Follow up of the E-cloud instability at the CERN SPS

Riccardo de Maria (BNL, Upton) with...

July 31, 2008

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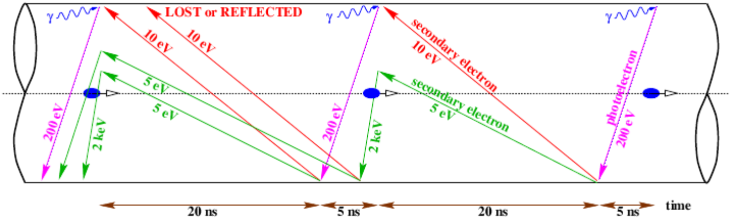
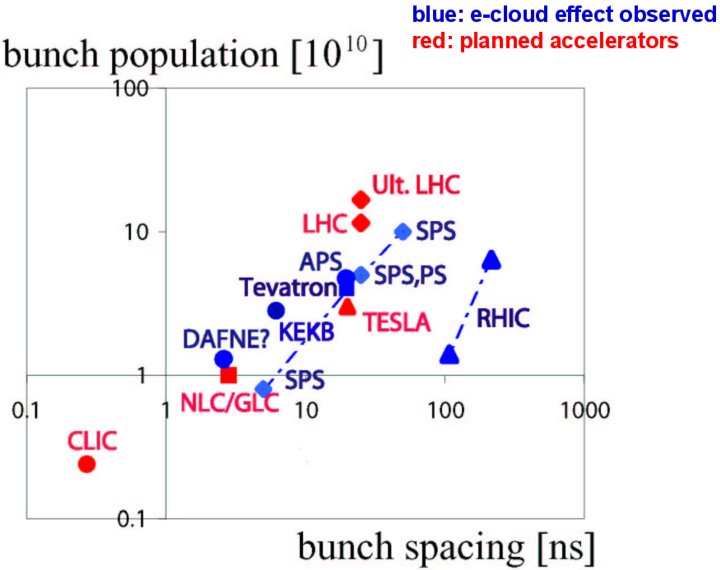
CERN: G. Arduini, E. Benedetto, G. Kotzian, W. Hoefle, E. Metral, G. Rumolo,
LBNL: J. Byrd, M. Furman, J. Vay, J. Thompson,
SLAC: J. Fox

E-cloud [1]



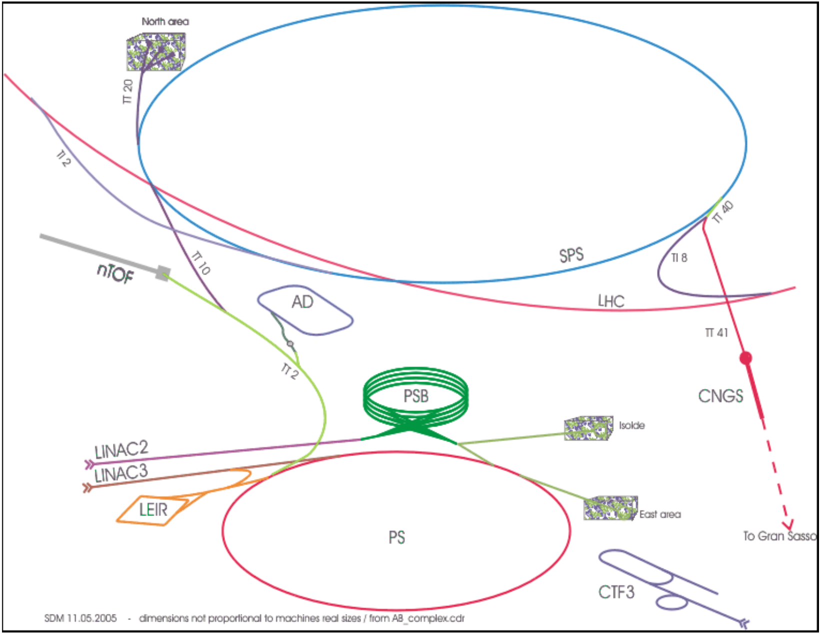
[1]F. Ruggiero, Electron Cloud in the SPS - Summary, presented at Chamonix X

E-cloud in accelerators [2]

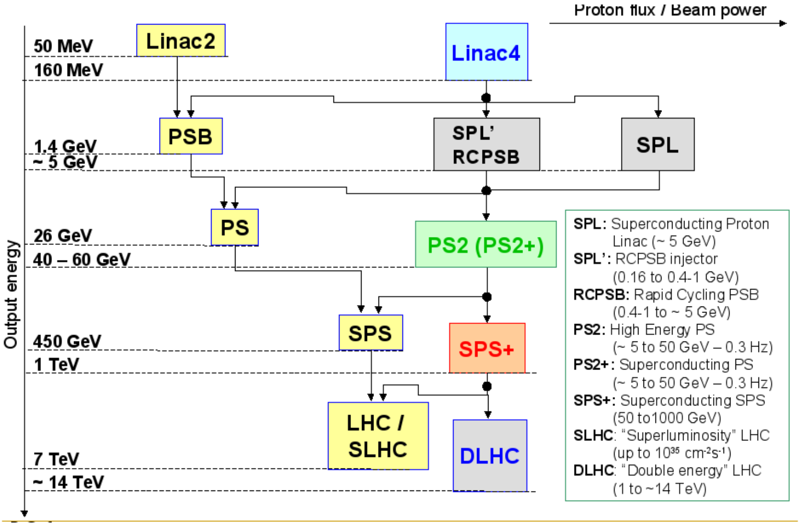


[2] F. Zimmermann, GSI Meeting, 2006

CERN accelerator complex



CERN proton injector chain (and upgrade)



SPS parameters

Momentum [GeV/c]	$26, 450$
Tunes	$Q_V = 26.18, Q_H = 26.13$
Gamma Transition	22.8
Max n. of batches	4
bunches per batch	72
Nominal bunch intensity	$1 \cdot 10^{11}$
Bunch spacing [ns]	$24.97, 24.95$
Full bunch length	$4, < 2$
Batch spacing [ns]	$224.7, 224.6$
r.m.s tran. emittance [um]	$< 3, < 3.5$
r.m.s long. emittance [eV s]	0.350.65

E-cloud: evidences

Observed since 1999, first as charge up of the feedback pick-ups during the passage of the LHC bunch train. This effect could be reduced by a weak solenoidal field. [3]. A solenoidal field of 100 gauss suppressed the effect of 6.25e10 ppb for 80 bunches spaced by 25ns.

A pressure increase by 3 to 60 in most parts of the SPS ring, even for a duty cycle of 3% [4].

A fast instability at injection (ECI), or after excitation, which affects the trailing bunches of a bunch train, and can result in beam loss and emittance growth. The instability rise time at the end of the LHC bunch train is only about 20 turns. [5]

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[3] W. Hoefle, Observation of the Electron Cloud on Pick-Up Signals in the SPS, presented at Chamonix X

[4] J. Jimenez, Electron Cloud: SPS Vacuum Observations with LHC Type Beams, presented at Chamonix X

[5] G. Arduini, Observations in the SPS: Beam Emittance, Instabilities, presented at Chamonix X

E-cloud instability

The behaviour of the electron cloud in the arcs (70%) determines the characteristics of the ECI ($N_{th} > 0.8 \cdot 10^{11}$).

Horizontal ECI: coupled bunch instability, rise time 40 turns, detuning, energy dependence (τ increase with energy) [6].

Vertical ECI: single bunch, (τ 500 at .3e11 , 100 at .5e11 , 40 at 1.1e11) [7].

Emittance growth (30% in 40 s) [8].

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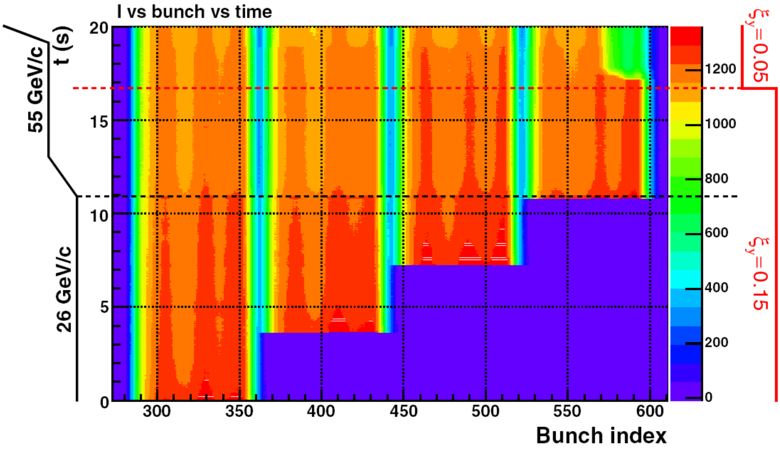
[6] G. Arduini, http://mgt-lhc-machine-advisory-committee.web.cern.ch/mgt-lhc-machine-advisory-committee/lhcmac15/OpenSession/garduini.pdf

[7] G. Rumolo et al. Dependence of the Electron-Cloud Instability on the Beam Energy, Phys. Rev. Lett. 100, 144801 (2008)

[8] E. Benedetto et al Incoherent Effects of Electron Clouds in Proton Storage Rings, Phys. Rev. Lett. 97, 034801 (2006)

Past measurements [9]



[9]G. Rumolo et al. Dependence of the Electron-Cloud Instability on the Beam Energy, Phys. Rev. Lett. 100, 144801 (2008)

Perspective: cures [11]

Reduce number of electrons: surface coating, surface scrubbing (very effective in the SPS, SEY from 2.3 to 1.5 [10]).
Suppress/modify electron propagation:bunch length, clearing electrodes, special filling schemes.
Raise instability thresholds: large chromaticity, high frequency feedback.

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[10] E. Metral, https://ab-div.web.cern.ch/ab-div/Meetings/APC/2008/apc080718/EM-APC-18-07-2008.pdf

[11] Zimmermann 2003: http://wwwslap.cern.ch/collective/electron-cloud/zimmermann/thd.pdf

Feedback

A feedback system has been proposed by J.Byrd, J.Fox, M. Furman within the LARP program and followed up at CERN by G. Arduini, W. Hofle, E. Metral, G. Rumolo.

A successful implementaion will allow the SPS provide bunches with intensity larger than nominal and contribute to the LHC luminosity to reach the ultimate luminosity and beyond.

Feedback can be implemented on a shorter timescale than new vacuum chambers, possibly also less expensive than new vacuum chambers.

Feedback challenges [12]

Emittance growth may be dominated by incoherent effects which cannot be damped.

Required power is excessive due to the fast growth rates, i.e. a FB might even require distributed kickers for stability if growth rates are faster than 10 turns.

Feasible but not robust enough:

- adjustment of loop delay will be very delicate for the high frequency high bandwidth system (GHz !),
- mix-up with longitudinal motion possible if bunches not absolutely stable longitudinally
- Suppression of common mode signal crucial to avoid amplifier saturation and a good usage of the dynamic range available (digitization)
- we may require to split the system into several bands in order to be able to cover the entire frequency range, overlap of bands becomes delicate

[12] W. Hoefle, private communication

Program for 2008

A measurement campaign has been setup up to:

- study the dynamics of the instability,
- study the main parameters that influence rise time and bandwidth
- identify (if possible make sense) the main parameter raise time and bandwitdh,
- allow design a feedback system: pickup, signal processing, power system, kickers.

In parallel measurements are being supplemented by simulations (HEADTAIL G. Rumolo and J. Thompson)

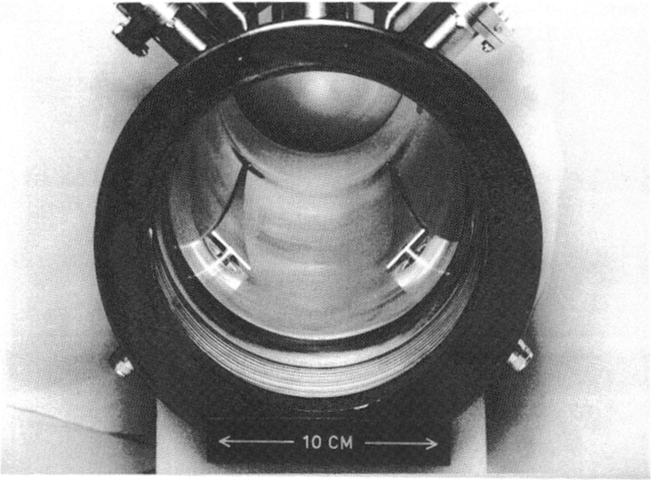
Challenges

The goal of the measurements campaign is study with the best possible accuracy the physics of the instability.
The main challenges are:

- generate the instability in a stable, controlled and reproducible way,
  - a machine well scrubbed with 4 batches and inject a fifth batch beam will be exactly usntable at injection of the fifth batch (this has been used in June)
  - shorten the bunches via the RF voltage to push a stable beam above the threshold (planned in August)
  - lower the chromaticity (tried in the past)
- acquire the transverse beam position with a fine resolution in the bunch with great accuracy and precision.

Exponential stripline

An exponential stripline pickup has been used [13]



[13] T. Linnecar, The high frequency longitudinal and transverse pick-ups in the CERN SPS accelerator, 1979

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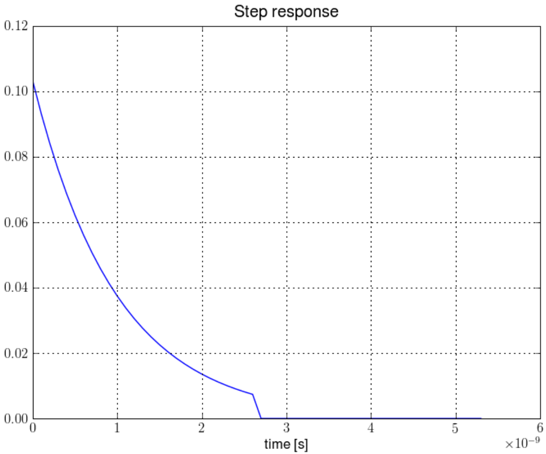

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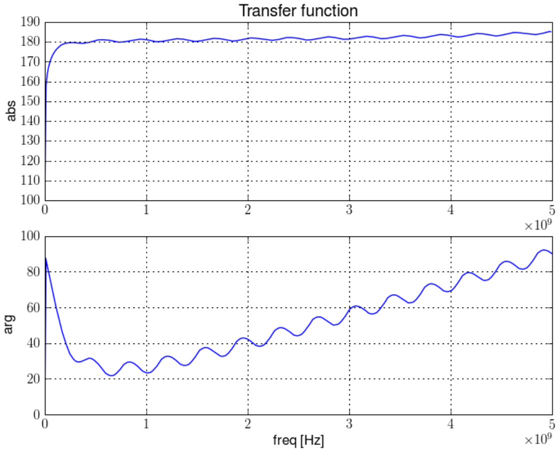

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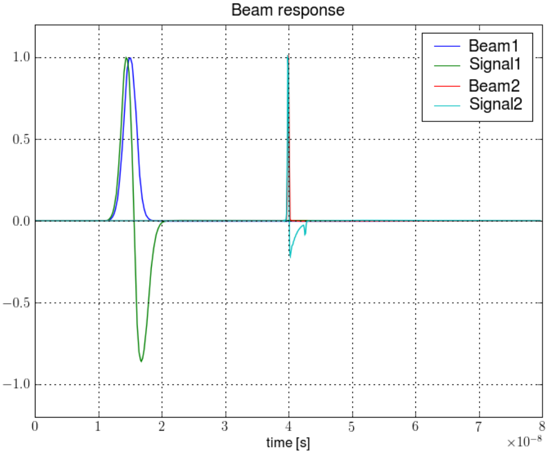
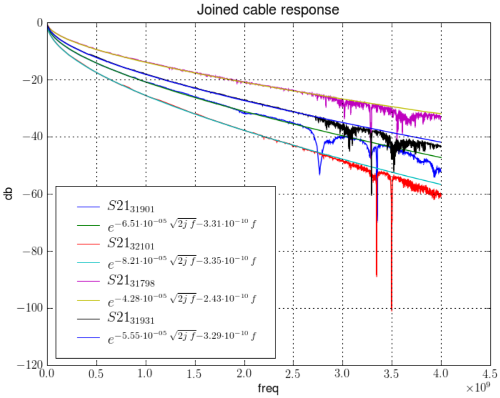


[13] T. Linnecar, The high frequency longitudinal and transverse pick-ups in the CERN SPS accelerator, 1979

Coaxial cable

The SPS is underground and at present the pickups are accesible only thru 7/8" air-filled coaxial cables (an optical link could be installed during the shutdown).



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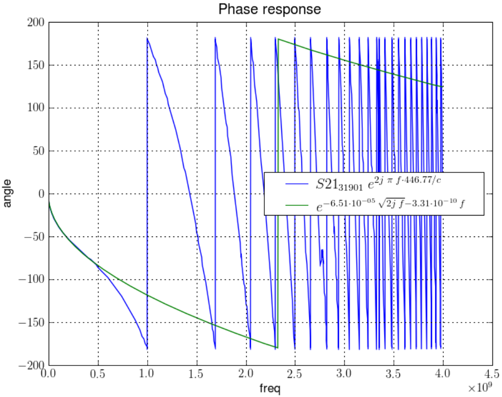

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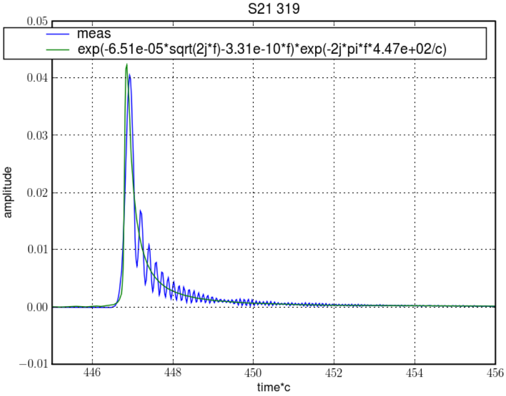
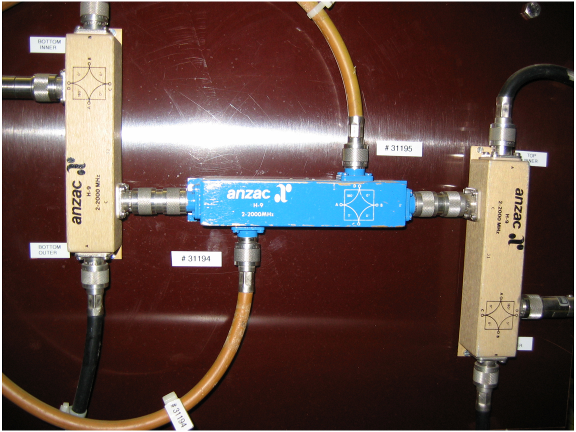


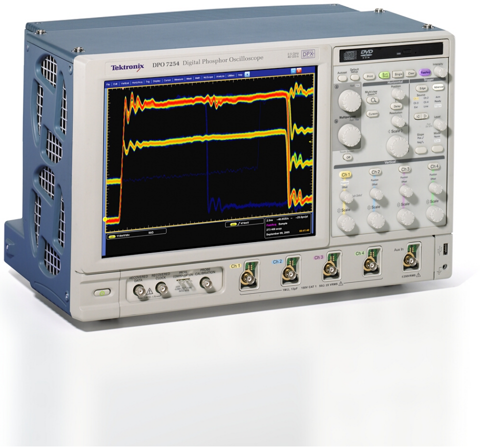
Present setup: Pickup

Present setup: Hybrids

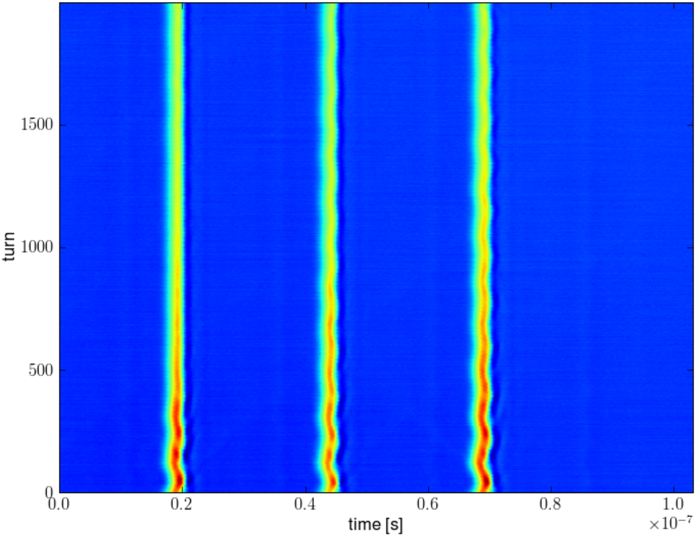


Present setup: Scope

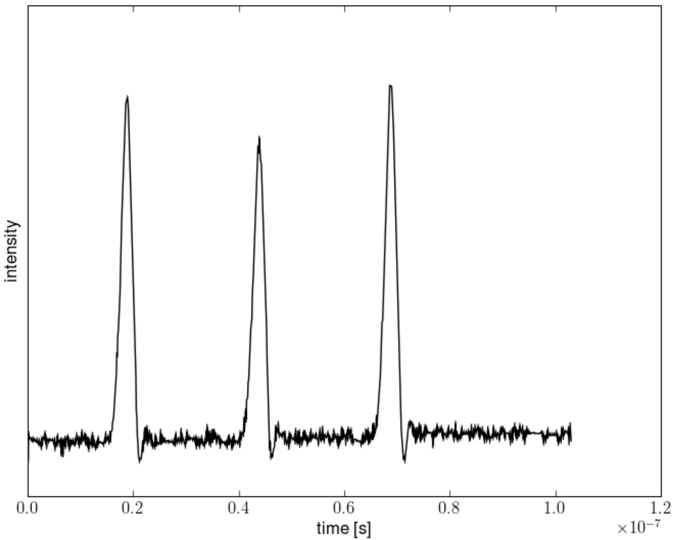
Tek DPO7254, 40G/s 1ch, 20G/s 2ch, 10G/s 4ch, 400MS.



First measurements: last bunches in the last batch (intensity)



First measurements: intensity at the first turn



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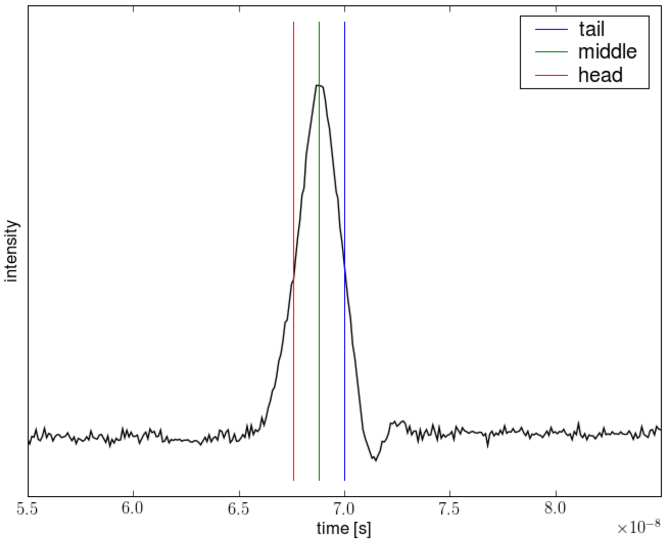

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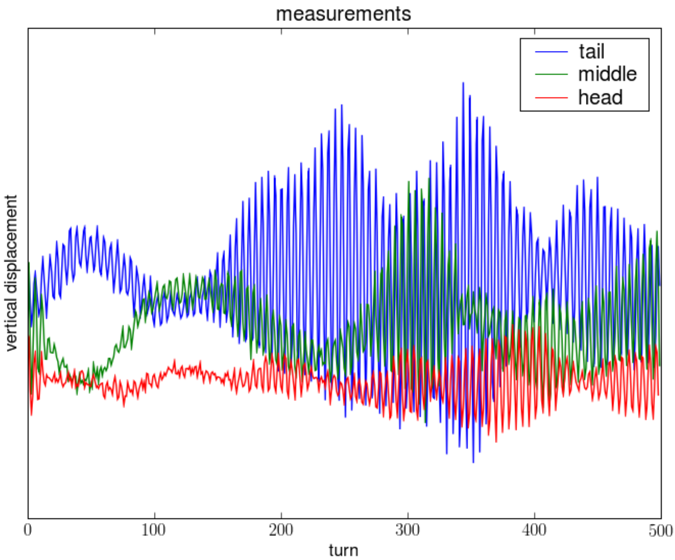

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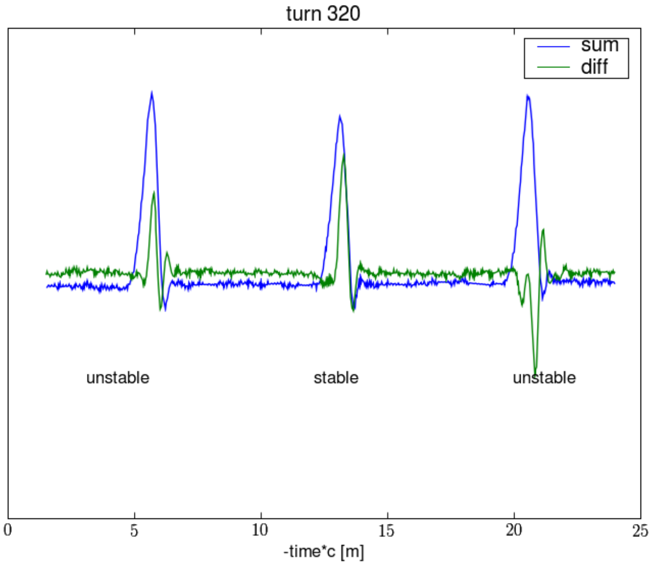
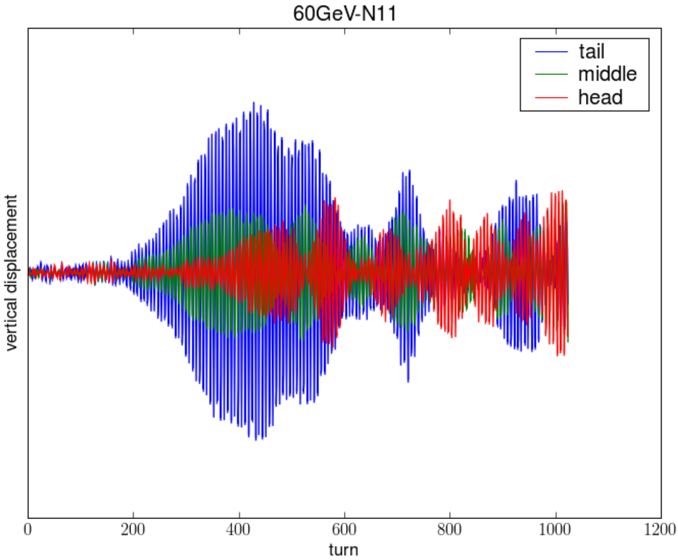


HEADTAIL Simulation [14]



[14] Data from G. Rumolo

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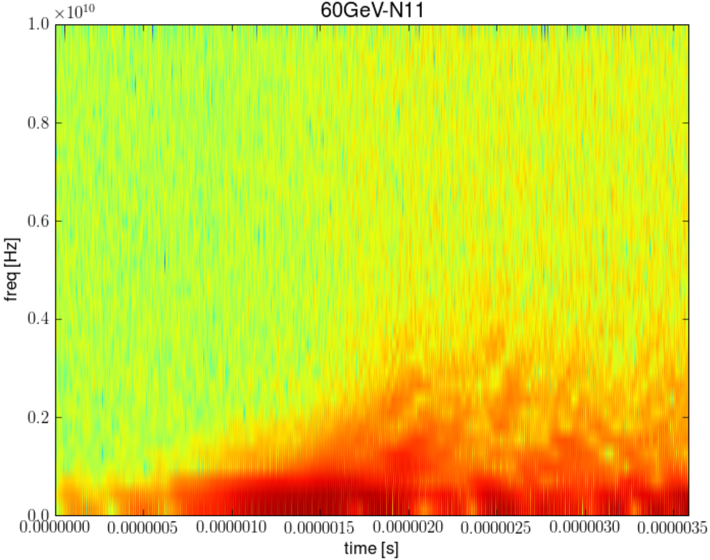

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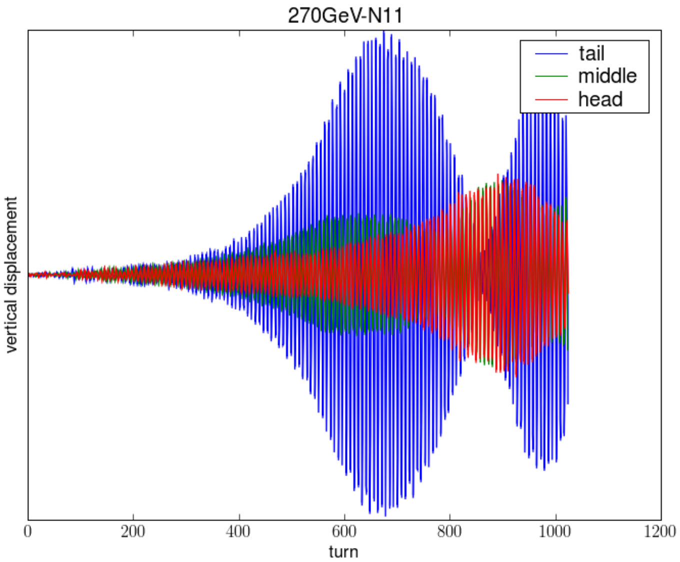

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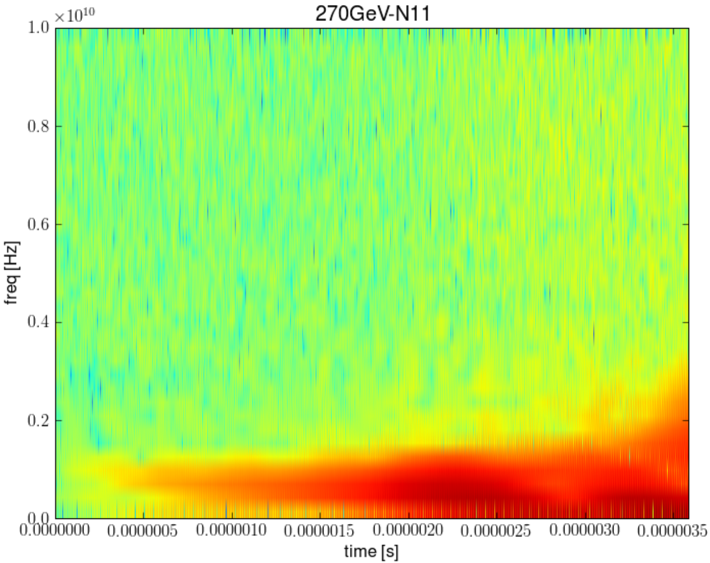

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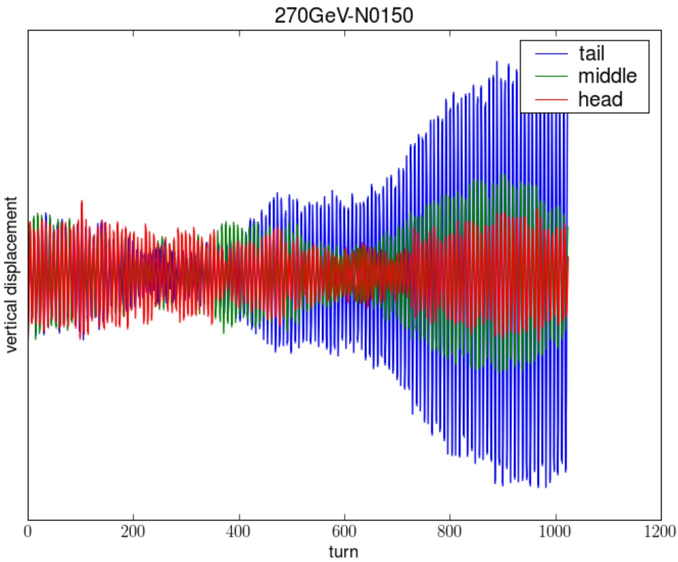

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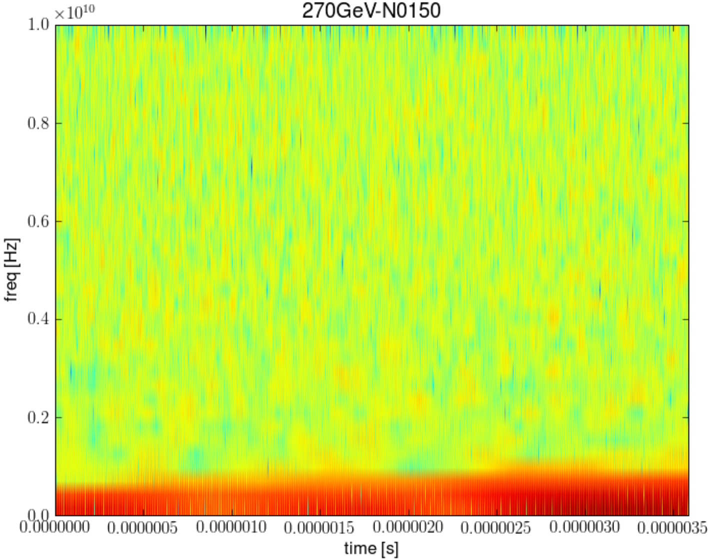

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Conclusion

The e-cloud has been recognized as a limitatating factor for intense positively charged beams.

In the SPS it limits the maximum bunch intensity to nominal value for the LHC beam and it represents a limitation for the LHC ultimate performance and beyond.

Extensive studies have been performed since 1999 to identify and study the e-cloud physics, limiting effects, possible cures.

In 2008 the campaign continue to assess the feasibility of a feedback system to damp the e-cloud instability.

First measurements has been done using a wideband stripline.

The results are encouraging but few issue related to the acquisition need to be addressed.

New measurements in dedicated machine studies are going to be performed in August and in the following months.

References

For a large and updated list of reference refer to:
http://ab-abp-rlc.web.cern.ch/ab-abp-rlc-ecloud/
For some of the results and data presented here refer to:
http://rdmcamp.com/ogg/SPS/

Aknowledgment

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