Preliminary results for electron cloud induced coupled bunch instability in DAFNE

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Thanks to K. Ohmi (KEK)

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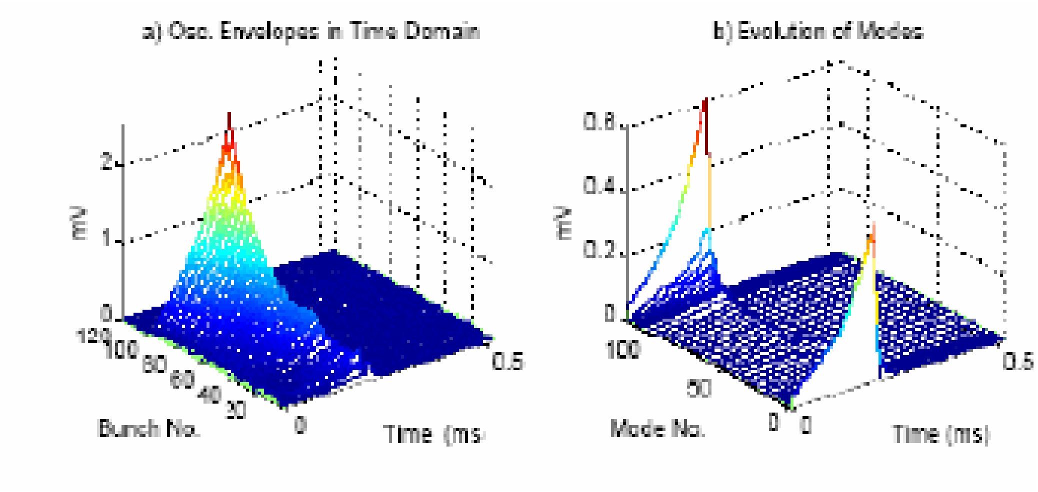
Plan of talk

- Electron cloud at DAFNE
- Electron cloud multi-bunch instability
  - Wake field
  - Tracking simulations
- Comparison with experiments
- Conclusions and outlook

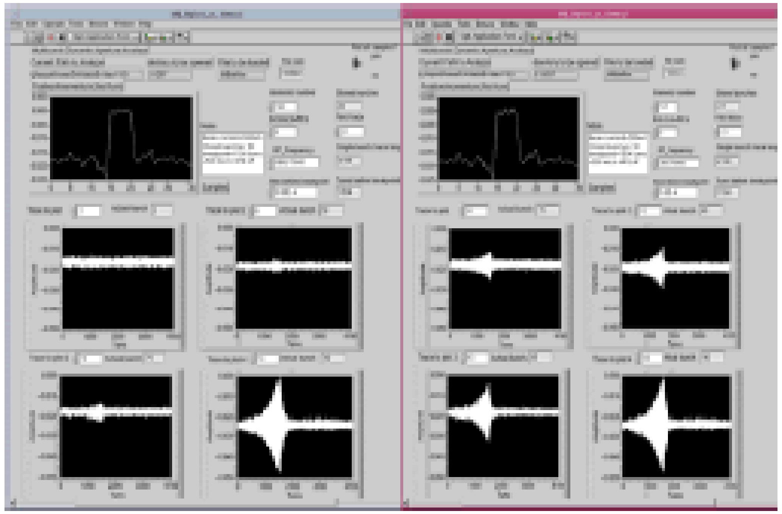
Electron cloud at DAFNE

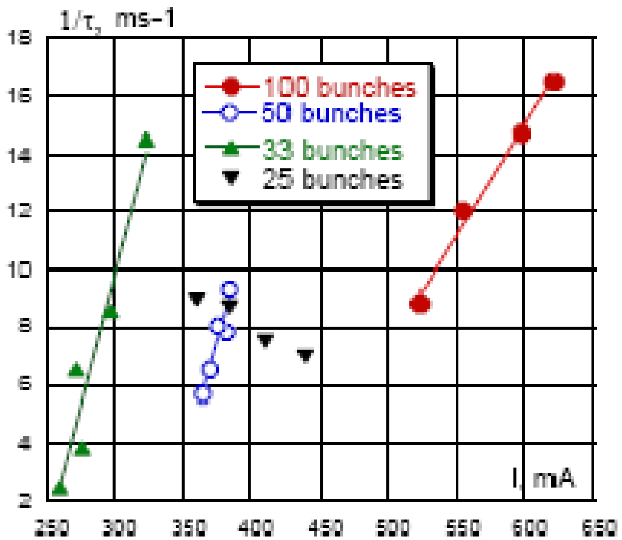
- e^+ current limited to 1.2 A by strong horizontal instability
- Large positive tune shift with current in e^+ ring, not seen in e^- ring
- Instability depends on bunch current
- Instability strongly increases along the train
- Anomalous vacuum pressure rise has been oserved in e^+ ring
- Solenoids installed in free field regions strongly reduce pressure but have no effect on the instability (see A. Drago talk)
- Instability sensitive to orbit in wiggler and bending magnets
- Main change for the 2003 was wiggler field modification

Typical measurments



Grow-damp measurements





Pattern dependence

- •Growth rates depends on bunch current
- •Most unstable mode is always a slow frequency mode (-1 mode)

Linear theory of e-cloud induced multibunch instability

[S.S. Win et al., Phys. Rev. ST-AB 8, 094401 (2005)]

Under linearity and superposition assumption, the momentum kick experienced by bunch i when bunch j is displached can be written as:

$$\Delta y'_{p,i} = \frac{N_p r_e}{\gamma} \sum_{j>i}^{i+N_w} W_1(z_i - z_j) y_{p,j}$$

$N_p = p.p.b.$

$\gamma = E / m_e c^2$

$\nu_\beta = \omega_\beta / \omega_0$

$M = harm.numb.$

Coupled bunch instability is characterized by the dispersion relation:

$$(\Omega_m - \omega_\beta) L / c = \frac{N_p r_e c}{2\gamma\omega_\beta} \sum_{\ell=1}^{N_w} W_1(-\ell L_{\mathrm{sp}}) \exp\left(2\pi i \ell \frac{m + \nu_\beta}{M}\right)$$

Bunches oscillate with a mode characterized by:

$$y_m(z_j) = a_m \exp[-i\Omega_m t + 2\pi i m j / M]$$

The momentum kick can calculated numerically using the PEI-M code (K.Ohmi, KEK).

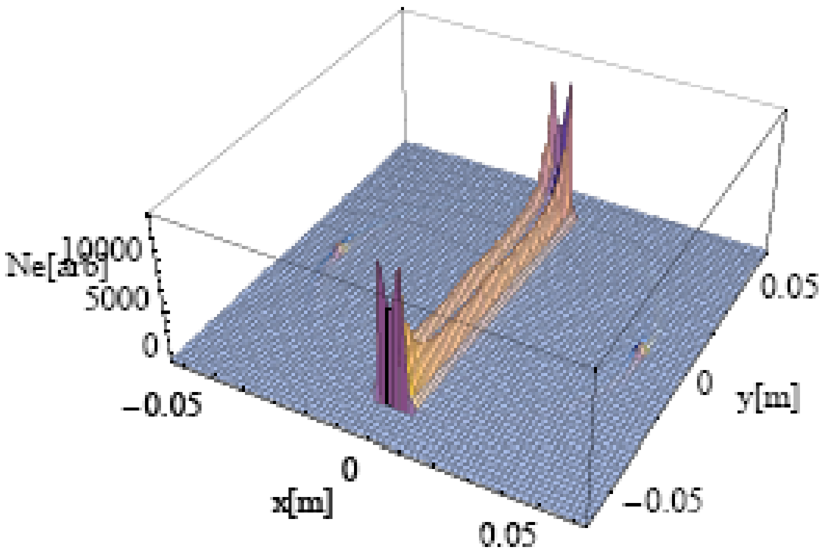
Simulation assumptions

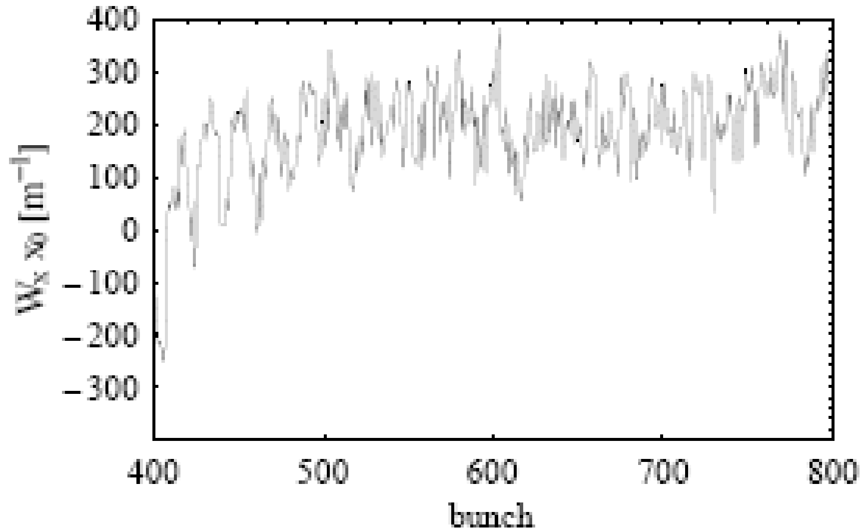
- Electron cloud uniformly distributed along the ring
- Electrons in the arcs are assumed to move in a uniform vertical magnetic field
- Circular chambers

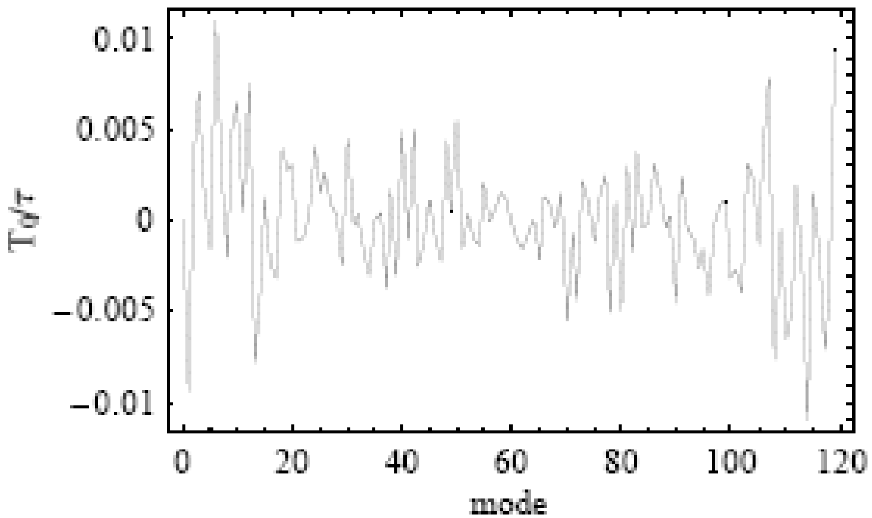
Input parameters for DAFNE simulations

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

Instability caused by electrons in the DAFNE arcs

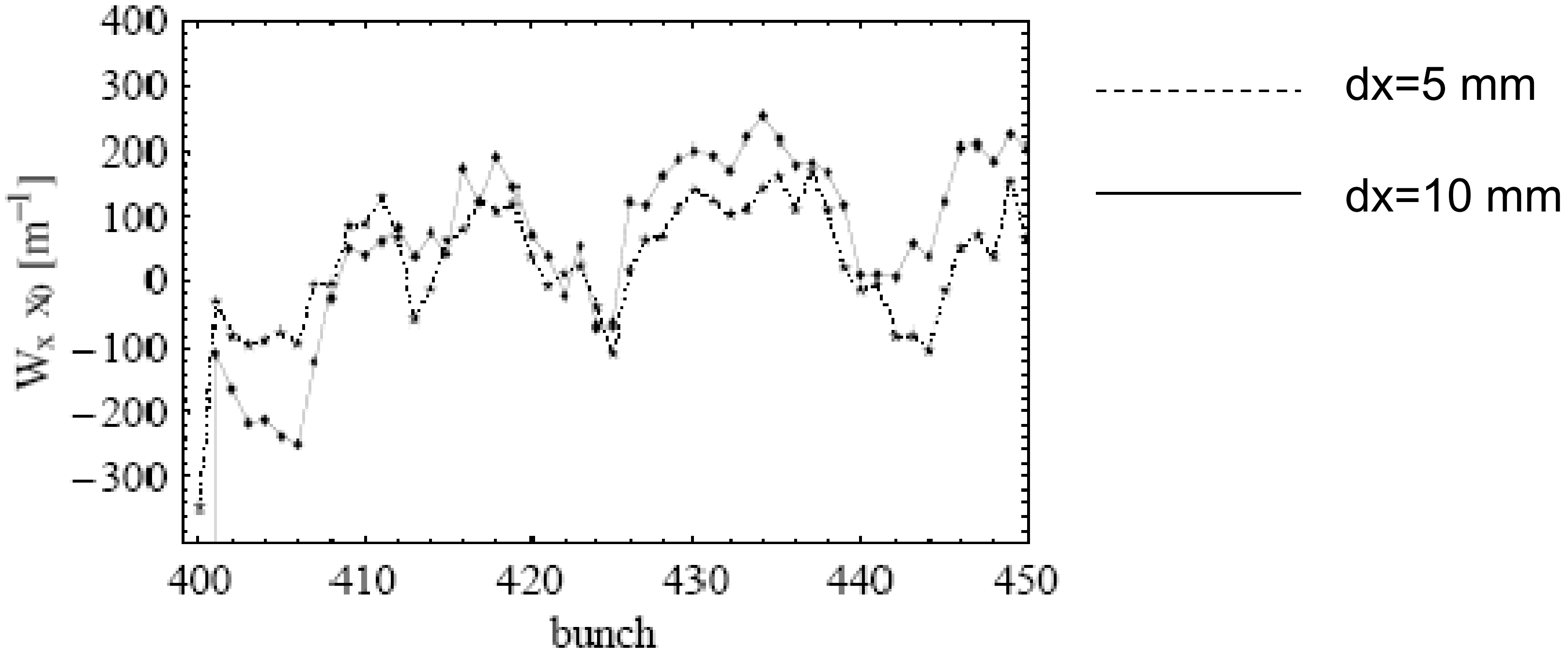






- Lsep= 0.8 m
- bunch 400 is hor. displaced (x_0=5mm)
- Electron distribution
- Wake force
- Growth rate ~ 100 turn

Wake linearity

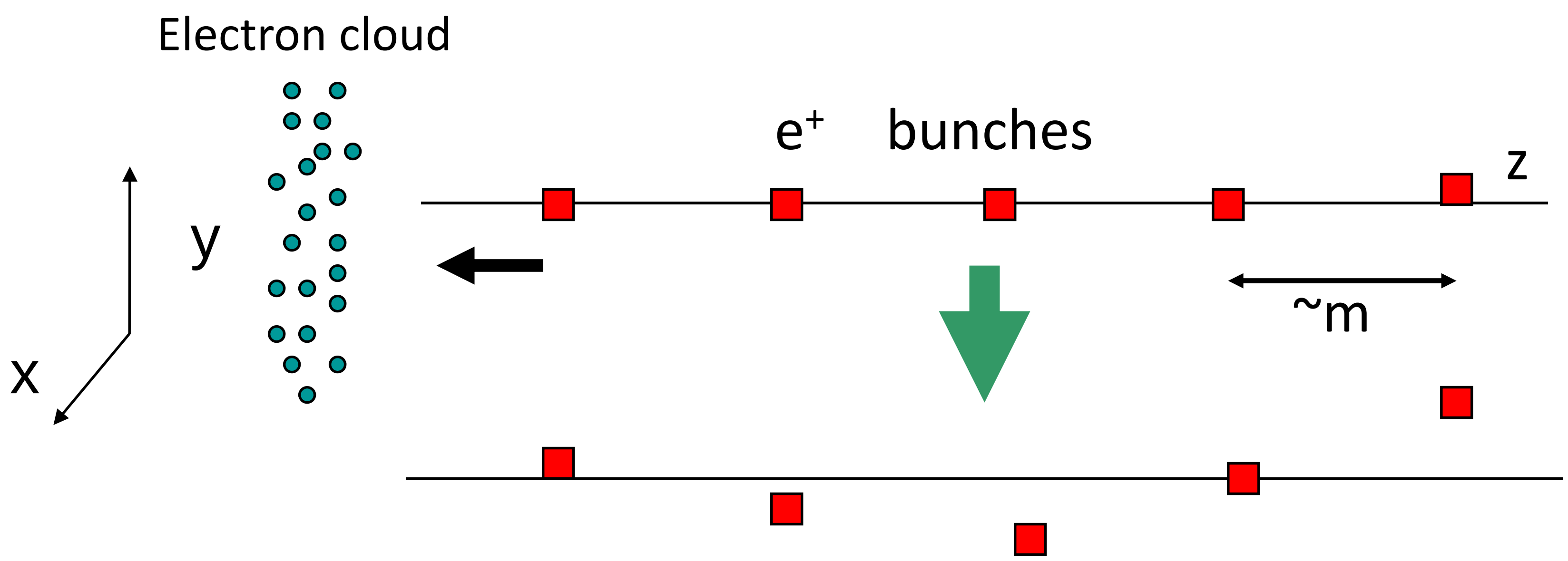


Linearity is satisfied up to no more than the 410th bunch

Tracking simulation

K.Ohmi, PRE55,7550 (1997)

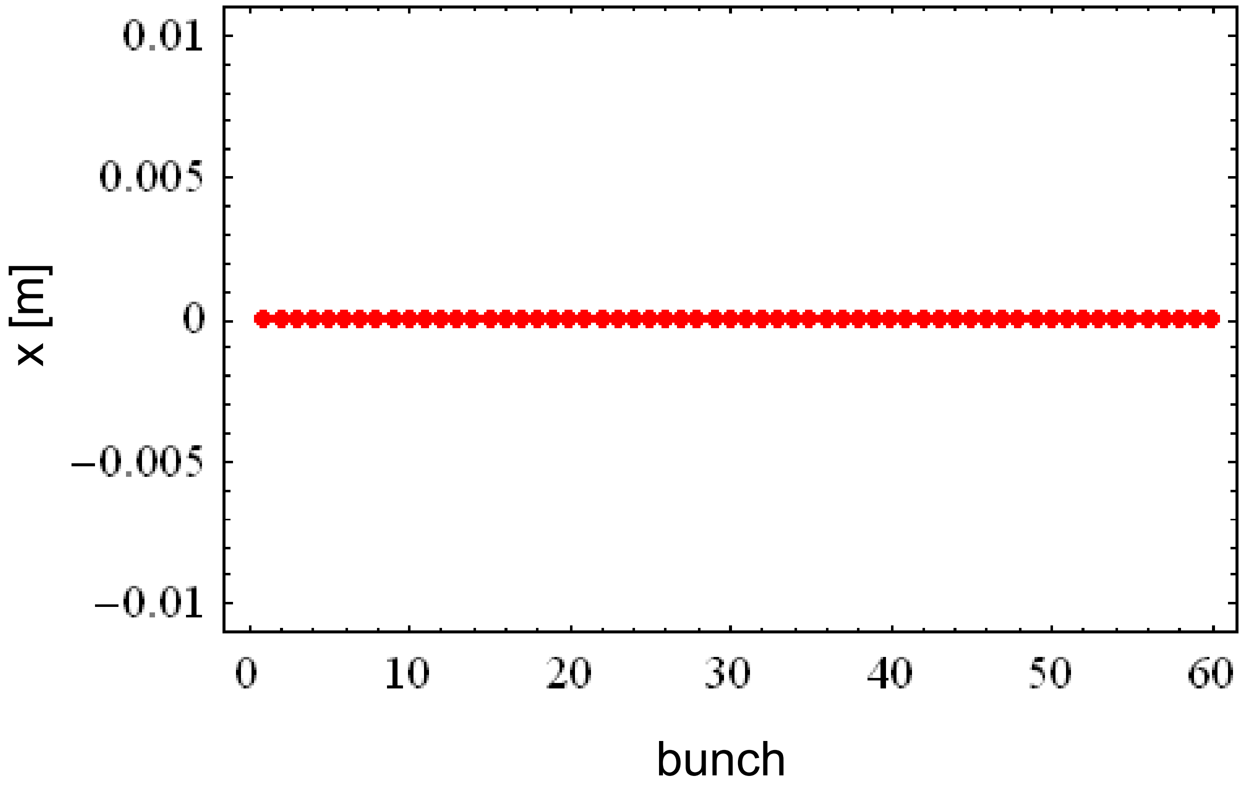
K.Ohmi, PAC97, pp1667.



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

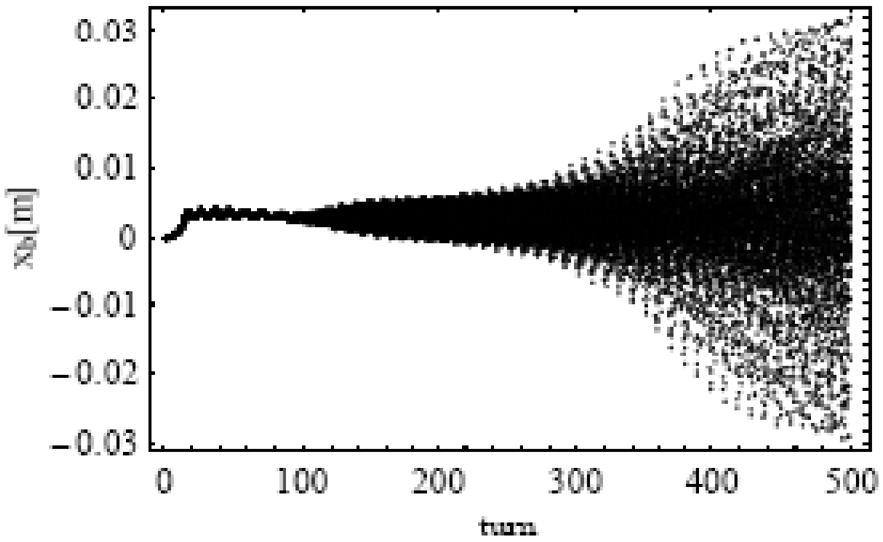
•Fourier transformation of the amplitudes gives a spectrum of the unstable mode, identified by peaks of the betatron sidebands.

Bunch train evolution



1.2 A in 60 equispaced bunches

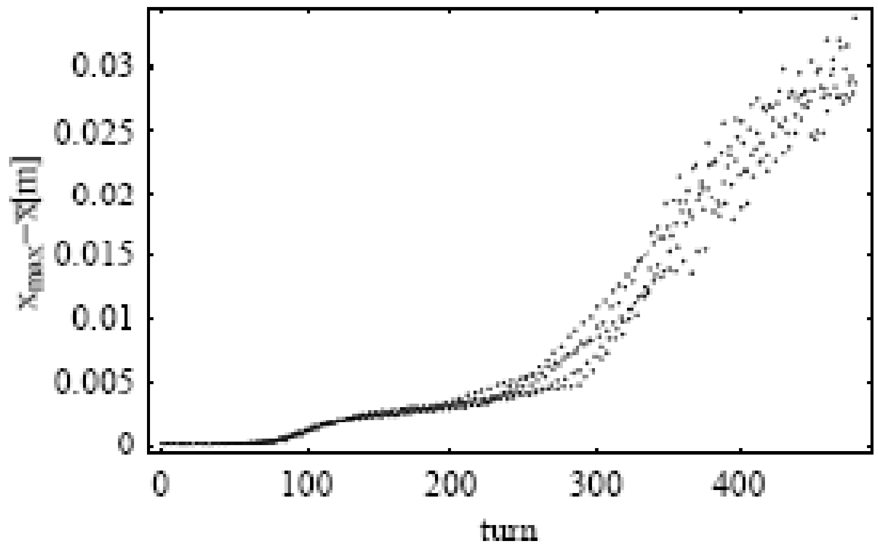
Mode spectrum and growth rate

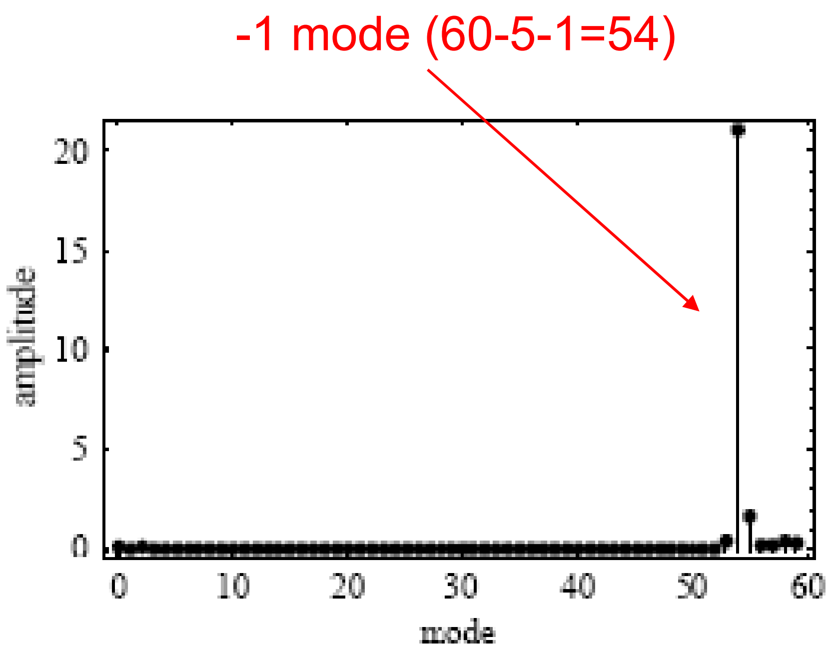


60 equispaced bunches

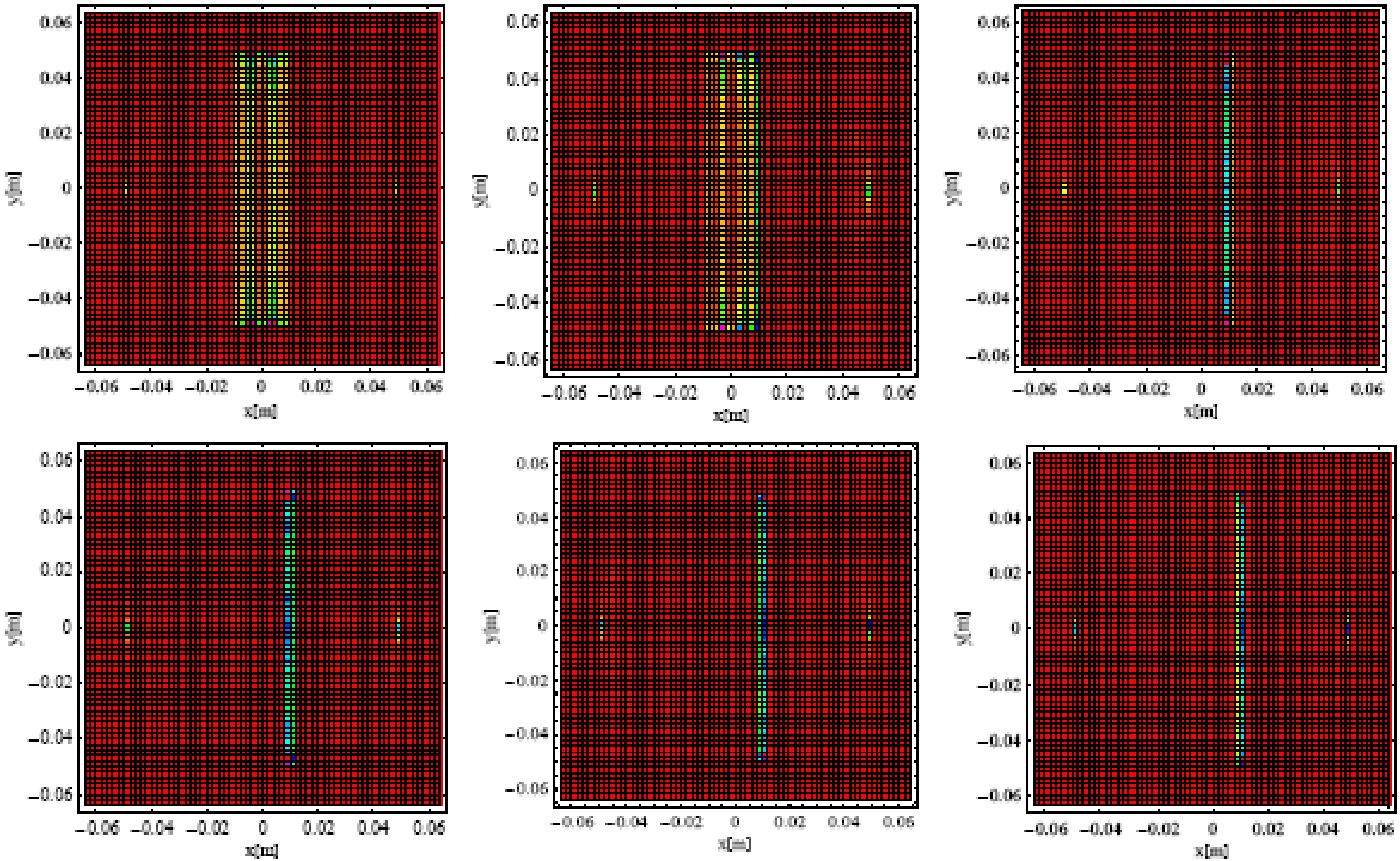
Beam current 1.2 A

Growth time ~ 100 turn

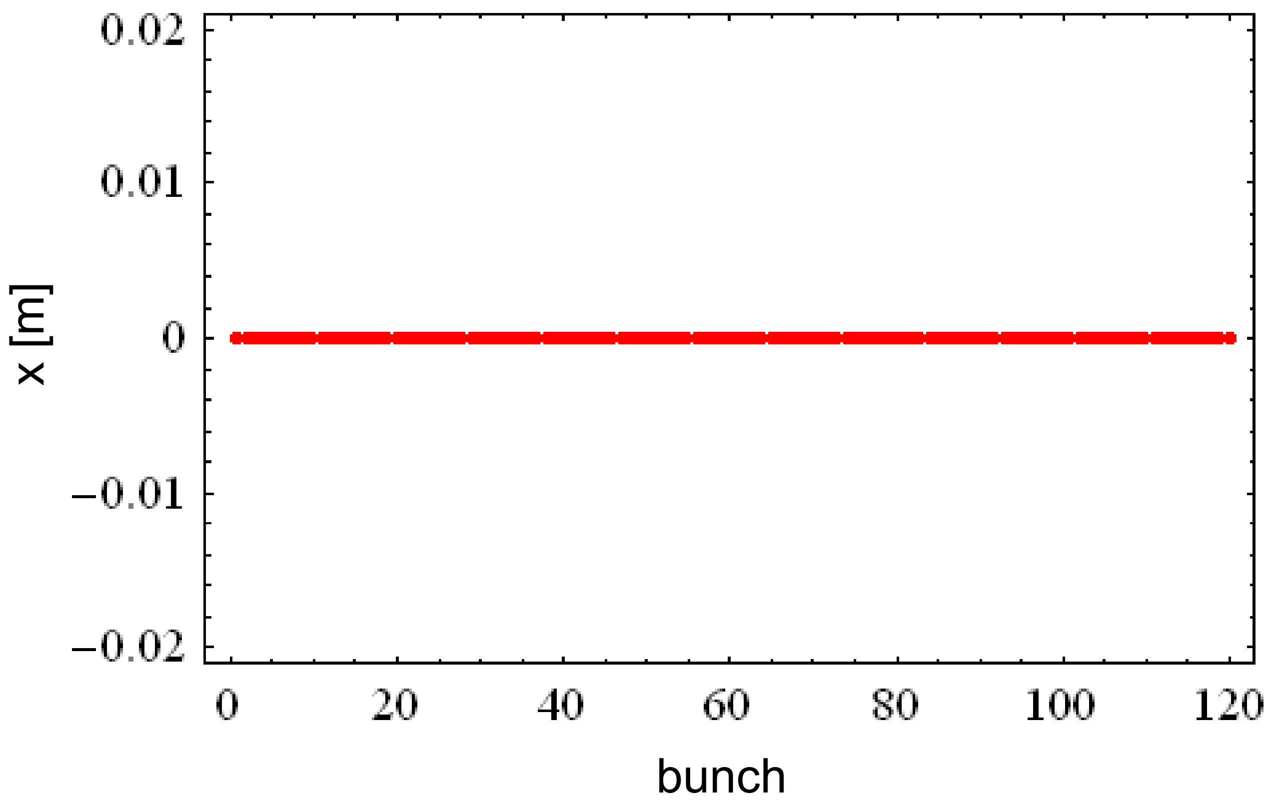




e-cloud density evolution



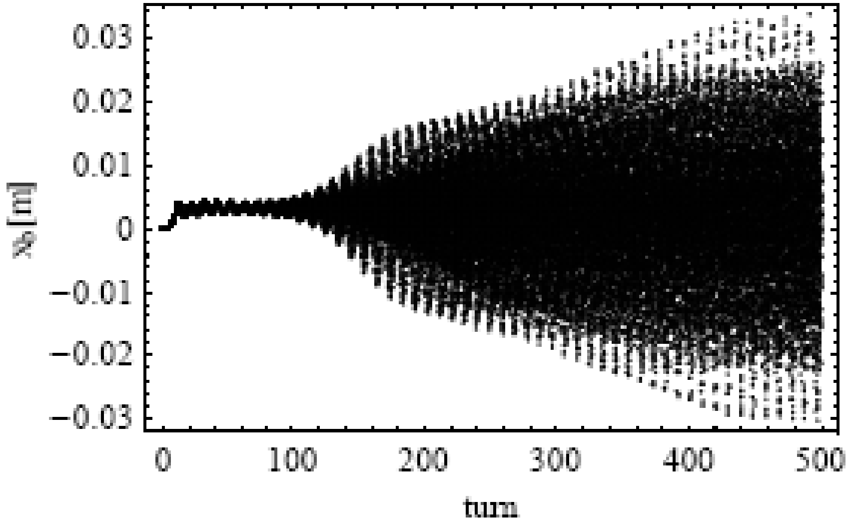
Bunch train evolution

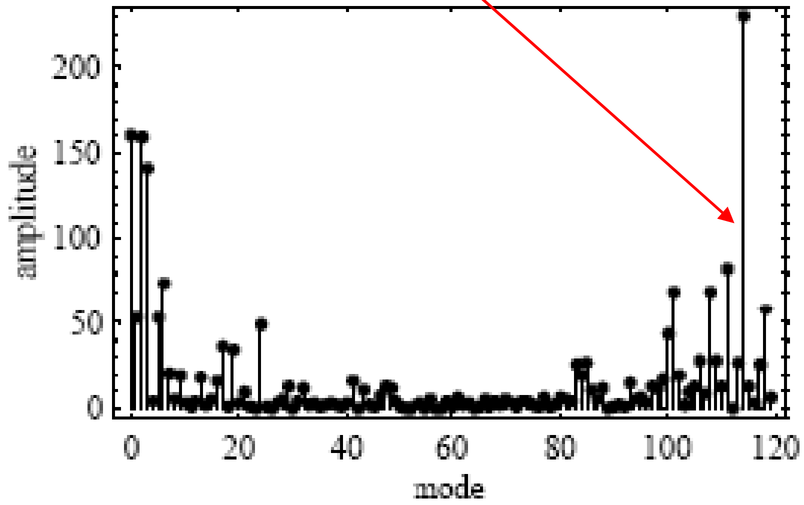


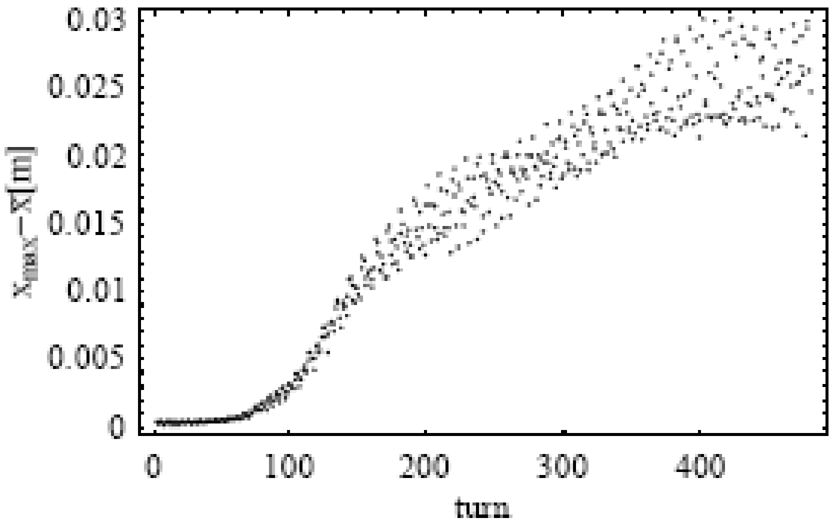
1.2 A in 120 equispaced bunches

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

Conclusions and oulook

- Coupled-bunch instability has been simulated using PEI-M for the DAFNE parameters
- Preliminary results are in qualitative agreement with grow-dump measurments
- Explore a wider range of beam and chamber parameters
- Compare the results with other codes (Ecloud, POSINST)
- Modify the code to include ellyptical boundaries