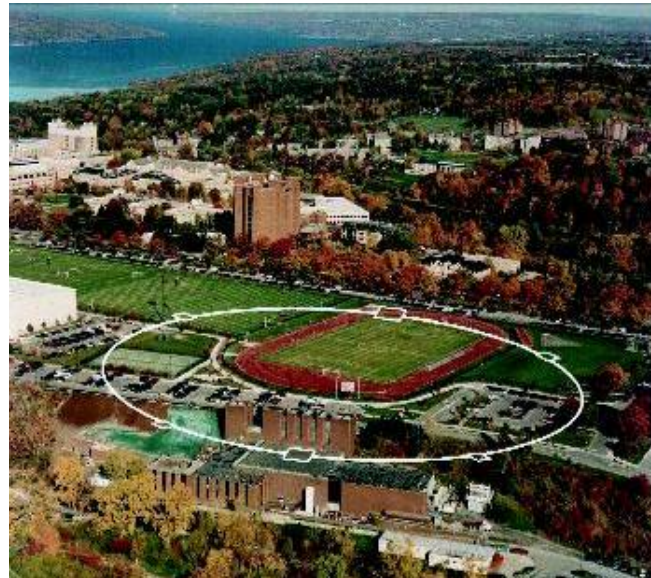




The Conversion and Operation of CESR as a Test Accelerator (CesrTA) for Damping Rings R&D

Mark Palmer

*Cornell University – CLASSE
for the CesrTA Collaboration*





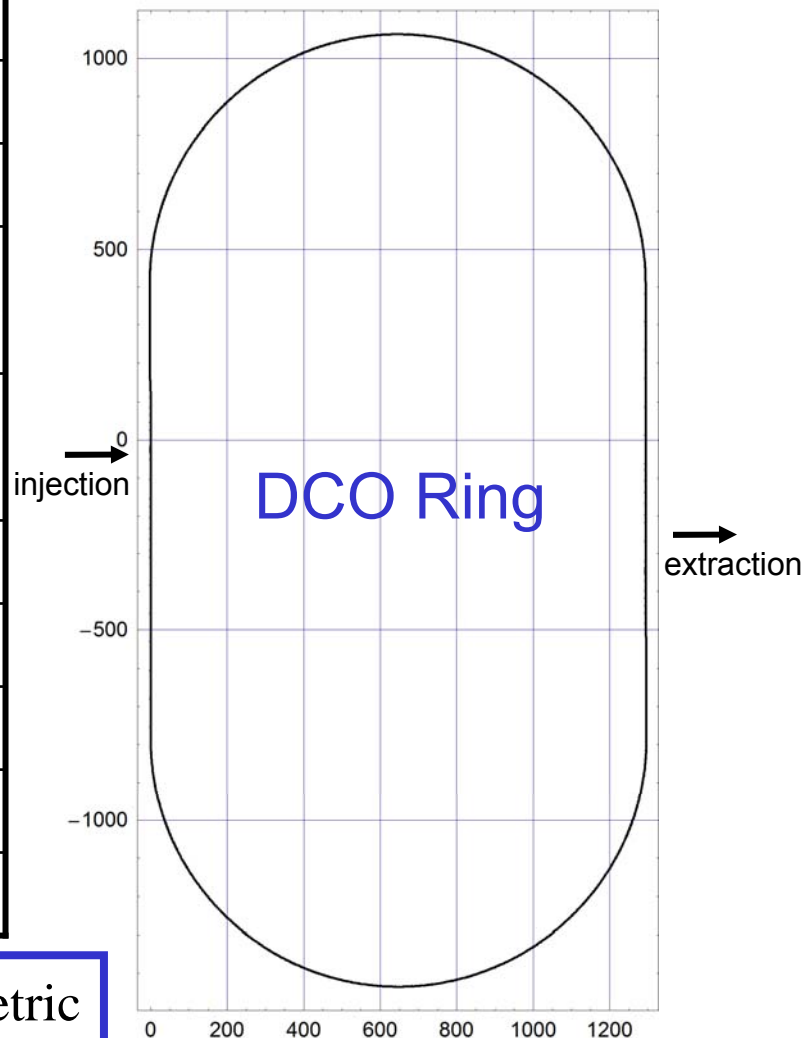
The ILC Damping Rings

Beam energy	5 GeV
Circumference	6476.44 m
RF frequency	650 MHz
Harmonic number	14042
Injected (normalised) positron emittance – $\gamma\epsilon_{x,y}$	0.01 m
Extracted (normalised) emittance $\gamma\epsilon_x \times \gamma\epsilon_y$	8 $\mu\text{m} \times 20 \text{ nm}$
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

250 km main linac bunch train
is “folded” into the DRs

2 pm-rad geometric
emittance

Present Baseline Design





ILC R&D Board S3 Task Force (Damping Rings) identified 12 *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 CEsrTA
effort with low
emittance e^+ beam



- **CesrTA (ILC DR Test Facility)**
 - Validation of EC modeling tools (including build-up and instability simulations) in a parameter regime relevant for the ILC damping rings
 - Demonstration of EC mitigations which will allow operation of the ILC damping rings meeting specifications for beam quality and stability
 - Demonstration of tuning techniques to achieve ultra low emittance with a positron beam
 - Development of an x-ray beam-size monitor to characterize ultra low emittance beams with bunch-by-bunch capability
- **KEK-ATF (ILC DR Test Facility)**
 - Operational demonstration of 2 pm vertical emittance
 - Characterization of the Fast Ion Instability in the ultra low emittance regime
 - Demonstration of Fast Kickers meeting the specifications for the ILC damping rings
- **DAΦNE**
 - Collection of data on electron cloud effects
 - Tests of EC mitigation techniques
 - Fast Kicker development and tests
- **KEKB**
 - Collection of data on electron cloud effects
 - Tests of EC mitigation techniques



- **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: $\varepsilon_v < 20$ pm-rad)
 - Implement beam instrumentation needed to achieve and characterize ultra low emittance beams
 - x-Ray Beam Size Monitor targeting 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 \Rightarrow ~240 running days over a 2+ year period



Energy [GeV]	2.085	2.085	5.0	5.0
No. Wigglers	12	12	0	6
Wiggler Field [T]	1.9	1.9	—	1.9
Q_x	14.57			
Q_y	9.6			
Q_z	0.055	0.075	0.043	0.043
V_{RF} [MV]	4.5	8.1	8	8
ε_x [nm-rad]	2.6	2.6	60	35
$\tau_{x,y}$ [ms]	57	57	30	20
α_p	6.76×10^{-3}	6.76×10^{-3}	6.23×10^{-3}	6.23×10^{-3}
σ_l [mm]	12.2	9	9.4	15.6
σ_E/E [%]	0.81	0.81	0.58	0.93
t_b [ns]	≥ 4 , steps of 2			

- Operating energies between ~ 1.5 and ~ 5.5 GeV
 - Intermediate energy optics available for beam dynamics studies
 - Allows significant control of primary photon flux in EC experimental regions



CESR offers:

- An operational wiggler-dominated storage ring
- The CESR-c 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 spacings suitable for damping ring tests
 - Most studies to date use 14 ns spacing
 - Feedback system upgrades to be completed in May will allow operation with 4, 6, 8... ns bunch spacings
- 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 to be 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
(coming on line in May)

Drift and Quadrupole diagnostic chambers

- New EC experimental regions
in arcs (wigglers \Rightarrow L0 straight)**

Locations for collaborator
experimental chambers

- CHES C-line & D-line Upgrades**

Windowless (all vacuum) x-ray line
upgrade

Dedicated optics box at start of each
line

Detectors share space in CHES user
hutches

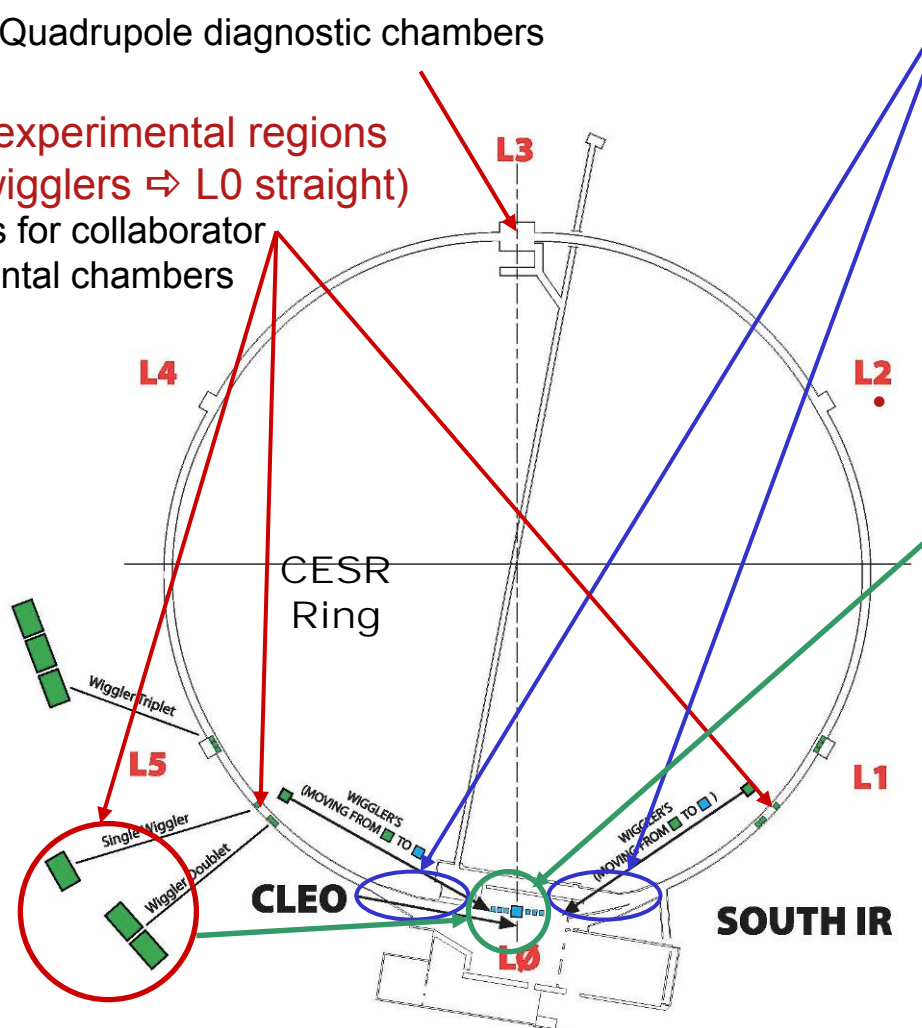
- L0 region reconfigured as a wiggler
straight**

CLEO detector sub-systems removed

6 wigglers moved from CESR arcs to
zero dispersion straight

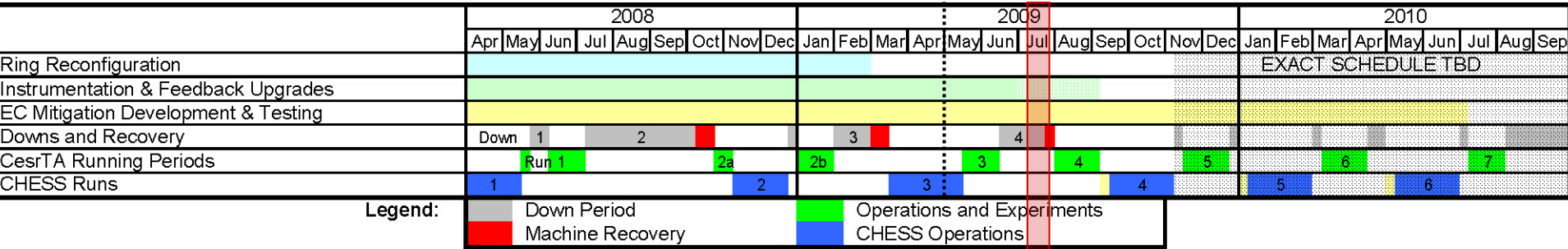
Region instrumented with EC
diagnostics and mitigation

Wiggler chambers with retarding field
analyzers and various EC mitigation
methods (fabricated at LBNL in
CU/SLAC/KEK/LBNL collaboration)





CesrTA Program



4 Major Thrusts:

- Ring Reconfiguration: Vacuum/Magnets/Controls Modifications
- 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 Measure
 - Feedback System upgrade for 4ns bunch trains
 - Photon stop for wiggler operation from 1.5 to 5 GeV
 - Local SEY measurement capability
- Experimental Program
 - Targeting ~240 running days over course of program (2/3's remain...)
 - Early results will feed into final stages of program

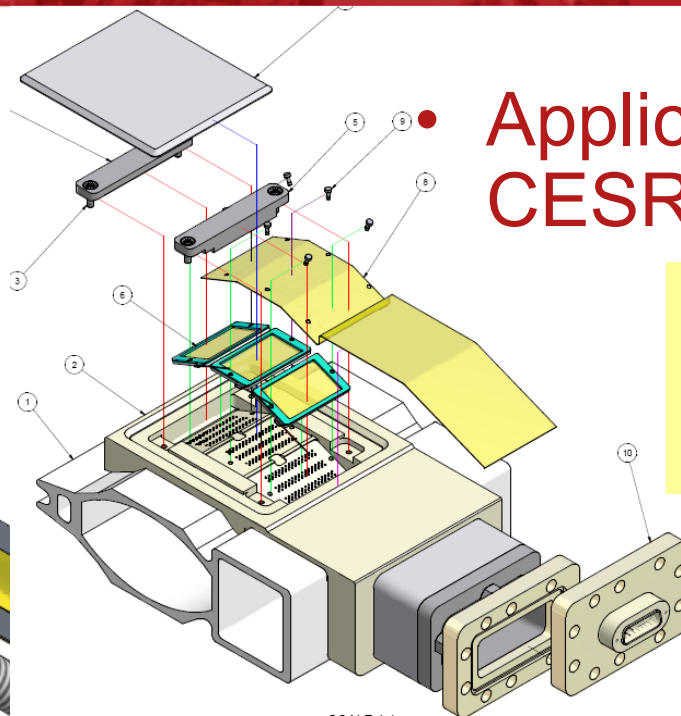
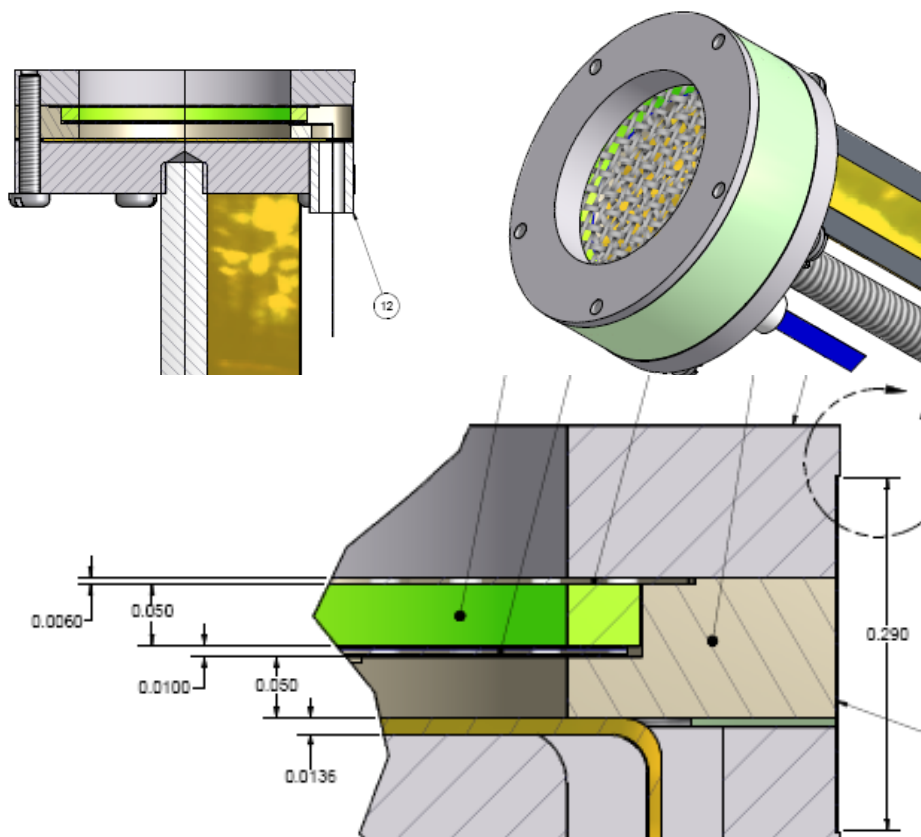
Goal is to complete bulk of upgrades by mid-2009 ⇒ enables an experimental focus thru mid-2010

Schedule coordinated with Cornell High Energy Synchrotron Source (CHES) operations



Thin RFA Design

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

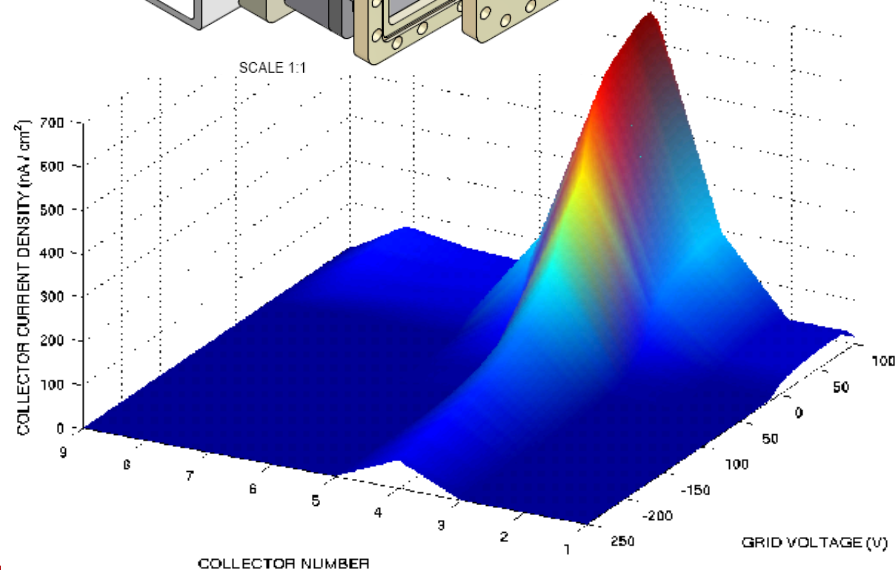


- Application to CESR Dipole

TH5RFP029

TH5RFP030

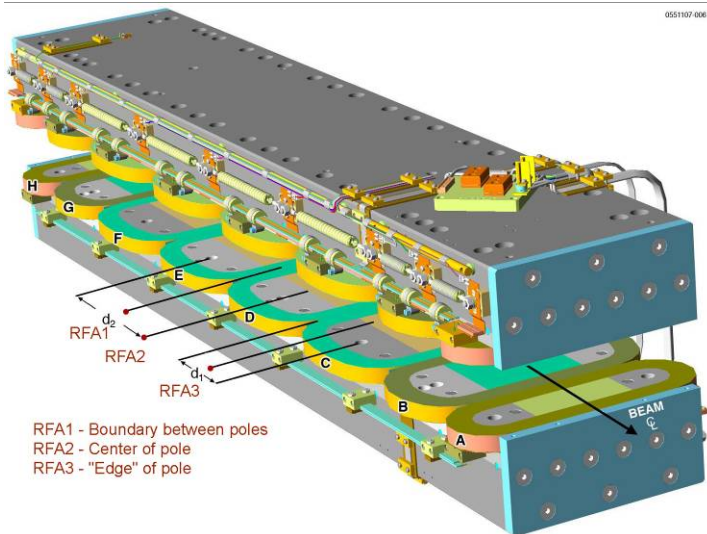
FR5RFP043



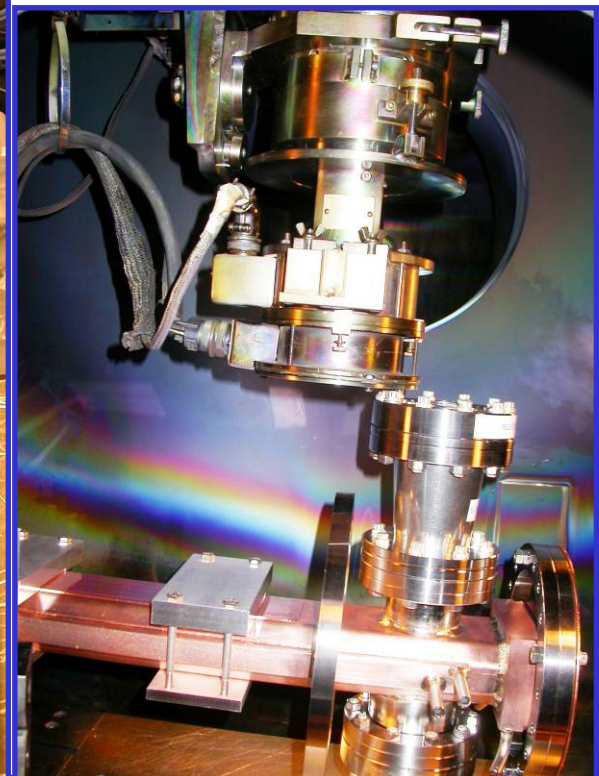


Upgrade Activities: Instrumented Wigglers

- Installed Oct 23-24, '08
 - 1 Cu VC; 1 TiN-coated VC

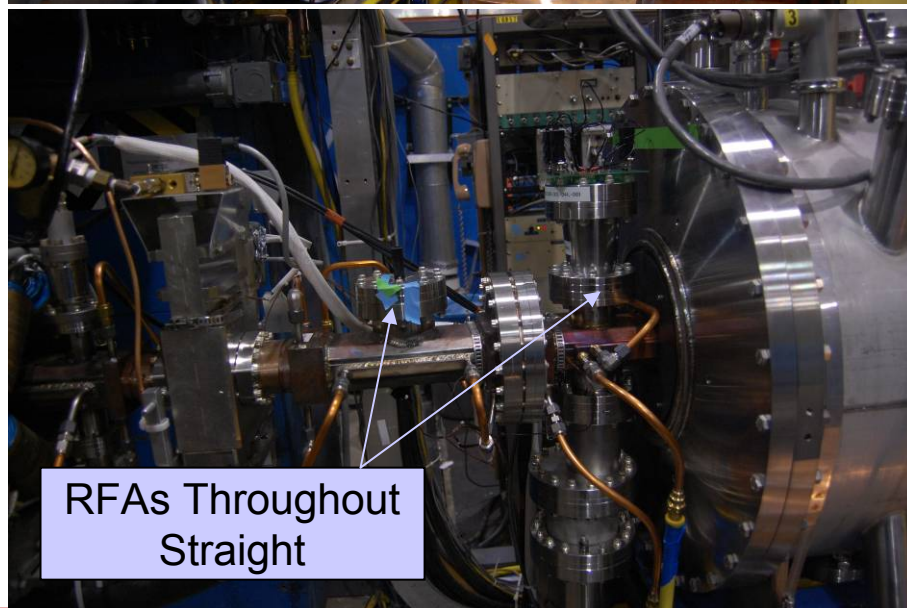
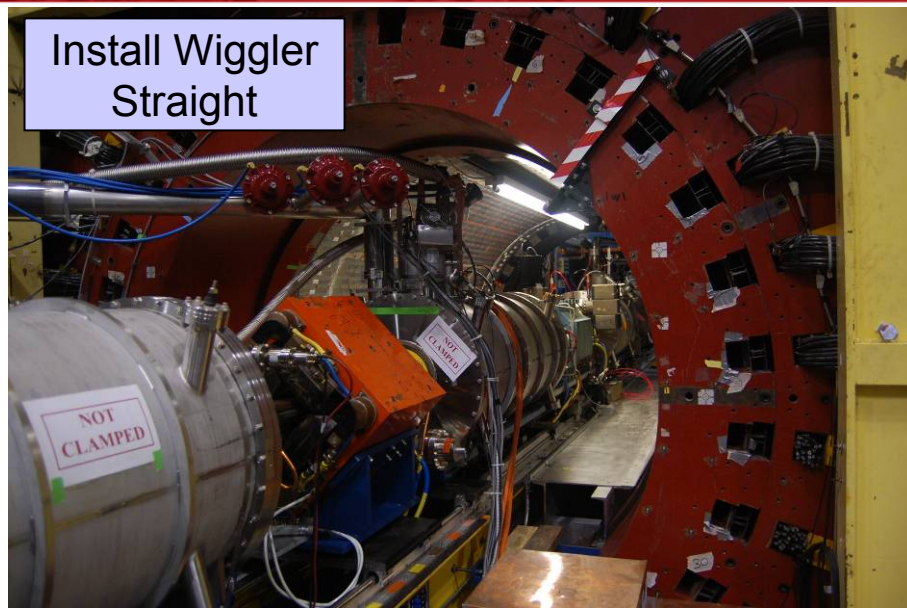
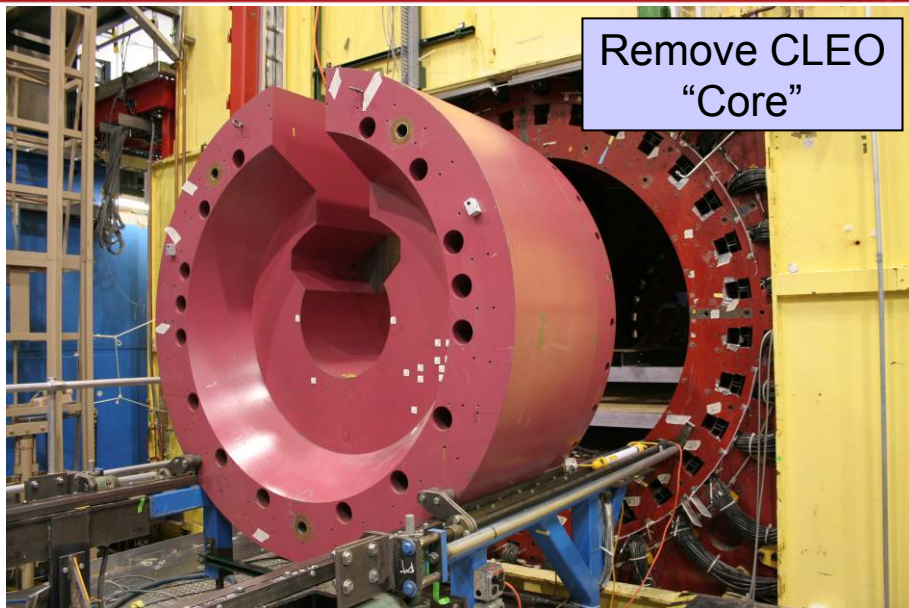


TH5RFP029





Upgrade Activities: L0 Modifications



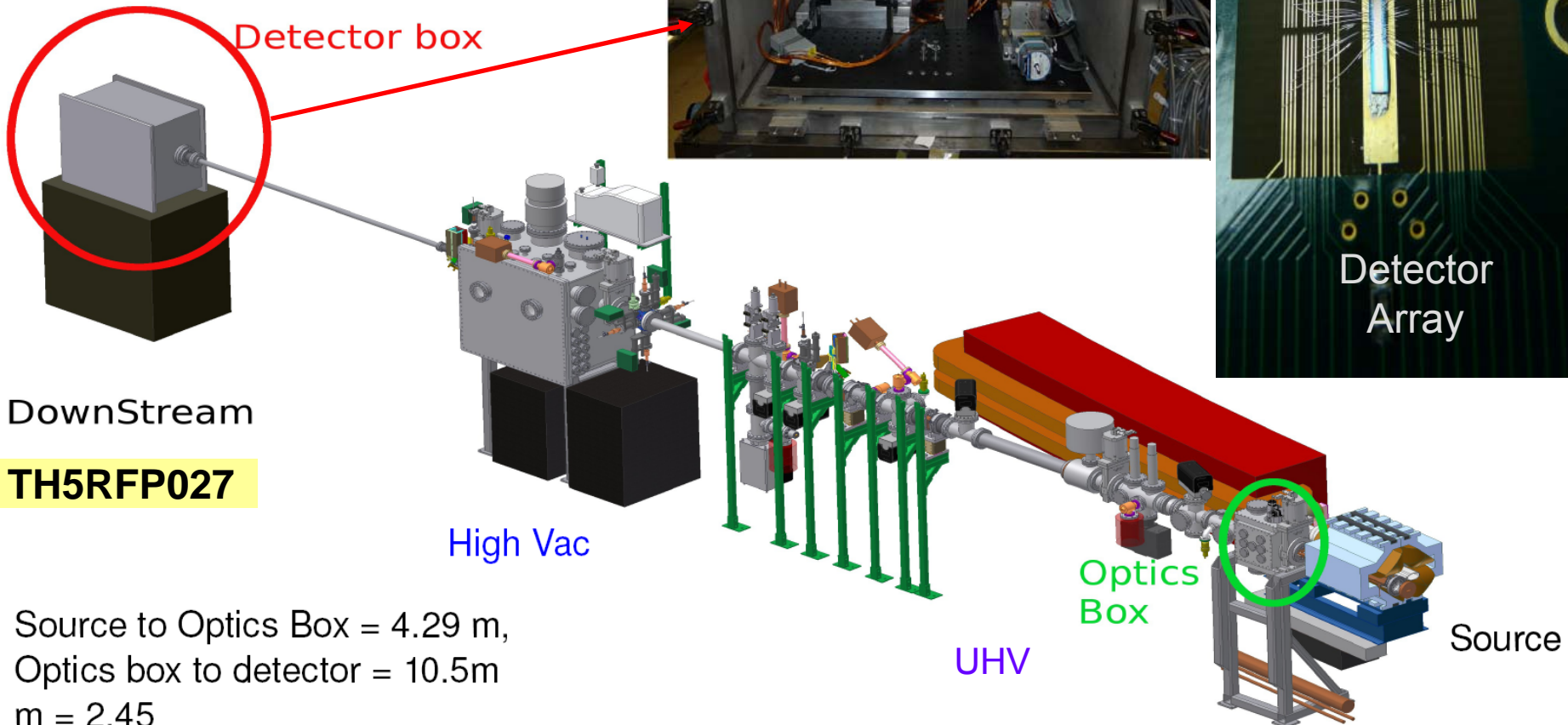


Upgrade Program: xBSM Optics Line & Detector

New all-vacuum optics
line for e^+ beam in collaboration
with CHES

2nd line for e^- beam in progress

Helium or Vacuum

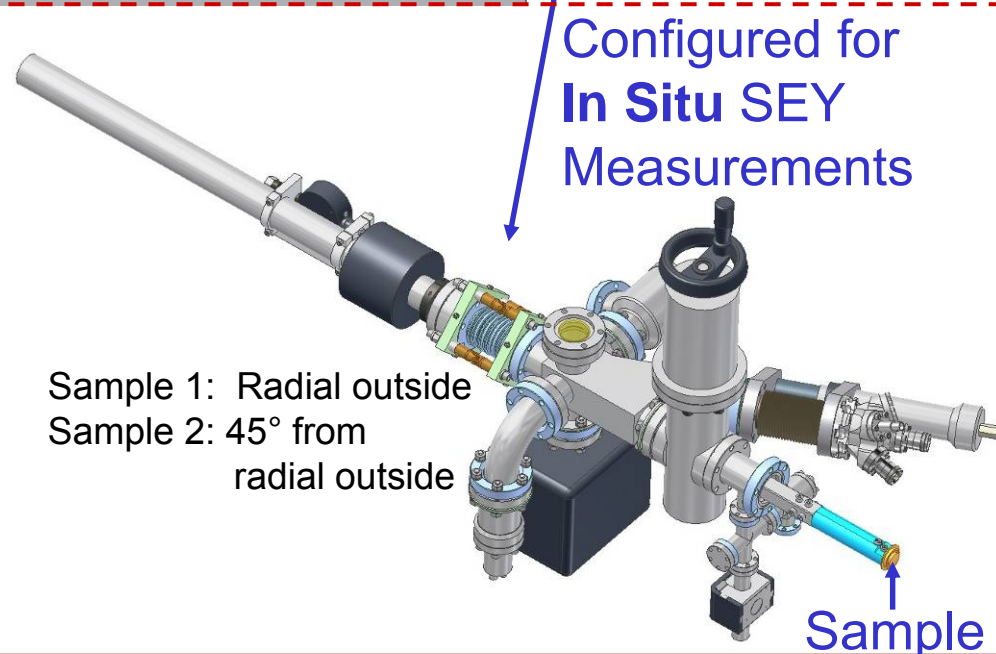
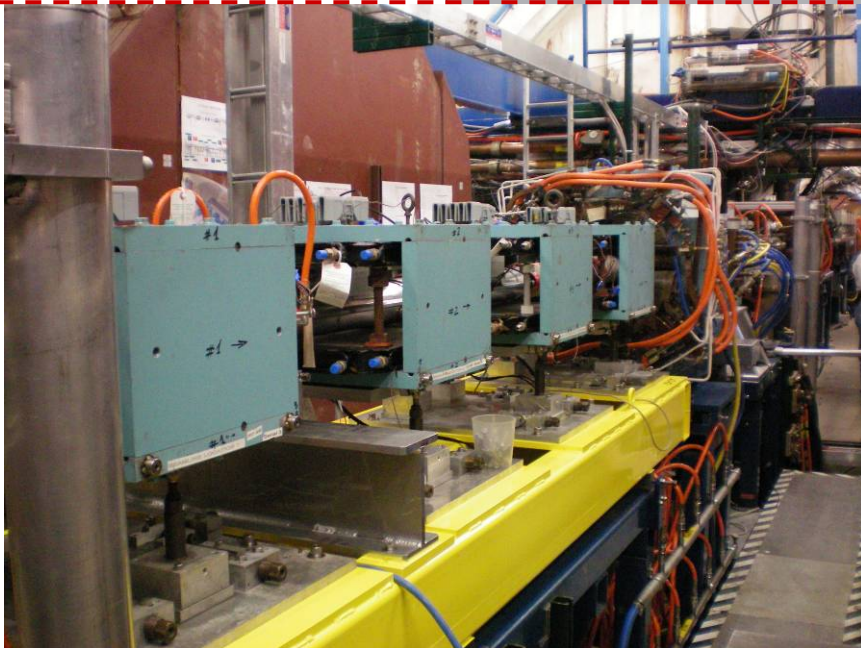
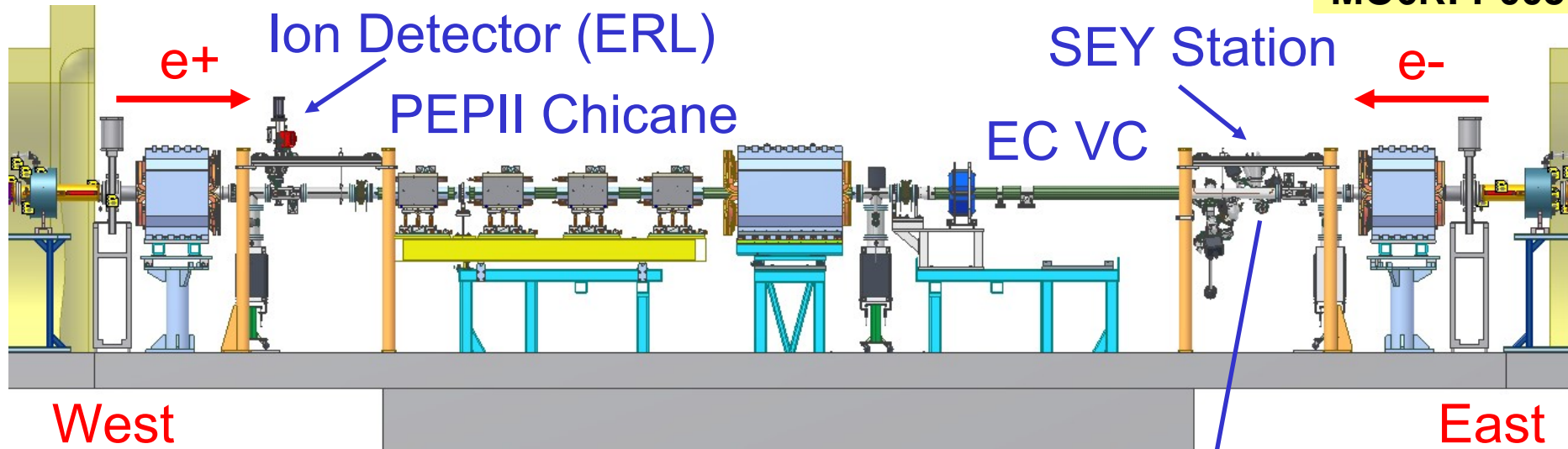


Source to Optics Box = 4.29 m,
Optics box to detector = 10.5m
m = 2.45



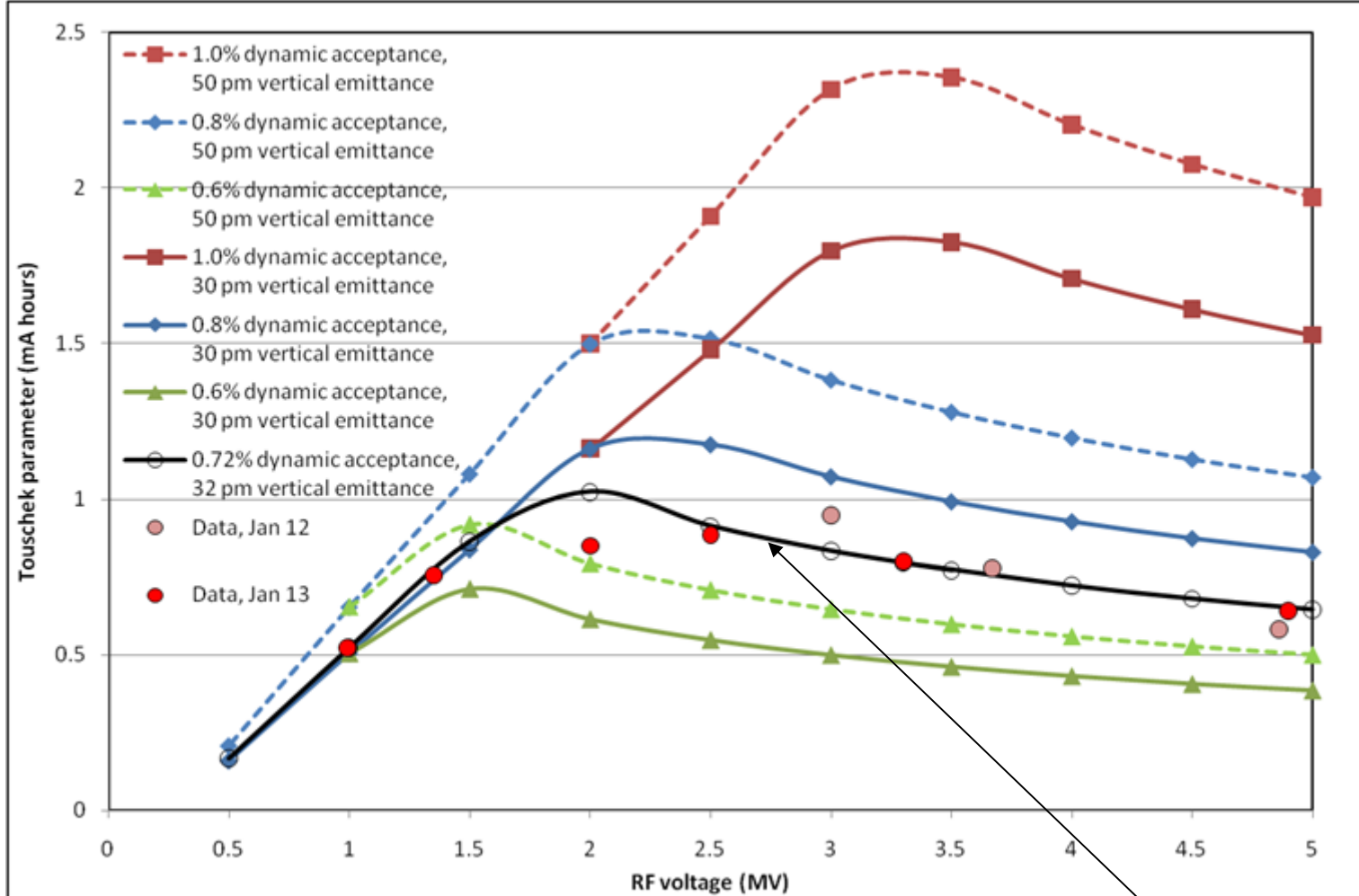
L3 Experimental Region

MO6RFP005





- Low emittance 2.085 GeV optics loaded and corrected
 - Correction methods tested **WE6PFP103**
 - Beam-based alignment measurements **WE6PFP104**
 - Coupling and dispersion bumps created for tuning
- Emittance measurements 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 to improve emittance
 - Alignment work has continued throughout our runs
 - Systematic errors with sextupole alignment have been identified as a significant contributor



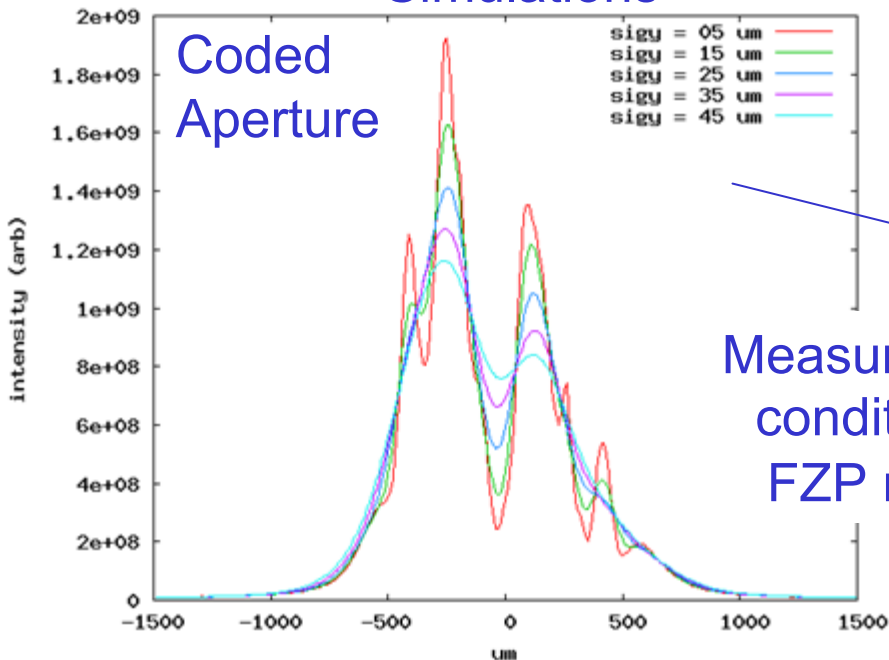
Measured energy acceptance = 0.7% $\rightarrow \epsilon_v \sim 32$ pm
From xBSM $\sigma_v \sim 15 \pm 5 \mu\text{m} \rightarrow \epsilon_v \sim 38$ pm
Within factor of two of 20 pm target...

P
r
e
l
i
m
i
n
a
r
y

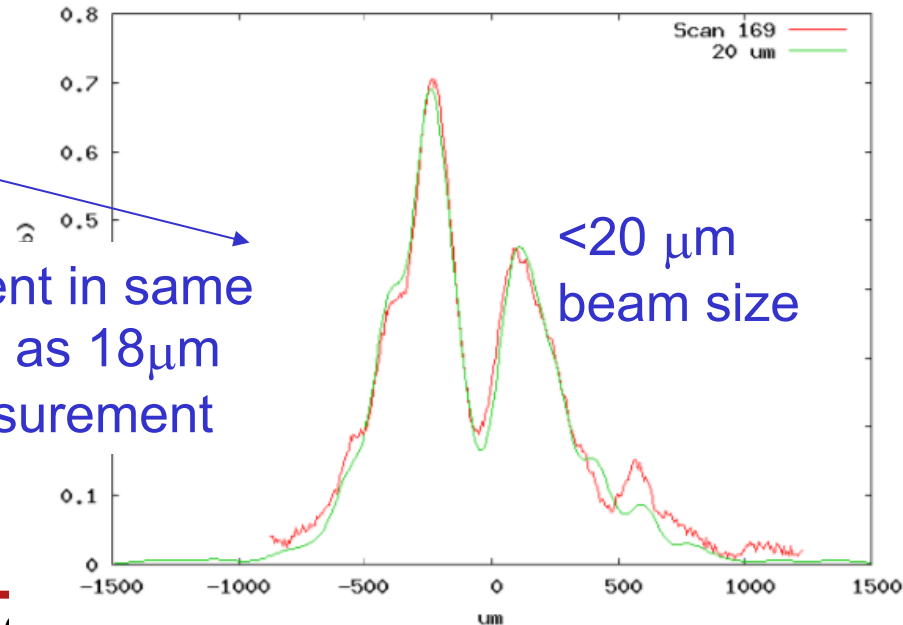
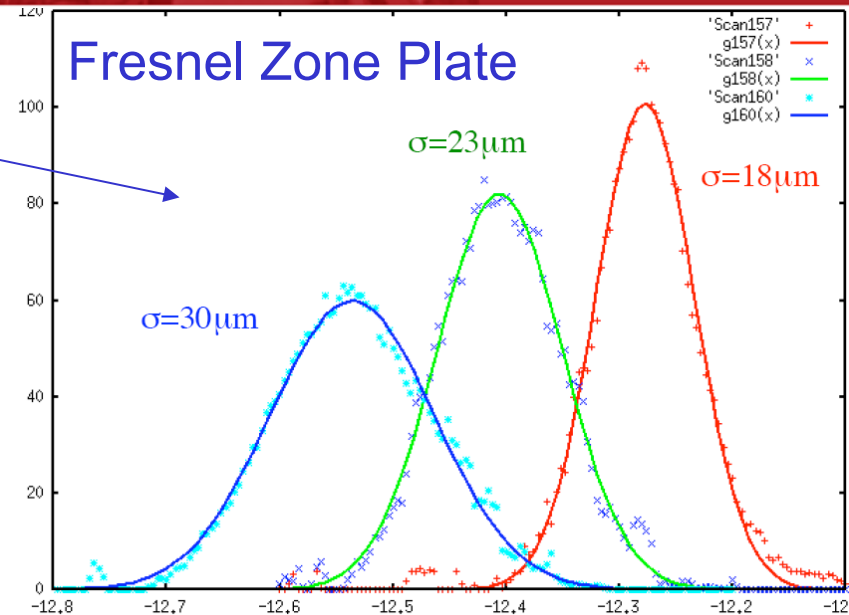


- Scan of coupling knob
- Coded aperture measurements
- Smallest recorded size:
~15 μm (but further calibration
work needed)

Simulations



Measurement in same
conditions as 18 μm
FZP measurement





- **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

TH5PFP047

FR5RFP043

FR5RFP044

WE1PBI01

FR5RFP067

- **Measurements:**

- RFA and TE Wave studies to characterize local EC growth
 - Wigglers, dipoles, drifts
 - 2 GeV and 5 GeV studies
 - Variety of bunch train lengths, spacing and intensities
- 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

CLEO straight (~17.4 m)

e^+ Beam

Instrumented wiggler
with TiN-coated VC

Instrumented wiggler
with untreated Cu VC

Wave transmitted from the
center of the straight and
switched to its E and W ends.



TE Wave & RFA Measurements in L0

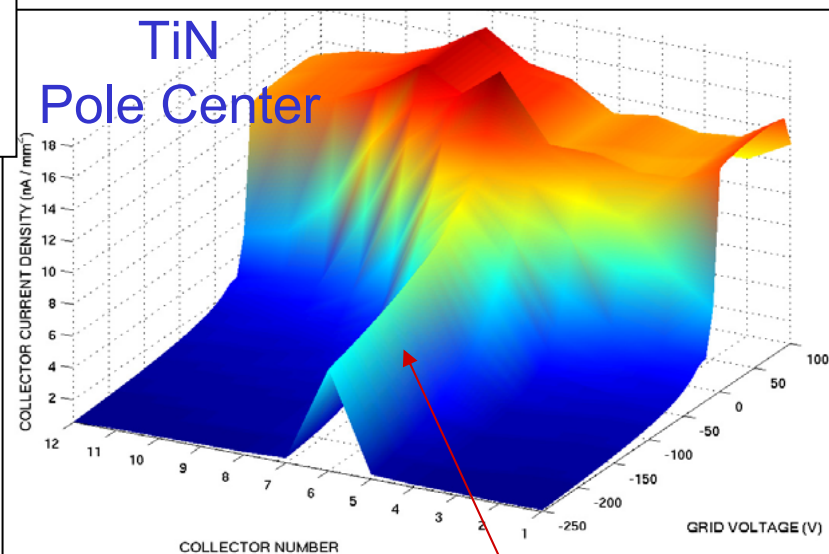
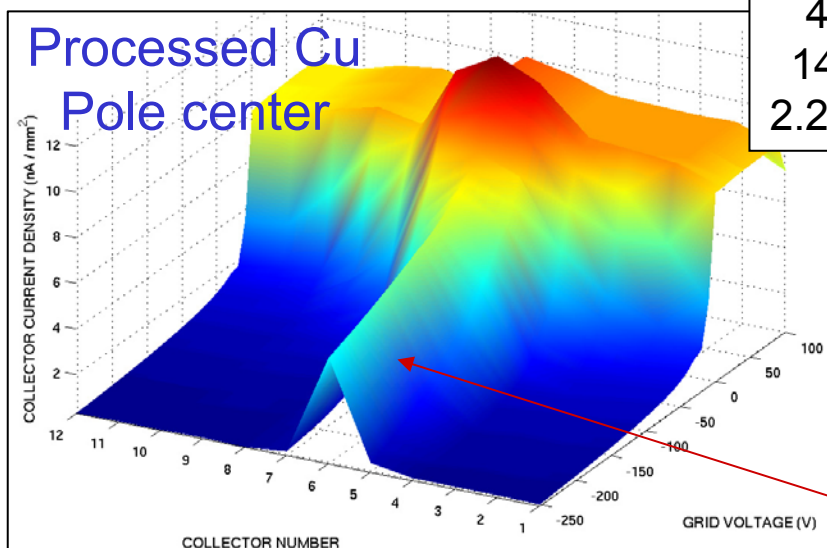
TH5RFP071

WE1PBI02

Processed Cu
Pole center

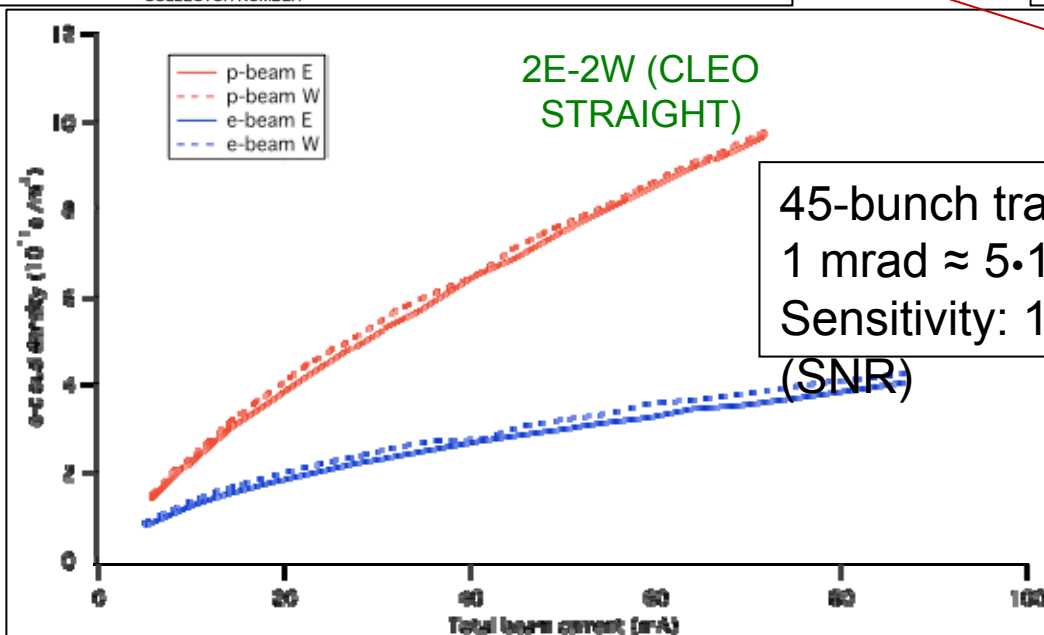
45 bunches
14ns spacing
 2.2×10^{10} /bunch

TiN
Pole Center



2E-2W (CLEO
STRAIGHT)

45-bunch train (14 ns)
1 mrad $\approx 5 \cdot 10^{10}$ e⁻/m³
Sensitivity: $1 \cdot 10^9$ e⁻/m³
(SNR)



Similar
performance
observed



Coherent Tune Shifts I

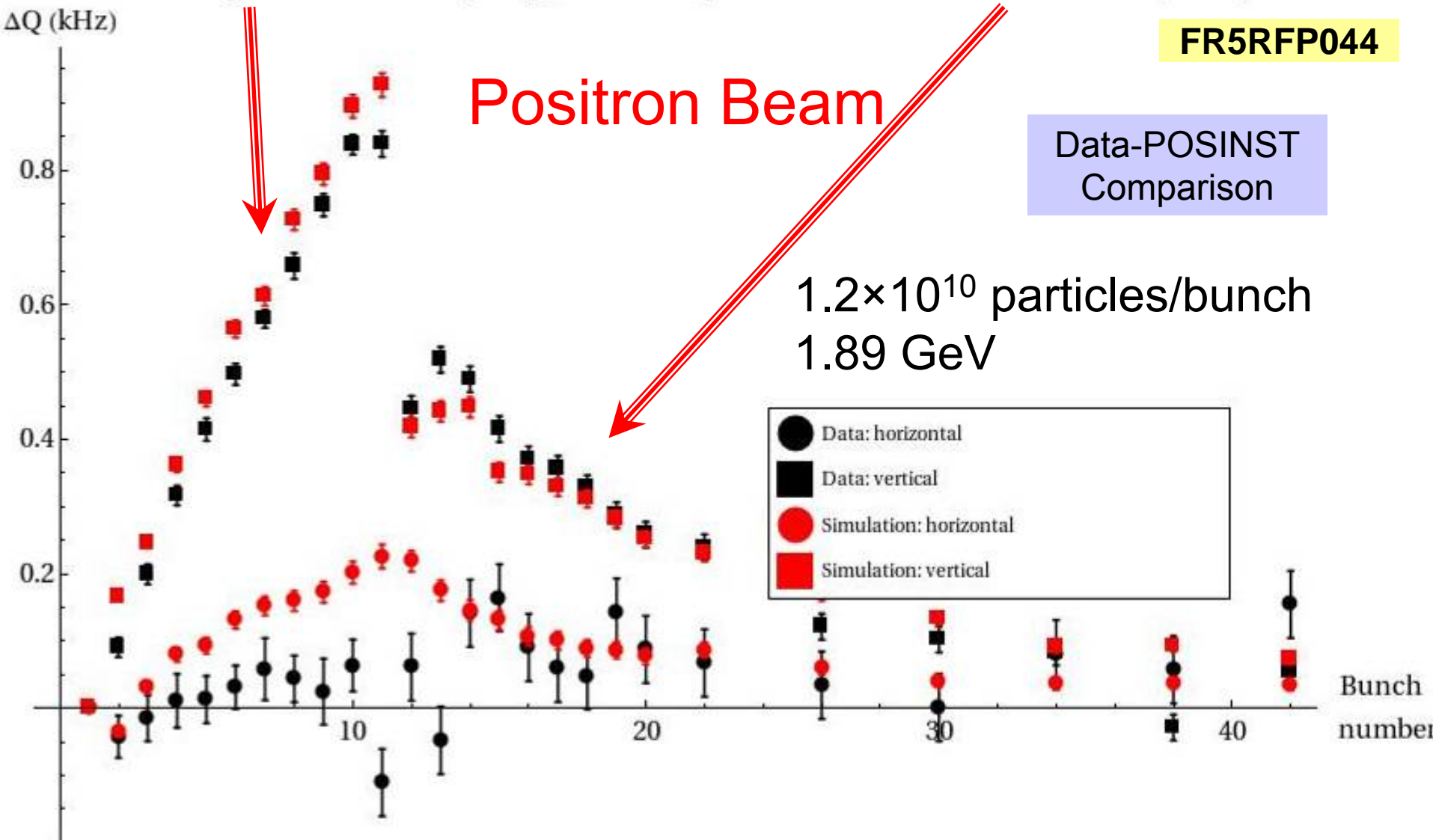
10 Bunch Leading Train (14ns spacing) with Trailing Witness Bunches

FR5RFP044

Positron Beam

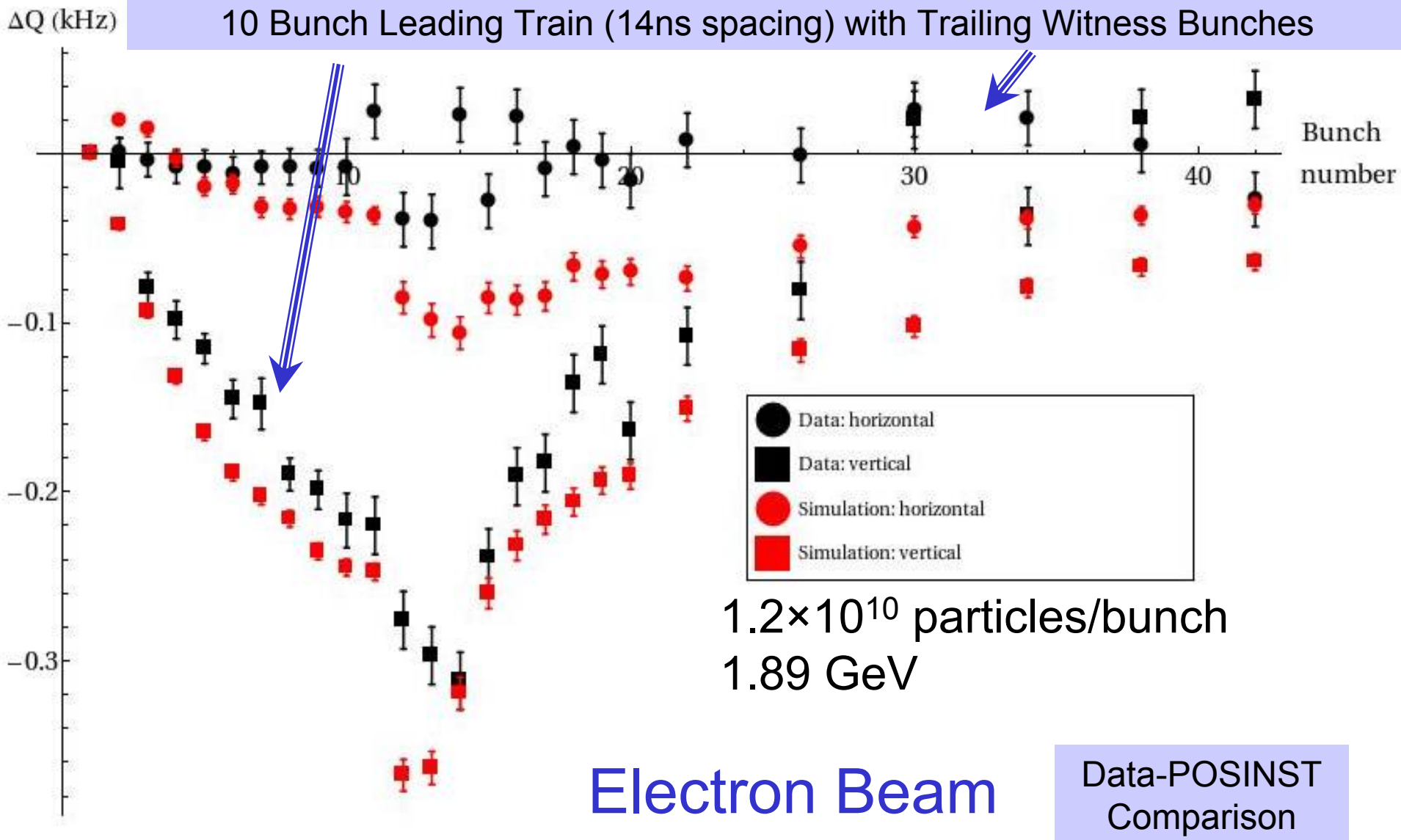
Data-POSINST
Comparison

1.2×10^{10} particles/bunch
1.89 GeV





Coherent Tune Shifts II

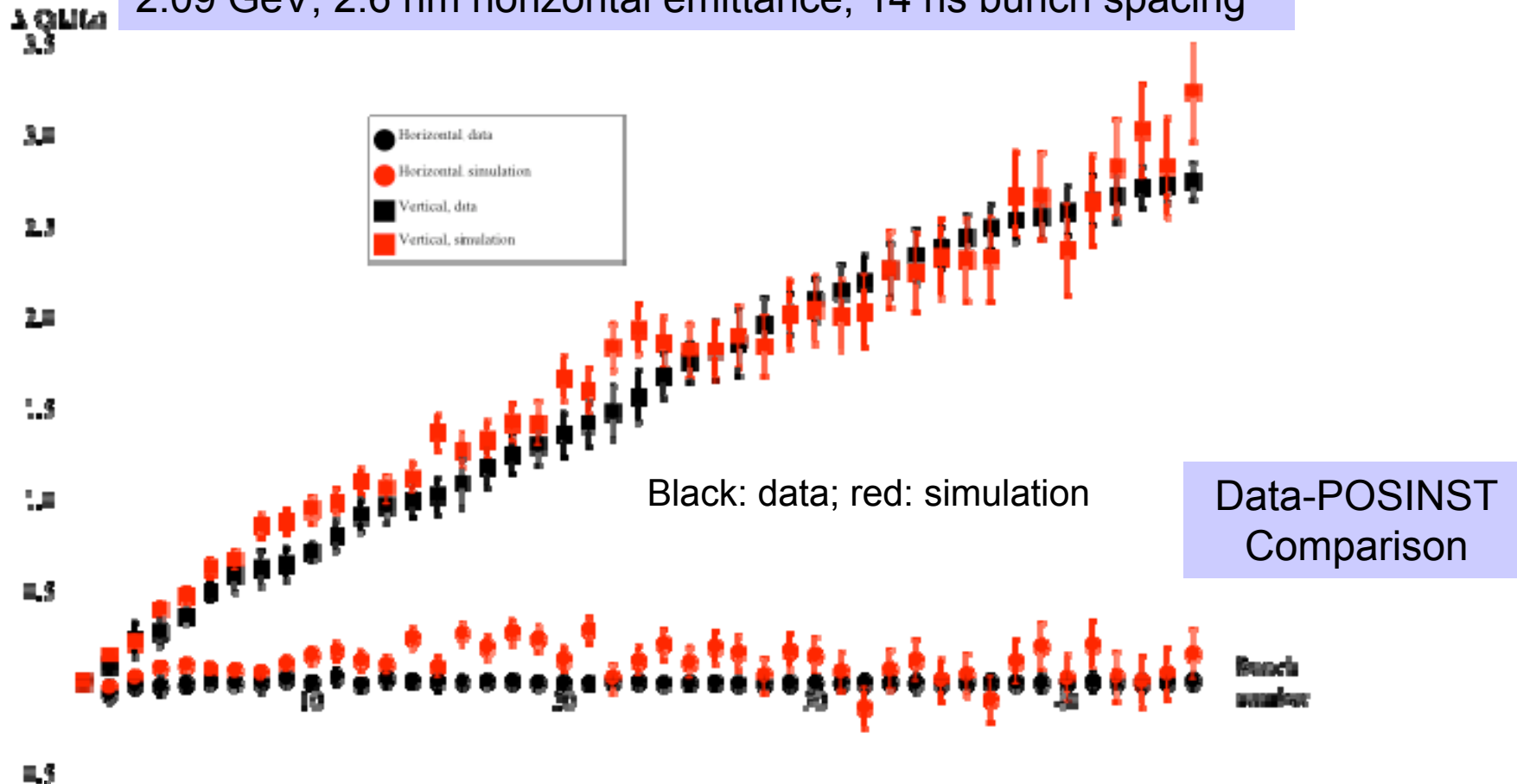




Coherent Tune Shifts III

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





Integration into the ILC DR Design

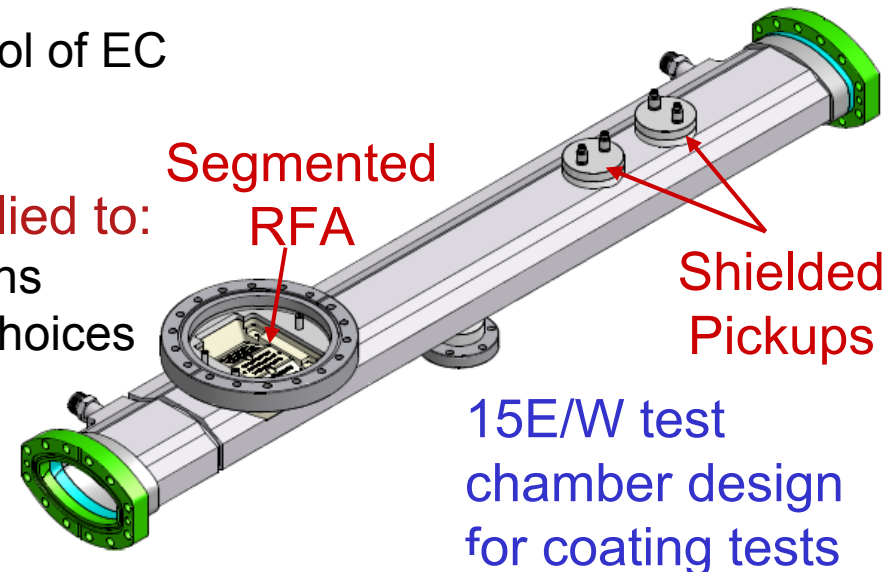
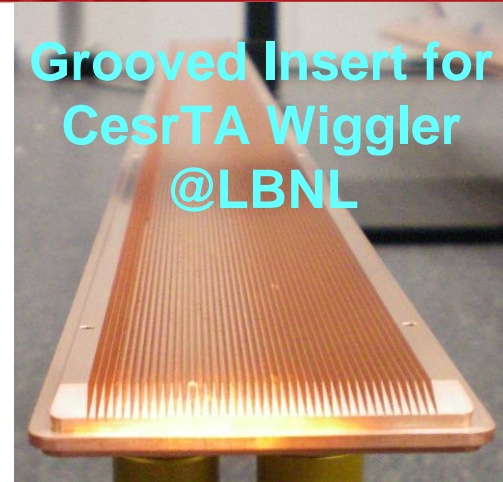
- We expect by 2010 to have placed the positron damping ring on a more solid foundation by having confirmed and updated our performance projections
 - Detailed comparisons of data and simulation in the low emittance regime will lead to significantly more reliable estimates in our DR simulations
 - Results 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

- Major CESR layout modifications now complete
 - Damping Ring configuration
 - 4 Experimental areas for EC build-up and mitigation studies
- Focus shifts towards detailed beam dynamics studies at ultra low emittance and ongoing mitigation tests
 - Mid-2009 \Rightarrow end of experimental program
 - Characterize instability thresholds
 - High resolution bunch-by-bunch beam size measurements to characterize incoherent emittance growth
 - Witness bunch studies for flexible control of EC interaction with beam
- In 2010, the CEsrTA results will be applied to:
 - Damping ring simulations and projections
 - Damping ring design \Leftrightarrow EC mitigation choices

Grooved Insert for
CesrTA Wiggler
@LBNL





- **Authors** M.A. Palmer, J. Alexander, M. Billing, J. Calvey, S. Chapman, G. Codner, C. Conolly, J. Crittenden, J. Dobbins, G. Dugan, E. Fontes, M. Forster, R. Gallagher, S. Gray, S. Greenwald, D. Hartill, W. Hopkins, J. Kandaswamy, D. Kreinick, Y. Li, X. Liu, J. Livezey, A. Lyndaker, V. Medjidzade, R. Meller, S. Peck, D. Peterson, M. Rendina, P. Revesz, D. Rice, N. Rider, D. Rubin, D. Sagan, J. Savino, R. Seeley, J. Sexton, J. Shanks, J. Sikora, K. Smolenski, C. Strohman, A. Temnykh, M. Tigner, W. Whitney, H. Williams, S. Vishniakou, T. Wilksen, CLASSE, Cornell University, Ithaca, NY 14853, U.S.A.
K. Harkay, ANL, Argonne, IL 60439, U.S.A.
R. Holtzapple, California Polytechnic State University, San Luis Obispo, CA 93407, U.S.A.
E. Smith, CCMR, Cornell University, Ithaca, NY 14853, U.S.A.
J. Jones, A. Wolski, Cockcroft Institute, Warrington, Cheshire, U.K.
Y. He, M. Ross, C.Y. Tan, R. Zwaska, FNAL, Batavia, IL 60510, U.S.A.
J. Flanagan, P. Jain, K. Kanazawa, K. Ohmi, H. Sakai, K. Shibata, Y. Suetsugu, M. Tobiyama, KEK, Tsukuba, Ibaraki 305-0801, Japan.
J. Byrd, C.M. Celata, J. Corlett, S. De Santis, M. Furman, A. Jackson, R. Kraft, D. Munson, G. Penn, D. Plate, A. Rawlins, M. Venturini, M. Zisman, LBNL, Berkeley, CA 94720, U.S.A.
D. Kharakh, M. Pivi, L. Wang, SLAC, Menlo Park, CA 90425, U.S.A.
- **Wilson Lab Technical Staff**
- **ILC Damping Rings Group**
- **Dmitry Teytelman (DIMTEL) and John Fox (SLAC)**