THE ACTIVE PREALIGNMENT OF THE CLIC COMPONENTS

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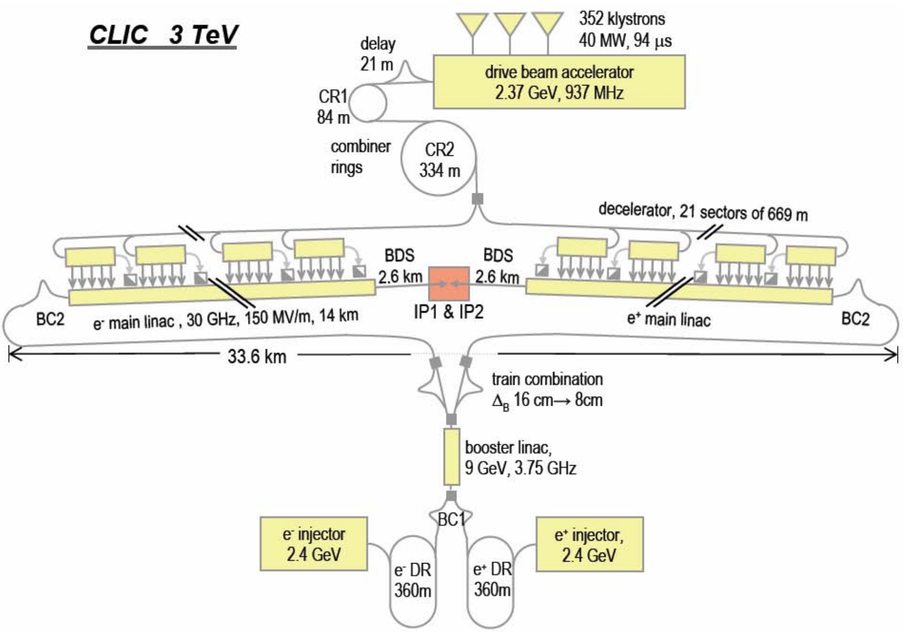
CERN

Overview

- Introduction : the CLIC study
- 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

The CLIC study



Overall layout of CLIC for a center of mass energy of 3 TeV.

High acceleration gradient (150 MV/m)

- "Compact" collider - overall length < 40 km
- Normal conducting accelerating structures
- High RF frequency (30 GHz)

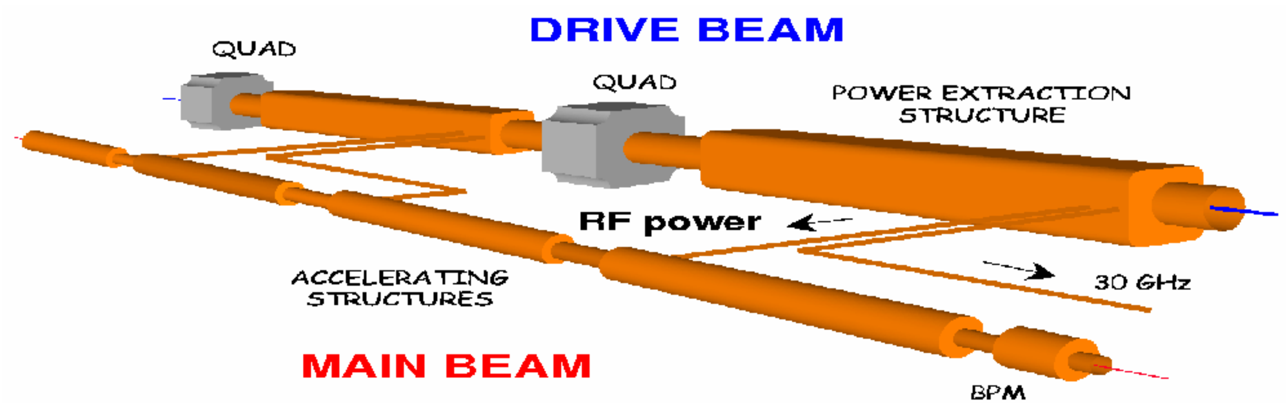
Two-Beam Acceleration Scheme

- Capable to reach high frequency
- Cost-effective & efficient (~ 10% overall)
- Simple tunnel, no active elements

Central injector complex

- "Modular" design, can be built in stages

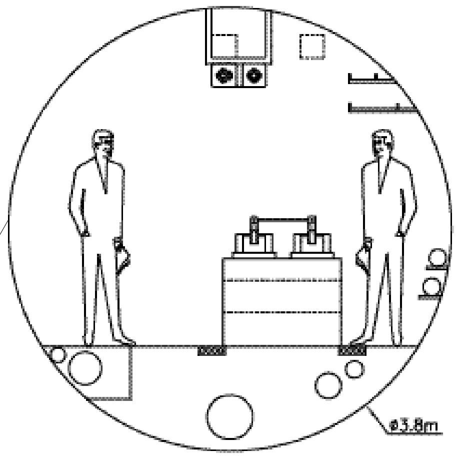
The CLIC study



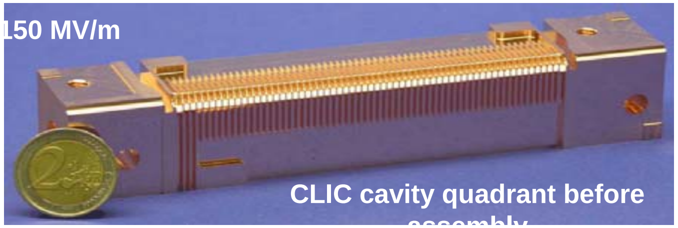
CLIC module layout

CLIC tunnel cross-section

3.8 m diameter

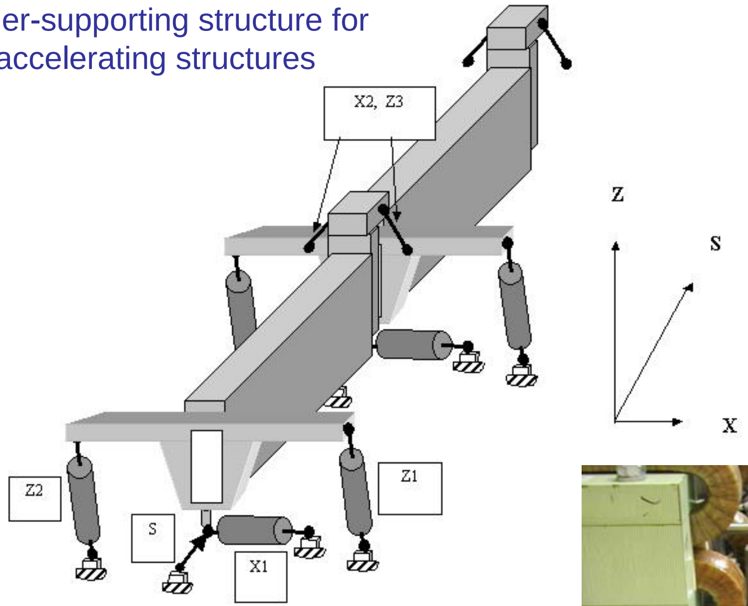


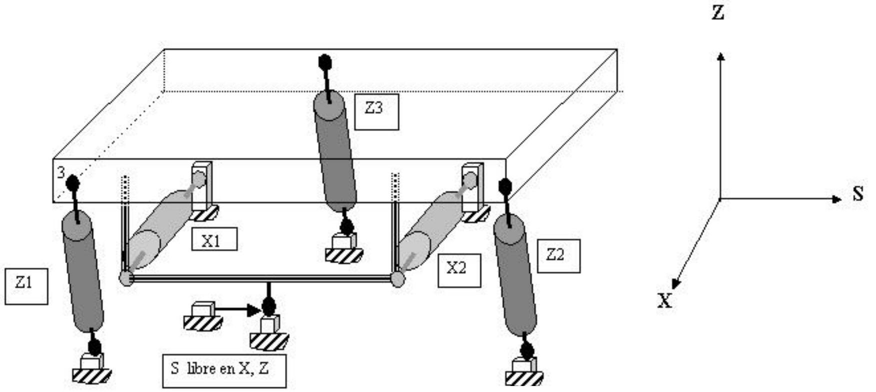
- Two Beam Acceleration (TBA) concept:
  - 30 GHz RF power generated by a high current electron beam
  - Drive beam decelerated in PETS and generated RF power transferred to the main beam



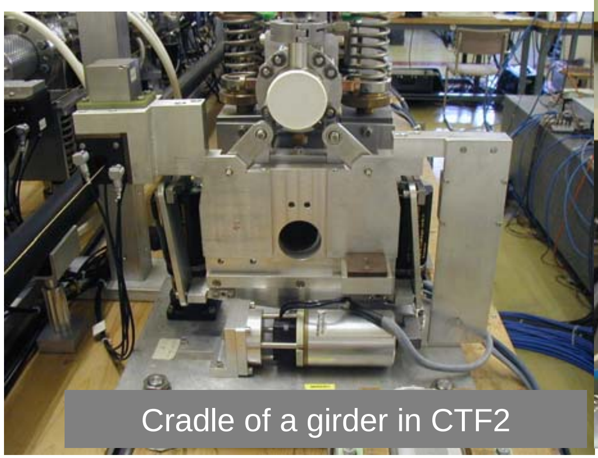
The CLIC study

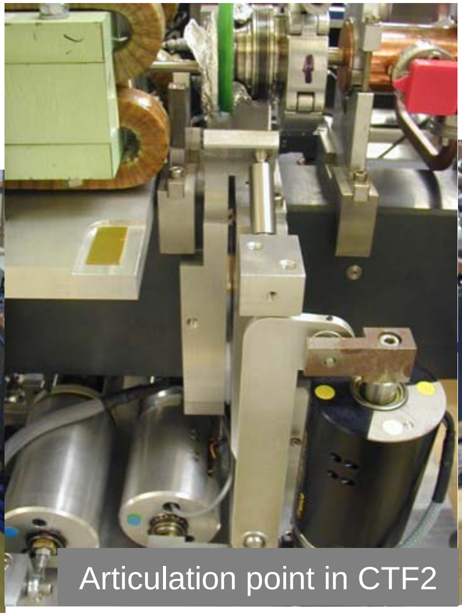
Girder-supporting structure for accelerating structures

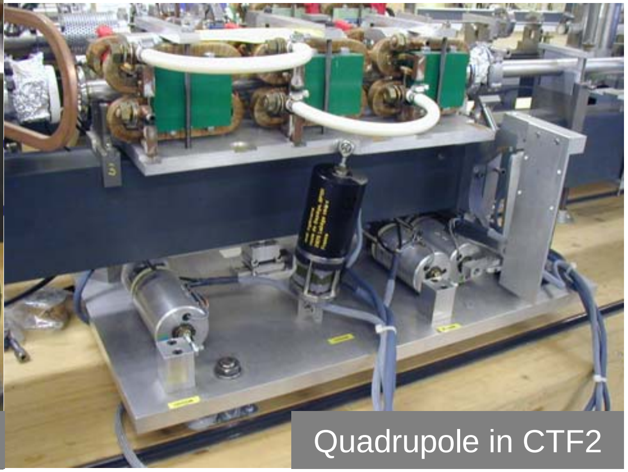




Support structure quadrupole


Cradle of a girder in CTF2


Articulation point in CTF2


Quadrupole in CTF2

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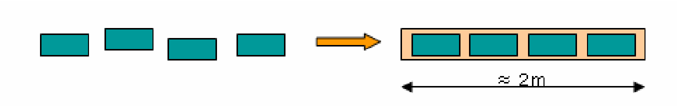
Steps of CLIC alignment

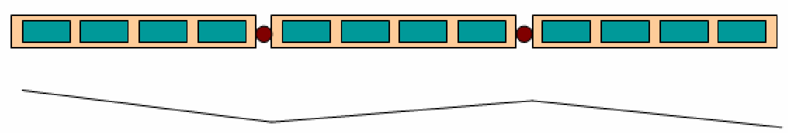
- Installation and determination of a geodetic tunnel network
- Installation and determination of the CLIC girders and quadrupoles w.r.t. the geodetic network
- Implementation of active prealignment → Girders and quadrupoles within ± 10 μm (3σ)
- Implementation of beam based alignment → Active positioning to the micron level
- Implementation of beam based feedbacks → Stability to the nanometer level

The active prealignment

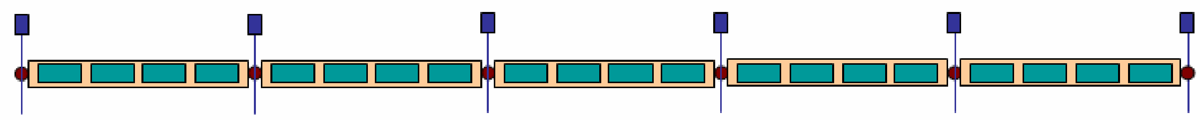
- Simplification of the problem by prealigning components on girders



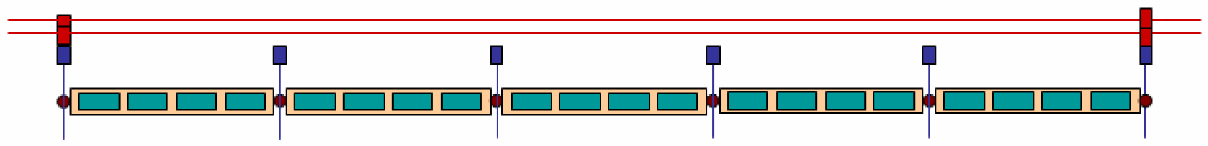
- Simplification of the alignment by linking adjacent girders by a common articulation point



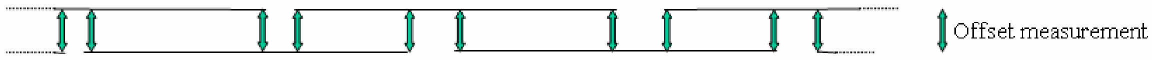
- Association of a « proximity network » to each articulation point



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



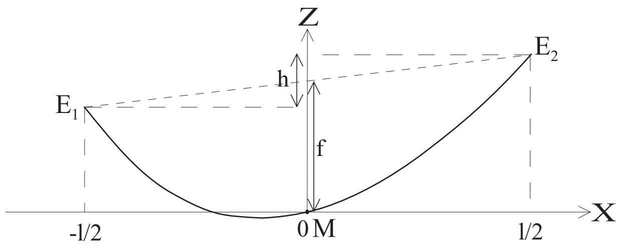
… reference frames overlapping on half of their length



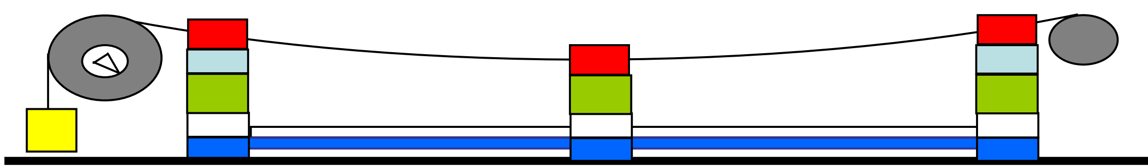
The active prealignment

- 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.



Wire with ends at different heights



Modlization of a wire using HLS sensors surrounded by WPS sensors.

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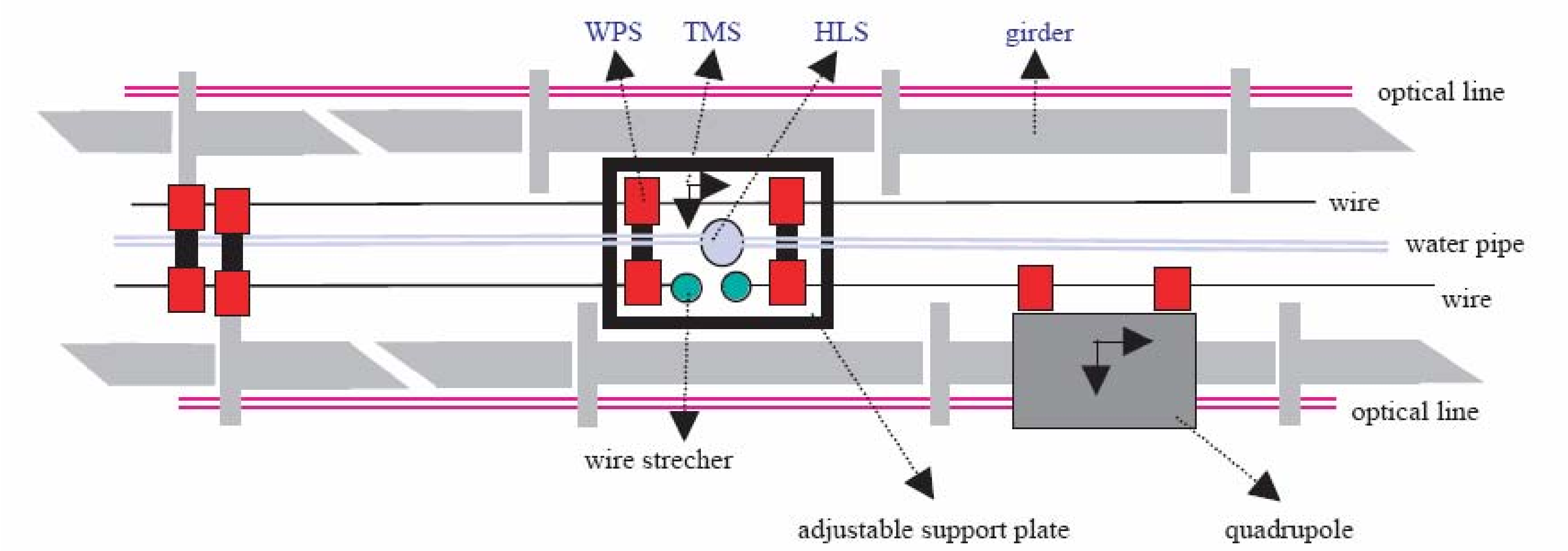
Studies context

- CLIC aim : develop technology for e+ e- collider with E_{CM}=1-5TeV.
- Present mandate: demonstrate all key feasibility issues by 2010
- Aim to provide the High Energy Physics community with the feasibility of CLIC technology for Linear Collider in due time, when physics needs will be fully determined following LHC results
- Safety net to the SC technology in case sub-TeV energy range is not considered attractive enough for physics.

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, W. Schnell and
- In 2003: one global solution proposed, with some points to be solved
- Studies stopped between 2003 and 2005 (LHC priority)
- 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.

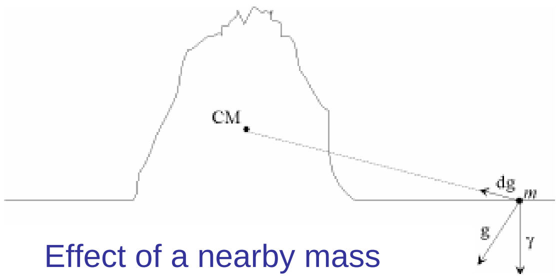
- Instrumentation tested on CTF2:
  - The elements on the girders and the quadrupole, were continuously maintained w.r.t. to the wire within a ± 5 μm window and
  - The alignment systems (HLS and WPS) operated reliably in a high radiation environment.

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

Active prealignment in 2003

- The metrology network must allow the rectilinear alignment of each of the 2 linacs.

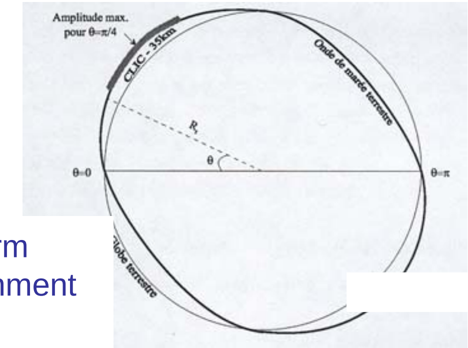
- The reference frames (wire and water surface) are sensitive to gravity:
  - The curvature of the earth, the altitude, latitude
  - The distribution of mass in the neighbourhood



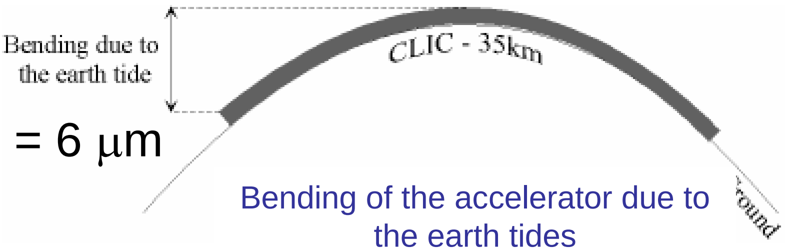
Effect of a nearby mass

Effect of a nearby mass

  - The attraction of moon and sun



Simplified tidal waveform propagated along the alignment of CLIC



Bending of the accelerator due to the earth tides

In the most unfavourable conditions:

Maxi. Amplitude: ± 40 cm

Period of elementary component with largest amplitude: 12h

Active prealignment in 2003

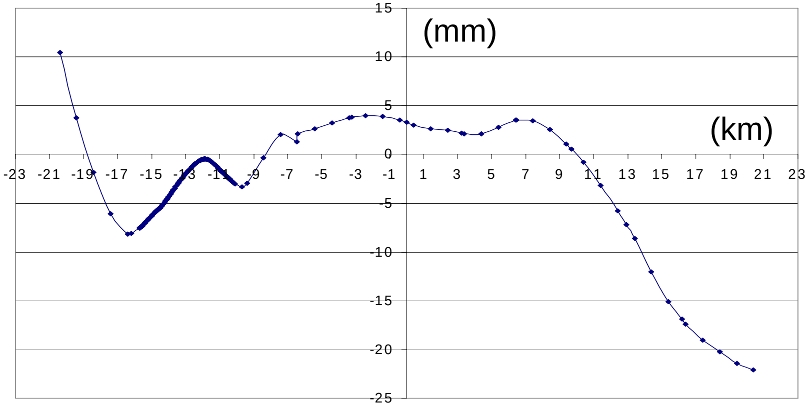
Influence on the WPS system:

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 determination of the geoïd
  - 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
  - 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 solution at a realistic and affordable cost. Some tracks:
  - 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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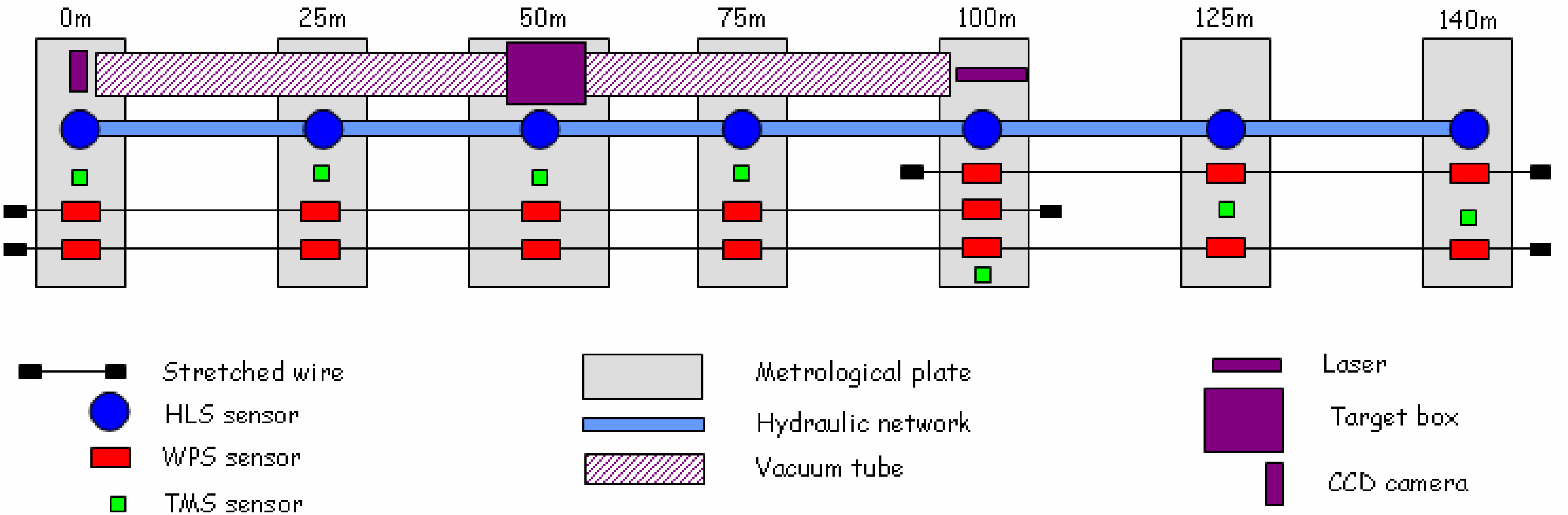
TT1 test facility

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

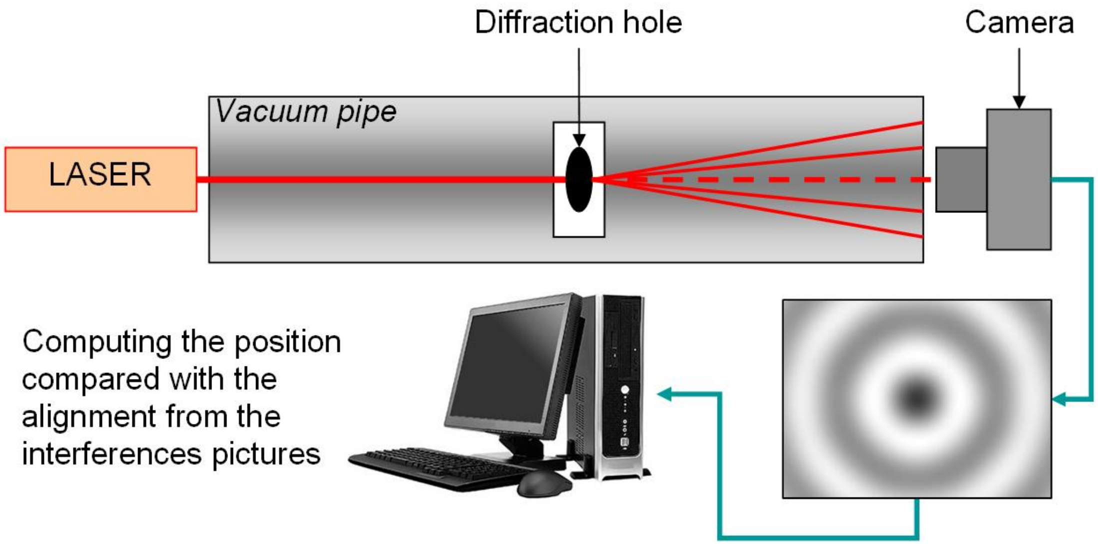
- Layout close to CLIC active prealignment proposal of 2003
- Two parallel overlapping lines
- Each plate is laid on moveable supports

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

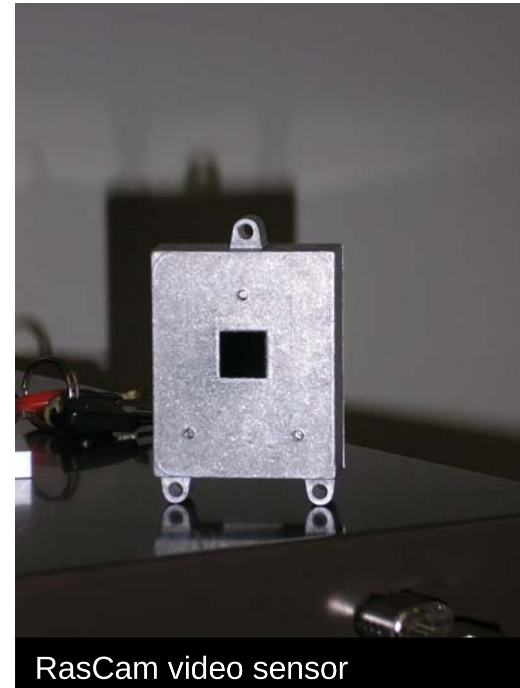


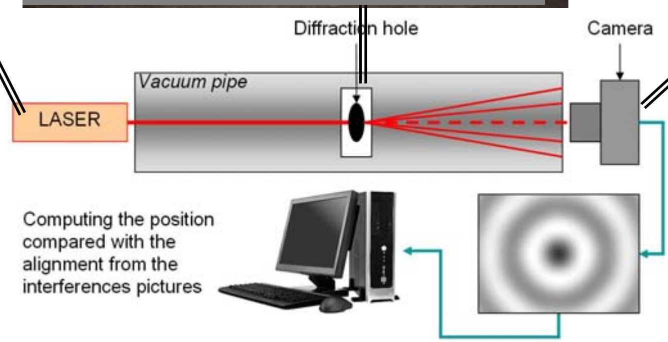
RASCLIC concept

RASCLIC alignment system


RASCLIC laser and its support

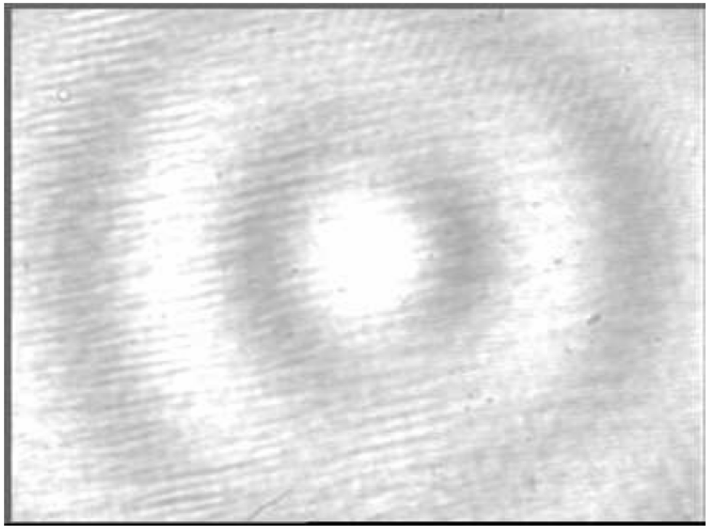

Some examples of targets


RasCam video sensor

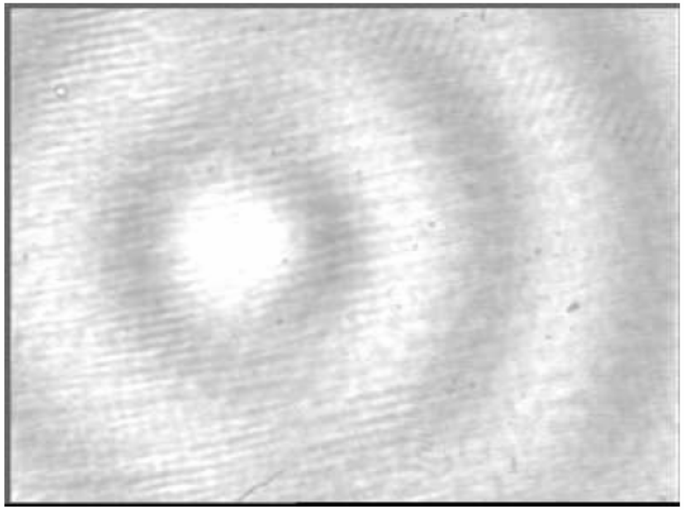


RASCLIC alignment system

- First images:



Interference pattern in the RasCam video

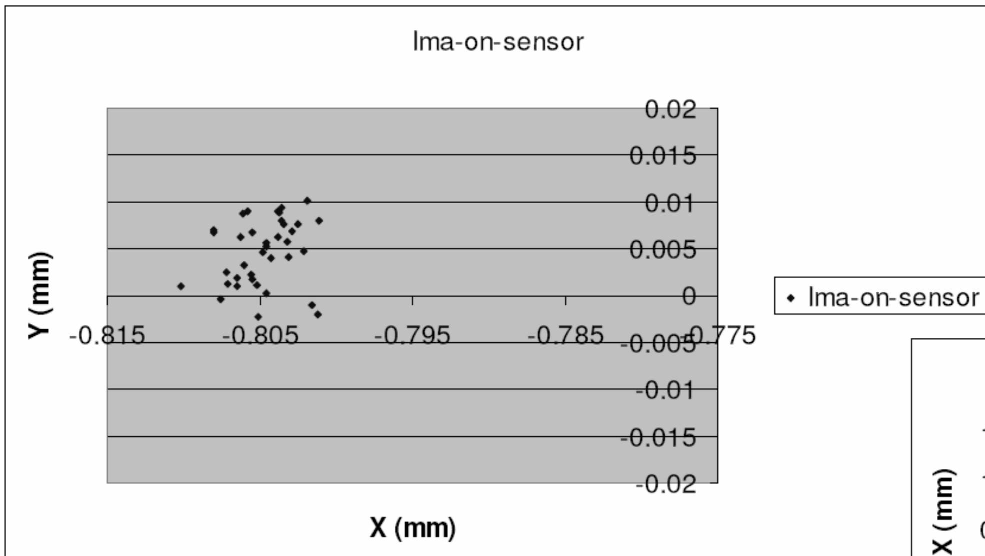


Diffraction pattern after shiting the zone lens 400μm. (shift of 800μm on the RasCam sensor).

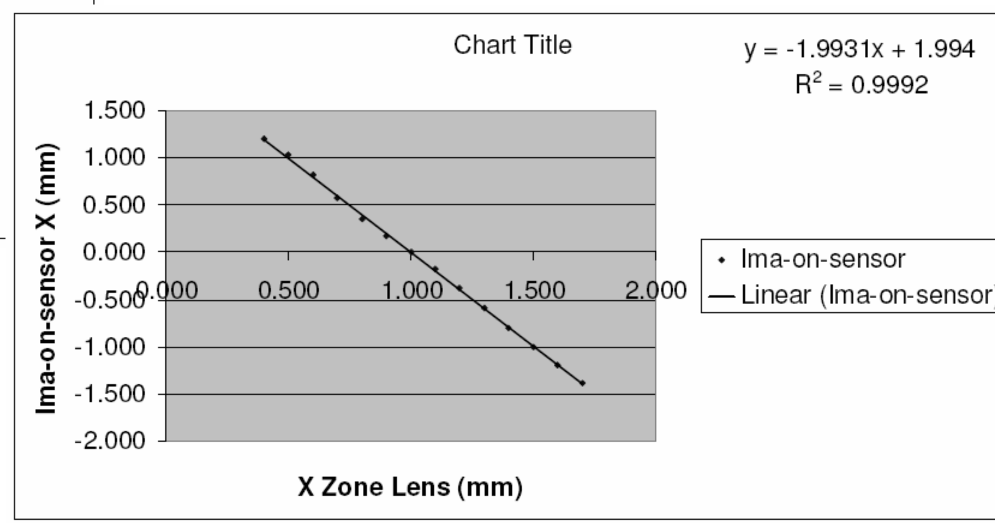
[By courtesy of H. Van der Graaf (NIKHEF)]

RASCLIC alignment system

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



Measured (X,Y) displacements of images on sensor



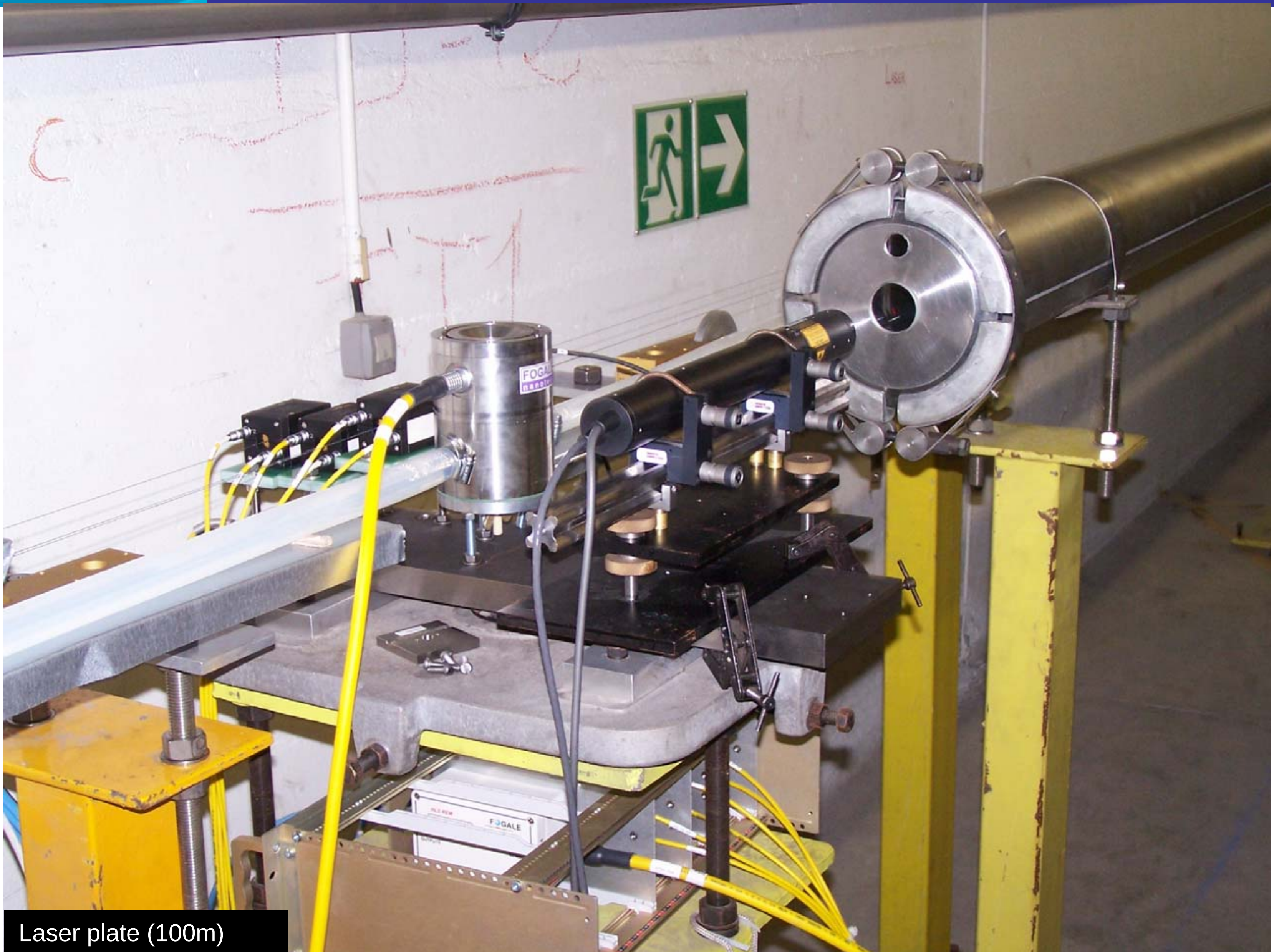
The relation between measured image position on the sensor and the position of the zone lens

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

TT1 test facility

TT1 tunnel

TT1 test facility



Laser plate (100m)

TT1 test facility

Target plate (50m)


Last plate (140m)

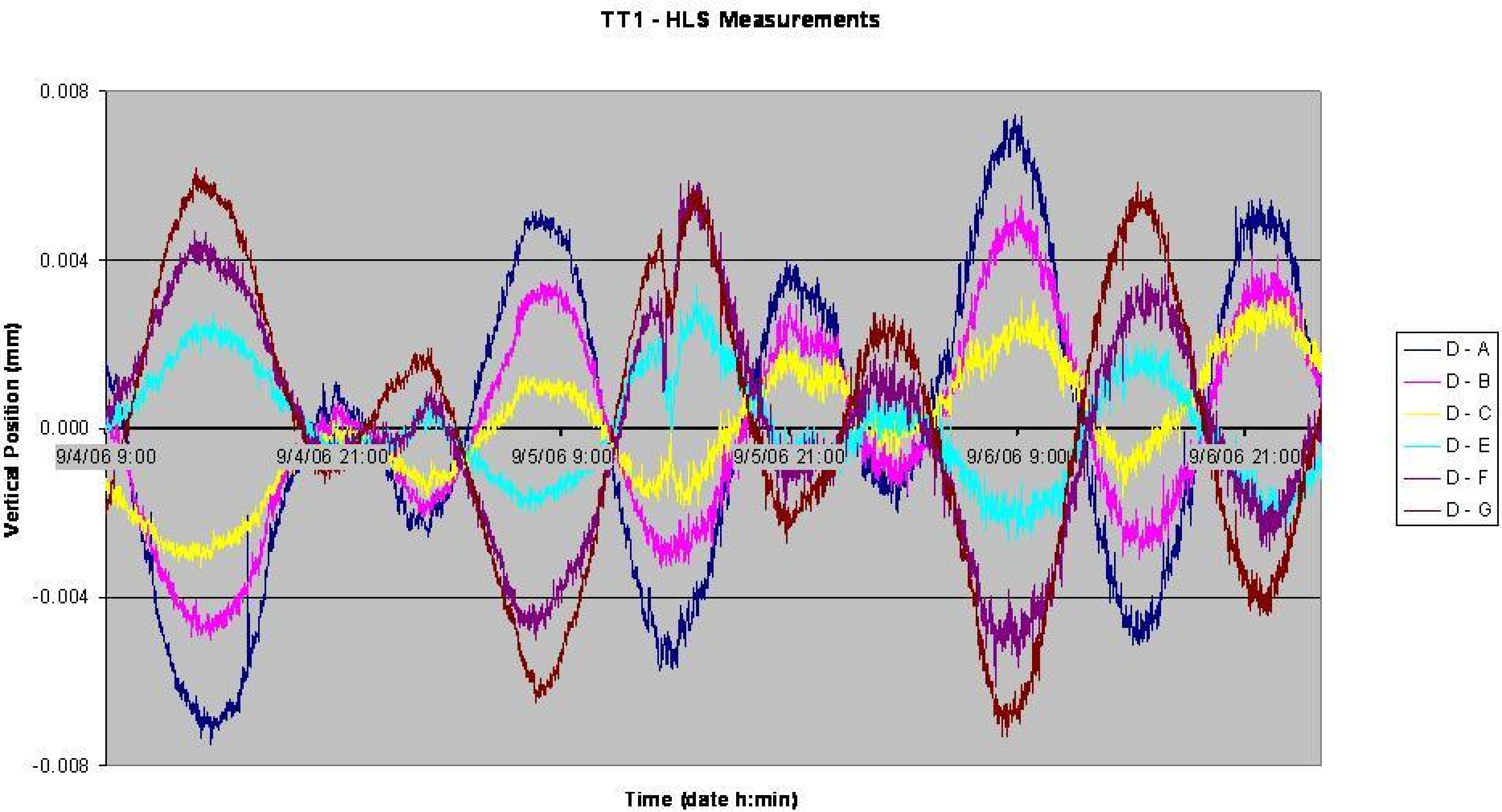
TT1 test facility

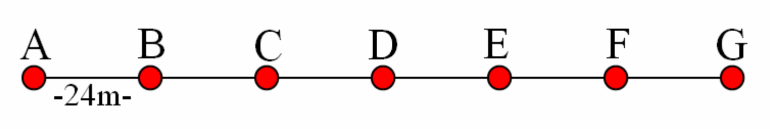
The different alignment networks

Some first TT1 results

WPS and HLS stability measurements

Some first TT1 results





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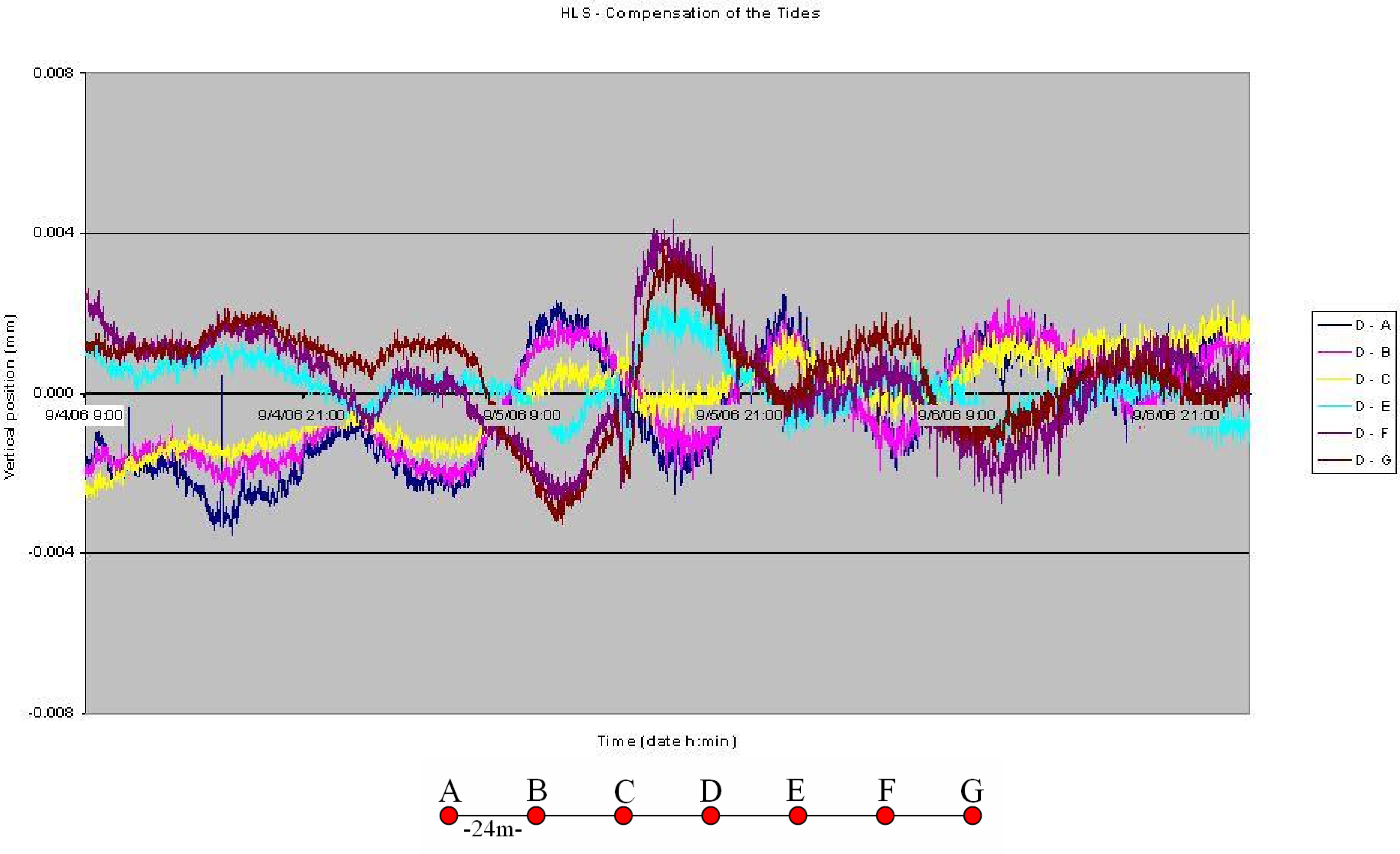

Conclusion

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…