May Resistive Wall Drive Longitudinal Couple-Bunch Instability?

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ICE short report, Sep 14 2011

Longitudinal Coupled Bunch Instability

- In a simplistic rigid-bunch approximation

$$\ddot{z}_i + \omega_s^2 z_i = \frac{N r_0 \eta c}{\gamma T_0} \sum_j W''((i-j)C/M)(z_i - z_j); \quad i, j = 1, \ldots, M$$

$$W''(s) = -\frac{3C}{4\pi a s^{5/2}} \sqrt{\frac{c}{\sigma}}.$$

- Due to the fast decay of $W''(s)$, only the nearest neighbors have to be taken into account. This yields the growth rate:

$$\tau^{-1} = \frac{N r_0 \eta c}{4\pi\gamma Q_s} W''(C/M) \sin(2\pi l/M); l = 0, 1, \ldots, M-1$$

For LHC

- For many bunches, $M \gg 1$ for $l = \pm M/4$, $\sin(2\pi l / M) = \pm 1$

$$\tau^{-1} = \frac{N r_0 |\eta| c}{4\pi\gamma Q_s} |W''(C/M)|$$

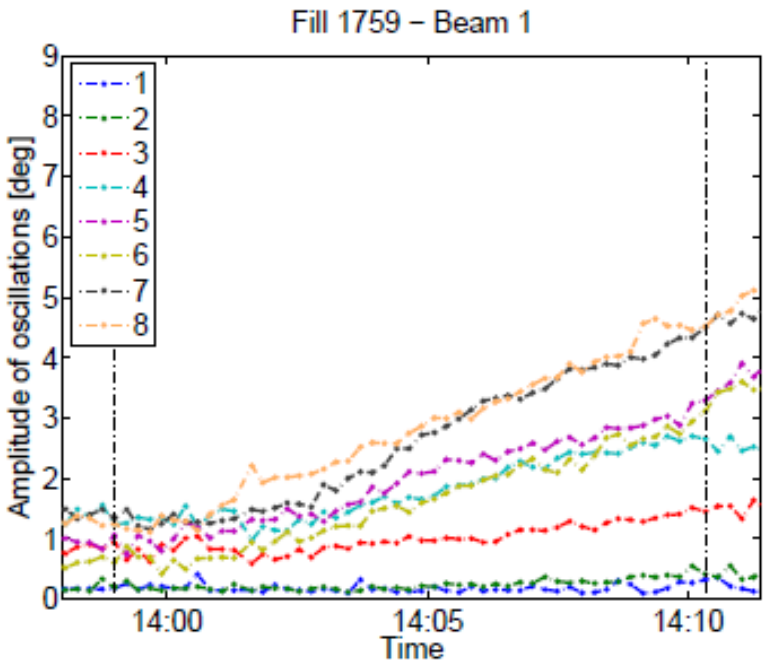
- For LHC parameters at injection, assuming

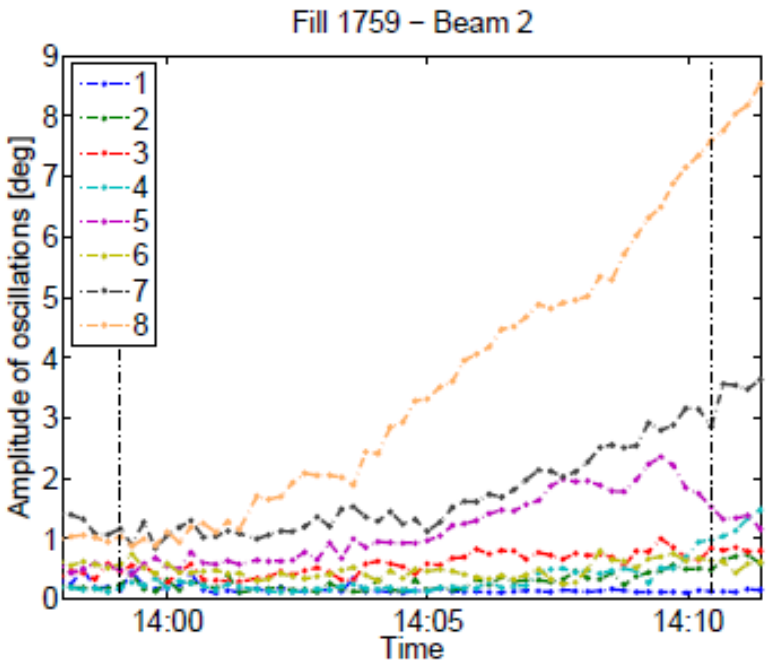
$$V_{\mathrm{RF}} = 16\,\mathrm{MV}, \quad N = 1.1 \cdot 10^{11}, \quad M = 1000,$$

with the resistive wall impedance of copper coating at low-temperature, it gives

$$\tau = 100 \text{ days}$$

That is why no exponential growth was seen:



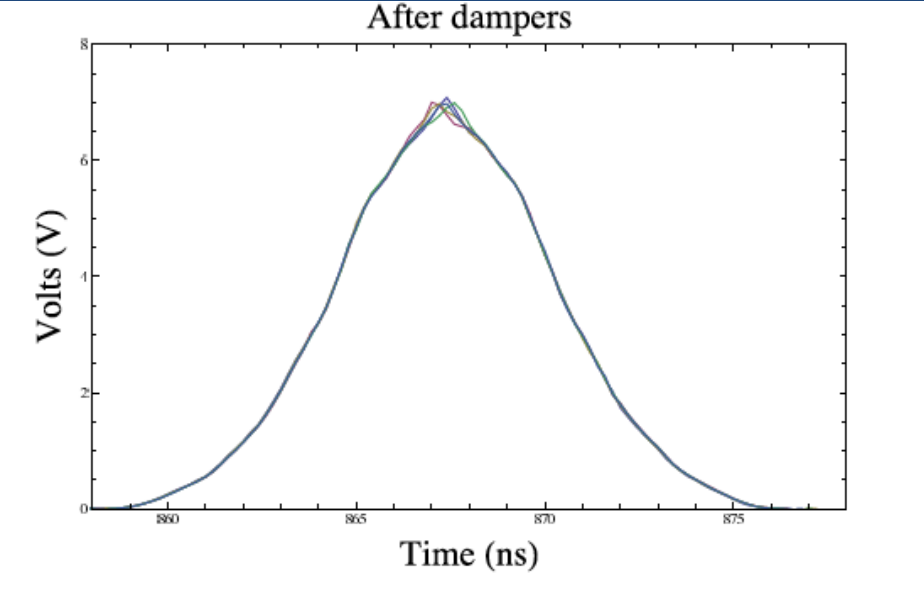


Amplitude of phase oscillations during acceleration cycle for 8 bunches (with different longitudinal emittances) of Beam1 (left) and Beam2 (right). Dashed vertical lines indicate start and end of the ramp.

E. Shaposhnikova et al., Proc. IPAC'11

For the Tevatron

- Due to the same reason, there were no dancing bunches in the Tevatron, where the damper was turned off after being on.



Conclusions

- Couple-bunch resistive wall wake is too week to drive longitudinal couple-bunch instability (LCBI) – for any practical case.

- Since the high-order cavity modes stay normally far from the resonance with the revolution frequency, and have low Q value, they can hardly drive LCBI either.

- Thus, if the fundamental harmonic is properly stabilized, there would be no couple bunch growth rate.