Tilt and Bow Tolerances in NLC Linac

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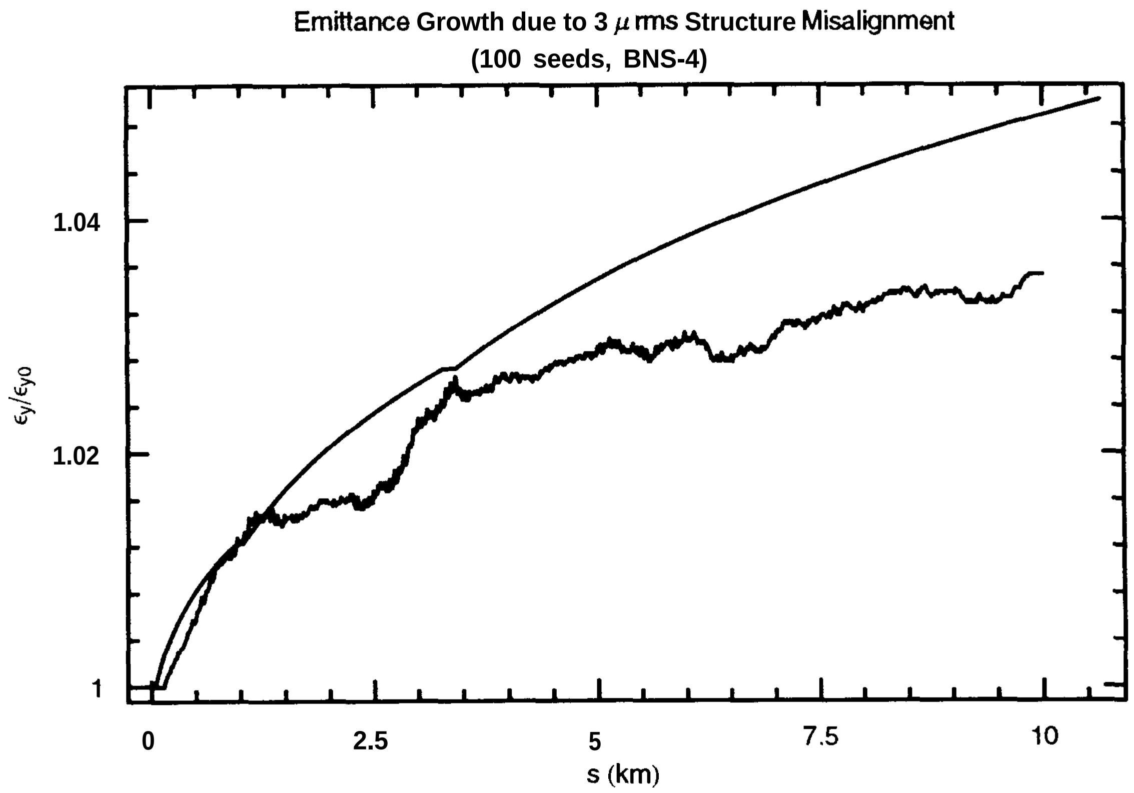
Random structure misalignments

assume that the structure is offset from the center line in the vertical direction by y_0. The PROJECTED emittance growth of a single bunch passing through the linac:

$$\Delta\epsilon_N = 0.15 \sum_{\text{struc}} \frac{\beta_i}{\gamma_i} \left(L_s y_0 w' N r_e \sigma_z\right)^2$$

β_i – beta function at the location of the structure
w' – the slope of the wake function at the origin
N – the number of particles in the bunch
σ_z – rms bunch length
L_s – the length of the structure
γ_i – the energy of the beam at that location
$w' = 9.43 \times 10^7$ V/pC/m^3

The sum β/γ was calculated numerically for the NLC linac lattice CD1.1. It is equal to 0.39 m for 500 GeV beam.

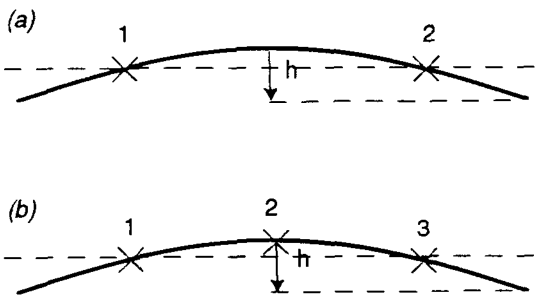


5 $\mu \rightarrow$ 10% emittance growth

16 $\mu \rightarrow$ 100% emittance growth

Structure bow

The vertical position of the structure can be corrected using structure RF bpms.



Parabolic shape, assume that SBPMs are $\frac{1}{4}L_s$ from the ends,

$$y(z) = 4h\left[\left(\frac{z}{L_s}\right)^2 - \frac{1}{16}\right]$$

Comparison with the rigid offset by h. The kick is proportional

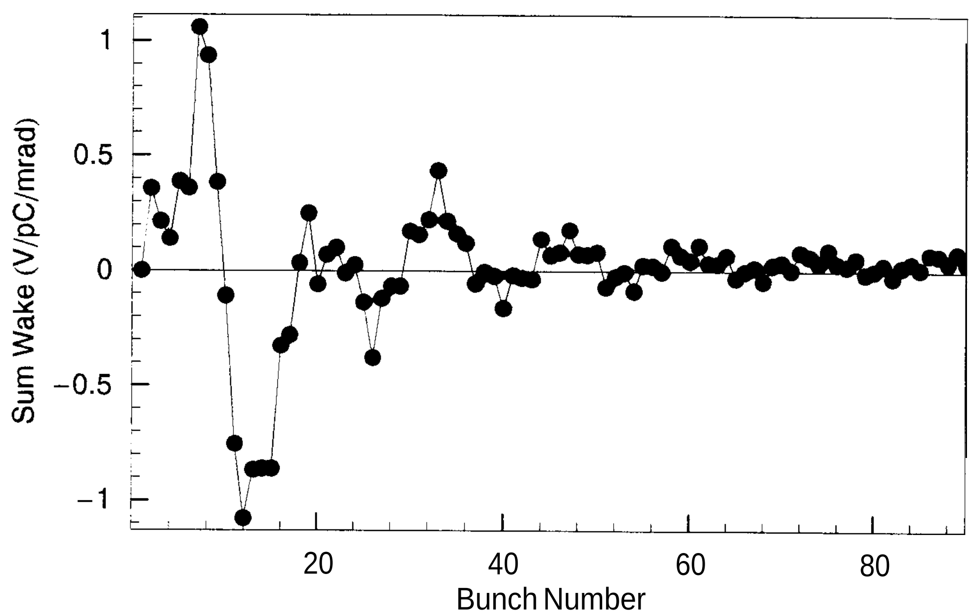
$$\frac{1}{h}\int_{-L_s/2}^{L_s/2} y(z)dz = \frac{1}{12} \approx 0.083$$

This means that the tolerance for the bow amplitude h is *12* times looser than the tolerance on y_0 (60 μ for 10% emittance growth).

Tilted structure

Emittance growth in the bunch train due to LONG RANGE wake for a tilted structures.

Sum Wake for Tilted Structure vs Bunch Number



The standard deviation of the sumwake is 0.29 V/pC/mrad. Emittance increase at the end of the linac

$$\gamma\Delta\epsilon = 6.7 \times 10^{-7}\alpha^2 \text{ m},$$

where α is the rms tilt angle in milliradians for the structures.

10% growth of the nominal normalized vertical emittance of 4 x 10^{-8} m is caused by

$$a = 80\ \mu\text{rad}.$$

Transverse kicks from the rf mode (single bunch effect). This kick is equal to $V_{\perp} = \frac{1}{2}\alpha V_{acc}$.

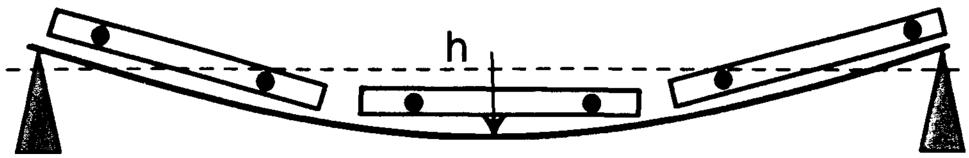
$$\gamma\Delta\epsilon = \frac{\beta\sin^2\phi}{2\gamma}\left(\frac{2\pi\sigma_z}{\lambda_{rf}}\frac{V_{\perp}}{mc^2}\right)^2,$$

Numerically calculated $\sum\frac{\beta_i\sin^2\phi_i}{2\gamma_i}$ is equal to 0.017 m. Assume $V_{acc} = 100$ MeV per structure

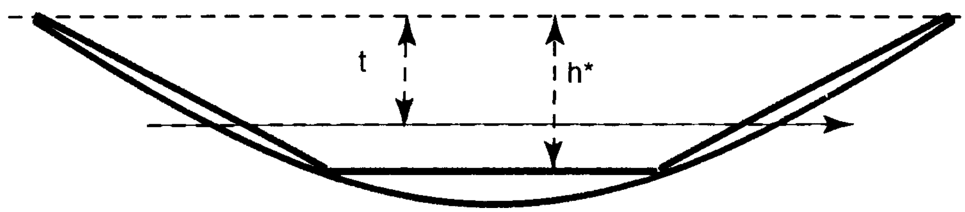
$$\gamma\Delta\epsilon = 0.11\alpha^2\ \text{m},$$

The requirement of 10% emittance growth gives

$$\alpha < 190\ \mu\text{rad}.$$



Three structures on the girder

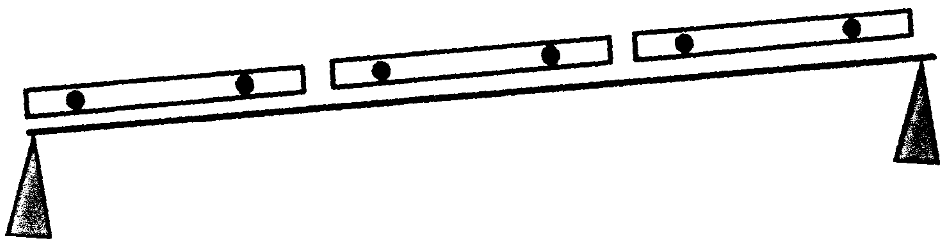


Alignment of the girder, $h^* = \frac{8}{9}h$, $t = \frac{2}{3}h^*$. In the first approximation, both short-range and long-range are compensated.

In the next approximation, due to finite length of the girder, the long-range wake is not compensated completely.

$$h_{tol} = f\,\frac{\beta_0}{L_s}\left(\frac{\gamma_f}{\gamma_i}\right)^{1/4} \quad \text{Ystruc tol} \approx 200 - 400\ \mu$$

Tilted girder:



$$\alpha_{\text{tol girder}} = \frac{1}{\sqrt{3}}\alpha_{\text{tol single struc}} = 45\ \mu$$