TRANSVERSE INSTABILITES

K. Cornelis, CERN Switzerland

ABSTRACT

1 INTRODUCTION

For the LHC beam three types of transversal instabilities are important. The single bunch intensity $1\ 10^{13}$ is high enough to suffer from head-tail instabilities. The total current is well above $2\ 10^{12}$. From this intensity onwards the fundamental mode of the resistive wall instability becomes dominant and a damper is needed to stabilise the beam. Higher order coupled bunch instabilities, due to shorter wake fields, were also observed. One slowly growing horizontal mode around 6MHz was found to be present for all kinds of beams (2 and 10 μsec-batches, 5 and 25 nsec bunch spacing). A second, very fast growing instability was only observed with the 25 nsec bunch spacing.

2 SINGLE BUNCH INSTABILITIES

Once the single bunch intensity is big enough to shift the tune out of the continuum the m=0 mode becomes unstable for negative chromaticity. For positive chromaticity the dipole mode is damped, the damping constant being proportional to the intensity and the transverse impedance [1].

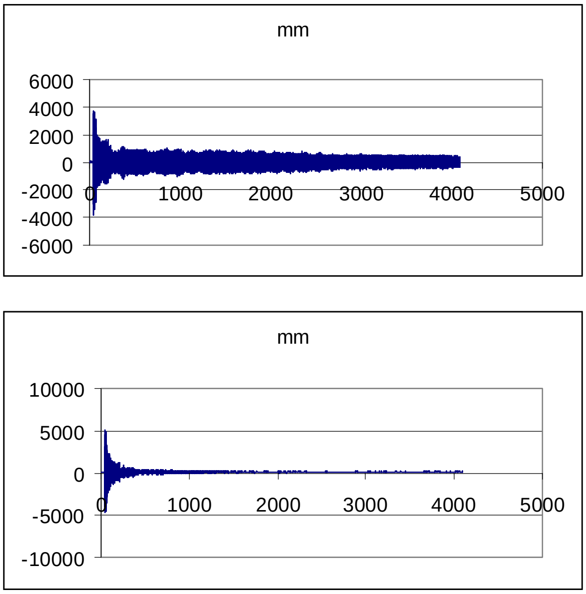

Fig 1 . The damping time with positive chromaticity is shorter for high intensity bunches.

3 RESISTIVE WALL INSTABILITY

A big part of the SPS impedance is coming from the induced wall current in the elliptic vacuum chambers in the dipoles. This creates a slowly decaying wake field which does not oscillate (the resonance is at zero frequency). When all the bunches move in phase the wake fields created by each of them add up coherently an can become very strong. This leads to so called “resistive wall instability”. The name points to the fact that the characteristics of the wake depend on the resistivity of the vacuum chamber. For a total current above $2\ 10^{12}$ a damper is needed in the SPS is needed in order stabilise the beam.

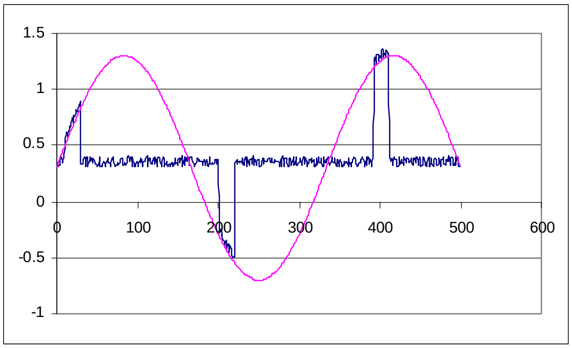

Fig 2. When the damper is of the beam starts to oscillate at the fundamental mode. The phase correlation between end and beginning of the batch shows that the responsible wake field is long range.

4 HORIZONTAL INSTABILITY DUE TO SHORT RANGE WAKE

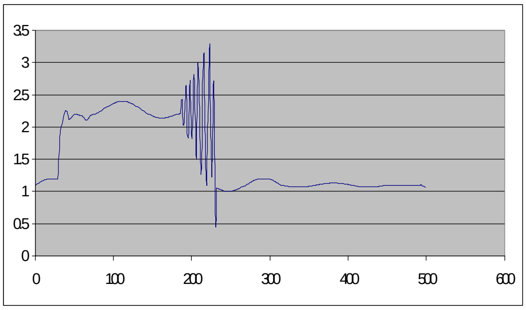

Fig 3 : Horizontal instability at the end of 2μsec batch.

Once the local density of the beam becomes higher then 1 10^{12}/msec, an horizontal instability develops at the end of the batch, 500msec to 600msec after injection (Fig 3). This instability appears for 2μsec long batches as well as for 10μsec long batches and is independent whether there is 5 nsec or 25 nsec bunch spacing. This kind of instability, where only the last part of the batch is oscillating is typical for short range wake fields. In order to measure the typical range of this wake field in the SPS the following experiment was performed : the first part of the batch was kicked with a Q-kicker and the evolution of the oscillation towards the end of the batch was measured.

This time behaviour can be written down in a crude model where the constant field is truncated at an interaction length L :

$$\frac{d^2y}{dt^2}+\omega_\beta y=k\int_{s-L}^{s}\frac{dy}{ds}ds_0$$

y(s,t) is the transverse coordinate, *s* the position in the batch, ω_β the betatron frequency, *k* the wake field strength and *L* the interaction length. For the boundary condition as in the experiment, it can be shown that the time evolution of the amplitude of the oscillation is as follows :

$$<y(s,t)> \sim t^{s/L}$$

In fig 4 the result of the experiment is shown. The three lines show the time evolution oscillation amplitude of the head, the middle and the end of the batch.

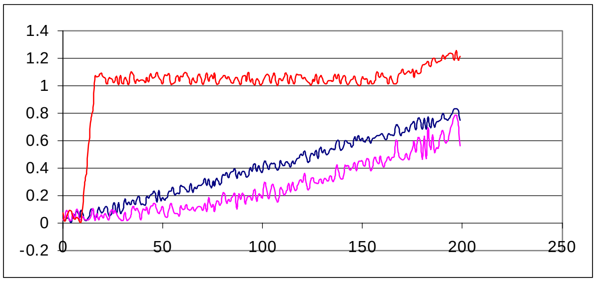

Fig 4 : the evolution of the amplitude of the head (highest line) the middle and the end (lowest line) of a 2μsec batch.

After the kick the head of the batch has a constant amplitude and the motion is transferred backwards in the batch. After 170 turns the resistive wall takes over and the whole bunch starts to oscillate in phase with a growing amplitude. From the evolution of the middle and the tail of the batch a value of roughly 1 μsec could be deduced for L.

5 ELECTRON CLOUD

This instability has only been observed for the LHC type beam with 25 nsec bunch spacing. For an intensity around
4 10^{12} particles in 2 μsec, the tail of the batch is unstable in both horizontal and vertical plane immediately after injection. The growth rate of the horizontal instability is in the order of 30 turns, in the vertical plane it is in the order of some 100 turns. From the spectra we can see that there is an energy transfer from horizontal plane to the vertical plan but not visa versa. The horizontal oscillation results in an immediate emittance blow up, whereas in the vertical plane the emittance blow up is slow. This is probably due to fact that the vertical coherent tune is way outside the single particle tunes. The onset of the instability coincides with a vacuum pressure increase and at certain pick up's negative charges could be collected.
Al this seems to indicate that we are confronted with an electron cloud instability. A whole session in this workshop has been dedicated to this phenomena where more detailed results will be presented.

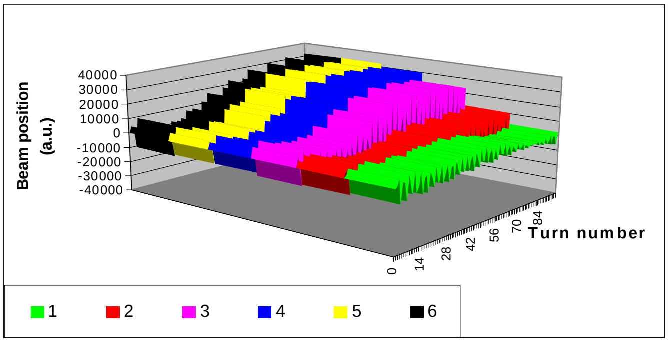

Fig 5 : Injection oscillations for six different slices in a batch. In the first two slises the injection oscillations are damped. In the other slices on can see after some initial damping a fast rising amplitude.

REFERENCES

[1] M.P. Zorzano, *Transverse impedances*, these proceedings.