Considerations on the LHC

According to D. Boussard, D. Brand and L. Vos (LHC Project Note 205, 1999) the LHC is expected to have enough longitudinal stability:

- Landau damping will suppress instabilities causing frequency shifts of

$$\Delta f_{\text{th,Landau}} = 0.025 \times 23\ \text{Hz} = 0.58\ \text{Hz}$$

- This results in an intensity safety margin of 41% for ultimate intensity (N_b= 1.7 × 10^{11} particles/bunch) and for $Z_L/n = 0.28\,\Omega$.

What to do, in case the effective impedance is larger?

- increasing RF voltage by keeping the bunch lengths

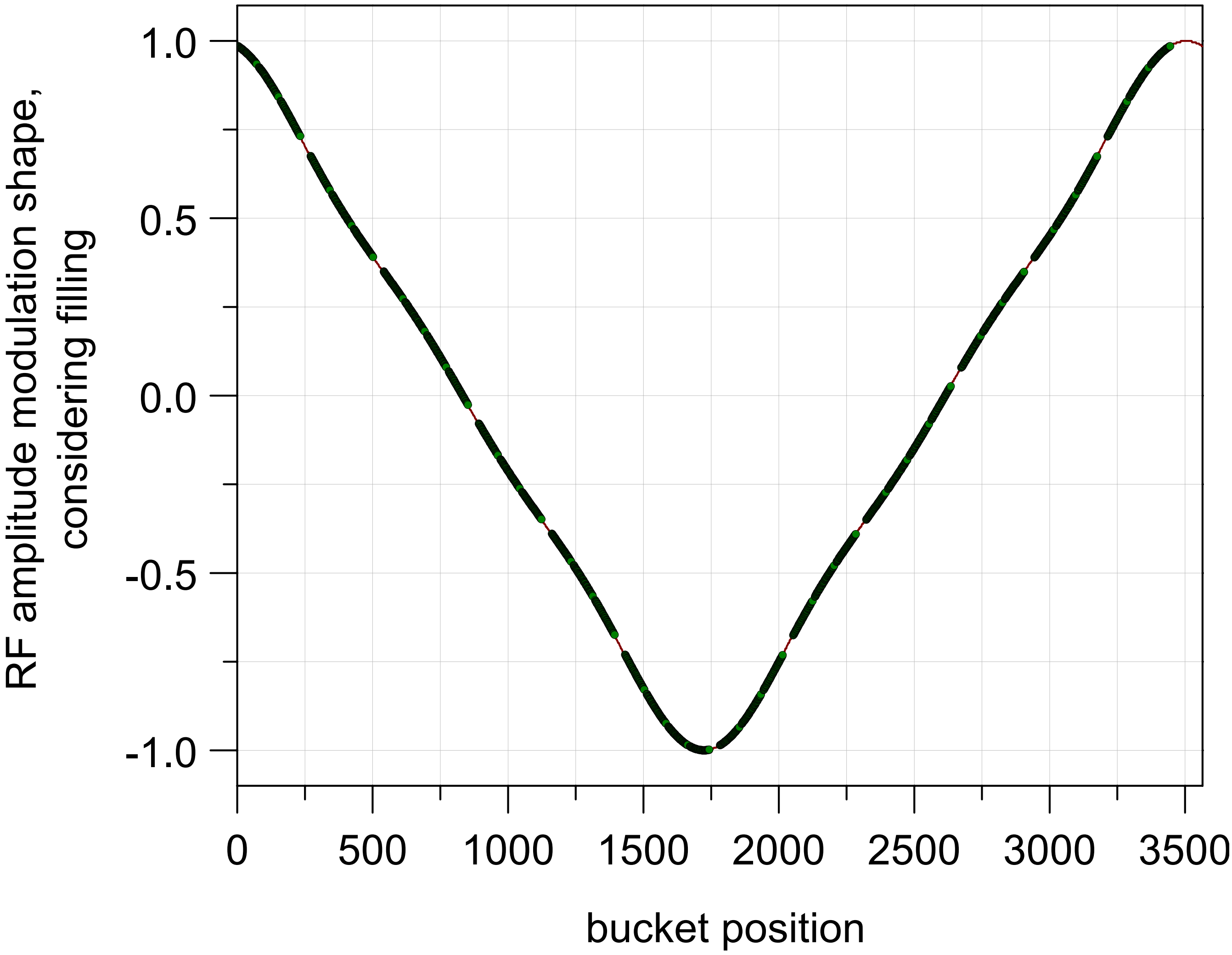
$$\Delta f_{\text{th,Landau}} \rightarrow \sqrt{\frac{V_{\text{increased}}}{V_{\text{nominal}}}}\,\Delta f_{\text{th,Landau}}$$

- installing 200 MHz RF System and use it for a longitudinal coupled bunch feedback

- third alternative: RF amplitude modulation …

Possible modulation shape at the LHC

(technical feasibility verified in calculations by J. Tückmatel)

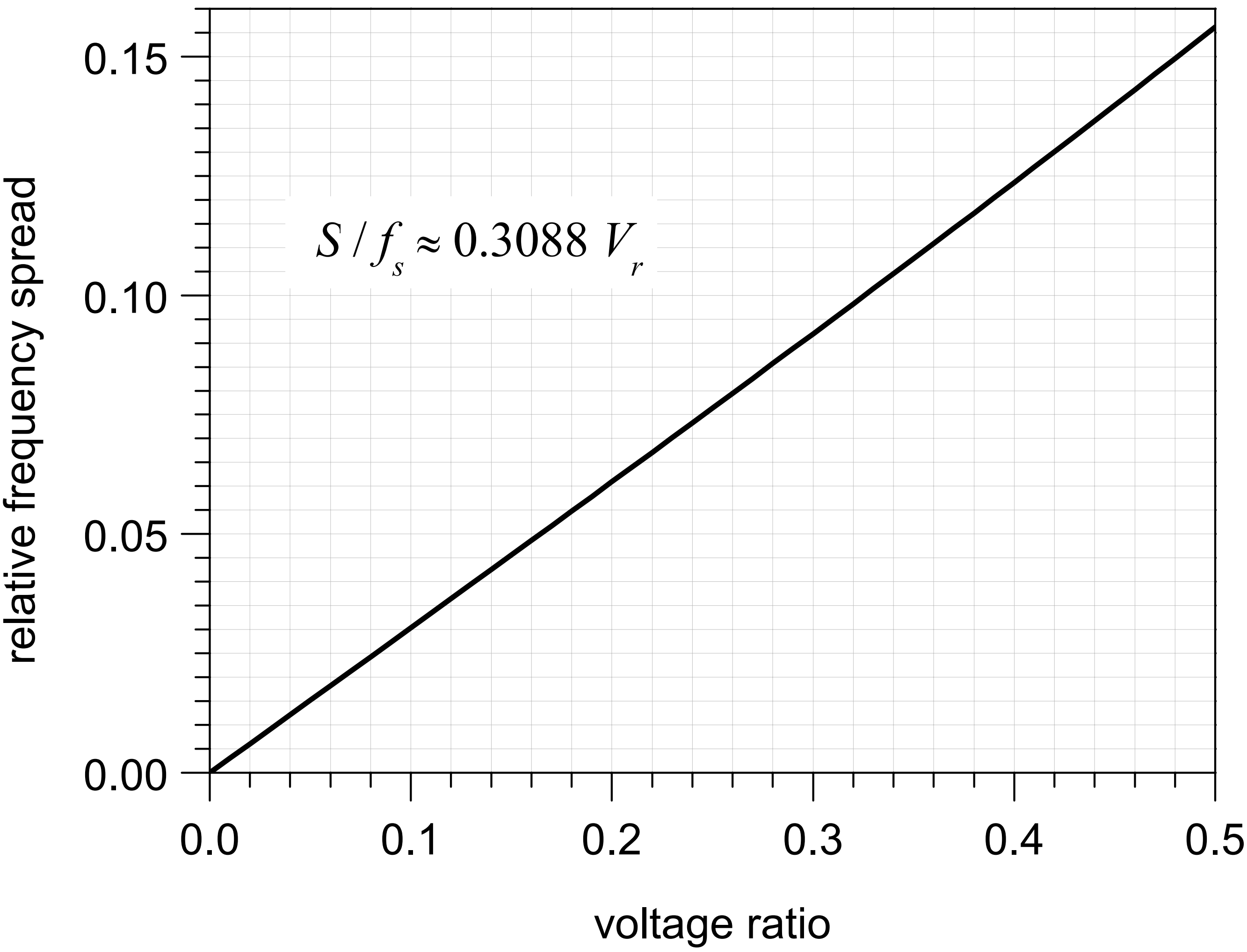


Theoretical technical limits (J. Tückmatel)
(**Attention:** these values consider no safety and no RF power for the correction of RF transients caused by gaps in the bunch filling)

- 12% with 16 MV (nominal Voltage)
- 16% with 14 MV (reduced Voltage)

Spread over modulation strength

For the LHC, we compute the following dependence:



Threshold values for the frequency shifts

For nominal RF voltage of 16 MV and 50% margin for technically problems and the correction of the effects, caused by the gaps in the fill pattern (is this sufficient?)

$$\Delta f_{\mathrm{th,6\%AM,16\,MV}} = 0.018 \times 23\ \mathrm{Hz} = 0.42\ \mathrm{Hz}$$

A remarkable point: in contrast to the situation at Landau damping, we gain stability by lowering the voltage:

$$\Delta f_{\mathrm{th,8\%AM,14MV}} = 0.024 \times \sqrt{\frac{14\ \mathrm{MV}}{16\ \mathrm{MV}}} \times 23\ \mathrm{Hz} = 0.52\ \mathrm{Hz}$$

Conclusion: From an application of an RF amplitude modulation at LHC, we expect a longitudinal stabilization of the same size as Landau damping.