CesrTA Program and Recent Results

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for the CesrTA Collaboration

November 21, 2008

Outline

- CesrTA Program
- CESR Reconfiguration & Startup
- EC Data from Commissioning Run
- EC Data-Simulation Comparisons
- Summary and Comments

CesrTA Program I

- CesrTA is an ILC Damping Rings R&D project
  - Joint NSF/DOE funding
  - Funding spans FY08-FY10
  - Funding levels consistent with a 2 year experimental program
- Project Goals
  - Characterize electron cloud build-up
  - Develop electron cloud suppression techniques
  - Develop modeling tools for electron cloud instabilities
  - Determine electron cloud instability thresholds
  - Conduct experiments in an ultra-low emittance positron ring
  - Provide significant amounts of dedicated experimental time (~240 running days over course of program)

CesrTA Program II

- R&D Targets:
  - 2008 through mid-2009
    - Machine reconfiguration for ultra low emittance operation
    - Deploy and commission instrumentation needed to characterize low emittance beams
    - Deployment of EC diagnostics and studies of EC growth and suppression in wigglers, dipoles, quadrupoles and drift regions
    - Implement ultra low emittance lattice and begin low emittance tuning program
  - Mid-2009 through April 2010
    - Work to achieve ultra low emittance operation
    - Ongoing EC growth and mitigation studies
    - EC beam dynamics studies at the lowest achievable emittances
    - Focus shifts much more heavily to experiment versus machine modifications
  - Provide evaluations for the ILC Technical Design Phase in mid-2010

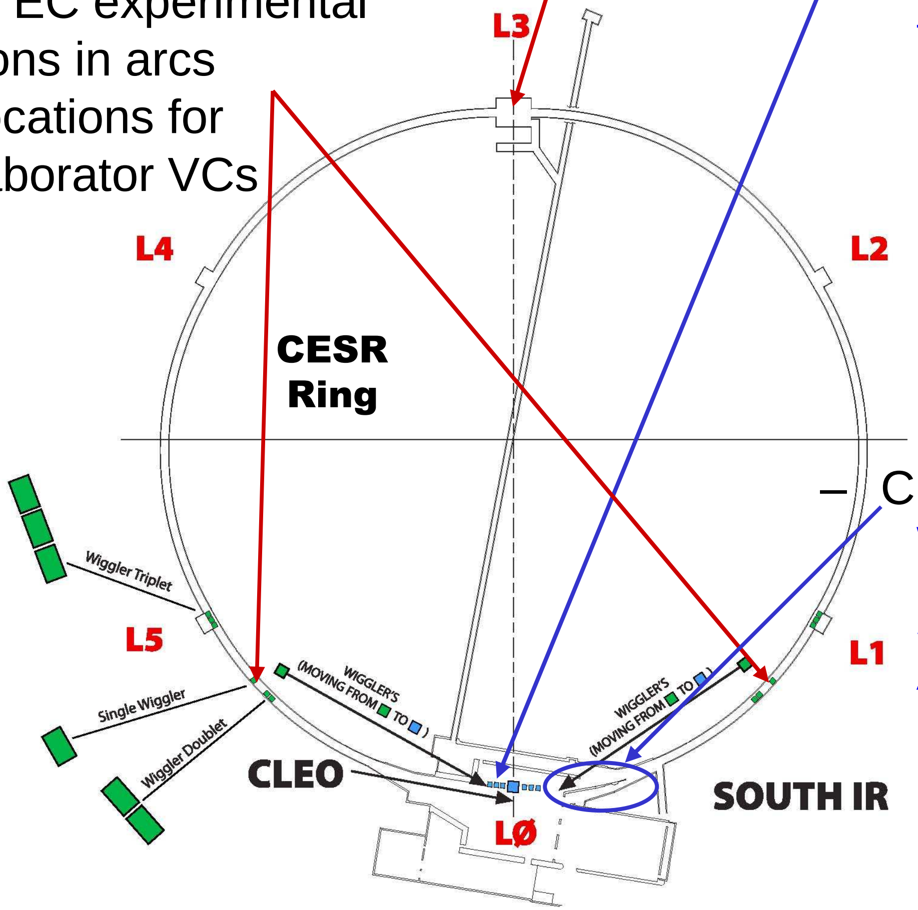
Low Emittance Parameters

Parameter	Value
E†	2.0 GeV
$N_{wiggler}$	12
B_{max}	1.9 T
ε_x (geometric)	2.5 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

† Operating range of 1.5 to 5.3 GeV

CESR Reconfiguration

- Electron Cloud Diagnostics
  - L3 region prepped for arrival of PEP-II EC hardware including diagnostic chicane
    - Delivered to Cornell this week
  - New EC experimental regions in arcs w/ locations for collaborator VCs
  - L0 region reconfigured as a wiggler straight
    - Instrumented with EC diagnostics
    - Wiggler chambers with retarding field analyzers (fabricated at LBNL) - scheduled for installation ~Oct 23rd
    - Chambers with EC mitigation (TiN coatings by SLAC)
  - CHESS D-line
    - Windowless (all vacuum) x-ray line upgrade for x-ray detector capable of single pass measurements
    - Addition of x-ray optics box
    - Detector setup in CHESS hutch
    - Option for longer optical lever arm by extending line to detector located in L0



CESR Startup in DR Configuration

- Reconfiguration down started July 7 and concluded in early October. Highlights:
  - CESR vacuum closed week of Sept 29th
  - Linac/Synchrotron startup commenced Oct 2nd
  - First injection into CESR took place Oct 8th
  - Stored beam in CESR early Oct 13th
    - Magnet coil problem
  - Diagnostic wigglers installed Oct 23-24
  - Operation at 5.3 GeV through morning of Nov 3
    - Machine processing
    - CesrTA machine studies (particularly hardware checkout)
  - 2.0 GeV CesrTA Experiments : Nov 3-Nov 10

    Electron Cloud Experiments

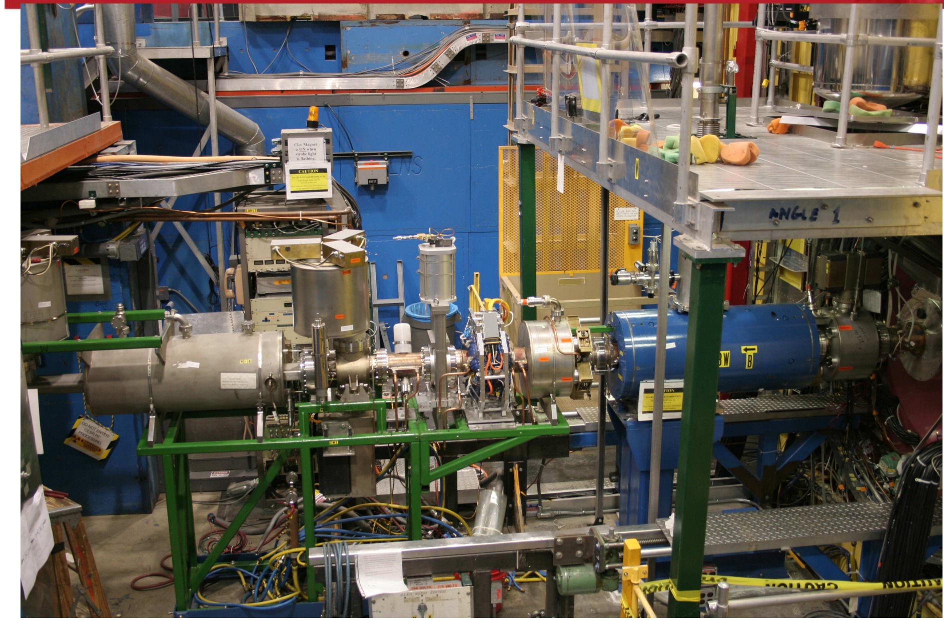
    Low Emittance Optics

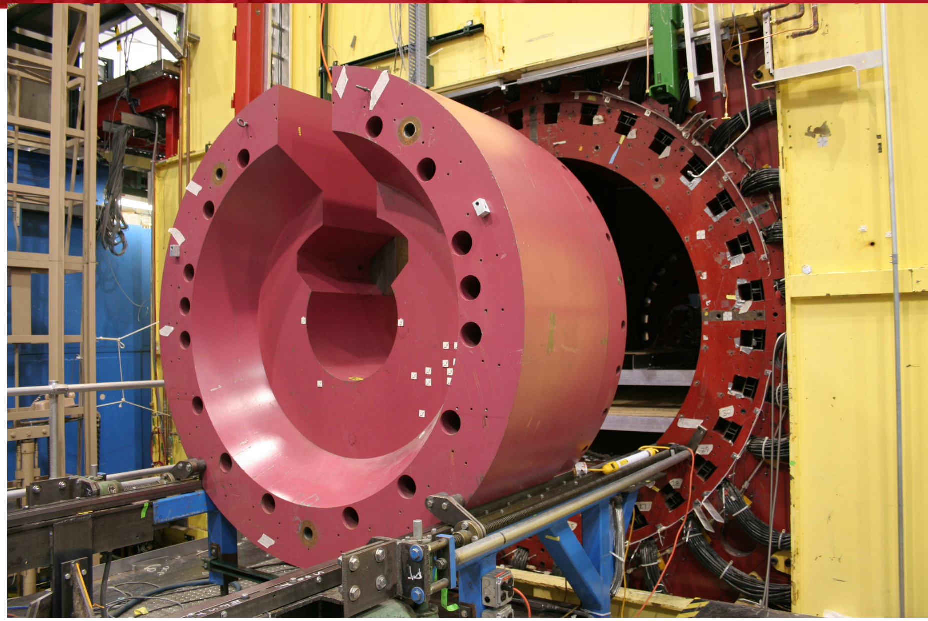
    X-ray Beam Size Monitor

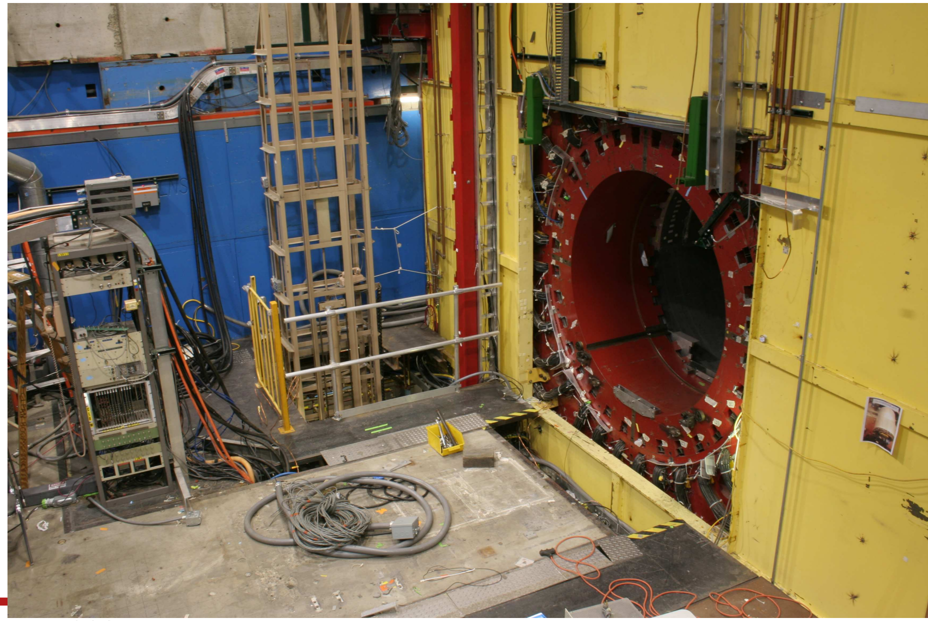
    Instrumentation Checks

Cornell University
Laboratory for Elementary-Particle Physics

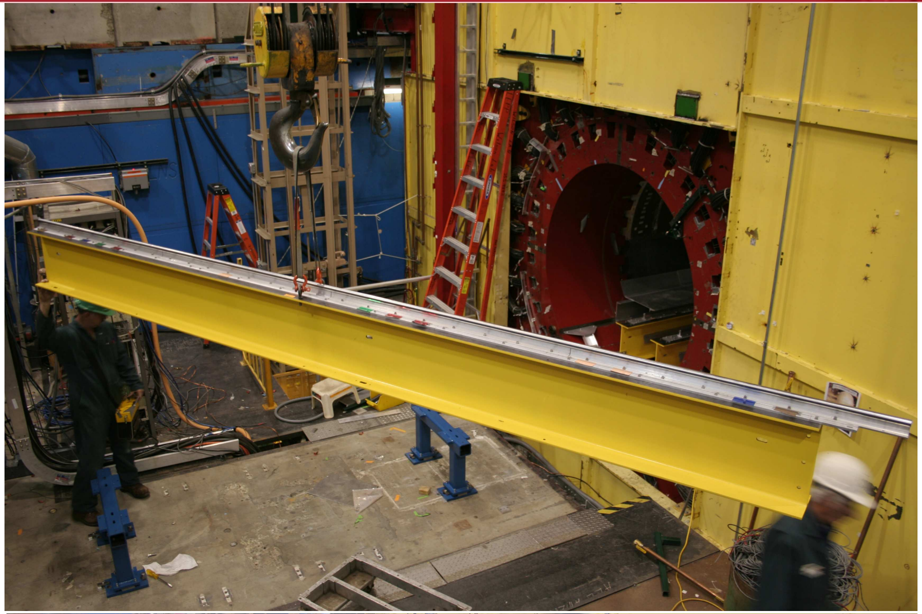
L0 Modifications

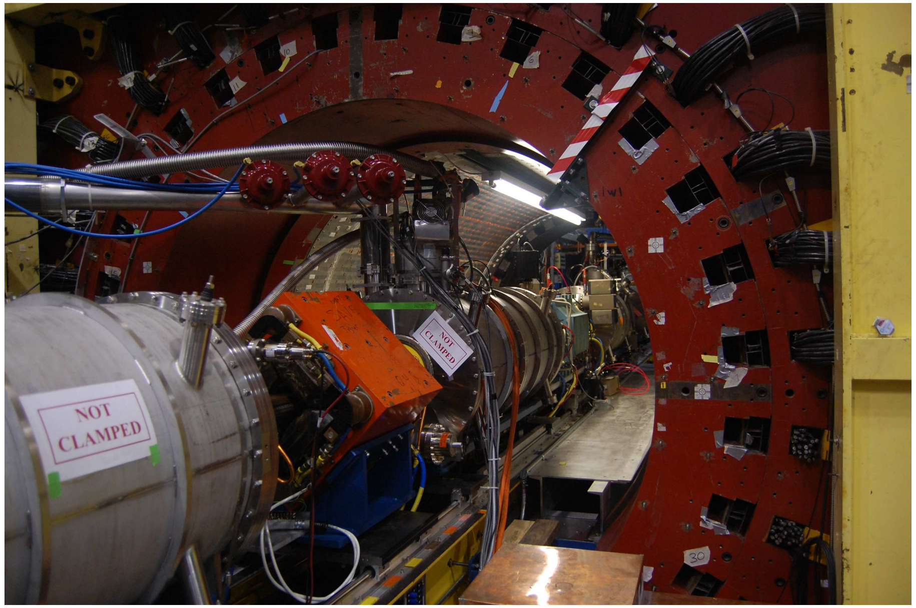


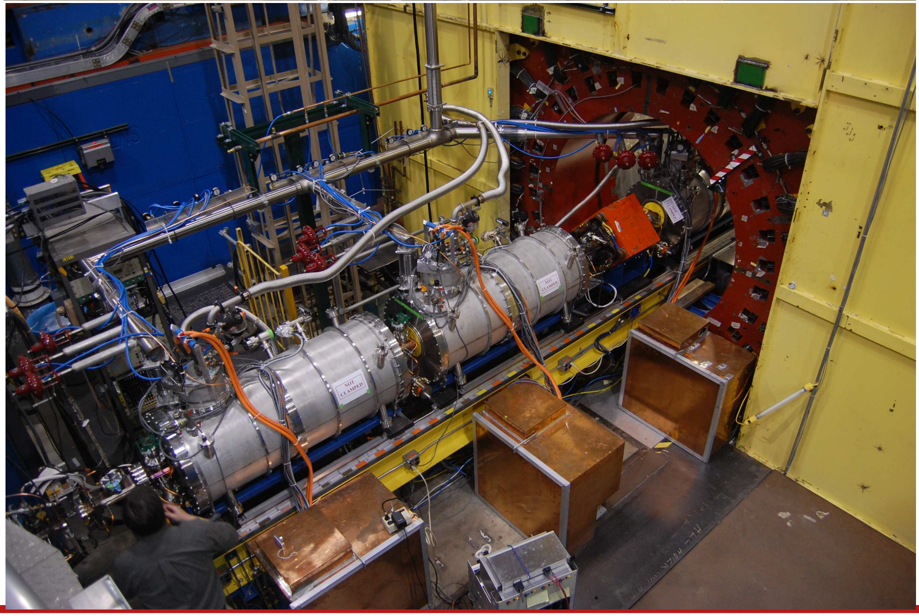


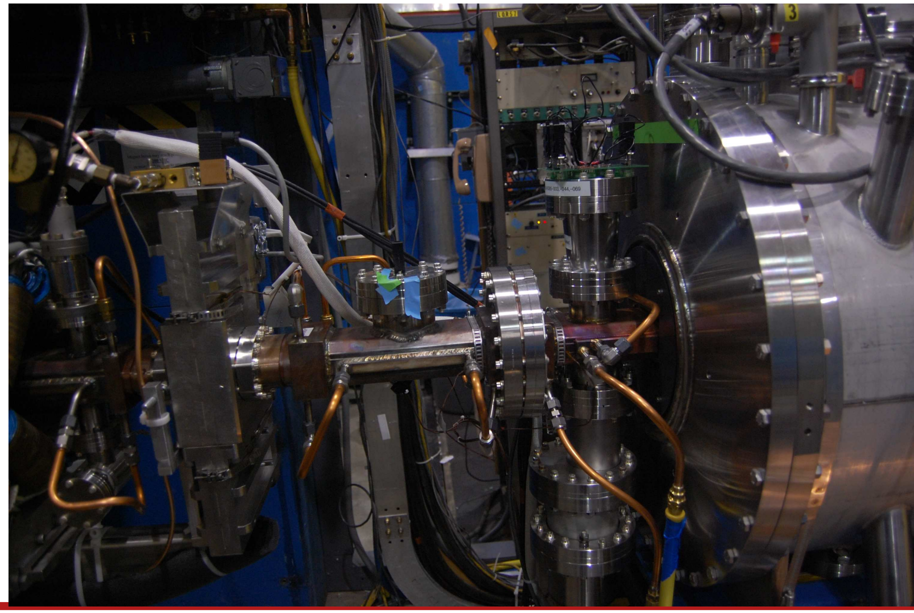


L0 Modifications



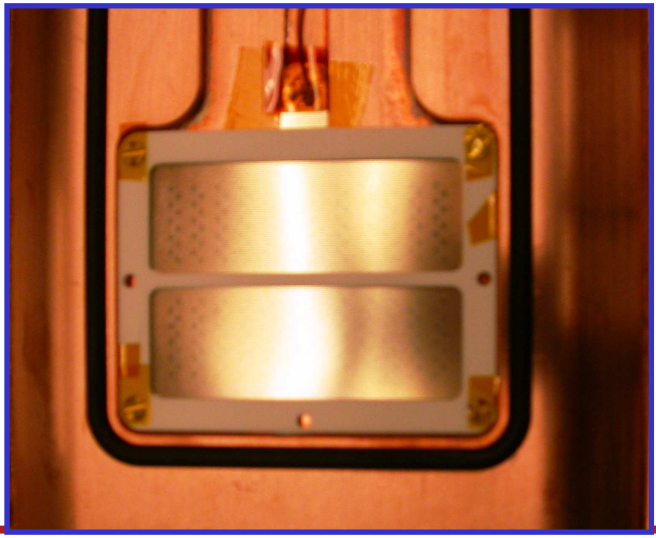


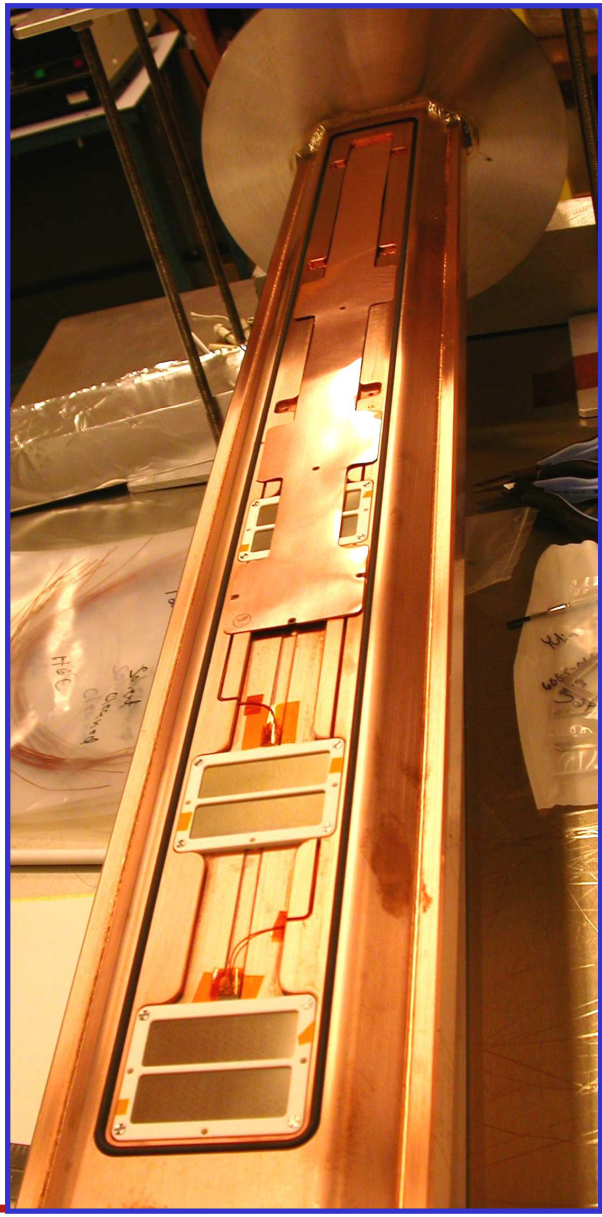


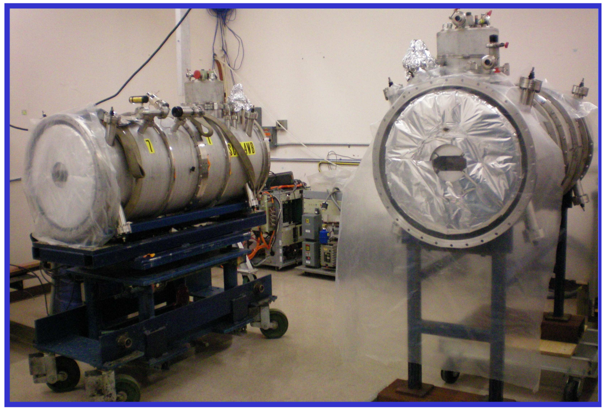


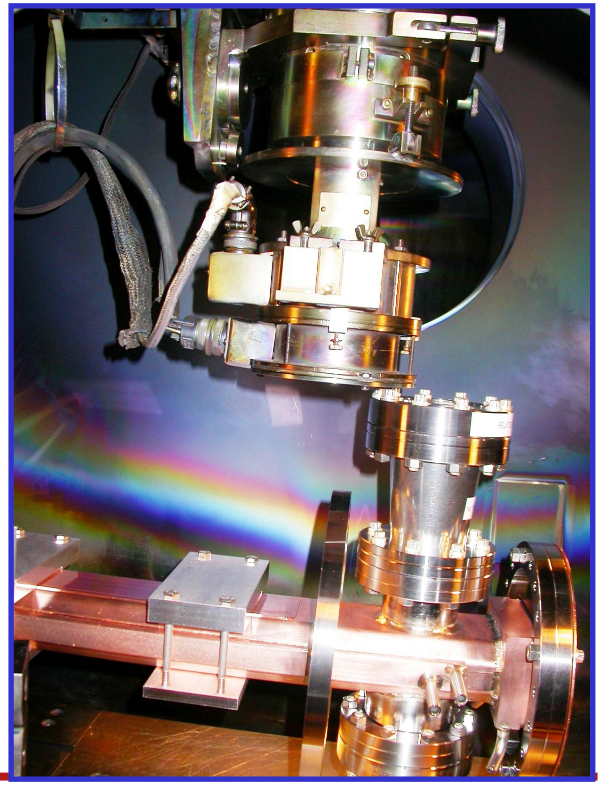
Wiggler EC Diagnostics

- RFAs assembled and checked for both VCs
- E-beam welding
  - 1^{st} VC complete
  - 2^{nd} VC on Oct 10
- Installed into cryostats week of Oct 14
- Installed into CESR Oct 23-24







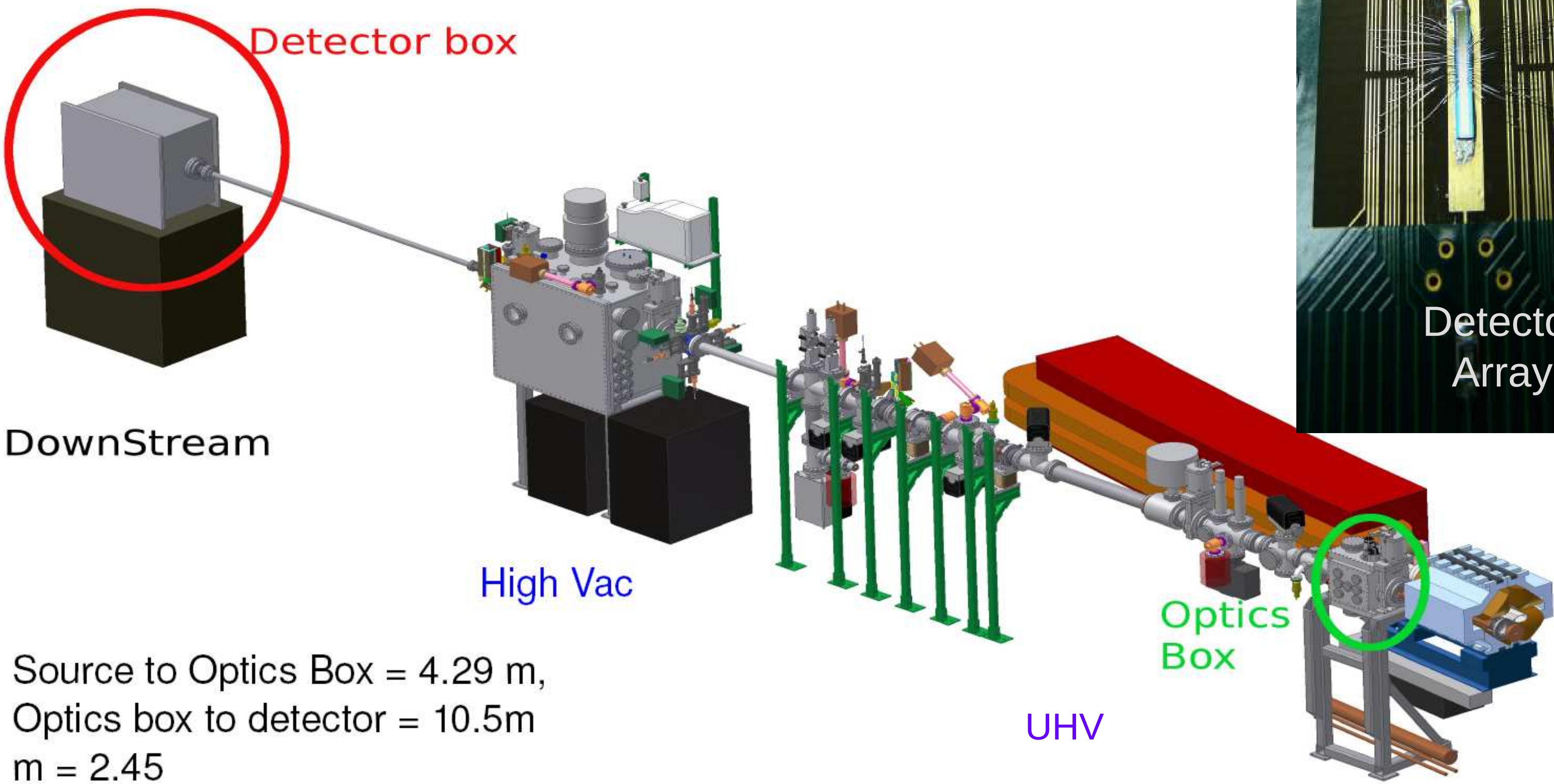


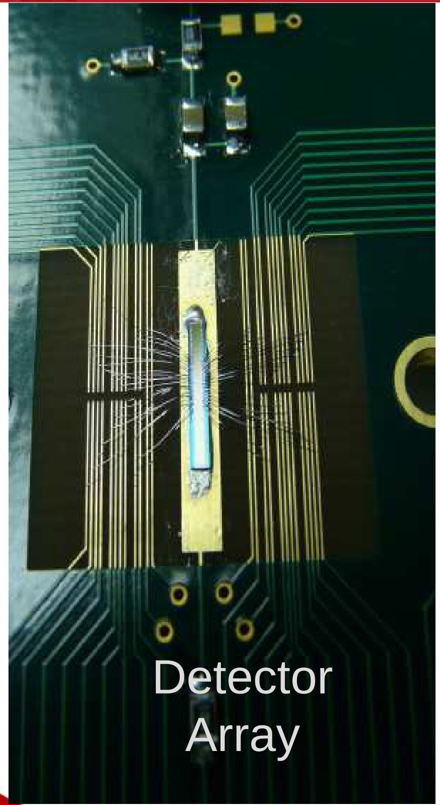
CesrTA - xBSM

- X-ray beam size monitor
  - Upgrade of the positron x-ray beam line is complete (windowless line)
    - 4μm diamond window to isolate storage ring and beam line vacuum will be tested with a beryllium backup in January run
  - X-ray optics
    - "Simple" optics (adjustable slit and 3 slit coded aperture) for Oct-Nov 2008
    - Optical Array Element from Applied Nanotechnologies arrives in December
      - 230 ring fresnel zone plate and 41 element coded aperture on a single substrate
  - X-ray detectors
    - Detectors (from 3 different vendors) tested in Oct-Nov
- X-ray beam size measurement
  - Measurement of the size of the positron beam with few micron resolution beginning in January 2009 run
  - Single bunch/single pass measurements in May-June 2009 run

xBSM

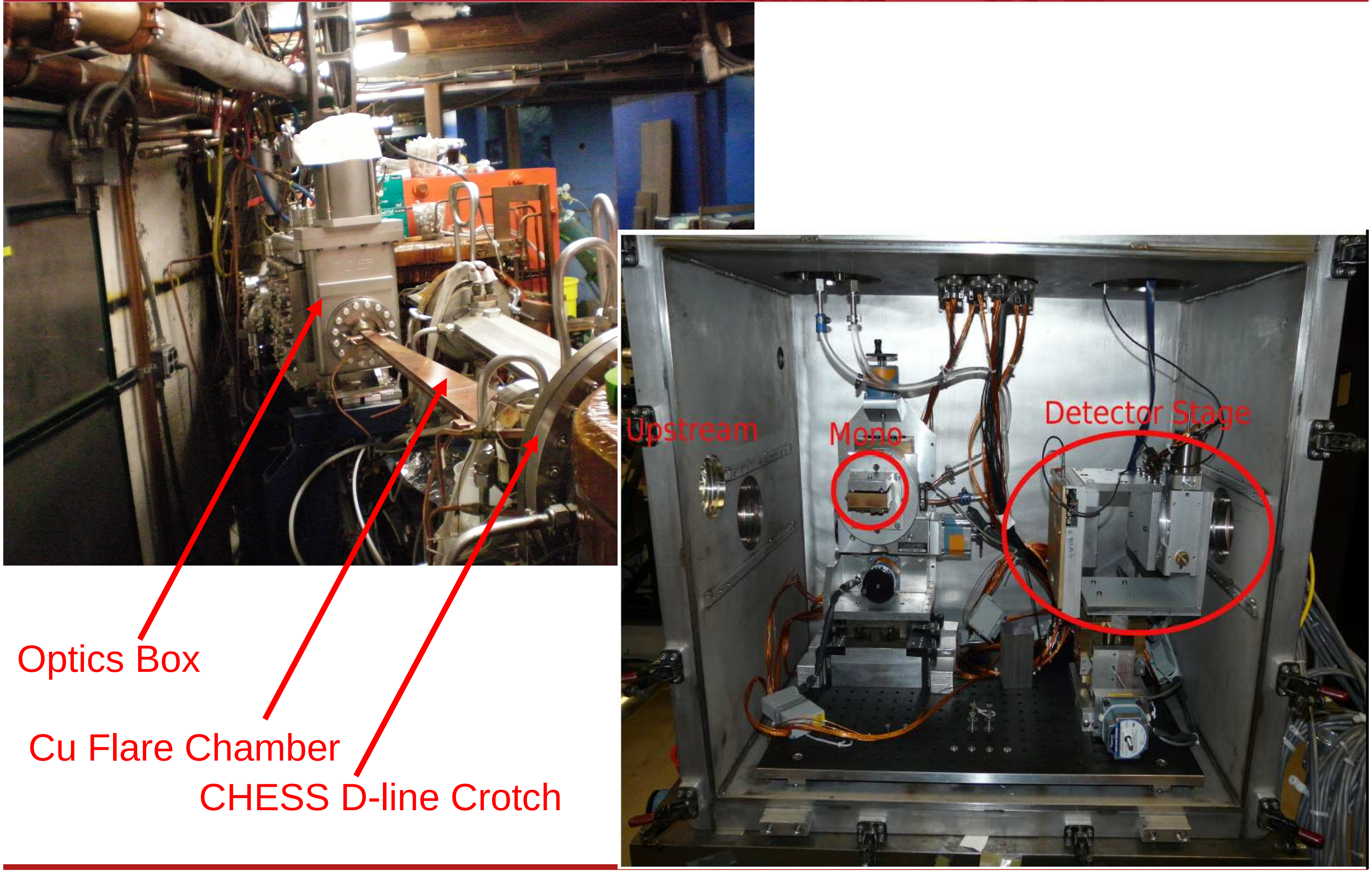
New optics line in collaboration with CHESS: All vacuum line



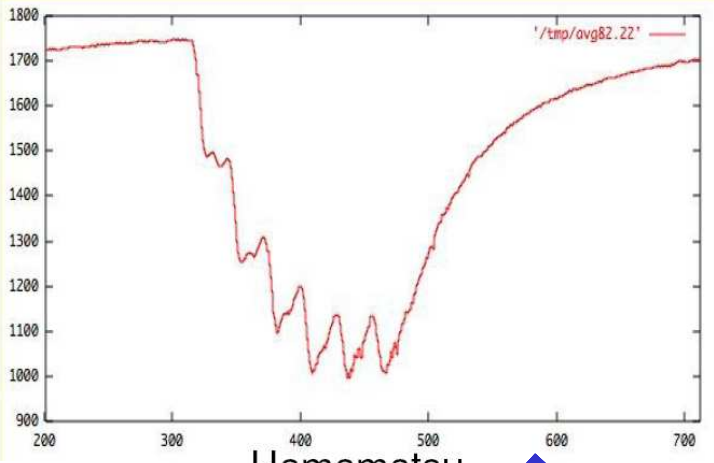


Source to Optics Box = 4.29 m,
Optics box to detector = 10.5m
m = 2.45

xBSM Optics Box



xBSM Detector Time Response



Hamamatsu
100 turn average

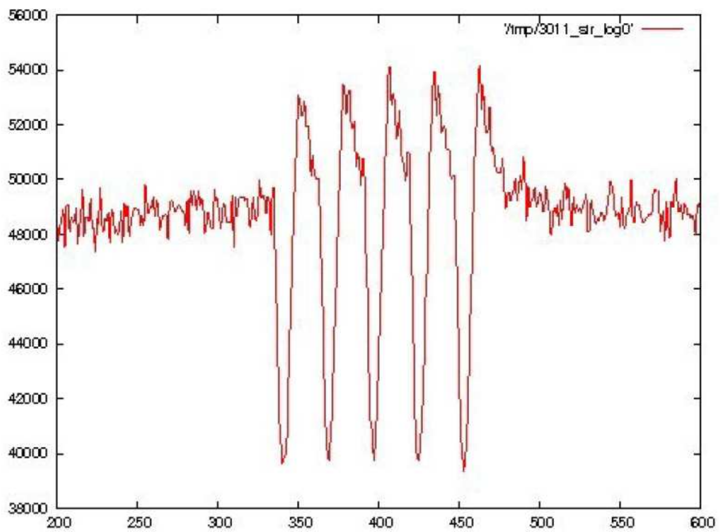
Single-pass measurement capability:

After previously discovering very slow recovery times with Hamamatsu diode arrays (fabrication issue – not fundamental), it was critical to test the response of alternate detector arrays. Excellent time response found from 2 suppliers!

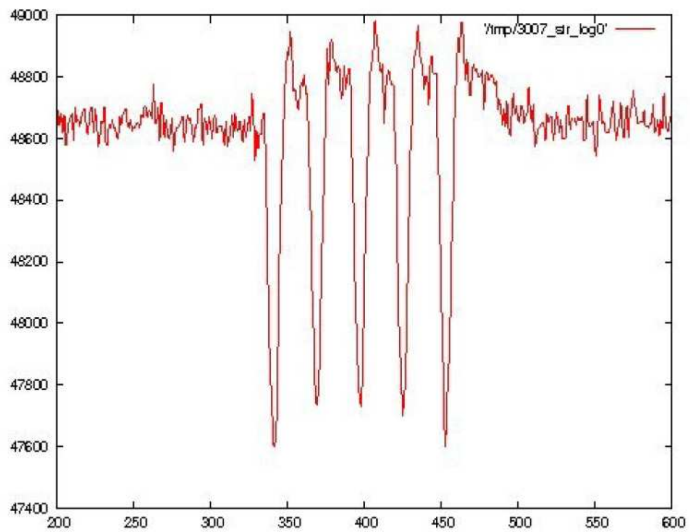
14 ns spaced bunches

Amplitudes are average over 100 turns

Kyosemi

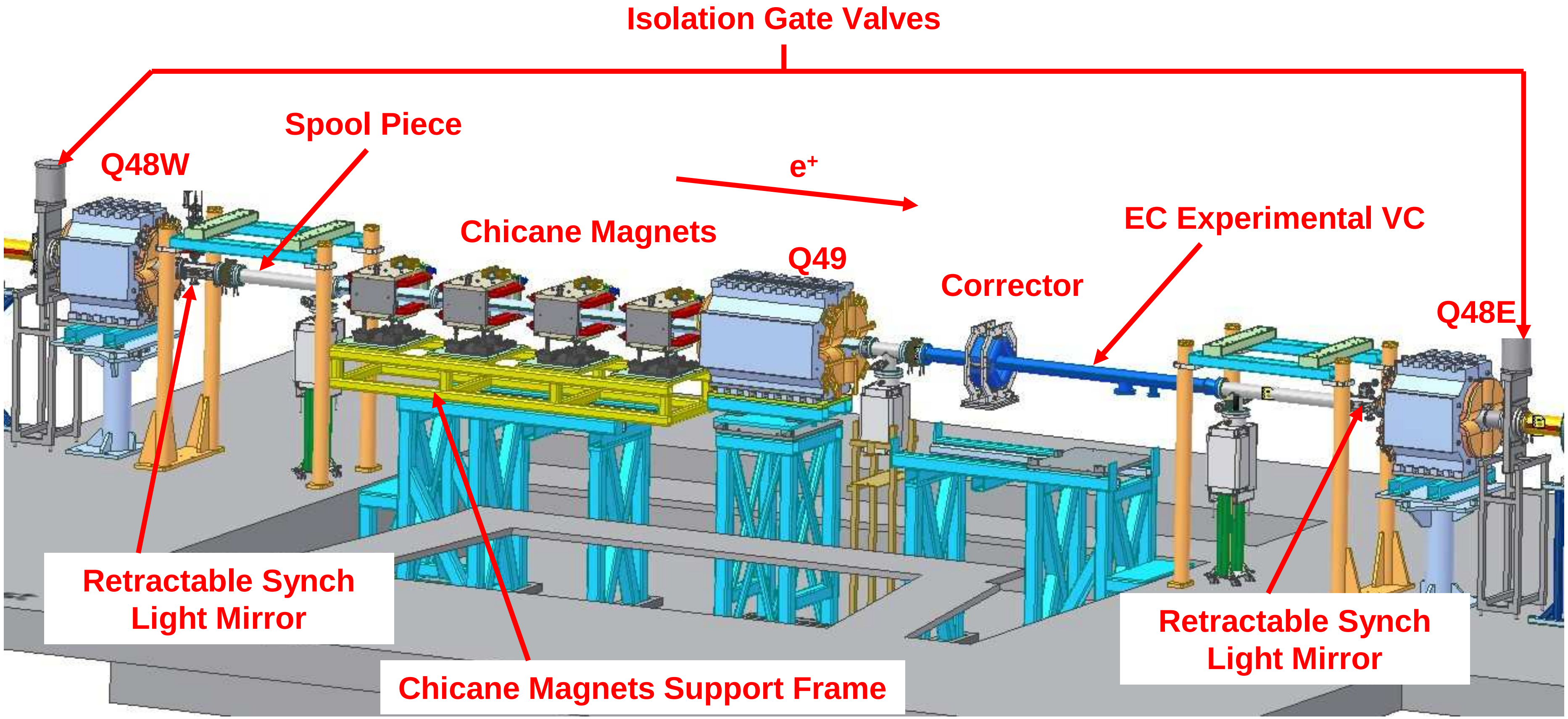


Fermionics



L3 Preparations

- In L3, removed vertical separators and installed gate valves to isolate experimental region
- PEP-II EC Hardware to arrive at Cornell by end of this week



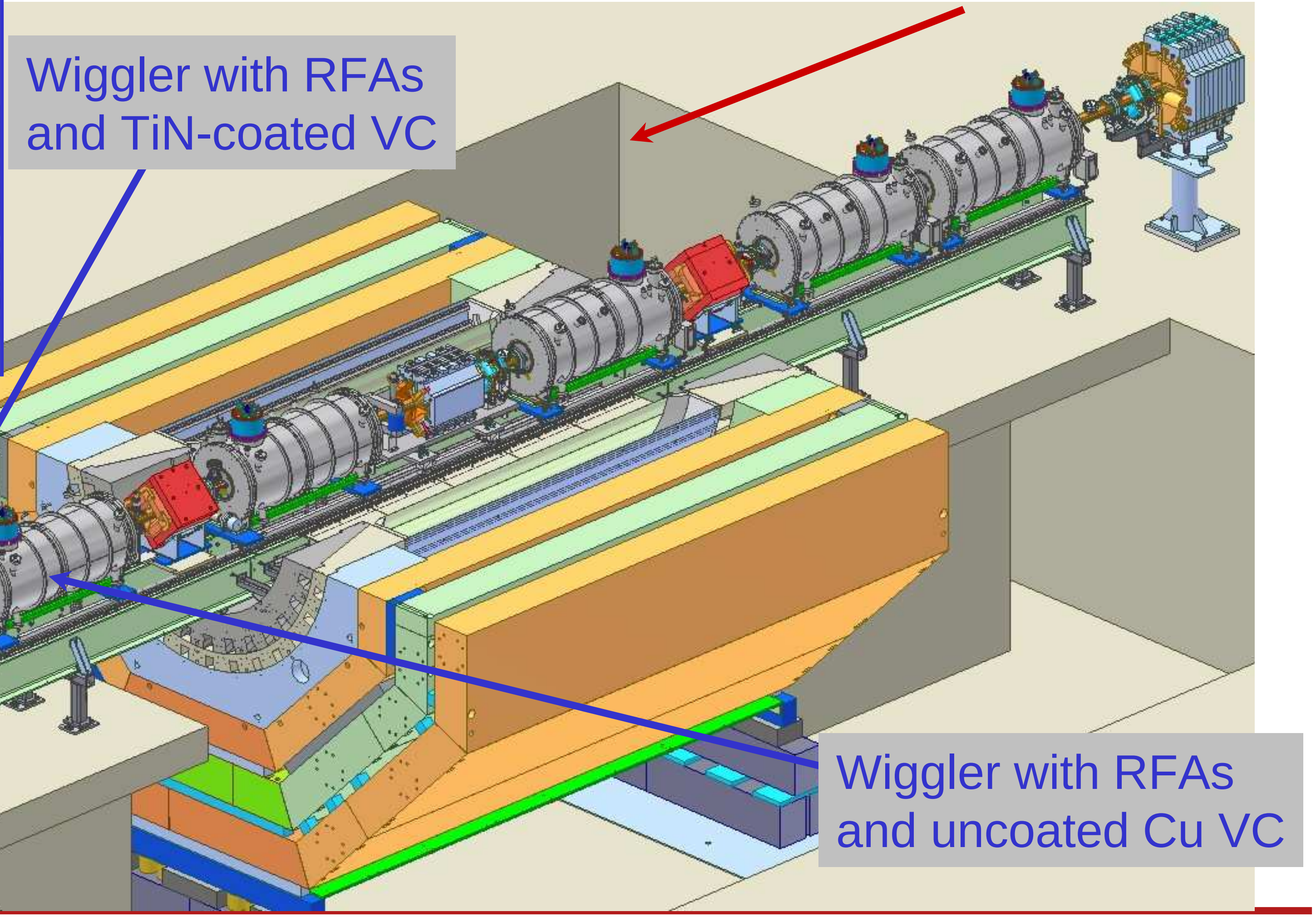
L3 Region Isometric View for February 2009

Commissioning Run

- Short 2 week commissioning/machine processing run
  - 1st week at 5.3 GeV (hardware commissioning)
  - 2nd week at 2.0 GeV (wigglers on/low emittance lattices)
- Key Goals
  - Electron Cloud Studies
    - Deploy and commission wiggler RFAs, carry out a minimal set of RFA experimental measurements
    - Study of systematic effects in multi-bunch tune measurements
    - Set up TE wave measurements in new wiggler straight
  - Optics and LET
    - Commission new ring layout and optics
    - Begin work on optics correction
  - Instrumentation and Feedback
    - X-Ray Beam Size Monitor (xBSM)
      - Commissioning of upgraded CHESS D-line, x-ray optics, and detectors
    - Beam Position Monitor System Tests
    - Feedback System (4ns)
      - Test upgraded transverse feedback system
      - Longitudinal instability threshold measurements and upgrade specifications
- All tasks time-limited
  - Initial checks only
  - Provide guidance for longer dedicated run in January 2009
- A few highlights are shown on the following pages…

Wiggler Straight

- Zero dispersion straight for low emittance
- Wiggler experimental region – local EC measurements
  - Retarding Field Analyzers
  - TE Wave Transmission Experiments

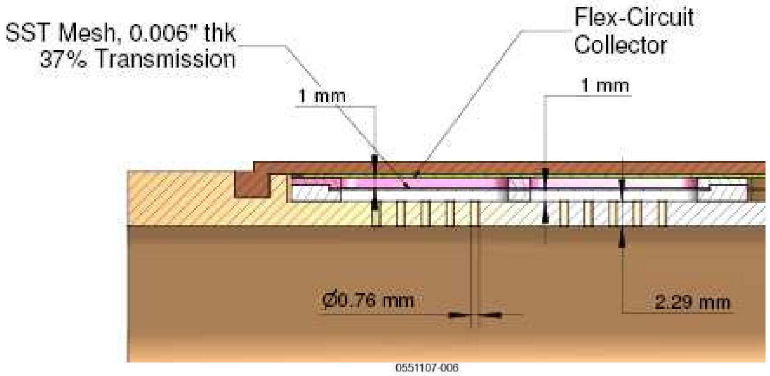


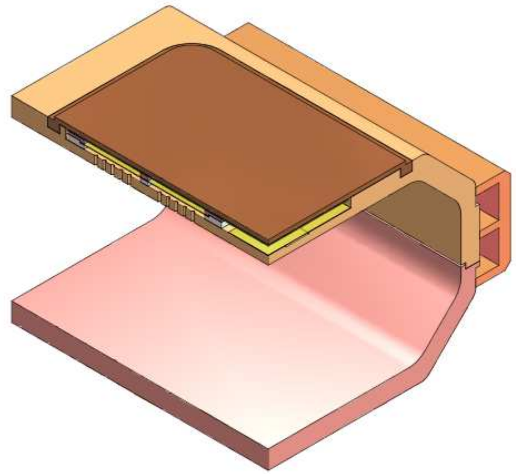
Optics

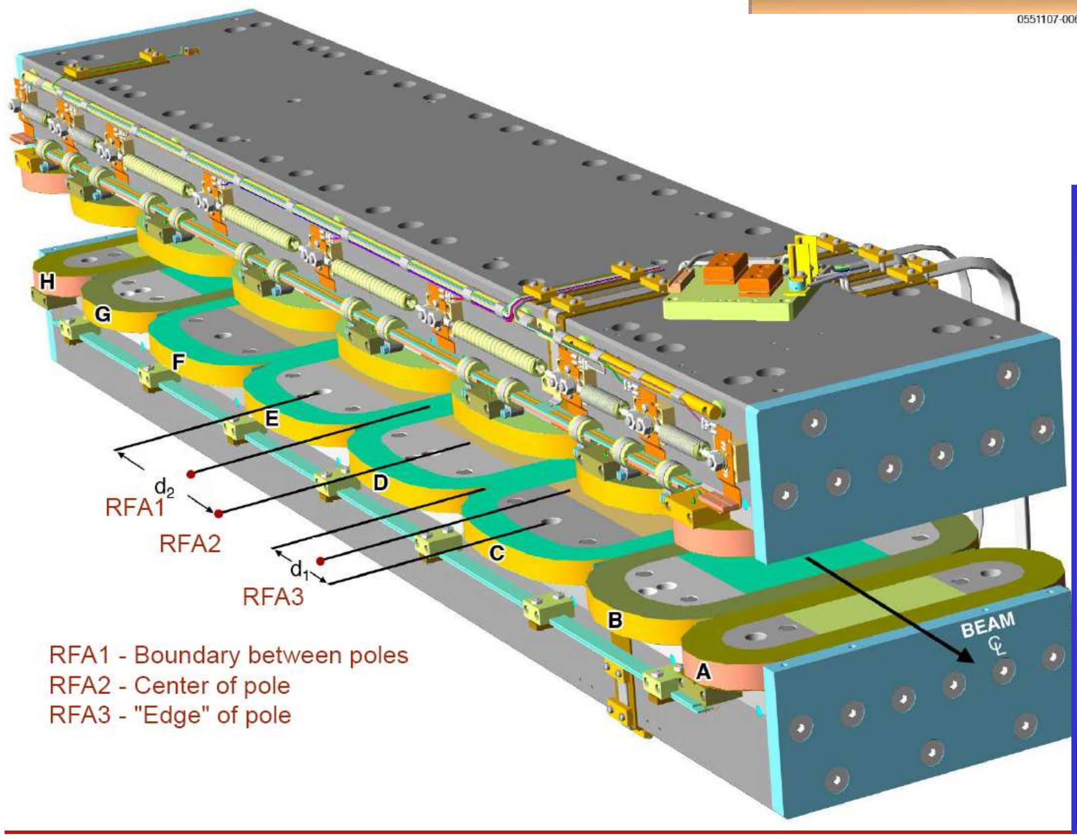
- A sequence of low energy optics was employed
  - Low energy "startup-optics"
    - Qx=10.57, 2.085GeV
    - Arc quads same as June 08 low energy operation (differences only in L0 and L3)
    - Wiggler field 1.9T
  - High tune - intermediate emittance optics
    - Qh=14.57, same L0 quads as "start-up", 2.085GeV
  - High tune - low emittance (2.6nm)
    - Tune up electron and positron injection.
    - Begin process of correcting betatron phase, coupling, dispersion
    - Create and tune orbit bumps to direct light onto xBSM
    - Good injection efficiency indicates that dynamic aperture is adequate
- Commissioning emphasis during run provided time for loading optics and establishing initial conditions but essentially no time for low emittance tune-up.

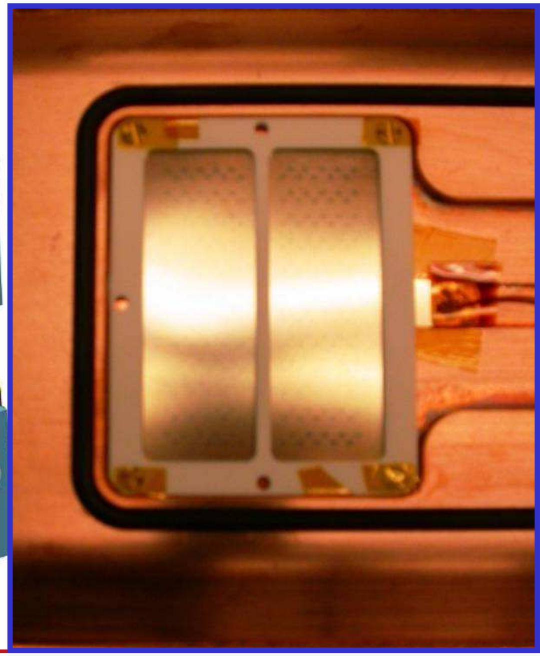
Wiggler RFAs

- RFA chamber during assembly and locations of detectors in superferric wiggler. 3 RFAs in each vacuum chamber at different field locations. (CU/KEK/LBNL/SLAC)









12 collectors across top of vacuum chamber

1 retarding grid spans the 12 collectors

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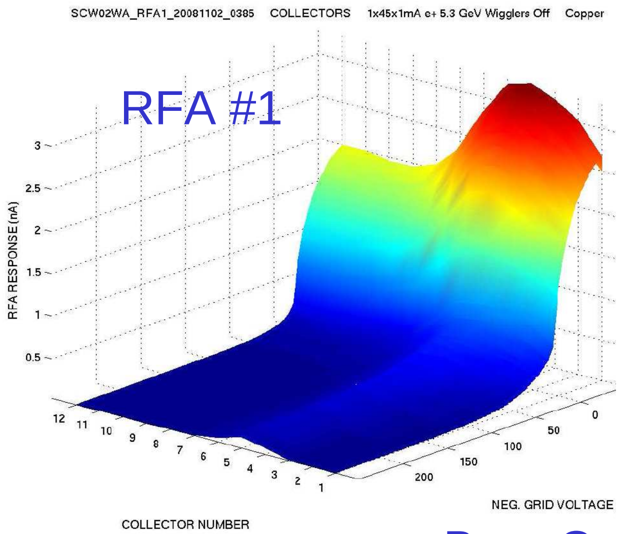
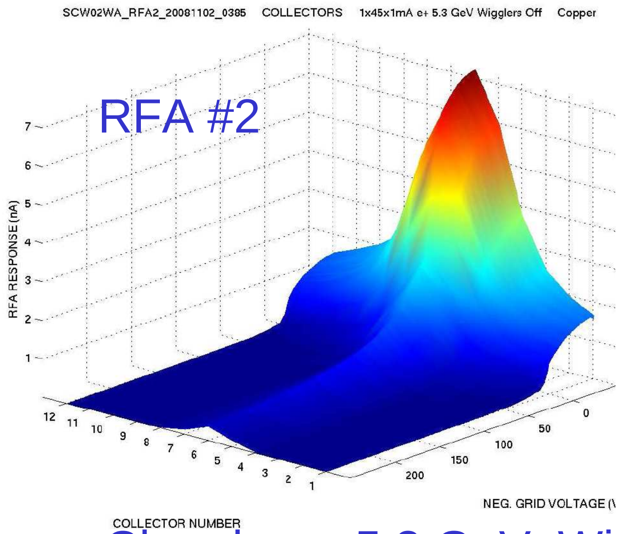
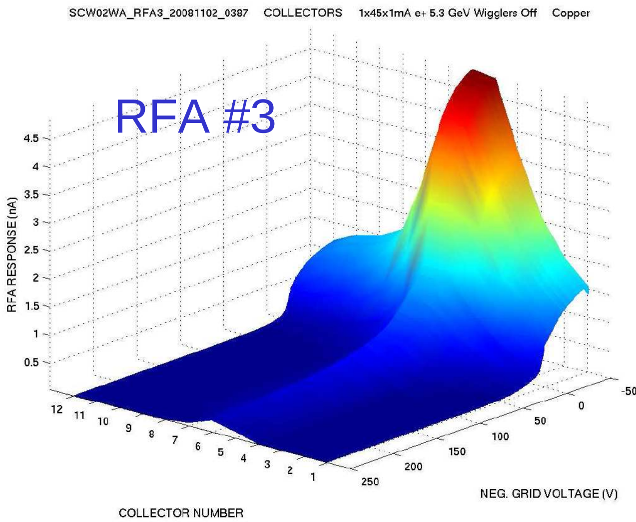
Wiggler RFA Characterization





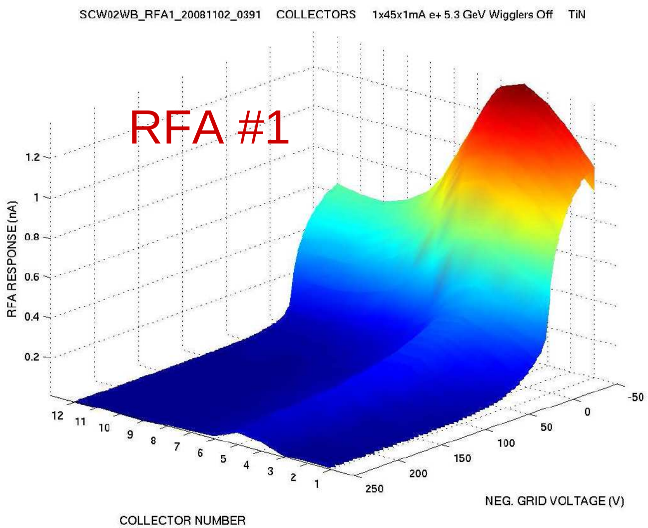


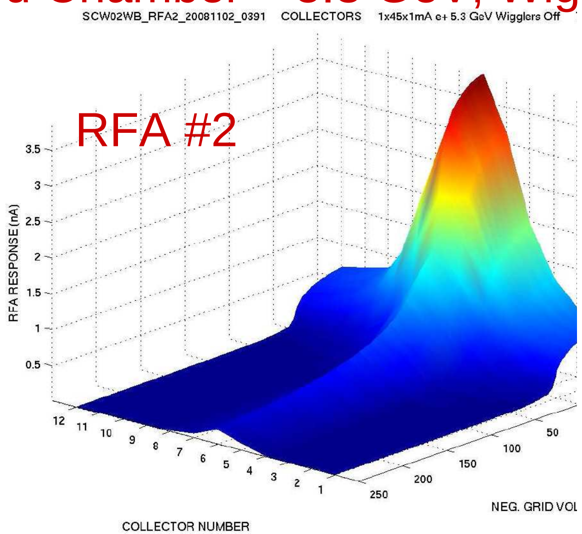
Bare Copper Chamber – 5.3 GeV, Wiggler OFF

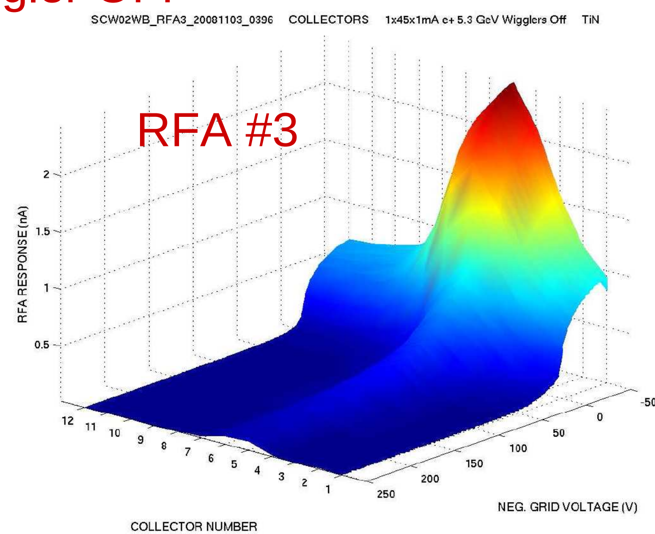
1x45x1mA positron beam, 14 ns bunch spacing

Some Residual Field Present

TiN-coated Chamber – 5.3 GeV, Wiggler OFF

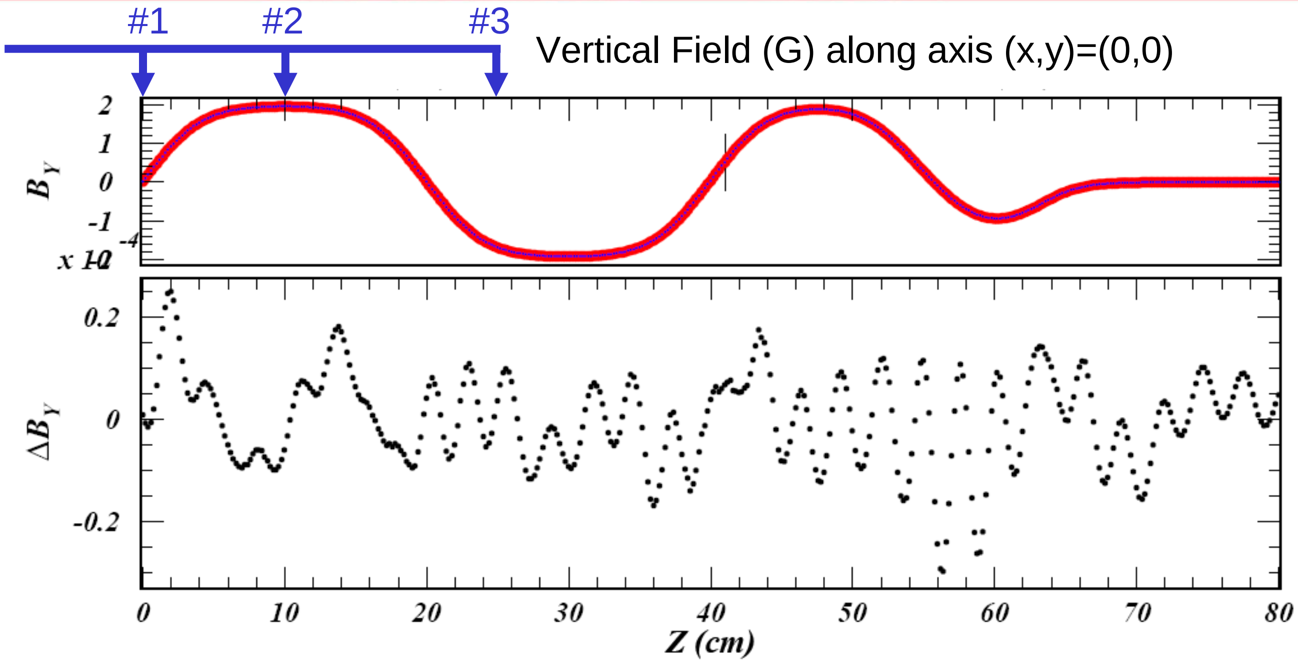






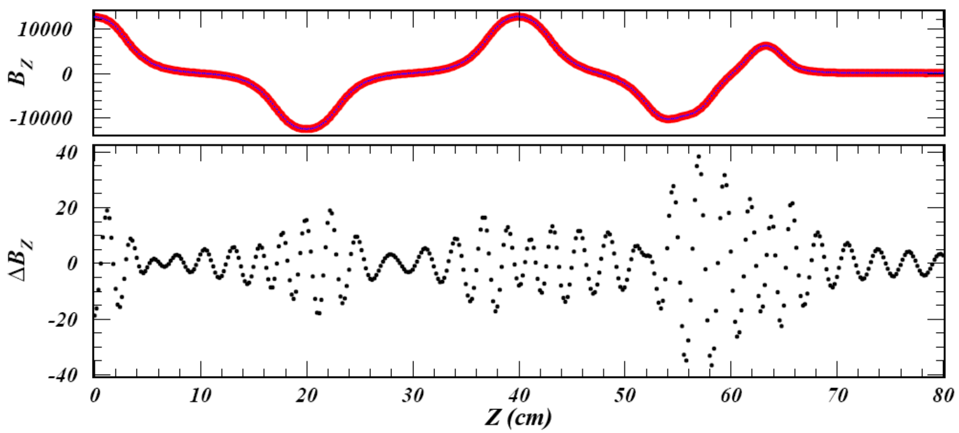
Fields in the Wiggler

Wiggler RFA Locations:



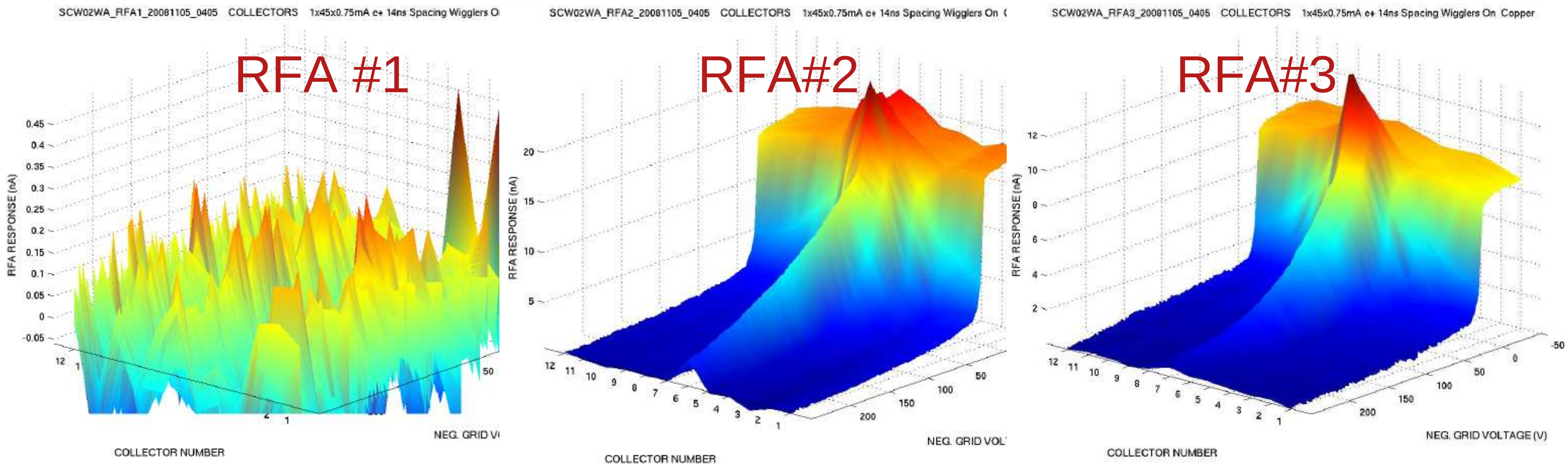
- Detectors
  - RFA #2 - choice of detector at peak field is obvious.
  - RFA #1 - should be a “canary”, ie, no EC electrons expected to penetrate longitudinal field lines with field applied.

Longitudinal Field (G) along axis (x,y)=(0,2.4) [cm]



Comparison of Wiggler RFAs

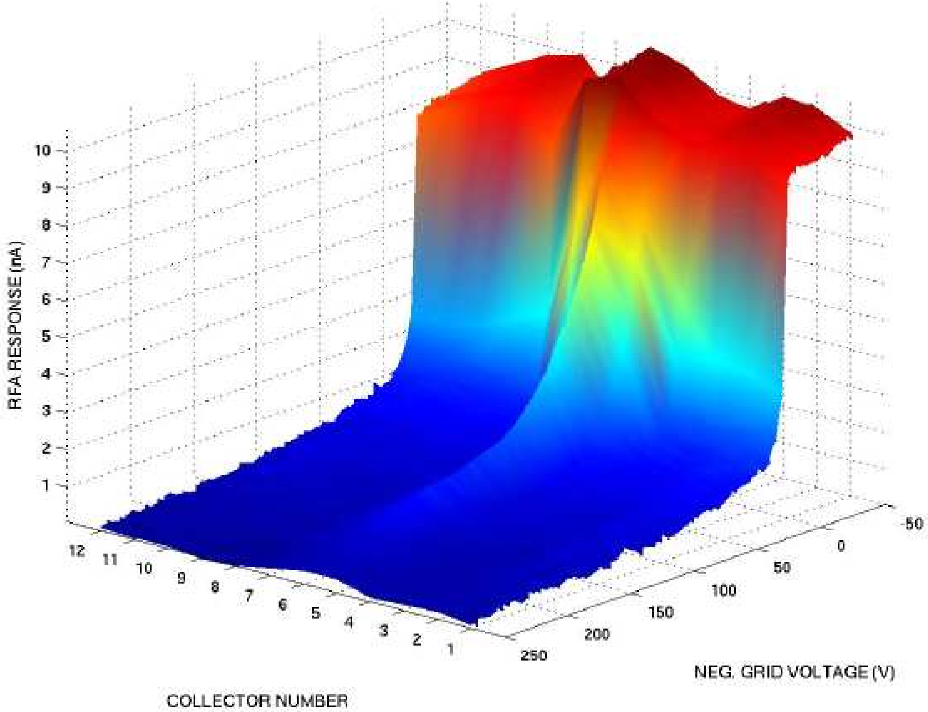
Cu Wiggler Chamber RFAs at 2 GeV:



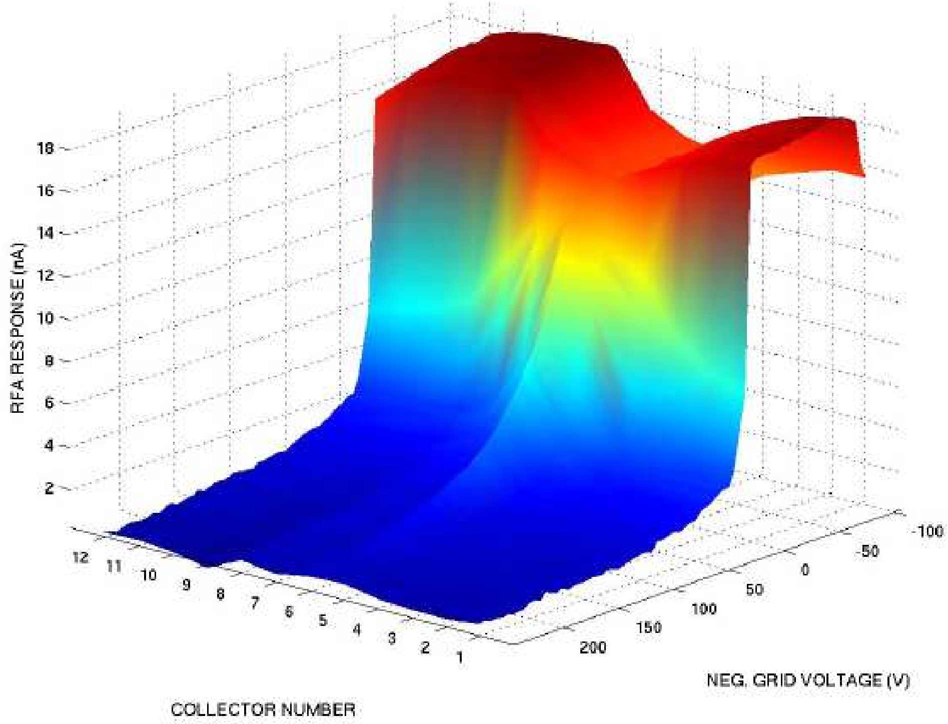
1x45x0.75mA (1.2x10^{10}/bunch)

More Cu vs TiN Comparisons

1 × 45 × 0.4 mA (0.64×10^{10}/bunch), 14ns, Cu



1 × 45 × 0.5 mA (0.8×10^{10}/bunch), 14ns, TiN

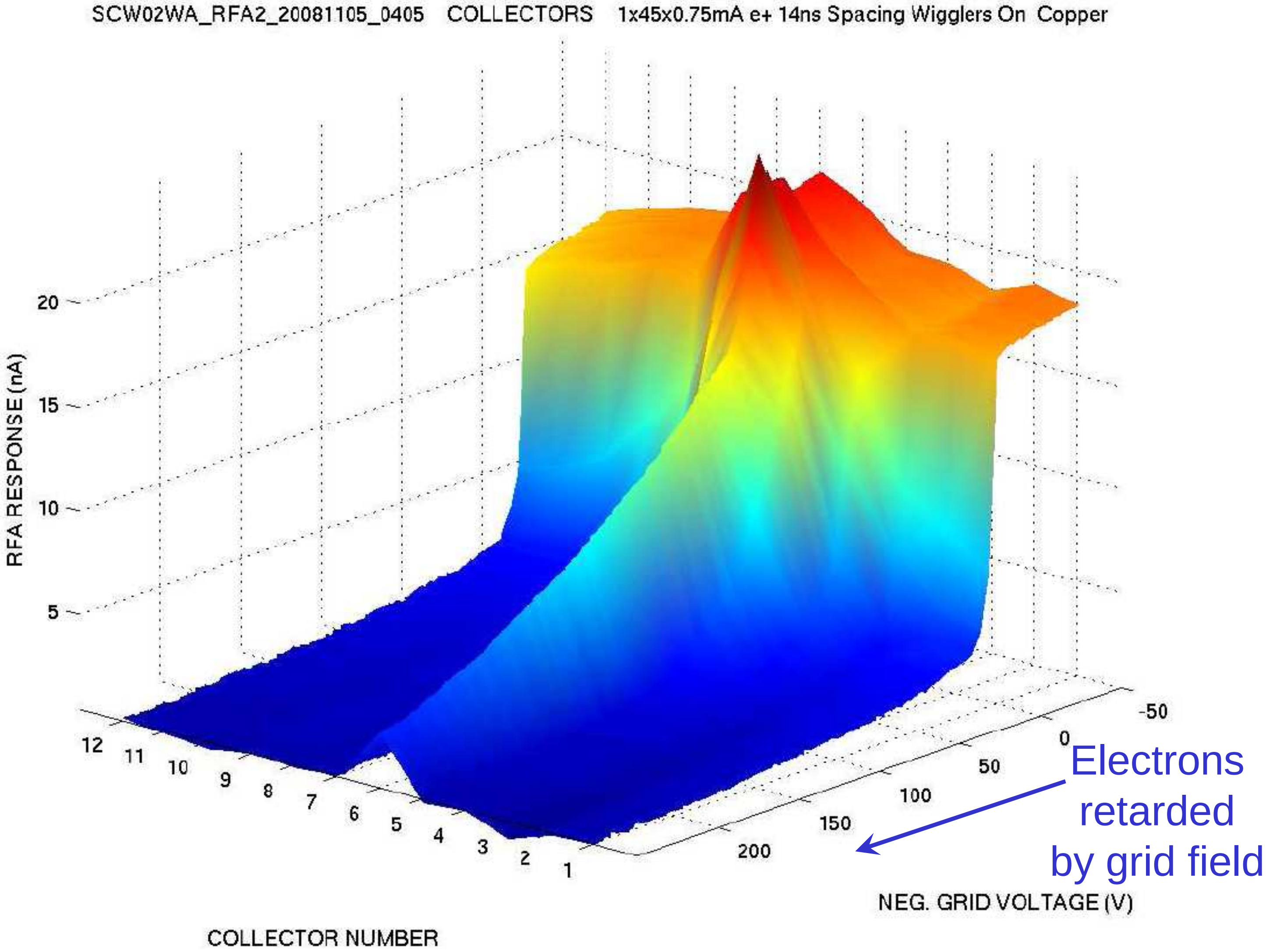


- Low bunch current checks
- RFA in center of pole for each wiggler

- Activity in central region appears suppressed

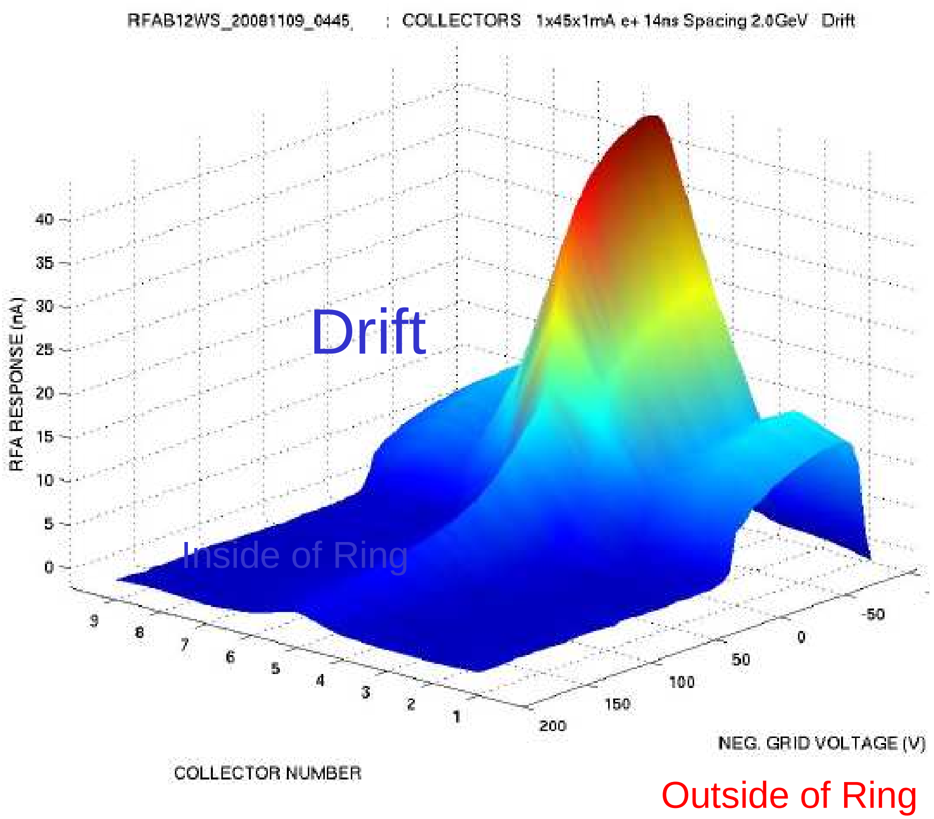
Wiggler RFA Data

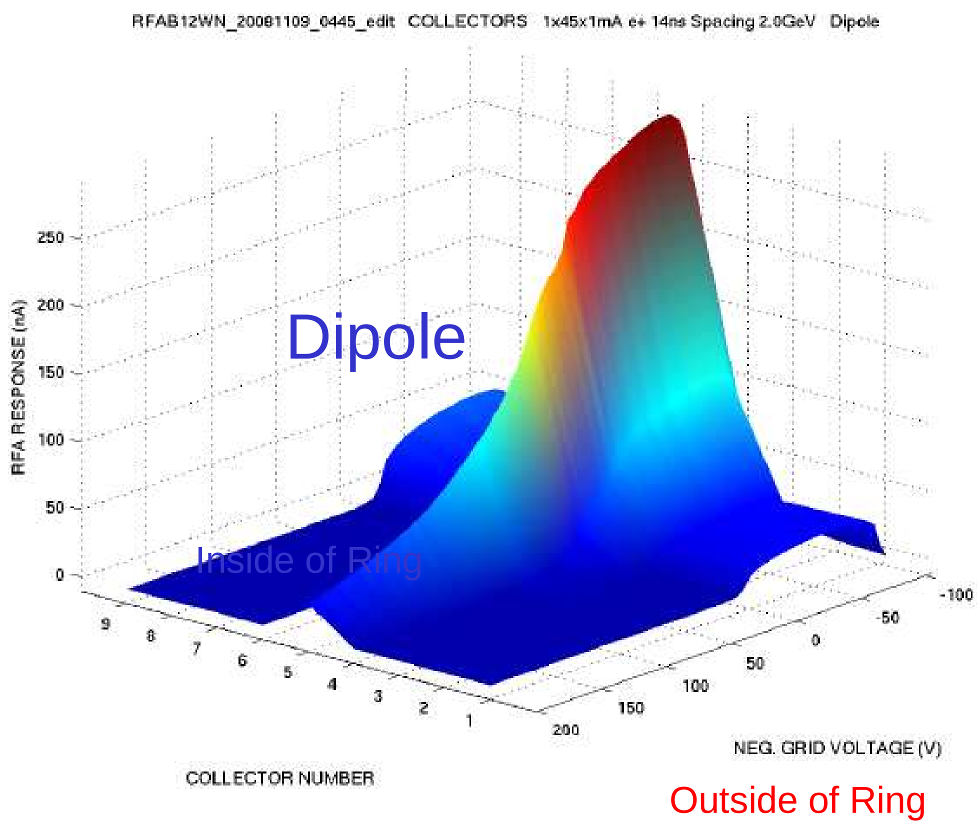
- 1 Train, 45 bunches, 1.2 × 10^{10} positrons/bunch



CESR Al Vacuum Chamber RFAs

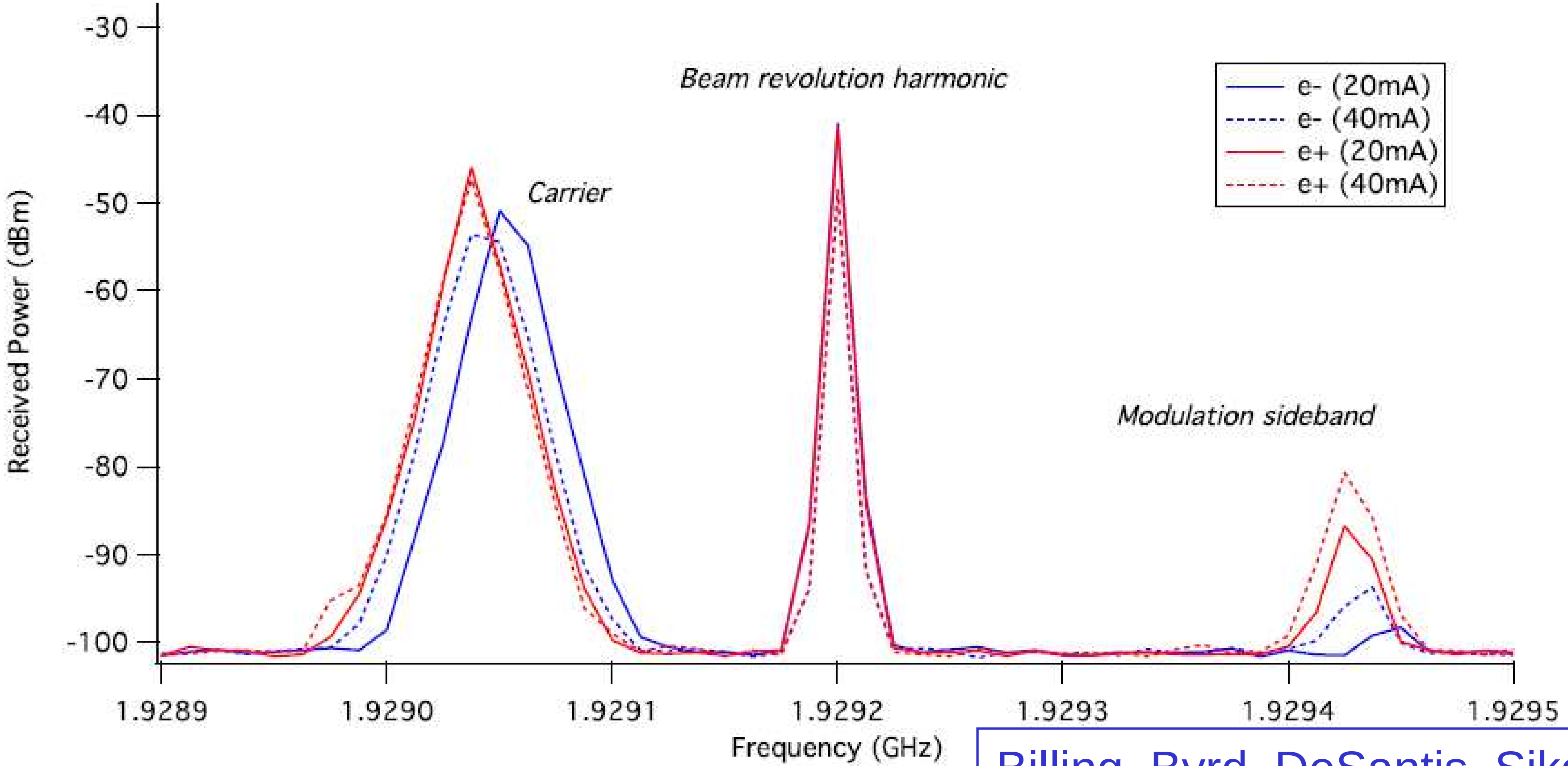
- Look at CESR vacuum chamber RFAs in drift and dipole
- 1× 45×1mA (1.6×10^{10}/bunch) at 2 GeV





TE Wave Measurements

Observed modulation signal for both electron and positron beams at 14W test location in CESR.



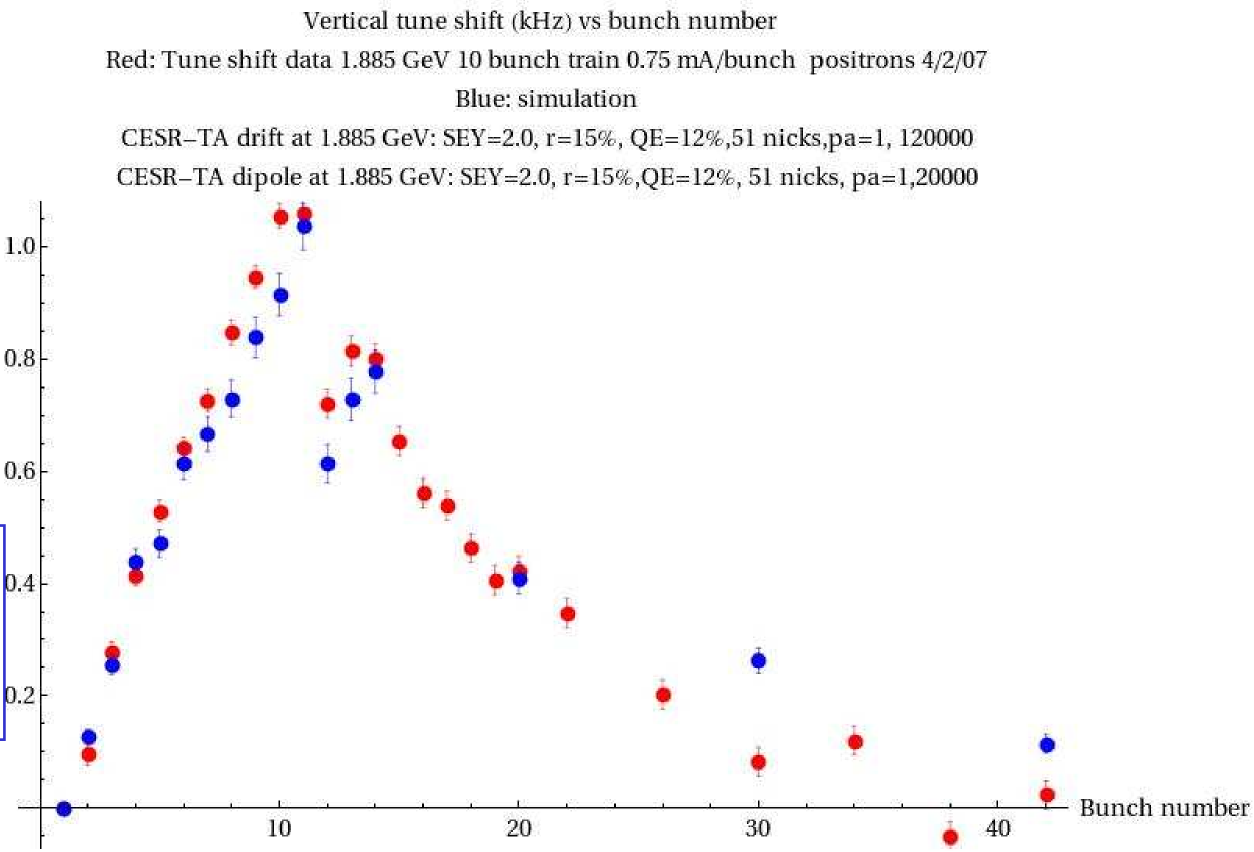
Billing, Byrd, DeSantis, Sikora

EC Simulation Effort

- Major effort underway to understand recent data as well as to benchmark codes in the CesrTA parameter regime:
  - RFA response
  - Data-simulation comparisons
  - Detailed comparisons between codes

G. Dugan, J. Calvey,
J. Crittenden, J. Livezey,
S. Greenwald, P. Jain

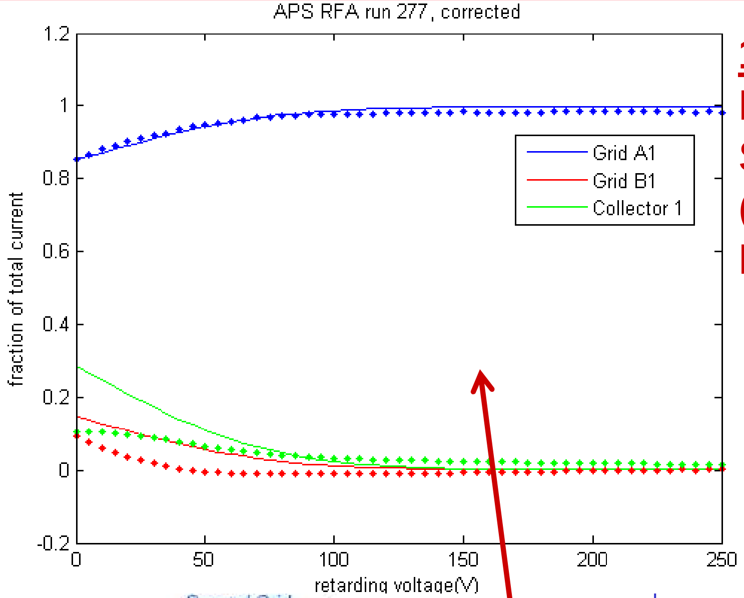
Comparison with data of 4/2/07
Coherent vertical tune shifts at 1.9 GeV



EC Simulation Goals

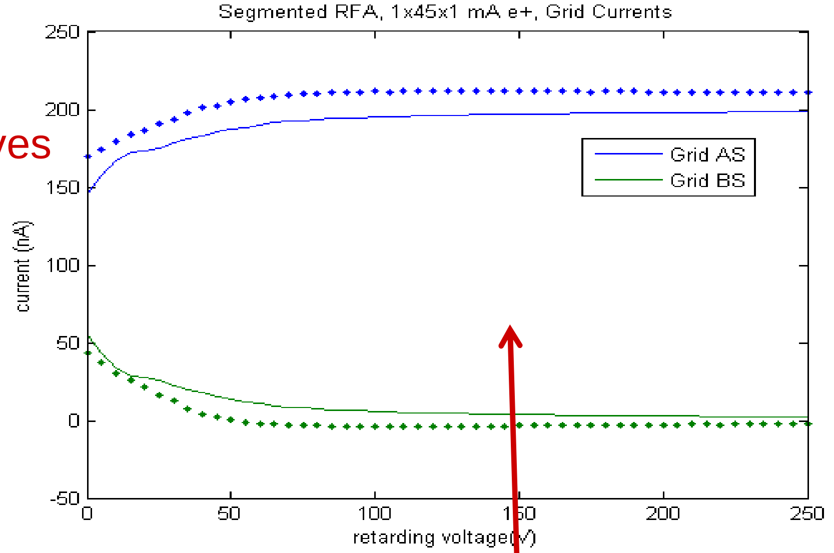
- Validate EC buildup and dynamics simulations using CesrTA data
  - Develop confidence in the application of these simulations to predict cloud behavior in the ILC damping ring
- Tools:
  - Simulation codes: POSINST, ECLOUD, CLOUDLAND
  - Analytic and numerical estimates of response of beam to cloud
  - RFA response models
- Initial steps:
  - Benchmark simulation codes using simple cases relevant to CesrTA and ILCDR conditions.
  - Simulate cloud buildup in RFA-instrumented chambers, and RFA instrumental response, to guide RFA experiments as probes of average cloud density.
  - Simulate coherent tune shifts, to guide tune shift measurements as probes of cloud density and dynamics
  - Compute EC-related parameters for all beamline elements in CesrTA
  - Simulate ring-averaged cloud buildup and compute coherent tune shifts

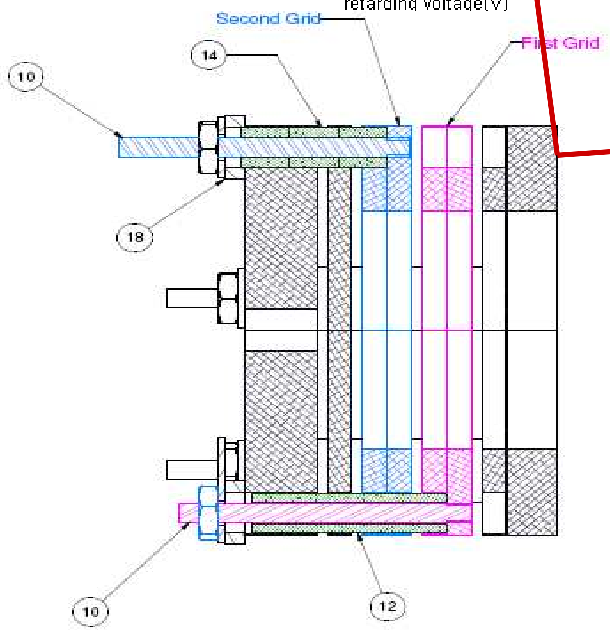
RFA Data and Simulation I

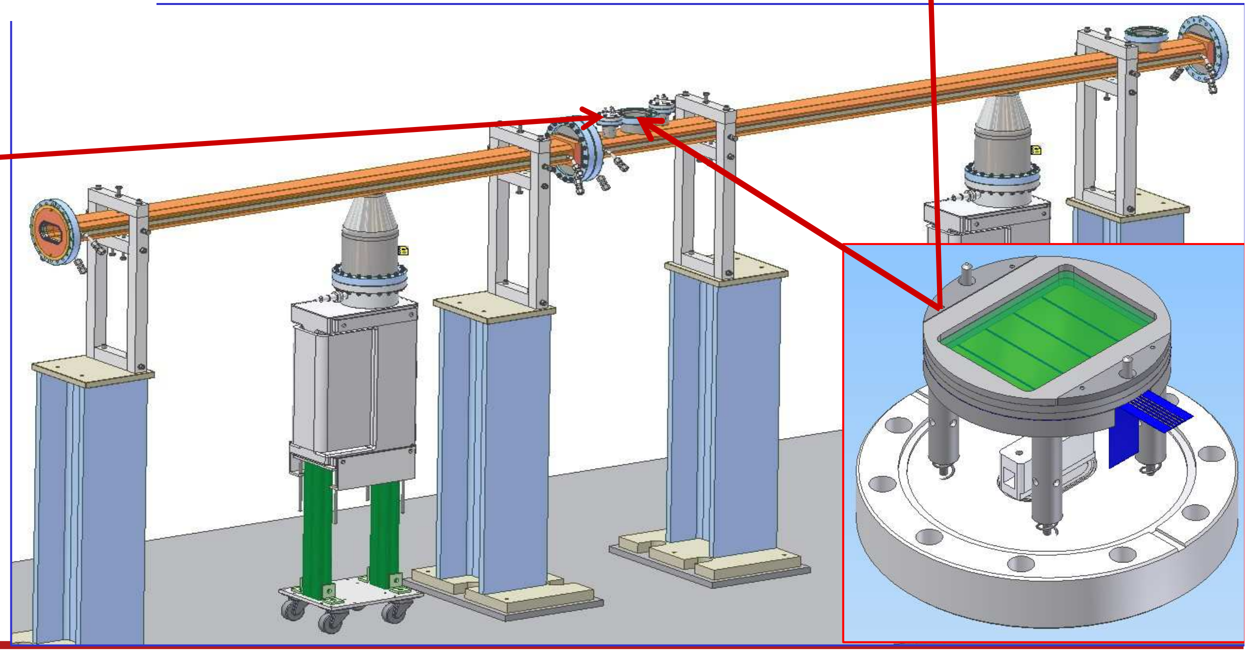


<u>1x45x1mA e$^+$</u>
Data – points
Simulation – curves
(POSINST plus
RFA model)

J. Calvey

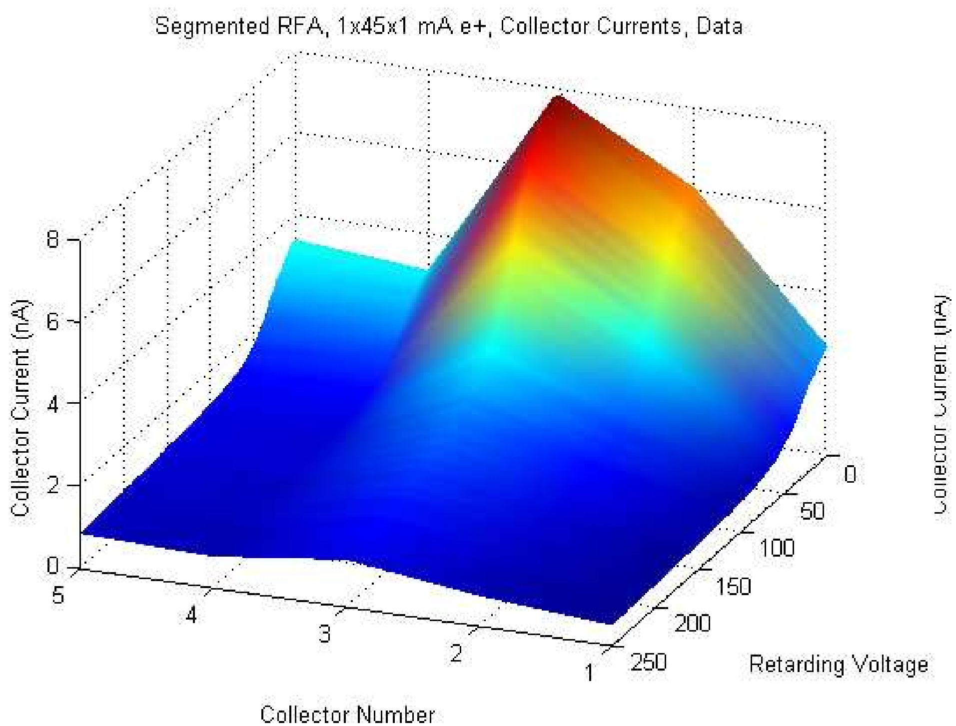


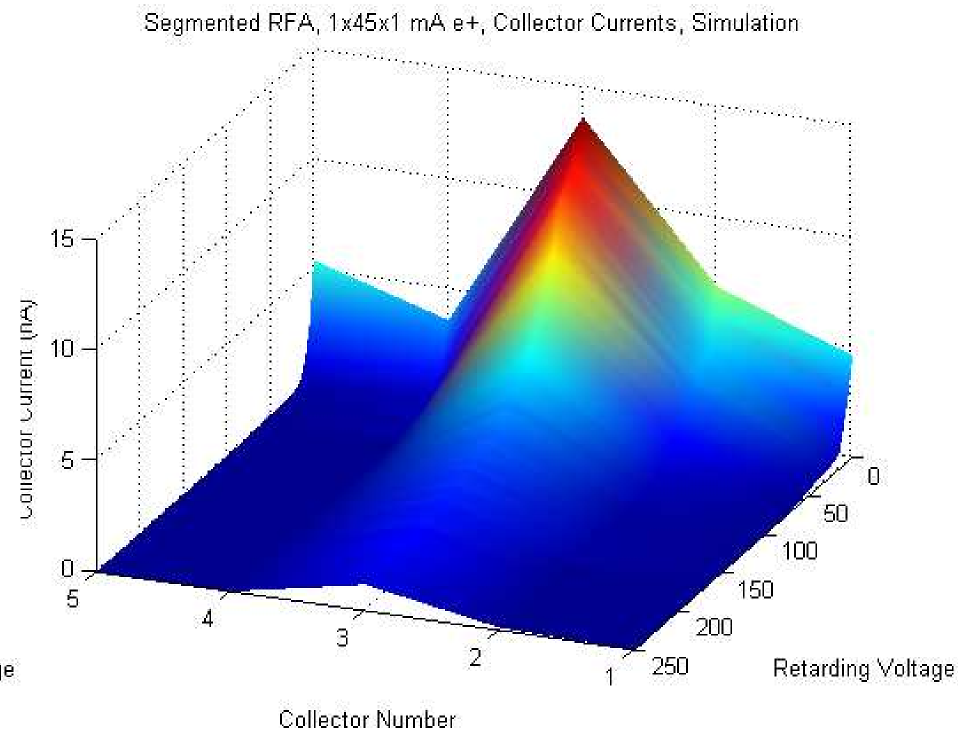




Segmented RFA

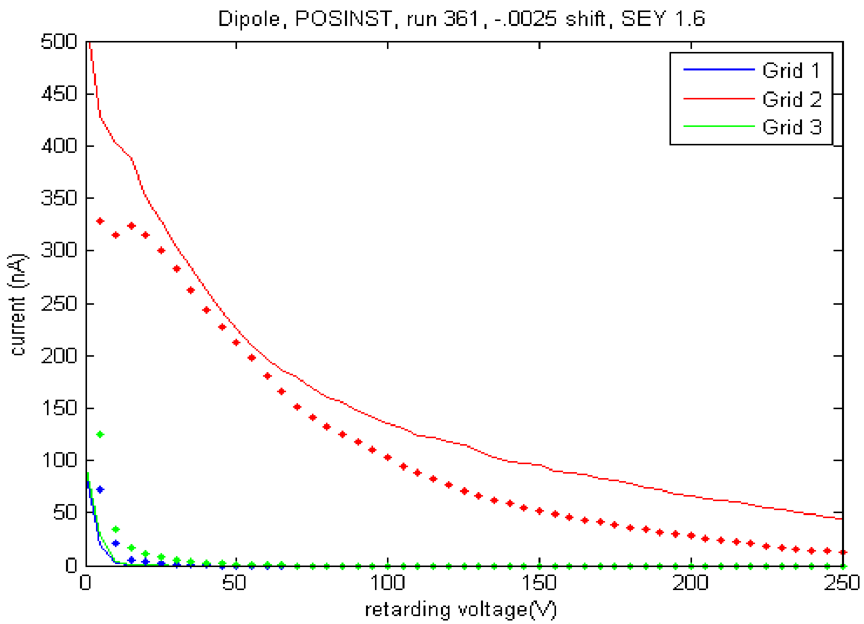
- Collector currents match qualitatively
  - Plots show collector current vs collector number (collector 1 is opposite source point) and retarding voltage
  - Data on left, simulation on right
- We will try to match the azimuthal distribution better by adjusting simulation parameters

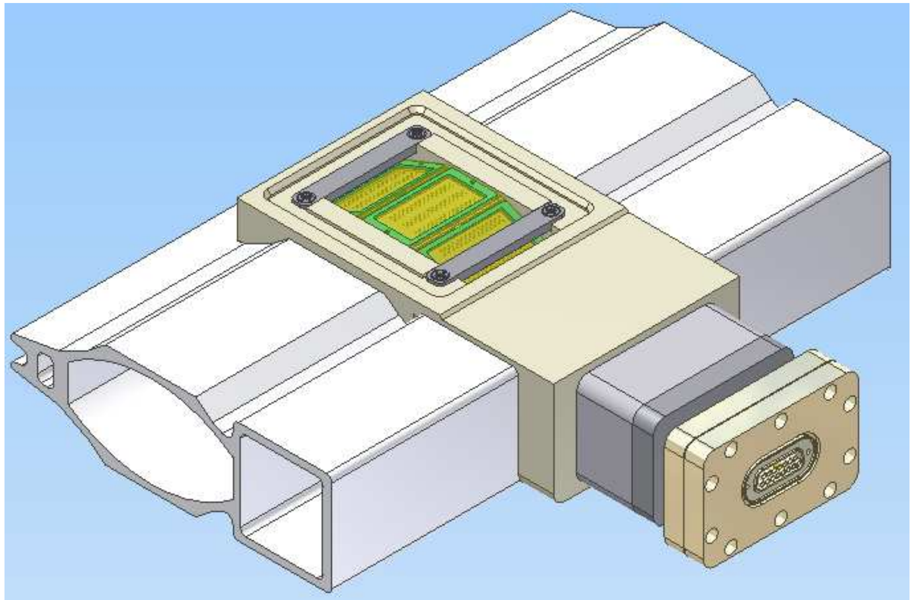




CESR VC RFA

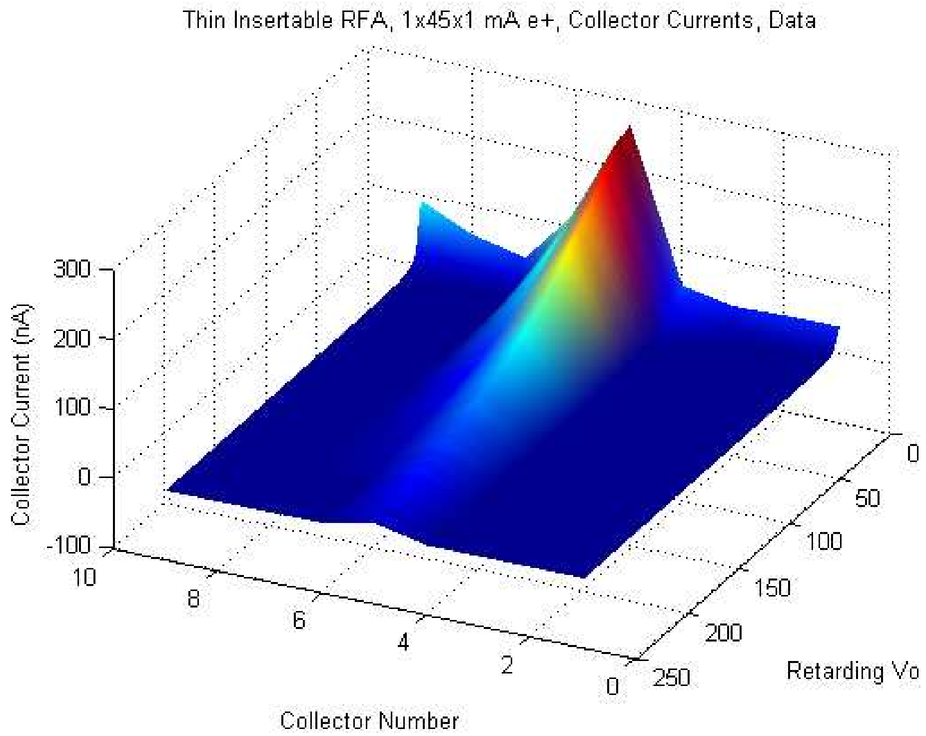
- 3 retarding grids, 9 collectors
  - One presently deployed in a dipole and one in a drift
- Attempting basic adjustments to model to obtain best data-simulation comparison
  - Adjust SEY parameters in POSINST (these plots are for an SEY peak of 1.6)
  - Shift RFA holes to represent a non-central beam

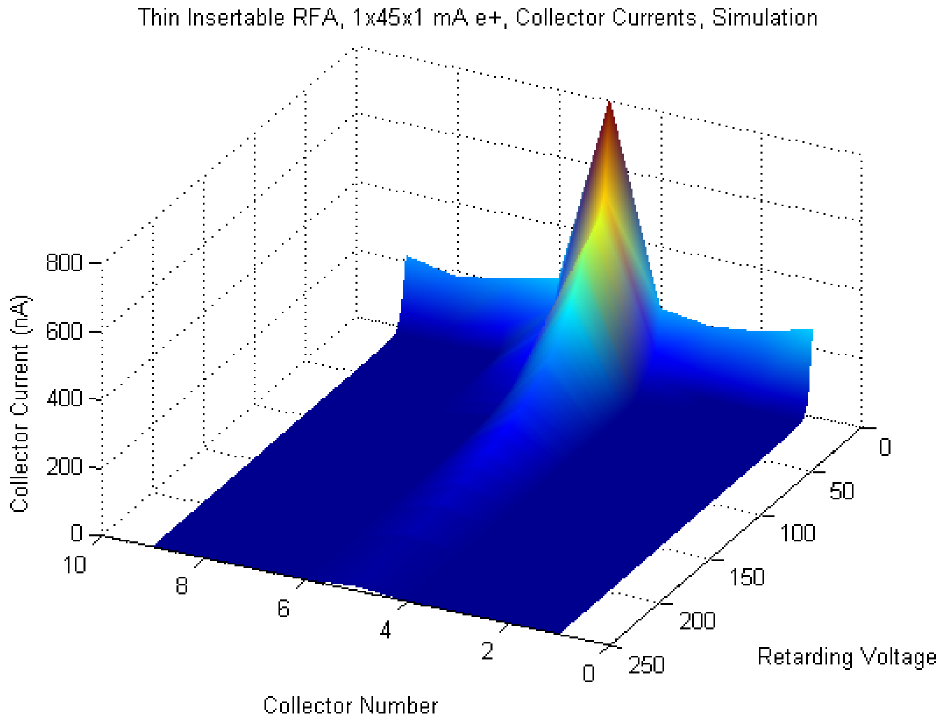




Dipole RFA

- Collector data is matches qualitatively between data and simulation
- Optimization of EC model parameters and further studies of RFA efficiencies underway to understand remaining differences between data and simulation

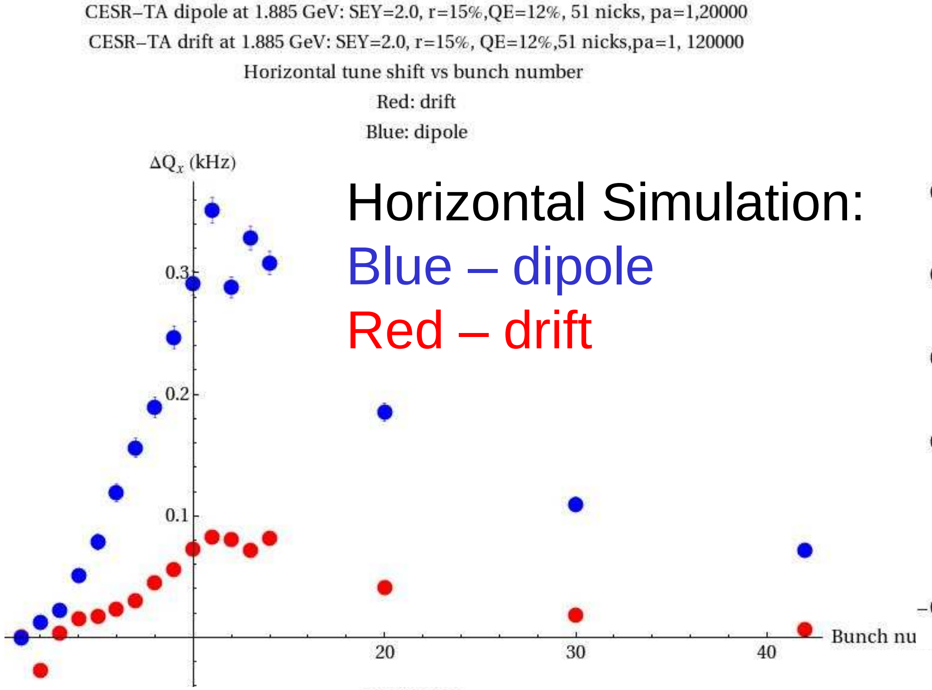




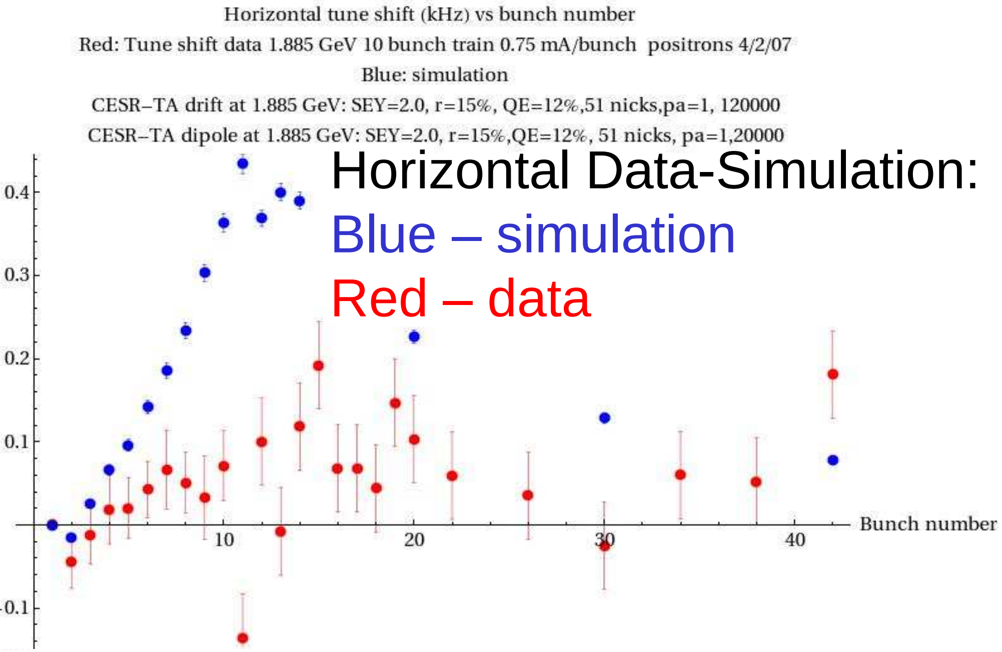
Coherent Tune Shift Studies

- "Witness bunch" technique:
  - a train of "loading bunches" generates a cloud density around the ring
  - "witness bunches" are placed at variable times after the loading train, and the coherent tune of the witness bunch is measured. The coherent tune shift is a measure of the beam-averaged field gradient due to the cloud charge density at the time of the witness bunch
- Coherent tune shift measurements (both vertical and horizontal tune) using the witness bunch technique have been done in a variety of conditions
  - Electrons and positrons
  - 1.9-2.1 GeV and 5.3 GeV
  - Various loading trains
- We have also made measurements of the systematic variation of tune shift along a train vs. bunch current
- Will show a few examples…

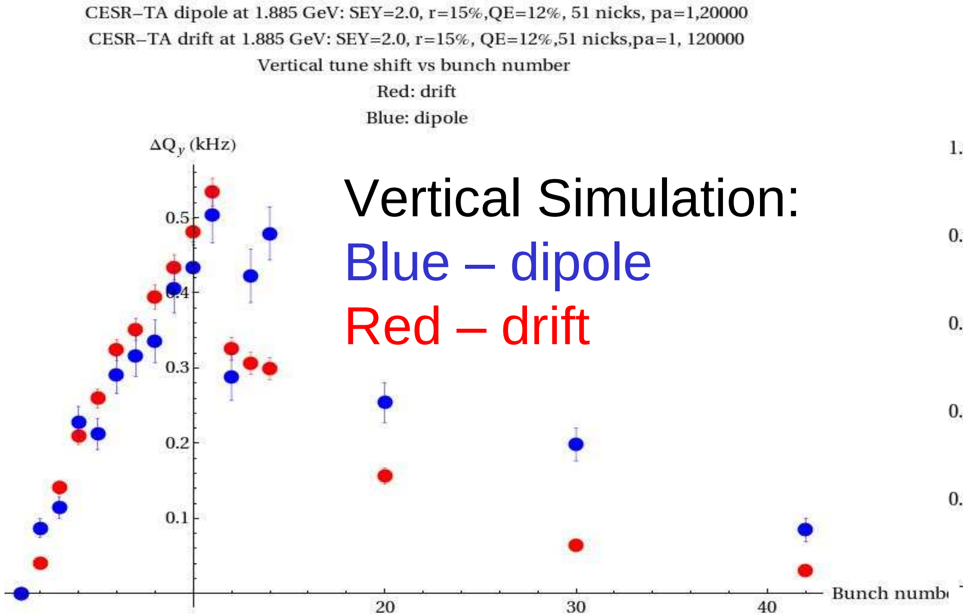
Positron Comparisons, 1.9 GeV



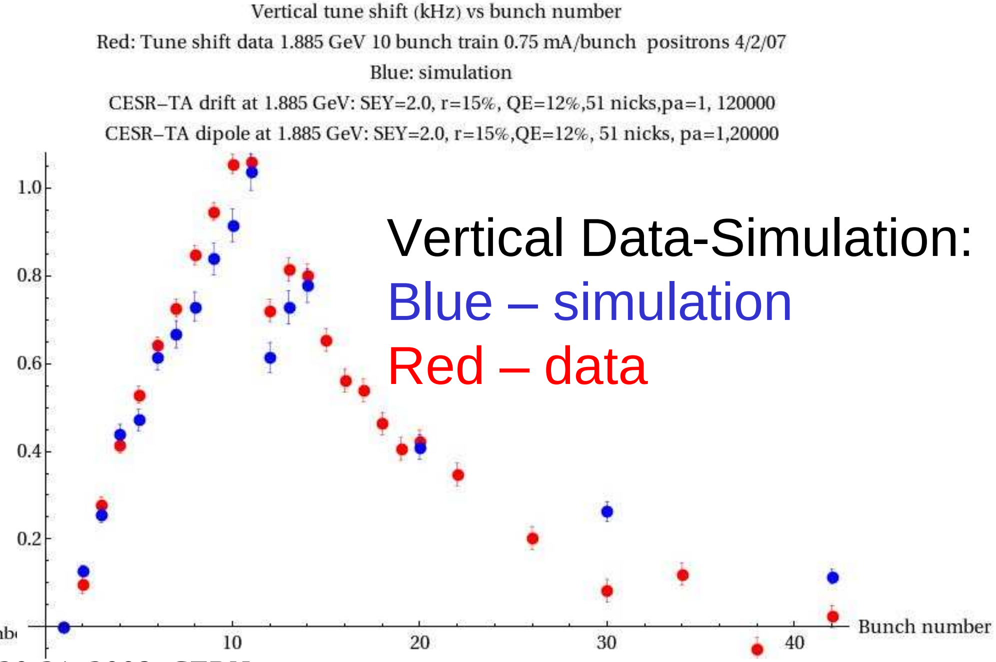
Horizontal Simulation:
Blue – dipole
Red – drift



Horizontal Data-Simulation:
Blue – simulation
Red – data



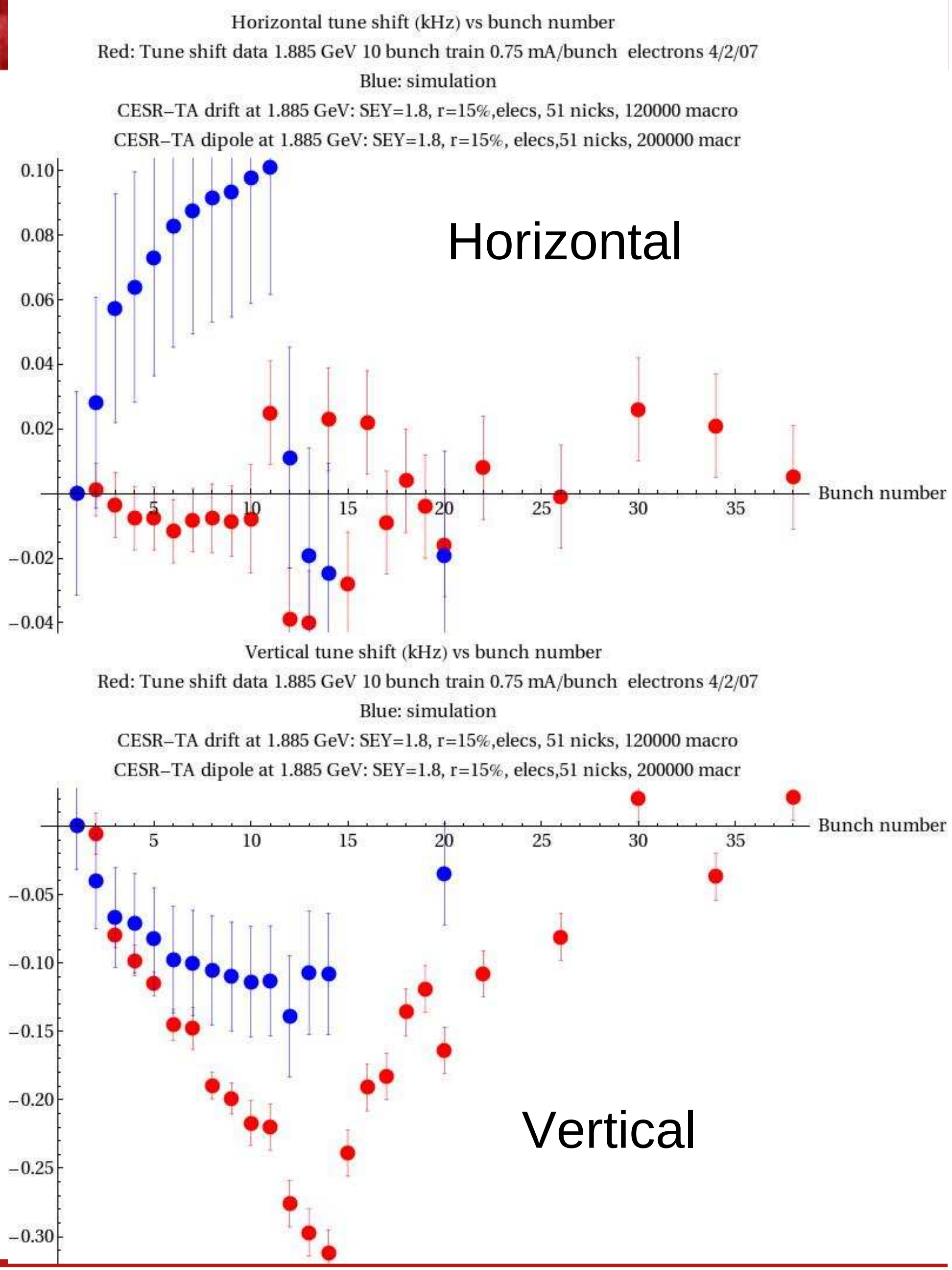
Vertical Simulation:
Blue – dipole
Red – drift



Vertical Data-Simulation:
Blue – simulation
Red – data

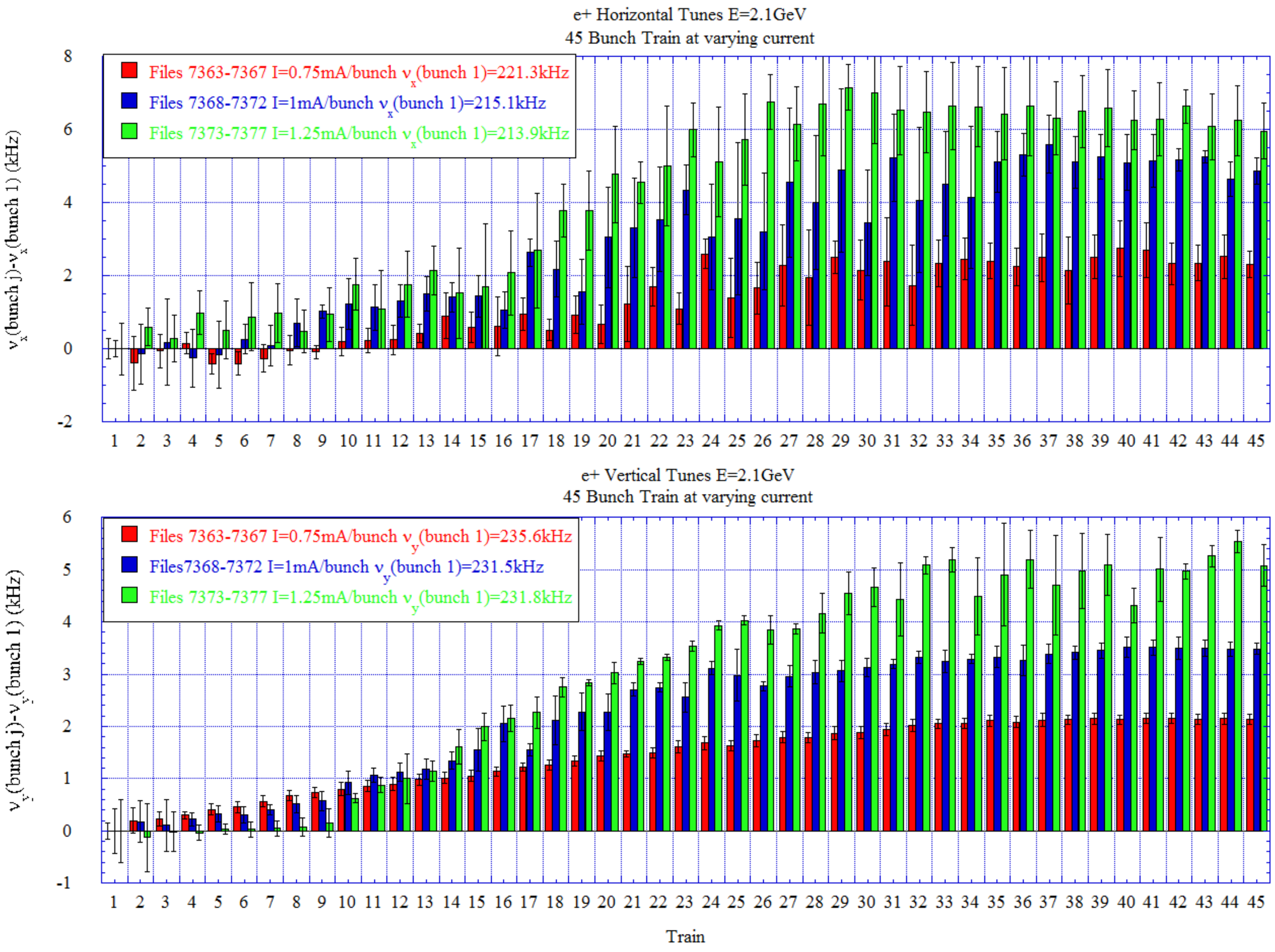
Electron Beam Tune Shifts

- 1.9 GeV Data
- To date have been unable to get good data-simulation comparisons for the electron beam
- Plots
  - – Blue Points – simulation
  - – Red Points – Data



A Surprise

- During a brief checkout at low energy, took tune data for 45 bunch trains versus bunch current:



- Observe significant horizontal tune shift for the first time!!
- What is driving the difference between data taken in the CESR-c configuration and the new CesrTA configuration???

Future Plans I

- Basic Goals for January Run:
  - Low Emittance Tuning
    - Begin detailed tuning of baseline lattice
    - Beam-based alignment
    - Integrate improved BPM system
  - Electron Cloud
    - Systematic studies of EC growth in CESR drifts, dipoles and wigglers
      - Growth versus wiggler parameters and primary photon flux (all adjustable in wiggler straight)
      - Impact of detectors on measurements
      - Growth versus bunch spacing
      - Growth versus energy
      - Detailed comparison of measurements with RFAs, measurements with TE wave transmission, and simulations
      - Electrons versus positrons
    - Continue dynamics studies
      - Explore recent observation of conditions with significant ΔQ_x
      - Explore new measurement techniques
      - Further checks of systematic effects
      - Instability measurements at lowest emittances achieved during January run
        - » Bunch-by-bunch tunes, bunch-by-bunch vertical beam size, and mode spectra for various train configurations

Future Plans II

- Simulation
  - Code Benchmarking
    - Particularly SEY models in ECLOUD, CLOUDLAND and POSINST.
  - Improved model of the RFA response is in progress.
  - Include dynamic effects in the tune shift calculations (requires integration of beam motion into the simulation codes).
  - We need a full 3D simulation of the damping wiggler . The present plan is to use WARP-POSINST, relying on our LBNL collaborators.
  - Simulation of incoherent emittance growth – to be compared with measurements using visible BSM and xBSM.
  - Simulations exploring the dependence of cloud effects on the beam as a function of energy, species, bunch population, bunch spacing, and emittance and comparison with measurement.
- February Down
  - 3 items directly associated with EC portion of program
    - Installation of PEP-II EC hardware
    - Wiggler photon stop to provide more flexible energy range for wiggler tests
    - Possible installation of collaborator test chambers
- Preparation of Test Chambers
  - Wiggler chambers with grooves and low-profile clearing electrode (CU/KEK/LBNL/SLAC)
  - Carbon coated chamber (CERN)
  - Groove chamber for chicane test (SLAC)
  - Enamel clearing electrode chamber (FNAL/Project X)
  - SEY sample chamber (SLAC/FNAL)

Cornell University
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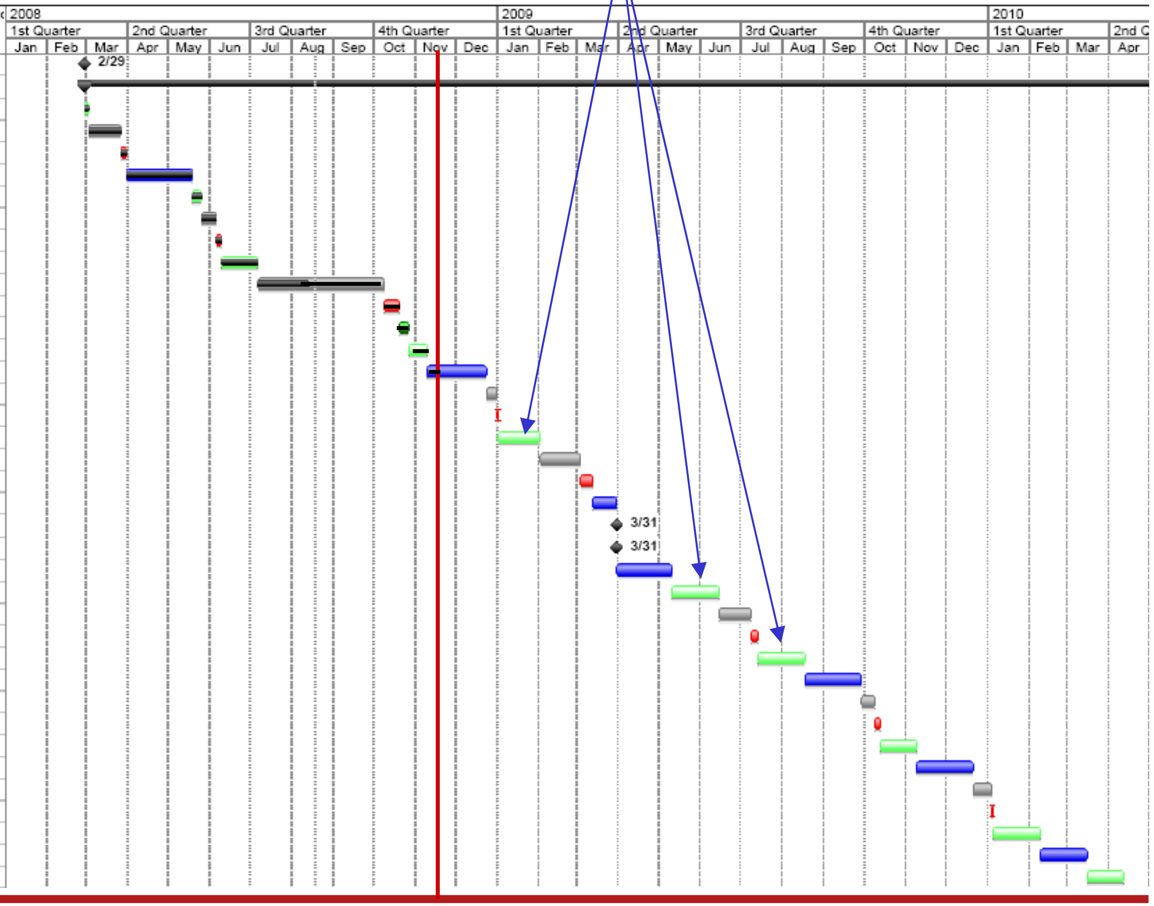
Schedule

- Upcoming runs (some fine-tuning of dates for runs 3 &4 still possible)
  - Run 2b: Jan 2 – Feb 2, 2009
  - Run 3: May 11 – Jun 15, 2009
  - Run 4: Jul 14 – Aug 18, 2009

Runs 2b, 3 & 4

ID		Task Name	Duration	UserDays	Start	Finish	Predecessors
34		CLEO Termination	0 days	0	Fri 2/29/08	Fri 2/29/08	
35		**CesrTA Modified**	**819 days**	0	**Fri 2/29/08**	**Fri 5/28/10**	
36	✓	CTA Run 0	3 days	3	Fri 2/29/08	Mon 3/3/08	34
37	✓	CESR Down 0	24 days	0	Mon 3/3/08	Thu 3/27/08	36
38	✓	Recovery 0	4 days	0	Thu 3/27/08	Mon 3/31/08	37
39	✓	CHESS Run 1	49 days	45	Mon 3/31/08	Mon 5/19/08	38
40	✓	CTA Run 1a	7 days	7	Mon 5/19/08	Mon 5/26/08	39
41	✓	CESR Down 1	11 days	0	Mon 5/26/08	Fri 6/6/08	40
42	✓	Recovery 1	4 days	0	Fri 6/6/08	Tue 6/10/08	41
43	✓	CTA Run 1b	27 days	27	Tue 6/10/08	Mon 7/7/08	42
44		CESR Down 2	94 days	0	Mon 7/7/08	Thu 10/9/08	43
45		Recovery 2	11 days	0	Thu 10/9/08	Mon 10/20/08	44
46		Cont/CTA Checkout/CHESS Setup	7 days	7	Mon 10/20/08	Mon 10/27/08	45
47		CTA Run 2a	14 days	14	Mon 10/27/08	Mon 11/10/08	46
48		CHESS Run 2	44 days	42	Mon 11/10/08	Wed 12/24/08	47
49		CESR Down 3a	8 days	0	Wed 12/24/08	Thu 1/1/09	48
50		Recovery 3a	1 day	0	Thu 1/1/09	Fri 1/2/09	49
51		CTA Run 2b	31 days	31	Fri 1/2/09	Mon 2/2/09	50
52		CESR Down 3b	30 days	0	Mon 2/2/09	Wed 3/4/09	51
53		Recovery 3b	9 days	0	Wed 3/4/09	Fri 3/13/09	52
54		CHESS Run 3a	18 days	15	Fri 3/13/09	Tue 3/31/09	53
55		CHESS Yr 1 Summary	0 days	**102**	Tue 3/31/09	Tue 3/31/09	54
56		CTA Yr 1 Summary	0 days	**82**	Tue 3/31/09	Tue 3/31/09	54
57		CHESS Run 3b	41 days	38	Tue 3/31/09	Mon 5/11/09	54
58		CTA Run 3	35 days	35	Mon 5/11/09	Mon 6/15/09	57
59		CESR Down 4	24 days	0	Mon 6/15/09	Thu 7/9/09	58
60		Recovery 4	5 days	0	Thu 7/9/09	Tue 7/14/09	59
61		CTA Run 4	35 days	35	Tue 7/14/09	Tue 8/18/09	60
62		CHESS Run 4	42 days	38	Tue 8/18/09	Tue 9/29/09	61
63		CESR Down 5	10 days	0	Tue 9/29/09	Fri 10/9/09	62
64		Recovery 5	4 days	0	Fri 10/9/09	Tue 10/13/09	63
65		CTA Run 5	27 days	27	Tue 10/13/09	Mon 11/9/09	64
66		CHESS Run 5	42 days	38	Mon 11/9/09	Mon 12/21/09	65
67		CESR Down 6	14 days	0	Mon 12/21/09	Mon 1/4/10	66
68		Recovery 6	1 day	0	Mon 1/4/10	Tue 1/5/10	67
69		CTA Run 6	35 days	35	Tue 1/5/10	Tue 2/9/10	68
70		CHESS Run 6	35 days	32	Tue 2/9/10	Tue 3/16/10	69
71		CTA Run 7	27 days	27	Tue 3/16/10	Mon 4/12/10	70



Collaborator Information

- Visiting Collaborators
  - Who to contact:
    - Mark Palmer for EC studies (map36@cornell.edu)
    - Dave Rubin for LET work (dlr10@cornell.edu)
  - Forms and computer registration:
  https://wiki.lepp.cornell.edu/ilc/bin/view/Public/CesrTA/VisitorsPage
  - Schedule Information:
  https://wiki.lepp.cornell.edu/ilc/bin/view/Public/CesrTA/CesrTASchedule
- Where to look:
  - 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
- Many areas restricted to the "CesrTA Collaboration"
  - Need to register for ILC Wiki
- Mailing List
  - CesrTA Collaboration Mailings via the new mailing list
  - Can subscribe from the main CesrTA Wiki page

Summary

- CesrTA is an ILC-driven R&D Program
  - Recent news:
    - Formal collaboration between CLIC-ILC DR efforts now in place (co-conveners of group: Yannis Papaphilippou and myself)
    - Major short term emphasis on exploiting EC experimental program
    - Integrated set of monthly WebEx meetings: ILC DR, CLIC DR, CesrTA
- CesrTA commissioning run is now complete
  - CESR is now operational in a damping ring configuration
- Critical data collected during a short 2-week run
  - New systems are successfully coming on line
  - Initial data will provide guidance for January experimental run as well as ongoing upgrade work
  - The initial commissioning work has yielded both expected results as well as some surprises
  - Ongoing collaborative effort critical to achieving full understanding and a productive project!