Instabilities at Transition Crossing in the CERN PS

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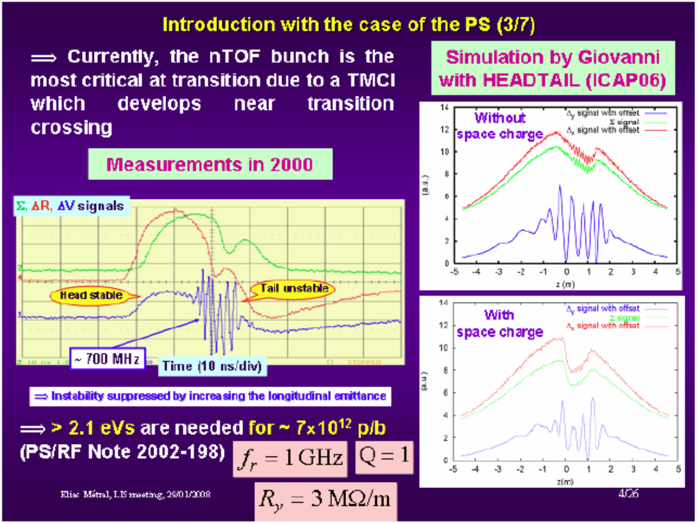
Outline

Motivations



- No broadband impedance
- No space charge impedance
- nTOF PS parameters (E. Métral)
- Transition Energy is constant ($\gamma_t \sim 6.08$)
- Higher orders of momentum compaction factor are not taken into account
- Beam momentum is increased linearly with time:

$$p(t) = p_0 + \left(\frac{\Delta p}{\Delta t}\right) \cdot t$$

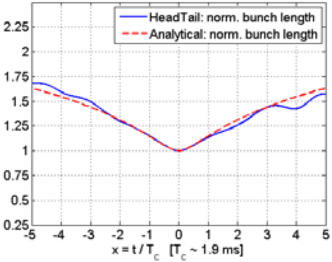
- Here $\left(\frac{\Delta p}{\Delta t}\right) = 46\ \mathrm{GeV/c/sec}$

	PS nTOF
R [m]	100
ρ [m]	70
Bdot [T/s]	2.2
Vrf [kV]	200
h	8
α_p	0.027
ϵ_L [eVs]	2/2.3/2.5
Bunch area A (Dieter's units)	0.051/59/64
N_b [10^{10} p/b]	800
ϵ_t (1σ, norm.) [μm]	5
β_t average [m]	16*
Pipe [cm × cm]	3.5 / 7
Q_t	6.25

Elias Métral, LIS meeting, 27/01/2003

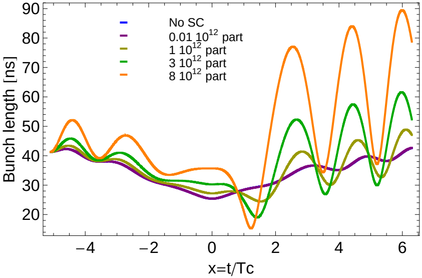
From Benoit April 2008

Neither Collective Effects nor $\gamma_{tr} - jump$



- Comparison analytical formulas of the normalized bunch length and HEADTAIL simulations with nTOF beam parameters (thanks to Benoit)
- Small oscillations from a numerical noise due to a small mismatch of the beam in the bucket.
- T_c is the adiabatic time, 0 is the transition time.

With Space Charge only



- HEADTAIL simulations with @ different intensities.
- Threshold between $0.01 \cdot 10^{12}$ and $1 \cdot 10^{12}$
- Minimum bunch length after transition: Space charge force focusing after transition and defocusing before transition.

Comparison with analytical formulas: thanks to Elias

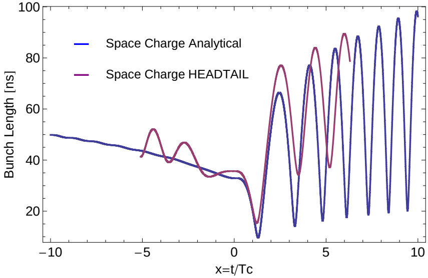
$$\frac{d}{dx}\left(\frac{1}{|x|}\frac{d\tau_b}{dx}\right)+\tau_b+\frac{10^{27}K_{SC}}{\tau_b^2}-\frac{10^{36}|x|S}{\tau_b^3}=0$$

with

$$K_{SC}=\frac{3N_b r_0 E_0 g_0 sgn(\eta)}{\pi^2 h f_0^3 R\gamma_{tr}^2 \hat{V_{RF}}|\cos\phi_s|}$$

$$S=\frac{64\epsilon_l^2\dot{\gamma}T_c^4}{\pi\beta^4\gamma_{tr}^8E_0^2}$$

$$T_c=\left(\frac{\beta^2 E_0\dot{\gamma}_t^4}{4\pi f_0^2 h\hat{V}_{RF}|\cos\phi_s|}\right)^{1/3}$$

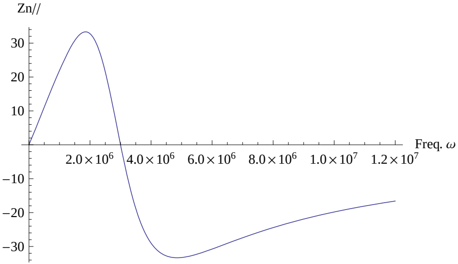


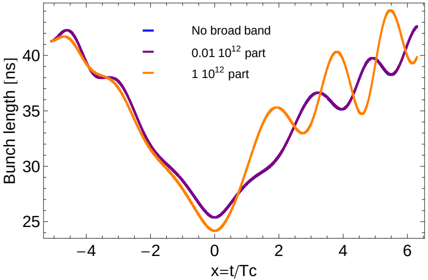
- Good agreement between the analytical formula and the simulations

Broad band impedance model

Shunt impedance $R_s = 30\text{MOhm/m}$ and quality factor $Q = 1$

$$Z^{||}_{BB}(\omega) = \frac{R_s}{1 + iQ\left(\frac{\omega}{\omega_r} - \frac{\omega_r}{\omega}\right)}$$

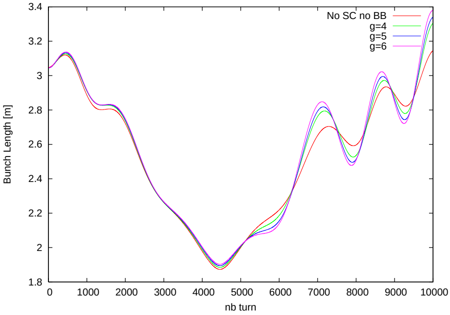




- HEADTAIL simulations with @ different intensities.
- Threshold between $0.01 \cdot 10^{12}$ and $1 \cdot 10^{12}$
- Bunch length is diverging before $3 \cdot 10^{12}$ on the simulation.
- Minimum bunch length at transition.

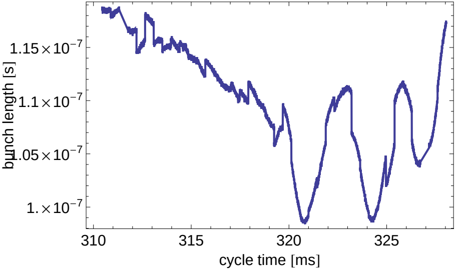
Compensation of the Space charge with the BB impedance

- Adjust the Space charge parameter $g = 0.67 + 2 \cdot \ln\left(\frac{b}{a}\right) \simeq 3.68$ to compensate the broadband impedance.



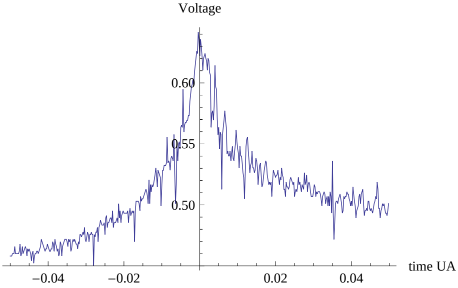
Bunch length measurements on ToF

ToF beam with an intensity $3.5 \cdot 10^{12}$ with Gammajump

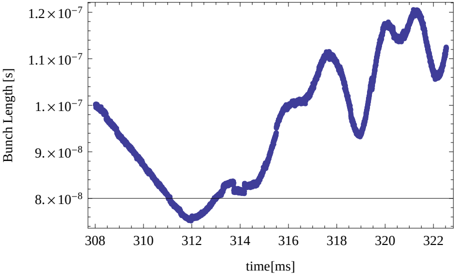


Measurements without Gammajump

Pick detected



Intensity $40 \cdot 10^{10}$, no oscillations.



Outlooks

- Bunch length measurements without Gammajump to find the best broadband impedance model.
- Include the Gammajump in HEADTAIL.
- Transverse instabilities measurements: instrumentation ready (thanks to Joseph)
- MD time is needed or copy the user TOF in a "scratch" user in the Booster.