Observations of SPS e-cloud instability with exponential pickup


April 9, 2009
Beam conditions

Measurement setup

Limitation of the measurements

Bunch profile

One unstable bunches

Few unstable bunches

Last batch

Last two batches

Measurements vs Simulation

Conclusion
Beam conditions

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

- 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 profile

Single bunch at injection

- Blue line: raw sum
- Cyan line: raw diff
Bunch profile

Single bunch unstable

- raw sum
- raw diff
Exponential wide band pickup
Exponential wide band pickup
Pickup effect

Pickup step response

time [s]

×10^{-9}
Pickup effect

Pickup transfer function

- abs [dB]
- angle [degree]
- freq [Hz]

0 1 2 3 4 5
1e9

0 1 2 3 4 5
1e9
Pickup effect

Pickup distortion

- orig bunch
- orig slice
- dist bunch
- dist slice
Pickup effect
Pickup effect

![Graph showing pickup distortion with different lines representing orig bunch, orig slice, dist bunch, and dist slice.](image)
Cable effect
Cable effect

Cable transfer function

![Graph showing cable transfer function with frequency on the x-axis and absolute value in dB on the y-axis. The graph displays a smooth decreasing trend with periodic oscillations.](image-url)
Cable effect

Cable distorsion

- orig bunch
- orig slice
- dist bunch
- dist slice
Propagating modes

freq [Hz]
Processing raw data
Processing raw data

Single bunch unstable

- raw sum
- raw diff
Processing raw data

Single bunch at injection

- raw sum
- raw diff
- filtered sum
- filtered diff
Processing raw data

![Graph showing single bunch unstable data with lines for raw sum, raw diff, filtered sum, and filtered diff.](image)
One unstable bunches

movie
Few unstable bunches
Few unstable bunches
Few unstable bunches
Few unstable bunches

![Graph showing bunch number + vertical displacement over turn number for 2008-08 ecloud9]
Last batch
Last batch
Last batch
Last batch
Last batch
Last batch
Last batch

2008-08 ecloud16

bunch number + vertical displacement

turn
Last batches
Last batches

![Graph showing 2008-06 ecloud6 data with various lines representing bunch number + vertical displacement over time (turns)].
Last batches
Last batches
Conclusion

- The measurements allowed a qualitative characterization of the instability.
- After injection oscillation, bunches in the last part of the last batch show a lower instability threshold compared to the one at the beginning.
- 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 for fast instabilities.
- 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.