THE CLIC ALIGNMENT STUDIES

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OVERVIEW

1. Introduction
2. The solutions foreseen for the pre-alignment
3. What remains to do

STEPS OF CLIC ALIGNMENT (1)

1. INTRODUCTION

Installation and determination of a geodetic tunnel network

Installation and alignment of the CLIC components w.r.t. the geodetic network

Implementation of active prealignment → Components within ± 10 μm (3σ)

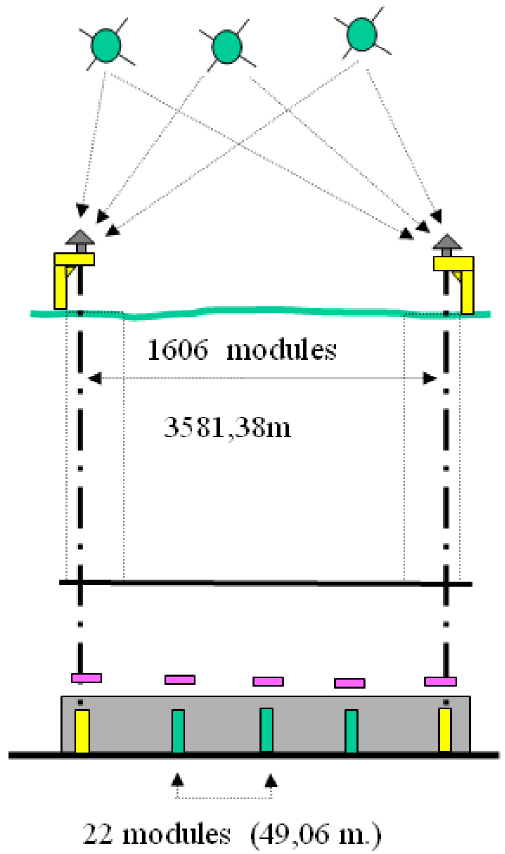
Implementation of beam based alignment → Active positioning to the micron level

Implementation of beam based feedbacks → Stability to the nanometer level

STEPS OF CLIC ALIGNMENT (2)

1. INTRODUCTION

- Installation and determination of the Survey network
- Transfer of reference into tunnel
- Installation and determination of the tunnel network
- Absolute alignment of the elements
- Relative alignment of the elements
- **Active prealignment**
- Control and maintenance of the alignment



Why an active pre-alignment ?

1. INTRODUCTION

Tolerance of ± 10 µm on a sliding window of 200m concerning the transverse position of the components.

- Ground motion
- Variations of temperature
- Human and industrial activity

} Necessity of an active pre-alignment

Pre-alignment must be precise enough to guarantee that the first beams injected will not be too far from the design trajectory and that they will detected by the BPMs.

For the LHC, the smoothing of the magnets on 100m to 150m is about ± 0.1 mm (1σ)

… a factor 30 between the smoothing of CLIC and LHC!

OVERVIEW

1. Introduction
2. The solutions foreseen for the pre-alignment
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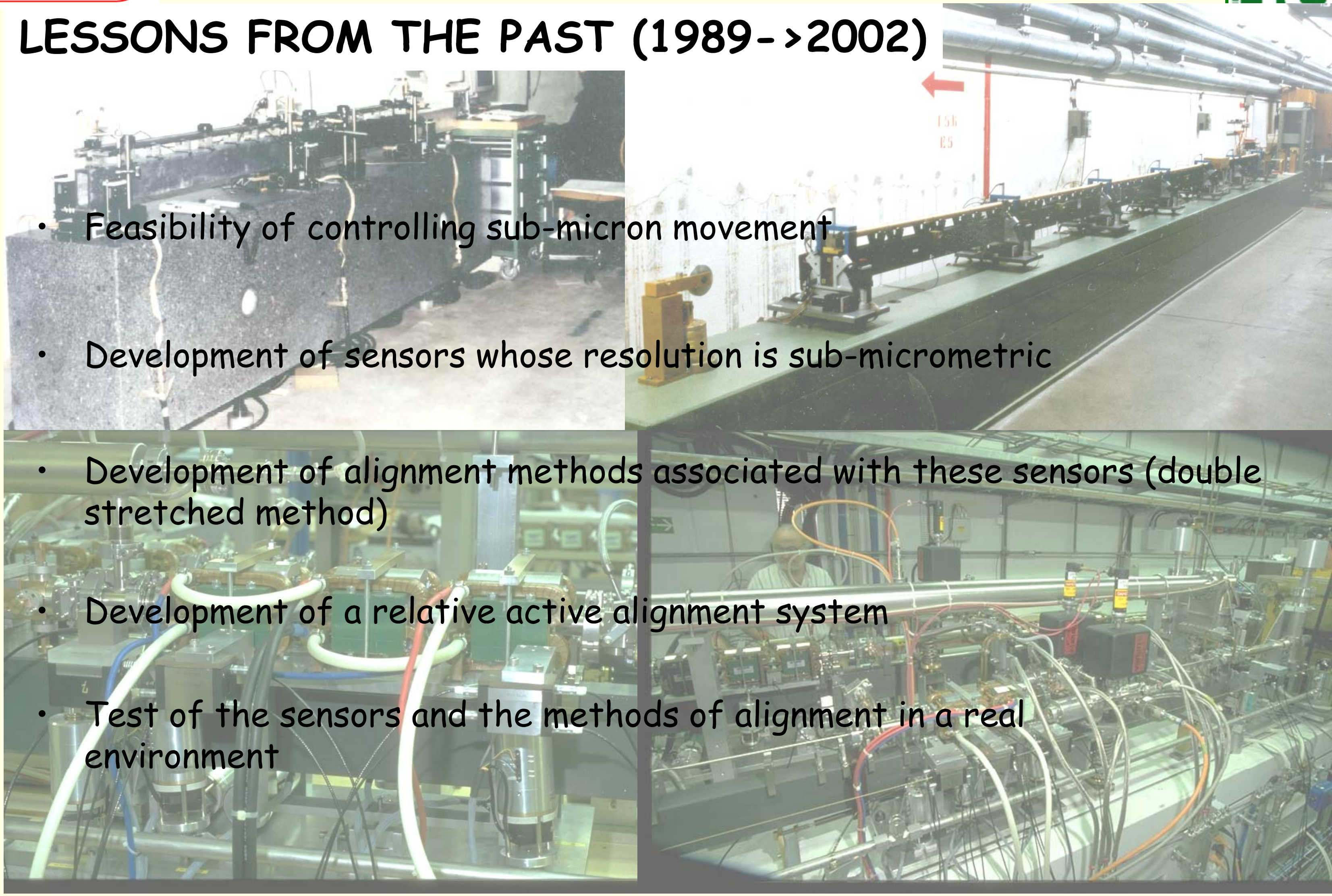
THE CLIC alignment studies…

2. ALIGNMENT SOLUTIONS

- ✓ Studies initiated in 1989 by I. Wilson, W. Coosemans and W. Schnell
- ✓ In 2003, one global solution was proposed, with some points to be solved
- ✓ Studies stopped between 2003 and 2006.

2. ALIGNMENT SOLUTIONS

LESSONS FROM THE PAST (1989->2002)

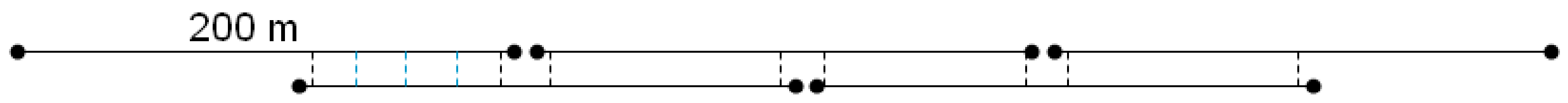


- Feasibility of controlling sub-micron movement
- Development of sensors whose resolution is sub-micrometric
- Development of alignment methods associated with these sensors (double stretched method)
- Development of a relative active alignment system
- Test of the sensors and the methods of alignment in a real environment

2. ALIGNEMENT SOLUTIONS

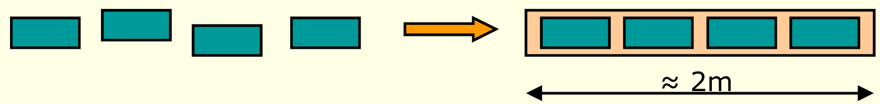
CONCEPT

The straight reference line between the two ends of the linac is obtained through overlapping reference lines.

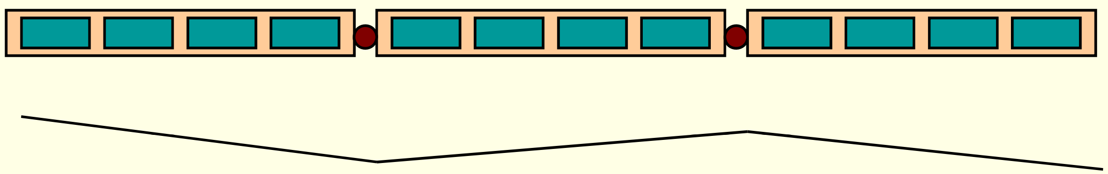


Zoom

a. Simplification of the problem by pre-aligning components on girders

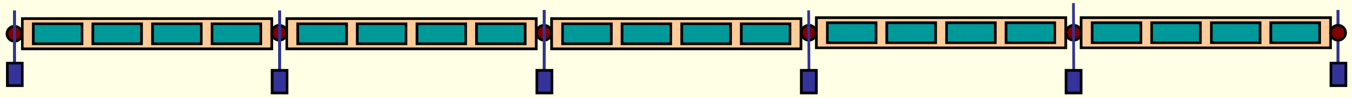


b. Simplification of the alignment by linking adjacent girders by a common articulation point

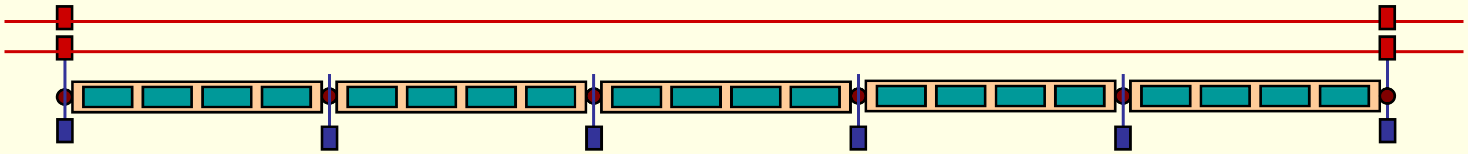


2. ALIGNEMENT SOLUTIONS

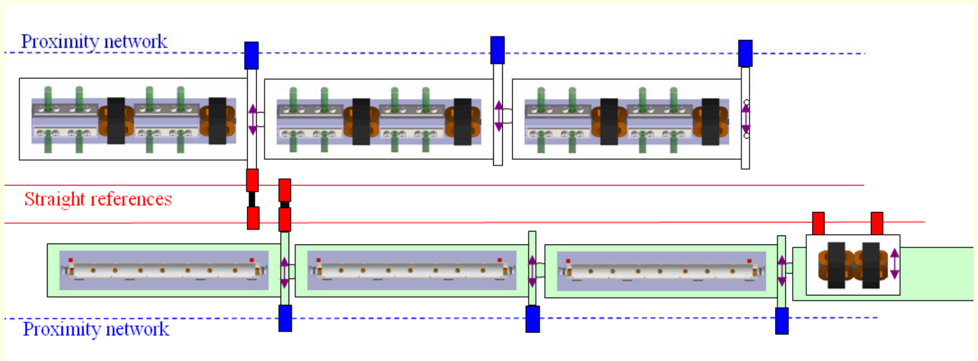
c. Association of a « proximity network » to each articulation point



d. Association of a « propagation network » every x articulation point



At the scale of the module…



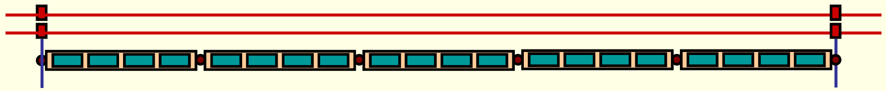
Drive beam *(PETS + quad on the same girder)*

Main beam (cavities on girder, quad independent)

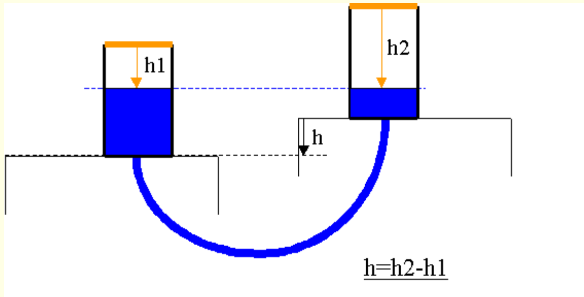
2. ALIGNEMENT SOLUTIONS

ALIGNMENT SYSTEMS PROPOSED

For the propagation network…

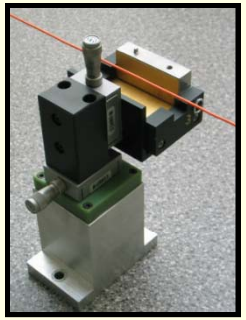


Hydrostatic Leveling System (HLS)



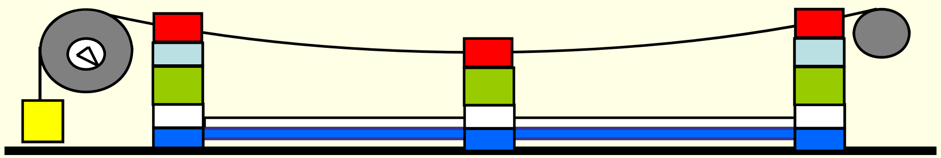
- ✓ Based on the communicating vessels
- ✓ Water network = reference surface
- ✓ Each vessel surrounded by a capacitive sensor which measure the distance to the water surface

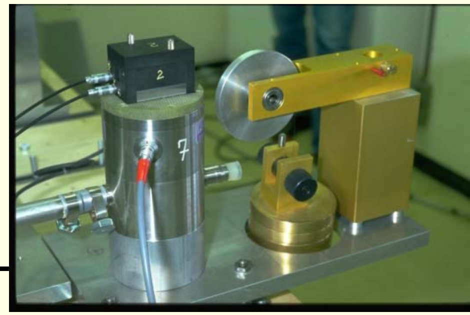
Wire Positioning System (WPS)



- o Also based on capacitive technology
- o Sub-micrometric resolution

- ✓ In the horizontal plane : wire = straight line
- ✓ In the vertical plane : wire = catenary

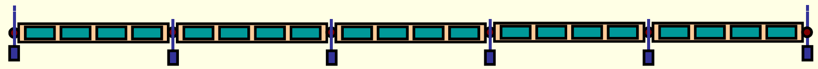




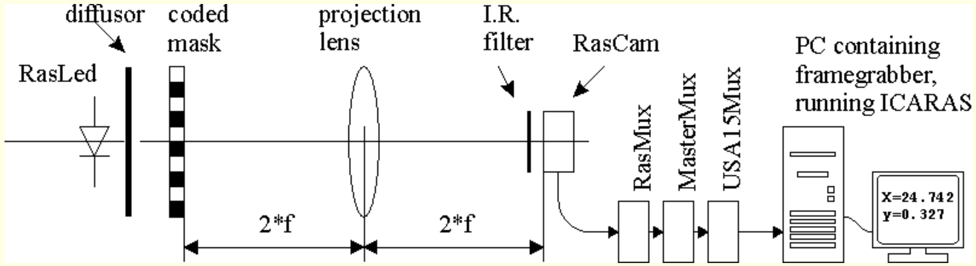
2. ALIGNEMENT SOLUTIONS

ALIGNMENT SYSTEMS PROPOSED

For the proximity network…

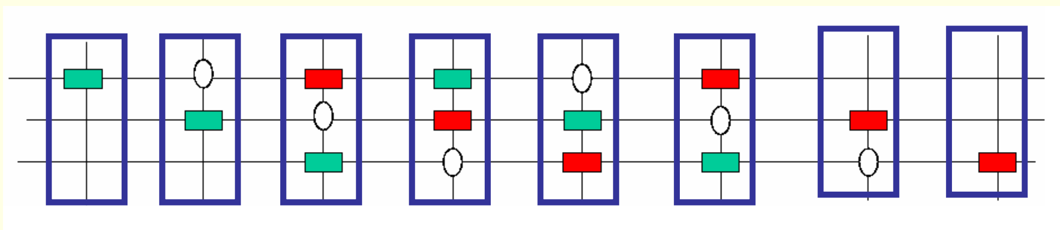


Red Alignment System from NIKHEF (RASNIK)



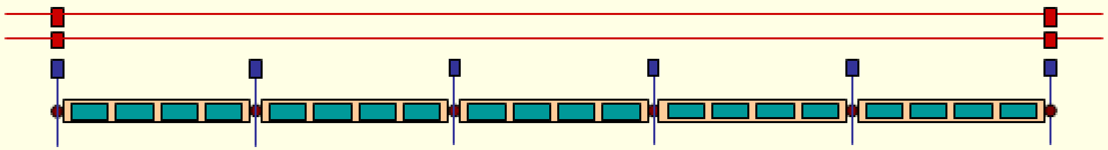
- ✓ Resolution: 0.01μm
- ✓ Range: 5mm
- ✓ Uncertainty of measurement 2.f = 2.5 m : 1 μm

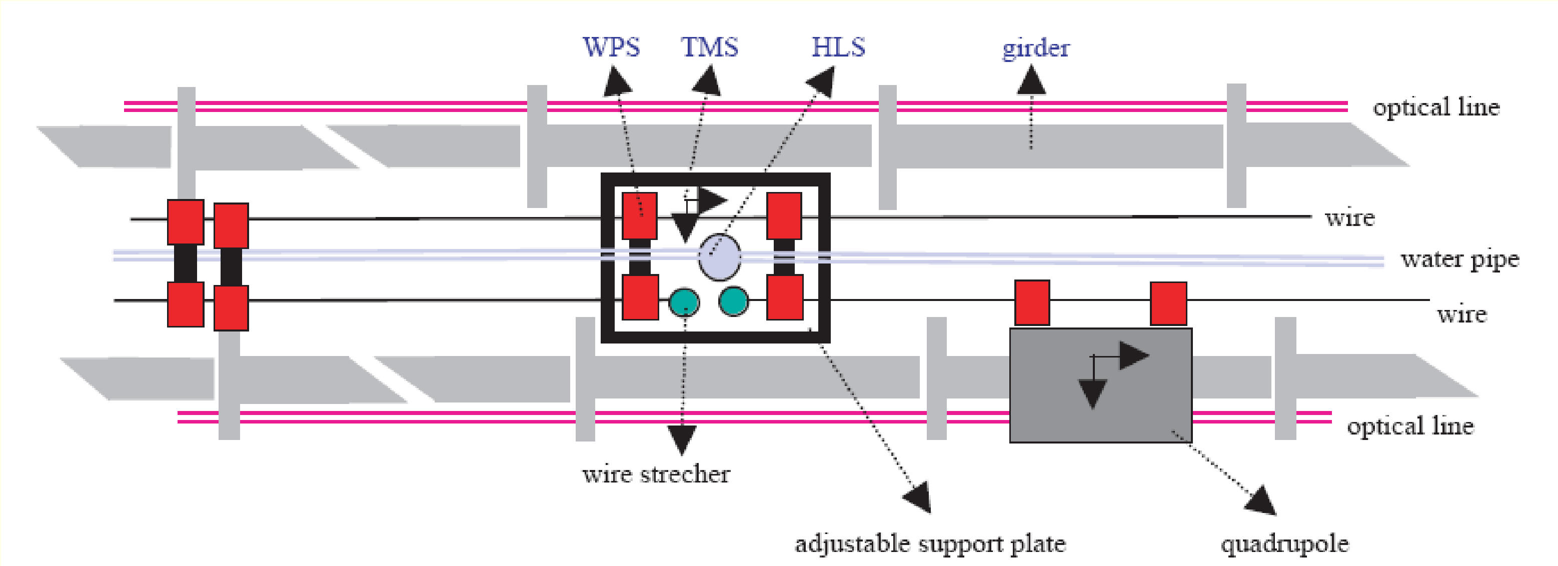
- ✓ Developed by NIKHEF
- ✓ Only on short distances



2. ALIGNMENET SOLUTIONS

CONFIGURATION OF SENSORS

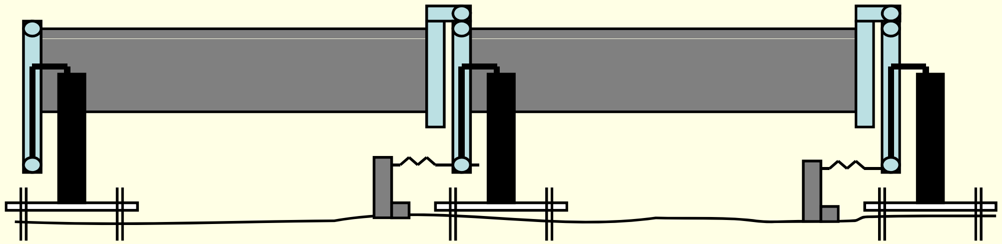


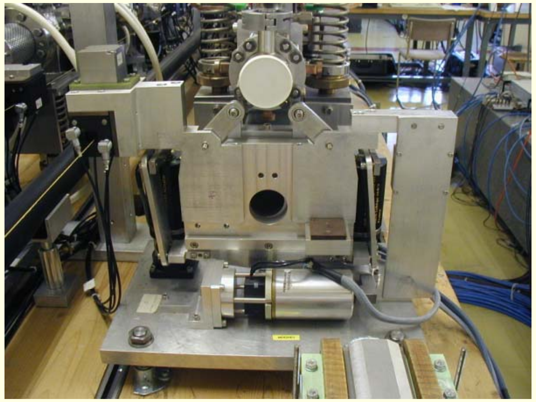


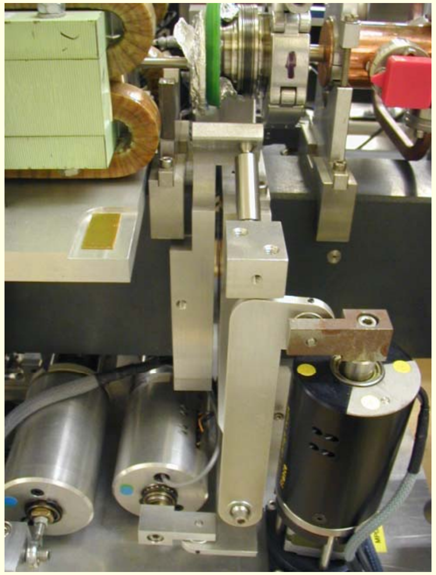
THE SOLUTION CONCERNING SUPPORTING

2. ALIGNEMENT SOLUTIONS

Adjacent girders linked by a common articulation point…

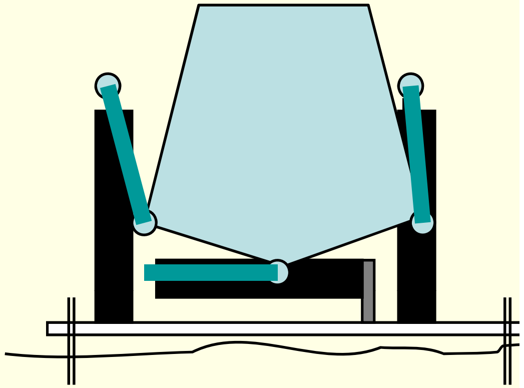






Advantages:

- ✓ Natural smoothing
- ✓ Mechanics tested and validated on CTF2
- ✓ Only 3 degrees of freedom (cost)



2. ALIGNEMENT SOLUTIONS

THE QUESTIONS IN 2003…

✓ Only few tests carried out on RASNIK alignment system, especially concerning its acquisition system along long distances

✓The use of stretched wires as reference had to be confirmed (go on its modelization, determination on the best length, better knowledge of its absolute uncertainty of measurement)

✓The study concerning the gravity effects on these alignment systems had to be achieved.

✓One last question: the components will have to be aligned along a straight line; WPS and HLS alignment systems follow the geoid. So the uncertainty of the determination of the geoid will be strictly added to the vertical alignment uncertainty.

Since 2003, two directions of studies are followed:

✓ The consolidation of the existing solution (stretched wire for propagation network, RASNIK system for proximity network), trying to answer all the remaining questions

✓ The development of a new solution laser alignment solution for the propagation network, in collaboration with NIKHEF.

Which led to the implementation of a new facility in order to get a better knowledge of our alignment systems, and develop and test the laser solution.

1. Introduction

2. The solutions foreseen for the pre-alignment

3. What remains to do
   - The latest results
   - The R&D studies

SOMMAIRE

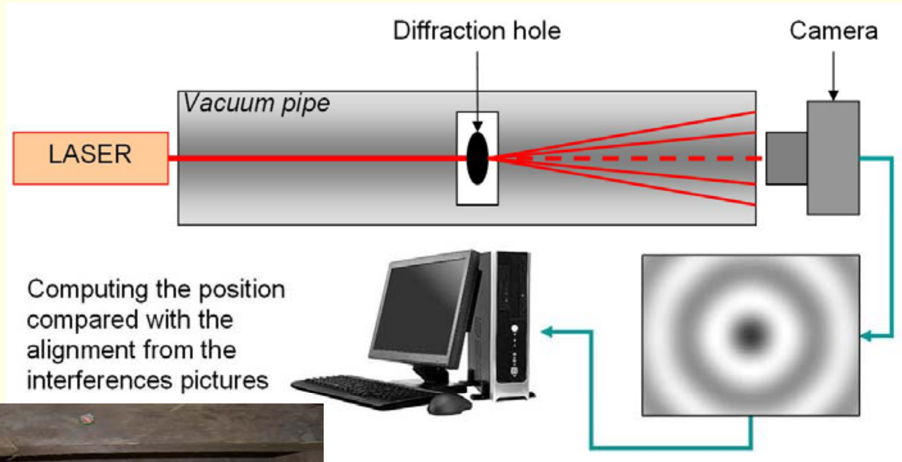
THE LASER SOLUTION…

3. FIRST RESULTS

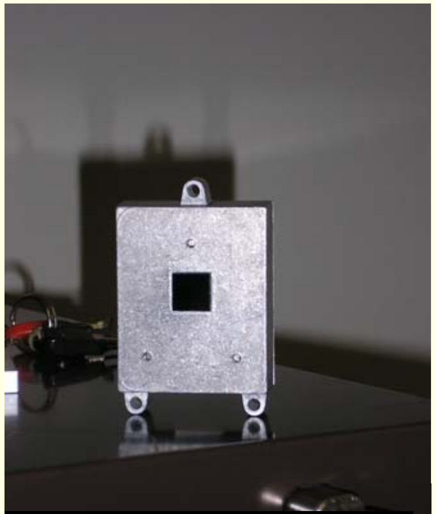
✓ Objective: to provide transverse positional data on targets distributed over 100 m, with an uncertainty of measurement better than 5 microns.

✓ Straight line = laser line between source and detector <u>under vacuum</u>

✓ Concept: target with a hole in order to determine the center of the diffraction patterns



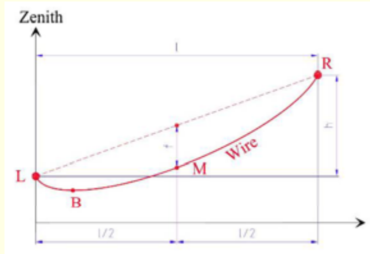

Some examples of targets

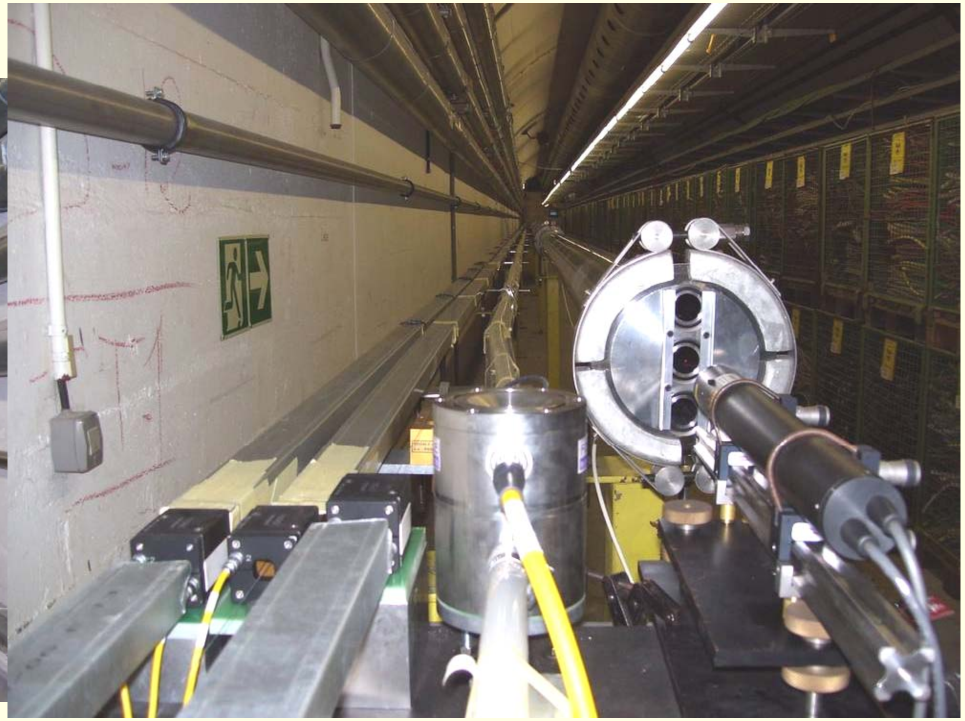

RasCam video sensor

THE TT1 Facility

3. FIRST RESULTS

- ✓ To measure the uncertainty of measurement of the overlapping stretched wires systems,
- ✓ To study the modelization of a stretched wire,
- ✓ To study the behavior of a long wire compared to smaller ones,
- ✓ To build and validate the laser solution.



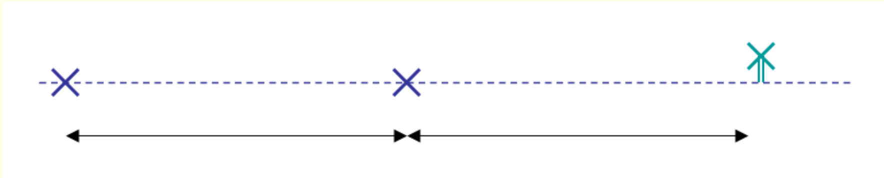


THE FIRST RESULTS CONCERNING THE LASER SOLUTION…

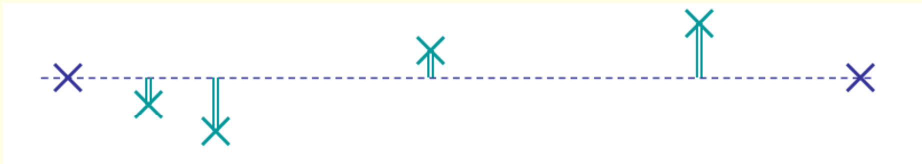
3. FIRST RESULTS

The laser solution was tested as a 3 point alignment system:

→ shows to be a very precise inclinometer, with a sub-micrometric resolution, on 100 m.

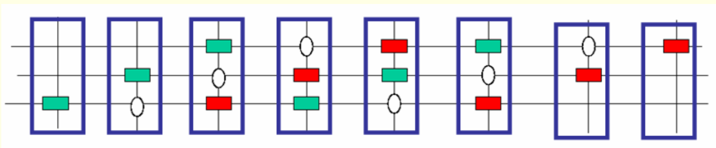


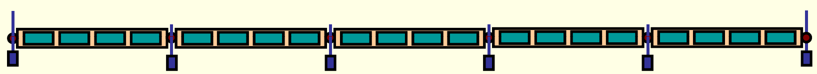
Difficult to be changed into a n point alignment system (in/out mechanics under vacuum, absolute measurement,…)



But can be converted to a low cost proximity alignment system (in order to replace the RASNIK system), as distances between articulation points are regular.

→ same configuration than RASNIK, but the lens is replaced by a hole

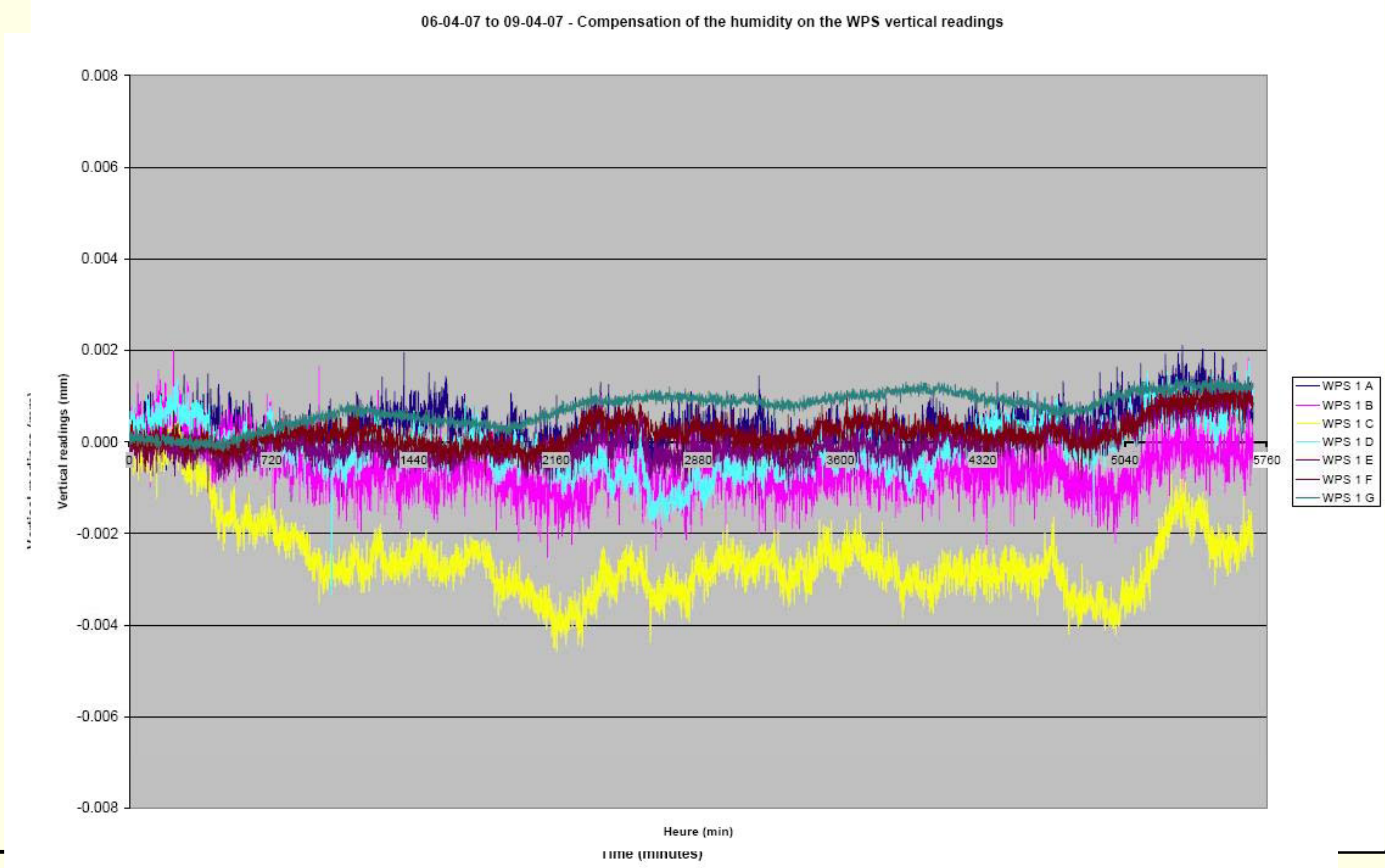




A better knowledge of HLS and WPS systems…

3. FIRST RESULTS

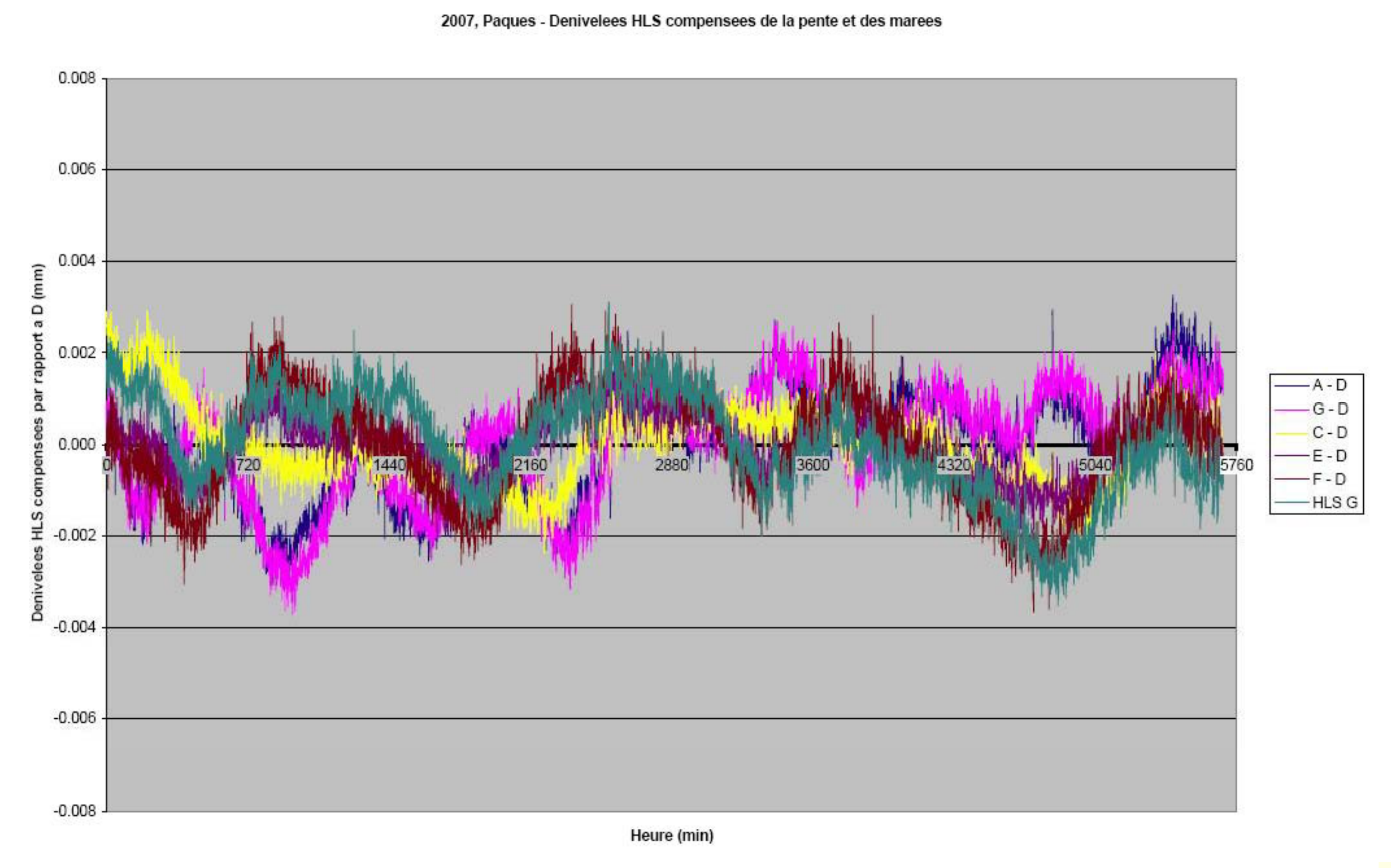
✓ Influence of humidity on WPS system



A better knowledge of HLS and WPS systems…

✓ Influence of humidity on WPS system

✓ Influence of lunar and solar tides on HLS system

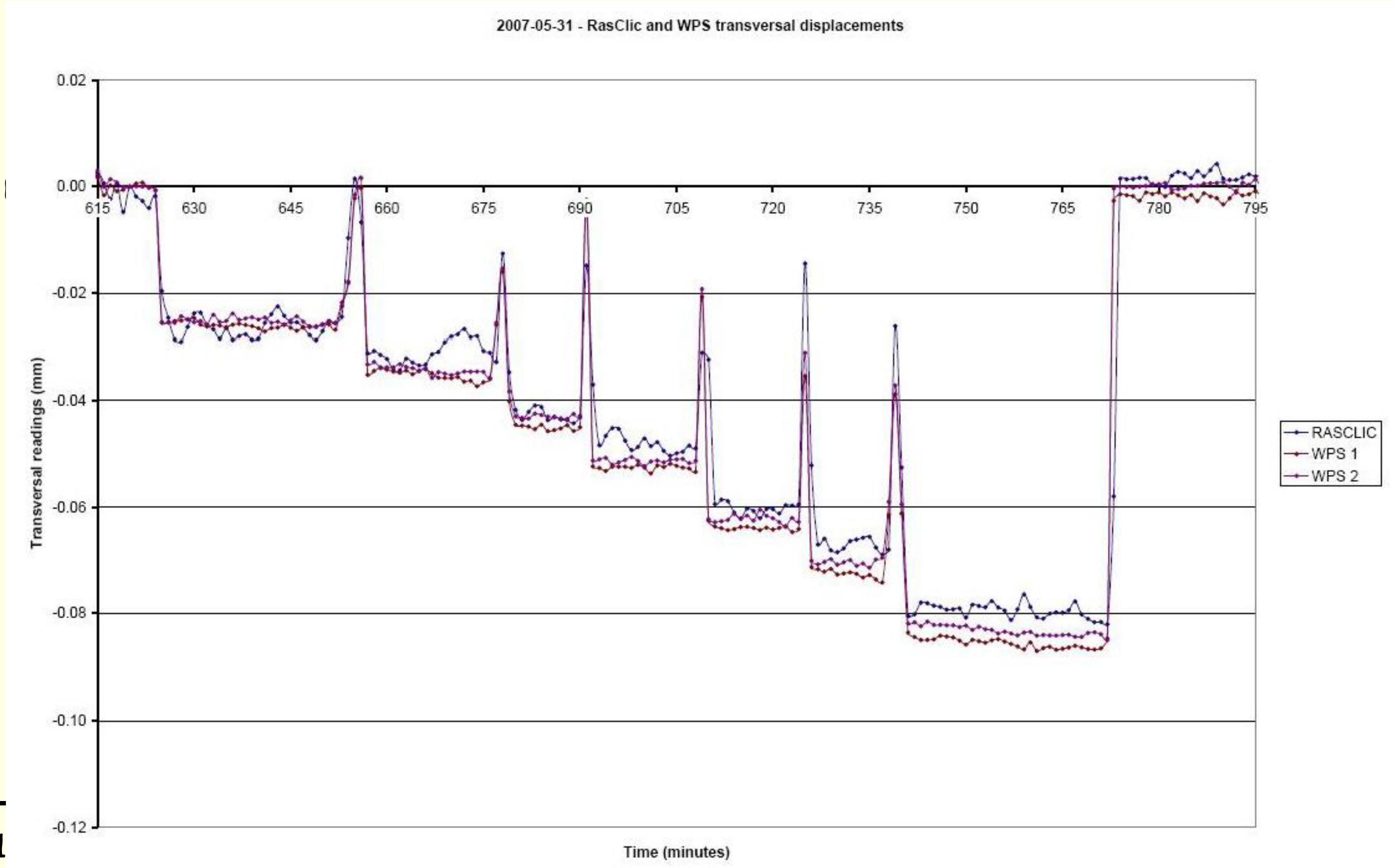


3. FIRST RESULTS

A better knowledge of HLS and WPS systems…

3. FIRST RESULTS

- ✓ Influence of humidity on WPS system
- ✓ Influence of lunar and solar tides on HLS system
- ✓ Comparison between alignment systems



A better knowledge of HLS and WPS systems…

3. FIRST RESULTS

4 objectives to fulfill…

3. WHAT REMAINS TO DO

Objective 1: mechanical alignment of the elements on the girders within a few microns.

Status: alignment of components on girders tested and validated in CTF2 but everything has changed.

R&D proposal:

✓To find several methods allowing to pre-align the components on the girders (self collimating telescope, CMM)
✓To compare this alignment with BPM integrated in the accelerating structure.

Objective 2: fiducialisation (link between the beam line and the alignment reference)

Status: never tested nor validated

R&D proposal:

✓To define the interfaces and references used for the fiducials
✓To propose a method, test and validate it on the Two Beam Test Stand.

4 objectives to fulfill…

3. WHAT REMAINS TO DO

Objective 3: pre-alignment of 10 microns over 200 m

Status: as explained before.

R&D proposal:

Concerning the alignment systems:
- ✓To validate the wire solution (gravitational effects, modelization, development of a sensor allowing sub-micrometric absolute positioning)
- ✓To validate the laser solution as proximity network
- ✓To adapt the laser solution into an n-point alignment system
- ✓To follow the alignment systems developed in other labs

Concerning the supporting system:
- ✓To develop some prototypes for the supporting of the main beam and drive beam girders, and quadrupoles
- ✓Compatibility with stabilization system
- ✓To validate on the Two Beam Test Stand

Concerning the alignment on long distances:
- ✓To validate all the steps in the Two Beam Test Stand
- ✓To validate the pre-alignment methods on a long distance facility

4 objectives to fulfill…

3. WHAT REMAINS TO DO

Objective 4: cost optimization

Status: simulations of pre-alignment uncertainty and optimization of the configuration of sensors.

R&D proposal:

✓To propose a global concept of alignment for CLIC for all areas (BDS, ML, RTML, INJ) and simulate the corresponding uncertainty of the components pre-alignment
✓To optimize the cost

Conclusion

The different test facilities and studies carried out have shown that it was not illusory to align components with tolerances of 10 microns over 200m.

Some questions however still subsist (micrometric absolute measurements, determination of the geoid within a few microns, gravitational effects on alignment systems,…), that need to be answered as soon as possible, with the adequate means.

CONCLUSION