ILC Damping Ring Test Facilities Status Report

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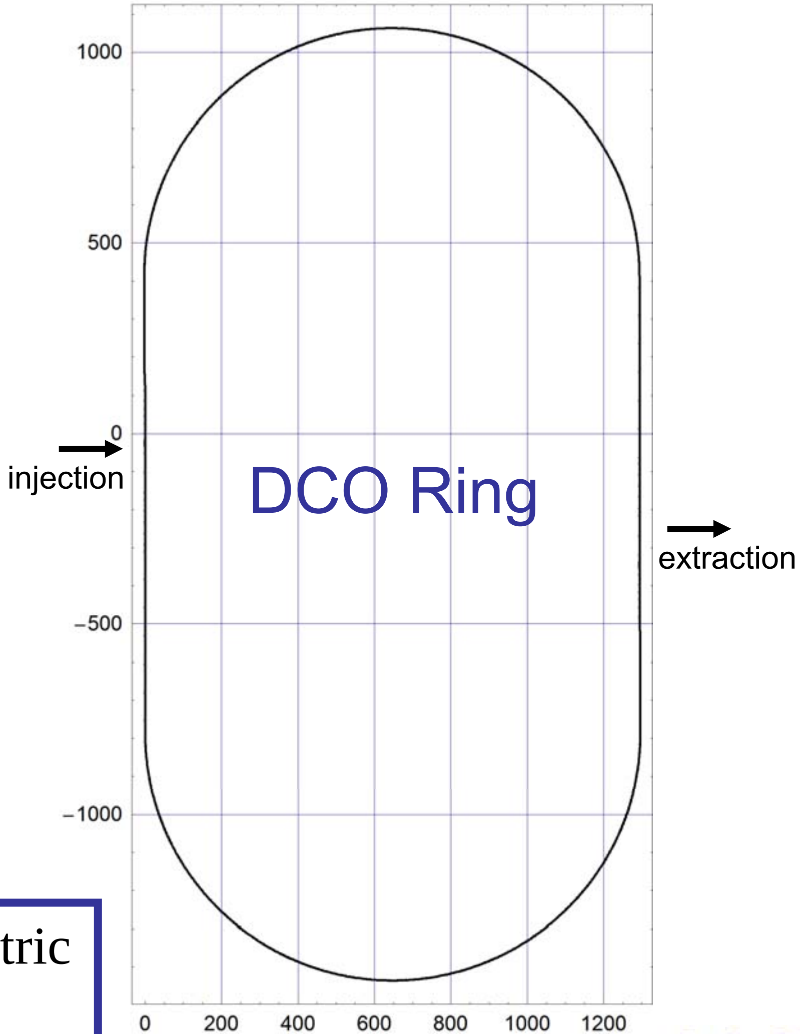
ILC PAC Review, Vancouver

The ILC Damping Rings

Beam energy	5 GeV
Circumference	6476.44 m
RF frequency	650 MHz
Harmonic number	14042
Injected (normalised) positron emittance – $\gamma\varepsilon_{x,y}$	0.01 m
Extracted (normalised) emittance $\gamma\varepsilon_x \times \gamma\varepsilon_y$	8 μm × 20 nm
Extracted energy spread	<0.15%
Average current	400 mA
Maximum particles per bunch	2×10^{10}
Bunch length (rms)	6 mm
Minimum bunch separation	3.08 ns

2 pm-rad geometric emittance

Present Baseline Design



Damping Rings R&D

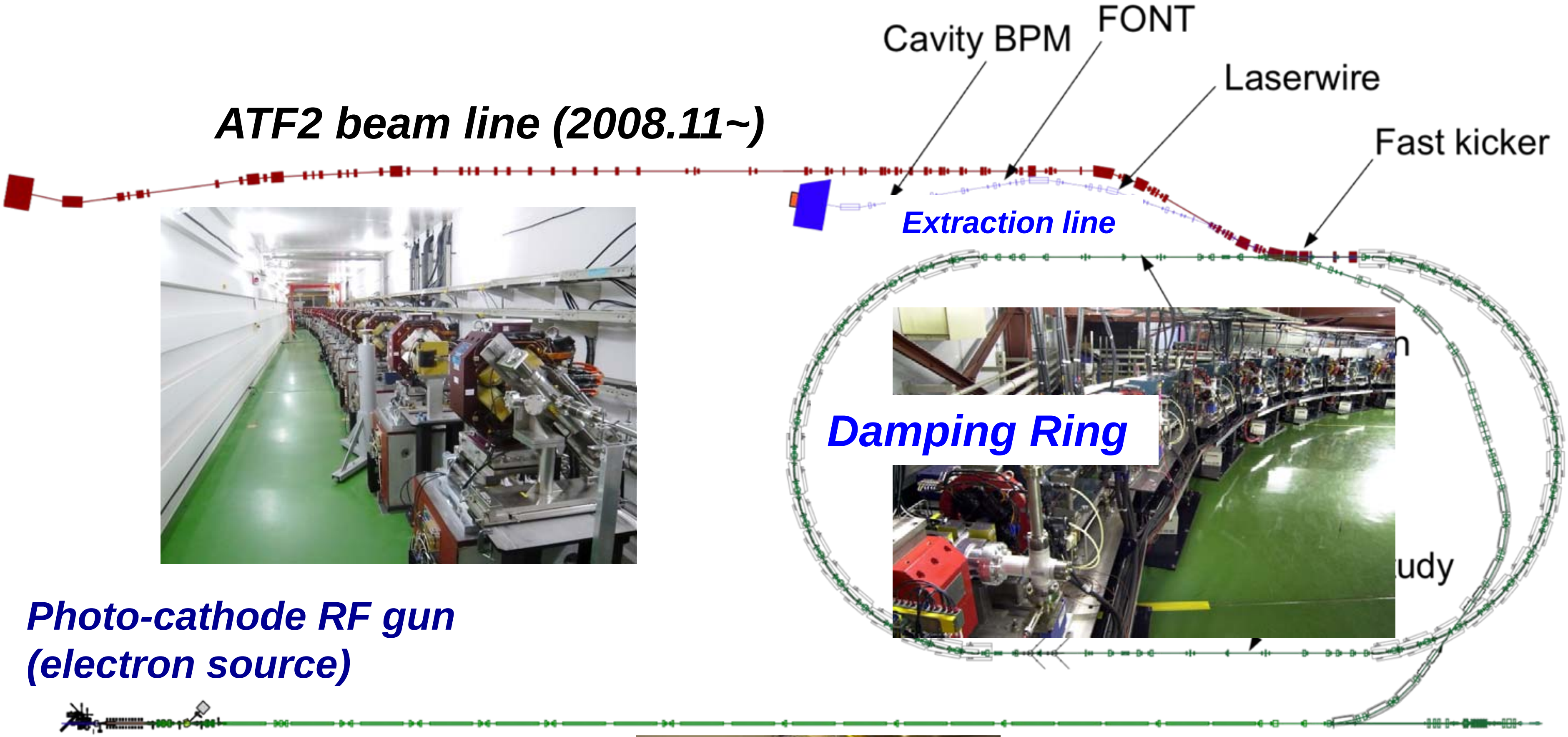
ILC R&D Board S3 Task Force (Damping Rings) identified 11 *very high priority* R&D items that needed to be addressed for the technical design:

- 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

Targeted for ATF Effort

Targeted for CesrTA Effort with Low Emittance e^+ Beam

Accelerator Test Facility

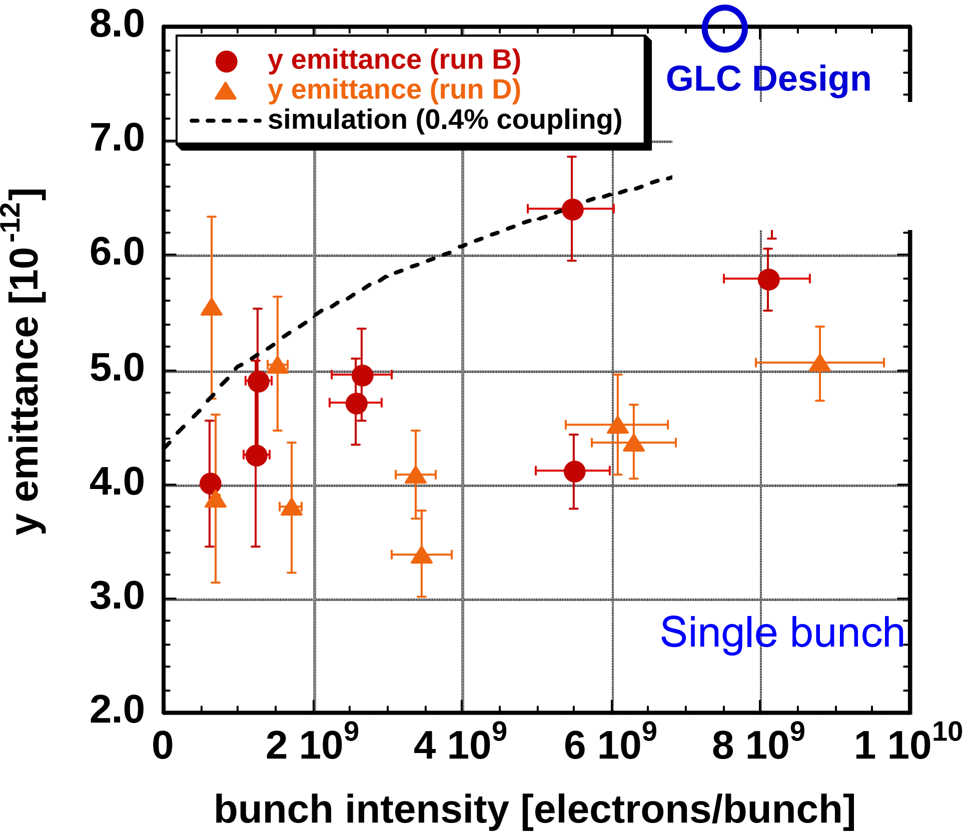


S-band Linac

Δf ECS for multi-bunch beam

Emittance Tuning at ATF

Vertical Emittance



Measured in DR, 2004

ATF achieved about 4pm vertical emittance in 2004

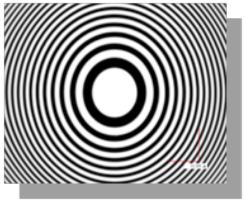
This was not reproduced in 2006 ➪ typical values of 20pm observed

Ring alignment issues were a major contributor

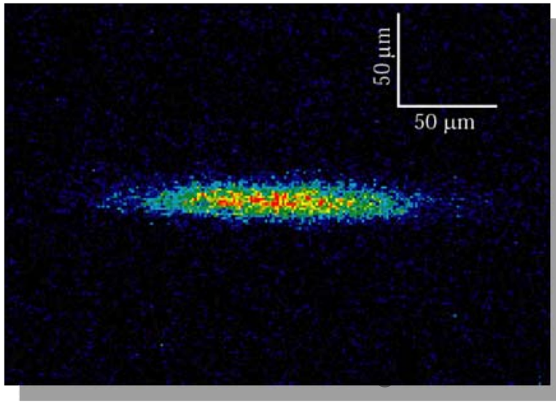
Focus areas:

- **Optics tuning**
- **Beam based alignment**
- **BPM alignment**

Improved real-time tuning capability since 2005 with the availability of the XSR monitor.



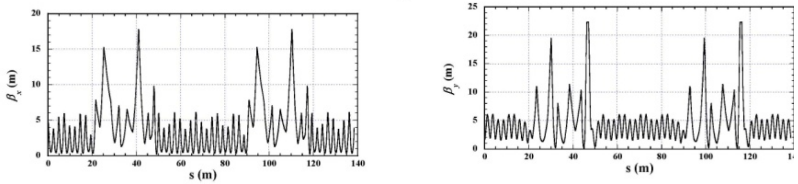
FZP



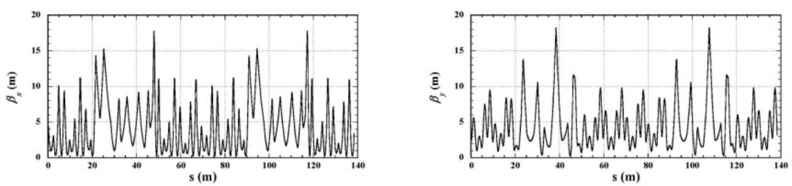
Beam Optics deformation was checked.

Optics retuning is necessary to recover ultra-low emittance.

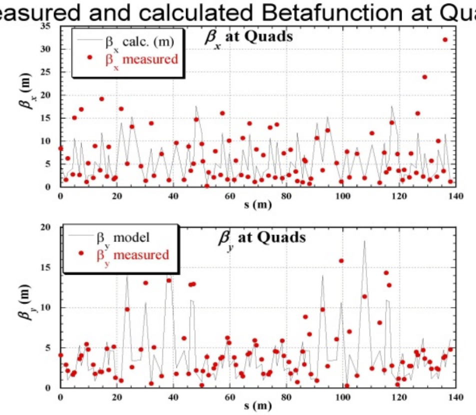
calculated from setting Dec. 10, 1999

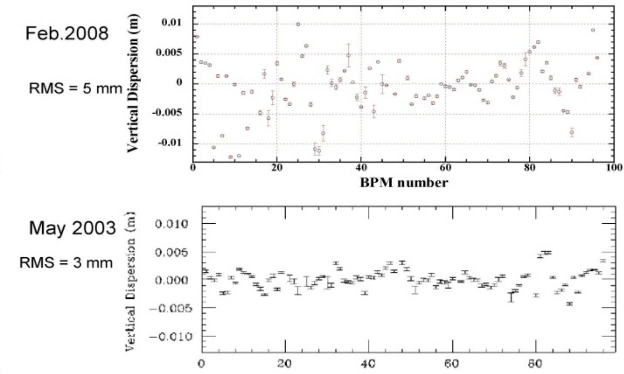


calculated from setting May 16, 2008

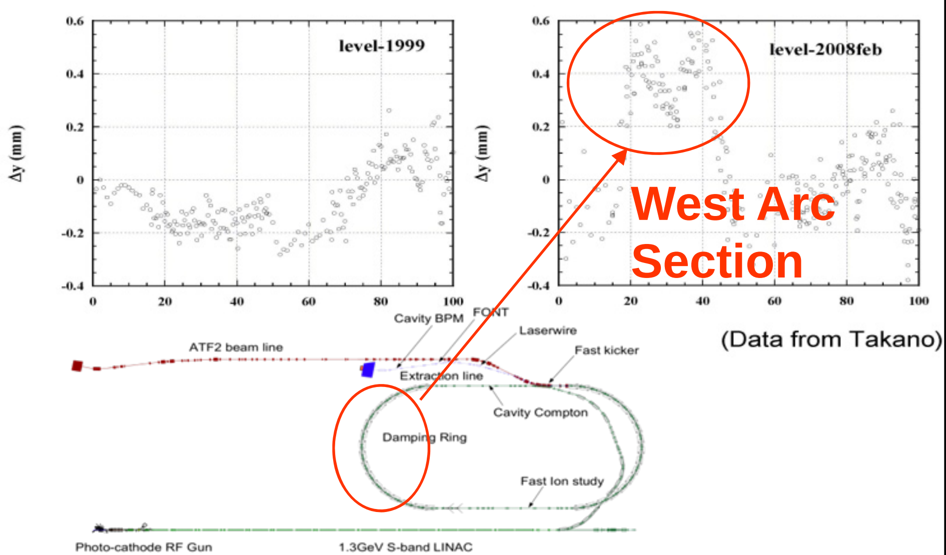


Measured and calculated Betafunction at Quads





Alignment Changes



Beam Optics Errors

Magnet alignment changes over extended period. West arc alignment badly degraded by ATF2 floor work

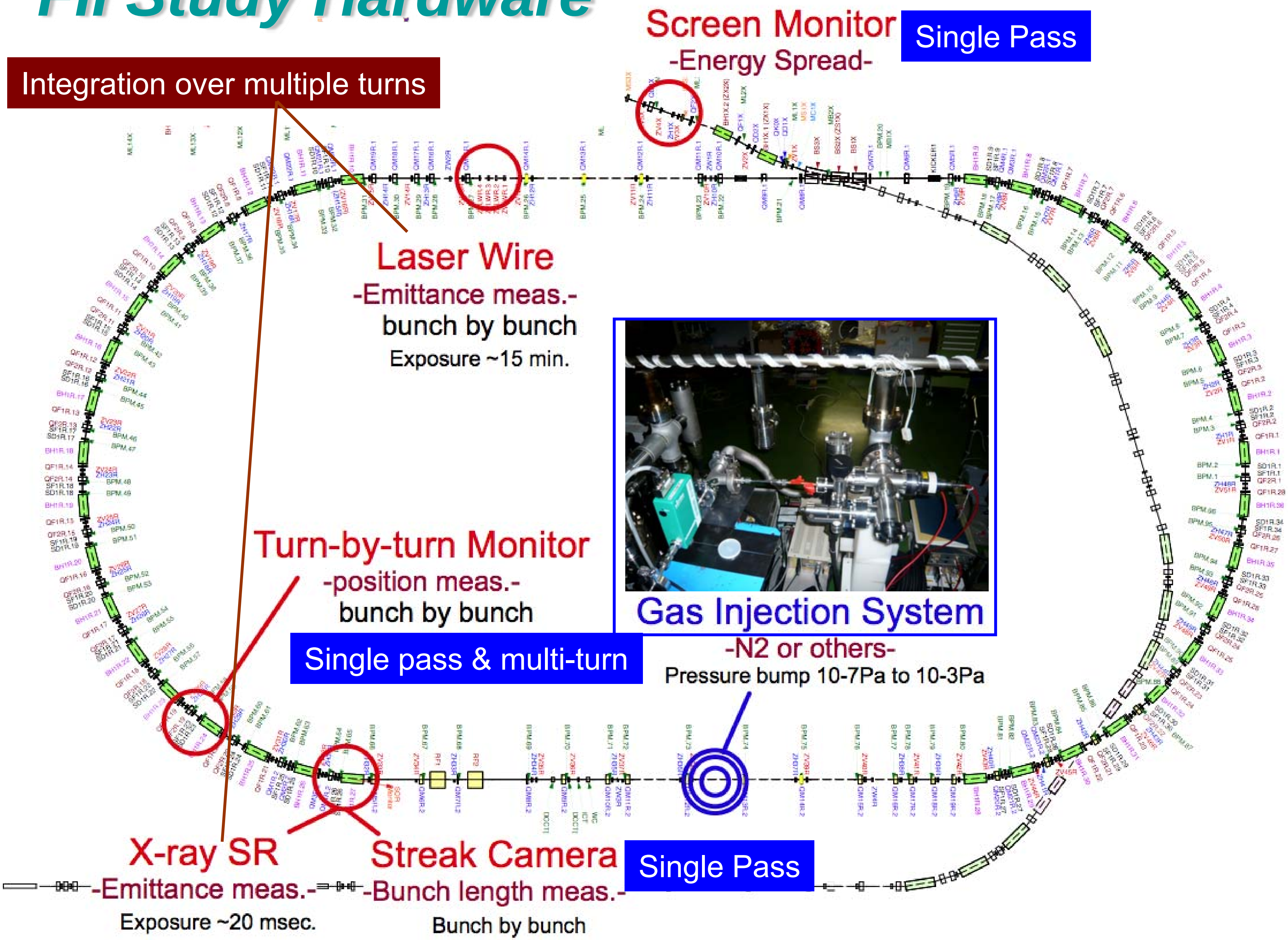
Additional issue – BPM alignment to quad centers addressed with BBA studies

Upgraded BPM system with few μm turn-by-turn resolution ready for testing

LET Summary for the KEK-ATF

- 2 pm is a TDP R&D plan deliverable for ATF
  - Recent demonstrations at light sources (eg., Diamond) may reduce the critical need for this demonstration
  - BUT, the lowest possible emittance is still needed for the ILC experimental R&D program (FII, ATF2,…)
- 4 pm achieved in 2004
  - LET based on Orbit Response Matrix analysis with iterative correction of orbit dispersion and coupling
  - In 2007 the same tuning procedures yielded 20-30 pm
- Critical Improvements
  - DR magnet re-alignment in 2008
  - BPM upgrade program is in progress
- April 2009: ε_y ~ 10 pm measured by XSR
  ε_y ~ 5 pm measured by Laser Wire

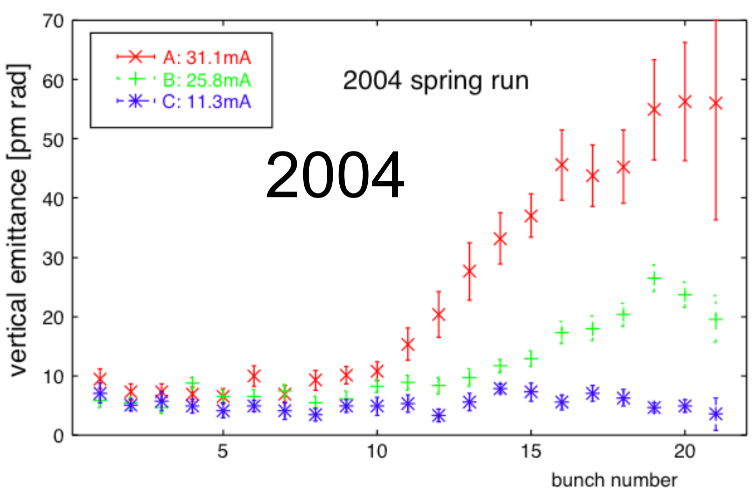
FII Study Hardware



Resuming FII Studies

Table 2: vacuum pressure in 2004

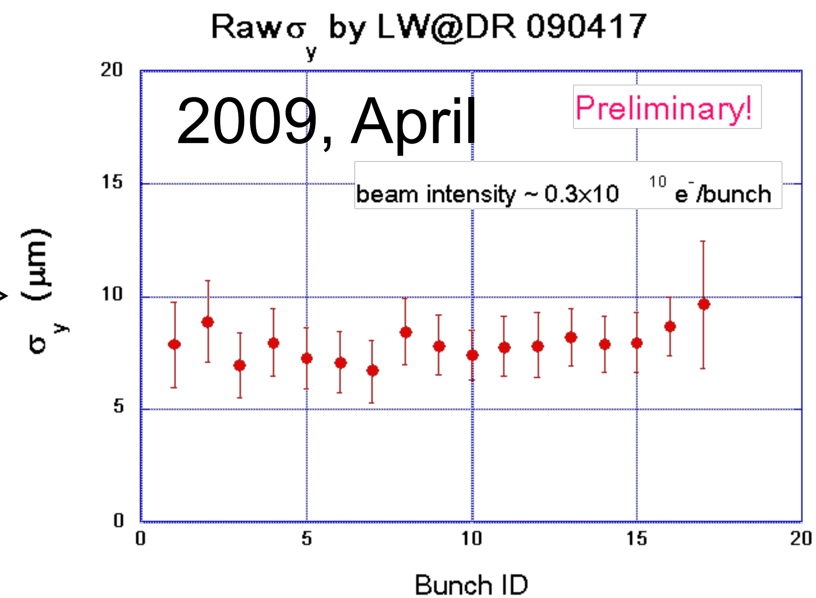
ion pump status	11mA	26mA	31mA
normal	4.0×10^{-6} Pa	6.0×10^{-6} Pa	6.5×10^{-6} Pa



Single bunch vertical emittance <5pm

2007-2008 Studies

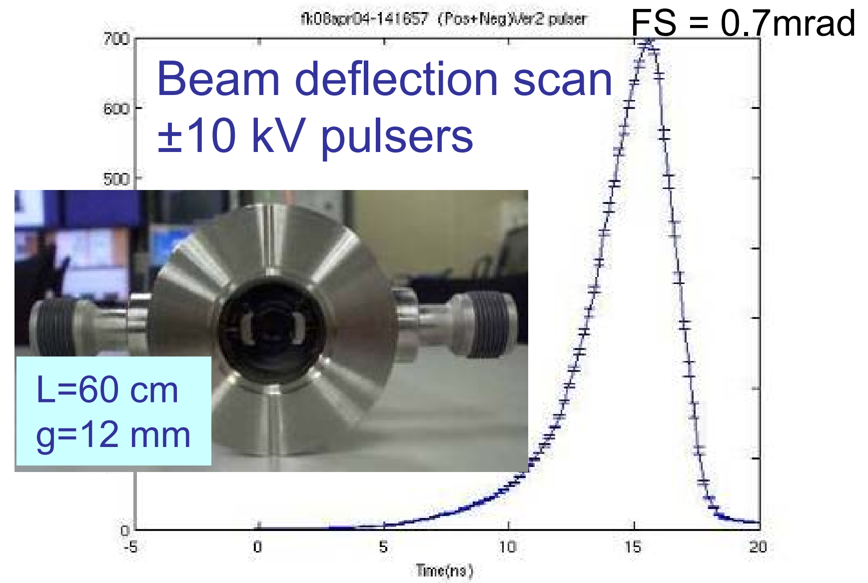
- Limited by typical vert emittance ~20-30 pm
- Alignment/optics correction/BPM efforts now returning ATF to performance levels suitable for ongoing studies.



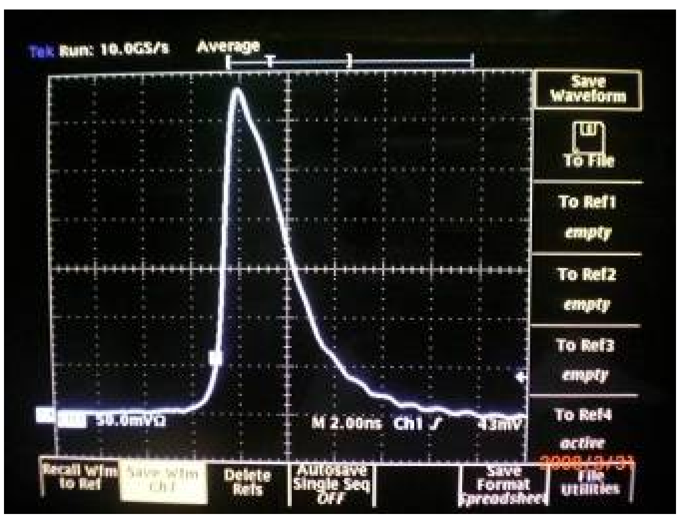
Single bunch vertical emittance <10pm. Now need a high bunch charge measurement.

Fast Kicker R&D at ATF

- Goal: provide bunch train with ILC-like time structure for ATF2, by extracting individual bunches from train in ATF
  - Present scheme requires kicker plus "slow bump" for extraction
  - Extraction tests planned for June `09
  - Future: Use 4ns wide pulser for "kicker-only" extraction tests



Pulser: FID FPG 10-6000KN



Maximum output voltage	10 kV
Rise time, 10 – 90%	< 1 ns
Rise time, 5 – 95%	< 1.2 ns
Pulse duration at 90% peak amplitude	0.2 – 0.3 ns
Pulse duration at 50% peak amplitude	1.5 – 2.0 ns
Output pulse amplitude stability	< 0.7%
Maximum pulse repetition frequency	6.5 MHz
Number of pulses per burst	110 (max)
Burst repetition frequency	5 Hz

CesrTA Goals

- Studies of the Electron Cloud
  - EC growth and mitigation methods (particularly in ***wigglers*** and ***dipoles***)
  - Instability thresholds and emittance dilution in a regime approaching that of the ILC DR
  - Validate EC simulations in the low emittance parameter regime
  - Validate projections for the ILC DR design
- Low Emittance Operations
  - Support EC studies with beam emittances approaching those specified for the ILC DR (CesrTA vertical emittance target: ε_v~**10-20 pm-rad**)
  - Implement instrumentation needed to characterize ultra low emittance beams (***xBSM*** – targeting bunch by bunch & turn by turn capability)
  - Develop tuning tools to achieve and maintain ultra low emittance operation in coordination with the ILC DR LET effort
- Inputs for the ILC DR Technical Design
  - Support an experimental program to provide key results on the 2010 timescale

CesrTA Parameters

CESR offers:

- A Wiggler-dominated storage ring
- The CESR-c damping wigglers (*technology choice of ILC DR*)
- Operation with ***positrons*** *and* ***electrons***
- Bunch spacings suitable for ILC DR studies (≥4ns)
- 1.5 to 5.5 GeV energy range

Ultra Low Emittance Baseline

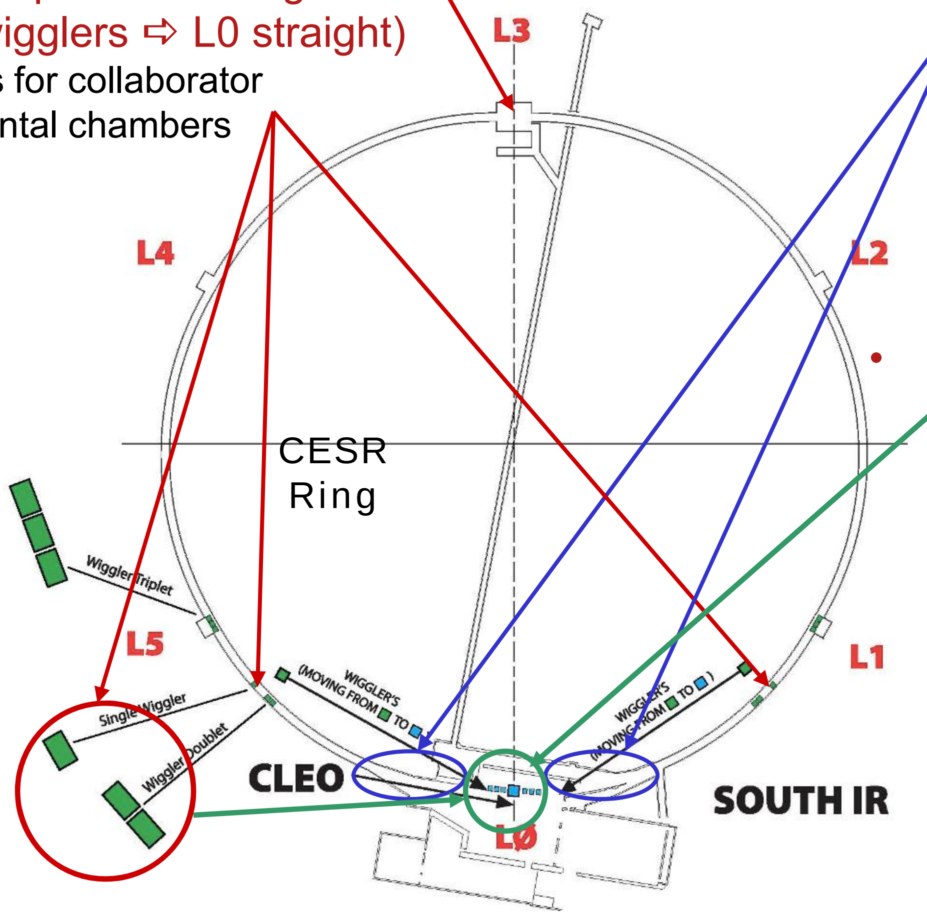
Energy [GeV]	2.085	5.0
No. Wigglers	12	6 ⇨ 0
$B_{wiggler}$ [T]	1.9	1.9 ⇨ 0
Q_x	14.57	
Q_y	9.6	
Q_z	0.075	0.043
V_{RF} [MV]	8.1	8
ε_x [nm-rad]	2.6	35 ⇨ 60
$\tau_{x,y}$ [ms]	57	20
α_p	6.76×10^{-3}	6.23×10^{-3}
σ_l [mm]	9	15.6 ⇨ 9.4
σ_E/E [%]	0.81	0.93 ⇨ 0.58
t_b [ns]	≥4, steps of 2	

CESR Reconfiguration

- L3 EC experimental region
  Hardware: PEP-II Chicane, upgraded SEY station, diagnostic drift and quadrupole VCs
- New EC experimental regions in arcs (wigglers ⇨ L0 straight)
  Locations for collaborator experimental chambers
- CHESS C-line & D-line Upgrades
  Electron and positron x-ray beam size monitors
- L0 region reconfigured as a wiggler straight (zero dispersion)
  CLEO detector sub-systems removed and 6 wigglers installed

  EC diagnostics and mitigations

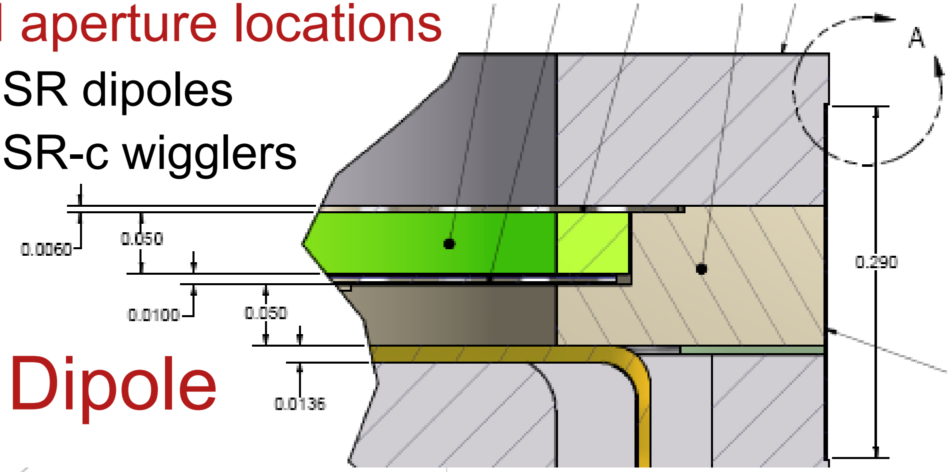
  CU/SLAC/KEK/LBNL collaboration on EC mitigation in wiggler chambers



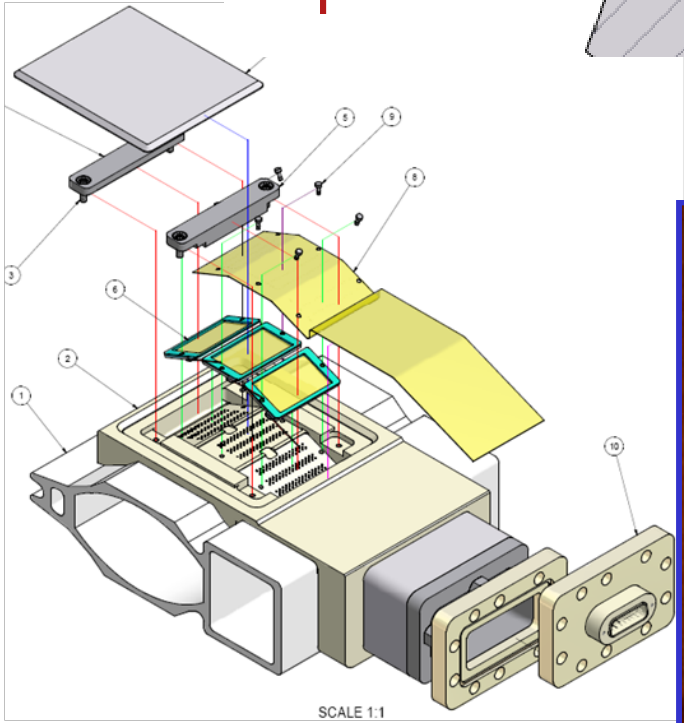
Thin RFA Design

- Thin structure developed for use in limited aperture locations
  - CESR dipoles
  - CESR-c wigglers

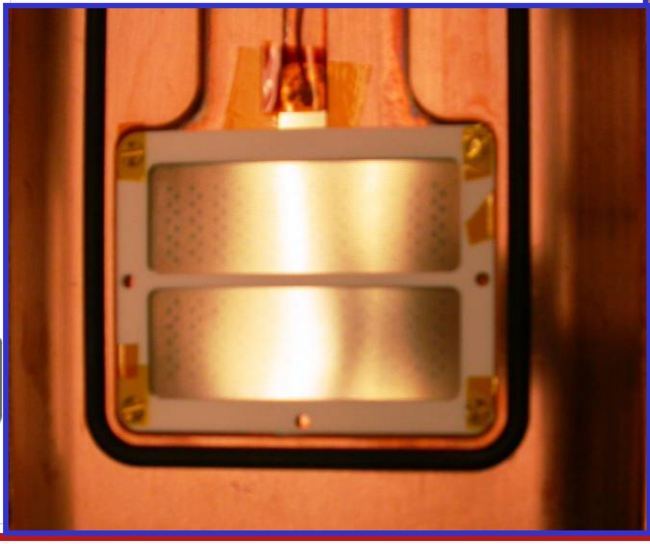
~1 mm

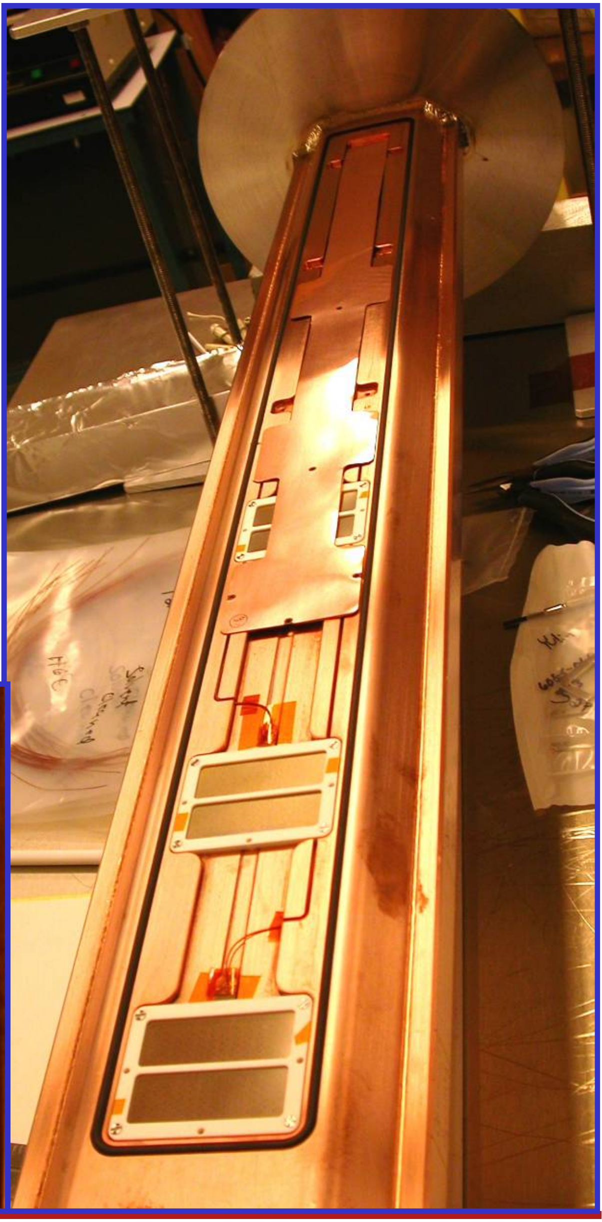


CESR Dipole

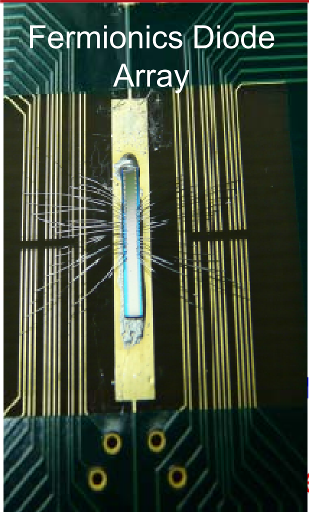


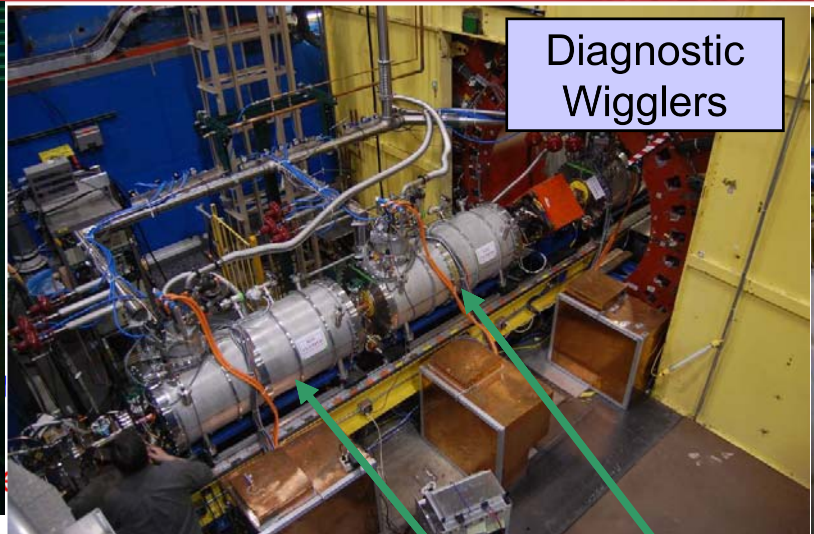
CESR Wiggler

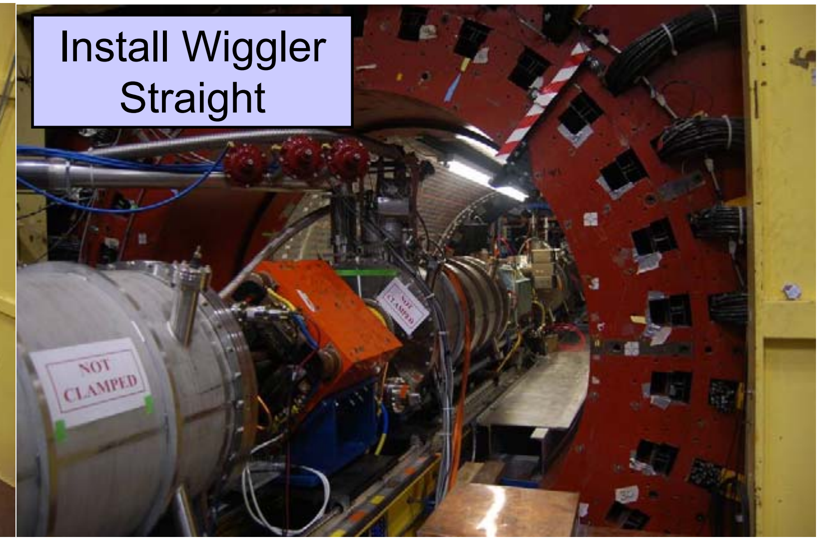


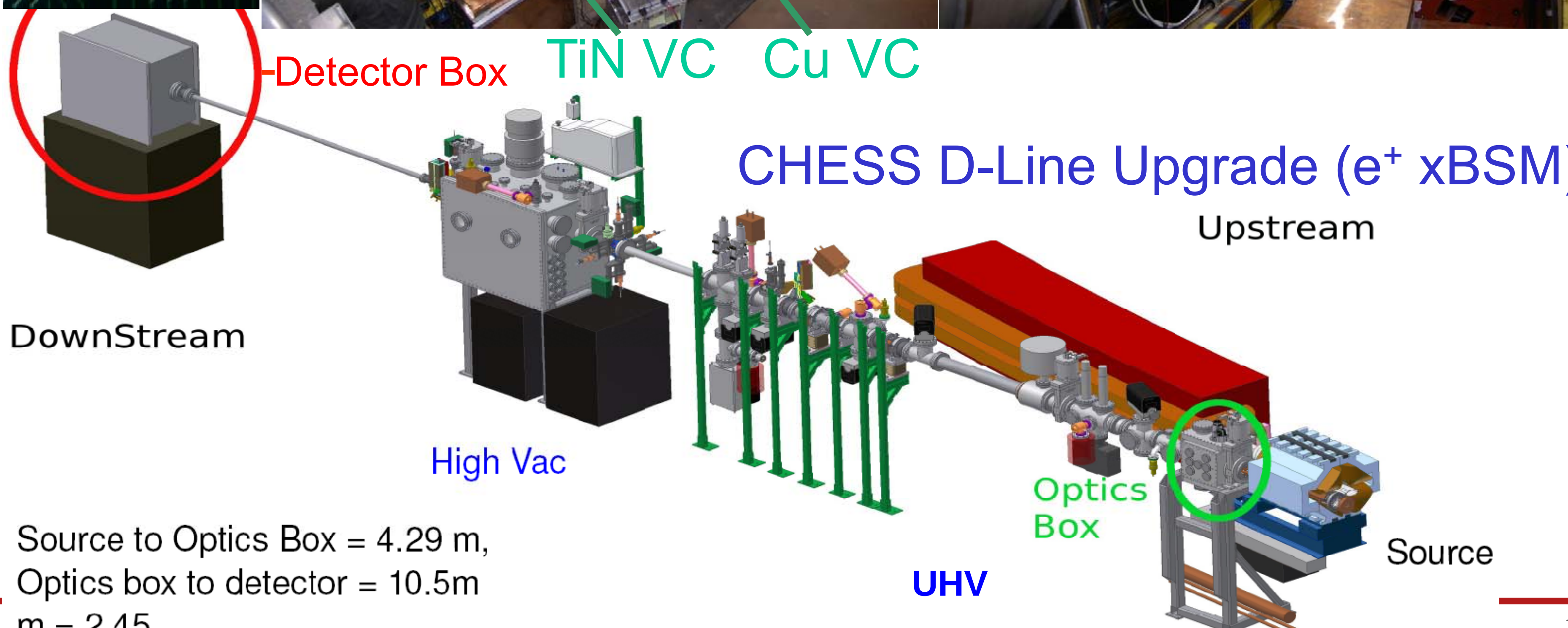


Upgrade Activities: L0 and xBSM



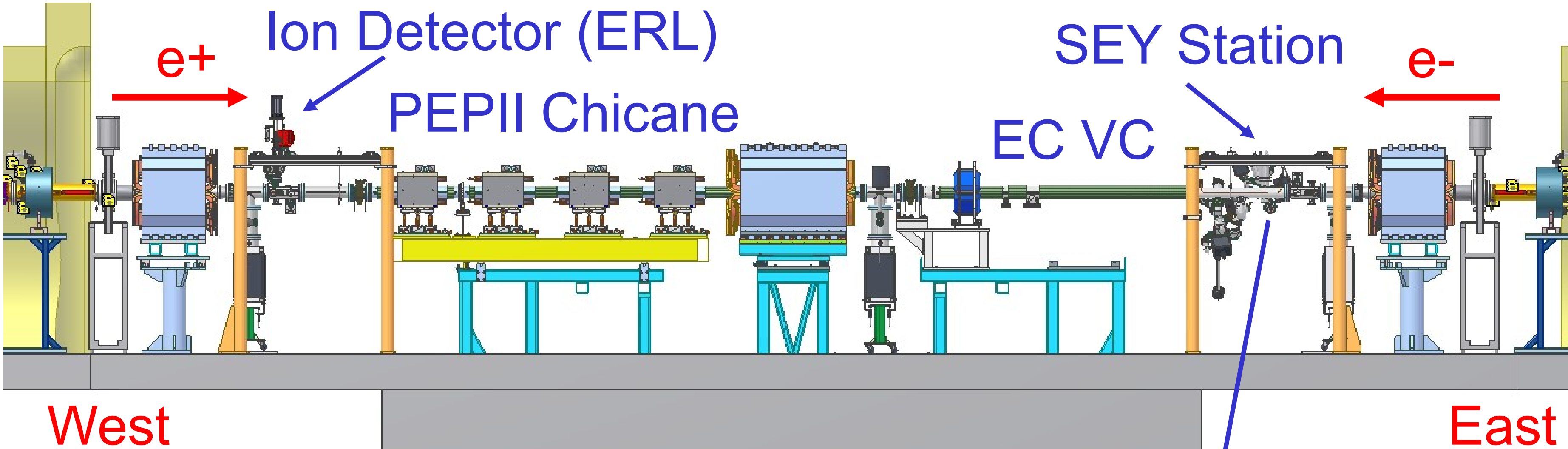


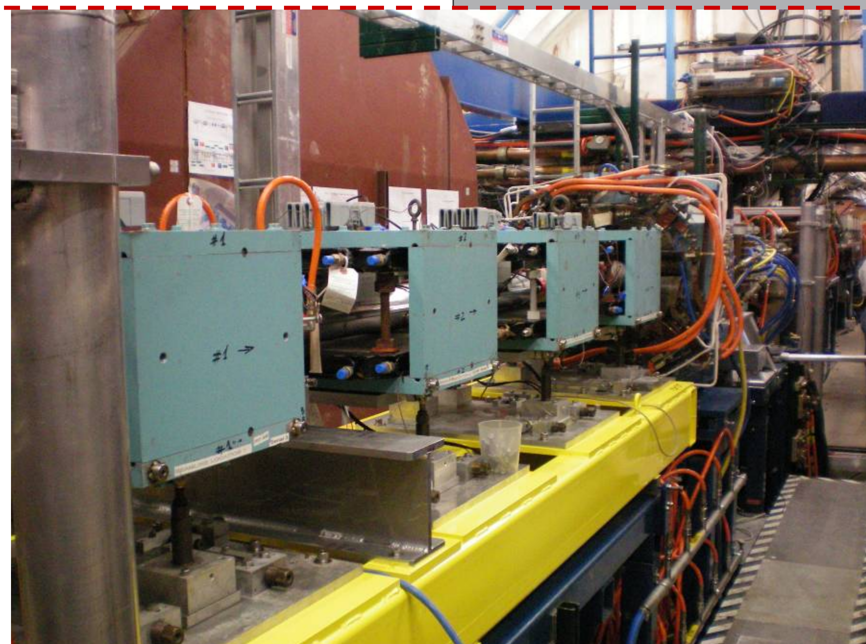


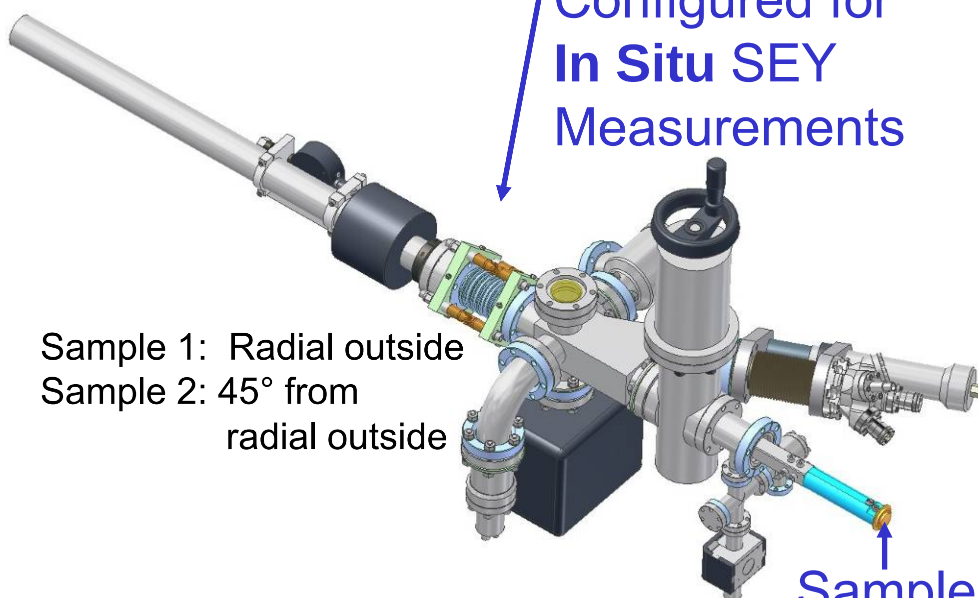


Source to Optics Box = 4.29 m,
Optics box to detector = 10.5m
m = 2.45

L3 Experimental Region



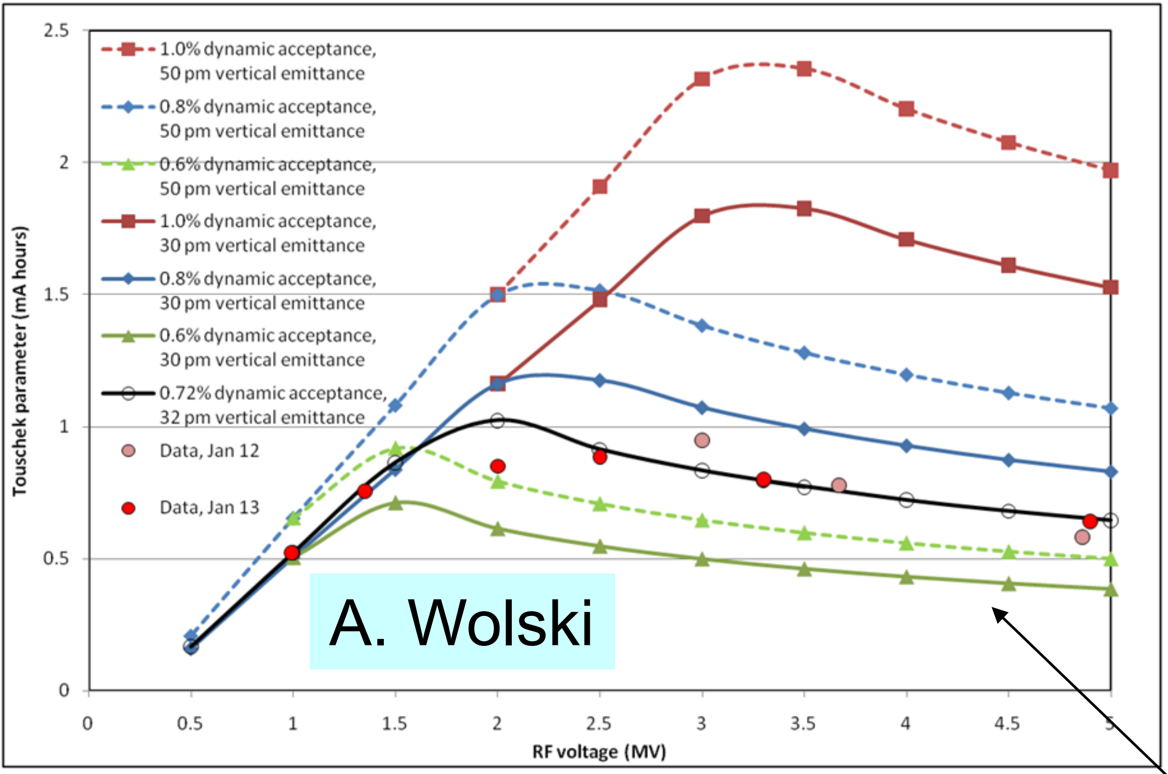




Optics and LET

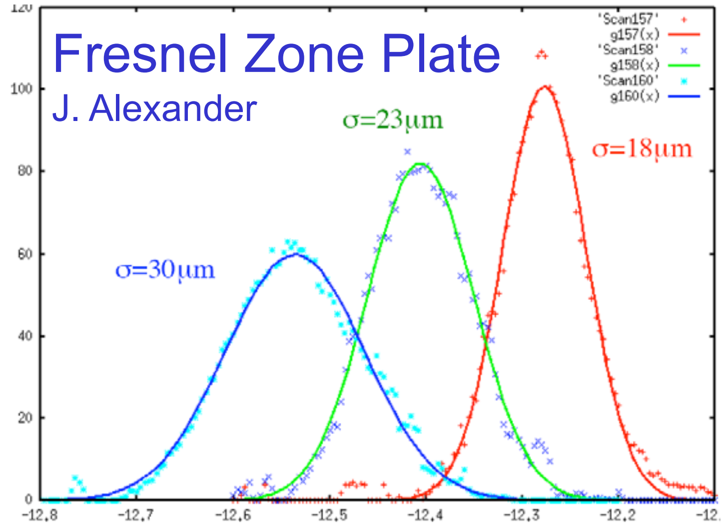
- Low emittance 2.085 GeV optics loaded and corrected
  - Correction methods tested
  - Beam-based alignment measurements
  - Coupling and dispersion bumps created for tuning
  - Magnet alignment
- Emittance measurements begun…
  - Touschek lifetime measurements initially used to characterize beam size
  - xBSM measurements carried out as detector and optics were characterized

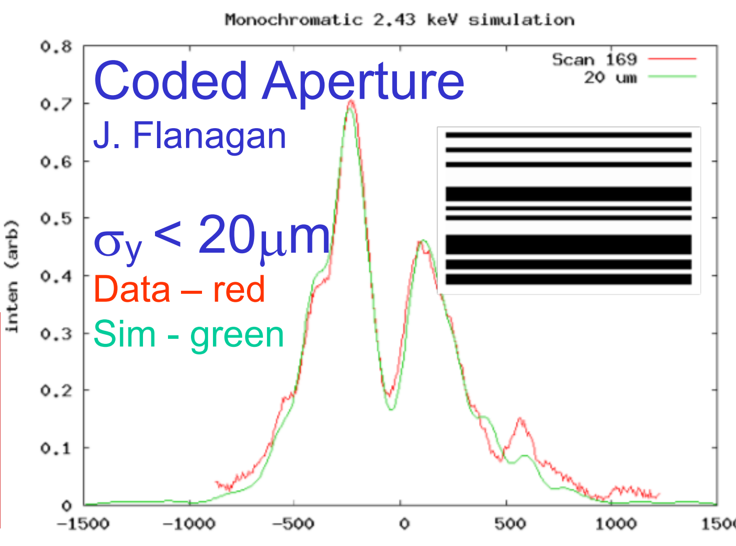
Emittance Characterization ⇨ Touschek Study ⇨ xBSM



$$\frac{di}{dt} = -\frac{i}{c} - \frac{i^2}{b} \qquad b = Touschek\ Parameter$$

Coupling Knob Scan





Energy acceptance = 0.7% $\rightarrow \varepsilon_v \sim 32$ pm
From xBSM smallest $\sigma_v \sim 15\pm5\ \mu m \rightarrow \varepsilon_v \sim 38$ pm
Within factor of two of 20 pm target…

Status of EC Studies

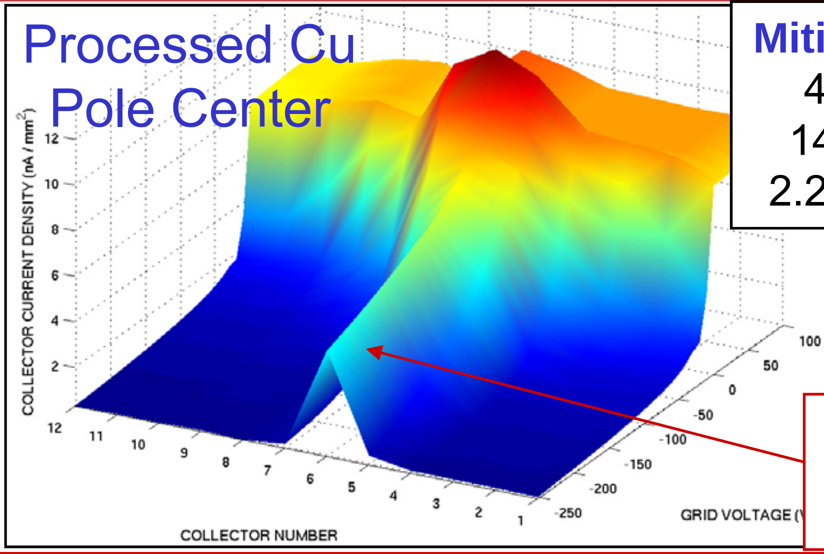
- Code Benchmarking (CLOUDLAND, ECLOUD, POSINST)
- RFA and TE Wave Measurements ⇨ Characterize local EC growth
  - EC Density Modeling
  - Measurements in wigglers, dipoles, quadrupoles and drifts
  - Wide parameter range: 2-5 GeV, various bunch train lengths, spacing and intensities, electrons and positrons
- Tune Shift & Witness Bunch Measurements ⇨ Characterize ring-wide EC for dynamics studies
  - Tune shifts characterize the integrated EC contributions around the ring
  - Parameter scans to constrain primary photoelectron and secondary electron emission models
  - Witness bunch studies characterize bunch behavior under a range of EC conditions
- EC Induced Instability Thresholds and Emittance Growth
  - Updated calculations for the ILC DR and CesrTA
  - Major focus of upcoming experimental runs

Cornell University
Laboratory for Elementary-Particle Physics

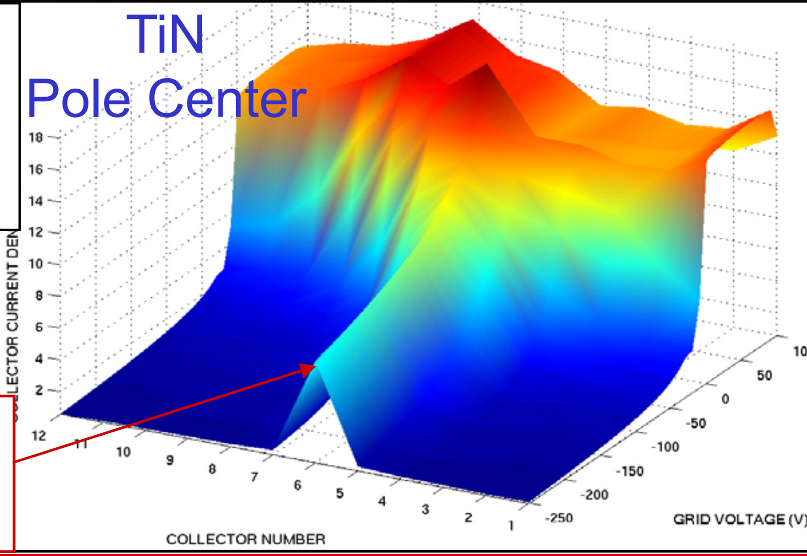
TE Wave & RFA Measurements in L0 Wiggler Straight

Mitigation Tests
45 bunches
14ns spacing
2.2×10^{10}/bunch

Processed Cu Pole Center

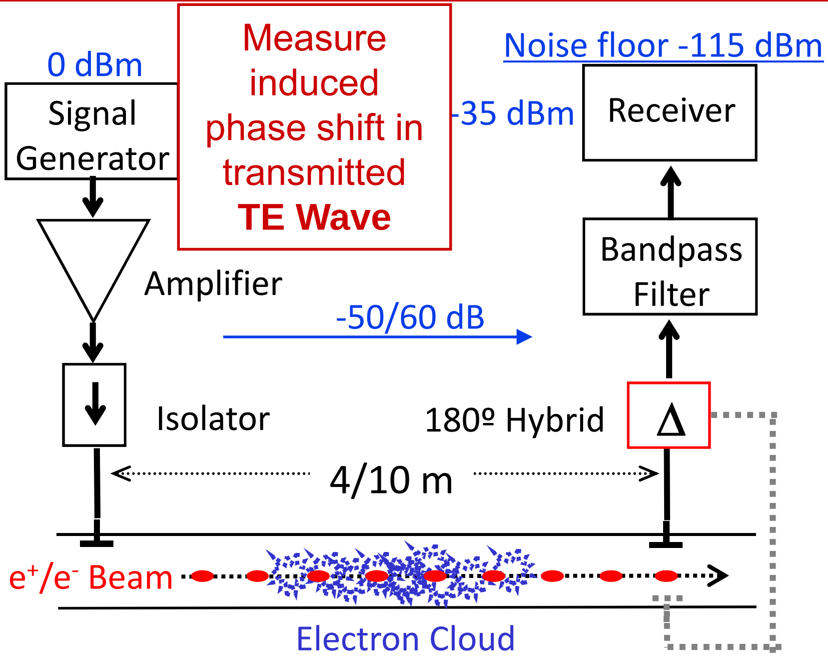


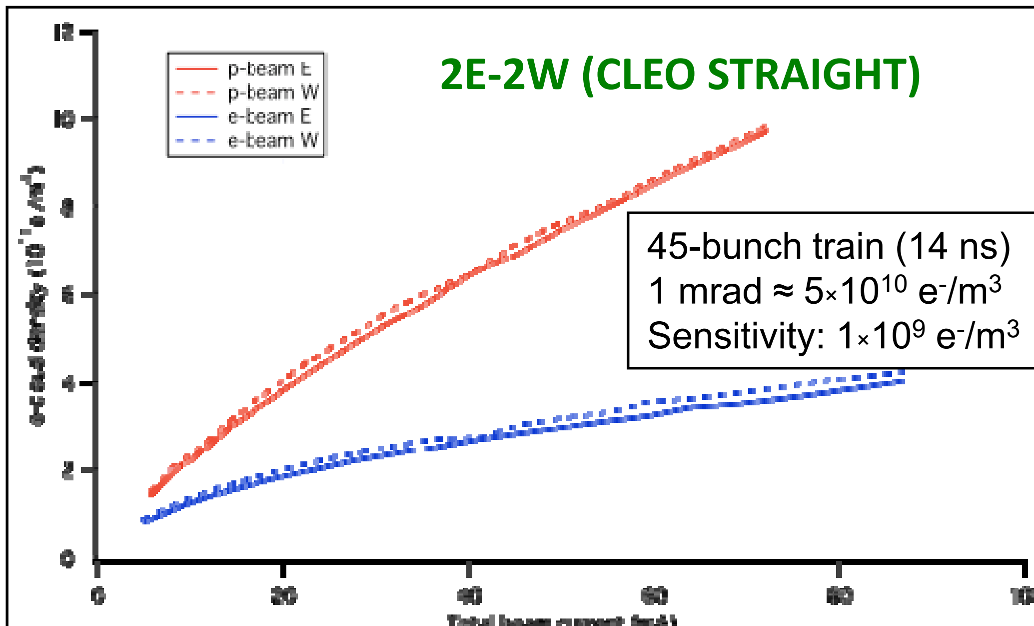
TiN Pole Center



Similar performance observed

Measure induced phase shift in transmitted **TE Wave**



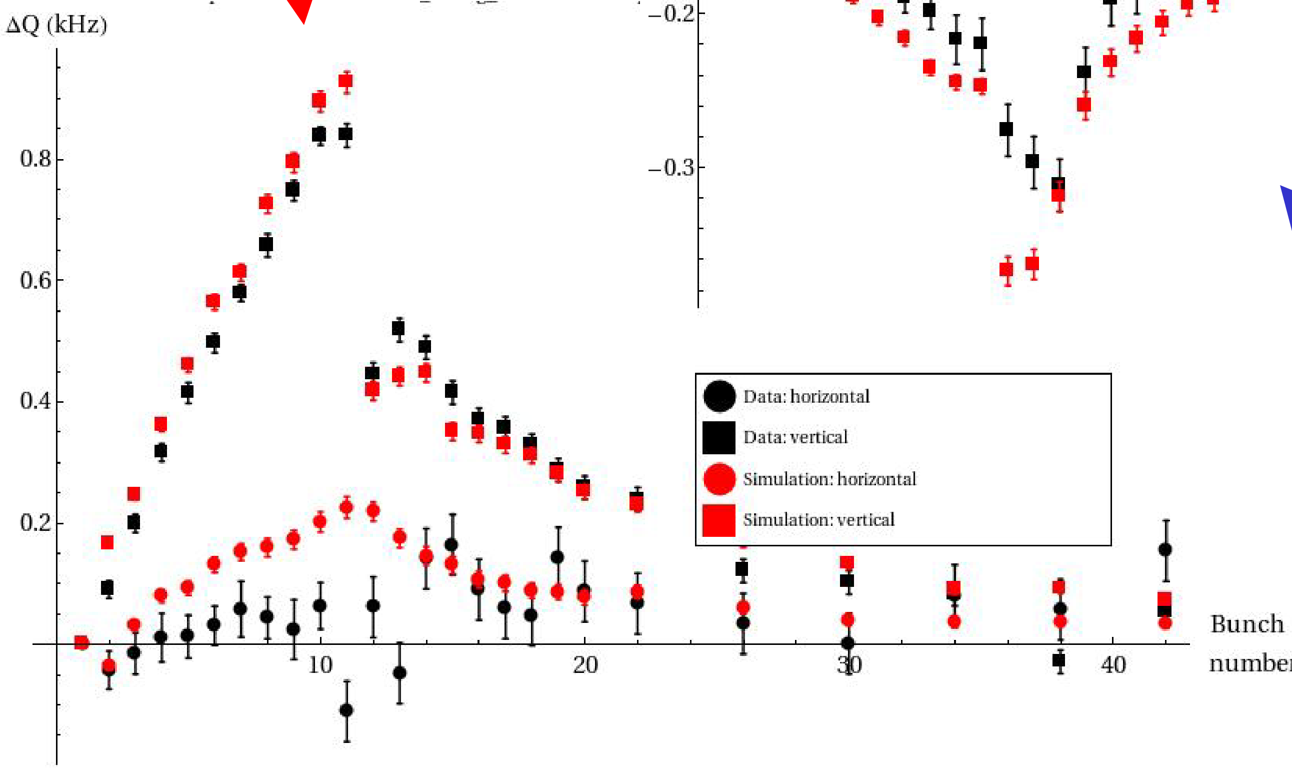


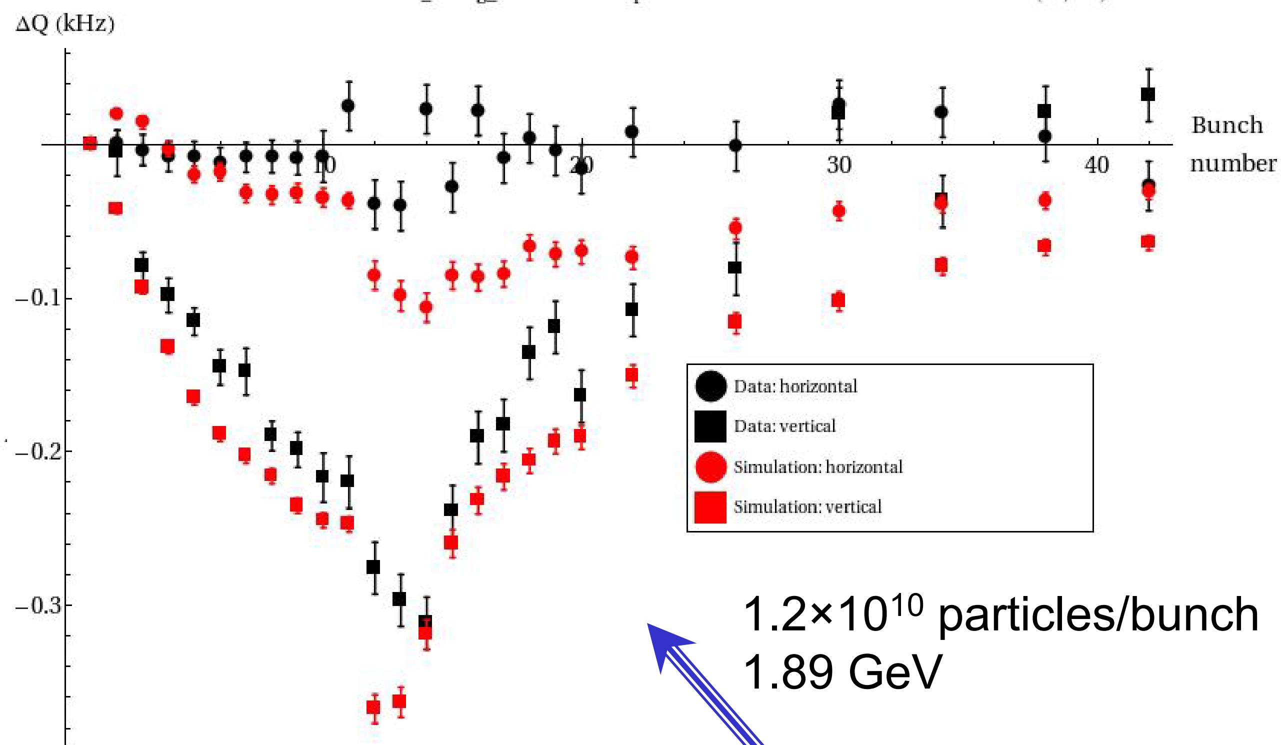
45-bunch train (14 ns)
1 mrad ≈ 5×10^{10} e⁻/m³
Sensitivity: 1×10^{9} e⁻/m³

Coherent Tune Shifts

10 Bunch Train with Trailing Witness Bunches

Positron Beam





1.2×10^{10} particles/bunch
1.89 GeV

Electron Beam

Data-POSINST Comparison

Summary

- Low Emittance Tuning and Vertical Emittance Demonstration
  - **Progress at both ATF and CesrTA towards emittance targets**
  - **Efforts underway for closer collaboration to achieve ultimate goals at both facilities**
  - **Low emittance tuning and measurement tools will be of general benefit to the accelerator community**
- Beam Dynamics Issues – FII and EC
  - **ATF will be in a position for the next series of FII measurements next month**
  - **CesrTA focus shifting from upgrades to experimental measurements**
    - Mitigation studies underway – arrival of chambers with new mitigations from CERN, LBNL, SLAC over the next 2 months
    - Instability and incoherent emittance growth studies will be a principal focus for last half of 2009
- Fast Kickers
  - **Beam demonstration effort continues at KEK**
  - **Development of a *reliable* fast pulser will continue to be a high priority R&D task**
- Integration of R&D Results into the ILC Damping Rings Design
  - **Improved projections (based on new measurements) for DR instabilities and emittance growth issues expected during 2010**
  - **Technical inputs for design (vacuum and feedback systems) available on the same timescale**
  - **Results applicable to both the 6.5 km baseline design as well as the proposed 3 km ring with fewer bunches**