Fast seismic motion at CERN and magnet dynamic stability issues

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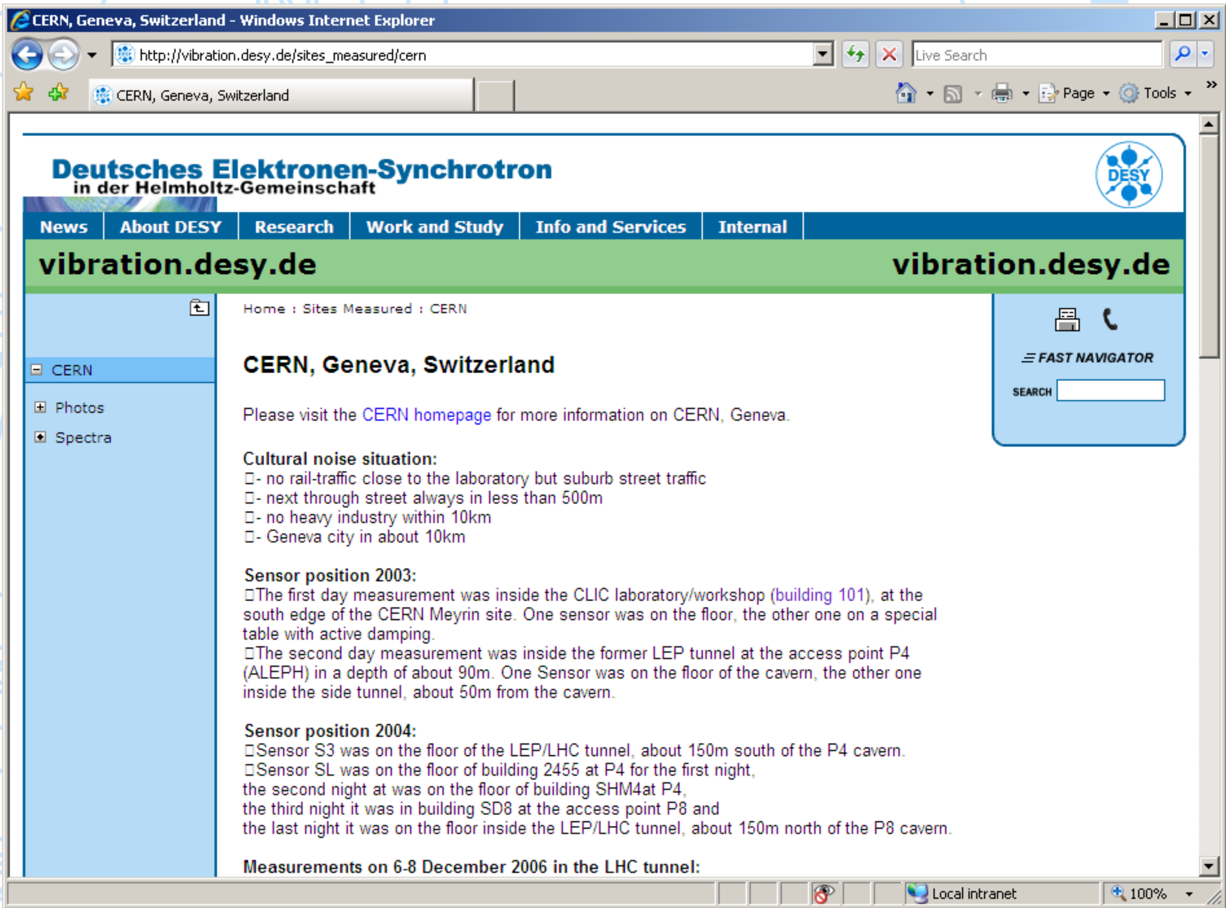
*CERN site visited by DESY team three times in the past:

2003 – W.Bialowons, H.Ehrlichmann

2004 – W.Bialowons, H.Ehrlichmann -> extended site investigation

2006 – R.Amirikas, A.Bertolini-> mechanical transfer function studies on LHC dipoles and low-ß quadrupoles


CERN, Geneva, Switzerland - Windows Internet Explorer

http://vibration.desy.de/sites_measured/cern

Deutsches Elektronen-Synchrotron
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CERN, Geneva, Switzerland

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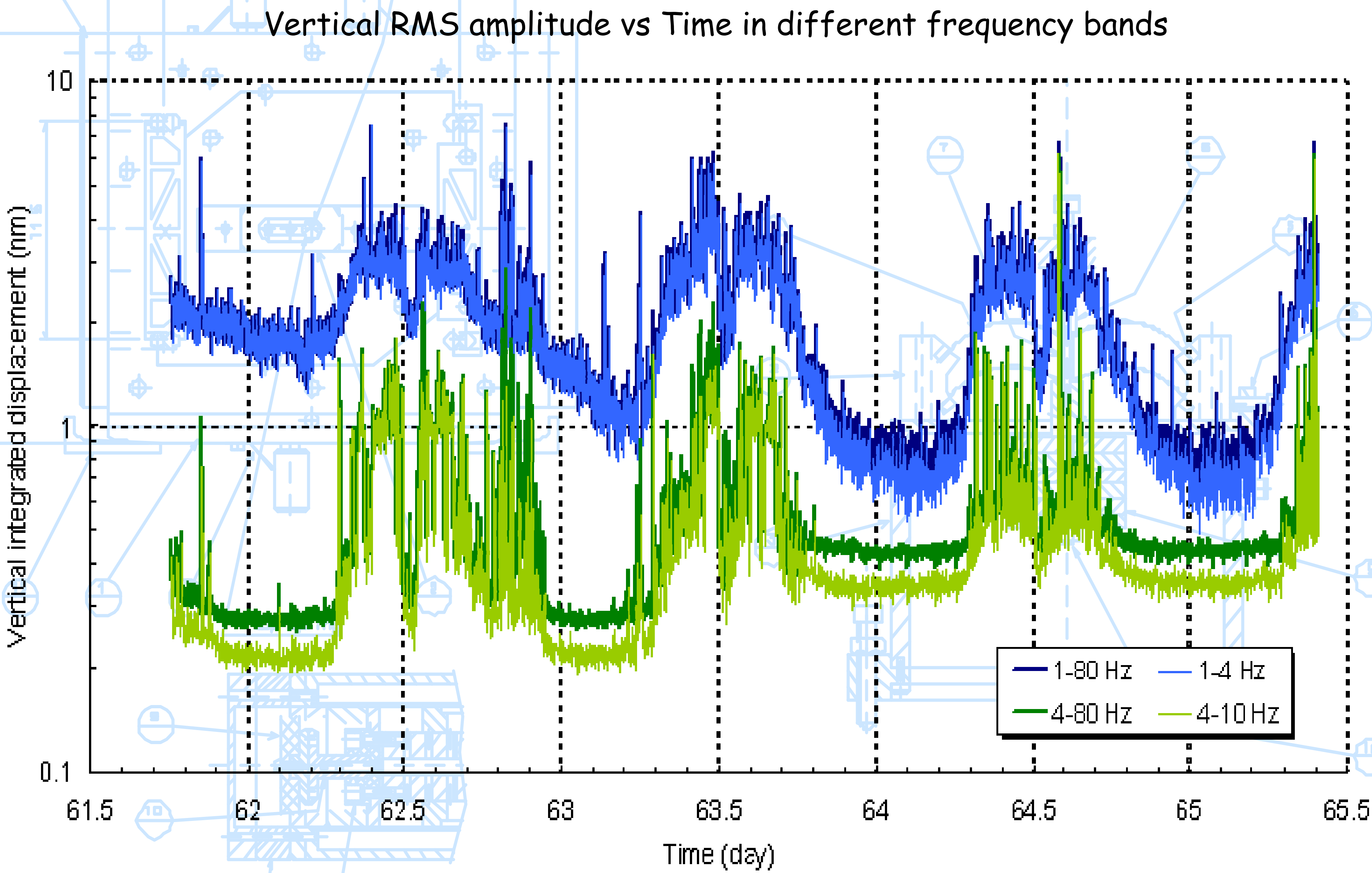
Cultural noise situation:
- no rail-traffic close to the laboratory but suburb street traffic
- next through street always in less than 500m
- no heavy industry within 10km
- Geneva city in about 10km

Sensor position 2003:
The first day measurement was inside the CLIC laboratory/workshop (building 101), at the south edge of the CERN Meyrin site. One sensor was on the floor, the other one on a special table with active damping.
The second day measurement was inside the former LEP tunnel at the access point P4 (ALEPH) in a depth of about 90m. One Sensor was on the floor of the cavern, the other one inside the side tunnel, about 50m from the cavern.

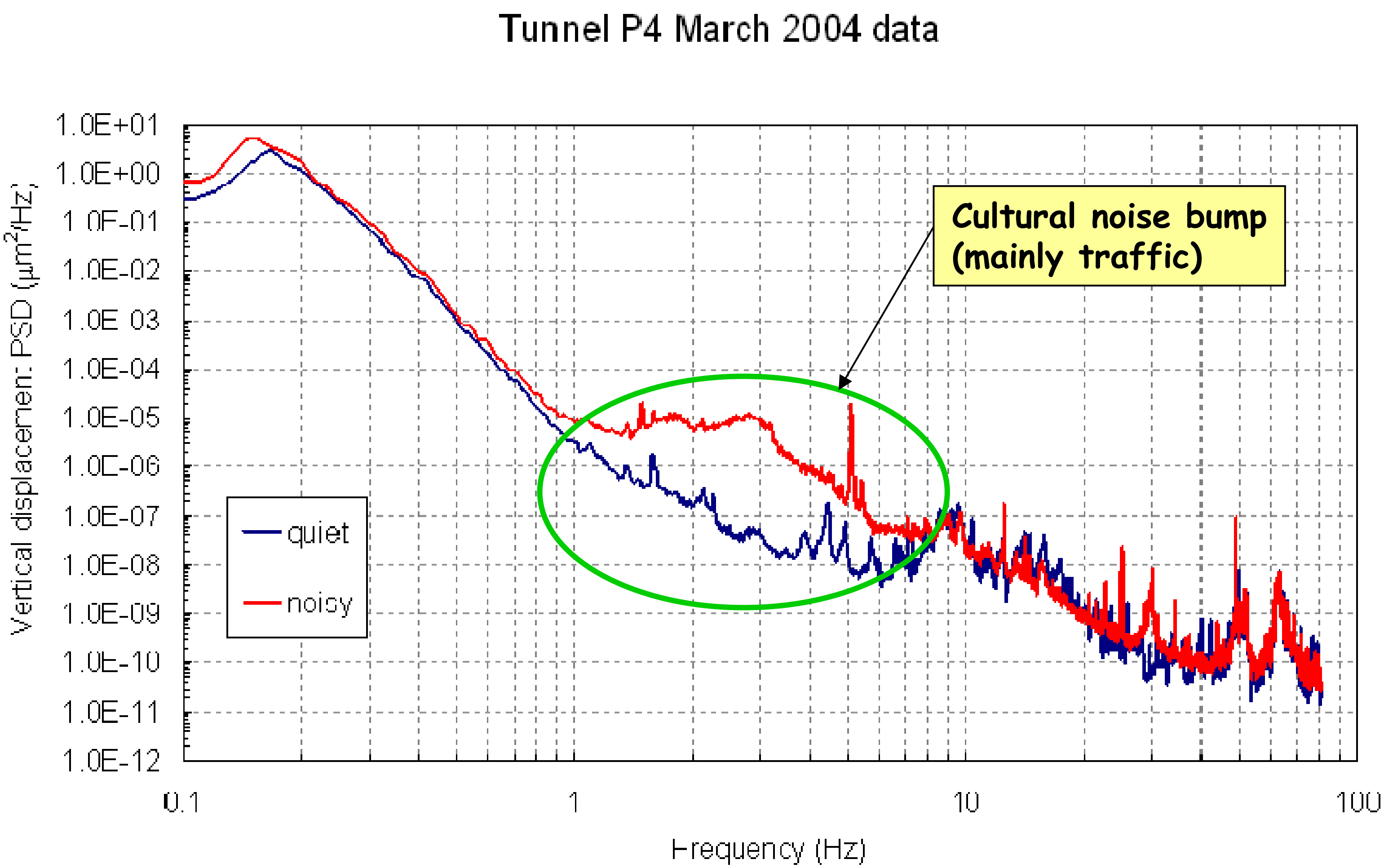
Sensor position 2004:
Sensor S3 was on the floor of the LEP/LHC tunnel, about 150m south of the P4 cavern.
Sensor SL was on the floor of building 2455 at P4 for the first night,
the second night at was on the floor of building SHM4at P4,
the third night it was in building SD8 at the access point P8 and
the last night it was on the floor inside the LEP/LHC tunnel, about 150m north of the P8 cavern.

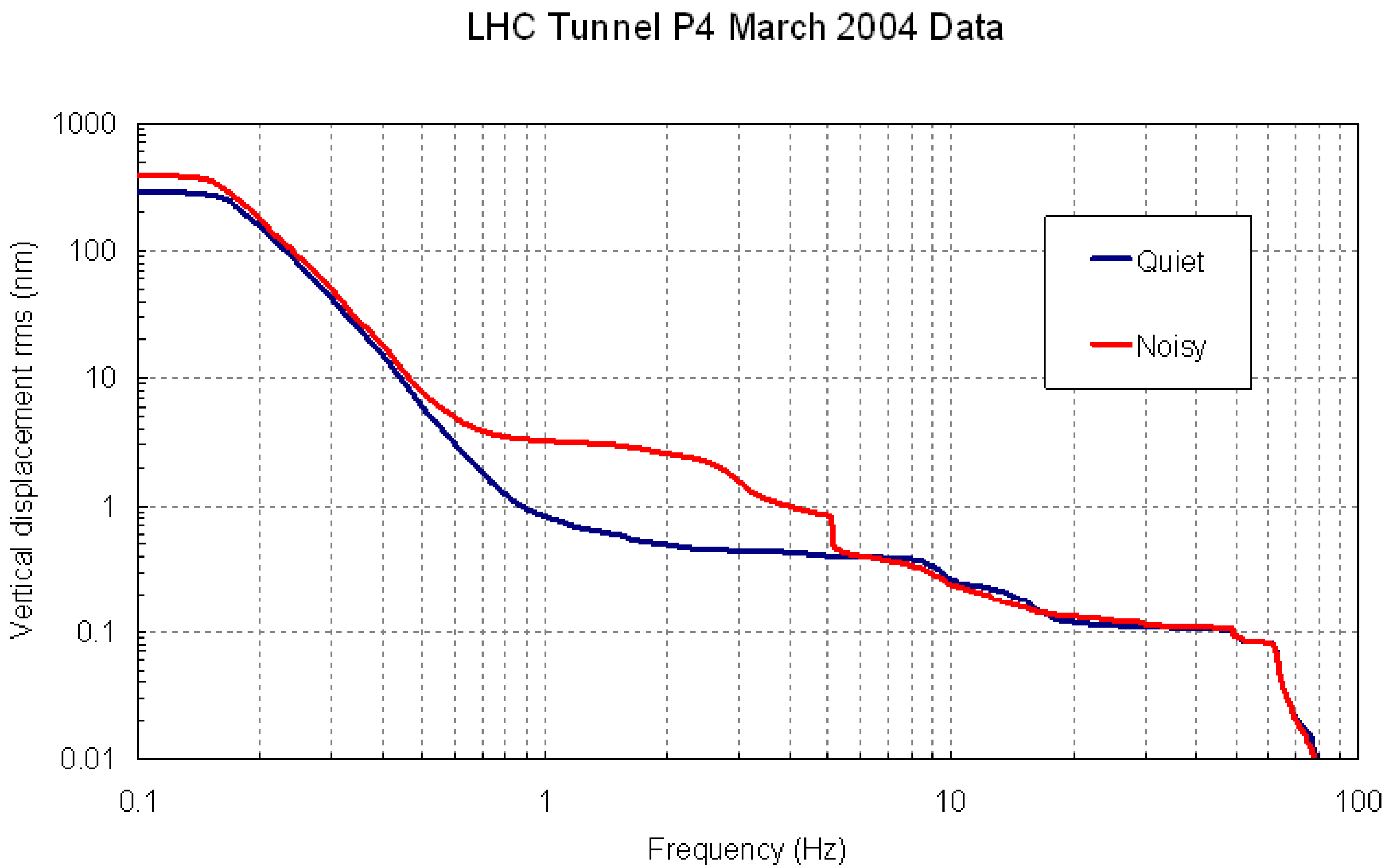
Measurements on 6-8 December 2006 in the LHC tunnel:

Local intranet 100%

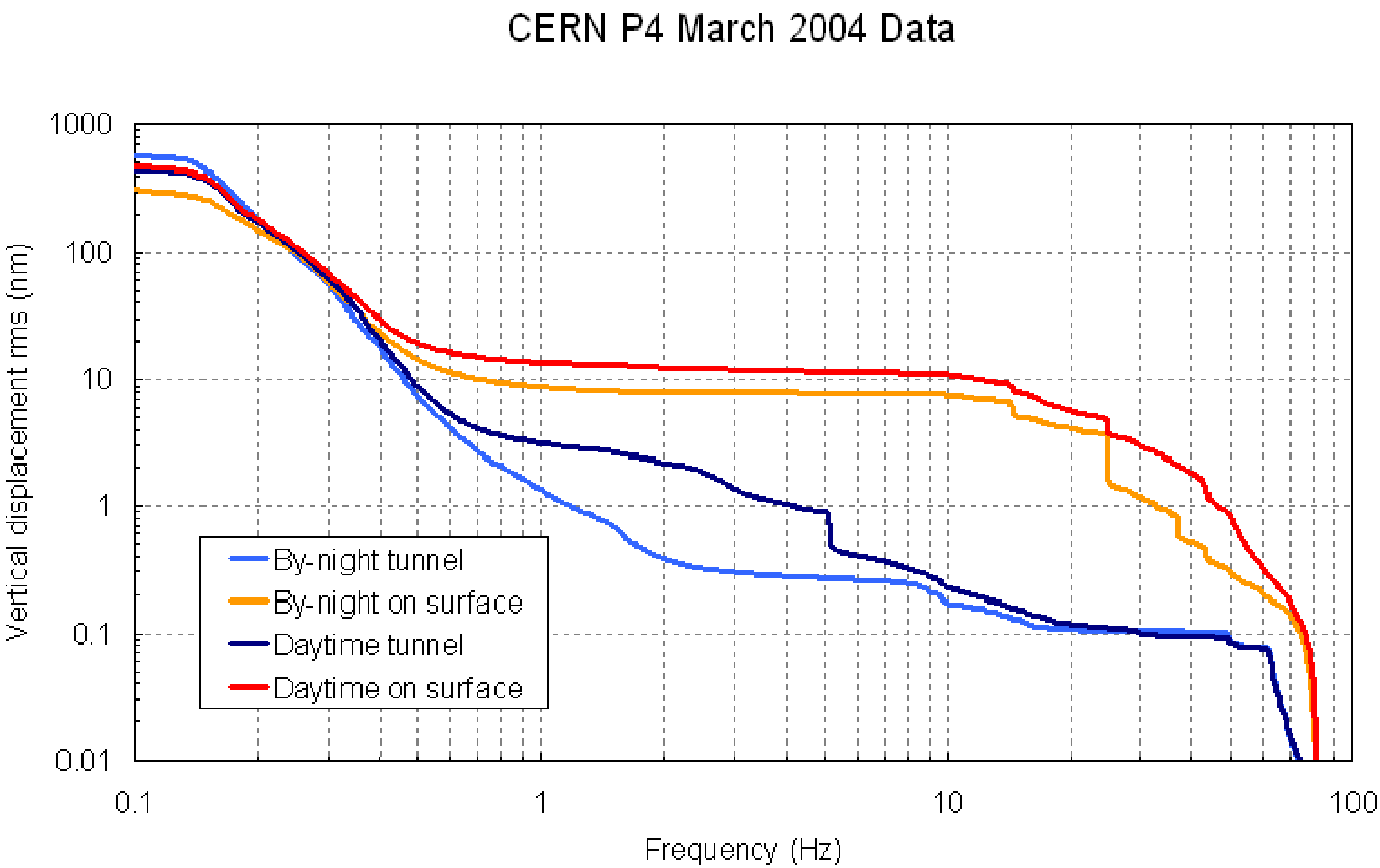


Vertical RMS amplitude vs Time in different frequency bands
10
1
0.1
Vertical integrated displacement (nm)
61.5
62
62.5
63
63.5
64
64.5
65
65.5
Time (day)
1-80 Hz
1-4 Hz
4-80 Hz
4-10 Hz


Tunnel P4 March 2004 data
Vertical displacement: PSD (µm²/Hz)
1.0E+01
1.0E+00
1.0E-01
1.0E-02
1.0E-03
1.0E-04
1.0E-05
1.0E-06
1.0E-07
1.0E-08
1.0E-09
1.0E-10
1.0E-11
1.0E-12
0.1
1
10
100
Frequency (Hz)
quiet
noisy
Cultural noise bump
(mainly traffic)



… the same but integrated



… typically the rms for f>4 Hz is 15-20 times lower in the tunnel, mostly due to a f> 10 Hz large difference (but also in the 4<f<10 Hz band there is a factor ~5).

<u>Comments:</u>

Fast motion (f>1 Hz) dominated by the `cultural` noise in the 1-4 Hz band with large day/night changes;

In the band (f> 4 Hz) very low noise levels measured:

- weekly average ~ 0.7 nm rms
- lower than 0.5 nm rms by night
- can rise up to 1 nm rms in the noisiest hrs of the day

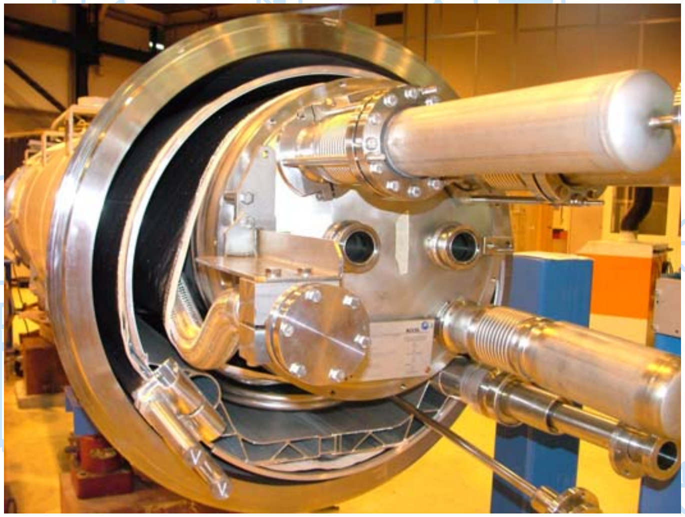
Noise on surface typically ~15-20 times larger

LHC standard cryodipole installed in the 3-4 arc section

Fiberglass cold mass supports

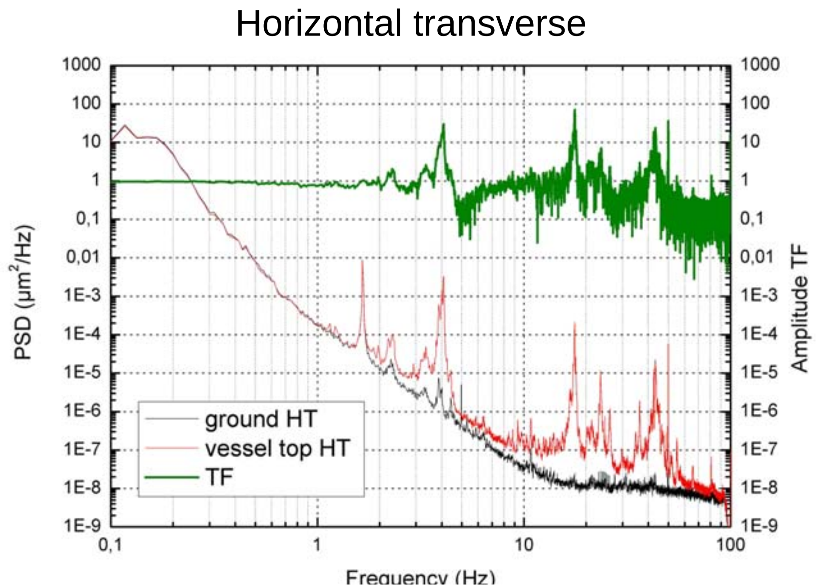
Length	17 m
Weight	32 tons
Cryostat diameter	~ 1 m
No.of jacks	3+1 at center for sagitta compensation
Cold mass support	3 fiberglass posts on the bottom

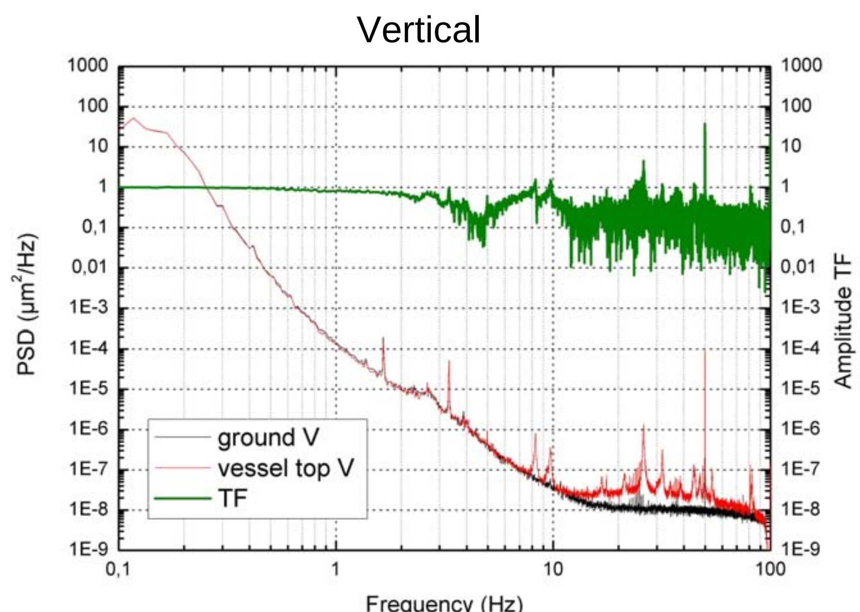
Characteristics of LHC standard dipoles



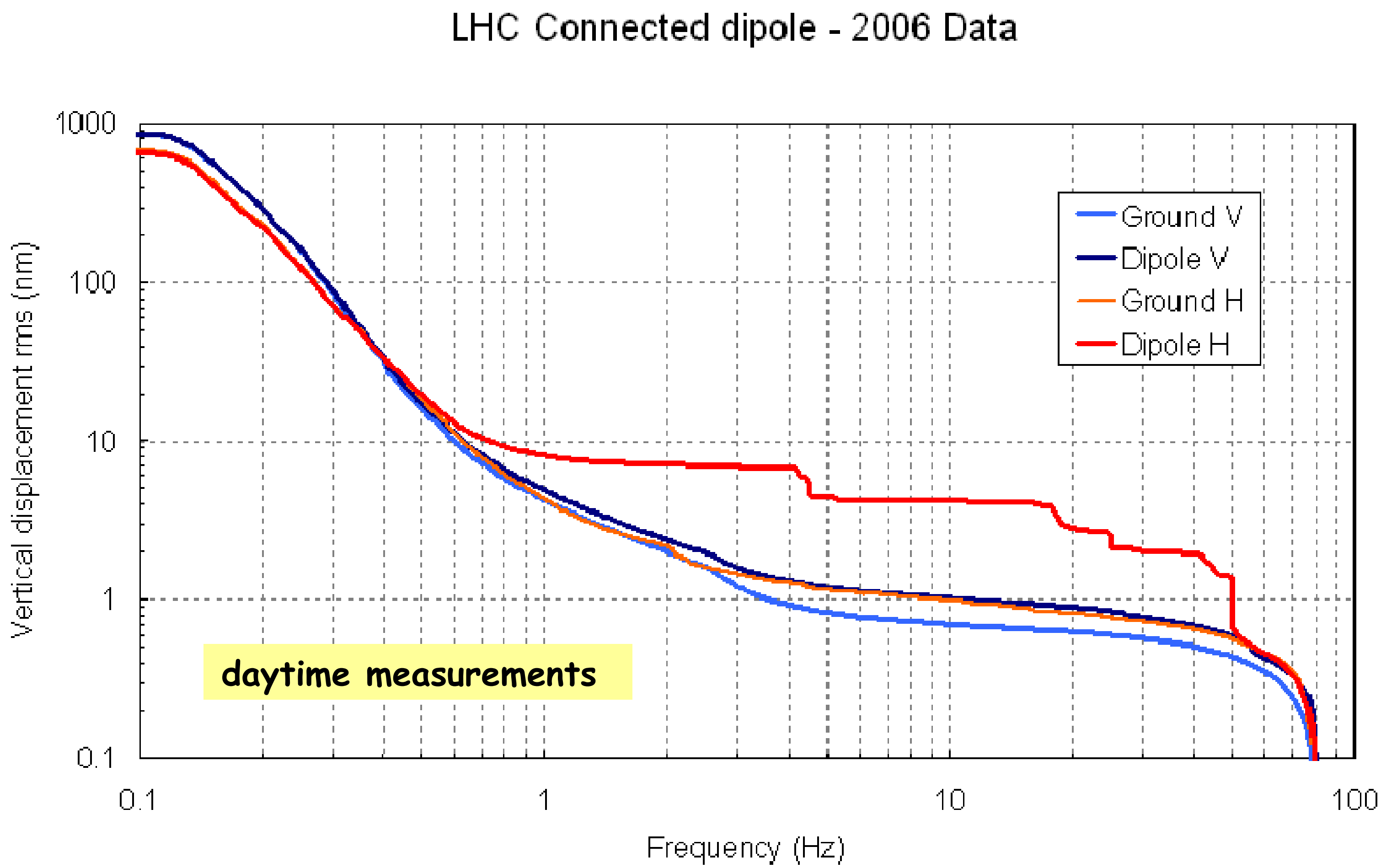
Cold mass view

Stand-alone configuration





- **Low frequency resonance at 4 Hz (Q~30) in the horizontal transverse direction. Other large amplitude modes at 17 and 42 Hz.**
- **Very rigid in vertical.**



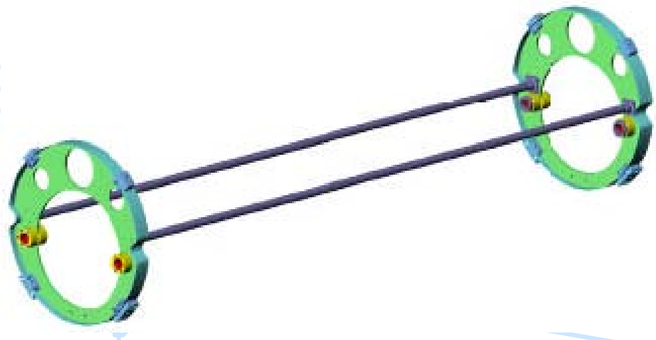
…frequency response almost identical to the stand alone case but with some damping of the resonances; very low amplitude vertical motion.

LHC low beta quadrupole next to ALICE Interaction region

View of the alignment jacks. Note the enlarged contact section and the extra layer of concrete.

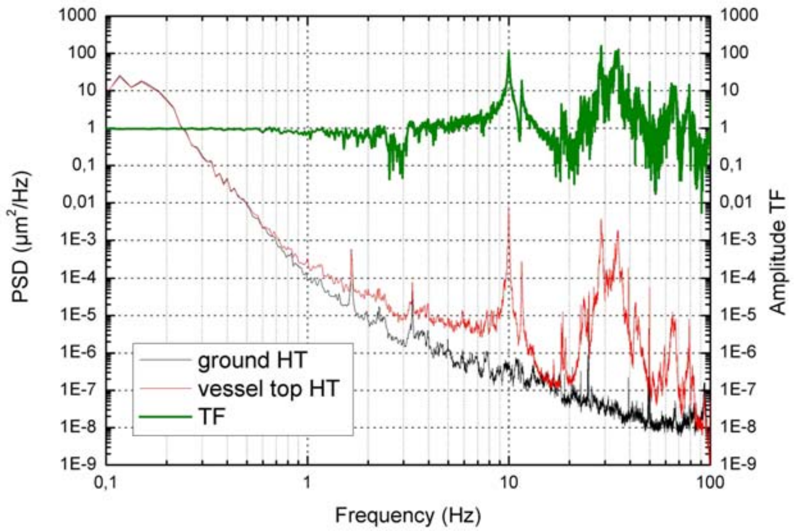
Length	~ 9 m
Weight	17 tons
Cryostat diameter	~ 1 m
No.of jacks	3 with enlarged footing section
Cold mass support	Full cross section collars

Characteristics of LHC low beta quadrupoles

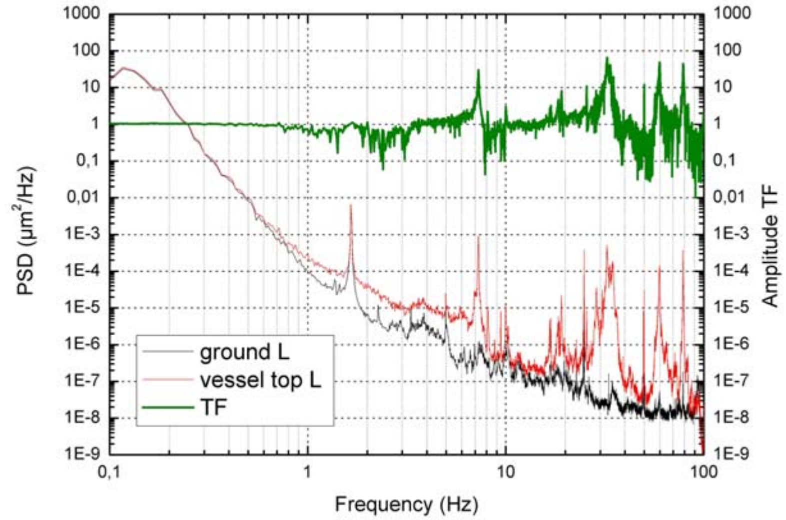


Composite spider-like cold mass support, designed for better rigidity.

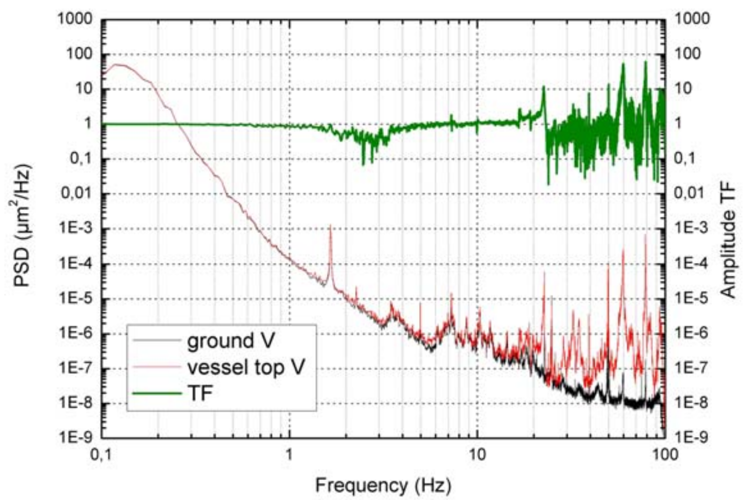
Ground to vessel top transfer function



Horizontal longitudinal

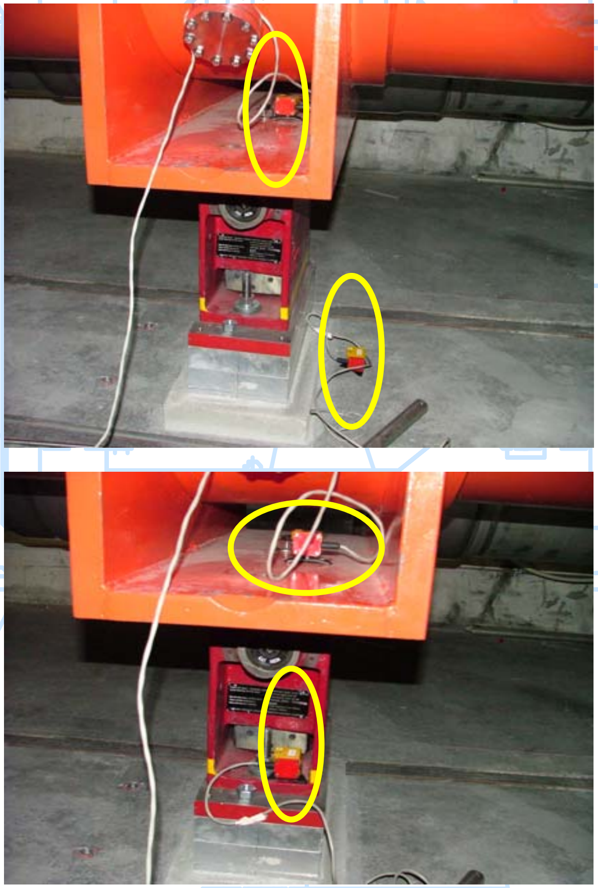


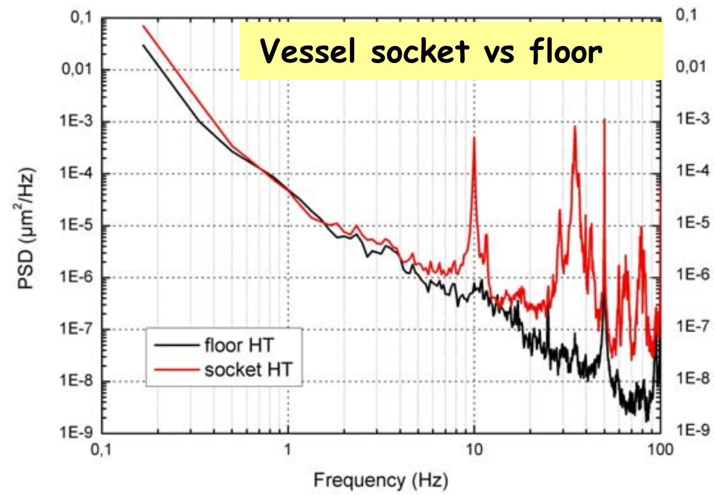
Vertical

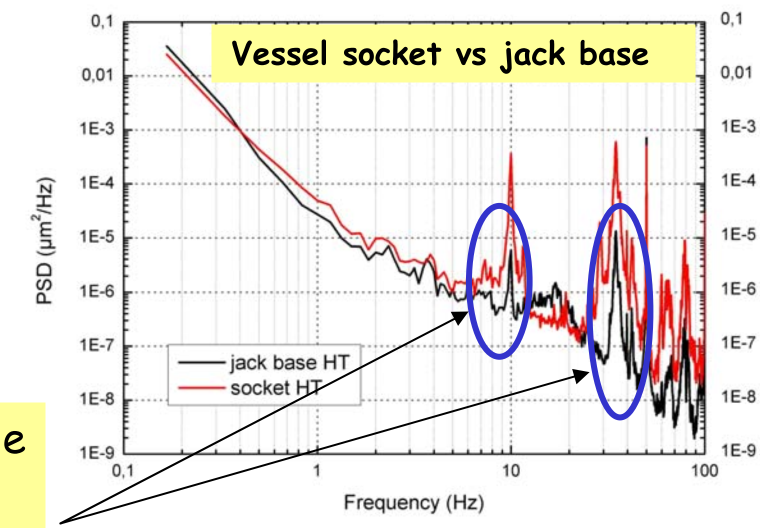


- **stiffer than dipoles along the transverse direction with the first mode at 10 Hz, but larger Q**
- **soft in the longitudinal axis with a 7.3 Hz mode**
- **rigid along the vertical direction**

Effect of the support foundation

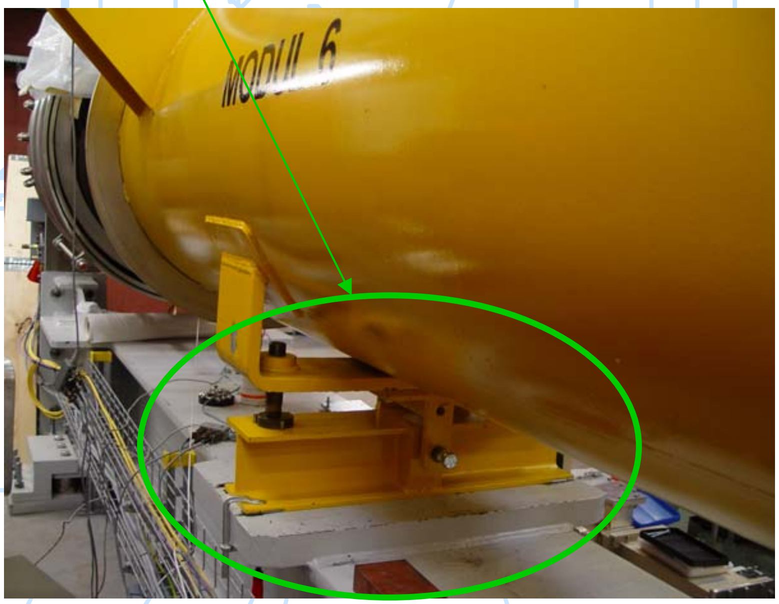


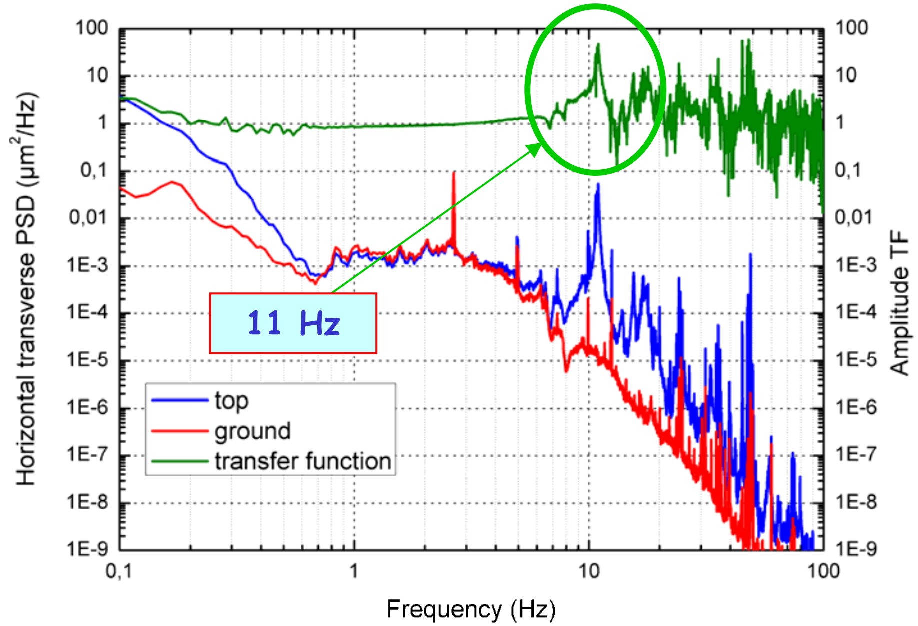




the transverse mode structure already visible at the interface between the jack and the concrete pad, but not in the floor: not structural resonances but rocking modes

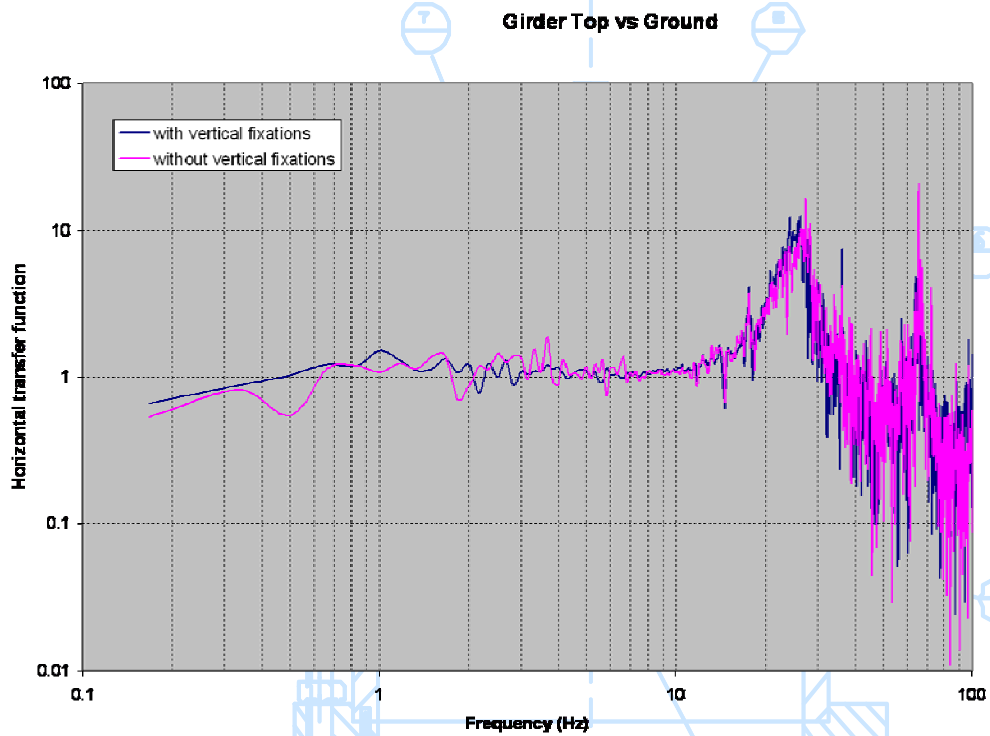
The 8-tons module sits on 4 leveling feet (two on each side); the interface feet/girder is a simple steel crossbar welded on top of the girder





The horizontal-transverse dynamics is dominated by a ~11 Hz resonance corresponding to the rocking of the cryostat around the contact surface between girder and crossbar. This mode causes large amplitude (200-300 nm rms) vibrations of the superconducting quad and cavities hosted in the module.
Depending of the degree of asymmetry also pitch modes (with coupling along the vertical direction) can be observed in some of the modules in the FLASH linac.

FEM model predicts ~ 65 Hz for the first structural resonance (horizontal transverse)…

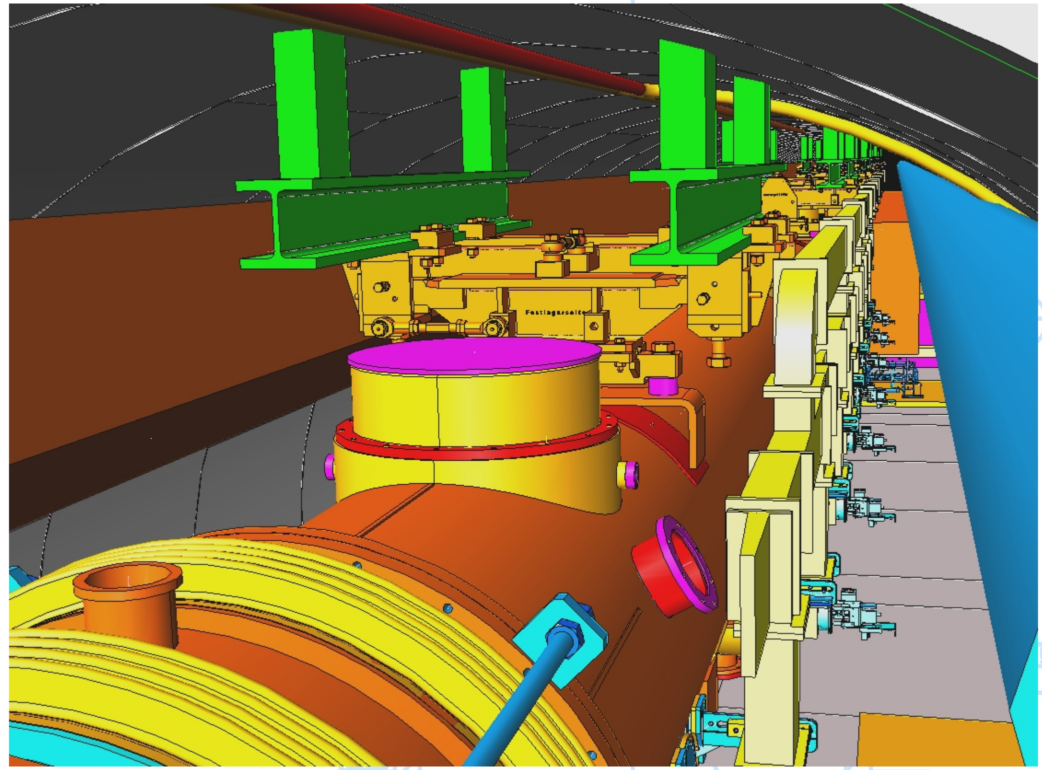


The measured TF on the prototype showed the first one at ~27 Hz !!

Again a rocking mode…they appear to be the dynamic stability limiting factor in many multi-ton installations…

The XFEL main linac will be a `hanging` machine to save space in the 1.4 km long single tunnel.

Cross section view of the XFEL tunnel

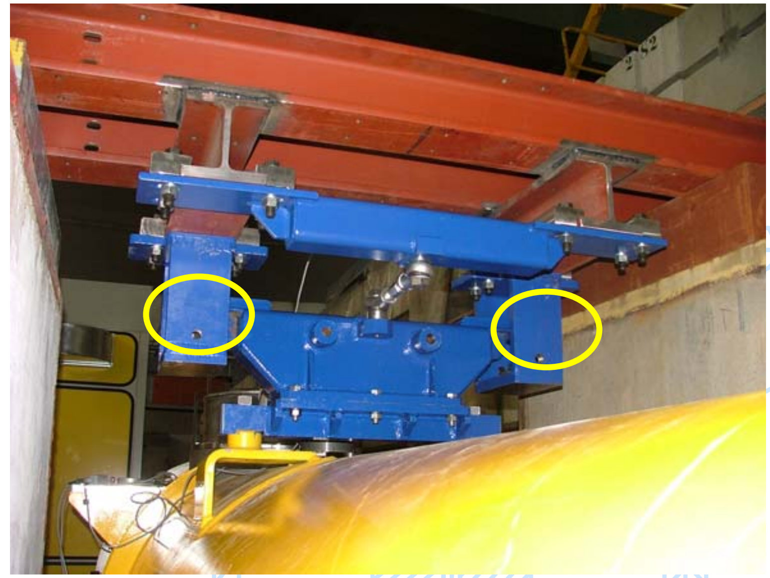


The tubes support the rails will be welded to steel plates embedded in the ceiling concrete

The alignment system has already proven a very good dynamic stability…

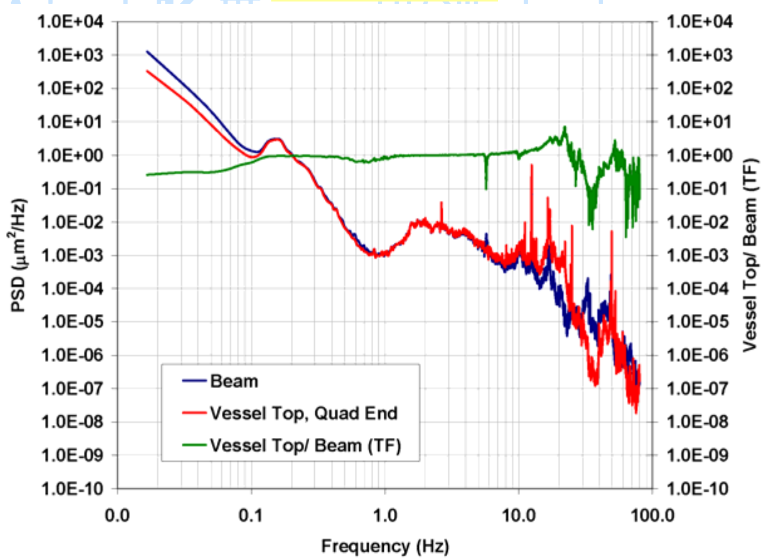
Alignment system test stand – November 2006

The two components of the alignment system

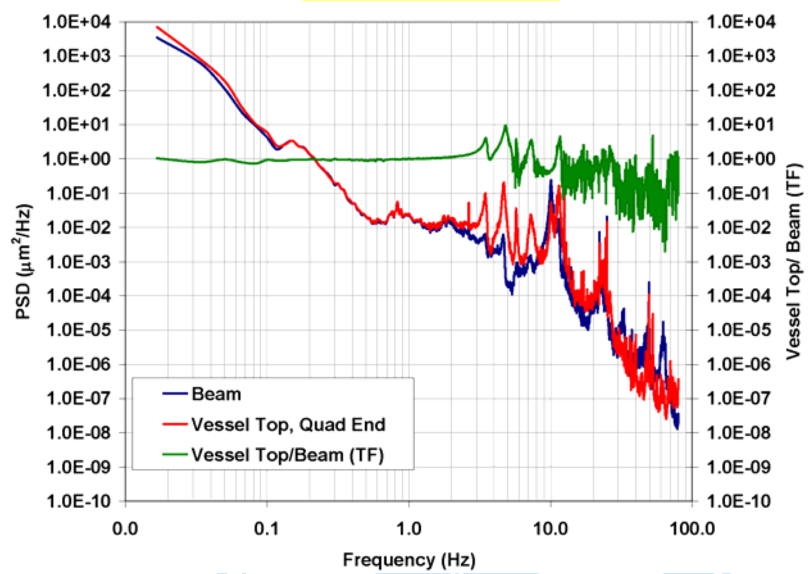


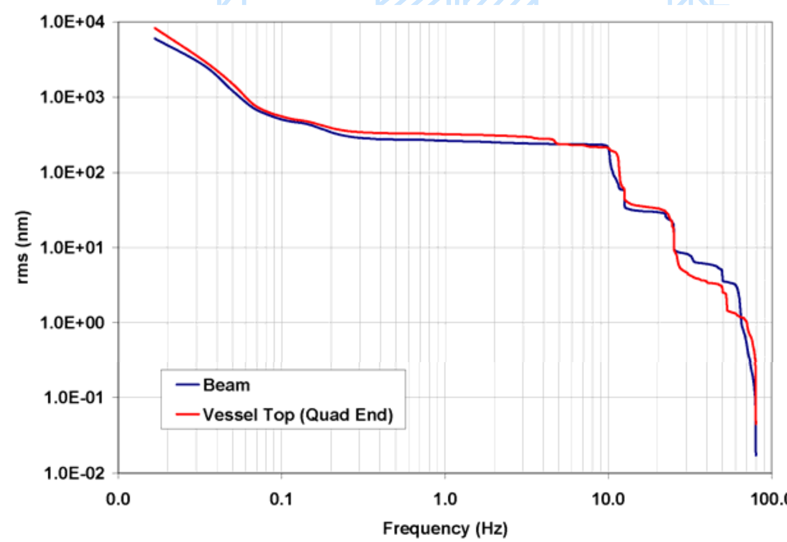
Design idea: the module is standing on three levelling bolts (positioned at the yellow circles in the photos); the weight is supported by the large cross section crossbars

Vertical TF



Horizontal TF



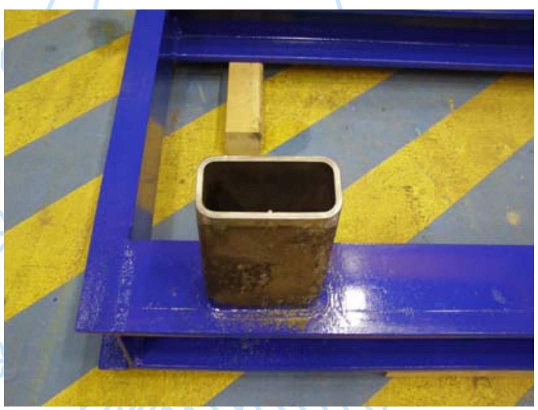


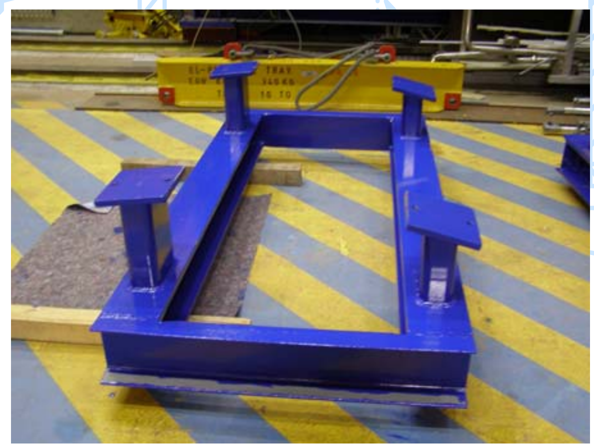
General comment

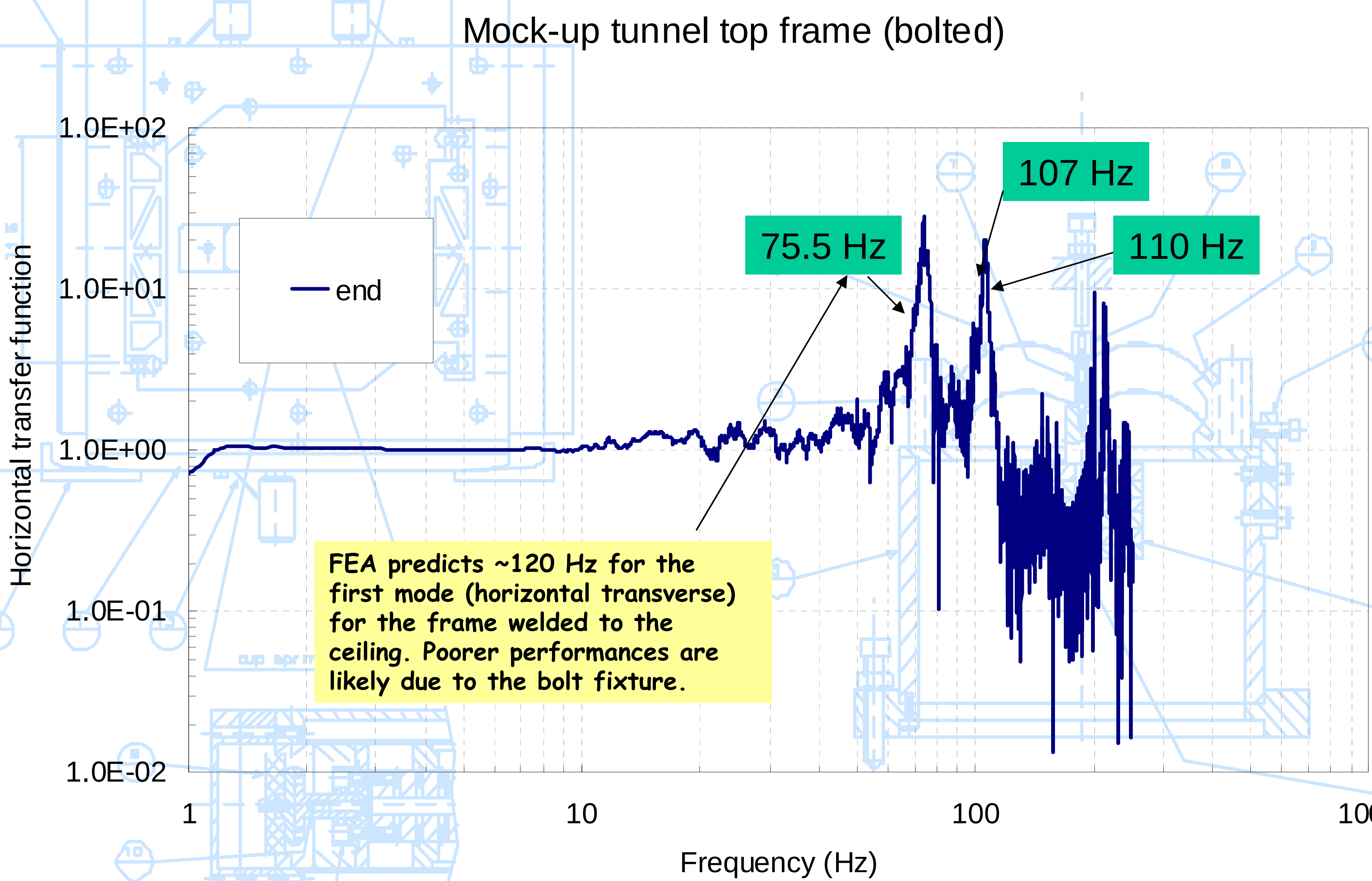
Same effect from the test stand but no evidence for low frequency internal resonances up to 100 Hz. (The wiggles in the horizontal TF are due to the test stand).

Horizontal transverse/Vertical: very well decoupled.

Test of the complete system in the XFEL mock-up tunnel – started December 2007







Mock-up tunnel top frame (bolted)
1.0E+02
1.0E+01
1.0E+00
1.0E-01
1.0E-02
Horizontal transfer function
1
10
100
1000
Frequency (Hz)
end
75.5 Hz
107 Hz
110 Hz
FEA predicts ~120 Hz for the first mode (horizontal transverse) for the frame welded to the ceiling. Poorer performances are likely due to the bolt fixture.

Coming next: transfer function measurements from ceiling to a dummy cryomodule (beginning of April)

Thanks !!!