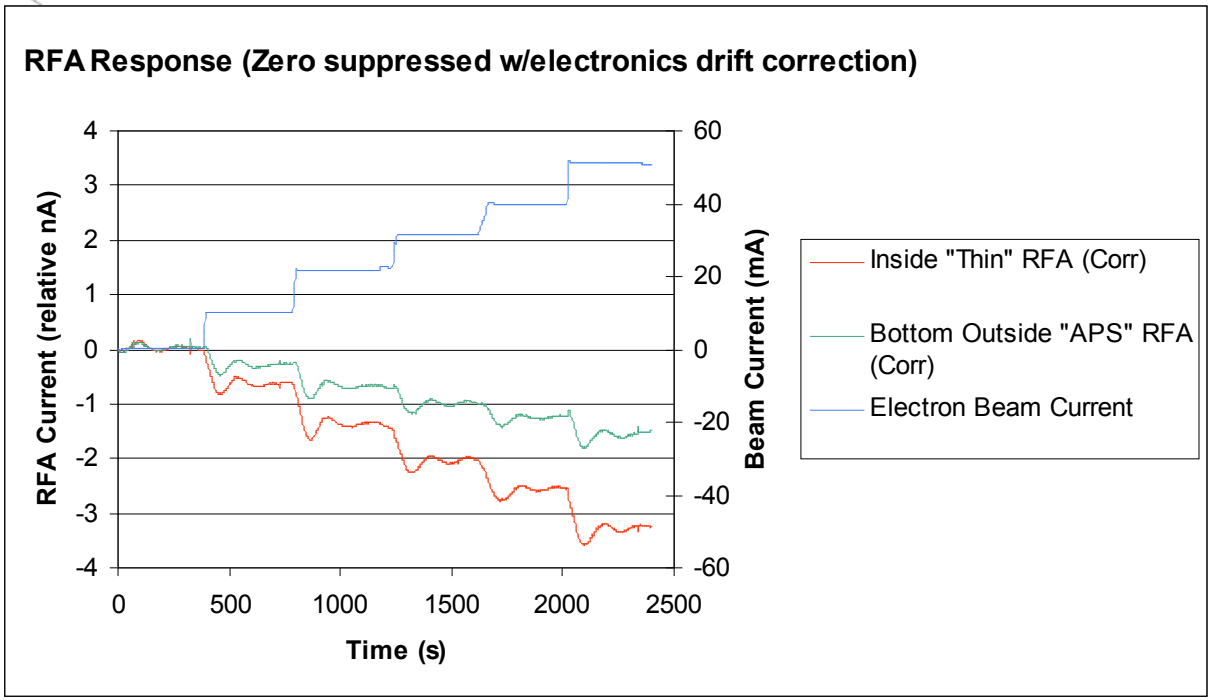
First Beam Test of "Thin RFA"





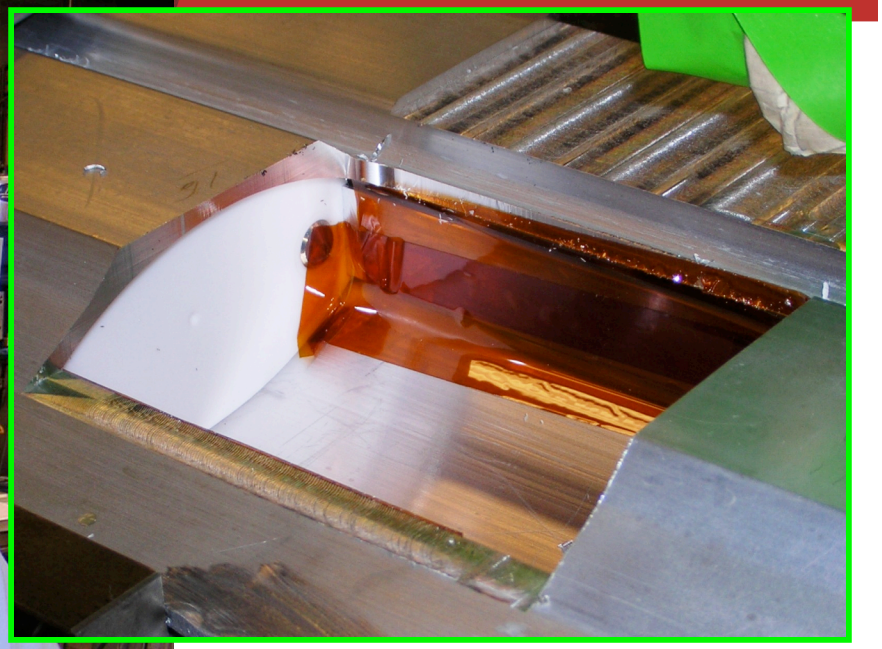
- First prototype "thin" RFA structure for wiggler chambers undergoing testing
- First beam test shows performance similar to APS-style RFAs

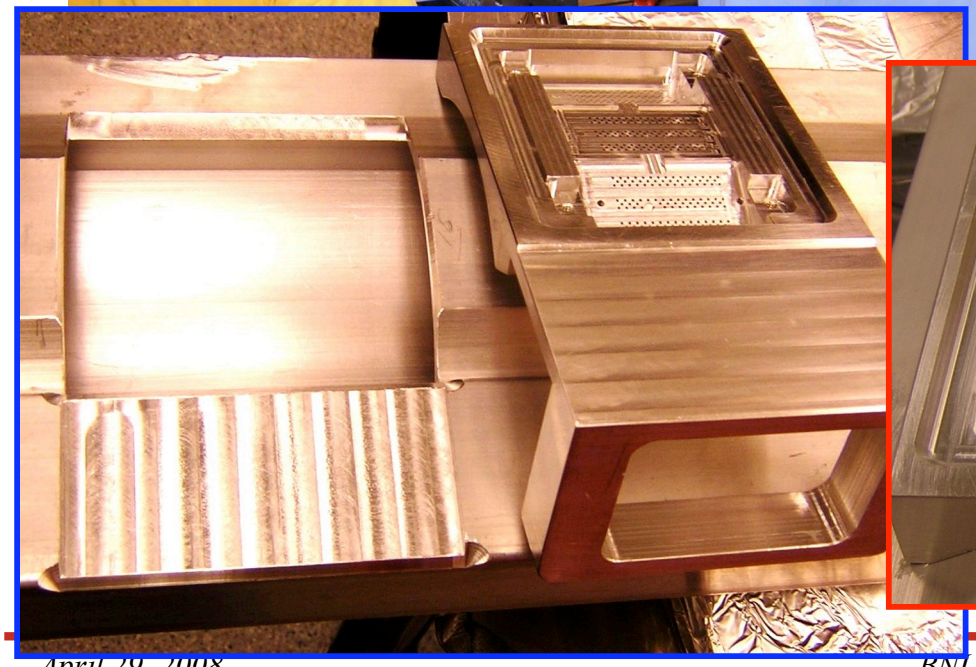
- Initial tests with 3mm test structure demonstrate key design aspects of the wiggler RFA
  - Calibration
  - Voltage test (no breakdown for DV = 600V)
  - Beam test
- Detailed design underway for wiggler structure
- Efficiency simulations to fully understand behavior in wiggler fields
- Finalize structure by late January

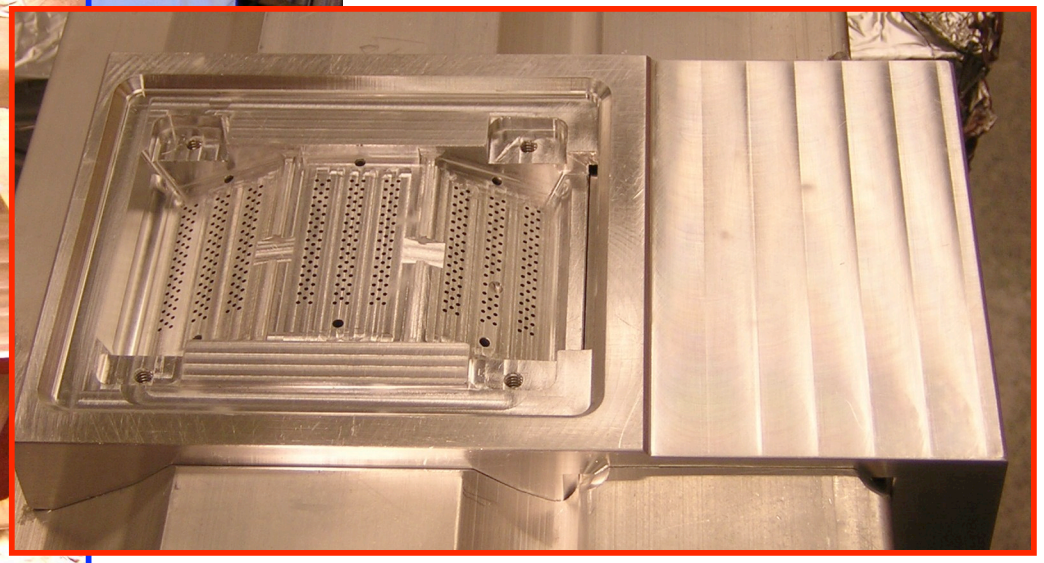


RFA Port Cut on New B12W Chamber



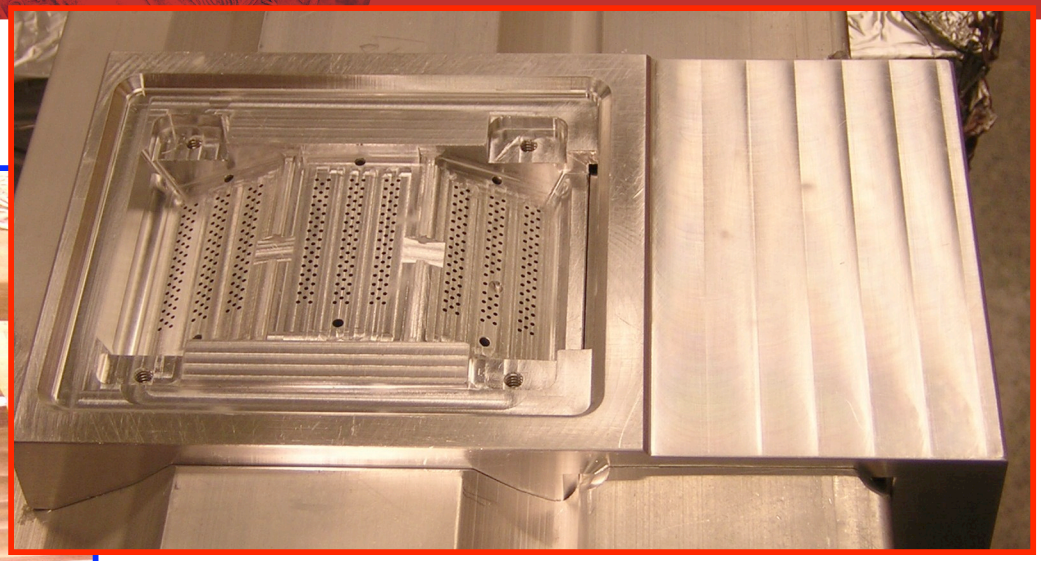


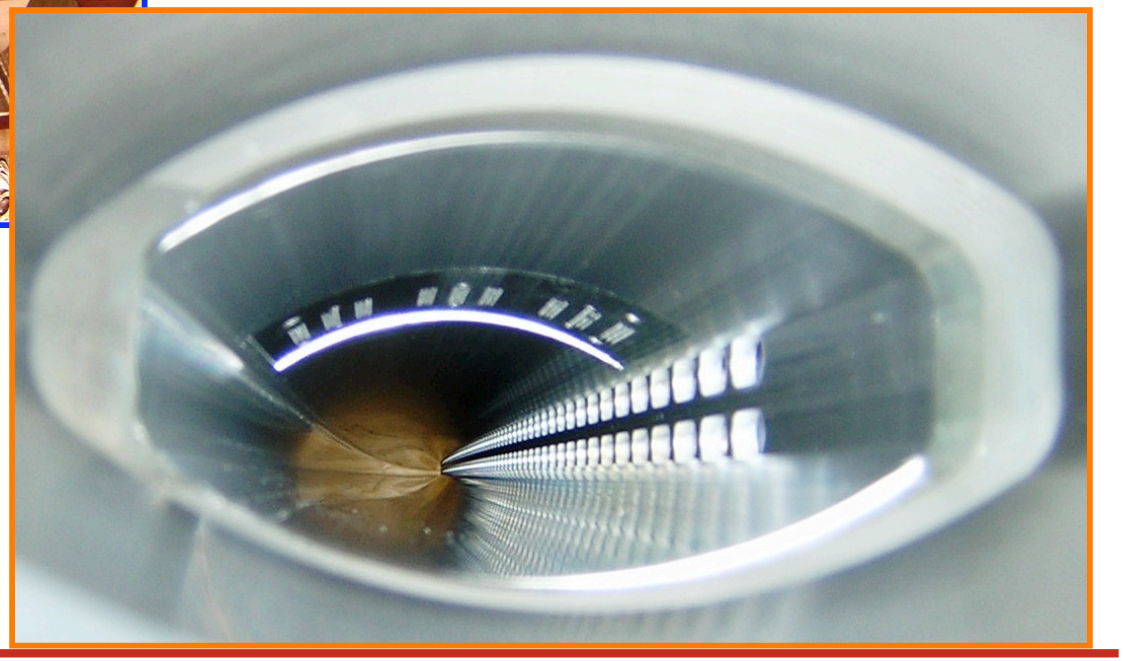


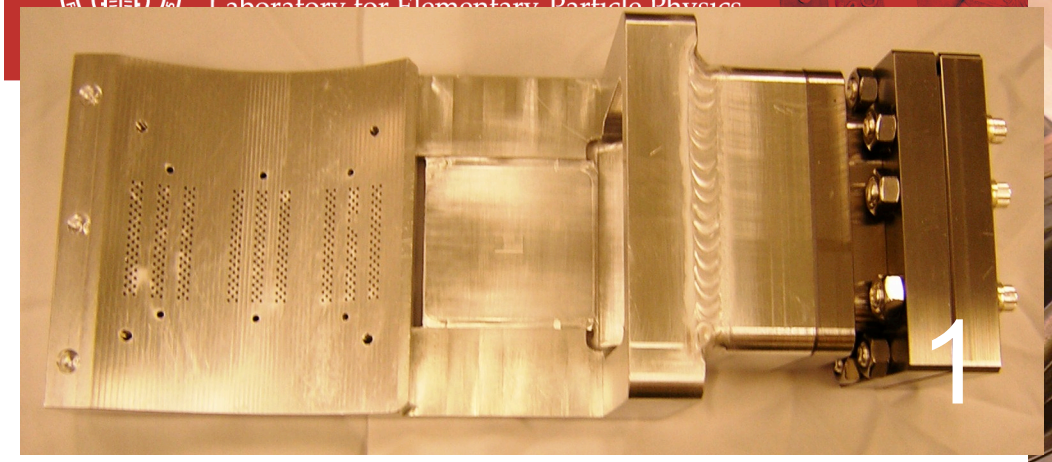


RFA Housing on New B12W Chamber





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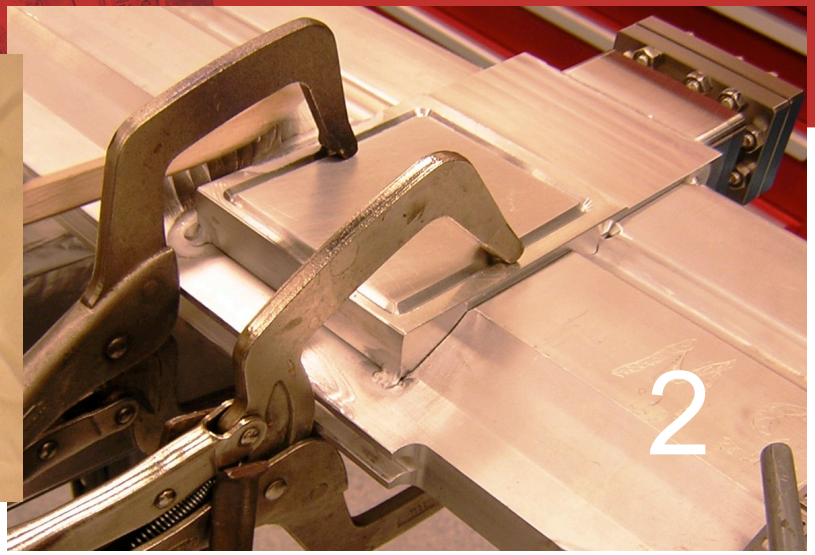
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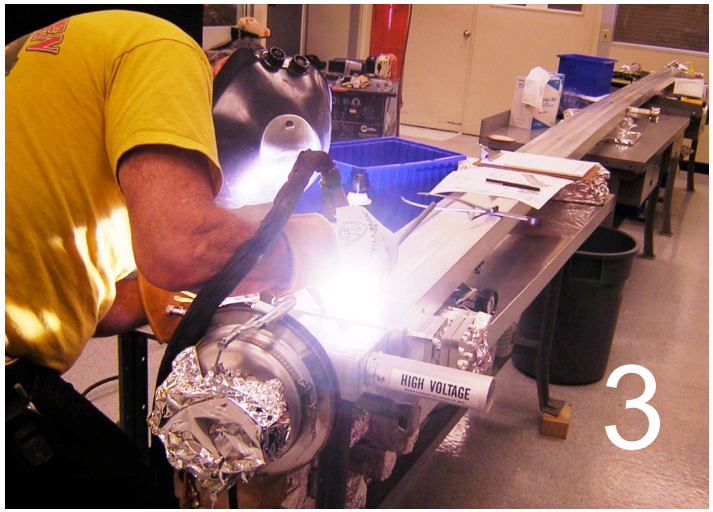
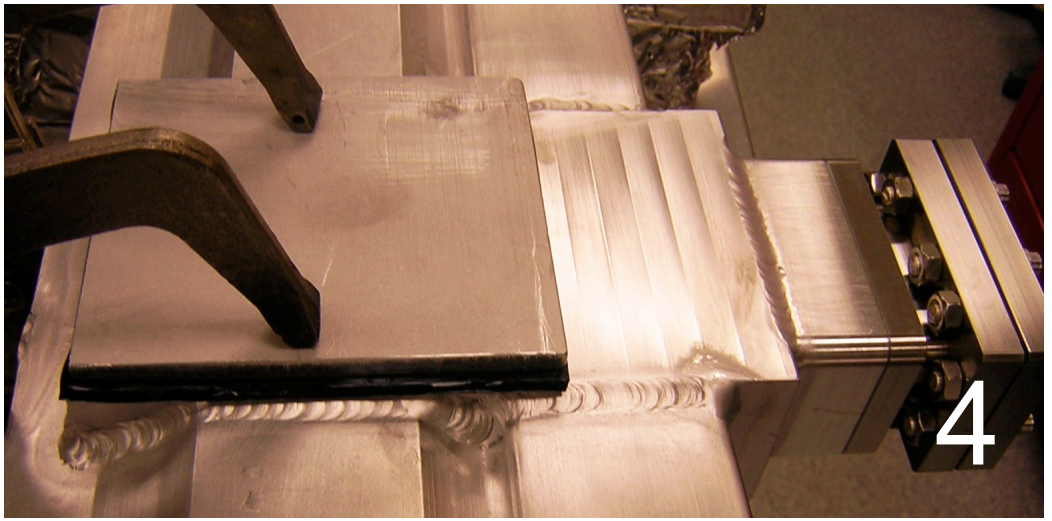

HIGH VOLTAGE
3


4

Experimental program

- Cesr TA electron cloud program
  - 2008
    - Install instrumented (RFA) dipole chambers (May)

    June
    - Electron cloud growth studies at 2-2.5GeV
    - Low emittance (~8nm) operation and alignment studies (Cesr-c configuration)

    July - August
    - Reconfigure CESR for low emittance (wigglers to IR)
    - Install wiggler chamber with RFA and mitigation hardware
    - Install dipole chicane
    - Optics line for xray beam size monitor
    - Extend turn by turn BPM capability to a large fraction of ring
    - Install spherical survey targets and nests and learn to use laser tracker

    Fall
    - Commission 2GeV 2.3nm optics [12 wigglers, CLEO solenoid off]
    - Survey and alignment
    - Beam based low emittance tuning
    - Characterize electron cloud growth with instrumented chambers
      Dependence on bunch spacing, bunch charge, beam size, beam energy
    - Explore e-cloud induced instabilities and emittance dilution
    - Commission positron x-ray beam size monitor (~2μm resolution)

Experimental program

- Cesr TA electron cloud program
  - 2009

Winter

- Install instrumented quadrupole chambers, and dipole chambers with e-cloud mitigation
- Complete upgrade of BPMs
- Complete survey and alignment upgrade
- Commission electron x-ray beam size monitor
- Install solenoid windings in drift regions

Spring

- Single pass measurement of orbit and dispersion
- Electron cloud growth, instability and emittance dilution
- Low emittance tuning

Summer

- Install optics line for electron xray beam size monitor
- Complete longitudinal feedback upgrade
- Install chambers with alternative mitigation techniques*
- Install photon stop for 5GeV wiggler operation

Fall

- Complete evaluation of electron cloud growth in wiggler, dipole, quadrupole
  - Compare with simulation
- Continue program to achieve ultra-low vertical emittance
- Characterize electron cloud instability and emittance dilution effects at lowest achievable emittance
- Measure electron cloud growth and mitigation in wigglers at 5GeV

Experimental program

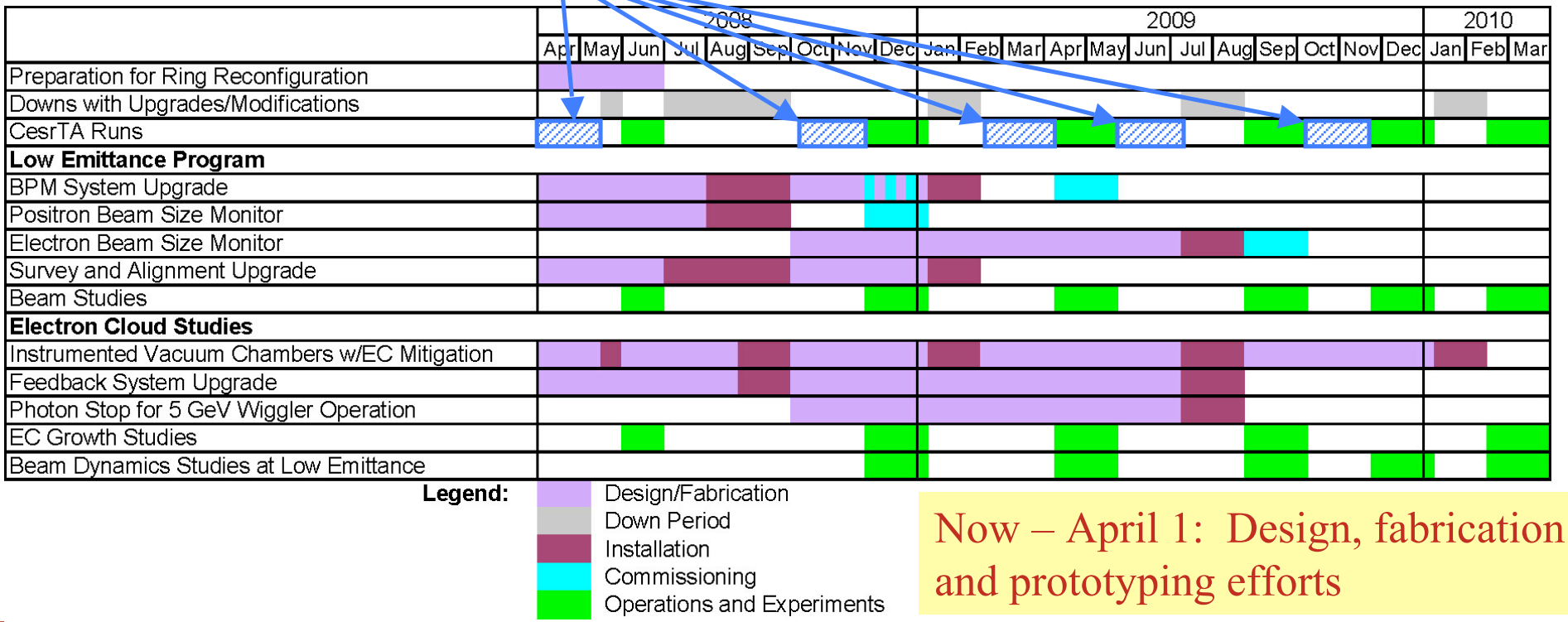
- Cesr TA electron cloud program
  - 2010

    Winter
    - Install addition chambers with E cloud diagnostics and mitigation*
    - Complete program to achieve ultra-low emittance
    - Characterize electron and positron instability thresholds and emittance dilution

Overview of the 2 Year Schedule

- Operations Schedule
  - 2 experimental runs in 2008
  - 3 experimental runs in 2009
  - 1 experimental run in 2010
  - Avg ~40 days/run
- Down Periods
  - Major Reconfiguration down Jul-Sep 2008
  - Hardware installation downs
    - 2 in 2008
    - 2 in 2009
    - 1 in early 2010

Proposed CHESS Runs

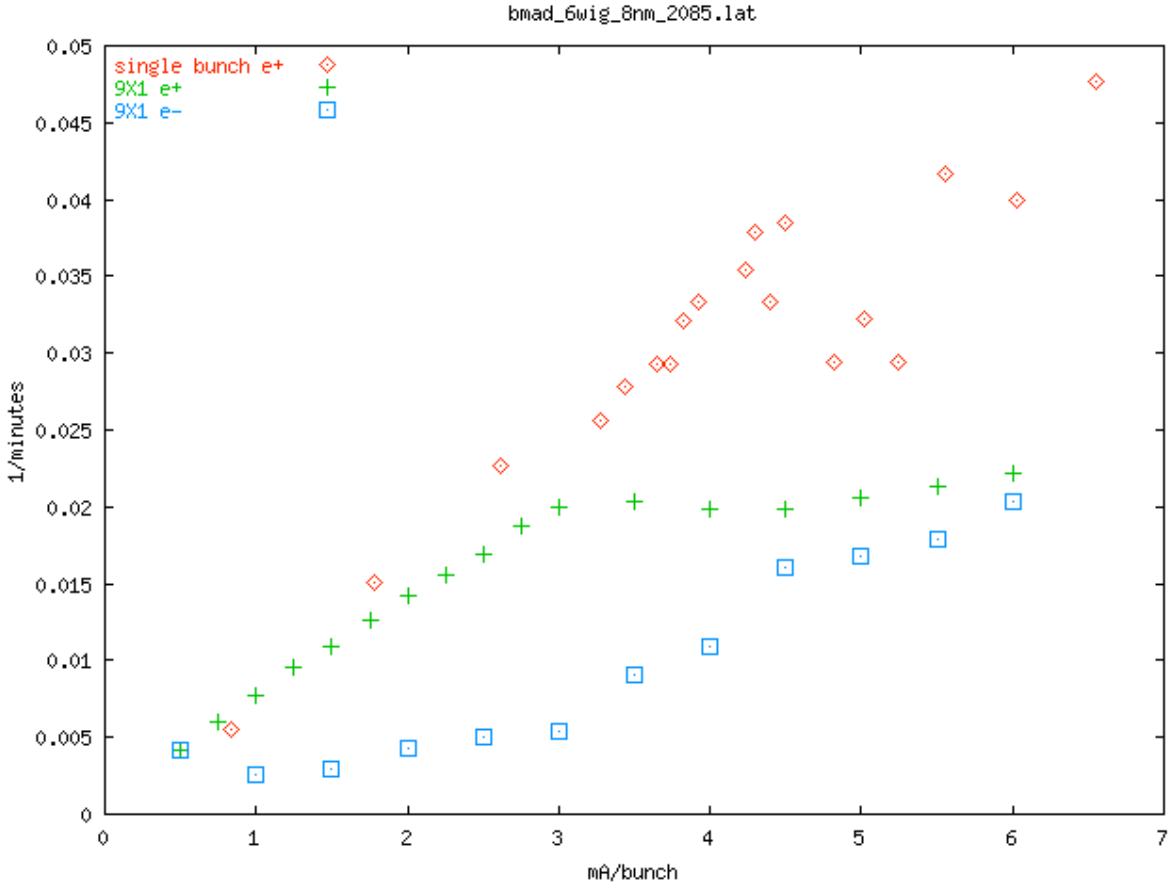


Now – April 1: Design, fabrication and prototyping efforts

System status

- Status of beam based measurement/analysis
  - Instrumentation - existing BPM system is 90% analog with relays and 10% bunch by bunch, turn by turn digital
    - Turn by turn BPM -
      - A subset of digital system has been incorporated into standard orbit measuring machinery for several years
      - Remainder of the digital system will be installed during the next year
  - Software (CESRV) / control system interface has been a standard control room tool for beam based correction for over a decade
    - For measuring orbit, dispersion, betatron phase, coupling
    - With the flexibility to implement one or two corrector algorithm
    - To translate fitted corrector values to magnet currents
    - And to load changes into magnet power supplies
    - ~ 15 minutes/iteration

- Lifetime vs current - 6 wiggler low emit optics - ε_x~7.5nm

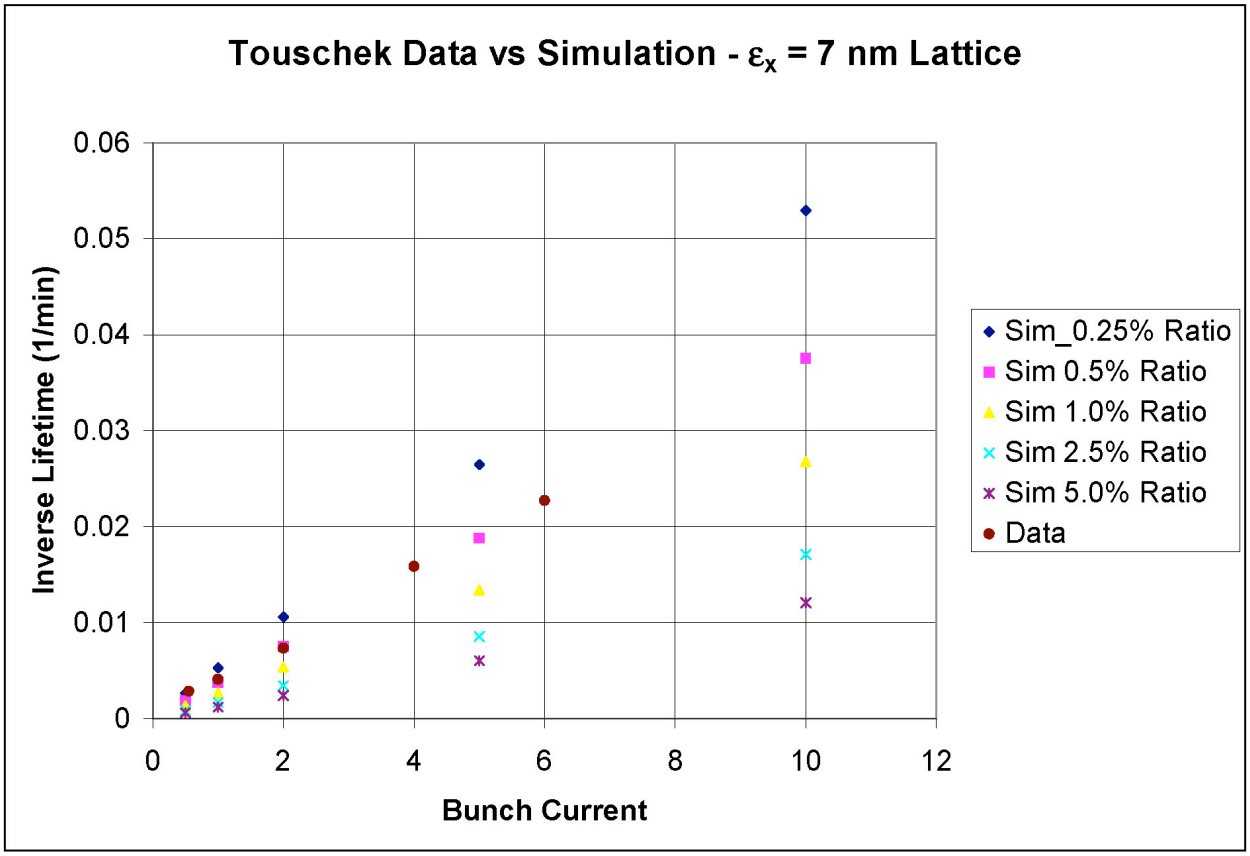


positrons and electrons

29-february-2008

Touschek Lifetime

6 wiggler, 1.89GeV optics

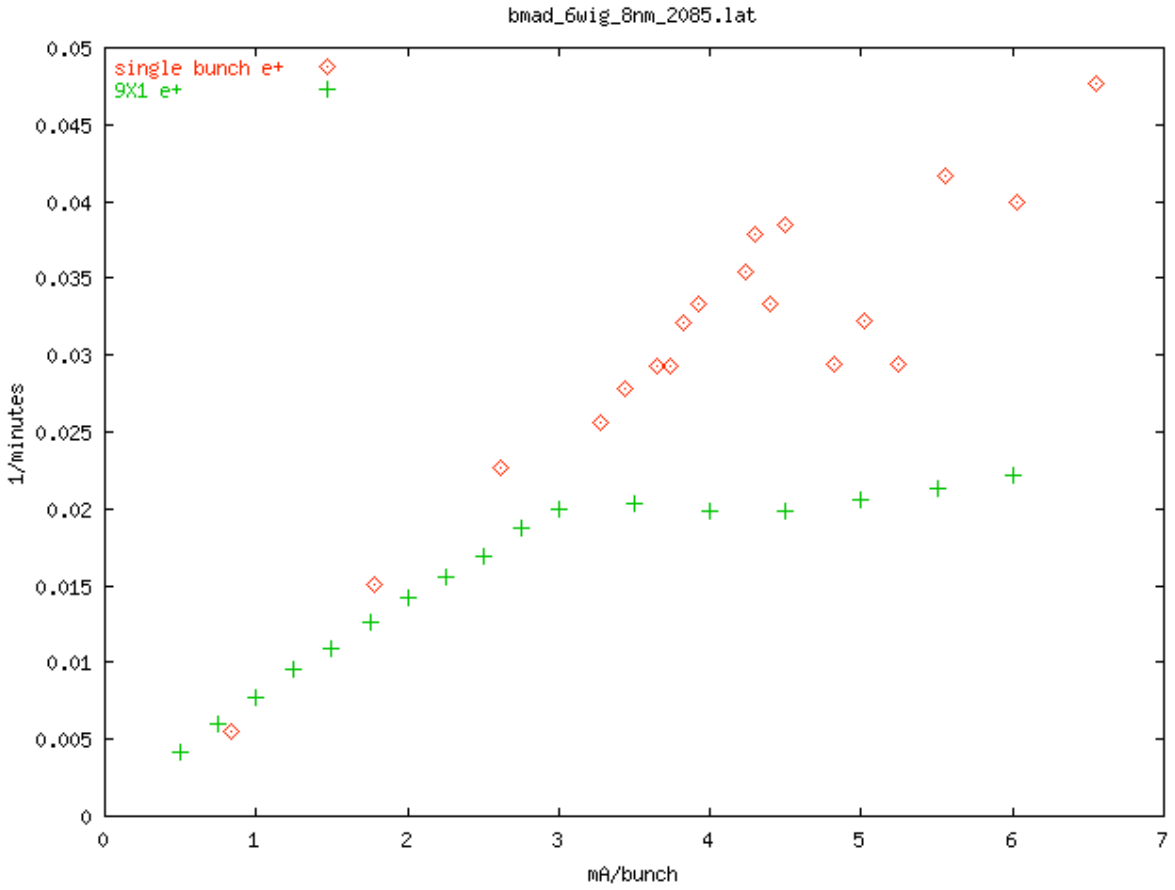


preliminary

11-September 2007

Lifetime

- Lifetime vs current - 6 wiggler low emit optics
- - ε_x~7.5nm
- 2.085GeV



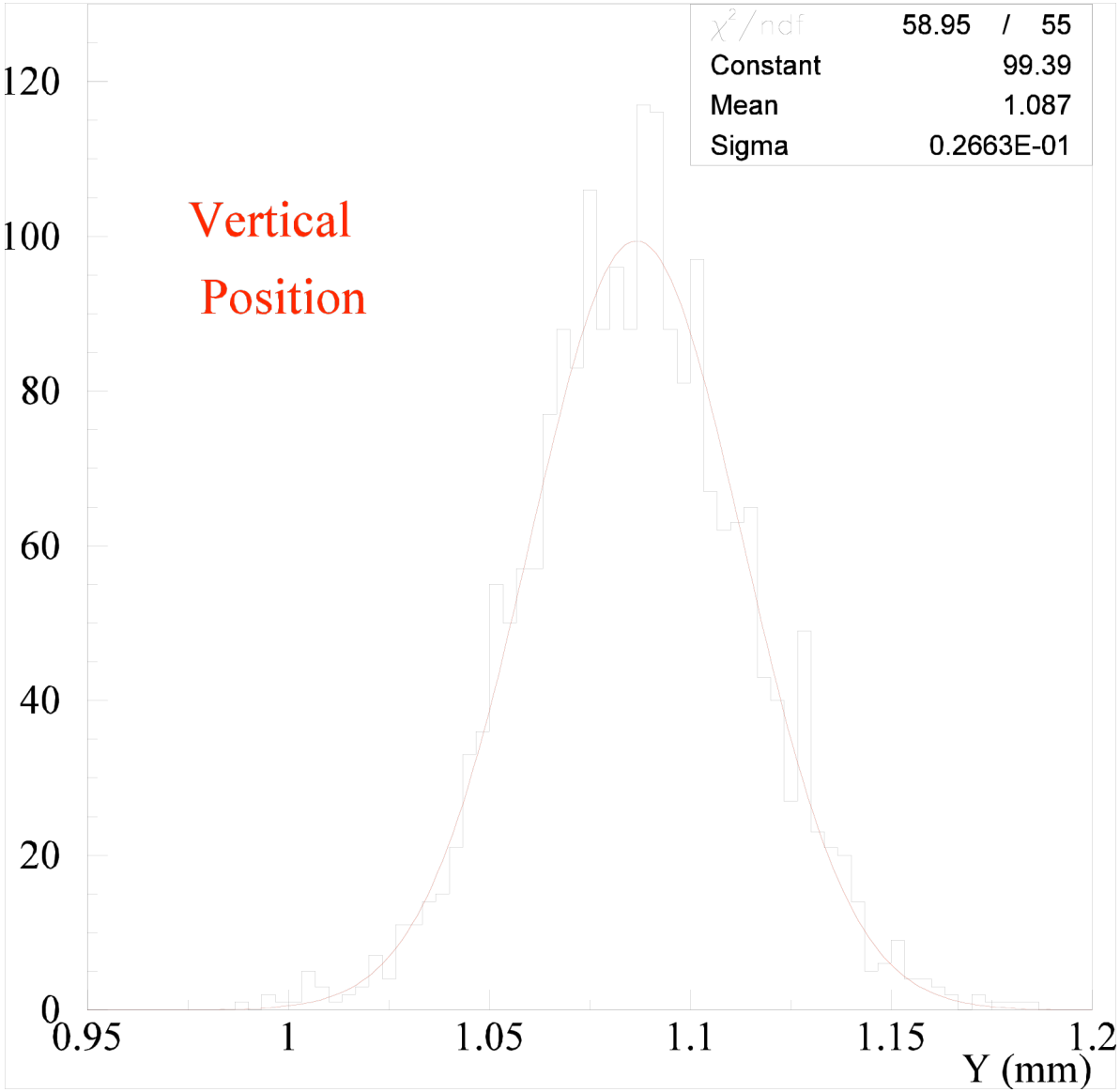
positrons

29-february-2008

preliminary

Beam Position Monitor System

- BPM resolution



Dispersion

- AC dispersion measurement

Dispersion is coupling of longitudinal and transverse motion

-Drive synchrotron oscillation by modulating RF at synch tune
-Measure vertical & horizontal amplitudes and phases of signal at synch tune at BPMs

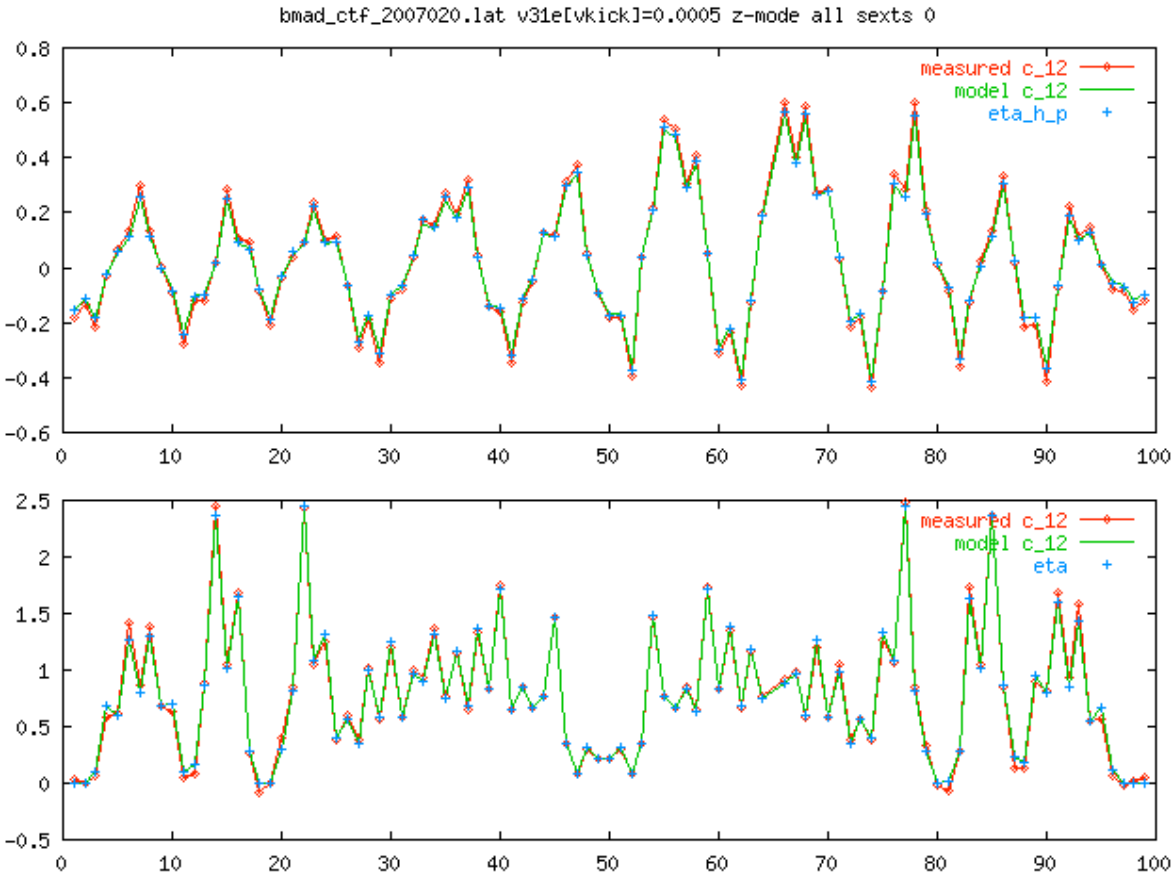
Then

$\{\eta_v/\beta_v\} = (y_{amp}/z_{amp}) \sin(\varphi_y - \varphi_z)$

$\{\eta_h/\beta_h\} = (x_{amp}/z_{amp}) \sin(\varphi_h - \varphi_z)$

Advantages:

1. Faster (30k turns)
2. Better signal to noise - filter all but signal at synch tune



"measured c_12" - 30k turn simulation
"model c_12" - Model y-z and x-z coupling
"model eta" - Model dispersion