Stabilization of the FF quads

A.Jeremie

B.Bolzon, L.Brunetti, G.Deleglise, N.Geffroy

A.Badel, B.Caron, R.Lebreton, J.Lottin

Together with colleagues from the CLIC stabilisation WG and CLIC MDI WG

Some comments

Tolerances	Main beam Quadrupoles	Final Focusing Quadrupoles
Vertical	1 nm > 1 Hz	0.1 nm > 4 Hz
Horizontal	5 nm > 1 Hz	5 nm > 4 Hz

Initially, only vertical direction was studied

Several PhDs:

- C.Montag (DESY) 1997
- S.Redaelli (CERN) 2003
- B.Bolzon (LAPP) 2007
- M.Warden (Oxford) ~2010
- R. LeBreton (SYMME) ~2012

- Active vibration control is not yet a mature technology.
- Activity should be defined as R&D but with CLIC engineering as objective.
- It will take time to achieve the final objective but a work plan has been agreed with CDR as an important milestone.
- Each time a new team starts this study, there is a non negligible “learning period”.

What can active stabilisation do?

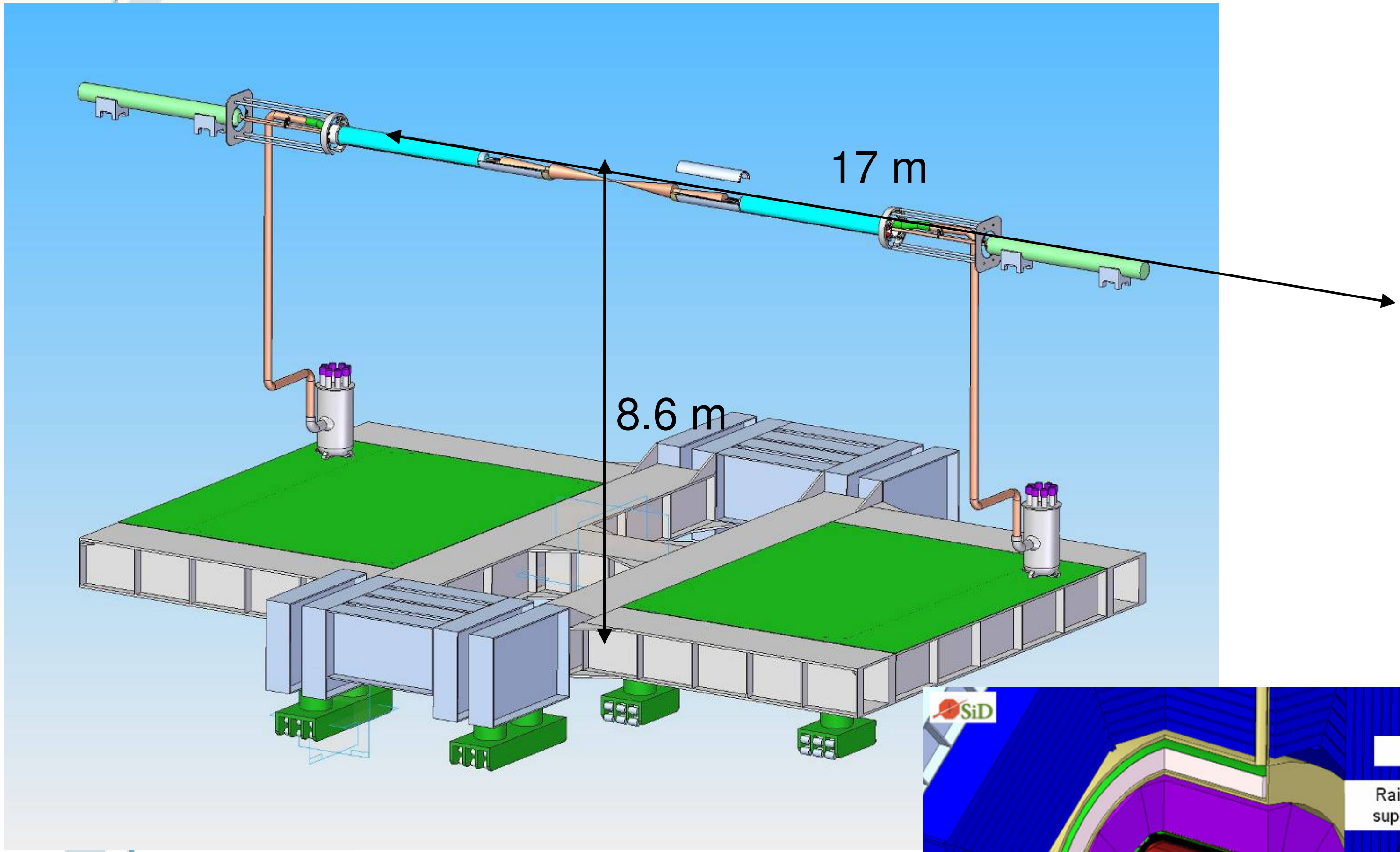
Since the isolation systems don't isolate 100%, but only reduce the vibrations by a given factor (x10 for common systems, x100 VERY difficult, x1000 "impossible")

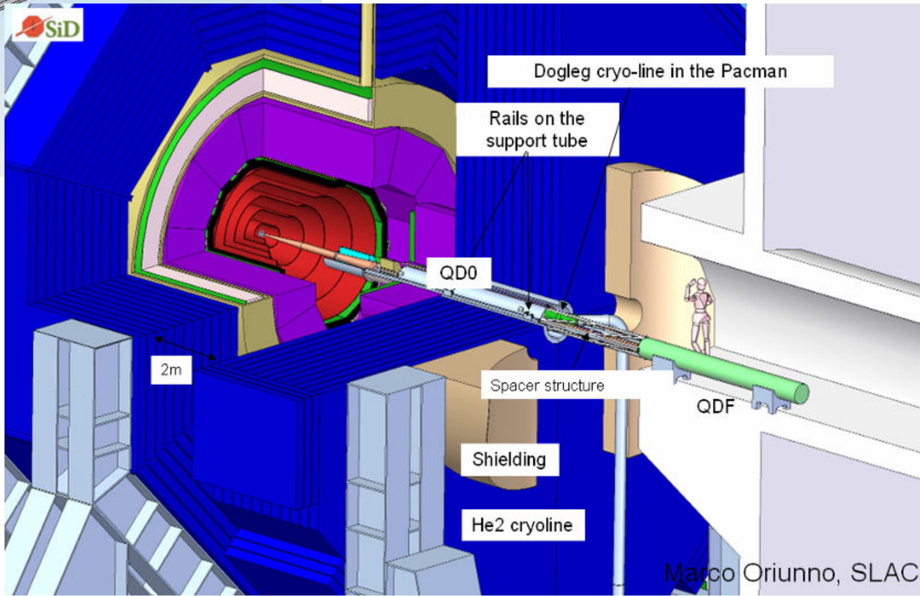
- The initial vibration background has to be as low as possible => if we want
  - MB stab of 1nm, the ground should already be 10nm
  - 0.15nm for the FF, the support should not be subjected to more than 2nm.
- Vibration measurements have shown:
  - Ground measurements at 1Hz vary from 2nm (LEP) to 150nm (ATF2).
  - Common detectors move already by 30nm to more than 100nm!

FF support issues

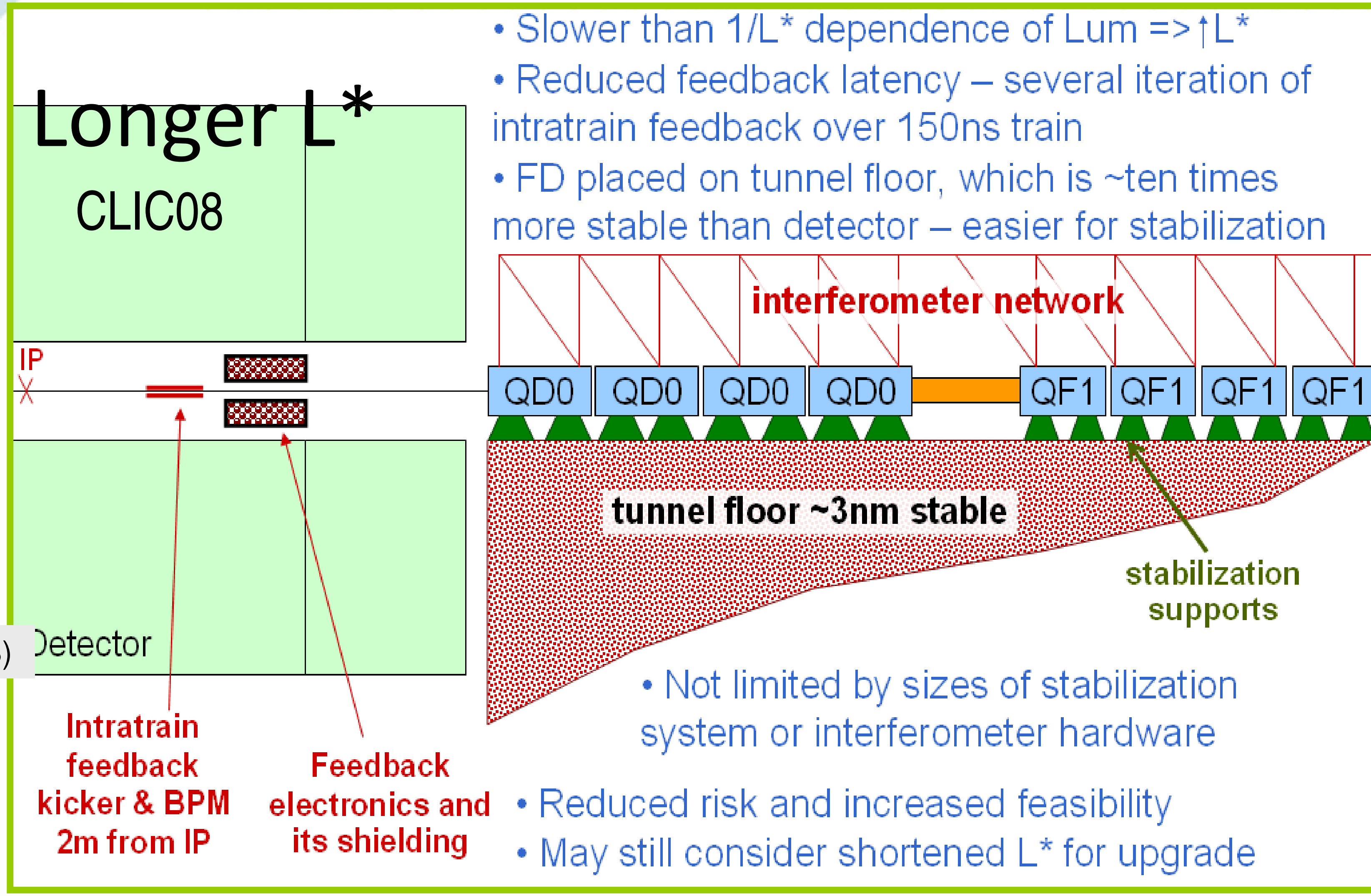
- How can it be supported inside the detector? Are we considering a Push-Pull scenario? A study to be done
  - Cantilever on detector
  - Cantilever from/on tunnel
  - Multifeet from detector
  - Cantilever from ground (height!!!)
  - Suspended from detector
  - Suspended from ceiling (correlation possible for both QD0?)
  - Common girder through detector…
- Need an in depth study with detector conception.
- A detector can never be built with the right vibration tolerances!

Integration for the Push-Pull





Longer L*



(A.Seryi, 2008)

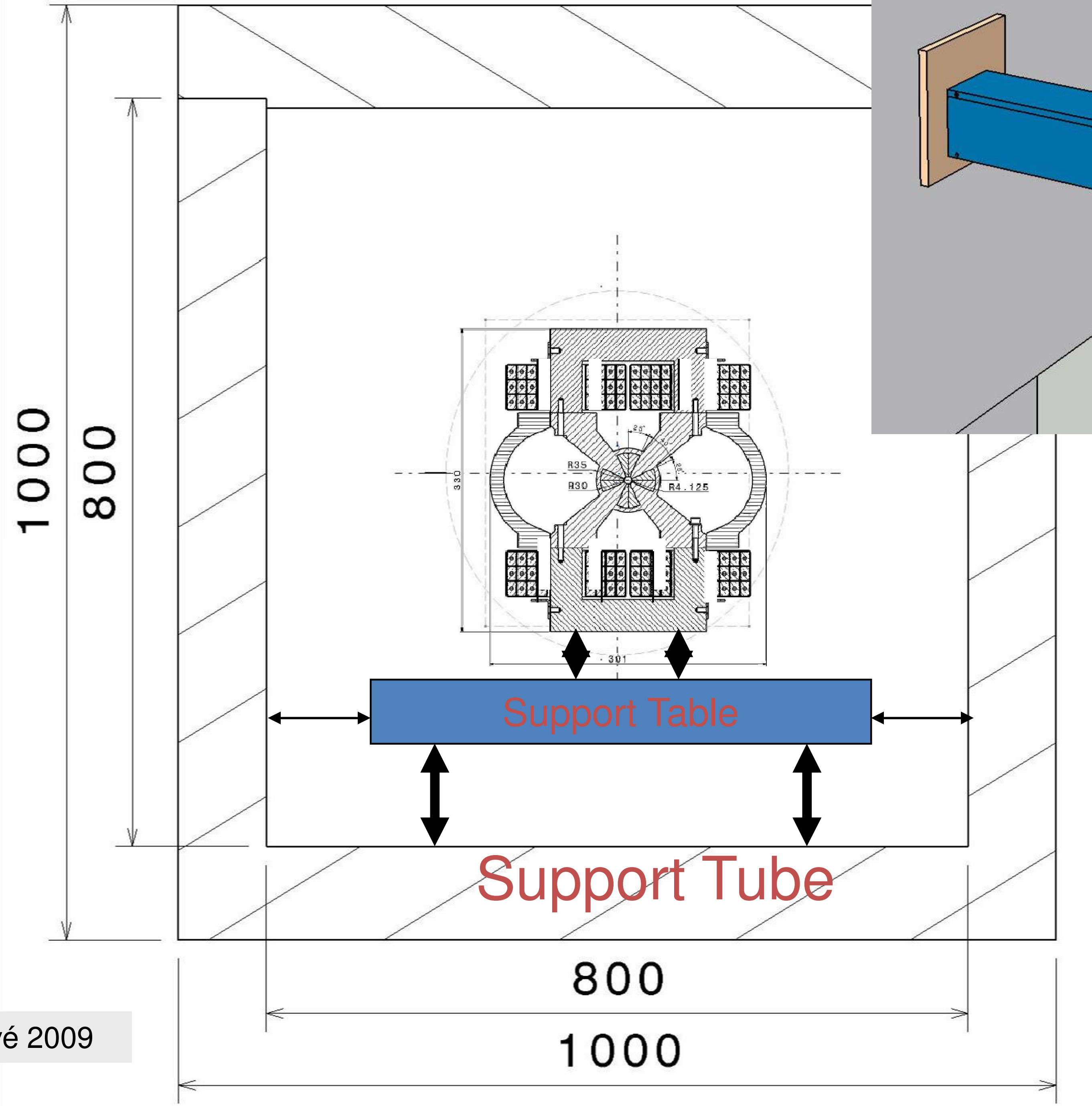
- Study prompted by the CLIC FD stability challenge (< 0.2nm)
- Double the L* and place FD on a stable floor

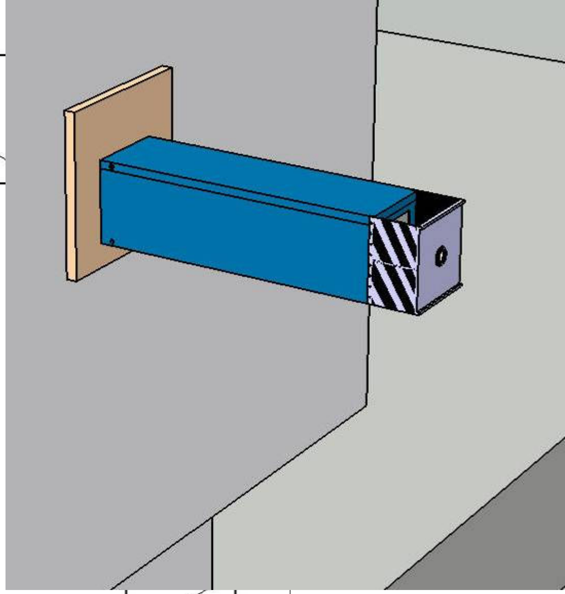
But there are drawbacks: R.Tomas et al have shown a ~30% luminosity loss and tuning trickier

FF support issues

- How can it be supported inside the detector? Are w... a Push-Pull scenario? A study to be done
  - ~~Cantilever on detector~~
  - Cantilever from/on tunnel
  - ~~Multifeet from detector~~
  - ~~Cantilever from ground ...~~
  - ~~Suspended from ...~~
  - ~~Suspended ... relation possible for both QD0?)~~
  - ~~Co...~~ ...ugh detector
- ... ...pth study with detector conception
- A ...ctor can never be built with the right vibration tolerances!
- Would the FF magnet be simpler for L*=8m (without the spent beam in the way)?

What if we only keep the L*=8m for the first stabilisation studies (or slightly shorter L* with cantilever FF)?


1000
800
R35
R30
R4.125
330
301
Support Table
Support Tube
800
1000

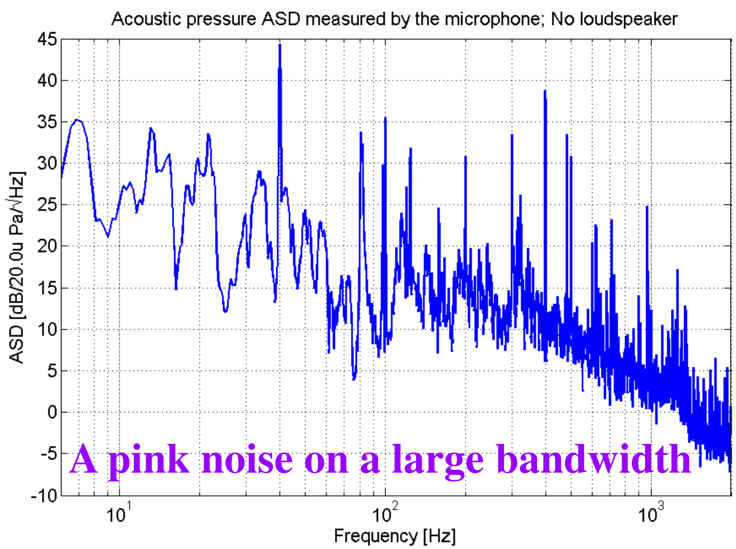


A.Hervé 2009

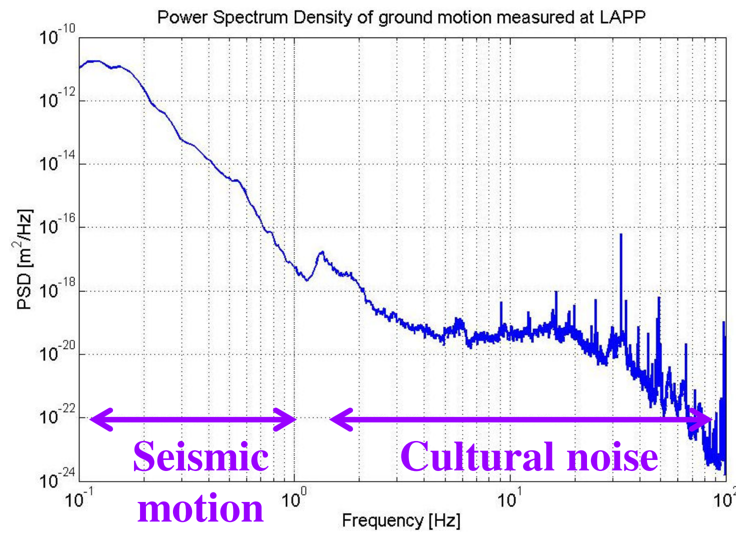
Stabilisation system study

Example of spectral analysis of different disturbance sources

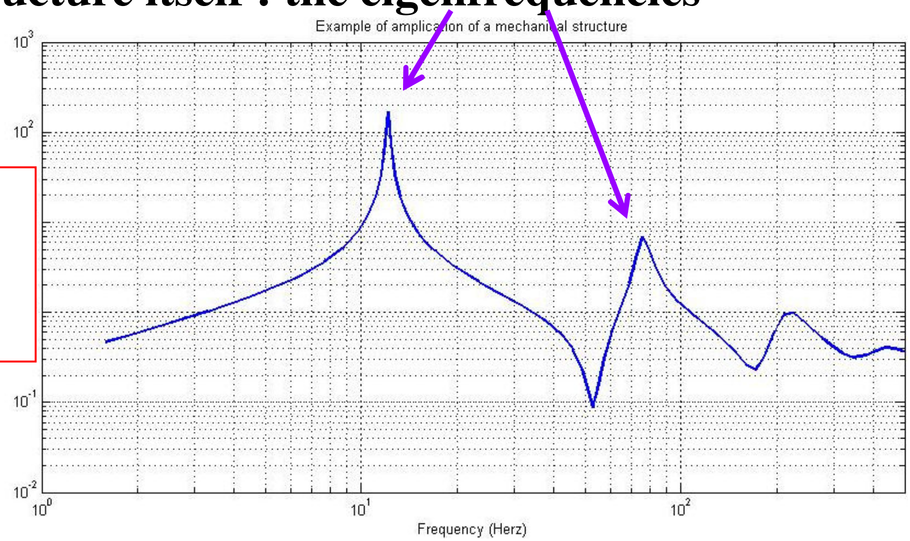
✓ **Acoustic disturbance :**



✓ **Ground motion :**

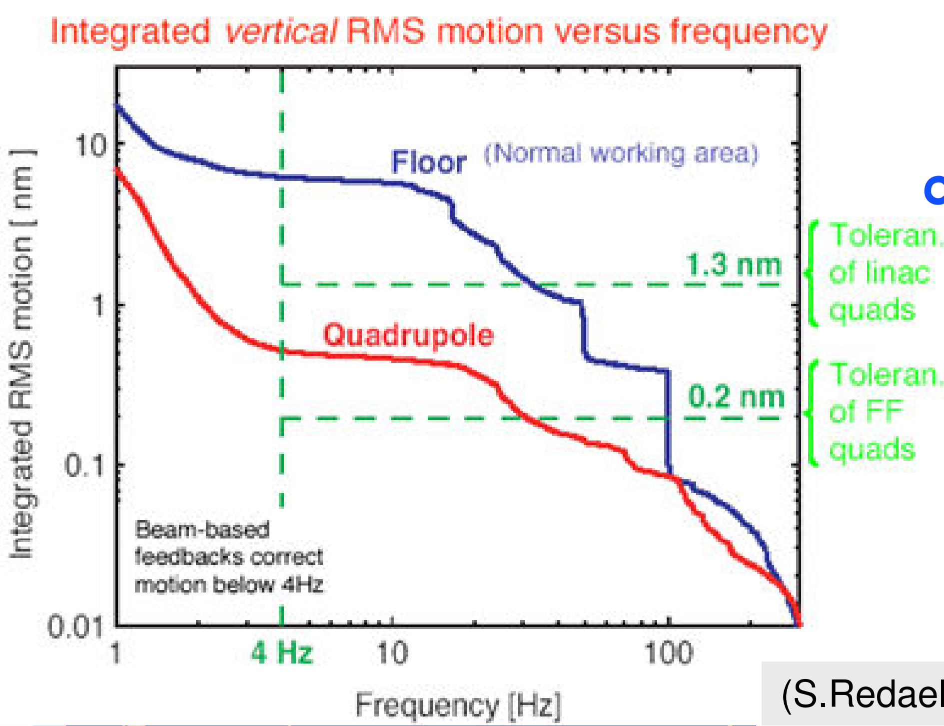


✓ **Amplified by the structure itself : the eigenfrequencies**



2 different functions:
- Isolate
- Compensate the resonances

Sub-Nanometer Isolation



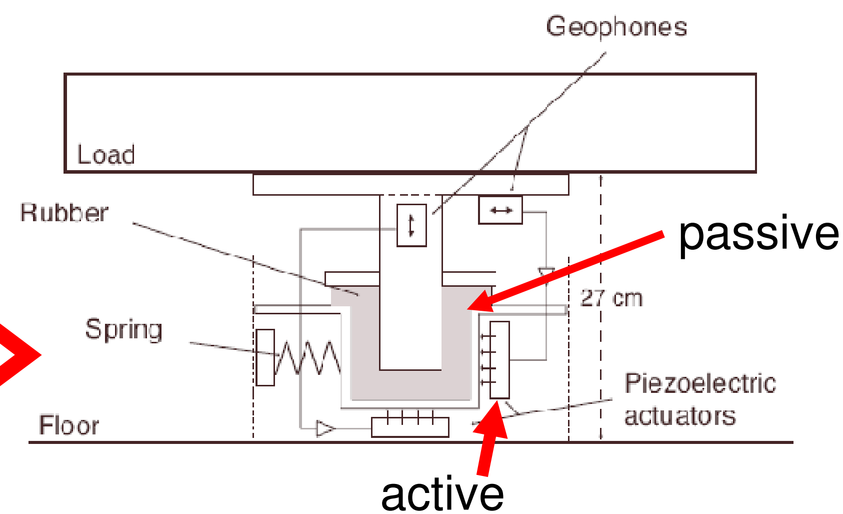
CLIC small quadrupole stabilised to nanometer level by active damping of natural floor vibration

RMS vibrations above 4 Hz

	Quad [nm]	Ground [nm]
Vertical	0.43	6.20
Horizontal	0.79	3.04
Longitud.	4.29	4.32

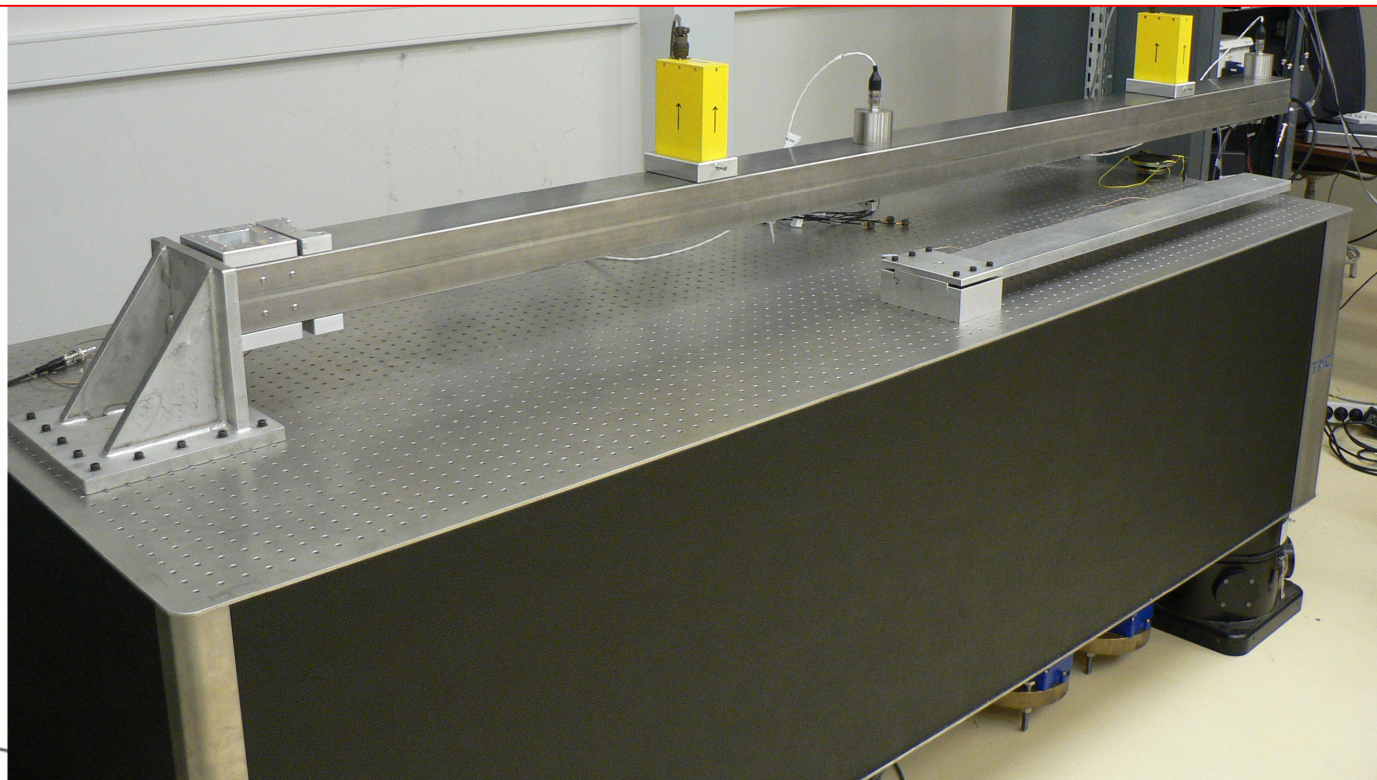
(S.Redaelli *2003*)

CERN vibration test stand



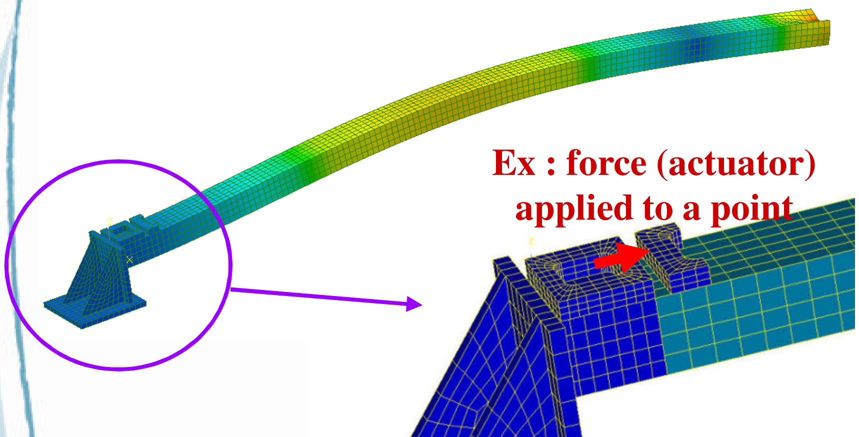
Resonance compensation

Al 2.5 m beam
First eigenfrequencies in the same region as the ILC FF SC magnet
Cantilever configuration considered for FF support
Compensation at end of beam where displacements are big



Tests in simulation

✓ **A finite element model of the structure :**



✓ **Dynamics equation :**

$$M.\ddot{u}(t) + C.\dot{u}(t) + K.u(t) = f_p(t)$$

- **M** : Mass matrix
- **C** : damping matrix
- **K** : stiffness matrix

➢ **A prediction of the mechanical structure response**

➢ **Requires an updating to be as representative as possible to the real setup**

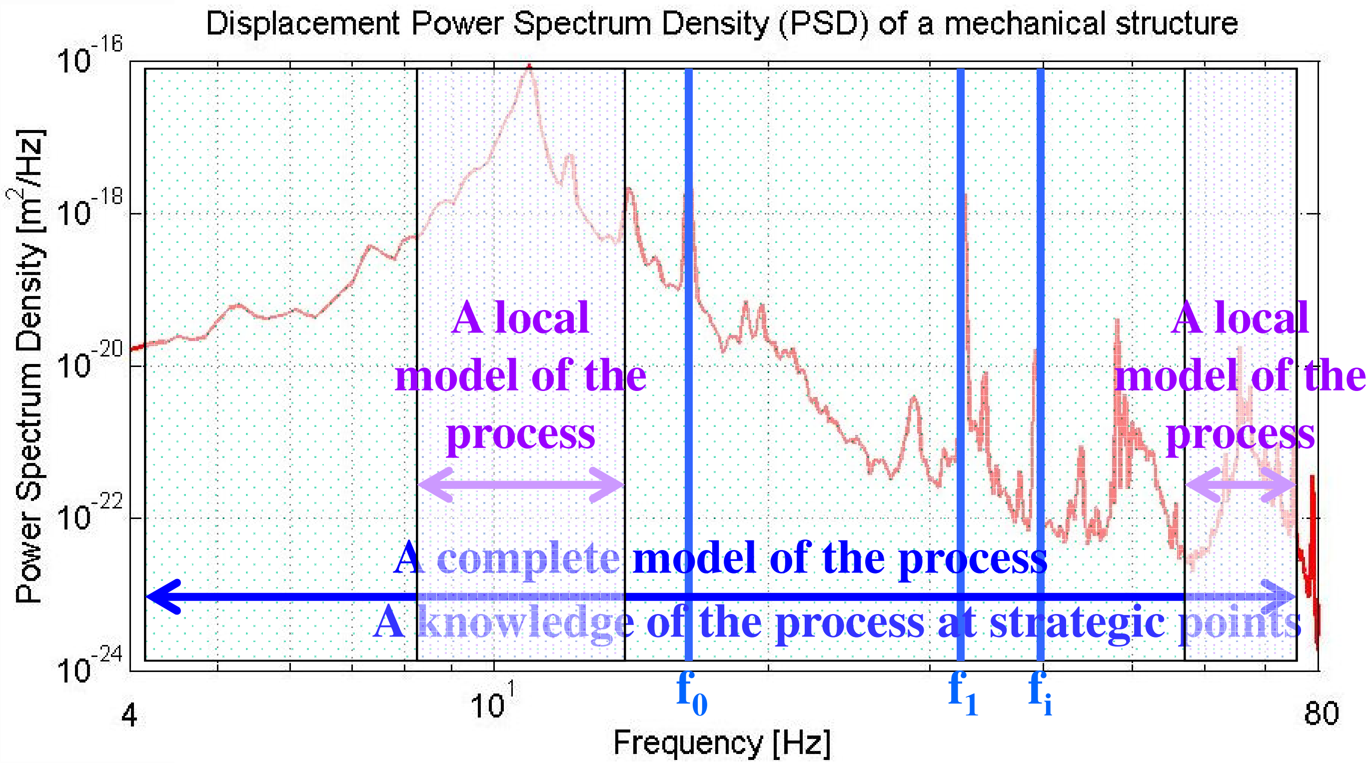
➢ **Available under Simulink, in the form of a state space model in order to test feedback loops.**

✓ **The purpose of the simulation :**

- To adjust the feedback loop
- To increase the test possibilities (multiple configurations for sensors, actuators…)
- To analyse the behaviour of the entire beam

Different approaches of the problem

✓ **The method used to build the controller :**



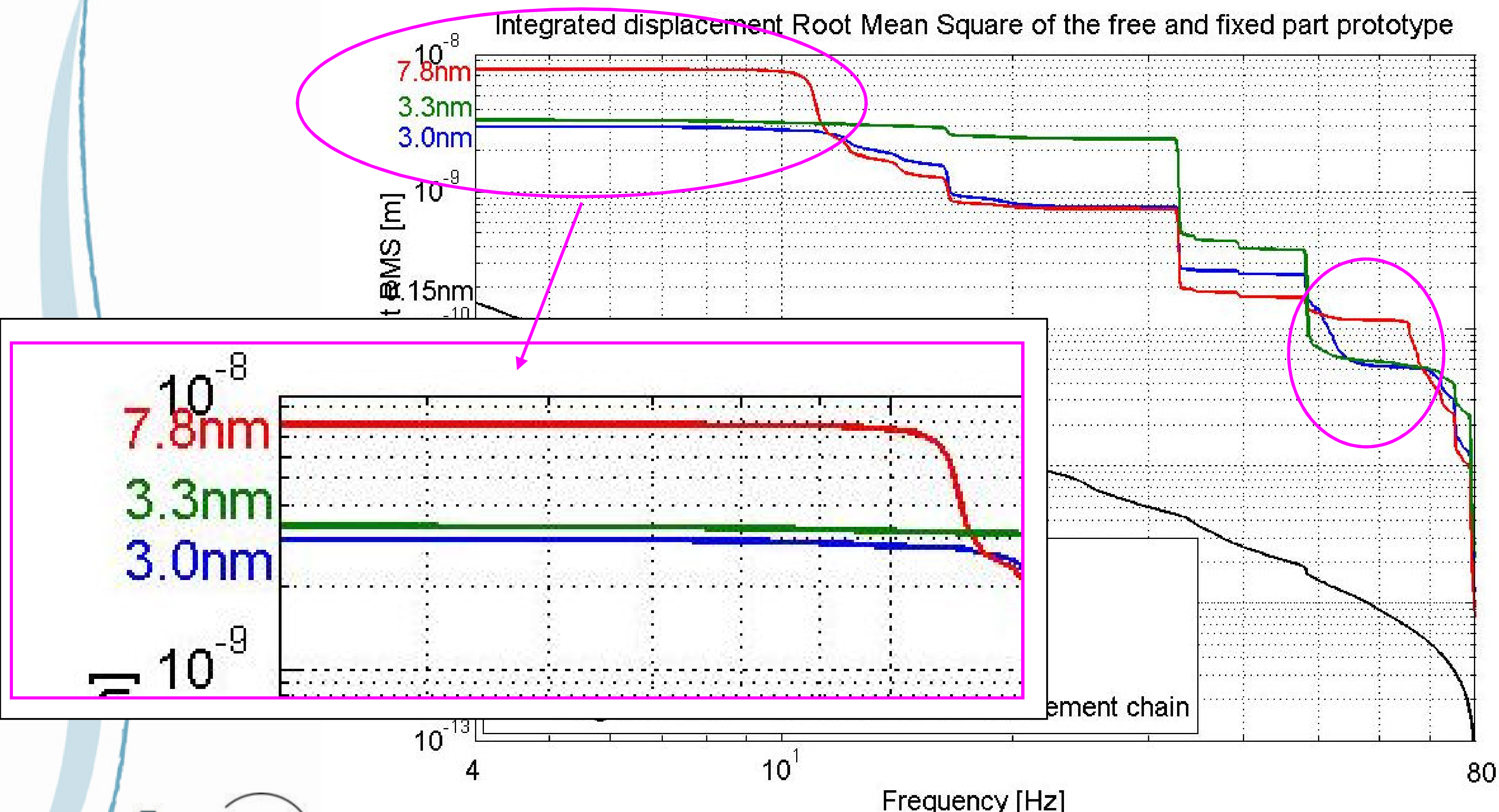
1 - A knowledge of the structure at strategic points : ***for lumped disturbances***

2 - A local model of the structure : ***for the disturbances amplified by eigenfrequencies.***

3 - A complete model of the structure : ***for the entire structure***

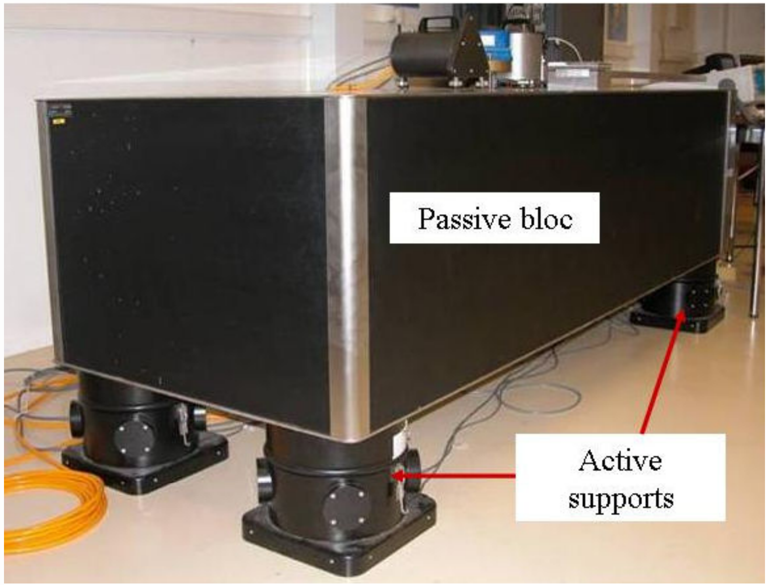
Tests with the large prototype

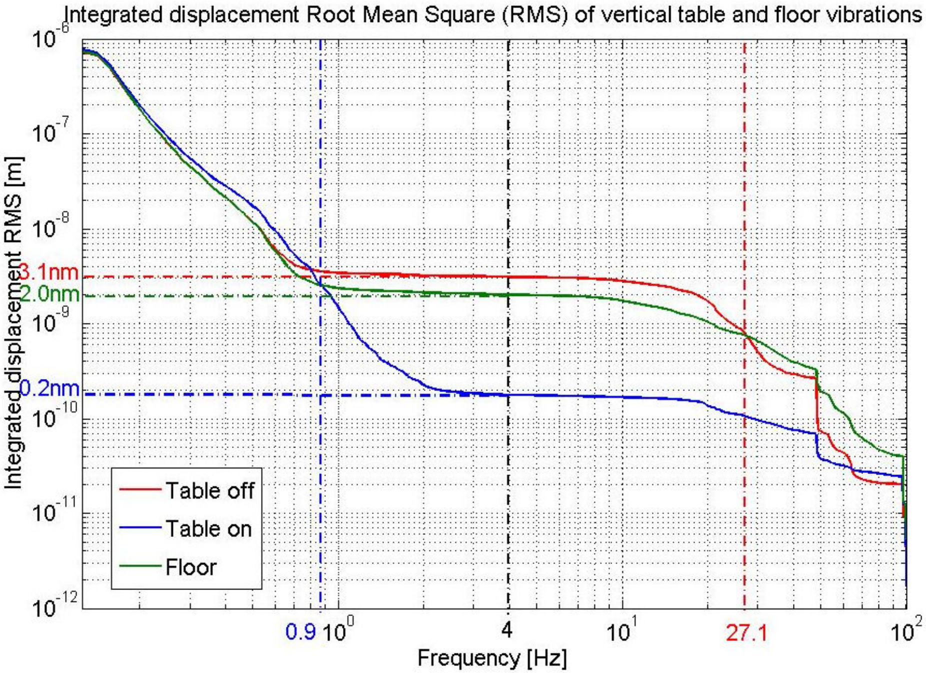
- **Results : integrated displacement RMS**



The industrial solution

✓ **An industrial solution : the TMC table of CERN.**



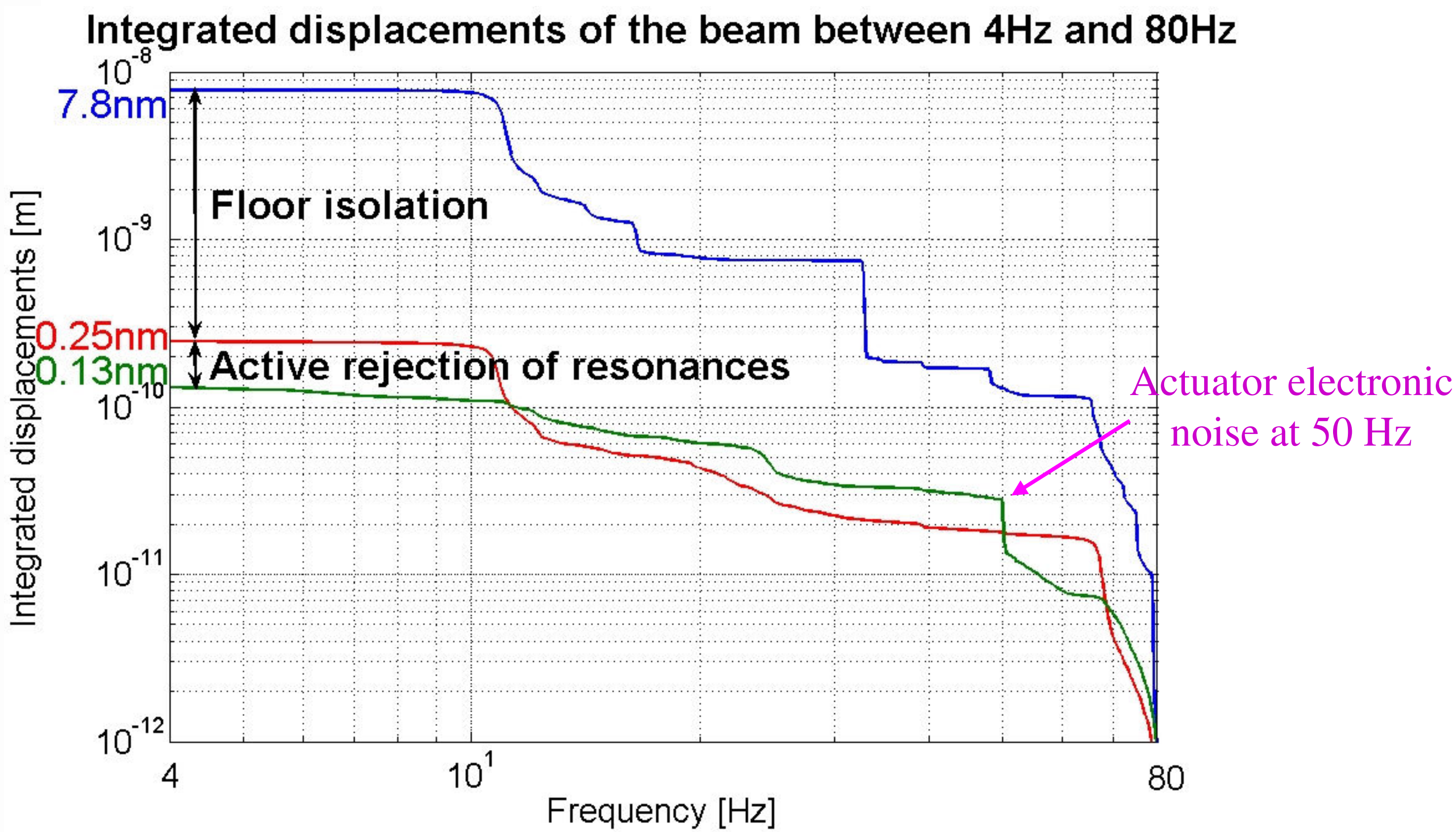


✓ **Composed of a passive bloc, placed on 4 active feet (STACIS).**

- Passive isolation : attenuates all the high frequency disturbances but amplifies the low frequency disturbances (like a resonant filter).
- Active isolation : attenuates the disturbance amplified by the passive isolation (low frequencies disturbances).

Tests with the large prototype

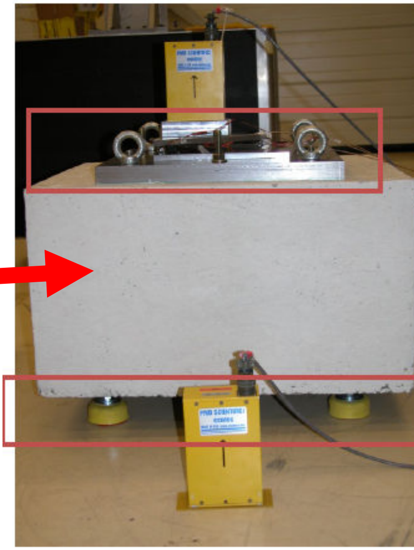
✓ **Results : integrated displacement RMS (with active table ON)**

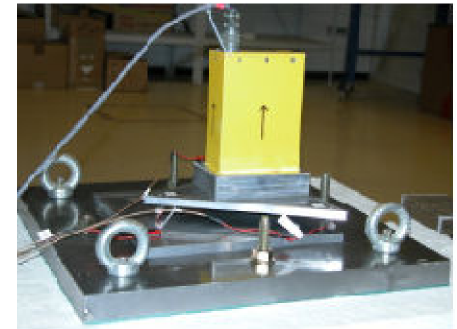


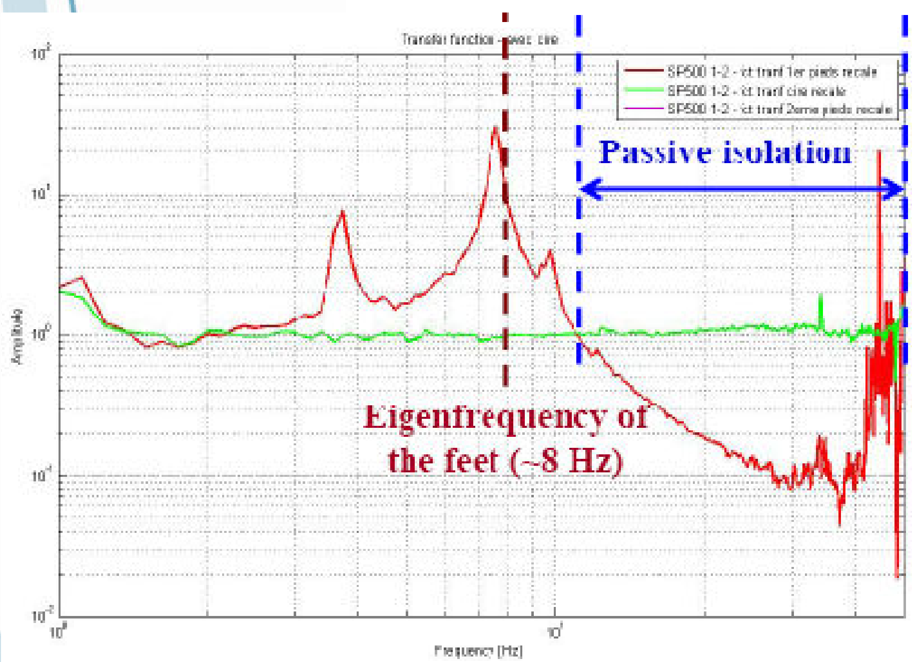
- No control
- With active isolation (TMC table)
- With active isolation (TMC table) and active compensation (PZT actuators)

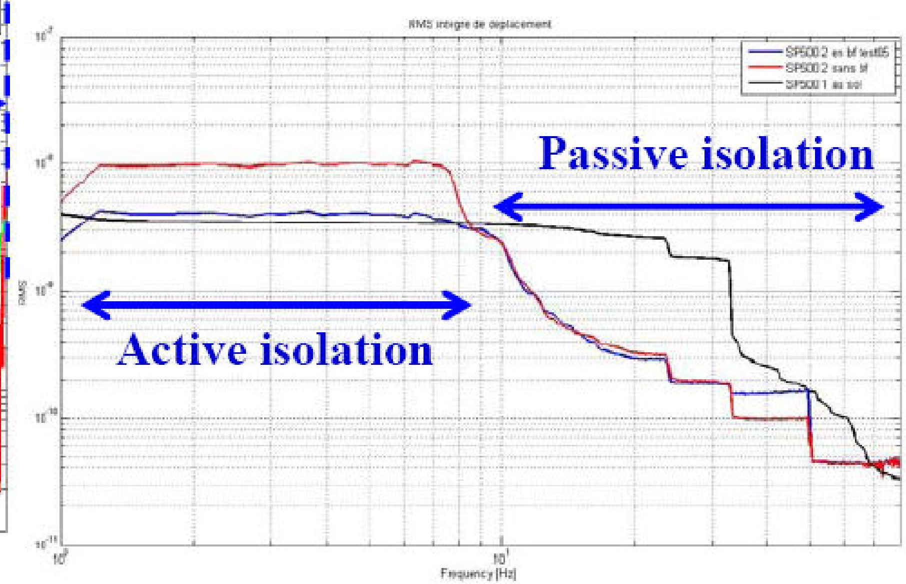
Future studies

Replace big TMC table by smaller device



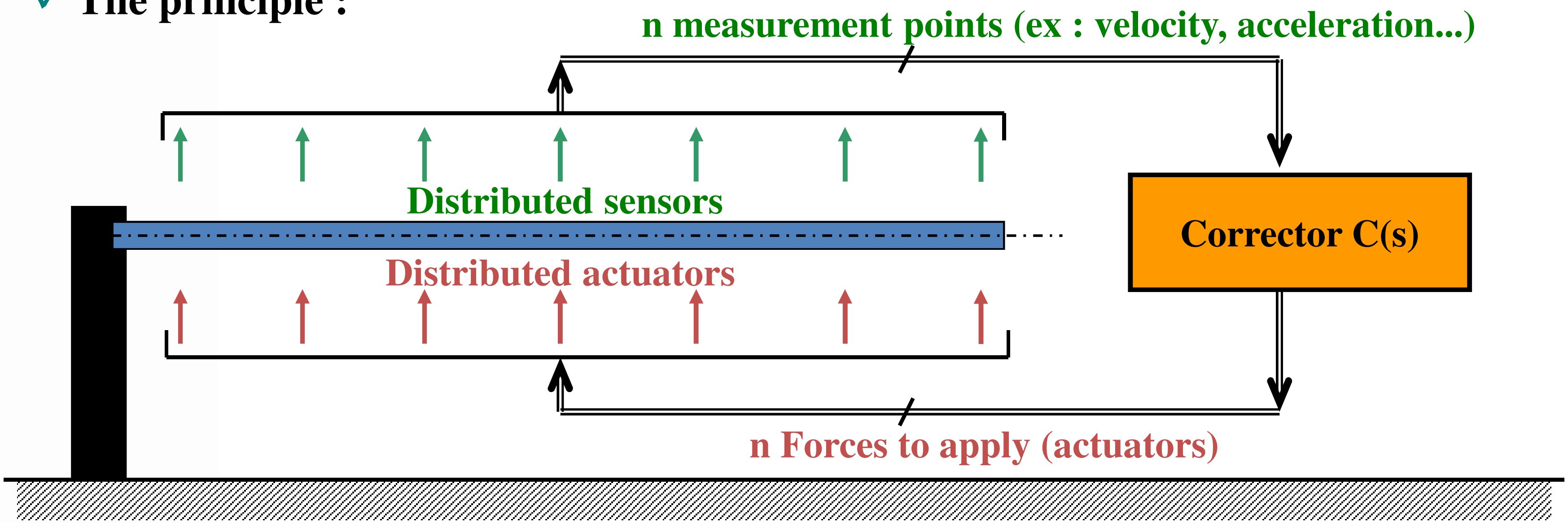






Multi sensors – Multi actuators

✓ **The principle :**



✓ **The method :**

- Develop a complete model M(s) of the structure (using the modelling -finite element) updated as a function of the behaviour of the structure - results in a state space form
- Compute a reduced model $M_r(s)$ which is representative of the structure given by the modelling stage.
- Build a robust corrector with the reduced model, using the method of the placement of poles and zeros.
- Test in simulation, next step: on the prototype.

General stabilisation issues

Item	Achievable	Critical
Sensors	Exist can give lots of info for CDR	Magnetic field issue! Final choice after CDR
Actuators	OK for CDR	Weight and size definition
Isolation system	Principle/design probably OK	For the active feet option: test underway
Test in accelerator environment	OK for CDR if quick test	Complete representative test after CDR (CesrTA, CTF3, ATF2…)
Ground vibration measurements	OK for CDR	List vibration sources
Compare different “sensors” (seismic/inertial vs laser)	OK for CDR	If test done next year in ATF2 between Monalisa and seismic sensors
Magnetic center stabilisation	Under study	If we measure outside of magnet, how can we be sure, the magnetic center is also stable?

FF specific

Item	Achievable	Critical
QD0 magnet design	OK for CDR	
FF stabilisation		Considering Plan B with larger L^*
QD0 mock-up	Design OK	Procurement?
FF stabilisation methodology/feedback		Extension of existing mock-up Multi-sensor/multi-actuator
Detector integration +push-pull		Related to QD0 stabilisation
Support simulations + measurements		Support under design (related to L* option)

•All these “critical” items are studied by limited resources
•Follow closely work done in the stabilisation group and MB specific work (module type 4 , isolator…)
•MDI-FF review January 2010 => better view of what will be possible for CDR