e-cloud studies at LNF

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Plan of talk

- Introduction
- ECLOUD Simulations for the DAFNE wiggler
- ECLOUD Simulations for build up in presence of solenoidal field
- New feedback system to suppress horizontal coupled-bunch instability.
- Preliminary analysis of the instabilities
- Conclusions

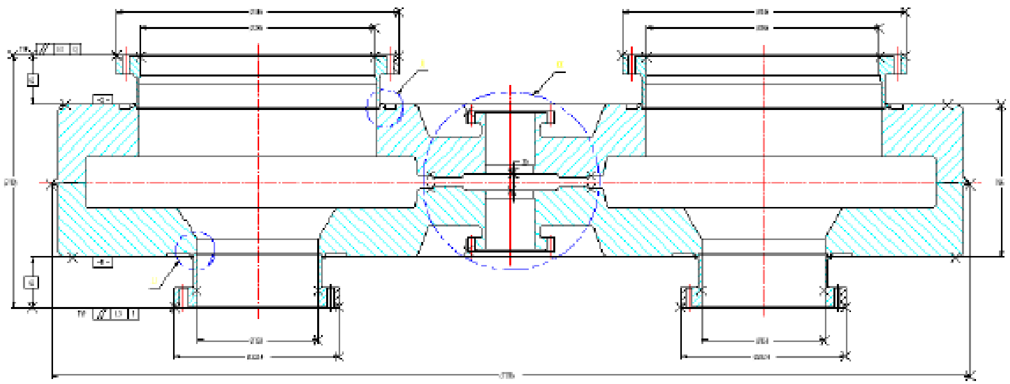
Electron cloud at DAFNE

- e^+ current limited to 1.2 A by strong horizontal instability
- Large positive tune shift with current in e^+ ring, not seen in e^- ring
- Instability depends on bunch current
- Instability strongly increases along the train
- Anomalous vacuum pressure rise has been oserved in e^+ ring
- Instability sensitive to orbit in wiggler and bending magnets
- Main change for the 2003 was wiggler field modification

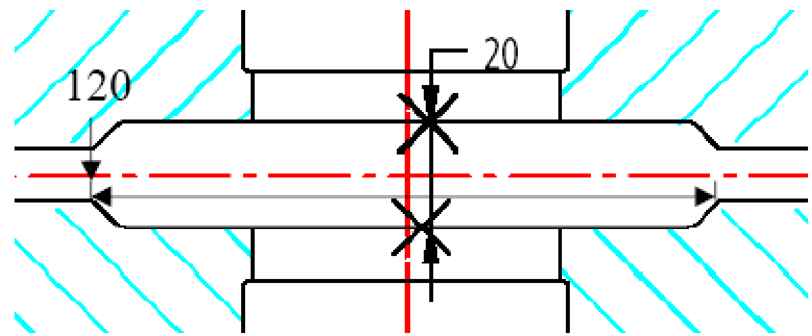
Wiggler vacuum chamber

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

M. Preger, DAFNE Tech. Note L-34; C.Vaccarezza, PAC05, p.779

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

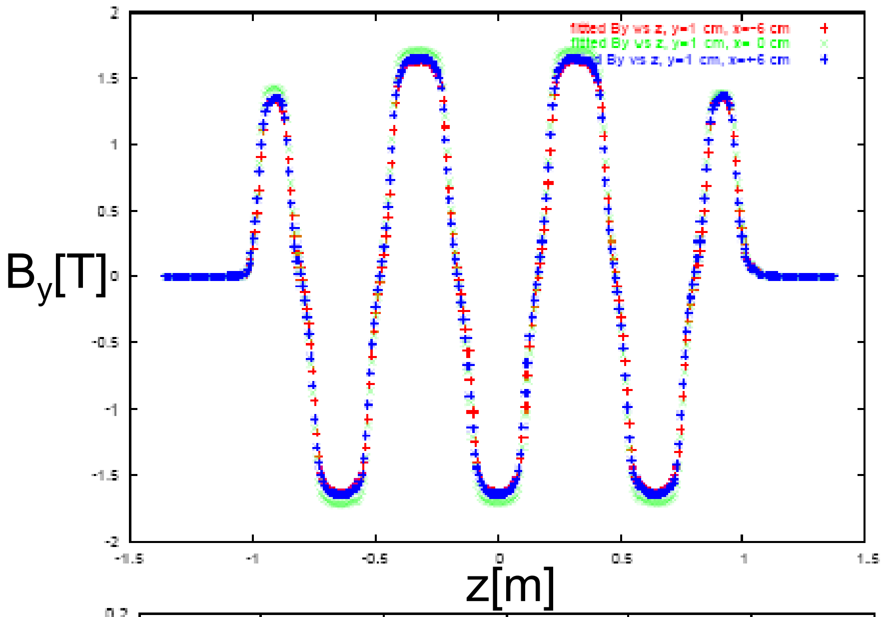
$$B_x = \frac{\partial B_y\left(x, y=0, z\right)}{\partial x} y$$

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

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

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

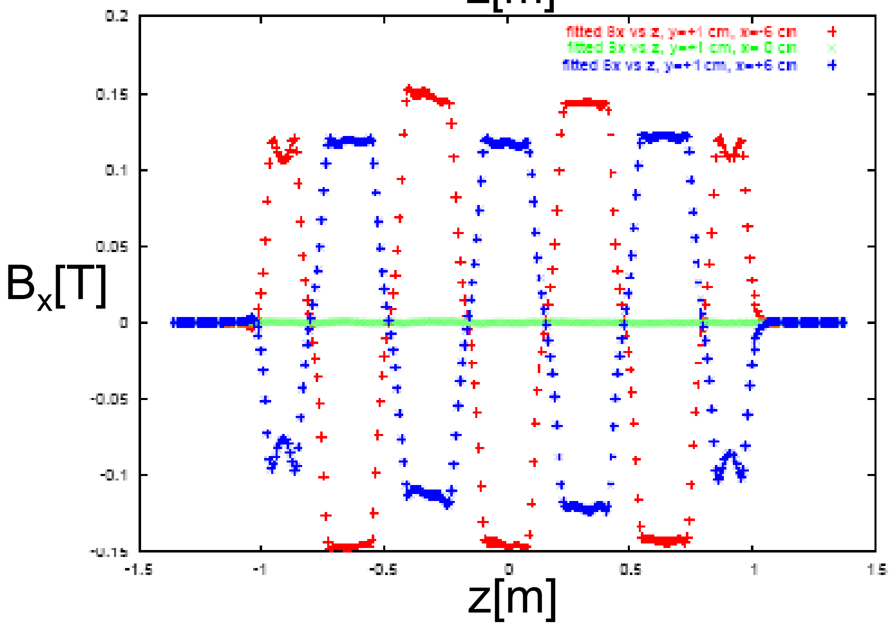
Wiggler magnetic field

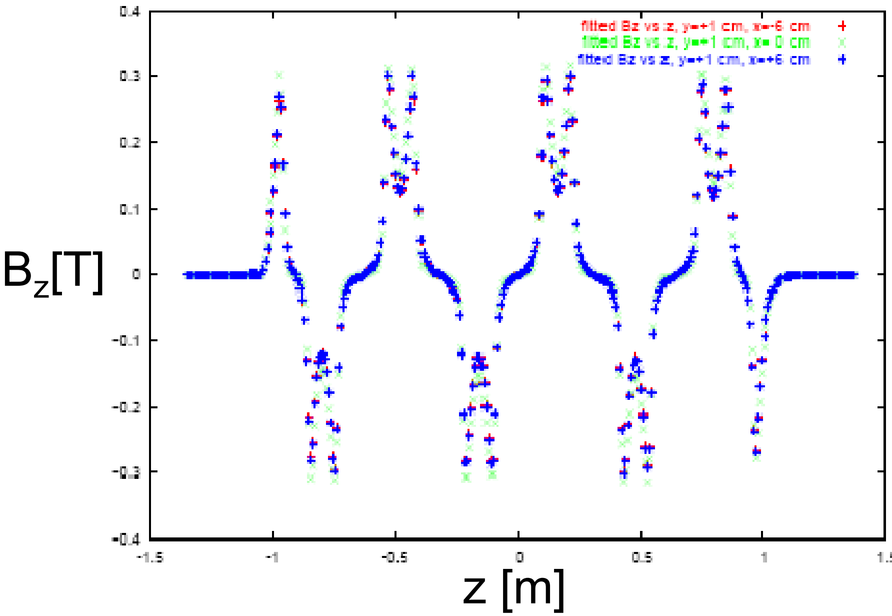


peak field ~1.7 T

period ~0.65 m

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



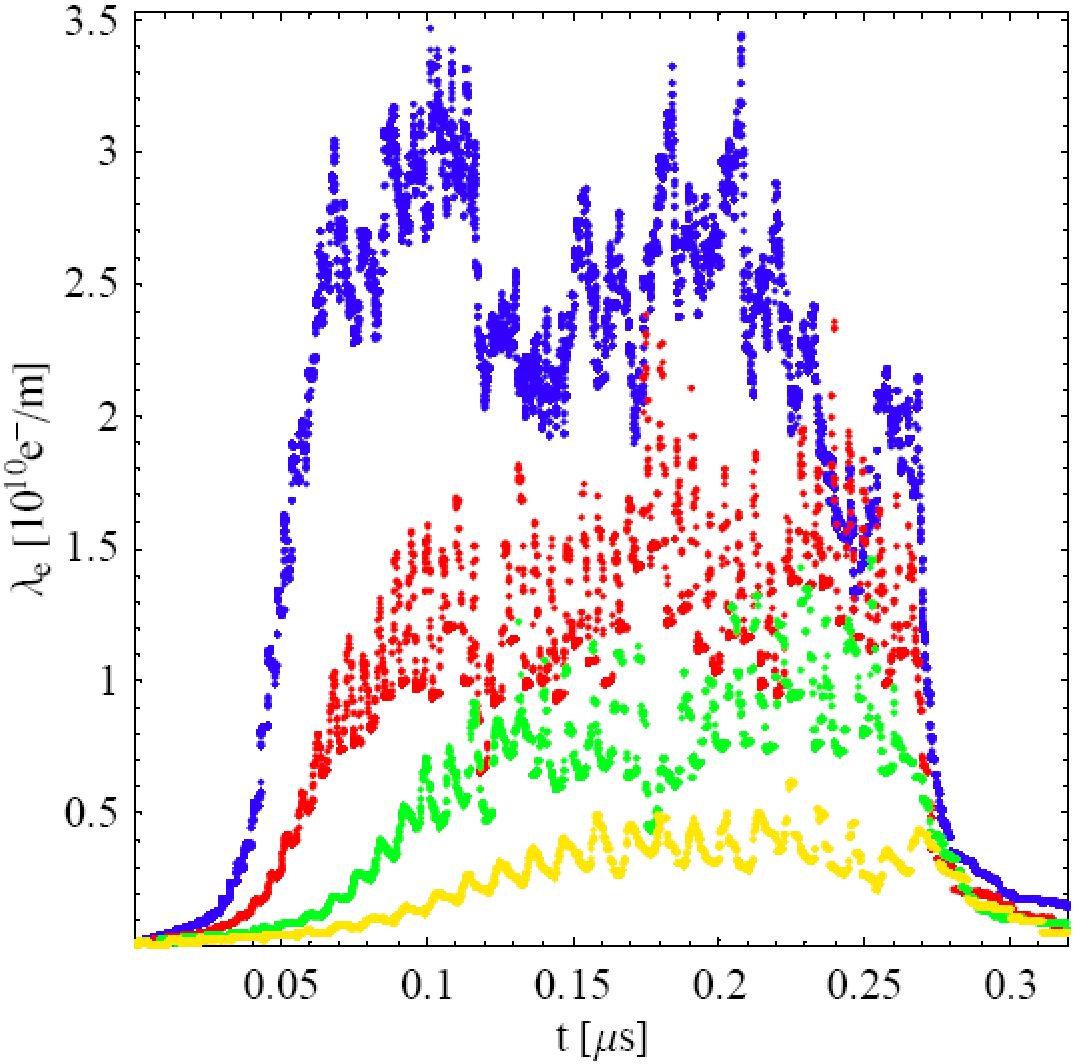


Input parameters for ECLOUD (DAFNE Wiggler 2003)

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.)	

* 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

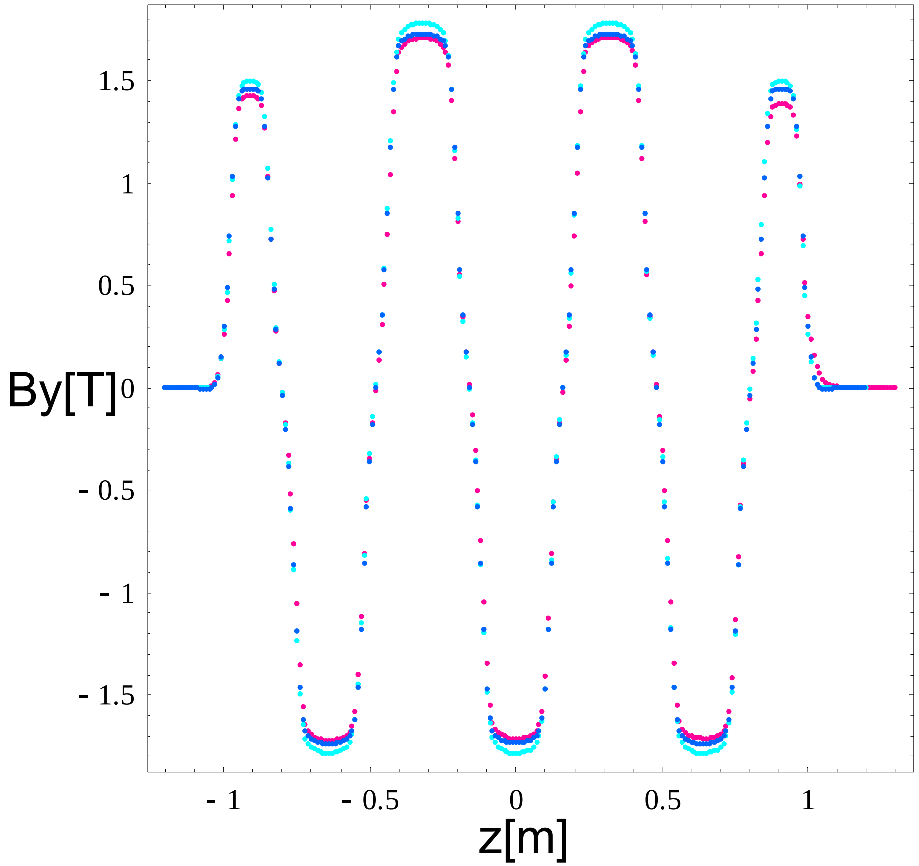
33 bunches

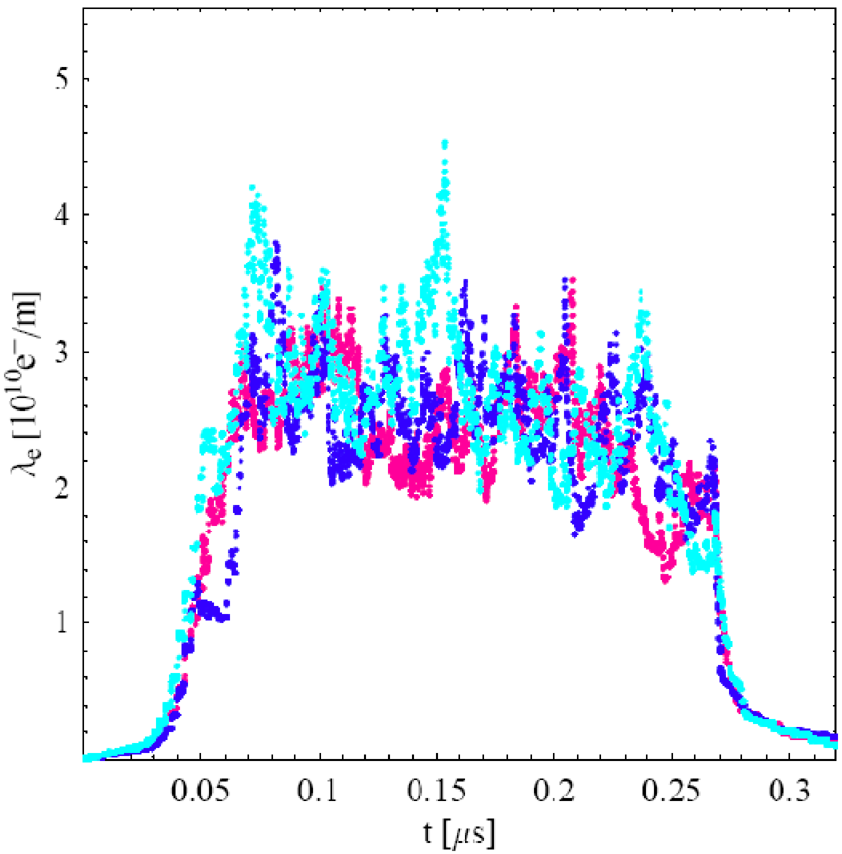
L_{sep}= 2.4 m

25 bunches

L_{sep}= 3.2 m

Magnetic field models





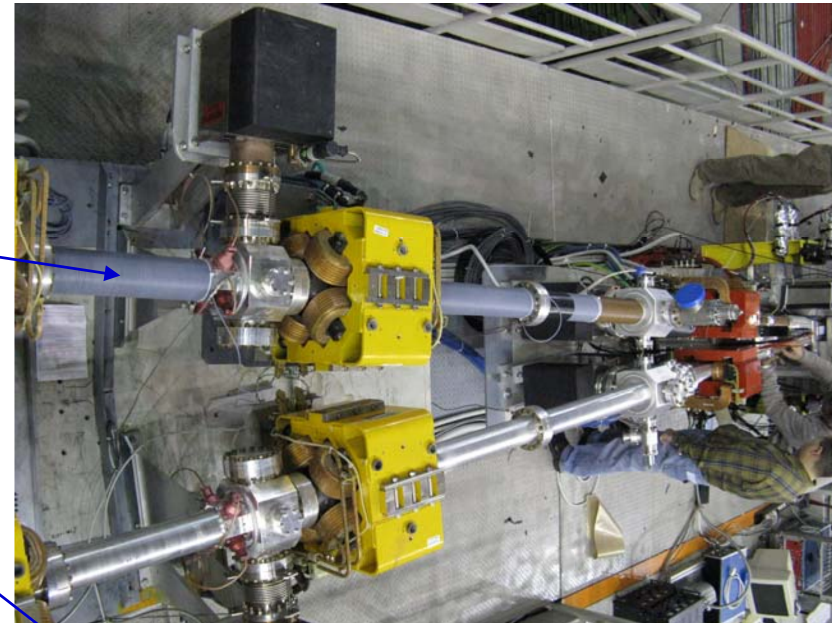
100 bunches, L_{sep}= 0.8 m, N_b=2.1 10^{10}

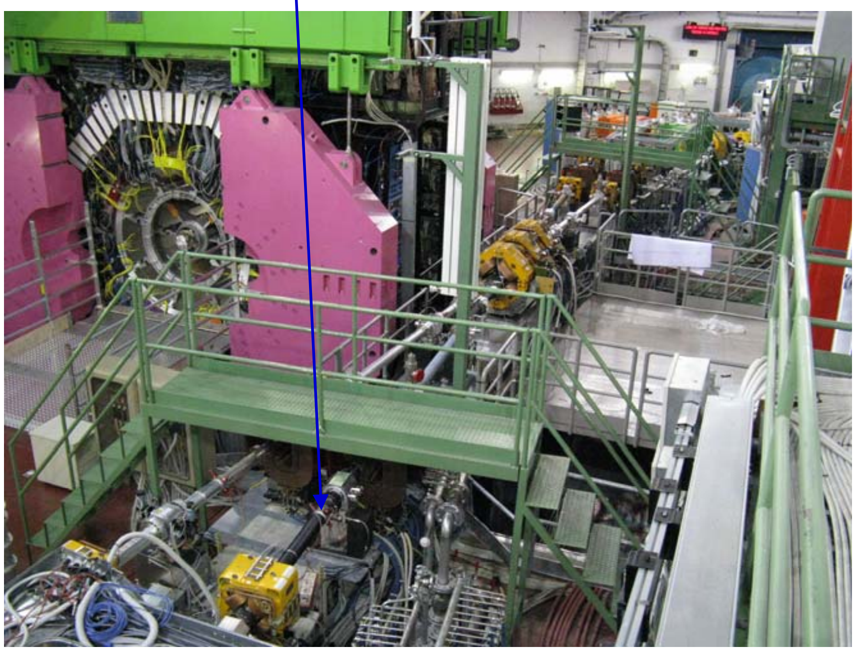
2003 wiggler 2002 wiggler 2007 wiggler (proposed)

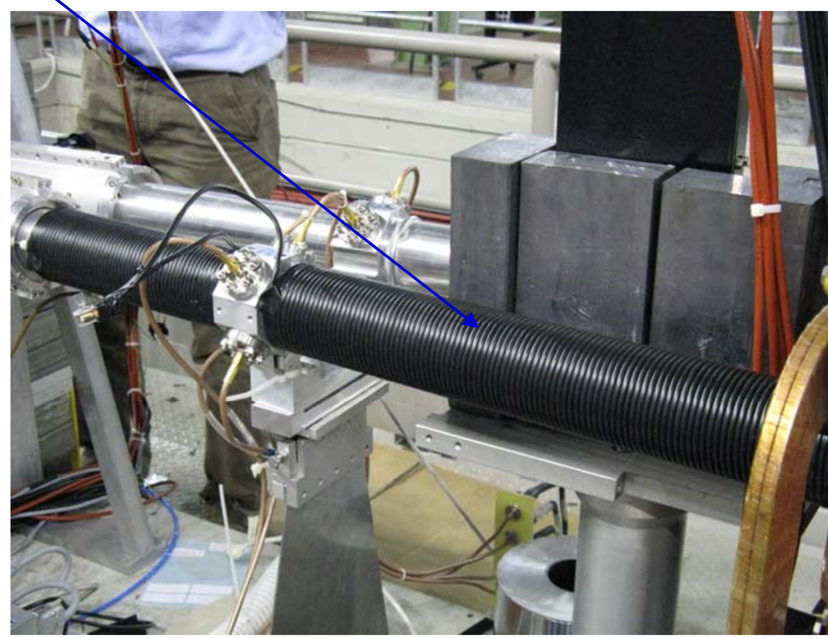
Solenoids Installation

- 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).

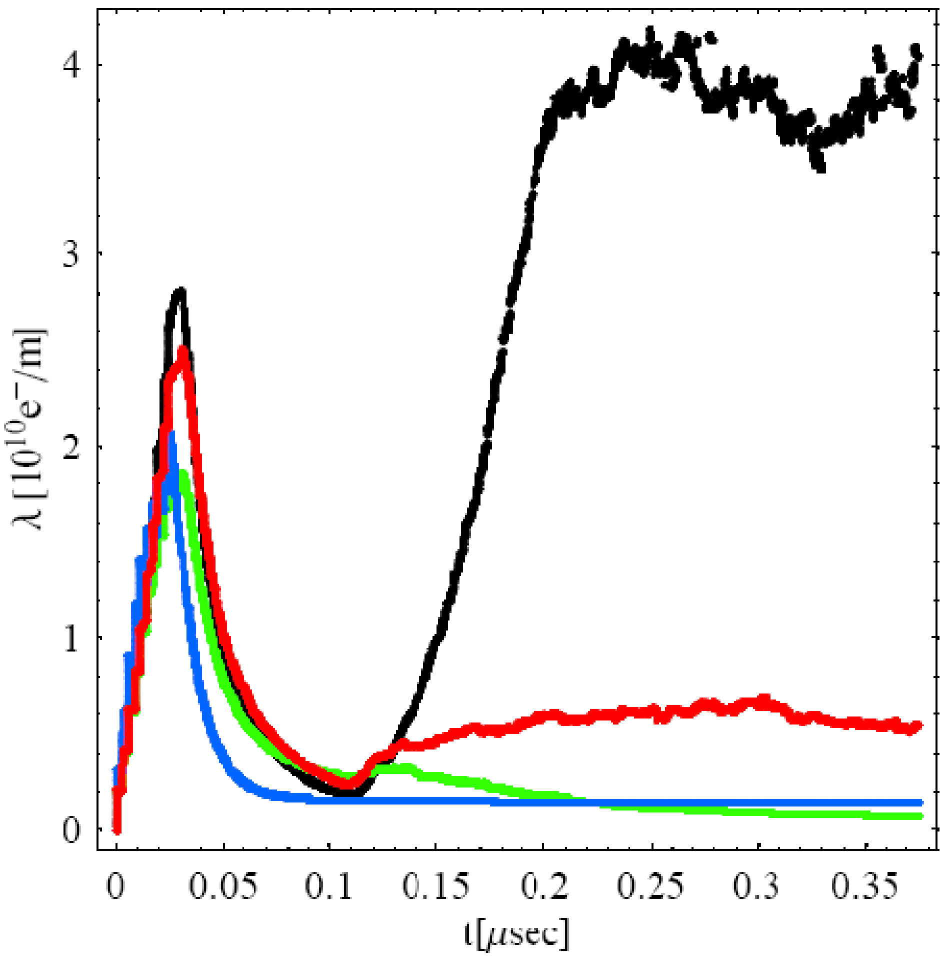
Solenoids







Multipacting Suppression



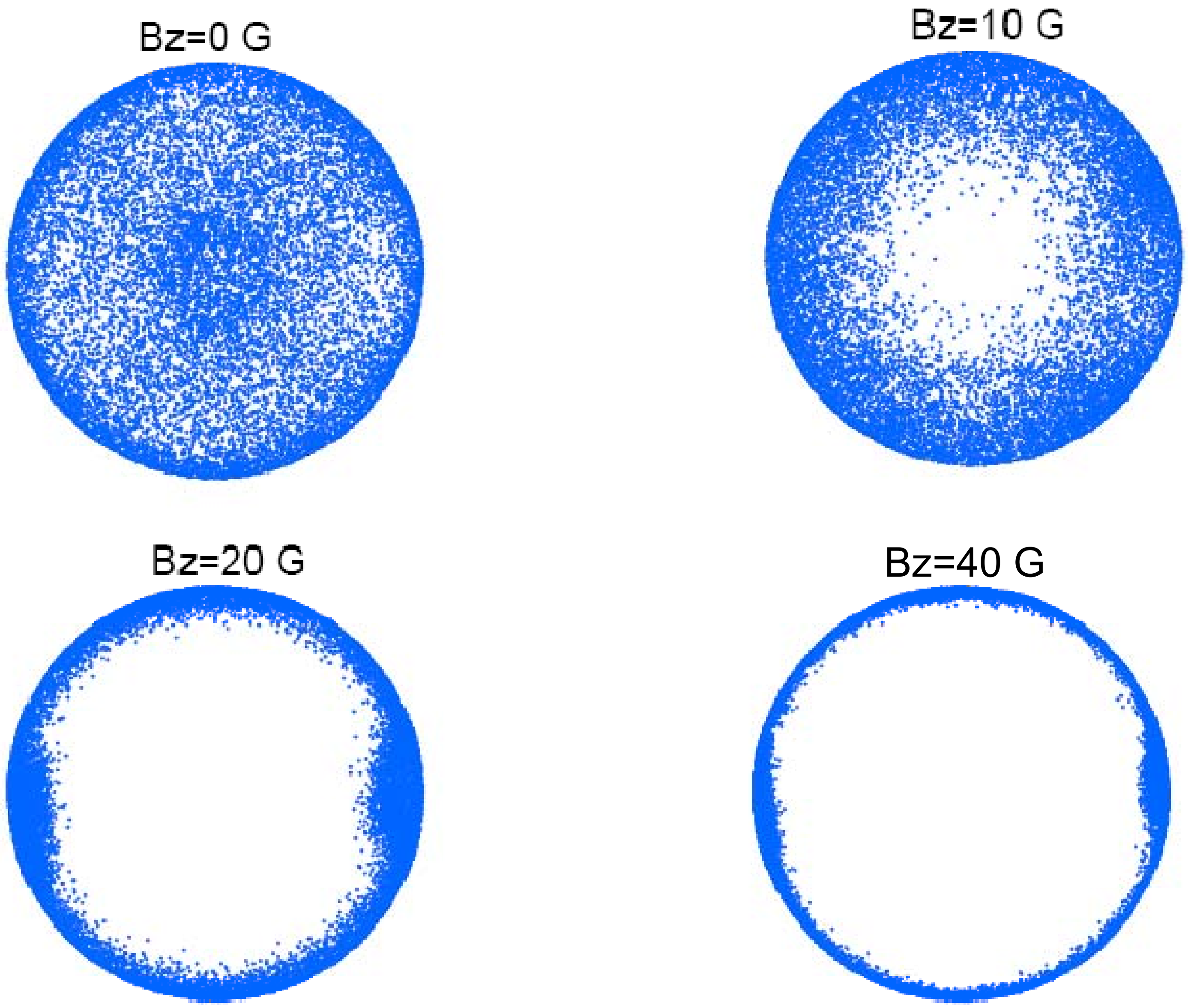
N_b=2.1x10^{10}
L_{sep}=0.8 m
R = 30 mm
δ_{max} =2.4

(10f-30e-100f)

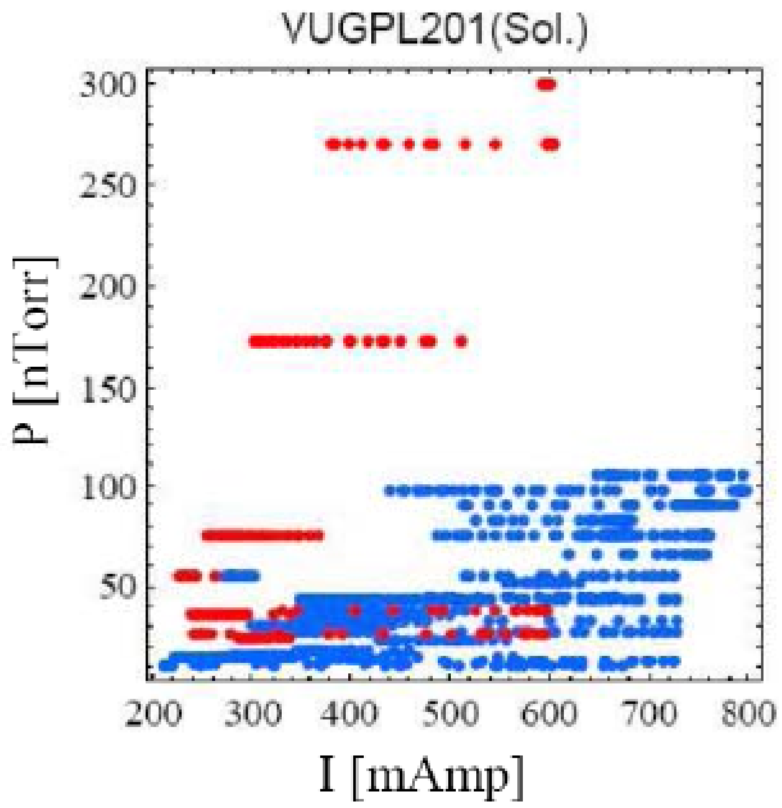
Bz=0 G
Bz=10 G
Bz=20 G
Bz=40 G

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).

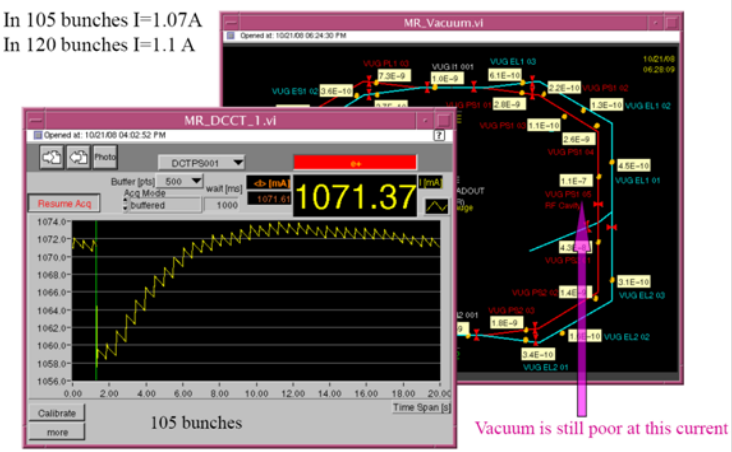
New DAFNE e^+ Transverse feedback

- Observing the linearity of the horizontal instability, growing > 70 (1/ms) for Ibeam>800mA

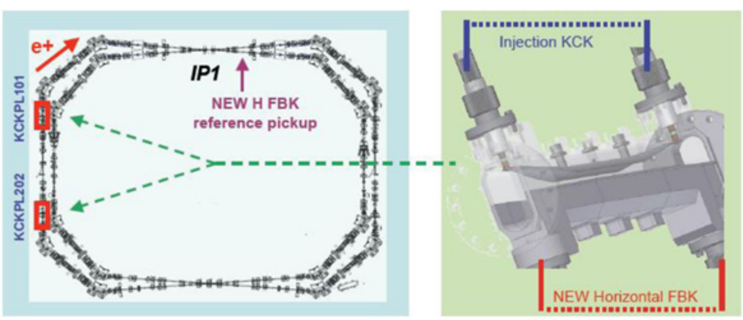
- We decide to double the feedback power from 500W to 1kW.

- We decide to test another pickup (to see if less noisy) and to use the spare striplines of the injection kickers.

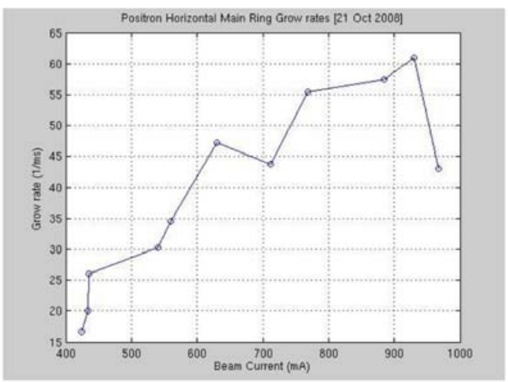
The current limit has been exceed



- **<u>New e+ Transverse Horizontal Feedback</u>**
- The damping times of the two feedbacks add up linearly
- Damping time measured:
- ~100 ms-1 (1 FBKs) ➔ fb damps in 30 revolution periods (~10 us)
- ~200 ms-1 (2 FBKs) ➔ fb damps in 15 revolution periods (~ 5 us)
- The power of the H FBK has been doubled

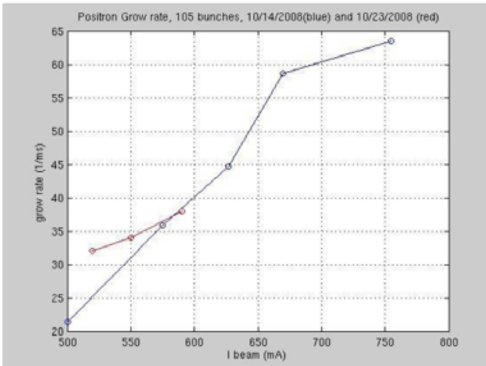


Grow rates at higher e+ current controlling instability by 2 feedback



Characterization of the Horizontal Instability

e+ instability grow rates by halving βx in the RF cavity

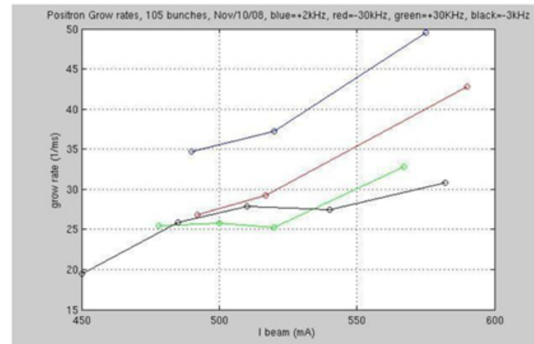


- OPTICS for collision (blue)
- βx 4 [m] -> 2 [m] in the RF cavity (red)
- $\nu^+_x = 6.096$,
- $\nu^+_y = 5.182$
- $\Delta\nu^+_x$ between the Wigglers unchanged

Conclusion: the instability does not depend on hypothetical high order mode in the e+ RF cavity

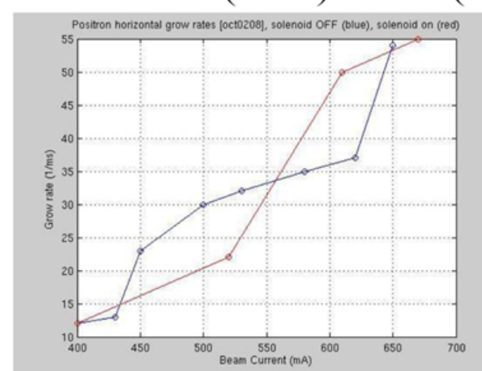
- the horizontal instability rise time cannot be explained only by the beam interaction with parasitic HOM or resistive walls
- Solenoids installed in free field regions strongly reduce pressure but have no effect on the instability
- Instability sensitive to orbit in wiggler and bending magnets

e+ instability grow rates versus orbit in the main ring dipoles



The orbit variation is performed changing the RF frequency and then compensating the beam energy

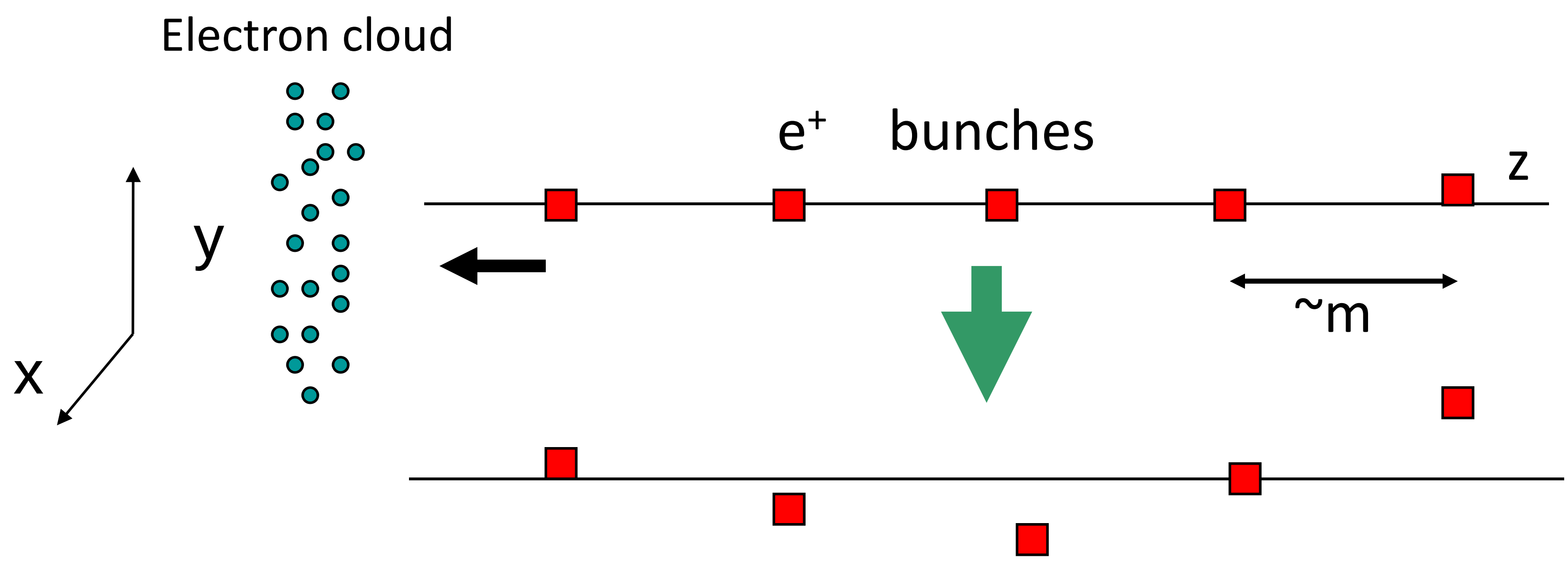
e+ instability behavior switching solenoids off (blue) & on (red)



- Switching off the solenoids installed in the positron ring the grow rates of the e+ instability does not change

PEI-M Tracking simulation

K.Ohmi, PRE55,7550 (1997),K.Ohmi, PAC97, pp1667.



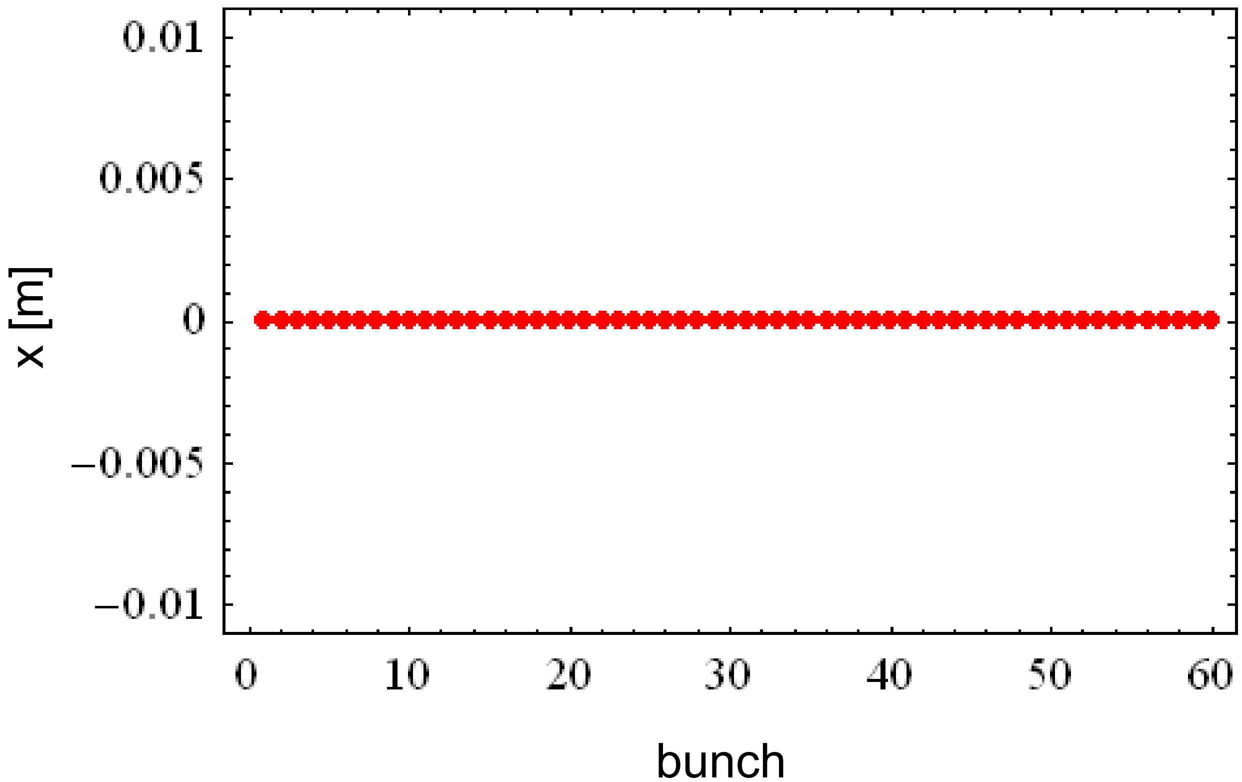
•Solve both equations of beam and electrons simultaneously, giving the transverse amplitude of each bunch as a function of time.

•Fourier transformation of the amplitudes gives a spectrum of the unstable mode, identified by peaks of the betatron sidebands.

Input parameters for DAFNE simulations

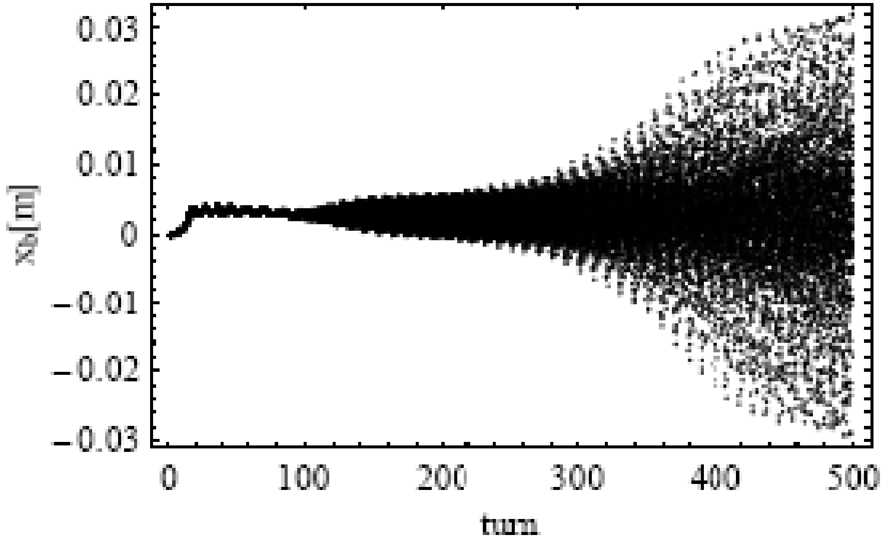
Bunch population	N_b	2.1; 4.2 $x10^{10}$
Number of bunches	n_b	120; 60
Missing bunches	N_{gap}	0
Bunch spacing	L_{sep}[m]	0.8;1.6
Bunch length	σ_z [mm]	18
Bunch horizontal size	σ_x [mm]	1.4
Bunch vertical size	σ_y [mm]	0.05
Chamber Radius	R [mm]	40
Hor./vert. beta function	β_x[m]/β_y[m]	4.1/1.1
Hor./vert. betatron tune	ν_x/ν_y	5.1/5.17
Primary electron rate	$d\lambda/ds$	0.0088
Photon Reflectivity	R	100% (uniform)
Max. Secondary Emission Yeld	Δ_{max}	1.9
Energy at Max. SEY	E_m [eV]	250
Vert. magnetic field	B_z [T]	1.7

Bunch train evolution



1.2 A in 60 equispaced bunches

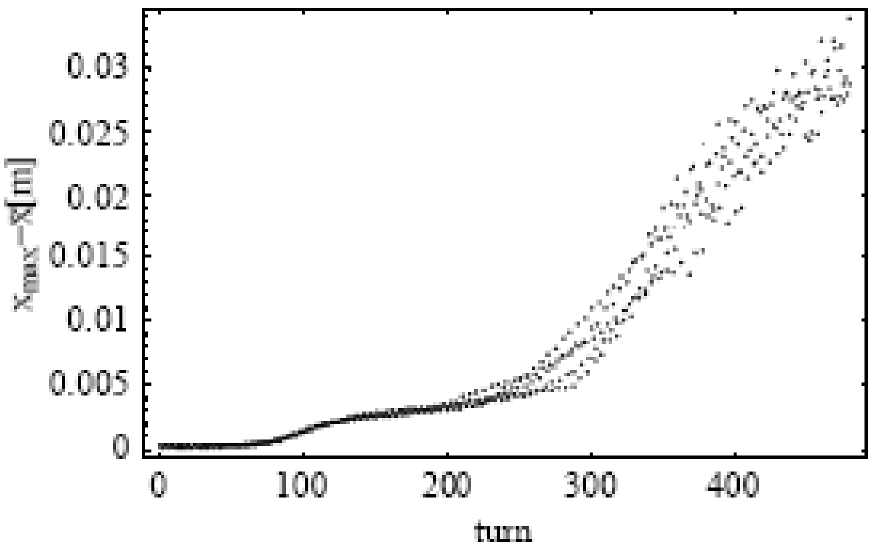
Mode spectrum and growth rate

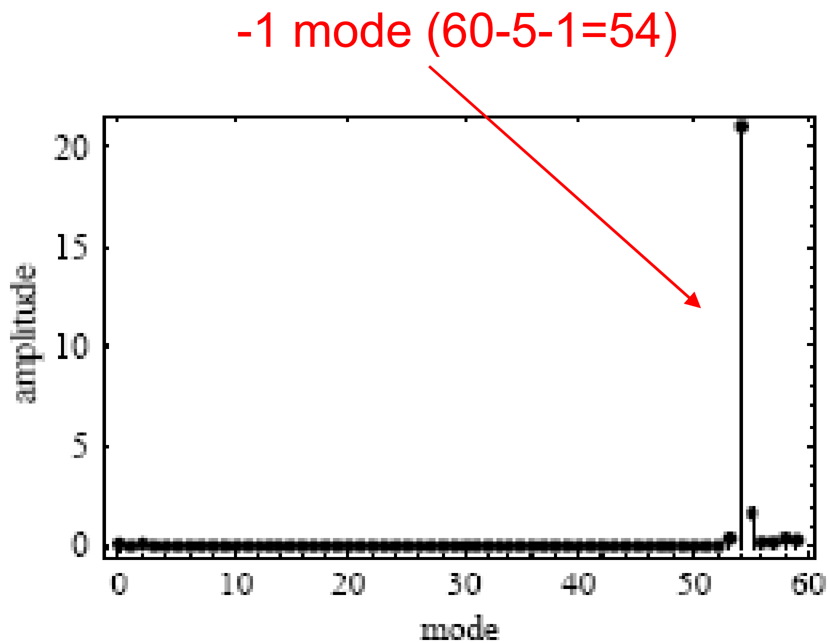


60 equispaced bunches

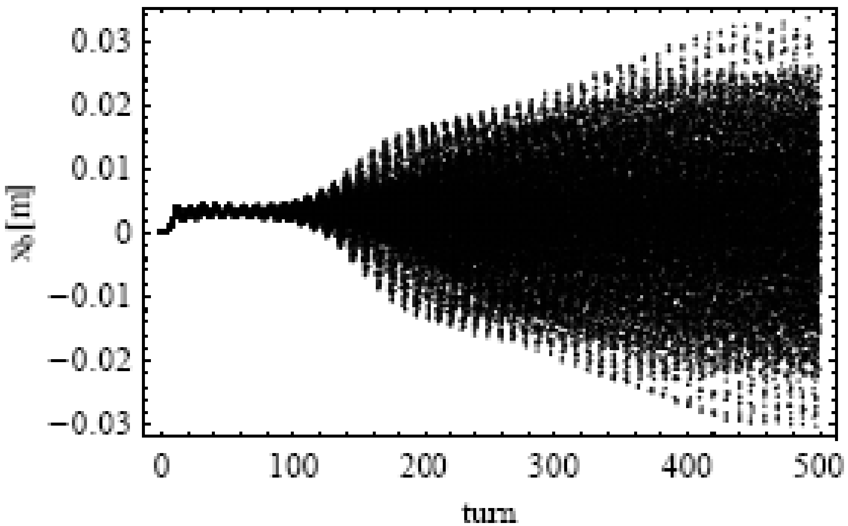
Beam current 1.2 A

Growth time ~ 100 turn

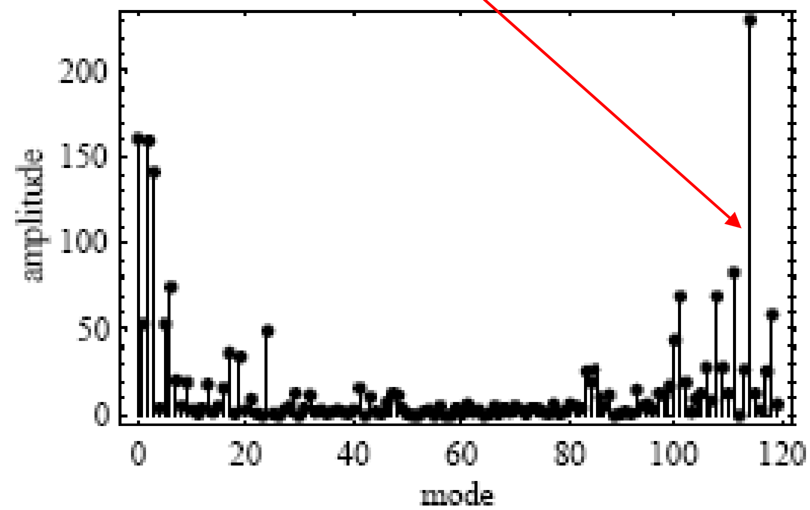


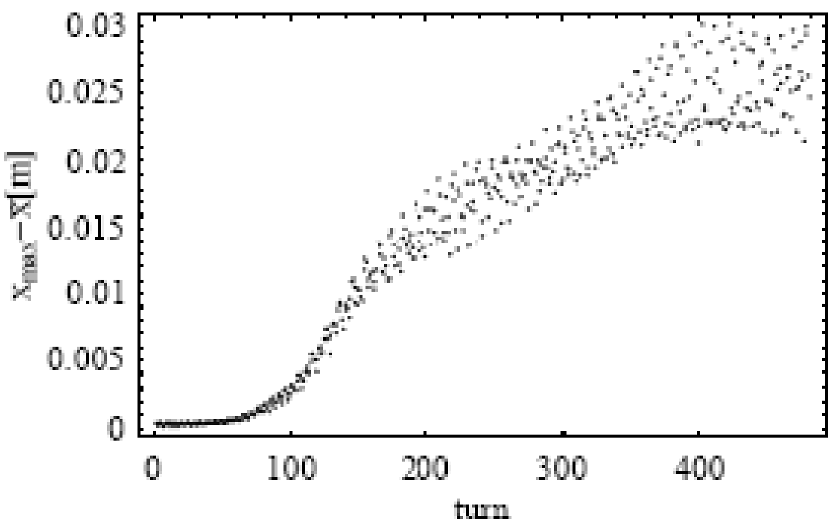


Mode spectrum and growth rate



-1 mode (120-5-1=154)





120 equispaced bunches

Beam current 1.2 A

Growth time ~ 100 turn

Simulations vs measurments

Measurment		Simulation	
I[mA]/nb	τ/T_0	I[mA]/nb	τ/T_0
1000/105	73	1200/120	100
750/105	56	900/120	95
500/105	100	600/120	130

Summary

- ECLOUD build-up simulations for the DAFNE Wiggler show:
  - no dependence of e-cloud build-up on magnetic field model
- Solenoids were installed at DAFNE, preliminary observation seems to confirm their effectiveness in reducing e-cloud build-up
- Two separate feedback systems for the same oscillation plane work in perfect collaboration doubling the damping time, keeping I+ MAX as higher as possible
- Coupled-bunch instability has been simulated using PEI-M for the DAFNE parameters
- Preliminary results are in qualitative agreement with grow-damp measurments