ALIGNMENT OF THE CLIC MAIN LINAC

6th CLIC Advisory Commitee

02-02-11

H. MAINAUD DURAND

SUMMARY

✓Introduction: required CLIC performances

✓ Status of activity
- o Pre-alignment of components on the supports
- o Support Pre-alignment Network (SPN)
- o Metrologic Reference Network (MRN)
- o Re-adjustment

✓ Short term program & expected results by end of 2012

✓ R&D planning for the next phase

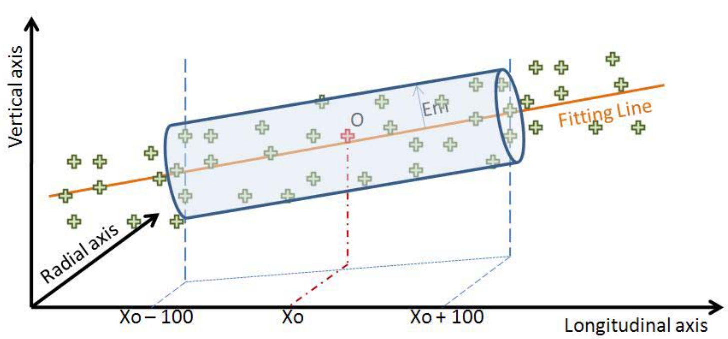
Introduction : required pre-alignment performances

PRE-ALIGNMENT (beam off)

Mechanical pre-alignment → Active pre-alignment → Beam based alignment / Beam based feedbacks

- Mechanical pre-alignment: Within +/- 0.1 mm (1σ)
- Active pre-alignment: Within a few microns

Active pre-alignment = Determination of the position of the components in a general coordinate system thanks to alignment systems
+
Re-adjustment thanks to actuators



After computation, for a sliding window of 200 m, the standard deviations of the transverse position of the zero of each component w.r.t a straight fitting line will be included in a cylinder with a radius of a few microns:

➔ 14 μm (RF structures & MB quad BPM)

➔ 17 μm (MB quad BPM)

Adjustment: step size of the order of 1 μm

Introduction: general strategy of re-adjustment

Several components will be pre-aligned on supports:

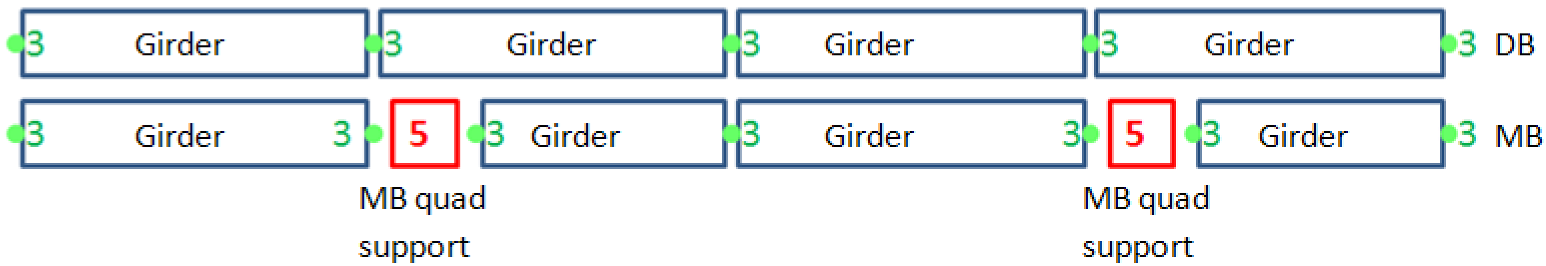
➔ Along the MB:

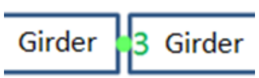
- ➔ RF structures on girders
- ➔ MB quad on interface plate

➔ Along the DB:

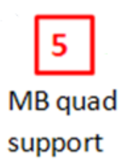
- ➔ PETS + DB quad on girders

Degrees of freedom: 3 / 5



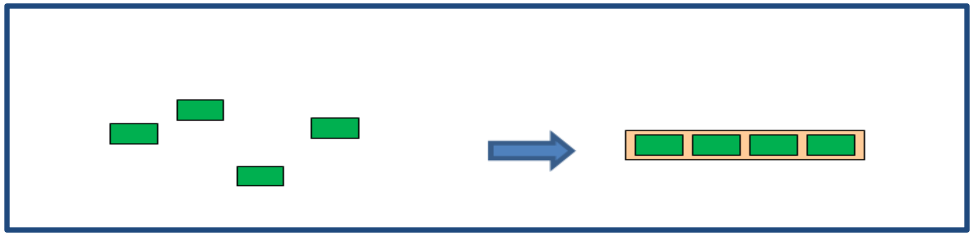


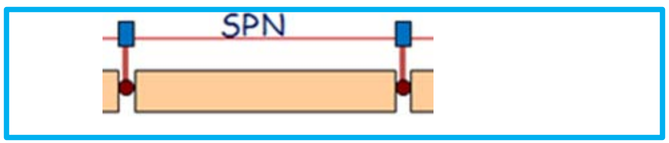
DB and MB girders will be interlinked with their extremities, based on so-called cradle. This allows a movement in the transverse girder interlink plane within 3 degrees of freedom ("articulation point between girders"). (Longitudinal direction adjusted thanks to a mechanical guiding).

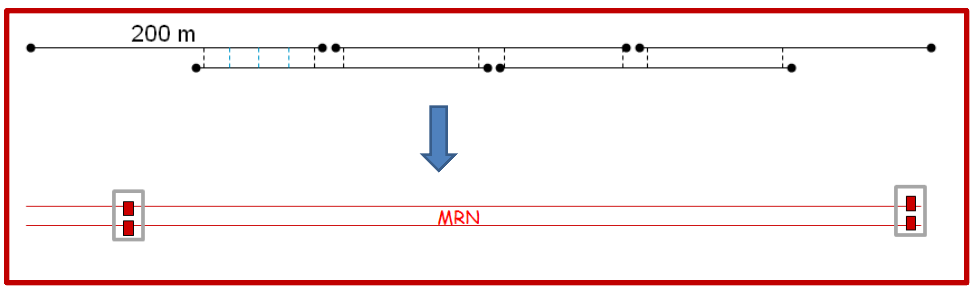


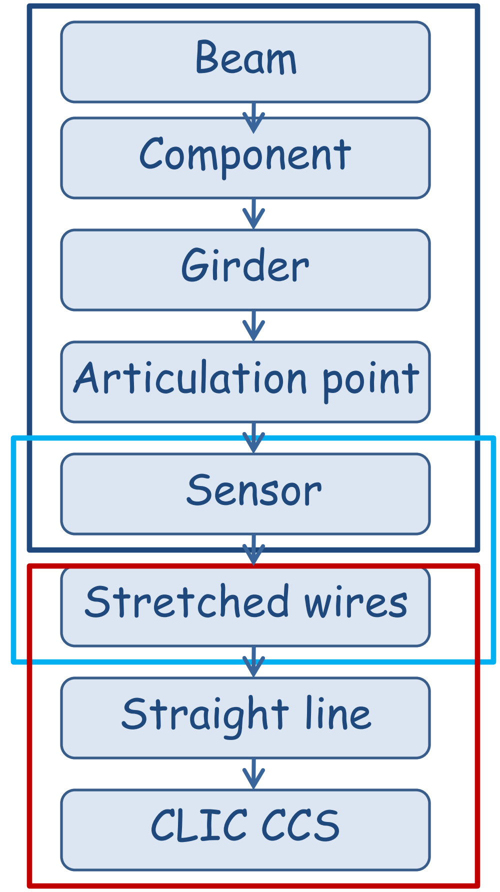
MB quad is mounted on an interface plate, allowing an adjustment along 5 degrees of freedom (longitudinal position will be positioned manually).

Introduction: general strategy of position determination





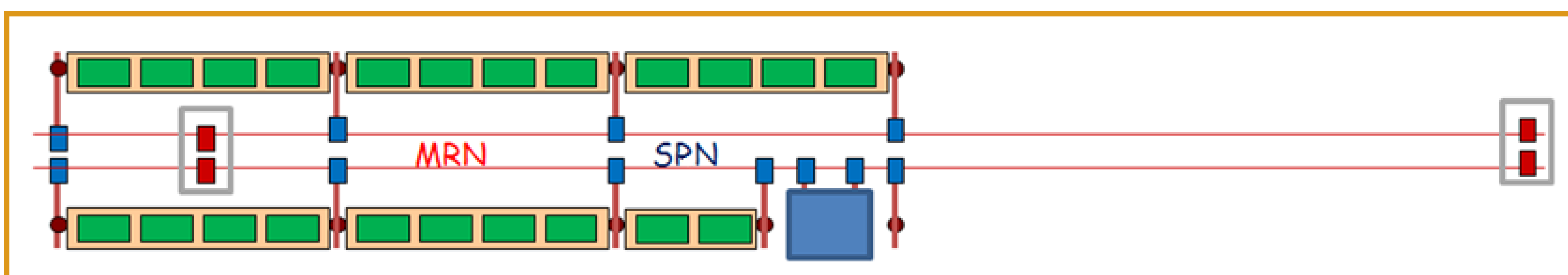




Alignment & Fiducialisation of Component (AFC)

Support Pre-alignment Network (SPN)

Metrologic Reference Network (MRN)



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Required solutions: feasibility of the concept

Active pre-alignment

STEPS	ISSUES
(MRN): Determination of the metrological network in the CLIC reference system	Stable alignment reference, known at the micron level
(SPN): Determination of the position of each support w.r.t metrological network	Submicrometric sensors providing « absolute » measurements
(AFC): Fiducialisation: determination of the zero of each component w.r.t SPN network (external alignment reference)	Measure 2m long objects within a few microns
Re-adjustment: 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

Re-adjustment: status of MB quad support

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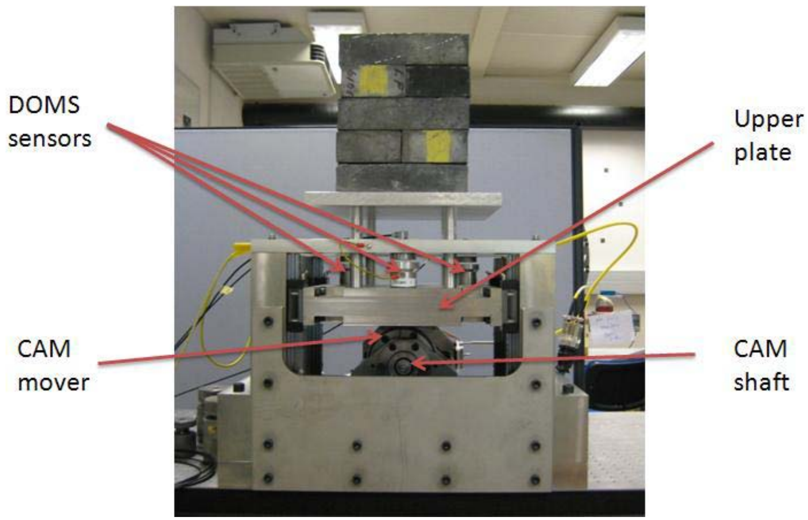
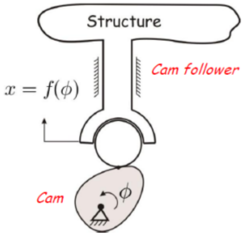
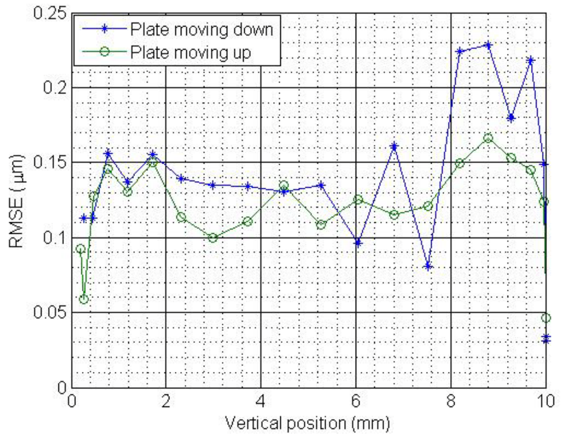
MB quad support

Validation of a SLS type cam mover (1 DOF test bench)





MB Quad // cam movers



Tested with 3 configurations of bearing and outer rink

Sub-micron repeatability achieved on full stroke with every configuration

Order of 5 improved cam movers ➔ Delivery : 07-Feb-11

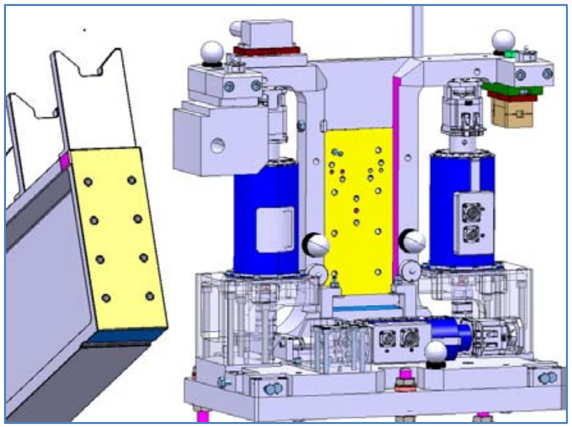
Validation of on the 1 DOF test bench

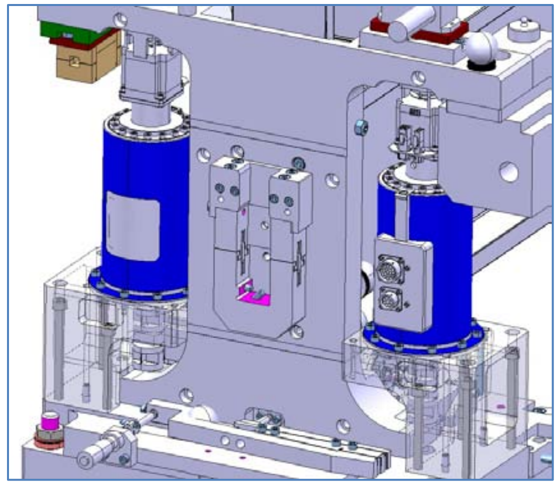
Validation of on a 5 DOF mock-up

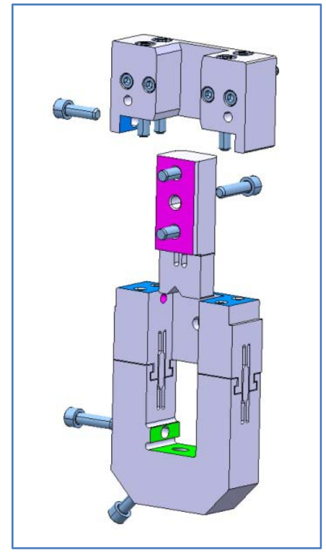
Re-adjustment: status of articulation point

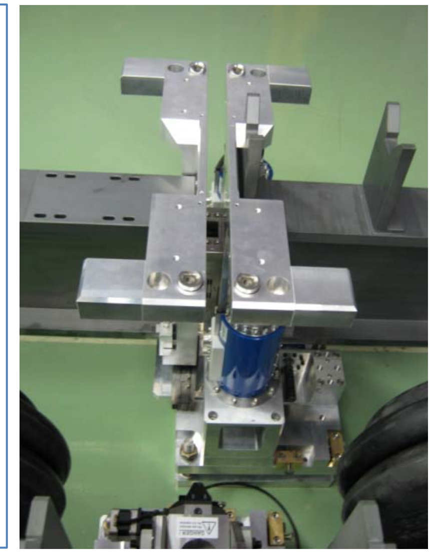
DB and MB girders // linear actuators

Design of a new "articulation point" concept

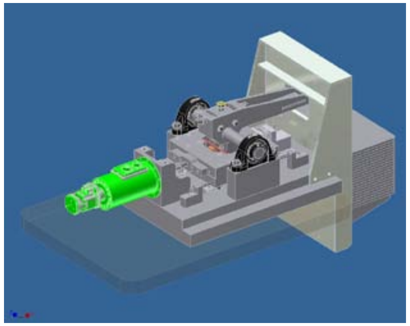








Validation on the 1 DOF test bench → before end of February



Validation on the two beam prototype modules

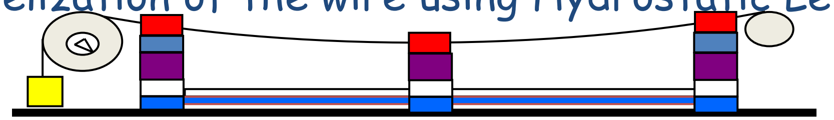
Determination of the position: feasibility and latest results

Stretched wire & MRN

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 two PhD theses:
« Determination of a precise gravity field for the CLIC feasibility studies » (S. Guillaume)
« Analysis and modeling of the effect of tides on Hydrostatic Leveling System » (J. Boerez)

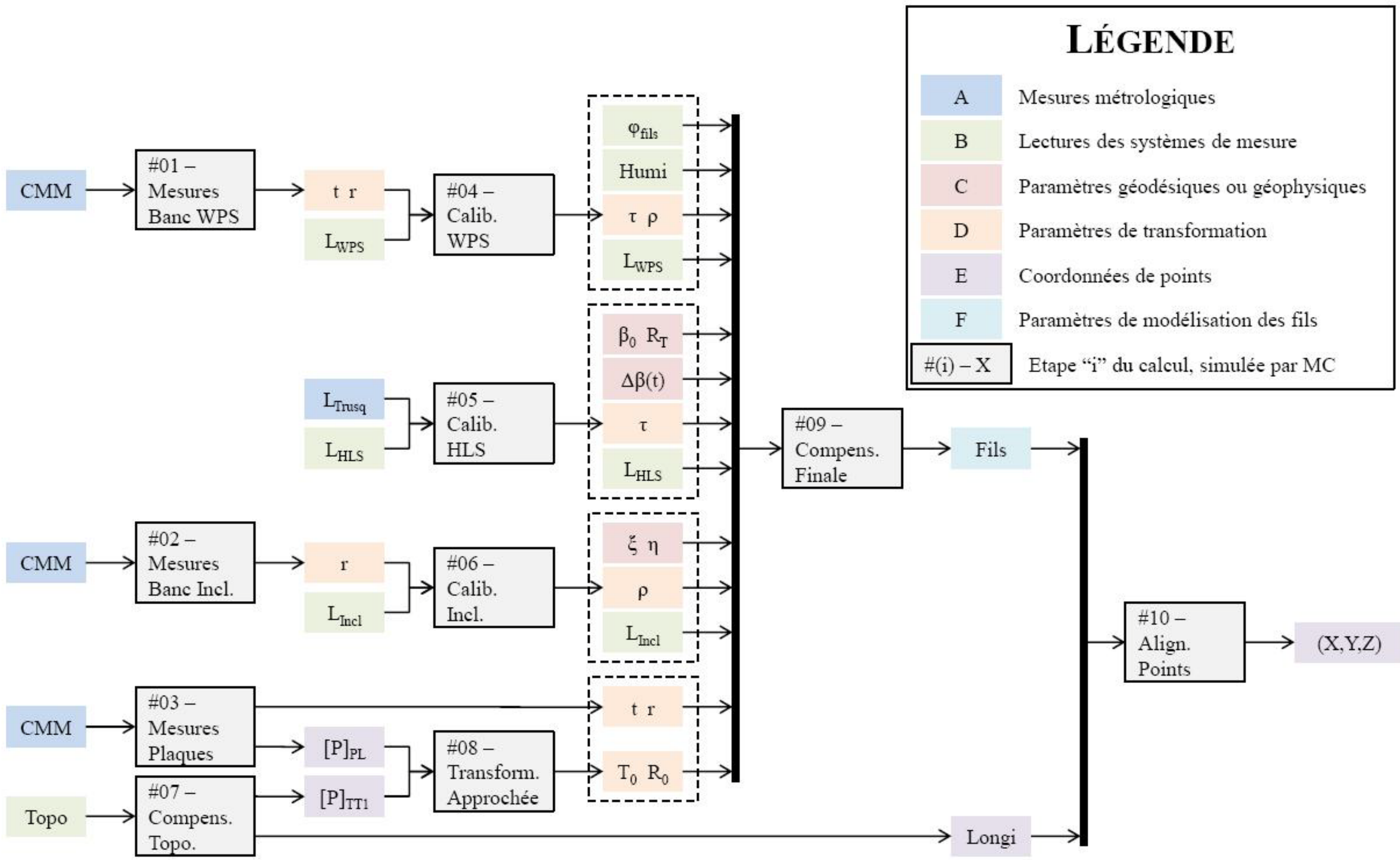
➔ Is a stretched wire really straight (radial direction)?

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

→ relative inter-comparison this month at CERN

Stretched wire and MRN

Minimum configuration

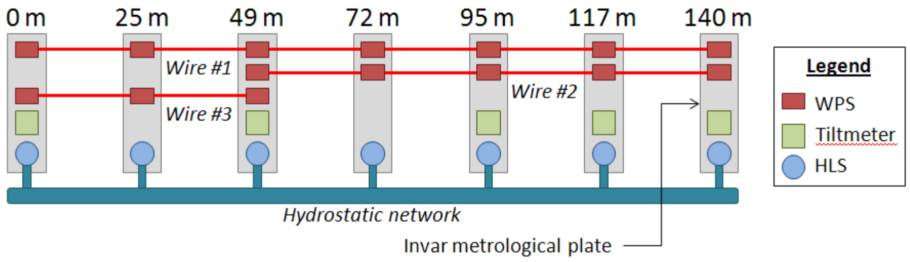


Algorithm describing the MRN & associated parameters

Stretched wire and MRN

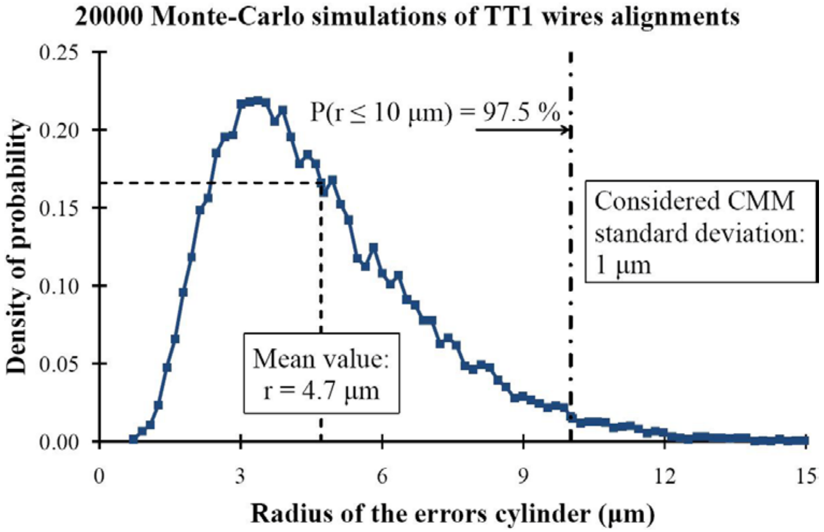
Algorithm describing the MRN & associated parameters

TT1 facility



One of the objectives :to determine the precision and accuracy of a MRN consisting of overlapping stretched wires.

Simulations

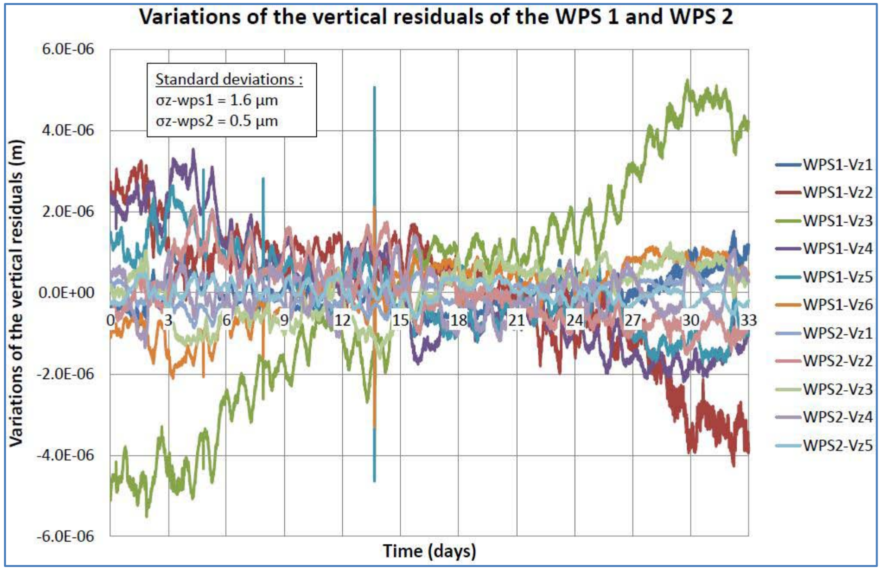


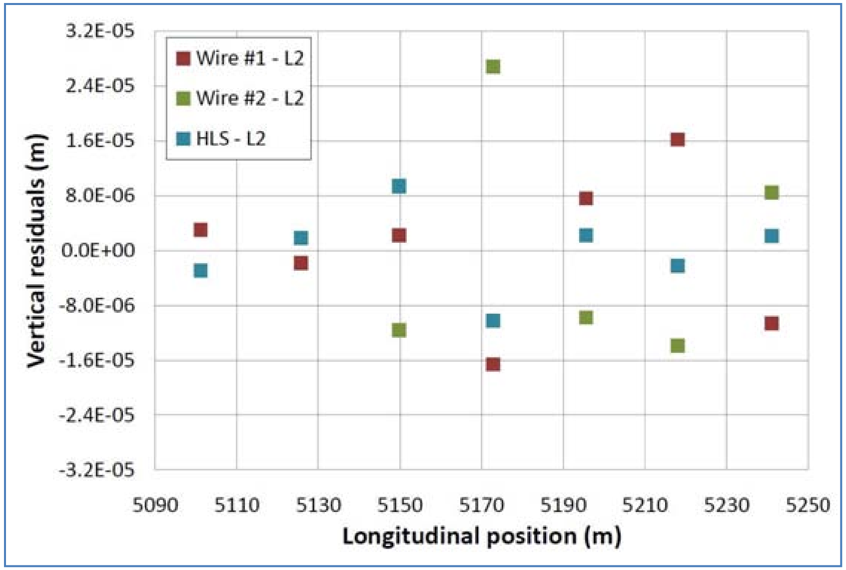
- ✓ Position & orientation of the metrological plates in the coordinate system of the tunnel
- ✓ Monte Carlo method using theoretical readings of sensors
  - ➔ in 97.5% of the cases, all the pre-alignment errors fit in a cylinder with a radius of 10 µm.

Stretched wire and MRN

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 µm
σ (wire 2) = 0.5 µm

Accuracy of the TT1 network adjusted by the least squares method in vertical:
σ = 11 µm r.m.s (27 µm max. value)

Subject of a PhD thesis: « Proposal of an alignment method for the CLIC linear accelerator: from the geodetic networks to the active pre-alignment » (T. Touzé)

Sub-micrometric sensors

Issue: WPS sensor fulfilling the requirements

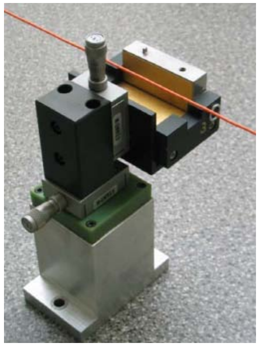
- ✓ « absolute measurements » (known zero w.r.t mechanical interface)
- ✓ no drift
- ✓ sub micrometric measurements

Upgrade of an existing WPS

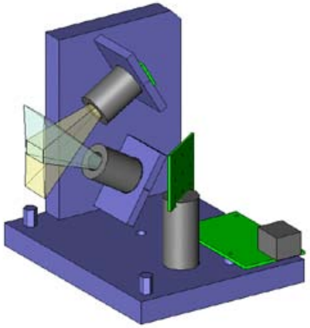
Development of a new WPS

Capacitive based WPS (cWPS)

Resolution: 0.2 µm
Range: 10 x 10 mm
Repeatibility: 1 µm
Bandwidth: 10 Hz

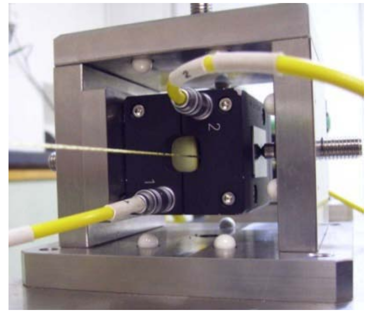


Optical based WPS (oWPS)



Parameter	Value
Aperture-CCD	10 mm
Pivot-CCD	10.4 mm
Aperture Diameter	200±5 µm
Aperture Centering	±100 µm
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 µm × 10 µm
Field of View	±160 mrad × ±110 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 (TBC)	~ 10 (TBC)
Repeatability (µm)	1	2 (TBC)
Precision (µm)	1	2 (TBC)
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	5 000 CHF	2 000 $

Status of fiducialisation

Issue: measure 2 m long objects within a few microns

- ✓ First solution: CMM measurements (dimensional control, pre-alignment of components on their supports, fiducialisation), but STATIC

MPE = 0.3 µm + L/1000 (L in mm)

AT 401: maximum offset in the determination of a point in space: ± 15 µm + 6ppm (3σ)

Micro triangulation

- ✓ Alternative solution: combination of measurements from Laser Tracker, measurements arm or micro triangulation in lab and tunnels (control after transport, during tests,…)

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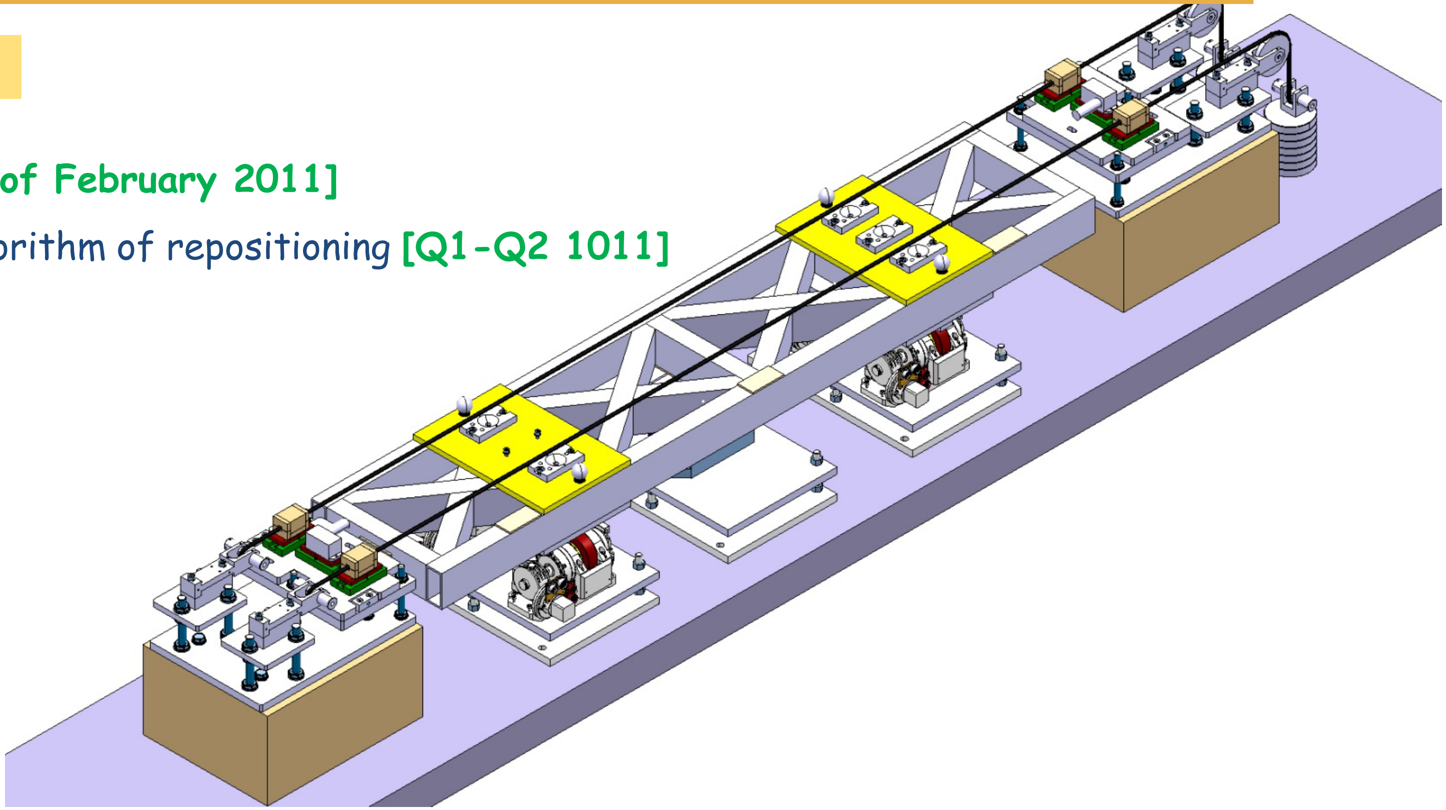
Short term program & expected results by end of 2012

MB quad mock-up

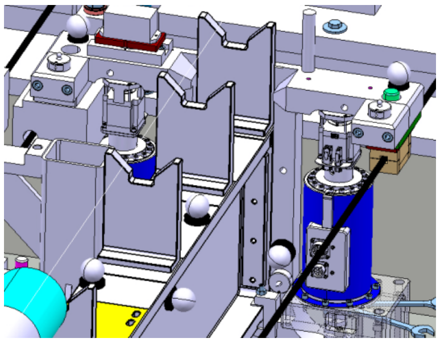
- ✓ Mock-up ready **[end of February 2011]**
- ✓ Validation of the algorithm of repositioning **[Q1-Q2 1011]**

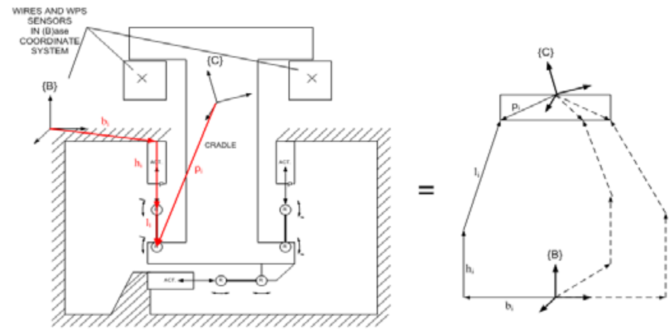


- ✓ Validation of sub-micrometric active alignment using WPS sensors and cam movers **[Q1-Q2 1011]**
- ✓ Compatibility with stabilization requirements (first Eigenfrequency > 50 Hz) **[Q2 2011]**
- ✓ Feedback for design of the MB quad mock-up type 1 and 4, foreseen for the two beam prototype modules in lab and CLEX **[Q3 2011 - Q1 2012]**

Short term program & expected results by end of 2012

Two beam prototype modules



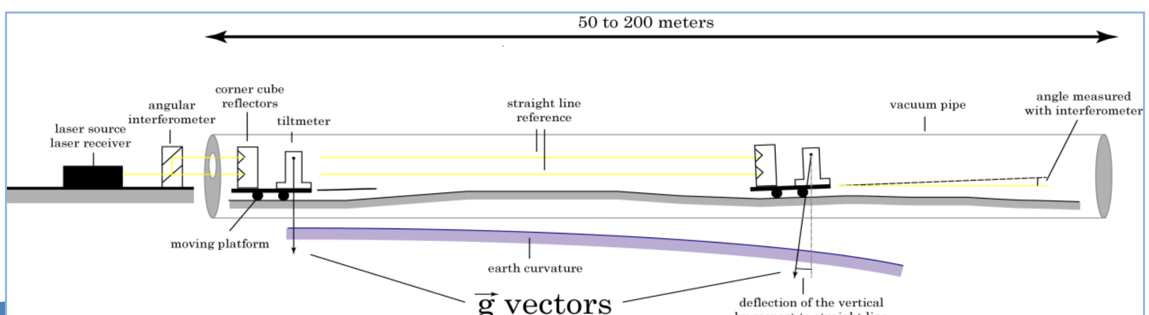


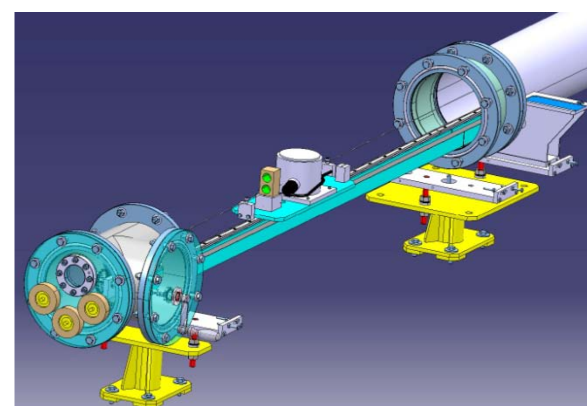
- ✓ Validation of the following strategies **[Q1- Q3 2011]**
  - o Pre-alignment of the components on their support within 10 microns, inter-comparison between methods (AT401, micro-triangulation,...)
  - o Articulation point : the adjacent extremities of girders follow within a few microns
  - o Micrometric adjustment using linear actuators
- ✓ Alignment systems providing a determination of the position with micrometric accuracy and precision **[Q2-Q4 2011]**
  - o Case of oWPS, cWPS
  - o Intercomparison between RASNIK and WPS **[Q3-Q4 2011]**
- ✓ Active pre-alignment: tests of the algorithms **[Q2 2011]**
- ✓ Feedback concerning schedule, cost, general strategy of installation, and two beam modules in CLEX
- ✓ Compatibility with other systems (vacuum, waveguides,...), stability **[Q3 2011 – Q3 2012]**

Short term program & expected results by end of 2012

Knowledge of static geoid

- A theoretical study showed that a determination of gravity field with an accuracy of 0.001 mm over 200m was possible provided dense astro-geodetic and gravimetric measurements
- Confirmed by measurements performed in 2009, every 10 m.
- But extremely fastidious when extrapolated over 40 km…
  - ➔ Deflectometer under study, allowing relative measurements of the direction of the vertical in the tunnel.
    - Validation on 12 m **[Q2 2011]**
    - Extrapolation over 100 m **[Design: Q4 2011, tests: Q2-Q3 2012]**





Short term program & expected results by end of 2012

Laser based alignment system

As an alternative

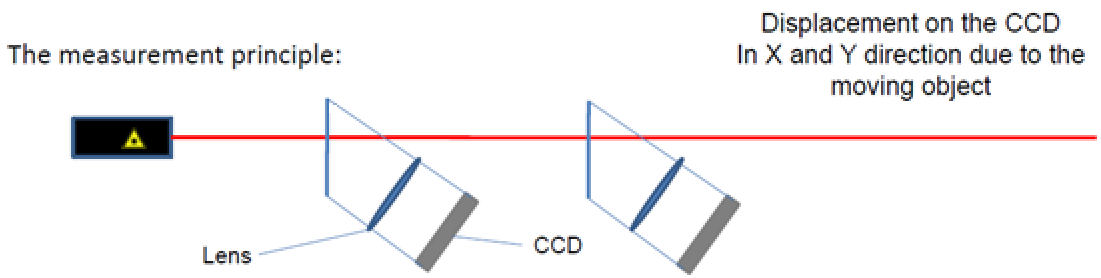
To validate the stretched wire solution

✓ In collaboration with NIKHEF :

- Design of a long range solution (3 point alignment system, diffraction pattern)
- Inter-comparison of the long range solution in TT1 (140 m) / TZ32 tunnels (500 m)
  ➔ Relative comparison [Q1-Q2 2011], « absolute » comparison [Q4 2011- Q1 2012]

✓LAMBDA project (Laser Alignment Multipoint Based – Design Approach

- 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) usi
- Measurement surface = mechanical or optical shutter



- First simulations performed: angular orientation & repeatability of shutter should be better than 0.2 mrad & 12 μm, in order to detect a micrometric displacement

- Next steps: validate the concept on short distance, without vacuum [Q3 2011], and then validate the concept on longer distance, under vacuum [Q3-Q4 2012].

Short term program & expected results by end of 2012

Consolidation of stretched wire solution

✓Validation of oWPS & cWPS

- On dedicated calibration benches, once controlled by sub-micrometric CMM **[Q2 2011].**
- Upgrade of existing sensors **[Q3-Q4 2011]** and tests on calibration benches **[Q1 2012]**
- Through inter-comparison on the two beam prototype modules in lab **[Q3-Q4 2011]**

✓ Analysis of experimental data of TT1, simulations for beam dynamics **[Q2 2011- Q2 2012]**

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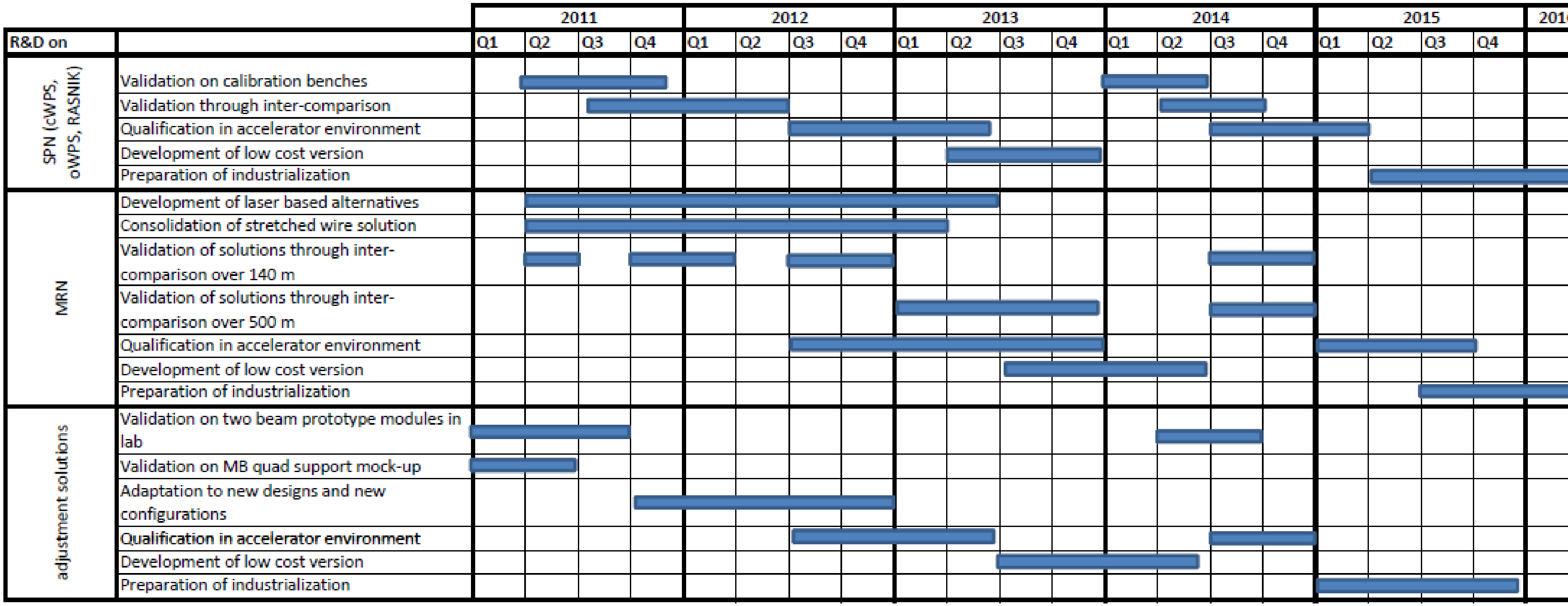
R&D planning for the next phase



CONCLUSION

- ✓ A global solution proposed for the CDR
- ✓ Very promising results concerning simulations and data in the TT1 facility
  ➔ next validation: on the two beam prototype modules in lab & CLEX
- ✓ R&D program in place in order to find alternative solutions for short range and long range alignment systems.
- ✓ Optimization and development program concerning low cost adjustment systems & low cost sensors