Cornell Laboratory for
Accelerator-based Sciences and
Education (CLASSE)

Damping Rings – Part 4

FIFTH INTERNATIONAL ACCELERATOR SCHOOL FOR LINEAR COLLIDERS
October 25 - November 5, 2010 • Villars-sur-Ollon, Switzerland

Lecture A3, Part 4 – Beam Dynamics

A. Overview of Impedance and Instability Issues
B. Review of Selected Collective Effects
C. R&D Challenges

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Damping Ring Lectures

Lecture A3, Part 1 – Damping Ring Basics
- Introduction to Damping Rings
- General Linear Beam Dynamics

Lecture A3, Part 2 – Low Emittance Ring Design
- Radiation Damping and Equilibrium Emittance
- Damping Ring Lattices

Lecture A3, Part 3 – Damping Ring Technical Systems
- Systems Overview
- Review of Selected Systems for ILC and CLIC
- R&D Challenges

Lecture A3, Part 4 – Beam Dynamics
- Overview of Impedance and Instability Issues
- Review of Selected Collective Effects
- R&D Challenges

Outline of DR Lecture – Part 4

Beam Dynamics Issues

- Brief Overview of Beam Impedance and Classical Instabilities
- Critical Beam Dynamics Issues
  - Fast Ion Instability
  - Electron Cloud
- ILC R&D Program
  - Dedicated Test Facilities
    - ATF
    - CESRTA
  - Other R&D Efforts
- Summary of R&D Challenges

Conclusion

ILC DR Impedance and Instability Issues

I will approach this lecture primarily from the point of view of the ILC Damping Rings.

The ILC damping rings will operate in a parameter regime that has not yet been explored by any operating machine. For the remainder of this lecture we will explore (*briefly*) several of the key physics issues that will determine how well the damping rings, and hence how well the ILC, will perform.

There are a number of effects that are important for the DR design. Existing machines have demonstrated the need to carefully control the impedance in machine components to minimize the impact of wake fields which can lead to single- and multi-bunch instabilities. In addition, effects like the fast ion instability and the electron cloud instability are expected to play a more dominant role in the ILC DR than they have in previous machines. We will review these effects and briefly look at the role that test facilities have to play in characterizing and learning to mitigate them.

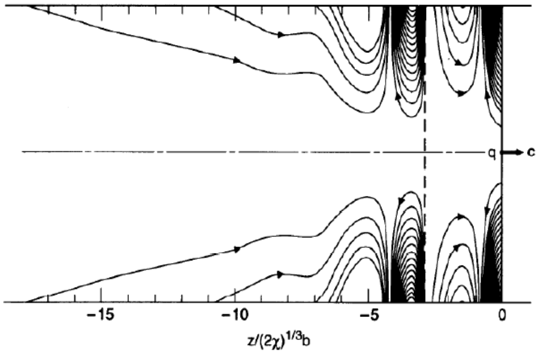
Wake Fields I

For a bunch travelling in a vacuum chamber:

- The EM fields must satisfy Maxwell's equations
- The vacuum chamber imposes boundary conditions that modify those fields from their free space values
- The interaction can result in having fields generated by the head of a bunch act on trailing particles, thus changing their motion
- If the impact on the trailing particles is sufficiently large, this can potentially cause an instability to develop

The EM fields generated by a particle or bunch during its passage are called ***wake fields***

Illustration: Wake fields following a point charge in a cylindrical beam pipe with resistive walls (K. Bane)



Wake Fields II

The wake fields generated by a bunch passage may be

- short range wakes which can impact particles in the tail of the bunch that generated them
- long range wakes which impact other bunches later in the bunch train

The formalism used to calculate the impact of the wakes left by charges on trailing charges is that of *wake functions and impedances.*

In designing a vacuum system that must include:

- RF cavities
- Beam diagnostics
- Sliding joints to handle thermal expansion issues
- Kickers
- Etc.

particular care must be taken to minimize the wake fields that will be generated as bunches move past these structures.

Collective Effects and Instabilities

A number of "classical" instabilities can result if these wakefields grow too large. Some examples are the

- Microwave instability (short range wake)
- Transverse mode coupling instability (short range wake)
- Resistive wall coupled bunch instability (long range wake)
- etc

Other collective effects that must be considered include:

- Intrabeam scattering
- Space charge effects
- Electron cloud effects in the positron ring
- Ion effects in the electron ring
- Touschek lifetime

A broad study of potential effects was undertaken during the initial ILC DR lattice selection process.

Unfortunately we won't have time to discuss them all here.

The ILC DR Configuration Choice

The potential instability issues were reviewed as part of the ILC DR configuration choice that took place at a meeting in November 2005 at CERN. Various lattices were studied, and while some were found to have specific problems (eg, see the next slide), viable candidates appeared to be present. One of the most difficult decisions was the choice of circumference. At the time, it was unclear what circumference would be required to ensure that the positron damping ring would not be adversely affected by the electron cloud. At that time the choice was made to pursue a
~6 km ring design with plans to use 2 positron rings, as needed.

Since that time, confidence has grown in the ability to meet the ILC DR specifications with a single 6.4 km ring and that has been the baseline.

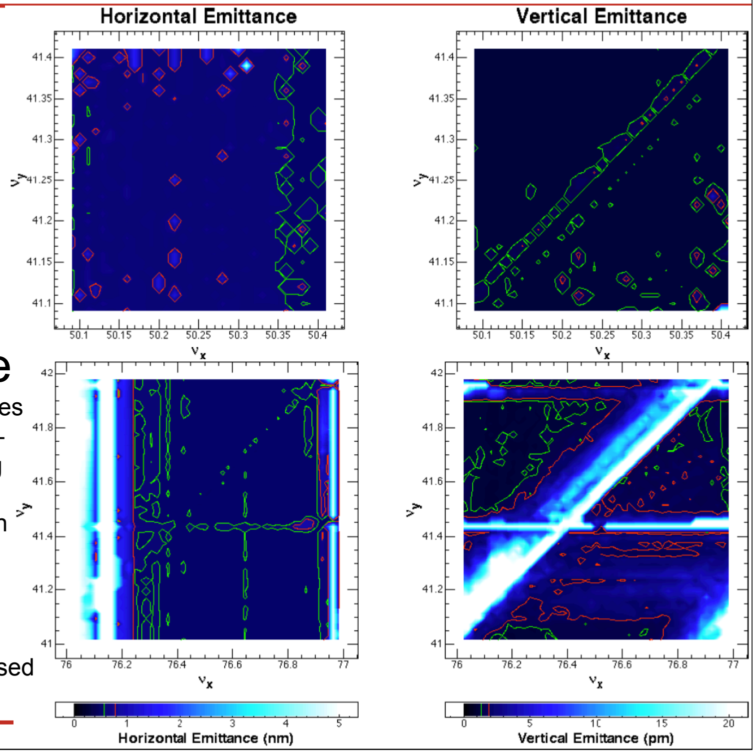
Space-Charge Comparison (OCS2 vs TESLA)

Emittance growth vs working point:

OCS Lattice

TESLA Lattice

For the TESLA lattice, studies were sensitive to the space-charge tune shift in the long straights. The incoherent tune shift grows linearly with circumference. The use of coupling bumps to mitigate the space-charge issue tended to drive coupling resonances which also caused vertical emittance growth.



Principal Instability Concerns

At the time of the configuration choice, two instabilities were identified as being of the greatest concern for the damping rings:

- The Fast Ion Instability in the electron damping ring
- The Electron Cloud Instability in the positron damping ring

We will focus on these for the remainder of the discussion on instabilities.

Ion Instabilities

In the electron damping ring, ions that are generated by the bunches interacting with the particle beam can be trapped by the fields of the beam. This can result in high concentrations of positive ions near the beam axis. The interaction of the beam with these ions can then lead to the onset of beam instabilities.

There are generally 2 classes of ion effects that are discussed in the context of an electron storage ring:

- For rings that are uniformly filled with electron bunches, the ions can build up over many turns
  - This effect is know as ion trapping
  - It can be mitigated by placing large "clearing" gaps in the bunch train during which the ions can drift away from the beam axis and escape the potential well formed by the beam
  - Clearing electrodes have also been used to help mitigate the ion build-up
- A more serious effect for the damping rings is the rapid build-up of the ion density along the bunch train during a single passage
  - This is known as the fast ion instability
  - This is expected to be a significant issue for the electron damping ring

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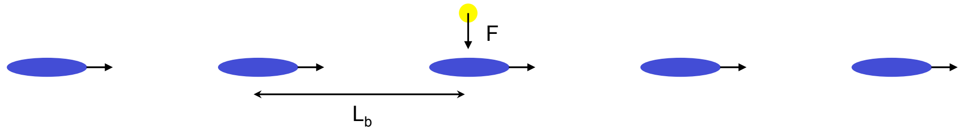
Ion-Beam Interaction

For an ion in the proximity of the beam, the electric fields of the bunches create a focusing force which acts on the ion and serves trap it near the beam axis.



The effective k-value of this focusing force is given by:

$$k = \frac{2r_p N_0}{A\sigma_y\left(\sigma_x + \sigma_y\right)}$$

where A is the atomic mass of the ion, r_p is the classical radius of the proton, and N_0, σ_x and σ_y are the bunch charge and transverse sizes of the electron beam.

Ion-Beam Interaction

The motion of the of the ion during the passage of one bunch can be expressed in terms of transfer matrices as we developed yesterday:

$$\mathbf{M} = \begin{pmatrix} 1 & s_b \\ 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} 1 & 0 \\ -k & 1 \end{pmatrix} = \begin{pmatrix} 1 - s_b k & s_b \\ -k & 1 \end{pmatrix}$$

The stability criteria is then: $Trace(\mathbf{M}) \leq 2$

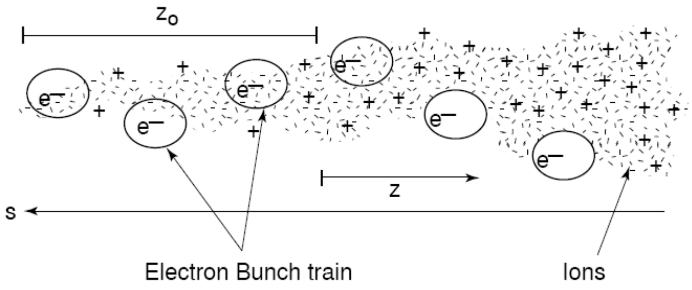
or

$$A \geq \frac{r_p N_0 s_b}{2\sigma_y (\sigma_x + \sigma_y)}$$

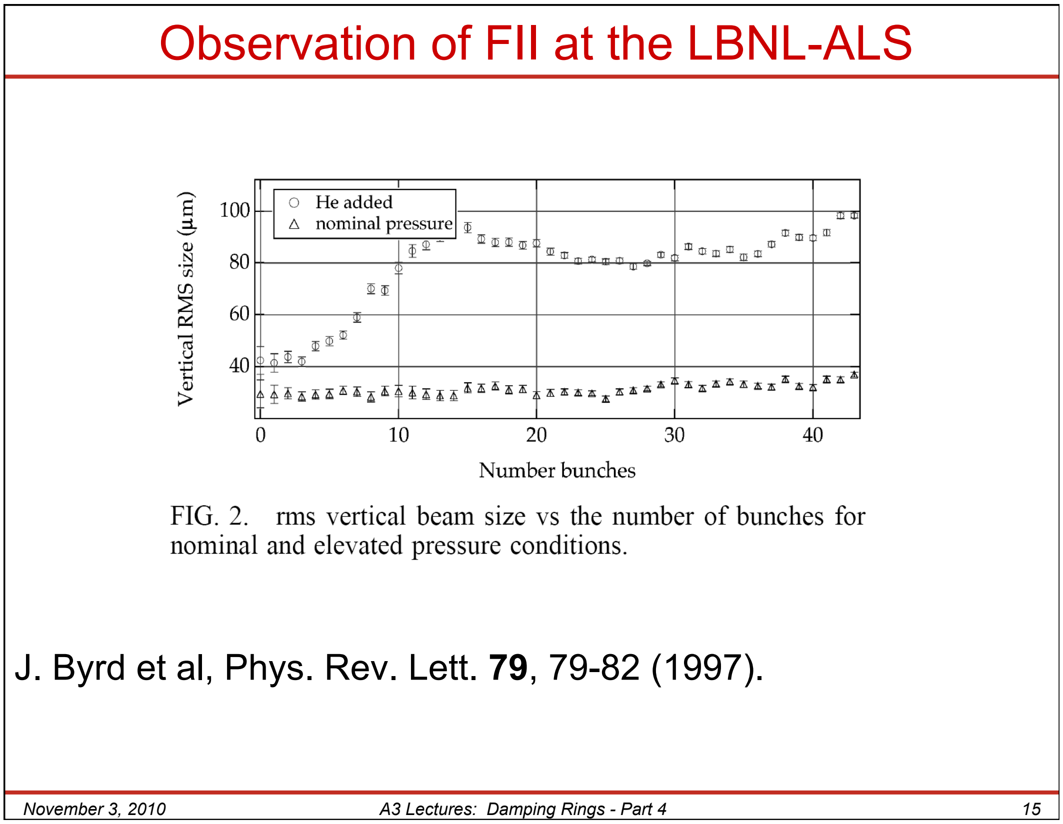
Thus, having high bunch charges or very small beam sizes increases the mass for which ion trapping will take place. For the damping rings, where the beam sizes change dramatically through the course of the damping cycle, this means that the mass of ions that can be trapped will change continuously throughout the machine's injection/extraction cycle. As already noted, this effect can be mitigated by having large gaps in the electron bunch train.

Fast ion instability

Even with large gaps in the electron bunch train, however, there can still be rapid build-up of ions along the train in a single passage. This effect was first discussed by Raubenheimer and Zimmerman and was subsequently observe in the ALS by Byrd, et al. as a blow-up in beam size along the ALS bunch-train when the pressure was artificially increased in one section of the ring by the addition of a He pressure bump.



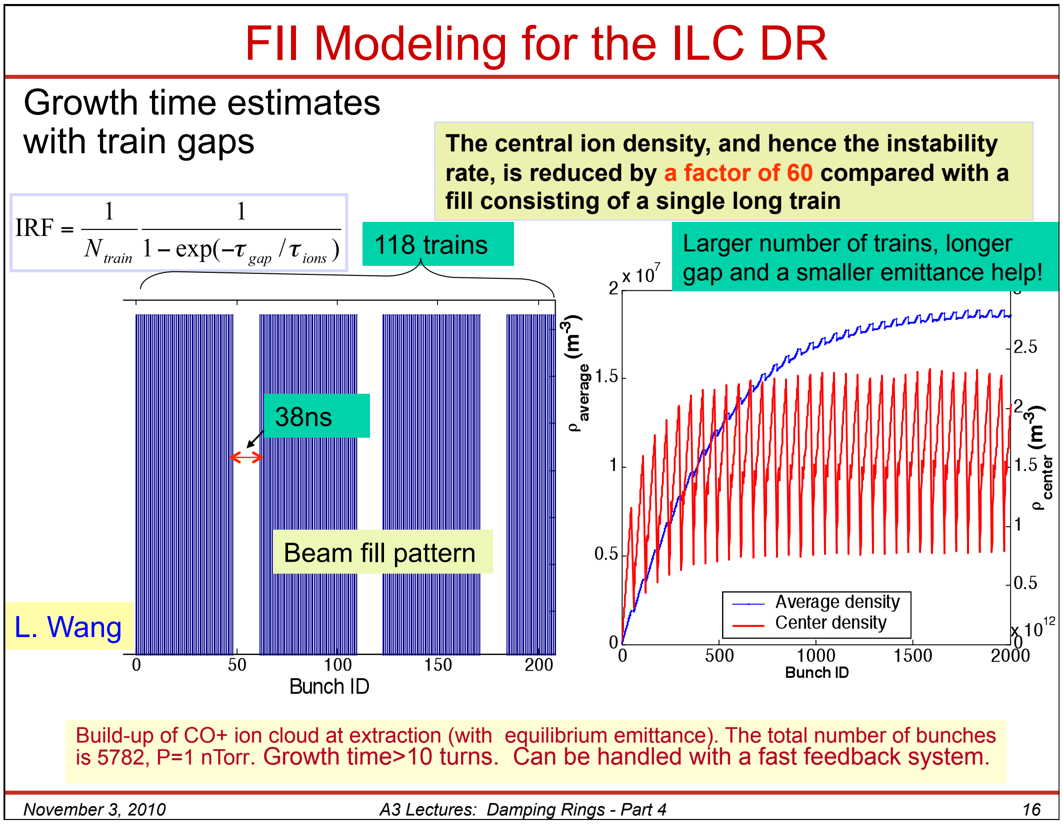
T. Raubenheimer and F. Zimmermann, Phys. Rev. E **52**, 5, 5487 (1995).



Observation of FII at the LBNL-ALS

FIG. 2. rms vertical beam size vs the number of bunches for nominal and elevated pressure conditions.

J. Byrd et al, Phys. Rev. Lett. **79**, 79-82 (1997).



FII Modeling for the ILC DR

Growth time estimates with train gaps

$$\mathrm{IRF} = \frac{1}{N_{train}} \frac{1}{1-\exp(-\tau_{gap}/\tau_{ions})}$$

The central ion density, and hence the instability rate, is reduced by a factor of 60 compared with a fill consisting of a single long train

118 trains

Larger number of trains, longer gap and a smaller emittance help!

38ns

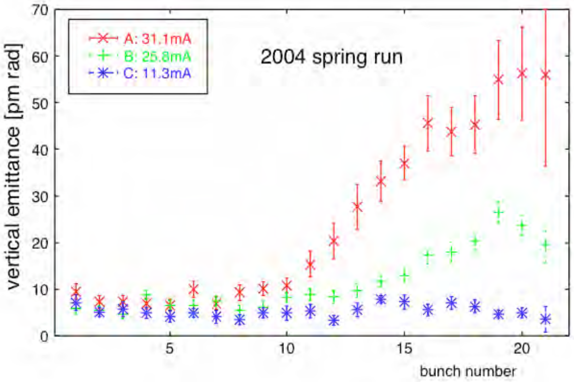
Beam fill pattern

L. Wang

Build-up of CO+ ion cloud at extraction (with equilibrium emittance). The total number of bunches is 5782, P=1 nTorr. Growth time>10 turns. Can be handled with a fast feedback system.

FII R&D

The FII has also been observed at the KEK-ATF:



Vertical emittances along a bunch train as measured during 2004 ATF run

Further measurements are planned in order to characterize the FII with the ultra-low emittance beams that ATF can provide. A critical deliverable is whether suitable specifications for the vacuum system, bunch train configuration, and bunch-by-bunch feedback system can be achieved to suppress this instability.

Electron Cloud Instability

The electron cloud instability has become the dominant issue for the operation of the ILC positron damping ring. A key component of the ILC Technical Design Phase is an ongoing R&D program into mitigation techniques to ensure that the build-up of the electron cloud can be reduced to levels that will not impact the emittance performance of the positron DR. In addition, beam dynamics studies with ultralow emittance beams are planned to characterize the cloud-induced dynamics in this regime and to provide data which can benchmark the modeling tools in a regime much closer to that of the ILC DR.

Electron Cloud Instability

Our discussion of the electron cloud (EC) instability will focus on several issues. We will:

1. Take a qualitative look at how the cloud is formed and interacts with a particle beam
2. Look at the predictions of how significant EC effects are expected to be for the operation of the ILC positron damping ring
3. Review of some of the existing observations of the cloud
4. Look at some of the methods that have been employed to measure the electron cloud
5. Look at ways to mitigate the electron cloud
6. Review the key components of the R&D plan for the ILC damping rings that are needed to give us confidence that we can successfully build and commission these challenging machines

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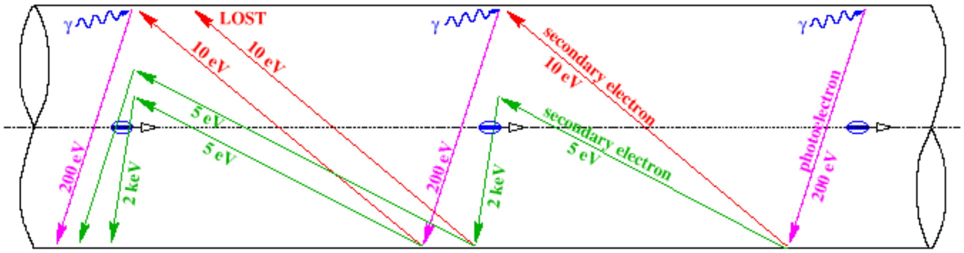
Electron Cloud Instability

The following picture illustrates the build-up of the electron cloud in a vacuum chamber and how it can interact with a positron beam



Key features of this picture are:

- Synchrotron photons striking the chamber walls produce primary photoelectrons
- The photoelectrons can strike the vacuum chamber wall and produce secondary electrons which typically have energies of a few eV
- When a cloud electron passes near a bunch, it receives a kick and can be accelerated to much higher energies before striking the wall
- Rapid multiplication of the number of electrons in the chamber along a bunch train can lead to cloud densities of sufficient magnitude to cause beam instabilities and emittance growth

Features of the EC Build-up

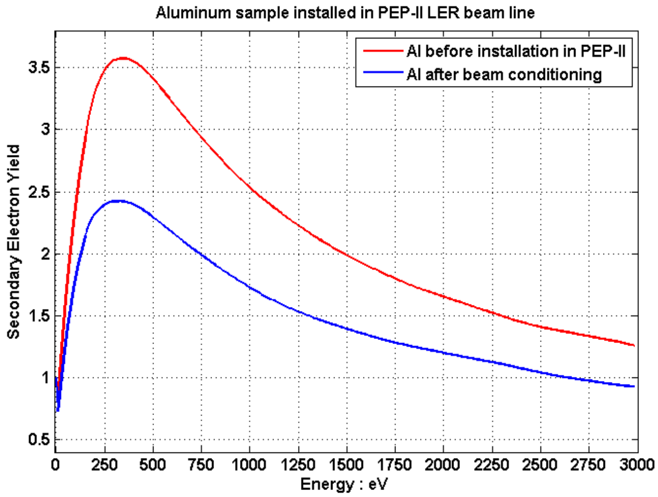
In an accelerator vacuum system the growth of the electron cloud is dependent on a wide range of parameters:

- The bunch structure of the beam, both intensity and bunch spacing
- The surface properties of the vacuum chamber
- The geometry of the vacuum chamber
- The presence and geometry of electric and magnetic fields in the vacuum chamber
- Various sources for electrons including primary photoelectrons, secondary electrons, and electrons from the ionization process
- The properties of electrons which are produced in the chamber (typical energy, angular spread)

All of these issues have been incorporated into a number of EC simulation codes which are used to model the growth of the cloud and its interaction with the beam.

The Secondary Electron Yield (SEY)

A key parameter for understanding the development of the electron cloud is the secondary electron yield. This parameter describes the number of secondary electrons produced when an incident electron strikes the surface of the vacuum chamber.

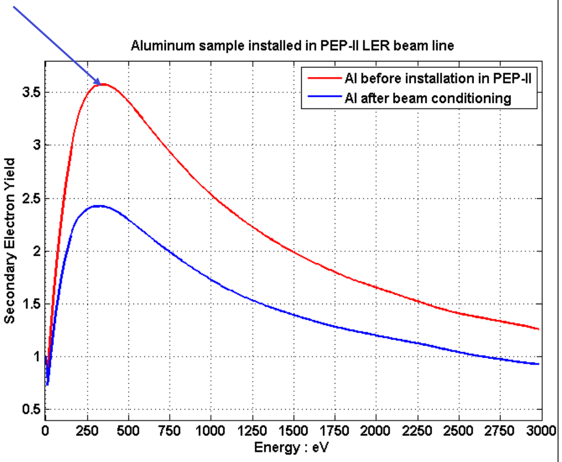


M. Pivi, SLAC
Measurements of the SEY yield of an Al surface before and after beam conditioning with synchrotron radiation

The Secondary Electron Yield (SEY)

Some comments on the SEY curve:

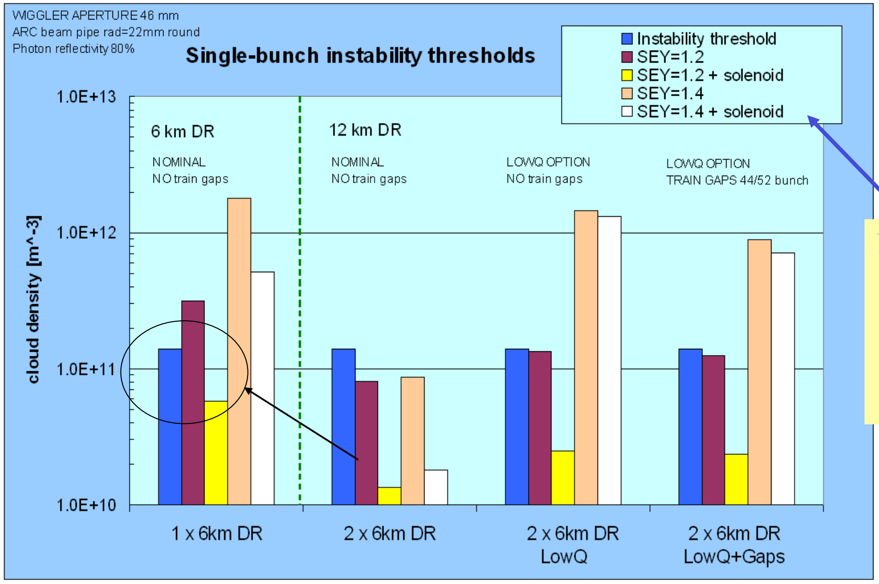
- When a single value for the SEY of a material is quoted, it is the height of the peak in the SEY curve.
- The SEY varies with the energy and angle of the incident particle.
- The SEY is dependent on the surface properties of a material. The surface properties may vary significantly depending on the history of the sample.



EC Predictions for the ILC e^+ DR

How large a ring is required???

M. Pivi
ILCDR06

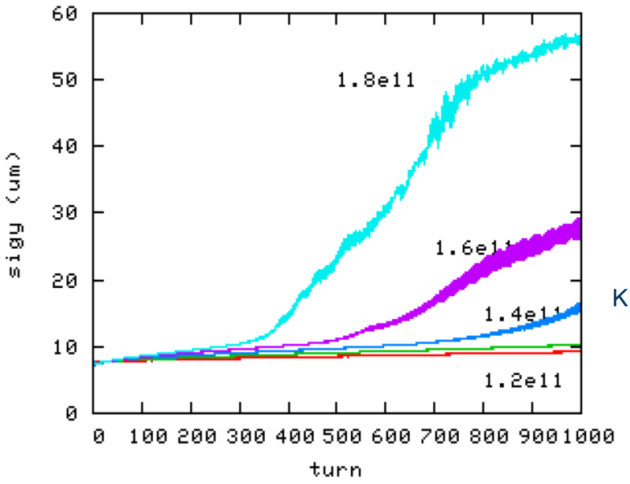


No additional suppression techniques assumed in dipoles and wigglers!

Cloud density near (r=1mm) beam (m^{-3}) before bunch passage, values are taken at a cloud equilibrium density. Solenoids decrease the cloud density in DRIFT regions, where they are only effective. Compare options LowQ and LowQ+train gaps. All cases wiggler aperture 46mm.

Emittance Growth Studies

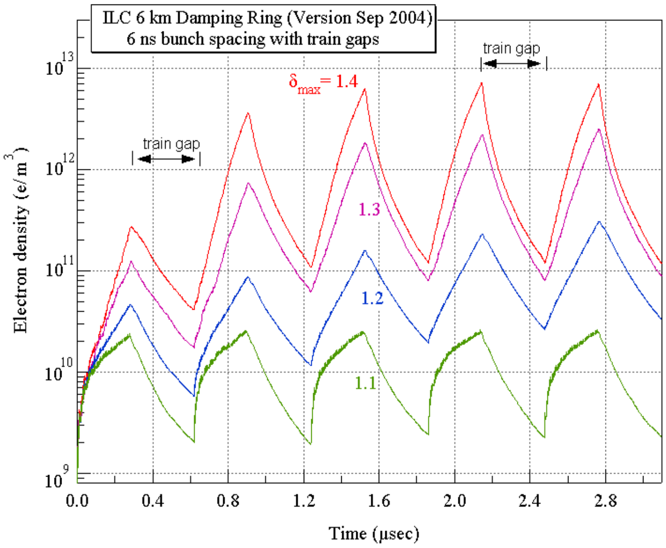
Studies of the EC interaction with the beam indicate that instabilities in the ILC DR positron beams will start at cloud densities of ~1.4×10^{11}m^{-3} (the simulation assumes that the SEY value in the vacuum chambers is ~1.2). Above this threshold, emittance growth of the beam sets in. This threshold places limits on acceptable SEY values for the damping ring vacuum chambers.



K. Ohmi KEK

Modeling the EC Growth

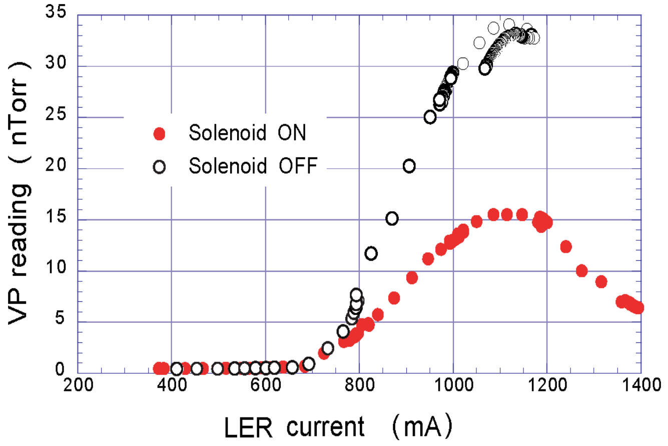
Growth of the EC in a drift space for a 6 km damping ring – simulated using POSINST



M. Pivi

Observations of the Electron Cloud

The electron cloud can be observed by looking at its impact on the vacuum in storage ring, by using local detectors mounted on the surface of vacuum chambers, and through its interaction with the beam.



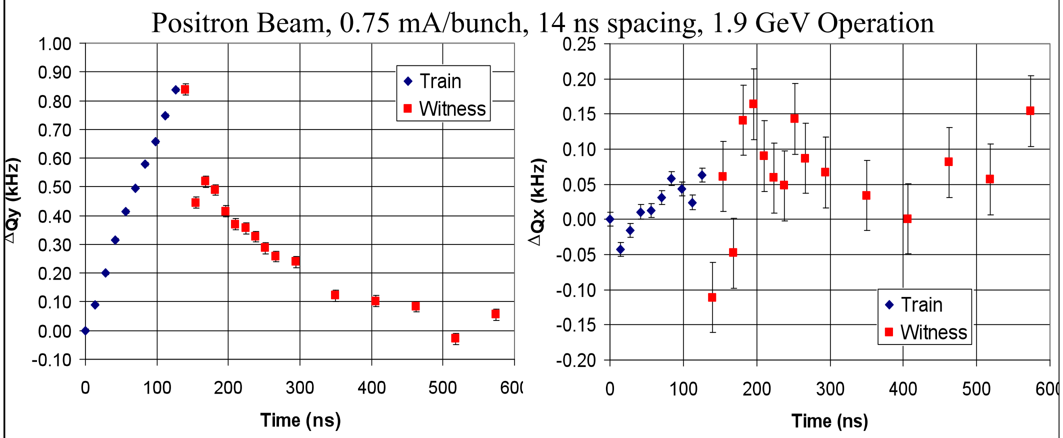
Pressure rise observed in the PEP-II LER

A. Kuliokov et al, PAC01

Measurements of the EC Tune Shift

Initial train of 10 bunches ⇨ generate EC

Measure tune shift and beamsize for witness bunches at various spacings



Error bars represent scatter observed during a sequence of measurements

1 kHz ⇨ $\Delta\nu = 0.0026$

$\rho_e \sim 1.5 \times 10^{11}$ m^{-3}

Ohmi, etal, APAC01, p.445

The EC Tune Shift

In order to understand the observed tune shifts, consider Poisson's equation which gives:

$$\frac{\partial E_x}{\partial x}+\frac{\partial E_y}{\partial y}=\frac{e\rho\left(x,y\right)}{\varepsilon_0}$$

We can then write:

$$\Delta Q_{x(y)}=\frac{e}{4\pi E_0}\oint ds\beta_{x(y)}\left\langle\frac{\partial E_{x(y)}}{\partial x\left(y\right)}\right\rangle_{beam\ distribution}$$

If we assume $\beta_x \sim \beta_y \sim \beta$, we can then write a very simple expression for the sum of the horizontal and vertical tune shifts:

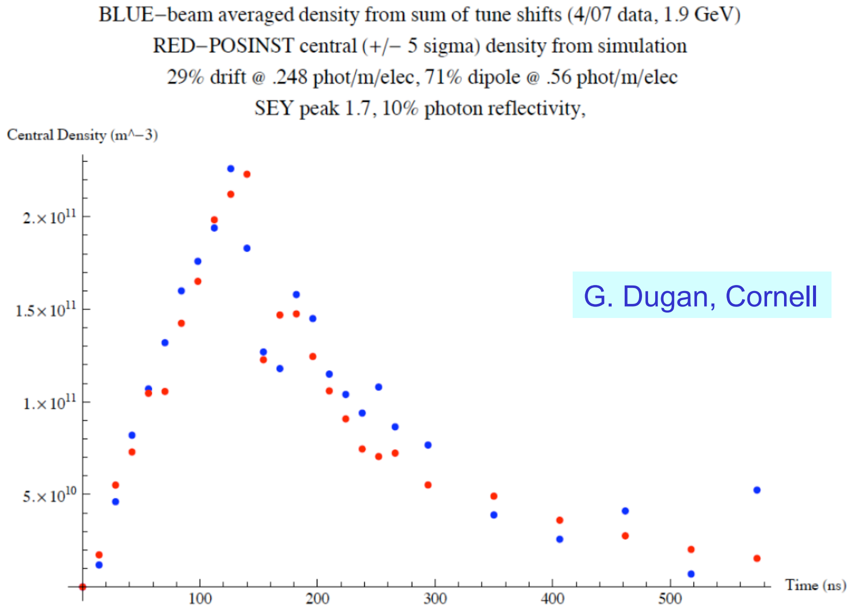
$$\Delta Q_x+\Delta Q_y=\frac{e}{4\pi E_0}\oint ds\left(\beta_x\left\langle\frac{\partial E_x}{\partial x}\right\rangle+\beta_y\left\langle\frac{\partial E_y}{\partial y}\right\rangle\right)$$

$$\approx\frac{e}{4\pi E_0}\oint ds\beta\left(\left\langle\frac{\partial E_x}{\partial x}\right\rangle+\left\langle\frac{\partial E_y}{\partial y}\right\rangle\right)$$

NOTE: This effectively assumes the EC distribution stays static during the bunch passage – not quite true ⇨ modifies the result somewhat. But this is quite close…

$$\boxed{\Delta Q_x+\Delta Q_y\approx\frac{e^2}{4\pi\varepsilon_0 E_0}\oint ds\beta\left\langle\rho\right\rangle_{beam\ distribution}}$$

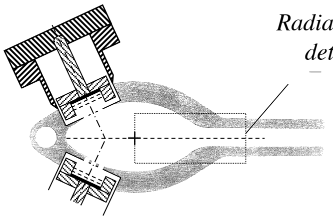
Data vs Simulation


BLUE–beam averaged density from sum of tune shifts (4/07 data, 1.9 GeV)
RED–POSINST central (+/– 5 sigma) density from simulation
29% drift @ .248 phot/m/elec, 71% dipole @ .56 phot/m/elec
SEY peak 1.7, 10% photon reflectivity,

G. Dugan, Cornell

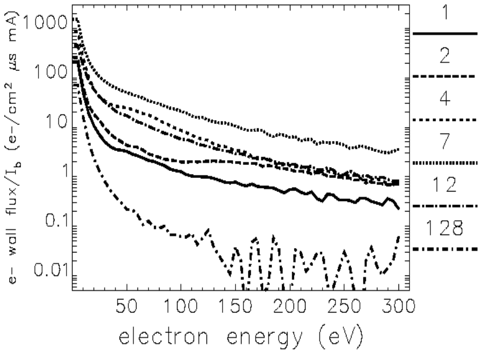
Retarding Field Analyzers

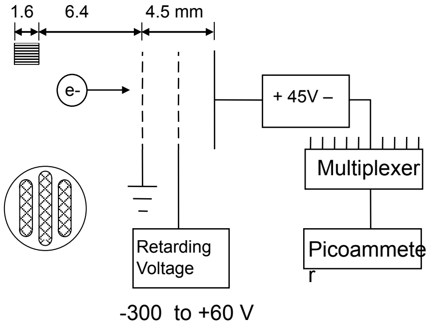
RFA measures distribution of EC colliding with walls, T~50%



Radiation fan at det. #6 for $^{-}$ *≥ 4 eV*

mounting on APS Al chamber ***behind vacuum penetration*** *(42* x *21 mm half-dim.)*

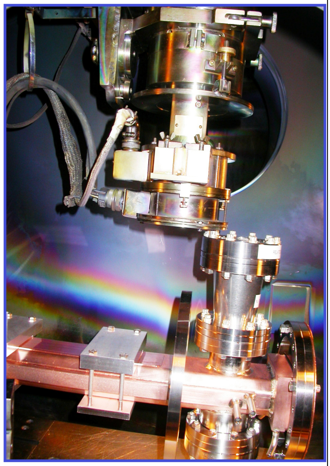


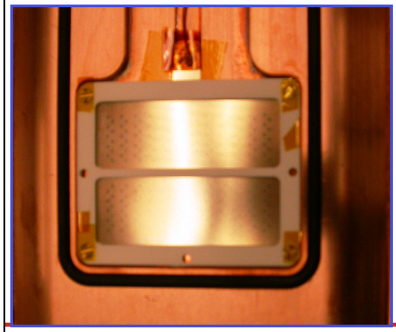


-300 to +60 V

K. Harkay, APS

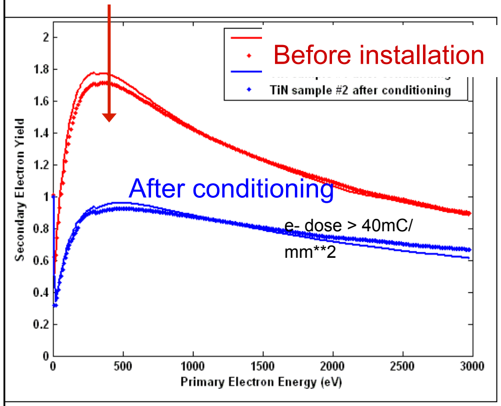
RFAs for CesrTA Diagnostic Wigglers

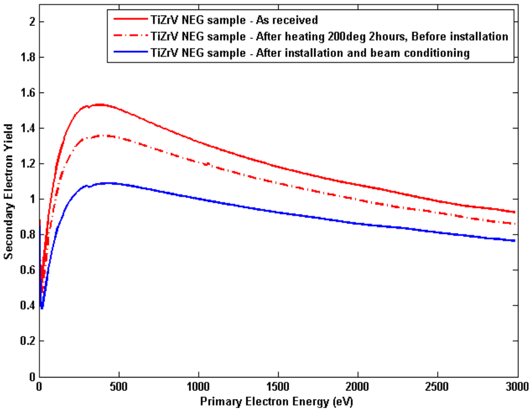




Mitigation of the EC

One method is to coat the surface of vacuum chambers with low SEY materials. TiN is an excellent candidate and shows SEY peak values that drop below unity after suitable processing. NEG coatings are also promising.



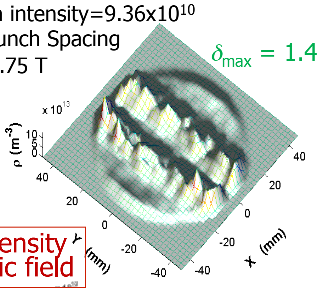


ILC tests, M. Pivi et al. – SLAC

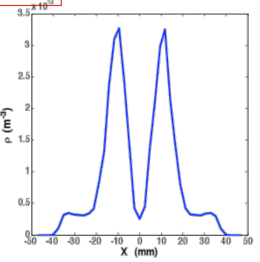
Clearing Electrodes to Suppress Electron Cloud in Wigglers

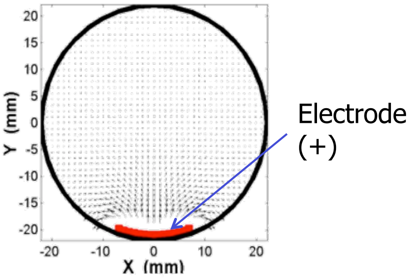
Simulations indicating the ability of an electrode to suppress the EC in an ILC DR wiggler chamber

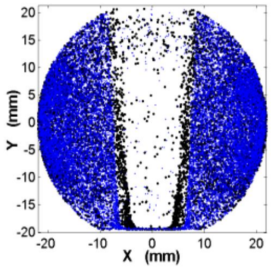
R-pipe=38mm
bunch intensity=9.36x10^{10}
3.5 Bunch Spacing
B = 0.75 T



Electron density in magnetic field







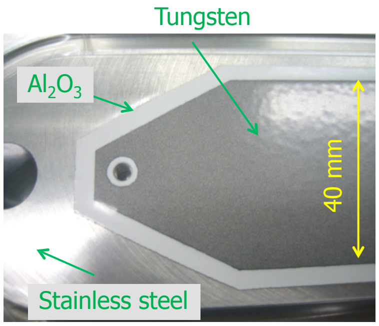
L. Wang et al, EPAC2006, p.1489

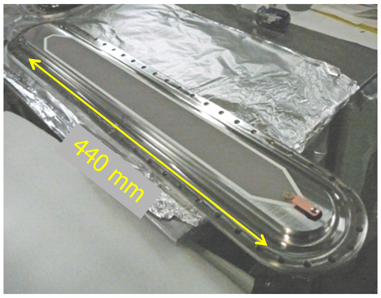
Electrode in KEKB Wiggler

New strip type electrode technology was developed.

Employs a very thin electrode and insulator;

- Electrode: ~0.1 mm, Tungsten, by thermal spray.
- Insulator: ~0.2 mm, Al_2O_3, by thermal spray.

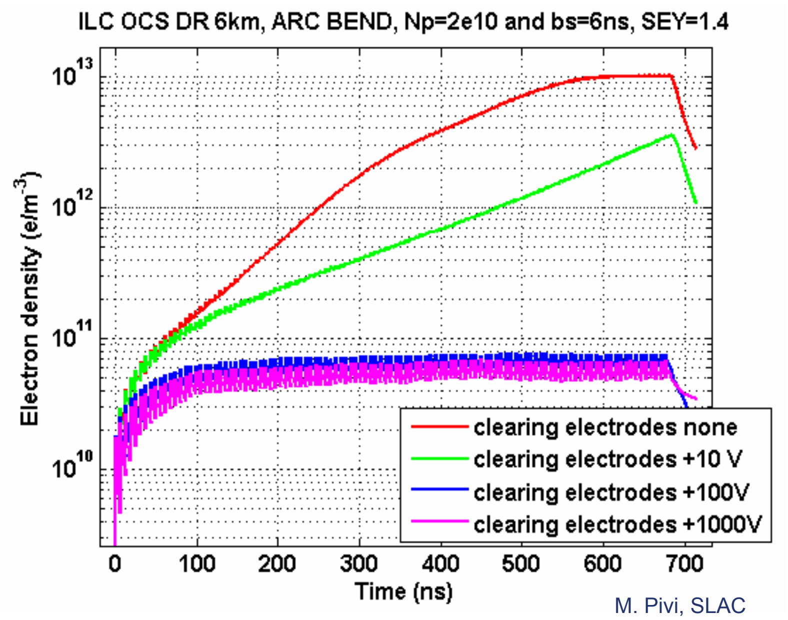




Y. Suetsugu,
KEKB

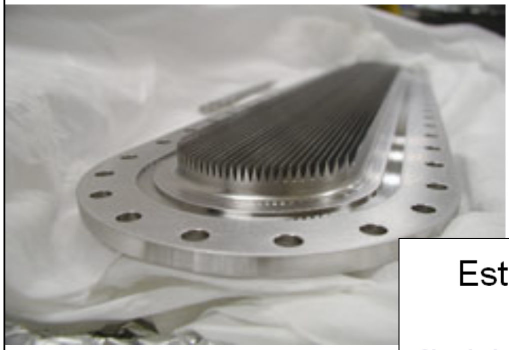
Clearing Electrodes for the ILC DR Dipoles

Modeling of electrodes for use in the ILC DR dipoles

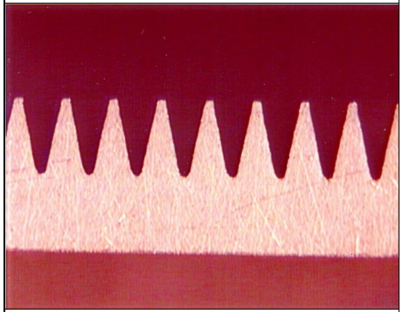


M. Pivi, SLAC

Grooved Surfaces



Grooved surfaces can also suppress the cloud (but increase the vacuum chamber impedance)



Estimation of SEY of the triangular groove

Simulation Parameters

Peak SEY δ_0=1.2

Width =2mm

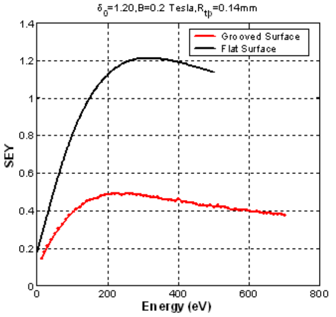
Height=3.82mm

Radius of tip=0.14mm

α=78.6º

Dipole field=0.2Tesla

1. Use the same radius for both tip and bottom
2. Slope angle is adjusted to keep the height same as the measured one

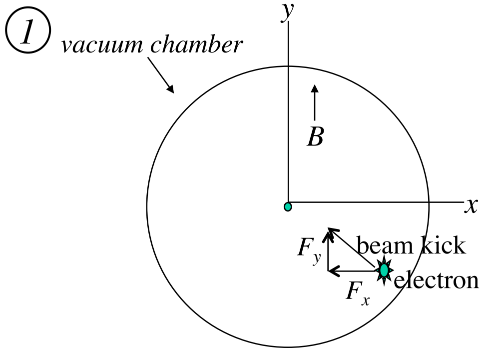


Recent estimation based on extruded groove chamber geometry

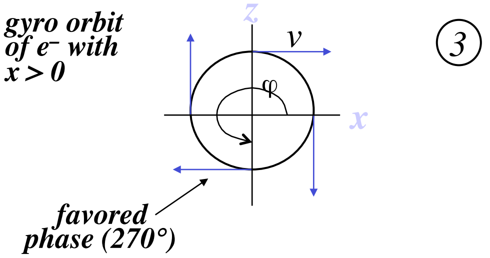
Resonant Excitation of Cloud in Magnetic Fields

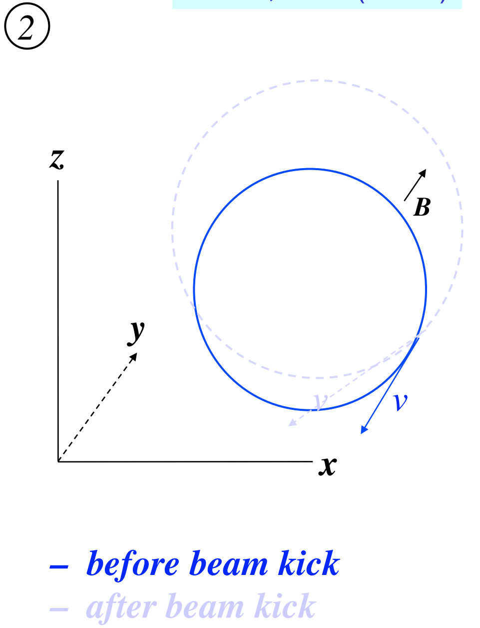
A recent discovery… Observed at PEP-II

Celata, et al. (LBNL)



F_x is always toward the center

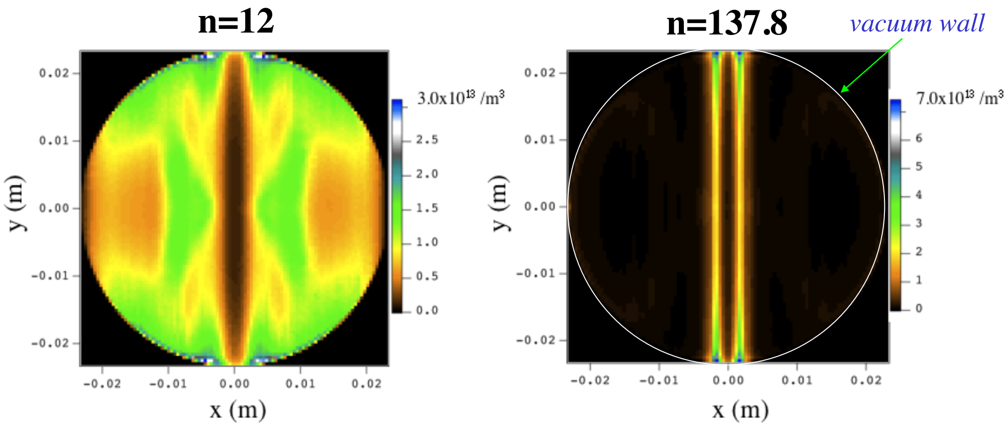




Simulation of Cyclotron Resonances in Cloud

Celata, et al. (LBNL)

Color contour plots of electron density averaged over entire simulation



The high-field(no resonance) case shows the characteristic "stripes" pattern seen in many experiments. At resonance the electrons are much more widely distributed in x.

ILC Damping Rings R&D Program

The ILC R&D program identified 4 key areas for work during part I (2008-2010) of the Technical Design Phase

- Understanding the electron cloud in the ILC DR parameter regime and developing methods to suppress it
- Ensuring that the fast ion instability can be controlled in the electron damping ring
- Developing fast injection/extraction kickers
- Demonstration of ultralow vertical emittance operation ($\varepsilon_y = 2\ pm$)
  This has now been demonstrated at light sources

Two dedicated test facilities were identified for this effort:

- CESRTA at Cornell (+ collaborators)
- ATF at KEK (+ collaborators)

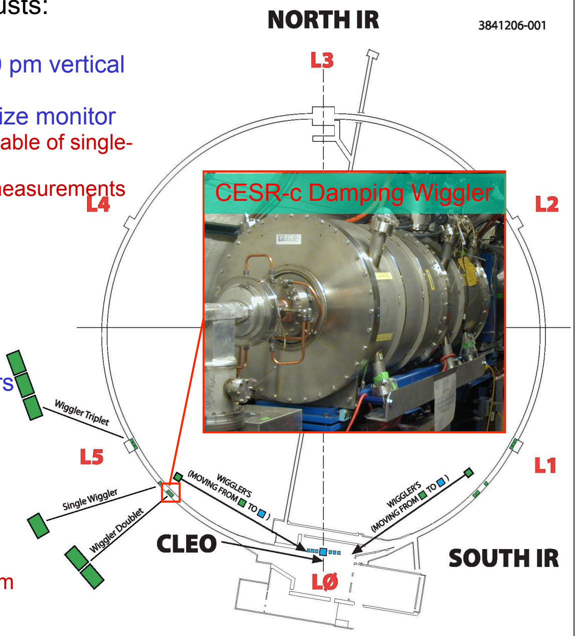
Contributors from institutions world-wide

- Simulation and Experiment
- EC Mitigation Methods
- Low Emittance Tuning
- Design Work

CESRTA Program

2.5 Year R&D Program with 3 major thrusts:

- ✔ Electron cloud studies
- ✔ Low emittance program (target of 20 pm vertical emittance)
- Development of a fast X-ray beam size monitor
  - ✔ Target bunch-by-bunch monitor capable of single-pass measurements for ILC DR
  - Resolution for ultra-low emittance measurements



CesrTA Configuration:

- 12 damping wigglers located in zero dispersion regions for ultra low emittance operation (move 6 wigglers from machine arcs to L0)
- Diagnostic vacuum chambers with EC suppression methods
- Designated sections available for installation of test devices
- Precision instrumentation
  - Multi-bunch turn-by-turn BPM system
  - Fast X-ray beam profile monitors
- 4 ns bunch train operation

CESRTA Parameters

Lattice Parameters

Ultra low emittance baseline lattice

Energy [GeV]	2.085	5.0	5.0
No. Wigglers	12	0	6
Wiggler Field [T]	1.9	—	1.9
Q_x	14.57		
Q_y	9.62		
Q_z	0.075	0.043	0.043
V_{RF} [MV]	8.1	8	8
ε_x [nm-rad]	2.5	60	40
$\tau_{x,y}$ [ms]	57	30	20
α_p	6.76×10^{-3}	6.23×10^{-3}	6.23×10^{-3}
σ_l [mm]	9	9.4	15.6
σ_E/E [%]	0.81	0.58	0.93
t_b [ns]	≥4, steps of 2		

Range of optics implemented

Beam dynamics studies

Control photon flux in EC experimental regions

E[GeV]	Wigglers (1.9T/PM)	ε_x[nm]	
1.8*	12/0	2.3	IBS Studies
2.085	12/0	2.5	
2.3	12/0	3.3	
3.0	6/0	10	
4.0	6 /0	23	
4.0	0 /0	42	
5.0	6/0	40	
5.0	0/0	60	
5.0	0/2	90	

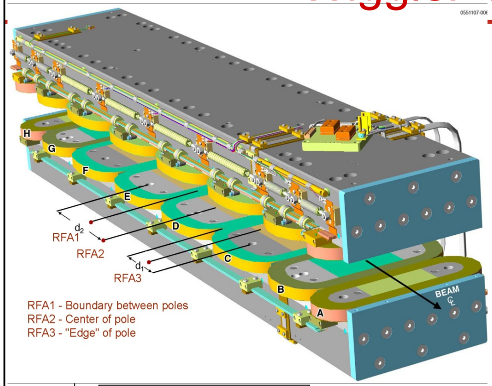
* Orbit/phase/coupling correction and injection but no ramp and recovery. In all other optics there has been at least one ramp and iteration on injection tuning and phase/coupling correction

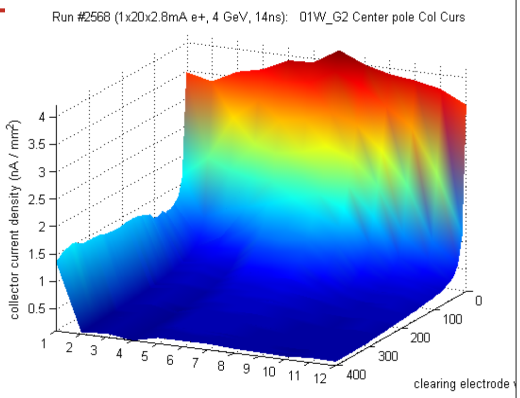
Mitigation Tests

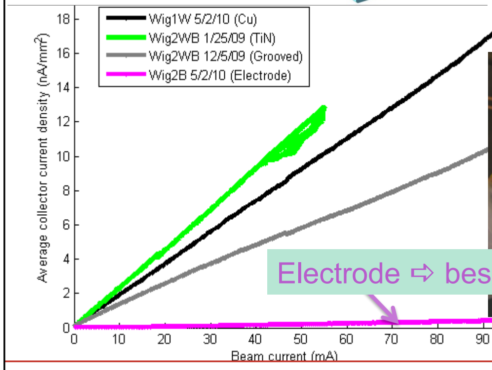
	Drift	Quad	Dipole	Wiggler	VC Fab
Al	✓	✓	✓		CU, SLAC
Cu	✓			✓	CU, KEK, LBNL, SLAC
TiN on Al	✓	✓	✓		CU, SLAC
TiN on Cu	✓			✓	CU, KEK, LBNL, SLAC
Amorphous C on Al	✓				CERN, CU
NEG on SS	✓				CU
Solenoid Windings	✓				CU
Fins w/TiN on Al	✓				SLAC
Triangular Grooves on Cu				✓	CU, KEK, LBNL, SLAC
Triangular Grooves w/TiN on Al			✓		CU, SLAC
Triangular Grooves w/TiN on Cu				✓	CU, KEK, LBNL, SLAC
Clearing Electrode				✓	CU, KEK, LBNL, SLAC

✓ = chamber(s) deployed ✓ = planned

Wiggler Observations







Thermal Spray Electrode (KEK)

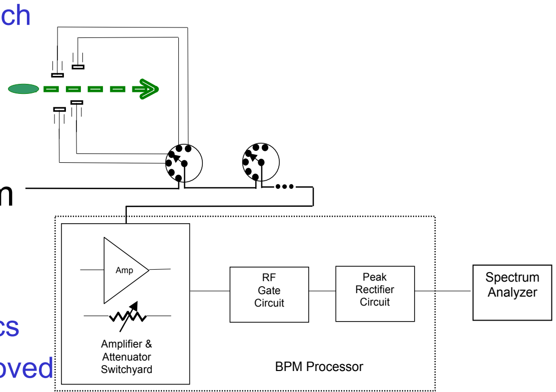
0.002" radius

Electrode ⇨ best performance

Measurement Technique for EC-induced Beam Dynamics

Frequency spectra of individual bunches from single button BPM routed to spectrum analyzer (10 s averaging)

- Sensitive to both V and H motion
- Signal is gated on a single bunch



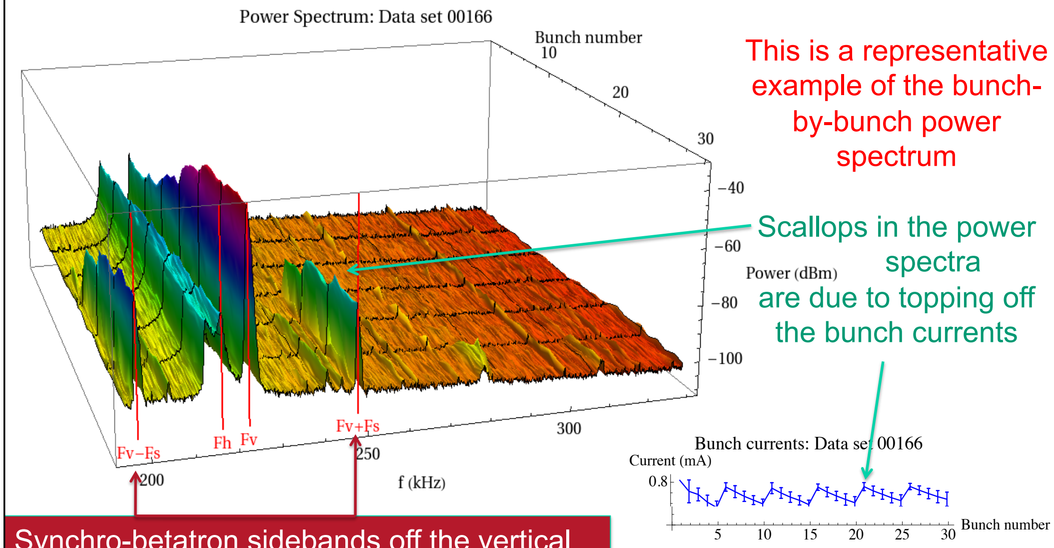
Machine conditions (e.g. bunch currents, magnet & feedback settings) recorded before and after each spectrum

Systematic checks:

- Ruled out inter-modulation distortion in the BPM electronics
- Betatron and head-tail lines moved as expected when vertical, horizontal, & synchrotron tunes were varied.

Conditions: 2.1 GeV, ε_H=2.6 nm, ε_V=20 pm, α_P=6.8x10^{-3}, σ_Z=10.8 mm, Q_H,Q_V,Q_S=14.57, 9.6, 0.065 30-45 bunch trains: 0.5-1 mA (0.8-1.6x10^{10})

Bunch-by-Bunch Power Spectrum

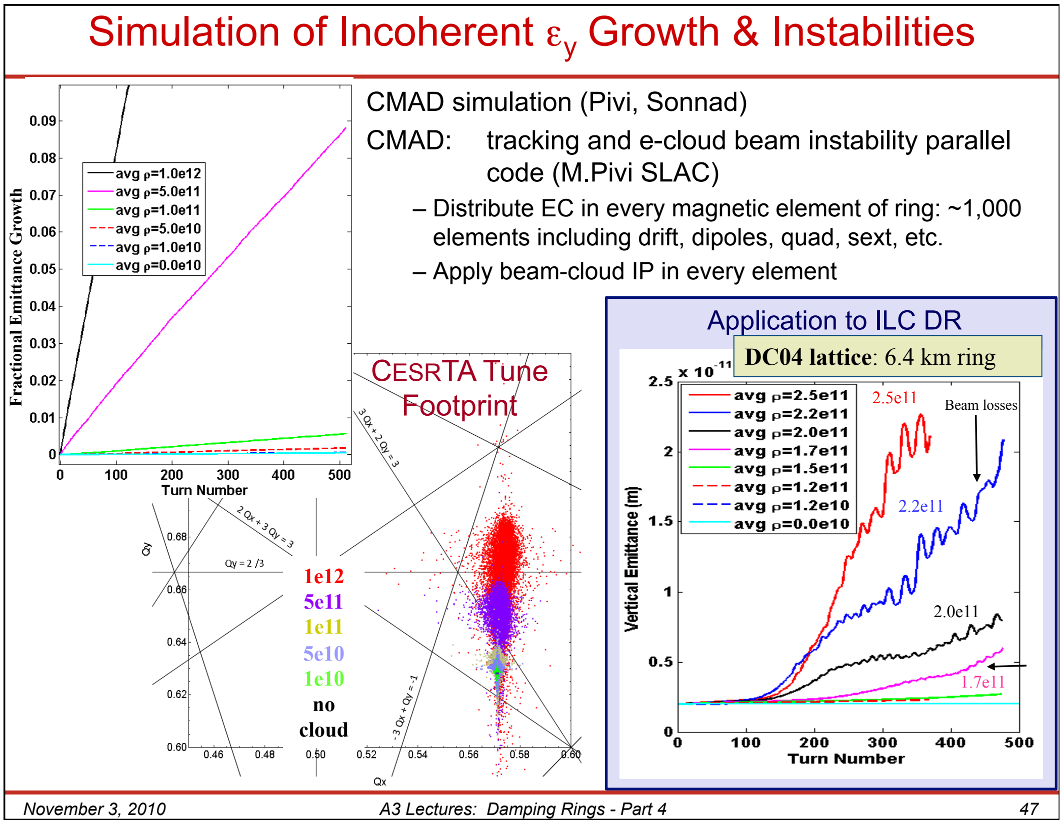


This is a representative example of the bunch-by-bunch power spectrum

Scallops in the power spectra are due to topping off the bunch currents

Synchro-betatron sidebands off the vertical tune are a signature of a head-tail instability. Onset around bunch 15 is consistent with this being an EC-induced instability.

(H,V) chrom = (1.33,1.155)
0.74 mA/bunch ➪ 1.2×10^{10}



Simulation of Incoherent ε_y Growth & Instabilities

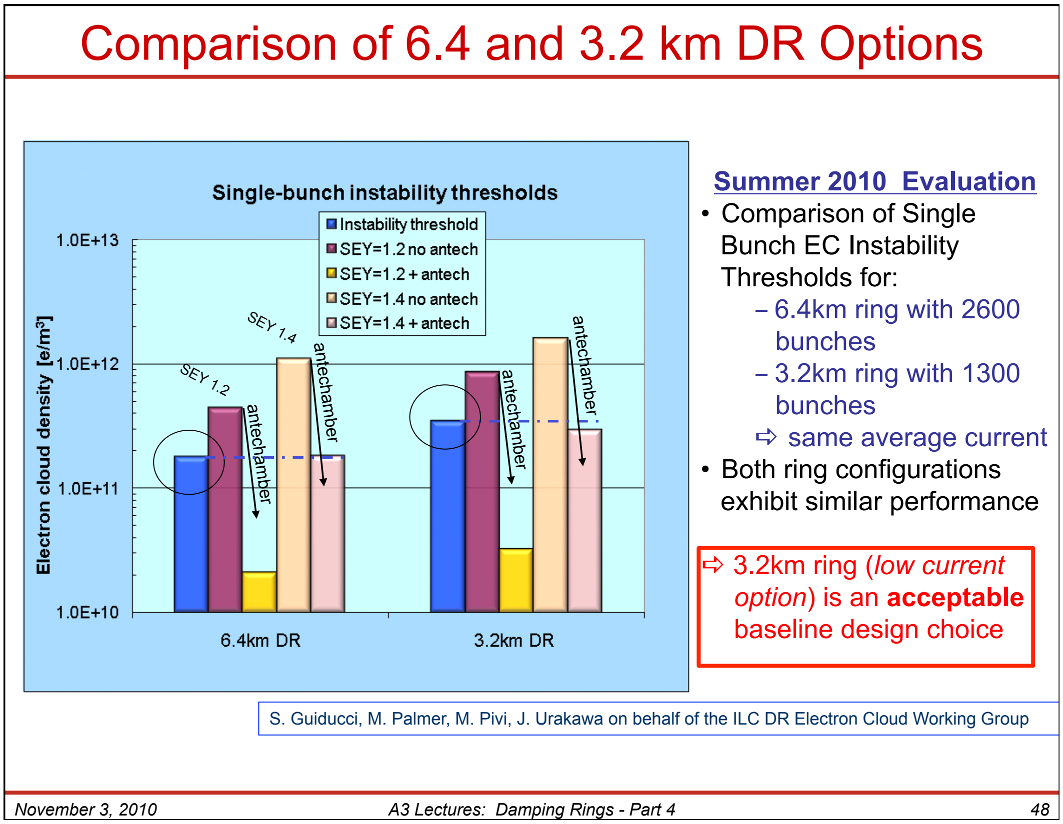
CMAD simulation (Pivi, Sonnad)

CMAD: tracking and e-cloud beam instability parallel code (M.Pivi SLAC)

- Distribute EC in every magnetic element of ring: ~1,000 elements including drift, dipoles, quad, sext, etc.
- Apply beam-cloud IP in every element

Application to ILC DR

DC04 lattice: 6.4 km ring



Comparison of 6.4 and 3.2 km DR Options

Summer 2010 Evaluation

- Comparison of Single Bunch EC Instability Thresholds for:
  - 6.4km ring with 2600 bunches
  - 3.2km ring with 1300 bunches
  - ⇨ same average current
- Both ring configurations exhibit similar performance

⇨ 3.2km ring (*low current option*) is an **acceptable** baseline design choice

S. Guiducci, M. Palmer, M. Pivi, J. Urakawa on behalf of the ILC DR Electron Cloud Working Group

EC Working Group Baseline Mitigation Plan

Mitigation Evaluation conducted at satellite meeting of ECLOUD`10 (October 13, 2010, Cornell University)

EC Working Group Baseline Mitigation Recommendation

	Drift*	Dipole	Wiggler	Quadrupole*
Baseline Mitigation I	TiN Coating	Grooves with TiN coating	Clearing Electrodes	TiN Coating
Baseline Mitigation II	Solenoid Windings	Antechamber	Antechamber	
Alternate Mitigation	NEG Coating	TiN Coating	Grooves with TiN Coating	Clearing Electrodes or Grooves

*Drift and Quadrupole chambers in arc and wiggler regions will incorporate antechambers

- Preliminary CESRTA results and simulations suggest the presence of *sub-threshold emittance growth*
  - Further investigation required
  - May require reduction in acceptable cloud density ⇨ reduction in safety margin
- An aggressive mitigation plan is required to obtain optimum performance from the 3.2km positron damping ring and to pursue the high current option

S. Guiducci, M. Palmer, M. Pivi, J. Urakawa on behalf of the ILC DR Electron Cloud Working Group

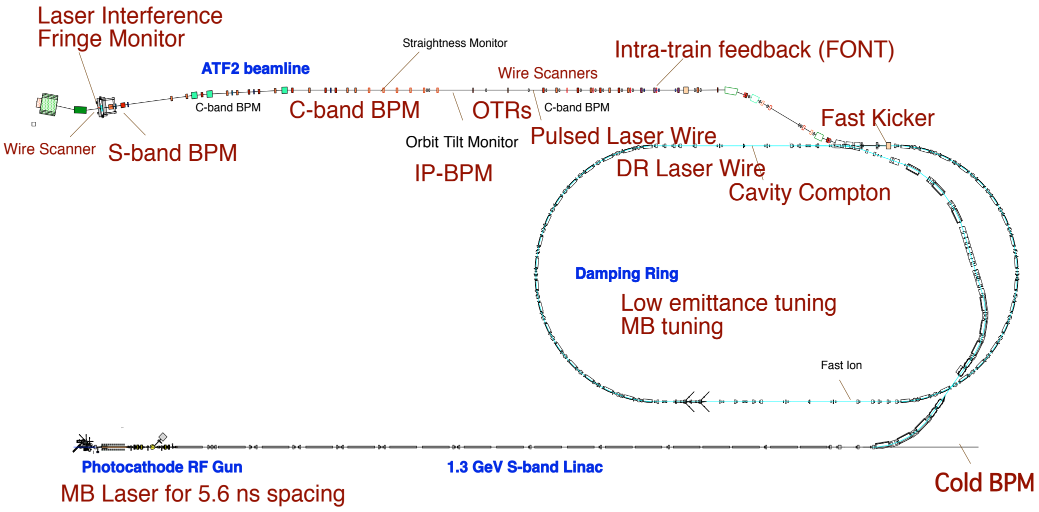
KEK-ATF and ATF2

ATF: 1.28 GeV

Bunch structure: 1-20 bunches/train, 2×10^{10}e/bunch (up to 3 trains)

Targeting 1 pm vertical emittance in damping ring

Now supporting Beam Delivery System R&D through the ATF2 beamline

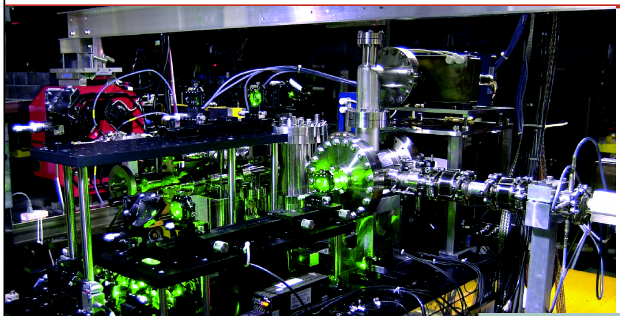


ATF

The ATF Damping Ring program has supported a wide range of important research for many years:

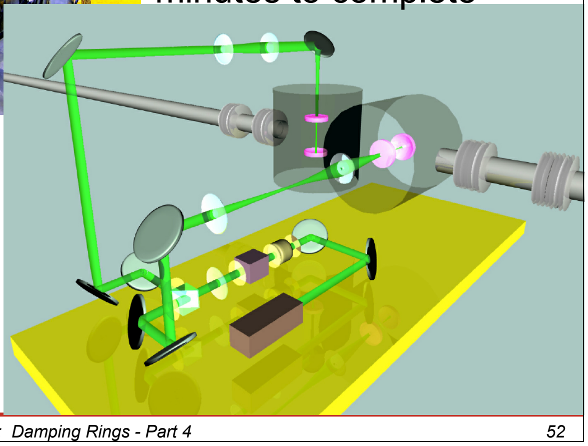
- Intrabeam Scattering Studies
- Studies of the Fast Ion Effect as shown earlier in this lecture
- Fast Kicker Studies
- Instrumentation Development of many types
    - Laser Wire
    - OTR
    - ODR
    - High Resolution X-ray Monitor
    - And others
- FONT Feedback System Development
- Compton Scattering experiment
- Etc.

Laser wire beam size monitor: KEK-ATF



Measure rate of scattered photons as laser beam scanned through e$^-$ beam

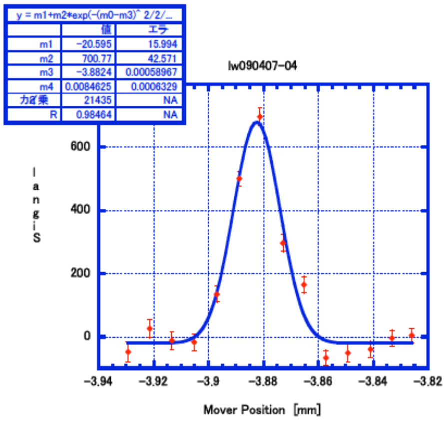
Measurement can be gatec for individual bunches, but typically takes several minutes to complete



High Resolution Beam Size Measurements

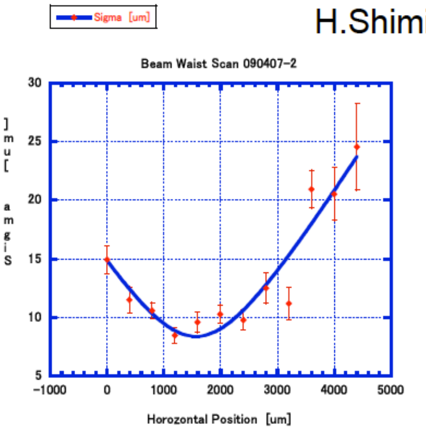
Laser Wire Measurement

H.Shimizu



y = m1+m2*exp(-(m0-m3)^ 2/2/...

	値	エラ
m1	-20.595	15.994
m2	700.77	42.571
m3	-3.8824	0.00058967
m4	0.0084625	0.0006329
カイ2乗	21435	NA
R	0.98464	NA



Minimum size measured=8.46um
Measured Laser waist=5.96um
→ e beam size=~6um

Scanning in horizontal position
Fitting with

$$\begin{aligned}\sigma^2_{\mathrm{Obs.}} &= \sigma^2_e + \sigma^2_{\mathrm{LW}} \\ &= \sigma^2_e + \frac{\lambda}{4\pi} z_0 \left\{1 + \frac{(z-c)^2}{z_0^2})\right\}\end{aligned}$$

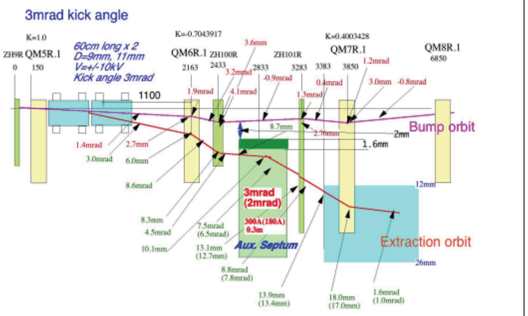
e beam size=6.41±1.07um

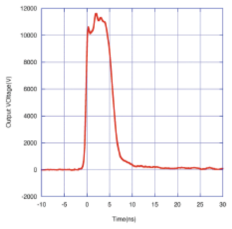
Assuming β_y~5m, ε_y=~7pm

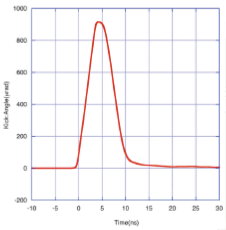
ATF Kicker Extraction Test Setup

T. Naito

- *The beam extraction test was proposed to confirm the performance of the strip-line kicker.*
- *The pulsed magnet kicker was replaced to two units of 60cm long strip-line kicker.*
- *To help the lack of the kick angle, a local bump orbit and an auxiliary septum is used.*

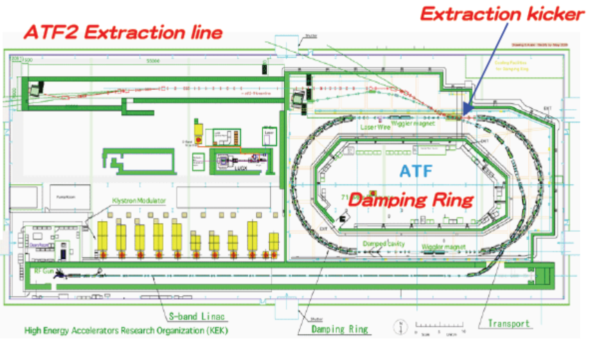






Kicker pulse

Kicker field

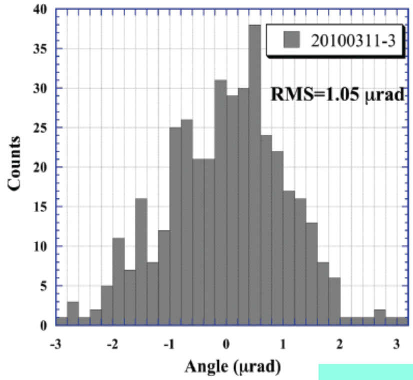


ATF Kicker Extraction Test – First Results

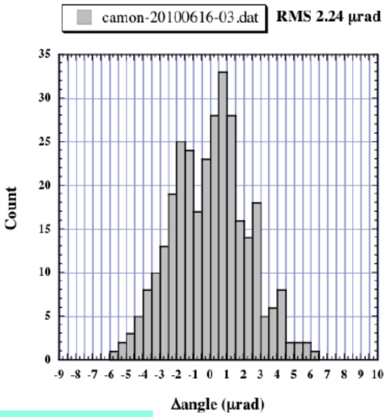
Distribution of fitted angle at EXT entrance

(single bunch)

Jitter 1.05e-6/3e-3=3.5e-4



Jitter 2.24e-6/3e-3=7.4e-4



K.Kubo

Very Promising!

Conclusion to the Damping Rings Lectures

Thank you all for your attention.

I hope that I've been able to provide you all with a useful and informative overview of the issues related to the ILC damping rings.

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