CLIC QD0 Stabilization

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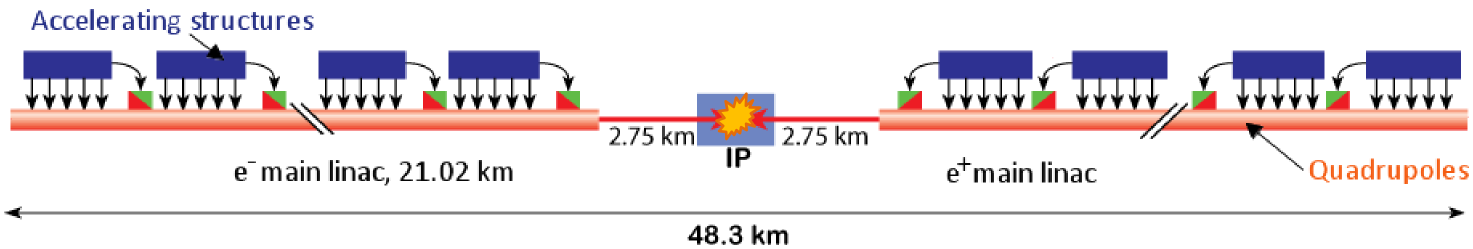
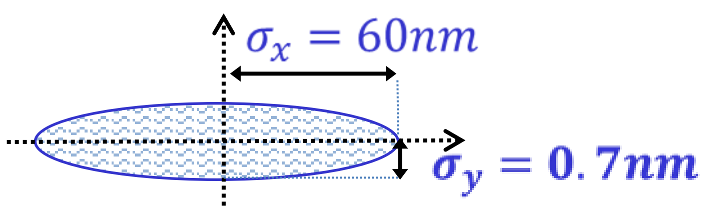
Outline

- Introduction
- IP feedback
- Active stabilization
  - Description & performances
  - Limitations
  - Work in progress
- ATF2

CLIC : stabilization challenge?

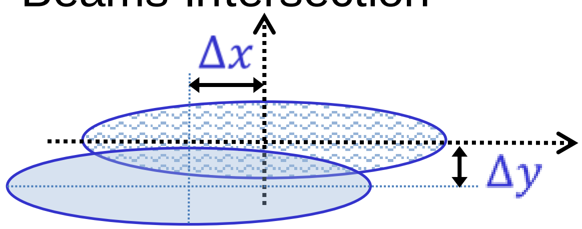


CLIC Beam dimension



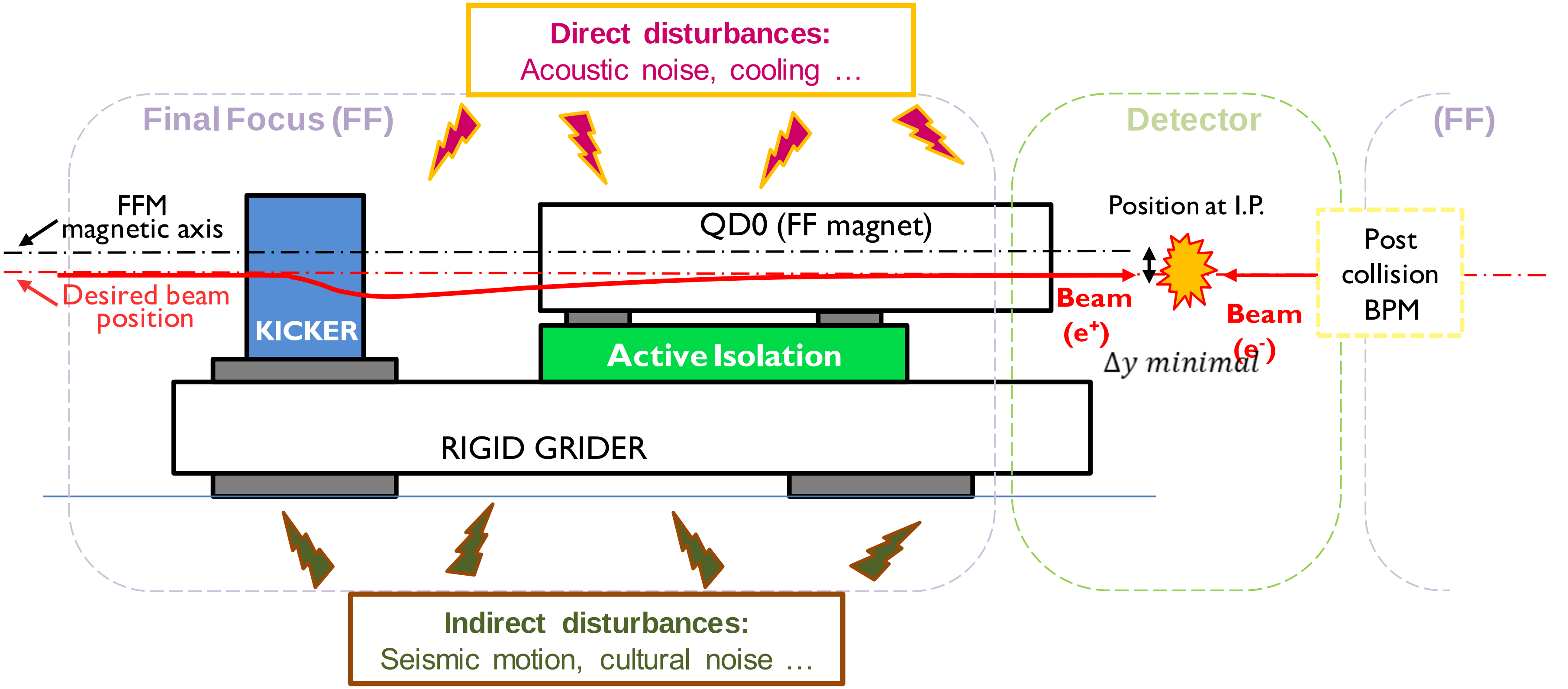
$$L(\sigma_{x,y},\Delta_{x,y}) \propto \frac{e^{-\frac{1}{4}\left(\left(\frac{\Delta x}{\sigma_x}\right)^2+\left(\frac{\Delta y}{\sigma_y}\right)^2\right)}}{\sigma_x\sigma_y}$$

Beams Intersection

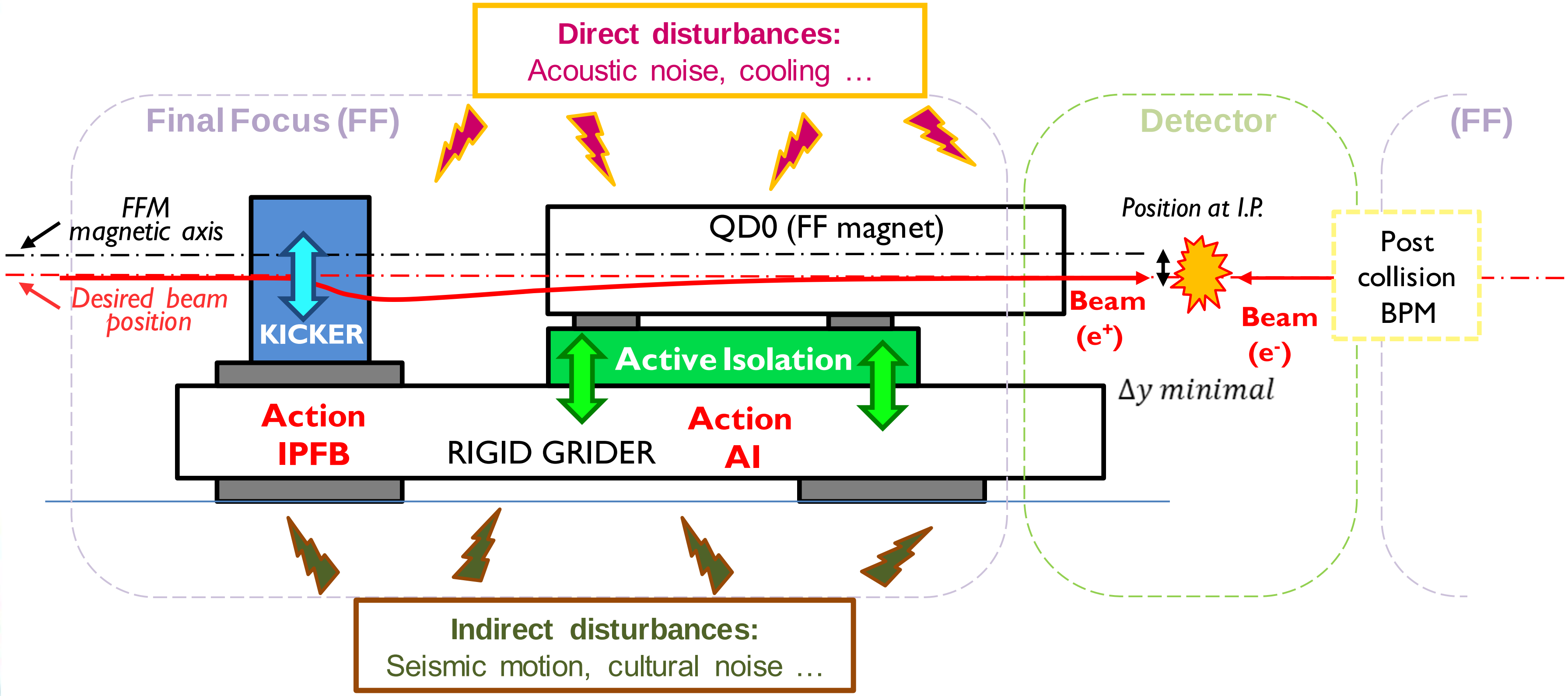


Relative mean motion between :		
	Main linac quadrupoles	Final Focus Magnets
Vertical	1.5 nm [1Hz ∞]	**0.2 nm [4Hz ∞]**
Lateral	5 nm [1Hz ∞]	5 nm [4Hz ∞]

Stabilization strategy



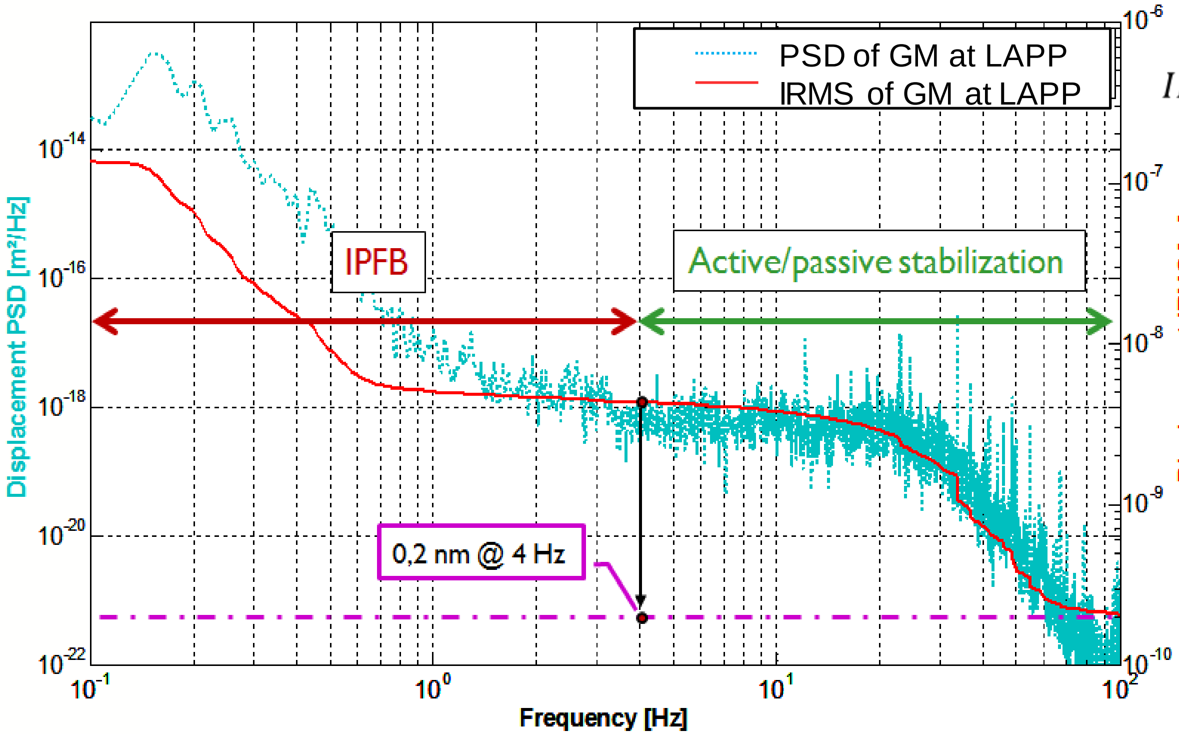
Stabilization strategy



BEAM stabilization (IPFB)
Measurement : BPM
Action : ***KICKER***

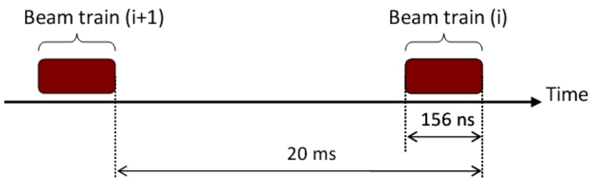
Mechanical stabilization (AI) :
Measurement : seismic sensors on QD0 and ground
Action : **Active Isolation (+ passive isolation)**

Stabilization strategy: ground motion



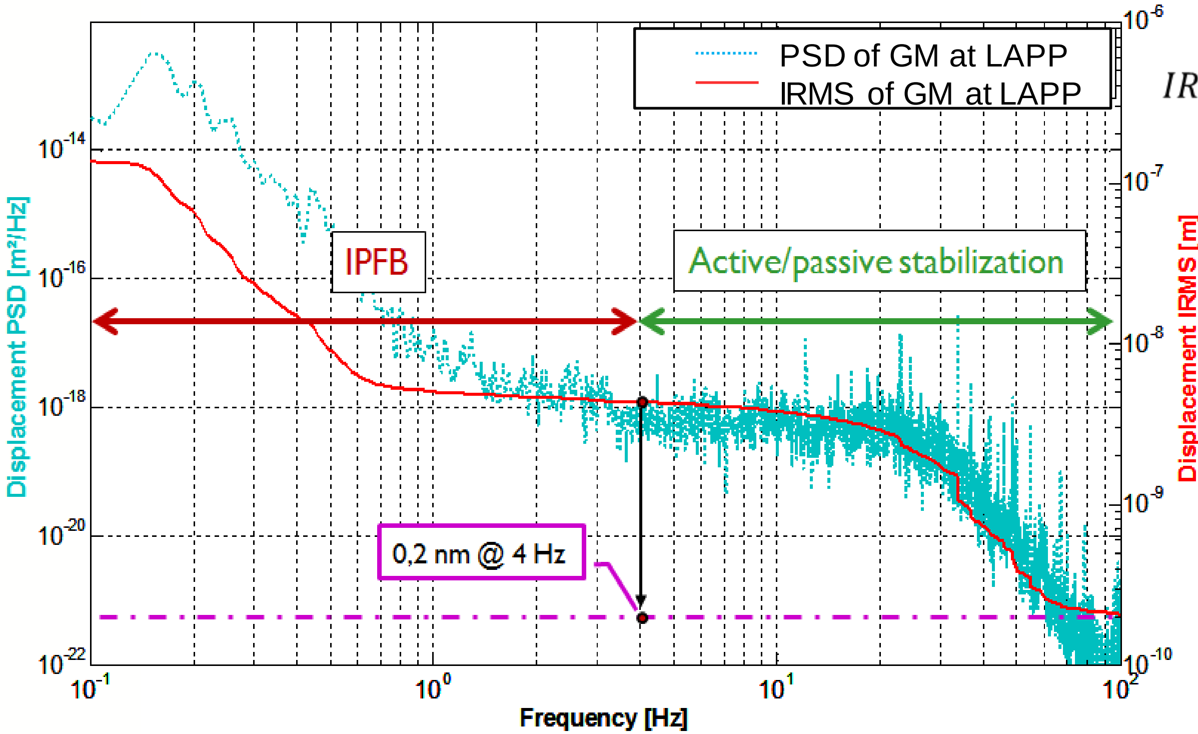
$$IRMS(k) = \sqrt{\int_{f}^{\infty} PSD(k)df}$$

Stabilization strategy: ground motion



Sample frequency = 50 Hz

→ Beam trajectory feedback only efficient at very low frequency

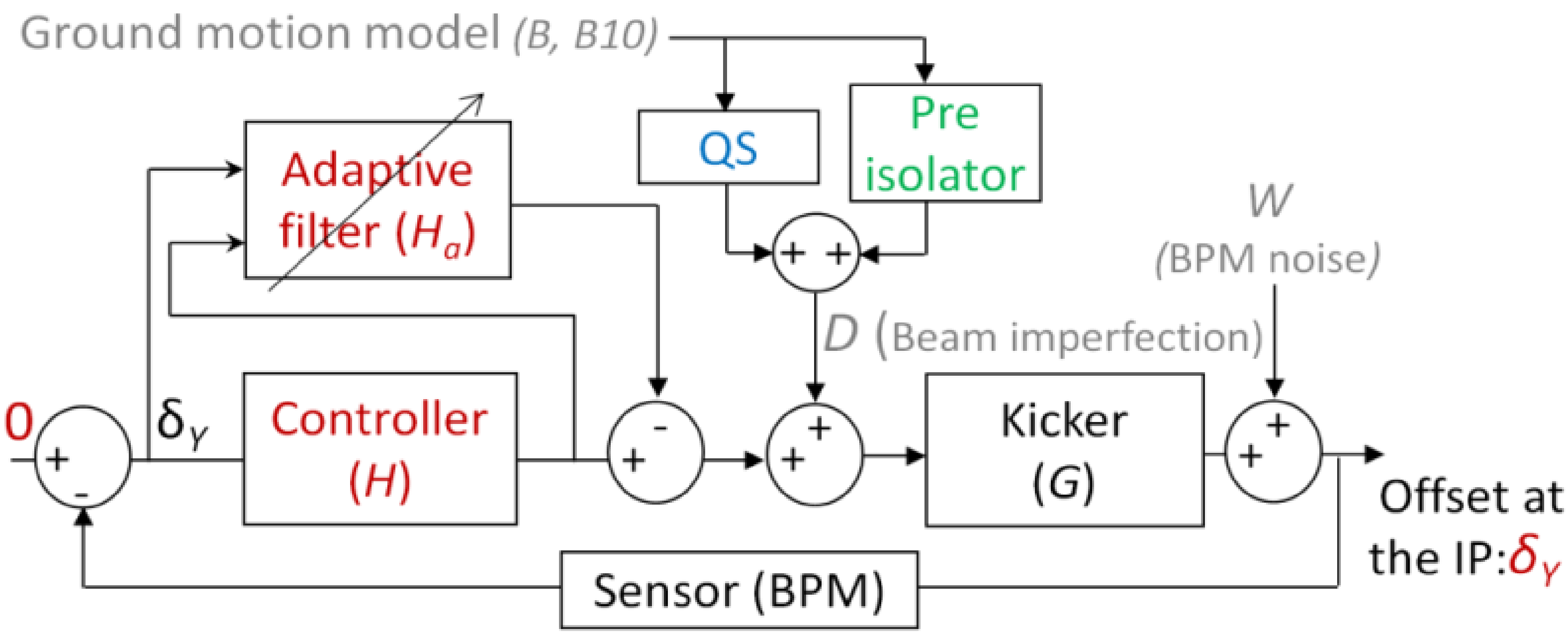


$$IRMS(k) = \sqrt{\int_f^\infty PSD(k)df}$$

At the IP (mechanical stabilization + beam feedback) we aim **0,2nm at 0,1Hz**

IP feedback (IPFB)

PLACET simulations
(collaboration with CERN)



IP feedback (IPFB)

PLACET simulations
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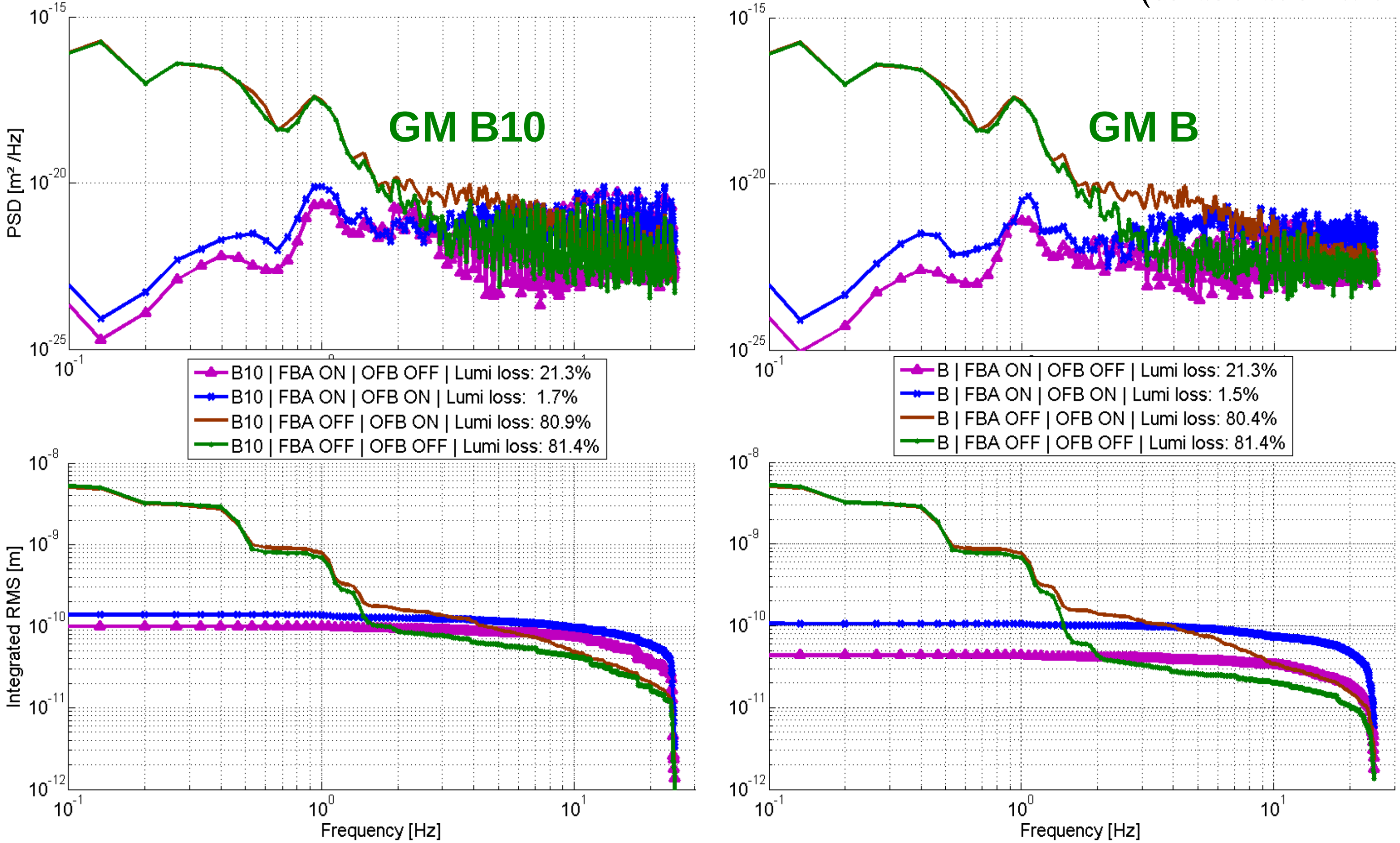


B. Caron et al, 2012, 236-247, Contr. Eng. Pract., 20 (3). ; G. Balik et al, 2012, N.I.M.A., 163-170

Reduction of **luminosity losses down to 2%** for different GM models

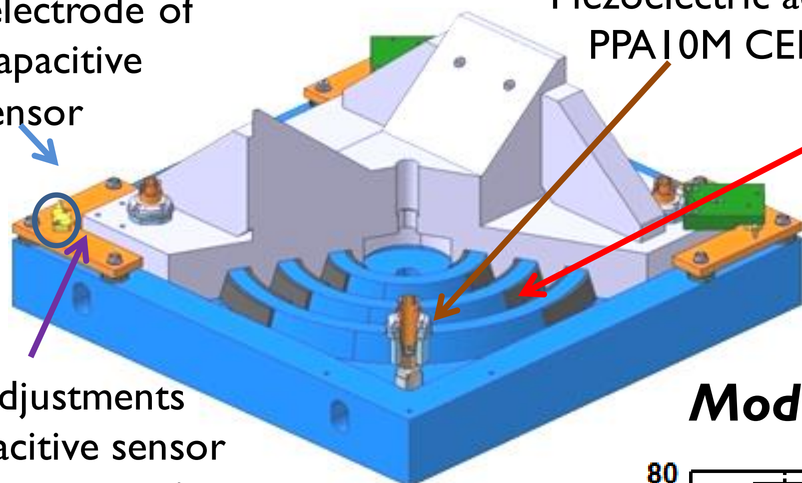
Active stabilization : active foot description

Active foot description

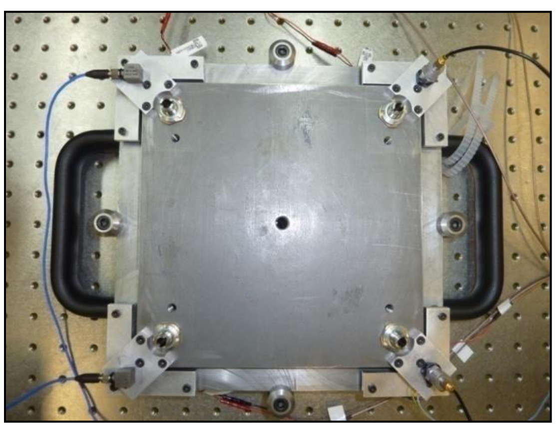
Lower electrode of the capacitive sensor

Piezoelectric actuators PPA10M CEDRAT

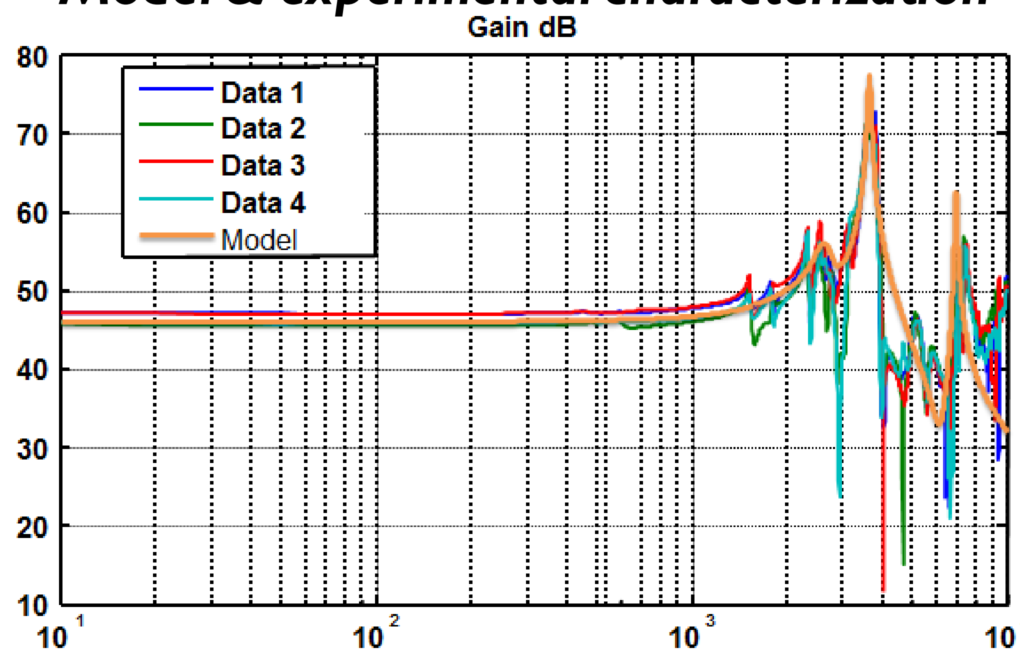
Elastomeric strips for guidance



Fine adjustments for capacitive sensor (tilt and distance)

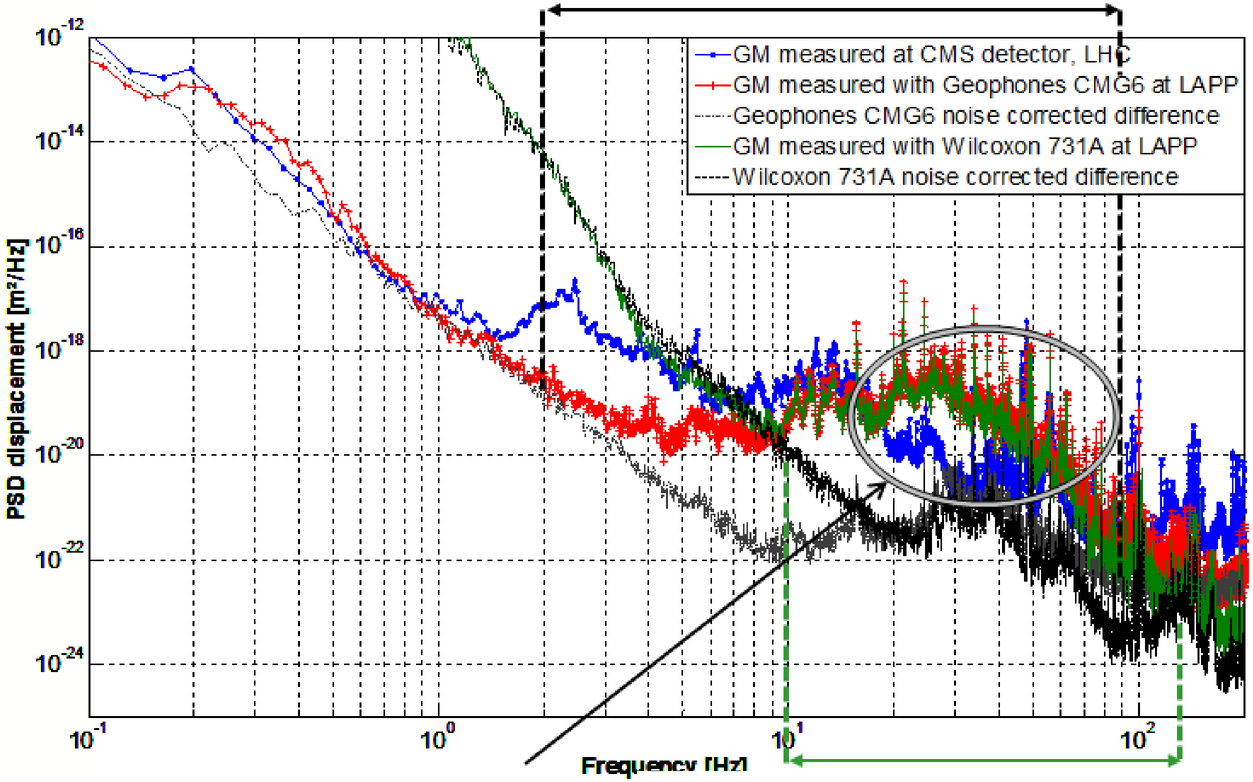


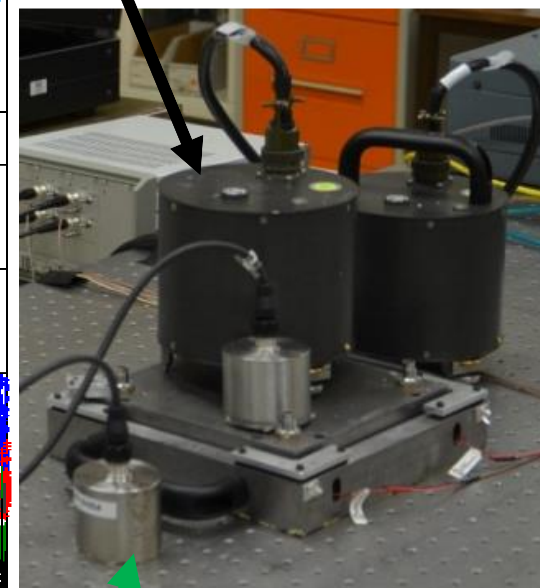
Model & experimental characterization



Active stabilization : sensors description

Geophone
[2 90] Hz

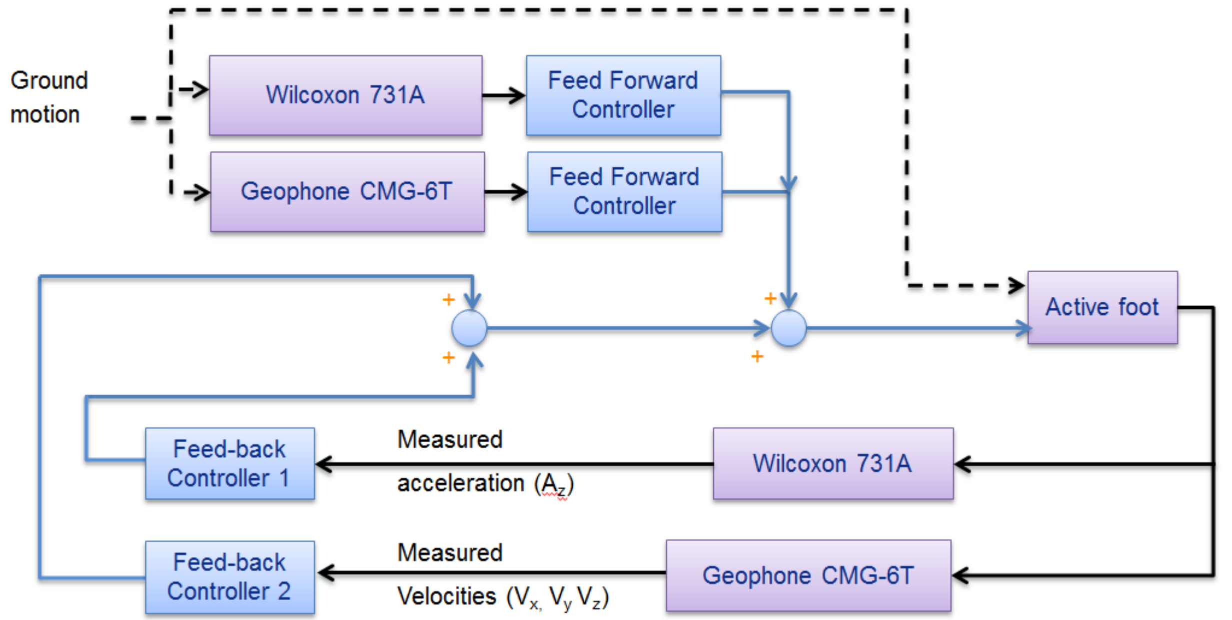




GM induced by cultural noise

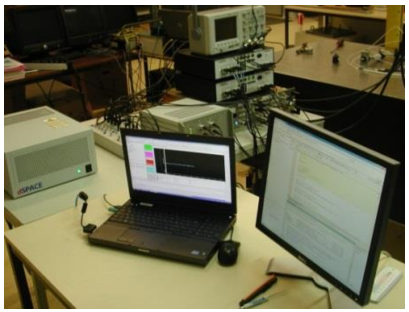
Accelerometers
[10 130] Hz

Active stabilization : control strategy



- ✓ Feedforward with 1 geophone and 1 accelerometer
- ✓ Feedback (loop shaping) with 1 geophone and 1 accelerometer
- ✓ Sensors are dedicated to the selected bandwidth.

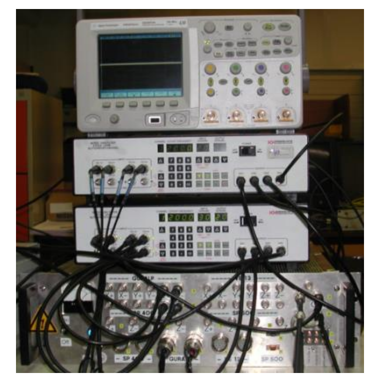
Active stabilization : Experimental set-up



Matlab and dSPACE ControlDesk
For monitoring and analysis

4 sensors :

- **2 Geophones GURALP CMG-6T**
- **2 Accelerometers : WILCOXON 731A**



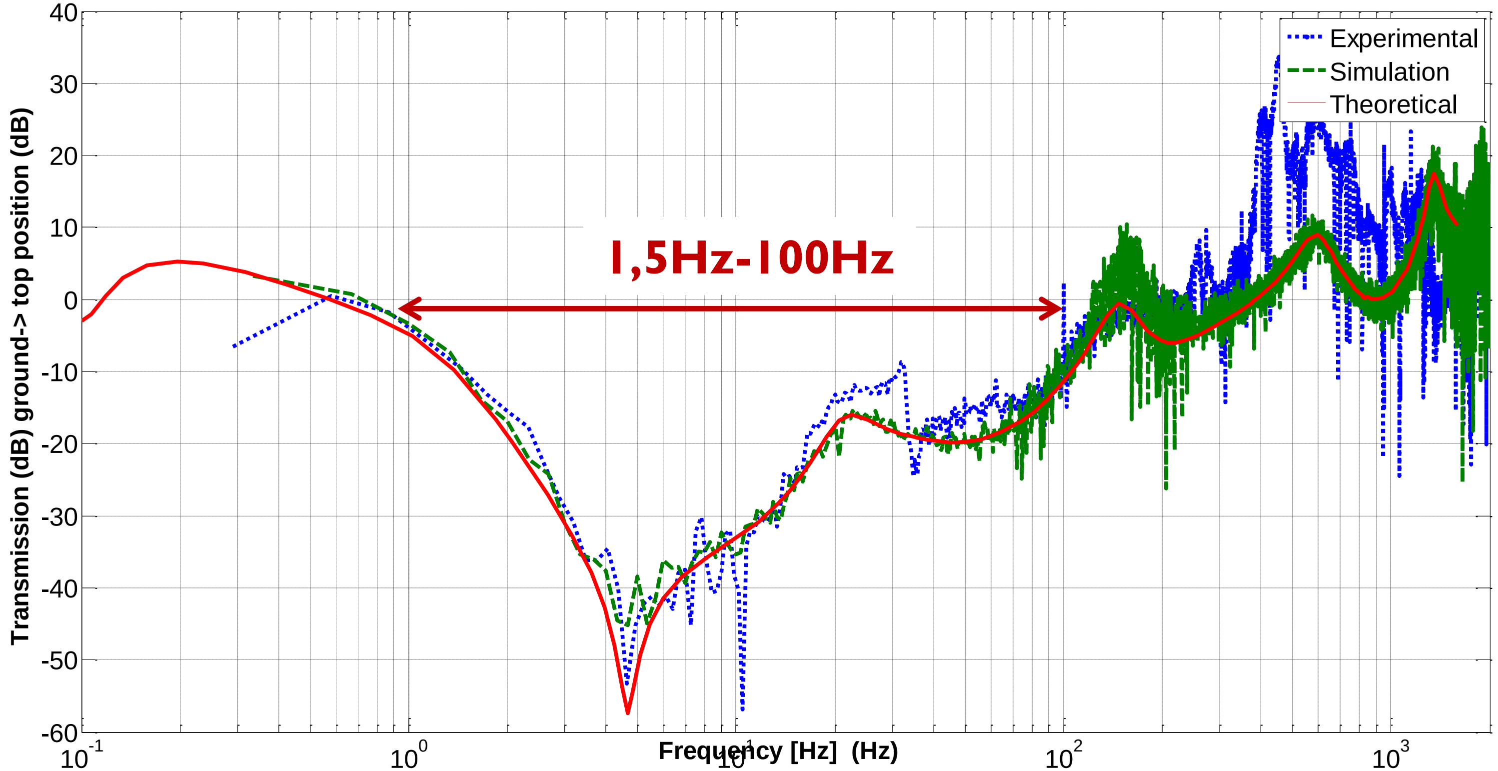
Amplifiers, filters input/output board for signal conditioning

dSPACE
Real time hardware for
Rapid Control Prototyping

All is taken into account in simulation (noise, ADC, DAC…)

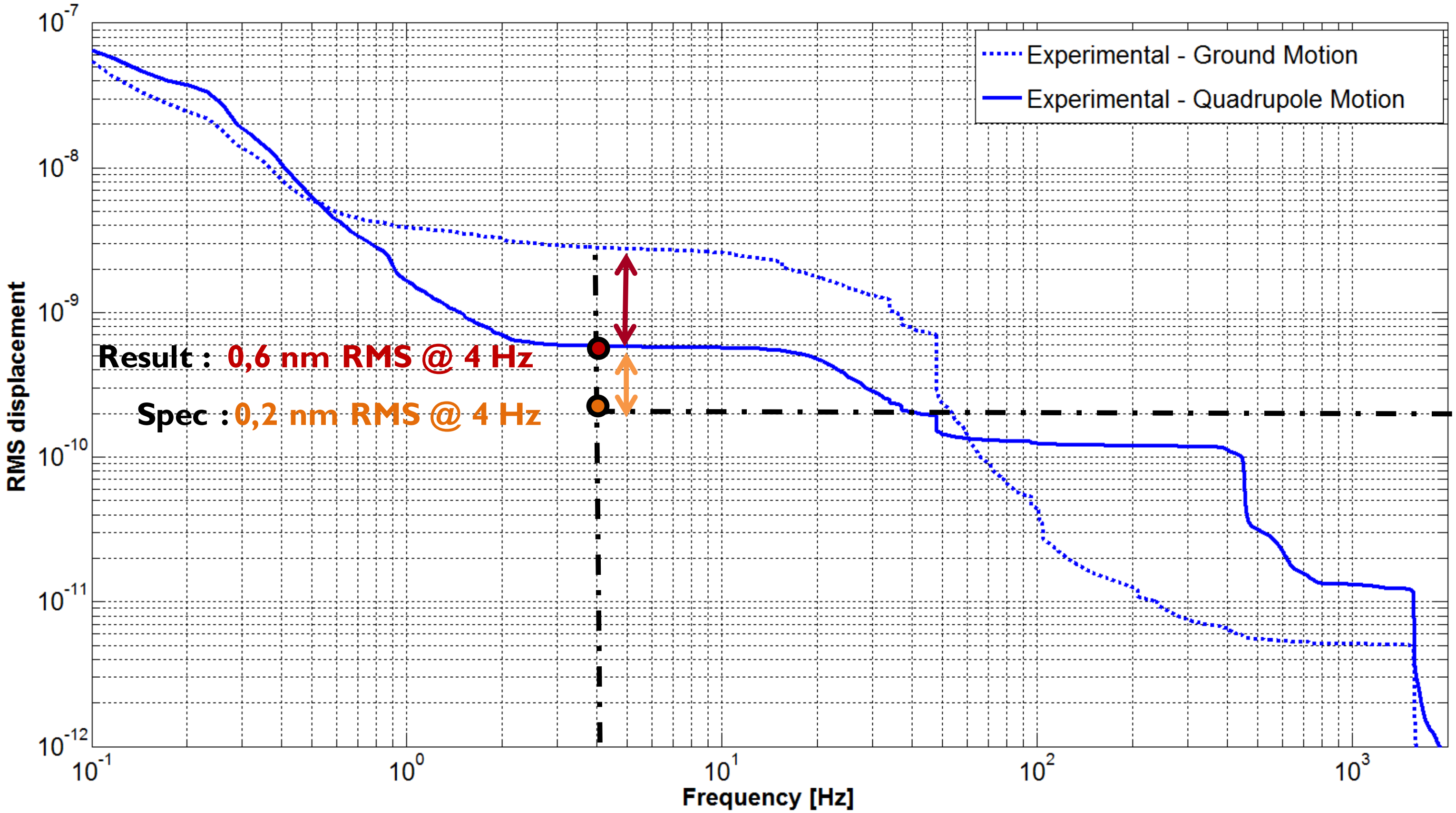
Active stabilization : results

Simulation and experimental results (attenuation)



- ***Attenuation up to 50dB between 1,5-100Hz***
- *Experiment matches simulation : process well understood*

Active stabilization : results



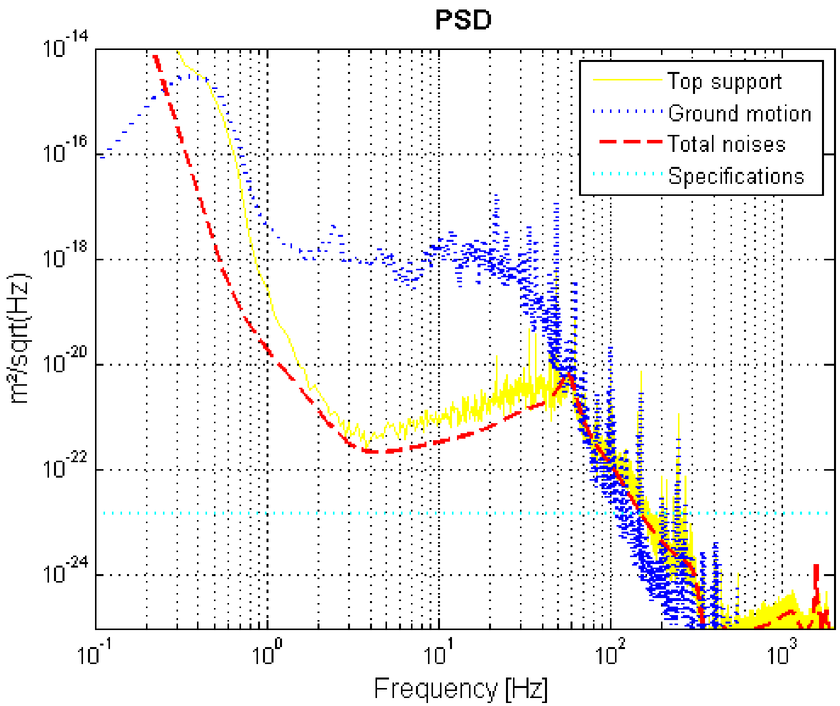
Balik et al, "Active control of a subnanometer isolator", JIMMSS. (accepted)

Active stabilization limited by Sensors …

- **Main limitations :**
  - Sensor noise
  - Sensor transfer function

- **Simulation + Experimental Test**

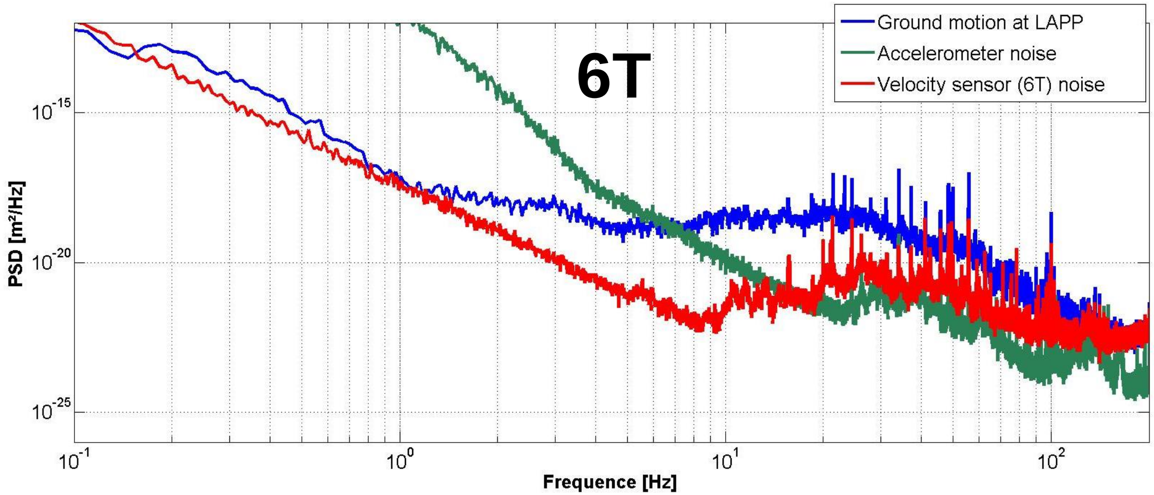
Help define seismic sensor performances needs :
  - noise level
  - frequency range



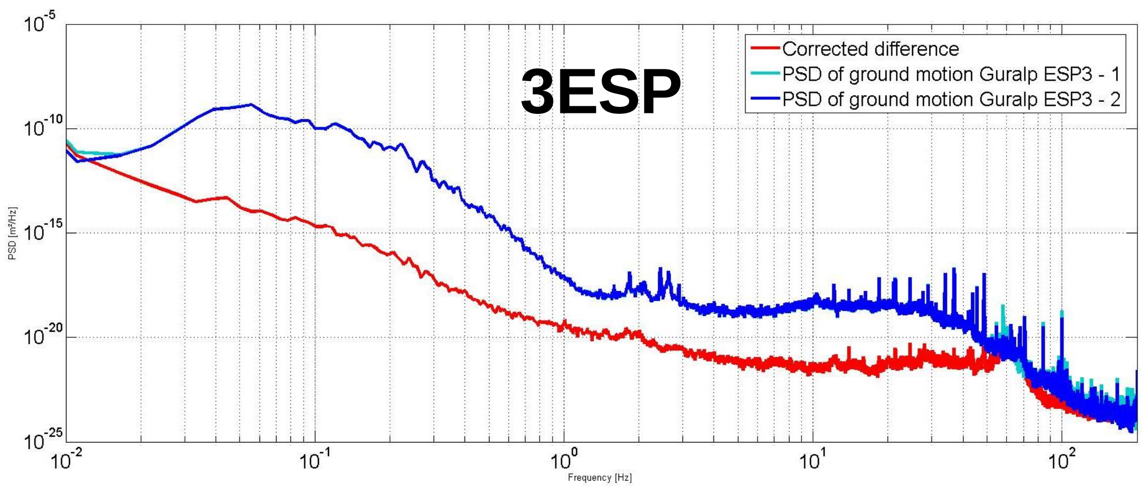
So…

- **Tests with a low noise sensor : geophone 3ESP**
- **Development of a new and dedicated sensor**

Active stabilization with Geophone 3ESP

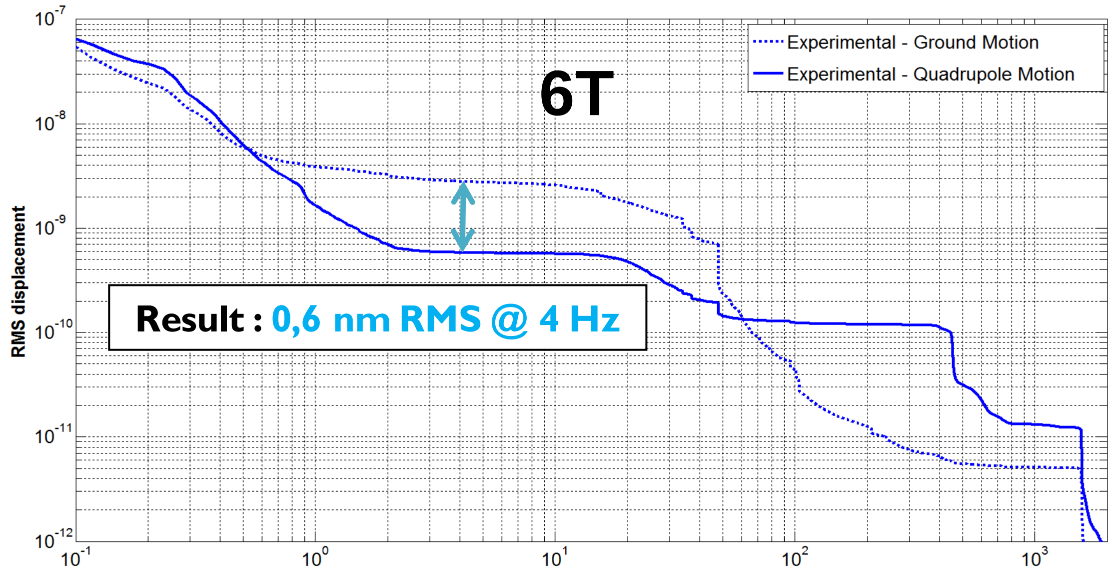


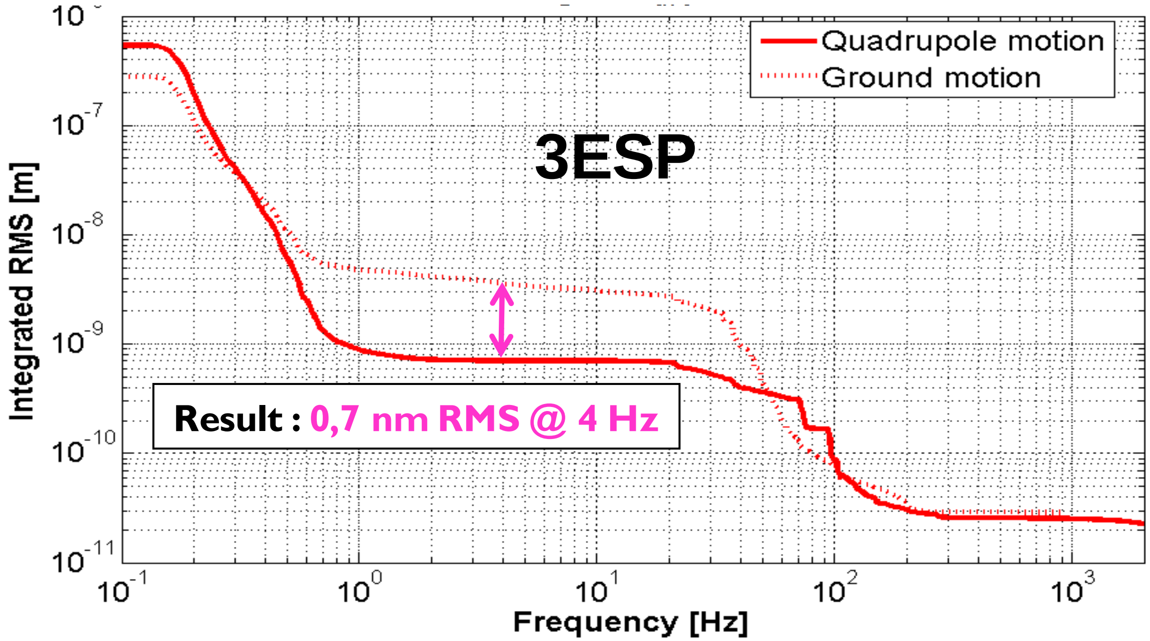
Ground Measurement with <u>geophones 6T</u>



Ground Measurement with <u>geophones 3ESP</u>

Active stabilization with Geophone 3ESP

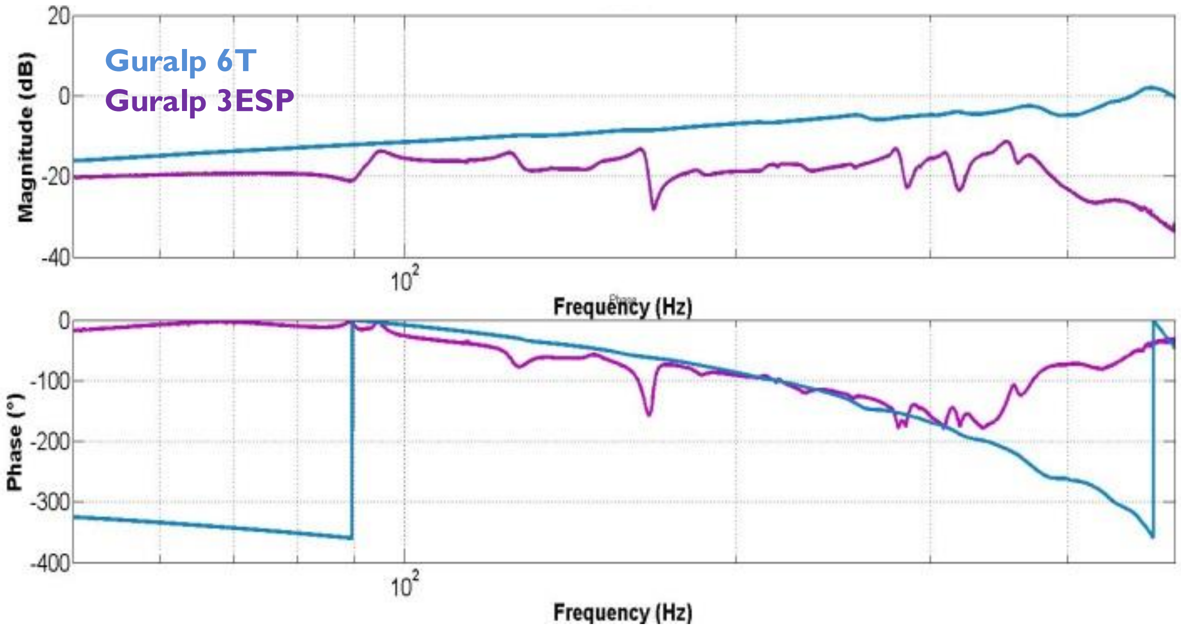




Example of control with 3ESP instead of 6T

Active stabilization with geophone 3ESP

Experimental *transfer function of « foot + sensor »*



3ESP transfer function more complex up to 90Hz

➔ Difficulties in managing the sensor model

➔ limits control performance and robustness

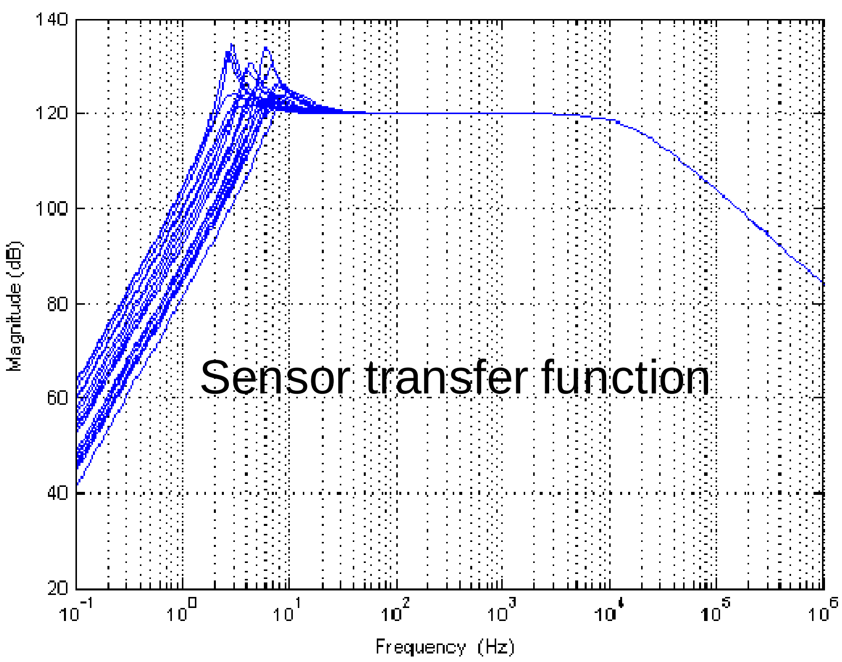
- **need of a new and dedicated sensor**

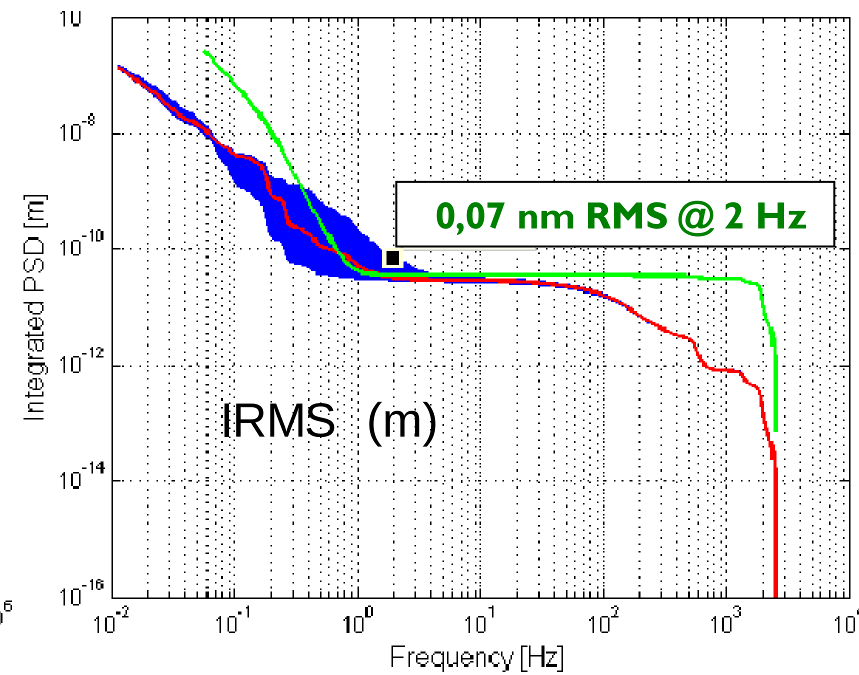
Dedicated sensor : Industrial solution

Managed by CERN : specifications (dedicated to main LINAC stabilization)

Parametrical study of those specifications :

- resonance frequency
- damping





Specification also match the QD0 stabilization

Dedicated sensor in development at LAPP

- **<u>1st prototype</u> : developed for process demonstration**
  - Dimensions 250 x 250 x 110 mm
  - Promising GM measurement performances
  - tunable bandwidth (<1Hz to >100Hz)

Patent is in progress, G. Deleglise, J. Allibe, G. Balik & J.P. Baud

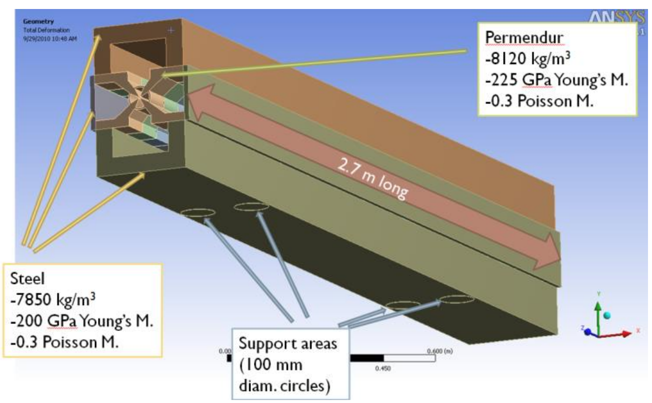
- **<u>2nd version</u> : miniaturized and optimized for control**
  - Dimensions 100 x 100 x 100 mm
  - Performances equivalent
  - Adapted transfer function
  - First tests in control encouraging

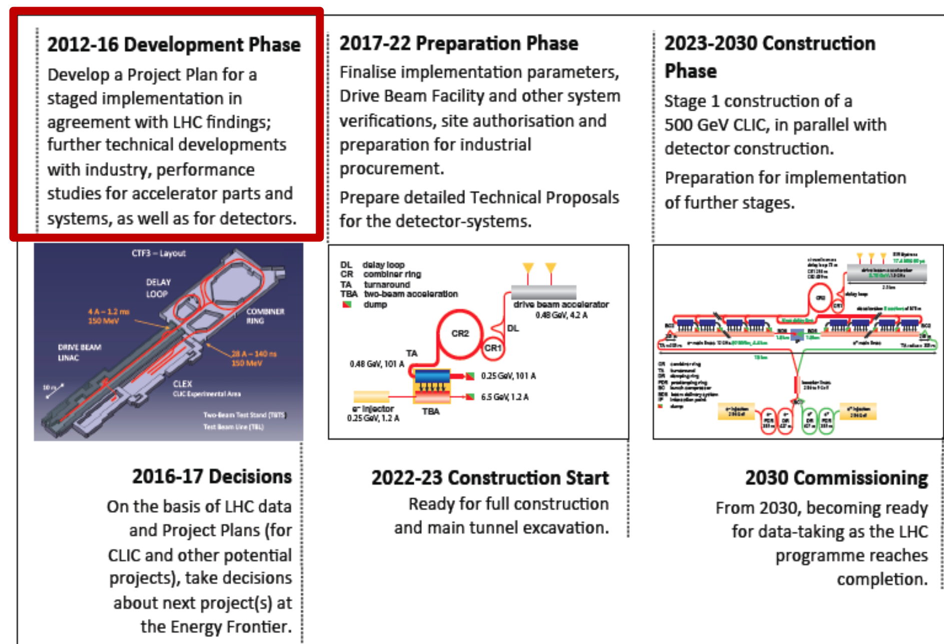
- **<u>Next Step</u> : Evaluation of the suitability for CLIC stabilizations in collaboration with CERN**
  - Further development and optimization
  - Robustness, reproducibility
  - Cost …

Two main objectives for 2016

- **Demonstration of the 0.2 nm @ 4Hz with an active table (sensor, control…)**

- **Application on a real scale QD0 prototype**

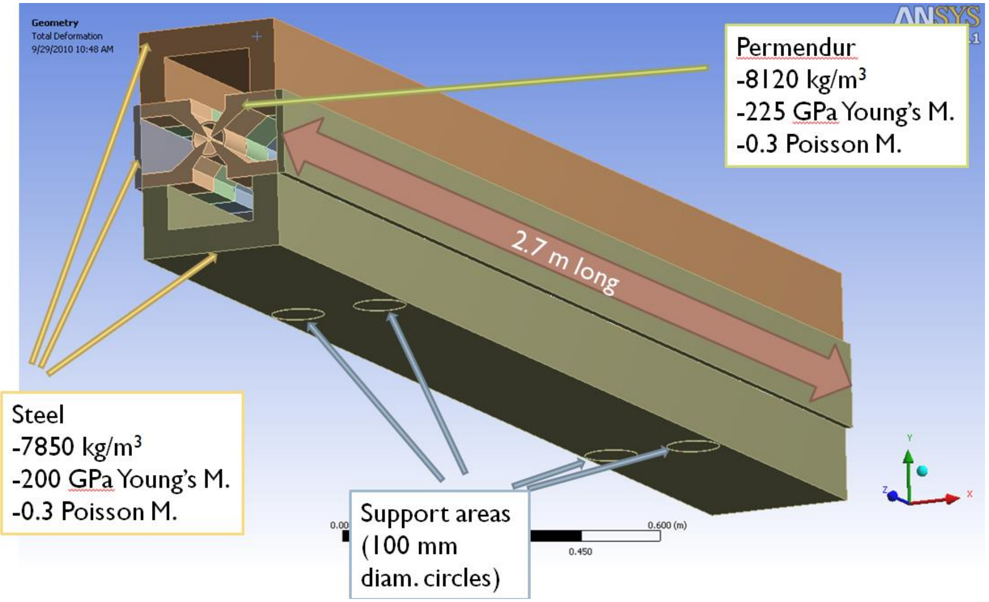




Stabilization application on QD0 prototype

Demonstration table, not made for QD0 at this state

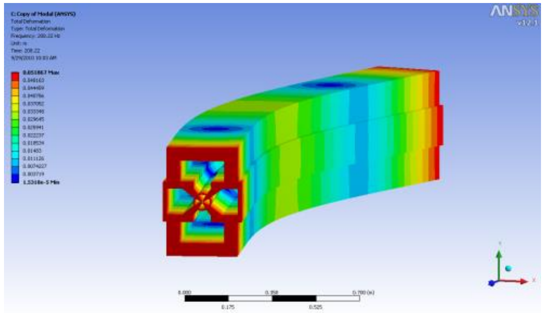
- Mechanics : Max load of 320 kgs per table vs 1500 Kgs of QD0
- Control : problems of Eigenfrequencies, coherence of the ground…

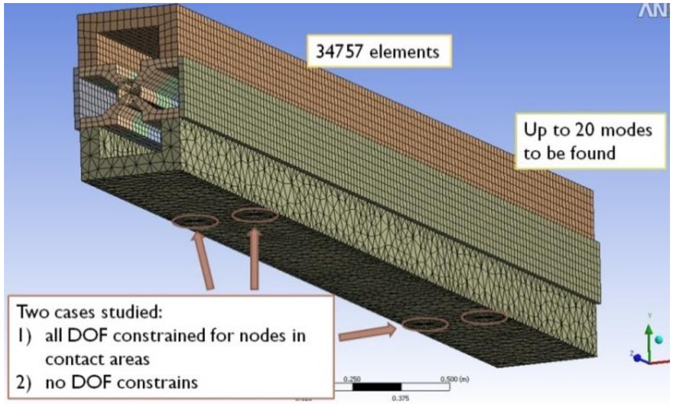


There is a need for a QD0 prototype

Stabilization application on QD0 prototype

- **Initial status :** Simulation studies of QD0 made by the team of M. Modena at CERN:
  - magnetics
  - mechanics aspects
  - …

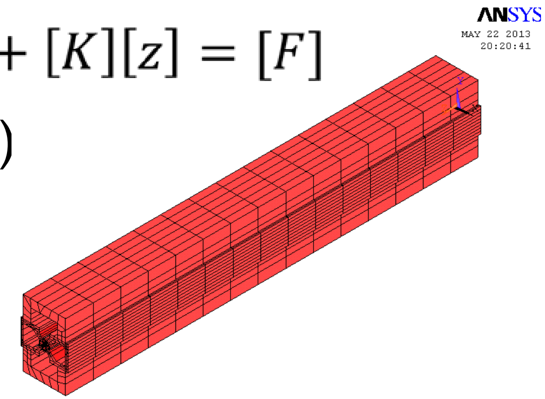


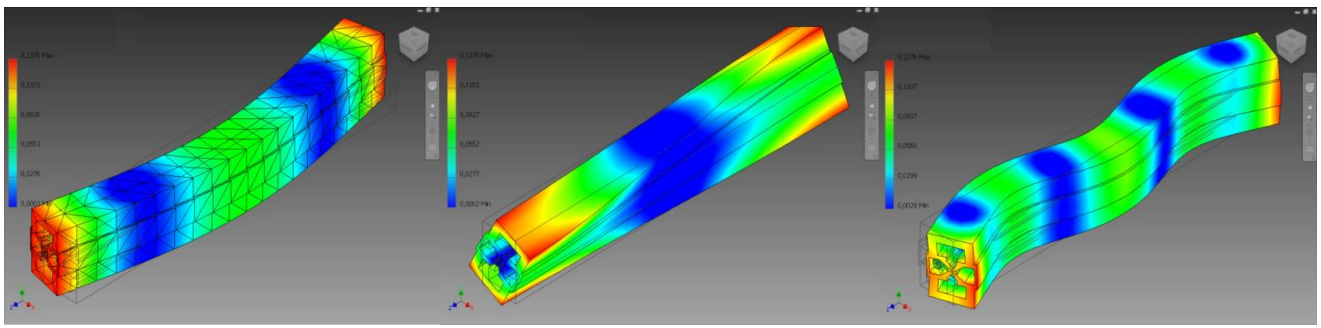


- **LAVISTA objective is to stabilized real scale QD0 prototype**
  - Development of a state-space model
  - Definition of the control strategy with simulation tool integrating this space-state model
  - Stabilization test on real scale « dummy QD0 magnet »

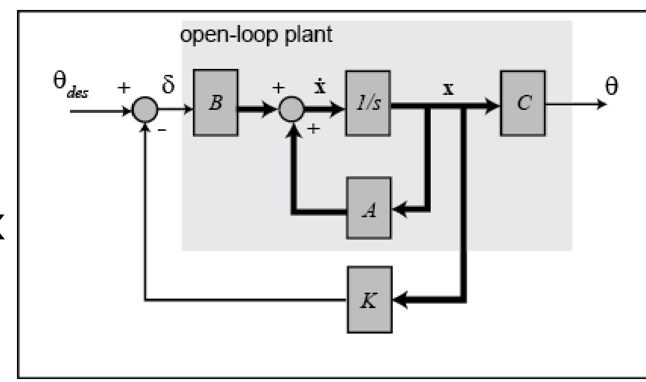
QD0 state-space model

- **Modal analysis using finite elements** $[M][\ddot{z}] + [K][z] = [F]$
  - Adapted to control study needs (inputs/outputs)
  - Select the significant modes to construct the accurate frequency response over the interest frequency range





- **State space Model** $\dot{x} = Ax + \mathrm{Bu}$
  - FE to space-state conversion $y = Cx$
  - Integration in a control loop using **simulink** for the whole simulation



QD0 stabilisation test bench

- **Simulation objective :**

several aspects have to be defined before feet realization :

- *Active feet : type, number, positioning*
- *degrees of freedom*
- *Type of control (SISO, MIMO)*
- *Conditioning, real time processing…*

- **Dummy QD0 magnet prototype realization :**

The most elementary for machining, assembling, cost and delay with most realistic :

- *Dynamic behavior* (Eigen-frequencies, damping…)
- *Dimensions*
- *Mass*

Stabilization study on ATF2

14 Ground Motion sensors on ATF2 for GM Feed-forward study

A.Jeremie (LAPP)
Y.Renier, K.Artoos, C.Charrondière, R.Tomas-Garcia, D.Schulte (CERN)

- Goal : Detect Ground Motion (GM) effect on beam trajectory. Vibration sensors can help with characterization of jitter sources
- Motivation : It would demonstrate possibility to make a feed-forward on beam with GM sensors
  - ⇒ trajectory correction based on GM measurements in CLIC
  - ⇒ avoid quadrupole stabilization on CLIC ?

Since May 2013
Sensors installed : positioned at critical locations with maximum effect
data acquisition on : Synchronized BPMs and GM sensors

Summary

IP feedback

PLACET simulations
(collaboration with CERN)

Reduction of **luminosity losses down to 2%** for different GM models

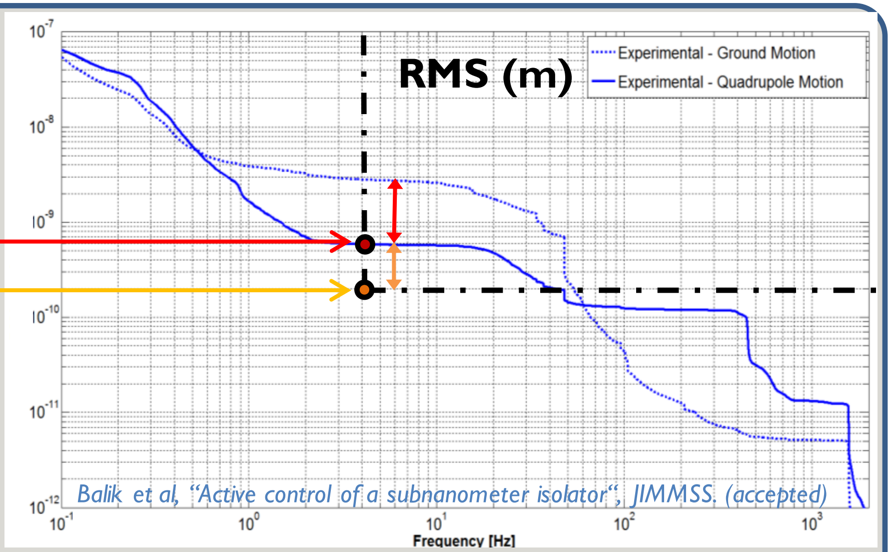
B. Caron et al, 2012, 236-247, Contr. Eng. Pract. , 20 (3). ; G. Balik et al, 2012, N.I.M. A., 163-170

Active stabilization (QD0)

2012 Result : 0,6 nm RMS @ 4 Hz

2 feedback + 2 feedforward
4 sensors : 2 geophones (Guralp6T)
2 accelerometers (Wilcoxon731)

Spec : 0,2 nm RMS @ 4 Hz



Main limitations from sensors : Signal/noise ratio and transfer function complexity

New sensor dedicated to control :
- Sensor specifications have been detailed by CERN
- A sensor prototype is currently studied and developed at LAPP, encouraging preliminary results. Future collaboration and tests with CERN are planed on this prototype.

QD0 dummy prototype

Real scale active stabilization strategy
(system dimensions, multiple feet etc..)

space-state model on going
prototype production before 2016

ATF2

Detect GM correlation with BPM signals.

15 Guralp6T sensors installed
data acquisition started last week