PRE-ALIGNMENT STUDY STATUS AND MODEL FOR THE BEAM DYNAMICS SIMULATIONS

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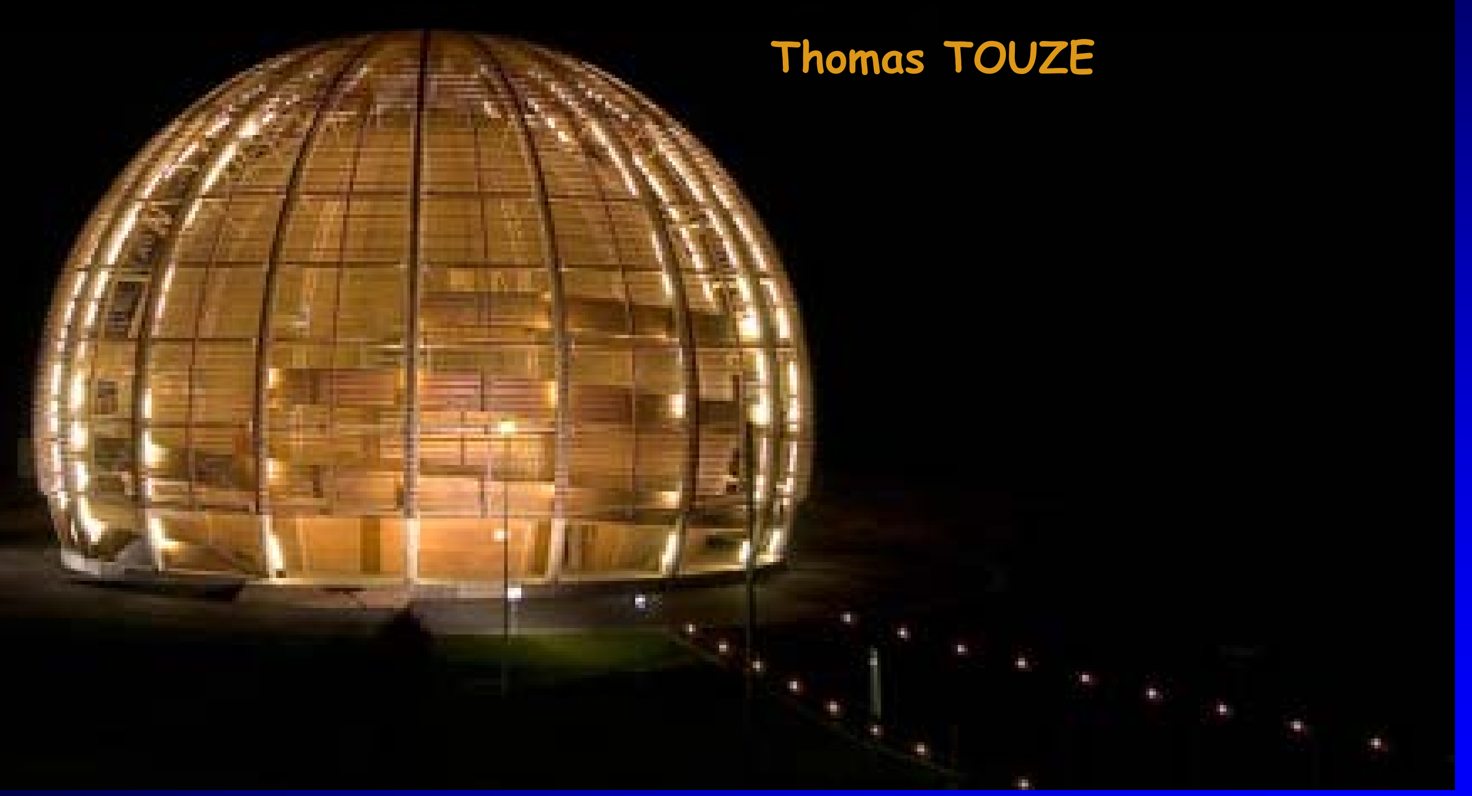


CLIC08 Workshop, CERN 14-17 October 2008

OVERVIEW

- ✓ INTRODUCTION – alignment requirements
- ✓ SURVEY AND ALIGNMENT GENERAL CONCEPT
- ✓ PRE-ALIGNMENT STUDY STATUS
  - A known and stable alignment reference
  - Sub-micrometric sensors
  - Fiducialisation and internal metrology
- ✓ MODEL FOR THE BEAM DYNAMICS SIMULATIONS
- ✓ CONCLUSION

STRATEGY OF CLIC ALIGNMENT

- Mechanical pre-alignment
  → Within +/- 0.1 mm (1σ)
- Implementation of active pre-alignment
  → Girders and quadrupoles within ± 10 μm (3σ)
- Implementation of beam based alignment
  → Active positioning to the micron level
- Implementation of beam based feedbacks
  → Stability to the nanometer level

PRE-ALIGNMENT REQUIREMENTS

- The tolerance of the transverse pre-alignment of the CLIC components is:

  <u>± 10 microns (3σ) on a 200msliding window along each linac</u>

- At the micron scale: this pre-alignment needs to be active (ground motion, noise of accelerator environment, temperature dilatations)

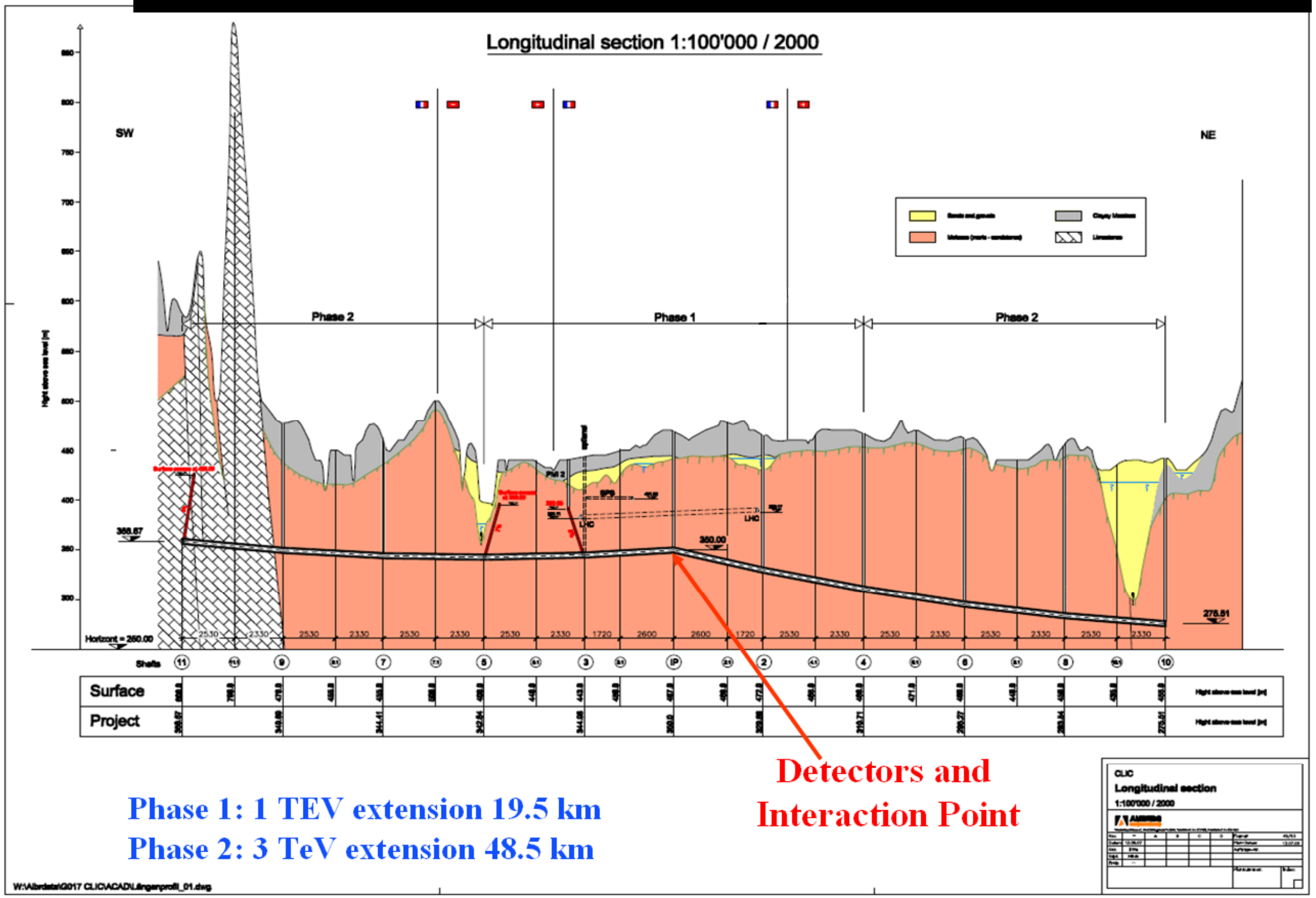
  → continuous monitoring of the position and re-adjustment when necessary.

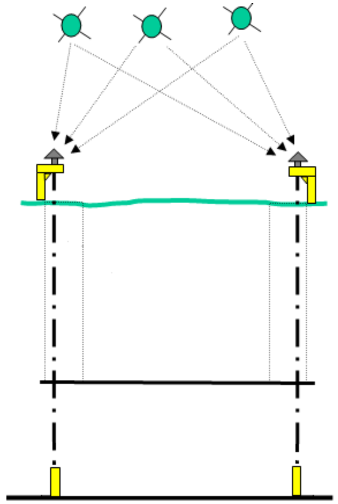
- A scale order concerning this pre-alignment :
  - For the LHC: ± 0.1 mm over 100 m (1σ)
  - For the ILC: ± 0.2 mm over 600 m (1σ) (in the vertical direction)

CLIC pre-alignment = technological challenge

GENERAL ALIGNMENT CONCEPT

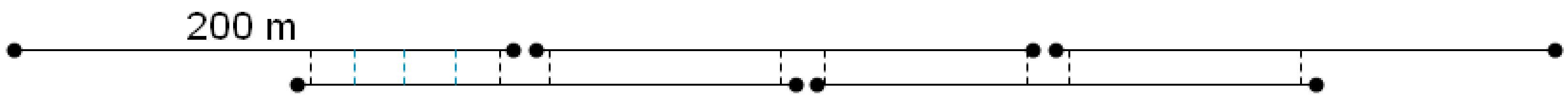
Longitudinal section of a laser straight Linear Collider on CERN site–





GENERAL ALIGNMENT CONCEPT

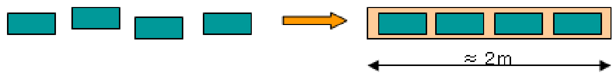
- As it is not possible to implement a straight alignment reference over 20 km: use of overlapping references



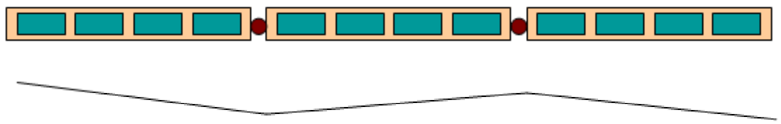
- Two references under study:
  - a stretched wire
  - a laser beam under vacuum

GENERAL ALIGNMENT CONCEPT

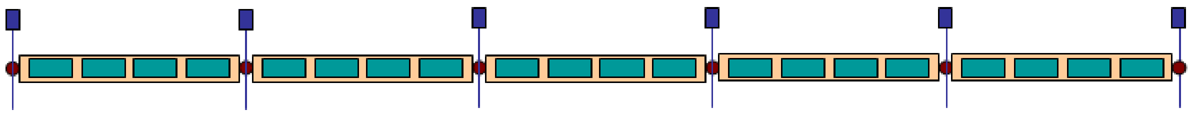
- Simplification of the problem by prealigning components on girders



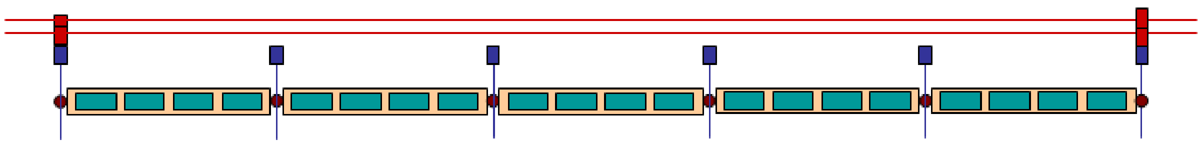
- Simplification of the alignment by linking adjacent girders by a common articulation point



- Association of a « proximity network » to each articulation point



- Association of a « propagation network » to every x articulation point



GENERAL ALIGNMENT CONCEPT

The feasibility is proved if one can demonstrate:

- A stable alignment reference, known at the micron level
- Sub-micrometric sensors
- A mechanical/electrical zero of each sensor perfectly determined with respect to the reference of the component to be aligned

This solution of pre-alignment must be compatible with the general alignment strategy, and with the other accelerator equipment or services.

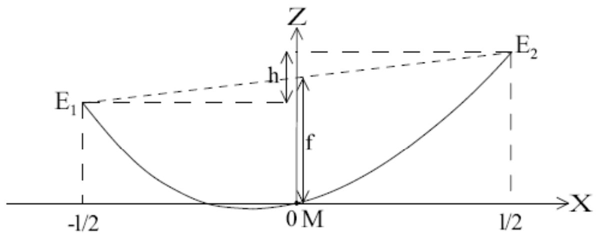
➔ Implementation of a R&D strategy in order to prove the feasibility of the pre-alignment solution, reviewing each key point carefully.

PRE-ALIGNMENT STUDY STATUS

- A known and stable alignment reference
- Sub micrometric sensors
- Fiducialisation and internal metrology

A STRETCHED WIRE AS AN ALIGNMENT REFERENCE

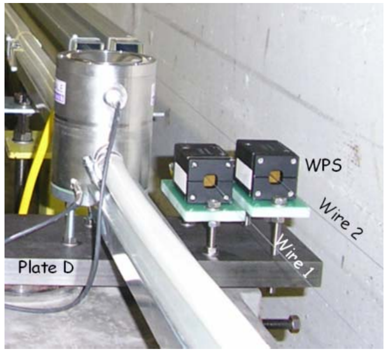
On the scale of a micron, the stability and the determination of the shape of the wire are far more difficult to reach.



$$Z = \frac{4f}{l^2}\left(X + \frac{lh}{8f}\right)^2 - \frac{h^2}{16f}$$

Among the parameters that can contribute to variation in the shape of the wire:

- ✓ Gravity change, function of:
  - ✓Wire location
  - ✓Distribution of the masses in the neighborhood
  - ✓Attraction of the moon and the sun
- ✓ Effect of the rotation of the Earth
- ✓ Weather report (humidity, temperature)
- ✓ Air currents



TT1 TEST FACILITY

First results:

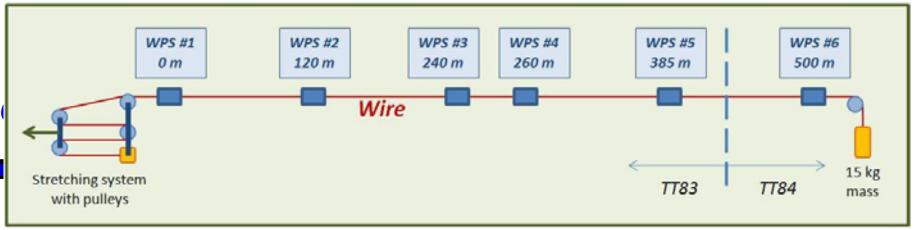
- Good knowledge concerning the installation of long stretched wires
- Great impact of humidity variations on the lineic mass of a wire (and on the sag), but we know how to correct it
- Very good uncertainty of measurement between sensors along 2 wires of different length (100 m and 140m):

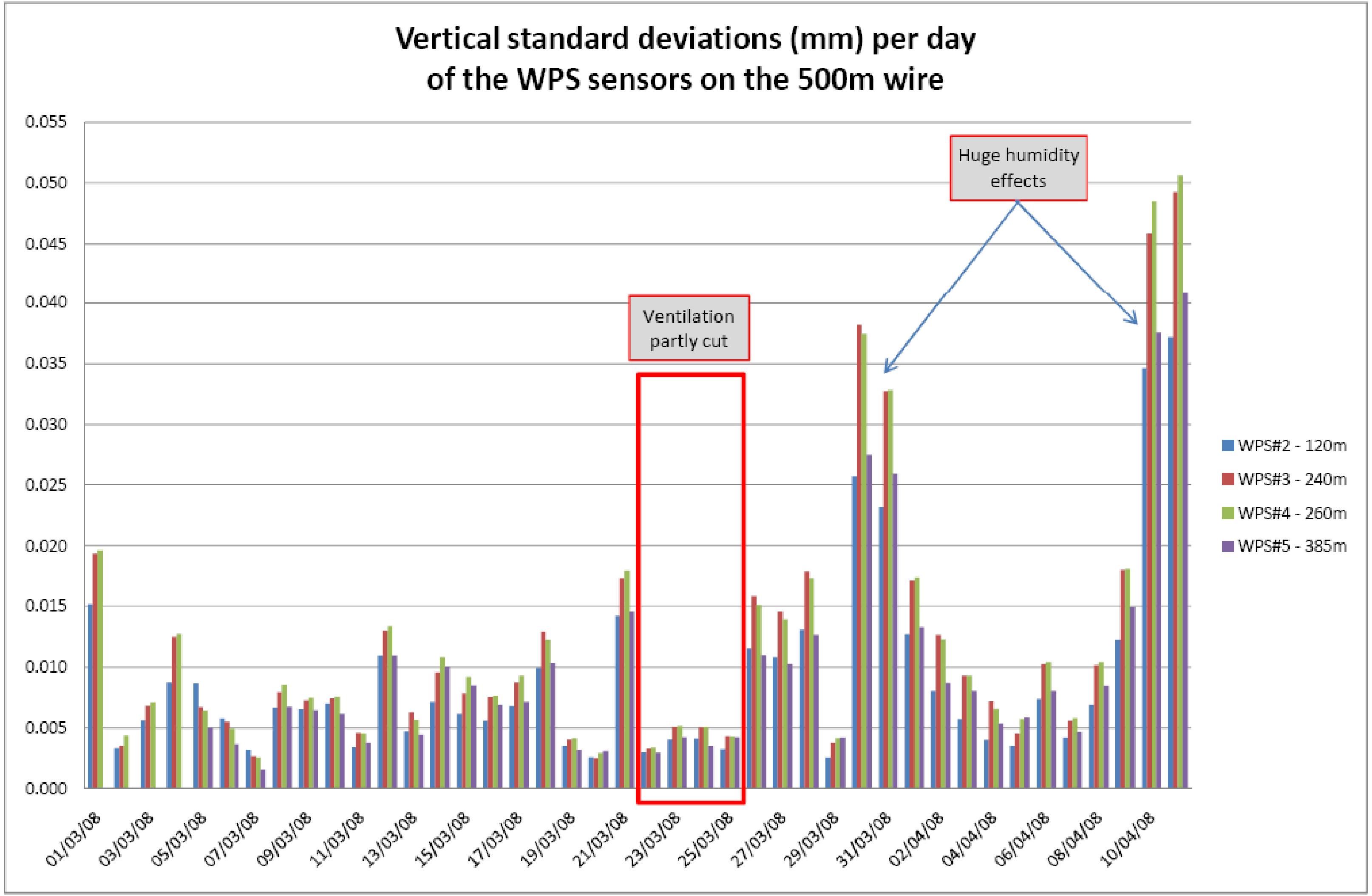
  → 0.4 μm (radial) and 0.6 μm (vertical) over 2 days (stable conditions)

Next steps: an upgrade of the facility

- To confirm the effect of the rotation of the Earth
- To modelize the vertical shape of a stretched wire without the HLS system

Why not to try to stretch longer wires, in order to decrease the propagation error along the linac?


WPS #1
0 m
WPS #2
120 m
WPS #3
240 m
WPS #4
260 m
WPS #5
385 m
WPS #6
500 m
Wire
Stretching system
with pulleys
TT83
TT84
15 kg
mass


Vertical standard deviations (mm) per day
of the WPS sensors on the 500m wire
0.055
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
Huge humidity
effects
Ventilation
partly cut
WPS#2 - 120m
WPS#3 - 240m
WPS#4 - 260m
WPS#5 - 385m
01/03/08
03/03/08
05/03/08
07/03/08
09/03/08
11/03/08
13/03/08
15/03/08
17/03/08
19/03/08
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31/03/08
02/04/08
04/04/08
06/04/08
08/04/08
10/04/08

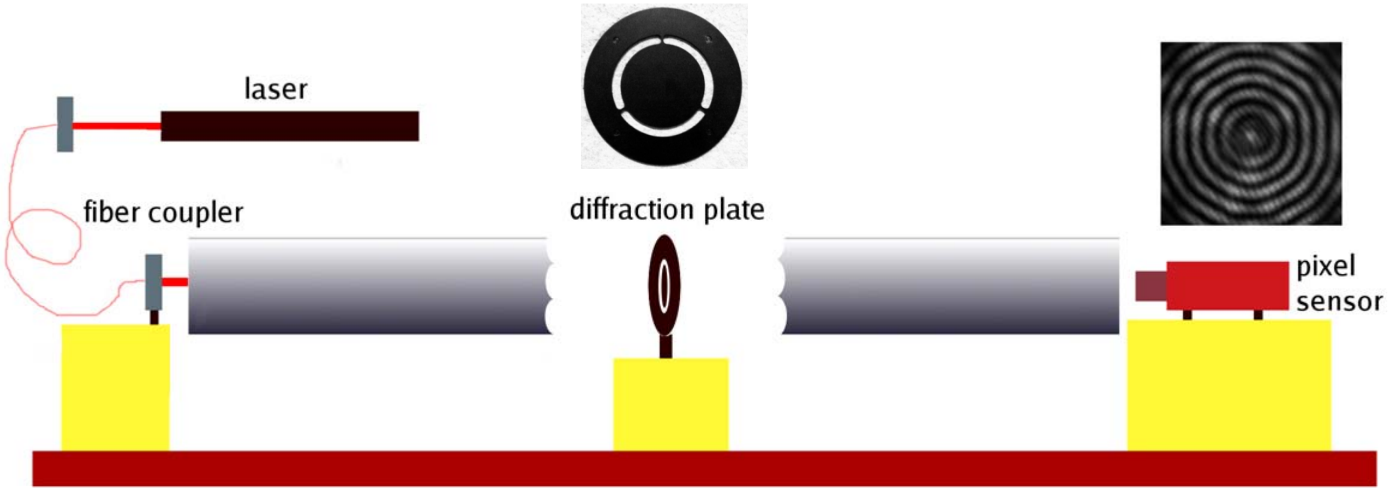
A STRETCHED WIRE AS AN ALIGNMENT REFERENCE

Next studies and tests…

- Study the influence of the gravity changes on a stretched wire and on the leveling system (foreseen for the modelization of the shape of the wire)
- To obtain a better knowledge of the parameters that influence the shape of the wire
- Gravimetric studies have been undertaken concerning the accuracy which can be obtained concerning the determination of the geoid.

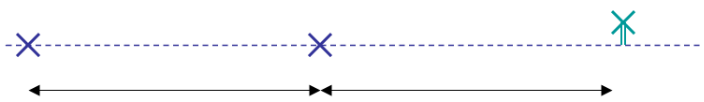
Alternative solution: development of an laser based alignment solution, in collaboration with NIKHEF.

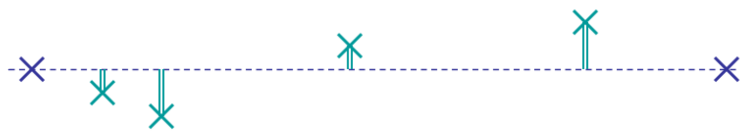
AN OTHER ALIGNMENT SYSTEM: RasCLIC



- Sub micrometric resolution
- Low frequency seismograph.

➔ Problem: how to use it for the CLIC pre-alignment?

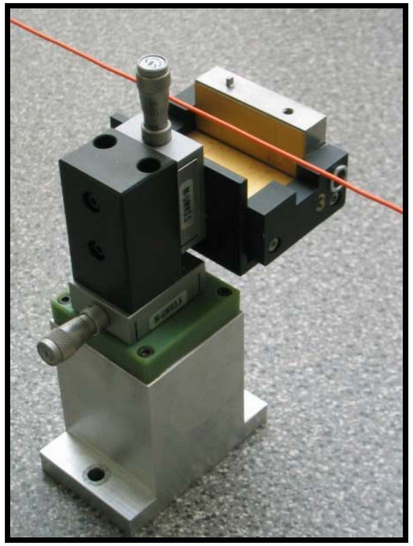




PRE-ALIGNMENT STUDY STATUS

- A known and stable alignment reference
- Sub micrometric sensors
- Fiducialisation and internal metrology

SUITABLE SENSORS



What is needed:

- A sub micrometric resolution
- A known and controlled drift
- A good interchangeability and a suitable mechanical interface
- Repeatability of measurement better than the micron

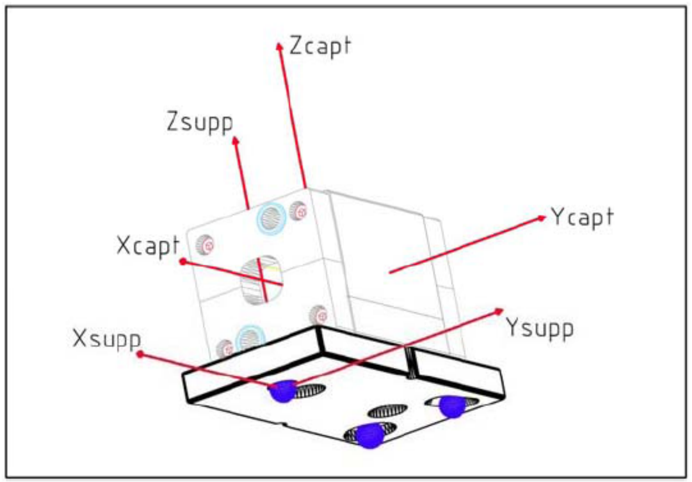
→ Upgrade of the existing capacitive-based WPS sensors

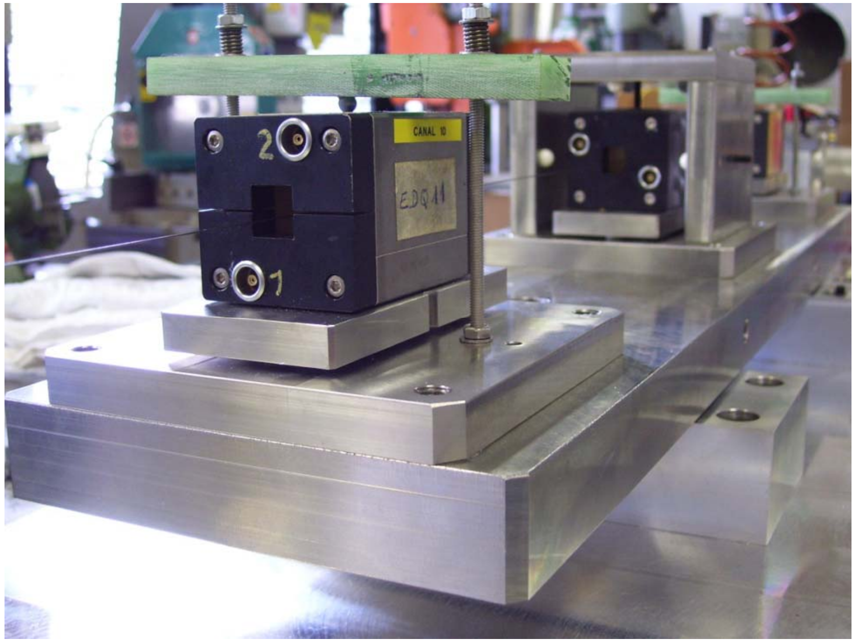
→ Development of an optical -based WPS sensor

SUITABLE SENSORS

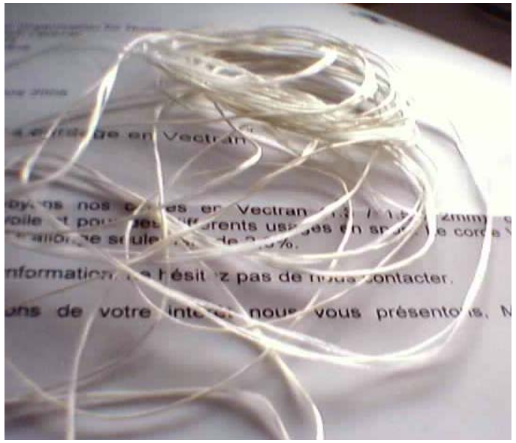
Upgrade of the existing capacitive-based WPS sensors

- A better interchangeability and determination of the zero (± 5 μm expected)
- A more suitable mechanical interface



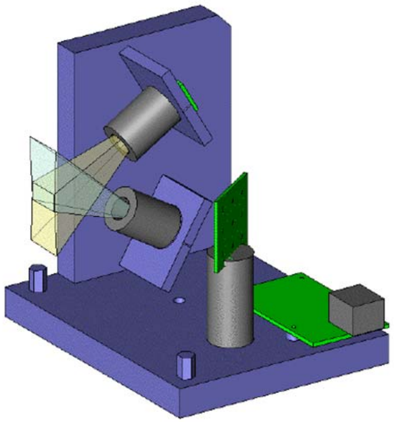


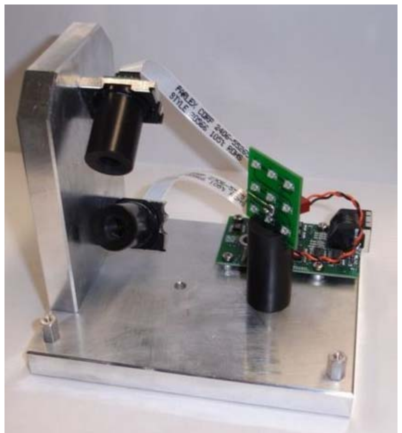
SUITABLE SENSORS



Development of an optical -based WPS sensor

- Promising Vectran wire
- A more suitable mechanical interface
- Absolute measurement within a few microns. (under tests)





PRE-ALIGNMENT STUDY STATUS

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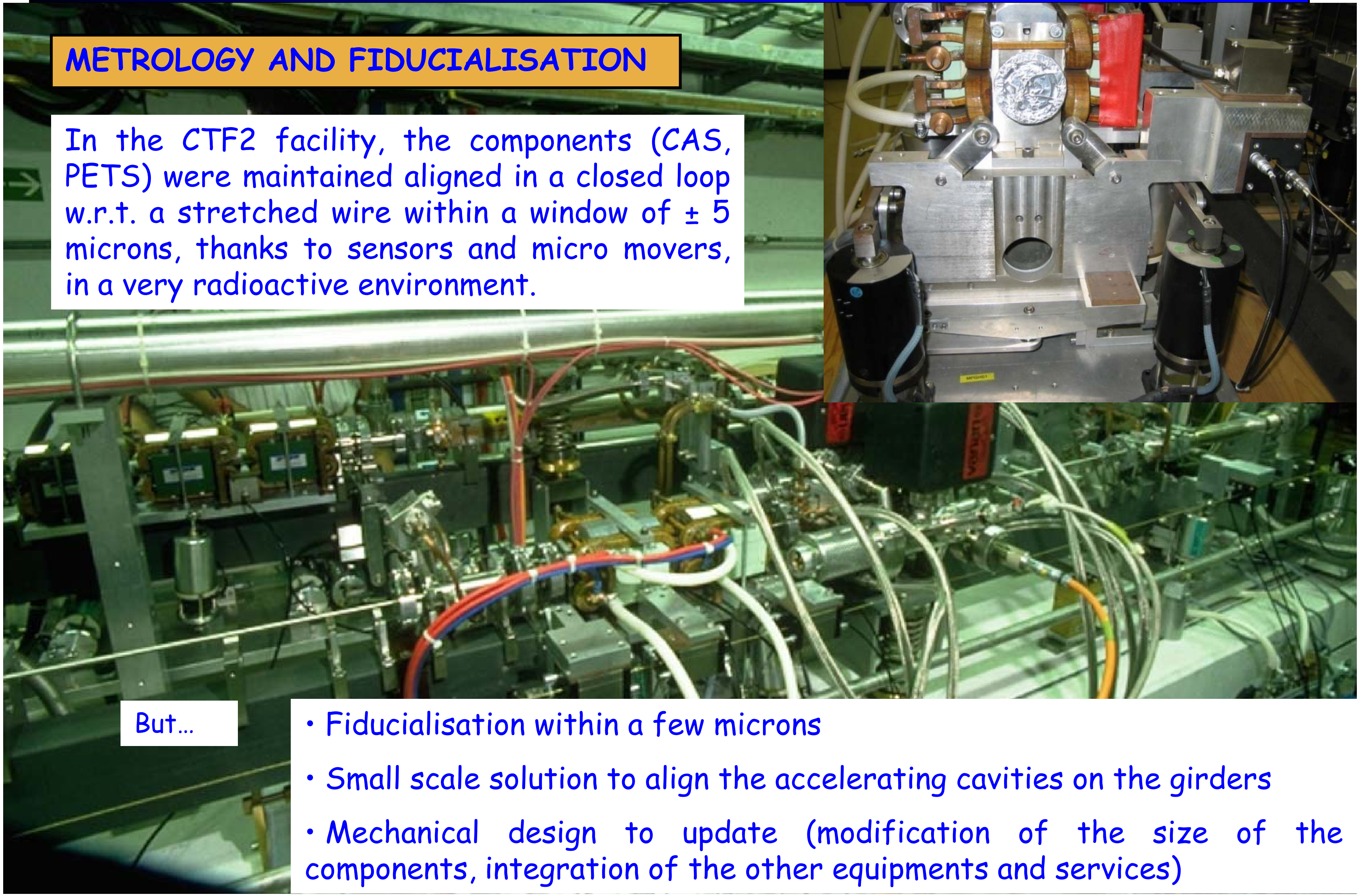
METROLOGY AND FIDUCIALISATION

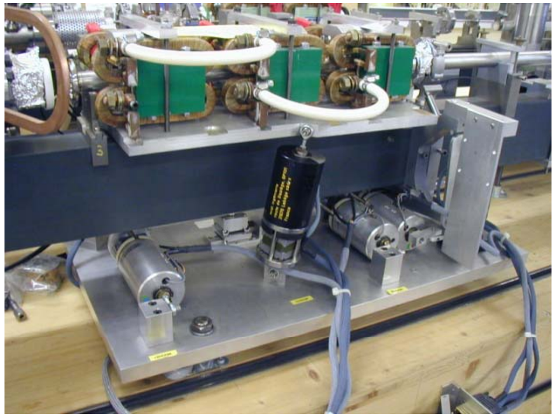
In the CTF2 facility, the components (CAS, PETS) were maintained aligned in a closed loop w.r.t. a stretched wire within a window of ± 5 microns, thanks to sensors and micro movers, in a very radioactive environment.



But…

- Fiducialisation within a few microns
- Small scale solution to align the accelerating cavities on the girders
- Mechanical design to update (modification of the size of the components, integration of the other equipments and services)

METROLOGY AND FIDUCIALISATION



The case of the « main beam » quadrupole

- Aligned independently from the girders along 5 degrees of freedom
- Micrometric supporting solution tested and validated in the CTF2 facility, but non compatible with the stabilization required (1 nm in vertical)

All these solutions will be tested in the CLEX facility (2010-2011), but before it is necessary:

- to propose a solution for the fiducialisation
- to finalize the technical specifications concerning the stepper motors in order to buy the propotypes asap.
- the compatibility between the pre-alignment solution and the stabilization solution concerning the « main beam » quadrupole is studied in conjunction with the Stabilization Working Group.

MODEL FOR THE BEAM DYNAMICS SIMULATION

- The simulations. Why ? How ?
- Simulation of the propagation network
- Simulation of the modules
- Validation of the simulations

THE SIMULATIONS. WHY ? HOW ?

The simulations of the CLIC prealignment are essential for the design of the alignment strategy. The results inform where improvements have to be done in order to reach the required alignment tolerance of 10 µm along a 200m sliding window.

But we weren't alone to be interested by these simulations. They are important for the beam dynamics studies. They need them in order to get an accurate idea of the misalignment effects on the beam itself.

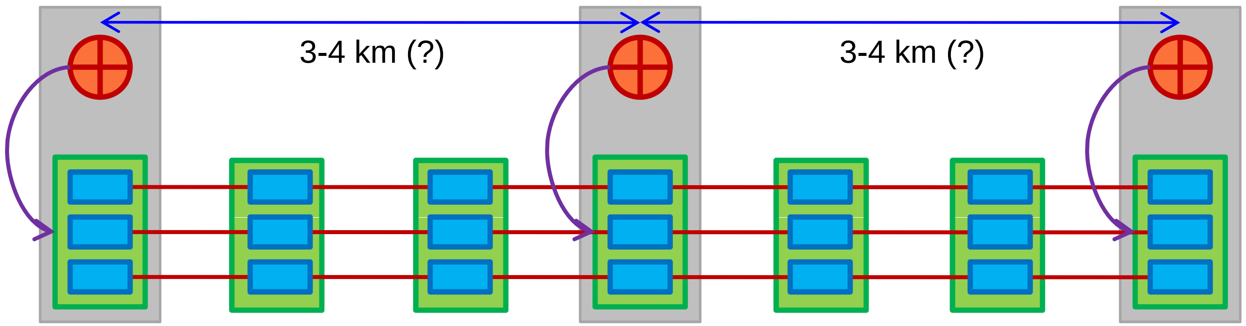
This presentation gives the first results of the CLIC prealignment simulations and the stategy which has been set up to validate them.

These simulations are a first approximation. All the modules degrees of freedom have not been taken into account.

THE SIMULATED MEASUREMENTS – STEP 1

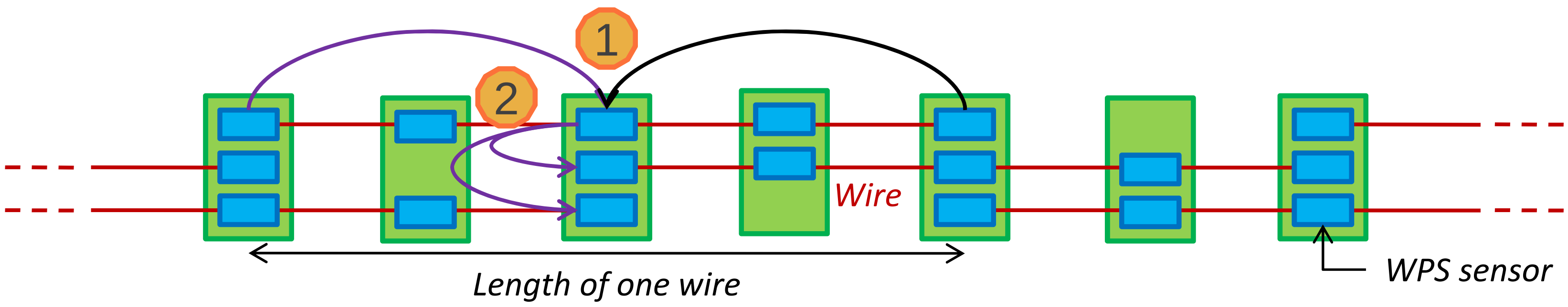
Reference points are defined at each pit according to the geodetic measurements made on the surface (GPS, triangulation).

The main plates of the propagation network are defined according to these points (metrological calibration).



The propagation network can now be built.

THE SIMULATED MEASUREMENTS – STEP 2



1. The position of the sensor in the middle of a wire according to the ones at its ends is given by ecartometry.

2. Thanks to a metrological calibration, the position of each sensor of the plate according to the others is known.

Now, the geometry of the whole propagation network, i.-e. of the whole wires, is known. We can align the modules according to it.

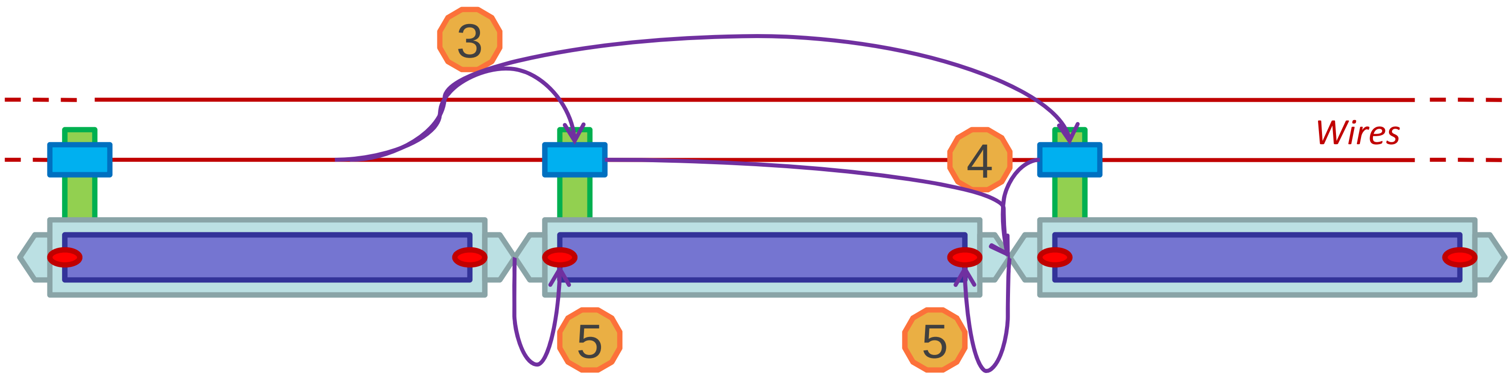
This is the minimum configuration. In order to optimize the accuracy, redundancy can be introduced.

THE SIMULATED MEASUREMENTS – STEP 3

3. On each module takes place a WPS sensor. Its position is known according to the wire by ecartometry.

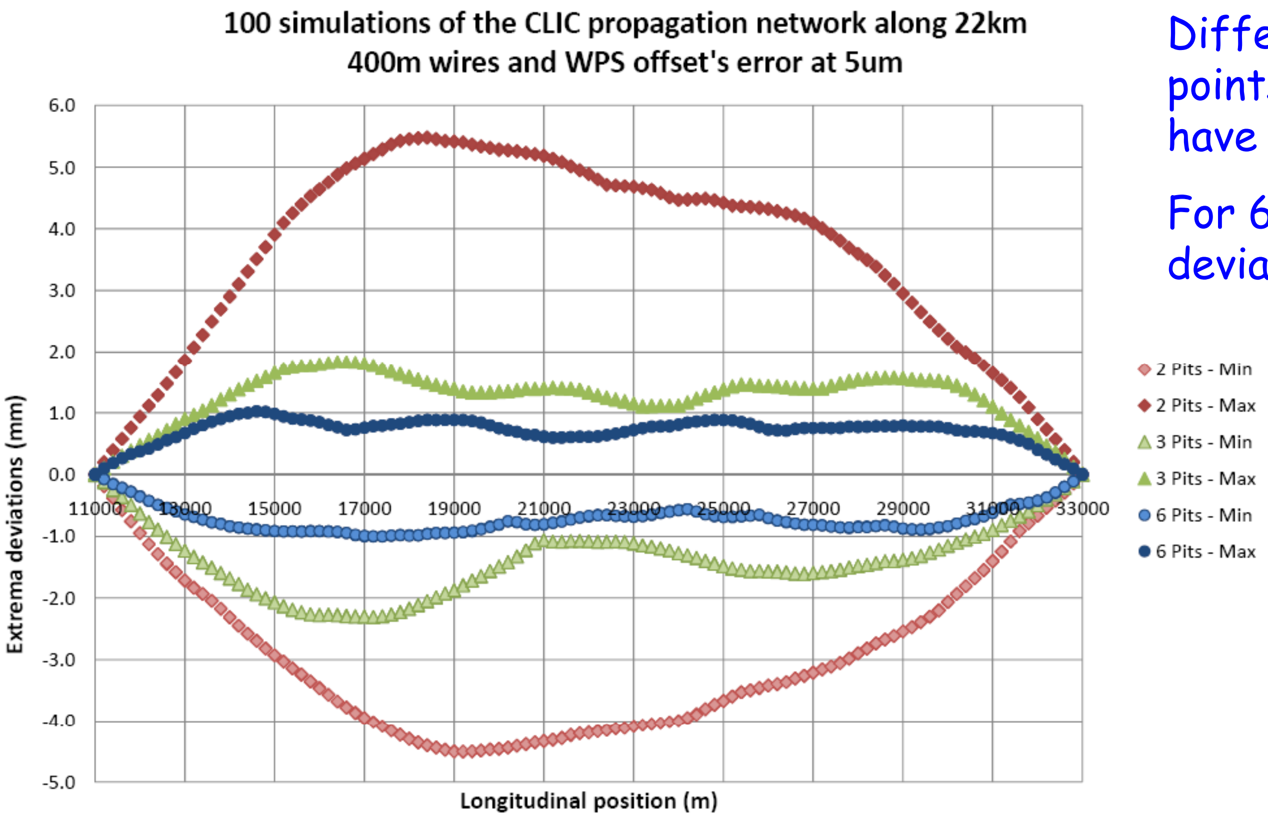
4. The position of the articulation point between 2 modules is known according to their sensors (metrological calibration).

5. The fiducialization : we get the beam entrance and exit points on one module from the articulations points.



SIMULATION OF THE PROPAGATION NETWORK (1)

The propagation network has been simulated along 22km in different configurations.

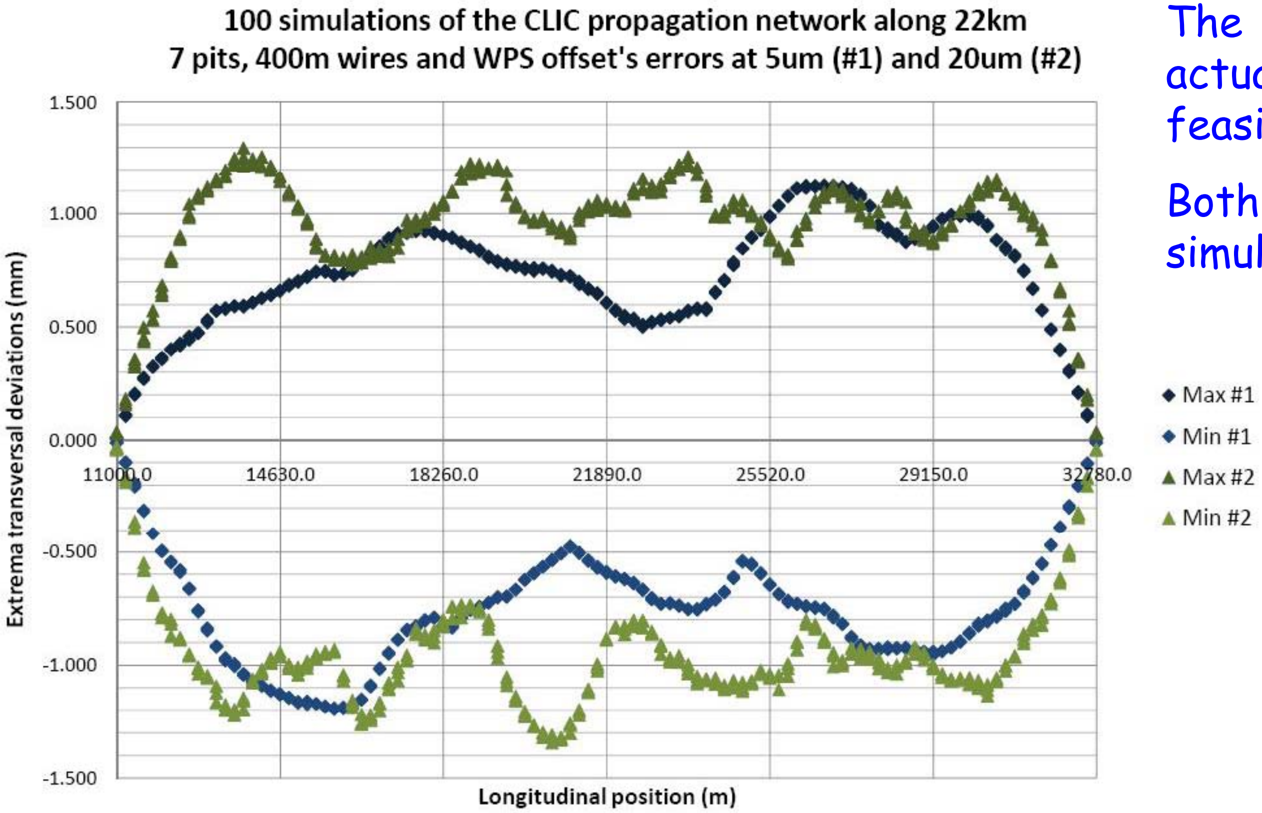


Different numbers of reference points, i-e the number of pits have been tested : 2, 3 and 6.

For 6 pits, the maximum deviation is ±1mm.

SIMULATION OF THE PROPAGATION NETWORK (2)

In order to pre-align the modules in the required tolerance, the deviation of the propagation network has to be as smooth as possible.



The offsets of the WPS are actually around 20µm. It seems feasible to reach 5µm.

Both of these values have been simulated.

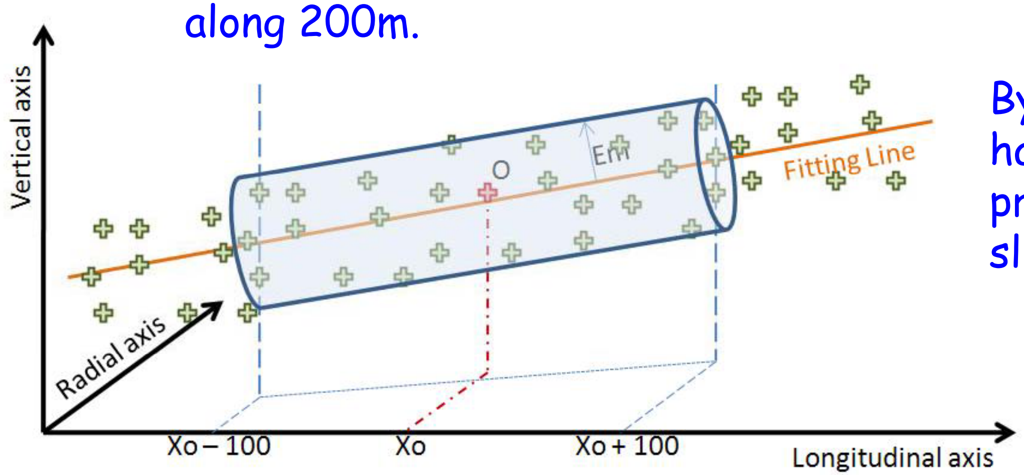
SIMULATION OF THE MODULES (1)

The pre-alignment tolerance in the transversal direction is 10µm along a 200m sliding window. It is a 3σ tolerance. I-e the accuracy is around 3µm.

The output of the modules simulations is the coordinates of their beam entrance and exit points.

Let us assume a module point O. Thanks to the least square method, the "best" straight line for all the modules points less than 100m apart from O is computed. We get the distances of each point to this line.

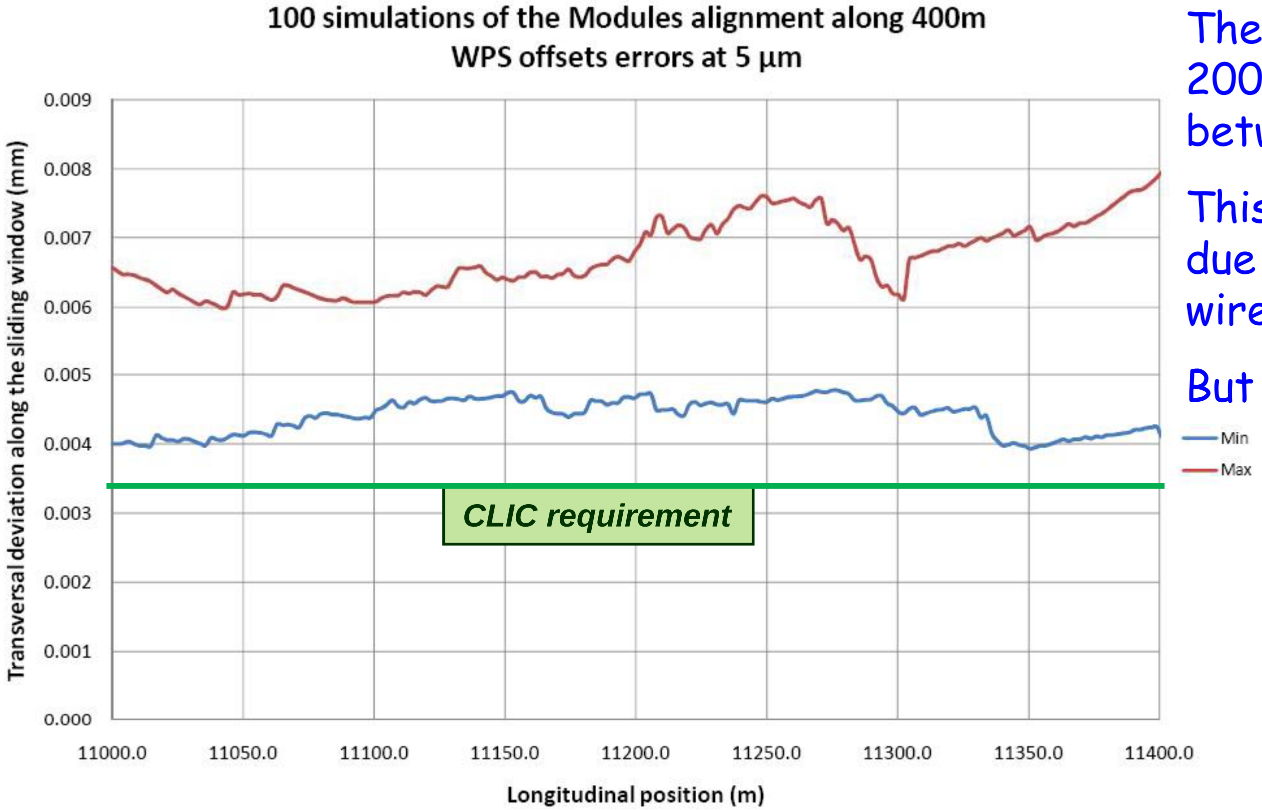
The standard deviation of theses distances is the pre-alignment accuracy along 200m.



By moving O along the linac, we have the accuracy of the modules pre-alignment along a 200m sliding window.

SIMULATION OF THE MODULES (2)

The modules pre-alignment has been simulated along 400m using 400m wires. The offsets of the WPS here are 5µm.



The accuracy along the 200m sliding window is between 4 and 8µm.

This includes the errors due to the overlapping wires.

But we are still less accurate than the CLIC requirement.

VALIDATION OF THE SIMULATIONS (1)

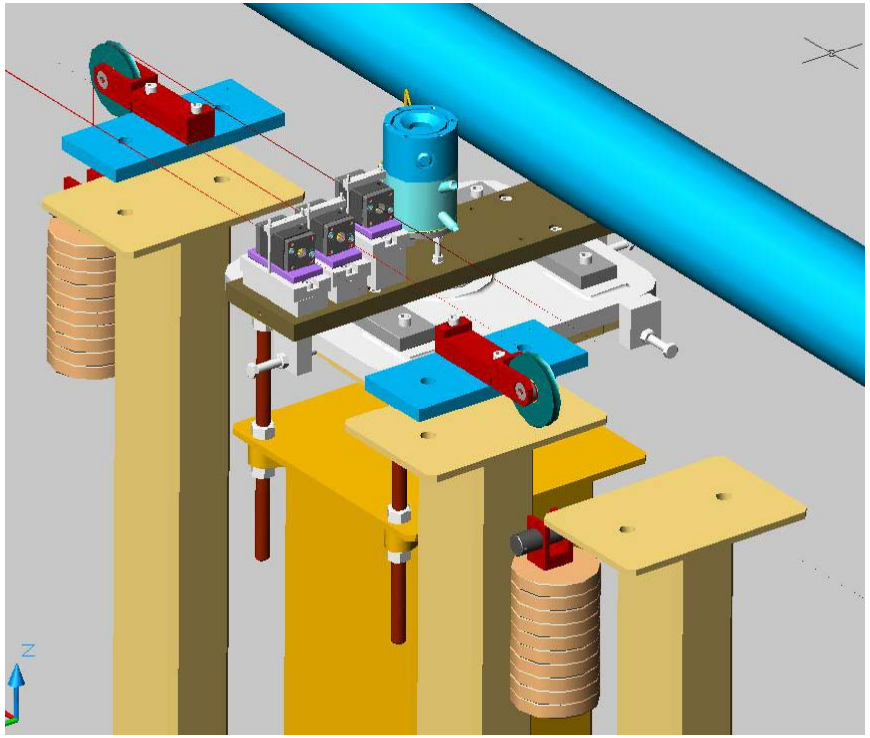
Some hypothesis have been assumed in these simulations. What about their validations ?

- The length of the wire (400m). It has been proven that the WPS can reach a 5µm precision along a 500m wire.
- The metrological calibration have a 5µm accuracy. It is the accuracy of the CMM machine used actually at CERN by the metrology laboratory (TS/MME).
- The accuracy of the CLIC components fiducialization is 2µm. This has not yet been proven.
- The accuracy of the WPS (offset error) is 5µm. This is the result we expect to have in the following months.

VALIDATION OF THE SIMULATIONS (2)

The 5µm accuracy of the WPS sensors used in these simulations has to be demonstated.

A new 3 balls fixation system and a calibration bench have been developped. It will be tested soon in the TT1 facility.



CONCLUSION

- A R&D strategy is being actively followed.

- CLIC team working full time on the subject:
  - a Surveyor doctorate student, in charge of the methods and strategies of alignment, the simulations, as well as the research studies on the wire itself.
  - a Fellow in charge of the mechanical studies, of the development of an optical WPS, being also an interface with the stabilization studies.
  - a geodesist doctorate student, in charge of the theoretical and practical studies concerning the influence of the gravity on a stretched wire.

- We also would like to open the CLIC survey and alignment studies to the Survey groups from other labs (FNAL, SLAC, Argonne, KEK, DESY), in particular concerning the development and qualification of sensors. The first contacts have already been taken.