# Ground Motion Activities at DESY – An Overview

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# Introduction

Ground motion is a concern in colliders where both beams experience different magnetic fields:

- Two-ring circular colliders (HERA, B-Factories, RHIC, LHC)
- Linear Colliders

Main problem:
Beam offsets at the IP

At DESY, ground motion has been studied for more than a decade.

# Circular colliders

Response of a pure FODO lattice to a single vertical plane ground wave (Rossbach):

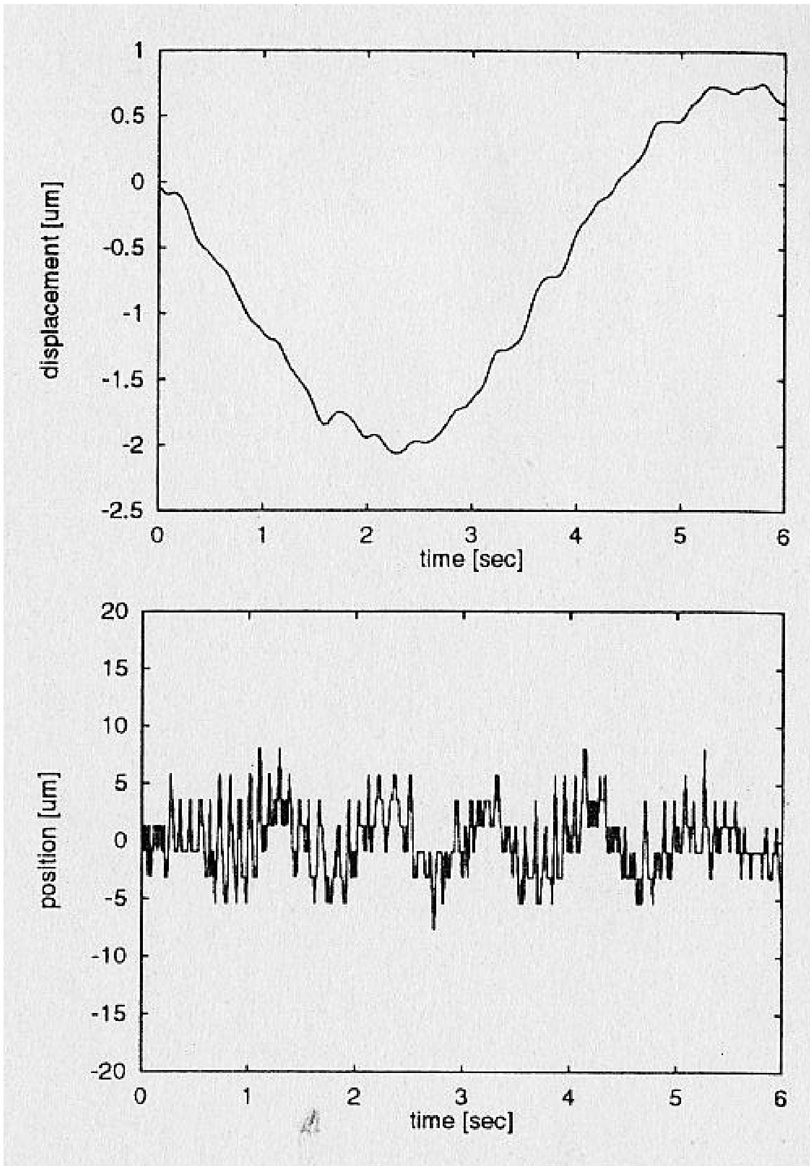
$$
\begin{aligned}
R_y &= \frac{\hat{y}_c}{\hat{y}} \\
&= \frac{\beta_0}{2f}\left\{\left[\sum_{p=-\infty}^{\infty} J_{4p}\left(\frac{C}{\lambda}\right)C_{4p} - J_{4p-2}\left(\frac{C}{\lambda}\right)C_{4p-2}\right]^2\right. \\
&\qquad \left. + \left[\sum_{p=-\infty}^{\infty} J_{4p-1}\left(\frac{C}{\lambda}\right)C_{4p-1} - J_{4p-3}\left(\frac{C}{\lambda}\right)C_{4p-3}\right]^2\right\}^{\frac{1}{2}}
\end{aligned}
$$

with

$$
\begin{aligned}
C_p &= \frac{(-1)^{p+1}}{\sin\left(\frac{\pi p}{N} - \frac{\mu}{2}\right)} \\
&\quad \cdot \left\{\sqrt{\hat{\beta}}\cos\left[p\left(\pi\frac{N+1}{N} - \theta_w\right) - \frac{\mu}{2}\right]\right. \\
&\qquad \left. - \sqrt{\check{\beta}}\cos p(\pi - \theta_w)\right\}
\end{aligned}
$$

- Resonant if $\lambda$ equals betatron wavelength
- Long wavelengths are suppressed

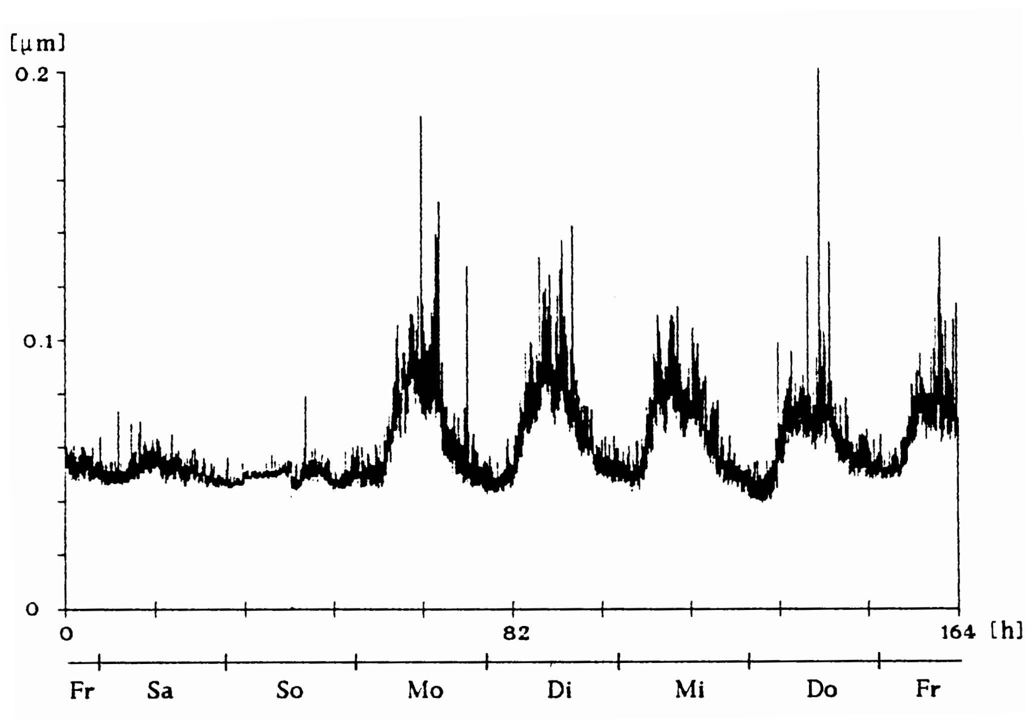
Measured ground motion (top) and vertical orbit jitter in HERA (bottom).




7 second microseismic motion does not affect the beam due to its large wavelength.

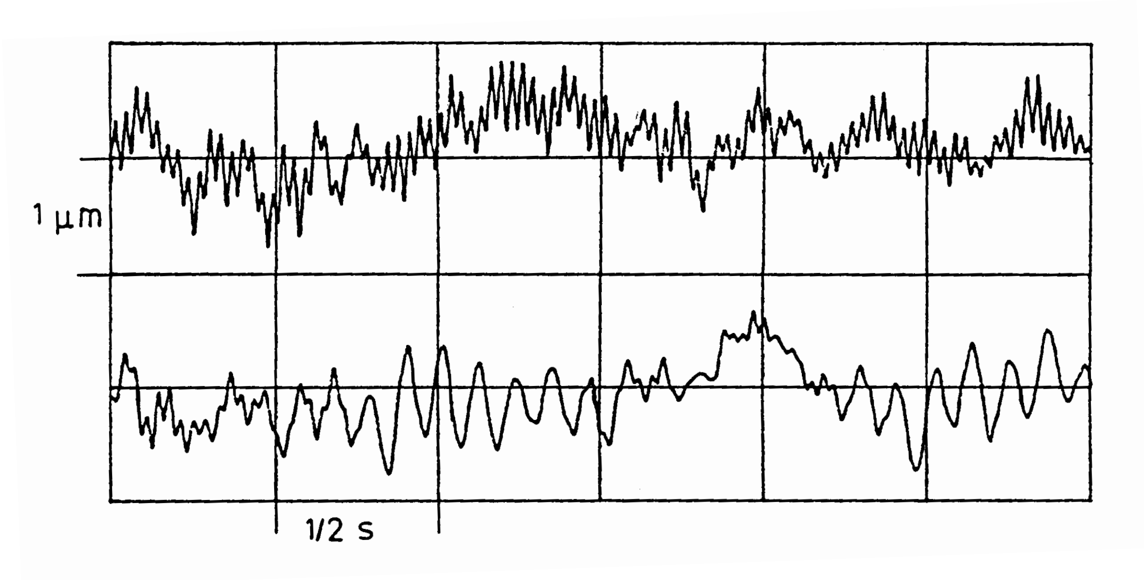
Measurements at HERA (Floettmann, Decking, Rossbach)

Tunnel floor vibration, rms amplitude during one week:




Cultural noise contribution in Hamburg.

Influence of cooling water flow on magnet vibration in HERA-e:




Cooling water causes high-frequency contributions.

# Linear Colliders

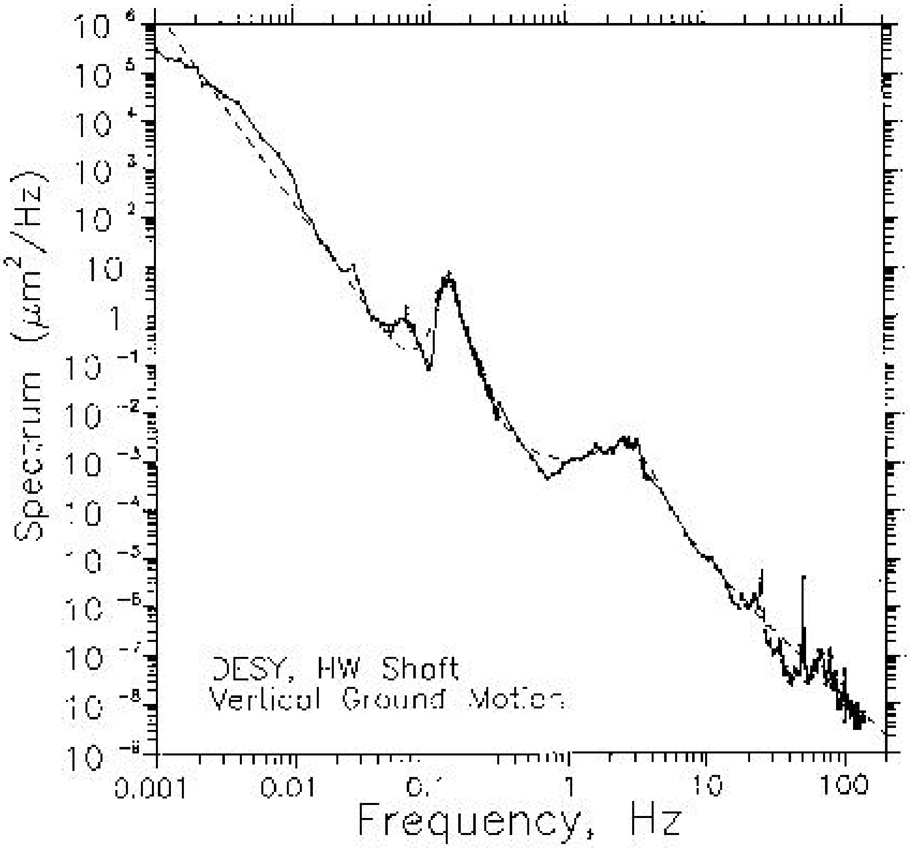
Estimate of uncorrelated quadrupole jitter tolerance (Rossbach):

$$\sigma_q = \sqrt{\frac{-2\epsilon_{\mathrm{end}}\overline{\beta}_{\mathrm{end}} \ln \frac{\mathcal{L}}{\mathcal{L}_0}}{N_q}} \cos \frac{\mu}{2}$$

SBLC: $\sigma_q = 40\,\mathrm{nm}$

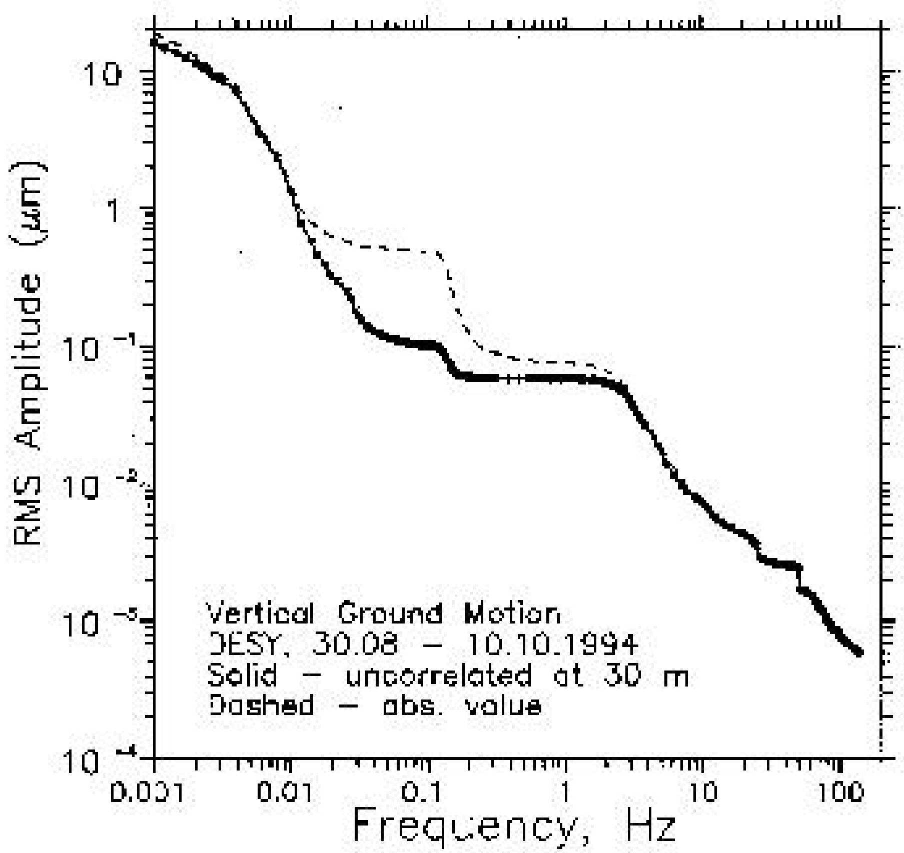
Slow vibrations ($f < f_{\mathrm{rep}}/25$): beam-based correction
SBLC: $f_{\mathrm{rep}} = 50\,\mathrm{Hz}$
$\rightarrow$ How large is the uncorrelated quadrupole jitter above $2\,\mathrm{Hz}$?

Power spectrum of vertical ground motion in HERA hall West (Shiltsev et al.):



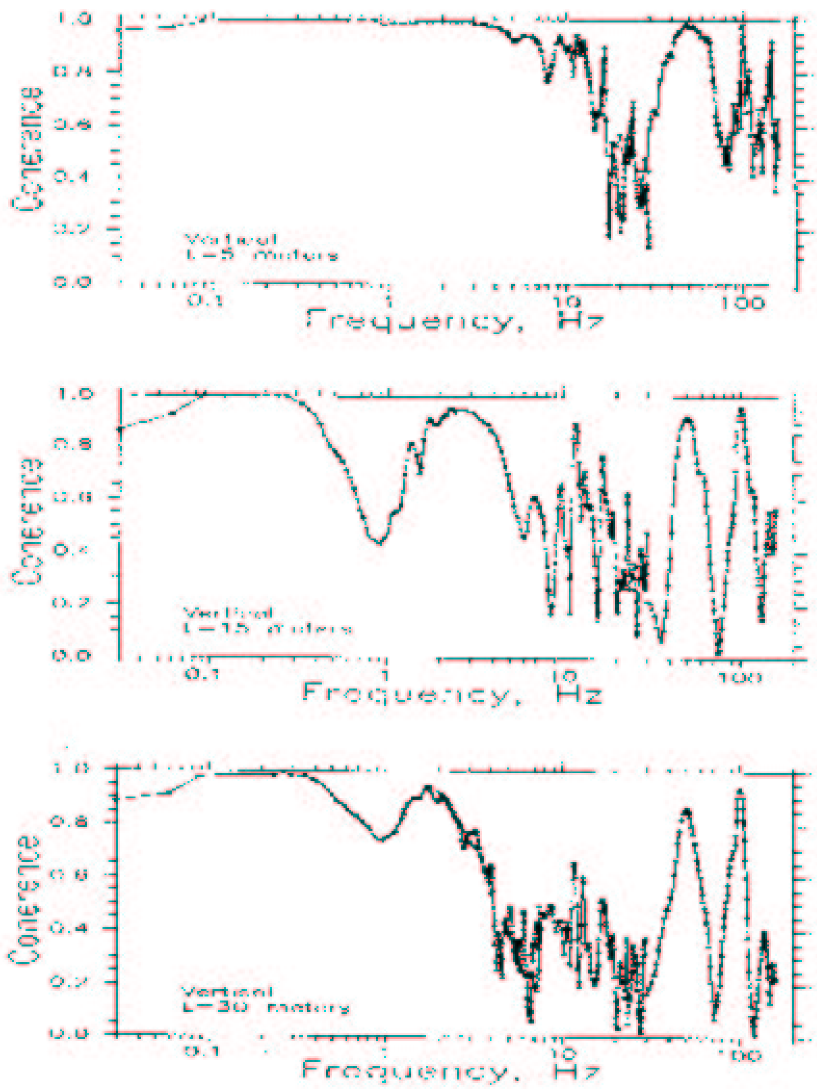
RMS ground motion $\sigma_z(f_{\text{lower}})$ in HERA hall West, obtained by integrating the power spectrum $\Phi(f)$ (Shiltsev et al.),

$$\sigma_z(f_{\text{lower}}) = \sqrt{\int_{f_{\text{lower}}}^{\infty} \Phi(f)\,\mathrm{d}f} :$$




$\rightarrow \sigma_z(2\,\mathrm{Hz}) = 70\,\mathrm{nm}$

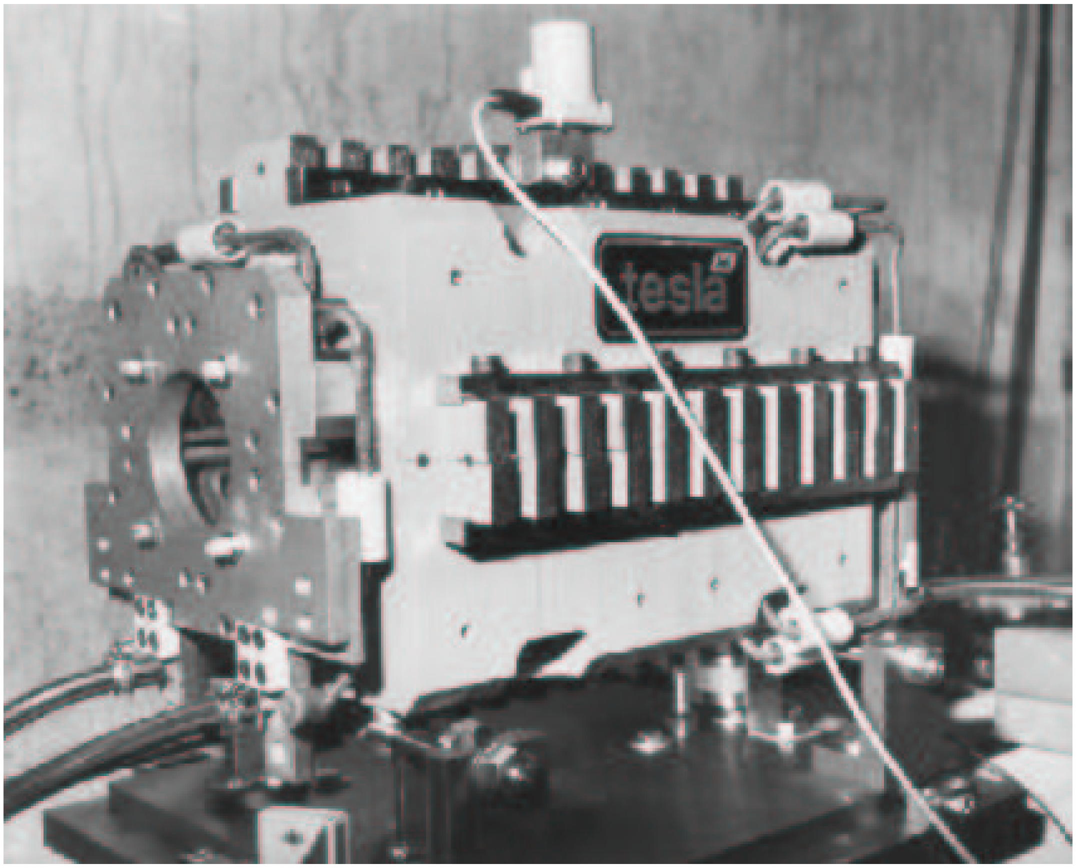
Coherence measurements in HERA hall West (Shiltsev et al.):



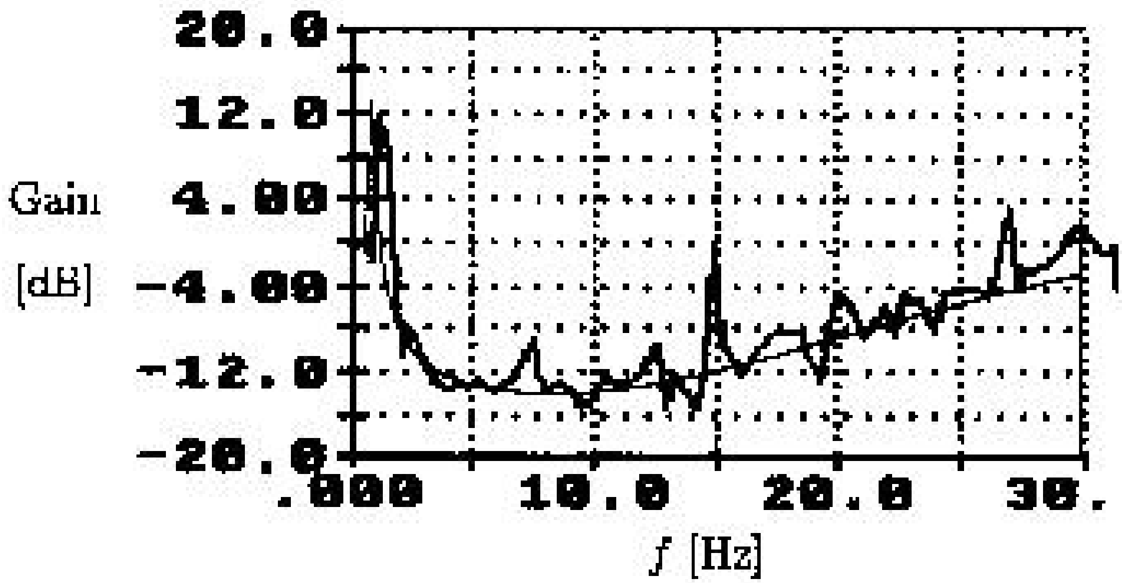

→ Quadrupole motion in SBLC will be uncorrelated for frequencies above 2 Hz.

→ Active stabilization required for SBLC.

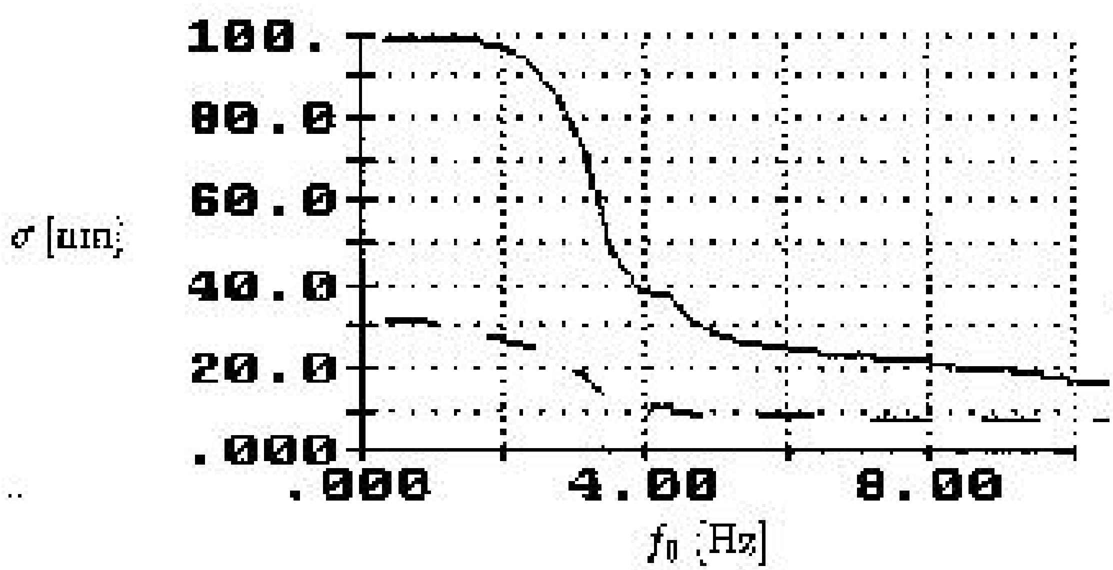
Active stabilization system (Montag):



Measured feedback gain:

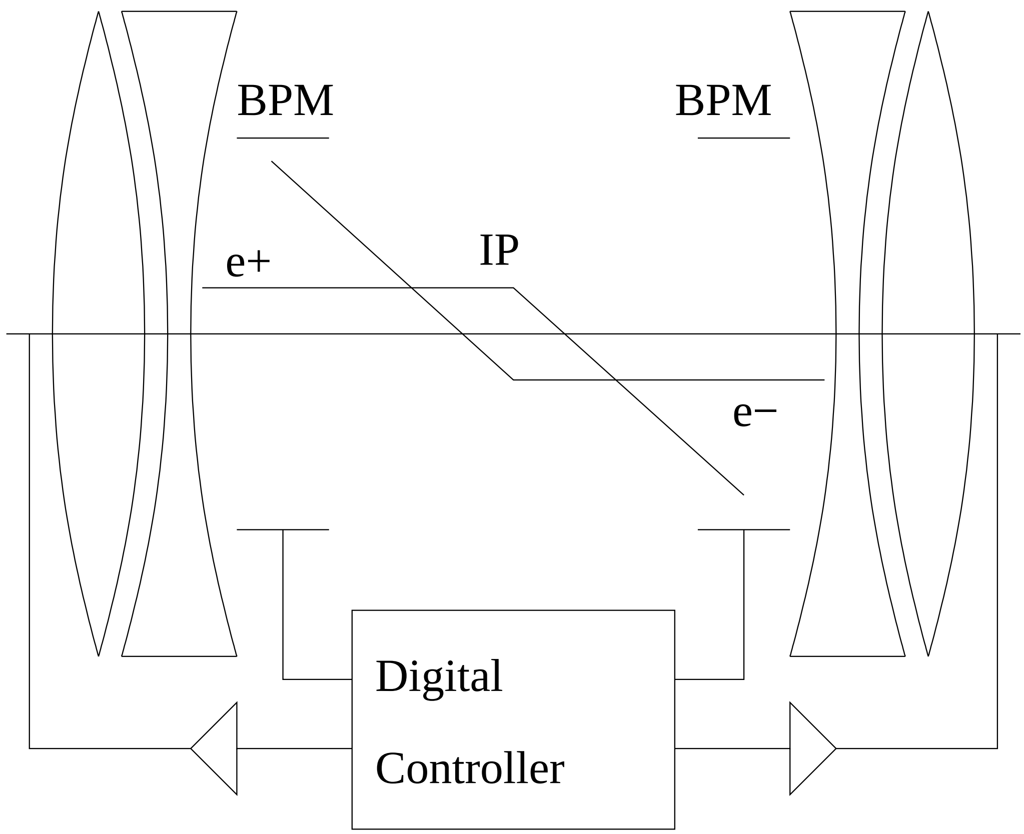



Measured rms vibration amplitude on the floor and on the magnet:



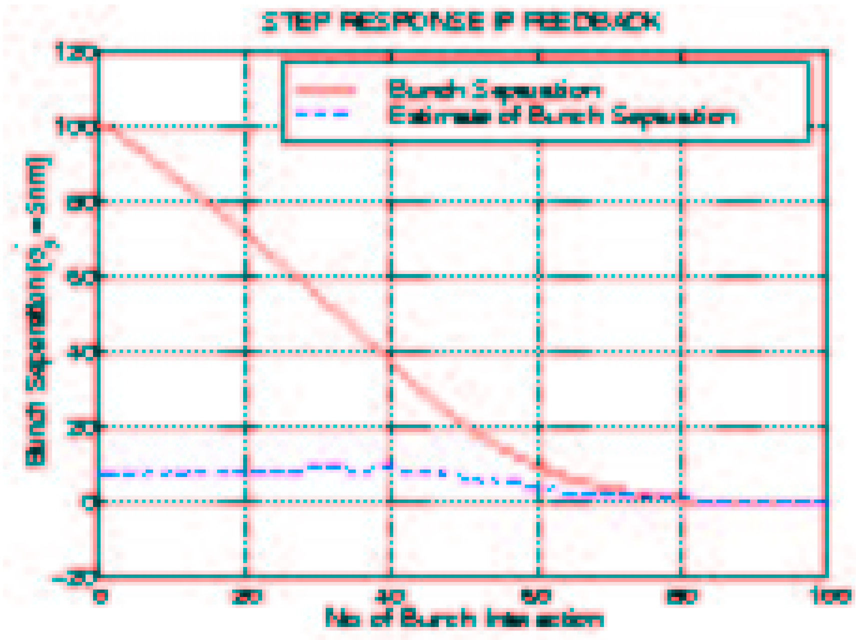
TESLA: Very long bunch trains with large bunch spacing allow for beam-based correction within the bunch train.

Beam-based bunch-to-bunch IR feedback for TESLA (Reyzl, Kohaupt):




Infer beam offset from beam-beam deflection.

Simulated feedback response to 100$\sigma$ step:

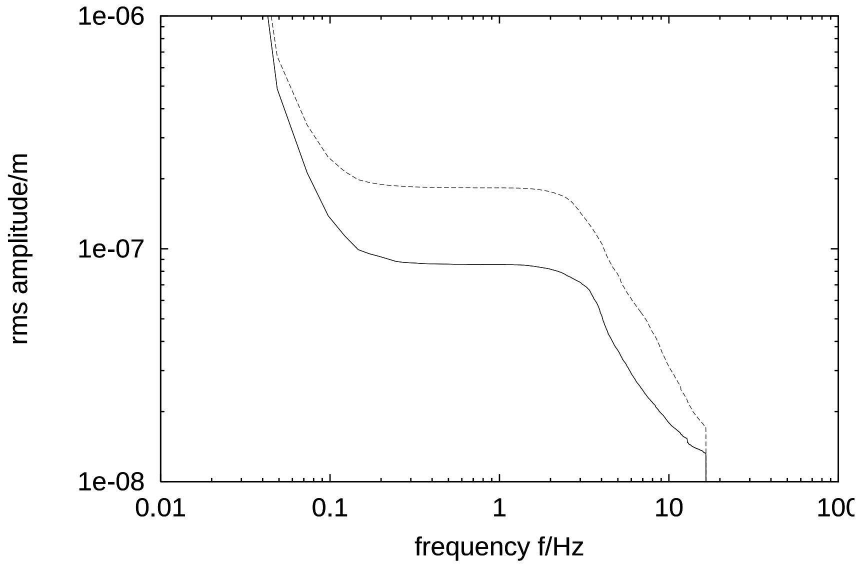


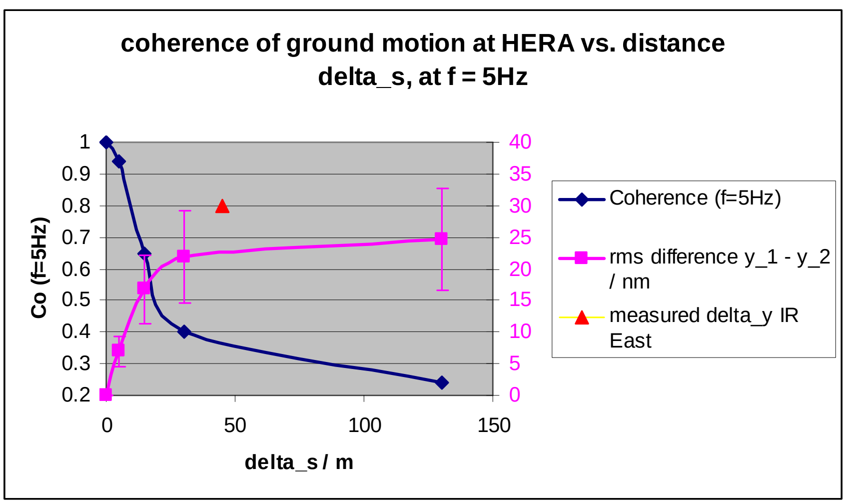

After 80 bunches, the initial beam separation of 100$\sigma$ has vanished.

But:

Can the machine be commissioned with single bunches?

Relative rms motion of tunnel ends in HERA IR, under noisy and quiet conditions (Montag, Shiltsev, Brinkmann):



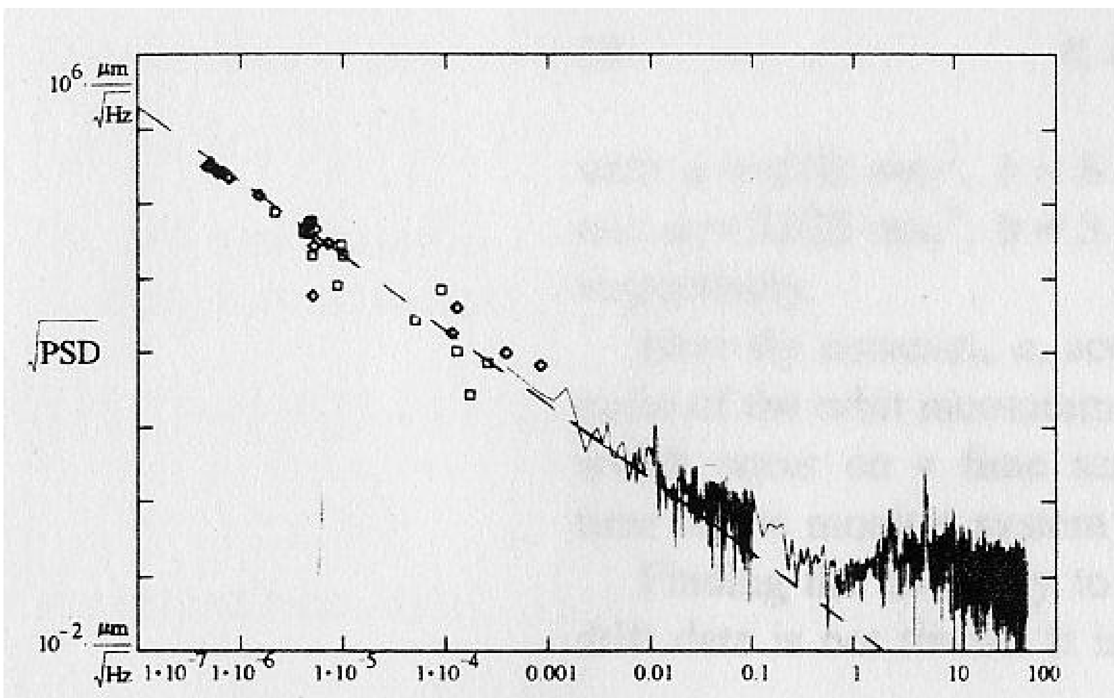




→ More than 100 nm relative motion of the two tunnel ends is at least an order of magnitude too much.

Possible remedy: relaxed optics during single-bunch commissioning.

Slow drifts - ATL

Measurement of proportionality constant $A$ from HERA orbits (Brinkmann, Rossbach):




$A = (4 \pm 2) \cdot 10^{-6} \, \frac{\mu\mathrm{m}^2}{\mathrm{m \cdot sec}}$

# Conclusion

- Ground motion has been studied at DESY for more than a decade; first for the two-ring e-p collider HERA, then for Linear Collider projects SBLC and TESLA.
- Cultural noise of the nearby big city of Hamburg significantly contributes.
- In spite of rather large ground motion amplitudes, a Linear Collider (SBLC or TESLA) could nevertheless be built at DESY, though active stabilization (SBLC) or fast bunch-to-bunch feedback (TESLA) is definitely required.