The Electron-Cloud Instability in the SPS

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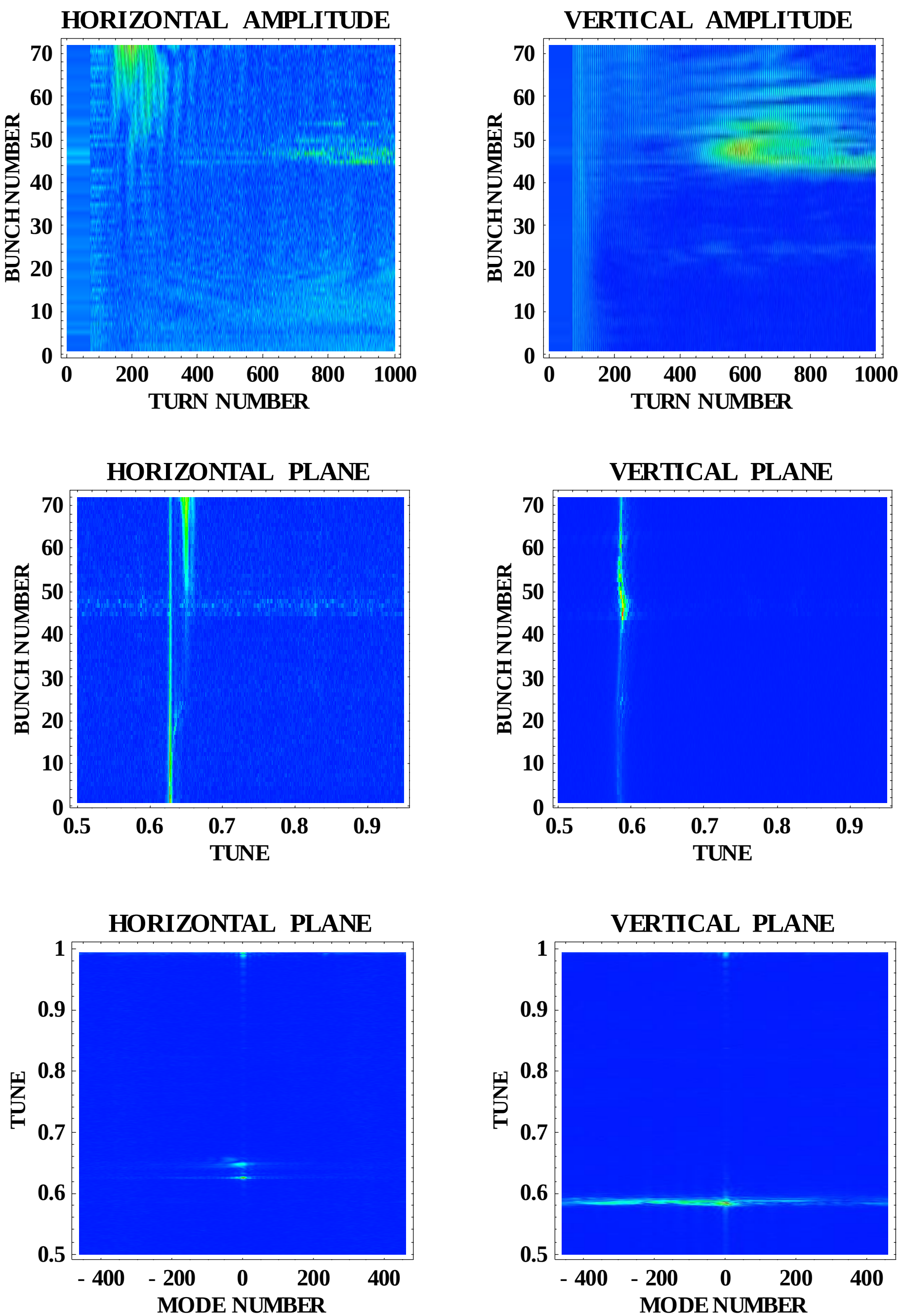
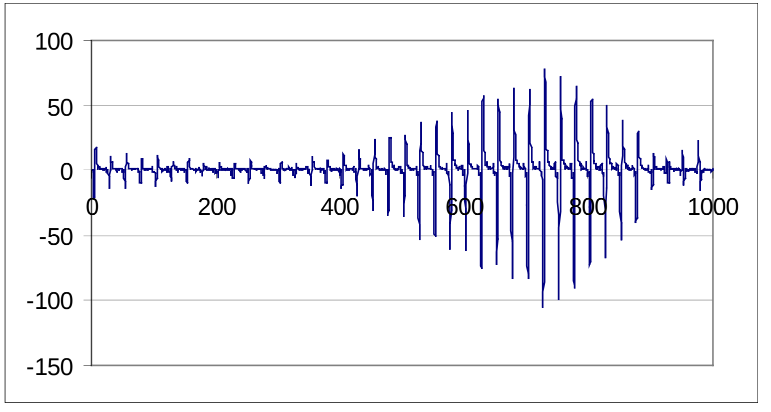
G. Arduini, F. Zimmermann, G. Rumolo, R. Jones, L. Jensen.

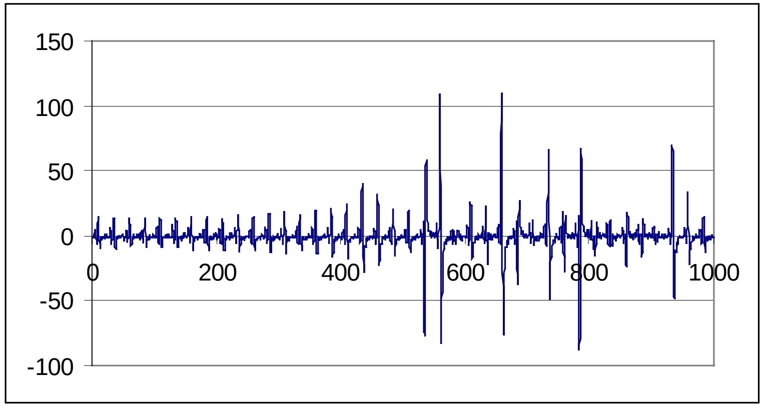
72.784, 745.769



The instability



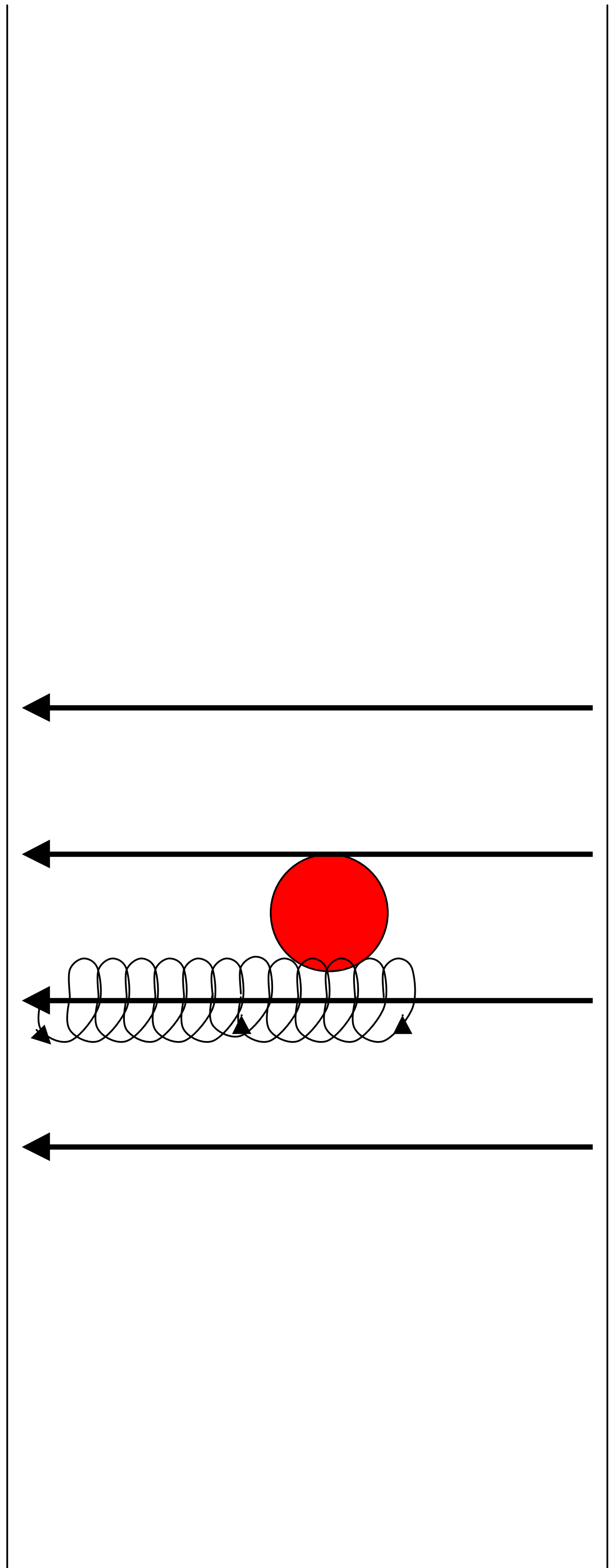
Snapshot of the horizontal instability



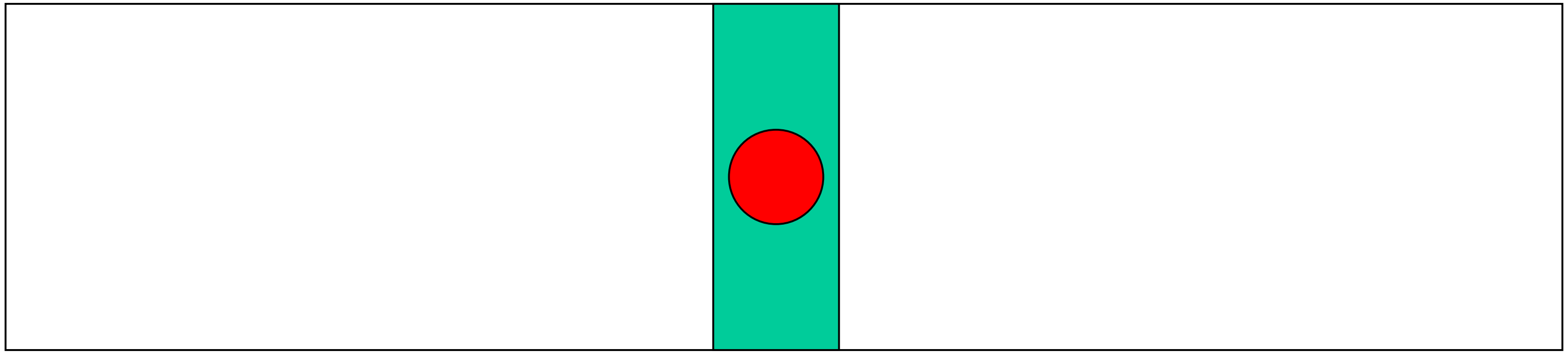
Snapshot of the vertical instability

Sumarising

- In the Horizontal plane the e-cloud provokes a fast growing coupled bunch instability of low order. Growth rate is ~50turn. Does not change much with intensity.
- In the vertical plane the instability looks like single bunch instability.Growth rate : ~500 turns just above threshold going to ~100 turns at two times the threshold.



How to understand this ?



In the SPS the electron cloud is created in the dipoles. It has the shape of a vertical ribbon. The horizontal density distribution depends on the bunch intensity, the bunch size and the magnetic field

A simple description of coupled Bunch motion

$$\frac{d^2}{dt^2}X_1 + \omega^2 \cdot X_1 := 0$$

.....

$$\frac{d^2}{dt^2}X_n + \omega^2 \cdot X_n := 0$$

$$\frac{d^2}{dt^2}X_{n+1} + \omega^2 \cdot X_{n+1} := k \cdot \left(X_{n+1} - X_n\right)$$

....

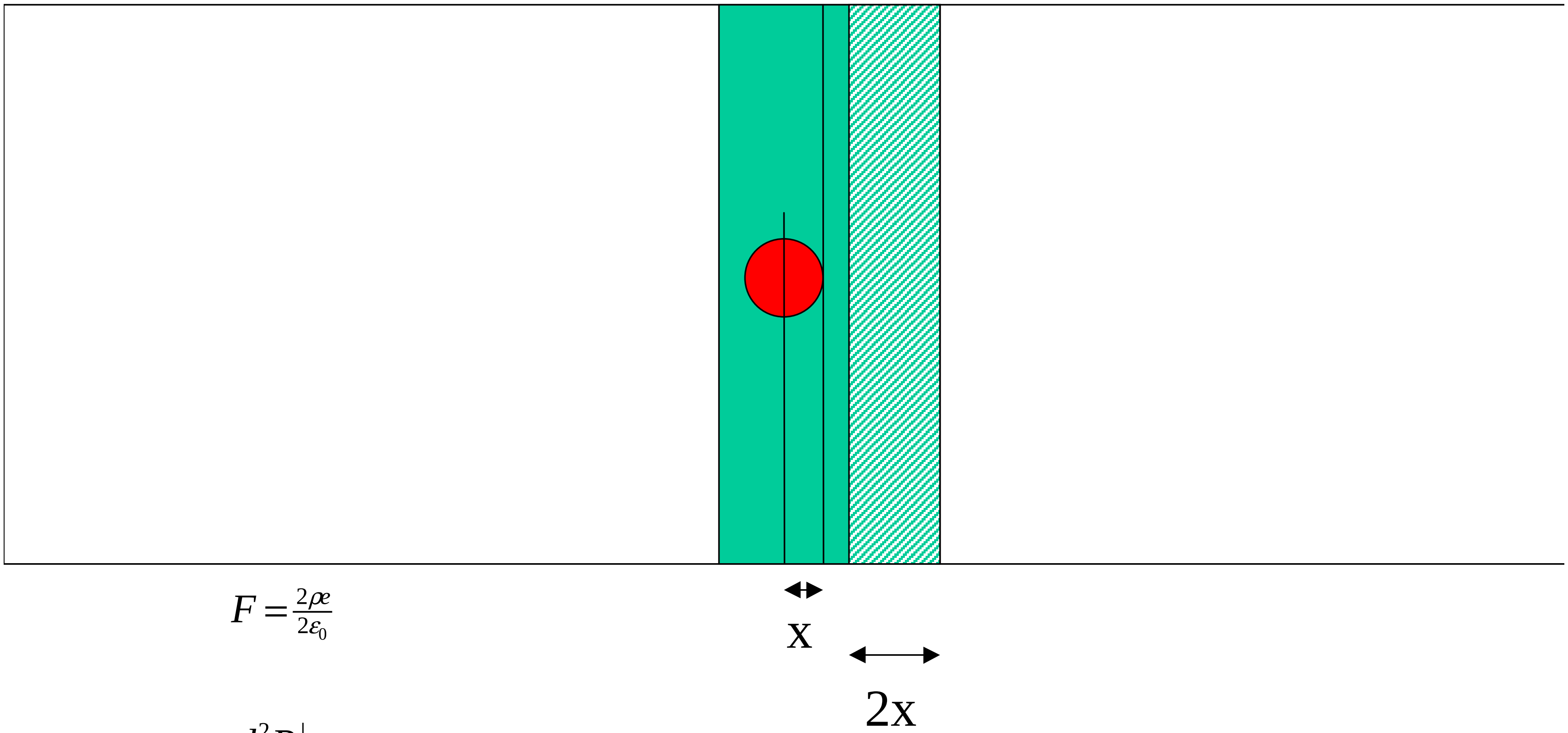
$$\frac{d^2}{dt^2}X_{72} + \omega^2 \cdot X_{72} := k \cdot \left(X_{72} - X_{71}\right)$$

TWO Eigen frequencies :

$$0 := \left(\omega^2 - k - \Omega^2\right)^{72-n} \cdot \left(\omega^2 - \Omega^2\right)^{72-n}$$

$$\Omega^2 := \omega^2$$

$$\Omega^2 := \omega^2 - k$$



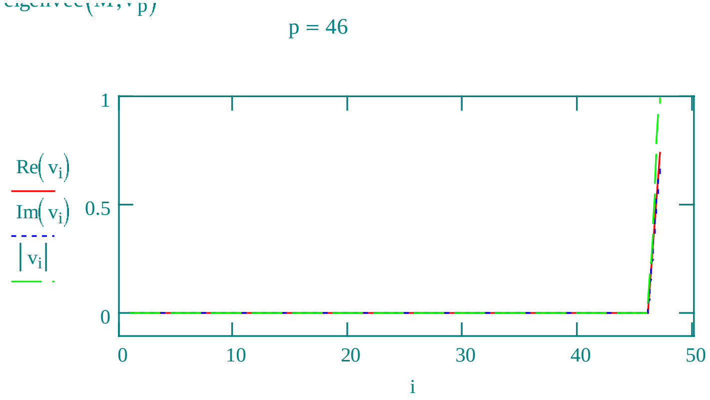
$$F = \frac{2\rho e}{2\varepsilon_0}$$

$$\frac{\frac{d^2 P^{\perp}}{dxds}}{P^L} = \frac{\rho e}{\varepsilon_0 c P}$$

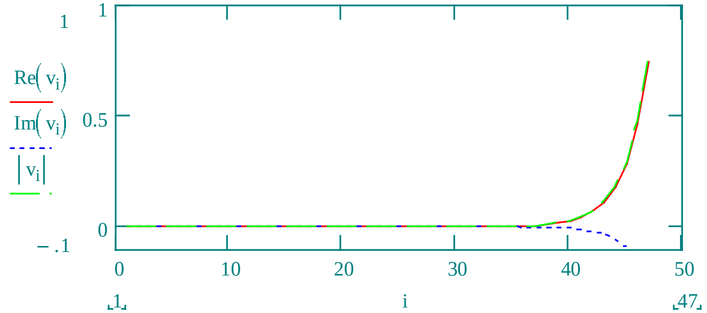
$$dQ = \frac{\rho \langle \beta \rangle L}{\varepsilon_0 26.10^9}$$

eigenvectors

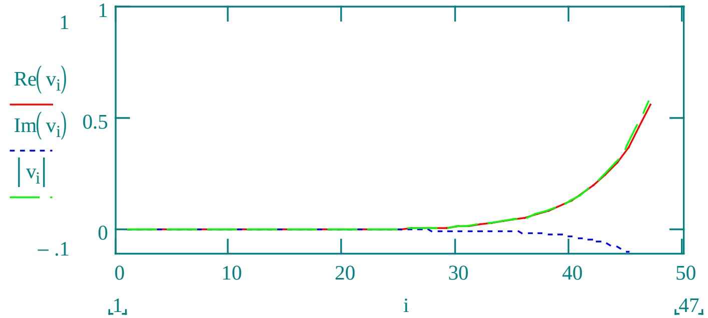
N=1



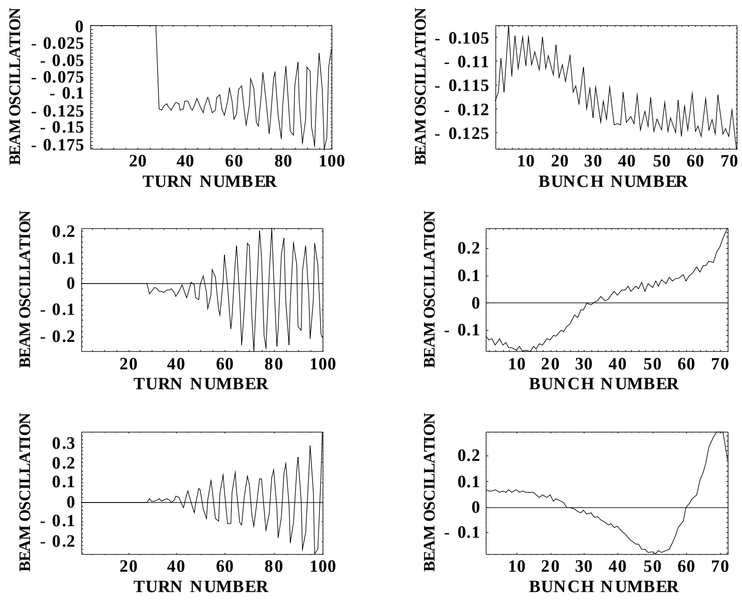
N=2



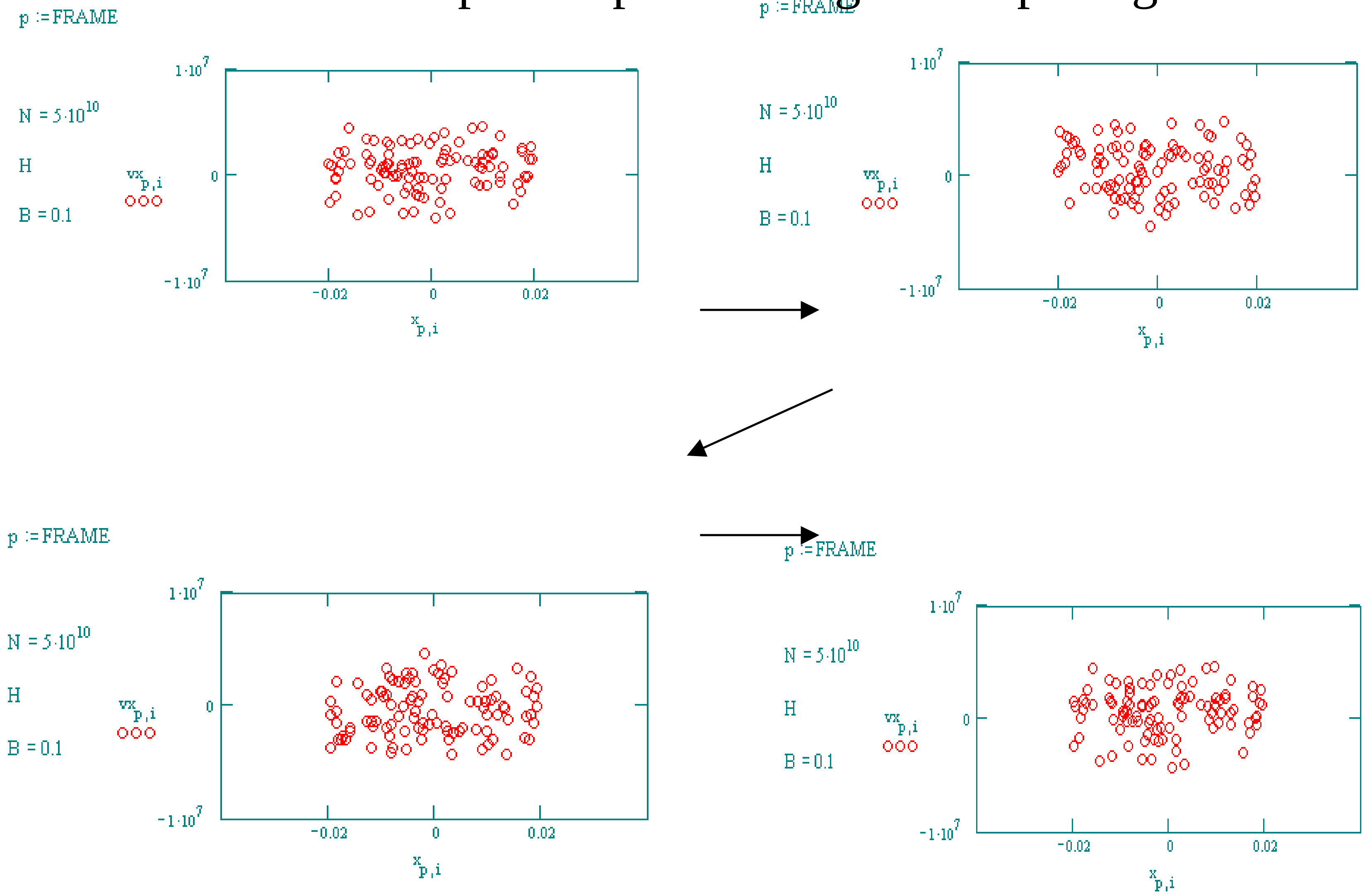
N=3



HORIZONTAL PLANE

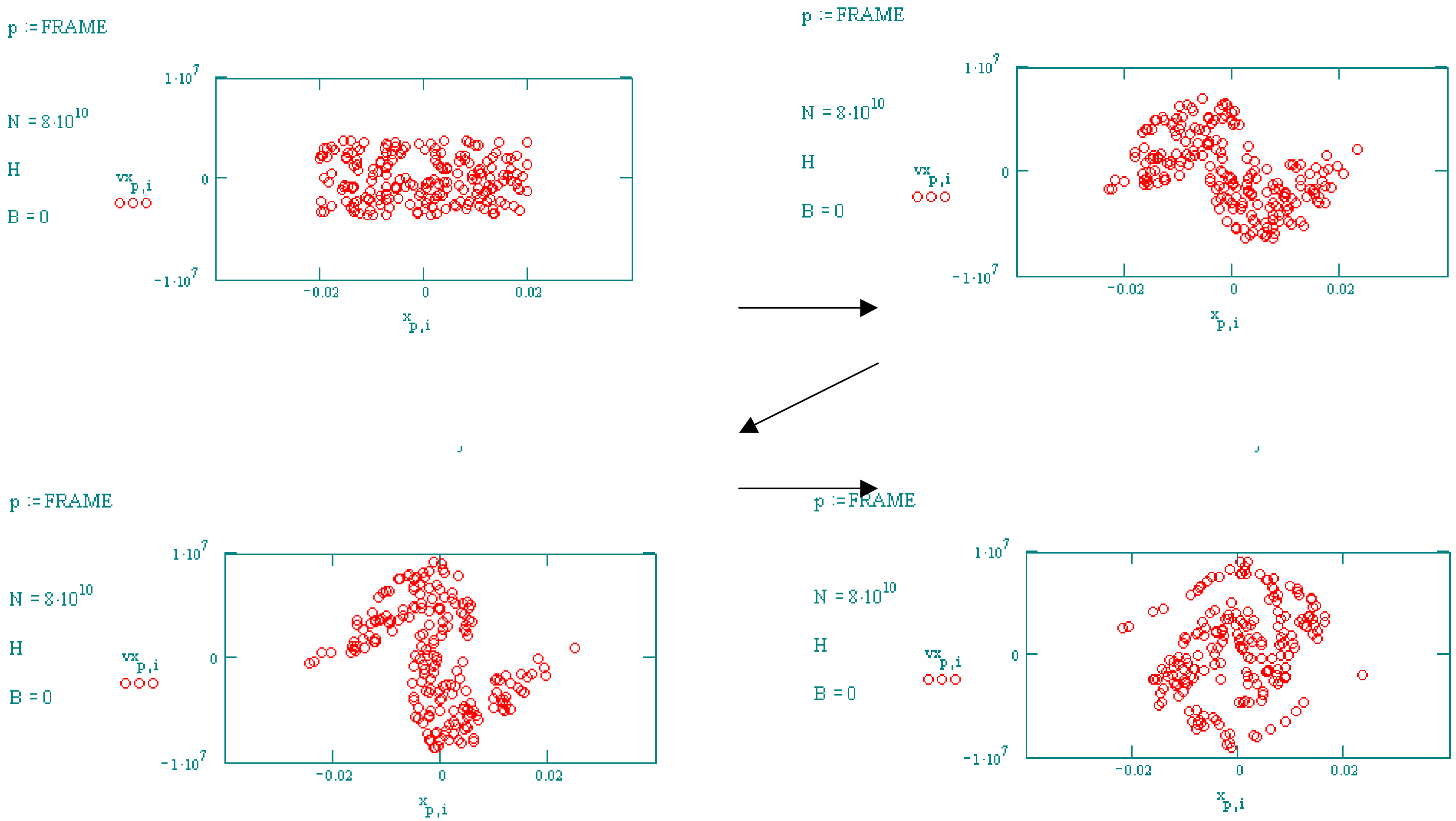


Electron phase space during bunch passage



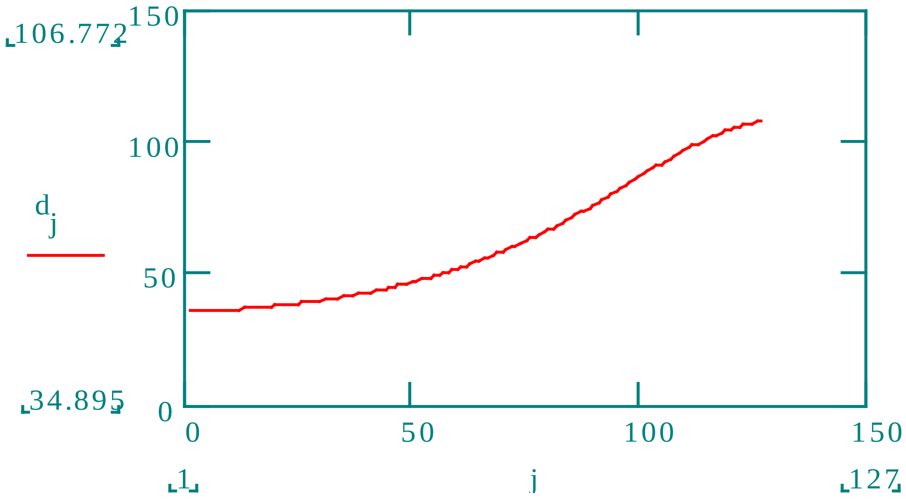
HORIZONTAL PLANE

Electron phase space during bunch passage

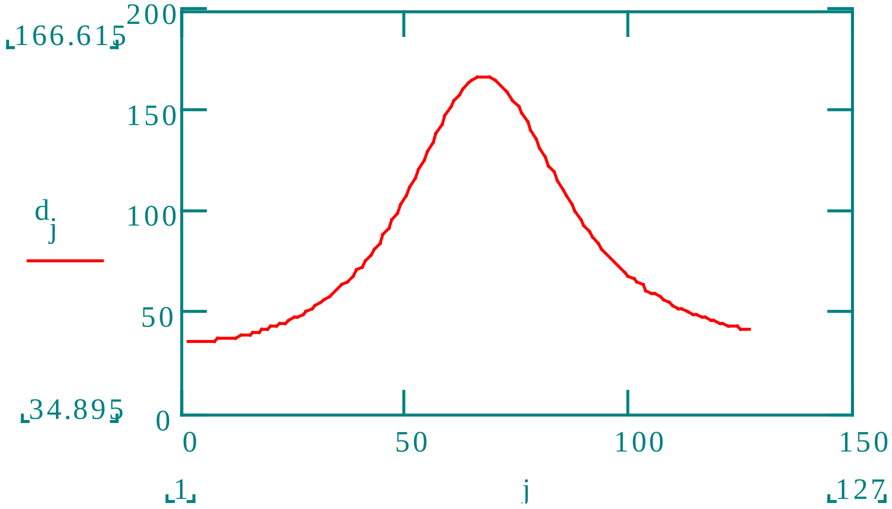


VERTICAL PLANE

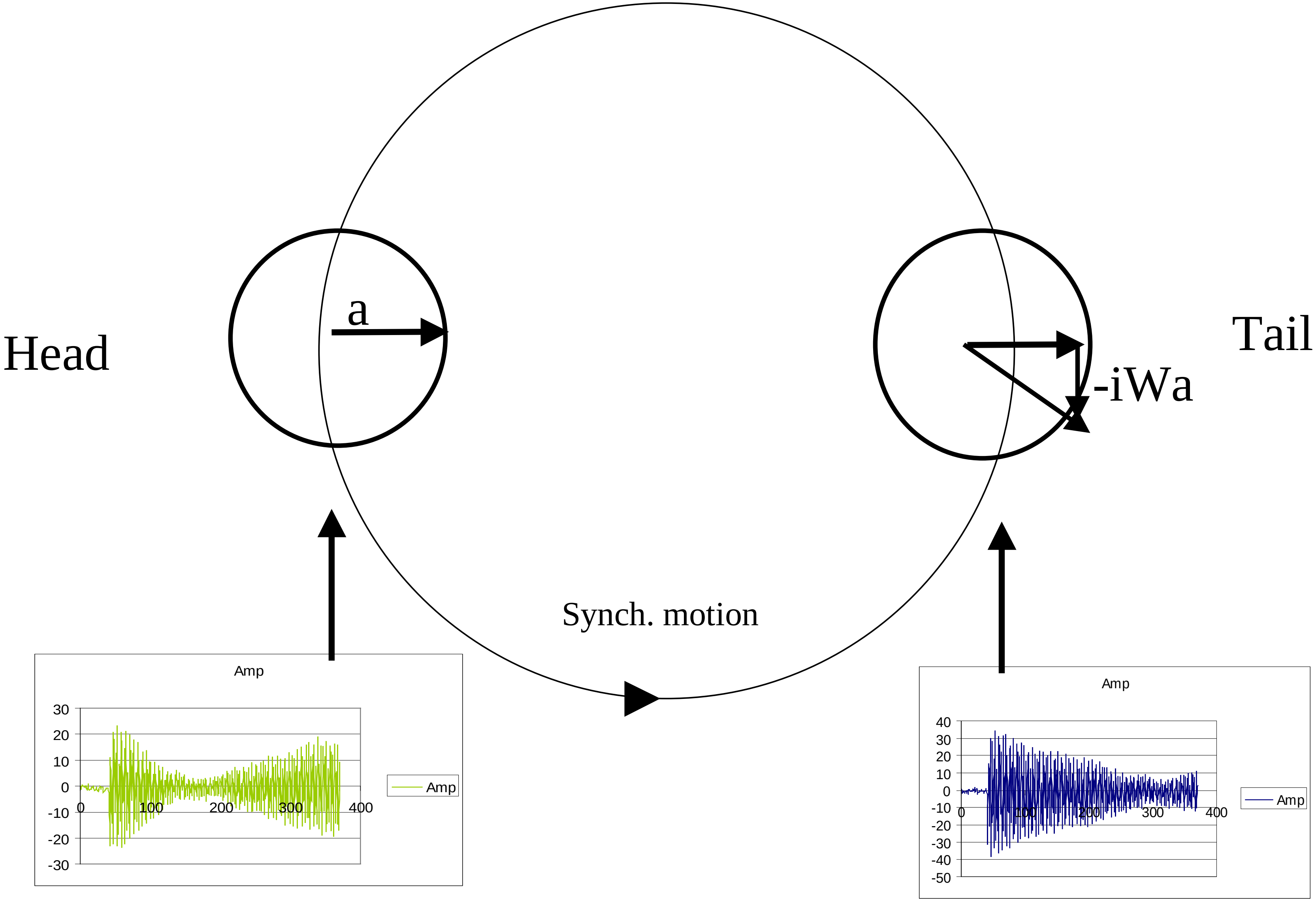
$2.5\ 10^{10}$



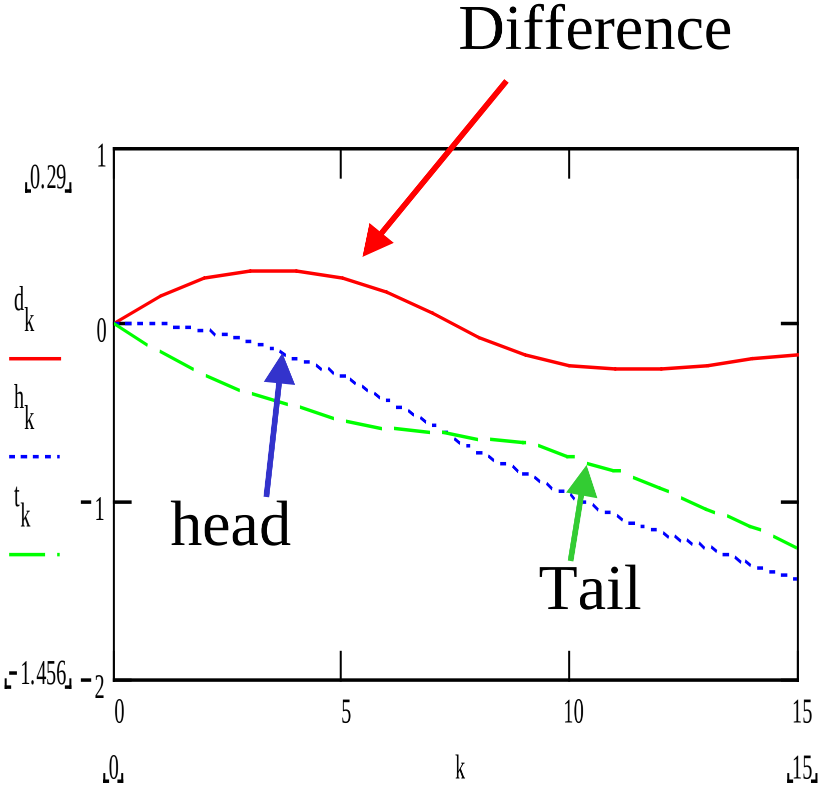
$8\ 10^{10}$



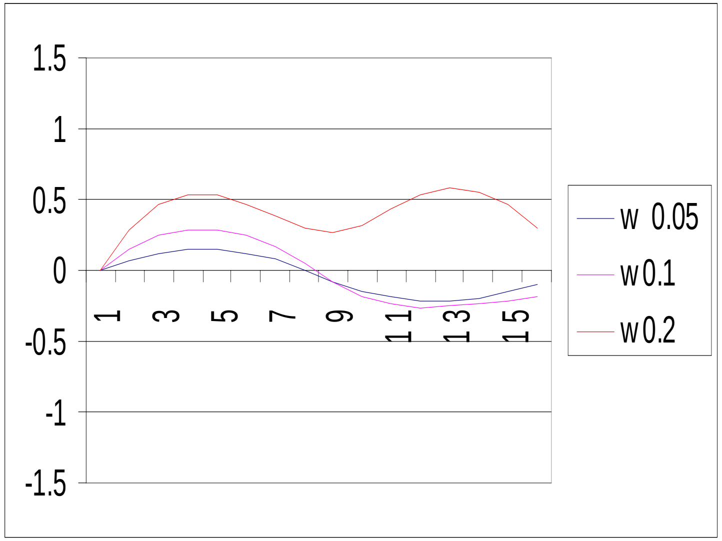
Phase difference due to impedance



Phase advance and Impedance

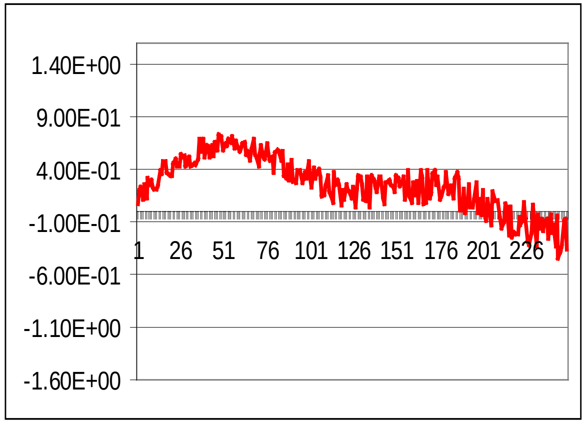


Phase advance of head and tail after kick over 1 synchrotron period

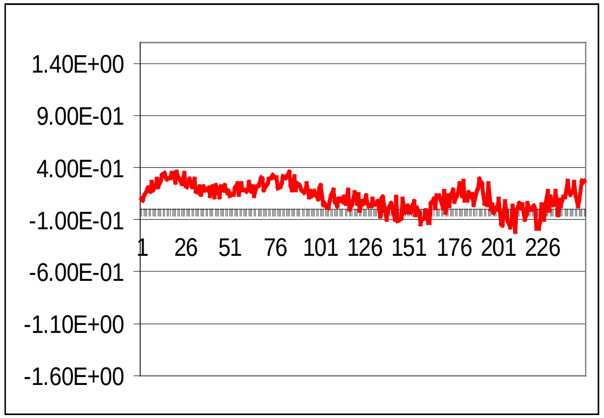


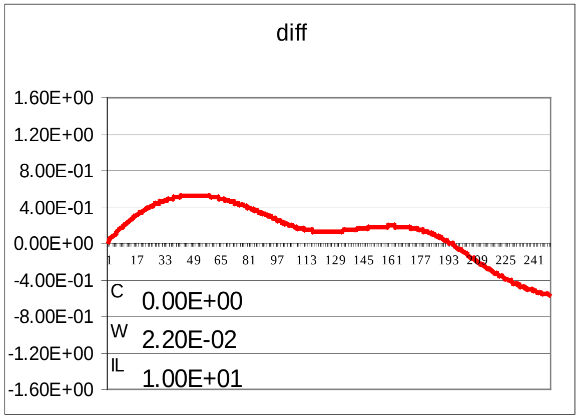
ϕhead – ϕ_{tail} as function of intensity.

Difference between head and tail of batch

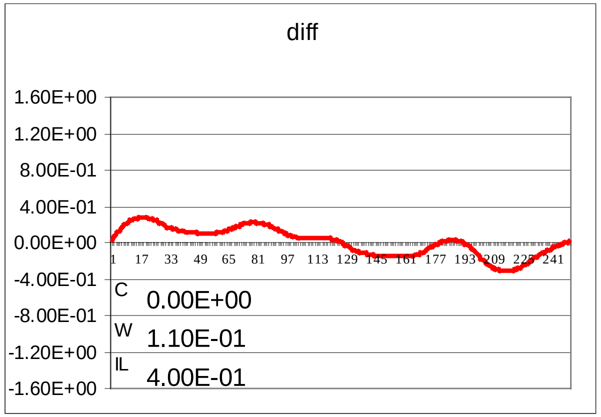


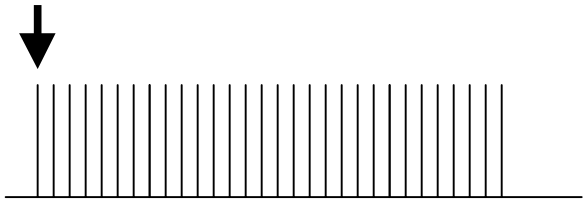
Measurement

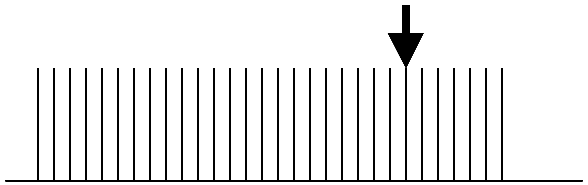




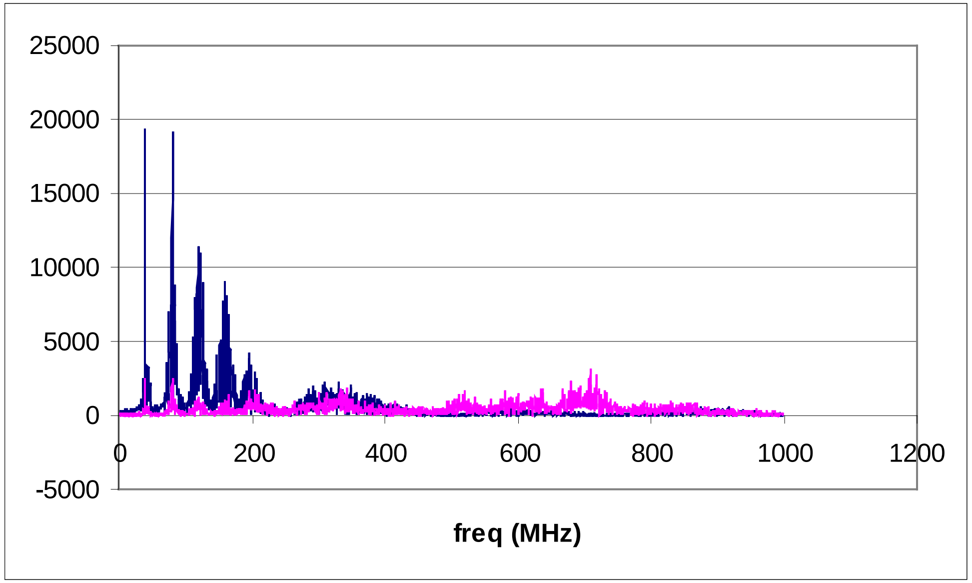
Calculation



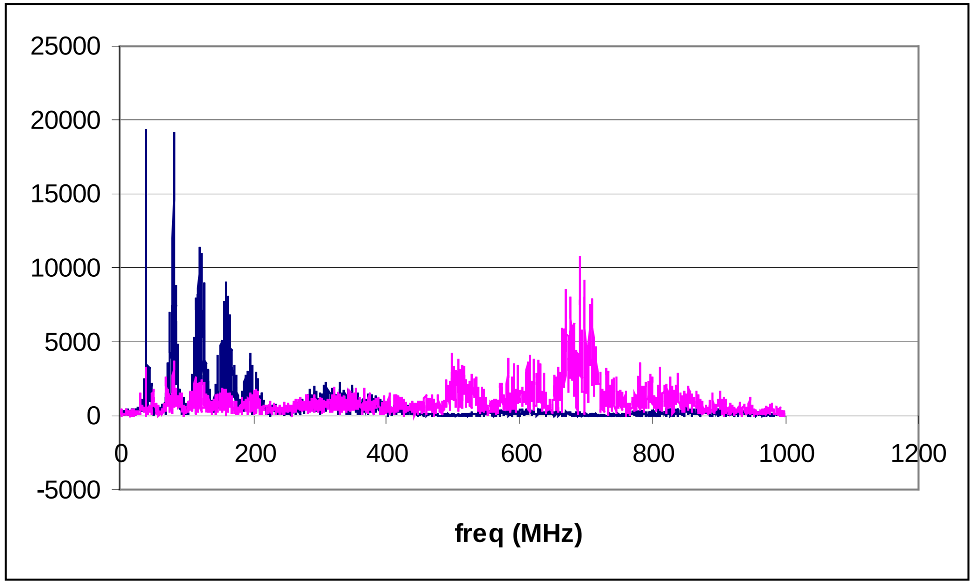




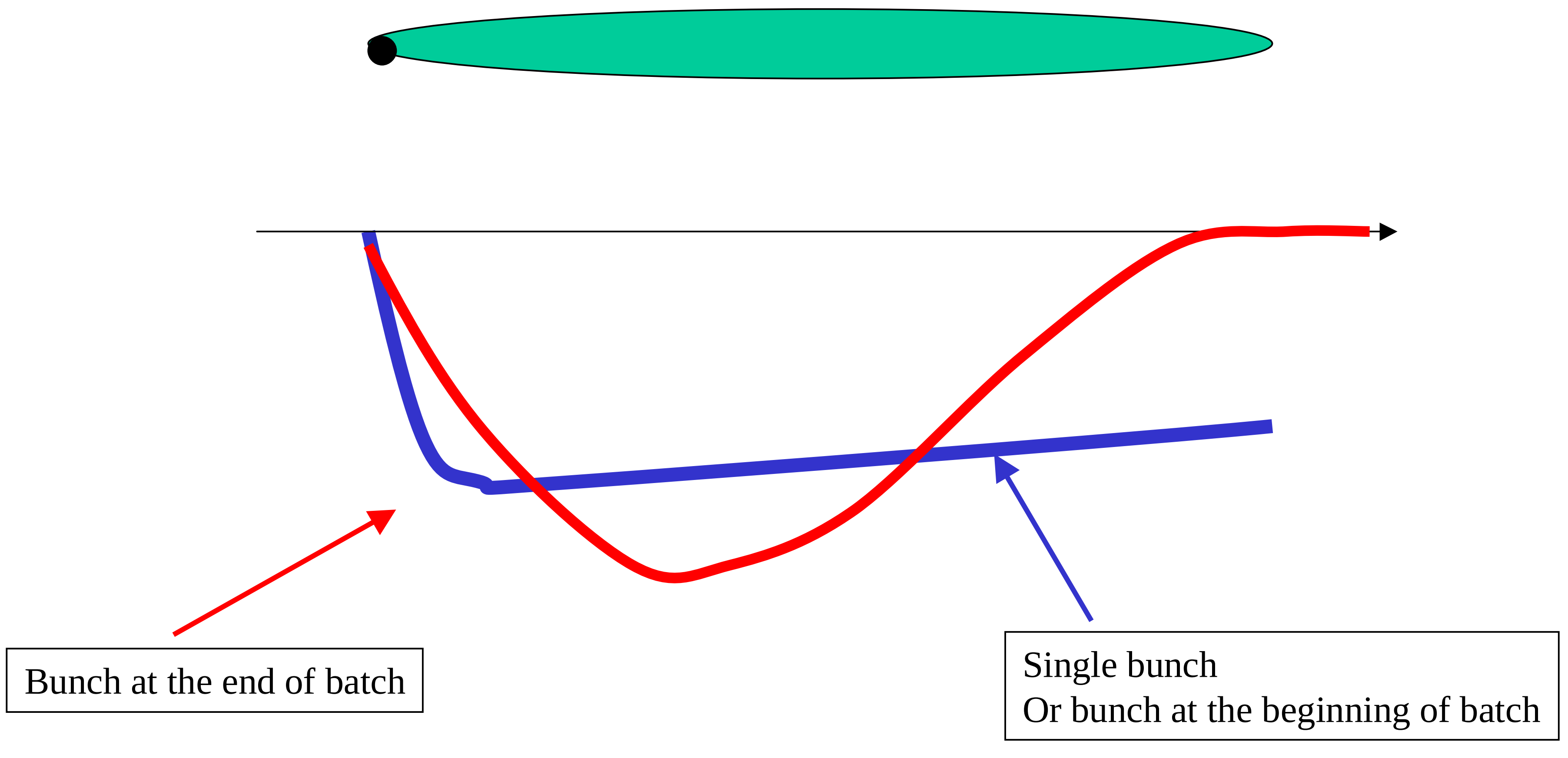
Bunch at beginning of batch



Bunch at the end Of batch



The Vertical Wakefield



CONCLUSIONS

- In the SPS the electron cloud is created in the dipoles.
- It results in a fast horizontal coupled bunch instability of low order that can be cured by feedback.
- The vertical instability is of single bunch nature (higher head tail mode). The growth rate depends on intensity.
- The vertical instability seems to be enhanced by a machine impedance 600-800 MHz