Ground Vibration Measurements

at DESY

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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

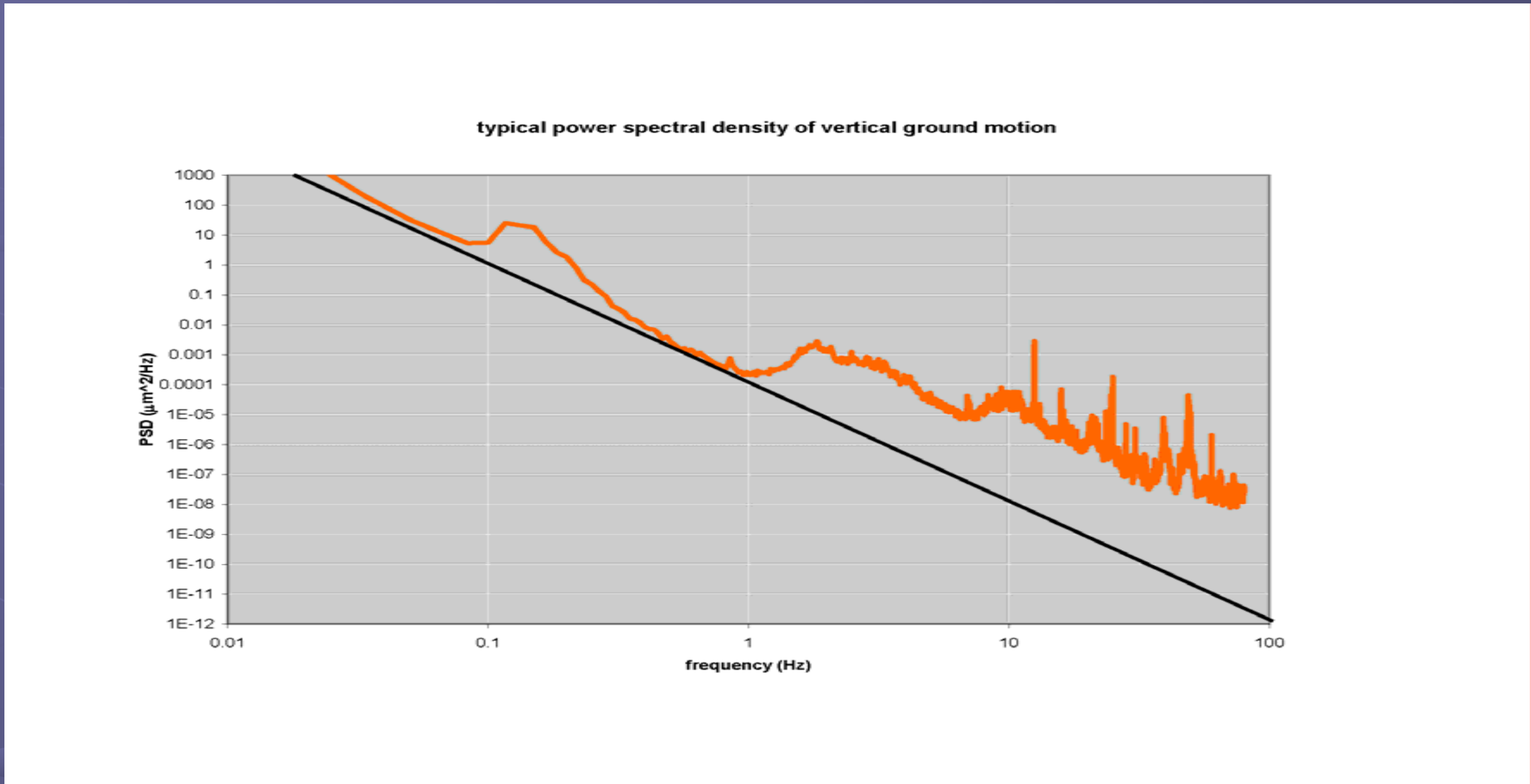
  usually without windowing
- integration (velocity -> motion)

  -> power spectral density (PSD) of motion
- integration above cut frequency

  -> rms-value of motion (in nm) versus f

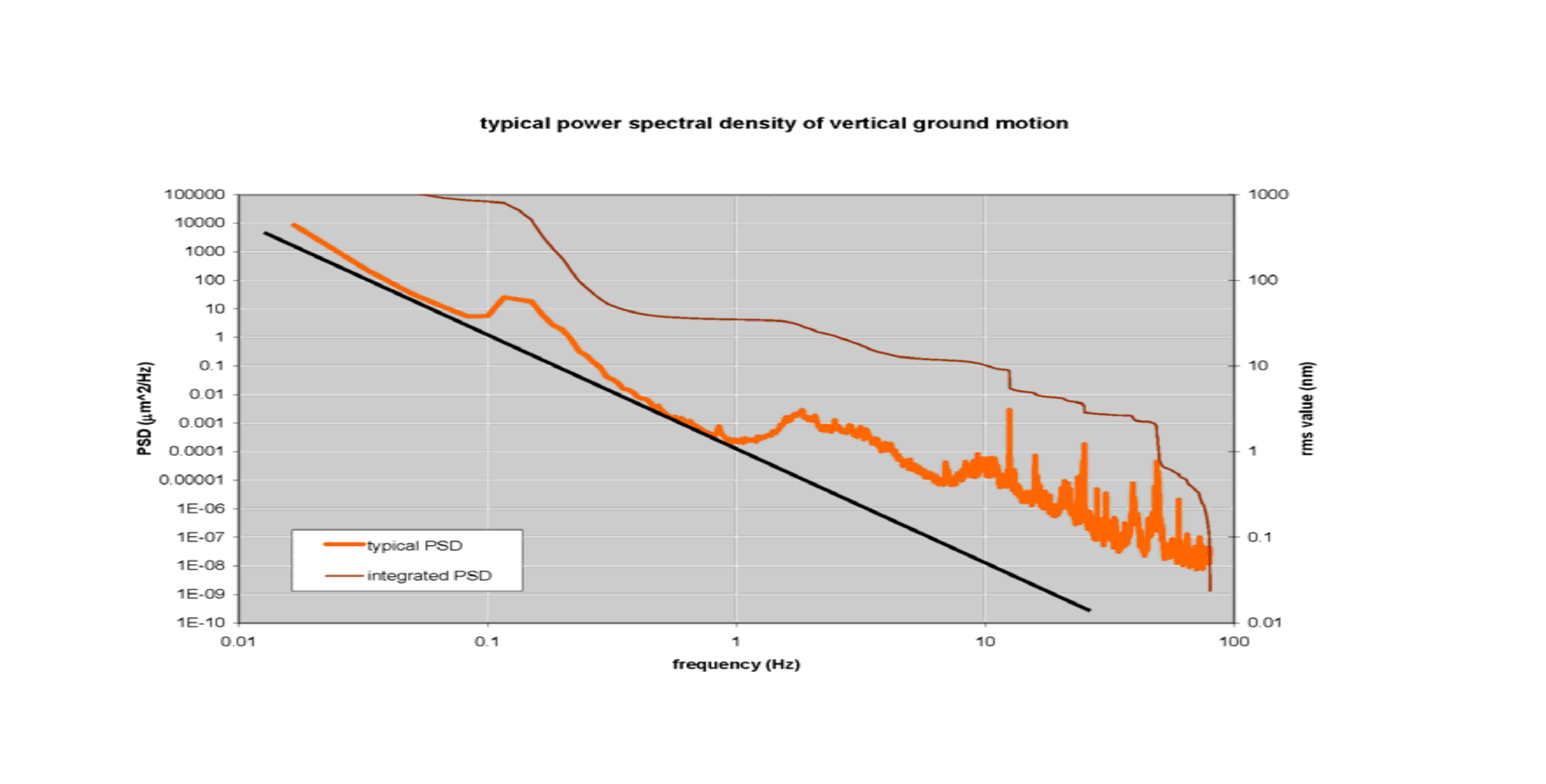
- interactive Visual Basic programs
- automated online analysis
  - focus on: vertical component

typical PSD



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

typical PSD + integrated view



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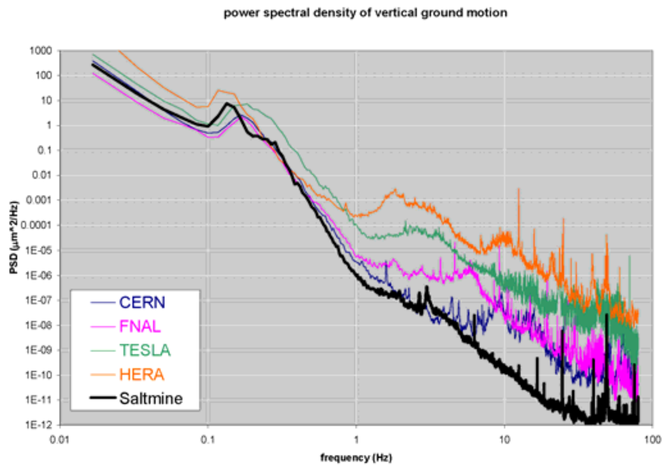
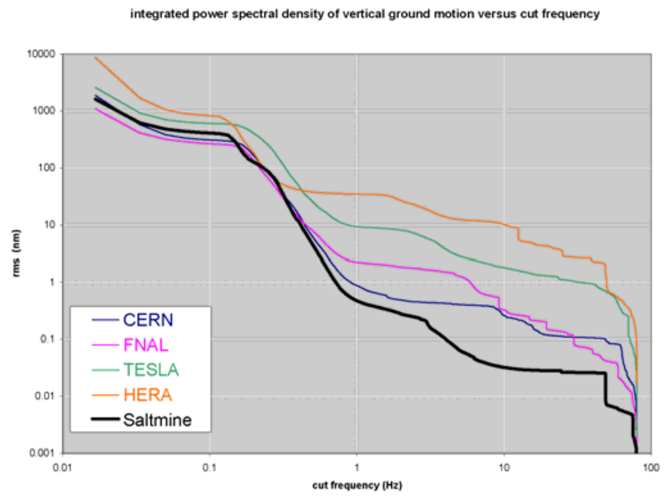
site comparison





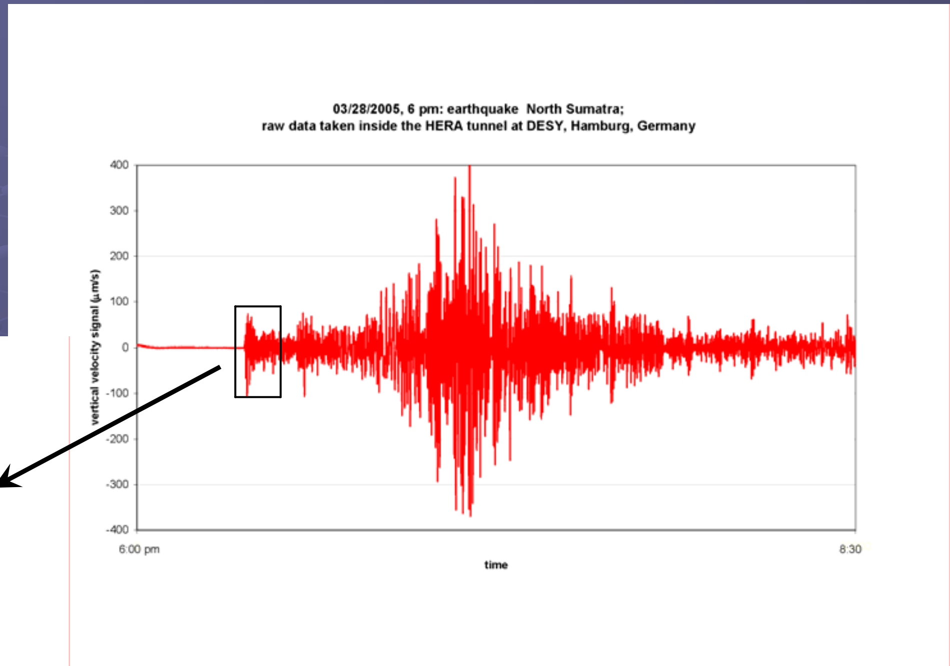
Example: Saltmine “Asse” (900m below surface)
in comparison to CERN, Fermilab, TESLA and DESY

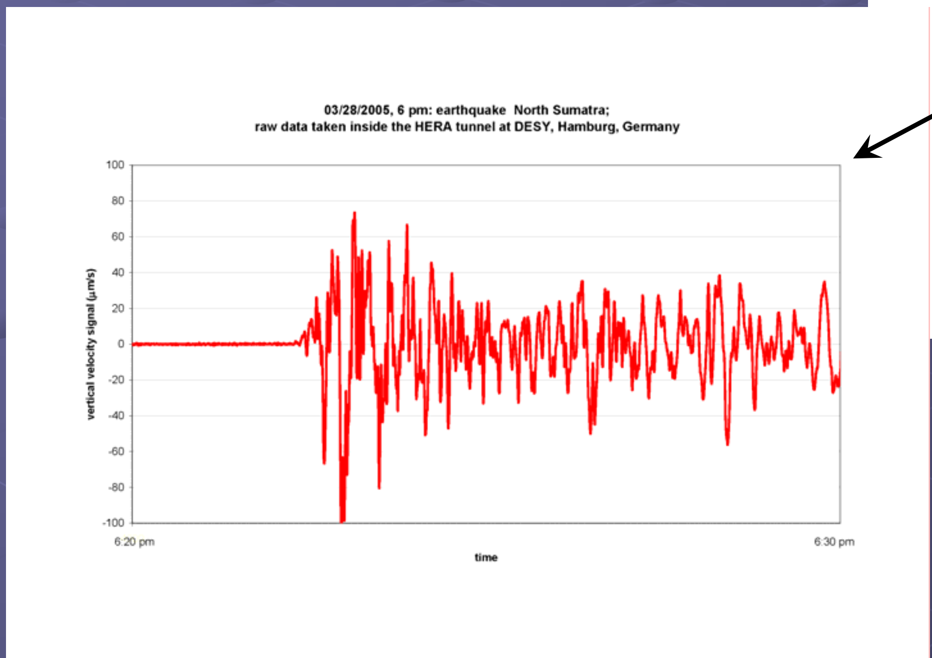
-> large difference in cultural noise

-> rms values (f>1Hz between 1nm and 100nm)

single events: earthquakes

2.5h raw data,
taken at DESY



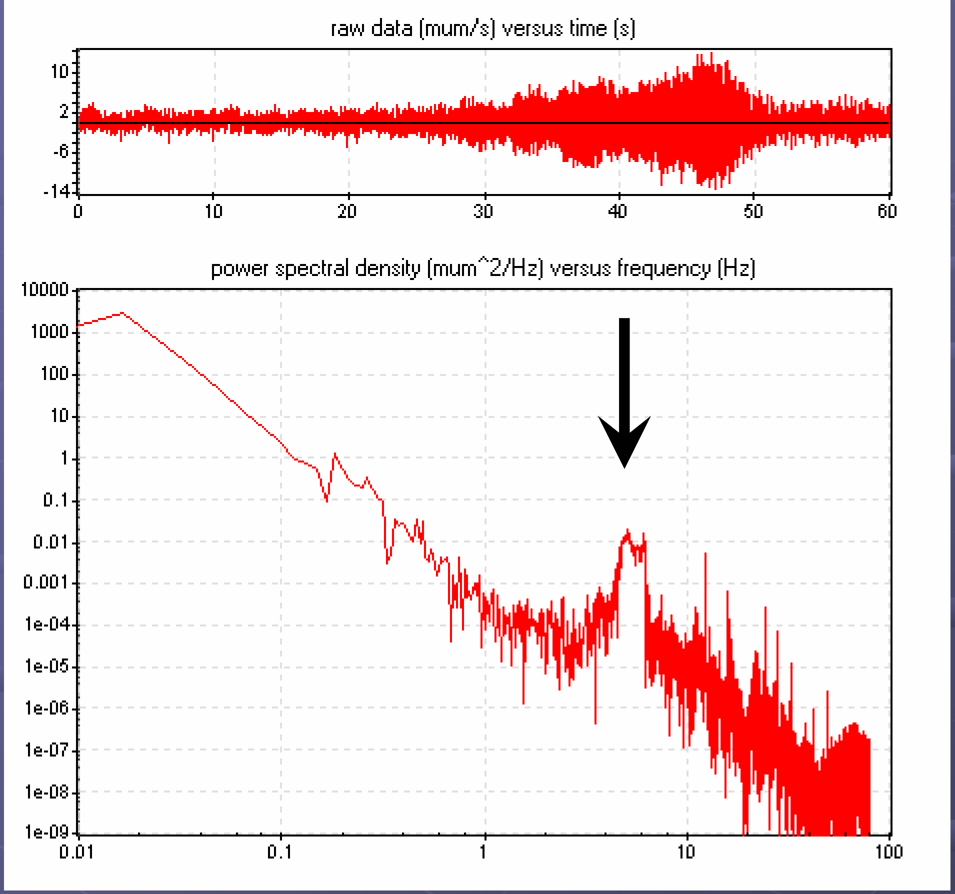


10min raw data,
taken at DESY

-> 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

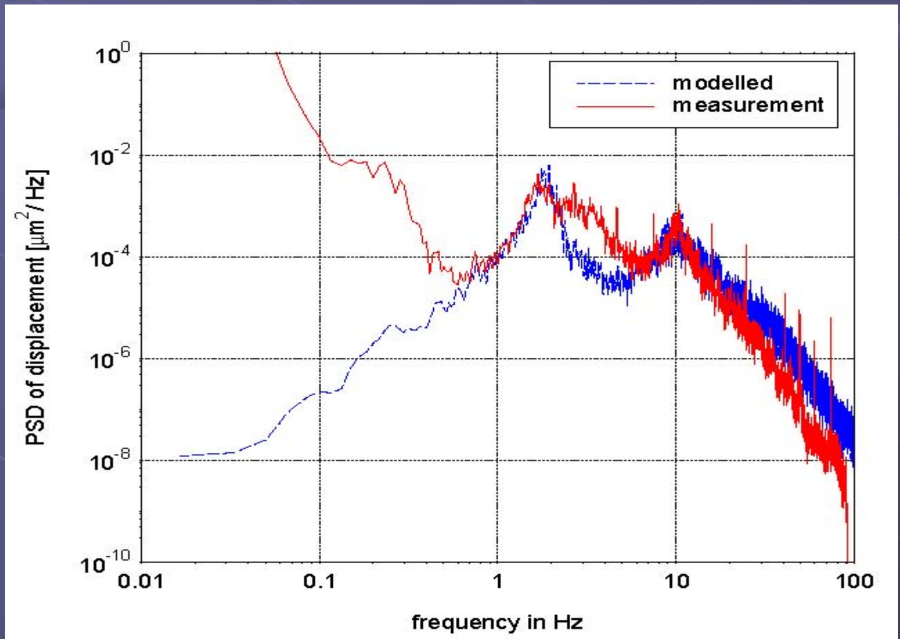
inputs: number of cars, trucks …, masses, damper characteristics,

unevenness of street/rail, distance to the street/rail

soil parameters

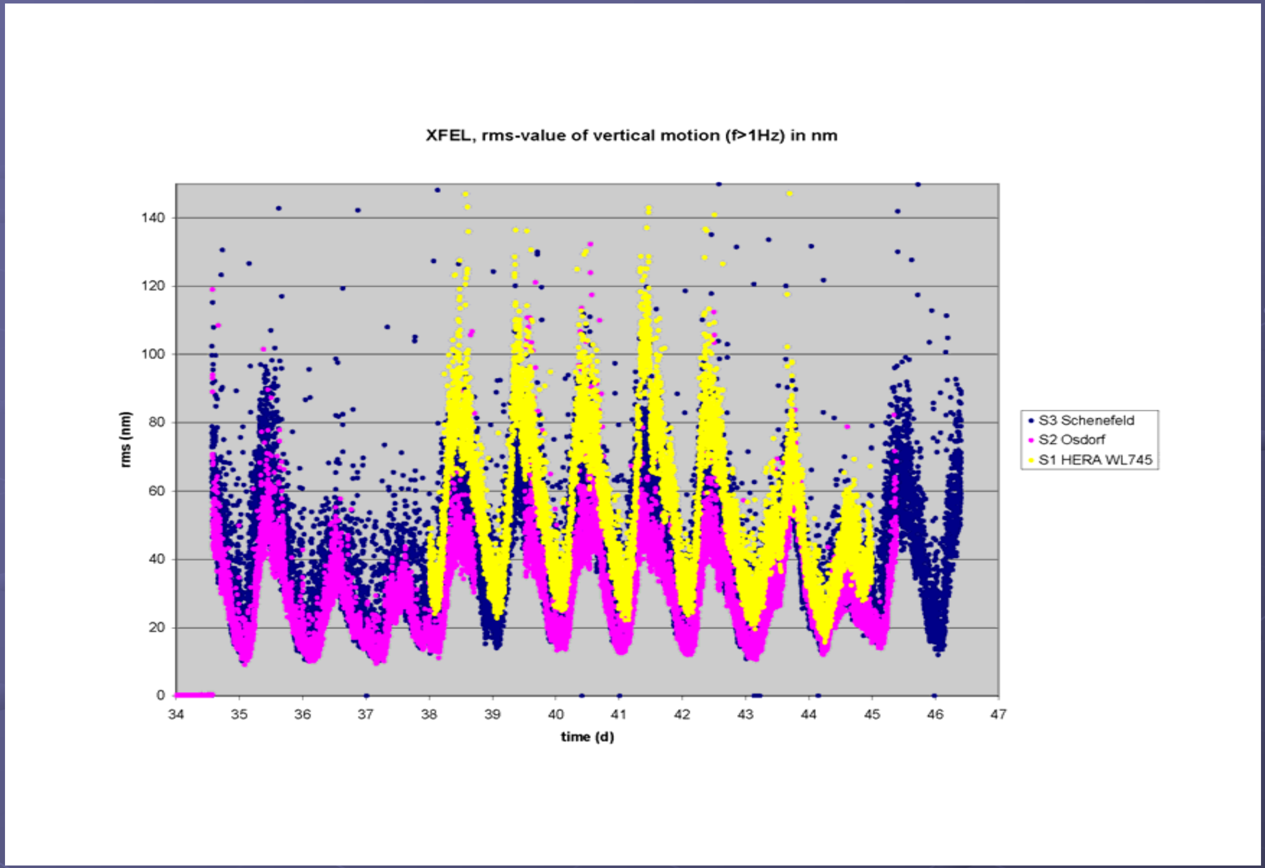
in cooperation with TU HH (Hamburg University of Technology)

preliminary result:



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

rms values vs. time



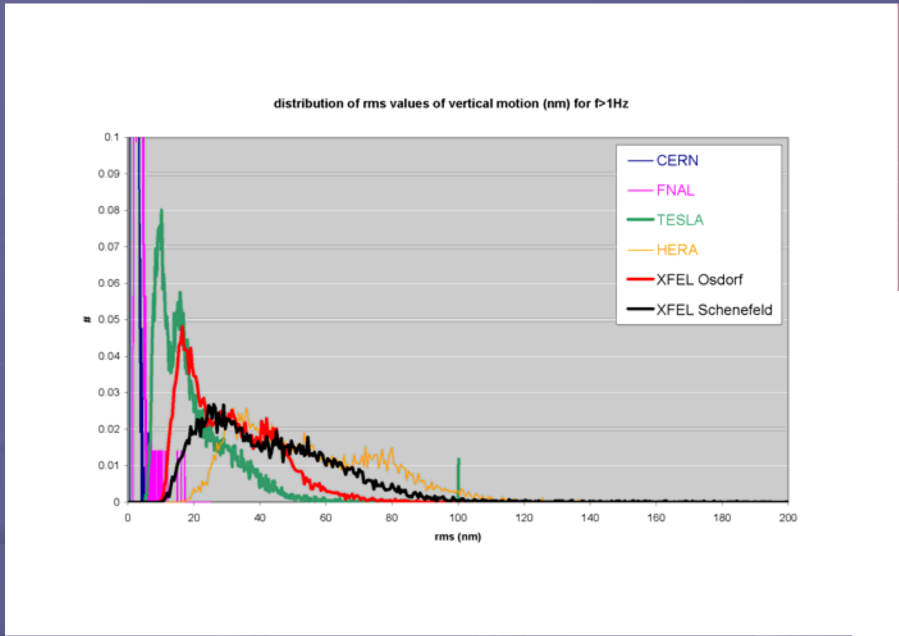
example: XFEL

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

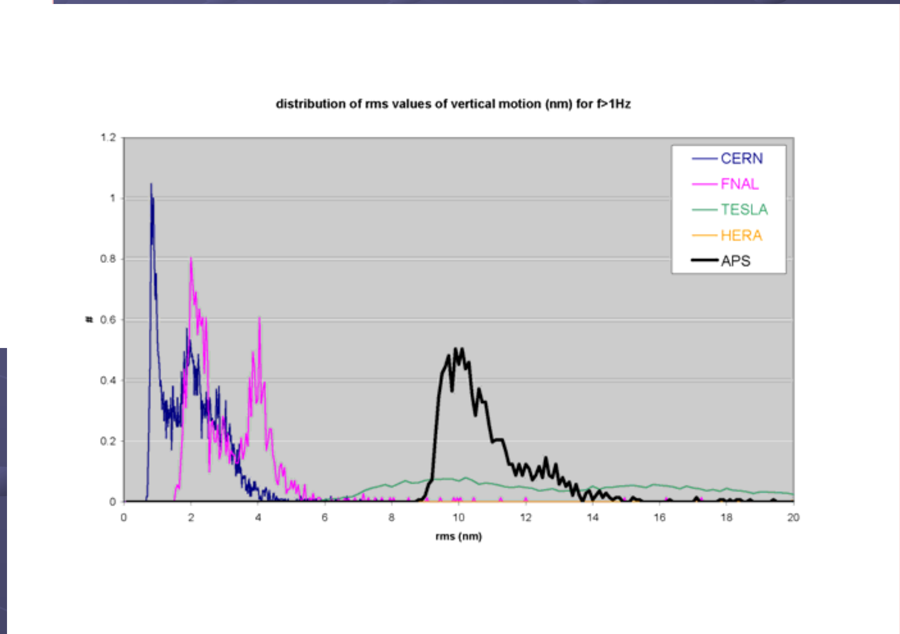
- day-night variation
- working day < > weekend difference

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

rms value distribution



distribution of the rms values of vertical motion (f>1Hz) for complete data taking periods



- usually no gaussian distribution
- two maxima

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

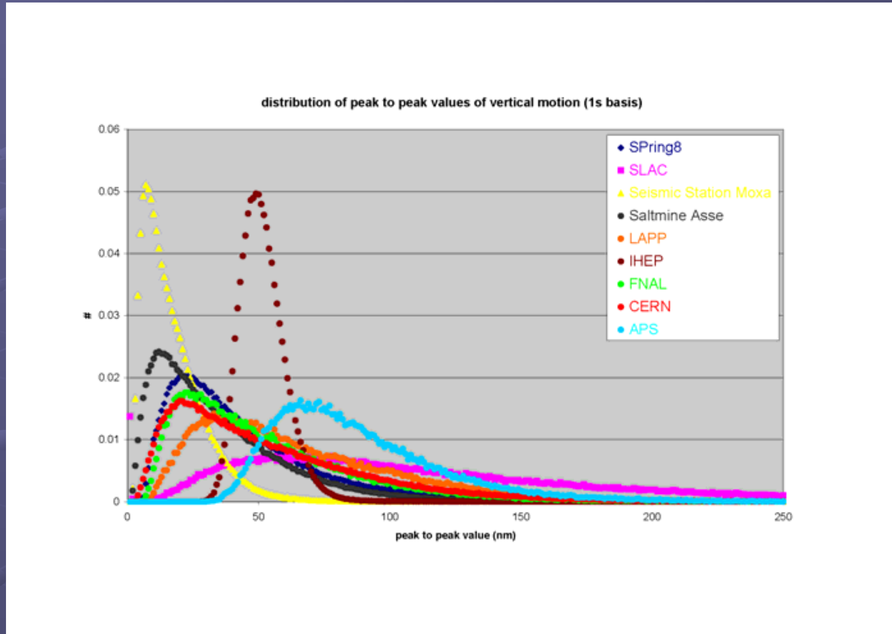
=> typical distribution for different sites

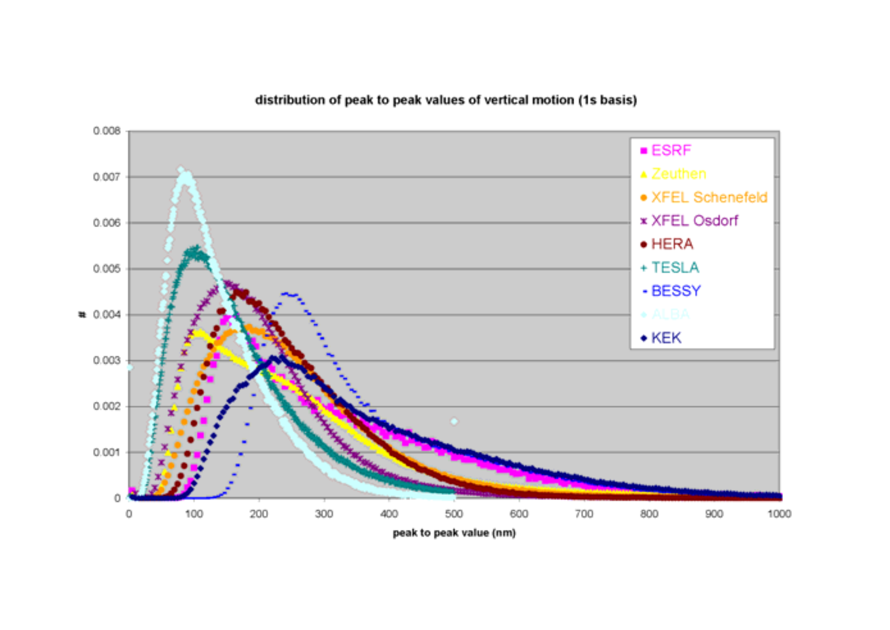
peak to peak value distribution

another characterisation technique:

•numerical integration of velocity raw data for 1s periods -> displacement (implied1Hz 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

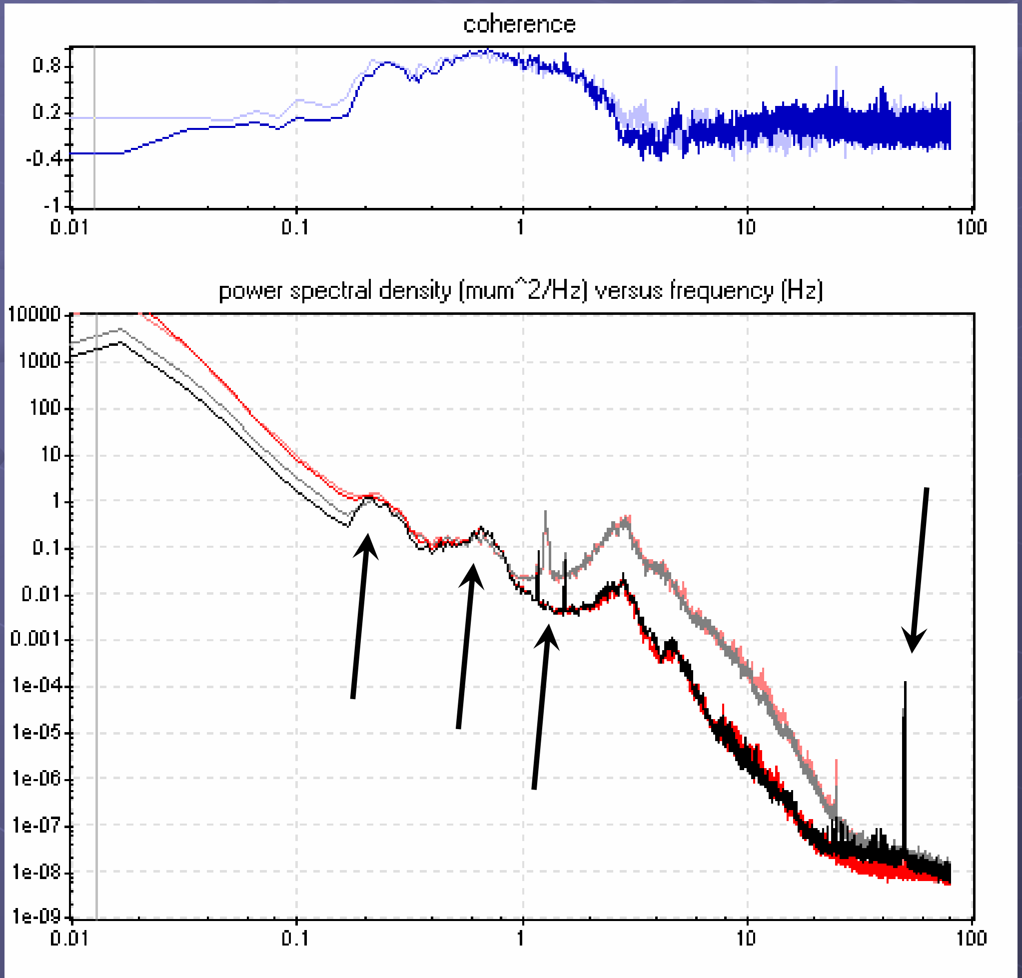
SSRF site measurements

- 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

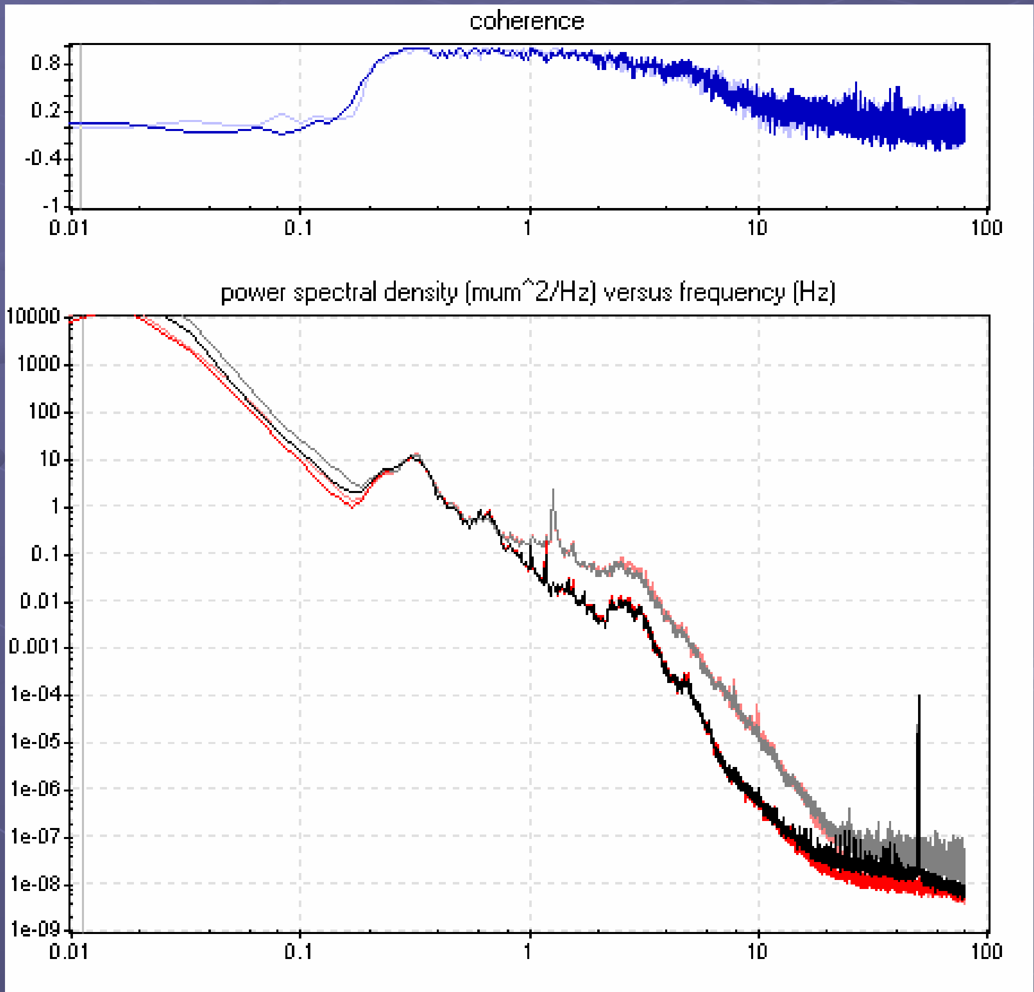


- strong influence of cultural noise above 1.5Hz
- clear microseismic peak at 0.23Hz
- clear second microseismic peak at 0.64Hz
- typical sharp peaks around 1.3Hz (one or two) (frequency not constant!)
- good "correlation" for 30m distance up to about 2Hz
- 50Hz signal (unimportant)

- rms values for f>1Hz:
  - **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

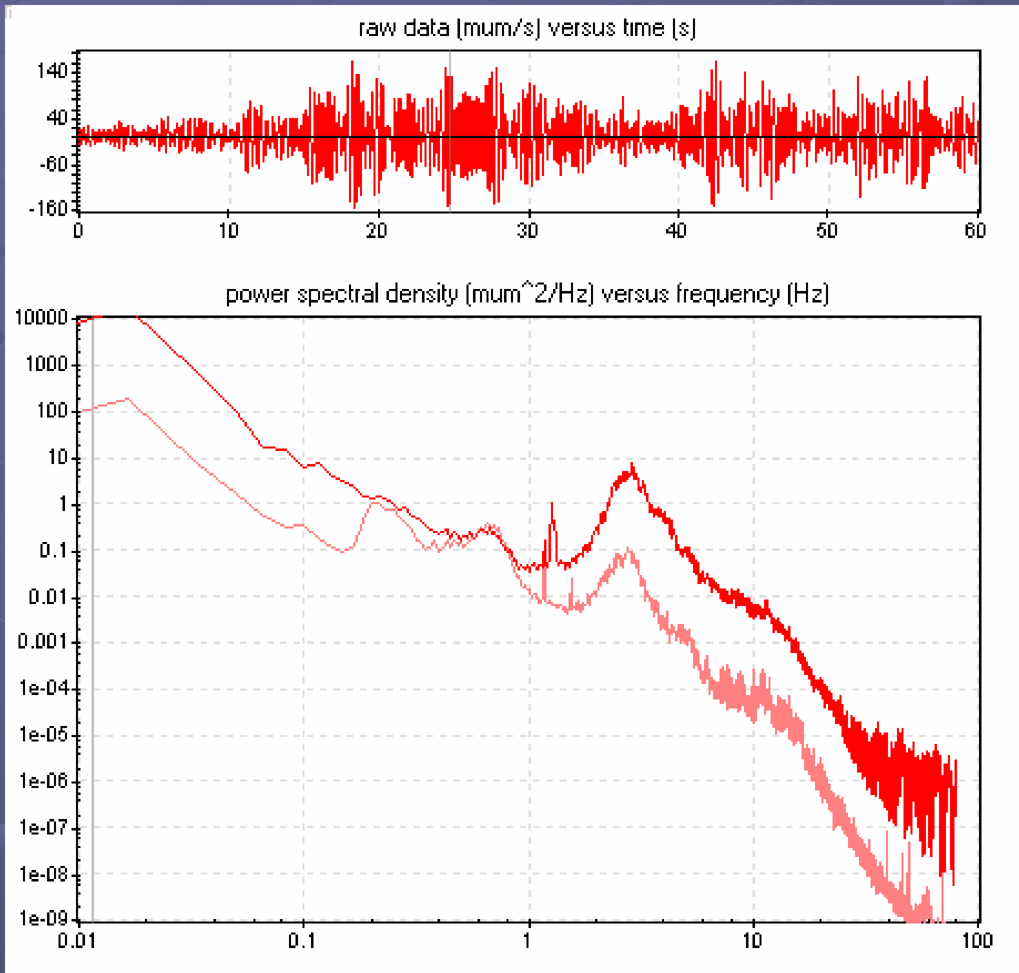


- similar
- also microseismic peaks at 0.23Hz and 0,64Hz
- good “correlation” also for frequencies above 2Hz

- rms values for f>1Hz:
  - **quiet: 127nm**
  - **noisy: 354nm**

results from SSRF site (3)

PSD comparison for **vertical motion**,
outside the experimental area,
average of1h quiet versus 1h noisy time



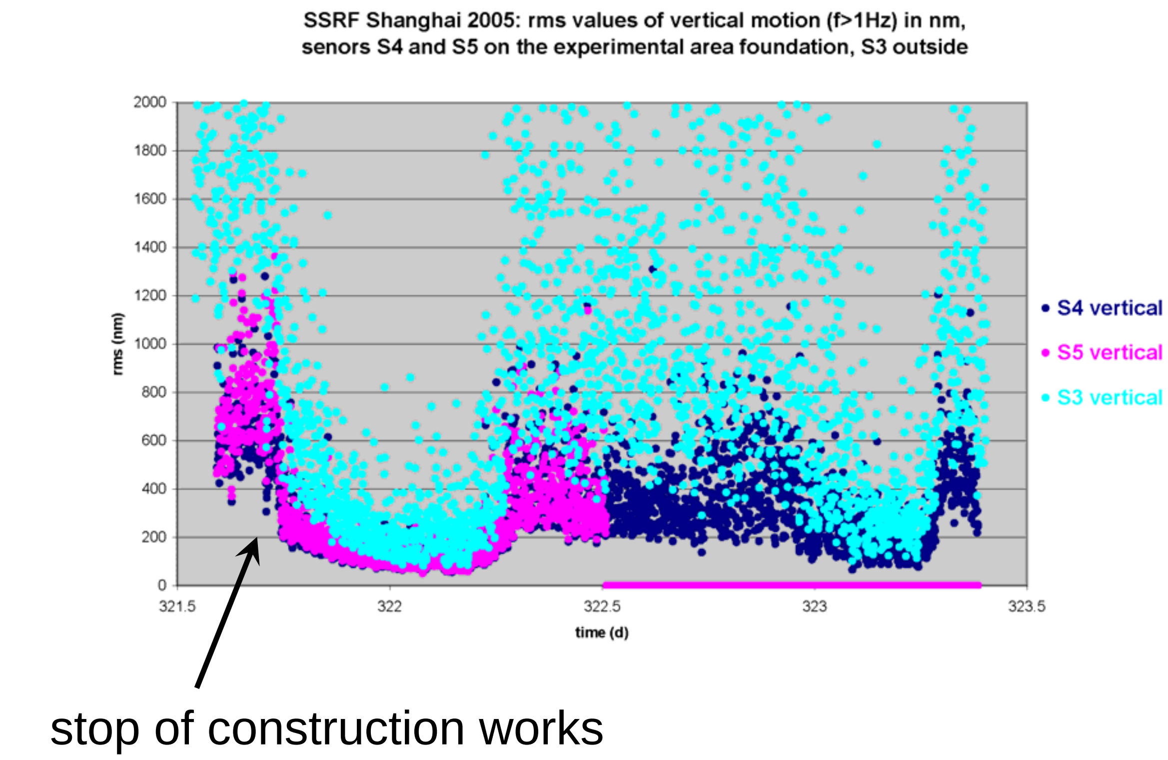
- strong events
- much larger amplitudes

- rms values for f>1Hz:
  - **quiet: 202nm**
  - **noisy: 1510nm**

=> experimental area foundation substantially improves the vibration situation !

results from SSRF site (4)

rms values of vertical motion (f>1Hz) versus time



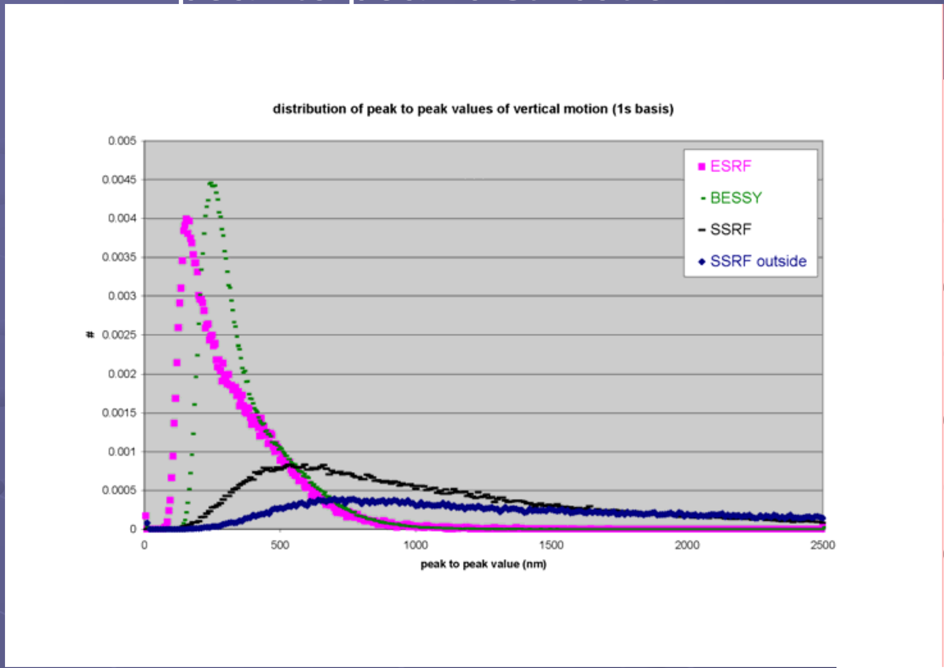
experimental area

outside

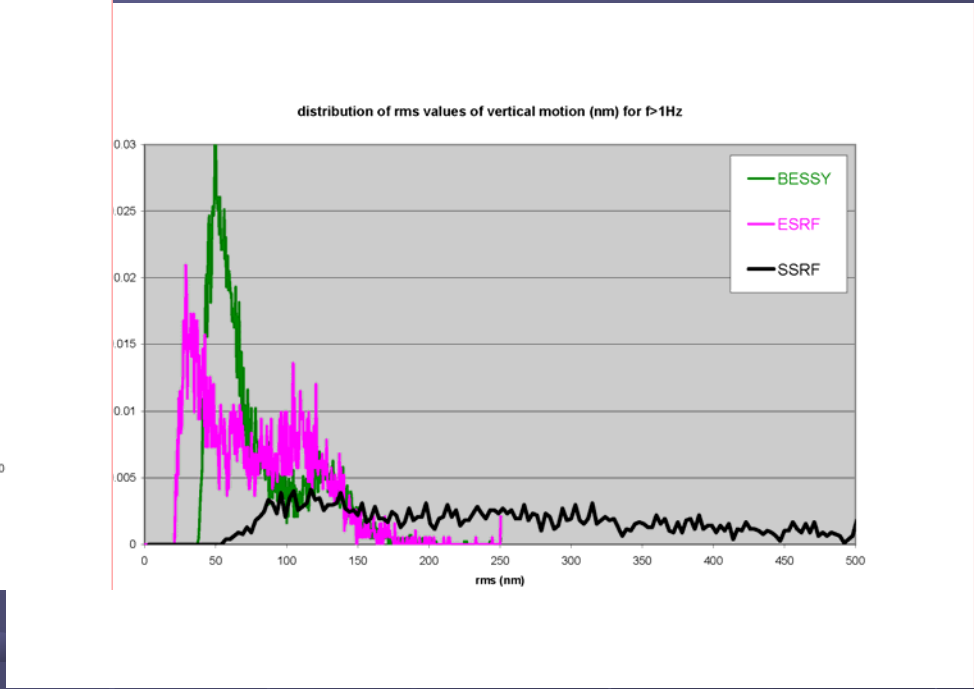
- “quiet” during the night
- maximum in the morning
- large fluctuations during noisy times

results from SSRF site (5)

peak to peak distribution



rms distribution

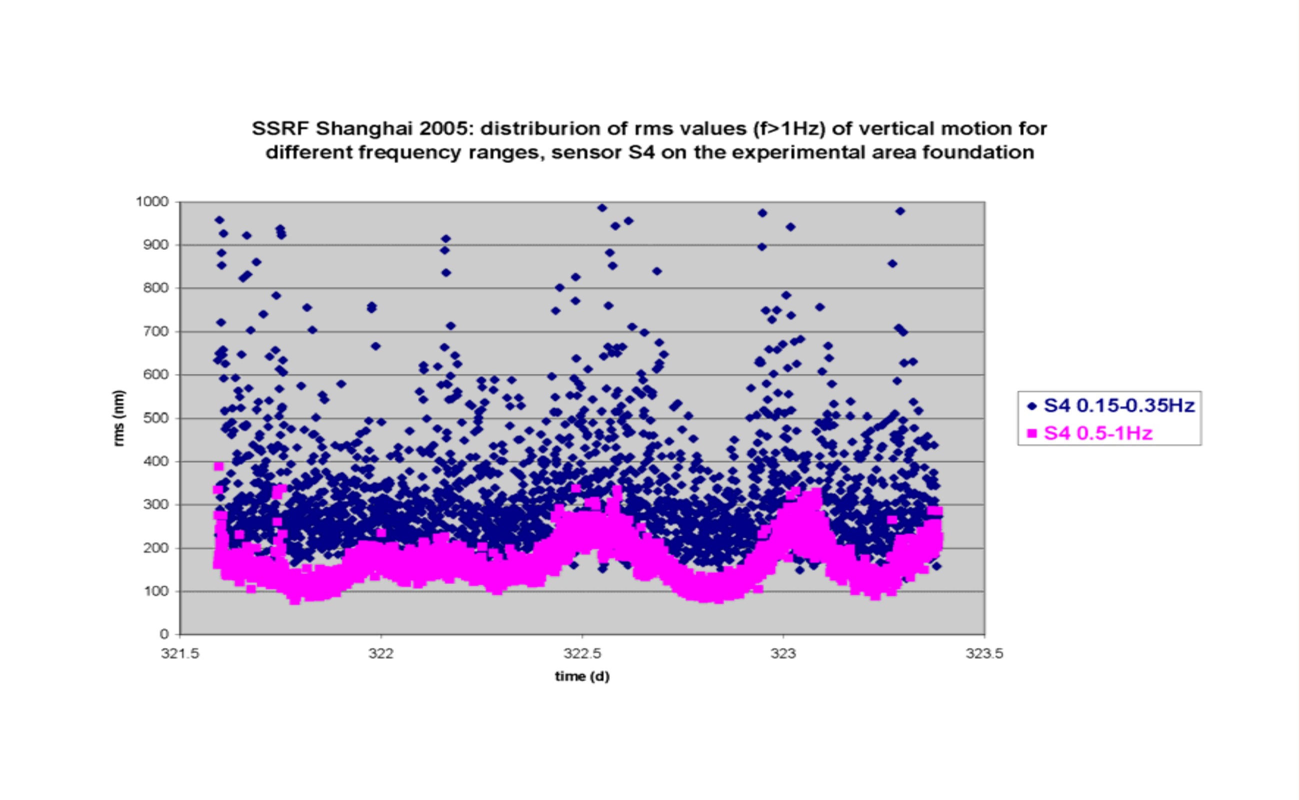


- broad distributions
- highest maximum value

=> noisiest site we measured up to now

results from SSRF site (6)

microseismic signal versus time

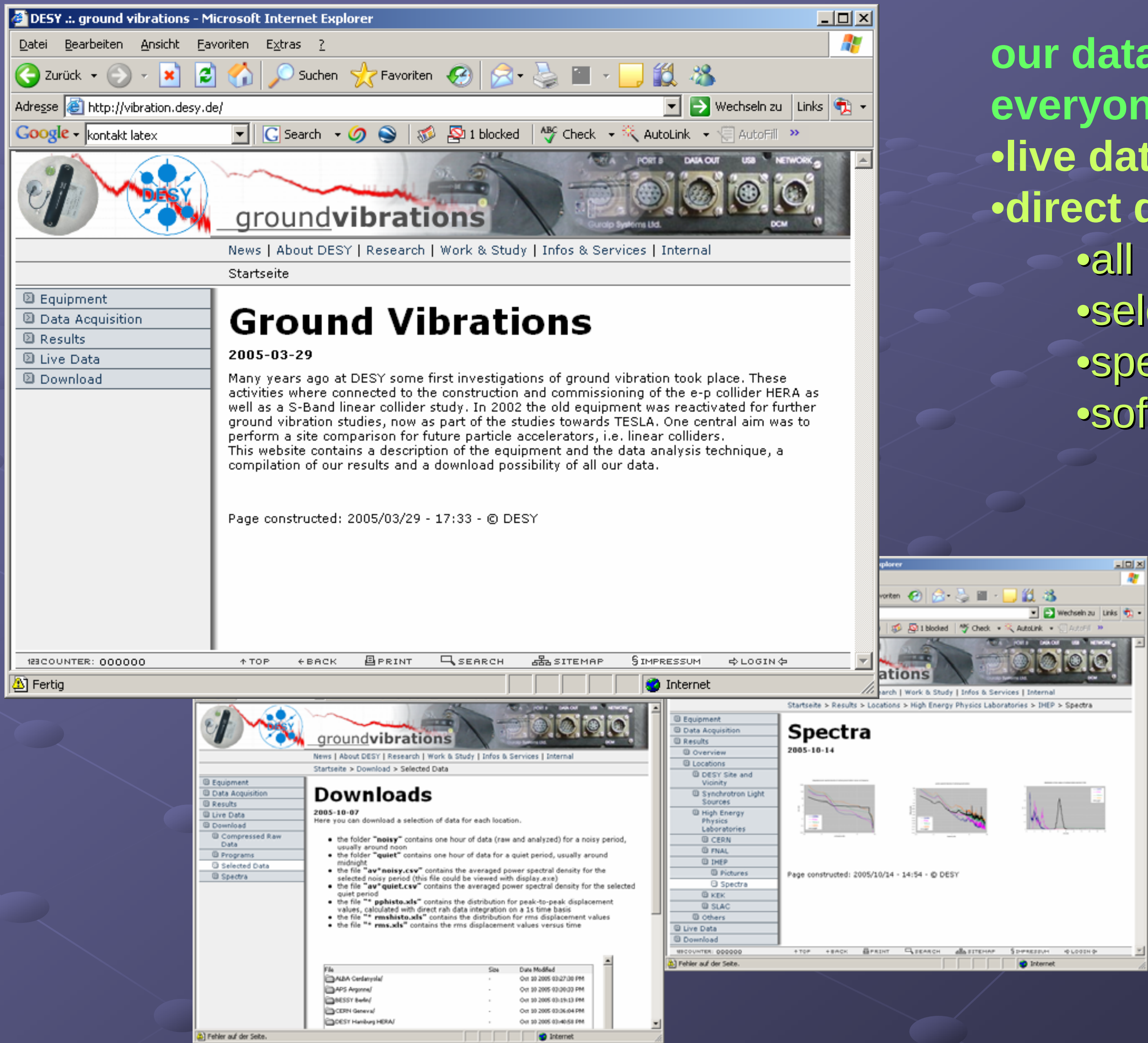


- tidal behaviour of second hum -> maxima ad flood time?
- is also the sharp signal at around 1.3Hz correlated to water waves on the river?

status of our site comparison

Location	Peak to Peak distribution Maximum pp (nm)	 FWHM (nm)	without highest 5 % Average RMS (nm)	 SD σ (nm)	Selected Data 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

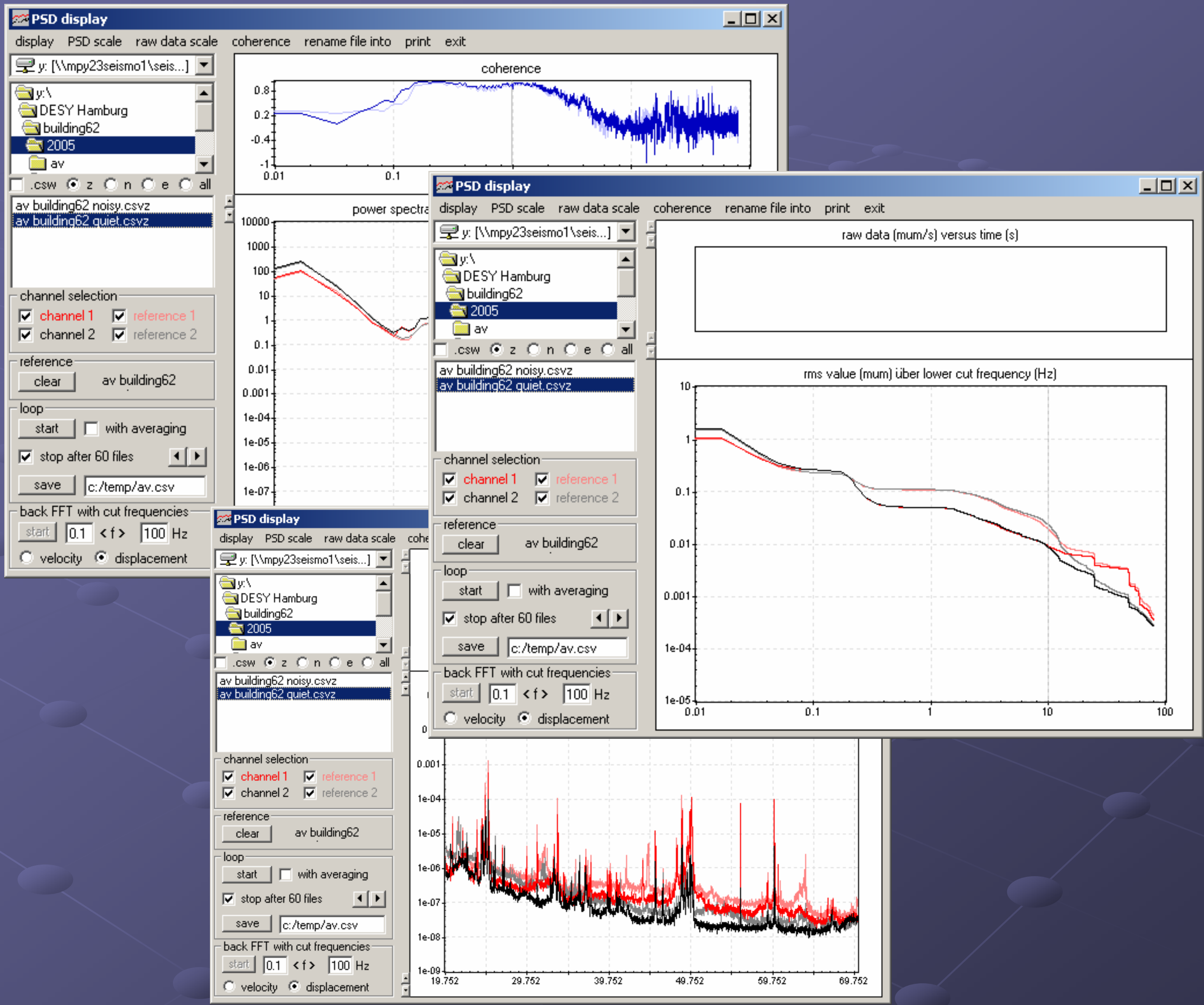
http://vibration.desy.de



our data is available for everyone

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

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:

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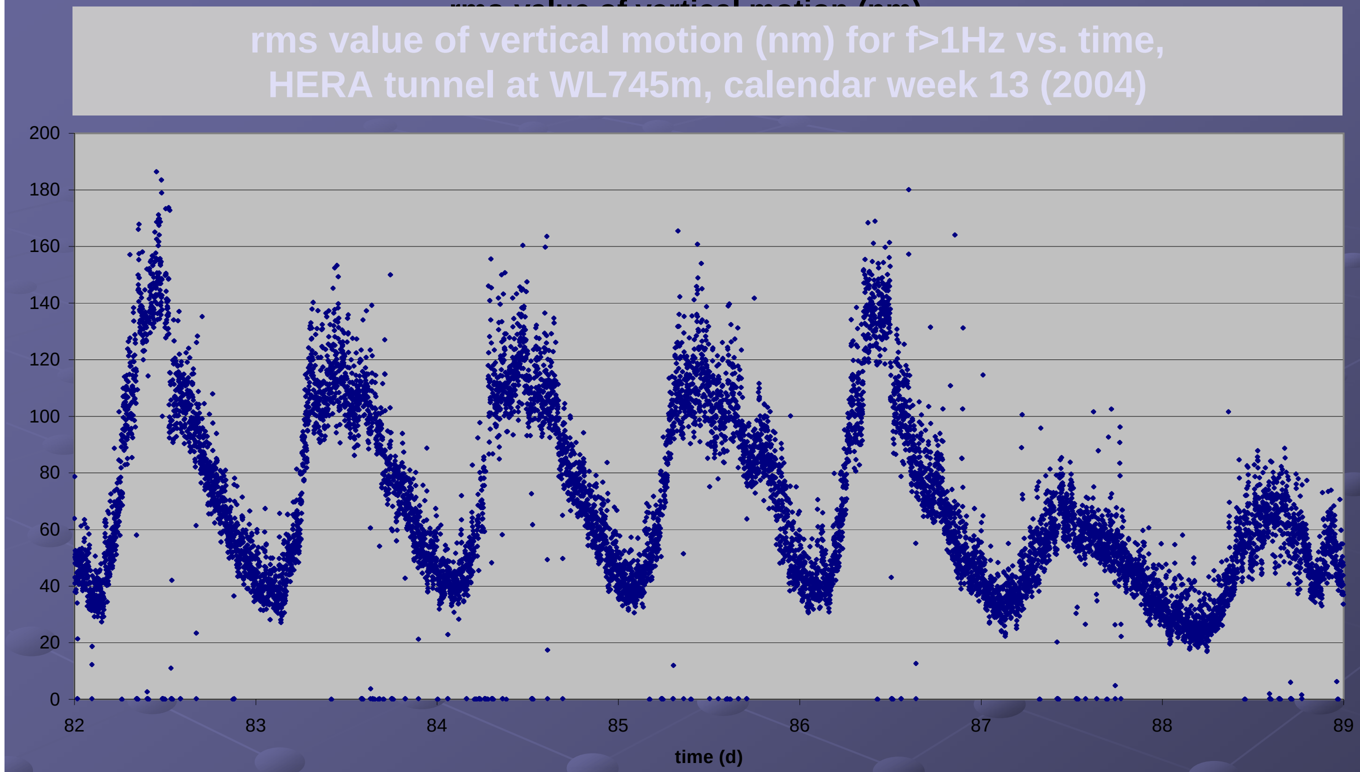
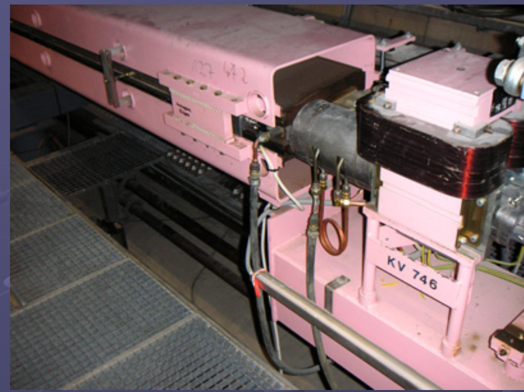
“seismic station”

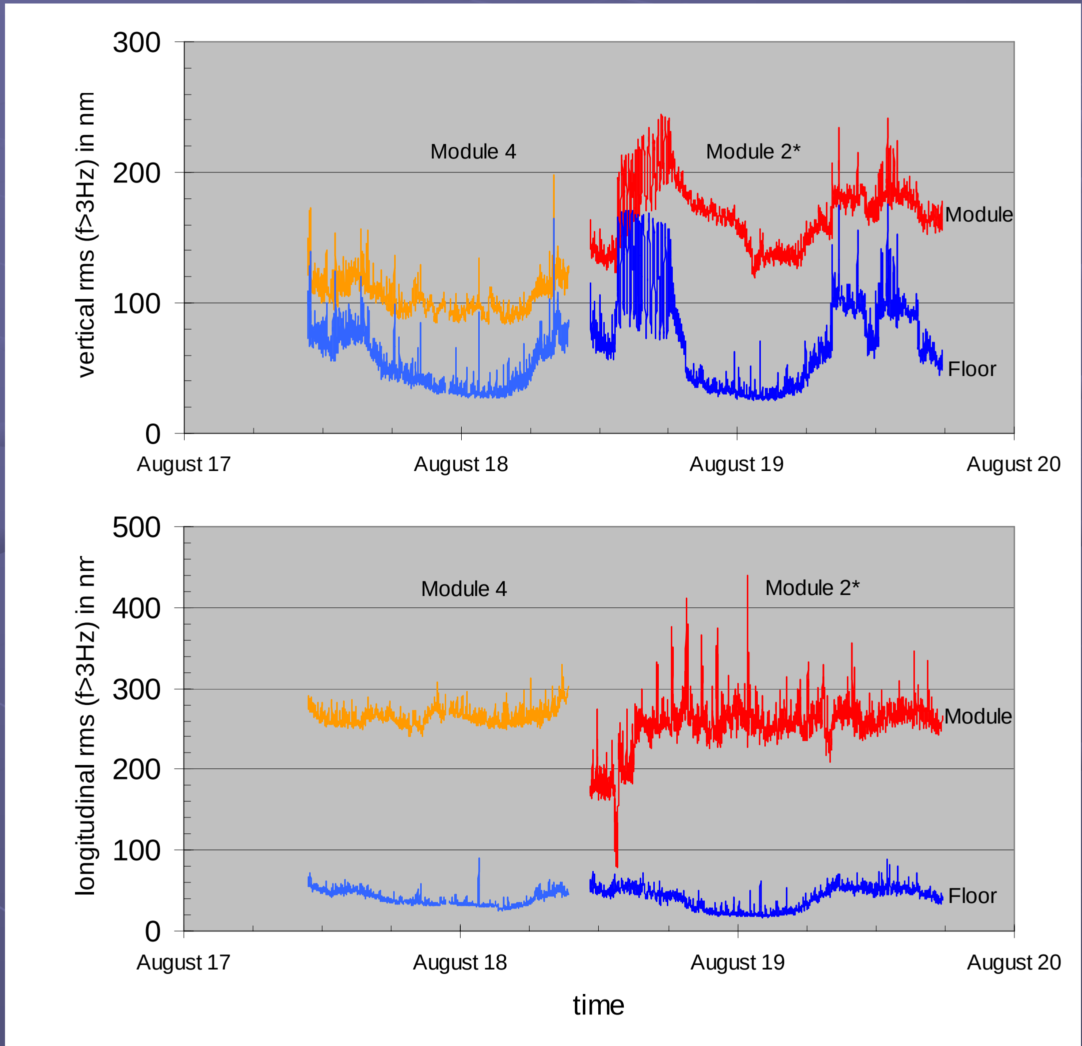


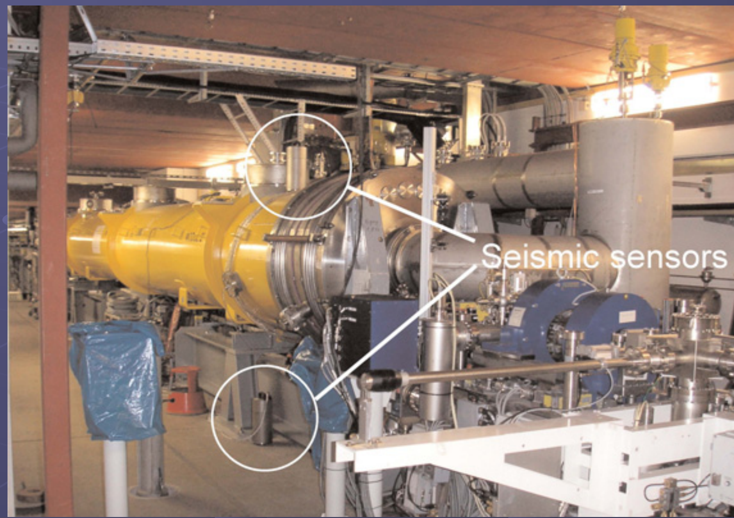


- permanent data acquisition
- permanent data transfer to the University of Hamburg -> geophysics
- online data available for everybody wordwide (on request) -> [SCREAM]

TESLA module vibration inside the TTF tunnel

rms value of motion for f>3Hz versus time





⇒ strong module vibration

⇒ vacuum installation?

⇒ module installation itself?

⇒ **further investigation is necessary**

… in action