STATUS AND PLANS OF THE CLIC SURVEY AND ALIGNMENT.

Many thanks to Friedrich Lackner, Thomas Touze and Sebastien Guillaume

Hélène MAINAUD DURAND

OVERVIEW

- ✓ INTRODUCTION – general alignment concept
- ✓ STATUS AND PLANS – around 4 key points
  - A stable and accurate alignment system
  - Associated sensors with the required uncertainty of measurement
  - Fiducialisation and internal metrology
  - Importance of the 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 on the MB quads

PRE-ALIGNMENT REQUIREMENTS

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

  ± 10 microns (3σ) on a 200m sliding window along each linac

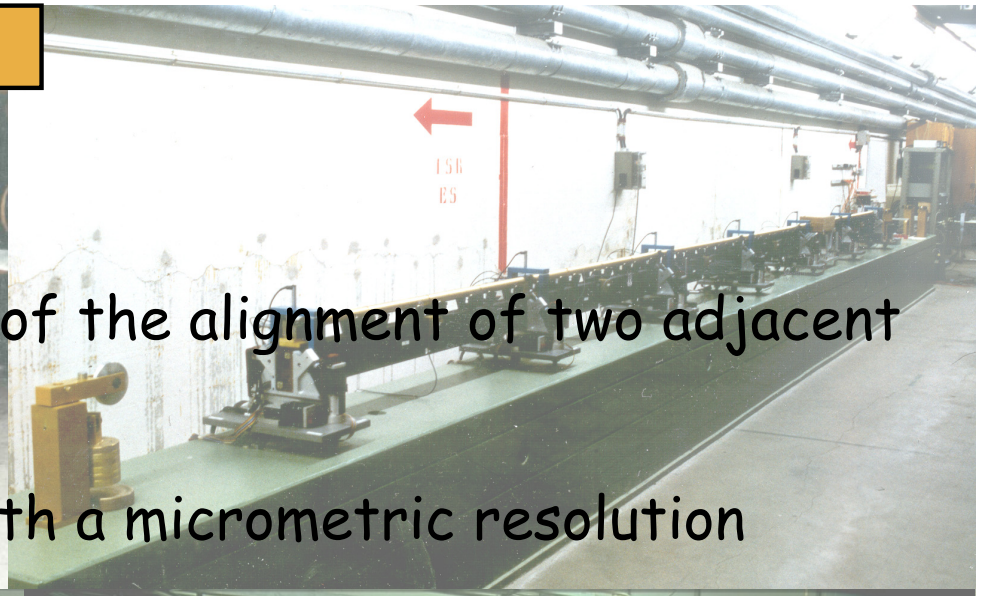
- At the micron scale: this pre-alignment needs to be active (ground motion, noise of accelerator environment, temperature dilatations)

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

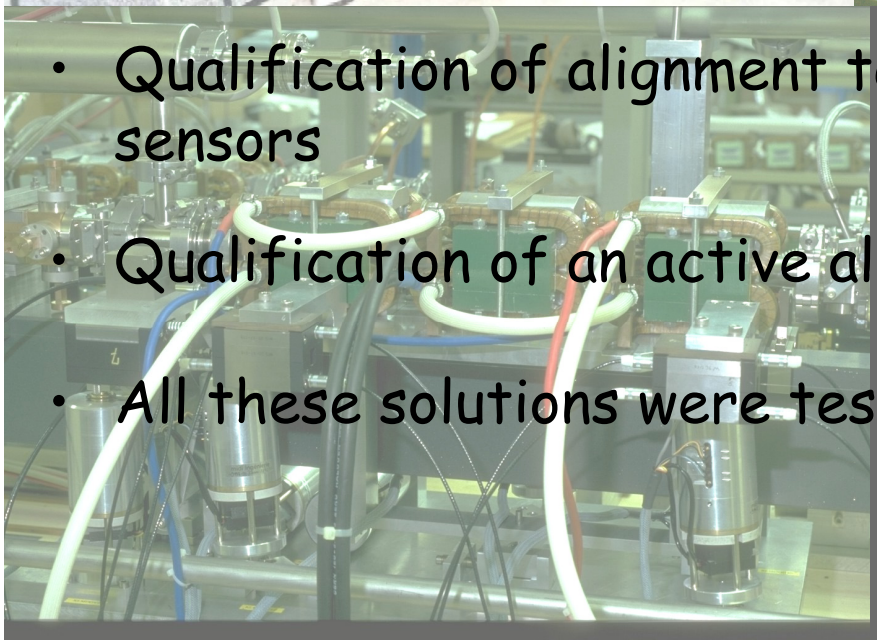
- A scale order concerning this pre-alignment :
  - For the LHC: ± 0.1 mm over 110 m (1σ)
  - For the ILC: ± 0.2 mm over 600 m (1σ) (in the vertical direction)

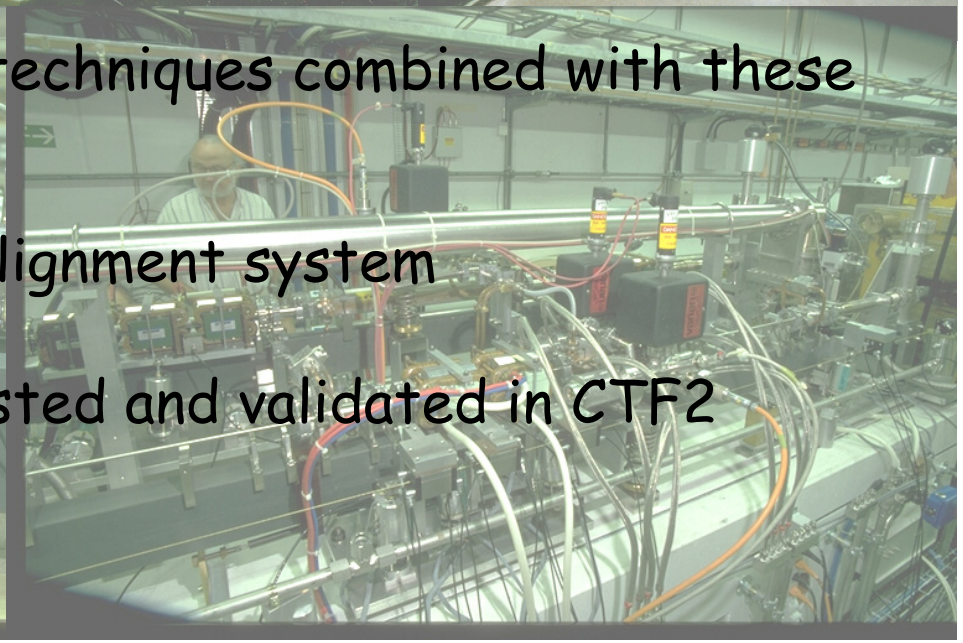
CLIC pre-alignment = technological challenge

LESSONS FROM THE PAST



- Positioning and maintening of the alignment of two adjacent girders within the micron
- Development of sensors with a micrometric resolution

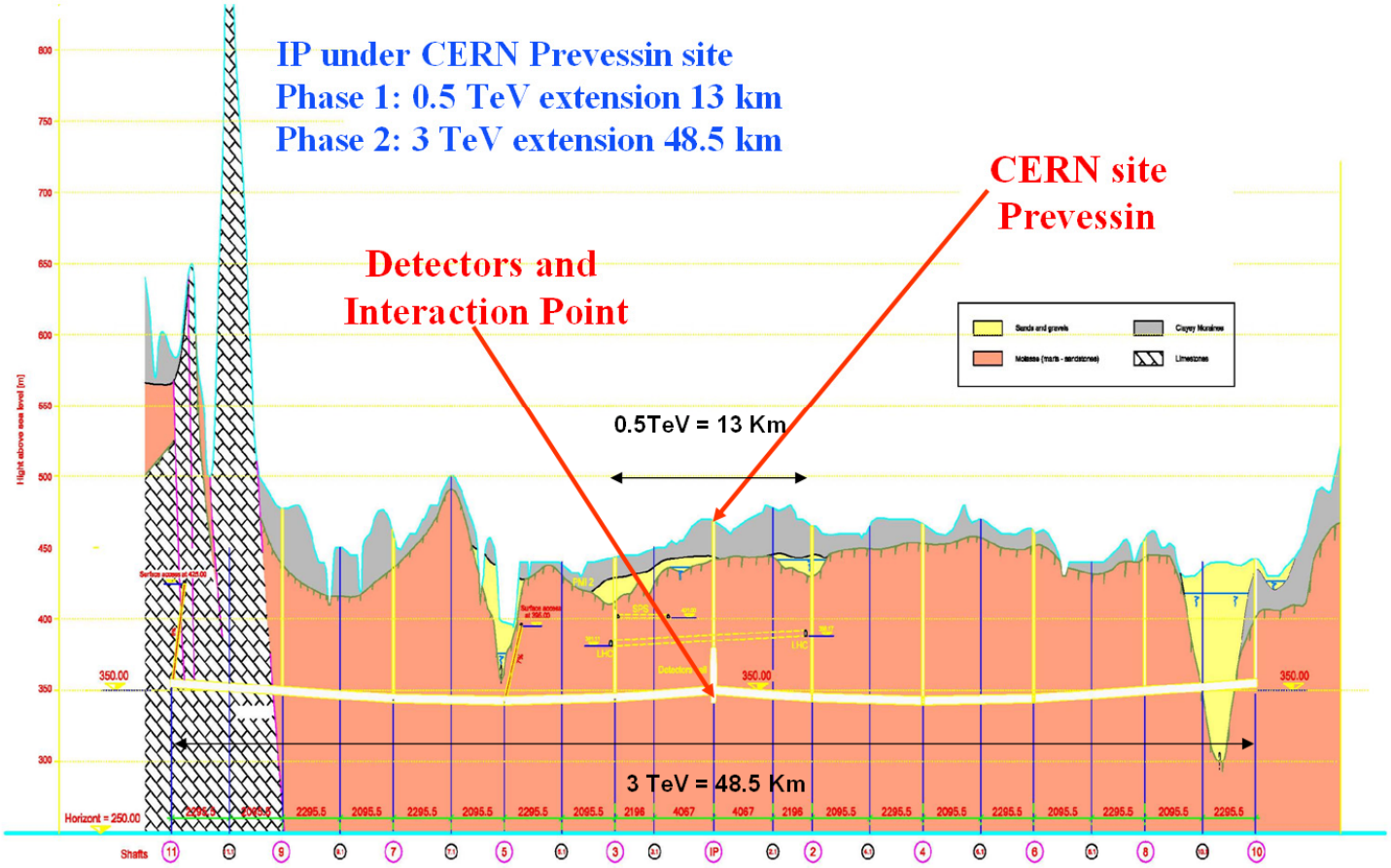


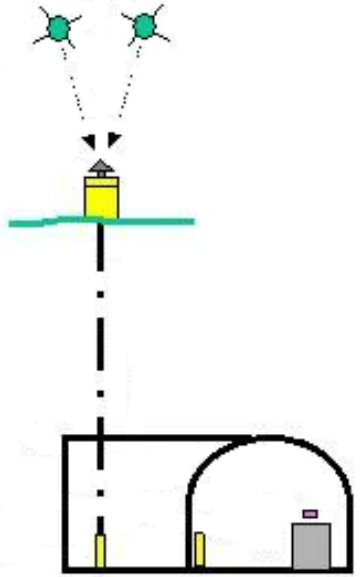


- Qualification of alignment techniques combined with these sensors
- Qualification of an active alignment system
- All these solutions were tested and validated in CTF2

GENERAL ALIGNMENT CONCEPT

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





Cross section

GENERAL ALIGNMENT CONCEPT

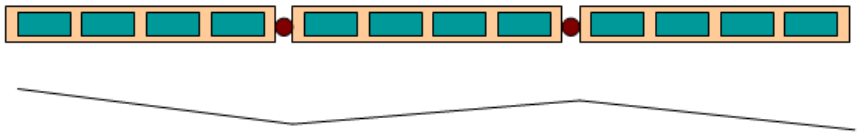
- As it is not possible to implement a straight alignment reference over 20 km: use of overlapping references

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

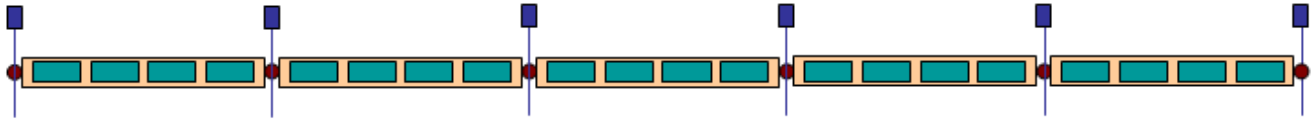
GENERAL ALIGNMENT CONCEPT

- Simplification of the problem by prealigning components on girders

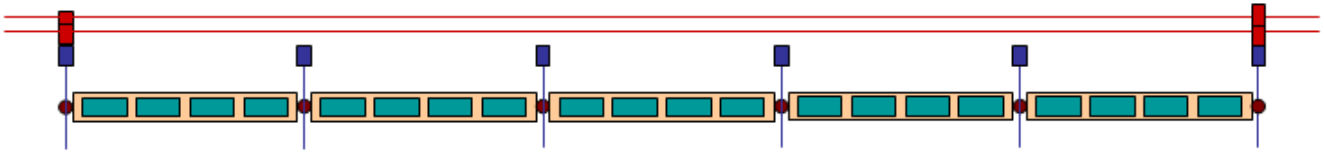
- Simplification of the alignment by linking adjacent girders by a common articulation point



- 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
- A solution of pre-alignment 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.

STATUS AND PLANS – around 4 key points

- A known and stable alignment reference
- Sub micrometric sensors
- Fiducialisation and internal metrology
- Importance of the simulations

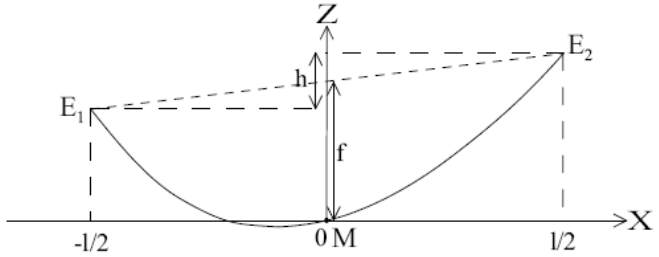

A STRETCHED WIRE AS AN ALIGNMENT REFERENCE FOR THE LHC

A STRETCHED WIRE AS AN ALIGNMENT REFERENCE FOR THE LHC

Wire Positioning System (WPS)

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

CLIC ALIGNMENT FACILITIES (see Thomas' presentation)

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)
- Wire stretched over 500m

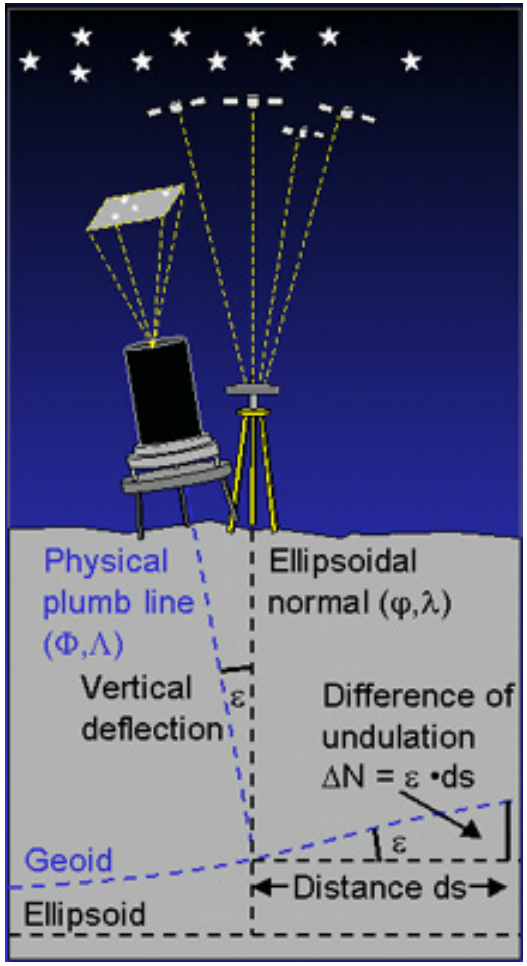
Next steps on the facilities:

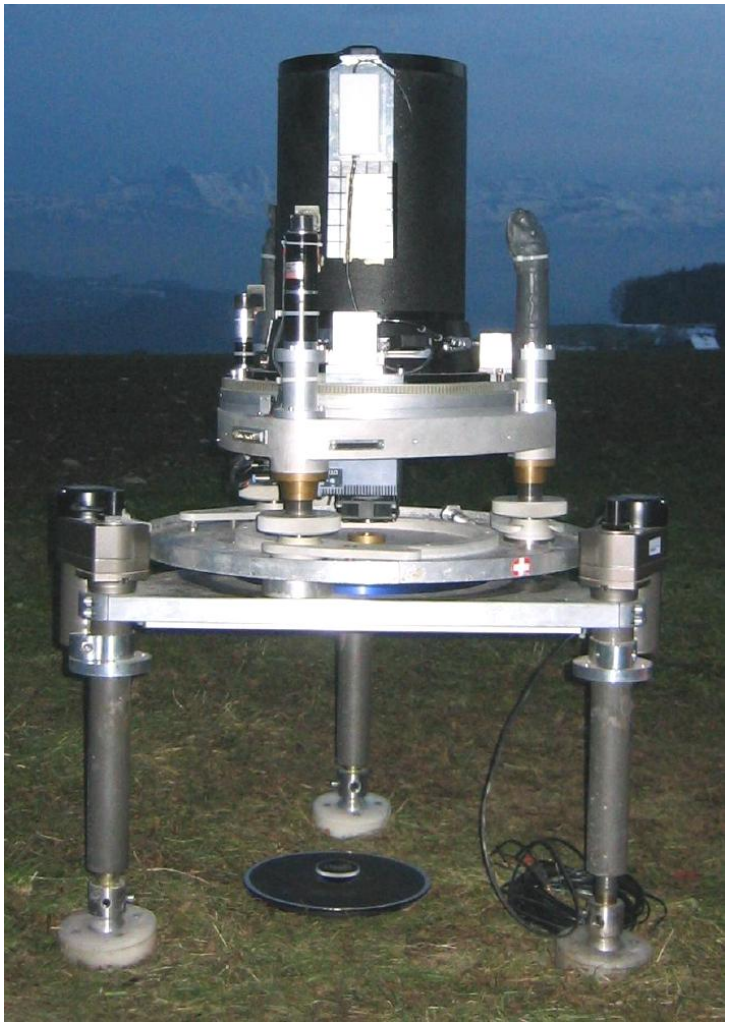
- To measure the uncertainty of measurement of overlapping wires
- To confirm the effect of the rotation of the Earth
- To modelize the vertical shape of a stretched wire without the HLS system

STATUS AND PLANS CONCERNING GRAVIMETRIC AND GEODETIC STUDIES

- ✓ **Improvement of the Zenith Camera System, ETH Zürich.**
  - *Today performance: **0.1-0.2** [arcsec] for 30 [min] of observations.*
- ✓ **Astrogeodetic and gravimetric measurement campaigns** at the earth's surface and in a straight tunnel of ~850 m length are planned to test and validate the chosen methodology.
  - *Zenith camera : 1 station every 10 [m] => a priori s_N ~ 10 [mm]/200 [m].*
  - *Gravimetry (CG-5, resolution of 1 [mgal] = 10^{-8} m/s^2) :*
    - *in the tunnel : 1 profile (6 points, 2 levels) every 5 [m].*
    - *on the surface : 1 profile (to be defined) every 5 [m].*
- ✓ **Data analysis, geoid computation and simulation** in order to judge of the feasibility of the determination of equipotential surfaces.
- ✓ **Development and research of other instruments** for measuring the shape of equipotential surfaces directly into the tunnel.

Astro-Geodetic Zenith Camera System of the ETH Zürich : DIADEM





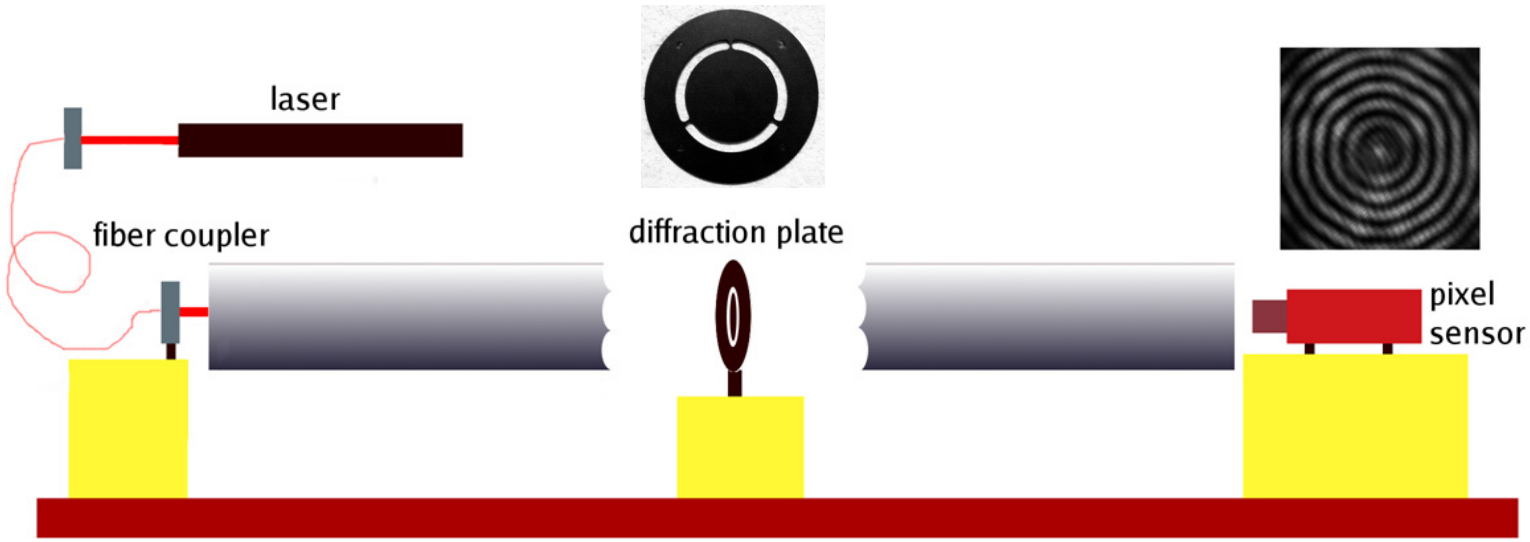
A STRETCHED WIRE AS AN ALIGNMENT REFERENCE

Next studies and tests (summary)…

- To obtain a better knowledge of the parameters that influence the shape of the wire
- 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)
- Gravimetric studies have been undertaken concerning the accuracy which can be obtained concerning the determination of the shape of equipotential surfaces with a relative accuracy of a few microns per 200m.
- Gravimetric measurements as well as vertical deviation measurements are under way at CERN, in collaboration with ETHZ.

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

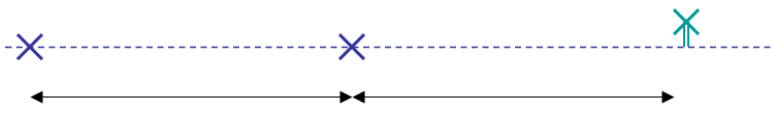
AN OTHER ALIGNMENT SYSTEM: RasCLIC

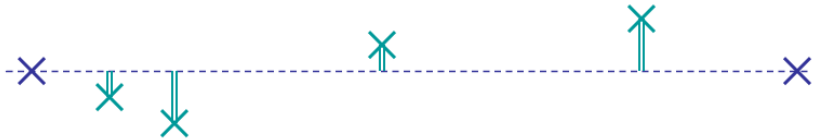


Several upgrades since 2006:

- Extension of the facility up to 140m
- Laser guided to the vacuum tube through an optical fiber
- Sub micrometric resolution
- Low frequency seismograph.

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





STATUS AND PLANS – around 4 key points

- A known and stable alignment reference
- Sub micrometric sensors
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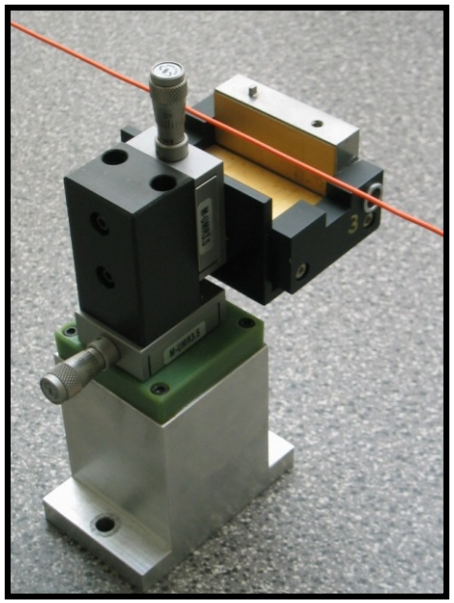
SUITABLE SENSORS

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



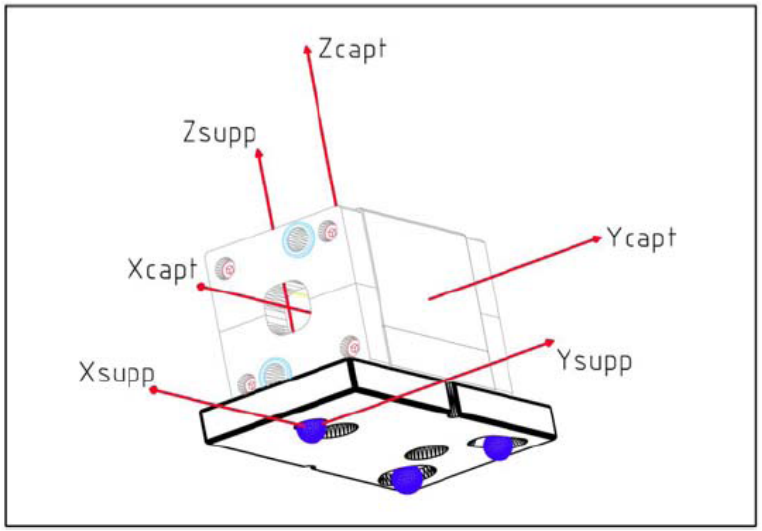
→ Upgrade of the existing capacitive-based WPS sensors

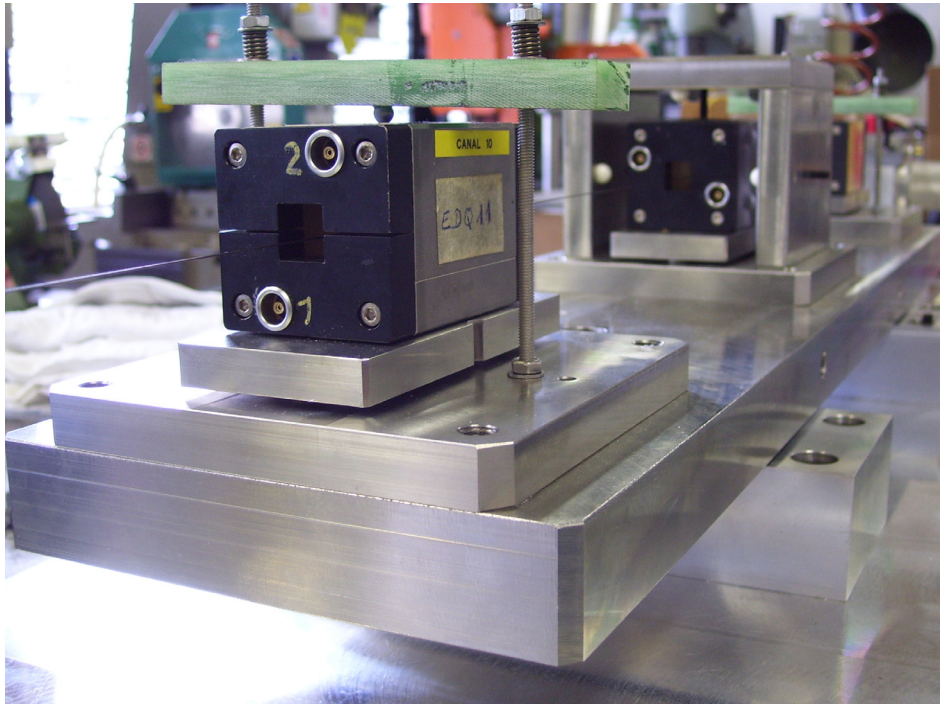
→ Development of an optical -based WPS sensor

SUITABLE SENSORS

Upgrade of the existing capacitive-based WPS sensors

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

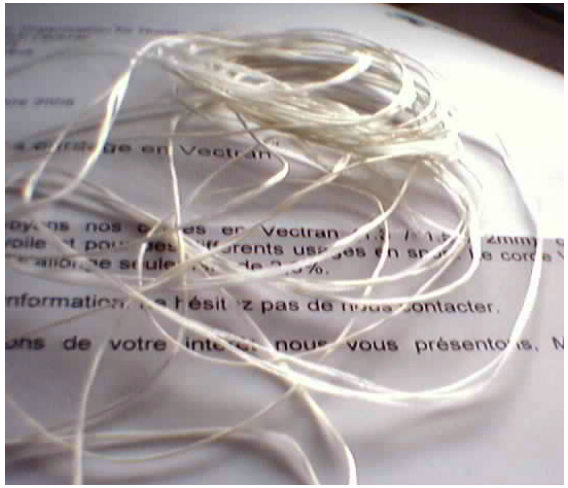




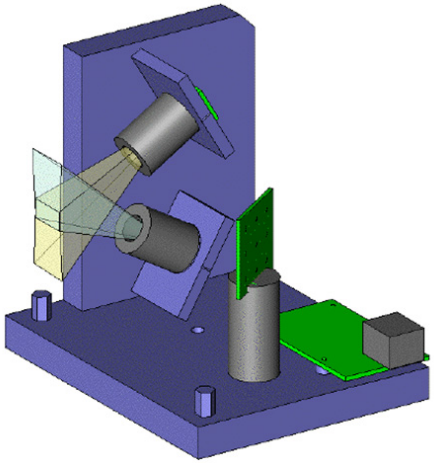
See Thomas' talk

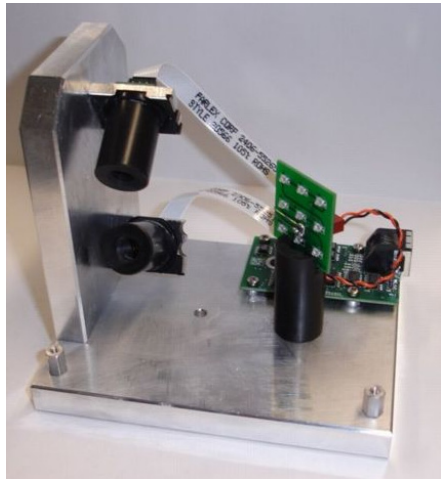
SUITABLE SENSORS

Development of an optical -based WPS sensor



- Promising Vectran wire
- A more suitable mechanical interface
- Absolute measurements within a few microns. (under tests)
- Possibility of auto-calibration?





See Friedrich's talk

STATUS AND PLANS – around 4 key points

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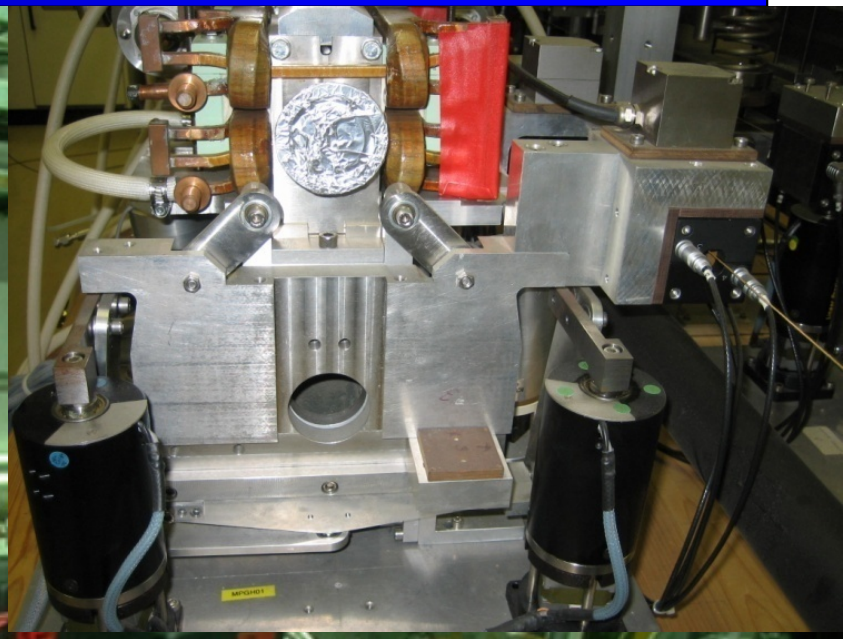
METROLOGY AND FIDUCIALISATION

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…

- 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)
- Fiducialisation within a few microns

METROLOGY AND FIDUCIALISATION

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

- to propose a solution for the fiducialisation, knowing that standard fiducials will be replaced by sensors. The fiducialisation carried out will have to be stable during time (temperature variations, during transport)
- to update the design, and take care of all the level arm effects.
- to finalize the technical specifications concerning the stepper motors in order to buy the prototypes 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.

STATUS AND PLANS – around 4 key points

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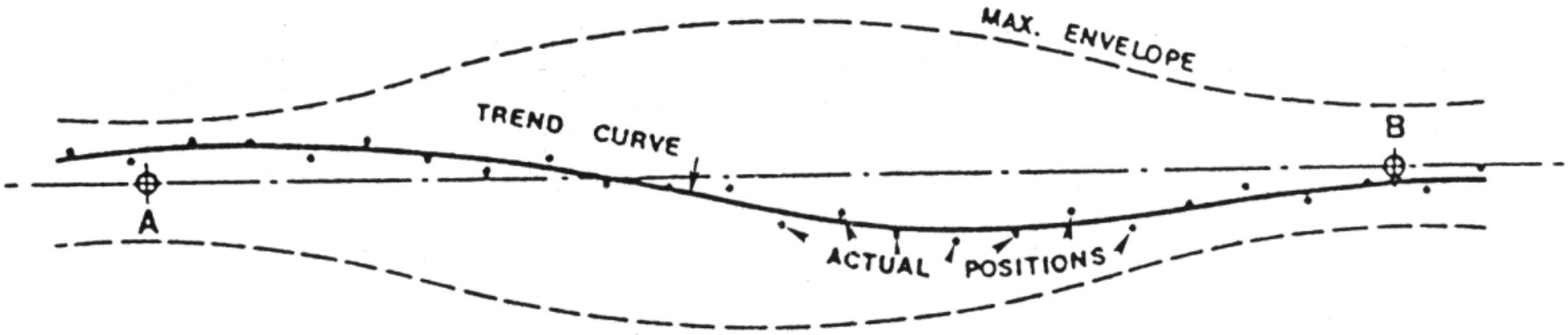
SIMULATIONS

Pre-alignment tolerance : ± 10 microns over 200 m



➔ To simulate the « absolute » uncertainty of position of the CLIC components along the linac, using the Survey standard tools, in order to get additional input for the simulations of the beam dynamics.

CONCLUSION

A R&D strategy is being actively followed.

WPS and HLS sensors are at the core of this strategy.

There is a strong will to open the CLIC studies to the Survey Groups from other labs, and more particularly concerning the development and qualification of sensors.

The studies concerning the sensors could benefit other projects: ILC final focus, LCLS, XFEL, as well as the upgrade of the LHC low beta quadrupoles (foreseen in 2013).

This workshop is a first step towards an inter-comparison between existing sensors.