Stabilization R&D for future linear colliders (CLIC & ATF2)

Journées Collisionneurs Linéaires

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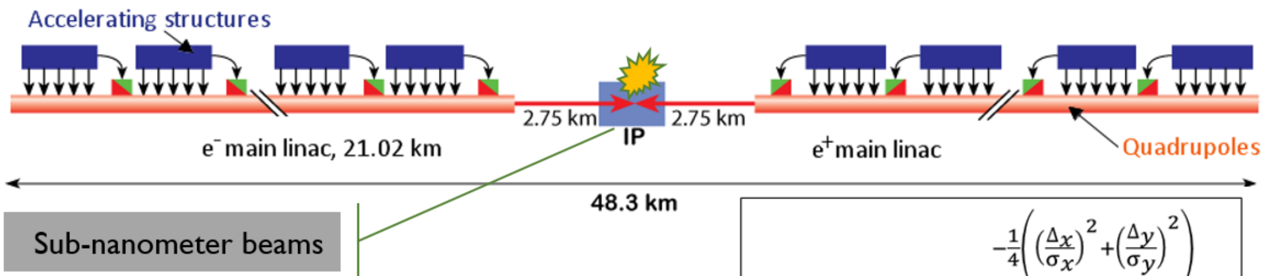
One of the CLIC Challenges : Beam stabilization

- **Final focus CLIC R&D:**

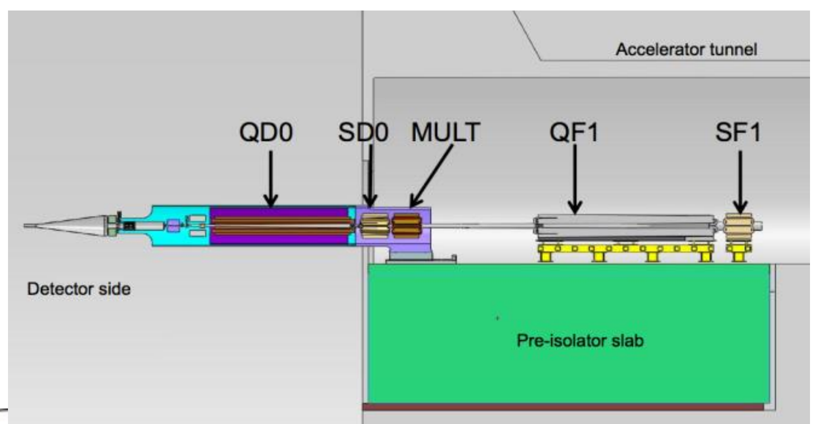


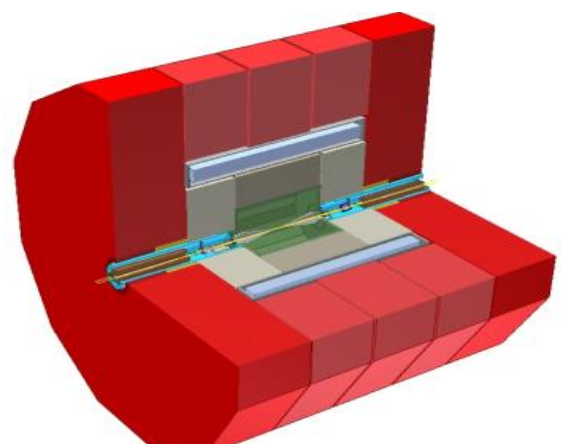
$$L(\sigma_{x,y}, \Delta_{x,y}) \sim \frac{e^{-\frac{1}{4}\left(\left(\frac{\Delta x}{\sigma_x}\right)^2 + \left(\frac{\Delta y}{\sigma_y}\right)^2\right)}}{\sigma_x \sigma_y}$$

Spéc. : 0,2 nm RMS @ 0,1Hz

- ❑ *Many controls will be performed all along the collider*

- **Most stringent specifications are at the final focus interaction point**

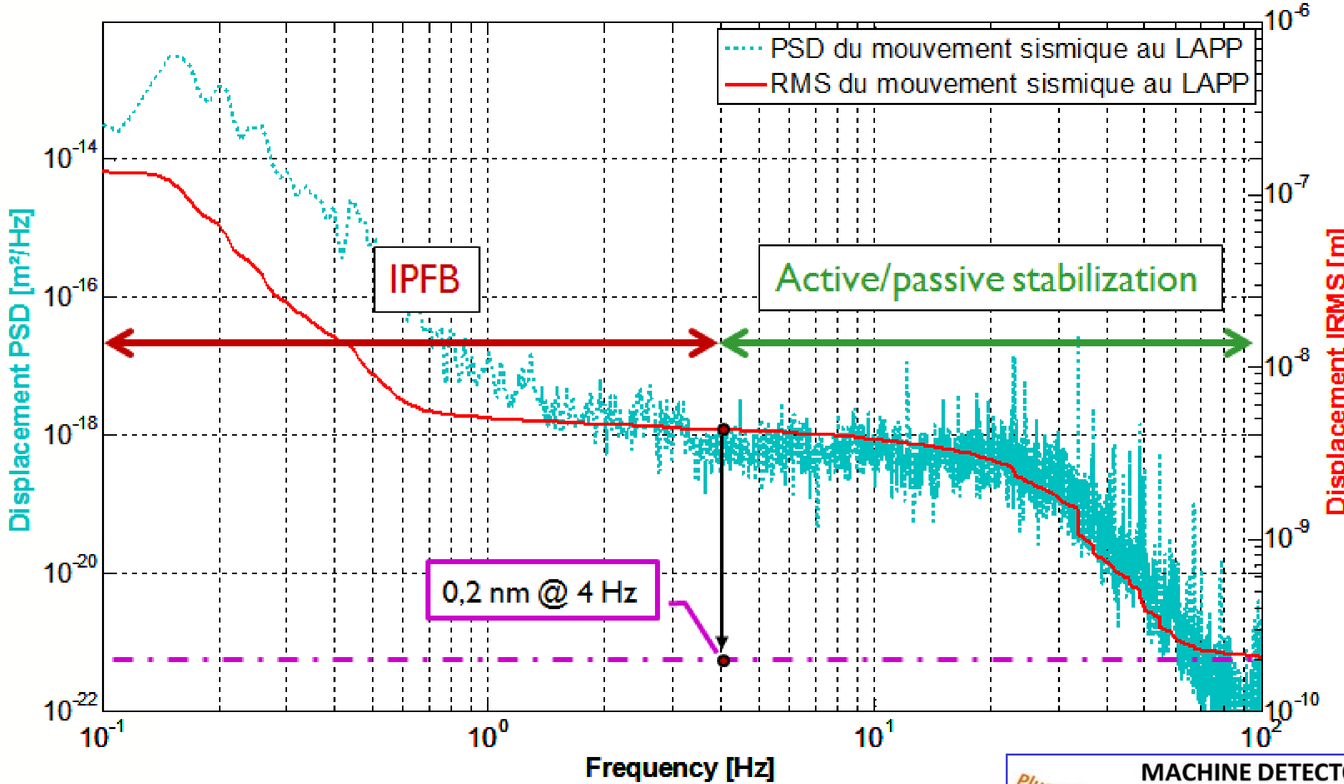




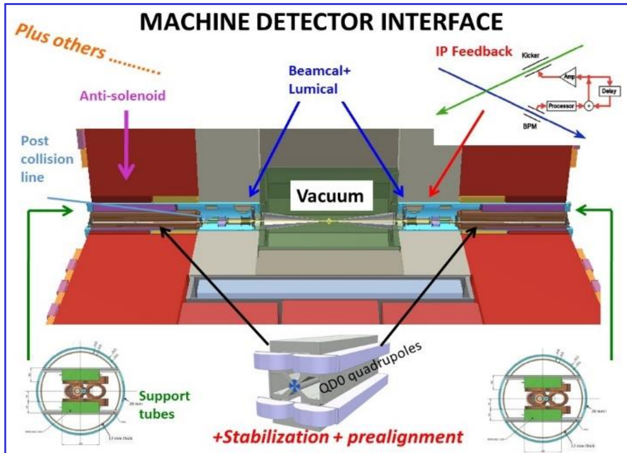
- ❑ *Final focus : LAPP responsibilities*

CLIC Final focus – beam stabilization strategy

- **Beam trajectory control & mechanical active control:**

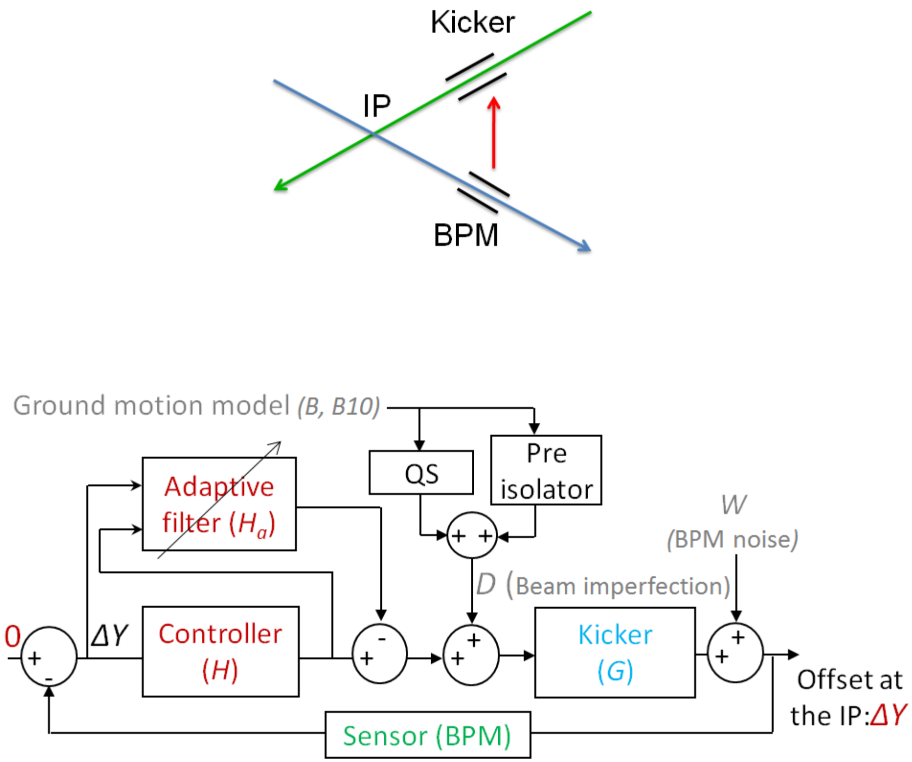


➢ At the Interaction Point (mechanical active control + beam feedback), we aim at **0,2 nm at 0,1 Hz**

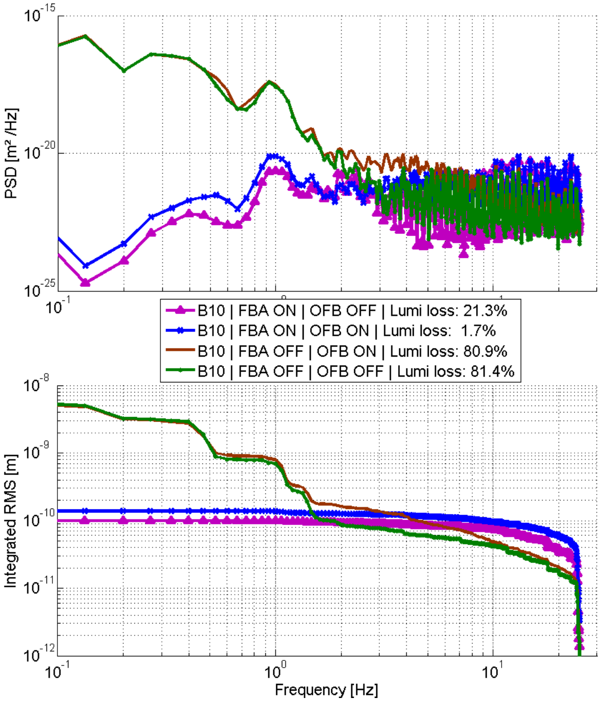


Beam control at the Interaction Point - IP Feedback

- **Beam trajectory control : simulation under Placet**



- *Bandwidth limited by the beam repetition*

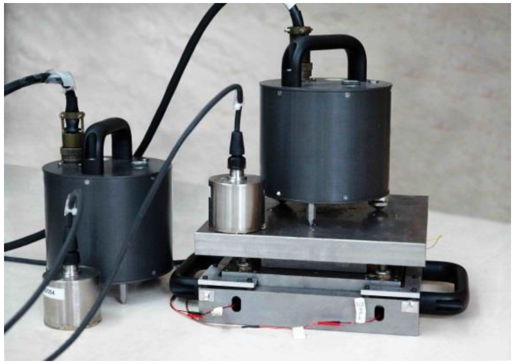


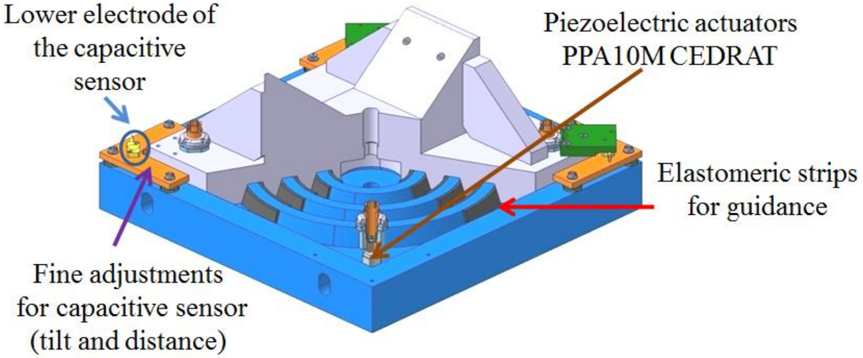
Luminosity vs control ON or OFF and vs model of seismic motion (deal under Placet)

- *Caron B et al, 2012, "Vibration control of the beam of the future linear collider", Control Engineering Practice.*
- *G. Balik et al, 2012, " Integrated simulation of ground motion mitigation, techniques for the future compact linear collider (CLIC) ", Nuclear Instruments and Methods in Physics Research*

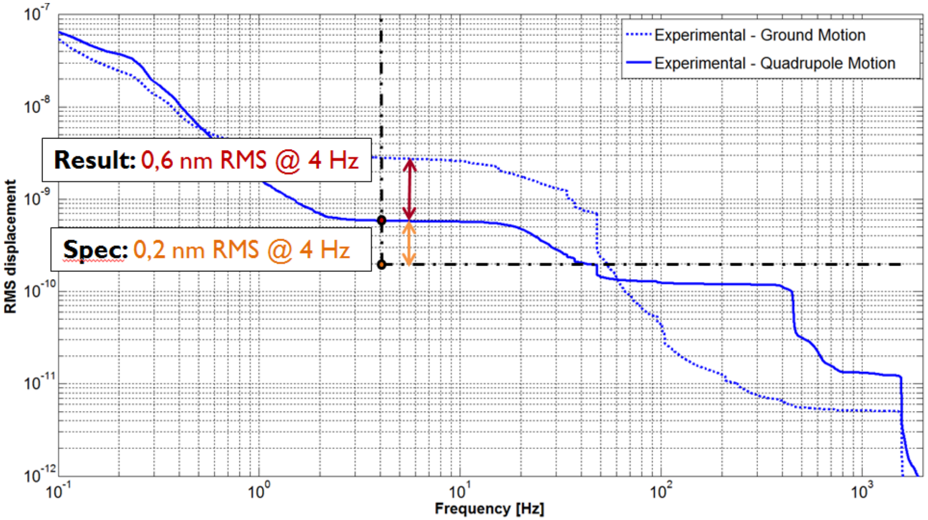
Mechanical active control

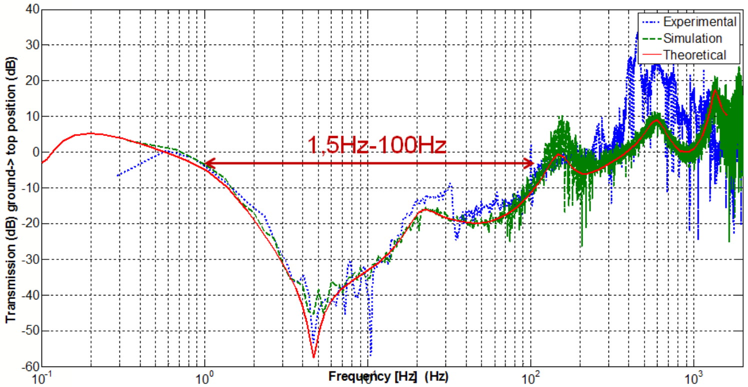
- **Demonstration at a sub-nanometer scale**





- ❑ *Control with commercial sensors (geophones and accelerometers) :* ***0,6 nm RMS@4Hz***





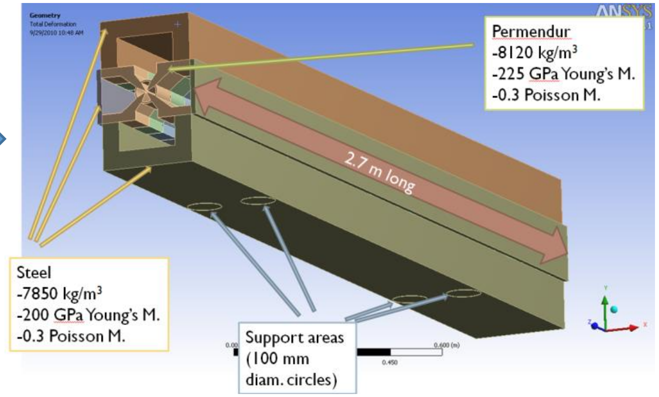
- *Balik et al, "Active control of a subnanometer isolator", JIMMSS, 2013.*
- *R. Le Breton et al, Nanometer scale active ground motion isolator, Sensors and Actuators A: Physical, 2013.*

- ❑ ***Main limitation : SENSOR (simulation and experiment).***

Transfer on a real scale

- **Active control of a real size magnet**

One active foot



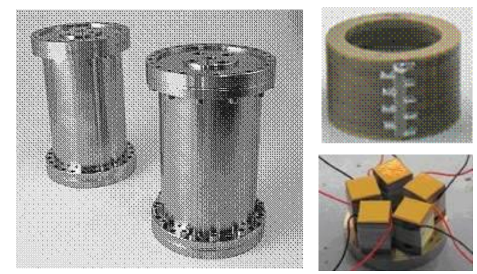
Several active feet

Displacement measurement
Vibrations sensor

Vibrations control
Actuators

- *Instrumentation have to be developed*

Small size PZT actuator

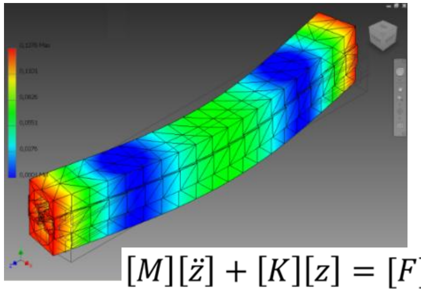


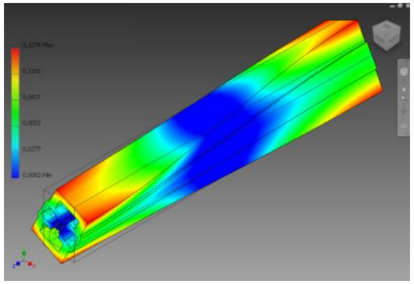
Example of a large actuator

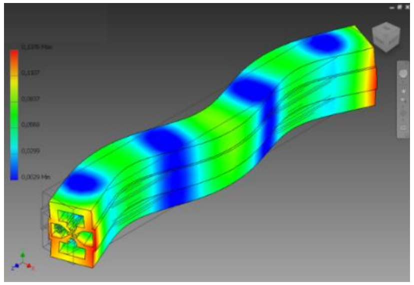
- ***Mecatronics challenge***
  - *Structure : QD0 Magnet*
  - *Sensors*
  - *Actuators*
  - *Integration: control, data processing, real time, layout, interfaces…*

Simulation of the whole system

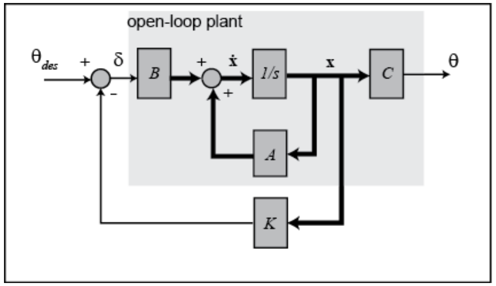
- **Simulation studies of QD0 magnet :**







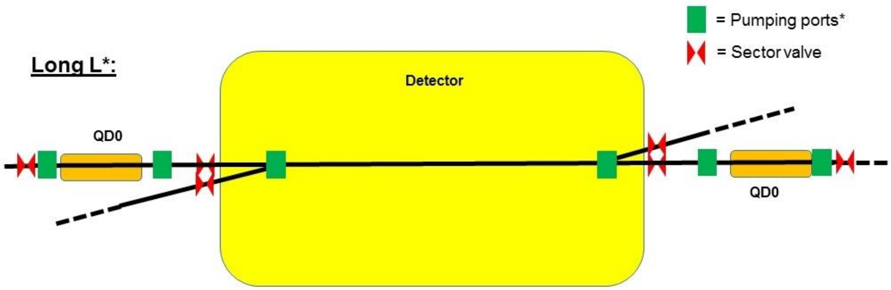
$$[M][\ddot{z}] + [K][z] = [F]$$



$$\dot{x} = Ax + \mathrm{B}u$$
$$y = Cx$$

- FEM : Modal analysis using finite elements - Determination of the most significant modes (frequency response characteristics)
- Expression in the form of a state space model and study of the control stategy
- Integration in a control loop (using Simulink for example) with the <u>whole simulation</u> (sensor, actuactor, ADC, DAC, Data processing…. And seismic motion model and its coherence)

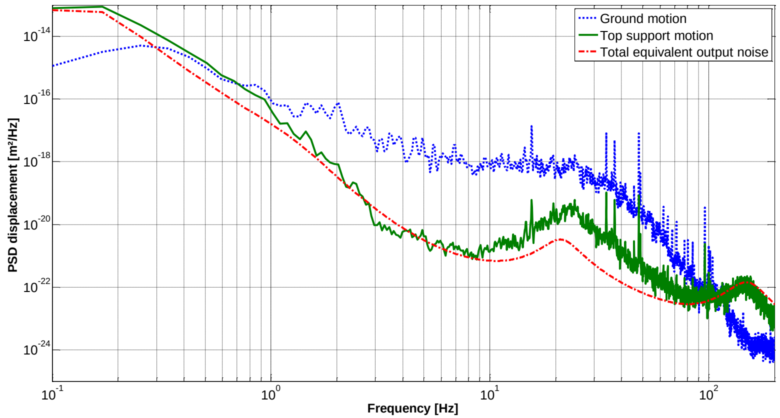
- Targets : several aspects have to be defined
  - *Location and number of active feet*
  - *Type of active feet*
  - *Degrees of freedom*
  - *Type of control (SISO, MIMO)*
  - *To adjust the specifications of actuators and sensors*
  - *Conditioning, real time processing…*



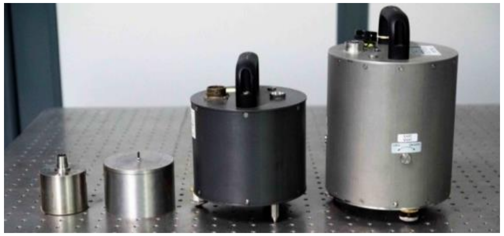
➢ This upgrade stage is in progress before a real size prototype demonstration

Vibrations sensor : R&D

- *Already the limitation for the «demonstration » active table:*



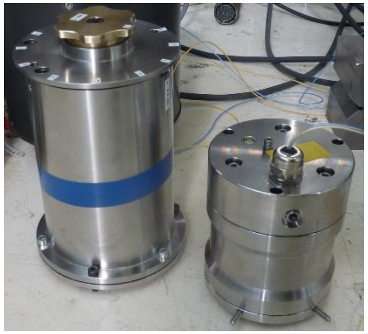
- No commercial solution
- Internal development at LAPP



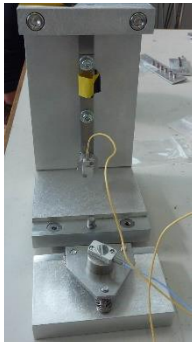
• Development of a vibration sensor:

- Promising results (similar to the best commercial sensors)
- **French patent (FR 13 59336), PCT extension in progress**
- Outreach with the SATT of Grenoble (Linksium)
- Optimised version in test (measurement in vertical or horizontal) for measurements and for active control
- Triaxial version in progress

Prototypes developed since 2011



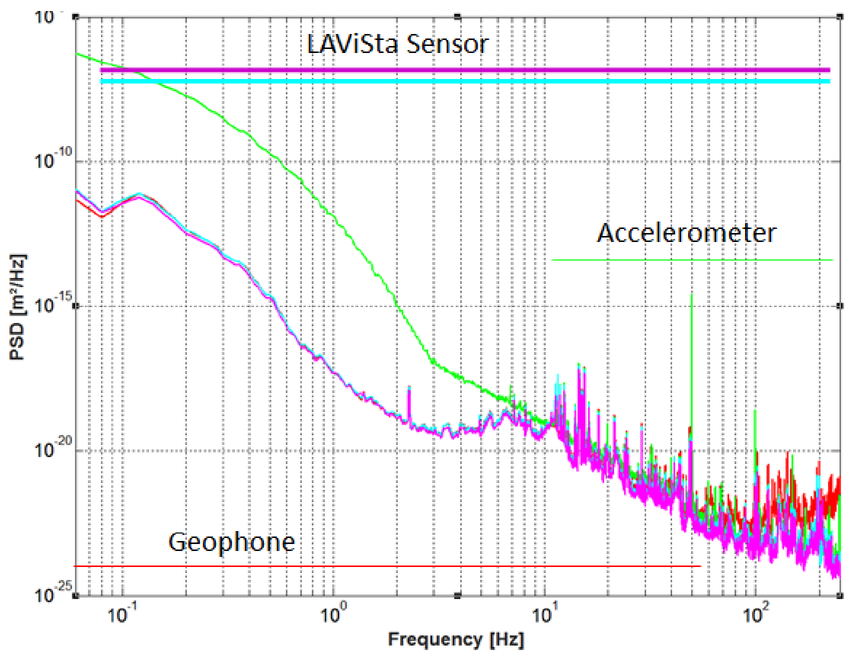
Latest one axis version



Prototype of tri-axes version

Vibrations sensor : Results

- **Comparison with industrial sensors at CERN (ISR – January 2015):**

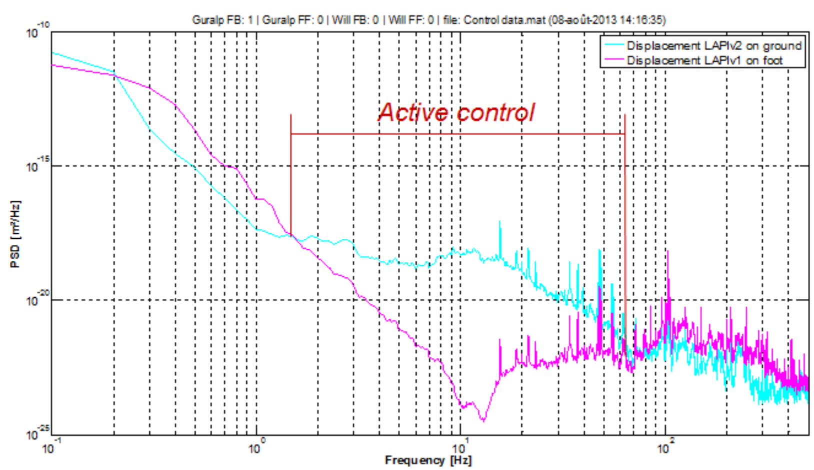


Geophone
(Güralp 3-ESP)
Low frequencies

Accelerometer
(Wilcoxon 731A)
Mid-High frequencies

LAViSta sensor
(x2)
Large bandwidth

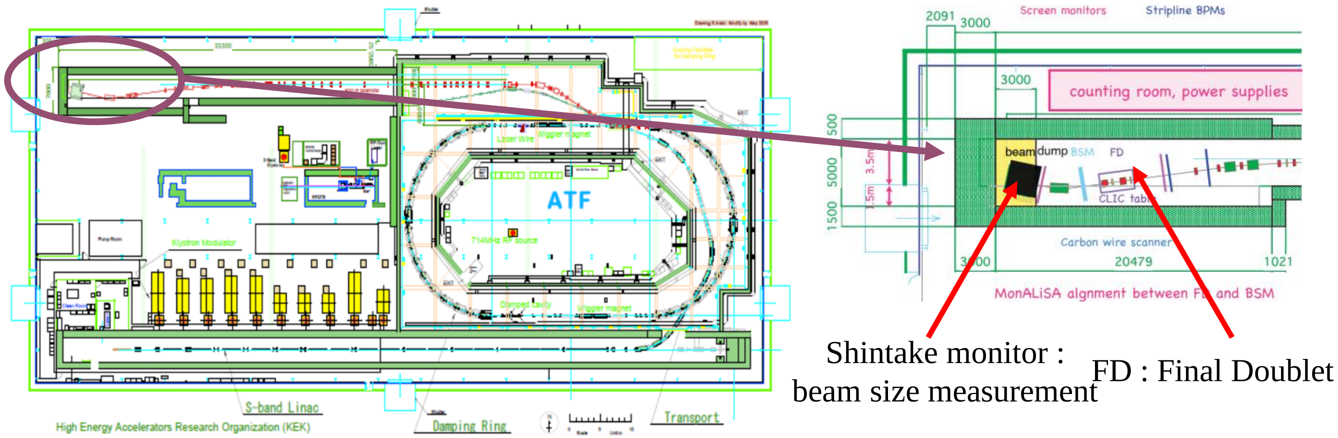
- **First tests in control:**

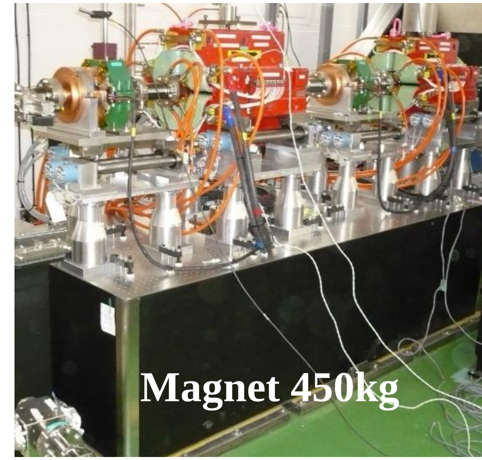


- ❑ *LAViSta Active Table*

- ❑ *LAViSta sensor*

ATF2: responsible of the final doublet relative displacement



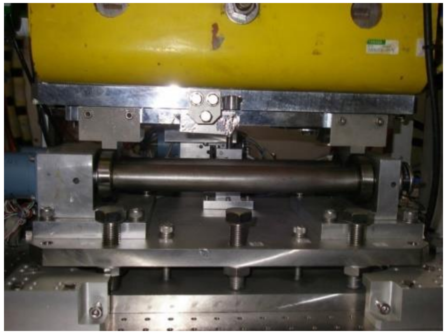


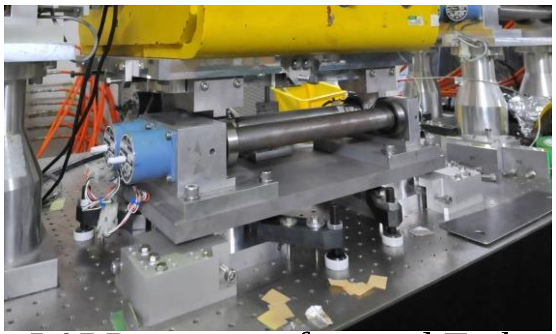
In 2012

- Relative motion between shintake monitor and final doublets of 6 nm RMS @ 0,1 Hz in the vertical axis (i.e. B. Bolzon results).
- Analysis of the upgrades influences and of the drift.

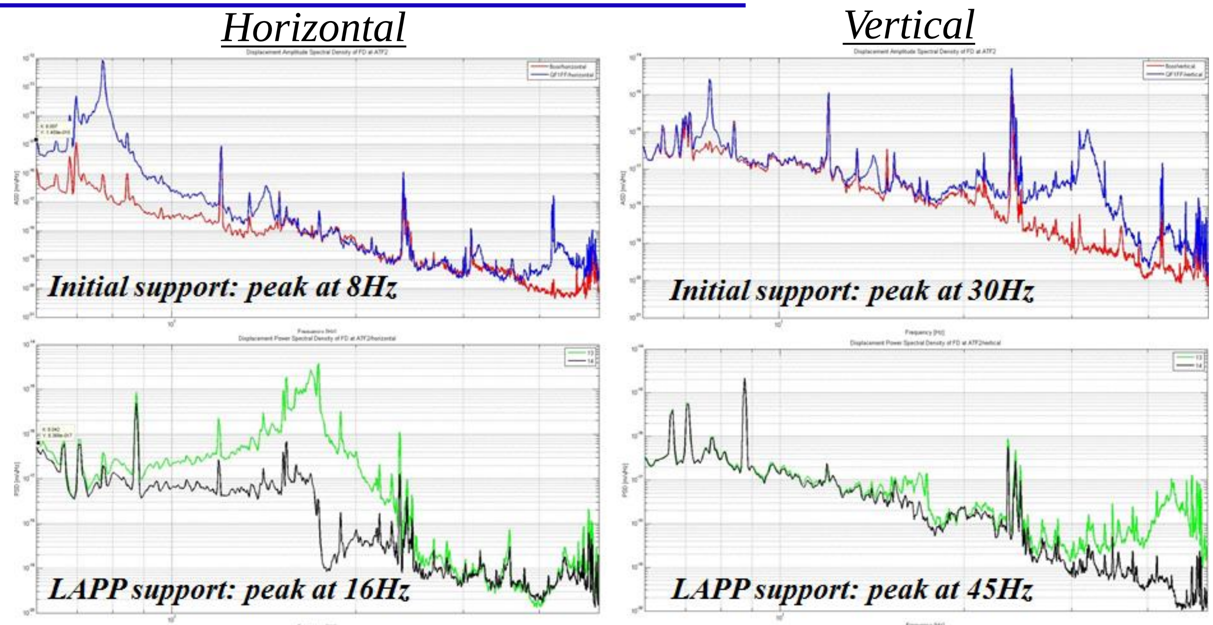
2008 by B. BOLZON	Tolerance	Measurement [SM-QD0]	Measurement [SM-QF1]
Vertical	7 nm (for QD0) 20 nm (for QF1)	4.8 nm	6.3 nm
Perpendicular to the beam	~ 500 nm	30.7 nm	30.6 nm
Parallel to the beam	~ 10,000 nm	36.5 nm	27.1 nm
2013 by A. JEREMIE	**Tolerance**	**Measurement [SM-QD0]**	**Measurement [SM-QF1]**
Vertical	7 nm (for QD0) 20 nm (for QF1)	4.8 nm	30 nm
Parallel to the beam	~ 10,000 nm	25 nm	290 nm

ATF2 upgrades



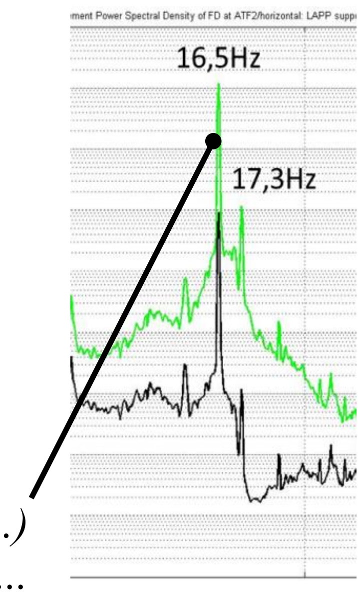


LAPP support: feet and T-plate



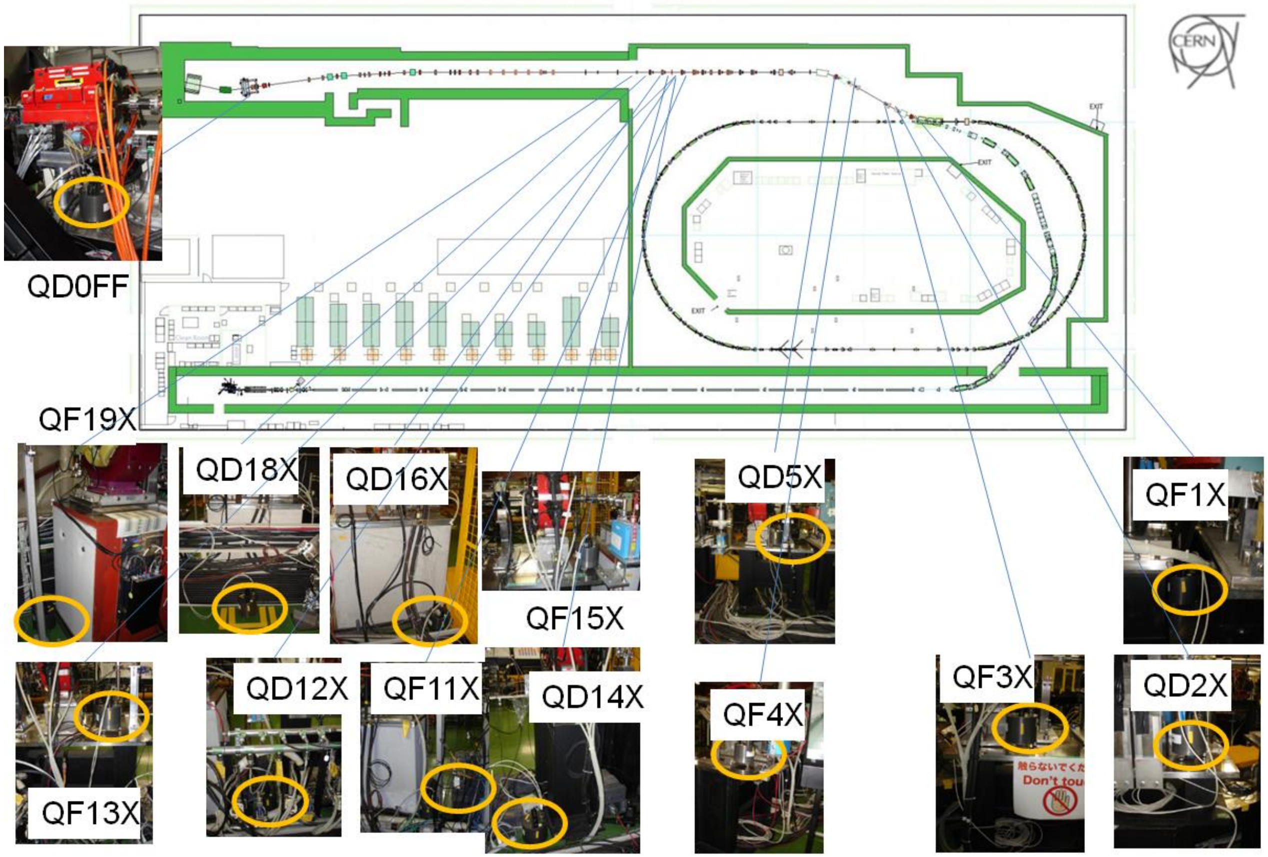
- Main resonance peaks pushed to higher frequencies

	Spec Shintake Monitor	Old Magnet	Initial support	New LAPP support without perturbation	New LAPP support with perturbation
Horizontal Rel. Displ. RMS (nm) @ 1Hz	≈500	30	290	52	244-356
Vertical Rel. Displ. RMS (nm) @ 1Hz	≈20	4	21	6	17-21



In horizontal direction, there is a perturbation (cooling, mechanics…) at about the same frequency than the resonance of the system…

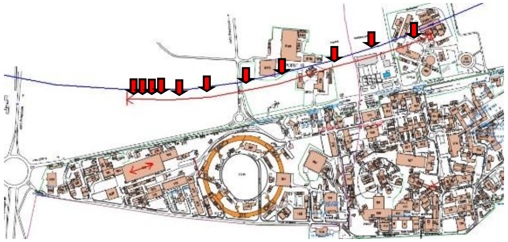
ATF2: expertise all along the collider



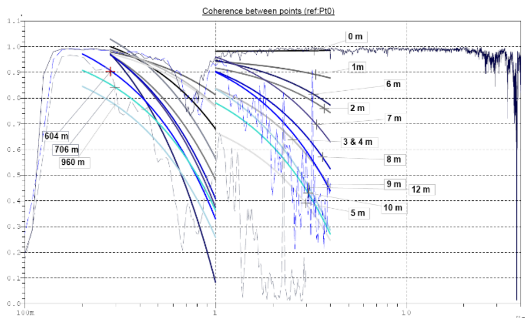
- Processing of 14 Guralp 6T sensors
- Guralp 6T: 0,5Hz-100Hz, two directions connected (vertical and horizontal can be placed parallel or perpendicular to beam direction); sensors similar to the ones used in 2008

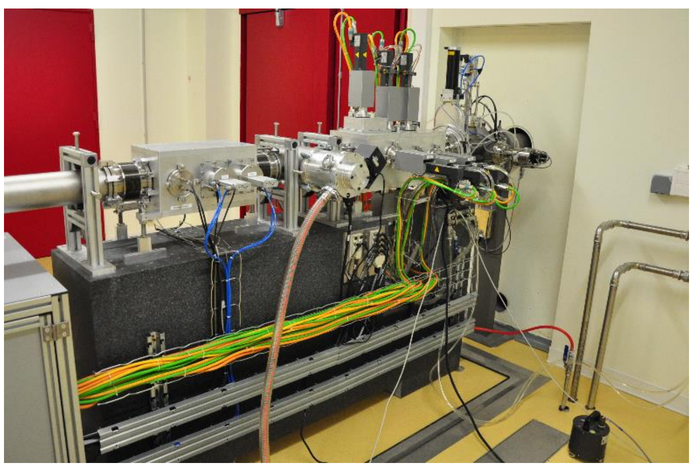
- Vibration sources identification
- Feedforward study: correlation between the ground and the beam motions.

Analysis and measurements activities on different experiments

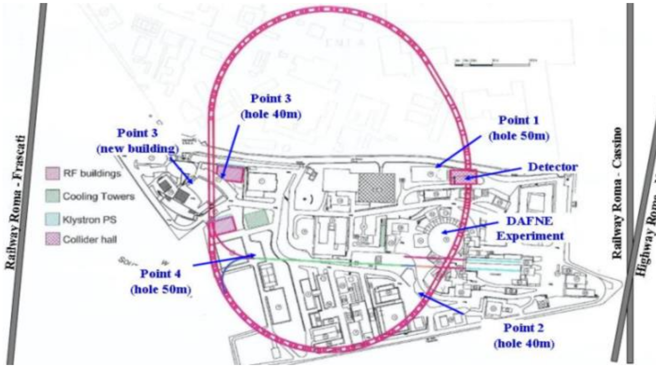


❑ *LHC measurements*

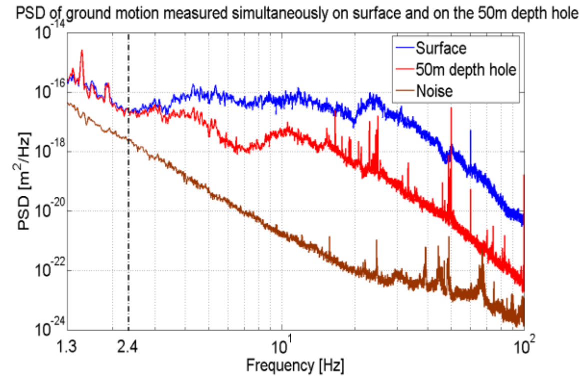




❑ *IRSN vibrations analysis*



❑ *SuperB analysis*



❑ *IPHC measurements*

Conclusions

- **CLIC**
  - Feasibility demonstration of active control at sub-nanometer scale
  - Development of an efficient vibrations sensor
  - Control of the QD0 magnet in progress

- **ATF2**
  - Optimization and analysis of the final doublet relative displacement
  - Vibrations analysis of the experiment for the feedforward study

lapp