Update on Two beam power loss analysis

F. Giordano, G. Rumolo, B. Salvant, C. Zannini

Many thanks to: L. Teofili
Phase impact on the power loss: what is it?

The phase shift is time that passes after one bunch of one beam enter a cavity until the correspondent bunch of the other beam enters it.

In figure is represented a phase shift of 0 ns (top) and a phase shift of 1 ns (bottom).
Two beam power loss formula

The results of the two beam power loss formula [1] have been compared with the power loss computed with CST

\[ \Delta W(s) = \left( \frac{\omega_0}{\pi} \right)^2 \sum_{p=0}^{+\infty} |\Lambda(p\omega_0)|^2 \text{Re}[Z^0_l(p\omega_0)](1 - \cos(p\omega_0\tau_s)) \]

The two beams have no offset.

[1]: Power loss calculation in separated and common beam chambers of the LHC

C. Zannini, G. Rumolo (CERN, Geneva),
G. Iadarola (Universit`a di Napoli Federico II, Napoli; CERN, Geneva)
Power loss with two beam: generalized equations

\[ \Delta E(x) = \Delta E_1(x) + \Delta E_2(x) = \]

\[ \frac{1}{2\pi} \int_{-\infty}^{+\infty} \left| \Lambda(\omega) \right|^2 \left[ \text{Re}[Z_{11}(x, \omega) + Z_{22}(x, \omega)] - 2 \text{Re}[Z_{12}(x, \omega)] \cos(\omega \tau_s) \right] d\omega \]

Impedance length
Distance from IP
L/s
The accuracy in the approximation made is expected to depend on the ratio L/s
Bad approximation
C. Zannini

Impedance taking into account beam path (transverse position and angle at the entrance of the structure)

Effect of charge in 1 evaluated in 2 without taking into account the counter-rotation

Delay between the two beams in the center of the structure
Delay will change in the structure due to the counter-rotation

\[ \tau_s = \frac{2s}{c} \]
Power loss with two beam: specialized equations

\[ \Delta E(\mathbf{x}) = \Delta E_1(\mathbf{x}) + \Delta E_2(\mathbf{x}) = \]

\[ \frac{1}{2\pi} \int_{-\infty}^{+\infty} |\Lambda(\omega)|^2 [\text{Re}[Z_{11}(\mathbf{x}, \omega) + Z_{22}(\mathbf{x}, \omega)] - 2 \text{Re}[Z_{12}(\mathbf{x}, \omega)] \cos(\omega \tau_s)] d\omega \]

Derivation become more involved due to the dependence on \( x', y' \)

\[ \Delta W(\mathbf{x}) = \left(\frac{\omega_0}{\pi}\right)^2 \sum_{p=0}^{\infty} |\Lambda(p\omega_0)|^2 \{ \text{Re} \left[ Z_{||}^0(p\omega_0) \right] + \\
\left[ \Delta y_1(\mathbf{x}) + \Delta y_2(\mathbf{x}) \right] \text{Re} \left[ Z_{||}^1(p\omega_0) \right] \} (1 - \cos p\omega_0 \tau_s) \]

Valid for 3D Impedances in the case of \( x', y' = 0 \)

C. Zannini
Radius scan

Radius scanned from 13 cm to 15 cm

The marked points in figure are the ones computed with CST.
The line plots are computed with the two beam formula.
Comparison with single bunch power loss

The maximum power loss reached is 3.8 times the single bunch case.
Longer range comparison

The agreement is kept also for bigger phase shift.
Cavity length scan

10% error for h=10. To be doublechecked.

More simulation needed to see if this error increase with h.

Possible explanation for t=0.5ns: For h=10 the transit time in the cavity is comparable with the phase shift.*

Why disagreement only at the maxima?

*already discussed with Carlo and Giovanni
Conclusion and next step

• Very good agreement between the CST computation and the two beam formula where the transit time in the cavity is small compared to the phase shift.
• Some disagreement only at the maxima when the transit time in the cavity is comparable with the phase shift.
• Better explore and understand the range were the transition time in cavity is comparable with the phase shift.
• Scan of: longer cavities, Q of the cavity, transverse offset, asymmetry of the cavity.