European Organization for Nuclear Research

STABILIZATION ACHIEVEMENTS AND PLANS FOR TDR PHASE

CLIC MAIN BEAM QUADRUPOLE MECHANICAL STABILIZATION

K. Artoos, C. Collette, P. Fernandez Carmona, M. Guinchard, C. Hauviller, S. Janssens, A. Kuzmin, R. Leuxe, A. Slaathaug.

Collaboration Stabilisation WG, participations from:

The research leading to these results has received funding from the European Commission under the FP7 Research Infrastructures project EuCARD

Outline

- Requirements
- Characterisation vibration sources
- Strategy stabilisation
- Four steps towards feasibility demonstration: achievements
- Summary and future work

Requirements

3992 CLIC Main Beam Quadrupoles:

Four types :

Mass: ~ 100 to 400 kg

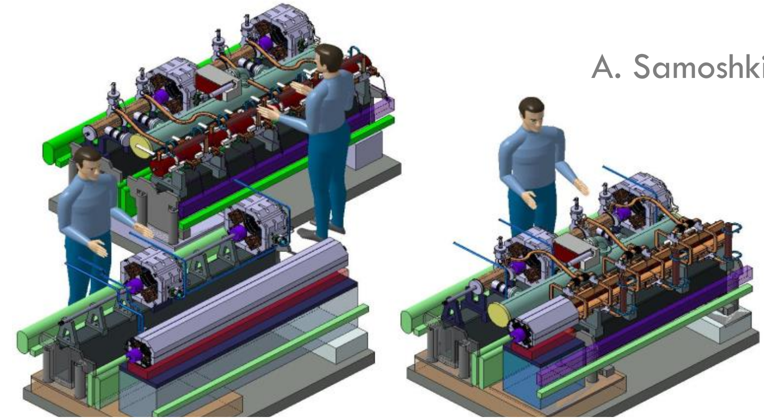
Length: 500 to 2000 mm

Stability (magnetic axis):

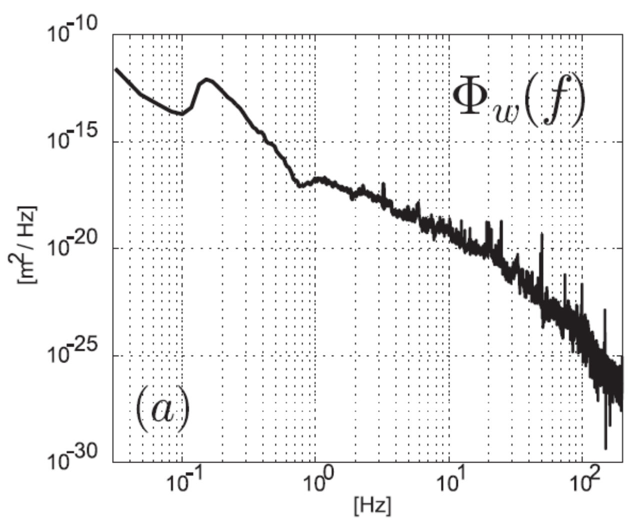
$$\sigma_x(f) = \sqrt{\int_f^{\infty} \Phi_x(\nu) d\nu}$$

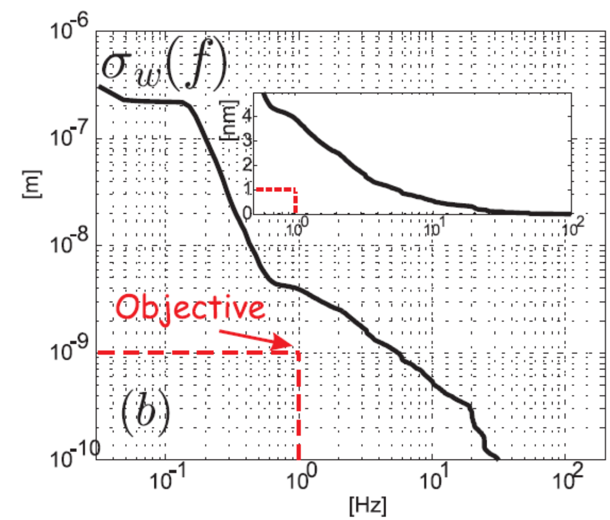
	Main beam quadrupoles
Vertical	**1.5 nm > 1 Hz** *(1 nm)*
Lateral	**5 nm > 1 Hz**

A. Samoshkin



Type 4: 2m, 400 kg Type 1: 0.5 m, 100 kg



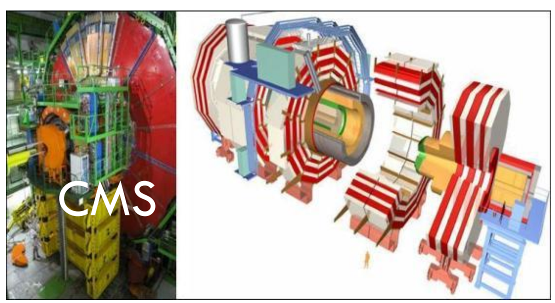


Characterisation vibration sources

Measurements LAPP, DESY, SLAC

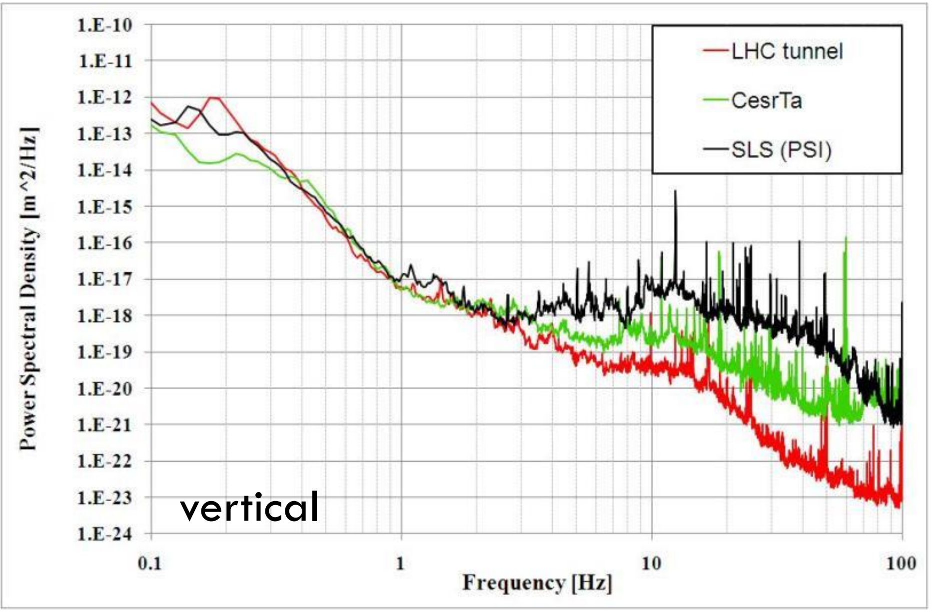
Broadband seismometers characterisation

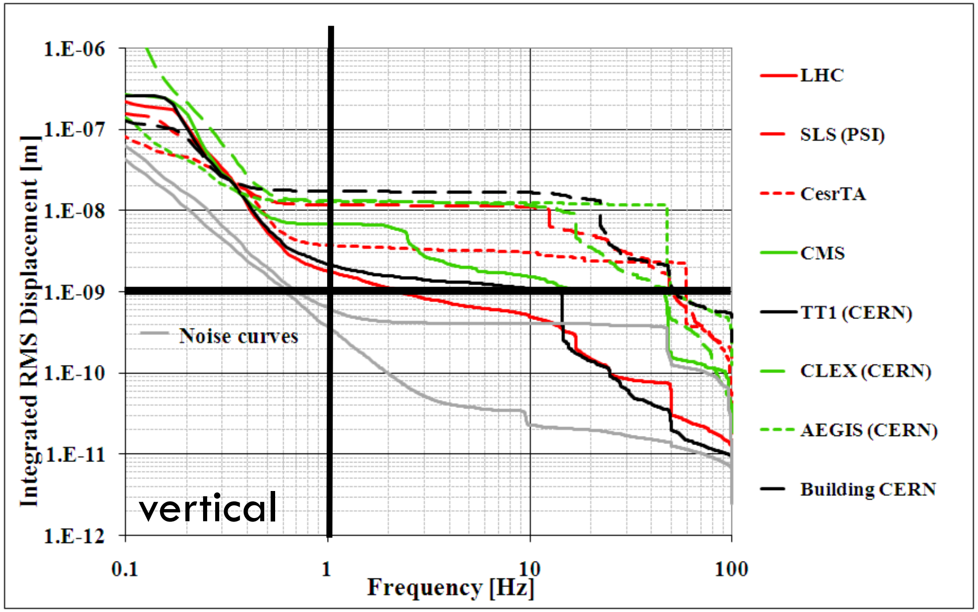
More measurements by CERN in accelerator environments



M. Sylte, M. Guinchard, A. Kuzmin, A. Slaathaug

Characterisation vibration sources





- Running accelerator in deep tunnel comparable to LHC:
- **between 2 and 5 nm** ground vertical integrated R.M.S. displacement
- Amplitude to be reduced by a **factor 4-5** in frequency range **1-20 Hz**
- **Above 20 Hz** contribution to integrated RMS is **small**
- Updated ground motion model with technical noise

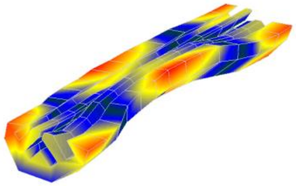
Technical vibration sources

• Ground vibrations: seismic back ground + technical noise

broadband excitation decreasing with increasing frequency

• Avoid amplification vibrations at resonances with low frequency

  - Stiff magnet and components
  - Stiff alignment stage
  - Low beam height



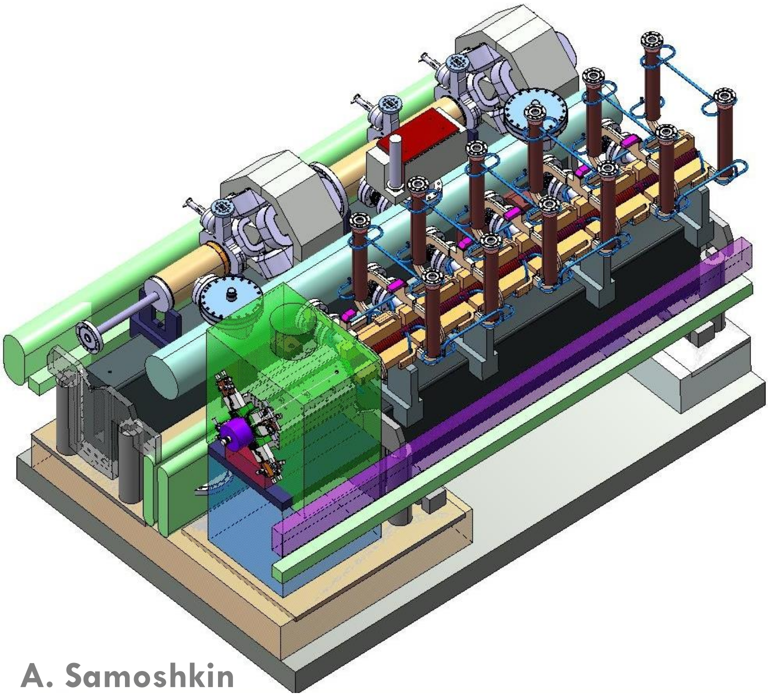
• Vibrations are attenuated in a concrete floor over distance

•Vibrations acting directly on the magnet:

  - Water cooling
  - Vacuum and vacuum pipes
  - Ventilation
  - Acoustic noise

First part STRATEGY: adapt accelerator environment to stability requirements

Other requirements



A. Samoshkin

<u>Stiffness-Robustness</u>

- Applied forces
- Compatibility alignment
- Uncertainty
- (Transportability)

Strategy STIFF support

Ref. Presentation Chr. Collette

<u>Available space</u>

Integration in two beam module

620 mm beam height

<u>Accelerator environment</u>

- High radiation
- Stray magnetic field

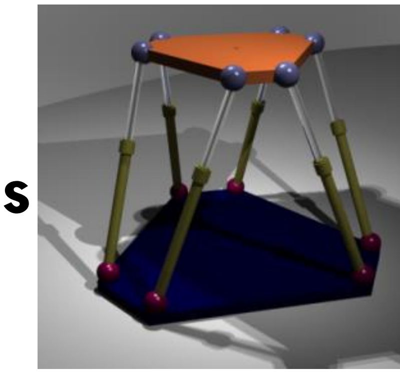
Strategy Support

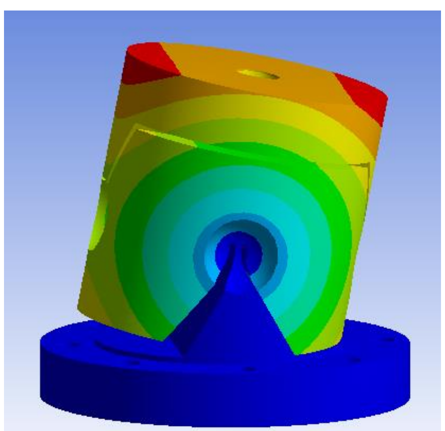
- Stiff structure
- At least four d.o.f.
- Precise motion
- Repeatability
- 0.1 nm resolution vertically

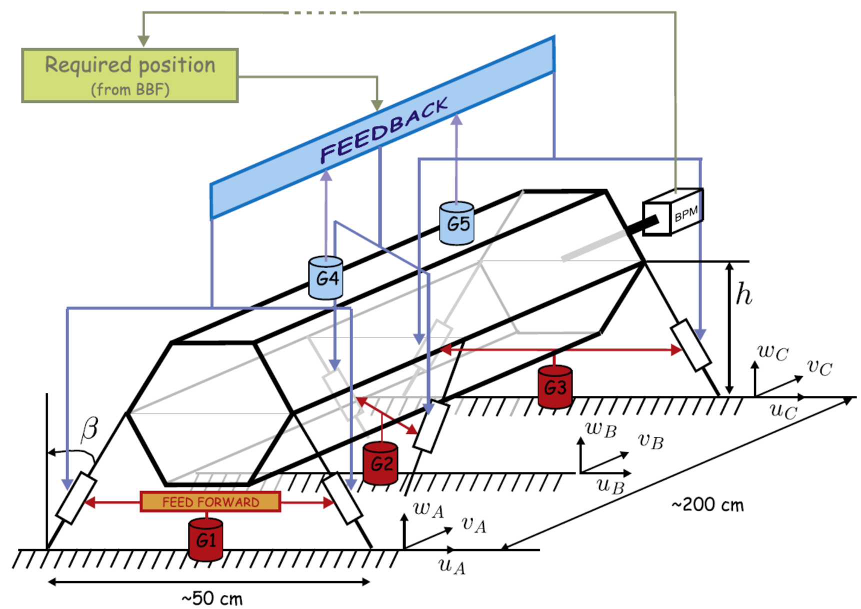
Parallel structure

Stiff piezo actuators

Flexural hinges







Sensors : Seismometers “to get started”

Strategy Support

Structural stiffness ⟷ Induced stresses in piezo

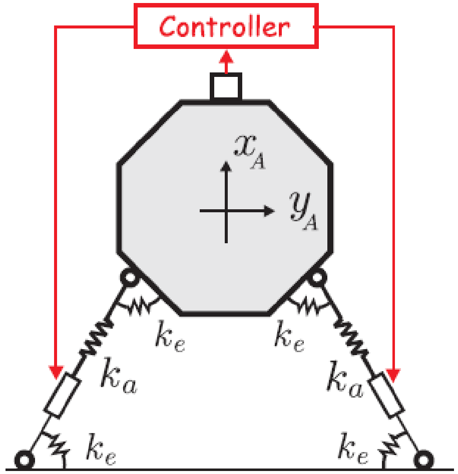
Inclination ⟷ Resolution, structure stiffness, forces

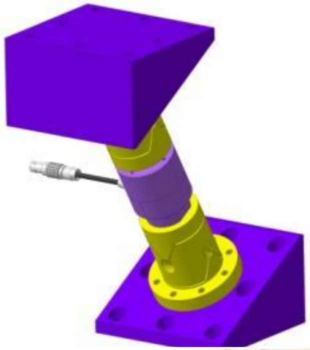
Number ⟷ # D.O.F. , COST
Resonant frequency
Solution 4 types

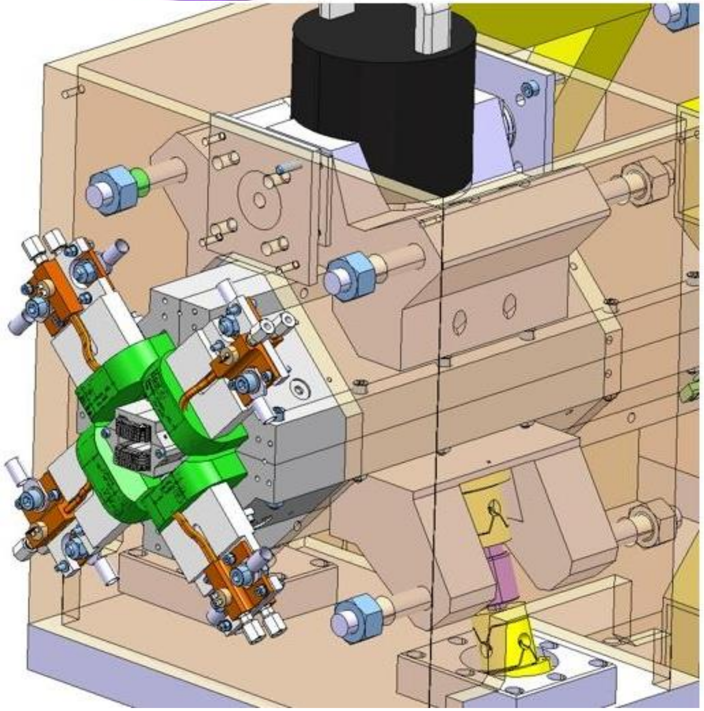
↓

Block longitudinal
Block roll

X-Y flexural guide

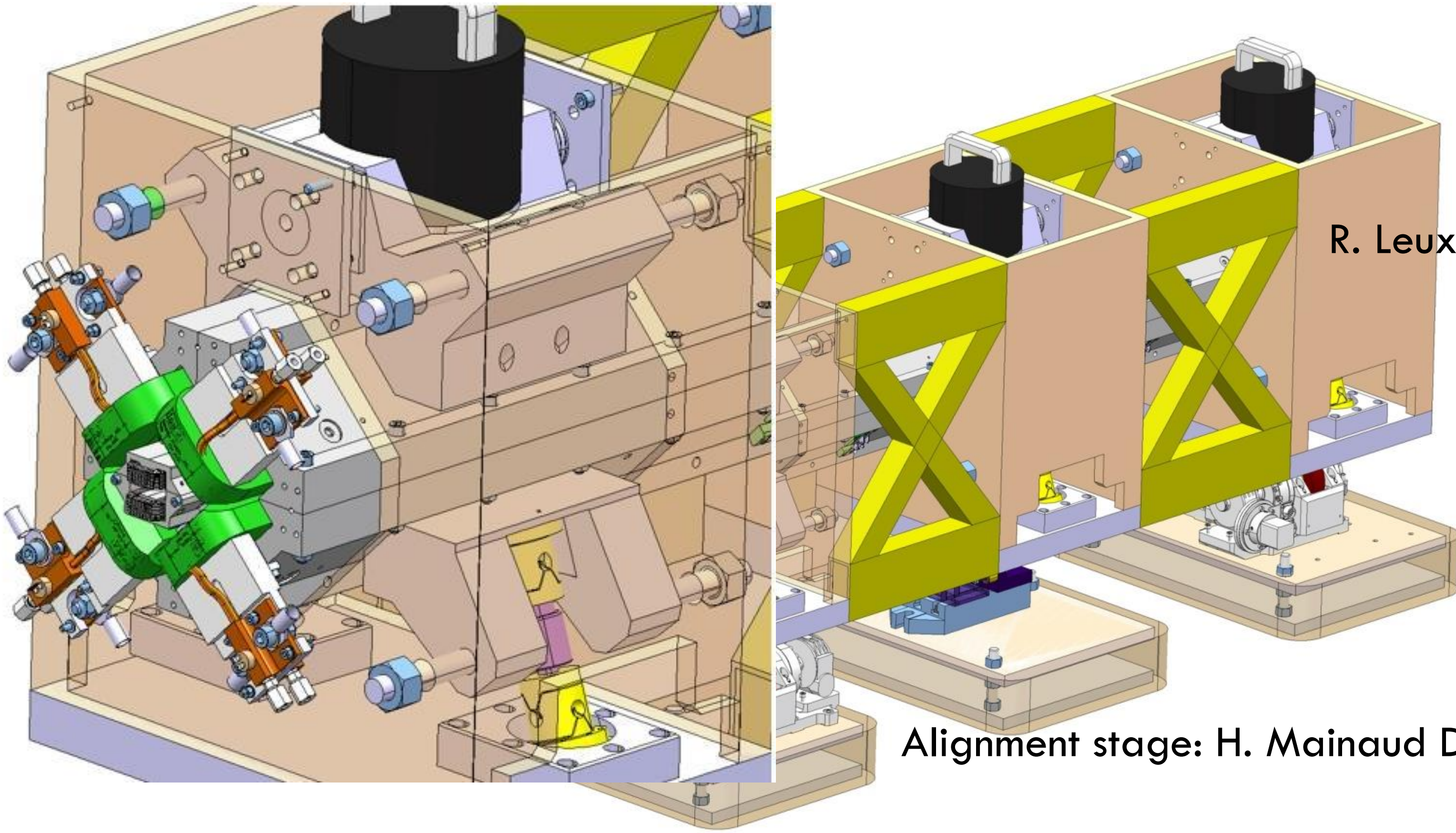






Concept drawing

Type 4



R. Leuxe

Alignment stage: H. Mainaud Durand

Stiff intermediate girder between alignment and stabilisation

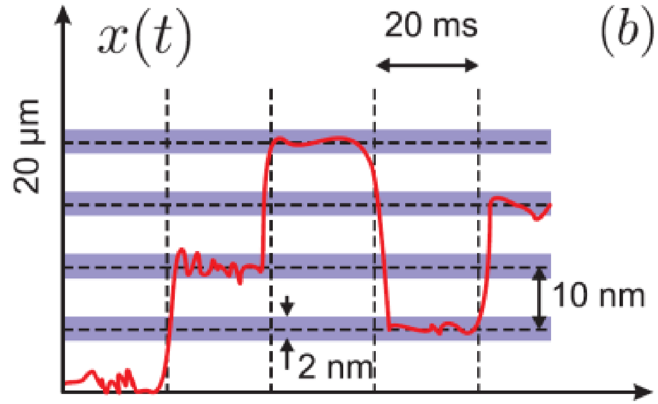
Lockable in longitudinal direction (transport)

Additional objectives

« Nano-positioning» proposal

Modify position quadrupole in between pulses (~ 5 ms)

Range ± 5 µm, increments 10 to 50 nm, precision ± 1nm



•In addition/ alternative dipole correctors

•Increases time to next realignment with cams

Compatible with pre-alignement ??

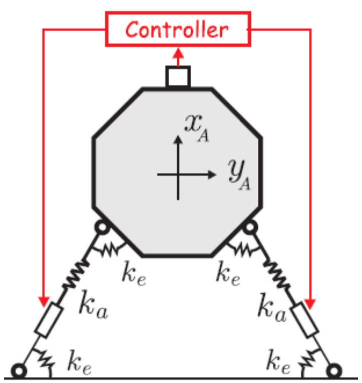
Additional objectives

NANOMETROLOGY and introduction REFERENCE position

- **Measurement of the x-y displacement** with respect to intermediate platform (**fiducials**)

Nanometre resolution

- Instrumentation in actuator legs
- Capacitive gauges in x-x guide
- Optical linear encoders with gratings in x-y guide (Introduction hardware reference position)



4 steps toward demonstration

2010 : 4 steps toward demonstration on MBQ type 4 (+ type 1):

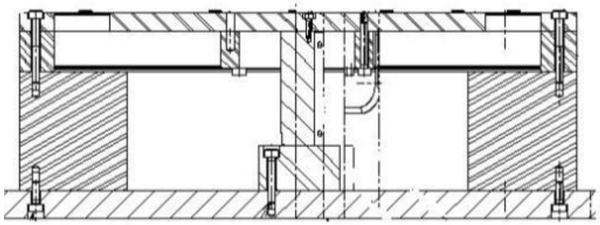
- **1.** Stabilisation **1 d.o.f. with small weight** ("membrane")
- **2.** Stabilisation **1 d.o.f. with type 1 weight** ("tripod")
- **3.** Stabilisation **2 d.o.f. with type 1 weight** ("quadriped")
- **4.** Stabilisation of **type 4 (and type 1)CLIC MB quadrupole proto type**

4 steps toward demonstration

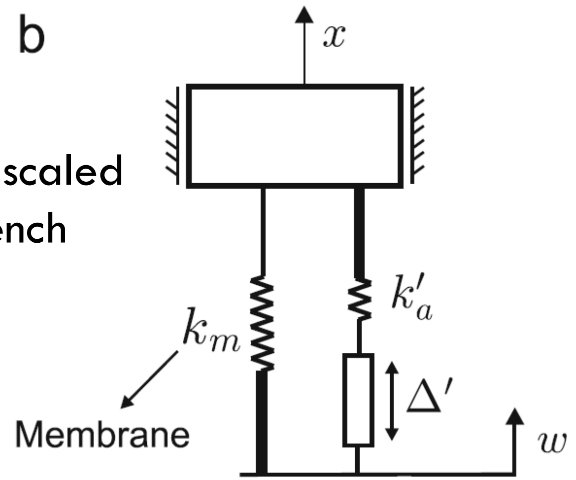
2010 : 4 steps toward demonstration on MBQ type 4 (+ type 1):

- 1. Stabilisation **1 d.o.f. with small weight** ("membrane")
- 2. Stabilisation **1 d.o.f. with type 1 weight** ("tripod")
- 3. Stabilisation **2 d.o.f. with type 1 weight** ("tripod")
- 4. Stabilisation of **type 4 (and type 1)CLIC MB quadrupole proto type**

Step 1: One d.o.f. scaled set-up



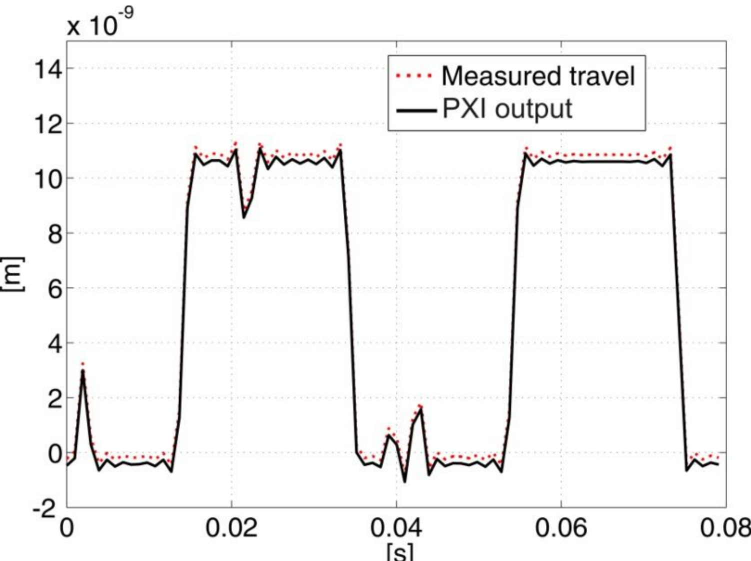
$$\frac{k}{m} = \frac{k'}{m'}$$



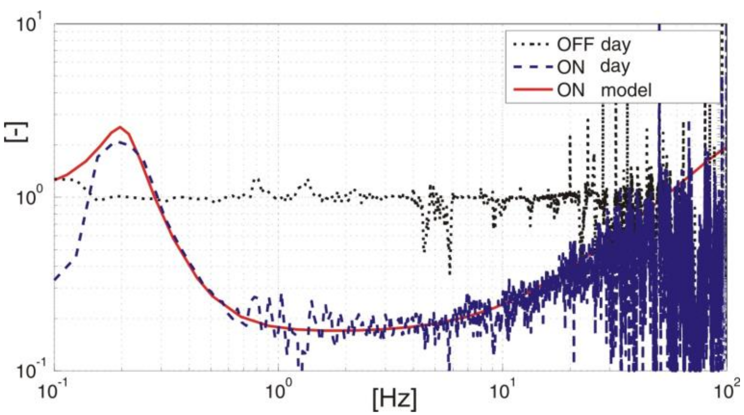
1d.o.f scaled test bench

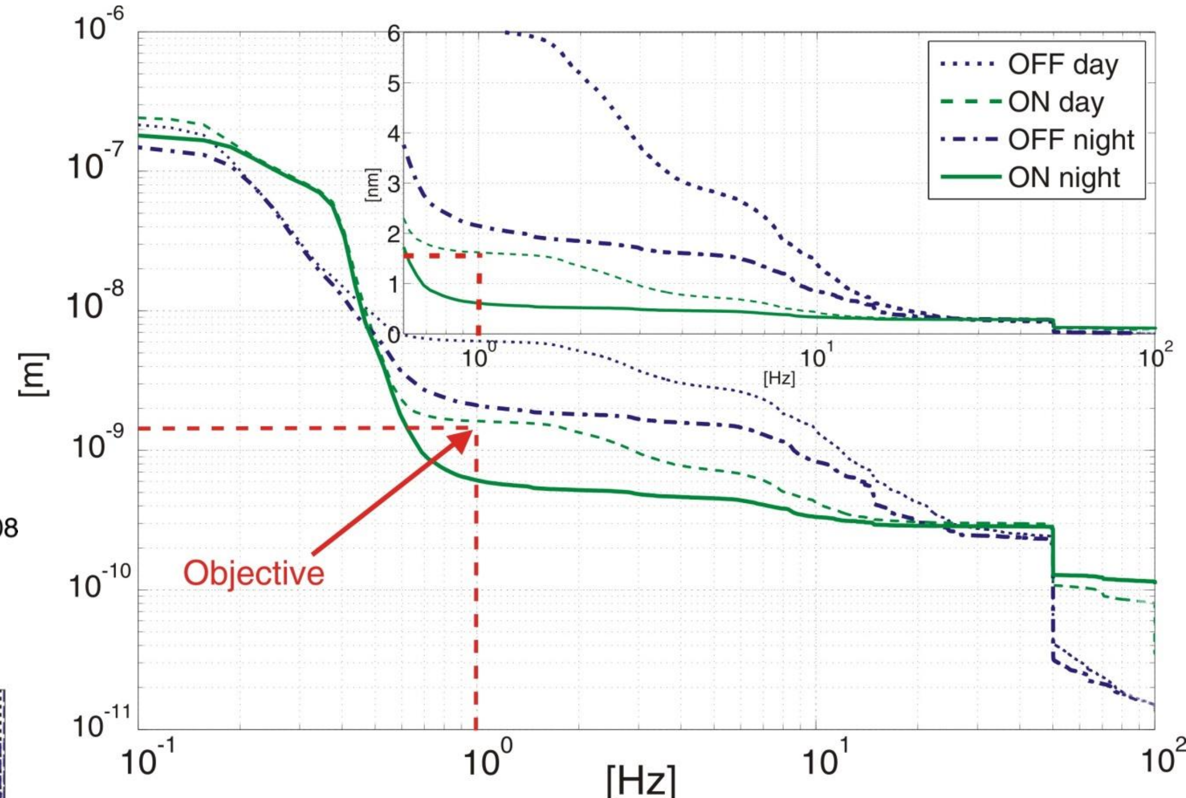
COLLETTE C., ARTOOS K., KUZMIN A., SYLTE M., GUINCHARD M. and HAUVILLER C., Active quadrupole stabilization for future linear particle colliders, *Nuclear instruments and methods in physics research section A*, vol.621 (1-3) pp.71-78 (2010).

Experimental results



Objectives reached





Result: 0.6 nm at 1 Hz from 2.2 nm
day: 1.6 nm from 6.4 nm
0.44 nm at 4 Hz

Controller hardware

Controller: Experimental validation with NI PXI 8106 RT + M series acquisition

Piezo amplifiers

Power supply and conditionners instrumentation

Main requirements:

High resolution (18 bit)
+ Low noise

Short cables + optimisation screening and cable paths

Small latency

Local controllers

Radiation hard

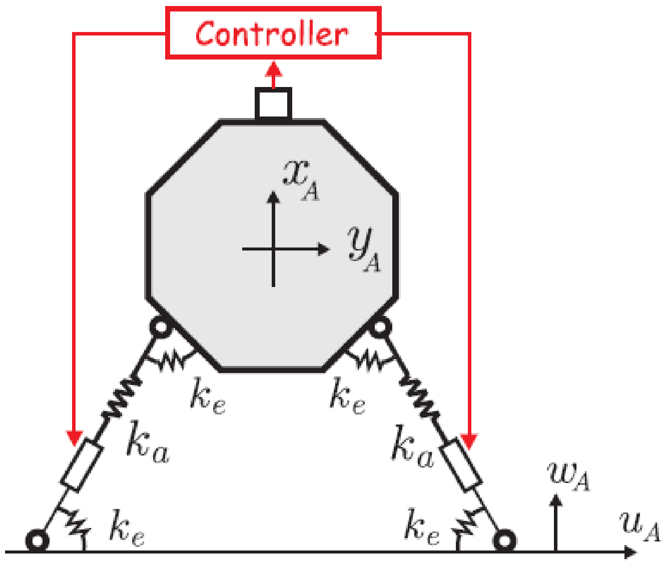
Screened rack space ?

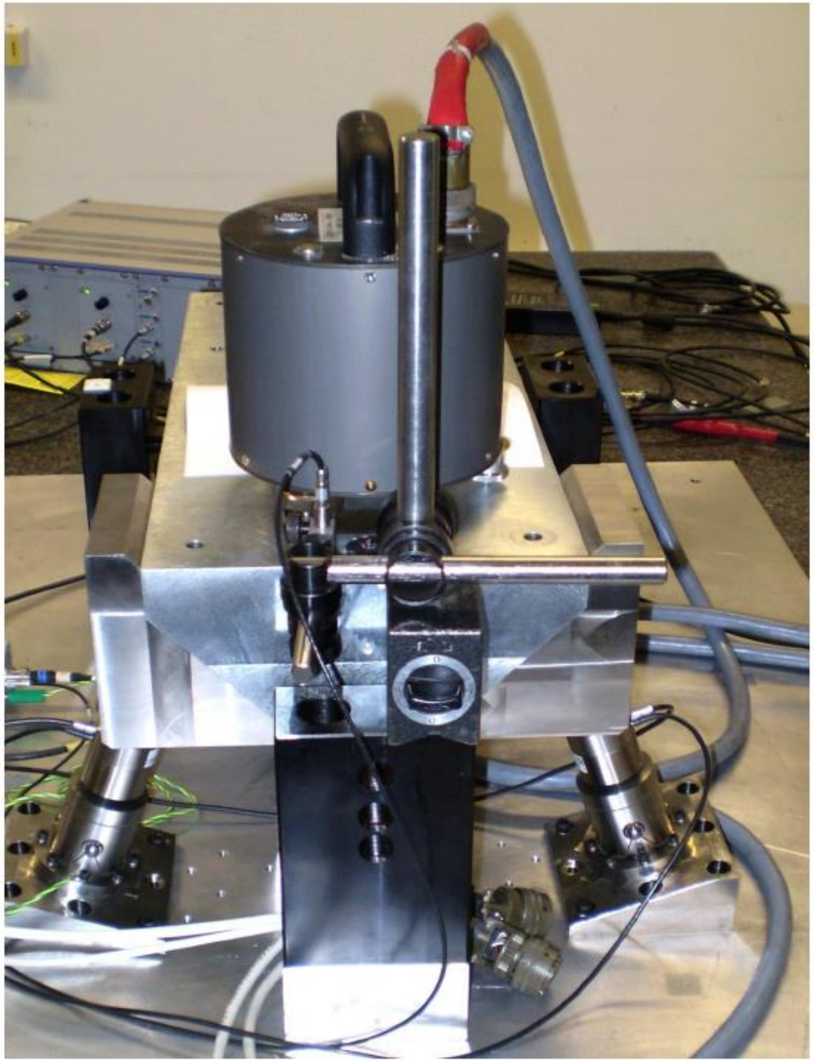
4 steps toward demonstration

2010 : 4 steps toward demonstration on MBQ type 4 (+ type 1):

- 1. Stabilisation **1 d.o.f. with small weight** ("membrane")
- 2. Stabilisation **1 d.o.f. with type 1 weight** ("tripod")
- 3. Stabilisation **2 d.o.f. with type 1 weight** ("tripod")
- 4. Stabilisation of **type 4 (and type 1)CLIC MB quadrupole proto type**

Step 3: 2 d.o.f. with type 1 mass

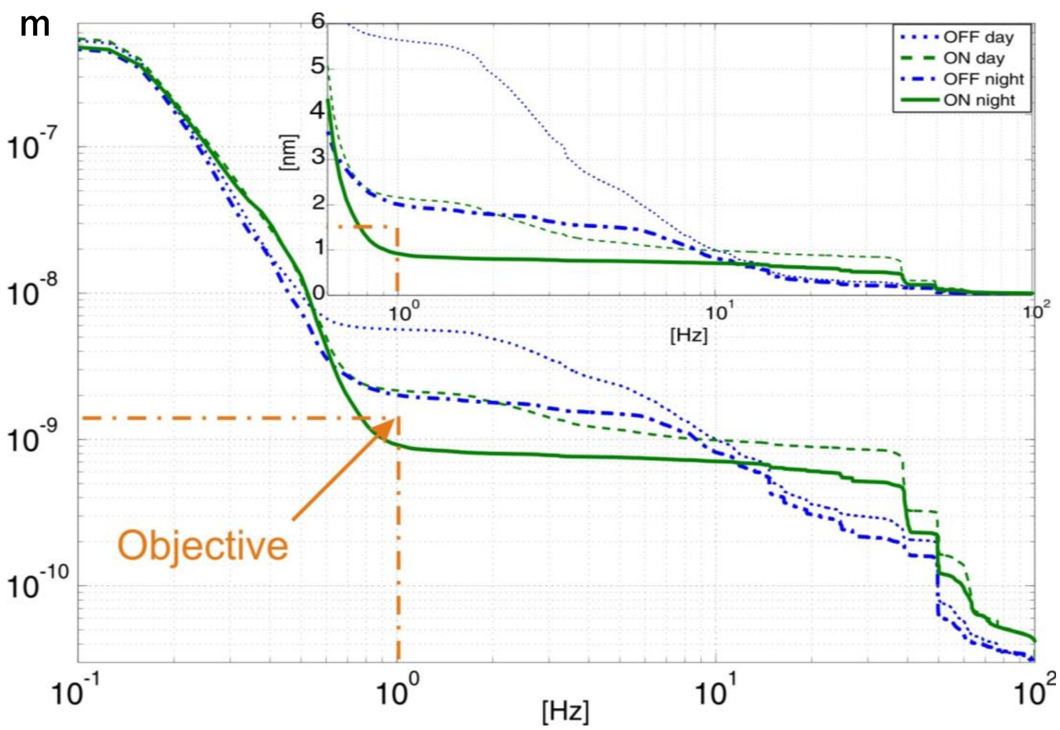




Objectives:

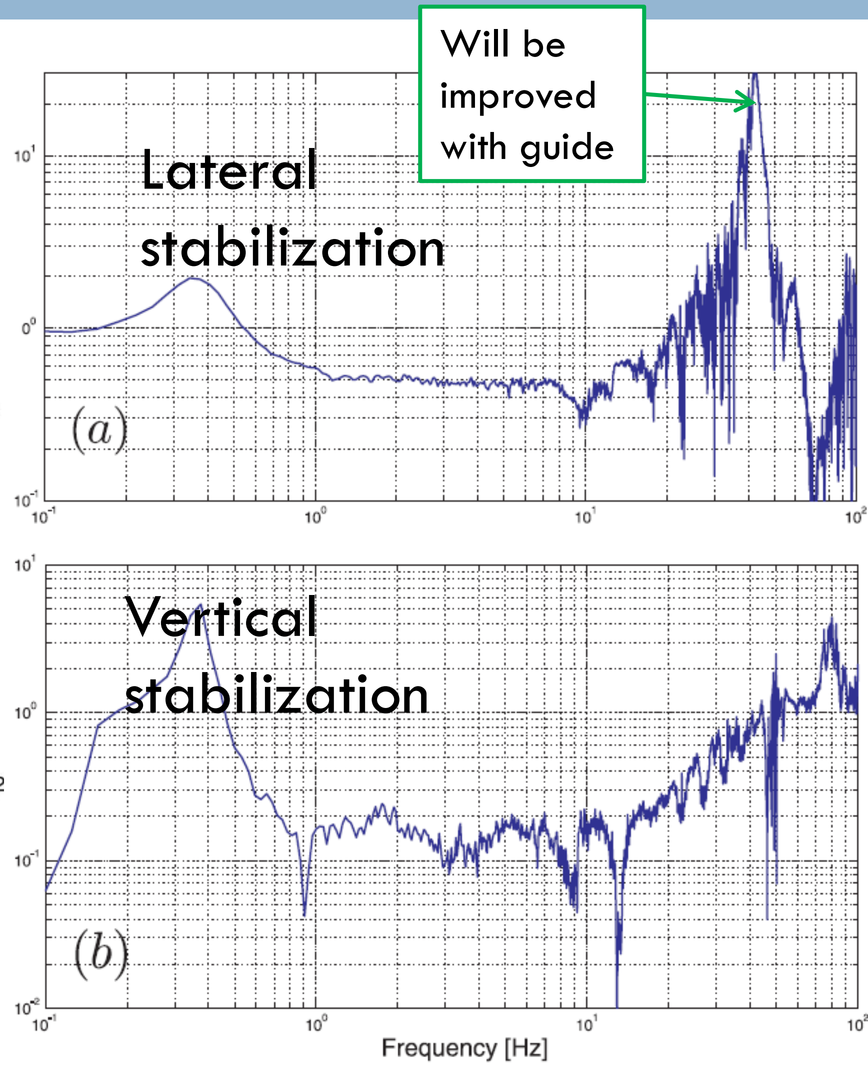
- Validate the strategy and controller in 2 d.o.f.
- Validate flexural hinge design
- Validate Mounting and assembly issues
- Validate nano positioning in 2 d.o.f.

Stabilization in 2 d.o.f.

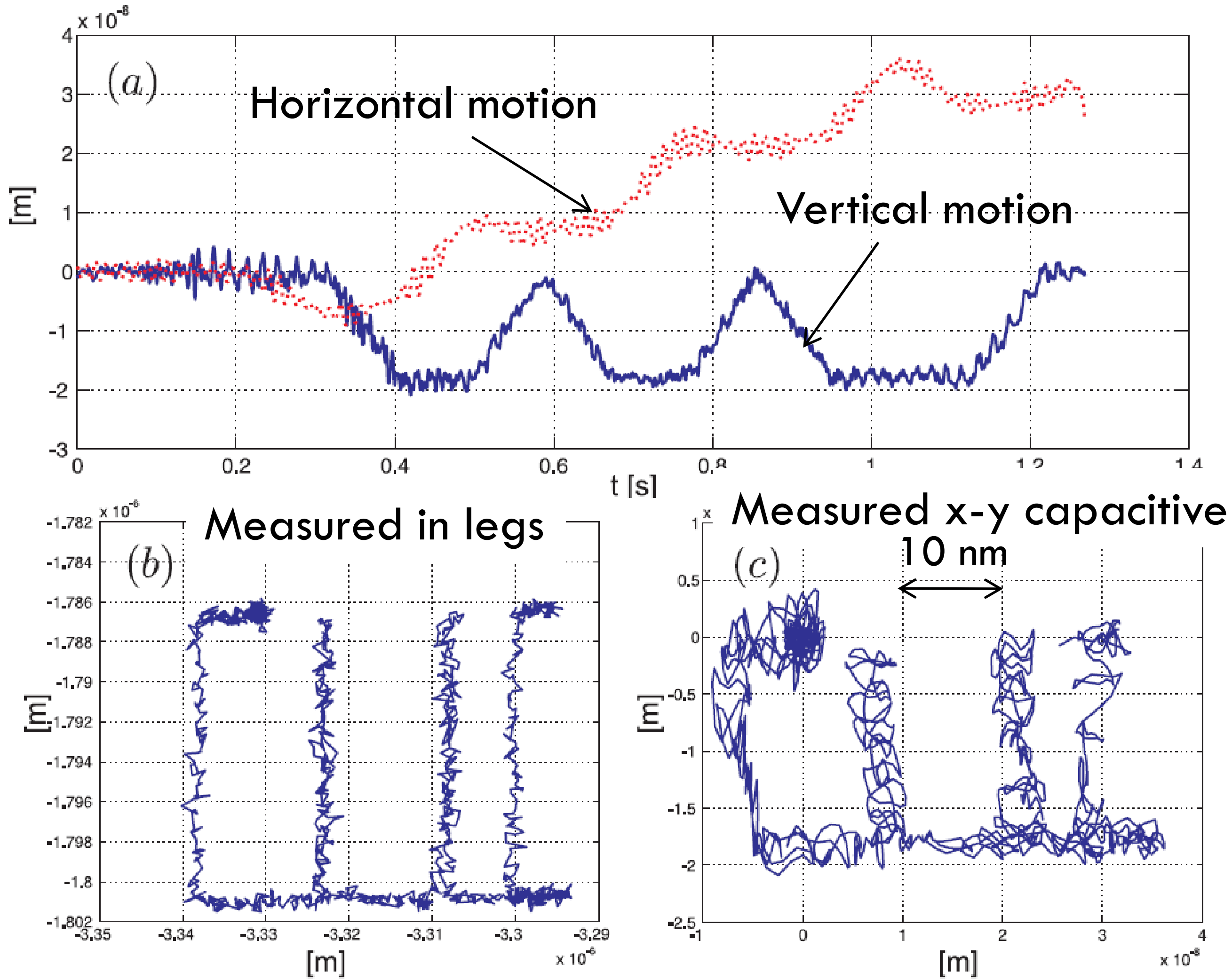


0.9 nm at 1 Hz

Can be improved still.



Positioning in 2 d.o.f.



Conclusions

- With STRATEGY **STIFF** stabilisation support based on parallel piezo actuator structure:
- We DEMONSTRATED in a **model** and on **test benches**

the **technical feasibility** to stabilise better than the required level at 1Hz in two d.o.f., from levels that were characterised in a running accelerator in a deep tunnel (LHC). This **with commercially available components.**

- We demonstrated **nano positioning** in two d.o.f.
- We have a concept design of the stabilisation support based on the validated actuator pair with flexural hinges.
- Compatible with module requirements and alignment and robust against external forces

Future work

- Characterise further the technical noise and propagation in CLIC test modules + test water cooling on MBQ
- Implement the concept design for the stabilisation support + optimise for each magnet type (#legs>cost)
- Improve the stabilisation controller and sensor: stability and resolution, see talk Chr. Collette
- Adapt and test in accelerator environment + with independent demonstrator (optical, with beam)
- Through collaborations

Thank you!

Publications last 6 months (1/2)

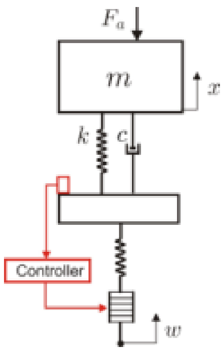
- COLLETTE C., ARTOOS K., KUZMIN A., SYLTE M., GUINCHARD M. and HAUVILLER C., Active quadrupole stabilization for future linear particle colliders, *Nuclear instruments and methods in physics research section A*, vol.621 (1-3) pp.71-78 (2010).
- COLLETTE C., ARTOOS K., GUINCHARD M. and HAUVILLER C., Seismic response of linear accelerators, *Physical reviews special topics – accelerators and beams* vol.13 pp. 072801 (2010).
- ARTOOS K., COLLETTE C., GUINCHARD M., JANSSENS S., KUZMIN A. and HAUVILLER C., Compatibility and integration of a CLIC quadrupole nano-stabilization and positioning system in a large accelerator environment, *IEEE International Particle Accelerator Conference IPAC10*, 23-25 May 2010 (Kyoto, Japan).
- ARTOOS K., COLLETTE C., GUINCHARD M., JANSSENS S., LACKNER F. and HAUVILLER C., Stabilisation and fine positioning to the nanometer level of the CLIC Main beam quadrupoles, *IEEE International Particle Accelerator Conference IPAC10*, 23-25 May 2010 (Kyoto, Japan).
- COLLETTE C., ARTOOS K., JANSSENS S. and HAUVILLER C., Hard mounts for quadrupole nano-positioning in a linear collider, *12th International Conference on New Actuators ACTUATOR2010*, 14-16 May 2010 (Bremen, Germany).

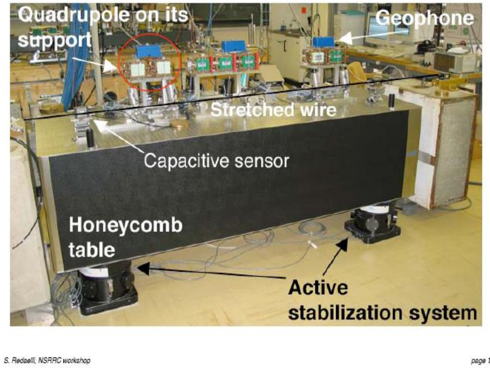
Publications last 6 months (2/2)

- COLLETTE C., JANSSENS S., ARTOOS K. and HAUVILLER C., Active vibration isolation of high precision machine (keynote lecture), *6th International Conference on Mechanical Engineering Design of Synchrotron Radiation Equipment and Instrumentation (MEDSI 2010)*, 14 July 2010 (Oxford, United Kingdom).
- COLLETTE C., JANSSENS S., ARTOOS K., GUINCHARD M. and HAUVILLER C., CLIC quadrupole stabilization and nano-positioning, *International Conference on Noise and Vibration Engineering (ISMA2010)*, 20-22 September 2010 (Leuven, Belgique).
- JANSSENS S., COLLETTE C., ARTOOS K., GUINCHARD M. and HAUVILLER C., A sensitiviy analysis for the stabilization of the CLIC main beam quadrupoles, *Conference on Uncertainty in Structural Dynamics*, 20-22 September 2010 (Leuven, Belgique).
- FERNANDEZ-CARMONA P., COLLETTE C., JANSSENS S., ARTOOS K., GUINCHARD M., KUZMIN A., SLAATHAUG A., HAUVILLER C., Study of the electronics architecture for the mechanical stabilization of the quadrupoles of the CLIC linear accelerator, Topical Workshop on Electronics for Particle Physics TWEPP 2010, 20-24 September 2010 (Aachen, Germany).

Spares

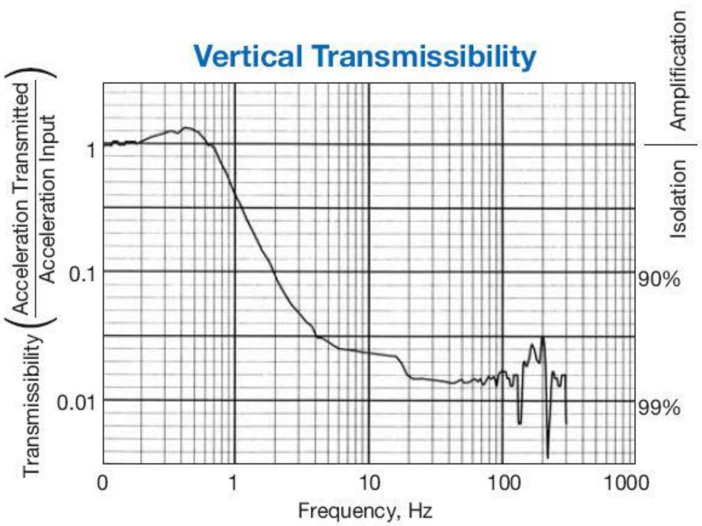
Previous performances on stabilization of accelerator components

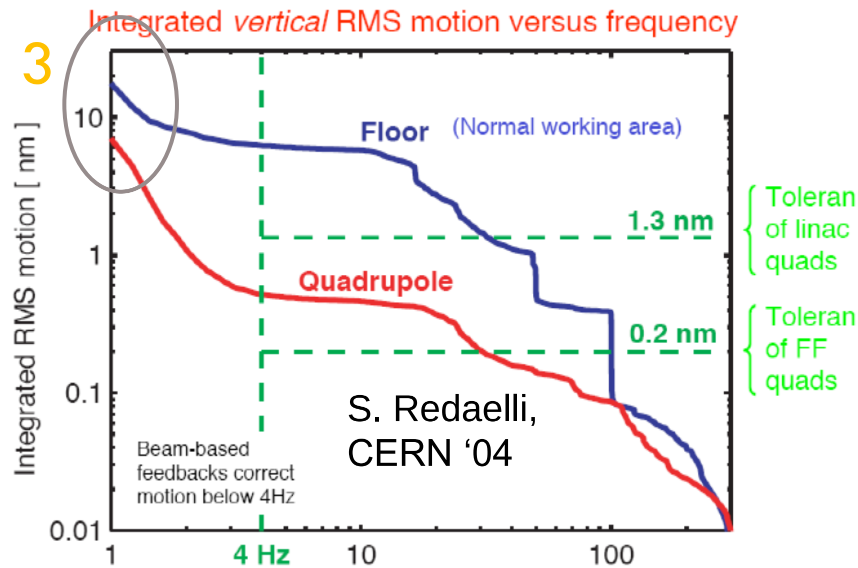


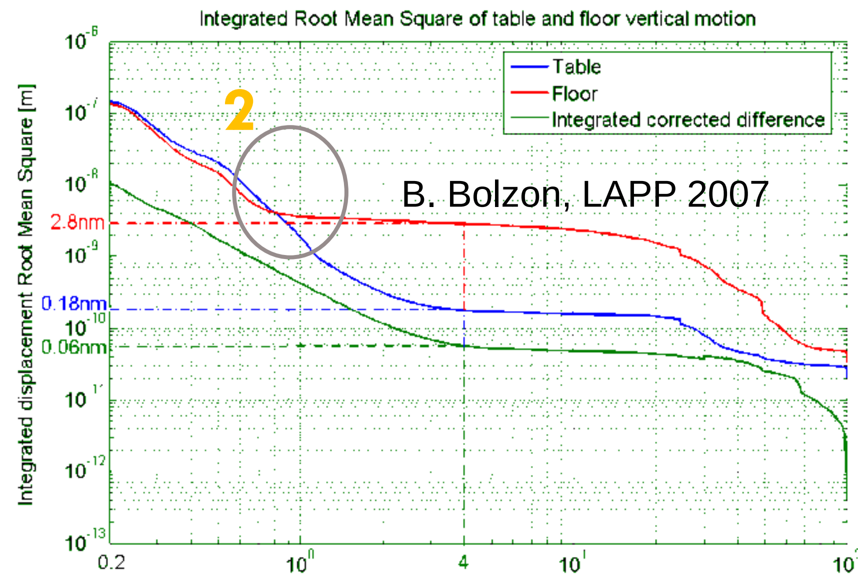


TMC STACIS™

TMC table:
Stiffness: 7 N/µm (value catalogue)







Previous performances on stabilization of accelerator components

C. Montag, DESY 1996