CesrTA Status and Planning

Mark Palmer
Cornell University

for the CesrTA Collaboration
(Participating Researchers from: ANL, CalPoly, CERN, Cockcroft, Cornell, FNAL, KEK, LBNL, SLAC)

2009 Joint DOE/NSF Review

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_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 ⇨ ~240 running days over a 2+ year period

CesrTA Parameters

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

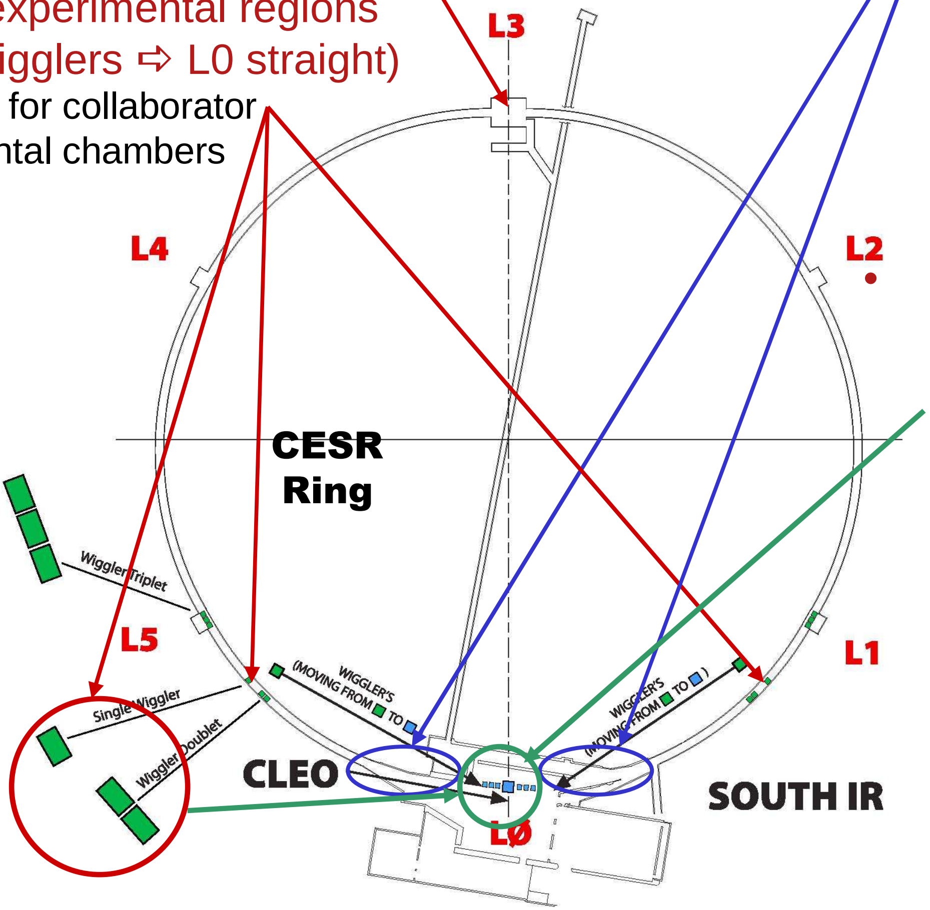
Unique Features of R&D at CESR

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 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 (~240 running days) 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

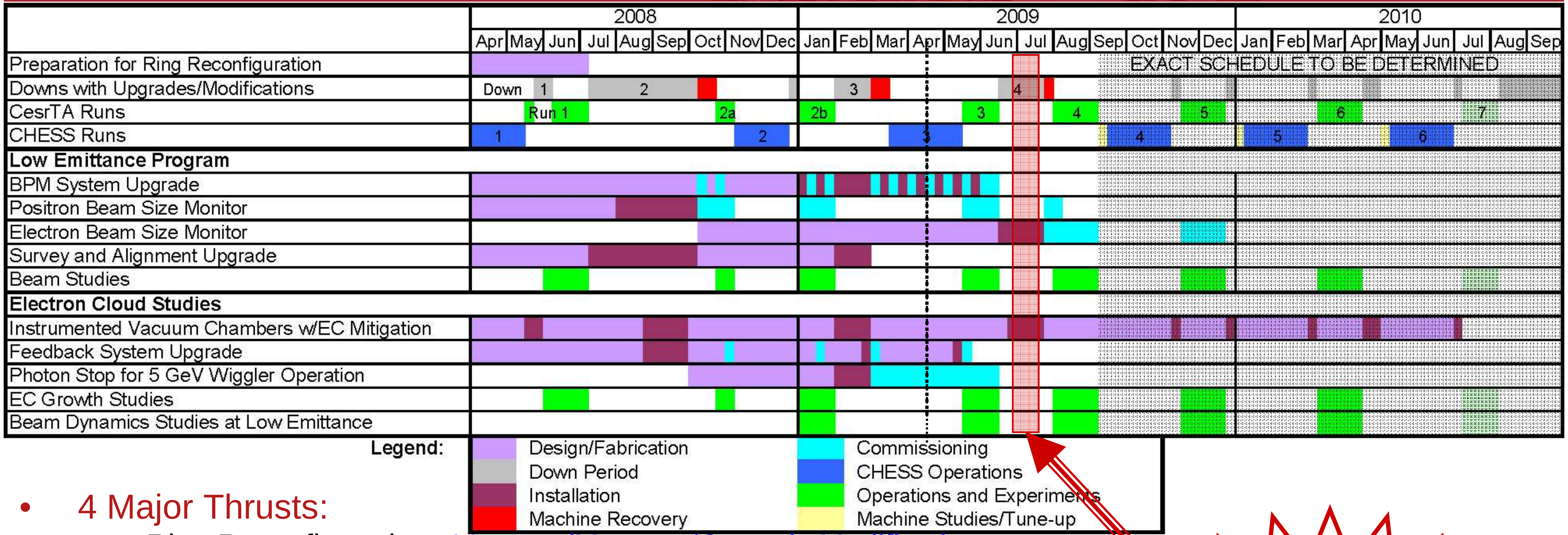
- L3 EC experimental region
  - PEP-II EC Hardware: Chicane, upgraded SEY station (coming on line in May)
  - Drift and Quadrupole diagnostic chambers
- New EC experimental regions in arcs (wigglers ⇨ L0 straight)
  - Locations for collaborator experimental chambers



- 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)

Cornell University
Laboratory for Elementary-Particle Physics

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 Size Monitors
    - Survey and Alignment Upgrade
  - Electron Cloud R&D Support
    - Local EC Measurement Capability: RFAs, TE Wave Measurements, Shielded Pi…
    - Feedback System upgrade for 4ns bunch trains
    - Photon stop for wiggler tests over a range of energies
    - Local SEY measurement capability
  - Experimental Program
    - Targeting ~240 running days over course of program
    - Early results will feed into final stages of program
- Schedule coordinated with Cornell High Energy Synchrotron Source (CHESS) operations

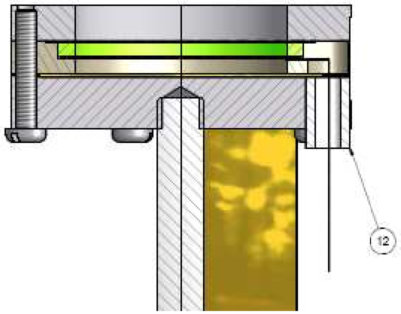
Goal is to complete bulk of upgrades by mid-2009 ⇨ enables an experimental focus thru mid-2010

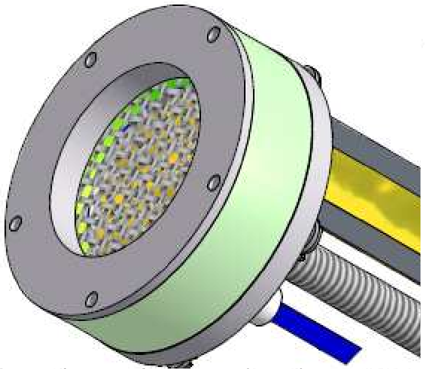
CesrTA Schedule: Upgrade Milestones

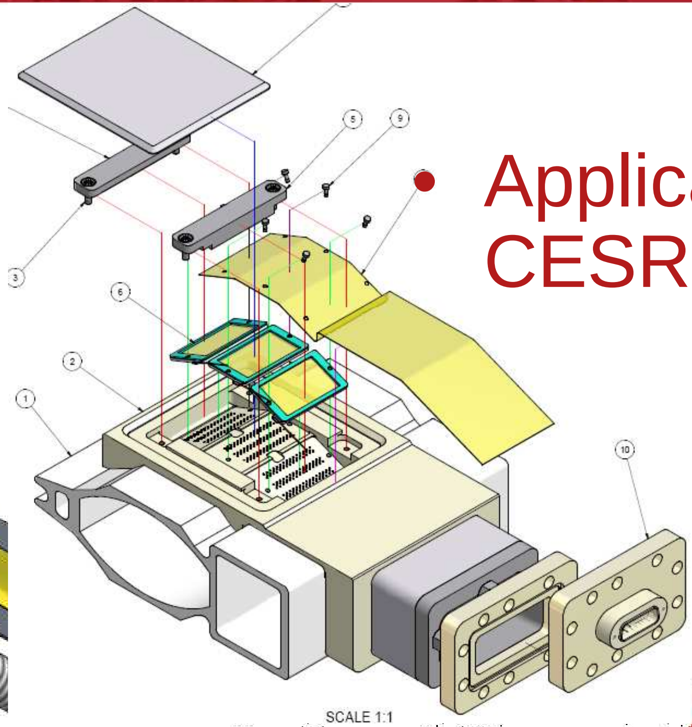
Period	Task	Target	Status	Special Comments
Down #1	1. Installation of 1st CESR dipole with RFA 2. Installation of instrumented drift VCs	FY08 Q3 FY08 Q3	Done Done	
Down #2	1. CESR layout for low emittance operation 1.L0 Wiggler straight (former CLEO IR) 2.Vertical electrostatic separator removal 3.CESR quadrupole alignment mechanism upgrade and improved ring survey	FY09 Q1	Done	**Major Contingencies**: Failed SRF cavity – removed, impacts bunch length • Vertical separators largest single source of impedance in ring
	2. Electron cloud diagnostic upgrades 1.Diagnostic wiggler VCs (with EC mitigation) 2.L3 EC experimental region preparation 3.EC diagnostics in CESR arcs and preparation of isolated test chamber sections	FY09 Q1	Done	• Diagnostic wigglers installed Oct 23-24, 2008
	3. Beam instrumentation upgrades 1.Installation of e+ x-ray beam size monitor beam line (upgrade of existing CHESS line) 2.Phased installation of BPM system hardware	Phased Installation - FY09 Q3	Ongoing	• e+ x-ray line completed – ongoing commissioning and development of new optics and detector hardware • BPM infrastructure upgrade begun
Down #3	1. L3 EC experimental hardware in ring 2. Photon stop for L0 wiggler straight 3. Beam instrumentation upgrades 1.Installation of e- x-ray beam line (upgrade of CHESS C-line) 2. Phased installation of new BPM system hardware 3. New streak camera optics lines in L3 region	FY09 Q2 FY09 Q4 Phased Installation - FY09 Q3	Done Done Ongoing	**Major Contingencies**: SRF cavity - replaced Dipole bus repair • L3 EC ring hardware installed – ⇨ operational in May `09 • Electron x-ray line front end modifications complete

Thin RFA Design

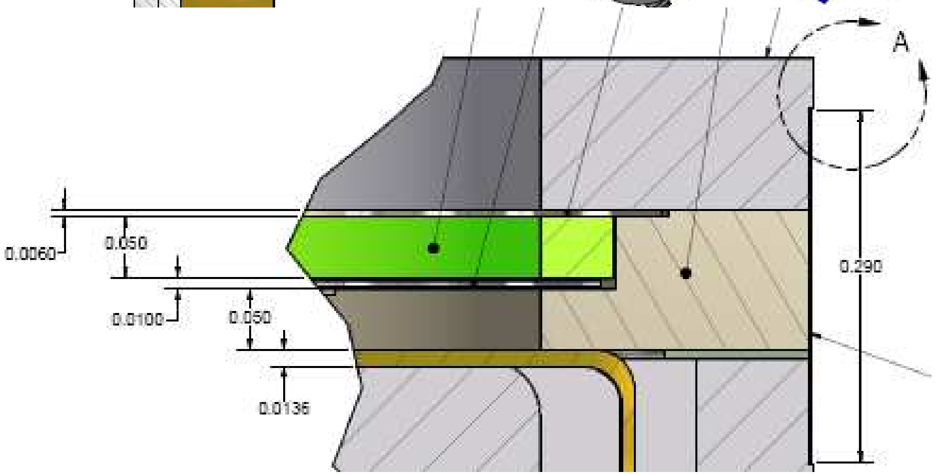
- Thin structure developed for use in limited aperture locations
  - CESR dipoles
  - CESR-c wigglers

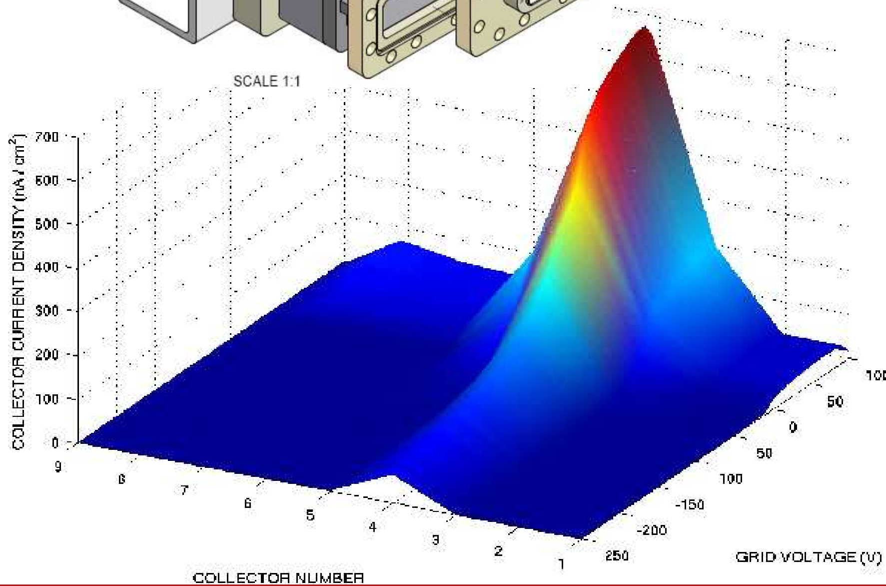






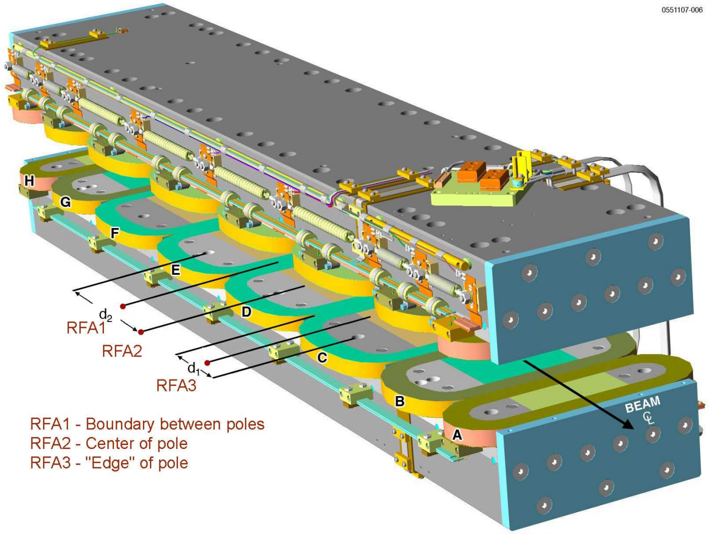
- Application to CESR Dipole

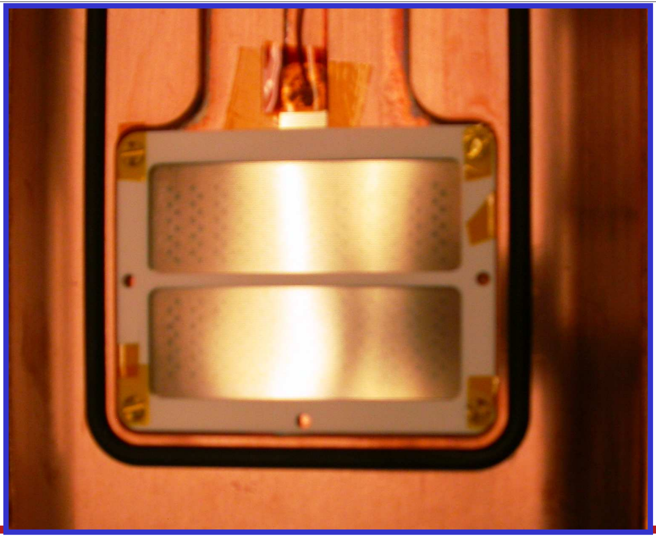


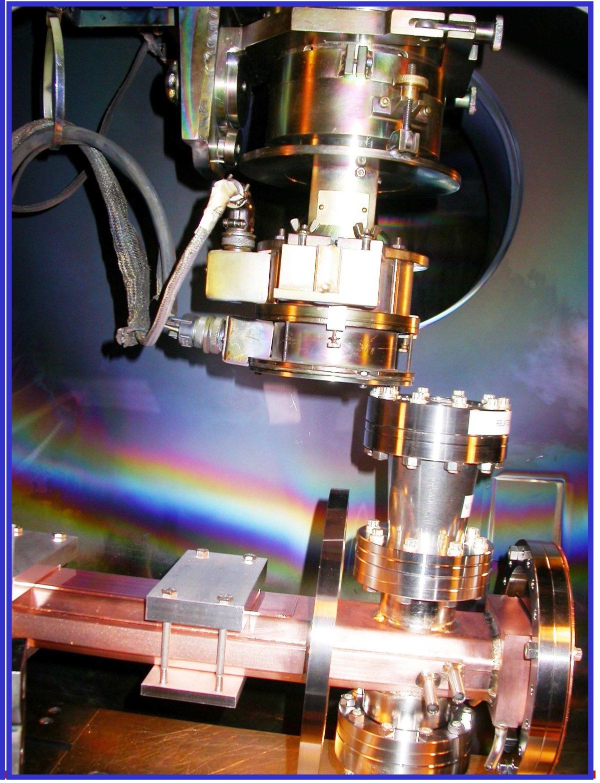


Upgrade Activities: Instrumented Wigglers

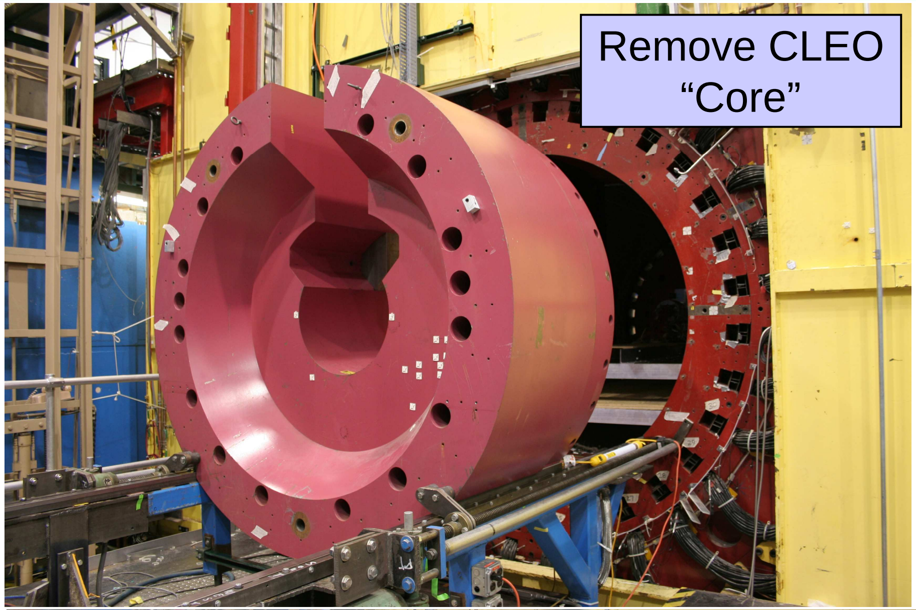
- Installed Oct 23-24, `08
  - 1 Cu VC; 1 TiN-coated VC

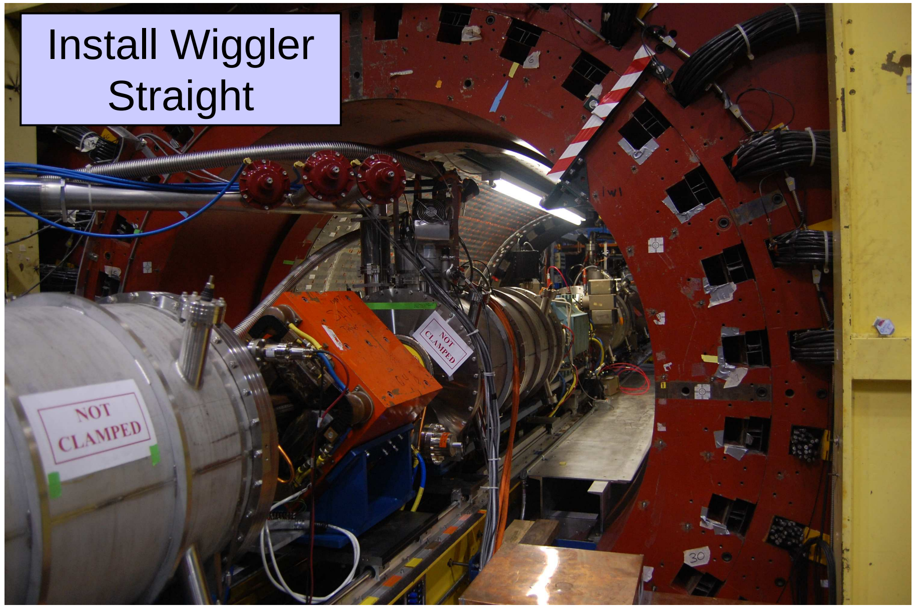


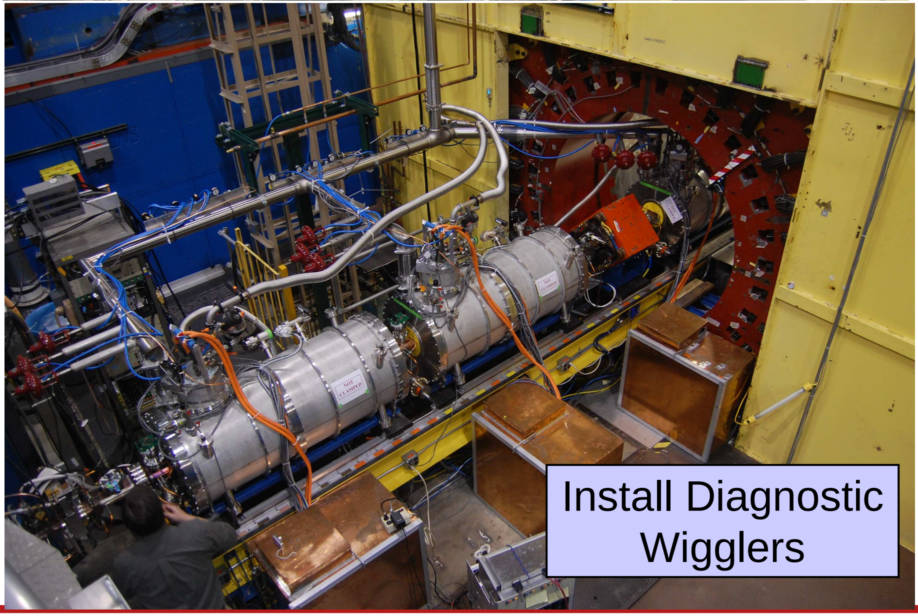


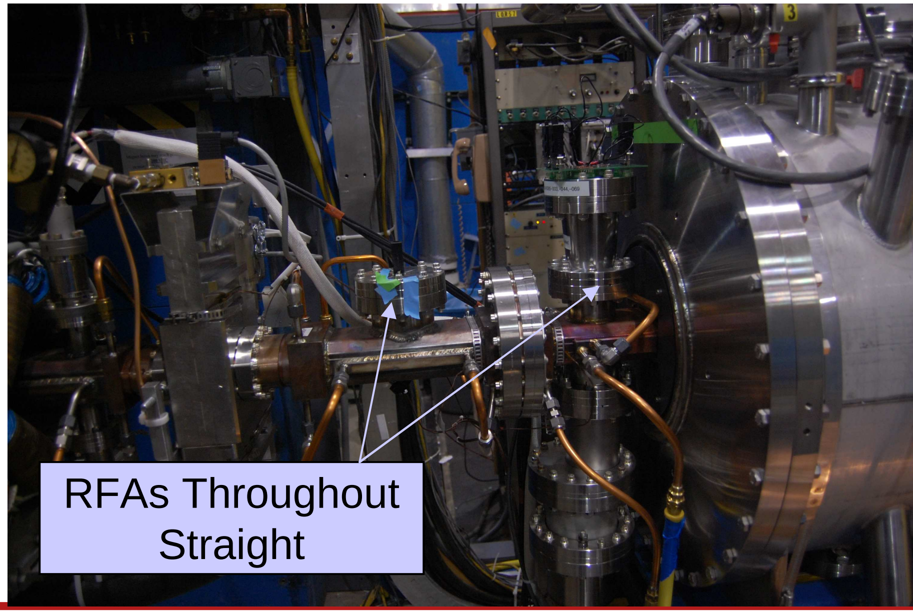


Upgrade Activities: L0 Modifications





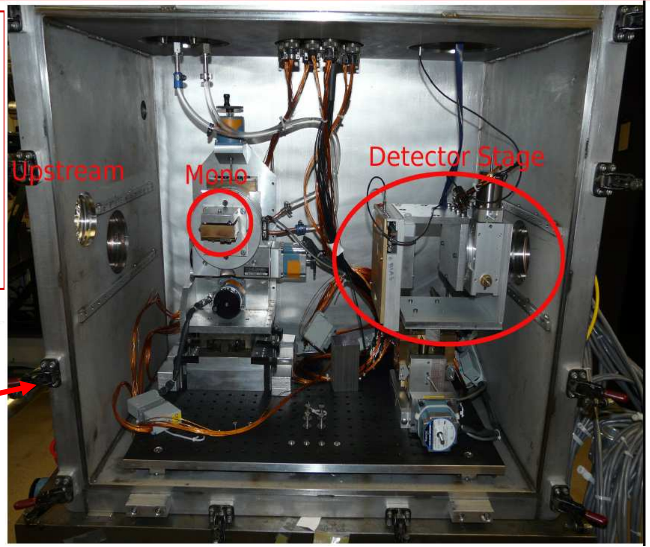


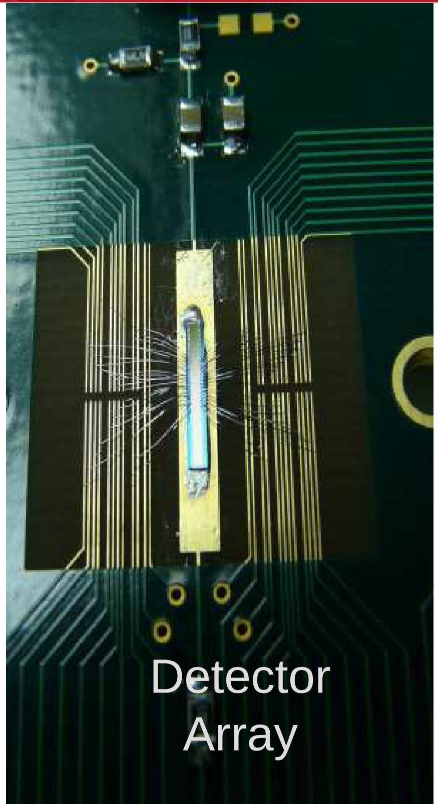


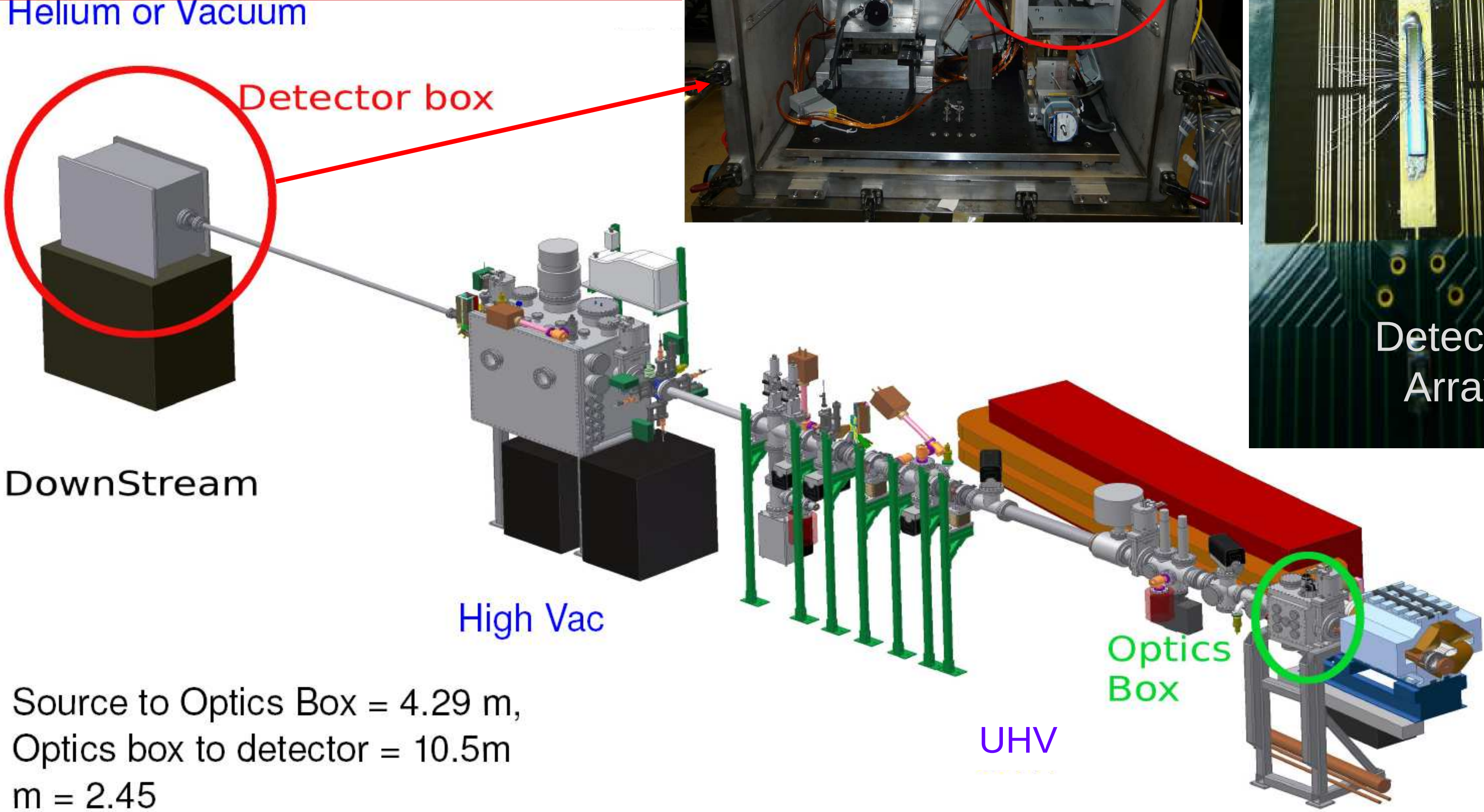
Upgrade Program: xBSM Optics Line & Detector

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

2nd line for e- beam in progress

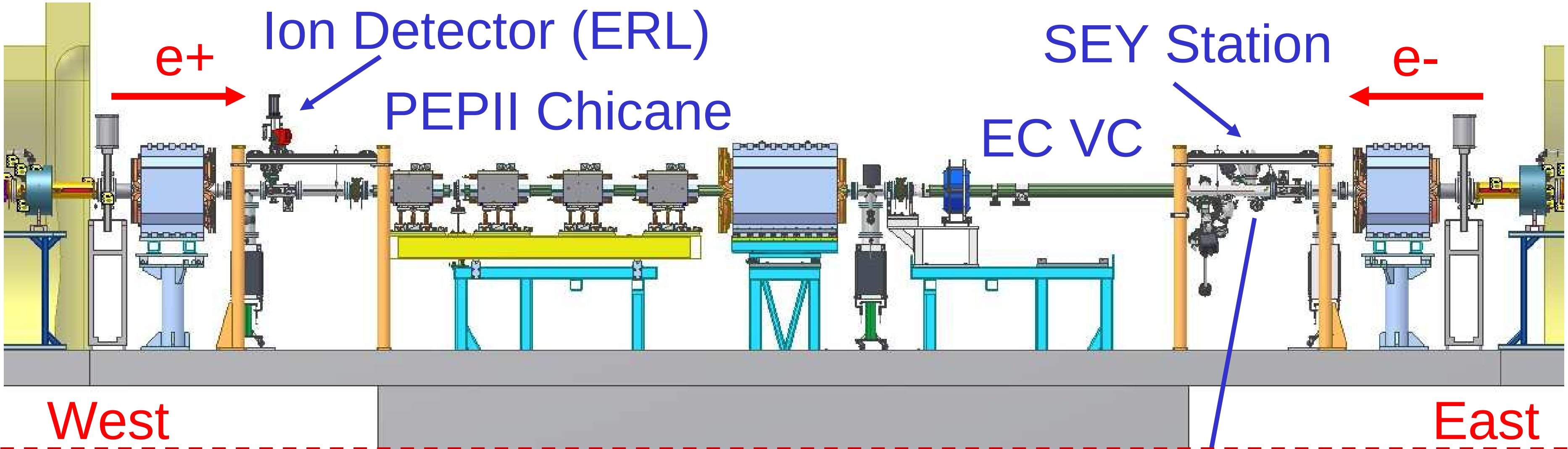


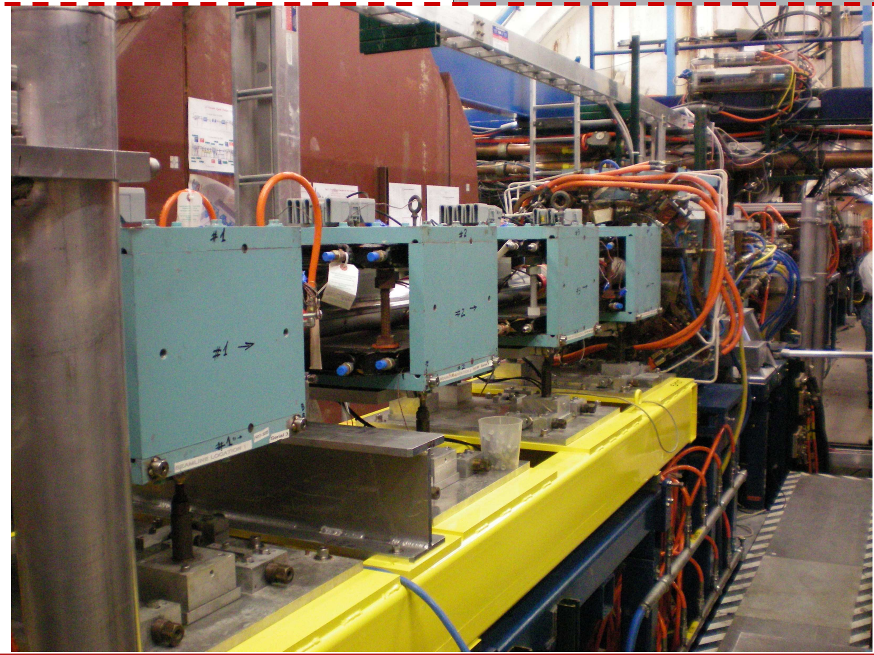


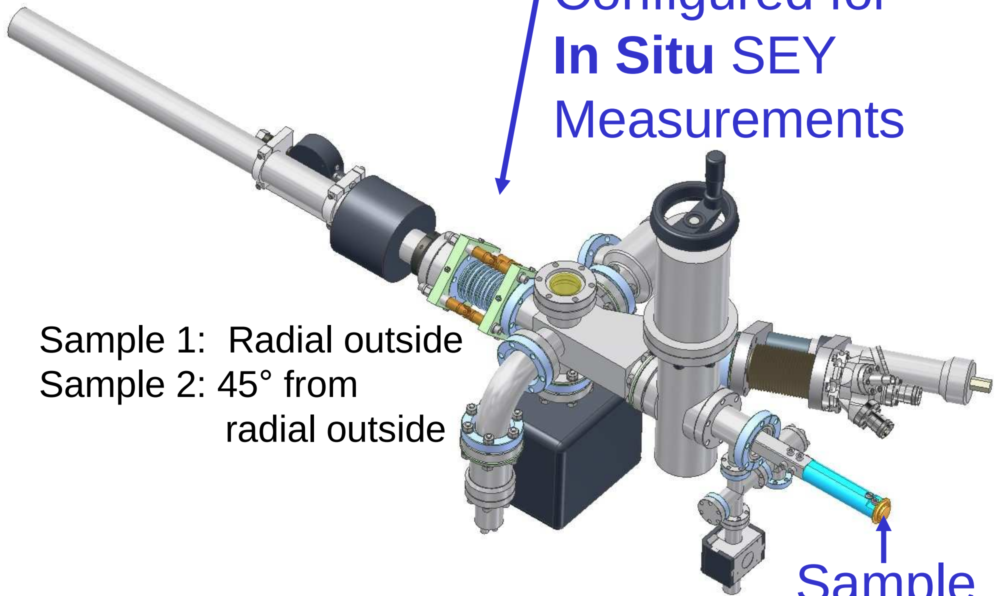


Source to Optics Box = 4.29 m,
Optics box to detector = 10.5m
m = 2.45

L3 Experimental Region







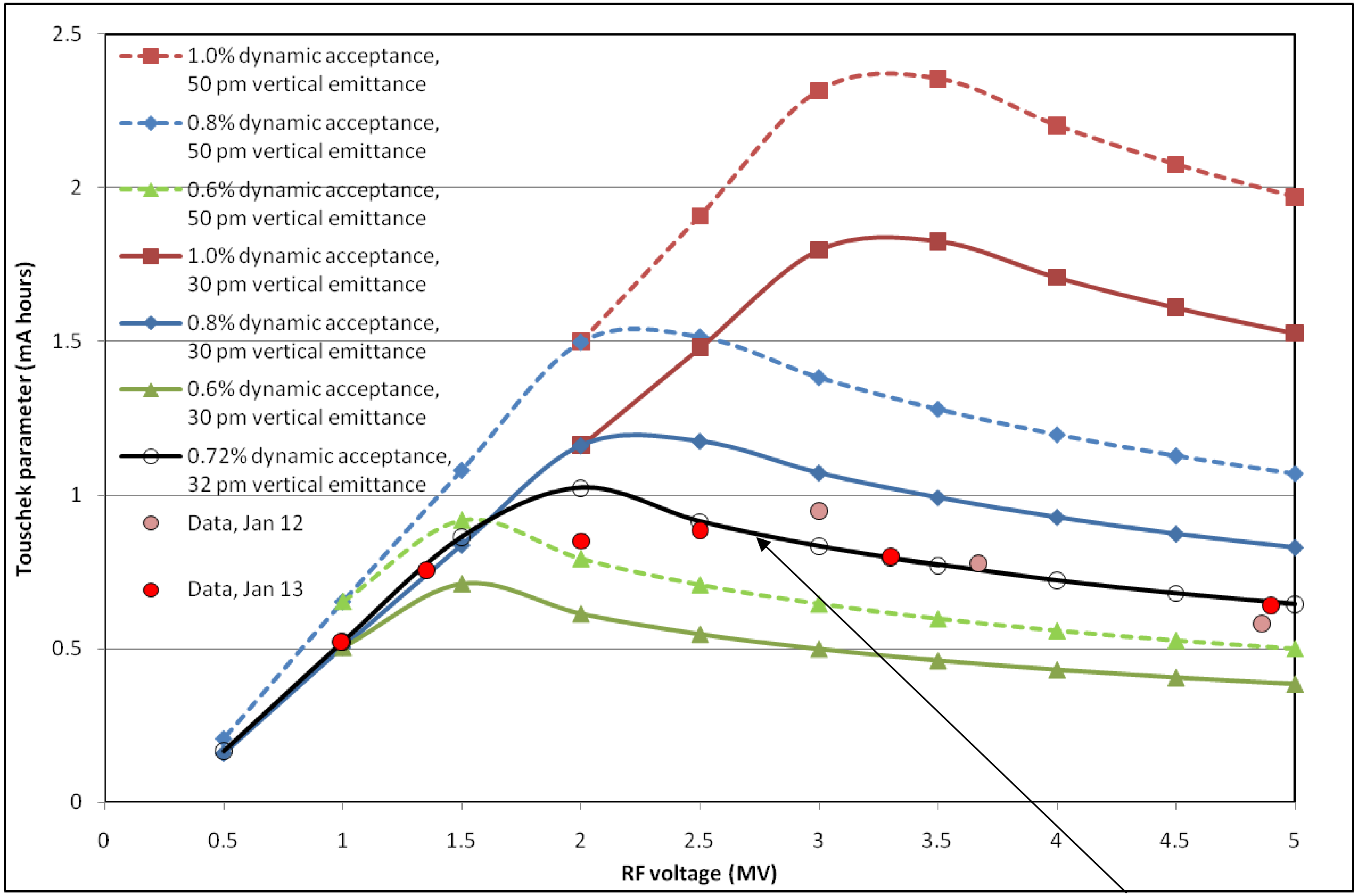
Remaining Upgrade Items

- Key tasks:
  - BPM system upgrade:
    - Phased switchover and testing of new system underway
    - Ongoing commissioning work during May-June run
  - xBSM upgrade:
    - Continued work with positron line development during May-June run
    - Complete electron line deployment (summer down) and commission (Aug. run)
  - 4ns upgrades
    - Feedback system (4ns system operational in all 3 dimensions for May-June run)
    - Upgraded digitizers for xBSM (targeting Aug. run)
  - L3 EC Hardware
    - Chicane, SEY station and EC chambers (commission/experiments ⇨ May-June)
  - New EC vacuum chambers
    - Wiggler chambers with grooves and electrode mitigation (CU-KEK-LBNL-SLAC)
    - Upgraded RFA detectors under development
    - Diagnostic quadrupole chamber for L3 experimental region (summer install)
    - Collaborator chambers: CERN (α-C coating); FNAL (enamel with electrode); SLAC (new groove design)
    - Additional chambers depending on initial results through remainder of program
  - EC solenoid windings on CESR drifts
- Challenges:
  - Machine contingencies:
    - Linac Gun replacement scheduled for summer `09
    - Some dipole bus repairs likely
  - Coordination of schedule with CHESS needs
  - Reduction in laboratory personnel after 2008 layoffs
  - Administrative & management resources

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
- Emittance measurements begun…
  - Touschek lifetime measurements initially used to characterize beam size
  - xBSM measurements as detector and optics were characterized
- Ongoing program of magnet alignment to improve emittance
  - Alignment work continued throughout the run
  - Systematic errors with sextupole alignment have been identified as a significant contributor

First Detailed Optics Correction ⇨ Touschek Study ⇨ xBSM Measurement

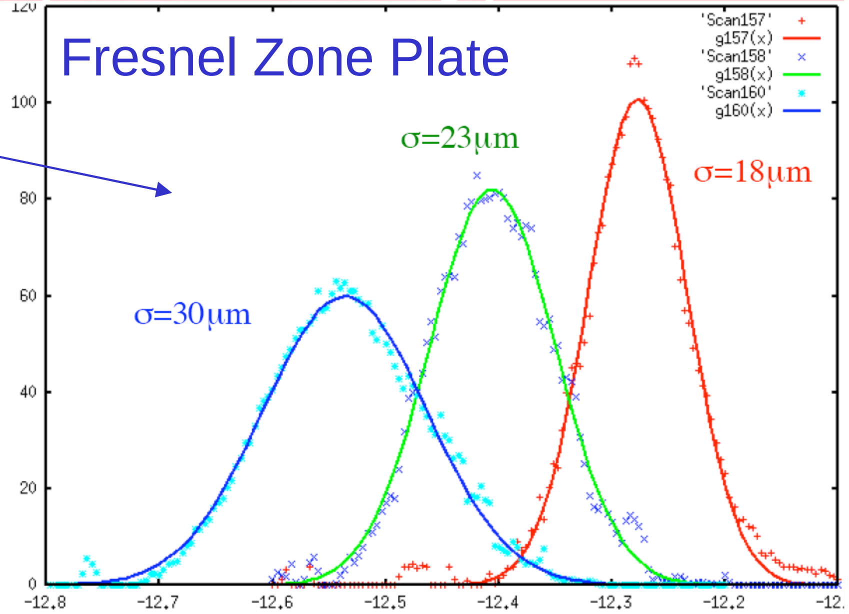


Preliminary

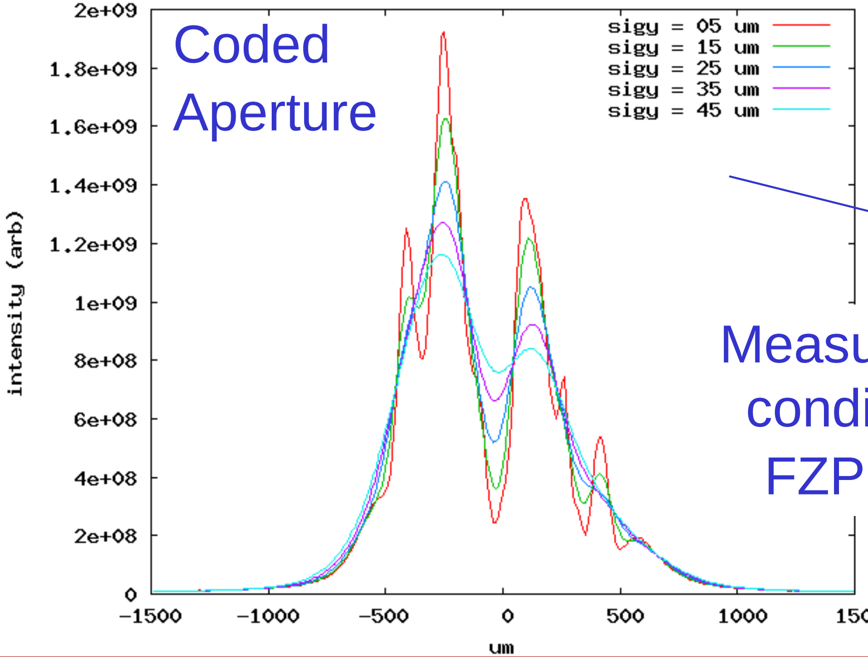
Measured energy acceptance = 0.7% → ε_v ~ 32pm
From xBSM σ_v ~ 15±5 μm → ε_v ~ 38pm
Within factor of 2 of 20pm target…

xBSM Snapshots (Preliminary)

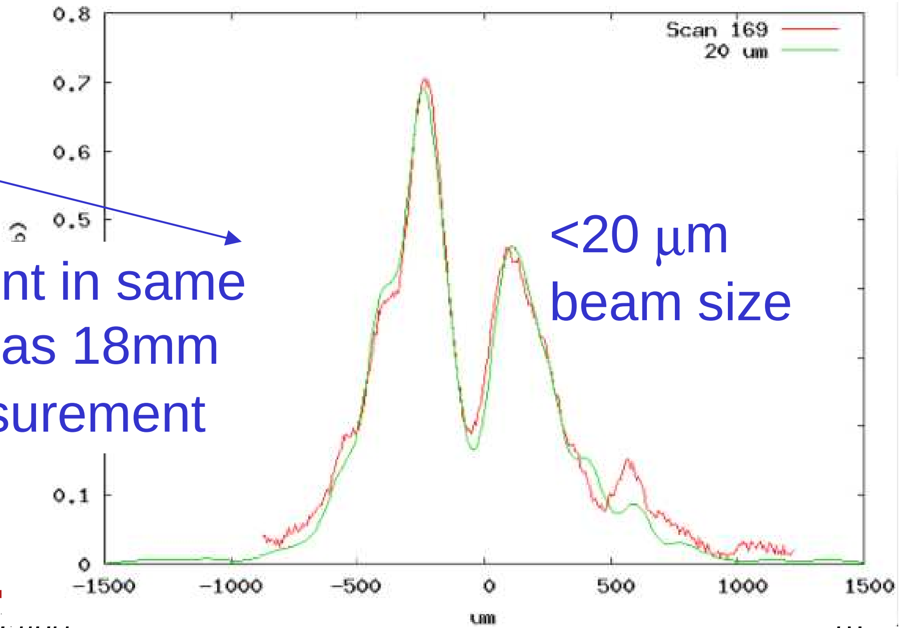
- Scan of coupling knob
- Coded aperture measurements
- Smallest recorded size: ~15 μm (but further calibration work needed)



Simulations



Measurement in same conditions as 18mm FZP measurement



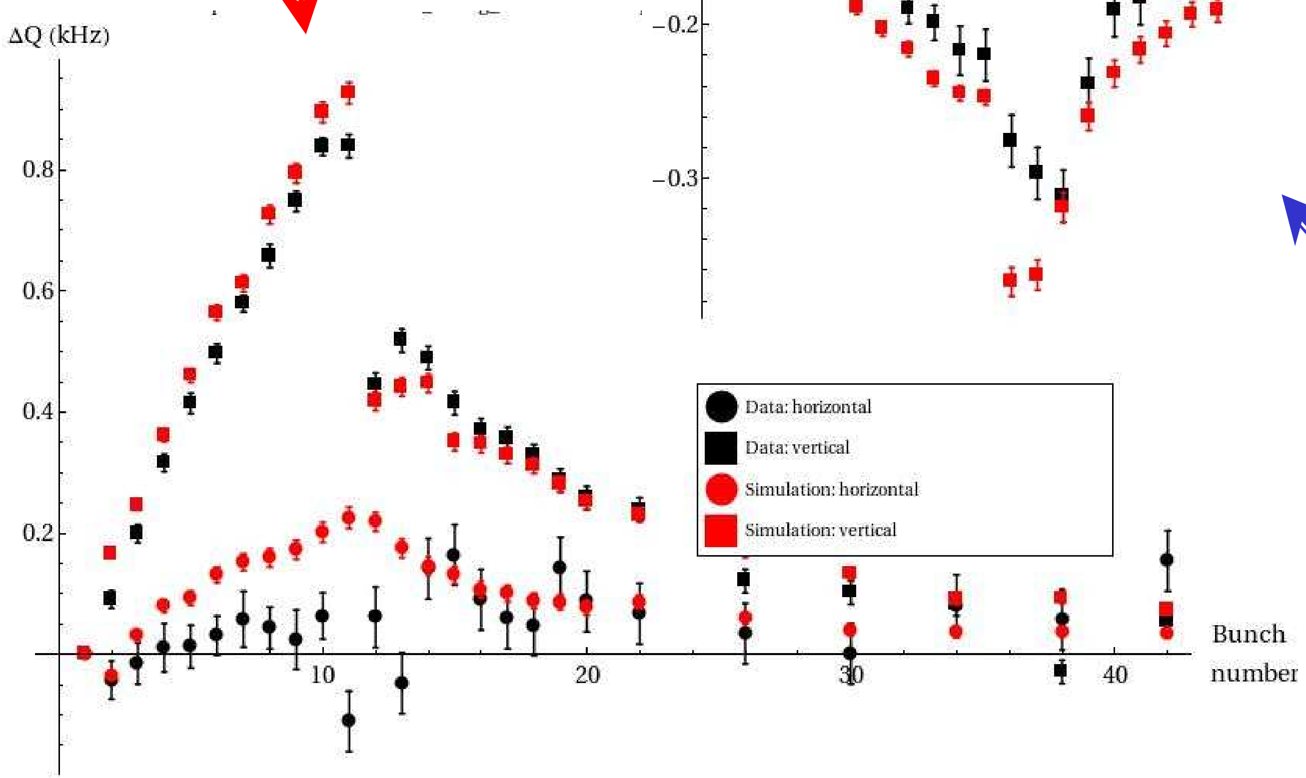
Status of EC Studies

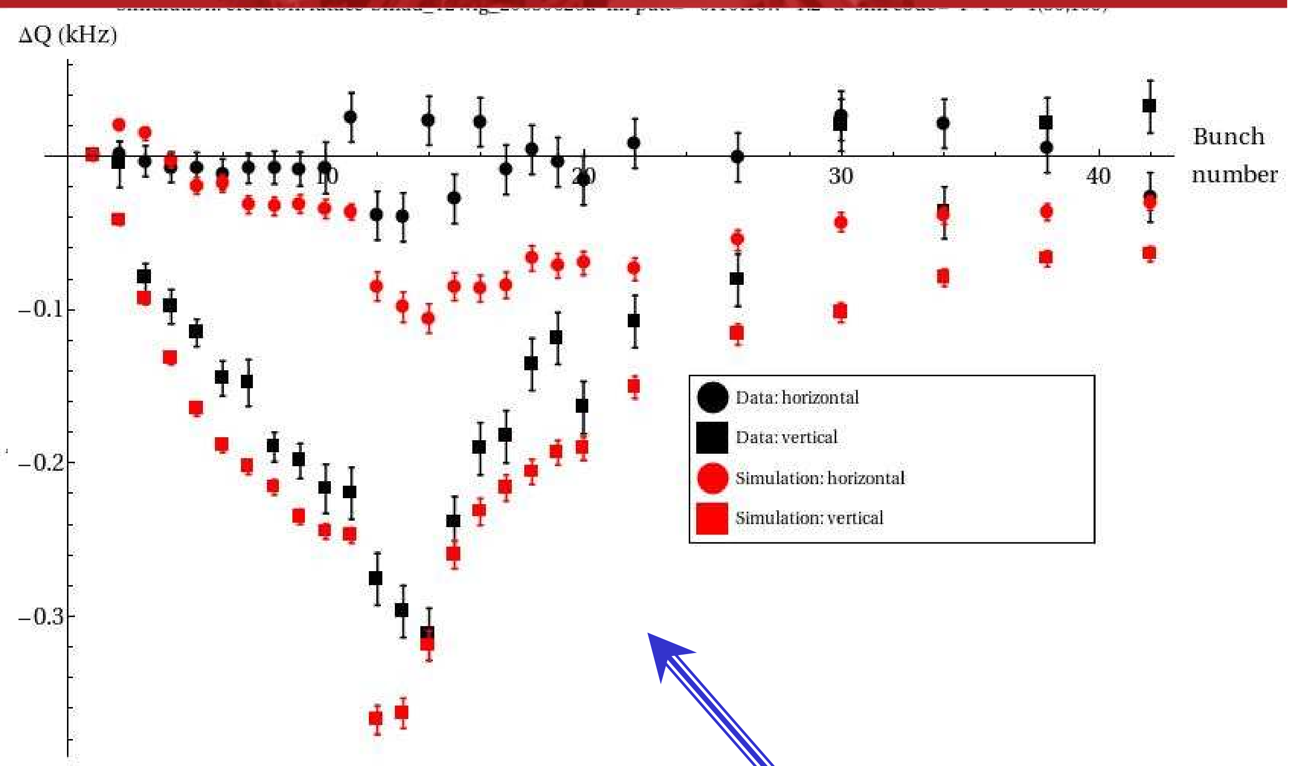
- Simulations of tune shifts in POSINST at Cornell and LBNL:
  - Using a new option in POSINST for offsetting the bunches, have shown that the tune shifts of a single bunch are different if the whole train is oscillating coherently, than if just the single bunch is oscillating.
  - Horizontal tune shifts in a dipole are much smaller when the whole train is oscillating coherently. This is particularly relevant for the tune shift measurements at CesrTA, since we kick the whole train coherently to do the measurement.
  - Tune shifts calculated for a coherently oscillating beam give better agreement with measurements: see following three slides.
- January run
  - Studies of systematic effects in the tune shift measurements were carried out.
  - Measurements of tune shift vs. current for long trains (10, 20, 45 and 116 and 145 bunches) were carried out (evidence of instability developing at the end of the 116 and 145 bunch trains)
  - RFA and TE wave measurements to characterize EC density in drifts, dipoles and wigglers
  - Work on comparisons between RFA and TE wave measurements as well as systematics checks for both

Coherent Tune Shifts I

10 Bunch Train with Trailing Witness Bunches

Positron Beam





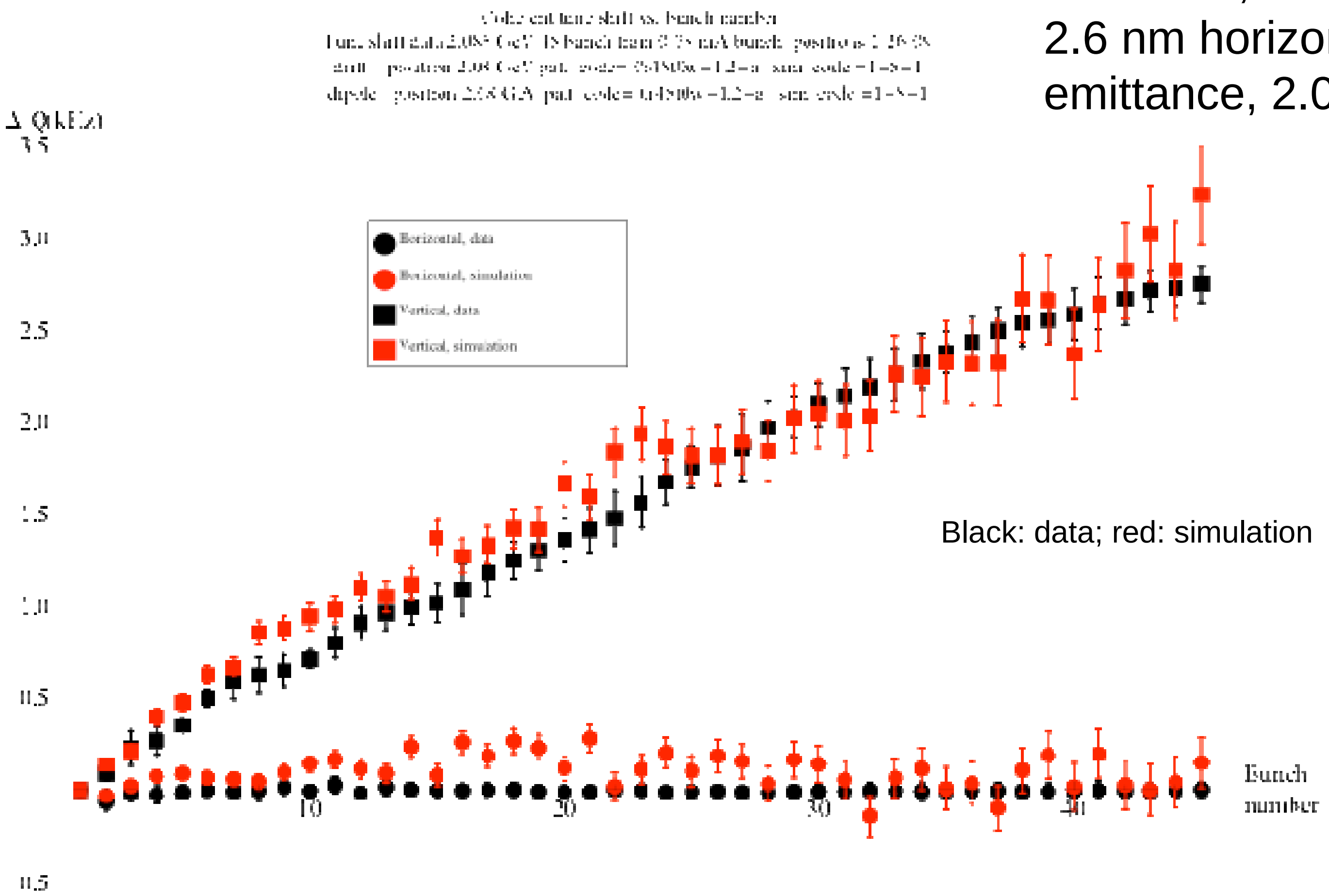
Electron Beam

Data-POSINST Comparison

Coherent Tune Shifts II

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

Positrons, 45 bunch train
2.6 nm horizontal emittance, 2.09 GeV



Black: data; red: simulation

POSINST

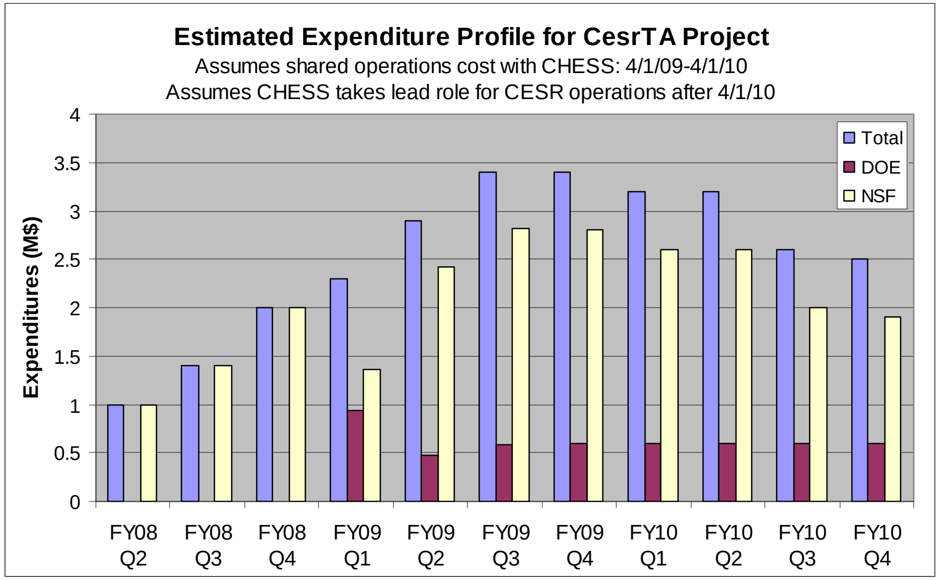
Integration into the ILC DR Design

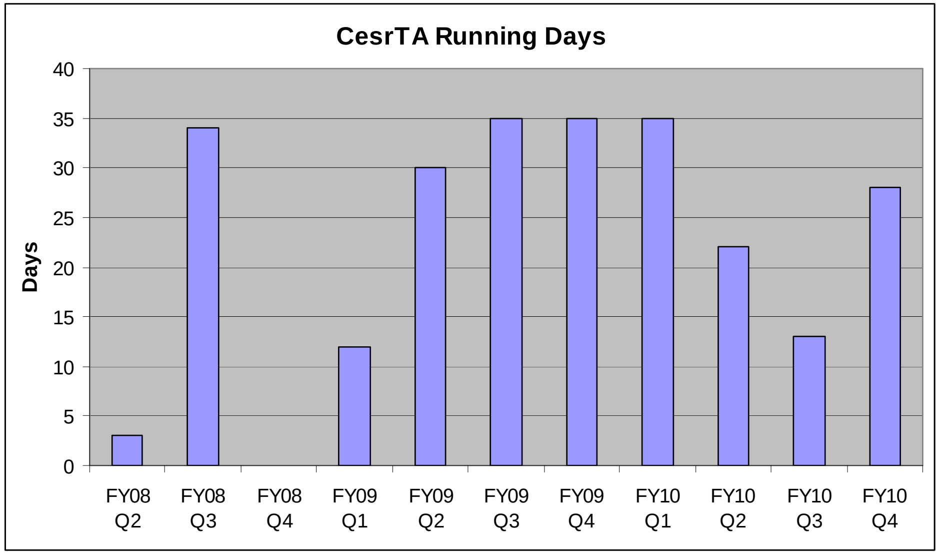
- We expect by 2010 to have placed the positron damping ring on a more solid foundation by having confirmed and updated our performance projections
  - **Detailed comparisons of data and simulation in the low emittance regime will lead to significantly more reliable estimates in our DR simulations**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

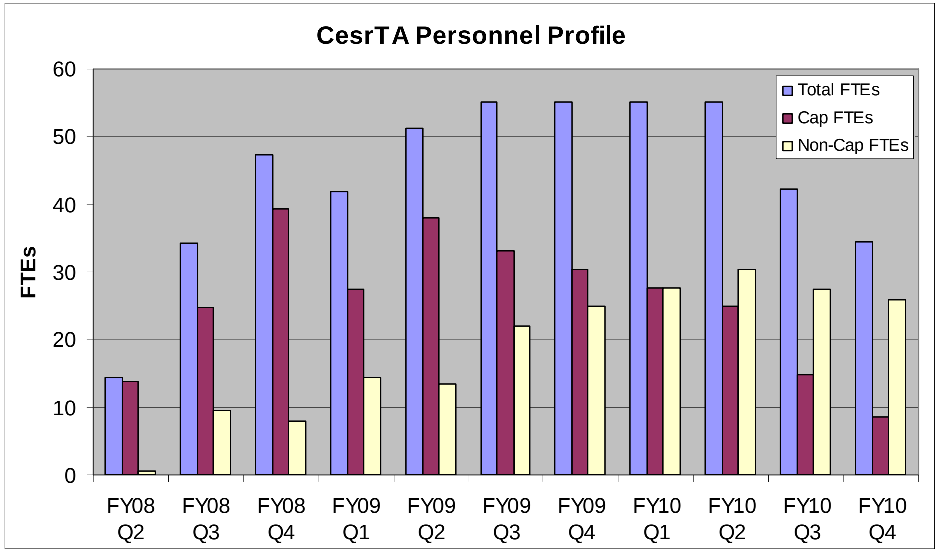
Cornell University
Laboratory for Elementary-Particle Physics

Projections for FY10, Looking Towards FY11…

- Profiles of Estimated Budget, Manpower, Running Days Thru End FY10
- Out Year Plans
  - Continued participation in ILC DR Development
    - Incorporate EC, LET and instrumentation deliverables into DR design
  - CesrTA infrastructure in place
    - Pursue funding for a modest program of continued DR R&D
    - Examples: Further LET development, durability studies of coatings for EC mitigation, additional prototyping work,…

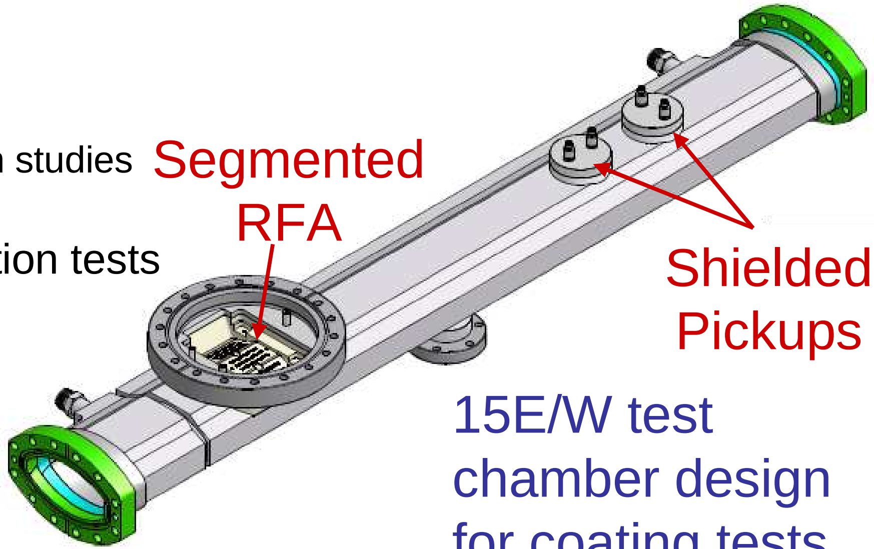






Conclusion

- 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 ➪ 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, expect a significant effort to be directed towards applying the CesrTA results to:
  - Damping ring simulations and projections
  - Damping ring design ⇔ EC mitigation choices
    - Vacuum design
    - Integrated performance evaluation of vacuum system with EC mitigation
- FY11-FY12
  - Continuing role in ILC DR design
  - Follow-up studies using the CesrTA configuration



15E/W test chamber design for coating tests