Laboratoire d'Annecy-le-Vieux de Physique des Particules

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# CLIC MDI stabilization update

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

In2p3

# 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

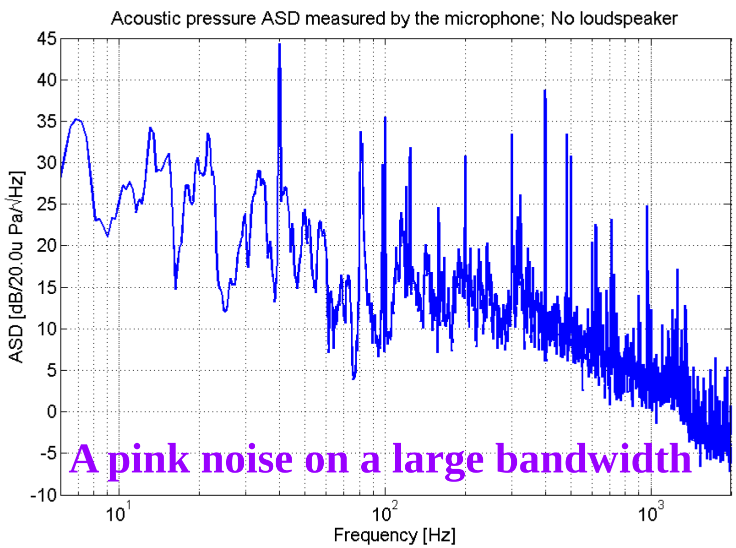
Several PhDs:

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

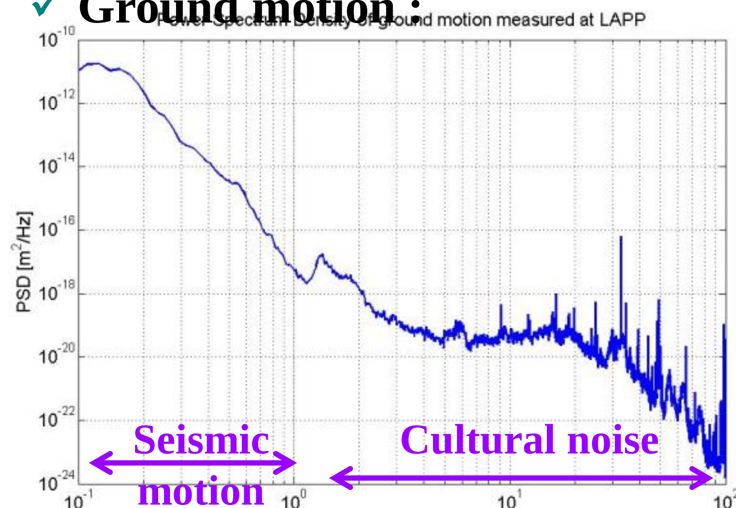
- There is no completely validated stabilization system (off the shelf) available yet…
- There are proofs of principle available.

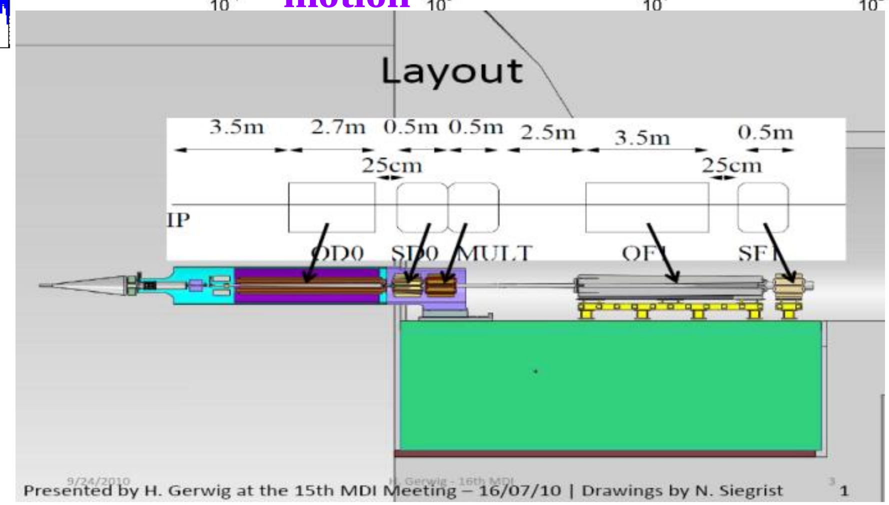
# Example of spectral analysis of different disturbance sources

- ✓ **Acoustic disturbance :**

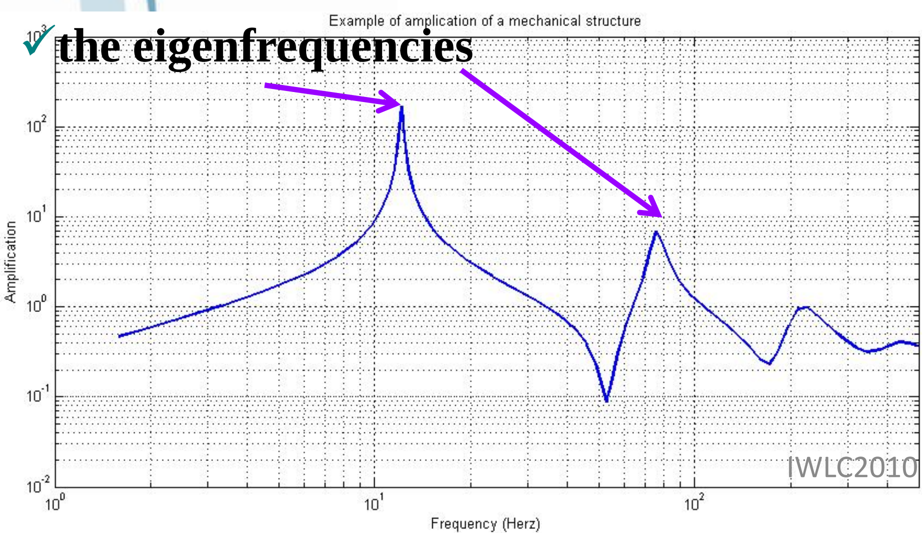



- ✓ **Ground motion :**



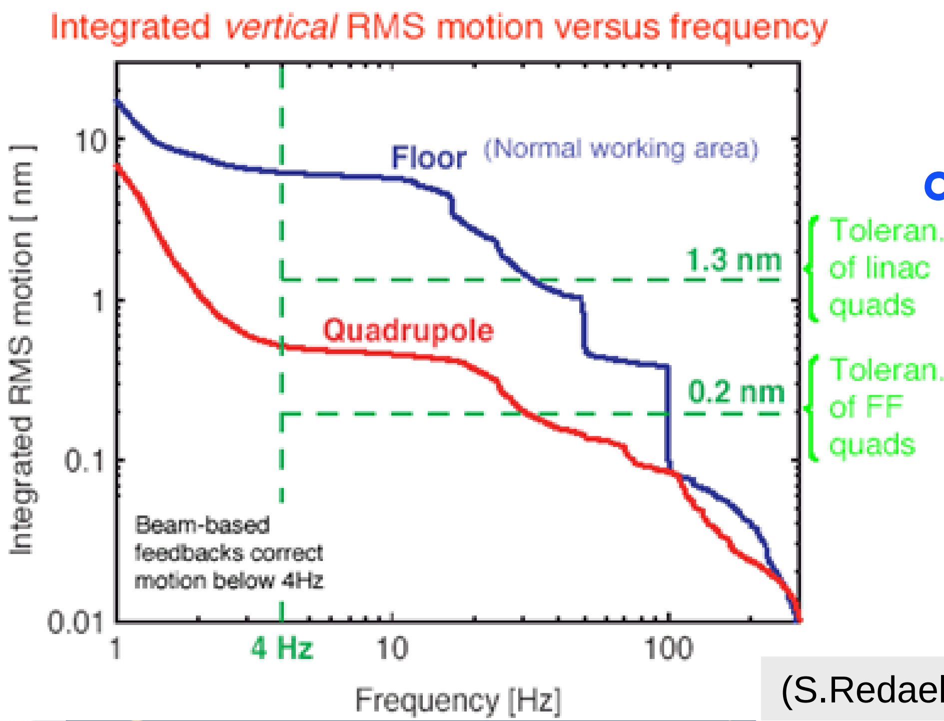




- ✓ **Amplified by the structure itself :**
- ✓ **the eigenfrequencies**




2 different mechanical functions:
- Isolate
- Compensate the resonances

# Sub-Nanometer Isolation



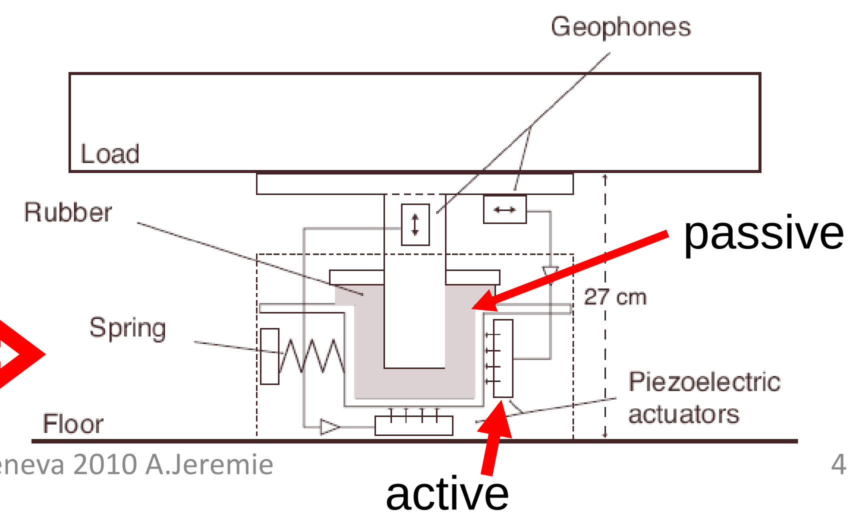

(S.Redaelli *2003*)

**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 |

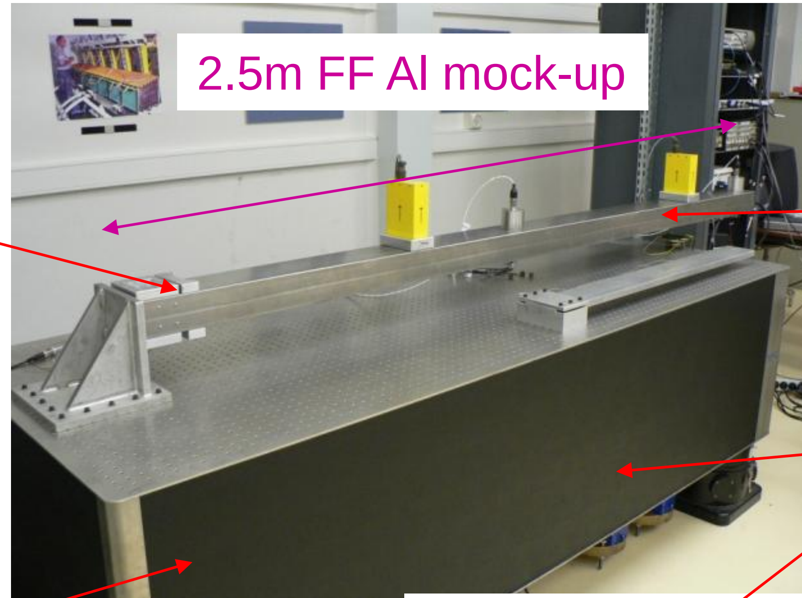
**CERN vibration test stand**



Feasibility already demonstrated

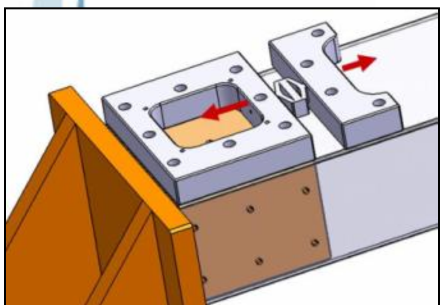
# Cantilever FF stabilisation

LAPP active system for resonance rejection

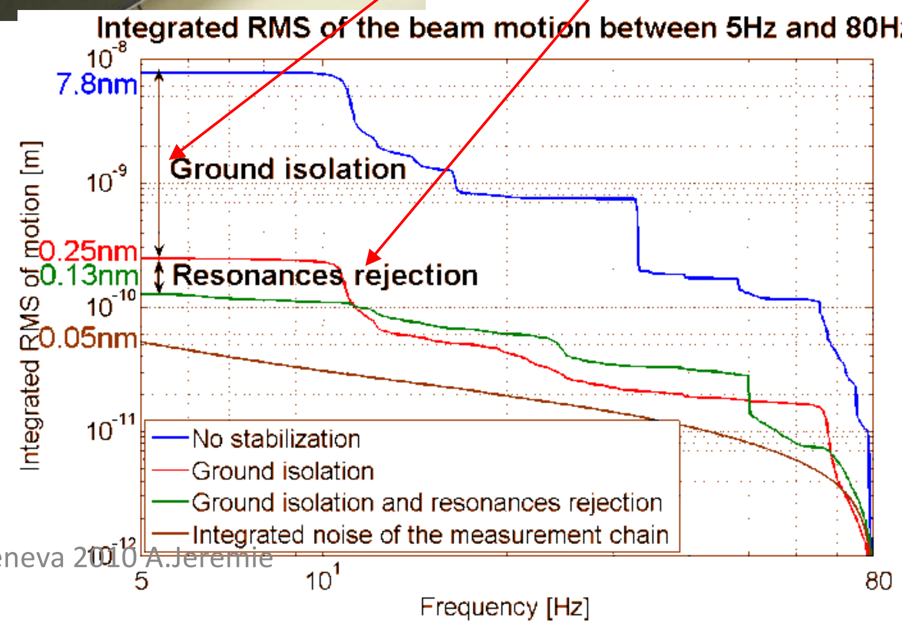



Resonance rejection

Isolation



CERN TMC active table for isolation

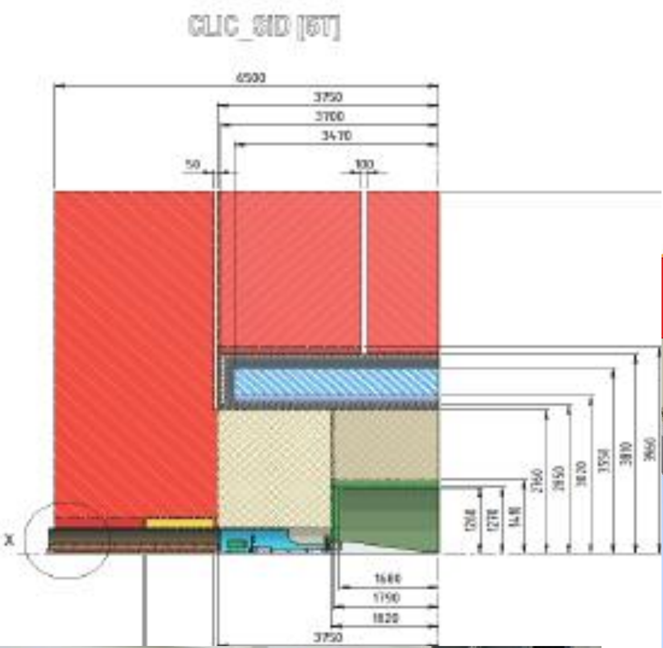


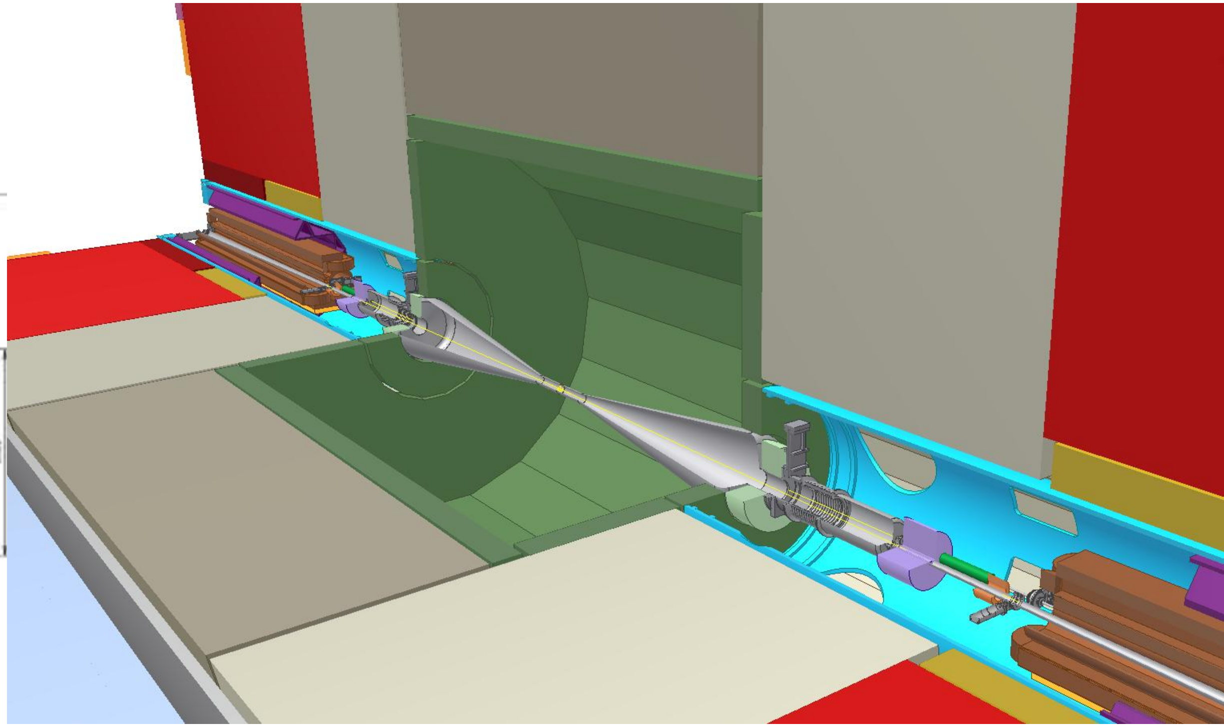

- **The two first resonances entirely rejected**
- **Achieved integrated rms of 0.13nm at 5Hz**

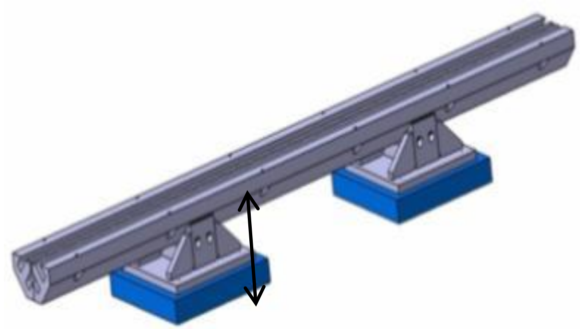
(L.Brunetti et al, 2007)

# Current studies

# Replace big TMC table by smaller device



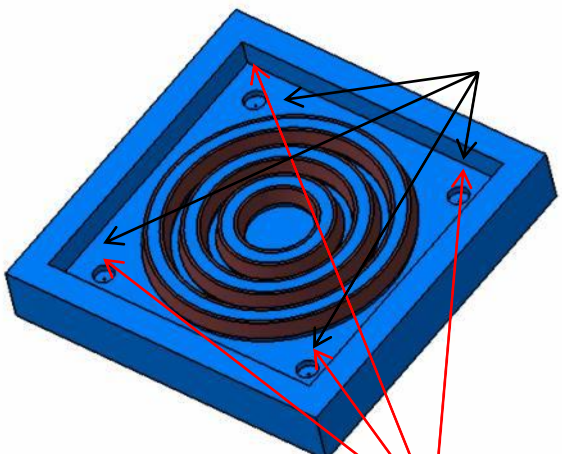


# Initial study hypthesis:
# Soft support and active vibration control

Rigid: less sensitive to external forces but less broadband damping

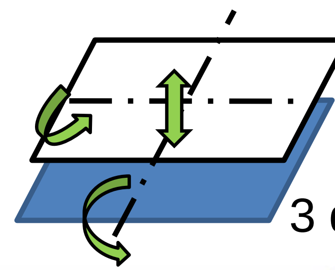
## Active vibration control

Relative sensors (more compact)

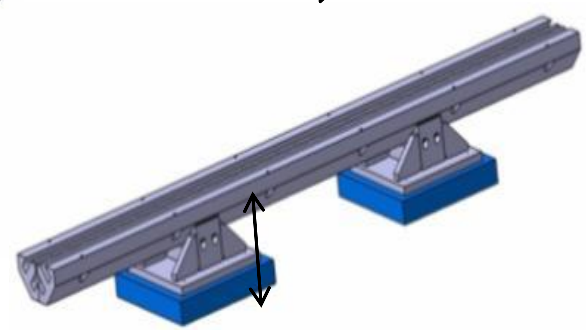


actuators

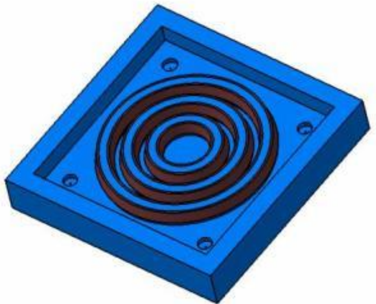
elastomere joint in between for guidance

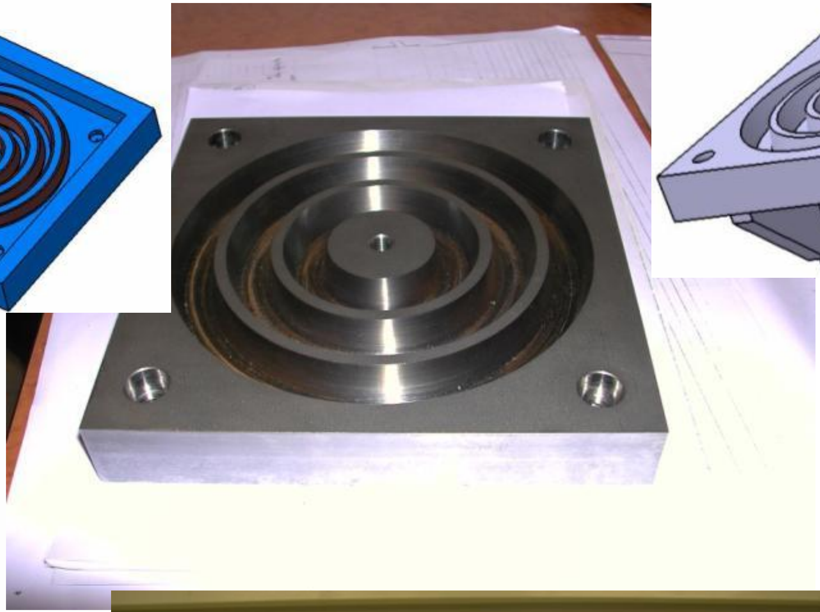


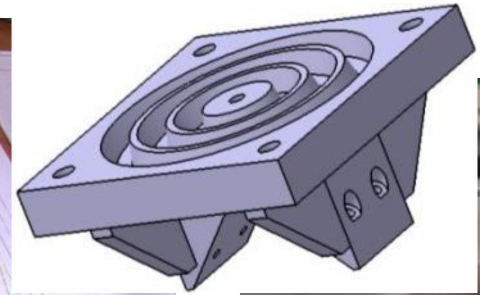
3 d.o.f. :

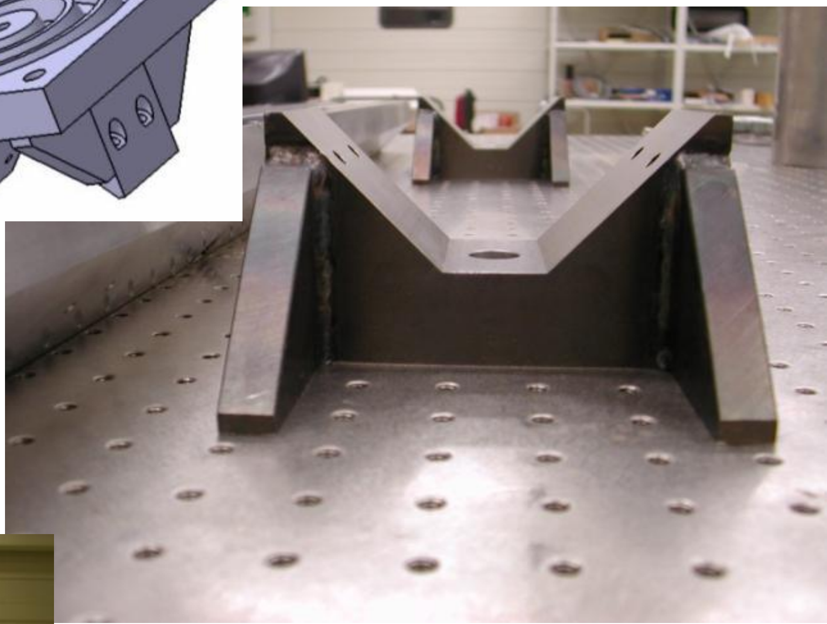


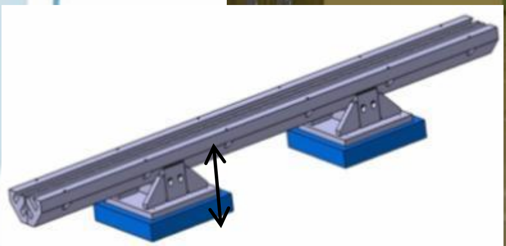
# Active vibration control construction

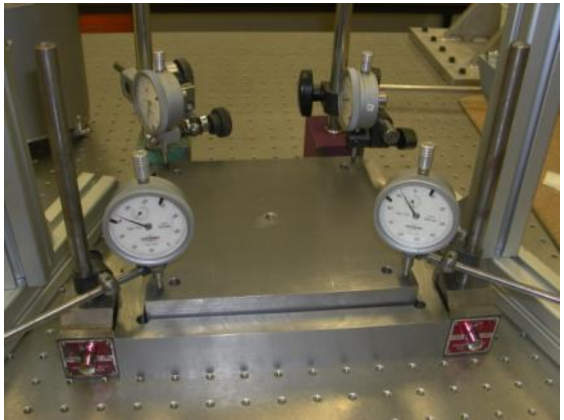




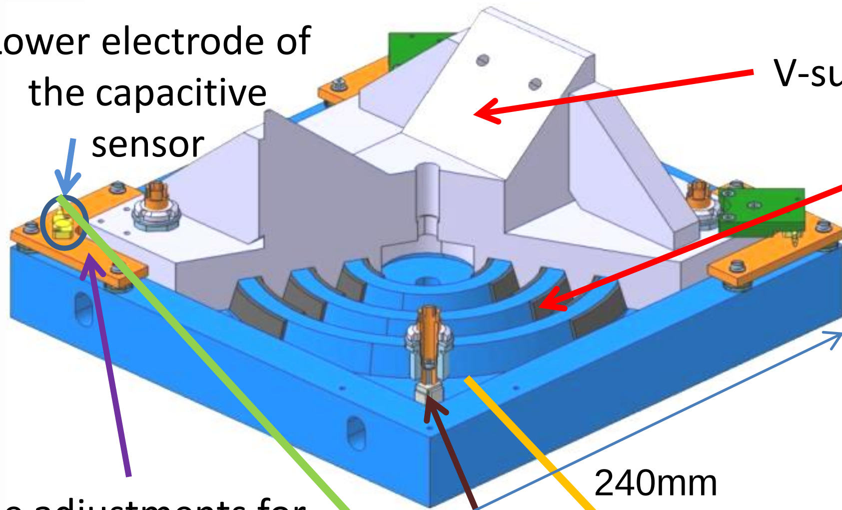


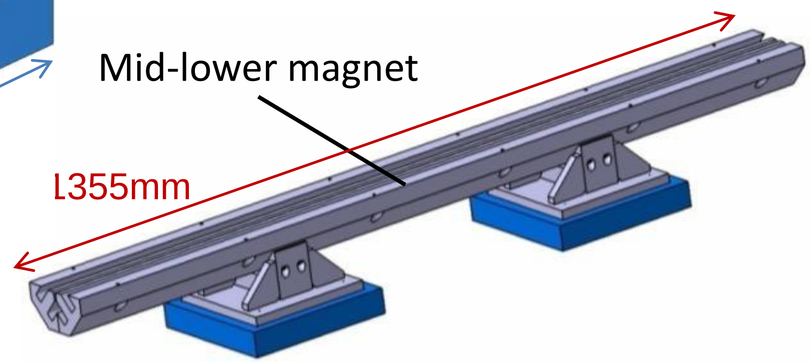


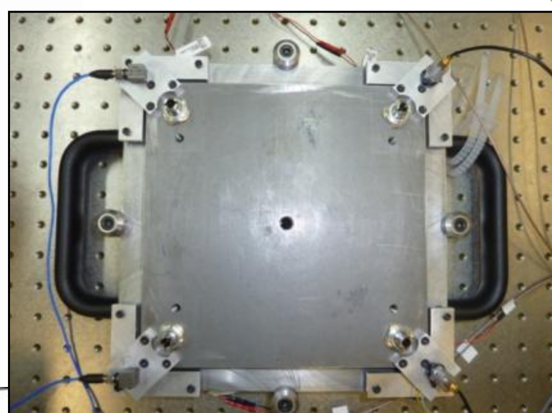


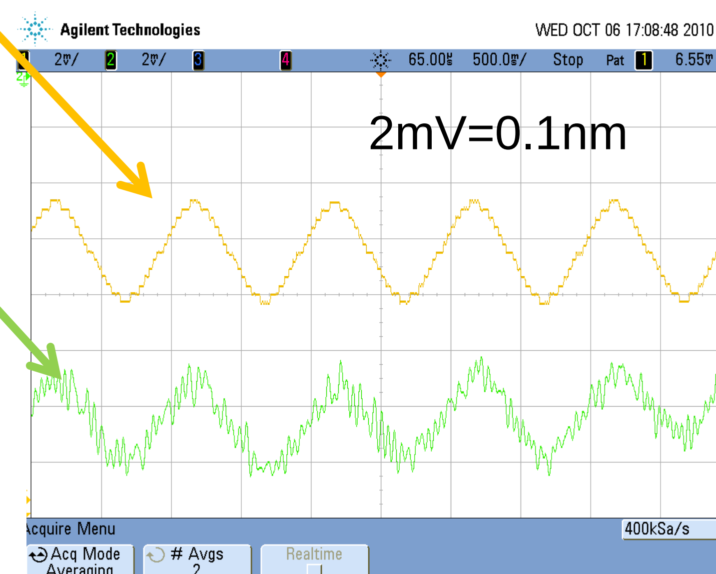


# First tests in Annecy



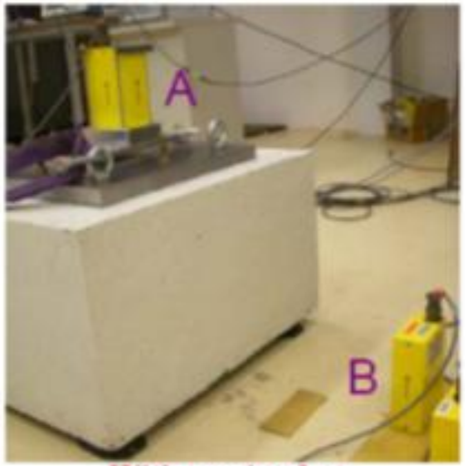



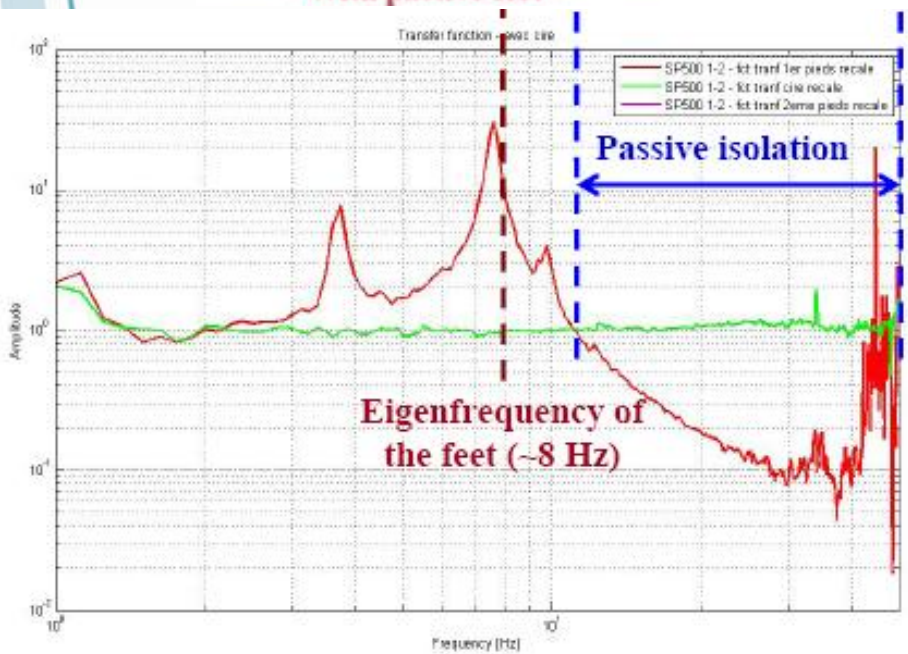


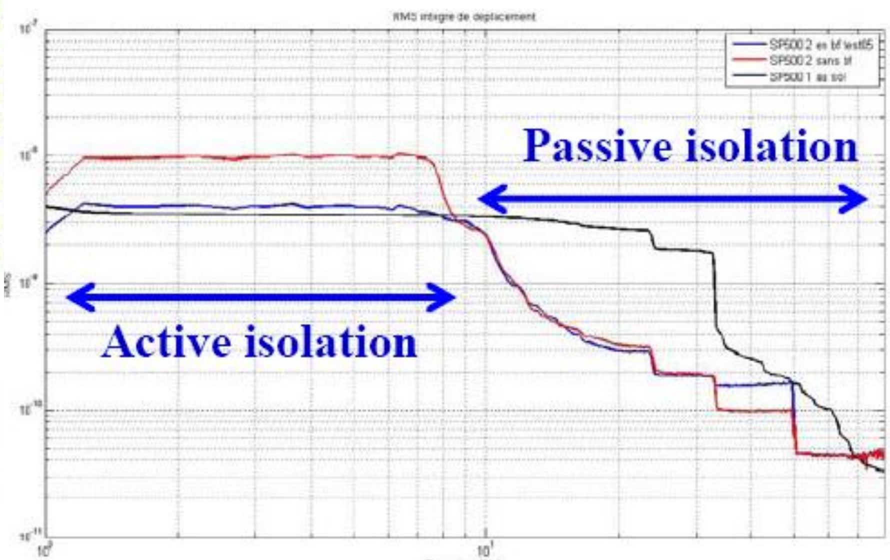

Next step: add feedback

# Later study adding “soft” material




- With passive feet -



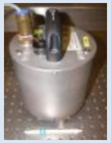



# Need sensors that can measure nm, 0.1Hz-100Hz in accelerator

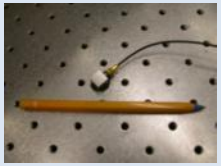
Absolute velocity/acceleration studied at LAPP:

| Type of sensors | Electromagnetic geophone | Electrochemical geophone | Piezoelectric accelerometers | | |
|---|---|---|---|---|---|
| Model | GURALP CMG-40T | SP500-B | ENDEVCO 86 | 393B12 | 4507B3 |
| Company | Geosig | PMD Scientific | Brüel & Kjaer | PCB Piezotronics | Brüel & Kjaer |
| Sensibility | 1600V/m/s | 2000V/m/s | 10V/g | 10V/g | 98mV/g |
| Frequency range | [0.033; 50] Hz | [0.0167; 75] Hz | [0.01; 100] Hz | [0.05; 4000] Hz | [0.3; 6000] Hz |
| Measured noise (f > 5Hz) | 0.05nm | 0.05nm | 0.25nm<br>>50Hz: 0.02nm | 11.19nm<br>>300Hz: 4.8pm | 100nm |

**Sub-nanometre measurements**







Relative displacement/velocity:

Capacitive gauges :Best resolution **10 pm (PI) , 0 Hz to several kHz**

Linear encoders best resolution 1 nm (Heidenhain)

Vibrometers (Polytec) ~1nm at 15 Hz

Interferometers (SIOS, Renishaw, Attocube) <**1 nm at 1 Hz**

CERN test bench : membrane and interferometer

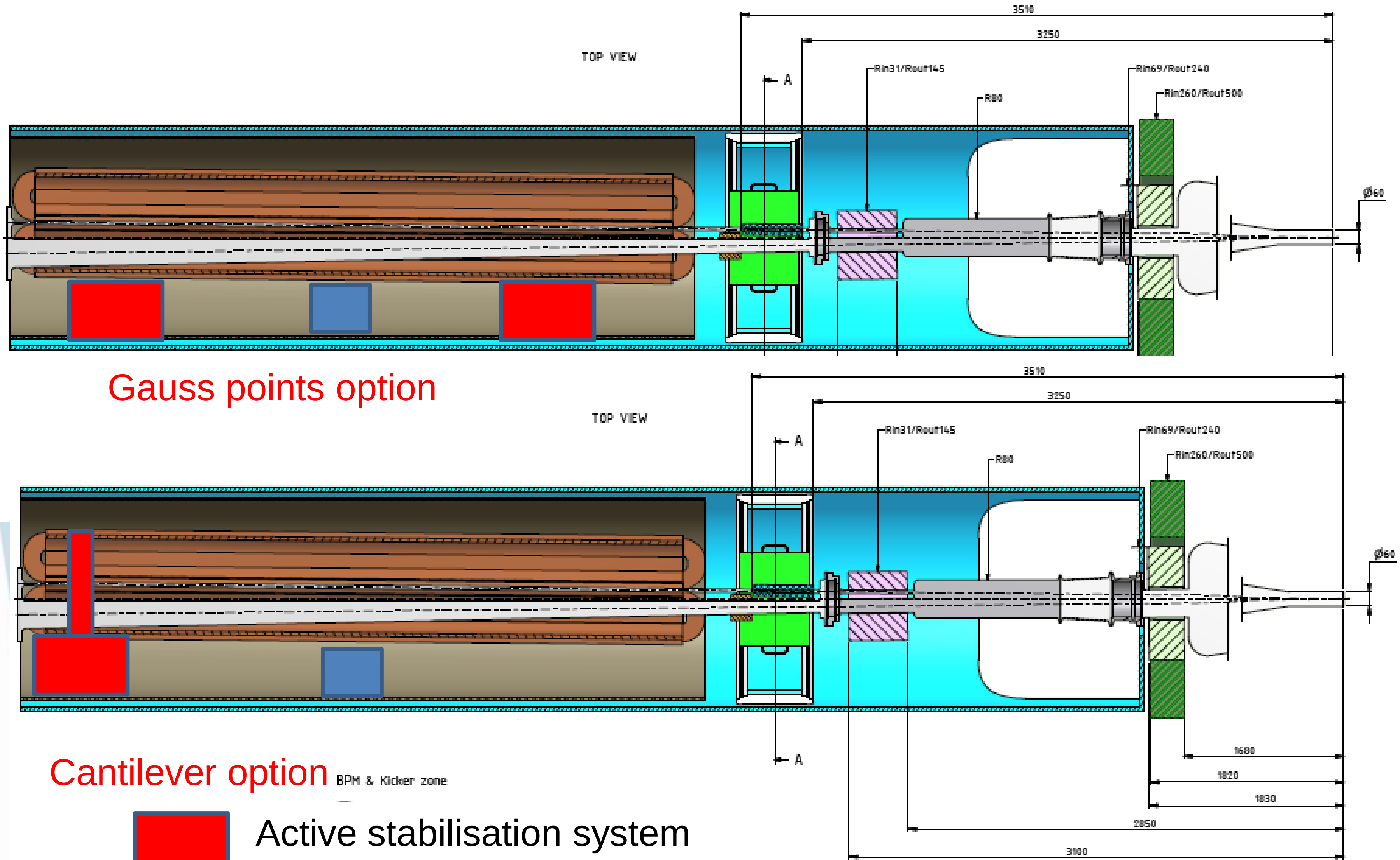
<u>OXFORD MONALISA (laser interferometry)</u>

Optical distance meters

Compact Straightness Monitors (target 1 nm at 1 Hz)

ATF2 vibration and vacuum test
⇒Validation
⇒Next: optical test

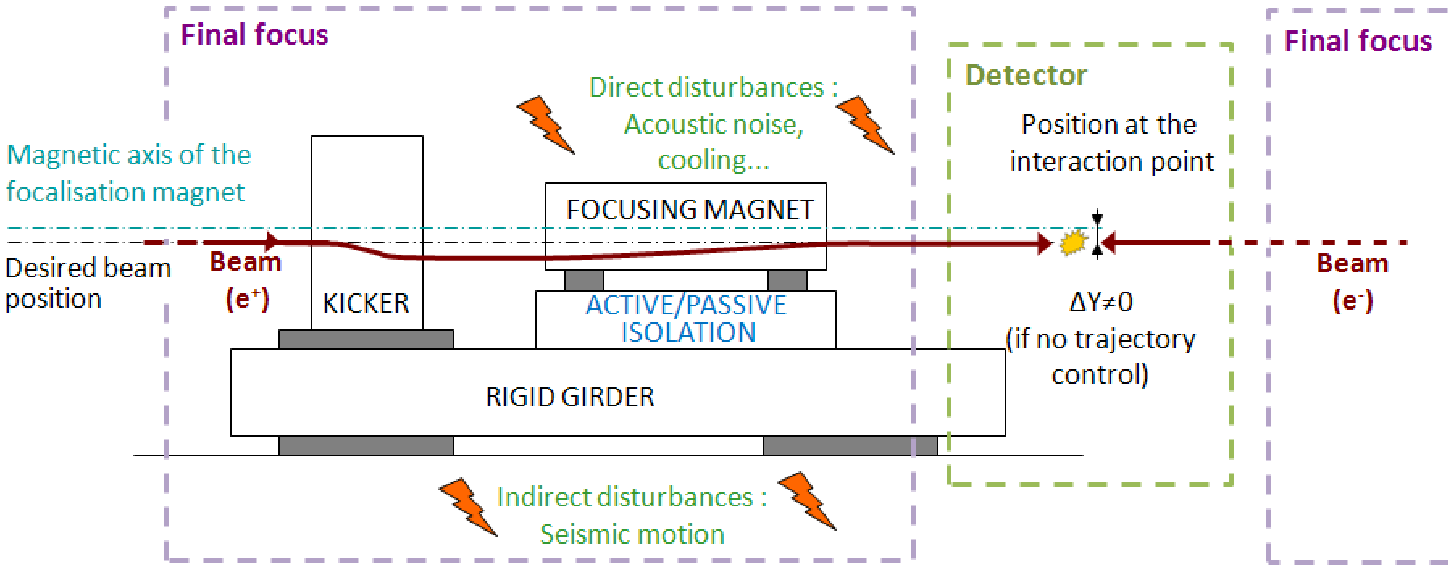
# How to integrate with the rest (cantilever or Gauss points)

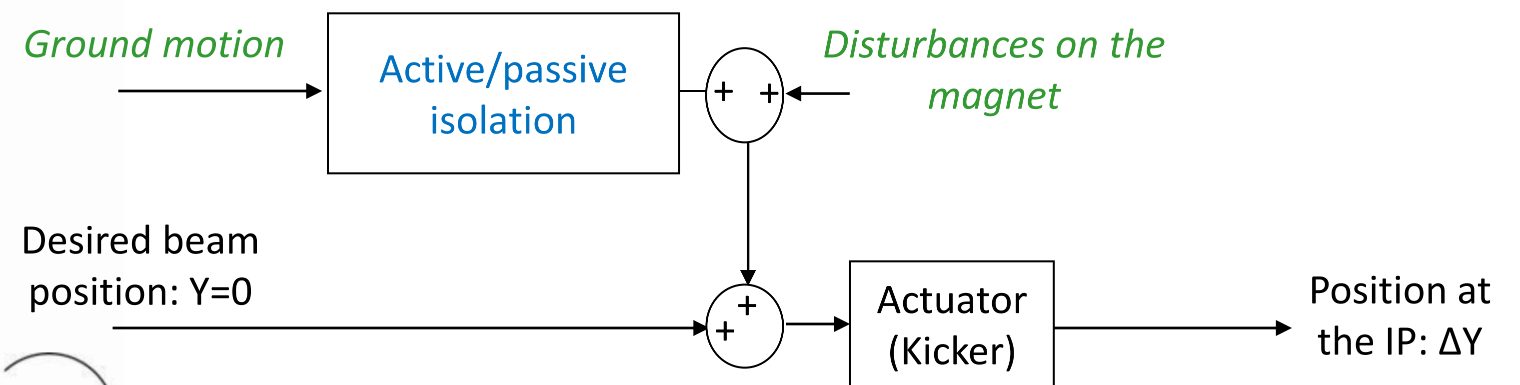



Active stabilisation system

Absolute measurement sensor

# Mechanical scheme and automation point of view

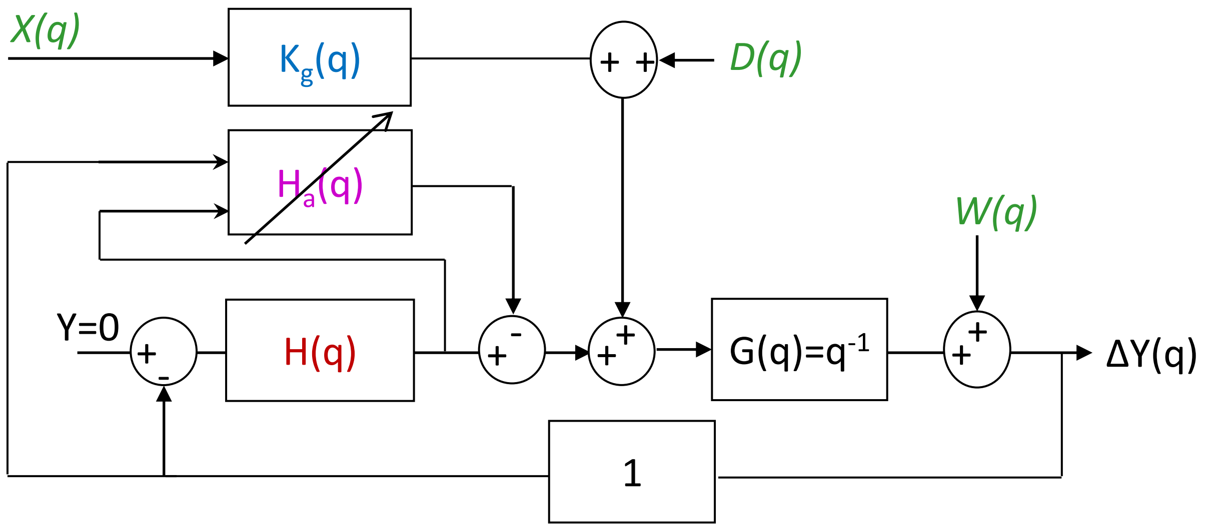


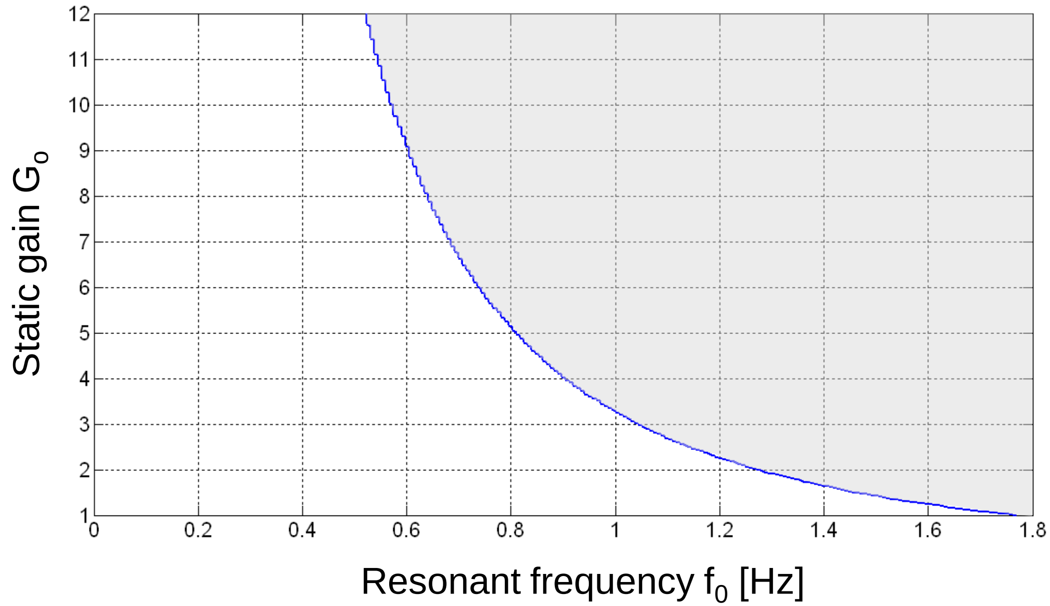

See G.Balik's talk

# Pattern of a global active/passive isolation

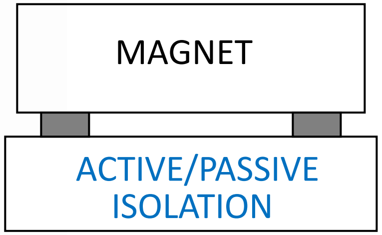
Possibility to determine the pattern of the global isolation ($K_g$)




Example if we consider Kg as a second order low pass filter:



# Illustration with industrial products

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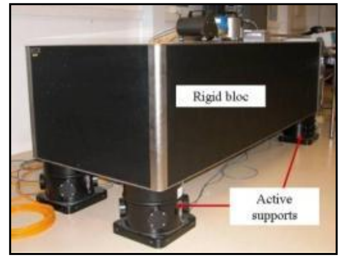
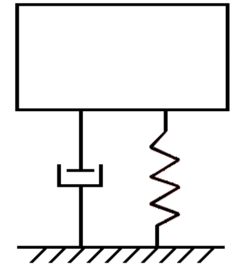
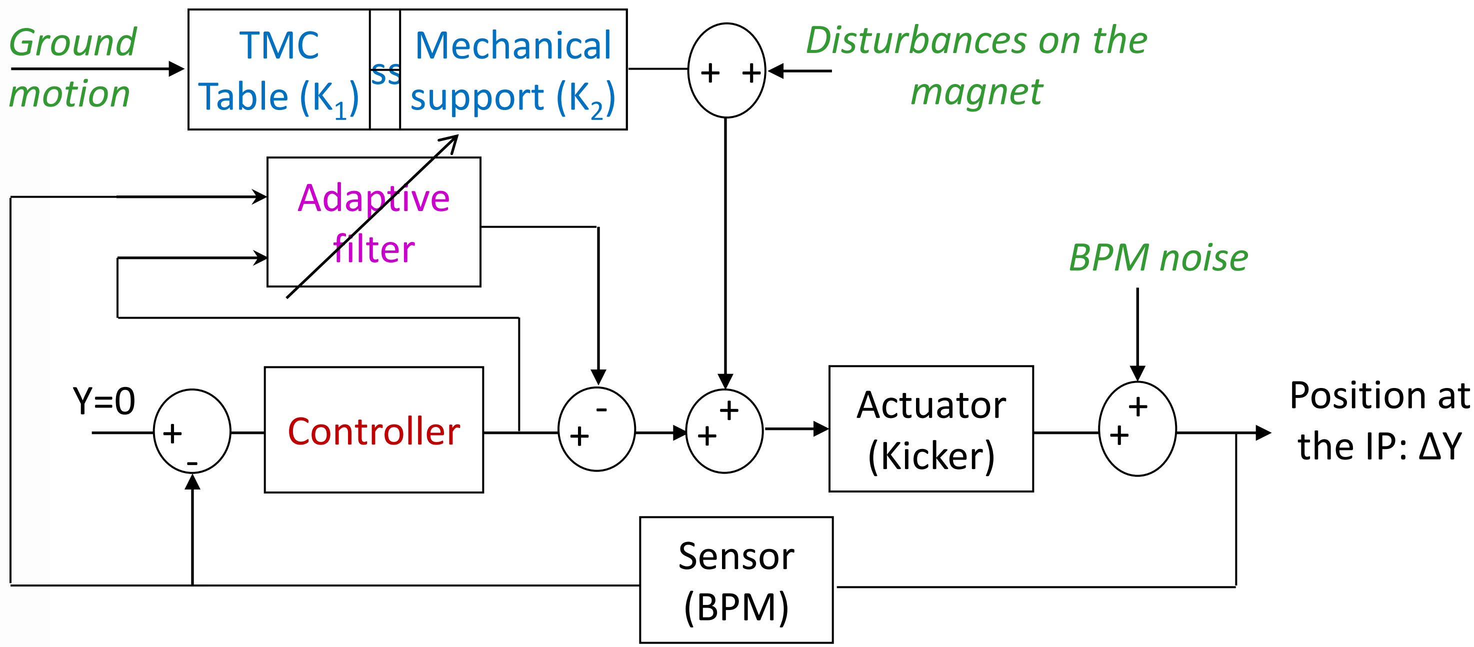



TMC table ($K_1$)

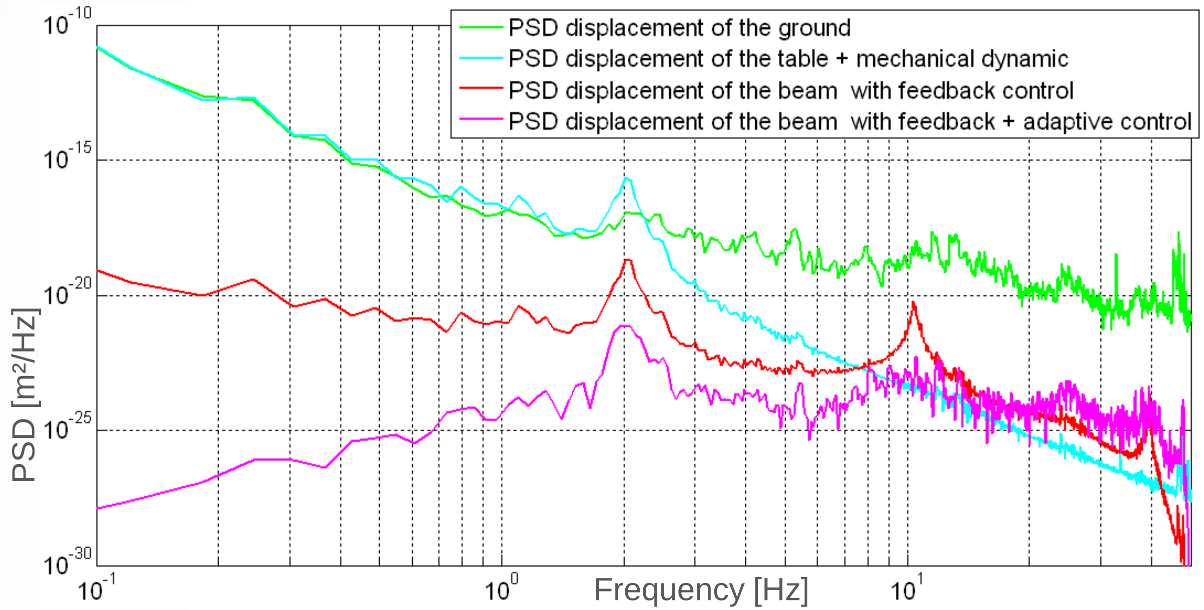
+

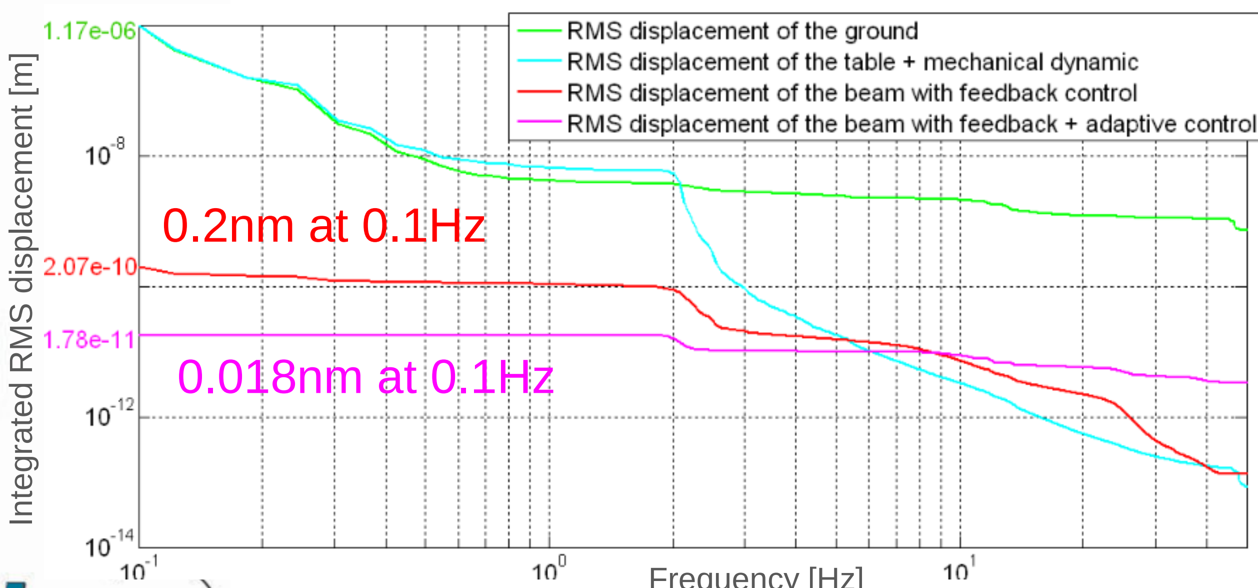


Mechanical support ($K_2$)



# Results



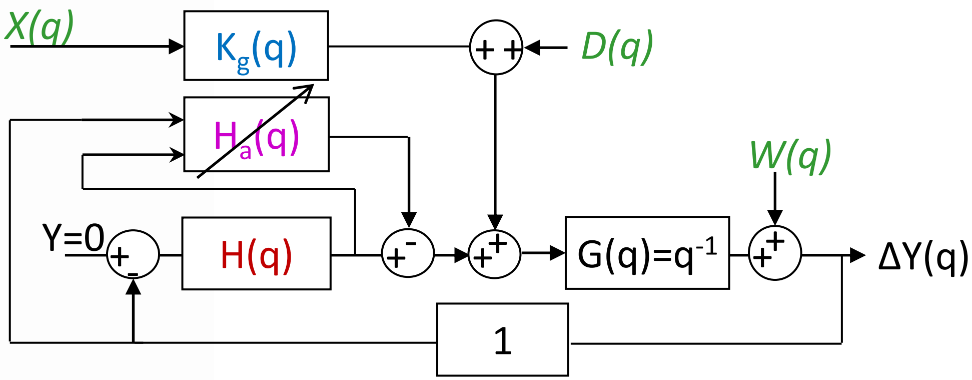

__For the simulation:__

The mechanical support behavior is as a first approximation considered as a second order low-pass filter

One single system doesn't seem enough: need to find the subtle combination of different stabilisation strategies

# Robustness (BPM noise)

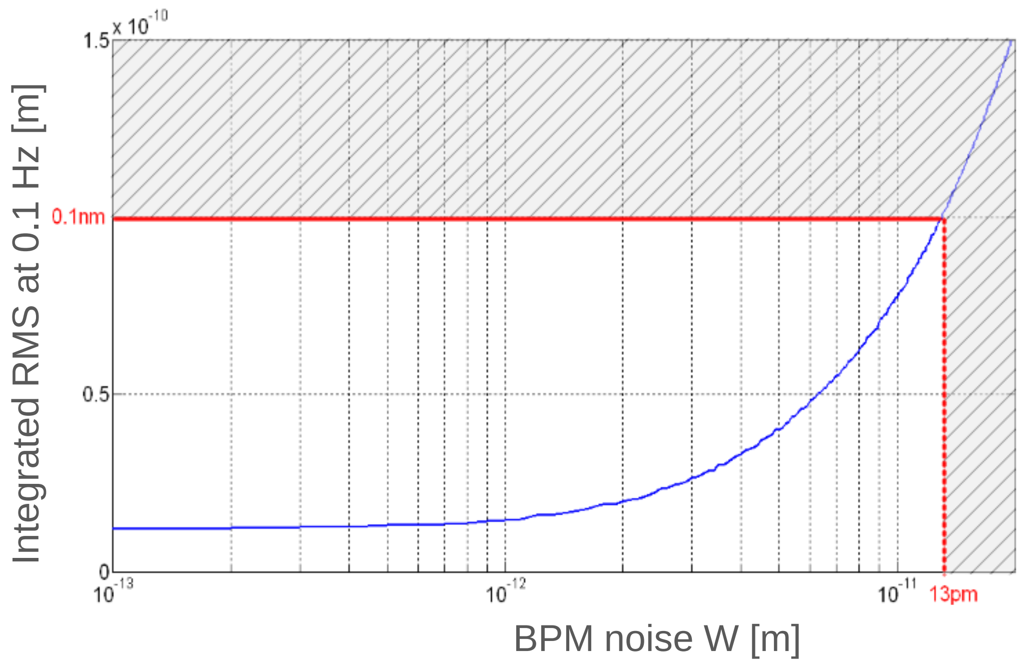
Integrated RMS displacement = f(W)




- W: white noise added to the measured displacement

BPM's noise has to be < 13 pm integrated RMS @ 0.1 Hz

The used BPM is a post collision BPM: Amplification of $10^5$




Next step: implement in Placet for final validation

# Conclusions

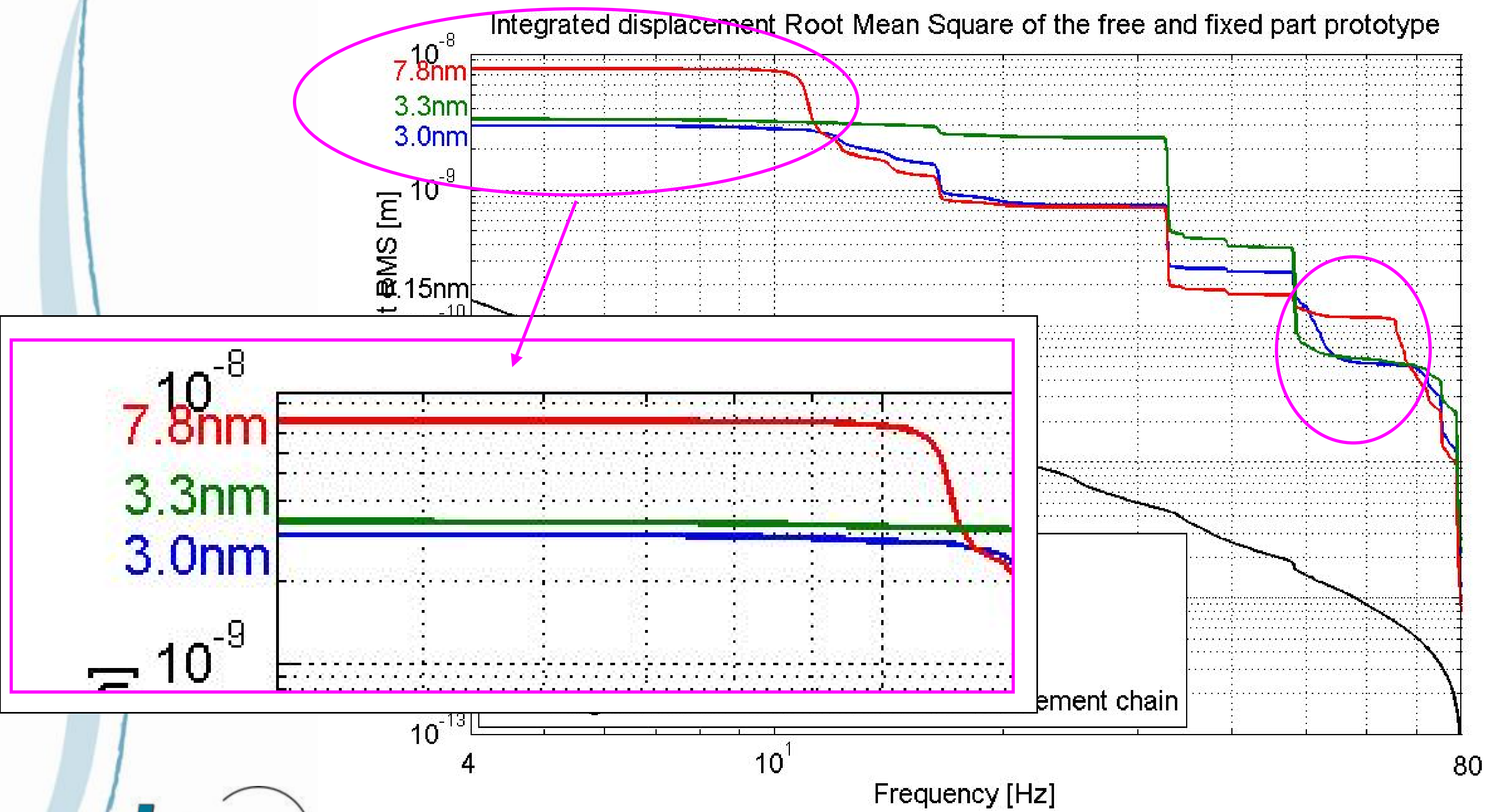
•Proof of principle for CLIC FF stabilisation OK for CDR
•Need final validation of the technical system better adapted to tight IR space
•Need a more realistic integration scheme

## Plans for TDR:

•Detailed technical validation
•Detailed integration
•Final sensor choice (develop a specific sensor?)
•Test on short version QD0 prototype (vibration measurements w/wout cooling and stabilisation…)

# Tests with the large prototype

✓ **Results : integrated displacement RMS**



# Güralp CMG-40T

Sensor type: electromagnetic geophone broadband

Signal: velocity x,y,z

Sensitivity: 1600V/m/s

Frequency range: 0,033-50Hz

Mass: 7,5kg

Radiation: Feedback loop so no

Magnetic field: no

Feedback loop

First resonance 440Hz

Temperature sensitivity: 0,6V/10°C

Electronic noise measured at >5Hz: 0,05nm

Stable calibration

# Endevco 86

Sensor type: piezoelectric accelerometer

Signal: acceleration z

Sensitivity: 10V/g

Frequency range: 0,01-100Hz but useful from 7Hz

Mass: 771g

Radiation: piezo OK, but resin?

Magnetic field: probably OK but acoustic vibrations?

Feedback loop

First resonance 370Hz

Temperature sensitivity: <1%

Electronic noise measured at >5Hz: 0,25nm, >50Hz 0,02nm

Stable calibration, flat response

Doesn't like shocks

# SP500

Sensor type: electrochemical, special electrolyte

Signal: velocity

Sensitivity: 20000V/m/s

Frequency range: 0,016-75Hz

Mass: 750g

Radiation: no effect around BaBar (don't know exact conditions)

Magnetic field: tested in 1T magnet => same coherence, amplitude?

Feedback loop

First resonance >200Hz

Electronic noise measured at >5Hz: 0,05nm

Unstable calibration, response not flat

Robust