Overview of Our Research Program & Vibration Studies of a XFEL/ILC Cryomodule at Room Temperature

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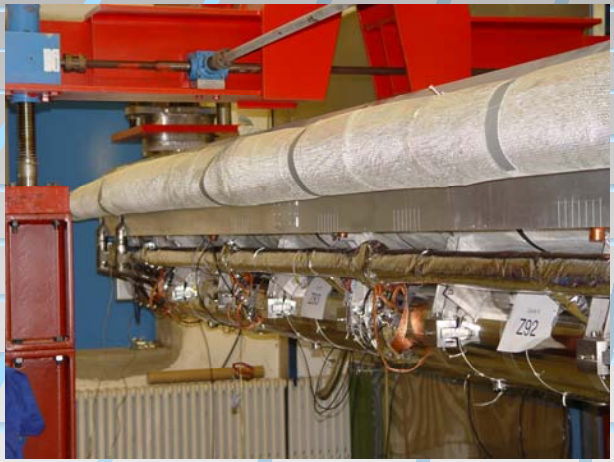
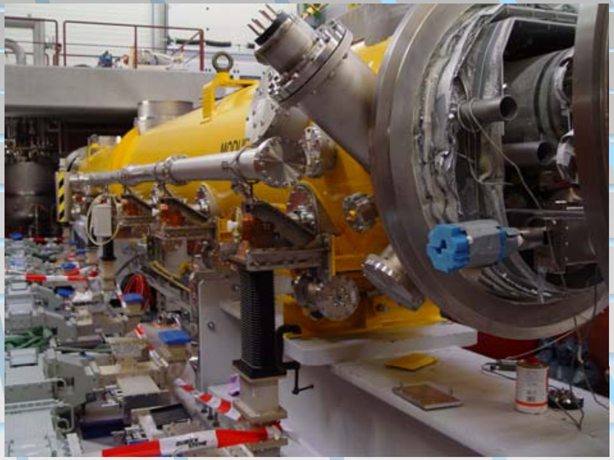
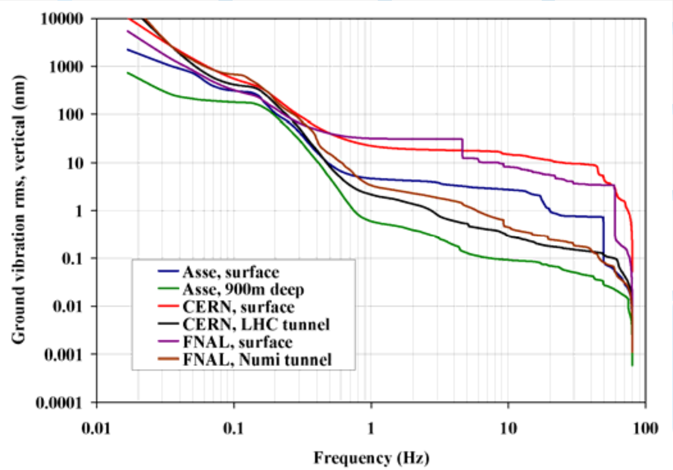
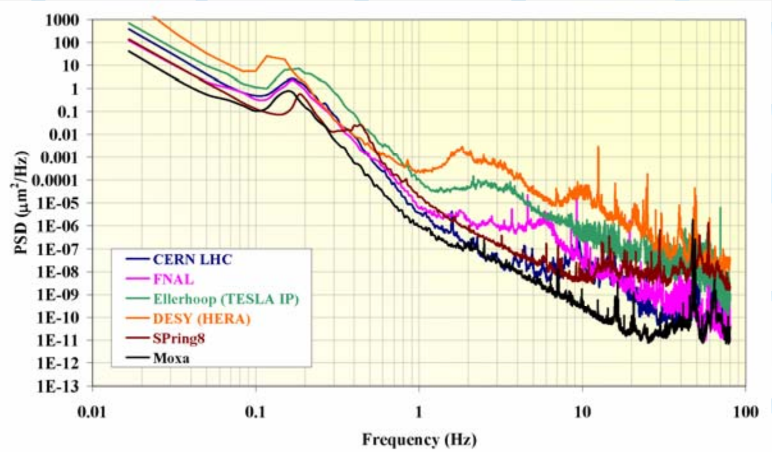






DESY



Overview of Our Research Program in DESY

❖Accelerator Component Vibration Studies; This program is relevant to both ILC and XFEL main Linacs

- ❖ Vibration stability study of XFEL/ILC cryomodules in both room temperature and 2K.

Status: study of two cryomodules (Superstruktur & Module6) at room temperature is complete. Results of the Superstruktur measurements were presented in EPAC06. Both XFEL and ILC@FermiLab are interested in our results for their module design. Measurements at 2K are planned on module6 via geophones and module8 via laser vibrometer in 2007/early 2008.

- ❖ Stability of cryomodule support structures, either hanging from the ceiling (XFEL) or on the floor of a tunnel (ILC)

Status: Since support structures and their installation in a tunnel are important on the stability of the cryomodules, and therefore, the stability of a linear machine, effort was put in to study the XFEL support structures (hanging from the ceiling) and the LHC cryomagnet jacks on the tunnel floor. Further measurements and design studies are planned in the XFEL mock-up tunnel, from July 2007.

- ❖ Facility noise: potential vibration sources in a tunnel

Status: to be done in the CMTB (Cryo-Module Test Bench) laboratory in DESY.

Overview of Our Research Program in DESY

❖Site Characterization Issues

❖ A database of ground vibration of 20 sites around the world is available: http://vibration.desy.de.

Status: In collaboration with DESY MPY IT group and M. Kubczigk, our homepage is undergoing redesign efforts in order to be able to utilize it as a data back up and retrieval tool. Our database was presented in Nanobeam2005 & EPAC2006. An invited extended contribution to PRSTAB (Physical Review, Special Topics: Accelerators & Beams) is currently under preparation. Measurement program has reached its maturity.

❖ Characterization of sites

Status: In collaboration with D. Kruecker (DESY), all the measured sites were characterized and results are ready for publication.

❖ Coherence/correlation studies of a site (DESY)

Status: Coherence/correlation studies provide valuable insight to site characterization. Measurements of DESY coherence spectra are ready for publication. First measurements in the LHC tunnel, as an example of a ´quiet´ site, were attempted early December 2006.

Overview of Our Research Program in DESY

❖Site Characterization Issues, in collaboration with D. Kruecker (DESY)

Aim: To characterize `cultural noise´ at f > 1 Hz of the measured sites.

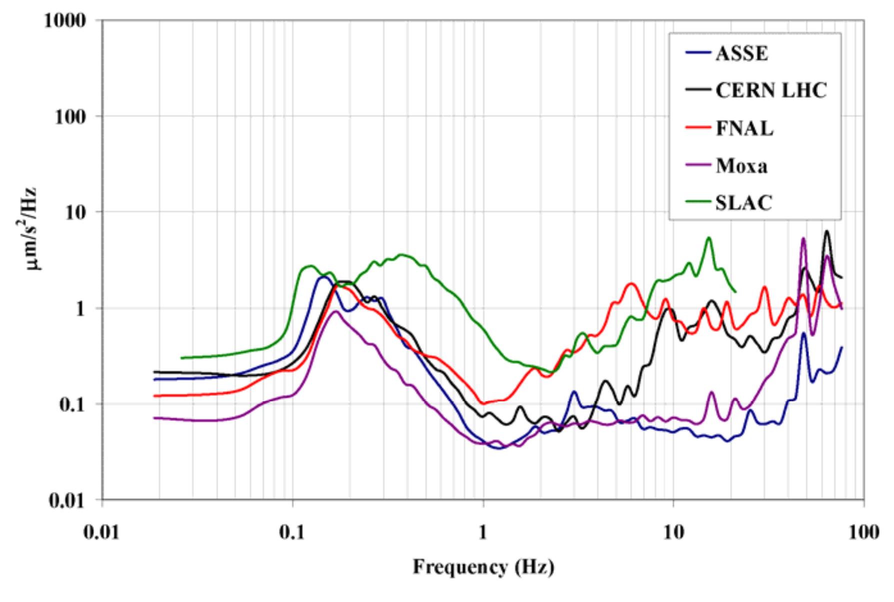
Method: depicting `cultural noise´ as deviation from $1/f^4$, or random noise walk behavior. Starting from displacement PSD, $S_x(f)$, we integrate twice to obtain Fourier transform of acceleration, $S_a(f)$, using the relation below:

FT [d/dt x(t) = -2πif FT [x(t)]

In order to see deviation beyond $1/f^4$ for each site, we plot:

$\sqrt{S_a(f)} = 4\pi^2 f^2 \sqrt{S_x(f)}$

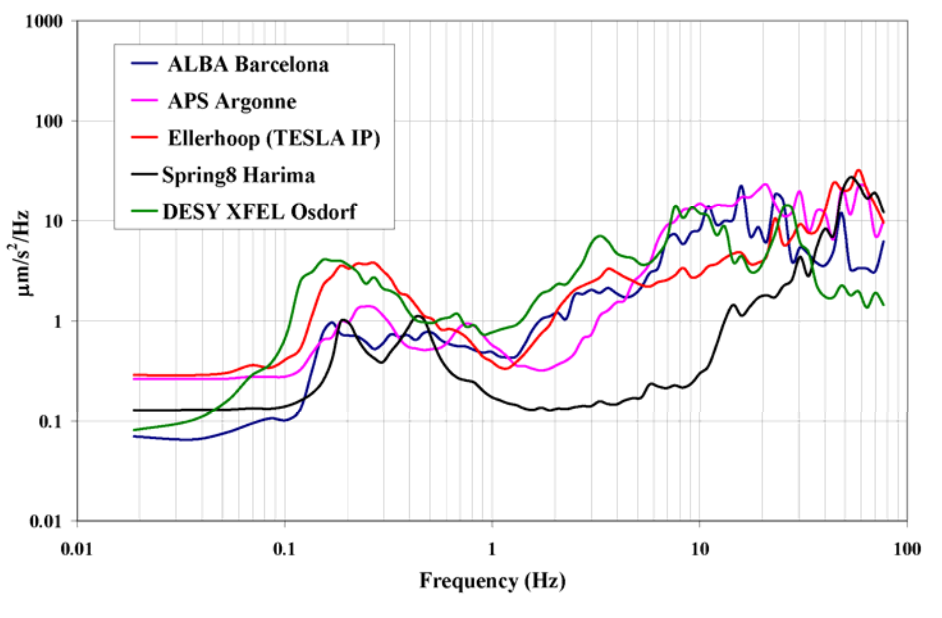
Anything above the flat distribution may be considered as `cultural noise´. The base level of the distribution, where it is flat, varies from site to site and gives further insight in the site characterization.



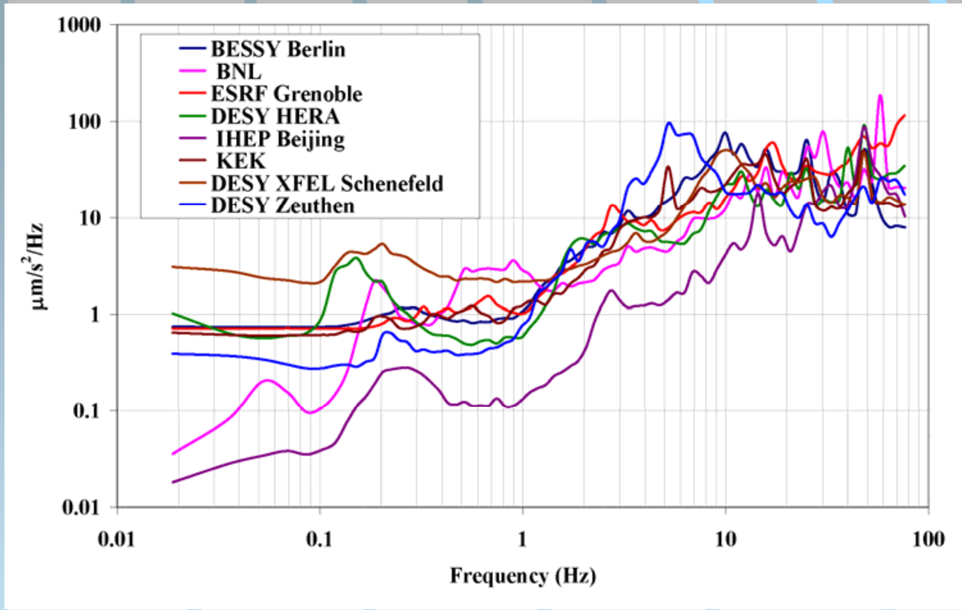
Acceleration vs. Frequency (quiet sites)

Overview of Our Research Program in DESY

❖Site Characterization Issues, in collaboration with D. Kruecker (DESY)



Acceleration vs. Frequency (medium sites)



Acceleration vs. Frequency (noisier sites)

Overview of Our Research Program in DESY

❖Site Characterization Issues; Coherence/Correlation Measurements of a Site (DESY)

$$\text{Correlation}(f) = \langle X(f).Y^*(f)\rangle / \sqrt{[\langle X(f)X^*(f)\rangle\langle Y(f)Y^*(f)\rangle]}$$

PSD= Power Spectrum Density ($\mu m^2/Hz$)

$$X(f)X^*(f) = PSD_{signal1}$$

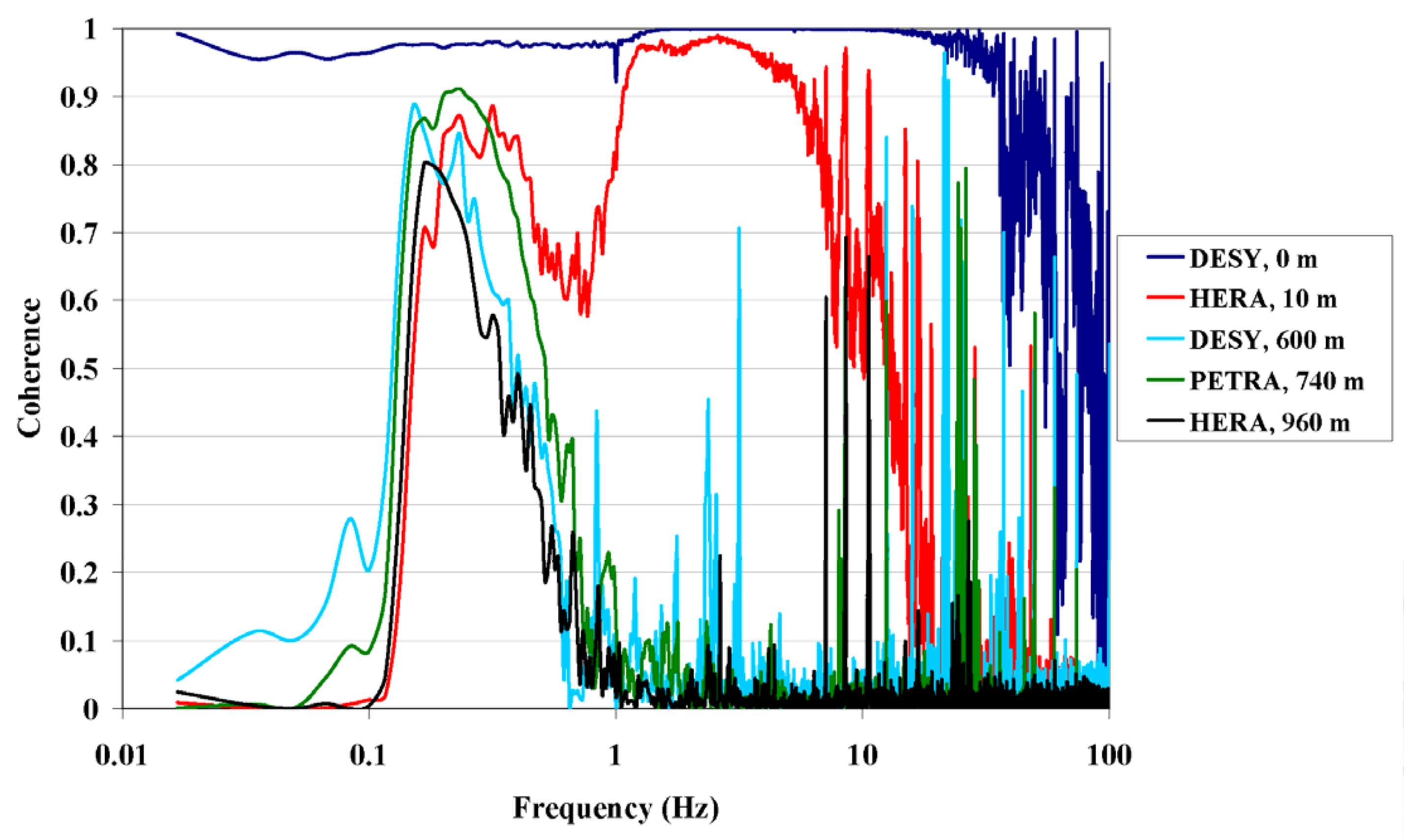
$$Y(f)Y^*(f)=PSD_{signal2}$$

$$\text{Coherence}(f) = |\text{Correlation}(f)|^2$$

$$\text{Amplitude Transfer Function} = |XY^*|/XX^* \approx \sqrt{PSD_{signal2}} / \sqrt{PSD_{signal1}}$$

Overview of Our Research Program in DESY

❖Site Characterization Issues; Coherence/Correlation Measurements of a Site (DESY)

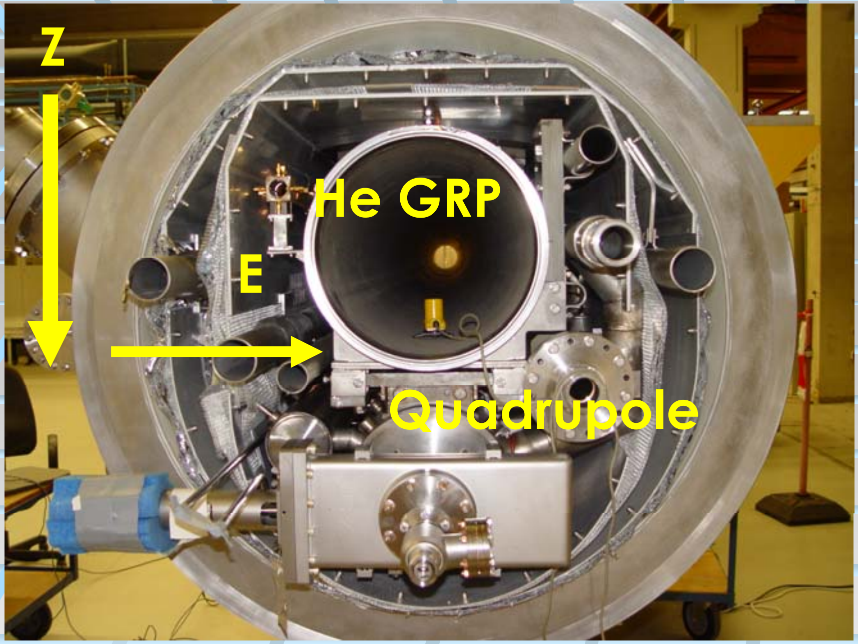


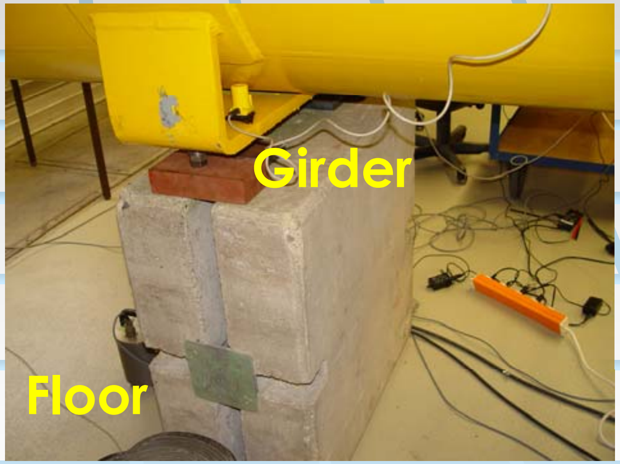
Good coherence signal (> 0.8) at distance (d) = 0 m upto ~13 Hz; at d = PETRA ring circumference, corherence is limited to the microseismic peak.

Vibration Studies of a XFEL/ILC Cryomodule at Room Temperature

- Systematic approach: from room temperature to 2K measurements in order to facilitate comparison between ´warm´ vs. ´cold´ on the same cryomodule.
- Repeated measurements on more than one cryomodule (eg. Superstruktur, Module 6 etc.) to gain a better understanding of a cryomodule stability as a whole.
- Repeated measurements on each cryomodule to check for reproducibility of data.
- Effect of the cryomodule support system (eg. ceiling vs. floor)
- Data management, storage and our homepage as a tool for communicating our data

Stability Within the Module

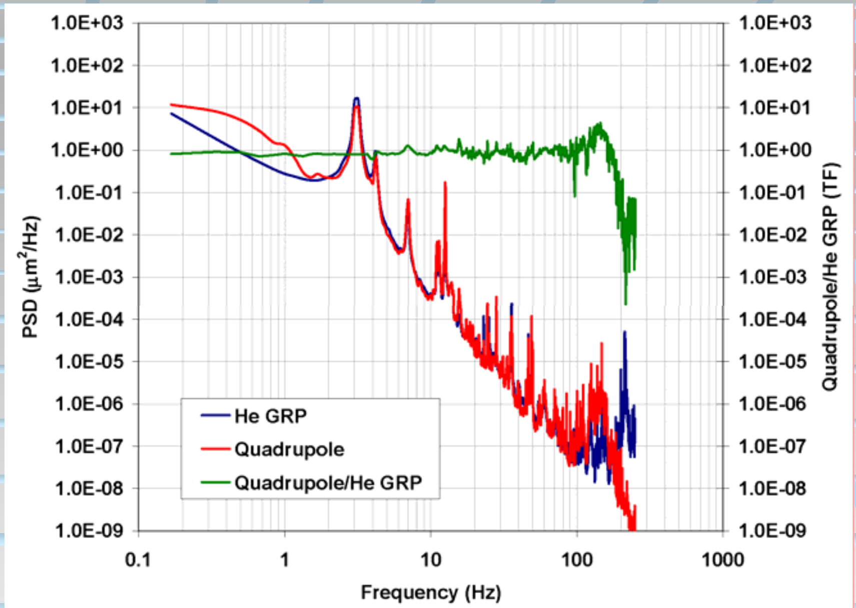




Sensor positions (in V + HT):

- Vessel top vs. He GRP
- He GRP vs. quadrupole
- Vessel top vs. quadrupole
- Reference measurement on the girder/floor

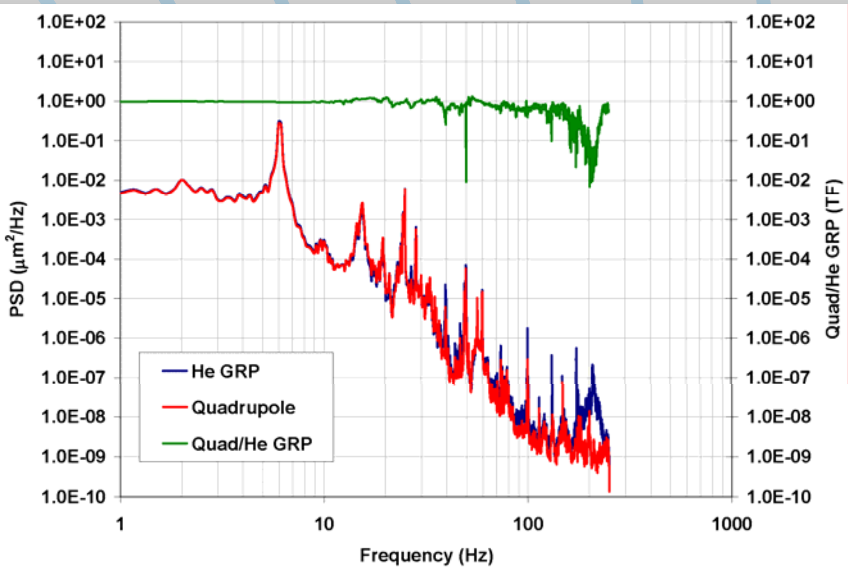
Stability Within the Module

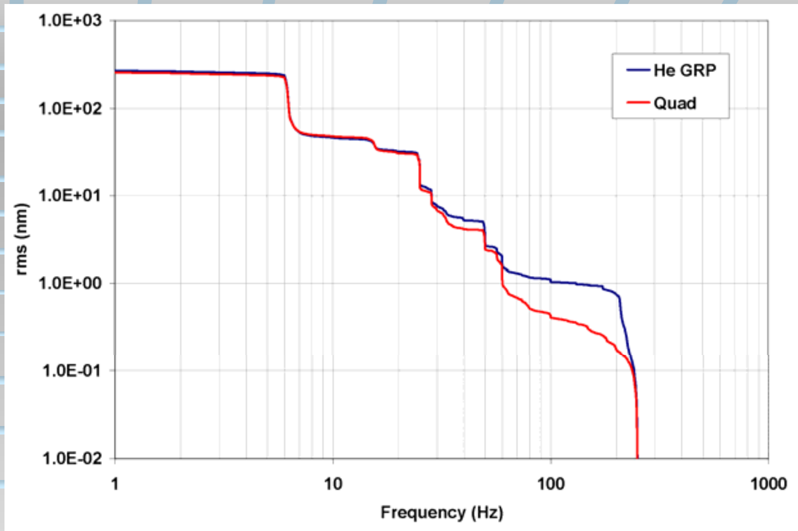


PSD (horizontal transverse) of module 6 core (He GRP, quad and the cavity string) before placement in the vessel (1 June 2006)

Integrated rms of motion > 1.7 Hz:
Vertical quad/He GRP=774/783 (~1%)
Horizontal transverse quad/He GRP=1488/1840 (~20%)

Stability Within the Module





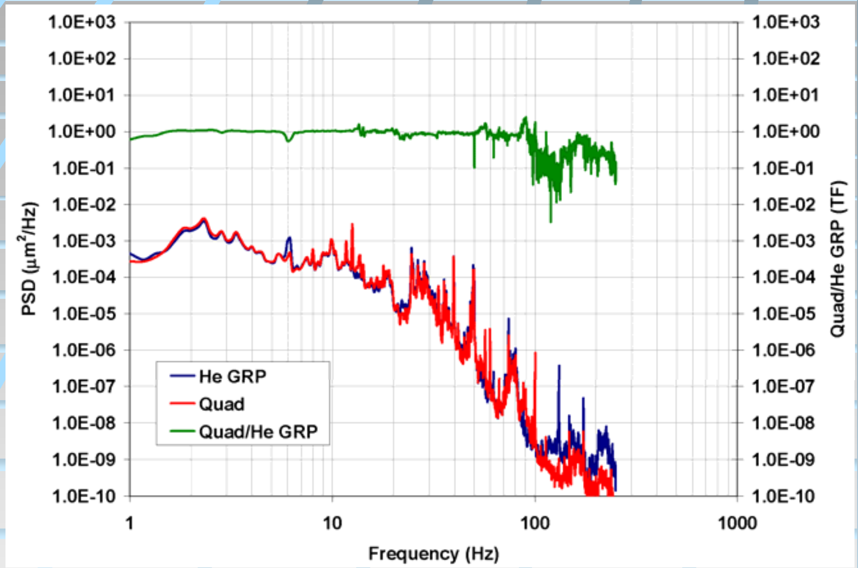
Girder resonance @ 6.0 Hz

PSD (HT) of module 6 (as placed on its test stand) on 25 August 2006, quad vs. He GRP

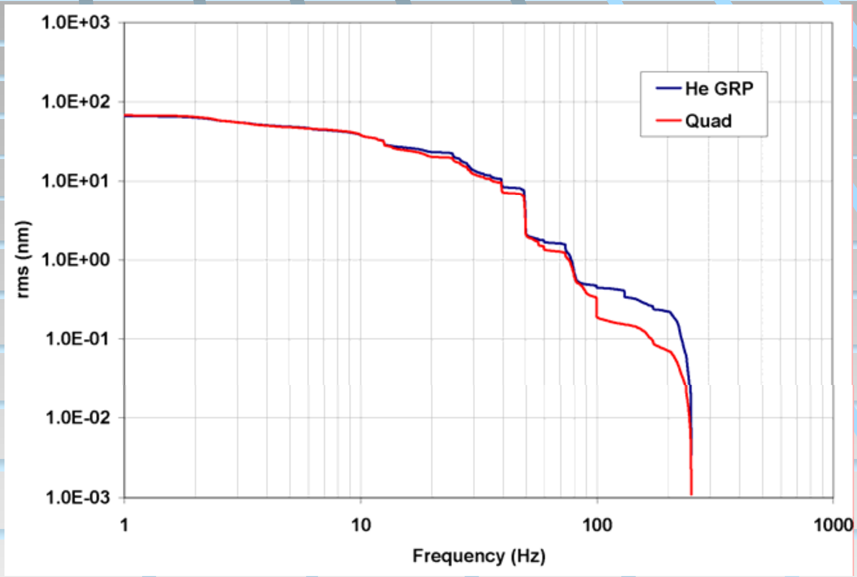
Integrated PSD (rms) @ f > 1.7 Hz: quad/He GRP=255/267~0.95

Module 6 on the test stand in #70

Stability Within the Module



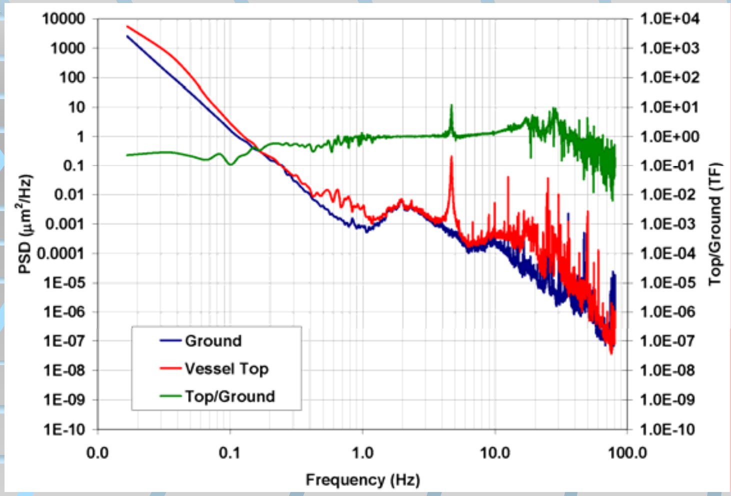
PSD (V) of module 6 (as placed on its test stand) on 25 August 2006, quad vs. He GRP

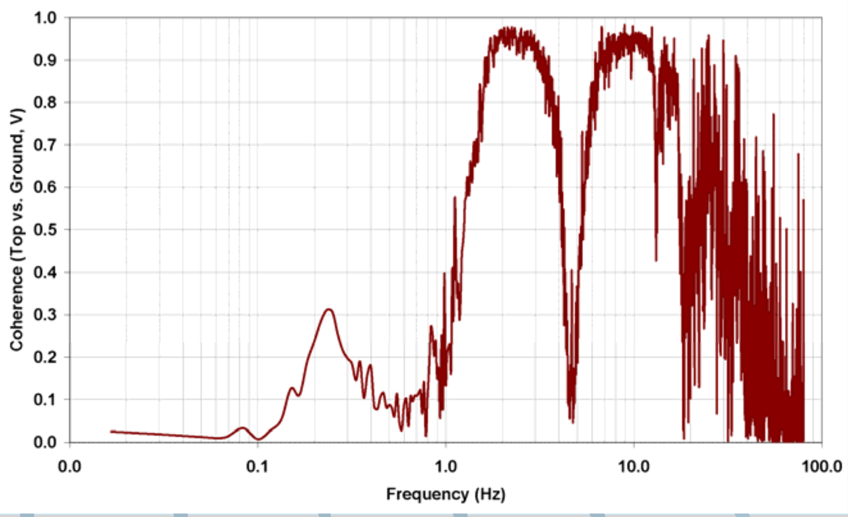


Integrated PSD (rms) @ f > 1.7 Hz: quad/He GRP=67/65 ~1

Conclusion: Throughout our measurement program, stability within the module (quad vs. He GRP, quad vs. vessel top) is consistently observed within a 20% window maximum.

Importance of Girder/Support Systems





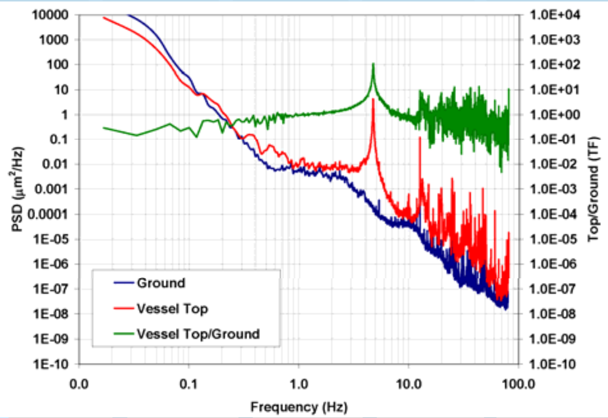
PSD (vertical) of module 6 (as placed on concrete blocks) on 23 June 2006, vessel top vs. floor

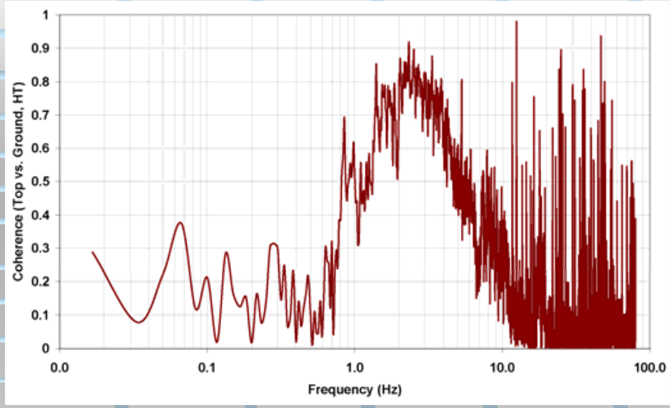
Coherence of the PSD signals shown on the left, loss of coherence at 4.7 Hz is clearly seen.

This girder resonance @ 4.7 Hz, is seen all the way along the length of the module.

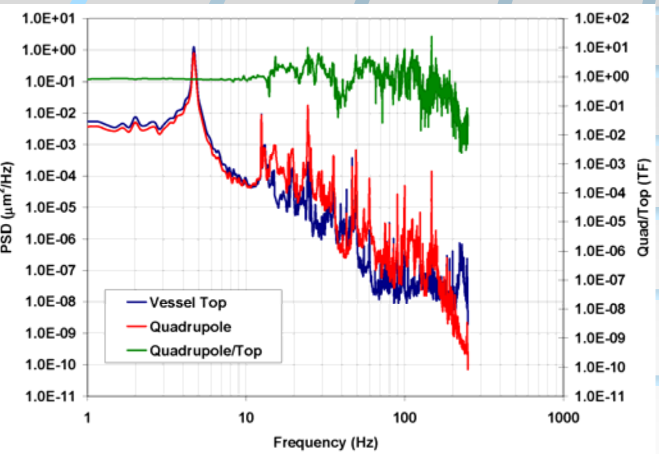
Module 6 on concrete blocks in Hall 3

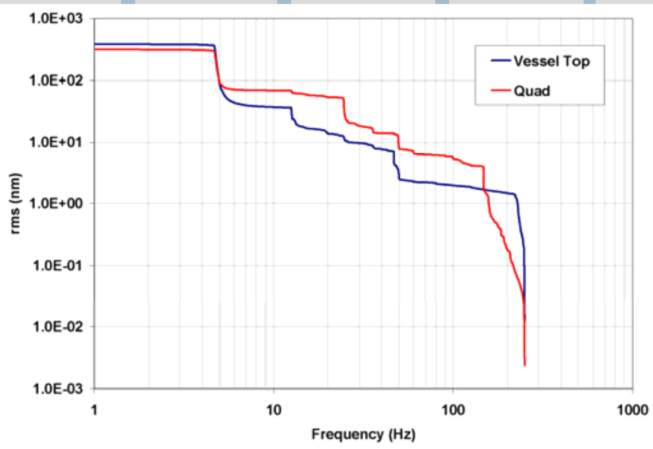
Importance of Girder/Support Systems

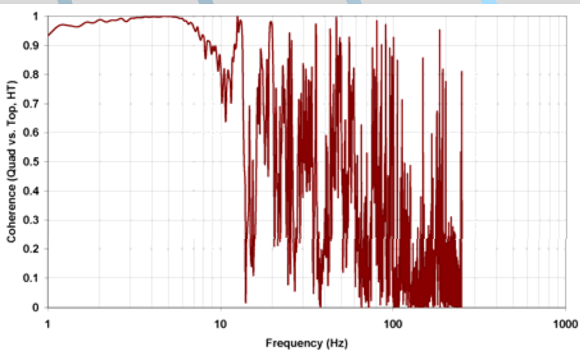




PSD (horizontal transverse) of module 6 (as placed on concrete blocks) on 23 June 2006, vessel top vs. floor and the resultant coherence plot (right)



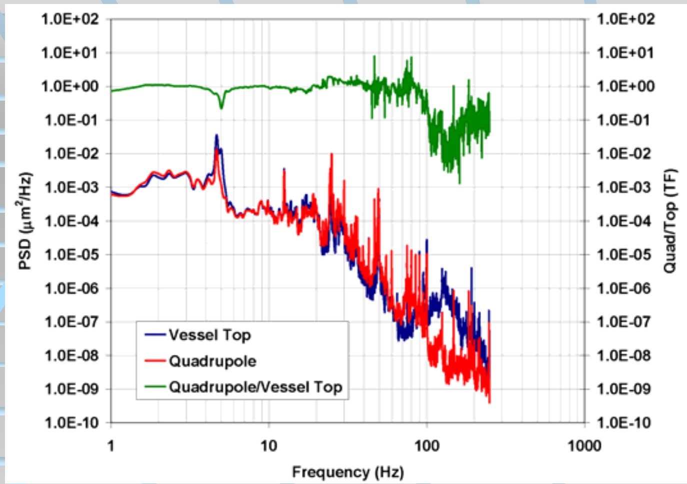


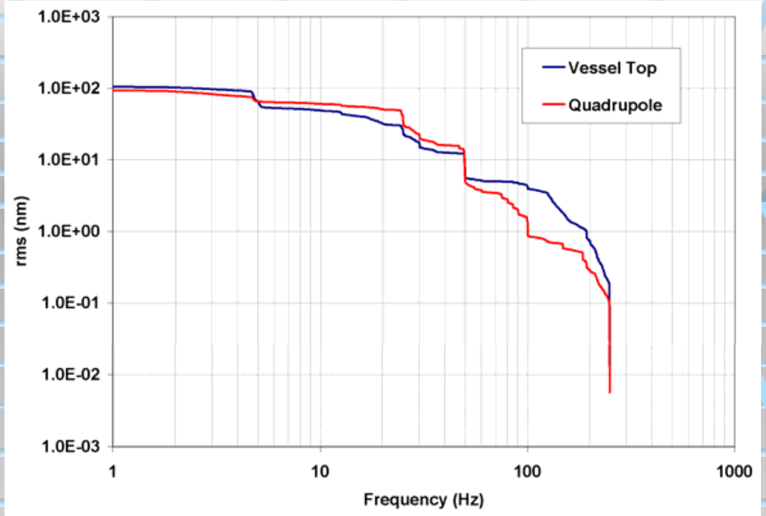


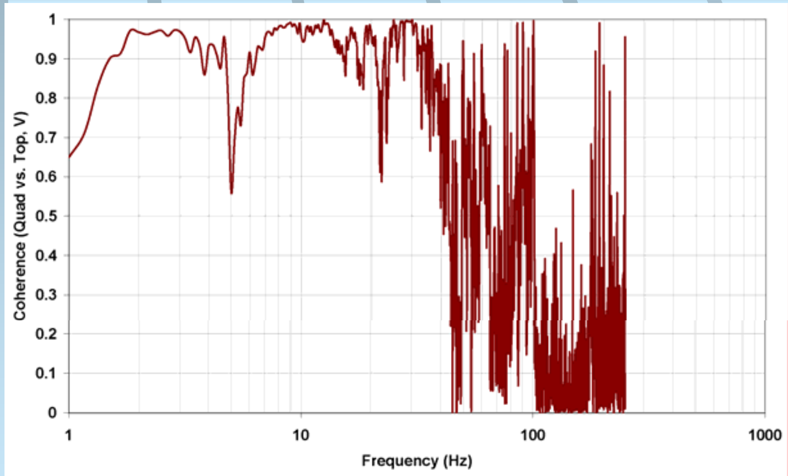
Girder resonance @ 4.7 Hz, can be seen on the quad measured on 23 June 2006.

PSD (HT) and integrated rms of motion > 1 Hz; TF @ 1 Hz, quad/top=320/390 ~0.82

Importance of Girder/Support Systems



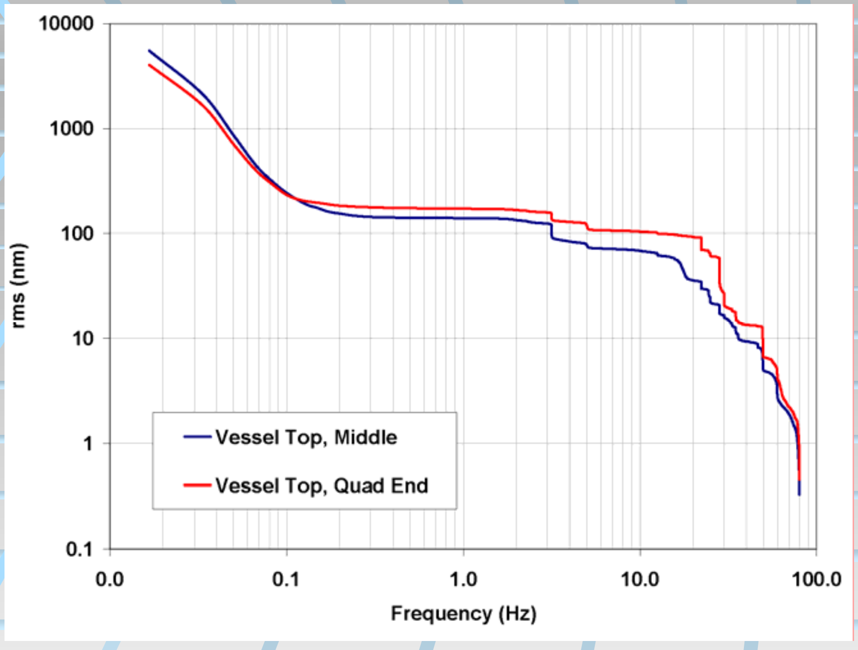




Conclusion: The support system used for a machine such as XFEL/ILC may play a crucial role in the stability and hence, the quality of its beam/s. A careful design of such girders/support systems should be implemented such that the overall system does not contain resonances below 10 Hz, at least.

PSD (V) and integrated rms of motion > 1 Hz; TF @ 1 Hz, quad/top=93/105 ~0.88

Stability Along the Module (Vessel Top, Vertical)

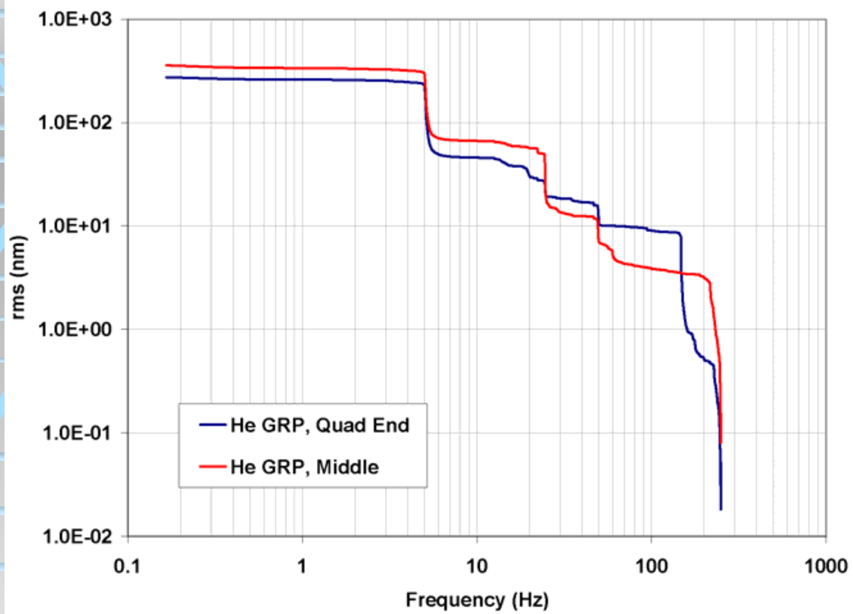


Average integrated rms of motion > 1 Hz (vertical);
TF @ 1 Hz: vessel top, middle(X2)/vessel top, quad end (X1)=139/167 ~0.8

Sensor positions (in V + HT) on 24 July 2006:

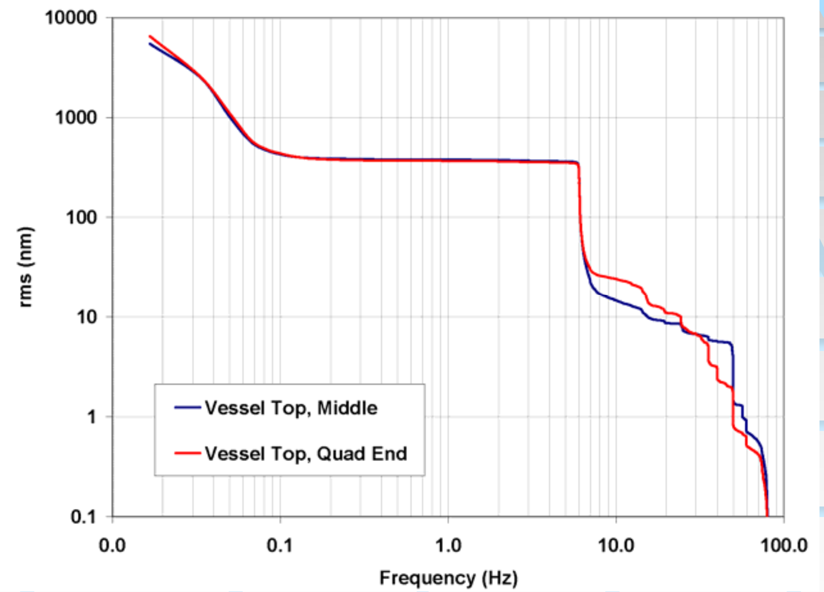
- Synchronized measurements on the vessel top, quad end (X1) and middle (X2)
- Simultaneous geophone measurements in the He GRP at the same positions, quad end (Y1) and middle (Y2)

Stability Along the Module (He GRP, HTransverse)



Conclusion: Our measurements show that in going from the quad end of the module to the other end, a variation of up to 20% (in vertical direction) and 30% (in horizontal transverse) is seen in the rms motion. This is a worse case scenario and it improves by a better girder and other connections. Please see below:

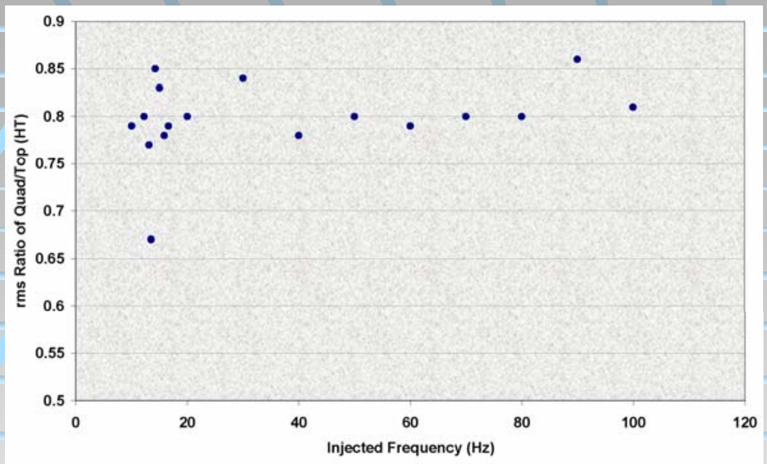
Average integrated rms of motion > 1 Hz (HT); TF @ 1 Hz, He GRP, middle (Y2)/He GRP, quad end (Y1)=340/264 ~1.29
(measurement on 24 July 2006)



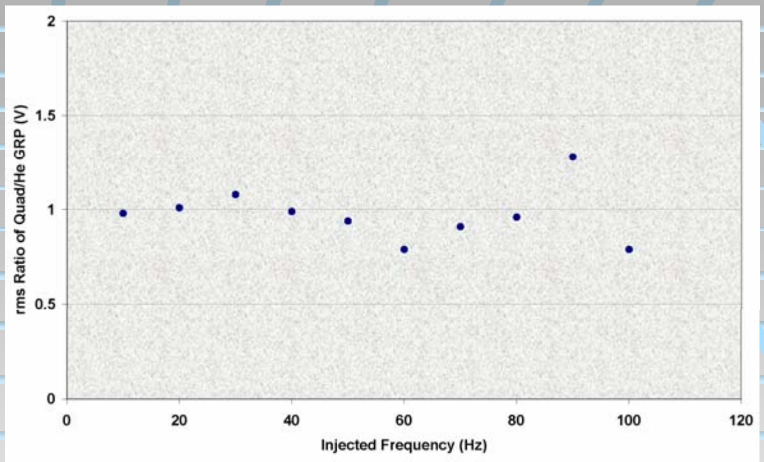
Average integrated rms of motion > 1 Hz (HT); @ 1 Hz, Vessel Top, middle /Vessel Top, quad end =378/368 ~1.0
(measurement on 29 August 2006 in #70)

Reproducibility of Our Data

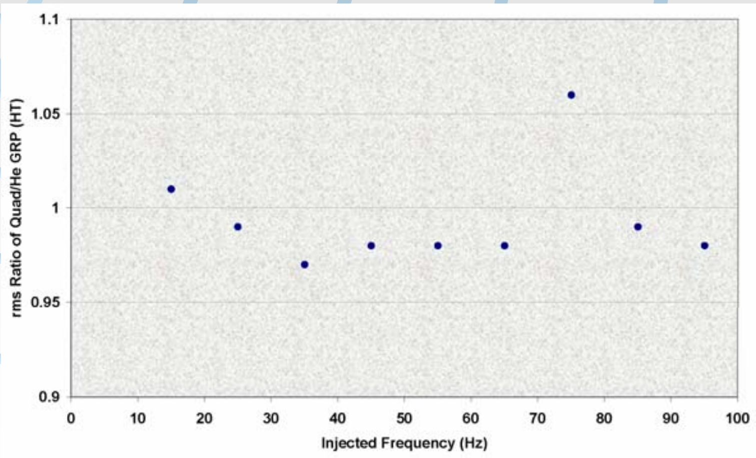
In order to check reproducibility in our measurements, a single frequency was injected in the system (i.e. floor and hence the module), via a shaker, in both vertical and horizontal transverse directions and the rms of the signal was measured via gepohones (@ f > 2 Hz)



Quad/Top @ 2 Hz in HT



Quad/He GRP @ 2 Hz in V



Quad/He GRP @ 2 Hz in HT

Conclusion: Our measurements within the vessel (quad vs. He GRP and quad vs. Vessel top) are reproducible.

Comparison of Ceiling vs. Floor of a Shallow Tunnel (HERA)

PETRA-HERA injection point (WR217)

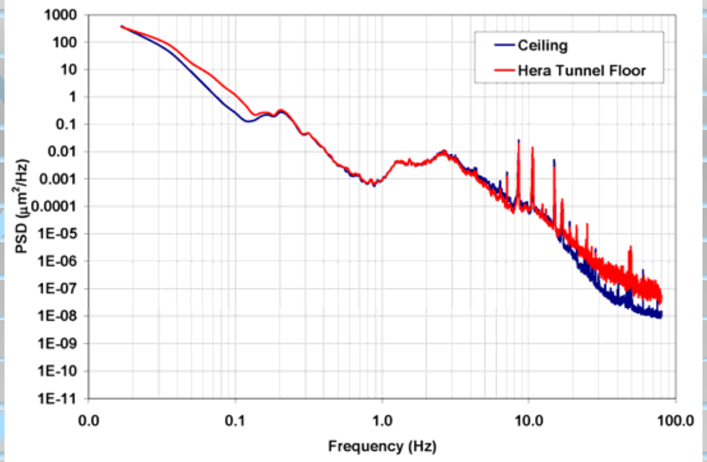
HERA tunnel is not a recent construction, therefore, a comparison study of ceiling vs. floor vibrations, may tell us about the behavior of future shallow tunnels constructed in DESY and vicinity.

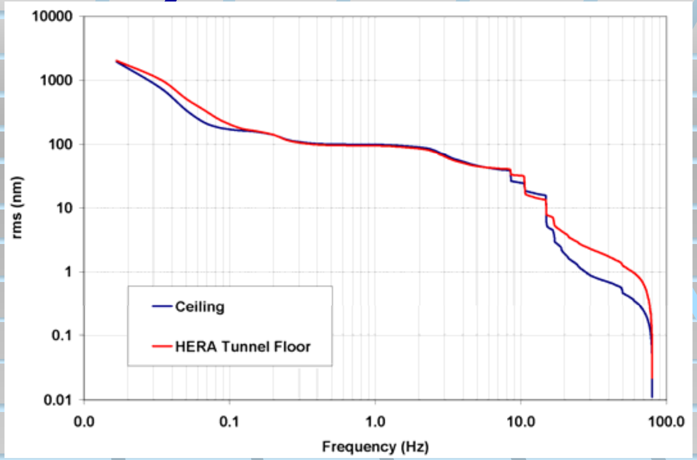
Site map: courtesy of DESY

Sensor positions:

- Sensor 1 on the ceiling (PETRA-HERA injection point)
- Sensor 2 on the floor of the HERA tunnel
- Data taking period:3 hours and 15 minutes on 25 October 2006

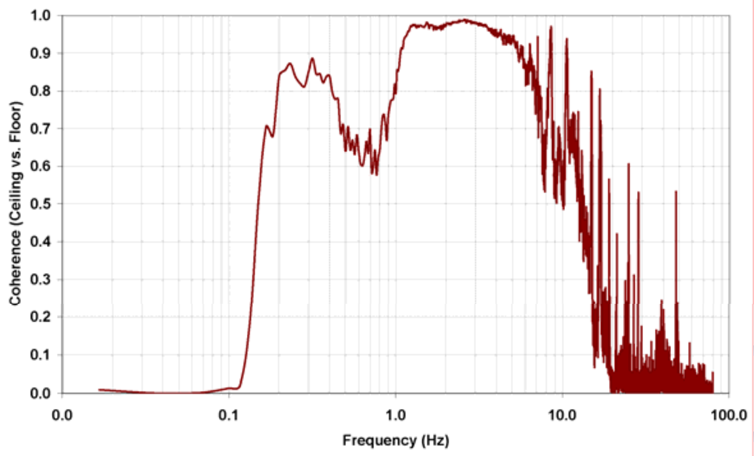
Comparison of Ceiling vs. Floor of a Shallow Tunnel (HERA)





Average psd (V) and integrated rms of motion (nm) > 1 Hz; @ 1 Hz, ceiling/floor=99/95 ~0.96, i.e., a difference at a 4% level is seen. Same result is obtained for the horizontal directions.

Conclusion:High f noise (> 10 Hz) is detected in both ceiling and floor, or as it were two parallel tunnels at a distance of ~ 10 m. However, low f noise (< 1 Hz) was detected on the floor only, or as it were a ´service tunnel´. However, in all these cases (machine in a single tunnel whether on the ceiling or on the floor, or two tunnel solution), facility noise should be damped/minimized.



Coherence signal between the two sensors placed at a distance of ~7 m. Good coherence (> 0.5) upto 13 Hz is seen.

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