

# Ground Vibration Measurements at DESY

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DESY

# motivation

magnet vibration could have a significant effect on the beam quality of particle accelerators

- betatron oscillation + decoherence -> emittance
- aberration effects -> emittance
- pointing stability (light sources)
- displacement at the IP (collider)

the beam quality requirements are increasing

- synchrotron light sources, third generation, fourth generation, ...
- linear collider

# our consequence

- study the impact of „cultural noise“ at several accelerator laboratories
- site comparison for future accelerators  
(in particular for ILC)

our approach: measurements using always the same equipment and data analysis technique

- > comparable data sets for all sites
- > creation of a public data base

# equipment

## ● broadband seismometers (GÜRALP)

measurement of acceleration, output signal: velocity

three components: vertical, 2x horizontal

integrated 24bit ADC, 200Hz sampling rate

data acquisition via notebook / PC

frequency ranges: 360s – 80Hz CMG-3T (old)  
120s – 80Hz CMG-3T (new)  
60s – 80Hz CMG-6T



## ● geophone system (KEBE)

SENSOR SM-6 geophones with nonlinear high gain amplifier

measurement of velocity, output signal: velocity

separate sensors for vertical or horizontal

16bit USB-ADC, 500Hz sampling

data acquisition via notebook / PC

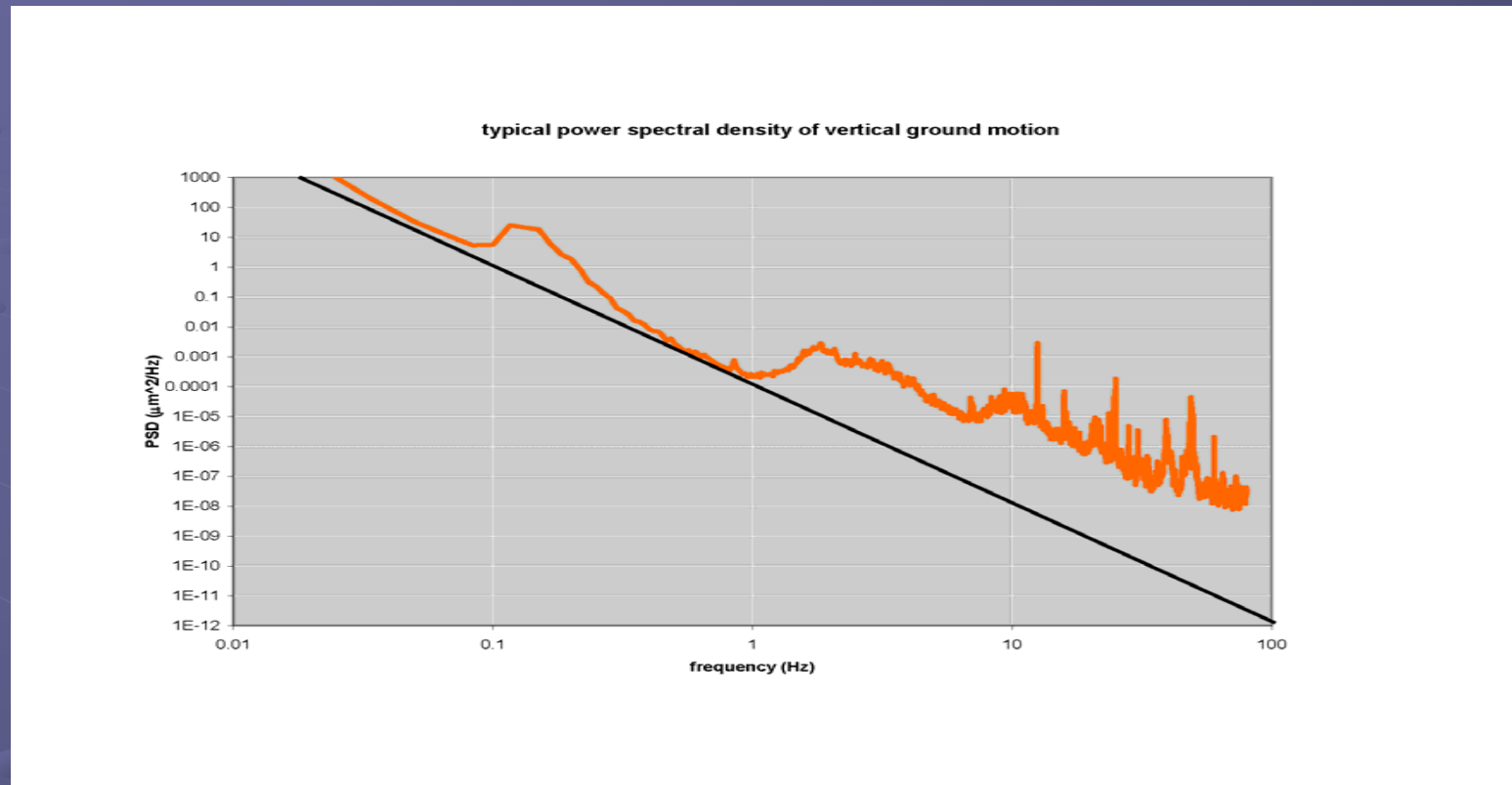
frequency range: 3Hz – 250Hz



# data taking and analysis

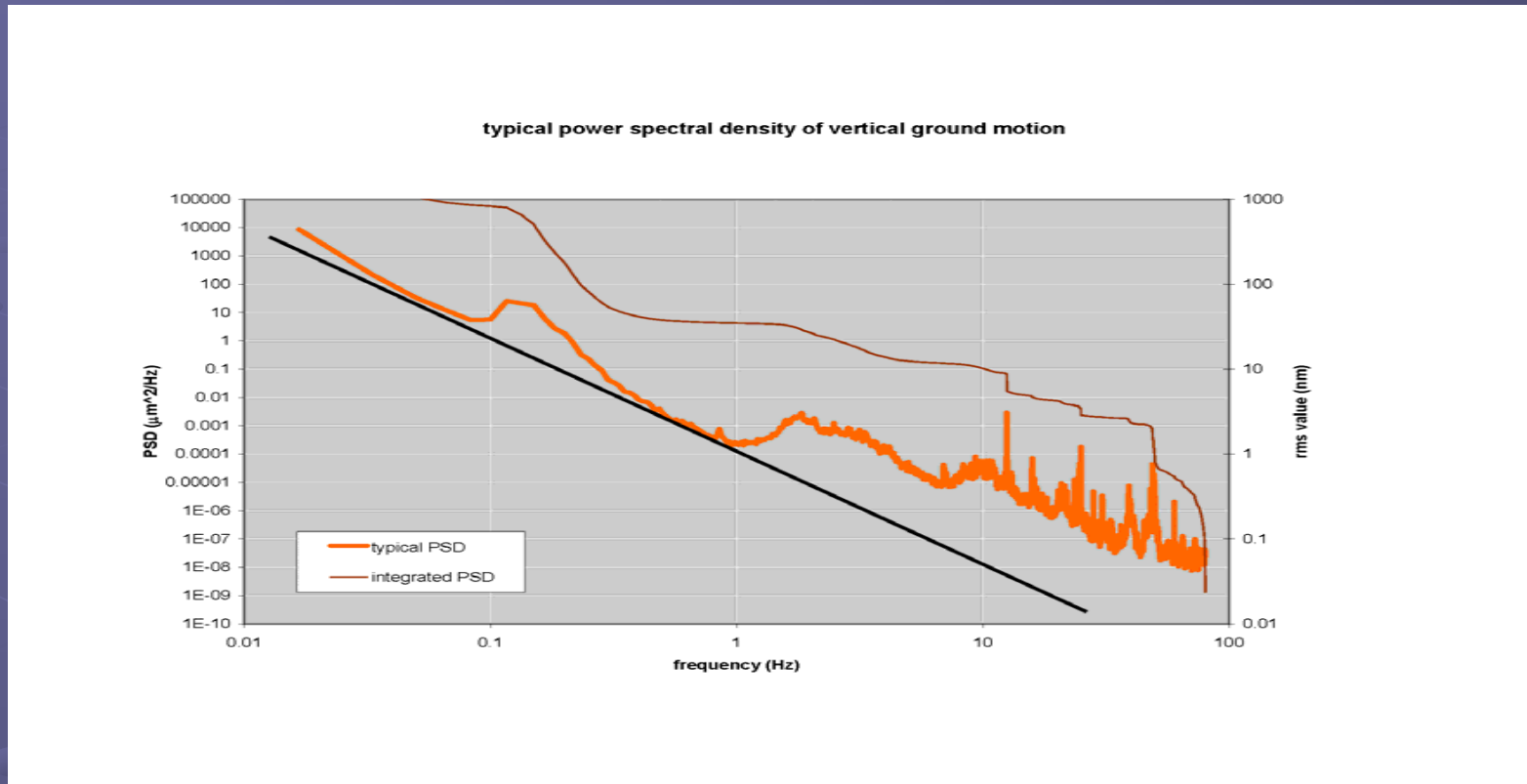
- continuous data acquisition for 24h or more
- one dataset per minute
  - > 700MB per day and sensor
- “FFT” based on this file structure
  - > 1/60Hz lower frequency limit
  - usually without windowing*
- integration (velocity -> motion)
  - > power spectral density (PSD) of motion
- integration above cut frequency
  - > rms-value of motion (in nm) versus  $f$
- interactive Visual Basic programs
- automated online analysis
  - focus on: vertical component

# typical PSD



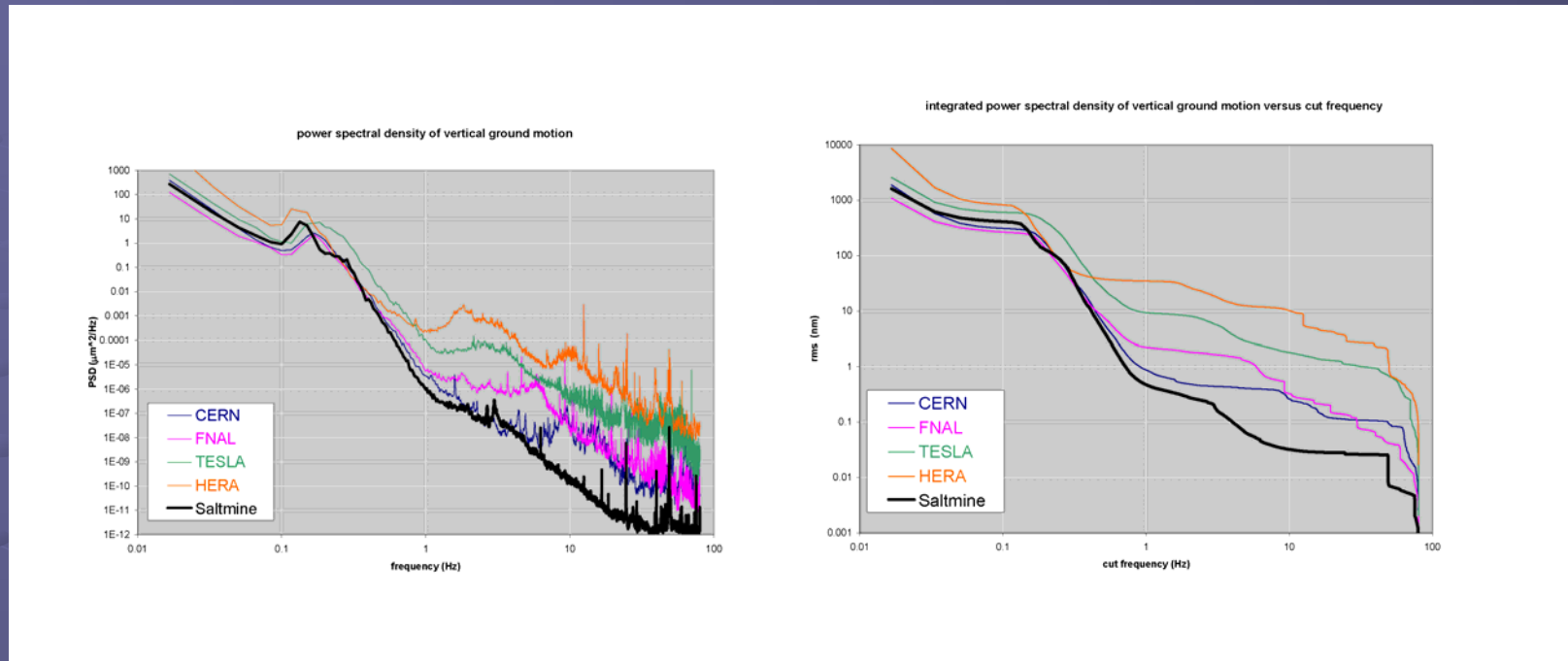
- $1/\omega^4$  drop -> random walk noise
- microseismic peak (seven second hum) at 0.1-0.2Hz
- $f > 1$ Hz: cultural noise -> uncorrelated

# typical PSD + integrated view



- $1/\omega^4$  drop -> random walk noise
- microseismic peak (seven second hum) at 0.1-0.2Hz
- $f > 1\text{Hz}$ : cultural noise -> uncorrelated

# site comparison



Example: Saltmine "Asse" (900m below surface)  
in comparison to CERN, Fermilab, TESLA and DESY

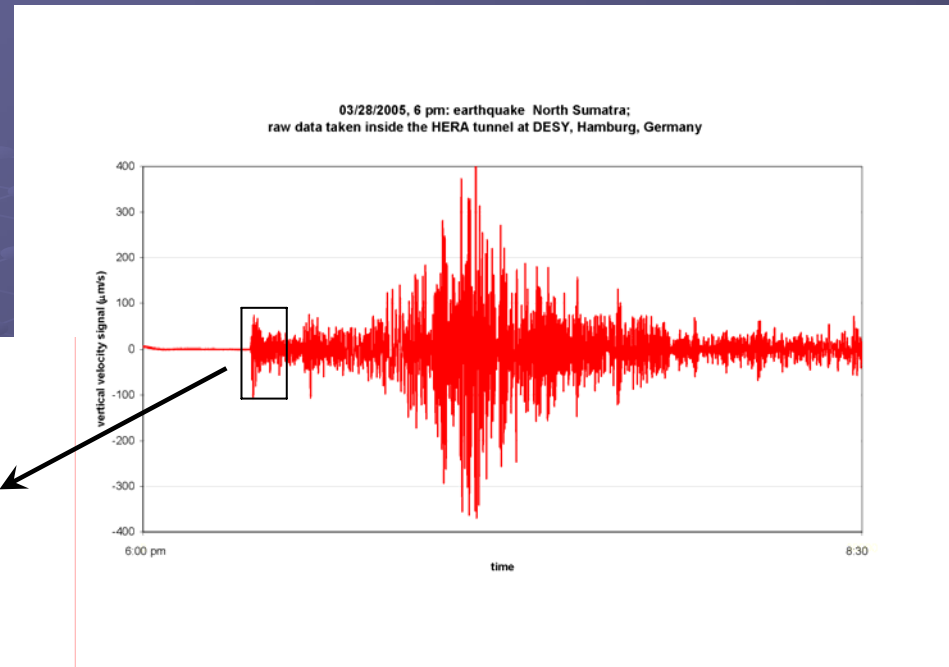
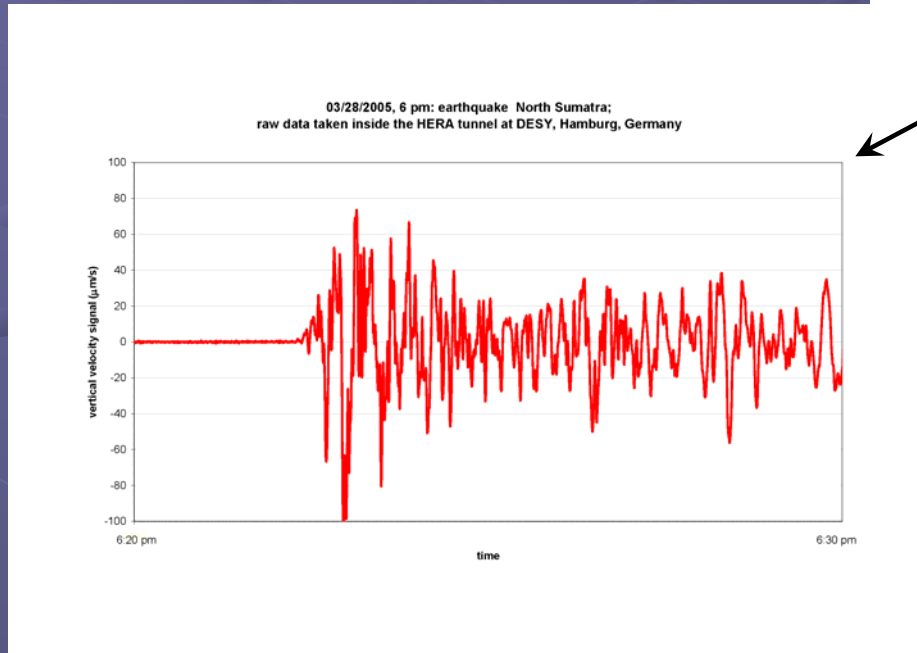
-> large difference in cultural noise

-> rms values ( $f > 1\text{Hz}$  between  $1\text{nm}$  and  $100\text{nm}$ )



# single events: earthquakes

2.5h raw data,  
taken at DESY

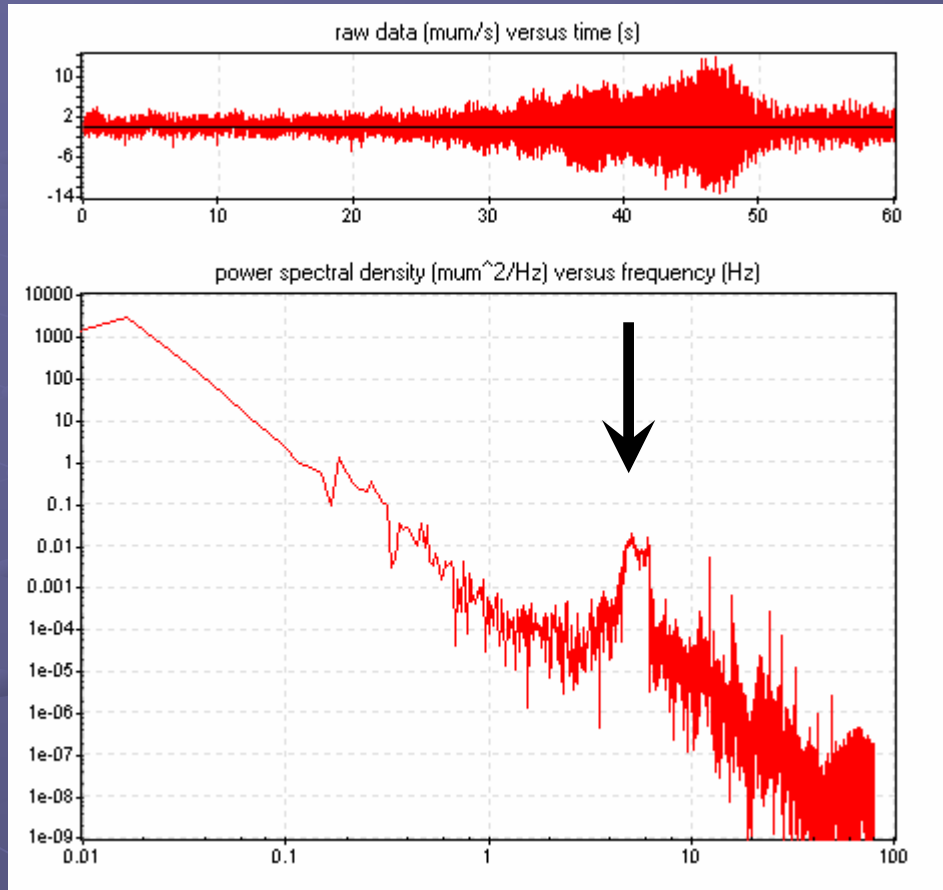


10min raw data,  
taken at DESY



- > magnitude 8.7 earthquake in Indonesia causes gigantic ground motion signals in Germany, but:
- > very low frequency => well below 1Hz

# single events: street traffic



raw data (velocity)

corresponding PSD

-> nearby street traffic causes signals in the frequency range between 1Hz and 10Hz

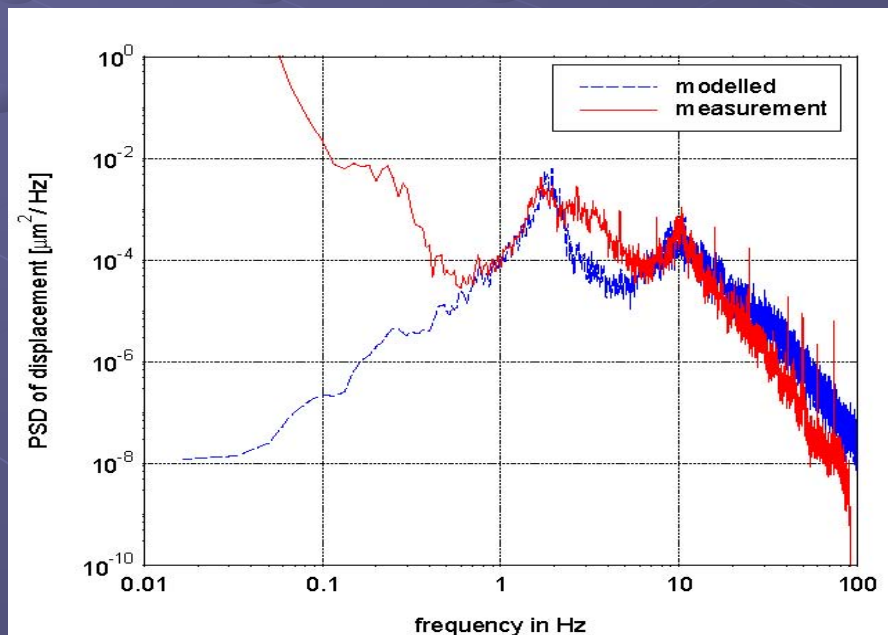
# modelling of cultural noise

- numerical ground mechanical model for street or rail traffic

inputs:      number of cars, trucks ..., masses, damper characteristics,  
                 unevenness of street/rail, distance to the street/rail  
                 soil parameters

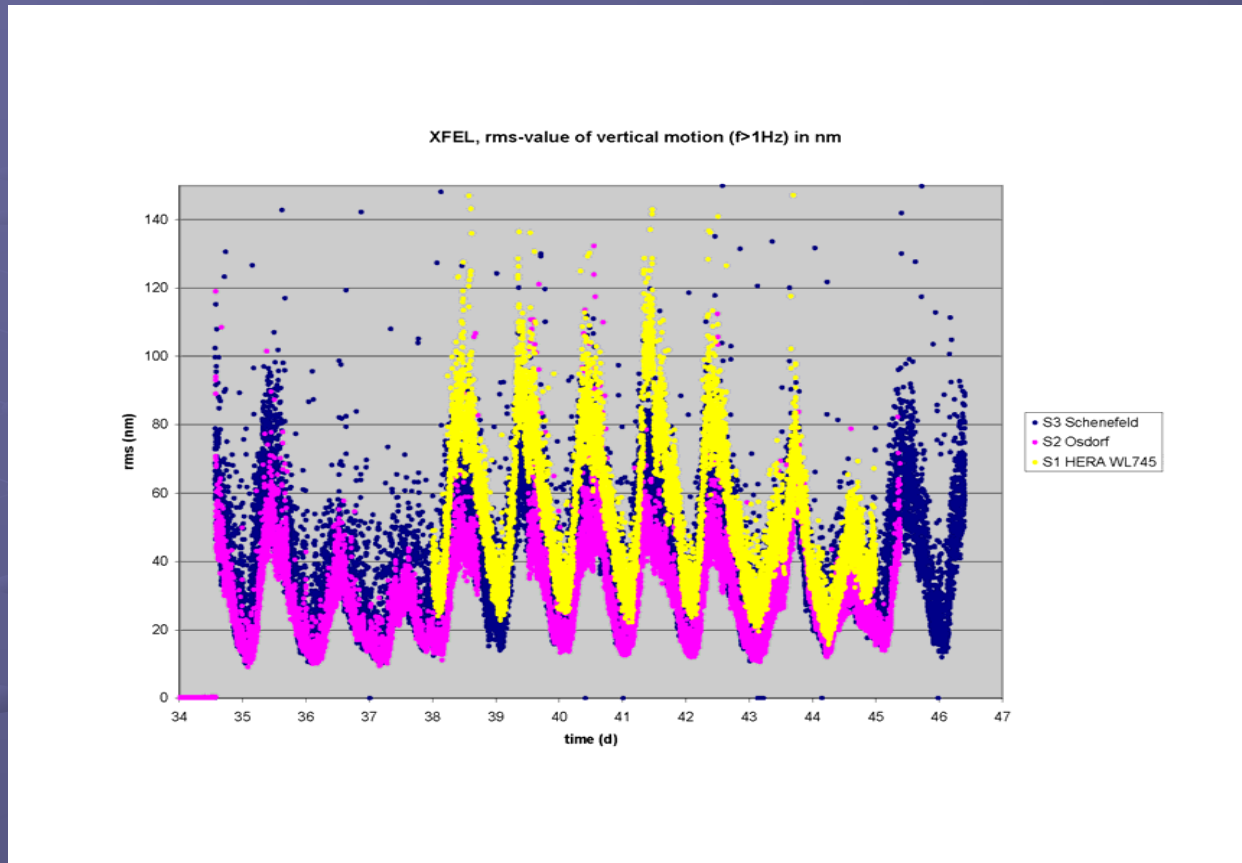
*in cooperation with TU HH (Hamburg University of Technology)*

*preliminary result:*



street (rail) traffic seems to be the main reason for “cultural noise”

# rms values vs. time



example: XFEL

synchronous  
measurement with  
three sensors along  
the foreseen XFEL  
site close to DESY

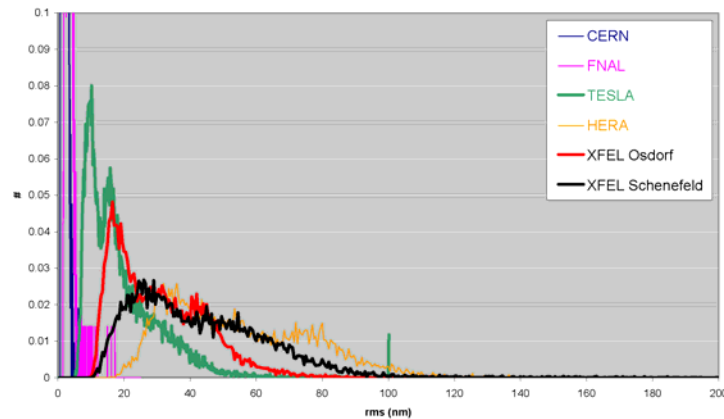


- day-night variation
- working day < > weekend difference

=> for site characterisation it's important to take data for long periods

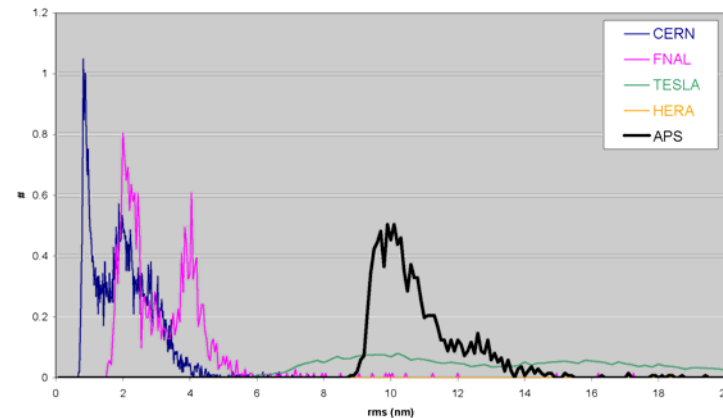
# rms value distribution

distribution of rms values of vertical motion (nm) for  $f > 1\text{Hz}$



distribution of the rms values of vertical motion ( $f > 1\text{Hz}$ ) for complete data taking periods

distribution of rms values of vertical motion (nm) for  $f > 1\text{Hz}$



- usually no gaussian distribution

- two maxima

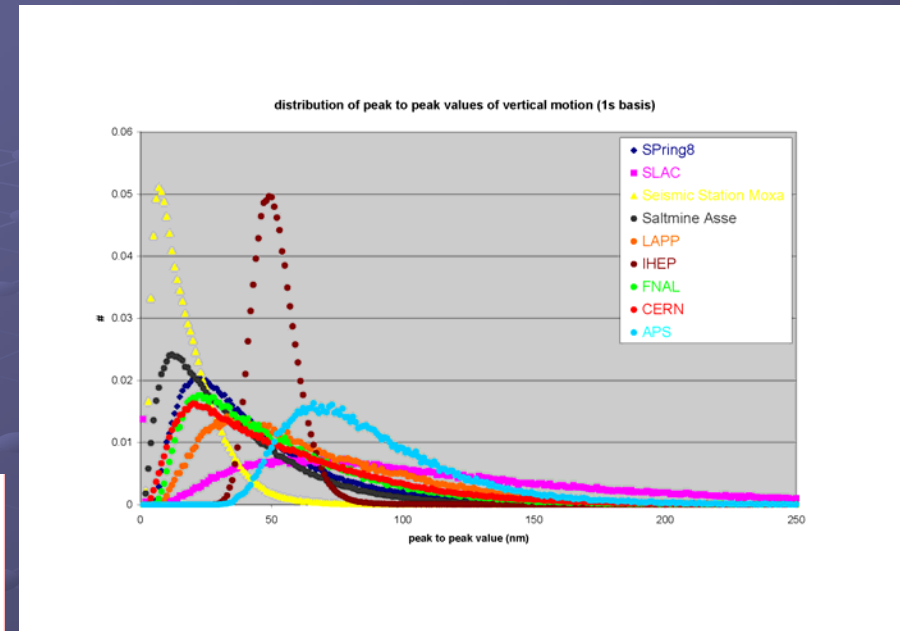
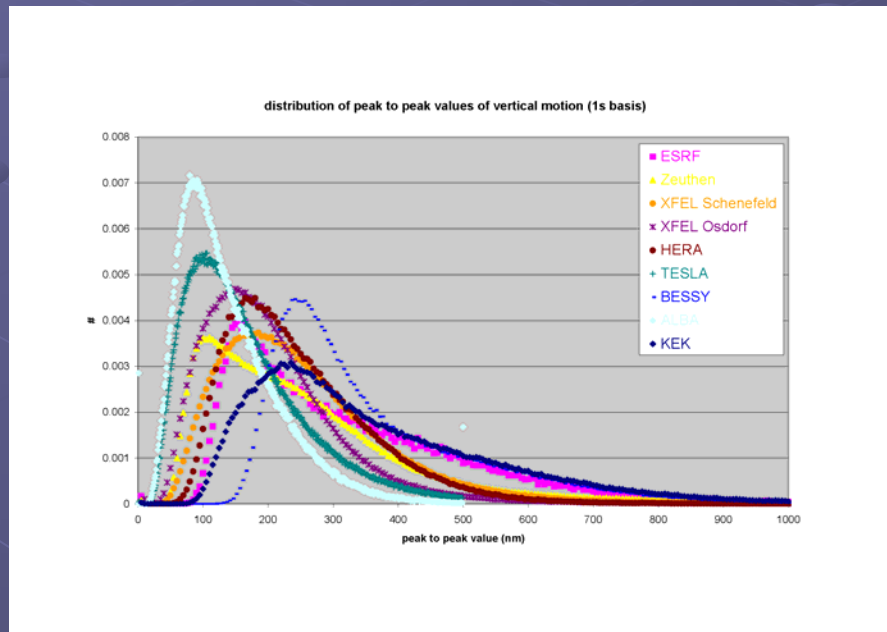
-> quiet times during the night, busy times during the working hours

=> typical distribution for different sites

# peak to peak value distribution

another characterisation technique:

- numerical integration of velocity raw data for 1s periods -> displacement (implied 1Hz frequency cut)
- peak to peak value analysis



- sensitive to short events (1s time scale, no averaging over 1min)

- worst cases included

=> maxima and width characteristic for different sites

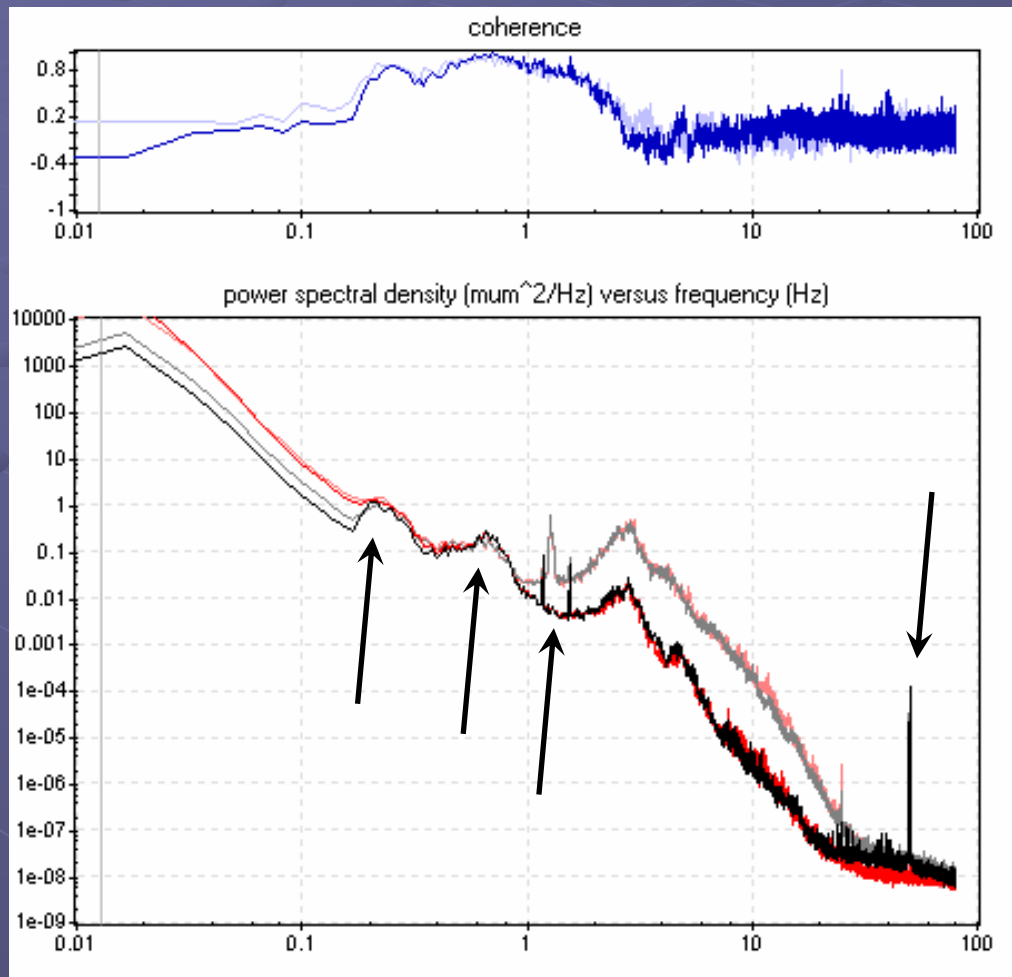
# SSRF site measurements

- data taking at the SSRF site in southeast Shanghai during ongoing construction work
- construction works stopped for 24 h
- four sensors used:
  - “S4” and “S5” (CMG-6T) on the concrete foundation of the foreseen experimental area
  - “S3” (CMG-3T) on a much thinner concrete foundation outside the foreseen buildings
  - “S2” outside the temporary office building
- data taking for about 48h
- GPS synchronization



# results from SSRF site (1)

PSD comparison for **vertical motion**,  
experimental area foundation,  
average of 1h quiet versus 1h noisy time

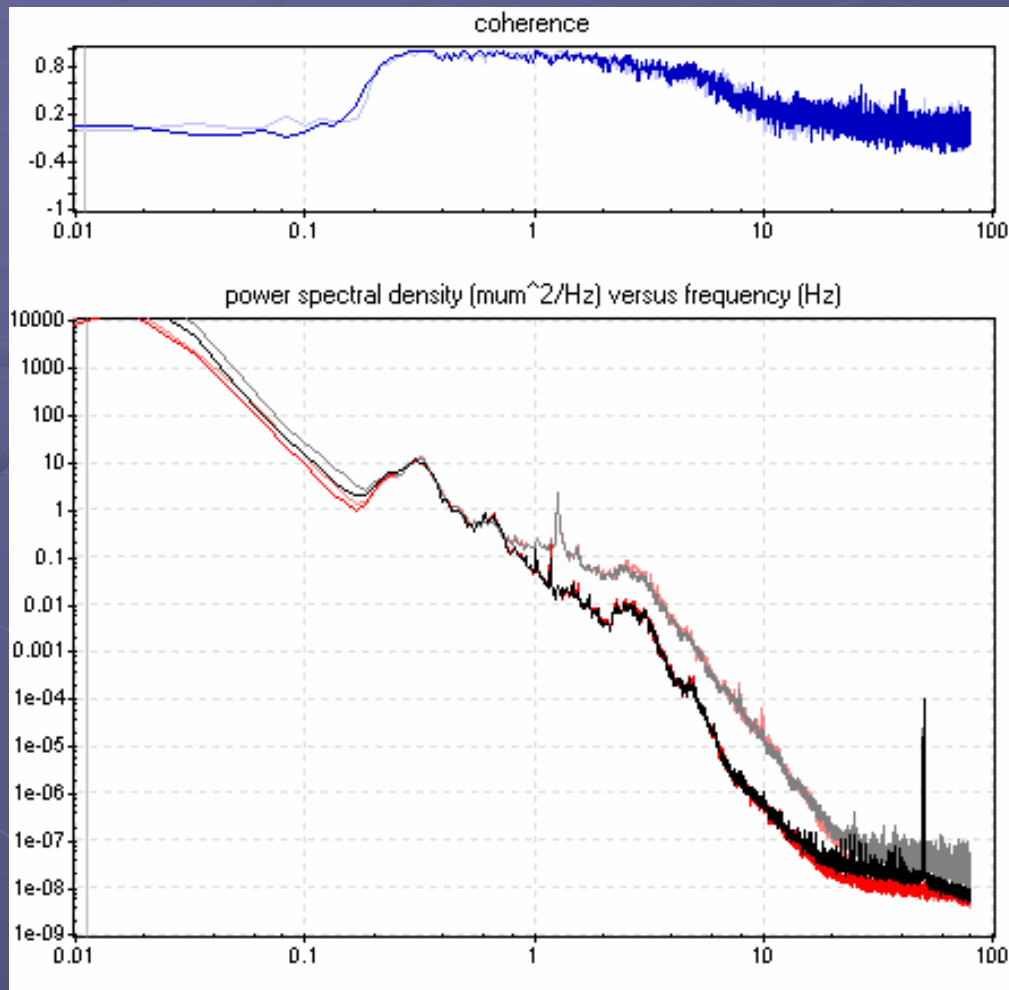


- strong influence of cultural noise above 1.5Hz
- clear microseismic peak at 0.23Hz
- clear second microseismic peak at 0.64Hz
- typical sharp peaks around 1.3Hz (one or two) (frequency not constant!)
- good “correlation” for 30m distance up to about 2Hz
- 50Hz signal (unimportant)
- rms values for  $f > 1\text{Hz}$ :
  - quiet: 102nm
  - noisy: 444nm



# results from SSRF site (2)

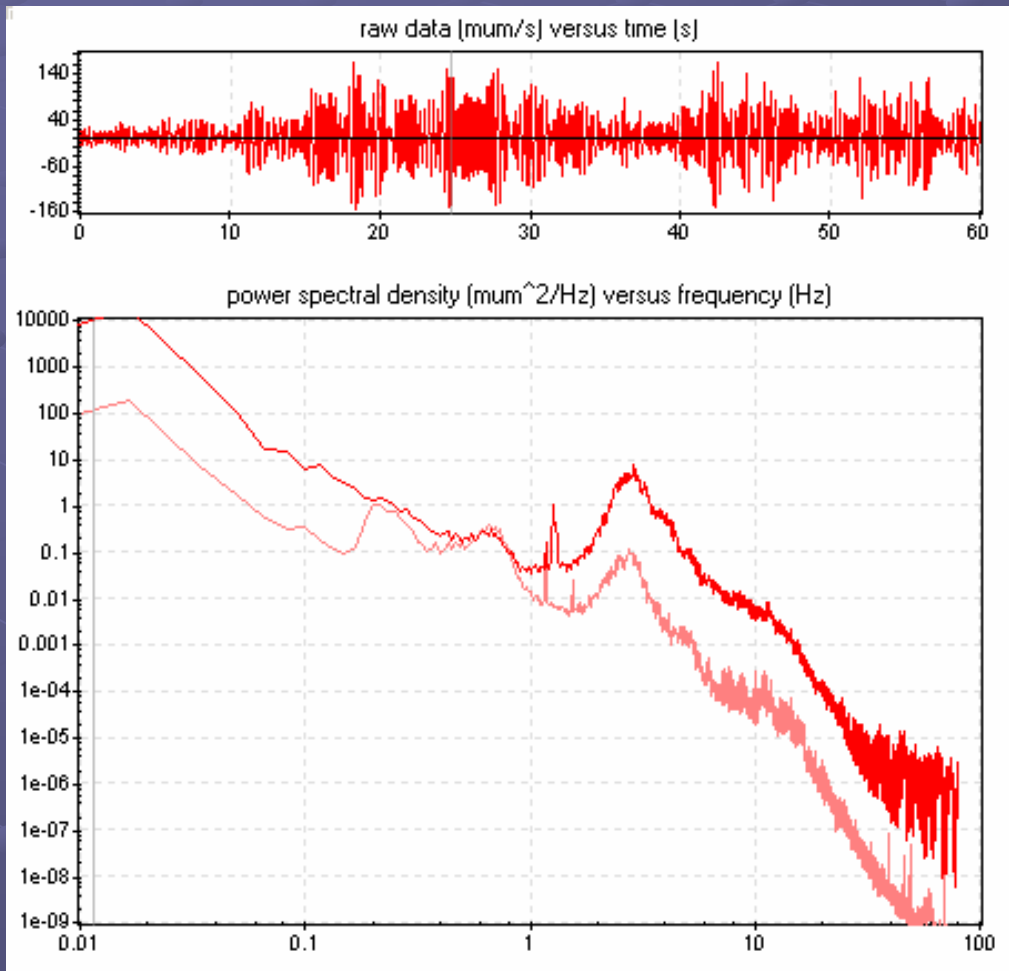
PSD comparison for **horizontal motion**,  
experimental area foundation,  
average of 1h quiet versus 1h noisy time



- similar
- also microseismic peaks at 0.23Hz and 0,64Hz
- good “correlation” also for frequencies above 2Hz
- rms values for  $f > 1$ Hz:
  - quiet: 127nm
  - noisy: 354nm

# results from SSRF site (3)

PSD comparison for **vertical motion**,  
**outside the experimental area**,  
average of 1h quiet versus 1h noisy time



- strong events
- much larger amplitudes

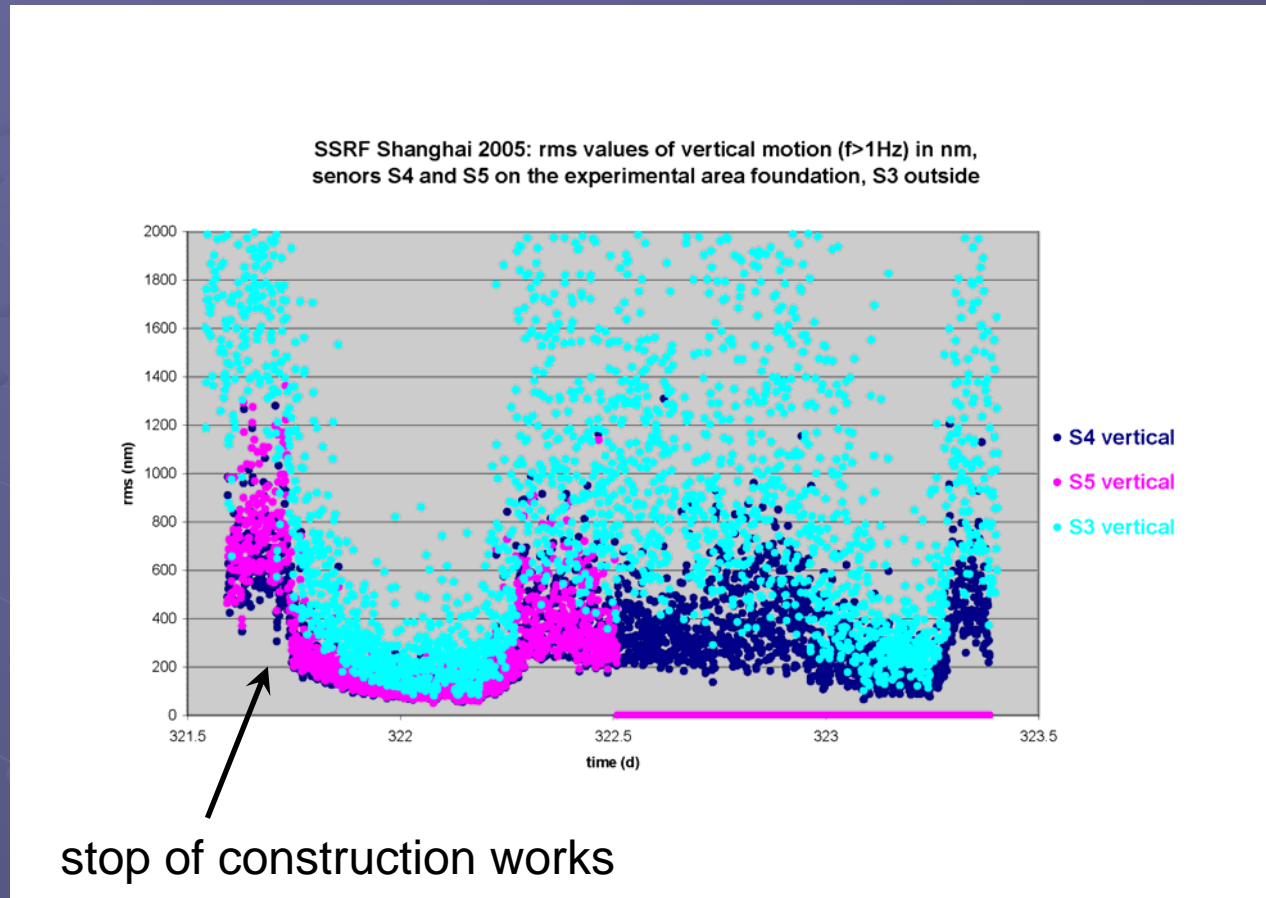
● rms values for  $f > 1$  Hz:

- quiet: 202nm
- noisy: 1510nm

=> experimental area foundation  
substantially improves the  
vibration situation !

# results from SSRF site (4)

rms values of vertical motion ( $f > 1\text{Hz}$ ) versus time

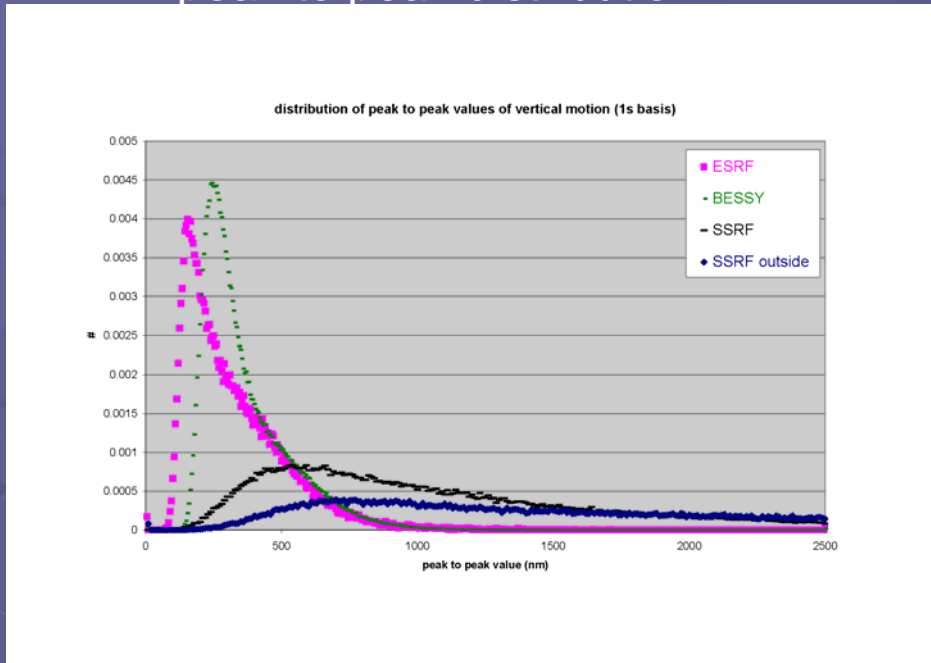


experimental area  
outside

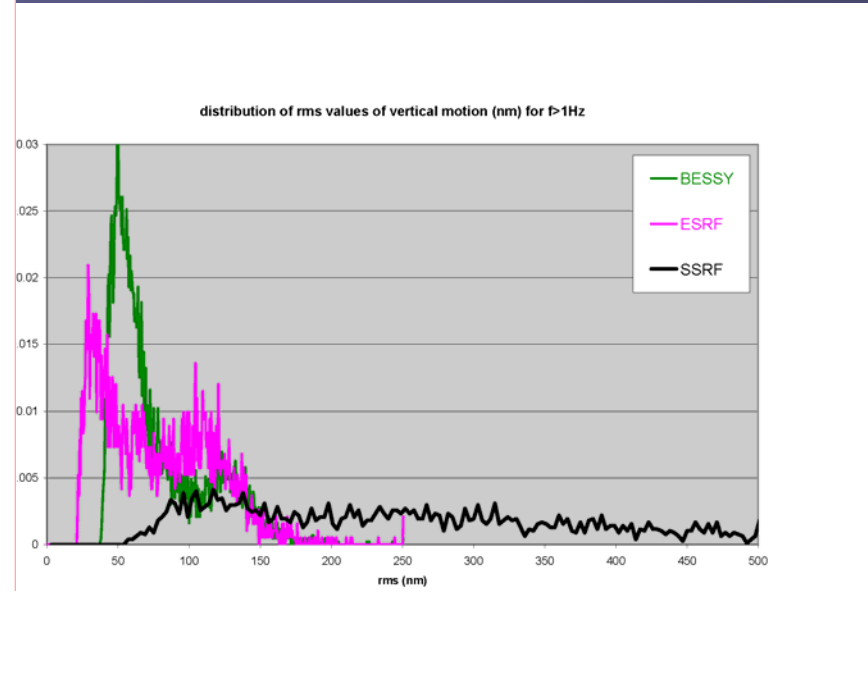
- “quiet” during the night
- maximum in the morning
- large fluctuations during noisy times

# results from SSRF site (5)

peak to peak distribution



rms distribution

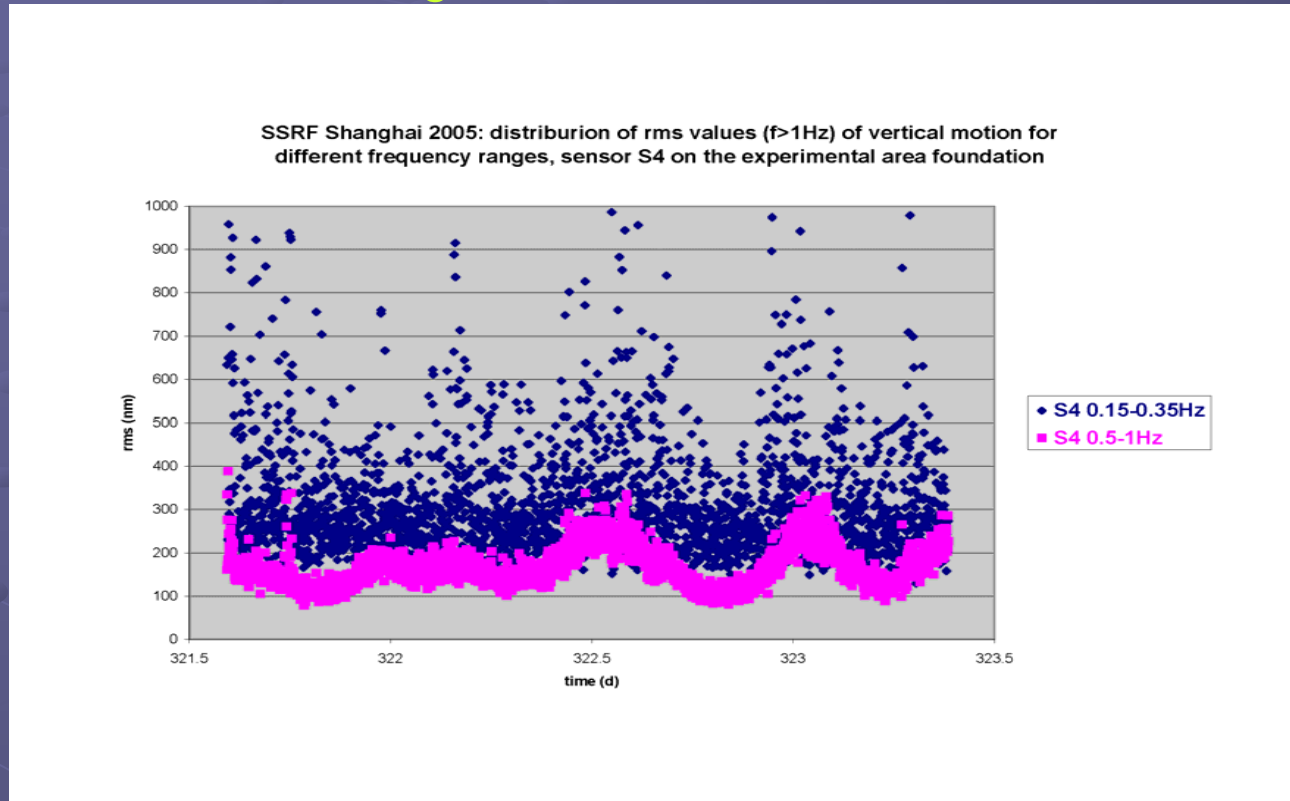


- broad distributions
- highest maximum value

**=> noisiest site we measured up to now**

# results from SSRF site (6)

## microseismic signal versus time



- tidal behaviour of second hum -> maxima ad flood time?
- is also the sharp signal at around 1.3Hz correlated to water waves on the river?

# status of our site comparison

Location	Peak to Peak distribution		without highest 5%		Selected Data	
	Maximum pp (nm)	FWHM (nm)	Average RMS (nm)	SD $\sigma$ (nm)	Quiet RMS (nm)	Noisy RMS (nm)
1 Seismic Station Moxa	7	17	0.6	0.1	0.5	0.9
2 Salt Mine Asse	12	35	0.5	0.1	0.5	0.7
3 CERN LHC Tunnel	21	53	1.8	0.8	0.9	2.9
4 Spring-8 Harima	22	40	2.0	0.4	1.8	2.5
5 FNAL Batavia	23	49	2.9	0.9	2.2	4.0
6 LAPP Annecy	35	59	3.3	1.6	1.9	7.0
7 IHEP Beijing	49	18	8.4	0.5	8.1	9.0
8 SLAC Menlo Park	60	105	4.8	1.2	4.1	7.4
9 APS Argonne	68	56	10.5	1.0	9.8	11.0
10 ALBA Cerdanyola	87	125	18.3	9.5	9.1	42.0
11 DESY TESLA	104	160	17.4	8.4	9.3	35.9
12 DESY XFEL Osdorf	150	195	28.9	11.9	19.5	48.4
13 DESY Zeuthen	105	235	64.0	40.4	88.5	75.6
14 ESRF Grenoble	155	175	71.6	34.9	40.2	137.2
15 DESY XFEL Schenefeld	180	245	38.7	16.6	35.1	70.0
16 DESY HERA	170	200	51.8	18.9	34.8	77.0
17 KEK Tsukuba	170	210	78.0	36.0	38.0	125.1
18 BESSY Berlin	245	160	72.8	28.1	53.1	140.7
19 SSRF Shanghai	550	1000	292	164	102	444

# <http://vibration.desy.de>

DESY .. ground vibrations - Microsoft Internet Explorer

Adresse <http://vibration.desy.de/>

groundvibrations

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- Download

## Ground Vibrations

2005-03-29

Many years ago at DESY some first investigations of ground vibration took place. These activities were connected to the construction and commissioning of the e-p collider HERA as well as a S-Band linear collider study. In 2002 the old equipment was reactivated for further ground vibration studies, now as part of the studies towards TESLA. One central aim was to perform a site comparison for future particle accelerators, i.e. linear colliders. This website contains a description of the equipment and the data analysis technique, a compilation of our results and a download possibility of all our data.

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our data is available for everyone

- live data from DESY
- direct download
  - all raw data
  - selected data
  - spectra, results
  - software

groundvibrations

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Startseite > Download > Selected Data

## Downloads

2005-10-07

Here you can download a selection of data for each location.

- the folder "noisy" contains one hour of data (raw and analyzed) for a noisy period, usually around noon
- the folder "quiet" contains one hour of data for a quiet period, usually around midnight
- the file "av-noisy.csv" contains the averaged power spectral density for the selected noisy period (this file could be viewed with display.exe)
- the file "av-quiet.csv" contains the averaged power spectral density for the selected quiet period
- the file "qgshisto.xls" contains the distribution for peak-to-peak displacement values, calculated with direct raw data integration on a 1s time basis
- the file "rmsshisto.xls" contains the distribution for rms displacement values
- the file "rms.xls" contains the rms displacement values versus time.

File	Size	Data Modified
ABA Central	-	Oct 10 2005 03:27:00 PPM
APS Argonne	-	Oct 10 2005 03:26:00 PPM
DESY Heide	-	Oct 10 2005 03:19:00 PPM
CEBN Geneva	-	Oct 10 2005 03:16:04 PPM
DESY Hamburg HERA	-	Oct 10 2005 03:46:00 PPM

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## Spectra

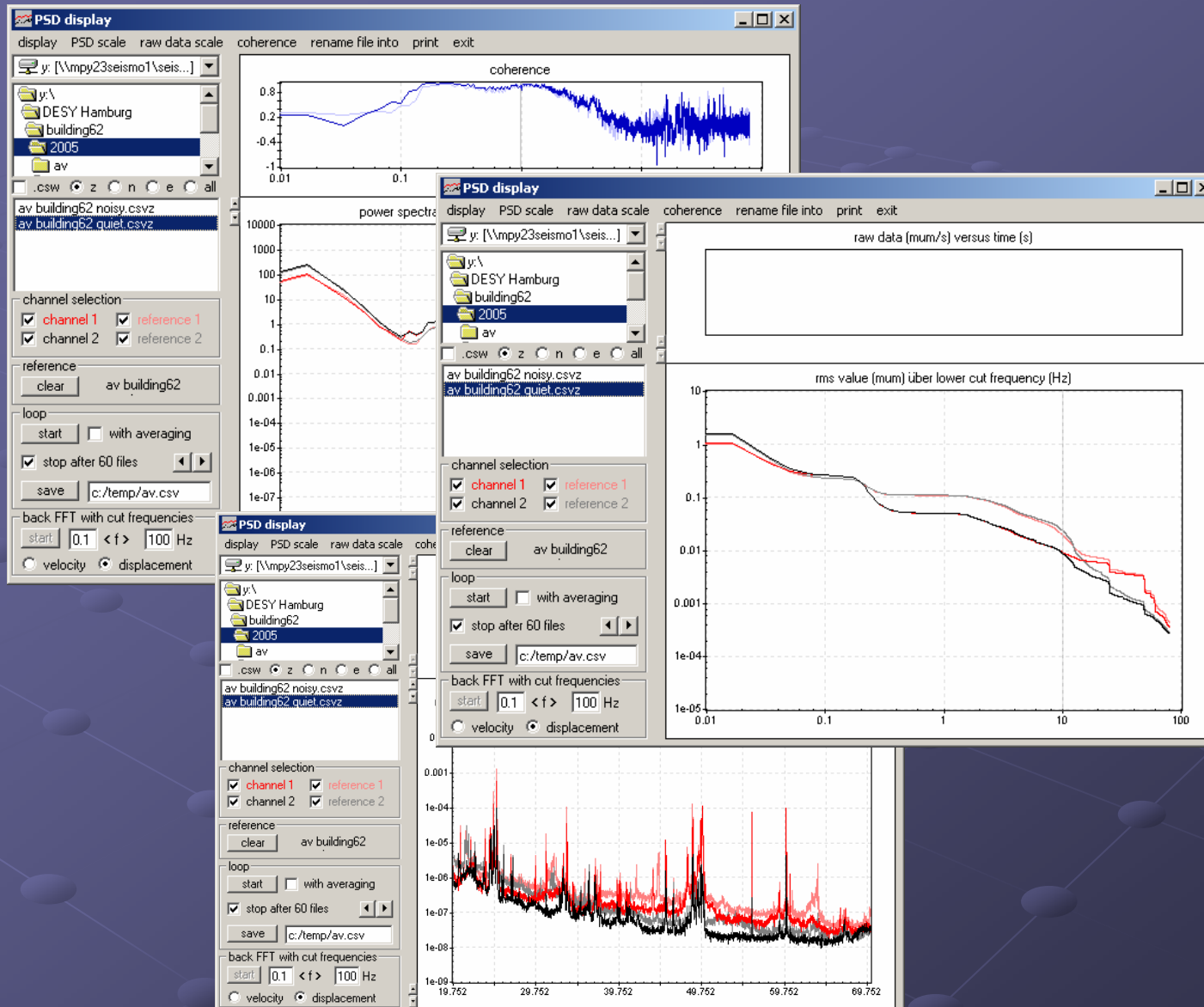
2005-10-14

DESY Site and Vicinity  
Synchrotron Light Sources  
High Energy Physics Laboratories  
CEBN  
FNAL  
DfEP  
Futures  
Spectra  
KEK  
SLAC  
Others  
Live Data  
Download

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# software download



interactive visual  
basic application  
for

- PSD display
- integrated view
- zoom etc.
- averaging
- back FFT

...



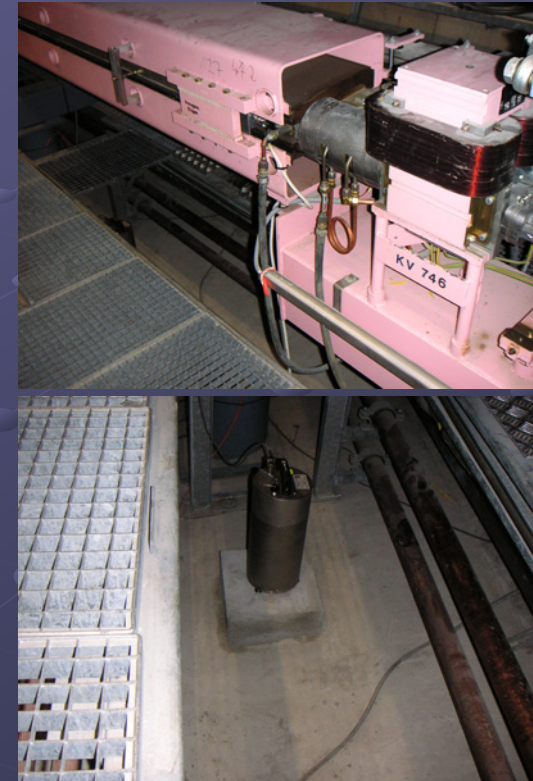
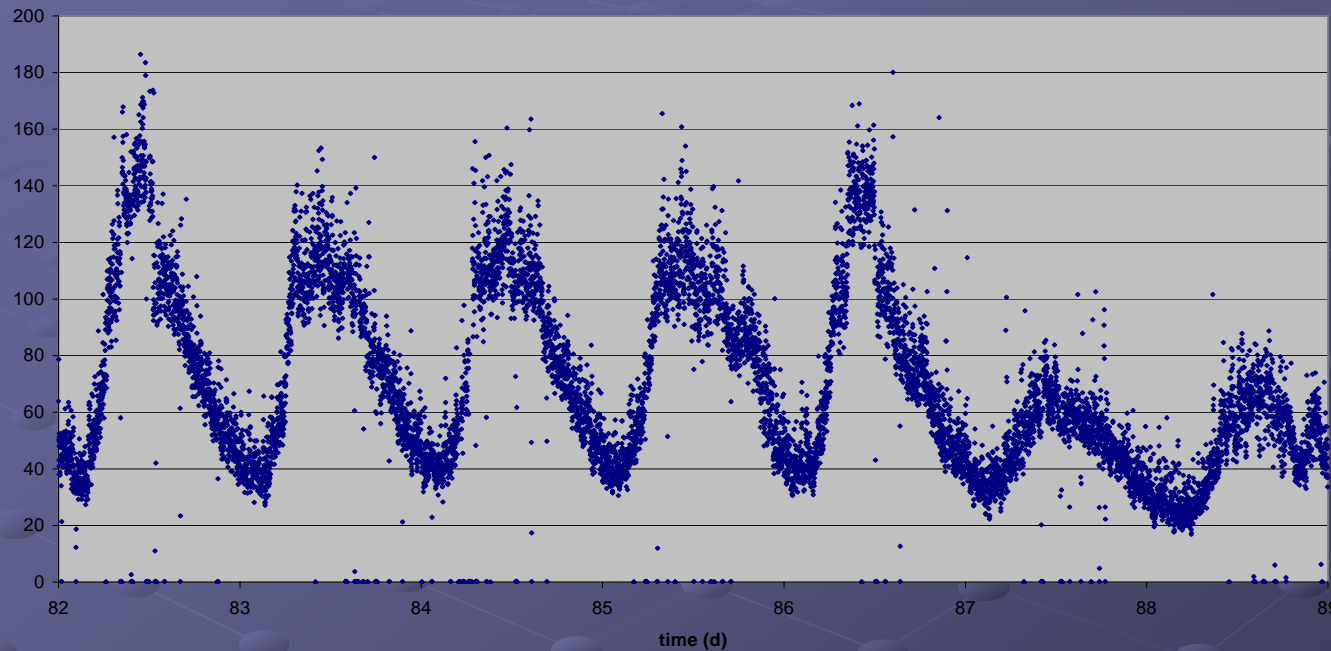
# acknowledgements

the measurements were done with the help of:

- David Carles from ALBA, Cerdanyola
- Louis Emery from APS, Argonne
- Jörg Feikes from BESSY, Berlin
- Ralph Assmann, Williame Coosemans, Andreas Herty and Stefano Redaelli from CERN, Geneva
- Vittorio Boccone, Carsten Kluth, Bartosz Poljancewicz and Frank Stefan from DESY
- Lin Zhang from ESRF, Grenoble
- Kai Desler, David Finley, Victor Kuchler from FNAL, Batavia
- Karl-Heinz Jäckel from GFZ, Potsdam
- Volker Behrens and Hui Fricke from GSF, Asse
- Yingzhi Wu and Chenghui Yu from IHEP; Beijing
- Thomas Jahr, Matthias Meininger and Wernfrid Kühnel from University of Jena
- Mika Masuzawa, Ryuhei Sugahara, Toshiaki Tauchi and Hiroshi Yamaoka from KEK, Tsukuba
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- Jerry Aarons, Fred Asiri, Frederic Le Pimpec, Marc Ross, Andrei Seryi and Javier Sevilla from SLAC, Menlo Park
- Sakuo Matsui, Tsumoru Shintake and Chao Zhang from SPring8, Harima
- Lingshan Bu, Jianhui Chen, Lianhua Ouyang, Lixin Yin and Xiao Wang from SINAP/SSRF, Shanghai
- Thorsten Bierer and Jürgen Grabe from TUHH, Hamburg

# “seismic station”

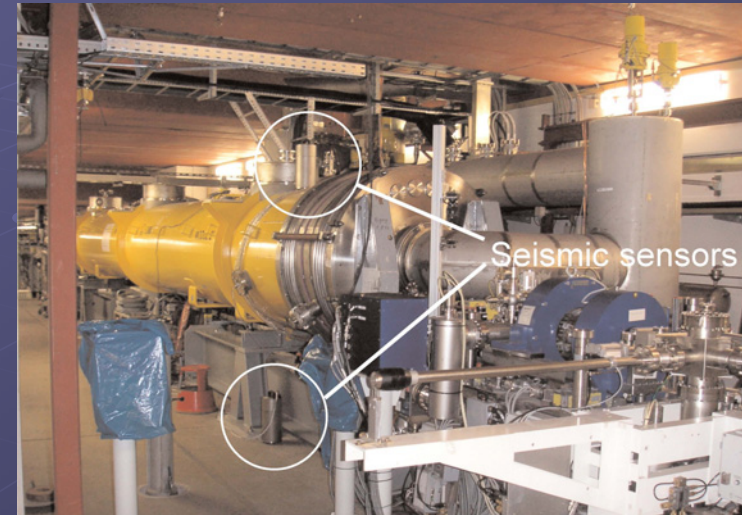
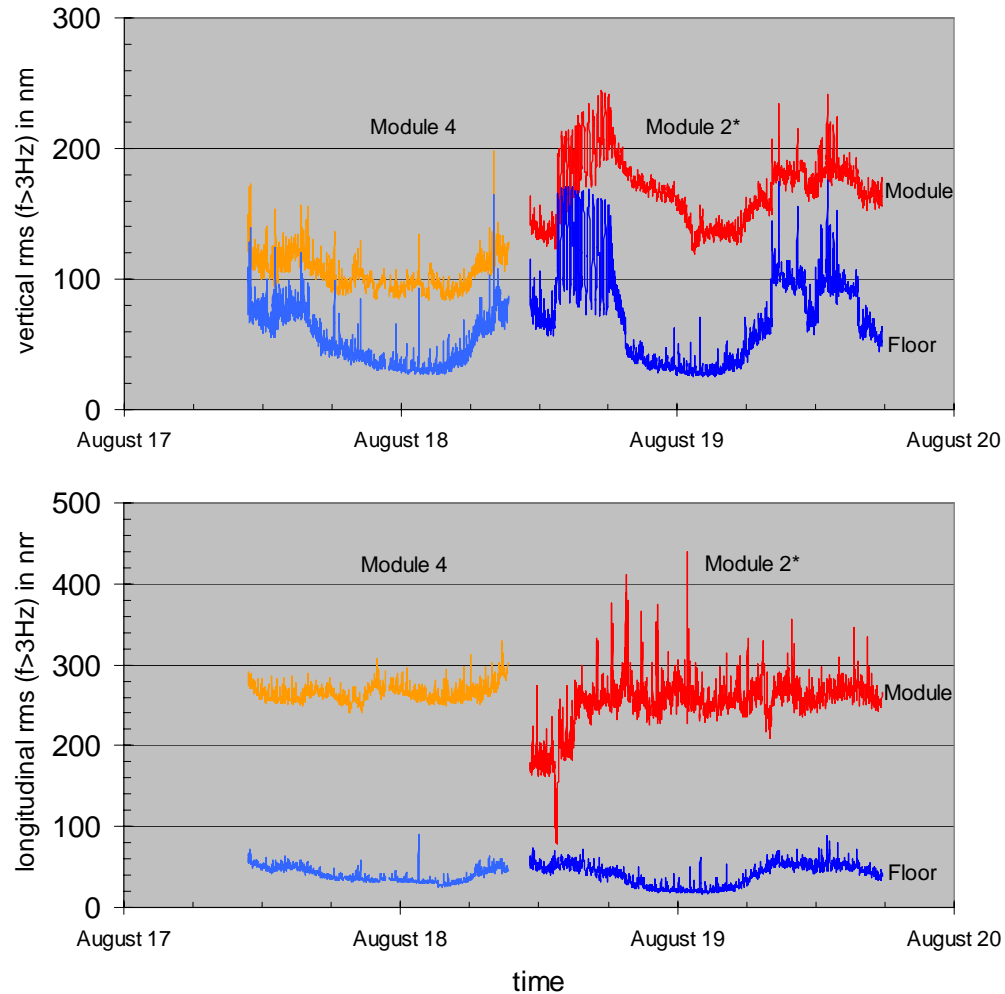
rms value of vertical motion (nm) for  $f > 1\text{Hz}$  vs. time,  
HERA tunnel at WL745m, calendar week 13 (2004)



- permanent data acquisition
- permanent data transfer to the University of Hamburg -> geophysics
- online data available for everybody worldwide (on request) -> [SCREAM](#)

# TESLA module vibration inside the TTF tunnel

rms value of motion for  $f > 3\text{Hz}$  versus time



⇒ strong module vibration

⇒ vacuum installation?

⇒ module installation itself?

⇒ further investigation is necessary

# ... in action

