Update on the simulations of the CLIC pre-alignment

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Introduction

The simulations of the CLIC pre-alignment are essential for the design of the alignment strategy. The results inform us where improvements have to be done in order to reach the required alignment tolerance of 10 µm along a 200 m 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 pre-alignment simulations and the strategy which has been set up to validate them. It also presents the modifications we plan to do in the next few months.

The simulated observations (1)

Methods and Hypothesis :

These simulations are made with LGC (Logiciel General de Compensation). It is a software written by the CERN's survey group in order to adjust or simulate the measurements.
The simulations are based on the Monte-Carlo method. LGC creates random errors on the observations according to their precision.

The observations that have been taken into account are as close as possible to the real CLIC pre-alignment. All the steps, except the mechanical pre-alignment, have been respected.

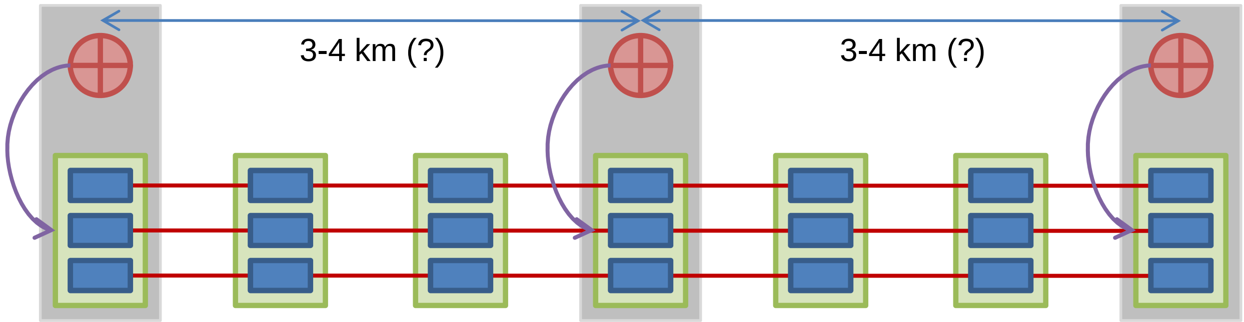
On each pit, reference points are defined from a geodetic network on the surface. The propagation network has to take place between these points. Then this network is built. The articulations points between the girder are aligned according to the wire. Finally, thanks to the fiducialization, the position of the beam entrance and exit points are known.

Let's see step by step !

The simulated observations (2)

First step, the reference point :

They are defined according to the geodetic network on the surface. They take place at the base of each pit. The distance between them is several kilometers (not yet defined). The accuracy of the points according to each other is 2 mm.

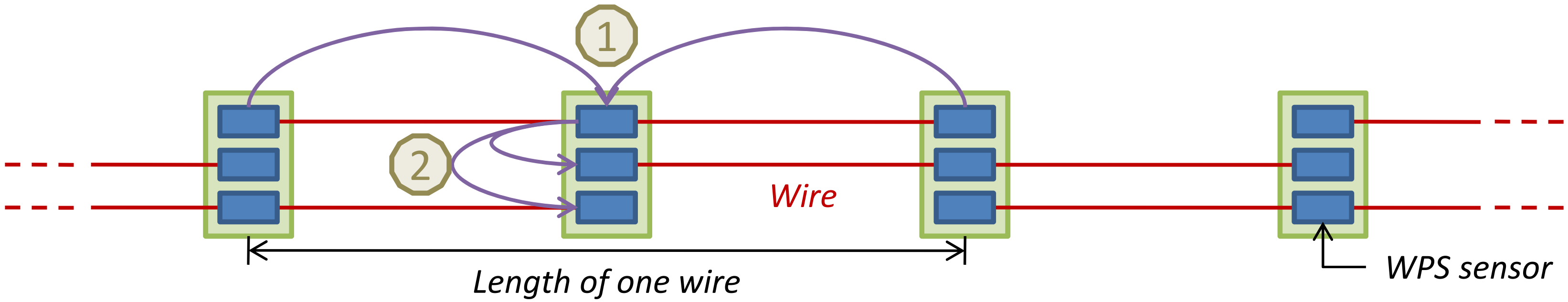


Let us consider the first point and its azimut to the last one as fixed. The propagation network has to go through these reference points. The more reference points there are, the smaller the transversal deviation of the network is.
The positions of the sensors according to their reference point are measured by metrological methods (σ = 5 μm).

Now the propagation network can be built…

The simulated observations (3)

The propagation Network :



1. The position of the sensor in the middle of a wire according to the ones at its ends is given by ecartometry. The length of the wire has been considered as a parameter.

   $\sigma = \pm 5\mu m$

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

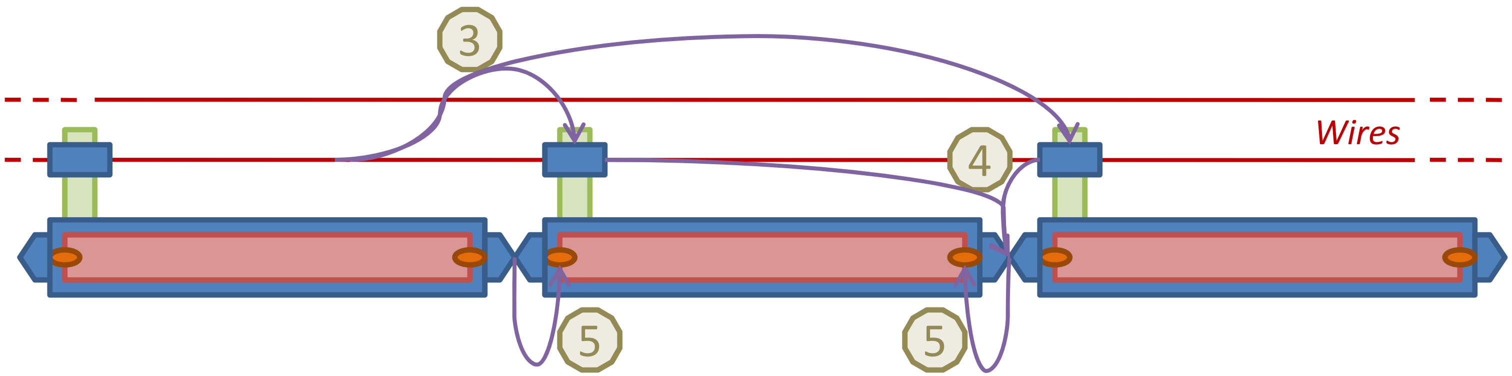
   $\sigma = \pm 5\mu m$

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

The simulated observations (4)

Alignment of the modules

3. On each module takes place a WPS sensor. Its position is known according to the wire.
   $\sigma = \pm 5\mu m$
4. The position of the articulation point between 2 modules is known according to their sensors.
   $\sigma = \pm 5\mu m$
5. The fiducialization : we get the beam entrance and exit points on one module from the articulations points.
   $\sigma = \pm 2\mu m$



The pre-alignment simulations (1)

10 µm along a 200 m sliding window !!!

This is the transversal alignment tolerance given by the beam dynamics team to the CLIC pre-alignment. It is a 3σ tolerance, i-e the accuracy that has to be reached is around 3.3 µm !

The actual results will be presented in 2 steps : the simulations of the propagation network along the whole linac (22km), then the modules prealignment along several hundreds of meters.

The ideal would be a global simulation of the module along the linac but it represents a huge amount of datas our software cannot deal with.

The pre-alignment simulations (2)

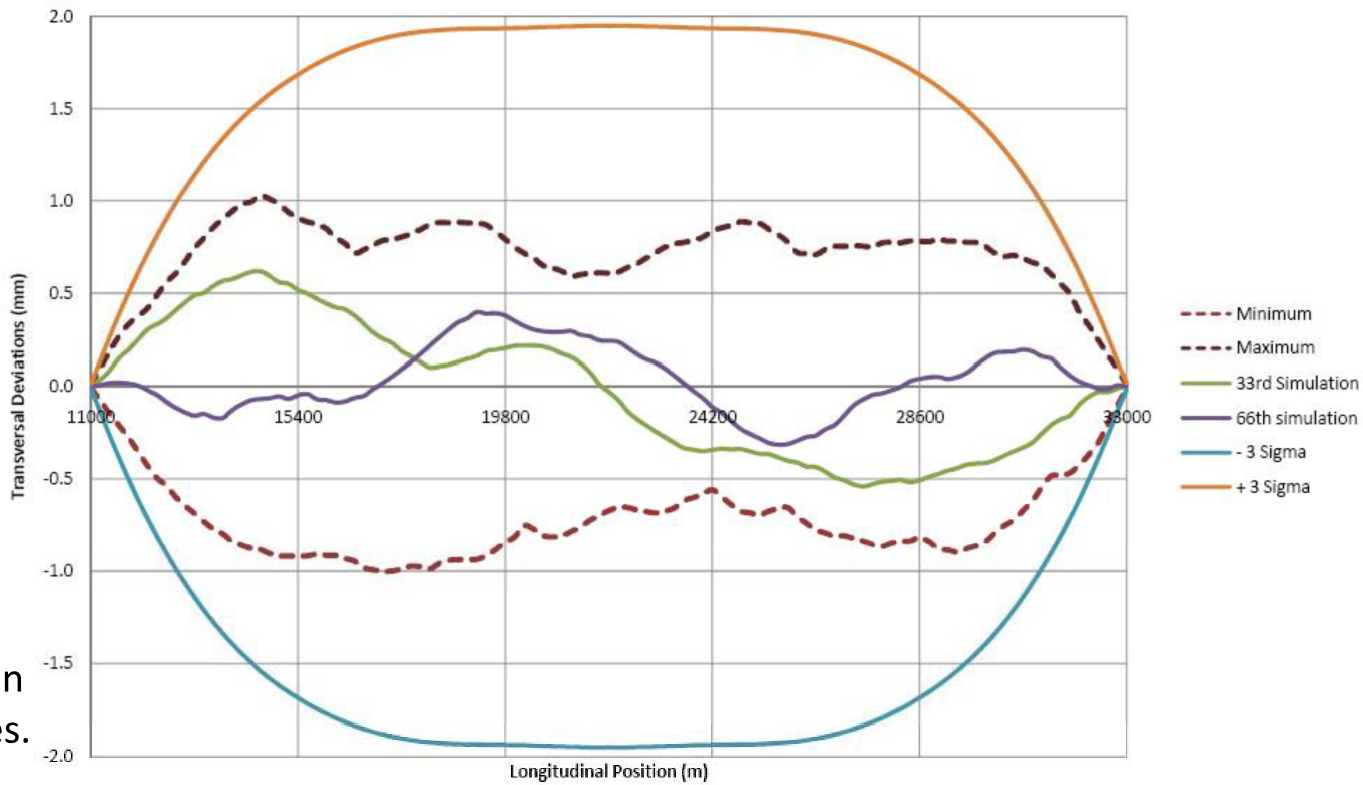
The propagation network

The simulation software gives us points coordinates and their precisions.

There are the results for all the points of one of the 3 wires.

Between the minimum and the maximum curves, everything can happen.
In any case, it is considered as good if it remains between both of the tolerances curves.

100 Simulations of the CLIC Pre-Alignment
400 m wires, 6 pits along the 22 km LINAC

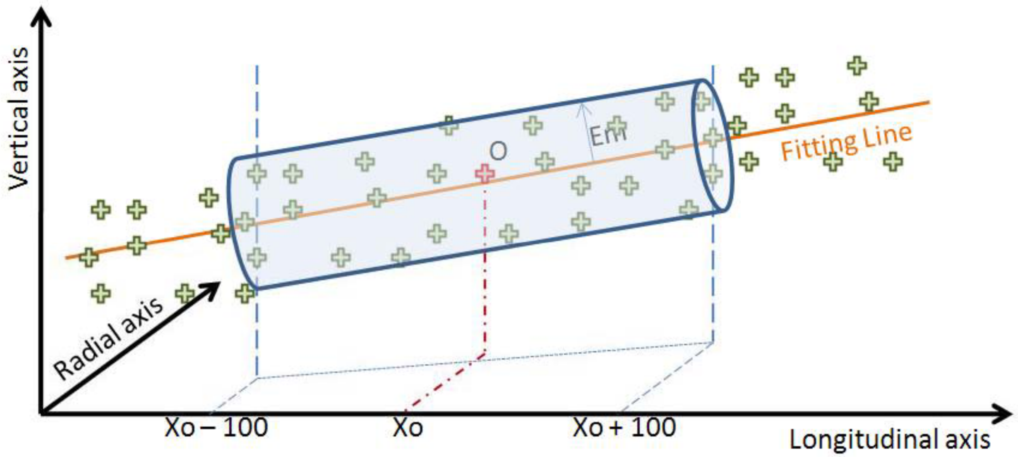


Here we have ± 1 mm of deviation along the 22km LINAC. It is a function of the propagation of the errors along the propagation network and of the number of pits.

The pre-alignment simulations (3)

The 200m sliding window

One simulation gives the positions of the modules points.

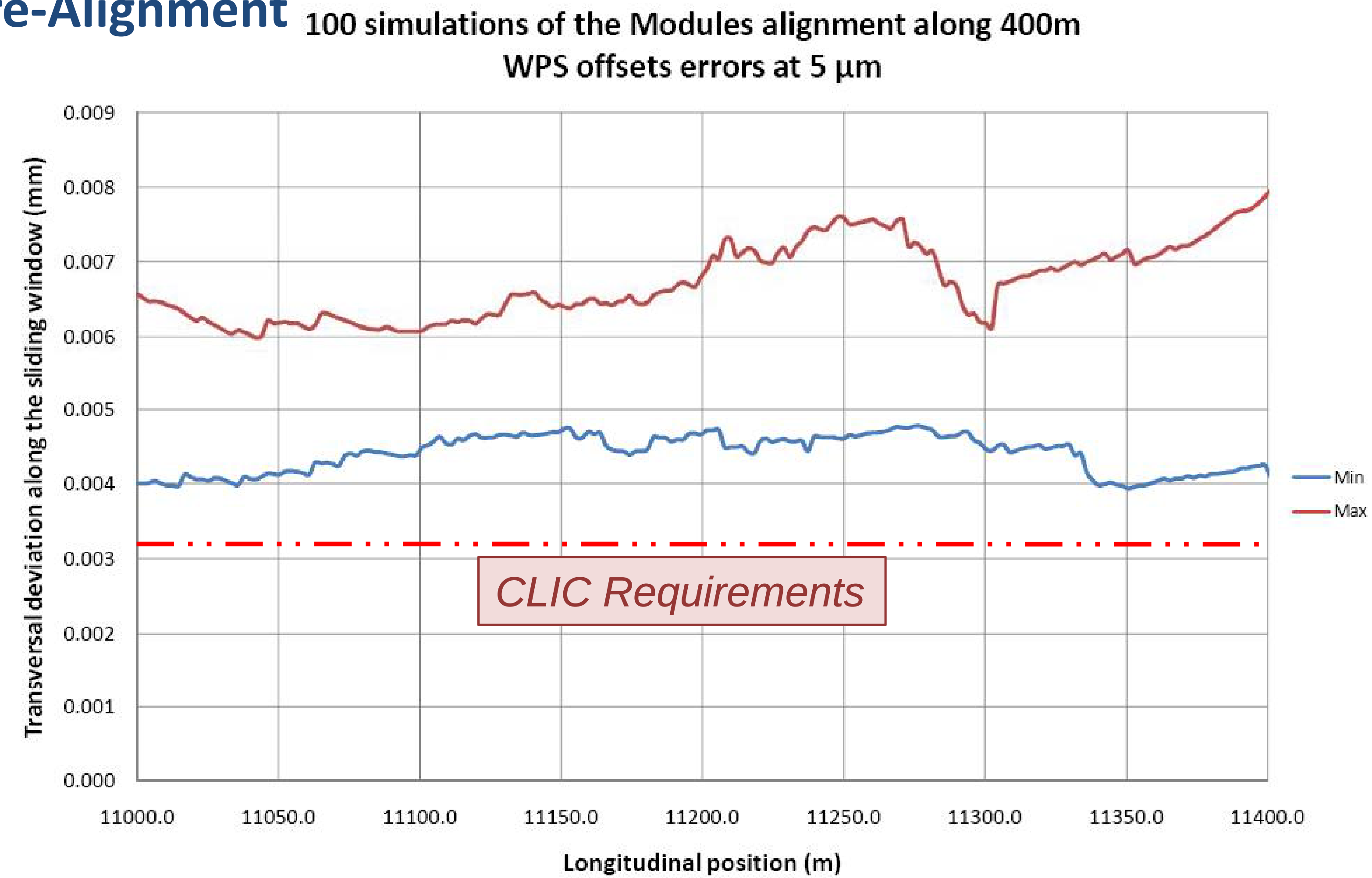


We consider one point O of one module. We compute, thanks to the least square adjustment method, the regression line from all the points less than 100m apart from O. We calculate the radial and the vertical distances from each of these points to the line.
The standard deviation of these distances corresponds with the radial and vertical precisions of our alignment along the 200m window centered in O.

By moving O along the linac, we have the precisions of the alignment along a 200m sliding window.

The pre-alignment simulations (4)

Module pre-Alignment



Validation of the simulations

Veracity of the hypothesis

According to the previous results, the CLIC prealignment accuracy is close to the requirements, around 6µm instead of 3µm. Today it seems to be the best that can be achievable. But it’s not yet proven.

As it has been shown, some hypothesis have been made in order to do these simulations. They are :
-The precision of the stretched wire is 5 µm,
-The accuracy of the WPS is 5 µm,
-The accuracies of the metrological calibrations are 5 µm.

Then it seems that 400m wire are required as a compromise between the error propagation and the feasibility of the stretched wire.

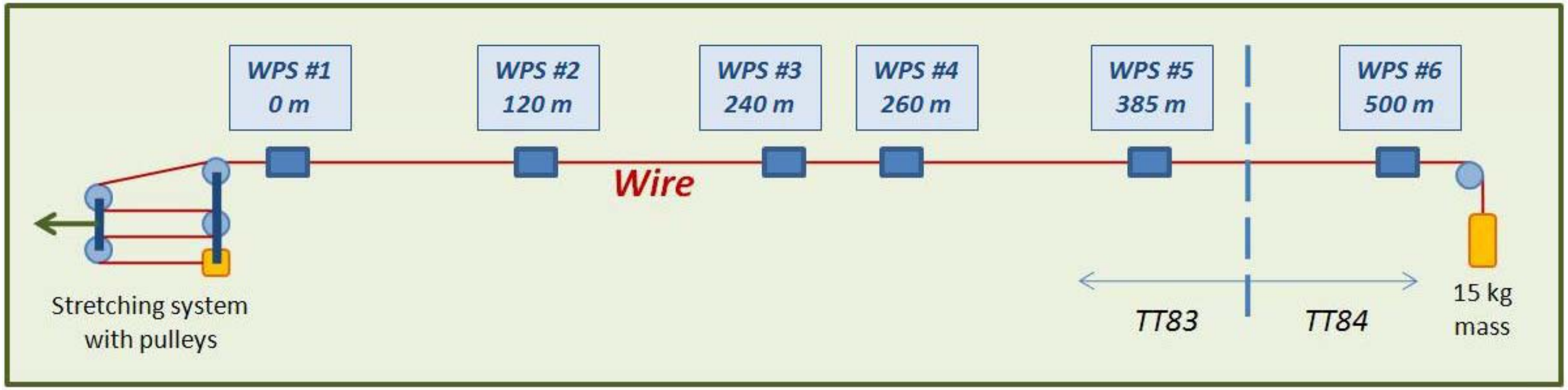
Different facilities have been developed since 2006 in order to prove each of these hypothesis, except the accuracies of the metrological calibrations. These ones are due to the accuracy of the CMM machine used by the metrology team (TS/MME).

Precision of the WPS (1)

The TT83 Facility

In december 2007, a 500m wire has been stretched at CERN in the TT83. During 5 months, 6 WPS have been measuring the position of this wire.

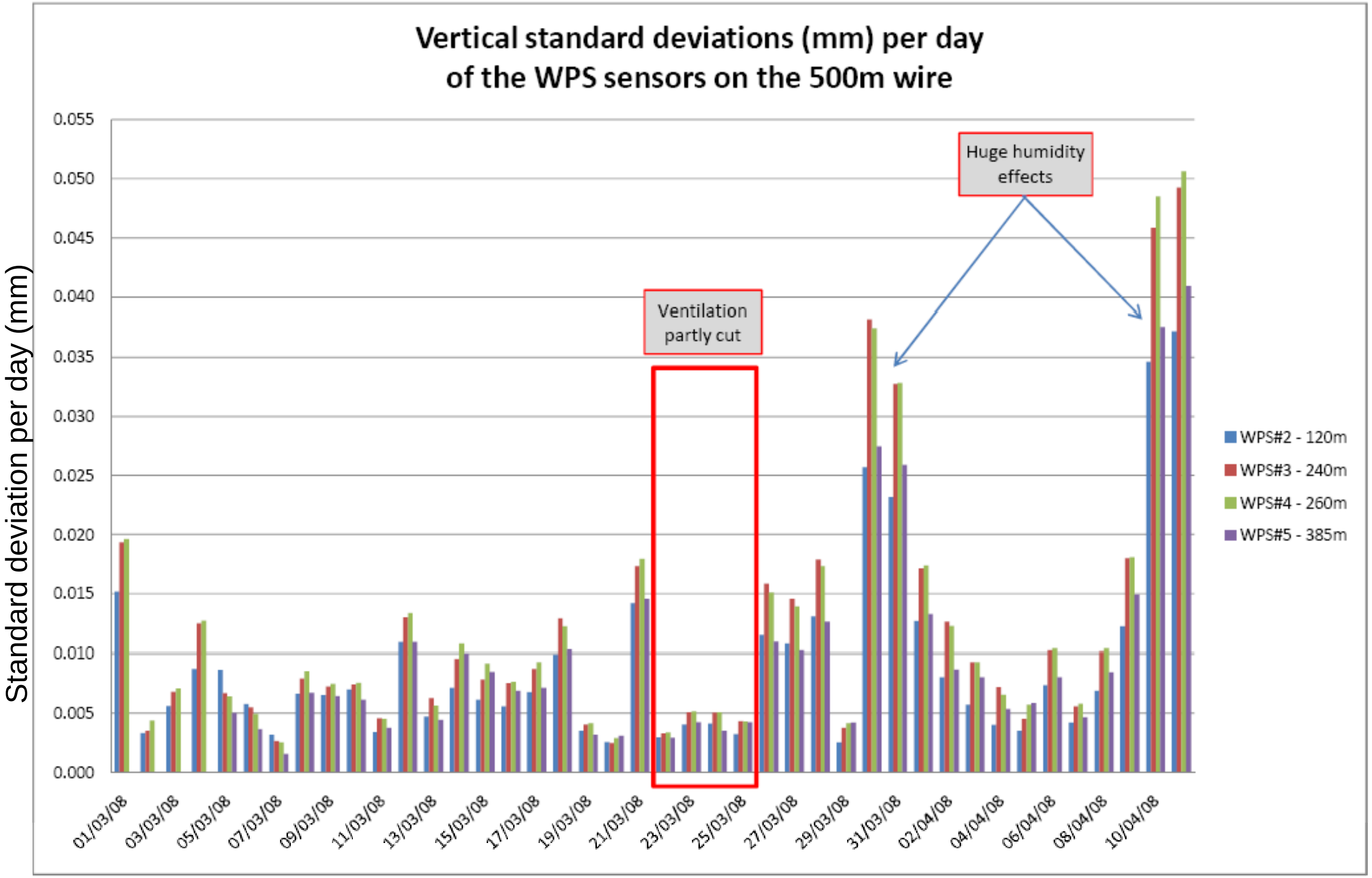
Thanks to this facility we have proven :
-It is possible to stretch such a long wire. The technology to make it feasible had been developed,
-When it is well protected from the ventilation, the precision of the WPS along the wire is 5 µm.



Precision of the WPS (2)

Thomas TOUZE

The results of the facility



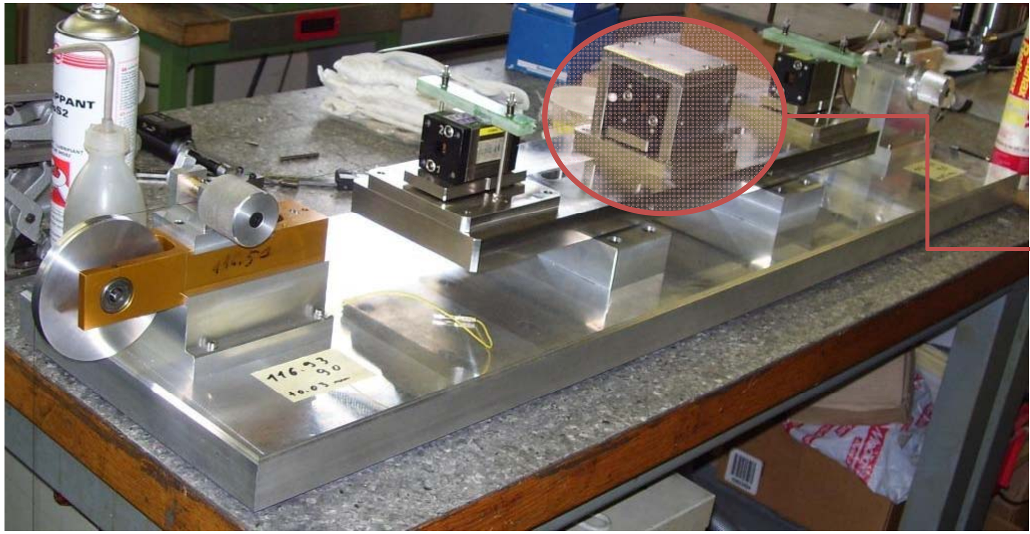
Accuracy of the WPS (1)

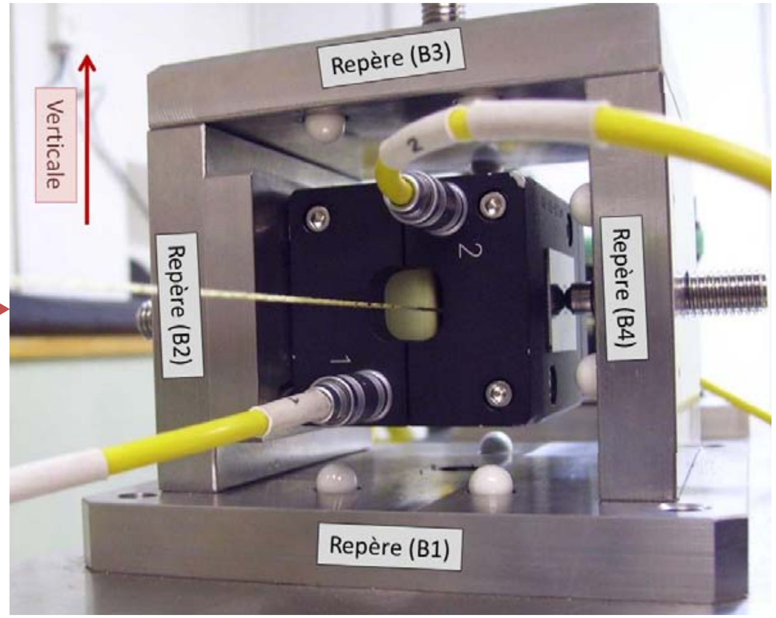
Development and calibration of new supports

A lot of sensors with micrometric precision exists on the market. But they are many less candidates for long distance alignment system.

What is much more difficult is to reach a micrometric accuracy.

In order to get this with the WPS, new supports have been developed and also the benches to calibrate them.





Accuracy of the WPS (2)

First result of the WPS calibration bench

Each WPS sensor from Fogale Nanotech gives a transversal and vertical readings to the wire according to its “natural” reference. A new fixation system for this sensor has been designed. It is composed by three balls. The position of the balls according to each other is given by a metrological measurement.

This calibration gives the translations and the rotations in order to express the reading of the sensor in the right handed reference of the three balls.

Resultats du 23.01.2009			
Parametre	*Valeur*	*Precision*	*Fiabilite*
τx (mm)	-34.784	2.278	3.008
τy (mm)	-0.517	0.003	0.015
τz (mm)	34.560	0.008	0.016
εx (rad)	1.49E-01	0.016	0.000
εy (rad)	-1.08E-03	0.001	0.010
εz (rad)	-5.95E-04	0.001	0.003

The first results show a quite good precision on the translations determinations. But the rotations are not so satisfying. This might be improved by calibrating the sensor several times, with the wire in different positions.

The propagation network (1)

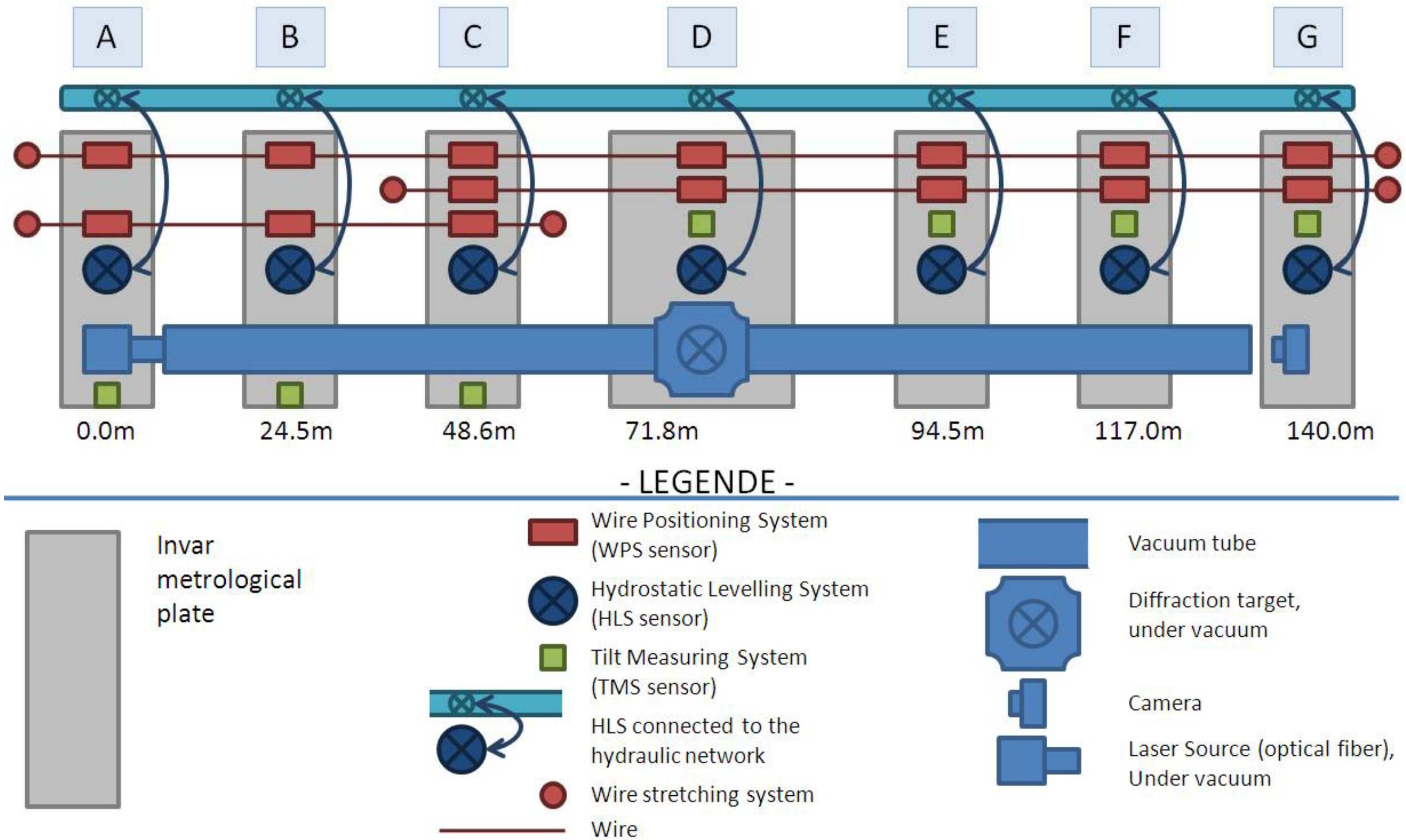
The TT1 facility

The TT1 layout is close to the propagation network design.

It measures 140m.

It has been designed and installed in 2006.

Many upgrades have been done since. The last upgrade should give us the accuracy of the WPS.



The propagation network (2)

New calibrated supports in the TT1

Conclusion

The simulations results presented previously were the first one. In collaboration with the beam dynamic studies, it has to be improved. And a lot a work remains to do in order to fully validate them.

As it has been seen, the number of points used for the propagation network is the minimum. There are just 2 common measurement points between 2 overlapping wires. In the next simulations, redundancy will be introduced (3, 4 or 5 common points). It should reduce the transversal deviation along 200m, but also the global deviation along the whole linac.

In order to simulate the beam dynamic of the whole CLIC project, it would be ideal to have pre-alignment simulations on both of the linacs at the same time. At least, if it represents too much data to compute, we can simulate one linac including the interaction point.

The first simulations of the beam dynamics have shown some local problems when we go from one wire to its neighbor simultaneously with phases change on the betatron oscillation. So instead of having a constant wire length along a linac, we can introduce a function in order to avoid this.

In these simulations, no systematic error has been taken into account. We can be sure it won't be the case in the reality. This can be an key issue in order to keep the transversal deviation within the specifications. One expected systematic effect is the variation of the gravity field. No one has actually an accurate idea of these effect. In collaboration with a PhD student from the ETHZ, we plan to study this.

Thanks for your attention.

Questions ???