

# Ground Motion in the Interaction Region

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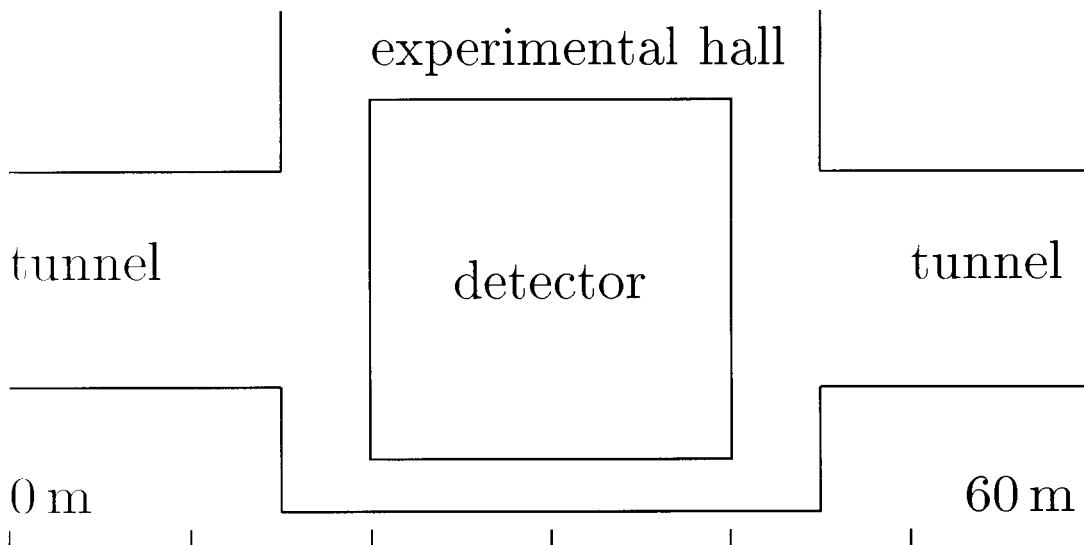
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# 1 Introduction and motivation

Ground motion in the interaction region is of particular concern, because displacements of the final focus quadrupoles translate to orbit distortions of similar magnitude at the IP.

Therefore vibration properties in the HERA tunnel have been measured, focused on the relative motion of the two tunnel ends in the interaction region.

Schematic side view of HERA Hall East with the detector and the accelerator tunnel ends:

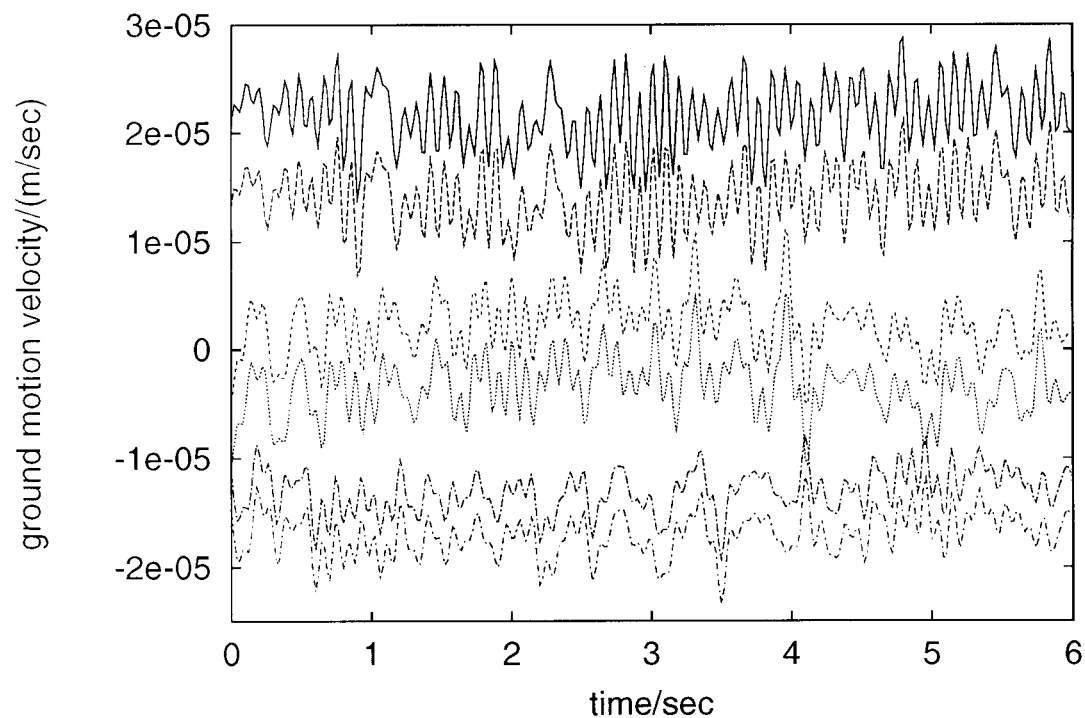


## 2 Measurements

### Sensor tests

With both sensors placed side-by-side, the internal noise level was determined from the difference signal.

Primary velocity output signals of the two seismometers placed side-by-side:



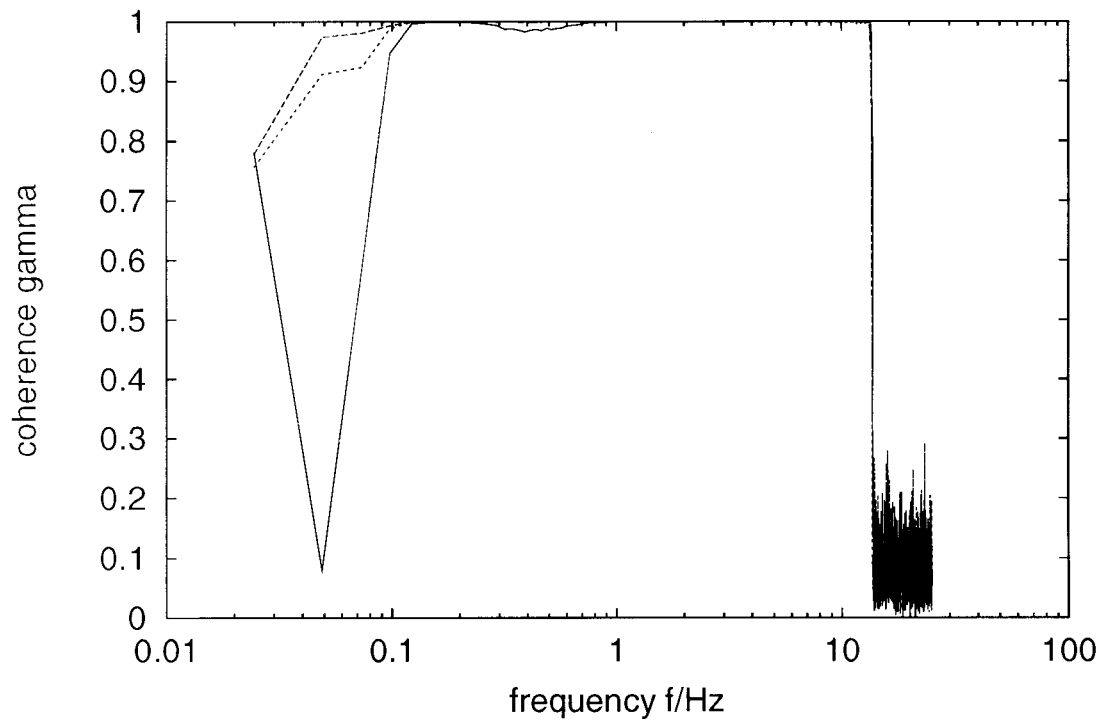
## Coherence function

$$|\gamma(\omega)| = \frac{|\langle X_1(\omega) X_2^*(\omega) \rangle|}{\sqrt{\langle X_1(\omega) X_1^*(\omega) \rangle \langle X_2(\omega) X_2^*(\omega) \rangle}},$$

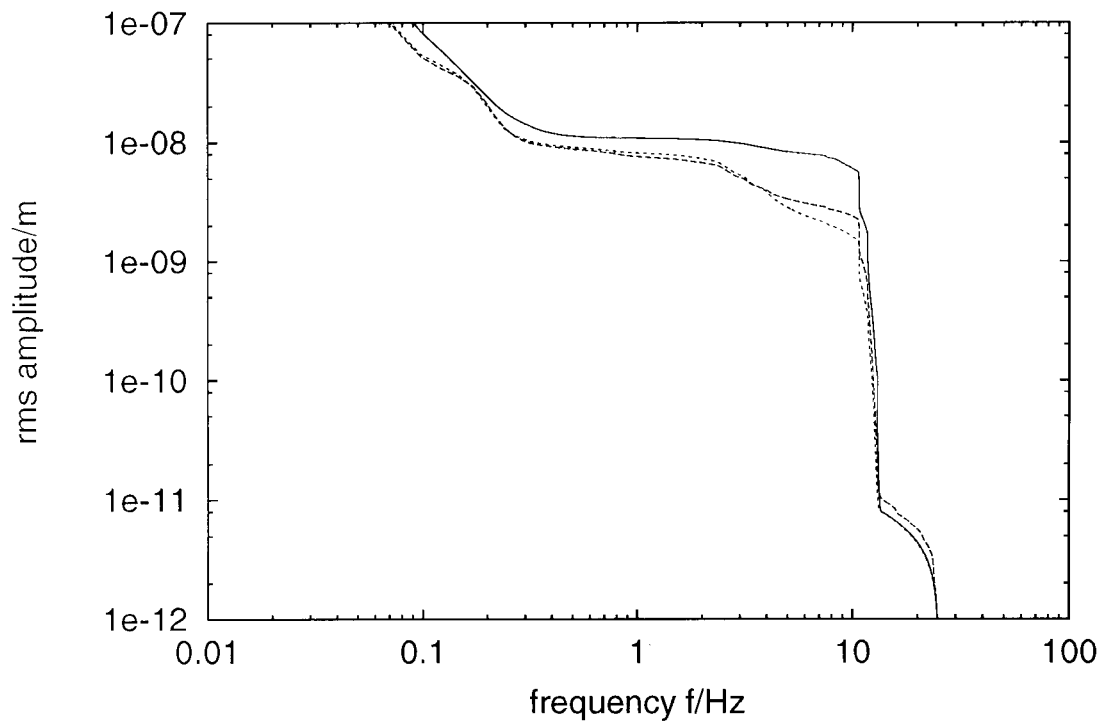
$$X_1(\omega) = \text{FFT}(x_1(t)),$$

$$X_2(\omega) = \text{FFT}(x_2(t)),$$

of the two sensors placed side-by-side:



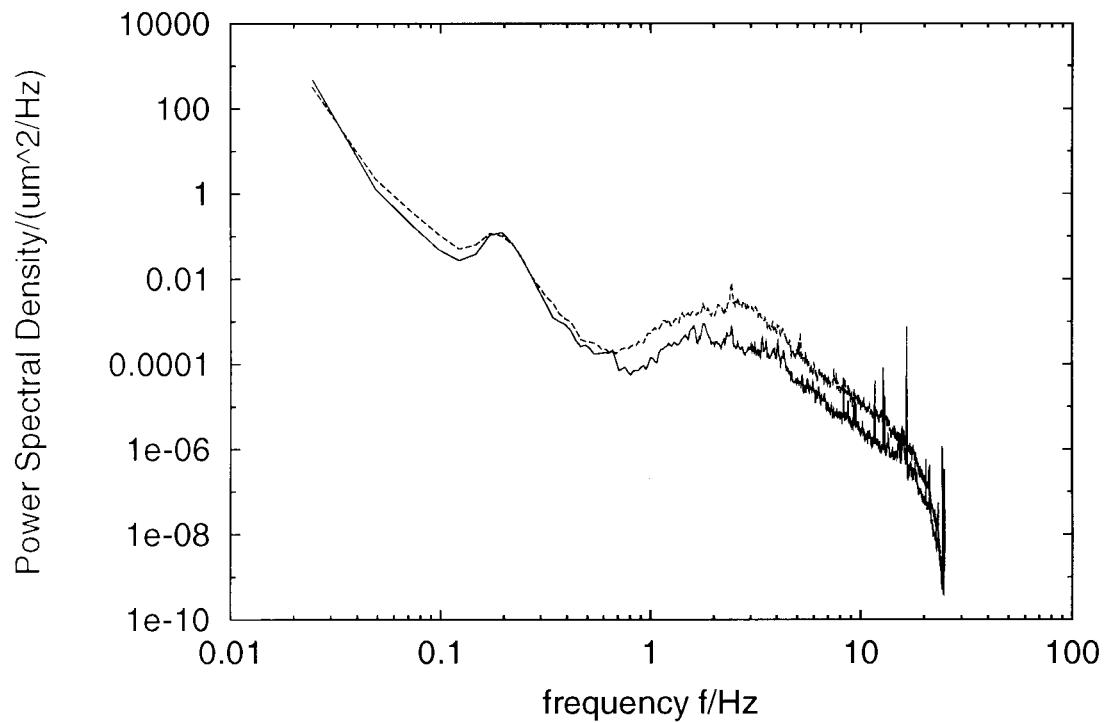
rms value of the difference signal  $x_1(t) - x_2(t)$  of the two sensors placed side-by-side, in the frequency range above  $f_0$ , given as a function of  $f_0$  :



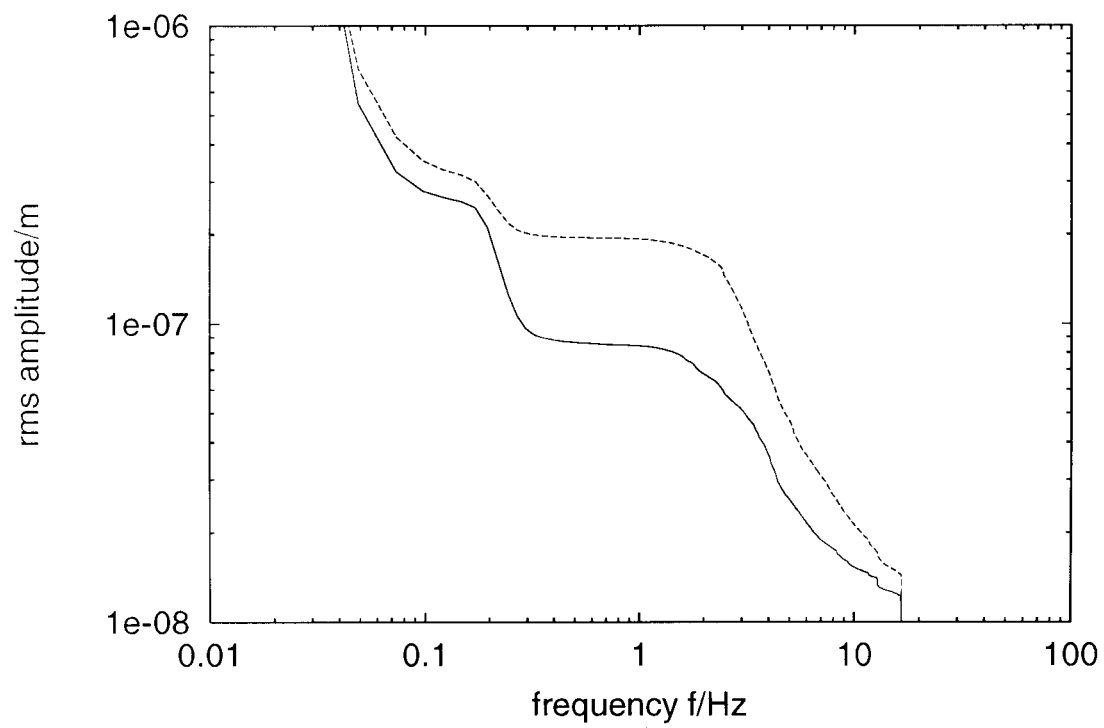
→ 10 nm resolution above 0.2 Hz

## Measurements in the HERA tunnel

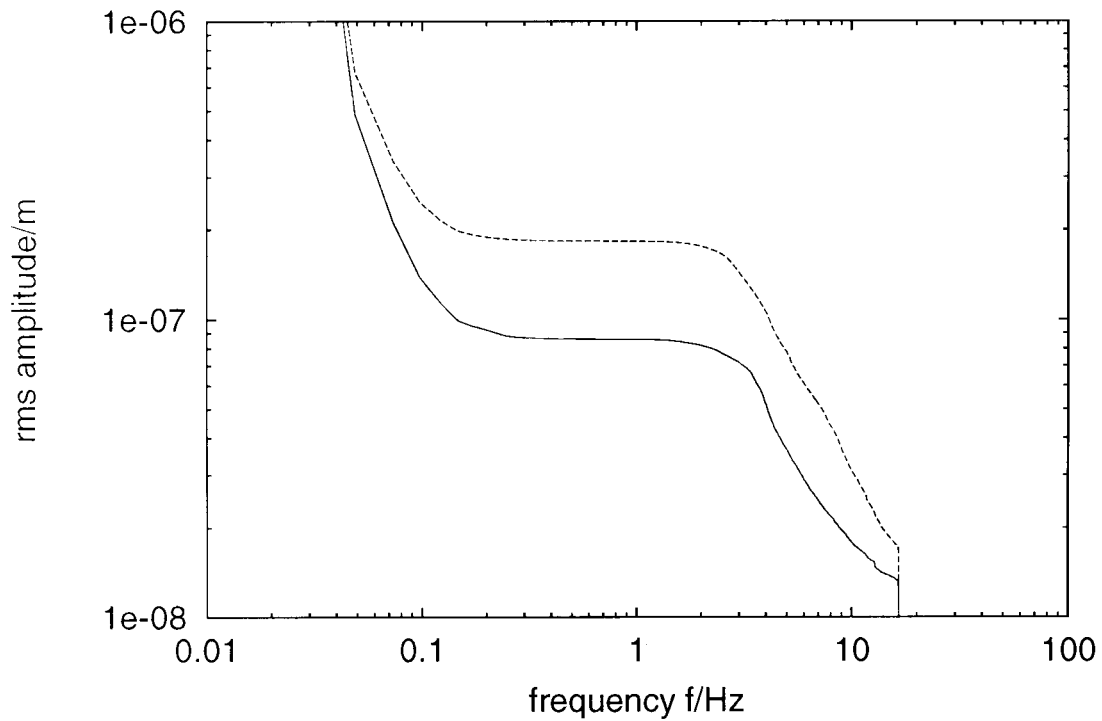
Vertical ground motion spectra obtained in a single point under quiet and under noisy conditions:



rms value of the vertical motion in a single point in the frequency range above  $f_0$ , given as a function of  $f_0$  :



rms value of the difference signal  $x_1(t) - x_2(t)$  of the vertical motion of the two tunnel ends, distance 34 m, in the frequency range above  $f_0$ , given as a function of  $f_0$  :



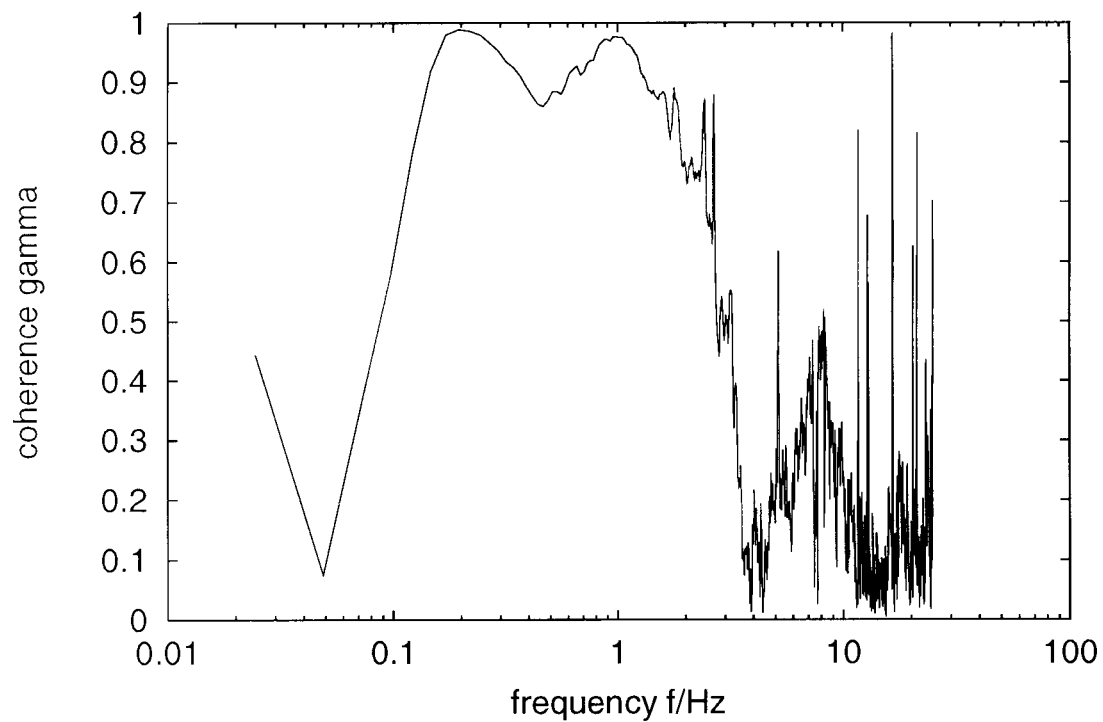
Corresponding coherence function

$$|\gamma(\omega)| = \frac{|\langle X_1(\omega) X_2^*(\omega) \rangle|}{\sqrt{\langle X_1(\omega) X_1^*(\omega) \rangle \langle X_2(\omega) X_2^*(\omega) \rangle}},$$

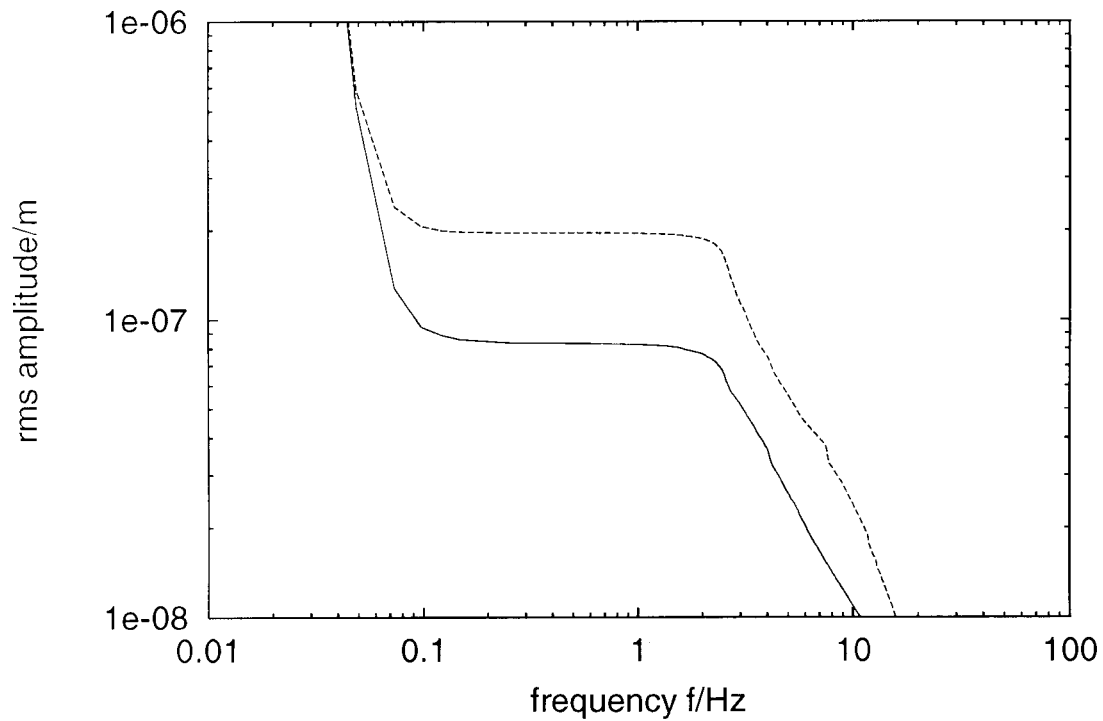
$$X_1(\omega) = \text{FFT}(x_1(t)),$$

$$X_2(\omega) = \text{FFT}(x_2(t))$$

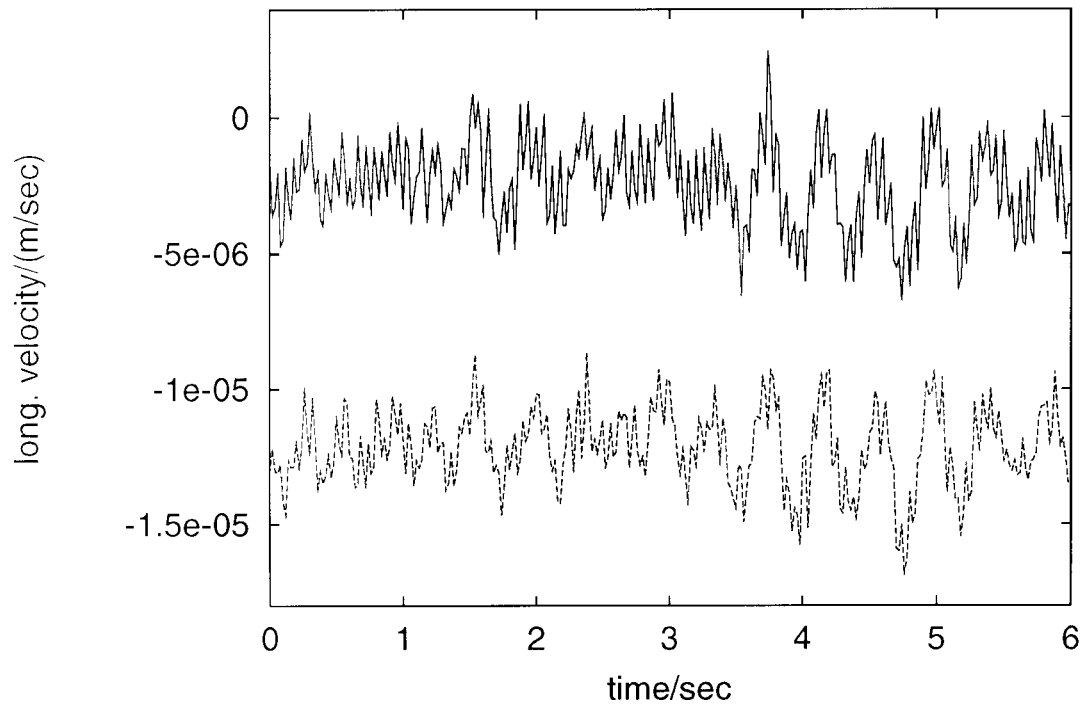
of the vertical motion left and right of the  
interaction point, distance 34 m:



rms value of the difference signal  $x_1(t) - x_2(t)$  of the horizontal motion of the two tunnel ends, distance 34m, in the frequency range above  $f_0$ , given as a function of  $f_0$  :



Longitudinal motion of the two tunnel ends at  
34 m distance (velocity signals):



### 3 Conclusion

- rms amplitudes of relative motion above a few Hertz exceed the vertical beam size by far
- active stabilization required to ensure single bunch operation
- horizontal motion seems to be tolerable
- further measurements at different sites desirable