NANOBEAM'08

CLIC

Techniques to approach the requirements of CLIC stability

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CERN, Geneva, Switzerland

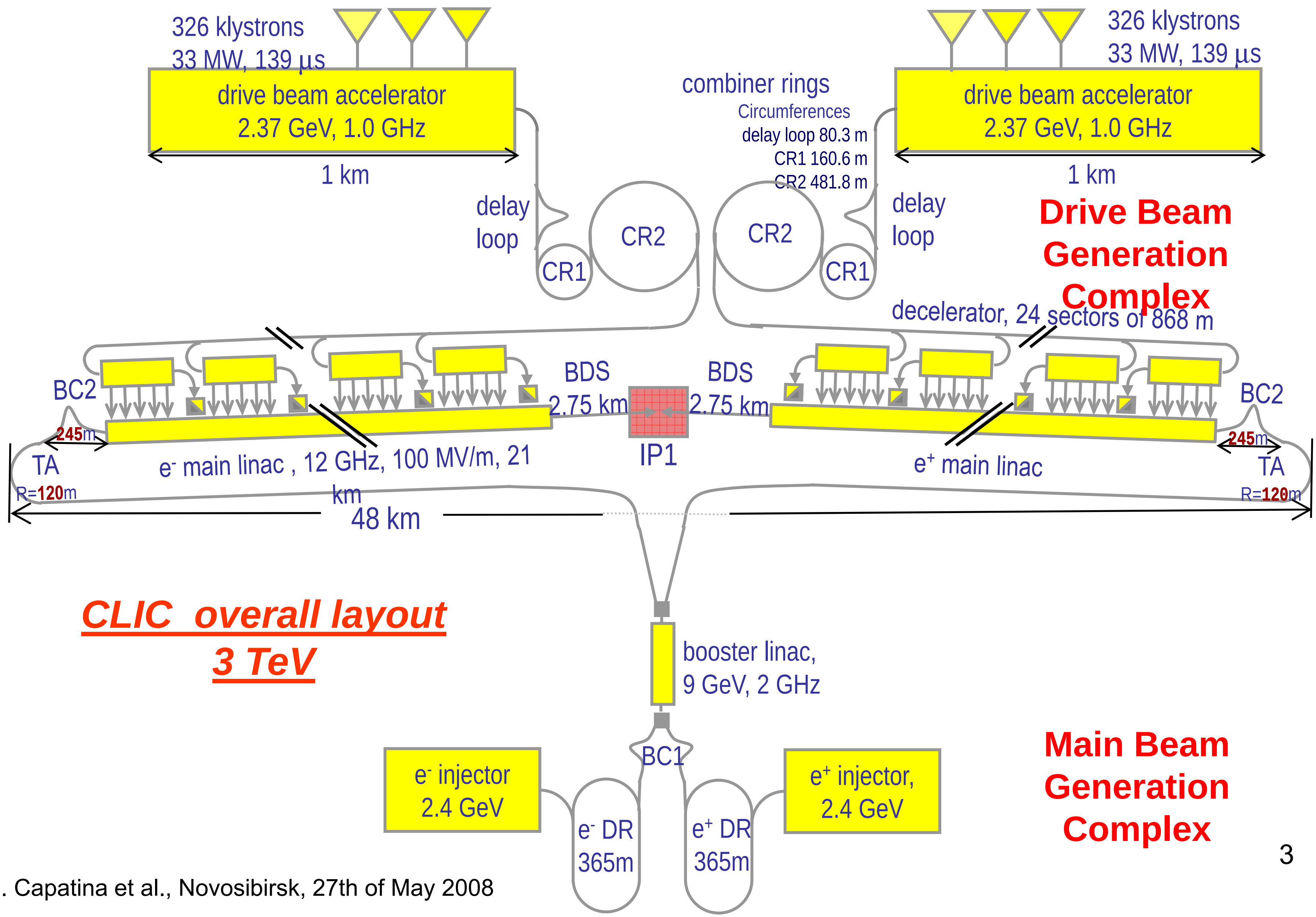
Nanobeam 08, Novosibirsk, 27th of May

Overview

- CLIC general description
- General stabilization requirements
- Techniques for mechanical stabilization
- CLIC stabilization team
- Work plan
- Conclusion

CLIC (Compact LInear Collider) complex

(new parameters)



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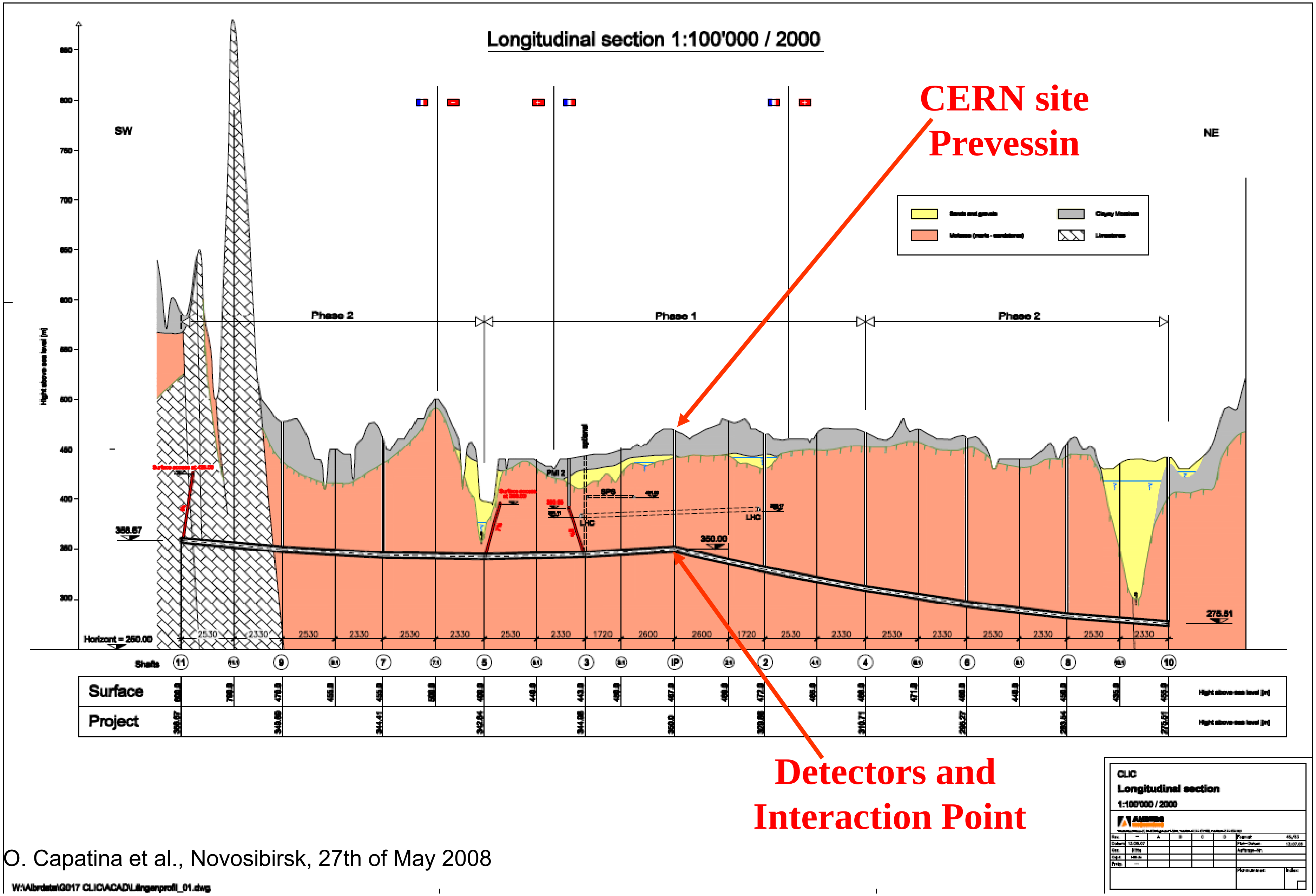
Longitudinal section of a laser straight Linear Collider on CERN site



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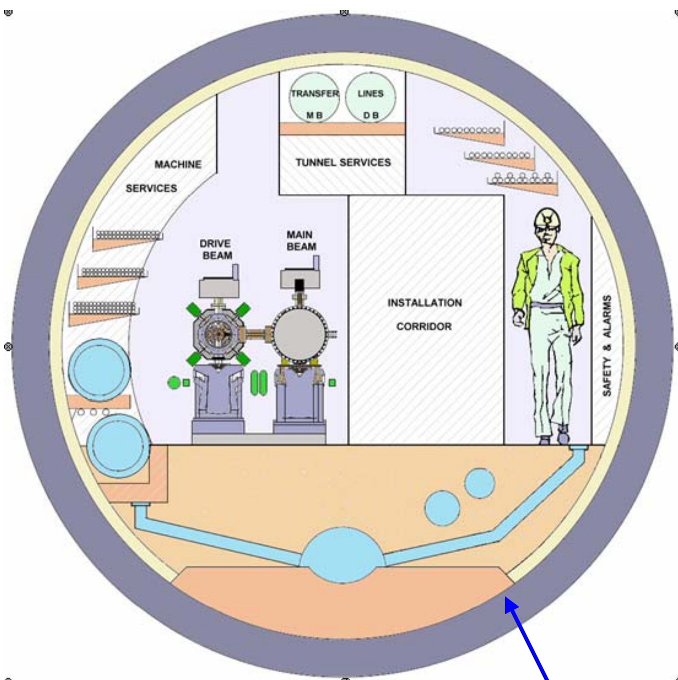
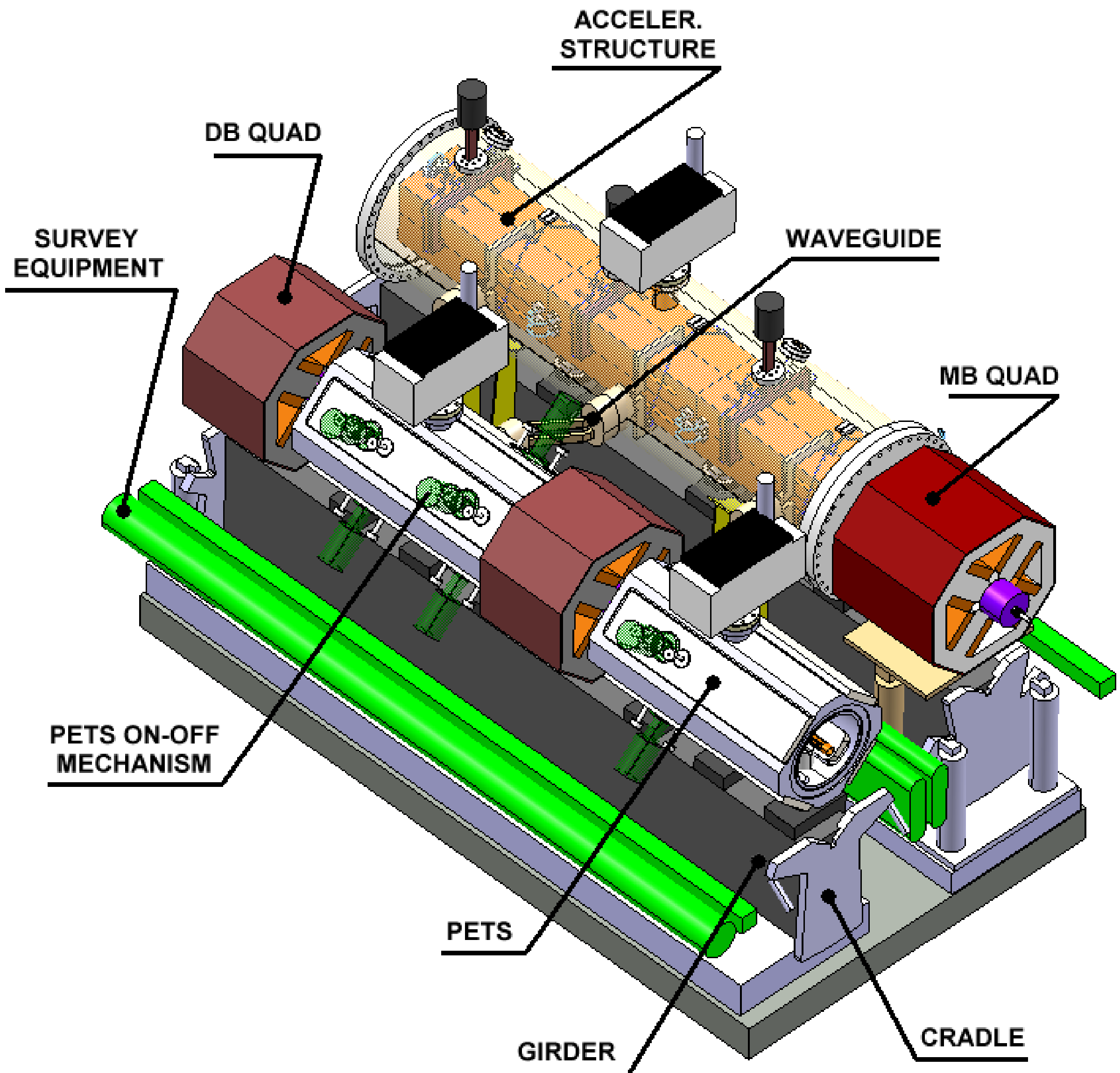
CLIC module

CLIC TUNNEL
CROSS-SECTION



4.5 m diameter
(Present status)

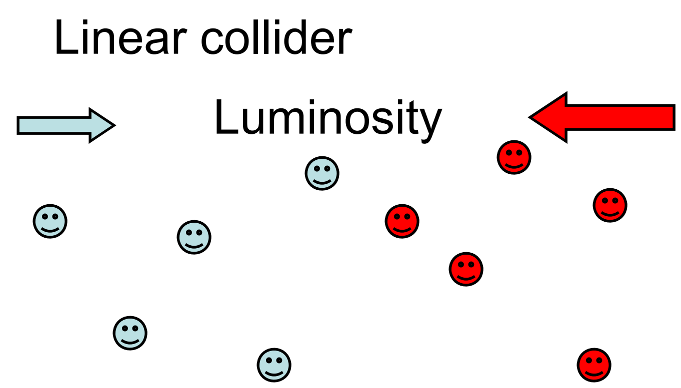


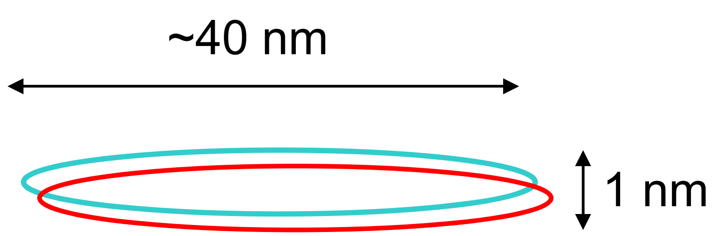
CLIC stabilization requirements

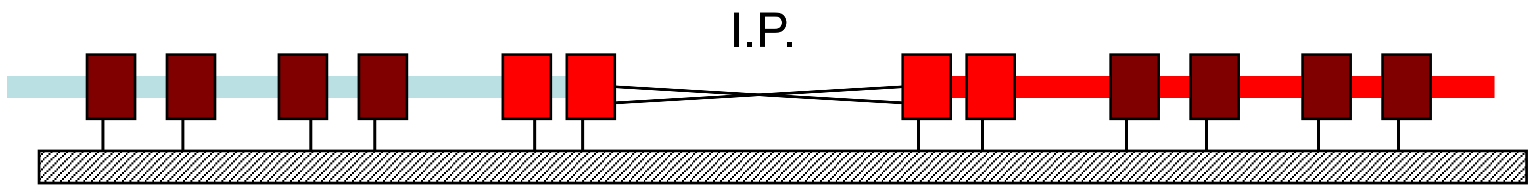
3 TeV CLIC Luminosity:

$L = 5.9 * 10^{34}\ cm^{-2}\ s^{-1}$

$$L = \frac{A}{\sigma_x \sigma_y}$$





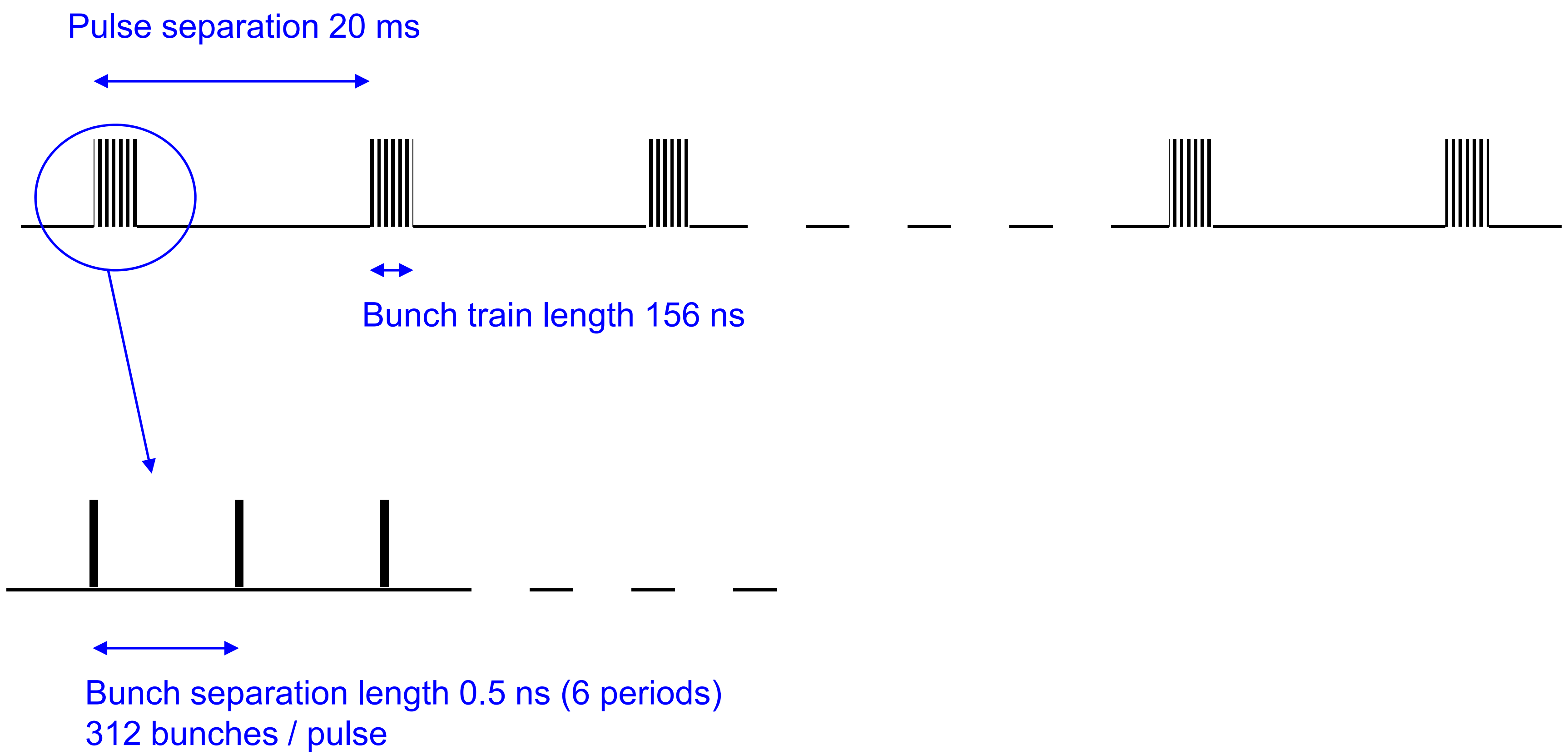


CLIC stabilization requirements

- A large number of luminosity loss sources exist
  - Need to allocate a budget for each of them
- Current luminosity loss allocated for magnet jiter:
  - 1% for main linac magnets
  - 1% for BDS magnets, except final doublet magnets
  - 1% for final doublet magnet
- These are a large fraction of the overall luminosity loss

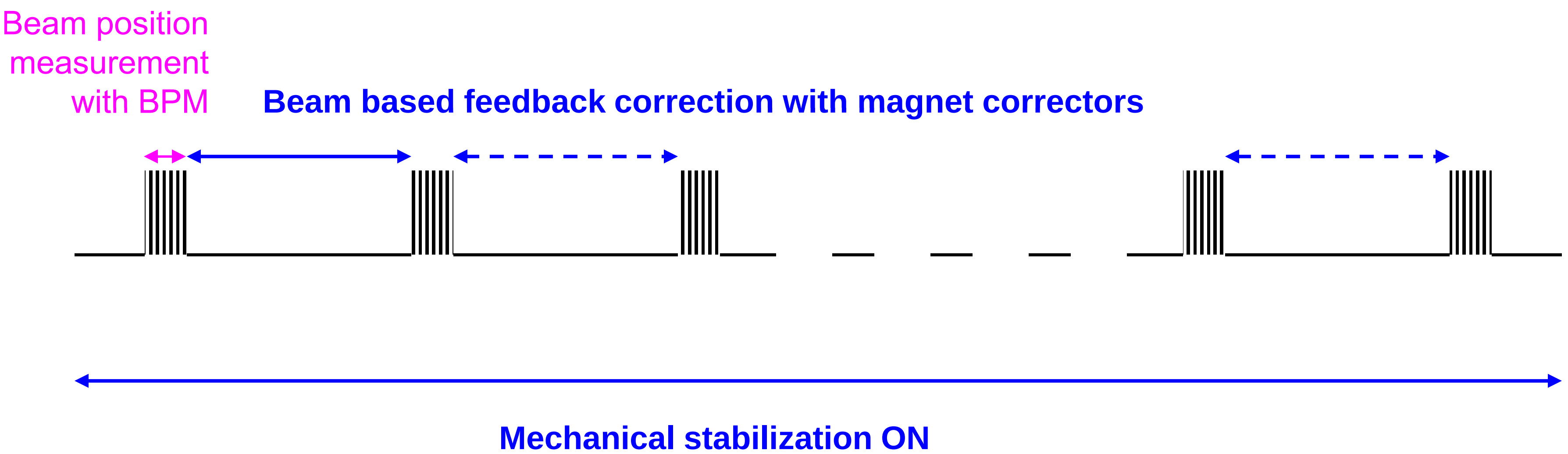
CLIC stabilization requirements

- Some CLIC overall parameters
  - Center of mass energy 3 TeV
  - Main linac RF frequency 12 GHz
  - Linac repetition rate 50 Hz



CLIC stabilization requirements

- Overview of the global alignment / stabilization strategy for main linac magnets
  - "Steady state" procedure:



  - But, before "Steady state", alignment has to be carried out

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CLIC stabilization requirements

CLIC

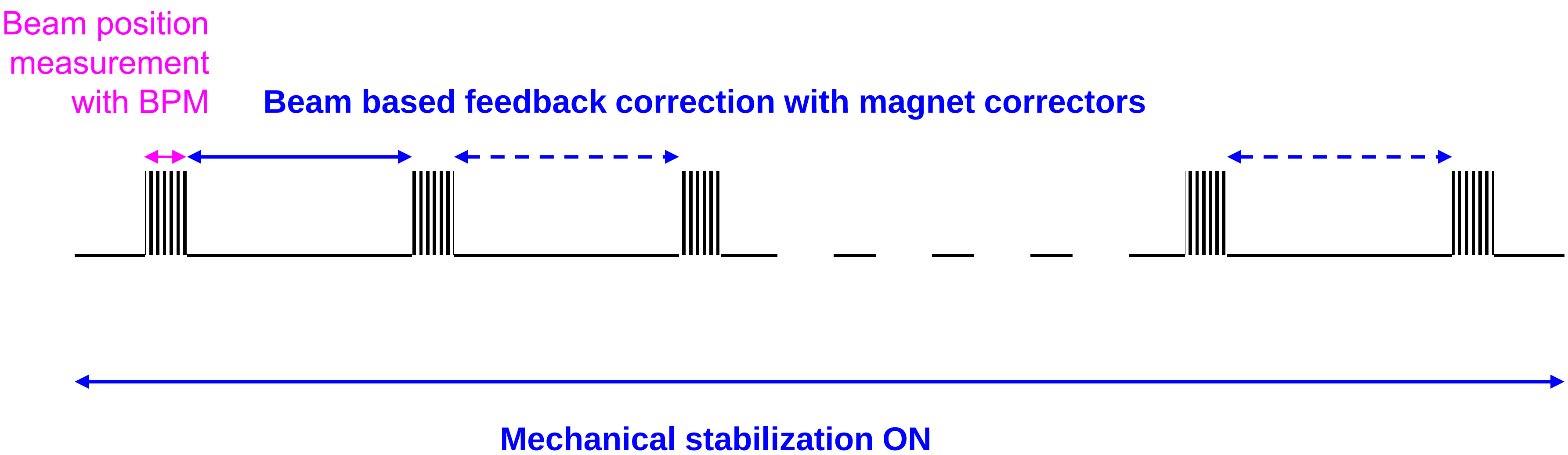
- Overview of the global alignment / stabilization strategy for main linac magnets
  - Once / year:
    1. Mechanical pre-alignment => 0.1 mm
    2. Active pre-alignment using HLS, WPS, RASNIK => +/- 10 μm on a sliding window of 200 m
    3. Beam based active alignment with movers – complex procedure => 1 μm
    4. Beam based alignment with magnet correctors => few nm

    (Steps 1–2: Beam OFF; steps 3–4: Beam ON. Steps 1–3: Mech. Stabil. OFF; step 4: Mech. Stabil. ON)

  - Once / few weeks
    - Repeat 2. + 3. + 4.
  - Once / couple of hours
    - Repeat 3. + 4. but "simplified" procedure
  - "Steady state" procedure presented before

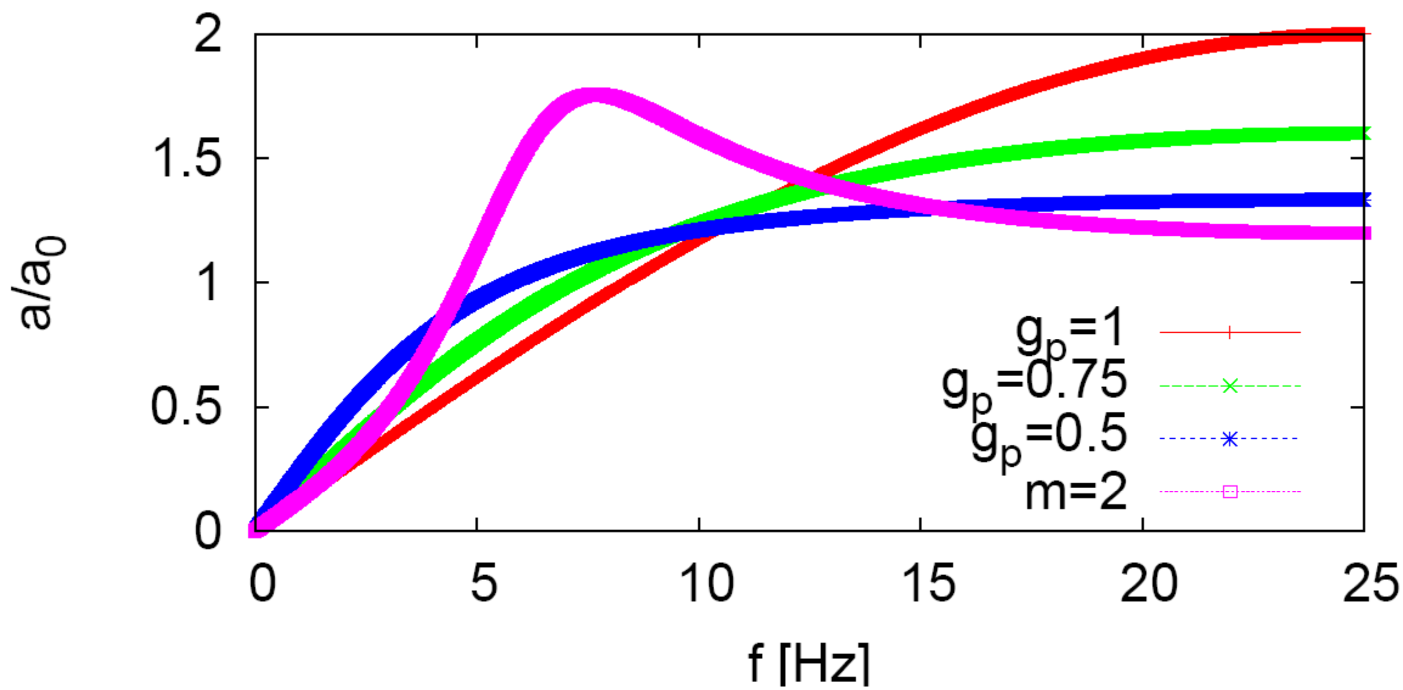
CLIC stabilization requirements

- Overview of the global alignment / stabilization strategy for main linac magnets
  - "Steady state" procedure:



CLIC stabilization requirements

- Numerical simulation:
  Ratio of the Beam based feedback On / feedback Off
  for the amplitude of the beam jitter at Interaction Point
  as a function of frequency



- The frequency at the limit between beam based feedback and mechanical stabilization is not very strict !

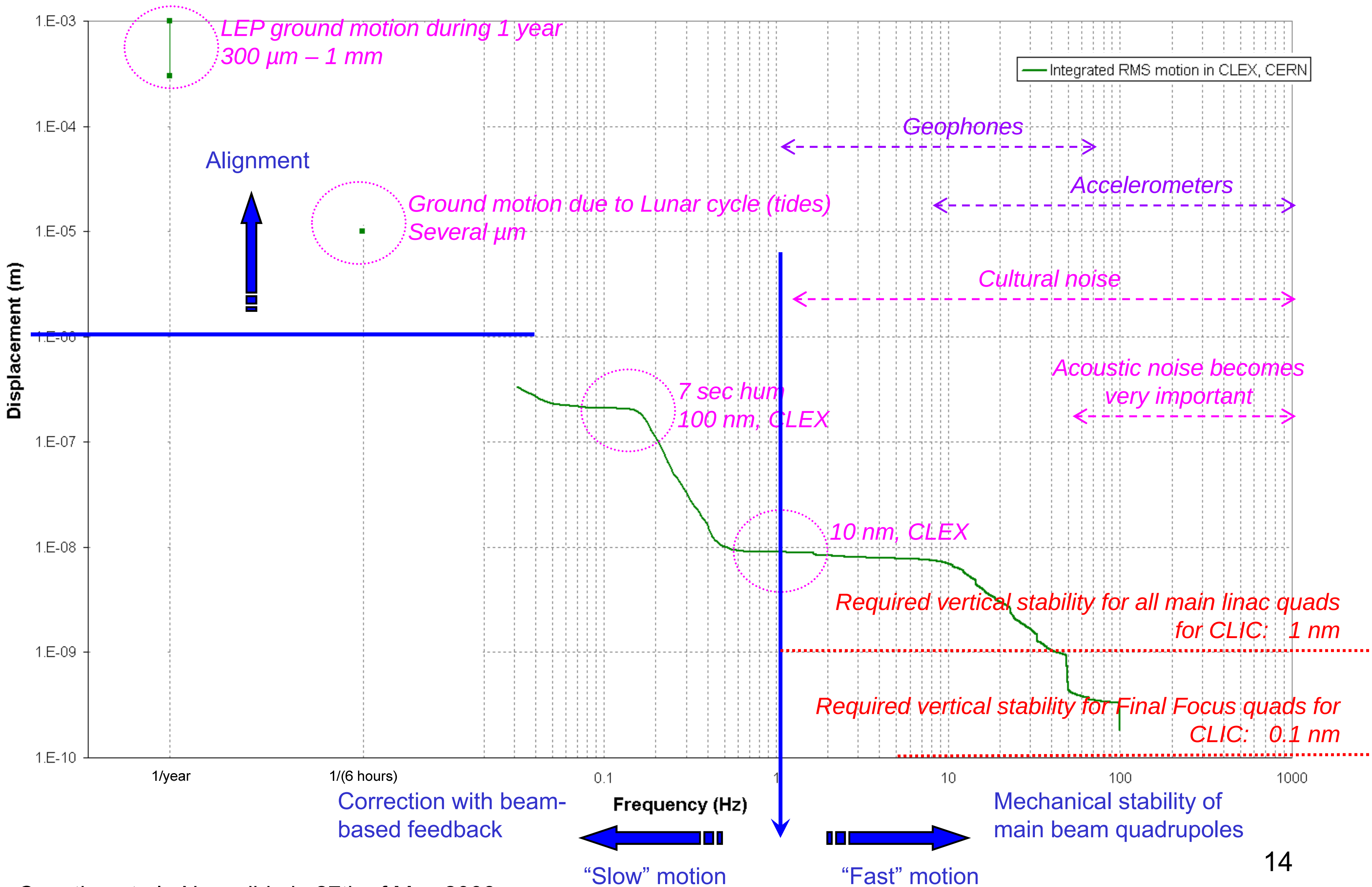
CLIC stabilization requirements

- Mechanical stabilization requirements:
  Quadrupole magnetic axis vibration tolerances:

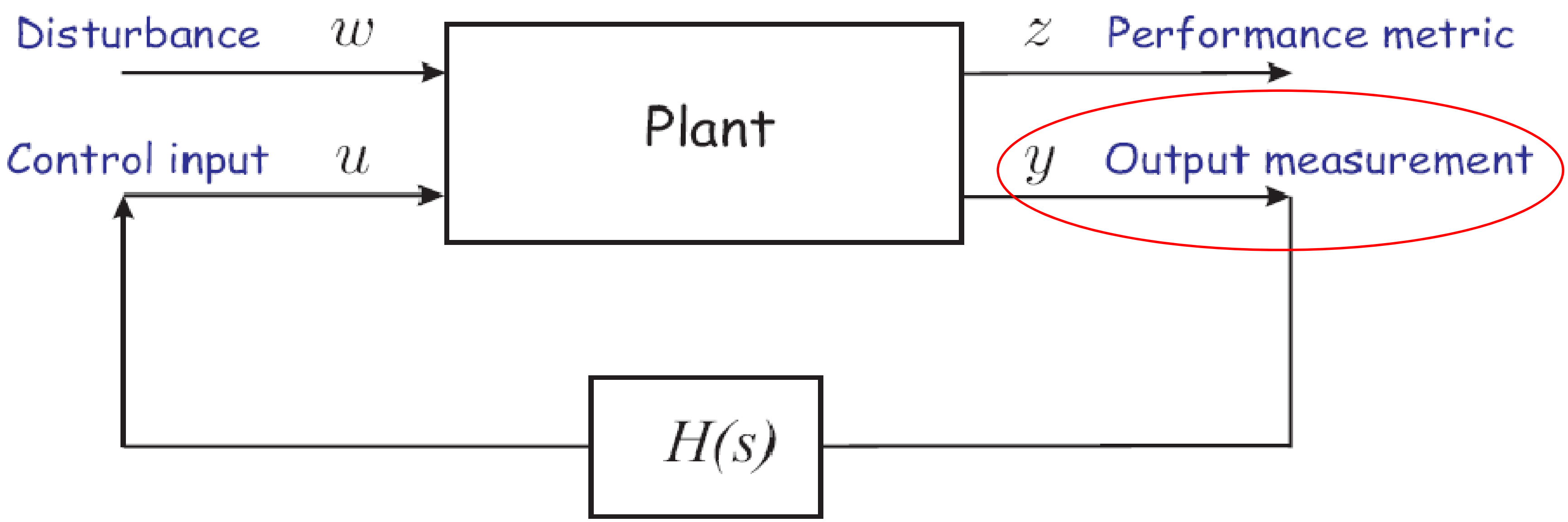
	Final Focusing Quadrupoles	Main beam quadrupoles
Vertical	0.1 nm > 4 Hz	1 nm > 1 Hz
Horizontal	5 nm > 4 Hz	5 nm > 1 Hz

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

Environmental vibration levels – orders of magnitude, CERN site



Techniques for mechanical stabilization



Structural control problem that needs an integrated approach

Output measurement

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	Eentec SP500	PCB 393B31
x,y,z	x,y,z	x,y,z	z	z
			electrochemical	
2*750Vs/m	2*750Vs/m	2*800Vs/m	2000Vs/m	1.02Vs^2/m
120 s -50 Hz	360s -50 Hz	30 s -50 Hz	60 s -70 Hz	10 s -300 Hz
13 kg	13.5 kg	7.5 kg	0.750 kg	0.635 kg
23 kCHF	19 kCHF	8 kCHF		1.7 kCHF

- **Vibrometer et interferometer** — MONALISA — Déplacement

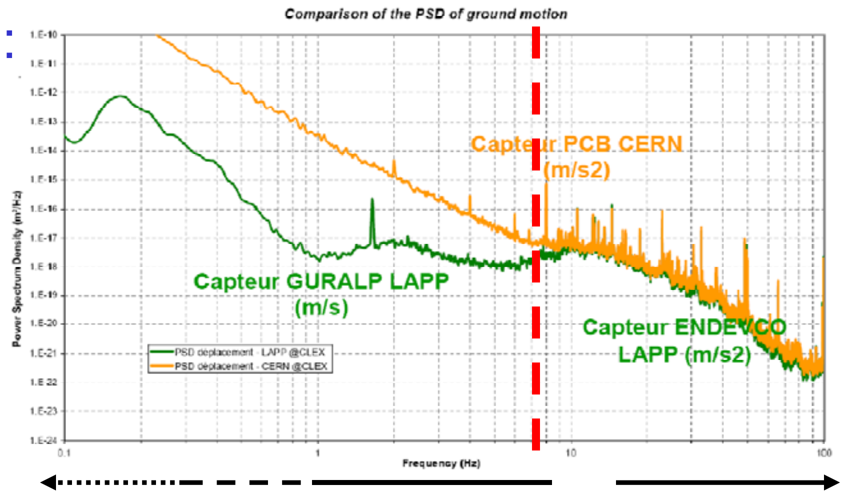
Output measurement

Characterization for low intensity signals:

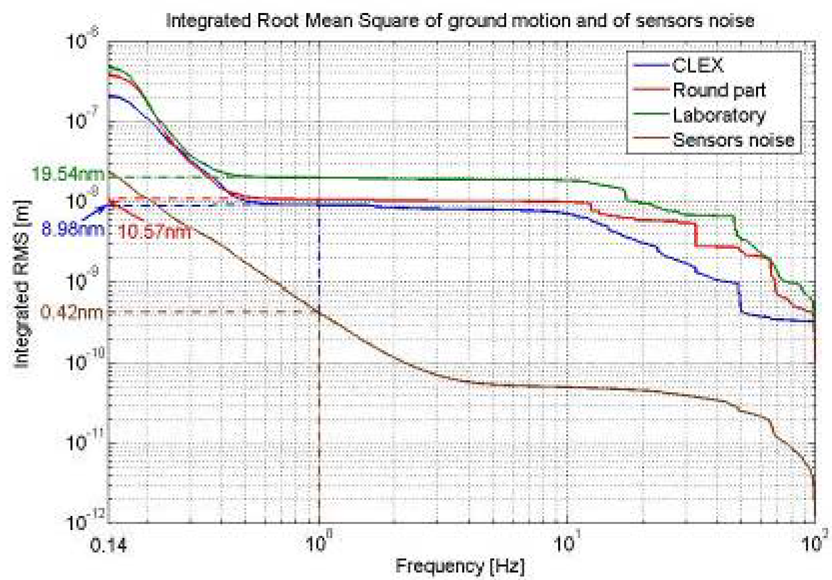
Sensitivity + resolution

Cross axis sensitivity,

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



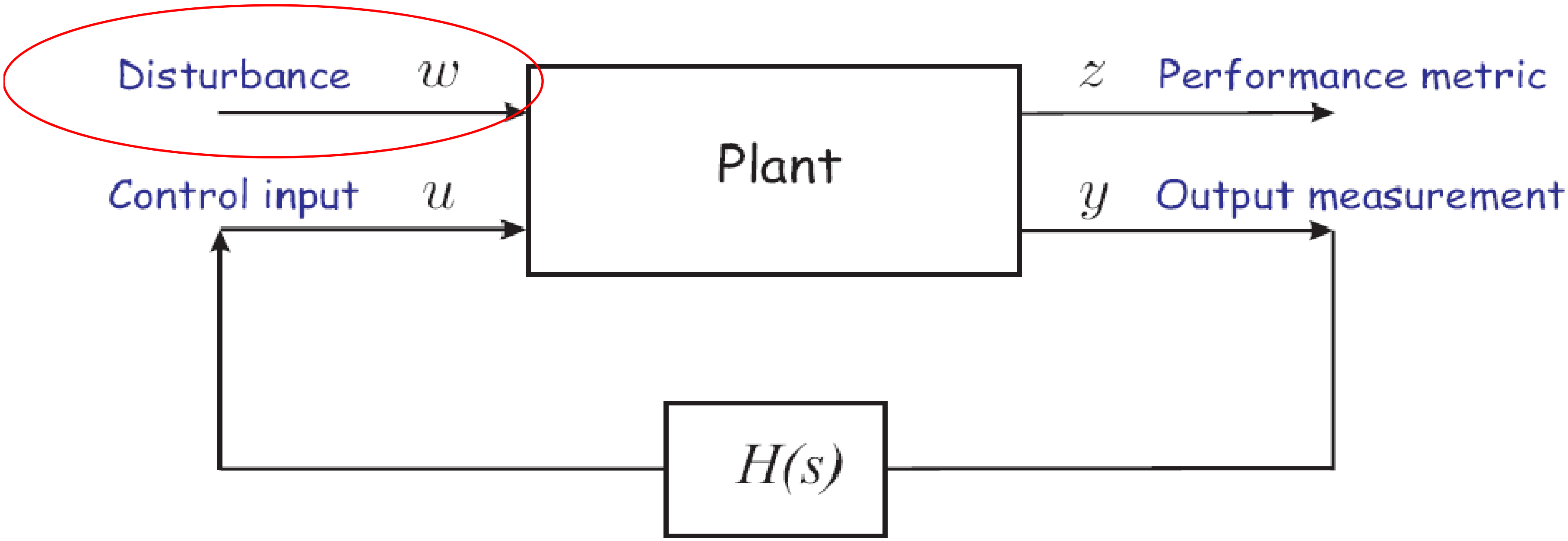
Signal processing: Resolution, filtering, window, FFT, DSP, integration, coherence >>



Can give values < sensor resolution

Characterization of measurement method, fix a standard

Techniques for mechanical stabilization



Structural control problem that needs an integrated approach

Disturbance sources

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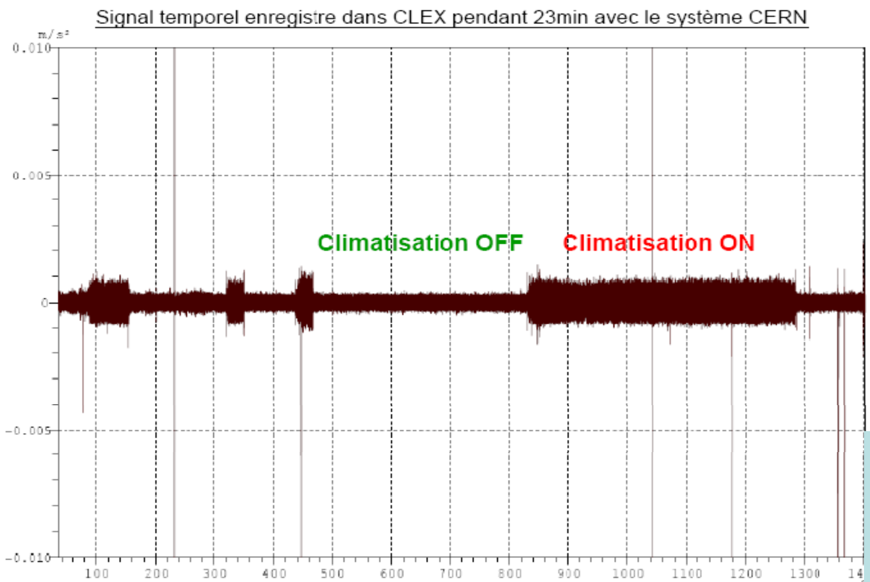
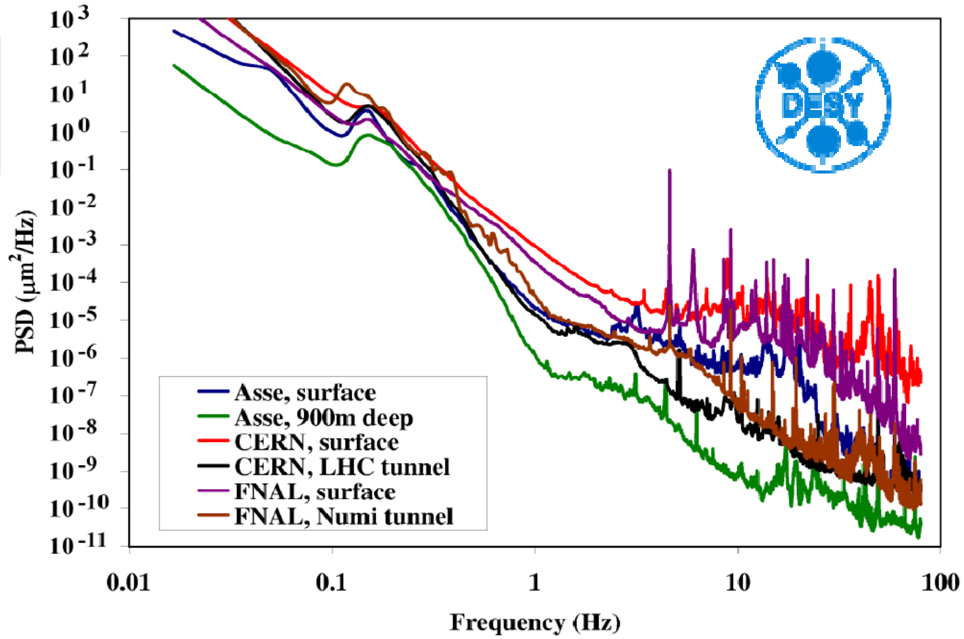
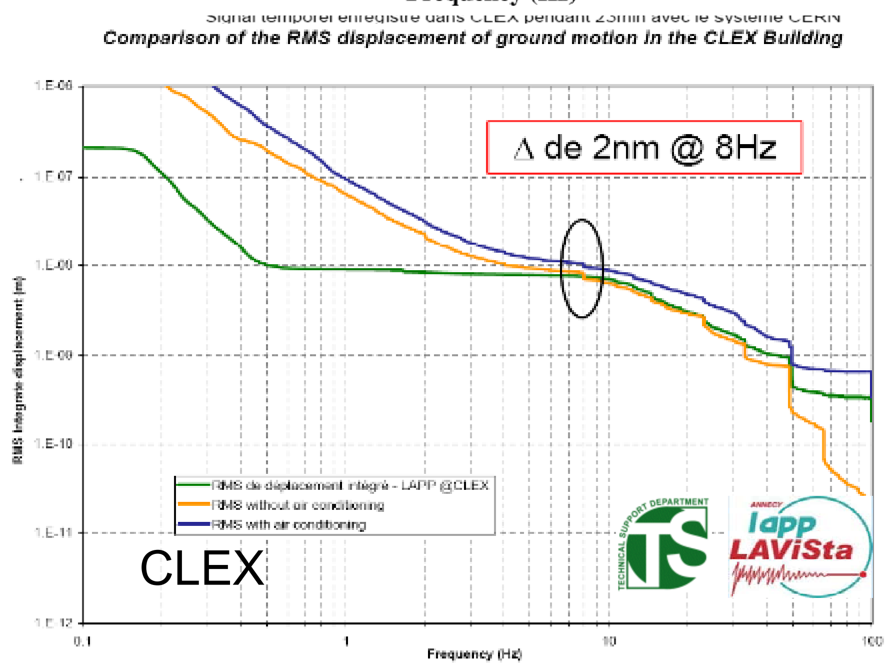
1. Ground vibration

DSP





R.M.S. Intégré



Remark: Measurement interpretation may depend on Signal processing !

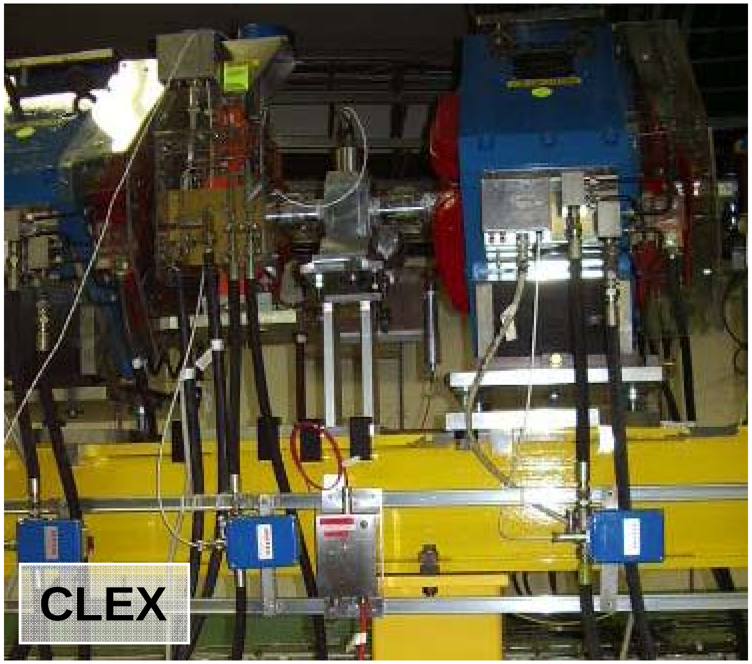
Disturbance sources

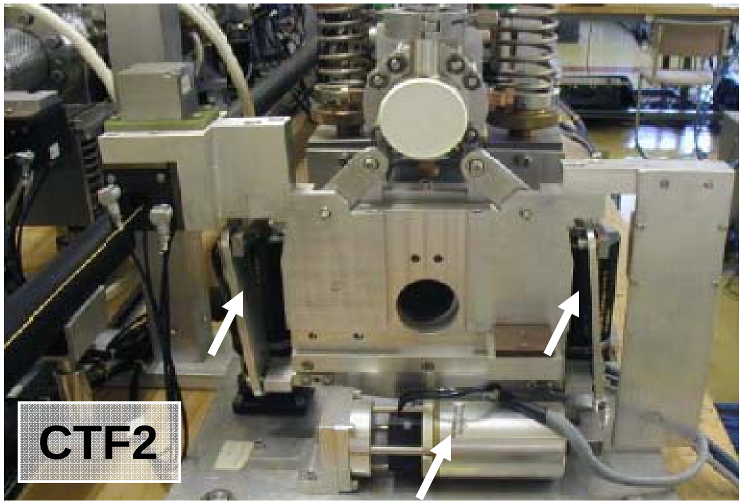
2. Direct forces on magnet

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

• Vibrations inside the structure to be stabilized:

- ➢ Cooling water circuit
- ➢ Active alignment with stepper motors





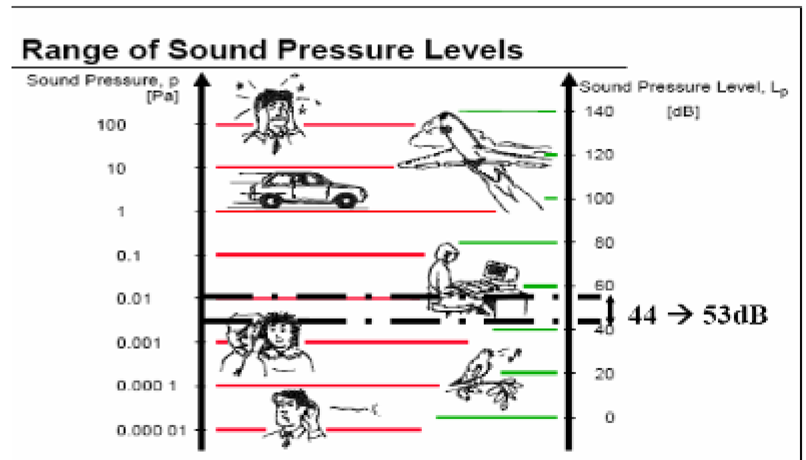
Disturbance sources

3. Acoustic noise

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

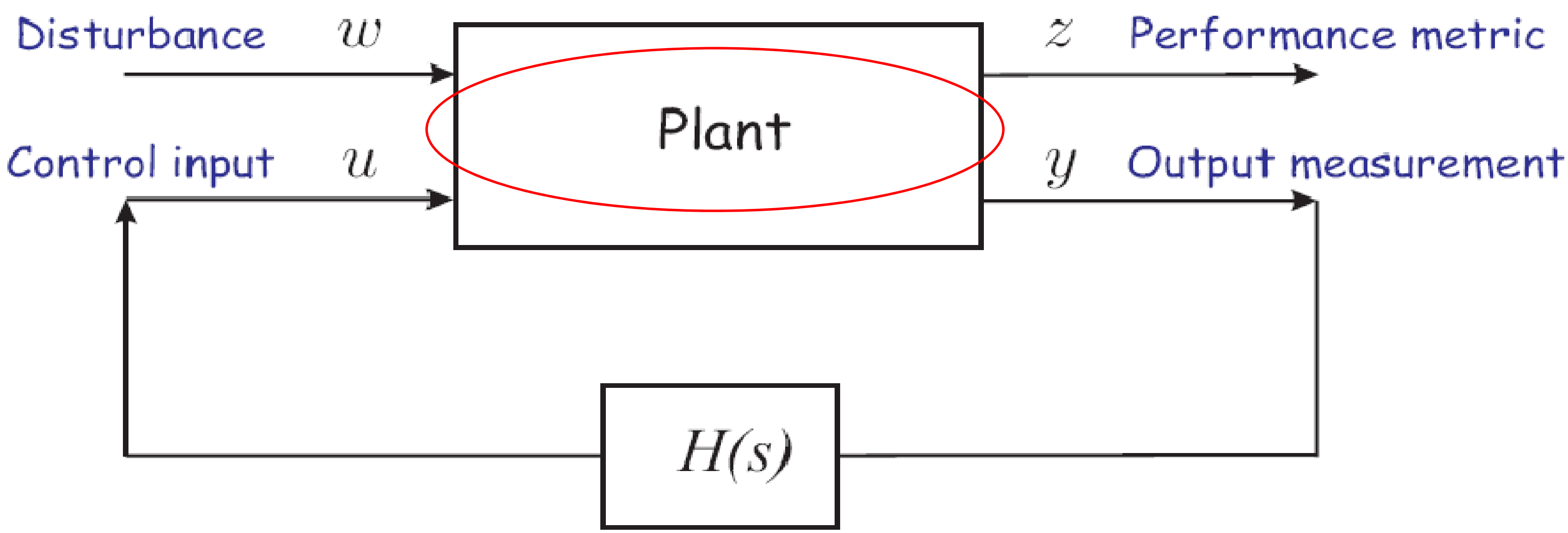
lapp LAViSta

See next presentation by B.Bolzon



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

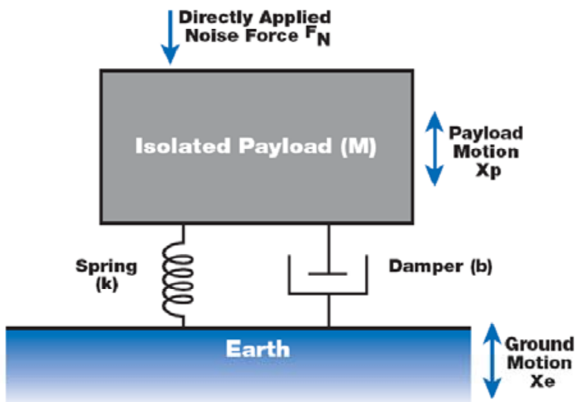
Techniques for mechanical stabilization



Structural control problem that needs an integrated approach

"Plant" characterization / optimization

Vibrations « Transmissibility »



$$\frac{Xp}{Xe} = \sqrt{\frac{1+\left(\frac{\omega}{Q\omega_0}\right)^2}{\left(1-\frac{\omega^2}{\omega_0^{\ 2}}\right)^2+\left(\frac{\omega}{Q\omega_0}\right)^2}}$$

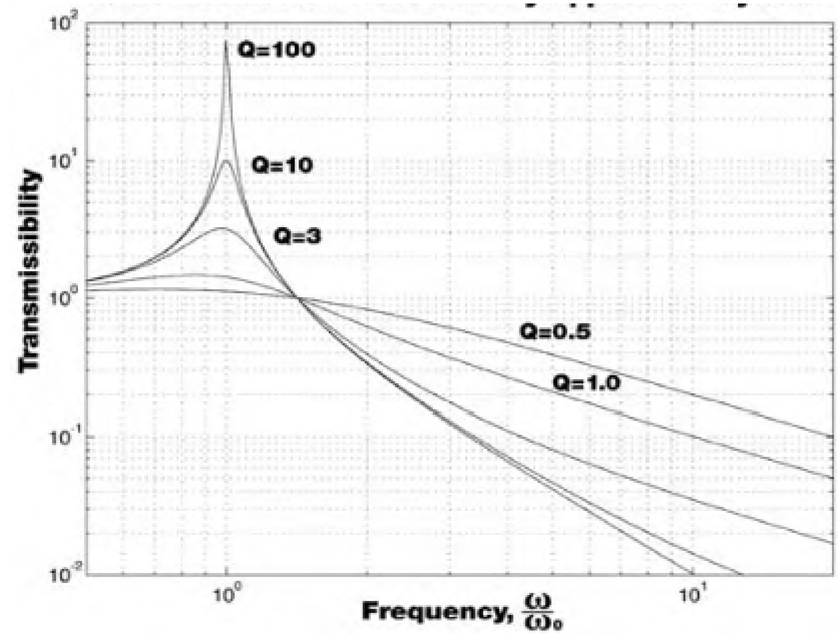
$$\omega_0 = \sqrt{\frac{k}{M}}$$

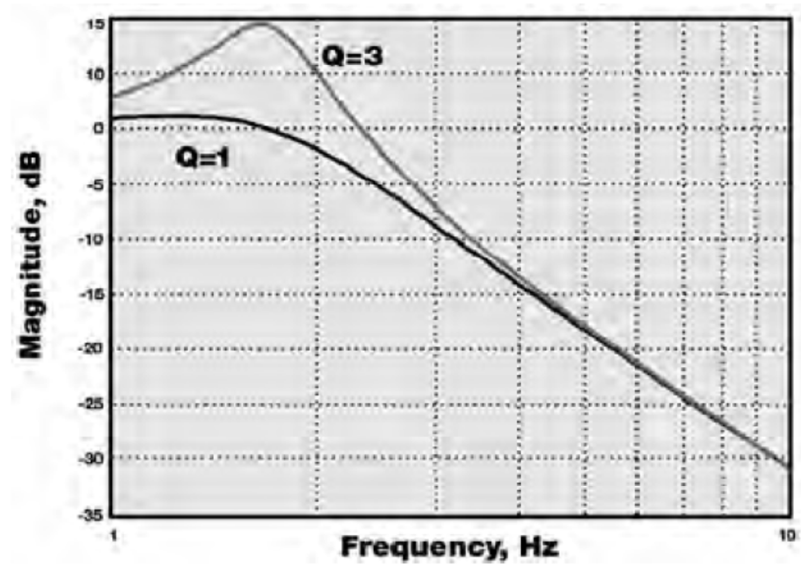
Natural frequency

Damping ratio

$$\xi = 1/2Q$$

$$\frac{x_p}{F_N} = \frac{Q}{M\sqrt{Q^2\left(\omega_0^{\ 2}-\omega^2\right)+\left(\omega\omega_0\right)^2}}$$





Magnet mechanical design to be carefully optimized !

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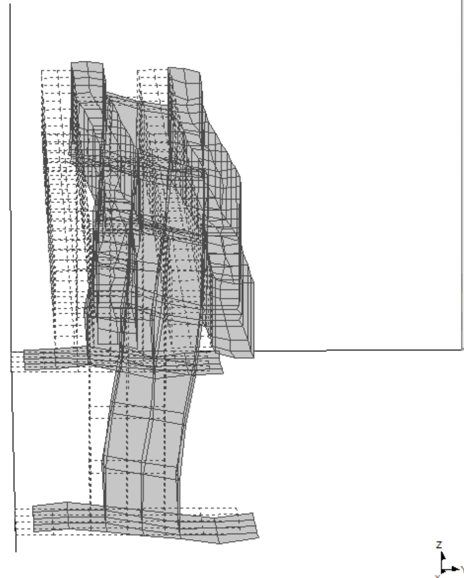
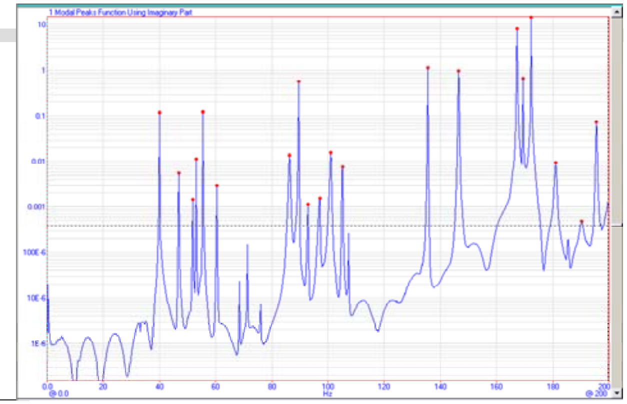
“Plant” characterization / optimization

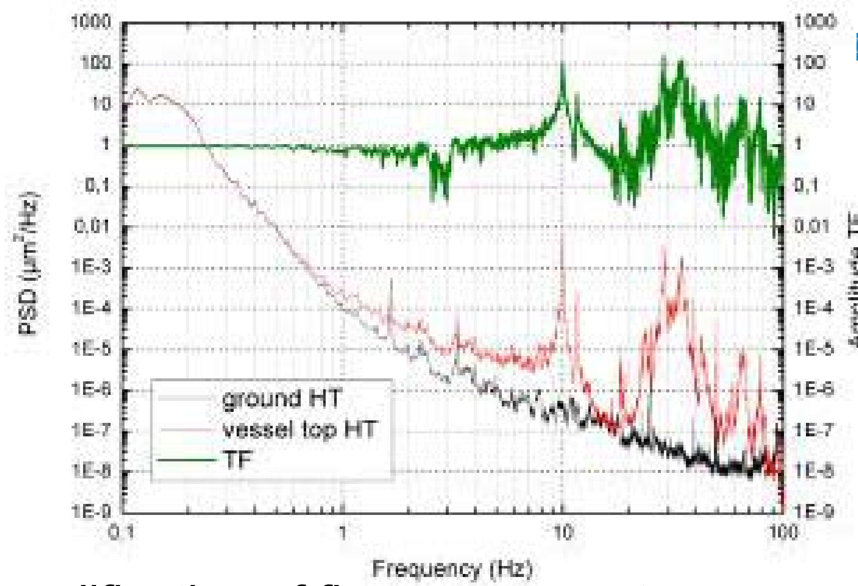
Real system:

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



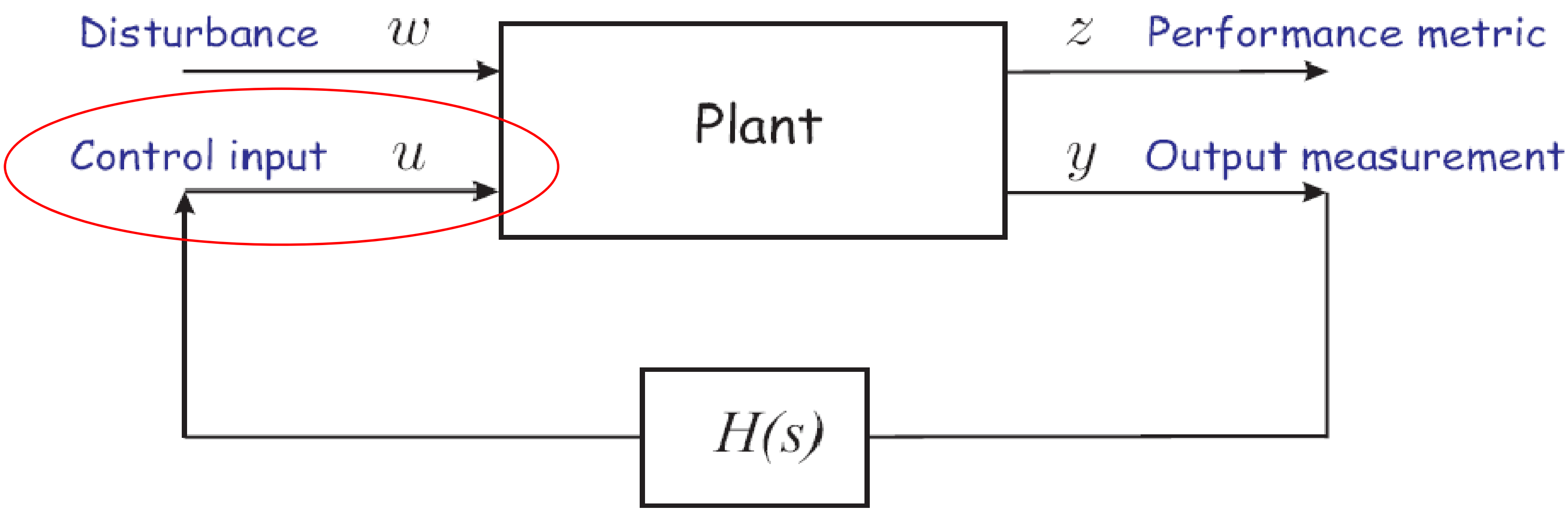


Experimental modal analysis on CLEX girder



Amplification of floor movement

Techniques for mechanical stabilization



Structural control problem that needs an integrated approach

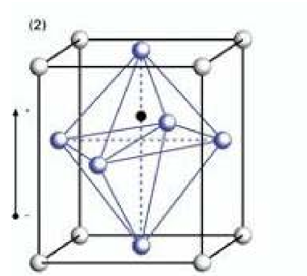
Control input

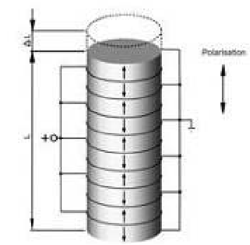
Actuators with 0.1 nm resolution?

Resolution, movement reproducibility?

Friction
Guiding systems with friction

Real resolution 1 μm (0.1 μm)

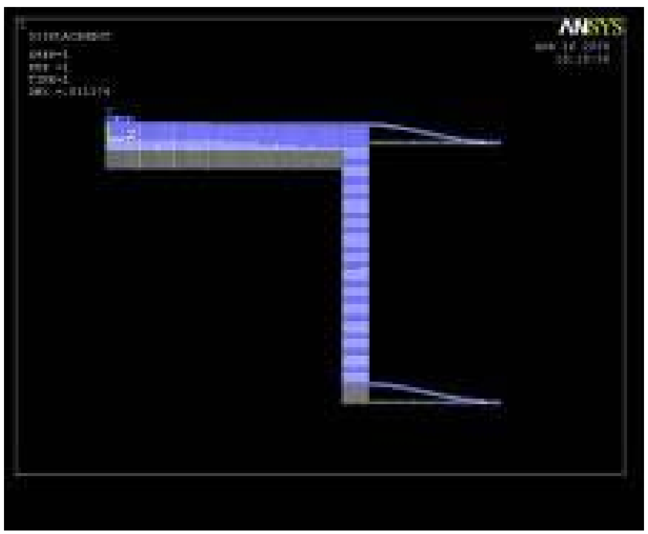




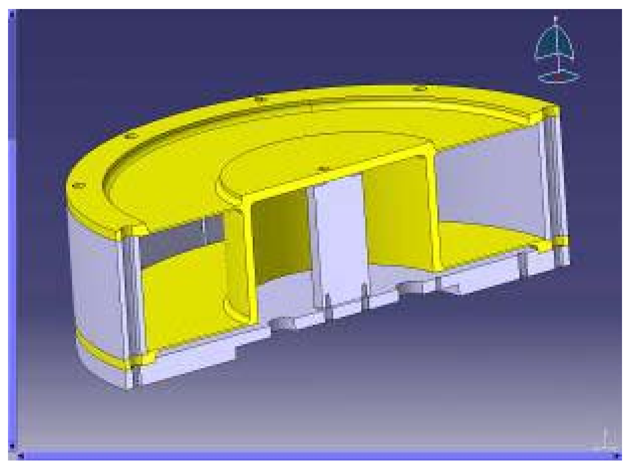
Solution: Piezo actuators PZT

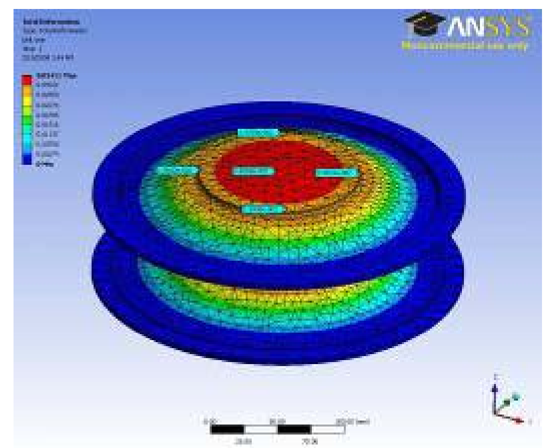
+ flexural guides

+ feedback capacitive sensor



0.1 nm 100 N Calibration bench flexural guides





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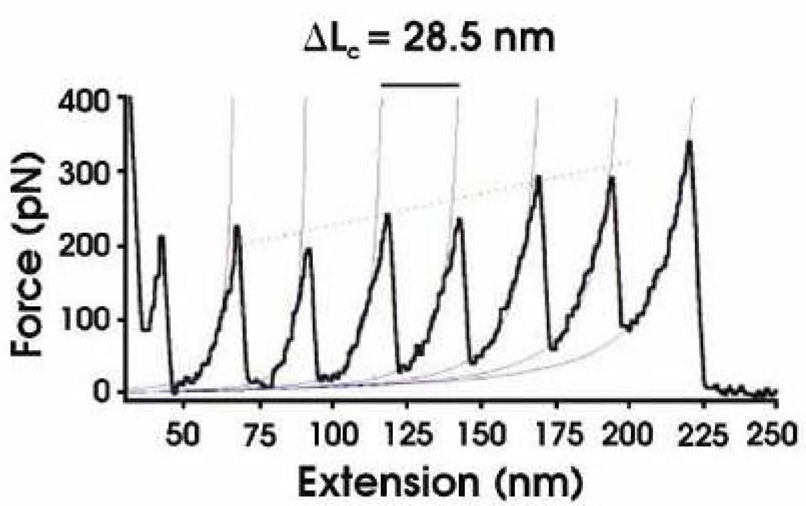
Techniques for mechanical stabilization

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 and rigid objects....

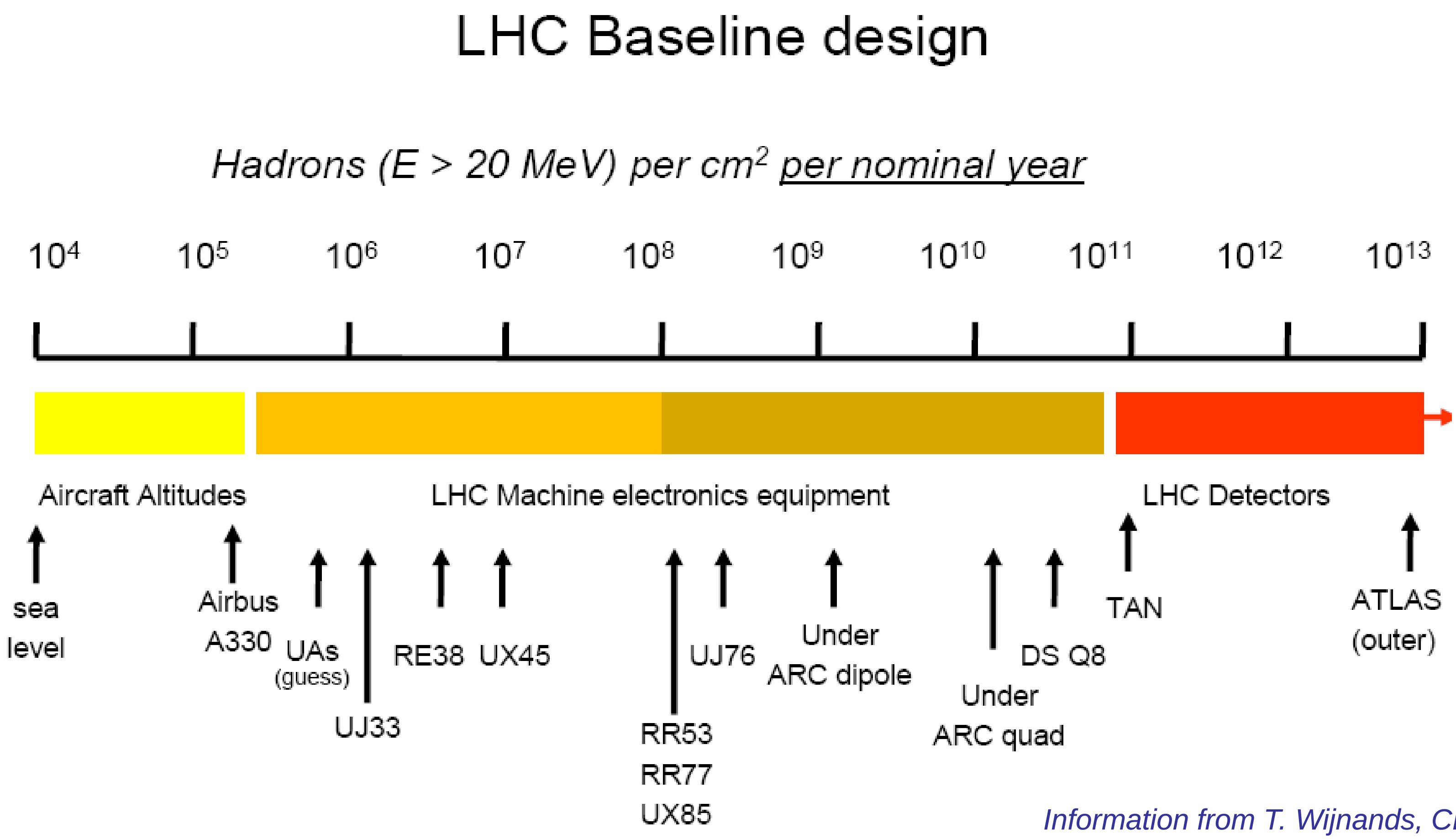
⇒ Techniques to be developed for heavier and larger structures

Techniques for mechanical stabilization

- Accelerator environment has to be taken into account
- In particular radiation effects have to be considered
  - Radiation level at CLIC not yet estimated
  - Radiation damage effects on electronics:
    - Total dose
    - Single event error
  - Experience with other CERN projects have shown Single event error can produce important failures

Radiation issues

- Expected single event error rate in the various underground regions for a nominal year of LHC operation

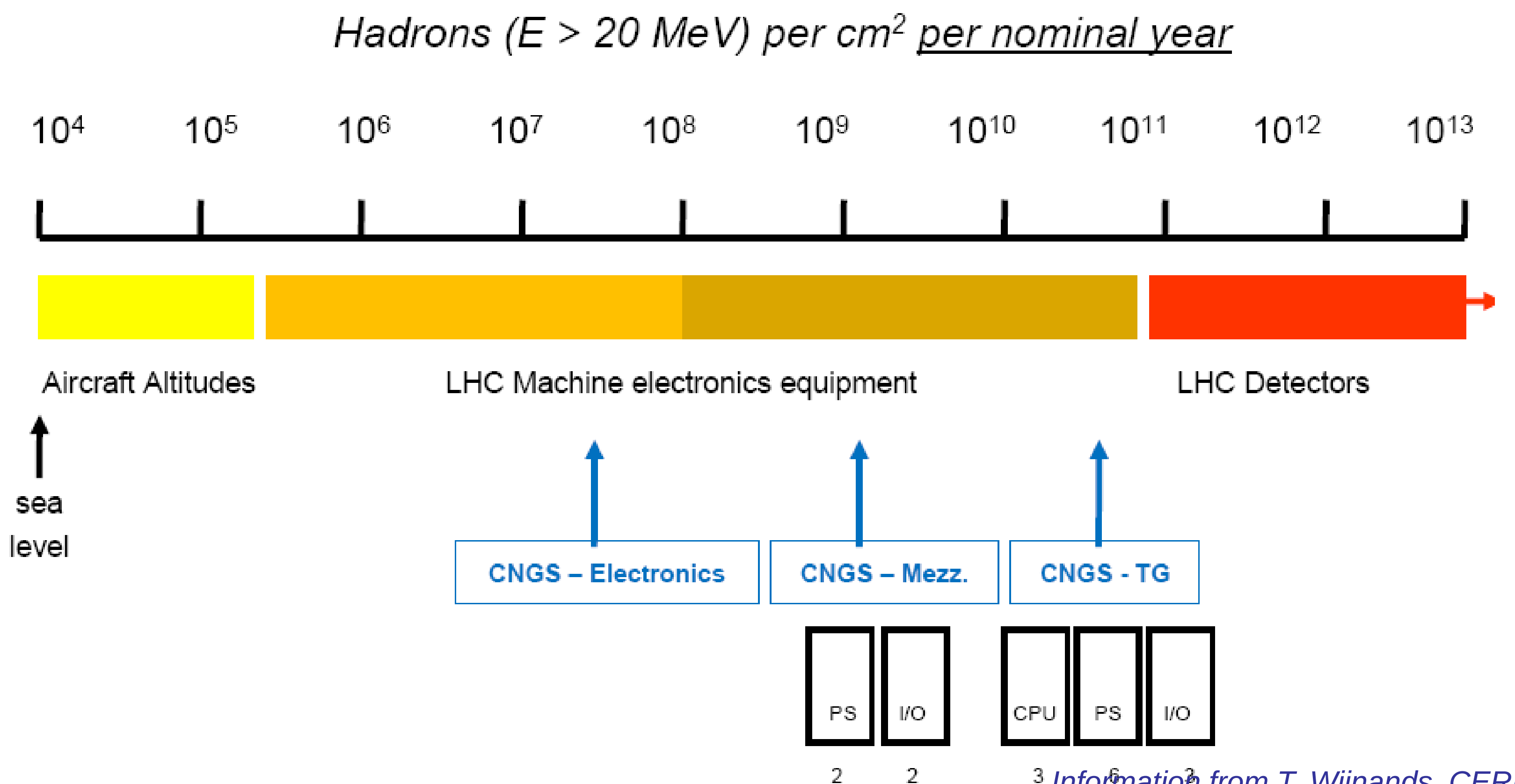


Information from T. Wijnands, CERN

Radiation issues

- And for CNGS

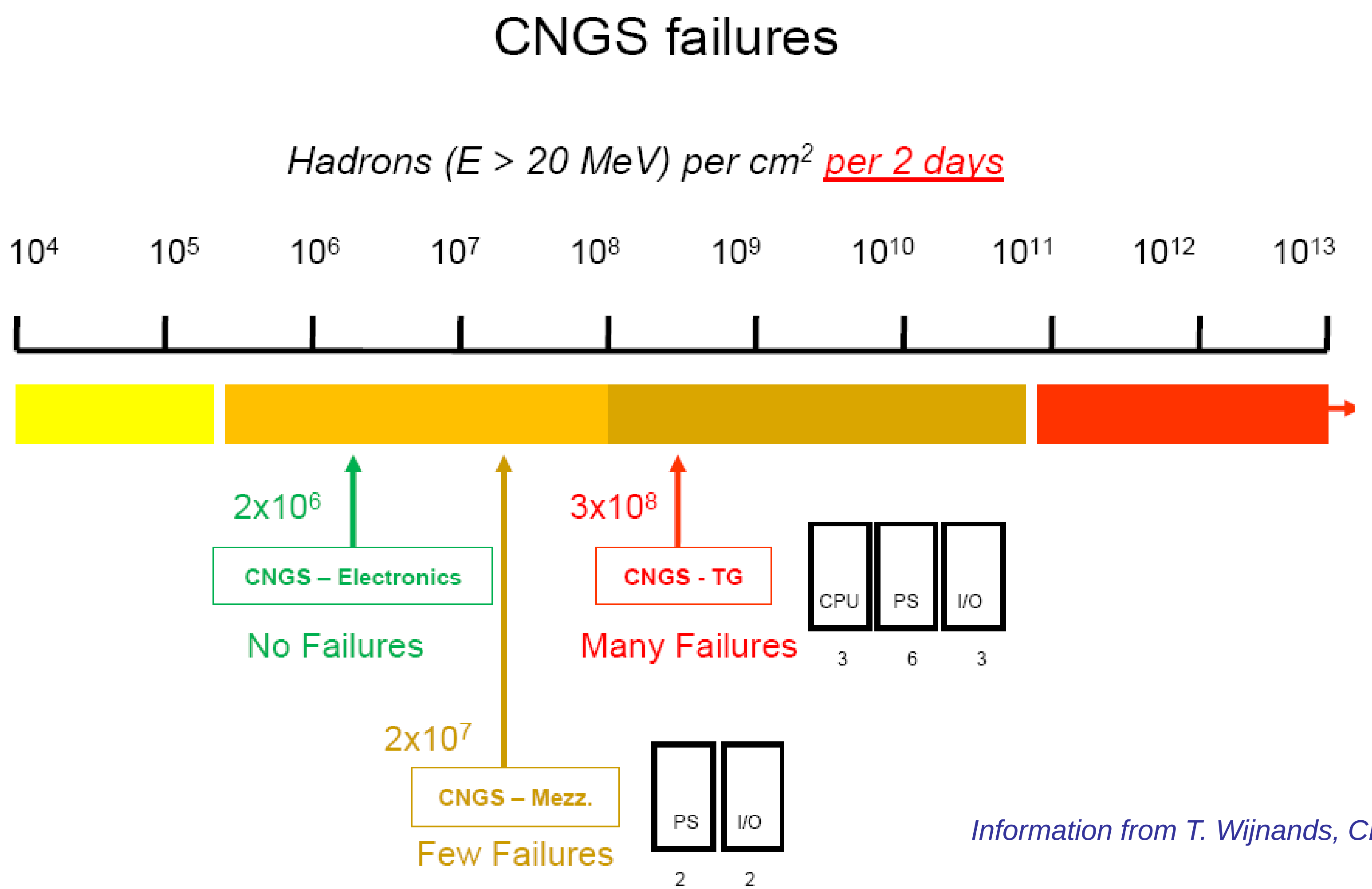
CNGS baseline design



Information from T. Wijnands, CERN

Radiation issues

- After just 2 days of operation in late 2007, Single Event Error failures occurred in two out of three of CNGS zones, at rates one or two orders of magnitude less than expected



Information from T. Wijnands, CERN

CLIC stabilization team

- Extensive work done between 2001 and 2003 concerning CLIC stabilization
- From 2004 to 2007:
  - Work continued only at Lapp Annecy, France
  - At CERN beam dynamic studies, update of stabilization requirements by Daniel Schulte
- Collaboration between several Institutes started in 2008

MONALISA IRFU/SIS

- Regular face-to-face meetings

Work plan

- Present goal for CLIC:
  - Demonstrate all key feasibility issues and document in a Conceptual Design Report by 2010

⇩

  - CLIC stabilization feasibility to be demonstrated by 2010

- Actions:
  - Characterize vibrations/noise sources in an accelerator and detectors
    - Summary of what has been done up to now
      - CLIC Stabilization Website: http://clic-stability.web.cern.ch/clic-stability/
    - Additional correlation measurements to be done at LHC interaction regions for distances from several m up to 1000 m
    - Continue measurements in CLEX environment at different installation phases

Work plan

- Actions:
  - Overall design
    - Linac
      - Compatibility of linac supporting system with stabilization (including mechanical design)
      - Design of quadrupole (we have to stabilize the magnetic axis) and build a mock-up with all mechanical characteristics
    - Final focus
      - Integration of all the final focus features: types of supporting structures, coupling with detector
  - Sensors
    - Qualification with respect to EMC and radiation
    - Calibrate by comparison. Use of interferometer to calibrate other sensors. Create a reference test set-up

Work plan

- Actions:
  - Feedback
    - Develop methodology to tackle with multi degrees of freedom (large frequency range, multi-elements)
    - Apply software to various combinations of sensors/actuators and improve resolution (noise level)
  - Overall system analysis
    - Stability, bandwidth,…
    - Sensitivity to relaxed specifications
  - Integrate and apply to linac
    - A mock-up should be ready to provide results by June 2010 with several types of sensors including interferometers
    - Mock-up to be integrated in accelerator environment – Where?

Conclusion

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Collaboration:

- Demonstrate stability of 0.1 nm > 4 Hz for final doublets
- Demonstrate stability of 1 nm > 1 Hz for main beam quadrupoles

With a realistic system, in an accelerator environment, to be checked using 2 different methods

- An integrated approach: stabilization elements to be taken into account at the design phase of CLIC composants, ground motion characterization, sensors, actuators, alignment compatibility with beam dynamics
- See next presentations in this workshop:
  - "Study Of Vibrations And Stabilization At The Sub-Nanometre Scale For CLIC Final Doublets" by Benoit BOLZON (LAPP)
  - "Monalisa status" (via Webex) by David Urner (University of Oxford)

Thank you!