QD0 stabilization and ATF2 ground motion measurements

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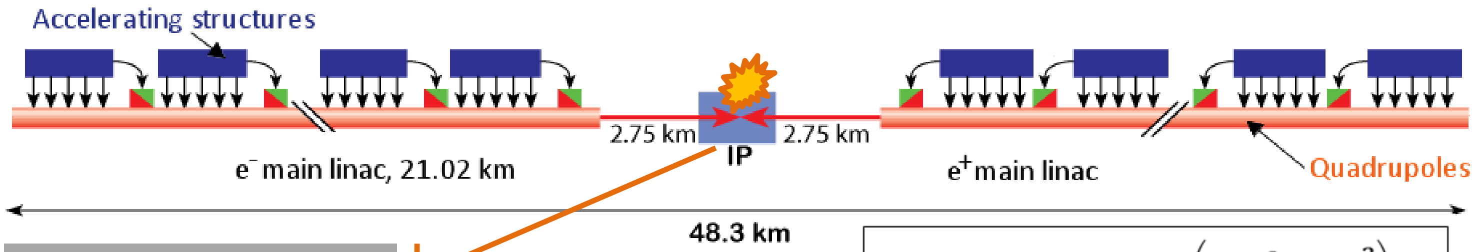
CLIC Challenge vs QD0 stabilization

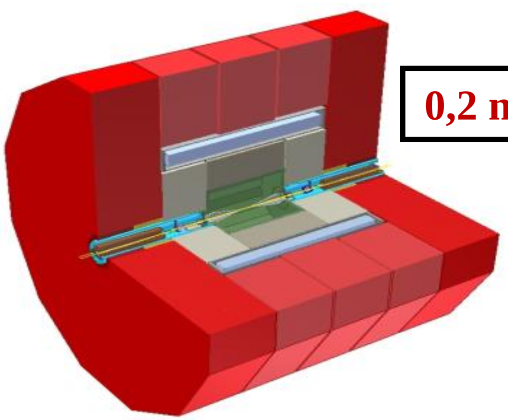
- ***Final focus CLIC R&D:***



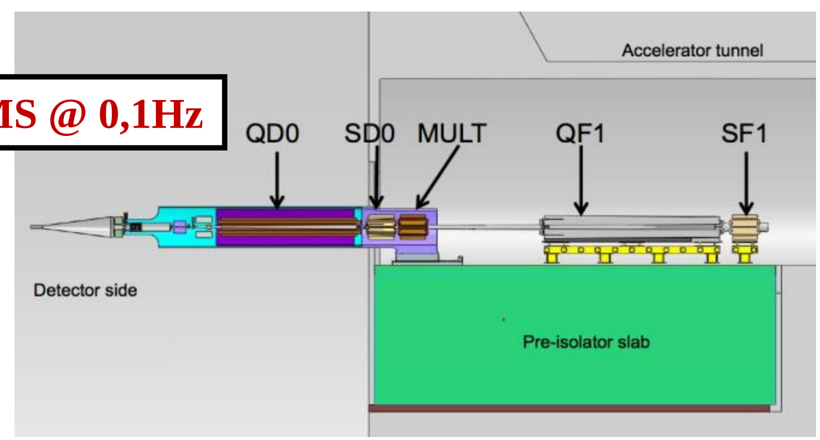
Sub-nanometer beams

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

- ***Developments of Lavista team are dedicated to the final focus***

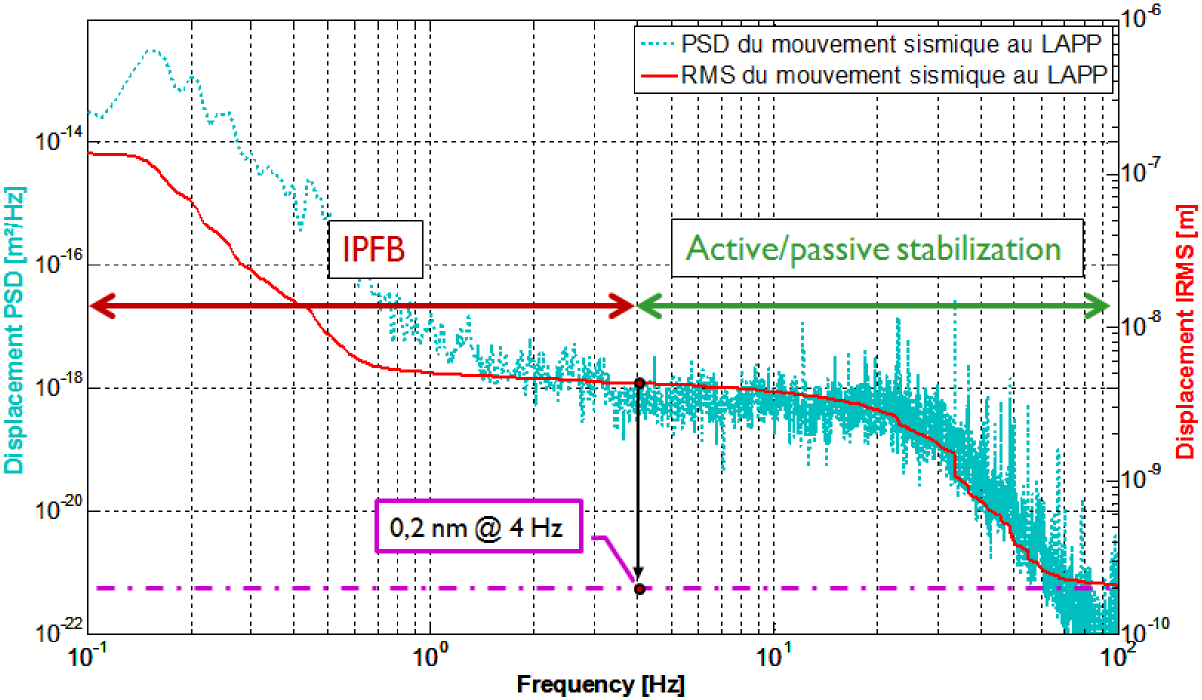


0,2 nm RMS @ 0,1Hz



Introduction

- ***Final focus : beam stabilization strategy***

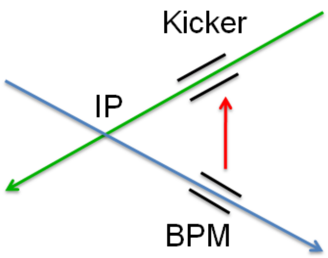


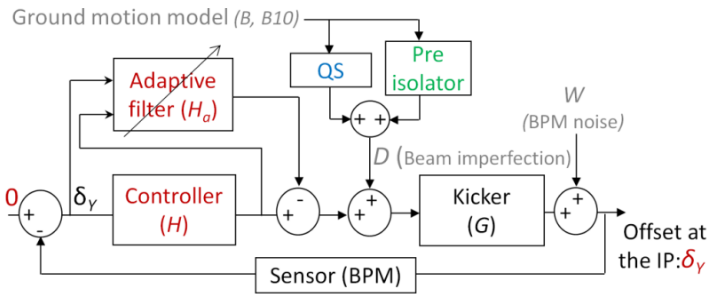
➢ At the IP (mechanical + beam feedback), we aim at **0,2nm at 0,1Hz**

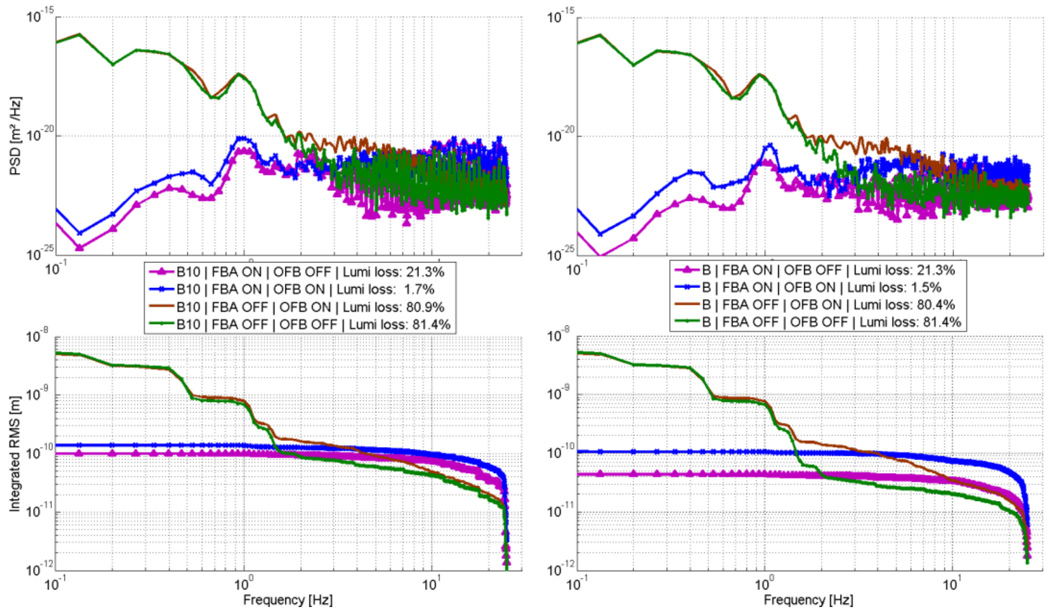
- **IP Beam based feedback : already developed in collaboration with CERN since 2010**
- **Mechanical stabilization has to be achieved**

IP feedback

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





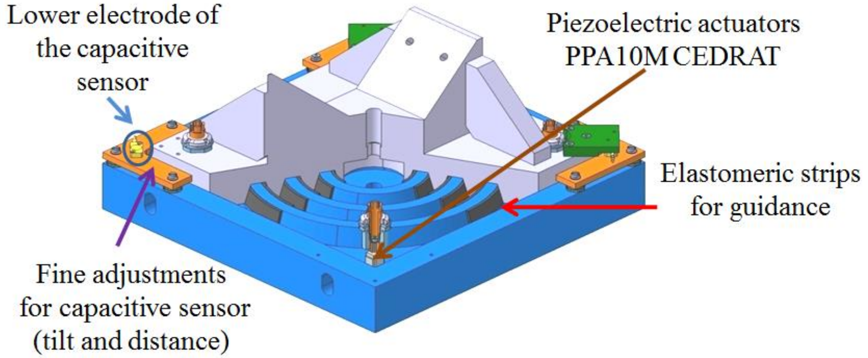


- *Luminosity vs control ON or OFF and vs model of seismic motion (deal under Placet)*

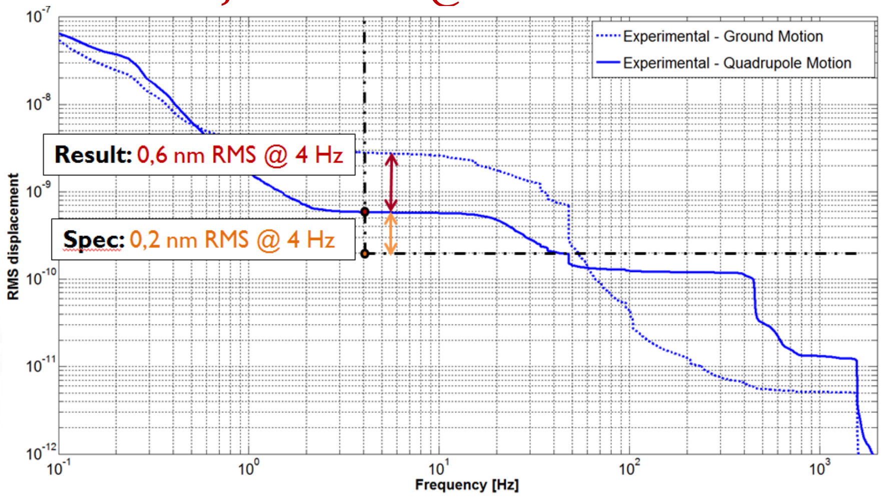
- *Caron B et al, 2012, "Vibration control of the beam of the future linear collider", Control Engineering Practice.*
- *G. Balik et al, 2012, " Integrated simulation of ground motion mitigation, techniques for the future compact linear collider (CLIC) ", Nuclear Instruments and Methods in Physics Research*

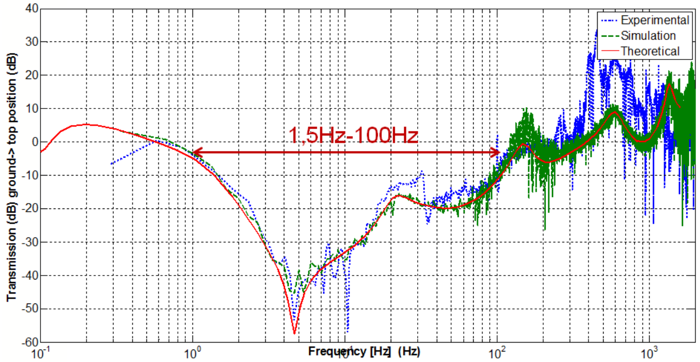
Active control demonstration

- ***Prototype :***



- ***Results : control with commercial sensors (2 geophones and 2 accelerometers)***
  - **0,6 nm RMS@4Hz.**





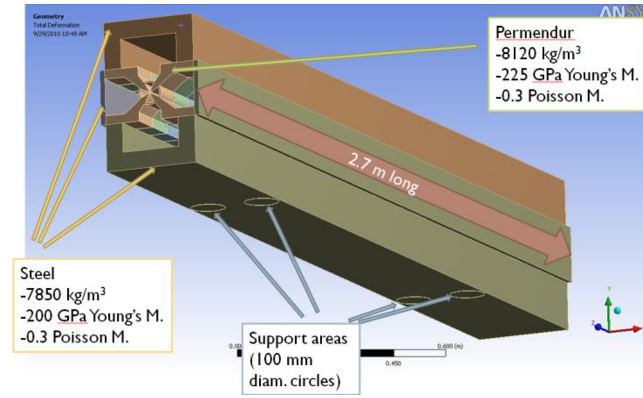
Balik et al, "Active control of a subnanometer isolator", JIMMSS.

➢ Main limitation : SENSOR (simulation and experiment).

Transfer on a real scale

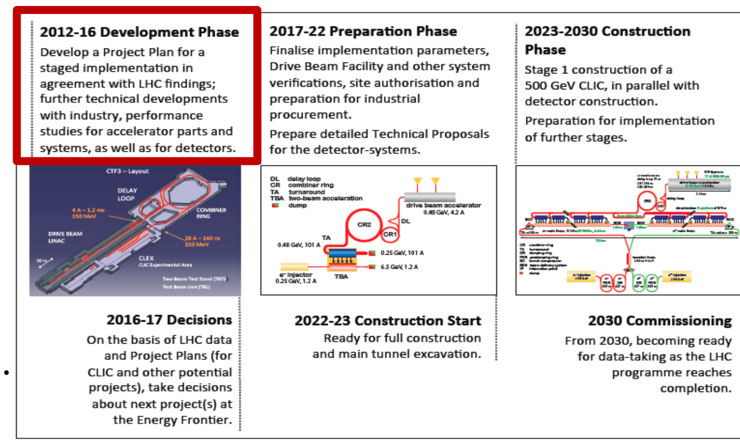
- ***Demonstration active table to QD0 active control ?***

One active foot



Several active feet

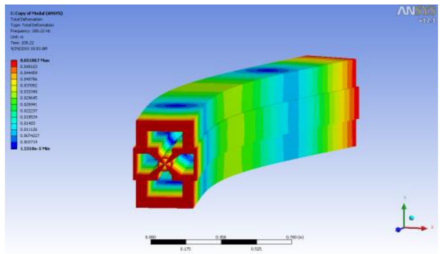
- ***Mecatronics challenge***
    - Structure : QD0 Magnet
    - Sensors
    - Actuators
    - Integration: control, data processing, real time…

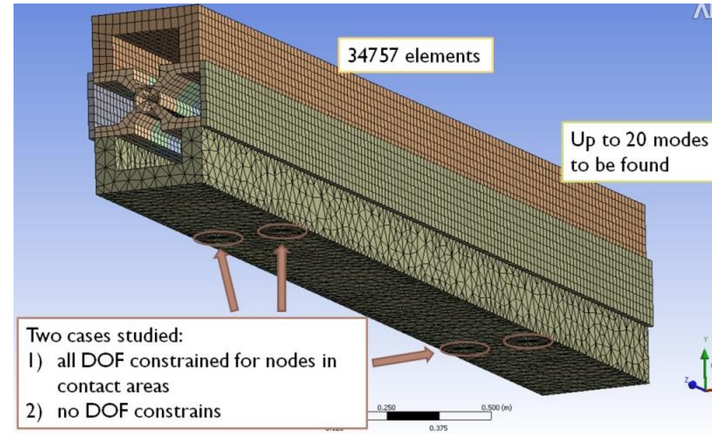


Schedule : CLIC development phase

Mechanical structure

- ***Simulation studies of QD0 :***
  - *Initial study performed by the team of M. Modena*
    - CERN : mechanics aspects…





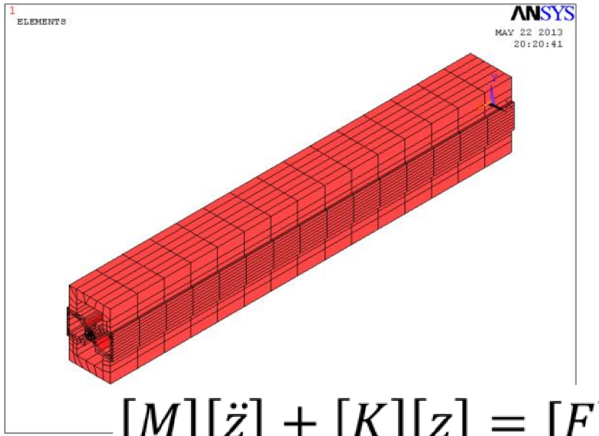
  - *LAVISTA : control of a elementary prototype*

    - FEM : dynamics of the quadrupole given its modal response
    - State-space model and control strategy
    - Test : on a real-scale prototype – "dummy QD0 magnet"

QD0 magnet – FEM

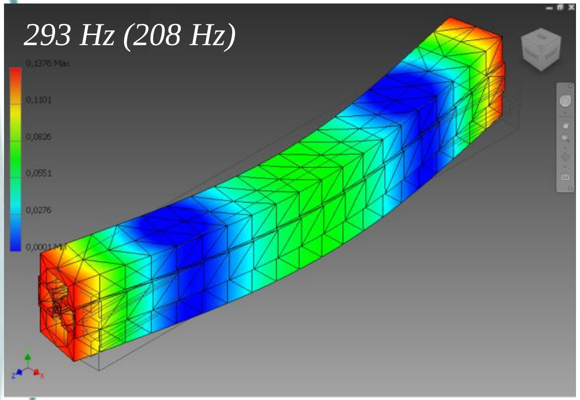
- ***(1) FEM study :***

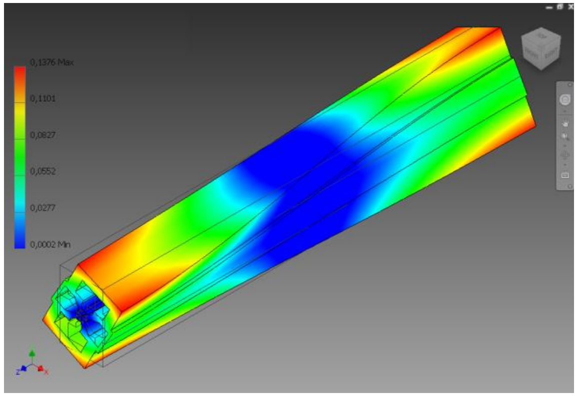
  - Modal analysis using finite elements.
    - The system is discretized and approximated to a mass-damper-spring system.
    - The finite element software solves the eigenvalues and eigenvectors of the system (modes and resonant frequencies)

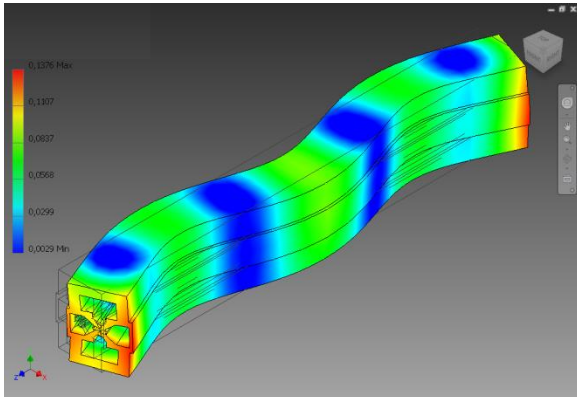


$$[M][\ddot{z}] + [K][z] = [F]$$

  - Determine the most significant modes that accurately construct the frequency response characteristics over a frequency range







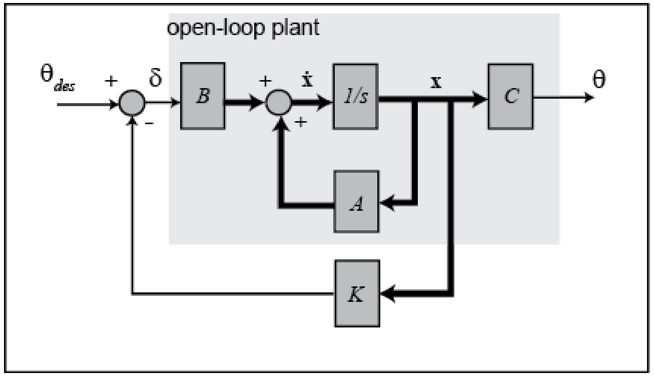
➢ **First version is done.**

QD0 activities

- *(2) State space model and control strategy :*

- After normalizing the spring mass system with respect to the mass matrix and after performing a change of coordinates, the system can be expressed in the form of a state space model

- Integration in a control loop using simulink with the whole simulation (sensor, actuactor, ADC, DAC, Data processing…. And seismic motion model and its coherence)



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

- 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 stage is in progress**

Test bench

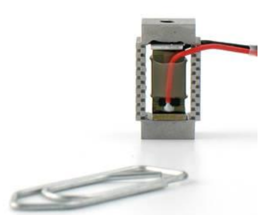
- ***(3) Dummy QD0 magnet prototype :***
  - Objectives :
    - Dynamics behavior (eigenfrequencies, damping…)
    - Size
    - Geometry
    - Mass
  - ➢ *Most elementary as possible for machining, assembling, cost, delays…*

➢ **The CAD and FEM are planned for next spring**

Actuator

- ***No commercial solution for dynamics, resolution, load, stiffness…***
  - ➢ Two challenging ways : internal development or <u>industrial partnership</u>…

- ***Industrial solution : PZT actuator***
  - Manufacturer identified
  - Past "similar" developments for vibration control dedicated to machining
  - Specifications will be the result of the whole simulation (prototype, sensor…)
  - Collaboration with another French laboratory for the powering part.



Small size PZT actuator

Example of an large actuator

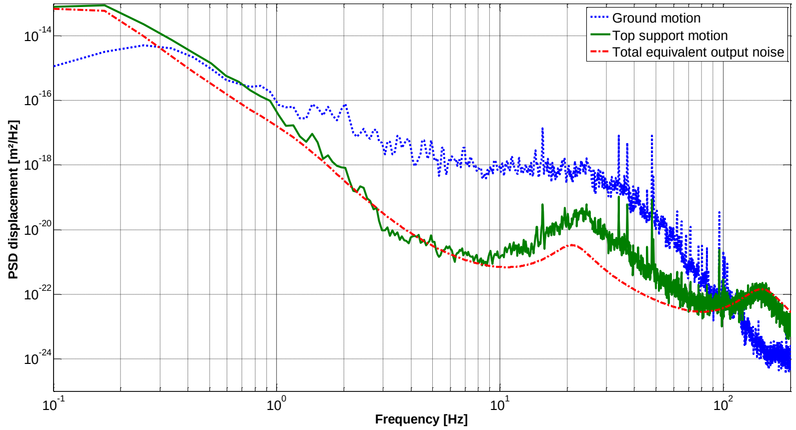
➢ Funding plan is needed

- A French proposal (to ANR agency) has been recently submitted…

➢ Has to be tested on the dummy magnet prototype

Sensor

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



✓ Sensors noise

✓ Sensors transfer function

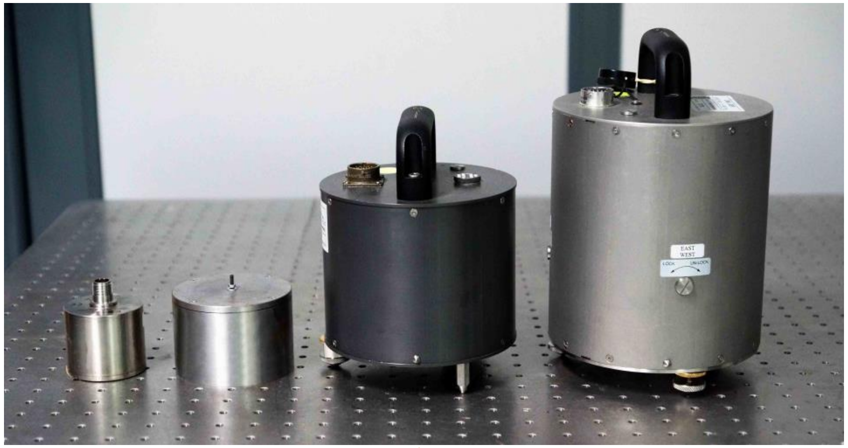
➢ No commercial solution , so different challenging options:
  - Laboratory developments
  - Commercial investigations
  - PACMAN program…

➢ Internal development at LAPP

Sensor

- ***Status:***
  - A first innovative version has demonstrated the feasibility : performance are about the same as Guralp 6T.
  - 2 miniaturized versions with our own electronics : still almost the same performance, but small adjustments have to be made (tuning, drift...)
  - Promising results in control

- ***Advantages:***
  - Adapted to control
  - Cost
  - Size



Accelerometer *LAPP sensor* *Geophone 6T* *Geophone 3ESP*

Sensor

- ***Development in progress:***
  - "Medium" bandwidth : machining in progress and will be soon assembled
    - 2-3 next weeks…
    - Validation of the machining and some of the sensor properties
  - "High" bandwidth: equivalent to accelerometers
    - About 1,5 month.
    - Less challenging
    - Could be interesting for control
  - "Large" bandwidth: development in progress in term of machining and method
    - Method tests will be done the next month.
    - If tests ok, ready for end 2013- beginning 2014
    - Most challenging – measure very low frequencies and on a large bandwidth
    - Very strategical for control

- ***Future:***
  - Sensitivity to magnetic field
  - Tests on an experimental site : first at CERN (stabilization group), then ATF2, CLIC module or CLEX…

Conclusion vs QD0 stabilization

- ***Structure:***
  - First version of FEM, done
  - Integration in the whole simulation for control, in progress
  - CAD and FEM of the dummy magnet, next spring
- ***Actuator:***
  - Partnerships identified and the strategy chosen
  - Funds, to be found
- ***Sensor:***
  - Efficient and innovative sensor is being developed
  - Several versions are manufactured to be able to build one for very low frequencies and efficient on a large bandwidth
  - Test on a site is foreseen

ATF2 : 2013 Measurement campaign

- FD relative displacement measurements
- Feedforward

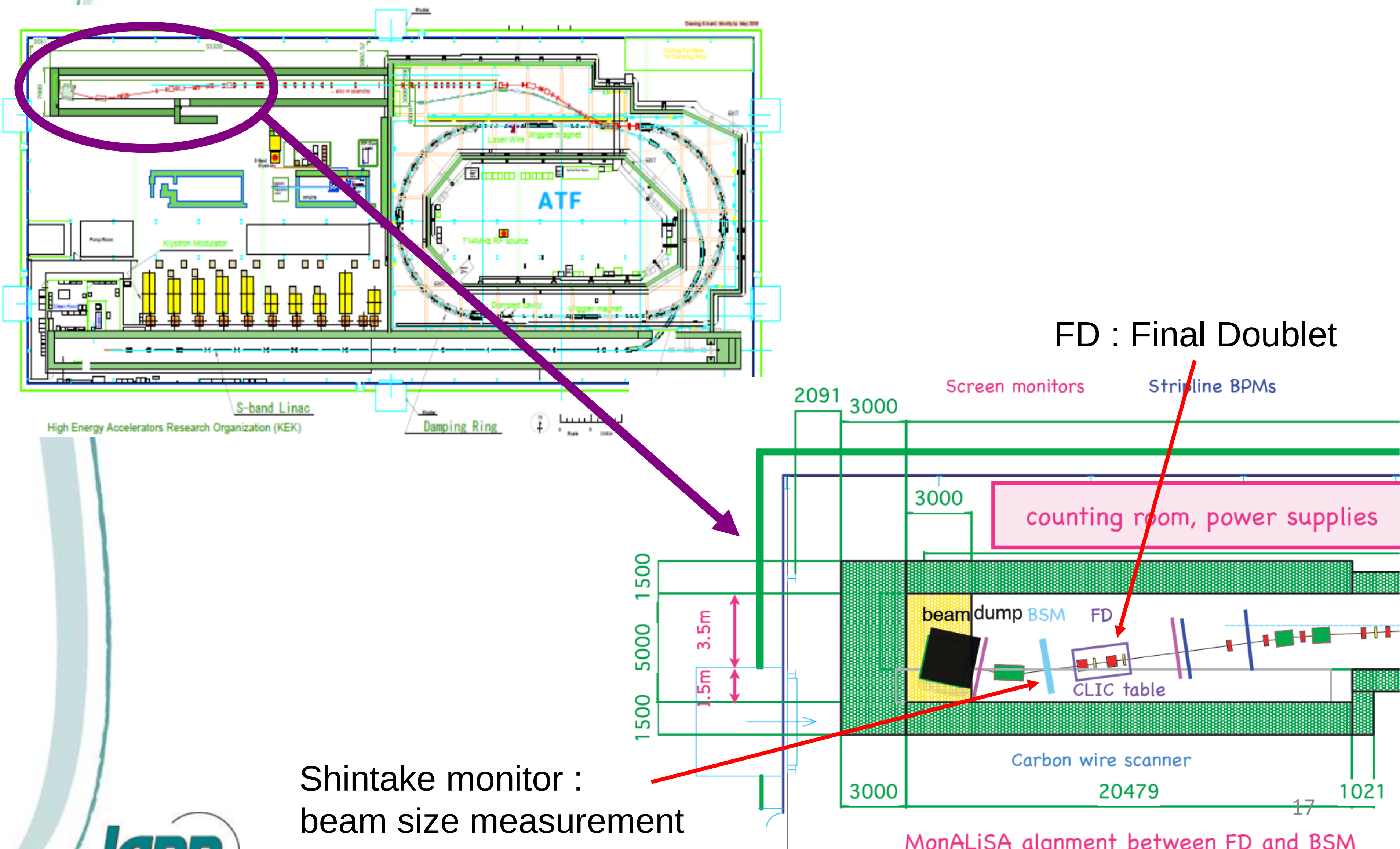
Collaboration LAPP - CERN

ATF2 GM System team:

A. Jeremie, K.Artoos, C.Charrondière, J.Pfingstner, D.Schulte, R.Tomas-Garcia, B.Bolzon (past experience)

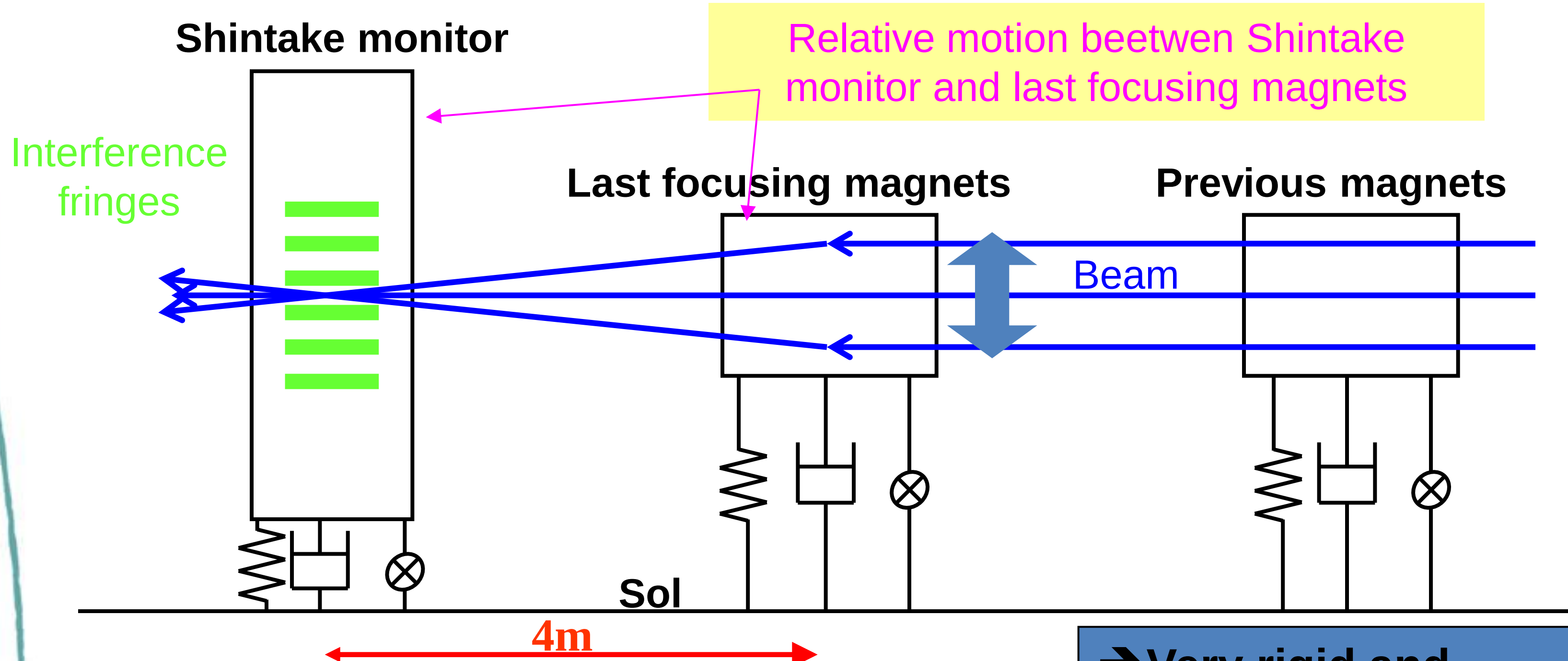
ATF2 layout

- ***Final Doublet relative displacement measurements :***



ATF2 – Strategy of stabilization

- ***ATF2 Objectives :***
  - Steady and repetitive beam with a radius of 37 nm at the focus point.



Efficient coherence of ground motion: measured on site

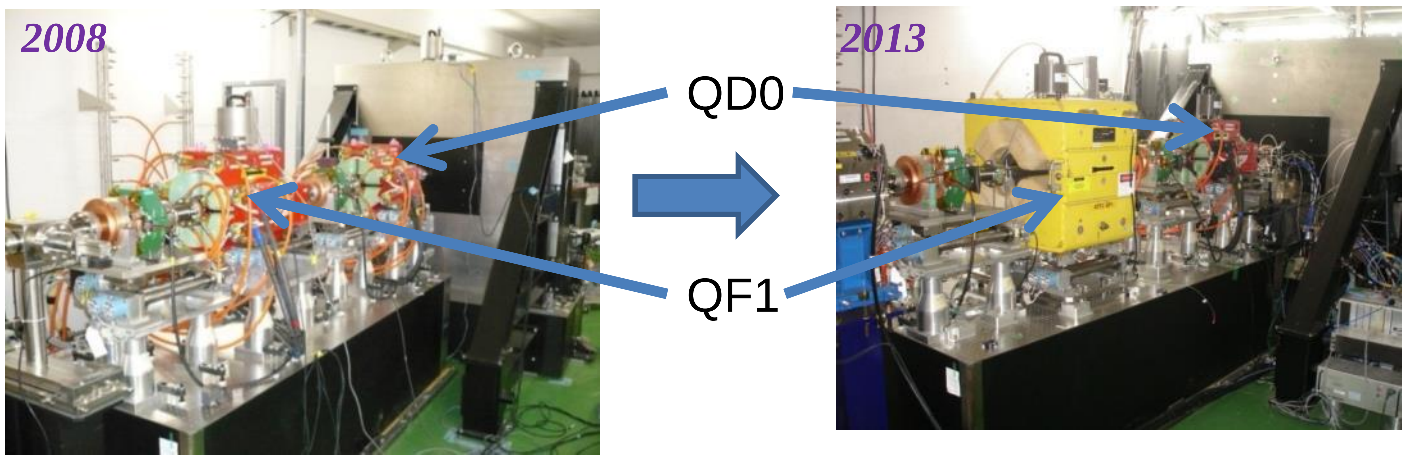
➔Very rigid and independent supports

i.e. B.Bolzon thesis

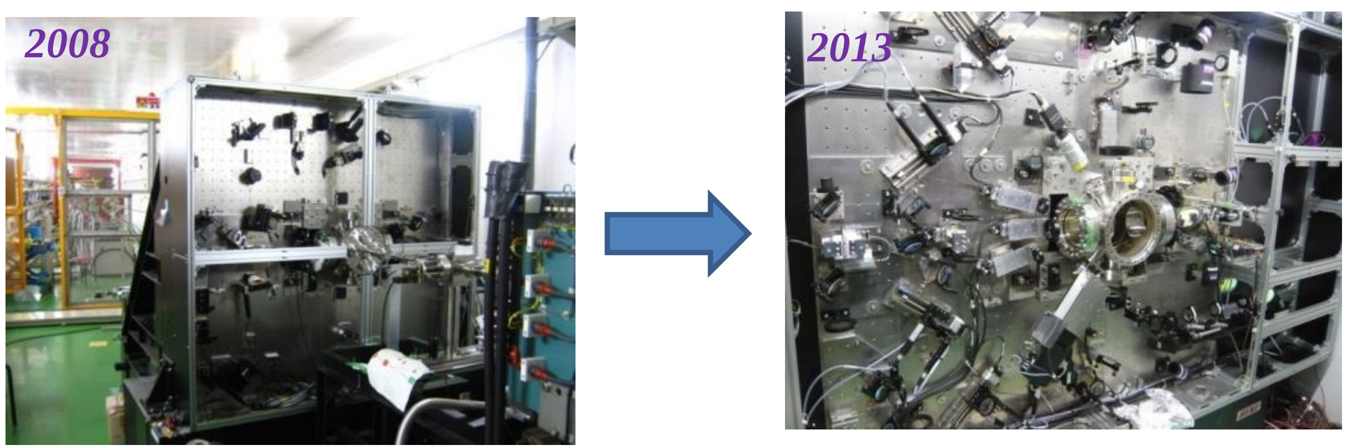
➢ **<u>Past</u> : relative motion between shintake monitor and final doublets of 6 nm RMS @ 0,1 Hz in the vertical axis (i.e. B. Bolzon results).**

ATF2 - Why making new measurements?

- ***QF1FF has been replaced by a heavier magnet with better field quality and larger radius:***

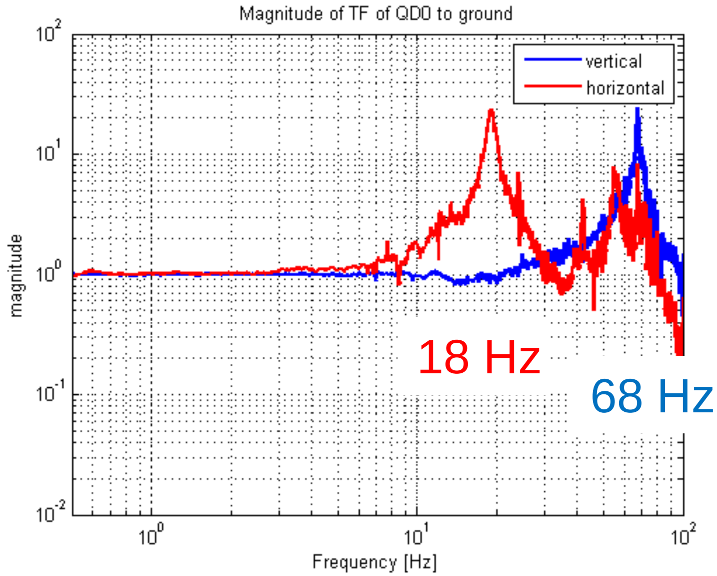


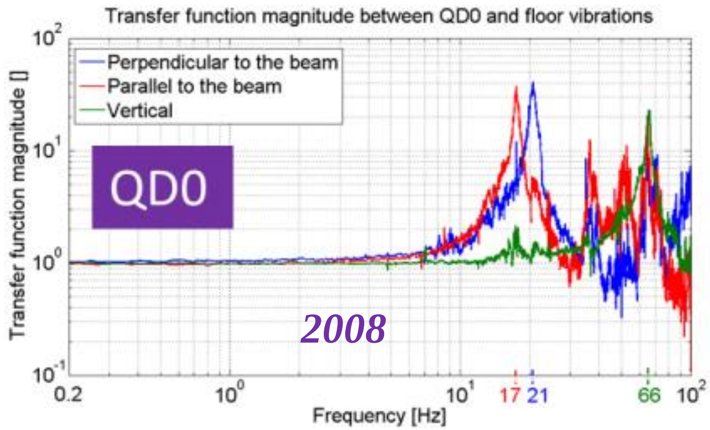
- ***Shintake monitor has more components and is in operation:***



QD0 relative to ground

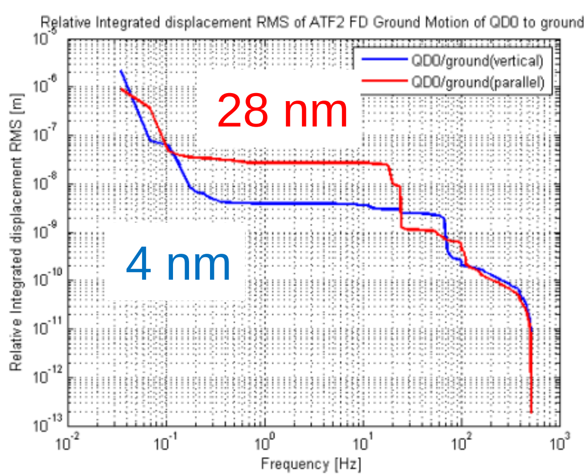
- ***Comparison transfer function QD0 to ground:***





! Benoit used green for « vertical »

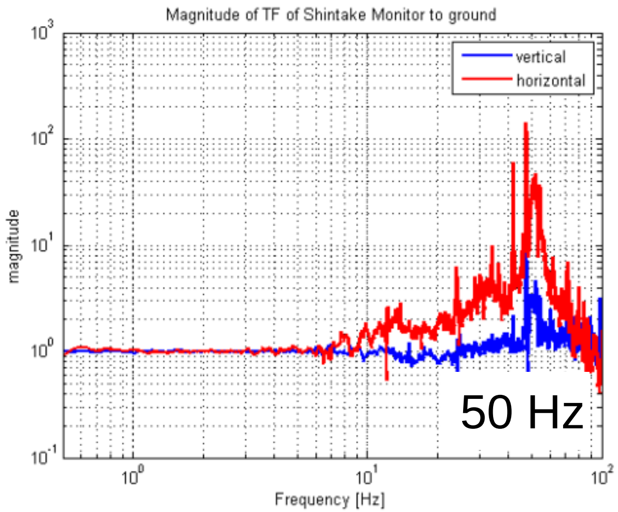
- ***Relative integrated RMS QD0 to ground:***

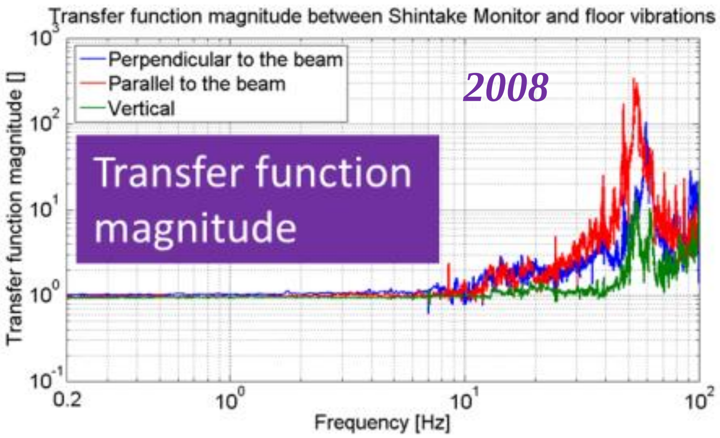


- Vertical resonance at 68 Hz
- Horizontal resonance at 18 Hz
- Vertical Relative displacement at 1Hz is 4 nm

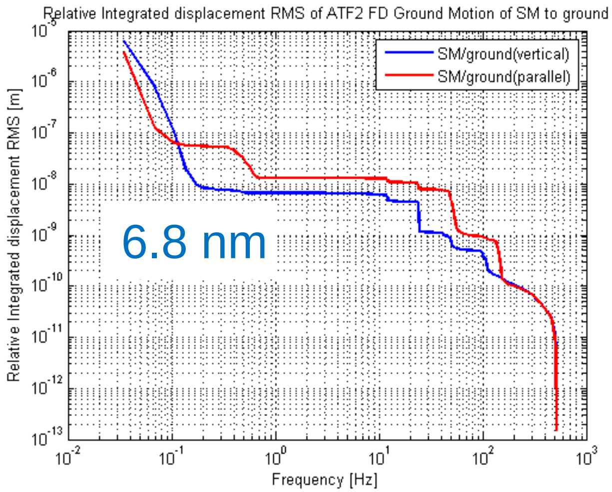
Shintake Monitor relative to ground

- ***Comparison transfer function SM to ground:***





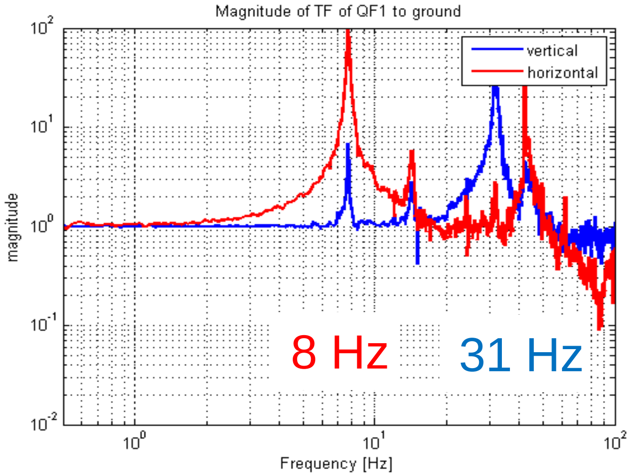
- ***Relative integrated RMS SM to ground:***

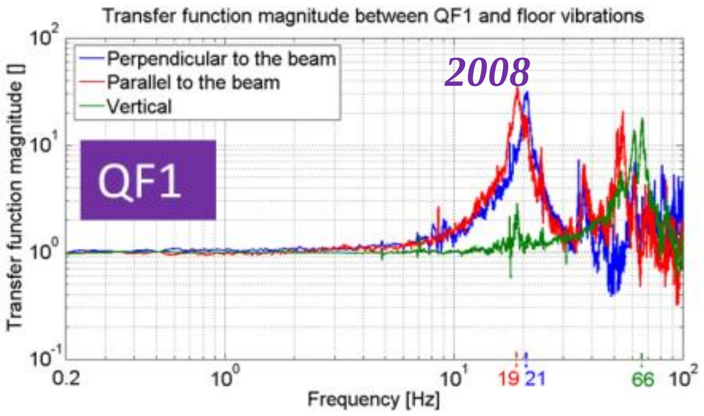


- ➢ Vertical resonance at 50 Hz
- ➢ Horizontal resonance at 50 Hz
- ➢ Vertical Relative displacement at 1Hz is 6.8 nm

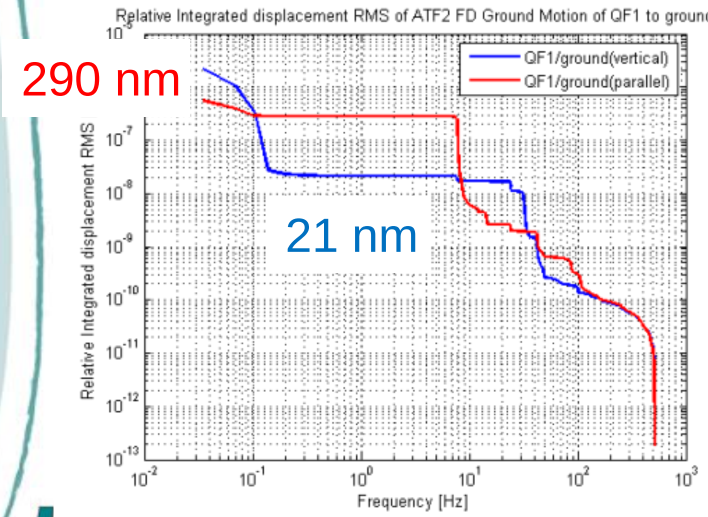
QF1 relative to ground

- ***Comparison of transfer functions QF1 to ground:***





- ***Relative integrated RMS QF1 to ground:***



- ➢ Coupling between vertical and horiz. vibrations
- ➢ Vertical resonance at 31 Hz
- ➢ Horizontal resonance at 8 Hz
- ➢ Vertical Relative displacement at 1Hz is 21 nm

Displacement relative to ground

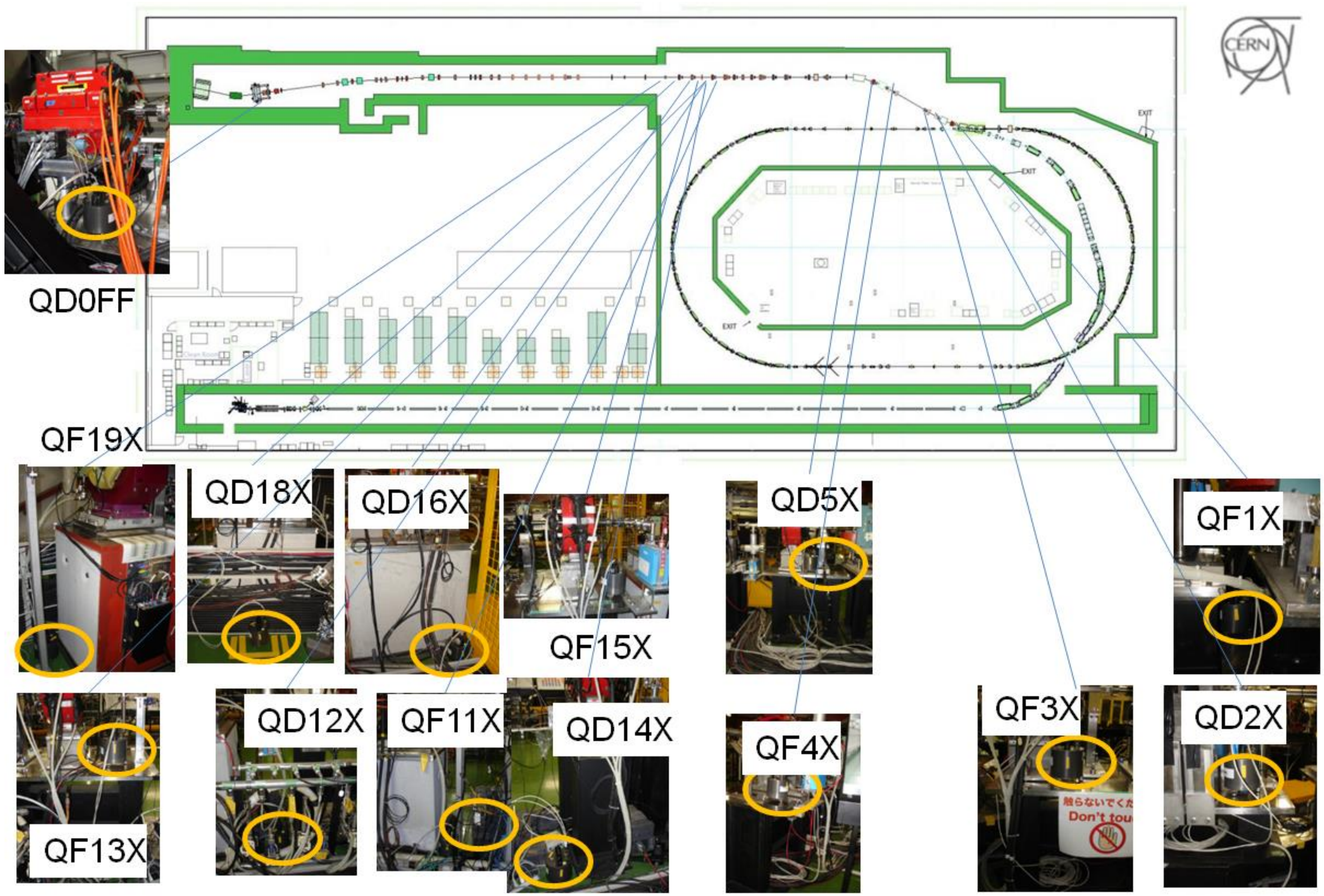
2013 (2008)	Shintake Monitor	QD0	QF1
Main resonance (vertical)	50 Hz (50 Hz)	68 Hz (66 Hz)	31 Hz (66 Hz)
Vertical displacement	6,8 nm (4 nm)	4 nm (3 nm)	21 nm (4 nm)
Main resonance (perpendicular)			15 Hz (21 Hz)
Displacement perpendicular to the beam	Not done	Not possible (hole on top QD0)	100 nm (30 nm)
Main resonance (parallel)	50 Hz (50 Hz)	18Hz (17 Hz)	8 Hz (19 Hz)
Displacement Parallel to the beam	13 nm (11 nm)	28 nm (25 nm)	290 nm (21 nm)

With ground motion, relative motion at 1 Hz of Shintake to [QD0; QF1] :

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

- New QF1 : relative motion of Shintake monitor to new QF1 > Tolerance
- Outside tolerance for 2% effect on beam!

14 Guralp 6T sensors all along ATF2



- 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

ATF2 conclusion

- Final Doublets relative displacement :
  - Instrumentation installed and processed since last summer
  - Influence of the new QF1 magnet vs relative displacement

- Feedforward :
  - i.e. presentation of J.Pfingstner
  - Next campaign of measurements next month