Damping Rings
Working Group 4 Summary

Mark Palmer
ILC Damping Rings Group

WG4 Session Outline

- Baseline Lattice Evaluation – Tuesday Morning
  - **OCS8**
  - **FODO4 ⇨ FODO5**
  - **DCO**
- ATF Status and Plans – Tuesday Afternoon
- CesrTA Discussion – Wednesday Morning
- Electron Cloud Status Reports – Wednesday Afternoon
- Closeout

Baseline Lattice Evaluation

- The Damping Rings Group stated goal was to settle on a baseline lattice prior to this meeting
- Recent events have conspired to make this a difficult task
  - **Loss of key design support for remainder of FY08**
  - **Incorporating slightly modified requirements**
- Discussions at the Damping Rings Workshop held at KEK in December resulted in:
  - **A relaxed momentum compaction requirement**
  - **The possibility of returning to a 6mm bunch length design without excessive RF requirements**

Updated Baseline Lattice Parameters

Main Parameters

Table 1: Main parameters of the baseline lattice for the RDR and proposed for the EDR.

	RDR [1]	Proposed for EDR		
		low rf	nominal	high threshold
Beam energy	5 GeV	5 GeV		
Harmonic number	14516	14042		
RF frequency	650 MHz	650 MHz		
RF voltage[1]	22.1 MV	13.2 MV	21.6 MV	25.8 MV
Number of rf cavities	18	8	16	16
Momentum compaction factor[1]	4×10^{-4}	1.1×10^{-4}	1.8×10^{-4}	2.7×10^{-4}
Natural rms bunch length[1]	9 mm	6.6 mm	6 mm	6.6 mm[(2)]
Natural energy spread	0.13%	< 0.13%		
Natural emittance	5 μm	< 8 μm		
Transverse damping times	25 ms	< 25 ms		
Betatron acceptance $(A_x + A_y)$	> 0.01 m	> 0.01 m		
Energy acceptance	± 0.5%	± 0.5%		

[1] These parameters should be variable over some range; see Table 2.

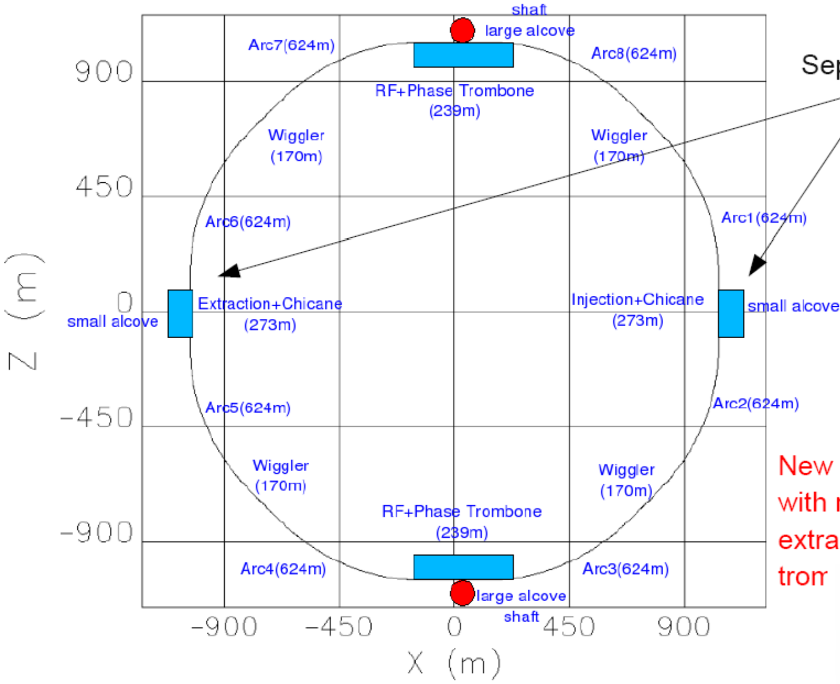
[2] Can be reduced to 6 mm with 30.8 MV total rf voltage (18 cavities): see Table 2.

Updated target (previously 4×10^{-4})

Max. value for bunch compressors

Lattice Options

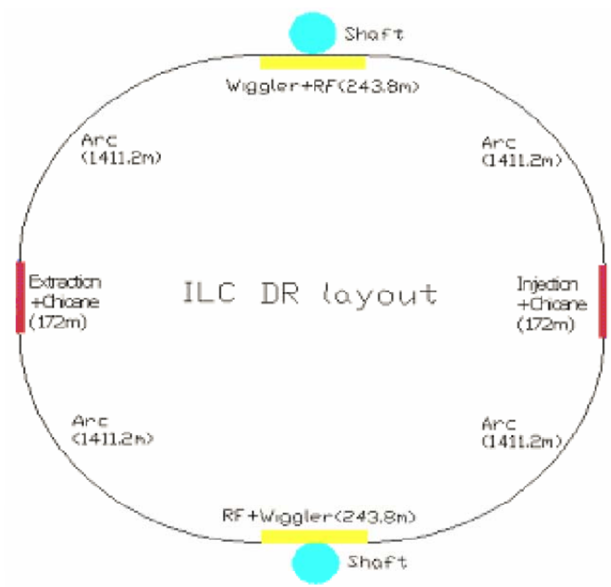
From the Damping Rings R&D Workshop at KEK, A. Wolski, December 2007



Separated Injection/Extraction

OCS8 (TME)

New lattice has 8 symmetries, with new rf; chicane; injection; extraction; and phase adjustment trom



4 arc sections.

4 straight sections, one for injection, one for extraction, and the other two for RF/wiggler.

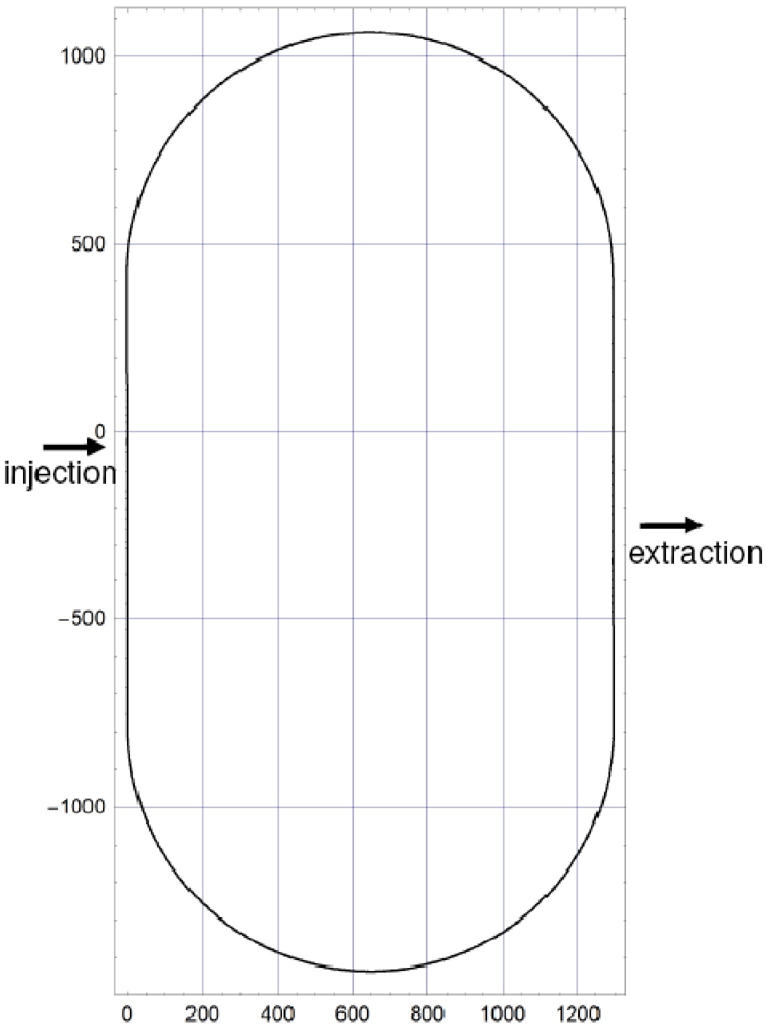
Two shafts in all and no TL.

Beam is counter-rotating.

FODO

Refined Version 4
⇨ Version 5

DCO at a glance



- Arcs consist of a total of 192 FODO cells
- Flexibility in tuning momentum compaction factor, given by phase advance per arc cell:
  - **72° phase advance: α_p=2.8×10^{-4}**
  - **90° phase advance: α_p=1.7×10^{-4}**
  - **100° phase advance: α_p=1.3×10^{-4}**
- No changes in dipole strengths needed for different working points.
- Racetrack structure has two similar straights containing:
  - **injection and extraction in opposite straights**
  - **phase trombones**
  - **circumference chicanes**
  - **rf cavities**
  - **"doglegs" to separate wiggler from rf and other systems**
  - **wiggler**

Parameter Comparisons

	OCS8	FODO4			FODO5			DCO		
Beam energy (GeV)	5.00									
Circumference (m)	6476.440									
RF frequency (MHz)	650									
Harmonic number	14042									
Number of straight sections	8	4			8			2		
Arc cell type	TME	FODO			FODO			FODO		
Arc cell length (m)	38.9	29.4			28.4			21.0		
Number of arc cells	128	184			188			192		
Number of dipoles per arc cell	1	2			2			1		
Arc dipole length (m)	6	2			2			2		
Arc dipole field (T)	0.146	0.142			0.139			0.273		
Number of quadrupoles per arc cell	4	2			2			2		
Number of sextupoles per arc cell	4	2			2			2		
Natural rms bunch length (mm)	9.00	9.00			6.00			6.00		
Natural energy spread (10^{-3})	1.28	1.28			1.28			1.27		
Transverse damping time (ms)	25	25			25			21		
Approximate phase advance per cell	90	60	72	90	72	90	108	72	90	100
Momentum compaction factor (10^{-4})	4.0	6.0	4.0	2.0	4.00	2.5	1.7	2.8	1.7	1.3
Normalised natural emittance (m)	5.2	5.4	4.2	3.4	3.9	3.1	2.6	6.5	4.7	4.3
RF voltage (MV)	21.2	31	22	15	45	29	21	32	21	17
RF acceptance (%)	1.46	1.65	1.48	1.21	2.70	2.45	2.17	2.35	1.99	1.72
Synchrotron tune	0.059	0.091	0.061	0.038	0.089	0.056	0.037	0.061	0.038	0.028
Horizontal tune	49.23	40.29	46.28	58.29	50.30	61.30	72.28	64.75	75.20	80.45
Natural horizontal chromaticity	-64	-48	-54	-74	-63	-79	-108	-77	-95	-107
Vertical tune	53.34	41.25	47.24	57.25	51.26	62.24	69.23	61.40	71.40	75.90
Natural vertical chromaticity	-64	-49	-55	-73	-63	-80	-100	-76	-93	-104

Lattice Evaluation

- The 4 lattices were evaluated on 8 criteria:
  - **Lattice Design and Dynamical Properties**
  - **Conventional Facilities and Layout**
  - **Magnets, Supports and Power Supplies**
  - **Vacuum System and Radiation Handling**
  - **RF System**
  - **Injection and Extraction Systems**
  - **Instrumentation and Diagnostics**
  - **Control System, Availability and Reliability**
- Rankings of 1-5 in each (5 is best)
- Where insufficient data for evaluations

Rankings

	OCS8	FODO4	FODO5	DCO
Net Score	**27.0**	**27.2**	**28.4**	**29.3**

- Tight clustering due to the fact that core work on all lattices at similar level
- Differences were driven by whether lower momentum compaction/shorter bunch length option was incorporated and items that affect cost, availability and reliability (eg, magnet counts, degree of clustering of major components near the two proposed access shafts, etc)

Recommendation

- Baseline Recommendation: **DCO**
- Alternative Recommendation: **FODO5**

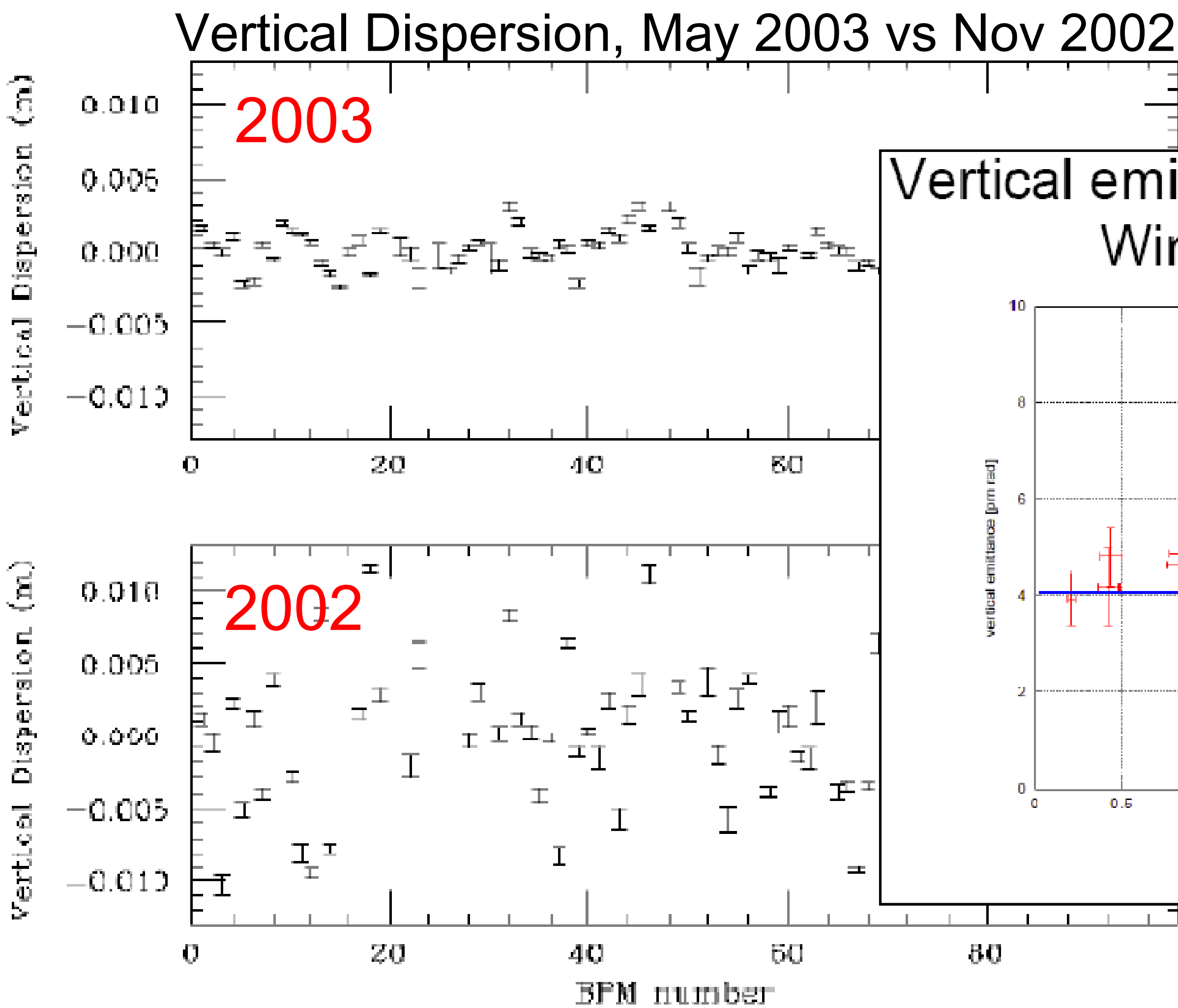
- Many thanks to the design groups for their thorough work:
  - **OCS**
    - Aimin Xiao & Louis Emery (ANL-APS)
  - **FODO**
    - Yi-Peng Sun (now at CERN), Jie Gao (IHEP), Zhi-Yu Guo (Peking Univ.), and Wei-Shi Wan (LBNL)
  - **DCO Designers**
    - Andy Wolski & Maxim Korostolev (Univ. of Liverpool, CI)

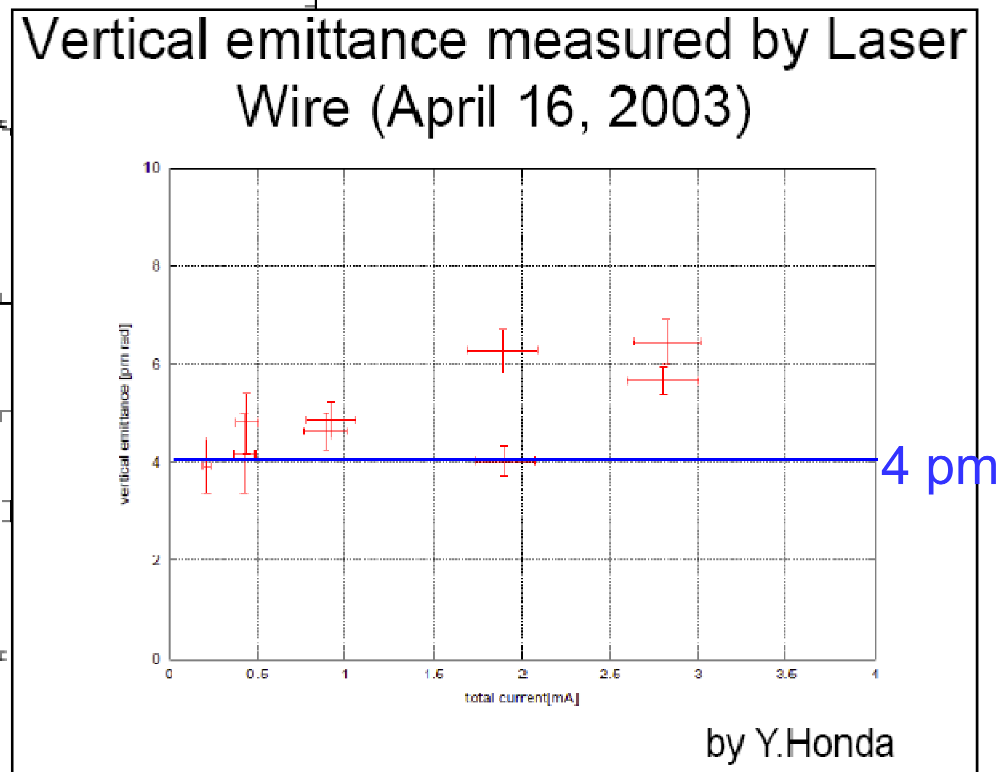
ATF Session

- Low Emittance Tuning
  - **Kiyoshi Kubo**
- Fast Ion Experiments,
  Kicker Test,
  and Upcoming Run Plan
  - **Junji Urakawa**
- Laser Compton Source for Polarized e^+
  - **Tsunehiko Omori**

Previously Achieved Emittance

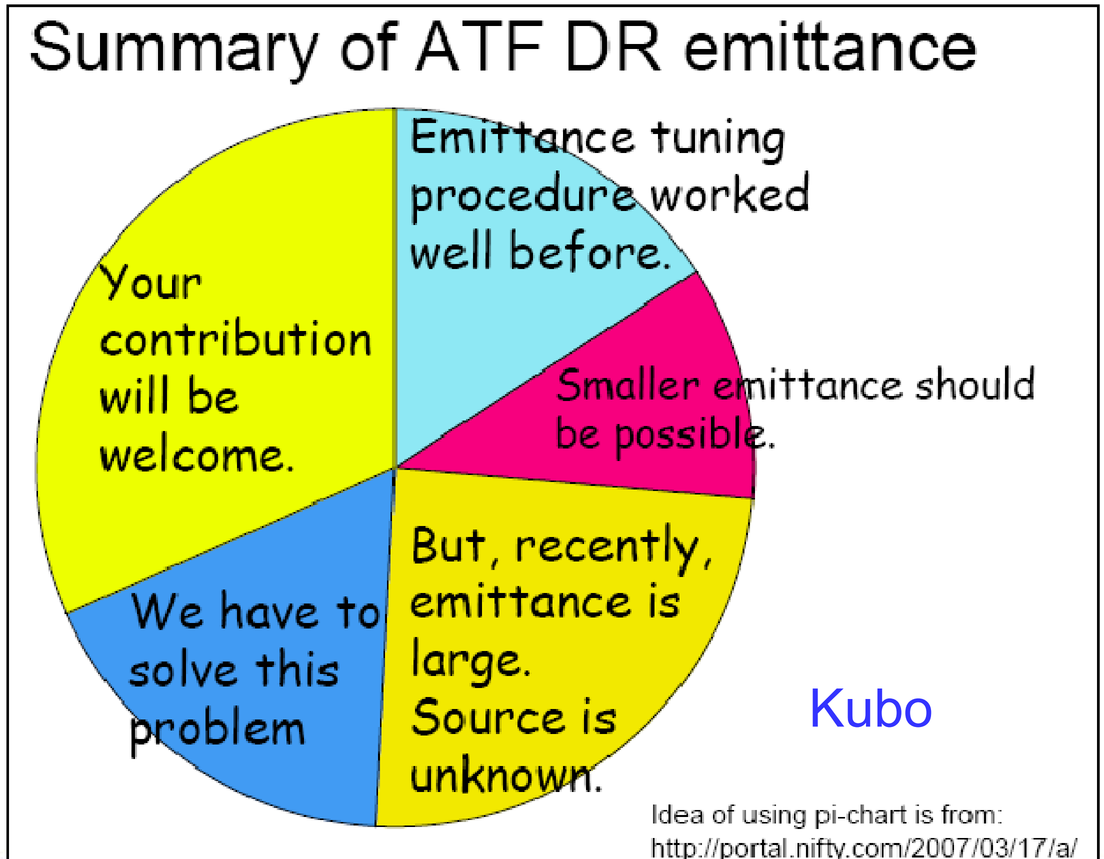
Kubo





Emittance Recovery

- Recent observed emittance performance has been ≥ 20 pm
- Plan outlined to recover low emittance
  - **Optics correction**
  - **BPM alignment and calibration**
  - **Magnet alignment**
  - **Other errors**

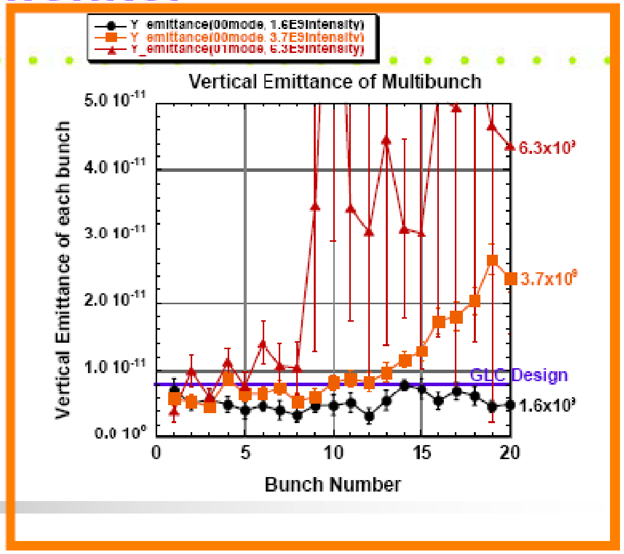


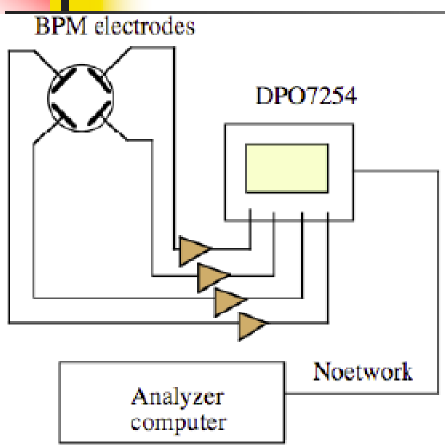
Fast Ion Studies (Urakawa)

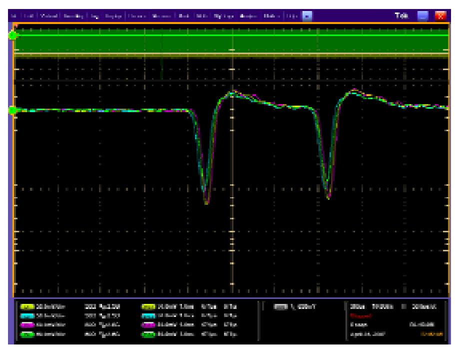
Multi-bunch Turn-by-turn monitor

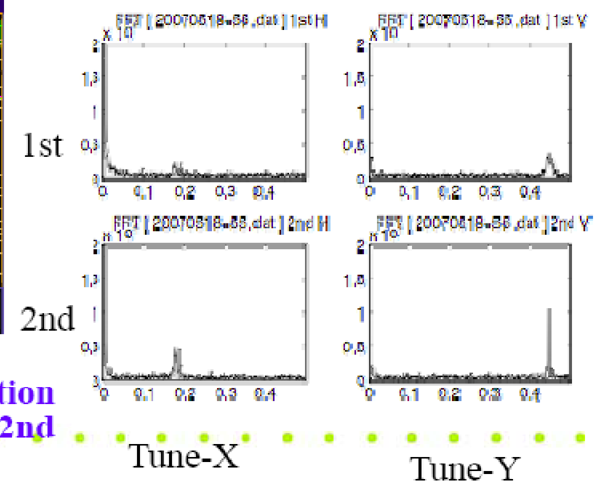
T. Naito (KEK)

The beam blowup at tail bunches was measured by the laser wire in ATF, which is assumed coming from FII effect. In order to observe the individual beam oscillation in the multi-bunch beam, multi-bunch turn-by-turn monitor has been developed. This monitor consists of front end circuits(amplifier and filter) and DPO7254 scope. The scope can store the waveform up to 2ms with 100ps time resolution.









The preliminary results shows the different oscillation amplitude of the tune-X and the tune-Y for the 1st and 2nd bunches at just after injection.

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Recent Fast Ion Work

Studies will continue with ongoing improvements: lower emittance, controlled pressure bump, etc.

Experimental Results measured by laser wire in DR

Urakawa

Table 2: vacuum pressure in 2004

ion pump status	11mA	26mA	31mA
normal	4.0×10^{-6} Pa	6.0×10^{-6} Pa	6.5×10^{-6} Pa

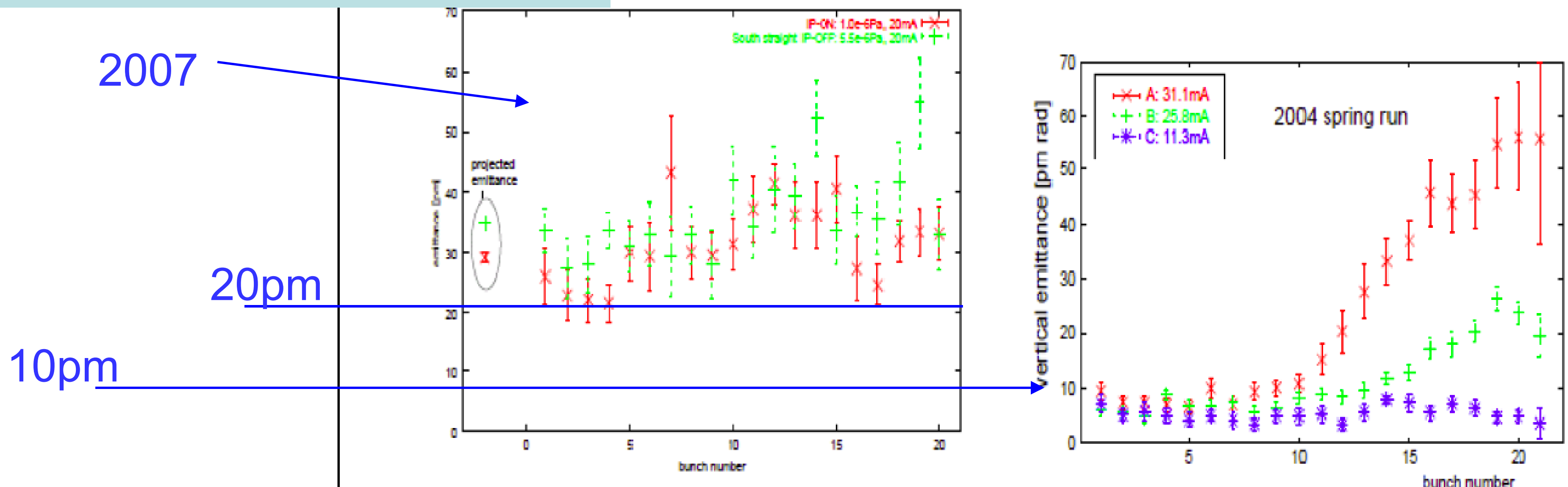

Figure 9: emittance of multi-bunch beam at 20mA/20bunches

Figure 10: data taken in 2004

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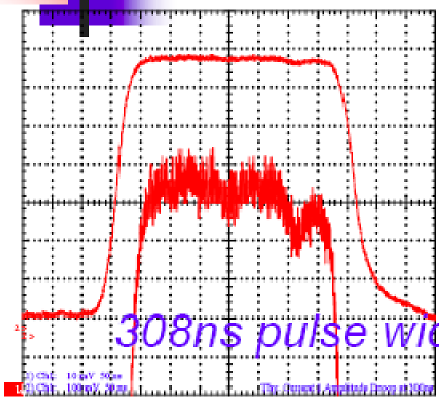
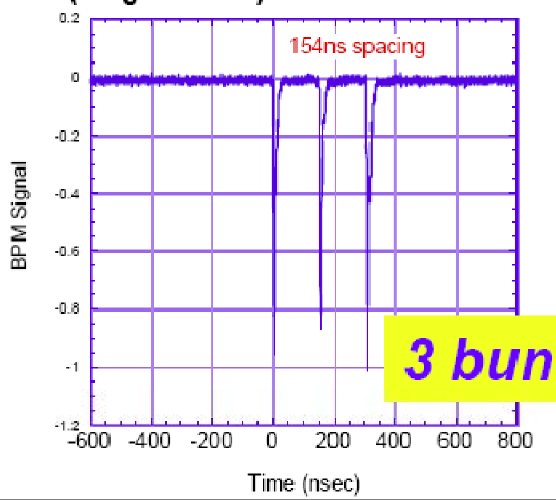
Design and beam test for strip-line fast kicker experiment

Urakawa

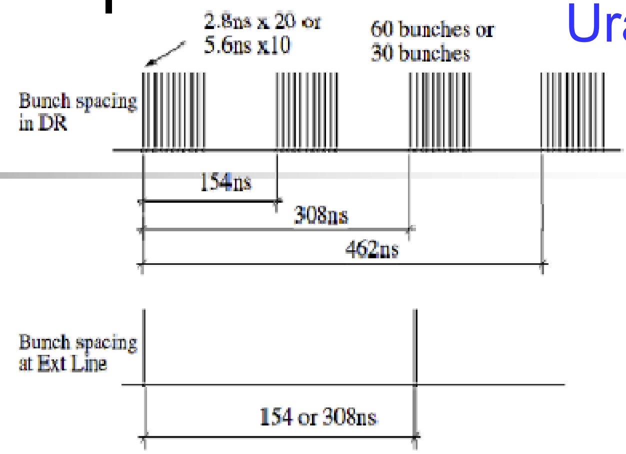
Present kicker stability
(Pulse magnet kicker system)



(Single bunch) x 3 Train Extraction



3 bunches, 154ns spacing



60 bunches with 154ns spacing or
30 bunches with 308ns spacing

10kV 1ns:rise time, fast Pulse power supplies

Multi-bunch beam supply to ATF-Ext.
60 bunches with 154 ns spacing.
30 bunches with 308 ns spacing.

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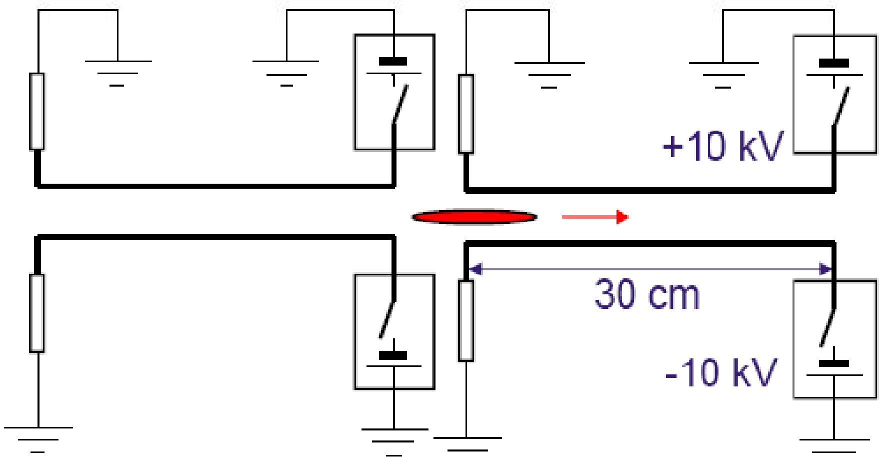
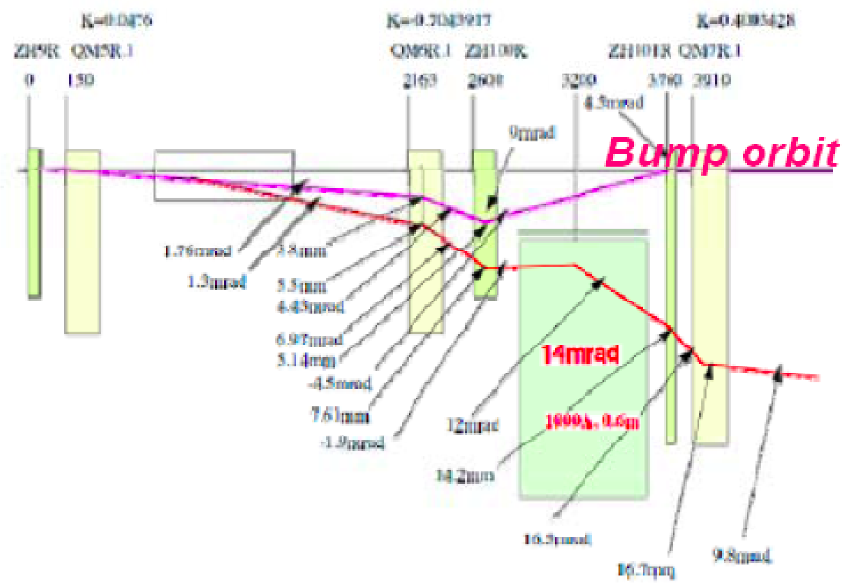
Future Kicker Tests at ATF

New septum and a "slow" orbit bump would allow fast extraction using two 30 cm strip lines, driven by ±10 kV pulsers.

Urakawa





The length of each strip-line is limited by the rise and fall time specifications: the maximum length is approximately 30 cm.
Each strip-line is driven by two pulsers operating at ±10 kV, providing a voltage between the electrodes of 20 kV.

Beam extraction at the end of 2008

Future plans

Urakawa

- ATF-II project
- Fast ion instability study with flat beam
- Fast Kicker R&D
- Feed-forward to stabilize the extracted beam
- High Intensity pol. gamma-ray generation based on Compton Scattering-→Omori's talk

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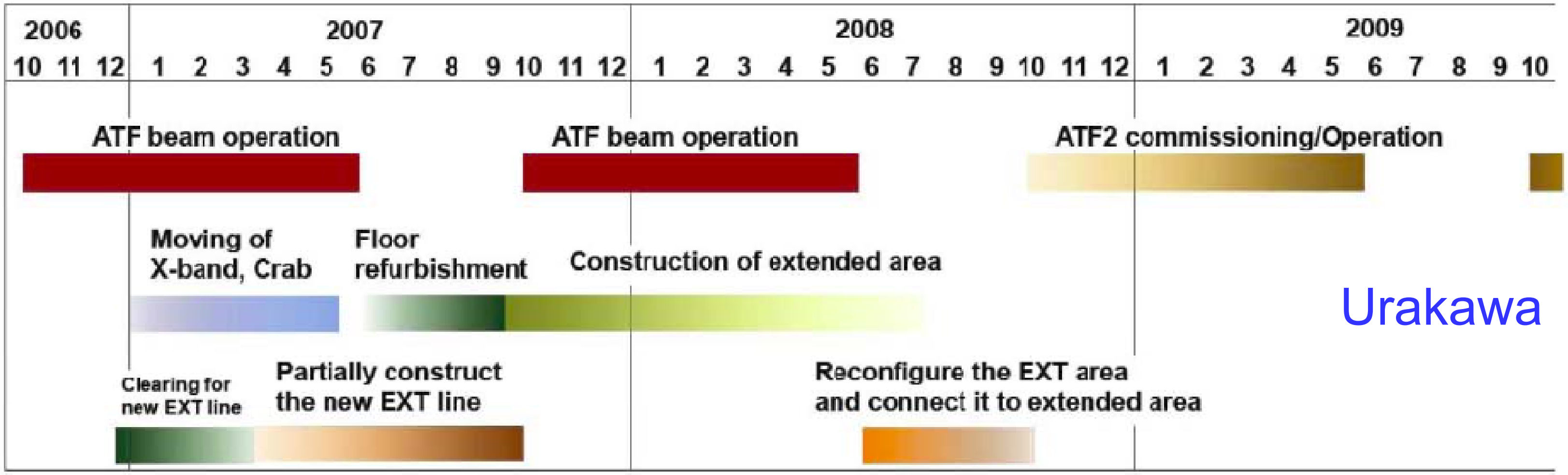
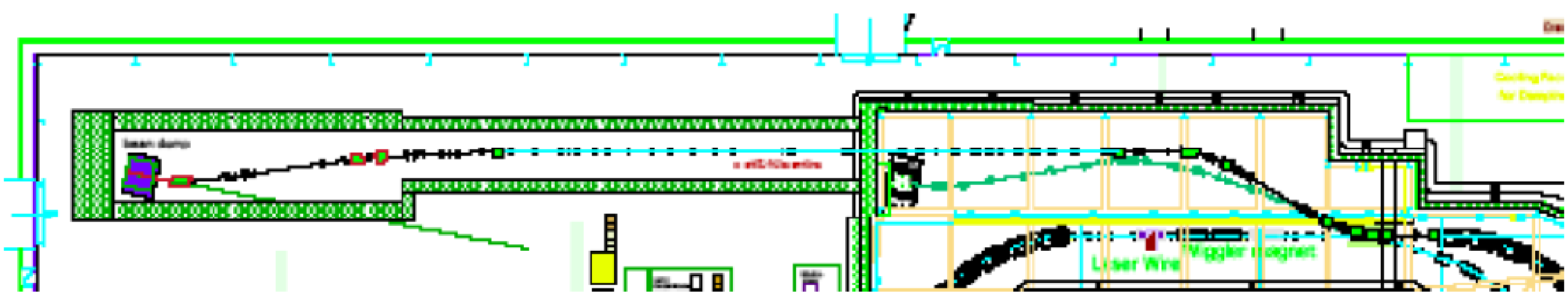
ATF2 construction schedule



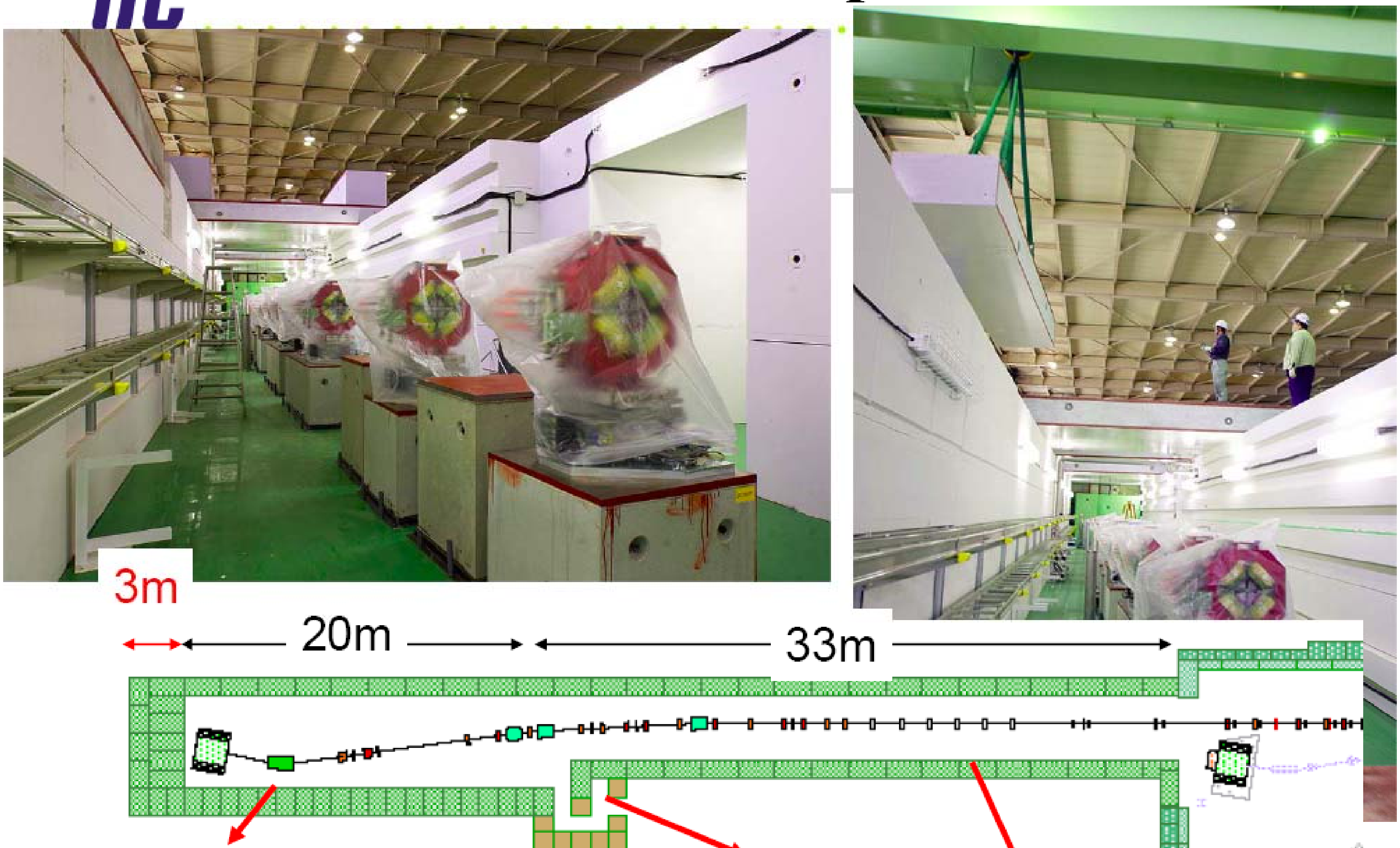
Urakawa



- **ATF2 beam will come in October, 2008.**

ATF2 construction present status

Urakawa

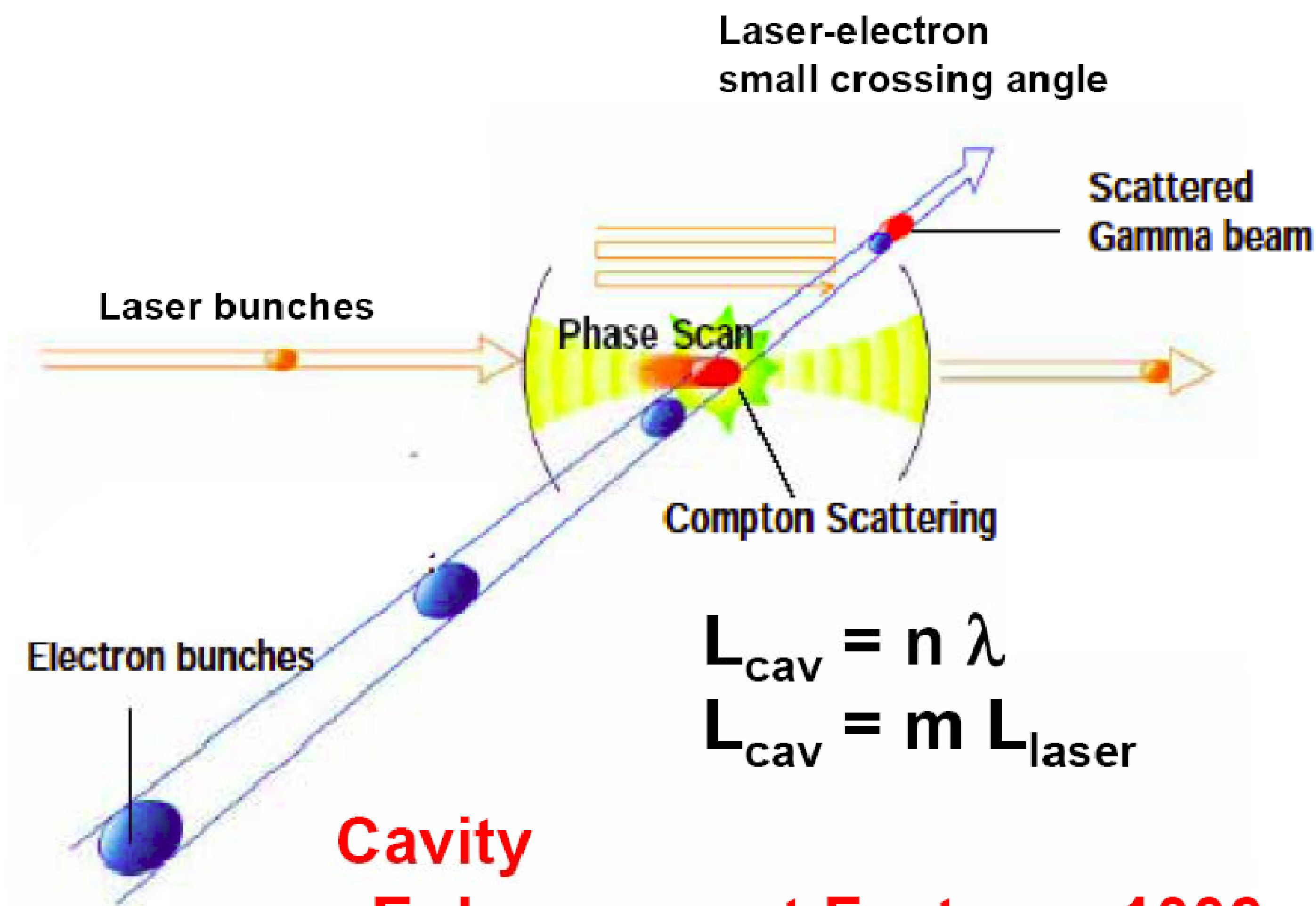


Side: 1~1.5m thick, Top: 1m thick
Inner width: 5m

Access Entrance
Moving shield door

Side: 1m, Top: 0.5m, Inner width: 3.5m

Laser Pulse Stacking Cavity



$$L_{cav} = n\ \lambda$$
$$L_{cav} = m\ L_{laser}$$

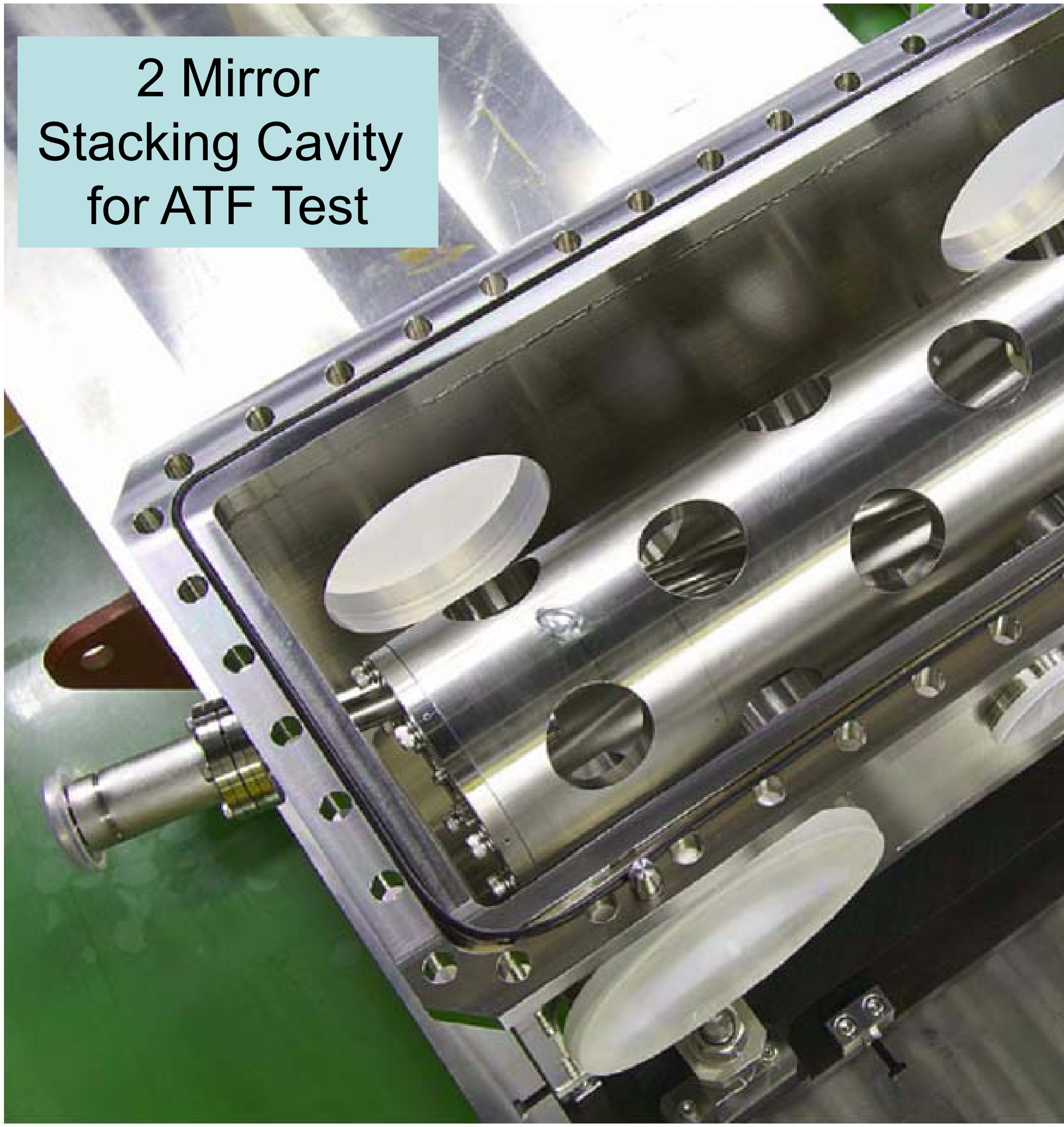
Cavity

Enhancement Factor = 1000 - 10^5

Omori

Optical Cavity in Vacuum Chamber

2 Mirror
Stacking Cavity
for ATF Test



4 Mirror Cavity
Development
at LAL

CesrTA Session

- Reports
  - **Introduction, Mark Palmer**
  - **Low Emittance Tuning, Dave Rubin**
  - **Electron Cloud Program, Mark Palmer**
  - **Schedule and Status, Mark Palmer**
- General Discussion

Cornell University
Laboratory for Elementary-Particle Physics

CesrTA Project Status I

- CesrTA project funding has been approved
  - Joint NSF/DOE funding
  - Funding spans FY08-FY10
  - Funding levels consistent with a 2 year experimental program
  - As of late February, funding agreements in place with NSF and DOE
- Research program and duration have been de-scoped from original proposal

De-Scoped CesrTA Program

- Plan continues to emphasize
  - EC Growth and Instability Studies
  - Development of low emittance tuning techniques (target $\varepsilon_y <$ 20pm)
  - Development of x-ray beam size monitor to characterize ultra low emittance beams (1-D camera array)
  - Program to preserve ~120 CesrTA operating days per year
- De-scoped items
  - Study of ion related instabilities and emittance dilution
  - 2-dimensional x-ray beam size camera upgrade
  - Contingency for:
    - Follow-up tests of alternative mitigation techniques
    - Tests of ILC prototype hardware
    - Further reductions in beam emittance, and further refinement of low emittance tuning methodology

CESR-c Wigglers ⇨ η=0 Region

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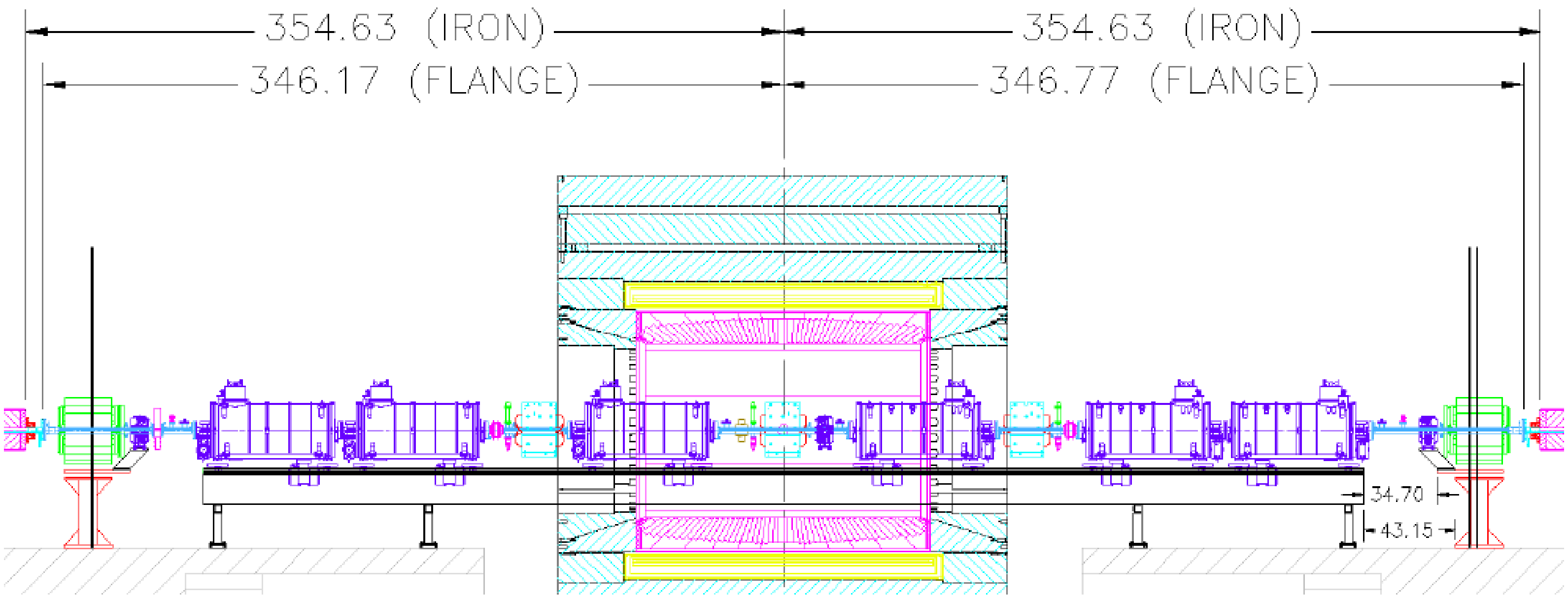
L0 Wiggler Region



MAIN COMPONENT POSITIONS

- L0 wiggler experimental region design work well underway
  - Installation during July down
  - Heavily instrumented throughout with vacuum diagnostics
  - Targeting full design review this month followed by full scale production
- Note: Part of CLEO will remain in place
  - At present unable to remove full detector
  - Time savings

Components of the EC Growth Plan

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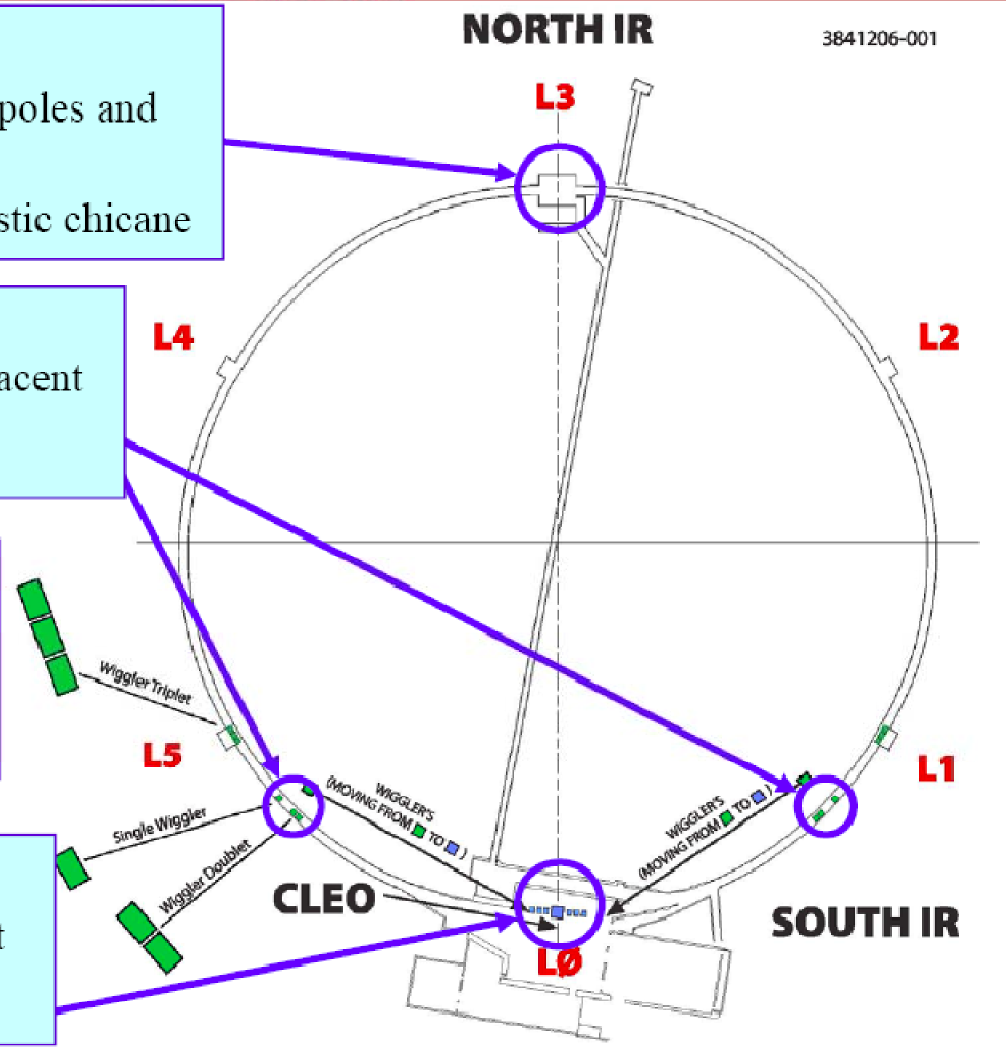
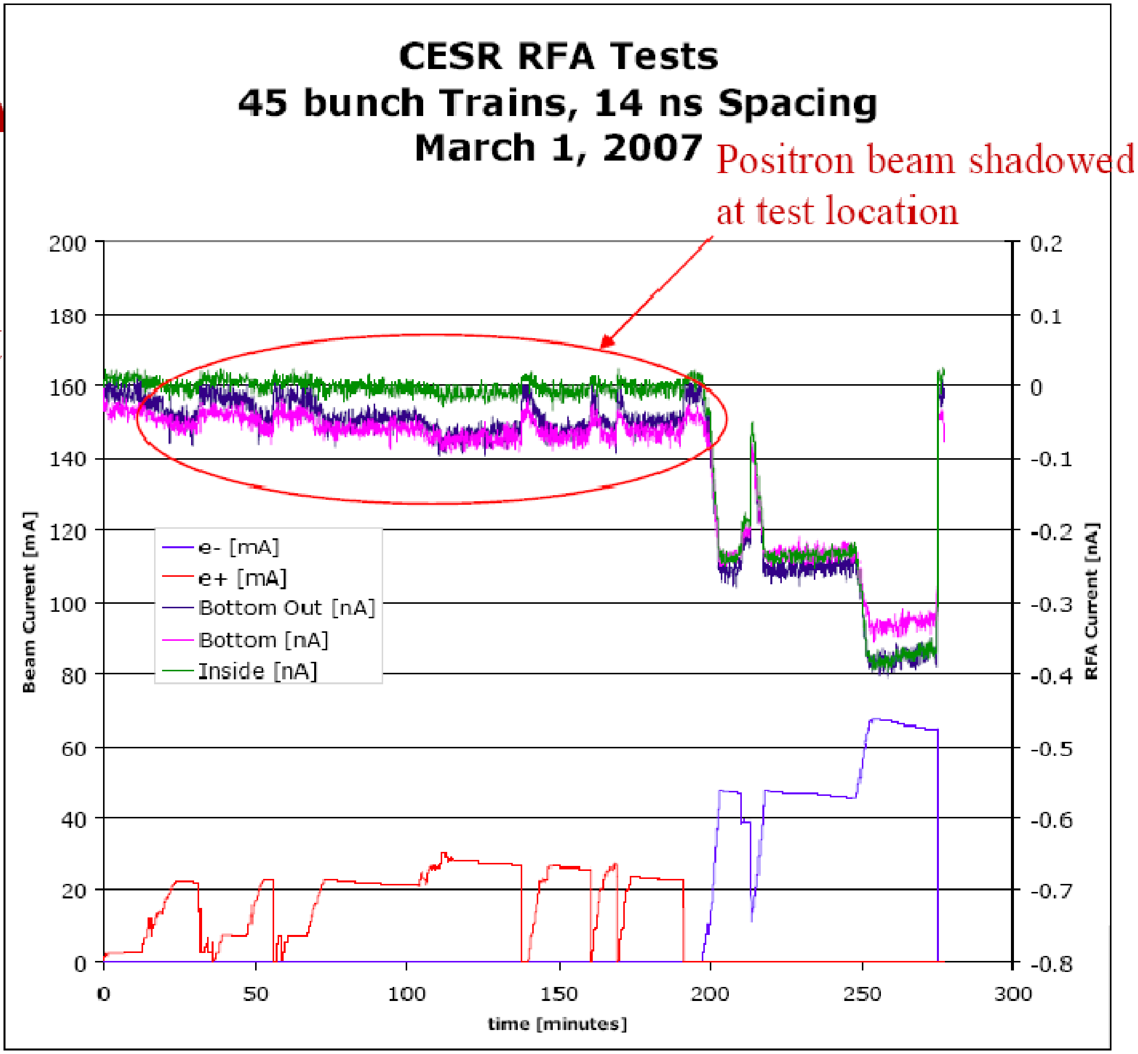
- L3 Straight
  - Instrument large bore quadrupoles and adjacent drifts
  - Proposed location for diagnostic chicane
- Arcs where wigglers removed
  - Instrumented dipoles and adjacent drifts
- Pressure bump capability planned for major diagnostic regions
  - Impact on ECE (and FII?)
- L0 Straight
  - Instrumented wiggler straight and adjacent sections



Retarding Field Analysers

- Beam tests have continued through CLEO-c conclusion
- Upgraded readout electronics for large channel count RFAs are now ready for production
- Thin RFA structure performing well



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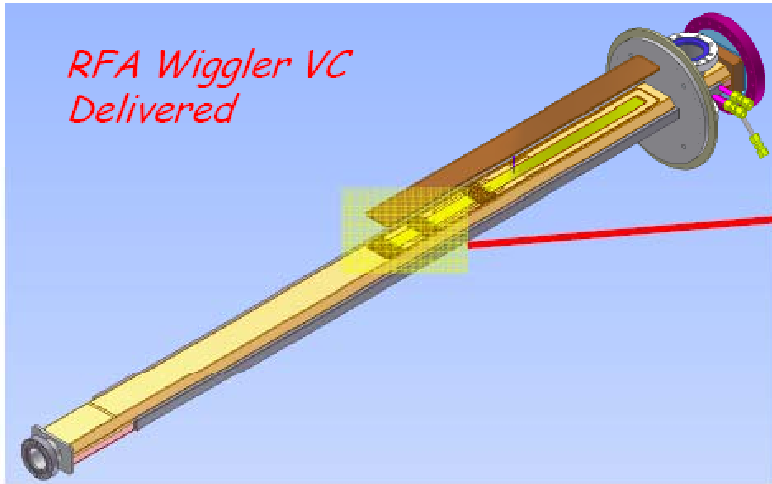
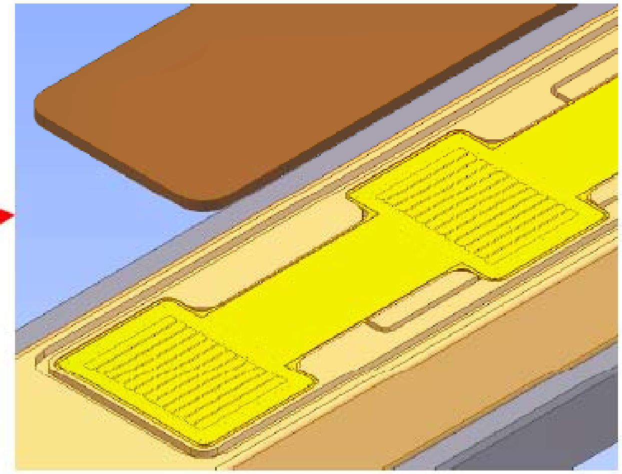
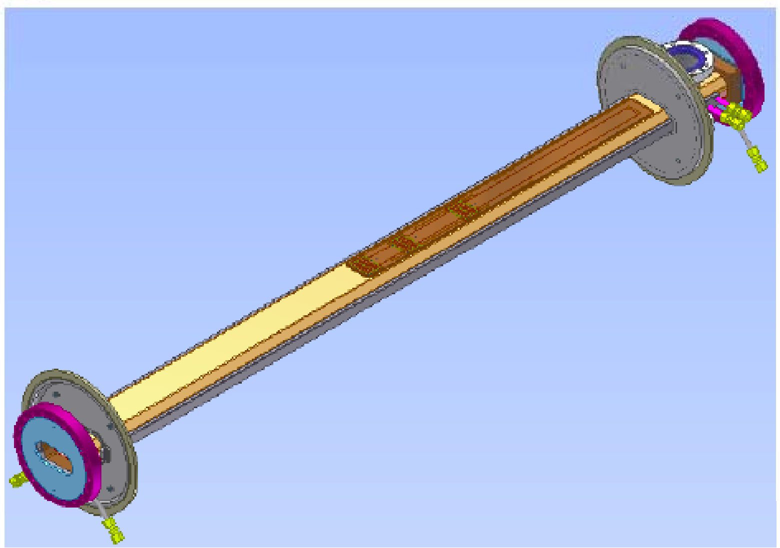
Chambers with Thin RFAs

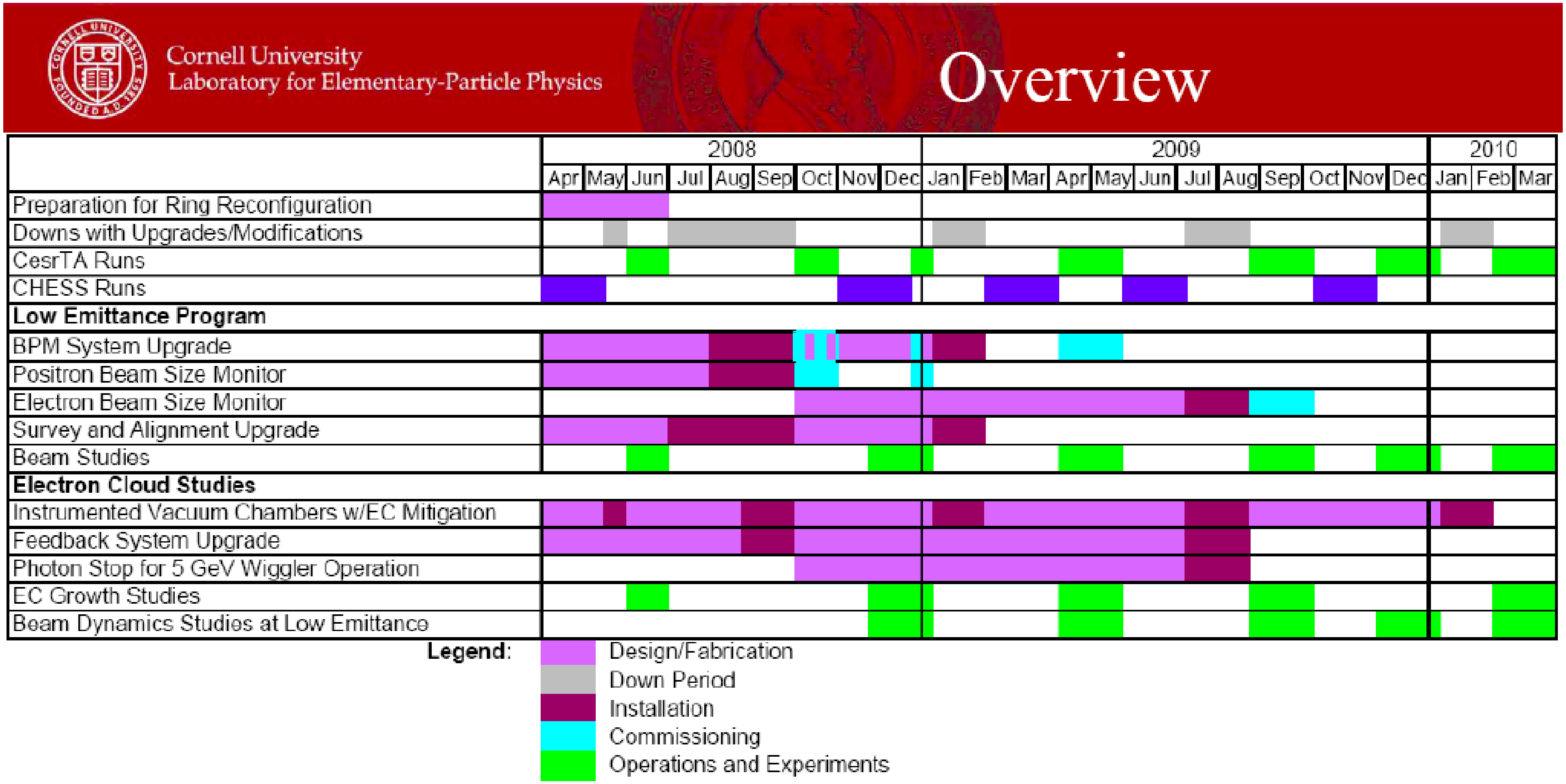






- Loss of US collaborators impacted development heavily
  - Cornell has picked up detailed design
  - Now ready for final design review
  - Working with KEK to see whether construction support might be available

CesrTA Schedule



Conclusion

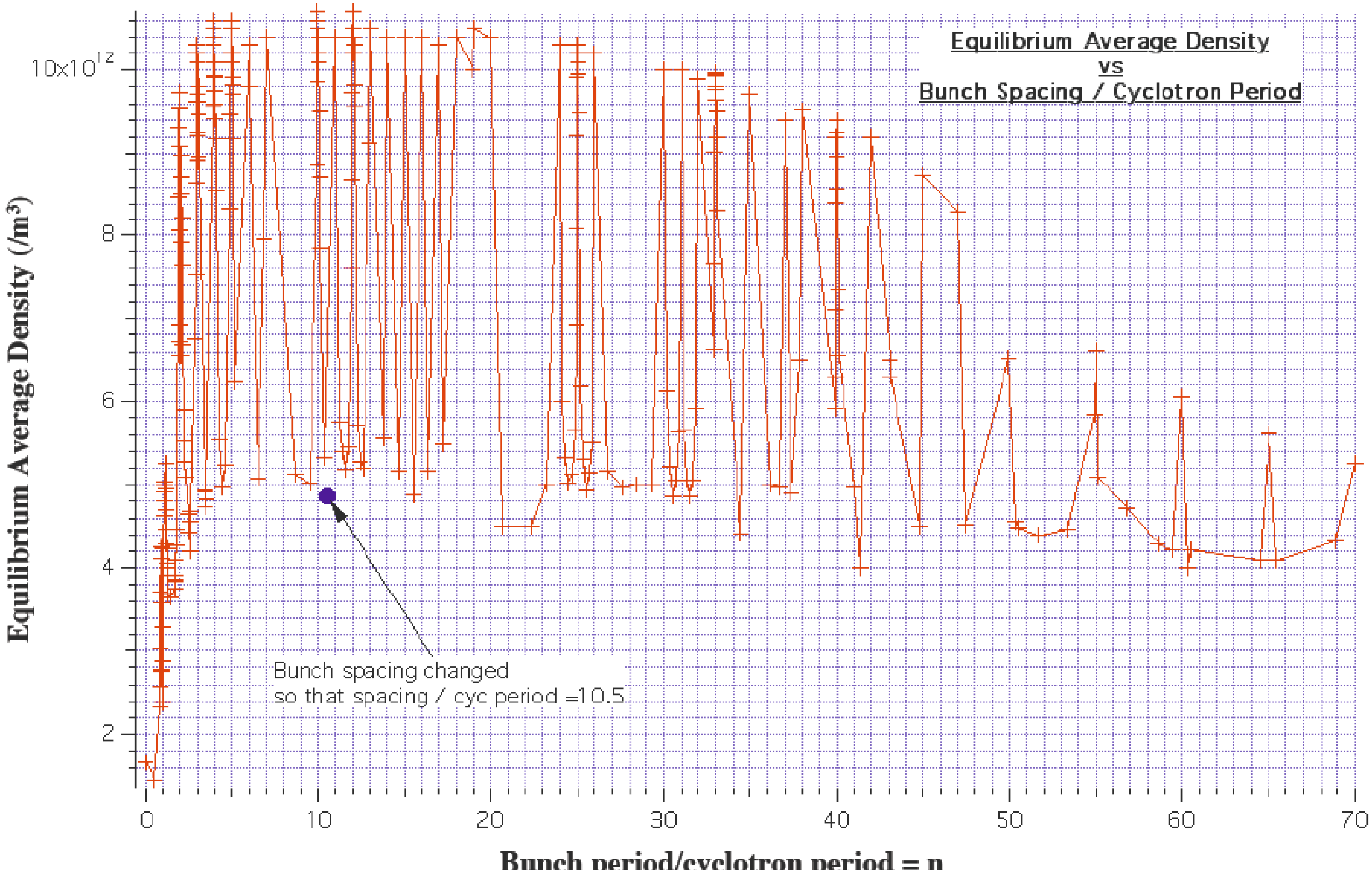
- CesrTA program is presently ramping up
- R&D Targets:
  - Now through mid-2009
    - Complete low emittance machine reconfiguration and upgrades
    - Deploy and commission instrumentation needed for low emittance program
    - Study EC growth studies in wigglers, dipoles, quadrupoles and drift regions in CESR
    - Initial EC mitigation studies
  - Mid-2009 through April 1, 2010
    - Work towards progressively lower emittance operation
    - Complete EC mitigation studies
    - EC beam dynamics studies at the lowest achievable emittances
- Immediate focus:
  - Engineering preparation for machine reconfiguration
  - Preparation/testing of EC vacuum chambers, vacuum diagnostics, and beam instrumentation

Electron Cloud Session

- Update on New Cyclotron Resonances in Electron Cloud Dynamics
  - **Christine Celata (LBNL)**
- Study of a Clearing Electrode at KEKB – First beam test
  - **Yusuke Suetsugu (KEK)**
- Electron Cloud Study for ILC Damping Ring at KEKB and CESR
  - **Kazuhito Ohmi (KEK)**
- Electron Cloud R&D
  - **Mauro Pivi (SLAC)**

Peaks occur where (bunch period)/(cyclotron period) = integer

Note: some peaks (and dips) missing because runs have not yet been done at that field



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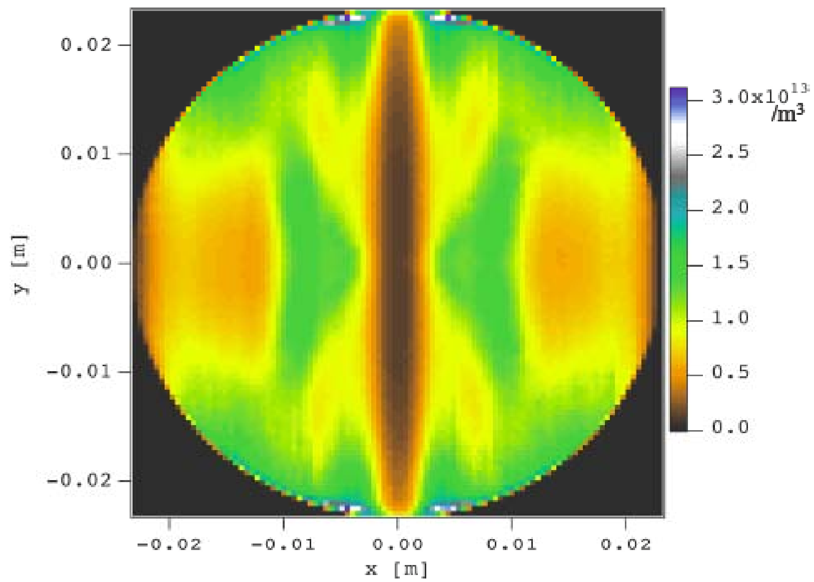
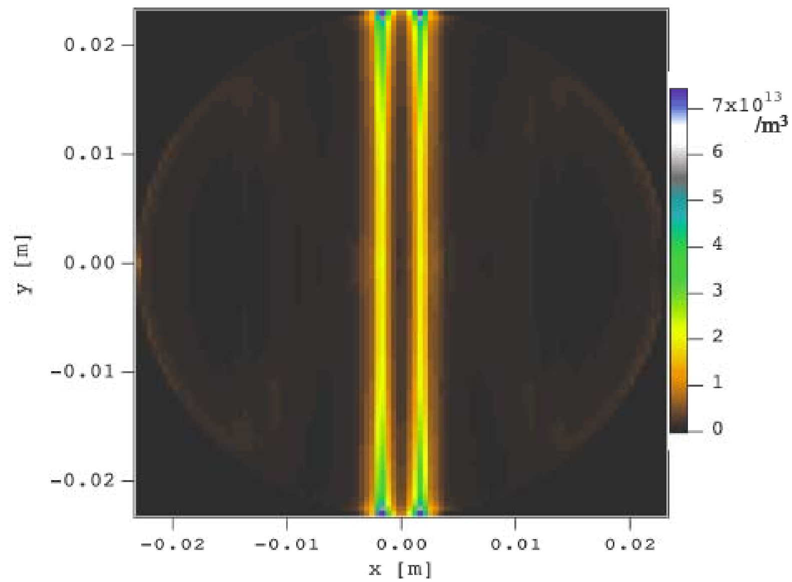
Another effect, from POSINST Simulation: Electrons more Dispersed in Resonant Case

Density Distribution Averaged over Run (POSINST)
X-Y Plane



B at a spike



High B

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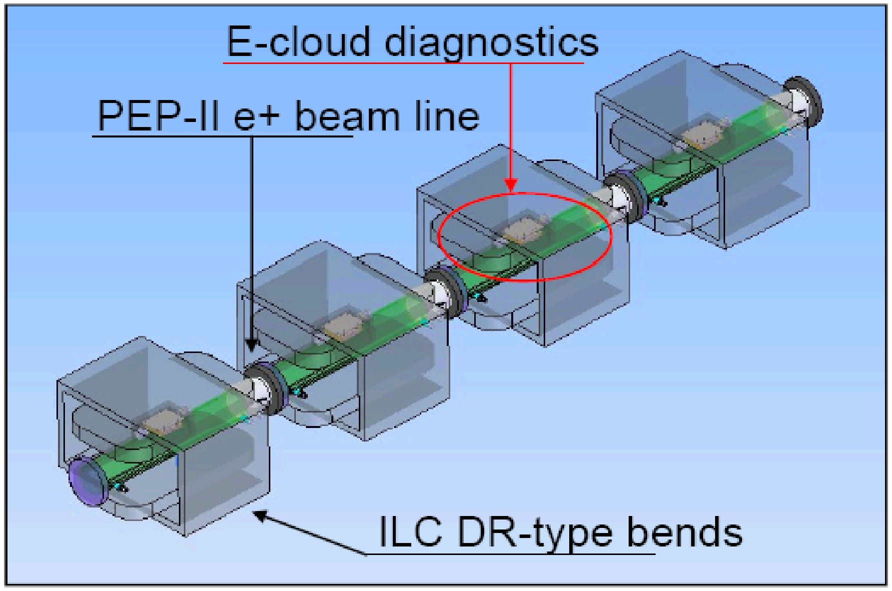
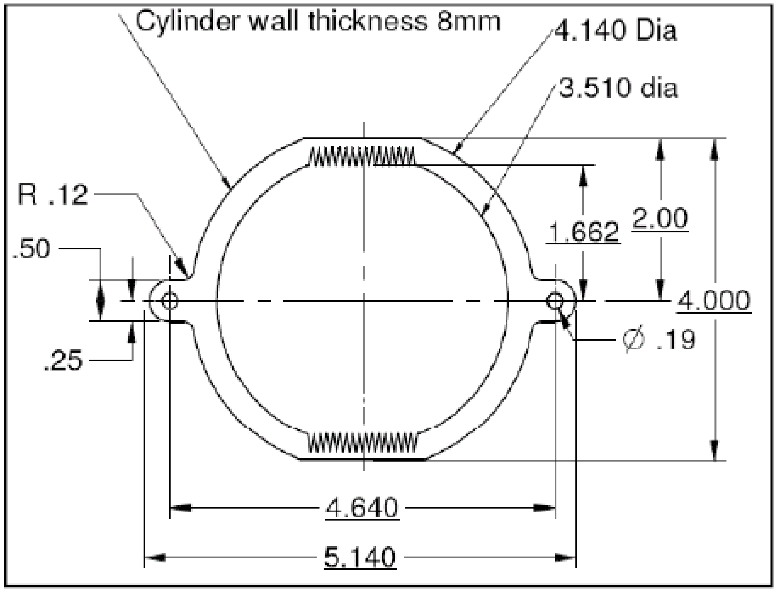
Mitigations Tests SLAC: New ILC Chicane Installation

- Verify efficiency of mitigation techniques in dipoles.
- Installation of a new chicane in PEP-II with ILC DR-type bends, to test chambers with coatings (and chambers with grooves)



Layout new chicane installation in PEP-II LER



PEP-II chamber with triangular grooves

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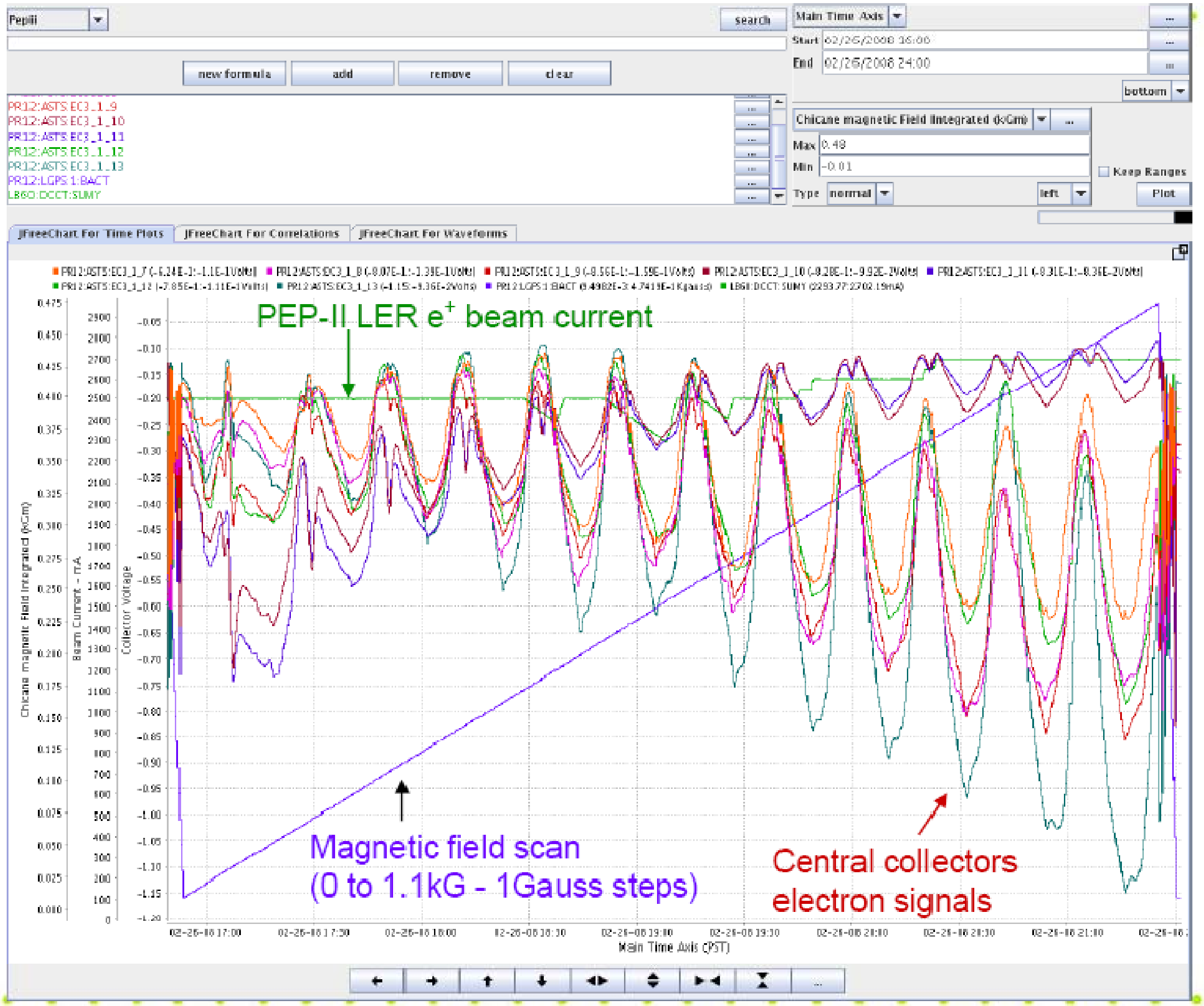
Scan Chicane Magnetic field: Preliminary Results



Pivi

Work in progress LBNL/SLAC to simulate PEP-II case. See C. Celata talk.

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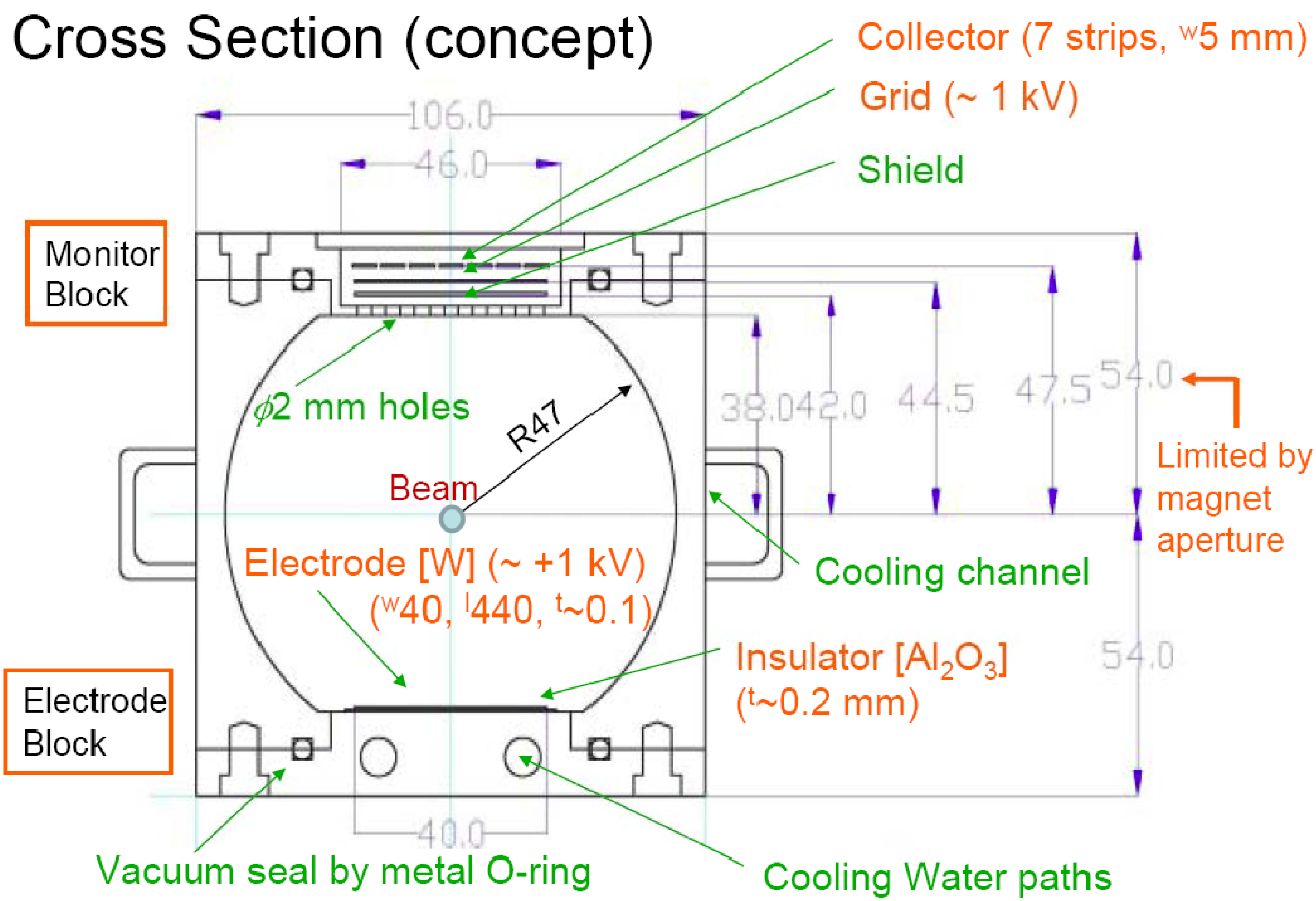
Wiggler Chamber w/Clearing Electrode

Suetsugu

Monitor and electrode

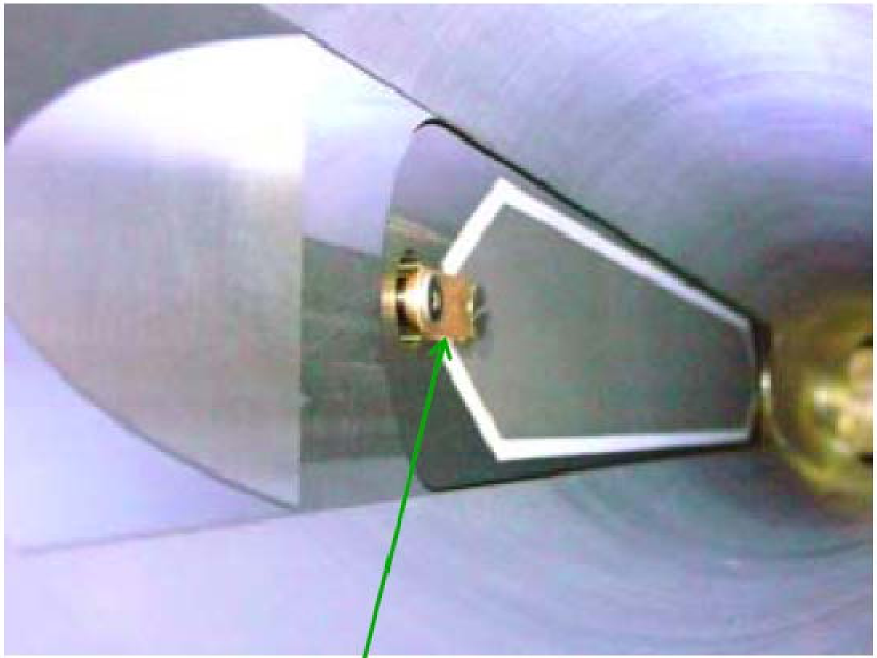
- Cross Section (concept)

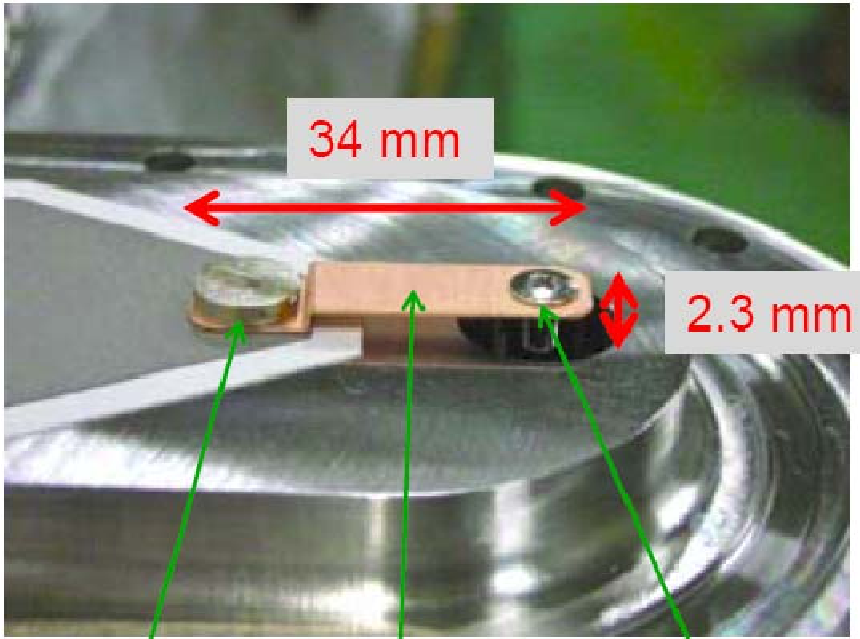


Assembly of electrode

- Connection part

Suetsugu





Connection to feed-through

Bakable up to 140 °C

Metal-coated Al_2O_3 screw

Copper bridge

Metal screw

Ring Comparisons for EC Dynamics

Optics parameters

	Physics run	Low emittance	CesrTA	OCS	PEP-II
Circumf. (m)	3016	3016	768	6	2200
E (GeV)	3.5	2.3	2.0	5.0	3.1
ε_x (nm)	18	1.5	2.3	0.5	48
α (10^{-4})	3.4	2.4	64	4.2	13
σ_z (mm)	6	4.2 (6.1)	6.8	6	12
Rf voltage	8.0	2.0 (1.0)	15	24	
σ_δ (%)	0.073	0.048	0.086	0.128	0.081
$\tau_{x,y}$ (ms)	40	150	56.4	26	40
Bucket height		1.86 (1.13)		1.5	

Emittance increases due to IBS. (ε_x(nm), ε_y(pm))

KEKB-DRT (1.5,1,5)->(5, 5) or (1.5, 6)->(4, 16)

CesrTA (1.8,4.5)->(6,16)

Ohmi

Head-Tail Instability Thresholds

Threshold for various rings

Ohmi

	KEKB	KEKB	KEKB-DRt	CesrTF	ILC-OCS	PEPII
L	3016	3016	3016	768.44	6695	2200
gamma	6849	6849	4501	3914	9785	6067
Np	3.30E+10	7.60E+10	2.00E+10	2.00E+10	2.00E+10	8.00E+10
ex	1.80E-08	1.80E-08	1.50E-09	2.30E-09	5.60E-10	4.80E-08
bx	10	10	10	10	30	10
ey	2.16E-10	2.16E-10	6.00E-12	5.00E-12	2.00E-12	1.50E-09
by	10	10	10	10	30	10
sigx	4.24E-04	4.24E-04	1.22E-04	1.52E-04	1.30E-04	6.93E-04
sigy	4.65E-05	4.65E-05	7.75E-06	7.07E-06	7.75E-06	1.22E-04
sigz	0.006	0.007	0.009	0.009	0.006	0.012
nus	0.024	0.024	0.011	0.098	0.067	0.025
Q	3.6	5.9	7	7	7	3.7
omegae	1.79E+11	2.51E+11	5.29E+11	5.01E+11	6.31E+11	9.20E+10
phasee	3.6	5.9	15.9	15.0	12.6	3.7
K	3.6	5.9	15.9	15.0	12.6	3.7
rhoeth	6.25E+11	3.81E+11	9.60E+10	2.92E+12	1.91E+11	7.67E+11

Closeout with PMs

- Lattice Selection
- Cost Reduction
- Proposed TDP Reorganization

Work Package #	Work Package Title
1	CesrTA
2	DR studies at KEK-ATF
3	DR studies at DAΦNE and other facilities
4	ILC DR Beam Dynamics
5	ILC DR Technical Systems

Wolski

Upcoming DR Workshop

- Damping Rings R&D Workshop *and* CesrTA Kick-off Workshop
  - **July 8-11, 2008**
  - **Cornell University ILR Conference Center**
  - **Details to appear soon**