LC e-Cloud Activities at CERN

G. Rumolo, F. Zimmermann

all e-cloud studies for linear colliders
are performed within the
EUROTeV WP3 Electron Cloud Task

WP e-cloud task contacts:
F. Zimmermann, CERN;
R. Wanzenberg, DESY;
C. Vaccarezza, LNF,
R. Cimino, LNF;
O. Malyshev, CCLRC;
R. Reid, CCLRC

recent e-cloud highlights

- ***complete study of e-cloud in wigglers for ILC, CLIC & DAFNE*** (photon flux, e- build up, instabilities)

  $\rightarrow$ *EUROTeV-Report-2006-002*
- development of a ***new electron cloud code***, which can simulate arbitrary boundary shapes, e- build up, cloud-beam interaction, & ions by Warner Bruns at CERN. It will be able to simulate 3D problems. Wigglers are important example.
- ***mechanisms of incoherent e-effects*** identified
  (periodic crossing of resonances or of region with linear instability)
- ***impedance of e- clearing electrodes*** computed (W. Bruns)
- ***e-cloud simulations for 2x6-km ring*** (next slides) confirm that, as expected, ***e-cloud likely no problem for ILC 2x6-km e+DR baseline but would be for 6-km ring***
- **Upgrade of HEADTAIL**: the electron distribution is taken from ECLOUD to have a more "self-consistent" model
- study of ***ion effects in DRs*** suggest problem for ILC, OK for CLIC $\rightarrow$ EPAC'06 paper (see Appendix)

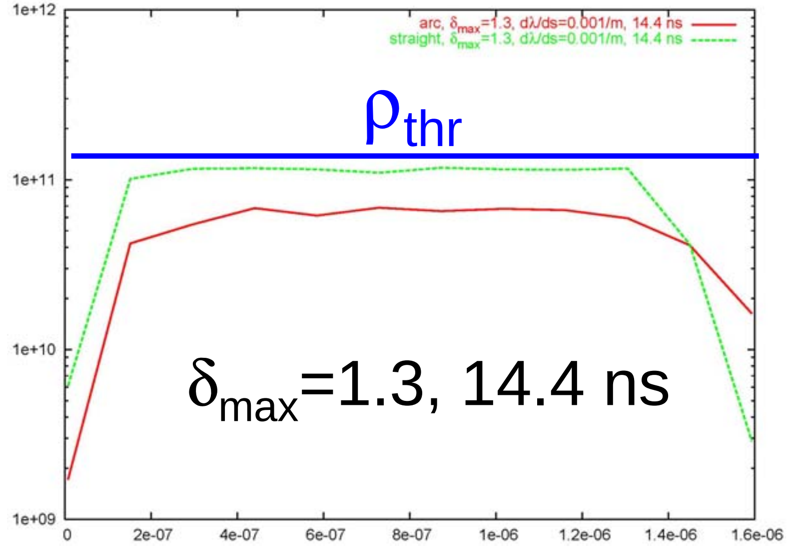
e- build-up for ILC 2(1)x6 km DR - 1

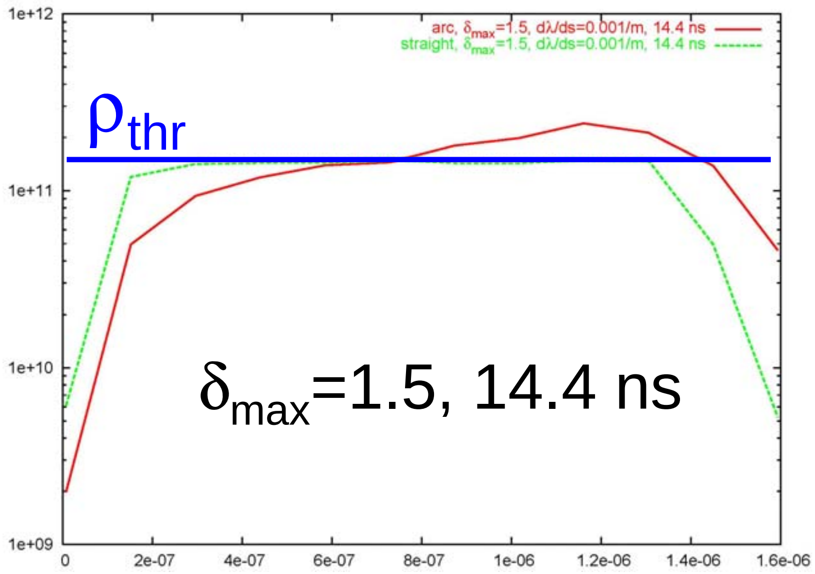
simulation parameters	value
max. sec. emission yield	1.3, 1.5, 1.7, 1.9
energy at maximum	234.75, 239.5, 244.25, 249 eV
primary e- rate (e-/m/e+)	0.001 (0.01% of wiggler γ emission, 0.1% of arc bend γ emission)
low-energy e- reflectivity	50%
bunch population	2×10^{10}
bunch spacing	14.4 or 7.2 ns
rms bunch length	6 mm
rms horizontal size	0.618 (arc), 0.128 mm (straight)
rms vertical size	0.008 (arc), 0.009 mm (straight)
beam momentum	5 GeV/c
arc chamber radius	25 mm
straight section radius	50 mm
dipole field	0.2 T (arc), 0 T (straight)

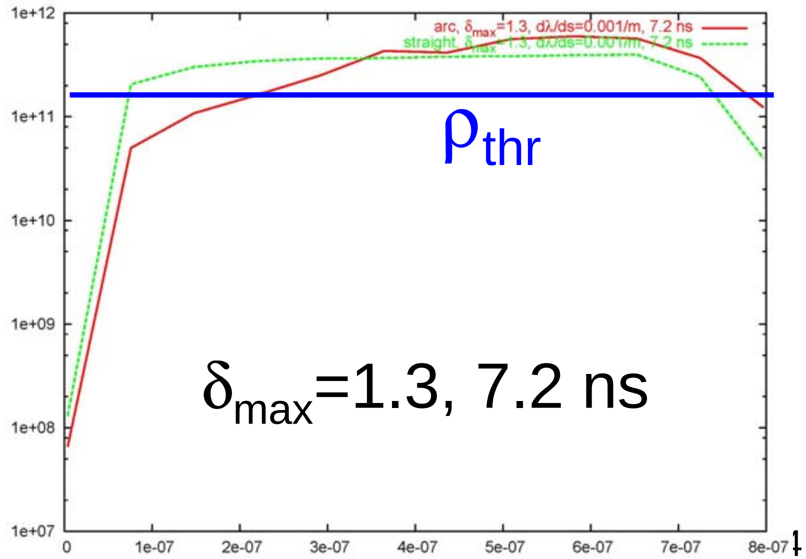
e- build-up for ILC 2(1)x6 km DR - 2

<u>example simulations</u>

centre density (m^{-3}) vs. time (s),
primary photo-electron rate:
$d\lambda/ds = 0.001\ m^{-1}$,
bunch train followed by gap,
arc & straight, log scale





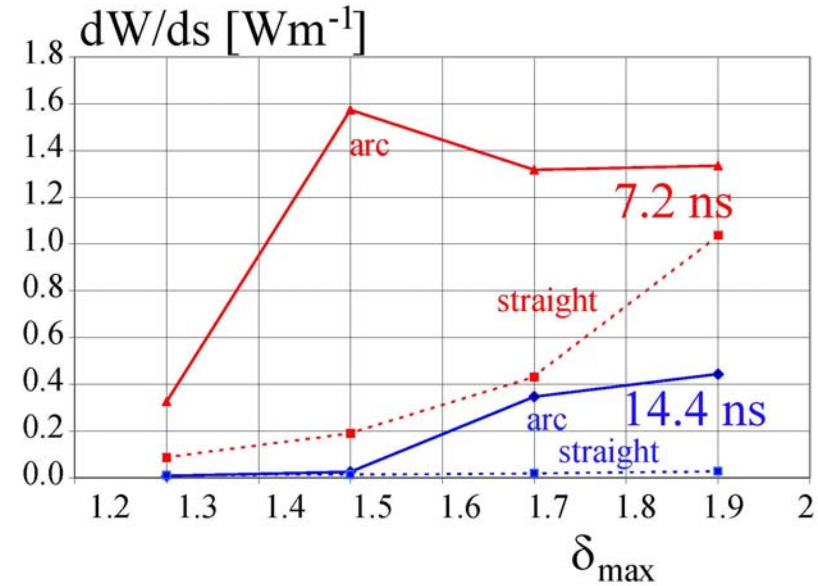


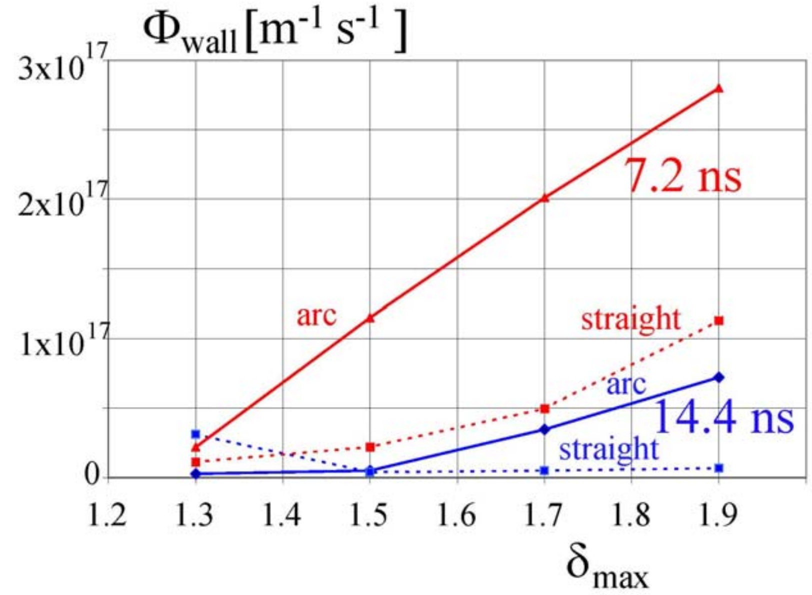
e- build-up for LC 2(1)x6 km DR - 3

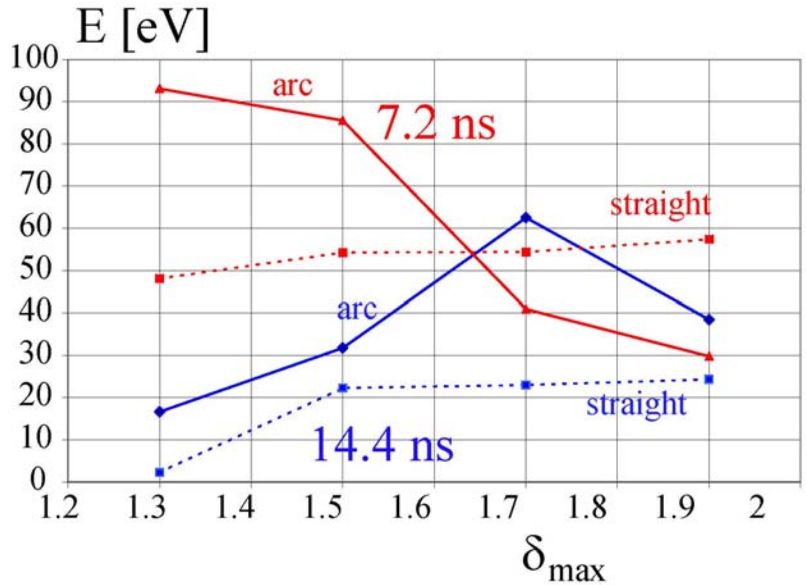
L_{sep} [ns]	δ_{max}	heat [W/m]	flux [e- $m^{-1}s^{-1}$]	central ρ_e [$10^{10}m^{-3}$]	e-energy [eV]
14.4	1.3	0.007	2.8×10^{15}	5.2	17
14.4	1.5	0.026	5.0×10^{15}	$13.7\sim\rho_{thr}$	31
14.4	1.7	0.347	3.5×10^{16}	83.4	63
7.2	1.3	0.325	2.2×10^{16}	34.5	93
7.2	1.5	1.574	1.2×10^{17}	121	86

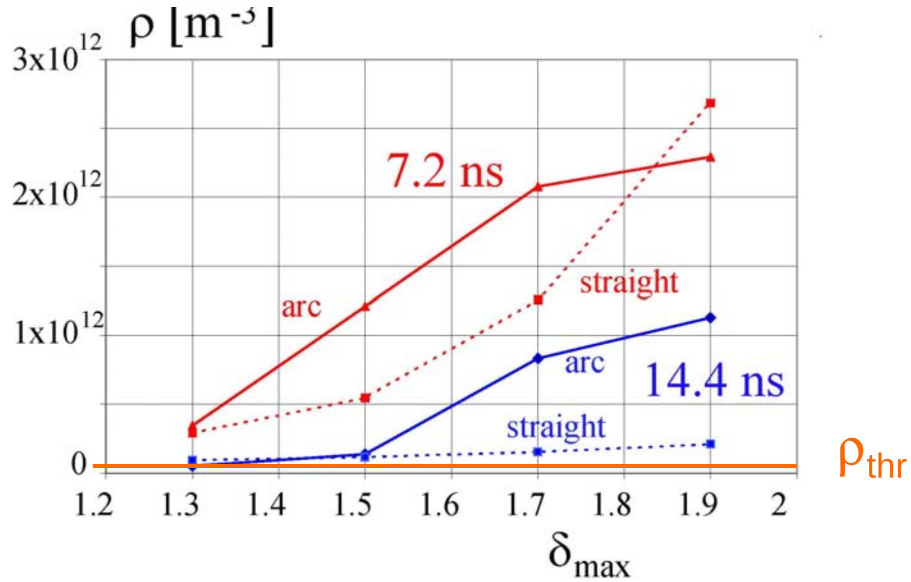
arc, $d\lambda_{\gamma e}/ds$=0.001 e+/m/s

e- build-up for ILC 2(1)x6 km DR - 4









ion effects in ILC & CLIC DR

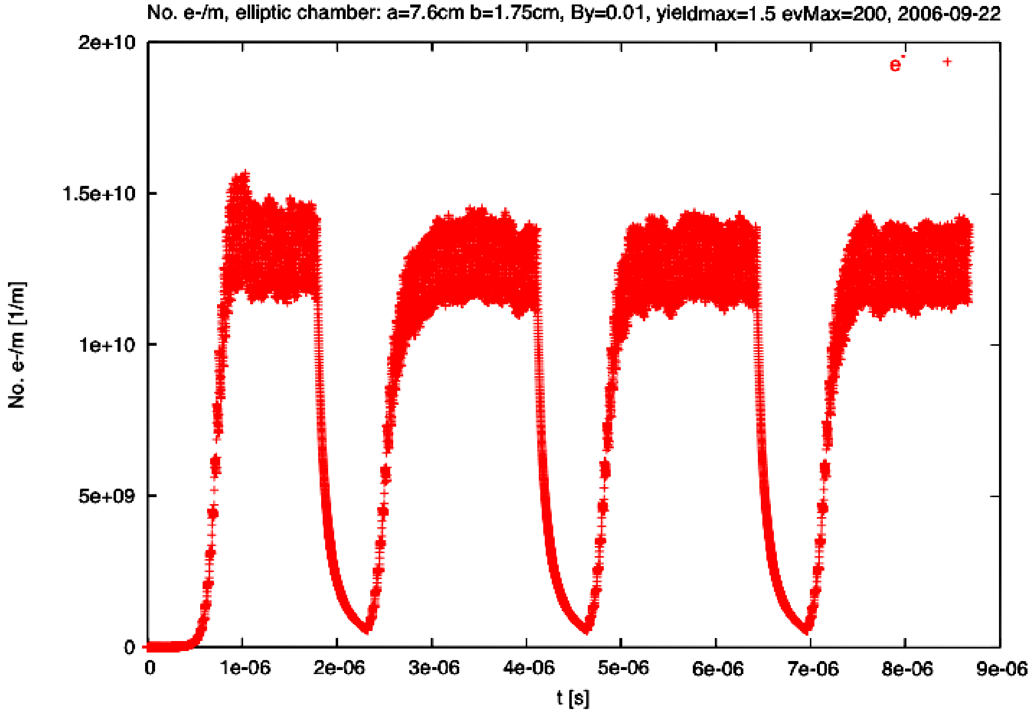
Table 2: Estimates for the incoherent tune shift and exponential fast beam-ion instability rise time for the three damping rings of Table 1. A partical CO pressure of 0.2 ntorr is assumed.

ring	ILC OTW			ILC OCS			ILC TESLA			CLIC	
	arc	wiggler	str.	arc	wiggler	str.	arc	wiggler	str.	arc	wiggler
critical mass	8	151	8	6	69	24	44	285	1	15	9
vert. ion freq. [MHz]	33.4	144	33.3	19.2	66.5	39.2	16.4	41.5	2.8	360	275
min. gap $L_{g,cl}$ [m]	29	7	29	50	14	24	58	23	340	2.7	3.5
ion dens. ρ_{ion} [cm^{-3}]	0.86	16.9	0.90	0.46	5.7	2.0	1.1	7.3	0.06	0.58	0.34
exponential rise time	22	6	6	32	9	6	18	5	102	189	185
at train end [μs]	[average rise time 10]			[average rise time 11]			[average rise time 47]			[av. rise t. 187]	
incoherent tune shift	0.011	0.0055	0.028	0.013	0.002	0.064	0.0154	0.0145	0.019	0.001	0.001
at train end ΔQ_y	[total $\Delta Q = 0.44$]			[total $\Delta Q = 0.79$]			[total $\Delta Q = 0.49$]			[total 0.0026]	

ILC DR rise time τ~1 turn, tune shift ΔQ~ 0.5;   CLIC: τ~200 turns, ΔQ~3x10^{-3}

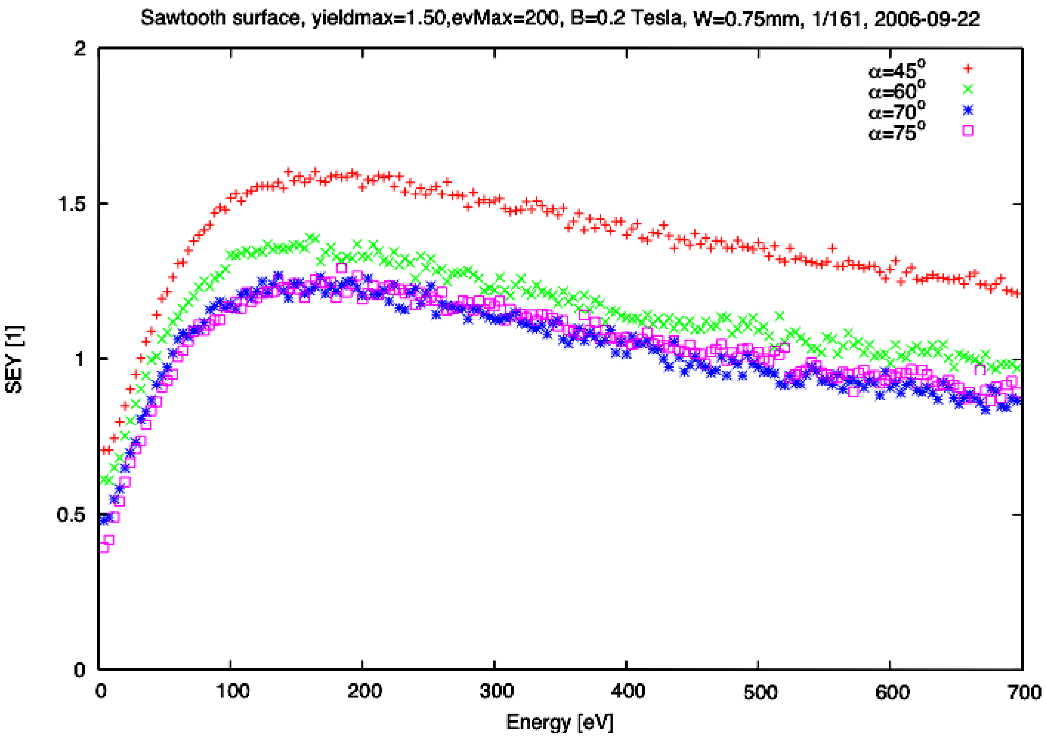
Summary Table of EPAC'06 paper
"ION EFFECTS IN THE DAMPING RINGS OF ILC AND CLIC"
F. Zimmermann, W. Bruns, D. Schulte

Sample results from the new e-cloud code developed by W. Bruns (I)



Elliptical flat chamber: build up pattern seems correct and saturation value of the cloud is about a factor 2 lower than the one predicted by ECLOUD. Discrepancy still under study.

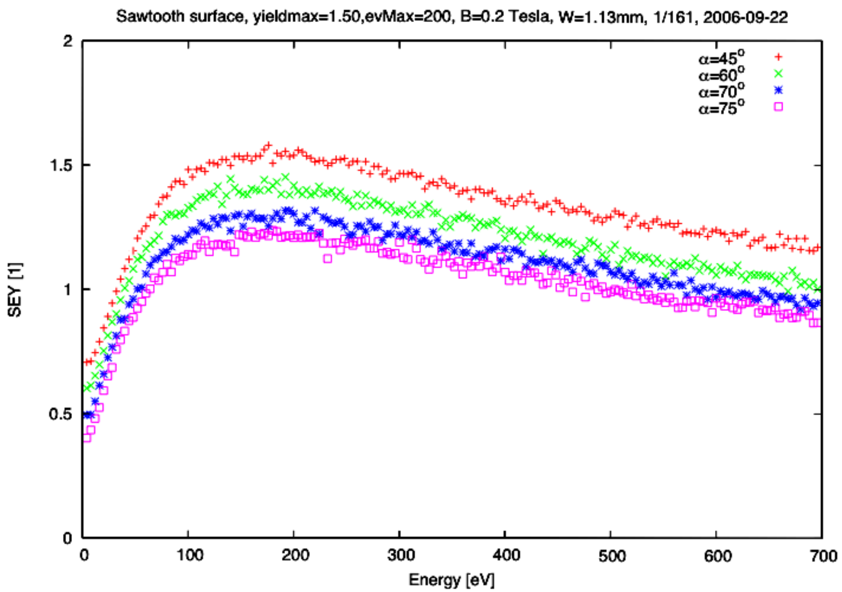
Sample results from the new e-cloud code developed by W. Bruns (II)

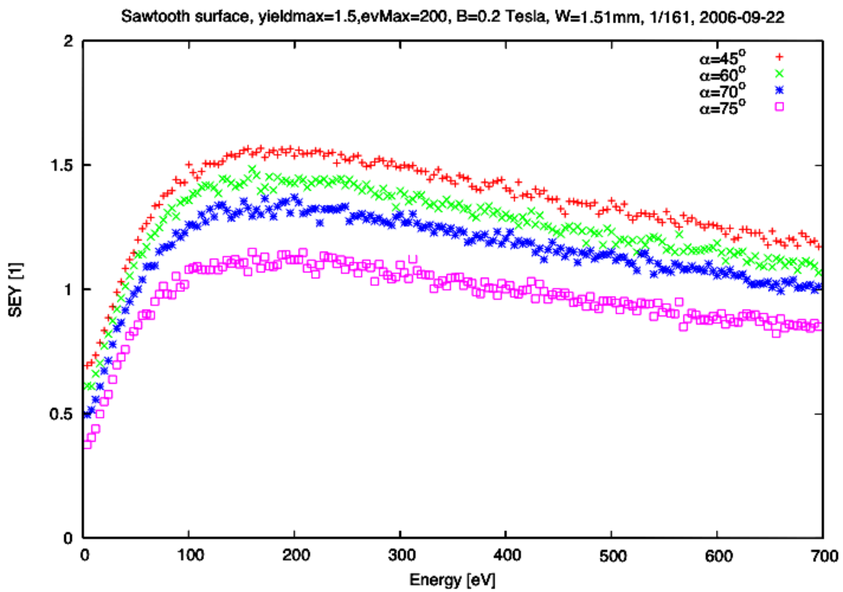


QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Following L. Wanga's approach (presented in Vancouver 19-22 July 2006), a **grooved surface** has been simulated with the **new e-cloud code** and the ***effective secondary emission yield*** has been evaluated for different **groove angles.**

Sample results from the new e-cloud code developed by W. Bruns (III)





More results on grooved surfaces (different saw-tooth width W):

The SEY decreases with increasing groove angle, but never goes below unity. Behaviour reproduced qualitatively Wanga‘s simulations, numbers need to be checked.

Headtail upgraded (I)

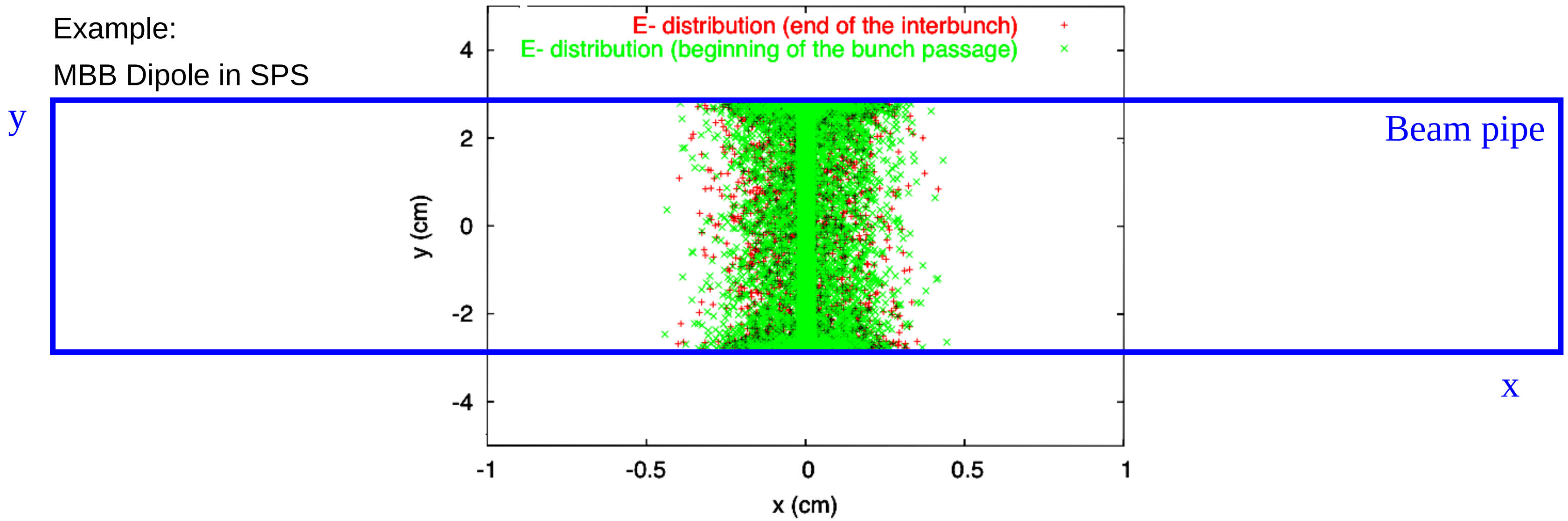
The electron distribution used in HEADTAIL was uniform in the beam pipe or with a single- or two-stripes to better fit the real distribution in a dipole field region...

→ Why not improve the model by using as an input the real distribution of electrons as it comes out of the build up ECLOUD code??

→ The electron distribution at the very beginning of a bunch passage is stored in a file from an ECLOUD run and subsequently fed into HEADTAIL. **This model is closer to self-consistent!**

Example:

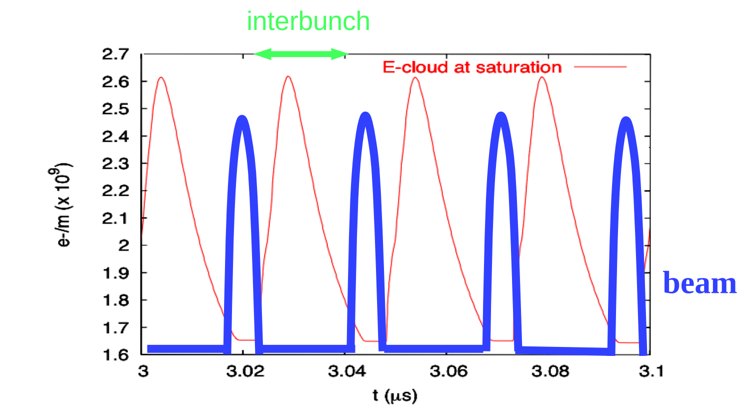
MBB Dipole in SPS

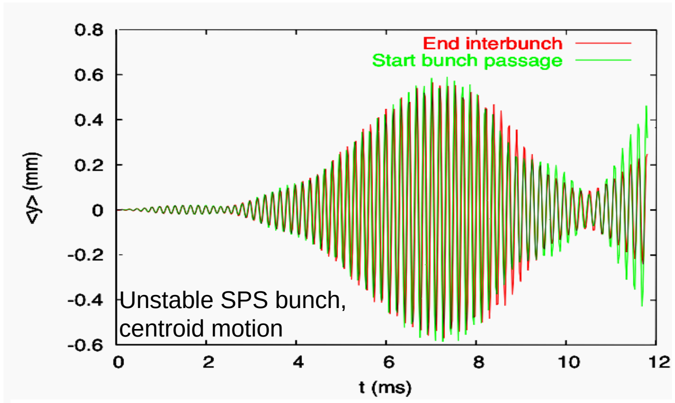


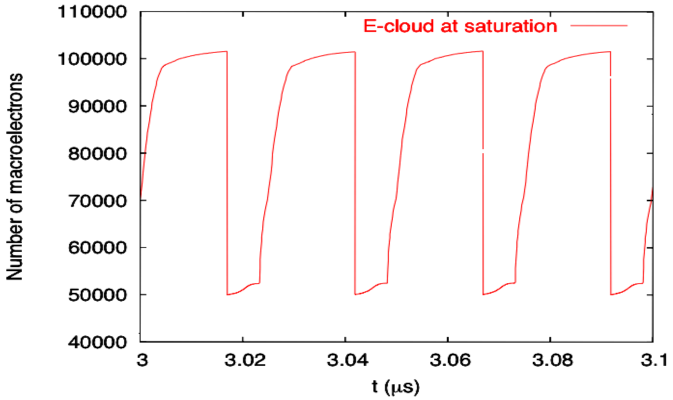
Headtail upgraded (II)

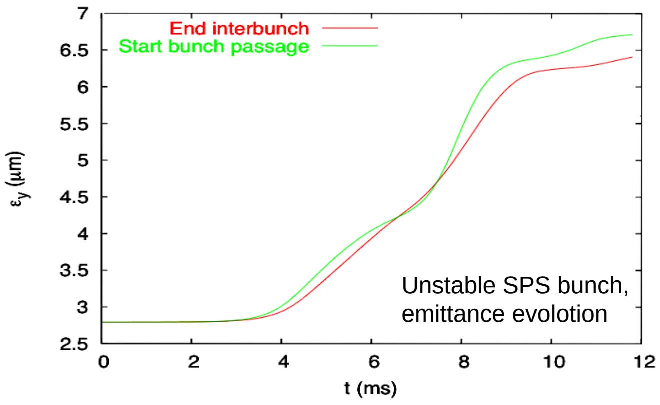
Between interbunch gap and bunch passage ECLOUD runs a `clean` routine to remove all the macro-electrons with very low charge.

Results of HEADTAIL simulations stay unchanged. The CPU time is about halved.









where do we stand?

fully accomplished
in progress

Financial Year	Jan 05				Jan 06			
Quarter	1	2	3	4	1	2	3	4
New RAs		**1.1**	**1.2** **1.3**					
Benchmarking of build-up simulations		**2.1**	**2.2**	**2.3**		**2.4**	**2.5**	
Benchmarking of instability simulations				**3.1**	**3.2** **3.3**			
Improvement of simulation codes		**4.1**	**4.2** **4.3** **4.4**		**4.5**	**4.6**	**4.7**	
Predict effect in the damping rings				**5.1** **5.2** **5.3**		**5.4**		**5.5**
Experimental determination of surface parameters		**6.1**			**6.2**	**6.3**		**6.4**
Vacuum design of damping rings		**7.1**		**7.2** **7.3**				**7.4** **7.5**

outstanding tasks from 04/05

2.3 December 05 (or June 06): Perform electron-cloud build up simulations for the DAFNE wiggler and perform qualitative comparison with measurements (pressure rise, beam instability, possibly designated electron detectors).

→ ***simulations run at CERN using field maps from LNF***

→ ***comparison (to be?) completed by LNF***

5.3 October 05: Simulate instability thresholds with HEADTAIL for a 3-km, 6-km and 17-km damping ring and compare them with predicted electron densities.

→ ***simulations were run at CERN and DESY*** in collaboration with M. Pivi (SLAC) and K. Ohmi (KEK); ***since 2x6-km configuration was selected, we have stopped simulations of the previous three rings***

7.3 December 05: Report on collated results of survey of secondary emission yields, psd, esd and isd yields, and develop work programme required to fill gaps in data.

→ delay due to hospitalization of O. Malyshev, ***completed in March06?***

tasks of 01/06

3.2 February 06: Compare experimental lifetimes at the SPS with HEADTAIL simulations of emittance growth below the fast instability threshold.

→ ***completed at CERN by E. Benedetto (see next slide)***

3.3 March 06: Compare measured instability growth rates in DAFNE with single-bunch growth rates simulated by the HEADTAIL code and with multi-bunch growth rates estimated from the ECLOUD build-up simulations

→ ***completed by CERN-DESY-INFN collaboration in 2005***

4.5 February 06: Implement an antechamber geometry, and, if foreseen by the ILC design, also synchrotron radiation photon stops and/or clearing electrodes, in ECLOUD code.

→ ***delayed; with present choice of ILC e+ DR less urgent***

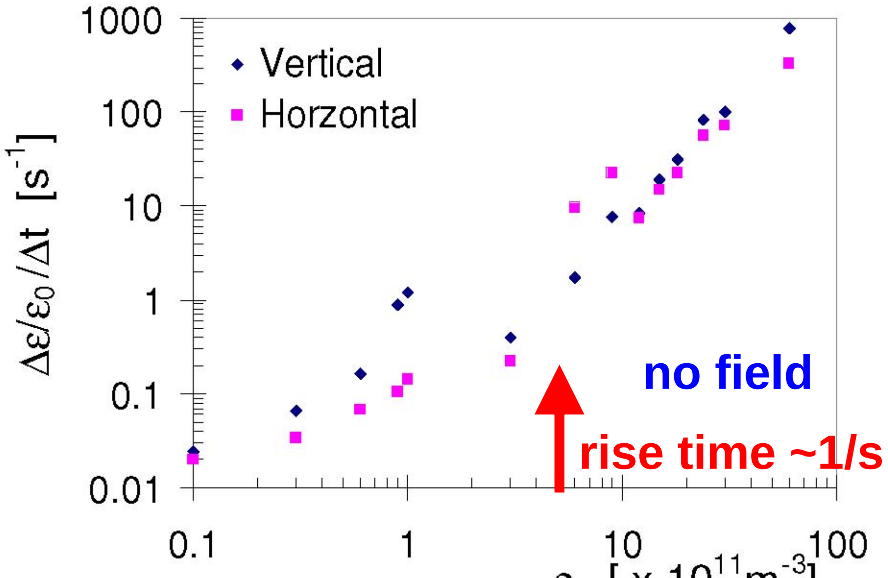
→ ***will be implemented in new e-cloud code at CERN***

6.2 Define sec. electron yield & electron reflectivity for the real Al- chamber DAFNE constructing material, and its relevance on the simulations based on more realistic input parameters.

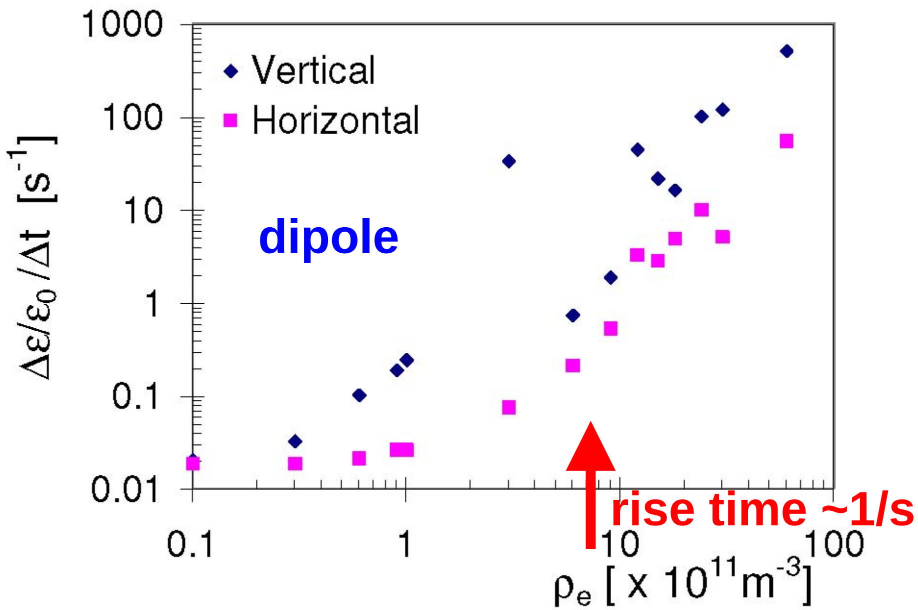
→ **DAFNE chamber characterized, LNF&CERN simulations**

emittance growth vs. electron density for SPS

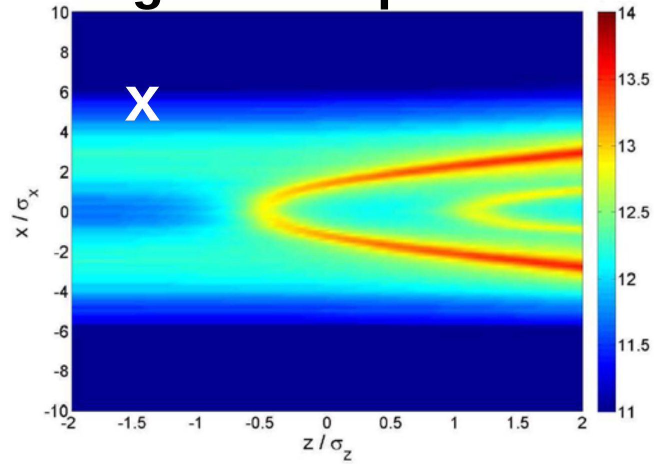
HEADTAIL simulations E. Benedetto
→ consistent with experimental observations within measurement uncertainties



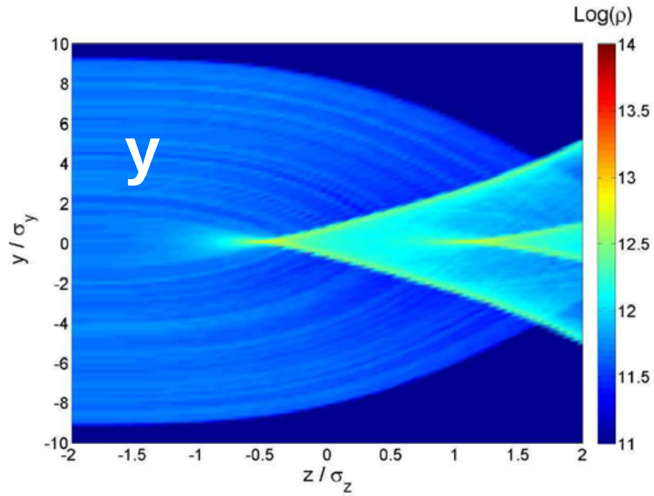
SPS 26 GeV/c



e- density evolution during bunch passage in a dipole field



SPS



tasks for 02/06

2.4 June 06: Study efficiency of various proposed countermeasures in simulations.

→ ***impedance of e- clearing electrodes was computed by GdfidL at CERN***

4.6 May 06**:** Update ECLOUD model parameters based on the results of code benchmarking.

→ ***updated elastically reflected electron component based on SPS benchmarking at CERN***; ***importance of re-diffused electrons is under scrutiny***

5.4 June 06: Estimate the importance of incoherent emittance growth due to electron cloud for the different damping-ring designs.

→ ***for 2x6-km ring in progress at CERN***

6.3 June 06: Study the dependence on electron and photon doses of the experimentally determined values of SEY and its relevance on the simulations based on more realistic input parameters.

→ ***in progress at LNF***

tasks for 04/06

5.5 December 06: Repeat electron cloud build-up and instability simulations using chamber material properties and vacuum chamber layout determined or developed in two other parts of this work package.

→ ***needs input from LNF & CCLRC***

6.4 December 06: Comparison of DAFNE Al surface properties with other possible materials.

→ ***task for LNF***

7.4 December 06: Report on pressure requirements (gas number densities) in the damping ring due to effects of electron cloud and other pressure related instabilities, and projected means of mitigating any deleterious effects.

→ ***task for CCLRC***

7.5 December 06: Results of work programme required to fill gaps in data.

→ ***task for CCLRC***

future e-cloud plans at CERN

- ***continue benchmarking of new e-cloud code*** against existing programmes, ***extend code to fully 3D***; explore ***role of ions***
- implement ***antechamber & possibly clearing electrodes*** in the simulation
- complete ***study of e-cloud driven instabilities for 2x6 km ring (upgraded HEADTAIL)***
- study ***e-cloud in damping-ring quadrupoles***
- ***repeat*** e-cloud build up and instability ***simulations*** for the ***chamber material properties and vacuum chamber layout developed in the other two parts of this work package*** (at Daresbury and Frascati)
- investigate ***e-cloud mitigation schemes for CLIC***
- possibly ***study halo generation by e-cloud***

joint CARE-HHH & EUROTeV

mini-workshop on
Electron Cloud Clearing
"ECL2"

CERN, February 2007

will address enamel based electrodes (under construction in German industry / initiative of F. Caspers); low and high resistance structures; other cures

http://care-hhh.web.cern.ch/CARE-HHH/ECL2

Recent EPAC'06 papers on LC e-cloud and ions with CERN contributions

MOPLS136
Ion Effects in the Damping Rings of ILC and CLIC
F. Zimmermann, W. Bruns, D. Schulte, CERN, Geneva
We discuss ion trapping, rise time of the fast beam-ion instability, and ion-induced incoherent tune shift for various incarnations of the ILC damping rings and for CLIC, taking into account the different regions of each ring. Analytical calculations for ion trapping are compared with results from a new simulation code.

WEPCH137
FAKTOR2: A Code to Simulate the Collective Effects of Electrons and Ions W. Bruns, D. Schulte, F. Zimmermann, CERN, Geneva
A new code for computing the multiple effects of slowly moving charges is being developed. The basic method is electrostatic particle in cell. The underlying grid is rectangular and locally homogeneous. At regions of interest, e.g., where the beam is, or near material boundaries, the mesh is refined recursively. The motion of the macroparticles is integrated with an adapted timestep. Fast particles are treated with a smaller timestep, and particles in regions of fine grids are also treated with a fine timestep. The position of collision of particles with material boundaries is accurately resolved. Secondary particles are then created according to user-specified yield functions.

EPAC'06 papers on LC e-cloud and ions with CERN contributions cont'd

THPCH075
Simulation of the Electron Cloud for Various Configurations of a Damping Ring for the ILC M.T.F. Pivi, T.O. Raubenheimer, L. Wang, SLAC, Menlo Park, California; K. Ohmi, KEK, Ibaraki; R. Wanzenberg, DESY, Hamburg; A. Wolski, Liverpool University, Science Faculty, Liverpool; F. Zimmermann, CERN, Geneva
… On the basis of the theoretical and experimental work, the baseline configuration specifies a pair of damping rings for the positron beam to mitigate the effects of the electron cloud.

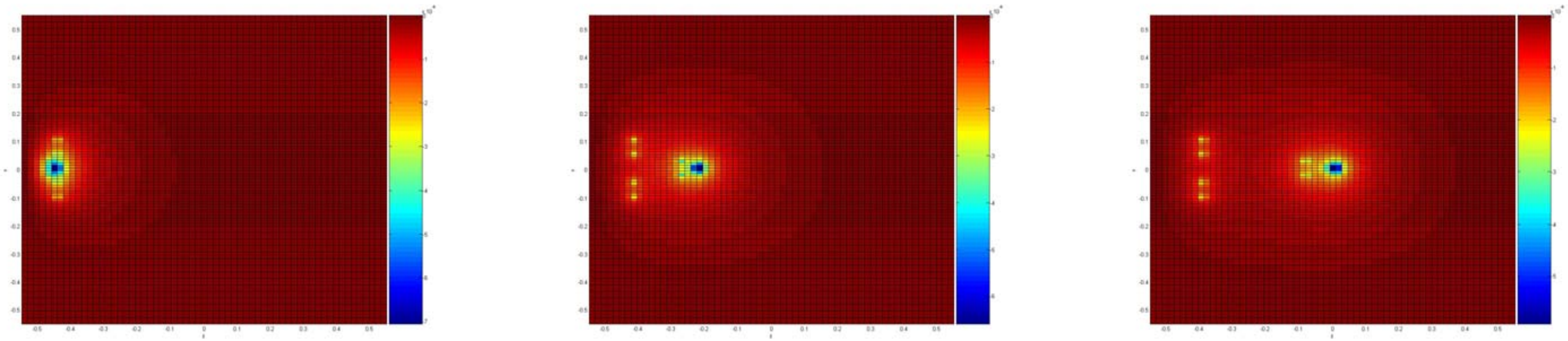
THPCH051
The Effect of the Solenoid Field in Quadrupole Magnets on the Electron Cloud Instability in the KEKB LER
H. Fukuma, J.W. Flanagan, T. Kawamoto, T. Morimoto, K. Oide, M. Tobiyama, KEK, Ibaraki; F. Zimmermann, CERN, Geneva
… to investigate the electron clouds in the quadrupole magnets, solenoids made of flat cables were developed and installed in 88 quadrupole magnets. The field strength of the solenoid is 17 Gauss. The effect of the solenoid field on the blowup is now under beam study….

Current Ecloud Activities:
Collaboration between the University of Rostock and DESY

Aleksandar Markovik, University of Rostock, Germany :
Particle Tracking Program - MOEVE

First version of the tracking routine

- Based on the Poisson solver for space charge fields in a beam pipe of elliptical shape
- Time integration of the particle equations with relativistic generalization of the equations



R. Wanzenberg

Current Ecloud Activities:
Collaboration between the University of Rostock and DESY

Current work:

- Improve the solver
- Implementation of external fields (longitudinal ***E***-, transversal ***B***-fields)
- Verification and comparison of the tracking routine with existing programs
- Parallelization of the code
- Definition of the initial particle distribution – possible use of available bunch generation programs

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