Preliminary ground motion measurements at LNF site for the Super B project

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Introduction

- ✓ Super B project: vertical beam size of 35nm
  - ➢ Mechanical relative stabilization of magnets probably needed (specifications not yet established)

- ✓ Ground Motion (GM): vibration source of magnet excitation
  - ➢ Need to be measured for Super B site characterisation

- ✓ Virgo team: preliminary GM measurements performed at one location at LNF

- ✓ LAPP: more detailed preliminary measurements done from 14 October to 16 October 2009
  - ➢ Give a first characterisation of LNF site
  - ➢ Allow determining future measurements to perform

Plan of my presentation

1. **Set-up**
   - location of measurements
   - instrumentation used
   - data analysis

2. **Evolution of the amplitude of ground motion with time**
   - measurements of vertical ground motion during 18 hours

3. **Comparison of ground motion amplitude for different locations**
   - on surface at different points (different sources of vibrations)
   - on surface and in underground (50m)

4. **Ground motion coherence at two locations (rigid/soft floor)**

5. **Summary**

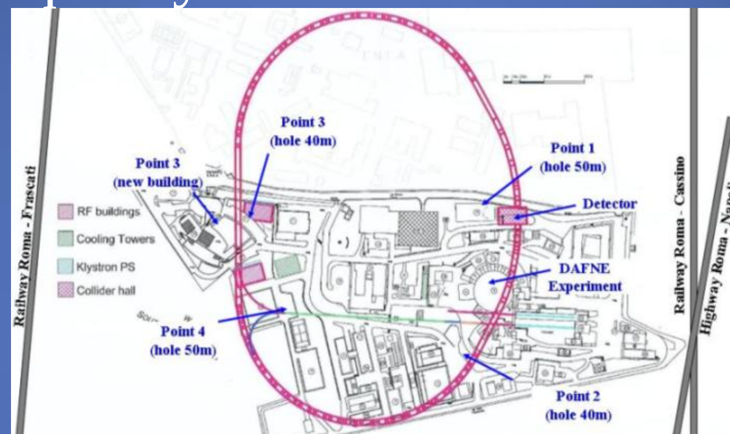
6. **Conclusion and future prospects**

1. Set-up

- location of measurements
- instrumentation used
- data analysis

Location of measurements

- ✓ **Measurements done at different locations of the LNF site**
  - ➢ influence of various vibrations sources (traffic, railway, track…)
  - ➢ influence of the quality of the concrete



- ✓ **Point 1:** location of the future detector (near a main road where there is much traffic and near a power plant)
  - ➢ measurements done simultaneously on the surface and inside a 50m depth hole

vertical GM measured

GM measured in the 3 axis

Location of measurements

✓ **Point 2:** near the DAFNE damping ring and the main pumping station of the DAFNE cooling plant

- ➢ Original plan: simultaneous measurements at the surface and in a dedicated hole (40m depth) but too much water found in the hole
  - ➔ Only surface measurements in the 3 axes

✓ **Point 3:** near a main road as point 1

- ➢ coherence measured on two floors close to each other: on the parking (soft floor) and in the new guest house basement (concrete)
- ➢ ground motion measured during 18 hours in this basement

✓ **N.B. 1:** no measurements done in the holes at points 3, 4 (3: blocked by a stone, 4: filled with water)

✓ **N.B. 2:** all points not far from the high way (Roma-Napoli) and the rail-way track (Roma-Napoli)

Instrumentation used

✓ In order to measure vertical GM from 0.1Hz to 100Hz (horizontal GM: 0.1Hz-50Hz), 2 types of vibration sensors were needed:

Sensor type	Model	Company	Sensitivity	Range [Hz]	Direction
Geophone	CMG-40T	Guralp systems	1600V/m/s	[0.03; 50]	3 axes
Accelerometer	Endevco 86	Endevco	10V/g	[0.01; 100]	vertical

✓ In fact, because of Signal to Noise Ratio, GM can be measured:

- ➢ with geophones: from about 0.1-0.2Hz to 50Hz (depending on the site)
- ➢ with accelerometers: from few Hz (1Hz: ATF / 10Hz: LAPP) to 100Hz

✓ Acquisition system: PULSE from Brüel & Kjaer (amplifiers included)

✓ Noise of the measurement chain, including PULSE, Guralp used from 0.2Hz to 50Hz and Endevco used from 50 to 100Hz, measured at LAPP:

Bandwidth [Hz]	[0.2;100]	[1;100]	[2; 100]	[4; 100]	[10; 100]	[50; 100]	[0.2; 1]
Int.RMS noise [nm]	10.5	0.42	0.12	0.06	0.05	0.03	10.5

- ➢ allow very accurate measurements of GM even for a quiet site
- ➢ noise plotted in each plot where PSDs and integrated RMS shown

Data analysis

- ✓ **FFT parameters used for the analysis of 18 hours measurements:**
  - ➢ Window: Hanning
  - ➢ Frequency resolution: 0.016Hz
  - ➢ **Time resolution: 20 min (54 spectra averaged for 20min each➔ 18 hours)**
  - ➢ **Spectra average: 55 (data set of 64 s),** exponential (2τ:1195s), 66.67% overlap

- ✓ **FFT parameters used for the other measurements:**
  - ➢ Window: Hanning
  - ➢ Frequency resolution: 0.016Hz
  - ➢ **Average : 50 (data set of 64 s),** exponential (2τ:1195s), 66.67% overlap
  - ➢ **Measurement time: 20 minutes**

➔ Average of the amplitude of GM (single event noise smoothed out)

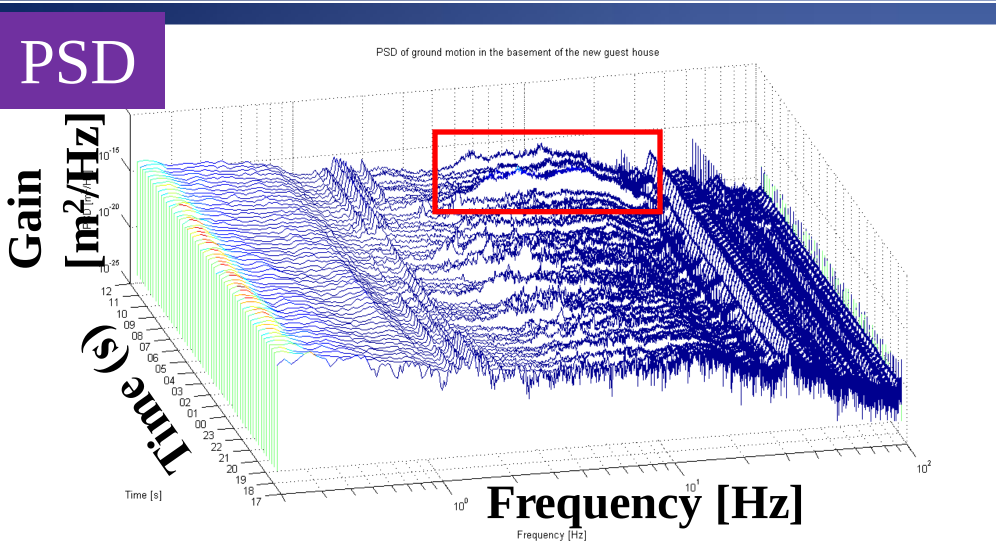
➔ Accurate measurements of transfer function and coherence

- ✓ GM measured in various sites in the world by Desy team
  - ➢ PSDs also measured during 60s and averaged for 15 min or longer
    - ➢ **Almost same analysis: amplitude of GM measured at NFL by us can be compared to the ones of various sites in the world**

2. Evolution of the amplitude of vertical ground motion with time:

Measurements from 15th October at 17h40 to 16th October at 11h40 in the basement of the new guest house (point 3) for its rigid floor

PSD of ground motion versus time and frequency

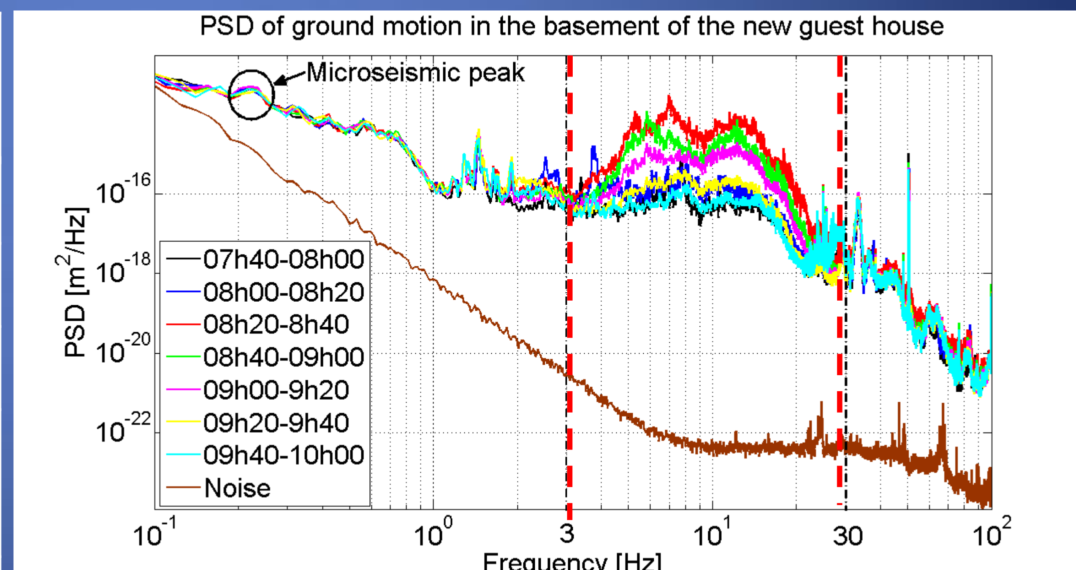


Quite same spectra with time except **for one area**

from 8h to 9h40: high increase of amplitude in the range **[3; 30]Hz**

➔ **correspond exactly to traffic**

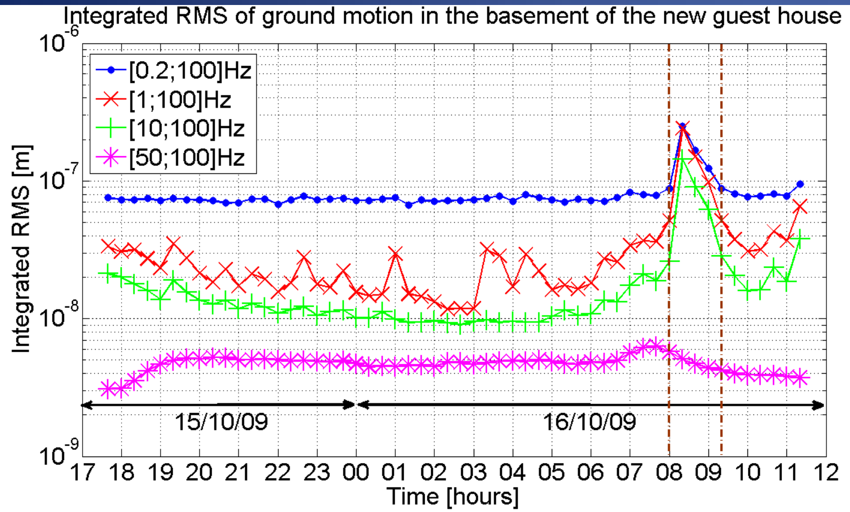
Time area of the increase	Peak observed in the range [3; 30]Hz
7h40-8h00	no peak
8h00-8h20	low level
8h20-8h40	highest level
8h40-9h40 (step: 20 min)	decrease of level step by step
9h40-10h00	no (same spectra as for 7h40-8h00)

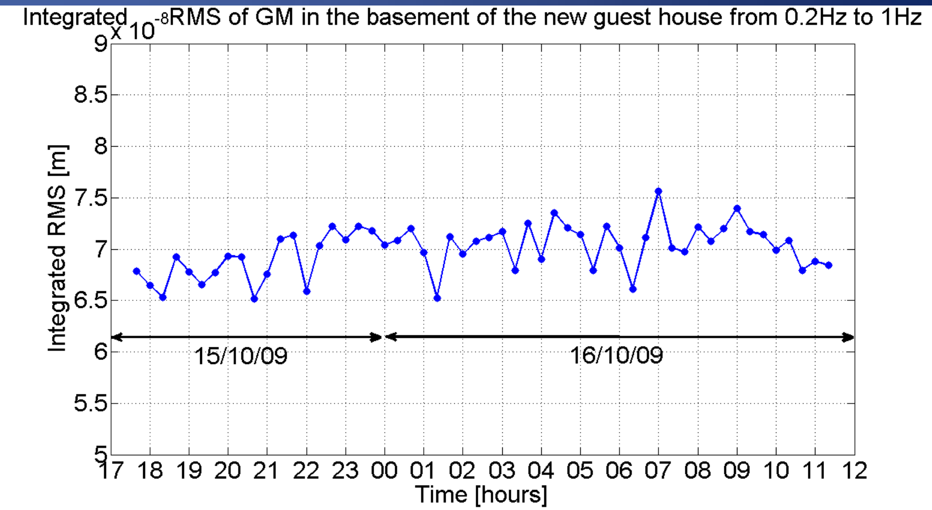


Microsismic peak (waves of ocean)

Cultural noise (human activities)

Integrated RMS of ground motion versus time





Range [Hz]	17h40-08h	08h-09h40	09h40-11h40
[0.2; 1]	vary from 65 to 76nm (low but may be higher for longer time: micro peak)		
[1; 100]	vary from 12nm to 35nm (lowest values the night due to reduced human activities)	8h->8h20->9h40: 51nm->240nm->51nm **High increase up to 240nm due to traffic**	increase from 38nm to 65nm (increase due to the beginning of activities the day)
[50; 100]	Slow variation from 3nm to 6nm (frequency range not subjected to traffic)		
Total: [0.2; 100]	vary from 67nm to 83nm	8h->8h20->9h40: 89nm->250nm->88nm	increase from 81nm to 94nm

3. Comparison of the amplitude of ground motion for different locations

- on surface at different points (different sources of vibrations)
- on surface and in underground (50m)

On surface at different pts (various vibration sources)

✓ Ground motion measured on surface at point 1 (1st location) the 14th October 09 and at point 2 (2nd location) and point 3 the 15th October 09

✓ For pt 1 and pt 2: measurements performed simultaneously in the 3 directions of space (2 horizontal: up to 50Hz, 1 vertical: up to 100Hz)

➢ Comparison of GM between vertical and horizontal axis possible (N.B: N/S and E/W sensor axes not oriented in the real cardinal points)

✓ For pt 3: measurements in the vertical direction on the parking (3rd location) and on the basement of the new guest house (4th location)

✓ Since it was shown that GM amplitude was quite the same the day during non rush hours although the site was located near a main road

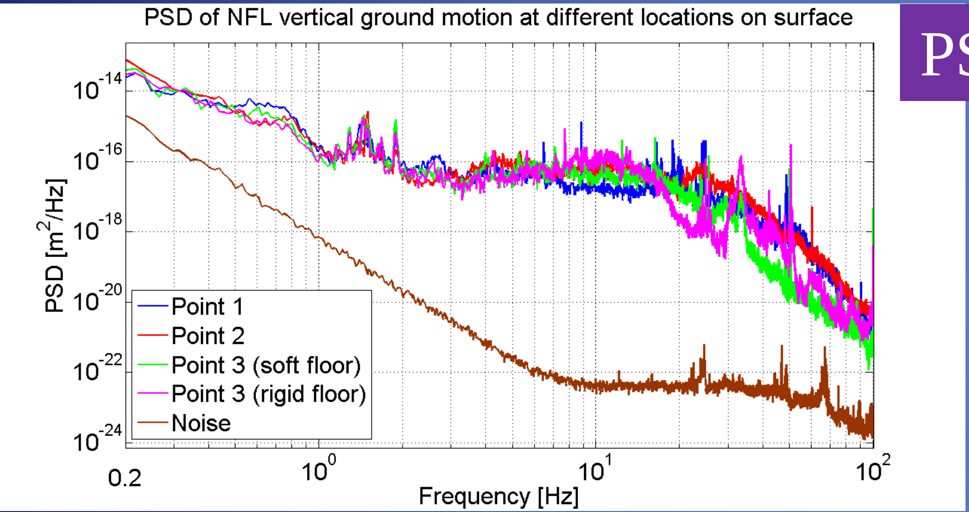
➔ results shown from measurements done during this period for good comparison between the 4 different locations in the vertical axis

➔ at 17h30, at 10h45, at 13h and at 16h for the 1st, 2nd, 3rd and 4th location respectively

On surface at different pts (various vibration sources)

Comparison of vertical GM for different locations

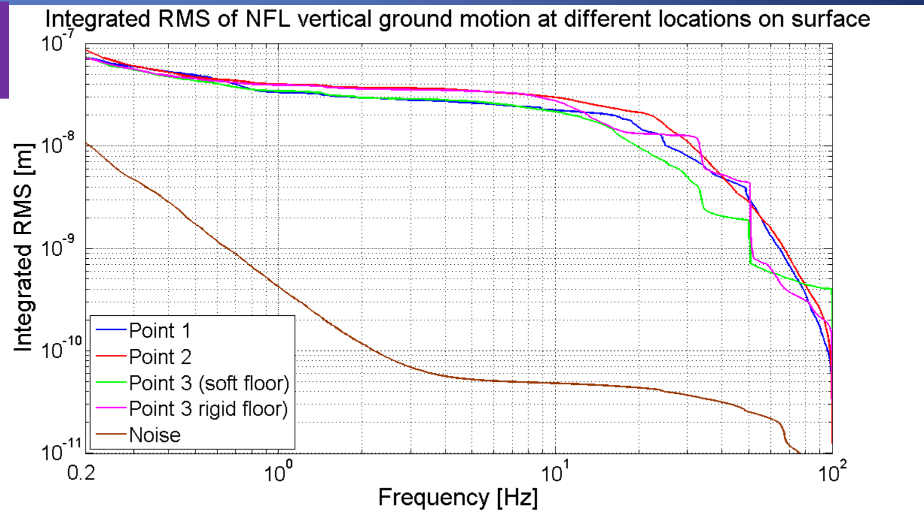
✓ Results shown above 0.2Hz, frequency from where data are reliable (high signal to noise ratio)



PSD

➢ Distribution of motion versus frequency quite the same for the four locations

Integrated RMS



➢ Amplitude almost the same for the four locations

- ➔ [0.2;100]Hz: ~70-80nm
- ➔ [1;100]Hz: ~30-35nm

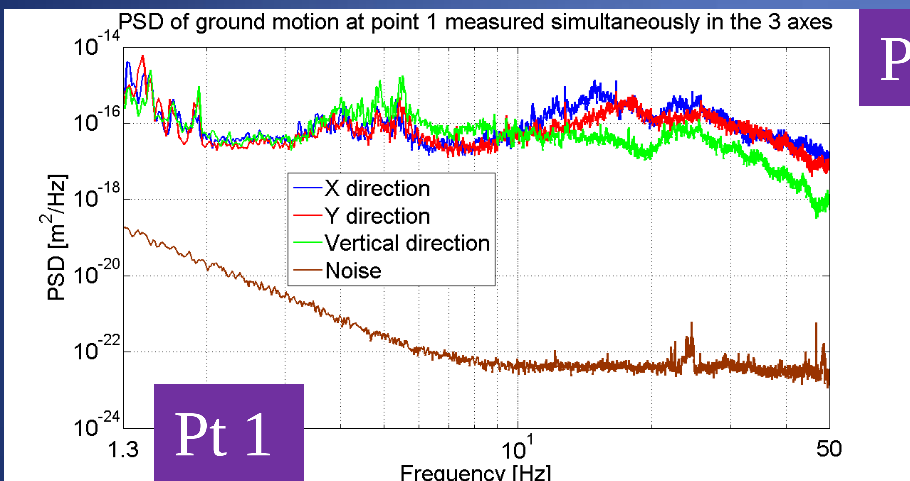
On surface at different pts (various vibration sources)

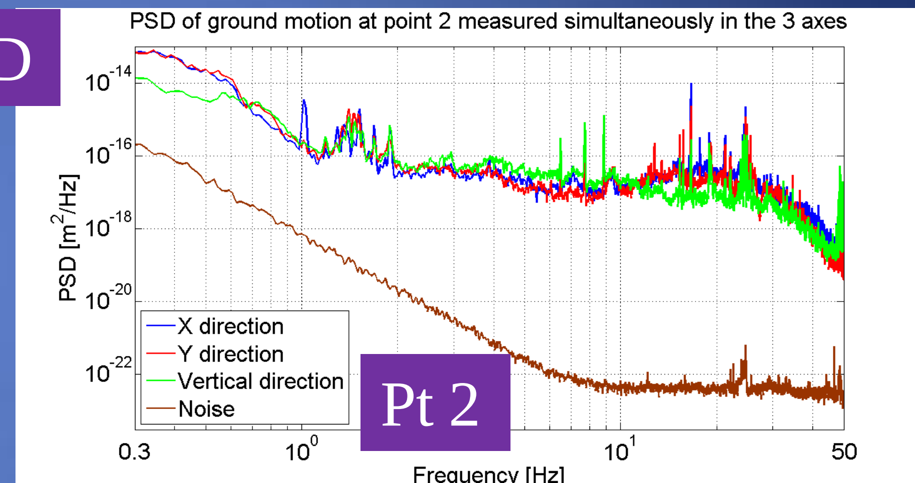
Comparison of GM between vertical / horizontal axes

✓ Pt 1 (16h45): results shown > 1.3Hz (problem with 1 of Guralp below)

✓ Pt 2 (11h30): results shown > 0.3Hz (low signal to noise ratio below)

PSD



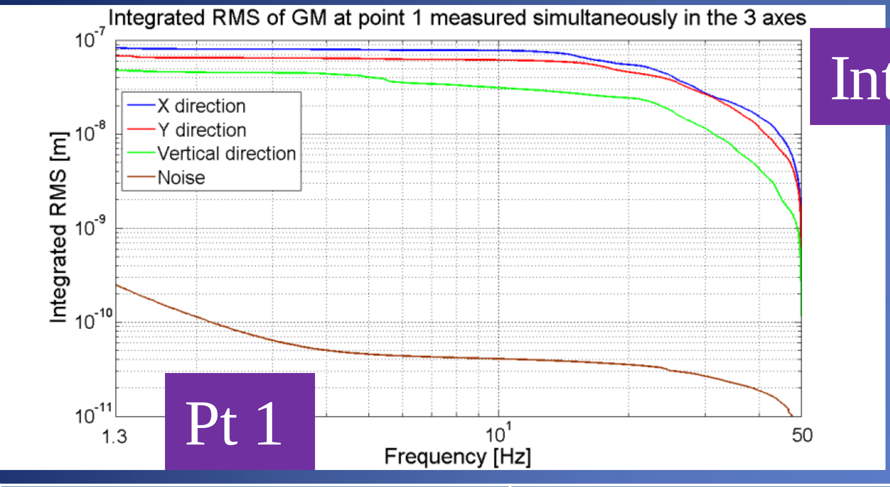


✓ For both pts 1 & 2, ground motion PSD in the vertical direction compared to the one in the two horizontal directions:

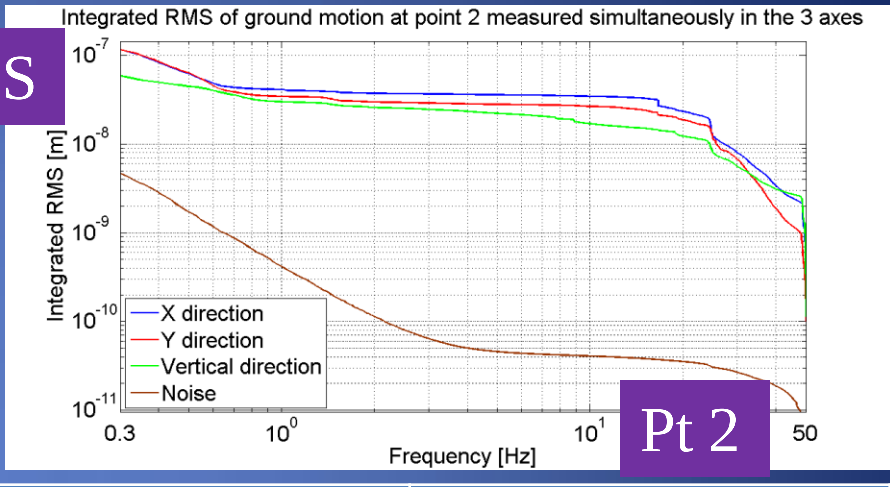
Range [Hz]	[0.3; 0.7]	[0.7; 4]	[4; 9]	[9; 50]
amplitude	lower (pt 2)	same	slightly higher	lower

On surface at different pts (various vibration sources)

Comparison of GM between vertical / horizontal axes



Int. RMS



Amplitude [nm]		Vertical axis	X axis (horizont)	Y axis (horizont)
Pt 1 [1.3; 100]Hz		48	83	68
Pt 2	[1.3; 100]Hz	29	40	34
	[0.3; 100]Hz	57	112	112

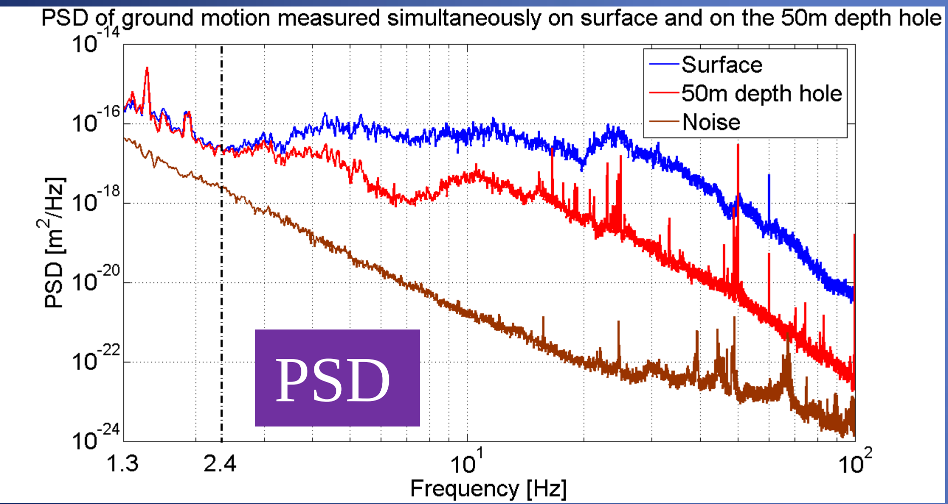
- ✓ Nominal horizontal beam size: 160 times larger than the vertical one
  - ➢ horizontal tolerances should be much less strict than vertical one
    - ➢ horizontal GM not so much higher than vertical one (both pts)

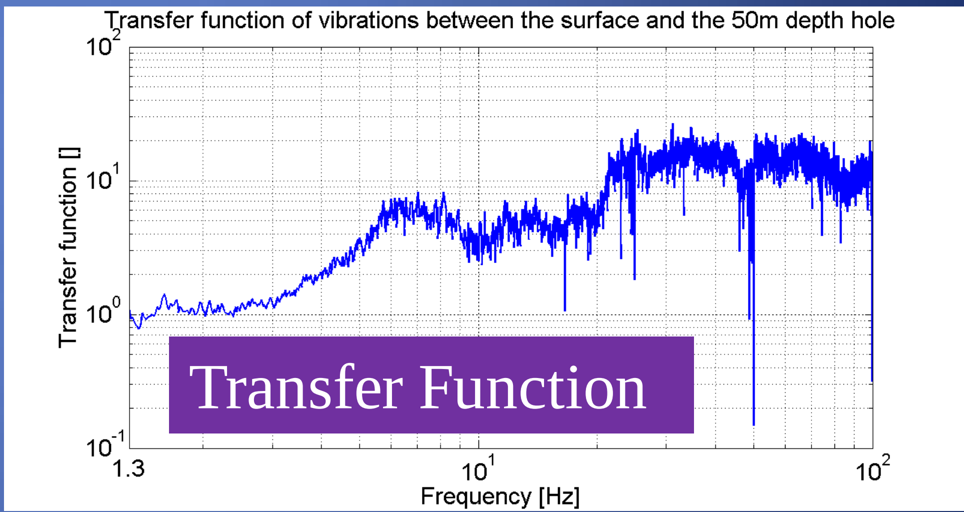
➔ GM only measured in the vertical direction for the other locations

On surface and in underground (50m)

✓ At point 1, GM measured simultaneously on the surface and on the hole of 50m depth with Endevco accelerometers (vertical direction) (Guralp geophone diameter to large to be put inside the hole (d=70mm))

✓ Results shown above 1.3Hz, frequency from where data are reliable (high signal to noise ratio)



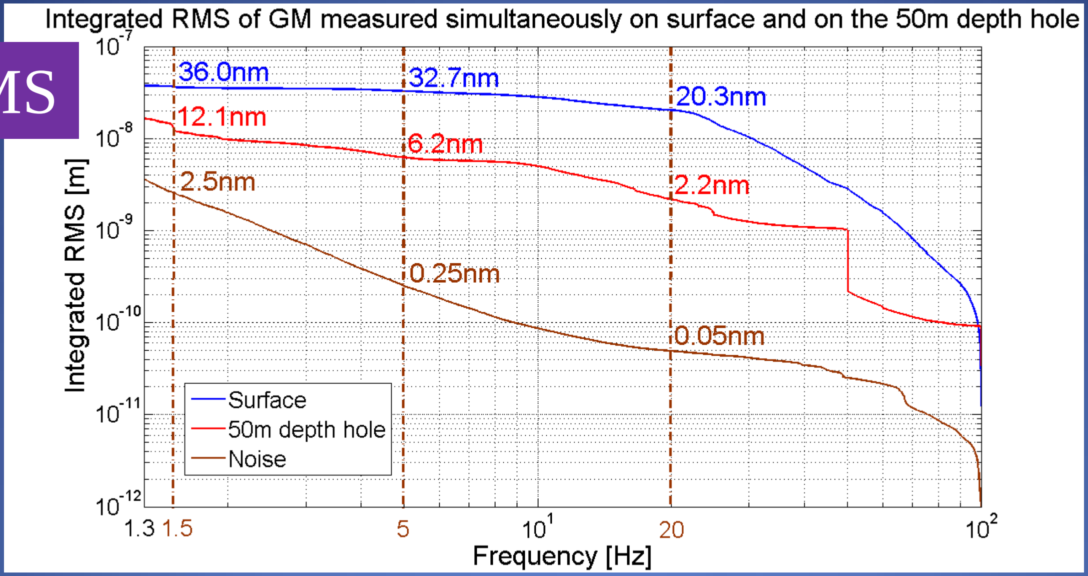


✓ Above 2.4Hz (beginning of cultural noise): vibrations of surface damped in the hole

✓ Above 20Hz: factor of damping goes up to 20 (transfer function)

On surface and in underground (50m)

Integrated RMS



Range [Hz]	Surface	50m depth hole	Damping factor
[1.5; 100]	36.0nm	12.1nm	3.0
[5; 100]	32.7nm	6.2nm	5.3
[20; 100]	20.3nm	2.2nm	9.2

✓ These factors probably well higher during rush hours since cultural noise is much more important

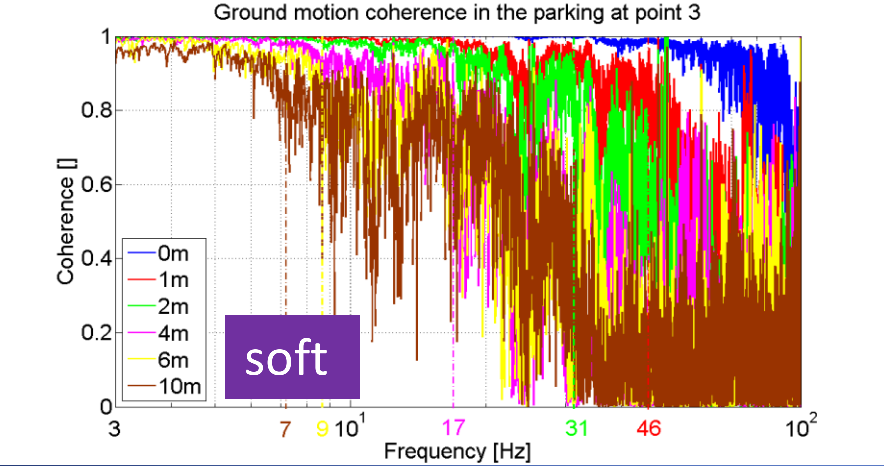
➔ All these results clearly show that cultural noise is really well attenuated in depth on its entire frequency range

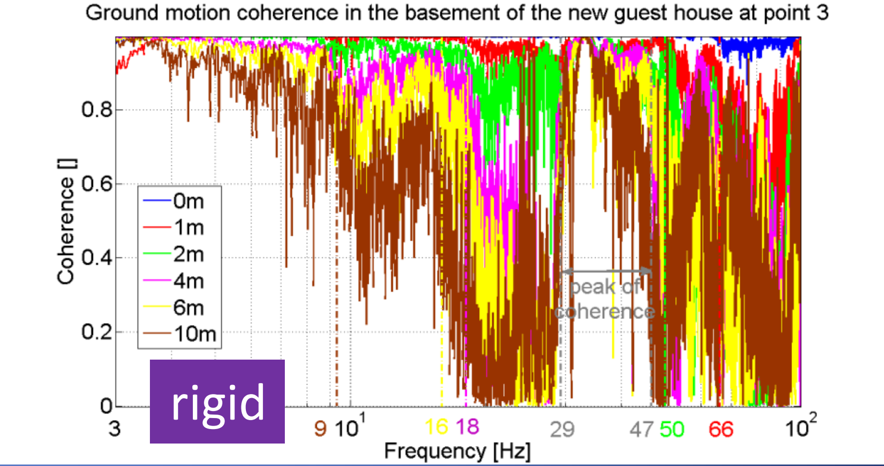
4. Coherence of vertical ground motion at two locations of point 3

- on the parking (soft floor)
- on the basement of the new guest house (concrete)

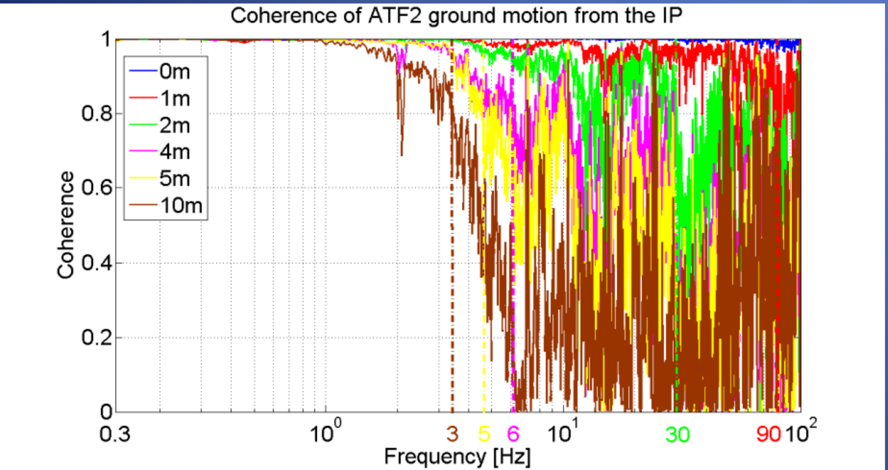
✓ Goal: confirmation of the importance of a rigid floor for stability and evaluation of the LNF floor

➢ Comparison done with coherence measured on the ATF2 where a special floor was built for stability (same data analysis performed)





LNF: Results shown above 3Hz (problem with one of Guralp) but coherence at 1 below (in fact, still at 1 for the highest distance (10m) from 3 to 6Hz (l) and from 3 to 4Hz (r))



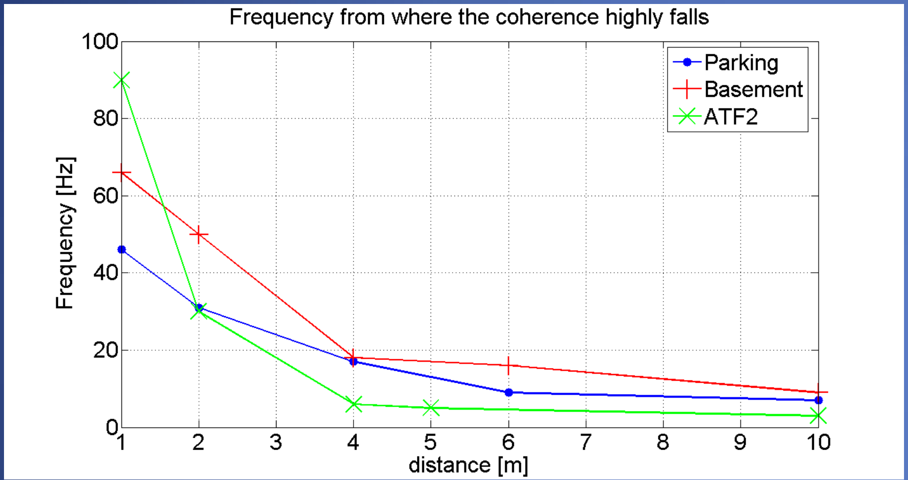
ATF2: results shown above 0.3Hz, frequency from where data are reliable (high signal to noise ratio)

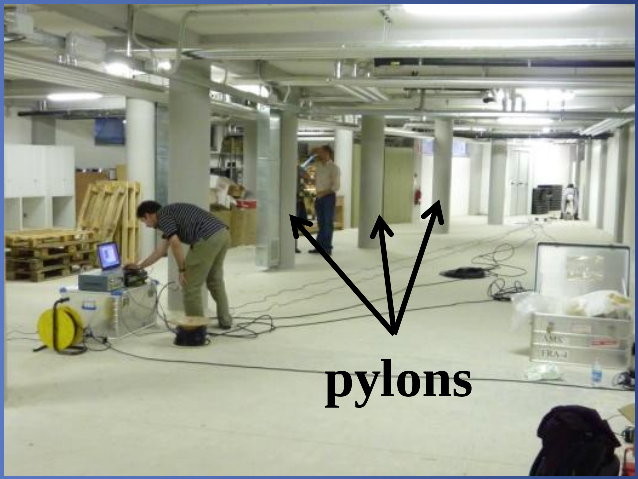
✓ In the 3 plots, the frequency where the coherence highly falls under a value of 0.8 is indicated for each distance (comparison possible)

NB: for the NGH basement, peak of coherence from 29Hz to 47Hz for each distance

➔ may be due to the pylons which transmit vibrations

➔ not taken into account to determine the frequency where the coherence falls





- Basement floor: coherence at higher frequency than parking floor

  ➔ confirm the importance of a rigid floor

- Basement (and parking) floor really better than ATF2 floor although ATF2 floor was built for stability whereas basement floor was not

- Moreover, basement not so stiff and there are empty volumes below

➔ LNF ground: very promising for good coherence properties

5. Summary

Vertical ground motion measurements during 18 hours

- ✓ [0.2; 1]Hz: vary from 65nm to 76nm → low compared to many other sites in the world (Desy team study) but may be higher in a longer time
- ✓ [1; 100]Hz: vary from 12 to 65nm (quite low) except from 8h to 9h40
  - ➔ increase up to 240nm due to traffic observed in the range [3; 30]Hz

GM measured at 4 locations on surface (various vibration sources)

- ✓ Almost the same (vertical GM) for the 4 pts (non rush hours the day)
  - ➢ GM measured for 18 hours (pt 3) well representative of LNF GM
- ✓ Horiz. GM not much higher than vertical GM compared to tolerances

GM measured simultaneously on surface and in a 50m depth hole

- ✓ Cultural noise well attenuated in depth on its entire frequency range
  - ➢ huge vibrations due to traffic should be well attenuated in depth

Coherence for different distances at 2 pts (soft and rigid floor)

- ✓ Rigid floor keeps the coherence at higher frequencies than a soft floor
- ✓ LNF concrete floor really better than ATF2 floor (built for stability)

6. Conclusion/future prospects

Conclusion

✓ LNF: very good site for nanobeam size if the tunnel is built by taking into account two specifications

- ➢ should be in underground since GM can be high in surface due to traffic but should be low in depth compared to many other sites
- ➢ its floor should be rigid ➔ very good coherence can be obtained

✓ For now, it is planned to build the tunnel in 25m depth and to make the tunnel floor in stiff concrete plate especially in the final focus area

- ➢ However, difficult to tell if needed since tolerances not yet given

Future prospects

✓ Holes planned to be made all around the future site of Super B for new campaigns of measurements (transient, long time measurements…)

✓ However, measurements take time and water inside holes need to be investigated (maybe measurements on summer could be a solution)

- ➢ tolerances are important to know (amplitude, frequency, sections to stabilize) and magnet informations (resonances, distance between FD)
  - ➢ give informations on which measurements are really needed