E-cloud instability growth rates and spectra

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Motivation

Machine development studies

Instrumentation: SPS wide band pickup

Limitation of the measurements

Results: growth rate

Motivation

Study the features of the e-cloud induced instability to evaluate the feasibility of a feedback system.
Observe the longitudinal dependent transverse motion during the onset of instability to measure the growth rate of the oscillating modes.
At the same time study the limits of the observation devices as one of the component of the feedback system.
Eventually estimate the specification needed by the feedback system using in addition simulation results and study the feasibility with the avaialble technology.

Machine development studies

The beam under study was the nominal LHC beam
($1.2 - 1.3 \cdot 10^{11}$ ppb spaced by 25ns)

- MD June 2008: Data taking during scrubbing run with low chromaticity up to 5 batches injected. Transverse instability observed. In parallel of data taking gained experienced with the pickups.
- MD August 2008: Machine well scrubbed, 4 batches with nominal beam stable. Low chromaticity and bunch length oscillations caused growing transverse oscillations.
- MD June 2009: Machine not scrubbed, lower chromaticity at injection (0.05) and chromaticity bumps ($\simeq 0$ but still positive) to provoke mild instabilities.

Instrumentation: SPS wide band pickup

Headtail monitor (BI): stripline used in the past for short bunches, usable in the control room, not enough memory to follow more than a bunch for many turns.

Exponential pickups: used for the first time in time domain for this application, two accessible in the faraday cage (flexible instrumentation, not for routine operation), two cabled in the CCR (potentially for routine use, software needs to be written).

For these MD we used only the exponential pickup.

Limitation of the measurements

Limitations of exponential: Bandwidth, RF interference, small signals, time domain distortions.
Bandwidth: < 1GHz, due to the different dynamic range of slow and fast signal, caused by the cable attenuation and the number of bit per sample.
Resonant modes and cutoff make difficult observe signal above 1.6GHz
Time domain distortions: due to imperfections of the electrodes and difficult to compensate for the lack of extensive bench measurement.

Chronology

Before June 15: parasitic beam test on the exponential pickup in the faraday cage and the CCR, analysis of the software requirements for routine operation in the control room, optimization of the measurement setup.
June 15, 9:00 md start; 16:00 first usable measurement for baseline; 19:23 started second batch; Chromaticity 0.05 v. Setup of transfer damper.
June 16, 17:00, pickup calibration measurements. 21:00 first instability but no losses at injection with bunch length oscillation; 22:09 data set taken. 22:30 high chromaticity; 23:00 setup of the chromaticity bump and measurements (3 good data set). Checks to assess chromaticity.
June 17, 00:14, chromaticity bump removed. Third and fourth batch injected with no observed instabilities.
After June 17. Additional parasitic measurement have been taken to study the pickup response.

Results: growth rate

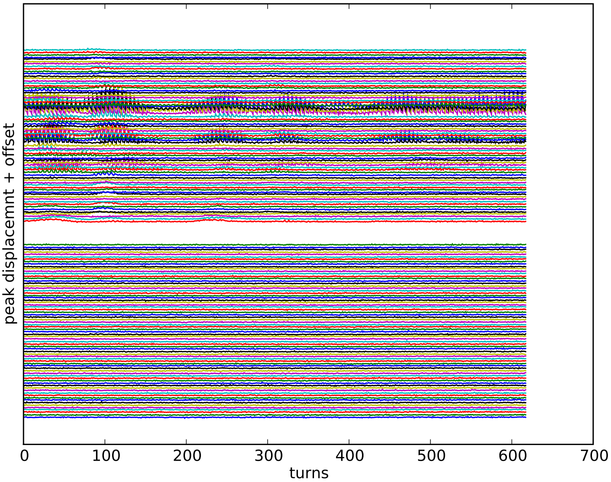
We are interested in the variation of the fast transverse displacement within the bunch.

We observed a growth of transverse oscillation:

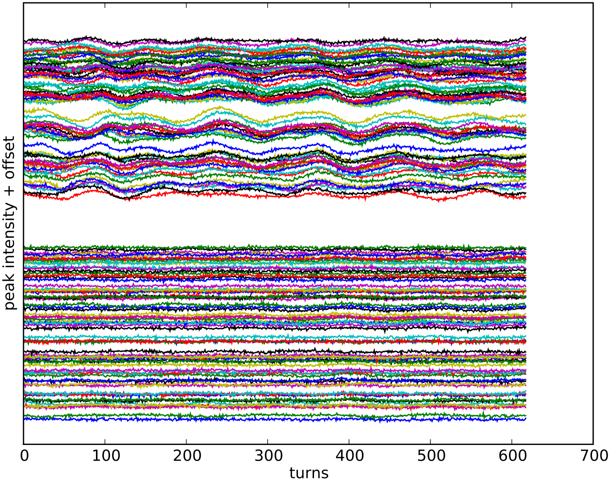
just after the injection of the second batch. The beam performed typical injection oscillation, but also quadrupole motion and capture losses.

as a result of a chromaticity bump before the ramp starting from stable condition. The bump was properly set to not cause global instabilities.

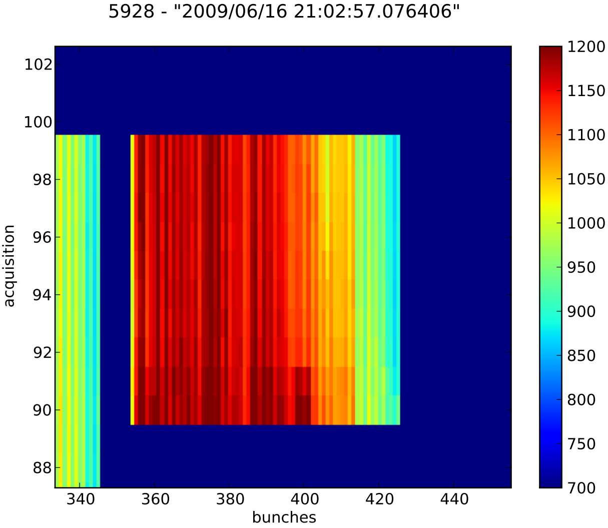
Results: injection



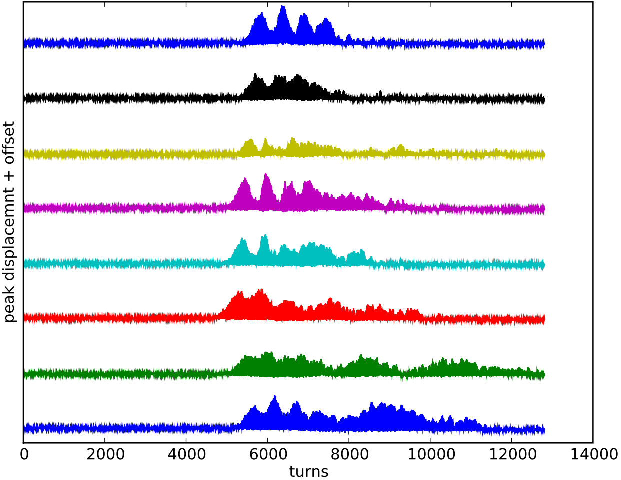
Results: injection



Results: injection

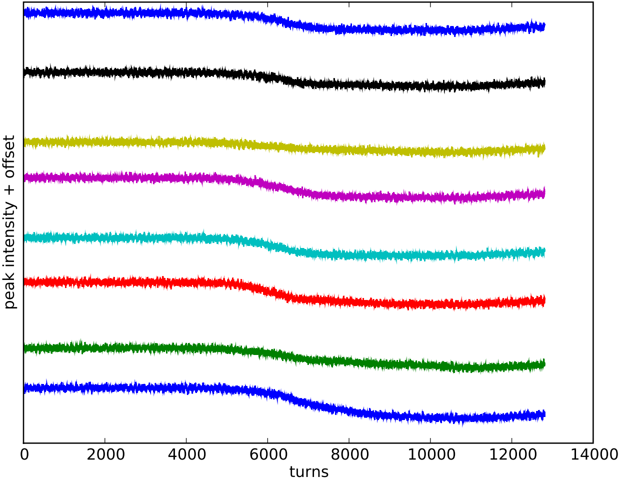


Results: chromaticity bump



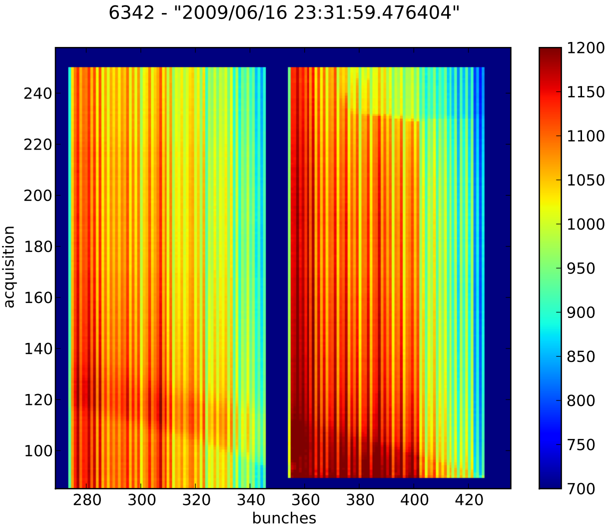
Chromaticity change is a slow process estimated to tens of ms.

Results: chromaticity bump



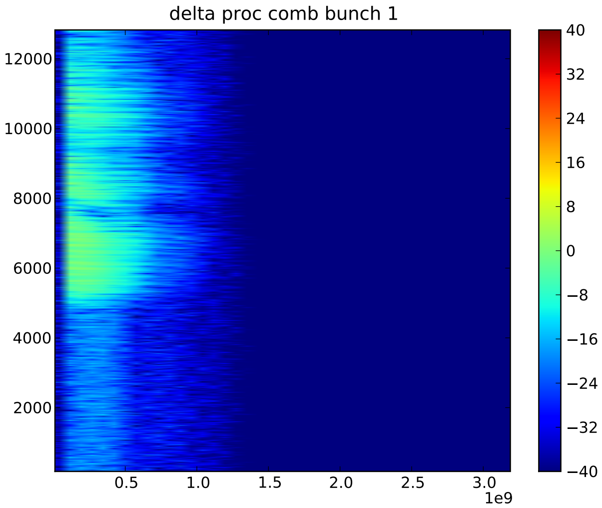
variation proportional to losses

Results: chromaticity bump



Fast BCT data. Acquisitions every 40ms.

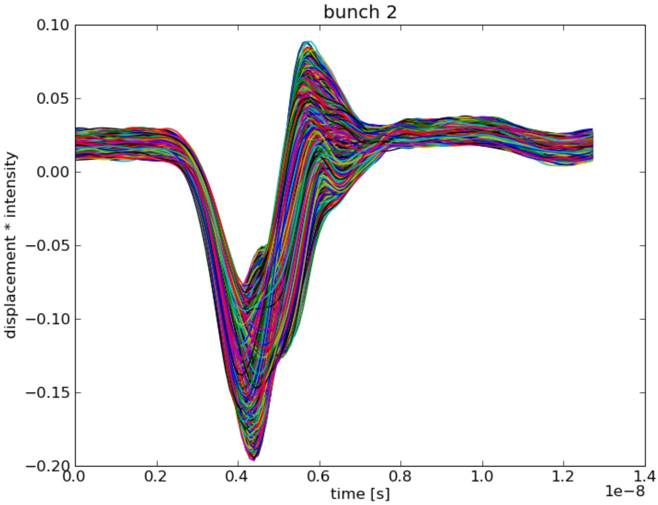
Results: excited modes



Unstable motion shows oscillation modes up to the limit of the instrumentation.

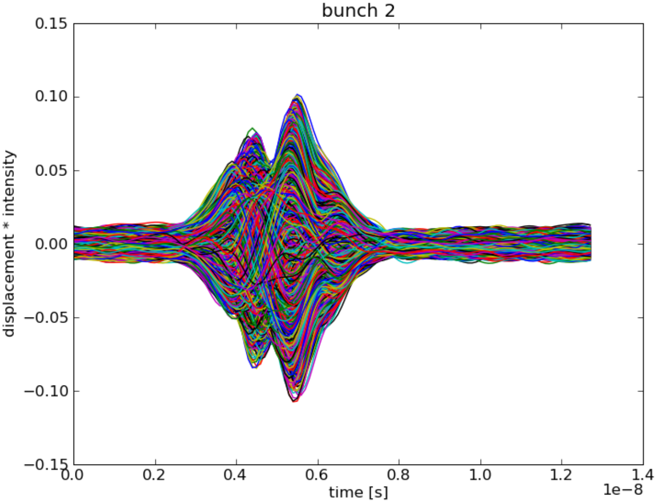
Results: excited modes

Envelope of the displacement of one bunch between turn 5000 to 7000.



Results: excited modes

Envelope of the displacement variation of one bunch between turn 5000 to 7000.



Conclusion

The observed growth oscillations often reach saturation very quickly and it makes difficult to estimate growth rates. At injection we observed saturation after 20 turns on average (without associated measurable losses). During chromaticity bump saturation is reached after 100 turns with associated measurable losses.

In case of slow chromaticity variation, the peak displacement initially follow the chromaticity.

The observed instabilities did not result in fast bunch losses because the machine was always kept very close to stable condition in order to optimize the scrubbing process that was taking place in parallel to the measurements.

The low order modes are dominant (rigid and head tail), higher order are not excluded but they are less excited.

Future plans

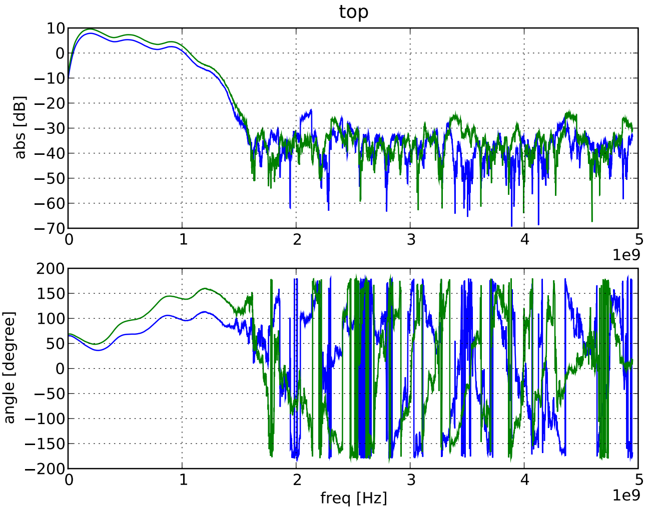
Data is still to be analyzed to the full extent. We have some uncontrolled variability of parameters, but no systematic scan has been performed.

In the summer we plan to excite the beam both as an additional diagnostic tool and to start to test solutions for feedback components.

The chromaticity bump data offer an interesting regime that could be simulated to validate beam dynamics models (HEADTAIL code).

Backup

measured 321 a and b tf



Backup

model accuracy compared to measurement