DESY Hamburg
Dep. MKS-4
Germany

Vibration Measurements at TTF
(Sep. 04)

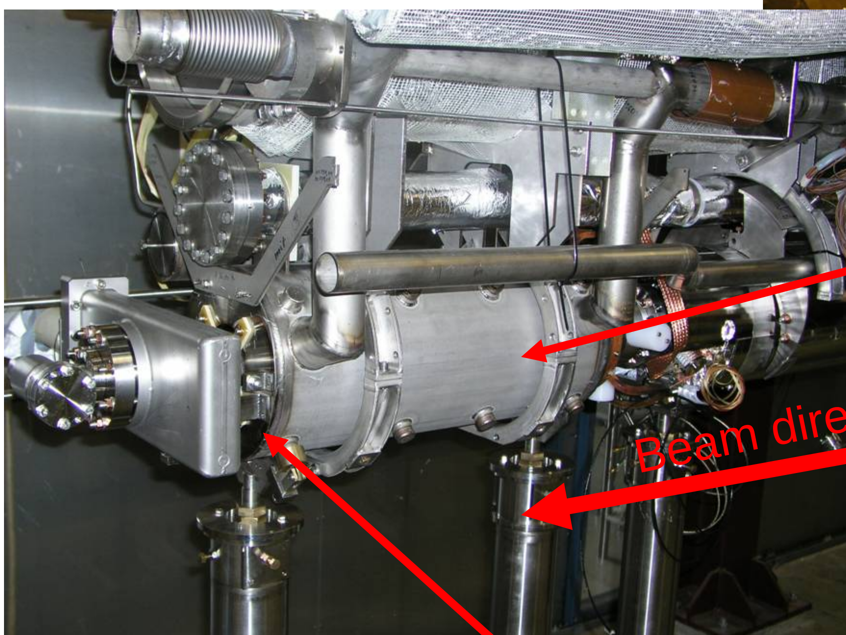
TESLA Meeting, Hamburg
March 31, 2005

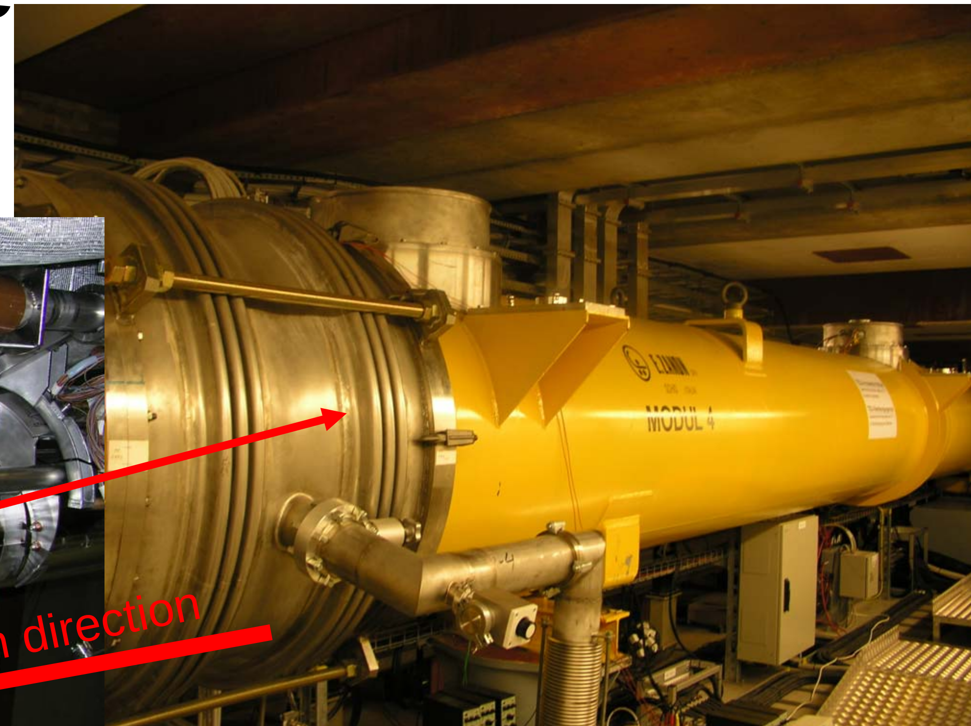
H. Brueck
Heiner.brueck@desy.de

Status from Vibration Measurements during Shutdown (Sep 2004)

- Measurements at ACC 4 only
  - Data acquisition close to sensors
  - Two sensors (cold) at the quadrupole vertical and transverse to the beam
  - Two sensors on top of the module
  - Two sensors on the ground/support
  - One geophone (vertical) at various places
- Measurements with various conditions
  - Comparison Piezo - Geophone
  - Day, night weekend
  - Vacuum pumps on, off, pumps dismounted from trailer

Quadrupole at the End of the Cavity String in a Module



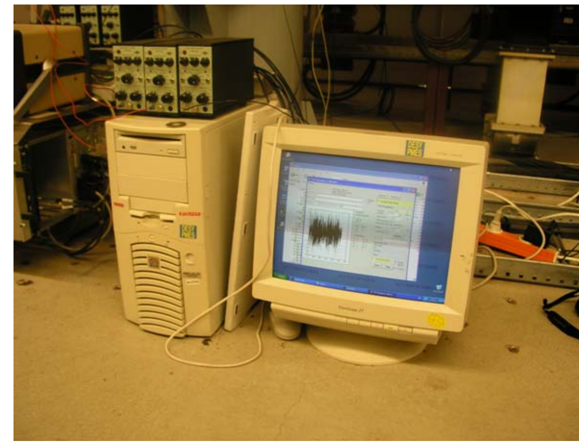


Piezo sensors

Module 4 at ACC4 of TTF

Measurement Conditions

- PC now close to sensors
- Preamplifier switched from acceleration to velocity
  - Implies a high pass at 1 Hz (.2 Hz in acc mode)
  - Low pass filter at 1 kHz
- Data analysis
  - Just FFT, ignoring non periodic effects, no corrections, no window-functions
  - Averaging over many measurements



Some Formulas

$$\ddot{x}(t) = P \cdot u(t)$$

Piezo Sensor acceleration

$$P = 10^4 \cdot \frac{\mu m / s^2}{V}$$

$$\dot{x}(t) = G \cdot u(t)$$

Geophone velocity

$$P = 10 \cdot \frac{\mu m / s}{V}$$

gain switch=1 on preamp

Fourier Transformations

Windows (Hanning window) tested but not used

Fourier Integral

$$F(\omega) = \frac{1}{T}\int_0^T u(t)\cdot e^{-i\omega\cdot t}dt$$

Fourier Transformation

$$U_j = \frac{1}{N}\sum_k u_k \cdot e^{-i\cdot\omega_j\cdot t_k} = \frac{1}{N}\sum_k u_k \cdot e^{-i\cdot\frac{2\pi}{N}\cdot j\cdot k}$$

$$k = 0,1\ldots N-1 \qquad j = 0,1\ldots\frac{N}{2}-1 \qquad u_k \in \mathrm{R}$$

Power Spectrum

With this definition U_j is only .5 of the real Amplitude

$$P(\omega) = \frac{2}{T}\left|\int_0^T u(t)\cdot e^{-i\cdot\omega\cdot t}dt\right|^2$$

$$P_j = 2\cdot T\cdot\left|U_j\right|^2$$

depends on T!

From Acceleration to Position

by double time integration which corresponds to by division by ω^2 of the Fourier coefficients

$$A_j \rightarrow \frac{U_j}{\omega^2} \qquad P_j \rightarrow \frac{P_j}{\omega^2}$$

Variance and RMS

$$RMS = \sqrt{\sigma^2}$$

$$\sigma^2 = \frac{1}{T}\int_0^T u(t)^2 \cdot dt$$ with zero average

$$\sigma^2 = \frac{1}{2\pi}\int_0^\infty P(\omega)\cdot d\omega$$

$$\sigma^2 = \frac{d\omega}{2\pi}\sum_j 2\cdot T\cdot\left|U_j\right|^2 = \frac{1}{T}\sum_j P_j = 2\sum_j\left|U_j\right|^2$$

Often one plots the RMS values as function of a lower frequency limit (ω_0)

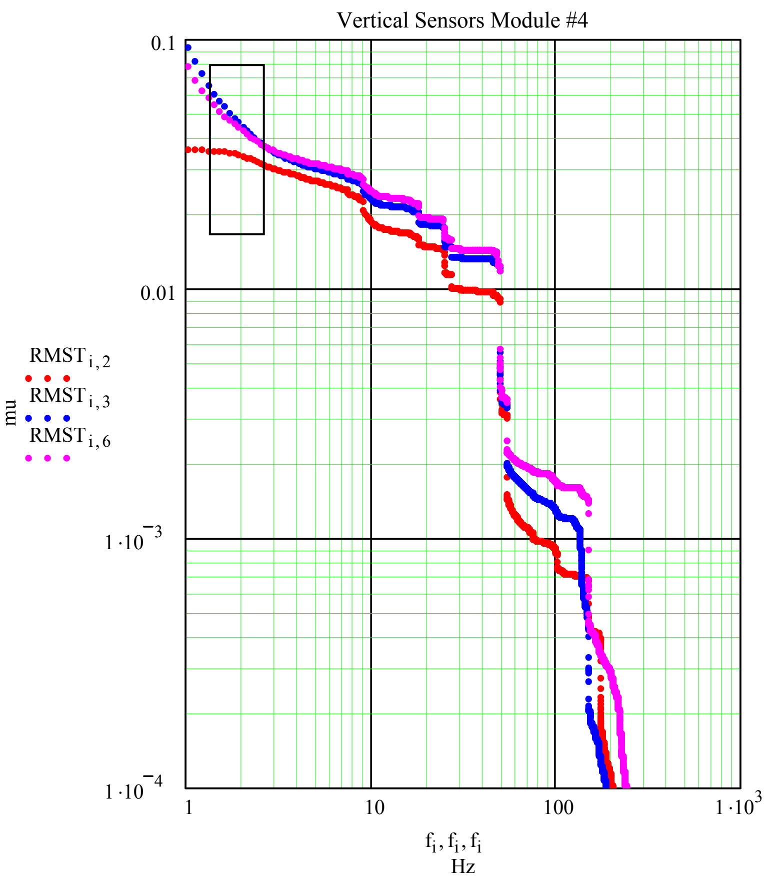
$$\sigma^2(\omega_0) = \frac{1}{2\pi}\int_{\omega_0}^\infty P(\omega)\cdot d\omega$$

$$\sigma_j^{\,2} = \frac{1}{T}\sum_{l=j}^{\frac{N}{2}-1} P_l = 2\sum_{l=j}^{\frac{N}{2}-1}\left|U_l\right|^2$$

$$RMS = \sqrt{\sigma^2}$$

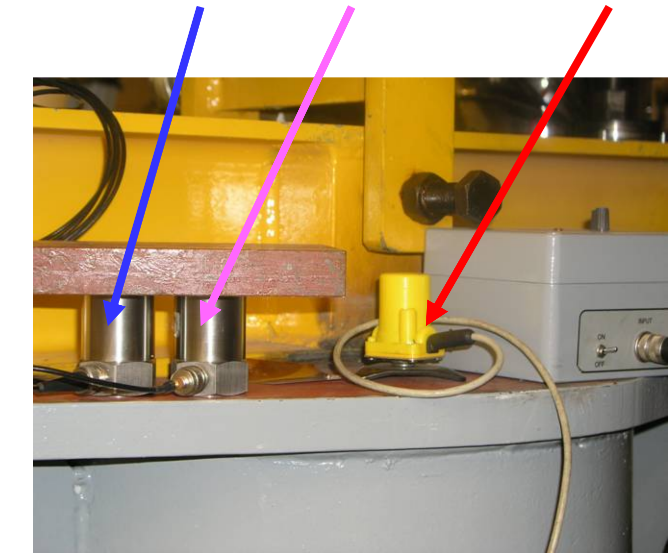
2 Piezos and a Geophone on the Socket

RMS average, Saturday midnight ± 1 hour



210804 2300 220804 0100

Piezo blue and pink, Geophone red

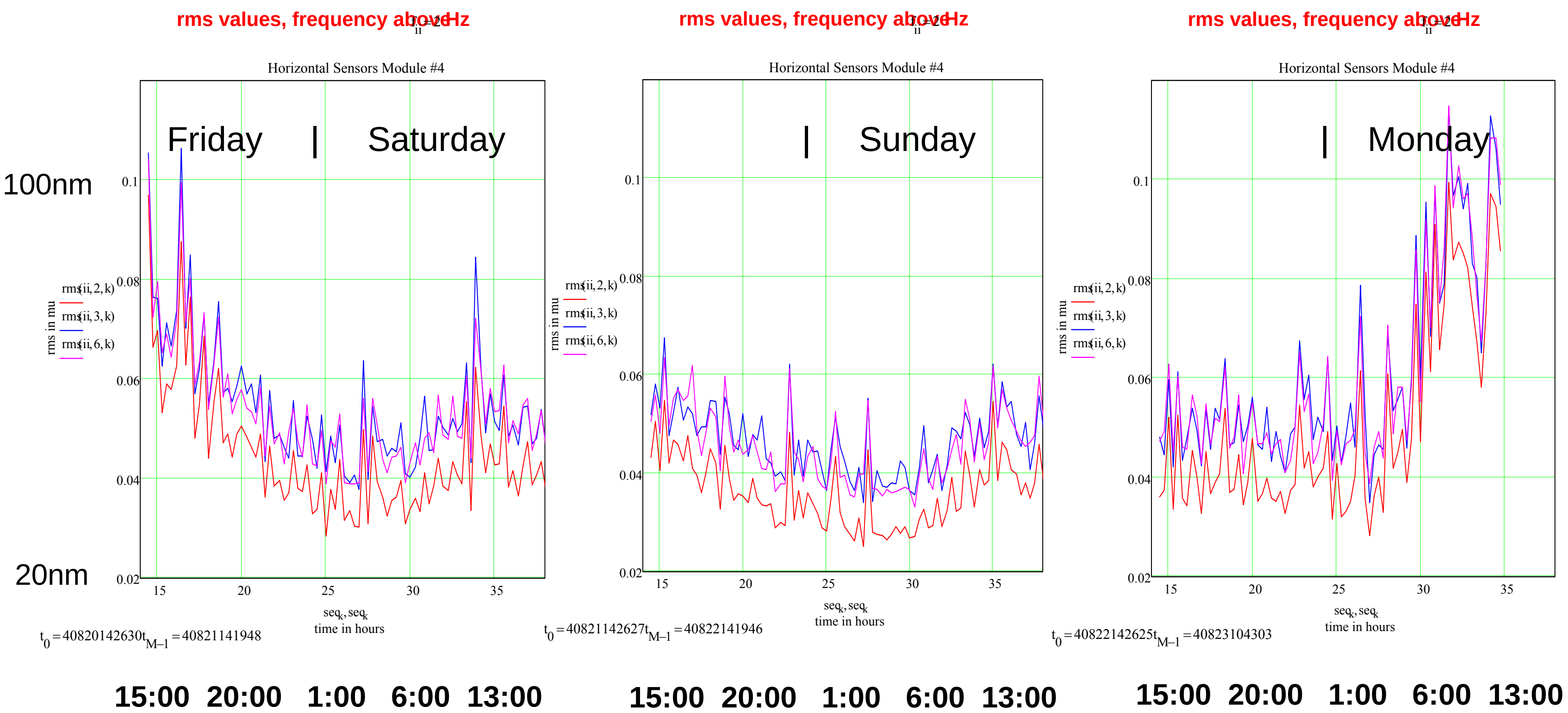


- Good agreement between
  - the two piezos
  - piezo and geophone (20%)
- Low RMS: 34 43 45 nm for f>2Hz
- Comparable with ground motions measured by Ehrlichmann
- At low frequencies the noise signal is probably getting dominant

Ground Vibration Time Dependence

Friday to Monday, RMS f>2Hz

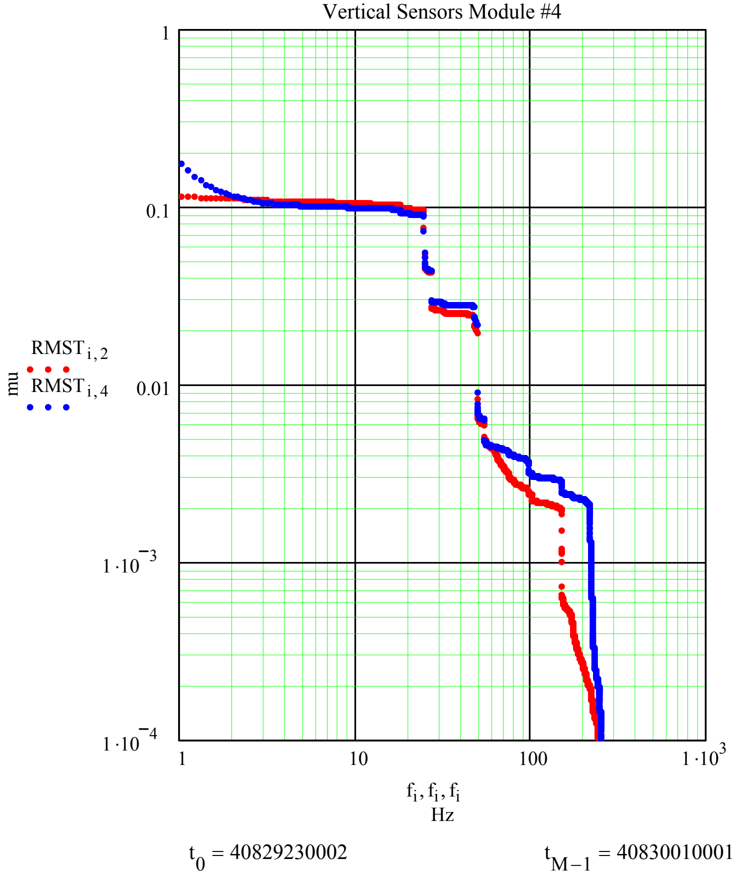
cultural noise



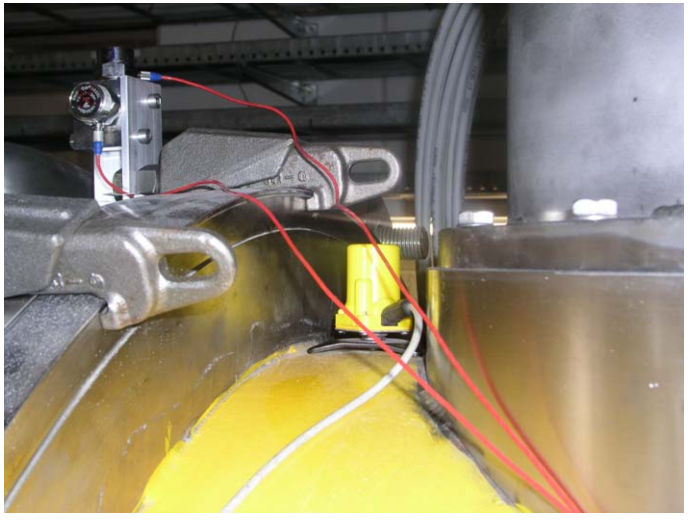
2 Piezos and a Geophone on the socket

Comparison of Piezo and a Geophone on Top of the Module (vertical)

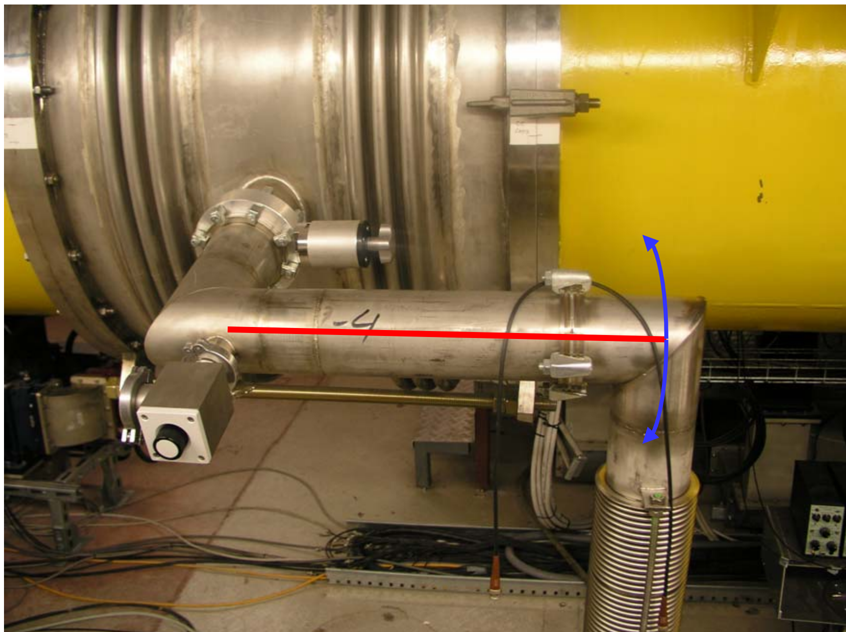
RMS average, satuday midnight ± 1 hour

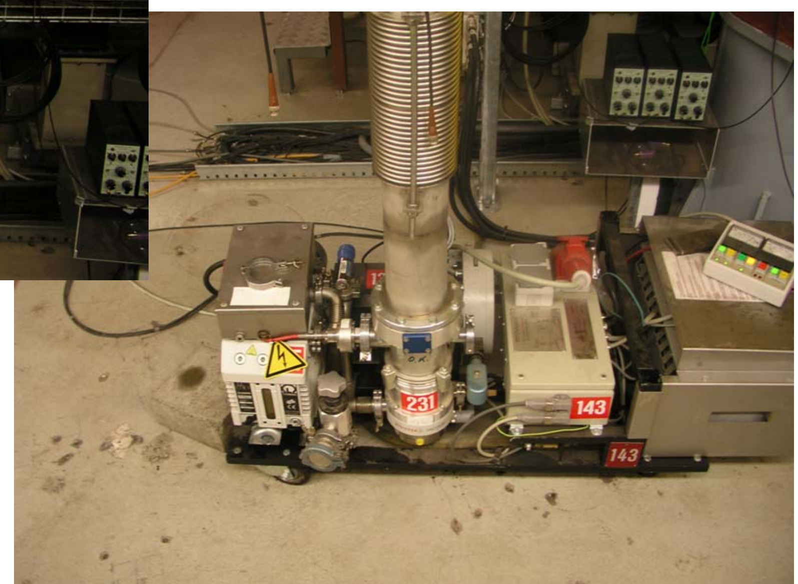


- Sensor positions on top of the module
- Good agreement, also Geophone and Piezo positions are not identical
- RMS: 115 nm for f>2Hz
- 2-3 time larger as at lower position (different weekend)



Check influence of the Pump Stand

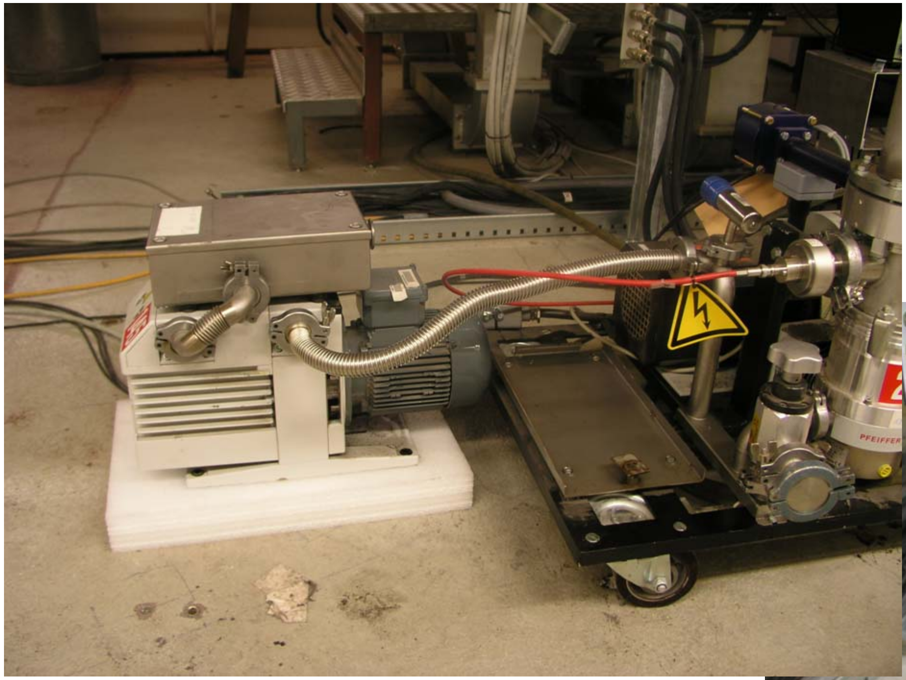


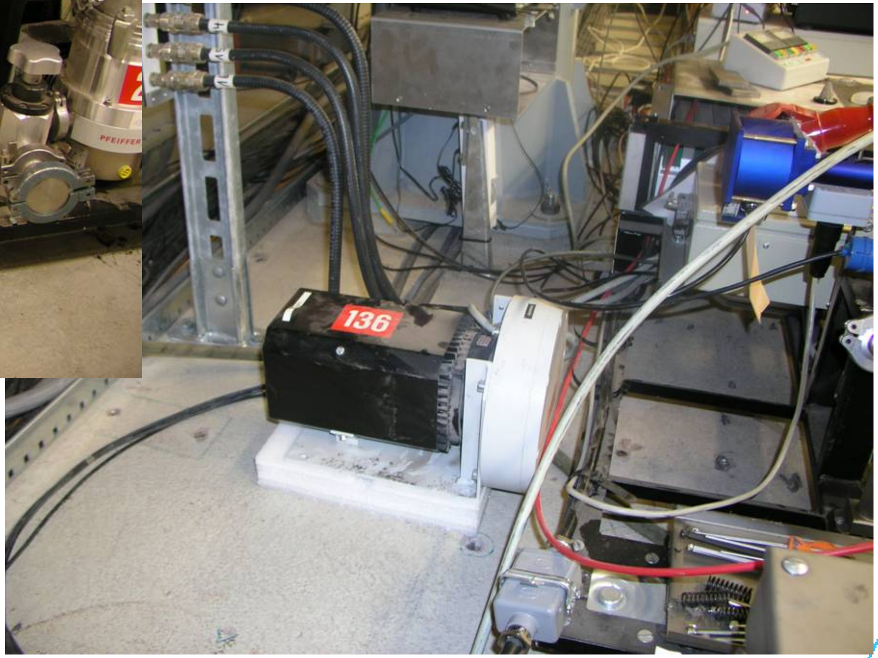


- Vibrations of the vacuum trailer generates a torque on the Schiebemuffe
- Long lever arm
- Vertical bellow fixed by bolts

Pump Stand Modifications

- Pump moved from trailer to floor
- Connected via a thin flexible line
- Frequency converter moved to the floor
- Internal dampers plus additional foam

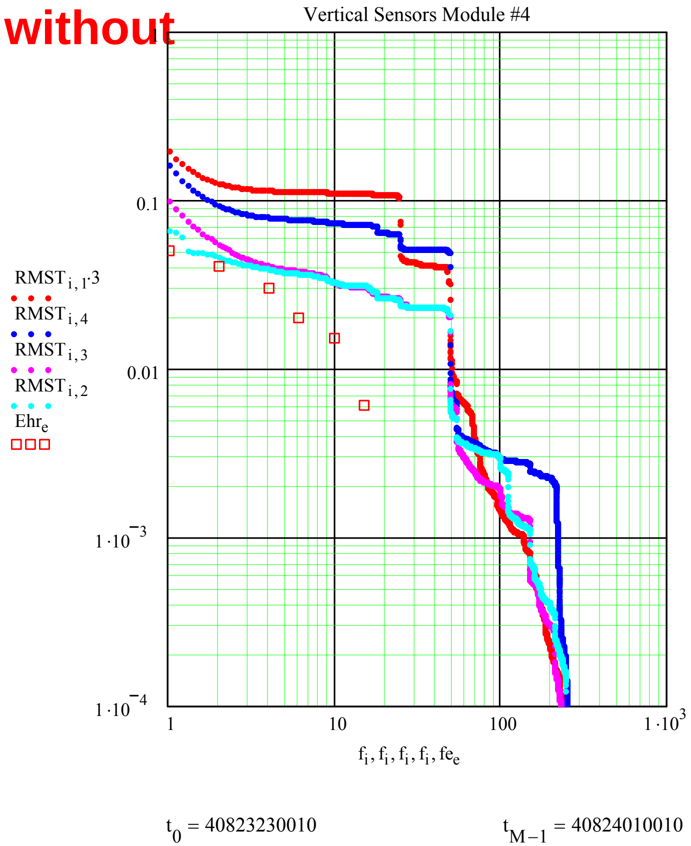




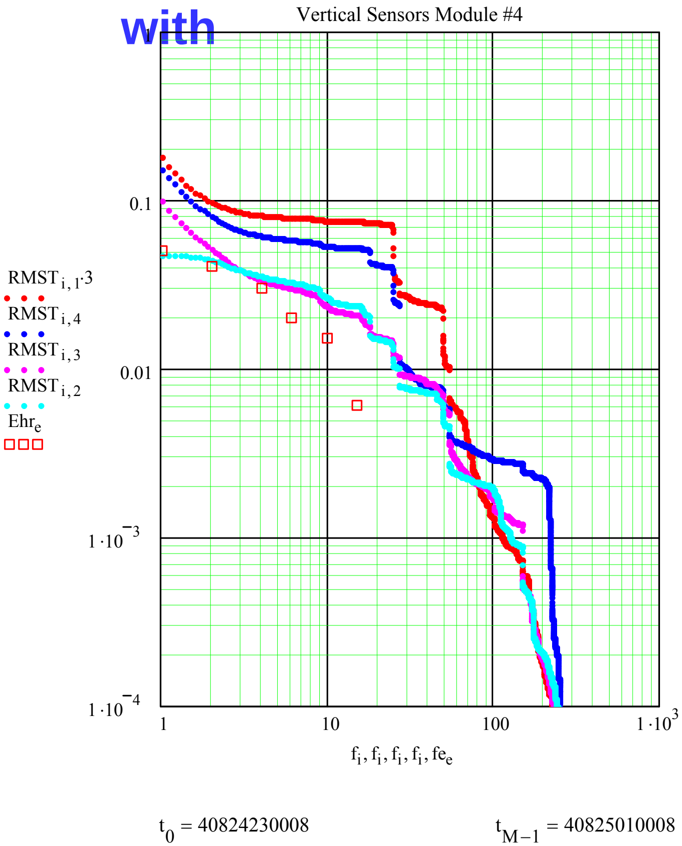
Pump Stand without/with Modifications
Vertical Sensors (2 different days)

RMS average, midnight ± 1 hour

without



with



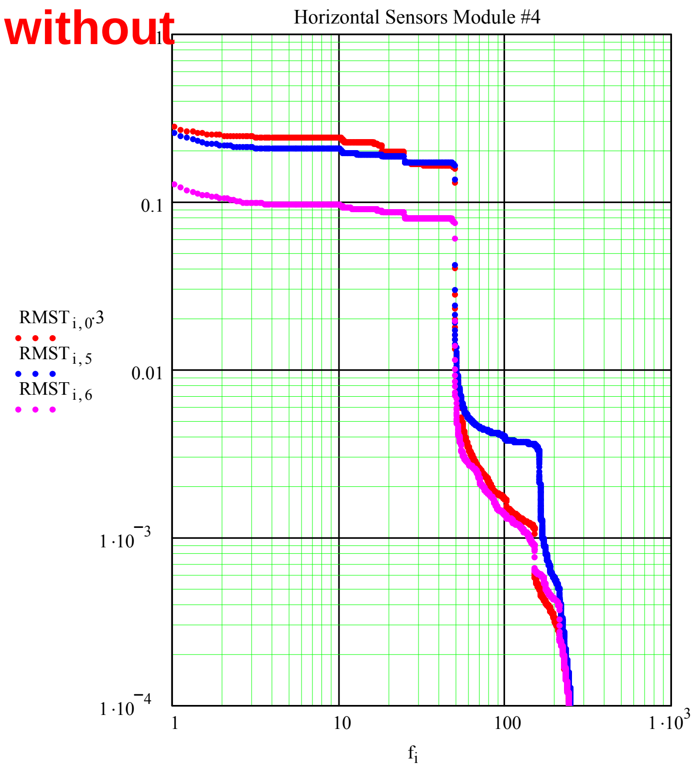
Sensors:
Cold
Top
Socket
Geophone
Socket

- Different days
  - Mon “without”
  - Tue “with”
- Cold Signal *3
- Some reduction below 25 Hz
- Large reduction between 25 and 50 Hz

Pump Stand without/with Modifications
Horizontal Sensors (2 different days)

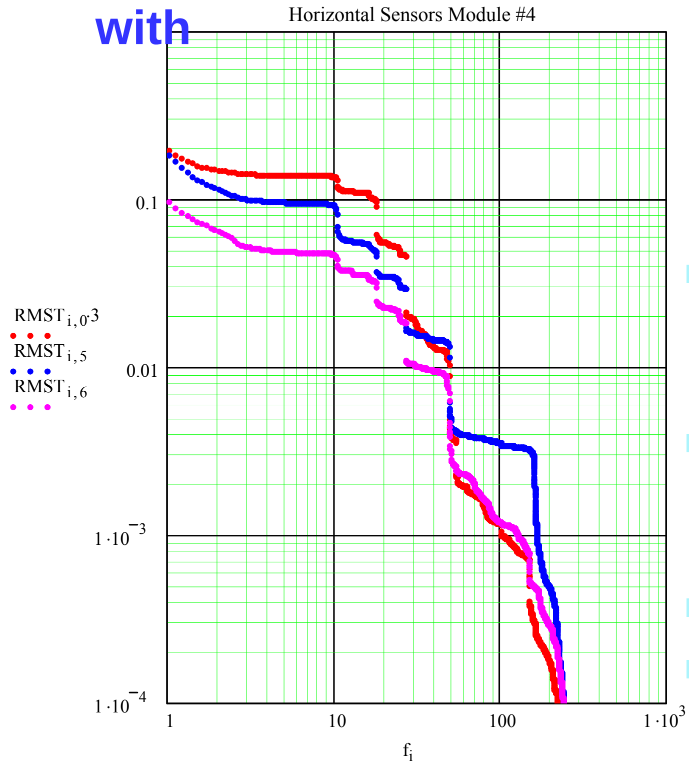
RMS average, midnight ± 1 hour

without



$t_0 = 40823230010$ $t_{M-1} = 40824010010$

with

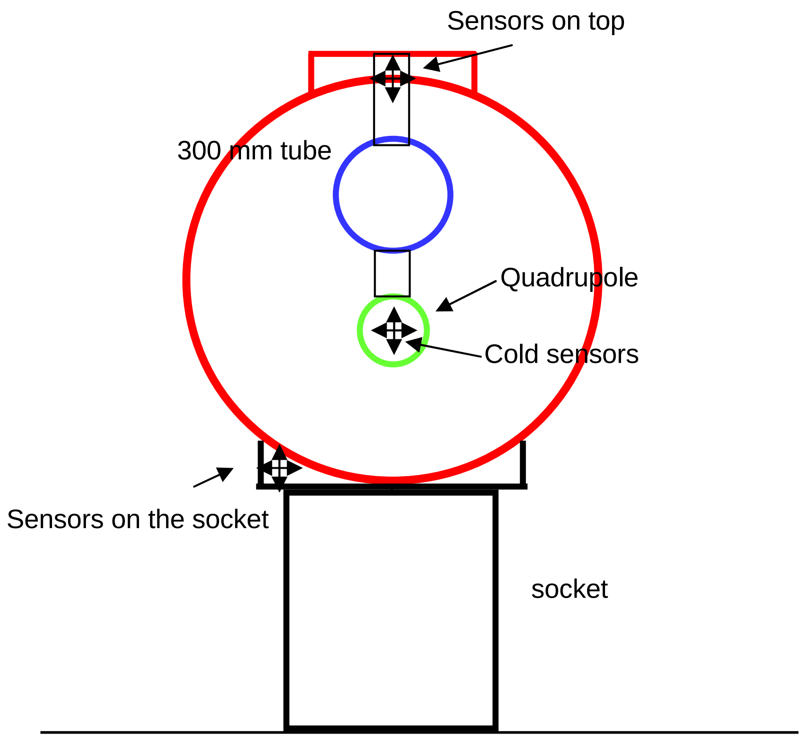


$t_0 = 40824230008$ $t_{M-1} = 40825010008$

Sensors:
Cold
Top
Socket

- Different days
  - Mon "without"
  - Tue "with"
- Horizontal vibrations much larger
- Cold Signal *3
- Some reduction below 25 Hz
- Large reduction between 25 and 50 Hz

Schematic View



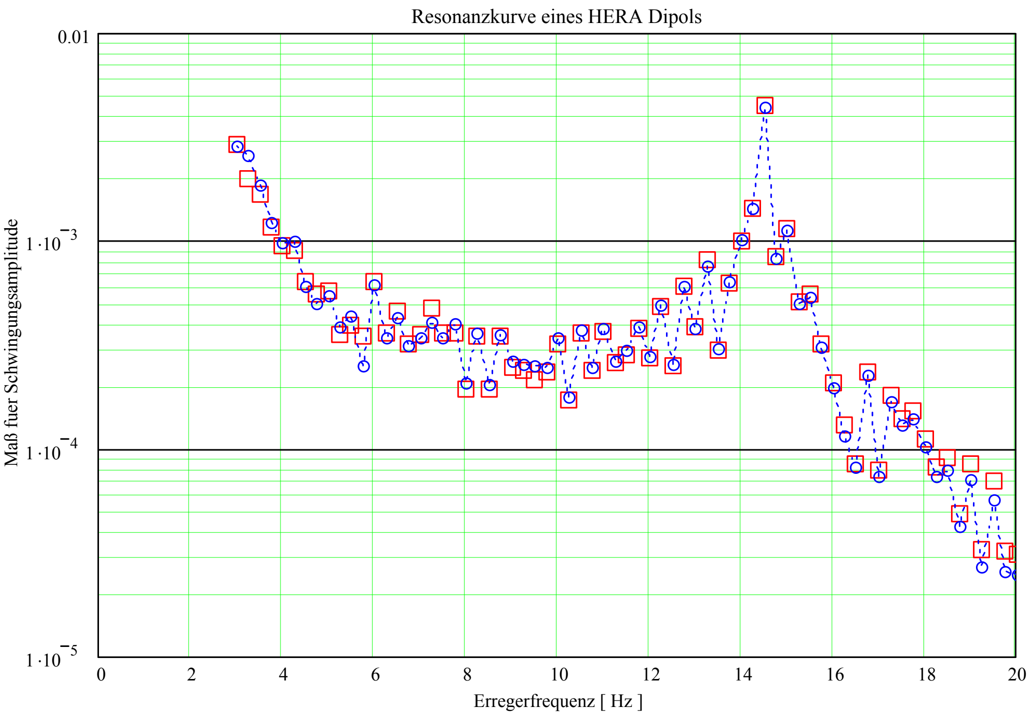
- The horizontal vibrations are larger (about factor 1.5)
- Cold mass essentially hanging
- Horizontal movements less constraint

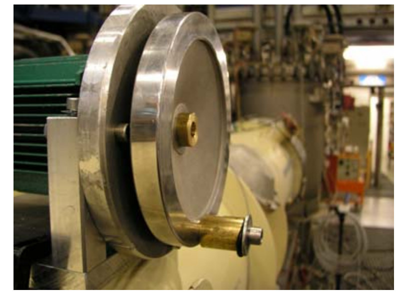
Present Summary

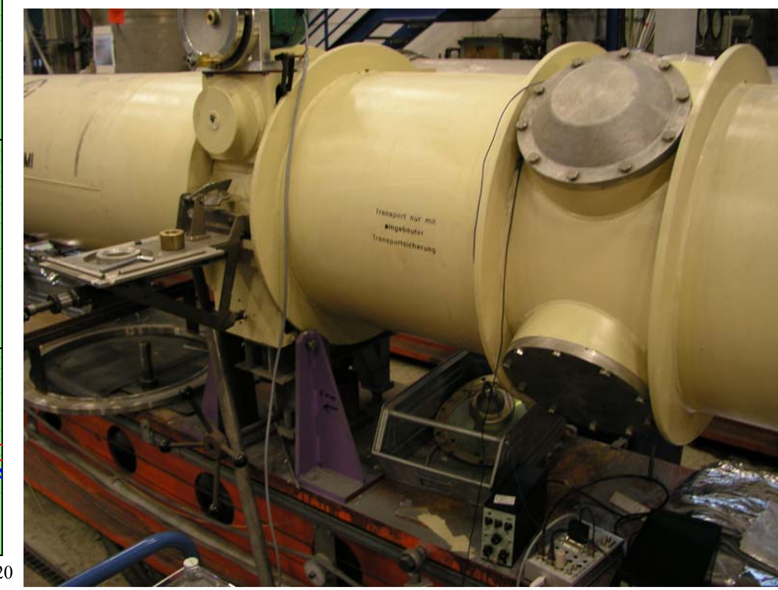
- Good agreement between the Geophone (our reference) and the Piezo in the frequency range from 2 to 100 Hz
  - at various positions
  - for averaged RMS and RMS vs. time
  - Cultural noise day/night/weekend
  - All in all data reliable
- Influence of vacuum pumps clearly seen
  - Effect vanishes after modifications
  - Pumps on/off not different anymore, which means turbo pump has no effect
- Next step
  - Analysis of data taken from forced vibrations using a motor with eccentric mass and tunable frequency
  - Analysis of data of pump stands optimizations

Forced Vibrations of a HERA Dipole Cryostat up to 20Hz

$$\text{Bint}(i1,i2,i3,di) := \frac{f0}{\left(MF_{i3}\right)^2} \cdot \left(\sum_{i = i1-di}^{i1+di} B(i,i2,i3) \right)$$



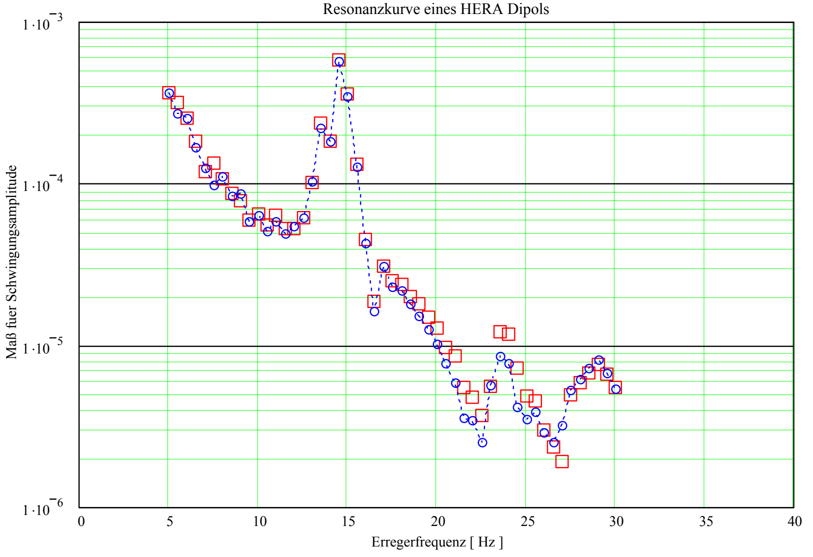




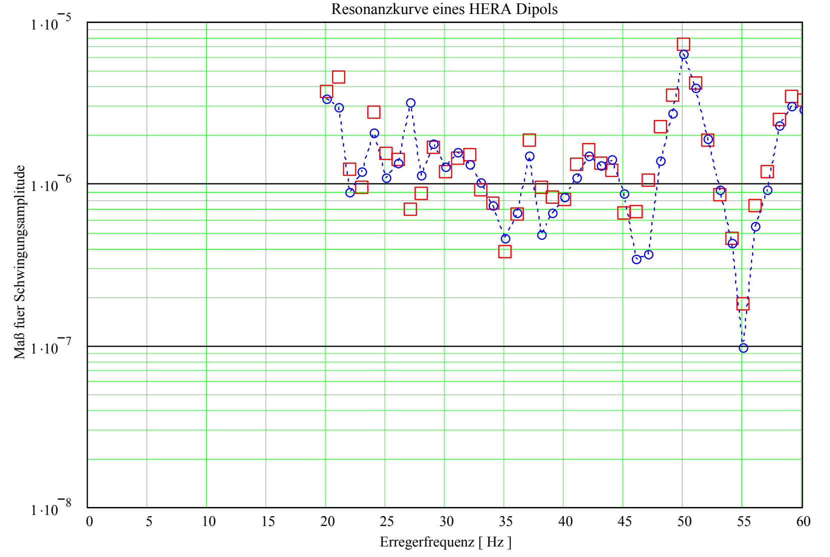
Strong resonance observed at about 14.5 Hz

Forced Vibration of a HERA Dipole Cryostat up to 60Hz

$$\mathrm{Bint}(i1, i2, i3, di) := \frac{f0}{\left(MF_{i3}\right)^2} \cdot \left(\sum_{i = i1-di}^{i1+di} B(i, i2, i3)\right)$$



$$\mathrm{Bint}(i1, i2, i3, di) := \frac{f0}{\left(MF_{i3}\right)^2} \cdot \left(\sum_{i = i1-di}^{i1+di} B(i, i2, i3)\right)$$



Different measurements with
decreasing eccenter mass

Forced Vibrations of a HERA Dipole Cryostat, RMS and Spectrum