ILC Damping Ring electron cloud R&D effort

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on behalf of ILC DR working group on e- cloud

LER Meeting CERN

Jan 12-15, 2010

ILC DR electron cloud R&D effort history

- Effort started in 2003 with extensive simulations of electron cloud build-up and instability.
- International collaboration effort: 2005-2006 simulation campaign culminating in the recommendation for the damping rings circumference reduction from

  17 km → 12 km and then further reduction

  12 km → 6.7 km
- The electron cloud is an issue in arc magnets and wigglers of the 6km DR.

ILC DR electron cloud R&D effort history

- Simulations give confidence on possible suppression techniques as clearing electrodes and grooves, 2007.
- A substantial R&D effort is needed to confirm possible mitigation techniques.
- Mitigations tests on coatings, clearing electrodes and grooves in accelerator beam lines at KEK and SLAC, CERN 2007-2009.
- CesrTA rigorous program on electron cloud studies and mitigations started 2008-2010 >>

ILC DR electron cloud R&D effort

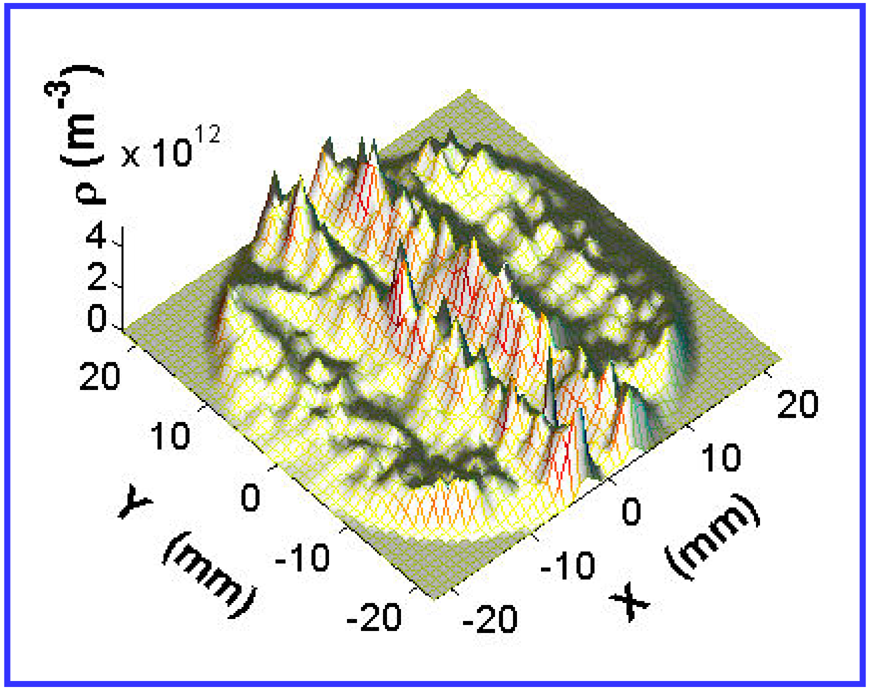
- Experimental tests are successful at confirming effectiveness of mitigations
- As part of the ILC “SB2009 rebaselining” effort and to reduce DR costs, presently with colleagues we are investigating, the reduction of the ILC damping ring circumference to → 3.2 km and its immunity with respect to electron cloud, 2009-2010.

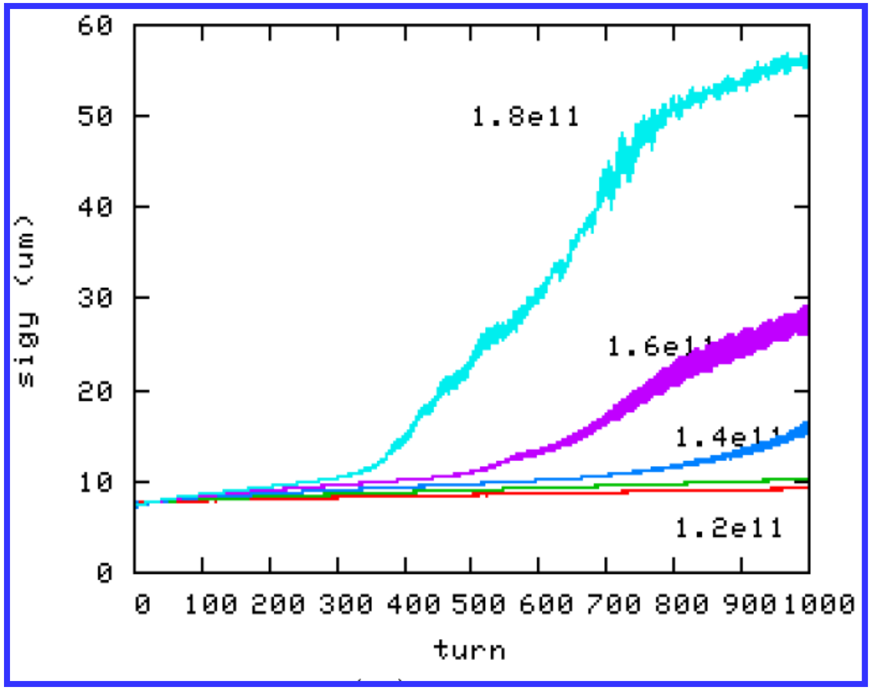
(Note: the ILC DR and CLIC DR lengths are approaching …)

Cloud build-up and instability threshold

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

Beam instability threshold (right plot) sets the tolerances on the maximum value of the Secondary Electron Yield (SEY) allowed at the vacuum chambers surface.



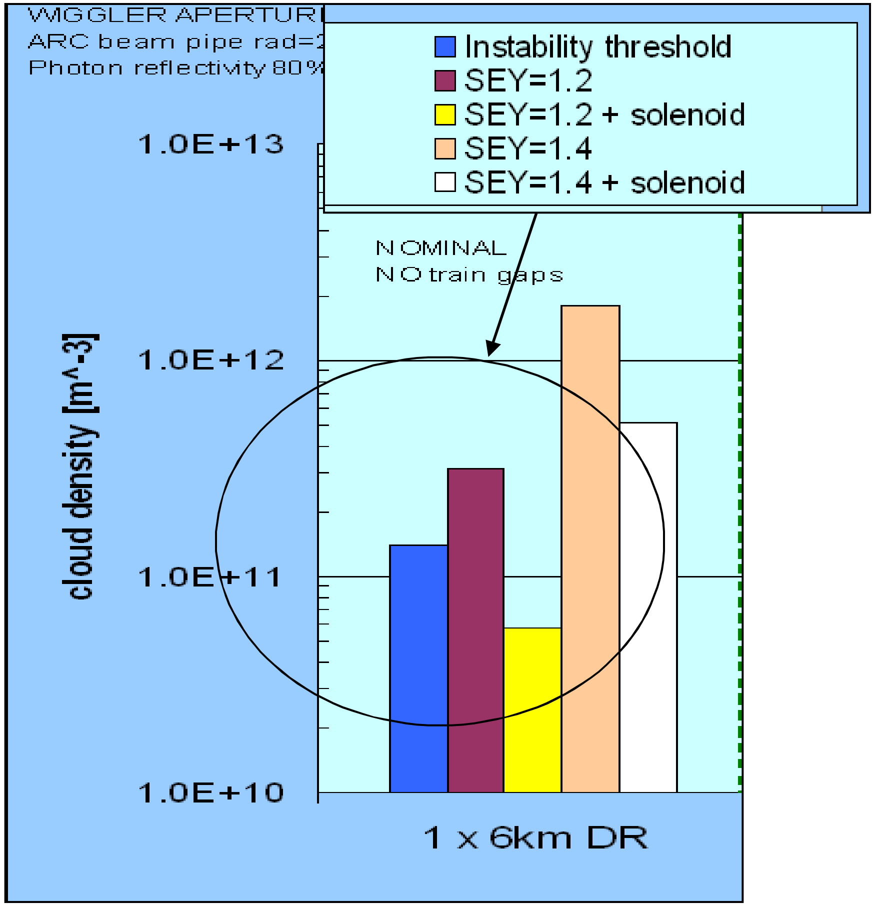


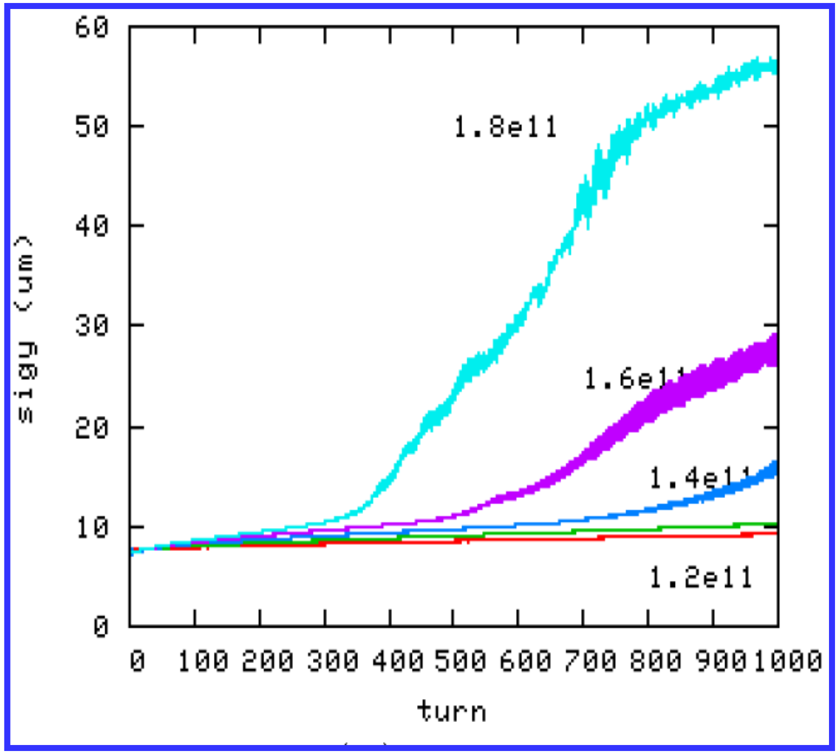
Histograms of the electron cloud in an arc bend, CLOUD_LAND simulations (L. Wang, SLAC).

Vertical beam size increase with cloud density, PEHTS simulations (K. Ohmi, KEK).

ILC DR simulations history: 2006

ILC DR 6.7km Ring OCS2 design





ILC DR 6.7 km. Vertical beam size increase with cloud density, PEHTS code.

Single-Bunch instability threshold (blue bar – see also picture on the right) and simulated ring averages cloud density according to assumed SEY values.

Work to Pursue during the ILC Technical Design Phase 2 (TDP2), 2010-2012

3km Ring: electron cloud for 6 ns bunch spacing

- For the nominal configuration with 1300 bunches and 6ns bunch spacing, electron cloud mitigation techniques are needed both for the 6km and the 3km rings.
- R&D is in progress at the dedicated test facility, CesrTA, and at other labs. Results are promising and a range of mitigation methods are being tested.
- We have convened a working group to apply the results of the R&D to the DR design. The findings will be used as input for the ring design that will be chosen for the new baseline.
- Given the same current and bunch distance we expect similar or even higher instability threshold for the shorter ring [M. Pivi presentation at LCWA09].

ILC DR Working Group goals

Goals of the LC DR Working Group are:

- To give a recommendation on the feasibility of a shorter damping ring by comparing the electron cloud build-up and instability for the 6.4km and 3.2km rings with a 6 ns bunch spacing by March 2010, then
- Following the CesrTA program, working to give our recommendation on e- cloud mitigations and evaluate the electron cloud in the shorter 3.2 km ring with a 3 ns bunch spacing.
- Furthermore starting later in 2010, to fully integrate the CesrTA results into the Damping Ring design.

ILC DR Working Group - Deliverables

Recommendation for the reduction of the ILC Positron Damping Ring Circumference

By March 2010

Recommendation for the baseline and alternate solutions for the electron cloud mitigation in various regions of the ILC Positron Damping Ring.

Following CesrTA program

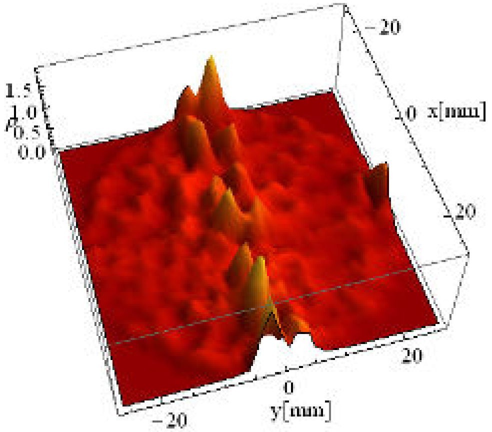
Build Up Input Parameters for Simulations

ilc-DR 6.4 Km, 6 ns bunch spacing*.

Bunch population	N_b	2.1x10^{10}
Number of bunches	N_b	45 x 4 trains
Bunch gap	$Ngap$	15
Bunch spacing	$L_{sep}[m]$	1.8
Bunch length	$\sigma_z\,[mm]$	6
Bunch horizontal size	$\sigma_x\,[mm]$	0.26
Bunch vertical size	$\sigma_y\,[mm]$	0.006
Photoelectron Yield	Y	0.1
Photon rate (e^-/e^+/m)	dn_γ/ds	0. 204
Antechamber protection	η	90%; 97%
Photon Reflectivity	R	20%; 50%
Max. Secondary Emission Yeld	δ_{max}	0.9-1.4
Energy at Max. SEY	$E_m\,[eV]$	300
SEY model	Cimino-Collins $(\delta(0)=0.5)$	

*https://wiki.lepp.cornell.edu/ilc/pub/Public/DampingRings/WebHome/DampingRingsFillPatterns.xls

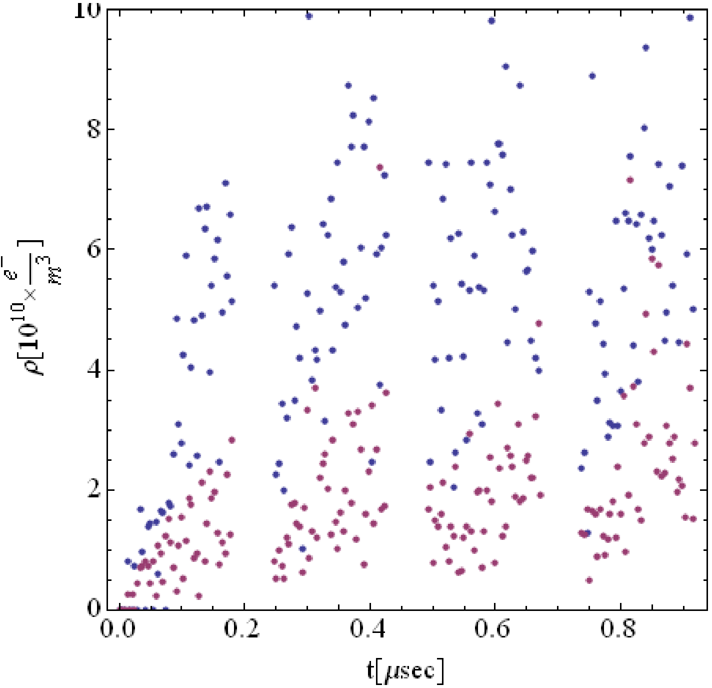
Buildup in ilc-DR arcs: Dipoles



Snapshot of the electron (x,y) distribution "just before" the passage of the last bunch

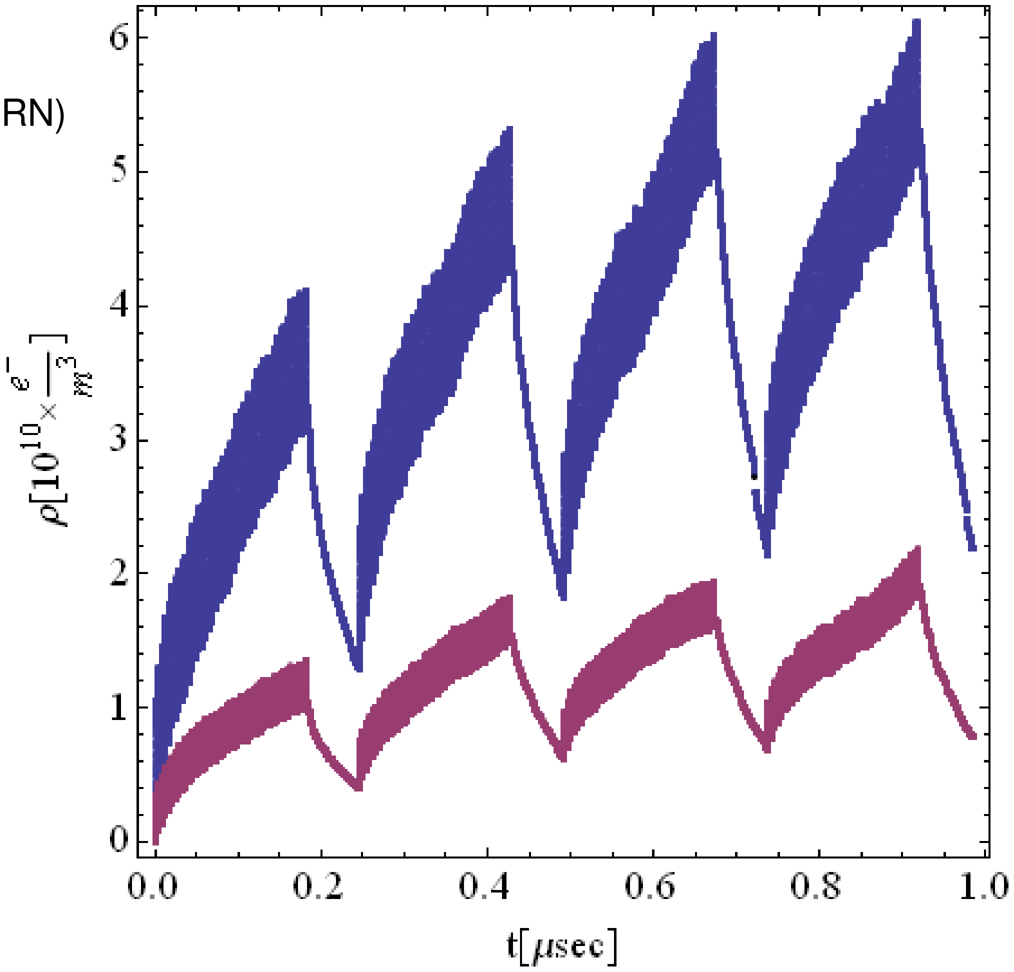
ECLOUD code (CERN)

<u>Secondary Electron Yield peak</u> = 1.2
By field=0.27 T; R=20%
antechamber absorb η=90% η=97%



Center density "just before" bunch passage

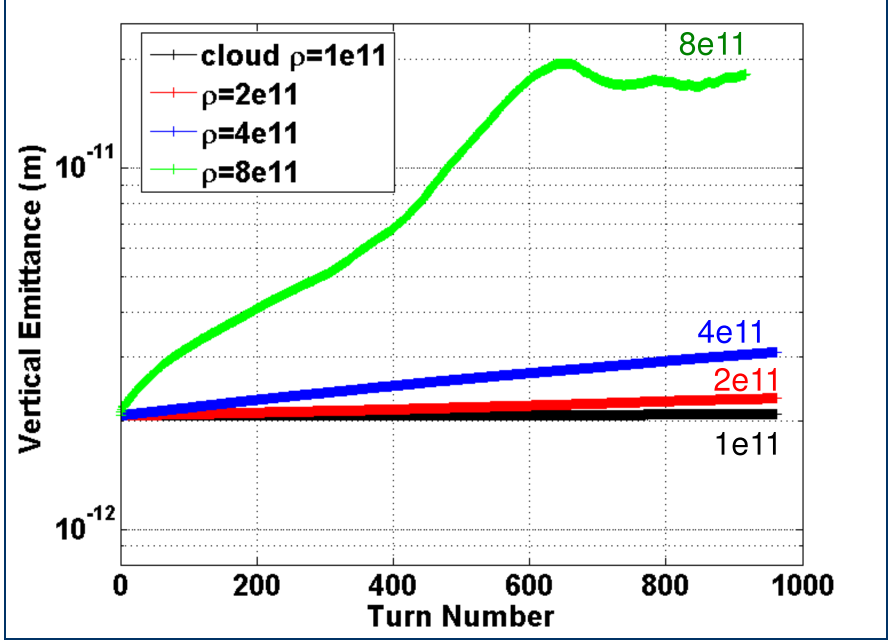
Average e-cloud density



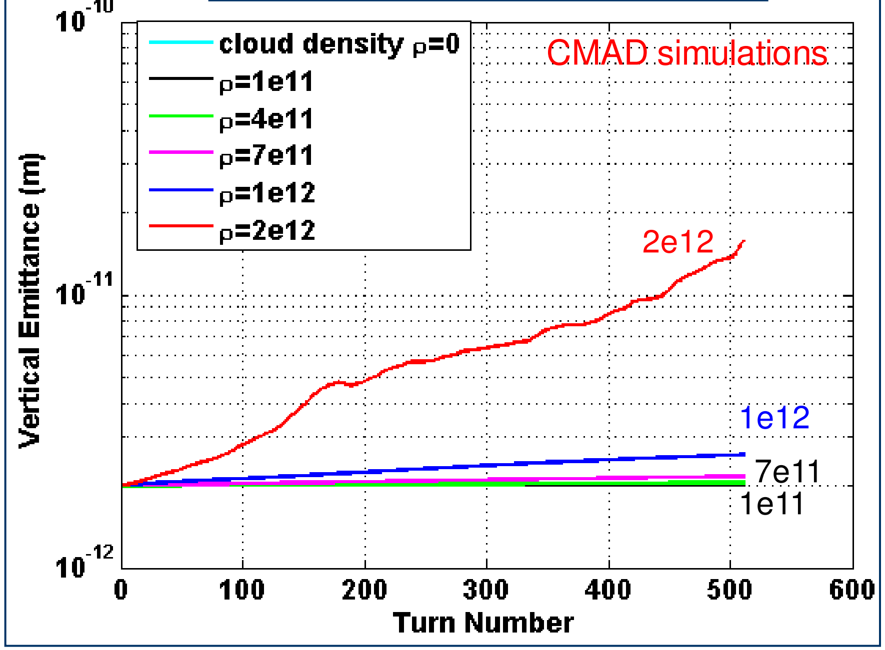
ILC DR instability simulations

- CMAD a tracking and e-cloud beam instability parallel code (M.P. SLAC)
- Taking MAD(X) optics file at input, thus tracking the beam in a real lattice and applying the interaction beam-electron cloud over the whole ring

DC04 lattice: 6.4 km ring

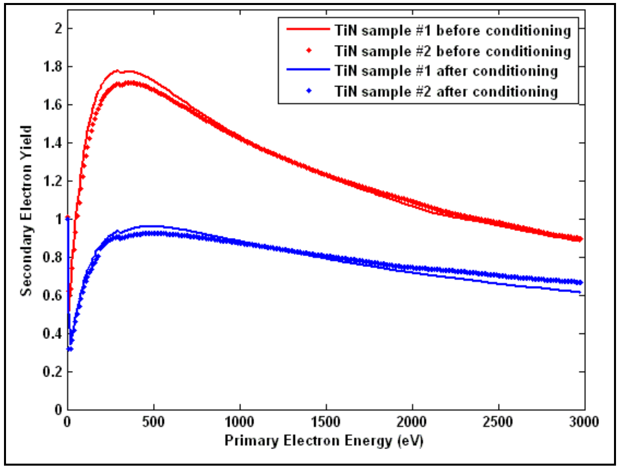


DSB3 lattice: 3.2 km ring

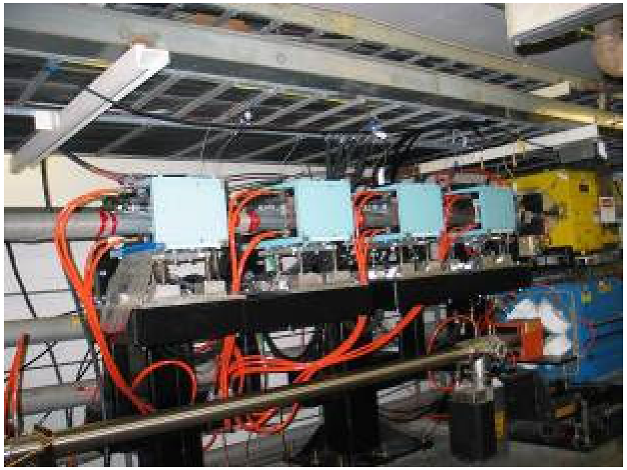


- Good News: Higher cloud density threshold in the shorter 3.2 km ILC DR.
- Adding intra-beam scattering IBS module into code.

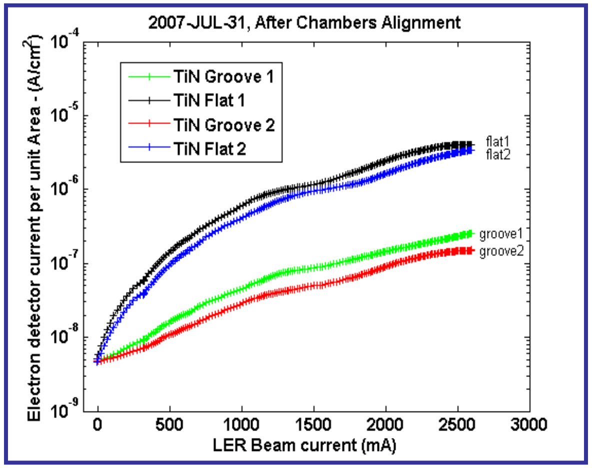
Mitigations R&D



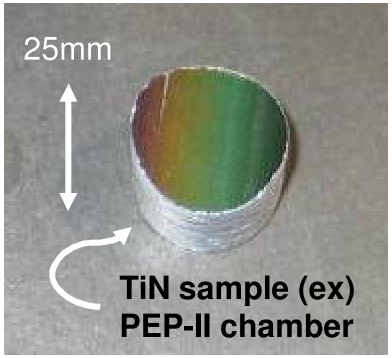
TiN conditioning *in situ* in PEP-II, SLAC. SEY stably below 1.



Mitigation studies in PEP-II, SLAC.



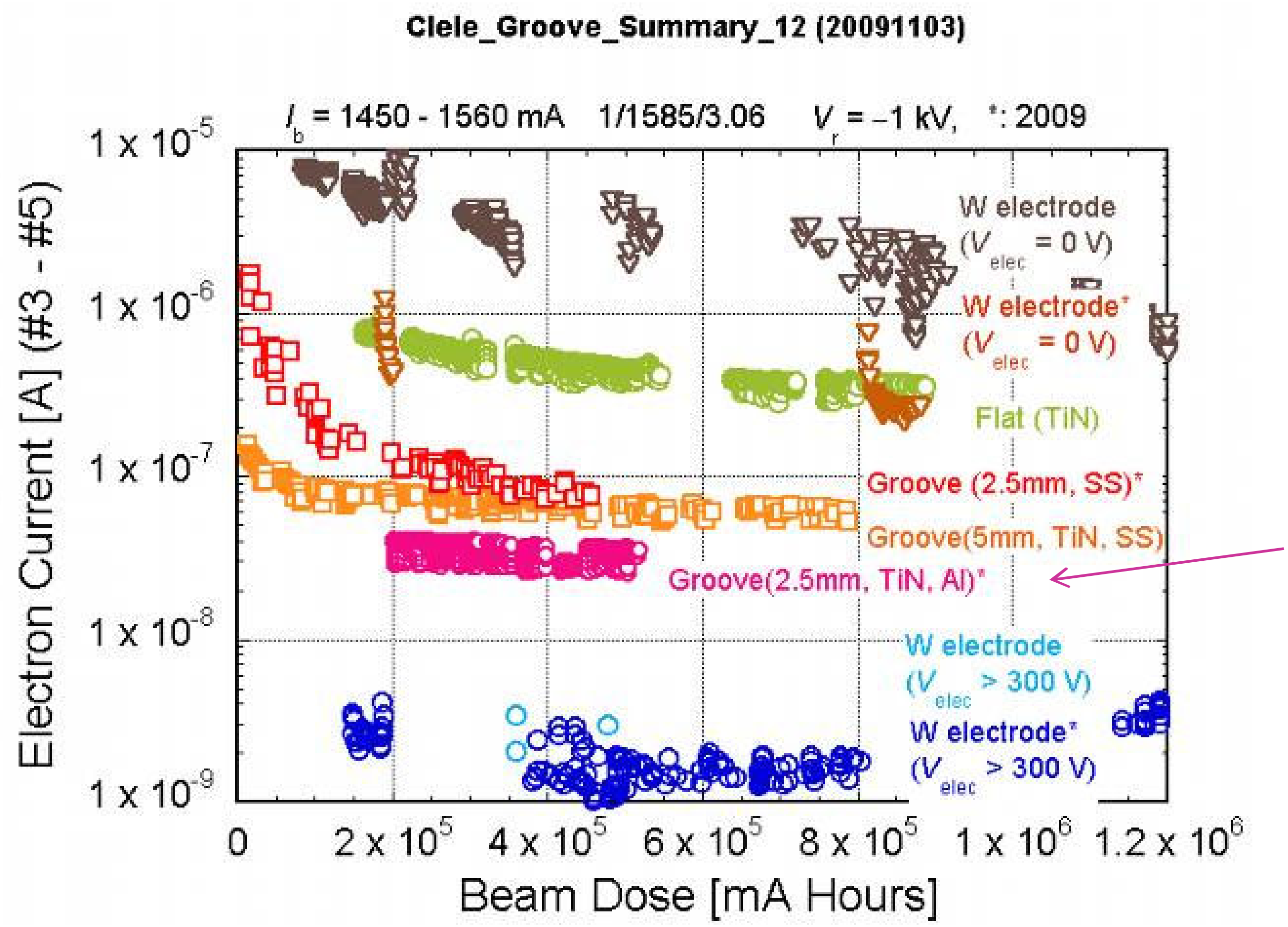
Groove chamber in PEP-II. Factor ~20 e-cloud reduction.



Recently, removed an arc dipole chamber from PEP-II for TiN surface "durability" studies. Samples thickness and stoichiometry being analyzed, Jan 2010.

Groove and Clearing electrode

- Compared to the case of TiN-coated flat surface;
  - Clearing electrode (> +300 V): 1/100~1/500
    - ~1/50 of groove structure

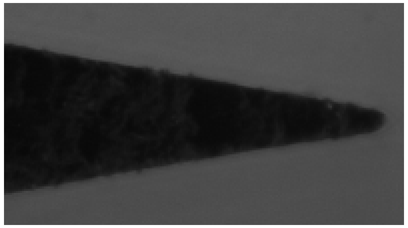


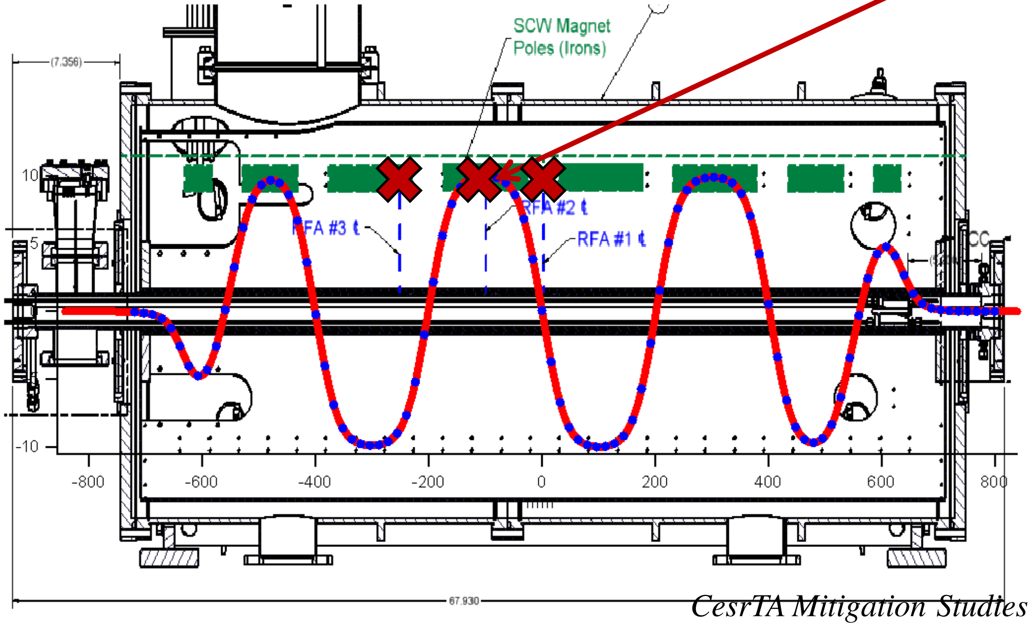
Latest improved design SLAC/KEK

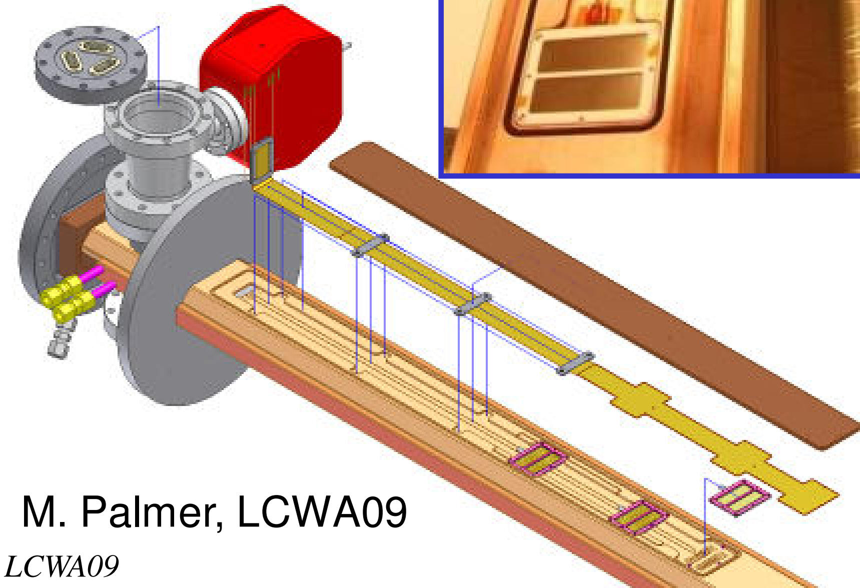
Wiggler Mitigation

- We have three wigglers instrumented with Retarding Field Analyzers (RFA)
  - Bare Cu
  - TiN coated
  - Grooved
- Each wiggler has three RFAs
  - Plots shown will be for an RFA in the center of a wiggler pole
  - There are also RFAs in a longitudinal and intermediate field
  - RFAs have 12 collectors and are built into the beam pipe

Groove tips/valley radius < 0.002" !!





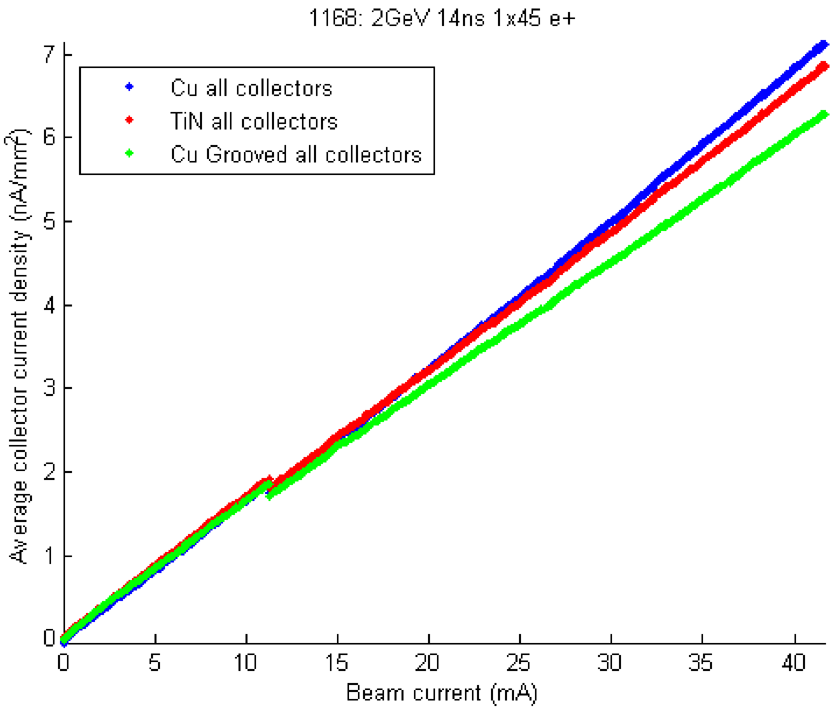


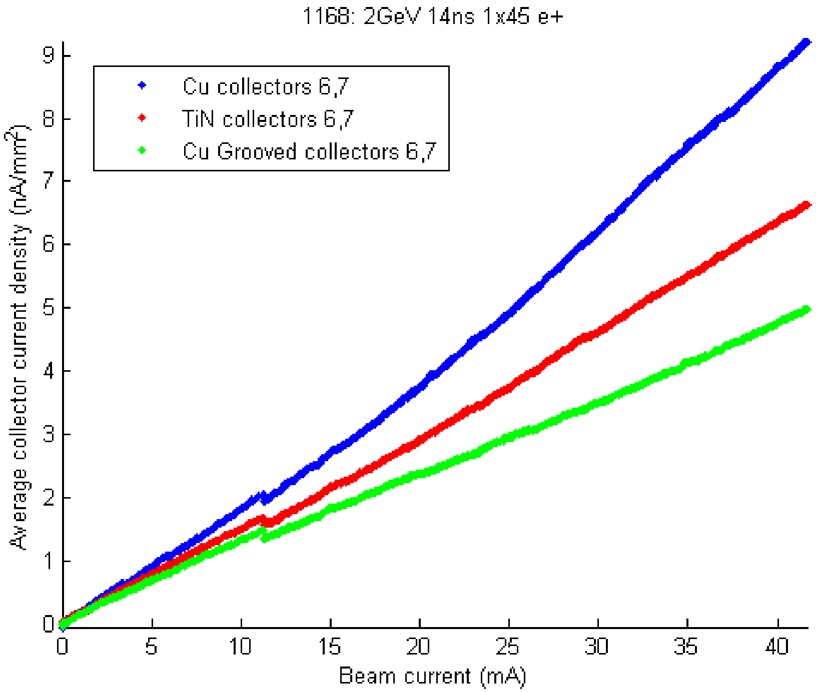
M. Palmer, LCWA09

Wiggler Current Scan

- Plots show average collector current density vs beam current
  - 1x45 e+, 2 GeV, 14ns
- Cu, TiN, and grooved chambers all have comparable responses (when normalized to photon flux)
  - Central collectors (right plot) show a more significant difference
    - This where one expects multipacting to occur

M. Palmer, LCWA09

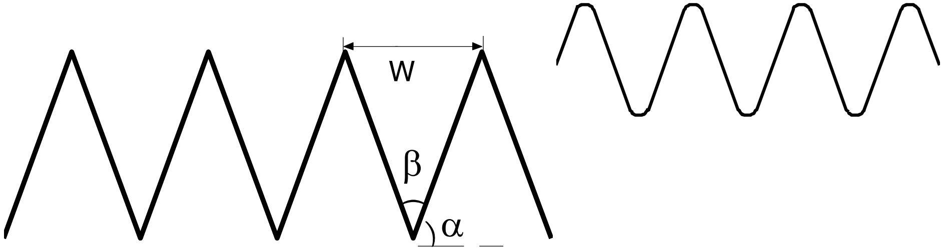




Impedance enhancement factor

(Code : Finite Element Method, PAC07 THPAS067, L Wang)

$$\eta = \frac{Z_{groovedsurface}}{Z_{smoothsurface}} = \frac{\int H^2 ds}{H_0^2 W}$$

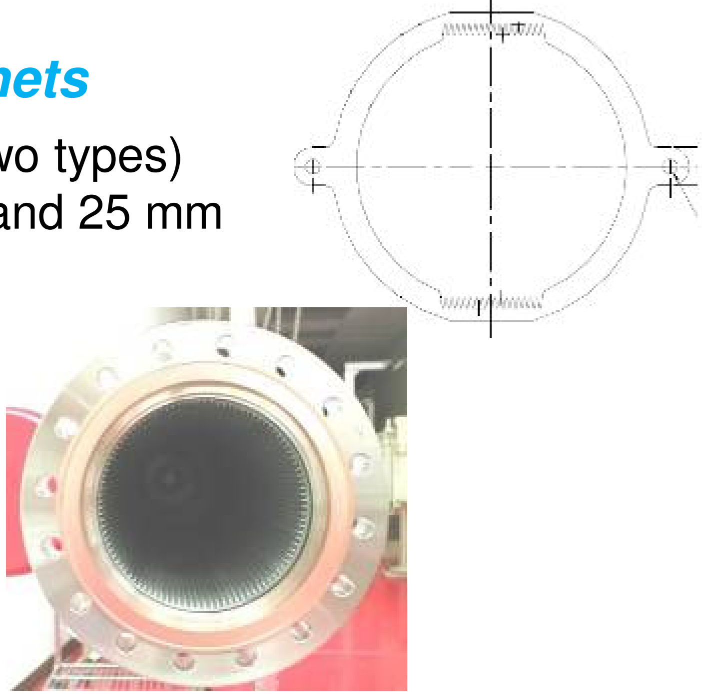


The total impedance enhancement= η * percentage of grooved surface
*percentage chamber length with grooved surface

Triangular groove in dipole and wiggler magnets

Round Chamber with radius: 30 mm or 23 mm (two types)
Width of grooves inside chamber: 25 mm on top and 25 mm on bottom

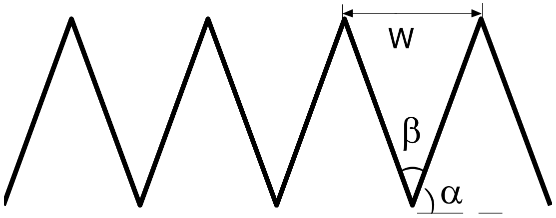
percentage of grooved surface=26.5%(34.6%)



Rectangular groove in drift region

percentage of grooved surface=100%

Triangular Grooved surface in Magnet(dipole & wiggler)

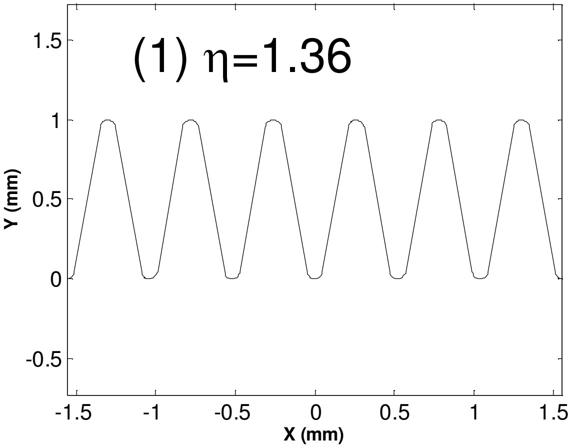


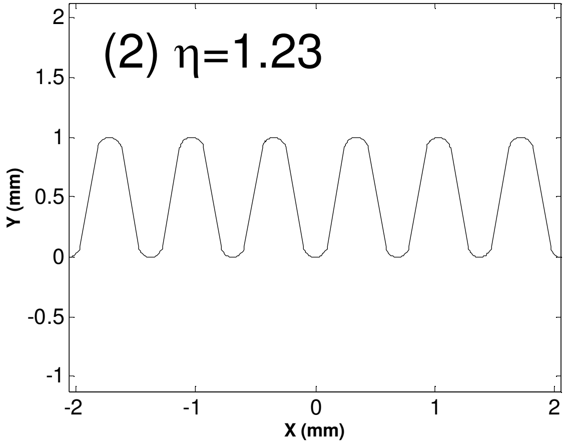
(1) α =80
  Groove depth: 1 mm
  Roundness: 50 um
  η=1.36

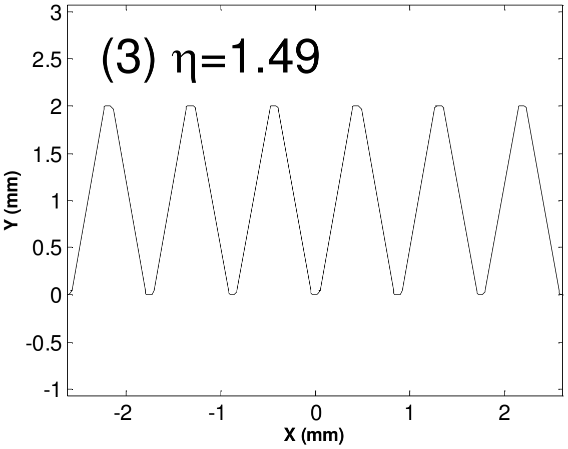
(2) α =80
  Groove depth: 1 mm
  Roundness: 100 um
  η =1.23

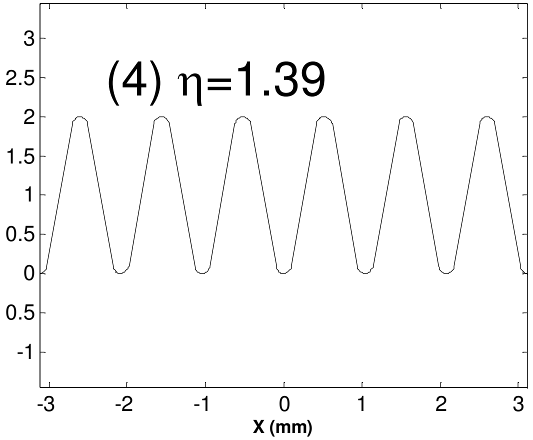
(3) α =80
  Groove depth: 2 mm
  Roundness: 50 um
  η =1.49

(4) α =80
  Groove depth: 2 mm
  Roundness: 100 um
  η =1.39









CLIC Damping Ring simulations

Build-up simulations

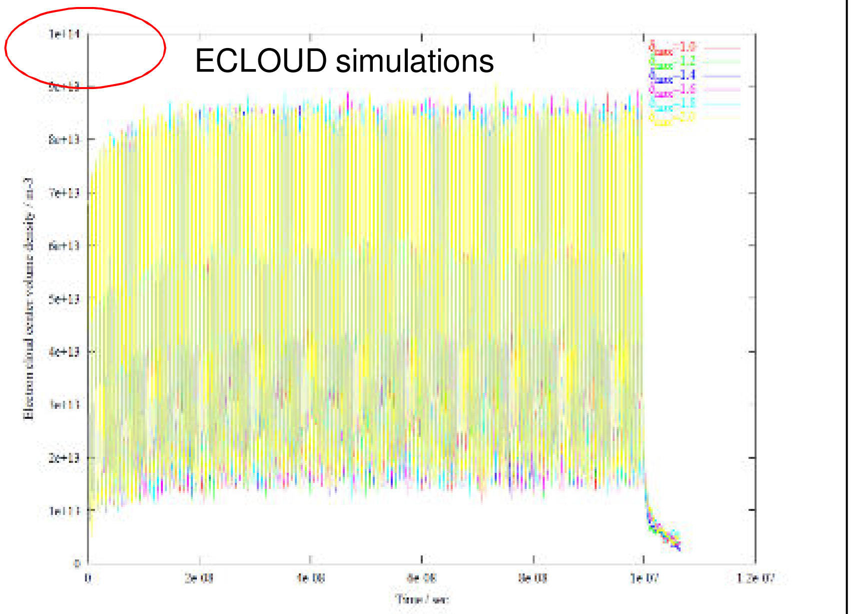
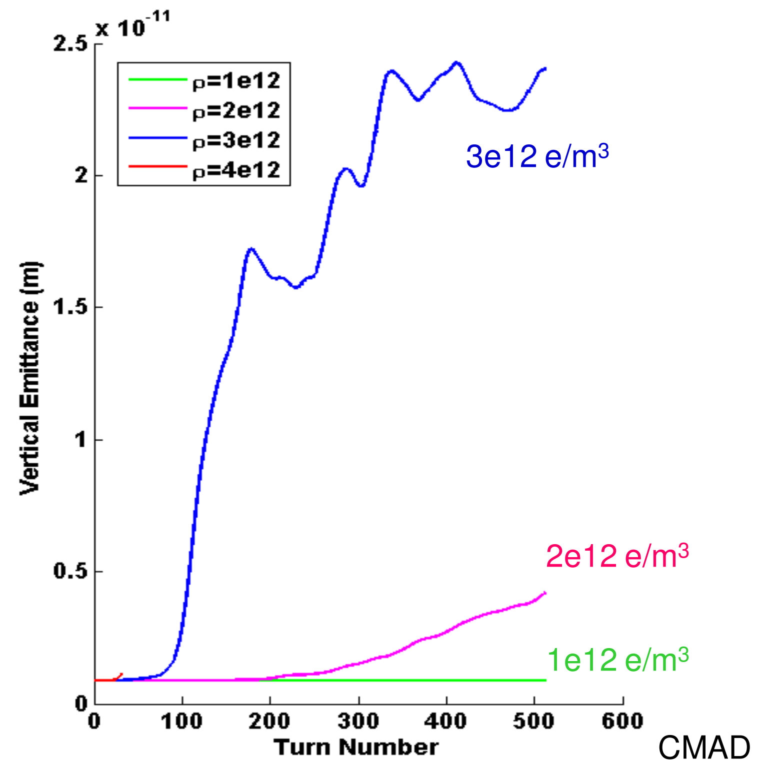


Figure 35: Central electron cloud volume density in units of m^{-3} as a function of time in s for a bend (top) and a field-free region (bottom) of the CLIC arcs, assuming $dN_{e^-}/dz = 0.0576$ photoelectrons per positron per meter; the various curves refer to 6 different values of $\delta_{\max}$.

Ref. ELECTRON-CLOUD EFFECTS IN THE TESLA AND CLIC POSITRON DAMPING RINGS D. Shulte, R. Wanzenberg, F. Zimmermann

Beam instability simulations. New
CLIC DR 2.86 GeV lattice, 2009



- Figure. CMAD (M.P. SLAC) parallel simulations with 100 IPs / turn and continuous focusing (constant beta functions). Instability threshold below electron cloud from build-up simulations (left figure), Jan 2010.
- Preparing to run with a complete MAD deck-type simulations: 14,500 elements …

Summary

- Promising simulation results towards a reduced 3.2 km ILC DR circumference.
- TiN and/or amorphous carbon coatings SEY condition below 1 and would be sufficient. Although one must opt for the largest suppression of the electron cloud, if aiming at reaching LC DR ~pm emittancies.
- Ongoing concerted R&D effort on developing mitigations, so far very promising.
- At CesrTA, the systematic work on e-cloud suppression techniques will be essential to give a recommendation on mitigations for the Linear Colliders DR.
- LC DR Working Group Goal is to integrate the CesrTA results into the Damping Ring design, starting from the end of 2010.
- CLIC simulations effort ongoing.

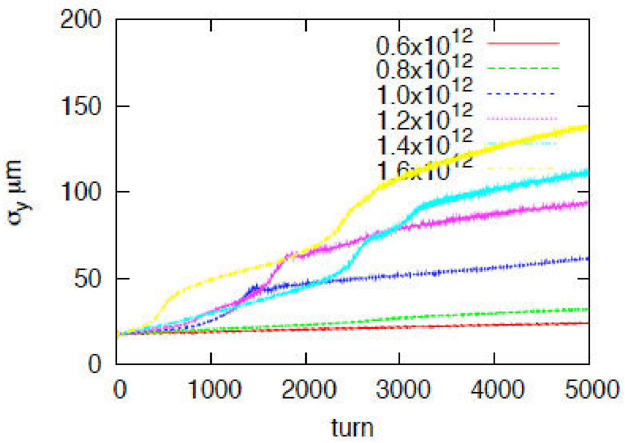
CesrTA Single-bunch instabilities

From Kazuhito Ohmi

Simulation of the strong head-tail instability

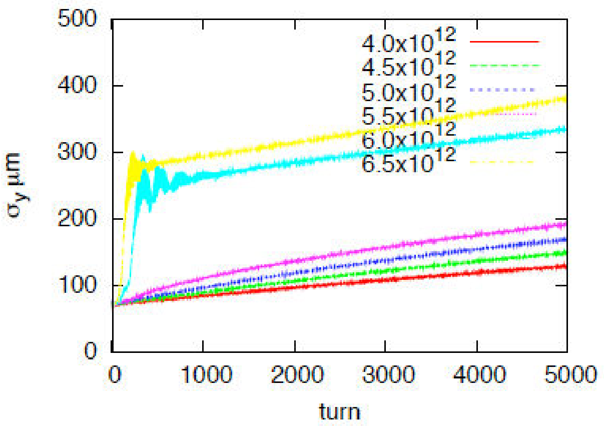
- Uniform beta model, integration step is L/8.

2 GeV



$\rho_{th}=1.0\times10^{12}\ \mathrm{m}^{-3}$

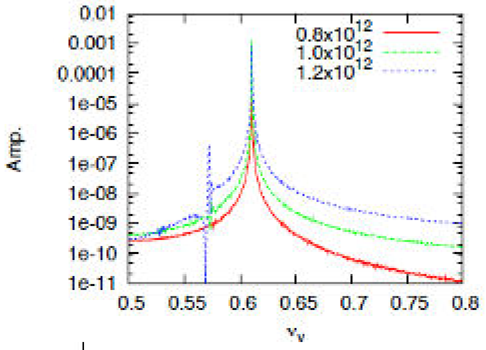
5 GeV



$6\times10^{12}\ \mathrm{m}^{-3}$

2GeV

ν_s=0.055



CesrTA simulations using PEHTS code (KEK)