Cornell University
Laboratory for Elementary-Particle Physics

Linear Collider Activities at CesrTA

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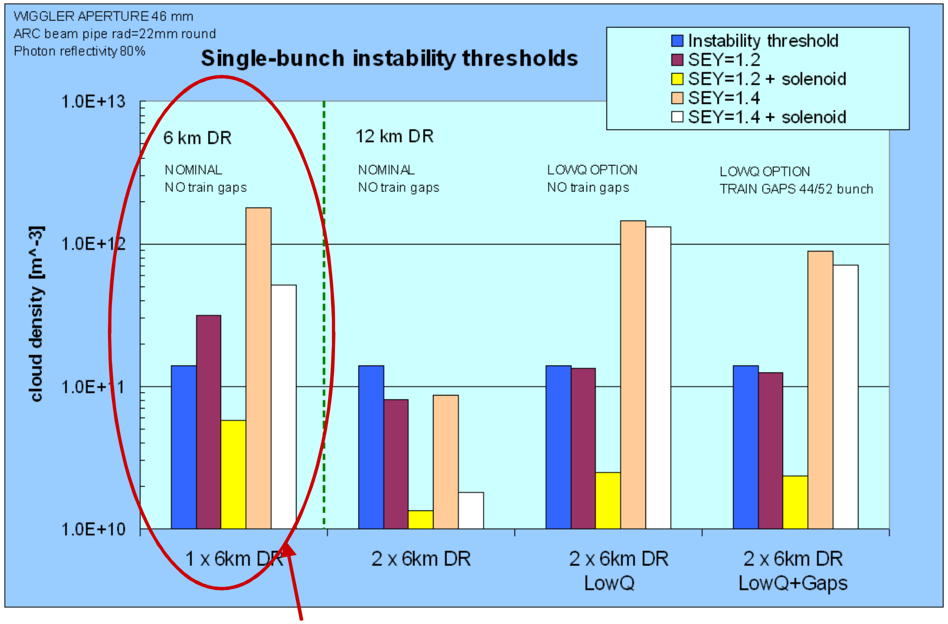
for the CesrTA Collaboration

CLIC09 Workshop

Outline

- CesrTA Program
  - Context, Goals, Parameters
  - Reconfiguration & Upgrades
  - Status and Schedule
- Recent Efforts
  - LET
  - EC Measurements
  - Collaboration
- Future Plans
- Conclusion

Electron Cloud in the ILC DR



- ILCDR06 Evaluation
  - M. Pivi, K. Ohmi, *etal.*
  - Single ~6km positron DR
    - Nominal ~2625 bunches with 6ns bunch spacing and $N_b=2\times10^{10}$
    - Requires SEY values of vacuum chamber surfaces with $\delta_{max}\leq1.2$ (assuming solenoid windings in drift regions) in order to operate below EC instability thresholds
    - Dipole and wiggler regions of greatest concern for EC build-up

- In 2007, the ILC R&D Board's S3 Task Force identified a set of critical research tasks for the ILC DR, including:
  - Characterize EC build-up
  - Develop EC suppression techniques
  - Develop modelling tools for EC instabilities
  - Determine EC instability thresholds
- CesrTA program targets:
  - Measurements with positron beams at ultra low emittance to validate projections to the ILC DR operating regime
  - Validation of EC mitigation methods that will allow safe operation of the baseline DR design and the possibility of performance improvements and/or cost reductions

CesrTA Goals

- Key Elements of the CesrTA R&D Program:
  - Studies of Electron Cloud Growth and Mitigation
    - Study EC growth and methods to mitigate it, particularly in the wigglers and dipoles which are of greatest concern in the ILC DR design.
    - Use these studies to benchmark and expand existing simulation codes and to validate our projections for the ILC DR design.
  - Studies of EC Induced Instability Thresholds and Emittance Dilution
    - Measure instability thresholds and emittance growth due to the EC in a low emittance regime approaching that of the ILC DR.
    - Validate EC simulations in the low emittance parameter regime.
    - Confirm the projected impact of the EC on ILC DR performance.
  - Low Emittance Operations
    - Support EC studies with beam emittances approaching those specified for the ILC DR (CesrTA vertical emittance target: ε_y<20 pm-rad with ε_x=2.5nm @ 2GeV).
    - Implement beam instrumentation needed to achieve and characterize ultra low emittance beams
      - x-Ray Beam Size Monitor targeting turn-by-turn, bunch-by-bunch readout capability
      - Beam Position Monitor upgrade
    - 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
    - Provide sufficient running time to commission hardware, carry out planned experiments, and explore surprises ⇨ ~240 running days over a 2+ year period

CesrTA Parameters

Lattice Parameters

Ultra low emittance baseline lattice

Energy [GeV]	2.085	5.0	5.0
No. Wigglers	12	0	6
Wiggler Field [T]	1.9	—	1.9
Q_x	14.57		
Q_y	9.62		
Q_z	0.075	0.043	0.043
V_{RF} [MV]	8.1	8	8
ε_x [nm-rad]	2.5	60	40
$\tau_{x,y}$ [ms]	57	30	20
α_p	6.76×10^{-3}	6.23×10^{-3}	6.23×10^{-3}
σ_l [mm]	9	9.4	15.6
σ_E/E [%]	0.81	0.58	0.93
t_b [ns]	≥4, steps of 2		

Range of optics implemented

Beam dynamics studies

Control photon flux in EC experimental regions

E[GeV]	Wigglers (1.9T/PM)	ε_x[nm]
1.8*	12/0	2.3
2.085	12/0	2.5
2.3	12/0	3.3
3.0	6/0	10
4.0	6 /0	23
4.0	0 /0	42
5.0	6/0	40
5.0	0/0	60
5.0	0/2	90

IBS Studies (first three rows)

* Orbit/phase/coupling correction and injection but no ramp and recovery. In all other optics there has been at least one ramp and iteration on injection tuning and phase/coupling correction

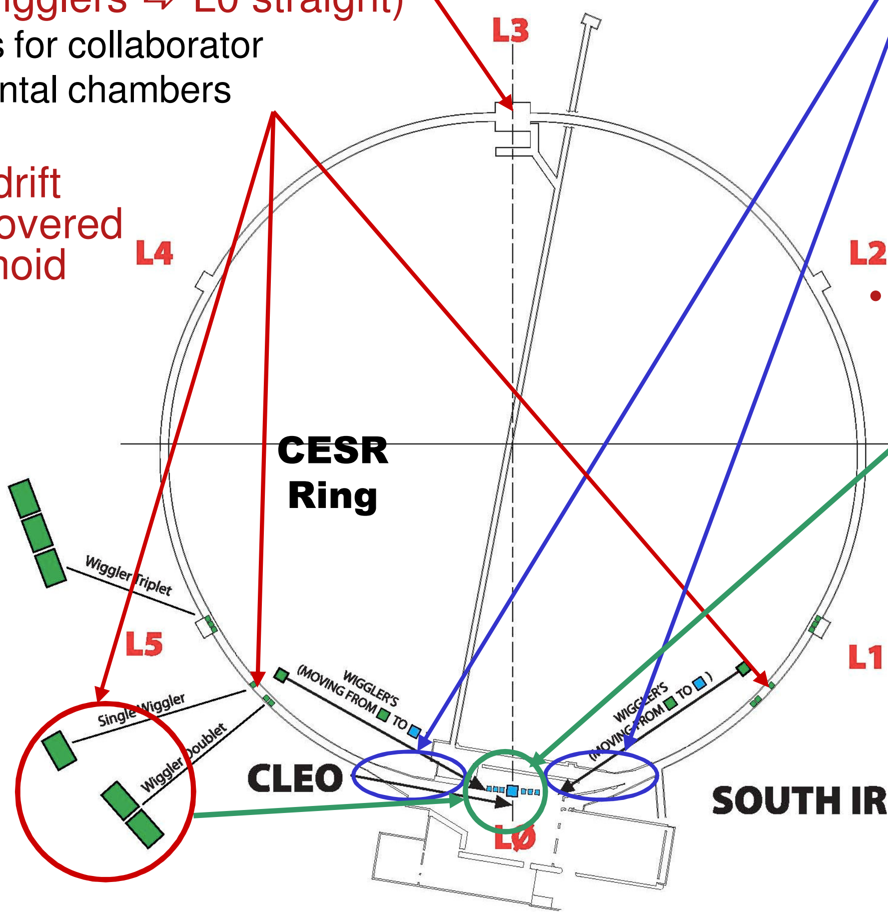
Unique Features of R&D at CESR

CESR offers:

- An operational wiggler-dominated storage ring
- The CESR-c superconducting damping wigglers
  - Technology choice for the ILC DR baseline design
    - Physical aperture: Acceptance for the injected positron beam
    - Field quality: Critical for providing sufficient dynamic aperture in the damping rings
- Flexible operation with ***positrons*** *and* ***electrons***
- Flexible bunch spacing suitable for damping ring tests (≥ 4ns)
- Flexible energy range from 1.5 to 5.5 GeV for EC growth and beam dynamics studies
- Dedicated focus on damping ring R&D for significant running periods during the funding period
  - Support for collaborator experiments
  - Support for electron cloud hardware (eg, PEP-II experimental hardware has been re-deployed in CESR to complete the SLAC measurement program)
- A useful set of damping ring research opportunities…
  - The ability to operate with positrons and with the CESR-c damping wigglers offers a unique experimental reach in the low emittance regime

CESR Reconfiguration

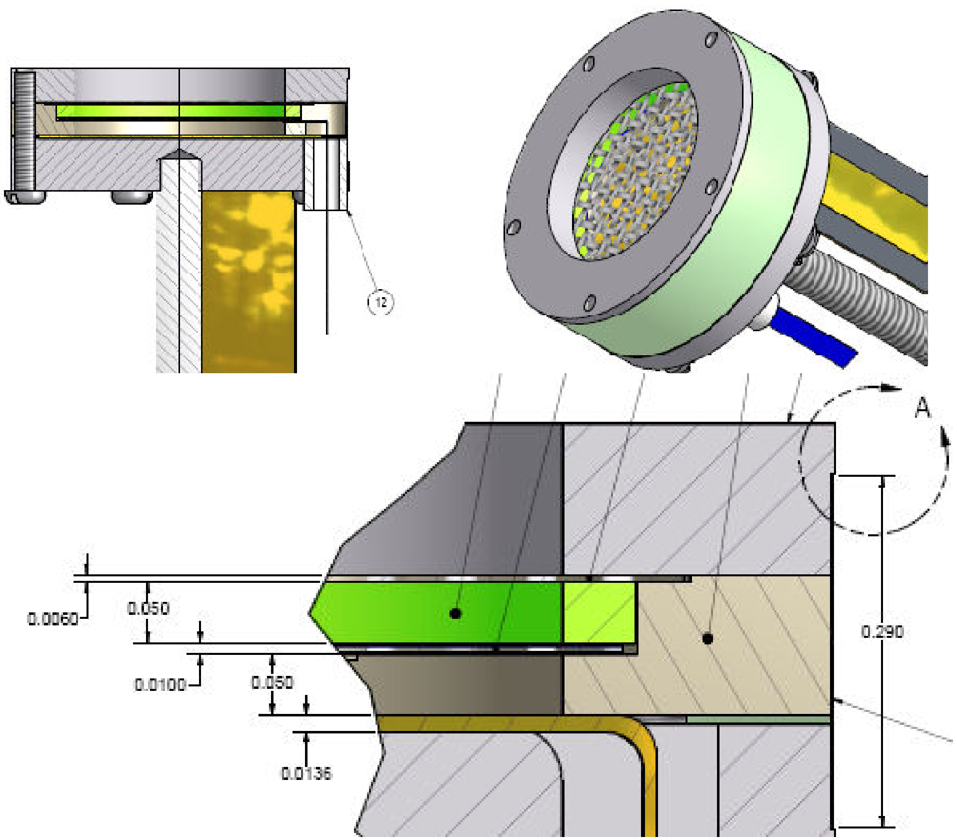
- L3 EC experimental region
  - PEP-II EC Hardware: Chicane, upgraded SEY station
  - Drift and Quadrupole diagnostic chambers
- New EC experimental regions in arcs (wigglers ⇨ L0 straight)
  - Locations for collaborator experimental chambers
- ~80% of drift regions covered with solenoid windings



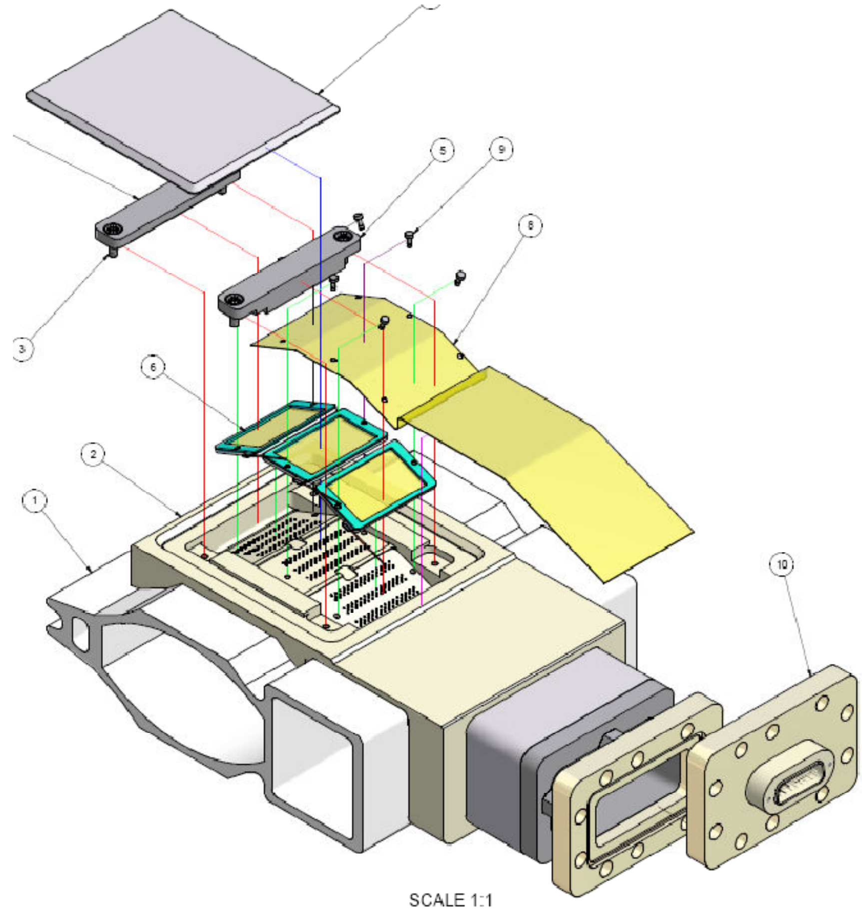
- CHESS C-line & D-line Upgrades
  - Windowless (all vacuum) x-ray line upgrade
  - Dedicated optics box at start of each line
  - Detectors share space in CHESS user hutches
- L0 region reconfigured as a wiggler straight
  - CLEO detector sub-systems removed
  - 6 wigglers moved from CESR arcs to zero dispersion straight
  - Region instrumented with EC diagnostics and mitigation
  - Wiggler chambers with retarding field analyzers and various EC mitigation methods (fabricated at LBNL in CU/SLAC/KEK/LBNL collaboration)

Thin RFA Design

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

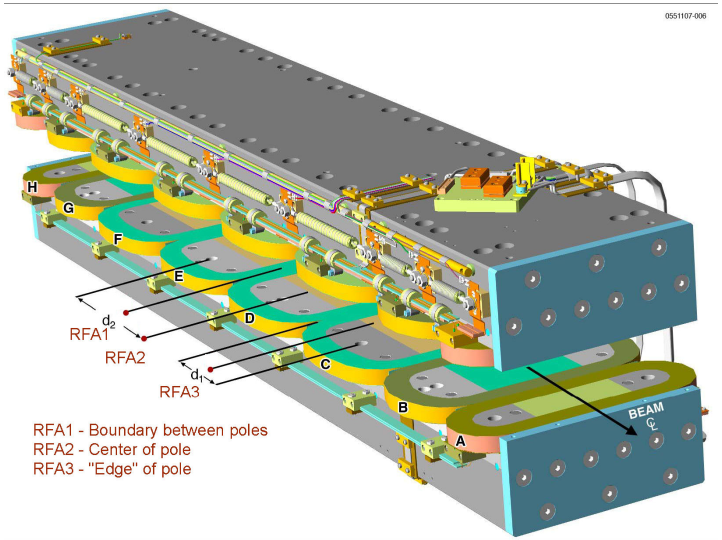


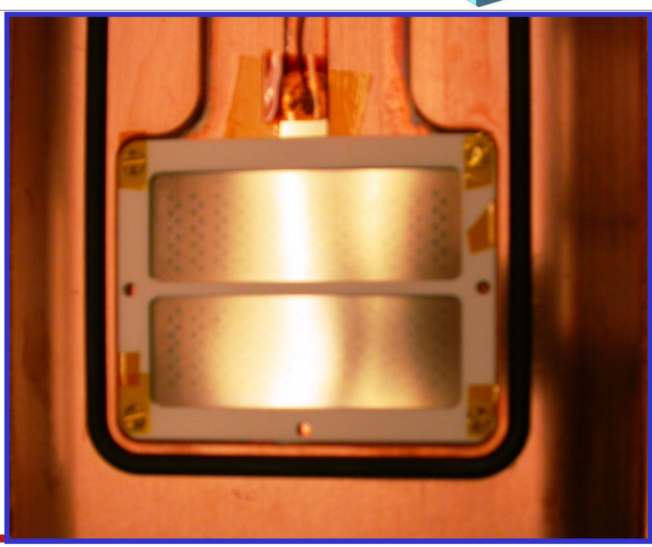
- Application to CESR Dipole

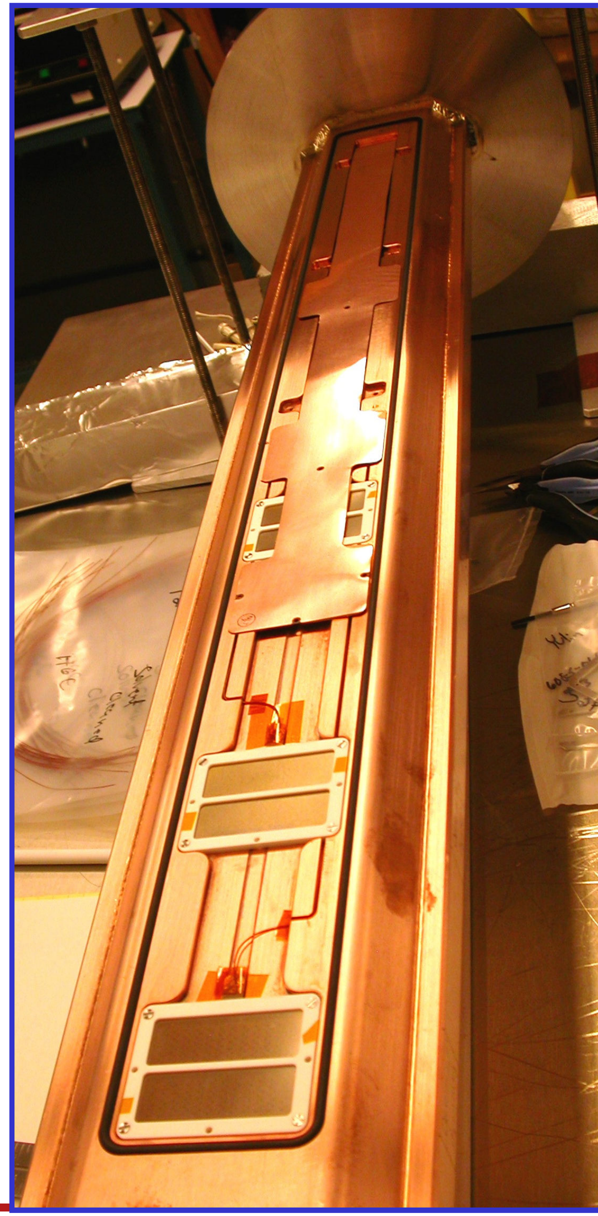


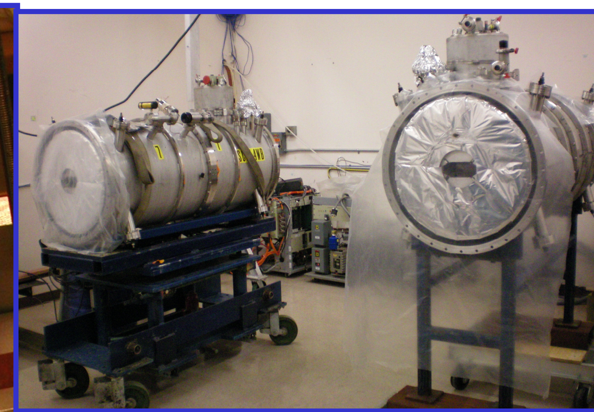
Upgrade Activities: Instrumented Wigglers

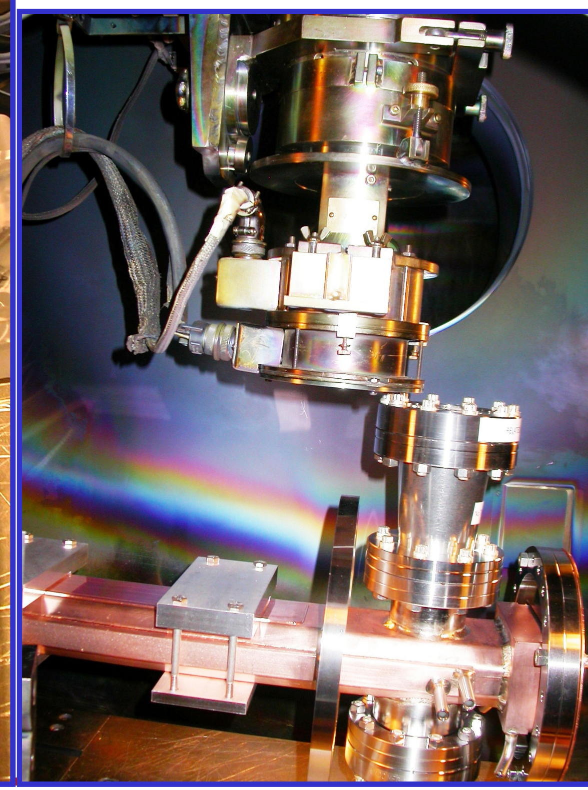
- Superferric wigglers (1.7-2.1T)
- Cu, TiN-coated, Grooved VCs



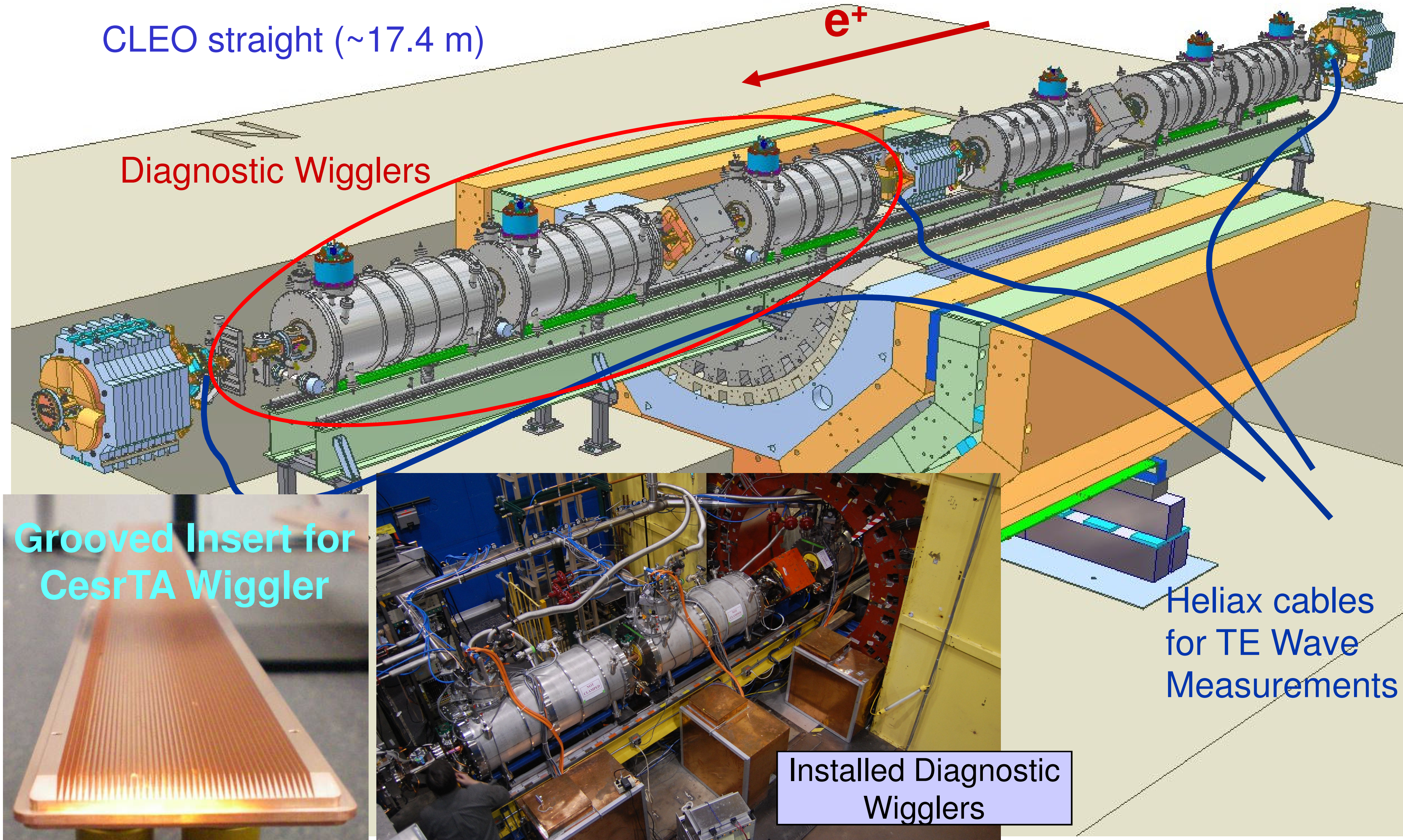




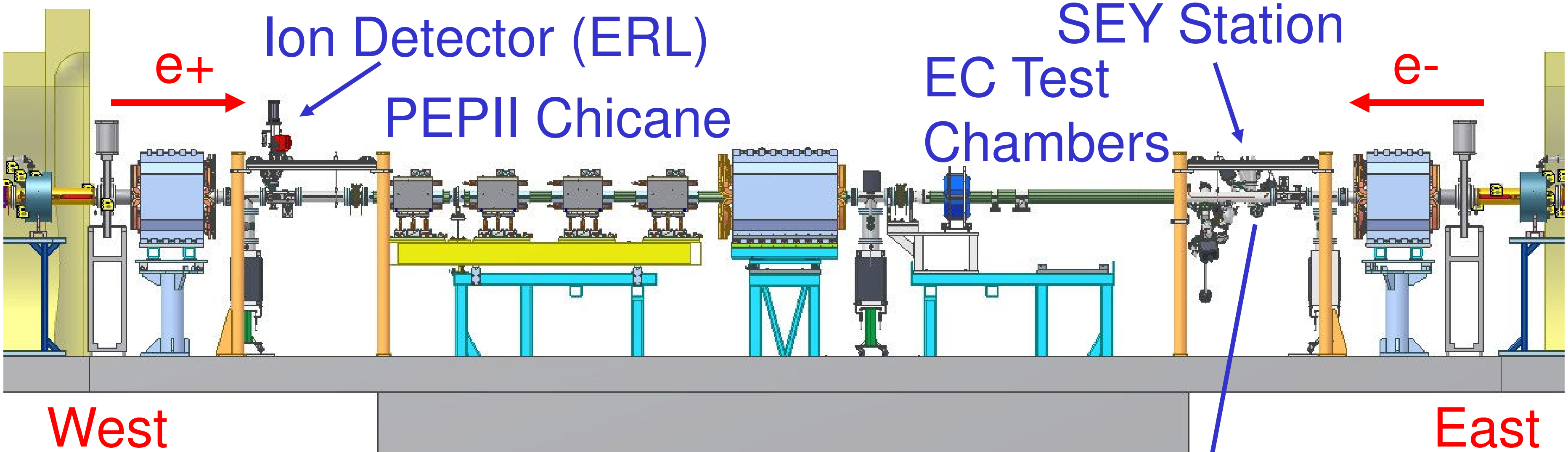


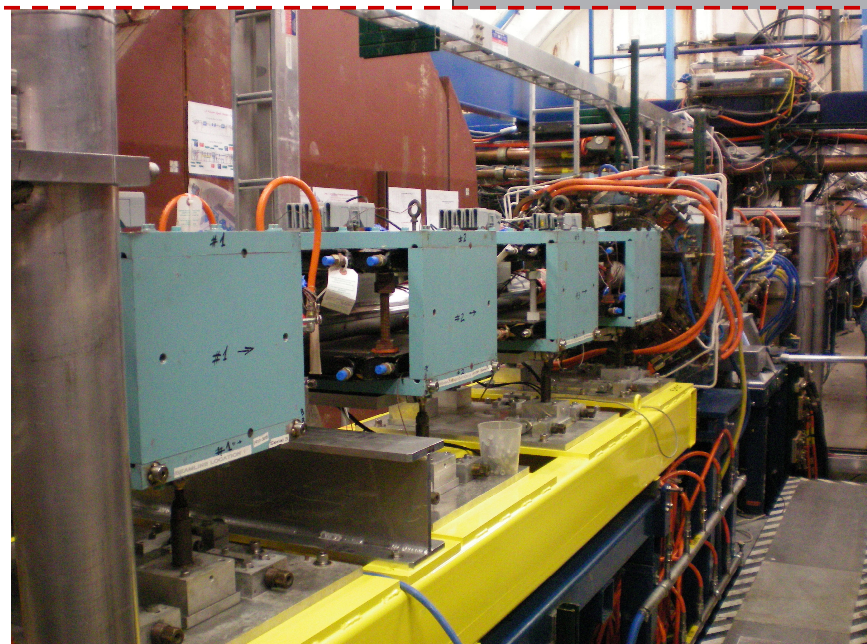


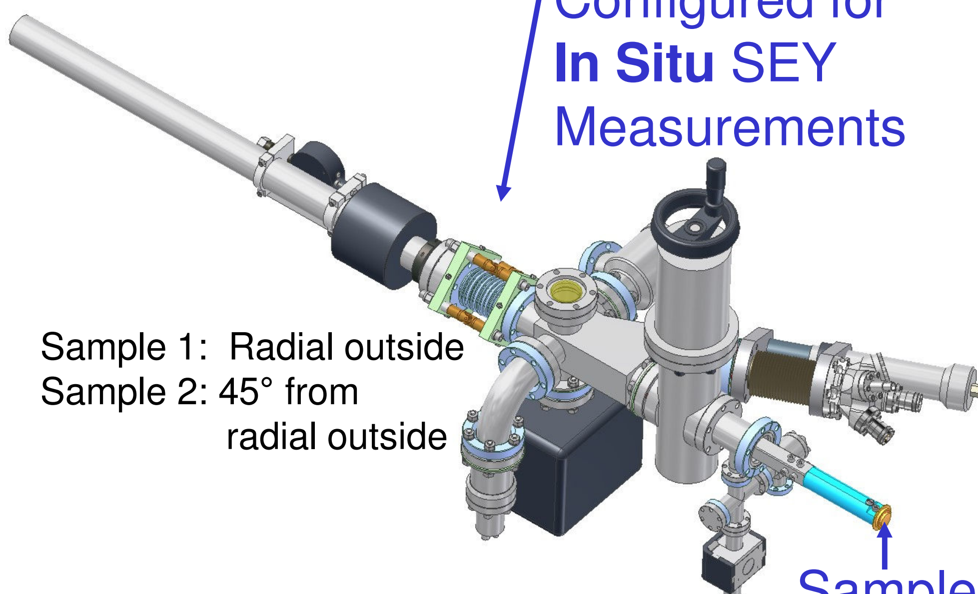
L0 Experimental Region



L3 Experimental Region

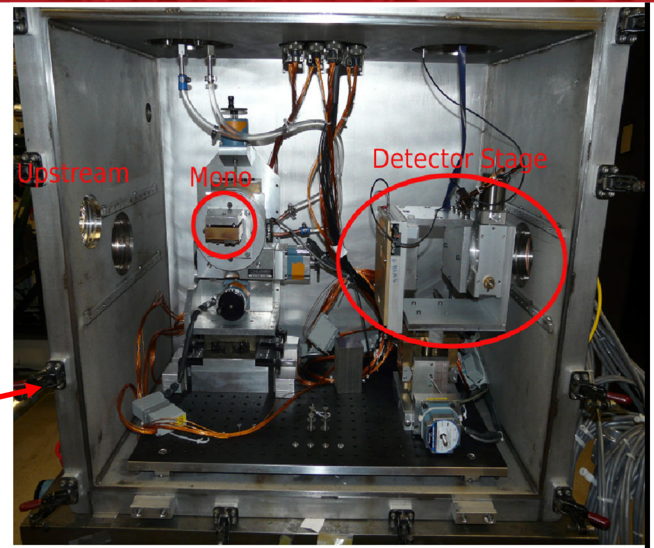


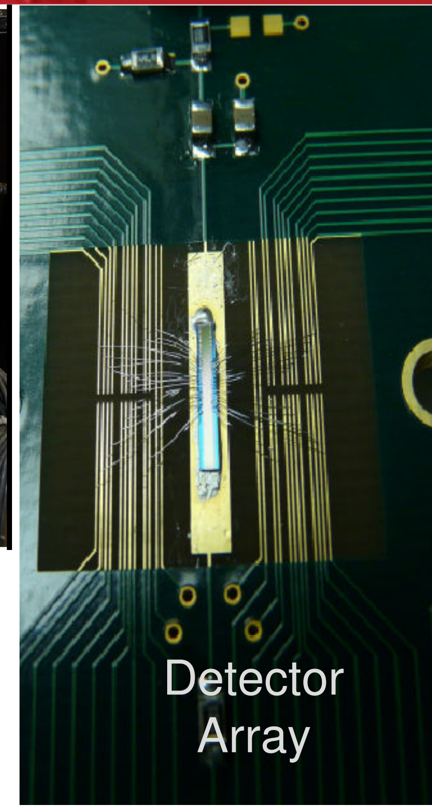


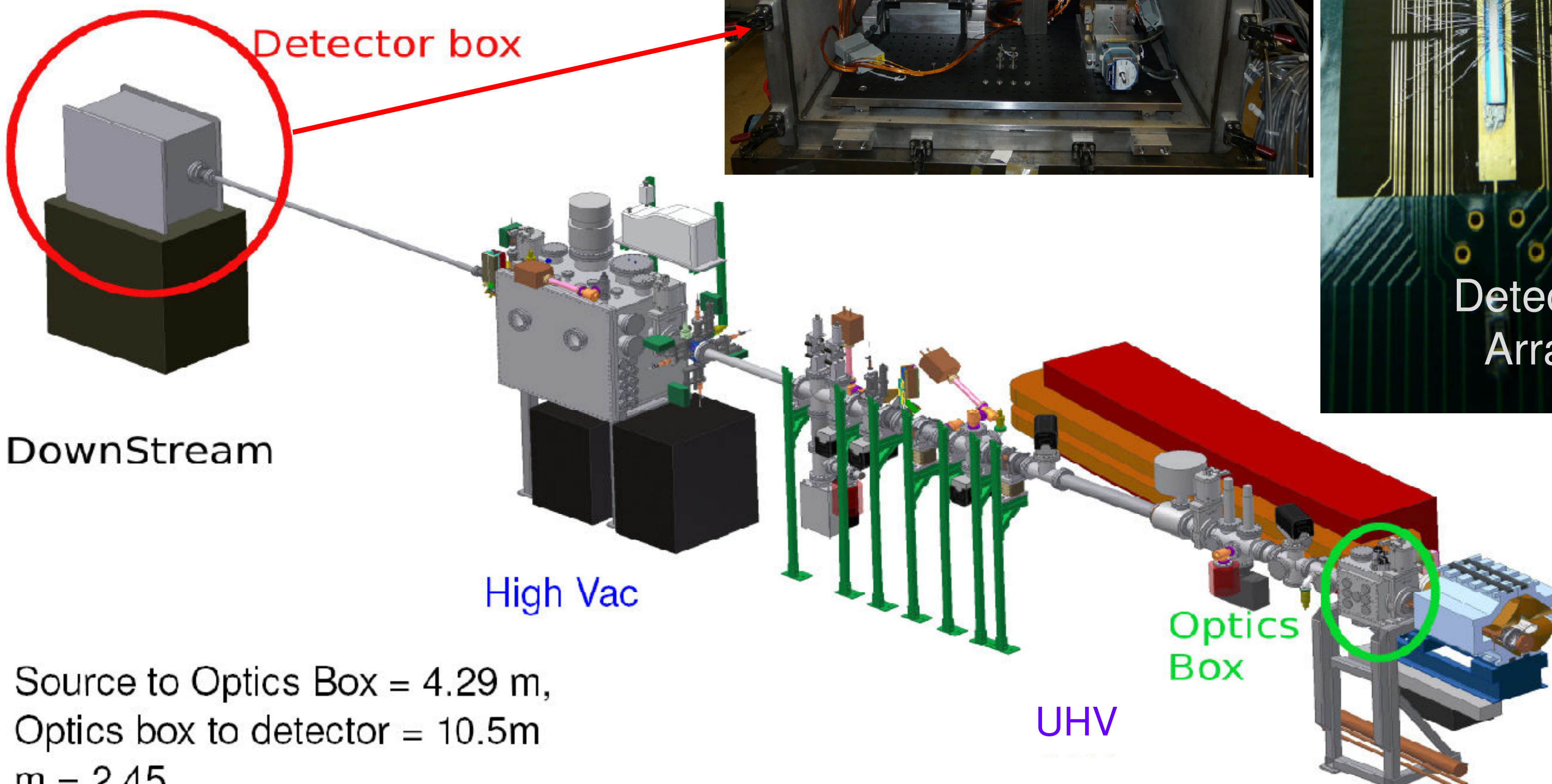


Upgrade Activities: xBSM Optics Lines & Detector

- All-vacuum optics lines for e+ and e- beams in collaboration with CHESS
- Detectors capable of single-pass bunch-by-bunch beam size measurements

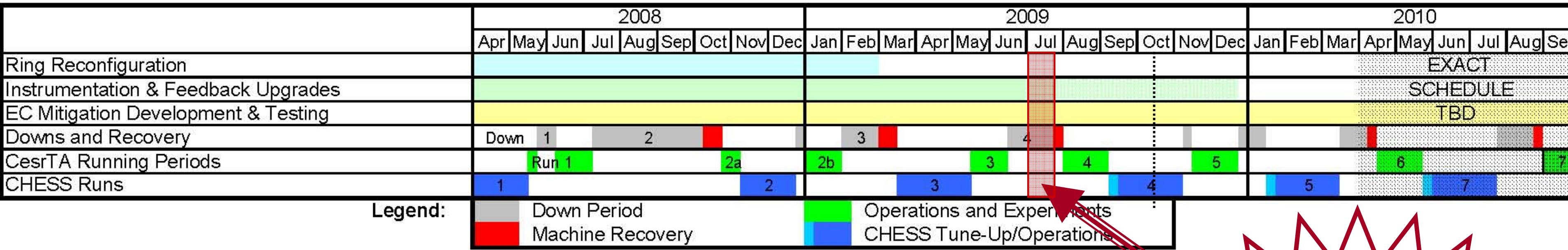






Source to Optics Box = 4.29 m,
Optics box to detector = 10.5m
m = 2.45

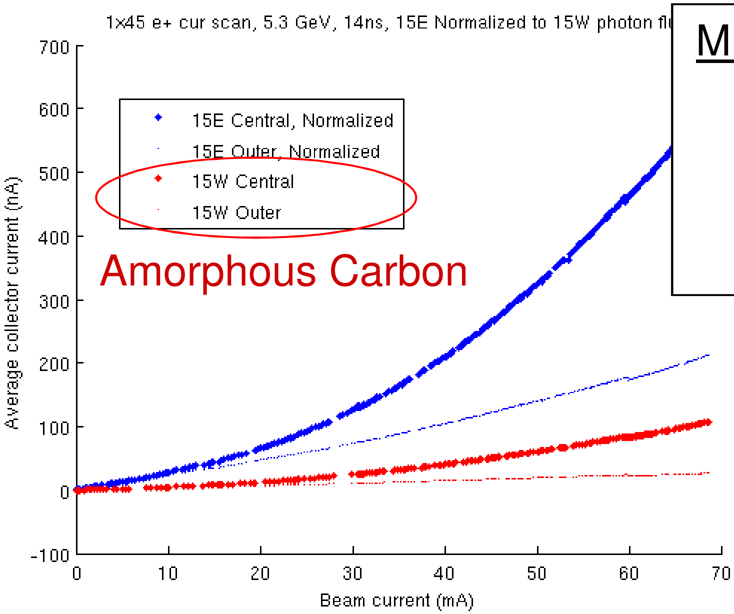
CesrTA Schedule



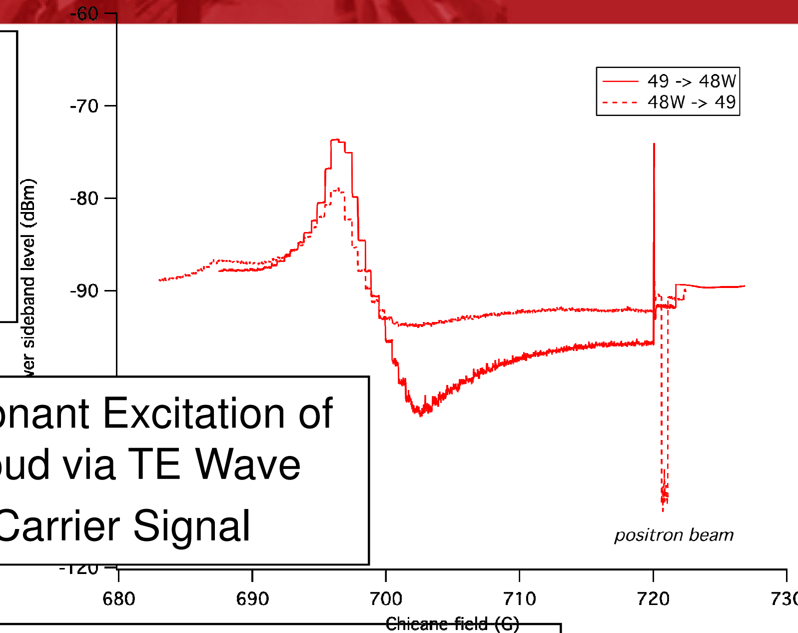
Bulk of upgrades completed by mid-2009 ⇨ enables an experimental focus thru mid-2010

- 4 Major Thrusts:
  - Ring Reconfiguration: Vacuum/Magnets/Controls Modificati
  - Low Emittance R&D Support
    - Instrumentation: BPM system and high resolution x-ray Beam
    - Survey and Alignment Upgrade
  - Electron Cloud R&D Support
    - Local EC Measurement Capability: RFAs, TE Wave Measurement Pickups
    - Feedback System upgrade for 4ns bunch trains
    - Photon stop for wiggler tests over a range of energies
    - Local SEY measurement capability
  - Experimental Program
    - Targeting 7 runs spread over a 2+ year period
    - Early results will feed into final stages of program
- Schedule coordinated with Cornell High Energy Synchrotron Source (CHESS) operations

A Few "Log Book" Snapshots

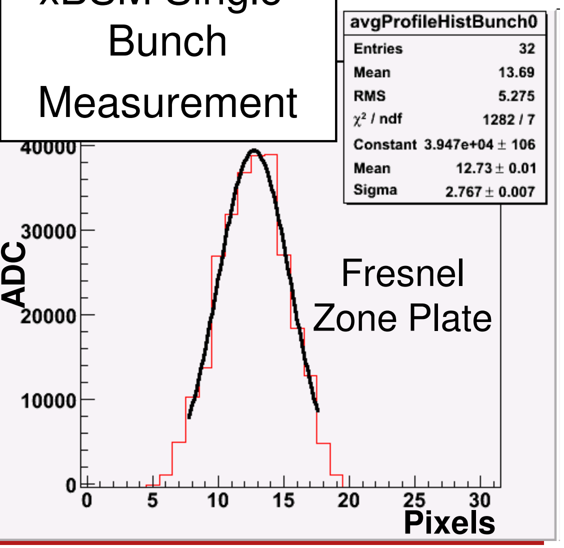


Mitigation Checks
Amorphous C-Coated VC (CERN)
vs Al VC

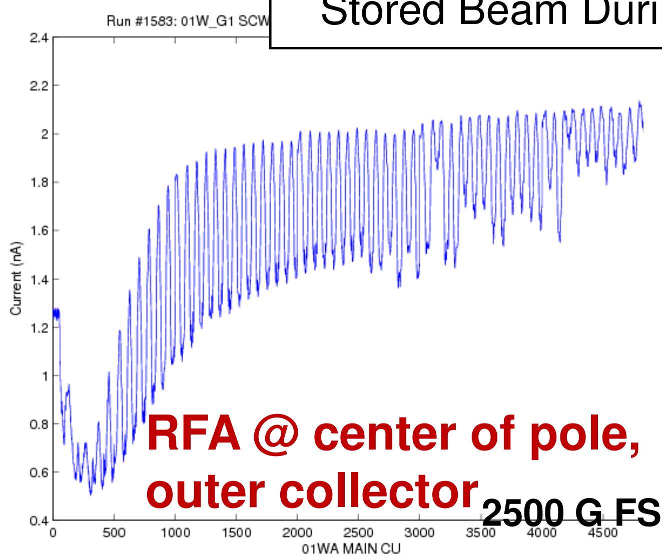


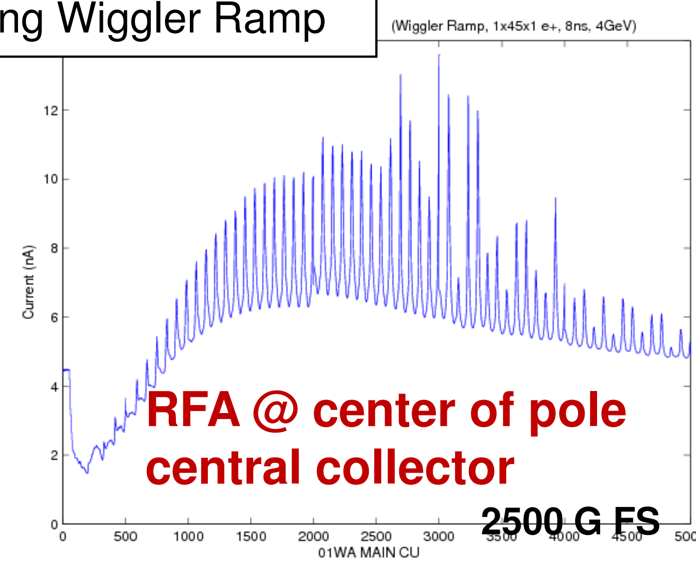
Resonant Excitation of Cloud via TE Wave Carrier Signal

xBSM Single-Bunch Measurement



Cyclotron Resonances
Stored Beam During Wiggler Ramp

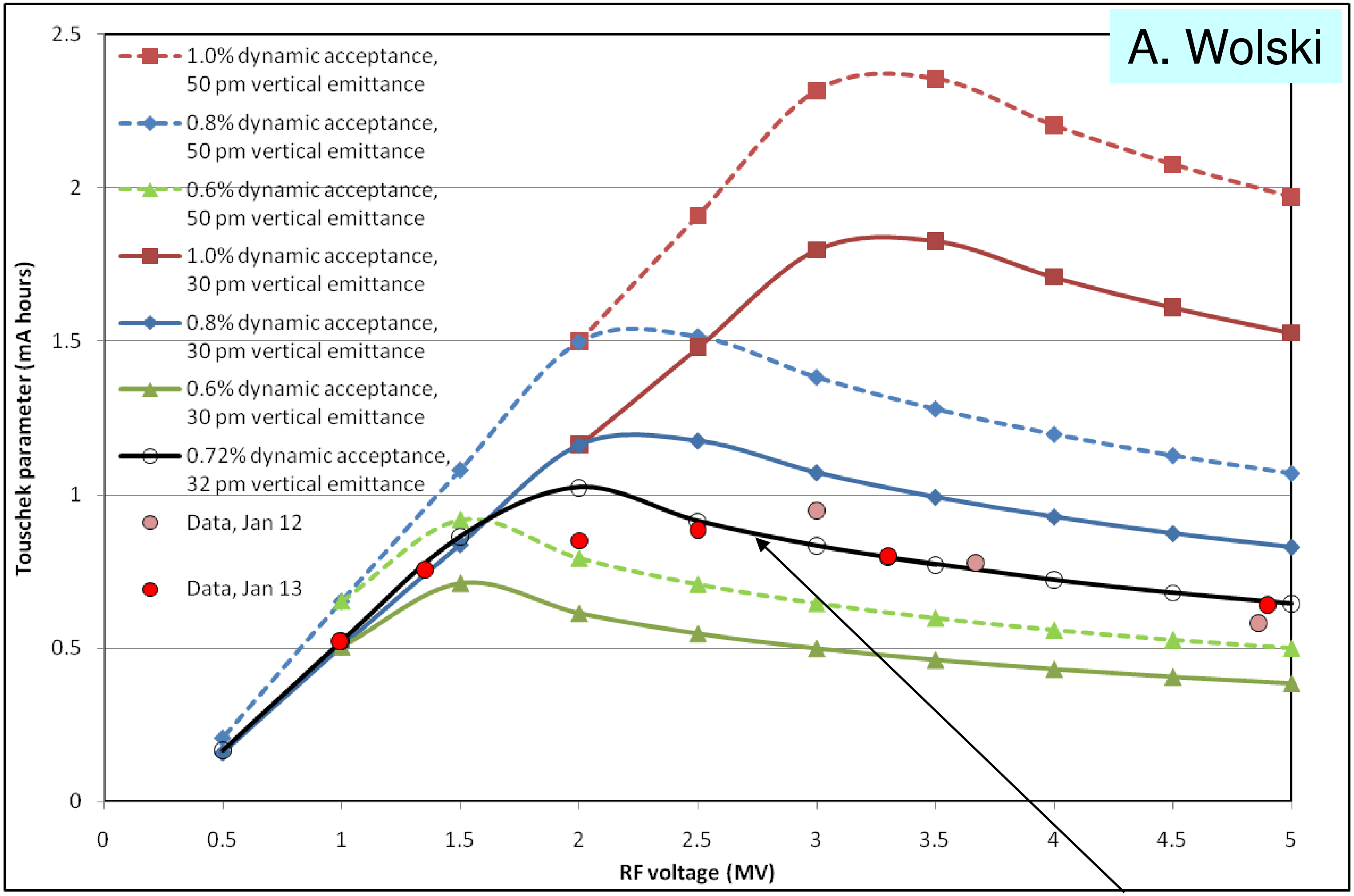




Optics and LET

- Low emittance 2.085 GeV optics (as well as others) have been loaded and corrected
  - Correction methods tested
  - Beam-based alignment measurements
  - Coupling and dispersion bumps created for tuning
- Emittance measurements have begun…
  - Touschek lifetime measurements initially used to characterize beam size
  - xBSM measurements carried out as detector and optics were characterized
- Ongoing program of magnet alignment and instrumentation (xBSM, BPM) upgrades to correct and monitor emittance
- Major focus of upcoming Nov-Dec 2009 run

First Detailed Optics Correction ⇨ Touschek Study ⇨ xBSM Measurement



Preliminary

Measured energy acceptance = 0.7% → ε_v ~ 32 pm
From xBSM σ_v ~ 15±5 μm → ε_v ~ 38 pm
Within factor of two of 20 pm target…

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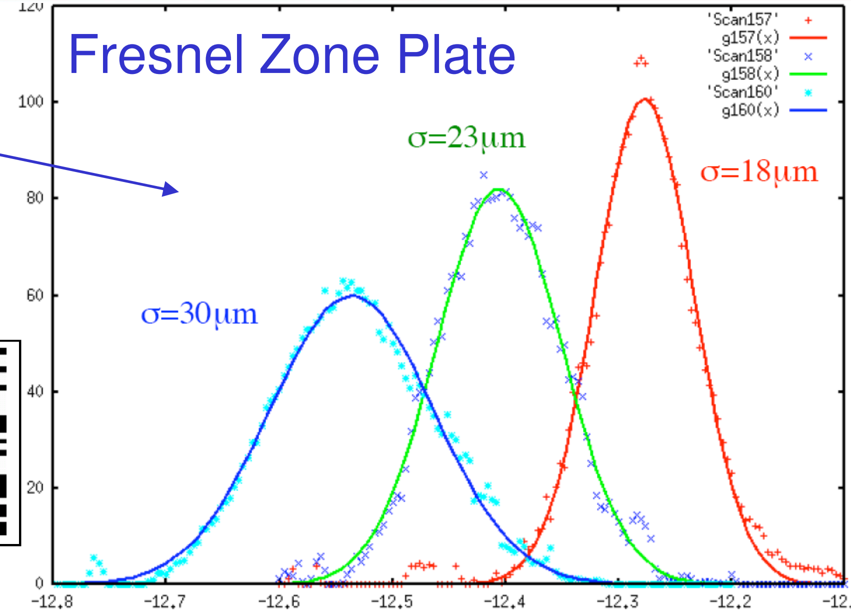
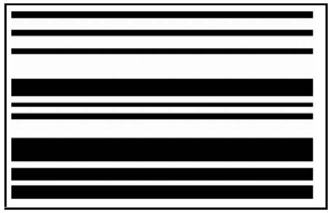
xBSM Snapshots

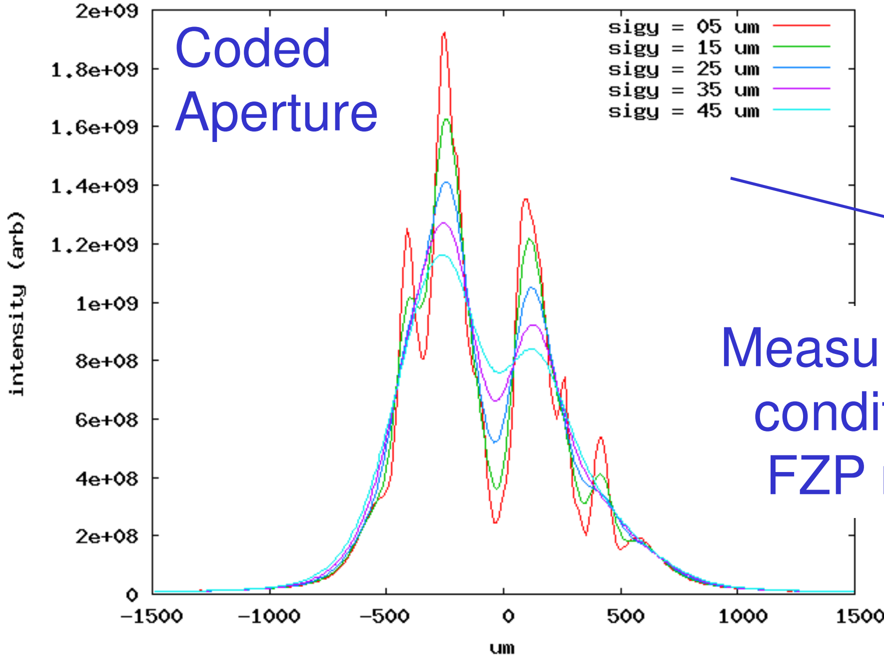
- Scan of coupling knob
- Coded aperture measurements
- Smallest recorded size:
  ~15 μm (but further calibration work needed)



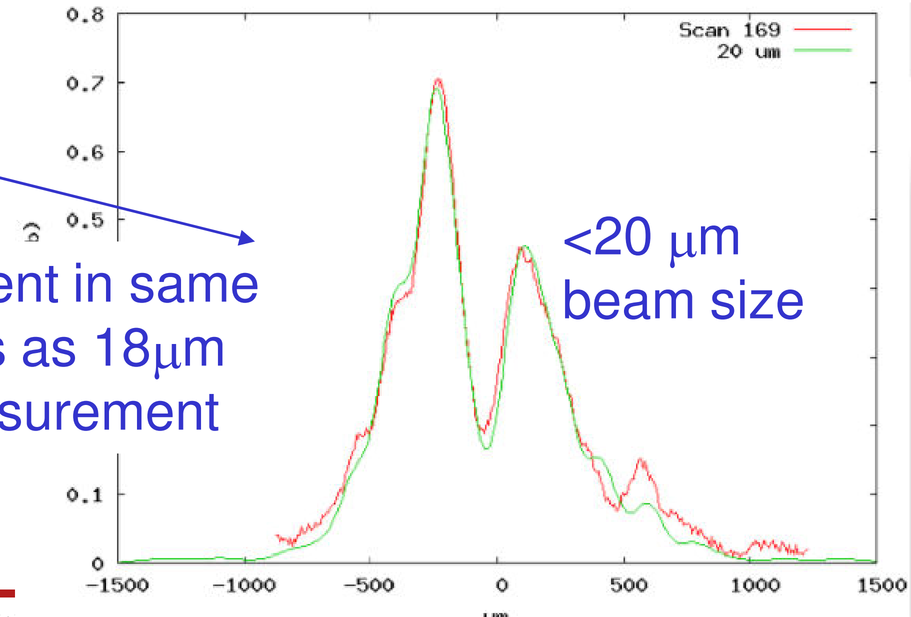
CA Structure



Simulations



Measurement in same conditions as 18μm FZP measurement



<20 μm beam size

Low emittance tuning

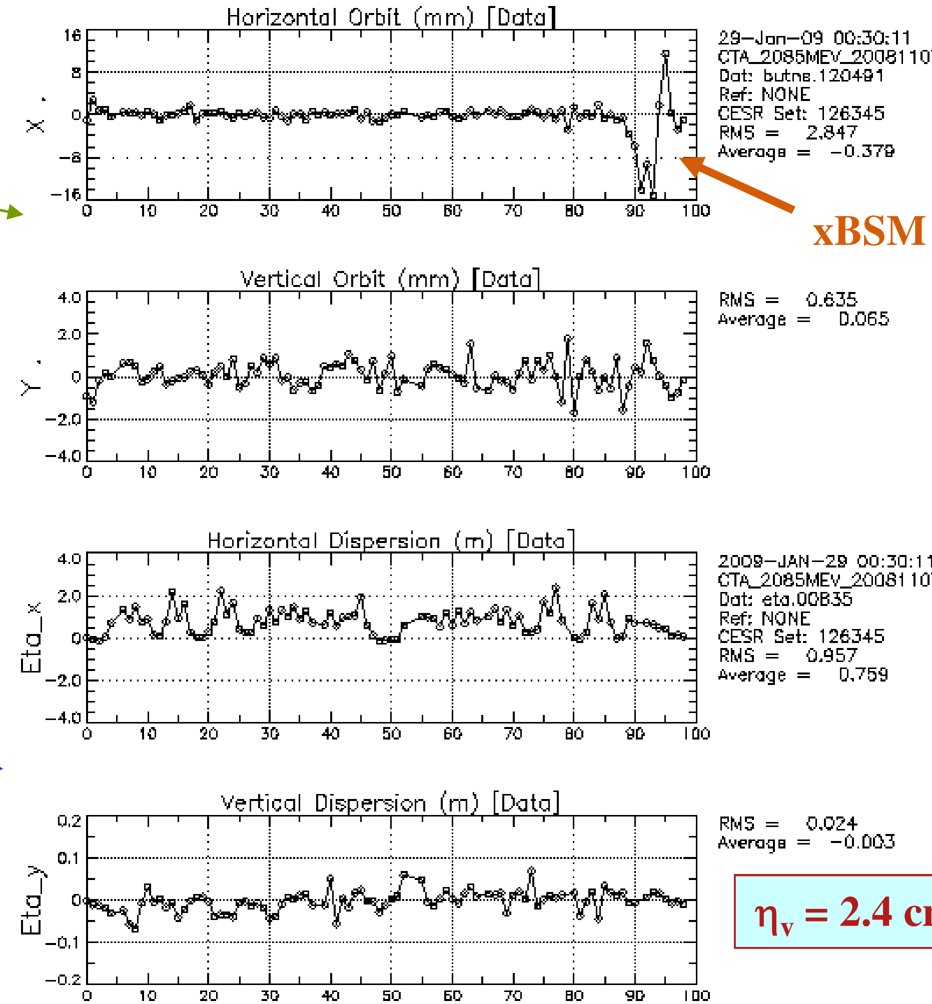
Orbit

A feature of the orbit is the closed horizontal bump required to direct xrays onto x-ray beam size monitor

-Measure and correct vertical dispersion using skew quads (14) and vertical steering magnets (~60)

Residual vertical dispersion
RMS ~ 2.4cm - Signal or systematic?
Accuracy of dispersion measurement is limited by BPM systematics

Measured with older *relay* BPM system!!



xBSM bump

η_v = 2.4 cm RMS

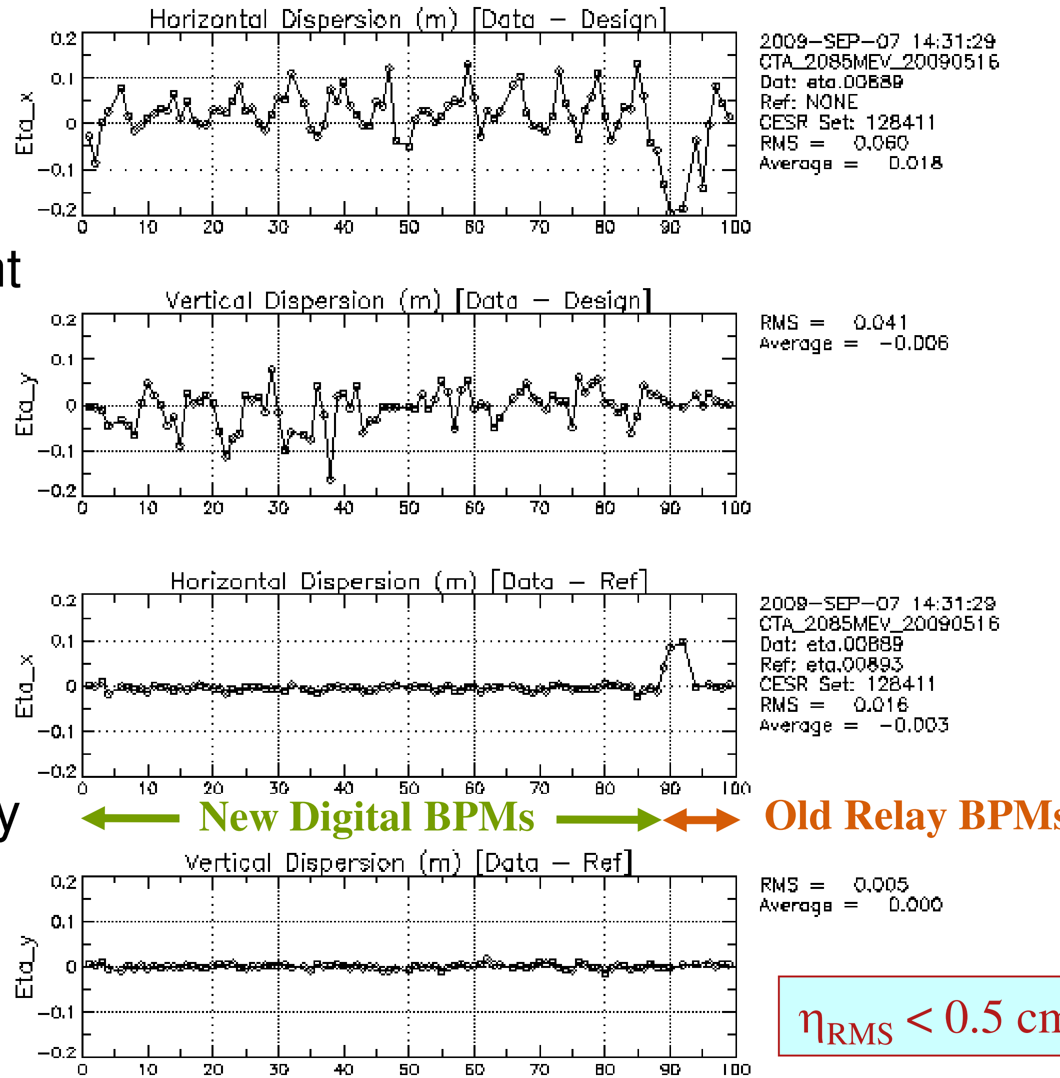
Note: Residual vertical dispersion 1 cm, corresponds to ε_v ~ 10pm

CBPM II Modules: V Dispersion

After Installation of 80+ CBPM II modules

Dispersion Measurement

Reproducibility



$\eta_{RMS} < 0.5$ cm

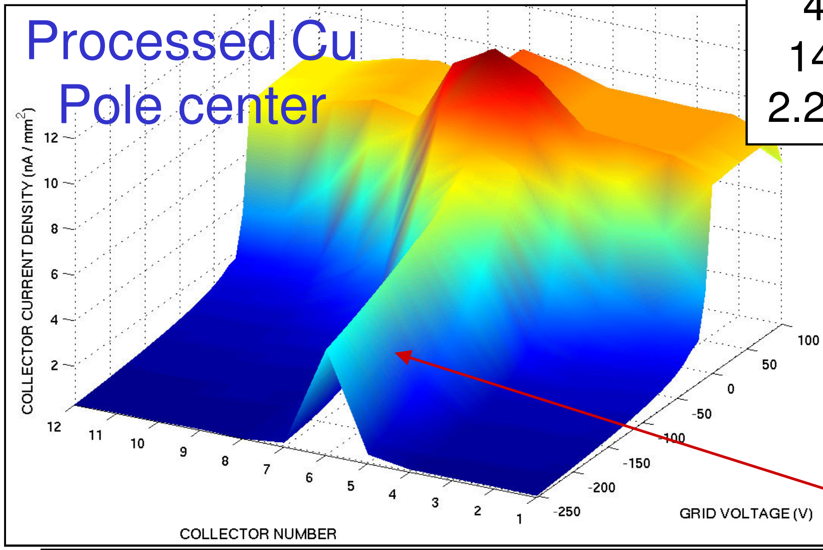
Present $\varepsilon_v \leq 40$pm
Will pursue 20pm with new BPM system during Nov-Dec Experimental run

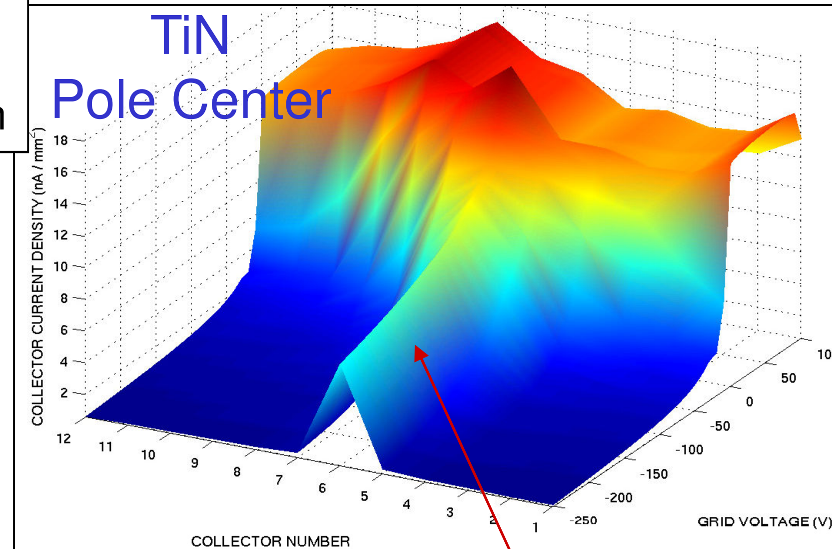
Status of EC Studies

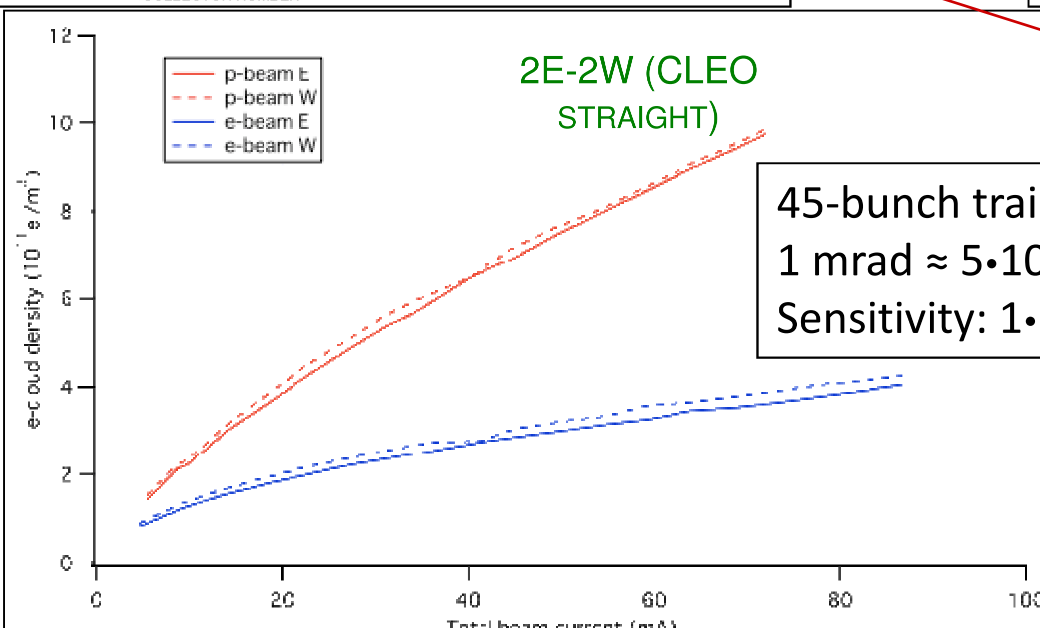
- Simulations:
  - Code Benchmarking (CLOUDLAND, ECLOUD, POSINST)
  - Modeling for RFA and TE Wave measurements
  - Tune shift calculations
    - Characterize the integrated SEY contributions around the ring
    - Now calculated for coherent oscillations of the beam
  - Instability estimates and emittance growth
- Measurements:
  - RFA and TE Wave studies to characterize local EC growth
    - Wigglers, dipoles, drifts, quadrupoles
    - 2 GeV to 5 GeV studies
    - Variety of bunch train lengths, spacing and intensities
  - Mitigation Comparisons
    - SC Wigglers:
      - Presently installed: Cu, TiN-coated Cu, Grooves (Cu, 2mm/20°)
      - Next: Clearing Electrode (Spring 2010)
    - Drifts:
      - Presently installed: Al, Cu, TiN-coated Cu, Amorphous C-coated Al
      - Next: TiN-coated Al (Late 2009), NEG (Spring 2010)
    - Dipole:
      - CESR Dipole: Al
      - L3 Chicane: Al, TiN-coated Al, Grooves (5mm/20°)+TiN-coated Al
    - Quadrupole:
      - Al
      - TiN-coated Al (Spring 2010)
  - Tune shift measurements and systematic checks
    - Pinged beam
    - Feedback system error signal
    - Witness bunch studies for dynamics
  - Instability and incoherent emittance growth (w/xBSM) studies will receive greater attention in upcoming runs

TE Wave & RFA Measurements in L0

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





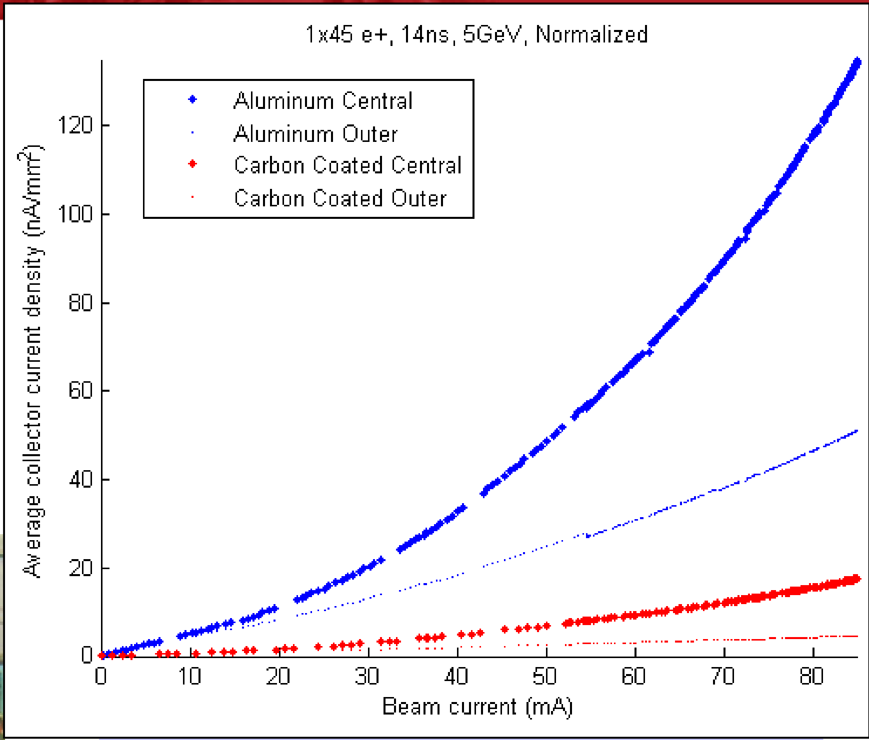


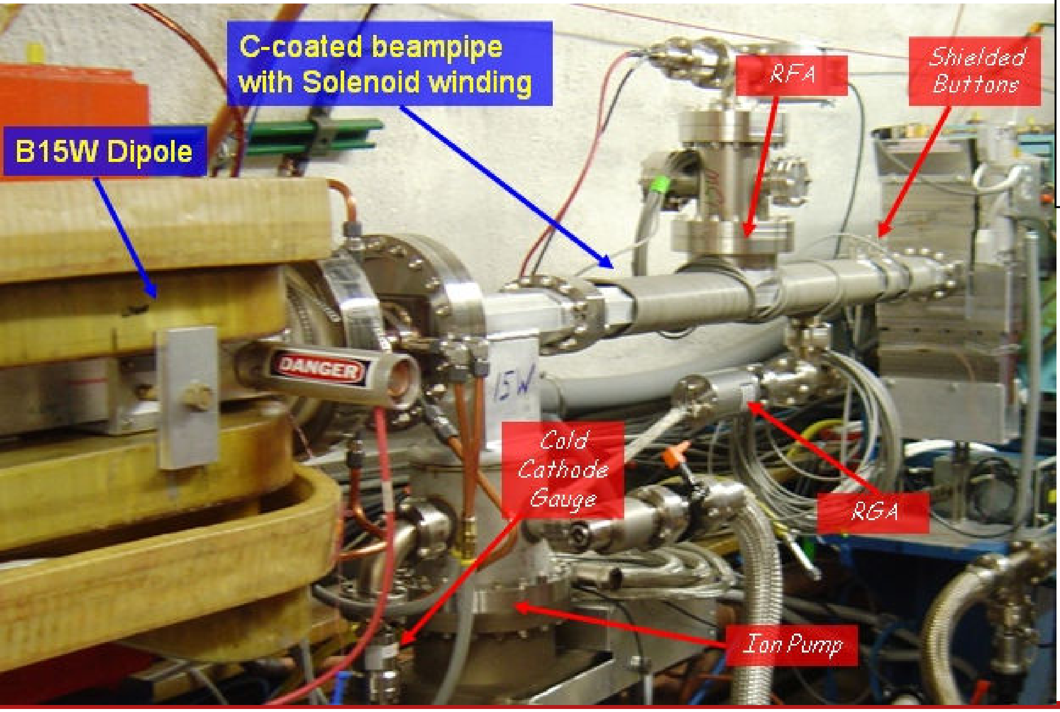
45-bunch train (14 ns)
1 mrad ≈ $5\cdot10^{10}$ e^-/m^3
Sensitivity: $1\cdot10^{9}$ e^-/m^3 (SNR)

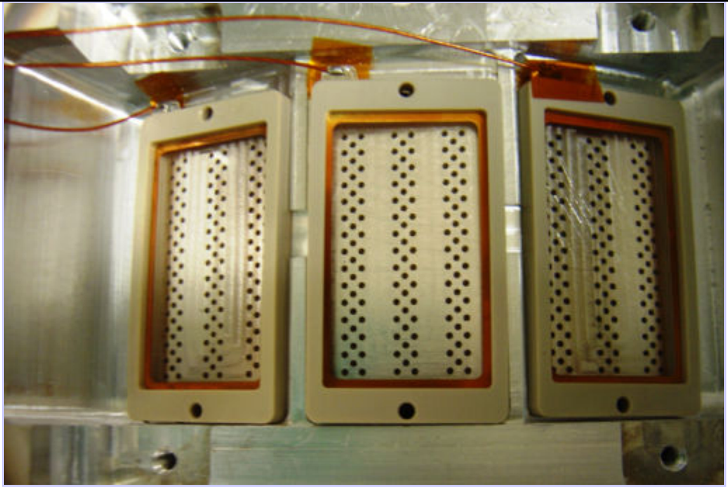
Similar performance observed

Mitigation Comparisons

- Presently have an amorphous carbon (CERN) and aluminum test chamber at two locations in ring (Q15 W & E)
- Plot at right shows current response of each, normalized to the photon flux striking at each location

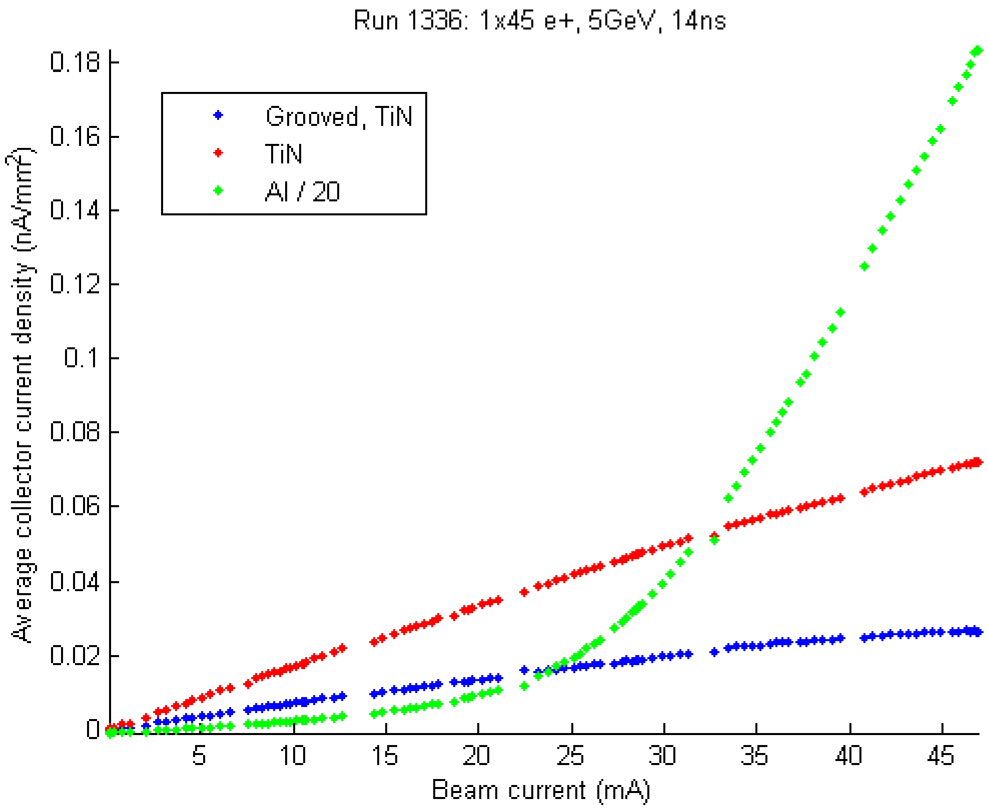




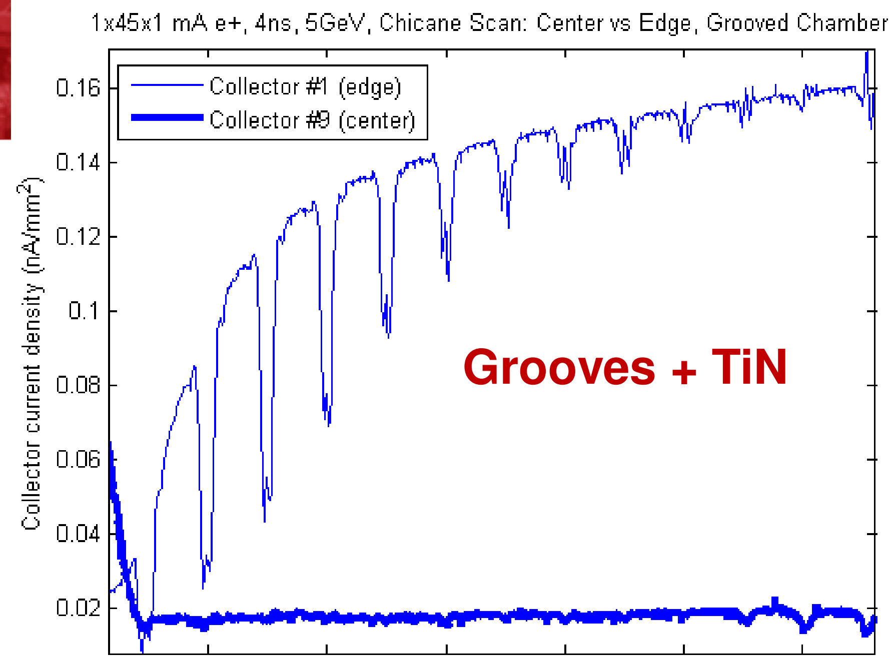


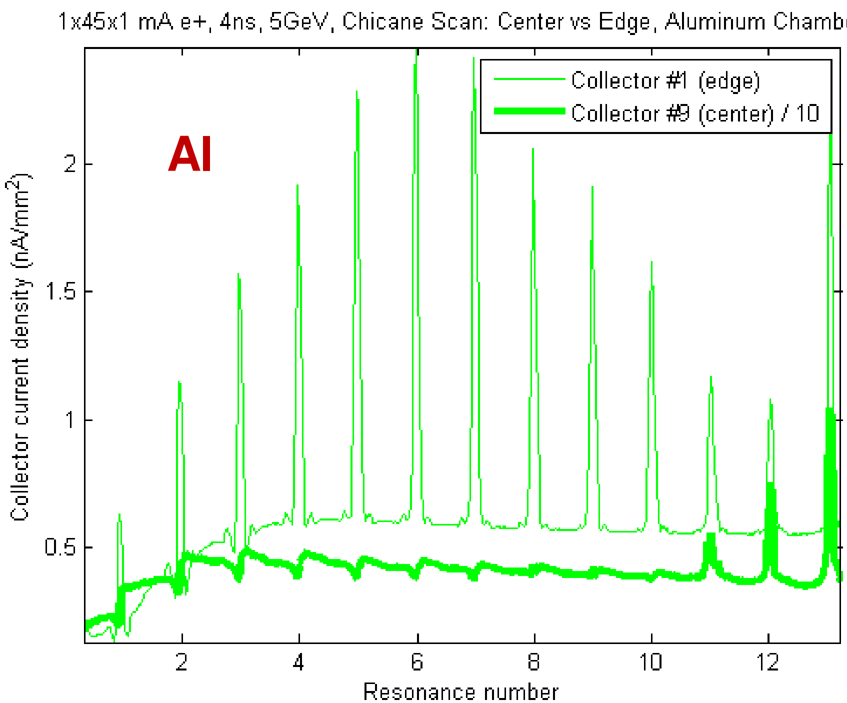
Dipole Mitigation Comparisons

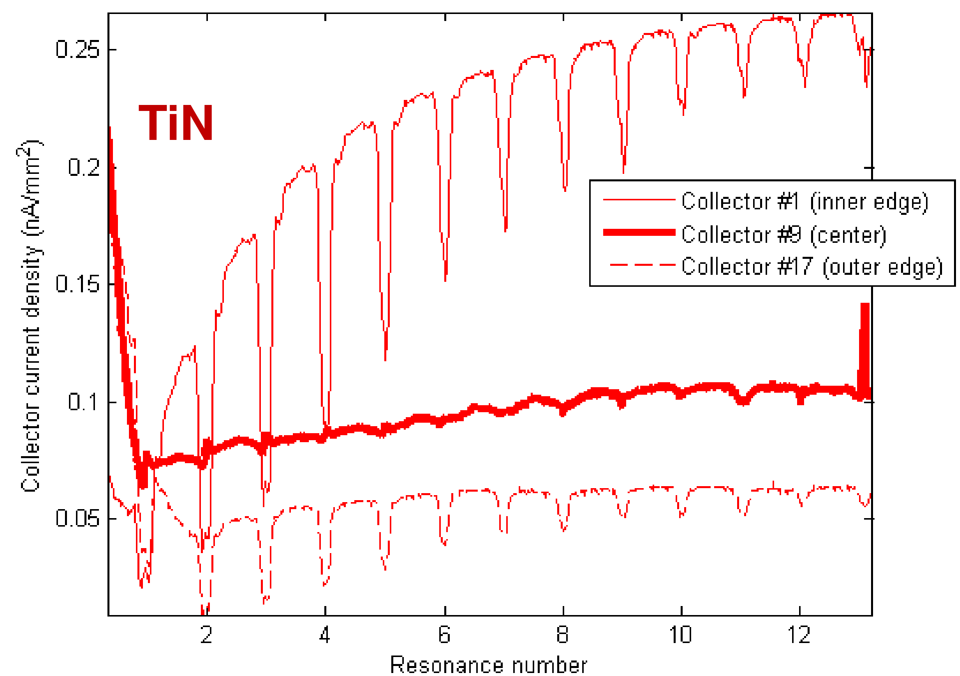
- Current scan in L3 Chicane, 1x45 e+, 14ns, 5GeV
  - Note: Al signal is divided by 20 to show on the same scale
  - Grooved chamber has 5mm deep 20° triangular grooves with TiN coating
  - Performance:
    - TiN+Grooves significantly better than TiN alone
    - Both TiN and grooves significantly outperform the bare Al surface, as expected



- **Chicane B-field Scans**
  - 1x45x1 mA, 4ns, 5GeV, e+
  - Resonance structure
  - Plots show
    - Central collector (near beam axis)
    - Collectors near edge of vacuum chamber
    - 17 collectors in each RFA

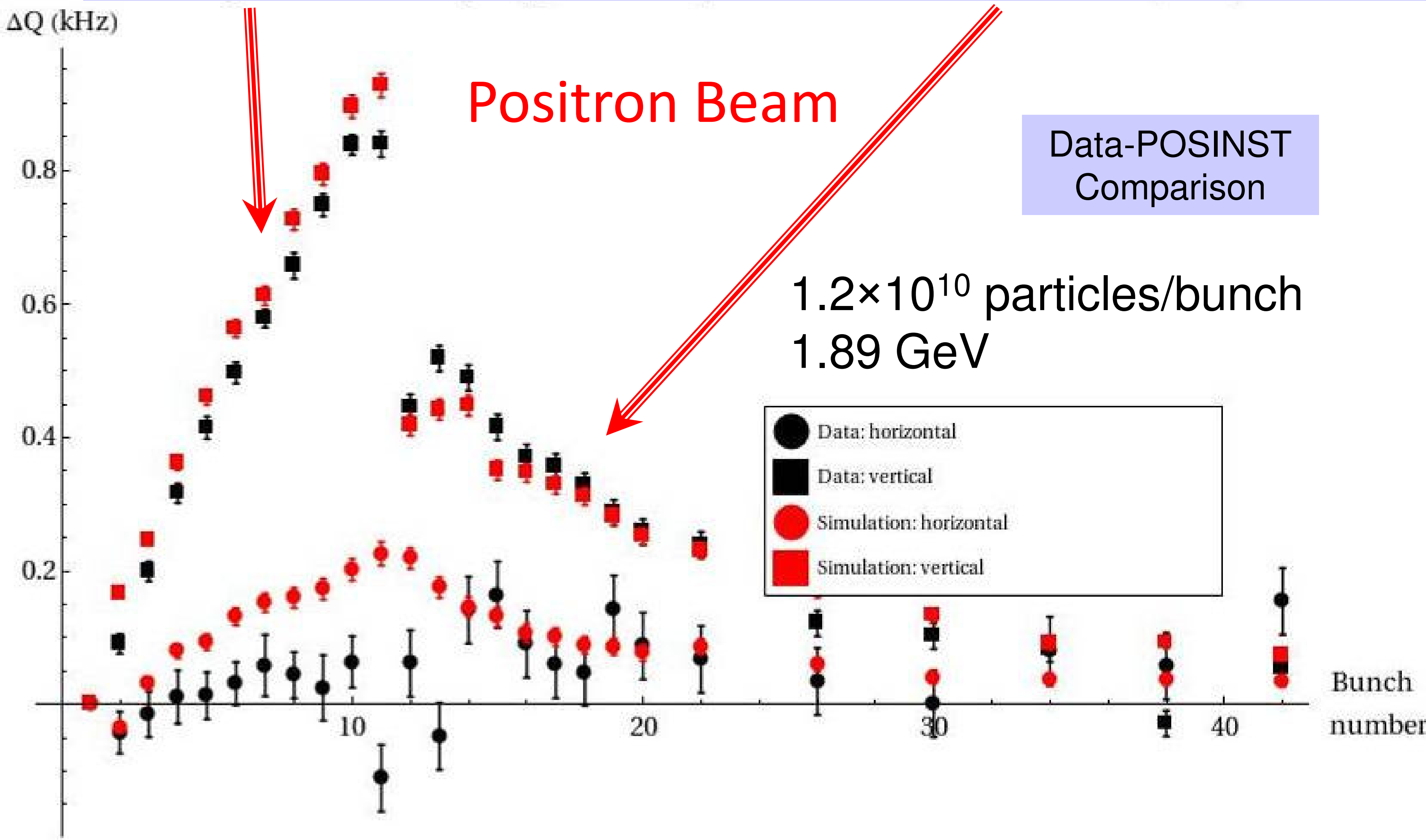






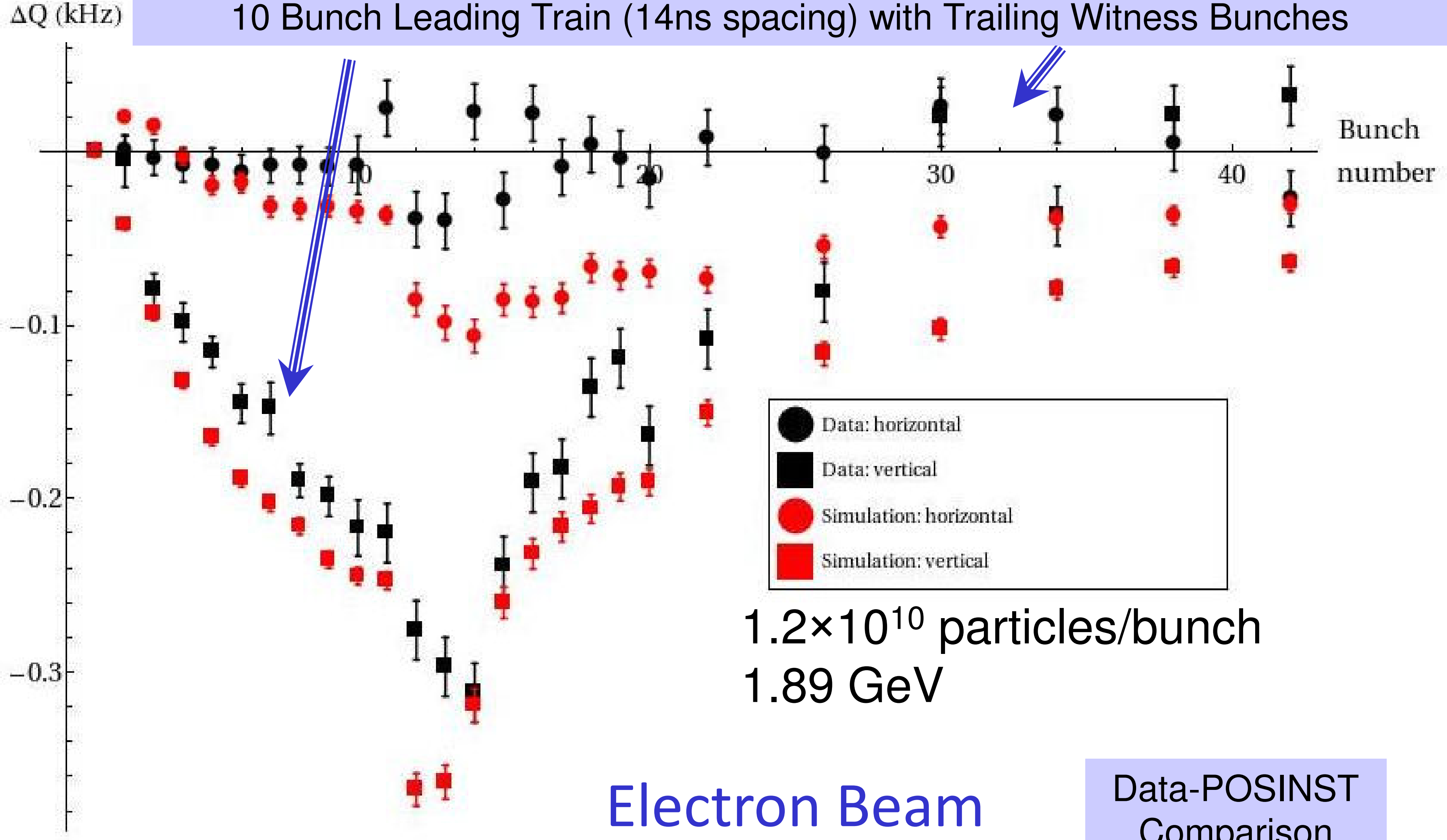
Coherent Tune Shifts I

10 Bunch Leading Train (14ns spacing) with Trailing Witness Bunches



Coherent Tune Shifts II

10 Bunch Leading Train (14ns spacing) with Trailing Witness Bunches



1.2×10^{10} particles/bunch
1.89 GeV

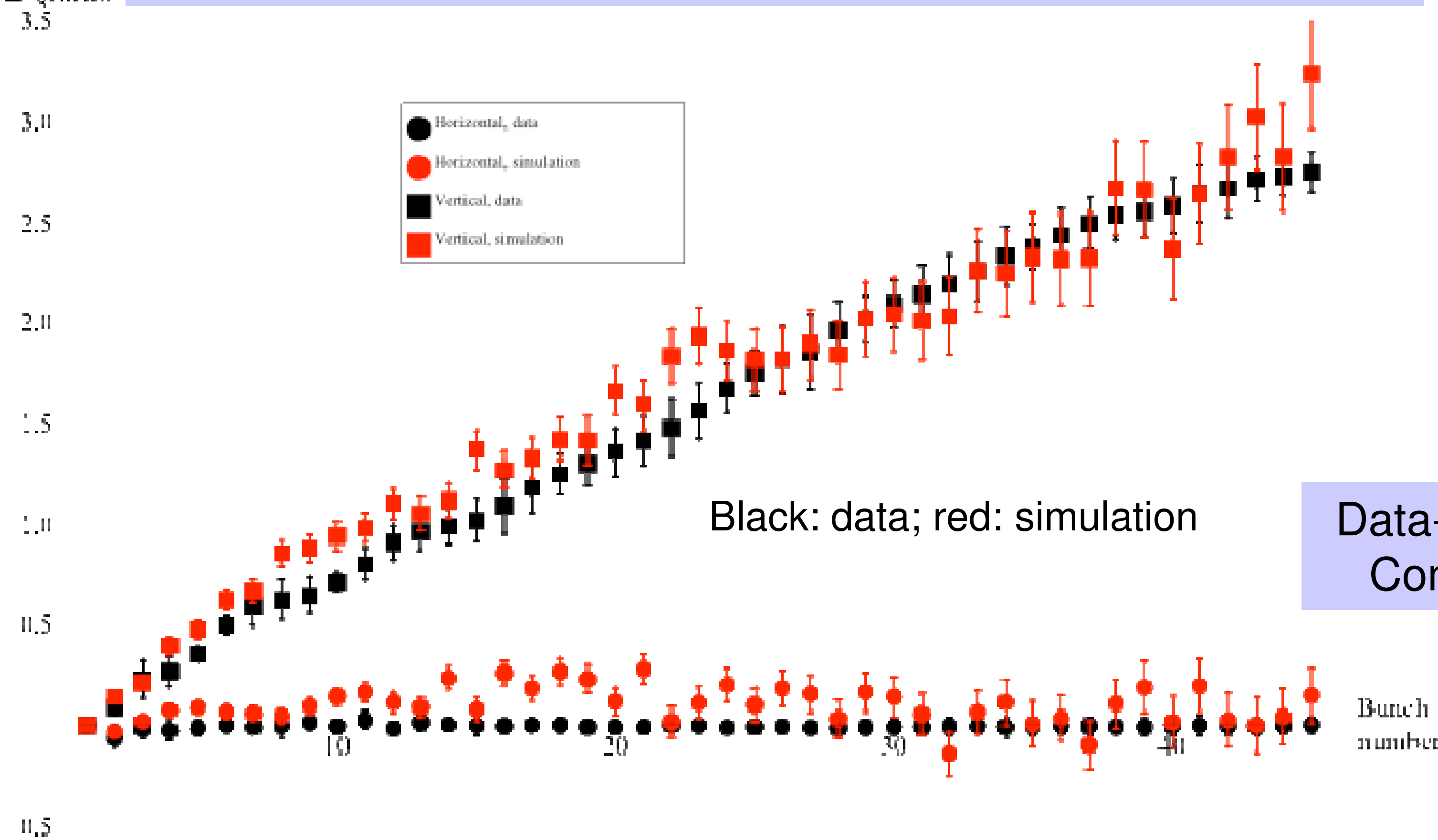
Electron Beam

Data-POSINST Comparison

Coherent Tune Shifts III

Long train data was taken in January, 2009, using low emittance lattice. Same cloud model parameters as for preceding slides.

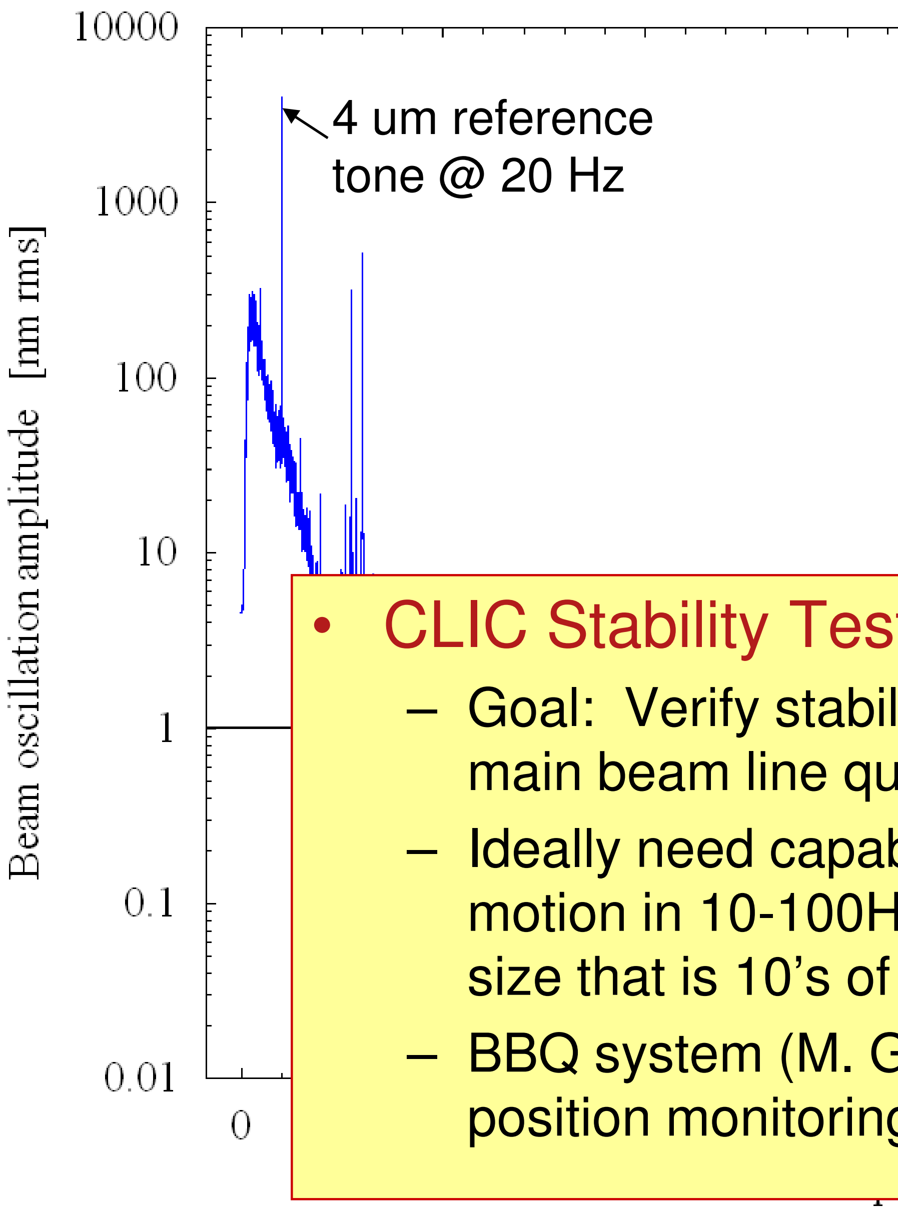
Positrons, 45 bunch train with 1.2×10^{10} particles/bunch
2.09 GeV, 2.6 nm horizontal emittance, 14 ns bunch spacing

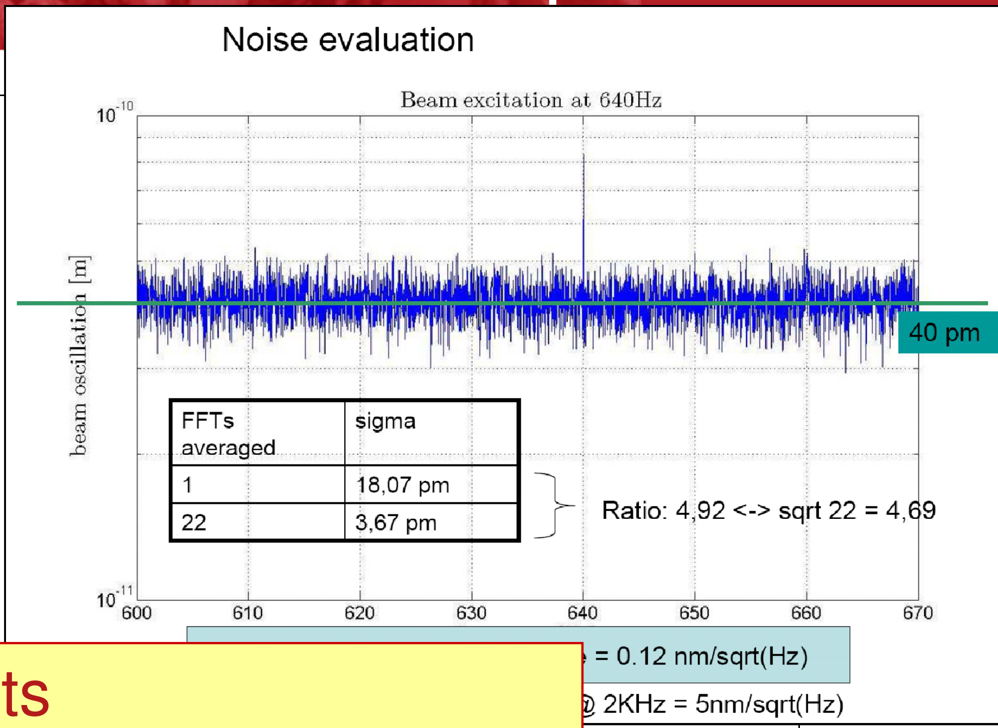


Black: data; red: simulation

Data-POSINST Comparison

Collaborator Experiments





- CLIC Stability Tests
  - Goal: Verify stabilization scheme for main beam line quadrupoles
  - Ideally need capability to measure <1nm motion in 10-100Hz range (with a beam size that is 10's of microns)
  - BBQ system (M. Gasior) for narrowband position monitoring

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Future Plans

- 3 additional runs are scheduled as part of the current CesrTA program
  - Run 5: Nov 17 – Dec 23, 2009 with major focus on:
    - Low emittance tuning
    - EC induced instabilities and emittance dilution at low emittance
    - Completing a range of EC characterizations with a scrubbed machine
  - Run 6 tentatively scheduled to begin April 2010
  - Run 7 tentatively scheduled to begin September 2010
  - CTA09 Workshop ⇨ List of critical studies to address in the next year: **https://wiki.lepp.cornell.edu/ilc/bin/view/Public/DampingRings/CTA09/WebHome**
  - Time exists in the schedule to support outside experimental requests

- ***ALSO*** ⇨ We have submitted a proposal to the NSF for operating funds to continue the program for another 3 years (thru March 31, 2013)
  - Reduced running schedule ≤ 40 days/year which will allow:
    - Long-term tests of mitigation performance
    - Targeting vertical emittance reduction to 5-10pm range
    - IBS and other beam dynamics studies
    - Characterization of instabilities in a regime closer to that of the ILC DR
    - Additional collaborator experiments
  - NSF site visit/review during next run: December 2-3 at Cornell
  - We would welcome your participation!

Integration into the ILC DR Design

- We expect by 2010 to have placed the positron damping ring on a more solid foundation by having confirmed and updated our performance projections
  - Detailed comparisons of data and simulation in the low emittance regime will lead to significantly more reliable estimates in our DR simulations
  - Results will confirm, or cause us to re-evaluate, our plans to move to a smaller circumference layout

- Testing of a range of mitigations in operational vacuum chambers will provide the necessary inputs for the technical design
  - Will allow us to proceed with detailed design work and costing on an updated baseline vacuum system
  - Fully expect that there will be significant ongoing work to validate the design details
    - Prototyping
    - Some tests such as durability checks of newer coatings may still await final results
  - We anticipate that these inputs can largely be incorporated as incremental changes to the DR design work presently underway

Conclusion

- The CESR reconfiguration for CesrTA is complete
  - Low emittance damping ring layout
  - 4 dedicated experimental regions for EC studies with significant flexibility for collaborator-driven tests
  - Instrumentation and vacuum diagnostics upgrades
- Recent results include:
  - Machine correction to ε_y < 40pm (within factor of 2 of target)
  - Preliminary EC mitigation comparisons
  - First single-pass bunch-by-bunch beam size measurements to characterize emittance diluting effects
  - Extensive progress on EC simulations
- 3 runs of total duration ~100 days remain over the course of the next year. During this time we will focus on:
  - Continued improvements in our ring instrumentation
  - LET effort to reach a target emittance of $\varepsilon_y \leq$ 20pm
  - Completion of our targeted EC mitigation studies
  - Detailed characterization of instabilities and sources of emittance dilution in the ultra low emittance regime (including first detailed IBS studies)
  - Application of our results to the damping rings design effort
- ***Collaborators are always welcome!***

Collaborating Institutions

- ANL
- BNL
- California Polytechnic State University
- CERN
- Cockroft Institute
- FNAL
- INFN-LNF
- KEK
- LBNL
- SLAC