The CLIC active prealignment studies

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Overview

- The alignment of CLIC
  - Steps of alignment
  - The active prealignment
- The situation of the studies on the active prealignment
  - Studies context
  - Active prealignment solution in 2003
  - Orientation of the studies in 2006
- The TT1 test facility and RASCLIC alignment system

Steps of CLIC alignment

- Installation and determination of a geodetic tunnel network
- Installation and determination of the CLIC girders and quadrupoles w.r.t. the geodetic network
- Implementation of active prealignment

  → 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

CLIC active prealignment requirements

- Active prealignment: ± 10 μm (3σ)

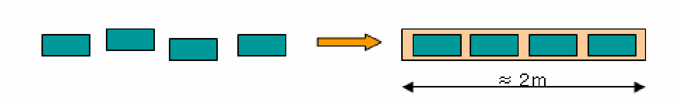
  → needs to be detailed : not the same tolerances for main linac and drive linac, for quadrupoles and girders.

- Tentative for discussion:
  - Main beam:
    - BPM attached to quadrupoles with precision mounts
    - Quadrupoles: active alignment
      - Horizontal and vertical translation: ± 3 μm (1σ) uncertainty
      - Skew: ± 1 μrad (1σ)
    - Beam accelerating structures: active alignment
      - Horizontal and vertical translation: ± 10 μm (1σ) uncertainty
      - Tilt and slope: ± 10 μrad (1σ)
  - Drive linac:
    - BPM attached to quadrupoles with precision mounts
    - Quadrupoles and PETS girders: static prealignment ± 100 μm(1σ)

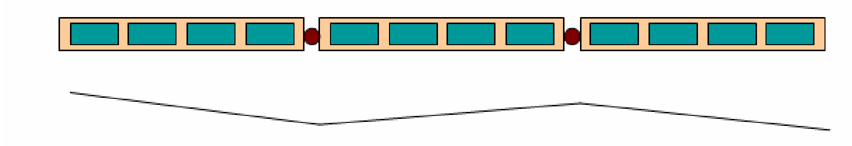
The active prealignment

Current strategy:

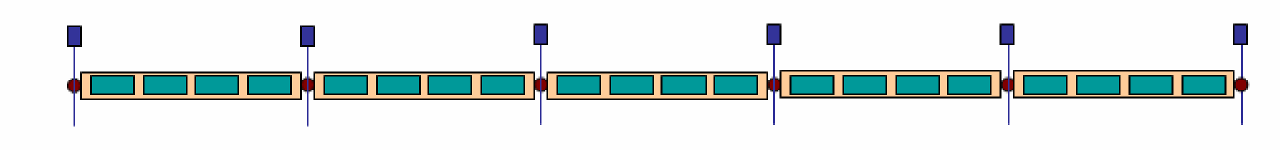
- Simplification of the problem by prealigning components on girders



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

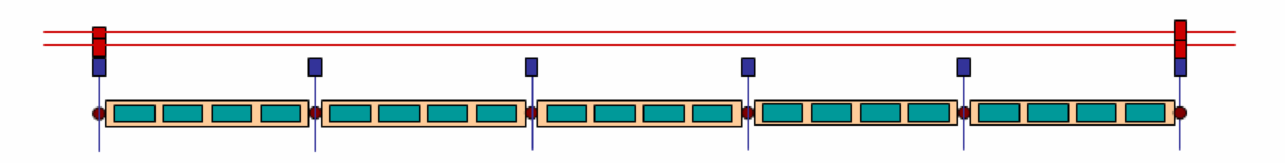


- Association of a « proximity network » to each articulation point

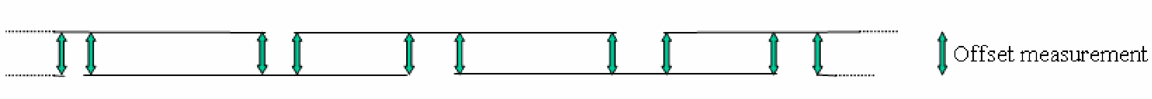


The active prealignment

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



… reference frames overlapping on half of their length

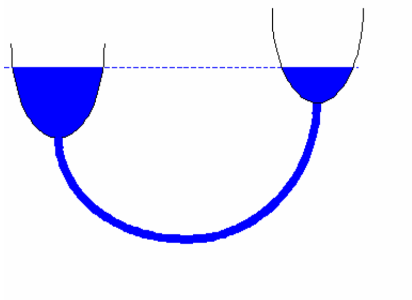


- Quadrupoles (independant from the girders) directly attached to the propagation network

- Different solutions:
  - Proximity network: RASNIK CCD system
  - Propagation network:
    - WPS system (stretched wires over 100m), using HLS system for the modelization
    - RASCLIC system, under development
  - In case of low cost propagation network: the proximity network could be suppressed.

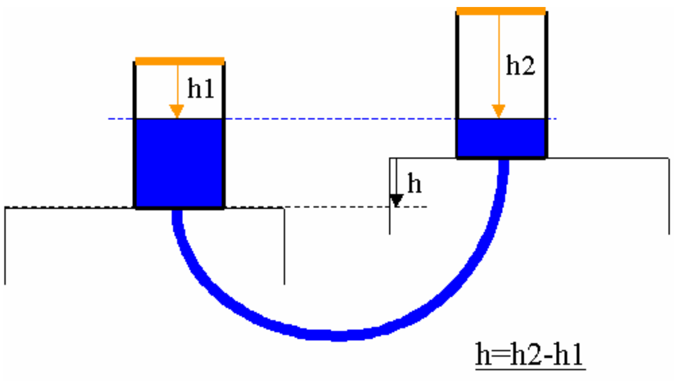
Introduction of alignment systems

- HLS system



- Based on the principle of communicating vessels
- Water network = reference frame
- A sensor is fitted to each vessel to determine the distance to the free surface of the water.
- Capacitive technology

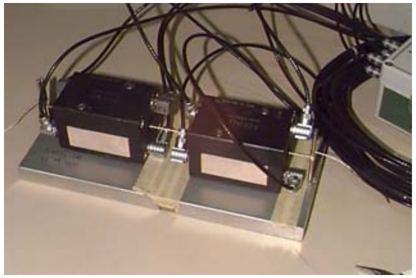
$$C = \frac{\varepsilon_o \varepsilon_r S}{d}$$



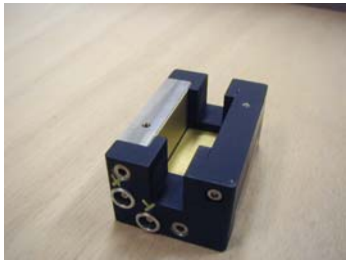
Resolution: 0.2 μm
Range: 5mm
Repeatibility: 1 μm
Bandwidth: 10 Hz

Introduction of alignment systems

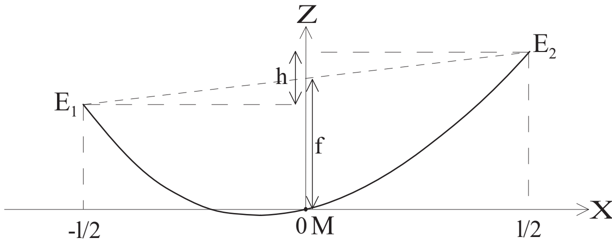
- WPS system



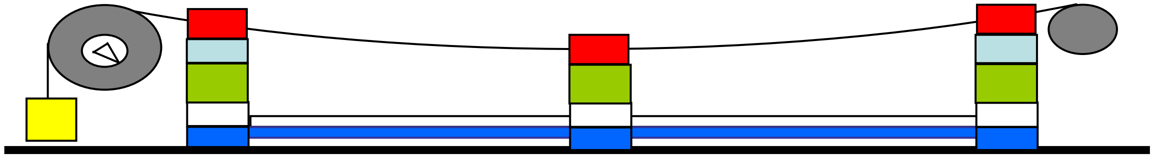
  - Based on capacitive technology
  - Reference frame = stretched wire (carbon peek)
  - Bi axial measurement device



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



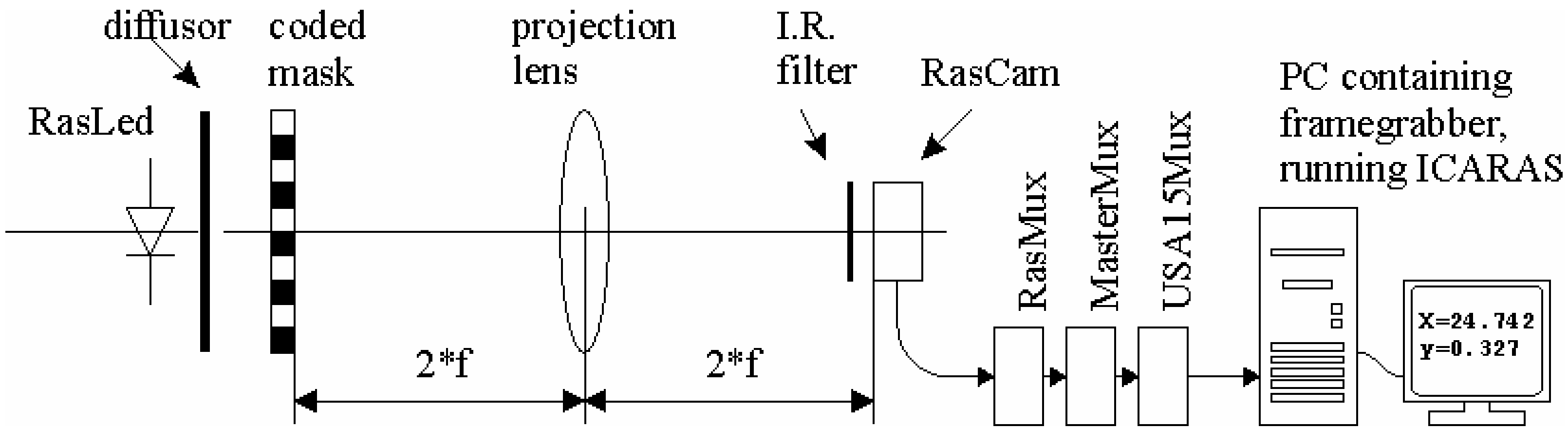
  - In the horizontal plane: wire = straight line
  - In the vertical plane: wire = catenary



  - First tests: modelization with an uncertainty of ± 5 μm

Introduction of alignment systems

- RASNIK system (Red Alignment System from NIKHEF)



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

- Developed by NIKHEF
- Light rays nearly insensitive to gravity
- But limited by the medium over long distances

Summary

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- The situation of the studies on the active prealignment
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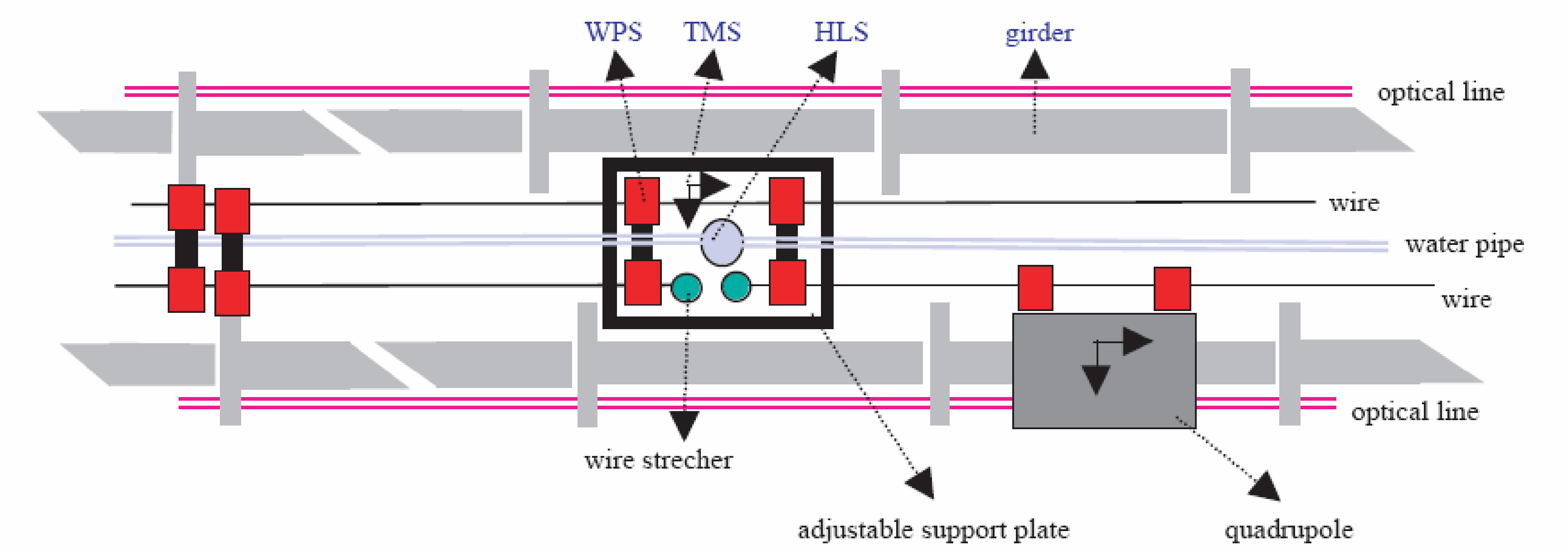
  - Active prealignment solution in 2003
  - Orientation of the studies in 2006
- The TT1 test facility and RASCLIC alignment system

Studies context

- CLIC study “is a site independent feasibility aiming at the development of a realistic technology at an affordable cost for an electron positron linear collider in the post-LHC era for physics up to the multi-TeV center of mass colliding beam energy range (0.5 to 5 TeV).
- Studies focused around these three key points
- Not calling into question all the solutions put forward previously, but trying to find solutions or alternatives to the points remaining, and trying to reduce the costs.
- Studies initiated in 1988 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 2005
- Since 2006: gradually starting again (1 fellow full time)

Active prealignment in 2003



Layout of the planned network

- Based on:
  - RASNIK CCD system for the proximity network (optical line)
  - WPS system for the propagation network (wires of 100m length)
  - HLS system for the wire modelization.

Active prealignment in 2003

- First simulations gave very encouraging results:
  - Uncertainty of relative alignment ranging between 8 and 14 μm on 200m (planimetry and altimetry)
  - Uncertainty of positioning girder to girder of about 5 μm

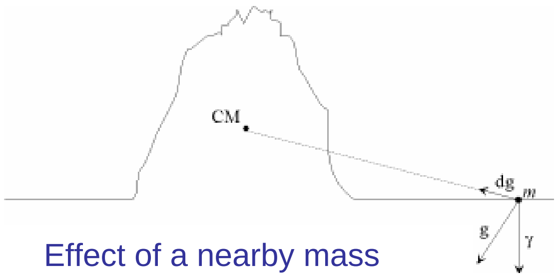
  … but hypotheses taken need to be validated.

- Instrumentation tested on CTF2:
  - The elements on the girders and the quadrupole, were continuously maintained w.r.t. to the wire within a ± 5 μm window and
  - The alignment systems (HLS and WPS) operated reliably in a high radiation environment.

- But, CLIC linacs must follow a straight line, and the reference frames (wire and water) are sensitive to gravity.

Active prealignment in 2003

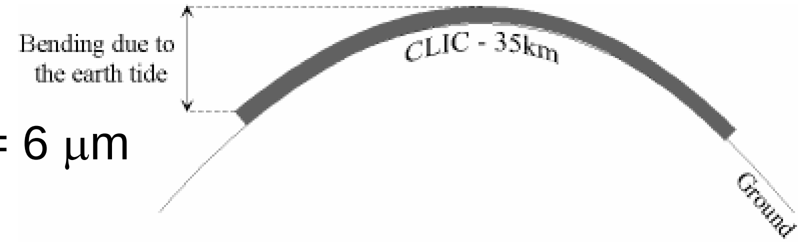
- The reference frames (wire and water surface) are sensitive to gravity:
  - The curvature of the earth, the altitude, latitude
  - The distribution of mass in the neighbourhood



Effect of a nearby mass

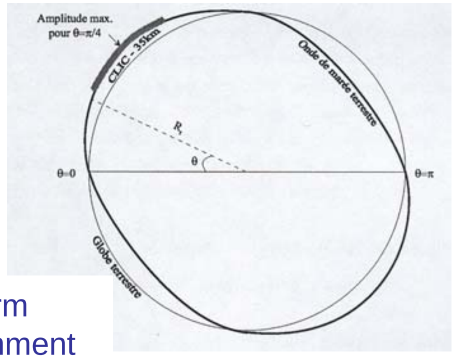
Effect of a nearby mass

  - The attraction of moon and sun



= 6 µm

Bending of the accelerator due to the earth tides



Simplified tidal waveform propagated along the alignment of CLIC

In the most unfavourable conditions:
Maxi. Amplitude: ± 40 cm
Period of elementary component with largest amplitude: 12h

Active prealignment in 2003

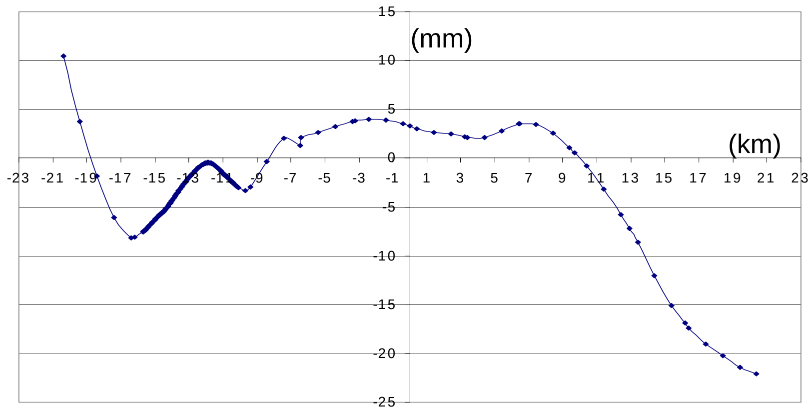
Influence on the WPS system:

The non uniformity of the gravitational field due to combined effect of latitude, altitude and the deviation of the vertical may deform the wire significantly (up to 15μm) but can be corrected (theoretical result to be confirmed by experiment).

Influence on the HLS system:

- ✓ HLS affected by oceanic and earth tides, but corrections can be applied
- ✓ Effect of nearby masses

Geoid profile along CLIC



Uncertainty of the determination of the geoid will be strictly added to the vertical alignment uncertainty.

A knowledge of the geoid within a few microns is very unusual in gravimetry.

Orientation of the studies…

- Studies to undertake to conclude on the feasibility:

  - The maximum achievable precision concerning the definition of the geoïd (in collaboration with the federal Office of Topography of Bern)
  - The search of another method of modelization of a stretched wire (with an uncertainty in the determination of a few microns)
  - The development of a laser solution, in collaboration with NIKHEF
  - The validation of the measurement uncertainties of these alignment systems
  - The integration of the alignment systems in the general layout of the machine (to be solved by CLIC module working group)
  - A final real validation of the solution on CTF3 test beam stand.

  … and of course a lot of interfaces with stability studies, cost study, beam diagnostics,…

...Orientation of the studies

- We need to propose a realistic solution at an affordable cost. Some options:
  - Renegociation of the alignment requirements
  - Increasing the length of a wire on a 500m test facility
  - NIKHEF is studying a low cost solution for the RASNIK system
  - Upgrade of the control command solution of sensors and actuators, in collaboration with the University of Mar del Plata.

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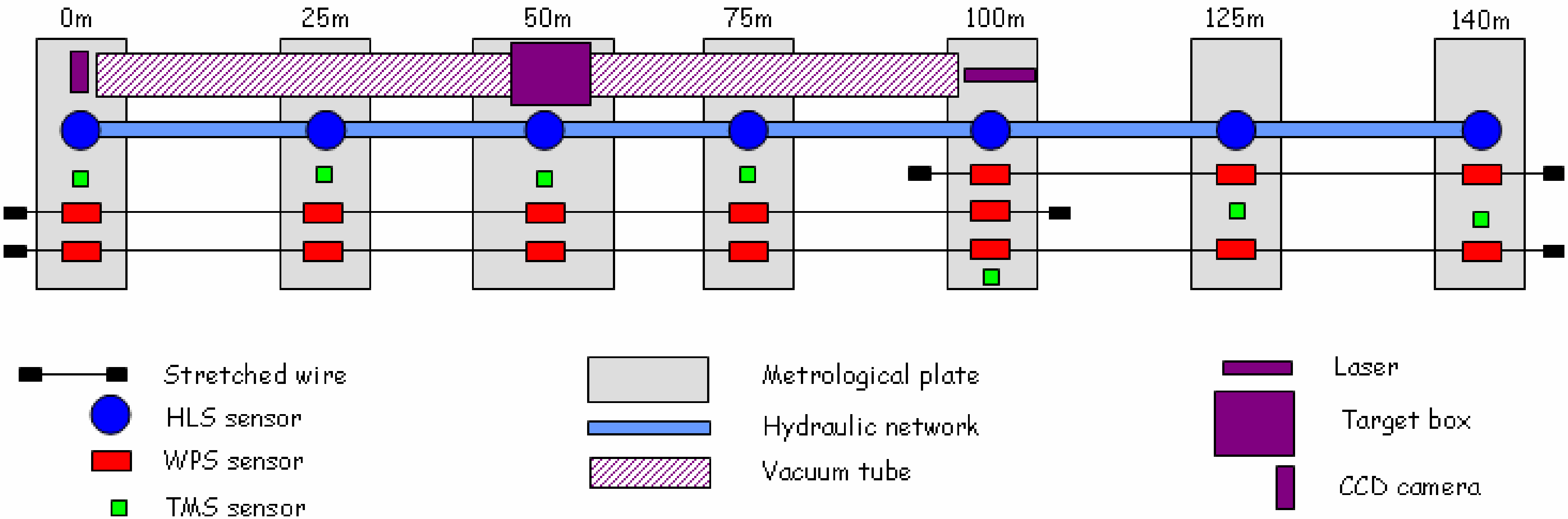
TT1 test facility

Objectives:

- Study the WPS aligment system
  - Problems of wire protection, length
  - Modelization of the wire
  - Other influences (T°, disturbances due to gravity)
- Study the optical RASCLIC
  - Diffraction
  - Loss of coherence of the laser
  - Reflection in the tube
  - Choice of the targets
  - Use of optical fibers
- Compare WPS, HLS, RASCLIC alignment system
- Validate the a priori accuracy chosen for the simulations

TT1 test facility

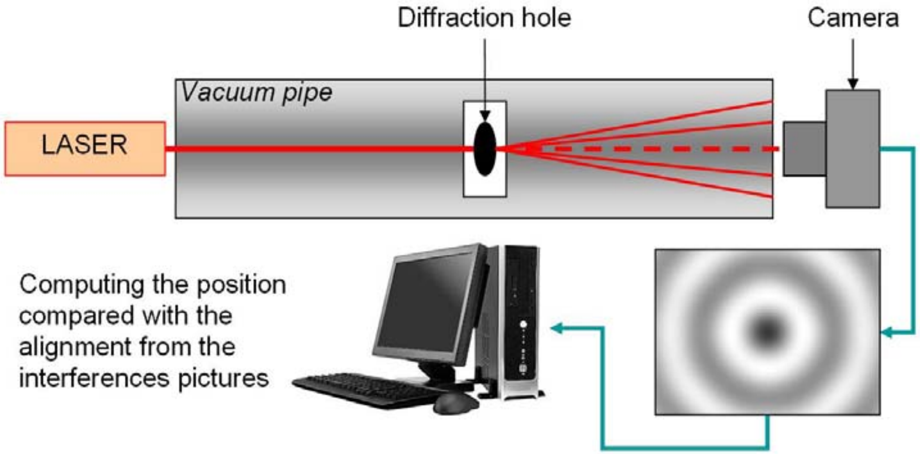


TT1 test facility layout

- Layout close to CLIC active prealignment proposal of 2003
- Two parallel overlapping lines of wires
- Each plate is laid on moveable supports

RASCLIC alignment system

- Objective: to provide transverse positional data on targets distributed over 100m, with an uncertainty of measurement better than 5µm.
- Straight line= laser line between source and detector under vacuum
- First idea: target with a hole in order to determine the center of the diffraction patterns
- One disadvantage: mechanics moving each target very complicated.

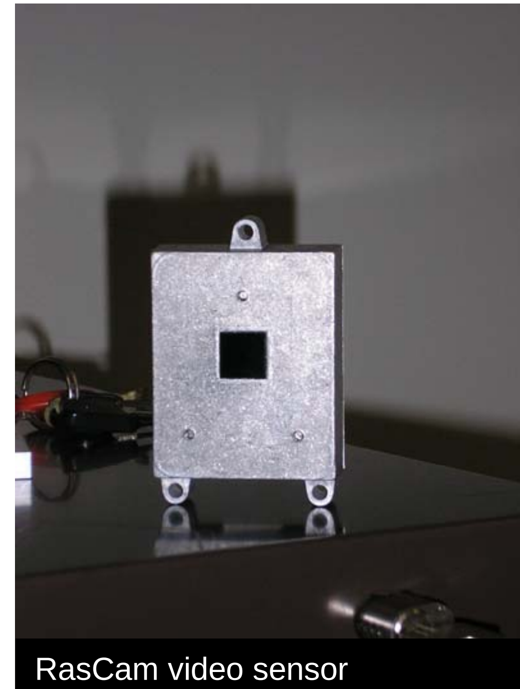


RASCLIC concept

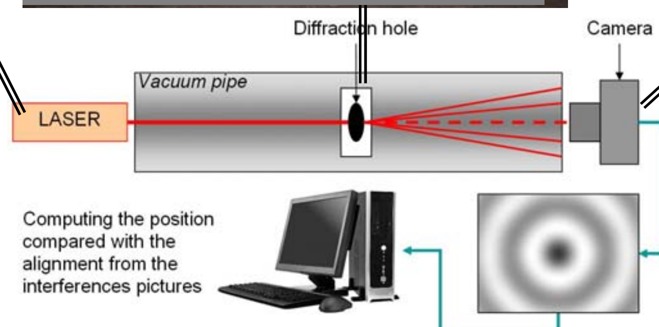
RASCLIC alignment system

RASCLIC laser and its support

Some examples of targets

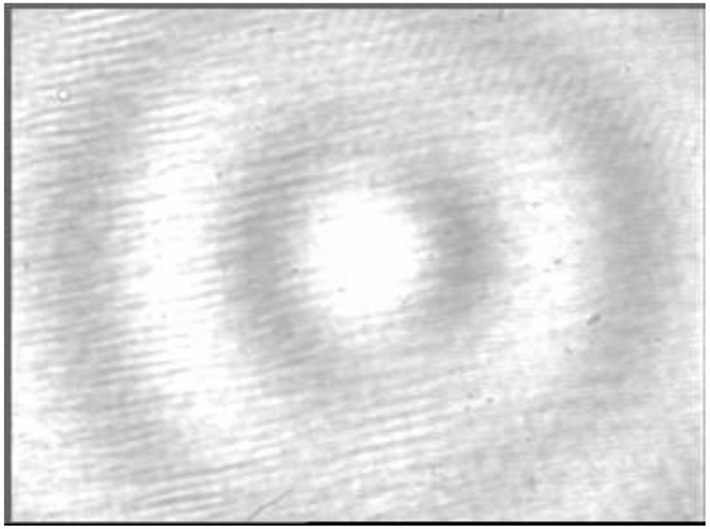


RasCam video sensor

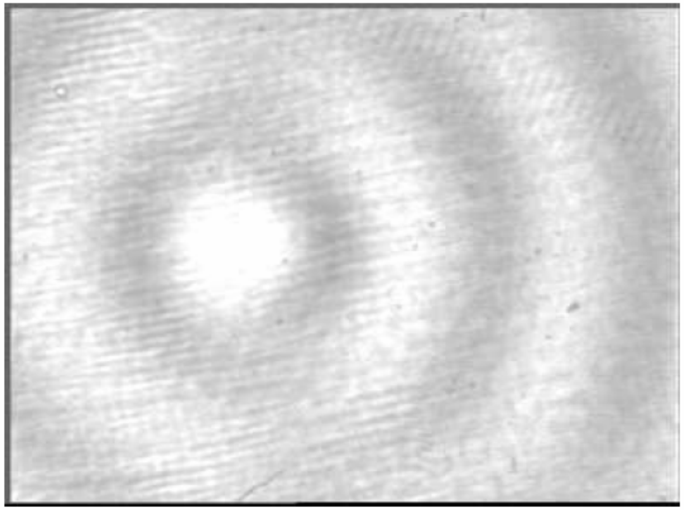


RASCLIC alignment system

- First images:



Interference pattern in the RasCam video

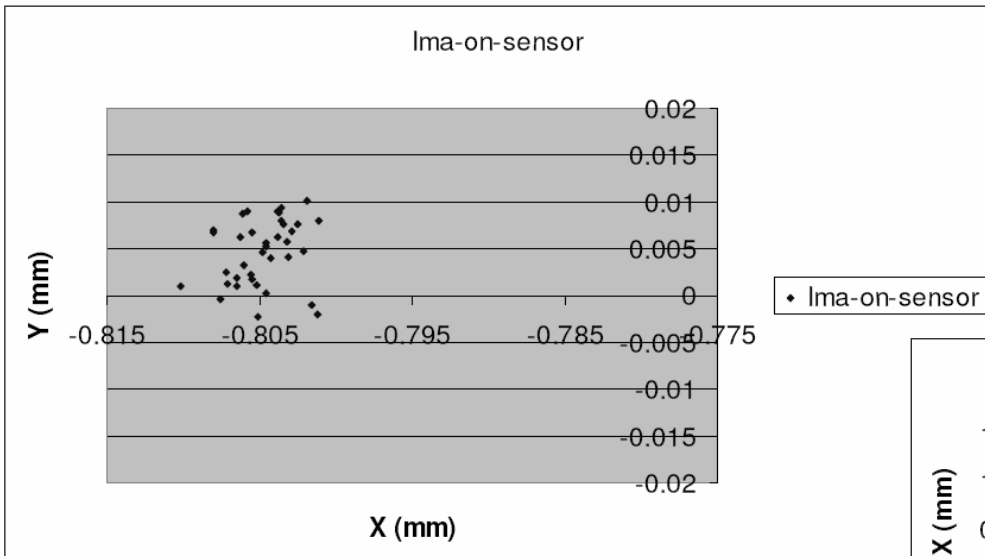


Diffraction pattern after shiting the zone lens 400μm. (shift of 800μm on the RasCam sensor).

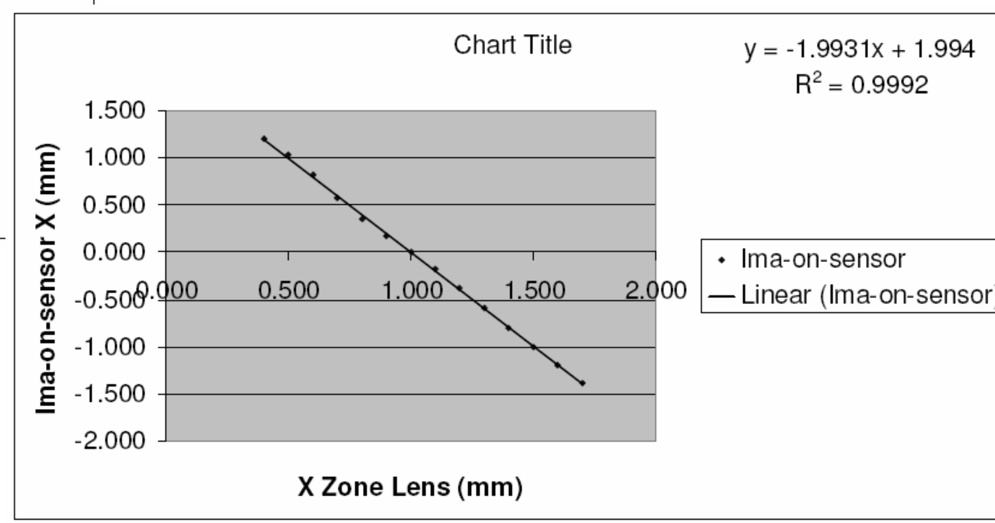
[By courtesy of H. Van der Graaf (NIKHEF)]

RASCLIC alignment system

- First data: measured displacements of images on sensor (not under vacuum)



Measured (X,Y) displacements of images on sensor



[By courtesy of H. Van der Graaf (NIKHEF)]

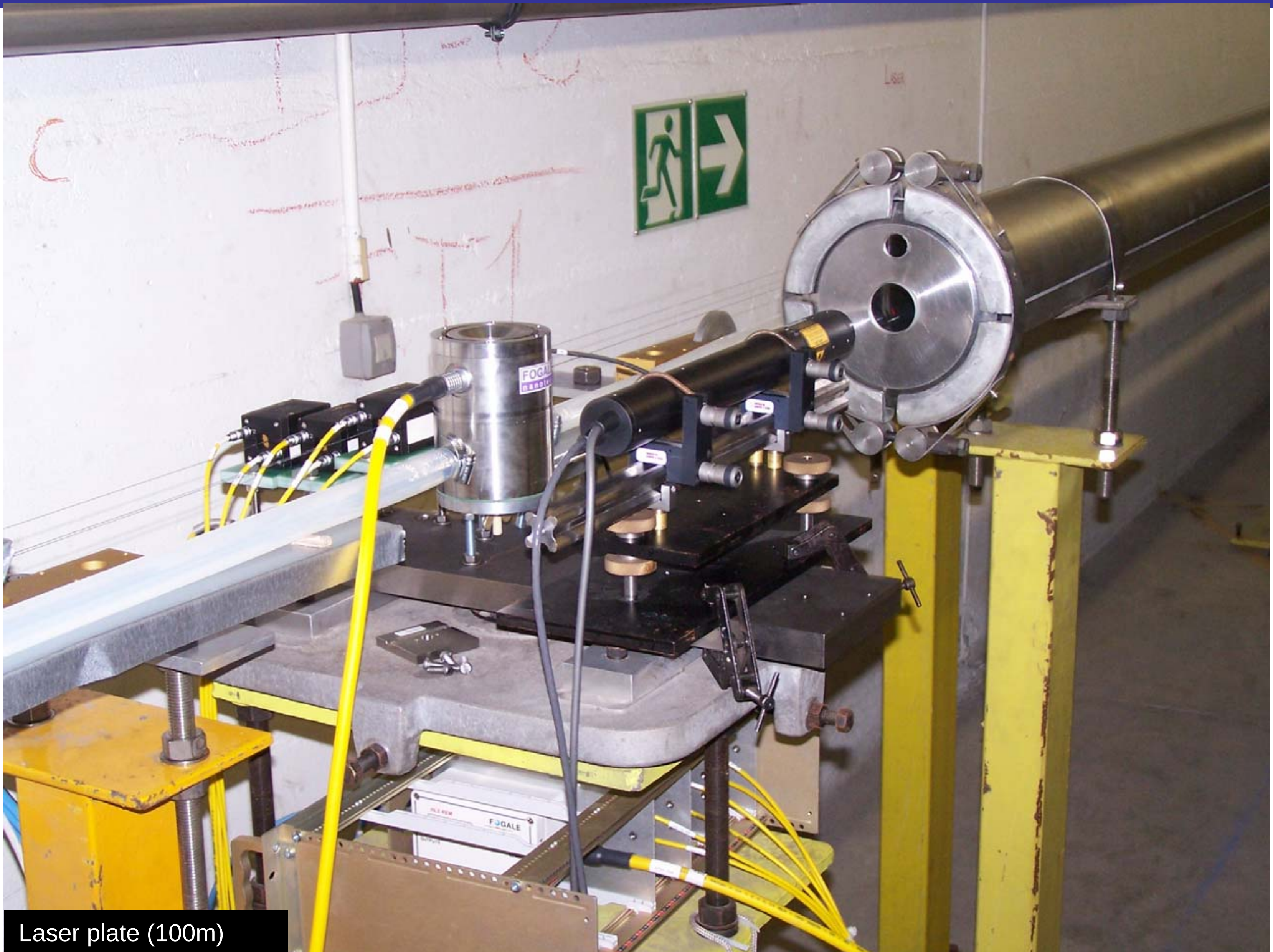
The relation between measured image position on the sensor and the position of the zone lens

TT1 test facility

Special thanks to: AB/ATB/EA

TT1 tunnel

TT1 test facility



Laser plate (100m)

TT1 test facility

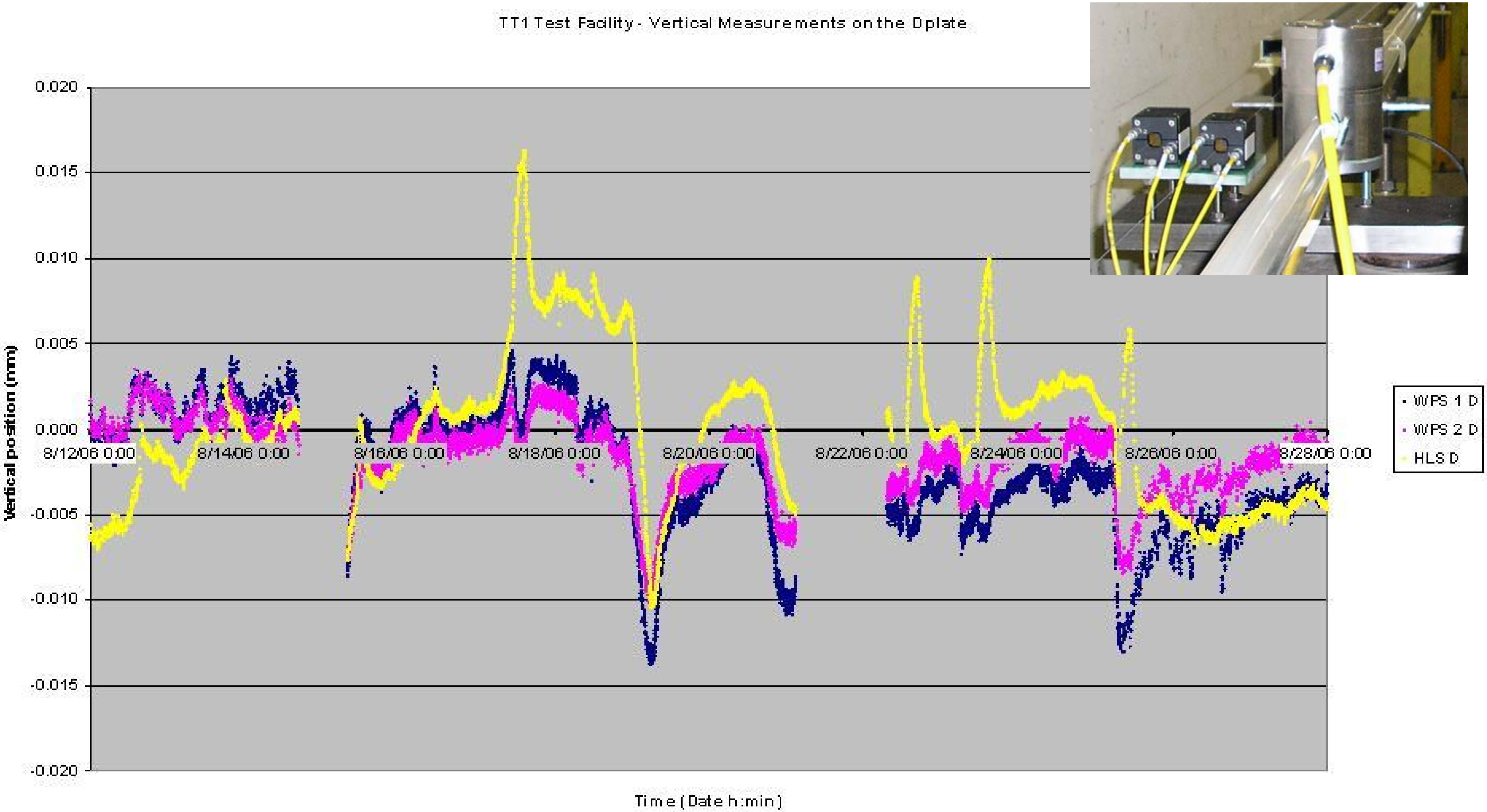

Target plate (50m)


Last plate (140m)

TT1 test facility

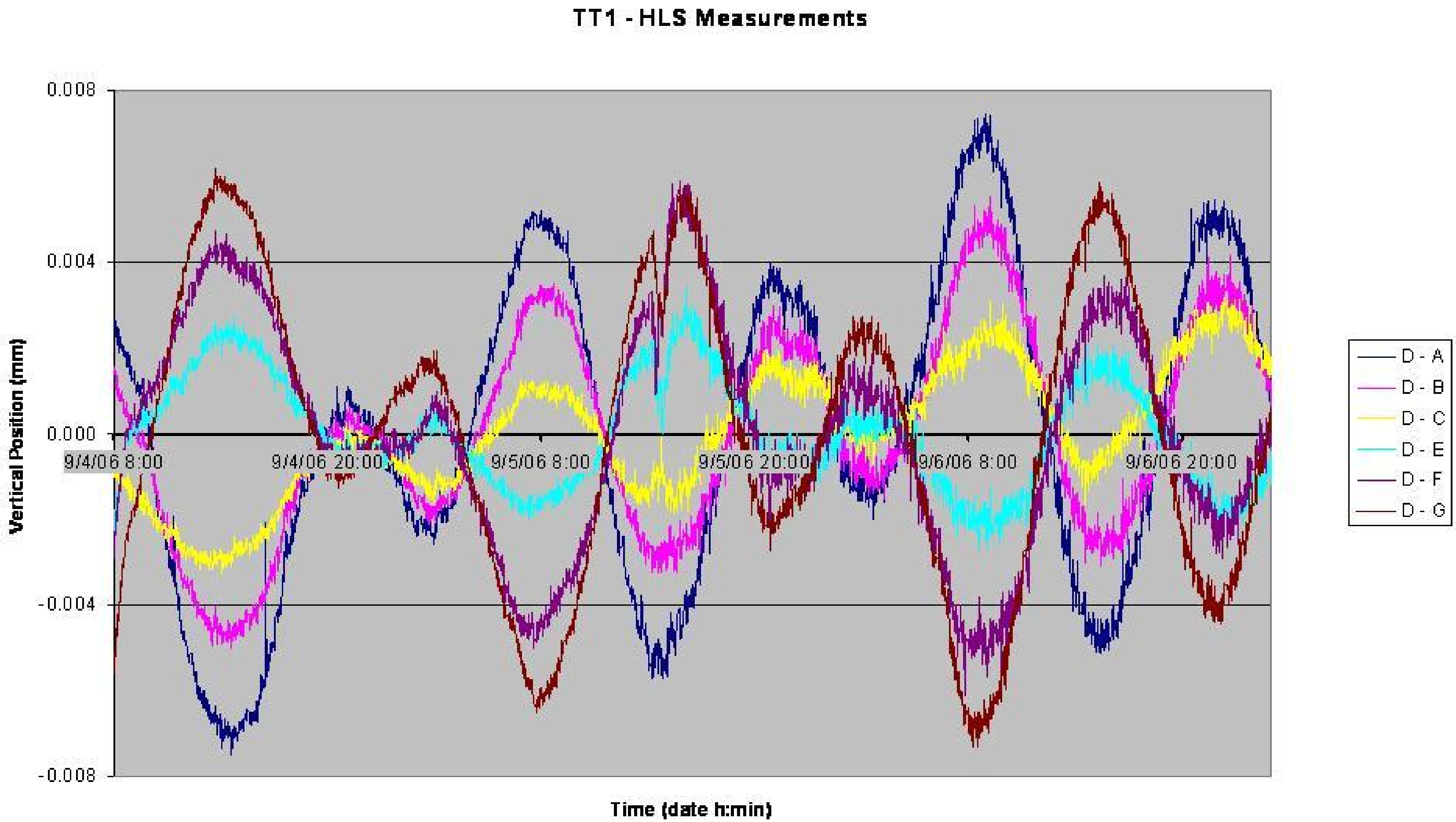
The different alignment networks

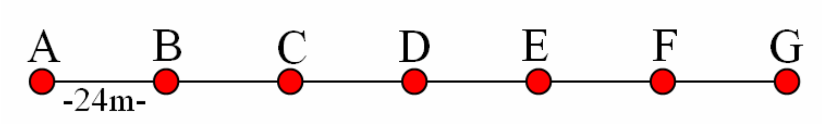
Some first results



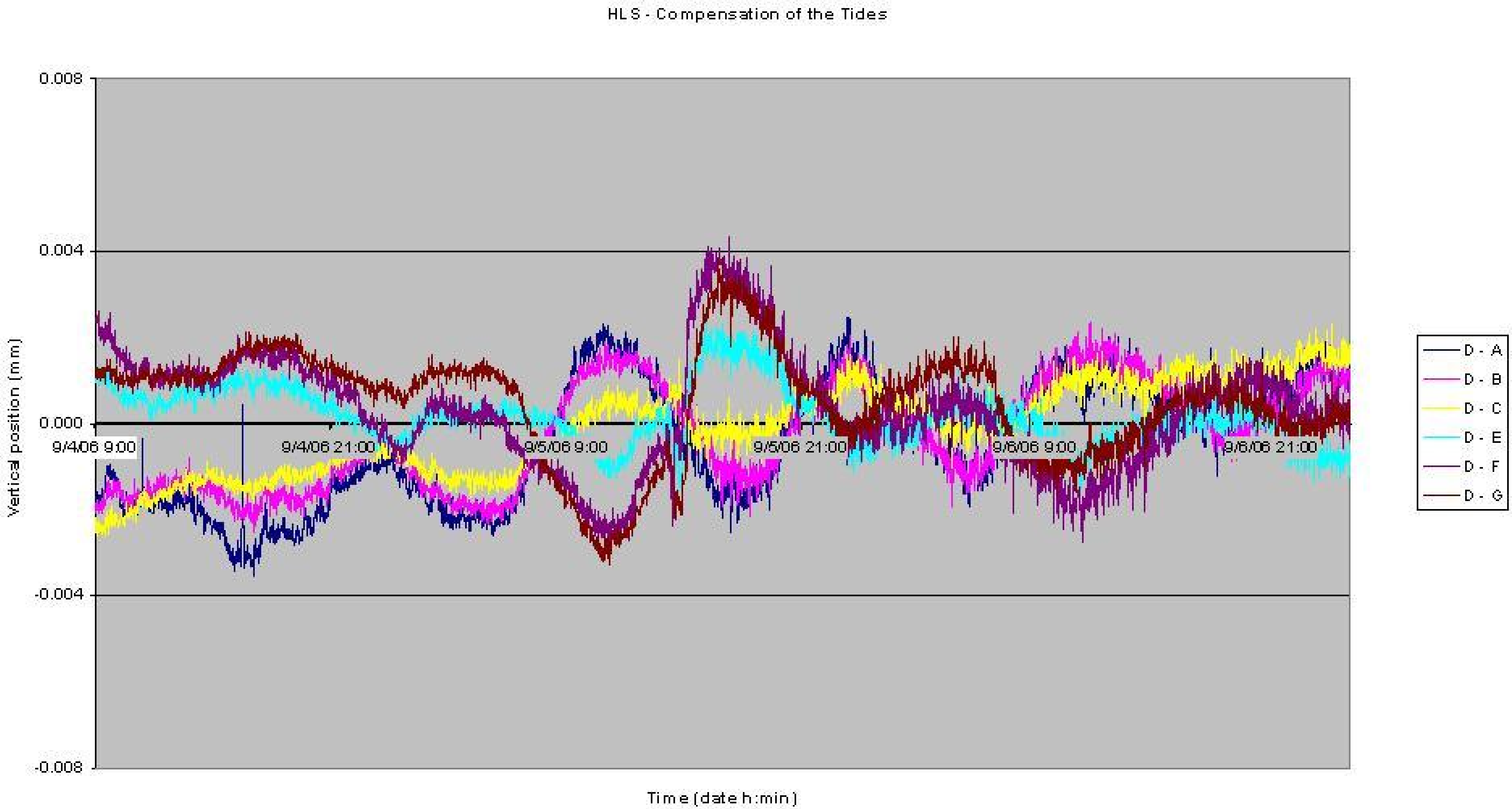
WPS and HLS stability measurements

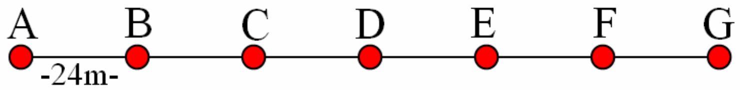
Some first results





Some first results





Conclusion

The active prealignment on a linear collider with a tolerance of ± 10μm over a sliding window of 200m is a challenge.

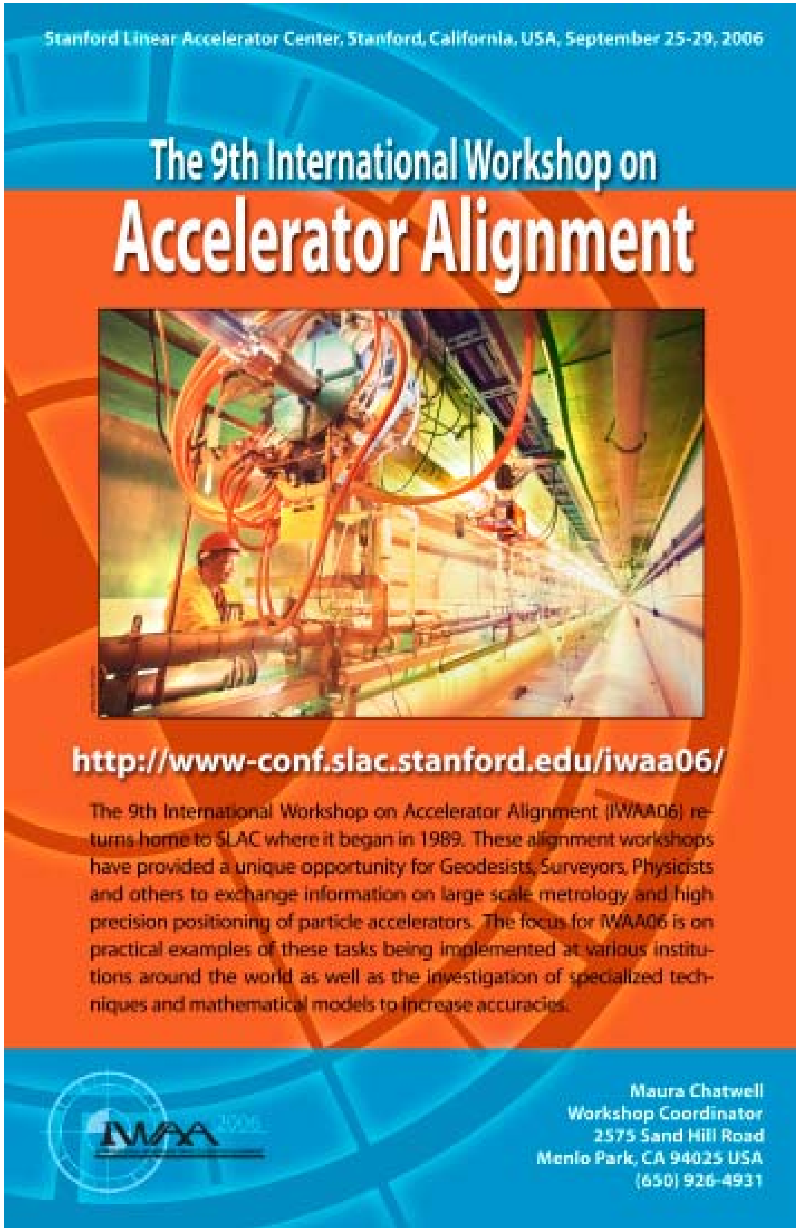
Since 1989, we have showed that it is not an Utopia.

WPS, HLS, RASNIK alignment systems tested and in some cases developped at that time are now used successfully on various applications.

One major point of the solution proposed in 2003 needs to be solved: the use of stretched wires for vertical measurements. 3 solutions /alternatives are explored. A fourth one could be to associate WPS with a « 3 points RASCLIC system » allowing to modelize the wire.

We also need to go on exploring new options, other possibilities of reducing the cost like longer stretched wires, other configurations of sensors, alignment systems or methods…

Conclusion


Stanford Linear Accelerator Center, Stanford, California, USA, September 25-29, 2006
The 9th International Workshop on
Accelerator Alignment
http://www-conf.slac.stanford.edu/iwaa06/
The 9th International Workshop on Accelerator Alignment (IWAA06) returns home to SLAC where it began in 1989. These alignment workshops have provided a unique opportunity for Geodesists, Surveyors, Physicists and others to exchange information on large scale metrology and high precision positioning of particle accelerators. The focus for IWAA06 is on practical examples of these tasks being implemented at various institutions around the world as well as the investigation of specialized techniques and mathematical models to increase accuracies.
IWAA
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