MODULE PRE-ALIGNMENT: Baseline and test program

CLIC09 Workshop

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CLIC Pre-alignment requirements

PRE-ALIGNMENT (beam off)

Mechanical pre-alignment

Within +/- 0.1 mm (1σ)

→

Active pre-alignment

Within ± 10 μm (3σ)

→

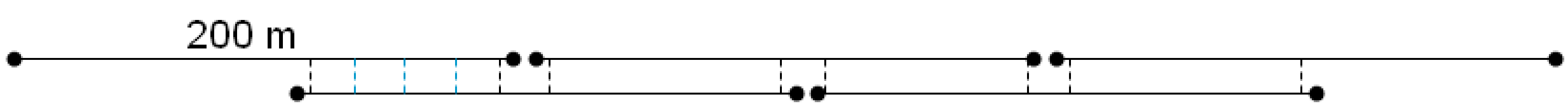
Beam based alignment
Beam based feedbacks

A scale order:
For the LHC: ± 0.1 mm over 100m (1σ)
For the ILC: ± 0.2 mm over 600m (1σ) (vertical direction)

CLIC active pre-alignment
=
technological challenge

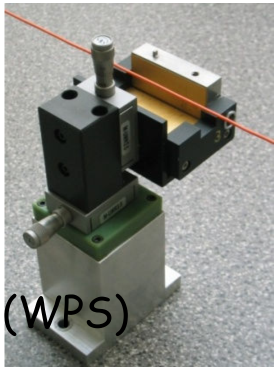
General pre-alignment concept

✓ Straight alignment reference over 20km consists of overlapping references



=
propagation network

Favoured pre-alignment concept

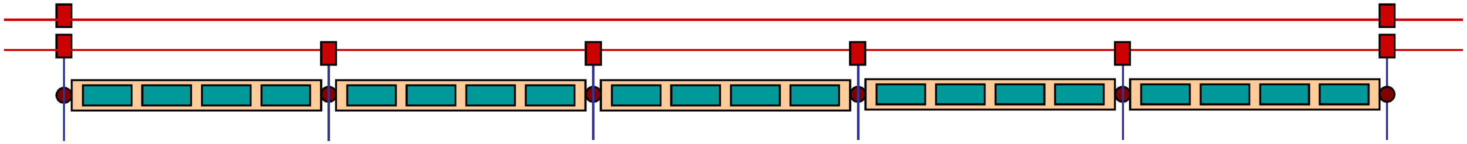


- ✓ straight reference = stretched wire
- ✓ vertical & transverse position measured thanks to Wire Positioning Sensors (WPS)

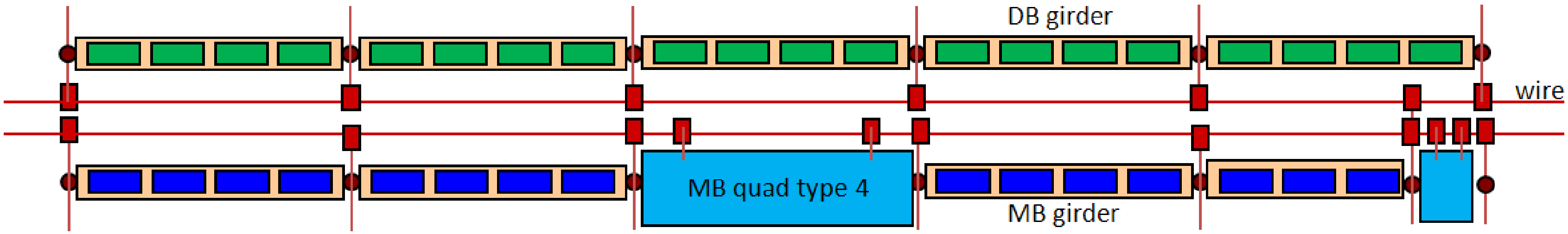
Accelerating structures
PETS + DB quad

} pre-aligned on independent girders

- ✓ DB and MB girders pre-aligned with 3+1 DOF (« snake system » / "articulation point")



- ✓ MB quad pre-aligned independently with 5+1 DOF



Feasibility of the concept

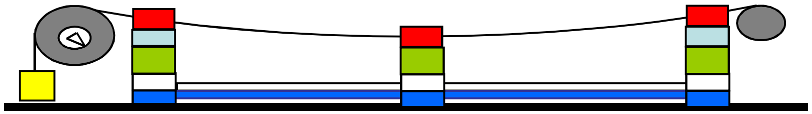
Active pre-alignment

STEPS		ISSUES
Determination of the propagation network	⇒	Stable alignment reference, known at the micron level
Determination of the position of each sensor w.r.t propagation network	⇒	Submicrometric sensors providing « absolute » measurements
Fiducialisation: determination of the zero of each component w.r.t the sensor (external alignment reference)	⇒	Stable determination of 2m long objects within a few microns
Repositionning: displacement of the component supporting structure according to the sensor readings	⇒	Submicrometric displacements along 3/5 DOF

Other issues:

- Compatibility with the general strategy of installation and operation
- Compatibility with other accelerator equipment or services

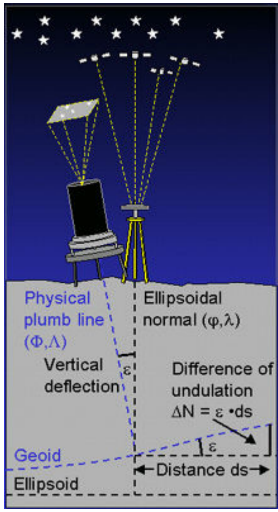
1st key point: a straight known and stable reference



Main issue: long term stability of a wire

(effects of temperature, humidity, creeping effects, air currents)

See next talk by T. Touzé : « Modelling of the CLIC propagation network- analysis of the TT1 facility results »



➔ Modelization of the wire using Hydrostatic Levelling Systems (HLS)

but only in the vertical direction

but HLS system follows the geoid which needs then to be known

➔ studies undertaken concerning the determination of the geoid

See the talk by S. Guillaume: « How to establish a straight line on the dynamic curved surface of the Earth? »

➔ Is a stretched wire really straight (transverse direction)?

First idea: comparison with a laser beam under vacuum (NIKHEFF)

Inter-comparison of different types of wires and technologies

→ on short distances (50 m) this autumn at SLAC

2nd key point: sub-micrometric sensors

Issue: WPS sensor fulfilling the requirements

- ✓ « absolute measurements » (known zero w.r.t mechanical interface)
- ✓ no drift
- ✓ sub micrometric measurements

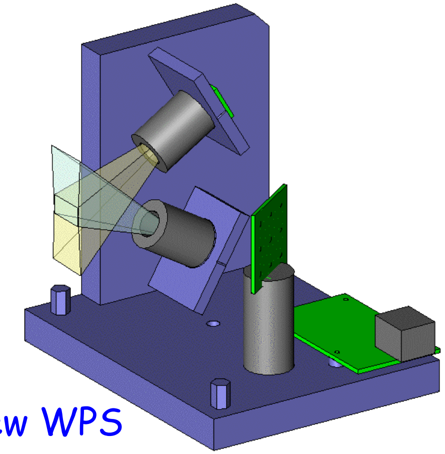
Upgraded WPS

➔ Upgrade of the existing capacitive based WPS sensor

- ✓ better mechanical interface
- ✓ better absolute calibration
- ✓ drift, CEM to be studied in further details

➔ Development of a new optical based WPS sensor

- ✓ 3 microns accuracy and precision to be validated



New WPS

3rd key point: simulations close to the reality

Objectives:

- ✓ Find the best strategy and configuration of alignment systems for the pre-alignment
- ✓ Model the impact of the pre-alignment errors on the beam emittance growth

First results:

- ✓ The pre-alignment tolerance could be achieved with wires longer than 425m.
- ✓ Beam simulations, based on these data showed that 400m wires were able to limit the long distance emittances.

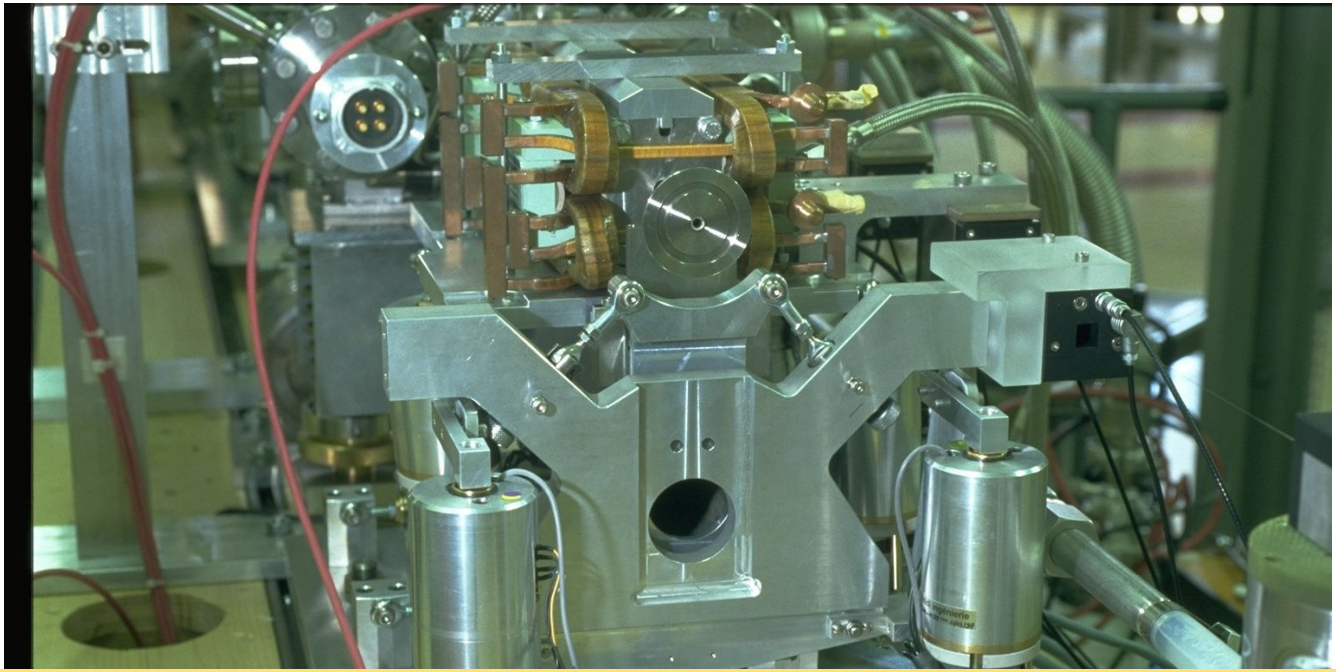
Next steps ➔ implementation of a new model, closer to the reality

- ✓ The requirements were defined in collaboration with the Beam Dynamics WG
- ✓ These steps are now mathematically defined
- ✓ The algorithms are being implemented and tested on the TT1 configuration (validation of the model on 150m)
- ✓ Development of a software allowing the modeling on the whole CLIC.

See next talk by T. Touzé : « modelling of the CLIC propagation network- analysis of the TT1 facility results

4th fiducialisation: stable determination of 2m long objects within a few µms

We need to demonstrate the MB quad and girder pre-alignment strategy, e.g: it is possible to position the zero of the MB quad and girder w.r.t. a straight line within a few microns.



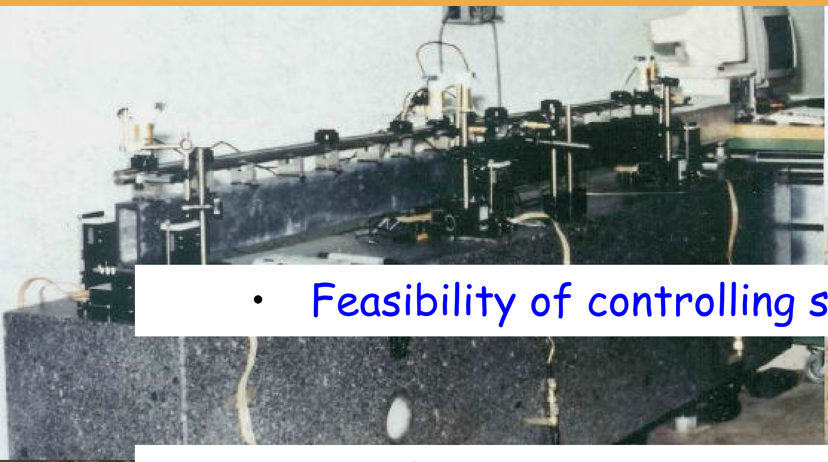
- ➔ What is the zero (mechanical, magnetic, RF)?
- ➔ How is it determine w.r.t external pre-alignment references
- ➔ Find the best design, implantation, configuration for these external pre-alignment references (stability during time, impact of thermal variations)
- ➔ Validation of the solution on a mock-up.

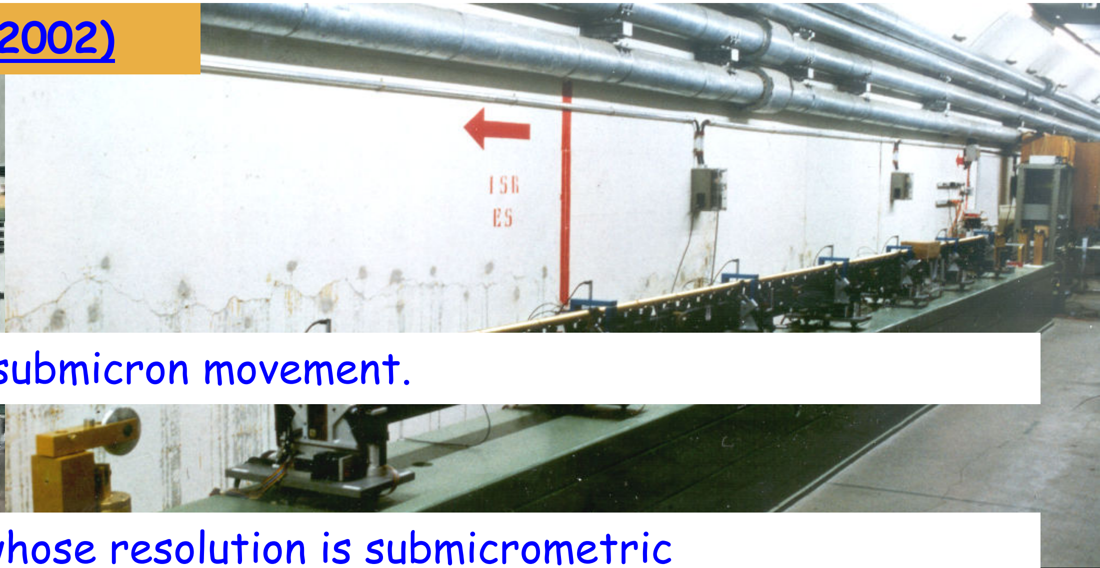
5th key point: repositioning issue

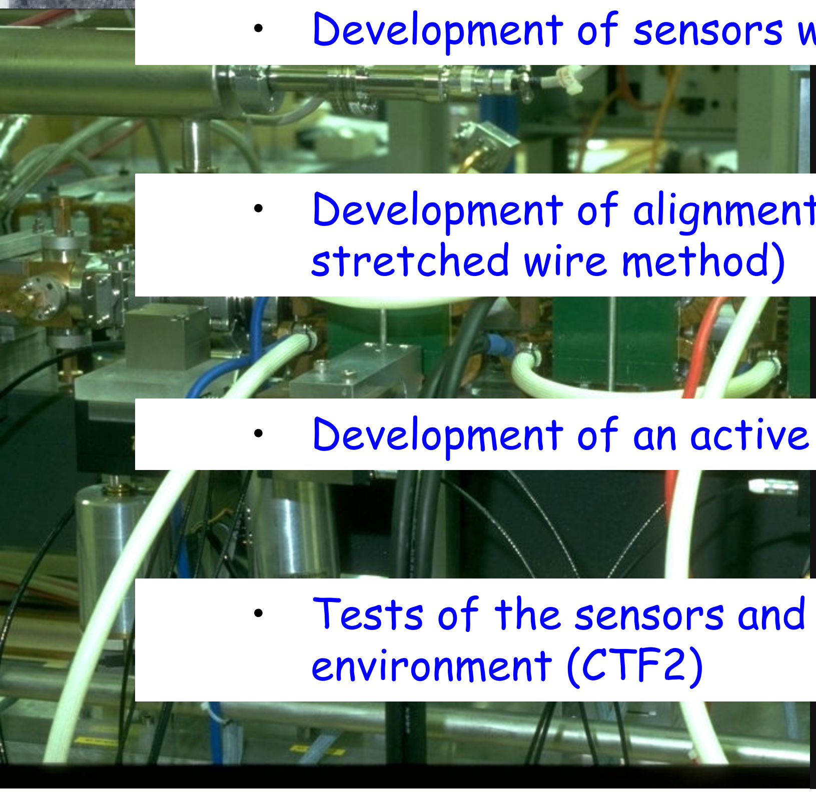
Outline:

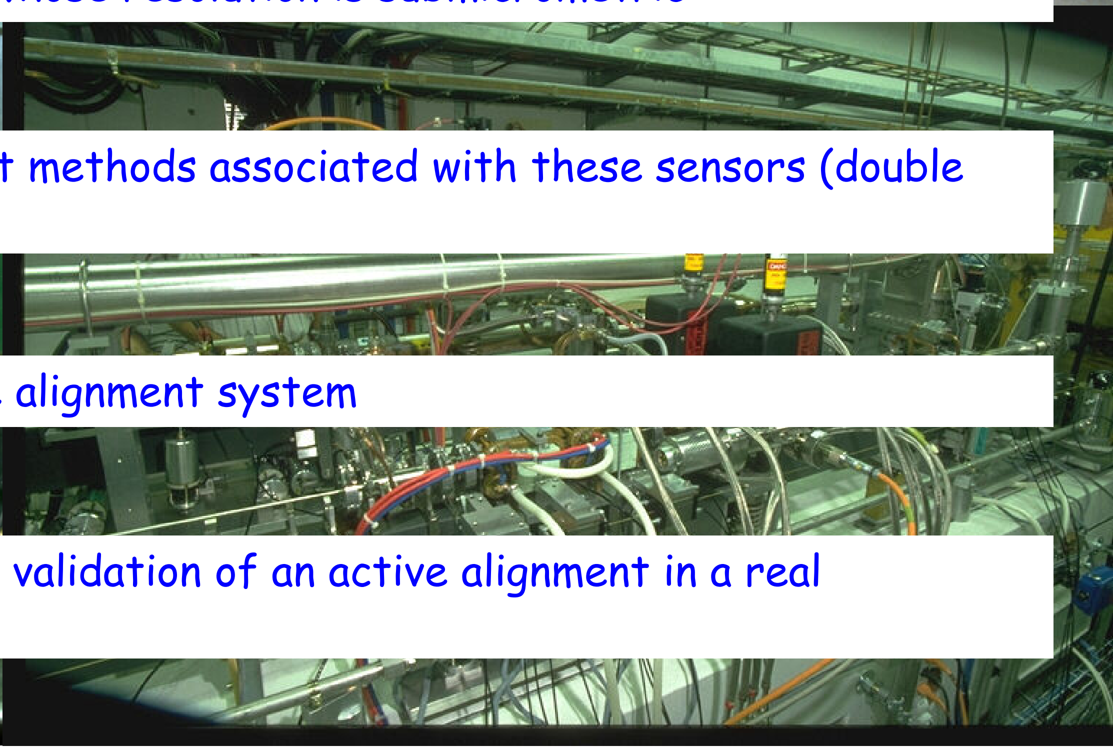
- ➔ lessons from the past
- ➔ status of the study and repositioning strategy
- ➔ validation on mock-ups and test program

LESSONS FROM THE PAST (1990->2002)





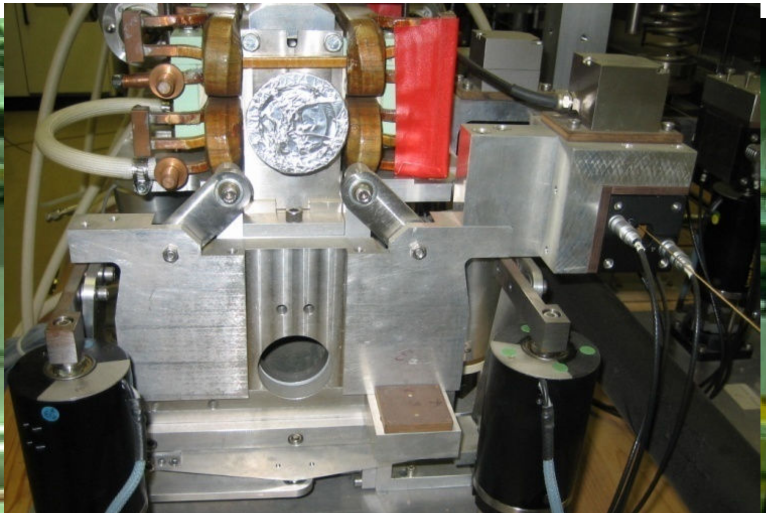




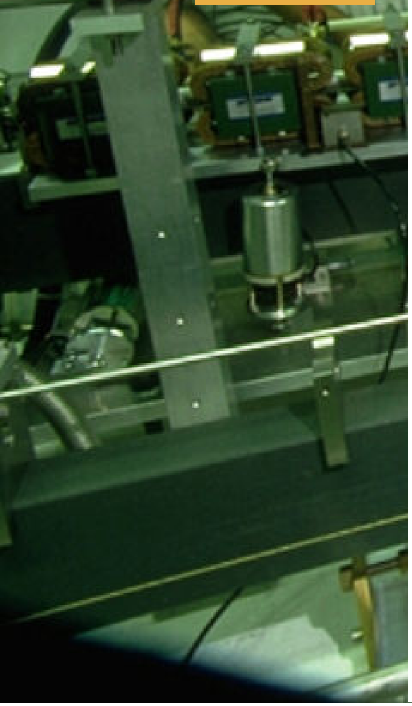
- Feasibility of controlling submicron movement.
- Development of sensors whose resolution is submicrometric
- Development of alignment methods associated with these sensors (double stretched wire method)
- Development of an active alignment system
- Tests of the sensors and validation of an active alignment in a real environment (CTF2)

LESSONS FROM CTF2

In the CTF2 facility, the components (CAS, PETS) were maintained aligned in a closed loop w.r.t. a stretched wire within a window of ± 5 microns, thanks to sensors and micro movers, in a very radioactive environment.

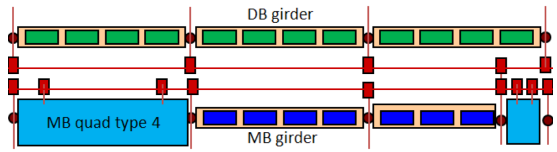


BUT…



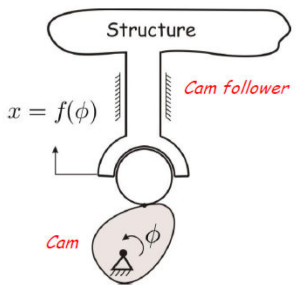
- Sensors and actuators were used for monitoring w.r.t a reference position and repositioning, not for pre-alignment
- The pre-alignment in that case was manual and iterative (no fiducialisation : the position of the WPS was not known w.r.t the reference axis of the accelerating cavities)
- Small scale solution to align the accelerating cavities on the girders
- Mechanical design to update (modification of the size of the components ➔ considerable increase of load ➔ some question marks concerning the clearances and kinematics)
- A solution of fiducialisation within a few microns must be found
- A new solution of pre-alignment for the MB quad must be found (CTF2 solution not compatible with stabilization requirements)

REPOSITIONING STRATEGY



➔ MB quad: find a new pre-alignment solution (Developed by F. Lackner)

✓ After inventory of different existing solutions → choice of a cam based solution (SLS type)



- Simple kinematics
- Low amount of internal degrees of freedom
- Low friction in contact points
- Should provide high first Eigenfrequency, rigidity for the supporting structure
- But resolution of displacement and contact stress to improve

✓ Study of the SLS cam system on a 1 DOF test bench

✓ Design of an improved cam system

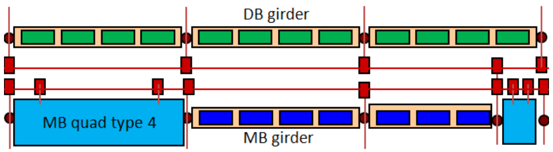
✓ Design of the pre-alignment interface and stabilization/pre-alignment interface (see next slide)

✓ Validation of the strategy of active pre-alignment on a 5 DOF mock-up

✓ Validation of the compatibility with stabilization requirements on a type 4 and type 1 MB quad.

✓ Preparation of the 104 repositioning solution for CLEX

REPOSITIONING STRATEGY



➔ DB and MB girders: Upgrade of the existing solution and proposal of an alternative solution

✓ Upgrade of the existing solution:
- Study of the CTF2 girder solution
- Design of the upgraded solution
- Study and validation of the upgraded solution

✓ Proposal of an alternative solution, based on a cam system
- Once the system is validated on the MB quad setup → adaptation for the girders
- Test and validation on mock-ups.

✓ Preparation of the repositioning solution for the « 104 » module

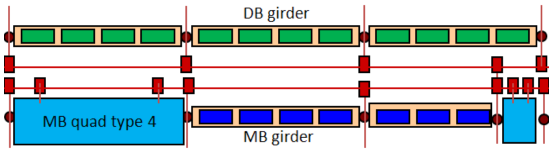
➔ Schedule:

✓ Before CDR:
- Validation of the upgraded solution for girders pre-alignment
- Validation of the improved cam solution for the MB quad pre-alignment

✓ After CDR:
- Study of a cam for the girders
- Preparation of the 104 solution for CLEX.

VALIDATION ON MOCK-UPS

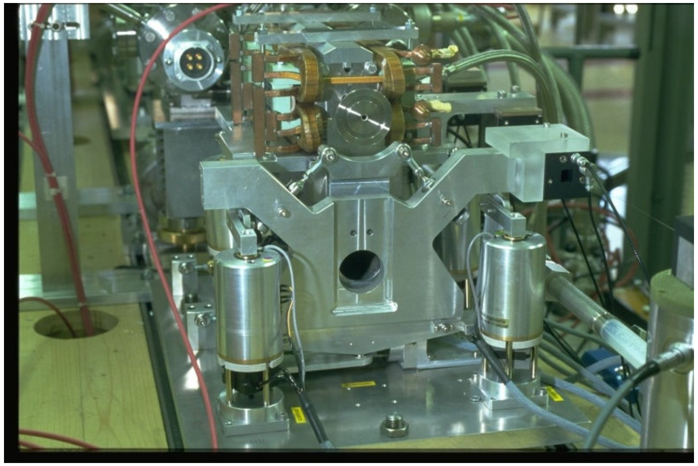
(Before the CDR)

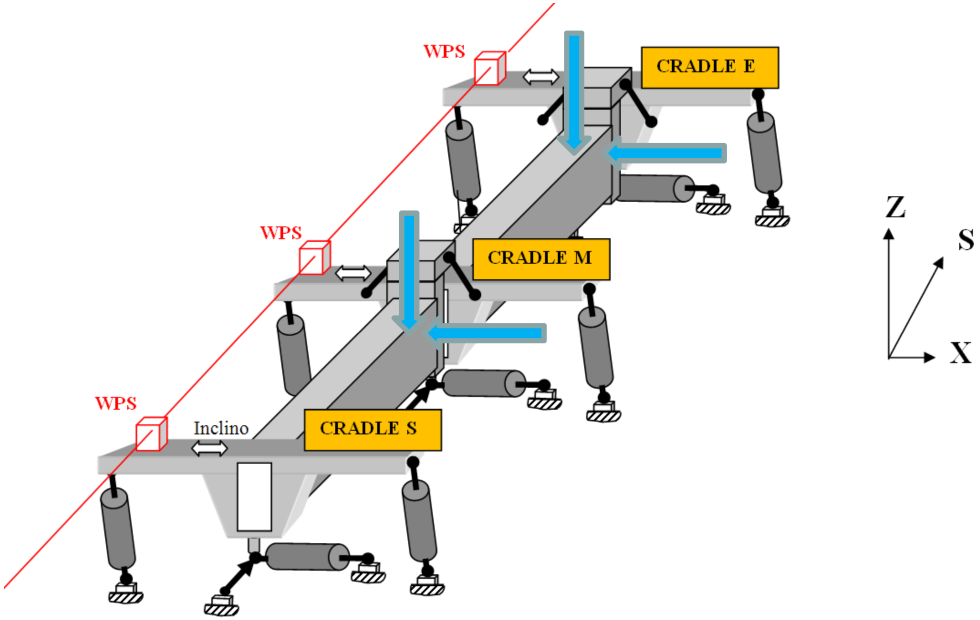


➔ Study of the CTF2 solution (old girder + equipment above ~ 40 kg)

✓ Installation of 2 girders + cradles, with the associated actuators and sensors

✓ Configuration:



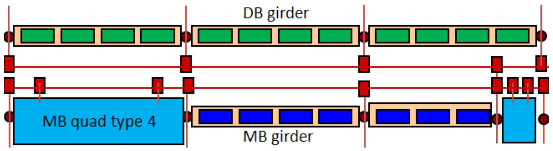


✓ Objectives:

- Impact of millimetric displacements on cradle M on the other cradles
- Impact of such displacements on the extremities of girders ⬅
- Better knowledge of the actuators and feedback for the next technical specification
- Better understanding of the girder behavior for the upgraded design

VALIDATION ON MOCK-UPS

(Before the CDR)

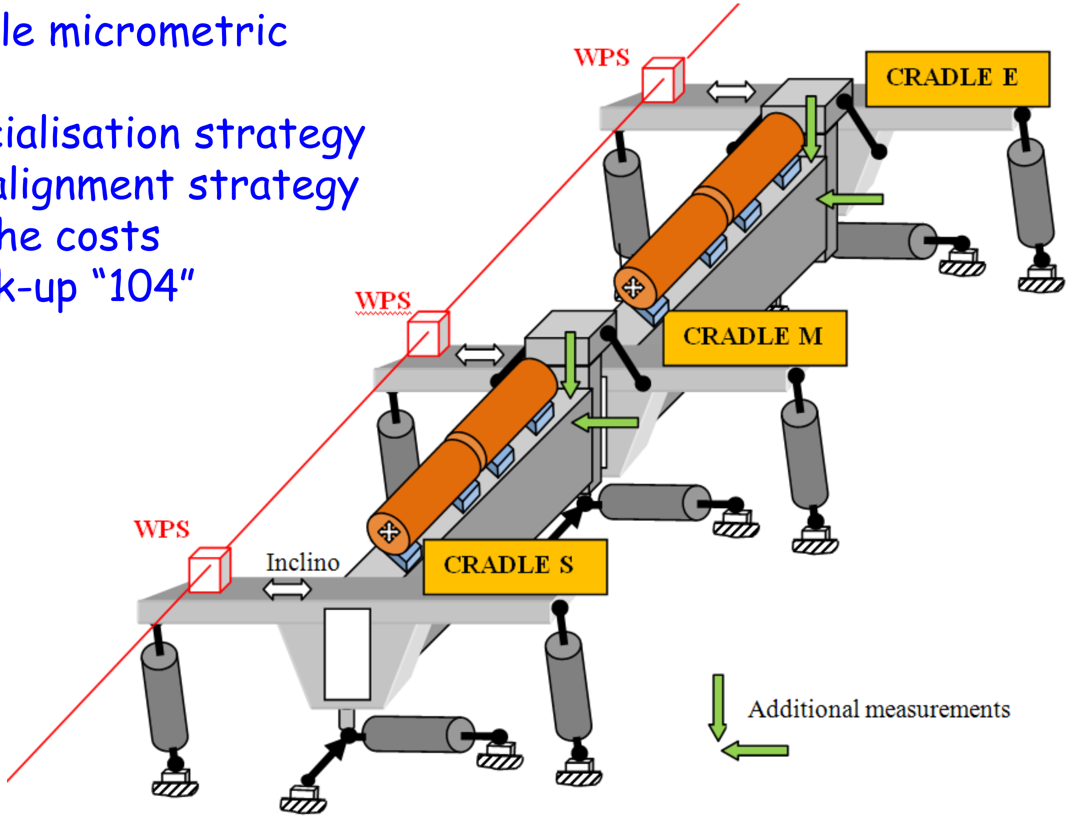


➔ Study and validation of the upgraded CTF2 solution (new girder + equipment ~ 800 kg)

✓ Installation with 2 girders and 3 cradles, with Ves and dummy cavities (same weight)

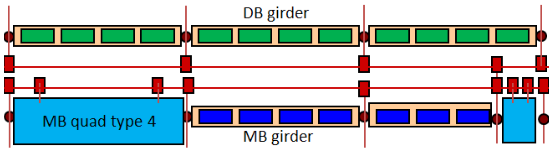
✓ Objectives:

- Validation of repeatable micrometric displacements
- Validation of the fiducialisation strategy
- Validation of the pre-alignment strategy
- Better knowledge of the costs
- Feedback for the mock-up "104"



VALIDATION ON MOCK-UPS

(Before the CDR)

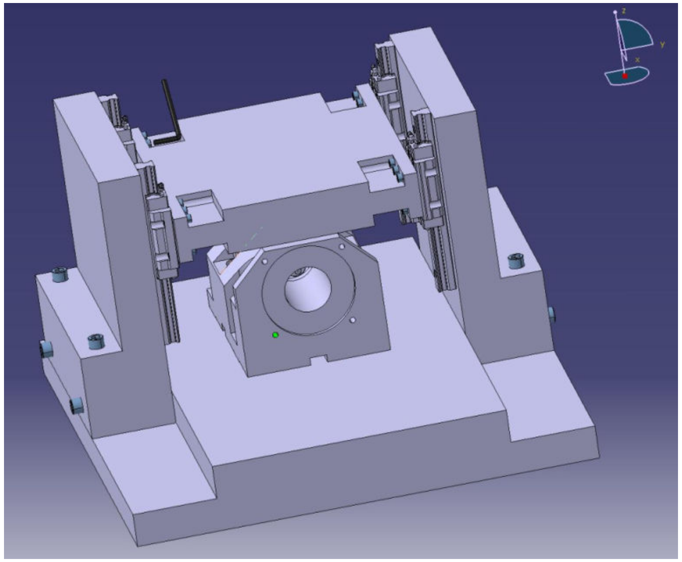


➔ Study of the SLS cam system on a 1 DOF test bench (Developed by F. Lackner)

✓ Objectives: *a better knowledge of the SLS cam system and upgrade towards a micrometric resolution of displacement*

- Determination of alignment accuracy in 1 DOF
- Sine wave response, repeatibility in short and long range alignment
- Modal behavior as function of load mass
- Study of material fatigue behavior
- Modular assembly in order to study CAM optimization based on the Hertzian theory

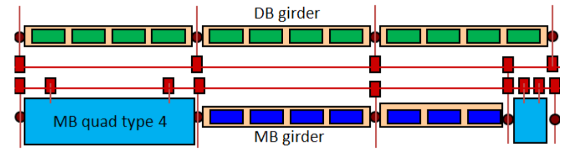
✓ Configuration:



(F. Lackner & L. Gentini)

VALIDATION ON MOCK-UPS

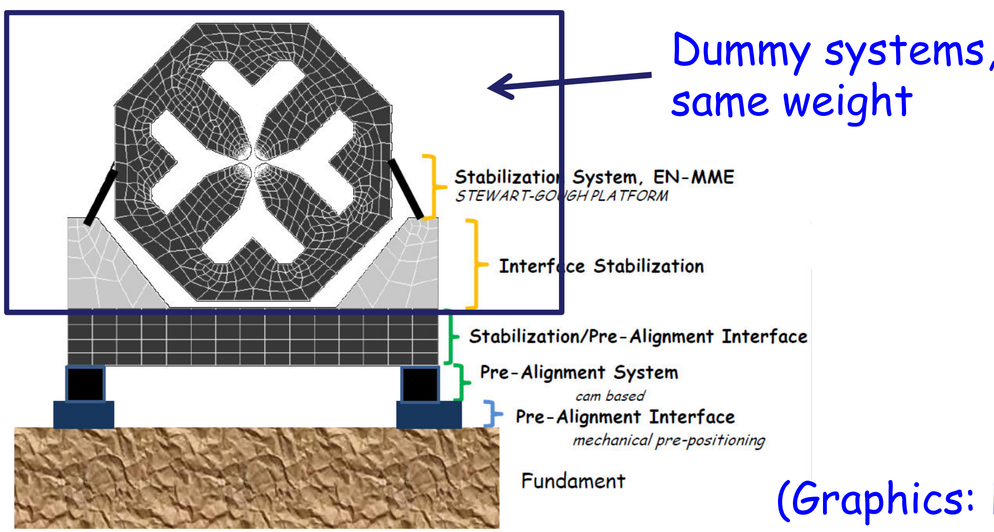
(Before the CDR)

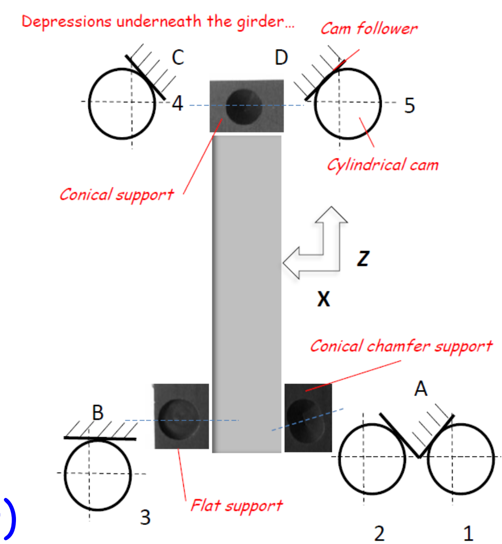


➔ Study of the SLS cam system on a 5 DOF test bench (Developed by F. Lackner)

✓ Objectives: *validation of the active pre-alignment solution*

- Validation of the steps of pre-alignment
  - Fundament/pre-alignment interface (manual positioning)
  - Cam based pre-alignment system w.r.t the metrological network
  - Pre-alignment/stabilization interface
- Validation of the repositioning algorithm
- Control of the rigidity of the pre-alignment solution, measure of the first Eigenfrequencies of the supporting structure.
- Feedback for the girder cam based solution and for the "104" module
- Validation of the fiducialisation strategy (pre-alignment of the pre-alignment/stabilization interface w.r.t a given straight line)

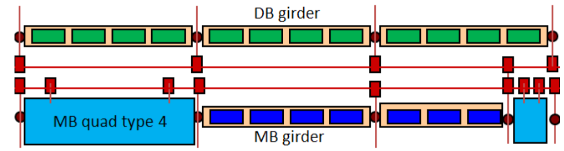




(Graphics: F. Lackner)

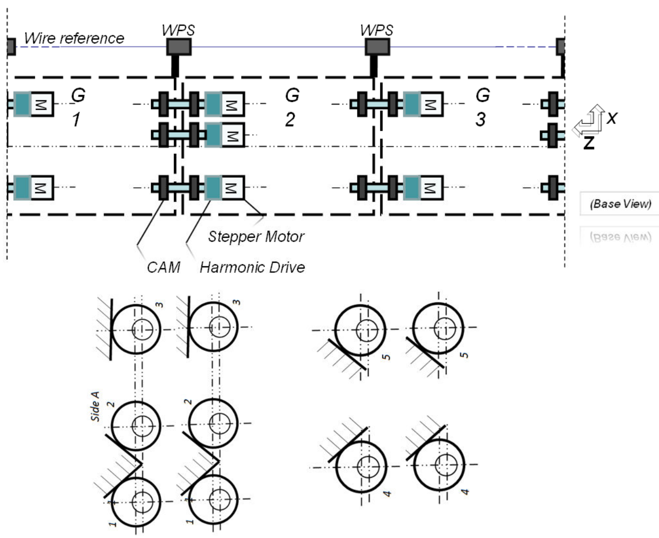
VALIDATION ON MOCK-UPS

(After the CDR)

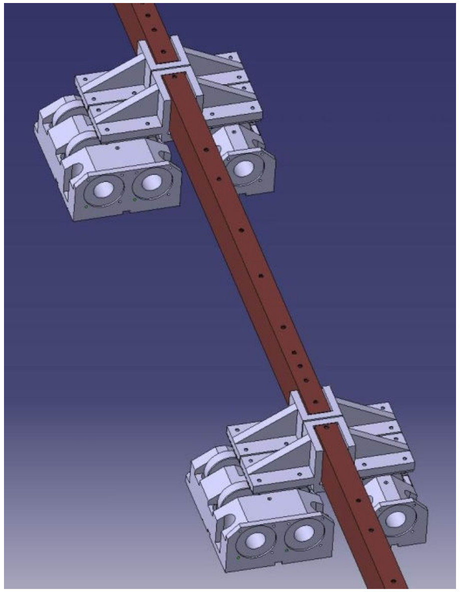


➔ Study and validation of the cam based solution for girders (new girder + equipment ~ 800 kg)

- ✓ Installation with 2 girders and 3 cradles, with Ves and false cavities (same load)
- ✓ Configuration



F. Lackner - Girder Alignment – 02.09.2009



- ✓ Objectives:
  - Validation of micrometric displacements
  - Validation of the pre-alignment strategy
  - Knowledge of the costs
  - Feedback for the mock-up 104

SUMMARY

- ✓ The issues concerning the feasibility of the active pre-alignment are the following:
  - A stable alignment reference, known at the micron level
  - Submicrometric sensors providing « absolute » measurements
  - Stable determination of 2 m long objects within a few microns
  - Submicrometric displacements along 3/5 DOF

  - Compatibility with the general strategy of installation and operation
  - Compatibility with the other equipments of the module.

- ✓ Each key point is being reviewed carefully

- ✓ Validation foreseen on mock-ups in 2010.

- ✓ Validation foreseen with beam in CLEX in 2012.