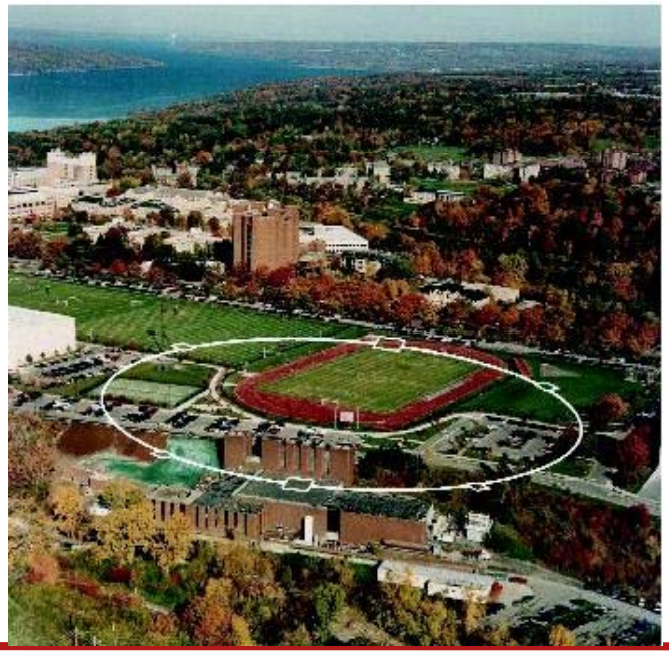
Cornell University
Laboratory for Elementary-Particle Physics

CesrTA Status and Plans

Joe Calvey

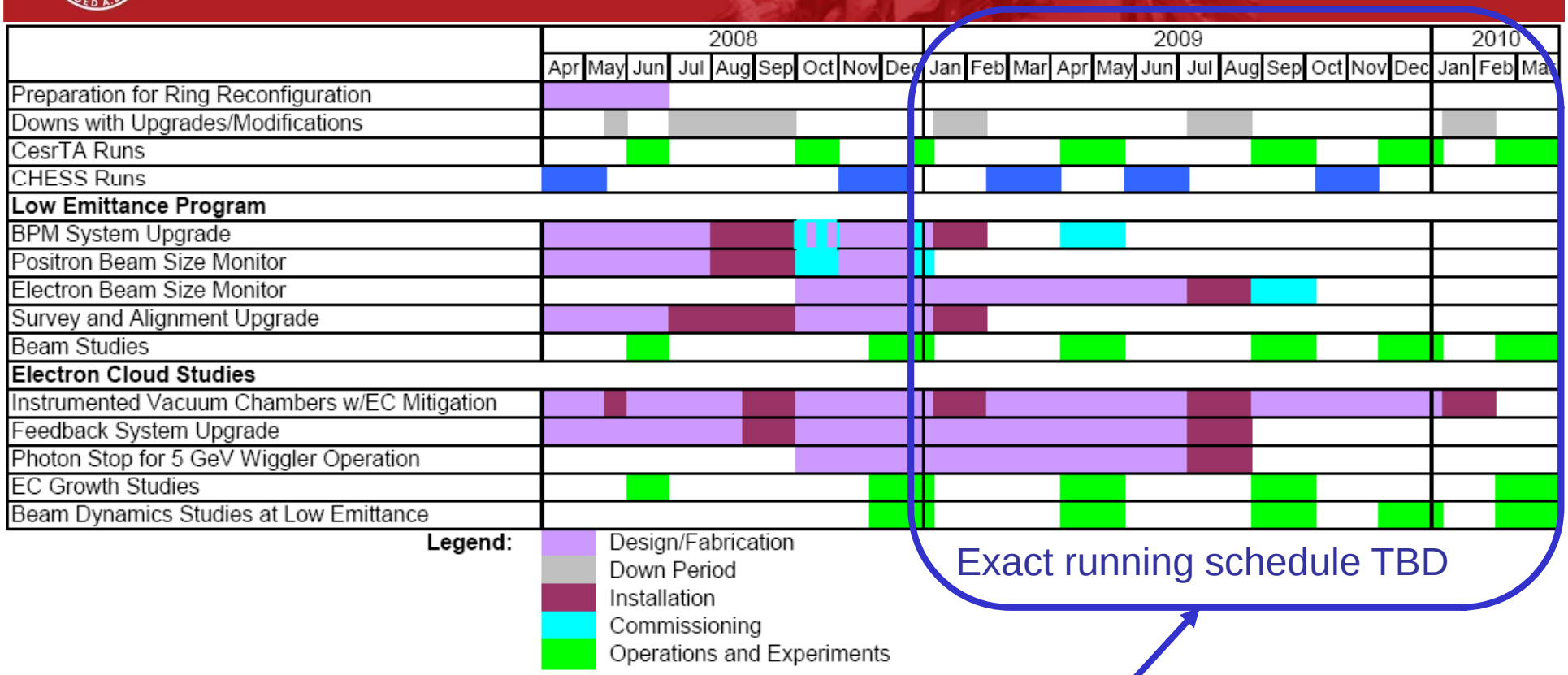
10/15/08



Introduction

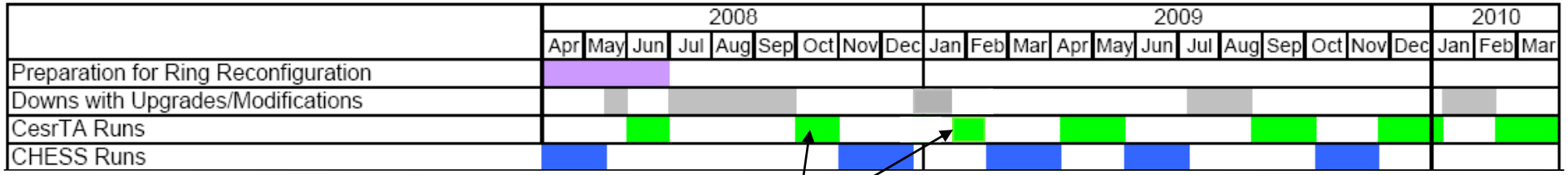
- CesrTA is a program to reconfigure the CESR storage ring at Cornell to perform experiments related to the ILC damping ring
- Two main areas of investigation:
  - Low emittance tuning
    - Perform detailed survey and re-alignment of magnets
    - Develop new analysis software
    - Develop instrumentation to characterize ultra low emittance beams
      - X-ray beam size monitor
      - Upgraded BPM system
    - Perform beam dynamics studies with electron and positron beams
  - Electron cloud studies
    - Characterize cloud using simulation programs
      - Code benchmarking
      - Tune shift measurements
      - RFA comparisons
    - Investigate different suppression techniques
    - Develop tools to understand instabilities

Schedule Overview



- Planned schedule as of early this year
  - Phased implementation of instrumentation
  - Phased installation of electron cloud diagnostics and support hardware
- Some adjustments are being made
  - Avoid holiday running
  - Maximize efficient use of limited resources

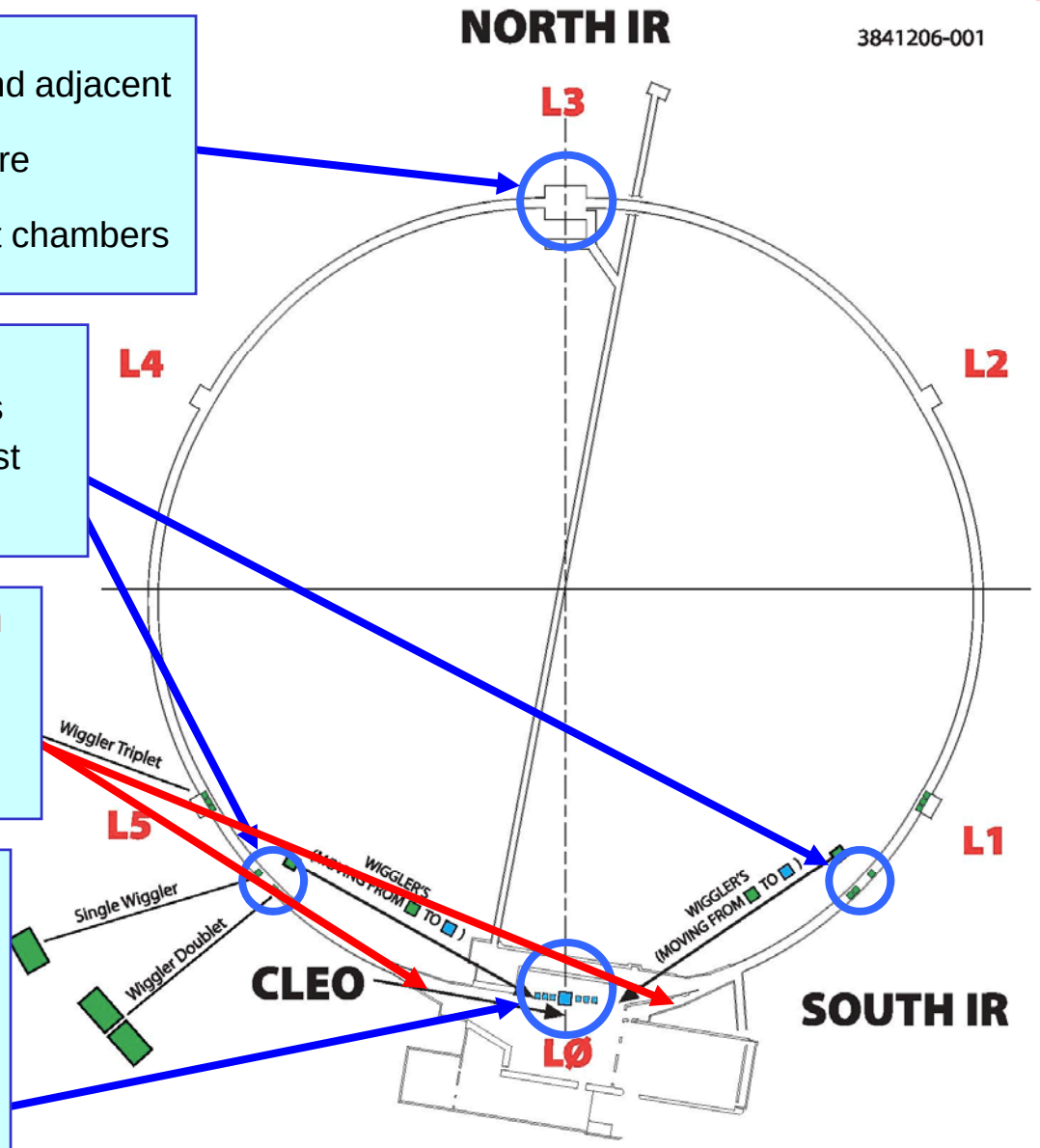
"Run 2"



- "Run 2" was recently split into 2 pieces, 2a and 2b
  - Accommodates CHESS request
  - Removes stress of a single long dedicated CesrTA run
  - Adds time to think between CesrTA periods
  - Exact dates in 2009 still undergoing discussion (eg, how long do we want the January '09 down to be? May want to add a short spring '09 down for some hardware installation)
- xBSM optics commissioning
- BPM system commissioning
- Beam-based alignment effort
- Test ultra low emittance lattice for first time
- Characterize electron cloud growth in chambers around the CESR ring (wigglers, dipoles and drifts)
- CESR down through the holidays to minimize power use and manpower limitations

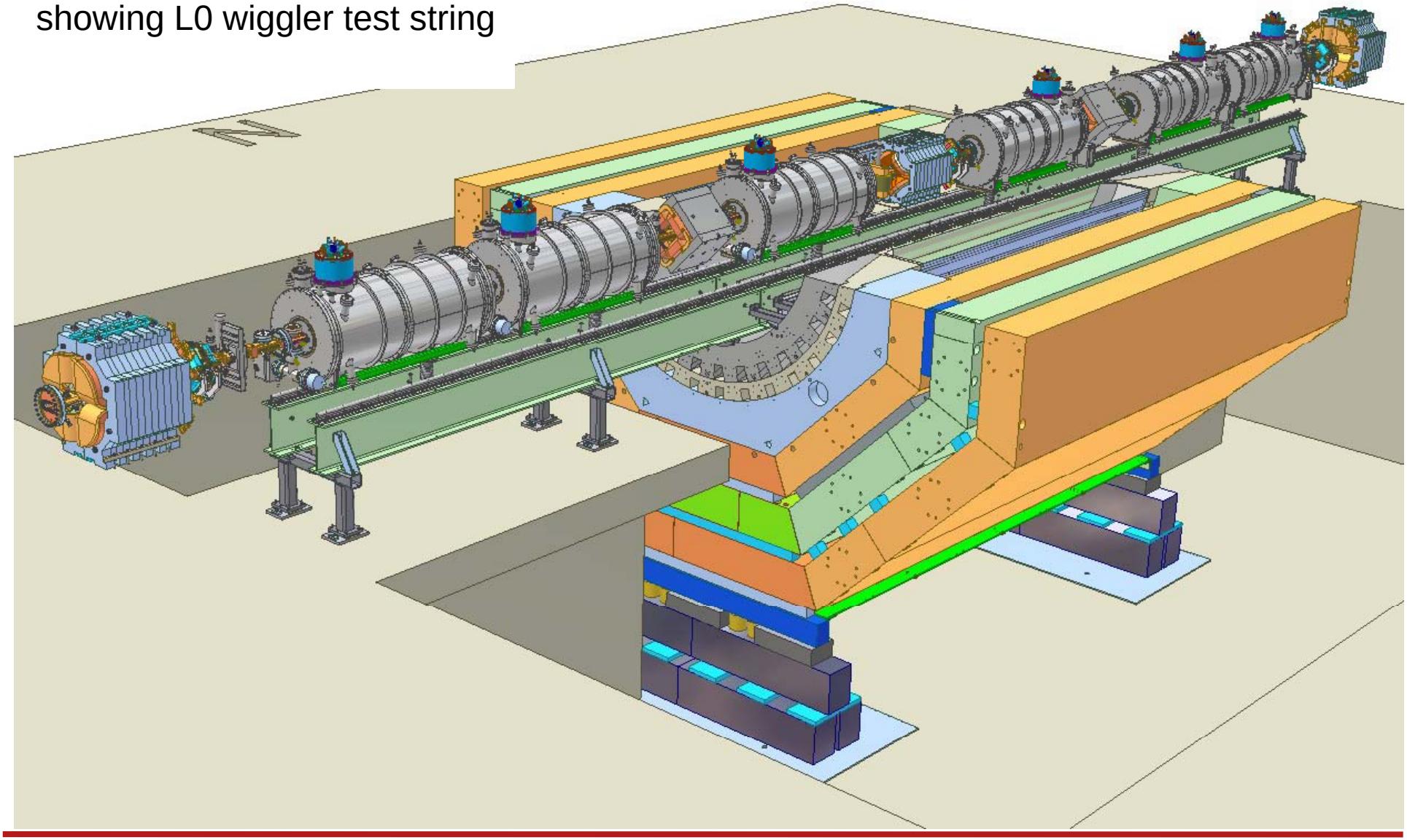
CESR Reconfiguration

- L3 Straight
  - Instrument large bore quadrupoles and adjacent drifts
  - Install of PEP-II experimental hardware (including chicane) in early 2009
  - Provide location for installation of test chambers
- Arcs where wigglers removed
  - Instrument dipoles and adjacent drifts
  - Provide locations for installation of test chambers
- CHESS line upgrades for x-ray beam size monitor
  - D-line this summer
  - C-line next year
- L0 Straight
  - All wigglers in zero dispersion regions for low emittance
  - Instrumented wiggler straight and adjacent sections



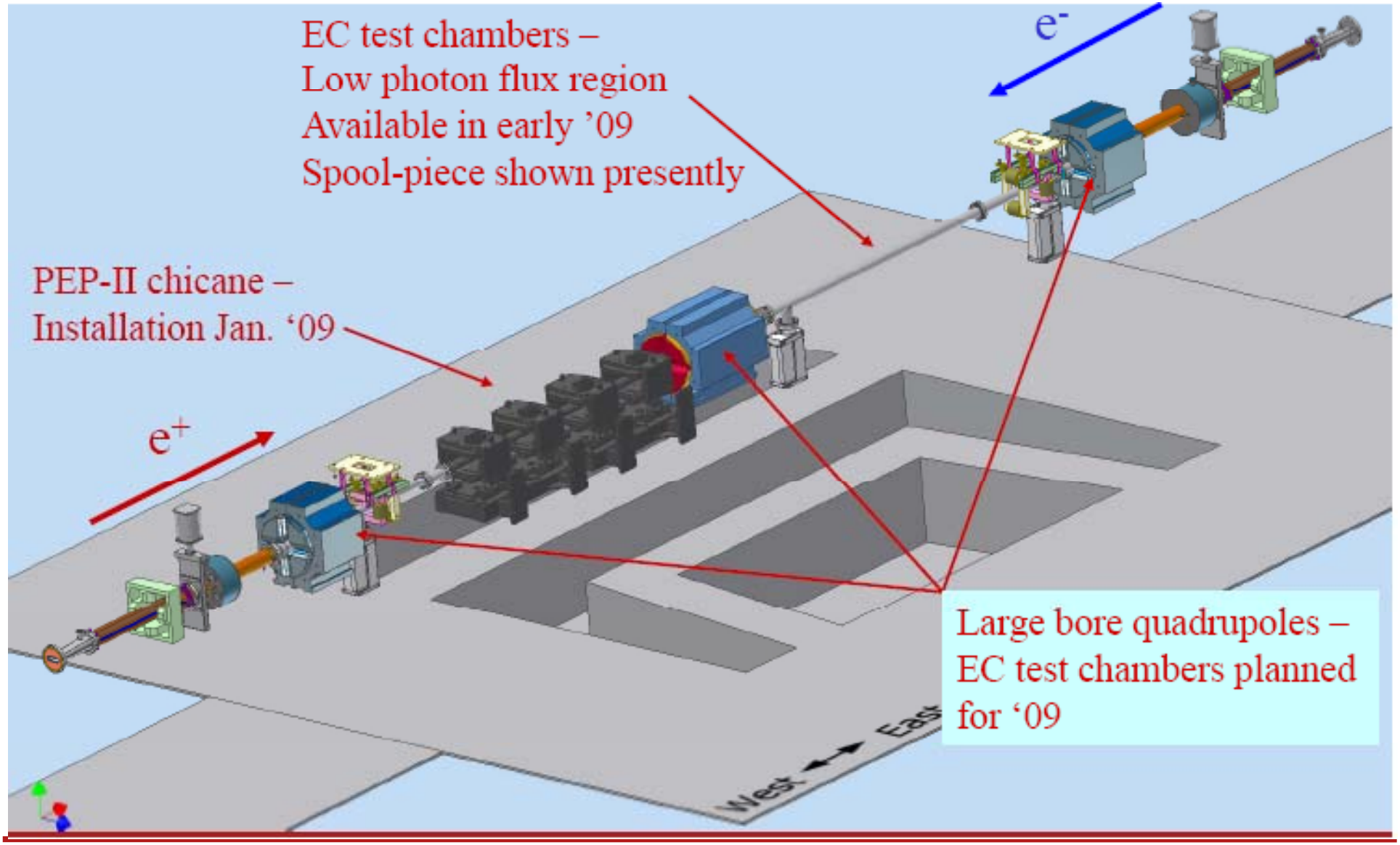
L0

- Cutaway through CLEO iron showing L0 wiggler test string



L0 Program Overview

- October 2008
  - Reconfiguration complete
  - First two instrumented wiggler chambers installed
    - One control chamber (uncoated Cu surface)
    - One chamber with TiN coating
  - Instrumentation support for a variety of EC experiments
- 2009
  - Further development based on results of initial tests
  - Follow-on wiggler chambers for additional mitigation tests (targeting chamber #3 to be constructed with a clearing electrode)
  - 5 GeV performance tests (requires addition of photon stop at end of L0 straight)

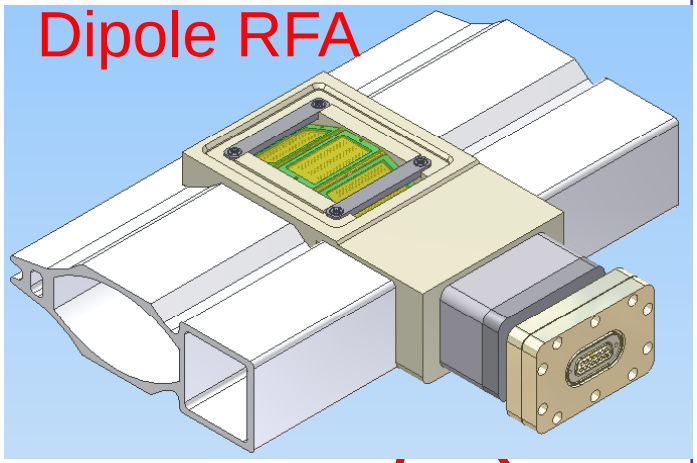

EC test chambers –
Low photon flux region
Available in early '09
Spool-piece shown presently
e-
PEP-II chicane –
Installation Jan. '09
e+
Large bore quadrupoles –
EC test chambers planned
for '09
West
East

RFAs

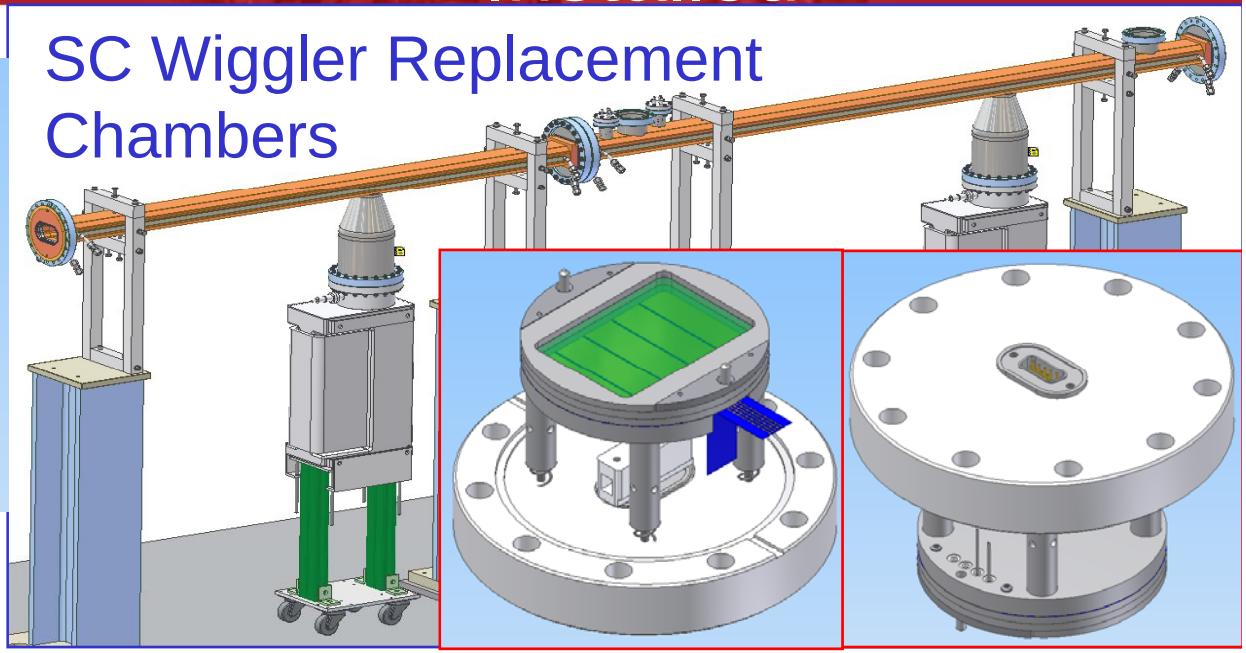
- Several different types of Retarding Field Analyzers are employed at CesrTA
  - "APS Style"
    - Well understood- use as a baseline to compare with more novel designs
    - 1 collector
    - Deployed in L1 and L5
  - Cornell "Insertable Segmented" RFAs
    - 5 collectors- probe azimuthal distribution of cloud
    - Deployed in L1 and L5
  - Dipole RFAs
    - Inserted in dipole chambers
    - 9 collectors
  - Wiggler RFAs
    - Deployed in L0 wigglers
    - 3 collectors at different field strengths along wiggler

Instrumented Chambers Installed

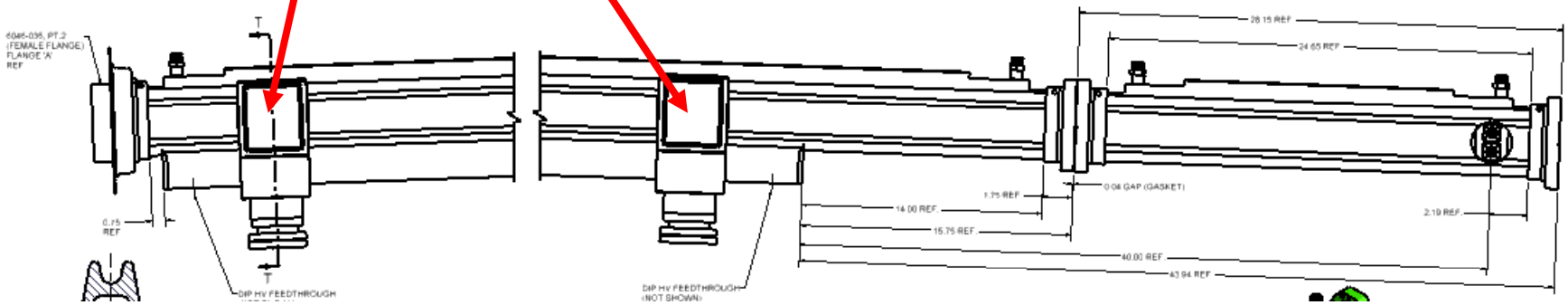
Dipole RFA



SC Wiggler Replacement Chambers

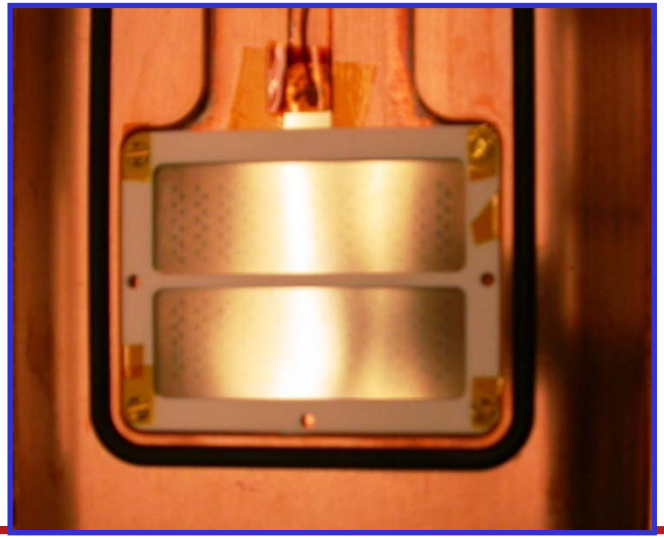


B12W Dipole Replacement Chamber



Wiggler EC Diagnostics

- RFAs assembled and checked for both VCs
- E-beam welding
  - 1st VC standard
  - 2nd VC TiN coated
- Installation into cryostats underway
- Installation into CESR ~Oct 23



Low Emittance Tuning

- Survey & Alignment
  - Complete network of survey monuments have been installed around the CESR tunnel
  - All CESR magnets have been measured with respect to network using laser tracker and digital level
  - Magnet mounting fixtures that permit precision adjustment are installed on all quadrupoles
  - Demonstrated during June run that we could reliably predict the effect on closed orbit and dispersion of ~100μm change in quadrupole offset
  - Survey network, digital level, and mounting fixtures provide for rapid correction of alignment errors

Low Emittance Parameters

Parameter	Value
$E^{\dagger}$	2.0 GeV
$N_{wiggler}$	12
B_{max}	1.9 T
ε_x (geometric)	2.3 nm
ε_y (geometric) Target	~~5-10 pm~~ 20pm
$\tau_{x,y}$	56 ms
σ_E/E	8.1×10^{-4}
Q_z	0.070
Total RF Voltage	7.6 MV
σ_z	8.9 mm
α_p	6.2×10^{-3}
$N_{particles}$/bunch	2×10^{10}
$\tau_{Touschek}$	10s of minutes
Bunch Spacing	Multiples of 4ns and 14ns

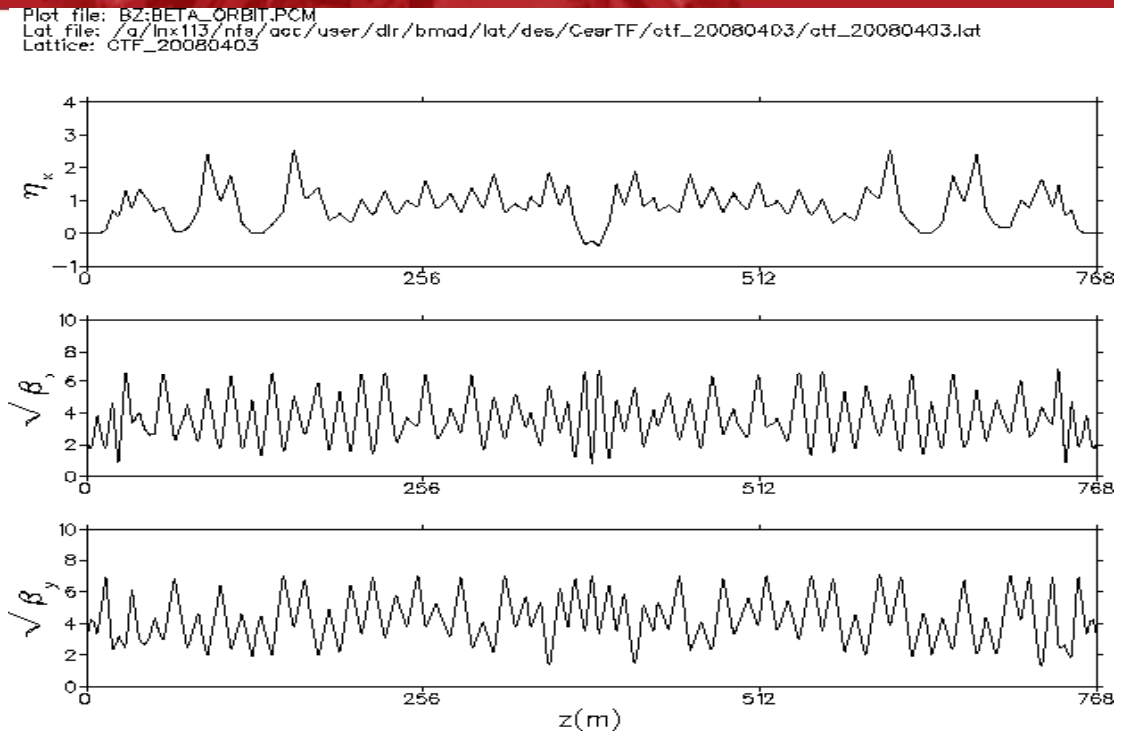
Low Emittance Tuning

- BPM upgrade
  - Digital bunch by bunch/ turn by turn BPM electronics and infrastructure is ready for installation
  - That installation will proceed in steps beginning after commissioning CesrTA optics
- Analysis software
  - Orbit response matrix
    - Control system software for collecting differential orbit data has been tested
    - Analysis of orbit differences (response) yields BPM tilts and shears
    - Effectiveness of ORM has been limited by BPM resolution and irreproducibility and it will significantly improve with installation of new BPM electronics
  - AC dispersion
    - Develop technique for measuring dispersion by exciting an energy oscillation and measuring amplitude and phase
    - Software to automate AC measurement is ready for testing
  - Phase/coupling measurement and correction
  - Gain mapping

Low Emittance Tuning

- CesrTA low emittance optics

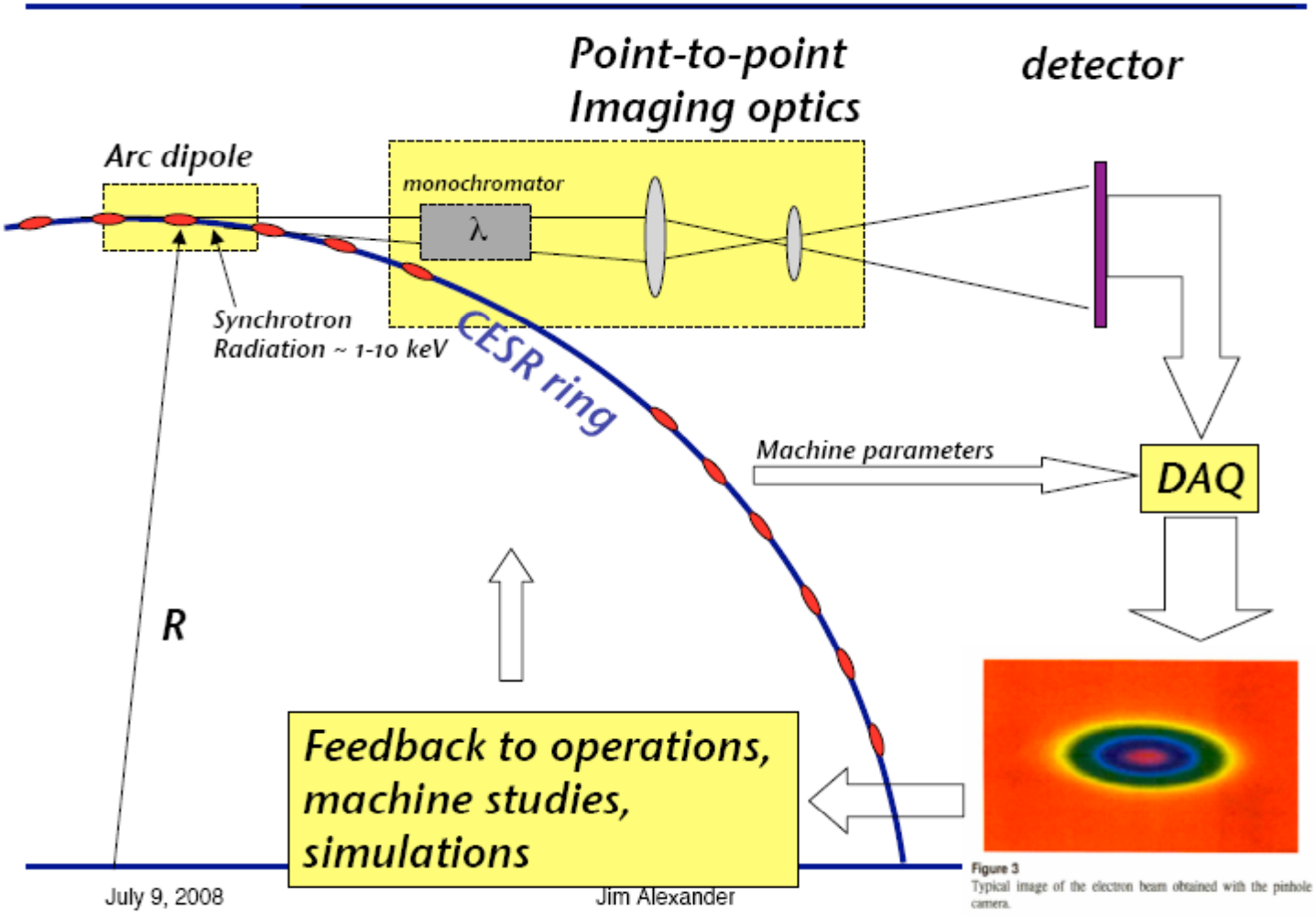
  We have low emittance optics designed for measurements at 2.0, 2.5, and 5.0GeV
- Accessible by collaborators in BMAD, MAD, or XSIF
- Optics will be commissioned during the October/November CesrTA run



Lattice	Energy[GeV]	Wigglers	B_{max}[T]	ε_x[nm]
cta_2000_v8_080403	2.0	12	1.9	2.5
cta_2500_20080521	2.5	12	1.9	3.6
cta_5000_v8_6wig_080506	5.0	6	1.9	31

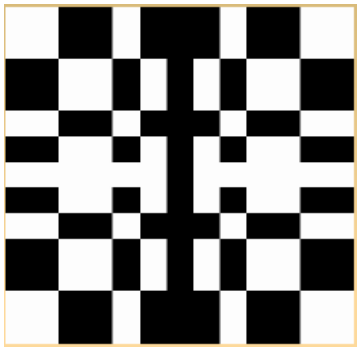
X-Ray Beam Size Monitor

- Bunch-by-bunch measurements of beam profile for fast emittance determination
  - Uses synchrotron radiation (installed at CHESS)
  - Image bunches spaced by 4ns
  - Transverse resolution < 10-15 μm



X-Ray Beam Size Monitor

- Different options for optics:
  - Traditional Fresnel zone plate
  - "Coded aperture"
    - Mask used to modulate incoming light
    - Resulting image must be deconvolved
    - Can achieve up to 50% open aperture area



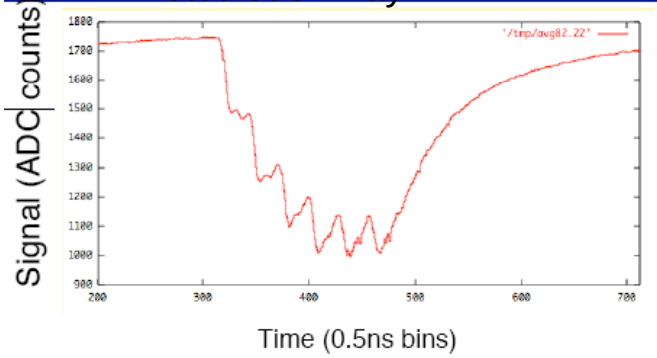
Coded aperture image courtesy of J. Flanagan

- Recent Progress
  - Upgrade of the positron x-ray beam line is complete (windowless line)
  - X-ray optics
    - "Simple" optics (adjustable slit and 3 slit coded aperture) scheduled for installation 10/22-23
  - X-ray detectors
    - Detectors (from 3 different vendors) will be tested in October/November
    - Readout software under development
- X-ray beam size measurement

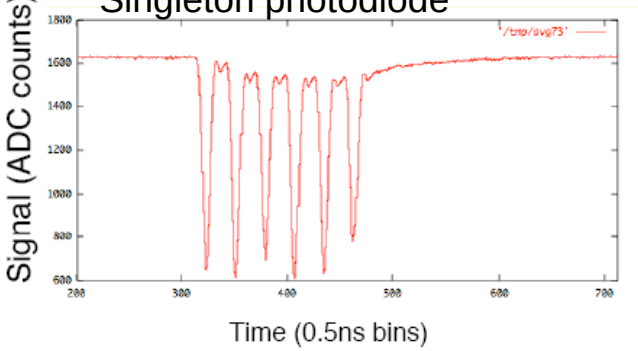
  - Measurement of the size of the positron beam with few micron resolution beginning in January

  - Single bunch/single pass measurement May-June

Photodiode Array



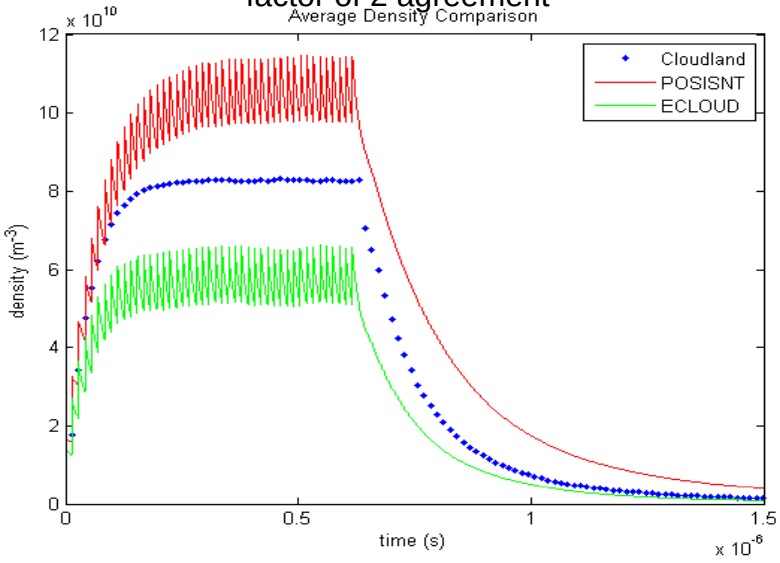
Singleton photodiode



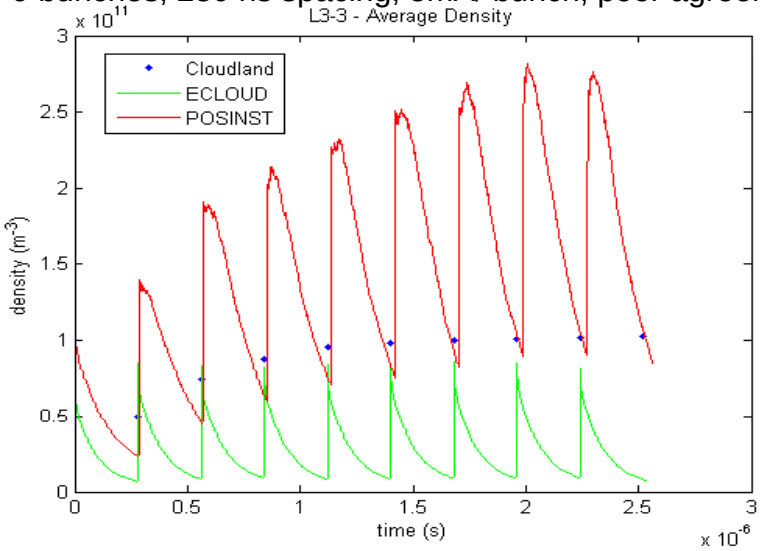
Electron Cloud Code Benchmarking

- "Benchmarking": comparison of different simulations with canonical parameter sets
- Three codes:
  - POSINST (M. Furman, M. Pivi)
  - ECLOUD (G. Rumolo, F. Zimmermann)
  - CLOUDLAND (L. Wang)
- Programs can disagree significantly
- Possible sources of discrepancies:
  - Different SEY models
  - Different primary models
- Example: average density plots on right

45 bunches, 14 ns spacing, 1mA/bunch
~factor of 2 agreement

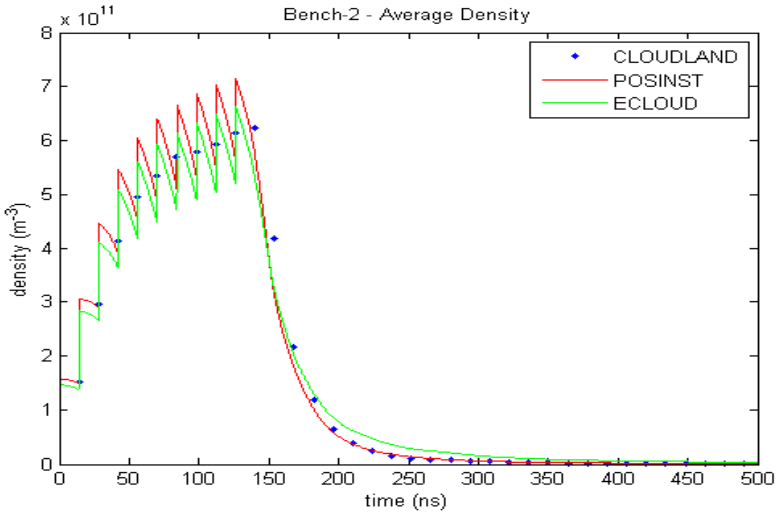


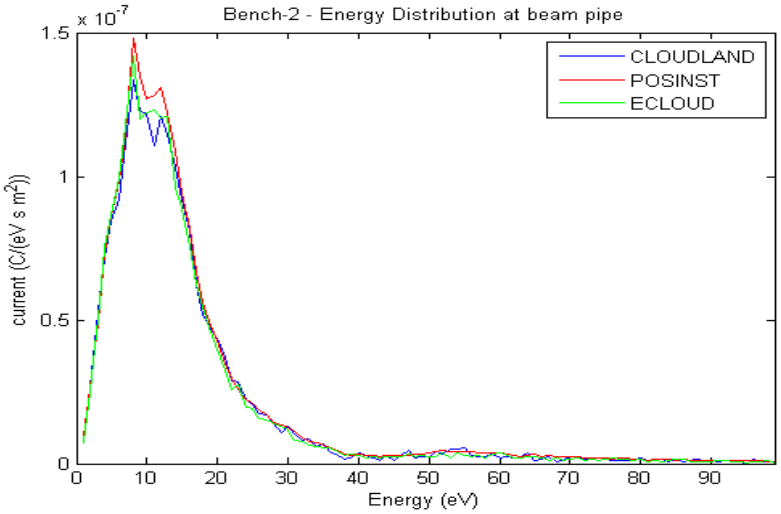
9 bunches, 280 ns spacing, 5mA/ bunch; poor agreement



Code Benchmarking

- With no SEY and same primary angular distribution, match is essentially perfect
  - reduces worries about systematic or statistical errors
  - Needs to be verified for other beam conditions

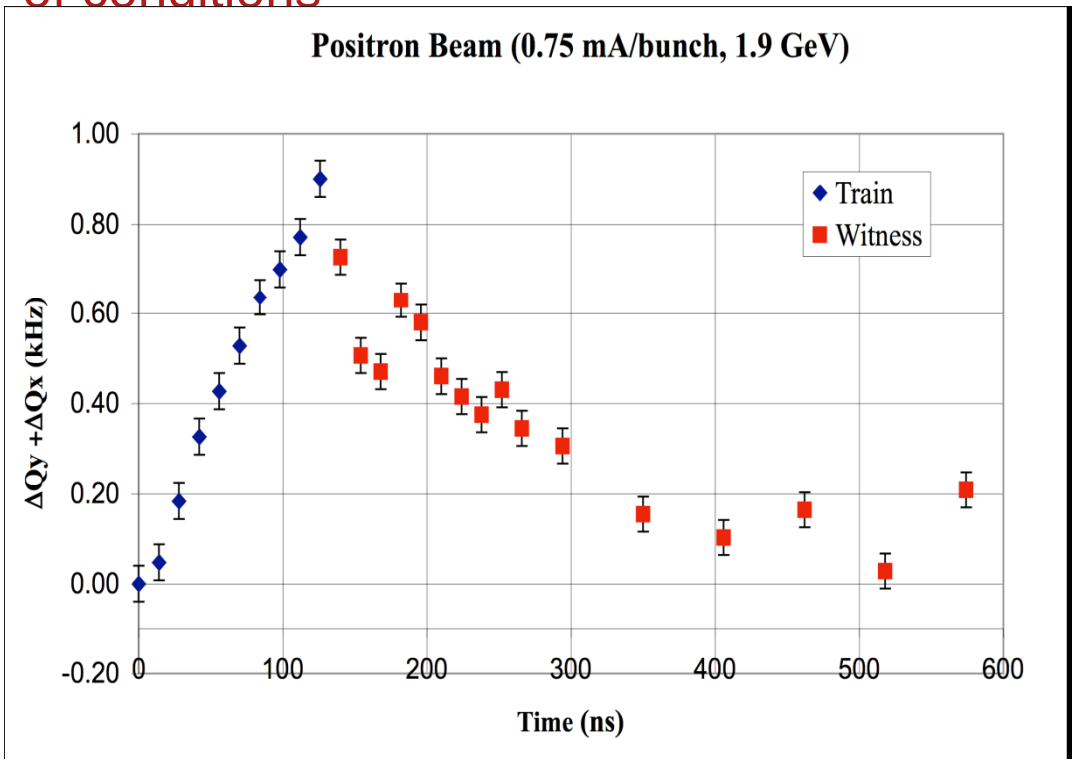




- Situation is more complicated for SEY models
- POSINST has more detailed model than ECLOUD or CLOUDLAND
  - Includes “rediffused” component
- Different parameterizations can lead to divergent behaviour, even for “similar looking” SEY curves
  - Ex: cannot simply turn off rediffused in POSINST
  - Low energy behavior particularly important

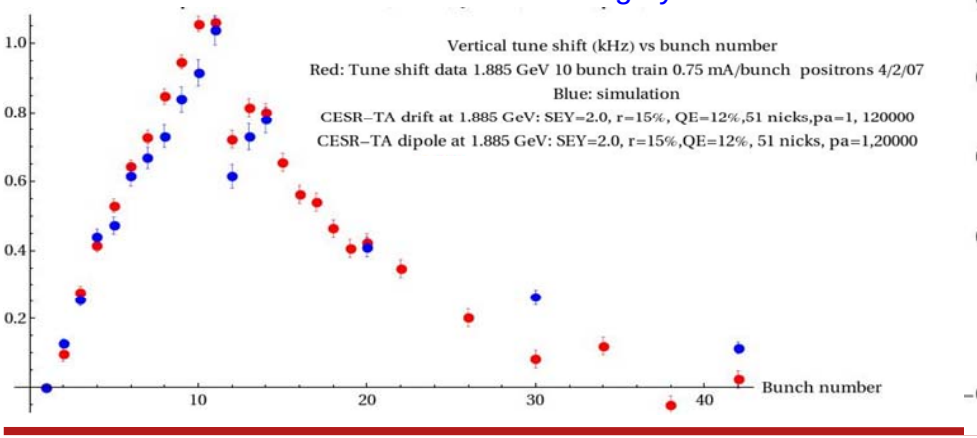
Tune Shift Measurements

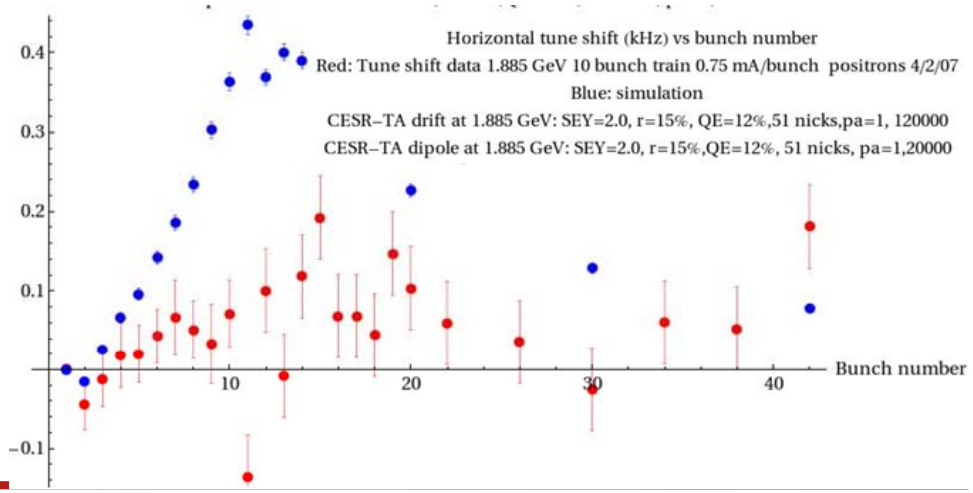
- Witness Bunch Method
  - Electron cloud is generated with a train of “loading bunches”
  - Cloud is probed at later times by measuring tune shift of “witness bunches”
  - The tune shift is a measure of the beam-averaged field gradient due to the cloud charge density at the time of the witness bunch.
  - Gives ring integrated field gradient due to cloud vs time
- Measurements taken in a variety of conditions
  - Electron & positron beams
  - 1.9 GeV and 5.3 GeV
  - Various loading trains
- Measurements are compared to predictions based on cloud simulations (POSINST)



Tune Shift Simulations

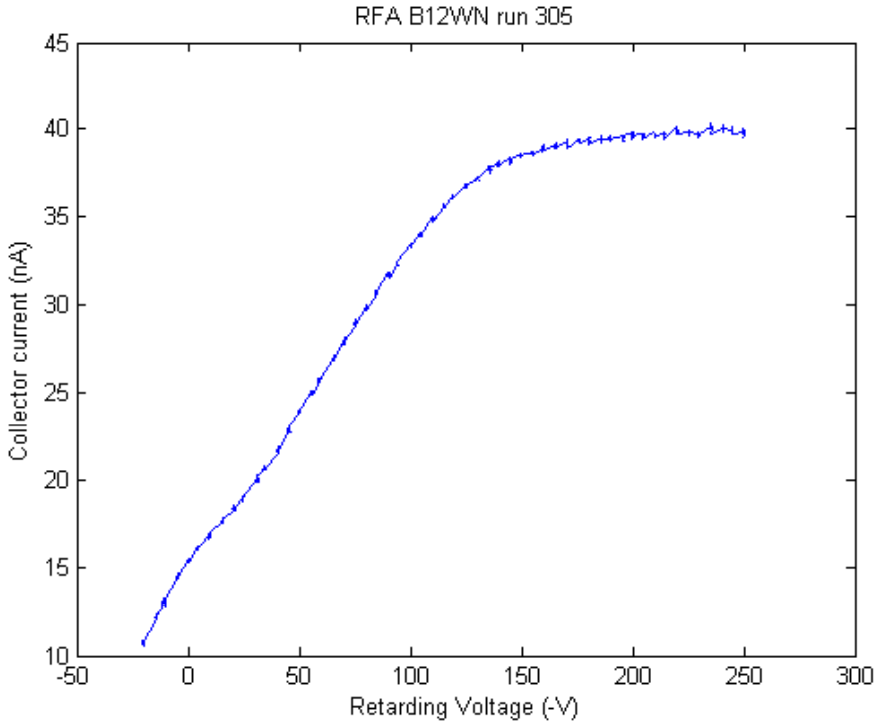
- Sum of tune shifts roughly proportional to beam averaged density of cloud:
- We run simulation separately for drifts and dipoles, add tune shifts together with appropriate ring weights
- It is necessary to include a number of corrections
  - Image charges
  - “Pinch effect” during bunch passage
  - “Dynamic effect” due to oscillation of electrons around beam
- By adjusting simulation parameters, we can fit the vertical tune shift well
  - Qualitative features (e.g. dip after generating train) maintained
  - Note that the “plausible” parameter space is quite large
- However, we haven’t been able to match the horizontal tune shift
  - Data are small, with large error bars
    - Some concerns about integrity of data





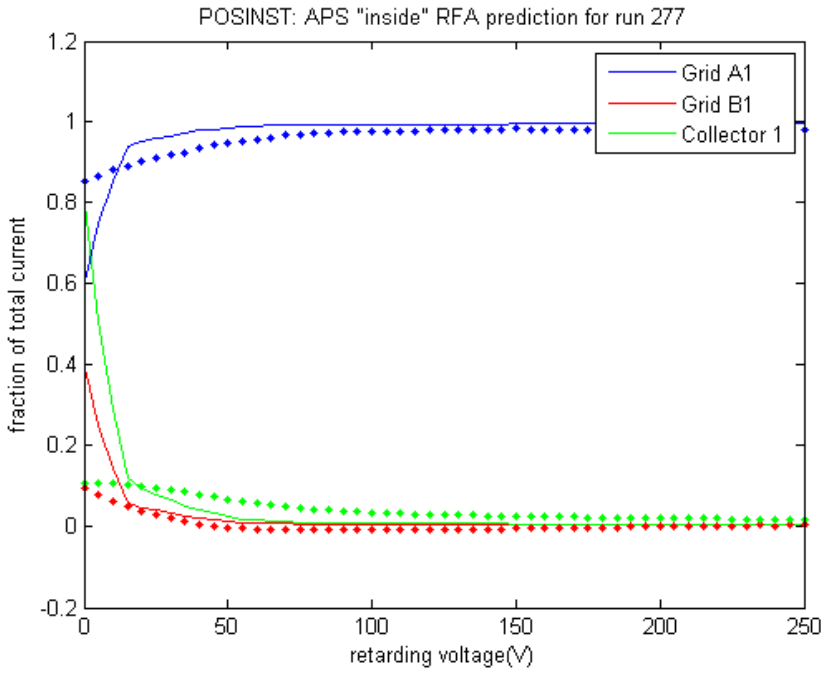
RFA Simulations

- We have lots of RFA data from June run
- RFAs provide direct measure of the cloud at a particular location
- RFAs themselves need to be simulated
  - Postprocessing output from cloud simulation codes
  - Data shows some idiosyncratic behavior
    - Negative grid currents
    - Collector currents that increase with retarding voltage! (see below)
- Three levels of detail
  - Rough analytic calculation
    - Can be off by an order of magnitude
  - Recursive semi-analytical "simulation"
    - Can include subtleties
      - SEY in the RFA
      - Electrons hitting inside of grids
  - Full particle tracking simulation
    - Includes focusing effects of fields
    - Cross check with semi-analytical model



RFA Simulations

- Simulations roughly match data
- But, a few discrepancies…
  - Simulations overestimate total current (by up to a factor of 2)
  - Predict current spike in collector for low retarding voltage, which is not seen in data
    - True in both semi-analytical and full particle tracking simulations
    - Could the cloud simulation programs be generating too many low energy electrons?
      - Perhaps this could shed some light on the question of low energy SEY
  - Can make fit better by fiddling with parameters
    - Grid efficiencies, SEY, etc.
- Preliminary example shown on right
  - APS RFA
  - Shows normalized current



Future plans

- Complete the code comparison (benchmarking) and fully understand the differences between the SEY models in ECLOUD, CLOUDLAND and POSINST.
- Improved model of the RFA response
- Fully include dynamic effects in tune shift calculations (requires integration of beam motion into the simulation codes).
- RFA's to be installed in new wiggler chamber will allow measurement of cloud-induced current in a wiggler field. We need a 3D simulation code to analyze this. The present plan is to use WARP-POSINST, relying on our LBNL collaborators.
- Measurements of cloud-induced incoherent emittance growth can be made using XBSM. We need to estimate this in a simulation.
- Dependence of cloud effects on beam as a function of energy, species, bunch population, bunch spacing, and emittance, in alliance with the simulation program, can provide a comprehensive validation of the codes.

Contact Information

- General CesrTA or scheduling questions:
  - Mark Palmer: map36@cornell.edu
- Low Emittance Tuning:
  - Dave Rubin: dlr10@cornell.edu
- Electron Cloud Studies:
  - Mark Palmer: map36@cornell.edu
  - Gerry Dugan: gfd1@cornell.edu
  - Joe Calvey: jrc97@cornell.edu
- More information at the CesrTA Wiki:
  - Main CesrTA Wiki Page:

https://wiki.lepp.cornell.edu/ilc/bin/view/Public/CesrTA/

  - CesrTA Collaboration Meetings Page:

https://wiki.lepp.cornell.edu/ilc/bin/view/Public/CesrTA/CollabMeetings

- Can subscribe to the mailing list from the main CesrTA Wiki Page
- Potential overlap with CLIC