Stabilisation studies for the final focus and the main linac "mechanical"

A.Jeremie

Slides taken from different presentations within the "stabilisation WG" http://clic-study.web.cern.ch/CLIC-Study/CLIC_Stabilisation/Index.htm

News from the CLIC Stabilization Working Group

- Collaboration: Laboratories participating (to-date):
  - LAViSta (LAPP, Université de Savoie-SYMME)
  - CERN (EN, TE, BE)
  - JAI- Oxford University
  - CEA-DSM-IRFU-SIS
  - PSI
  - Information from DESY, SLAC,…
  - Contacts with universities

•Extra financing through FP7/EuCARD and collaborating institutes

- WG coordinator: C.Hauviller (CERN),
  - MB stabilisation coordinator: K.Artoos (CERN)
  - FF stabilisation coordinator: A.Jeremie (LAPP)

J.P.Delahaye CLIC'08

CLIC feasibility issues

	SYSTEMS (level n)	Critical parameters	Feasibility issue	Performance issue	Cost issue
Structures	<u>Main beam acceleration structures</u> Demonstrate nominal CLIC structures with damping features at the design gradient, with design pulse length and breakdown rate .	100 MV/m 240 ns 3·10-7 BR/(pulse*m)	X	X	X
Structures	<u>Decelerator structures</u> Demonstrate nominal PETS with damping features at design power, with design pulse length, breakdown rate on/off capability	136 MW 240 ns	X		X
Drive Beam	<u>Validation of drive Beam</u> - production - phase stability , potential feedbacks - MPS appropriate for beam power	0.2 degrees phase stability at 12 GHz	X	X	
Two Beam	Test of a relevant linac sub-unit with both beams	NA	X		
Beam Physics	- Preservation of low emittances (main linac + RTML)	Absolute blow-up Hor: 160nradm Vert: 15 nradm	X	X	
Stabilization	Main Linac and BDS Stabilization	Main Linac : 1 nm vert (>1 Hz) BDS: 0.15...1 nm vert (>4 Hz) depending on implementation of final doublet girder	X	X	X
Operation and reliability	Commissioning strategy Staging of commissioning and construction MTBF, MTTR Machine protection	Handling of drive beam power of 72 MW	X	X	X

!

A.J

de Physique des Particules

09

Some comments

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

Initially, only vertical direction was studied

Several PhDs:

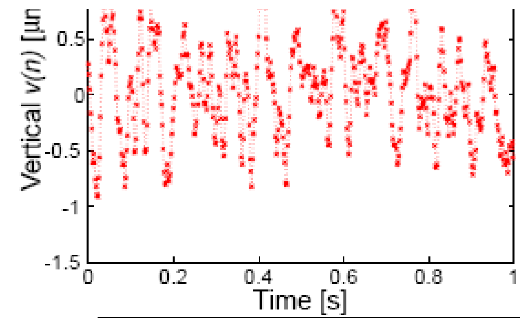
- –C.Montag (DESY) 1997
- –S.Redaelli (CERN) 2003
- –B.Bolzon (LAPP) 2007
- –M.Warden (Oxford) ~2010
- –R. LeBreton (SYMME) ~2012

- Active vibration control is not yet a mature technology.
- Activity should be defined as R&D but with CLIC engineering as objective.
- It will take time to achieve the final objective but a work plan has been agreed with CDR as an important milestone.
- Each time a new team starts this study, there is a non negligible “learning period”.

What type of graphs are used

We measure discrete velocities

$$v(n) = v(t_0 + n\Delta t)$$

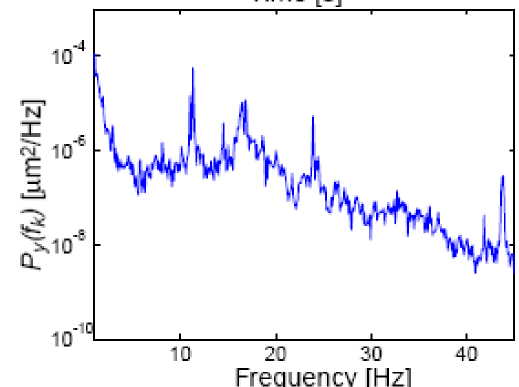


FFT of velocities

$$\tilde{v}(f_k) = \Delta t \sum_{n=1}^{N/2} v(n) e^{-2\pi i \frac{kn}{N}}$$

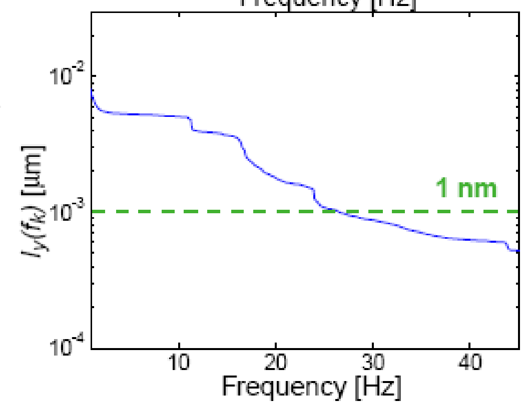
Power spectral density of displacements

$$P(f_k) = \frac{N \Delta t^3}{2\pi^2 k^2} \left| \sum_{n=1}^{N} v(n) e^{-2\pi i \frac{kn}{N}} \right|^2 \sim \frac{|\tilde{v}(f_k)|^2}{(2\pi f_k)^2}$$



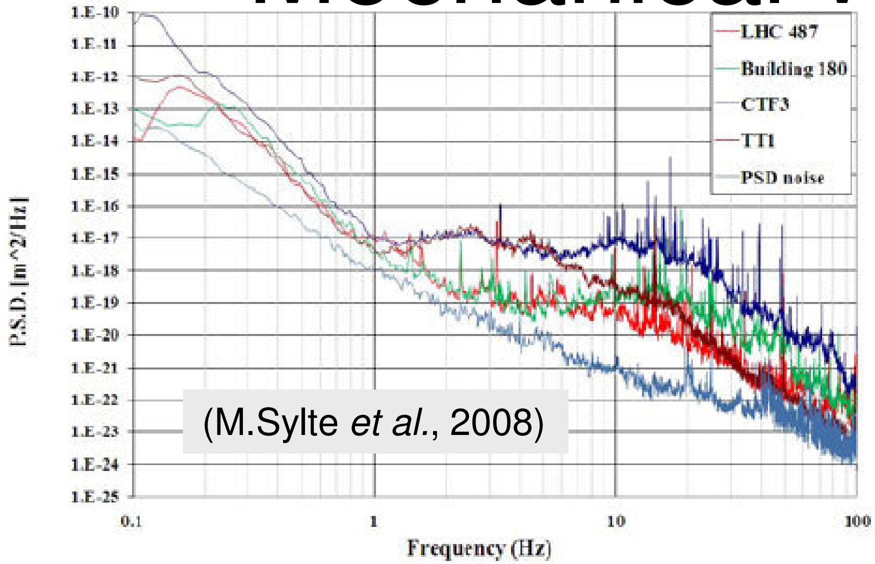
Physical picture: integrated rms motion above f_0

$$I(f_{k_0}) = \sqrt{\frac{1}{N \Delta t} \sum_{k'=k_0}^{N/2} P(f_{k'})}$$



(All formulae implemented in MatLab® routines and tested on simple + advanced examples)

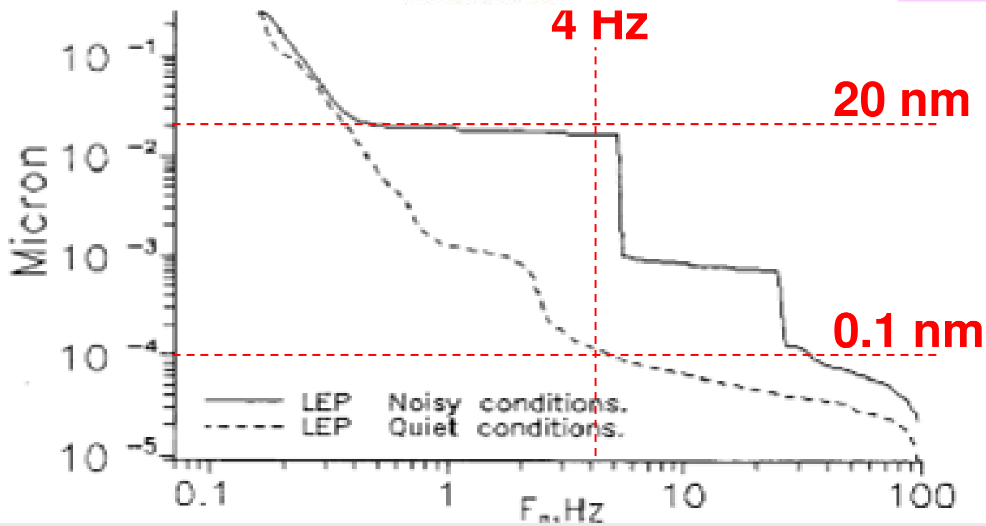
Mechanical vibration sources



(M.Sylte *et al.*, 2008)

Sources:
Ground motion, Traffic, Lifts, cooling water, ventilation, pumps, machinery, acoustic pressure

Transmitted:
•from the ground through the magnet support,
•directly to the magnet via beam pipe, cooling pipes, cables...



Measurements in the LEP tunnel (W. Coosemans *et al.*, 1993)

We cannot rely only on the quietness of the site

Stabilization techniques have to be developed

What can active stabilisation do?

Since the isolation systems don’t isolate 100%, but only reduce the vibrations by a given factor (x10 for common systems, x100 VERY difficult, x1000 “impossible”)

- The initial vibration background has to be as low as possible => if we want
  - MB stab of 1nm, the ground should already be 10nm
  - 0.15nm for the FF, the support should not be subjected to more than 2nm.
- Vibration measurements have shown:
  - Ground measurements at 1Hz vary from 2nm (LEP) to 150nm (ATF2).
  - Common detectors move already by 30nm to more than 100nm!

Need to measure vibrations and act

What type of sensors are needed:

- Small
- nanometre displacements
- frequency range 0.5Hz to 100Hz
- radiation hard
- magnetic field

=>So far only coil sensors or piezos used and the molecular sensors don't seem to be stable in time.

What type of actuators are needed:

- Same requirements as sensors

⇒ piezo stacks (Cedrat, PI) OK.

⇒ Still to confirm weight range and displacement range.

Instrumentation study (sensors and actuators)

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

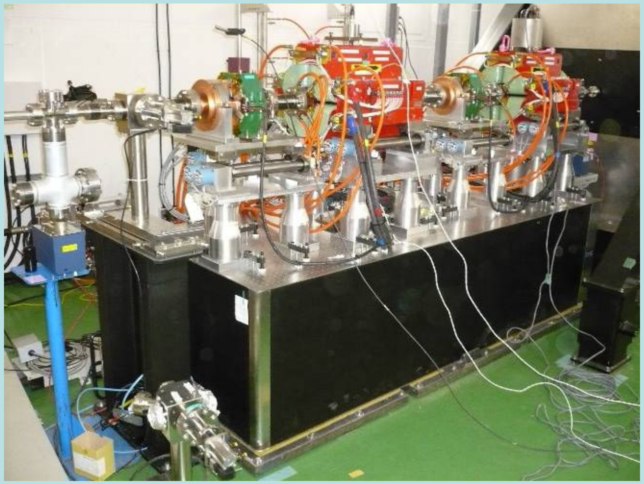
electrochemical

Streckeisen STS2	Guralp CMG 3T	Guralp CMG 40T	Eentec SP500	PCB 393B31	Endevco 86	PCB 393B12	B&K 450B3

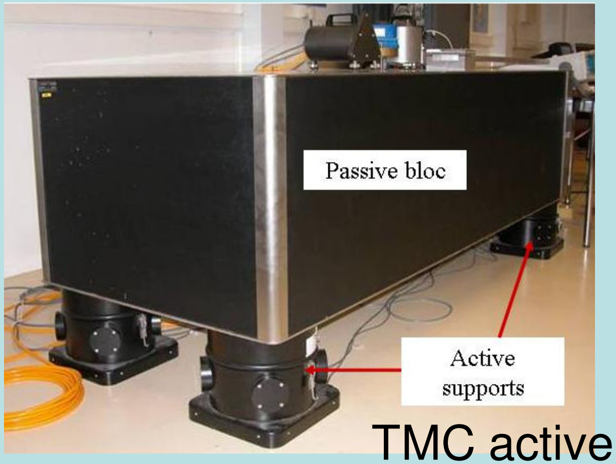
Low vibrations => support design

✓ **Rigid support : ATF2 approach**

Transfer function of ~1 between the floor and the support

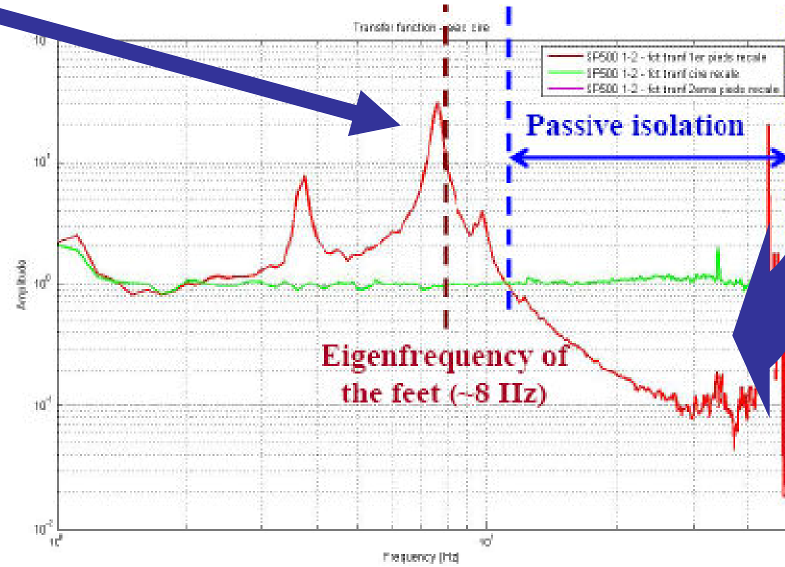


✓ **Active isolation : CLIC approach**



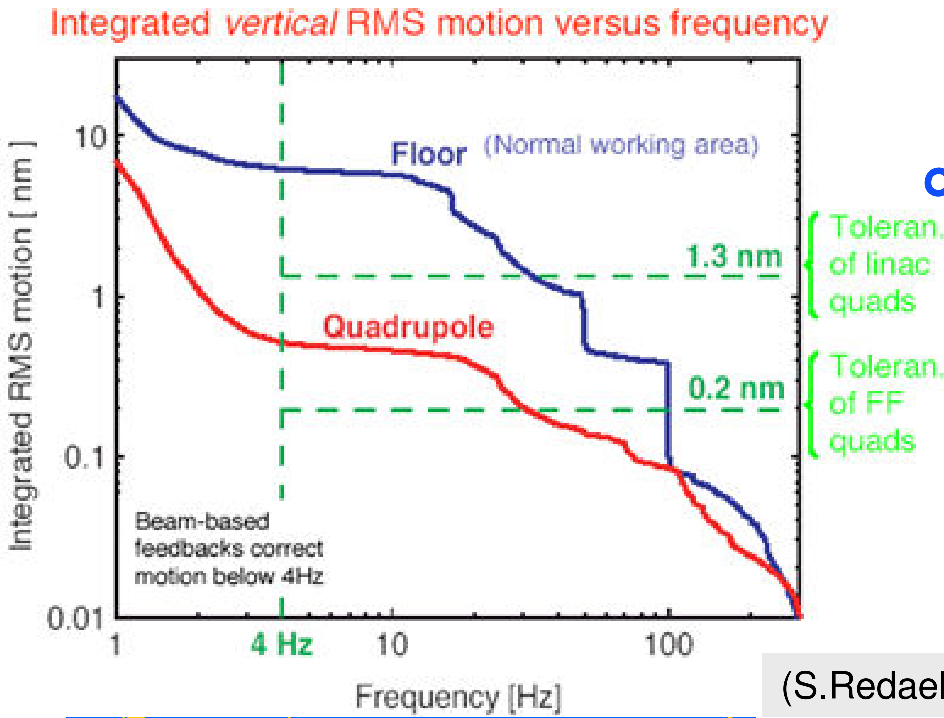
TMC active table

- Passive isolation :
  - Reduces ground motion above a few Hz
  - Increases ground motion under a few Hz
- Active isolation :
  - attenuates the disturbances amplified by the passive isolation



A soft support improves the isolation but :
(i)makes the quadrupole more sensitive to external forces
(ii)Cannot be positioned at high speed

Nanometer linac Stabilisation



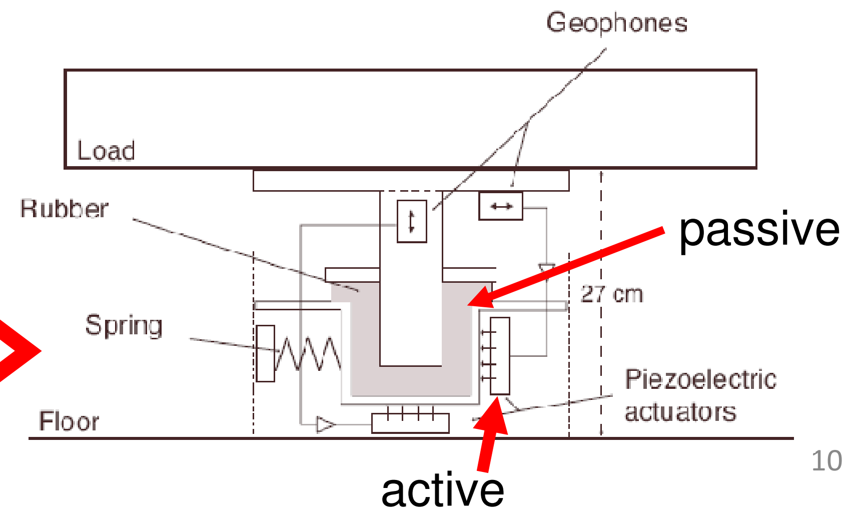
CLIC small quadrupole stabilised to nanometer level by active damping of natural floor vibration

RMS vibrations above 4 Hz

	Quad [nm]	Ground [nm]
Vertical	0.43	6.20
Horizontal	0.79	3.04
Longitud.	4.29	4.32

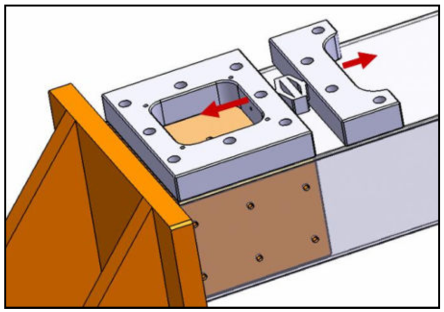
(S.Redaelli *2003*)

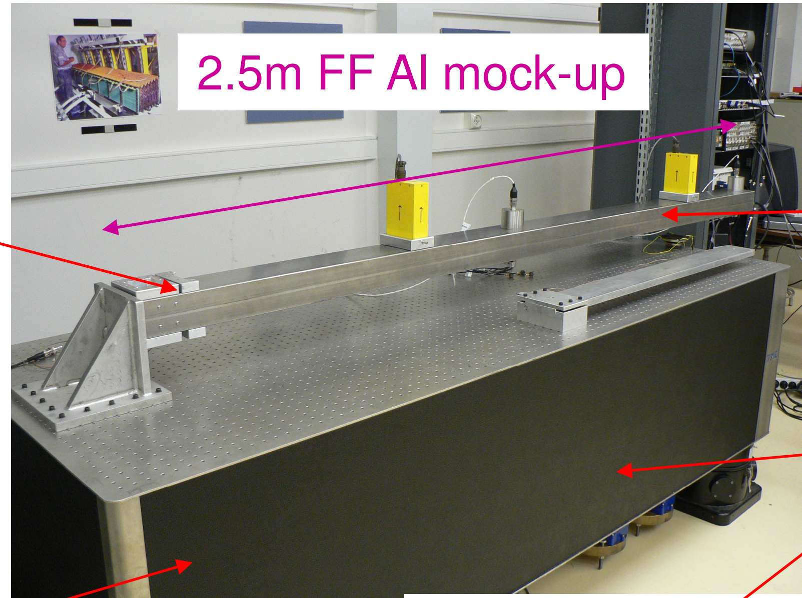
CERN vibration test stand



Cantilever FF stabilisation

LAPP active system for resonance rejection

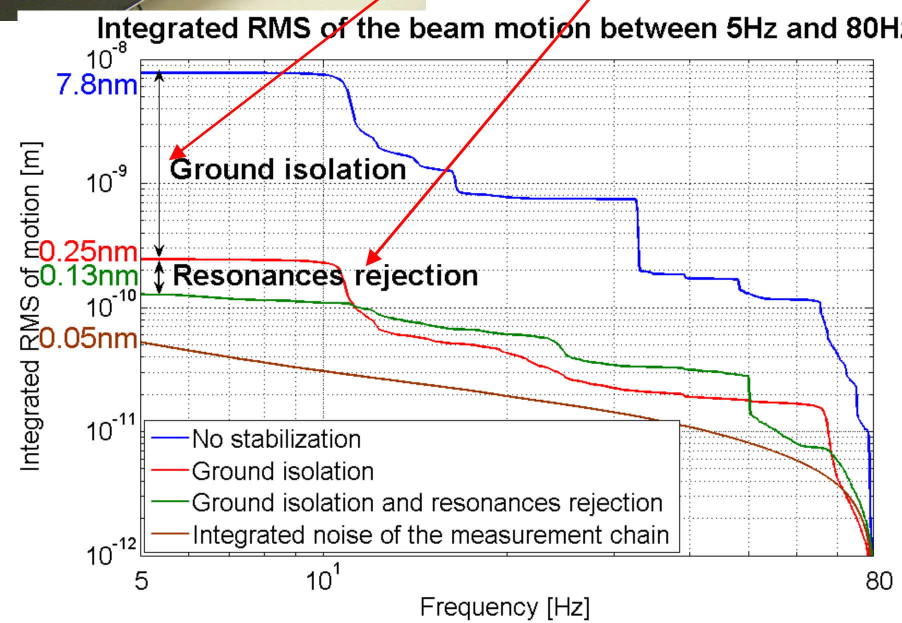




Resonance rejection

Isolation

CERN TMC active table for isolation



- **The two first resonances entirely rejected**
- **Achieved integrated rms of 0.13nm at 5Hz**

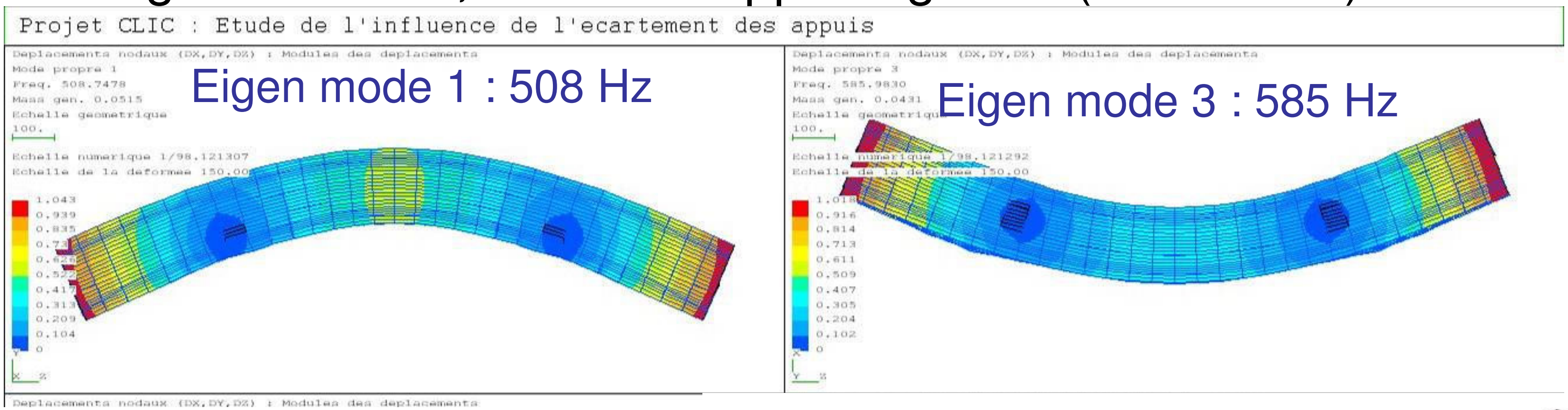
(L.Brunetti et al, 2007)

MB linac specific

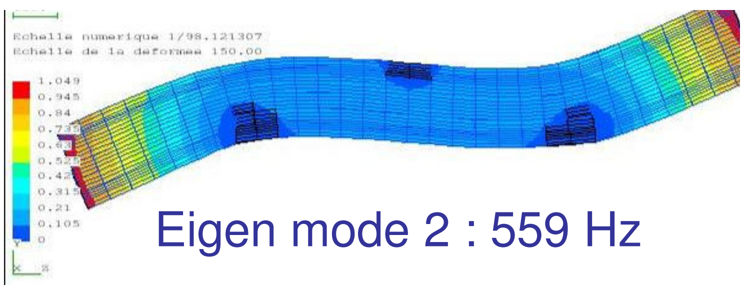
Dynamic analysis

(G.Deleglise 2009)

- Length 1500 mm, 4 lateral supporting lines (d=350 mm)

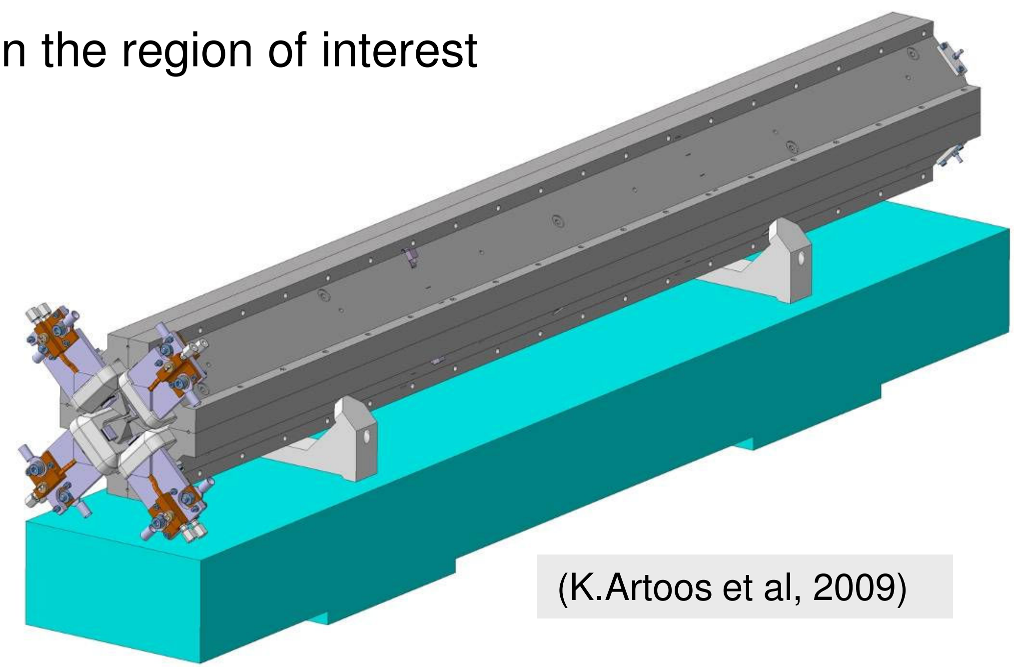


At least, the magnet does not vibrate in the region of interest



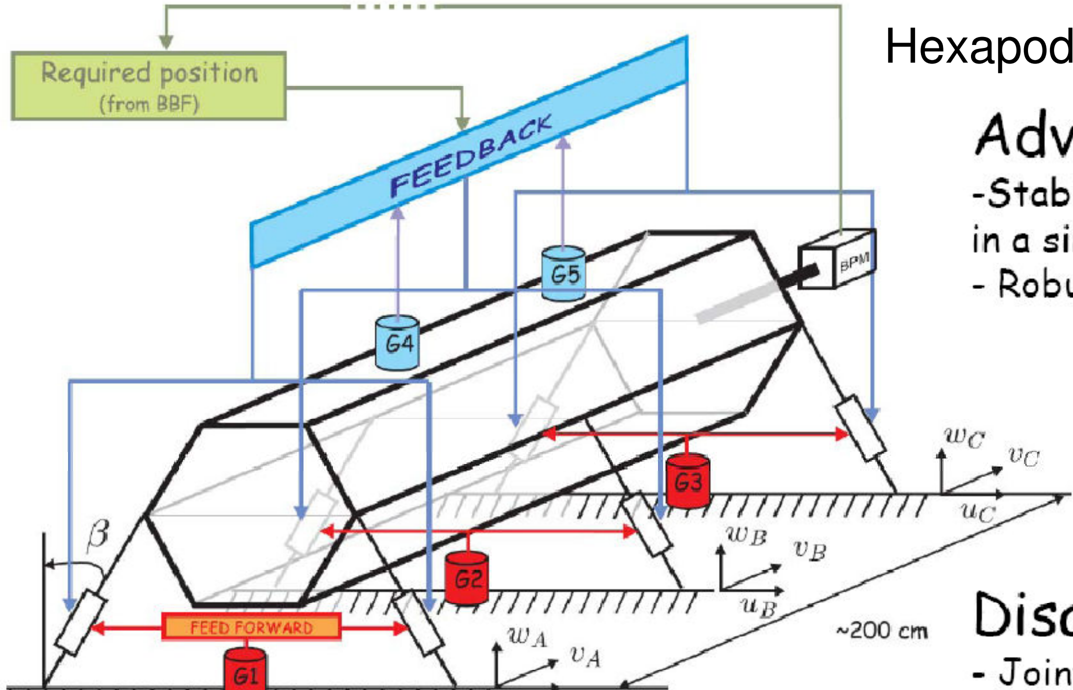
Support:

- **Maximise rigidity**
- **Minimise weight**
- **Minimise beam height**
- **Optimise support positions**



(K.Artoos et al, 2009)

Support study



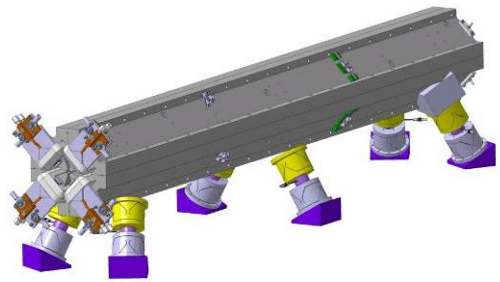
Hexapod

(C.Colette et al 2009)

Advantages:

-Stabilization & Positioning in a single stage

- Robust to external forces



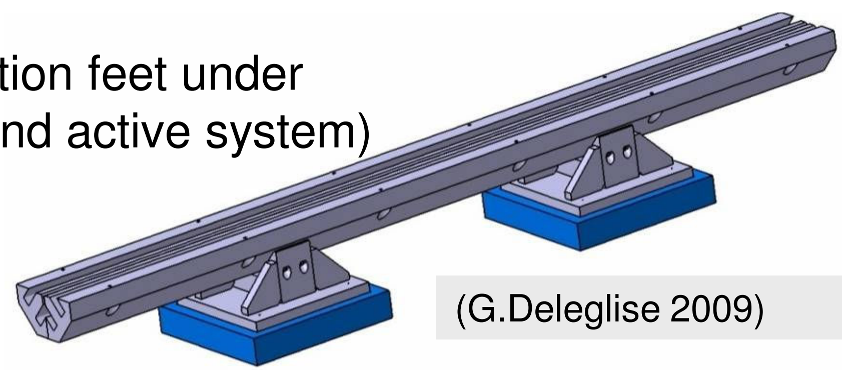
Disadvantages:

- Jointure issues

- Quadrupole flexibility

Vibration transmission other than ground motion has not yet been addressed in detail

Other option: isolation feet under magnet (passive and active system)

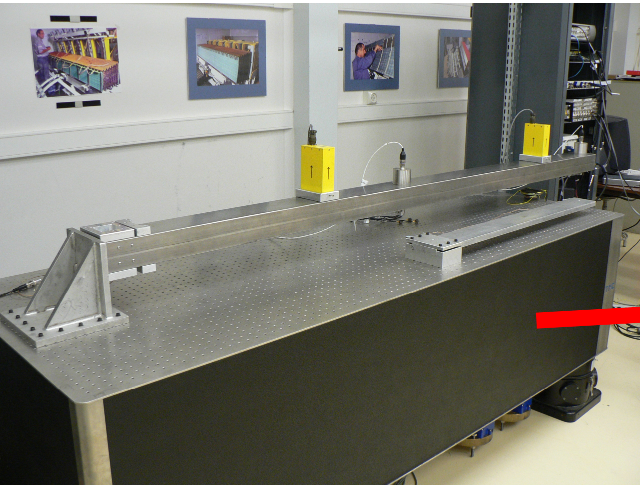


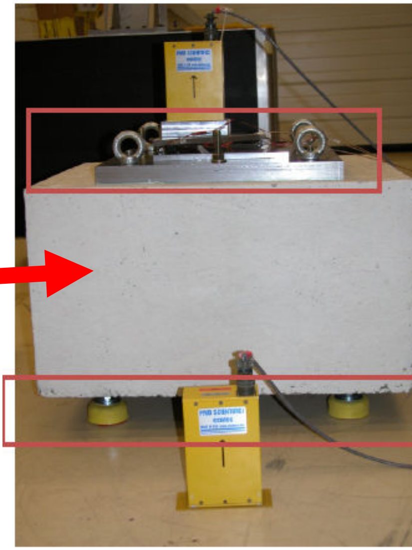
(G.Deleglise 2009)

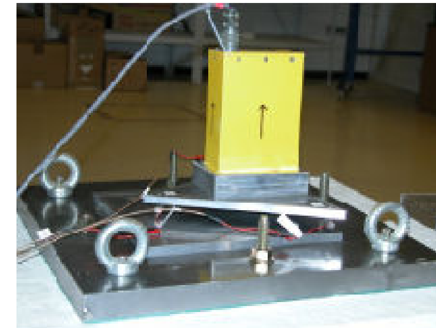
A.Jeremie

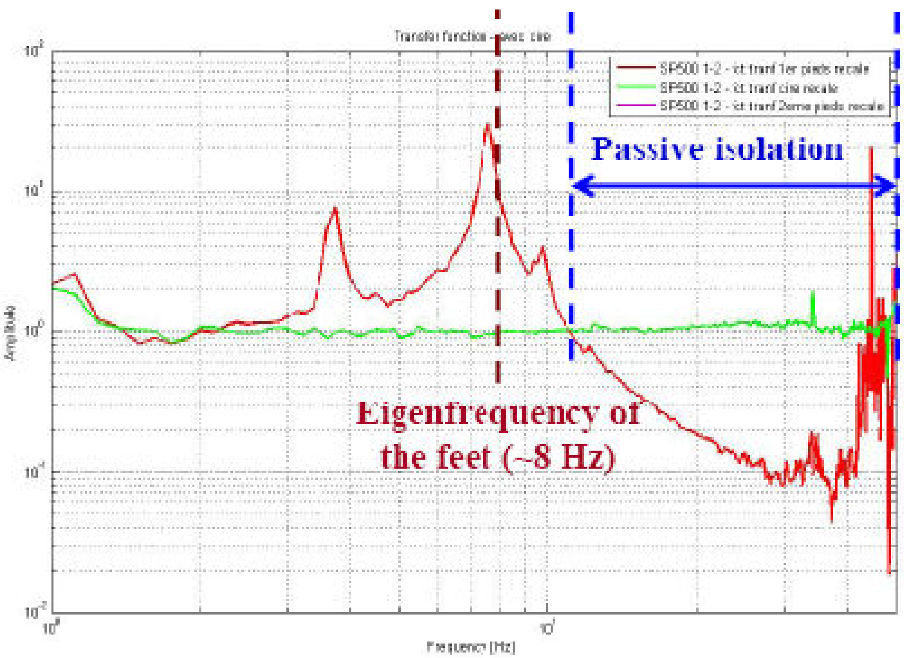
Laboratoire d'Annecy-le-Vieux de Physique des Particules

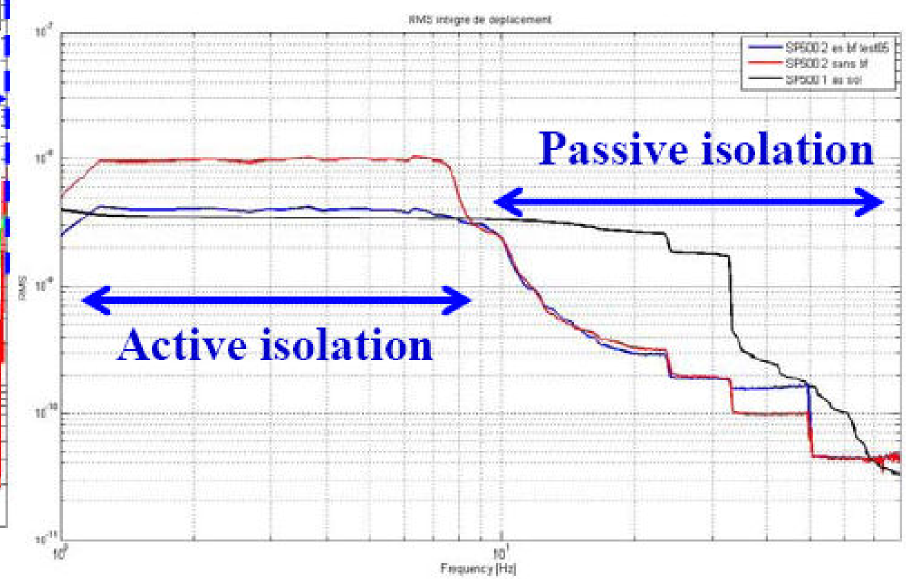
Replace big TMC table by smaller device











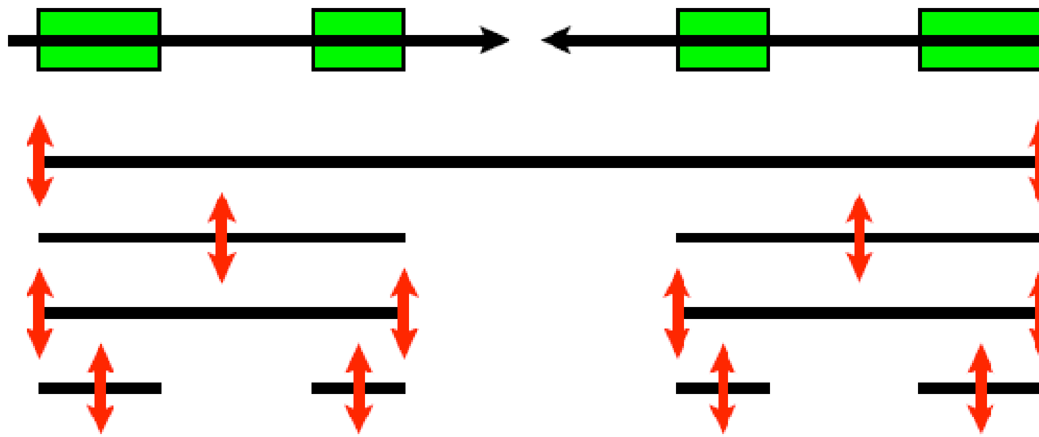
A.Jeremie
Laboratoire d'Annecy-le-Vieux de Physique des Particules

(L.Brunetti et al 2009)

FF specific

Final Doublet Jitter

- Support points are assumed to be independent
- Main effect is beam-beam offset at interaction point
- One support structure
  - relative tolerance on end points $\approx 3.6\sigma_{beam-beam}$
- Two support structures
  - relative tolerance of mid points $\approx 0.7\sigma_{beam-beam}$
  - relative tolerance of end points $\approx 0.64\sigma_{beam-beam}$
- Four support structures
  - relative tolerance of mid points $\approx 0.5\sigma_{beam-beam}$
  - end points $\approx 0.7\sigma_{beam-beam}$



$\Rightarrow$ Single support seems excluded

$\Rightarrow$ Chose two or four

- need to consider motion on support

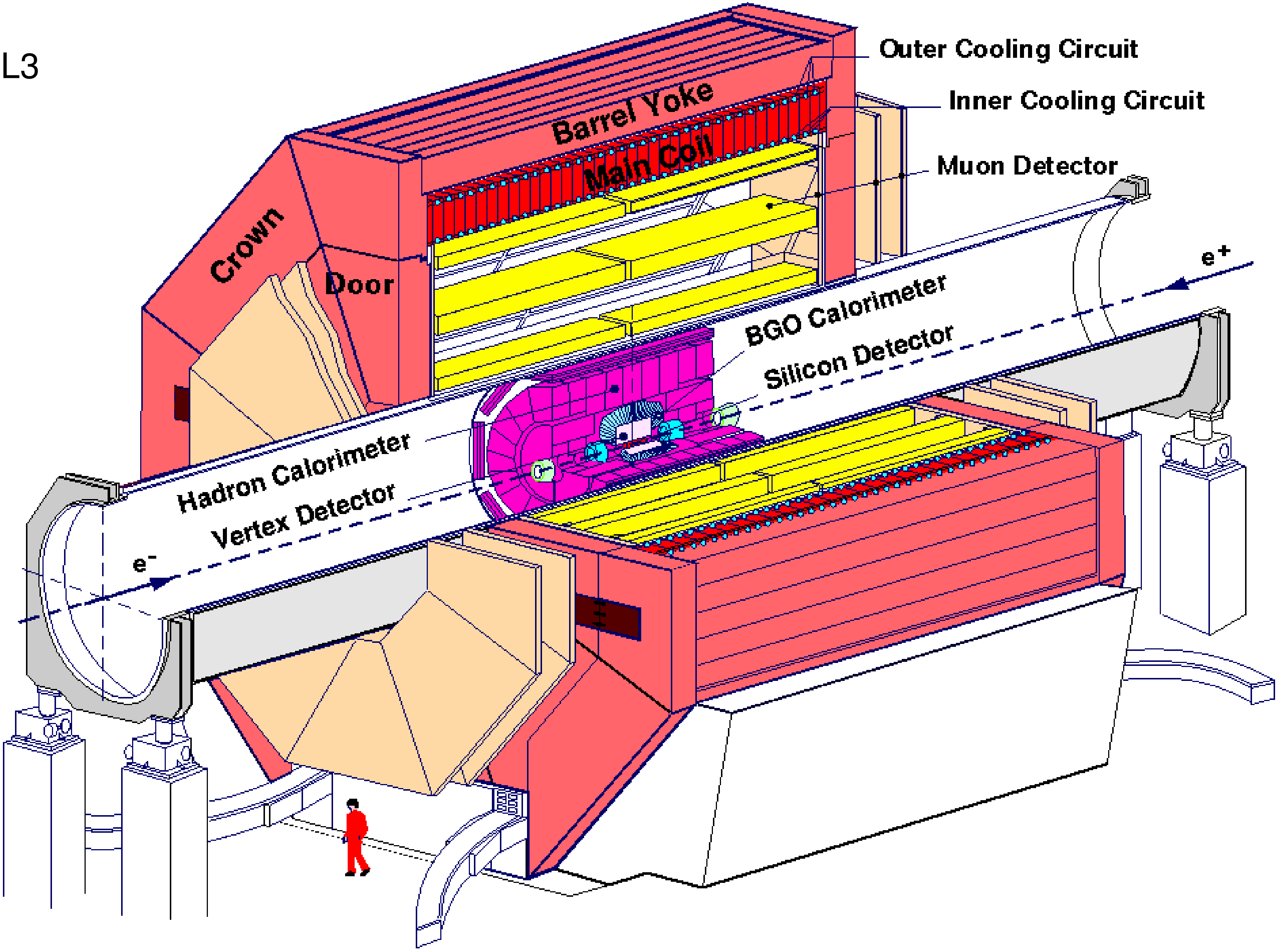
$\Rightarrow$ Raw tolerance for quadrupole supports is 0.17–$0.85\,\mathrm{nm}$ depending on configuration

- assuming independent support point jitter

- Integration of support and stabilisation system in detector is important to study

(D.Schulte et al, 2008)

L3

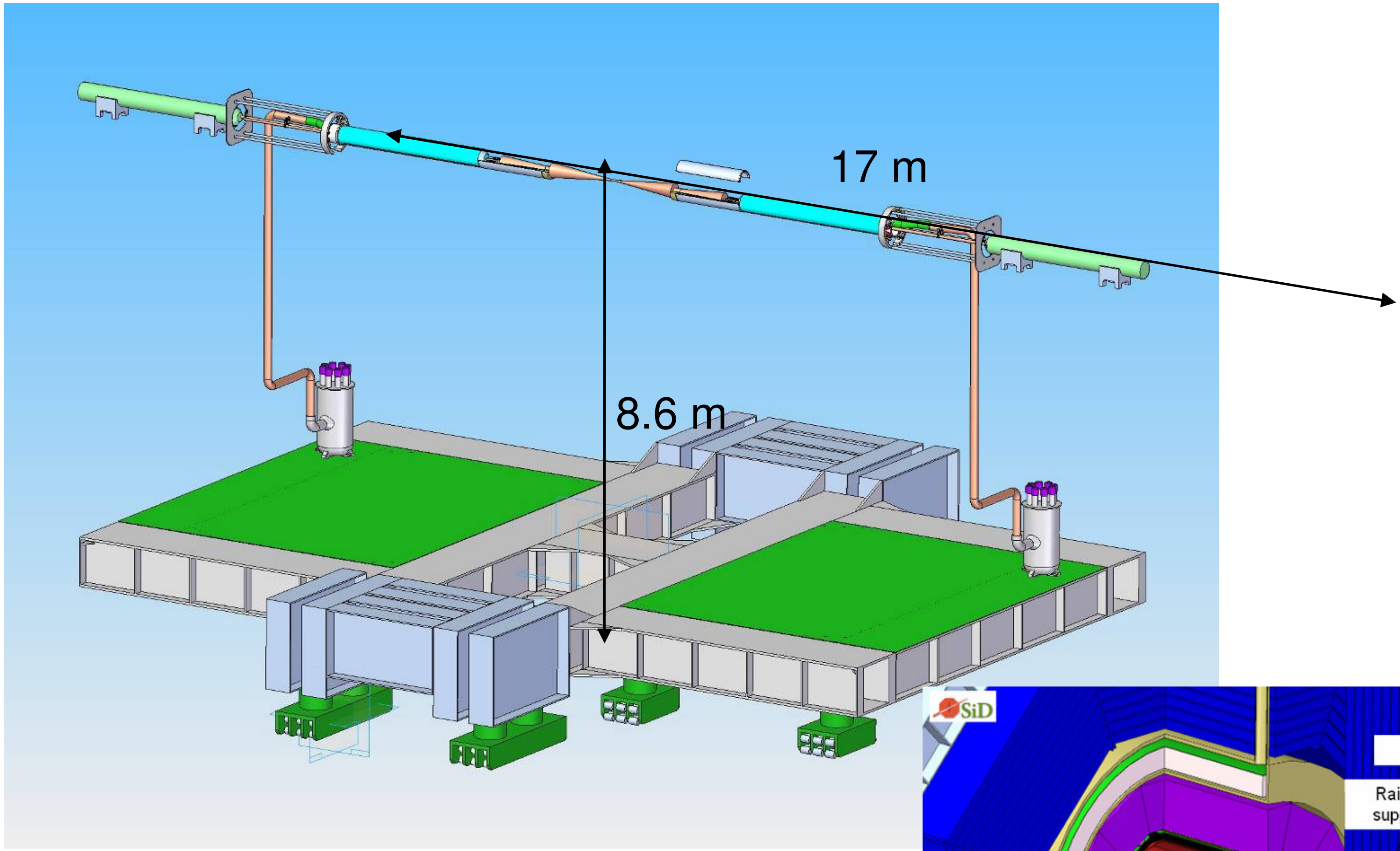


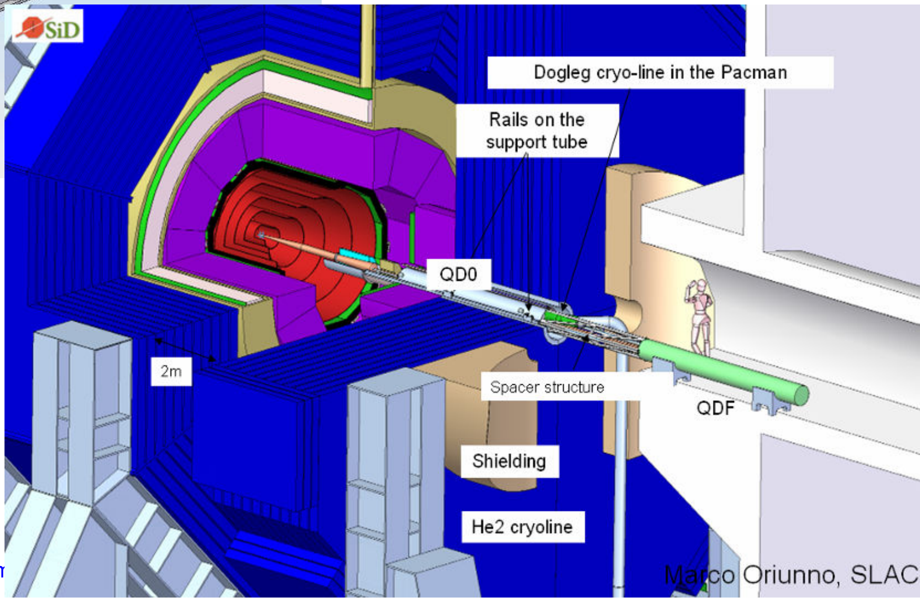
Outer Cooling Circuit
Inner Cooling Circuit
Muon Detector
Barrel Yoke
Main Coil
Crown
Door
e+
BGO Calorimeter
Silicon Detector
Hadron Calorimeter
Vertex Detector
e-

FF support issues

- How can it be supported inside the detector? Are we considering a Push-Pull scenario? A study to be done
  - Cantilever on detector
  - Cantilever from/on tunnel
  - Multifeet from detector
  - Cantilever from ground (height!!!)
  - Suspended from detector
  - Suspended from ceiling (correlation possible for both QD0?)
  - Common girder through detector…
- Need an in depth study with detector conception.
- A detector can never be built with the right vibration tolerances!

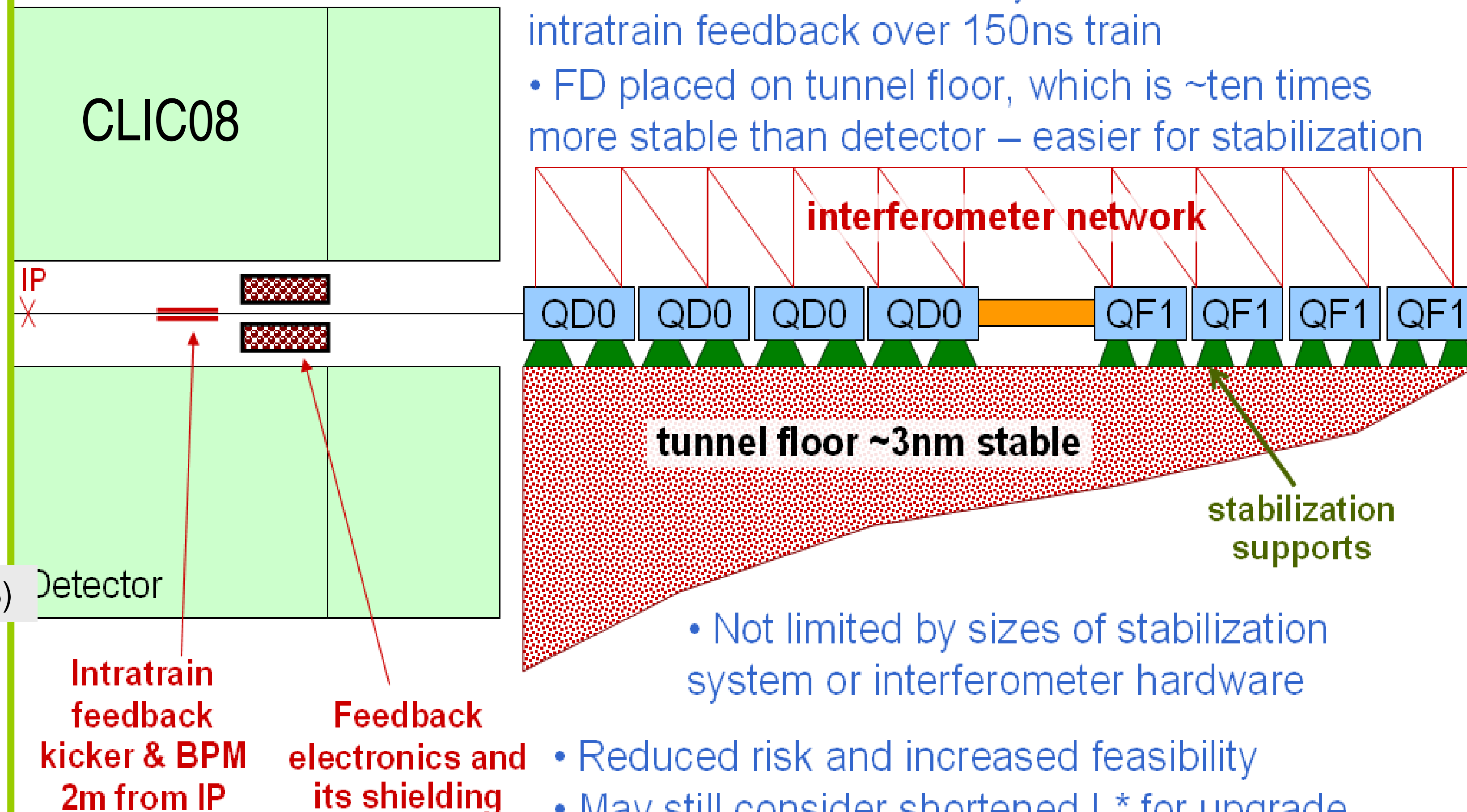
Integration for the Push-Pull





Longer L*

- Slower than 1/L* dependence of Lum => ↑L*
- Reduced feedback latency – several iteration of intratrain feedback over 150ns train
- FD placed on tunnel floor, which is ~ten times more stable than detector – easier for stabilization



(A.Seryi, 2008)

- Not limited by sizes of stabilization system or interferometer hardware
- Reduced risk and increased feasibility
- May still consider shortened L* for upgrade

- Study prompted by the CLIC FD stability challenge (< 0.2nm)
- Double the L* and place FD on a stable floor

But there are drawbacks: R.Tomas et al have shown a ~30% luminosity loss and tuning trickier

FF support issues

- How can it be supported inside the detector? Ar… considering a Push-Pull scenario? A stud…
  - ~~Cantilever on detector~~
  - Cantilever from/on tunnel
  - ~~Multifeet from detector~~
  - ~~Cantilever from groun…~~
  - ~~Suspended fro…~~
  - ~~Suspend… (correlation possible for both QD0?)~~
  - ~~Co…~~ …ough detector
- … …epth study with detector conception
- A … …ector can never be built with the right vibration tolerances!
- Would the FF magnet be simpler for L*=8m (without the spent beam in the way)?

What if we only keep the L*=8m for the first stabilisation studies (or slightly shorter L* with cantilever FF)?

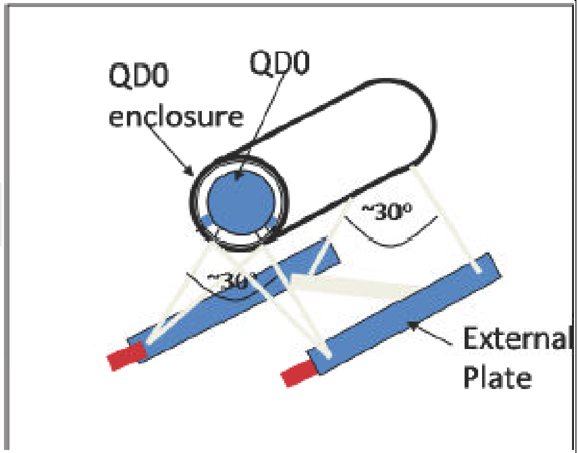
Accelerator environment

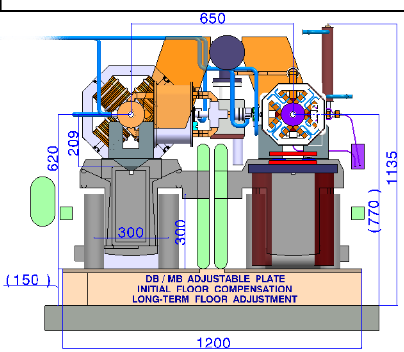
- Up to now, studies have been done in laboratory environment
- Important to show it works in an accelerator environment
- Plans for equipment and component tests in accelerator environment:
  - CesrTA/PSI quick test with existing components (2009-2010)
  - CTF3 “104” module (see next talk by G.Riddone) (2010-2011)
  - ATF2 replace current FD magnet by more ILC/CLIC like FD => stabilisation? (2013)

Related studies

Monalisa and compare to inertial sensors

(D.Urner et al 2008)



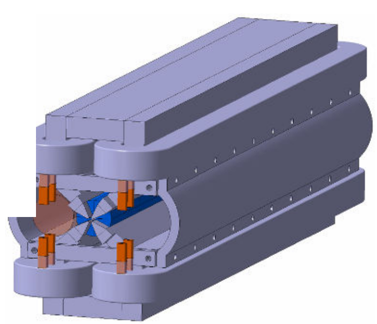


Compatibility with pre-alignment

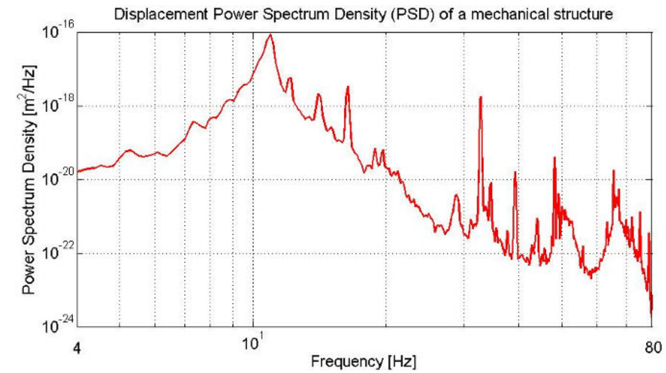
(H.Mainaud-Durand et al 2009)

FF magnet design: Planned vibration measurements in different conditions

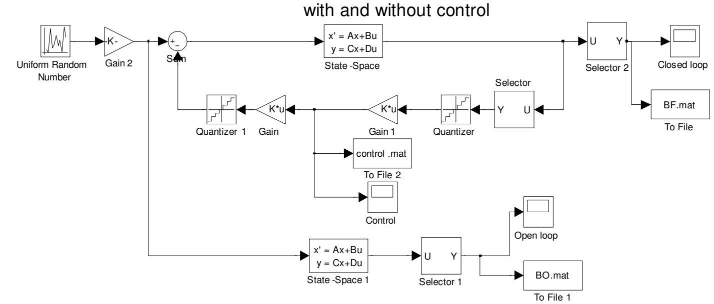
(E.Solodko 2009)



Feedback development



Cantilever beam simulation with and without control



Different strategies studied:

- A knowledge only at strategic points
- A local model for the disturbances amplified by eigenfrequencies.
- A complete model

(B.Caron et al 2008)

General stabilisation issues

Item	Achievable	Critical
Sensors	Exist can give lots of info for CDR	Magnetic field issue! Final choice after CDR
Actuators	OK for CDR	Weight and size definition
Isolation system	Principle/design probably OK	For the active feet option: test underway
Test in accelerator environment	OK for CDR if quick test	Complete representative test after CDR (CesrTA, CTF3, ATF2…)
Ground vibration measurements	OK for CDR	List vibration sources
Compare different "sensors" (seismic/inertial vs laser)	OK for CDR	If test done next year in ATF2 between Monalisa and seismic sensors
Magnetic center stabilisation	Under study	If we measure outside of magnet, how can we be sure, the magnetic center is also stable?

MB specific

Item	Achievable	Critical
full scale demonstrator with an MB quadrupole built and qualified.	OK for CDR	Support design needed
1 system for stabilisation + positioning?	OK for CDR	
Module Type 4	Design OK	Different options will be tested
Compatibility with pre-alignment system	OK for CDR	On type 4 and other “lab” modules
Support optimization / eigenmode analysis		Well advanced
inventory of modal behaviour and rigidities of components		Support needs to be better defined
Cost reduction	ongoing	4000 MB quadrupoles per “arm”

FF specific

Item	Achievable	Critical
QD0 magnet design	OK for CDR	
FF stabilisation		Considering Plan B with larger L^*
QD0 mock-up	Design OK	Procurement?
FF stabilisation methodology/feedback		Extension of existing mock-up Multi-sensor/multi-actuator
Detector integration +push-pull		Related to QD0 stabilisation
Support simulations + measurements		Support under design (related to L^* option)

All these “critical” items are studied by limited resources

Related talks
Wednesday October 14

Technical systems sessions in the afternoon

- MB quad stabilization by Christophe COLLETTE (14:20 - 14:50)
- Detector vibrations and QD0 support by Alain HERVE (16:20 - 16:40)
- Stabilization of the FF quads + supports by Andrea JEREMIE (16:40 - 17:00)
- Progress on QD0 quadrupole by Michele MODENA (17:00 - 17:15)