Preliminary results for electron cloud induced coupled bunch instability in DAFNE

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Thanks to K. Ohmi (KEK)

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

a) Osc. Envelopes in Time Domain

b) Evolution of Modes
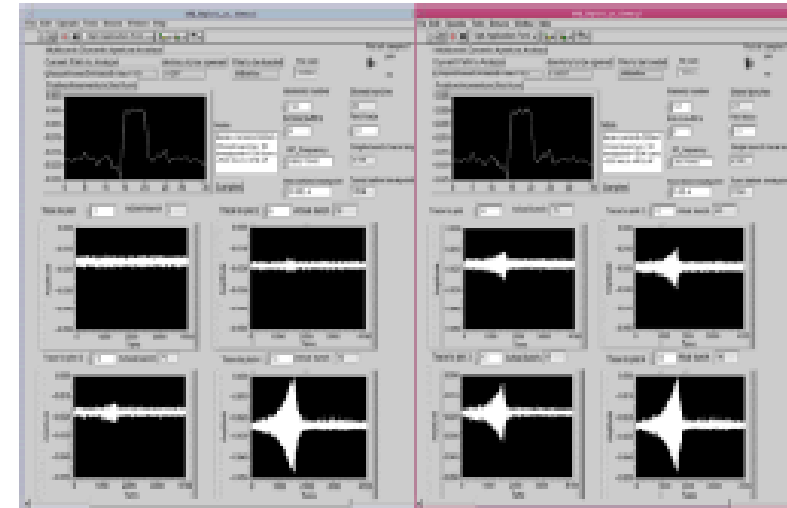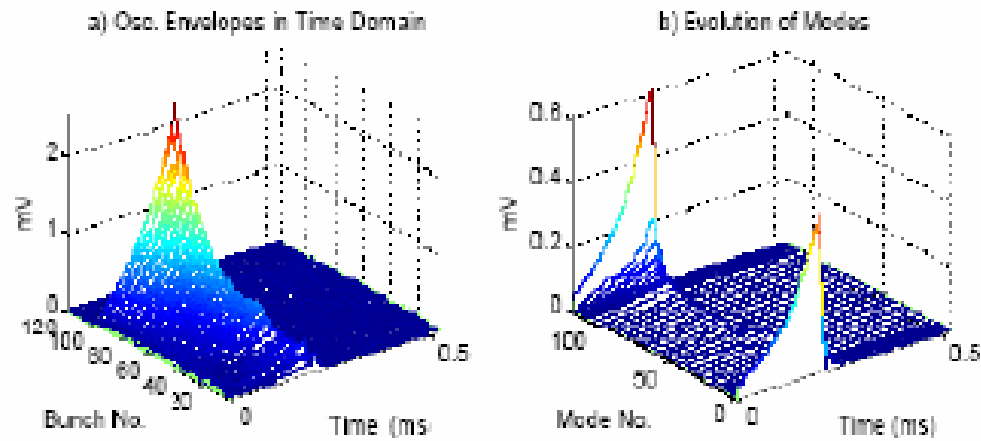
Grow-damp measurements
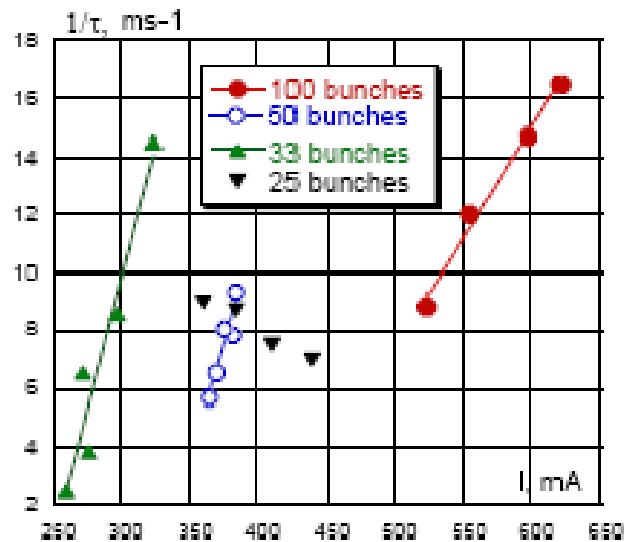
Pattern dependence

- 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:

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

Coupled bunch instability is characterized by the dispersion relation:

$$N_p = p.p.b.$$
$$\gamma = E / m_e c^2$$
$$\nu_\beta = \omega_\beta / \omega_0$$
$$M = harm.\, numb.$$

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

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.

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 $\times 10^{10}$
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
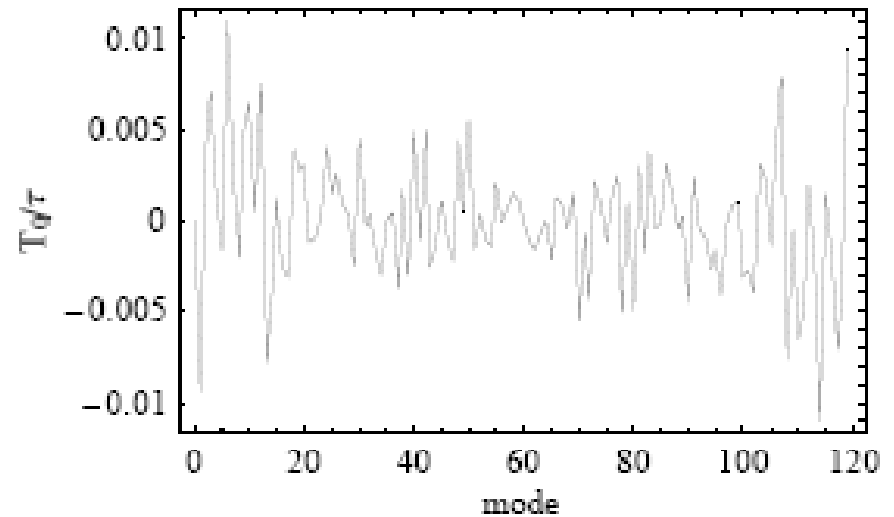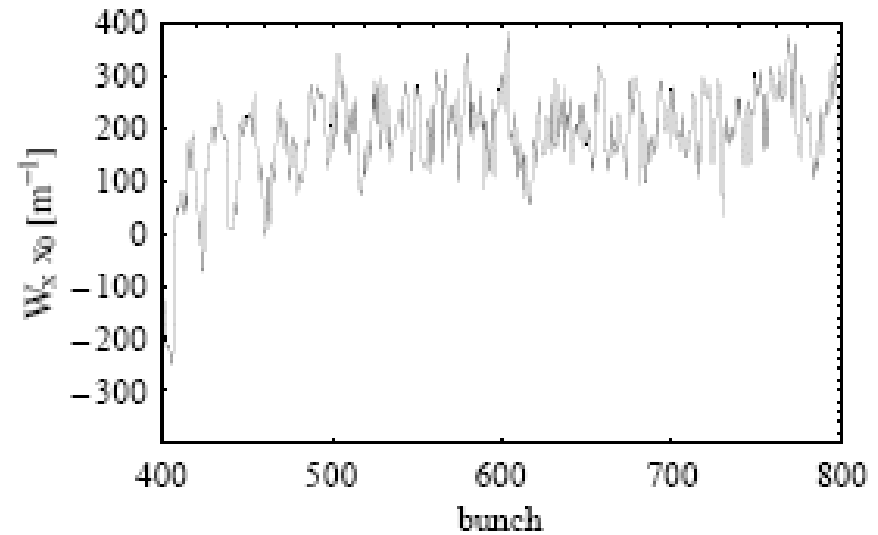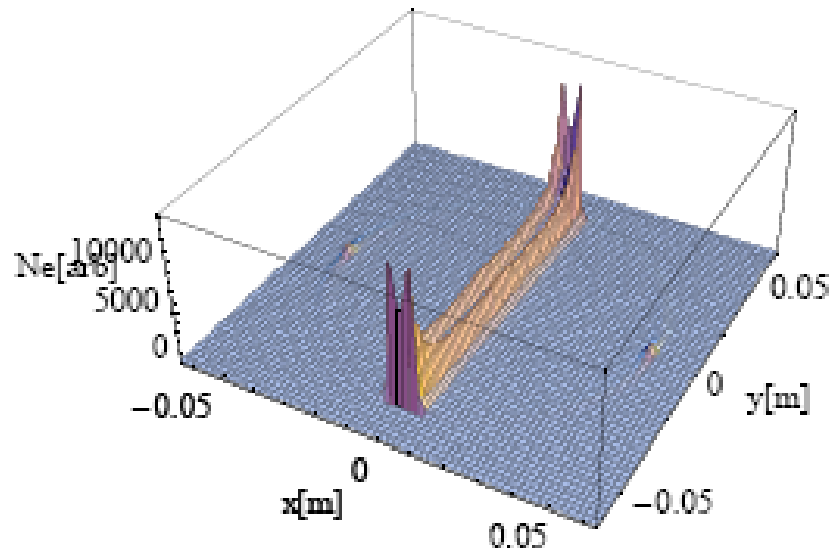
- Lsep= 0.8 m

- bunch 400 is hor. displaced (x_0=5mm)

- Electron distribution
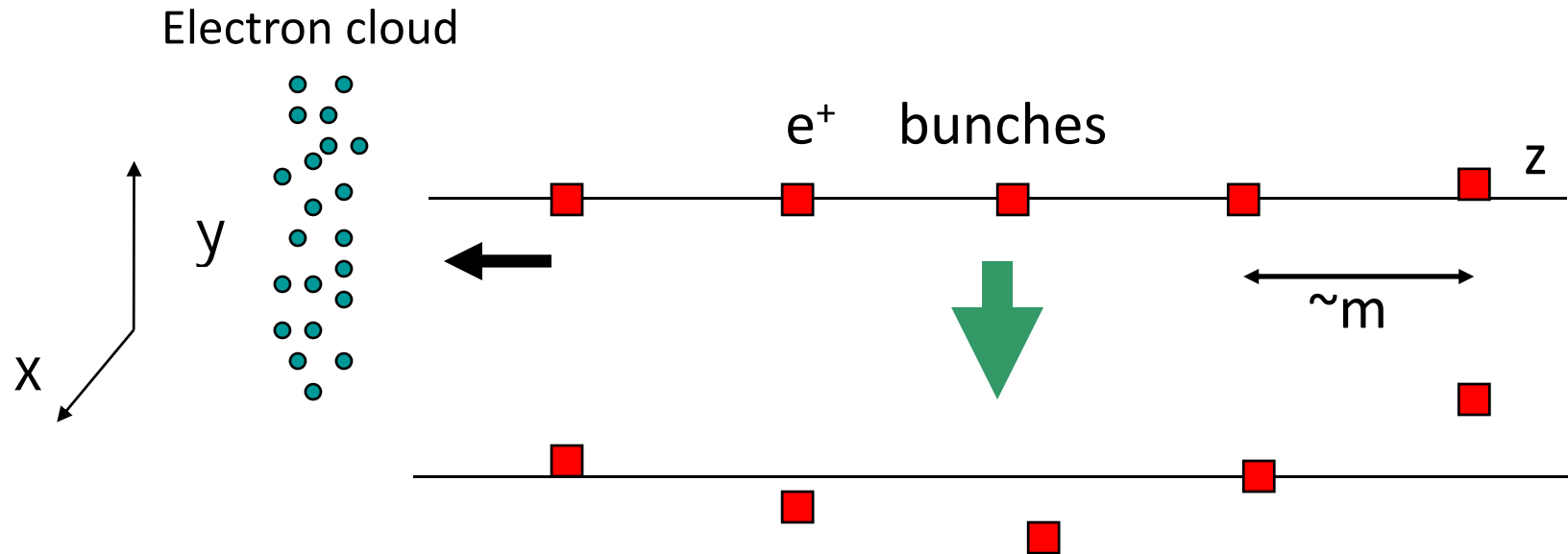
- Wake force

- Growth rate ~ 100 turn

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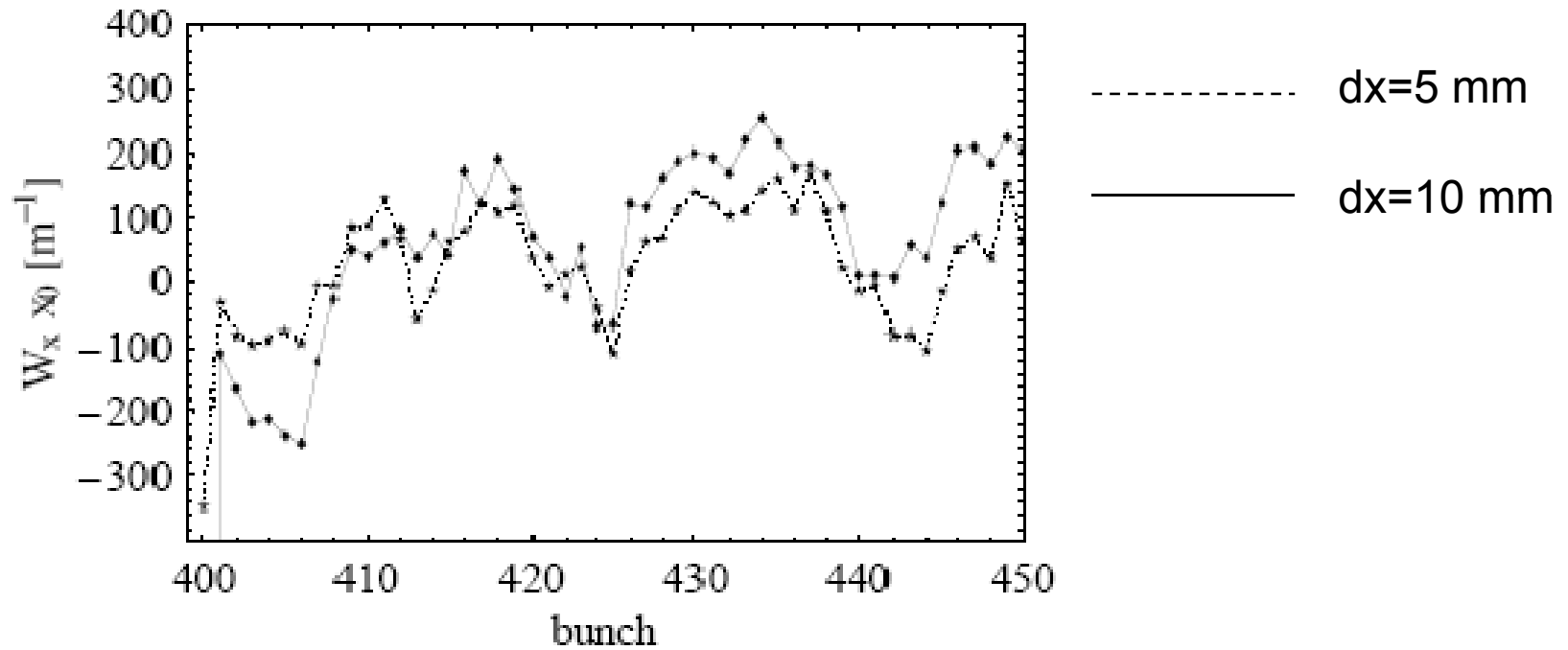
Linearity is satisfied up to no more than the 410th bunch

Tracking simulation

K.Ohmi, PRE55,7550 (1997)

K.Ohmi, PAC97, pp1667.

Electron cloud

e^+ bunches

z

y

x

~m

•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
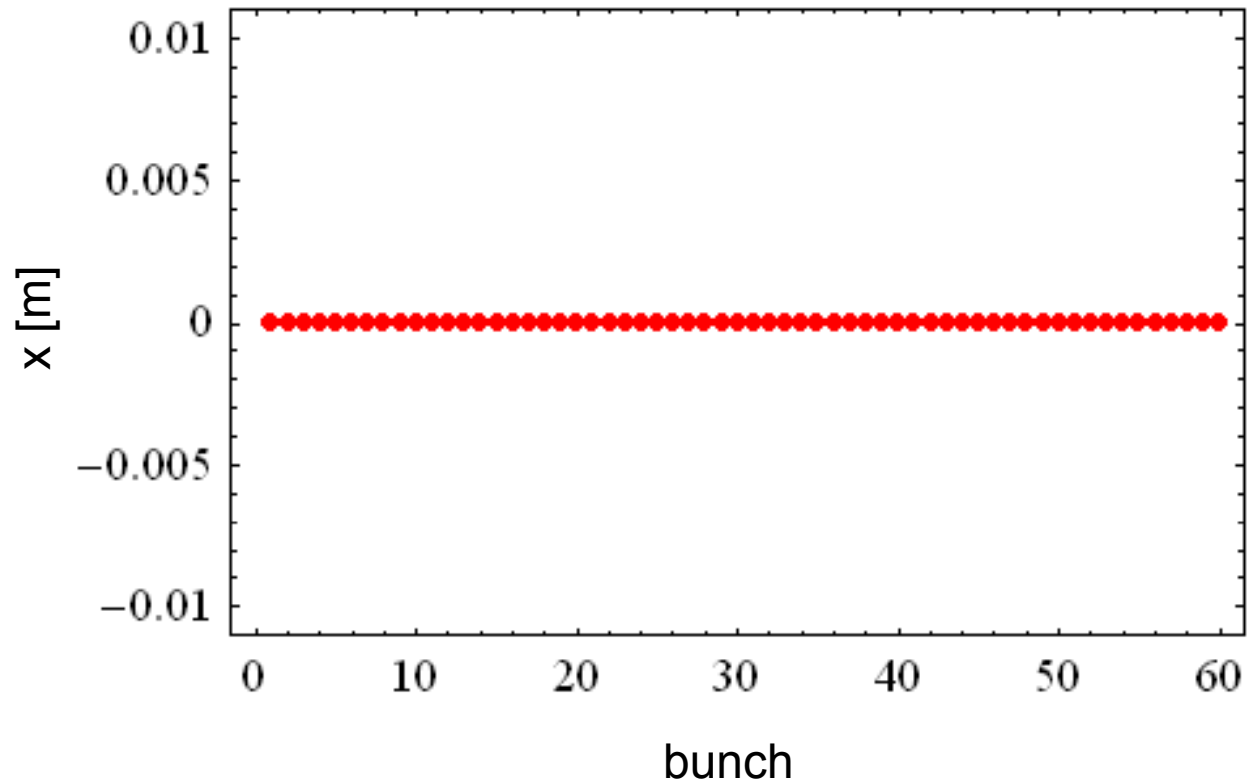
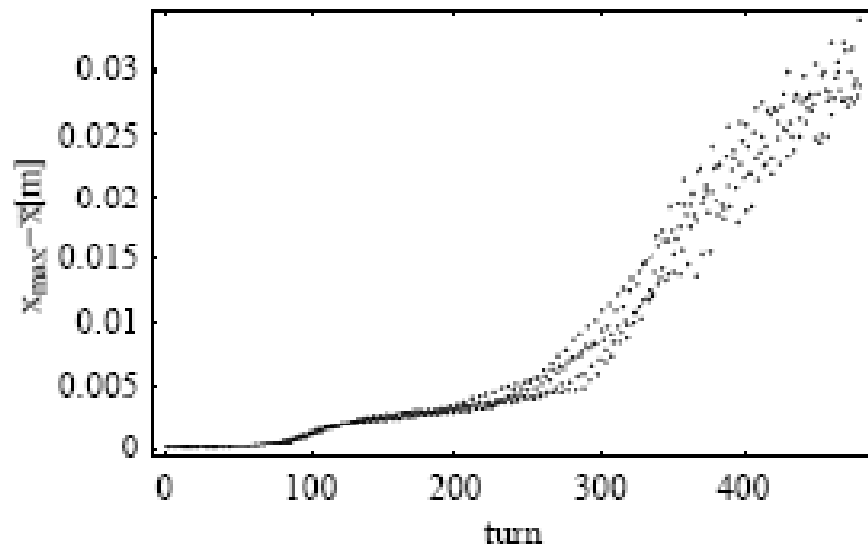1.2 A in 60 equispaced bunches

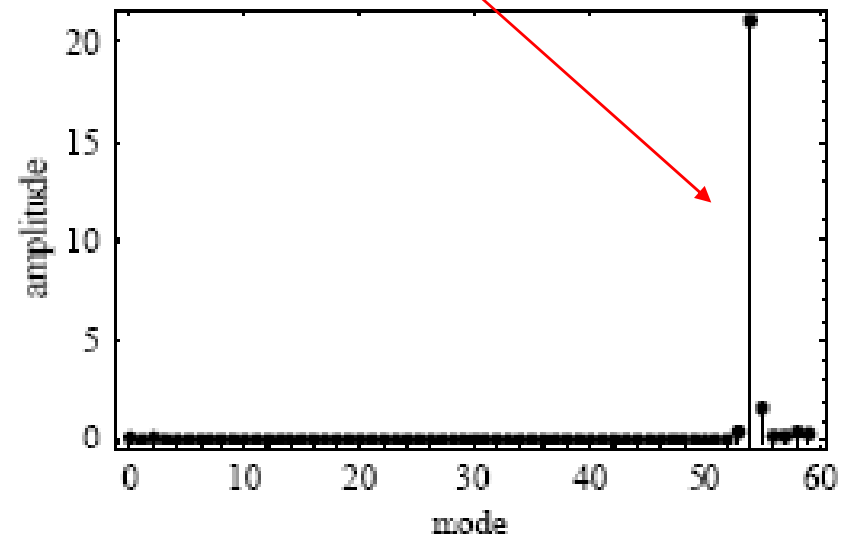# Mode spectrum and growth rate
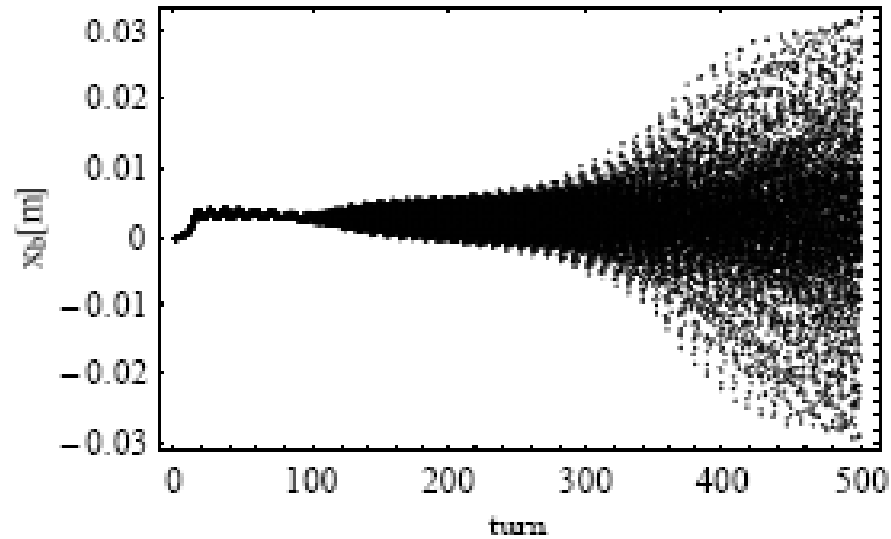
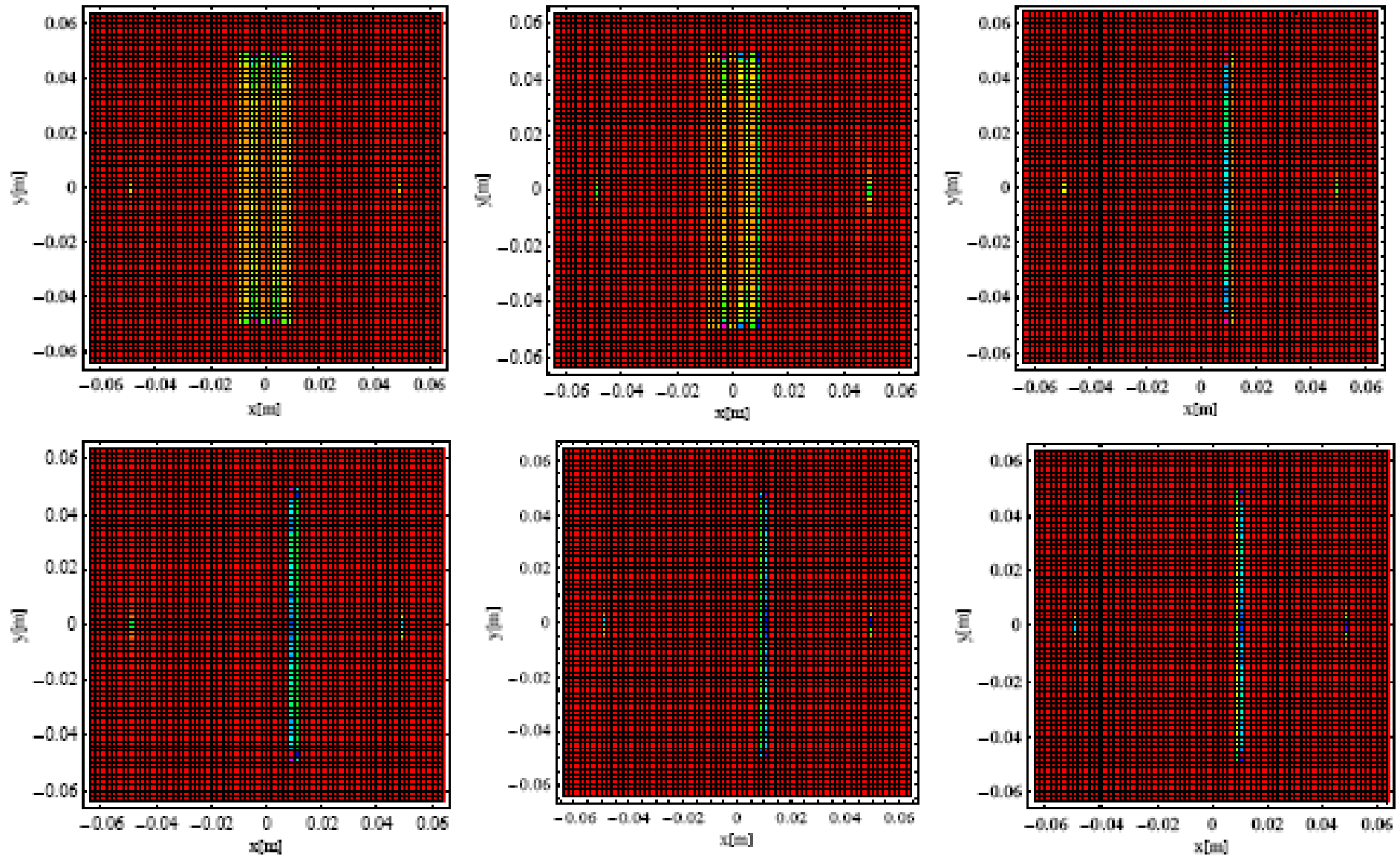60 equispaced bunches
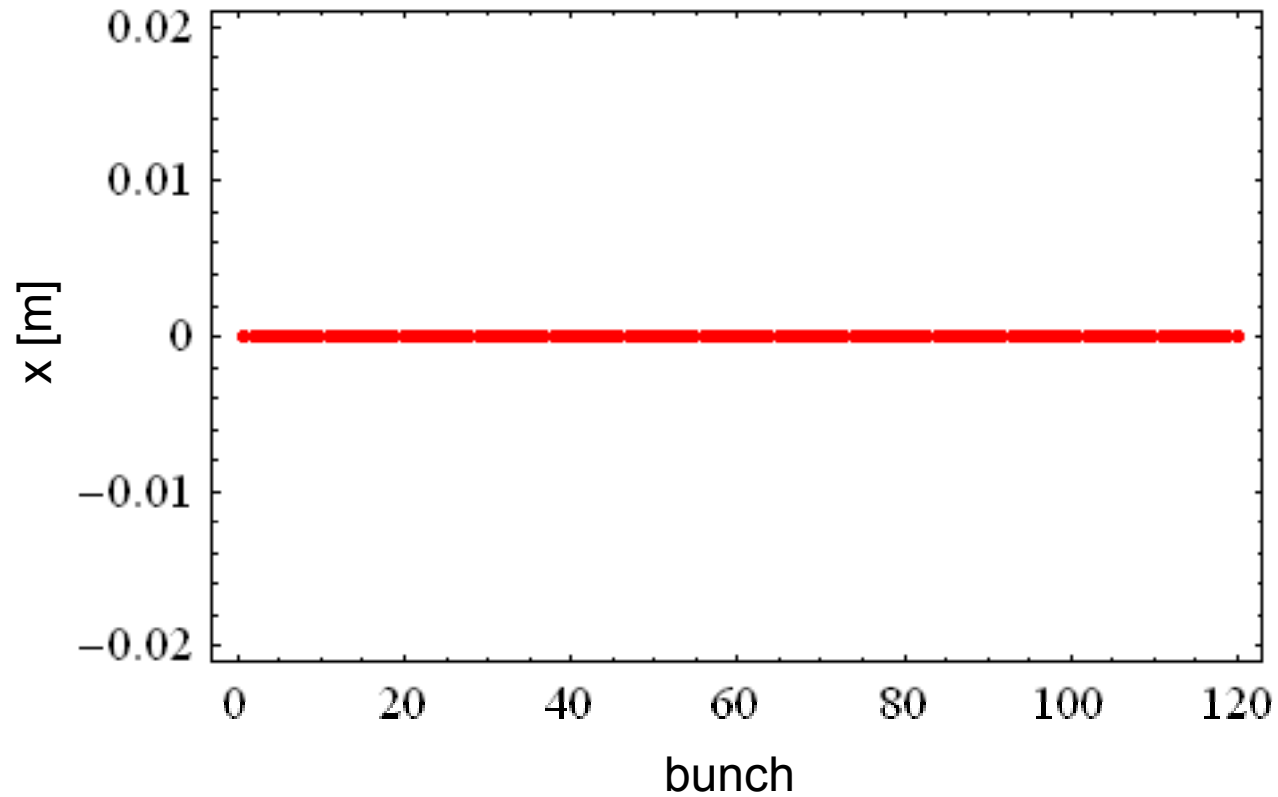
Beam current 1.2 A

Growth time ~ 100 turn

-1 mode (60-5-1=54)
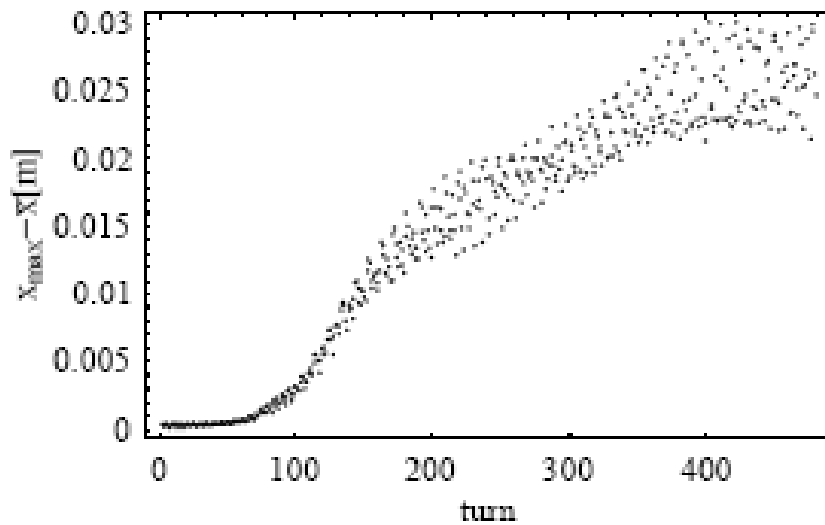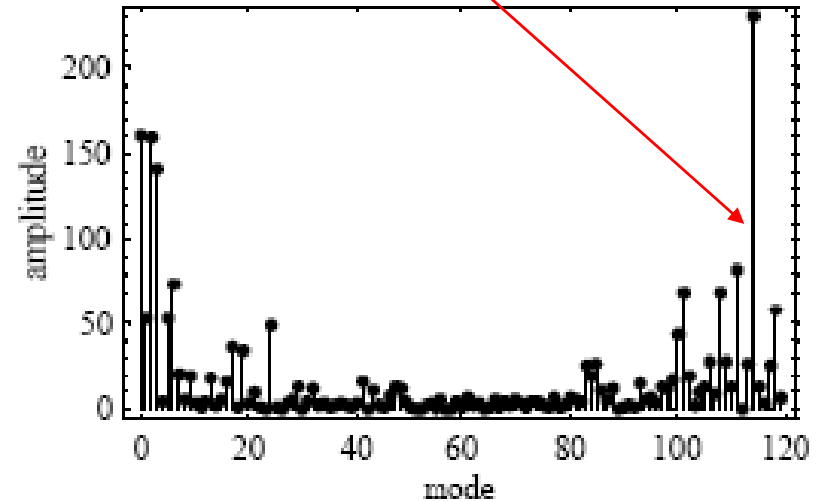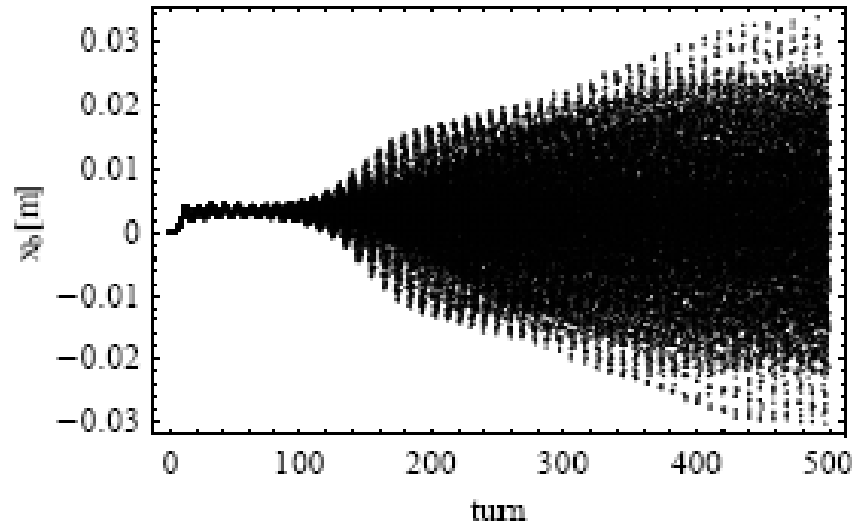
e-cloud density evolution

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