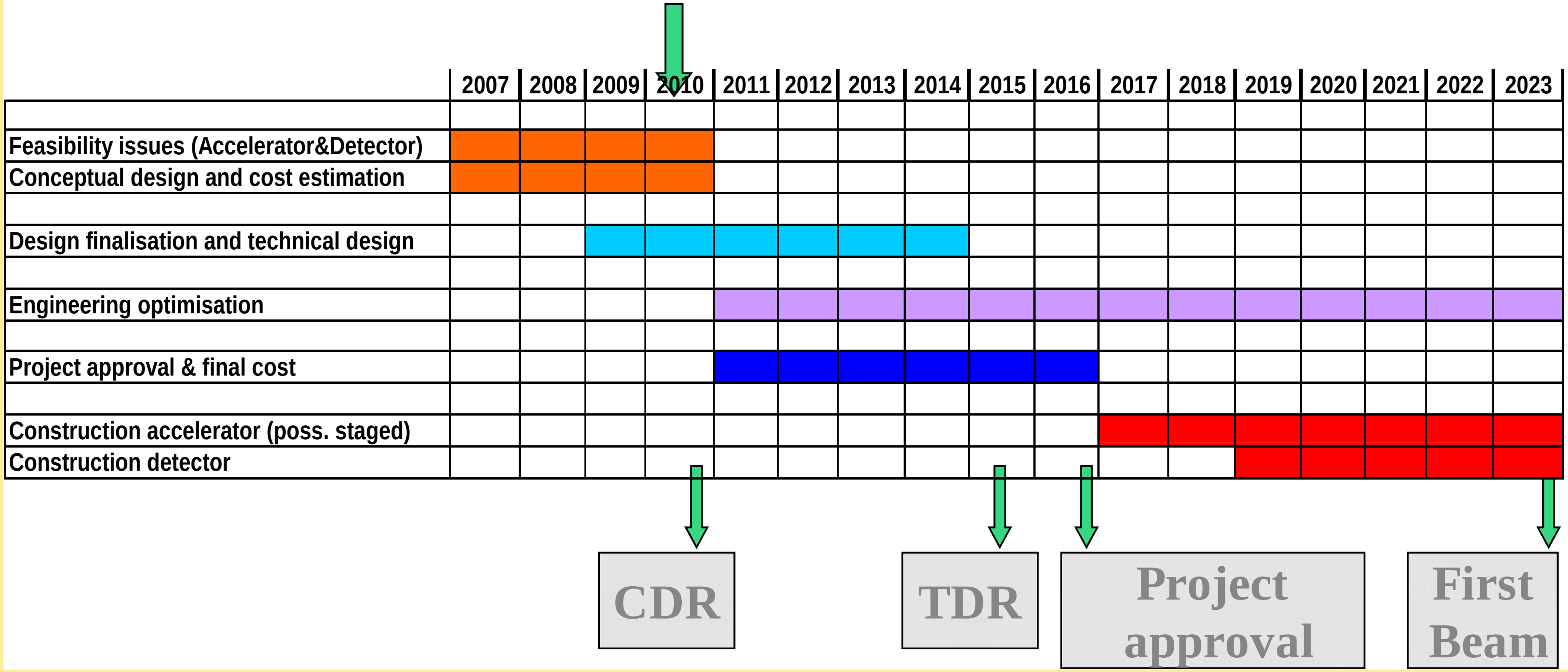
Our way to the CLIC CDR

1. Definition of CDR and TDR
2. CLIC feasibility items
3. Organization of technical preparation
   - CTC (=CLIC technical committee) with its mandate; what was done so far
   - List of critical items; action list; web documentation and collection of parameter specifications
4. Basic Concept of the CLIC CDR
   Present layout of the CDR chapters
5. Possible Time Scale
6. Summary
7. Details on Stabilization Work (picked as example)

Tentative long-term CLIC scenario
Shortest, success oriented and technically limited schedule

Technology evaluation and Physics assessment based on LHC results for a possible decision on Linear Collider funding with staged construction starting with the lowest energy required by Physics



What’s a CDR ? (Definition as discussed in CLIC project)

- Proof that all components of a facility and their interplay are conceptually understood
- Quantify expected overall performance and related component requirements
- Scientific case
- Proof of feasibility issues and cost estimate
- Evolution path to TDR

What’s has a TDR in addition?

Readiness to receive funding for building the facility, this implies:

- Technical design of all components which are critical for schedule
- Technical feasibility of all components; prototypes tested.
- Detailed site consideration
- Detailed construction Schedule
- Detailed material cost and manpower resource estimates and risk analysis

What are the CLIC feasibility issues?

- The already published and discussed work objectives of CTF3 and of the design and test work on accelerating structures:

  Main beam acceleration structures
  Demonstrate nominal CLIC structures with damping features at the design gradient, with design pulse length and breakdown rate .

  Decelerating Structures
  Demonstrate nominal PETS with damping features at the design power, with design pulse length, breakdown rate and on/off capability

  Drive Beam
  Generation of Drive beam, Handling of Beam Power, Phase Stability

  Demonstration of two beam acceleration scheme
  Relevant Linac subunit with two beams

- Other issues? What work-plan to demonstrate them by 2010?

Mandate CLIC Technical Committee (CTC)

(created in spring 2008)

- **General objective:**
  Towards a Project Oriented and Cost Conscious CLIC Design in preparation for the Conceptual Design Report to be edited in 2010.

- **Specific responsibility:**
  Set-up and keep updated:
  - an overall nomenclature of the components of the whole project,
  - a complete and coherent CLIC Work Breakdown Structure with components specifications derived from the present design by the Parameters WG
  - The related documentation structure integrating a description of all technical components

  Review the ensemble of technical equipments in the present CLIC design in terms of:
  - Specifications
  - Technical feasibility
  - Fabrication and prospective in industrialization
  - Integration (machine/tunnel)
  - Interface with the detectors
  - Installation
  - Schedule (including fabrication & installation)
  - Cost (investment and exploitation)

Mandate CLIC Technical Committee (CTC) (2)

- In close collaboration with the technical responsibles identify technical key issues requiring specific R&D or prototyping in view of the Conceptual Design Report.
- Assess present R&D program and propose prioritized R&D including schedule and milestones on the various systems or components for approval by the CLIC Design & Parameters Committee
- Following a value analysis of individual components or ensemble of components, suggest possible improvements towards global project optimization aiming at a performance to cost and risk ratio as high as possible
- Elaborate for approval by the CLIC Design & Parameters Committee and description in the CLIC Conceptual Design Report:
  - a baseline scenario and schedule including prototyping, fabrication, equipment integration, installation and HW commissioning
  - a CLIC baseline complex
  - possible options for improved performance and/or reduced cost and the corresponding R&D program

Organisation:

- Set-up ad-hoc working groups on dedicated subjects and/or integrate existing ones.
- Manage a dedicated web site with links to updated key documentation
- Regularly report to the CLIC Design & Parameters Committee for approval and to the CLIC meeting for information

Specific responsibility

- *Set-up and keep up-to-date:*
  - *an overall nomenclature of the whole project*
  - *a complete and coherent CLIC Work Breakdown Structure with components specifications derived from the design by the Parameters WG*
  - *the related documentation integrating a description of all technical components*

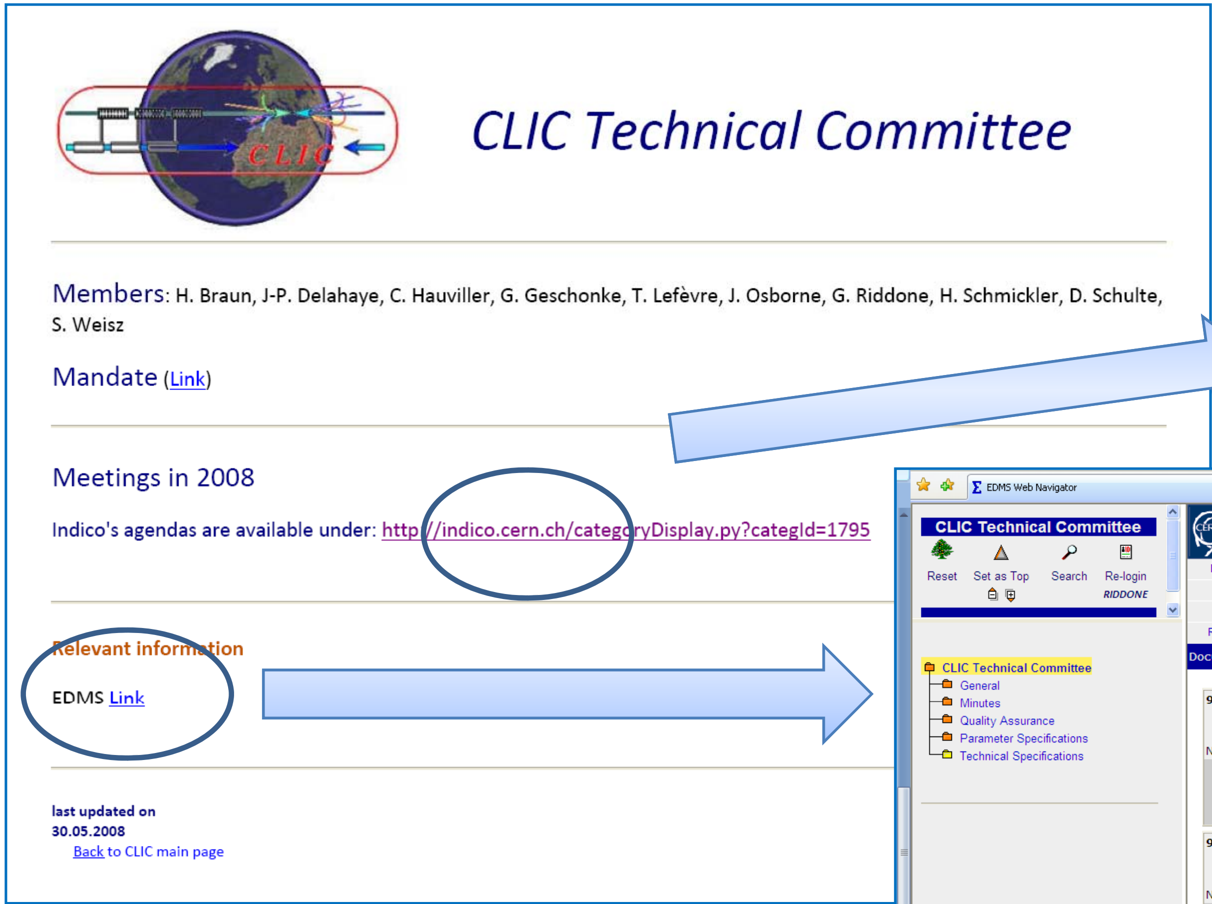
Put in place a specific Quality Assurance Working Group on a short term basis.

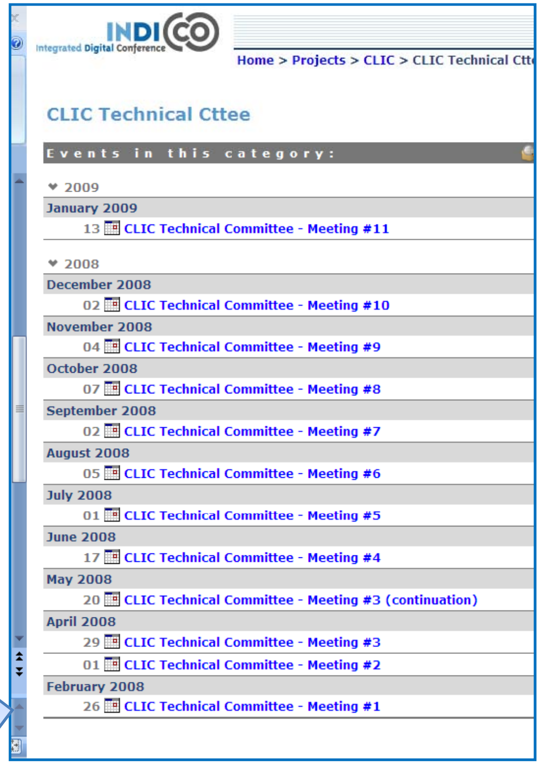
Objective: freeze PBS, WBS, nomenclature, … end 2010

Specific responsibility

- *Review the ensemble of technical equipments in terms of:*
  - *Specifications*
  - *feasibility*
  - *Fabrication and prospective in industrialization*
  - *Integration (machine/tunnel)*
  - *Interface with the detectors*
  - *Installation*
  - *Schedule (including fabrication & installation)*
  - *Cost (investment and exploitation)*

Organisation





Organization

- *Set-up ad-hoc working groups on dedicated subjects (including already existing ones)*

Working Groups

- Civil Engineering and Services (CES)
- Two Beam Module (TBM)
- Machine Detector Interface (MDI)
- Stabilization (STA)
- Instrumentation

Status of written parameter specifications (=PS)

- We have a list of all specifications to be produced
- PS for all vacuum systems approved
- Warm magnets:
  → Detailed PS for main linac quadrupole under approval
  (most urgent for stabilization working group)
  → Summary PS for all other magnets prepared
  → In the MDI working group a time limited study (3 months) will re-iterate the existing design option of a permanent magnet candilever design for the final focus. We expect an approved PS for early 2009.
  → 1st round of resource discussions with magnet group in order to achieve a main-quadrupole mockup magnet in 2009 plus further studies on the other magnets.
- Beam instrumentation: Presently collecting parameter specifications. Details will be discussed in this workshop. Summary on Thursday.
  The idea is to organize a mini-workshop later this year in order to decide what instrumentation requirements are within technical reach and what instruments still need major R&D/are likely to need revision of specs.

CTC: “List of critical items”

- Complements the already published and discussed work objectives of CTF3 and of the design and test work on accelerating structures.
- Is a Prioritized list of items.
- Three categories:
  - cost issue
  - performance issue
  - crucial design choice (= CLIC feasibility)
- All critical items have been compiled into one list.

Feasibility issues extracted from list (1/2) complement to Rf structures/ CTF3 work)

- Instrumentation:

  BPMs with 50 nm resolution (large quantities; reliability)
  Phase monitors (0.1 degrees at 12 GHz)
  1 micrometer beam size monitors
  machine protection instrumentation
  main linac wake field monitors (142000 monitors!)

- Machine availability:

  machine protection, MTBF, MTTR, large component counts,
  calibration runs (i.e. ballistic steering)
  → maximum expected uptime for luminosity production

Feasibility issues extracted from list (2/2) complement to Rf structures/ CTF3 work)

- Transport of ultra low emittance beams through main linac:

  - several RT-feedbacks
  - complicated interplay of online correction algorithms (using BPMs and corrector coils) and stabilization system.

  Basic concept:
  Low frequency dynamic errors are measured with BPMs and corrected. Resolution of BPMs critical. Demagnification of noise sources (=gain of this system) tested in simulations.
  Needs active stabilization system for higher frequency components.

- Stabilization system (1nm (above 1Hz) in main linac quadrupoles and 0.1 nm in FF quadrupoles in vertical plane)
  Active search for a demonstrator installation in a typical beam environment

Basics of CDR

- 3 TeV option for CLIC as baseline for the optimization of the parameters.
- Construction staging starting from the lowest demanded energy (let us say 500 GeV) as indicated by LHC results up to the full 3 TeV machine.
- Parameter changes and optimization for the “500 GeV” machine plus additional consequences for later energy upgrades in a separate chapter
- Description of the physics and beam dynamics of all machine components following the order in the newly elaborated CLIC PBS.
- Technology chapters grouped together by disciplines.

Like ILC report

Layout of CDR

Vol1: Executive Summary: target 20 pages

Vol2: Physics at CLIC

progress will depend on LHC results; presently we use the report from 2004; no action before mid 2009

Vol3: The CLIC accelerator and site facilities

Vol4: The CLIC physics detectors

just received first breakdown from co-coordinating authors

Detailed value Estimate

will be treated in volumes 2-4; summary in volume 1.

Possible Time Scale

- We have defined 5 sample authors (all CERN), who will deliver before the CLIC october workshop different chapters of the CDR. Those will be made available to all collaboration members and those templates should be used as style templates. (→ until october 2008)
- Some PR work will be made during the workshop in order to motivate authors; in particular non CERN authors
  → definition of authors (for volume 3) by the end of 2008
- Summer 2009 we schedule a “90% draft” of volume 3
- Summer 2010 we schedule a full draft of the whole CDR.

These deadlines can only be met if the progress in the still necessary R&D has been successfully achieved.
We expect a reaction from the CERN management to assign the resources as documented in the white paper.

Summary

- CDR layout defined. Waiting for positive response from CLIC October workshop to get good authors.
- One major task of the CDR is to document the feasibility of the CLIC project
  - the CTC has started to organize the necessary technical documentation
  - the CTC will prioritize the remaining R&D and follow up actions (complement to CTF3 and Rf-Structures Work)
  - for each item on the list of critical items an individual approach has to be found. Additional collaboration much needed.
- The human resources situation is critical. In case the CERN resources allocated through the "white Paper" will manifest, a CLIC feasibility demonstration (and a CDR) by 2010 is feasible.

For entertainment:

- Many more details on stabilization work (picked as example)
- Slides taken from:

O. Capatina et al., Novosibirsk, 27th of May 2008

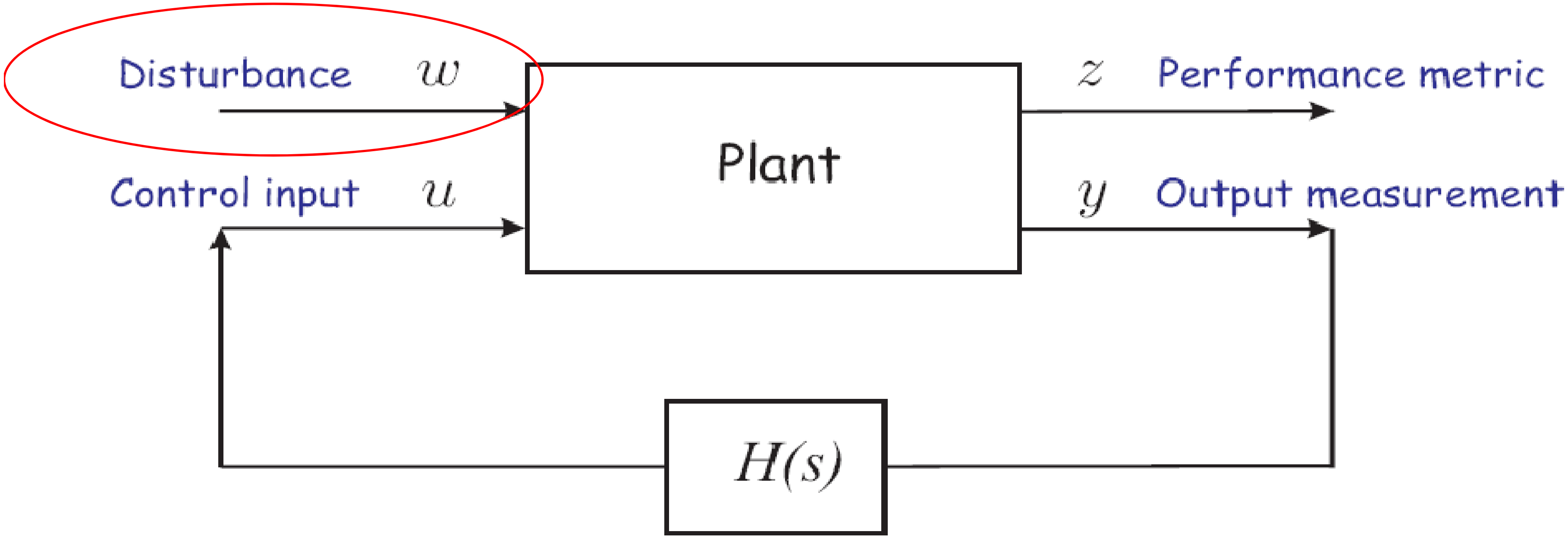
CLIC stabilization requirements

- Mechanical stabilization requirements:
  Quadrupole magnetic axis vibration tolerances:

	Final Focusing Quadrupoles	Main beam quadrupoles
Vertical	0.14 ...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

Techniques for mechanical stabilization

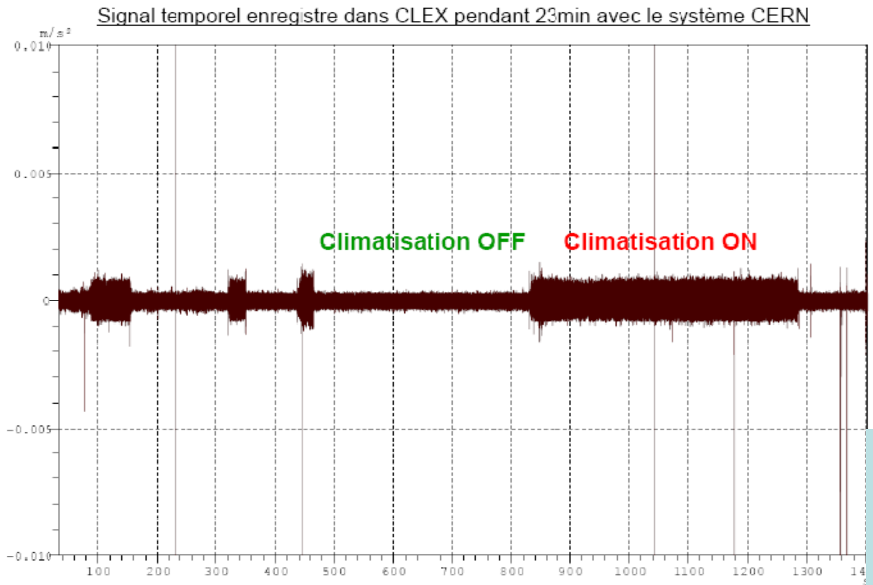


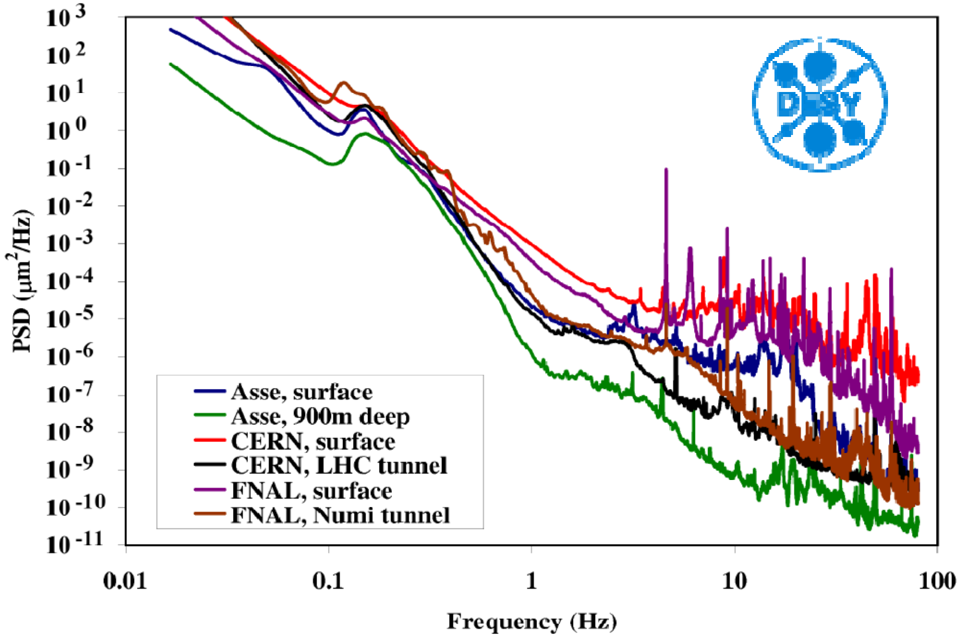
Structural control problem that needs an integrated approach

Vibration sources

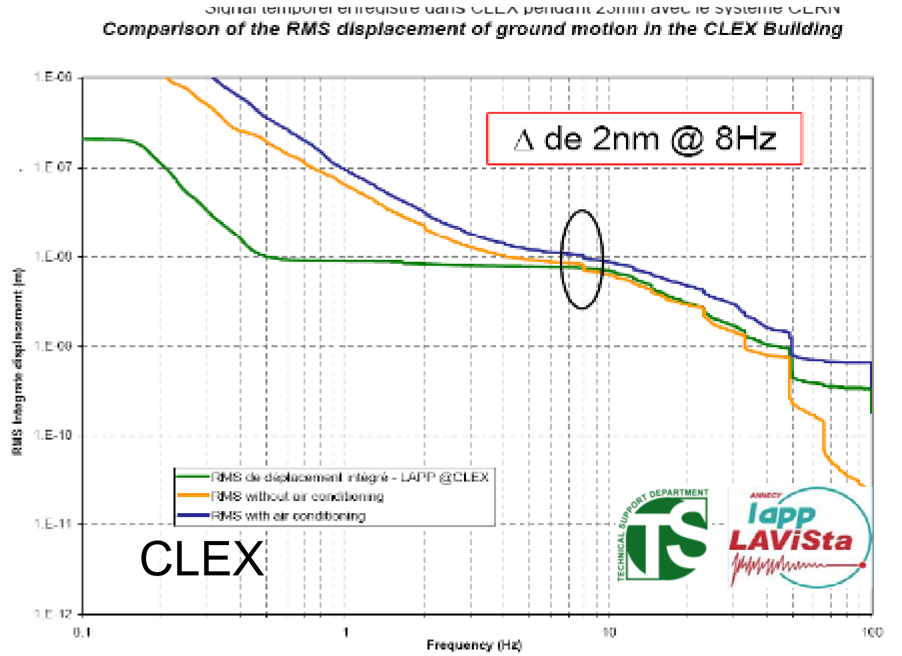
1. Ground vibration

DSP





R.M.S. Intégré



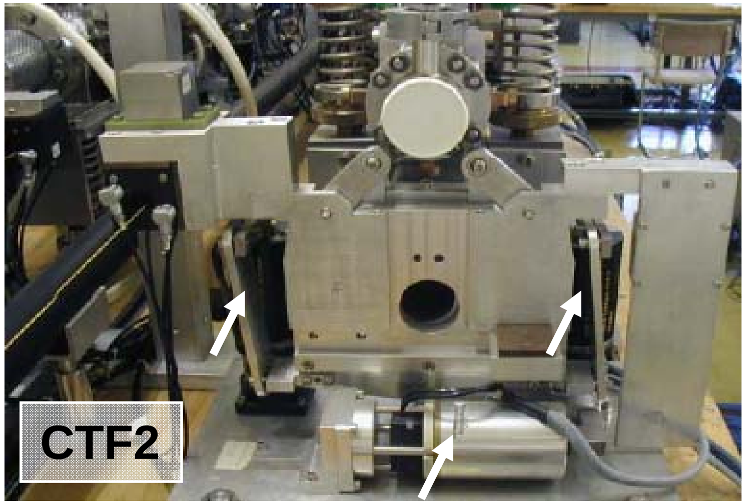
Remark: Measurement interpretation may depend on Signal processing !

Vibration 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
  - Inter pulse alignment with stepper motors

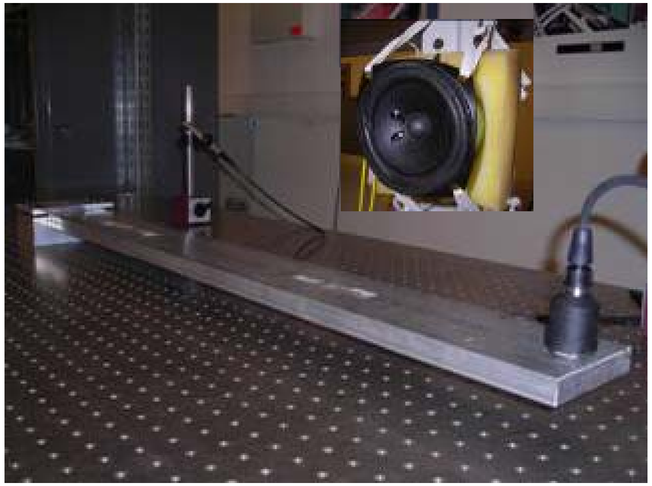


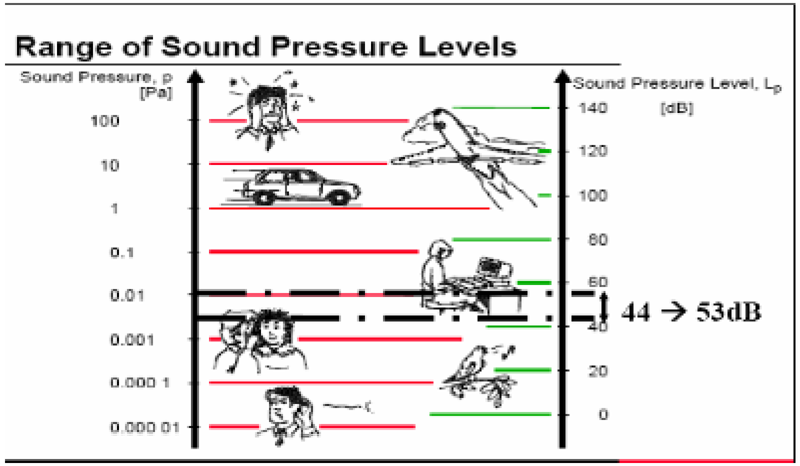
Vibration sources

3. Acoustic noise

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

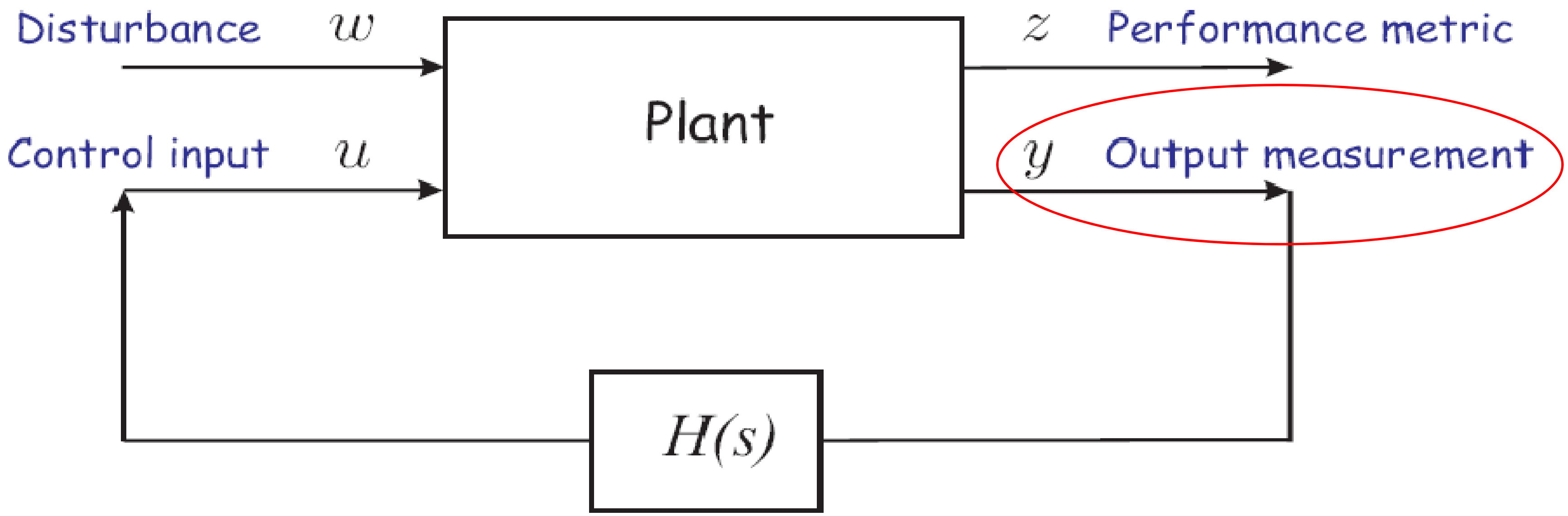
See next presentation by B.Bolzon





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

Techniques for mechanical stabilization



Structural control problem that needs an integrated approach

Output measurement

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

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

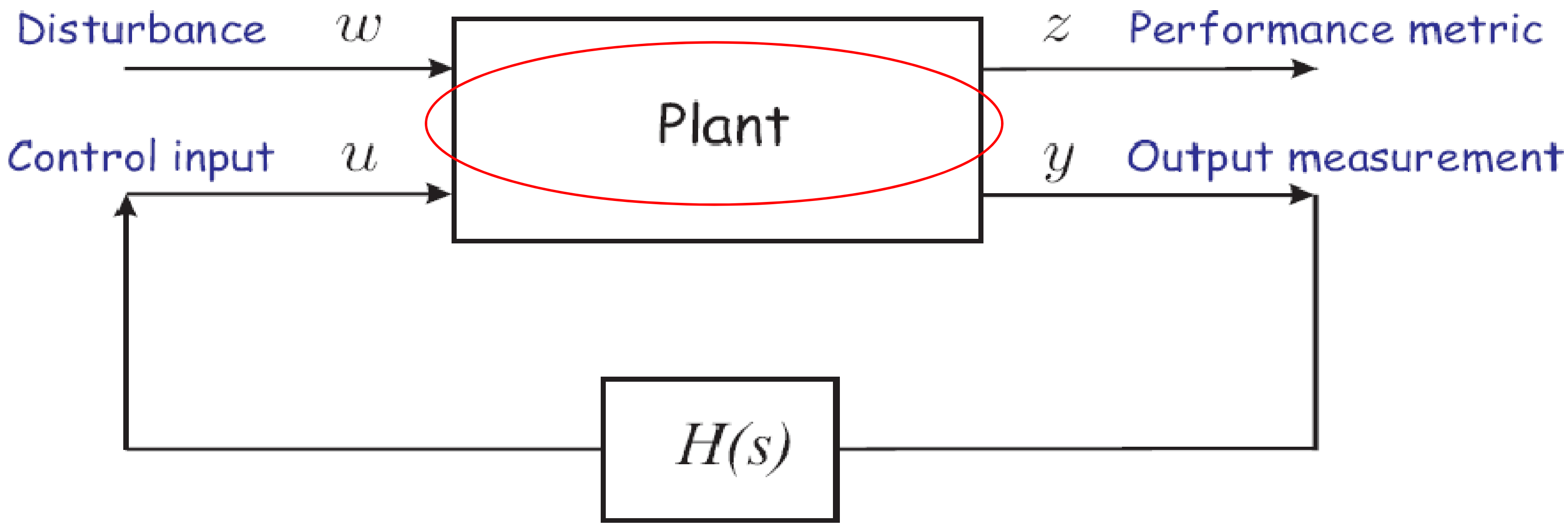



Streckeisen STS2	Guralp CMG 3T	Guralp CMG 40T	Eentec SP500	PCB 393B31
x,y,z	x,y,z	x,y,z	z	z
			electrochemical	
2*750Vs/m	2*750Vs/m	2*800Vs/m	2000Vs/m	1.02Vs^2/m
120 s -50 Hz	360s -50 Hz	30 s -50 Hz	60 s -70 Hz	10 s -300 Hz
13 kg	13.5 kg	7.5 kg	0.750 kg	0.635 kg
23 kCHF	19 kCHF	8 kCHF		1.7 kCHF

- **Vibrometer et interferometer** — Déplacement

MONALISA

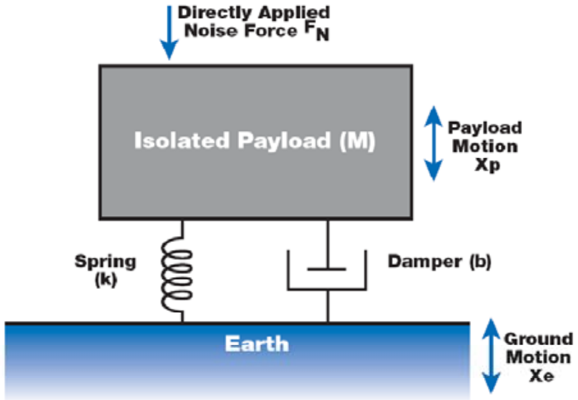
Techniques for mechanical stabilization



Structural control problem that needs an integrated approach

"Plant" characterization / optimization

Vibrations « Transmissibility »



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

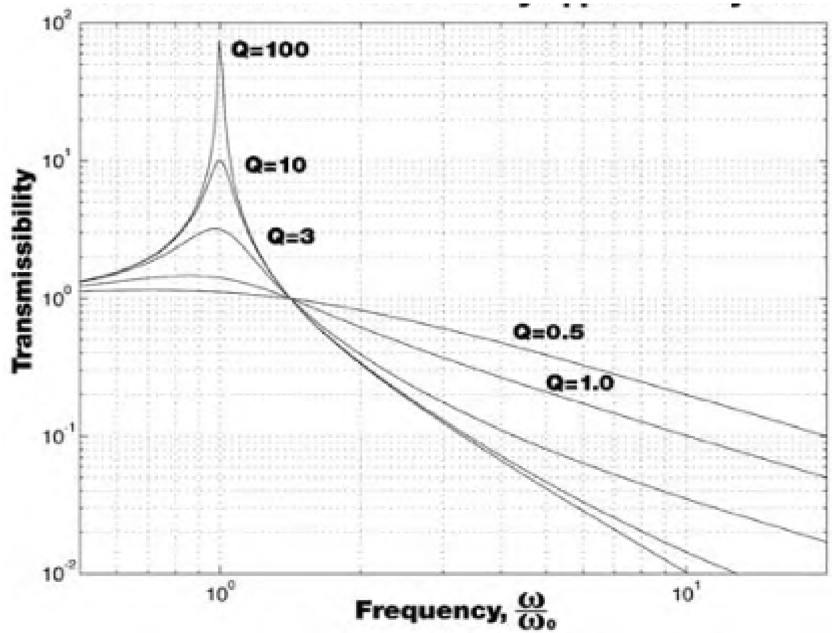
$$\omega_0 = \sqrt{\frac{k}{M}}$$

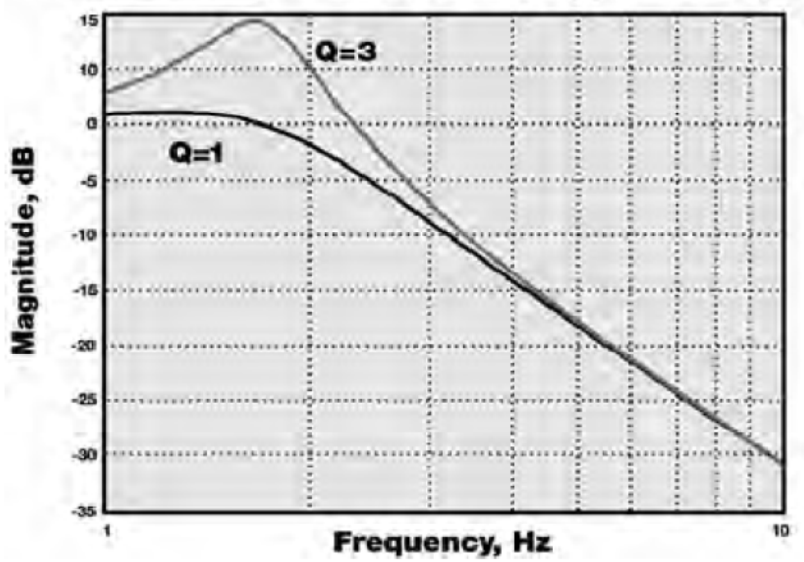
Natural frequency

Structural damping

$$\xi = 2Q$$

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



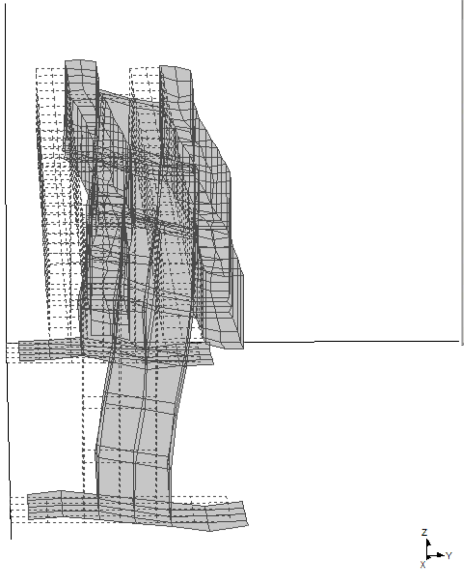


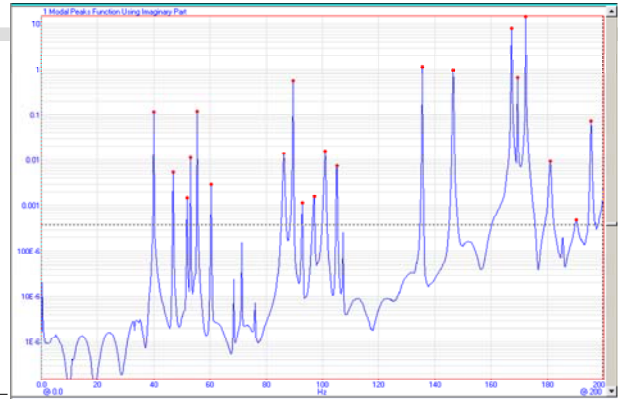
Magnet mechanical design to be carefully optimized !

"Plant" characterization / optimization

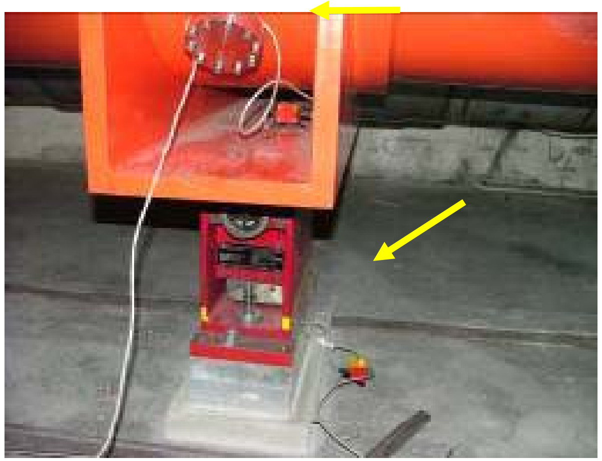
Real system:

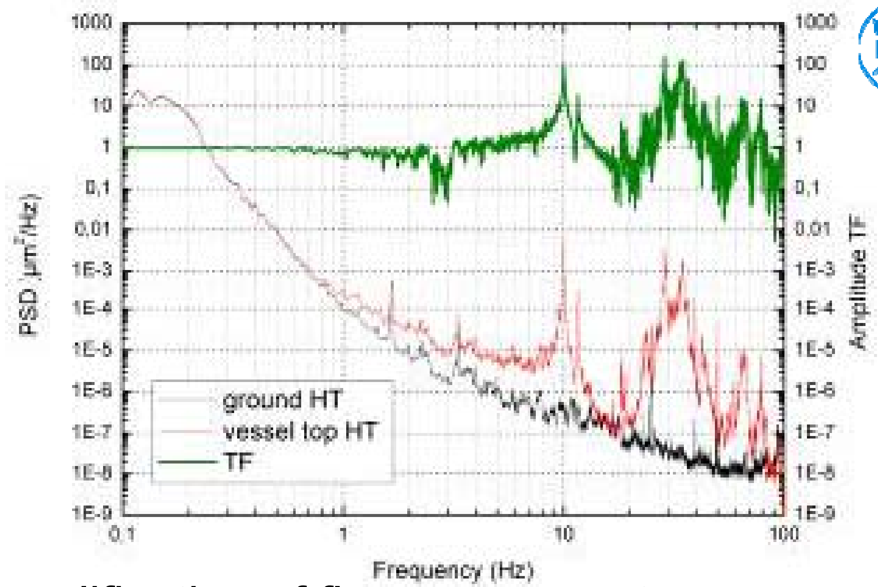
Multi degrees of freedom and several deformation modes with different structural damping





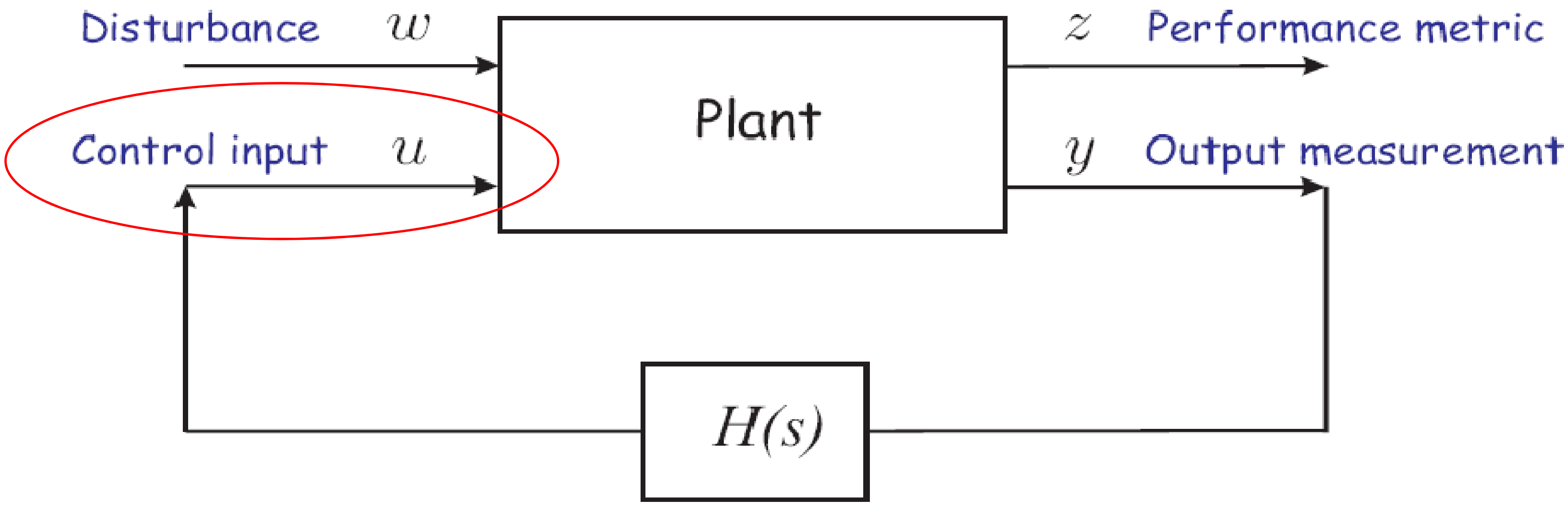
Experimental modal analysis on CLEX girder





Amplification of floor movement

Techniques for mechanical stabilization



Structural control problem that needs an integrated approach

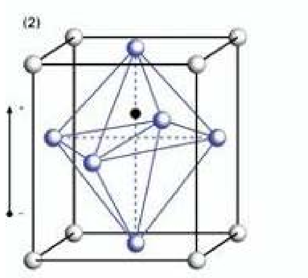
Control input

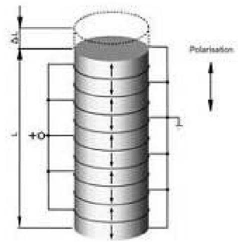
Actuators with 0.1 nm resolution?

Resolution, movement reproducibility?

Friction
Guiding systems with friction

Real resolution 1 µm (0.1 µm)

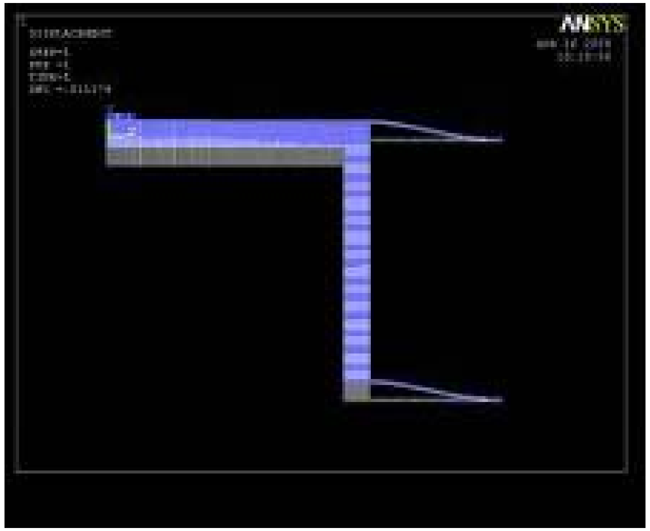




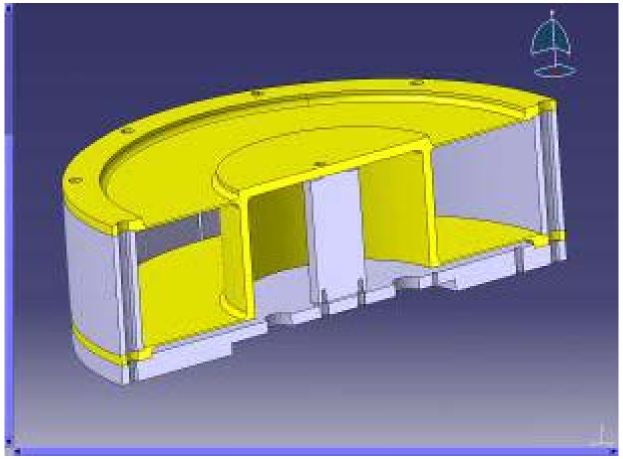
Solution: Piezo actuators PZT

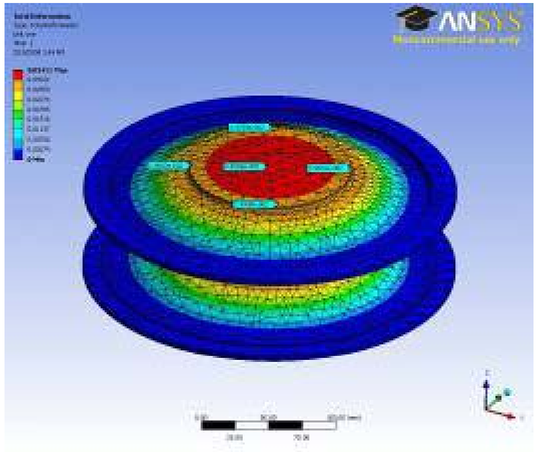
+ flexural guides

+ feedback capacitive sensor



0.1 nm 100 N Calibration bench flexural guides





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

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?