ATF2 project:
Final Doublets support studies at LAPP

Laboratories in Annecy working on Vibration Stabilization

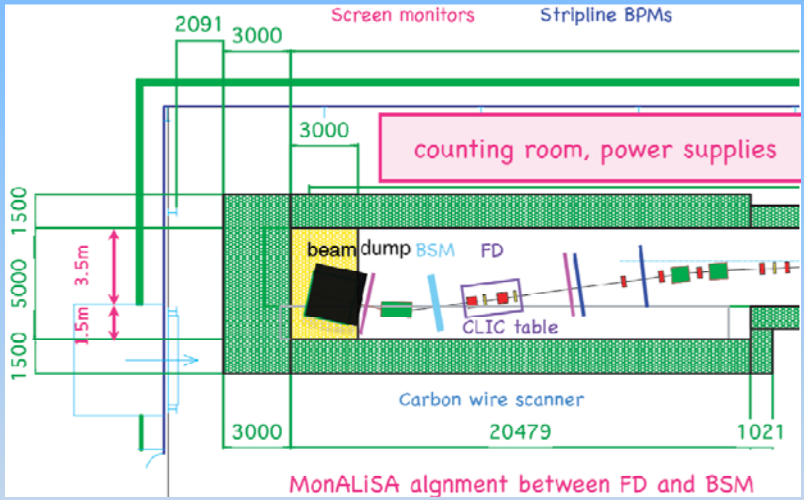
Benoit BOLZON Fourth ATF2 project meeting, DESY, 31 May 2007

Introduction : ATF2 constraint

✓ Beam-based feedback only **below 0.1Hz (repetition rate: 1Hz)**

➔ **Above 0.1Hz:** Relative vertical motion between the Shintake monitor and the last magnets < 6nm (Horizontal motions: tolerances of a factor 10 to 100 less strict)

✓ Final magnets and Shintake monitor separated by 4 m on 2 separate supports



✓ **ATF2 floor:** Ground motion coherence good up to a distance of 4-5m

✓ **Idea:** Shintake monitor and last magnets movement same than ground

→ Stiff supports well fixed to the floor

Candidate as stiff support

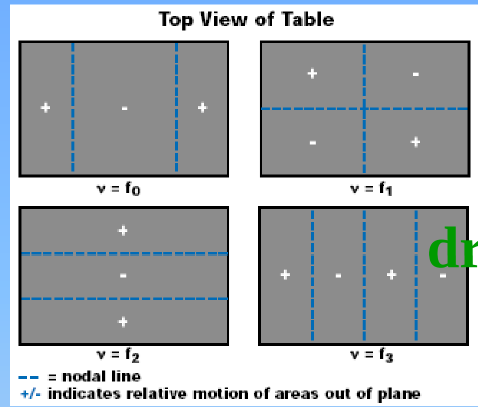
✓ **Candidates as stiff support for the last magnets (for large sizes)**

	Steel lightweight honeycomb table	Solid-composite laminate	Granite table
Stiffness	Very stiff	Very stiff	Very stiff
Amplification factor Q	High level of dry damping →Q~4	Moderate levels of damping	Low levels of damping→Q~460
Mounting to surfaces	Best for bolt-down mounting	Difficult to securely mount object to	No large number of mounting holes
Nonmagnetic properties	Nonmagnetic stainless steel	Ferromagnetic stainless steel	Yes
Weight	light	heavy	heavy
Thermal proper.	very good	good	bad
Cost	high	Very high	Very very high

→ Steel honeycomb table: Good candidate as a support for magnets

CLIC Honeycomb table characteristics

✓ **At LAPP: Steel honeycomb table from CERN with 2 characteristics measured by TMC Company in free configuration**

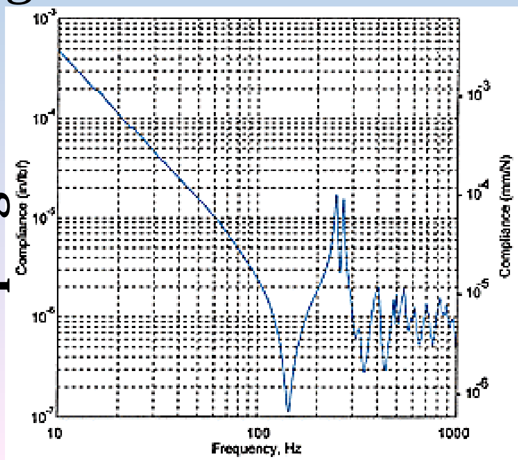


- **Minimum Resonant Frequency**: 230Hz
- **Maximum factor Q**: 1.5 **(Table with maximum dry damping level available at TMC Company)**

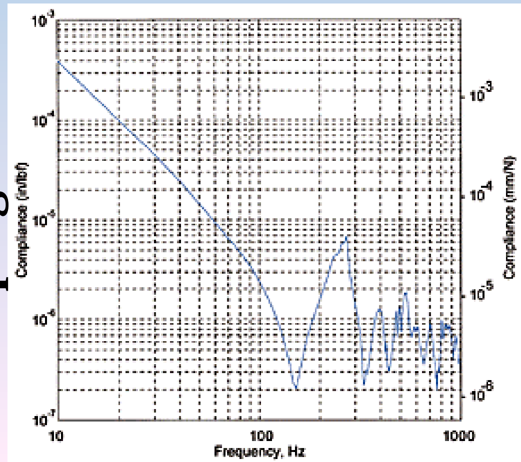
✓ **Compliance curve measurement:** impact testing hammer / accelerometer

✓ **Free configuration:** Table supported at four points by pneumatic isolators along the 2 nodal lines 22% from the ends of the table

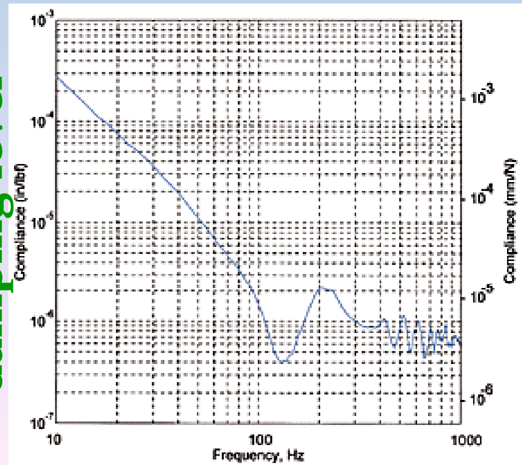
Nominal dry damping level



Standard dry damping level



Maximum dry damping level



Simulation: Idea of first eigenfrequency evolution with weight and boundary conditions

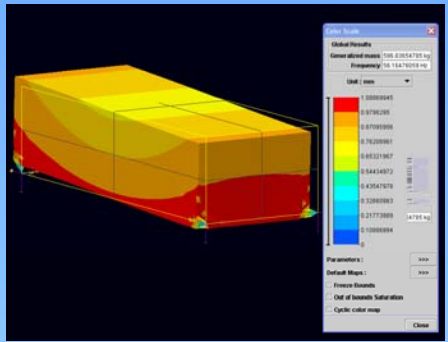
- ✓ **Fixation of this table to the ground to have the same motion**
  - ➢ **Fixed configuration: Eigenfrequencies not the same**
- ✓ **Weight of all magnets to be put on the table: 1400Kg**
  - ➢ **Fall of eigenfrequencies by comparison with no weight**
- ✓ **Idea of eigenfrequency change with weight / boundary conditions**

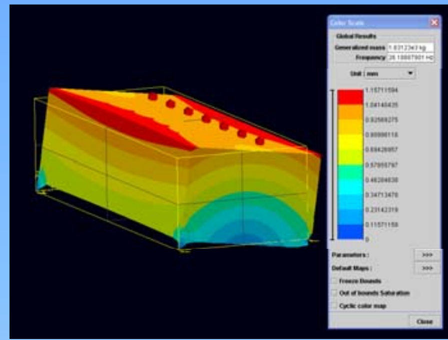
➔ **Simple block simulation done by Nicolas Geffroy:**

- ➢ Full block of the table dimensions (240*90*60cm)
- ➢ Calculation of the density to obtain the table weight (700kg)
- ➢ Young modulus chosen (rigidity) to obtain the first eigenfrequency of the table in free configuration (230Hz)

Simulation: Idea of first eigenfrequency evolution with weight and boundary conditions

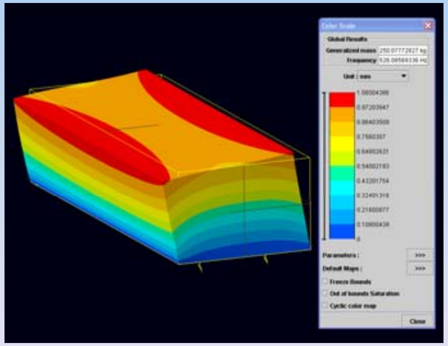
✓ **Boundary conditions:** table put on / fixed to 4 rigid supports at its corners

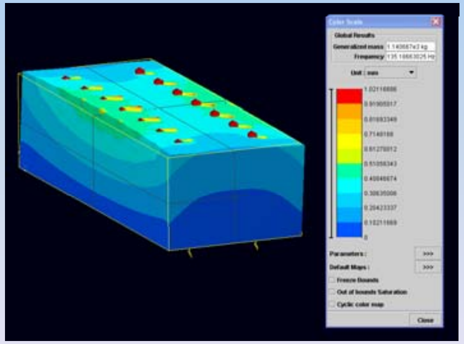




- ➢ **Without any masses: 56.2Hz**
  → Well lower than in free configuration!
- ➢ **With masses: 26.2Hz**
  → Fall of the eigenfrequency

✓ **Boundary conditions:** table fixed directly to the floor on 1 entire side





- ➢ **Without any masses: 526.1Hz**
  → Well higher than in free configuration!
- ➢ **With masses: 135.2Hz**
  → Fall of the eigenfrequency but still enough high

Measurements outline

✓ **First test:** Vibration measurements done with table put on 4 rigid supports (quick and easy!)

→ **Goal:**

- Table vibratory behavior understanding and comparison with simulation
- Idea of relative motion value compared to tolerances fixed

✓ **Vertical vibration transmissibility study between table and floor with and without any masses of 1400Kg**

→ Coherence calculation between table and floor

→ Table transfer function calculation

✓ **Expected relative motion between table and floor at ATF Ring with and wihout any masses of 1400Kg**

Experimental set-up

✓ Simultaneous measurement acquisition of the 5 sensors with/without masses

Table with no masses

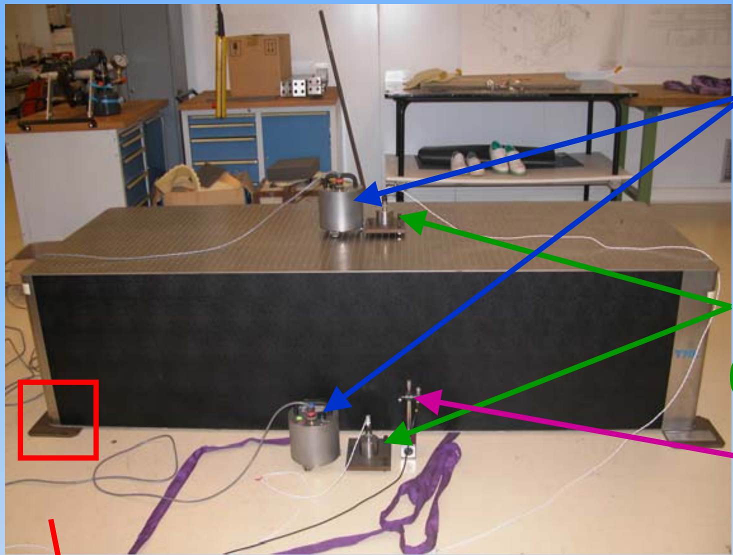
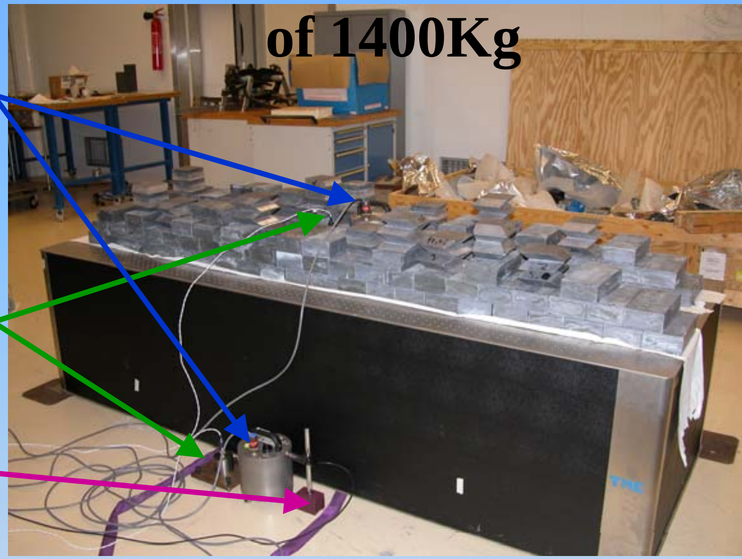


Table with lead masses of 1400Kg

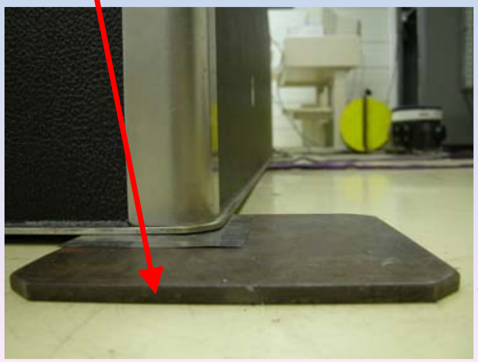


Guralp velocity sensors (0.033Hz-40Hz)

ENDEVCO accelerometers (40Hz to 100Hz)

Microphones

Sensors put on middle of table where vibrations biggest at first eigenfrequency



✓ 4 high steel supports (thickness precision: 0.1mm) at corners

✓ Ground not perfectly flat: One spacer of 0.1mm at one corner

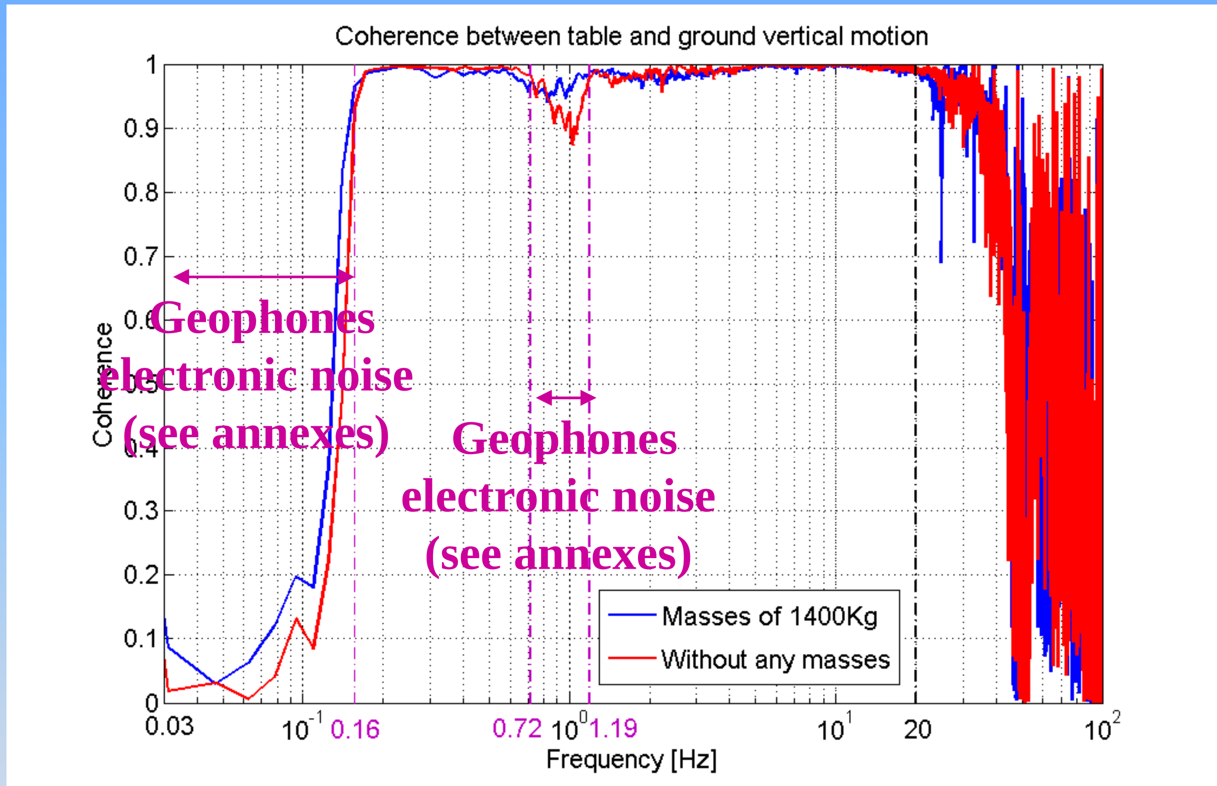
→ **May not be sufficient:** gap of **1um** can impair vibrations transmissibility between table and floor

Vibrations transmissibility study between table and floor

- ✓ Coherence calculation between table and floor
- ✓ Table transfer function calculation

Vibrations transmissibility study between table and floor

✓ **Coherence between table and floor motion:**



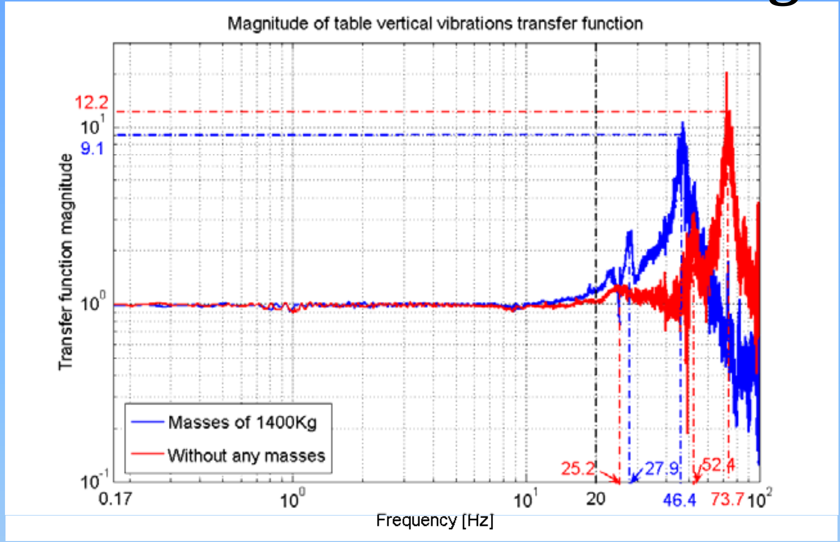
✓ **Up to 20Hz :** Coherence around 1 **but above 20Hz:** Fall down of coherence

➢ **May be due to non linear vibrations transmissibility: supports not fixed to the table and to the ground**

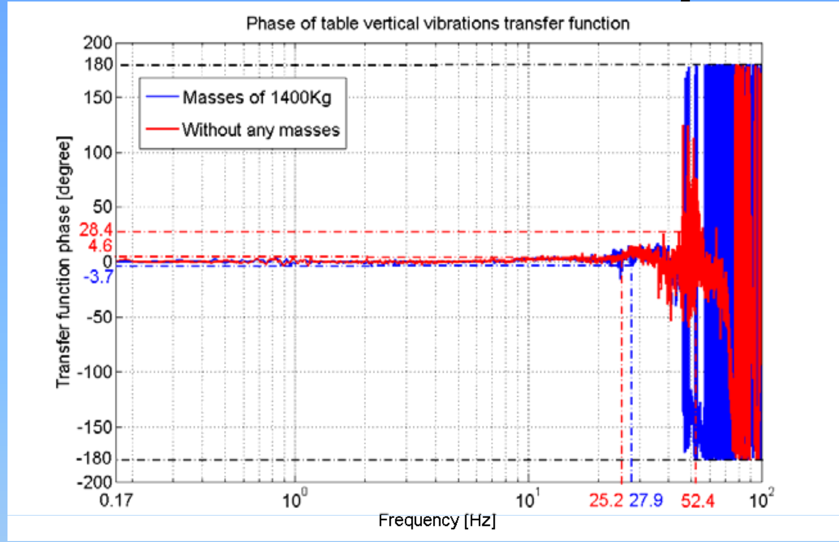
➢ **And may be due to the table eigenfrequencies**

Vibrations transmissibility study between table and floor

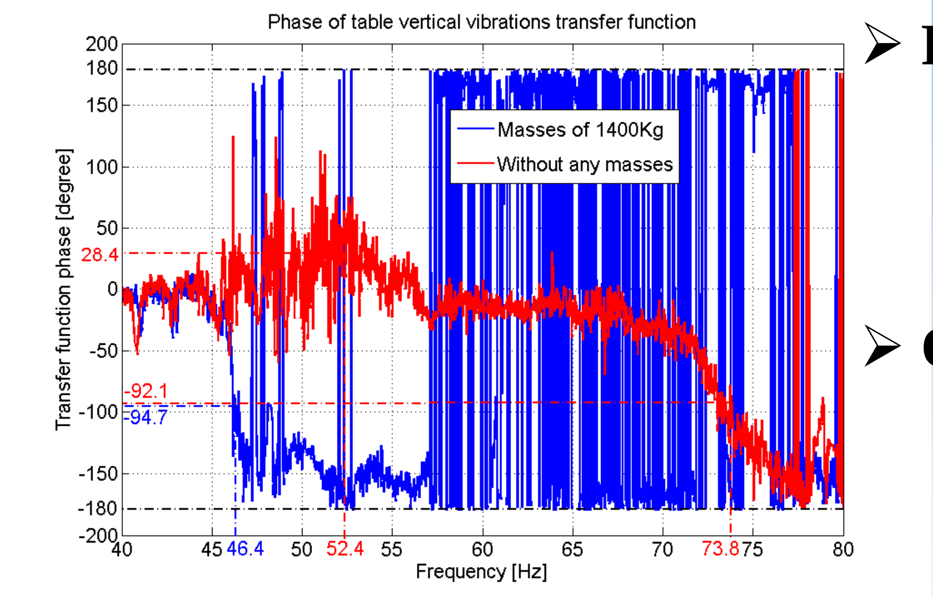
✓Table transfer function magnitude



✓Table transfer function phase



✓Table transfer function phase (zoom)



- ➢ **First eigenfrequency: phases of 90°**
  - **- Masses: 46Hz (Factor Q=9)**
  - **- No masses: 74Hz (Factor Q=12)**
- ➢ **Other peaks: not eigenfrequencies**
  - **- Masses: 28Hz**
  - **- No masses: 25Hz, 52Hz**

SUMMARY: Vibrations transmissibility study

✓ **First eigenfrequency measured:**

➢ **With no masses: 74Hz (Q=12)**

➢ **Masses of 1400Kg: 46Hz (Q=9)**

✓ **First eigenfrequency simulated:**

➢ With no masses: 56Hz

➢ Masses of 1400Kg: 26Hz

➔ **Simulations done: give a good idea of eigenfrequency evolution with masses and boundary conditions**

✓ **Other table transfer function peaks:**

➢ With no masses: 25Hz and 52Hz

➢ With masses: 28Hz

Due to the fact that supports are not fixed to the table and to the ground

✓ **Factor Q of the lowest eigenfrequency without any masses:**

➢ **Free configuration: Q=1.5**

➢ **Table put on 4 supports: Q=9**

➔ **Q bigger than in free configuration (not the same mode shape)**

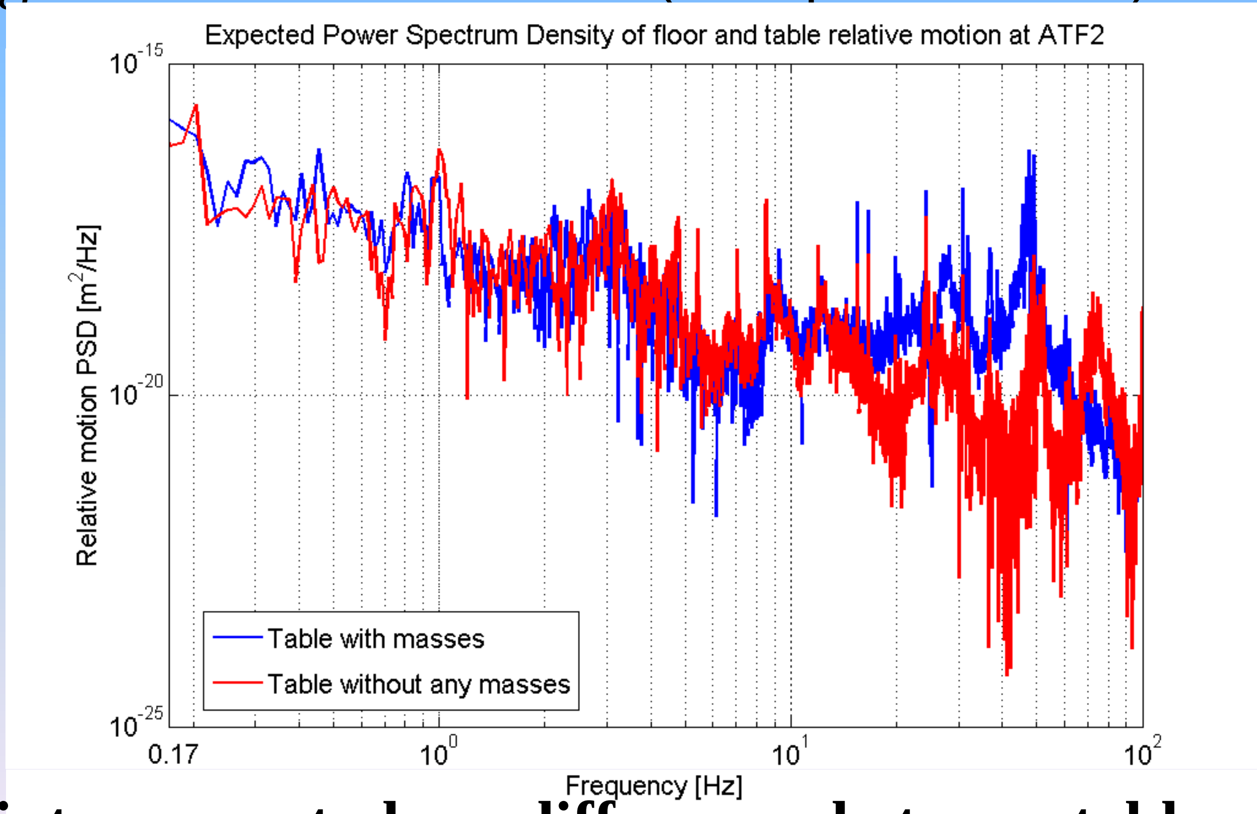
Expected relative motion between table and floor at ATF Ring

Relative motion between table and floor at ATF Ring

✓ **Power Spectrum Density (PSD) of relative motion at ATF Ring:**

= ATF floor displacement PSD * [1+Re(g)^2 - 2*Re(g) + Im(g)^2] with:

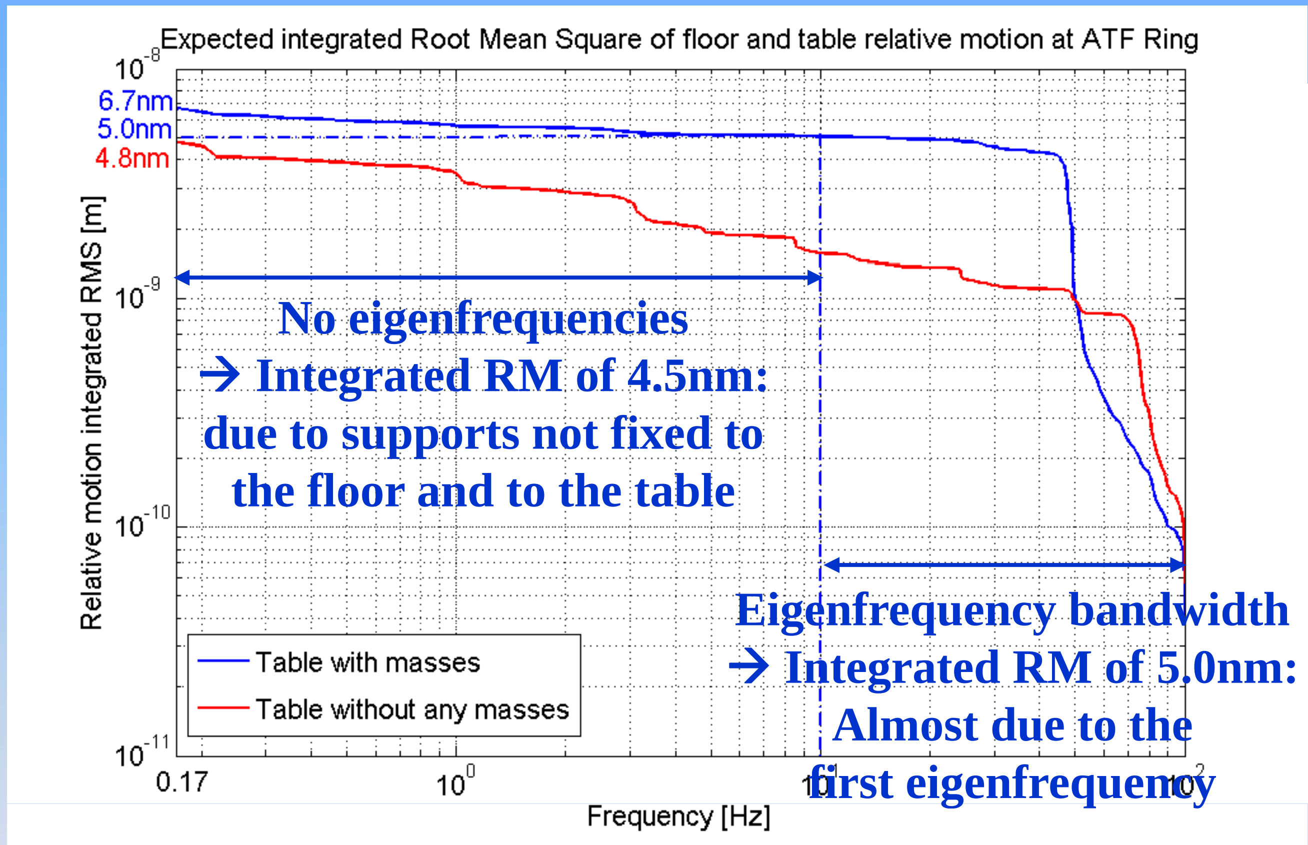
- g: Table transfer function (Complex number)



→ **Take into account phase differences between table and floor (see transfer function phase)**

Relative motion between table and floor at ATF Ring

✓ **Integrated Root Mean Square of relative motion at ATF Ring:**



➢ **Integrated RMS of relative motion with masses of 1400Kg:**

- From 0.17Hz to 100Hz: 6.7nm → Above ATF2 tolerances (6nm)!!

- From 10Hz to 100Hz (first eigenfrequency bandwidth): 5.0nm→ Tight

Conclusion

✓ **Integrated RMS of relative motion above 0.17Hz with 1400Kg:**

- **Table just put on 4 supports:** 6.7nm→ Slighty above ATF2 tolerances
- **If the 4 supports perfectly fixed to the floor and to the table:**

→ Relative motion: only due to the first eigenfrequency at 46Hz **(Q=9)**

→ Relative motion of 5nm: too close to tolerances because of imperfect fixations and of magnet resonances which may add relative motion

➔ Change of table boundary conditions to have a higher first eigenfrequency: table fixed directly to the floor on 1 entire side

1400Kg on table

- **First eigenfrequency simulation: 135Hz**
- **Factor Q should be well lower than 9**

⇨ **Relative motion should be well below tolerances**

✓ **Candidate to fix the table directly to the floor: concrete polymer**

→ Very good vibrations transmissibility and better than fixing structures with bolts (see R.Sugahara presentation done the Feb. 3 - 5, 2006)

ANNEXES

Experimental set-up

Sensors	Guralp CMG-40T	ENDEVCO86
Measurement directions	X, Y, Z	Z
Sensitivity	2000V/m/s	10V/g
Frequency range	[0.033–50]Hz	[0.01–100]Hz
Quantity	2	2

✓ **Limitation of the measurement:**

➢ **Guralp sensors:**

- **From 0.033Hz:** Frequency response not flat below
- **To 50Hz:** Frequency response not flat above

➢ **ENDEVCO sensors:**

- **From 10Hz:** Electronic noise to high below
- **To 100Hz:** Frequency response not flat above

Measurement analysis:

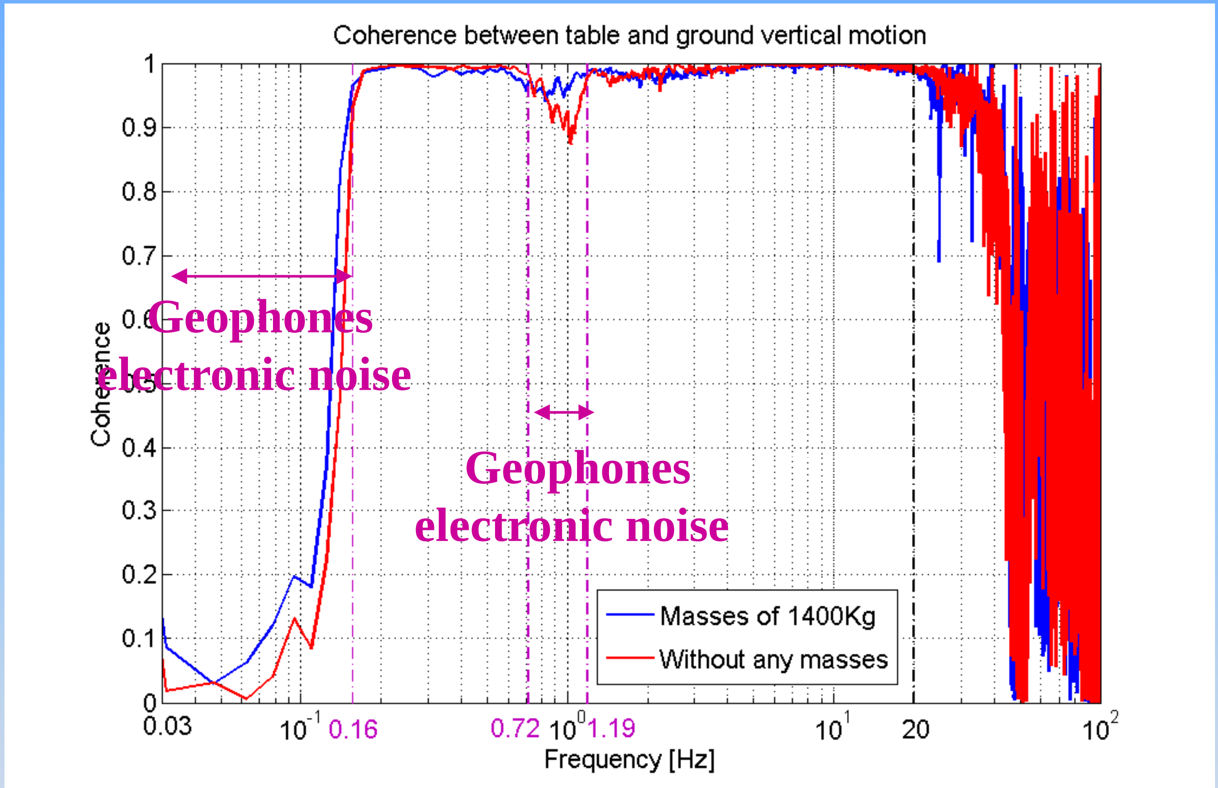
GURALP:
0.033Hz to 40Hz

ENDEVCO:
40Hz to 100Hz

✓ **Analysis: 50 averages done with an overlap of 66.67%; Window: Hanning**

Vibrations transmissibility study between table and floor

✓ **Coherence between table and floor vertical motion measured at LAPP:**



✓ **Up to 20Hz :** Coherence around 1 **but above 20Hz:** Fall down of coherence

➢ **May be due to non linear vibrations transmissibility: bad fixation of the supports to the table and to the ground**

➢ **And may be due to the table eigenfrequencies**

Vibrations transmissibility study between table and floor

- ✓ **Sensors noise estimation (Corrected difference calculation):**

  → Two sensors of the same model put side-by-side

$$PSD_c(f) = 2(1 - C(f))\sqrt{PSD_1(f)PSD_2(f)}$$

- ✓ **Environmental conditions:**

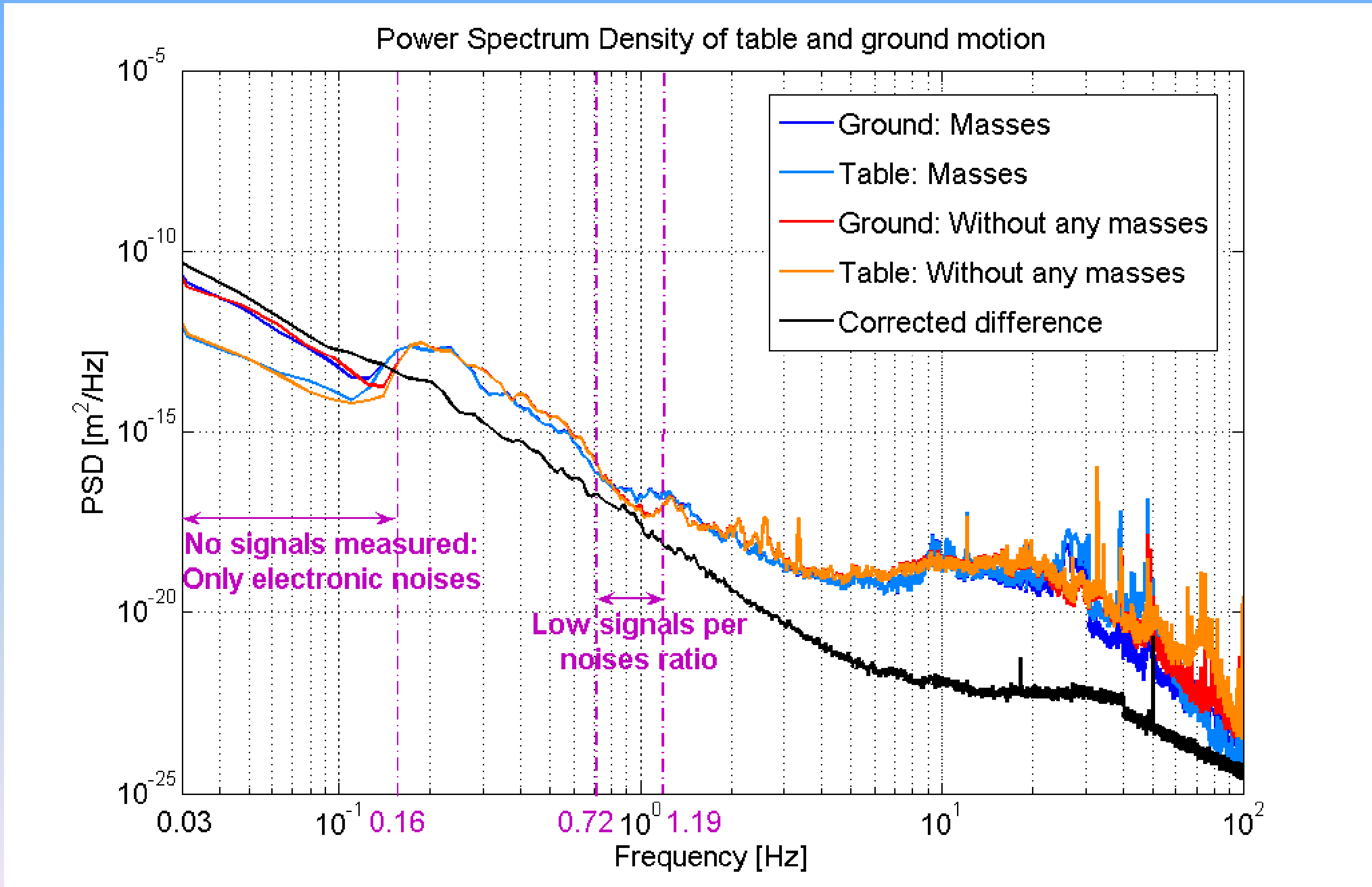
  1. Very low ground motion (coherence as low as possible: best estimation)
  2. Low-frequency noise: No fast temperature and pressure change in time

1. **Sensors on the CLIC active table / Measurements done the night / Shutdown of all computers / Acquisition system outside the room**

2. **Ventilation cut / Doors closed: 10 hours before measurements**

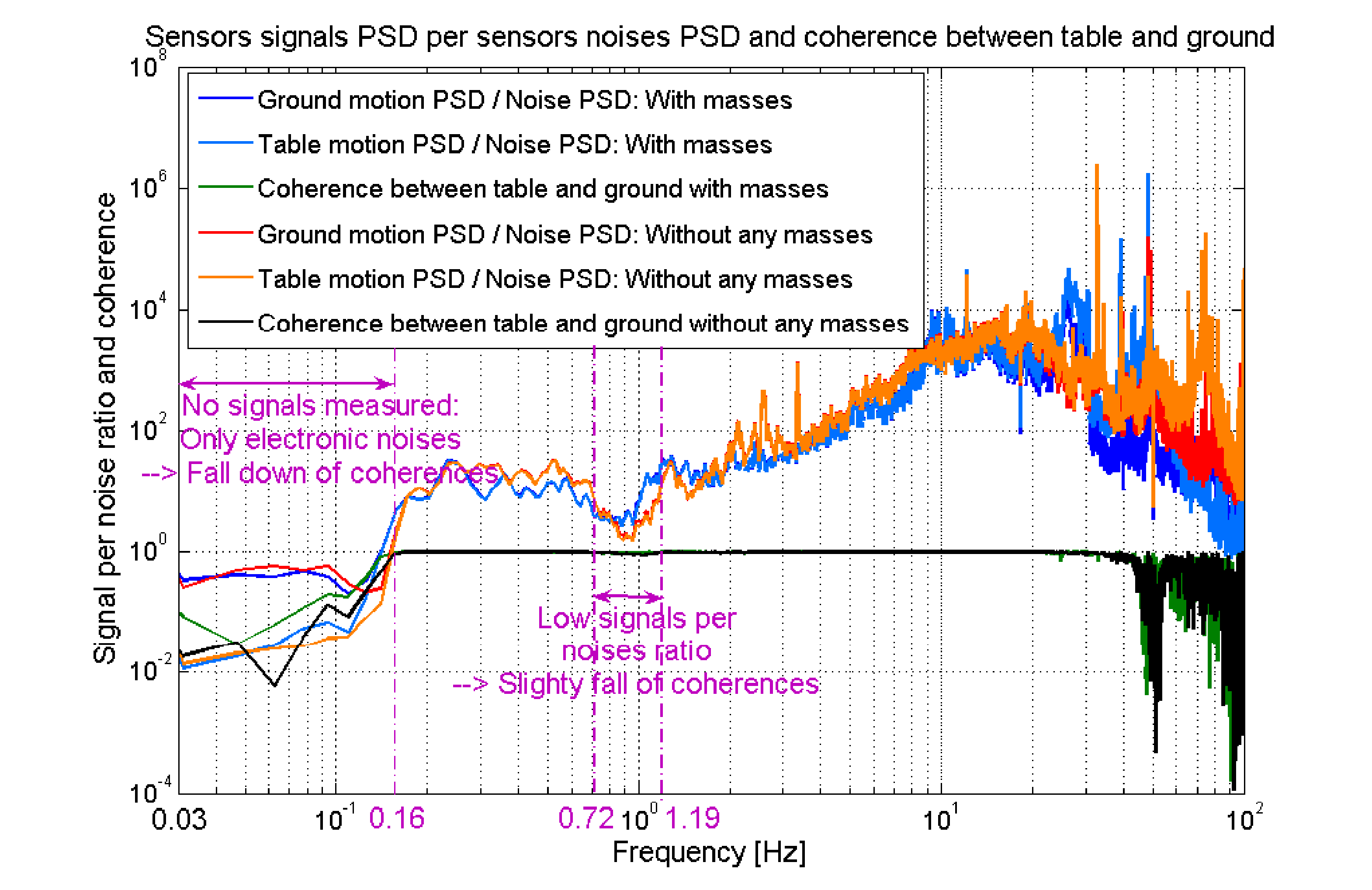
Vibrations transmissibility study between table and floor

✓ **Power Spectrum Density of floor motion and of sensors noise:**



Vibrations transmissibility study between table and floor

✓ **Floor motion PSD / Sensors noise PSD and the effect on coherence between table and ground vibrations:**



Experimental set-up for the compliance test

Sensors	Accelerometers model 4507B3	Hammer model 2302-10
Measurement direction	Uniaxial	/
Sensitivity	100mV/g	2.27mV/N
Frequency range	0.3 - 6 kHz	Max : 8KHz
Quantity	2	1

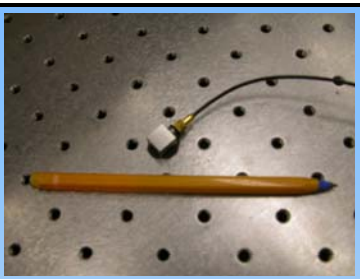
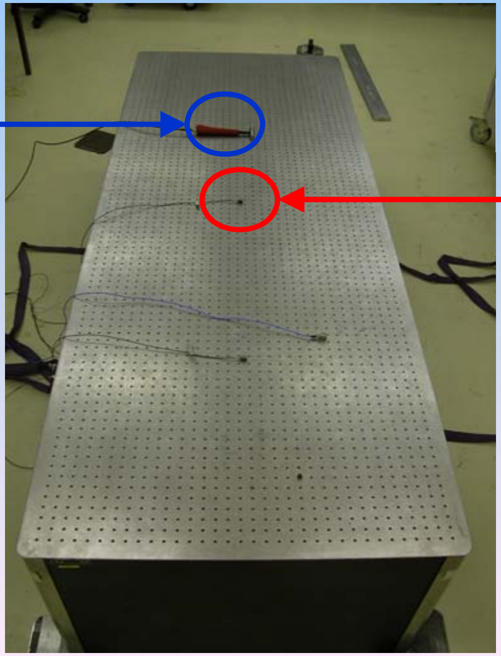


Table hit in this area



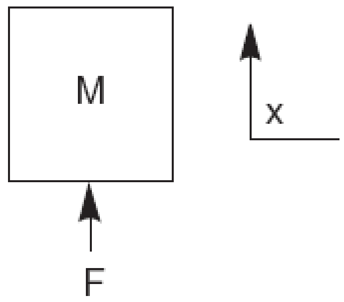
Sensors put on the middle of the table where vibrations are the biggest at the first eigenfrequency

20 averages done with a Hanning window and an overlap of 66.67%

Factor Q measurements with compliance curves

- ✓ **Slide done by R. Suguhara**

Compliance in case of ideal rigid body



Ideal free rigid model, Mx”=F

definition

$$C = \frac{|x|}{|F|}$$

C Compliance

$|F|$ Applied force

$|x|$ Displacement

$$x = x_0 \sin(\omega t)$$

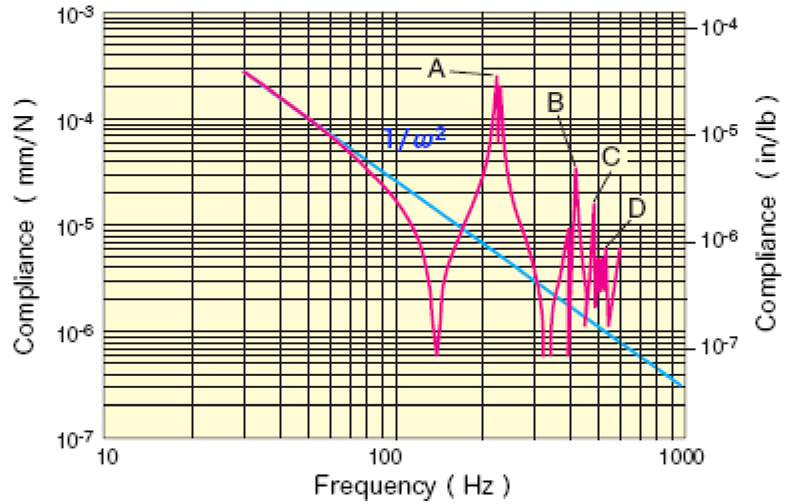
where $x_0 = -\dfrac{F}{M\omega^2}$

$$C = \frac{|x_0|}{|F_0|} = \frac{1}{M\omega^2}$$

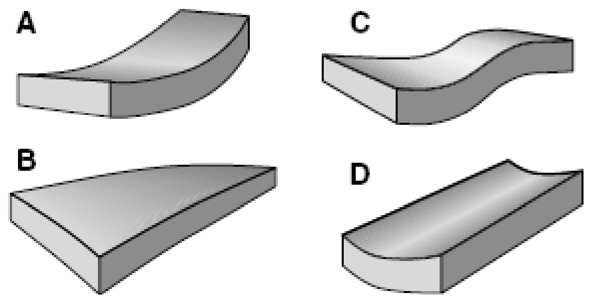
from Newport co. www.newport-japan.jp/pdf/vc_0852.pdf

Factor Q measurements with compliance curves

✓ **Slide done by R. Suguhara**



Typical compliance curve of table-top with no damping

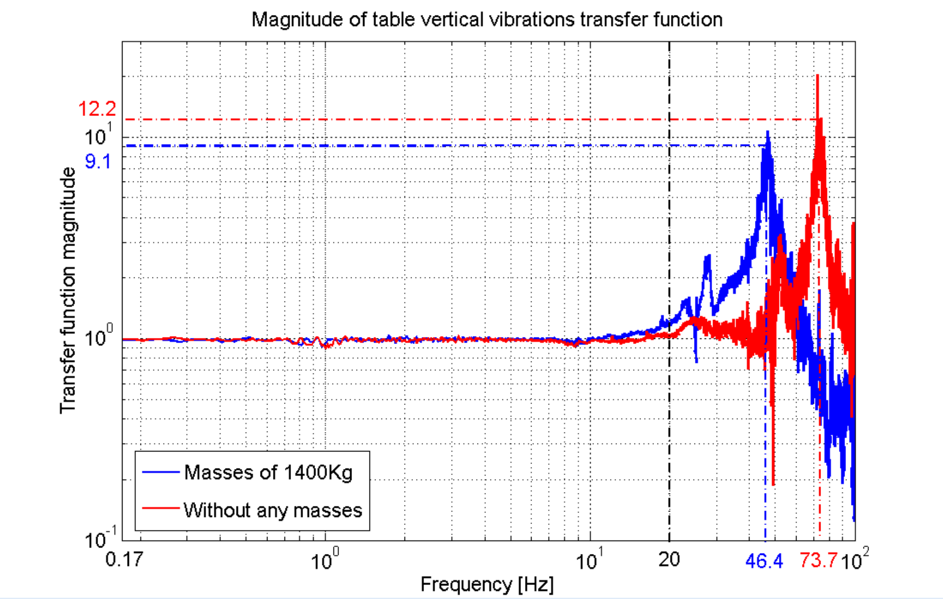


Vibration modes

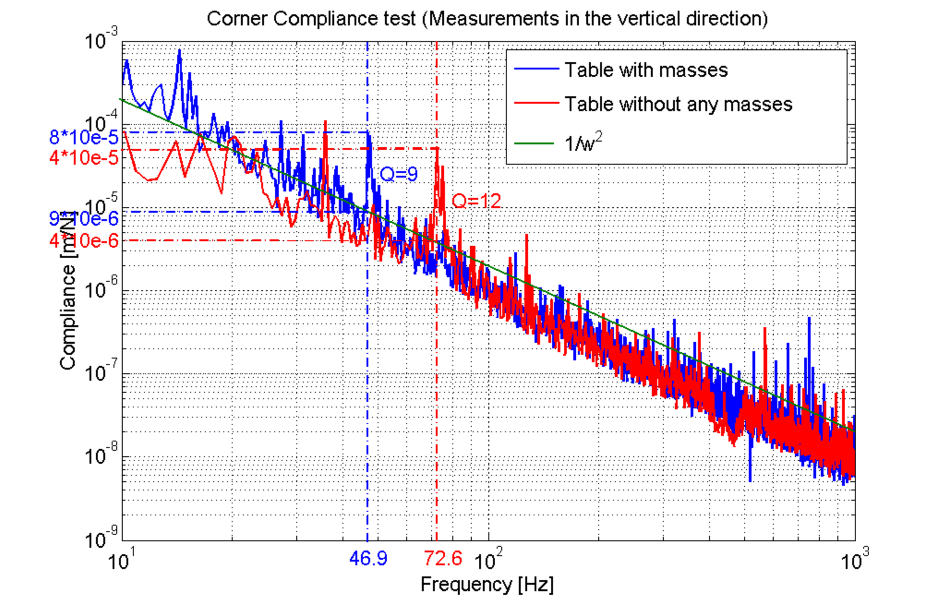
from Newport co. ,www.newport-japan.jp/pdf/vc_0852.pdf

Comparison transfer function / Compliance curve

✓ **Table transfer function magnitude**



✓ **Table compliance curve**



✓ **First eigenfrequency with and without masses: 47Hz with a factor Q=9 and 74Hz with a factor Q=12**

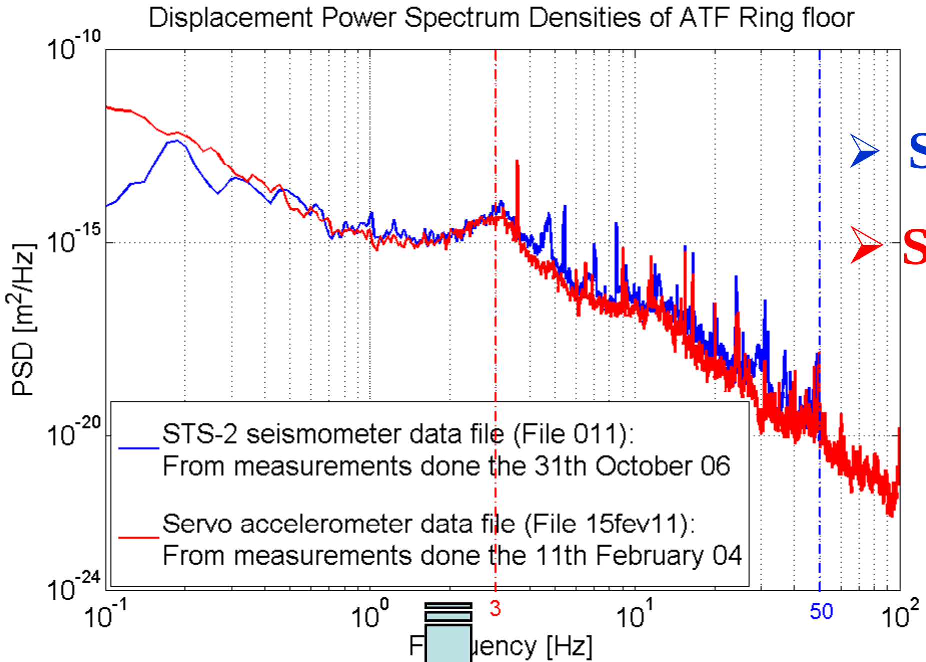
✓ **Other measured peaks with the transfer function magnitude:**

- With no masses: 25Hz and 52Hz
- With masses: 28Hz

Due to the fact that supports are not fixed to the table and to the ground

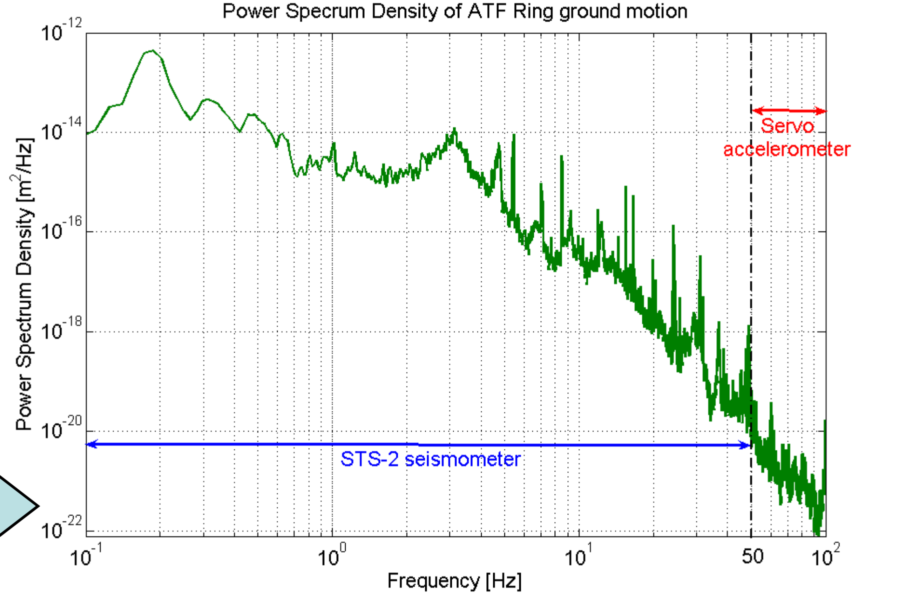
Expected floor and table vibrations at ATF Ring

- ✓ **Floor vibrations at ATF Ring: 2 data files from 2 types of sensors**
  - ➢ **STS-2 seismometer:** Good coherence from 0.1Hz to 50Hz
  - ➢ **Servo accelerometer:** Good coherence from 3Hz to 100Hz



ATF Ring floor vibrations data:

- ➢ **STS-2 seismometer: from 0.1Hz to 50Hz**
- ➢ **Servo accelerometer: from 50Hz to 100Hz**

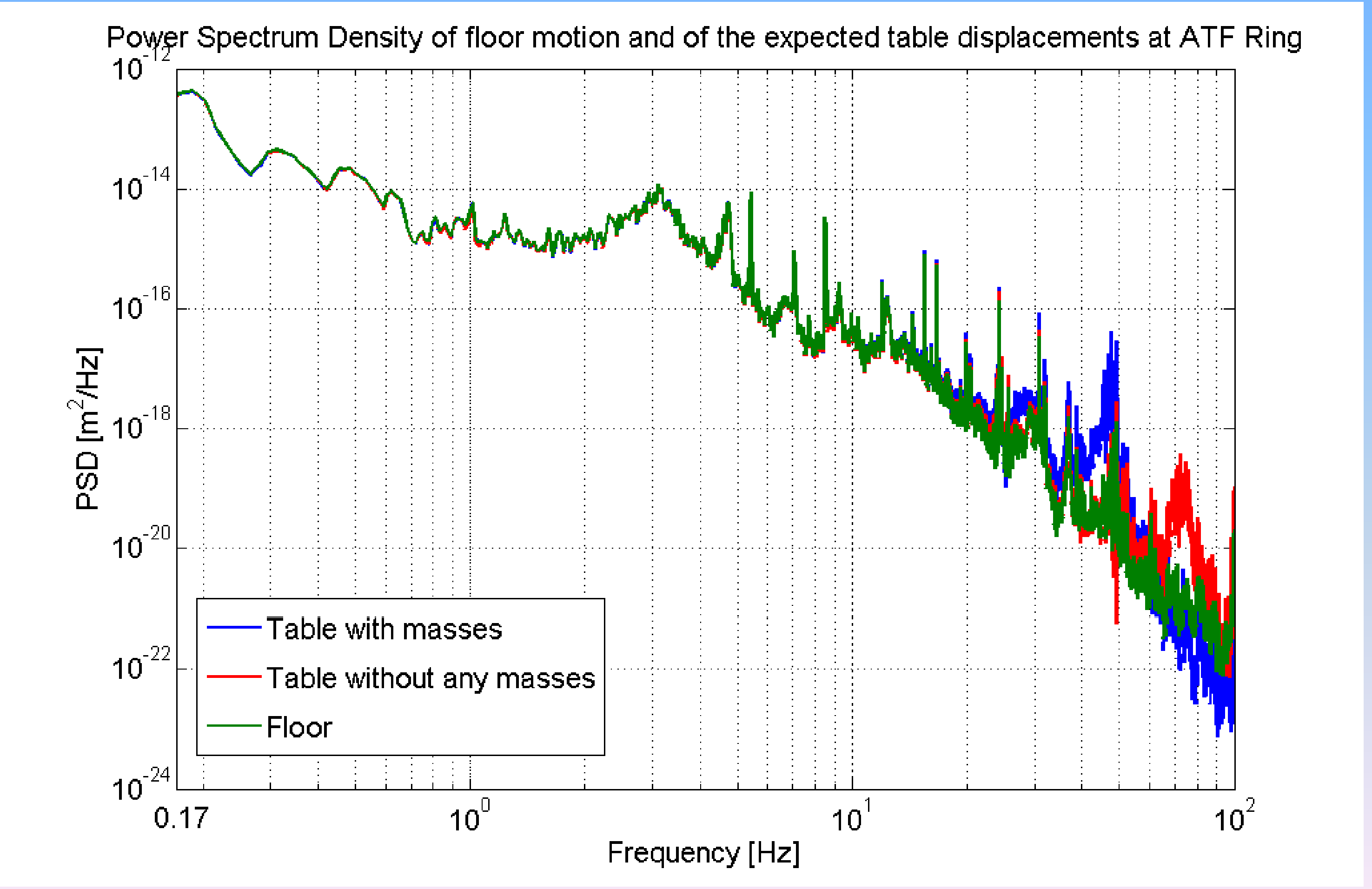


Ground motion quite the same

Expected floor and table vibrations at ATF Ring

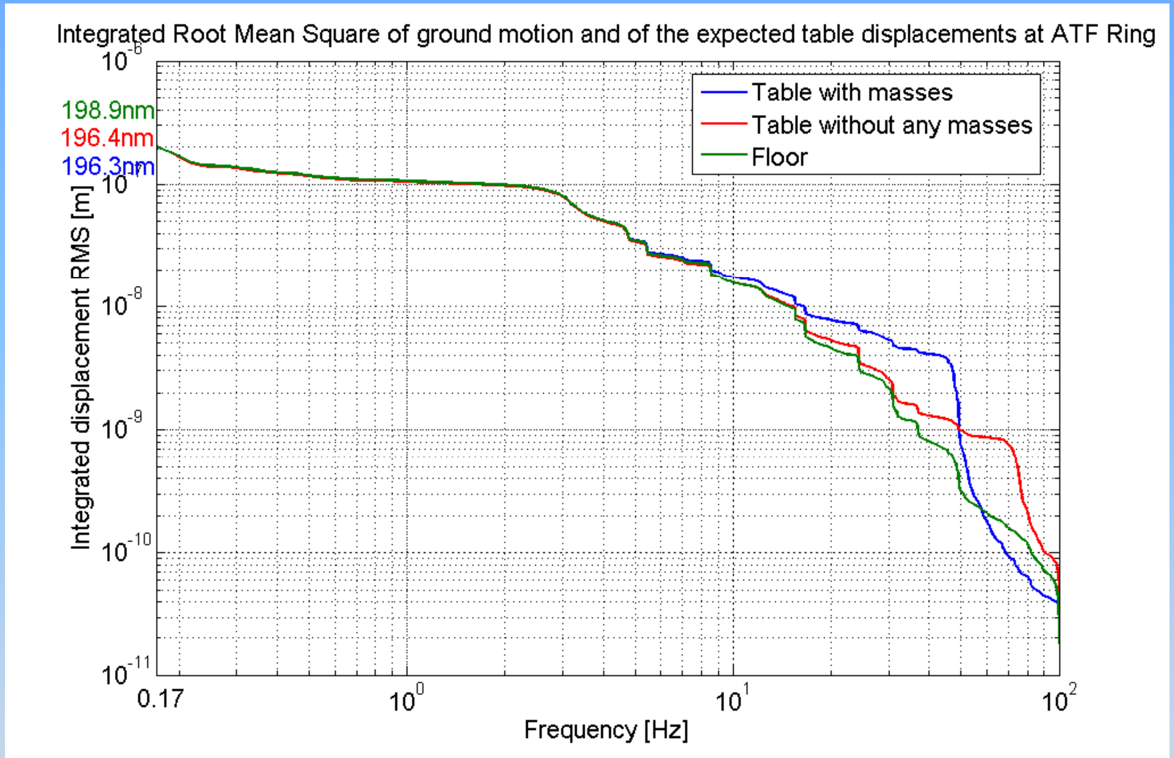
- ✓ **Displacement Power Spectrum Density (PSD) of the table at ATF**

= (Table transfer function magnitude)^2 *ATF floor displacement PSD



Expected floor and table vibrations at ATF Ring

✓ **Integrated displacement Root Mean Square at ATF Ring:**



✓ Difference of integrated displacement RMS from 0.1Hz to 100Hz

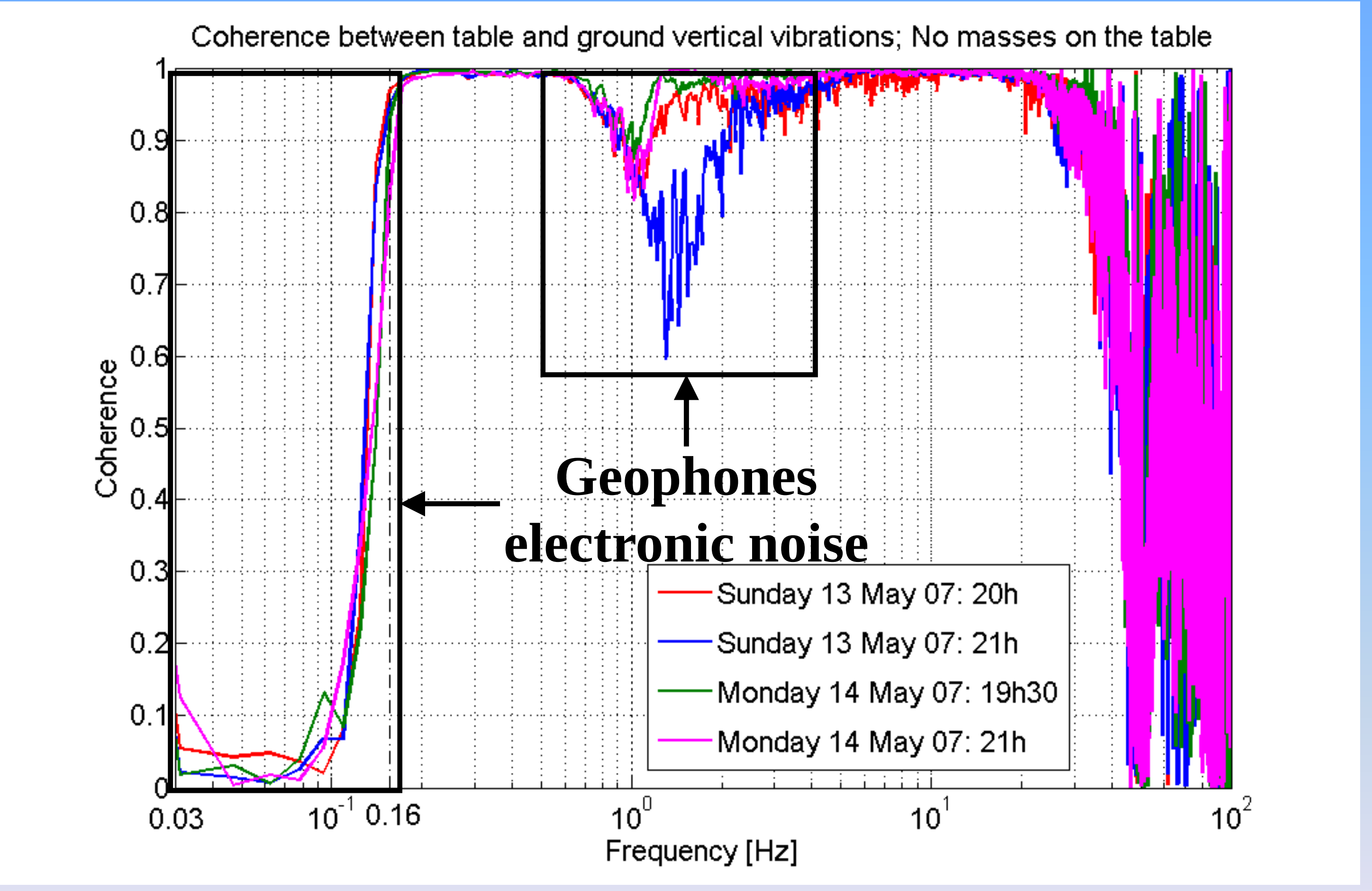
- ➢ With no masses: 2.5nm / With masses: 2.6nm → Below ATF tolerances!

✓ But phase differences between table and floor not taken into account

- ➢ Relative motion calculation to know the real difference of motion

No masses on the table: 4 measurements done

✓ **Coherence between table and floor:**

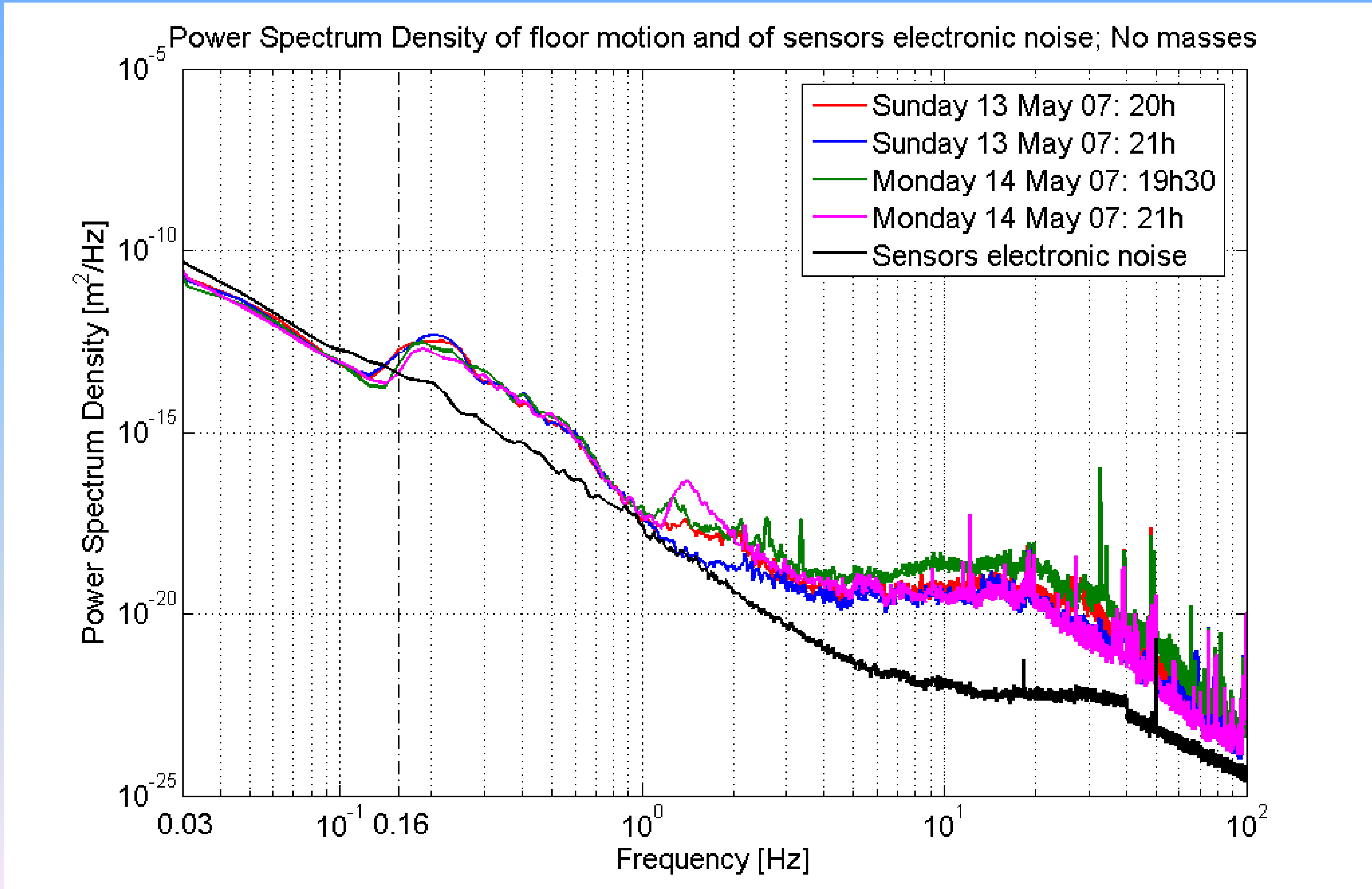


✓ **Measurements with lowest electronic noise:**

→ **Monday 14 May 07 at 19h30: Data taken for the analysis**

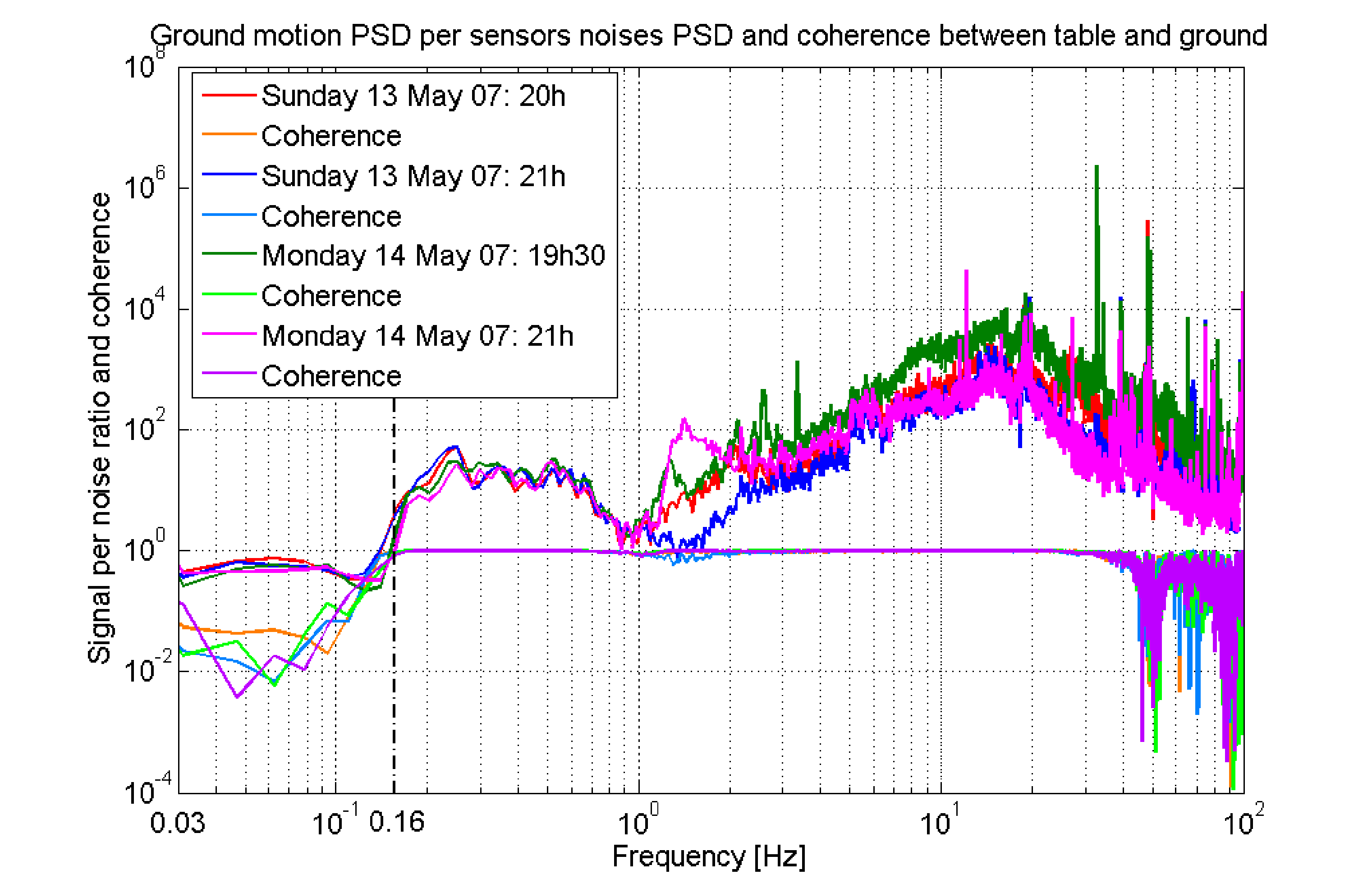
No masses on the table: 4 measurements done

- ✓ **Power Spectrum Density of floor motion and of sensors noise:**



No masses on the table: 4 measurements done

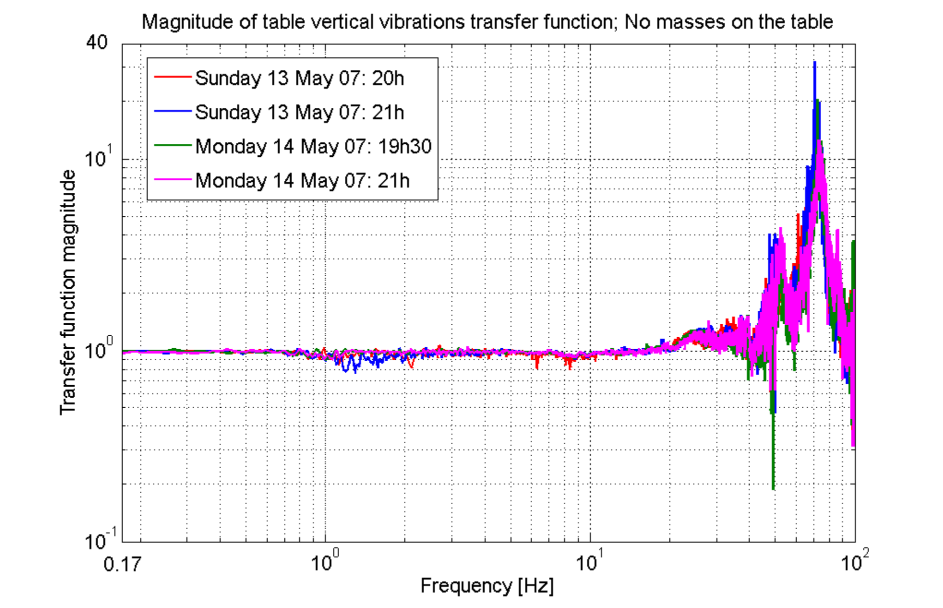
✓ **Floor motion PSD / Sensors noise PSD and the effect on coherence between table and ground vibrations:**

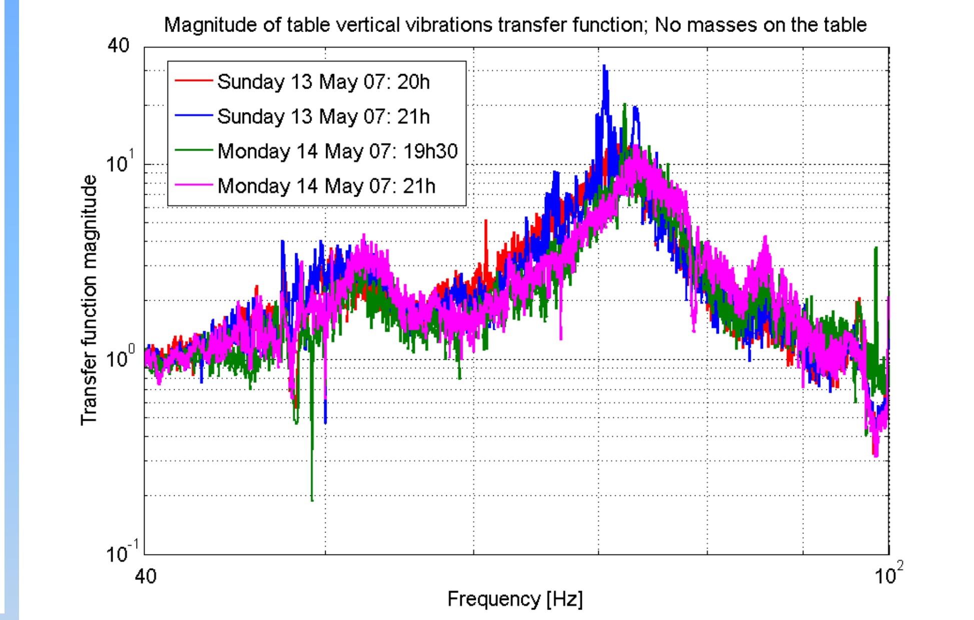


✓ **Low signal per noise ratio → Low coherence**

No masses on the table: 4 measurements done

✓ Table transfer function magnitude

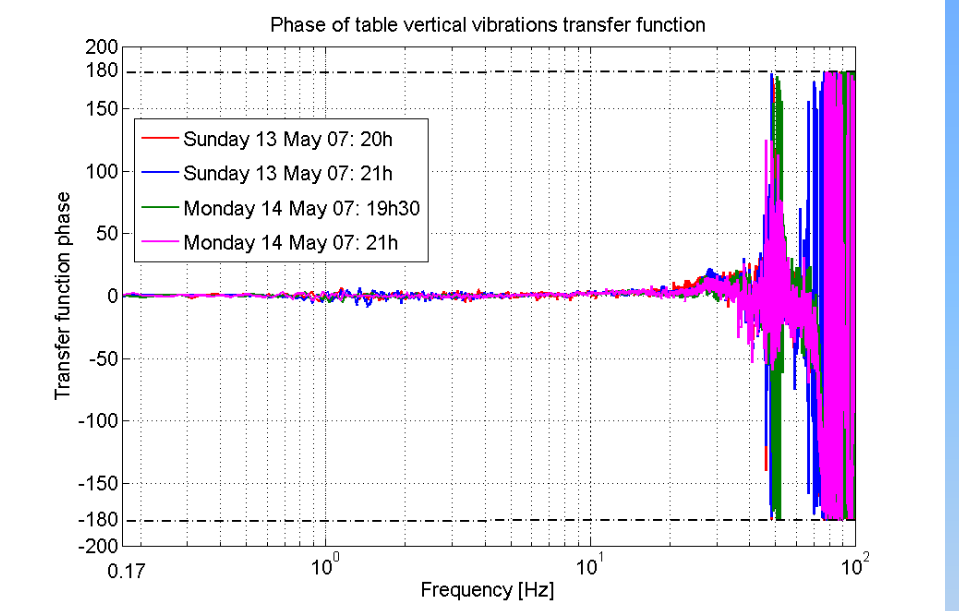


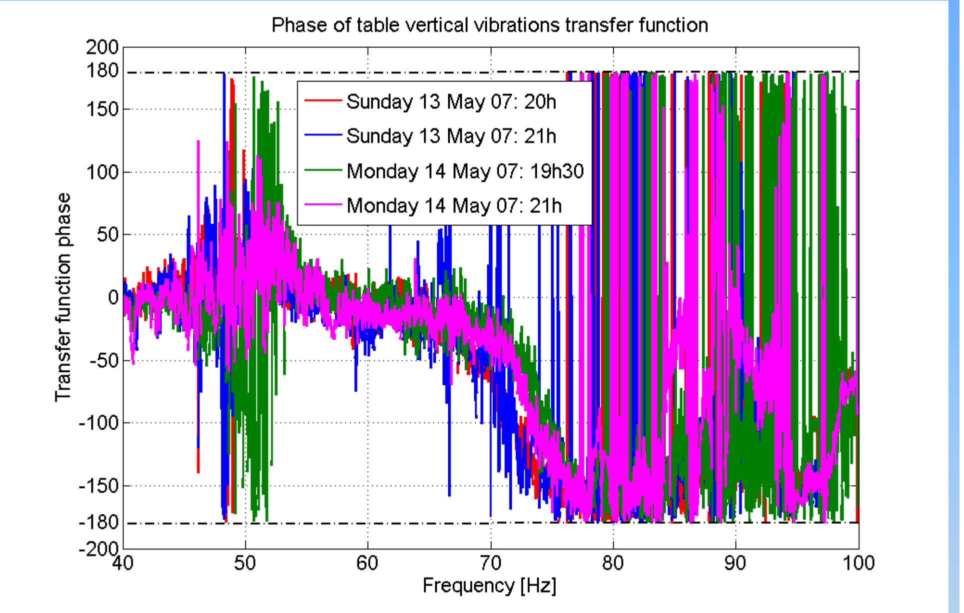


- **Good repetability of measurements**
  - → Same value of eigenfrequency (74Hz)
  - → Same factor Q of amplification at the eigenfrequency

No masses on the table: 4 measurements done

✓ Table transfer function phase



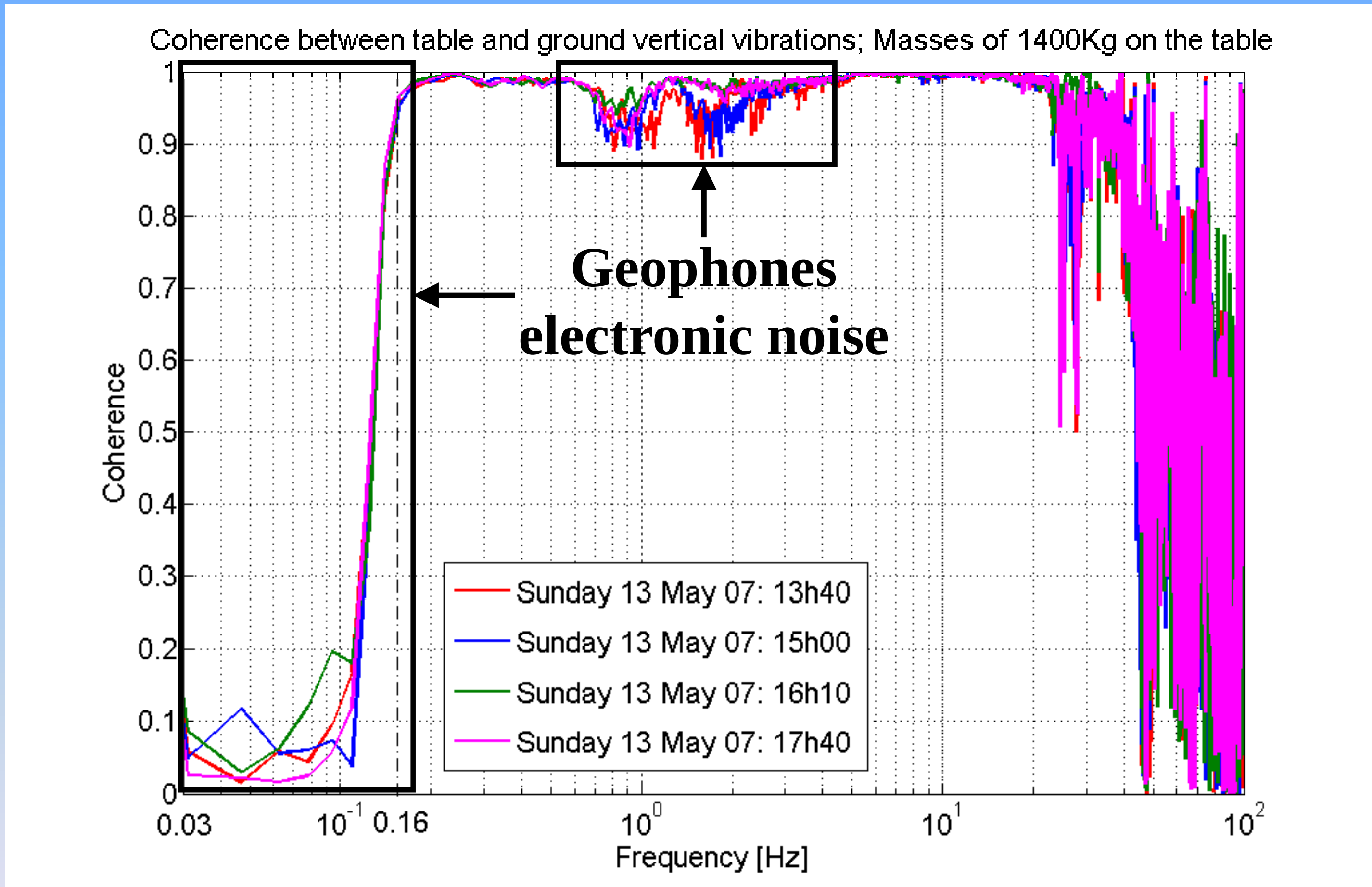


- **Good repetability of measurements**

  → Same value of eigenfrequency (74Hz: phase of 90 degrees)

Masses of 1400Kg on the table: 4 measurements done

✓ **Coherence between table and floor:**

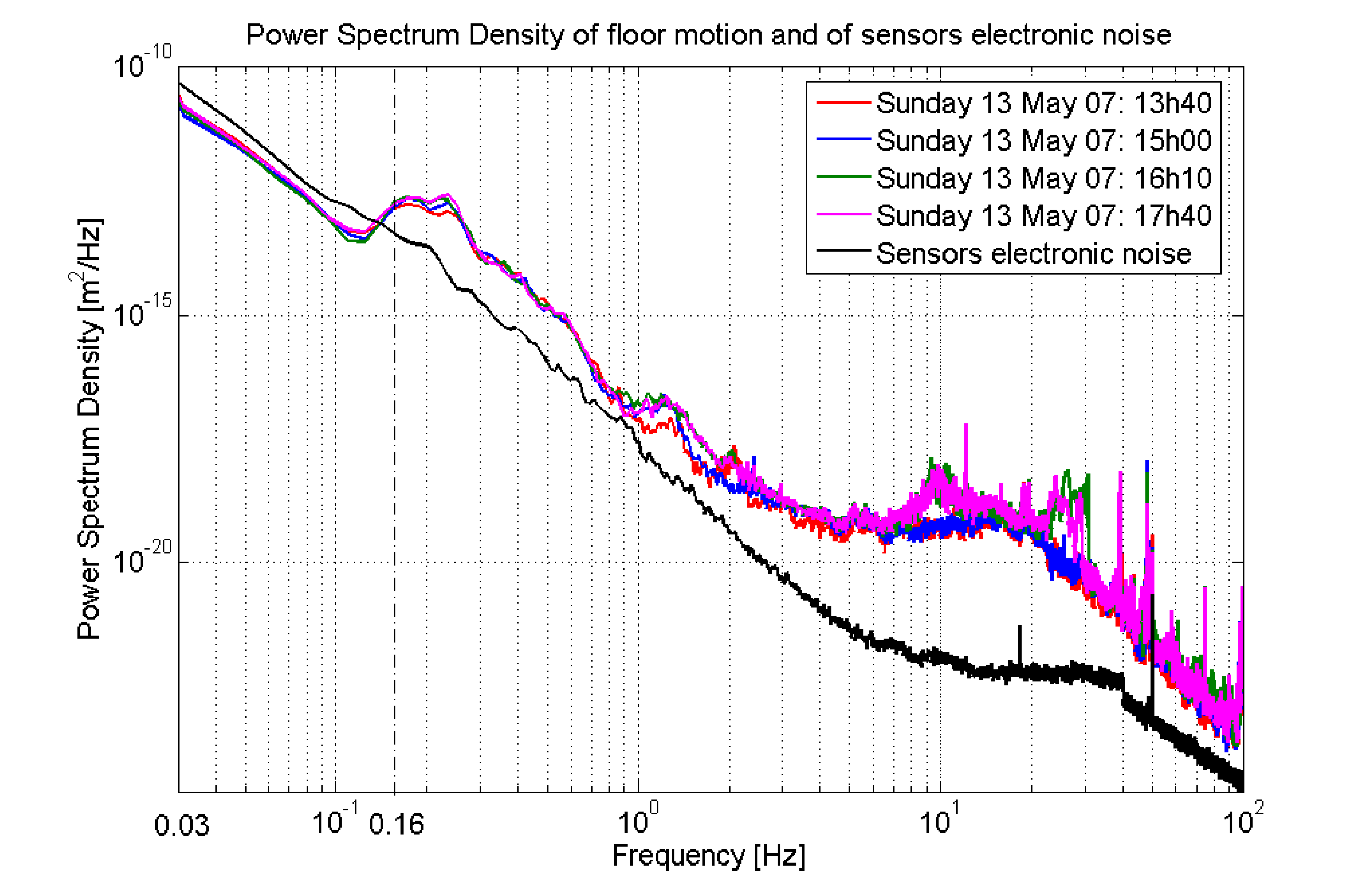


✓ **Measurements with lowest electronic noise:**

→ **Sunday 13 May 07 at 16h10: Data taken for the analysis**

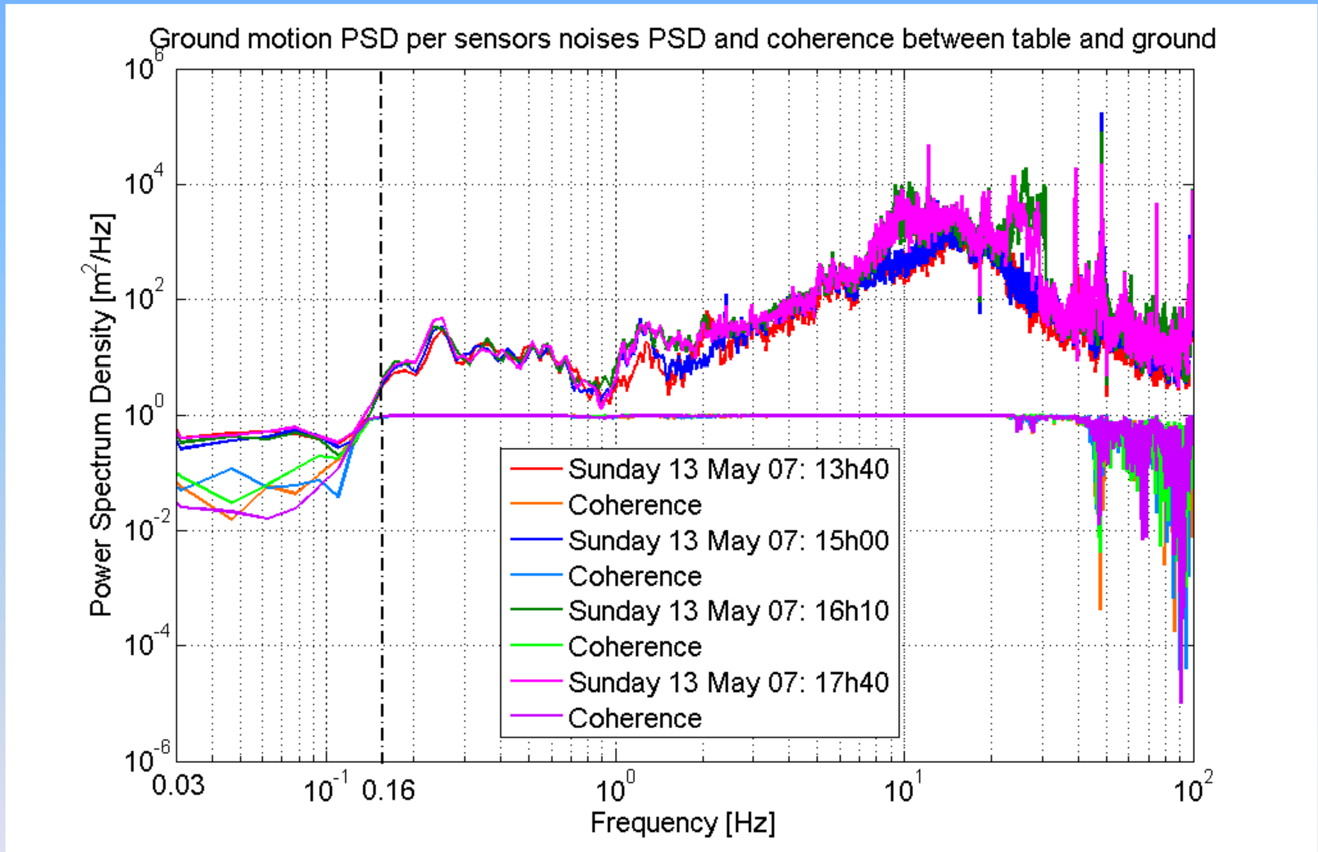
Masses of 1400Kg on the table: 4 measurements done

- ✓ **Power Spectrum Density of floor motion and of sensors noise:**



Masses of 1400Kg on the table: 4 measurements done

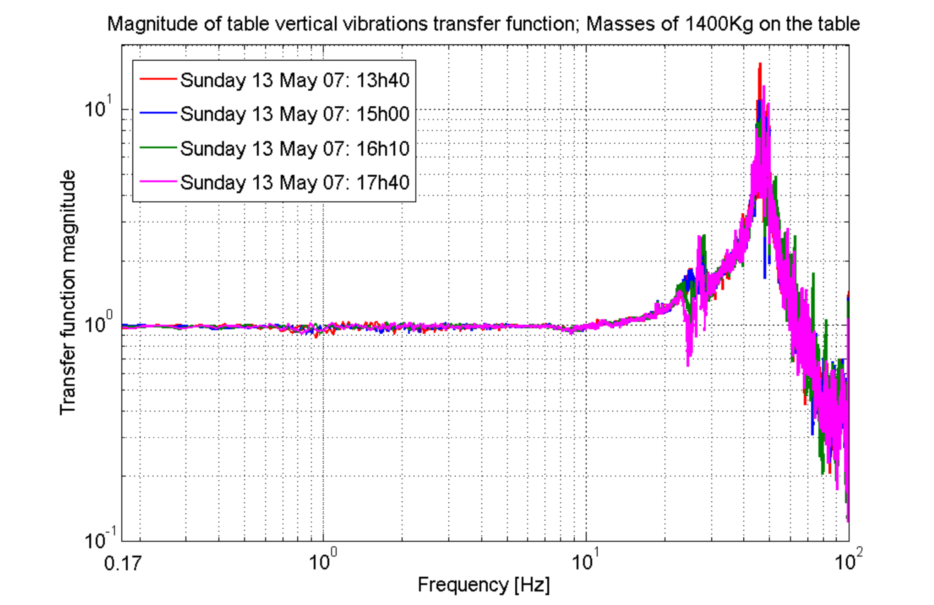
✓ **Floor motion PSD / Sensors noise PSD and the effect on coherence between table and ground vibrations:**

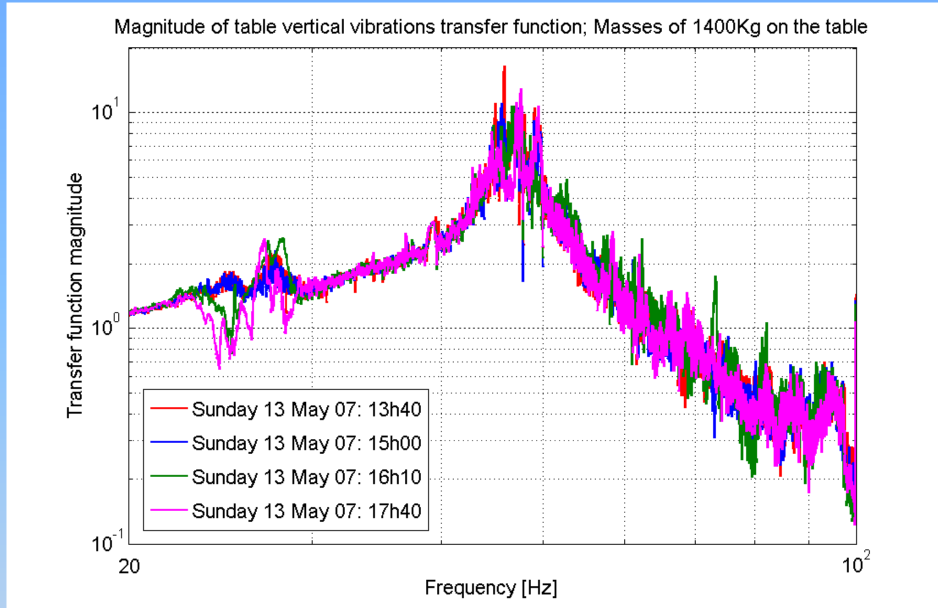


✓ **Low signal per noise ratio → Low coherence**

Masses of 1400Kg on the table: 4 measurements done

✓ **Table transfer function magnitude**





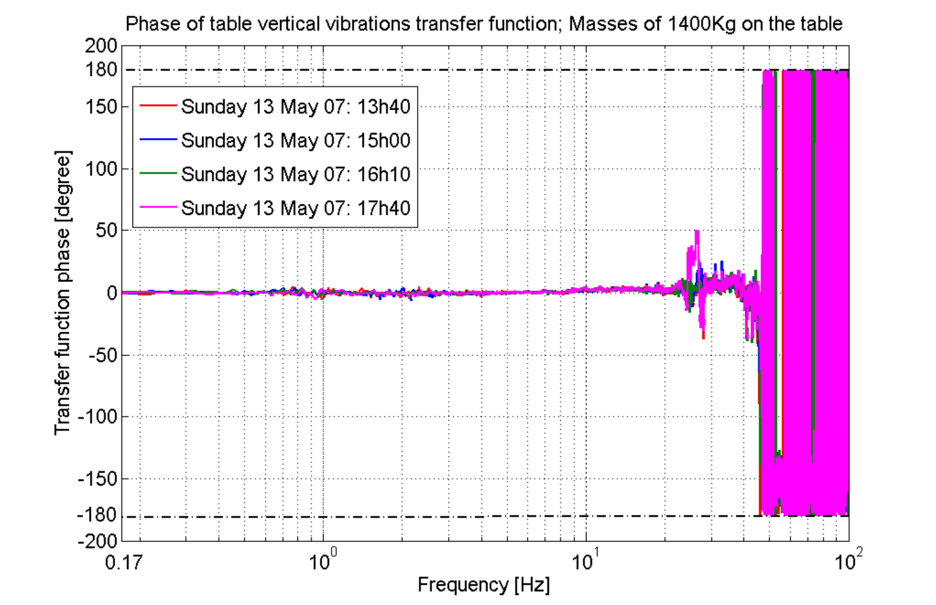
➢ **Good repetability of measurements**

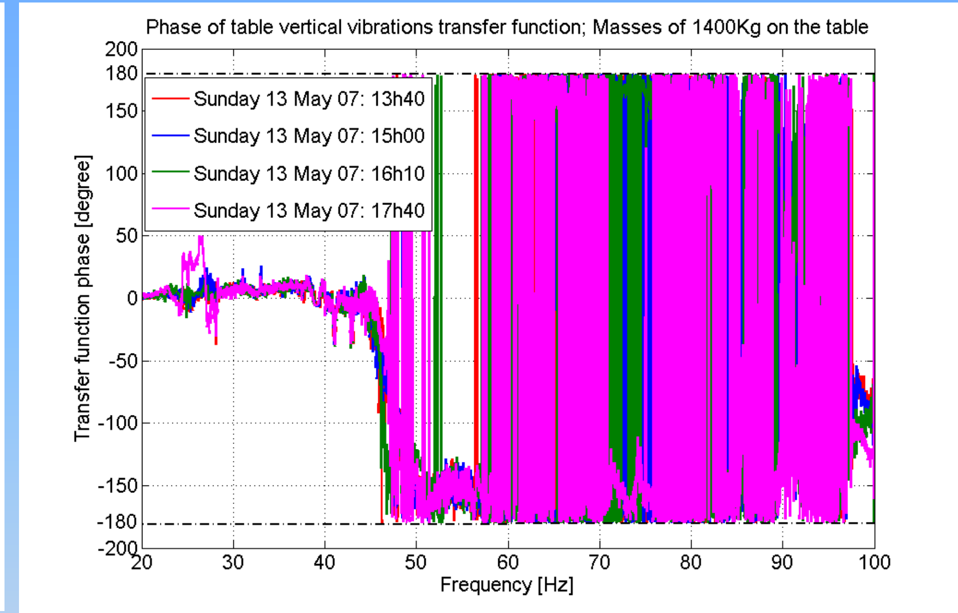
→ Same value of eigenfrequency (46Hz)

→ Same factor Q of amplification at the eigenfrequency

Masses of 1400Kg on the table: 4 measurements done

✓ **Table transfer function phase**





➢ **Good repetability of measurements**

→ Same value of eigenfrequency (46Hz: phase of 90 degrees)