Electron Cloud Work Package

M. Pivi

Damping Rings EDR Kick-Off Meeting
Daresbury, United Kingdom
5-7 November 2007

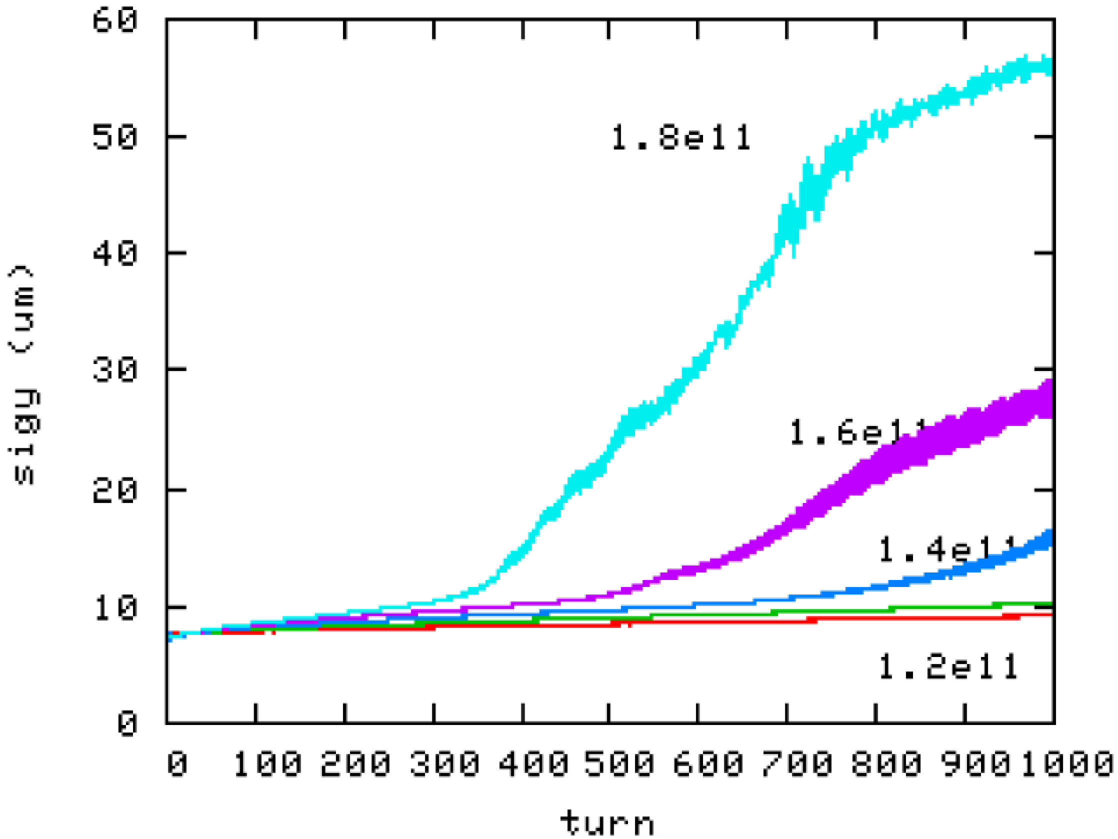
Work done for the Reference Design Report (RDR)

- The electron cloud develops quickly as photons (or electrons ionized) striking the vacuum chamber wall knock out electrons that are then accelerated by the beam, gain energy, and strike the chamber again, producing more electrons.
- The peak secondary electron yield (**SEY**) of typical vacuum chamber materials is >1.5 even after surface treatment, leading to amplification of the cascade.
- Once the cloud is present, coupling between the electrons and the circulating beam can cause a single-bunch (head-tail) instability and incoherent tune spreads that may lead to increased emittance, beam oscillations, or even beam losses.

Work done for the RDR

- Because the electron cloud is difficult to suppress in the dipole and wiggler regions of the ring, this is where its effects are expected to be most severe.
- A large synchrotron tune is beneficial, as it raises the threshold for the electron cloud head-tail driven instability. Single-bunch instability simulations for the 6.7 km damping ring lattice show that the instability sets in above an average cloud density of 1.4e11 e/m^3, where an incoherent emittance growth is observed

Work done for the RDR



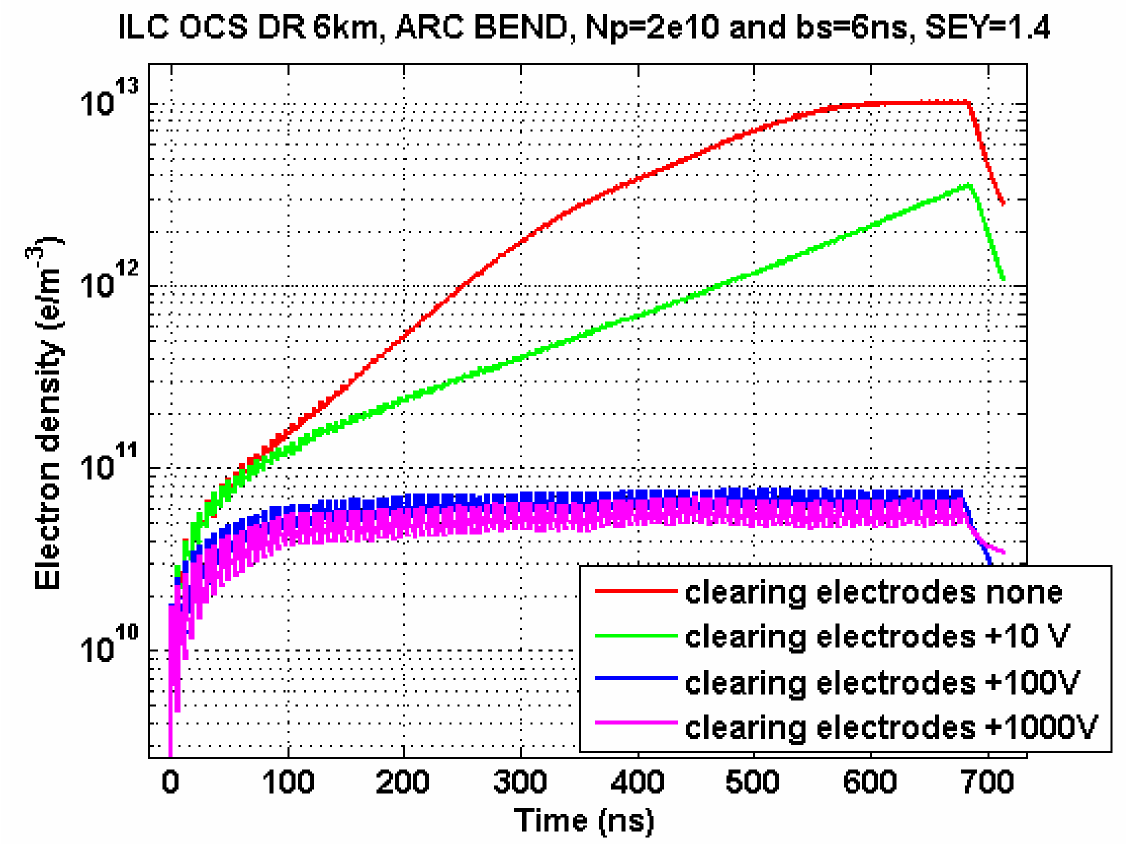
K. Ohmi KEK

Emittance growth from single-bunch instability driven by electron cloud in the 6.7 km positron ring (electron cloud densities in e/m^3 are indicated). Instability threshold set tolerances on maximum allowed SEY.

Work done for the RDR

- Tune shifts on the order of 0.01 are expected near threshold.
- Simulations indicate that a peak secondary electron yield of 1.2 results in a cloud density close to the instability threshold.
- Based on this, the aim of ongoing experimental studies is to obtain a surface secondary electron yield of 1.1.
- Simulations also indicate that techniques such as grooves in the chamber walls or clearing electrodes, besides coating, will be effective at suppressing the development of an electron cloud.

Work done for the RDR



M. P., SLAC

Buildup of the electron cloud and the suppression effect of clearing electrodes in an arc bend of the 6.7 km ring.

Work done for the RDR

- A clearing electrode bias potential of +100 V is sufficient to suppress the average (and central) cloud density by more than two orders of magnitude.
- Techniques such as triangular or rectangular fins or clearing electrodes need further R&D studies and a full demonstration before being adopted.
- Nonetheless, mitigation techniques appear to be sufficient to adopt a single 6.7 km ring as the baseline design for the positron damping ring.

Overview of the work related to the ILC Damping Ring RDR and EDR, from collaborating Institutions

received slides from colleagues in charge of either RDR and EDR phases' work packages

Electron Cloud Workshops: 2007

Two workshops this year:

- Electron Cloud Clearing ECL2 Workshop, CERN, March 07
- ECLOUD07 Workshop, Daegu Korea, June 07

- DR R&D meeting at KEK, 18-20, December
  - Electron cloud
  - Fast injection/extraction kickers
  - Impedance and impedance effects

Mitigations and Simulations R&D: Frank Zimmermann

- ECL2 workshop on technological countermeasures against e-cloud including proceedings as EUROTeV report (Caspers, Scandale, Schulte, Zimmermann)
- Studies with clearing electrodes and e-cloud detector in the PS (Mahner,Kroyer, Caspers)
- Development of enamel based clearing electrodes (Caspers, Kroyer + German industry)
- Investigations of TiN coating schemes (Chiggiato et al)
- Experimental studies of e-cloud build up and e-cloud instabilities in the SPS in particular concerning the energy+beam-size dependence of the instability (Rumolo, Shaposhnikova)
- Completion of "Faktor2" code (Bruns)

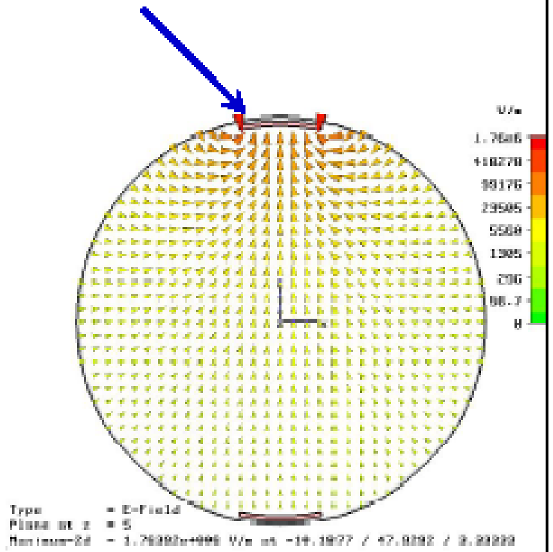
Mitigations and Simulations R&D: Frank Zimmermann

- Studies on e-cloud suppression by slotted chamber and grooves (Bruns)
- Progress in modelling the incoherent e-cloud effect for a dipole field: (Franchetti)
- PAC07 paper on incoherent e-cloud effects with numerous authors from all around the world
- Preparation for mitigation techniques tests in the SPS (Arduini, Shaposhnikova)

High resistivity electrode

- The idea consists of building a thin electrode structure directly attached to the beam screen. Let's assume a 50 mm radius pipe.
- As the insulating dielectric a thin enamel layer can be used, e.g. a single 25 mm wide strip with 0.5 mm thickness
- On top of that a highly resistive 20 mm wide strip is deposited
- At one end of the strip a feedthrough is installed to bias the resistive strip to say -1 kV to ground (beam pipe)
- Each section of the electrode could have to length of up to a few meters and be installed in straight sections as well as in magnets
- Such a structure has a several advantages:
  - Good mechanical stability
  - Small aperture reduction
  - Good thermal contact to the beam pipe
  - The SEY of the electrode should probably not have such a large impact, since it repels electrons

An insulating enamel layer on the beam pipe, on which a resistive layer is deposited that acts as an "invisible" electrode



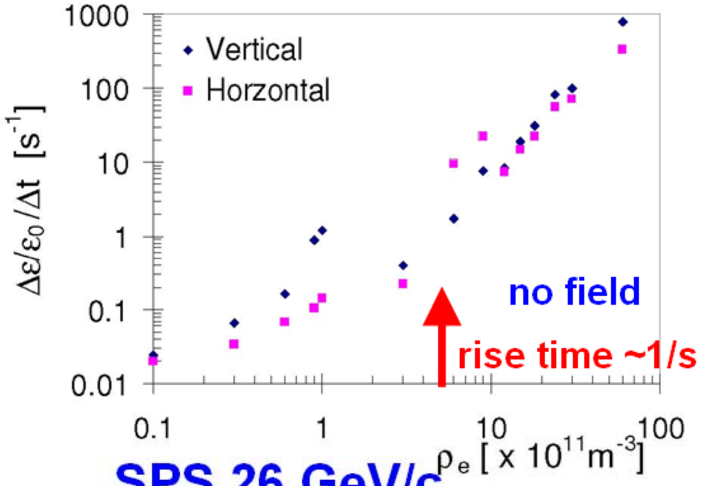
T. Kroyer, F. Caspers, Clearing electrode impedance, 2 March 2007

12

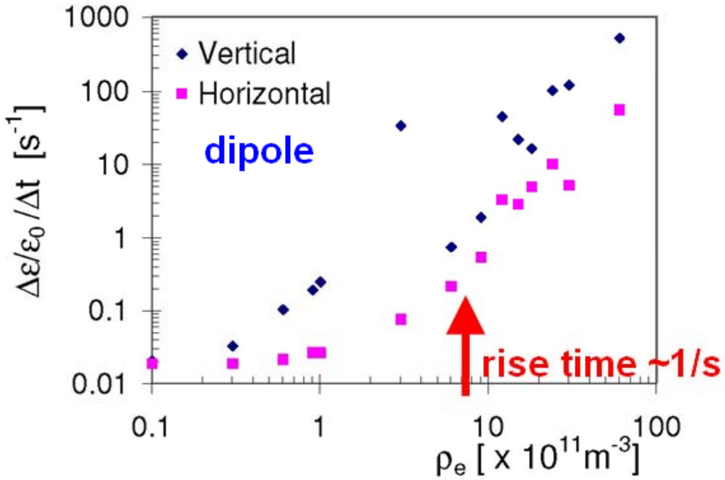
Limitation for the SPS (LHC): Frank Zimmermann

emittance growth vs. electron density for SPS

HEADTAIL simulations E. Benedetto
→ consistent with experimental observations within measurement uncertainties

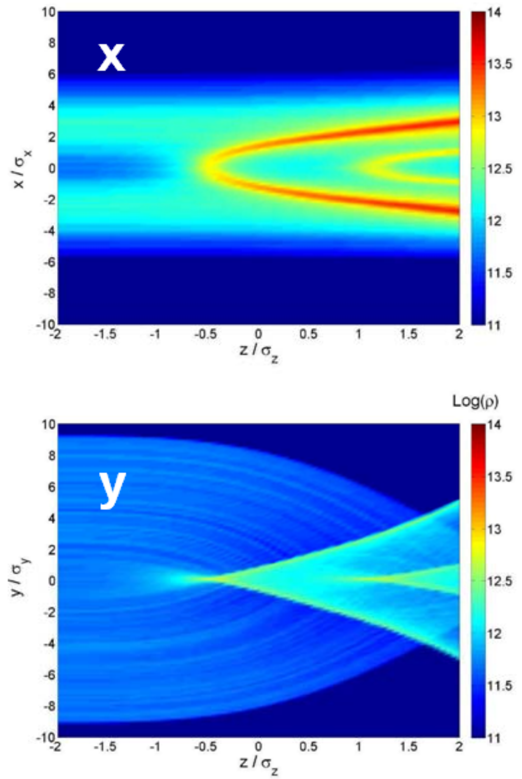


SPS 26 GeV/c



e- density evolution during bunch passage in a dipole field

SPS

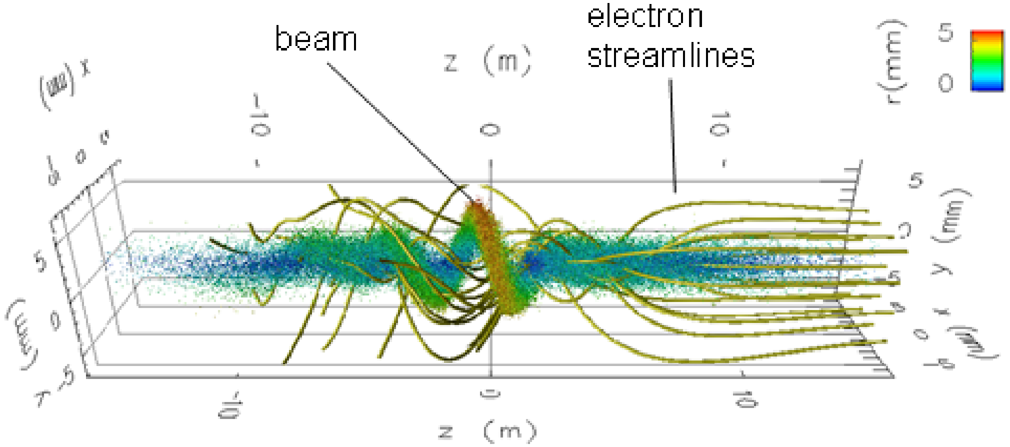


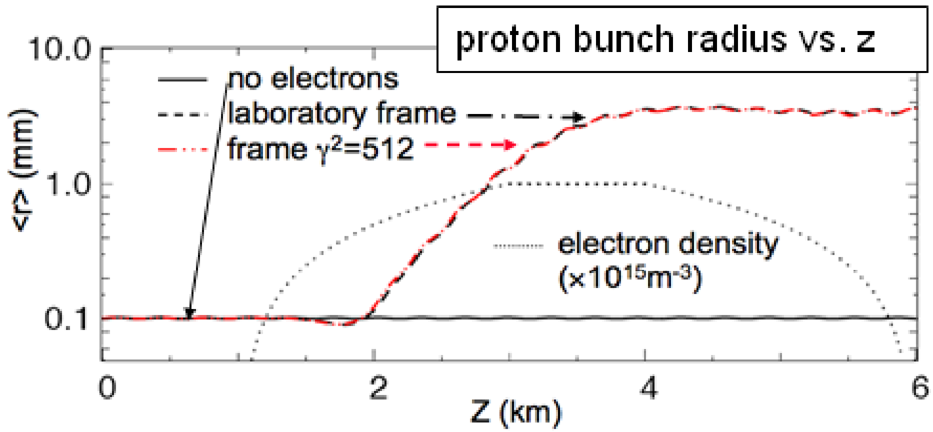
We have discovered: calculation in the right reference frame greatly reduces CPU time*

This is a proof-of-principle test: hose instability of a proton bunch & specified ecloud

Proton energy: γ=500 in Lab
• L= 5 km, continuous focusing

Code: WARP (Particle-In-Cell)





CPU time:
- lab frame: >2 weeks
- frame with γ²=512: <30 min

Speedup x1000

*J.-L. Vay, PRL 98, 130405 (2007)

LARP — The Heavy Ion Fusion Science Virtual National Laboratory — PPPL

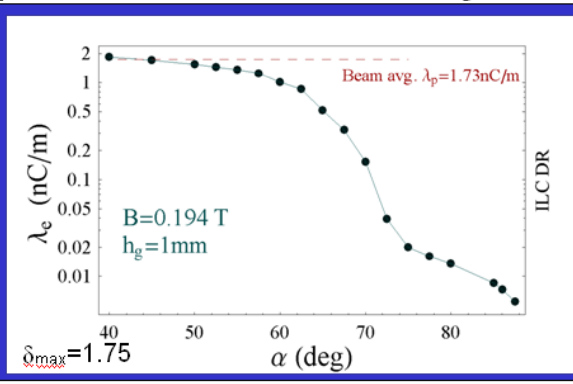
Estimated grooves reduction: Christine Celata

Progress Cont'd – Modeling e-cloud accumulation in grooved chambers

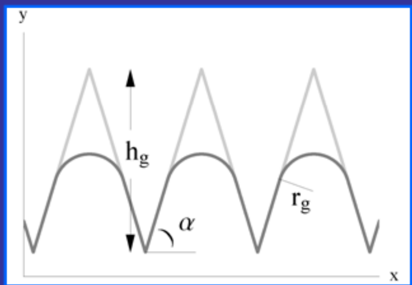
Simulations show that a triangular groove geometry with a sufficiently steep angle can suppress e-cloud effectively

Max. longitudinal density of e⁻ accumulated through a 111 e+ bunch train in DR dipoles drops by 100 for α=75º

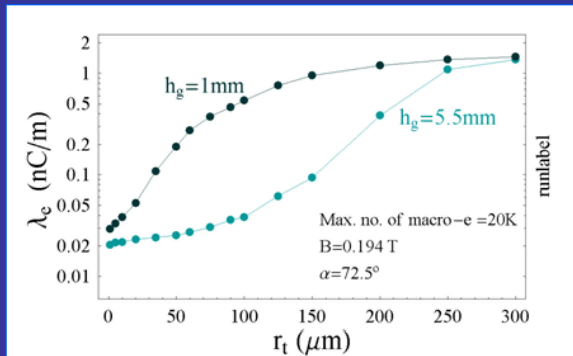
Simulations done w/ augmented version of POSINST (Venturini, Furman)



To mitigate impedance, rounding the tips would be desirable …



… but it spoils the effectiveness of grooves



5

Plans for EDR: Christine Celata

LBNL Ecloud Research for the EDR

FY2008

- Finish benchmark of 2D against 3D
- Compare 2D & 3D results for cloud buildup in wiggler. If differences are significant, do 3D parameter scans of beam and fill pattern params.
- Simulate (POSINST) PEP-II expt - grooved chambers in dipoles
- Begin 3D simulations of head-tail instability in wiggler
- Calculations for CESR-TA:
  - POSINST parameter scans of ILC-like experiments, including optimizing diagnostic placement
  - Modeling of RFA experiments

FY2009

- Compare quasi-static model simulations and full 3D simulations of head-tail instability.
- Finish 3D calculations of head-tail instability
- First 3D fully self-consistent simulations of entire DR wiggler. Extend to times ~ damping time
- Calculations for CESR-TA:
  - Support data analysis and experimental design, including diagnostic placement
  - First simulations of beam evolution

9

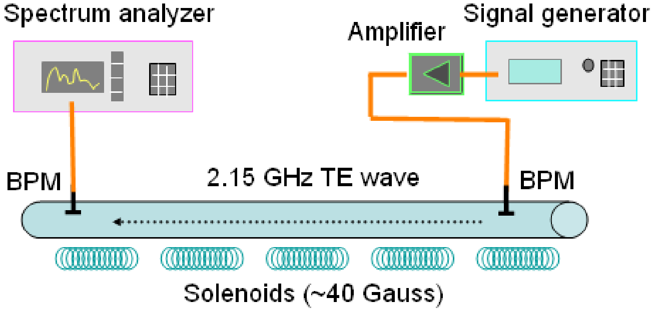
RF transmission measurements: J. Byrd, S. De Santis

Electron Cloud Density measurements in the PEP-II LER

TE Wave Propagation Method

- We excite a TE wave in the LER beam pipe and measure its propagation over a 50 m-long section.
- The electron cloud affects the phase of the propagating wave.
- A 100 ns-long gap in the LER fill transforms the different phase velocity with and without electron cloud into a phase modulation of the transmitted signal.
- Solenoids around the beam pipe for electron cloud clearing can be turned on and off. We can compare the modulation sideband amplitude.
- **Cloud density measured at 6e11 e/m^3.**

Experimental Setup



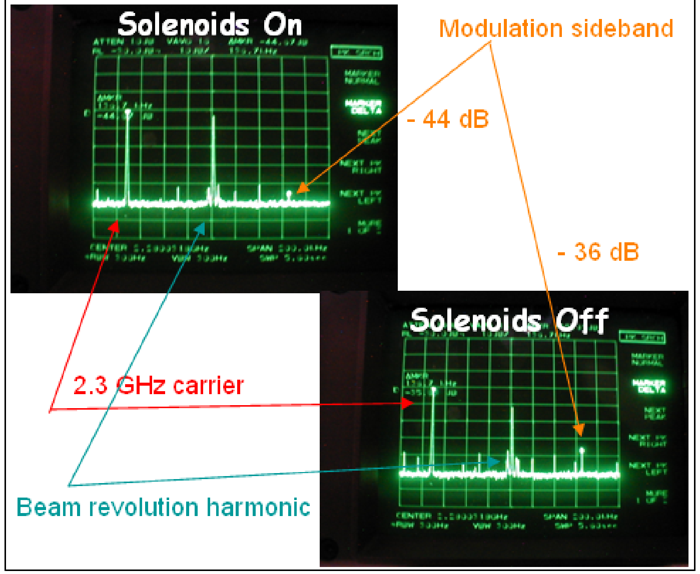
Analytical Estimates

Phase delay per unit length can be calculated:

$$\frac{\Delta\phi}{L} = \frac{1}{c}\left[\left(\omega^2 - \omega_c^2\right)^{1/2} - \left(\omega^2 - \omega_c^2 - \omega_p^2\right)^{1/2}\right]$$

We estimate ~2° phase delay due to e-cloud at 2.15 GHz and 2.1 A. This means a -35 dB sideband amplitude relative to carrier.

Experimental Results (May '07)



R&D so far

- Using KEKB positron ring (LER)
  - Comparison of TiN coating, NEG coating and Cu surface (without coating) using a test chamber installed into an arc section and a straight section.
    - SEY and photoelectron yield was evaluated from a measured electron current.
    - It was found to be important to reduce photoelectrons in order to utilize a surface with a low SEY.
    - SEY of TiN after sufficient aging was estimated to be about 0.9-1.0, and was the best.

R&D so far (Cont'd)

- Using KEKB positron ring (LER)
  - Direct measurement of electron density at a drift space (without magnetic field).
    - Densities of about 1E11 electrons/m^3 were obtained at 1 mA/bunch.
    - Comparison of TiN coating, NEG coating and Cu.
    - TiN coating was the best again.

R&D plans

- Using KEKB positron ring (LER)
  - Test of clearing electrode and groove in a magnetic field (B-field).
    - Test chamber with electron monitor and clearing electrode is under manufacturing.
    - The test chamber will be installed in a wiggler magnet.
    - Test will start from next February, at earliest.

R&D plans (Cont'd)

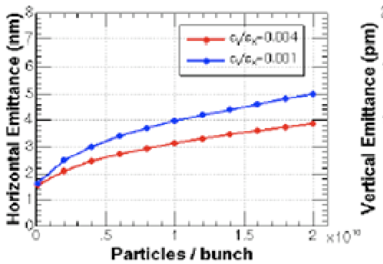
- Using KEKB positron ring (LER)
  - Measurement of SEY and surface analysis of samples irradiated to beam, especially to SR, at an arc section.
    - Test chamber is under manufacturing.
    - Test will start from next February, at earliest.

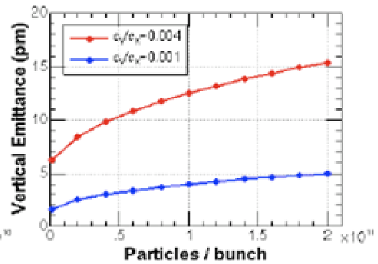
KEKB low emittance operation for DR study

	Physics run	Low emittance		
Energy	3.5	2.3		GeV
Horizontal emittance	18	1.5		nm
Momentum compaction	3.4	2.4		E-4
Bunch length		4.2	6.1	mm
Rf voltage	8.0	2.0	1.0	MV
Momentum spread	0.073	0.048		%
Longitudinal damping time	23	50		ms
Bucket height		1.86	1.13	%

- Low energy operation 3.5 to 2.3 GeV
- Emittance due to IBS

Vc = 1.0 MV



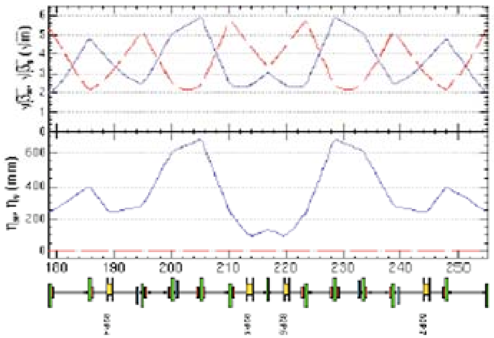


Optics (ring & cell)

◆All magnetic fields are scaled from 3.5 to 2.3 GeV.

◆Wiggler field: 0.77 → 0.51 T

◆Detuned β*x/y: 90/3 cm



Electron cloud density with linear scaling and simulated threshold

- Cloud density is bellow the threshold in 2.3 GeV operation.
- Effect of ante-chamber can be studied at KEKB. Possibility for 3000 m option will be tried.
- Incoherent emittance growth is further slower than the radiation damping.

	Nor ε	Nor ε	Low ε–I	Low ε–II
E (GeV)	3.5	3.5	2.3	5.0
N_+ (10^{10})	3.3	7.6	2.0	2.0
N_b	1000	1338	1250	2500
I (mA)	500	1700	400	800
ε_x (nm)	18	18	1.5	1.0
σ_z (mm)	6	7	9	9
ν_s	0.024	0.024	0.011	0.011
$\omega_e \sigma_z/c$	3.1	5.1	12.5	12.5
$\rho_{e,th}$(m^{-3})	8×10^{11}	4×10^{11}	1×10^{11}	2.2×10^{11}
ρ_e(m^{-3})	8×10^{11}	4×10^{11}	0.6×10^{11}	2.7×10^{11}

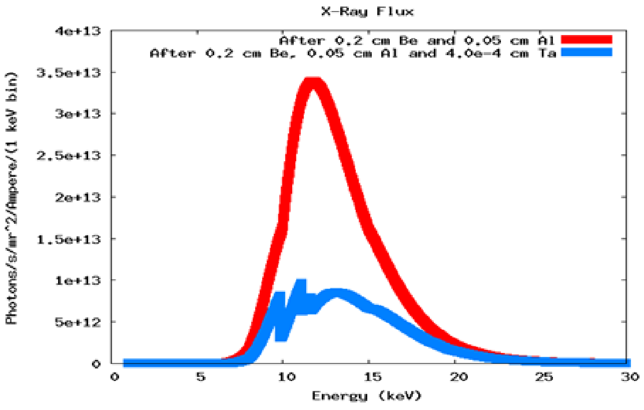
- ω_e: electron frequency in a bunch
- $\rho_{e,th}$: threshold density,
- ρ_e: estimated or predicted electron density for cylindrical chamber

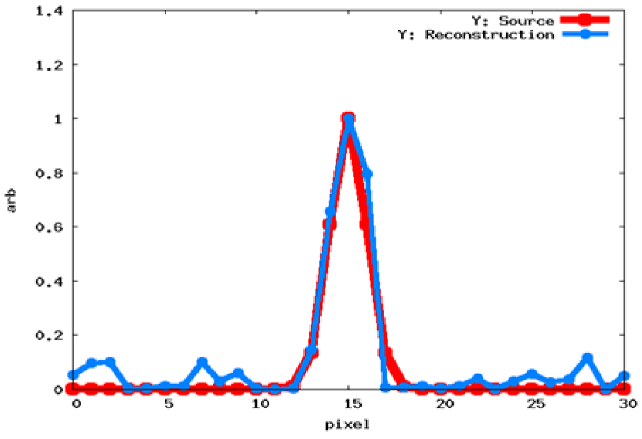
Test Facilities: Proposal to use KEKB for ILC.

X-ray monitors: J. Flanagan

Measurement of electron cloud instabilities
J.W. Flanagan, KEK

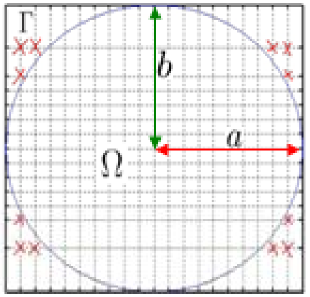
- Bunch-by-bunch, turn-by-turn beam profile measurements needed for measurement of electron-cloud head-tail instability.
- We are looking at x-ray monitors. To maximize x-ray flux and minimize number of beamline components, we are investigating the use of a modified form of pinhole camera. Also looking into design of high-speed detector and readout system, in cooperation with U. Hawaii and Cornell.
- Initial simulations promising using KEKB low-emittance mode (possible ILC study mode). Proof-of-concept development underway.





Achievements of the Collaboration between the University of Rostock and DESY

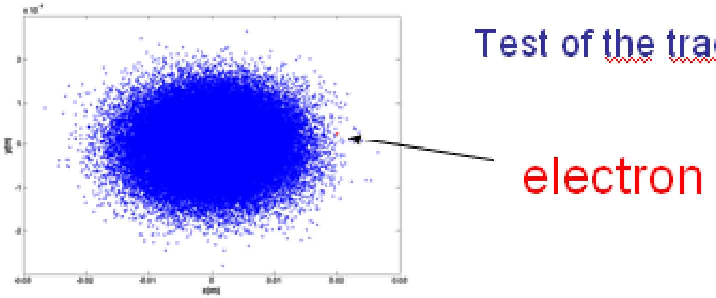
$\Gamma = [-a, a] \times [-b, b] \times [-c, c]$



3D Space charge fields of bunches in a beam pipe of elliptical cross section, part of MOEVE 2.0

- iterative solvers: BiCG, BiCGSTAB
- step size: non-equidistant

Time integration of the Newton-Lorentz equation for each macro particle (leap frog scheme),

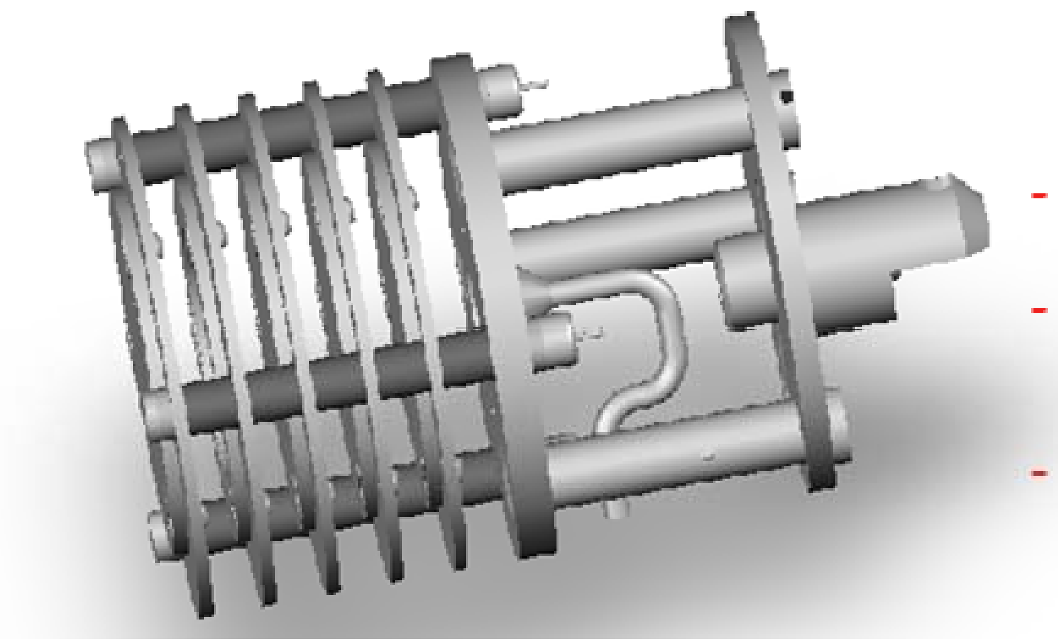


Test of the tracking algorithm

Tracking of one electron in the space charge field of a Gaussian bunch

Plans for measurements in DAΦNE: Roberto Cimino

At DaΦne we plan to measure the electron cloud by inserting in the machine Energy-resolved El. Detectors.



To be inserted in 3 positions looking trough the existing slots at the beam:

- electron-ring (for reference)
- Positron ring (Uncoated chambrer)
- Positron ring (TiN coated chambrer?)

Need to characterize Photoemission in DR parameters range: R. Cimino, O. Malyshev

For ILC-DR one need to circulate Samples, to put resources (also for SR) and manpower to study:

1) 0-1keV Electron induced el. emission yield (SEY)
2) and its angular dependence
3) Photoemission Yield and Photoemission induced el. energy distribution (also Angle resolved!)
4) Photon - reflectivity
5) Electron induced energy distribution curves
6) Heat load
7) Photon and electron induced desorption
8) Surface properties changes during conditioning.
9) Chemical modifications vs. conditioning.
10) Relation between photon and electron conditioning.

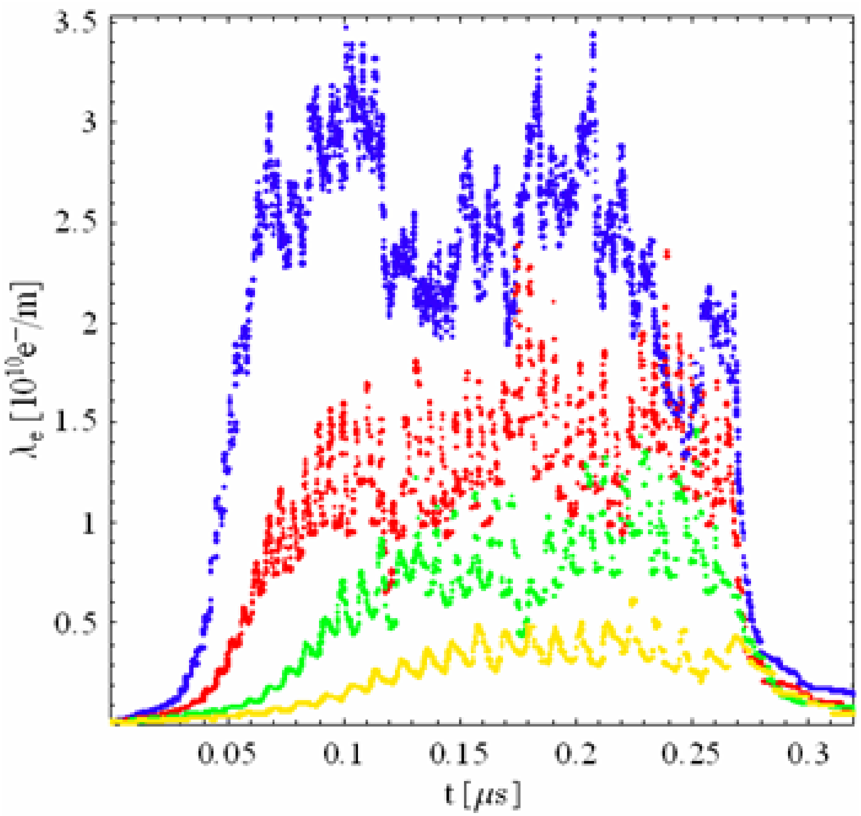
... and this on all vacuum high tech. materials...

ILC 2007, DESY, May31, 07. R.

Input parameters for Ecloud (DAFNE Wiggler 2004)

Bunch population	N_b	2.1×10^{10}
Number of bunches	n_b	100;50;33;25
Missing bunches	N_{gap}	20
Bunch spacing	L_{sep}[m]	0.8;1.6;2.4;3.2
Bunch length	σ_z [mm]	18
Bunch horizontal size	σ_x [mm]	1.4
Bunch vertical size	σ_y [mm]	0.05
Chamber hor. aperture	2 h_x [mm]	120
Chamber vert. aperture	2 h_y [mm]	10
Al Photoelectron Yield	Y_{eff}	0.2
Primary electron rate	dN/ds	0.0088
Photon Reflectivity	R	50%
Max. Secondary Emission Yeld	δ_{max}	1.9 (0.2) 1.1
Energy at Max. SEY	E_m [eV]	250
SEY model	Cimino-Collins (50%;100% refl.)	

Bunch Patterns



N_b=2.1 10^{10}

100 bunches

L_{sep}= 0.8 m

50 bunches

L_{sep}= 1.6 m

33 bunches

L_{sep}= 2.4 m

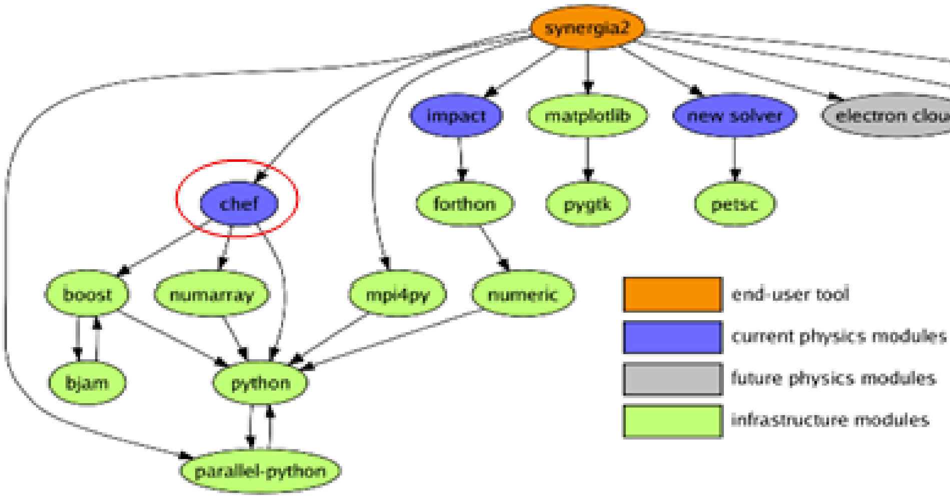
25 bunches

L_{sep}= 3.2 m

Propose to use Synergia code to model e-cloud: Panagiotis Spentzouris

Fermilab & SciDAC code: the Synergia framework

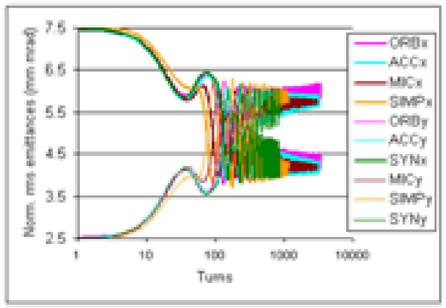
PAC07, TUZBC02



3D, parallel, high order optics

Multi-physics (space-charge, impedance, ecloud generation)

state of the art numerical libraries



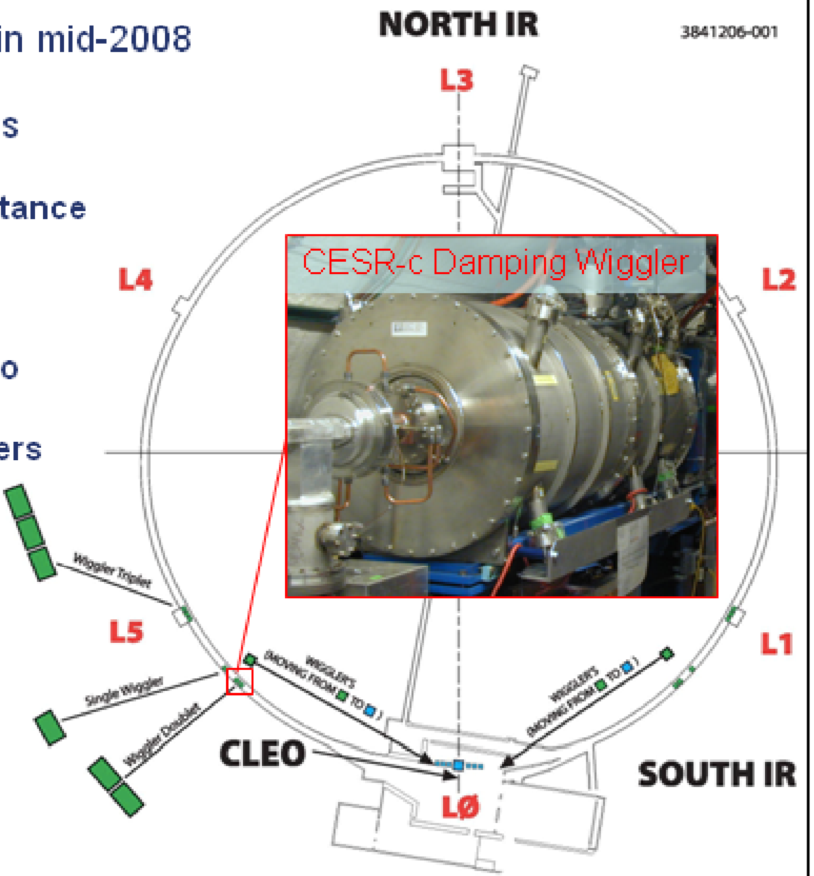
Synergia: well tested Poisson solvers (JCP06), participated in space-charge benchmark effort lead by I.Hofmann

Easy to use interface

Test Facilities, CesrTA: Mark Palmer

Electron Cloud Studies at CesrTA

- Dedicated DR R&D program starting in mid-2008
- Primary focus on electron cloud issues
  - Electron cloud growth
  - Emittance dilution in ultra low emittance conditions
- 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



Test Facilities, CesrTA: Mark Palmer

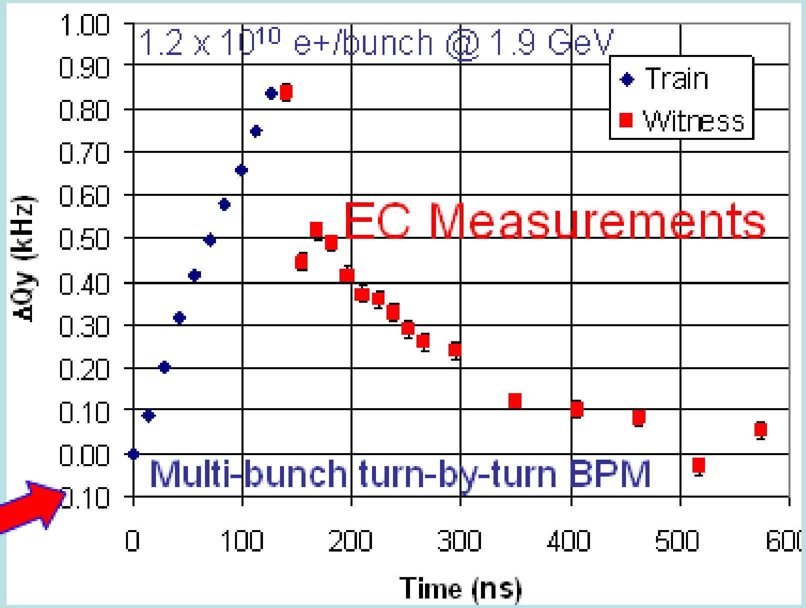
CesrTA Parameters & Capabilities

Baseline Configuration

Parameter	Value
No. of Wigglers	12
Wiggler Field	2.1 T
Beam Energy	2.0 GeV
Energy Spread (ΔE/E)	8.6×10^{-4}
Target Vertical Emittance	5 – 10 pm (or better)
Horizontal Emittance	~2 nm
Damping Time	47 ms
Bunch Spacing	4 ns
Bunch Length	9 mm

- Parameters:
  - **Baseline optics at 2 GeV for ultra low emittance studies**
  - **Energy flexibility will allow EC growth studies at 5 GeV as specified for the ILC DR**

- EC Measurements:
  - **Multi-bunch turn-by-turn instrumentation has been commissioned**
  - **Measured vertical tune shift along a train generating the electron cloud and for witness bunches trailing the train at various intervals**

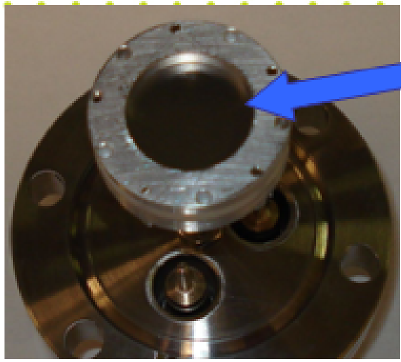


Test Facilities, CesrTA: Mark Palmer

CesrTA Experimental Program

Experimental Overview:

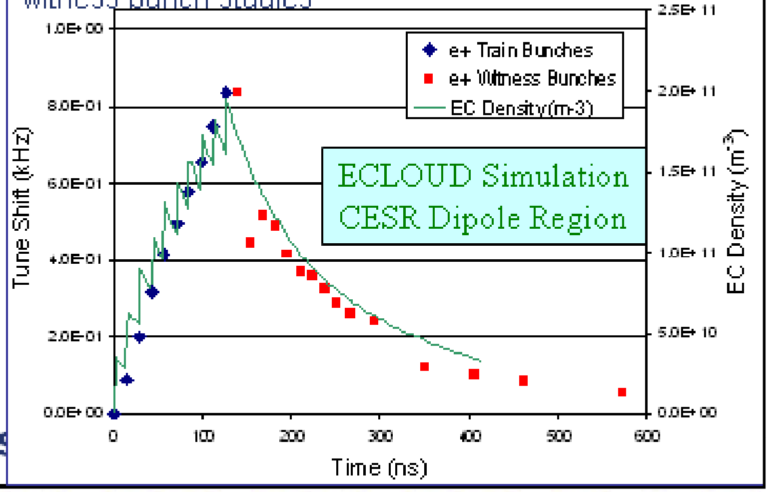
- **EC Growth and Mitigation Studies, particularly in the damping wigglers**
  - Bunch trains similar to ILC DR
  - Instrumented vacuum chambers
- **Ultra Low Emittance Operation**
  - Correction algorithms
  - Measuring, tuning for, and maintaining ultra low emittance
- **Beam Dynamics Studies**
  - Detailed inter-species comparisons (distinguish EC, ion and wake field effects)
  - Characterize emittance growth in ultra low emittance beams
  - Demonstrate ultra low emittance operation with a positron beam



- First prototype "thin" RFA structure for wiggler chambers ready for testing
- Wiggler chambers being developed in collaboration with LBNL and SLAC

Work on Data-Simulation Comparisons

Seeing qualitative agreement with shape of electron cloud growth/decay and vertical tune shift data from witness bunch studies

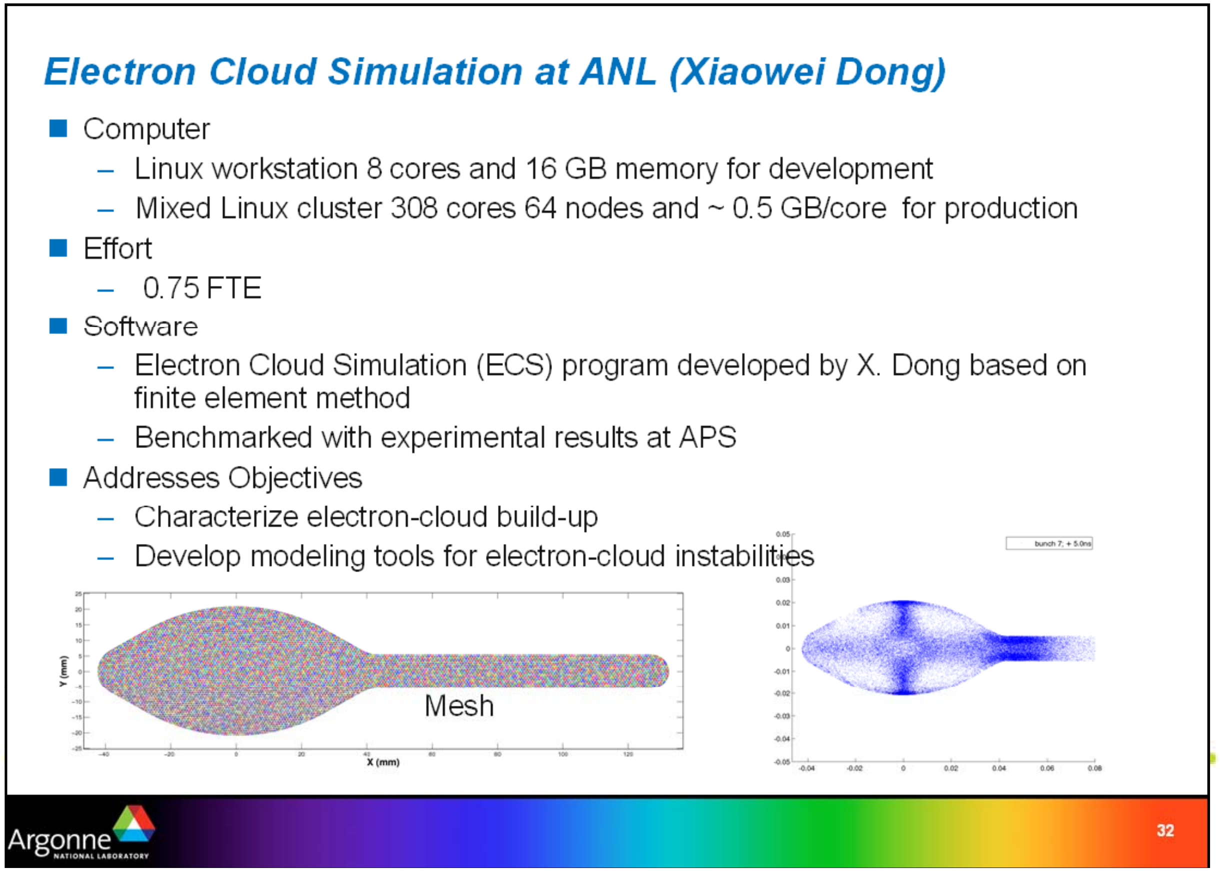


3 November 2007

Global Des

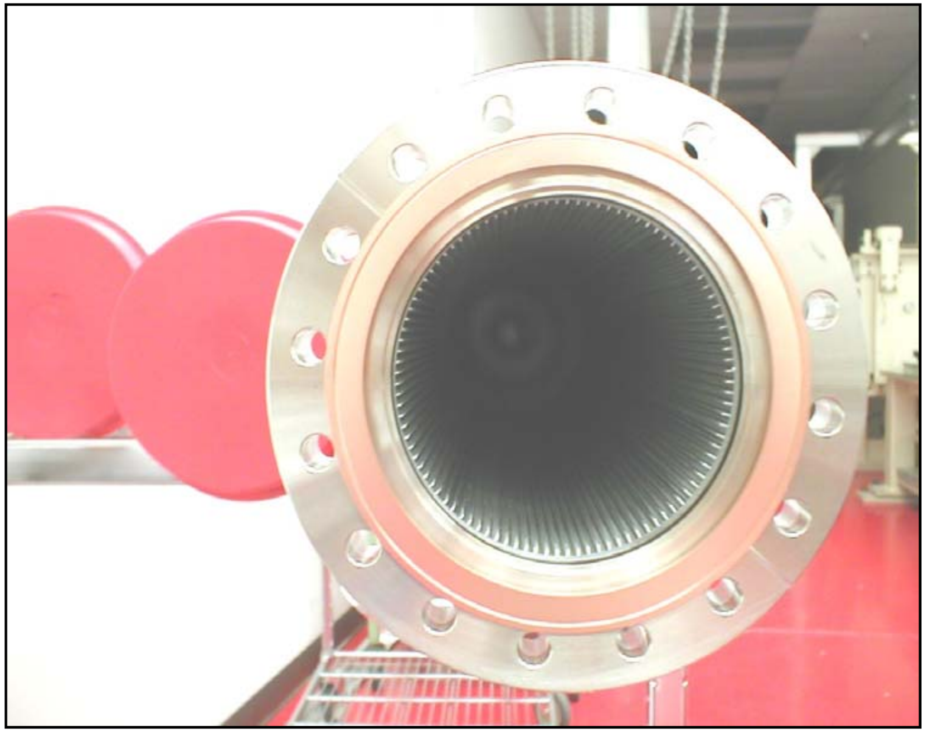
Proposal to develop code for electron cloud build-up: Louis Emery

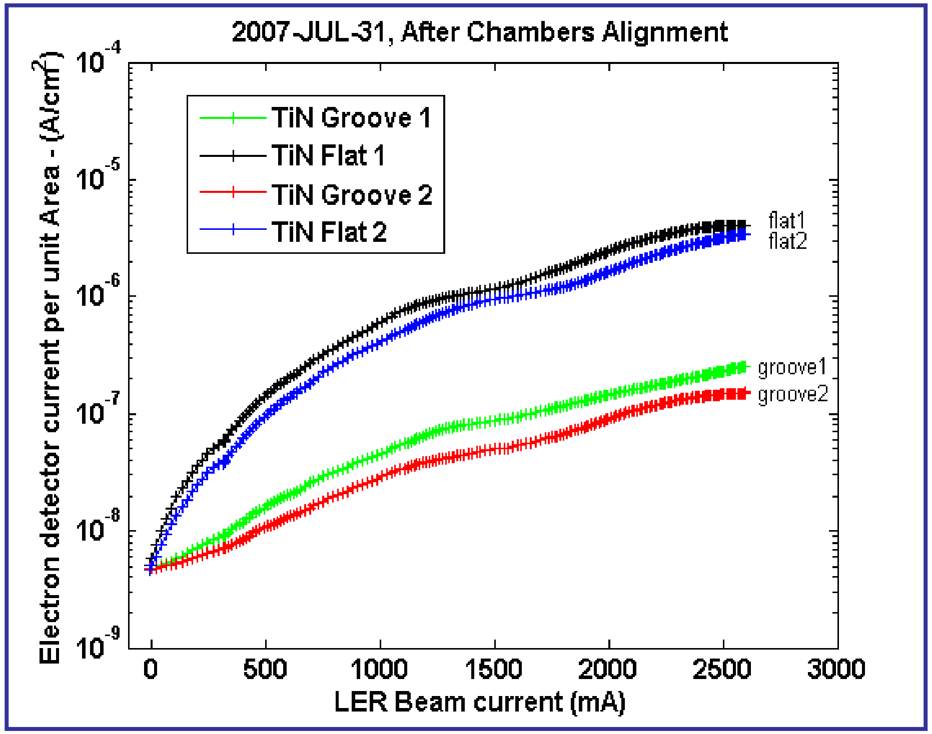
- New postdoc started few months ago at Argonne. Didn't do work on ILC yet, but he is developing further his e-cloud program.
  - **In the expression of interest ANL suggested his contribution 0.25 FTE.**



- Installed 5 chambers in PEP-II straight, in January 2007:
  - **A chamber station that allows the insertion of samples directly into beam line and measure the reduction of the SEY due to beam conditioning**
  - **4 Grooved and Smooth chambers installed to measure performance in PEP-II beam environment**
- Experimental results obtained for sample surfaces exposed to PEP-II (and similarly at KEK) beam line: SEY decreases stably to ~0.9 for TiN surfaces.
  - **Working to fully characterize the conditioning of various materials in beam lines**

Performances in PEP-II beam environment. Straight field free regions.

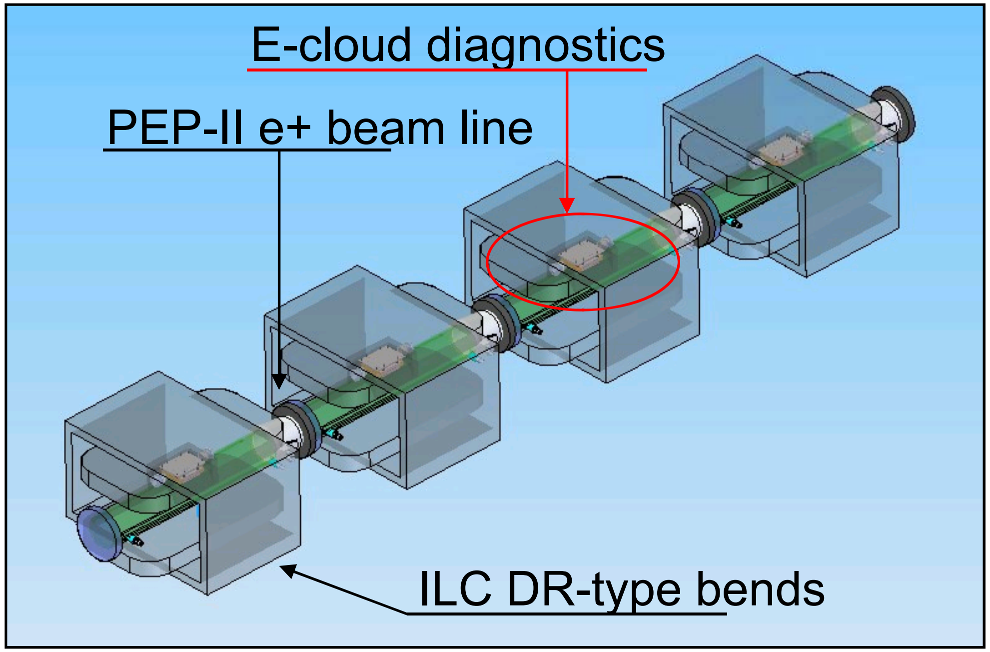




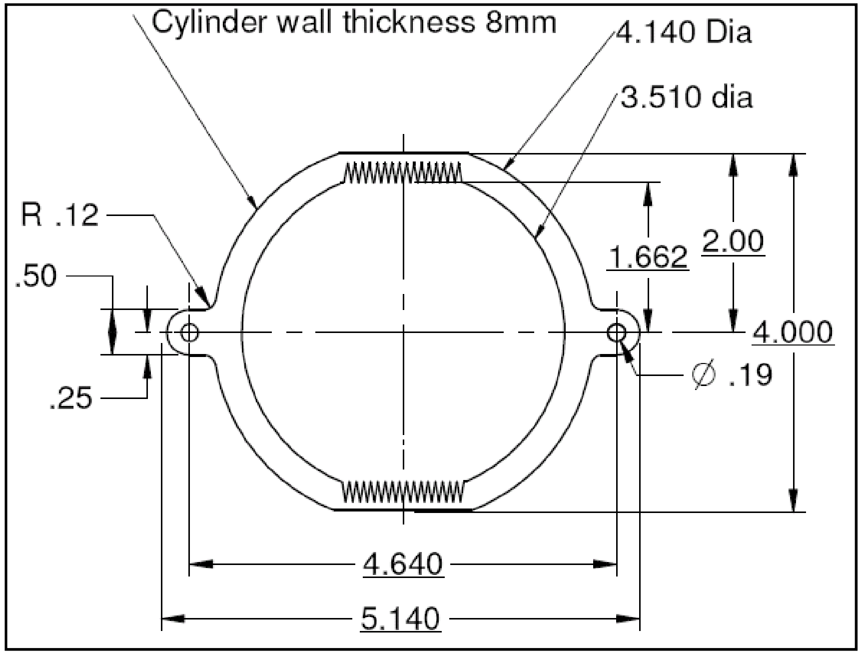
Successfully measured electron signal in Groove chambers much lower than Smooth (flat) chambers. All chambers with TiN coating.

Mitigations tests, new installation: Mauro Pivi

- Verify efficiency of mitigation techniques in dipoles.
- Ongoing 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

Estimation of groove efficiency in magnetic fields: Lanfa Wang

Estimation of SEY of the triangular groove

Simulation Parameters

Peak SEY δ_0=1.2

Width =2mm

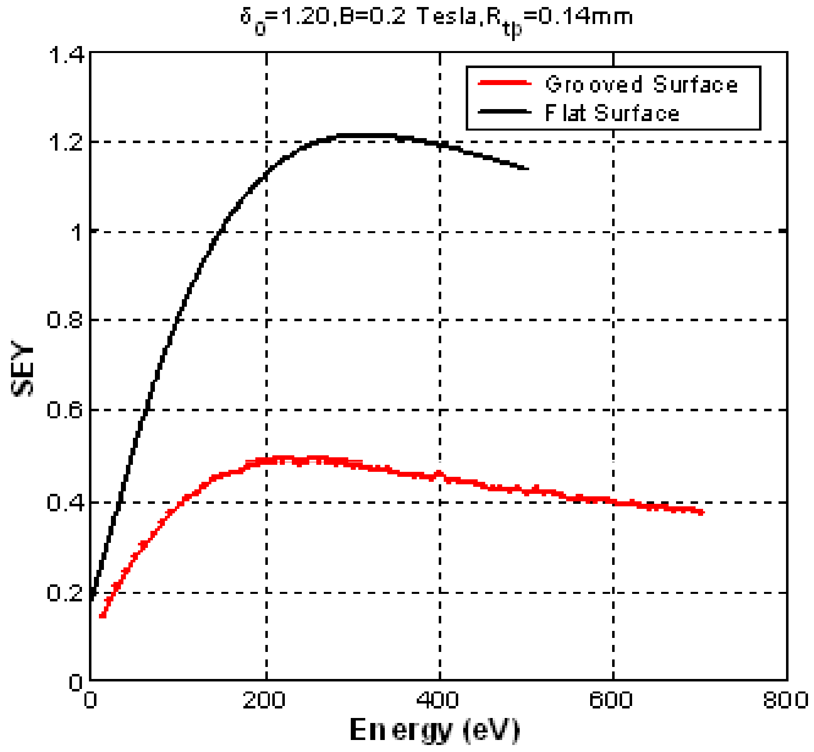
Height=3.82mm

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

R&D work plans for the EDR

- Presently, the R&D plan is inclusive.
  - **For example, WP 7 (Electron Cloud) lists 45 potential investigators. Not all these investigators are likely to get funding for their activities.**
- Coordination and elimination of duplication should happen by communication and agreement.
  - **The specific tasks identified in the R&D plan should form a focus for the discussions that need to take place.**
- The Work Package Coordinator should play a role in ensuring that the necessary discussion happen, and happen constructively.
  - **Difficult decisions may be needed, but holding collaborations together is essential. We need to work positively with each other to achieve the R&D goals.**

Working Package 7 (e-cloud)

Potential Investigators

In transition from previous RDR structure…

CERN
Fritz Caspers
Daniel Schulte
Frank Zimmermann
Cockcroft Institute
Oleg Malyshev
Ron Reid
Andy Wolski
Cornell
Jim Crittenden
Mark Palmer
DESY
Rainer Wanzenberg
FNAL
Panagiotis Spentzouris
INFN-LNF
David Alesini
Roberto Cimino
Alberto Clozza
Pantaleo Raimondi
KEK
John Flanagan
Hitoshi Fukuma
Ken-ichi Kanazawa
Kazuhito Ohmi
Kyo Shibata
Yusuke Suetsugu
Shigiri Kato

LANL
Bob Macek
LBNL
John Byrd
Christine Celata
Stefano de Santis
Art Molvik
Gregg Penn
Marco Venturini
Miguel Furman
Kiran Sonnad
Mike Zisman
PAL
Eun-San Kim
Rostock University
Aleksander Markovik
Gisela Poplau
SLAC
Karl Bane
Bob Kirby
Alexander Krasnykh
Mauro Pivi
Tor Raubenheimer
Tom Markiewicz
John Seeman
Lanfa Wang

DR Work Packages

The present structure

WP#	WP Title	ANL	Cornell	FNAL	SLAC	LBNL	LANL	LLNL	UIUC	UM	CI	DESY	LNF	KEK	IHEP	KNU	Tot. FTE	Potential WP Leader
1	Lattice design and acceptance	X	X			X				??			X		X	X	1.25	Louis Emery
2	Orbit, optics and coupling correction	X	X		X	X				??	X		X	X			7.85	David Rubin
3	Wiggler		X			X											1.90	Mark Palmer
4	Instrumentation, diagnostics, controls		X	X		X								X	X		6.40	Manfred Wendt
5	Impedance & impedance-driven instabs.	X			X	X					X			X	X		3.25	Gennady Stupakov/Cho N
6	Fast feedback systems				X	X							X				1.50	John Fox
7	Electron cloud	X	X	X	X	X	??						X		X	X	8.45	Mauro Pivi
8	Power systems		X		X												2.30	Paul Bellomo
9	Other collective effects		X	X	X	X							X		X		1.45	Marco Venturini
10	650 MHz RF system		X		X	X											3.10	Derun Li
11	Magnets and supports					X									X		0.20	Steve Marks
12	Systems integration and availability										??						0.00	Cockcroft Institute (FNAL)
13	Vacuum system				X	X					X		X		X		3.10	Oleg Malyshev
14	Injection and extraction systems		X	??	X	X		X	X				X	X			7.55	Susanna Guiducci
15	Ion effects		X		X	X						X		X	X	X	4.65	Junji Urakawa
16	Conventional facilities and cryogenics	X		X		X									X			Tom Lackowski/Alan Jac
	Global Systems Work Packages																	
	Conventional facilities																0.00	
	Control systems					X									X		0.50	
	Cryogenics systems	X															0.10	
	Survey and alignment	X															0.25	
	Installation and commissioning plans	X															0.25	
	Polarisation										X	X					0.30	

X = “Expression of Interest” for the EDR phase

FY07-FY10, WP 7 (e-cloud)

WBS	Objective	Priority
2.2.3.1	**Characterize electron-cloud build-up**	Very High
2.2.3.2	**Develop electron-cloud suppression techniques**	Very High
2.2.3.3	**Develop modelling tools for electron-cloud instabilities**	Very High
2.2.3.4	**Determine electron-cloud instability thresholds**	Very High

Staff effort (FTE)

WBS	2007	2008	2009	2010
2.2.3.1	2.0	2.0		
2.2.3.2	3.0	3.0		
2.2.3.3	2.0	2.0		
2.2.3.4	1.5	1.5		

(WBS enumeration during previous S3 phase)

Travel, at US$10k/FTE (US$k)

WBS	2007	2008	2009	2010
2.2.3.1	20	20		
2.2.3.2	30	30		
2.2.3.3	20	20		
2.2.3.4	15	15		

M&S (US$k)

WBS	2007	2008	2009	2010
2.2.3.1	0	0		
2.2.3.2	730	920		
2.2.3.3	0	0		
2.2.3.4	0	0		

WP 7 (e-cloud)

Achieving the objective of developing suppression techniques for the electron cloud will involve the following tasks:

1. **<u>Study coating techniques</u>, test the conditioning *in situ* in PEP-II, KEKB, SPS and CesrTA.**

2. **<u>Test clearing electrode concepts</u> by installing chambers with clearing electrodes in existing machines and in magnetic field regions in KEKB, SPS, CesrTA and HCX (LBNL). Characterize the impedance, the generation of higher order modes, and the power deposited in the electrodes.**

3. **<u>Test "groove" concepts</u> by installing chambers with grooved or finned surfaces in existing machines, including bend and wiggler sections in PEP-II, KEKB, SPS and CesrTA. Characterize the impedance and HOMs.**

Example: WP 7 (e-cloud)

- Objective: Develop electron-cloud suppression techniques:

Potential Investigators on these tasks will be:

David Alesini
Fritz Caspers
Alexander Krasnykh
Bob Macek
Art Molvik
Cho Ng
Mark Palmer
Mauro Pivi
Yusuke Suetsugu
Lanfa Wang

A total effort of 3 FTE per year for two years will be required. Work includes mainly experimental studies with support of simulations.

An M&S budget of $730k in 2007, and $920k in 2008 is required.

Work is ongoing. The goal is to complete all three tasks by the end of 2008 as input for the Engineering Design Report (EDR).

Example: WP 7 (e-cloud)

The required input includes:

- **Experimental data from machines including CesrTA, PEP-II, KEKB, SPS and LHC. Data should include detailed comparison of electron cloud density in sections with mitigation techniques compared with the electron cloud density in sections without mitigating techniques.**

The deliverables will include:

- **Technical specifications for techniques to be used to suppress build-up of electron cloud in the positron damping ring, consistent with aperture and impedance requirements.**
- **Guidance for the design of the vacuum chamber material and geometry (Objective 3.1.1.1), and for the technical designs for principal vacuum chamber components (Objective 3.1.1.2).**

WP 7 (e-cloud)

ILC DR Challenge: 2 pm vertical emittance

If the electron cloud density is not reduced below the threshold level for beam instabilities, then the positron damping ring will be unable to provide a beam meeting the specifications for beam quality, stability and intensity; this will have a potentially significant impact on the luminosity of the ILC.

Test Facilities: CesrTA

- Cesr-c is a wiggler-dominated electron-positron collider.
- The proposed development of CESR into CesrTA would allow a unique opportunity for electron cloud studies at a dedicated test facility, operating in a parameter regime directly relevant for the ILC damping rings.
  - **Requires relocation of wigglers to allow tuning for low natural emittance; upgrade of instrumentation for tuning for low vertical emittance; installation of instrumented test chambers in wigglers.**
- A range of other important studies will also be possible (e.g. low-emittance tuning, development of instrumentation for fast beam-size measurements of ultra-low emittance beams).

- Presently, funding agencies are evaluating the proposal.

Test Facilities: KEKB

- Electron cloud effects have already been studied extensively at KEKB, but not in the same low-emittance parameter regime in which the damping rings will operate.
- Solenoid fields in the straight sections have been effective at suppressing electron cloud effects in the B factories; but recent interest in a SuperB factory motivates further research.
- Tests of grooved and coated chamber surfaces for suppressing e-cloud are already underway at PEP-II, but studies of suppression techniques in wigglers with low emittance beams will require other facilities. Clearing electrode tests are planned at KEKB.
- KEKB LER could be tuned for ~ 1 nm emittance by reducing the energy from 3.5 GeV to 2.3 GeV.
- For the next two years, the priority for KEKB will be to continue to provide luminosity for BELLE. However, there may be some limited opportunity for electron cloud studies for ILC in that time, if the operational (power) costs of the machine are provided.

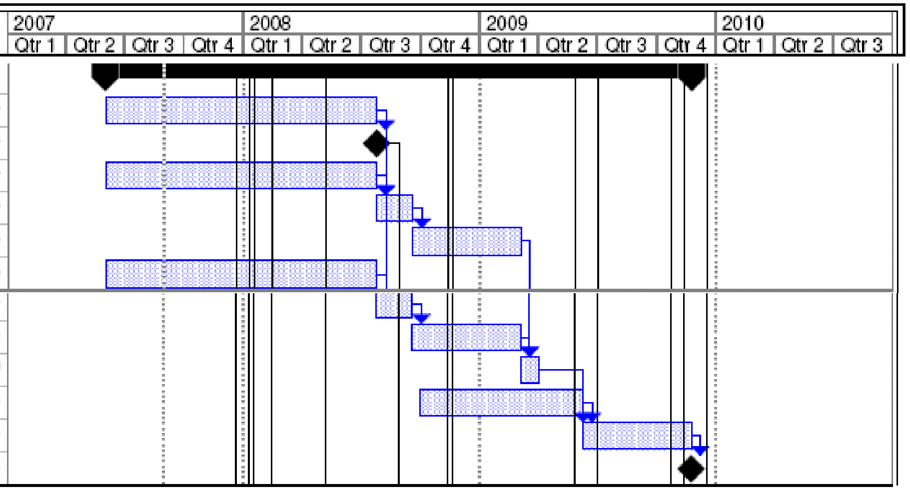
Other Test Facilities

- DAΦNE
  - **electron cloud**
  - **fast injection/extraction kickers**
- PEP-II
  - **electron cloud**
- SPS and LHC
  - **electron cloud**

R&D work plans for the EDR

From “Damping Rings EDPhase Gantt Links” document

ID	Task Name	Duration
28	**Electron cloud**	**648 days**
29	Evaluate electron cloud mitigation techniques	15 mons
30	Specify baseline ecloud mitigation techniques	0 days
31	Start construction of test dipole chamber	15 mons
32	Finalise construction of test dipole chamber	2 mons
33	Test ecloud mitigation techniques in dipole chamber	6 mons
34	Start construction of test wiggler chamber	15 mons
35	Finalise construction of test wiggler chamber	2 mons
36	Test ecloud mitigation techniques in wiggler chamber	6 mons
37	Model ecloud build-up with baseline mitigation techniques	1 mon
38	Benchmark electron cloud instability codes	9 mons
39	Model electron cloud instabilities	6 mons
40	Validate design for ecloud mitigation, and predict ecloud instability safety n	0 days



Milestones to ILC EDR

The goal is to complete the following tasks by early 2010 as input for the Engineering Design Report (EDR)

- Test coating techniques and determine conditioning effectiveness in existing accelerator beam lines
- Characterize the efficiency of conditioning on TiN coatings with respect to NEG coatings.
- Characterize thin-film coating durability after long term exposure in an operating accelerator beam line: analyze PEP-II TiN-chambers after ~10 years operation.
- Need to experimentally characterize Photoemission in ILC DR parameters range to estimate initial seed of electrons
- Characterize the electron cloud build-up by simulations and measurements in existing accelerators
- Characterize the electron cloud in wigglers and quadrupoles

Milestones to EDR

- Characterize the electron cloud instability by measurements in existing facilities possibly also at CesrTA or KEKB operating at ultra-low emittances
- Characterize the ILC DR electron cloud instability by simulations

Evaluate the need for Additional Mitigation techniques (besides coating):

- Test clearing electrodes in magnetic field regions including wigglers at KEKB and CESR and dipoles at PEP-II and SPS
- Test triangular groove or slots in magnetic field regions including wigglers and dipoles PEP-II, KEKB and SPS
- Characterize the impedance and HOMs of mitigation techniques
- Use of antechambers

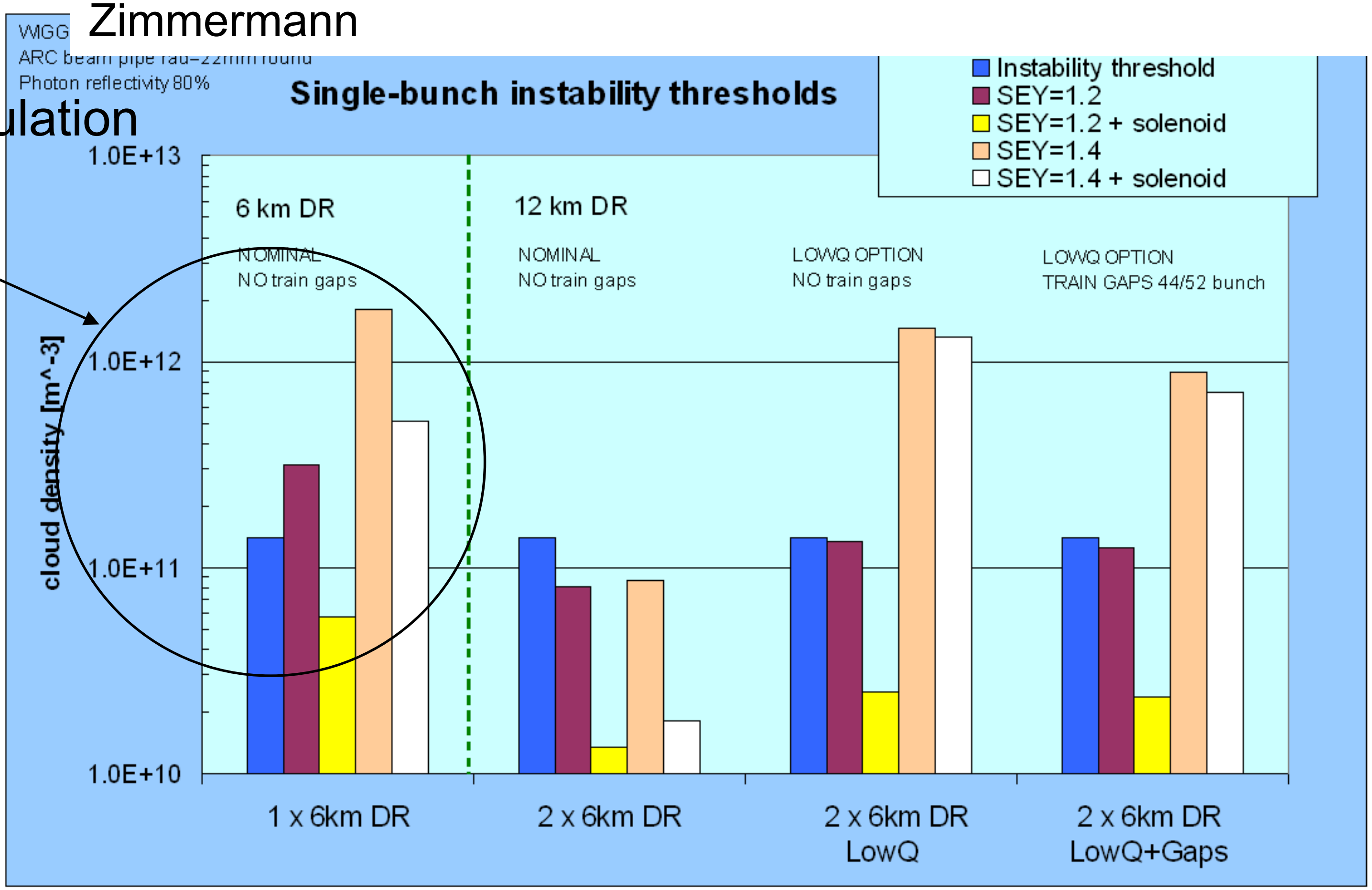
Recommendation of mitigation techniques to prevent the electron cloud in the ILC damping ring as input for the EDR

Additional slides

ILC DR simulations history

R&D simulation coordinators (2005-2006): K. Ohmi, M. Pivi, F. Zimmermann

2006 simulation campaign



Instability Threshold (blue bar) and Ring average cloud density.

Simulation campaign: 1) need detailed build-up simulations with SEY~1, and 2) more accurate photoelectric yield input parameters from experiment (see Cimino &

Simulation Efforts on ILC

Build-up code
Instability code

- KEK: PEI and PEHTS K. Ohmi
- SLAC: POSINST, (CMAD) M. Pivi,
  CLOUD_LAND L. Wang
- LBNL: POSINST M. Furman,
  WARP/POSINST J. L. Vay et al.
- CERN: ECLOUD, FAKTOR2, HEAD-TAIL & (TAIL- HEAD) F. Zimmermann, D.

Modeling tools for electron-cloud instabilities

Collaboration between the
University of Rostock: A. Markovik, G. Pöplau, U. van Rienen
and
DESY: R. Wanzenberg
with recent contributions
from K. Ohmi during his visit at DESY in Aug. 2007

Achievements:
1) Poisson solver to calculate space charge fields
2) Test of particle tracking routines

The collaboration will end in 2008

We can not make a commitment for a contribution from the collaboration to the Engineering Design Phase of the ILC

R&D so far (Cont'd)

- Using KEKB positron ring (LER)
  - Evaluation of ante-chamber scheme
    - Great reduction of photoelectrons was confirmed.
  - Measurement of SEY and surface analysis of samples irradiated to beam at a straight section.
    - Results similar to those in a laboratory was obtained.
- At laboratory
  - Measurement of SEY and surface analysis of various samples.
    - Graphitization of the surface was found to be an important factor to reduce SEY.

R&D plans (Cont'd)

- Using KEKB positron ring (LER)
  - Measurement of electron density in a beam duct with ante-chambers and TiN coating
    - Combination ante-chamber and TiN coating.
    - Coating system has been set up in KEK.
    - Test will start from next February.
  - Direct measurement of electron density in a quadrupole magnet.
    - Manufacturing of a test chamber with electron monitor will start soon.
    - Test will start from next spring (?).

Fermilab: Panagiotis

FNAL ecloud & multi-physics DR modeling

- We propose to use Synergia to model ecloud and in the future multi-physics effects in the same simulation
  - Use the same lattice as the optics design
    - Employ higher order maps if necessary
  - Incorporate both cloud generation and dynamics
    - Utilize existing generation module and Synergia solvers
  - To enable long term simulations, define "ecloud regions" in the geometry, for generation and ecloud acting on the beam