Main Beam Quadrupole Support

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CLIC08 Workshop

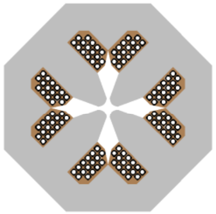
Outline:

- CLIC Main Beam Quadrupole Magnet
- The Alignment Concept
- Expected Properties of a the Support Structure
- Foreseen Mockups
- FEA on the Quad Mockup
- Mockup-Tests and Lab Studies
- Stepper Systems – Stabilization Systems
- CLIC Alignment Website
- Discussion

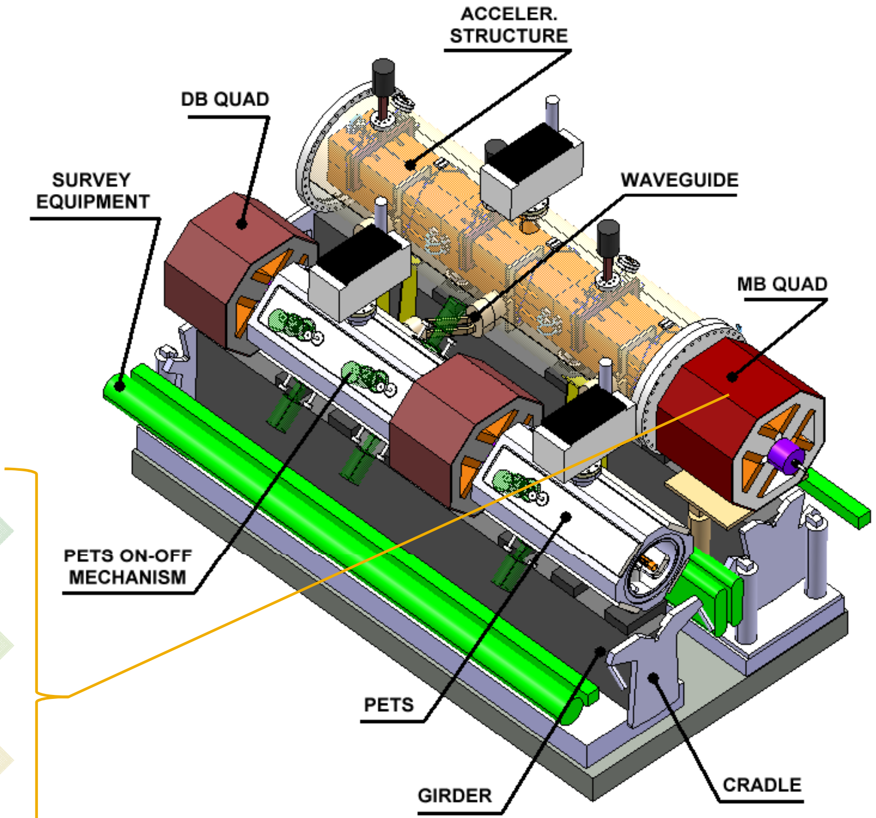
Baseline: Four different types of Main Beam Quadrupoles:

Length:	Weight:
-420 mm	~200 to 500kg
-920 mm	
-1420 mm	
-1920 mm	

Alignment & Stabilization Concept:

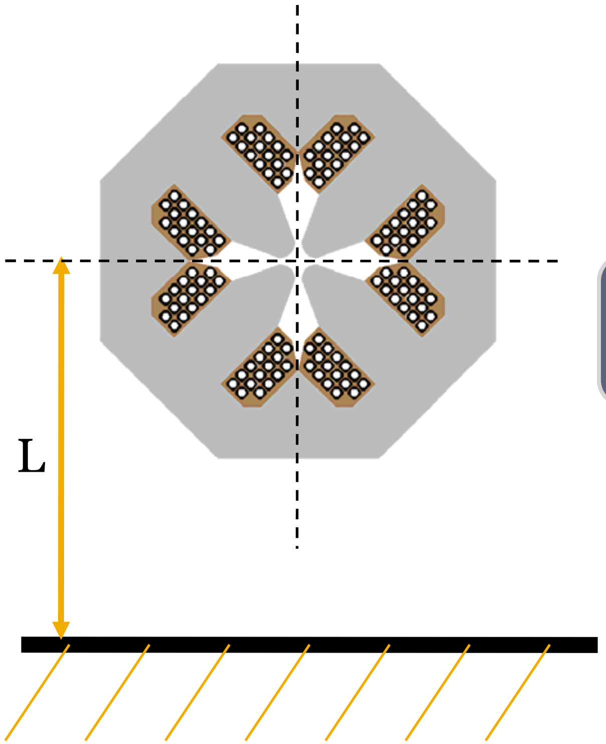


~1 nm	•Final alignment/Stabilization *(Beam Based) Interval: hours & <*
~1 µm	•Active pre-alignment *(Beam Based) Interval: hours*
~10 µm	•Active pre-alignment *(Movers) Dof.: 5; Interval: weeks*
~0.1 mm	•Mechanical pre-alignment *(Movers) Dof.: 6; Interval: year*



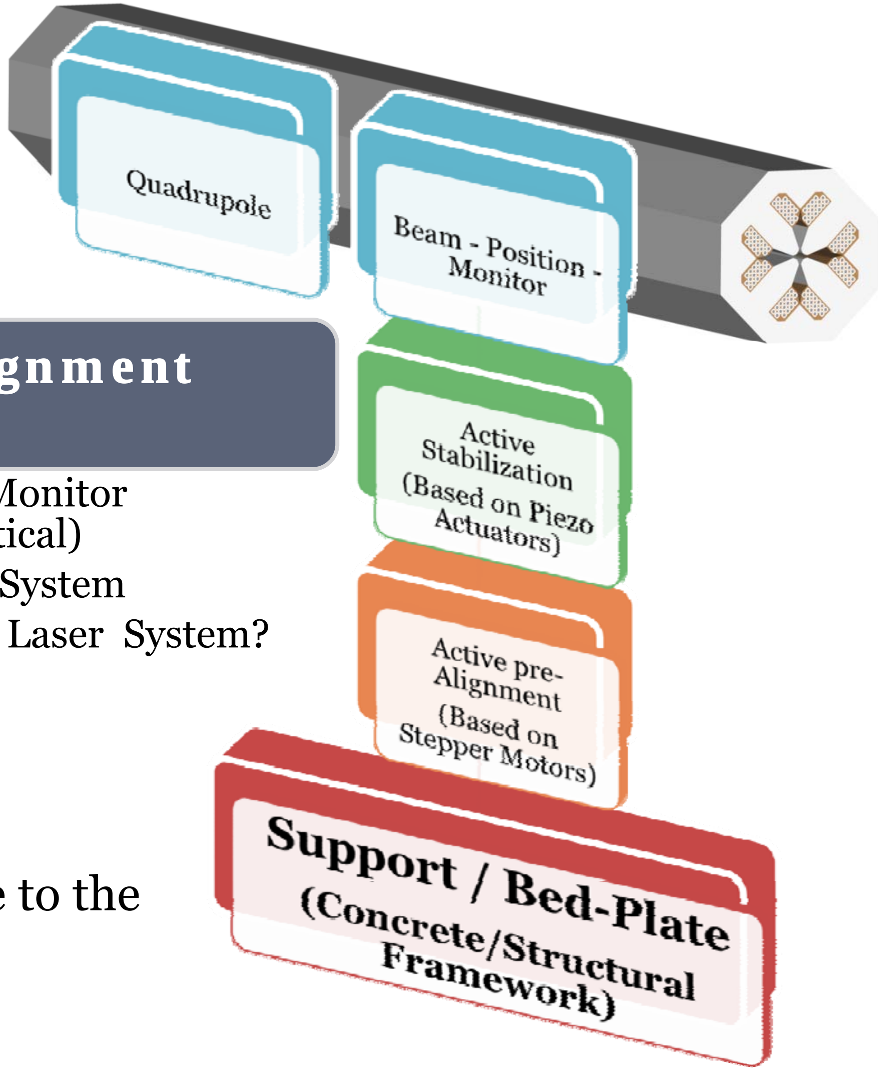
Current layout: MB Quad is supported to the ground

MB-Quad Alignment/Stabilization Concept



Current Alignment Sensors:

- Wire Position Monitor (Capacitive, Optical)
- Water Leveling System
- Rasclic or other Laser System?



Support height (L) should be minimized due to the high stiffness and damping ratio required .

$$k = \frac{AE}{L} \qquad \zeta = \frac{c}{2\sqrt{km}}$$

Expected Properties of a CLIC Mainbeam Quadrupole Support

Installation

- Weight *(optimized)*
- Compact Design
- Easy to Transport
- Easy to Align
- Easy to re-Adjust
- Installation Time *(low)*
- Cost-Efficient

Operation

- Damping Ratio *(high)*
- Stiffness Characteristics *(excellent)*
- Availability *(high during entire life cycle)*
- Temperature *(low sensitivity)*
- Humidity *(low sensitivity)*
- Radiation *(high resistance)*
- Magnetic field *(high resistance)*

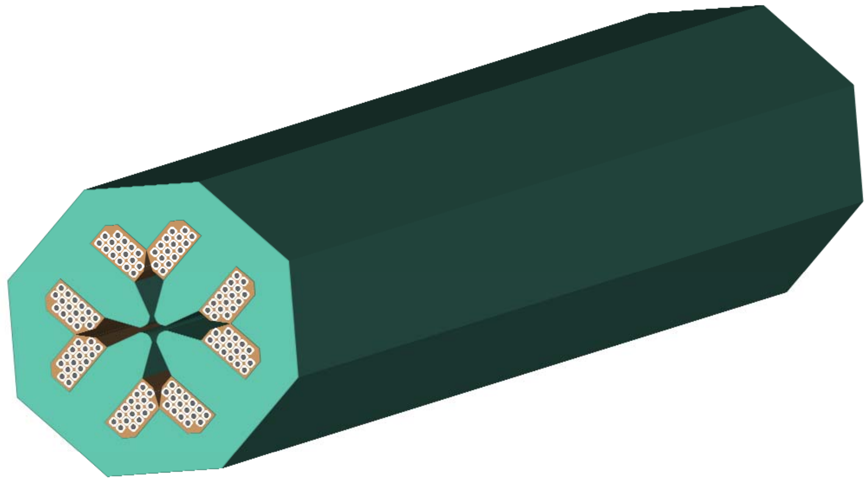
Requires mockup studies to find best solution

Most complicate version will be studied based on a mockup:

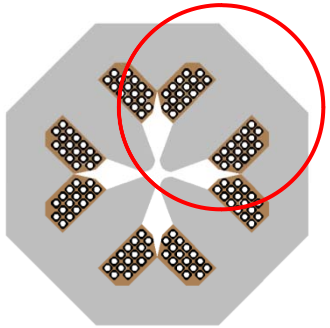
CLIC Main Linac Quadrupole (V4e)

Magnet	
Nominal gradient	200.1 T/m
Nominal integrated gradient	370.0 Tm/m
Aperture radius	5.0 mm
Iron length	1844.0 mm
Effective length	1849.0 mm
Total magnet weight	393.3 kg
Total magnet length	1914.7 mm
Total magnet width	192.0 mm
Total magnet height	192.0 mm
Coil	
Conductor height	5.6 mm
Conductor width	5.6 mm
Cooling hole diameter	3.6 mm
Total number of turns	16
Cooling	
Number of cooling circuits per coil	1.0
Pressure drop	4 bar
Current density	6.59 A/mm2
Temperature rise	22.3 K
Coolant velocity	1.1 m/s
Total cooling flow	2.6 l/min
Electrical parameters	
Nominal current	140 A
Magnet resistance (hot)	201.0 mOhm
Power consumption	4108.5 W
Total stored energy	420.7 kJ
Inductance	42.9 mH
Voltage drop (R*I)	29.3 V

Magnet Mockup Design: Thomas Zickler (CERN)



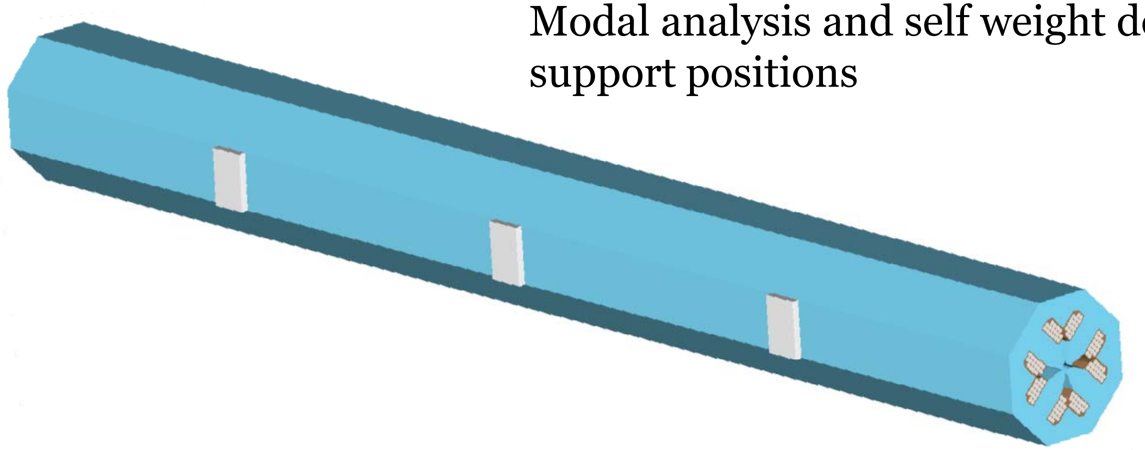
Quadrupole Mockup (Length = 1920mm)



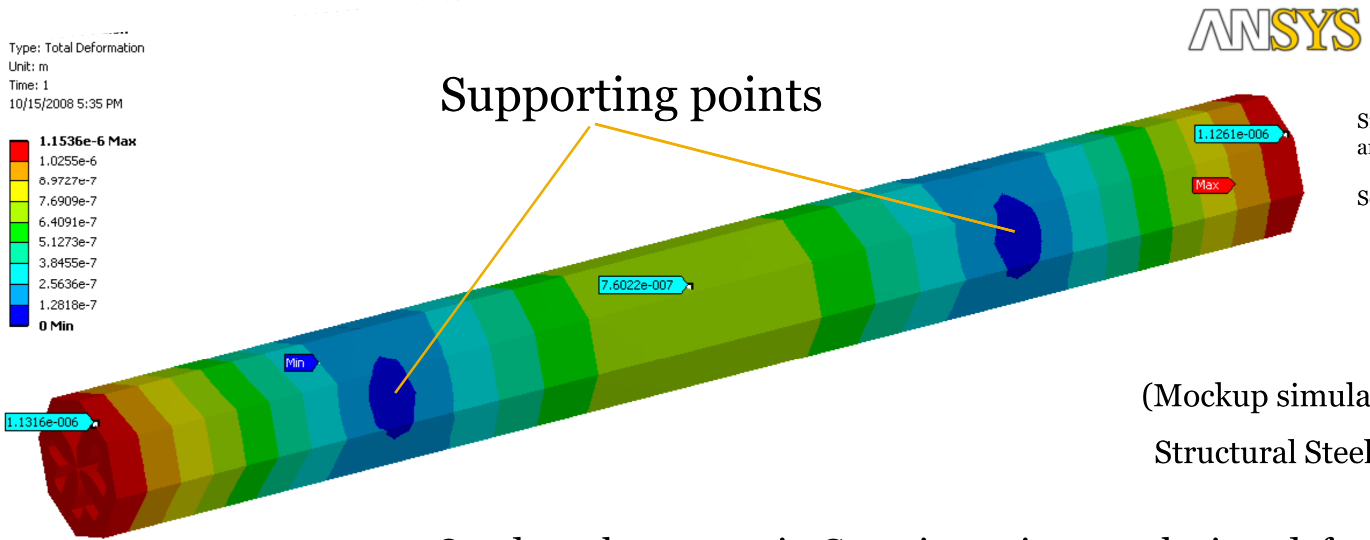
Preliminary Mockup based on a T-shaped Profile will be studied based on a layered assembly and as a solid.

Layered Profiles will be based on Electromagnetic steel (e.g. Stabolit 70 – Thyssen Krupp)

Quadrupole mockup simulation results:



Modal analysis and self weight deformation studied using different support positions



Simulation with ANSYS WB and ANSYS Classic

Solid45 elements & Structural Steel

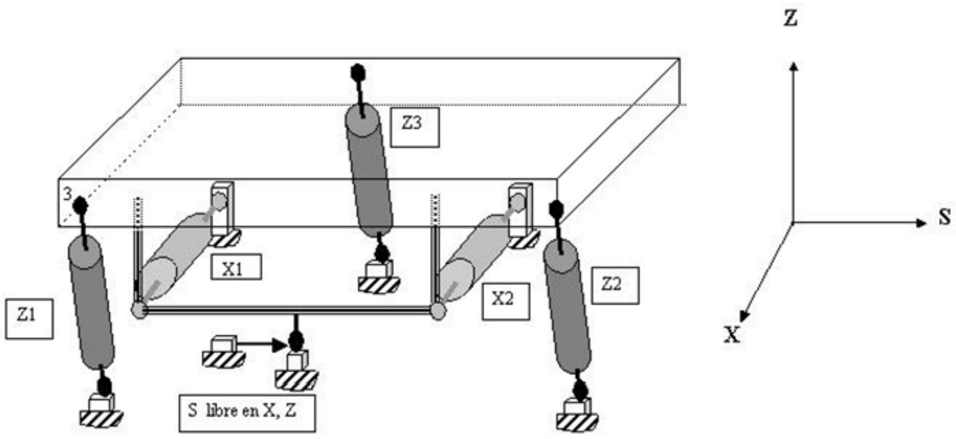
(Mockup simulation without coil)

Structural Steel; Mass: 333.45 kg

Quadrupole support in Gaussian points results in a deformation on self load of: 1.1um

Mockup-Tests and Lab Studies

Previous tests (S. Redaelli, CERN):



Main focus in the 90th was given in the vertical stabilization of the quadrupole magnet

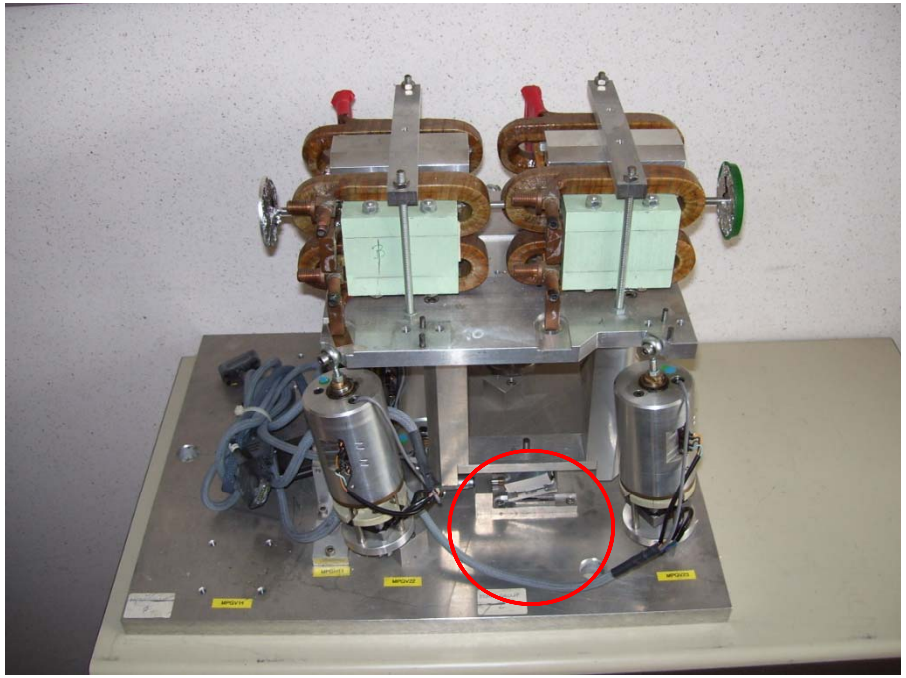
5 Stepper motors were used to align the support to 5 DOF

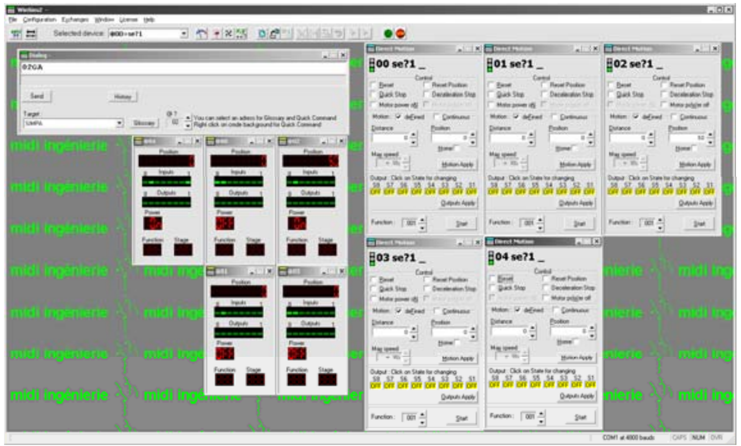
Supports were joints and bearings with low friction

Change of requirements in pre-alignment and especially higher loads requires complete redevelopment. Furthermore documentation regarding reachable Repeatability, Accuracy and Resolution in the 5 DOF of the former System undiscoverable.

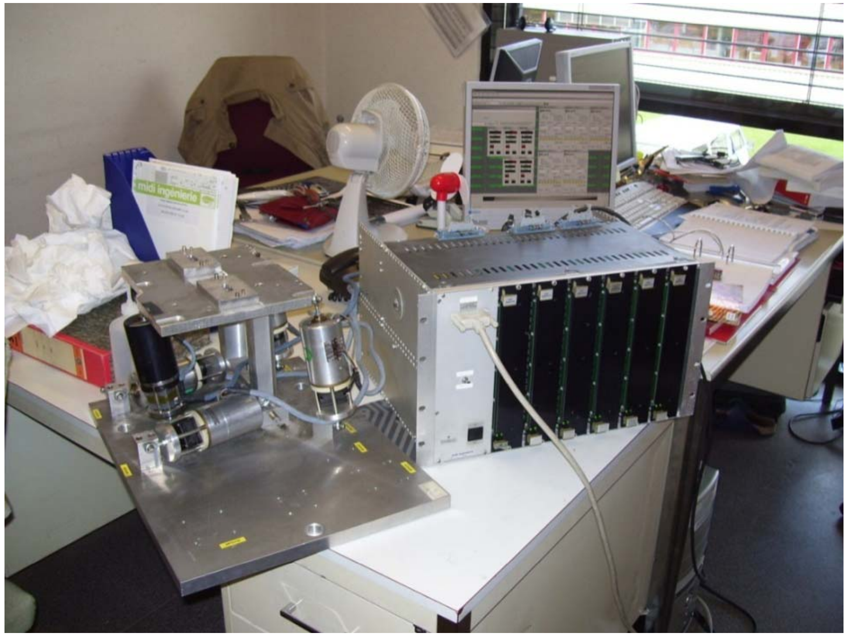
→ Behavior of Stepper System can be studied by using the old setup as occasionally mockup

CTF2 Stepper System reactivated:





New software version still communicates with the old setup…



First operations…

Foreseen steps:
- Implementation of feedback loop
- Redesign of critical parts (guiding)

Frictionless Operation Possible?

What to learn from an old Setup?

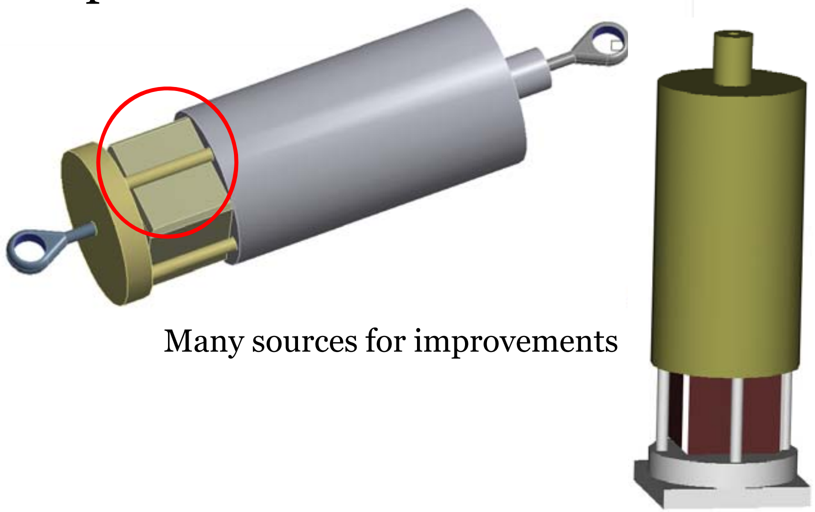
• Will provide important information for the stiffness of the entire support system.

• Important information of friction and clearance behavior

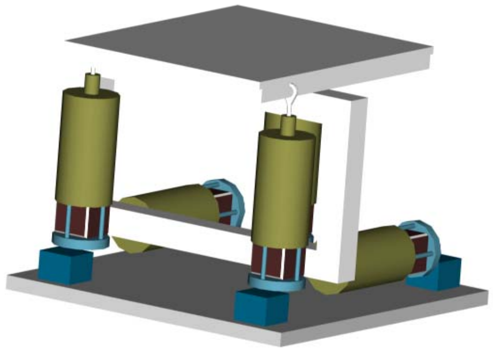
• Repeatability of important alignment parameters

• Important input for ANSYS and for all further studies

•Modal measurement for CTF2 stepper motor planned within the next weeks.



CTF2 Alignment Concept studied using the FEM



Will help to select adequate movers for CLIC
Also answers the question -> Frictionless pre-alignment required?

Regarding Movers:

Main issue: Insufficient load capacity -> most µ movers and hexapods on the market can adjust loads up to max. 40kg

Market research on suppliers for stepper motor development and "frictionless" joints

- PI- Karlsruhe (D)
- ZTS -VVU – Kosice (Sk): Stepper system supplier for LHC low beta magnets
- Midi ingenierie – Labege (F): Stepper system supplier for CTF2

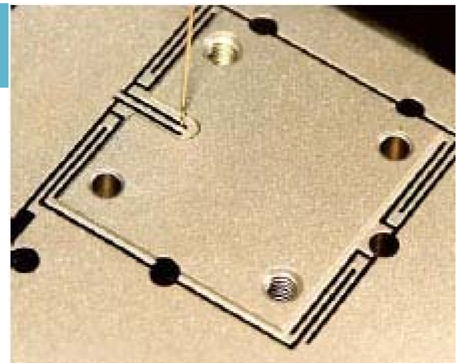
E.g.: PI MIKE M-238 unidirectional repeatability: 0.3 µm, max. load: 40kg

Further development of the M-238 for a load of 100kg -> 15000 CHF/Piece and complete new design for loads up to 200kg

Progress on research for the nano stabilization of the MB-quad:

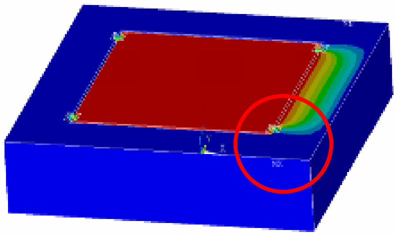
Nano membran -> studied by Kurt Artoos et al. (TS-MME)

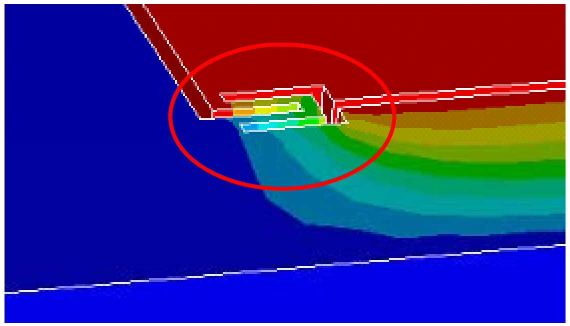
Further possibilities using piezo stacks are studied



Guiding Flexures: Available solutions are not able to provide required load capacity

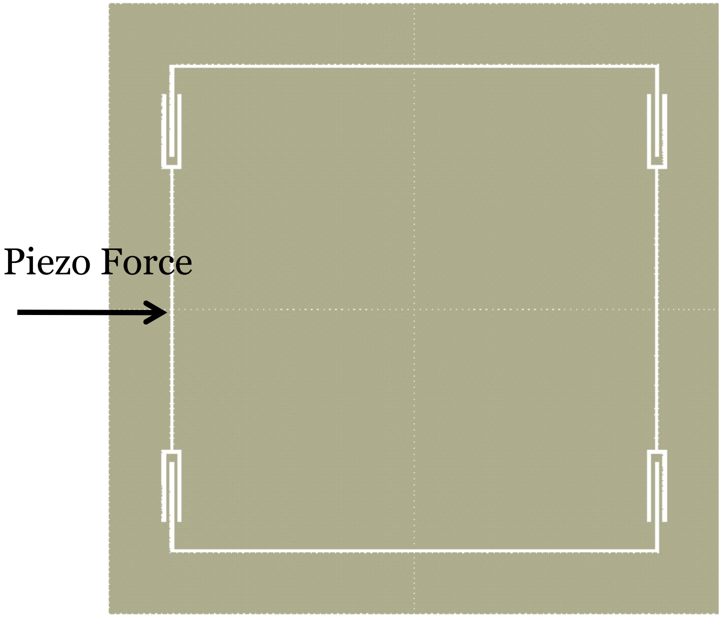
Foreseen: Production of a guiding flexure at CERN using wire -electro discharge machining is foreseen.

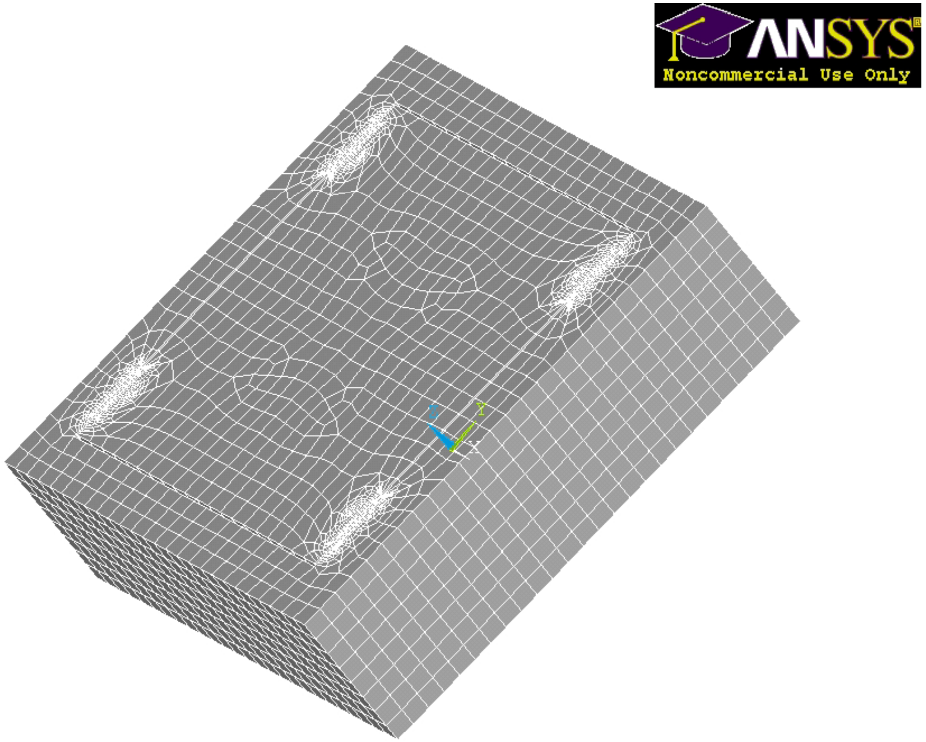


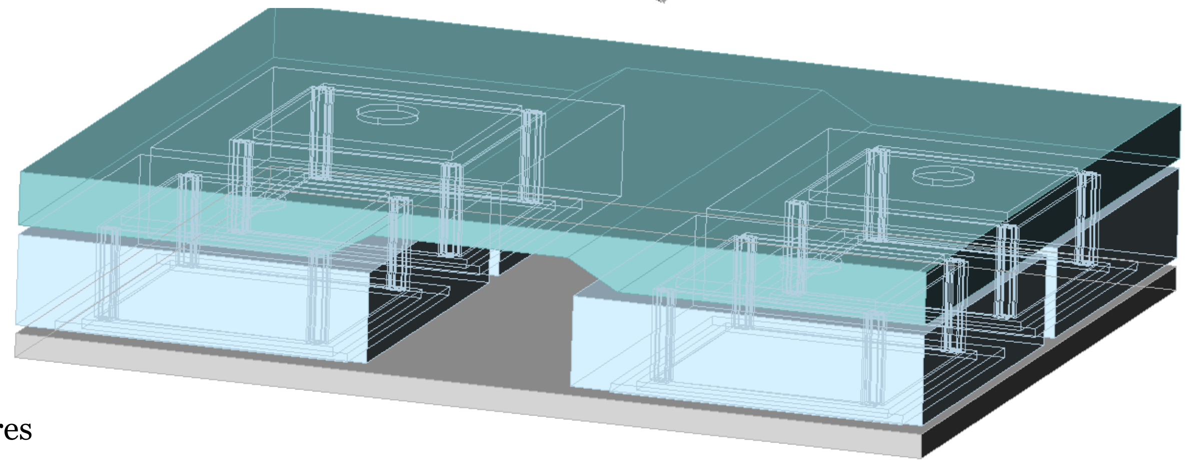


Critical: Implementation and fixation of the piezo actuator

Frictionless support 'guiding flexure'







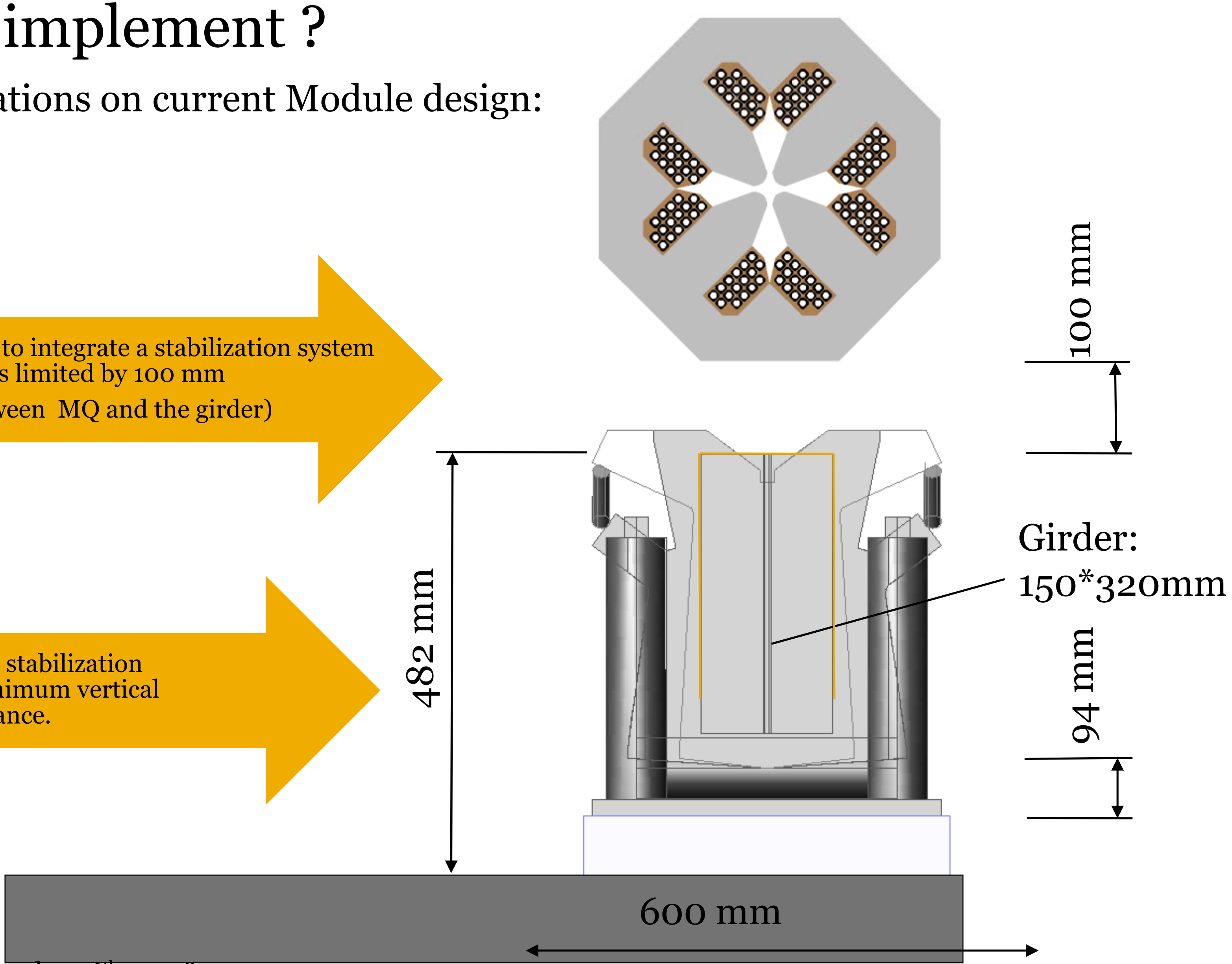
Sketch: Layout using four guiding flexures

How to implement ?

Space limitations on current Module design:

Vertical space to integrate a stabilization system is limited by 100 mm
(between MQ and the girder)

Remark: nm stabilization requires a minimum vertical distance.



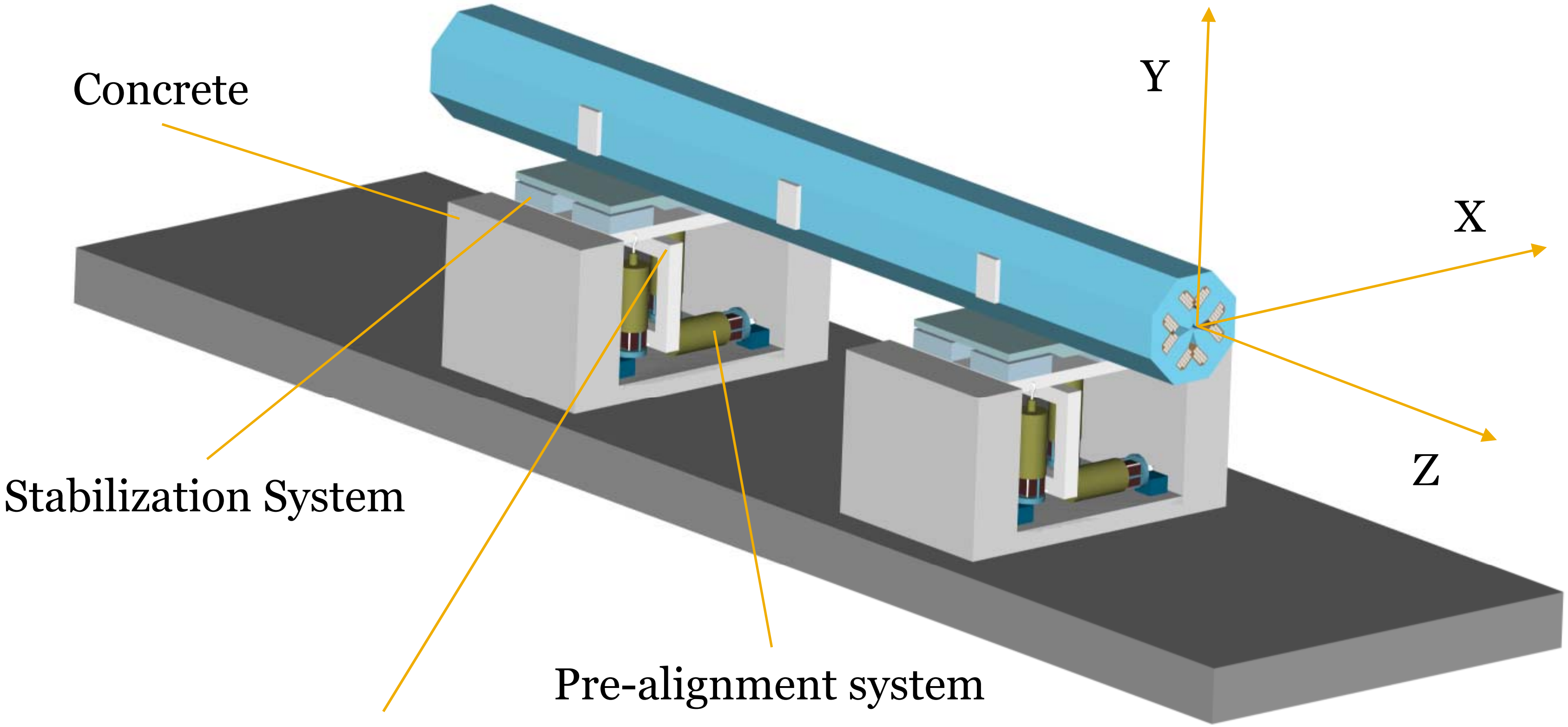
Many solutions, proposals and open work -> still there are so many more open questions to be studied, e.g.:

Frictionless operation of the pre-alignment system by applying linear elastic deformation?

How to provide optimal stiffness characteristics for the stabilization system on beam level?

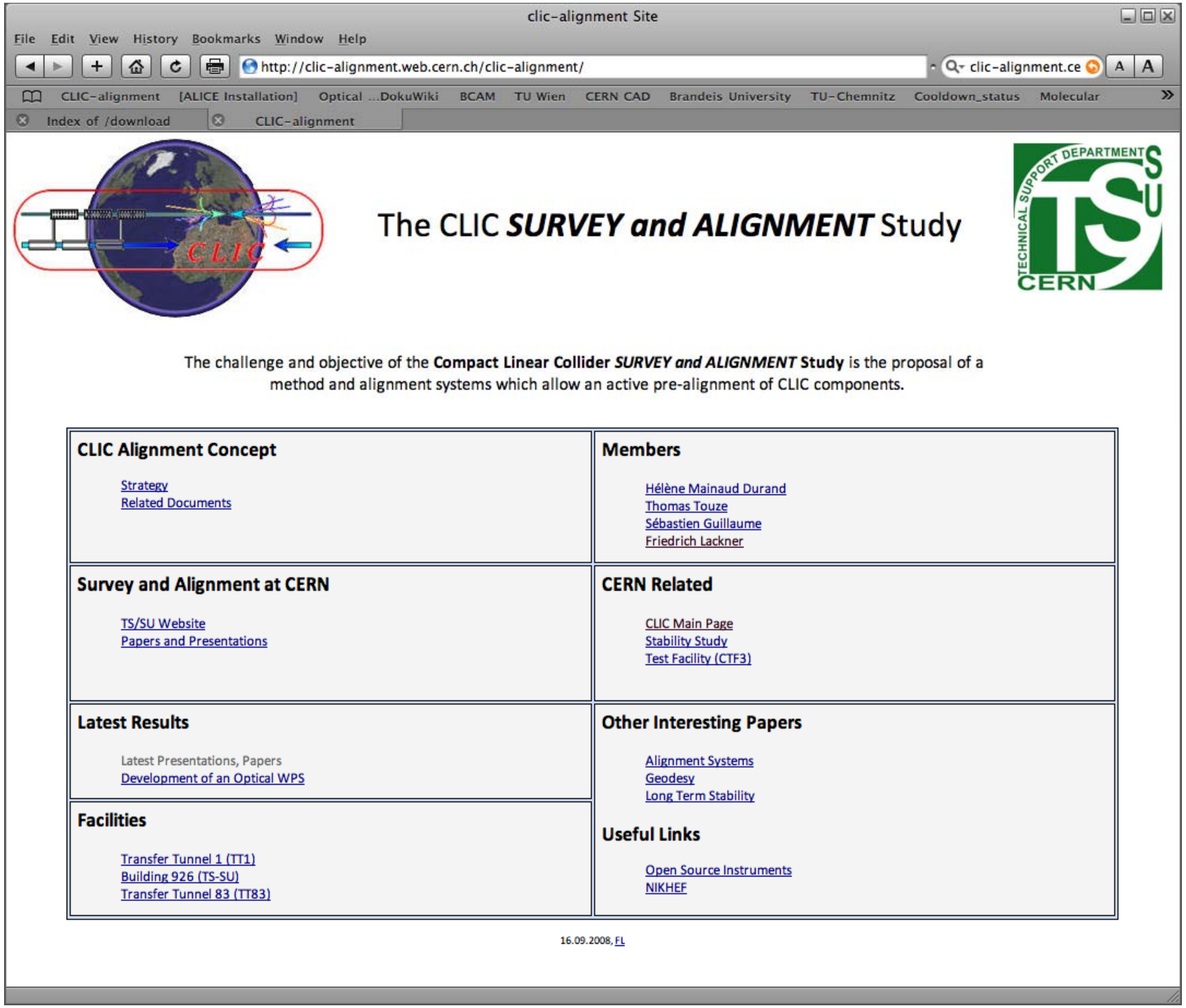
Decoupling between pre-alignment and stabilization system.

Proposal for Mockup studies:



Idea: Increasing the stiffness for a stabilization system by clamping the pre-alignment system to concrete support (applying clamping force in non critical Z direction).

http://clic-alignment.web.cern.ch/clic-alignment/



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