SOLEIL strategy for beam position stability

Study of the overall stability: from ground to magnets

Orbit stability requirements

Brilliance reduction

↑

Emittance growth

↑

Time dependent
Orbit Oscillations

↑

Magnets motion

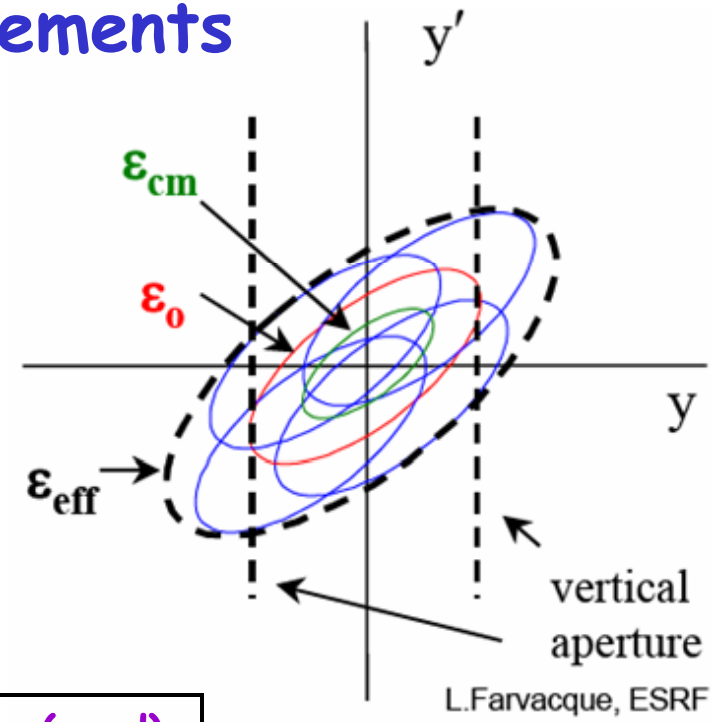
↑

Girders (support) motion

↑

Ground Vibration

$\sigma_{COD} < 0.1\ \sigma_{Beam}$
and
$\sigma'_{COD} < 0.1\ \sigma'_{Beam}$



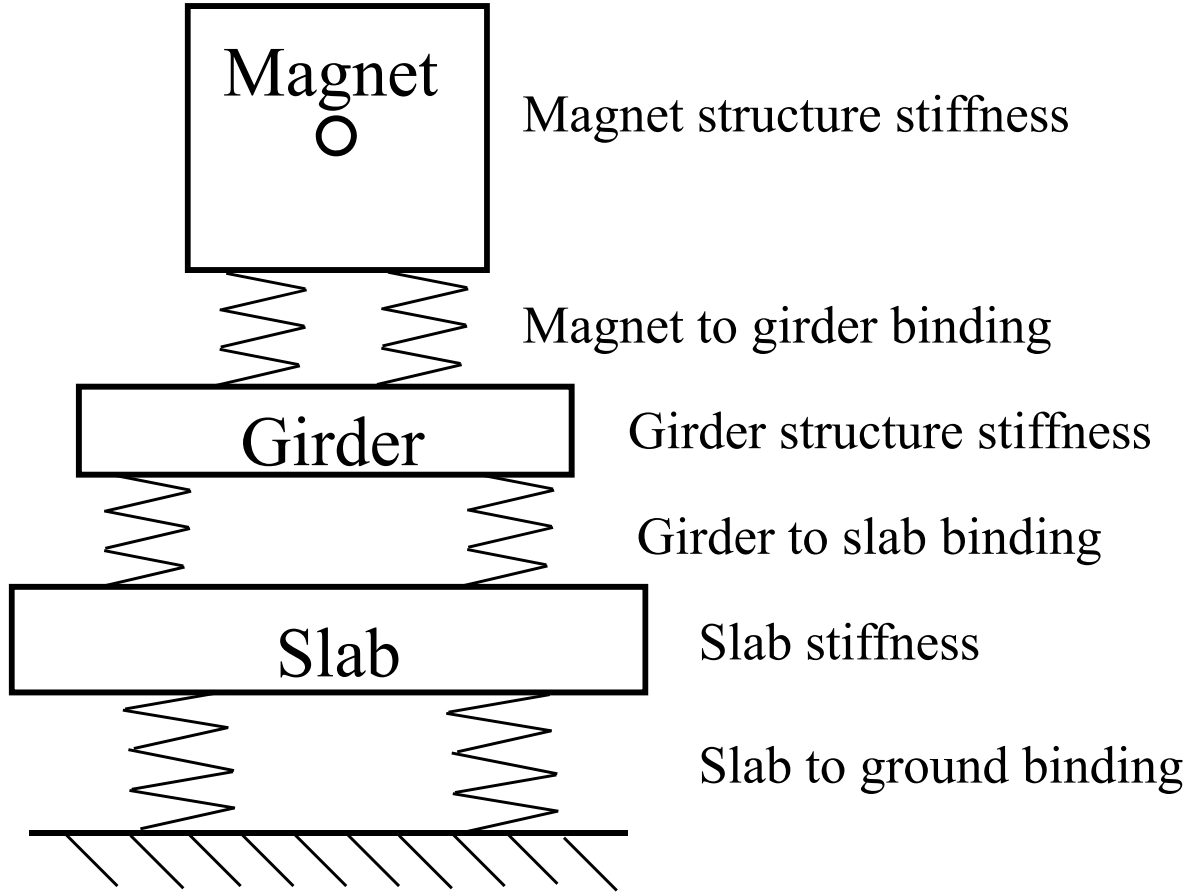
Stability	σ_{COD} (μm)	σ'_{COD} (μrad)
Horizontal	18	3
Vertical	0.8	0.5

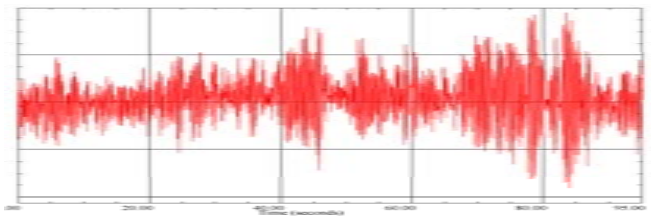
Use of girders to reduce C.O.D
1st vibration mode at 50 Hz

C.O.D= closed orbit distortion

Vibration Transmission Chain

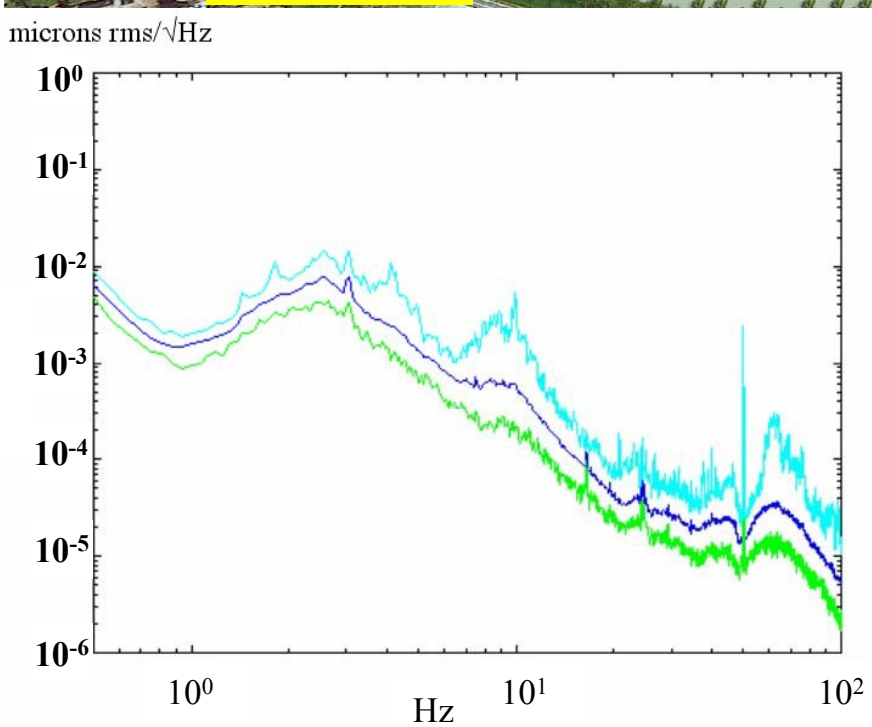
External and internal vibration sources



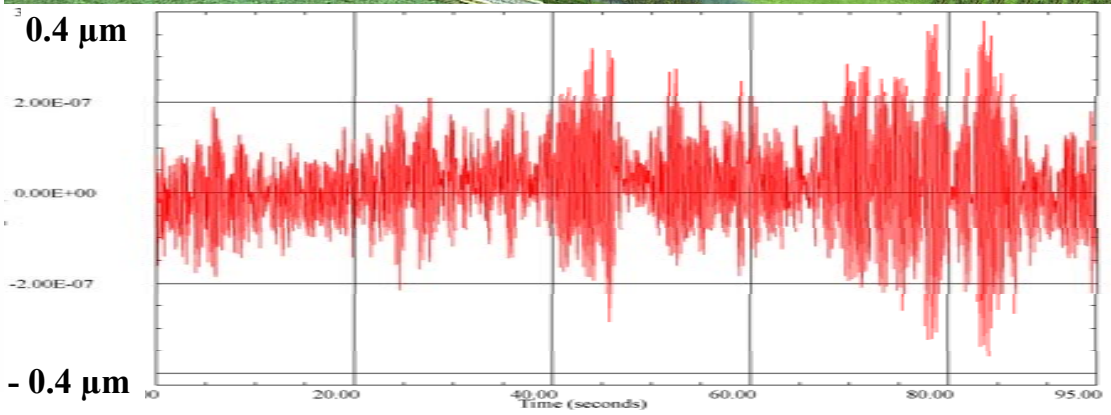


Ground Vibration

Measurement of ground vibration



VIBRATION SOURCES: SPECTRAL DENSITY



TEMPORAL MEASUREMENT OF VERTICAL DISPLACEMENT
(maximum observed on site)

Internal instability sources

- Thermal expansion/contraction of buildings
- Thermal expansion of mechanical structures
- Drying of concrete
- Traffic on circular ring of experiment hall
- Crane
- Water flow in pipes and rotating devices (air conditioners, vacuum pumps..)
- Water flow in magnets
- Air flow in storage ring tunnel

Air temperature regulation in storage ring and experiment hall: 21°± 1°

Water cooling of devices: 21°± 0.1°

Position survey of girders. Easy and accurate alignment

Circulation ring isolated from main slab

Crane rails on independant surface foundations.

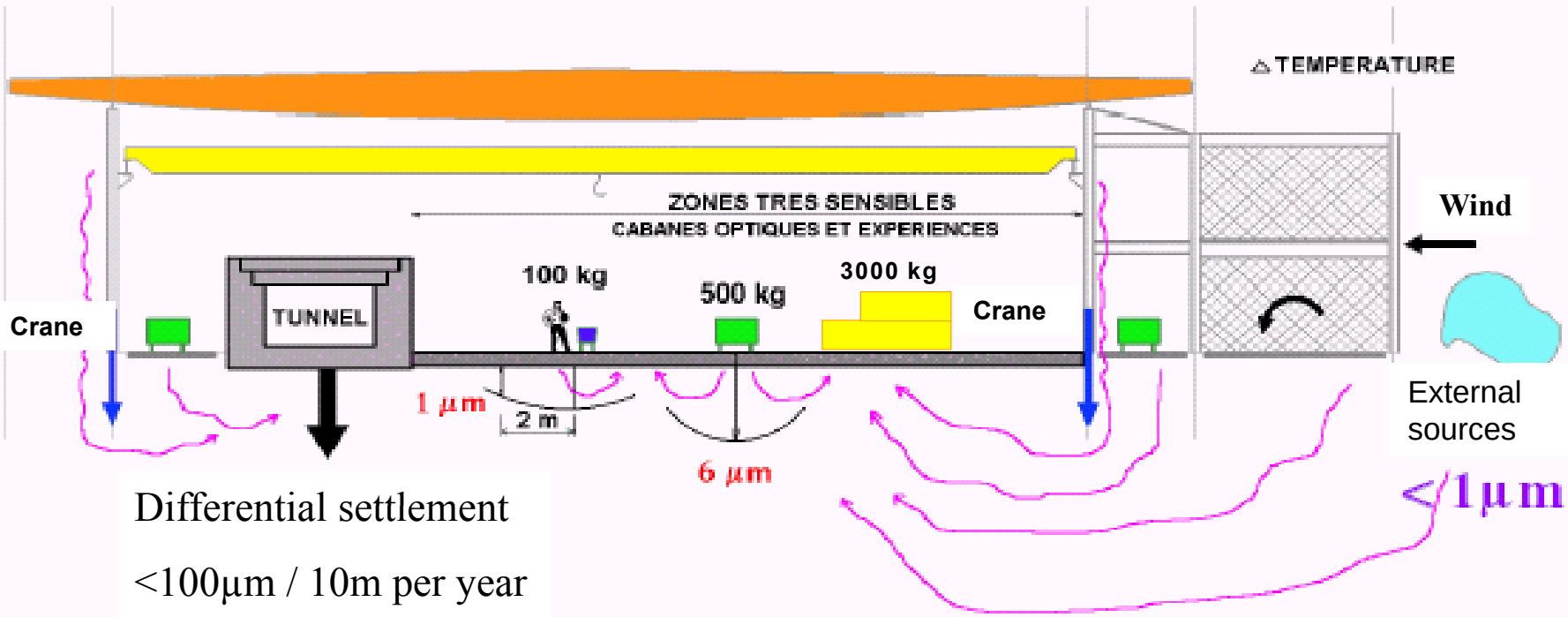
Insulation with elastic and damping supports

Low water speed (typically < 2 $m.s^{-1}$)

Low air blowing speed, flow dispatched on many small air conditioner units

Building stability : design criteria

STATIC AND DYNAMIC SOLLICITATION TO BE CONSIDERED



Differential settlement

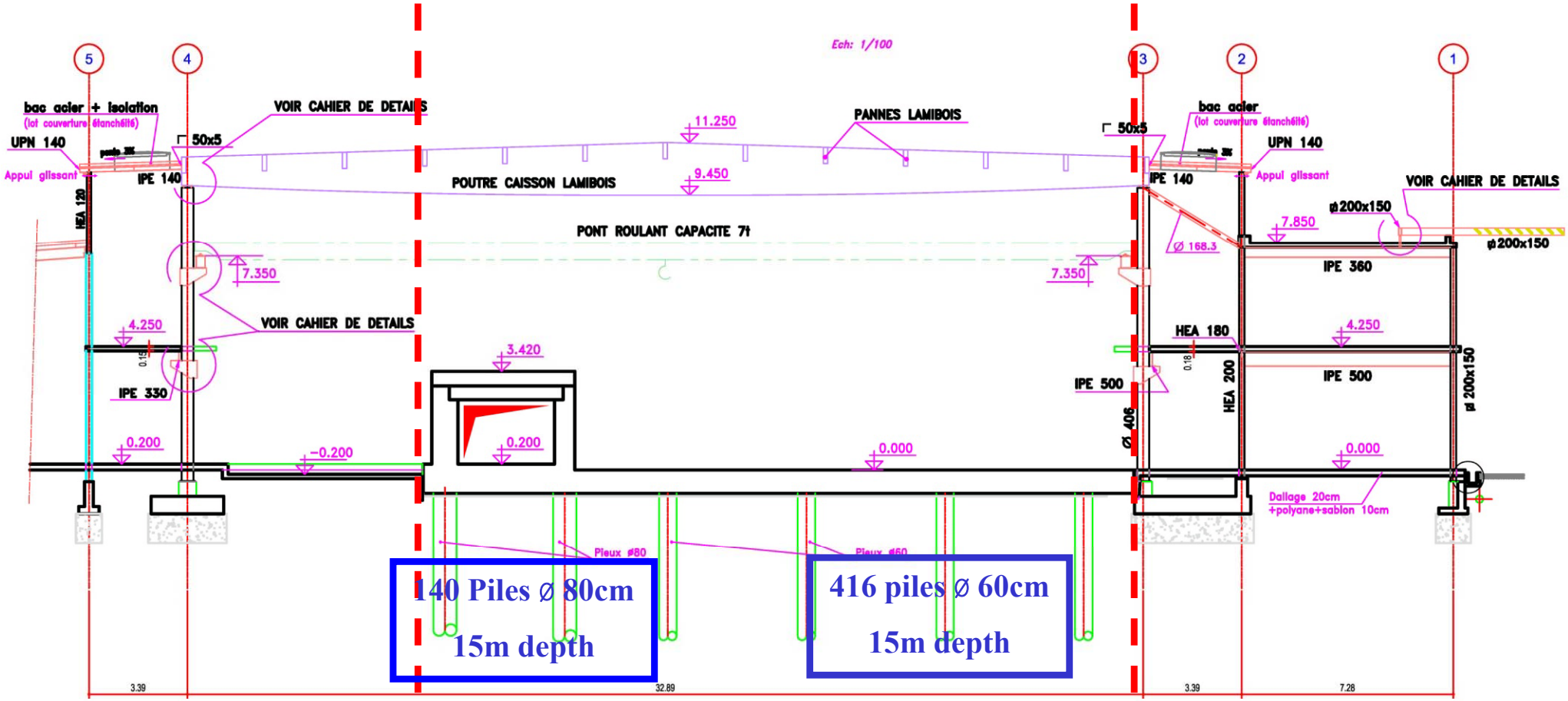
<100µm / 10m per year

Vibrations (0,1 – 70 Hz) due to all effects induced by the facilities, added to the external effects :

$\Delta z < 1$ µm peak to peak

$\Delta x < 4$ µm peak to peak

Synchrotron building design



Technical area

- Control rooms
- Process rooms
- Process laboratories
- Offices

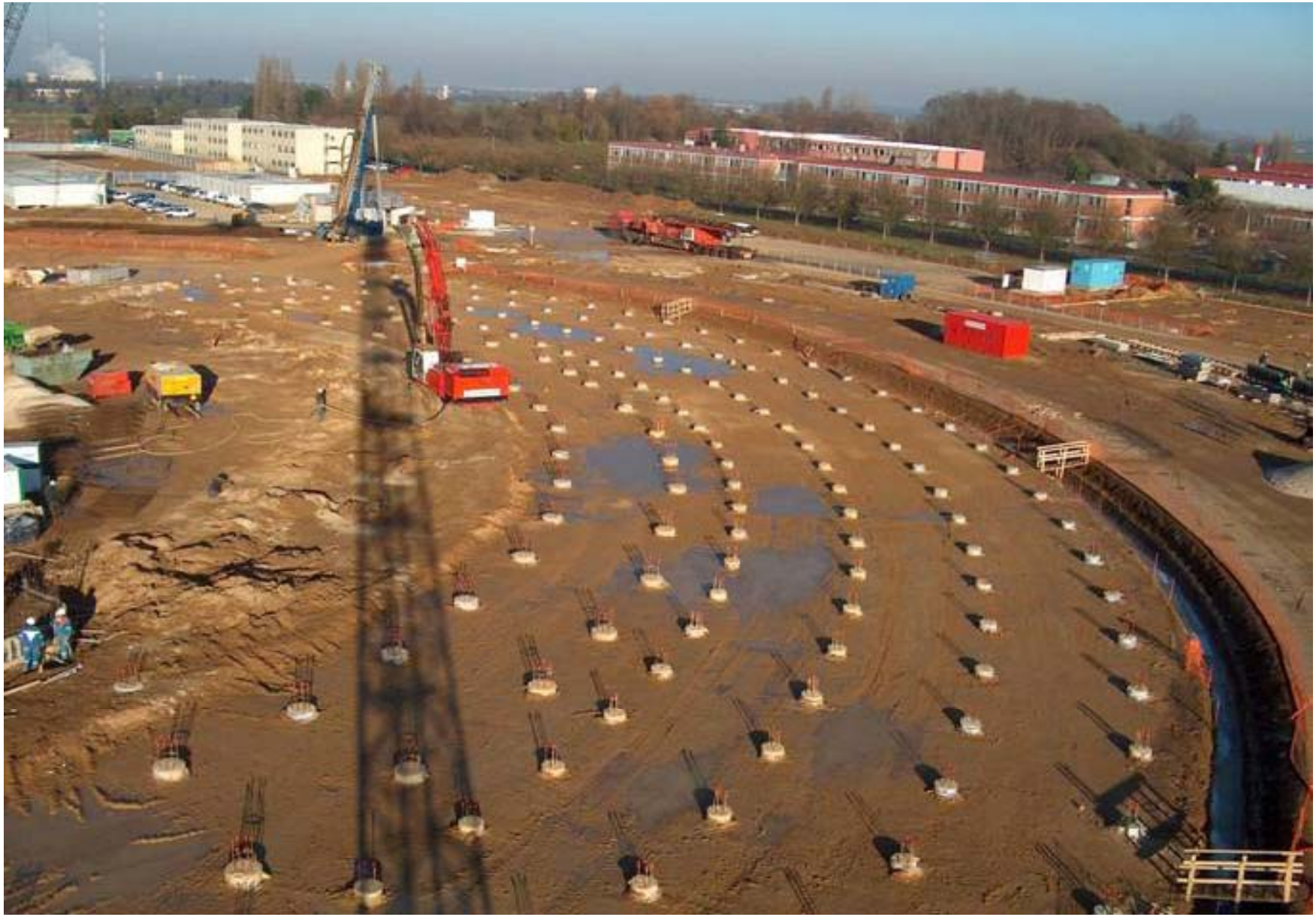
Highly sensitive area

- Linear Accelerator
- Booster
- Synchrotron ring
- Experimental slab

Experiments area

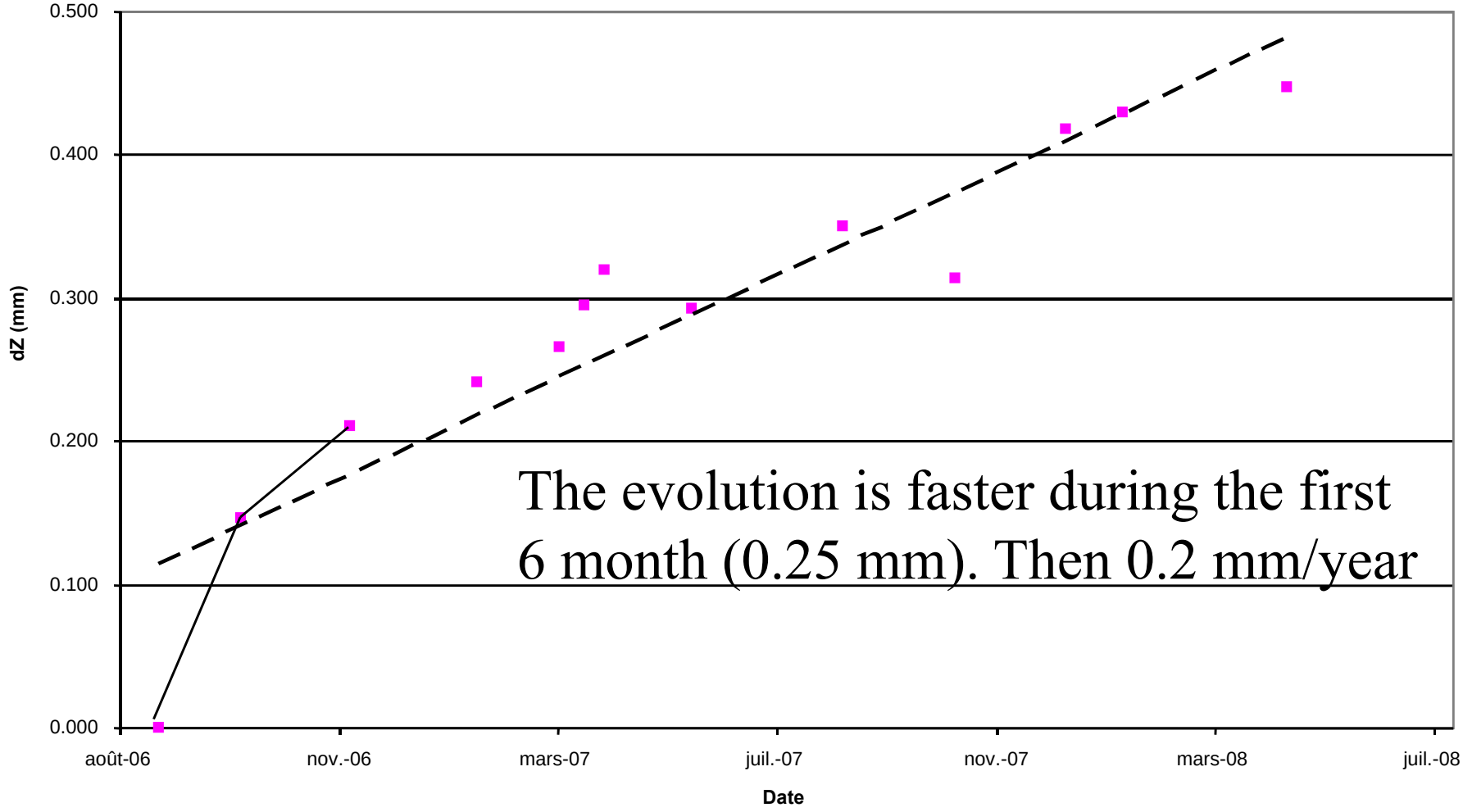
- Laboratories
- Offices
- Experiment's preparation
- Used as "windscreen"

Detail of piles

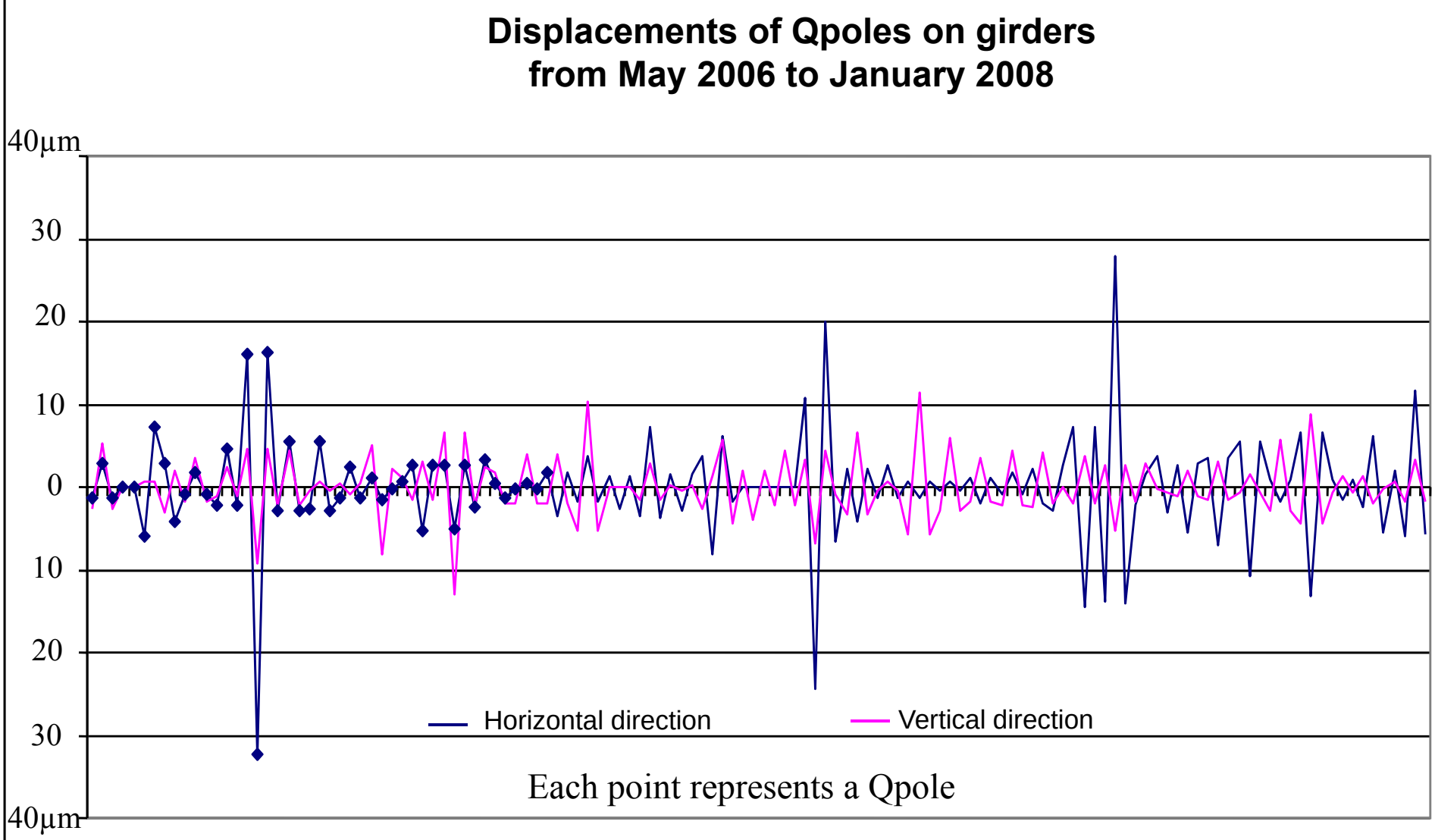


Storage ring evolution

SOLEIL Storage Ring vertical Alignment
Peak-to-peak evolution from August 2006



Storage ring evolution



Building foundations – Dynamic studies

⇒ **Dynamic studies** (FEA codes)

– Software SASSI: impedance of piles (stiffness, damping)

– Software ANSYS: answer of a structure to a dynamic request (piles simulated by 3 springs)

• The ground shows an amplification at 2.5 Hz ; 6 and 8 Hz (smaller)

• The ground + structure: 1^{rst} mode at 13.6 Hz

• Simulation of a propagating wave (same characteristics as those measured on the site at the center of the ring)

2.5 Hz ; amplitude 0.7 µm peak to peak :

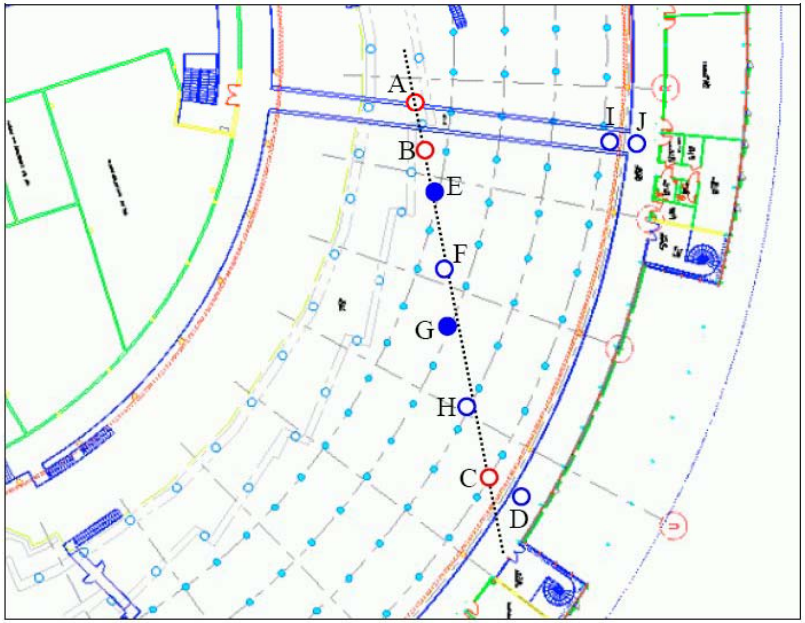
⇒*slab displacement:* 0.78 µm peak to peak

⇒ *no amplification by the slab*

Measurements of dynamic behavior of storage ring and hall slab

Facilities operating– Simulation of vibration excitations

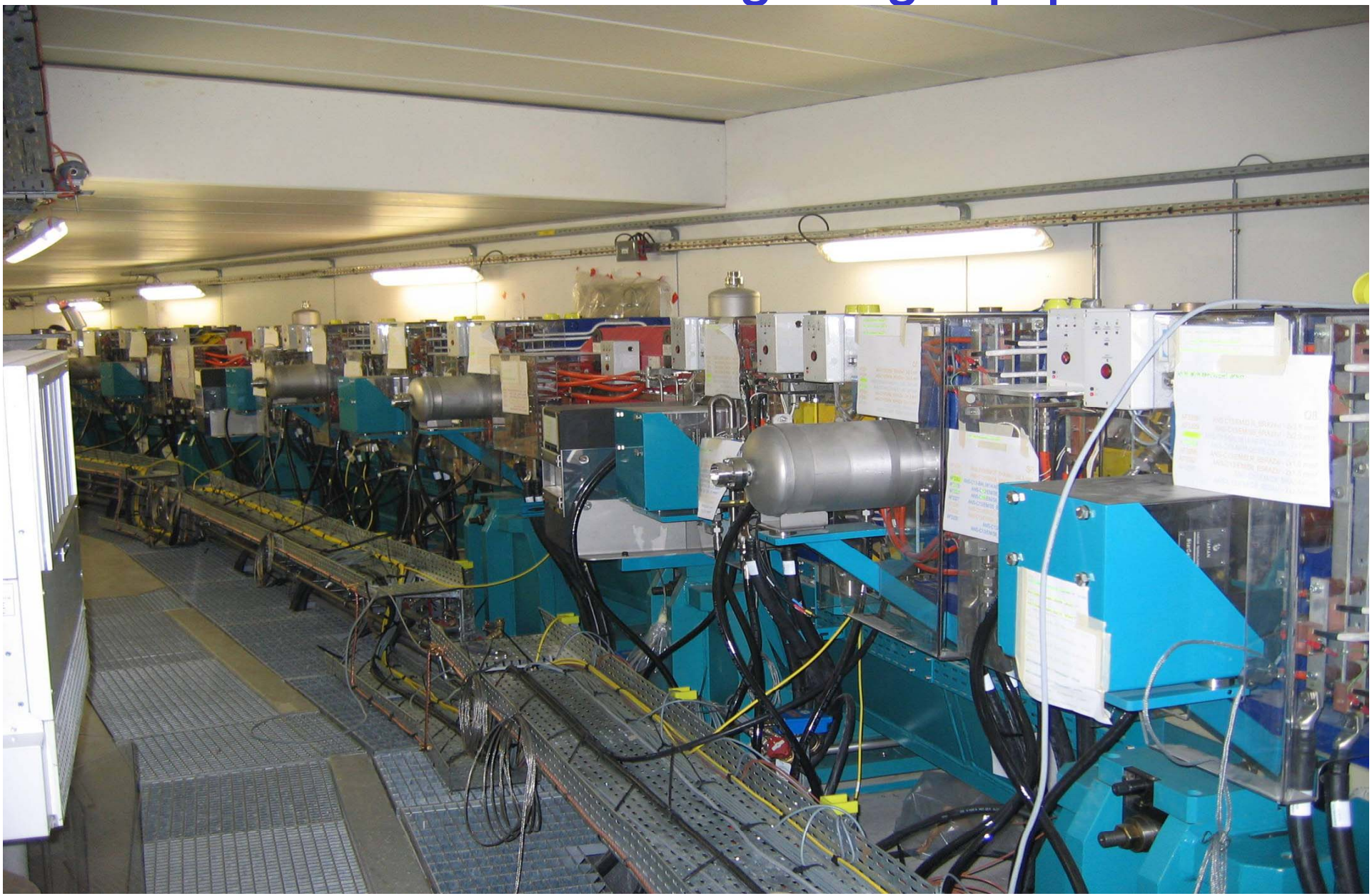
Specification: H=4 µm V=1 µm



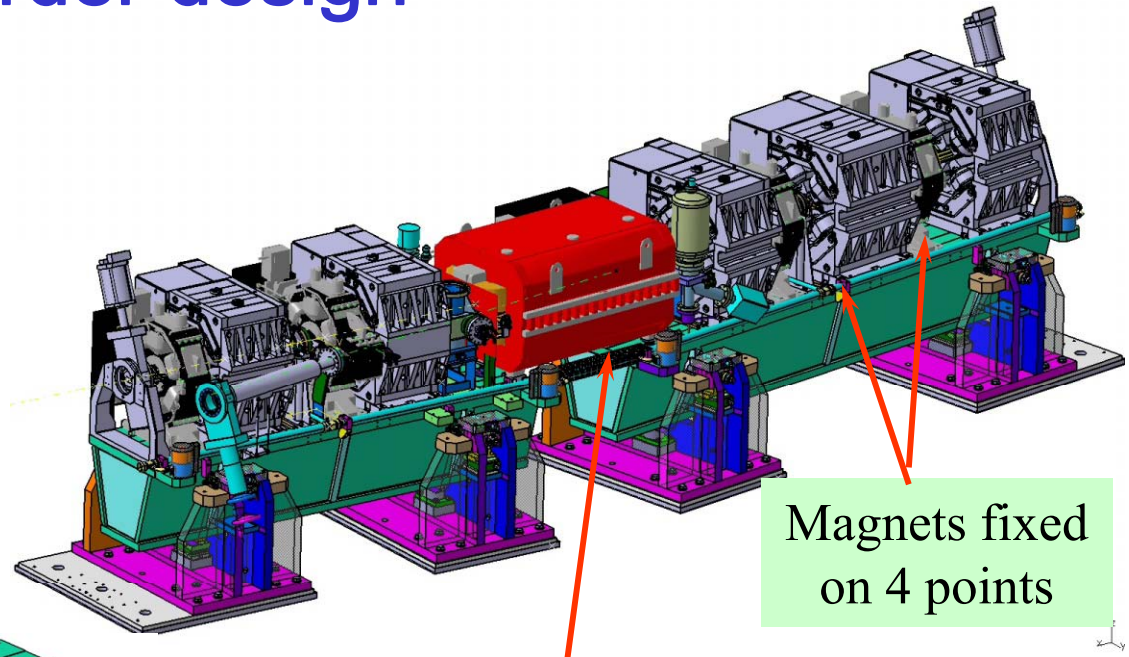
Capteur unidirectionnel
Capteur tridirectionnel
Point hors tête de pieux
Point en tête de pieux

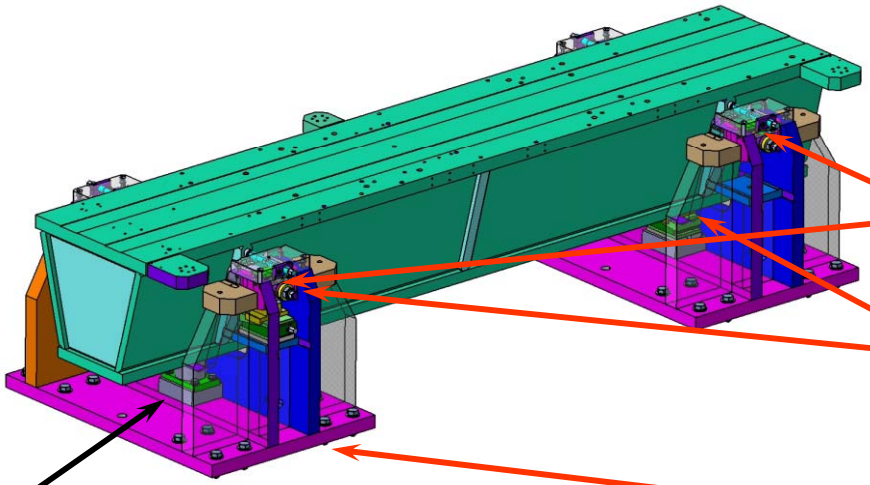
TEST	Lowest value µm p-p	Highest value µm p-p
Facilities operating: Water cooling, air conditioning	H=0.16 V=0.15	H=0.26 V=0.19
Traffic of technical vehicles (forklift)	H=0.19 V=0.60	H=0.75 V=1.16 Abrupt lay down of a 3 ton load
Operating crane	H=0.17 V=0.16	H=0.22 V=1.25 High speed travel of crane nr2 with 2.5 ton load
Operators circulation	H=0.14 V=0.13	H=0.24 V=0.18

Stabilisation of storage ring equipment



Girder design





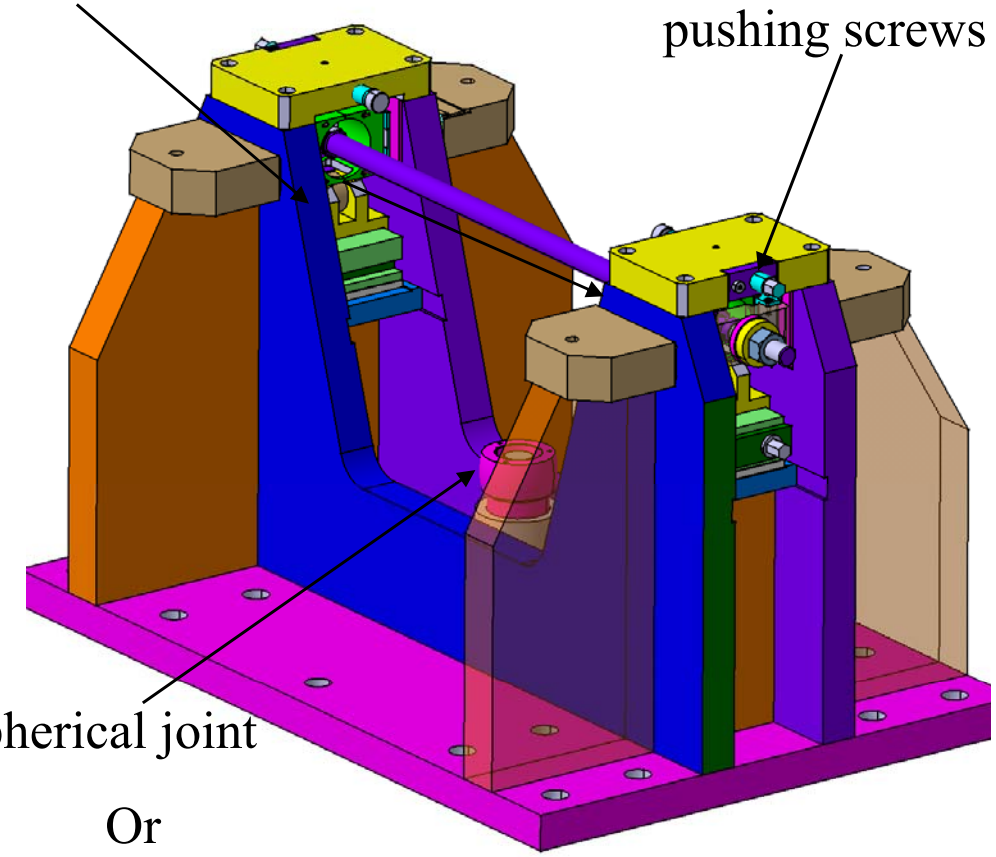
- Dipole fastened on girders
- Fastening of girder on 4 points (during normal operation)
- Setting of girder on 3 points when released (for alignment operation)
- Stands glued to the ground

Girder stand design

AIRLOC® jacks

travel z= +8/-6 mm

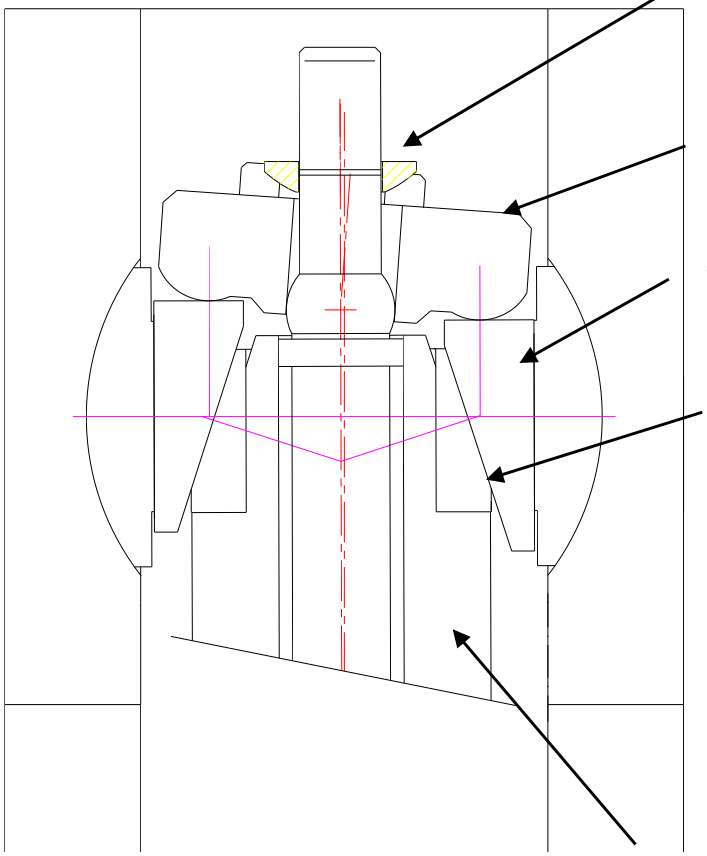
X setting pushing screws



Spherical joint

Or

AIRLOC® jack



Spherical washers

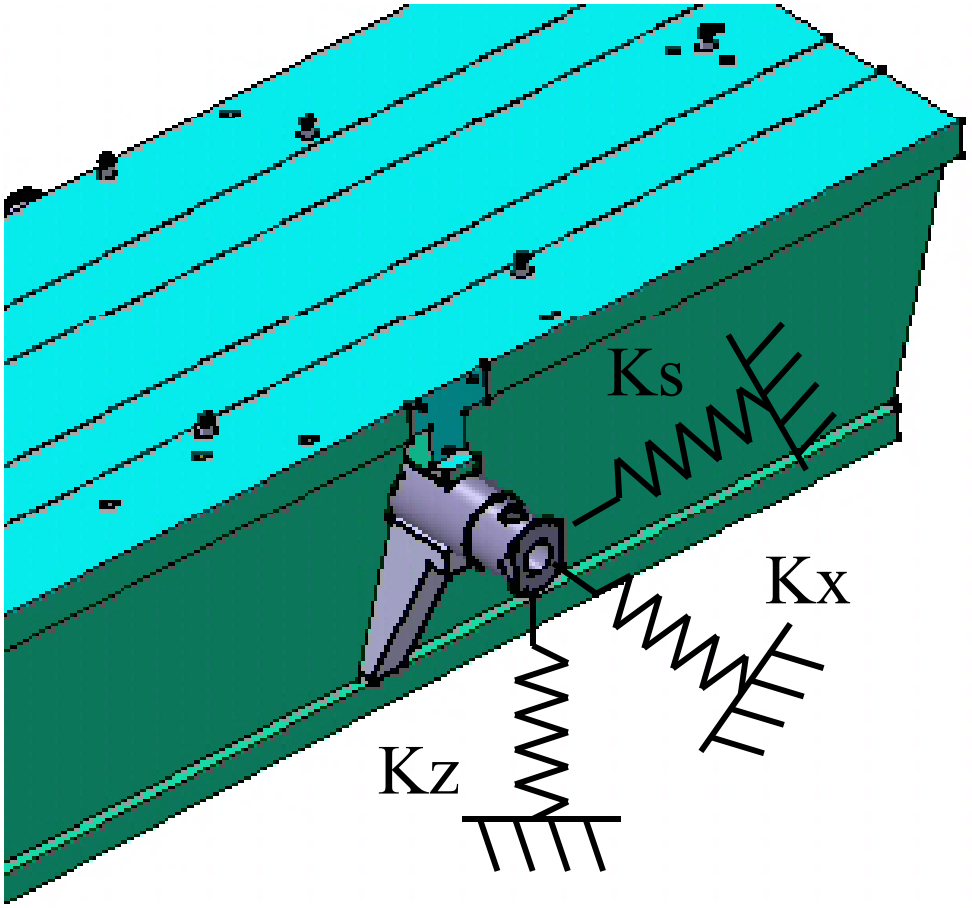
Fly lever

Wedges

Half shells

Girder trunnion

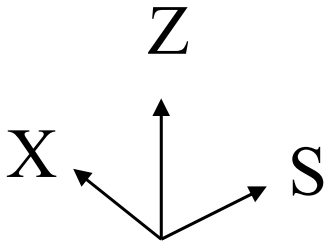
Girder to ground binding modeling



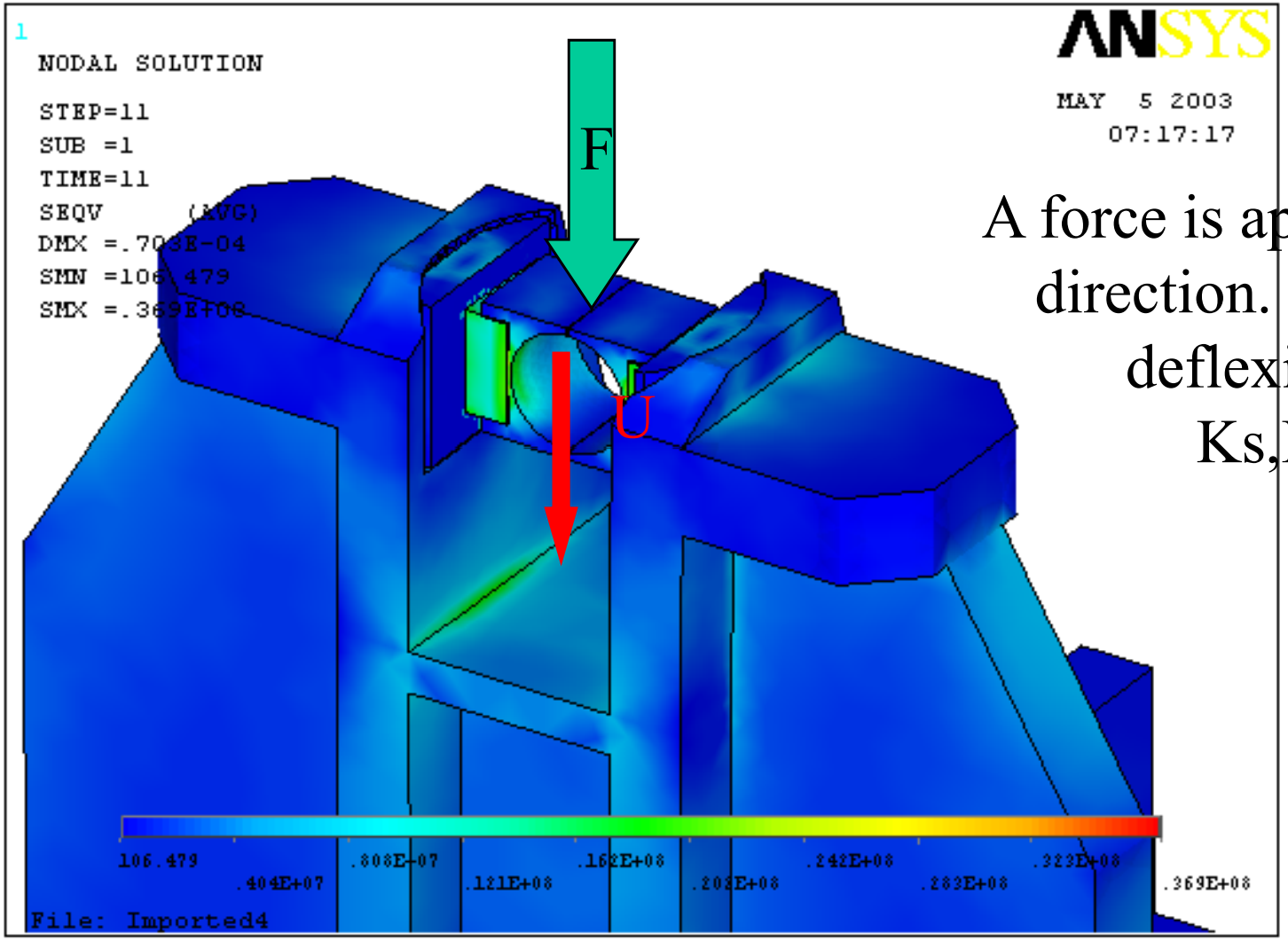
1 equivalent spring along each axis.

The stiffness of each spring is calculated from a FEA of the stand assembly.

The stiffness values are then used as input data for modal analysis



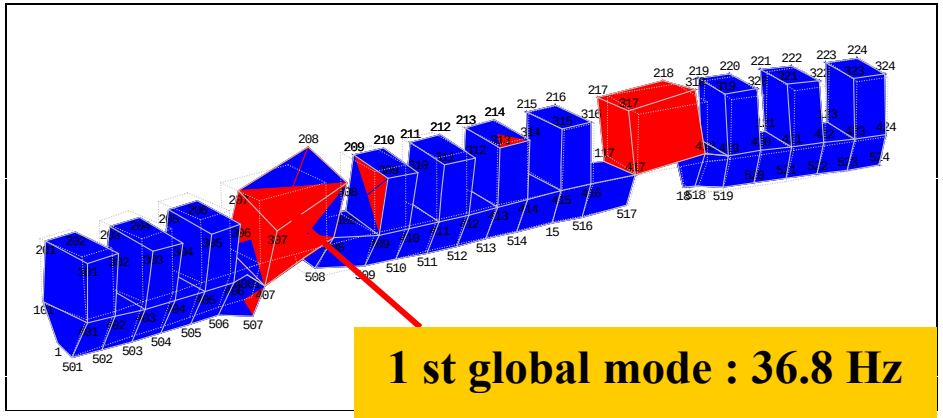
Stiffness calculation



A force is applied in each direction. The resulting deflexions yield the Ks,Ky,Kz values

Dipole Experimental Modal Analysis

Measurement on storage ring



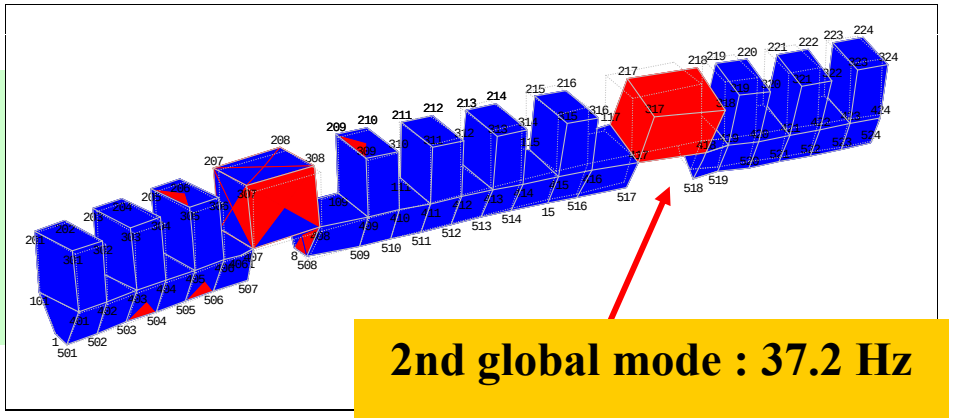
1 st global mode : 36.8 Hz

ζ 2.5% Dipole 1

Experimental measurement

Dipole laying on 3 balls : F1 = 14.5 Hz

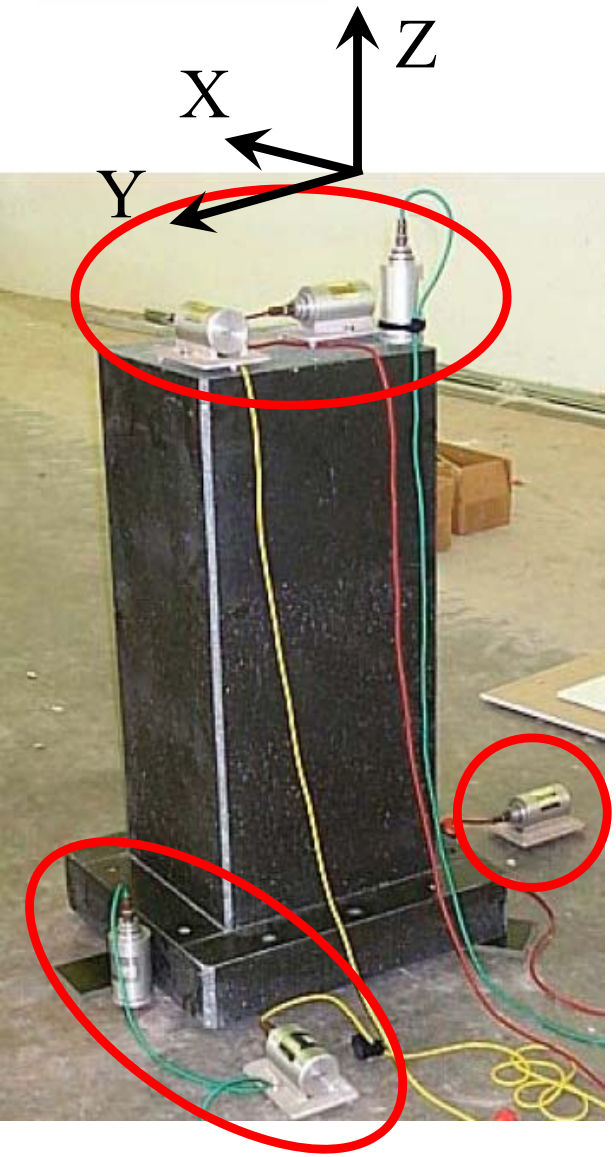
Dipole with fastening : F1 = 36.8 and 37.2 Hz



2nd global mode : 37.2 Hz

ζ 1.6% Dipole 2

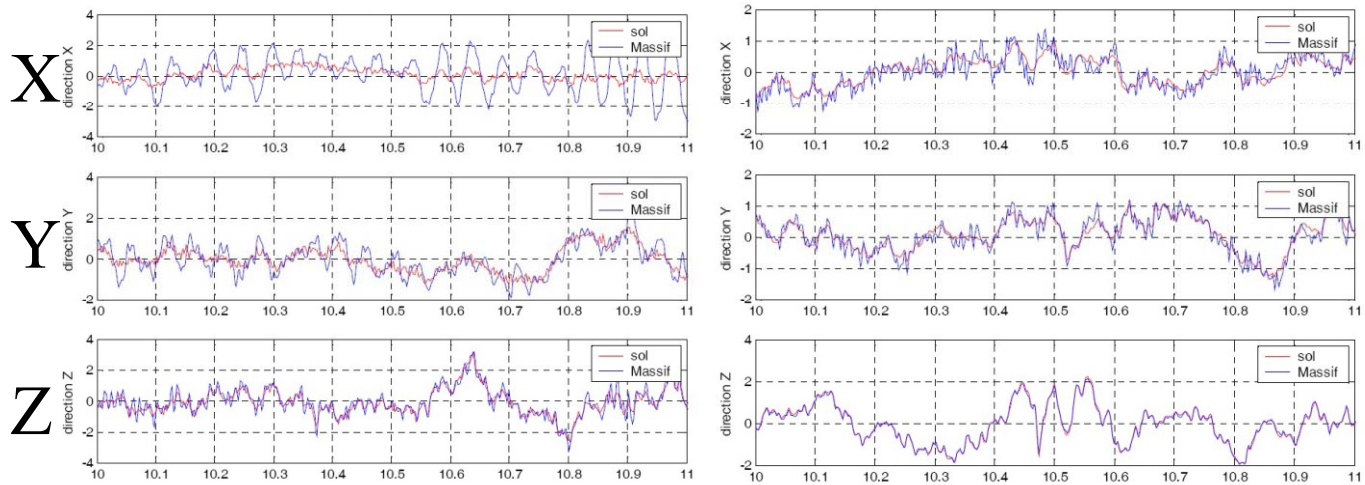
Influence of ground binding



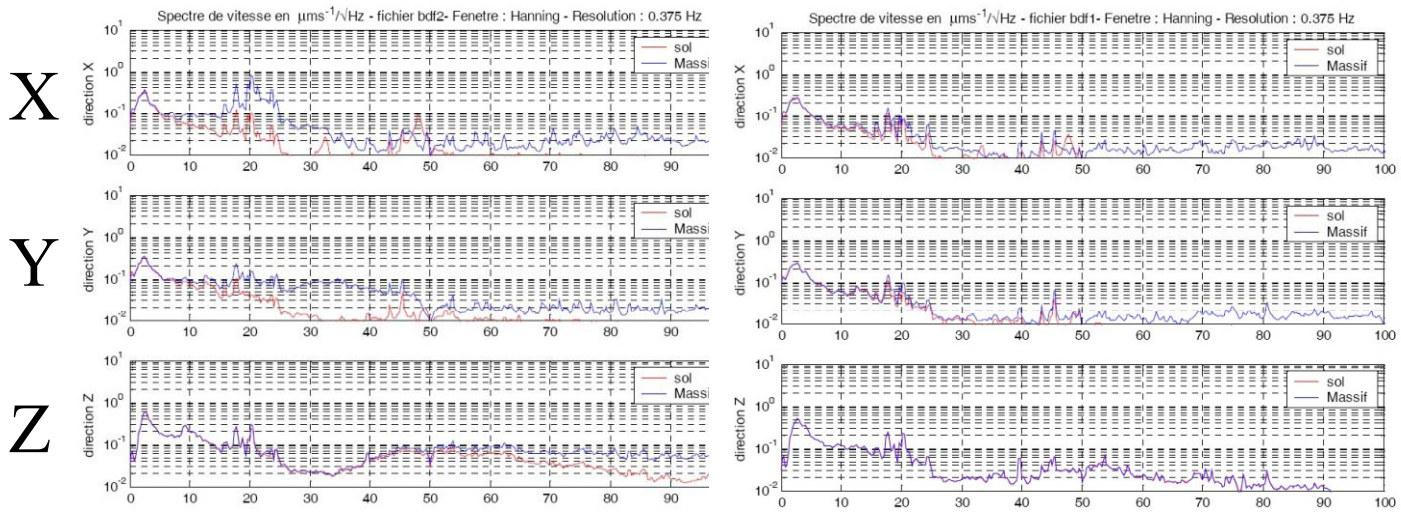
Synthetic granite stand – Mass= 500Kg

With ground noise of slab

Laying stand | Glued stand

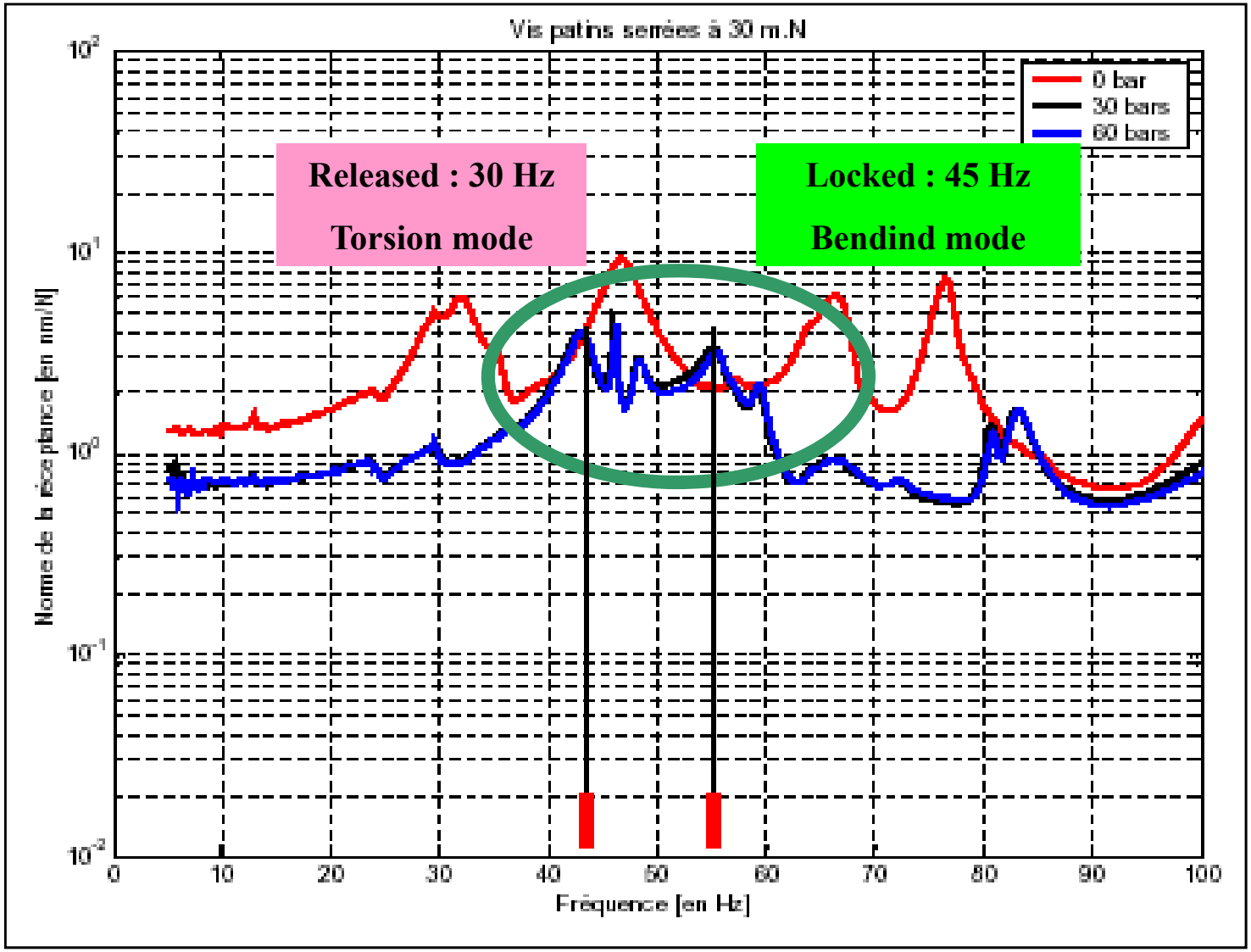


Speed µms^{-1}



Speed spectrum µms^{-1}/√Hz

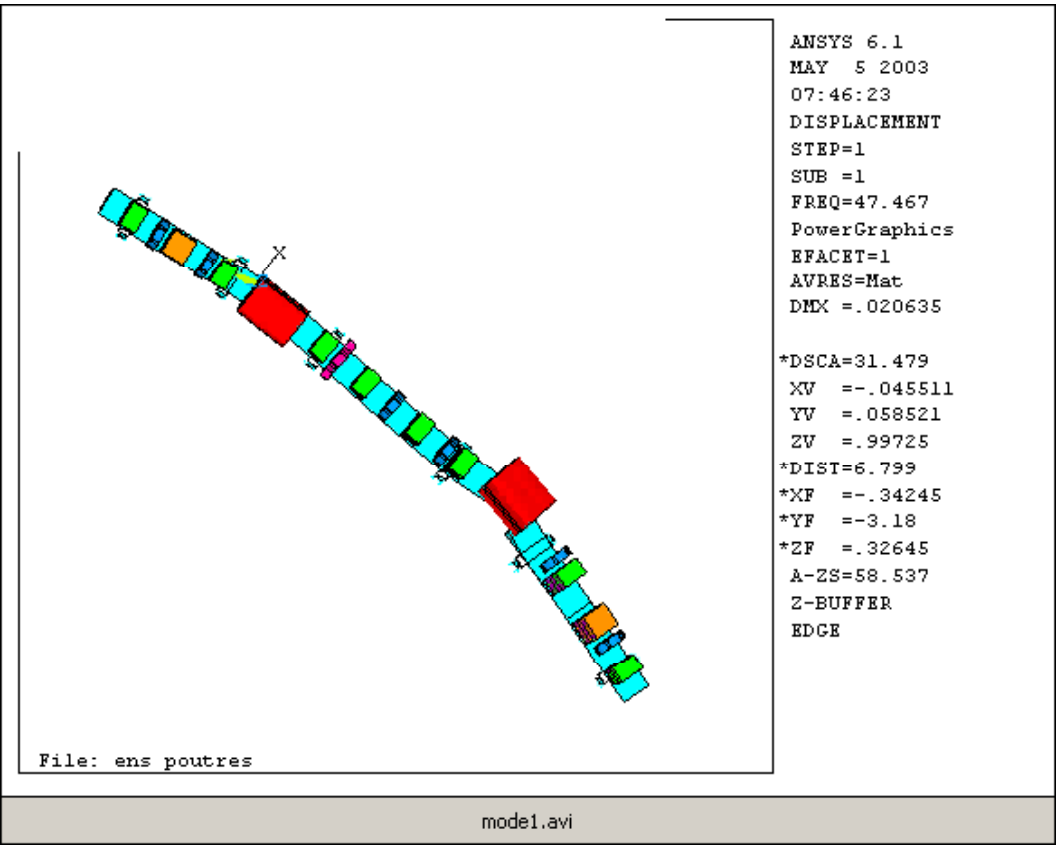
Influence of clamping on girders



Frequency response for 3 values of the clamping force

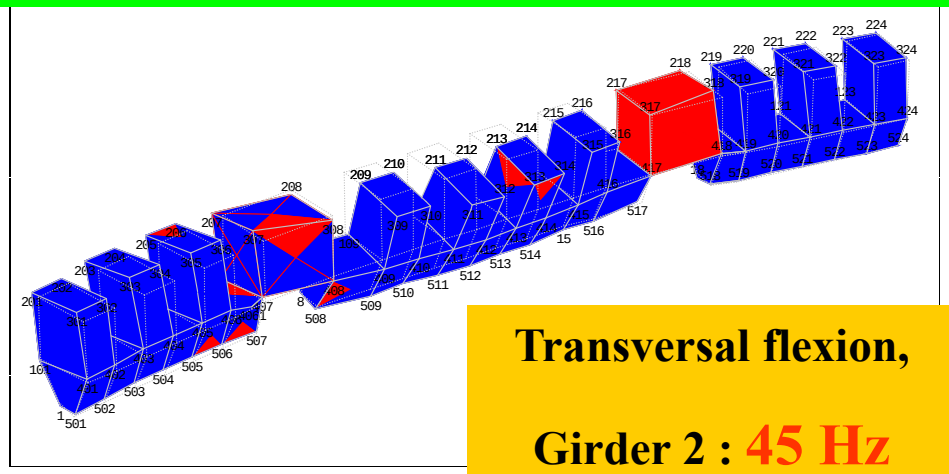
Calculation & Experimental Modal Analysis of girders

FEA calculation



First mode: Calculated: 47.5 Hz

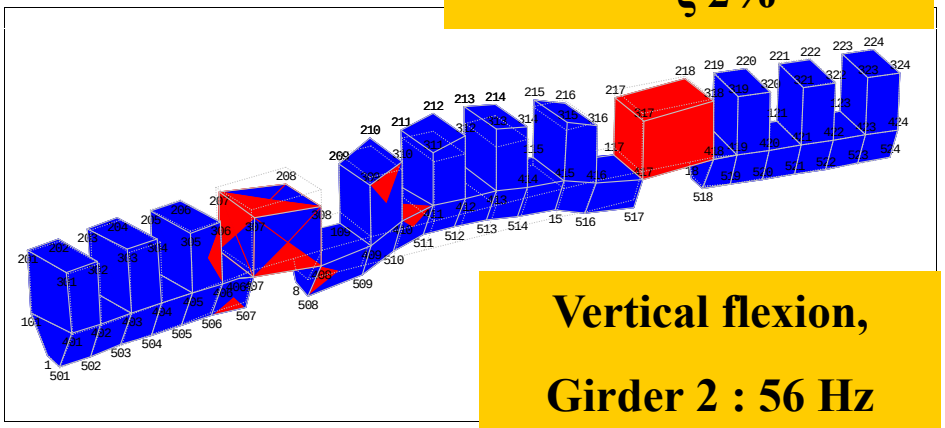
Measurements on storage ring



Transversal flexion,

Girder 2 : 45 Hz

ζ 2%



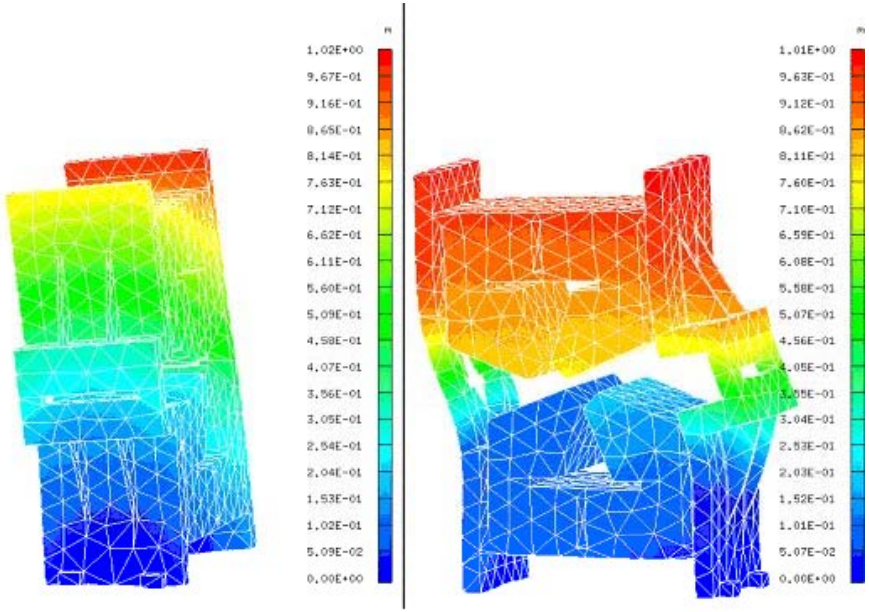
Vertical flexion,

Girder 2 : 56 Hz

ζ 1.2%

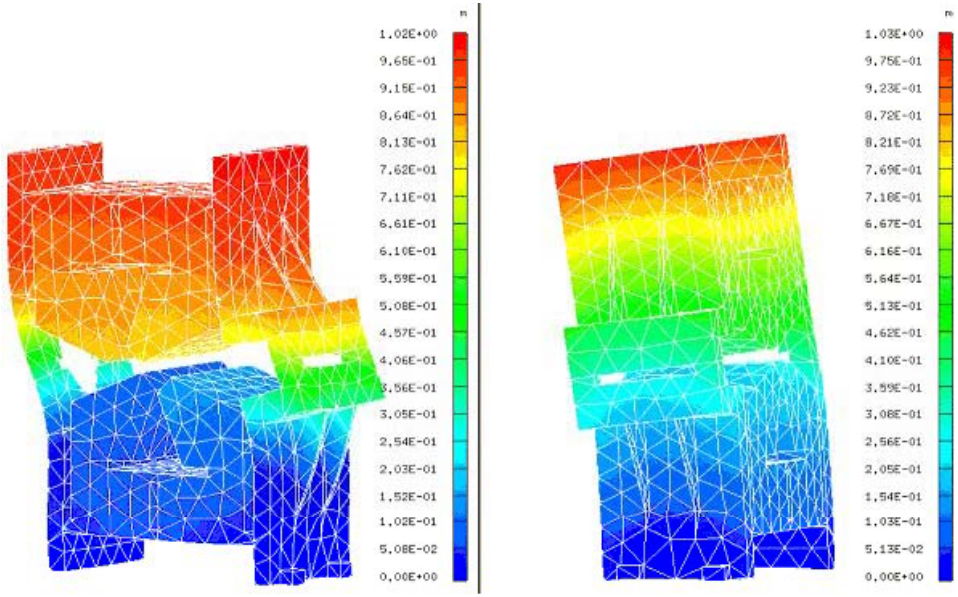
Dynamic study of quadrupoles

The use of hyperstatic binding increases the lowest vibration modes of structures



*First mode : **79** Hz* *2nd mode : 106 Hz*

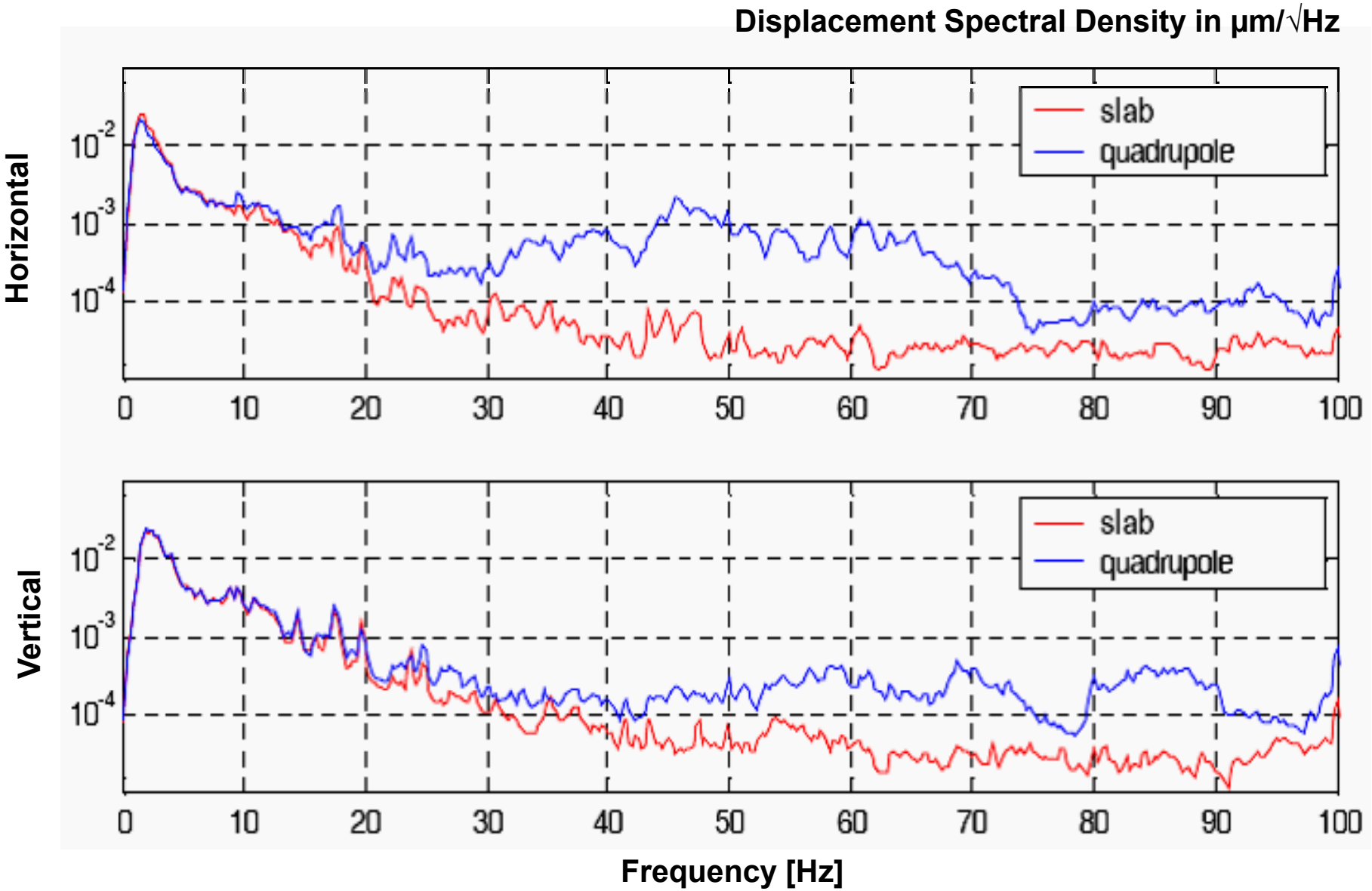
Quadrupole fastened on 3 points



*First mode : **110** Hz* *2nd mode : 122 Hz*

Quadrupole fastened on 4 points

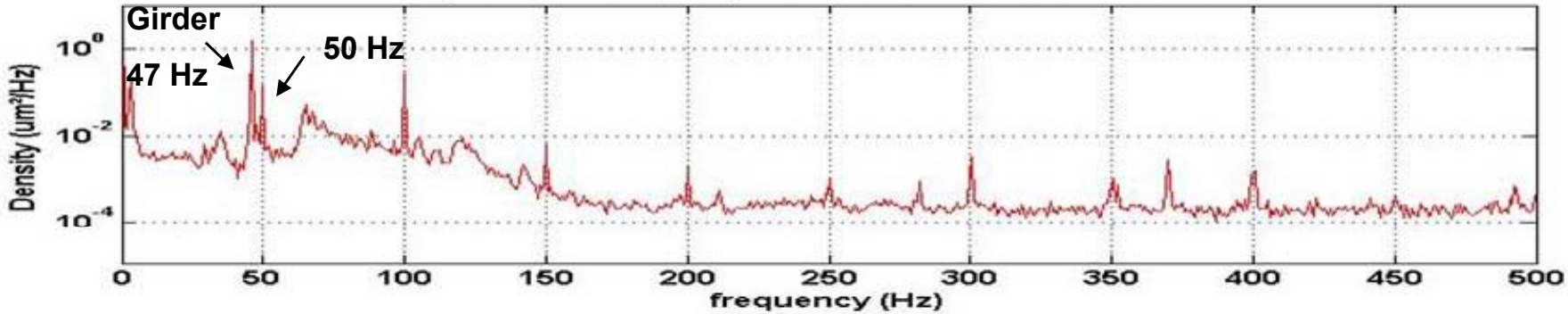
Residual levels with all utilities ON (cooling, ventilation,..)



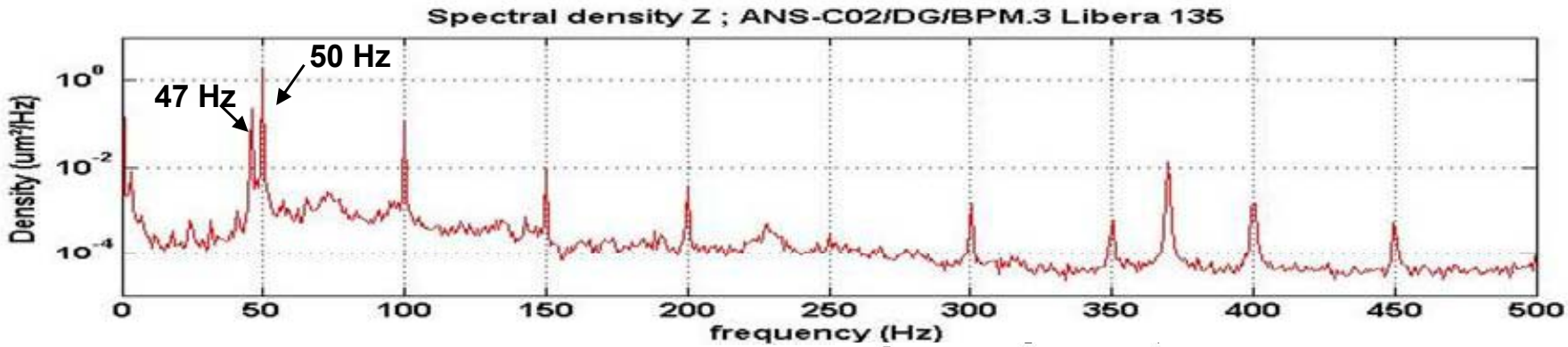
Measurement on electron beam by BPM's

Typical noise spectrum. Vibrations have low influence on beam

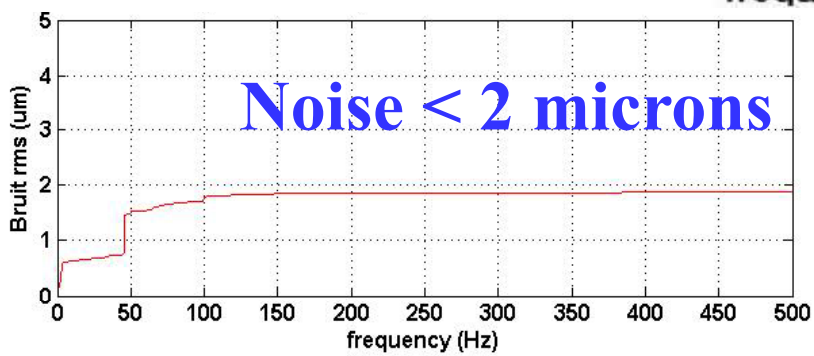
H



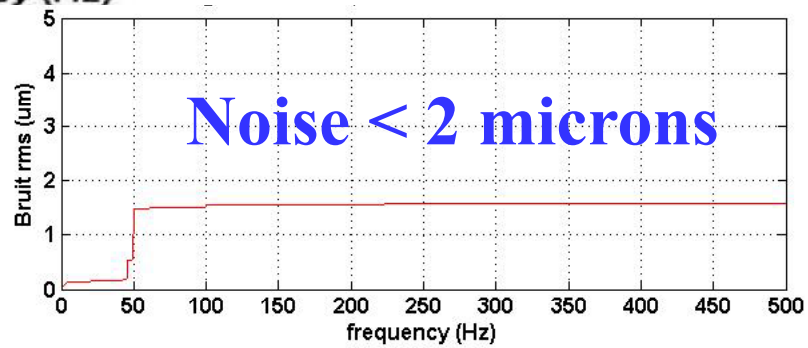
V



H



V



Conclusion

Overall strategy to improve the stability of SOLEIL synchrotron implied the use of specific solutions in order to:

- **minimize vibrations sources when it was possible.**
- **reduce their transmission to the beam in other cases.**

✓ **Systematic dynamic analysis where carried out during the design of all critical components of the chain.**

✓ **Particular care was taken for modelisation of real binding between elements.**

✓ **Theorical calculation have been correlated to experimental measurements in order to validate the models and improve their accuracy.**

✓ **Innovative solutions such as girders alignment and clamping system allowed to meet the requirements.**

Aknowledgments

All these results have been possible by a strong involvment of all the SOLEIL team.

Special « copyright » thanks to:

J-M Filhol, A.Lestrade, A.Nadji, for several slides.

AVLS company for measurement results.

THANK YOU FOR YOUR ATTENTION