Ground motion measurements at Tor Vergata

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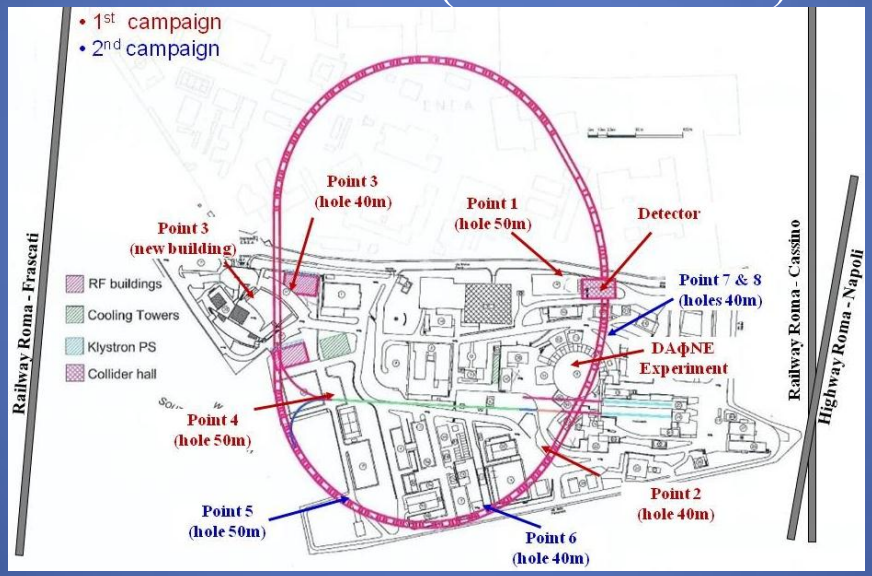
Introduction

- ✓ Super B project: very sensitive to vibrations due to nanometer beam size
- ✓ Two sites are foreseen for the Super B project: INFN and Tor Vergata
- ✓ We performed in the past two campaign of measurements in the INFN site in order to analyse the level of vibrations of this site (2009 and 2010)



- ✓ Goal of this new campaign of measurements at Tor Vergata
  - ➔ Evaluate the level of vibrations of this site
  - ➔ Compare this site with the INFN site to analyse which one is the less noisy

➔ Make a conclusion of the quality of Tor Vergata and INFN site

Location of measurements at Tor Vergata

Monday 18	1 (afternoon time)	At the interaction point
Tuesday 19	2-3 (morning – afternoon)	Near the highway/100m from the highway
Wednesday 20	4 (all day long)	At the injection point
Thursday 21	5-6 (morning – afternoon)	Around the highway/At the interaction point
	7 (all night long)	At CNR basement

Overview

- ✓ 1. Instrumentation used
- ✓ 2. Data analysis
- ✓ 3. Point 2: near the highway
- ✓ 4. Point 5: Around the highway
- ✓ 5. Point 3: 100m from the highway
- ✓ 6. Point 4: At the injection point
- ✓ 7. Point 7: At the CNR basement
- ✓ 8. Points 1 and 6: At the interaction point
- ✓ 9. Comparison between the different points
- ✓ 10. Comparison with INFN site
- ✓ 11. Conclusion

1. 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	1600V/m/s	[0.03; 50]	3 axes
Accelerometer	Endevco 86	Endevco	10V/g	[0.01; 100]	vertical
Accelerometer	731A	Wilcoxon	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: Frascati / 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

2. Data analysis

✓ FFT parameters used for the average analysis:

- Window: Hanning
- Frequency resolution: 0.016Hz
- **Time resolution: 20 min**
- **Spectra average: 55 (data set of 64 s),** exponential (2τ:1195s), 66.67% overlap

➔ 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

- **Almost same analysis: amplitude of GM measured at Tor Vergata by us can be compared to the ones of various sites in the world**

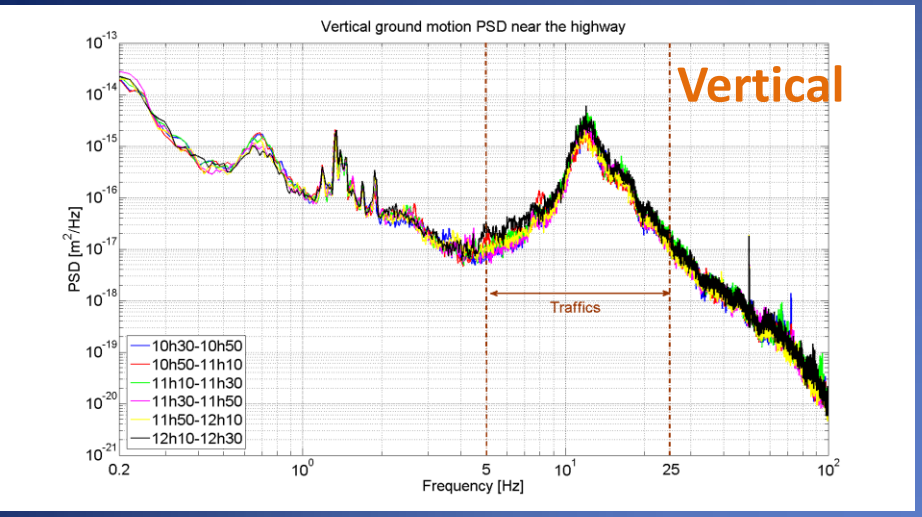
✓ FFT parameters used for the transient analysis

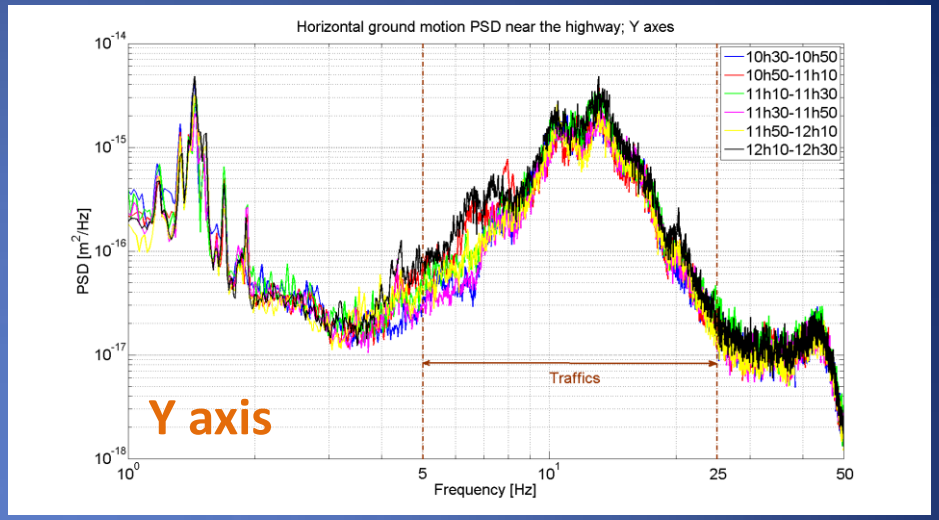
- Window: Hanning
- Frequency resolution: 0.1563Hz
- **Time resolution: 6s** (trigger of the multibuffer)
- **Spectra average: 1 average,** exponential (2τ: 6.4s), 66.67% overlap

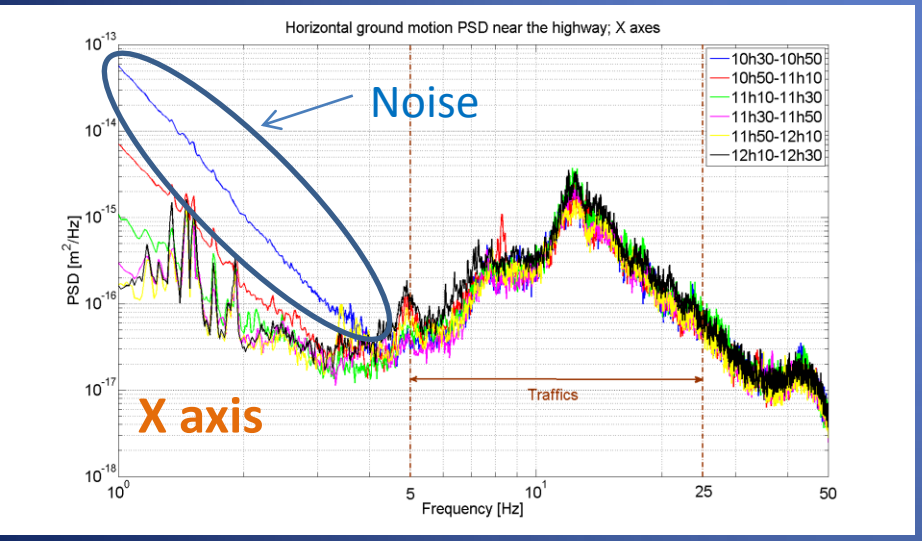
➔ **Allow tracking of every single event (like car, train, …)**

3. Point 2: Near the highway (below the bank)

PSD of ground motion



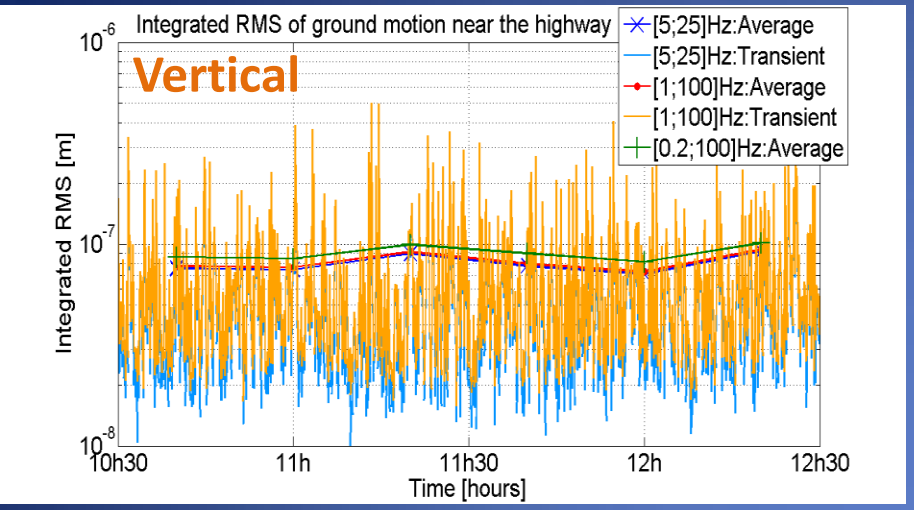


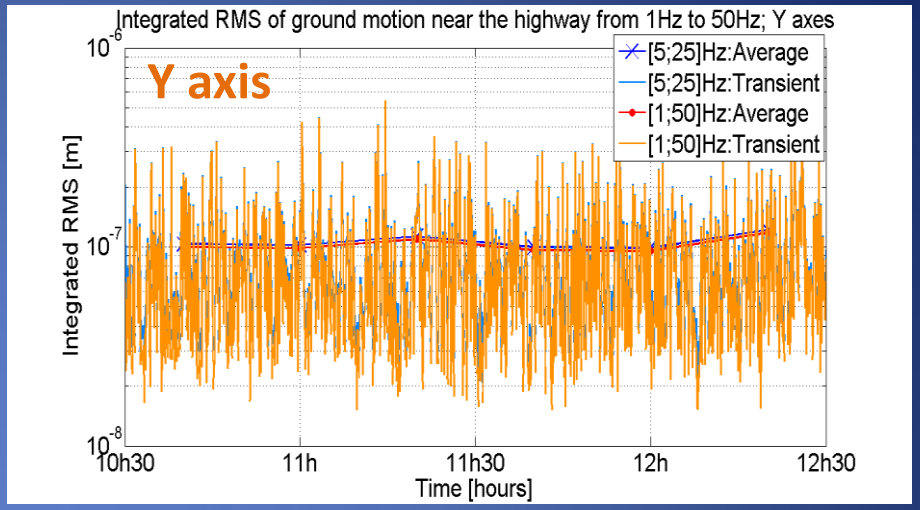


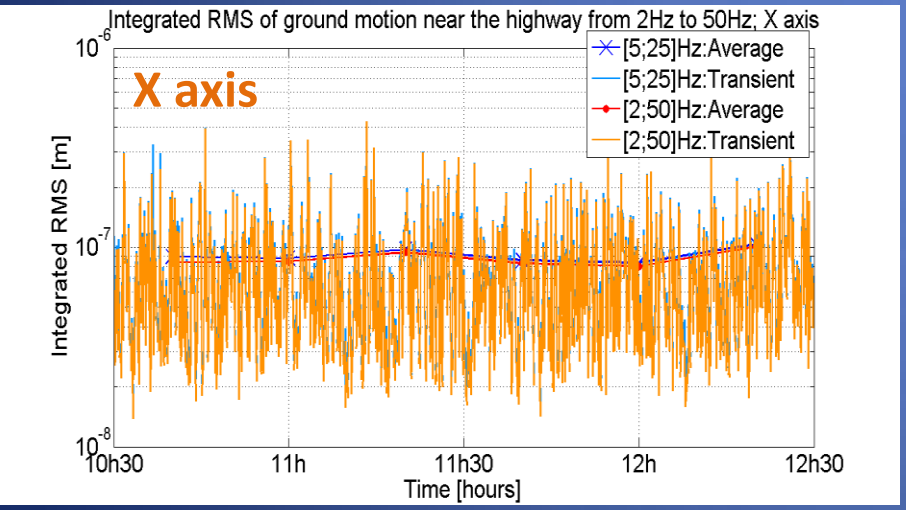
N.B: X axis➔ noise below 2Hz
Y axis➔ noise below 1Hz
Z axis➔ noise below 0.2Hz

➔ Frequency range of the high peak corresponds exactly to traffics in the three axes
➔ Amplitude of PSD almost the same with time in the three directions

Integrated RMS of ground motion



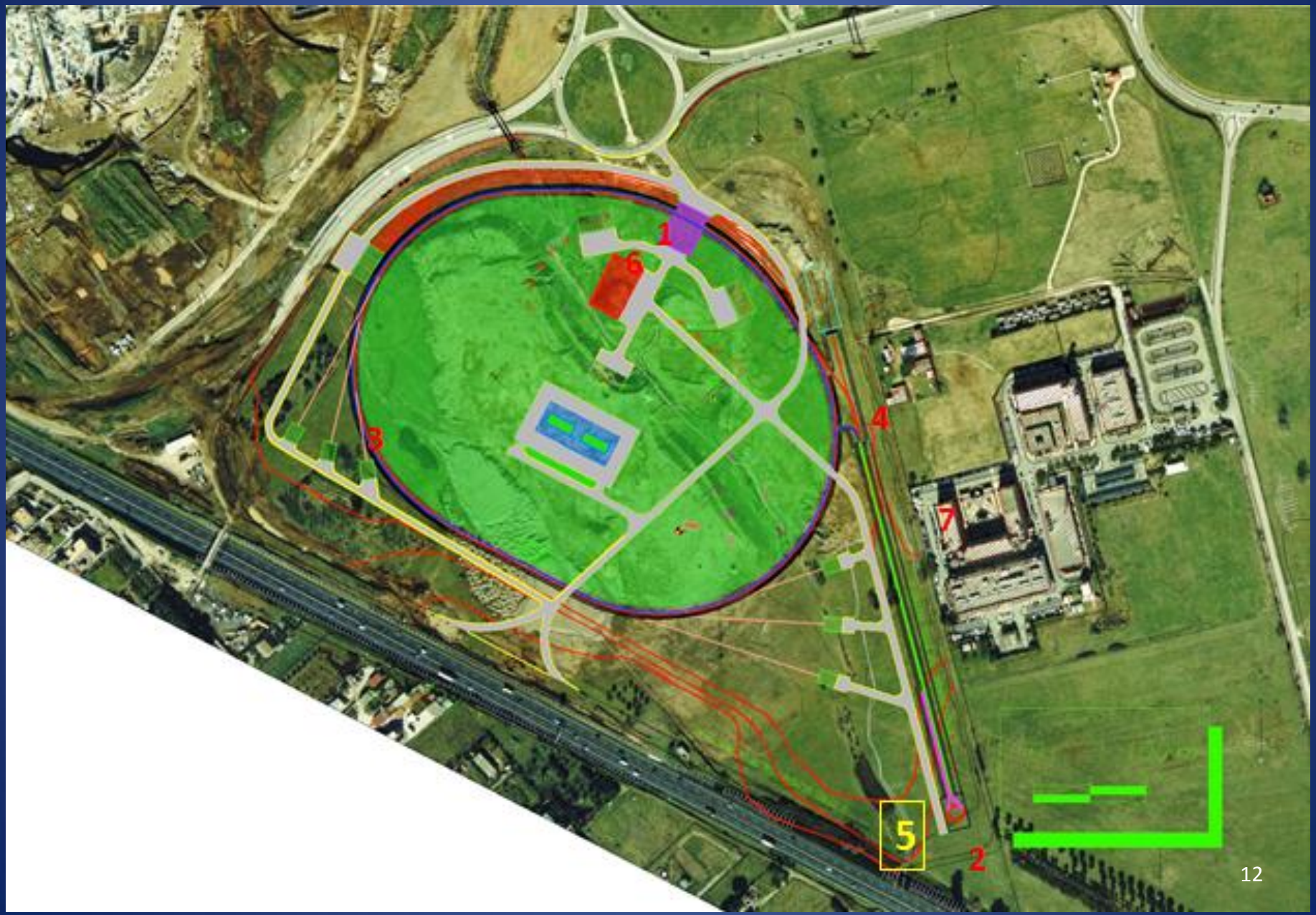




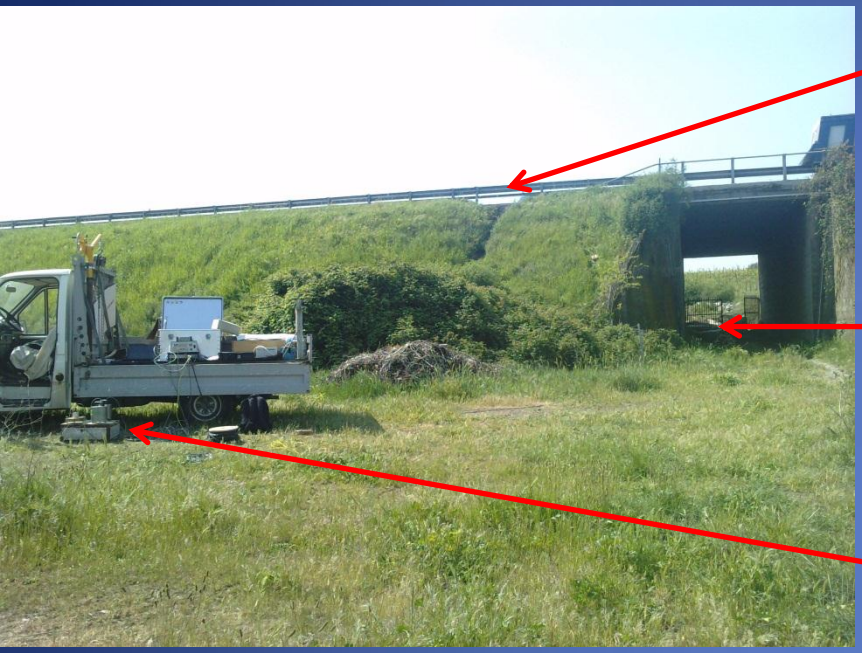
- ✓ Horizontal ground motion slightly higher than the vertical one as usual
- ✓ Ground motion from 0.2Hz to 100Hz almost the same than from 5Hz to 25Hz
  - ➔ Most of the vibrations come from the highway: very high source of vibrations

- ✓ Vertical ground motion varies from 73nm to 94nm in the frequency range [1; 100]Hz
  - ➢ Not that high since it is very near the highway!!

4. Point 5: Around the highway



Experimental setup



Accelerometer on the hard shoulder of the highway

Accelerometer below the bridge on a rigid floor

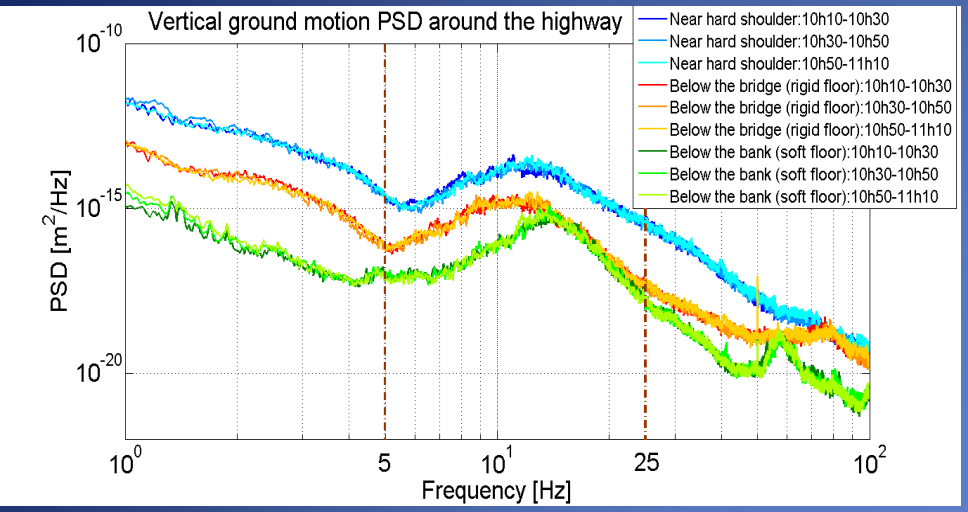
Accelerometer below the soft bank on the soft floor

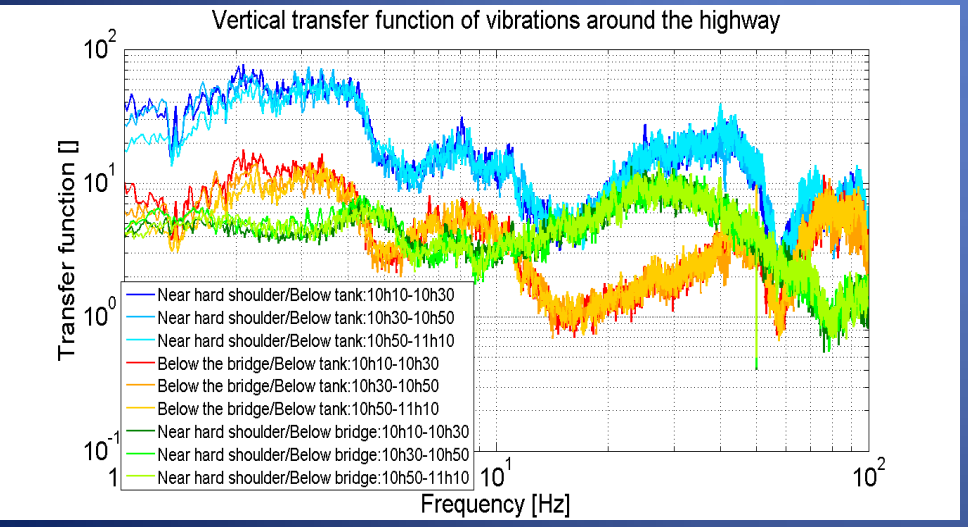
Rigid structure: good transmission of vibrations

- ✓ Evaluation of the damping factor of vibrations between:
  - ➢ The hard shoulder of the highway and the soft floor below the bank
  - ➢ The hard shoulder of the highway and the rigid floor below the bridge

➔ Goal: to show that the measured low vibrations of the Tor Vergata site are due to the very good properties of its floor (soft floor)

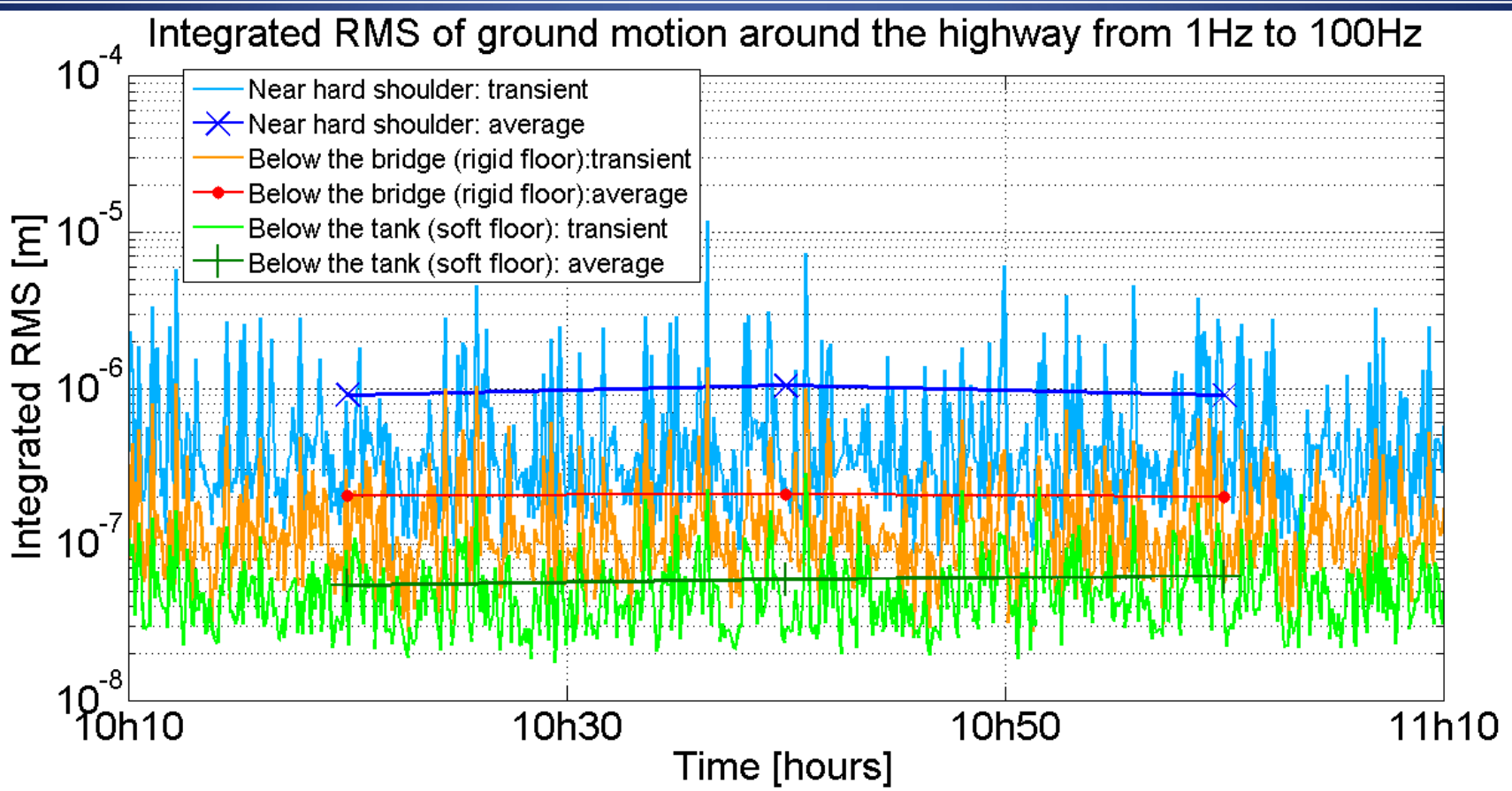
PSD and Transfer Function





- The soft floor attenuates much the vibrations compared to the rigid floor
- The highway seems to excite the floor on the entire bandwidth of measurements!!
- The peak of traffics (5Hz-25Hz) is reduced in amplitude and bandwidth below the bridge (rigid floor) and even more below the bank (soft floor)

Integrated RMS of ground motion



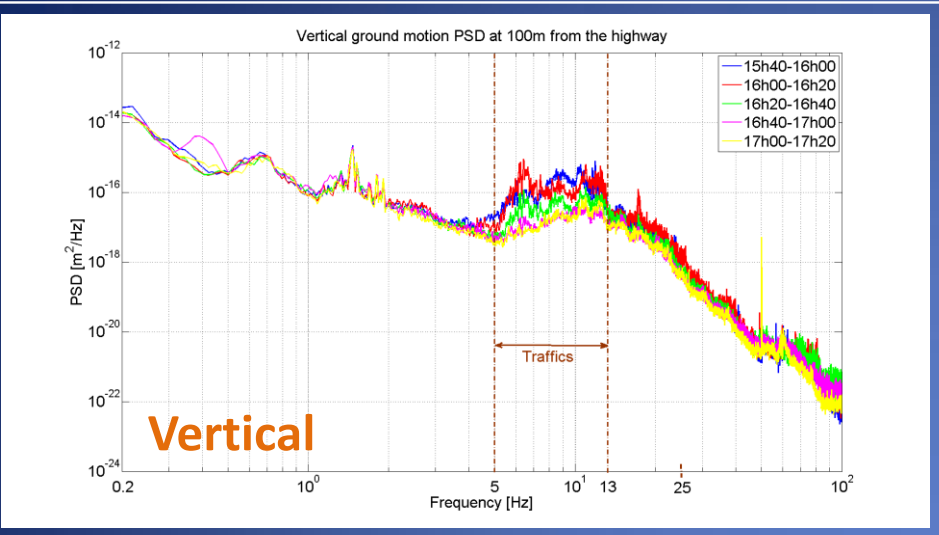
- ✓ **Near the hard shoulder: around 1µm** (between 900 nm and 1040nm in average)
- ✓ **Below the bridge (rigid floor): around 200nm** (between 202 and 209nm in average)
- ✓ **Below the bank (soft floor): around 60nm** (between 54m and 62nm in average)

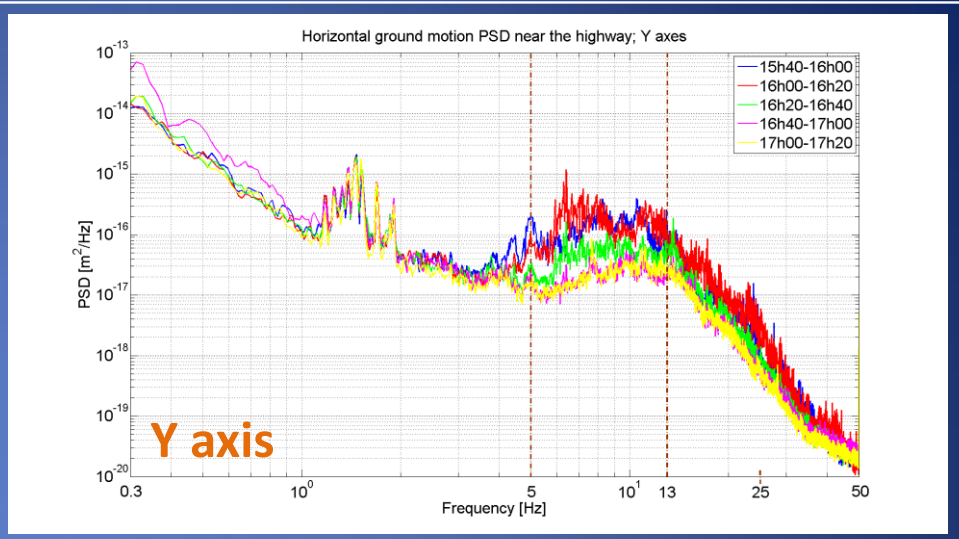
➔ **Soft floor: factor 17 of damping!! Very good floor!!**

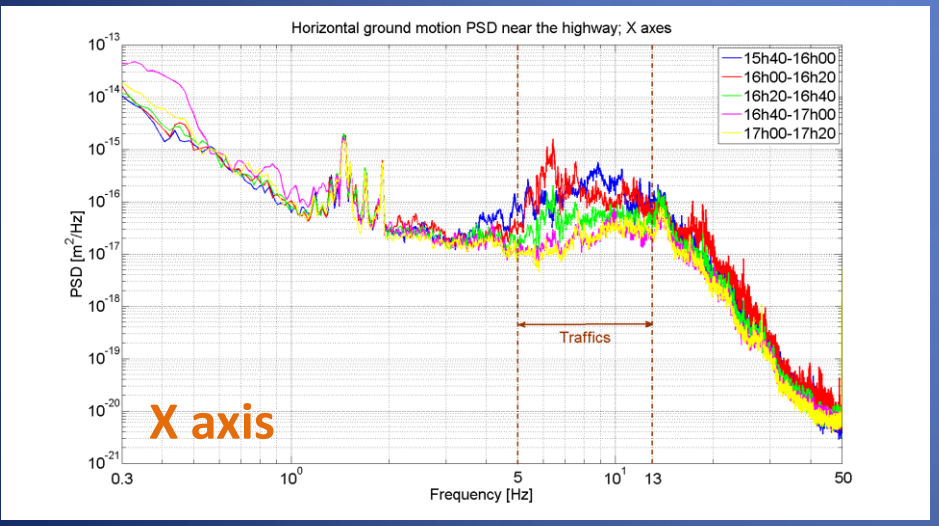
➔ **If we had a rigid floor: only a factor 5 of damping**

5. Point 3: 100m from the highway

PSD of ground motion



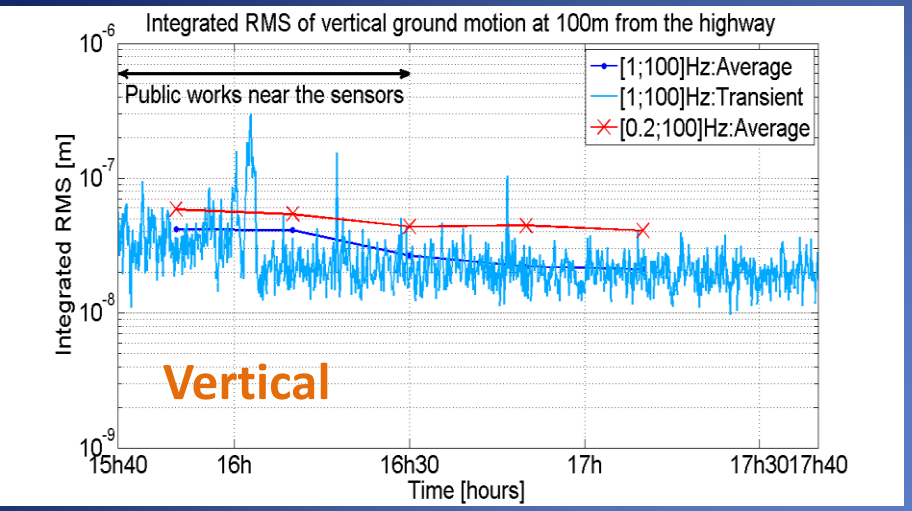


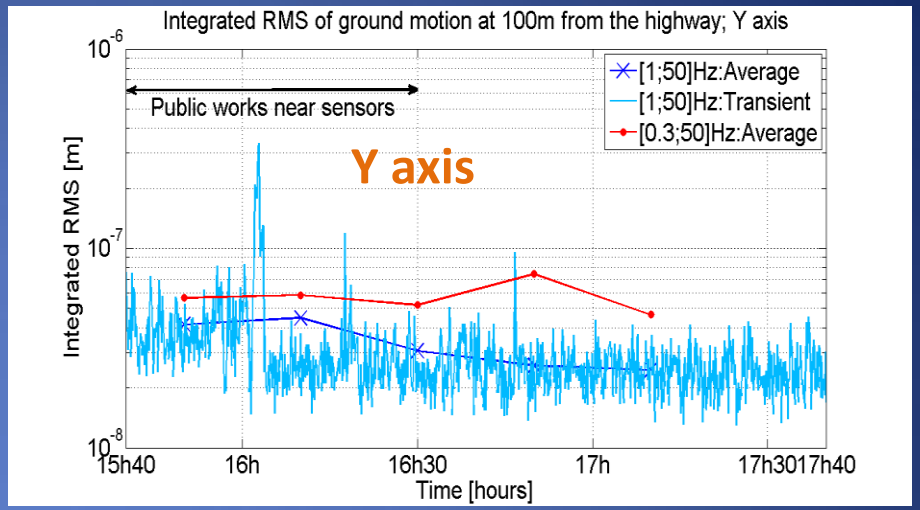


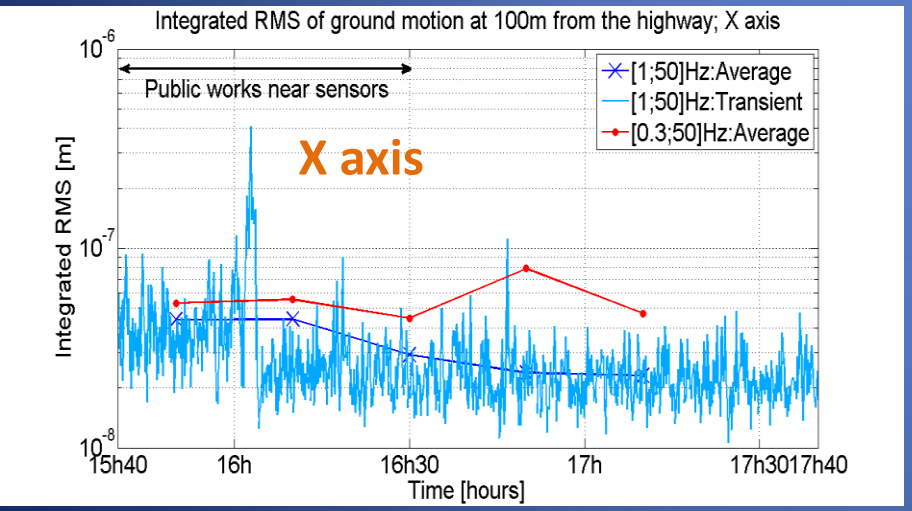
N.B: X axis➔ noise below 0.3Hz
Y axis➔ noise below 0.3Hz
Z axis➔ noise below 0.2Hz

➔ In the 3 axes: the high peak of traffic becomes lower with time and its amplitude and bandwidth are well lower than the one from measurements near the highway

Integrated RMS of ground motion







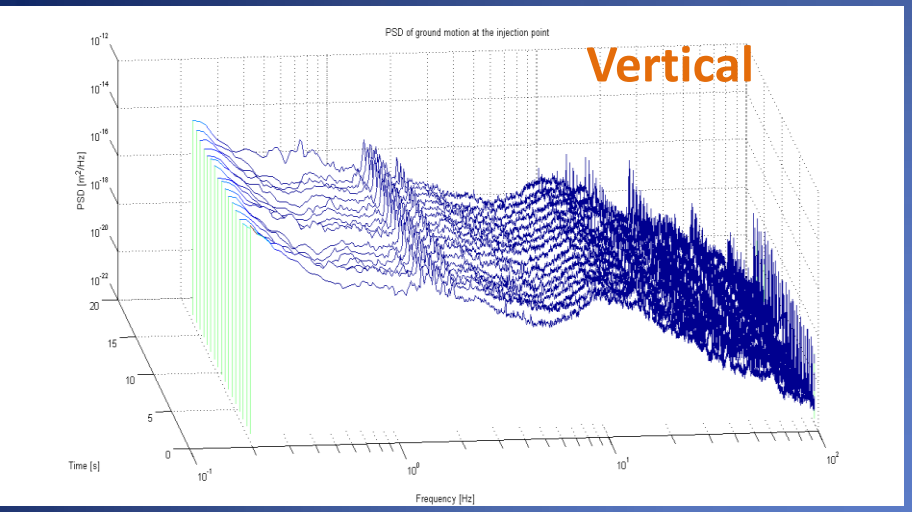
✓ N.B: Public works near the measurement point from 15h40 to 16h30

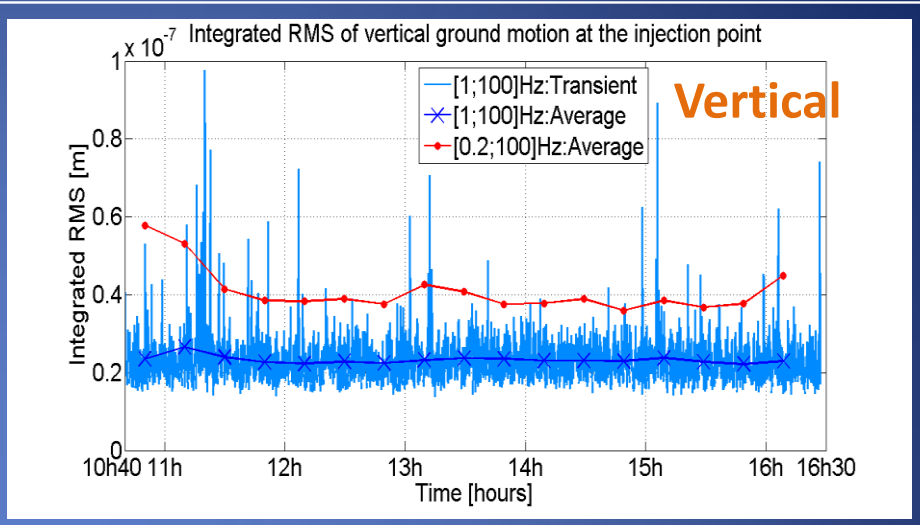
✓ Except during the public works, ground motion very low: between 20nm and 30nm in the three directions!!

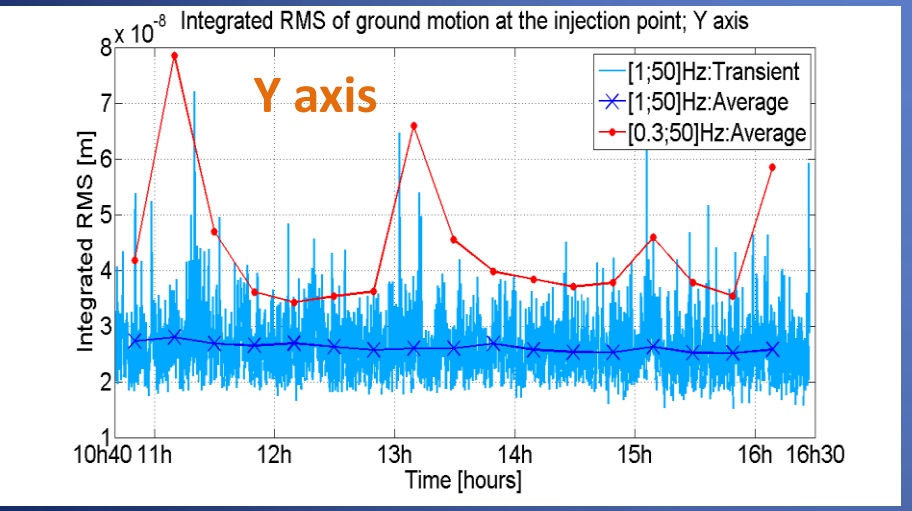
➢ Vibrations of the highway well attenuated with the distance (100m)!!

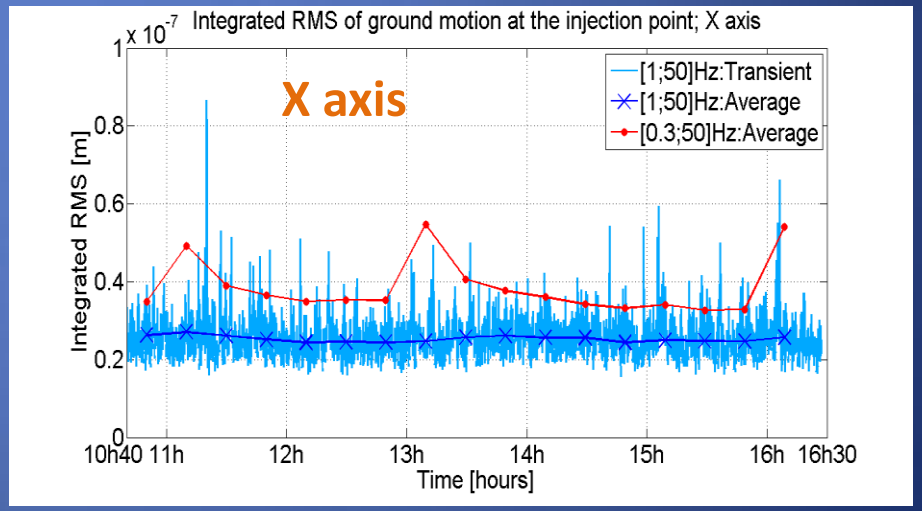
6. Point 4: Injection point

PSD and integrated RMS of ground motion



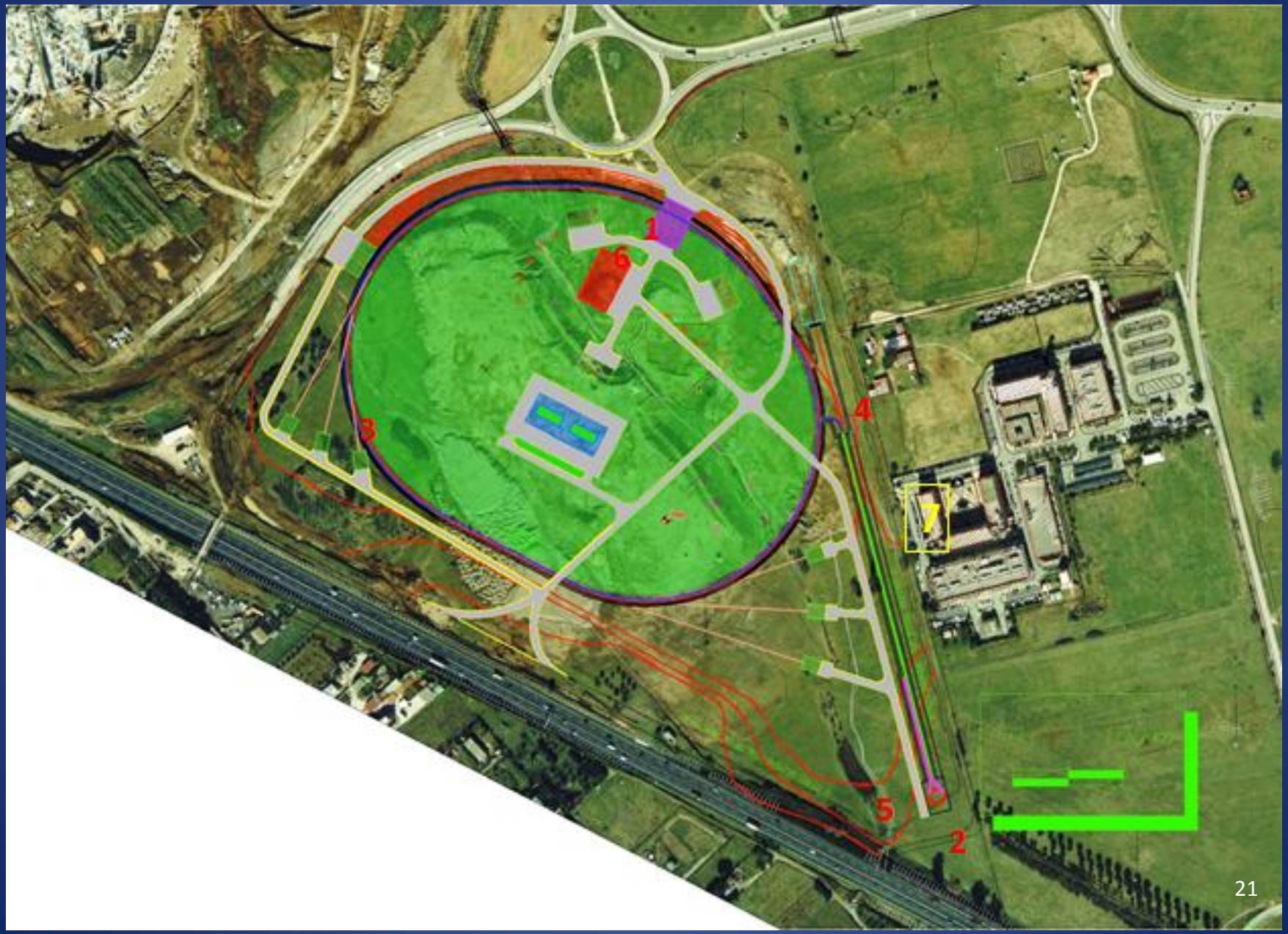




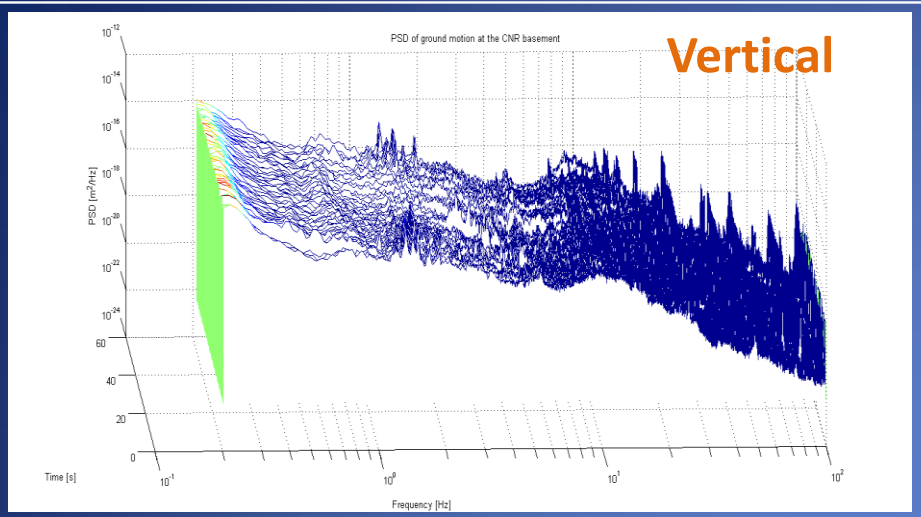


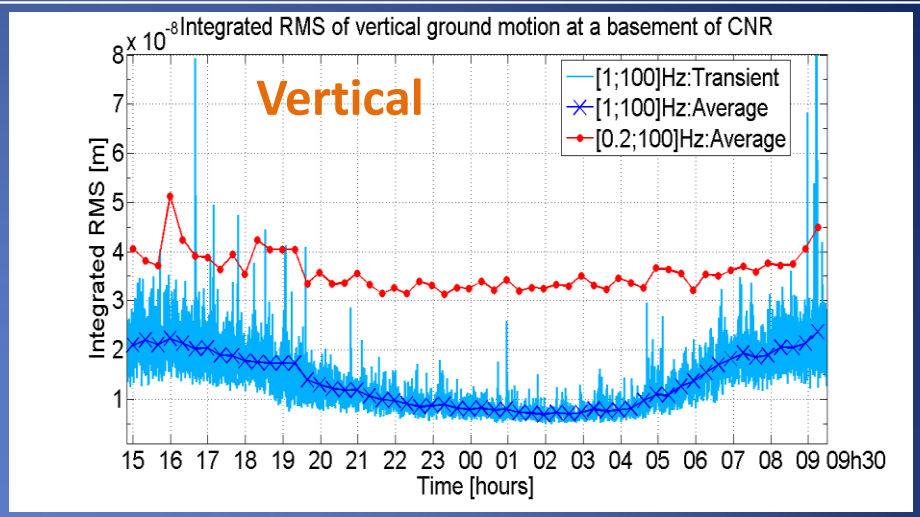
- ✓ Ground motion PSD almost the same with time
- ✓ Amplitude very small in average and transient: between 20nm and 30nm above 1Hz in the three directions!!

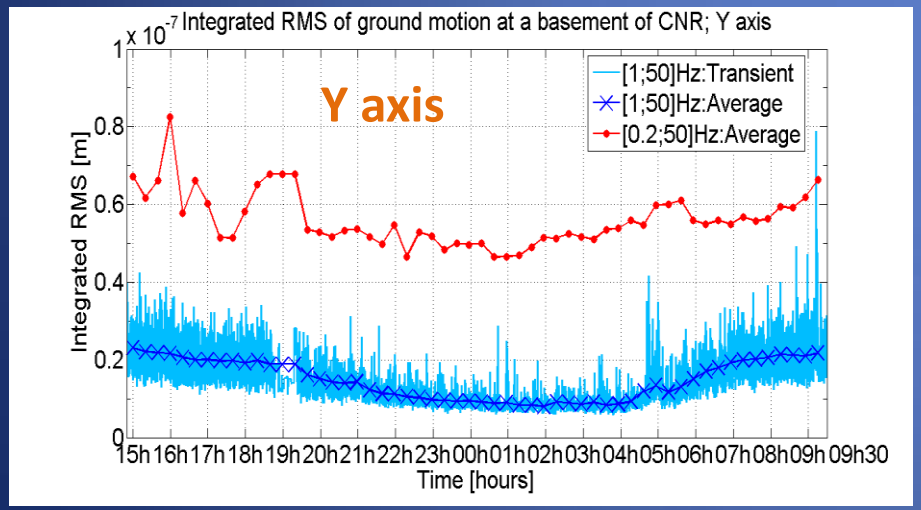
7. Point 7: CNR basement

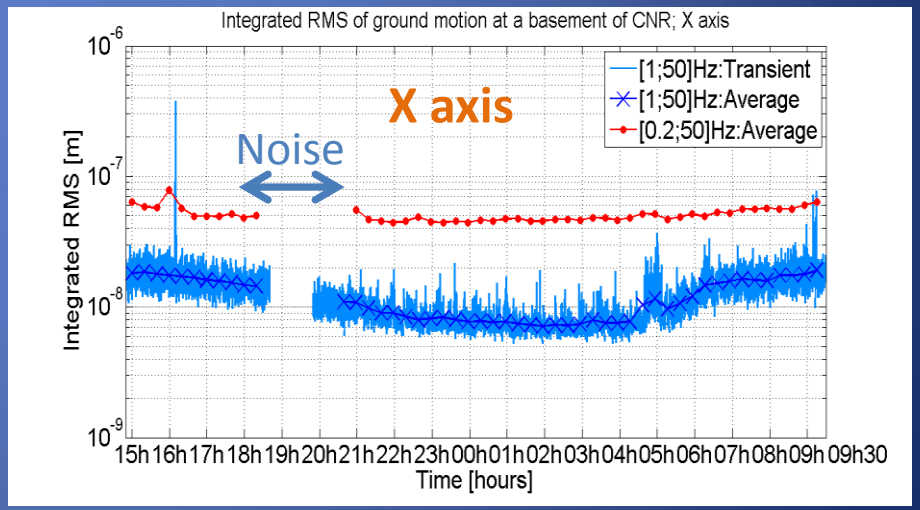


PSD and integrated RMS of ground motion





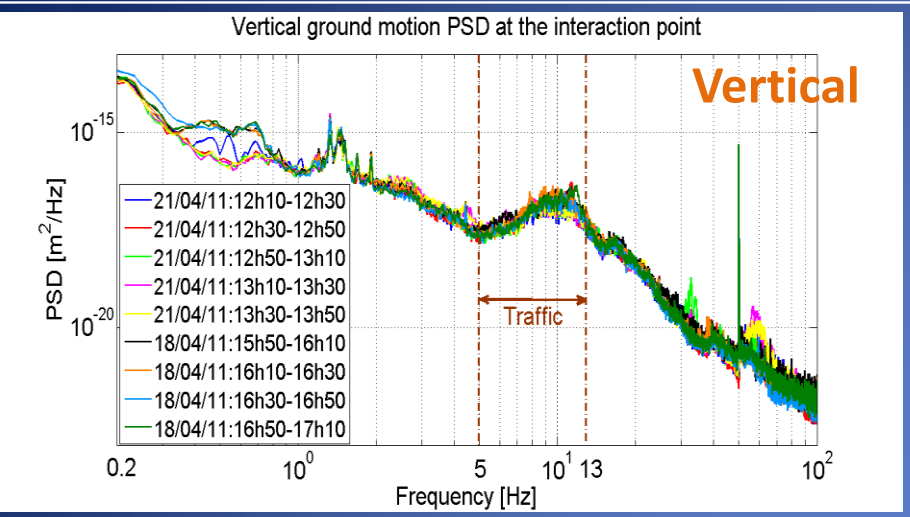


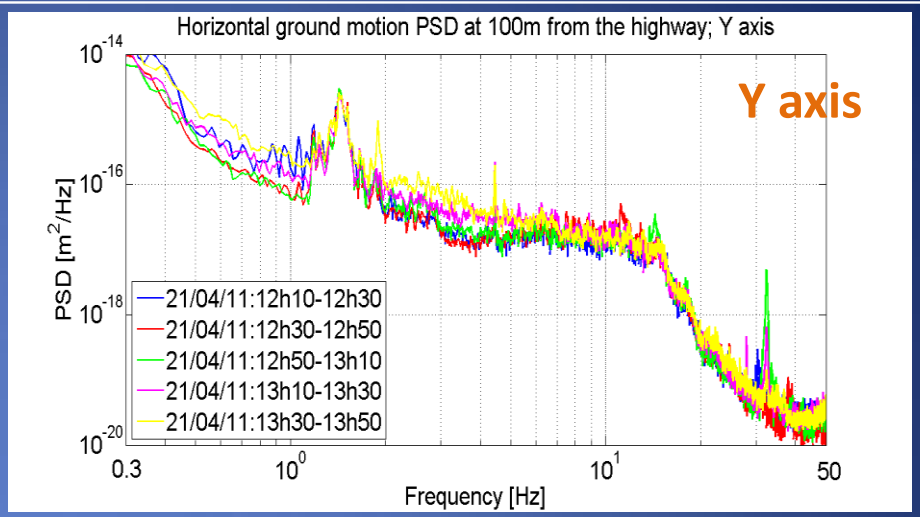


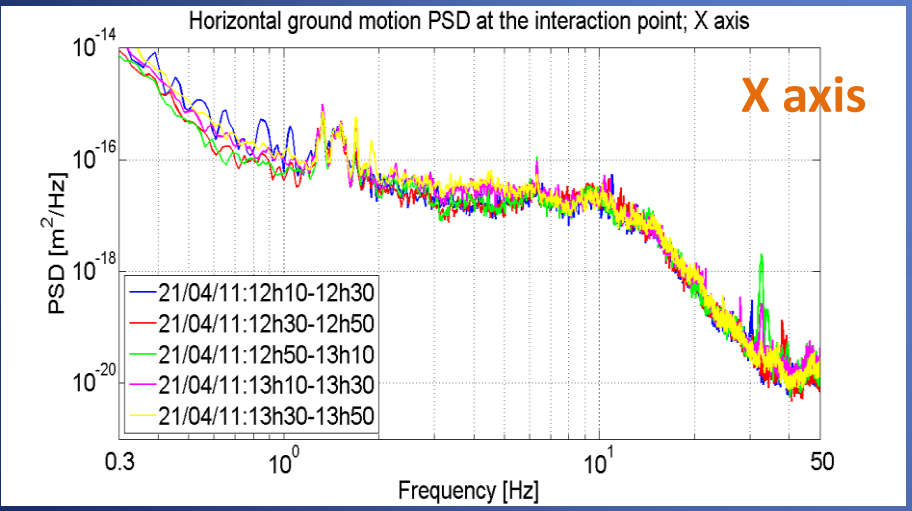
- ✓ Evolution of amplitude versus time: average and sigma (transient) decrease from 14h50 to 02h50 and increase from 02h50 to 09h30
- ✓ Amplitude very small in average and transient: from 10nm to 30nm above 1Hz in the three directions!!

8. Points 1 and 6: At the interaction point

PSD of ground motion

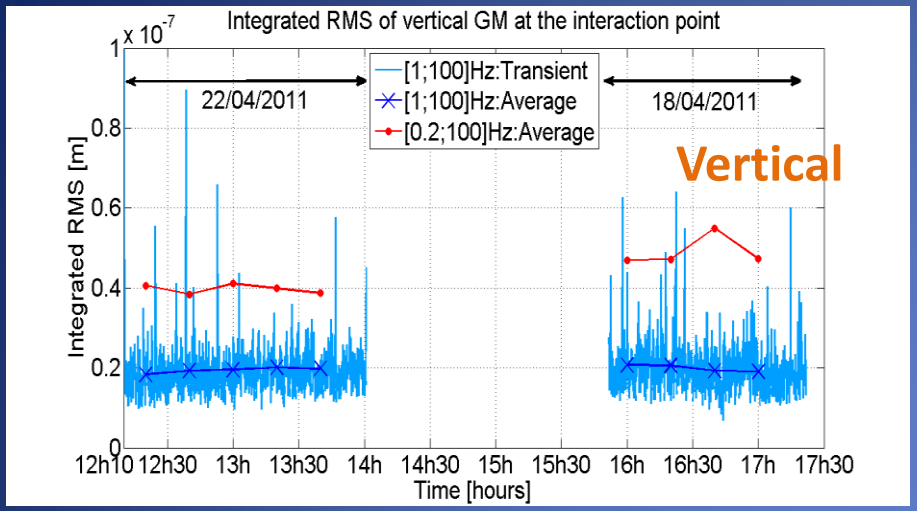


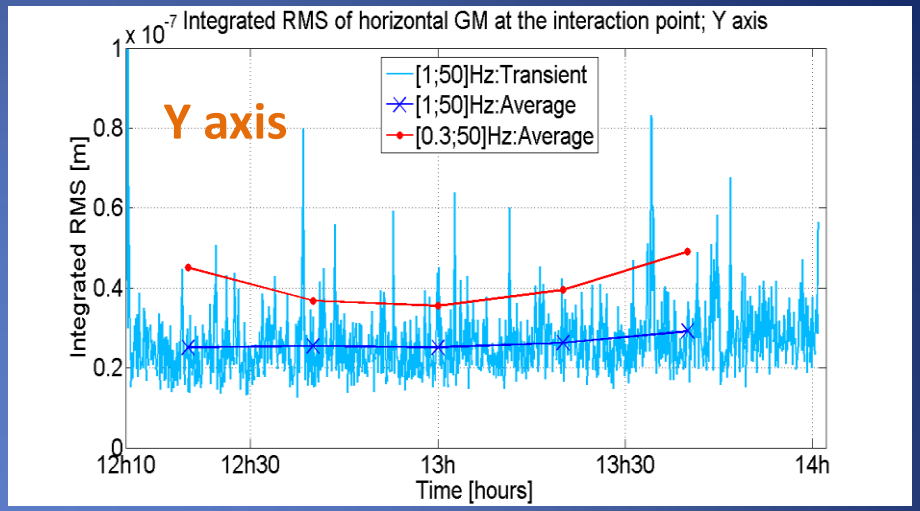


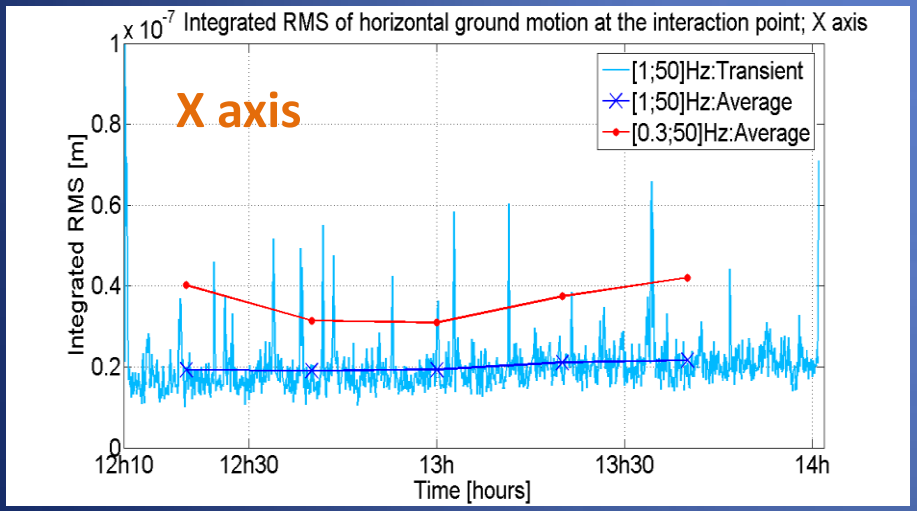


- In the vertical direction: Amplitude and frequency range of the traffic peak is small
- In the horizontal directions: No peak in the frequency range of traffic
- Amplitude of the PSD is the same versus time (and versus day!)

Integrated RMS of ground motion





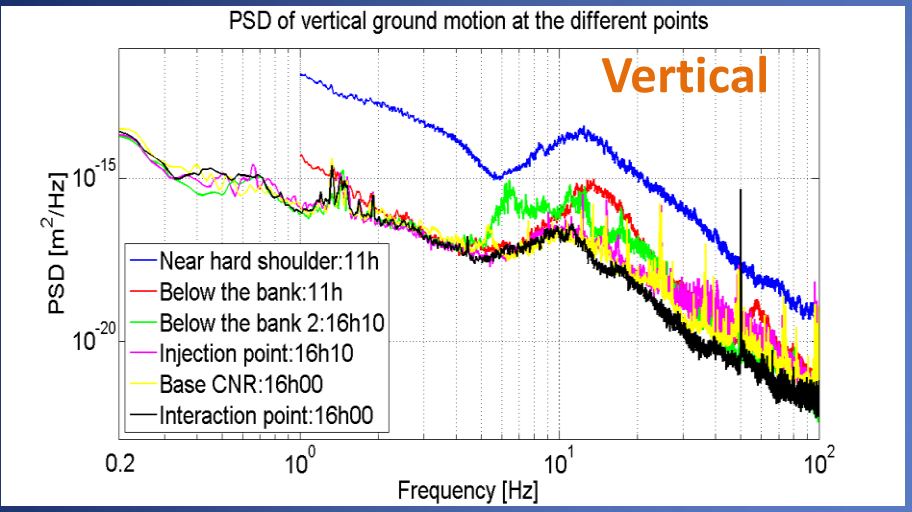


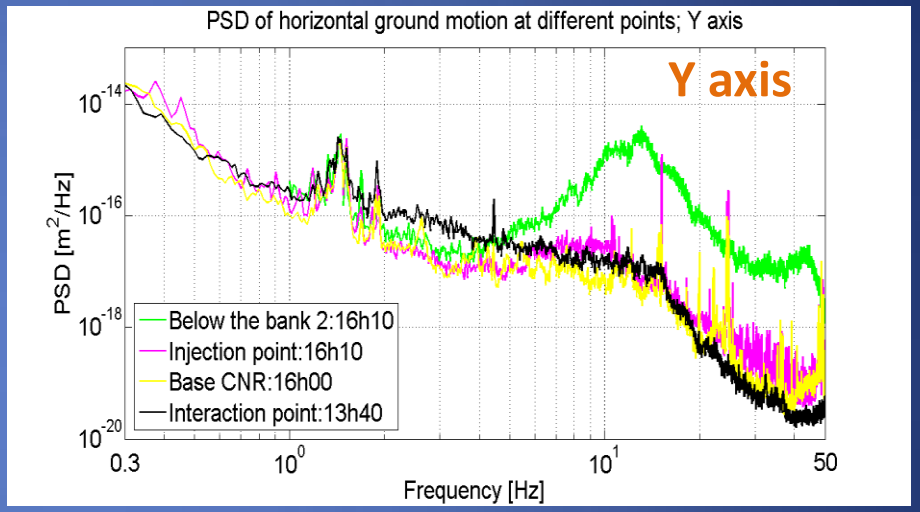
➔ Amplitude of GM very small in average and even in transient (sigma): around 20nm above 1Hz and 40nm above 0.2Hz (above 0.3Hz in horizontal)!!

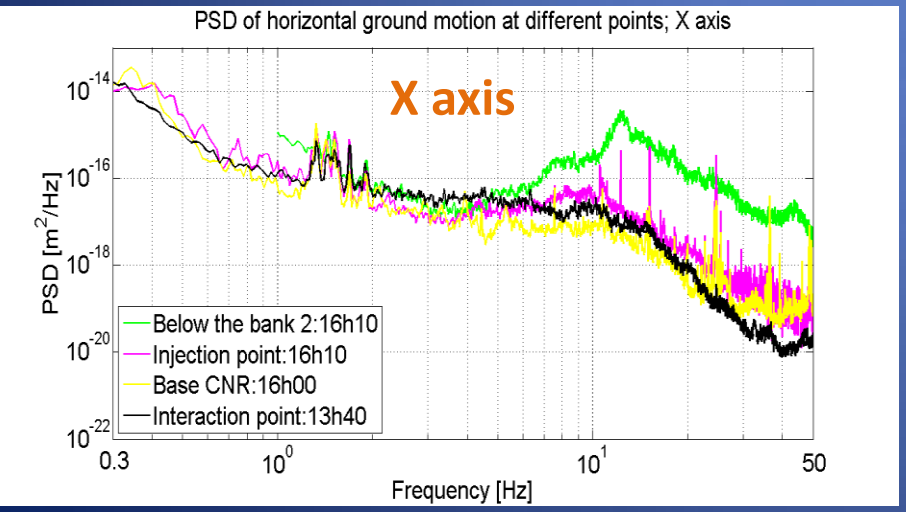
9. Comparison between the different points

PSD of ground motion

- For each measurement point: data (in average) of the highest amplitude was taken for comparison



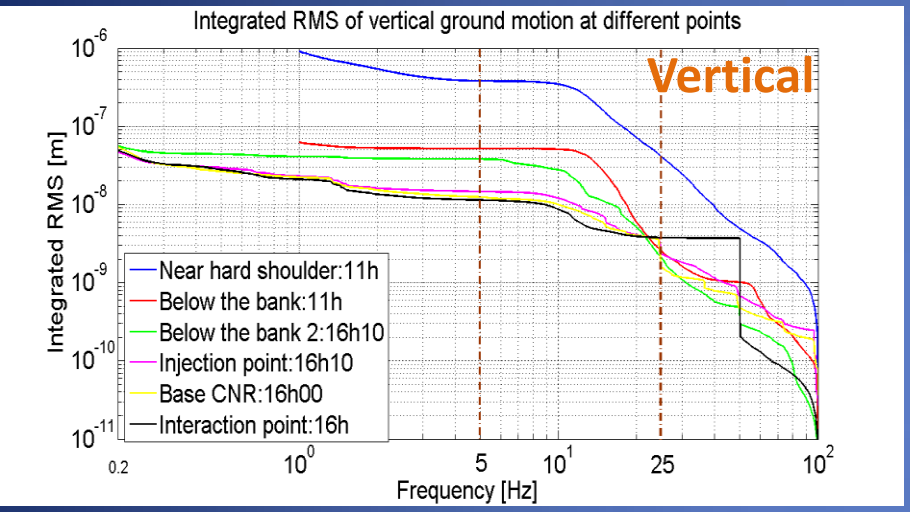


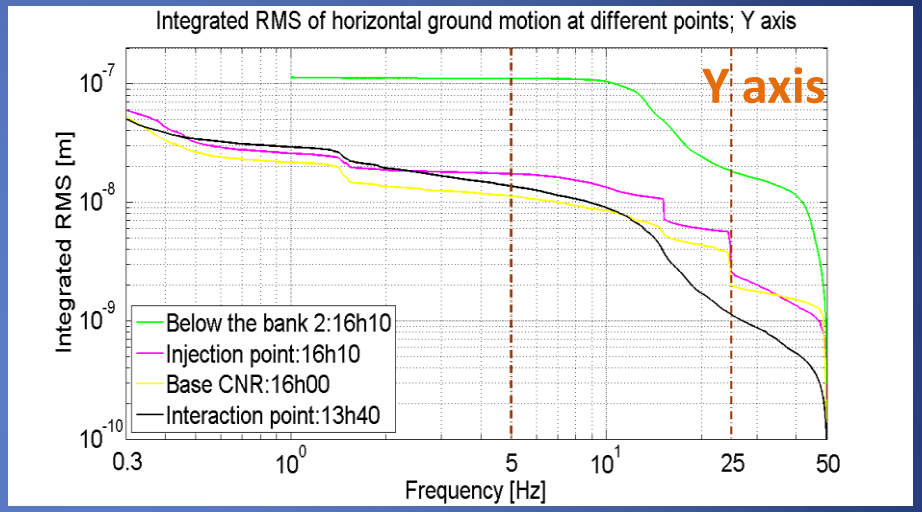


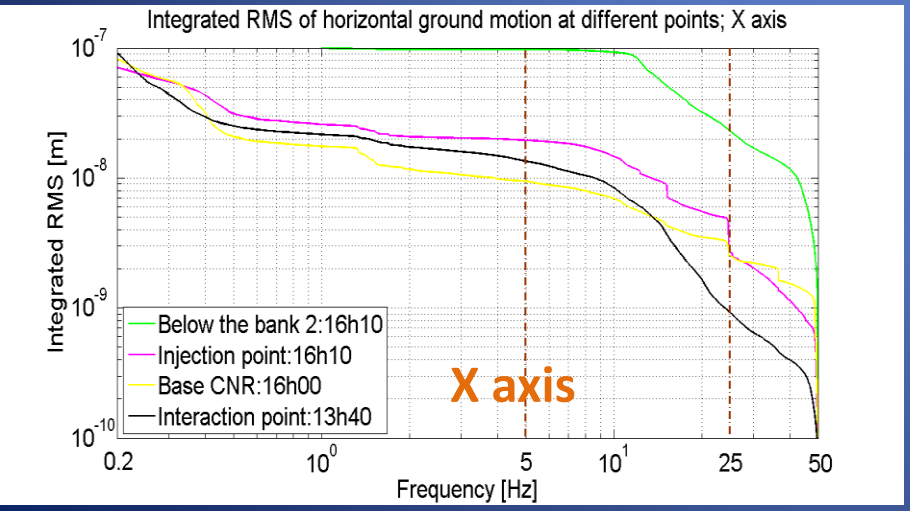
- Amplitude on the whole bandwidth of measurements (and on the bandwidth of the traffic peak) decreases with the distance from the highway

Integrated RMS of ground motion

- For each measurement point: data (in average) of the highest amplitude was taken for comparison

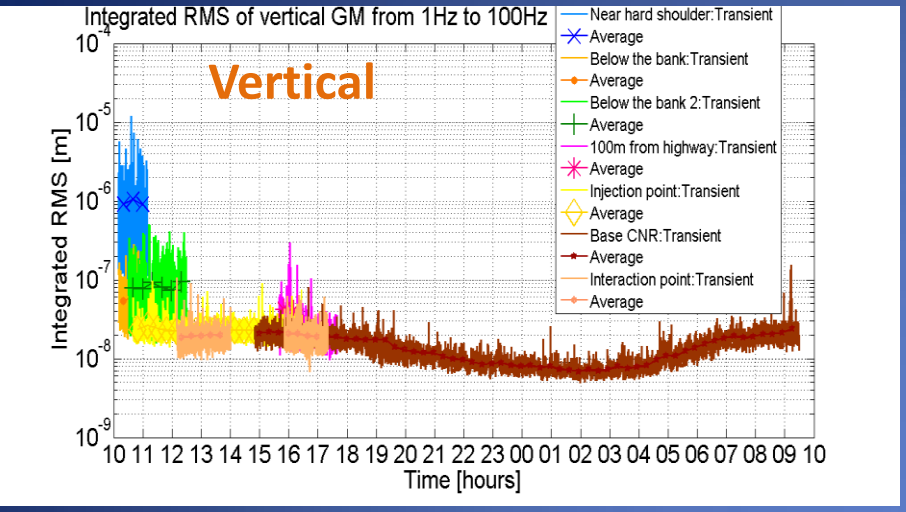


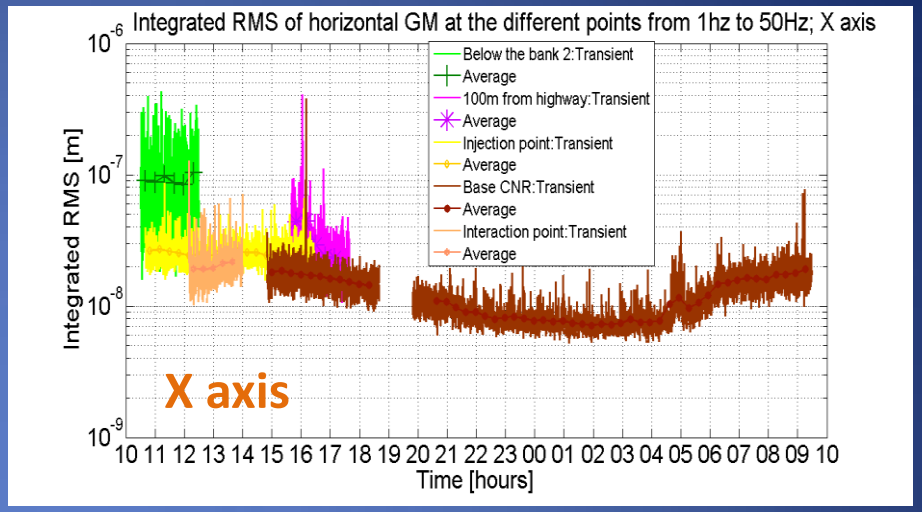


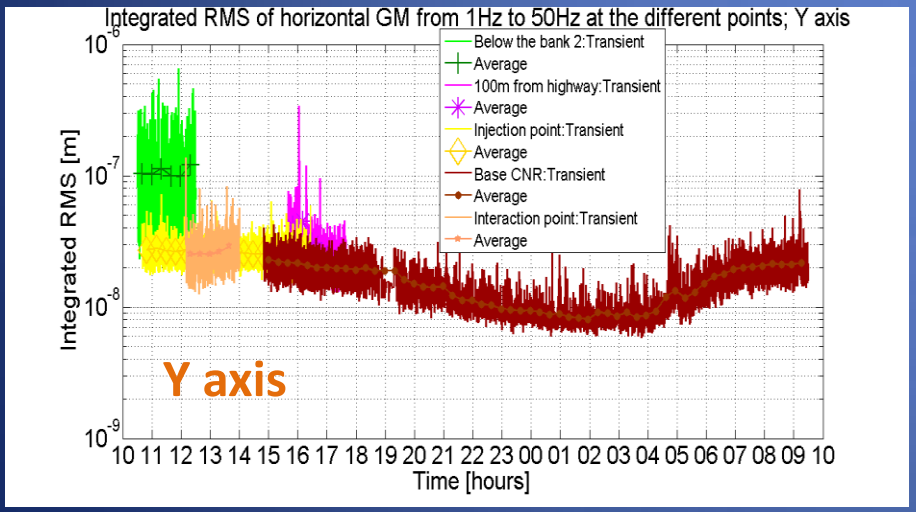


- Same remark than in the previous slide
- Amplitude of the traffic peak has a big impact on the amplitude of the whole bandwidth of measurement

Integrated RMS of ground motion from 1Hz







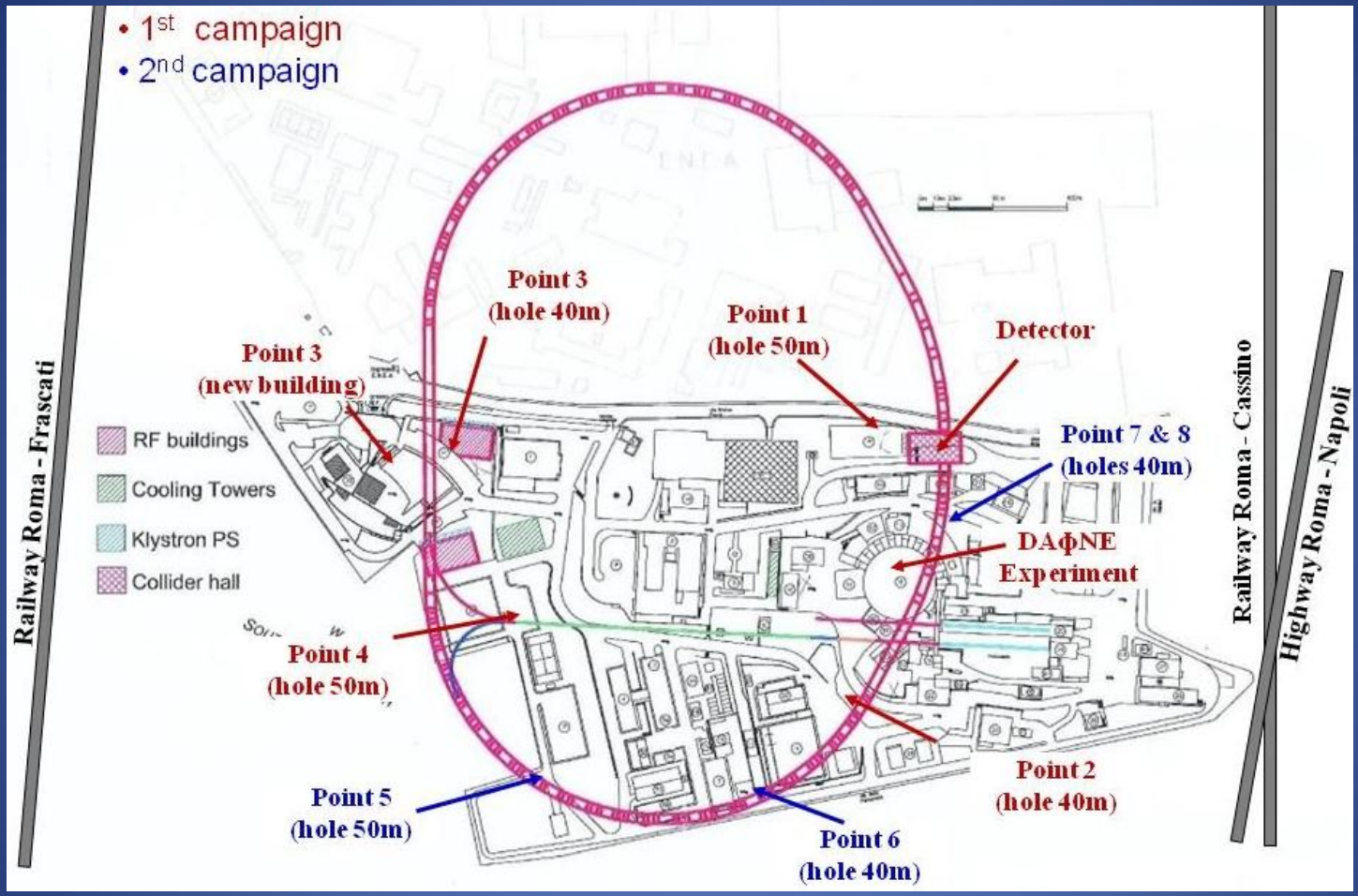
N.B.: from 2Hz to 50Hz in X for « Below the tank 2 »

- Amplitude on the whole bandwidth of measurements (and on the bandwidth of the traffic peak) decreases with the distance from the highway

- Amplitude of vibrations becomes very low at 100m from the highway (point 3) and is almost the same than the other points which are further than the point 3

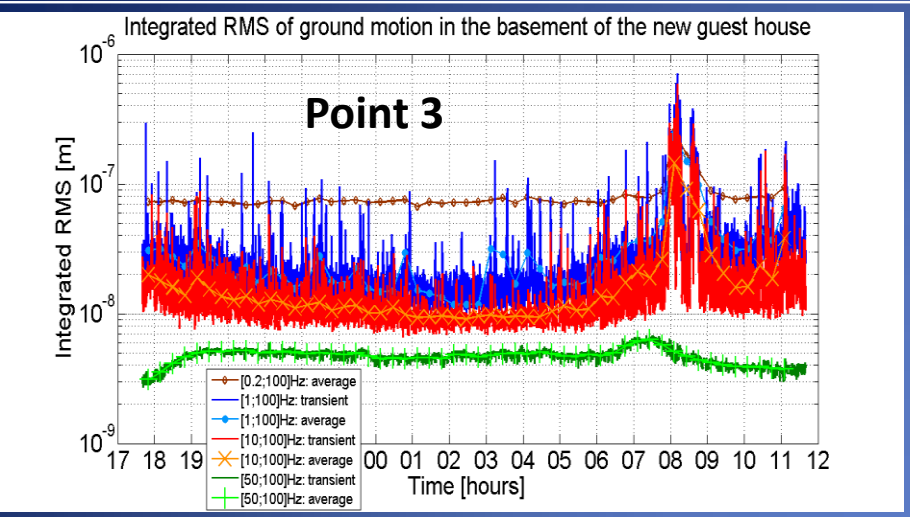
10. Comparison with INFN site

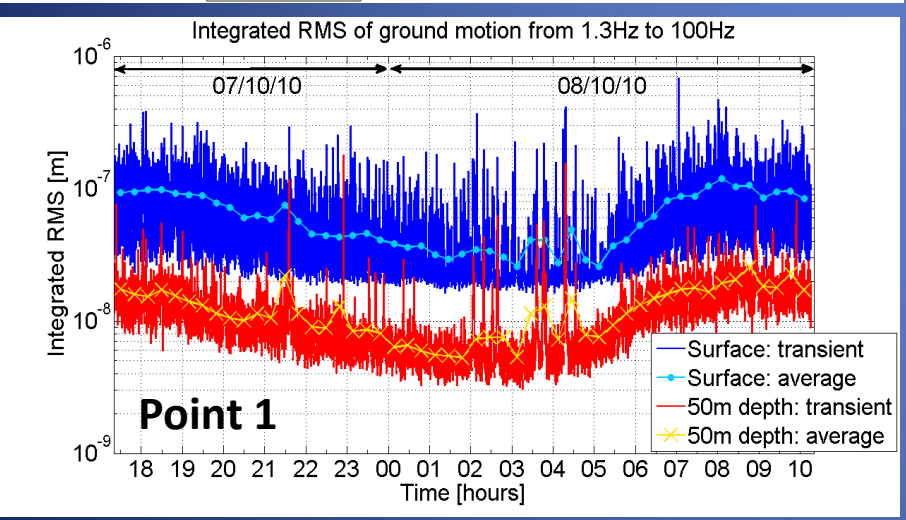
Measurement points done at INFN



- ✓ Point 1, Point 3 and Daphne experiment: Long term measurements performed
- ✓ Points 1 and 3: Near a main road where there is much traffic and near a power plant
- ✓ Daphne experiment: far from main roads

Integrated RMS of vertical ground motion





- ✓ Due to traffic observed in the frequency range [3; 30]Hz, it increases up to :
  - 240nm (Average of 20')
  - 700 nm (Transient of 6s)

- ✓ Evolution of amplitude with cultural noise (day and night):
  - From 30nm to 100nm in average
  - Up to 400nm in transient

- ➢ INFN site: too close to main roads and the floor does not damp vibrations like it does at the Tor Vergata site

  ➔ Vibrations can be huge in the INFN site during the day and especially during traffic time contrary to the Tor Vergata site

11. Conclusion

✓ Main source of vibrations of Tor Vergata Site: the highway

✓ However, vibrations well damped near the highway (just below the bank) thanks to the very soft floor of this site

✓ Moreover, the Super B will be built at a minimum of 100m from the highway where vibrations are very low

➔ In the 3 axes: Amplitude varies from 8nm to 30nm for all the points above 1Hz (and from 30nm to 60nm above 0.2Hz)

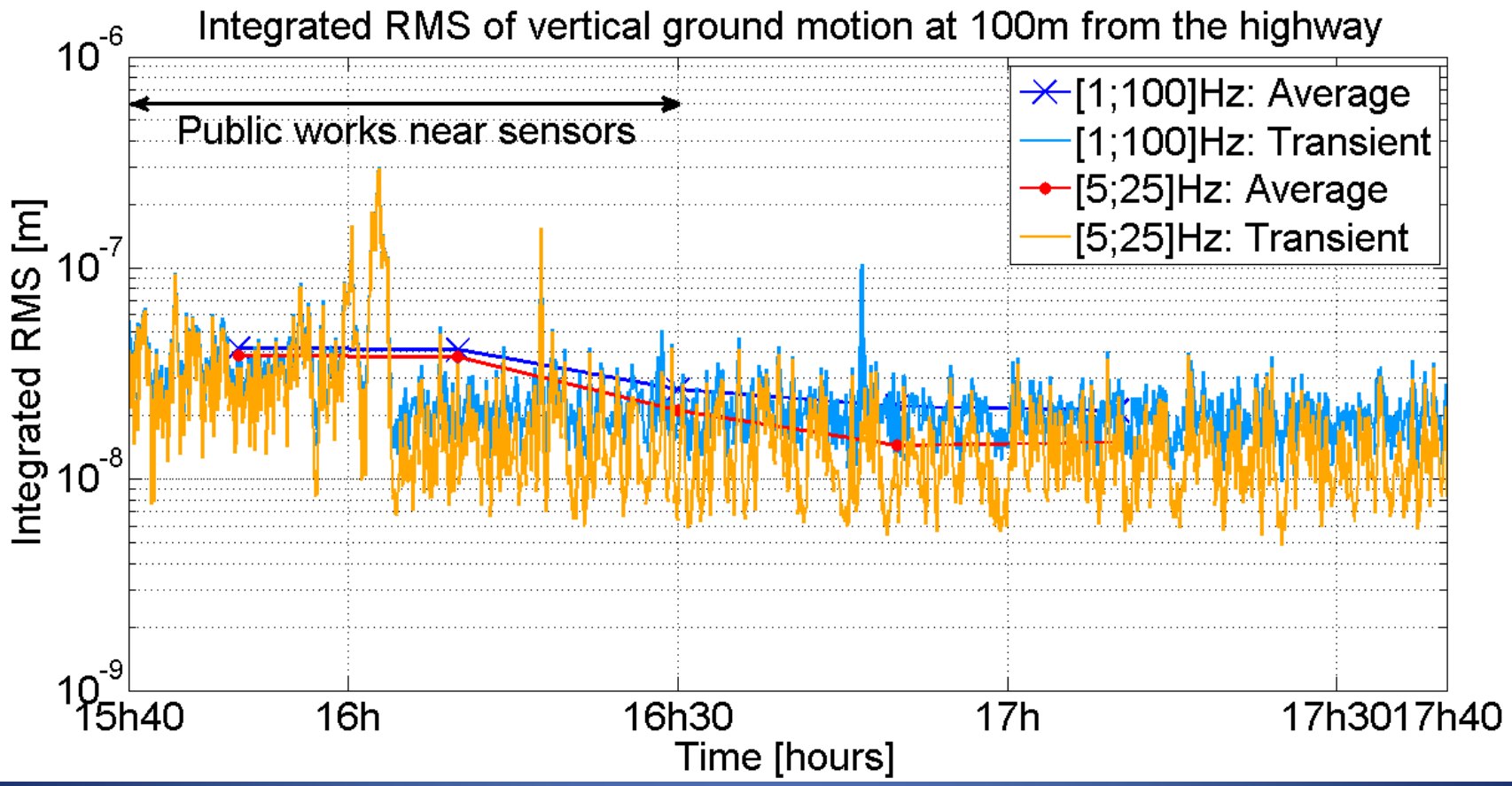
➔ For the interaction point: a road is planned to be made soon near this point but since there is also a high bank, vibrations should be well damped

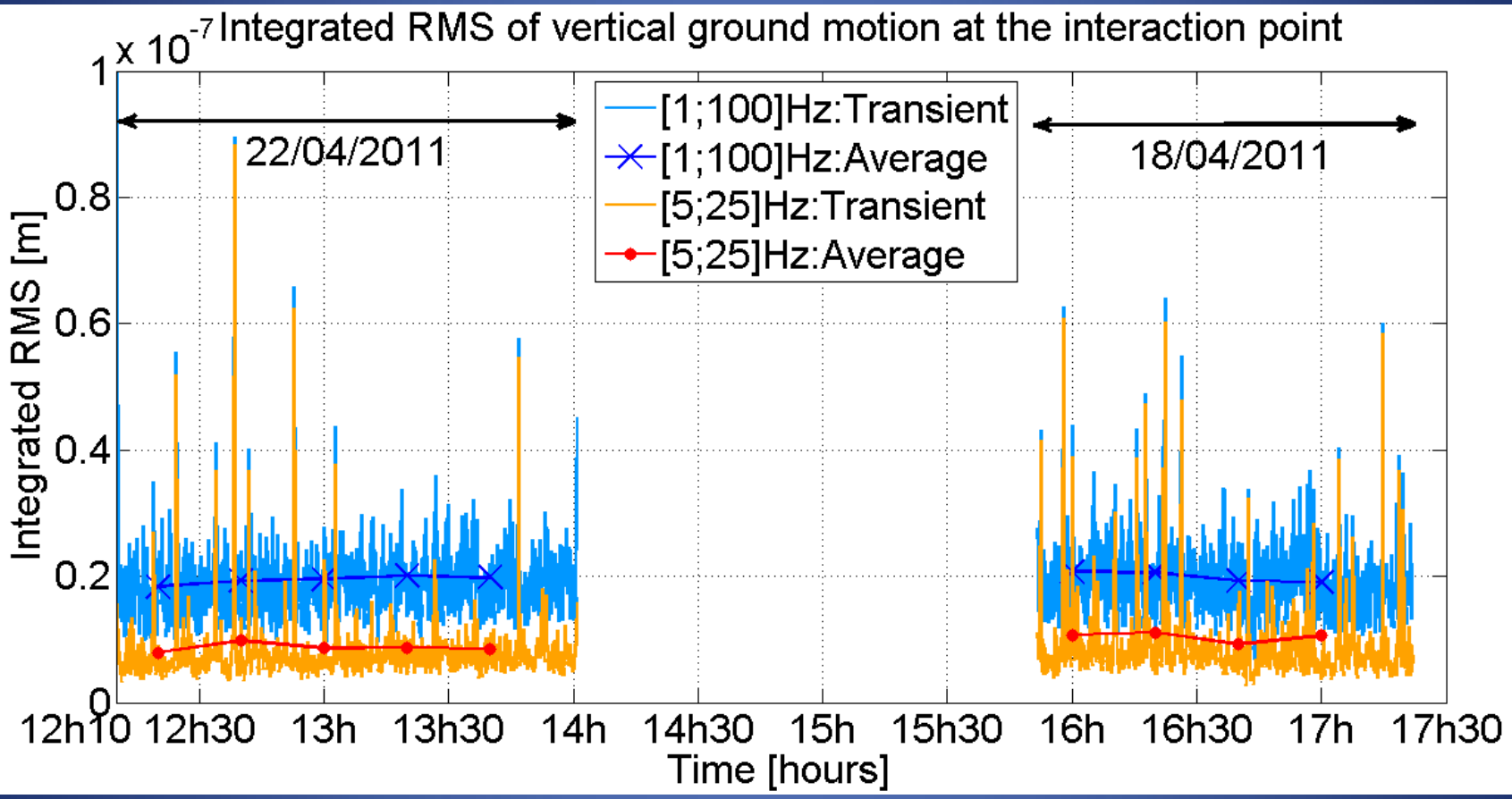
➢ INFN site: too close to main roads and the floor does not damp vibrations like it does at the Tor Vergata site

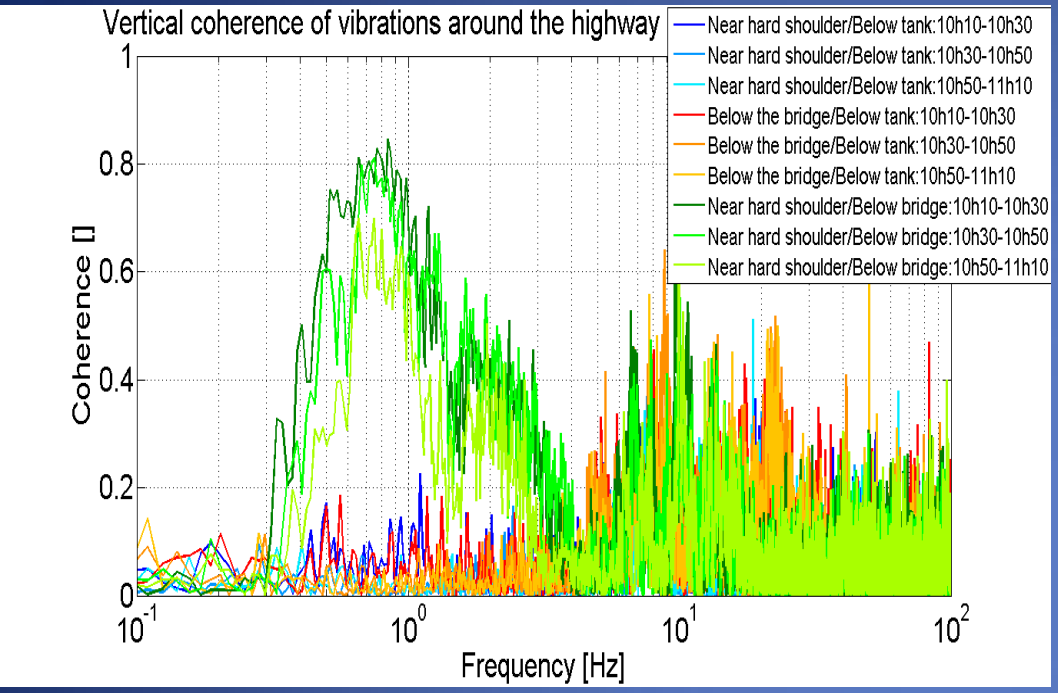
➔ Vibrations can be huge in the INFN site during the day and especially during traffic time contrary to the Tor Vergata site

➔ Tor Vergata seems to be a very good site for the Super B project compared to the INFN site where the only choice is to build a tunnel in underground

EXTRA SLIDES


Integrated RMS of vertical ground motion at 100m from the highway
Public works near sensors
[1;100]Hz: Average
[1;100]Hz: Transient
[5;25]Hz: Average
[5;25]Hz: Transient
Integrated RMS [m]
10-6
10-7
10-8
10-9
15h40
16h
16h30
17h
17h30
17h40
Time [hours]


Integrated RMS of vertical ground motion at the interaction point
x 10^-7
Integrated RMS [m]
1
0.8
0.6
0.4
0.2
0
22/04/2011
18/04/2011
[1;100]Hz:Transient
[1;100]Hz:Average
[5;25]Hz:Transient
[5;25]Hz:Average
12h10
12h30
13h
13h30
14h
14h30
15h
15h30
16h
16h30
17h
17h30
Time [hours]



- Quite good coherence between « hard shoulder » and « below the bridge » from 0.4Hz to 4Hz!! Confirm that the highway excites the floor in a large bandwidth and below 1Hz!! Very interesting!!
- Need to investigate more in details the vibrations below 1Hz thanks to sensor noise: will be done soon
- N.B: coherence is lost above 4Hz because of the distance only