INCREASING THE TMCI INTENSITY THRESHOLD IN THE SPS BY LINEAR COUPLING: HEADTAIL SIMULATIONS

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- **Many thanks to Giovanni for his installation of the code and all his very clear explanations to use it!!!**

⇒ I succeeded to make my first analysis/simulations with HEADTAIL!

- **It is a follow-up of the RLC presentation on 20/01/2006 (same parameters as for the other simulations on the time evolution)**
  - **Interaction with a Broad-Band impedance**
  - **Linear coupling between the transverse planes**
  - **0 chromaticity**
  - **No space-charge**

$$\sigma_t = 0.7 \text{ ns} \qquad R_y = 20 \text{ M}\Omega/\text{m} \qquad Q = 1 \qquad f_r = 1 \text{ GHz}$$

SLIDE OF 20/01/06

- **Round chamber** $N_b^{th,x} = N_b^{th,y} \approx 2.8 \times 10^{10}$ p / b

- **Flat chamber** $N_b^{th,y} \approx 3.5 \times 10^{10}$ p / b $\quad 2.8 \times \frac{12}{\pi^2} = 3.4$

  $N_b^{th,x} \approx 8 \times 10^{10}$ p / b $\quad 2.8 \times \frac{24}{\pi^2} = 6.8$

⇒ **The intensity threshold is increased in a flat chamber by**

- The vertical Yokoya factor in the V-plane

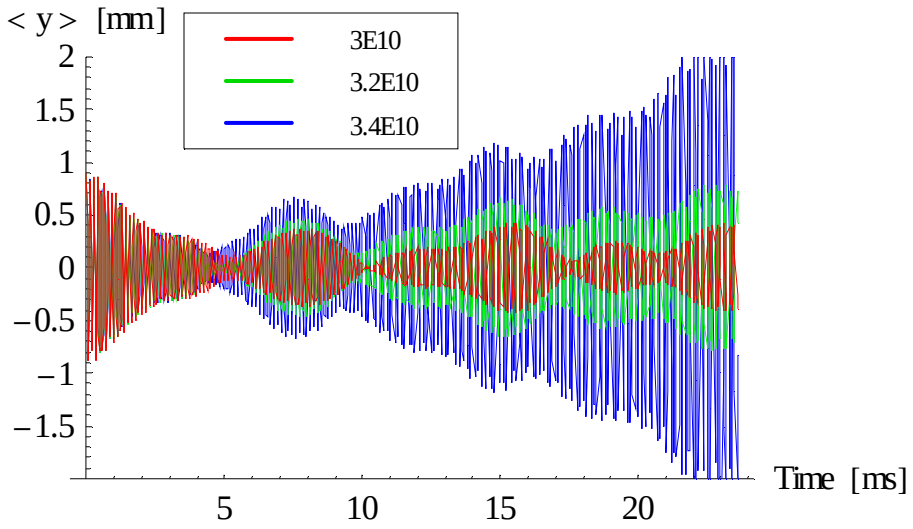
- Slightly more than the horizontal Yokoya factor in the H-plane (it is not suppressed and the effect of the detuning impedance, if any, seems small and in the plane of higher threshold)

⇒ **This is the starting point for our study on the effect of linear coupling**

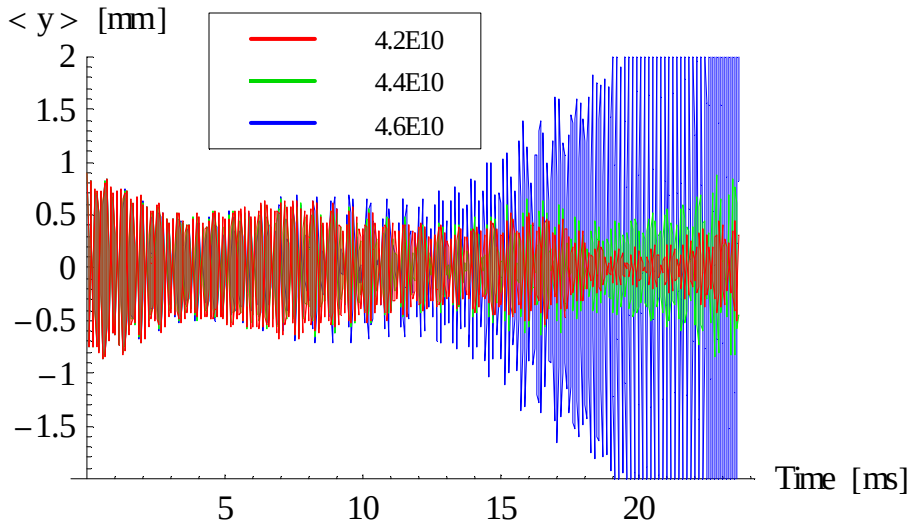
NEW RESULTS WITH THE HEADTAIL CODE

- **Linear coupling introduced**
- **Proposed working point** $Q_x = 26.180$ $Q_y = 26.185$

$N_b^{y,without} \approx 3.3 \times 10^{10}$ p / b



$N_b^{y,with} \approx 4.5 \times 10^{10}$ p / b



⇒ **Gain in intensity of** $N_b^{y,with} / N_b^{y,without} \approx 36\%$

- **Reminder: For instance, to go from nominal to ultimate, 48% are needed**

COMPARISON WITH A PREVIOUS ANALYTICAL PREDICTION (1/2)

- Linear coupling is used in the PS since many years to damp a head-tail instability (First paper published with this idea + analytical predictions in 1997)
  - In 1989, a coherent instability of the quadrupolar mode type driven by ions from the residual gas has been observed by D. Mohl *et al*. in the CERN-AA and successfully cured by adjusting both tunes close to 2.25
  - In 1993, a single-bunch instability of the dipolar mode type driven by the resistive wall impedance has been observed by R. Cappi in the CERN-PS and "sometimes cured" by adjusting both tunes close to 6.24

COMPARISON WITH A PREVIOUS ANALYTICAL PREDICTION (2/2)

- **Idea to use linear coupling also for TMCI (paper published in 1999)**
- **Also proposed for the "TMCI-like" instability due to e^- cloud as the horizontal "impedance" is much smaller than the vertical one in 2/3 of the SPS, i.e. in the dipole-field regions (Ecloud'02 workshop)**

$\Rightarrow$ Could replace the use of chromaticity or help to reduce the value of the chromaticity (which is better for the lifetime)

Approximate gain in intensity (if same chromaticities, same tunes and $Z_y = \lambda\, Z_x$ **)** $\Rightarrow$ $$N_b^{y,with} = N_b^{y,without} \times \frac{2\,\lambda}{\lambda + 1}$$ **(see Ecloud'02 workshop)**

If, as in the present case, $\lambda \approx 8 / 3.5 = 2.28$ $\Rightarrow$ **Gain in intensity of 39%**

OBSERVATIONS OF THE BENEFICIAL EFFECT OF LINEAR COUPLING IN OTHER MACHINES (Slide of a PS seminar in 2000)

- **LANL-PSR (from B. Macek)**

  "Operating at or near the coupling resonance $Q_h - Q_v = 1$ with a skew quad is one of the most effective means to damp our 'e-p' instability"

- **BNL-AGS (from T. Roser)** $Q_h = 8.845 \quad Q_v = 8.890$

  "The injection setup at AGS is a tradeoff between a 'highly coupled' situation, associated with slow loss, and a 'lightly coupled' situation where the beam is unstable (coupled-bunch instability)"

- **CERN-SPS (from G. Arduini)** $Q_h = 26.62 \quad Q_v = 26.58$

  "A TMCI in the vertical plane with lepton beams at 16 GeV is observed. Using skew quads ('just turning the knobs'), gains in intensity of about 20-30%, and a more stable beam, have been obtained"

  => MDs are foreseen to examine these preliminary results in detail

- **CERN-LEP (from A. Verdier)** $Q_h = 98.28 \quad Q_v = 96.26$

  "The TMCI in the vertical plane at 20 GeV sets the limit to the intensity per bunch. The operation people said that it's better to accumulate with tunes close to each other"

  => MDs are foreseen to examine these preliminary results in detail

SUMMARY AND CONCLUSION (1/3)

- A gain in intensity of 36% is predicted for the SPS with the HEADTAIL code, using the same beam parameters and Broad-Band impedance model as for the study of the time evolution (0 chromaticity, no space charge, no octupoles and no feedback)

$$Q_x = 26.180 \qquad Q_y = 26.185 \qquad K_{skew}^{\mathrm{HEADTAIL}} = 0.005\,\mathrm{m}^{-1}$$

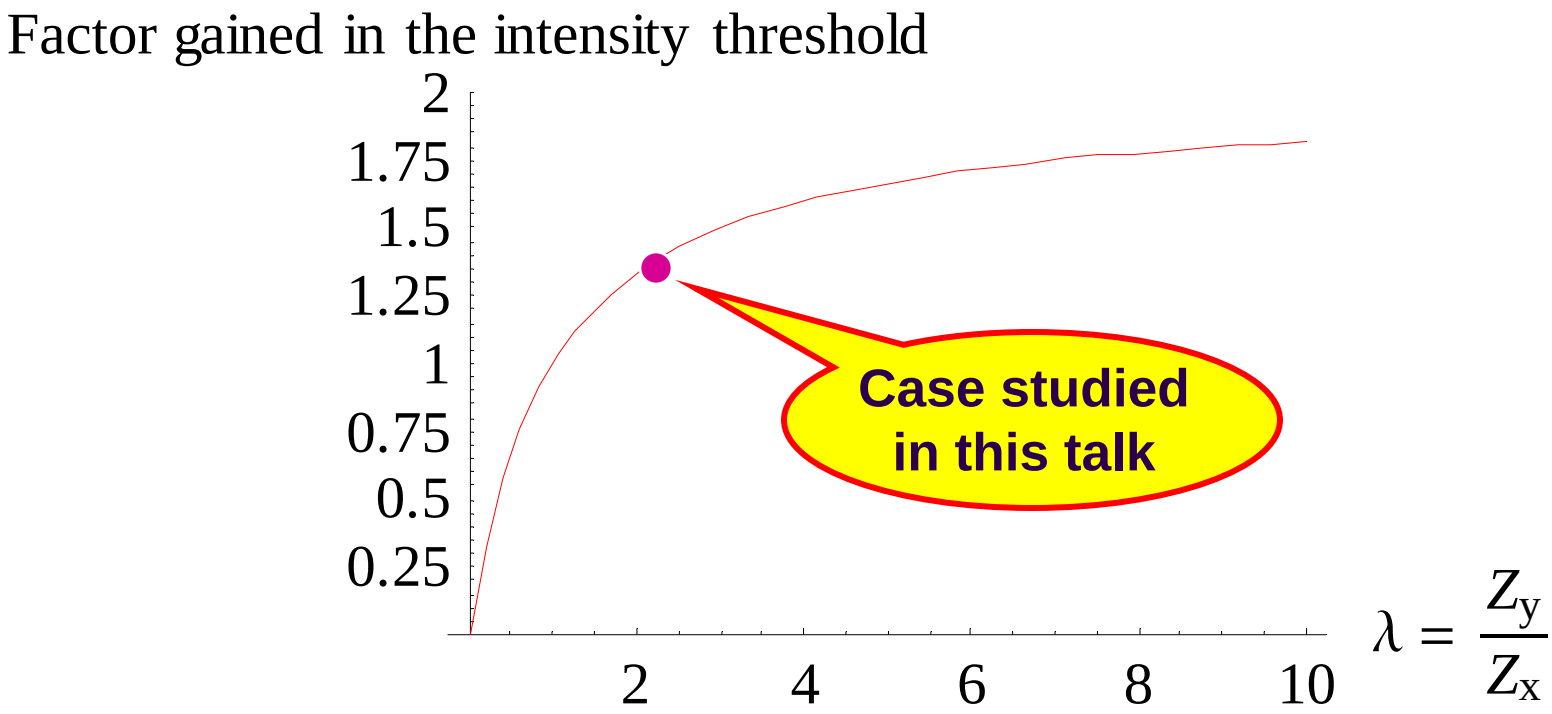
- A gain in intensity of 39% was predicted from a simple (approximate) theory

- Next work
  - Check these results (I hope I did not make too many mistakes using HEADTAIL)

SUMMARY AND CONCLUSION (2/3)

- **Try to reproduce the theoretical prediction by varying the ratio between the vertical and horizontal impedances (idea from Massimo)**

From simple (approximate) theory



SUMMARY AND CONCLUSION (3/3)

- Re-do the same with space-charge and chromaticity and see by how much one can reduce the value of the chromaticity $\Rightarrow$ Better for the lifetime

- Try to measure the beneficial effect (if any) during the future MDs in the SPS

- Refine the analysis with a better transverse impedance model of the SPS including e^- cloud ($\Rightarrow$ PHD student)