Observations of SPS e-cloud instability with exponential pickup

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Motivation

One effect of the e-cloud in the SPS is to cause a particle beam instability that limits the total bunch current that can be injected in the machine.

When a bunch encounters an e-cloud, the field of the bunch distorts the e-cloud density that in turn distorts the bunch distribution. In certain conditions, the process is unstable and amplifies turn after turn, it causes a bunch blow up that leads to beam loss.

A feedback system may be designed to interact with the process and to control the instability.

One of the first steps to design a feedback system is to know the main features of the unstable dynamics, namely: bandwidth of the associated signal and rise time.

In 2008 a measurement and simulation campaign has been carried out to address these questions.

Beam conditions

During summer there were two occasions to perform the measurements:

- In June during the so called "scrubbing run"
- In August in a dedicated machine development (MD) time.

The beam under study is the nominal LHC beam ($1.2 \cdot 10^{11}$ ppb spaced by 25ns in 4 trains of 72 bunches).
In nominal conditions the beam is stable, but the LHC performance development relies on 4 times the currents. In order to simulate this conditions, several measures has been taken:

- a fifth batch of 72 bunches is injected in order to increase the e-cloud density (June);
- chromaticity (which is an instability dumping mechanism) is lowered to minimal level (June, August);
- longitudinal emittance has been artificially reduced using quadrupolar oscillation (August);

Measurement setup

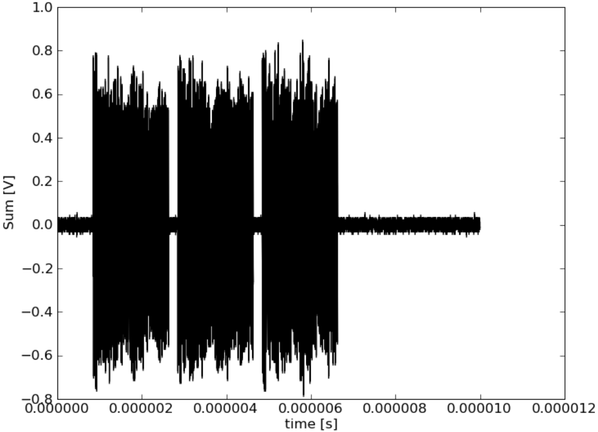
The aim is too look at the vertical deformations of the bunch density (normally Gaussian in the three dimensions).
We used a strip-line pickup optimized for large bandwidth (exponential pickup) has been used to measure the longitudinal profile density and the vertical displacement.
The signal of the strip line is brought to the surface through a 100m coaxial cables.
The signal at the surface are acquired by a fast digital scope.

Limitation of the measurements

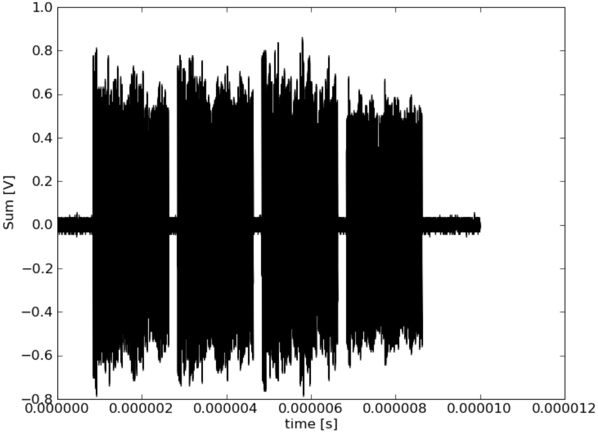
The measurements are not easy for several reasons:

- machine reproducibility: current and emittance, vary bunch by bunch and cycle by cycle. Chromaticity variations are relevant due the low set value.
- not enough high current (in particular after the machine is scrubbed) to provoke a strong instability.
- high bandwidth is difficult to be preserved in all the acquisition chain: pickup (no measurements a high frequency, , hybrids, cable).
- information on the vertical displacement is entangled with the longitudinal distribution.

Bunch trains



Bunch trains



Bunch in the first batch

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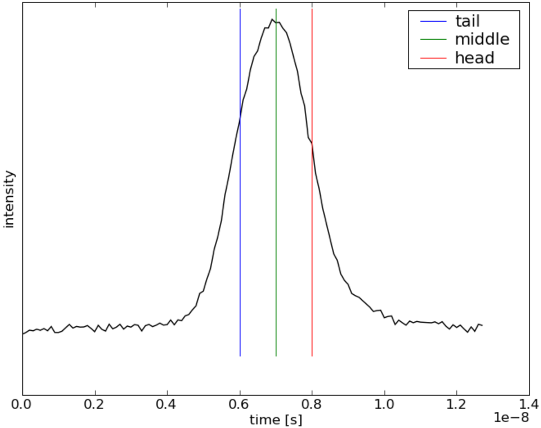
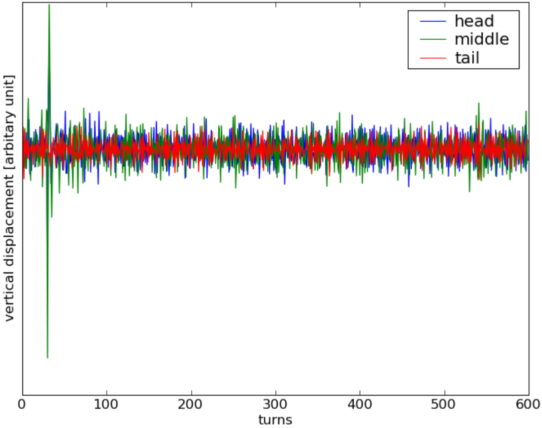
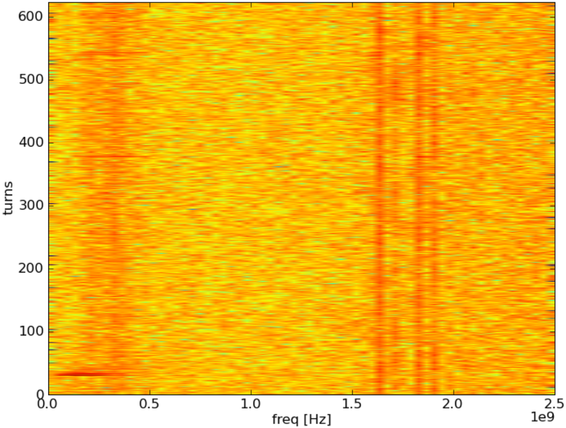
Bunch in the first batch



Bunch in the first batch



Bunch in the first batch



Bunch in the last (unstable) batch (June)

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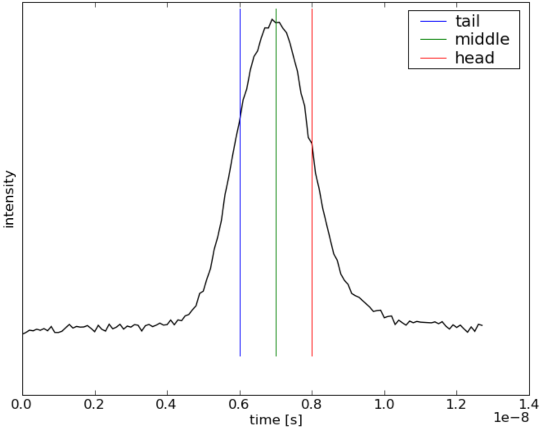
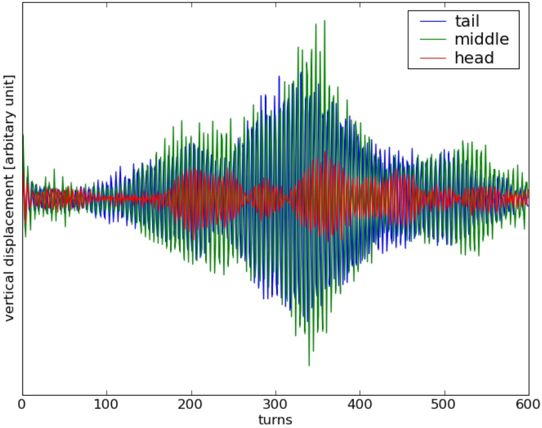
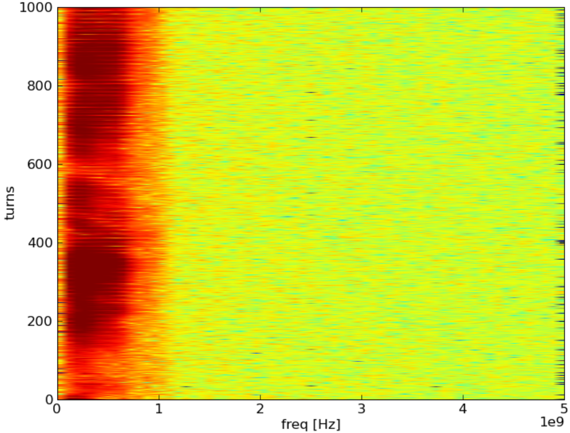
Bunch in the last (unstable) batch (June)



Bunch in the last (unstable) batch (June)



Bunch in the last (unstable) batch (June)



Bunch in the last (unstable) batch (August)

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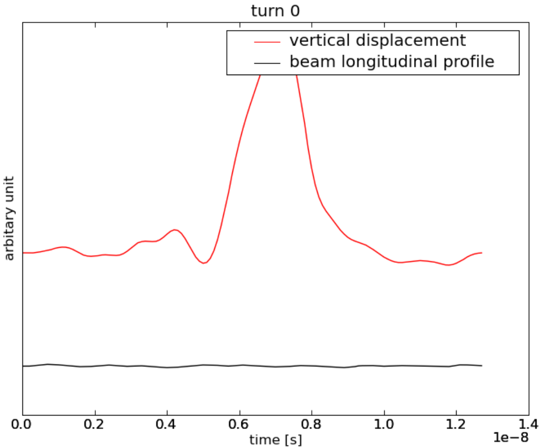
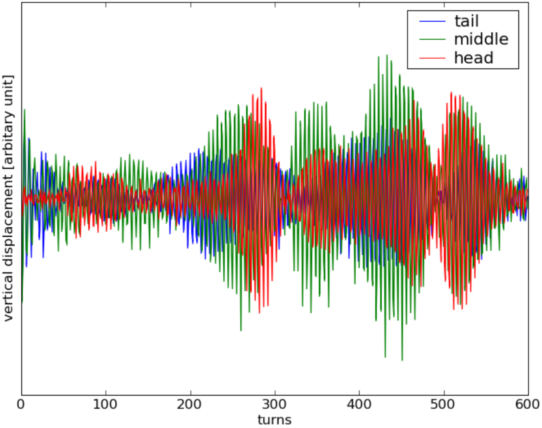
Bunch in the last (unstable) batch (August)



Bunch in the last (unstable) batch (August)



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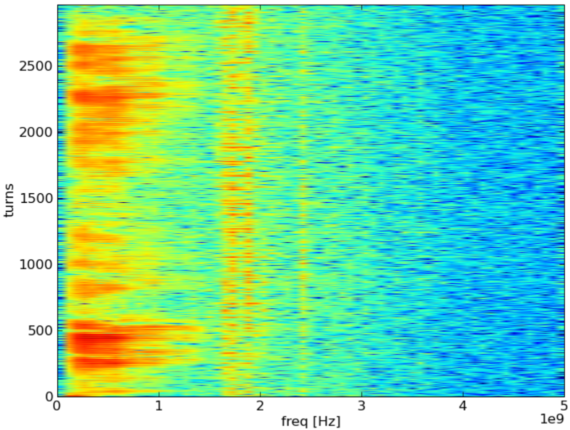
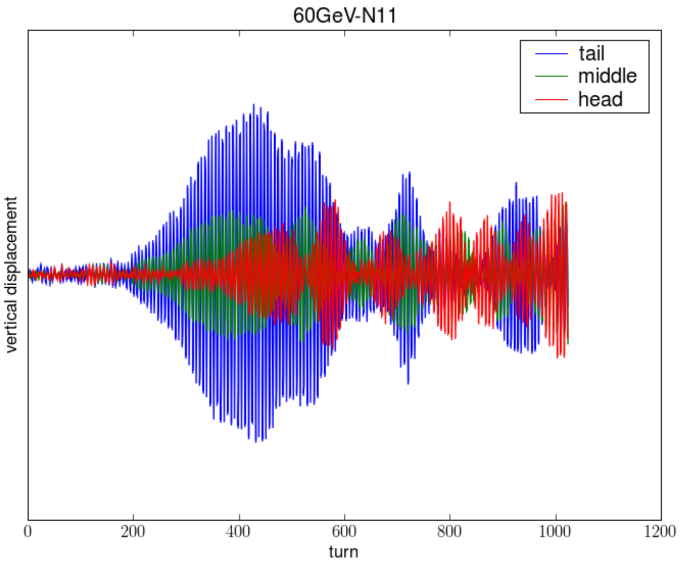


HEADTAIL Simulation [1]



[1]Data from G. Rumolo

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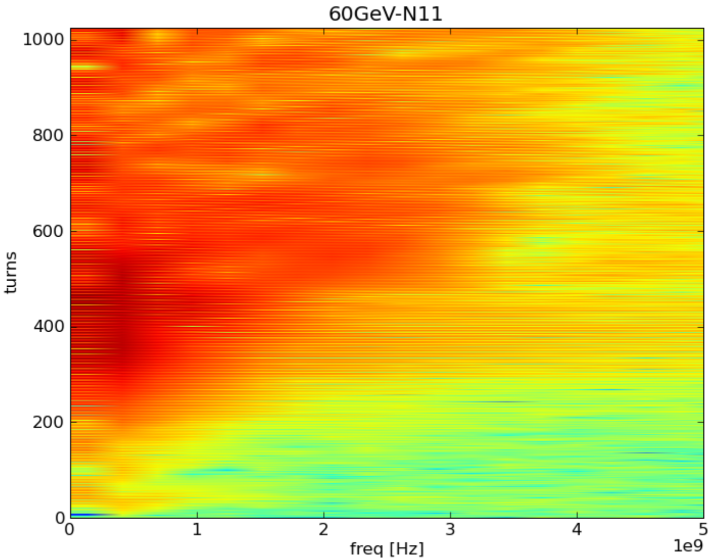

[1] Data from G. Rumolo

Conclusion

- The measurements allowed a qualitative characterization of the instability.
- The bunch distortion are complex and they presents a large bandwidth frequency content (up to 1.5GHz).
- The rise time is in the order of 30-100 turns.
- The dynamics is diverse: the only recurrent pattern is that the tail and middle first starts to oscillate and the head follow with a delay of 50-100 turns.
- Comparison with simulation are encouraging.

Future plans

- The measurements can be used to benchmark the simulation.
- To get more quantitative data, additional measurements are necessary.
- Simplified dynamic parameters can be extracted from the measurements and used as input for the feedback design.