Electron Cloud Studies

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Plan of talk

Electron Cloud Studies at DAFNE

- ECLOUD Simulations for the DAFNE wiggler
  - Secondary Emission Yield
  - bunch patterns
  - magnetic field models
- Preliminary analysis of the instabilities
- Experimental plans
  - Energy-resolved e^- detectors
- Conclusions

Summary of WP3 ECL Task Force Work

Electron cloud at DAFNE

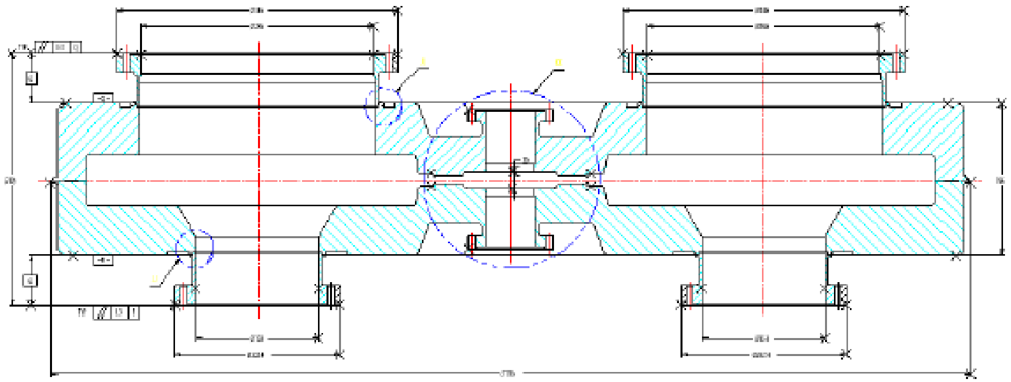
A. Drago et. Al DAFNE Tech. Note: G-67 (2006)

- e^+ current limited to 1.2 A by strong instability (~ 10 μs)
- large positive tune shift with current in e^+ ring, not seen in e^- ring
- instability depends on bunch current (not total current)
- instability strongly increases along the train
- anomalous vacuum pressure rise has been oserved in e^+ ring
- wound solenoids in field-free sections w/o any effect on the instability
- instability sensitive to orbit in wiggler (few mm)
- main change for the 2003 was wiggler field modification

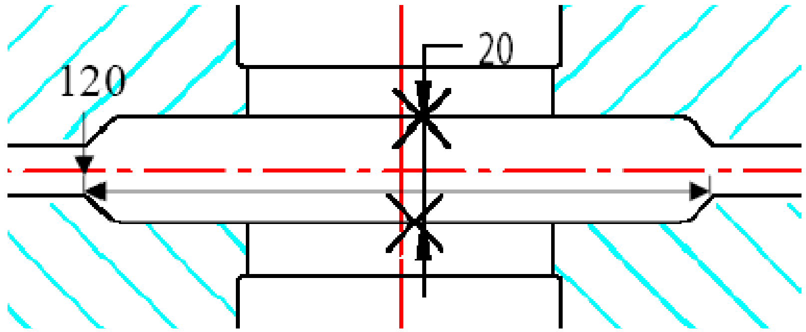
Wiggler vacuum chamber

A. Chimenti et Al., Proc. Of PAC 93

Wiggler vacuum chamber cross section



Wiggler beam chamber detail



- Al alloy 5083-H321 chamber (120 mm x 20 mm)
- 10 mm slots divide the beam channel from the antechambers where absorbers and pumping stations are located
- 95% of photon flux is intercepted in the antechambers

Wiggler magnetic field model in ECLOUD simulations

C. Vaccarezza et. Al., Proc of PAC05, pp 779-781

magnetic field (*Bx, By, Bz*) inside the wiggler as a function of x,y,z coordinates is obtained from a bi-cubic fit of the measured 2-D field-map data *By* (*x,y=0,z*); field components *Bx* and *Bz* are approximated by

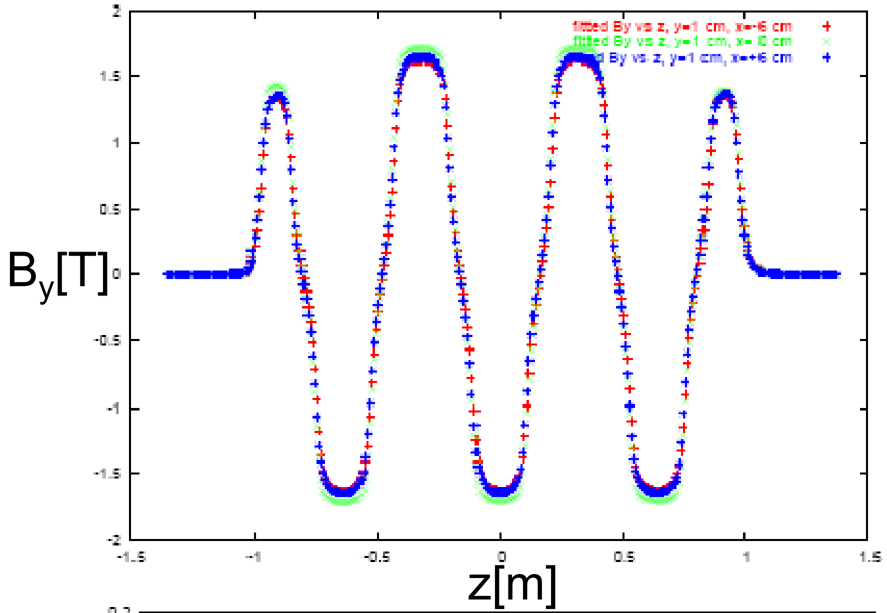
$$B_x = \frac{\partial B_y\left(x, y=0, z\right)}{\partial x} y$$

$$B_z = \frac{\partial B_y\left(x, y=0, z)\right)}{\partial z} y$$

$$B_y\left(x, y, z\right) = B_y\left(x, y=0, z\right) - \frac{y^2}{2}\left(\frac{\partial^2 B_y\left(x, y=0, z\right)}{\partial x^2} + \frac{\partial^2 B_y\left(x, y=0, z\right)}{\partial z^2}\right)$$

consistent with Maxwell's equations: $\vec{\nabla} \times \vec{B} = 0, \quad \vec{\nabla} \cdot \vec{B} = 0$

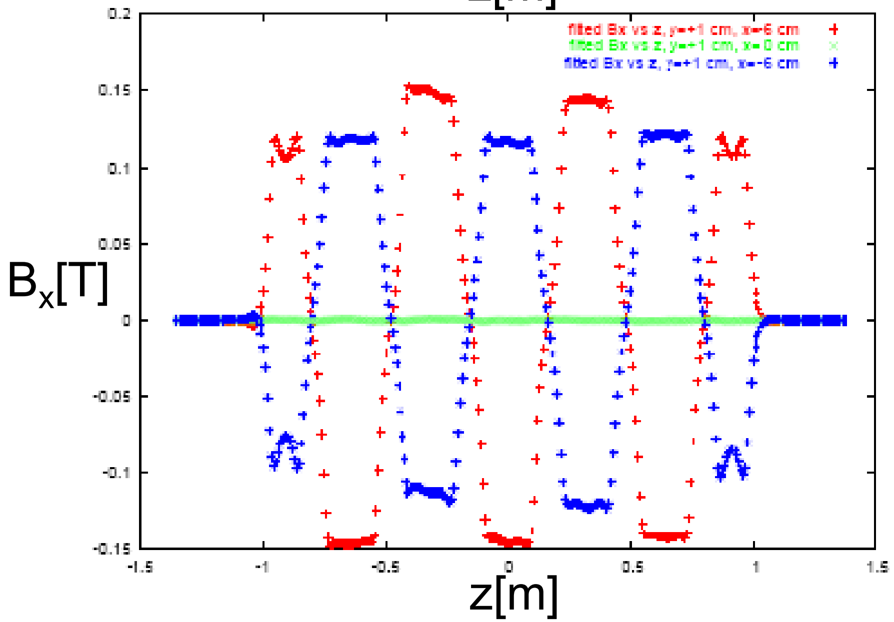
Wiggler magnetic field

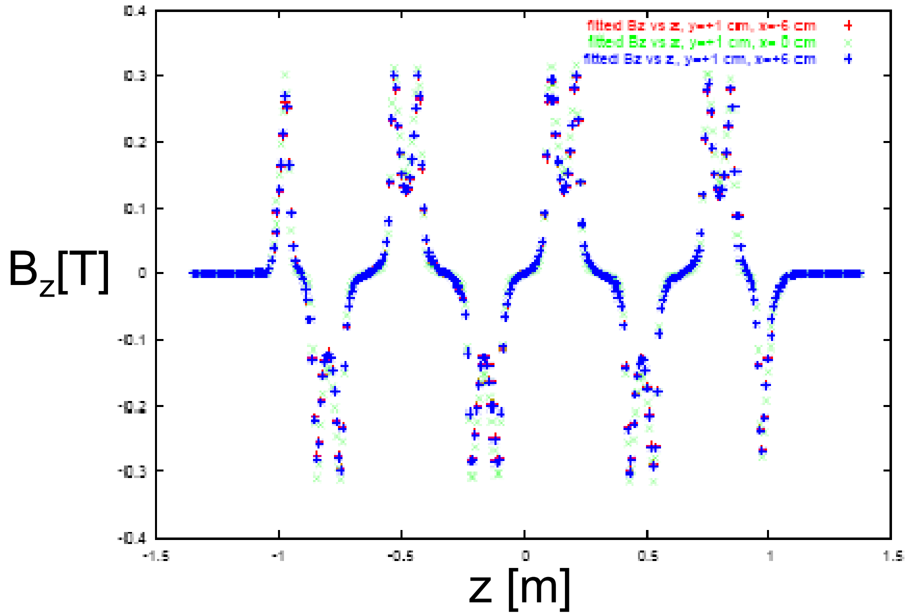


peak field ~1.7 T

period ~0.65 m

x=-6 cm, x= 0 cm, x= +6 cm



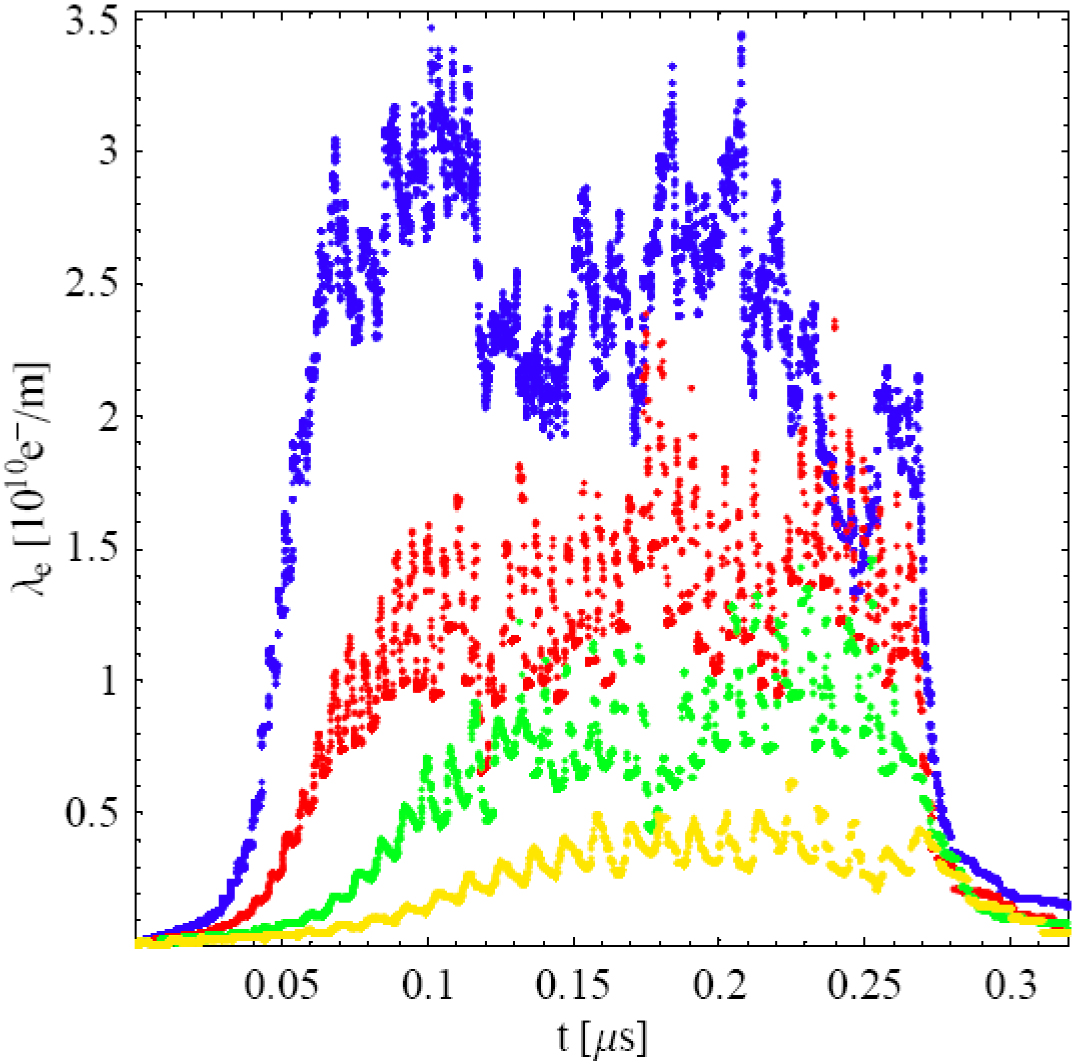


Input parameters for ECLOUD (DAFNE Wiggler 2003)

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	$d\lambda/ds$	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

δ_{max}=1.9



N_b=2.1 10^{10}

100 bunches

L_{sep}= 0.8 m

50 bunches

L_{sep}= 1.6 m

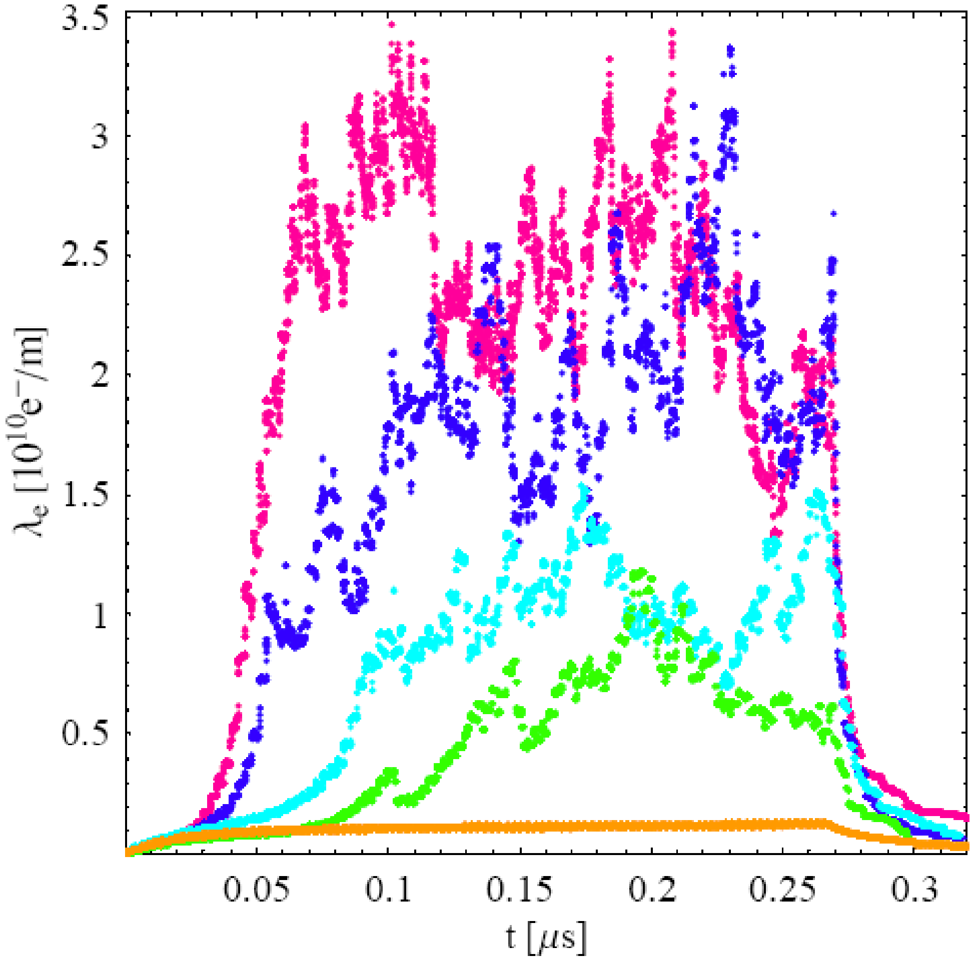
33 bunches

L_{sep}= 2.4 m

25 bunches

L_{sep}= 3.2 m

Secondary emission yield maximum (δ_{max})



δ_{max}=1.9

δ_{max} =1.7

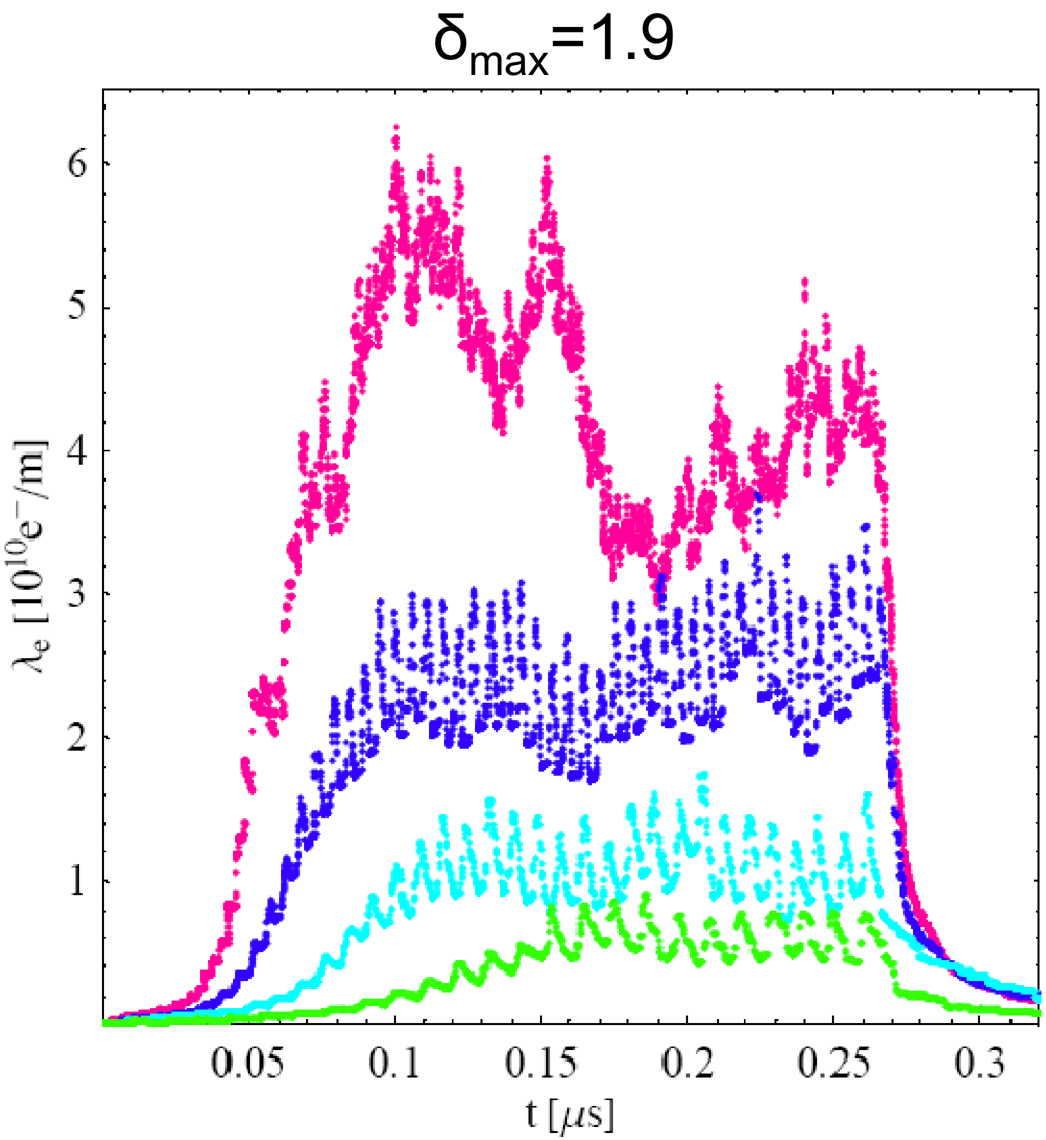
δ_{max} =1.5

δ_{max} =1.3

δ_{max} =1.1

100 bunches (N_b= 2.1x10^{10} ; L_{sep}=0.8m; N_{gap}= 20)

Electron reflectivity at 0 energy δ_0 = 100 %



N_b=2.1 10^{10}

100 bunches

L_{sep}= 0.8 m

50 bunches

L_{sep}= 1.6 m

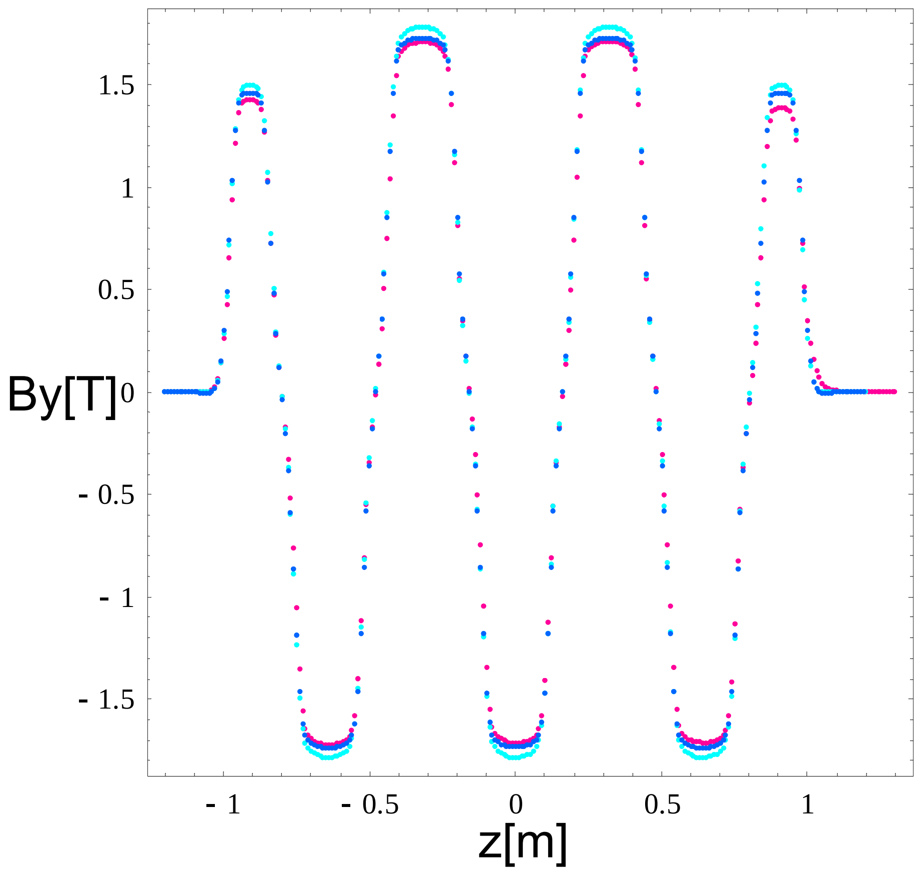
33 bunches

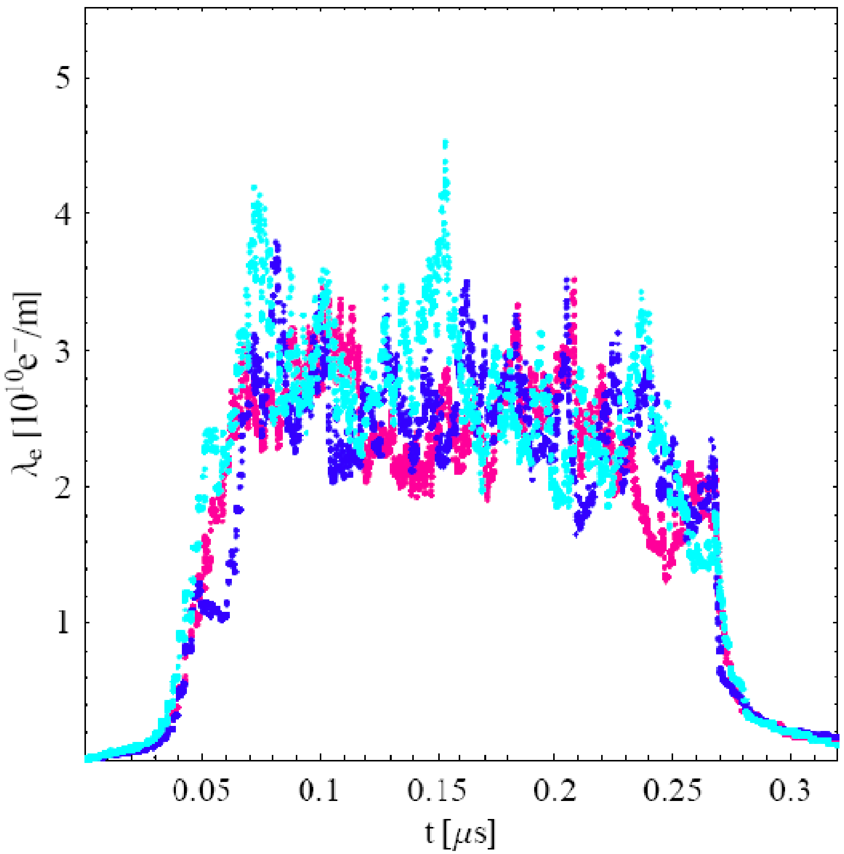
L_{sep}= 2.4 m

25 bunches

L_{sep}= 3.2 m

Magnetic field models



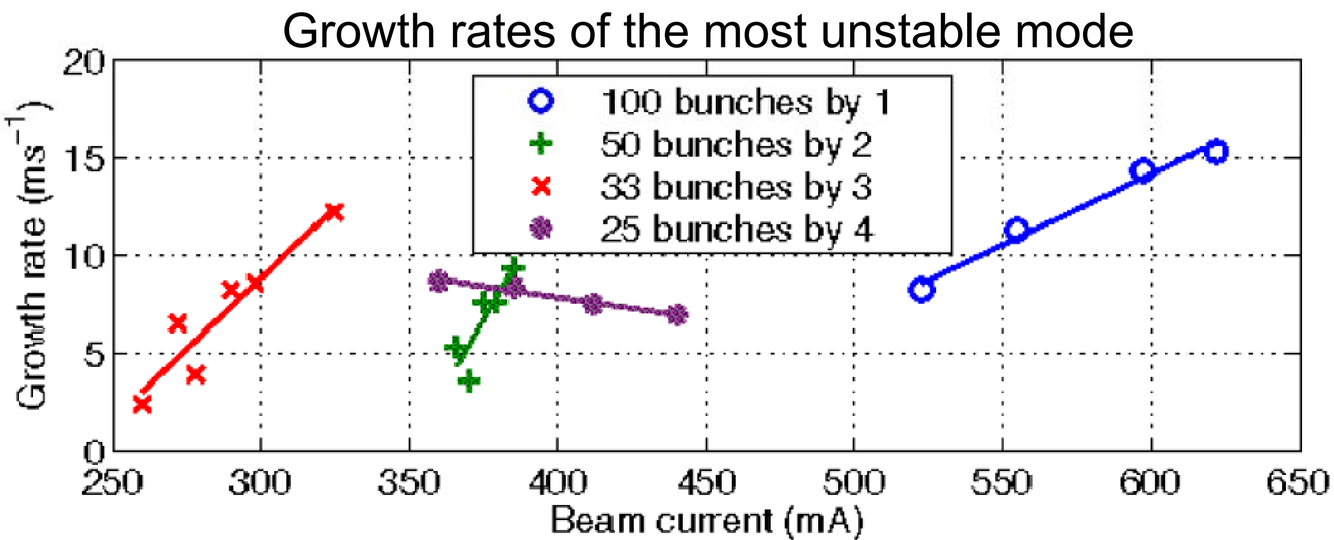


100 bunches, L_{sep}= 0.8 m, N_b=2.1 10^{10}

2003 wiggler 2002 wiggler 2007 wiggler (proposed)

Instability growth rates

Switching off the horizontal feedback for short periods, transverse grow-damp measurements have been performed to estimate the instability growth rates at different beam currents.



Horizontal growth rates recorded in July 2004. (A.Drago et Al. Proceedings of PAC 2005)

1/♦ ~ 8 ms^{-1} →

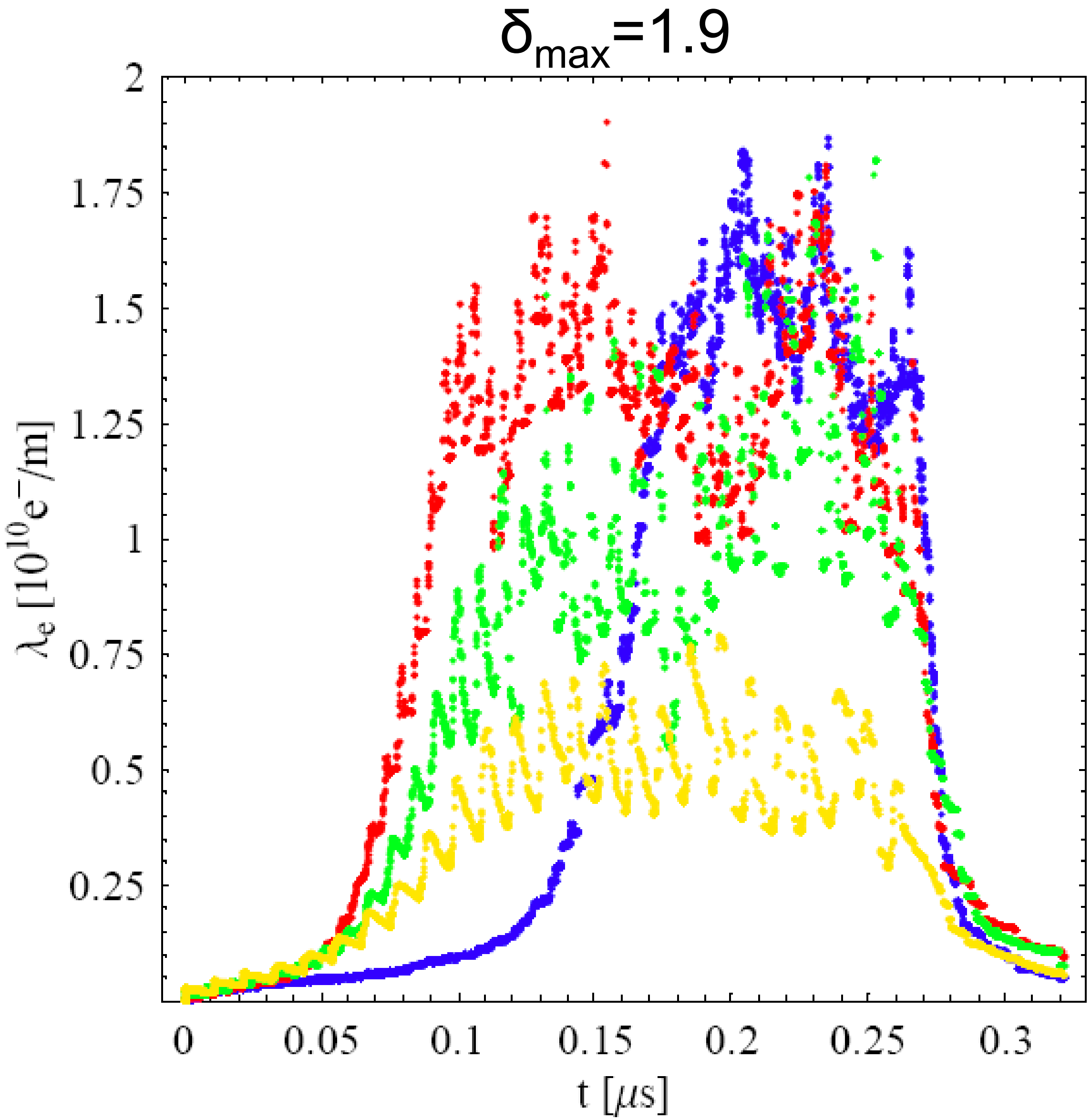
Nb=1.06 · 10^{10} (100 bunches)

Nb=1.5 · 10^{10} (50 bunches)

Nb=1.9 · 10^{10} (33 bunches)

Nb=3.13 · 10^{10} (25 bunches)

Bunch patterns (fixed growth rate)



100 bunches
Nb=1.06 10^{10}
Lsep= 0.8 m

50 bunches
Nb=1.5 10^{10}
Lsep= 1.6 m

33 bunches
Nb=1.9 10^{10}
Lsep= 2.4 m

25 bunches
Nb=3.13 10^{10}
Lsep= 3.2 m

Work in progress

- It is not yet completely clear whether the instability has a coupled or single bunch nature.
- Work is in order to perform simulations of single-bunch and coupled bunch instability (including modal analysis) simulations and compare the results with observations.

Experimental plans at DAFNE

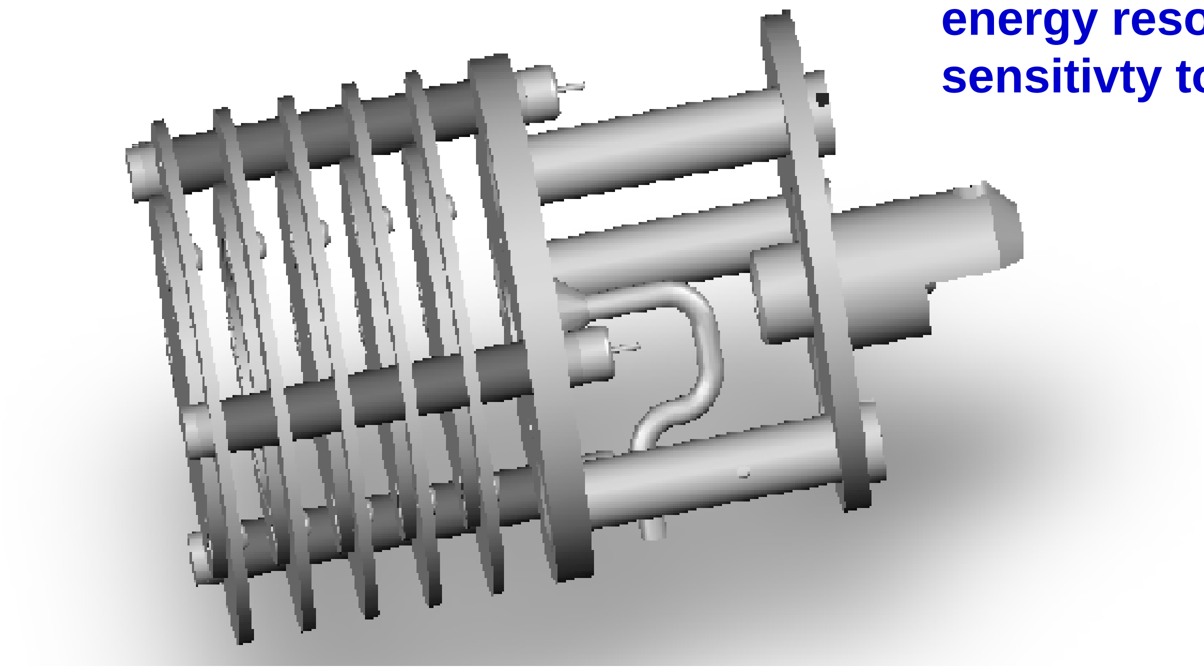
For ILC-DR one needs to study the vacuum high tech. materials properties, including:

- 0-1Kev Electron induced el. Emission yield (SEY)
- photoemission yield and photoemission induced electron energy distribution
- surface properties changes during conditioning
- …

Use the results as input for the simulation codes and compare the results with measurements on a real machine.

Energy-resolved e$^-$ detectors at DAFNE (R. Cimino)

5 grids for:
energy resolution
sensitivty to low energy electrons



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

- **electron-ring (for reference)**
- **positron ring (uncoated chamber)**
- **positron ring (TiN coated chamber?)**

Conclusions

- ECLOUD build-up simulations for the DAFNE Wiggler show:
  - expected dependence of e-cloud build-up on SEY parameters δ_{max} and δ_0
  - no dependence of e-cloud build-up on magnetic field model
  - bunch patterns behavior compatible with experimental observation (multi-bunch and single-bunch instability simulations are needed)
- Energy-resolved e^- detectors are under test and are planned for installation at DAFNE

Summary of WP3 ECL Task Force Work

Simulation and modeling

•The 3-D version of the novel Faktor2 build-up code, developed at CERN in the framework of EUROTeV, was partially parallelized and released.

•3-D build up simulations were performed for various filling patterns in wiggler and dipole magnets of the ILC damping ring.

•The HEADTAIL code was used to study the threshold electron density above which the single-bunch electron-cloud instability occurs in the CLIC damping ring.

•Analytical and simulation work on incoherent electron cloud effects was successfully extended a dipole field. [A benchmarking effort for the simulation of incoherent electron cloud effects by a multi-laboratory worldwide collaboration was presented atPAC07.]

Summary of WP3 ECL Task Force Work

Mitigation Techniques

•In 2007, several new technological remedies (slotted chambers, enamel-based clearing electrodes, grooves) for the electron cloud were proposed, developed, and already (partially) tested with beam at the CERN PS and in PEP-II

•Electron cloud studies in the CERN PS explored the electron cloud build up in the presence of a dipole magnetic field and a clearing electrode.

Summary of WP3 ECL Task Force Work

Fast Ion-Beam Instability

•In December 2007, a fast beam-ion experiment at the KEK/ATF, where, by means of a new dedicated gas-injection system, the vacuum pressure in a straight section of the damping ring can now be arbitrarily varied and controlled. [CERN, DESY]

Vacuum Studies

•Influence of e-cloud and electron multipacting on the vacuum and the influence of the vacuum chamber design on the electron cloud. [Cockcroft Inst.]

•Ion-induced pressure instability in the positron DR. [Cockcroft Inst.]