



Cornell University
Laboratory for Elementary-Particle Physics

CesrTA Program Overview & ILC Damping Rings Electron Cloud Effort

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- CsrTA Presentations Overview
 - Present Talk -
 - CsrTA Program Overview
 - Program, Schedule, Status
 - ILC DR EC Effort
 - Laboratory Efforts and Coordination
 - CsrTA Electron Cloud R&D – G. Dugan
 - Experimental Overview
 - Simulation Overview
 - Results and Next Steps
 - Damping Ring Needs/Projections
 - CsrTA Low Emittance Tuning Effort – D. Rubin
 - LET Tools
 - Techniques and Instrumentation
 - Results and Next Steps



- **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



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

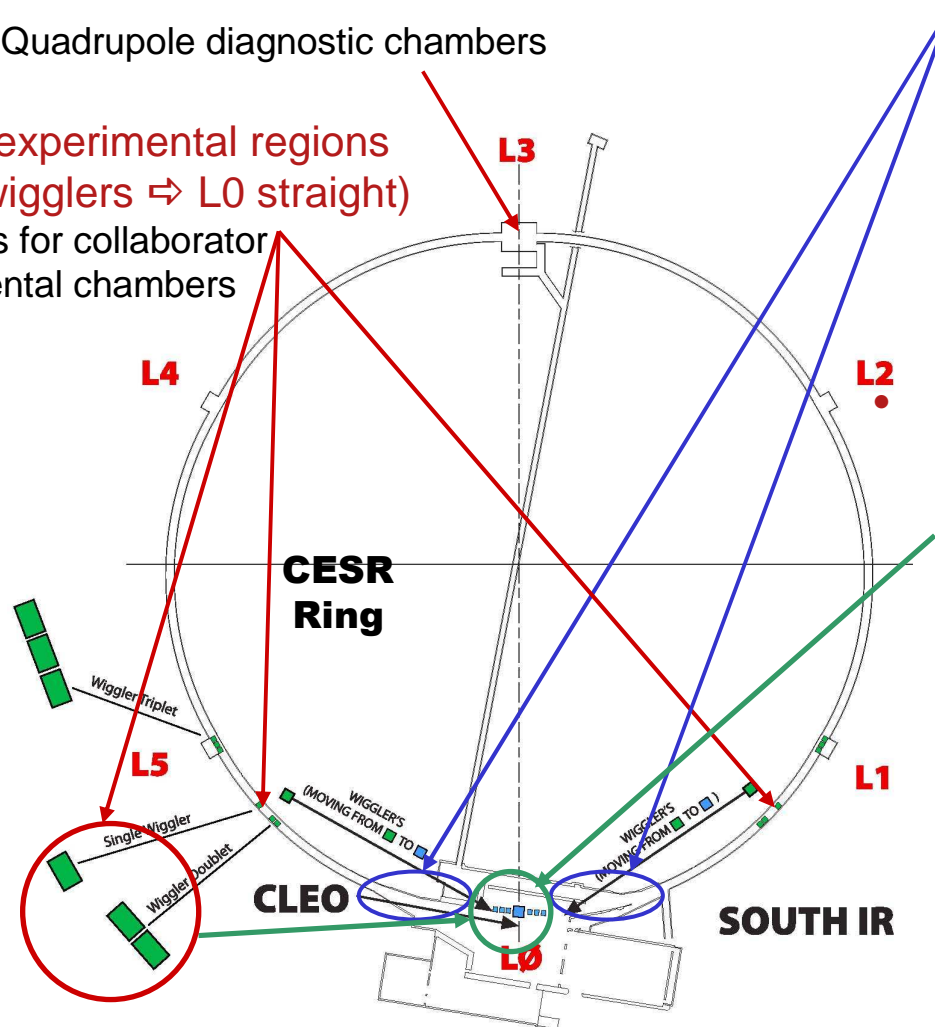
- L3 EC experimental region**

PEP-II EC Hardware: Chicane, 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



- 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

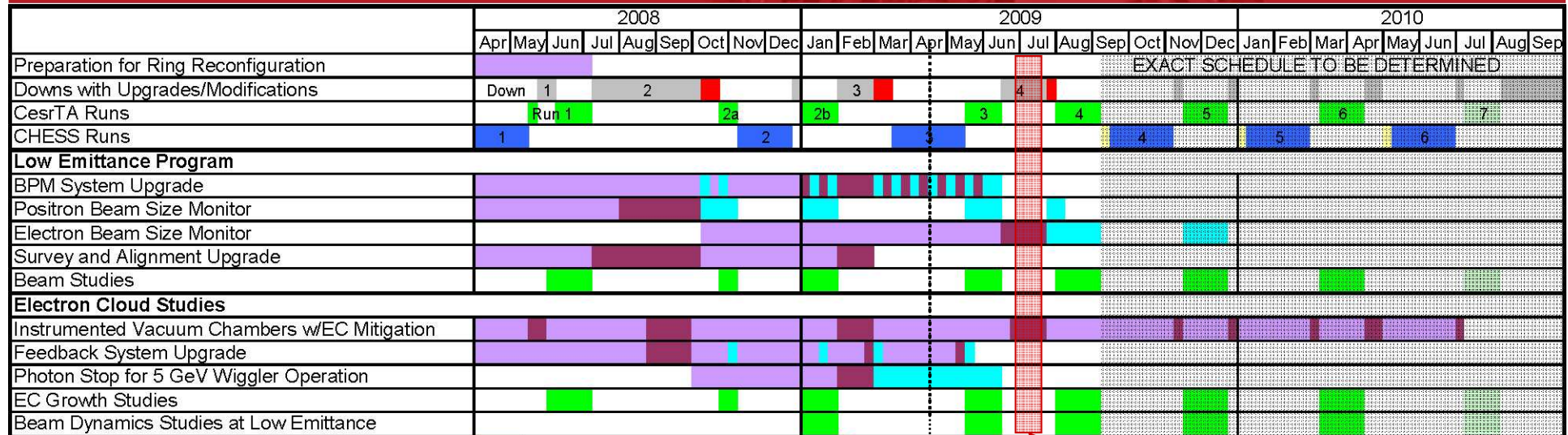
6 wigglers moved from CESR arcs to zero dispersion straight

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)



CesrTA Program



Legend:



- 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 Beam
- 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 spring 2010



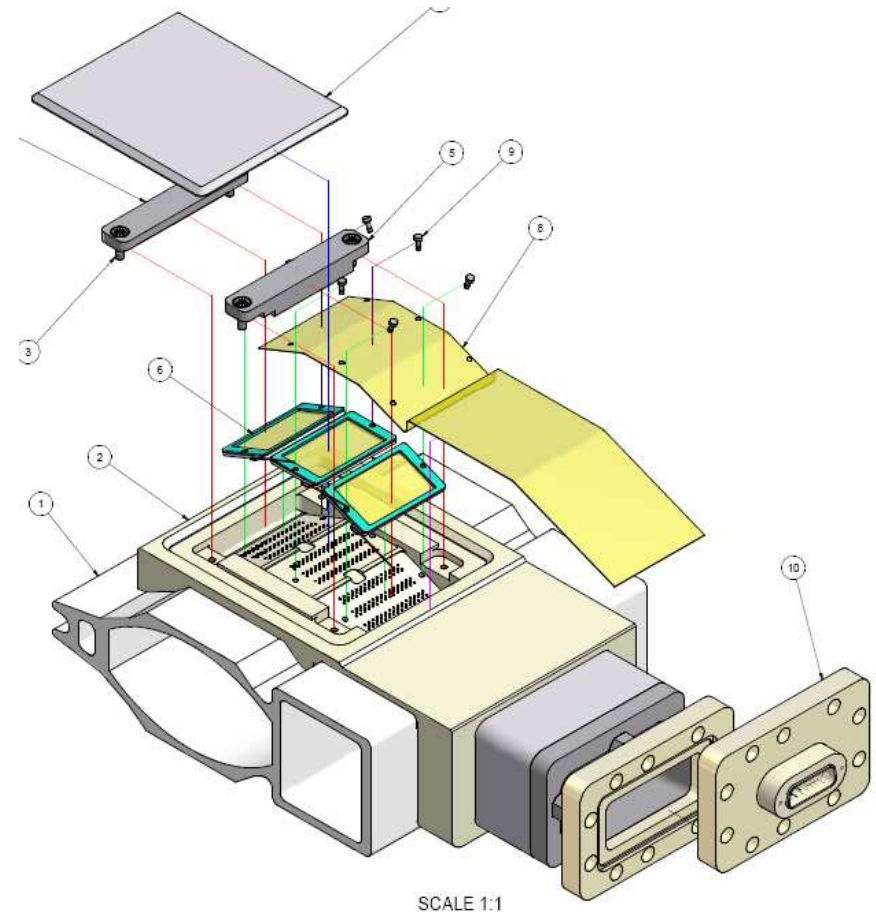
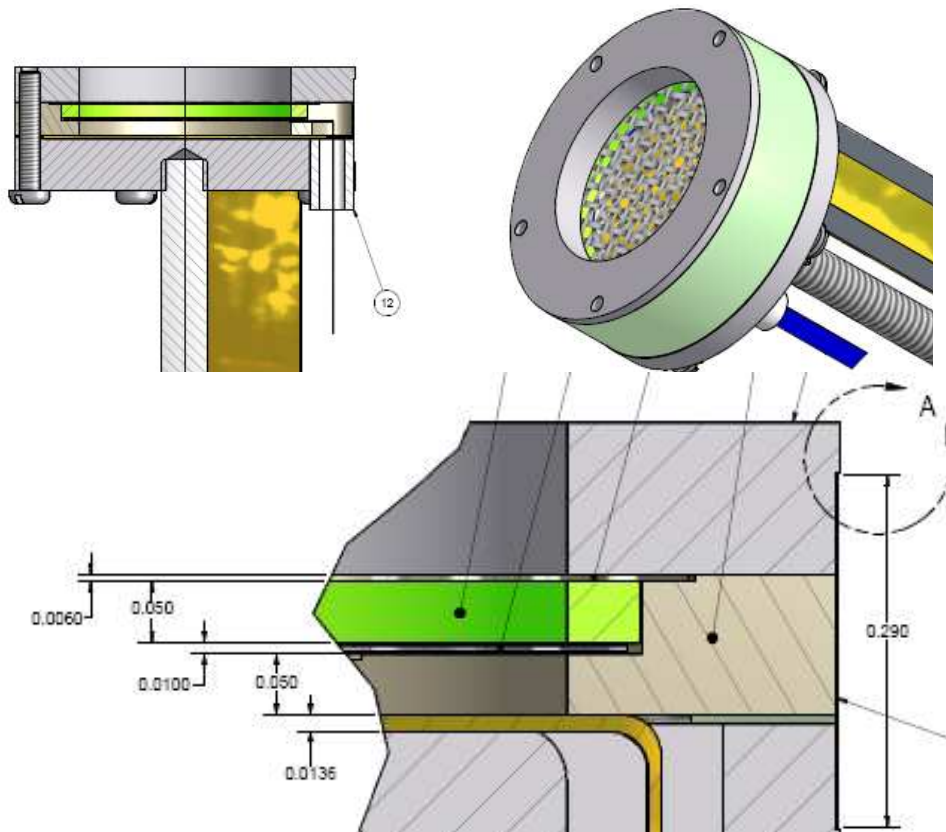
CesrTA Schedule: Upgrade Milestones

Period	Task	Target	Status	Special Comments
Down #1	1. Installation of 1 st 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 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 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	FY09 Q1 FY09 Q1 Phased Installation - FY09 Q3	Done Done Ongoing	Major Contingencies: Failed SRF cavity – removed, impacts bunch length • Vertical separators largest single source of impedance in ring • Diagnostic wigglers installed Oct 23-24, 2008 • 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

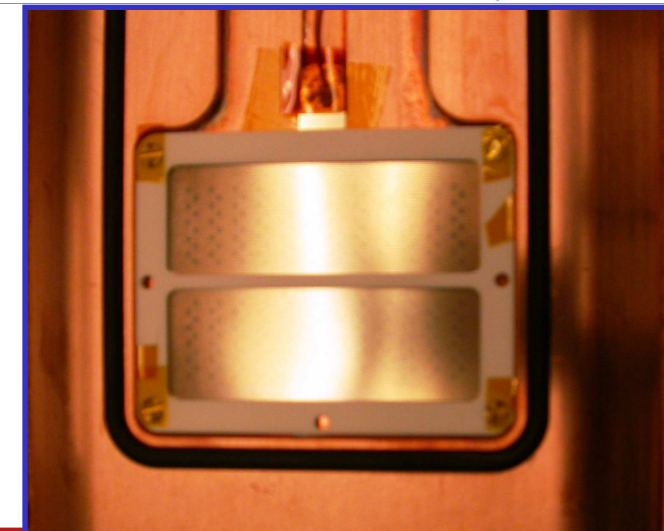
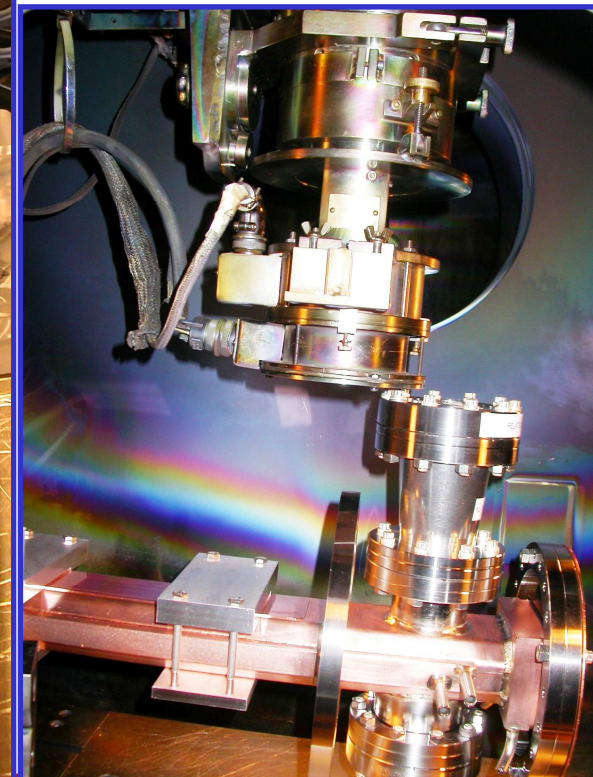
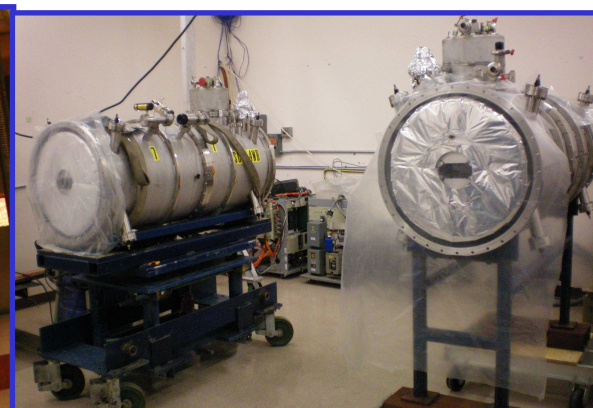
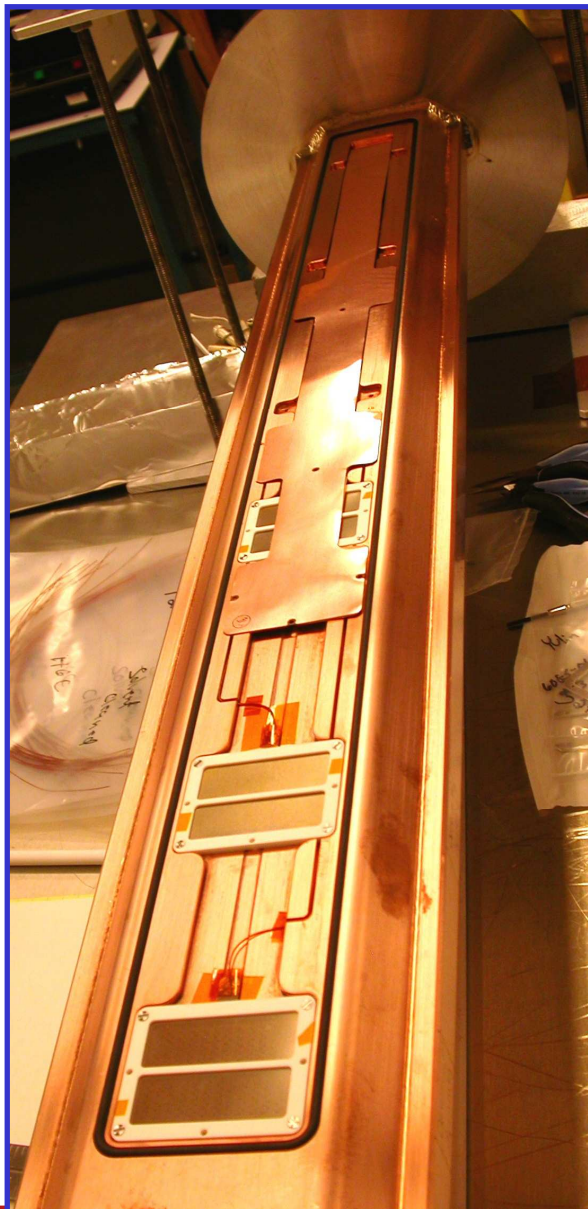
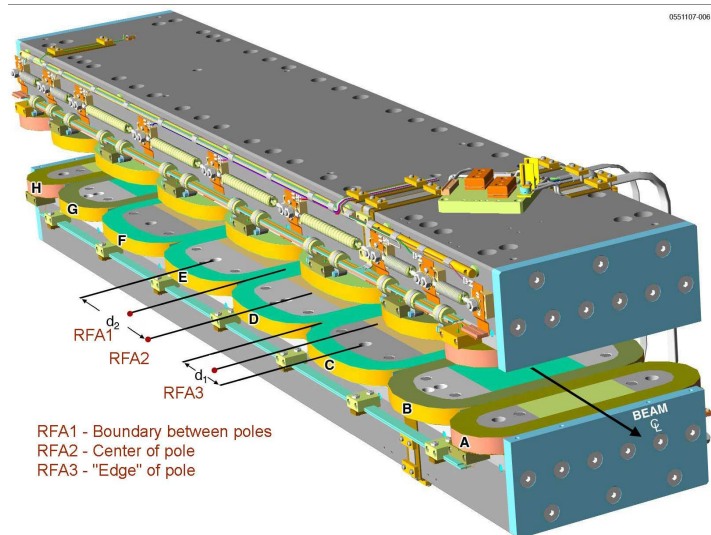
- Thin structure developed for use in limited aperture locations
 - CCSR dipoles
 - CCSR-c wigglers
- Application to CCSR Dipole





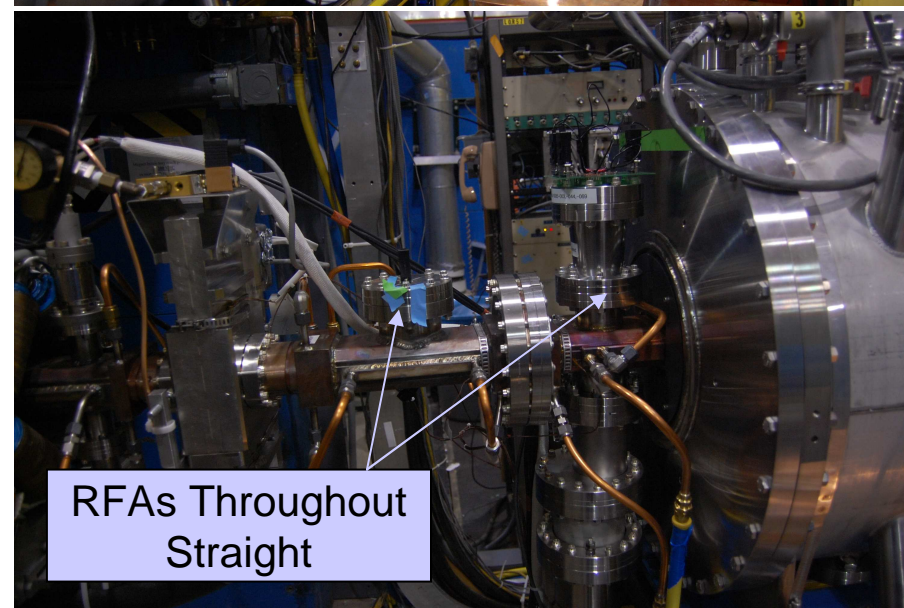
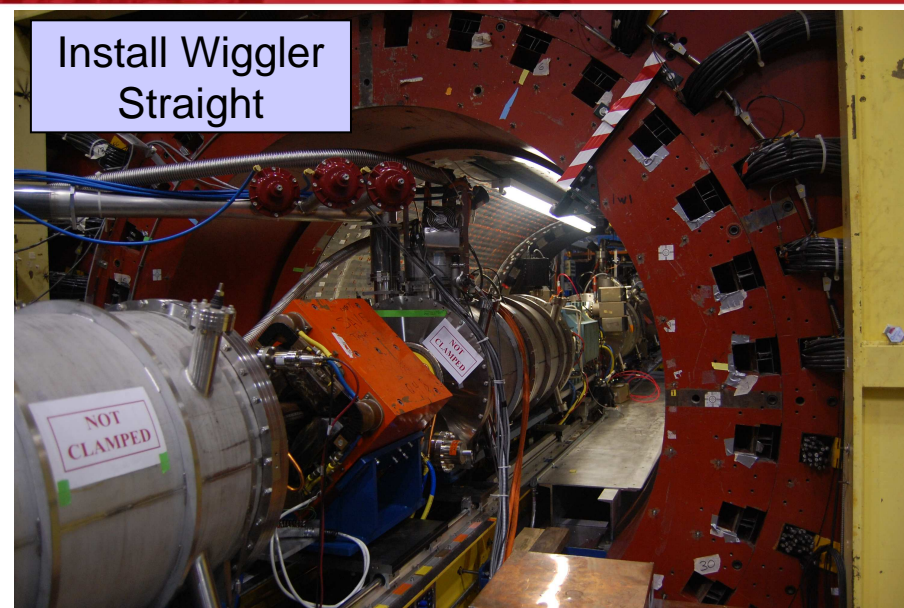
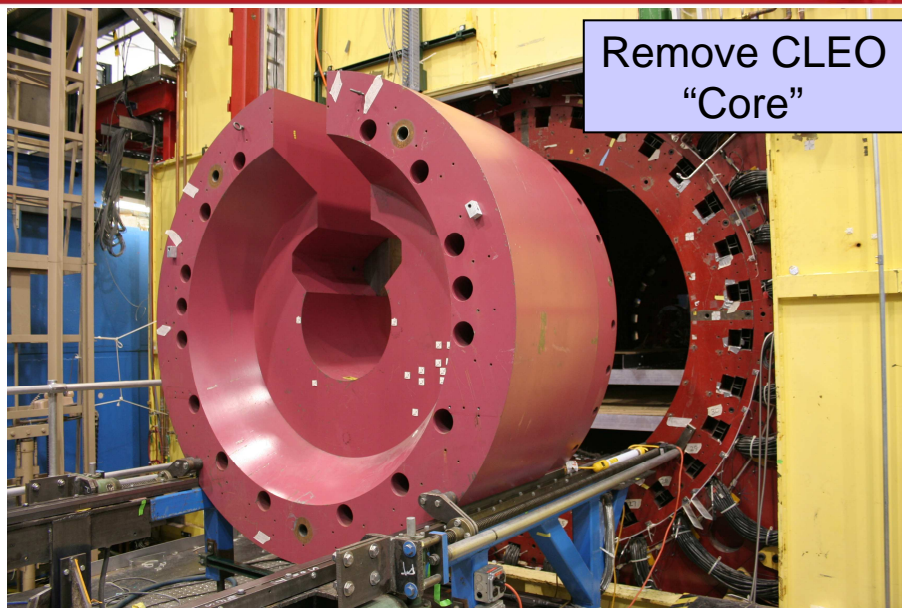
Upgrade Activities: Instrumented Wigglers

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





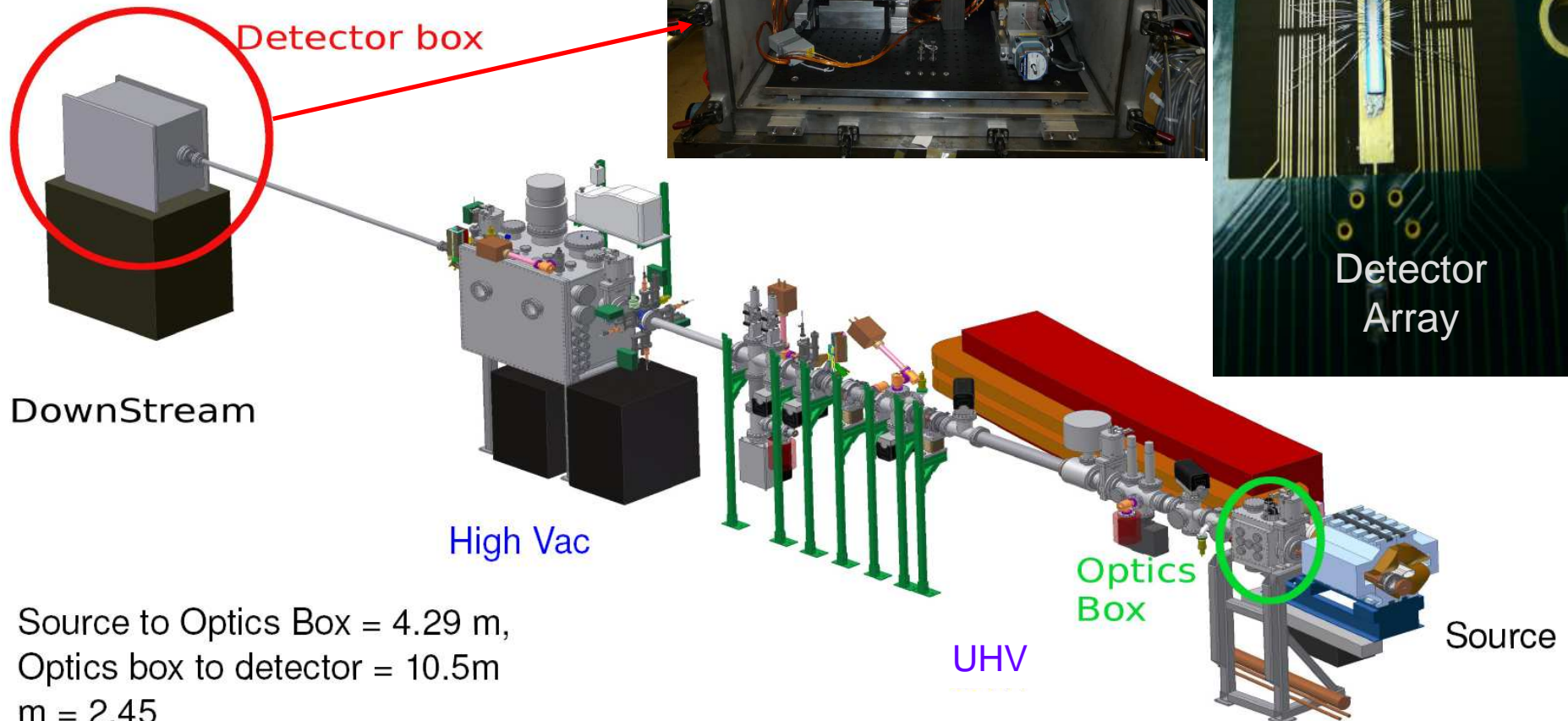
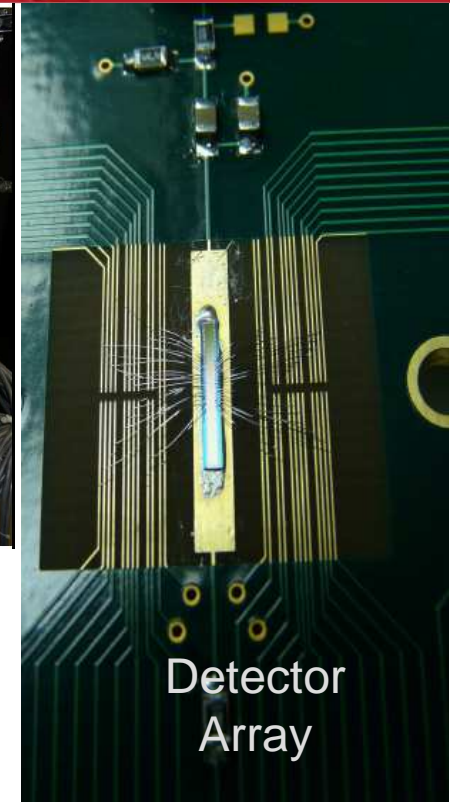
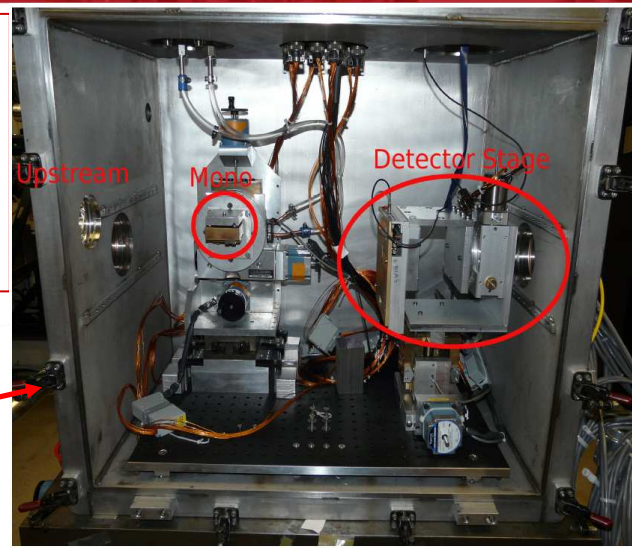
Upgrade Activities: L0 Modifications





Upgrade Program: xBSM Optics Line & Detector

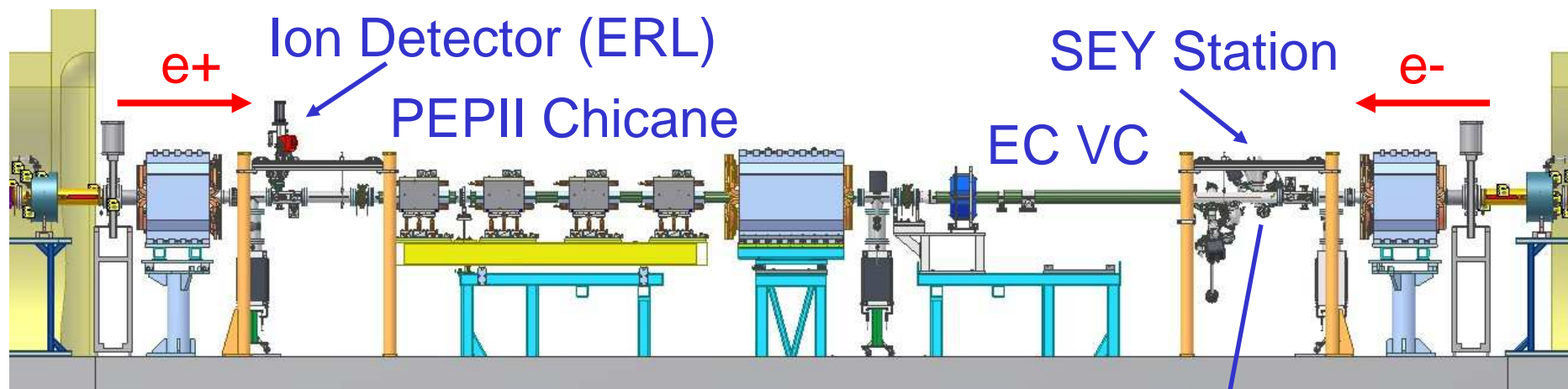
New all-vacuum optics
line for e^+ beam in collaboration
with CHES
2nd line for e^- beam in progress
Helium or Vacuum



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

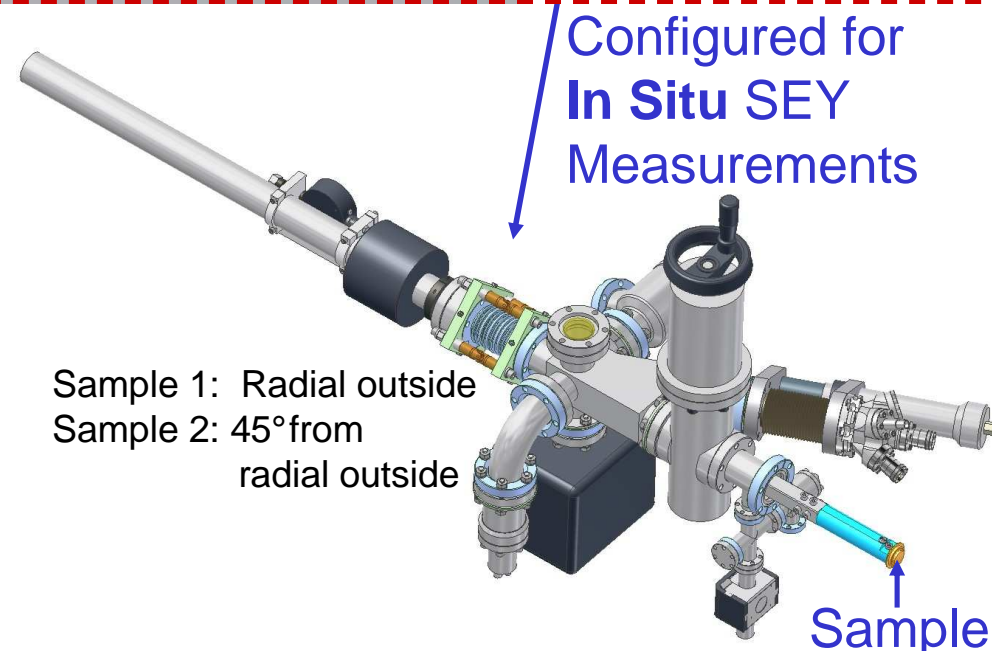
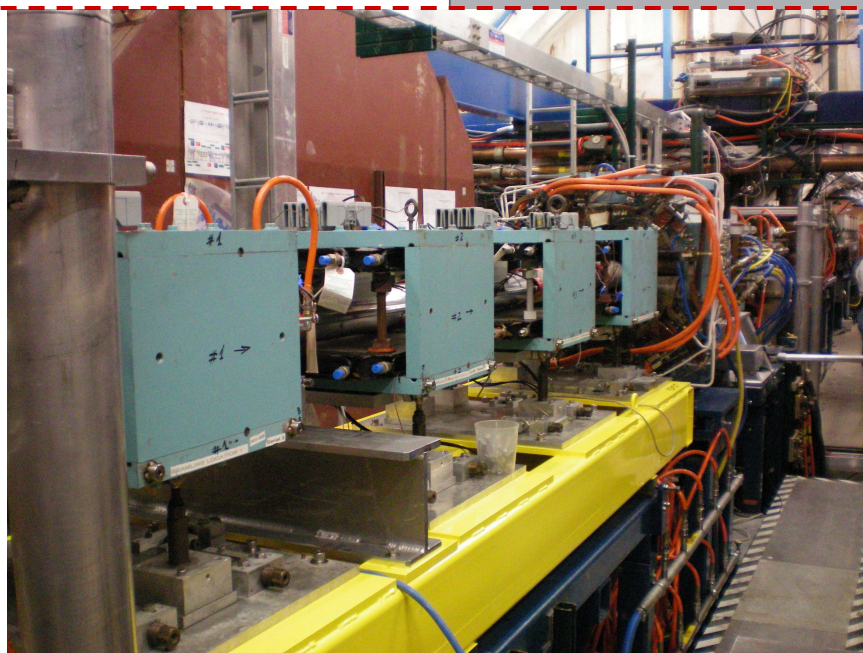


L3 Experimental Region



West

East





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 development during May 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 \Rightarrow 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
 - Additional dipole bus repairs likely
 - Coordination of schedule with CHESS needs
 - Reduction in laboratory personnel after 2008 layoffs
 - Administrative & management resources



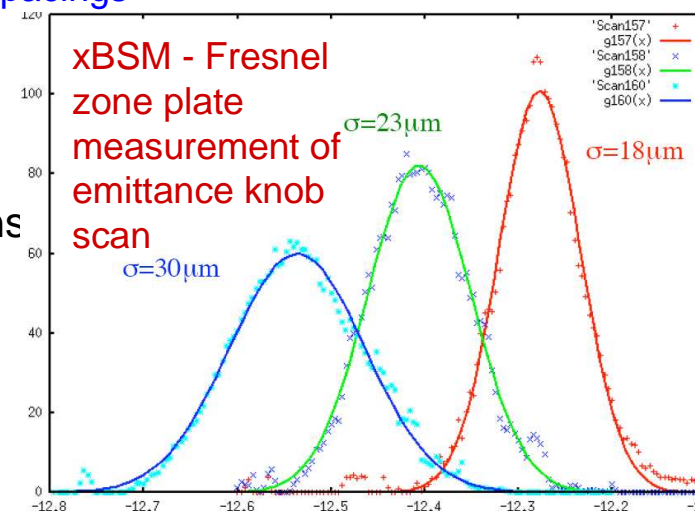
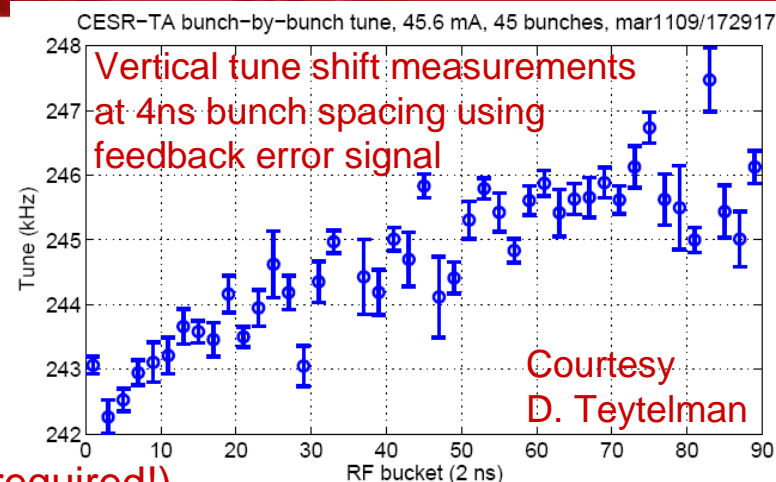
Experimental Program Milestones and Status

- **Experimental Schedule**

- Running Days
 - Planned : 70 days planned for 4/1/08-4/1/09 period
 - 76 days provided (32% of planned total)
- Dominated by commissioning activities
 - EC hardware
 - Beam instrumentation
 - Accelerator optics

- **Experimental Status**

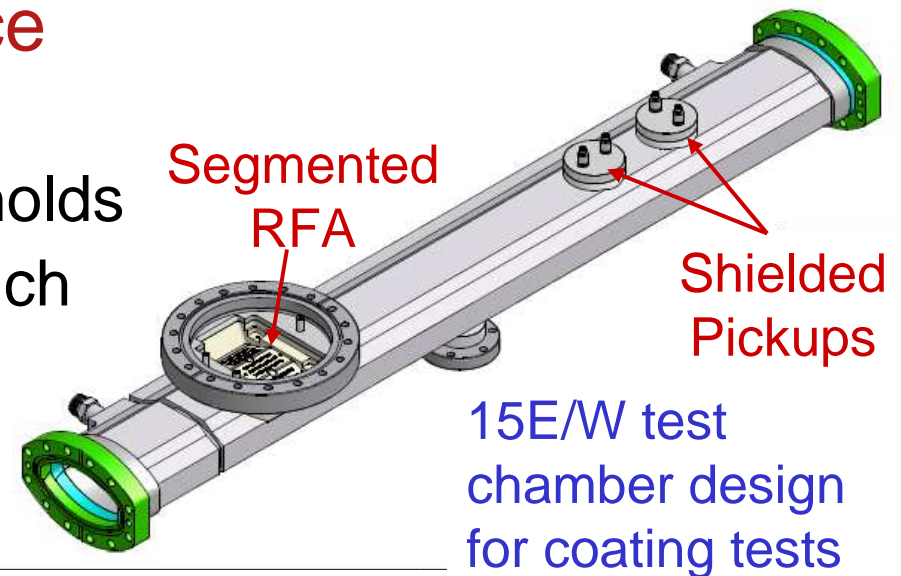
- Electron Cloud Studies (**Strong simulation support required!**)
 - Significant progress on overall understanding of integrated EC distribution
 - Local measurements show the importance of fully integrating the RFAs in the growth simulations
 - An effect which was also noted in the PEP-II chicane studies
 - Comparison efforts underway with different techniques to make local measurements of the cloud
 - Upcoming runs will focus on studies with flexible bunch spacings
- Low Emittance Studies
 - Significant progress on tool development \Rightarrow next phase to incorporate new BPM system
 - Initial measurements indicate <40 pm vertical emittance
- xBSM – first measurements in low emittance conditions
- Program is providing support for collaborative R&D
 - CLIC
 - NSLS-II
 - Project X
 - Completion of EC studies begun at SLAC
 - ERL





CesrTA Summary

- 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
 - Mid-2009 \Rightarrow end of 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





ILC Damping Rings Electron Cloud Program

- ILC-specific electron cloud R&D is concentrated at 5 labs:
 - Cornell
 - INFN-LNF
 - KEK
 - LBNL
 - SLAC
- Integrated global program offers
 - Detailed studies of key mitigation methods as inputs for the technical design
 - A broad approach to understanding critical dynamics issues
- Following pages provide short lab summaries from each...

Electron Cloud Activities at LNF

Electron Cloud Activity at LNF are focused on the study of electron cloud effects on the beam and include:

- Electron Cloud Simulations;
 - Build-Up in various regions of the DAFNE e⁺ ring;
 - Coupled-bunch instability simulations;
 - benchmarking of simulations with observations on beam;
- Development and test of a new feedback system to suppress horizontal coupled-bunch instability.

Work is in progress to:

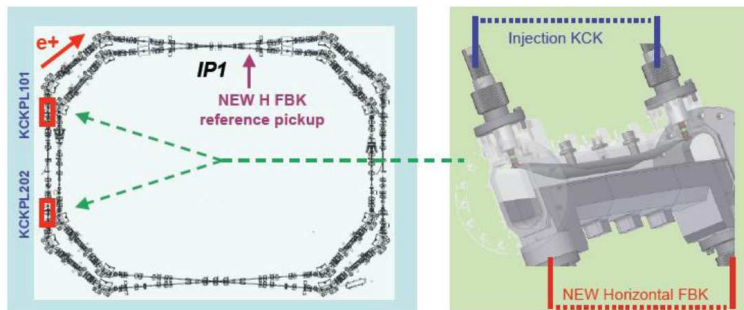
- Design and install clearing electrodes to suppress e-cloud build-up in bending magnets and wigglers;
- Update the simulation code PEI-M to take into account the effect of clearing electrodes on coupled-bunch instability.

New DAFNE e⁺ Transverse feedback

- Observing the linearity of the horizontal instability, growing > 70 (1/ms) for Ibeam>800mA
- We decide to double the feedback power from 500W to 1kW.
- We decide to test another pickup (to see if less noisy) and to use the spare striplines of the injection kickers.

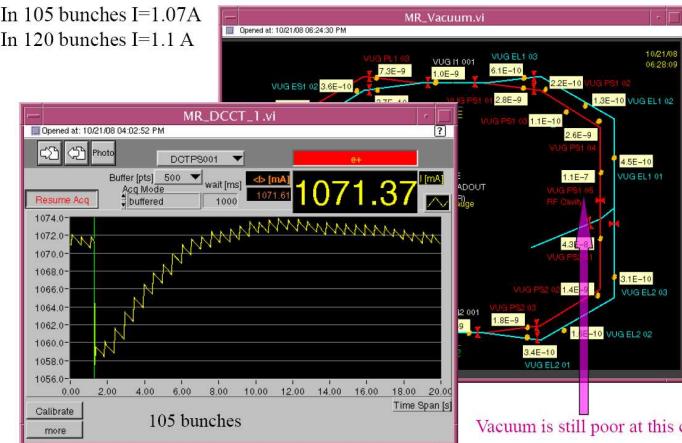
• New e⁺ Transverse Horizontal Feedback

- The damping times of the two feedbacks add up linearly
- Damping time measured:
 - ~100 ms-1 (1 FBKs) → fb damps in 30 revolution periods (~10 us)
 - ~200 ms-1 (2 FBKs) → fb damps in 15 revolution periods (~5 us)
- The power of the H FBK has been doubled

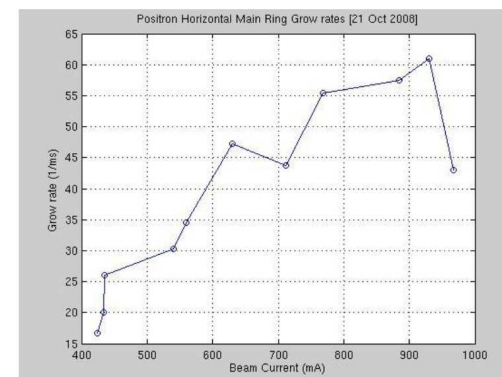


The current limit has been exceed

In 105 bunches I=1.07A
In 120 bunches I=1.1 A

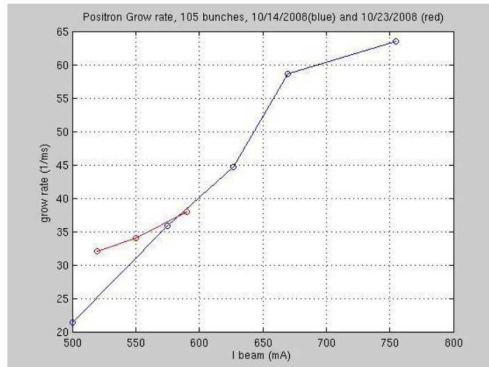


Grow rates at higher e⁺ current
controlling instability by 2 feedback



Characterization of the Horizontal Instability

e^+ instability grow rates by halving β_x in the RF cavity

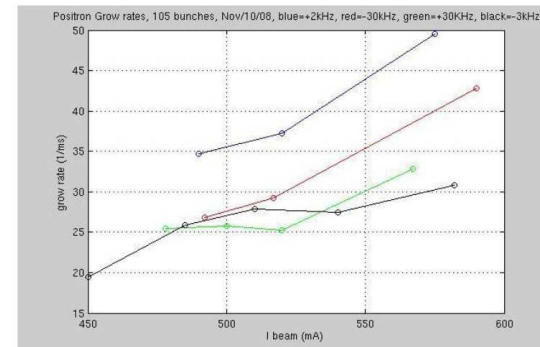


- OPTICS for collision (blue)
- $\beta_x 4 [m] \rightarrow 2 [m]$ in the RF cavity (red)
- $v_x = 6.096$,
- $v_y = 5.182$
- Δv_x between the Wigglers unchanged

Conclusion: the instability does not depend on hypothetical high order mode in the e^+ RF cavity

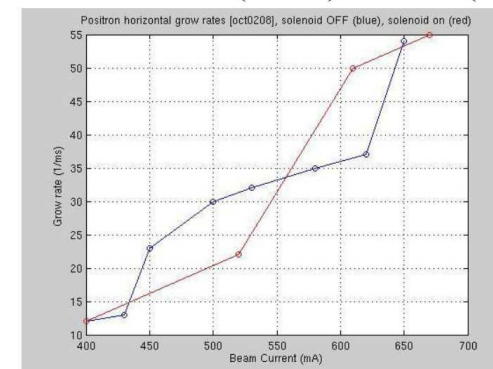
- the horizontal instability rise time cannot be explained only by the beam interaction with parasitic HOM or resistive walls
- Solenoids installed in free field regions strongly reduce pressure but have no effect on the instability
- Instability sensitive to orbit in wiggler and bending magnets

e^+ instability grow rates versus orbit in the main ring dipoles



The orbit variation is performed changing the RF frequency and then compensating the beam energy

e^+ instability behavior switching solenoids off (blue) & on (red)

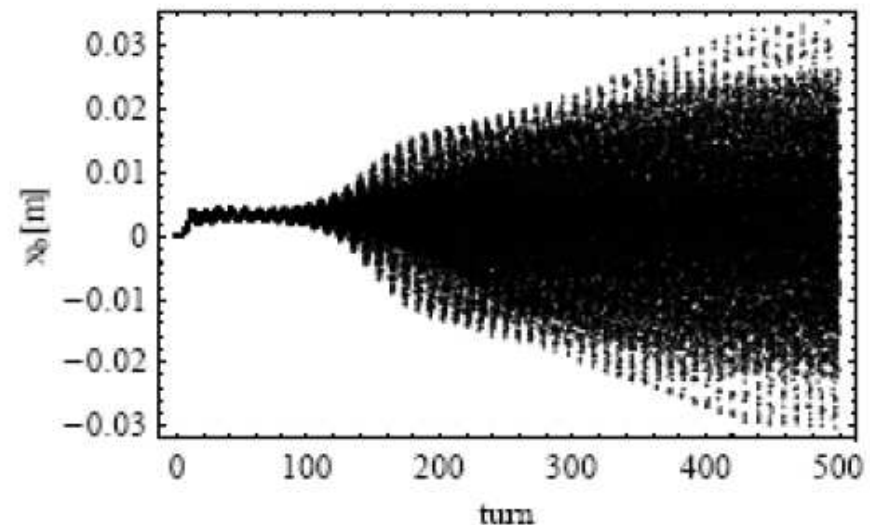


- Switching off the solenoids installed in the positron ring the grow rates of the e^+ instability does not change

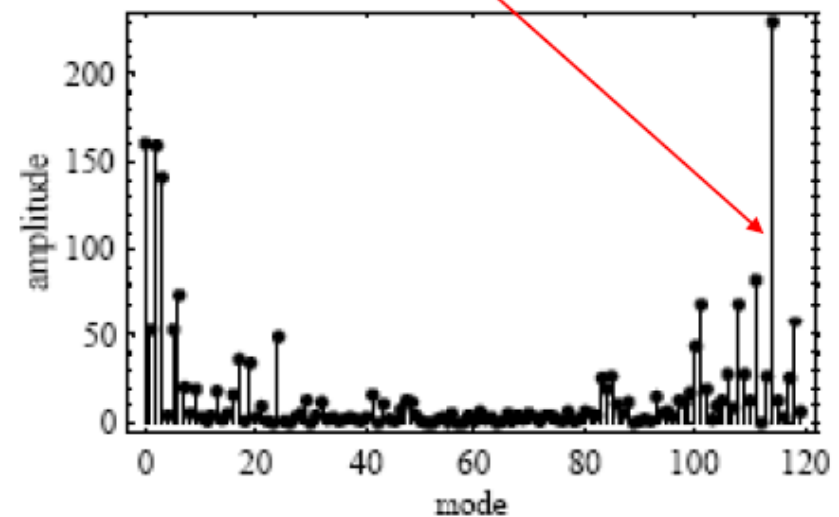
E-Cloud Induced Coupled-Bunch Instability Simulations

- Simulations performed with PEI-M
 - beam and electrons are tracked self-consistently.
 - the transverse amplitude of each bunch (X_b) is stored as a function of time.
 - Fourier transformation of the amplitudes gives a spectrum of the unstable modes.
 - instability growth-rates are obtained by an exponential fit to the bunch amplitude envelope.

Measurment		Simulation	
$I[A]/nb$	τ/T_0	$I[A]/nb$	τ/T_0
1.0/105	73	1.2/120	100
0.75/105	56	0.9/120	95
0.5/105	100	0.6/120	130



-1 mode (120-5-1=154)





EC Studies at KEKB



- Various EC studies have been carried out utilizing the KEKB positron ring.
 - 3.5 GeV, $\sigma_z \sim 6$ mm
 - ~ 1 mA/bunch ($\sim 6 \times 10^{10}$ e⁺/bunch), 6~8 ns spacings
- Diagnostics
 - Beam size blow-up: SR monitors
 - Beam instabilities : Head-tail instability, coherent instability
 - Electron density: at drift space, in a solenoid and Q-magnet
 - SEY (Secondary Electron Yield): at lab. and *in situ*
- Mitigation
 - Solenoid field: at drift space
 - Beam pipe with antechambers
 - Coating to reduce SEY: TiN, NEG, graphite, DLC
 - Clearing Electrode: in a B-field
 - Groove surface: in a B-field



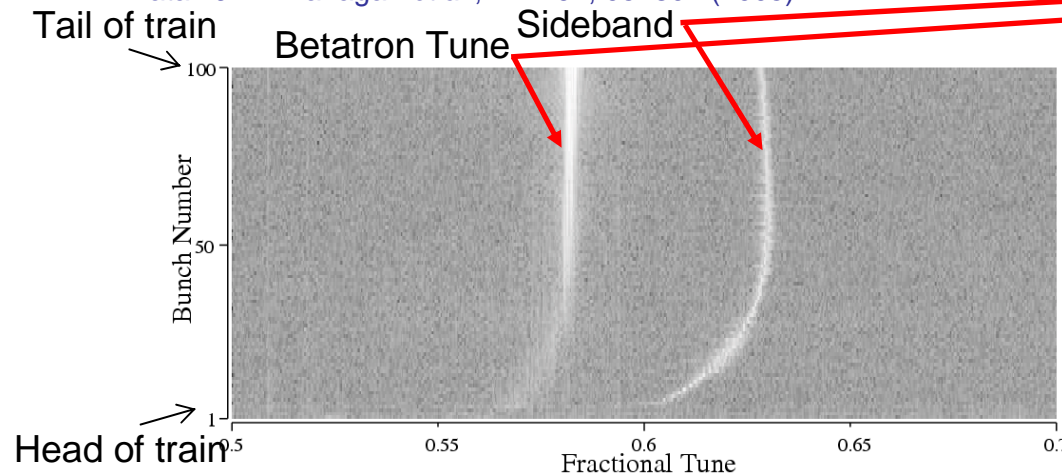
Single-bunch measurements : Synchro-betatron sidebands



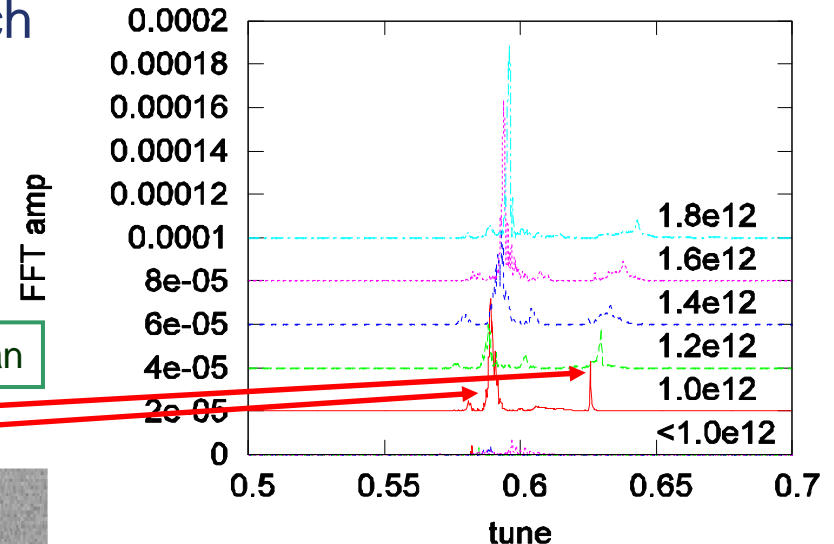
- Vertical betatron sidebands found in bunch-by-bunch position spectra, which appear at blow-up threshold and appear to be signatures of fast head-tail instability due to electron clouds, and are used as diagnostics for such.
- Sidebands have been reproduced in simulation.

Data: J.W. Flanagan *et al.*, PRL 94, 054801 (2005)

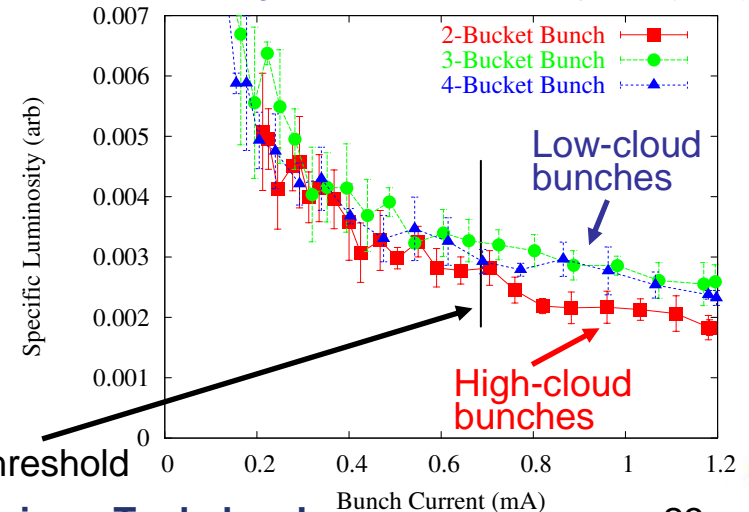
J. Flanagan



Simulations: E. Benedetto *et al.*, Proc. PAC07, p. 4033 (2007)



Data: J.W. Flanagan *et al.*, Proc. PAC05, p. 680 (2005)

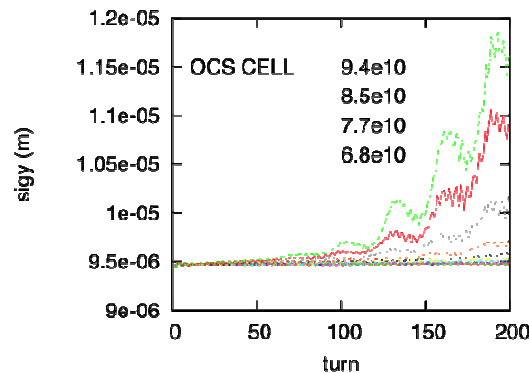




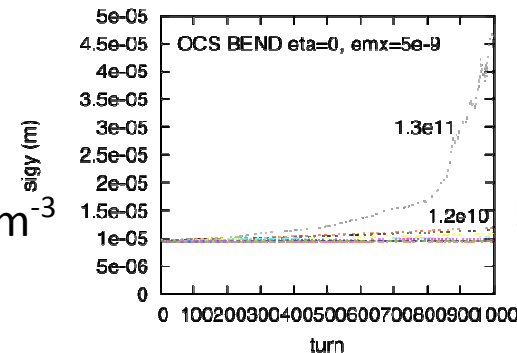
Coherent instability and incoherent emittance growth



- Coherent instability threshold is predicted with a simple model. The threshold density is very high, $\rho_e = 2.9 \times 10^{12} \text{ m}^{-3}$, $\Delta v = 0.016$.
- Simulations show dispersion degrades the threshold. Measurement of coherent signal is planned this summer.



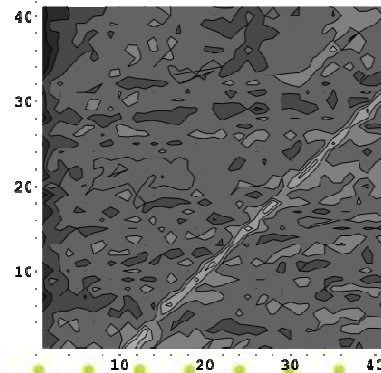
Dispersion,
 $\rho_{th} = 6.8 \times 10^{10} \text{ m}^{-3}$
(ILC-OCS)



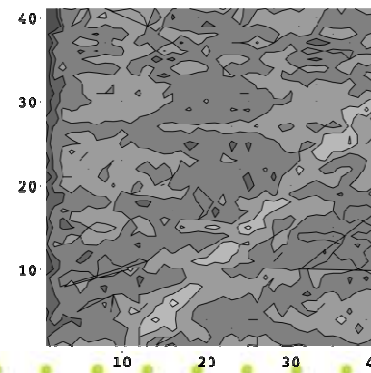
K. Ohmi

No dispersion,
 $\rho_{th} = 13 \times 10^{10} \text{ m}^{-3}$
(ILC-OCS)

- Beam size in tune plane was measured to study incoherent emittance growth in Chess operation. No clear growth was observed.



No electron cloud



$v_x = 0.525 - 0.577$,
 $v_y = 0.628 - 0.679$

Under presence of electron cloud

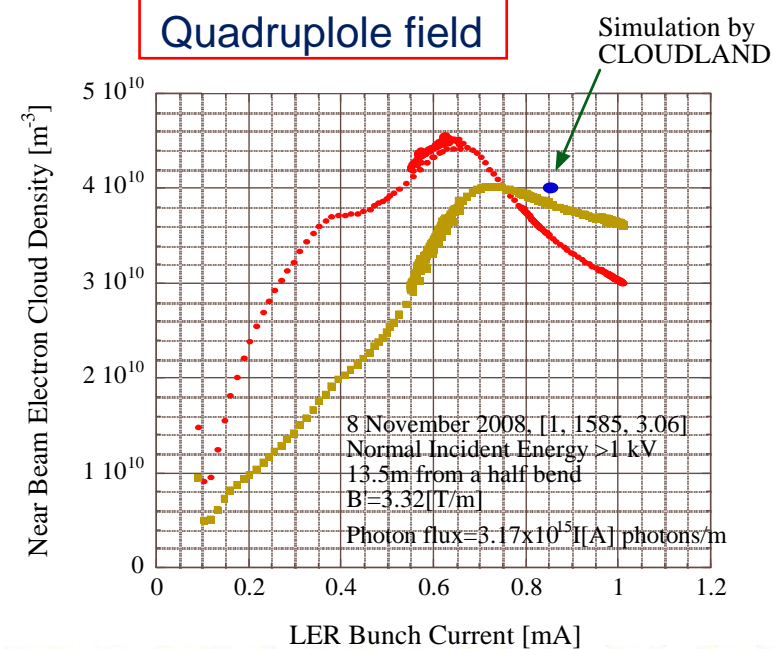
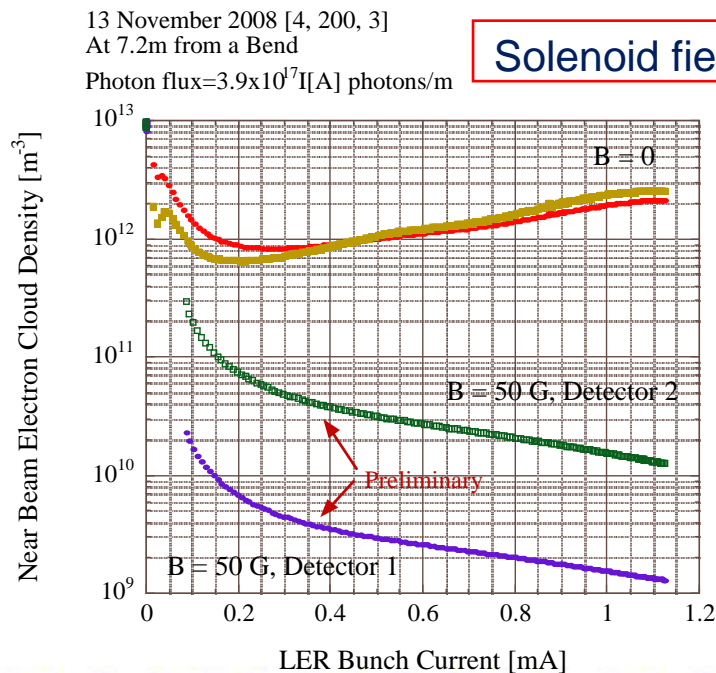


Measurement of the electron cloud density in a magnetic field



- A solenoid field of 50 G reduces the near beam cloud density two or three order (or more). The effectiveness of the solenoid field to reduce the cloud density is experimentally confirmed.
- The measured density is lower than that in a drift space by two orders of magnitude. The result is very close to the value obtained by simulation.

K. Kanazawa and H. Fukuma



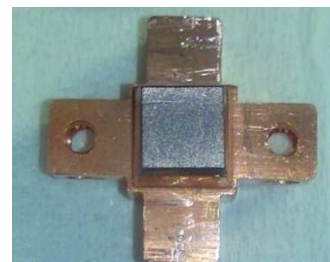
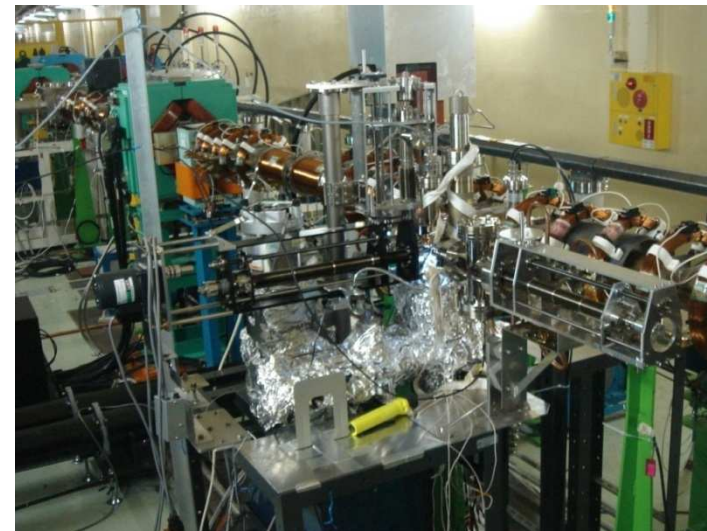
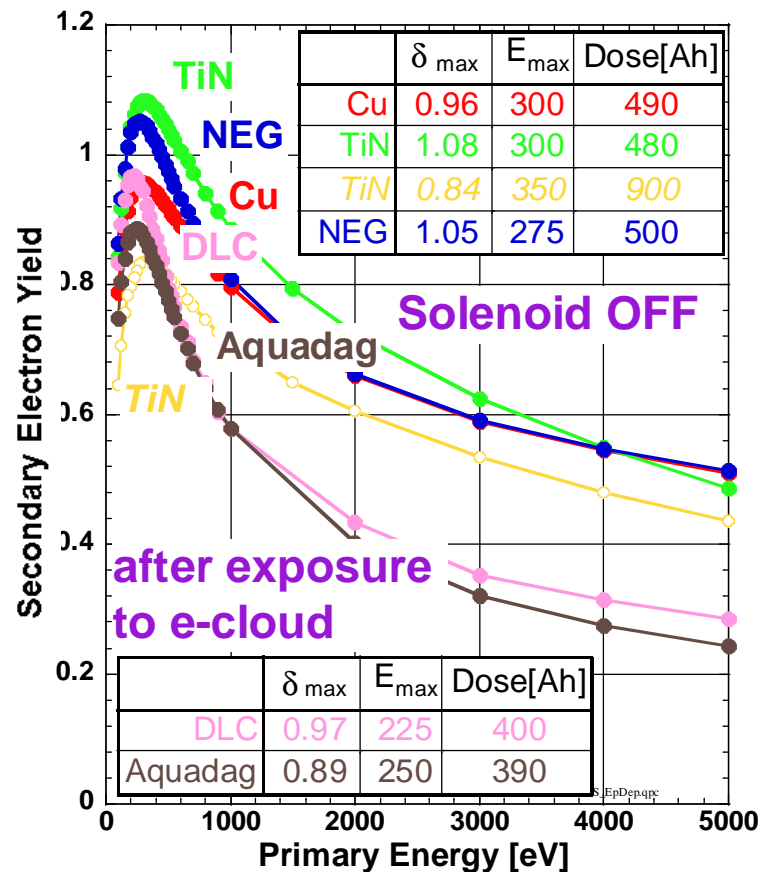


In-situ measurement of SEY

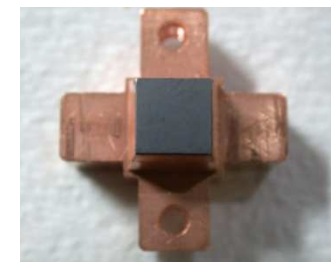


- After scrubbing by beam, the SEY of DLC (Diamond Like Carbon) and Aquadag shows the lowest peak value (δ_{\max}) and a large reduction in a high primary energy

M. Nishiwaki and S. Kato



DLC 1 μ m



Aquadag 2~3 μ m

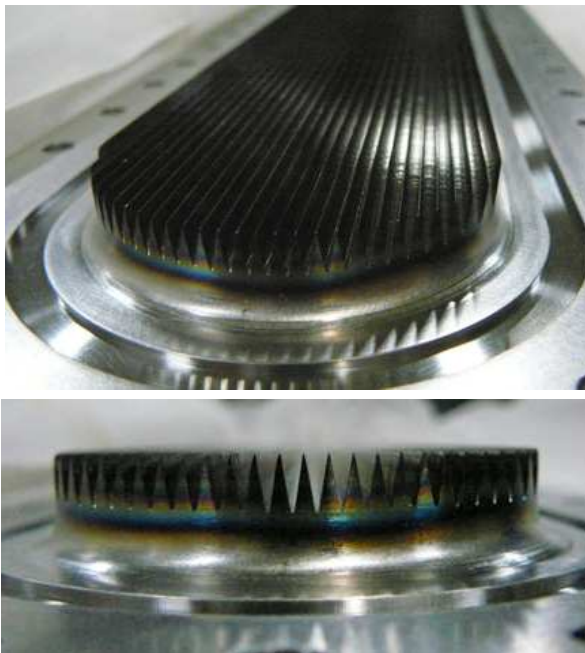


Beam test of a grooved surface (Collaboration with SLAC)

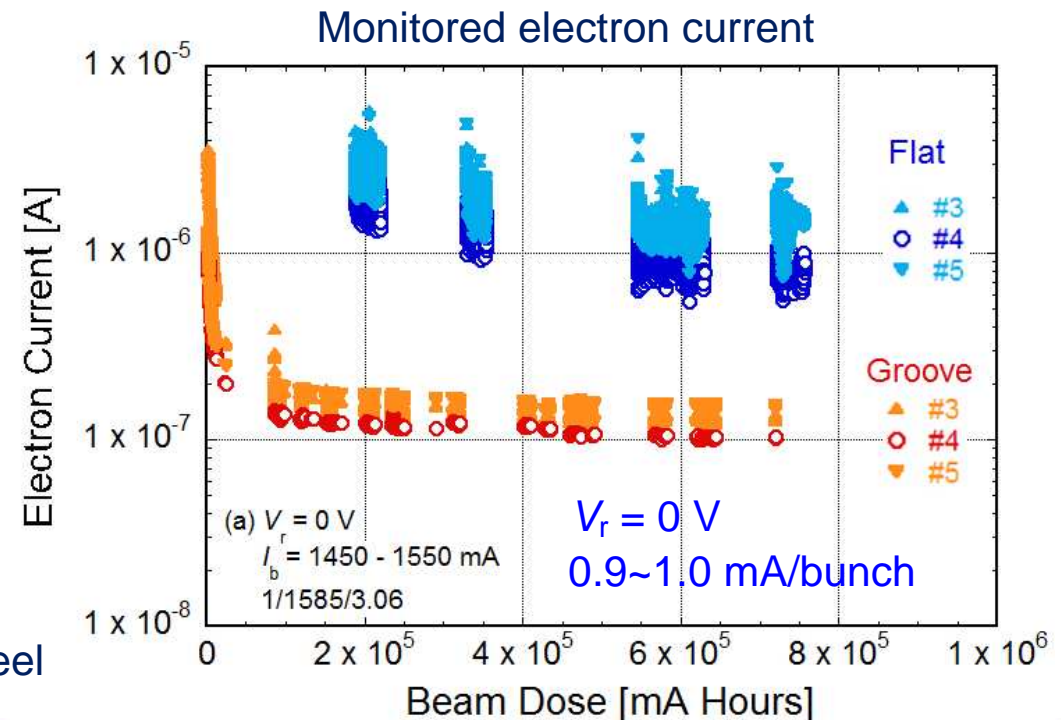


- Monitored electron current with the grooved surface is $1/5 \sim 1/10$ of that of a flat TiN coated stainless steel surface.
- The effectiveness of the grooved surface for the reduction of the electron cloud density is confirmed even in a strong magnetic field (0.76 T).

Y. Suetsugu, H. Fukuma,
M. Pivi and L. Wang



TiN coated grooved stainless steel
surface prepared by SLAC



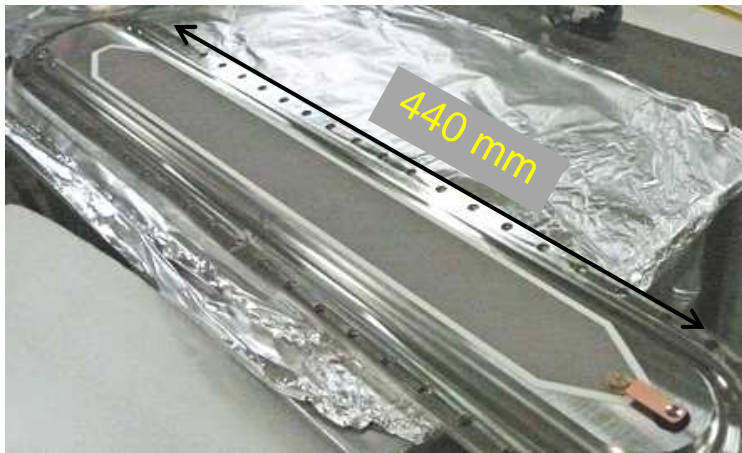


Beam test of a clearing electrode

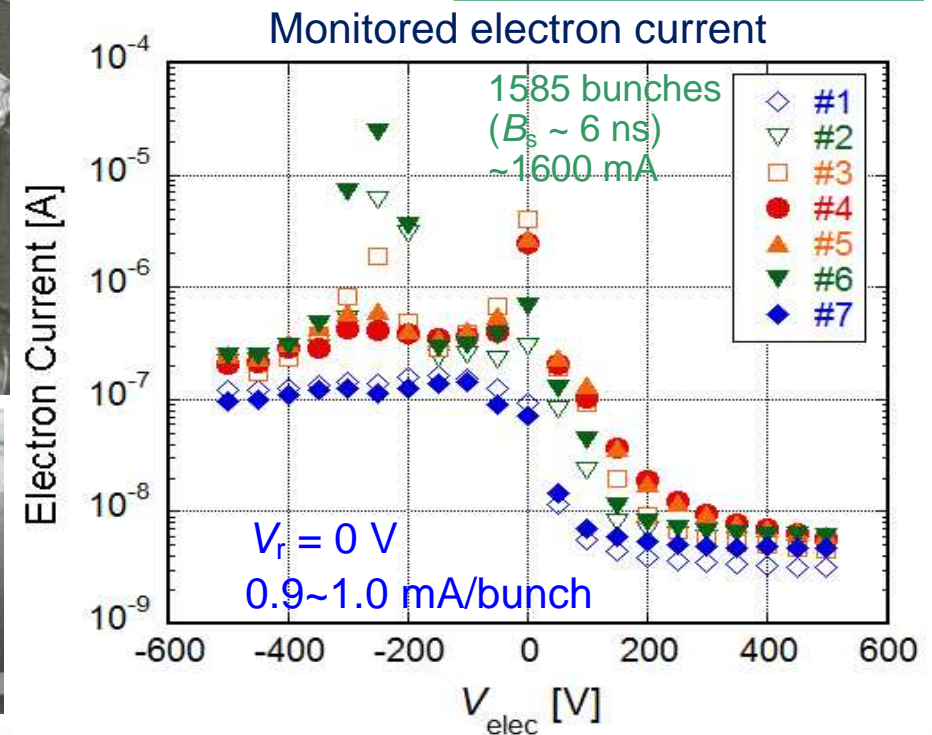
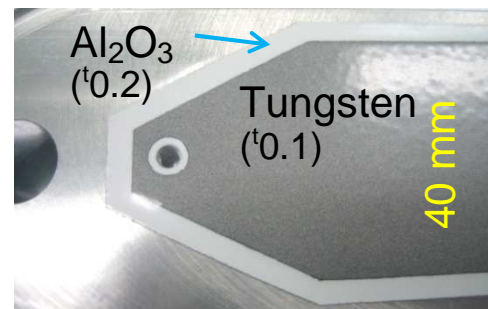


- Monitored electron current at an electrode voltage (V_{elec}) of + 300 V decreased to $\sim 1/100$ of that at $V_{\text{elec}} = 0$ V.
- The effectiveness of the clearing electrode in a strong magnetic field (0.76 T) was demonstrated experimentally.

Y. Suetsugu, H. Fukuma,
M. Pivi and L. Wang



Electrode for test
formed by
thermal spray



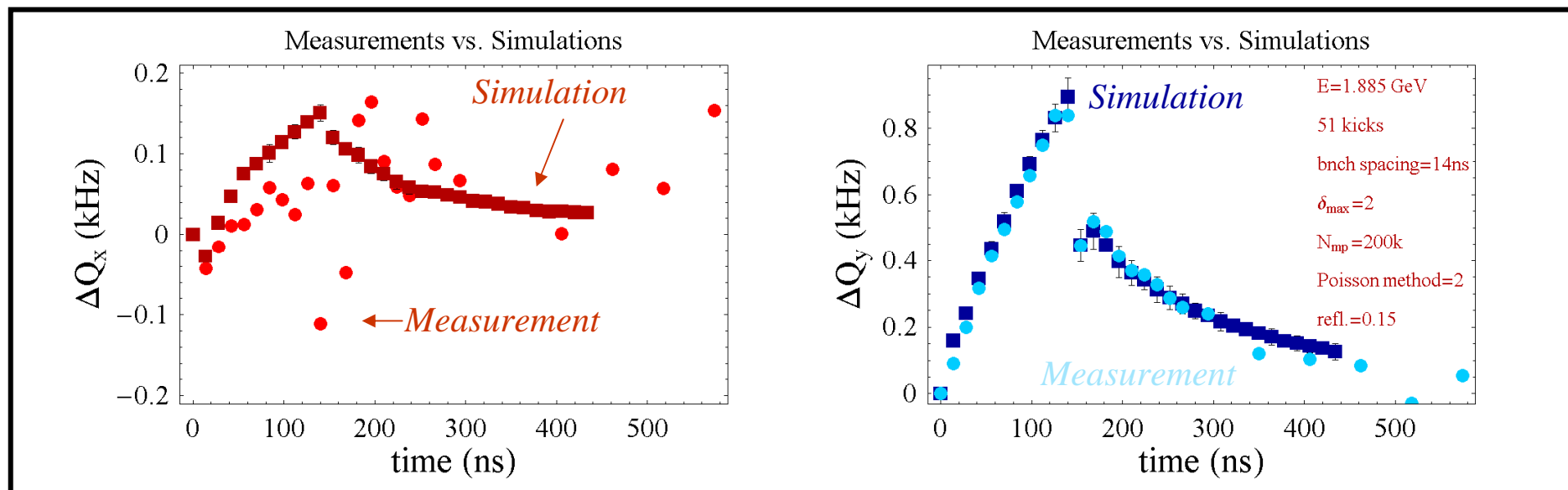


ILC Activities at LBNL

- Theoretical studies of the e-cloud accumulation in wigglers and in the presence of strong magnetic fields (C.Celata, G. Penn – see talk by Gerry Dugan)
- Modelling of tune shift induced by the e-cloud in various accelerator elements and application to Cestr-TA measurements (M. Venturini)
- Experimental measurements of the e-cloud density in various portions of the Cestr-TA ring by TE wave transmission method (S. De Santis – see talk by Gerry Dugan)
- Fabrication of wiggler chambers for Cestr-TA incorporating different e-cloud mitigation techniques: TiN coating, clearing electrode, grooves (D. Munson)



Modelling of Cestr 2007 Tuneshift Measurements for e^+ using POSINST



Agreement Experiment vs. Simulations looks good in y, less so in x.

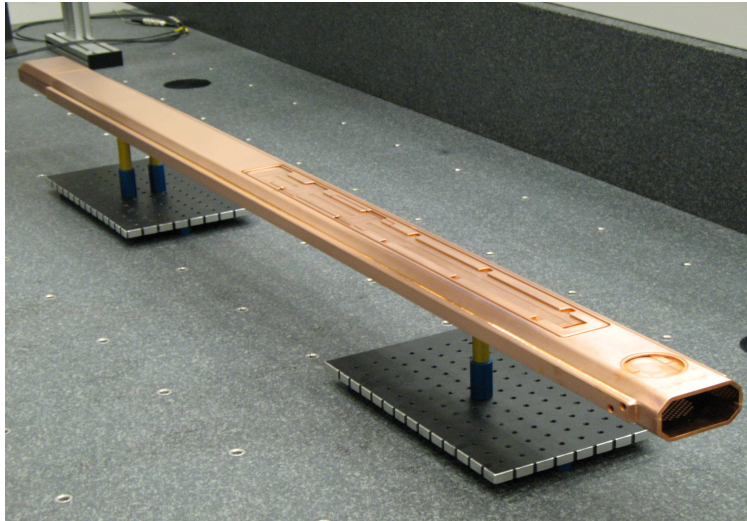
But:

- ❑ Simulated tuneshift includes contribution from ecloud in all dipoles and drifts spaces (it does not include contribution from any other elements)
- ❑ Other elements (quads, wiggler, sext ...) occupy ~50% of total drift space (if they behave like drifts add ~0.25kHz and ~0.05kHz to top values of ΔQ_y and ΔQ_x)

Note: in figs above data points for time ≤ 126 ns are for the 10-bunch train; others are for witness bunches

Wiggler chambers fabrication

CHAMBER WITH RFA HOLES AND COOLING CHANNELS

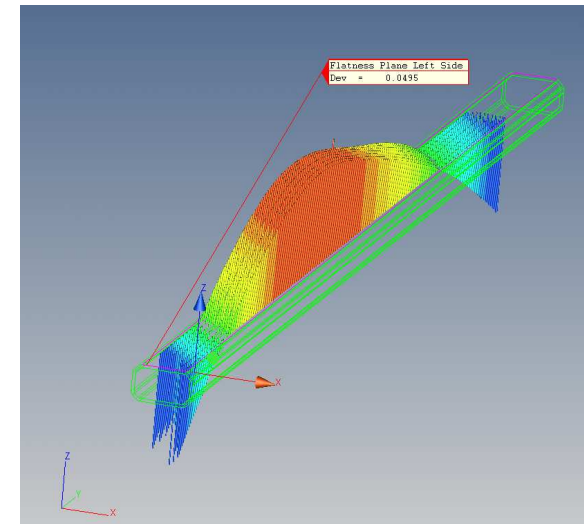


Fabrication of 4 instrumented wiggler vacuum chambers for testing of e-cloud mitigating techniques: reference, coating (TiN), grooves, clearing electrodes.

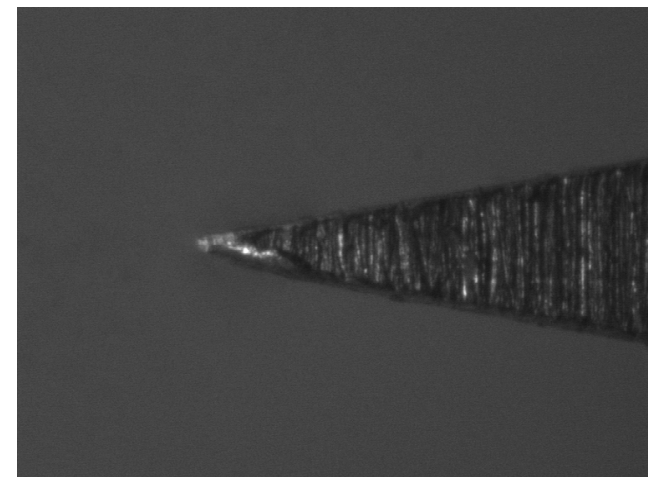
First two chambers delivered, two others currently in production.

LBNL has worked closely with Cornell personnel to develop the processes used in the fabrication.

FLATNESS MEASUREMENT



GROOVE TIP DETAIL





SLAC EC Contributions

Code Development

CMAD simulation code:

- Tracking the beam in a MAD lattice and with the presence of electron Cloud, parallel code, interaction with cloud at each element in the ring and with different cloud distributions, single-bunch instability studies, threshold for SEY, tune shift.
- Goal: simulate detail of instability threshold driven by e-cloud in the LC DRs, CEsTA, SPS and LHC, and storage rings
- ILC DR and CEsTA preliminary estimations at PAC09.

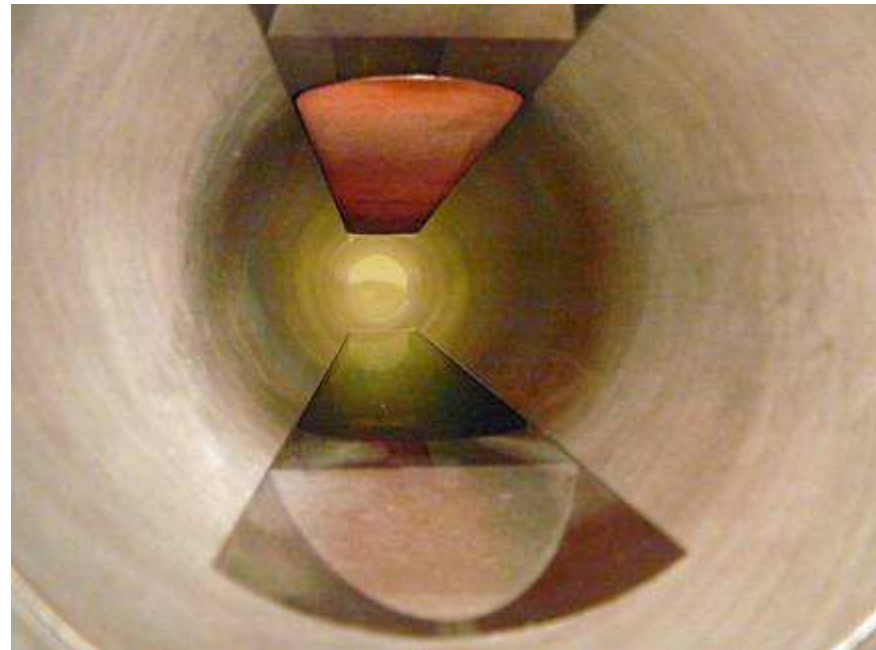
Tests of Mitigations for Electron Cloud

- Groove insertions for tests in KEK-B: successfully tested 5mm groove insertion in wiggler (NIM-A paper in publication) with up to an order of magnitude cloud reduction. Now
 - **i) improving coating on existing groove insertion and**
 - **ii) planning to manufacture insertions with reduced size grooves for future tests**
- Manufacturing small groove insertions for tests in the SPS.
- Redeployment of PEP-II experiments and chambers in CEsTA

M. Pivi, SLAC

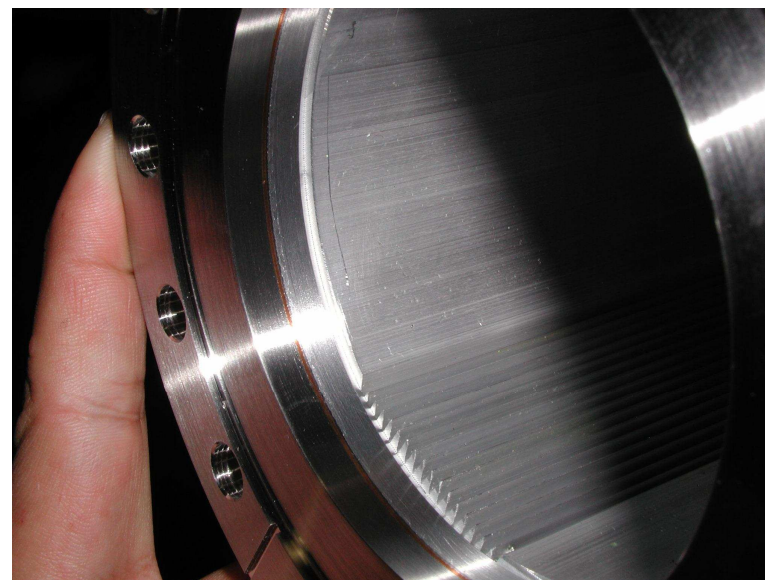
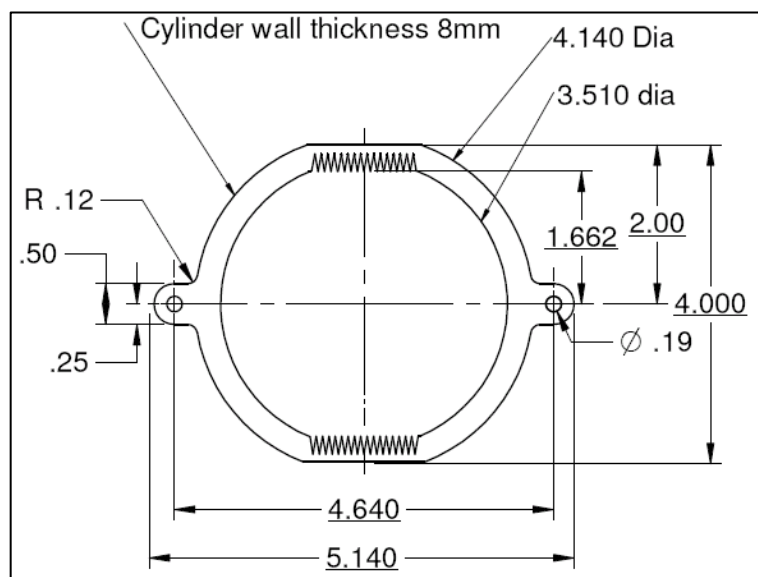
Grooves and coating (SLAC)

- **Both inserts have been coated with TiN**
 - A smooth insert (Right) and TiN coating has been manufactured (SLAC) and used as reference. It is shown as installed in KEK-B wiggler beam pipe.
 - An insert with grooves (Left) and TiN coating, manufactured by SLAC, have been placed at the same location to trap stray electrons within its triangular grooves.



SLAC grooved chamber for test at CEsR-TA

- * Fit into PEP-II 4-magnet chicane redeployed at CEsr-TA
- * 4mm grooves running longitudinally are located on top and bottom portion of the dipole chamber.
- * The chamber is supplied with an electron cloud Retarding Field Analyzer RFA to measure electron energy distribution and current.



Chamber fabricated, being assembled and TiN coated Pivi, Morrison, Wang, SLAC



- A robust global program of electron cloud R&D is underway
- CEsrTA offers a unique opportunity for exploring EC effects in an ultra low emittance regime
 - Coupled tightly to ILC LET effort
 - Significant experimental time to explore EC effects in detail
- The next talks by Gerry Dugan and Dave Rubin will expand on the key details...