Ground Motion and Vibration for LET Simulation, "Point of Contact"

Paul Lebrun

CD/FNAL

And…

Remarks on Fast Groundmotion

- DESY GM Database
- Examples
- Remarks for Simulations

Dirk Kruecker
DESY

Thanks to
R. Amirikas
A. Bertolini
W. Bialowons

Motivation & Context

- Focus of LET simulation will be on dynamic issues
  - **Quality of Steering or re-Steering on realistic beam lines and accelerators.**
    - Vibrations and short term ground motion. (minutes to hours)
  - **Keep it aligned => Feedback loops**
    - Ground motion on longer time scales.
- Critical!
  - **In the current design, beam based alignment is** *solely* **used to keep the LET operational..**
    - (Is this wise?)
  - **Feedback loops relatively trivial without Ground Motion or vibration..**

Terminology

- Slow Motion
  - **ATL like**
- Fast Seismic Vibration
  - **Elastic waves**

A. Seryi
Models ABC

0.1 Hz

- Cultural noise & technical noise
  - **Ground motion by human activity**
  - **Cryogenic pumps etc.**

DESY Database

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Experts (Real Name)

- Cultural Noise and Vibration (Dirk Kruecker, DESY)
  - **R. Amirikas,… DESY.**
  - **Mike McGee et al, FNAL**
  - **CERN, KEK ?**
- Ground Motion (Paul Lebrun, FNAL)
  - **KEK : R.Sugahara, .. (S. Takeda…)**
  - **DESY : H. Ehrlichmann**
  - **CERN : ?**
  - **FNAL : Jim Volk, (S. Singantulin, V. Shiltsev,..)**

References

- Relatively recent, far from complete, but it’s a start:
  - Ground Motion & Comparison of Various Sites. R. Amirikas et al, EUROTeV report 2005-023
  - Introducing a Homepage for Information Retrieval and Backup and.. R. Amirikas et al, PAC07 WEPMN07
  - A high precision double tubed Hydrostatic leveling system for Accelerator Alignment systems. Fermilab-Conf 06-508-AD, S. Singantulin, et al
  - Characteristics of Ground Motion At KEK and Spring-8, Y. Nakayama et al, EPAC 2004.
  - Incoherent Ground Motion, S. Takeda et al, EPAC 2000
  - A. Seryi, Ground Motion Models for Future Linear Colliders, EPAC 2000, THP6A14

Raw Data Repositories

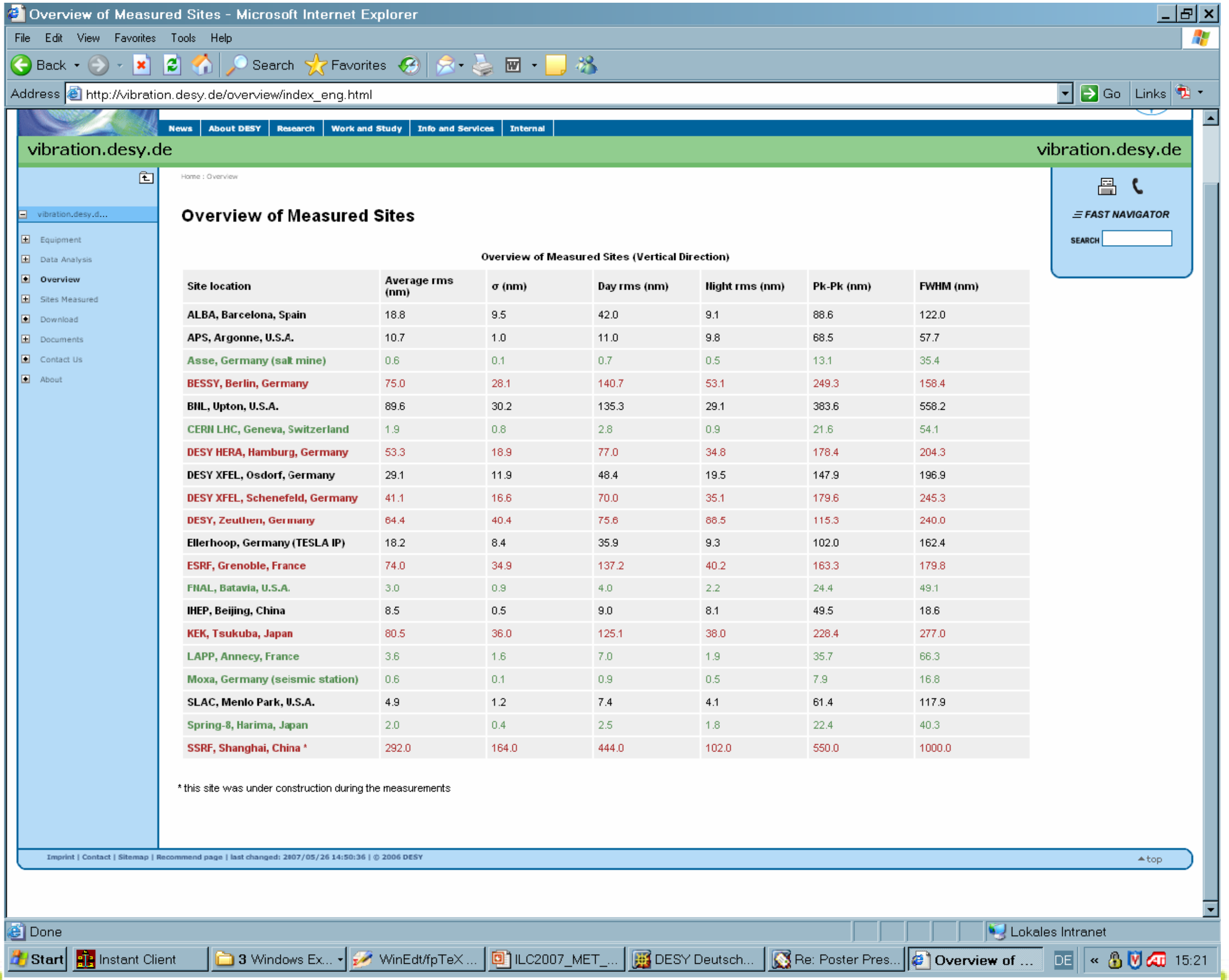
- Data repository:
  - http://vibration.desy.de/
    - – Impressive collection of data from around the world
    - – Seimisc, same instrument
  - http://rexdb01.fnal.gov:8081/ilc/ILCGroundApp.py/index
    - – Access to FNAL Hydrostatic level data, NuMi tunnel and Aurora mine.

The DESY Database on Ground Motion

http://vibration.desy.de

- GM measurements since 2002
  - **Seismometer and geophone measurements**
- 20 sites all over the world including:
  - **FNAL, SLAC, CERN, KEK, DESY, ...**
    - several locations for each site: tunnel, surface etc.
  - **In most cases 1 week of data taking**
    - day and night variations
- Processed (PSD etc.) and raw data (200Hz sampling)
- In addition cold and warm Cryomodule measurements

DESY Ground Vibrations Database - a Snapshot



Overview of Measured Sites

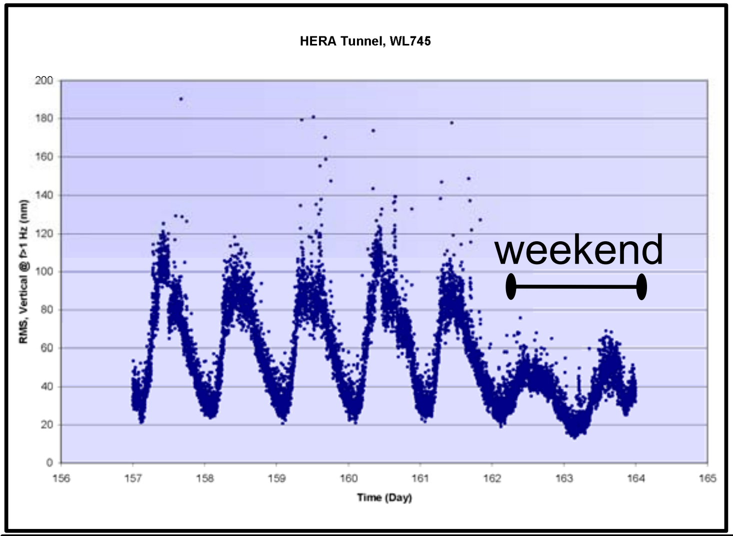
Overview of Measured Sites (Vertical Direction)

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
BNL, 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	68.5	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
FNAL, 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

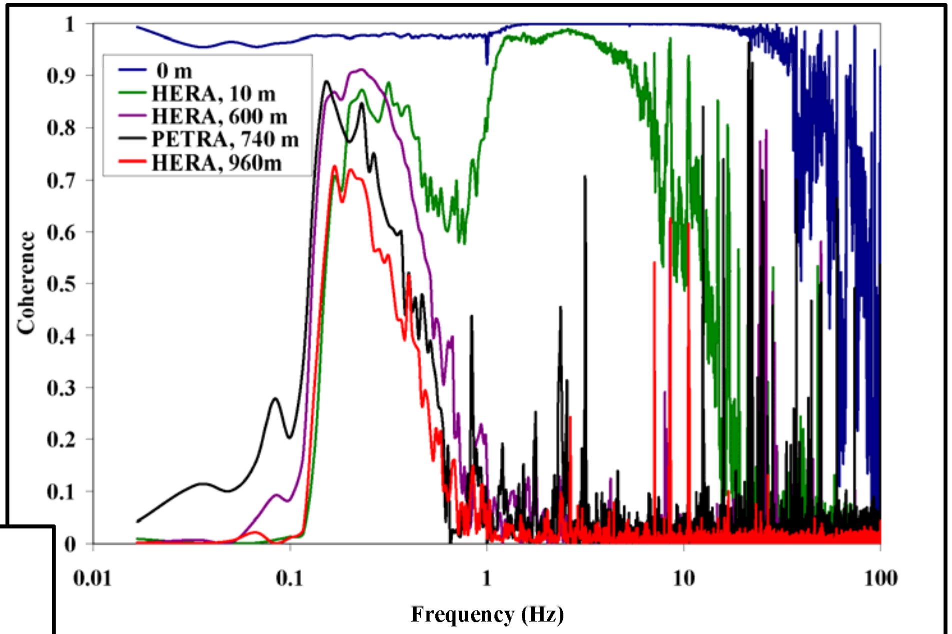
* this site was under construction during the measurements

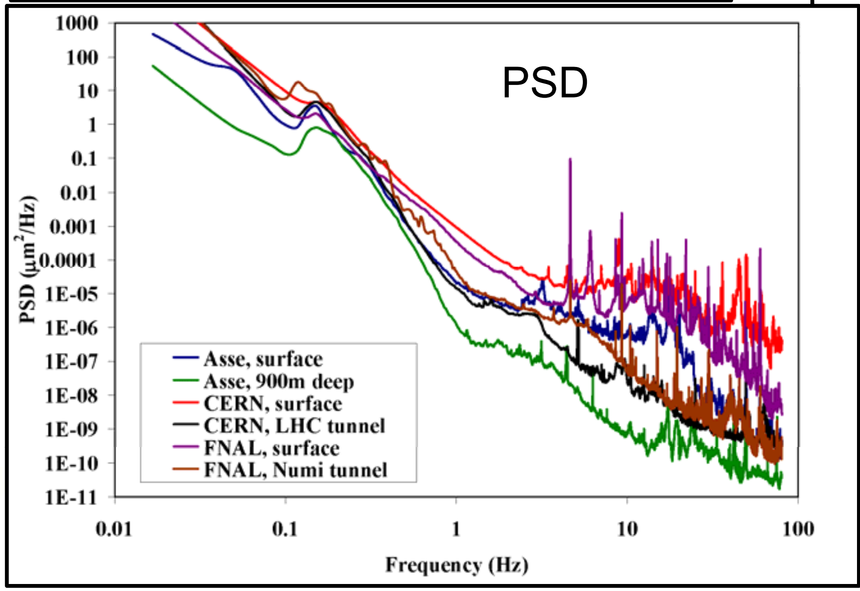
Examples

Day and night variation HERA



Coherence measured at different distances





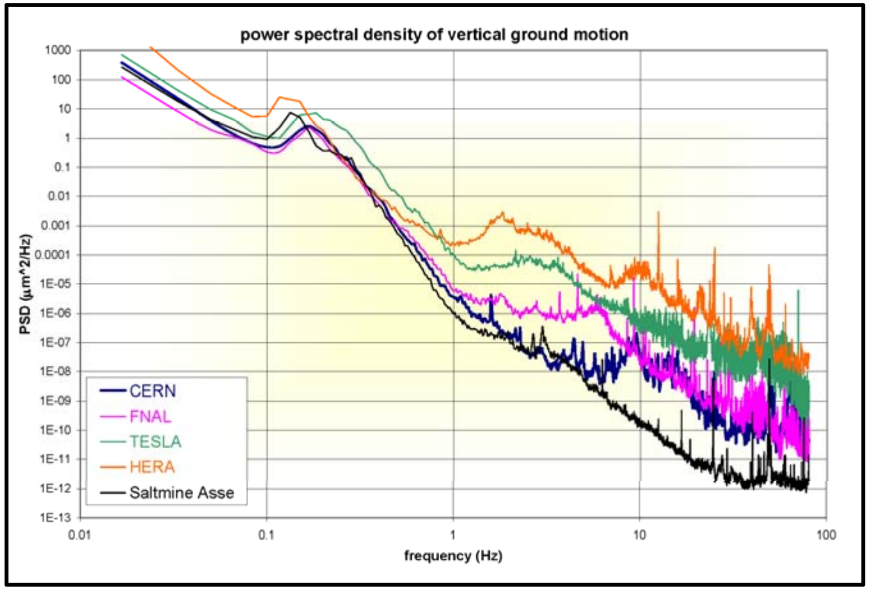
Variation vs. Tunnel Depth
for some quiet places

RMS(f > 1 Hz) (surface)	Asse:	5 nm
	CERN:	22 nm
	FNAL:	32 nm

Asse (900 m underground): 5 nm
CERN (LHC tunnel): 2 nm
FNAL (Numi tunnel): 3 nm

Asse is a salt mine in Germany

PSD - Integrated PSD



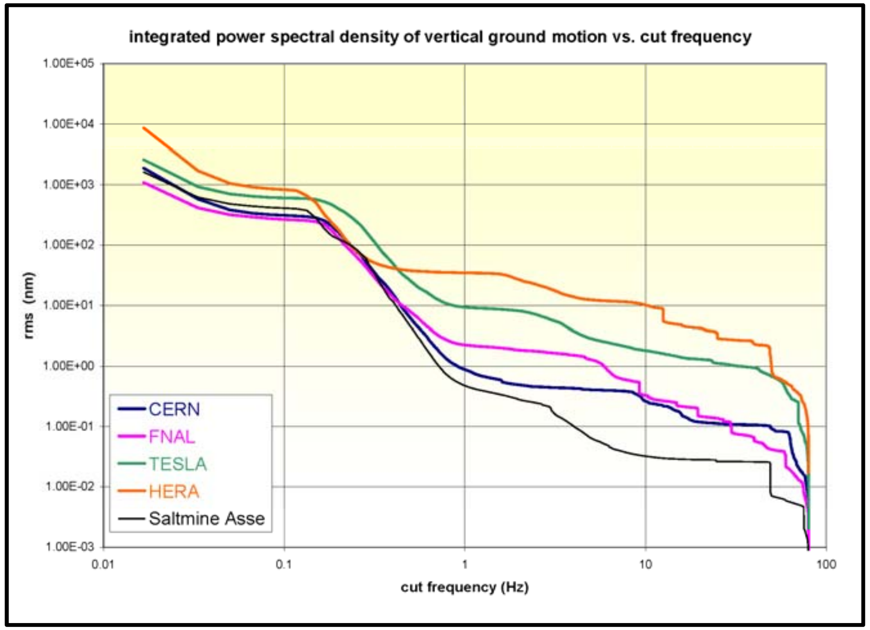
Power Spectral Density

$$S_x(f) = 2\lim_{T\to\infty}\frac{1}{T}[X(f)]^2$$

$$X(f) = \int_{-T/2}^{T/2} x(t)e^{-2\pi i f t}\,dt$$

The integrated PSD is related to the RMS

$$RMS(f_1, f_2) = \sqrt{\int_{f_1}^{f_2} S(f)\,df}$$



Upper limit from this plot for [f1,f2=80Hz]:
less than 500 nm above 1Hz
(1 µm above 0.1Hz)
10 nm above 1Hz for quiet labs

How does this translate
Into component vibration?

Cryomodule vibration stability data

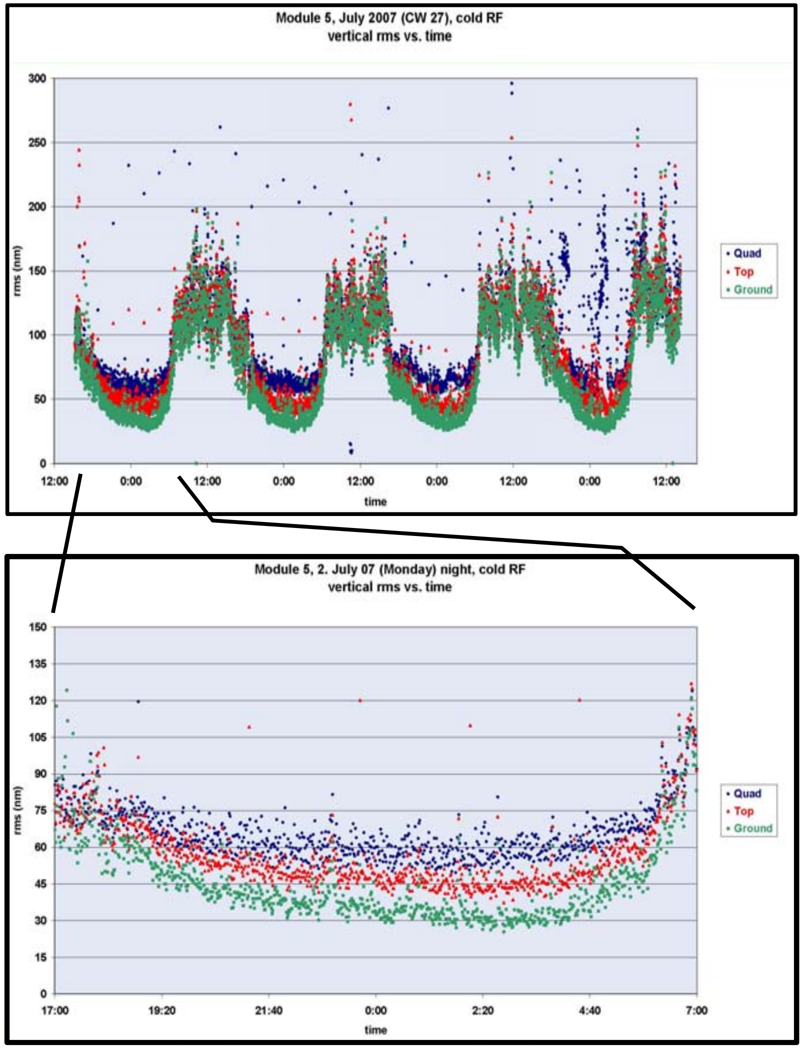
- Data available
  - Superstruktur (type II), later was re-named module 7, room temperature
  - Module 6 (type III), both room temperature and cold (4.5 K)
  - Module 5 (type III), both room temperature and cold (4.5 K)
- Currently we are measuring
  - Vibration measurements in a string of cryomodules in FLASH (DESY): modules 4,5,6 7 at 4.5 K
  - Module 8 (type III+), both at room temperature and @ 2K, coming at the end of this year….
  - We will also study mechanical stability versus quad position in module 8.

Cryomodule vibration stability data

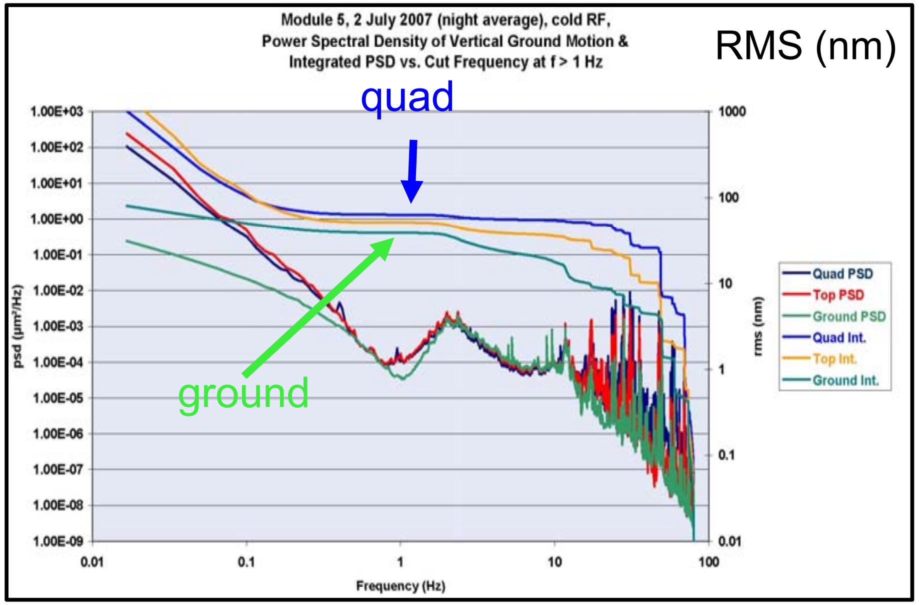
- What do we measure?
- Quad vs top vessel and ground in the vertical direction
- Room temperature and cold (4.5 K)
- Please take a look at:

http://vibration.desy.de/sites_measured/cryomodules/index_eng.html

Cryomodule 5 - Vibration Stability



cold measurements
RF in operation (klystron nearby)
noisy due to day time activities



Remarks for Simulations (D.K.)

- There is no common pattern
  - **Cultural noise is site dependent**
  - **It depends on the technical installations inside and outside of the tunnel etc.**
- A simple white noise (RMS <10 nm – 500 nm) model might be sufficient as upper limit
  - **On top of a slow motion model**
- The problem under consideration defines the frequency range and the tolerable RMS
- A typical value for a quad inside a cryomodule is 100 nm
- Our raw data could be used as simulation input if a real world model is needed
- Transfer functions for cryomodules are available

From Raw Data to LET models..(P.L)

- Comments on Mission on "Simulation Input people":
  - **Usually a bit more than conveying information**
- For Ground Motion & Vibrations, "package(s)" are mostly likely needed to convert Raw Data to an actual simulated motion of a list of element.
  - **Uncorrected Raw Data can be misleading.**
    - And not very practical
  - **But: Instrument bias..**
    - Let's take a break from software and look at..

Ground Motion Detectors

- Mostly, two types
  - **Hydrostatic Level Sensors: (HLS)**
    - Measure vertical distances between a given equipotential line. --> differences (And this is what we want!)
    - Accuracy : fraction of 1 micron (V. Shiltsev claims 50 nm, but disputed, need to be settled..)
    - Frequencies: < one minute… (~ 0.01 Hz)
  - **Seismic sensors & Geophone**
    - Mostly, accelerometers: Need to convert to change of position and Power Density Spectrum.. Calibration accurate to ?
    - Fast, > 0.01 Hz to tens of KHz..
- Others:
  - **Frequency Scanned Laser Interferometers (FSLI)**
  - **Fiber Optic based Strain gauges..**

Ground Motion & Vibration: A Gap?

- The range of 1.0 Hz to 0.01 Hz
  - **from 5 to 500 ILC pulses: typical inverse time delay between successive tuning phases of sub-sections of the machine!.**
  - **Boundary between “fast” and “slow”**
  - **Accuracy required: few hundred nm.**
  - **Instrumentation: ?**
    - Hydrostatic : too slow
    - Seisometers: -> calibration? systematic errors ?
    - FSLI: 100 nm over a distance of ~ 1 m. But over ~ 100 m? And cost!

So, From Raw Data to LET models..

- Modeling is most likely needed:
  - **Raw data from HLS could be used, in principle..**
    - From limited system (~ 100 m.), If no spatial correlation is epected over such a distance scale.
    - Correction due to instrument resolution is small.
  - **Mostly, we are using the model of A. Seryi, or similar.**
    - Obtained by fitting the Power spectrum to the “P~/($\omega^2 k^2$), the “ATL” model
    - With non-linear correction
    - “Add-On: Cultural noise”

GM model… Limitations.

- ATL does not consistently handle:
  - **Quasi-periodic motion**
    - Tides are clearly visible in FNAL recent data.
  - **Hydrology**
    - Change in the Water table…ILC FNAL site is expected to be better than NuMI, yet, it will be a factor.
  - **Other “systematic effects”**

    $\Delta x^2 \sim \mathrm{sqrt}(L)$
    - yet to be determined

GM models…Options

- Starting point:
  - **ATL : Just one number.. easy!**
  - **ATL + corrections.. (A. Seryi, V. Ivanov)**
    - Available in LIAR, Lucretia, CHEF
    - Other codes?
  - **No attempt at correlation “Natural” and “Cultural”, i.e. add deviations in quadrature.**

- Upgrades:
  - **Tides simulation**
  - **Review “cultural noises” and vibrations.**
    - Better white noise? 100 nm -> few hundred nm ?
  - **Correlations across the ~0.1 Hz boundary**
  - **Benchmark different implementations.**