

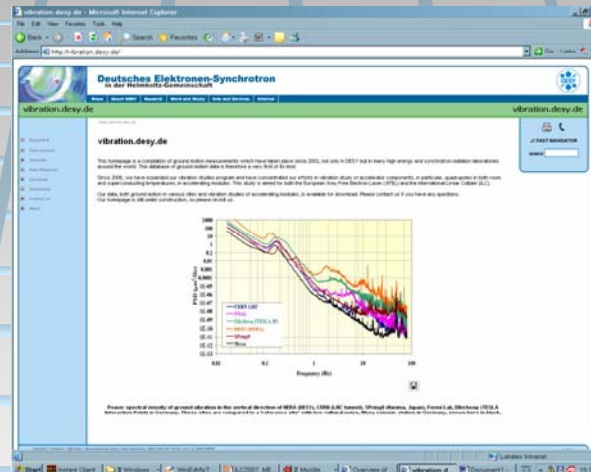
Review of Ground Motion Measurement Program of DESY in Various Sites

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ILC 2007 @ DESY, 30 May- 2 June 2007



LHC tunnel, CERN



**Ground vibrations database @
DESY**



HERA tunnel, DESY



Special thanks to: H. Ehrlichmann, D. Krücker, M. Kubczig, P. van der Reest

Program Objectives

- ❖ To collect ground vibration data in various sites and build up a database; first database of its kind; few TB of data.
- ❖ To understand the effects of 'cultural noise' and geology in various sites around the world at $f > 1$ Hz, the so called 'fast' uncorrelated motion.
- ❖ upto 20 sites in three continents have been measured.
- ❖ This database is meant to be a guide and a reference point for understanding issues pertaining to siting for an accelerator complex.
- ❖ Measurements are recent (2003-2006).

Methodology

- ❖ Utilize the same equipment and analysis technique.
- ❖ 24 h measurements, including a weekend.
- ❖ Compare measurements with reference sites which have very low 'cultural noise' content; in our case two sites in Germany were chosen, Asse & Moxa.
- ❖ Each site was measured in various points, such as tunnels, experimental areas, surface buildings, locations nearby roads to assess influence of traffic.
- ❖ Few measurements have been repeated in two successive years.
- ❖ Analysis is performed in vertical direction direction mainly.

Equipment & Data Analysis

❖ Broadband Seismometers, GÜRALP CMG

- ❖ Measurement of acceleration, output signal: velocity
- ❖ Three components: vertical, 2x horizontal
- ❖ Integrated 24bit ADC, 200Hz sampling rate
- ❖ Data acquisition via notebook
- ❖ Frequency ranges:
 - 360s – 80Hz CMG-3T (old)
 - 120s – 80Hz CMG-3T (new)
 - 60s – 80Hz CMG-6T



$x(t), y(t)$ time series of length T, N points each

$X(v_i), Y(v_i)$ FFT

$\langle XX^* \rangle, \langle YY^* \rangle$ Estimated displacement power spectral density (PSD)

$\frac{|\langle XY^* \rangle|^2}{\langle XX^* \rangle \langle YY^* \rangle}$ Coherence

$\sqrt{\frac{|\langle XY^* \rangle|}{\langle XX^* \rangle}}$ Transfer function amplitude

$\sqrt{\frac{1}{T} \sum_{i=k}^{N/2} \langle XX^* \rangle (v_i)}$ Integrated RMS amplitude at frequency v_k

DESY Ground Vibrations Database, a Snapshot

Overview of Measured Sites - Microsoft Internet Explorer

Address http://vibration.desy.de/overview/index_eng.html

vibration.desy.de

Home: Overview

Overview of Measured Sites

Overview of Measured Sites (Vertical Direction)

Site location	Average rms (nm)	σ (nm)	Day rms (nm)	Night rms (nm)	Pk-Pk (nm)	FWHM (nm)
ALBA, Barcelona, Spain	18.8	9.5	42.0	9.1	88.6	122.0
APS, Argonne, U.S.A.	10.7	1.0	11.0	9.8	68.5	57.7
Asse, Germany (salt mine)	0.6	0.1	0.7	0.5	13.1	35.4
BESSY, Berlin, Germany	75.0	28.1	140.7	53.1	249.3	158.4
BIL, Upton, U.S.A.	89.6	30.2	135.3	29.1	383.6	558.2
CERN LHC, Geneva, Switzerland	1.9	0.8	2.8	0.9	21.6	54.1
DESY HERA, Hamburg, Germany	53.3	18.9	77.0	34.8	178.4	204.3
DESY XFEL, Osdorf, Germany	29.1	11.9	48.4	19.5	147.9	196.9
DESY XFEL, Schenefeld, Germany	41.1	16.6	70.0	35.1	179.6	245.3
DESY, Zeuthen, Germany	64.4	40.4	75.6	86.5	115.3	240.0
Ellerhoop, Germany (TESLA IP)	18.2	8.4	35.9	9.3	102.0	162.4
ESRF, Grenoble, France	74.0	34.9	137.2	40.2	163.3	179.8
FIAL, Batavia, U.S.A.	3.0	0.9	4.0	2.2	24.4	49.1
IHEP, Beijing, China	8.5	0.5	9.0	8.1	49.5	18.6
KEK, Tsukuba, Japan	80.5	36.0	125.1	38.0	228.4	277.0
LAPP, Annecy, France	3.6	1.6	7.0	1.9	35.7	66.3
Moxa, Germany (seismic station)	0.6	0.1	0.9	0.5	7.9	16.8
SLAC, Menlo Park, U.S.A.	4.9	1.2	7.4	4.1	61.4	117.9
Spring-8, Harima, Japan	2.0	0.4	2.5	1.8	22.4	40.3
SSRF, Shanghai, China *	292.0	164.0	444.0	102.0	550.0	1000.0

* this site was under construction during the measurements

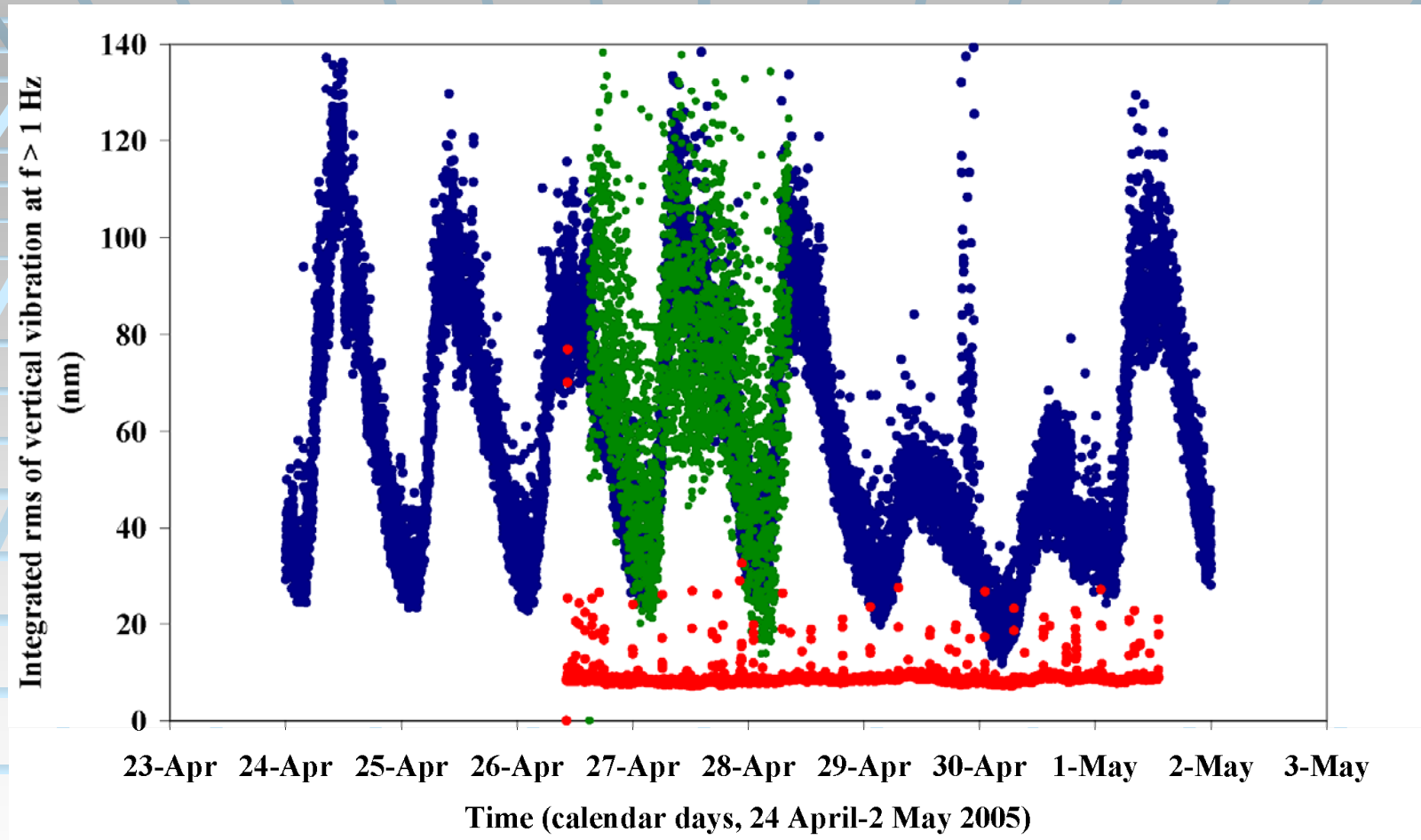
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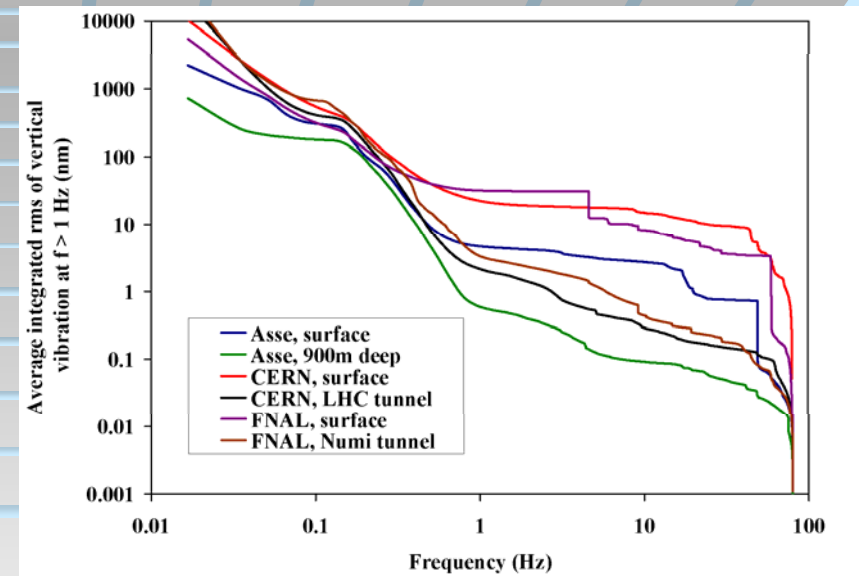
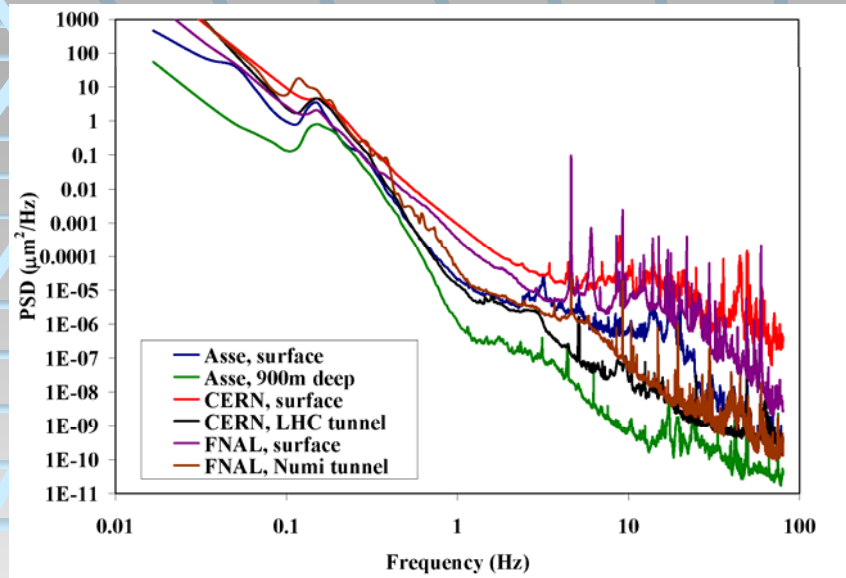
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Examples: Variation vs. Time HERA (Hamburg) vs. IHEP (Beijing)



Legend: HERA tunnel (Blue), IHEP south entrance gate, road nearby (green), IHEP experimental hall, south interaction region (red)

Examples: Variation vs. Tunnel Depth



rms @ $f > 1$ Hz (surface)

Asse: 5 nm
CERN: 22 nm
FNAL: 32 nm

rms @ $f > 1$ Hz (depth)

Asse (900 m underground): 0.5 nm
CERN (LHC tunnel): 2 nm
FNAL (Numi tunnel): 3 nm

Examples: Attempting to Understand 'Cultural Noise' & Characterize Measured Sites

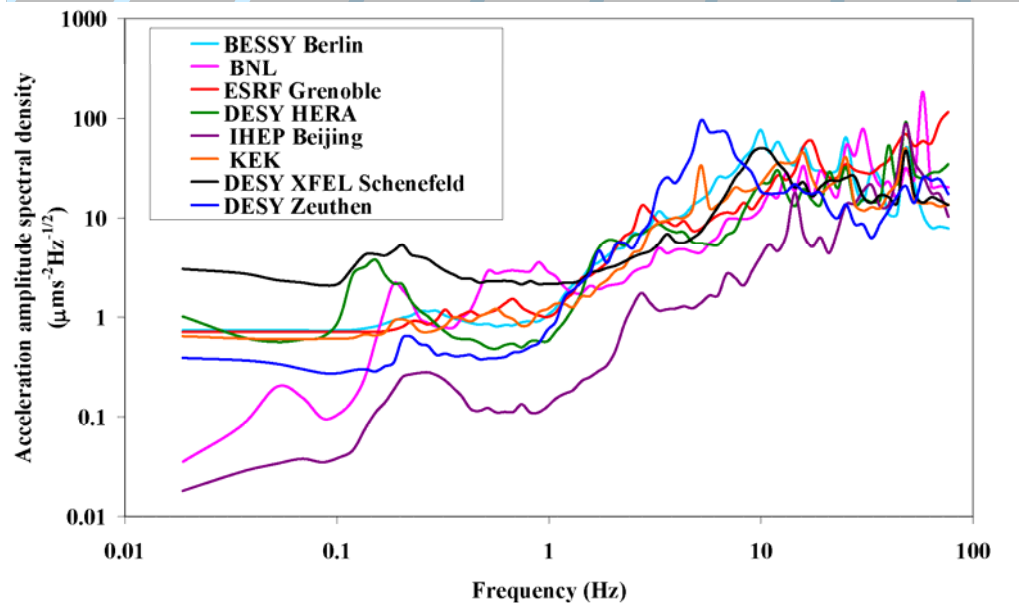
Aim: To characterize 'cultural noise' at $f > 1$ Hz of the measured sites.

Method: depicting 'cultural noise' as deviation from $1/f^4$, or random noise walk behavior.

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

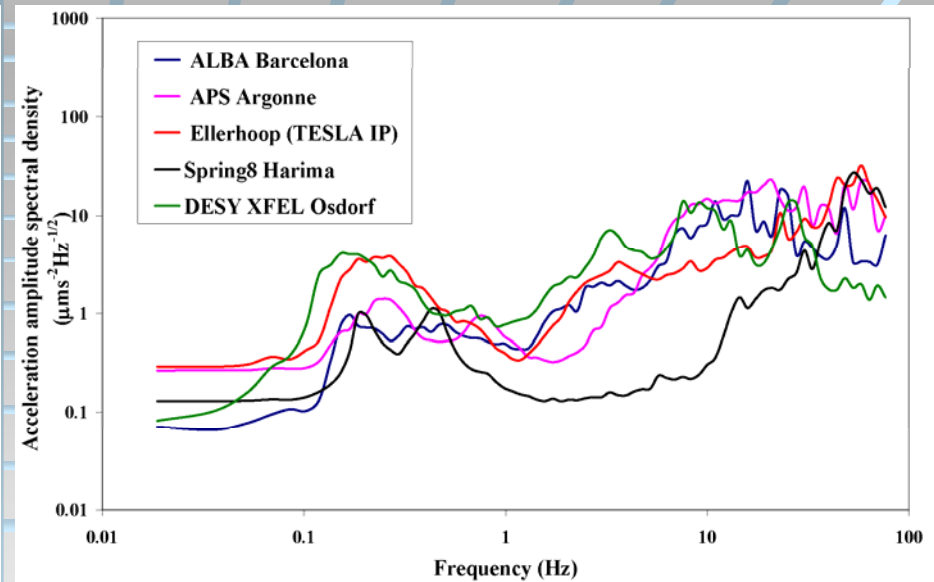
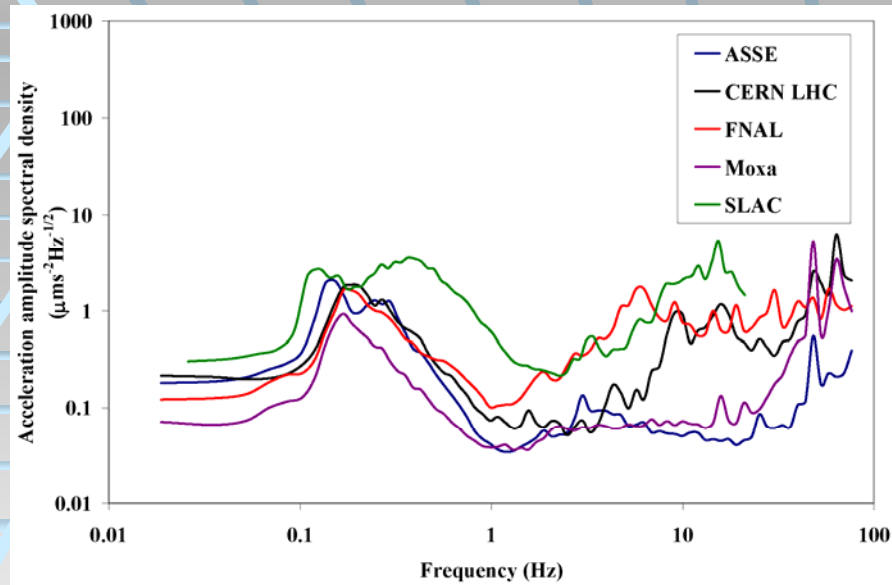
$$\sqrt{S_a(f)} = (2\pi k/T)^2 \sqrt{S_x(f)}$$

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.



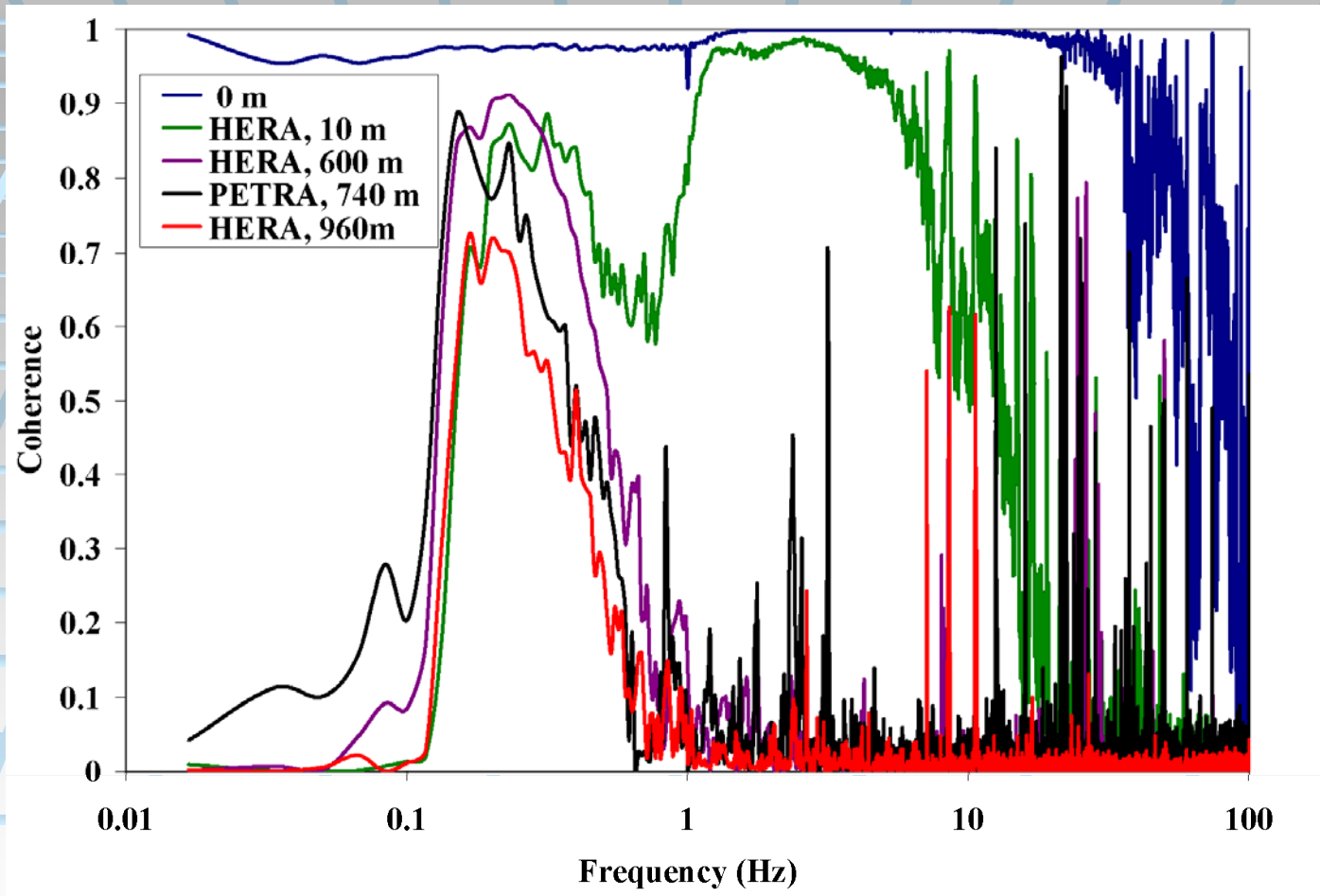
Acceleration amplitude spectral density for sites with high 'cultural noise' content with average rms vibrations greater than 50 nm.

Examples: Attempting to Understand 'Cultural Noise' & Characterize Measured Sites



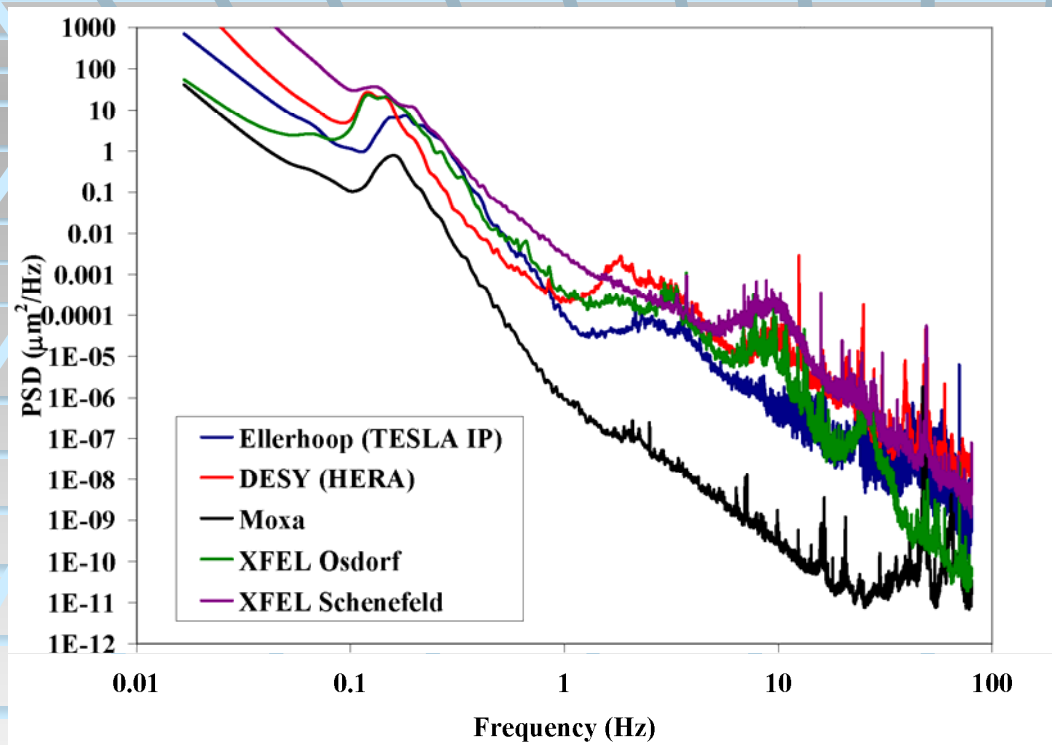
Acceleration amplitude spectral density for sites with low 'cultural noise' content with average rms vibrations less than 10 nm (left) and medium with average rms vibrations of 10-30 nm (right).

Examples: Coherence/correlations and hence, Rayleigh wave velocities



Coherence measured at DESY

Planned XFEL Site Measurements



Measurements at XFEL Schenefeld & Osdorf sites were surface measurements (February 2005)

- ❖ Shallow tunnel (few tens of meters in depth) ground/tunnel floor vibrations measurements once the XFEL tunnel construction is on its way.
- ❖ Assessment the impact of traffic and other sources of 'cultural noise' along the XFEL linac, undulators and its experimental halls .
- ❖ Coherence/correlation studies.
- ❖ Measurements in many points along the 2 km tunnel as the geology at Schenefeld, for example, is different from DESY.
- ❖ An assessment of facility noise based on our earlier experience within DESY.
- ❖ We can contribute to European sample site studies for the ILC.

Our Homepage:

<http://vibration.desy.de>

Our homepage is a venue for communication, retrieval & backup of our database. It uses AFS volumes to store our database:

- ❖ Raw data, FFT data**
- ❖ Minute by minute PSDs & averages (15 minutes)**
- ❖ PSD & rms spectra, variation vs. Time for each site, spectra of noisiest and quietest times of the day for each site and their corresponding rms**
- ❖ A program to display spectra**
- ❖ Documents**
- ❖ Everything is downloadable.**