CLIC08 Workshop

CERN, 14-17 October 2008

News from the Stabilization Working Group

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CERN

The Stabilization Working Group

- Stabilization work for CLIC started beginning of the century, then stopped at CERN due to LHC priority. Kept alive at LAPP. CERN is now back.
- Working group established beginning 2008 in the framework of the CLIC Technical Committee
- Collaboration between institutes
- Face-to-face meetings every 3 months
- Chairman: Claude Hauviller

- http://clic-study.web.cern.ch/CLIC-Study/CLIC_Stabilisation/Index.htm

Organization

- Collaboration: Laboratories participating (to-date):
  - LaViSta (LAPP, Universite de Savoie-SYMME)
  - CERN (TS, AB)
  - JAI- Oxford University
  - CEA-DSM-IRFU-SIS
  - Information from DESY, SLAC, PSI?
  - Potential contacts with universities

MONALISA IRFU/SIS

Tasks defined in the mandate

- Demonstrate 1nm quadrupoles stability above 1Hz *(Linac)* *(going below 1Hz would be appreciated)*
- Demonstrate or provide evidence of 0.1nm stability above 5Hz *(Final Focus)*
- Differences compared to previous studies
  - 0.1 nm is beyond what we have shown
  - apply stabilization in an accelerator environment (e.g. 2BTS)
  - achieve 1nm with realistic equipment (a complete system), not simple elements on a special table
  - verify performance with (two) different methods
- Characterize vibrations/noise sources in an accelerator
- Compatibility with alignment
- Sensitivity to relaxed specifications

CLIC stabilization requirements

- Mechanical stabilization requirements:
  Quadrupole magnetic axis vibration tolerances:

	Final Focus quadrupoles	Main beam quadrupoles
Vertical	0.1 nm > 4 Hz	1 nm > 1 Hz
Horizontal	5 nm > 4 Hz	5 nm > 1 Hz

- Main beam quadrupoles to be mechanically stabilized:
  - A total of about 4000 main beam quadrupoles
  - 4 types
  - Magnetic length from 350 mm to 1850 mm
- Mechanical stabilization might be On at some quads and Off of some others

Actions list (keywords)

- Sensors
- Characterize vibrations/noise sources in an accelerator
- Actuators
- Feedback
- Overall design + analysis
- Integrate and apply to Linac

Sensors

<u>Program of work</u>

– Develop and test sensors
– Qualification with respect to EMC and radiation
– Calibrate by comparison.
  - Interferometer to calibrate other sensors (at OXFORD).
  - Create a reference test set-up (at CERN)
– State of the art of sensor development and performances by end of 2008 (to be updated on a yearly basis)

Sensors

How to measure vibrations/ dynamic displacements with amplitudes of 0.1 nm?

- **Seismometers** (geophones) Velocity
- **Accelerometers** (seismic - piezo) Acceleration

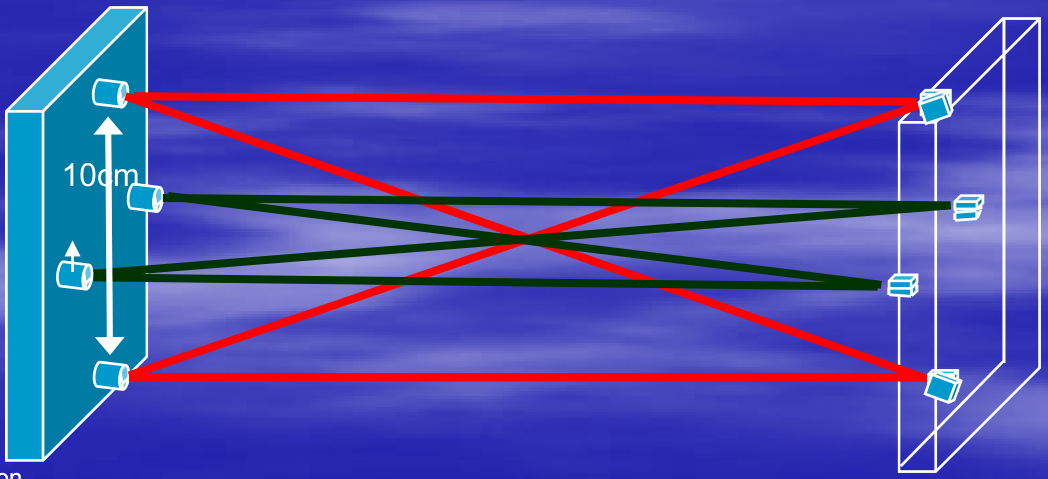



Streckeisen STS2	Guralp CMG 3T	Guralp CMG 40T	Guralp CMG 6T	Eentec SP500	PCB 393B31
x,y,z	x,y,z	x,y,z	x,y,z	z	z
				electrochemical	
2*750Vs/m	2*750Vs/m	2*800Vs/m	2*1000Vs/m	2000Vs/m	1.02Vs²/m
120 s -50 Hz	360s -50 Hz	30 s -50 Hz	30s-80Hz	60 s -70 Hz	10 s -300 Hz
13 kg	13.5 kg	7.5 kg		0.750 kg	0.635 kg

Improved performances
Lab environment

Sensors

- Optical sensors
  - Vibrometer
    Supplier Polytec; found at CERN
    Under performances qualification
  - Interferometer (measures displacement)
    - Various options under study (CEA)
    - “Optical transducer” under development with precision of 1pm at 1Hz
    - Compact Straightness Monitor MONALISA at Oxford



- 6D position transferred from left to right
  - breaking of symmetries is important
- Preliminary simulation results of CSM Resolution:
  - σ_y:10nm
  - distance meter resolution: 1nm = Resolution in z-direction
  - Positional change of optics components with respect to each other: 1nm.

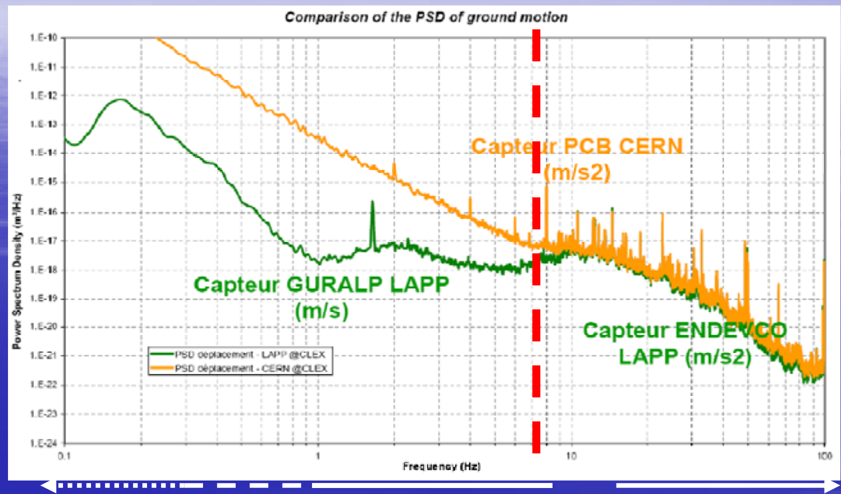
Sensors

Characterization for low intensity signals:

Sensitivity + resolution

Cross axis sensitivity,

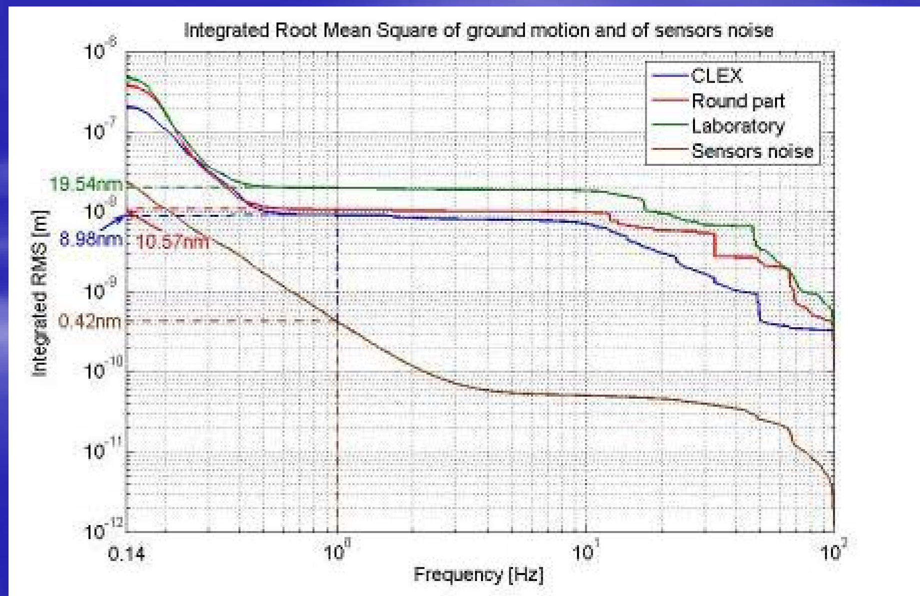
Noise level, « self noise » measurement (ex. blocking the seismic mass or by coherence)



Signal processing: Resolution, filtering, window, FFT, DSP, integration, coherence >>

Can give values < sensor resolution

Characterization of measurement method: fix a standard



Characterize vibrations/noise sources in an accelerator and detectors

- <u>Program of work</u>
  - Summary of what has been done up to now (several studies done by DESY, SLAC, LAViSta, CERN)

    Large number of measurements done for years in many places including third generation light sources. Critical analysis of the results based on sensors and methodologies. Pertinence for CLIC ? Qualification of labs (quiet enough?)

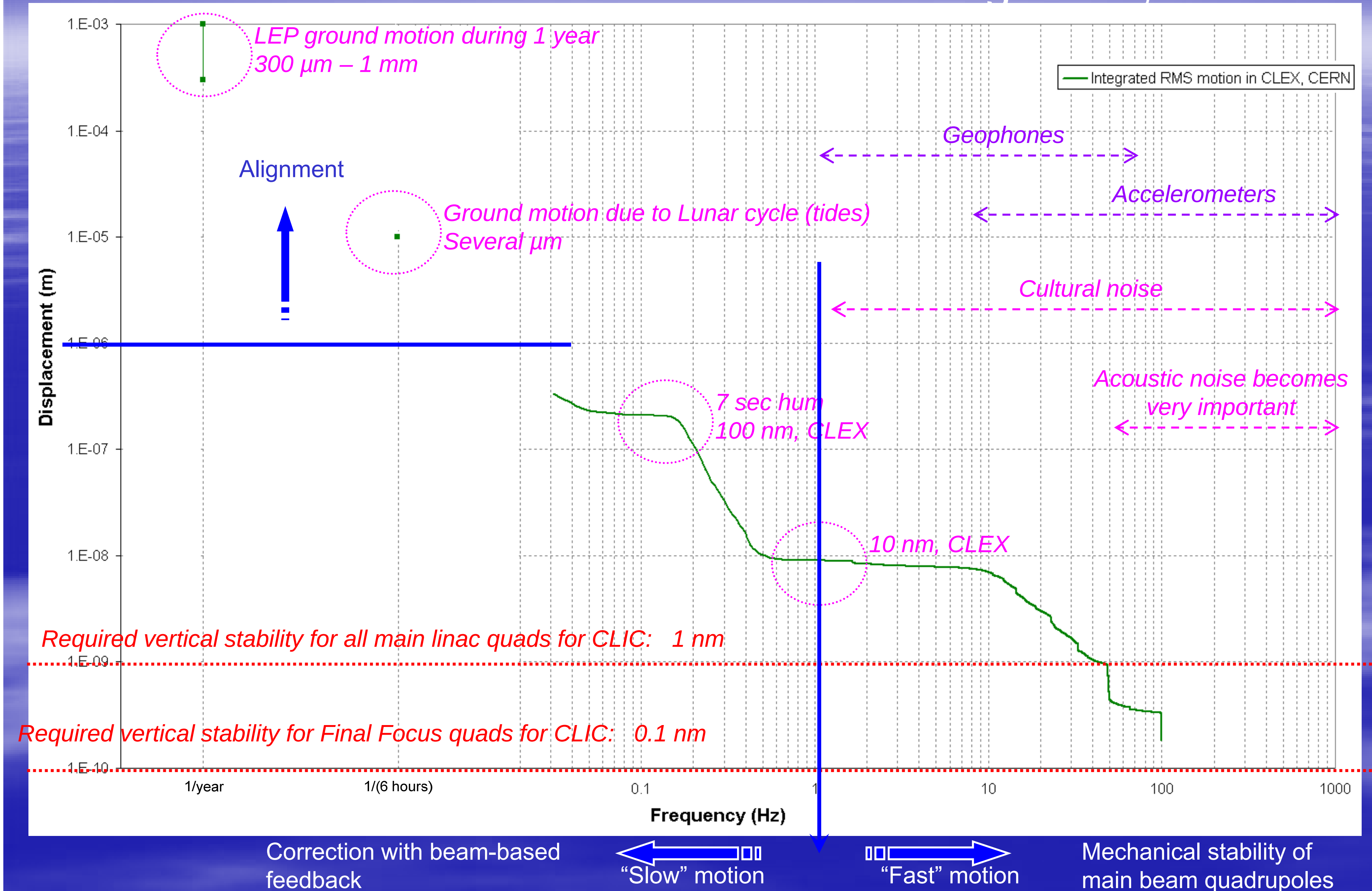
  - Additional correlation measurements to be done at LHC interaction regions for distances of ~ 100m

    Done this summer. Under analysis.

    Presented by Kurt Artoos at this session.

  - Continue measurements in CLEX environment at different installation phases

Environmental vibration levels – orders of magnitude, CERN site



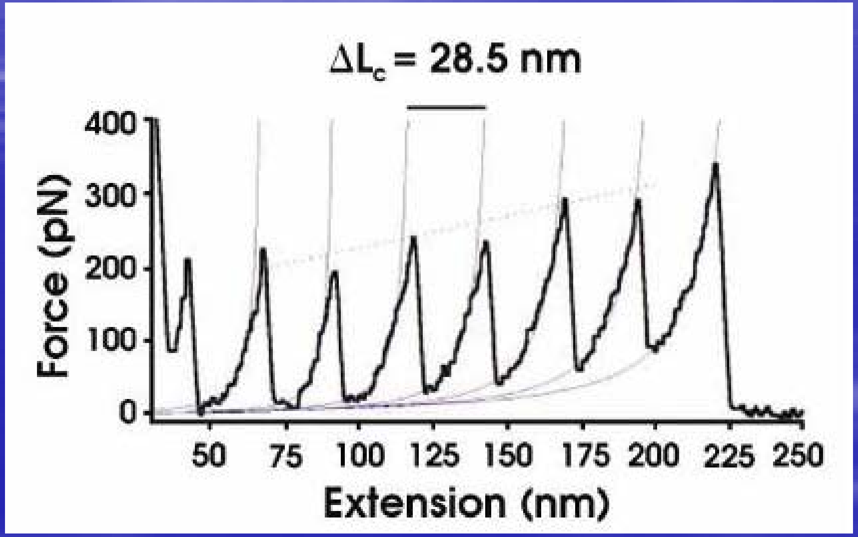
Actuators

<u>Program of work</u>

- State of art of actuators development and performances by end of 2008 (to be updated on a yearly basis)
- Develop and test various damping techniques (passive and active)

Actuators

Stabilized structures and Piezo-actuators with resolution of 0.05 nm exist!



Fernandez Lab, Columbia University NY
Traction test on a protein

But only for few kg et rigid objects....

Techniques to be developed for heavier (up to 400Kg) and larger structures (up to 2 meter long)

Actuators

Usable actuators with 0.1 nm resolution?

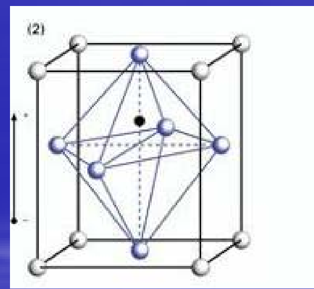
Resolution but also movement reproducibility?

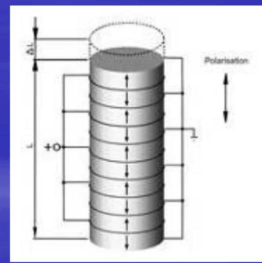
Friction Guiding systems with friction	→ Real resolution limited to 1 µm (0.1 µm)

<u>Solution under development:</u> Piezo actuators PZT

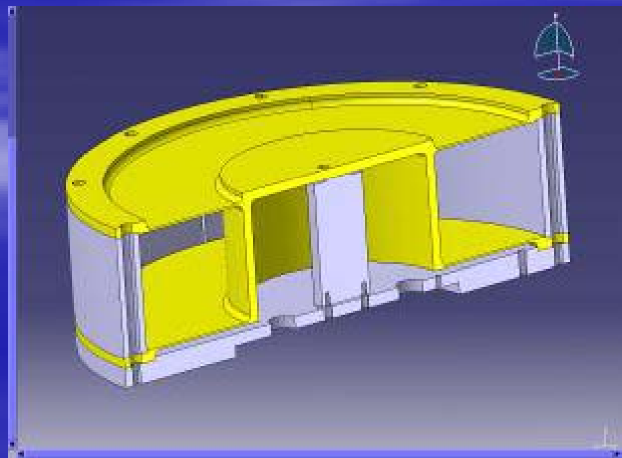
+ flexural guides

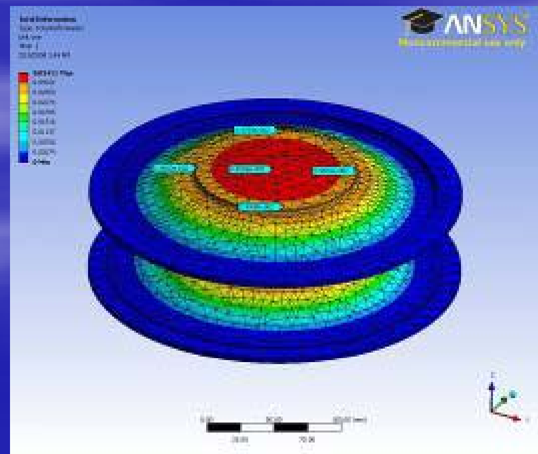
+ feedback capacitive sensor





0.1 nm 100 N Calibration bench flexural guides

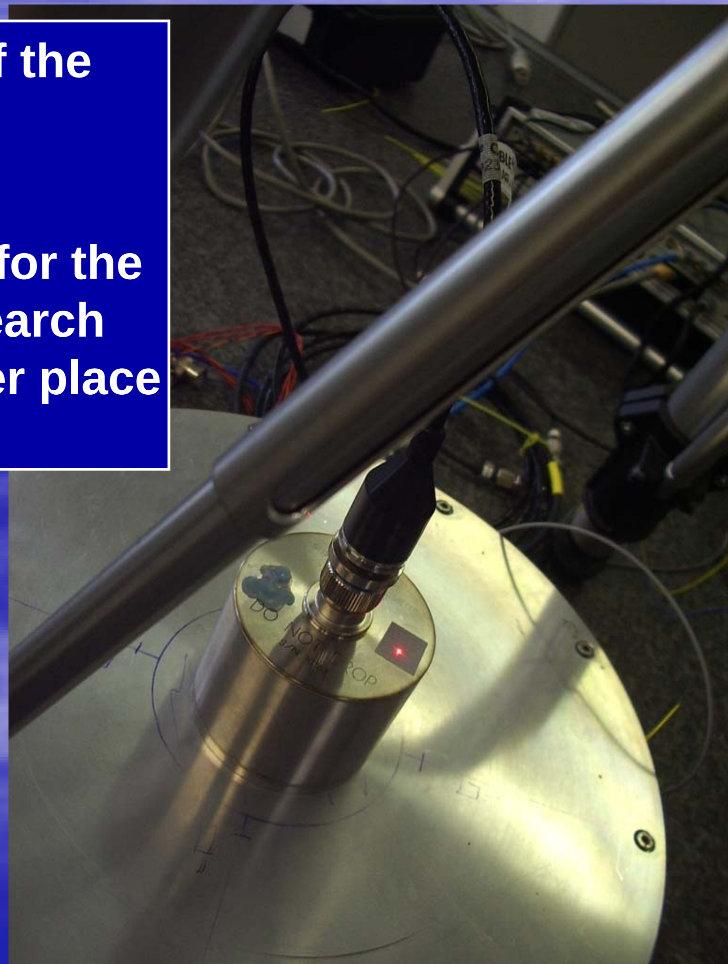




Actuators

Recent calibration of the new actuator with a vibrometer

Our lab is too noisy for the nanometer range: search going on for a quieter place at CERN



Feedback

Program of work

- Develop methodology to tackle with multi degrees of freedom (large frequency range, multi-elements)

  LAViSTa demonstrated feasibility on models

  Similar problems elsewhere like the adaptative optics of the European ELT

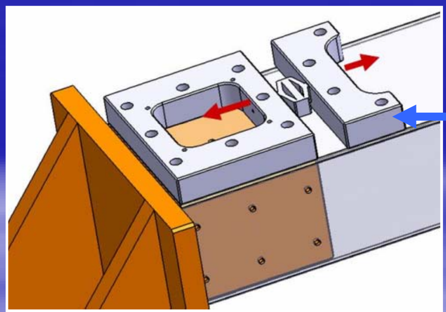
- Apply software to various combinations of sensors/actuators and improve resolution (noise level)

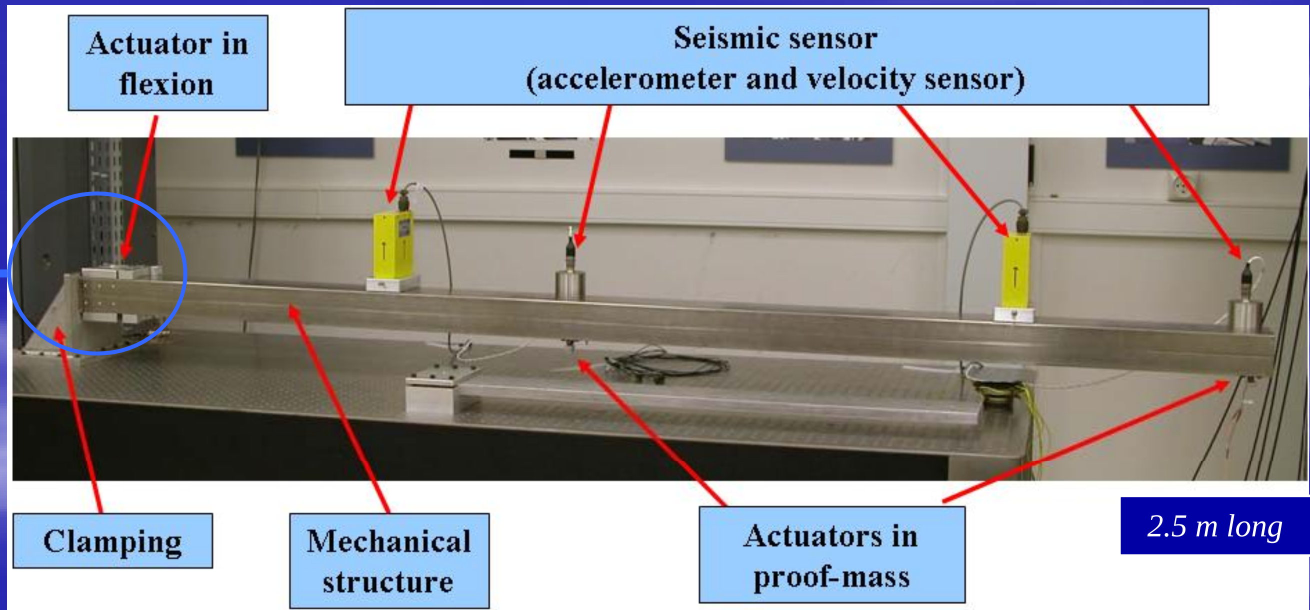
  High quality acquisition systems at LAViSTa and CERN

Feedback

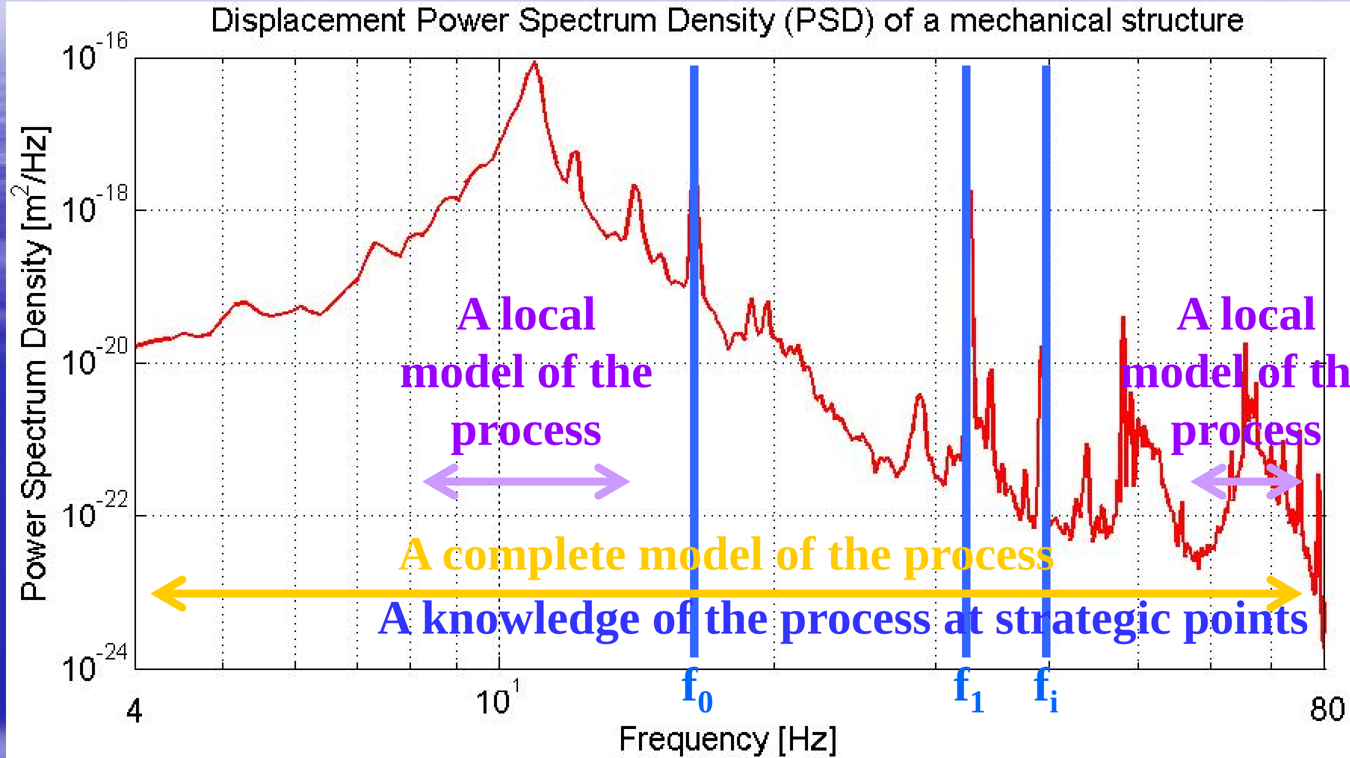
Active rejection of canteliver beam resonances: home-made

Mechanical structure and its instrumentation





Feedback



1 - A knowledge of the structure at strategic points : ***for lumped disturbances***

2 - A local model of the structure : ***for the disturbances amplified by eigenfrequencies.***

3 - A complete model of the structure : ***for the entire structure***

Overall design

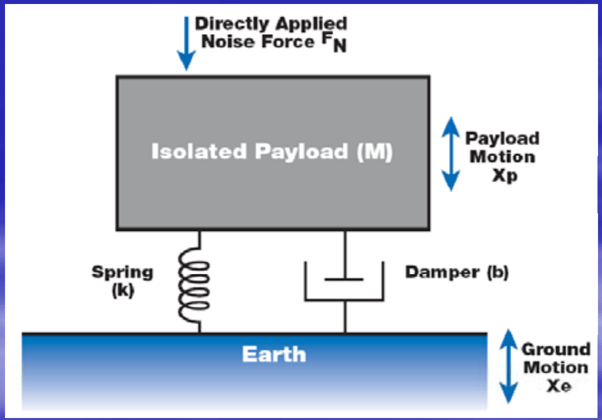
Program of work *(as defined in March 2008)*

- Linac (a demonstrator mock-up will be built)
  - Compatibility of linac supporting system with stabilization (including mechanical design): eigenfrequencies, coupling between girders, coupling of mechanical feedback with beam dynamics feedback,…
  - Design of quadrupole (we have to stabilize the magnetic axis) mock-up will have “real” physical dimensions and all mechanical characteristics but not the field quality required by CLIC
- Final focus (no dedicated mock-up for FF will be done (?) - special features to be integrated in the Linac mock-up)
  - Integration of all the final focus features: types of supporting structures, coupling with vertex detector, forward detectors,…

Overall design

Build the complete supporting system including the magnet and the pre-alignment

A simple stand-alone model



$$\omega_0 = \sqrt{\frac{k}{M}}$$

Natural frequency

$$\xi = 2Q$$

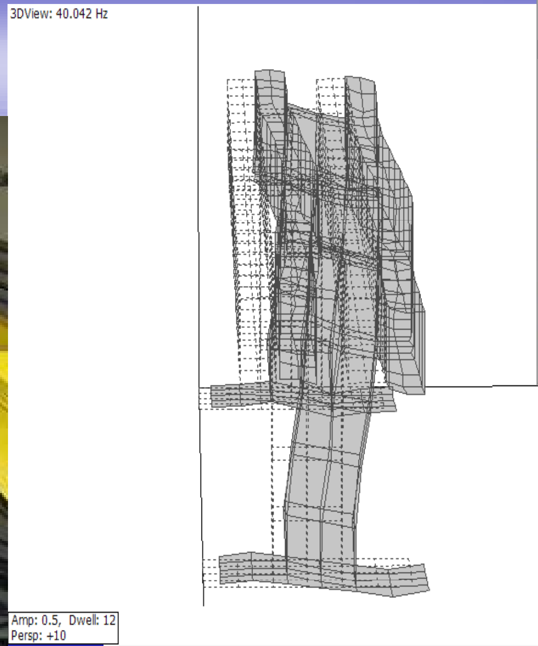
Structural damping

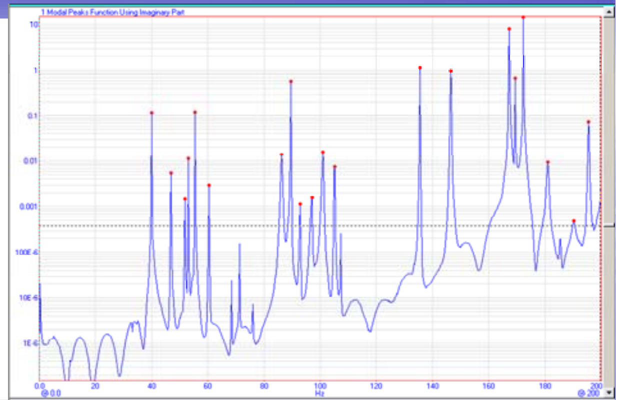
Supporting presented by Friedrich Lackner at this session

Overall design

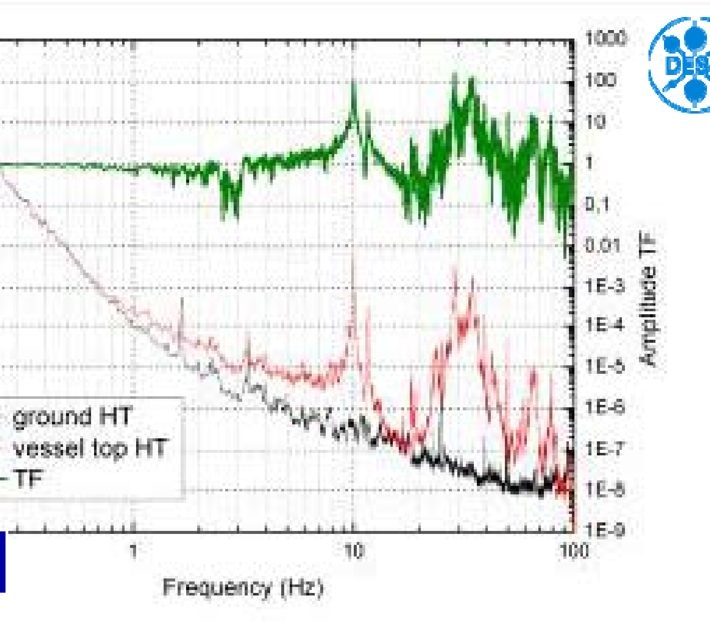
Support design

Multi degrees of freedom and several deformation modes with different structural damping





Experimental modal analysis on CLEX girder



Amplification of floor movement

Overall design

A way to avoid amplification

Table fixed on one entire face to the floor

Honeycomb table

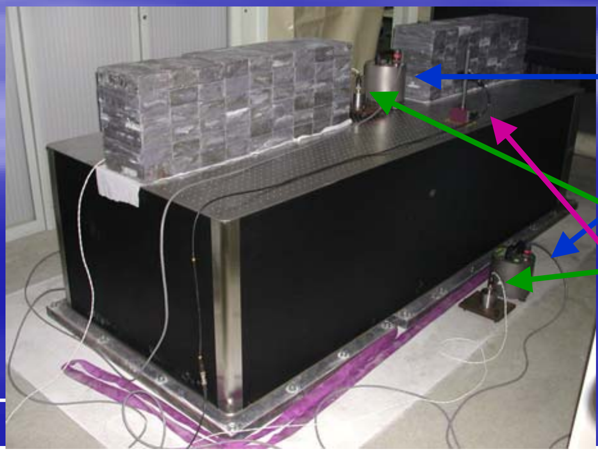
Bees wax

3 steel plates bolted to the floor

Space between plates to move the table with slings

Bees wax: can be unglued, stable in time, insensitive to radiation

Evolution of resonances with masses simulating FD weight



GURALP geophones (0.033Hz - 13Hz)

ENDEVCO 86 accelerometers (13Hz - 100Hz)

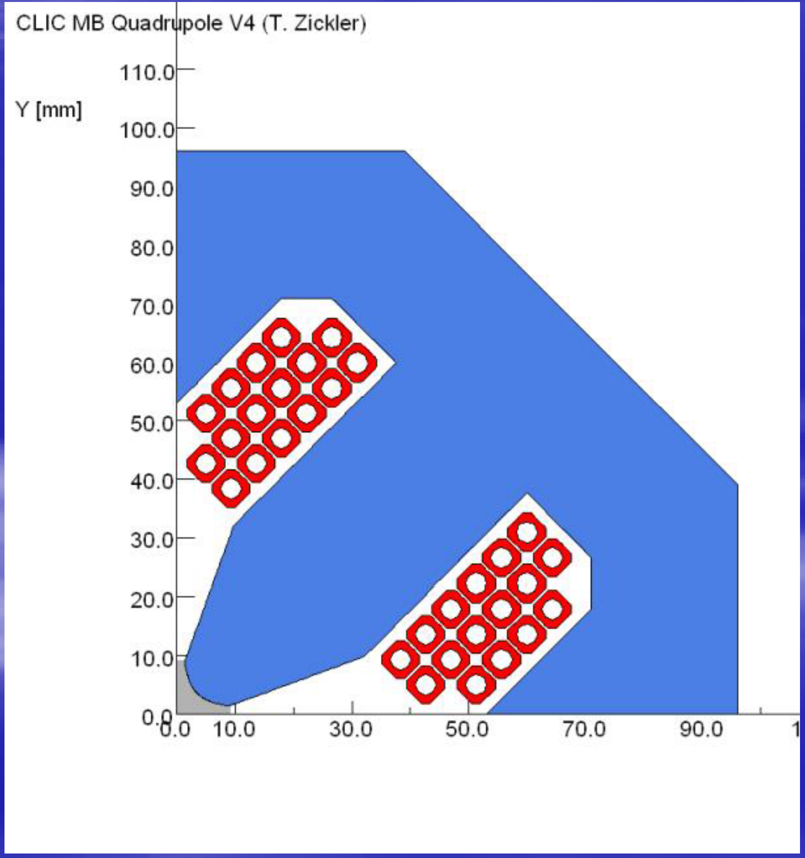
Microphone of type 4189

Overall design

Quadrupole design *Presented yesterday by Thomas Zickler*

Magnetic Design :

Long and slim: Magnetic length up to 1850 mm and width < 200 mm



Some of the points to be looked at:

- Movements of the pole tips and field quality
- Water-induced vibrations
- Overall stability
- External support…

Integrate and apply to Linac

Program of work *(as defined in March 2008)*

– A mock-up should be ready to provide results by June 2010 with several types of sensors including interferometers (intermediate milestones to be defined accordingly). The mock-up should perform better than required for main linac in order to “provide evidence” for final focus requirements.

– Mock-up to be integrated in CLEX (important to have the stabilization together with the alignment) or in other accelerators

Integrate and apply to Linac

<u>Work launched on the Main Beam Mock-up within the collaboration</u>

- **Functionalities**
  - Demonstrate stabilization in operation:
    - Magnet powered, Cooling operating
    - Configurations
      - 1- Stand-alone,
      - 2- Integrated in Module,
      - 3- Interconnected
    - Accelerator environment
- **Parts / Measuring devices**
  - Support
  - Pre-alignment
  - Stabilization
  - Magnet
  - Vacuum chamber and BPM
  - Independent measurement

Integrate and apply to Linac

- Revise the policy on Final focus:
  - A dedicated mock-up for FF must be developed
  - Main features being studied by MDIWG to define the inputs:
    - Type of magnet : permanent or/and superconductors
    - Type of supporting structures: cantilevered beams or connected through the experiment
- Define the program afterwards
- A subject for the CLIC/ILC collaboration ?

Integrate and apply to Linac

- Test the mock-up('s) in accelerators (options)
  - Discussion started with CESRTA (storage ring)
    - 1st step: vibrate an existing quad with a narrow band excitation and measure the beam blow-up (BPM equipped with BBQ)
    - 2nd step: install a full mock-up
  - Install the main beam mock-up in CLEX after qualification (single pass)
  - Request access to ATF2 for a FF mock-up (single pass) *LAViSTa already there. See talk by Andrea Jeremie this afternoon*

Conclusion

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The Stabilization Working Group is up and running but we work on a challenge.

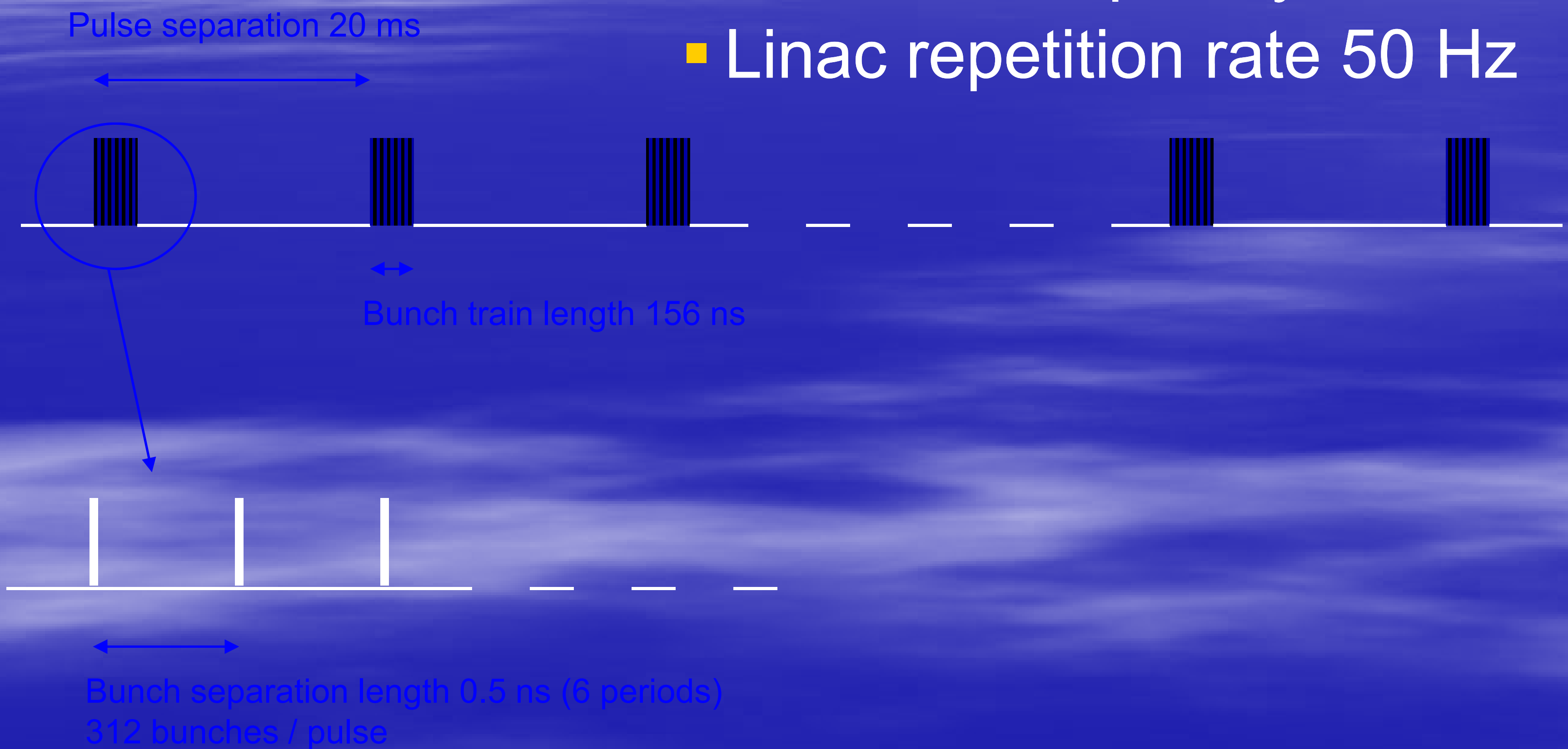
Actions plan are in place.
A pragmatic approach.
Probably too many actions but
the collaboration group is growing.

Let's do it.

Back-up slides

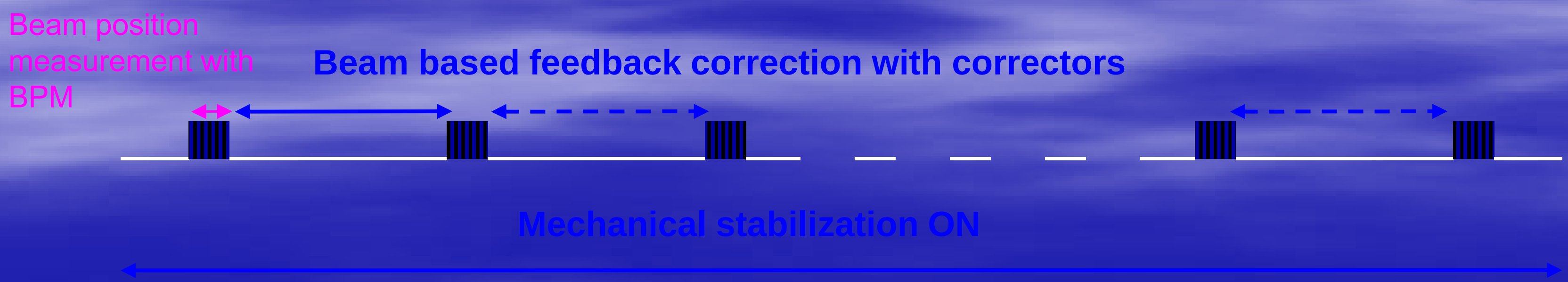
CLIC standard operating mode

- Main linac RF frequency 12 GHz
  - Linac repetition rate 50 Hz



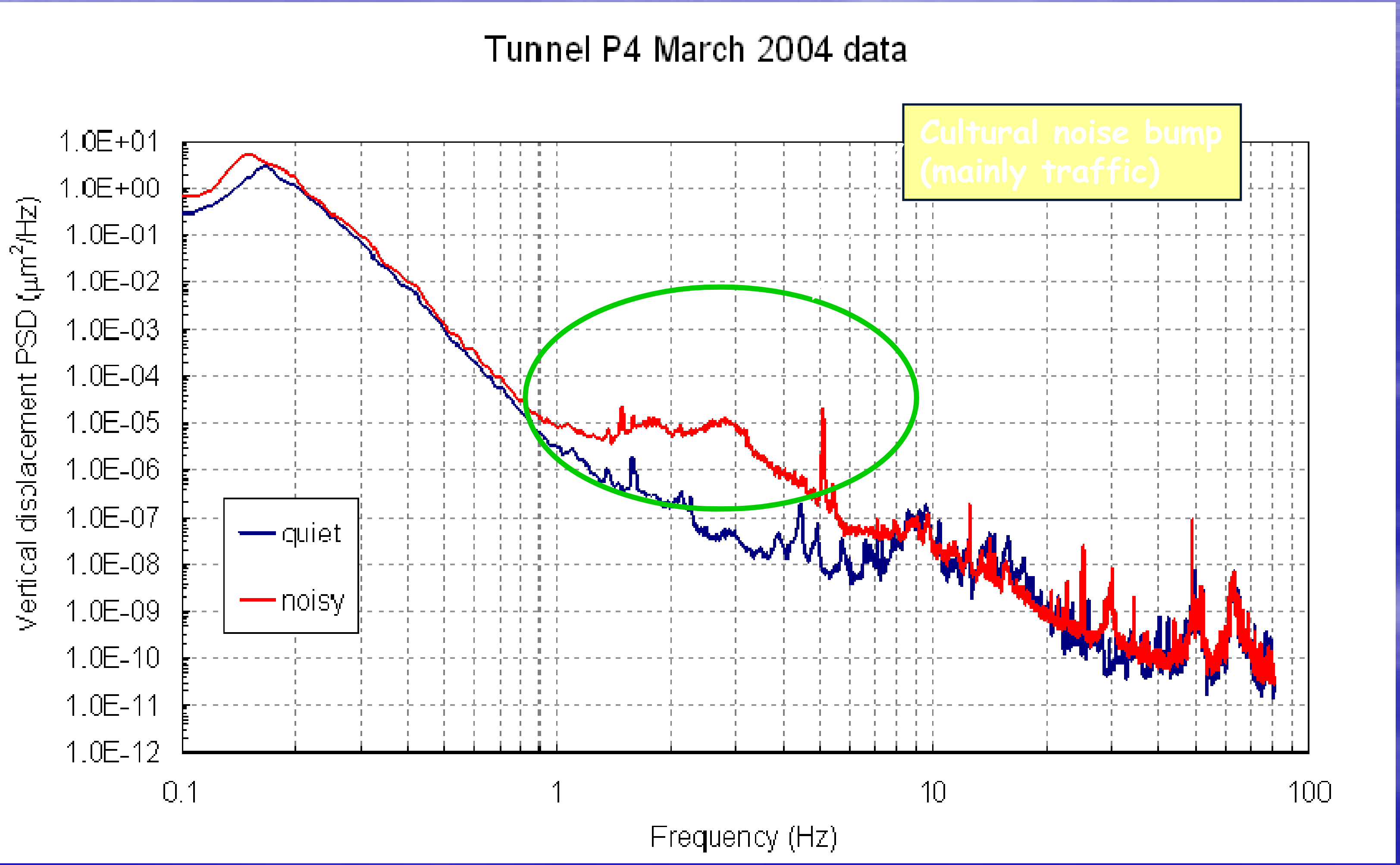
Global alignment / stabilization strategy for main linac magnets

- Once / year
  - Mechanical pre-alignment => *0.1 mm*
- Once / few weeks
  - Active pre-alignment using HLS, WPS, RASNIK => +/- *10 μm* on a sliding window of 200 m
- Once / couple of hours
  - Beam based active alignment with movers – complex procedure => *1 μm*
  - Beam based alignment with magnet correctors
  - and mechanical stabilization on=> *few nm*
- "Steady state"



Characterize vibrations/noise sources in an accelerator

DESY's fast seismic motion studies @ CERN – LHC Tunnel P4 Noisy vs Quiet



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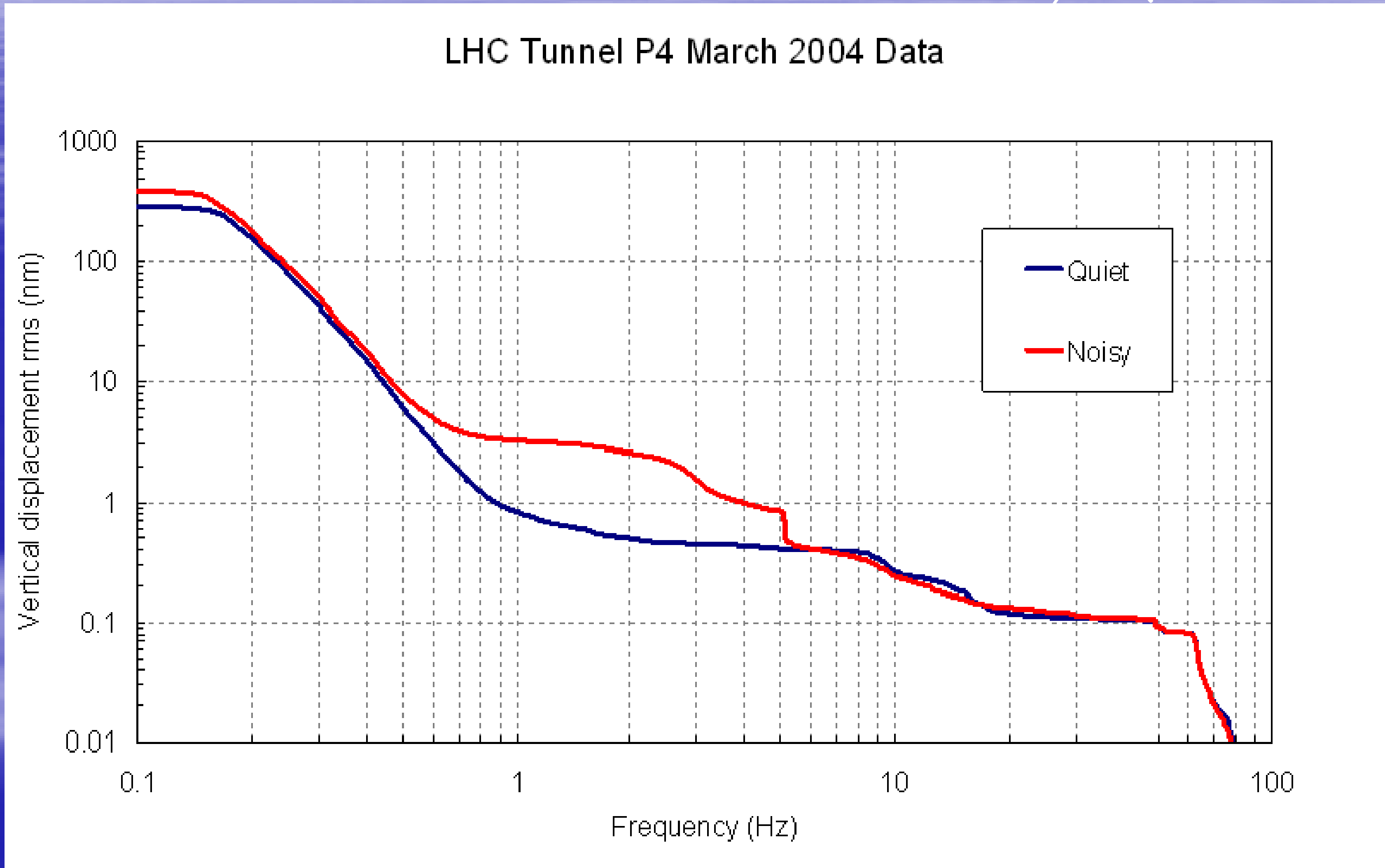
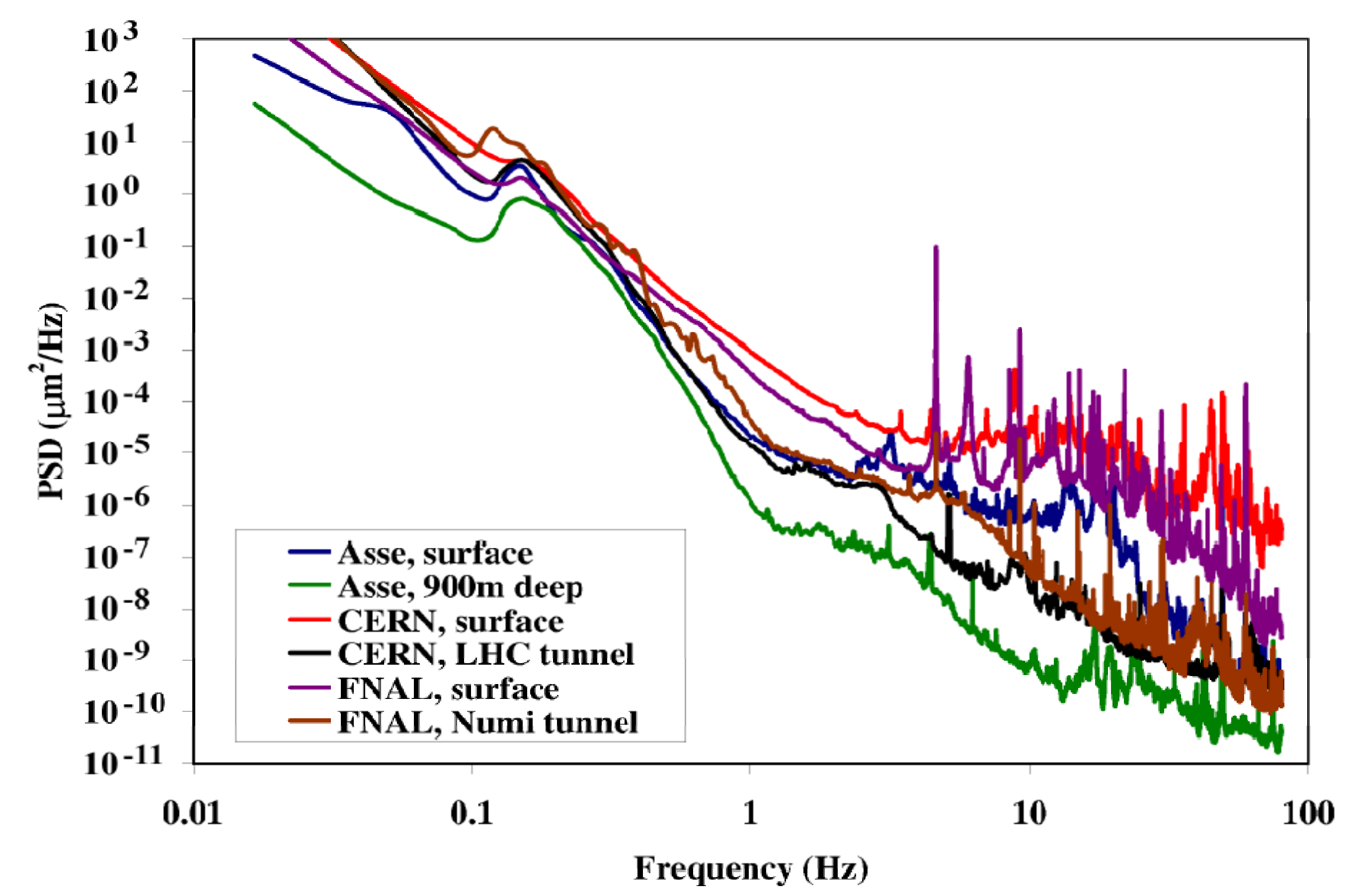


… s!

Characterize vibrations/noise sources in an accelerator

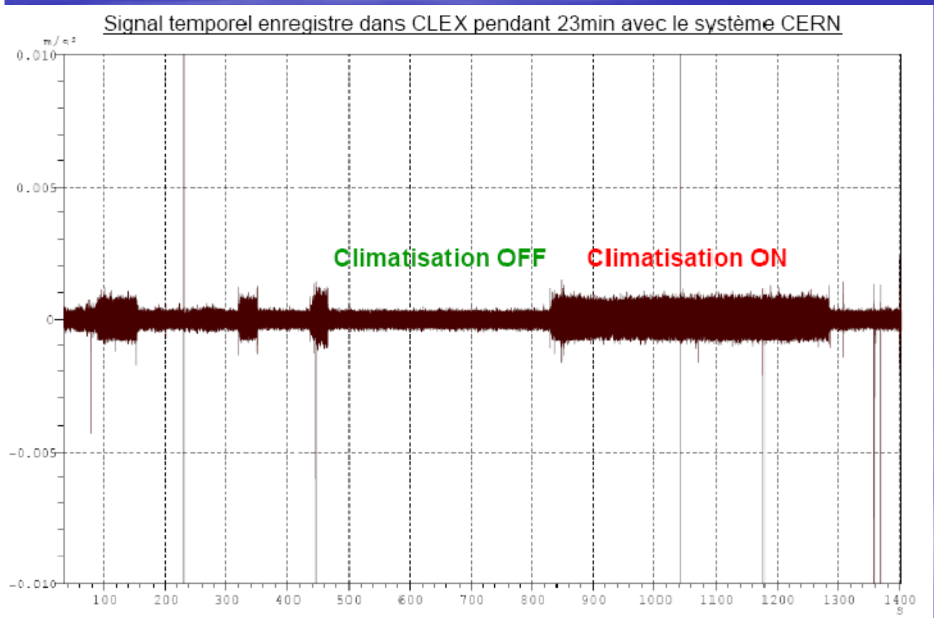
Influence of the sites / depth

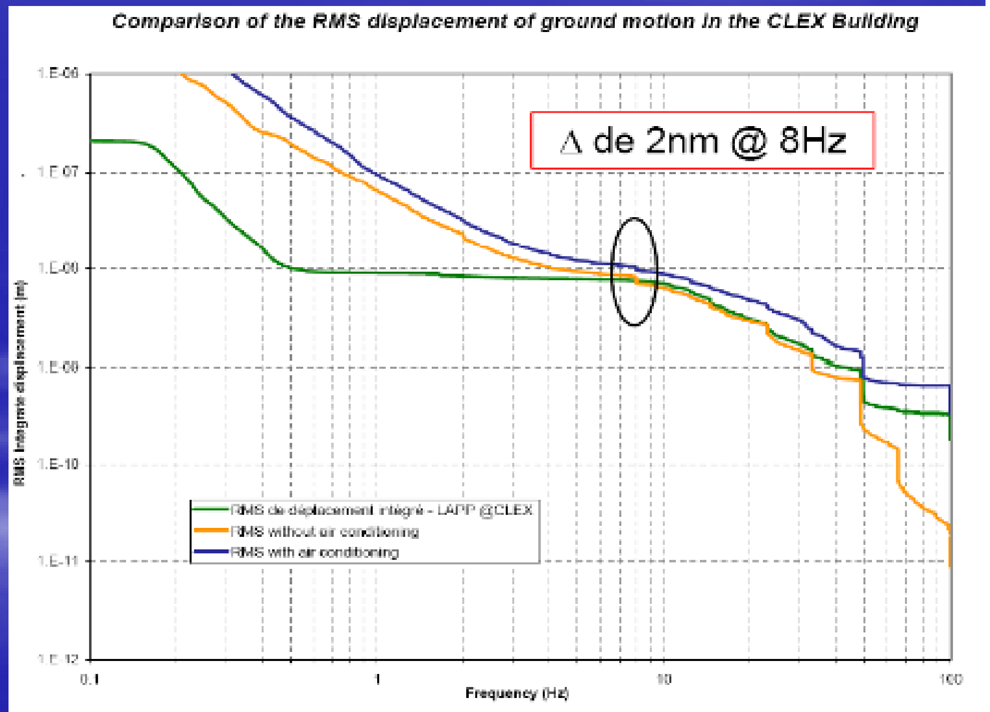


CLEX

Characterize vibrations/noise sources in an accelerator

Influence of the ventilation in the CLEX building



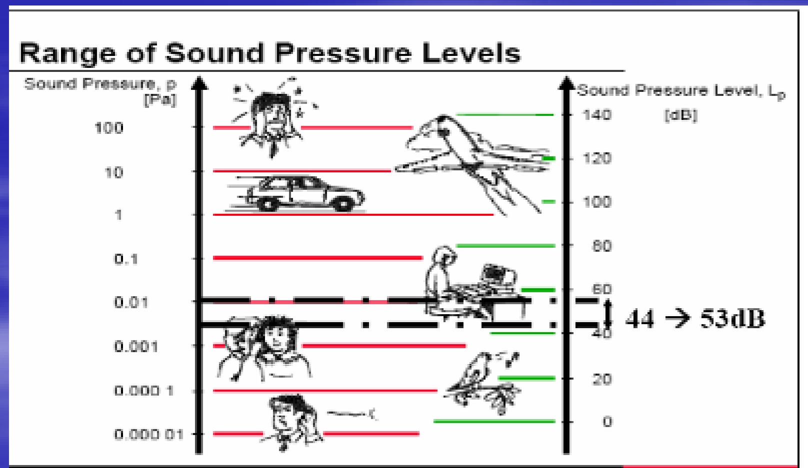


CLEX

Characterize vibrations/noise sources in an accelerator

Acoustic noise

Acoustic noise = air pressure waives
Acoustic noise as dominant source de vibration > 50 Hz

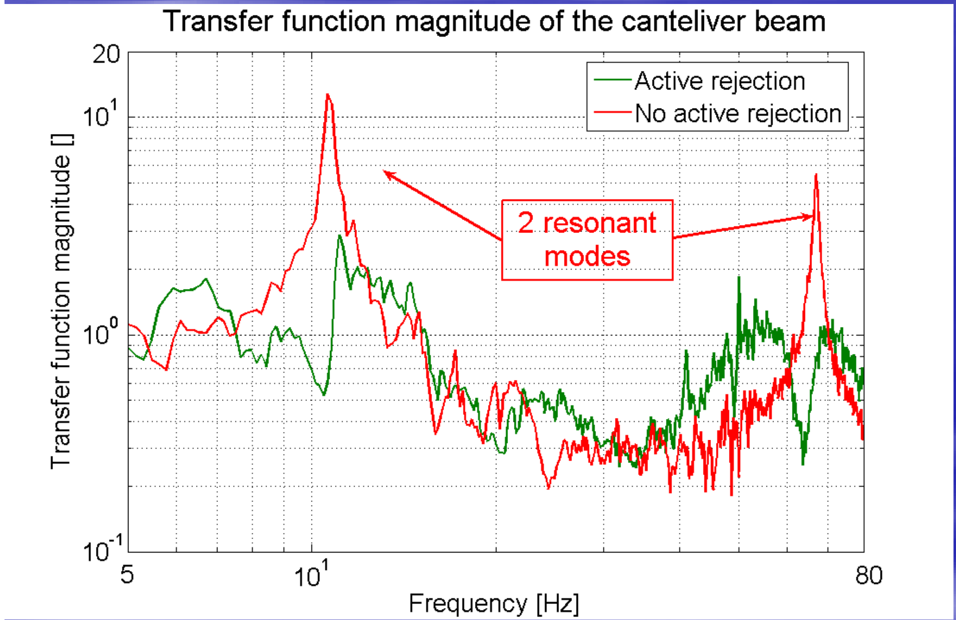


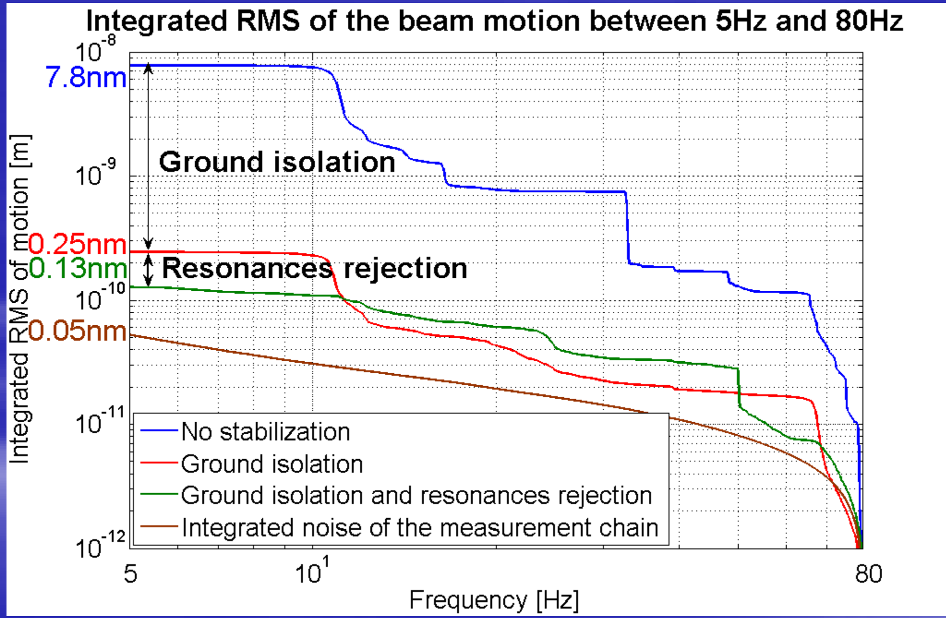
For high frequencies > 300 Hz, movements > tolerances may be induced

Feedback

Experimental test

➢ The two first resonances entirely rejected





➔ Factor 60 of damping between 5Hz and 80Hz down to 0.13nm

Overall design

Accelerator environment

- Mechanical coupling via beam pipe, cooling pipe, instrumentation cables,...

- Vibrations inside the structure to be stabilized:
    - Cooling water circuit
    - Inter pulse alignment with stepper motors

•Radiation

-Radiation level at CLIC not yet estimated

-Radiation damage effects on electronics:

Total dose
Displacement
Single event error