

CLIC ACTIVE PRE-ALIGNMENT STUDIES: STATUS FOR CDR AND PROSPECTS FOR TDR PHASE

IWLC2010 International Workshop on Linear Colliders 2010

H. MAINAUD DURAND,
on behalf of the CLIC active pre-alignment team

SUMMARY

✓ Introduction

✓ Status for CDR

- Solutions concerning re-adjustment
- Solutions concerning the determination of the position

✓ Validation on two beam prototype modules

✓ Towards TDR

Introduction of the main challenge

PRE-ALIGNMENT (beam off)

Mechanical pre-alignment

Within $\pm 0.1 \text{ mm}$ (1σ)



Active pre-alignment

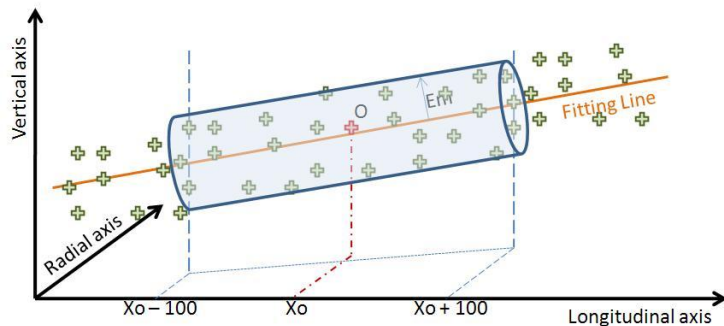
Within $\pm 3 \mu\text{m}$



Beam based alignment
Beam based feedbacks

Pre-alignment of 3 microns along a sliding window of 200 m, all along each linac

After computation, for a sliding window of 200 m, the standard deviations of the transverse position of each component w.r.t. the straight fitting line must be inferior to $3 \mu\text{m}$



Determination of the position of the components
in a general coordinate system thanks to
alignment systems

Introduction: hypotheses for study

3 μm over 200 m (1σ) is a target for study and development.



« trade off » with beam dynamics for realistic and achievable values for CDR.

Budget errors → Determination of the position

Steps	RF structures	MB quad
Zero of component to external references	5 μm (1σ)	10 μm (1σ)
External references of component to sensor interface on support	5 μm (1σ)	5 μm (1σ)
Sensor interface to Sensor zero	5 μm (1σ)	5 μm (1σ)
Sensor measurement w.r.t straight reference	5 μm (1σ)	5 μm (1σ)
Stability, knowledge of straight reference	10 μm (1σ)	10 μm (1σ)
TOTAL Error budget (1σ)	14 μm	17 μm

Main linac mover requirements

- Range: ± 3 mm
- Step size: ~ 1 μm , resolution: ~ 0.5 μm

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General strategy : re-adjustment

Several components will be pre-aligned on supports:

→ Along the MB:

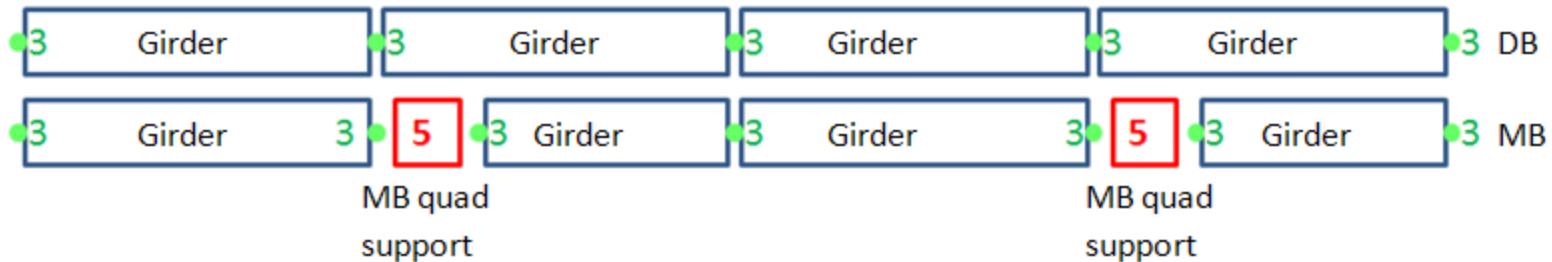
→ RF structures on girders

→ MB quad on interface plate

→ Along the DB:

→ PETS + DB quad on girders

Degrees of freedom: 3 / 5



DB and MB girders will be interlinked with their extremities, based on so-called cradle. This allows a movement in the transverse girder interlink plane within 3 degrees of freedom ("articulation point between girders"). (Longitudinal direction adjusted thanks to a mechanical guiding).

5

MB quad
support

MB quad is mounted on an interface plate, allowing an adjustment along 5 degrees of freedom (longitudinal position will be positioned manually).

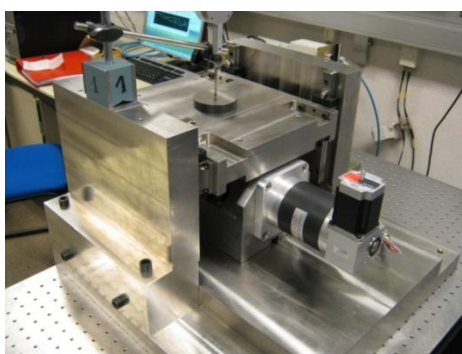
Strategy of re-adjustment

5

MB quad
support

MB Quad // cam movers

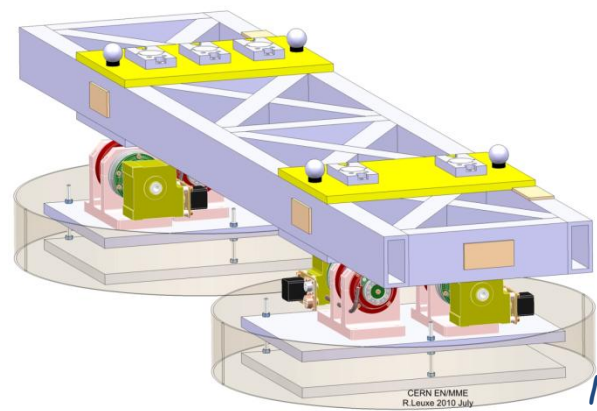
Validation of a SLS type cam mover (1 DOF mock-up)



Tested with 3 configurations
of bearing and outer rink

Sub-micron repeatability
achieved on full stroke with
every configuration

Validation of on a 5 DOF mock-up



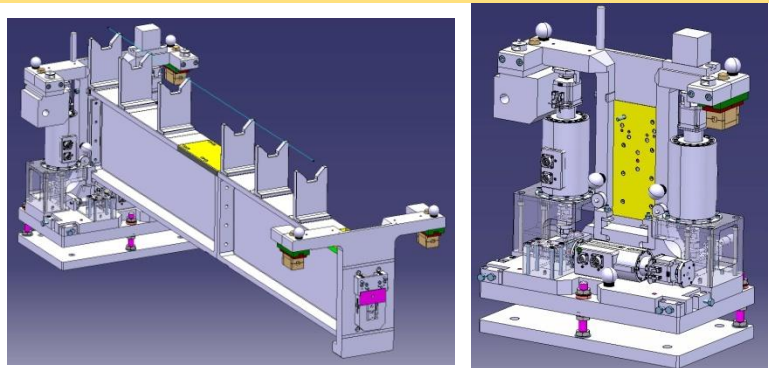
Mock-ups ready end of 2010

Validation on the two beam prototype modules

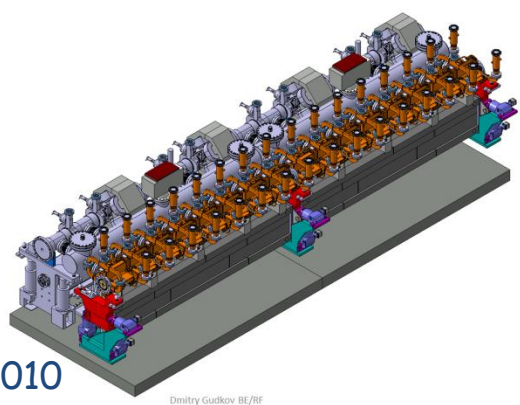
Girder 3 Girder

DB and MB girders // linear actuators

Design of a new "articulation point" concept



Validation on a pre-alignment mock-up



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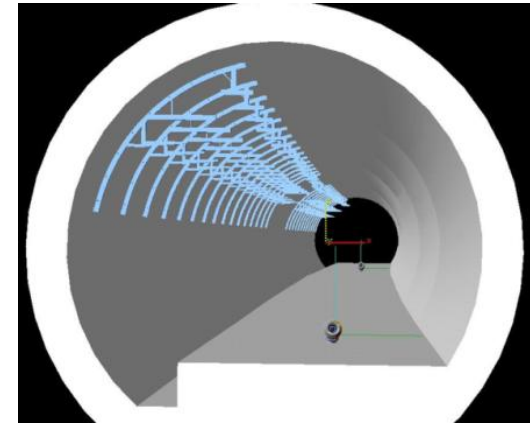
✓ Towards TDR

General strategy: determination of the position of the components

Geodetic Reference Network (GRN)

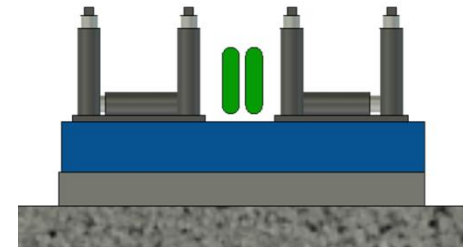
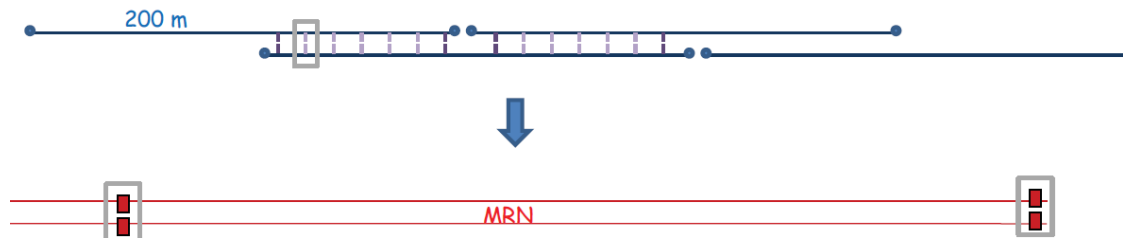
Backbone for all the tunnels and areas

Will allow the installation of all services
and of the MRN



Metrologic Reference Network (MRN)

- As it is not possible to implement a straight alignment reference over 20 km: use of overlapping references



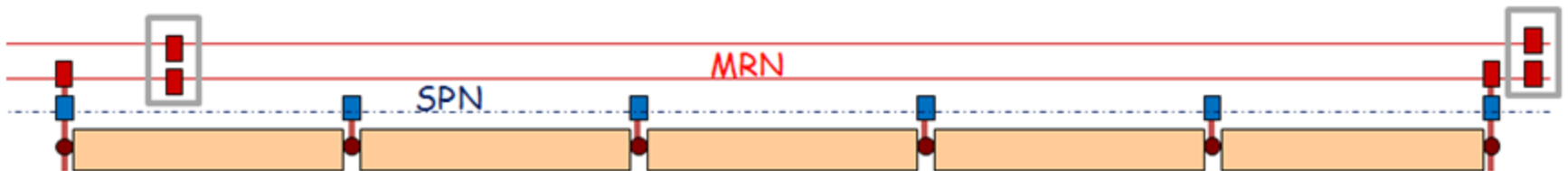
- For CDR: reference = wire stretched over 200 m

General strategy: determination of the position of the components

Geodetic Reference Network (GRN)

Metrologic Reference Network (MRN)

Support Pre-alignment Network (SPN)



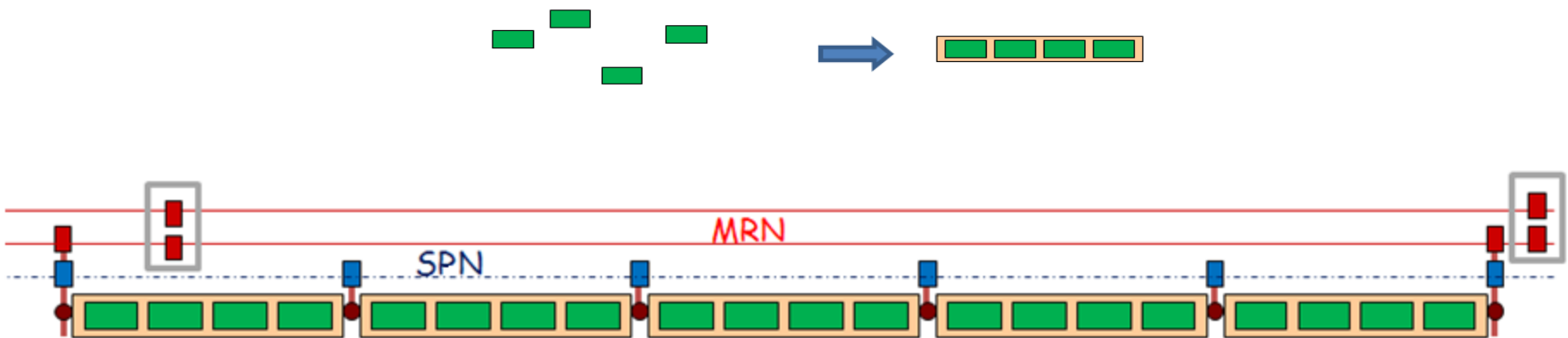
General strategy: determination of the position of the components

Geodetic Reference Network (GRN)

Metrologic Reference Network (MRN)

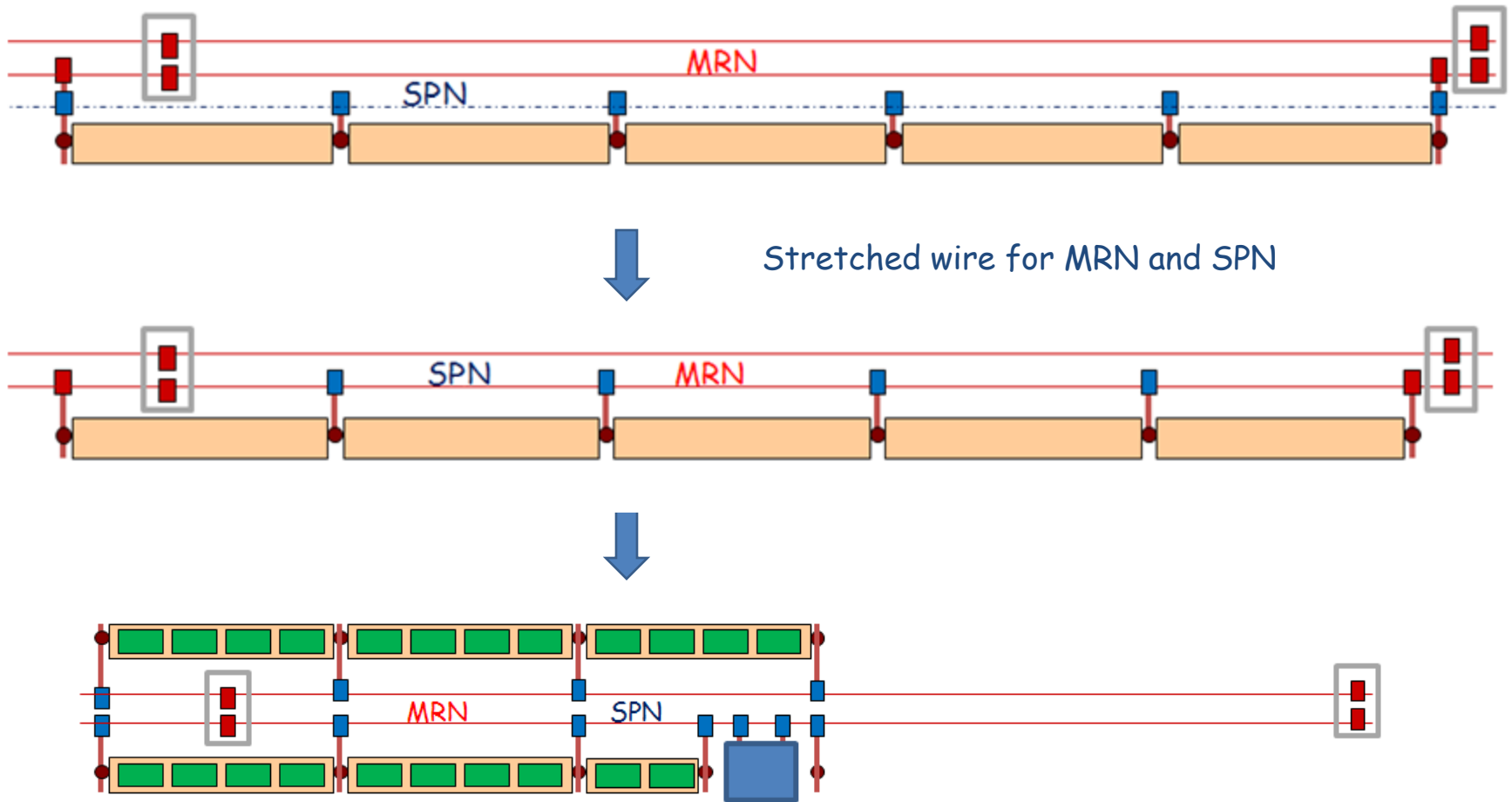
Support Pre-alignment Network (SPN)

Alignment and fiducialisation of each component on the supports (AFC)

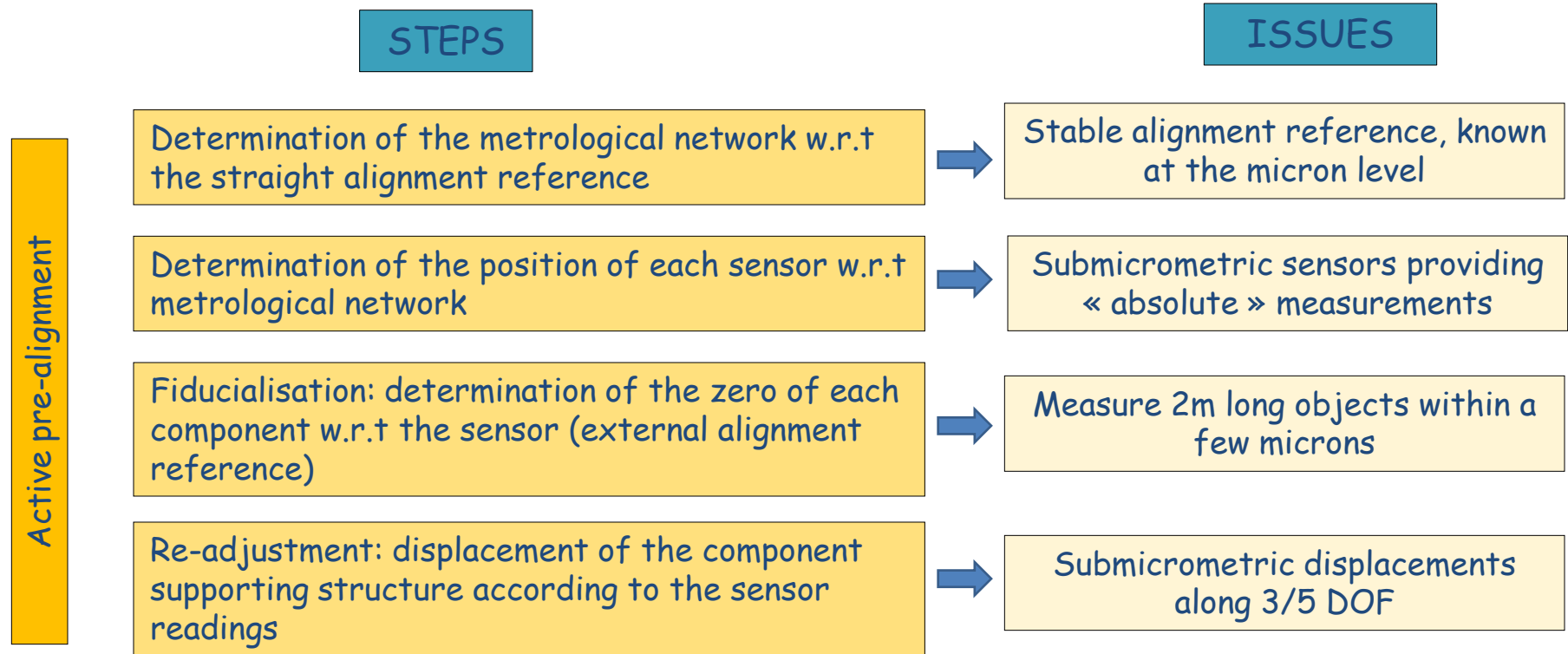


Status of the different solutions

Strategy towards the feasibility



Required solutions: feasibility of the concept



Other issues:

Compatibility with the general strategy of installation and operation

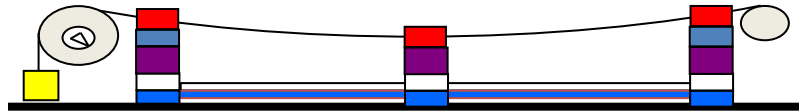
Compatibility with other accelerator equipment or services

Stretched wire

Main issue: long term stability of a wire

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

→ 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

Subject of a thesis: « Determination of a precise gravity field for the CLIC feasibility studies » Sébastien Guillaume

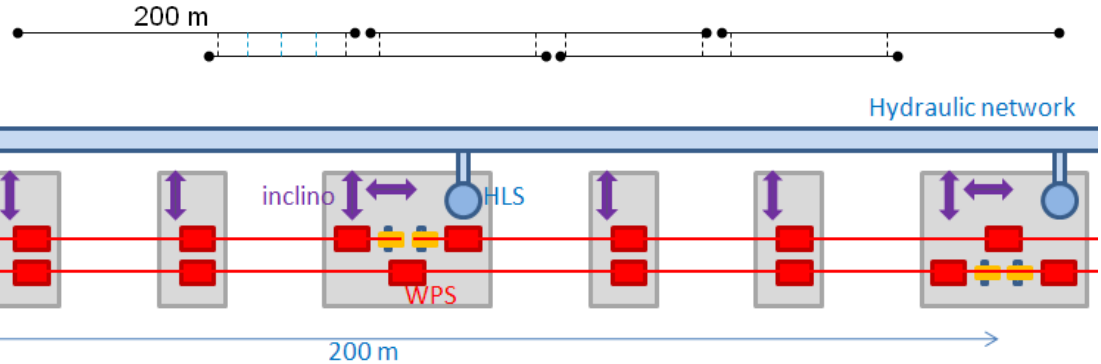
→ Is a stretched wire really straight (radial direction)?

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

→ on short distances (50 m) this autumn at CERN between WPS systems

Stretched wire and MRN

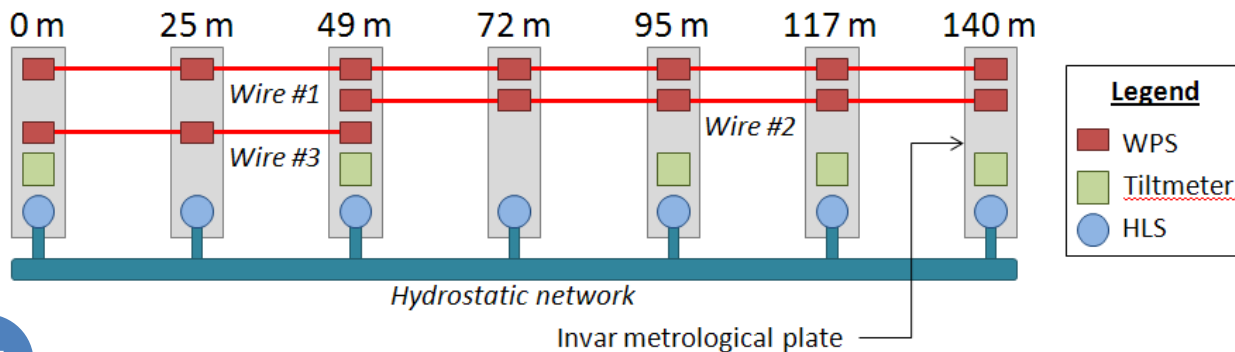
Minimum configuration



TT1 facility

Objectives:

- ✓ To determine the precision and accuracy of a MRN consisting of overlapping stretched wires
- ✓ To study the behavior of wires of different lengths
- ✓ To study the modelization of a stretched wire

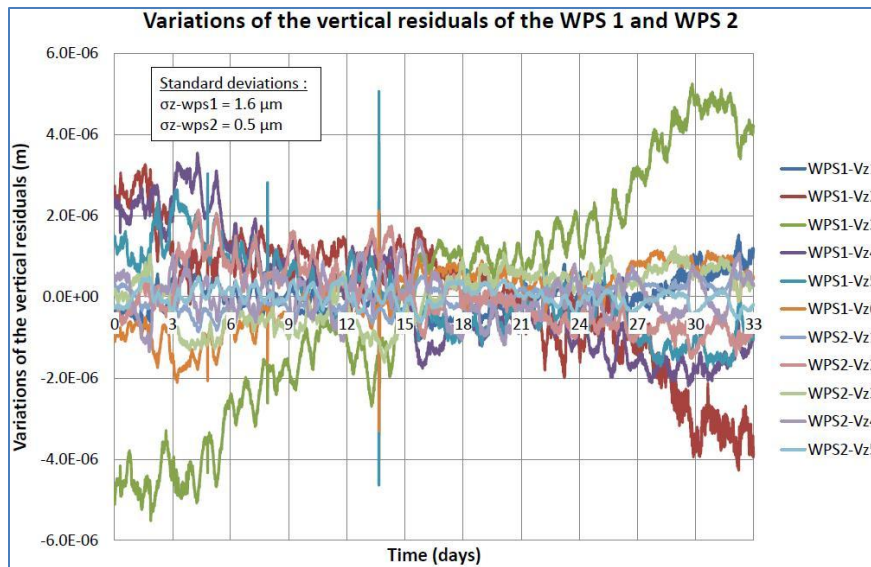


Stretched wire and MRN

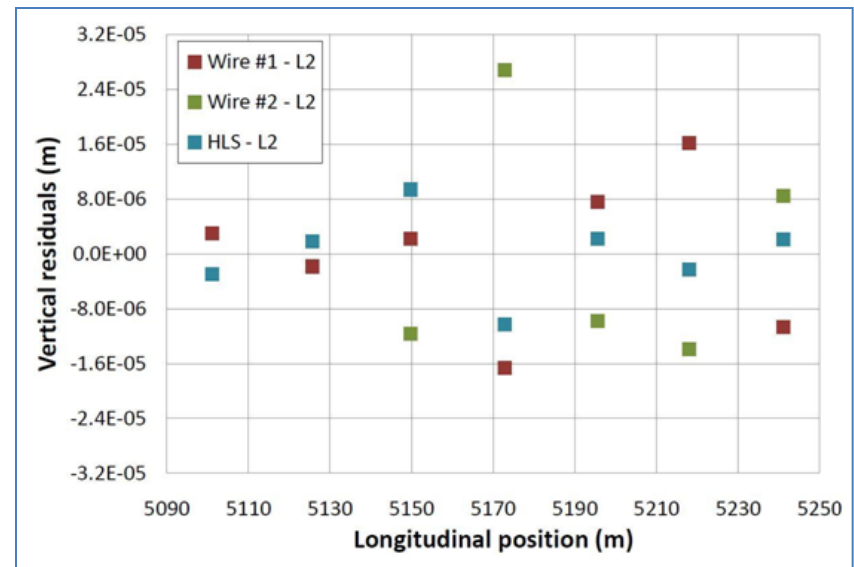
See next talk by Thomas Touzé

Results in TT1

- ✓ Precision on a 140 m wire: better than 2 microns over 33 days
- ✓ Accuracy: 11 microns in vertical, 17 microns in radial. Can be improved!



Vertical residuals of the 2 longest wires:
 σ (wire 1) = $1.6 \mu\text{m}$
 σ (wire 2) = $0.5 \mu\text{m}$



Accuracy of the TT1 network adjusted by the least squares method in vertical:
 $\sigma = 11 \mu\text{m}$ r.m.s ($27 \mu\text{m}$ max. value)

Subject of a thesis: « proposal of an alignment method for the CLIC linear accelerator: from the geodetic networks to the active pre-alignment » Thomas Touzé.

Sub-micrometric sensors

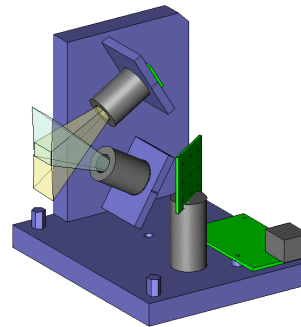
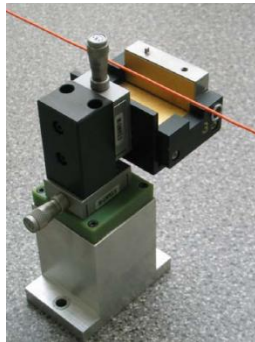
Issue: WPS sensor fulfilling the requirements

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



Capacitive based WPS (cWPS)

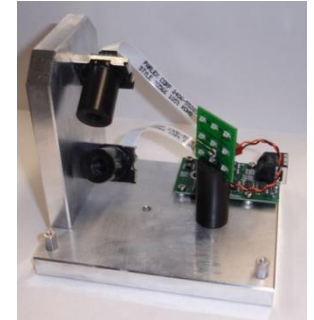
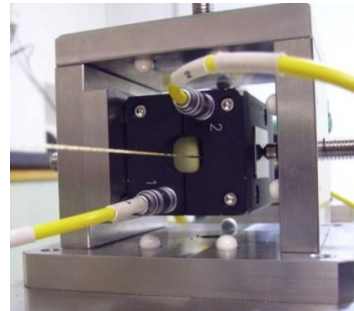
Resolution: $0.2 \mu\text{m}$
Range: $10 \times 10 \text{ mm}$
Repeatability: $1 \mu\text{m}$
Bandwidth: 10 Hz



Optical based WPS (oWPS)

Parameter	Value
Aperture-CCD	10 mm
Pivot-CCD	10.4 mm
Aperture Diameter	$200 \pm 5 \mu\text{m}$
Aperture Centering	$\pm 100 \mu\text{m}$
Lens Focal Length	9 mm
Focal Point of Lens to CCD	11 mm
Flat of Lens to CCD	12 mm
CCD Width	3.4 mm
CCD Height	2.4 mm
CCD Pixel Size	$10 \mu\text{m} \times 10 \mu\text{m}$
Field of View	$\pm 160 \text{ mrad} \times \pm 110 \text{ mrad}$
Aperture Height Above End Plate	15 mm
Aperture to Front of CCD Mounting Plate	5 mm

Status of the different sensors technologies



	cWPS	oWPS
Technology	Capacitive	Optical
Accuracy (μm)	7	~ 10 (TBC)
Repeatability (μm)	1	2 (TBC)
Precision (μm)	1	2
Acq. Frequency (Hz)	100	1 /sensor
Resistance to radiation	200 kGy (sensor) 500 Gy (remote electronics)	TBC
Wire	Carbone peek	Vectran
Sag (mm) for 200 m	76.5 mm	45.5 mm
Cost	5000 CHF	500 \$

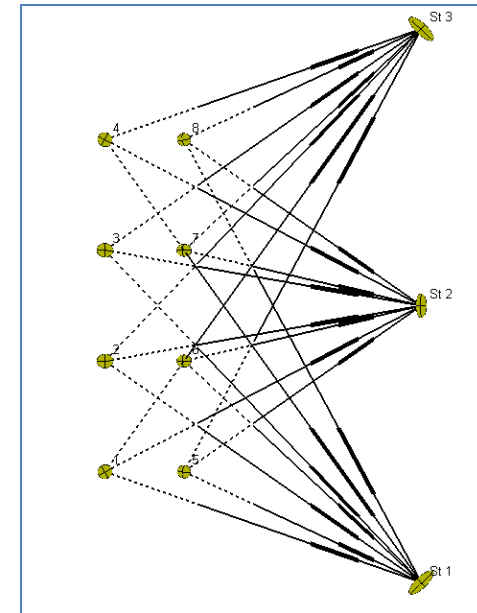
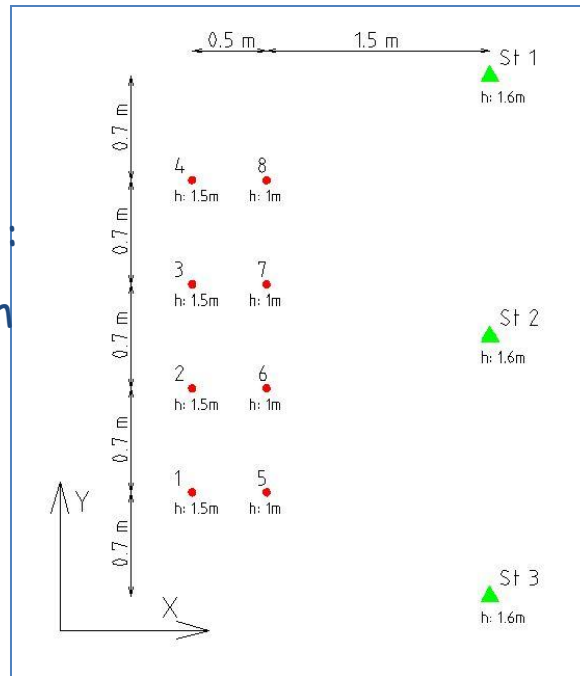
Status of fiducialisation

Issue: measure 2m long objects within a few microns.

Solution proposed for CDR: use of Laser Tracker from LEICA AT401:

- ✓ Maximum offset in the determination of a point in space: $\pm 15 \mu\text{m} + 6\text{ppm}$ (3σ)
- ✓ Maximum offset in the determination of distance between 2 points: $10 \mu\text{m}$
- ✓ Centering of target: $\pm 2.5 \mu\text{m}$ (3σ)

Points distributed in :
2.1 m x 0.5 m x 0.5 m



Inter-comparison between sensors:

Web site: <https://clic-pral.web.cern.ch/clic-pral/>



CLIC PRE-ALIGNMENT WORKSHOP

2-3 April 2009 CERN

Objectives

Timetable

Overview

Participants

Information

Links

Contact

Support

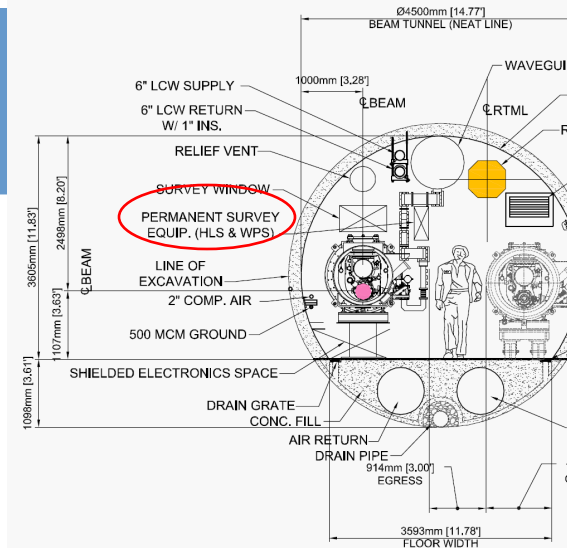
At the last CLIC workshop held at CERN in October 2008, a strong willingness was expressed to regroup synergies between the CLIC and the ILC projects. As far as the alignment activity is concerned, the ILC and CLIC Beam Delivery Areas encounter similar difficulties due to the high accuracy of alignment of the components requested before the beam based alignment phase.

In the frame of the CLIC project and in accordance to its research and development (R&D) plan, the CERN Survey Team, which is responsible for the survey and alignment of the CLIC project, intends to organize in a first step an inter-comparison concerning WPS and HLS sensors that are used or being developed by different laboratories.

The objectives of this mini workshop are the following

- to inventory the existing WPS and HLS sensors
- to record the means, methods and conditions of tests on these sensors
- to define the tests to be performed on these sensors during the inter-comparison
- to establish a basis for inter-comparison and envisage collaboration with your laboratory on this study

Institutes invited to participate to this mini workshop are: BINP, DESY, ERSF, Fermi, KEK, PSI, SLAC, Soleil, SPring-8, USTC



Status of the inter-comparison:

➔ WPS [SLAC, CERN] : inter-comparison at SLAC. Facility ready in July 2010.

➔ HLS [Fermilab, SLAC, DESY, USTC]: long term stability tests at Fermilab, other tests at CERN.

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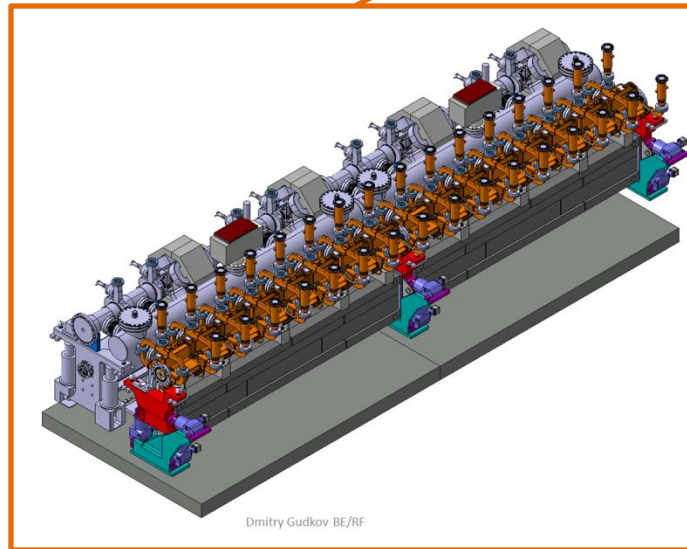
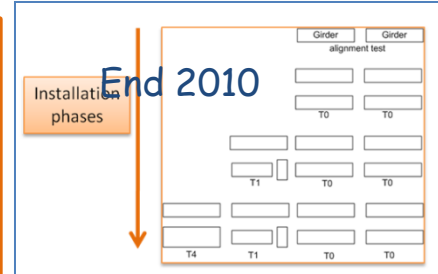
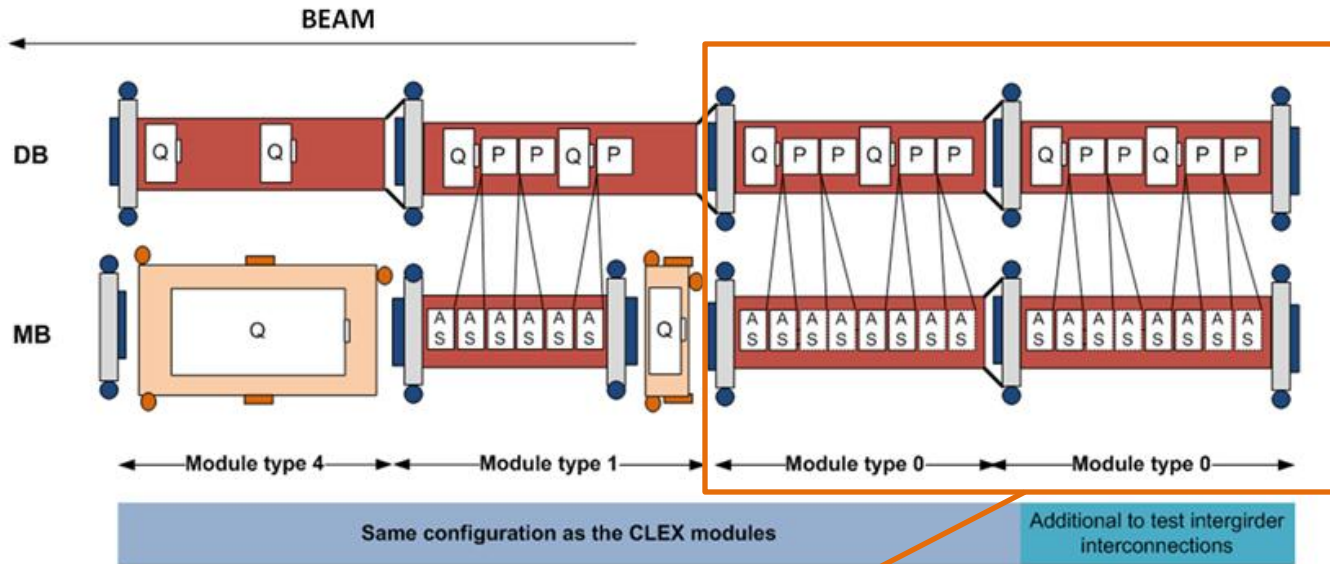
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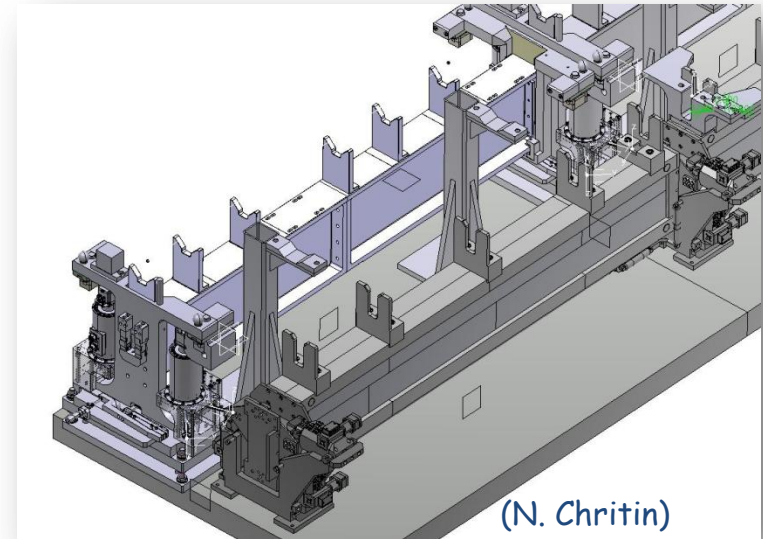
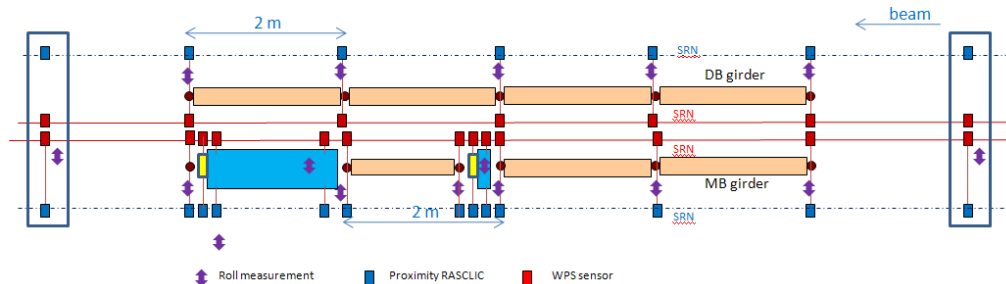
✓ Validation on two beam prototype modules

✓ Towards TDR

Test program on CLIC two beam prototype modules



Proposed solution for two beam prototype modules



- ✓ Validation of the repositioning concept (possibility of sub-micrometric displacements)
 - Before the installation of all other systems (waveguides, vacuum,...)
 - After installation of all other systems (waveguides, vacuum,...)
- ✓ Measurement of the eigenfrequencies of the girders
- ✓ Validation of the fiducialisation strategy
- ✓ Validation of the stability of the components on the girders
 - Impact of the transport on a micrometric pre-alignment
 - Impact of variation of temperature, thermal cycles
- ✓ Feedback for the CLEX test module, and all associated technical specifications
- ✓ Feedback for the general strategy of installation
- ✓ Feedback for the schedule
- ✓ Inter-comparison between solutions of SPN networks.

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Alternative studies for TDR

Determination of the position of the components:

- In collaboration with NIKHEF : development of alternative solutions (laser beam)
 - Design of a short range / long range solution adapted for CLIC requirements
 - Integration of the short range solution on the two beam prototype modules
 - Inter-comparison of the long range solution in TT1 / TZ32 tunnels

Re-adjustment:

- Validation of the concept of articulation point with cam movers

Other studies (in order to reduce the number of sensors):

- Study of a mono-girder (DB & MB components)
- Study of longer girders
- Development of low cost WPS sensors based on capacitive technology (technical specification under definition)

Development of a n-point laser based alignment system → LAMBDA project

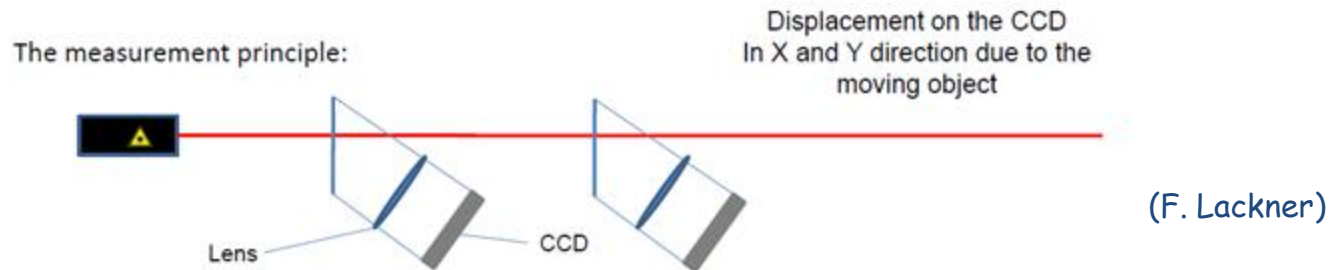
LAMBDA Project



LAMBDA for Laser Alignment Multipoint Based - Design Approach

Description:

- Reference of alignment : laser beam under vacuum
- N-point alignment system: sensors distributed along the beam
- Speckles are measured on a surface on each point (sensor) using a CCD



- Measurement surface = mechanical or optical shutter, which will not alter the beam and keep the straightness of the reference of alignment.
- Each sensor consists of a measurement surface, a convergent lens and a CCD camera, allowing an indirect observation of the speckles on the surface by the CCD
→ reducing the angular sensitivity of the system.
- According to the first simulations, to detect micrometric displacement, angular orientation should be better than 0.2 mrad, and repeatability of shutter 12 μm

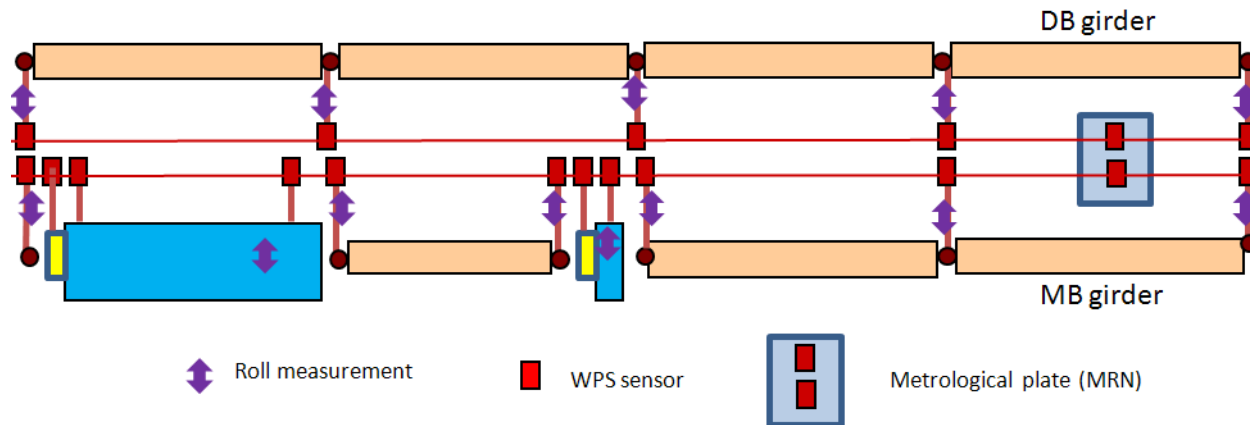
Status: looking for a PhD student.

CONCLUSION

Proposed solution for CDR

Determination of the position of the components:

→ stretched wire + WPS sensors for MRN and SPN



Re-adjustment:

→ MB quad: cam mover

→ Girders: high precision linear actuators

Feasibility will be endorsed on the CLIC
prototype modules

Thank you very much for your attention