Impact of random and determinist acoustic noise on vibrations at high frequencies of a free-fixed beam

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Introduction

- ✓ **Linear collider: 2 FD stabilisation at the subnanometer scale**
  - ➢ Ground motion negligible above 300Hz
  - ➢ Acoustic noise above?

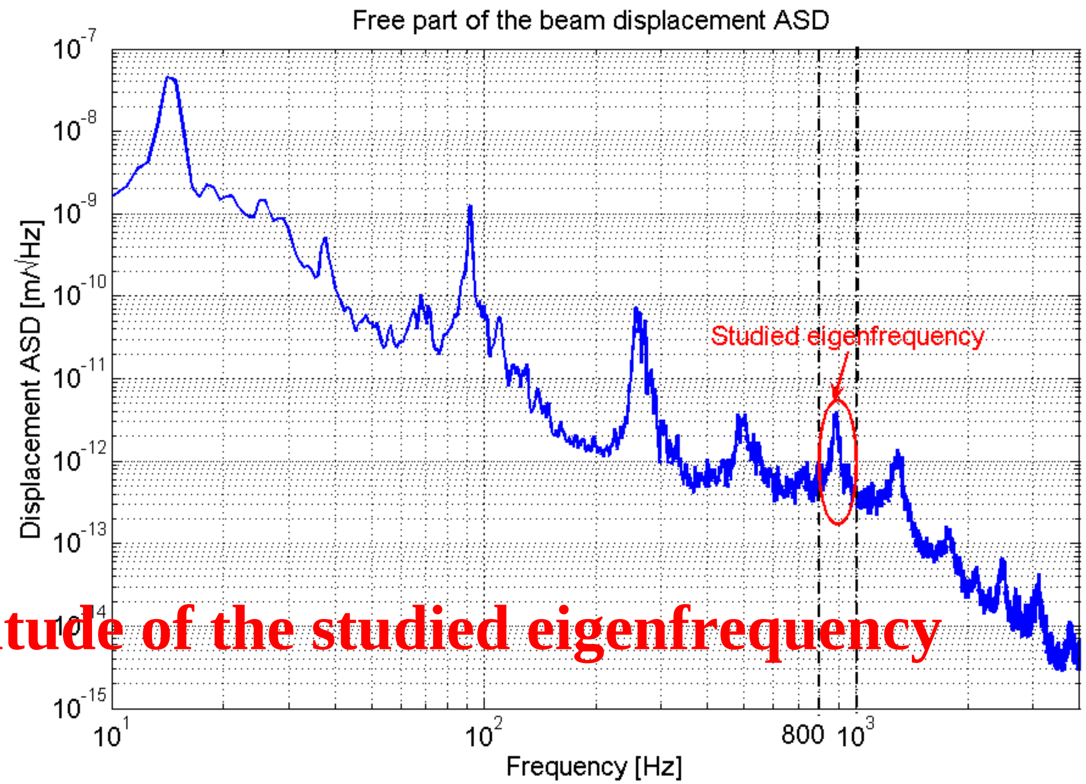
- ✓ **Goal of this presentation:**
  - ➢ Studies on the acoustic noise impact on free-fixed beam (ILC configuration) vibrations above 300Hz
  - ➢ Conclusion on the necessity to stabilise the 2 FD above 300Hz

Introduction

✓ **Studies on a 1 metre free-fixed beam with a full rectangular section**

- Acoustic noise impact on a high eigenfrequency: [800-1000]Hz

Vibration measurements in the LAVISTA working room



→ Very small amplitude of the studied eigenfrequency

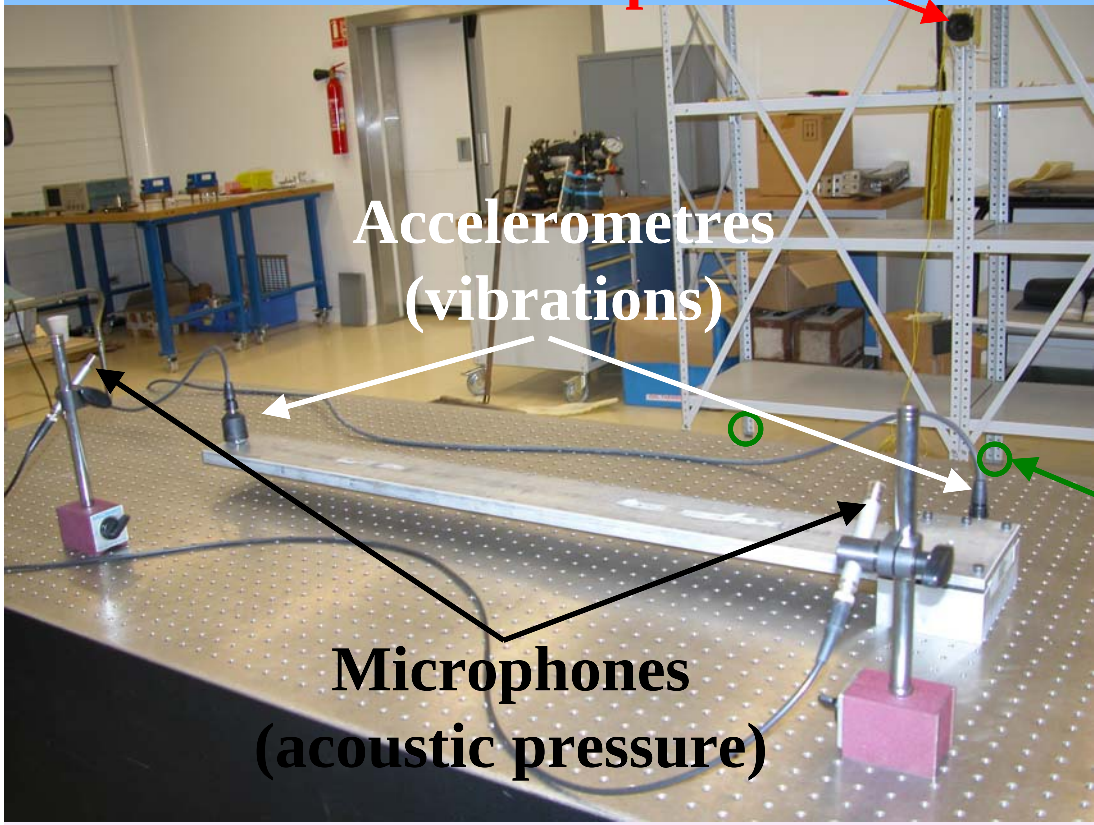
✓ **Same study presented at Orsay in May 2006 but below 100Hz**

Experimental set-up

Acoustic pressure and vibration measurements:

→ At the free part of the beam

→ At the fixed part of the beam

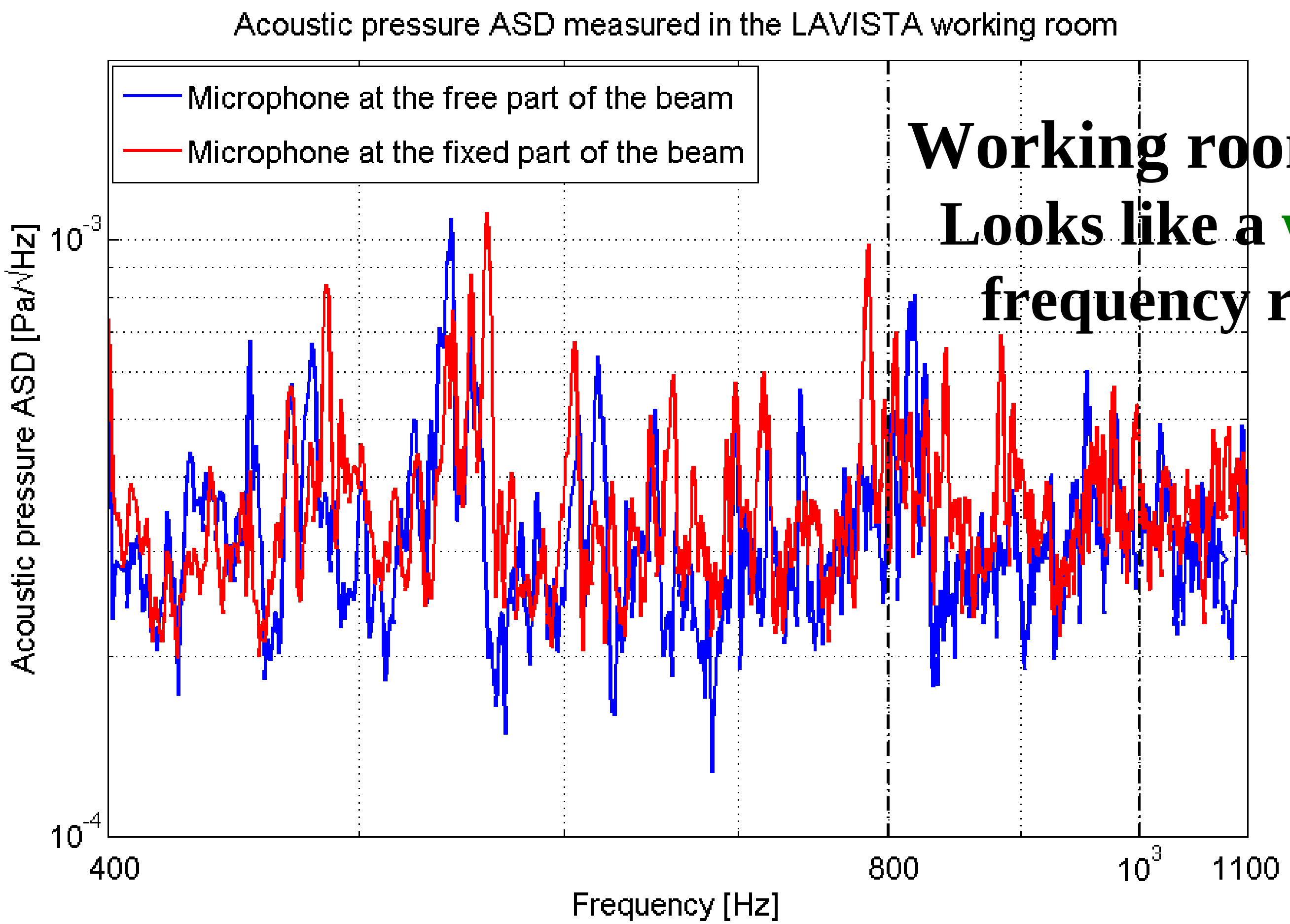


Passive damping:

Isolation of the loudspeaker from the ground to avoid mechanical vibration

Experimental set-up

✓ **Random acoustic noise impact study on the [800-1000]Hz eigenfrequency: Working room acoustic noise simulation**



Working room acoustic noise:

Looks like a white noise in the frequency range of interest

→ **Loudspeakers with white acoustic noise of different levels**

Experimental set-up

✓ **Determinist acoustic noise impact study on the [800-1000Hz] eigenfrequency: Pump noise simulation**

- Loudspeakers with 881Hz sine of different levels

✓ **For each level of acoustic noise:**

- Acquisition of **microphones/accelerometres** data

Sensors Data sheet

Sensors	**Accelerometres 393B12**	**Microphone 4189**
Sensitivity	10V/g	50mV/Pa
Frequency range	0.1 - 4 kHz	6 – 20 kHz
Quantity	2	2

White acoustic noise

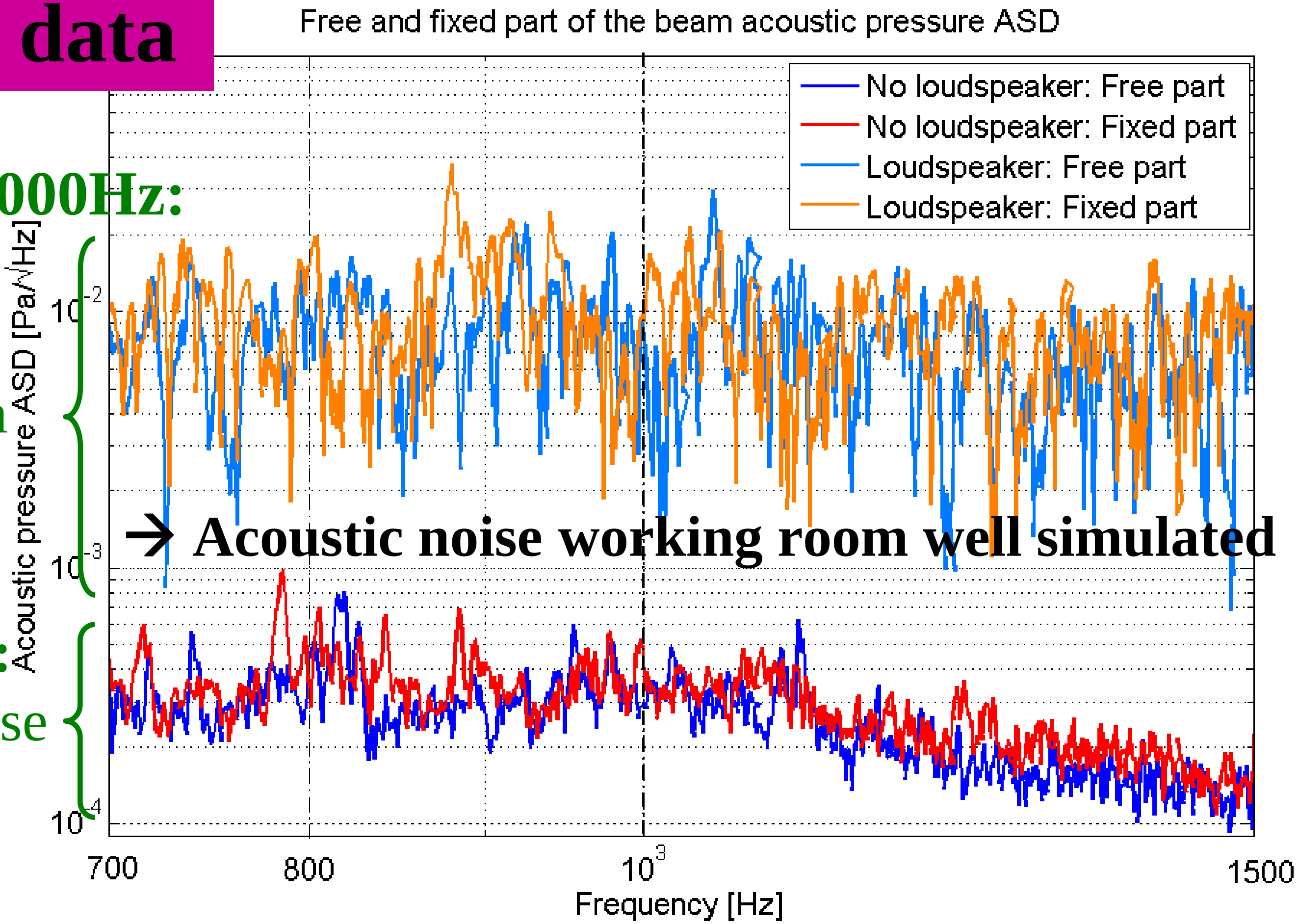
Comparison between a natural working room acoustic pressure and a higher simulated one

Microphones data

From 800Hz to 1000Hz:

Loudspeaker:
White noise at a 79dB level

No loudspeaker:
Working room noise at a 49dB level



→ **Acoustic noise working room well simulated**

→ ~ Same acoustic noise levels at the fixed and at the free part of the beam

White acoustic noise

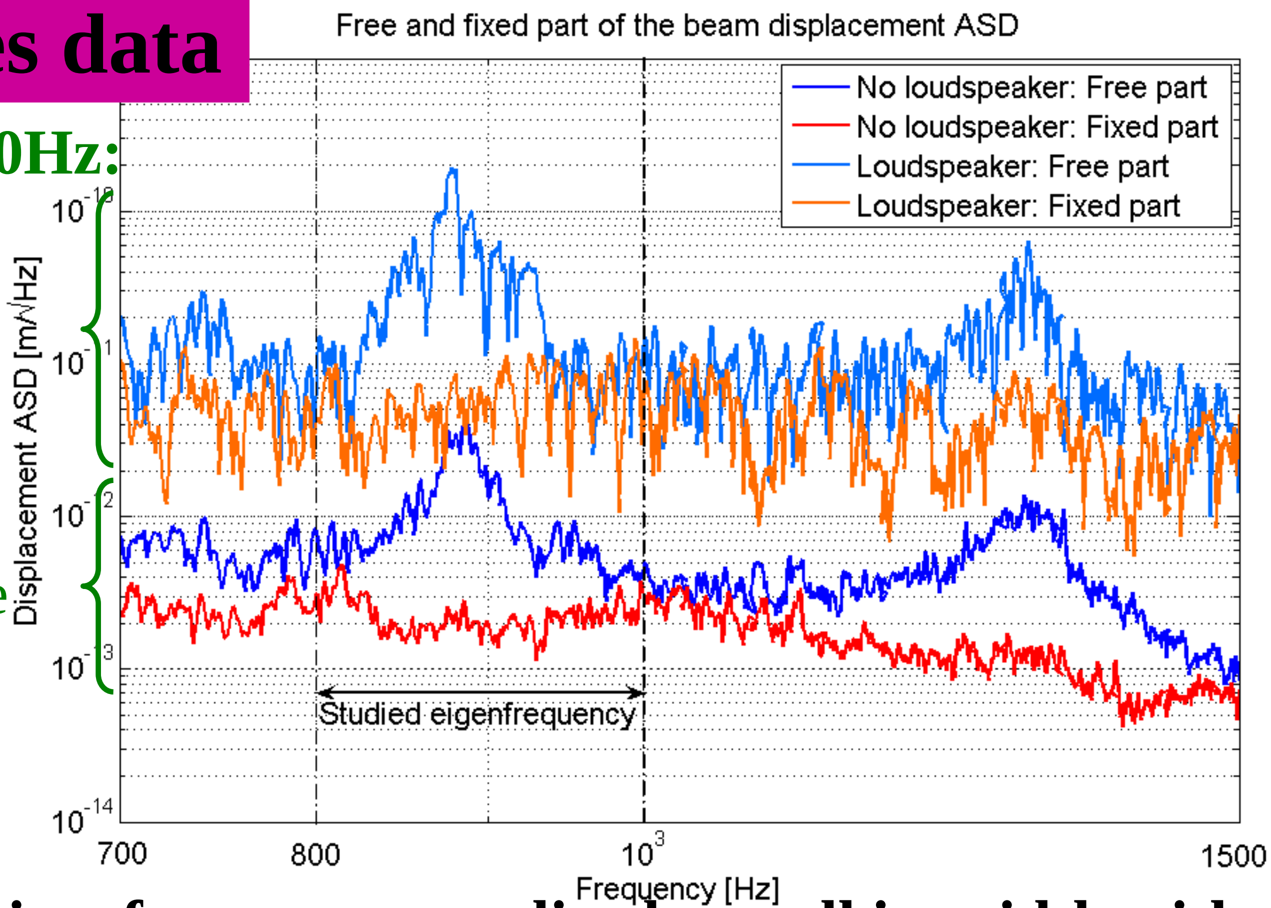
Impact of an increase of working room acoustic noise level on the beam eigenfrequency

Accelerometres data

From 800Hz to 1000Hz:

Loudspeaker:
White noise at a 79dB level

No loudspeaker:
Working room noise at a 49dB level

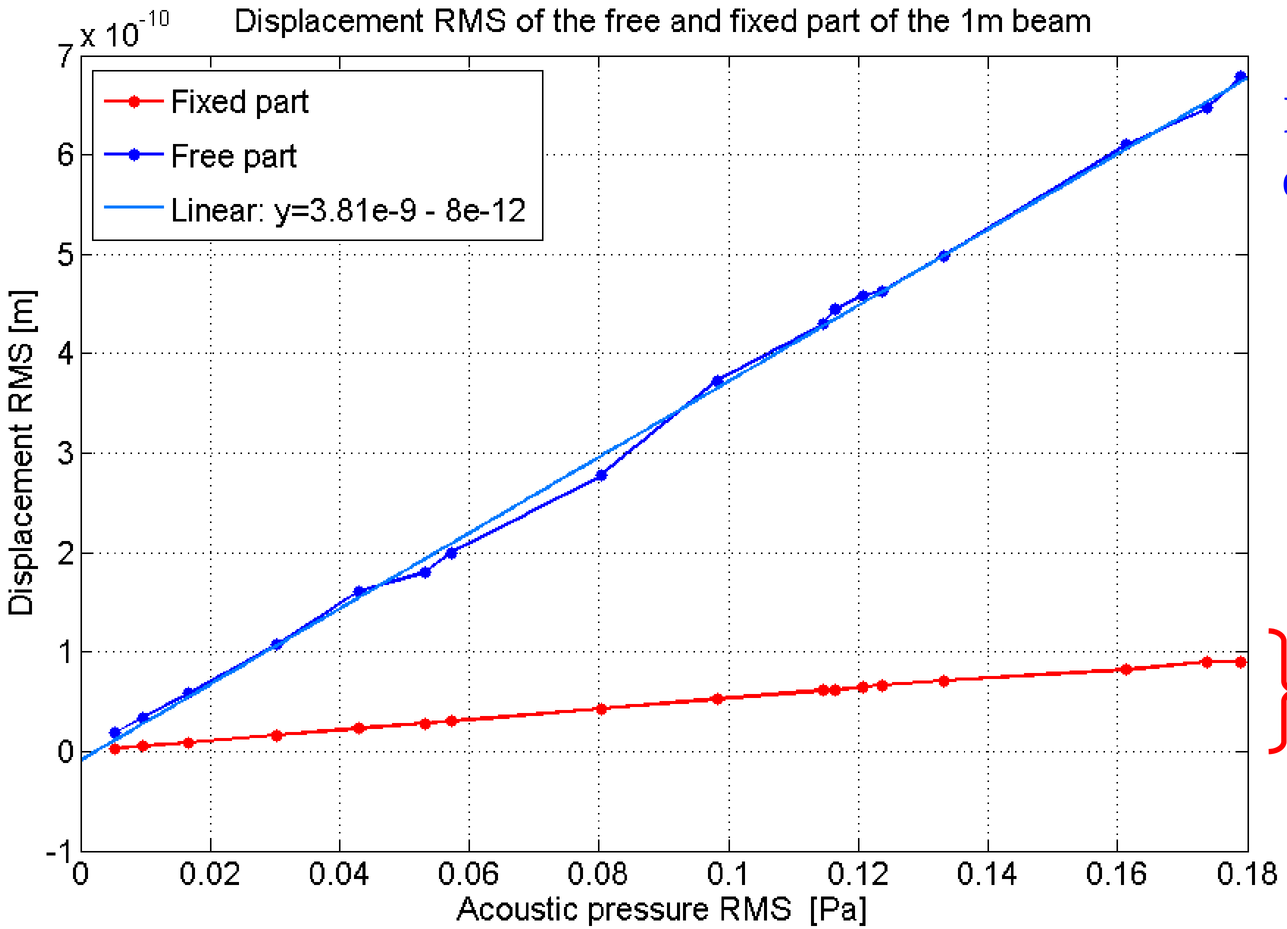


→ Increase of the eigenfrequency amplitude on all its width with white acoustic noise

White acoustic noise

Integrated displacement RMS of the free and fixed part of the beam versus Integrated acoustic pressure RMS

→ **Integrated RMS in [800-1000Hz]**



Linearity of the beam displacement with the acoustic pressure

⬇

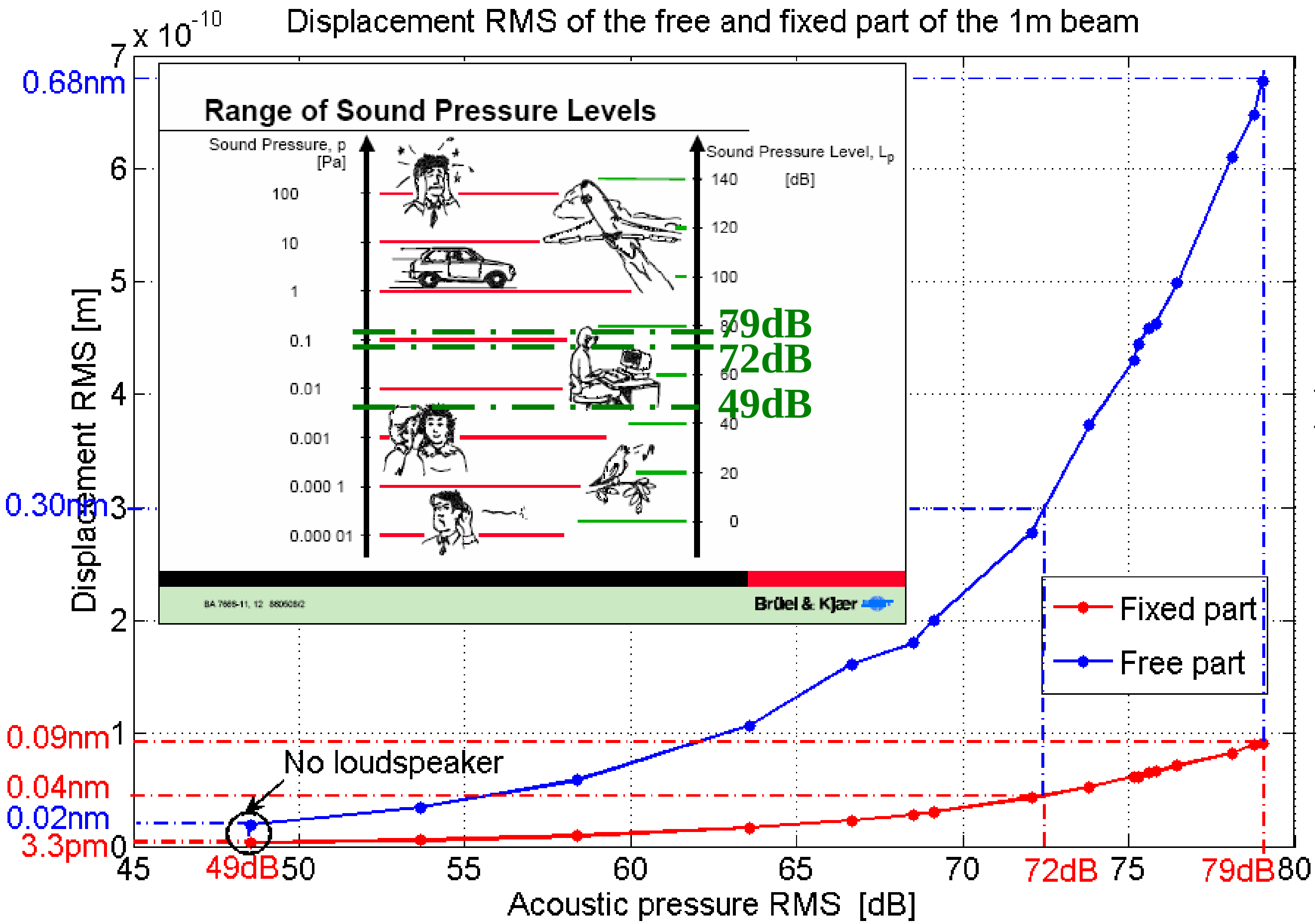
Linear regression performed

Ground motion : slightly excited

White acoustic noise

Integrated displacement RMS of the free and fixed part of the beam versus Integrated acoustic pressure RMS

→ Integrated RMS in [800-1000Hz]



Small increase of acoustic pressure

Non negligible beam displacement in the frequency range [800-1000Hz]

Ground motion : slightly excited

Sine acoustic noise

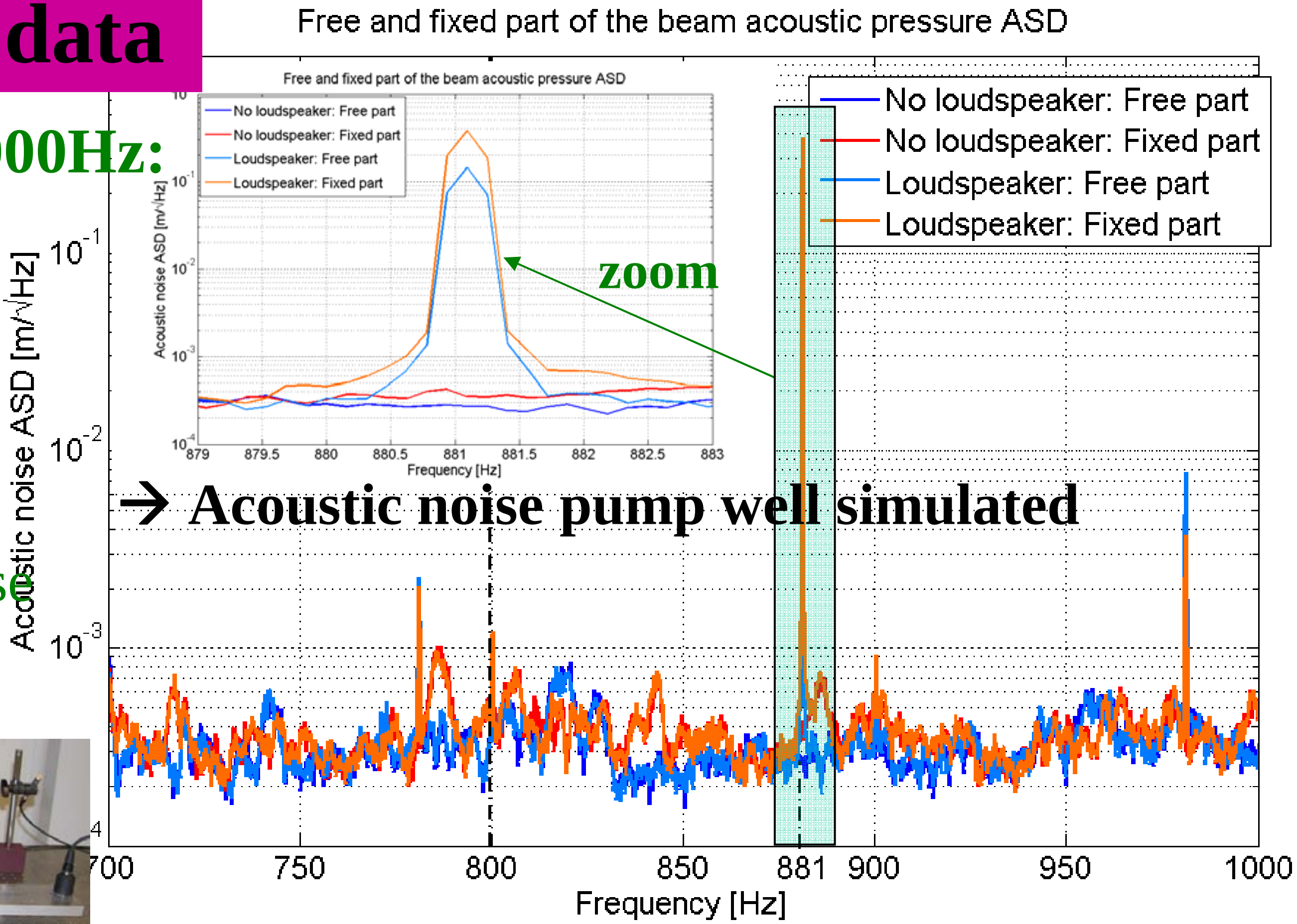
Comparison between a natural working room acoustic pressure and a pump acoustic pressure simulated

Microphones data

From 800Hz to 1000Hz:

Loudspeaker:
Sine noise at a 79dB level

No loudspeaker:
Working room noise at a 49dB level



→ Acoustic noise pump well simulated

→ ~ Same acoustic noise levels between the fixed and the free part of the beam

Sine acoustic noise

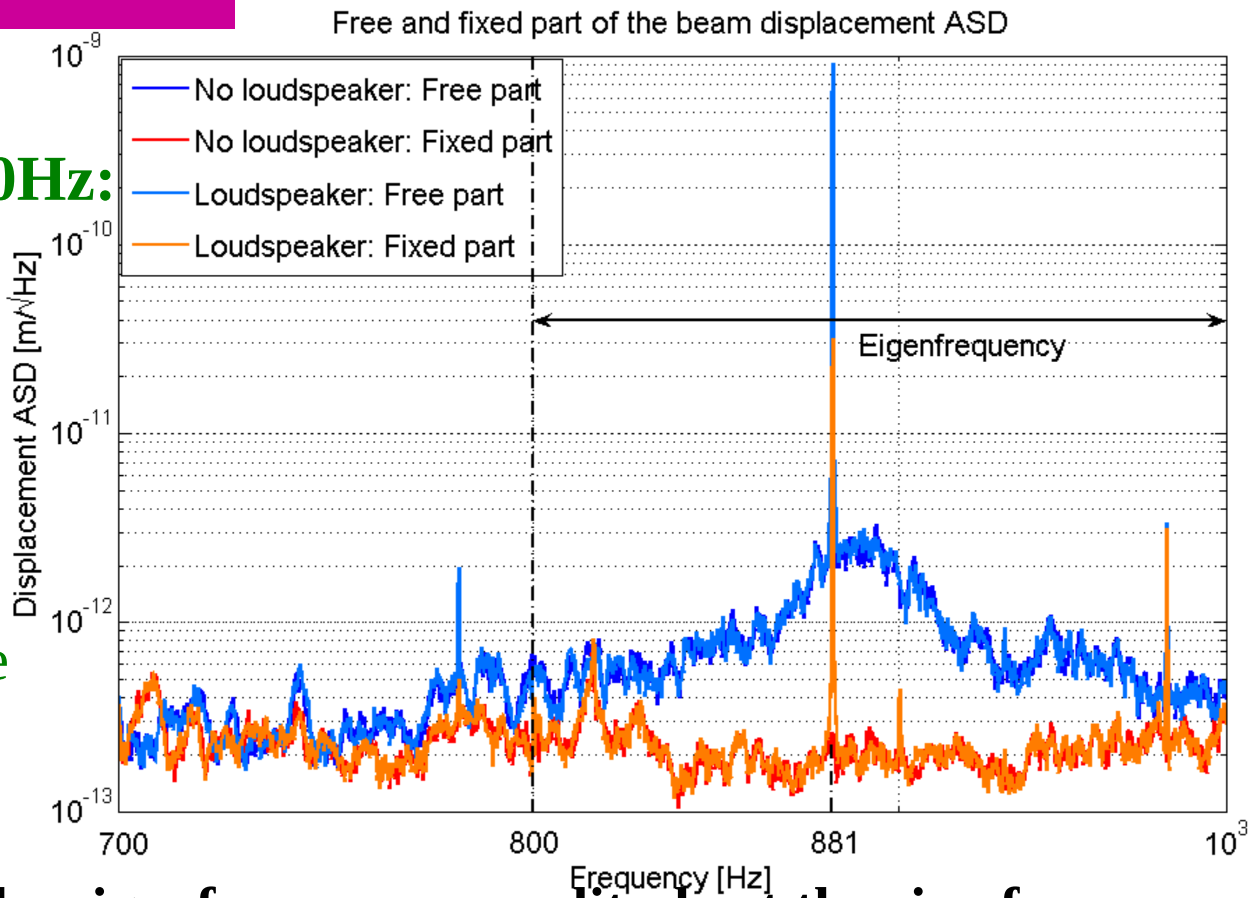
Impact of a pump acoustic noise on the beam eigenfrequency

Accelerometres data

From 800Hz to 1000Hz:

Loudspeaker:
Sine noise at a 79dB level

No loudspeaker:
Working room noise at a 49dB level



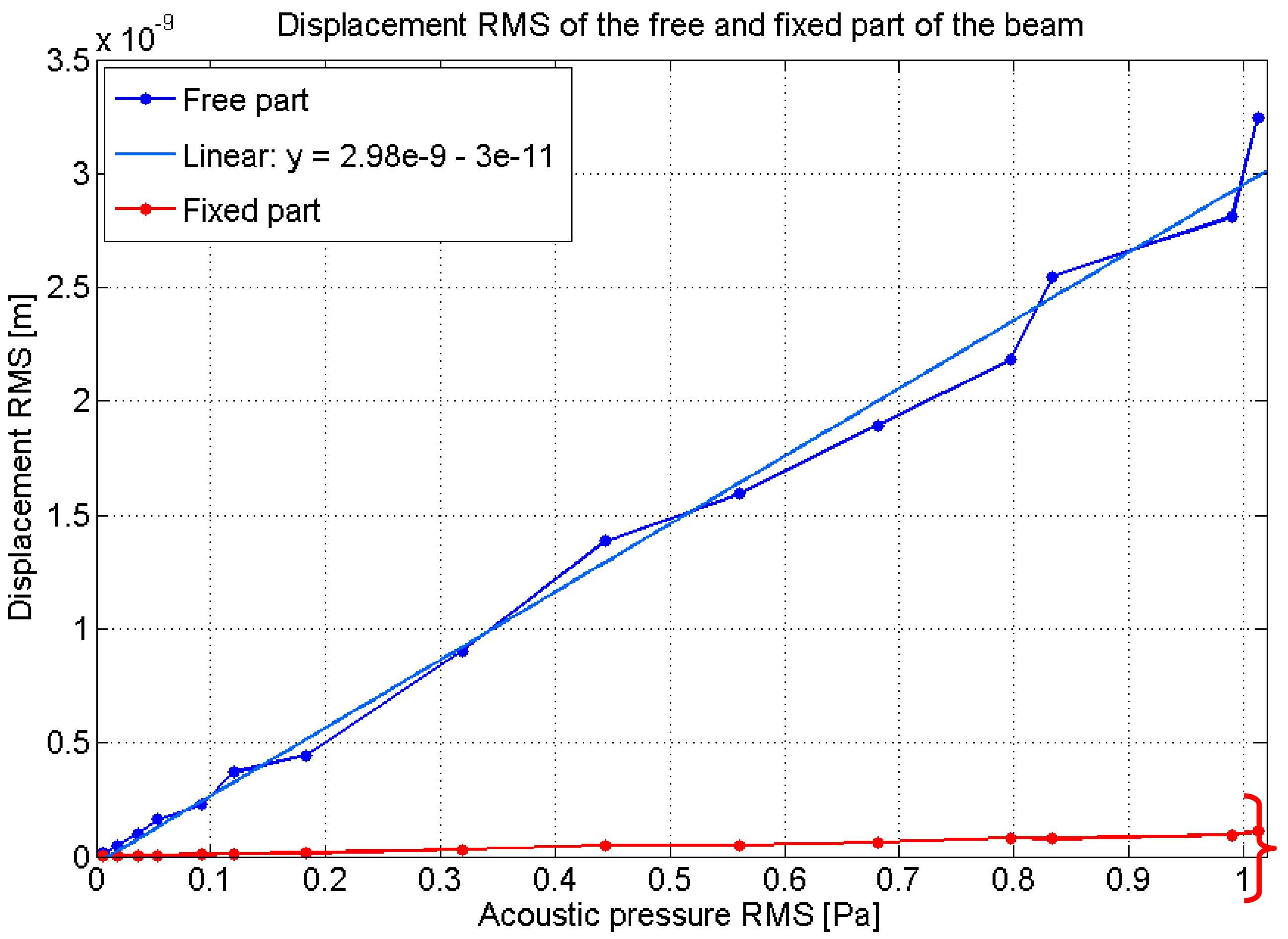
→ **Huge increase of the eigenfrequency amplitude at the sine frequency**

→ **Non increase of the eigenfrequency amplitude outside the sine frequency**

Sine acoustic noise

Integrated displacement RMS of the free and fixed part of the beam versus Integrated acoustic pressure RMS

→ **Integrated RMS in [800-1000Hz]**



Linearity of the beam displacement with the acoustic pressure

↓

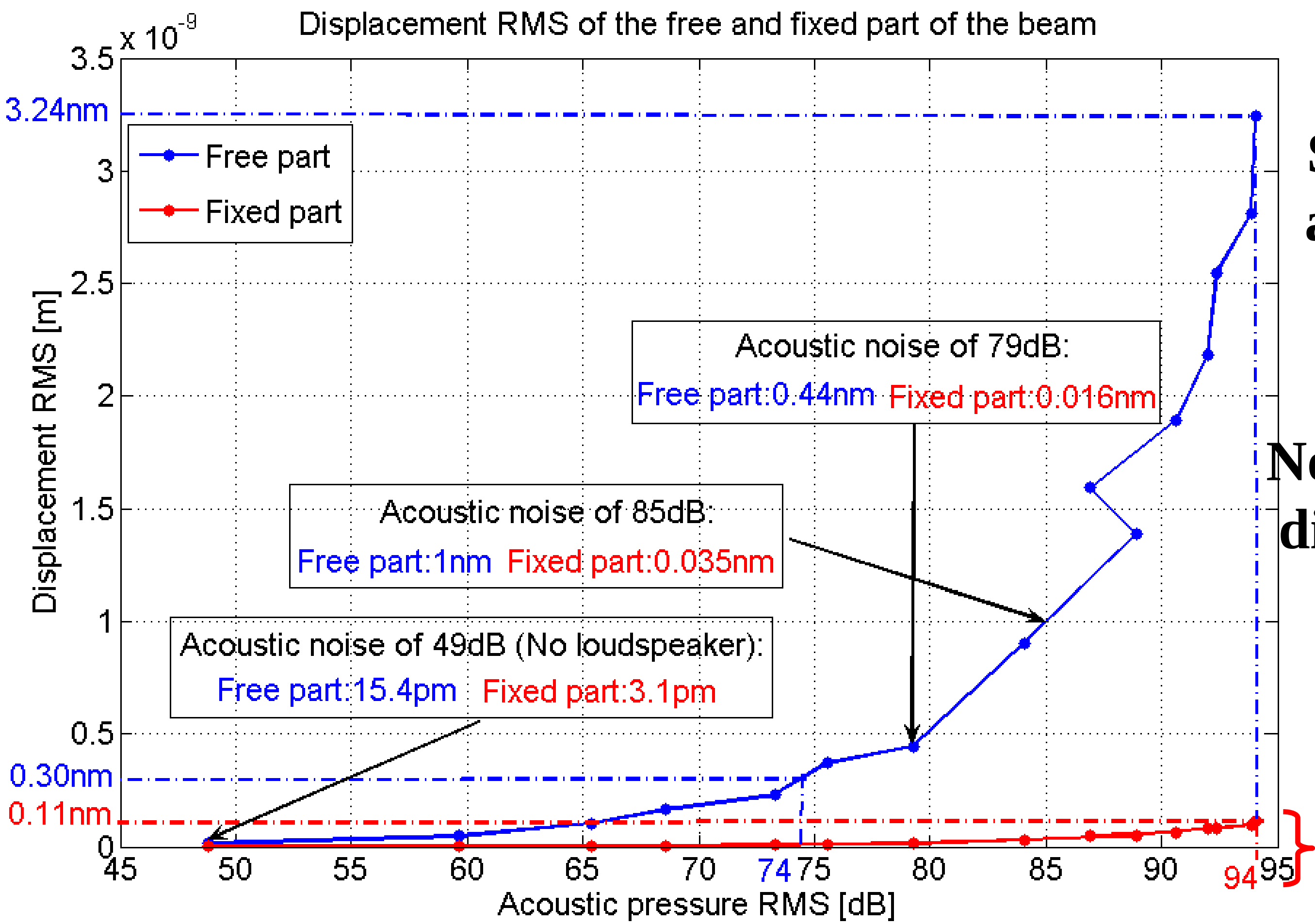
Linear regression performed

Ground motion not excited

Sine acoustic noise

Integrated displacement RMS of the free and fixed part of the beam versus Integrated acoustic pressure RMS

→ **Integrated RMS in [800-1000Hz]**



Small increase of acoustic pressure

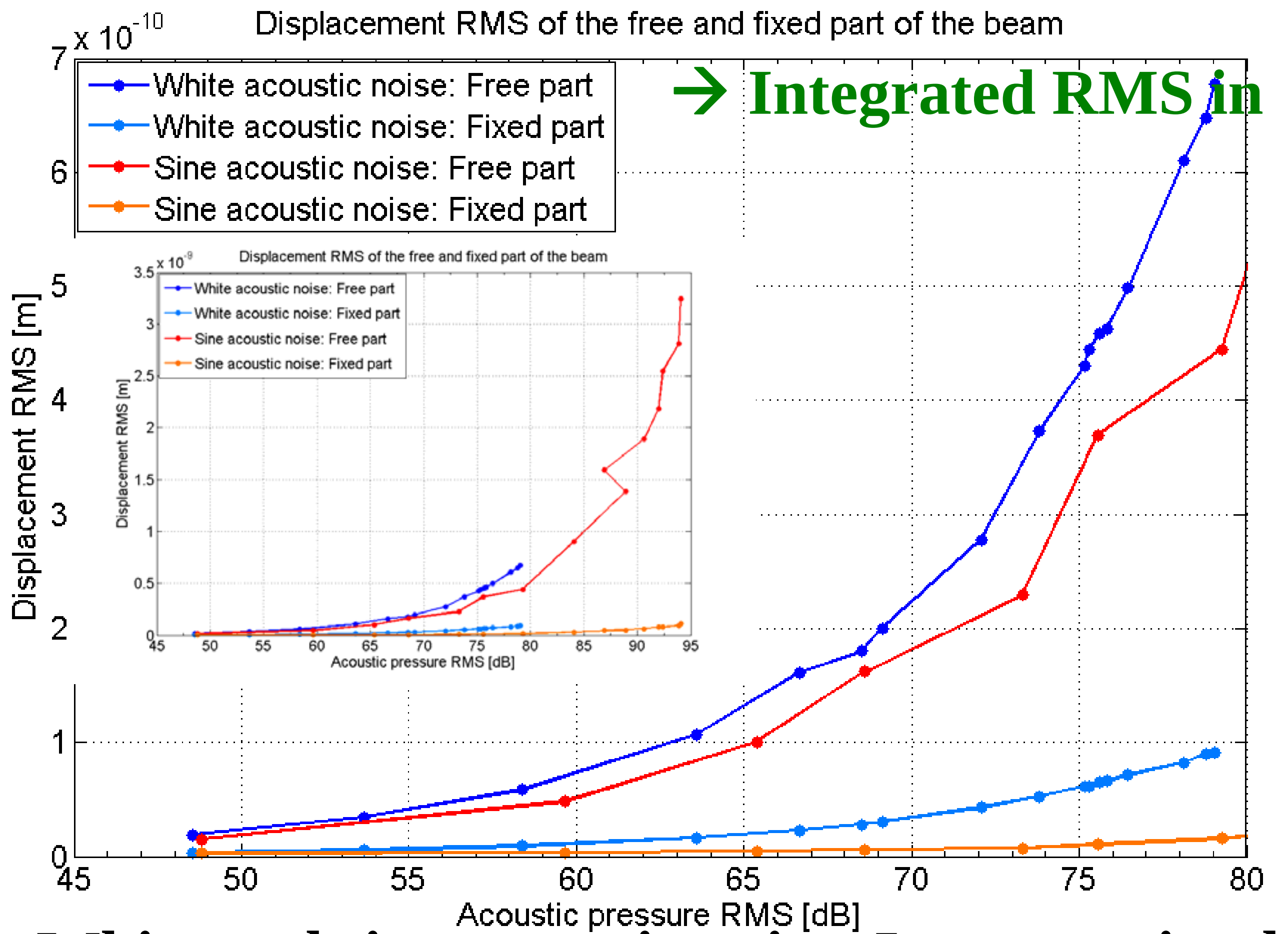
↓

Non negligible beam displacement in the frequency range [800-1000Hz]

Ground motion not excited

Summary: Sine and white acoustic noise

Integrated displacement RMS of the free and fixed part of the beam versus Integrated acoustic pressure RMS



→ Integrated RMS in [800-1000Hz]

→ White and sine acoustic noise: Impact quite the same on the beam displacement in the eigenfrequency range [800-1000Hz]

Conclusion

✓ **Small increase of random/determinist acoustic pressure in the frequency range [800Hz-1000Hz]**

→ Non negligible displacement of the free-fixed beam because of the resonance induced at the given eigenfrequency

✓ **Linear collider: environment with high acoustic noise**

→ Necessary to stabilise also above 300Hz to at least 1000Hz!!!

→ Good acoustic pressure coherence may help for relative stabilisation (Need to go on with this coherence study)

→ Alternative: fixed-fixed beam configuration

✓ **Predictive model : only ground motion excitation**

→ Should include acoustic noise

Vibration active rejection in the nanometre scale:

First results

Presentation of the instrumentation

Data sheet

✓ **NI PCI-6052 Multifunction DAQ**

PCI-6052E	Quantity	Resolution	Rate	Conversion	Range	Noise
Analog Input	8 Differential/ 16 Single-ended	16bits	Up to 333kS/s	Successive approximation	±0.05 to 10V	60uV from DC to 1MHz
Analog output	2 Single-ended	16 bits	333kS/s	Successive approximation	±10V	

Fast card **Low noise card**

➢ Compatible Matlab/Simulink (Softwares used for the algorithm)

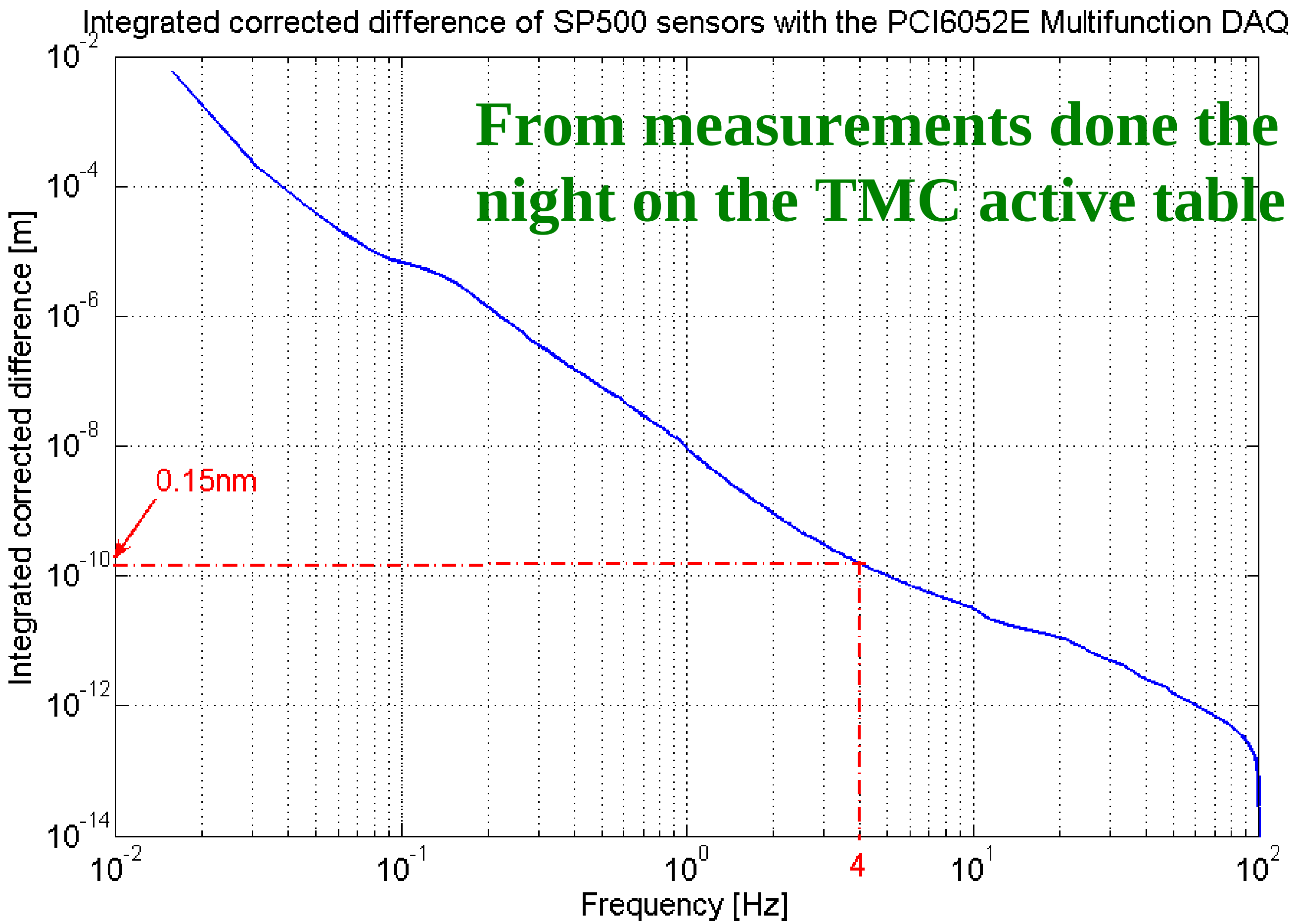
✓ **Sensors used to do vibration active control**

Sensors	SP500B	ENDEVCO86
Sensitivity	2000V/m/s	10V/g
Frequency range	0.0167 – 75Hz	0.01 – 100 Hz
Integrated electronic noise above 4Hz	0.085nm	0.6nm
Quantity	2	2

Non magnetic

Presentation of the instrumentation

Measurement chain electronic noise



Non magnetic SP500B sensor

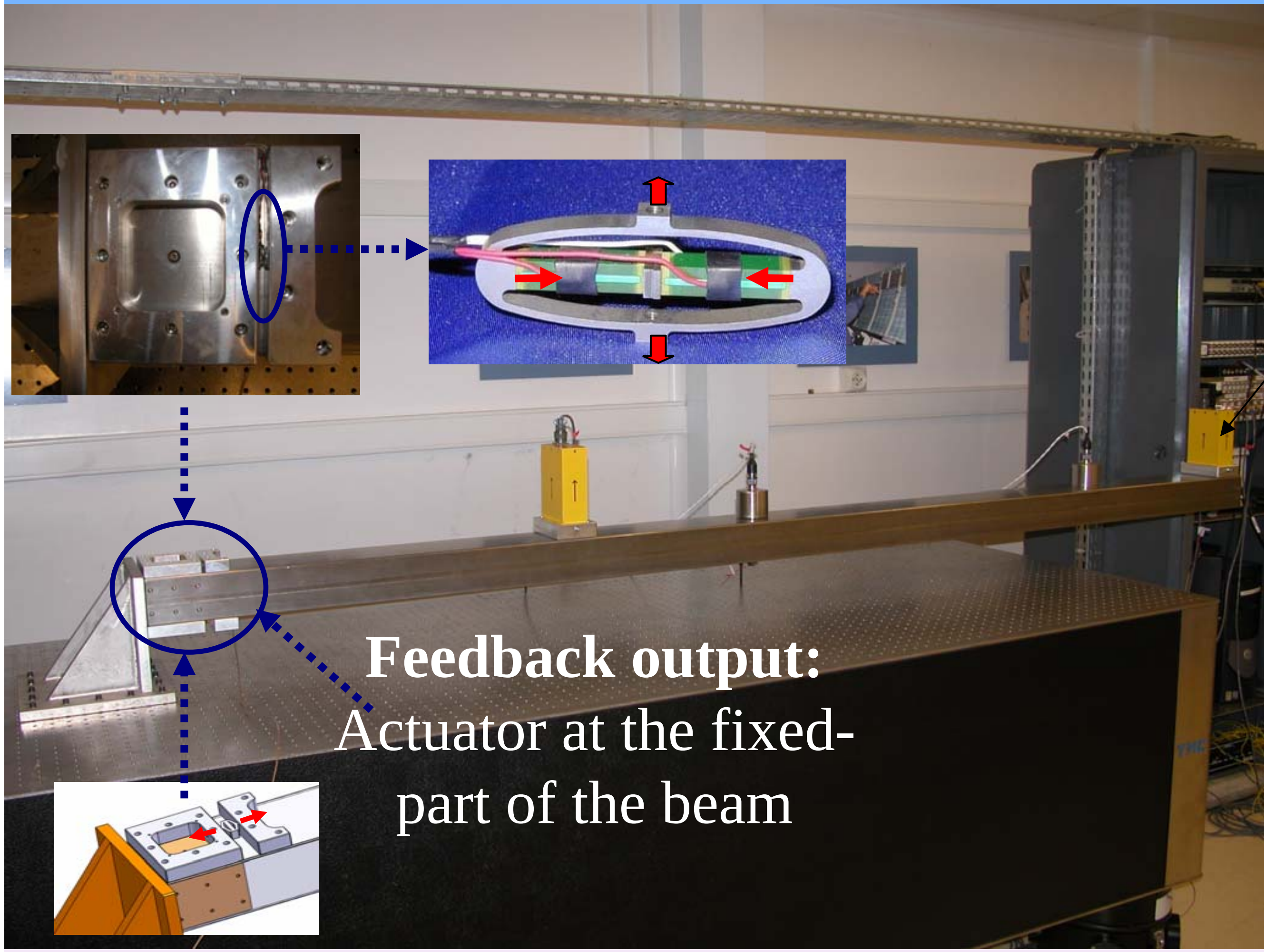
PCI6052 DAQ

✓ Integrated electronic noise of the total measurement chain above 4Hz:

- 0.15nm : enough to do active control at the nanometre scale

First results of stabilisation in the nanometre scale

Experimental set-up

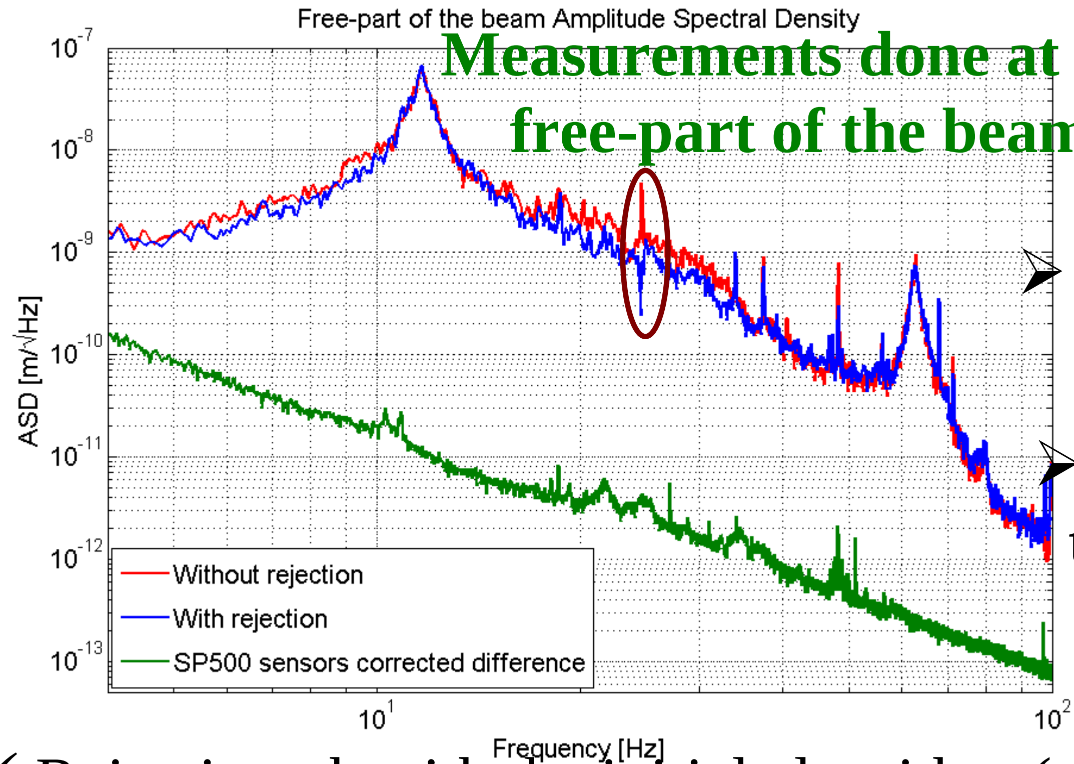


Feedback input:
Sensor at the free-part of the beam

PCI6052 DAQ:
Sensor acquisition and actuator control

First results of stabilisation in the nanometre scale

Active rejection of one unknown disturbance frequency



Measurements done at the free-part of the beam

Actuator:

- **Make the beam move in the nanometre scale**
- **Voltage control well above the output electronic noise**

✓ Rejection ok with the initial algorithm (state space) for frequencies which correspond to unknown source disturbances

For eigenfrequencies, necessity to control a larger bandwidth

→ Test of a new algorithm (internal model command), which need also just a punctual knowledge of the system

Conclusion

✓ **Instrumentation OK to work in the nanometre scale:**

- ➢ **Measurement chain:** Integrated electronic noise of 0.15nm above 4Hz
- ➢ **Actuator:** Make the beam move in the nanometre scale for a voltage control well above the output electronic noise

✓ **Feedback loop:**

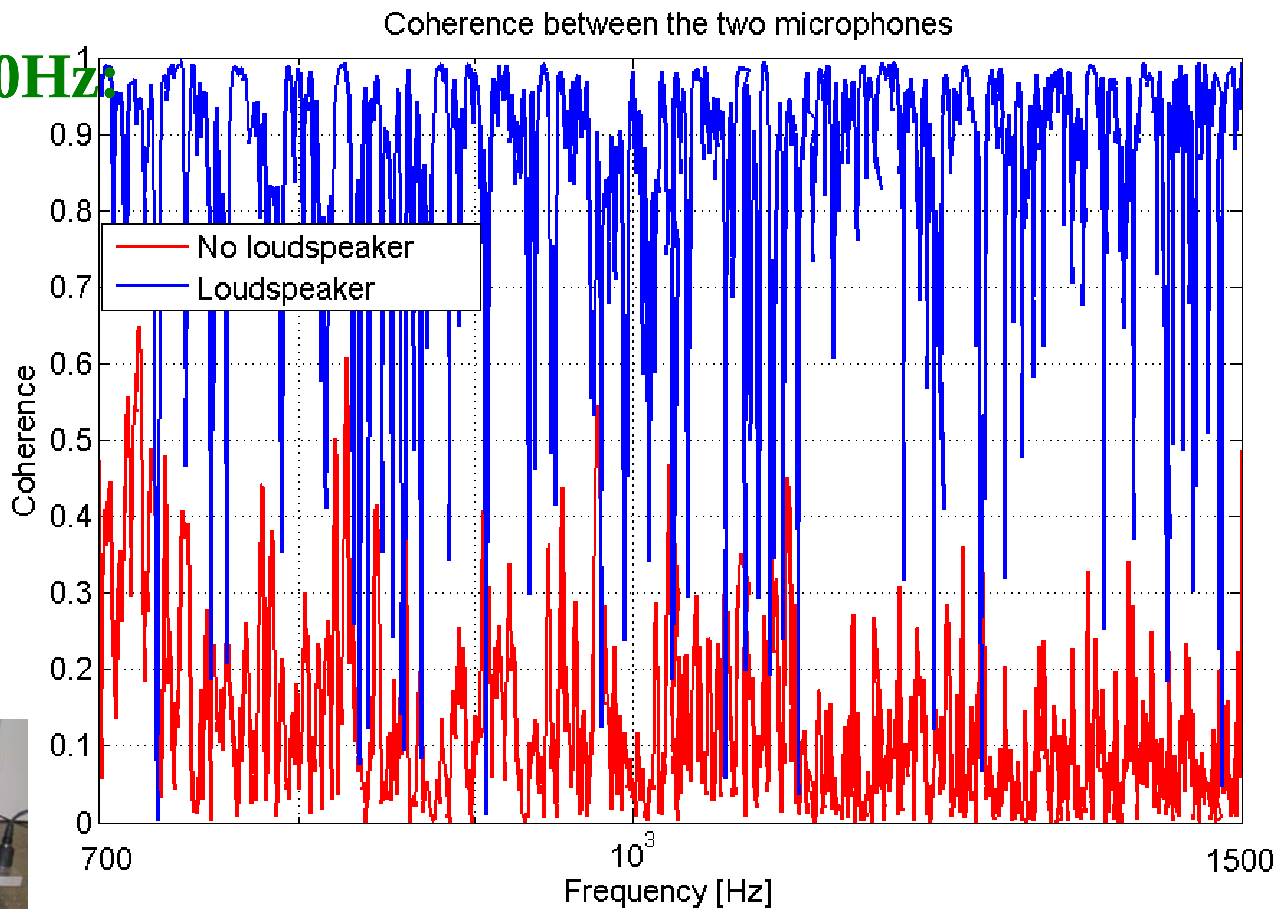
- ➢ **Today:** Work well for narrow picks
- ➢ **Test of a new algorithm to control eigenfrequencies**

✓ **Future prospects:**

- ➢ Improvement of the algorithm for multiple inputs/outputs
- ➢ **New algorithm based on position control to work on a very large bandwidth:** important if necessary to stabilise above 300Hz

White acoustic noise

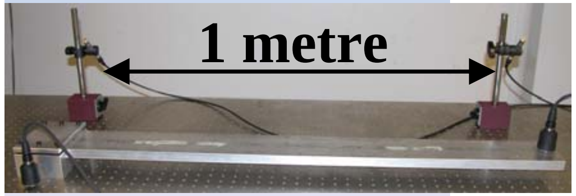
Acoustic pressure coherence for two levels of white acoustic noise



From 800Hz to 1000Hz:

Loudspeaker:
White noise at a 79dB level

No loudspeaker:
Working room noise at a 49dB level



→ **Increase of the coherence with the level of acoustic pressure**

→ **79dB level: Quite good coherence between the 2 microphones**