Linear Collider Alignment & Survey

Metrology and Stabilisation

summary of ELAN LTECNC session yesterday

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LAPP-IN2P3-CNRS

Annecy

C. Adloff, B. Bolzon, Y. Bastian, L.Brunetti, F. Cadoux, G. Cougoulat, P.Y. David, N. Geffroy, C. Girard, A. Jeremie, Y. Karyotakis, J.Lottin, F. Peltier

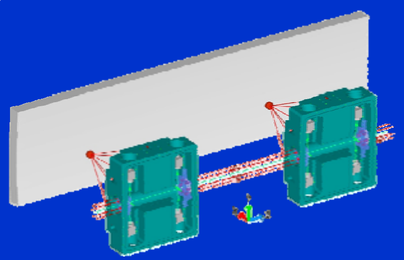
R. Amirikas, A. Bertolini, W. Bialowons, H. Ehrlichmann

P.Cole, T.Handford, B.Ottewell, A.Reichold, D.Urner, R.Wastie, S.Yang

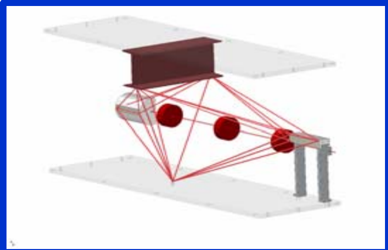
WP7 Metrology and stabilisation

METSTB

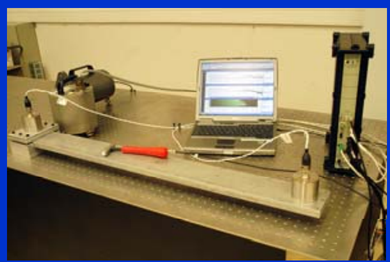
RTRS



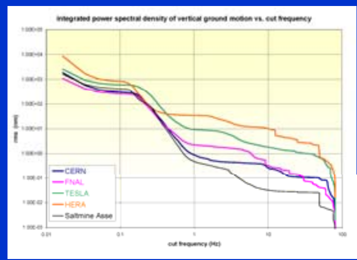
StaFF



MSTBT



PGMS



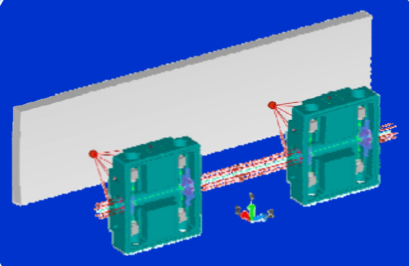
RTRS : rapid tunnel reference system

See Armin Reichold's Highlight talk

StaFF : Laser interferometer based final focus stabilisation

METSTB

RTRS



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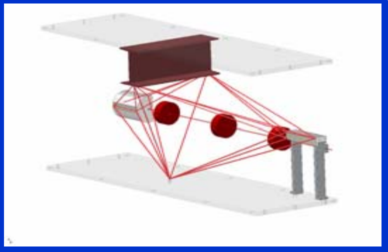

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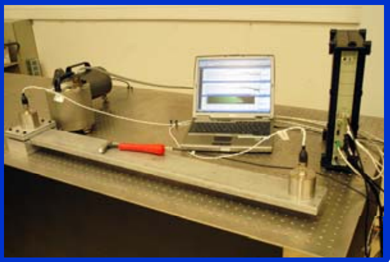
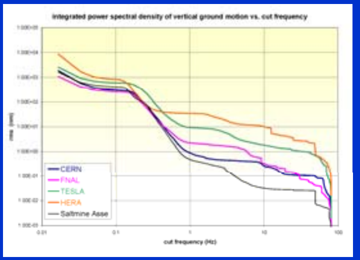
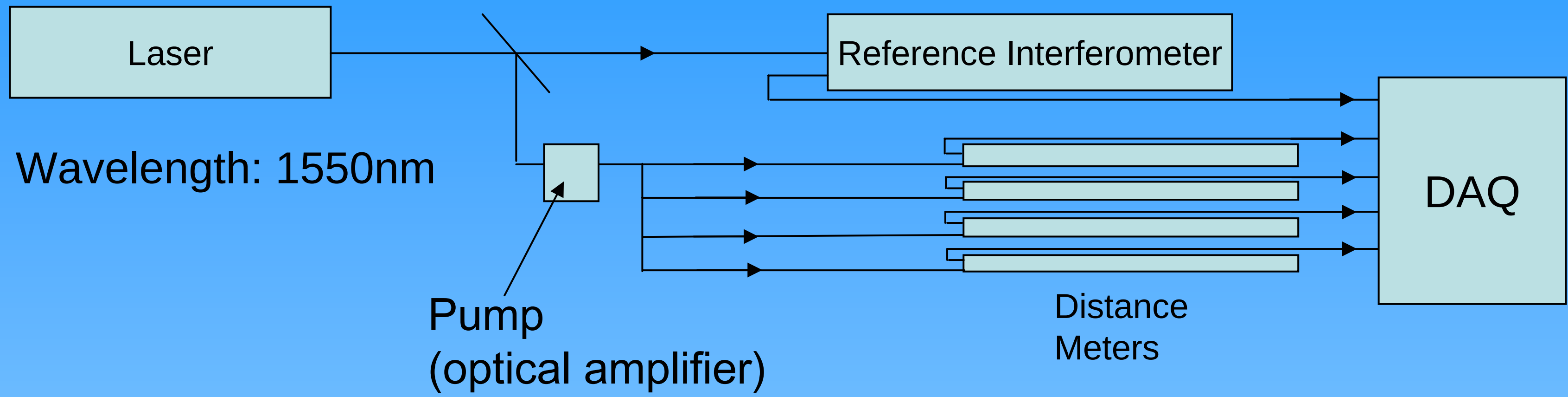


PGMS



Distance Meter: Method of Measurement

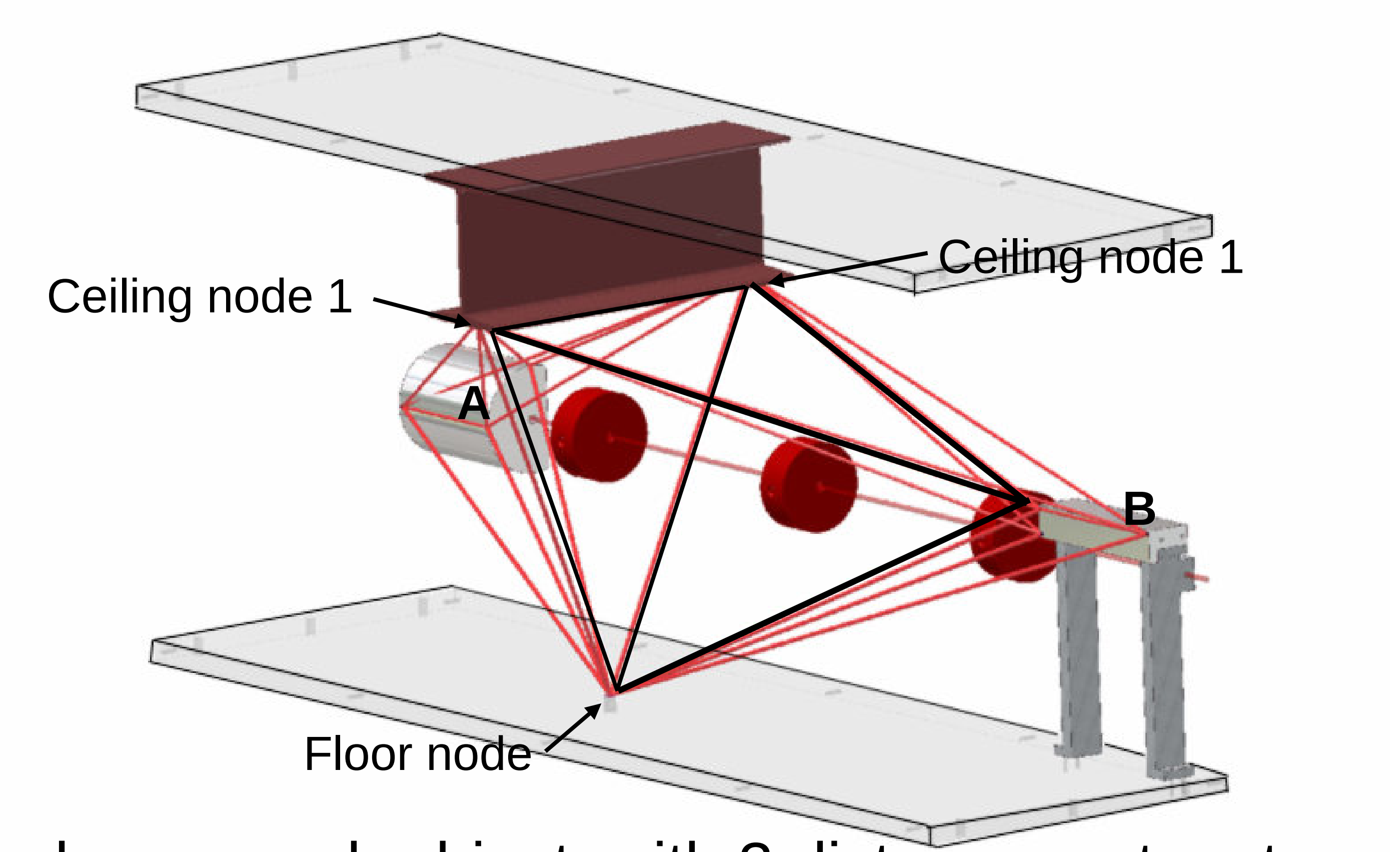
by D.Urner



- Keep costs down for distance meters so that overall cost scale favourably.
- Distance meter 2 modes:
  - Michelson mode:
    - fast,
    - relative distances
    - resolution nm
  - FSI mode:
    - slow
    - Absolute distances
    - Precision 1μm.

A Straightness Monitor Made from Distance Meters

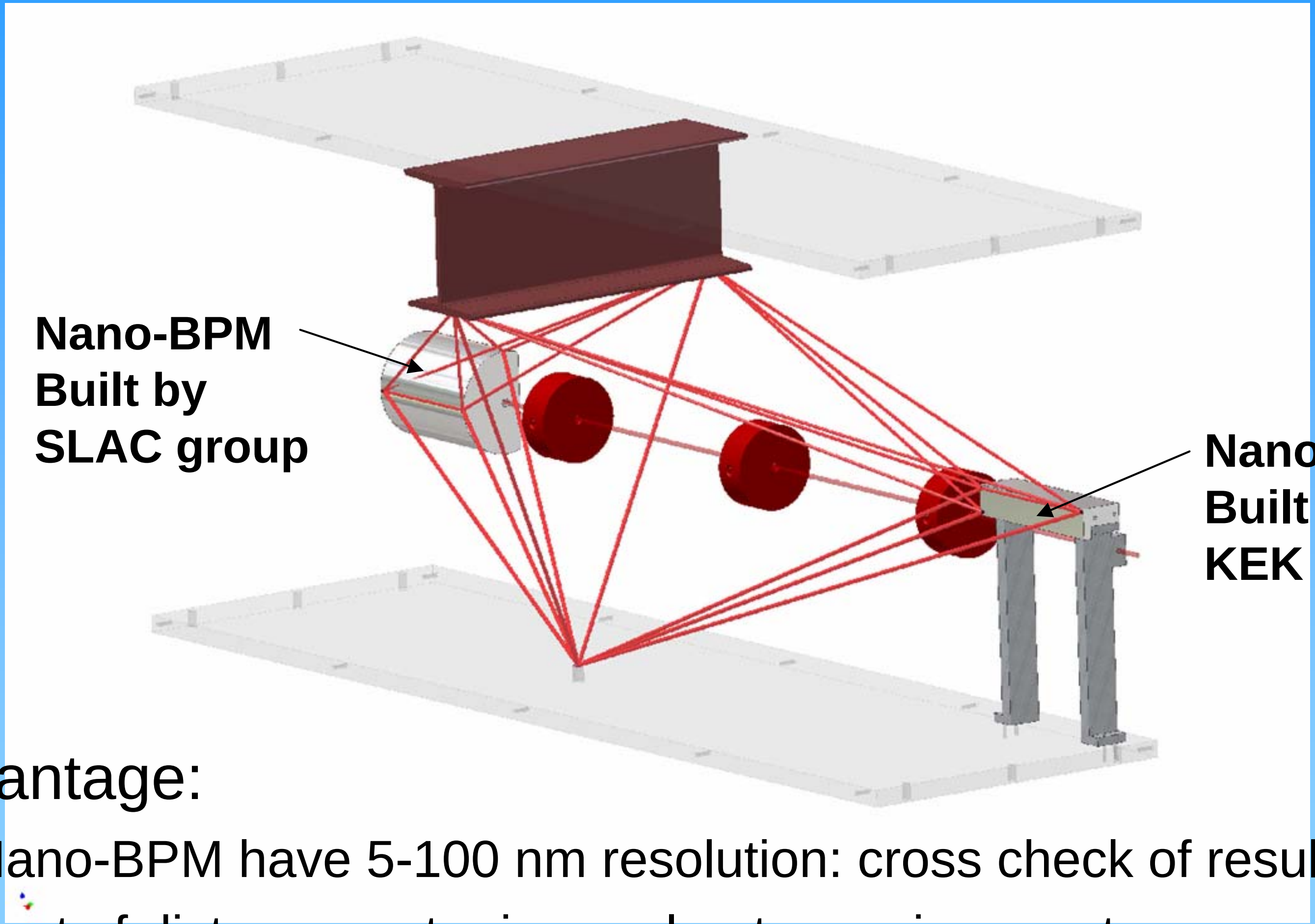
by D.Urner



- 3 nodes on each object, with 3 distance meters to each triangle node

Implement system at ATF/KEK relating positions of nano-BPM's

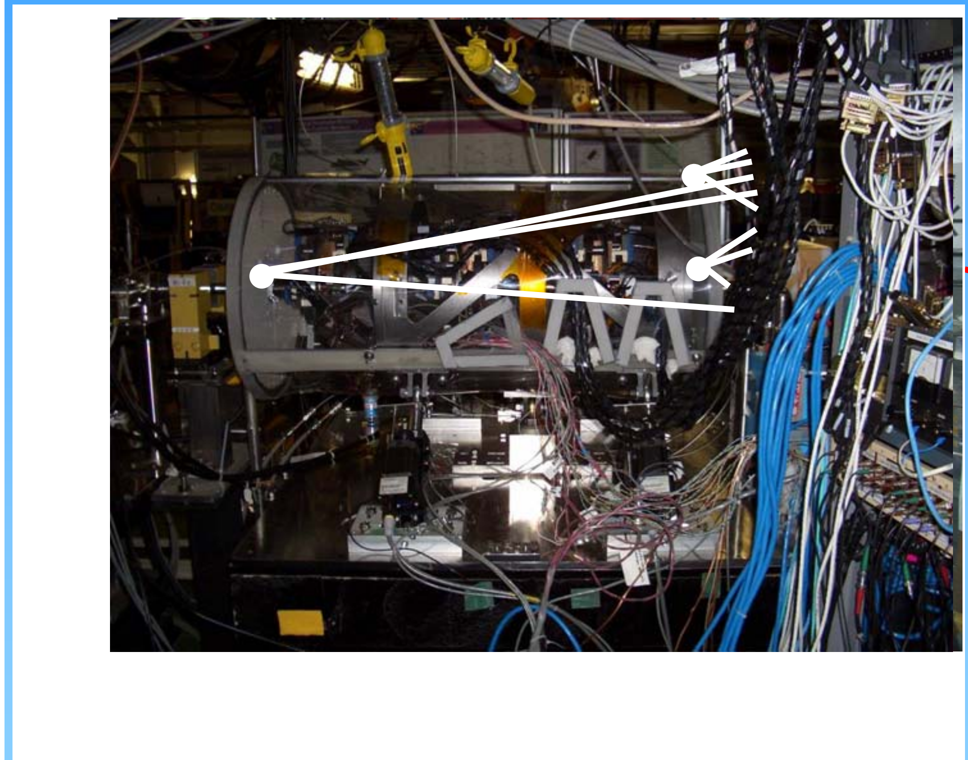
by D.Urner

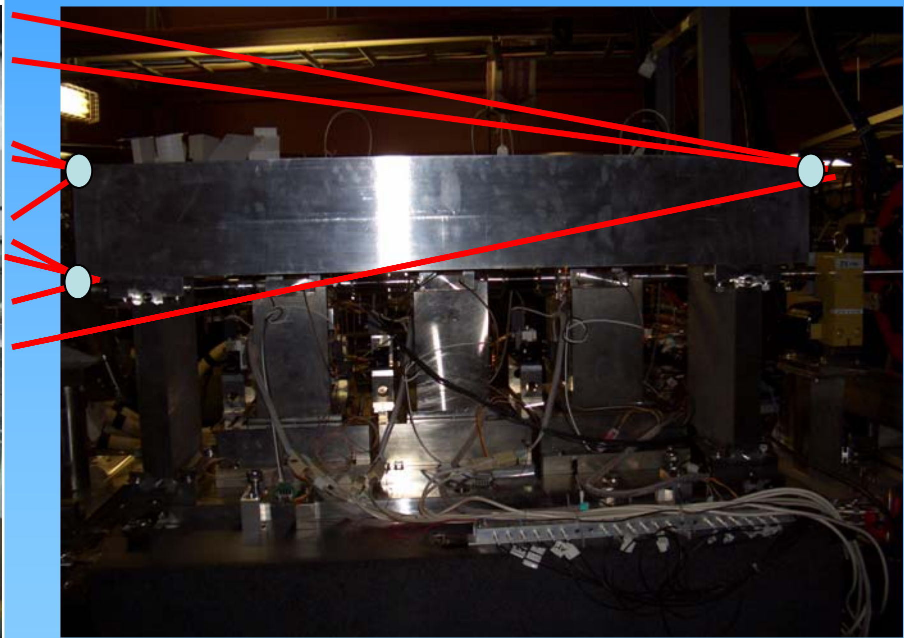


- Advantage:
  - Nano-BPM have 5-100 nm resolution: cross check of results
  - Test of distance meter in accelerator environment

Spider web Design with Opto-Geometrical Simulation: Simulgeo

by D.Urner

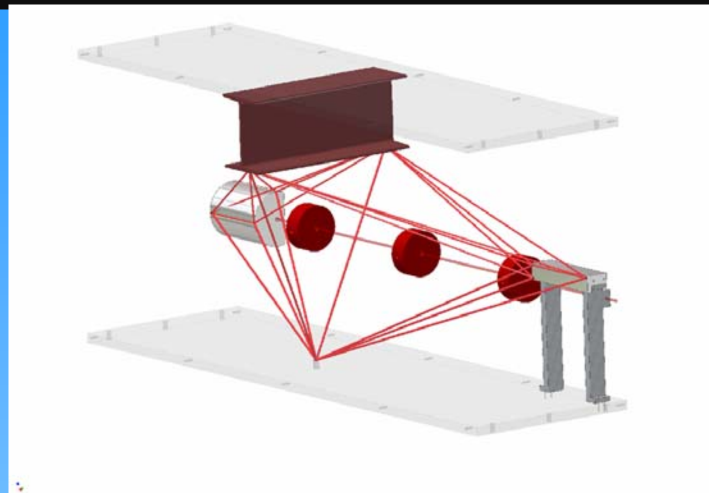


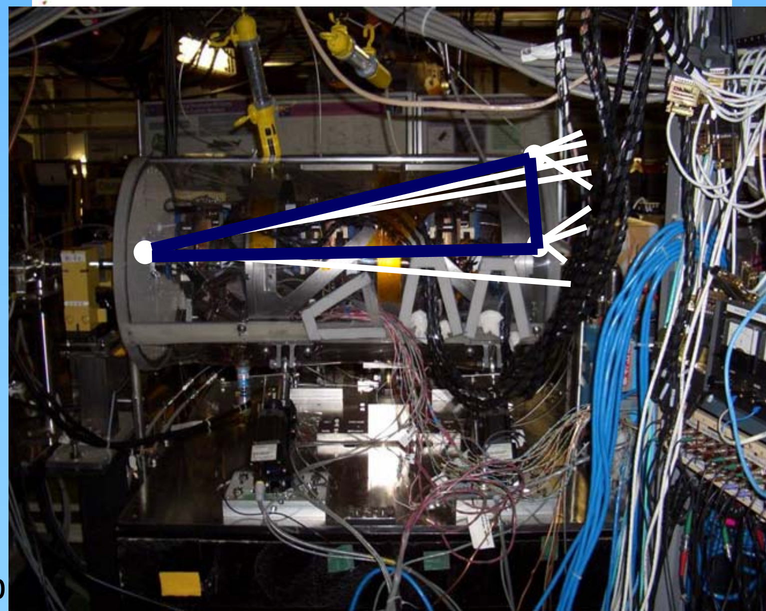


BPM Nodes

by D.Urner

- One wide angle retro-reflector (cateye) for each node
- Challenges:
  - Relative position between retro-reflector needs to be known to 1nm
    - Requires measurement between 3 nodes on each nano-BPM.(blue lines).
  - Attachment of vacuum lines to BPM's
    - Requires zero-force design.

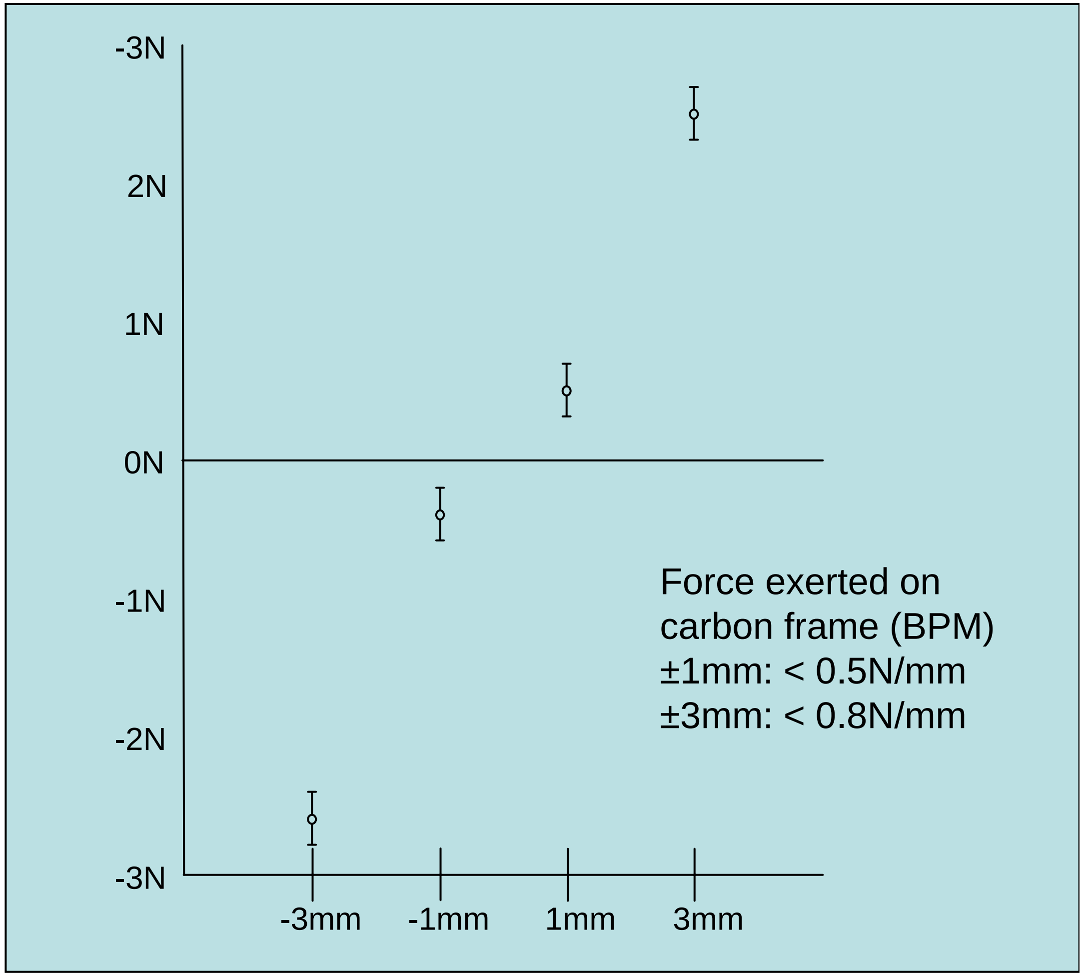




Force Free Mount

by D.Urner

- Needs bellow to allow motion of BPM
  - Vacuum causes a force order of 100N!
- Develop small force vacuum mount using double bellow system.
- Allows small motion (~1 mm) of BPM-system
- Test stand to measure remaining (perpendicular) force on BPM frame.



Force exerted by perpendicular motion

Concluding Remarks

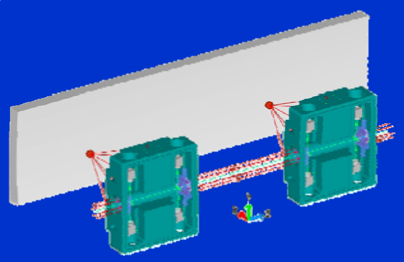
by D.Urner

- Developing
  - Software to understand distance meter.
  - Hardware to characterize laser.
  - Temperature sensing system.
- First optical simulation in place.
- Force Free mount system seems to work.
- Starting work on Mount/Alignment system for distance meter setup at KEK
- Still much to do
  - but things start to fall into place

WP7 Metrology and stabilisation

METSTB

RTRS



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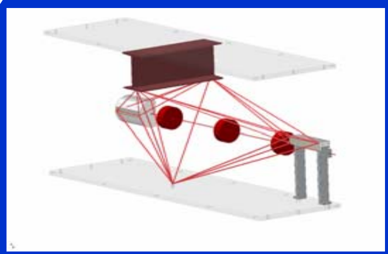
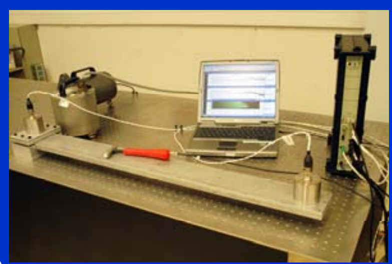
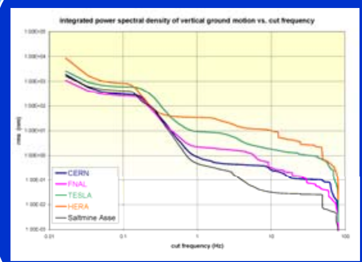


MSTBT



PGMS



EuroTeV WP7 projects

by R. Amirikas and A.Bertolini

Metrology in DESY
- **Site characterization and parameterization of data**
- **Correlation measurements; related to site characterization**
- **Floor motion due to building foundation (e.g. piled foundation & floor slabs)**

Stabilization in DESY
- **Accelerator component vibration studies:**

❖ **Cryomodule vibration studies in warm and cold environments, geared towards main linac design (one of the main cost drivers for the ILC)**

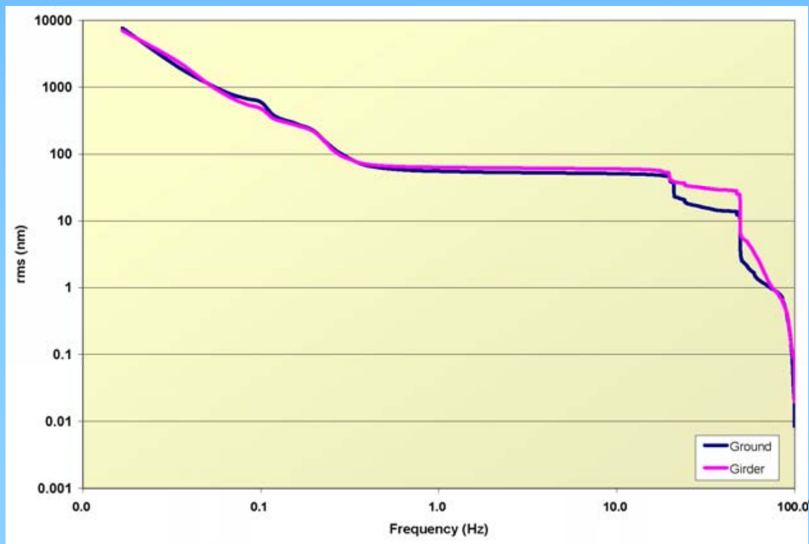
❖ **Stability of support structures, such as girders**

❖ **Facility noise: potential vibration sources in a tunnel, e.g. vacuum pumps, modulators**

Stability of accelerator components; case study: MAXLab (Lund) girder

by R. Amirikas and A.Bertolini

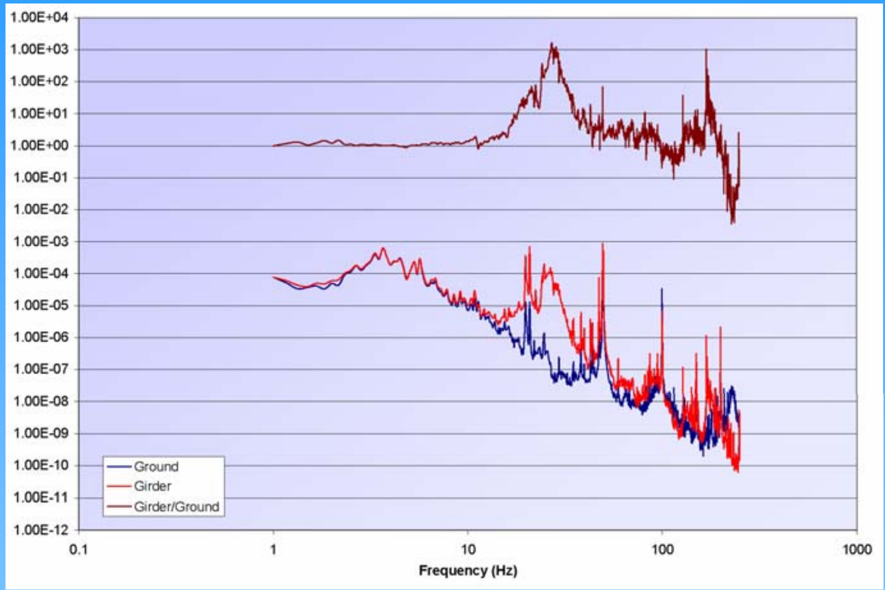
- **Study of support structures, e.g. girders is important for the stability of the cryomodules in the ILC; MaxLab girder measurements (visit funded by ALBA)**
- **EuroTeV report 2006-020 submitted to ALBA & MAXLab**



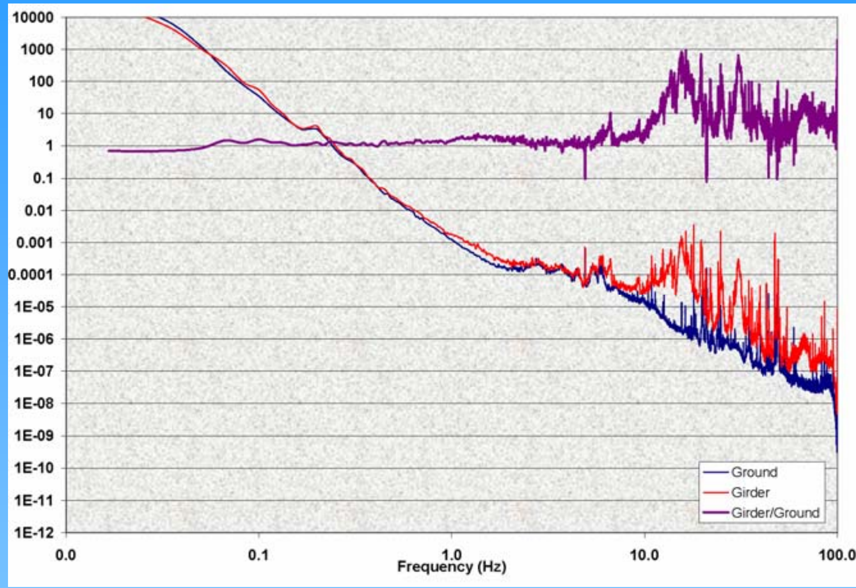
Vertical vibration measurement via a seismometer, transfer function girder/ground ~1.2 @ 1 Hz

Stability of accelerator components; case study: MAXLab (Lund) girder

by R. Amirikas and A.Bertolini



Horizontal vibration (longitudinal to the beam direction) measurement via geophones,
Resonance: ~28-30 Hz, transfer function, girder/ground~2 @ 1.7 Hz

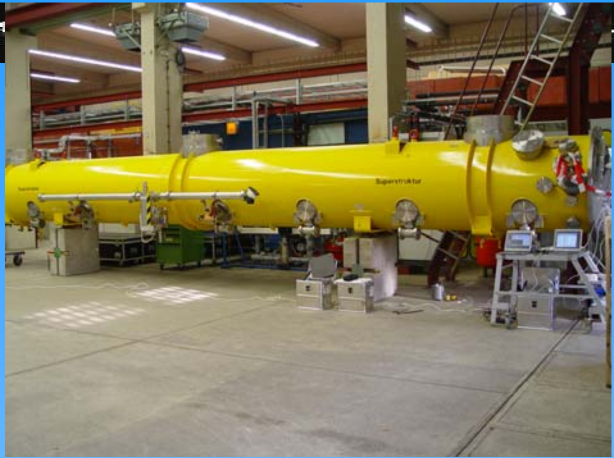


Horizontal vibration (transverse to the beam direction) measurement via a seismometer,
resonances: ~15-16 & 30 Hz, transfer function, girder/ground ~2 @ 1 Hz

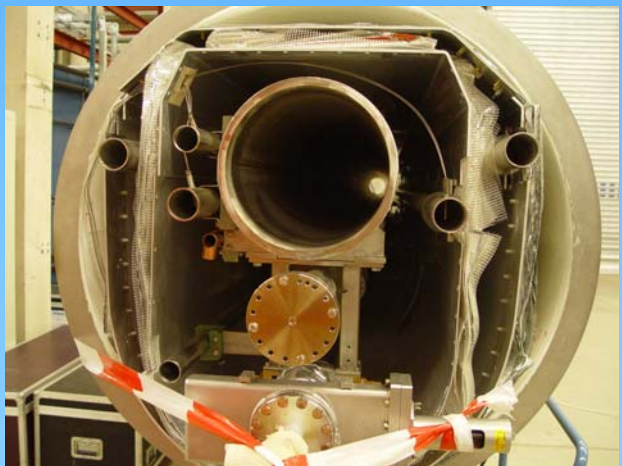
➢ **Conclusion: MaxLAB girder is stable vertically, but not horizontally; A better girder design should be pursued in the horizontal direction.**

Stability of accelerator components: Measurement of the stability of a 'warm' cryomodule (Type II Superstruktur)

by R. Amirikas and A.Bertolini



2 Seismometers, one on the vessel top, the other, on the ground; simultaneous geophone measurements



With quadrupole (back view)

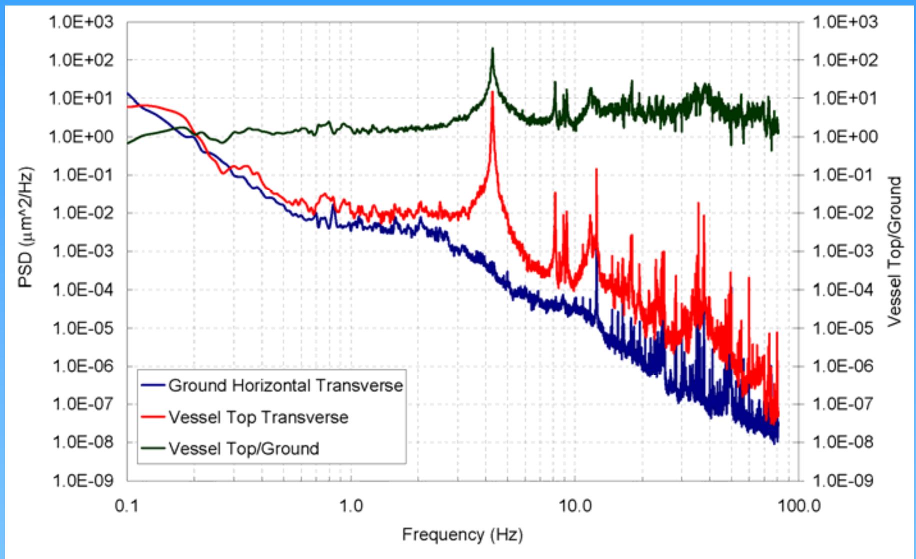
Seismometer Güralp CMG-6TD inside Helium Gas Return Pipe (GRP)

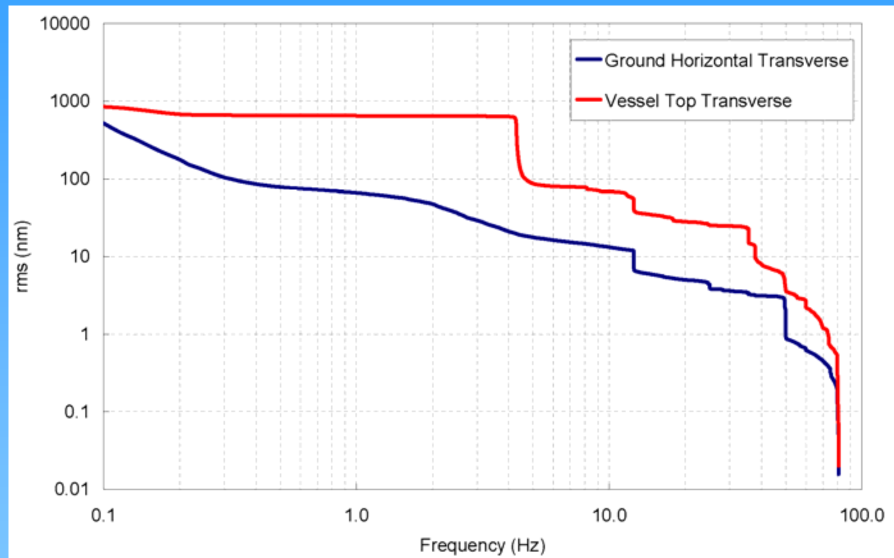
Sensor SM-6 vertical geophone placed on the cryostat

Stability of accelerator components: Measurement of the stability of a ‘warm’ cryomodule (Type II Superstruktur)

by R. Amirikas and A.Bertolini

Ground to vessel top (transverse to the beam direction)





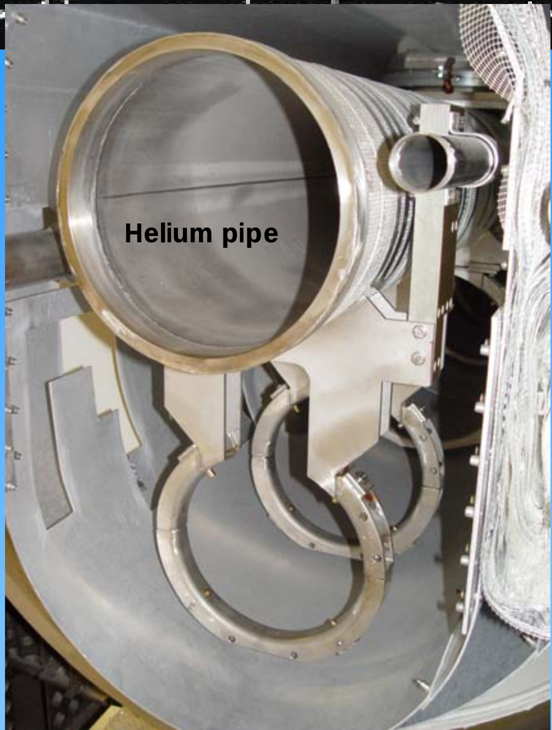
PSD in transverse direction to the beam pipe as measured via seismometers, Vessel top vs. Ground, Vessel resonances: ~4.3, 8.0, 9.0 Hz; vessel rocks due to bad girder support (in this case concrete slabs) & steel pads

Integrated transverse vibration for f>1Hz as measured via seismometers, amplification @ 1 Hz: Top/Ground~ 10

Amplification factor for Ground/Quad = Top/Ground*Helium/Top*Quad/Helium =10.0*0.80*1.06= 8.48 ~10

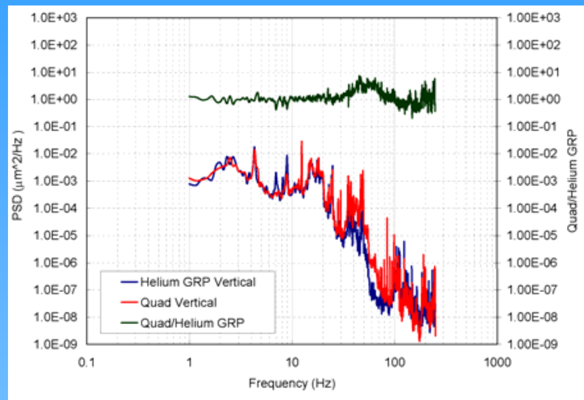
Stability of accelerator components: Measurement of the stability of a 'warm' cryomodule (Type II Superstruktur)

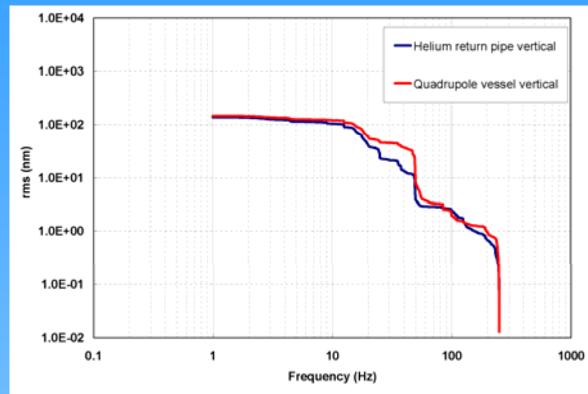
by R. Amirikas and A.Bertolini



Quadrupole support structure
(shown without the quad)

Helium pipe (vertical) to the cryostat





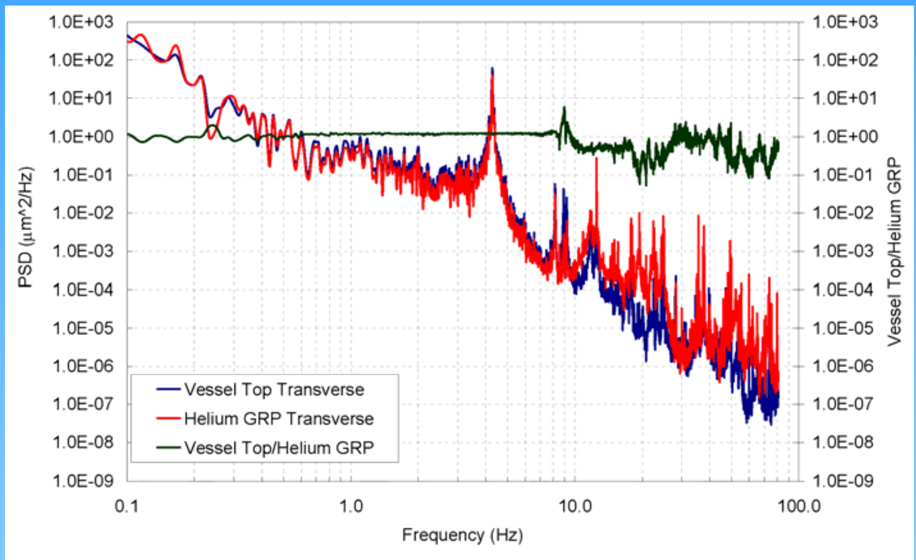
Integrated vertical vibration for f > 1 Hz as measured via geophones of Helium pipe vs. quadrupole, amplification @ 1 Hz: Quad/Helium~1.06 or ~10%
Connection from the Helium pipe to the quad is rigid within 10%

- **EuroTeV report & EPAC06 contribution (in preparation)**

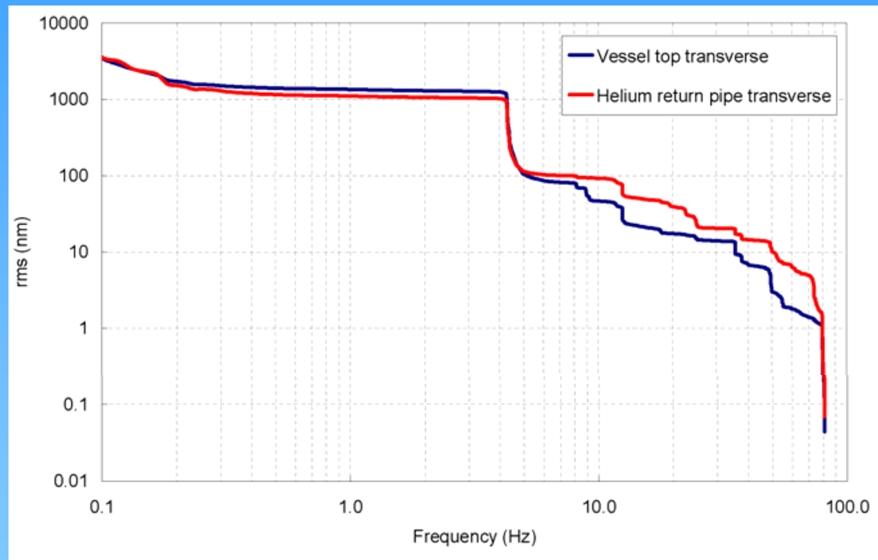
Stability of accelerator components: Measurement of the stability of a ‘warm’ cryomodule (Type II Superstruktur)

by R. Amirikas and A.Bertolini

Vessel top to Helium pipe (transverse to the beam direction)



PSD in transverse direction to the beam pipe as measured via seismometers, Vessel top vs. Helium pipe



Integrated transverse vibration for f > 1 Hz as measured via seismometers, amplification @ 1 Hz: Top/Helium~1.22, or ~22%

Cold mass test plan

by R. Amirikas and A.Bertolini

Motivation:

- Evaluate the rigidity of the quad supporting structure to confirm 1:1 vessel to quad transfer function (in warm and cold)
- Evaluate quantitatively return He-flow contribution, perhaps with different flow rates
- Use the same setup to test other interferometric position sensors (Oxford) & POLYTEC

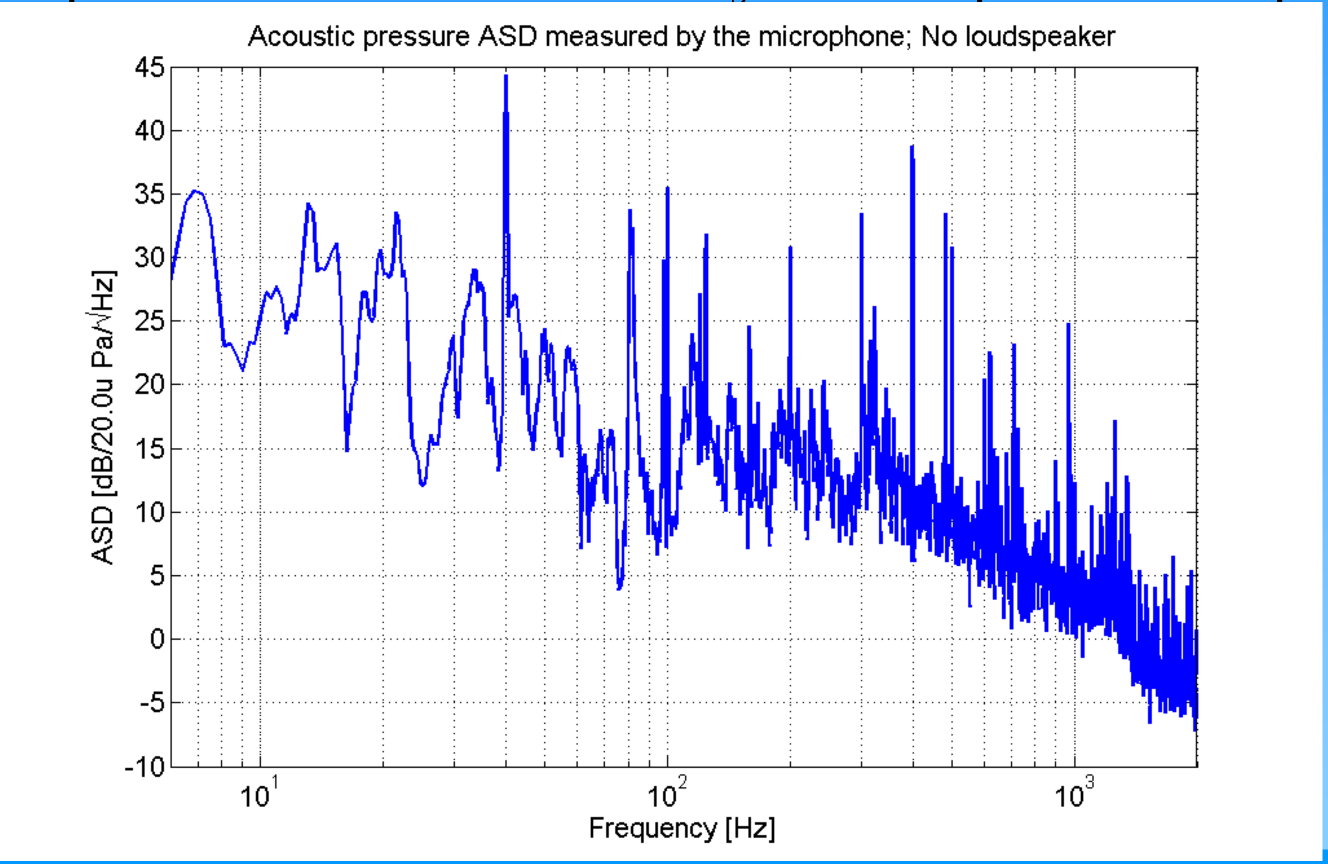
Technique:

- Place two 'mirrors' directly on the cold quadrupole He vessel
- Measure their motion with respect to a reference frame by means of a laser interferometer (self-calibrated, sub-nanometer resolution etc.); measure the frame motion with a seismometer
- Use different reference frames can provide different information and offer data-quality check
- Reference frames: ground, inertial platform, cryomodule vessel (essential to measure small amplitude differences, otherwise the vessel rocking modes dominate the dynamics)

Free-fixed beam under indoor environmental acoustic noise

by B.Bolzon

✓ Acoustic pressure ASD measured by a microphone in a quiet room :

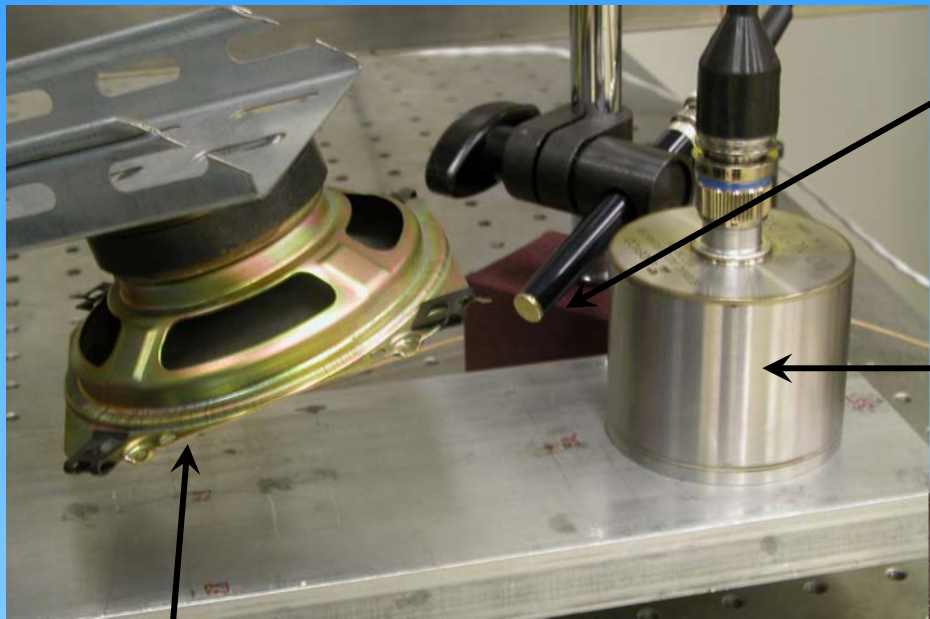


→ **Like a pink noise :** random signal with PSD inversely proportional to the frequency

Free-fixed beam under indoor environmental acoustic noise

by B.Bolzon

Experimental setup



Measurement of the acoustic pressure

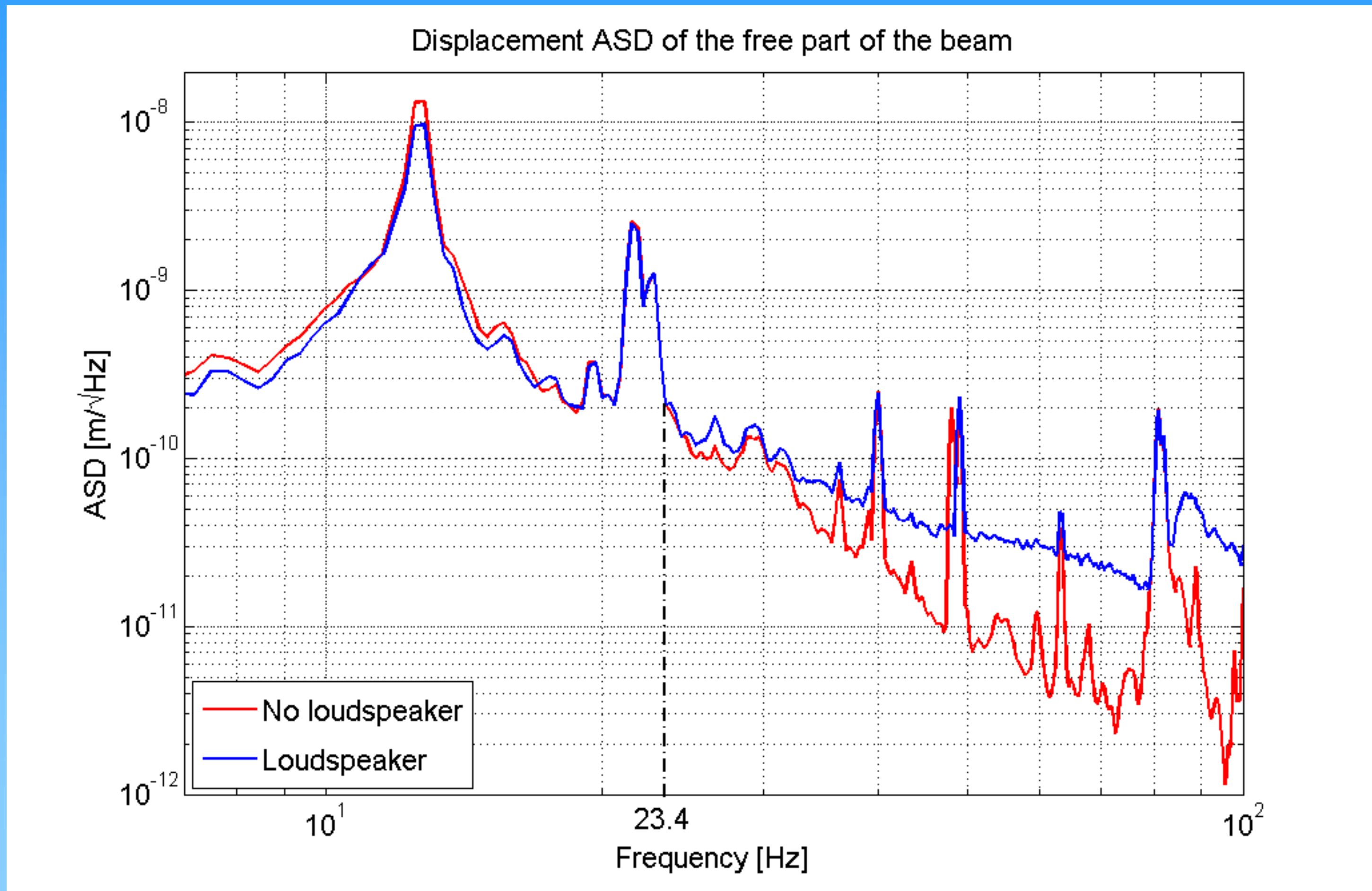
Measurement of the beam vibrations

Loudspeaker creating some acoustic noise

Measurement of the ground motion

Impact of the loudspeaker on the vibrations of the beam

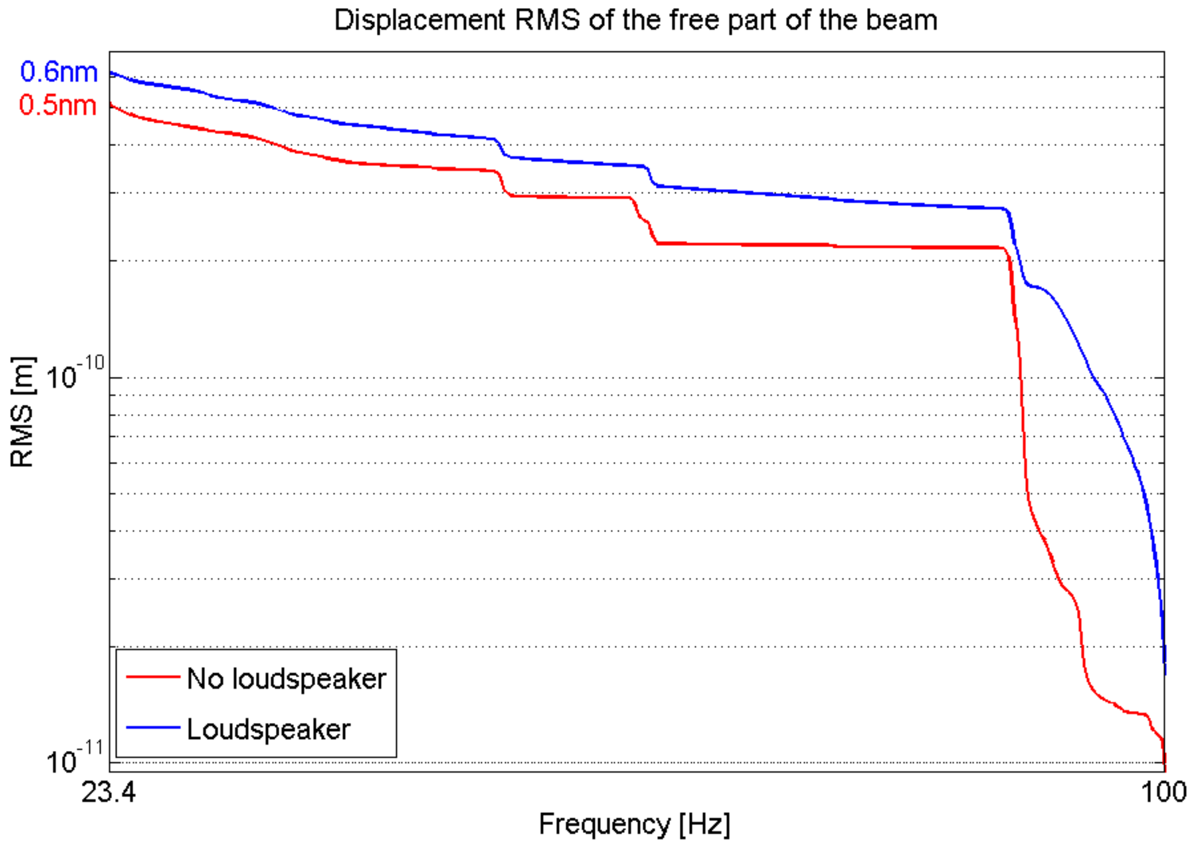
by B.Bolzon



✓ **Above 23.4Hz :** Vibrations of the beam higher with the loudspeaker

Impact of the loudspeaker on the vibrations of the beam

by B.Bolzon



Very small increase of acoustic pressure : 44dB→53dB

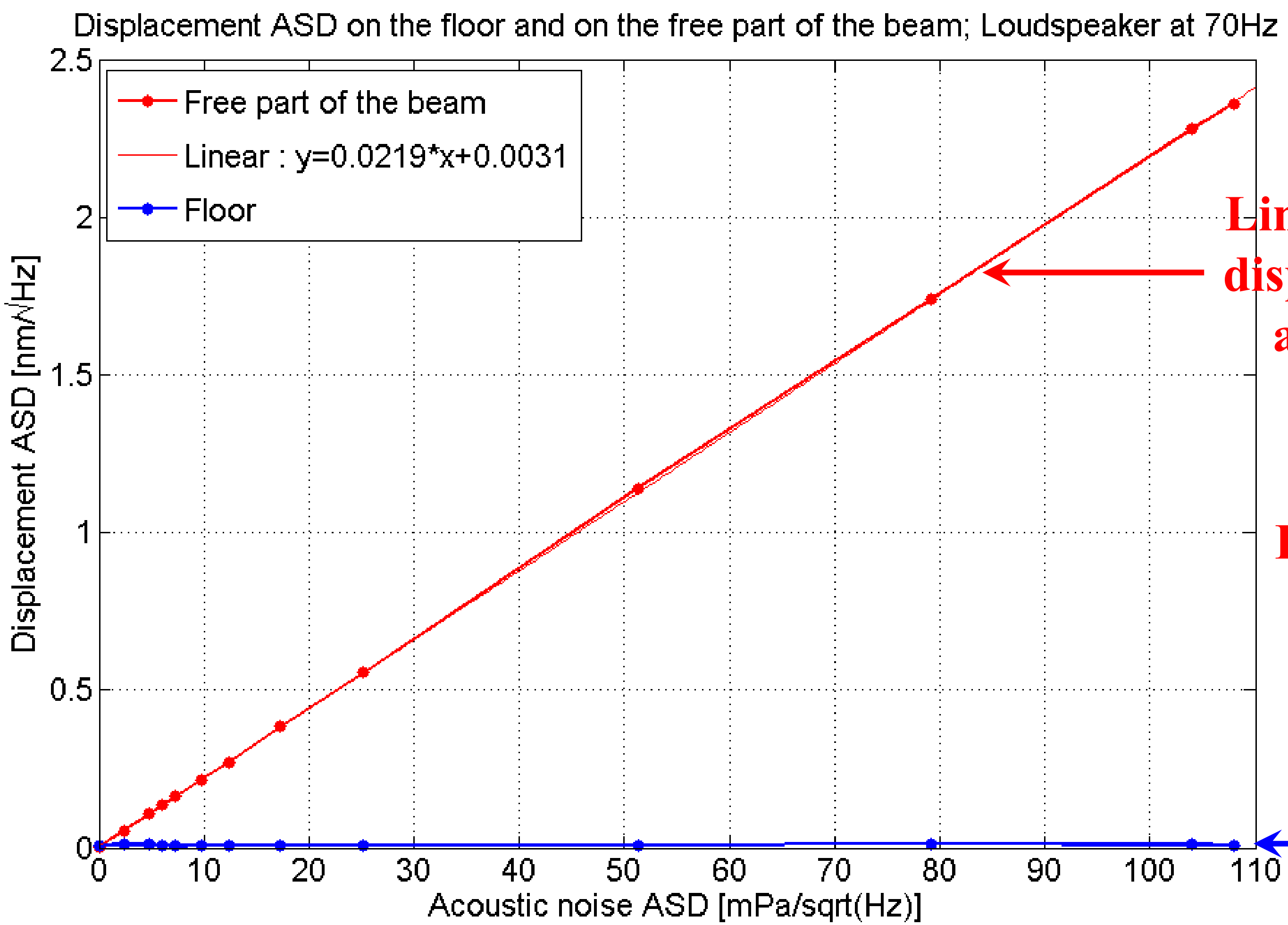
Small increase of the beam displacement : 0.1nm

✓ For sure, impact of acoustic pressure on the vibrations of a free-fixed beam

✓ But need of more measurements to evaluate if this impact is important

Linear behaviour of the beam under acoustic noise

by B.Bolzon



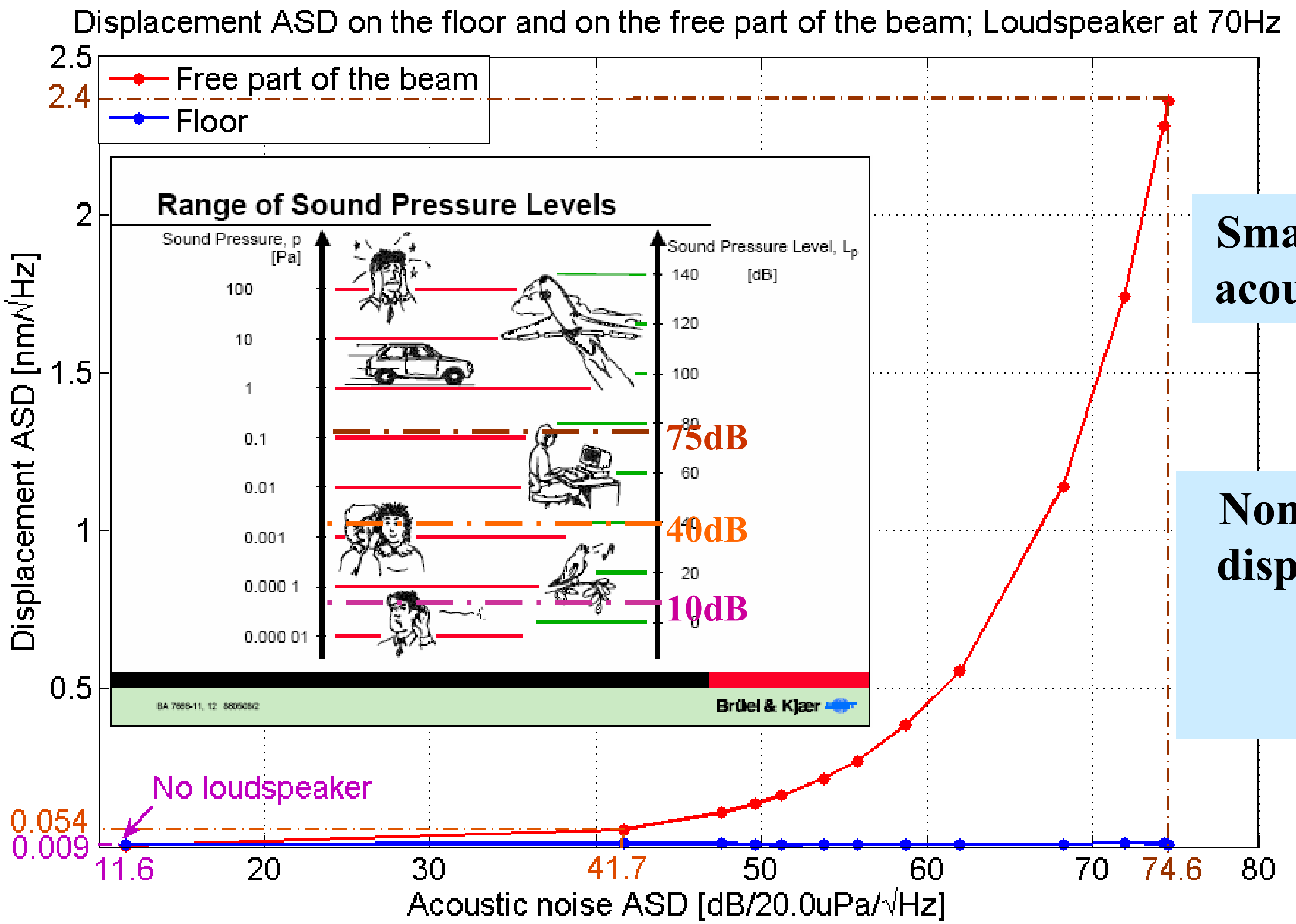
Linearity of the beam displacement with the acoustic pressure

Linear regression performed

Stationarity of the ground motion

Linear behaviour of the beam under acoustic noise

by B.Bolzon



Small increase in acoustic pressure

Non negligeable displacement on beam

General conclusion and future prospects

by B.Bolzon

✓ **Small increase of acoustic pressure ⟹ Increase of the beam displacement non negligible**

→ Non negligible impact of acoustic noise on the displacement of the beam proved

✓ **In a linear collider, acoustic noise very important :**

→ Need to go on with the study of acoustic noise

✓ **Excitation on a predictive model : only ground motion**

→ Maybe should include acoustic noise

✓ **Other future prospects :**

→ Acquisition of an acoustic enclosure to put the free-fixed beam in

Strategy of the approach

The Spectrum of disturbances is not a white noise
(ground motion, acoustic noise…)

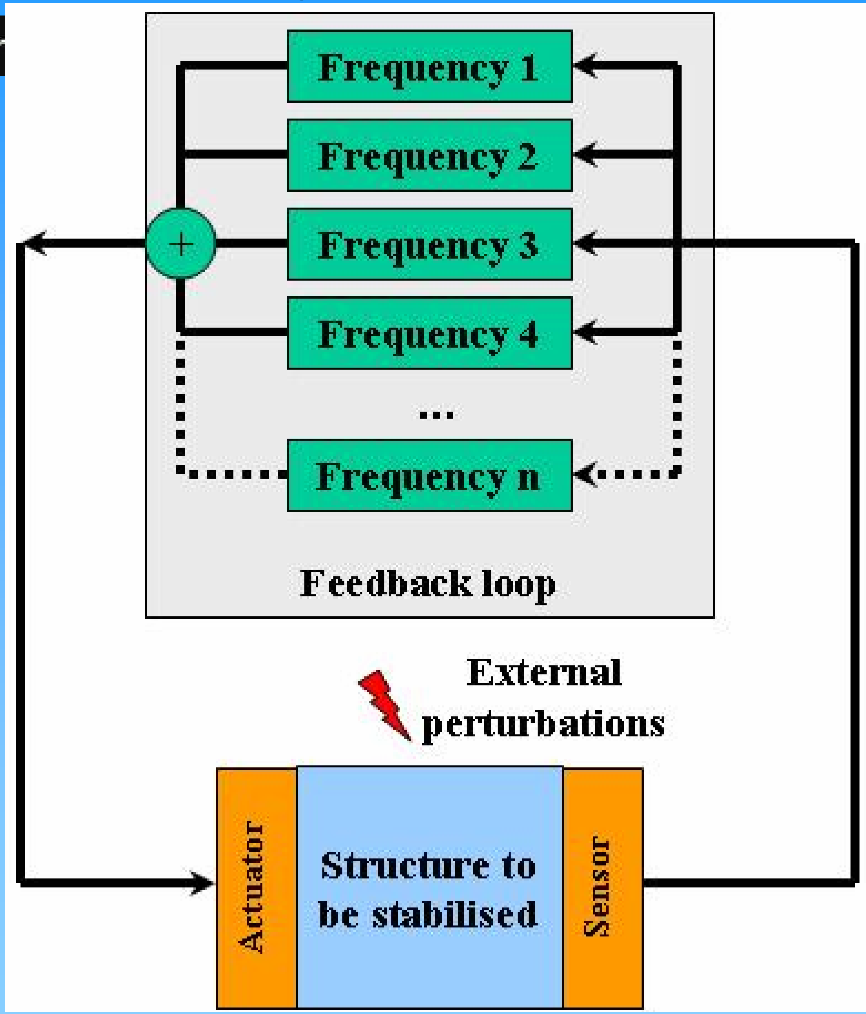
Filtering by the mechanical structure

The global effect of the disturbance contains :

- *Some frequencies which are amplified*
- *All frequencies are independent*

Strategy : to control independently every main frequency

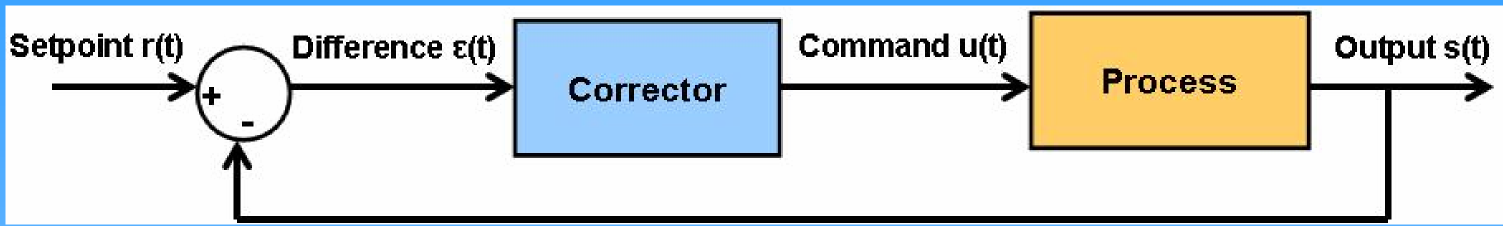
by L.Brunetti



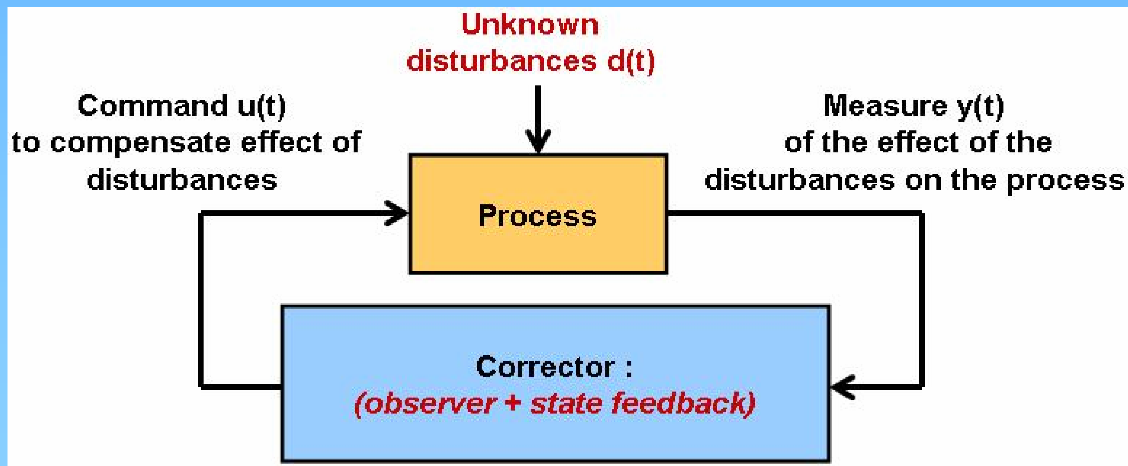
Originalities of the method : the algorithm

by L.Brunetti

Usually, a classic algorithm (ex : PID), depends on the model of the process :



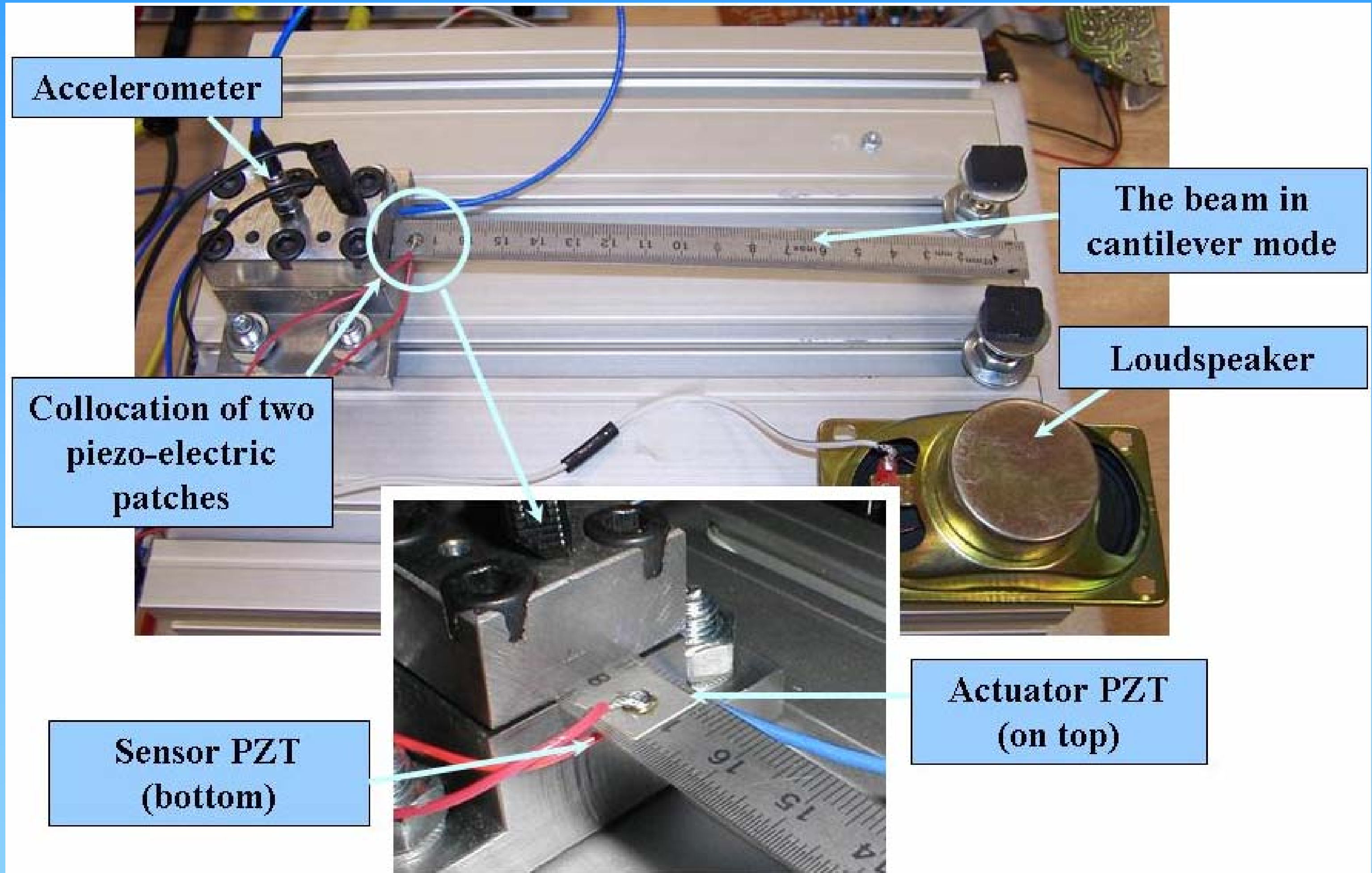
It is not a classic algorithm, it is a compensation of the disturbance :
(without knowing the model of the process, only its behaviour at certain frequencies)



Test the algorithm with a small prototype

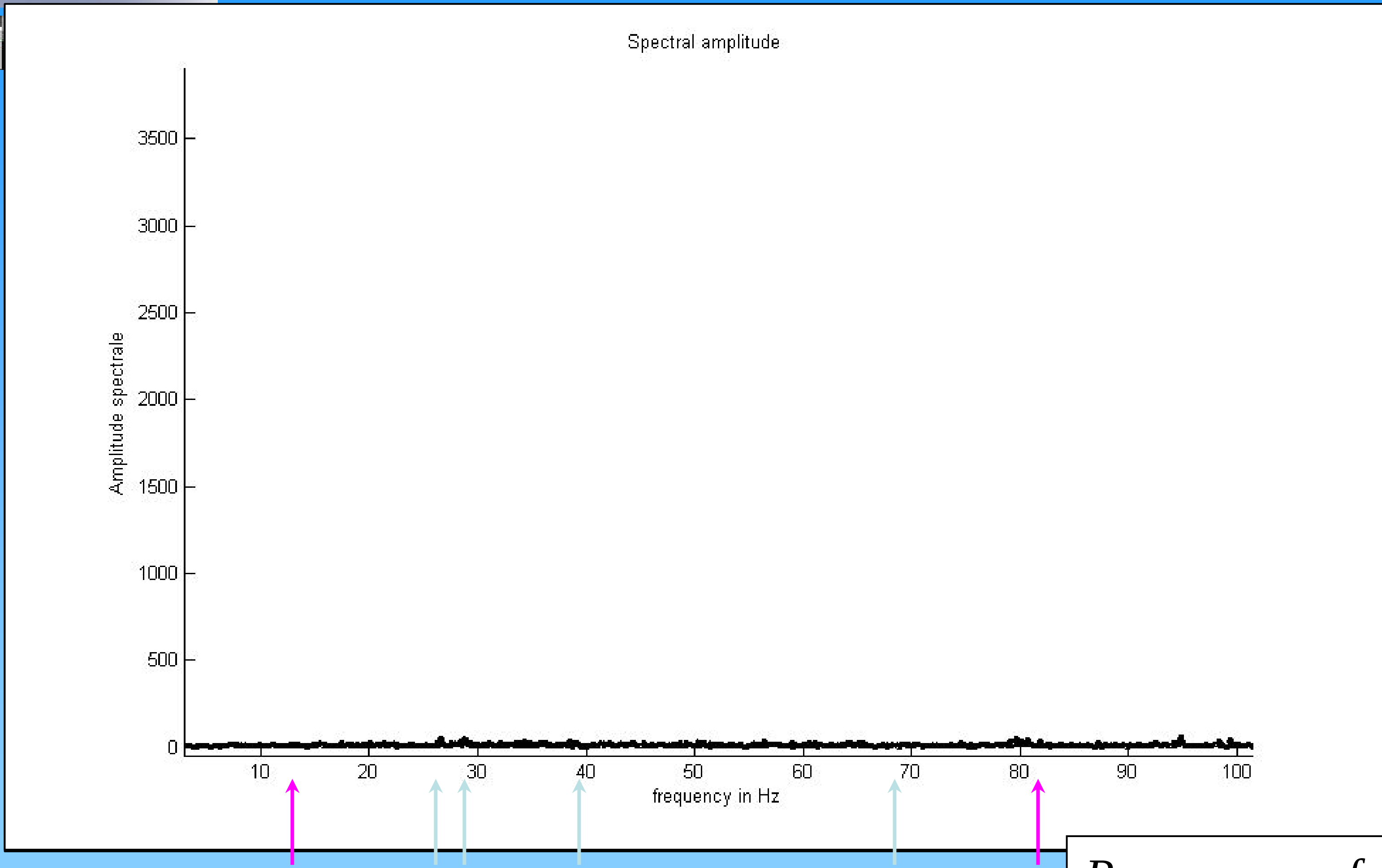
by L.Brunetti

Description of the prototype :



Results

Rejection of 6 resonances : (without and with rejection) by L.Brunetti

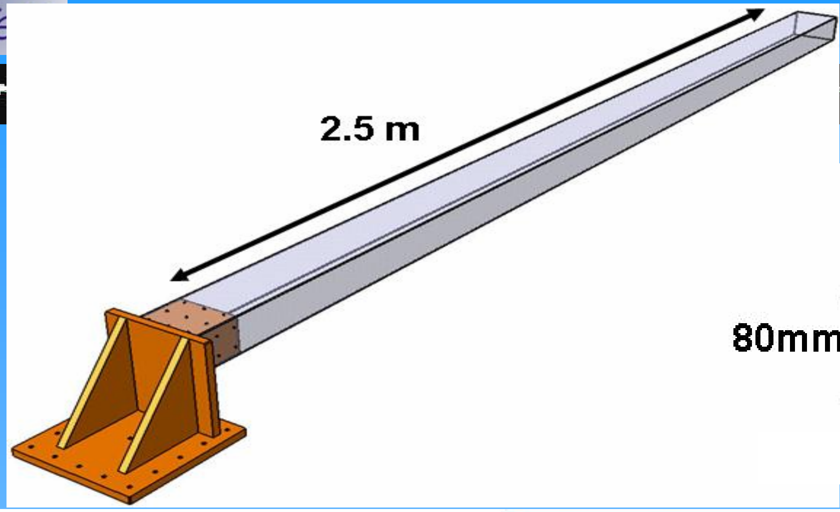


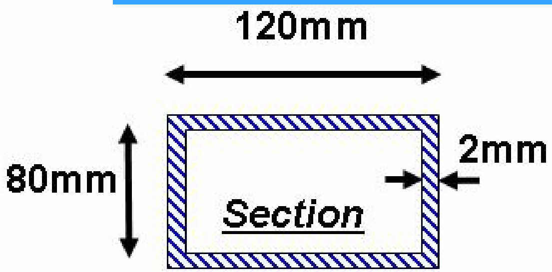
Resonances of : -beam
-support

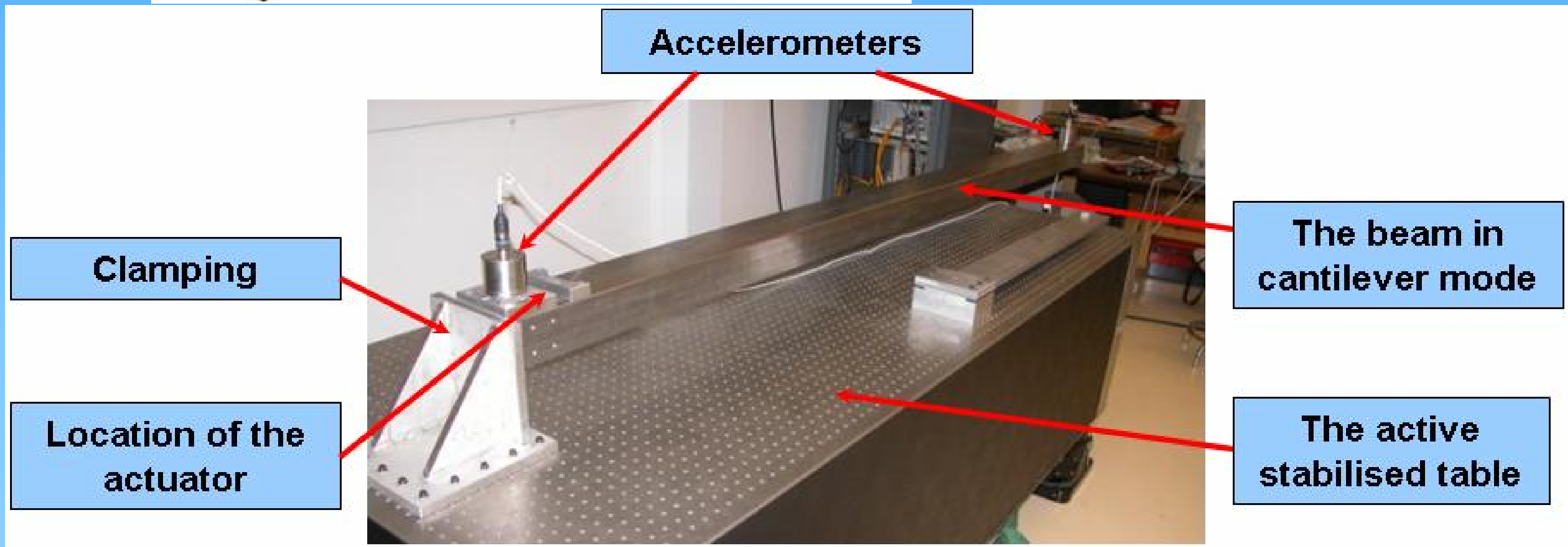
A large scale prototype

The mock-up :

by L.Brunetti







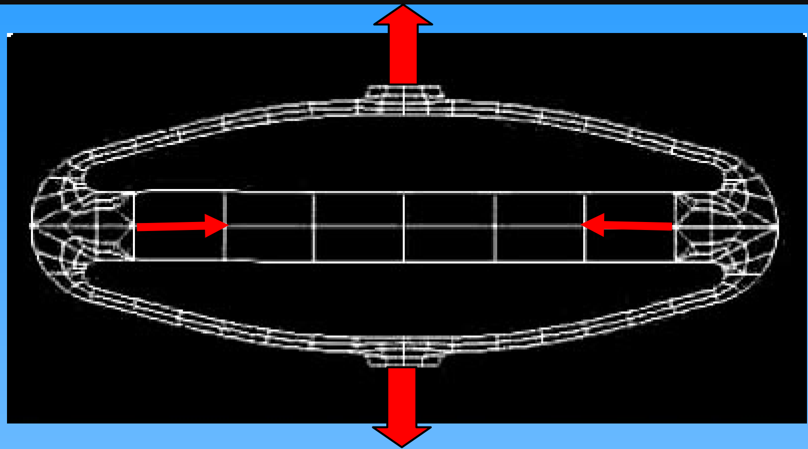
The actuator : description

by L.Brunetti

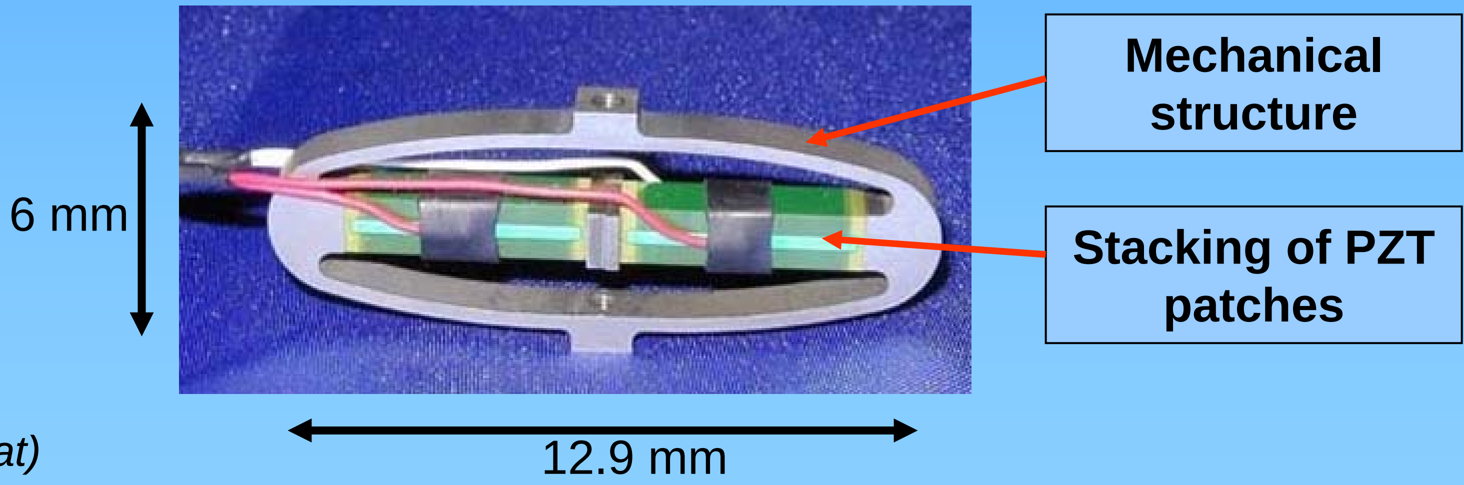
Force = 19.3 N

Maximal displacement = 27,8 µm

Resolution = 0,28 nm



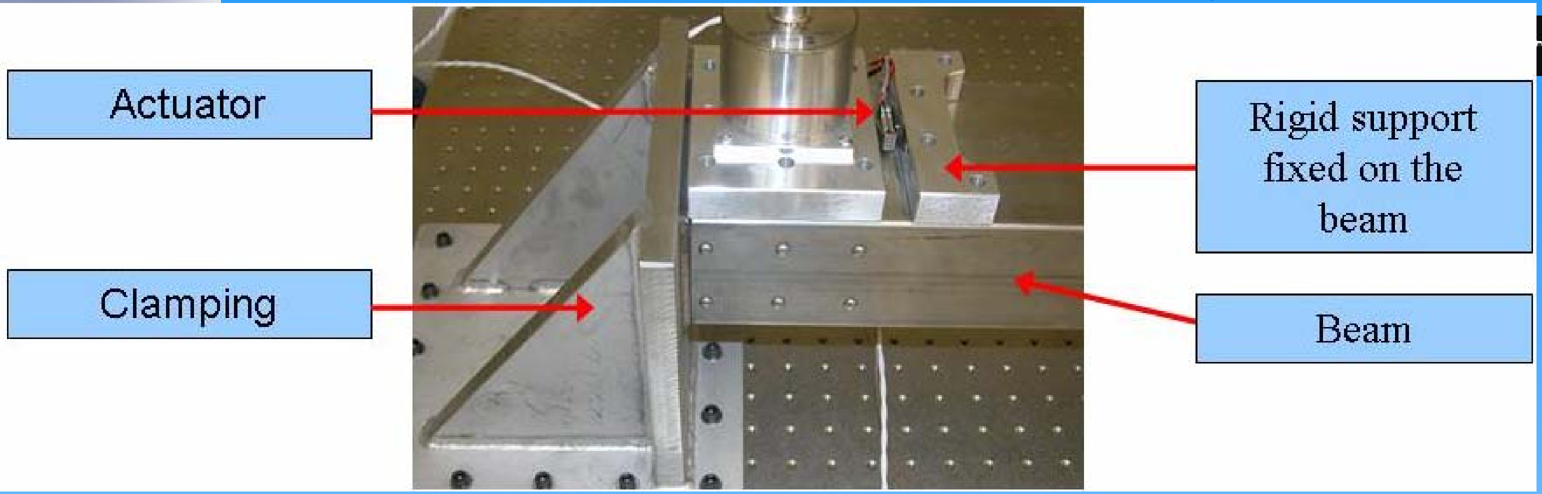
The deformation of the PZT patches is amplified by the mechanical structure

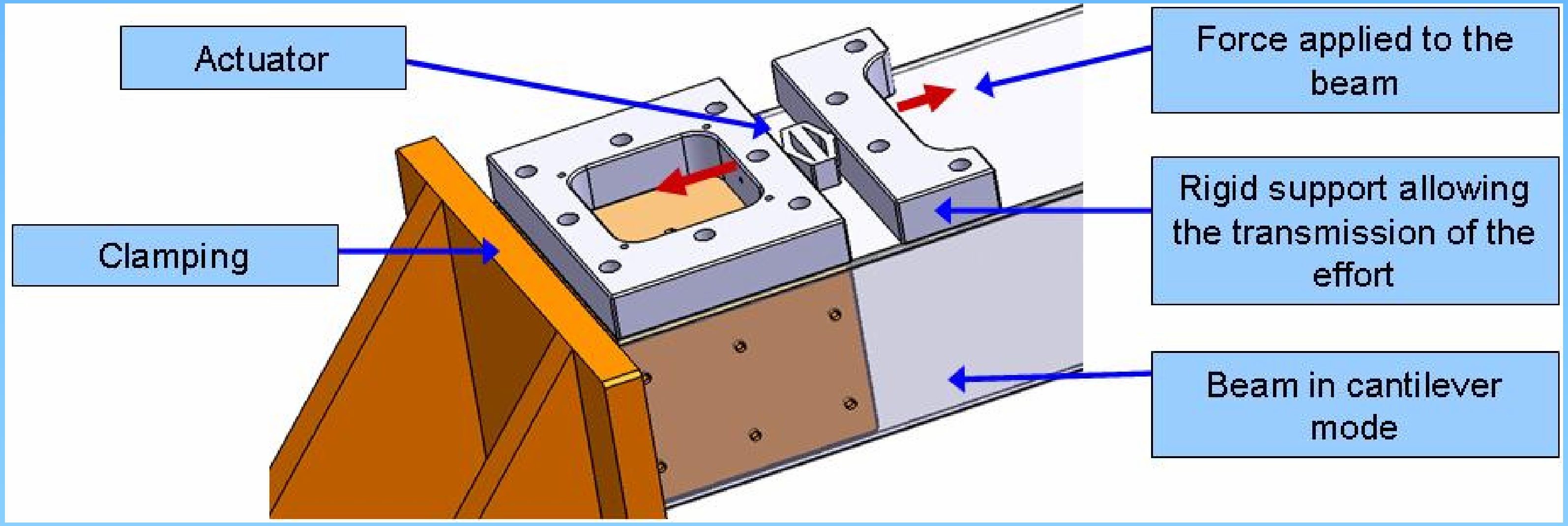


(Produced by Cedrat)

The actuator applies a force in flexion

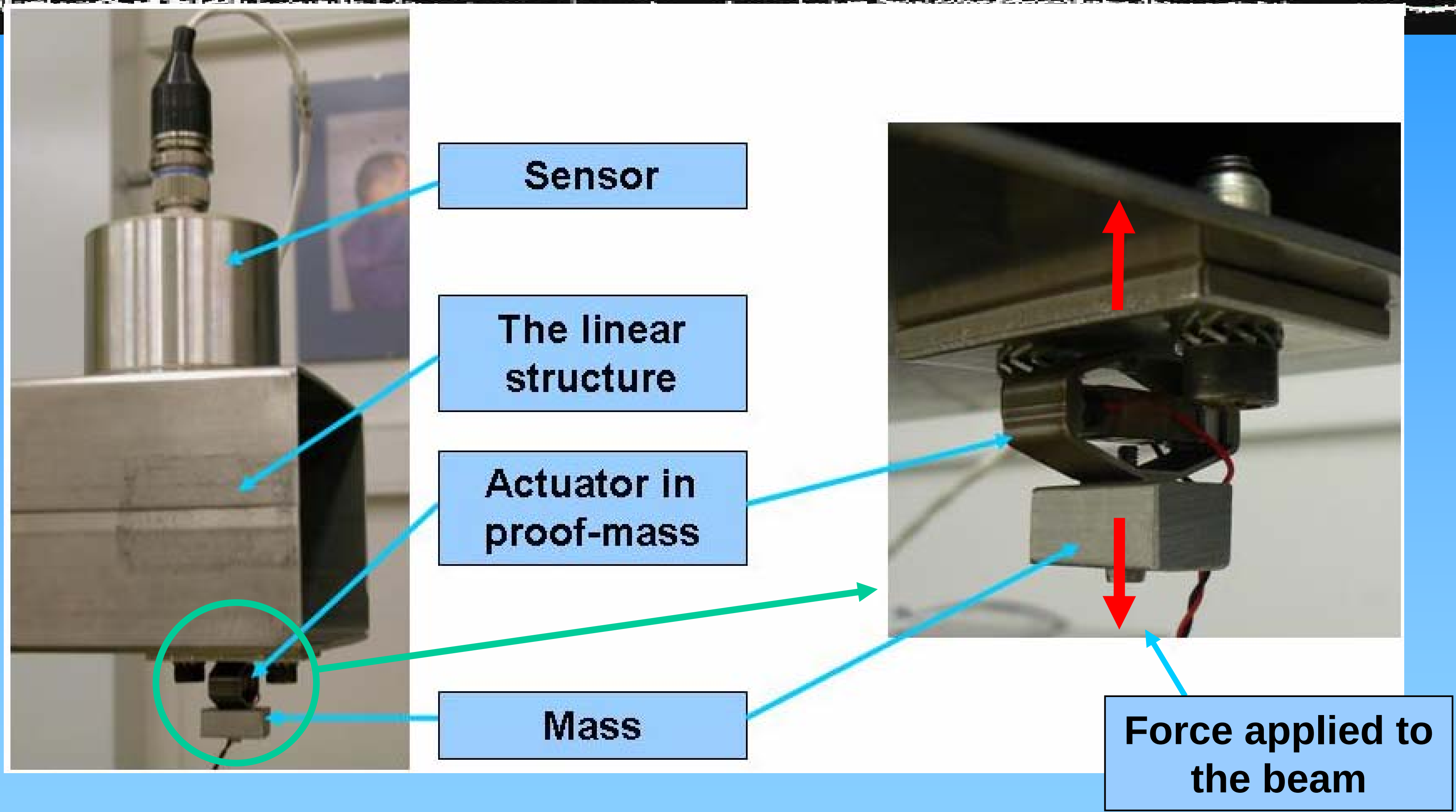
by L.Brunetti





The actuator applies a force in “proof-mass”

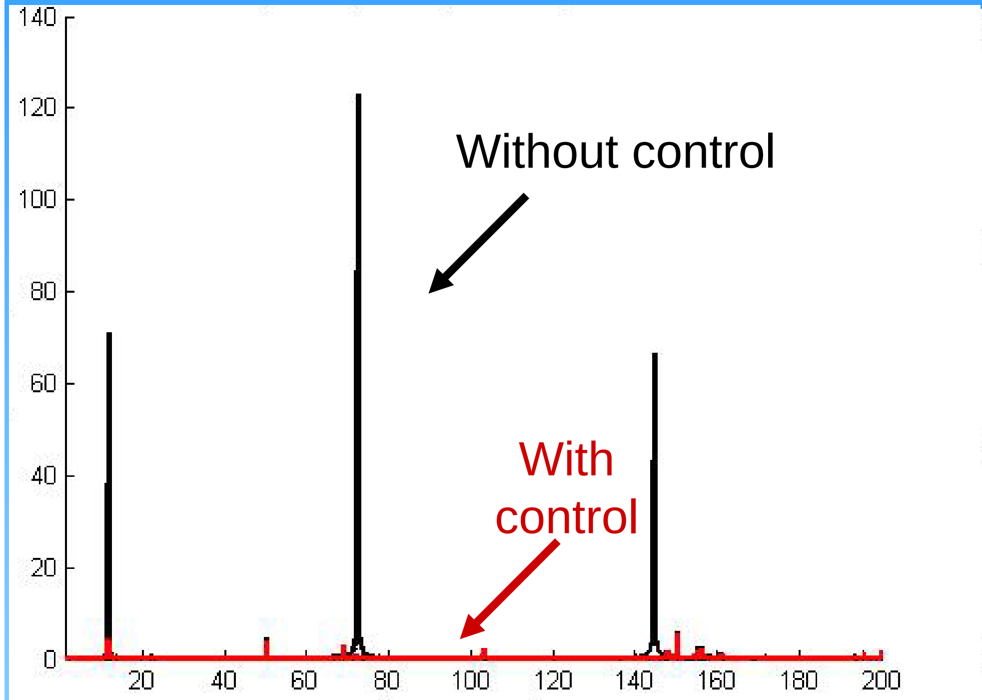
by L.Brunetti



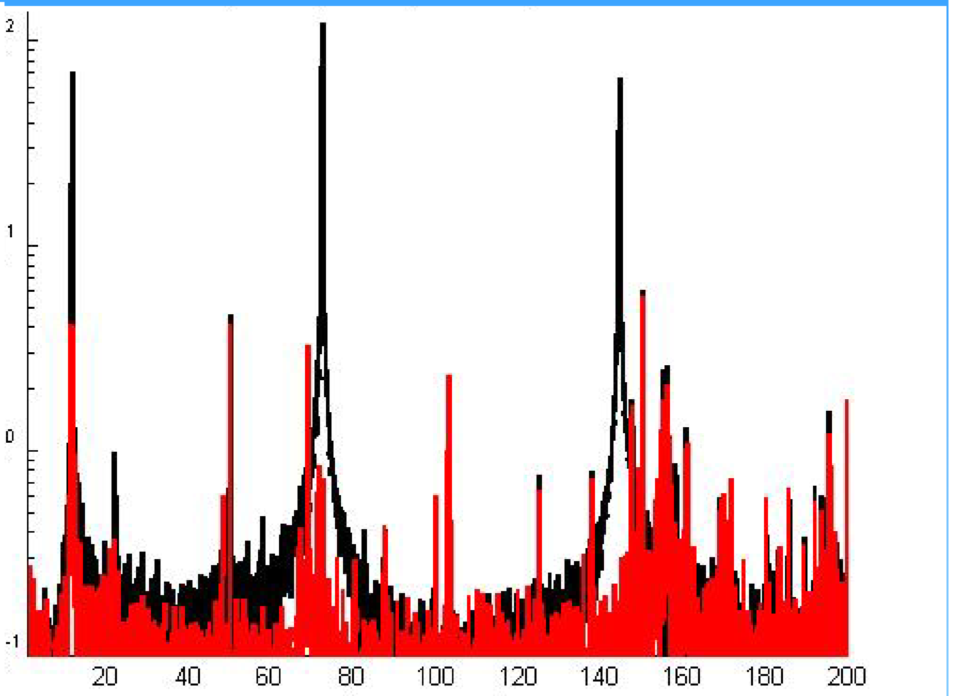
Results : rejection of 3 fixed frequencies of disturbances

by L.Brunetti

Spectral amplitude of measured signals



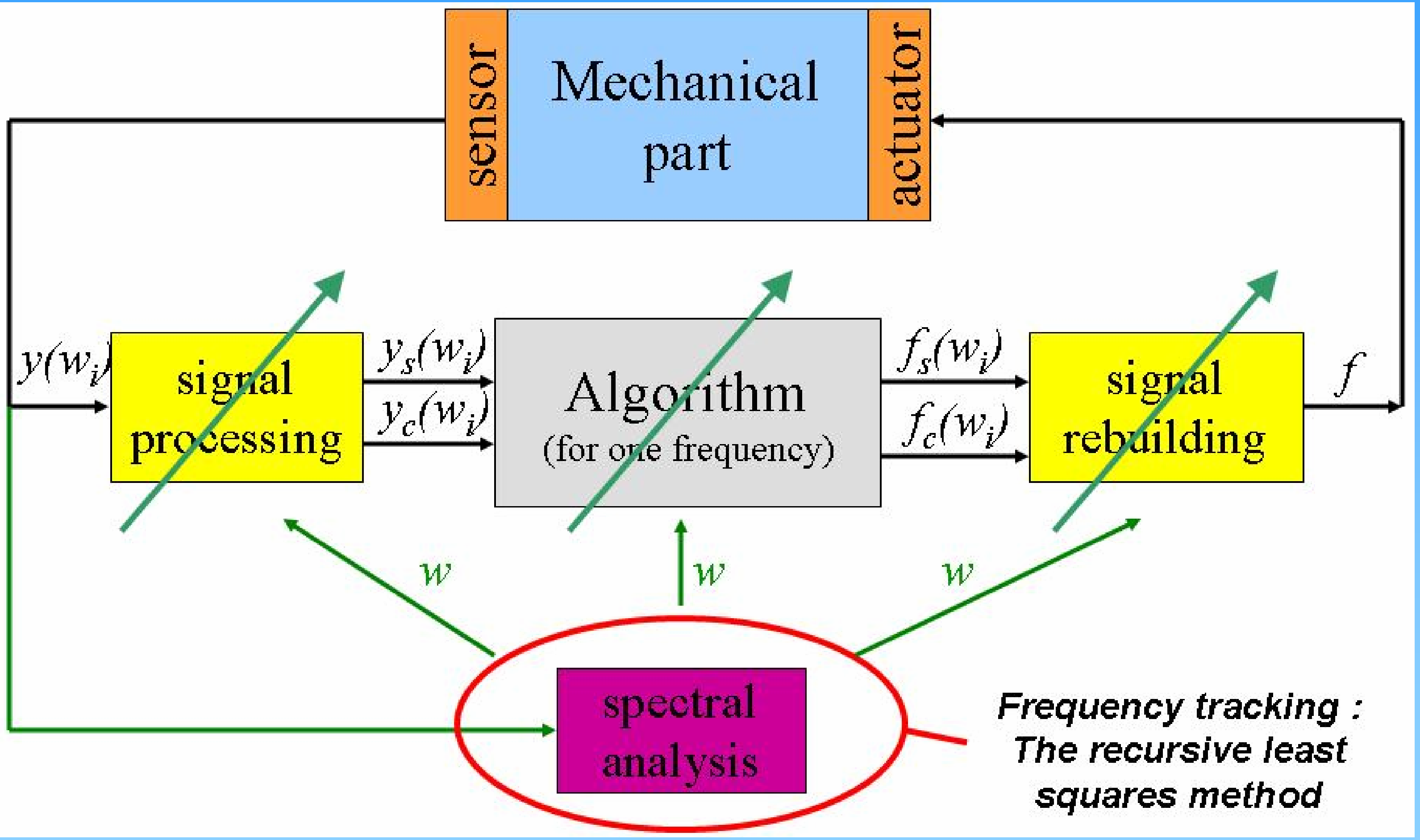
Frequency (Hz)



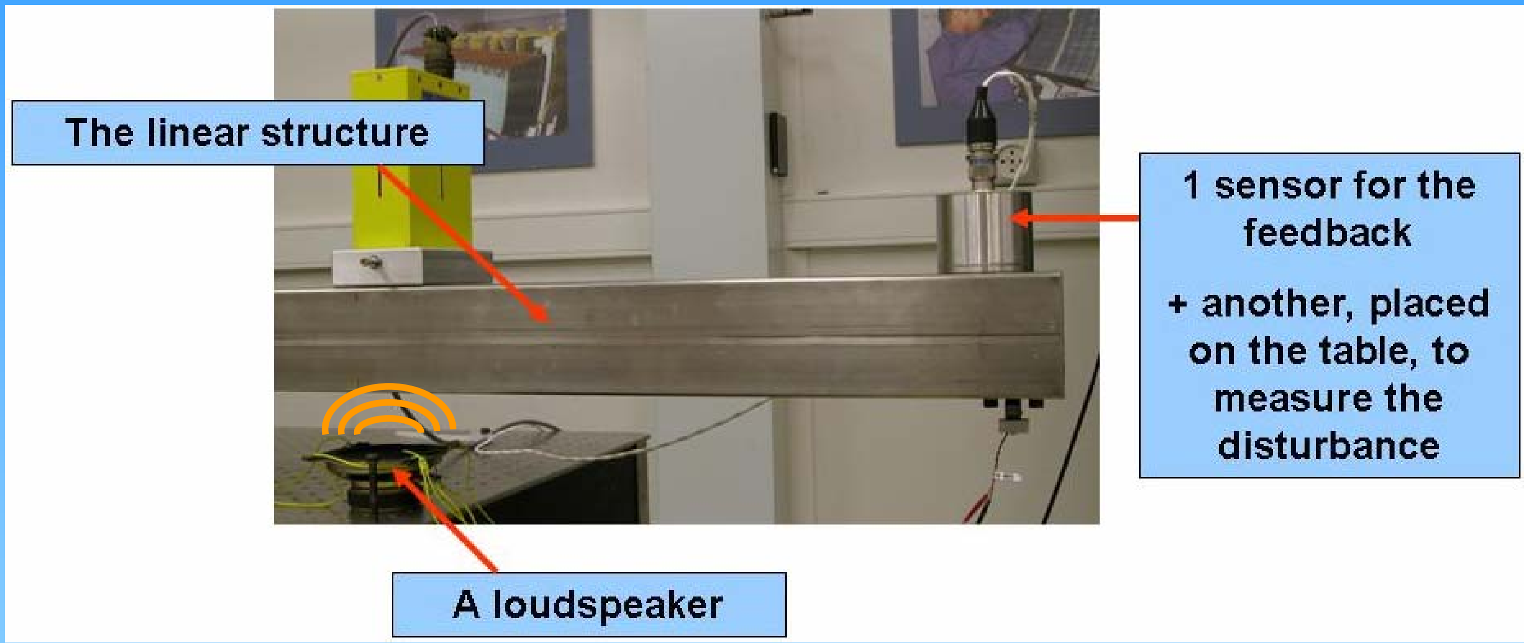
Frequency (Hz)

Efficient vibration rejection

- As each frequency is rejected independently, the robustness depends on the estimation of the real value of the disturbance frequency :



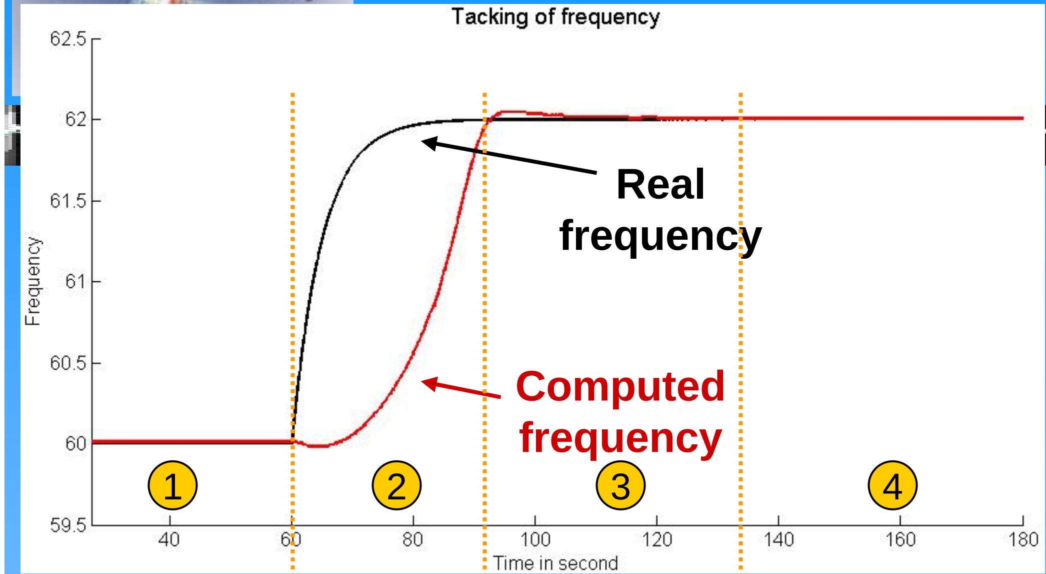
- External disturbance simulation with a step frequency function (response of a 1st order process) :

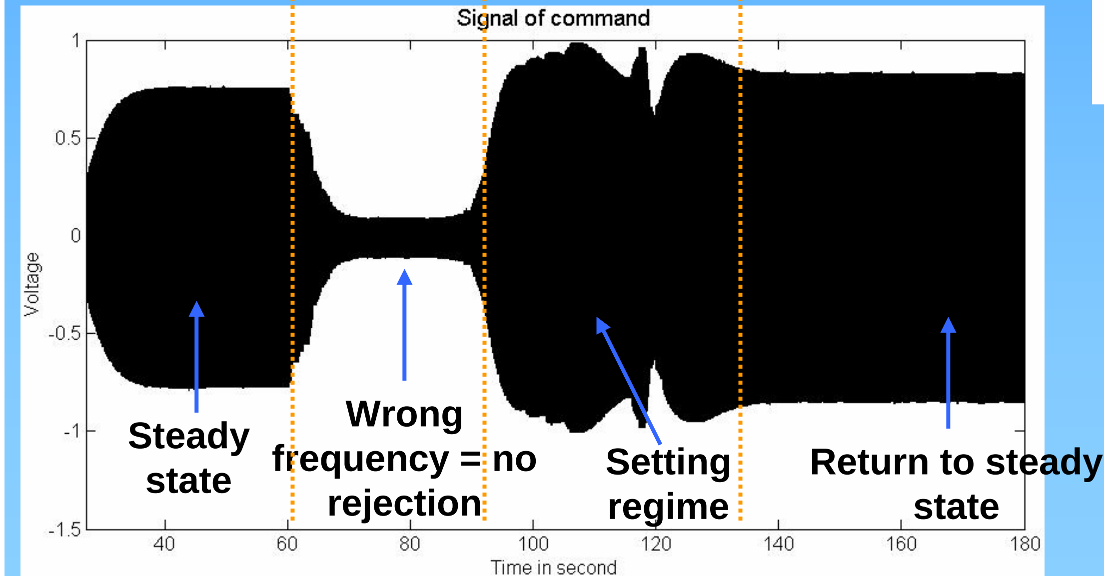


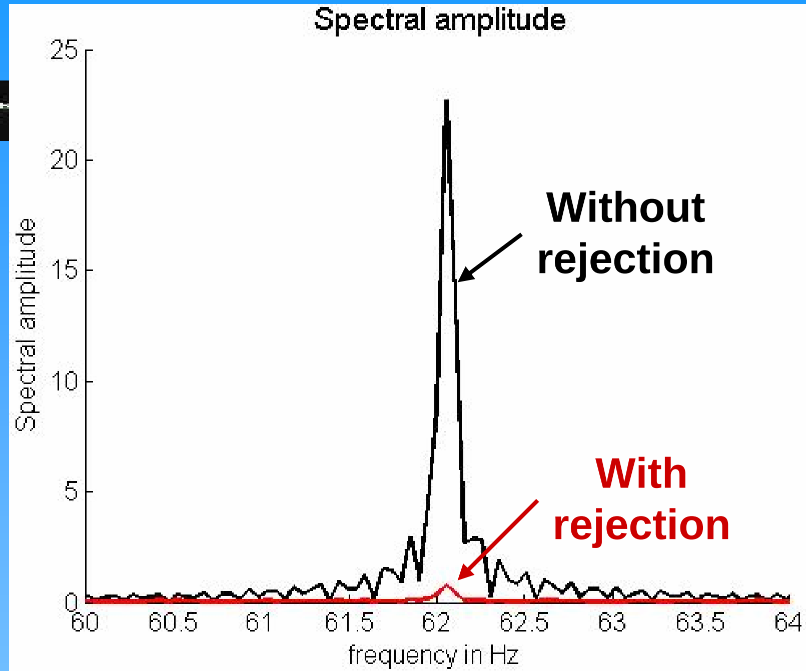
➡ The loudspeaker generates a step of frequency which simulates, for example, a change of speed of a pump near the final focus.

Experimental results

Frequency tracking in real time
by L.Brunetti





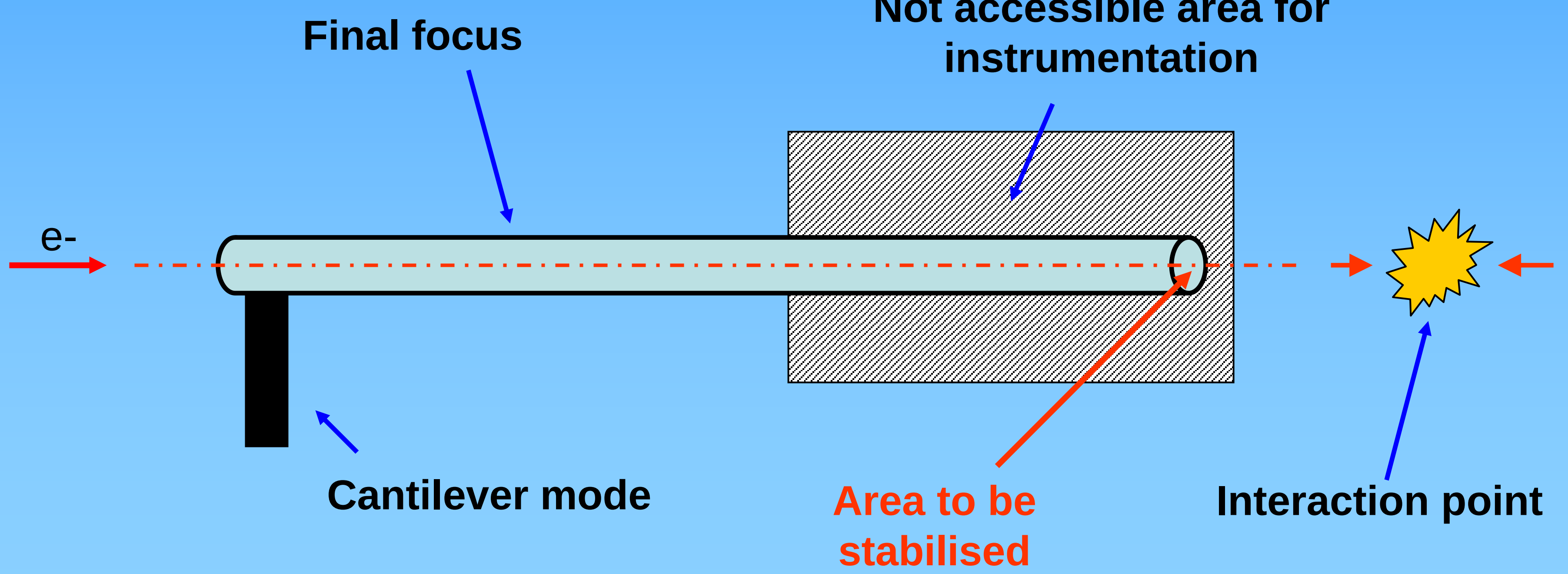


Efficient rejection if the variation is slow

Problem : No access to the area to be stabilised

by L.Brunetti

- **Where is the optimal location and what technology for the instrumentation?**
- **What are the effects of a local control on the global movement of the beam?**
- **How to be sure that the end of the beam is stabilised in real time?**

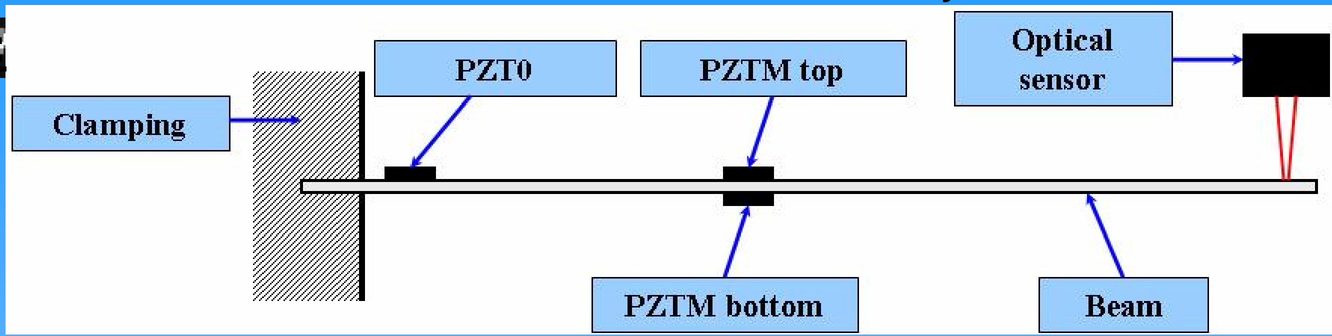


Location and technology of the instrumentation

Small mock-up

by L.Brunetti

The prototype :



Experimental results :

Actuator	Sensor	PZT0	PZTM	Optical
PZT0	PZTM		***VG***	*G*
PZT0	Optical		*G*	***VG***
PZTM	PZT0	***VG***	*VB*	*G*
PZTM	PZTM	*N*	***VG***	*N*
PZTM	Optical	*G*	*VB*	***VG***

Very bad | No effect | Good | Very good

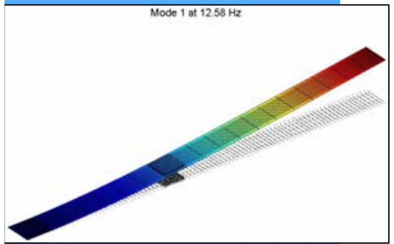
The rejection always works at the measurement point of the feed-back.

The behaviour of the beam changes with the configuration.

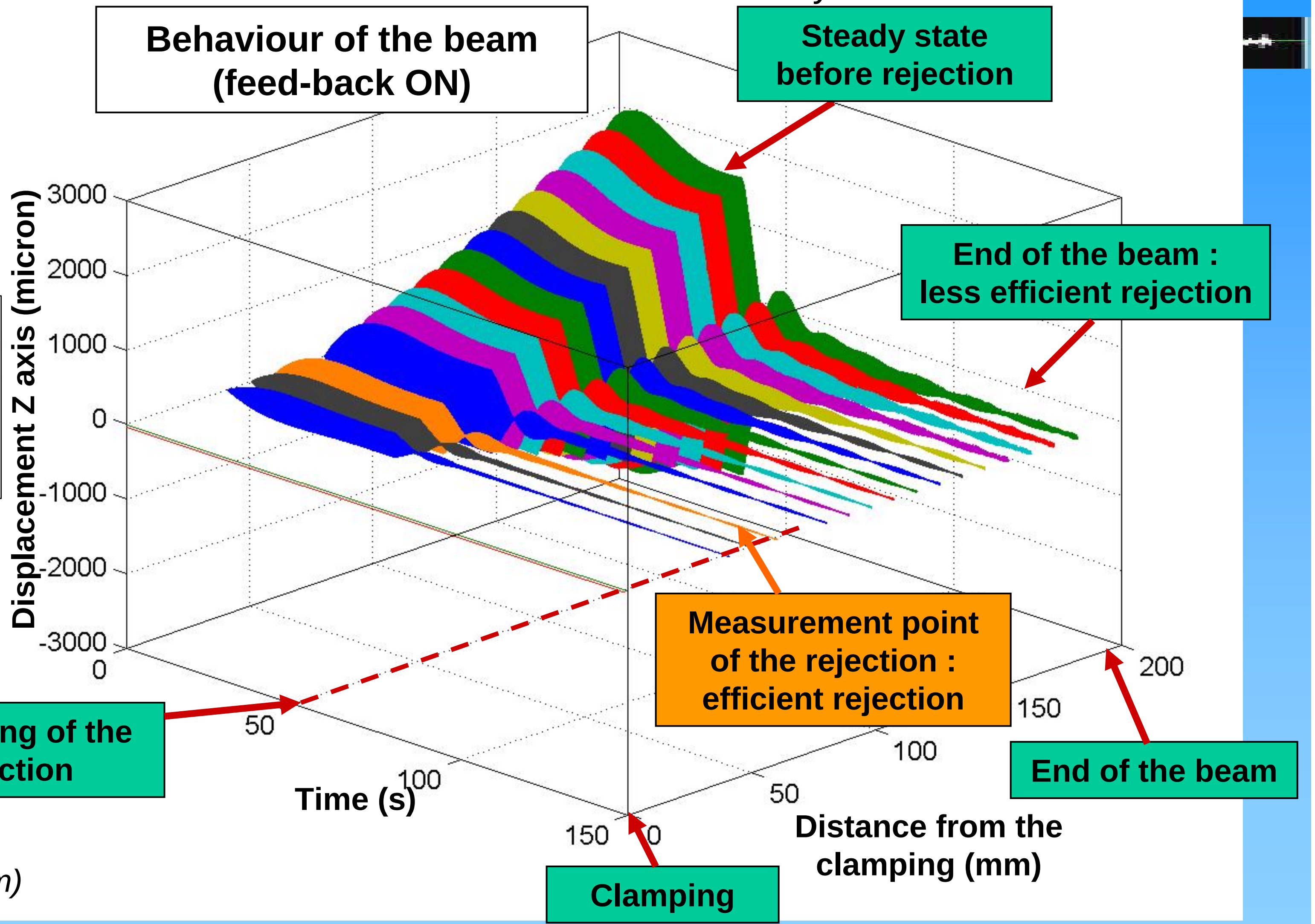
Numerical simulation of the small mock-up

by L.Brunetti

Results :



(1st mode of the beam)



Conclusions

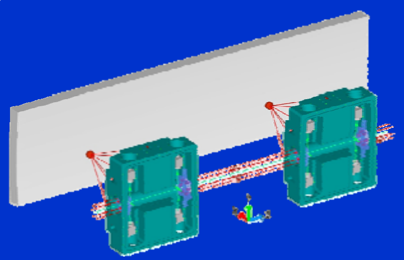
by L.Brunetti

- Active feedback loop on a large scale prototype
  - → **Validation of the method for the micrometer scale**
  - → **Validation of the frequency tracking**
  - → **Requirement of an efficient hardware (data acquisition) to get results at nanometer scale**
- Choice of the location and the technology of the instrumentation
  - → **First approach with experimental tests**
  - → **Requirement of simulation for validation (with accurate updating models)**
  - → **Multivariable problem with many sensors and actuators using different technologies**

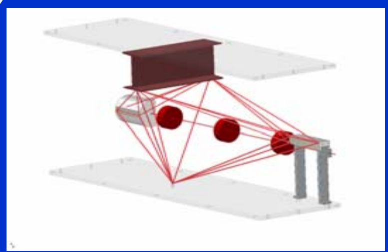
WP7 Metrology and stabilisation

METSTB

RTRS

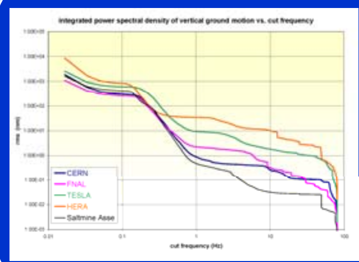


StaFF



MSTBT

PGMS



EuroTeV WP7 projects

by R. Amirikas and A.Bertolini

Metrology in DESY

- **Site characterization and parameterization of data**
- **Correlation measurements; related to site characterization**
- **Floor motion due to building foundation (e.g. piled foundation & floor slabs)**

Stabilization in DESY

- **Accelerator component vibration studies:**

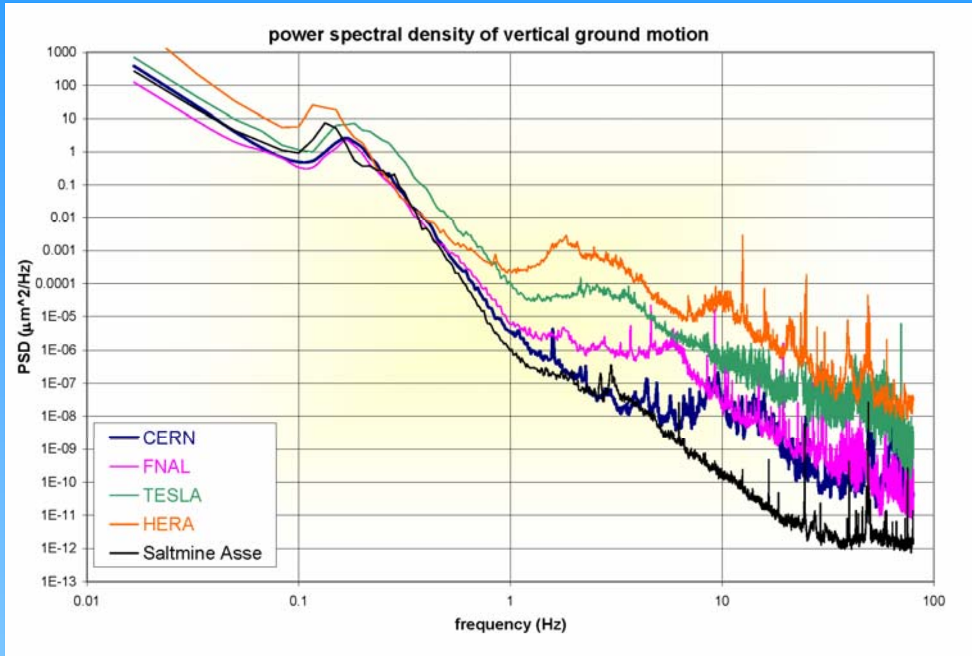
❖ **Cryomodule vibration studies in warm and cold environments, geared towards main linac design (one of the main cost drivers for the ILC)**

❖ **Stability of support structures, such as girders**

❖ **Facility noise: potential vibration sources in a tunnel, e.g. vacuum pumps, modulators**

Metrology: site measurement & characterization

by R. Amirikas and A.Bertolini

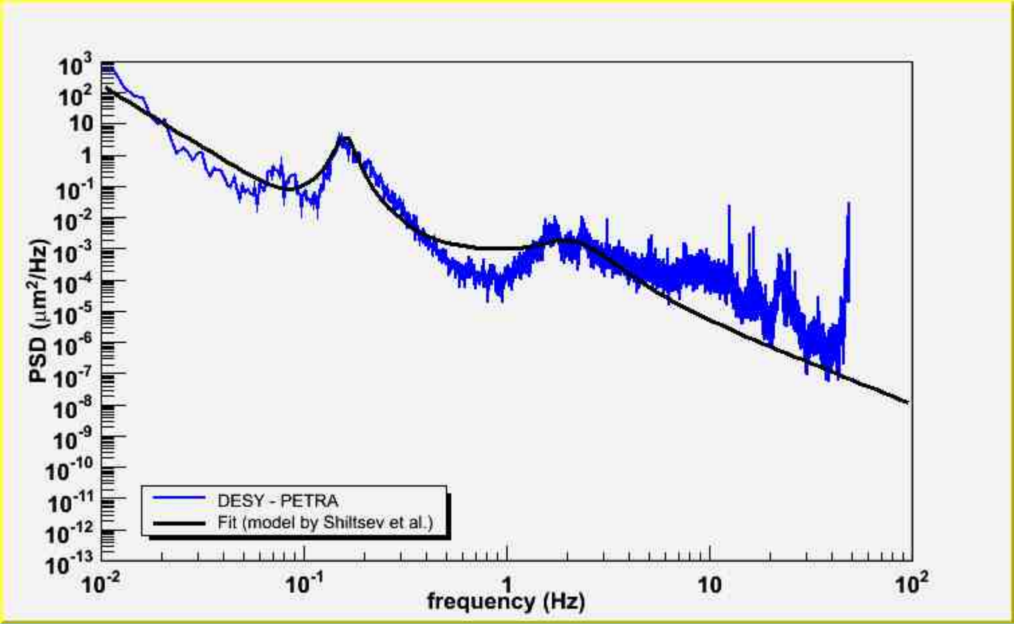


Power spectral densities for five measured sites

- Study the impact of 'cultural noise' @ f >1 Hz, at several accelerator laboratories & synchrotron light sources
- 19 sites are measured so far. Database available: http://vibration.desy.de
- Same equipment and data analysis tools are applied to each case; Therefore, direct comparison is possible
- This work will continue albeit with a lower priority, often combined with other measurements
- Publications: presentations in Nanobeam2005 (EuroTeV report-2005-023) and EPAC06 contribution, in preparation

Metrology: site characterization via parameterization (in collaboration with D. Kruecker (DESY)) & Correlations

by R. Amirikas and A.Bertolini



A fit to the power spectral density of Petra (preliminary)

- Parameterization of power spectral densities measured, repereseenting 'noisy', 'quiet' and 'medium' sites; This is done via root; Starting model is obtained from V. Shiltsev et al, DESY HERA 95-06
- Measurement of correlation length of a few sites, including DESY
- Study of floor motion (a civil engineering issue) as opposed to ambient ground motion (influenced by geology in each site)

Conclusion

StaFF: Distancemeters are starting to take form
straightness monitor tests at ATF foreseen

MSTBT: .Correlation measurements of “warm” cryomodule: rigid !; “cold” is next on the menu
.Acoustic effects non negligible: take into account in beam dynamics models?
.Feedback loop works with frequency tracking
Sensor and actuator configuration?
But will all the LC feedback loops interfere?

PGMS: .site characterisation continues
Parameterisation going on