Ultimate LHC Beam

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Acknowledgements: K. Hanke, S. Hancock, E. Métral, B. Mikulec, G. Rumolo, E. Shaposhnikova, B. Spataro (INFN-LNF), R. Steerenberg

Outline

- The Ultimate LHC beam
- PSB limitations
- PS limitations
- SPS limitations
- Summary

Ultimate vs. Nominal LHC beam

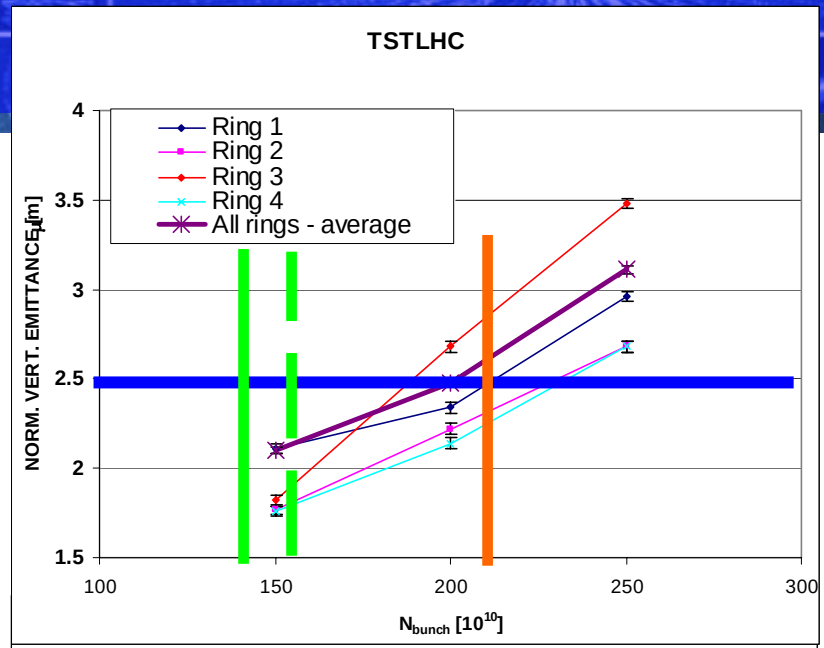
	PSB@inj	PSB@extr	PS@inj	PS@extr	SPS@inj	SPS@extr
p [GeV/c]	0.31	2.14	2.14	26	26	450
K [GeV]	0.050	1.4	1.4	25.08	25.08	449.06
T_{rev} [μs]	1.67	0.572	2.29	2.1	23.07	23.05
Q (H/V)	4.3/4.45	4.2/4.2	6.22/6.25		26.13/26.18	
γ_{tr}	4.15		6.11		22.83	
bunches/ring	0-1	0-1	1-6	1-6x12 1-6x4	2-4×12-72 2-4×4-24	2-4×12-72 2-4×4-24
N_b [10^{11} p]	13.8 20.4	13.8 20.4	13.8 20.4	1.15 1.7	1.15 1.7	1.15 1.7
ΔT_{bunch} [ns]	-	-	326.88	24.97	24.97	24.95
τ_b [ns]	571	190	190	4	4	<2
$\varepsilon^*_{H,V}$ [μm]	-	<2.5	-	<3	-	<3.5
ε_L [eV.s]	~0.7	1.4	1.4	0.35	0.35	<0.8

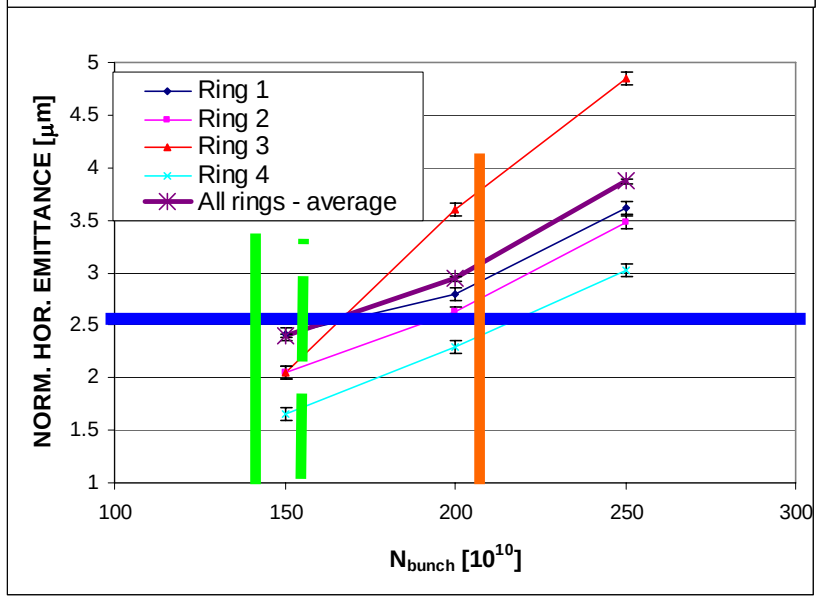
PSB limitations

Space Charge is considered to be the main limitation for:

- LHC beam brightness in PSB. Feasible for the NOMINAL beam in spite of the margin required to account for losses in PS and SPS (dashed line). Not within reach for the ULTIMATE beam.

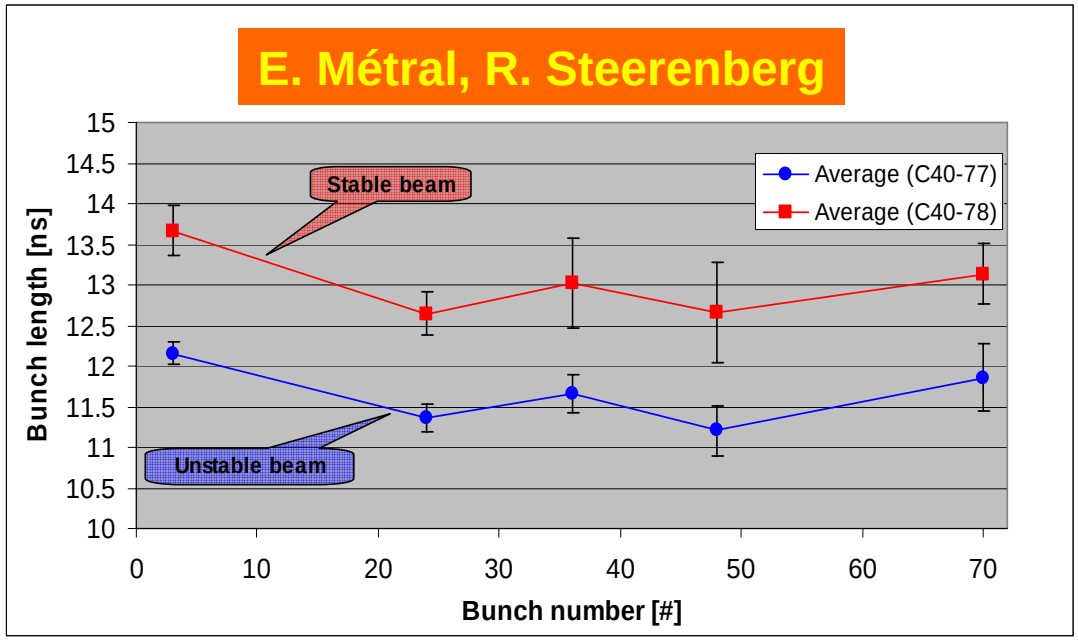
Minimizing the losses in the downstream machines is mandatory!





K. Hanke, B. Mikulec

PS limitations



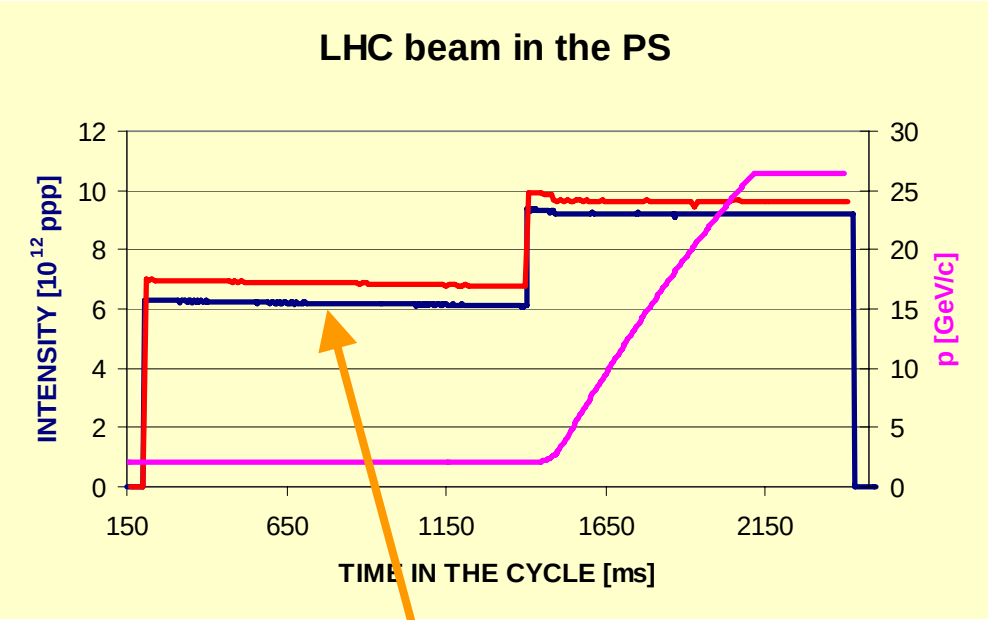
Electron-cloud instability observed for bunches shorter than 12 ns in 2006 for the nominal bunch intensity.

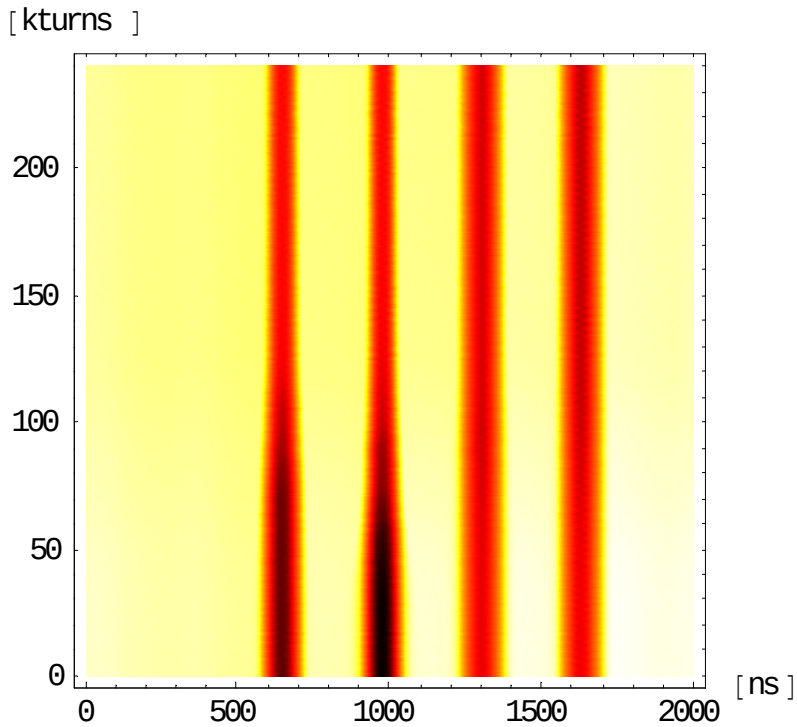
Studies have started to:

- Review the RF gymnastics at high energy
- Commission the transverse feedback
- Study the electron cloud build-up in the PS at extraction

PS limitations

S. Hancock, E. Métral



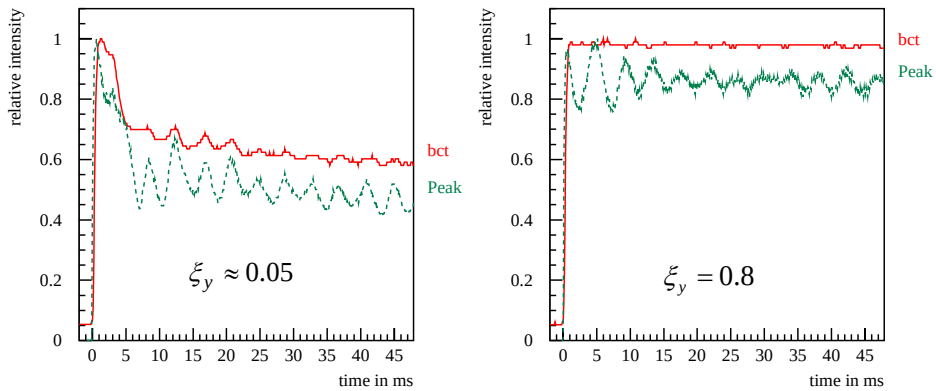


Losses mainly affecting more intense and/or shorter bunches due to space charge driven resonance trapping phenomena.

SPS limitations

E. Shaposhnikova will highlight the challenges for the SPS on Friday.

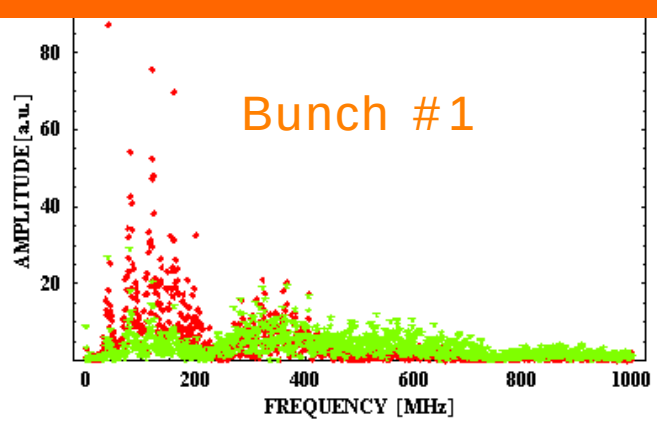
Single-bunch fast vertical instability observed for LHC bunches with low longitudinal emittance (ε_L**~0.2 eV.s < $\varepsilon_{L\ LHC}$ =0.35 eV.s**) for $N_b > 0.6 \times 10^{11}$ p ➔ Driven by Z_{tr} . In 2006 **instability threshold close to ultimate for ε_L =0.35 eV.s.** Cure: large ξ_V ➔ lifetime

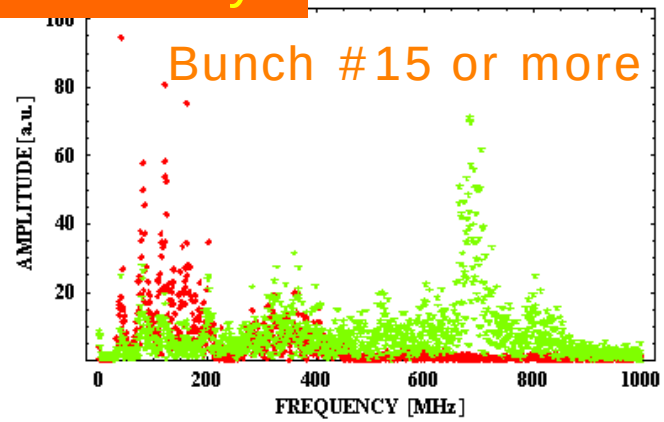


Significant contribution from the kickers (in particular extraction kickers) to the longitudinal impedance but ALL together they seem to contribute to less than 50% of the overall transverse impedance. Studies are ongoing to identify the various contributions and to reduce the impedance of the kickers ➔ E. Métral on Friday

SPS limitations

Vertical Electron Cloud Instability





Σ, Δ

TMCI-like instability (~700 MHz) affecting trailing bunches at injection above the threshold for electron multipacting (typically 0.8-0.9 × 10^{11} p/bunch after scrubbing). Cure: Large ξ_V ➔ Lifetime

ε_H=3.0 ± 0.3 and ε_V= 3.6 ± 0.3 for the nominal LHC beam obtained so far.

- Do we have more efficient methods to suppress the electron cloud? (S. Calatroni, F. Caspers, T. Kroyer, M. Taborelli on Friday)
- How threshold and instability mechanisms scale with energy?
- Simulation and experimental studies ongoing (G. Rumolo on Friday)

Conclusions

The nominal LHC beam is at the performance limit of the LHC injectors:

- space charge in the PSB limits the maximum bunch intensity within nominal transverse emittances to ~75 % of the ultimate bunch intensity

No sizeable margin exists for the operation above the nominal LHC beam in the PS and even more in the SPS.

Studies and experiments have started to address the PS & SPS limitations above the nominal and towards the Ultimate beam but they need to be intensified (*manpower and machine time*).