STRETCHED WIRE OFFSET MEASUREMENTS: 40 YEARS OF PRACTICE OF THIS TECHNIQUE AT CERN

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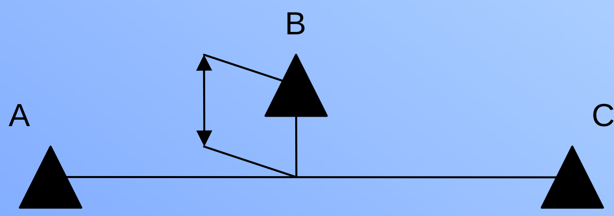
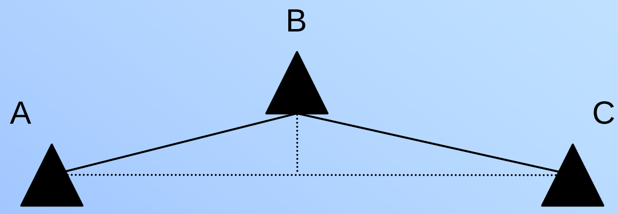
- The principle
- Some applications in the existing machines
- A possible futur for this technique

Principle of the technique

- The straight line is a stretched wire
- To measure the shortest distance of a point to a straight line.



Offset measurement



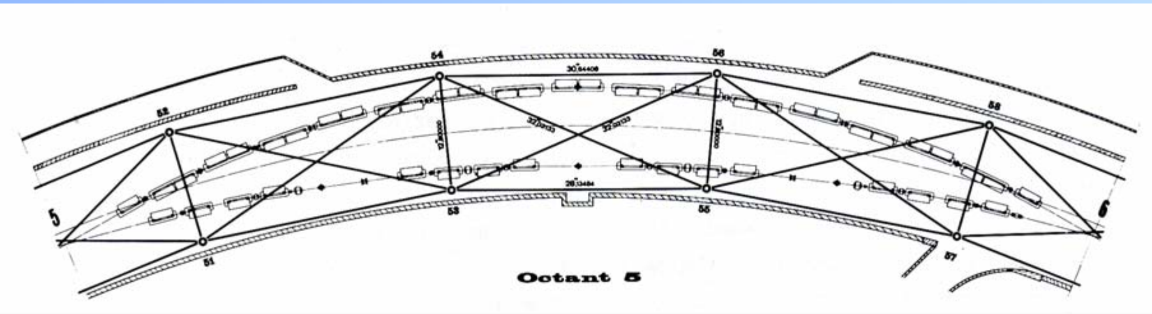
Angular measurement

- We can measure up to 1.40 m long offset
- Classical wire length <= 120m. Test to extended to 500 m under way.

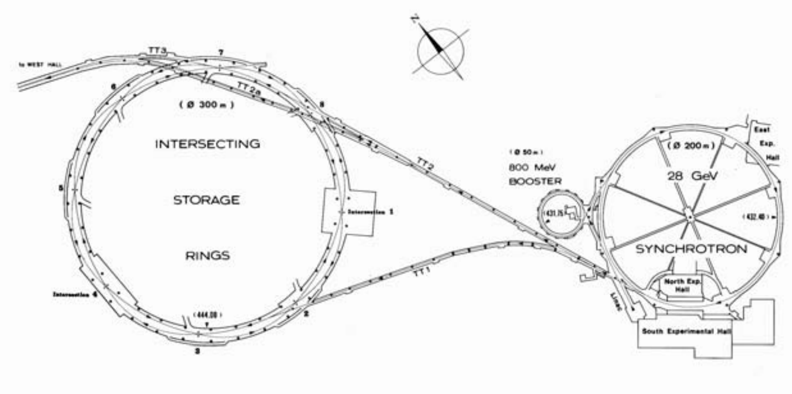
Initial goals

- To skip the refraction problems linked to optical methods
- To speed up the optical methods
- To simplify the calculations (40 years ago, no portable computers…!)

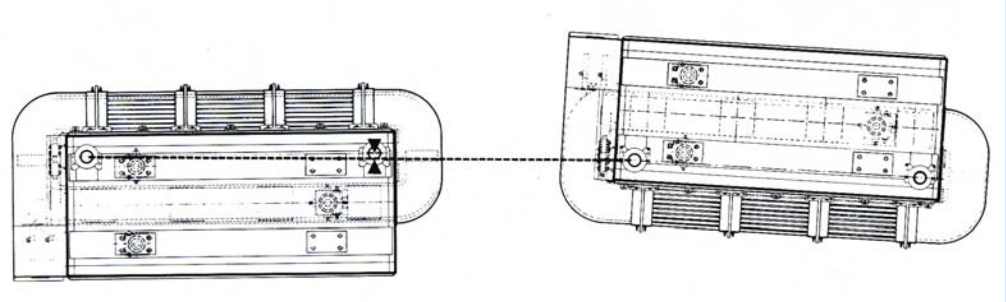
The ISR (1969)



The network: 32 quadrilaterals
Total length = 930 m



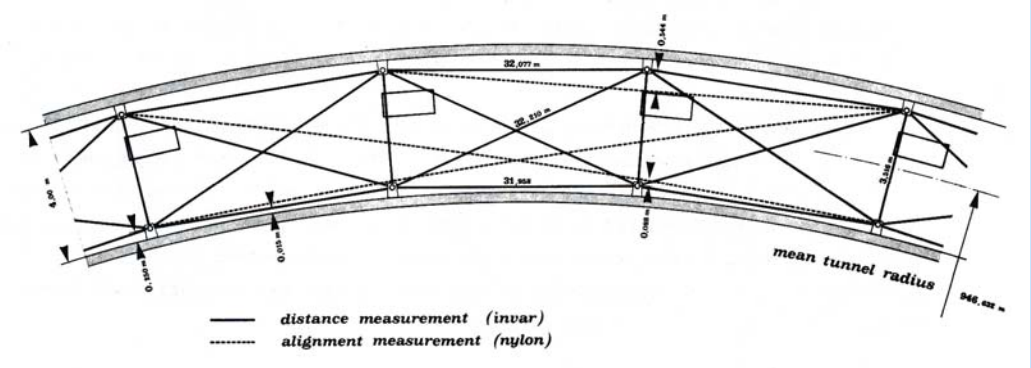
Two ~400m transfer lines

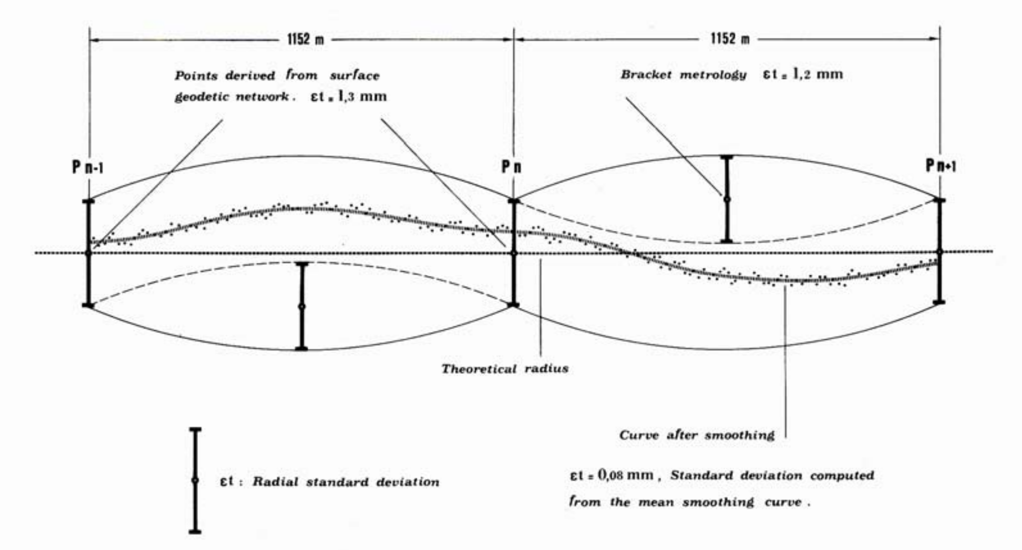


Alignment with the wire

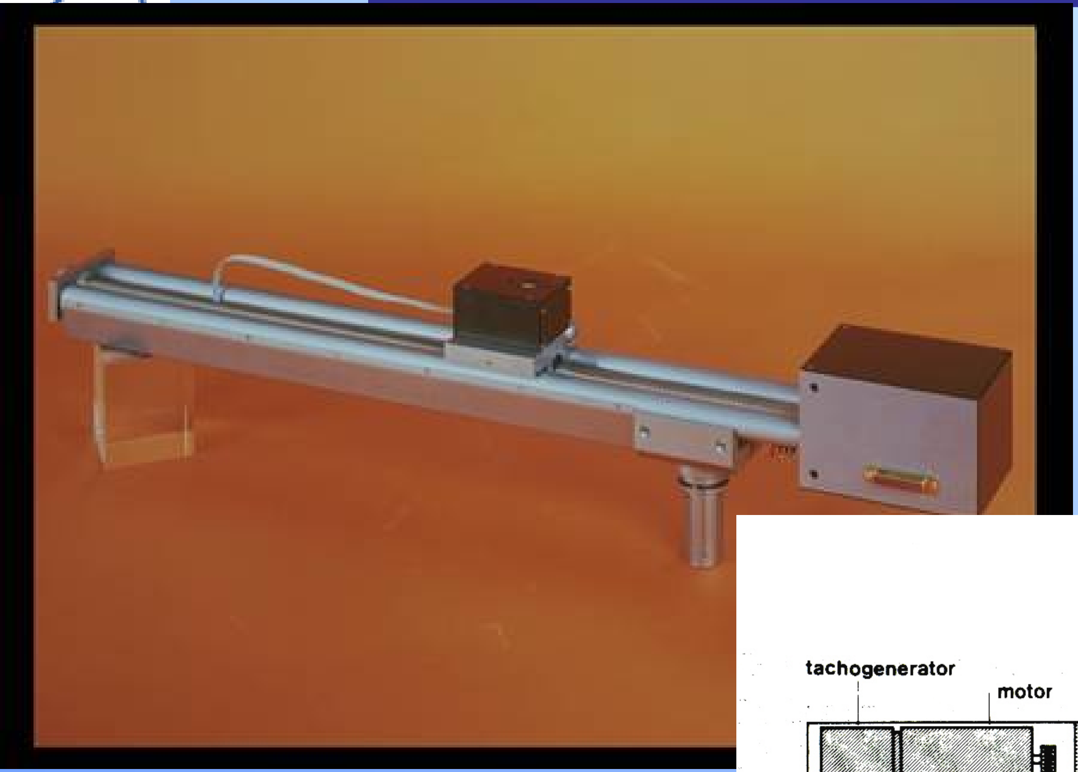
The SPS (1975)

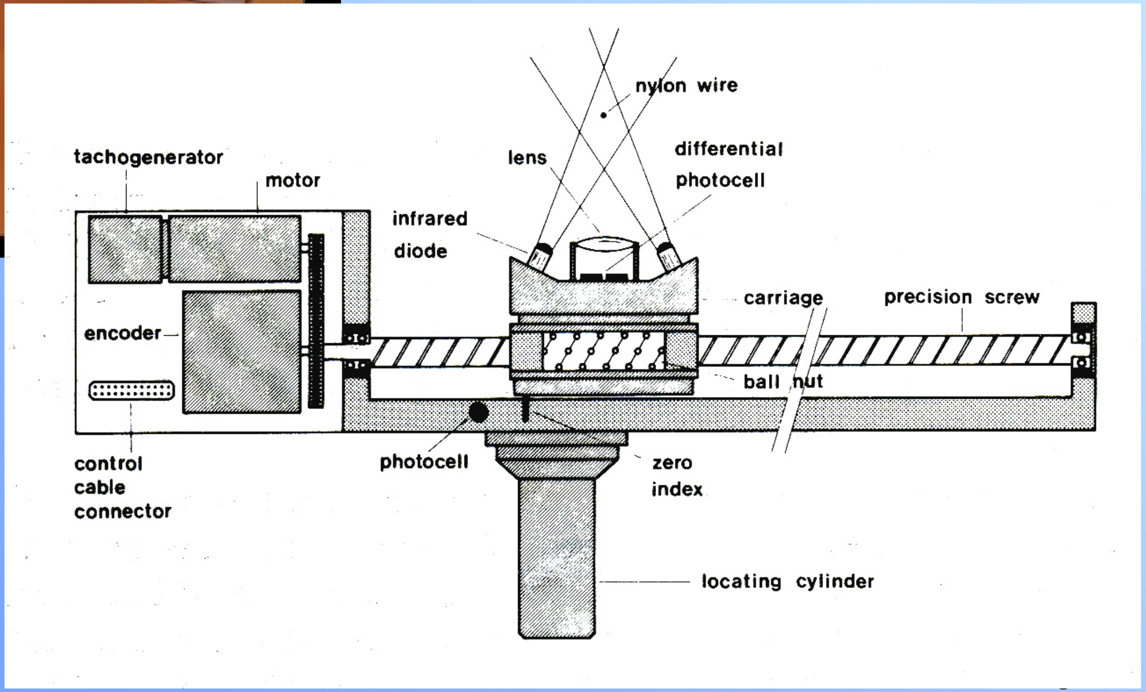
- Circonference : 6700 m
- 6 access pits
- The half-cell length is 32m
- Network measured by invar wires (distances) and wire offset measurements
- The first smoothing of the quadrupoles





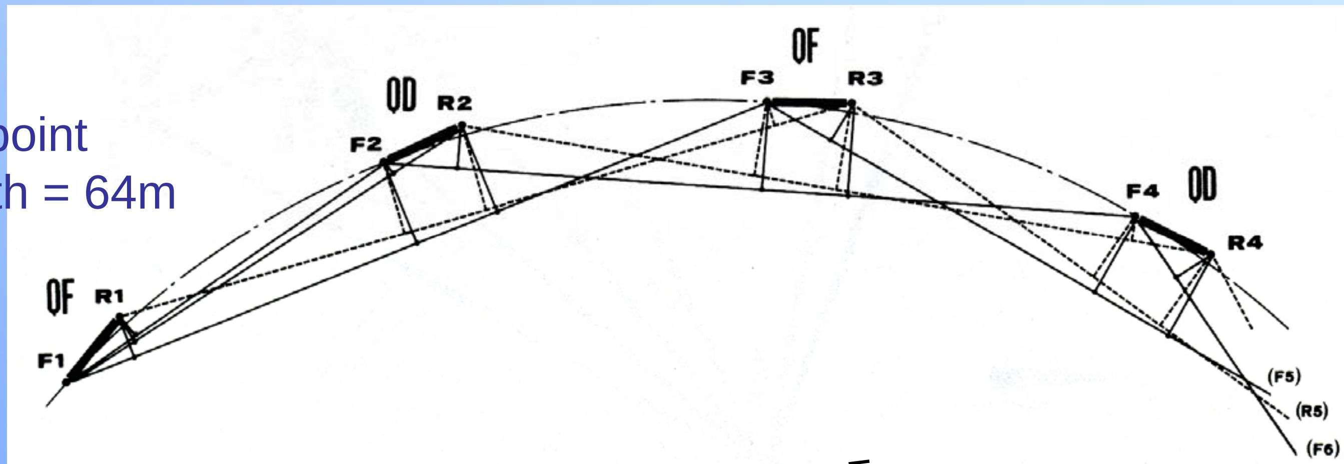
The SPS – a new ecartometer

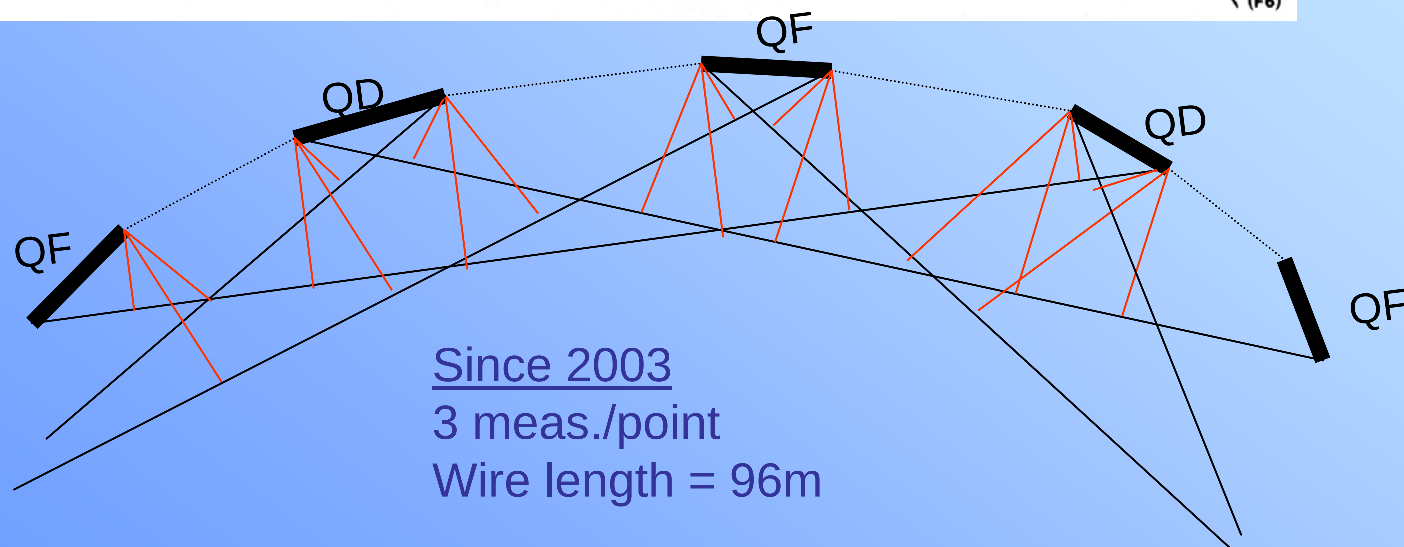




The SPS: the smoothing process

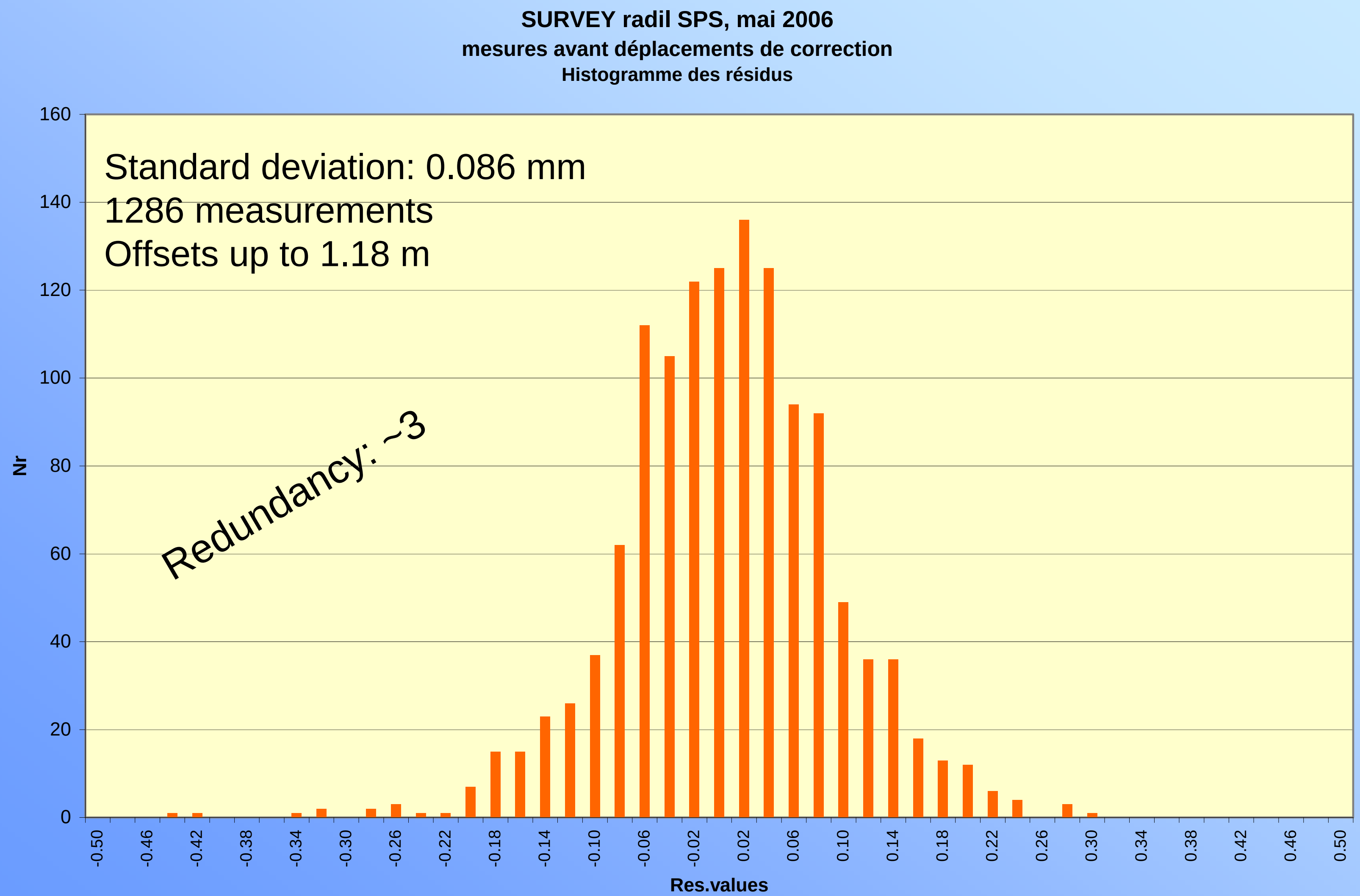
1975
2 meas. /point
Wire length = 64m



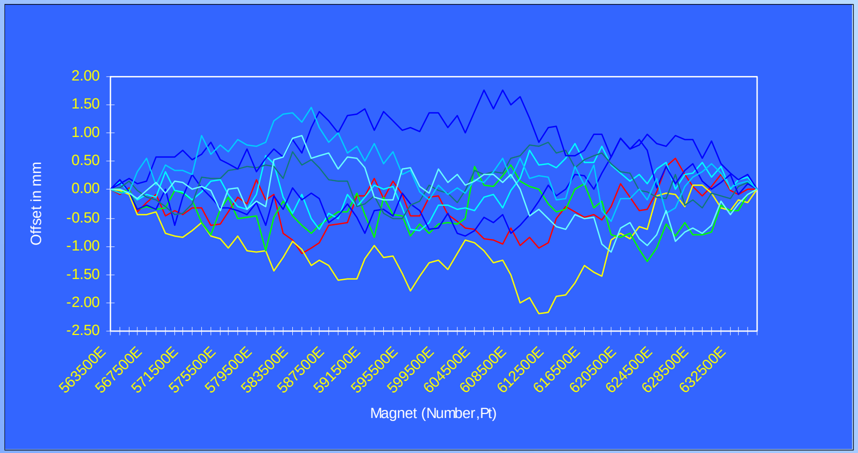


Since 2003
3 meas./point
Wire length = 96m

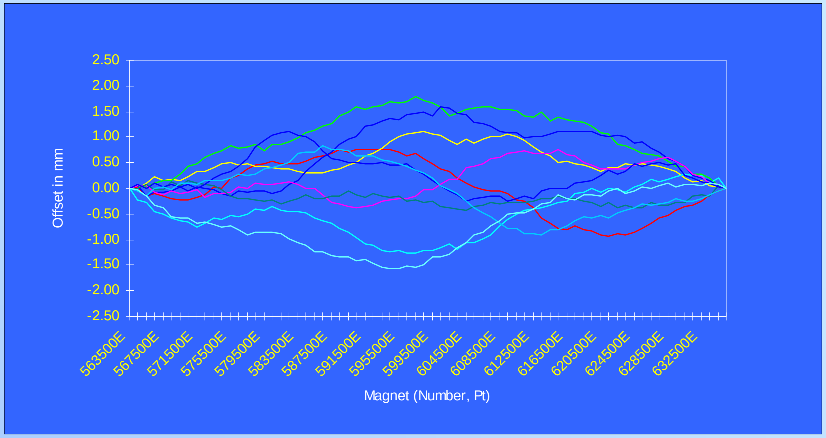
The SPS : radial smoothing results



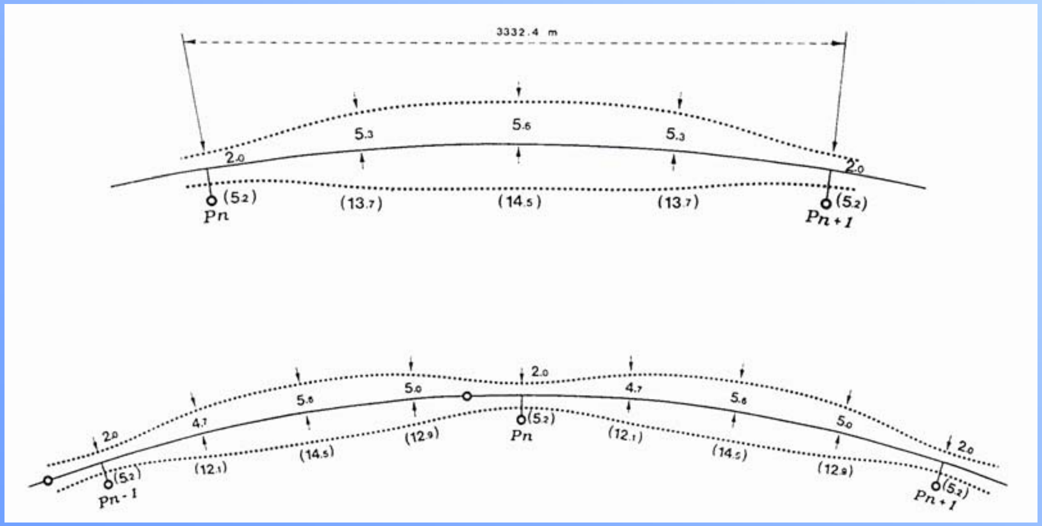
The LEP : The network



Gyroscopic measurements only

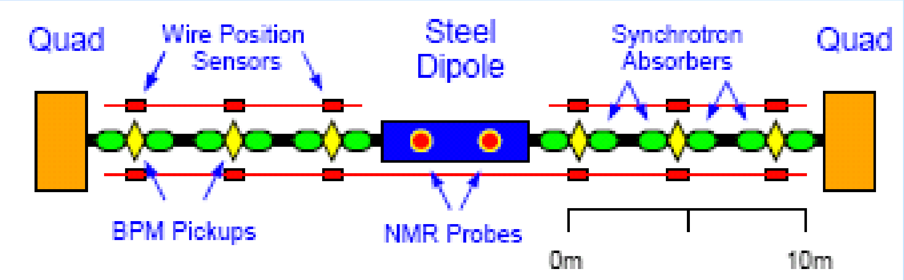


Gyroscopic + wire offset measurements

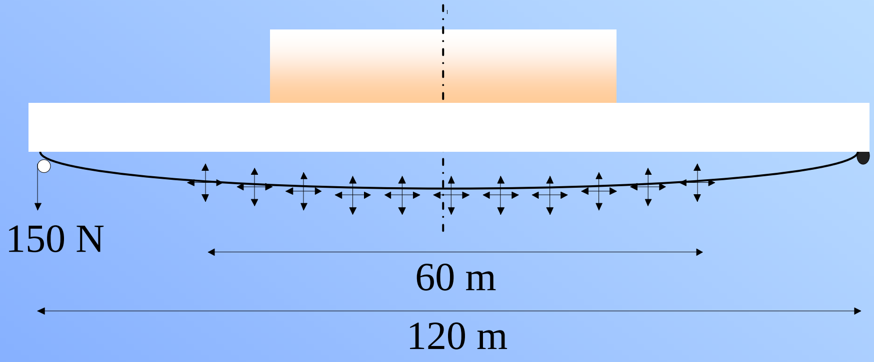


The LEP

- Monitoring of the energy spectrometer
  - 30m long wire
  - Submicrometric sensors
  - Bi-directional measurements
  - Possibility to shield the sensors
  - Sensitivity to radiation



- Monitoring of the motion of the machine elements during the civil engineering works for ATLAS and CMS
  - 120 m long wire
  - Accuracy of ~0.03 mm
  - Bi-directional measurements



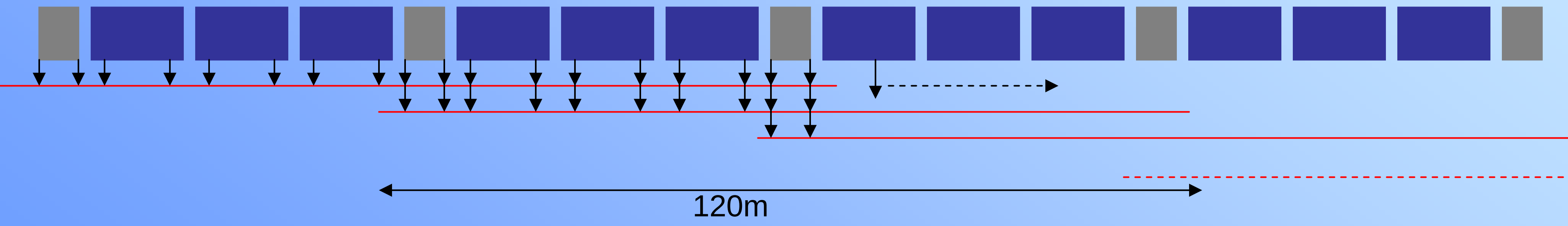
- Radial smoothings
  - Similar to SPS

The LHC

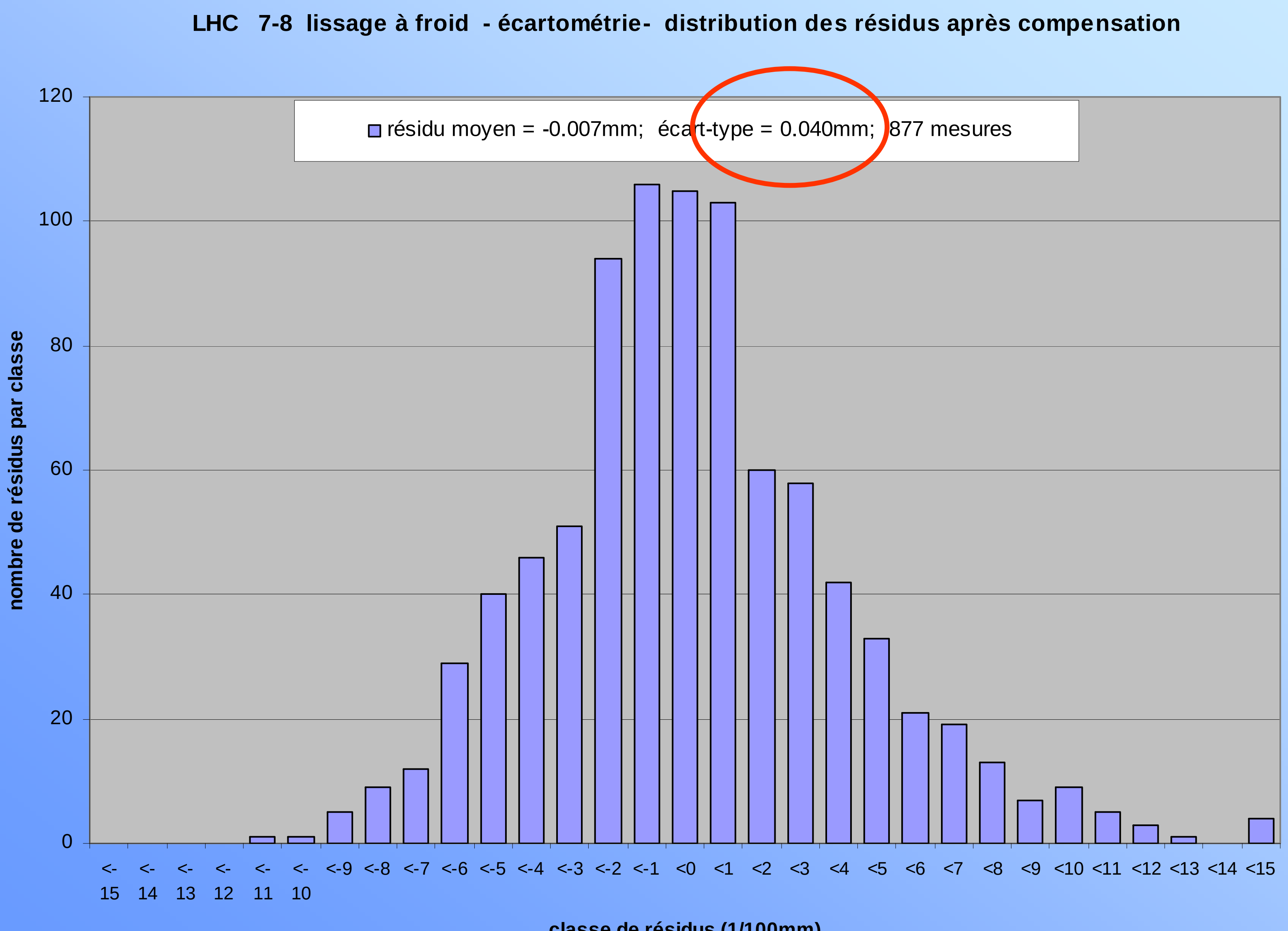
The LHC

Sketch of the measurements

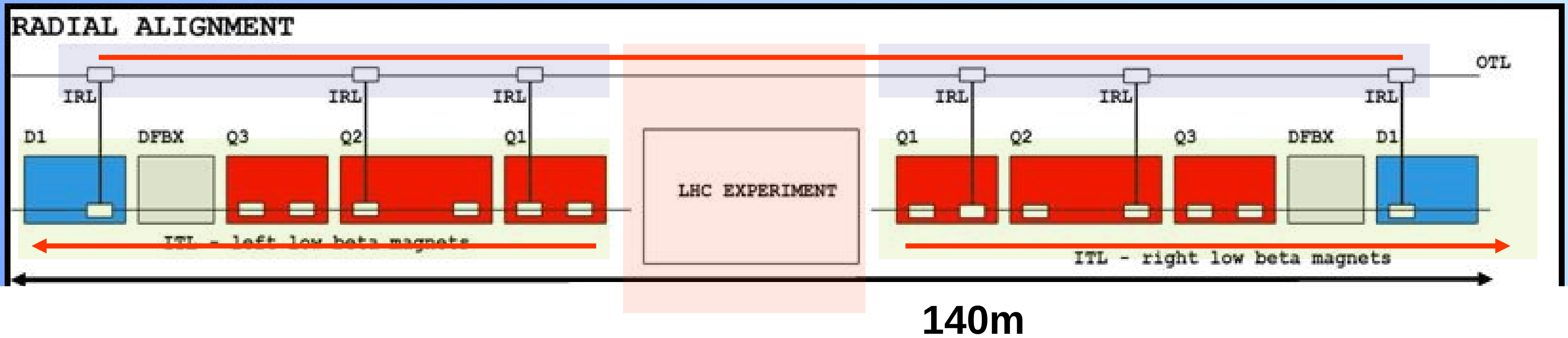
- Radial: ~550 points measured/sector. Redundancy=2, ~450m /day/2 pers. (9 wires/day, 18 meas./wire)



Wire offset measurements: results

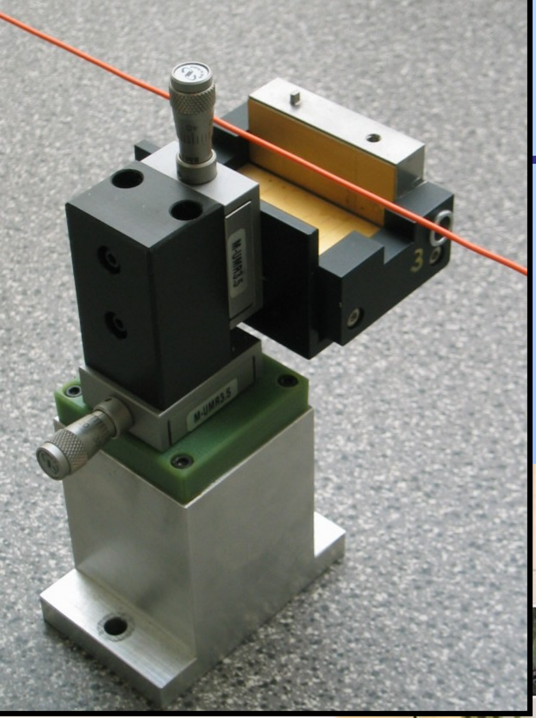


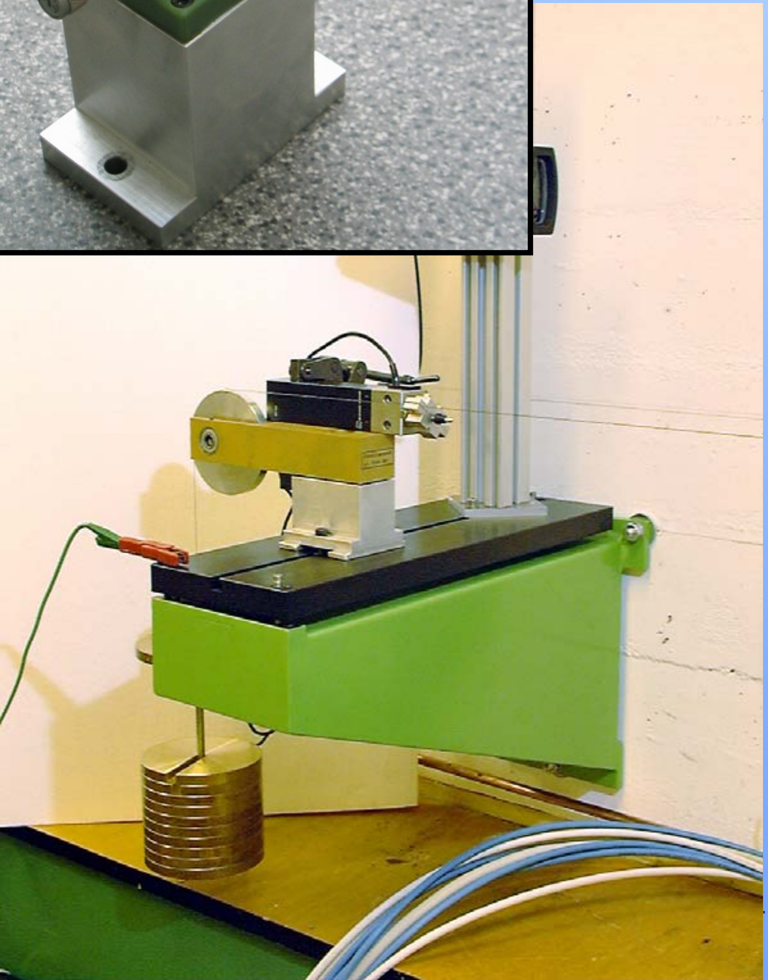
LHC: monitoring of the low beta sections



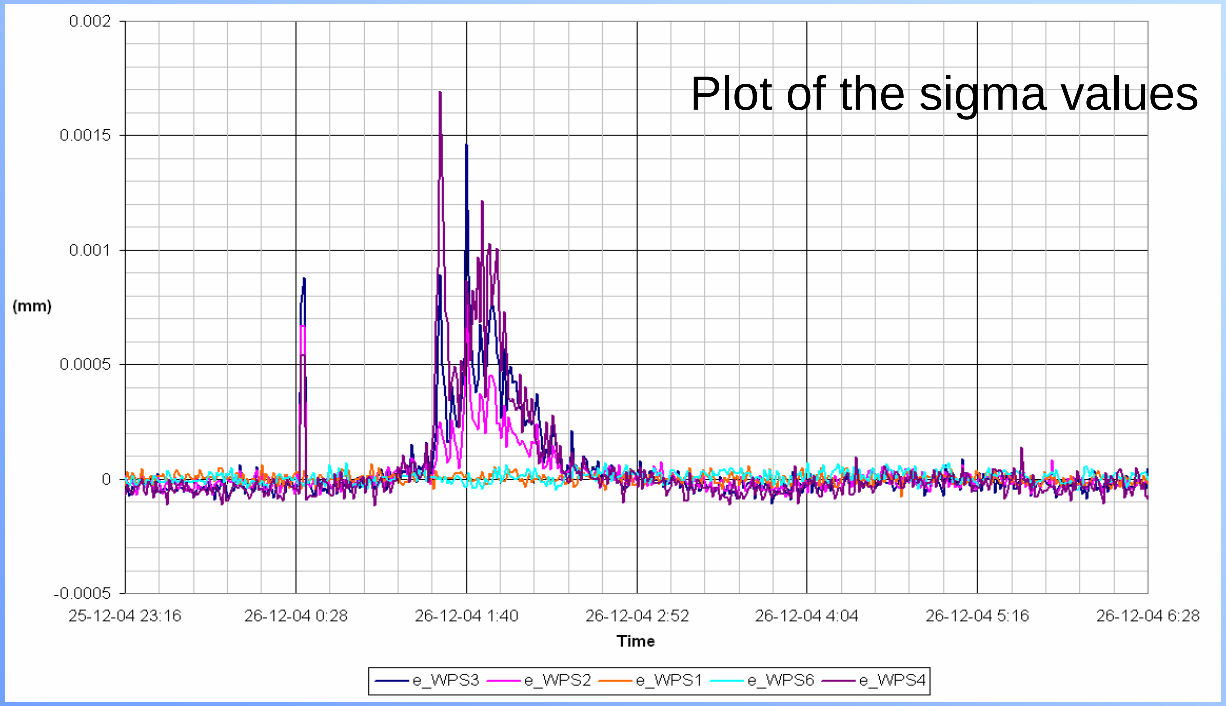
Alignment system in the survey tunnel

HLS + WPS





- 26-dec-2004 1:25 UTC. Signal of the ground motion in Asia recorded by the wire offset sensor at CERN.

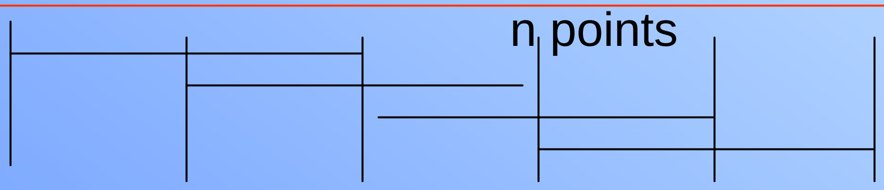


Main characteristics

- Very basic and cheap equipment, (for 0.1mm over 120m)
- Mainly used for radial alignment but can be used for vertical controls
- Accuracy independent of the distance
- Accuracy proportional to the number of wires
- Very sensitive to the systematic errors
  - Zero and scale factor of the sensors
  - Position of the ends of the wire
  - Wind
  - Shape of the wire

Propagation law for a systematic error

$E = (n-2) * (n-1) * s$



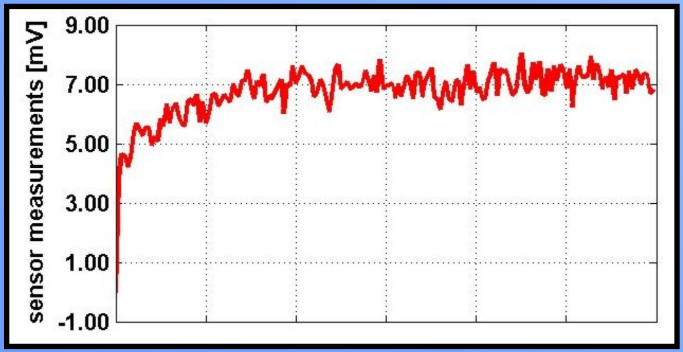
For s=0.1mm, E=7.2mm after 10 points

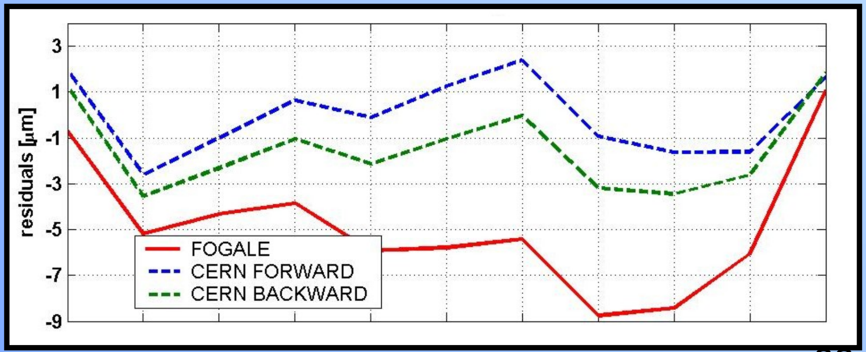
Calibration of the sensors

types of controls for sensor validation are

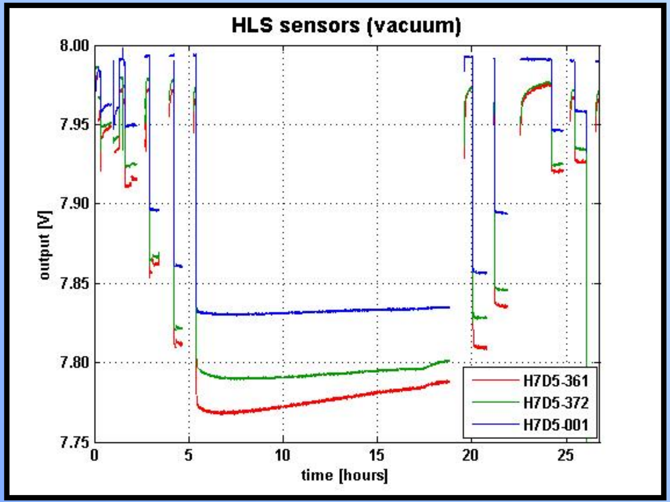
- warm up
- stability
- linearity / coherence with calibration
- radiation
- relative / absolute referencing

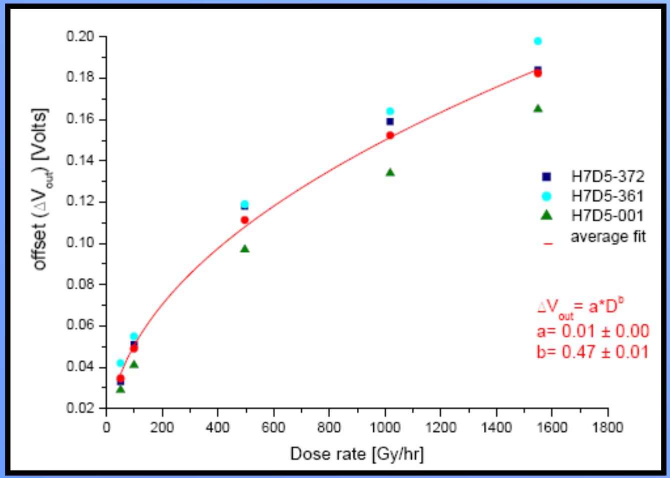
Courtesy of A. Herty





Influence of radiations

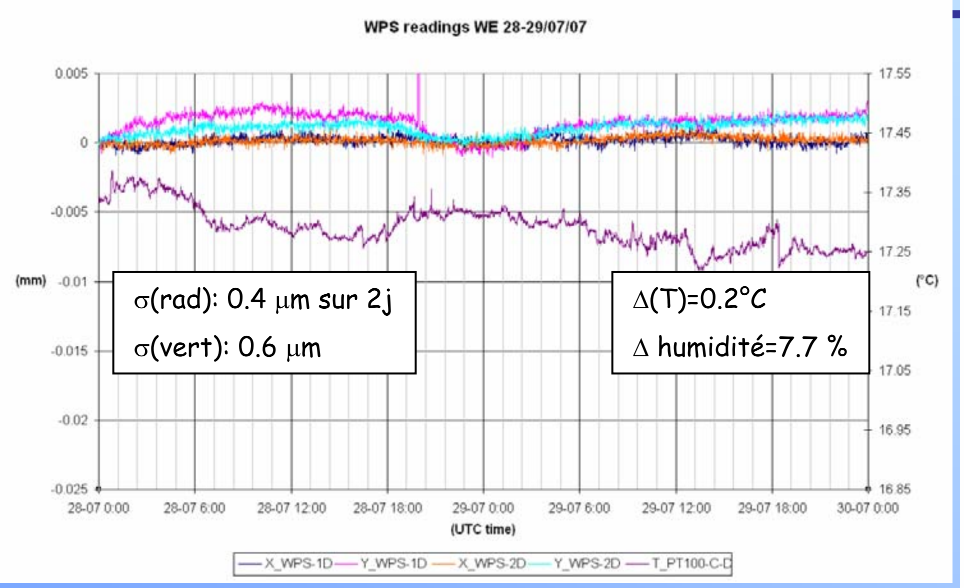


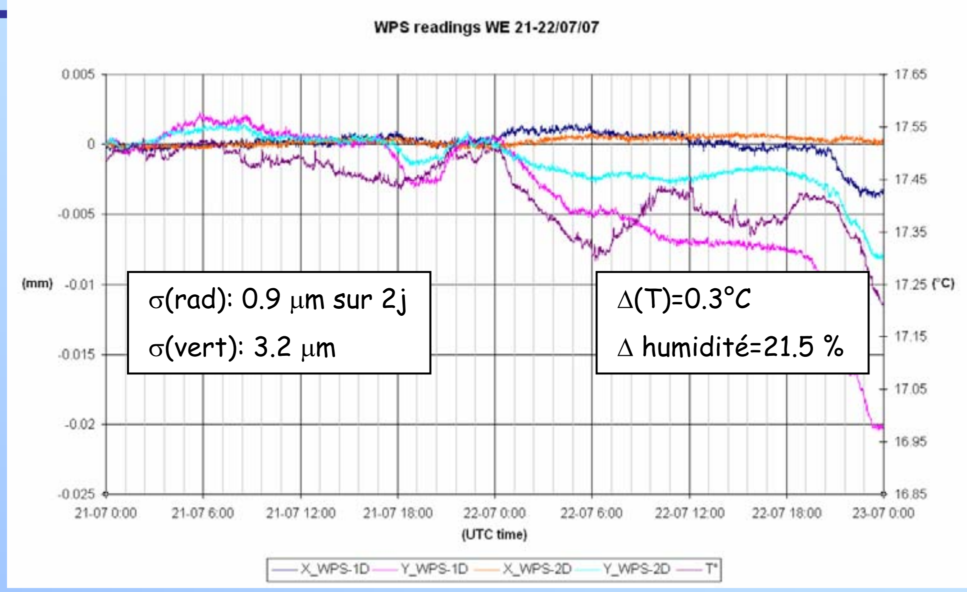


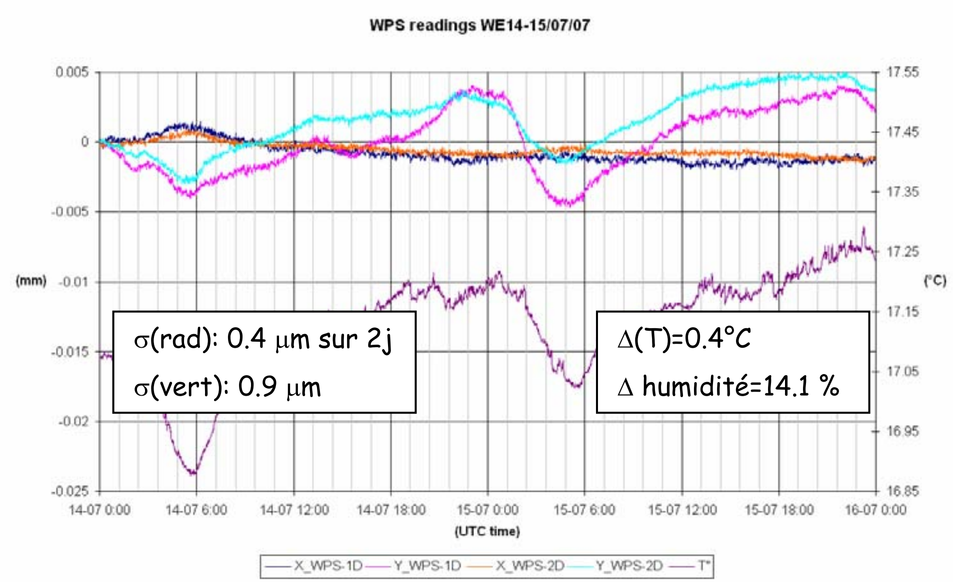
- radiation dose has influence on measurements (capacitive sensors)
- ionization of air between electrodes
- stochastic model determined
- corrections can be applied

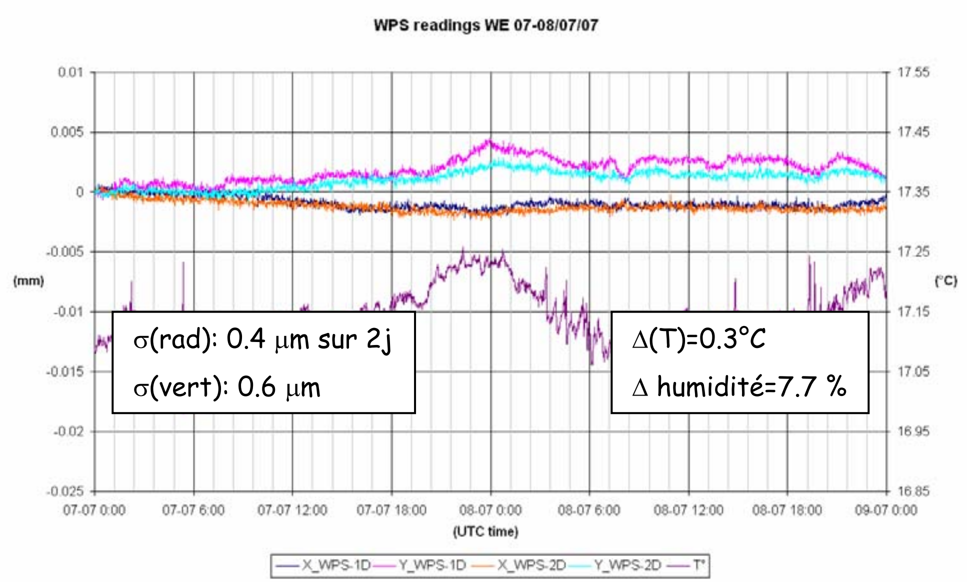
Courtesy of A. Herty

Humidity effects on the wires (140m)



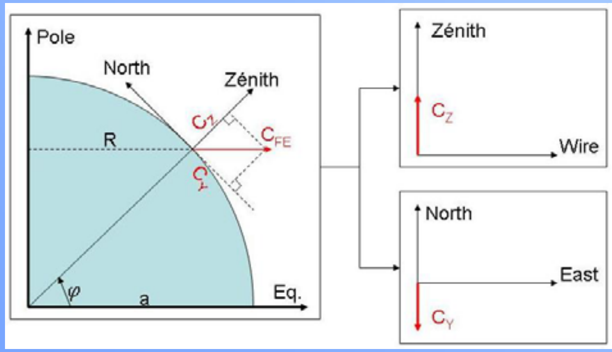


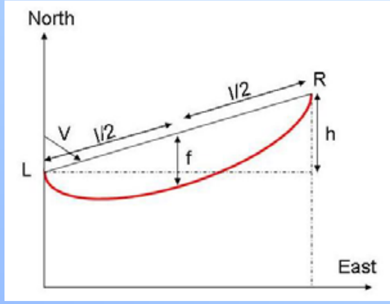




Effect of the rotation of the Earth on the wire

- Effect on the vertical sag
- Effect on the radial sag
- Depends on the azimuth of the wire and the latitude
- The radial deviation is 0.04 mm on the 125 m long wire across ATLAS.



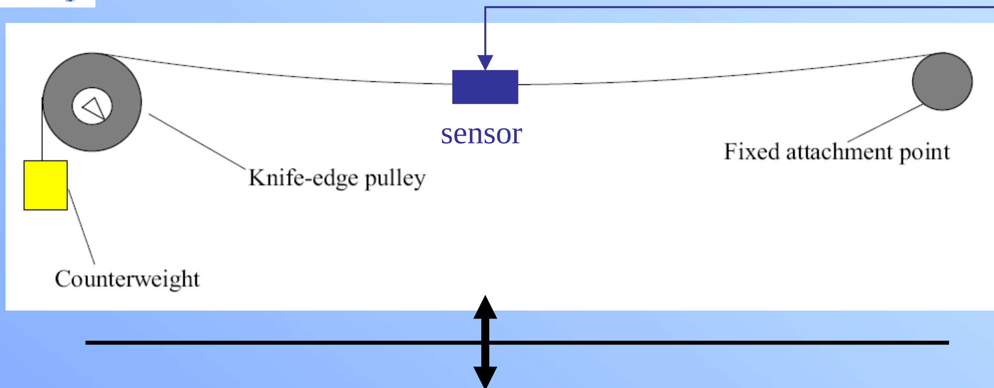


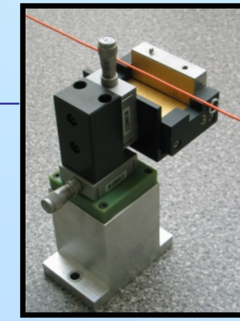
$$C_{Fe} = \left\| \overrightarrow{C_{Fe}} \right\| = q.R.\Omega^2 = \frac{Cm.R.\Omega^2}{g}$$

$$\begin{cases} C_Y = -C_{Fe}.\sin(\varphi) \\ C_Z = C_{Fe}.\cos(\varphi) \end{cases}$$

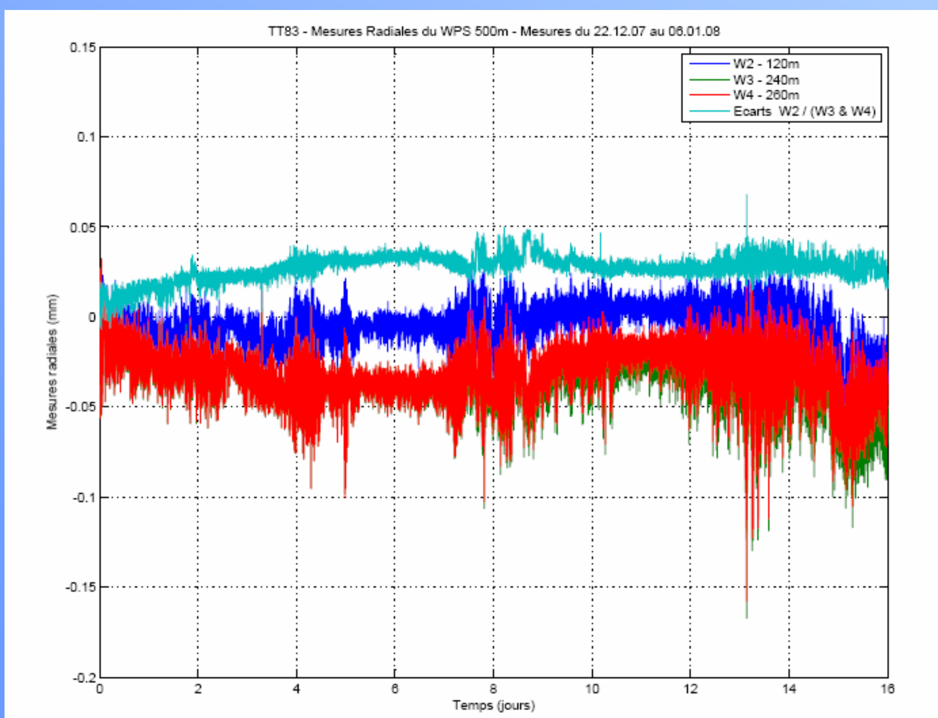
$$f_H = \frac{C_Y.l^2}{8T}$$

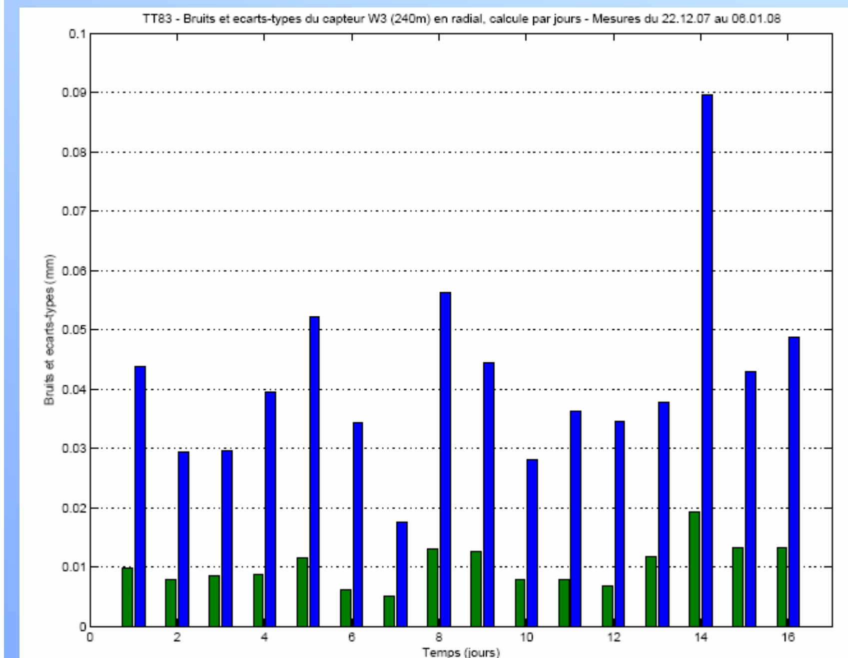
500 m long stretched wire: first results





0 m 250 m 500 m





Calibration facility

The Trioptic 3D measuring machine from SIP (Geneva).
(equipped with laser interferometer for measuring the translations)

Optical wire sensor prototype

Conclusion (1)

- The stretched wire technique is used intensively at CERN.
- Very cheap and simple for an accuracy up to 0.1 mm (price is of sensor ~1 KCHF, the price of the wire is negligeable, calculations…etc)
- Fast
- Avoid all the problems due to the refraction of the air
- Can be easily protected against the wind
- Needs to prevent from the systematic errors (calibration + process)

Conclusion (2)

- Comparison with optics on the CLIC test bench.
- Influence of the rotation of the Earth to be taken into account
- Long wires (500m) open new applications for linear accelerators and also the long straigth section in circular accelerators.
- Investigation for new fibres
  - No elasticity
  - No creep
  - No sensitivity to humidity
- Studies for a new optical sensor, wireless for powering and data acquisition.