Electron Cloud and Scrubbing Studies for the LHC

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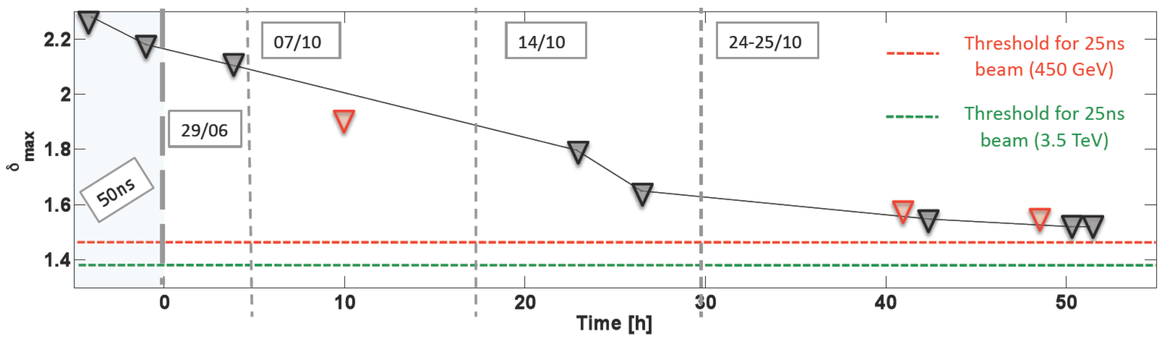
Abstract

Electron cloud (EC) build-up resulting from beam-induced multipacting is one of the major limitations for the operation of the LHC with beams with close bunch spacing. Electron clouds induce unwanted pressure rise, heat loads on the beam screens of the superconducting magnets and beam instabilities. Operation with bunch spacing of 50 ns in 2011 and 2012 has required decreasing the Secondary Electron Yield of the beam screens below the multipacting threshold for beams with this bunch spacing. This was achieved by continuous electron bombardment induced by operating the machine with high intensity beams with 50 and 25 ns spacing during dedicated periods at injection energy (450 GeV) and at top energy (3.5 and 4 TeV). The evolution of the Secondary Electron Yield during these periods, in different sections of the machine, can be estimated by pressure rise, heat load and by bunch-by-bunch RF stable phase measurements. The experimental information on the scrubbing process is discussed and a possible "scrubbing strategy" to allow the operation with 50 ns and 25 ns beams after the Long Shutdown in 2013-2014 is presented.

The 2011 experience

SEY evolution in the arc dipoles



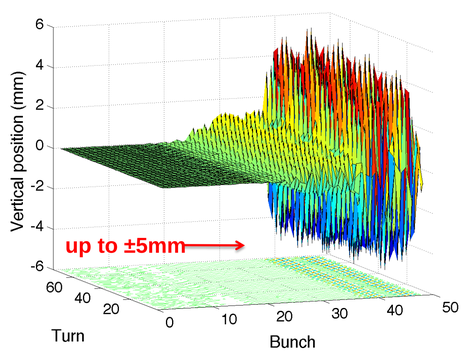
Estimation obtained comparing measured heat load against PyECLOUD simulations

The EC build up with 50 ns beams could be efficiently suppressed in most of the machine by means of an initial scrubbing run with 50 ns beams.

Tests with 25 ns beams showed much more severe EC effects. Transverse instabilities were observed, affecting the trailing bunches of the injected trains. These could be avoided using high chromaticity settings, allowing first scrubbing tests with several bunches (up to 2100) with 25 ns spacing.

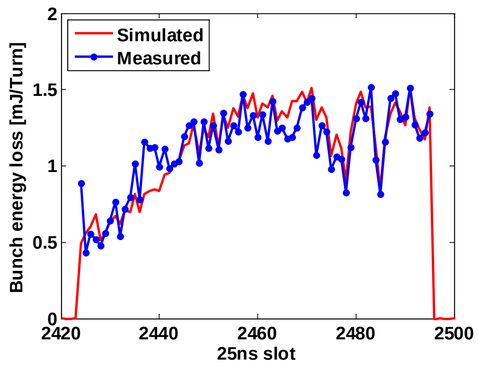
A considerable amount of scrubbing could be achieved, leading to an estimated final value of δ_{max} of 1.52. At this stage the beams exhibited much reduced degradation although the heat load in the arcs, bunch by bunch energy loss, lifetime and emittance measurements still indicated the presence of a significant EC in the LHC.

EC driven instability



Transverse feedback pickup measurements

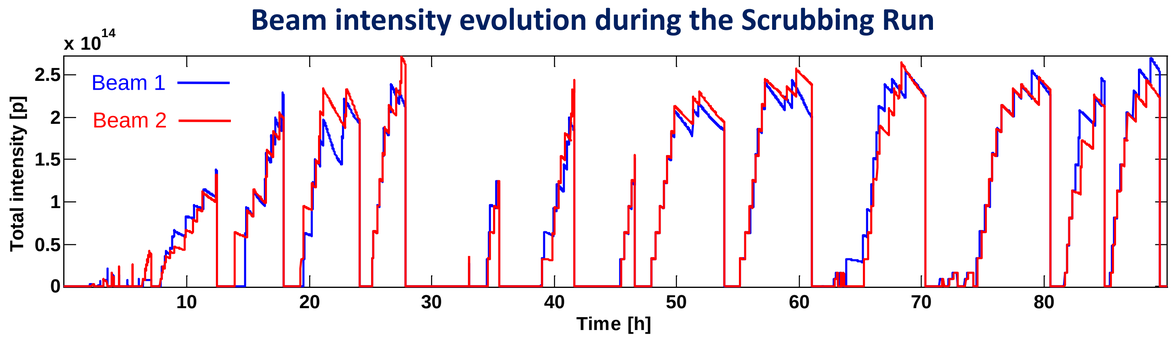
Bunch by bunch energy loss



Simulation and stable phase measurements

25 ns beams in the LHC in 2012

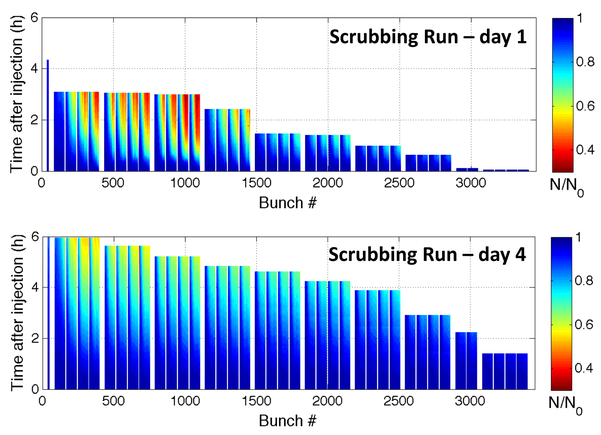
Beam intensity evolution during the Scrubbing Run



A Scrubbing Run with 25 ns beams at injection energy was carried out between 6 and 10 December. The machine could be filled several times with record beam intensities (up to ~2.7x10^{14} p), maintaining a significant scrubbing dose all along the scrubbing period. An evident improvement could be observed both on the heat load in the arcs and on the beam quality during the first 60 - 70 hours, while later the scrubbing process significantly slowed down.

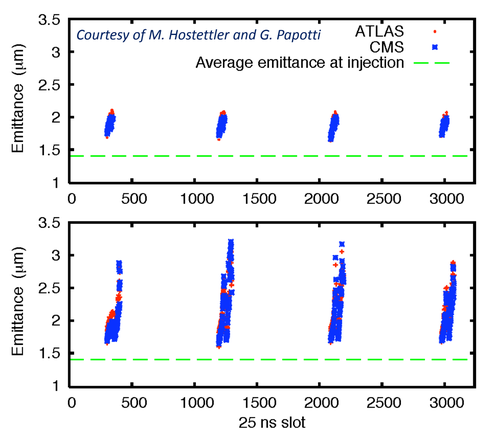
The achieved improvement was sufficient to allow machine studies and a pilot physics run with 25 ns beams at 4 TeV. Probably due to photoelectrons, at 4 TeV the heat load measured in the arcs was significantly enhanced with respect to the value measured at 450 GeV. Notwithstanding this, thanks to the increased beam rigidity at 4 TeV, the beam quality during the high energy stores did not exhibit any signs of further degradation that could be attributed to EC.

Bunch intensity



Values normalized to the injected intensities

Transverse emittance

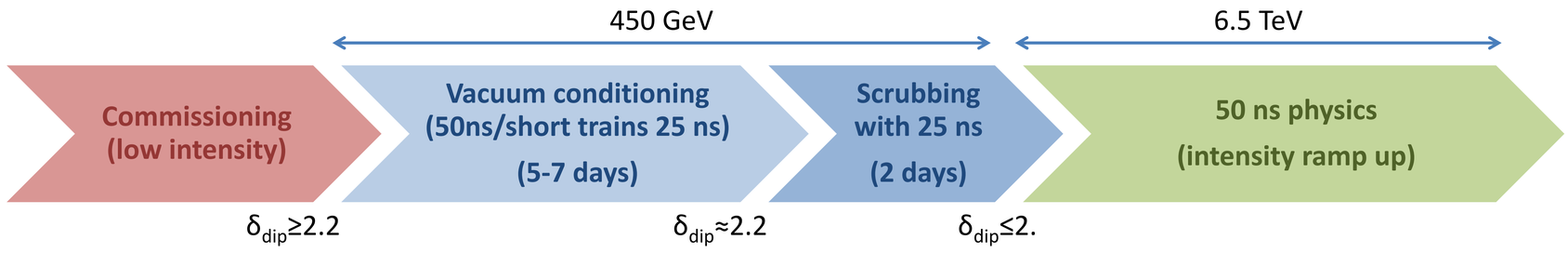


Estimation from luminosity measurements during the 25 ns pilot physics run

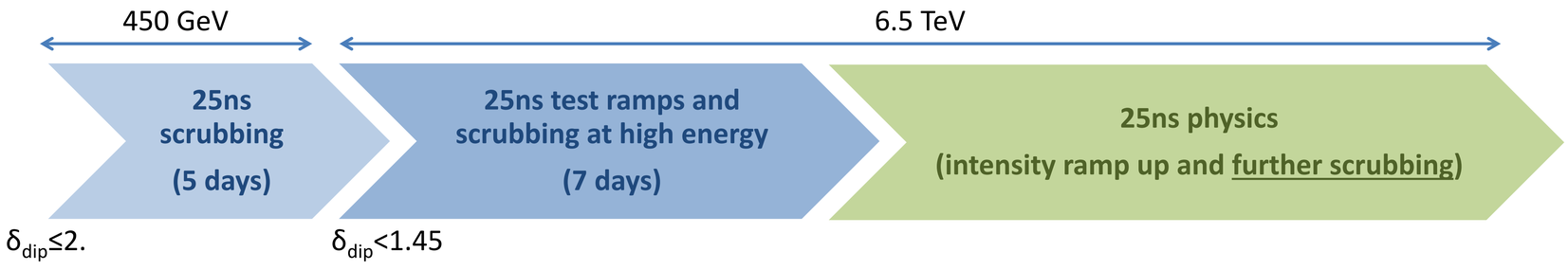
Scrubbing strategy for operation restart in 2015

Requirements for operation with 50 ns beams:

After the 2013-14 Long Shutdown, the Secondary Electron Yield of the beam screen in the arcs will likely be reset to values higher than 2.3, as it was before the 2011-2012 machine scrubbing.



Further requirements for operation with 25 ns beams:



According to the 2012 experience, the proposed scrubbing run(s) will not completely suppress the EC in the LHC. Further scrubbing will have to be achieved during the physics run implying a slow down of the intensity ramp-up process due to heat load, emittance blow up and poor lifetime.

References

[1] G. Rumolo et al., "LHC experience with different bunch spacings in 2011 (25, 50 & 75 ns)" in Proceedings of LHC Performance Workshop Chamonix 2012 (2012, Chamonix, France)
[2] H. Bartosik et al., "Benchmarking of Instability Simulations at LHC", in Proceedings of ECLOUD12 (2012, Isola d'Elba, Italy)
[3] J. Esteban Muller et al., "Synchronous Phase Shift at LHC", in Proceedings of ECLOUD12 (2012, Isola d'Elba, Italy)
[4] G. Iadarola et al., "Electron cloud and scrubbing in 2012in the LHC" in Proceedings of LHC Beam Operation workshop (2012, Evian, France)