Experience with clearing voltages and solenoids at SPS damper pick-ups

W. Hofle

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LHC-VAC, SL-HRF
T. Bohl
T. Linnecar
R. Louwerse
J.-F. Malo
J. Tuckmantel

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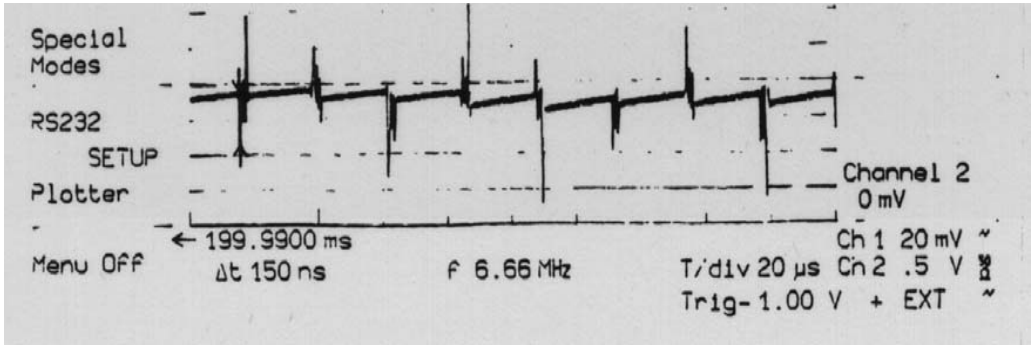
Electron cloud effect on pick-up signals

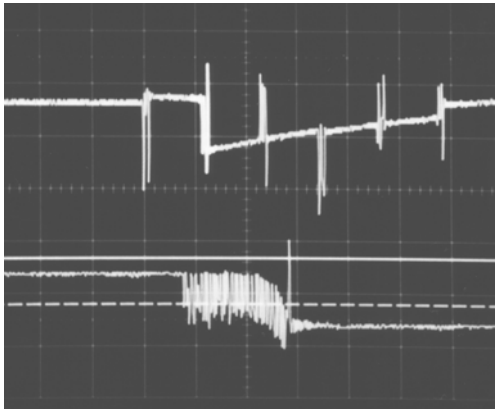
- first observations
- electrostatic SPS pick-ups with damper head amplifiers
- threshold of effect on pick-up signals
- influence of bias voltage and solenoid field
- effect on damper performance
- observations at multiples of bunch frequency

First observations



01.09.98
2-3 10^{12} protons/batch
LHC beam
25 ns bunch spacing

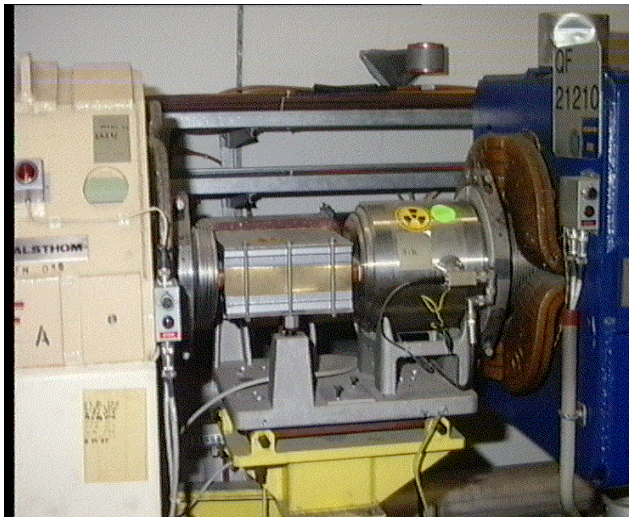
Observation:
Baseline drifts on pick-up signals during the passage of an LHC batch
What is going on?



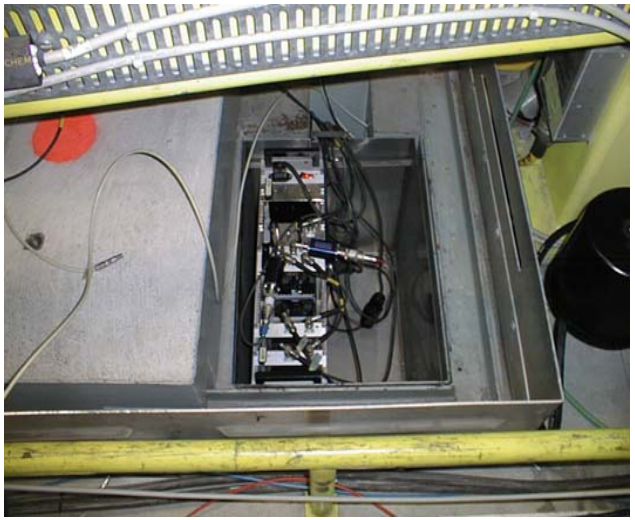
14.06.99
2-3 10^{12} protons/batch
LHC beam
25 ns bunch spacing
Top trace: 20 µs/div
Bottom trace: 1 µs /div

SPS electrostatic pick-ups

- SPS pick-ups are electrostatic (“shoe-box design”)
- closed orbit system uses 200 MHz frequency band
- 8 pick-ups are shared with the damper system (transverse FB)
- damper system uses high impedance head amplifiers (base-band)



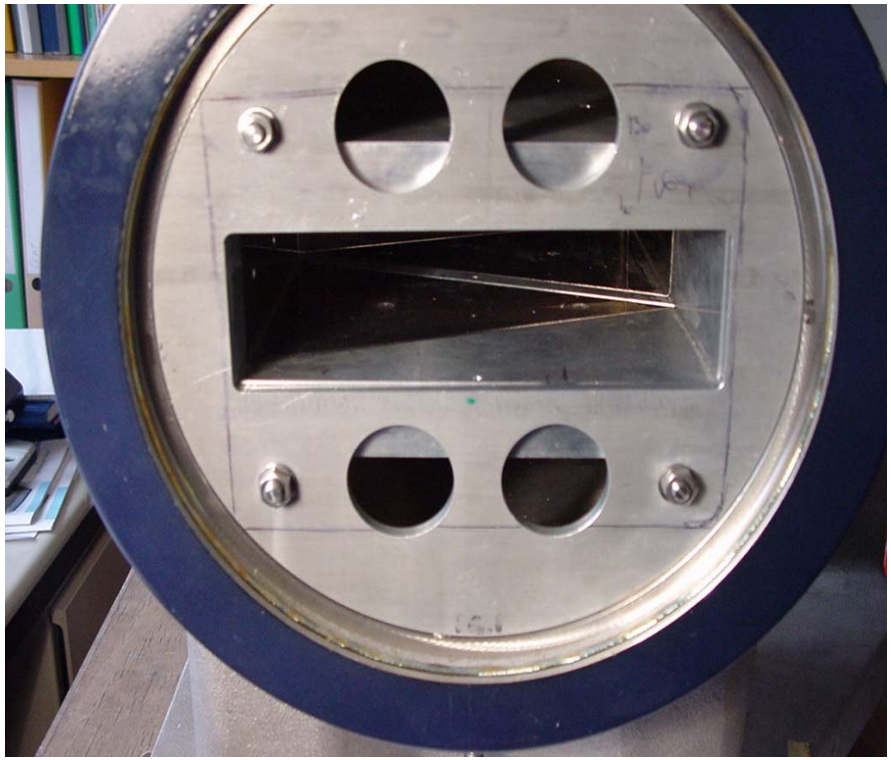
Horizontal pick-up in SPS



Amplifiers for damper in tunnel

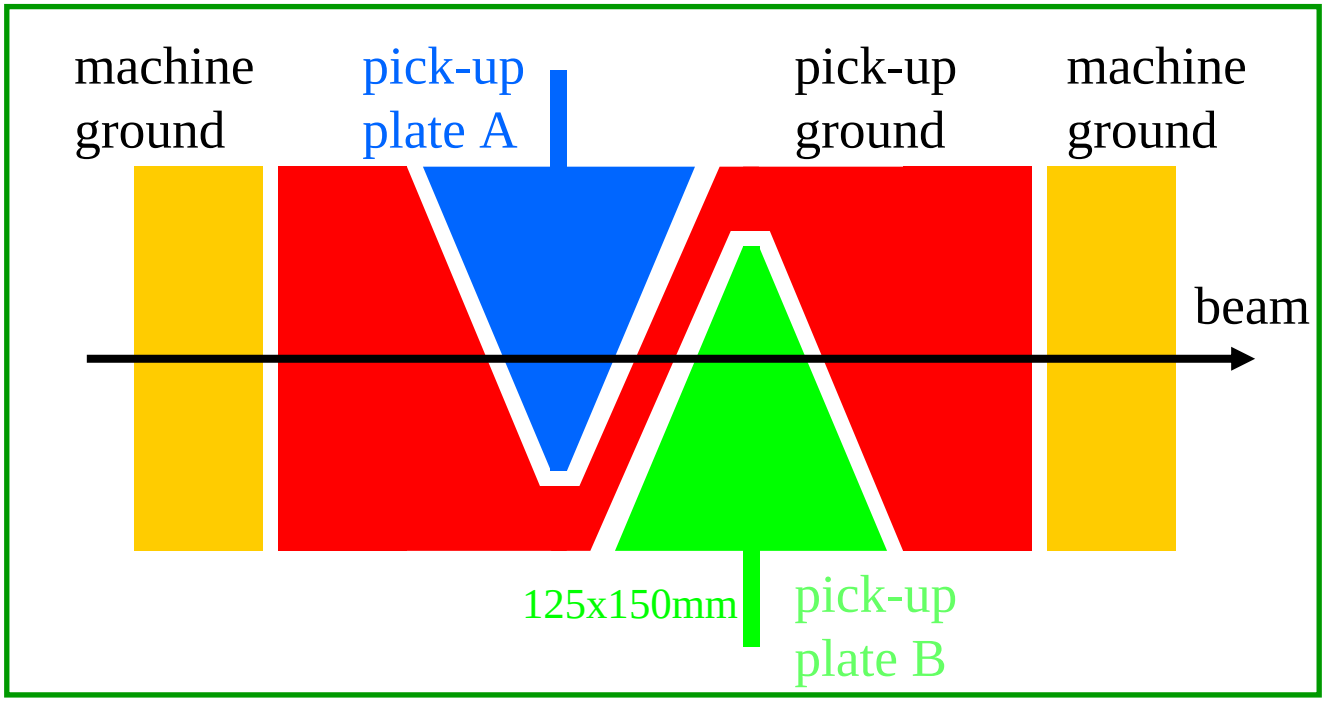
SPS electrostatic pick-ups

- triangular electrodes
- capacitive, 58 pF
- at 200 MHz (MOPOS) matched to 50 Ohms
- damper uses baseband
- For LHC beam: use of filters (on 4 pick-ups) to limit the peak amplitude and compensate for a flat frequency response

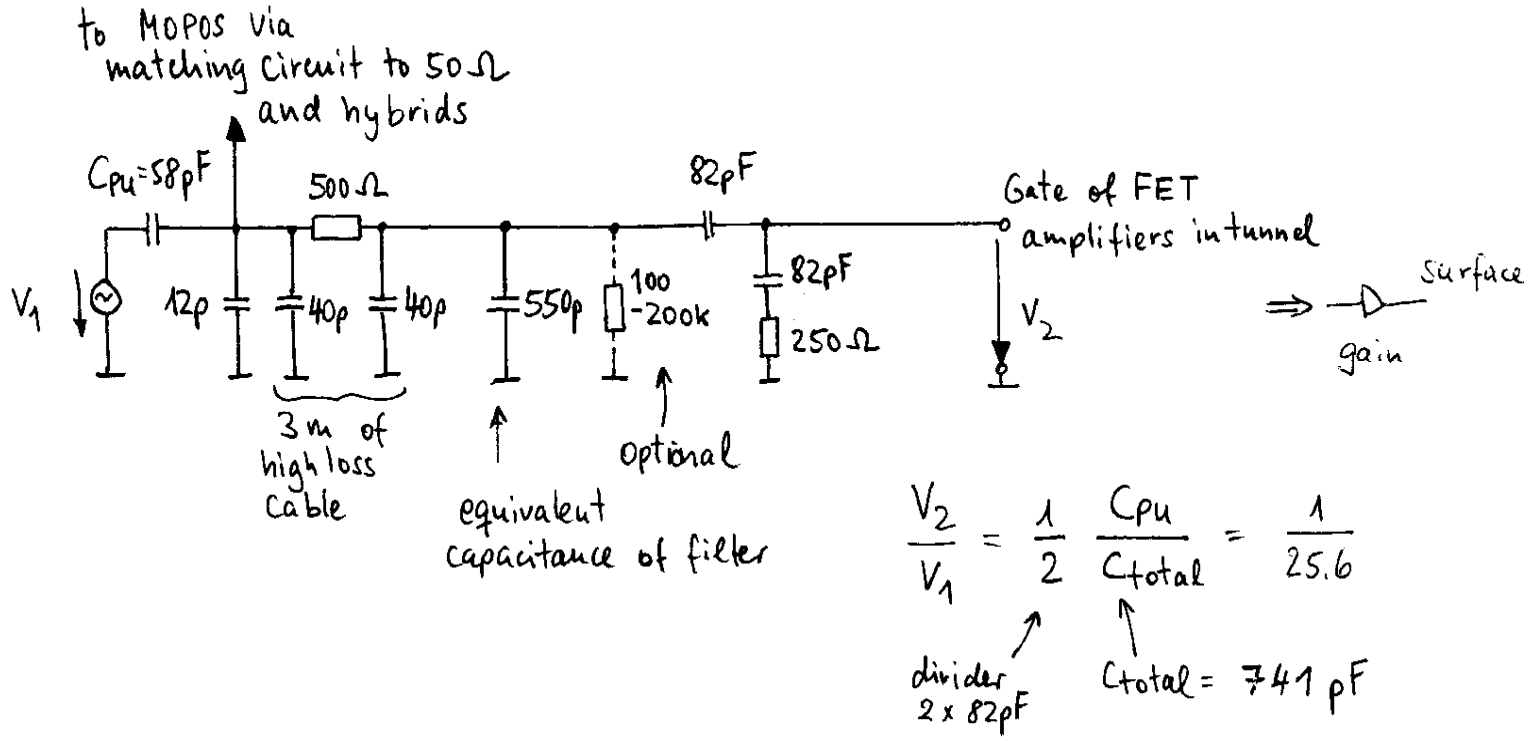


SPS electrostatic pick-ups

schematic of horizontal pick-up (mechanical, top view)

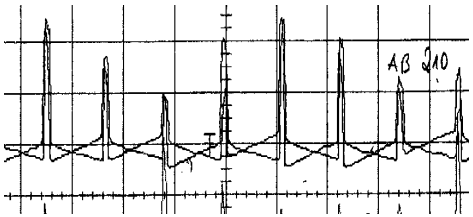


Equivalent circuit of pick-up-to-head -amplifier connection in tunnel



Estimation of number of electrons captured during single batch passage

Example: horizontal pick-up 2.10 on 22.07.99



scale 20 µs/div

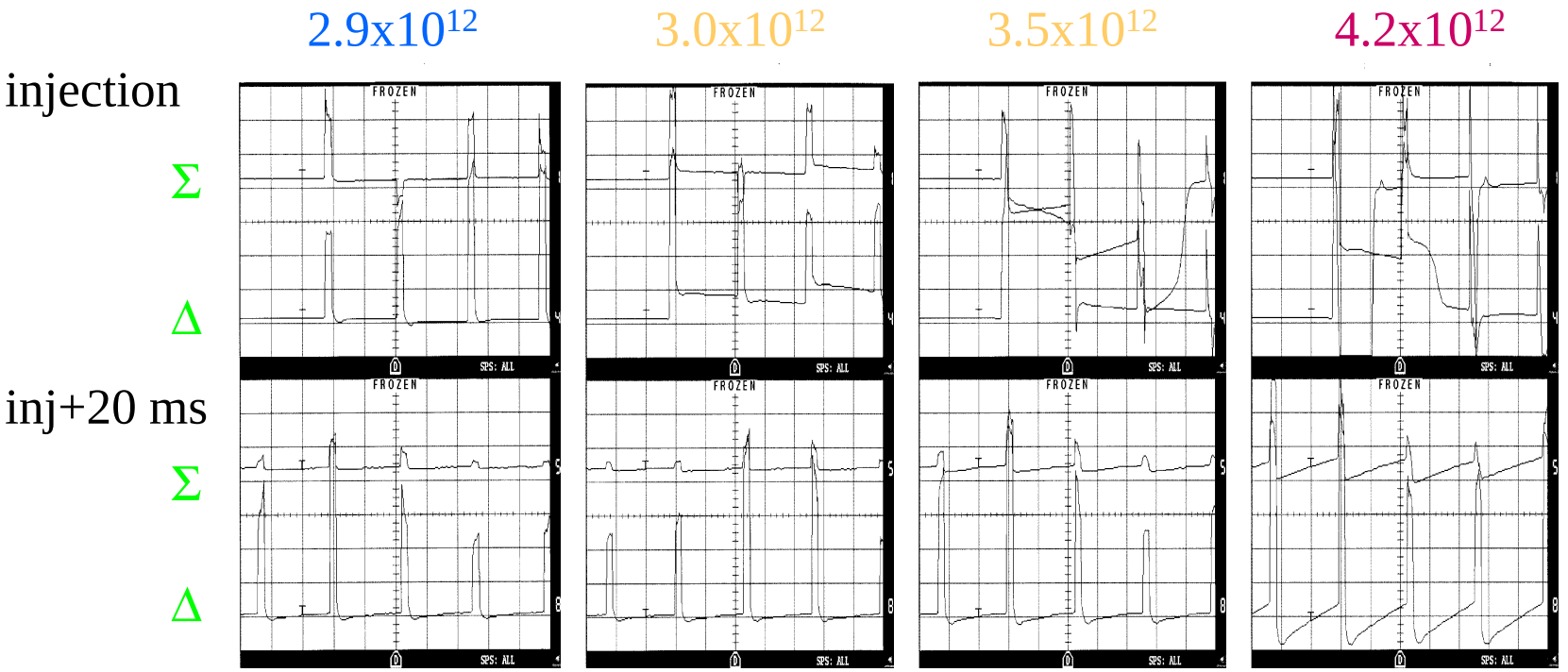
pick-up dimensions:	125x150 mm (triangle)
pick-up area (one triangle!):	9.4×10^{-3} m^2
beam intensity:	4×10^{12} protons in one LHC batch
observation time in cycle:	3 ms after inj, beam stable & centered
electron cloud effect starts:	after approximately 30 bunches
total charges collected / batch:	$4 - 6 \times 10^8$
charges per bunch and m^2 wall:	about 10^9

Correlation with machine state and beam parameters

- the effect is very violent at injection,
  and also when the beam is transversely oscillating (e.g. kicked)
- it is very regular (turn by turn) when the beam ist not oscillating
- no correlation with beam losses at the pick-ups were observed
- no correlation with the orbit was seen
- there was no correlation with the presence of lepton beams
  on the SPS lepton cycle within the super-cycle
- the threshold intensity decreased during the summer 1999
- the threshold intensity increased (went back to the original state
  of the beginning of the 1999 run) during the ion run (autumn 99)

Threshold intensity

Example pick-up 2.14 (horizontal) 09.10.99



all scales 10 μs/div

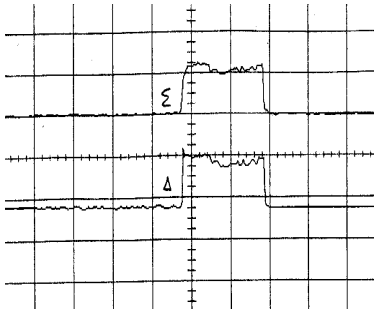
Different bunch spacings

at the same average beam current/batch

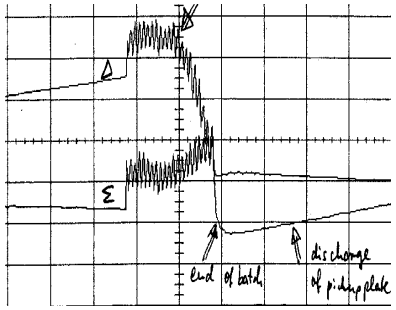
clean signals for 5 ns bunch spacing (10^{10} protons per bunch)

Electron cloud effect for 25 ns bunch spacing ($5x10^{10}$ protons per bunch)

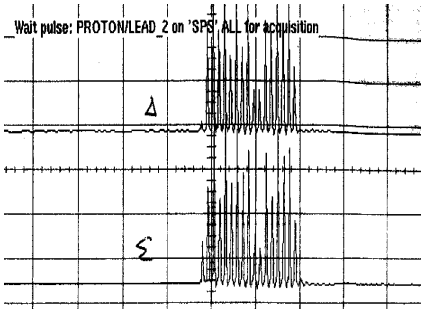
no effect for 130 ns bunch spacing ($25x10^{10}$ protons per bunch - long bunch)



5 ns bunch spacing



25 ns bunch spacing

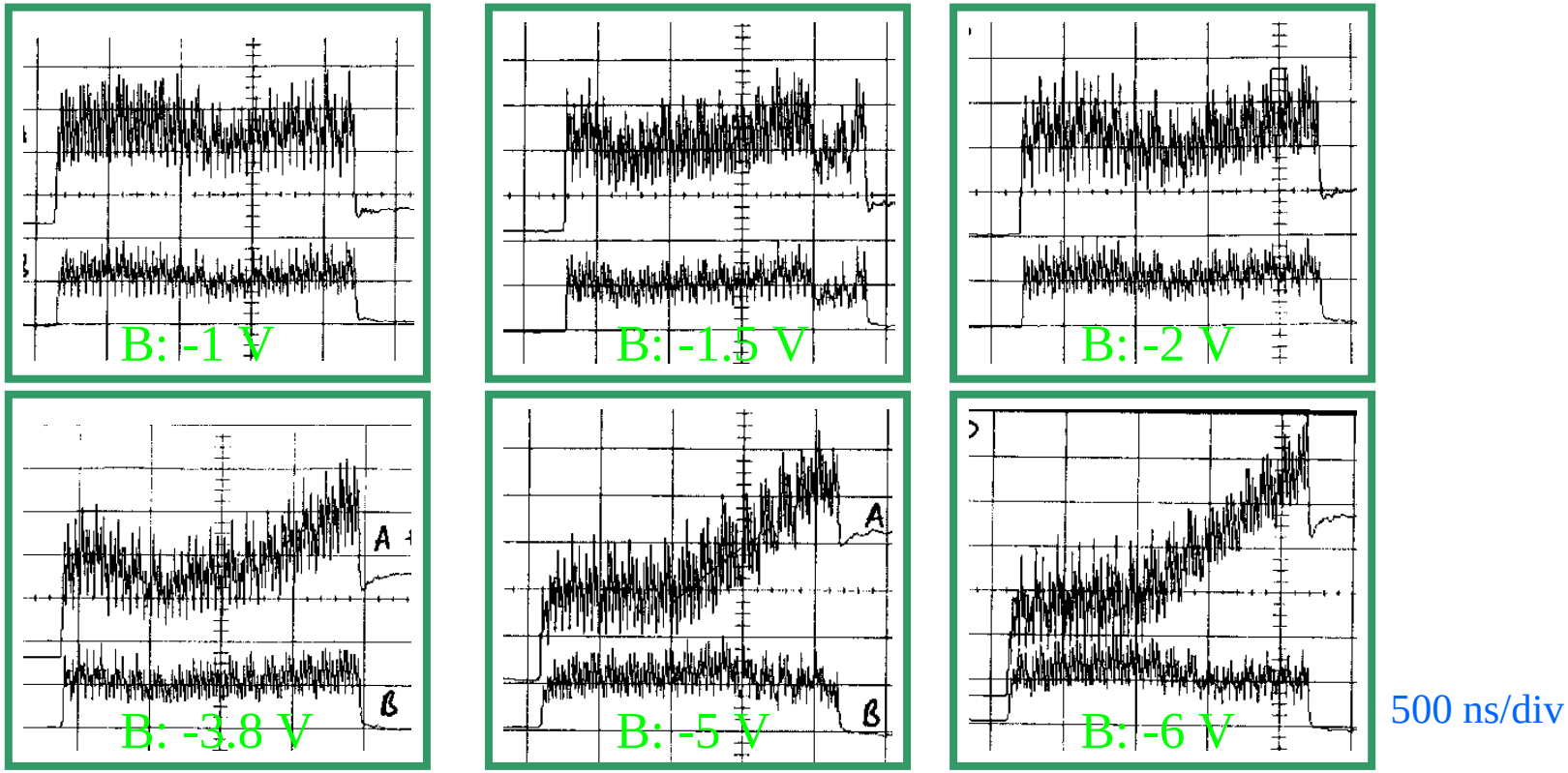


130 ns bunch spacing (bunches on PS h=16)

scale: 1 μs/div

Influence of electrode bias

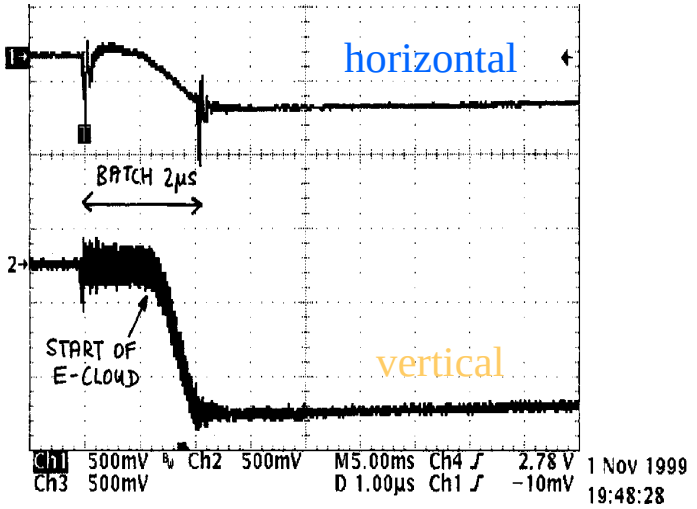
top trace: signal on A electrode with +1 V of bias to ground
bottom trace: signal on B electrode with varying bias to ground



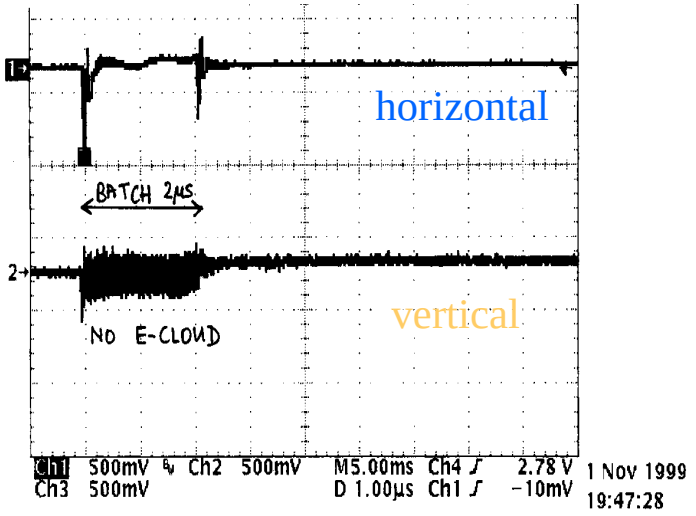
Magnetic solenoid field

The resonant build-up of the electron generation can be disrupted by applying a magnetic solenoid field

without solenoid



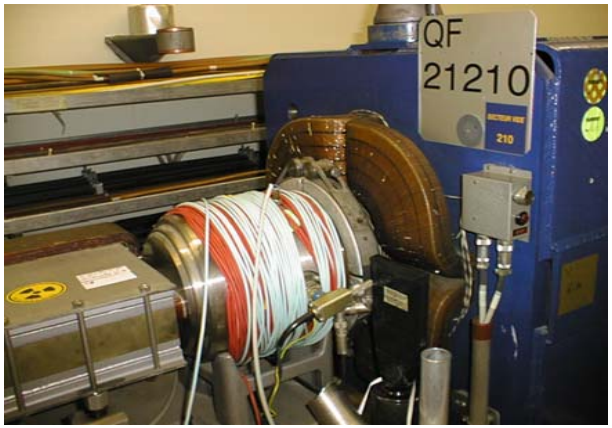
with solenoid (100 gauss)



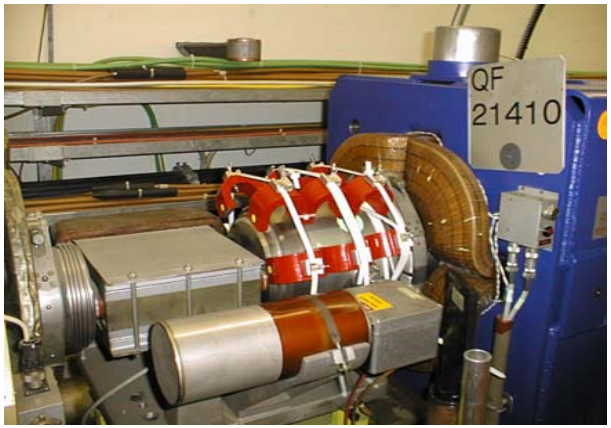
scales 1 μs/div

Magnetic solenoid field - realization

60 - 80 windings
20 A maximum current
5 pick-ups (in series)
power supply in tunnel (1.2 kW)
CW operation with blowers

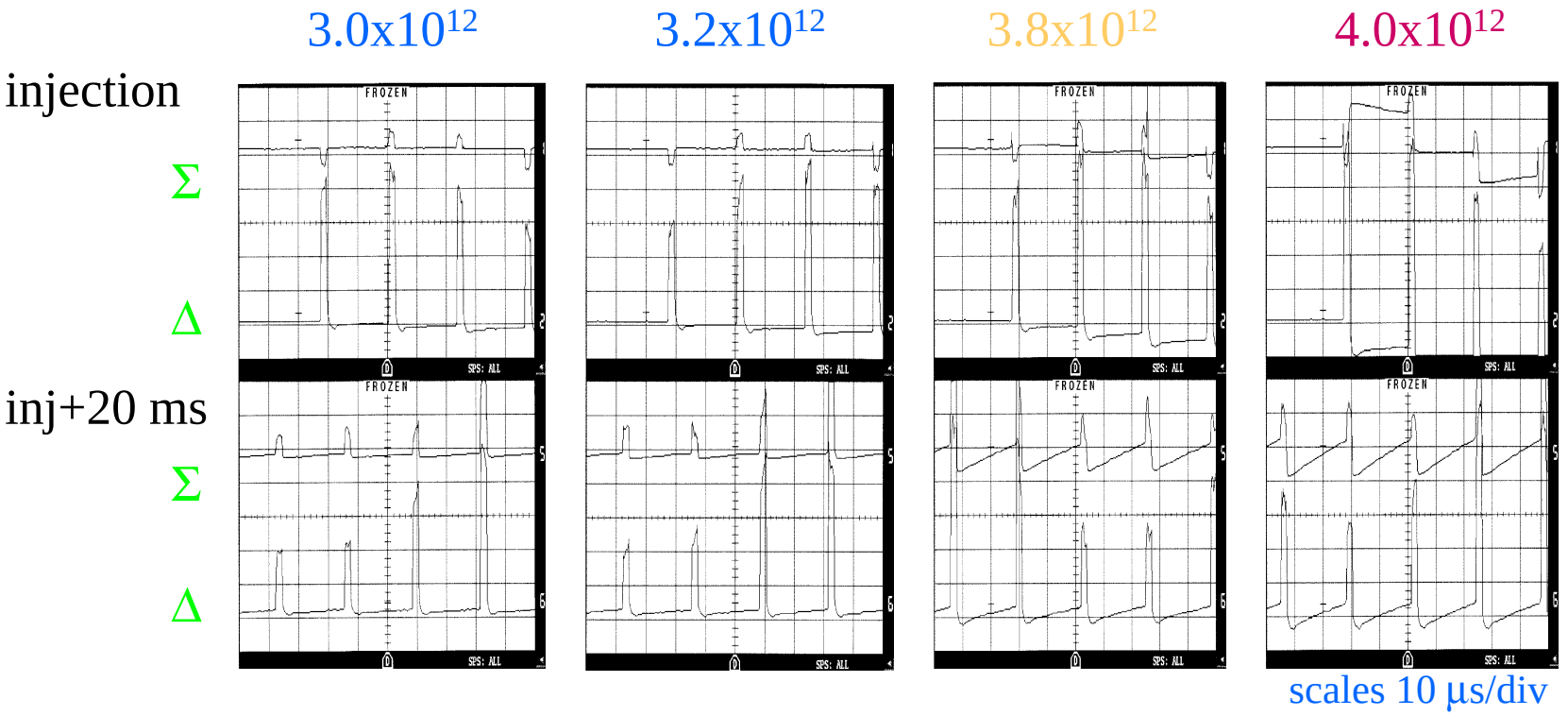


17 permanent magnets (350 kN)
6-fold symmetry
solenoid field component
not very efficient
small effect on electron cloud



Threshold intensity with permanent magnets

Example pick-up 2.14 (horizontal) 10.10.99

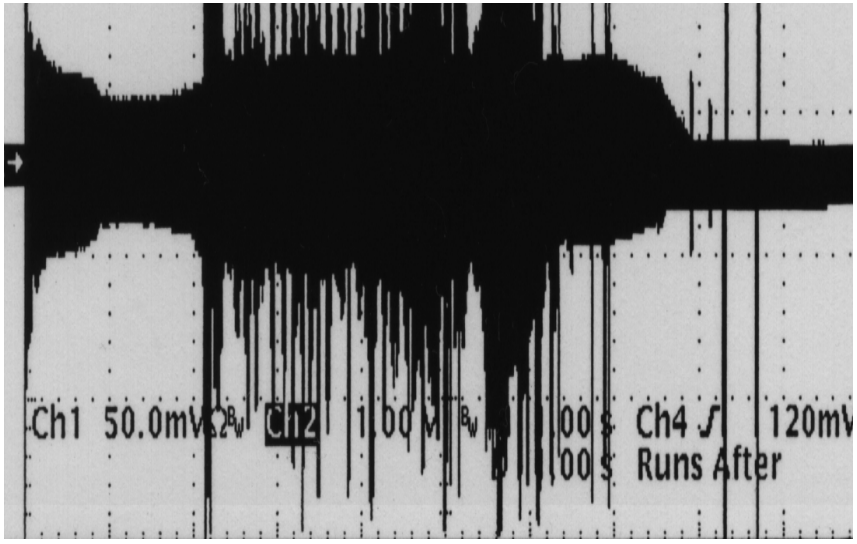


Effect on damper performance and beam stability

The damper performance suffered from the electron cloud effect due to the contaminated pick-up signals.

It will only be possible to investigate to what extent the electron cloud effect causes coupled bunch instabilities, once we have clean pick-up signals for all intensities.

Single LHC batch,
accelerated
typical damper signal
2 s after injection solenoids are switched off and beam starts strong oscillations

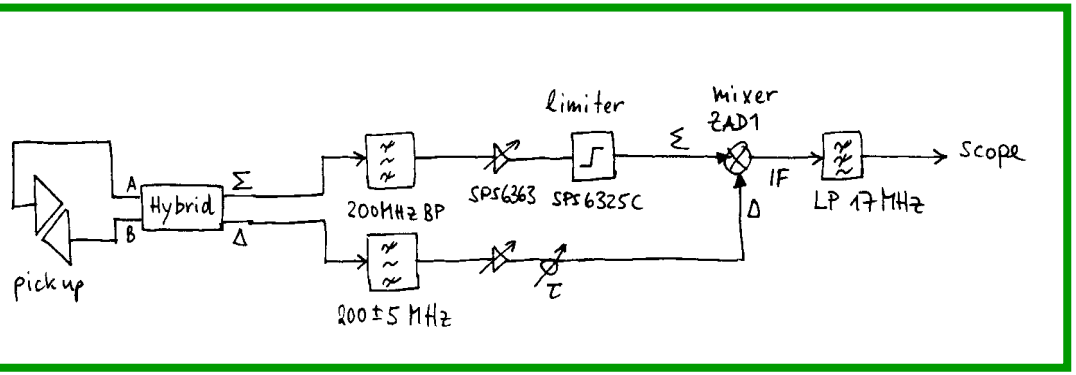


Scale: 1s/div

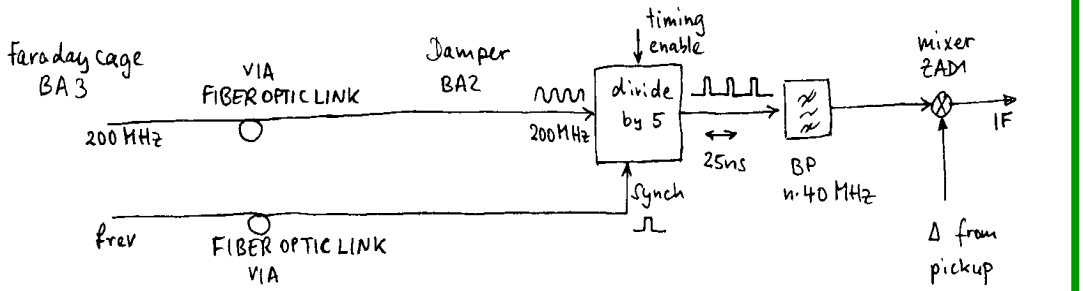
Observation at multiples of the bunch frequency - principle

Due to the 40 MHz bunch repetition rate all envelope information of bunch-to-bunch oscillations repeats every 40 MHz

Mixing of sum and difference signal



Mixing of difference signal with beam synchronous RF



Observation at multiples of the bunch frequency – always clean signal !

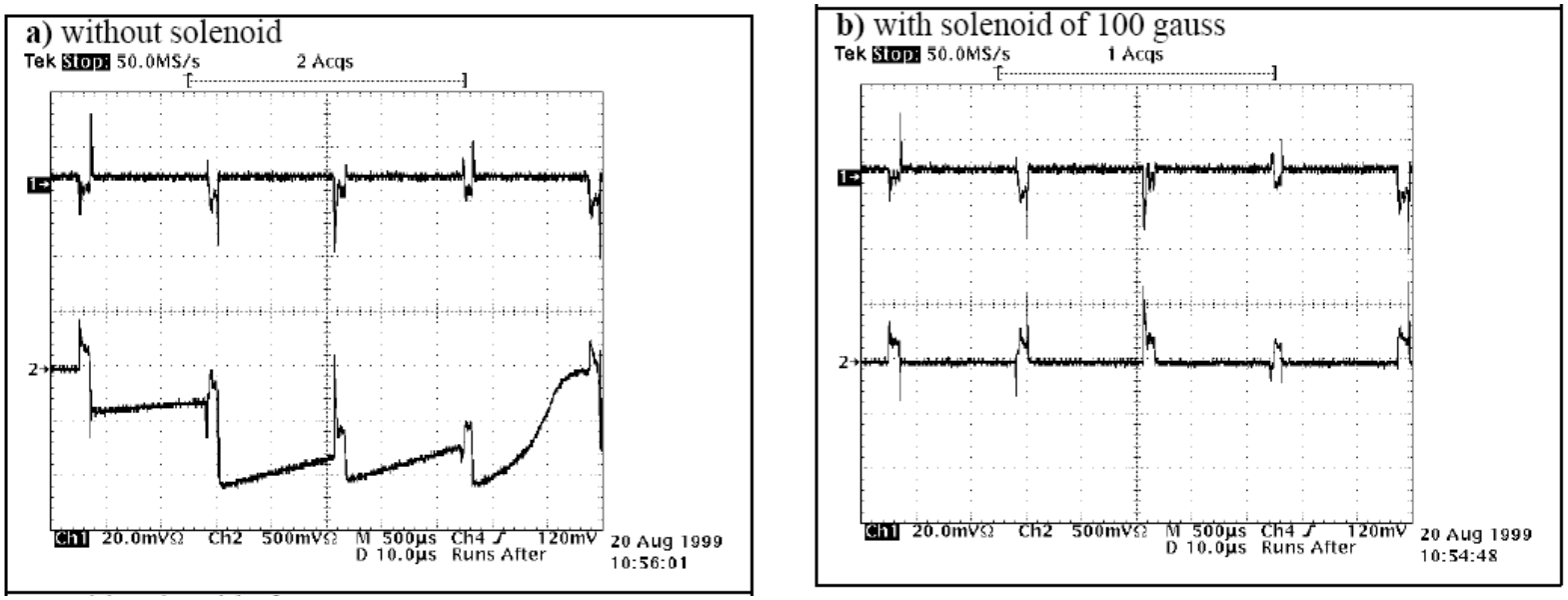


Figure 7: Comparison of base-band signal with high impedance FET amplifiers (bottom traces) and 200 MHz detection by mixing Σ and Δ signals (top traces) of a horizontal pick-up with and without solenoid. The 200 MHz detected signal is "electron-cloud free".

Evolution in 1999

9-12/98 base-line jumps of pick-up signals were not identified as problem

6/99 base-line jumps recognized as problem, investigations started
searched for correlations (beam and machine parameters)
Are the pick-ups charging up?

7-8/99 frequent accesses in the tunnel to install and modify hardware:
bias tests, PU grounding, disconnect MOPOS, PU adapter, diodes
clear threshold visible, effect only seen with LHC type beam,
improving vacuum in PU does not help, multi-pacting?

8/99 installation of solenoids, effect can be suppressed in PU
but above 5×10^{12} the field is insufficient

8-9/99 several tests were made that showed that it is only a low frequency effect, signals from 40 MHz onwards are not affected

Summary

- electron cloud effect is visible on electrostatic pick-ups
- in 1999: threshold around 3×10^{12} protons per batch of 81 bunches
- effect is not seen for 5 ns and 130 ns bunch spacing
- small bias voltages can “steer” the flow of electrons
- solenoid field of 100 gauss can suppress the effect (up to 5×10^{12})
- in 1999 damper was not performing correctly due to corrupted PU signals
- effect is not visible at multiples of the bunch frequency
- solution for damper: processing of pick-up signals at (e.g.) 120 MHz