Electron Cloud Studies at DAFNE

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Plan of talk

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

Electron cloud at DAFNE

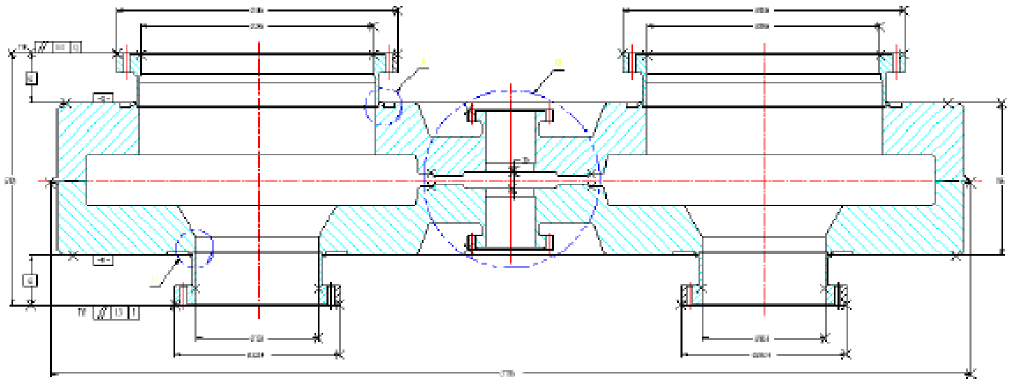
A. Drago et. Al DAFNE Tech. Note: G-67 (2006)

- 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
- instability sensitive to orbit in wiggler (few mm)
- main change for the 2003 was wiggler field modification

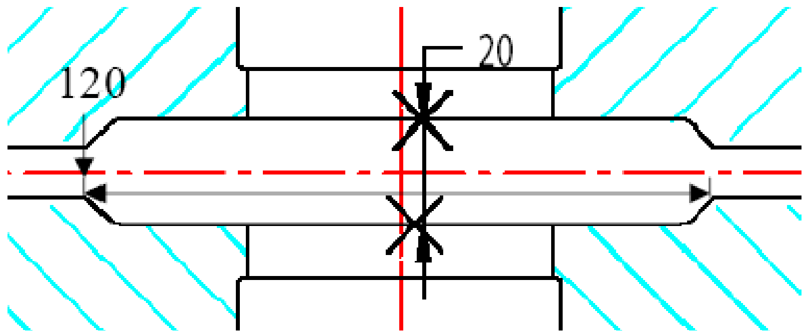
Wiggler vacuum chamber

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 (cite.)

Wiggler magnetic field model in ECLOUD simulations

M. Preger, DAFNE Tech. Note L-34 (2003)

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

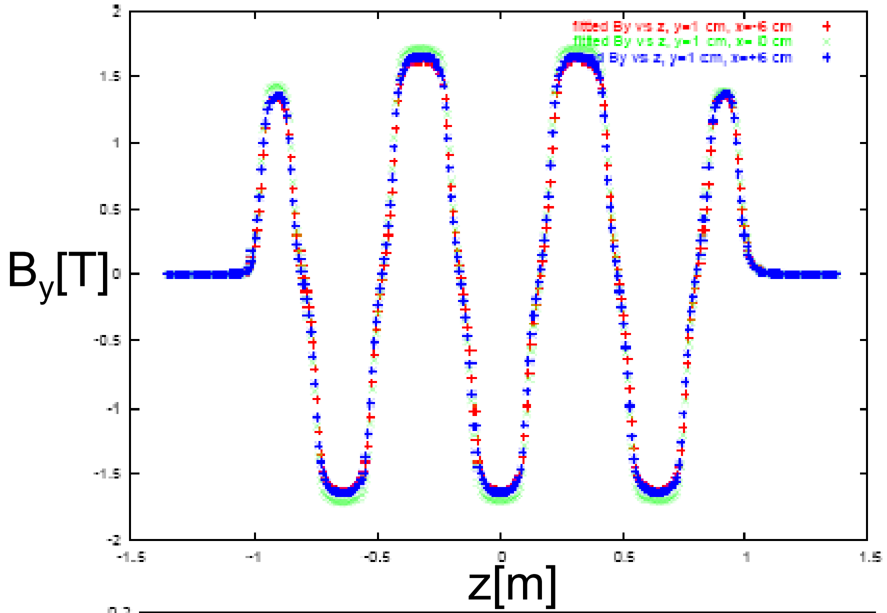
$$B_x = \frac{\partial B_y(x, y=0, z)}{\partial x} y$$

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

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

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

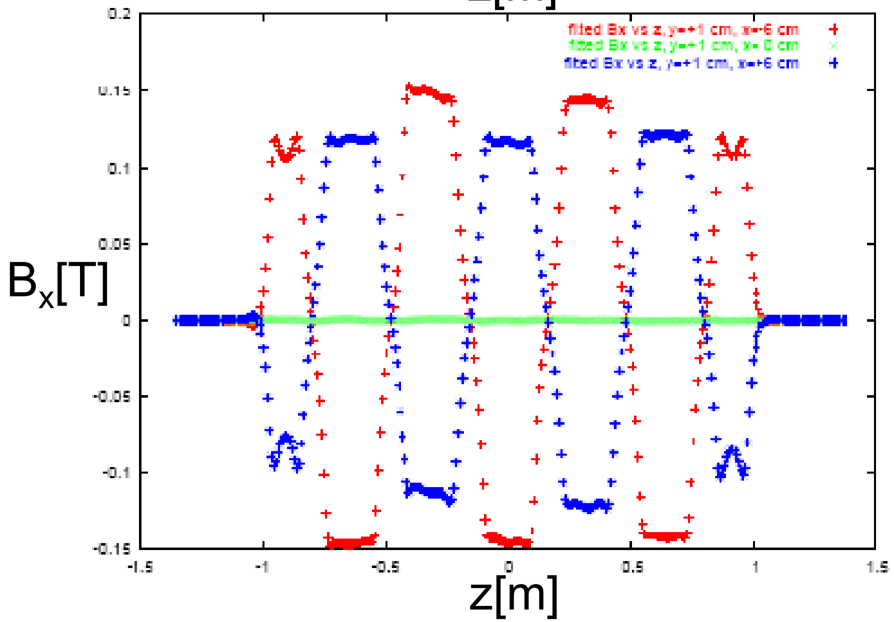
Wiggler magnetic field

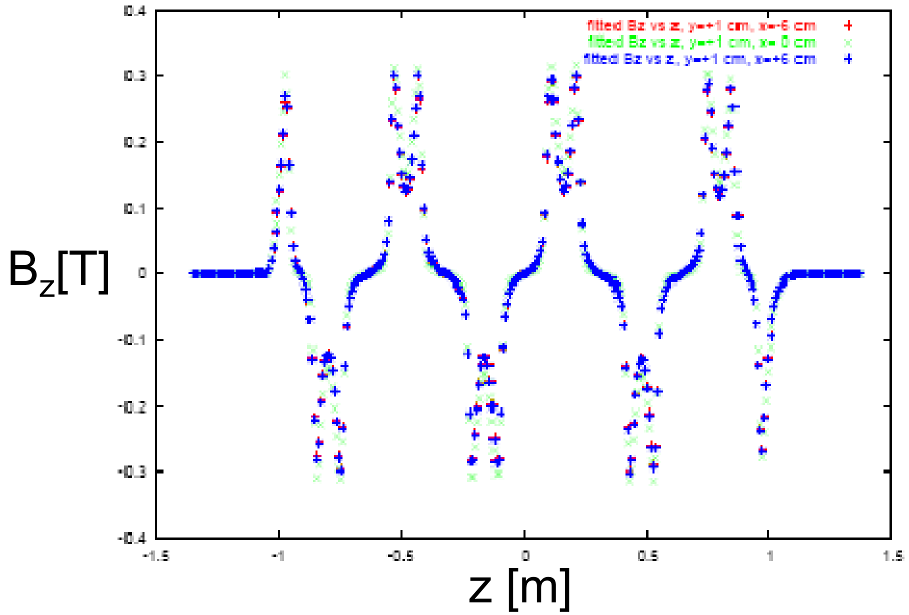


peak field ~1.7 T

period ~0.65 m

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



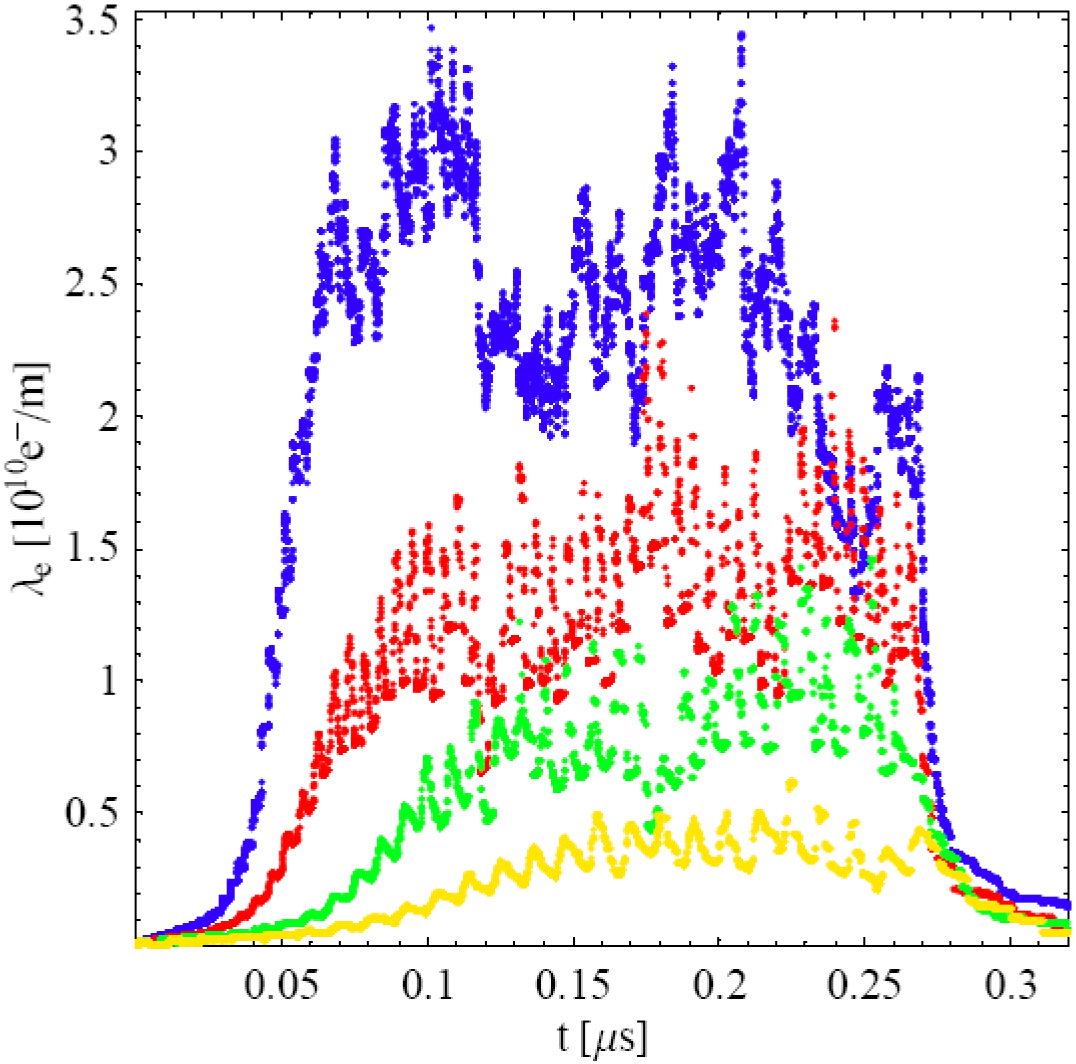


Input parameters for ECLOUD (DAFNE Wiggler 2003)

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.)	

* As measured on Al sampels with same finishing of the actual vacuum camber
N.Mahne et Al. , PAC'05

Bunch patterns



N_b=2.1 10^{10}

100 bunches

L_{sep}= 0.8 m

50 bunches

L_{sep}= 1.6 m

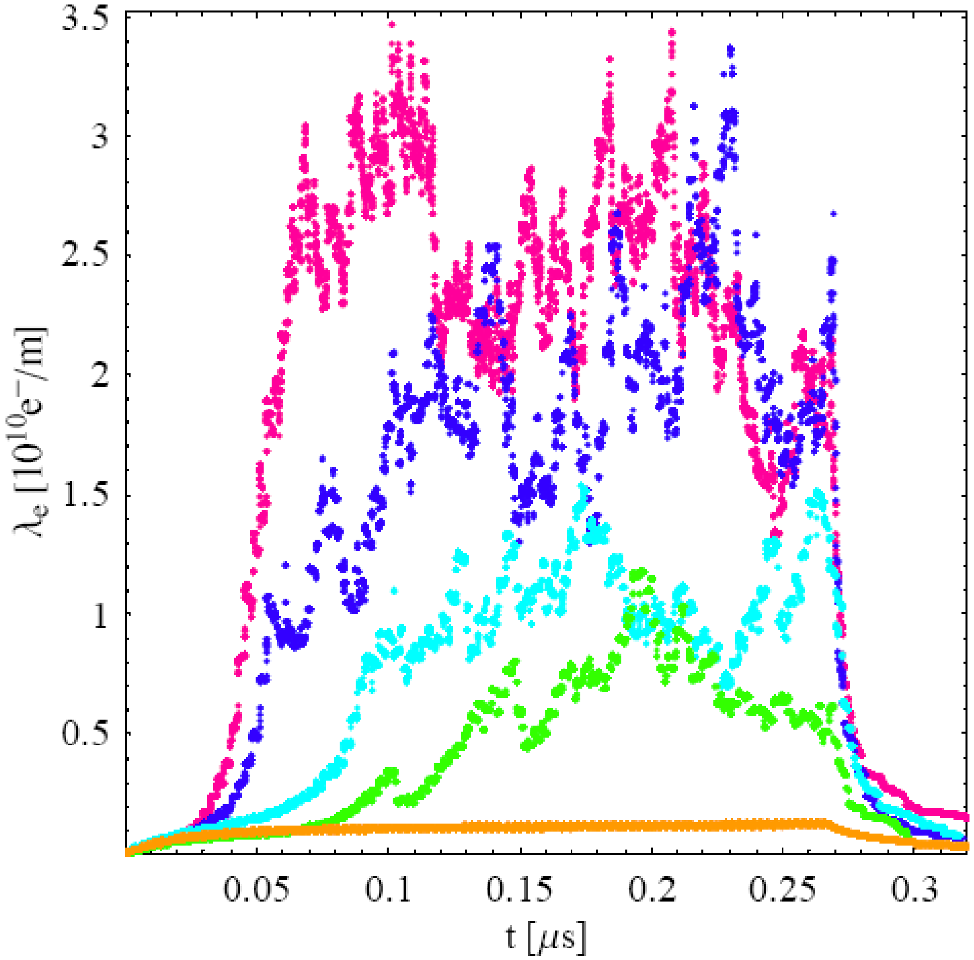
33 bunches

L_{sep}= 2.4 m

25 bunches

L_{sep}= 3.2 m

Secondary emission yield maximum (δ_{max})



δ_{max}=1.9

δ_{max} =1.7

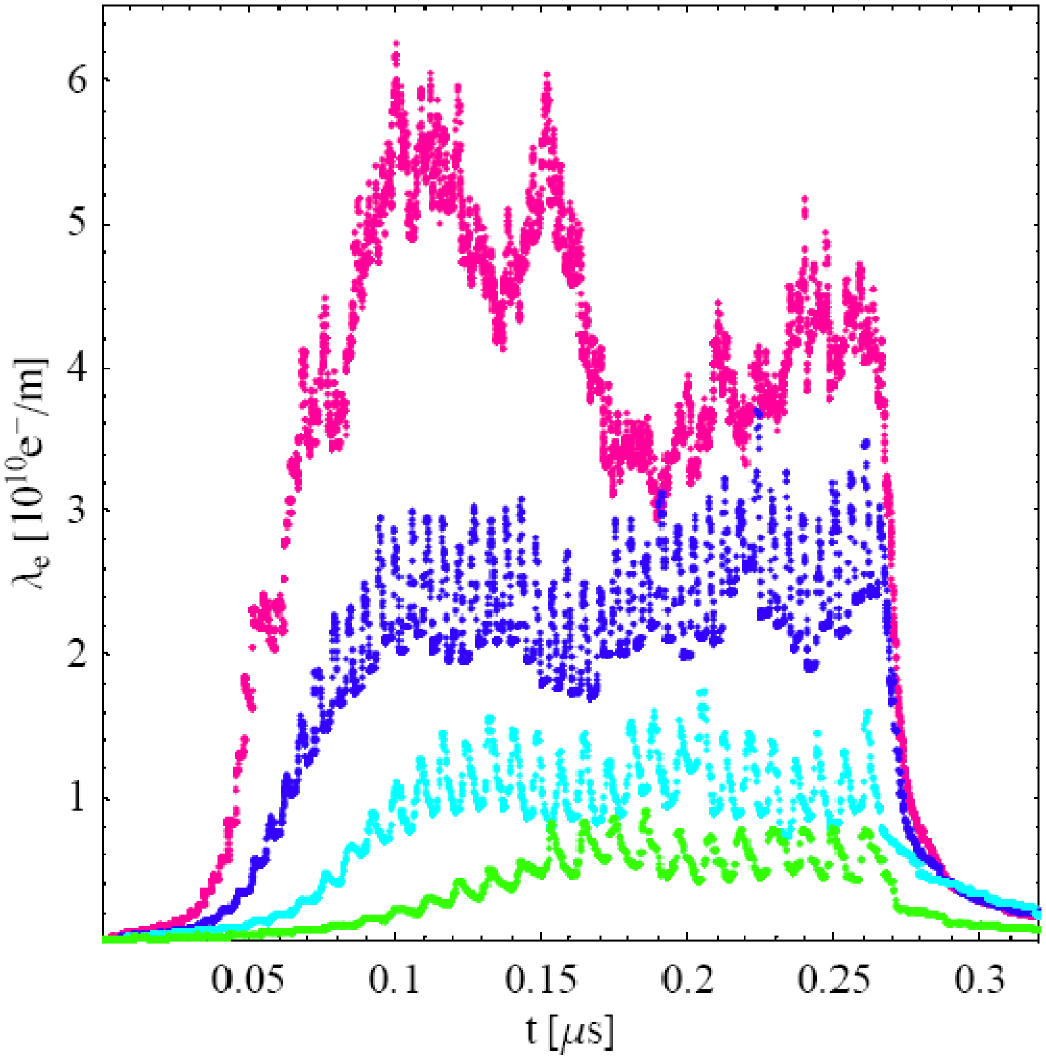
δ_{max} =1.5

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

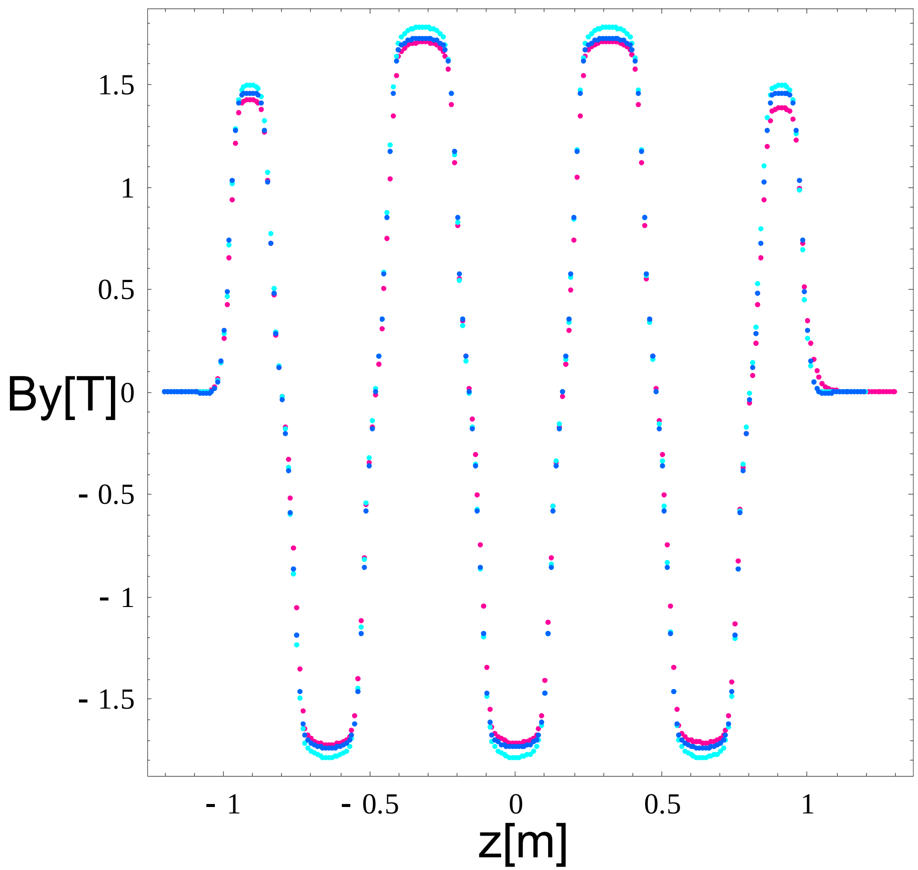
33 bunches

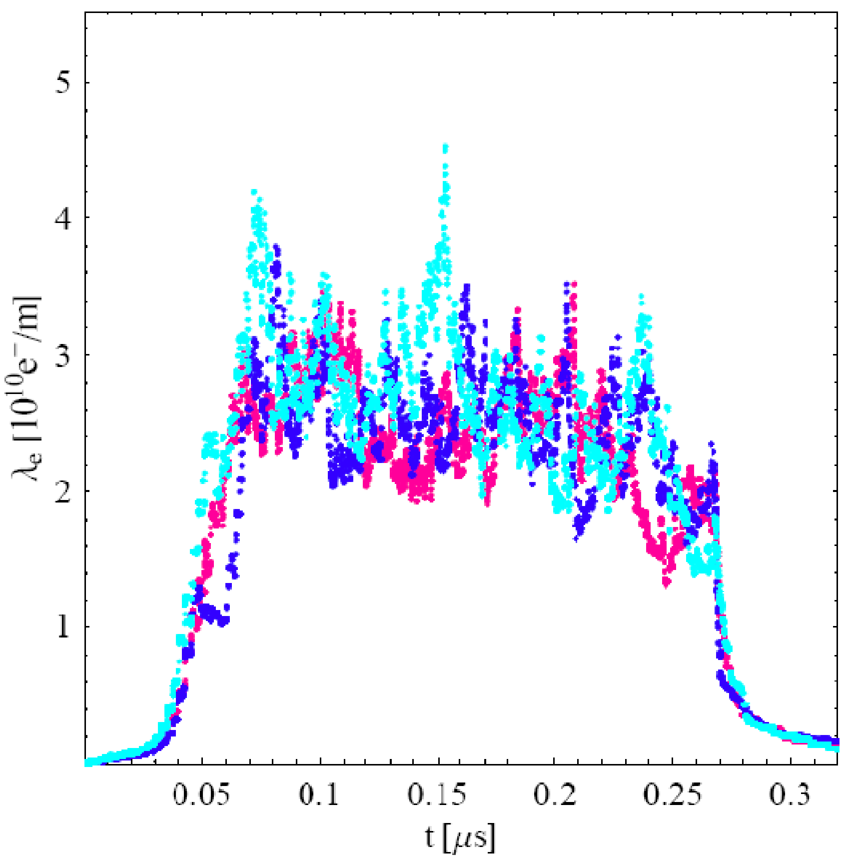
L_{sep}= 2.4 m

25 bunches

L_{sep}= 3.2 m

Magnetic field models



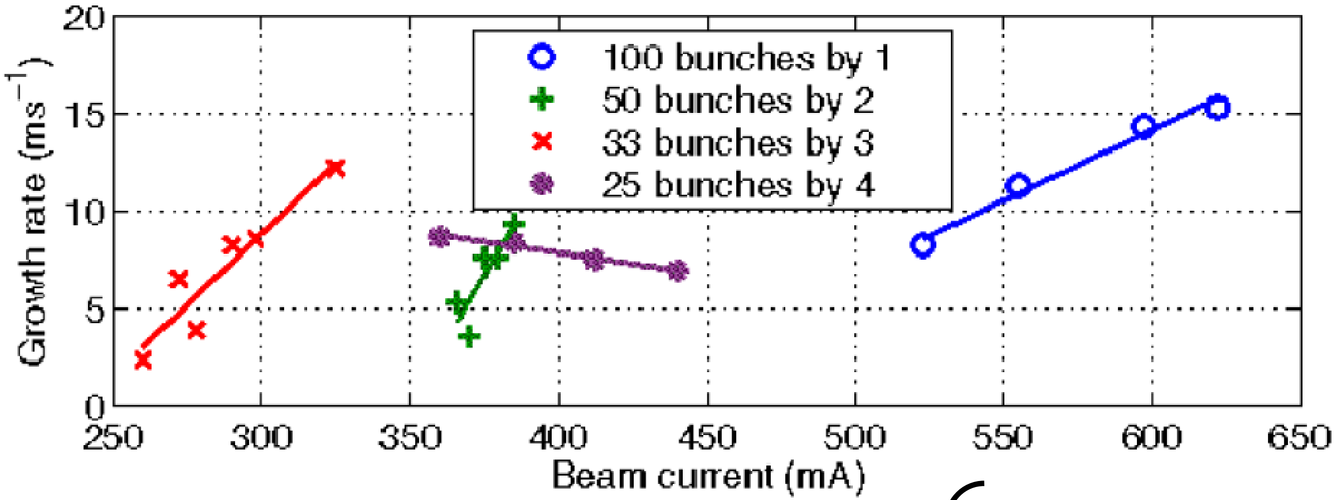


100 bunches, L_{sep}= 0.8 m, N_b=2.1 10^{10}

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} $\longrightarrow$

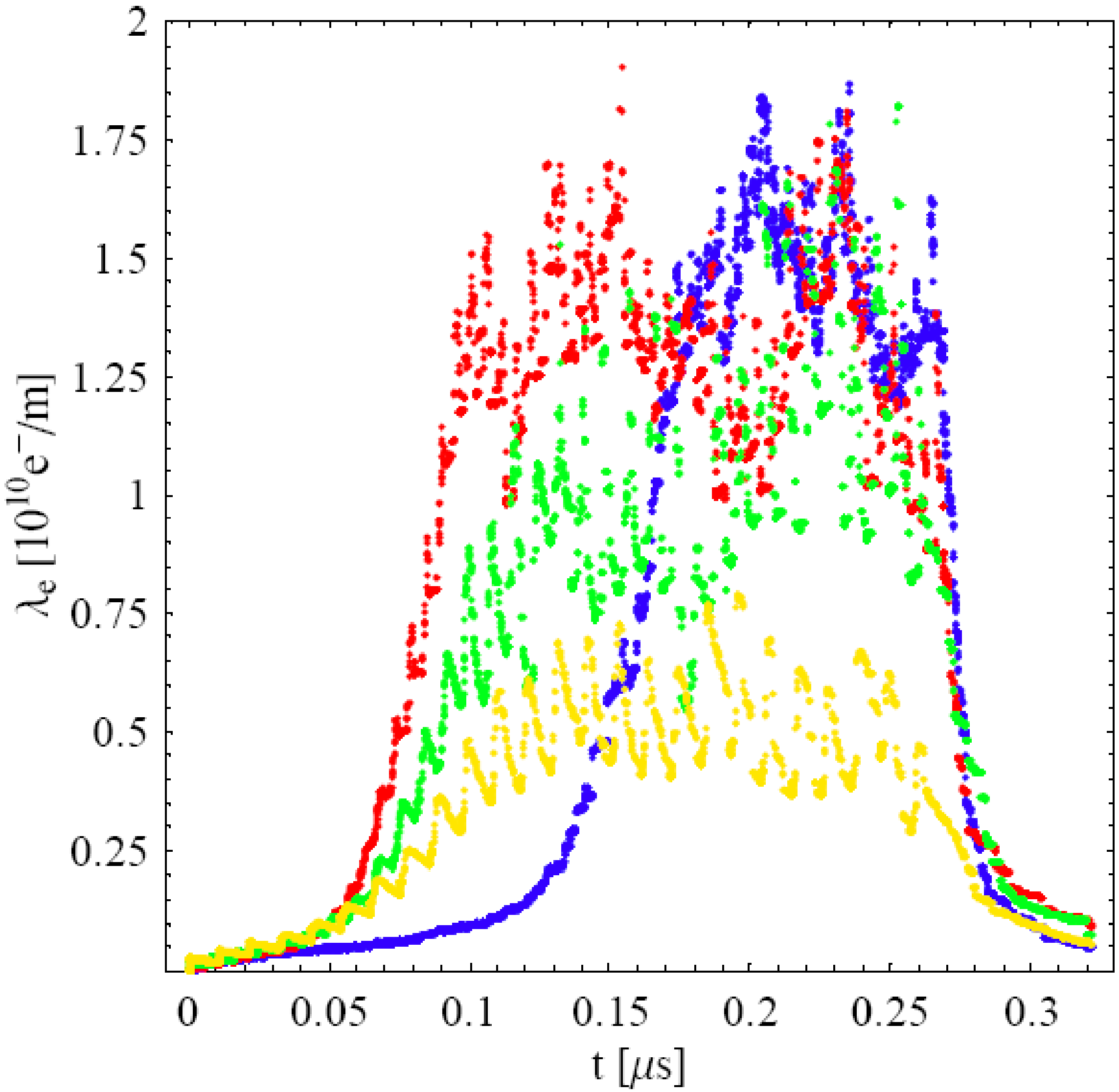
$Nb=1.06 \cdot 10^{10}$ (100 bunches)

$Nb=1.5 \cdot 10^{10}$ (50 bunches)

$Nb=1.9 \cdot 10^{10}$ (33 bunches)

$Nb=3.13 \cdot 10^{10}$ (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

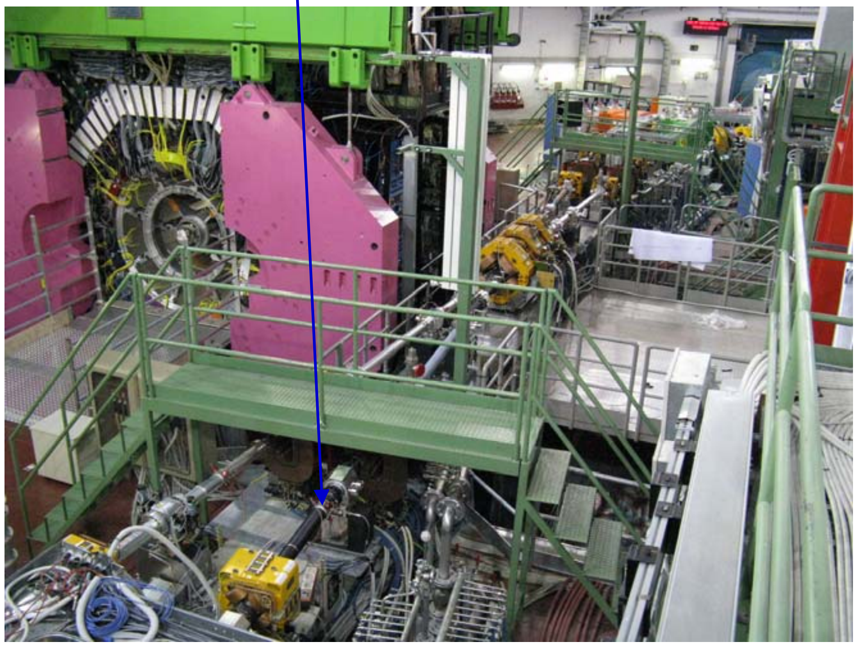
33 bunches
Nb=1.9 10^{10}
Lsep= 2.4 m

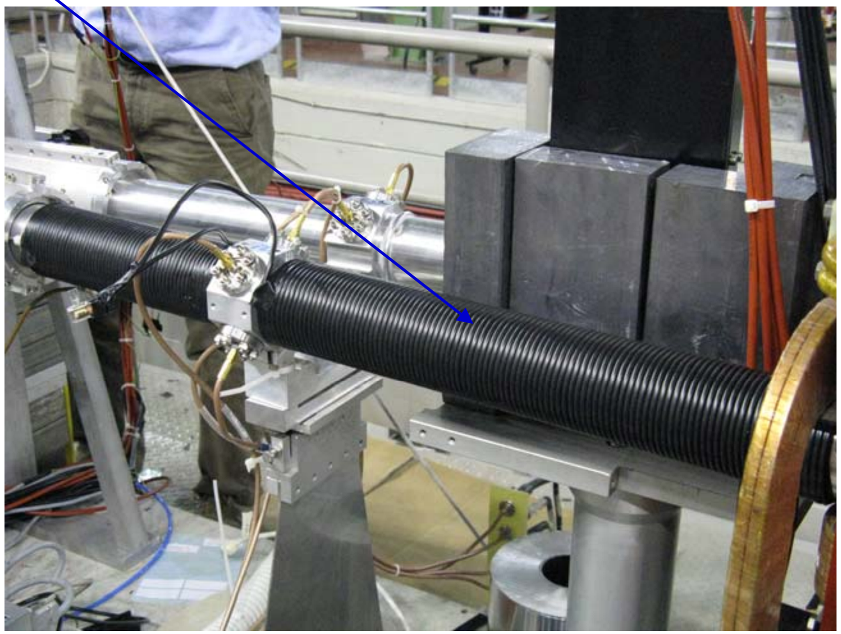
25 bunches
Nb=3.13 10^{10}
Lsep= 3.2 m

Work in progress

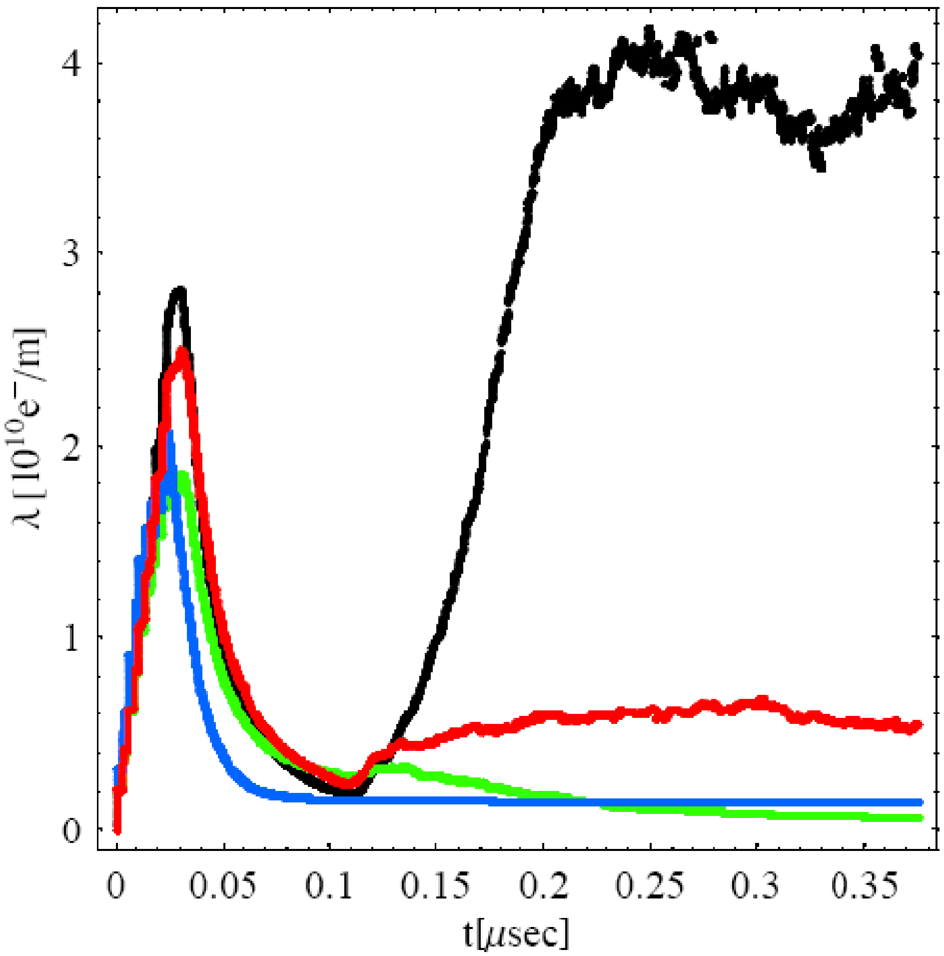
- At the startup after the recent shutdown for the setup of the crab waist collision scheme the instability threshold dropped to   270mA for the positron current (feedback switched off).
- Main change was the installation of new interaction regions (20 m straight sections of alluminum SEY>2)
- In the attempt to find a remedy solenoids were installed in the field free regions of DAFNE, leading to an increase of the threshold to 400mA (feedback switched off).

Solenoids





Multipacting Suppression



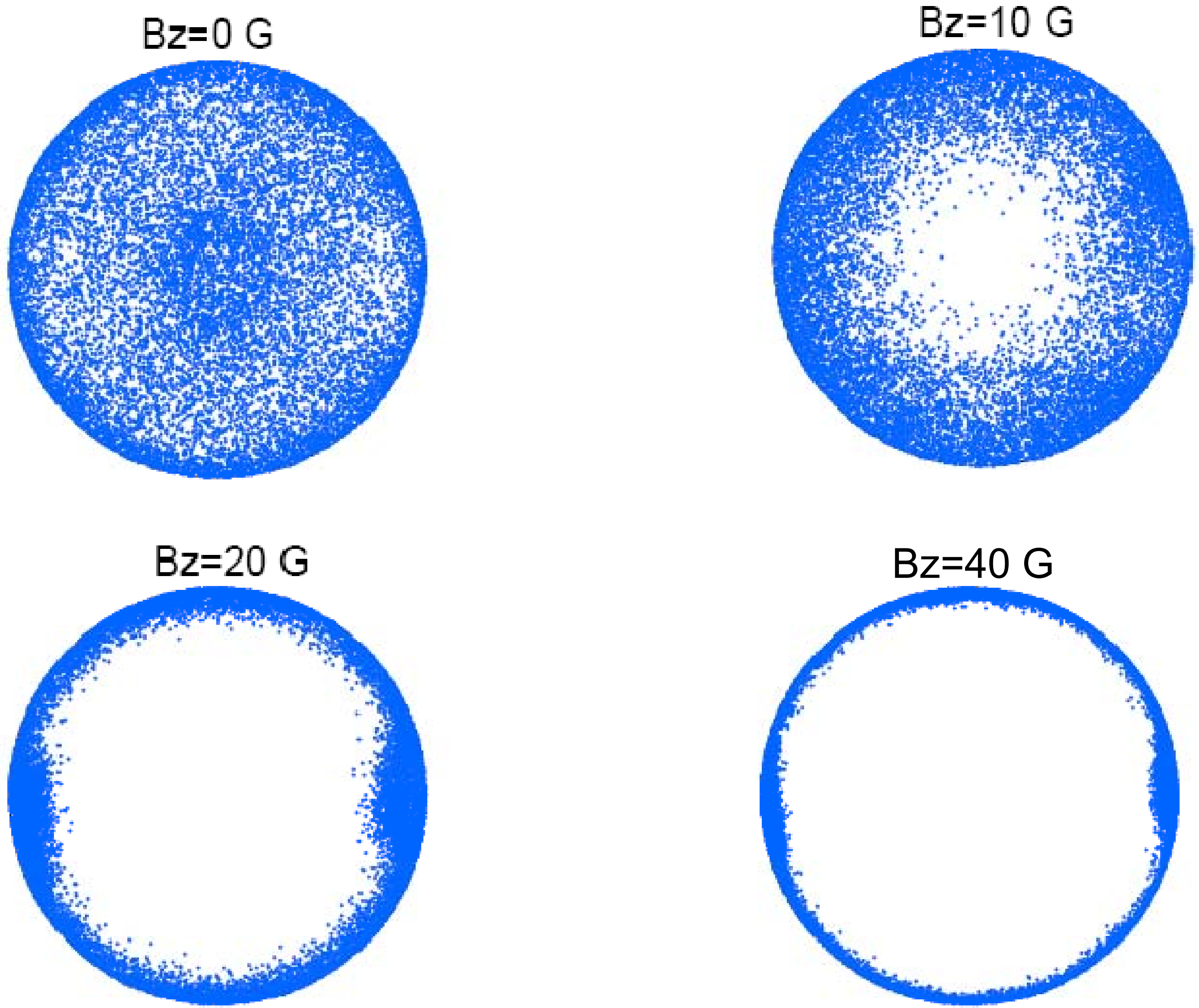
N_b=2.1x10^{10}
L_{sep}=0.8 m
R = 30 mm
δ_{max} =2.4

(10f-30e-100f)

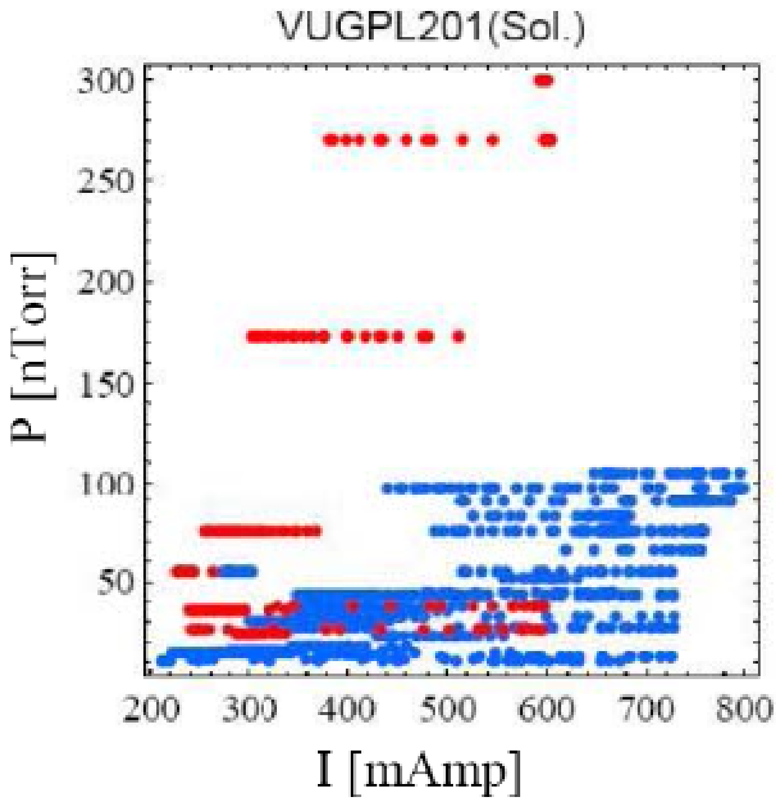
Bz=0 G
Bz=10 G
Bz=20 G
Bz=40 G

Photoelecrons are produced only during the passage of the first 10 bunches.

x-y Phase-Space Snapshot



Effects of Solenoids on Vacuum Pressure Rise



(100f,20e)

Lsep=0.8 m

Bz= 40 G

Sol. Off/Sol. On

Vacuum pressure read-out vs. total current as recorded in a straight section of the positron ring where a 40 G solenoidal field was turned on (blue dots) and off (red dots).

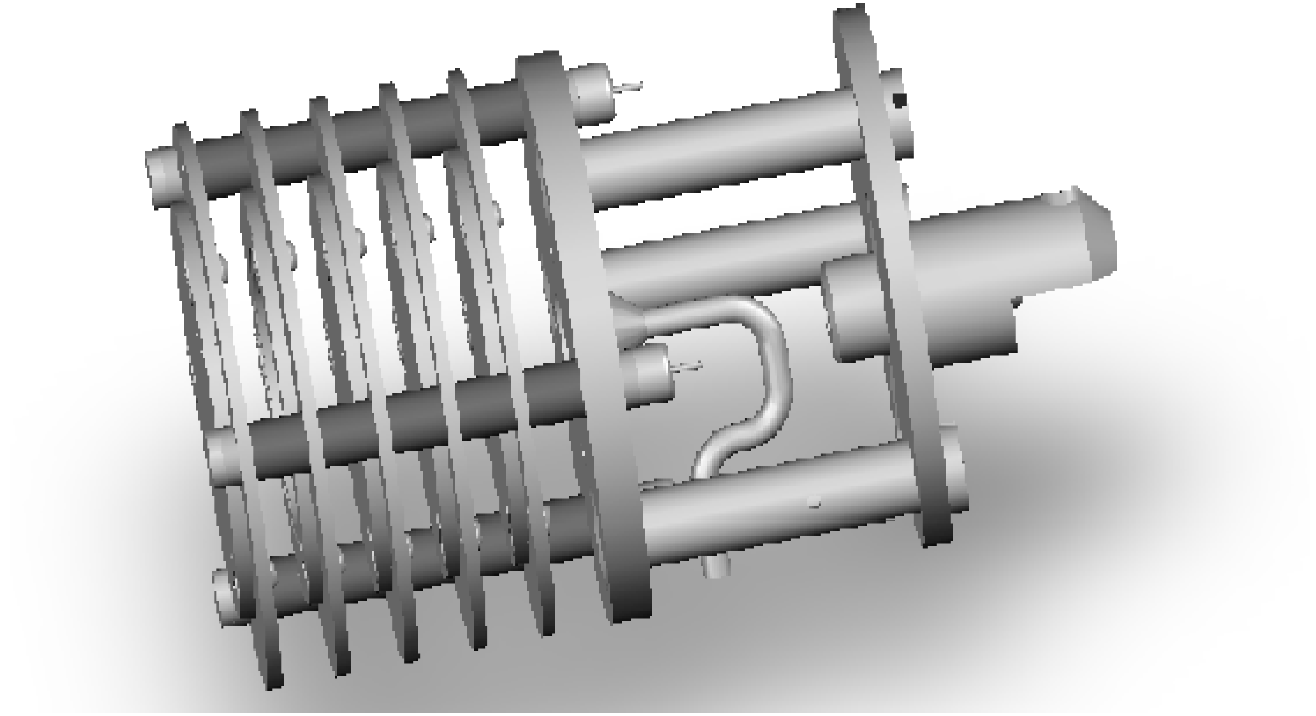
Experimental plans at DAFNE

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)



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?)**

Summary

- 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 (check with other codes is needed)
  - bunch patterns behavior compatible with experimental observation.
- Solenoids were installed at DAFNE, preliminary observation seems to confirm their effectiveness in reducing e-cloud build-up.
- Energy-resolved e^- detectors are under test and are planned for installation at DAFNE.
- Multi-bunch and single-bunch instability simulations are being prepared to directly compare results with measurements planned for the next future.

E-Cloud Task

August 2008

(1) new achievements

(2) deliverable no. 1: documented and experimentally benchmarked code(s) for e-cloud simulations

(3) deliverable no. 2: report on impact of e-cloud and fast ion instabilities on DR performance, including recommendations for controlling the effects

F.Zimmermann, CERN

new achievements

- scaling of e-cloud instability with beam energy

    - experimental results from SPS, benchmarked by simulations
    - G. Rumolo et al, Phys.Rev.Lett.100:144801,2008

- microwave transmission for e-cloud diagnostics (F. Caspers)

    - method pioneered at SPS now applied at PEP-II and CESR-TA

- improved models for pinch & incoherent e-cloud effects

    - PAC'07; G. Franchetti & F. Zimmermann, 2 papers at EPAC'08

- studies of e-cloud and ion effects for the CLIC DR

    - G. Rumolo et al, "Electron Cloud Build Up and Instability in the CLIC Damping Rings'' and "Collective Effects in the CLIC Damping Rings,'' EPAC'08 Genoa

- development & tests of novel countermeasures (ECL2)

    - enamel-based clearing electrodes, grooved surfaces
    - TiZrV NEG, TiN, black gold & carbon coatings (P. Chiggiato et al)
    - beam measurements in PS and SPS testbeds

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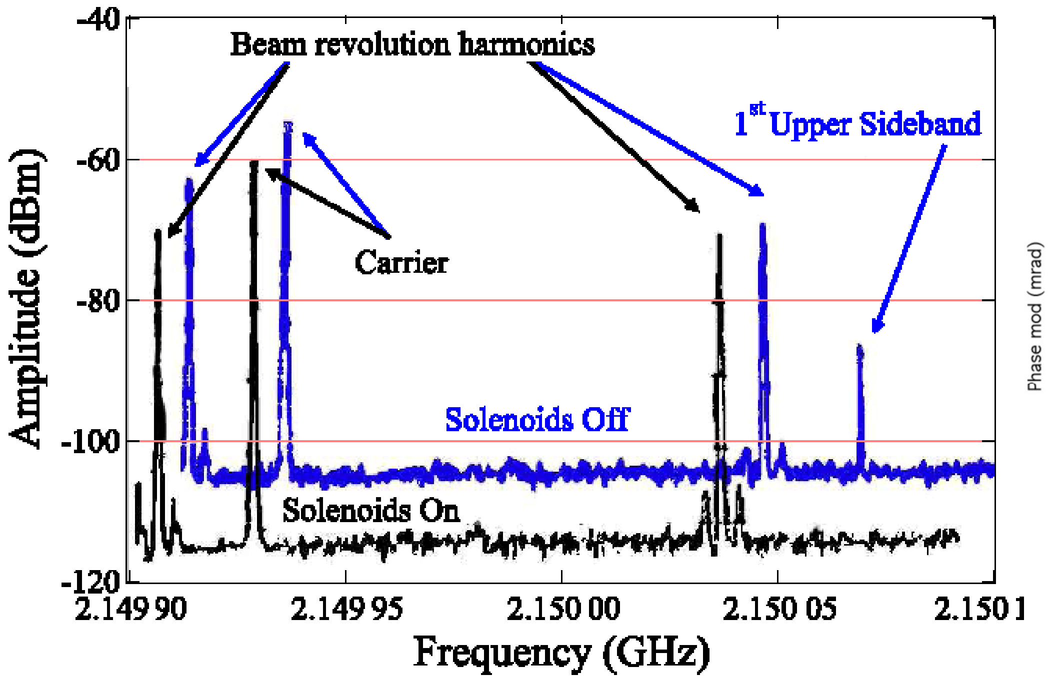
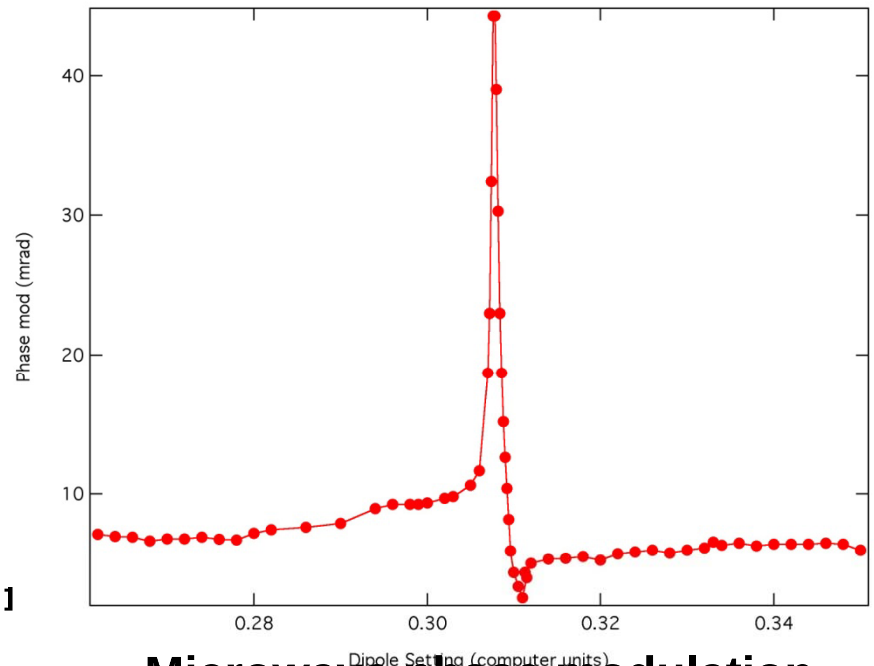
example highlight: microwave transmission



Spectrum analyzer traces showing microwave carrier and beam signals measured in the PEP-II Low Energy Ring over a distance of 50 m with a carrier at 2.15 GHz. A phase modulation sideband appears when the solenoid fields of 20 G covering the entire region is turned off, allowing the electron plasma to fill the beam pipe. Only upper sideband is shown.

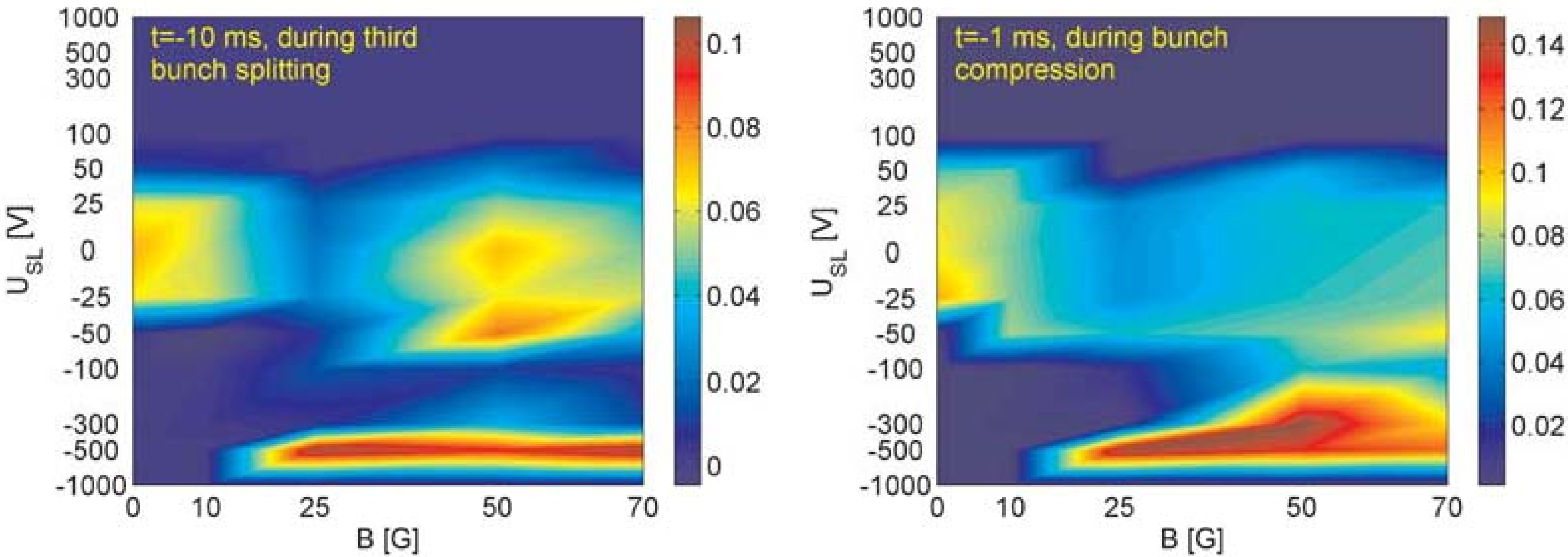
D. Santis et al, *Phys. Rev. Lett.* 100, 094801, 2008.



Microwave phase modulation amplitude measured over a length of 4 m in the CESR-TA accelerator with a carrier frequency of 2.015 GHz. The dipole setting at the peak of about 0.307 units corresponds to a field of 700 T and to a cyclotron resonance near 2 GHz.

J. Byrd et al, *ILC Damping Ring R&D Workshop 2008*, 8-11 July 2008

example highlight: PS clearing electrode study



Electron cloud signal at the CERN PS in units of Volt measured for various clearing electrode voltages (-1 kV < U_{SL} < +1 kV) and magnetic dipole fields (0 G < B < 70 G).

Measurements were taken continuously during the last 50 ms before beam extraction at t = 0 ms.

E. Mahner, T. Kroyer, F. Caspers, “Electron cloud detection and characterization in the CERN Proton Synchrotron,” *PRST-AB*, 2008

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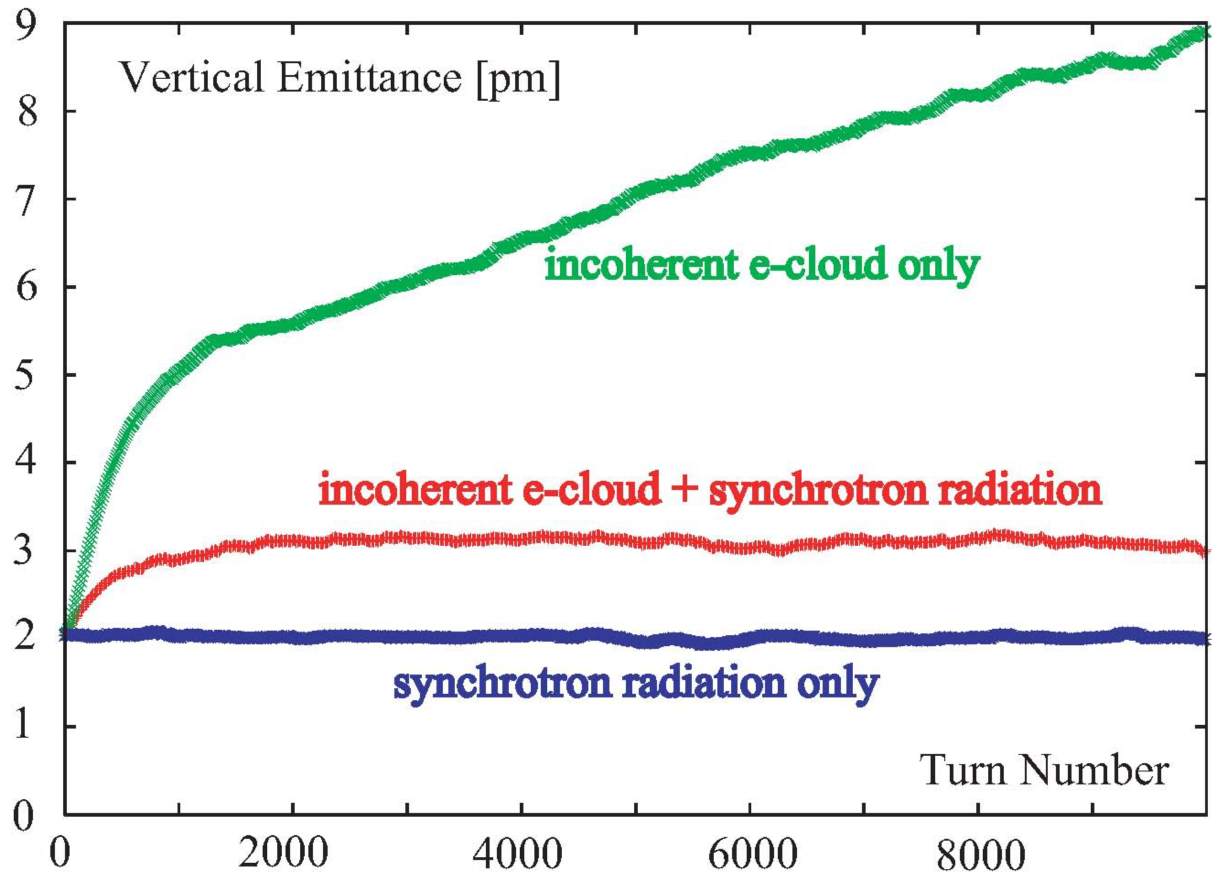
example highlight: incoherent e-cloud effect



Vertical emittance in the ILC 6-km damping ring (OCS) as a function of turn number, with synchrotron radiation only, with a frozen electron cloud pinch only, and with the combined effect, simulated by IECP using a single beam electron "IP" per turn and an initial tune shift, at the head of the bunch, of ΔQ≈0.01, corresponding to an electron density of2e11/m^3. The incoherent tune shift is taken to increase 140 times during the bunch passage.

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deliverable 1: e-cloud code

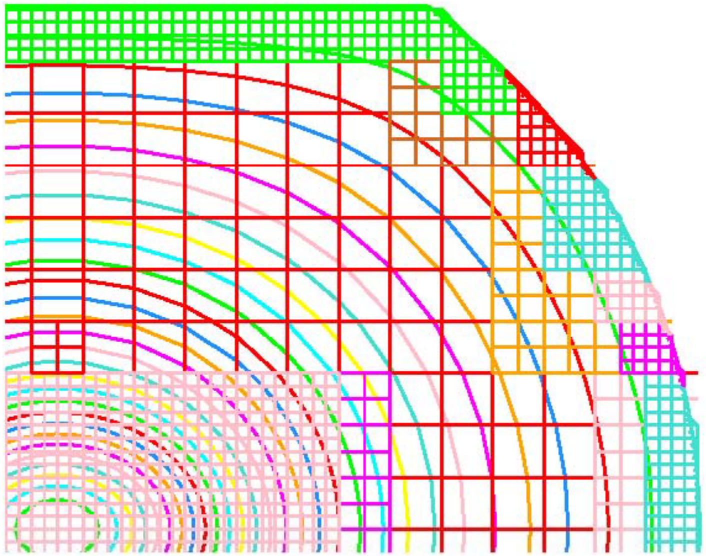
the work-horse e-cloud codes: ECLOUD, HEADTAIL, IECP, MICROMAP (also see e-cloud code repository at *http://oraweb.cern.ch/pls/hhh/code_website.disp_category?cat_name=ElectronCloud* **and the e-cloud code benchmarking web site** *http://care-hhh.web.cern.ch/CARE-HHH/Simulation-Codes/Benchmark/ElectronCloud.htm***)**
were complemented by a new code developed within EUROTeV: FAKTOR2 – a 3D code able to treat arbitrary boundaries

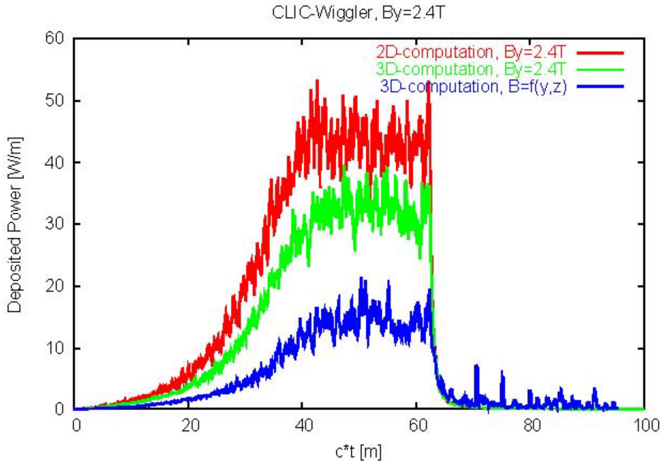
Faktor2 Documentation:

W. Bruns, "Faktor2: Usage," EUROTeV-Report-2007-071.
W. Bruns, "Faktor2: Rationale," EUROTeV-Report-2007-072.

Faktor2 Custodian:
Giovanni Rumolo (CERN)

Faktor2 code examples

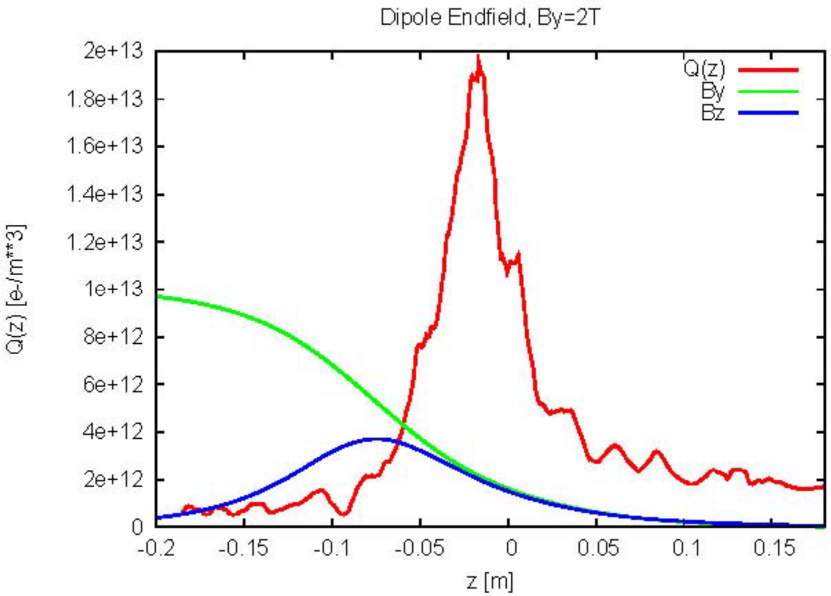




Power deposited by e-cloud inside a CLIC wiggler from 2D and 3D Faktor2 simulations

Subdivision of the grid near the pipe boundary and at the location of the beam. Two levels of refinement are applied. The different colours of the refined cells indicate clusters of cells which are treated as rectangular grids. The curved lines are lines of constant potential of an elliptical beam at the center.

W. Bruns et al, PAC'07



Time average of the electron density near the axis in the end region of a dipole. Red: Electron density. Green and blue: shape of the By and Bz component.

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deliverable 2: report on e-cloud & ion impact on DR

electron cloud:

Build-up and instability simulations show that the electron cloud is a serious problem for the positron damping rings. An antechamber absorbing 99.9% of the synchrotron radiation and a maximum secondary emission yield SEY below 1.3 could ensure stable operation by suppressing electron cloud formation. (G. Rumolo, EPAC'08).

Coatings with NEG, black gold or carbon may guarantee SEY<1.3 and could solve this problem (S. Calatroni, P. Chiggiato, M. Taborelli)

ions:

A good vacuum pressure of 1 ntorr plus a fast bunch-by-bunch feedback acting after about one turn would suppress the fast beam-ion instability. (G. Rumolo, EPAC'08)

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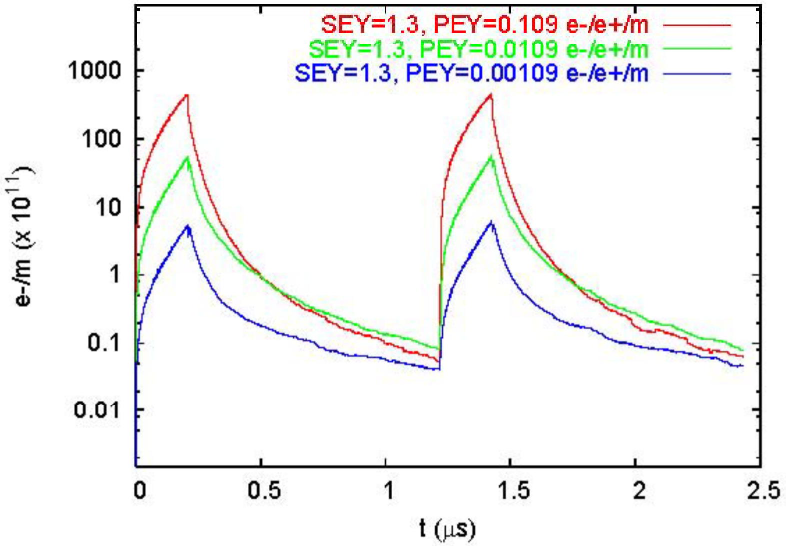
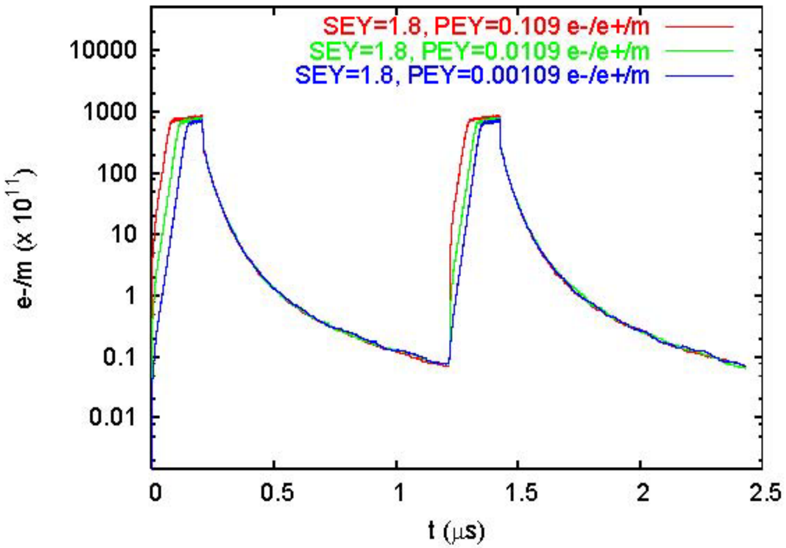
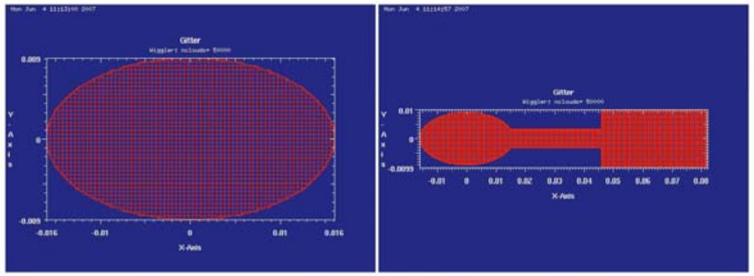
example results related to deliverables 1 & 2

ECLOUD simulations for wiggler chamber of CLIC DR considering different values of SEY and of antechamber absorption efficiency

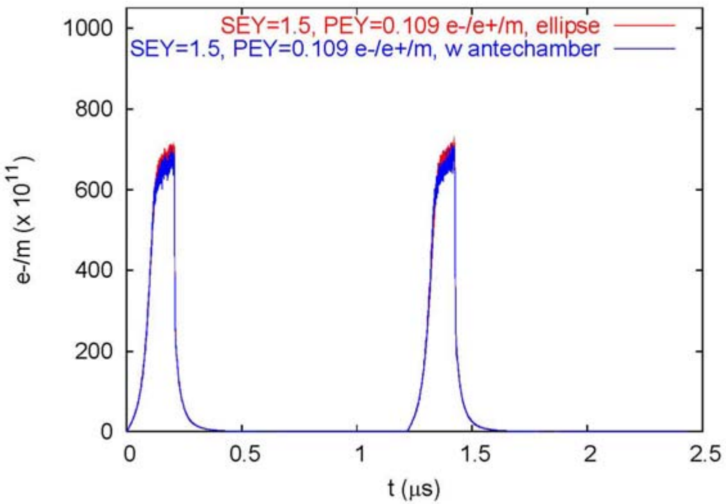




Faktor2 simulations exploring the effect of a real antechamber geometry



Simulated geometries and grids for theFaktor2 calculations. Ellipse (left) and geometry with antechamber (right).



Electron central densities in the wiggler chamber of the CLIC DRs for the labelled value ofphotoemission yield, and $\delta_{max} = 1.5$ (simulations with and wihout the antechamber).

W. Bruns,, G. Rumolo et al, EPAC'08

ECLOUD Task - epilogue

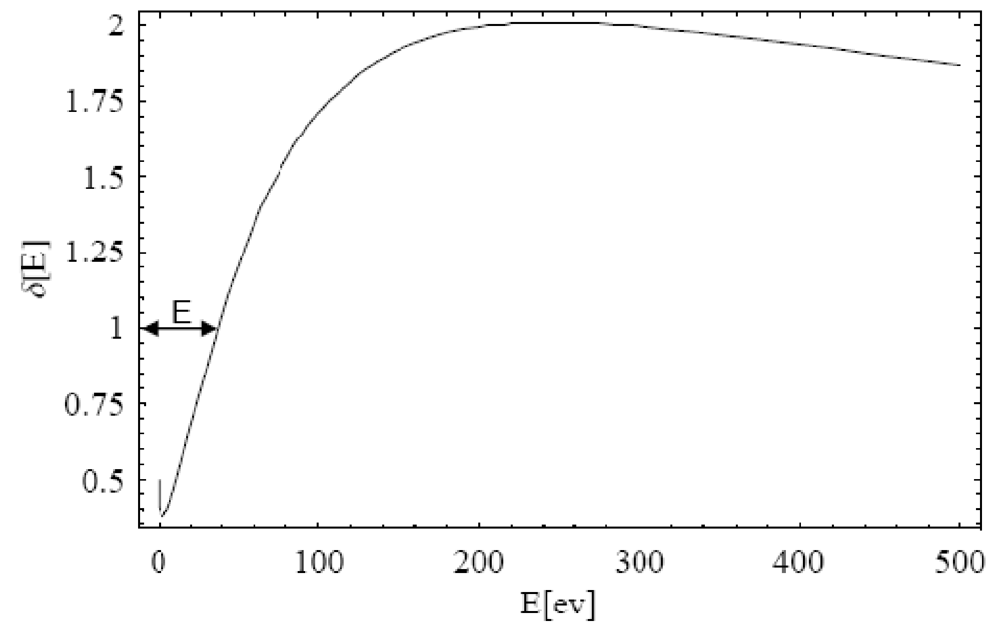
the last years have witnessed a remarkable progress in electron cloud diagnostics and suppression techniques

using a suitable technique and with proper precaution the electron cloud will not limit DR performance

F.Zimmermann, CERN

Cyclotron Resonance

Y. Cai et Al., Phys. Rev. ST-AB 7, 024402 (2004)



- Resonance condition

$$T_c / 2 = L_{sep} / c \quad \Rightarrow \quad B_z^{res} = \frac{\pi m_e c^2}{e L_{sep}} \approx 66G$$

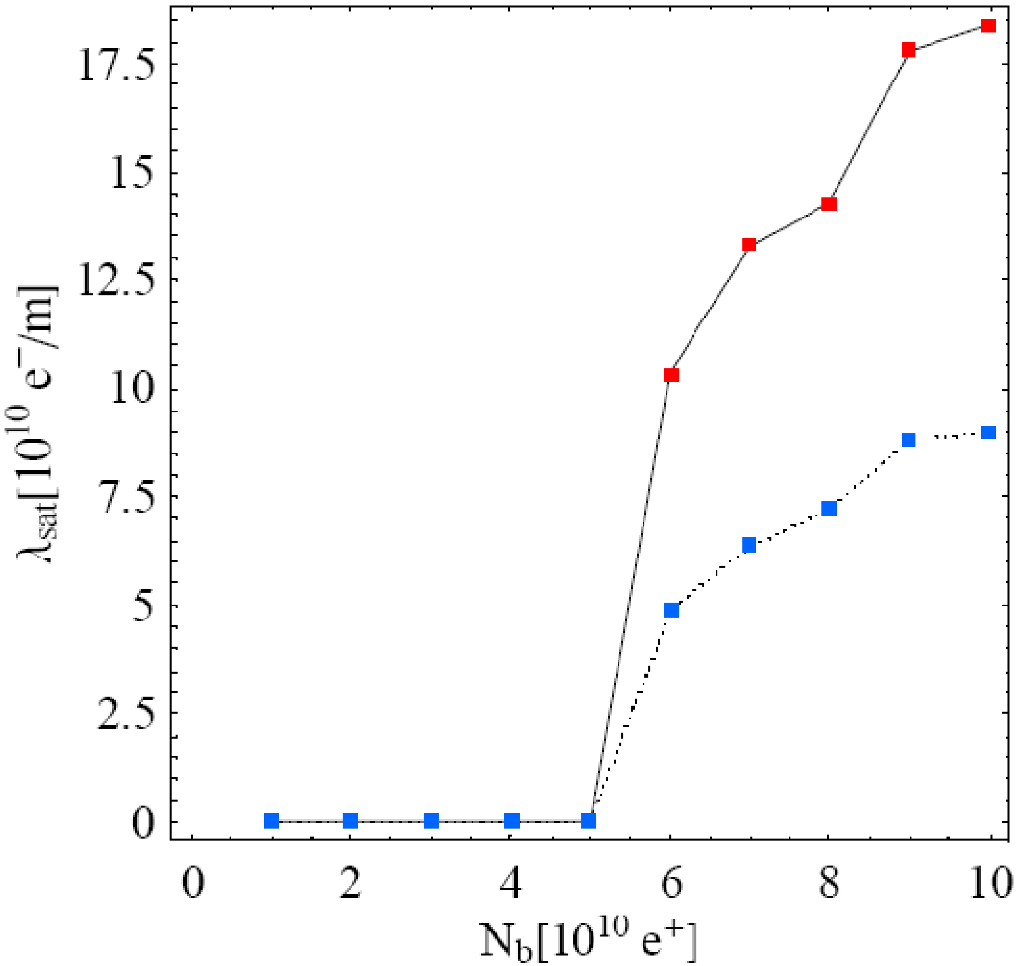
- Intensity threshold

$$\Delta E_{kick} \geq E_{\delta=1} \quad \Rightarrow \quad N_b = \frac{R}{r_e}\sqrt{\frac{E_{\delta=1}}{2 m_e c^2}} \approx$$

$7.1 \cdot 10^{10} e^+$ (R=33 mm, δ_{max}=2.4)

$9.5 \cdot 10^{10} e^+$ (R=44 mm, δ_{max}=1.9)

Simulated Intensity Threshold



Bz=66 G; Lsep

Bz=33 G; 2Lsep

R=30mm

δ_{max} =2.4

$N_b \approx 5x10^{10}$ for both Lsep and 2Lsep is above the DAFNE operated current.