First lessons learnt concerning pre-alignment on Two Beam Test Modules (TBTM)

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OUTLINE

- ✓ Introduction: CLIC active pre-alignment
- ✓ Pre-alignment strategy on short range
- ✓ Module test setup and associated results
- ✓ First lessons learnt

CLIC Workshop 2013
from January 28, 2013 to February 1, 2013

CLIC active pre-alignment

PRE-ALIGNMENT (beam off)

Mechanical pre-alignment → Active pre-alignment → Beam based alignment

Within +/- 0.1 mm (1σ) | Within a few microns | Beam based feedbacks

Active pre-alignment = Determination of the position of the components in a general coordinate system by alignment systems

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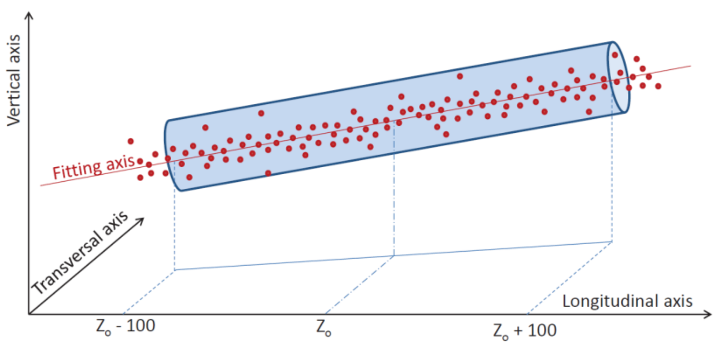
Re-adjustment by actuators



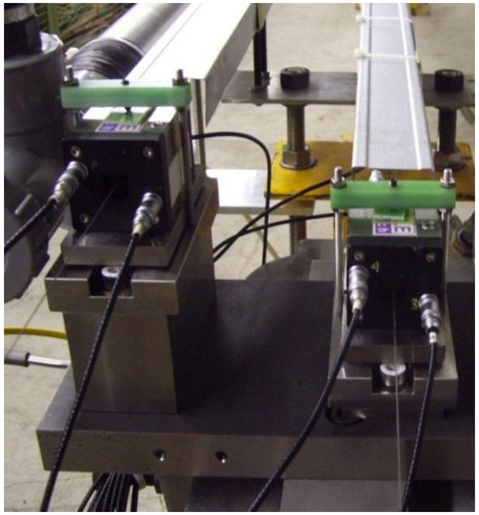
The zero of each component will be included in a cylinder with a radius of a few microns:

→ 14 μm (RF structures & MB quad BPM)

→ 17 μm (MB quad)

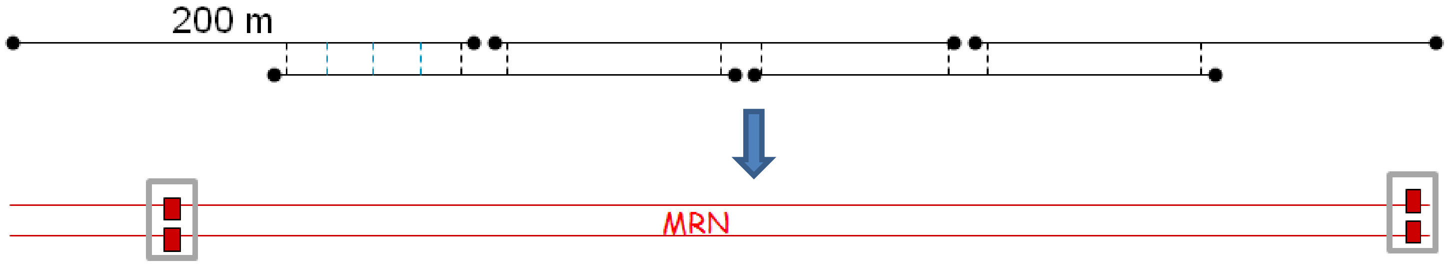
Adjustment required: step size below 1 μm

Pre-alignment strategy on long range



The position of the components will be determined in 2 steps:

- ✓ The determination of a straight alignment reference line all along the main linac and BDS. As it is not possible to implement a straight alignment reference over 20 km: use of overlapping references over at least 200 m



For the CLIC CDR:

- Straight reference = 200m long stretched wire
- Sensor = capacitive Wire Positioning Sensors (cWPS), performing radial and vertical offsets w.r.t. a stretched wire, with a sub-micrometric resolution)

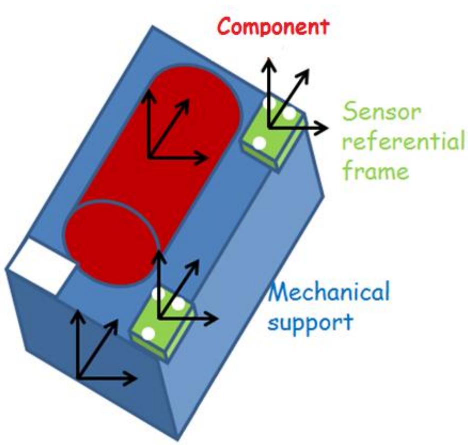
- ✓ The measurements of WPS sensors located on the components (or on their common support) with respect to the straight alignment reference line

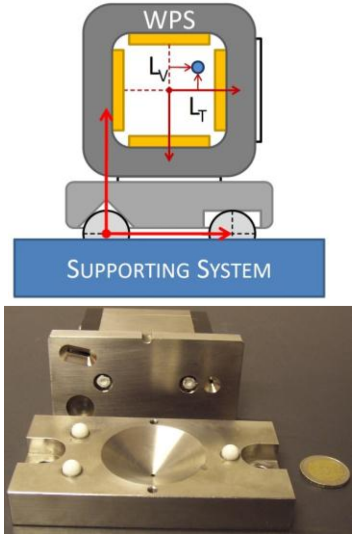
Pre-alignment strategy on short range

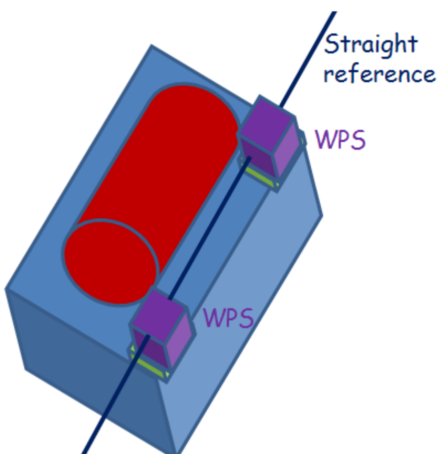
The pre-alignment must ensure that the beam axes of the CLIC components form a straight line along 200 m, which means the following steps:

- ✓ Fiducialization of each component: the position of the alignment targets (fiducials) is determined at the micron w.r.t the reference axis of the component
- ✓ In case of an assembly of components, each component is pre-aligned on the support within a few microns (and the position of its fiducials is determined within a few microns in the support coordinate system)
- ✓ Sensors are associated to each support to be aligned, and the coordinate system of each sensor is known in the coordinate system of the support (or component) within a few microns

The short range strategy of pre-alignment consists of linking coordinate systems through micrometric measurements

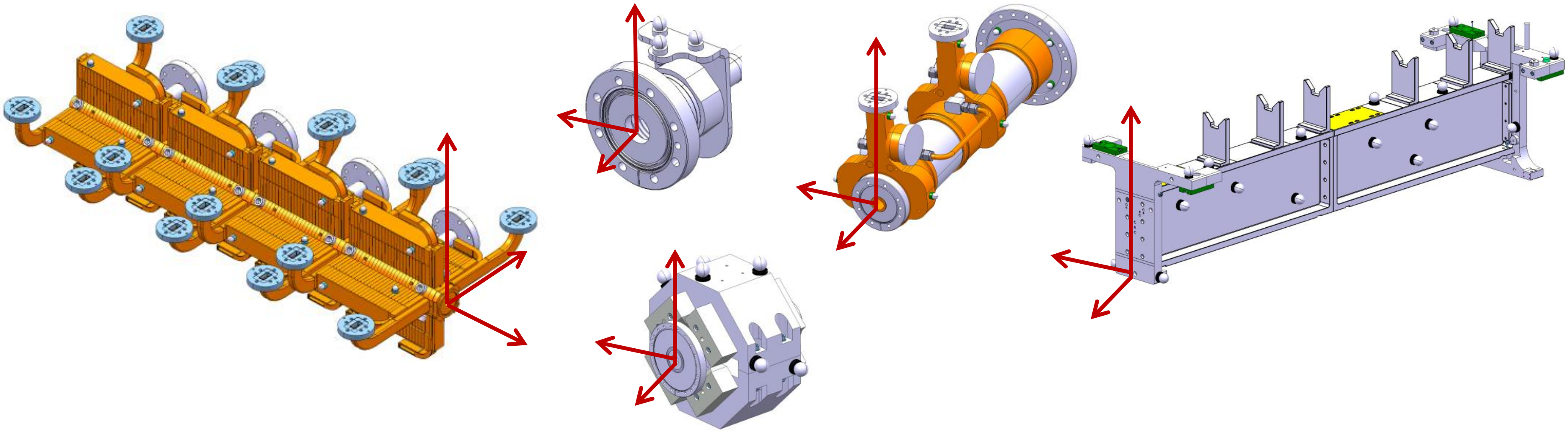




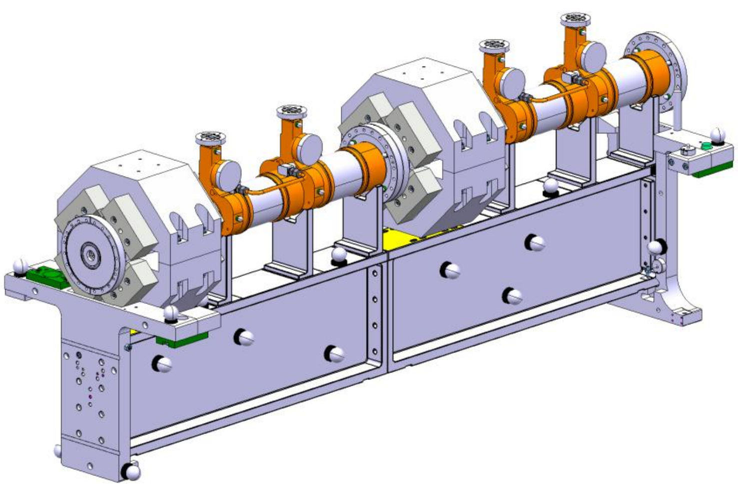


Short range strategy

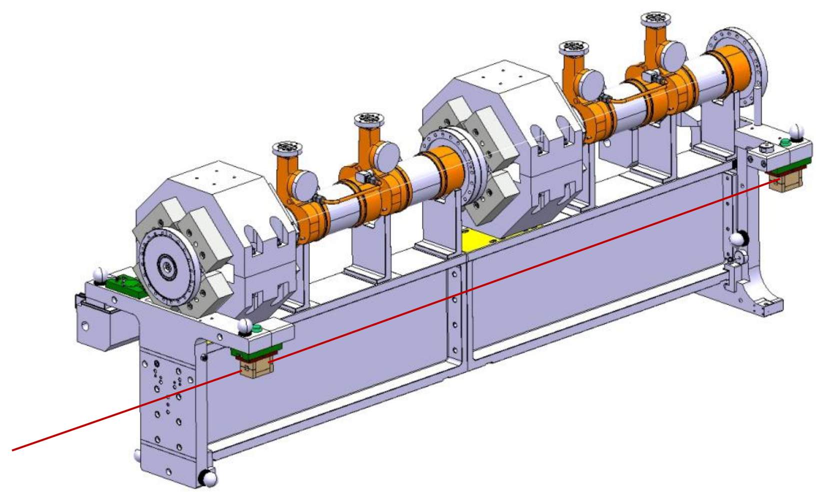
Fiducialisation of components and supports



Alignment on a common support



Installation of WPS sensors



Re-adjustment strategy

Several components will be pre-aligned on supports:

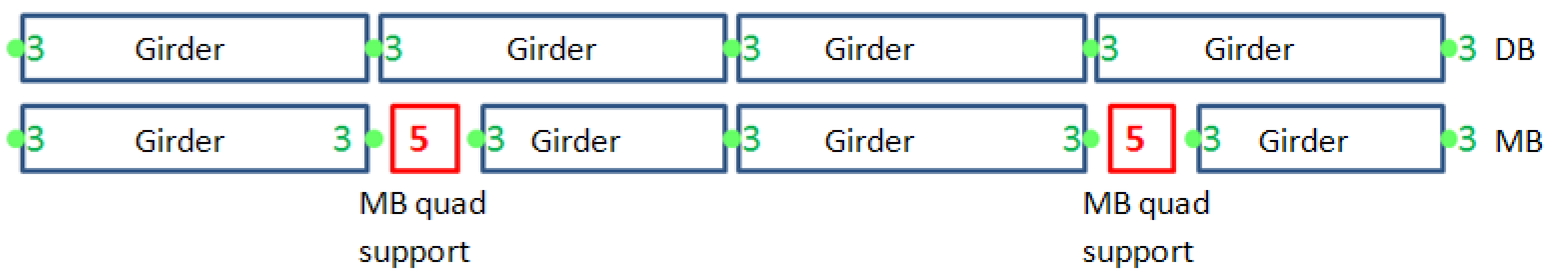
➔ Along the MB:

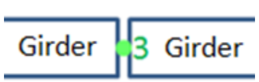
- ➔ RF structures on girders
- ➔ MB quad on interface plate

➔ Along the DB:

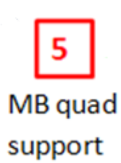
- ➔ PETS + DB quad on girders

Degrees of freedom: 3 / 5





DB and MB girders will be interlinked with their extremities, based on so-called cradle. This allows a movement in the transverse girder interlink plane within 3 degrees of freedom ("articulation point between girders"). (Longitudinal direction adjusted using a mechanical guiding).

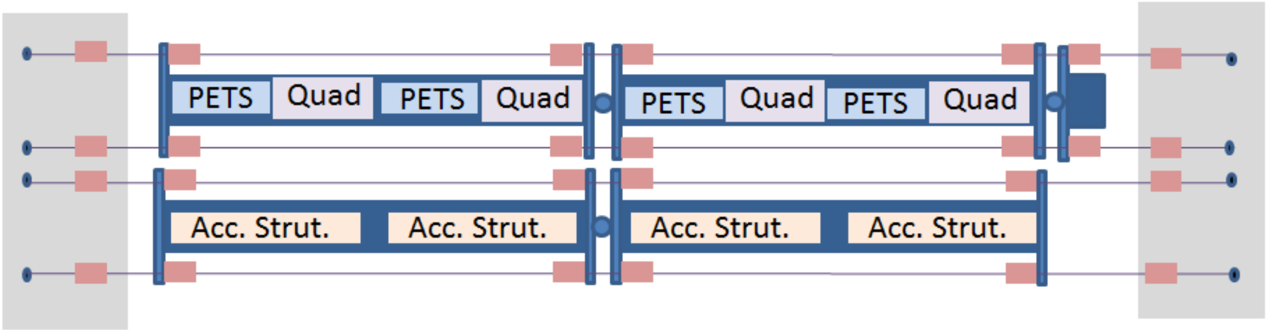


MB quad is mounted on an interface plate, allowing an adjustment along 5 degrees of freedom (longitudinal position will be set manually).

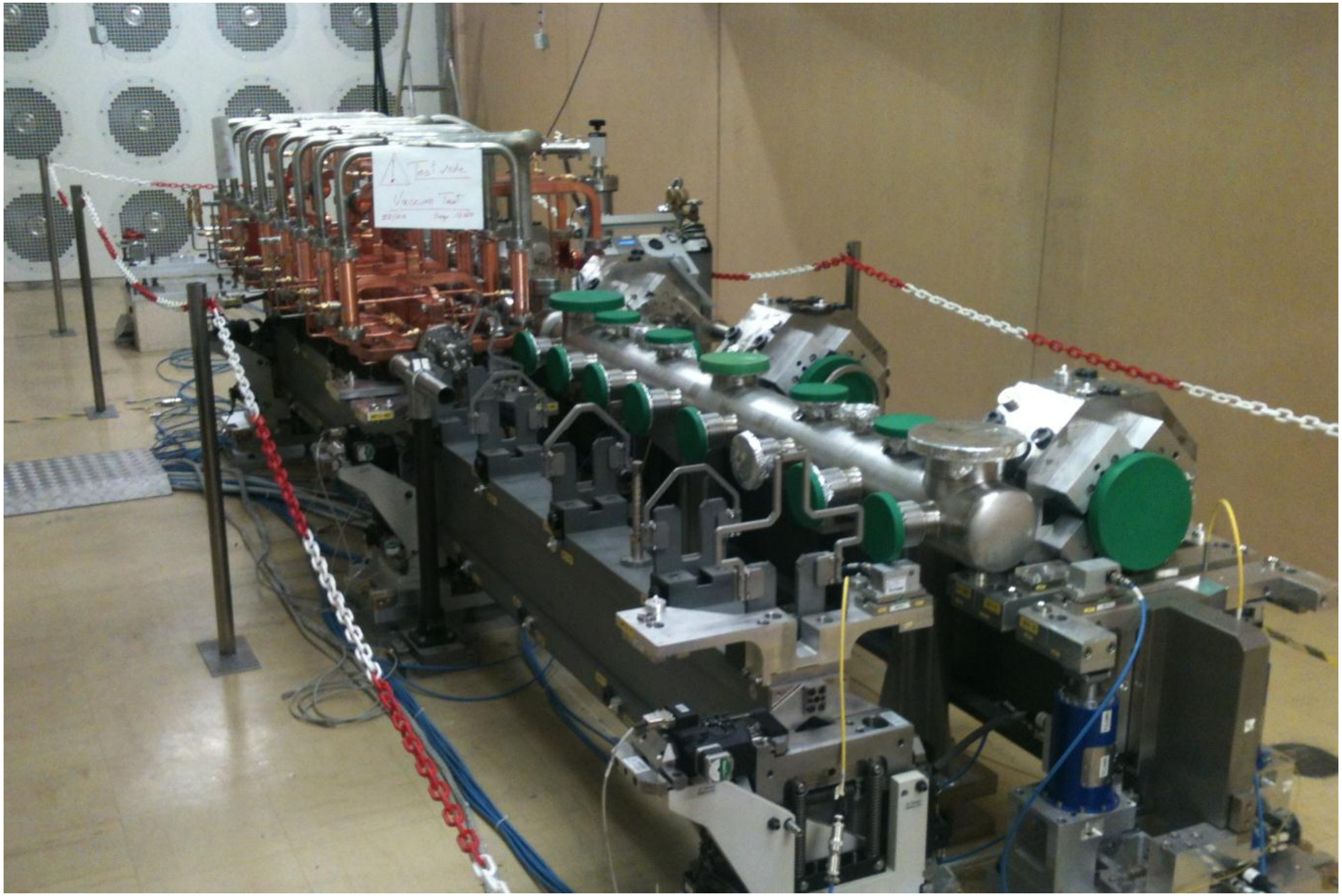
Description of Two Beam Test Modules (TBTM)

- ✓ Objective: demonstration of the two beam module design:
  - Assembly and integration of all the components and technical systems (vacuum, stabilization, alignment, beam instrumentation, supporting, RF components and their associated water cooling and waveguides)
  - Validation of sub-systems such as vacuum, supporting and alignment
  - Concerning alignment:
    - Validation of the fiducialisation strategy according to different configurations of girders and actuators
    - Validation of the pre-alignment strategy on short range

- ✓ Current configuration:
  - 2 modules
  - Installed in a laboratory environment (no beam)



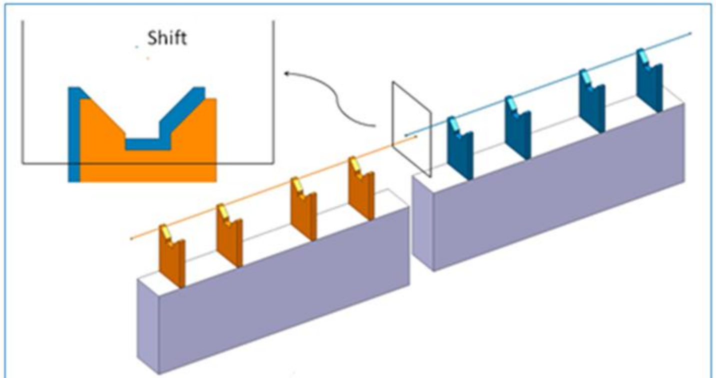
Description of Two Beam Test Modules (TBTM)



Strategy of adjustment

<u>2 solutions of adjustment</u>:

- Solution 1:
  - ✓ Two adjacent girders are linked through a main unit acting as an articulation point
  - ✓ The following side of a girder is laid on rollers of the main unit while the master side of the adjacent girder is screwed on the main unit via flexural blades
  - ✓ Adjustment of the mean axis performed by playing on the clearance
- Solution 2
  - ✓ Accuracy and precision needed are reached using very tight tolerances of machining for reference surfaces and components.



	Solution 1		Solution 2	
	Vertical	Horizontal	Vertical	Horizontal
Shift	20 microns	18 microns	16 microns	9 microns

3 DOF linkage (Slave versus Master)	Solution 1	Solution 2
Vertical Translation	3-5 µm	1-2µm
Horizontal Translation	2-3µm	1-2 µm
Roll	2µrad	1µrad

Active adjustment

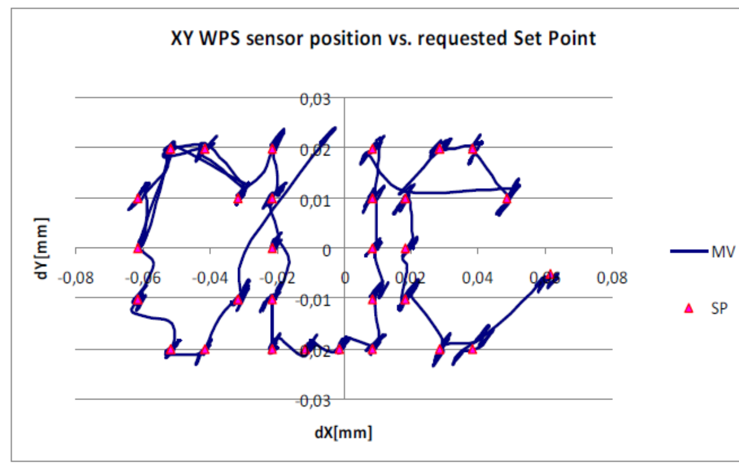
- ✓ All actuators (from solution 1 and 2) validated successfully, when no constraints are applied on the girders to be displaced (no vacuum, no waveguides between two girders)

- ✓ Active adjustment of the master cradle and its associated girder, based on sensor readings and fiducialisation measurements, has been validated successfully for relative measurements:

  ➔ closed loop algorithm is convergent in maximum 2 regulation cycles at the micron level for shifts lower than ± 0.5 mm on vertical and radial axes.

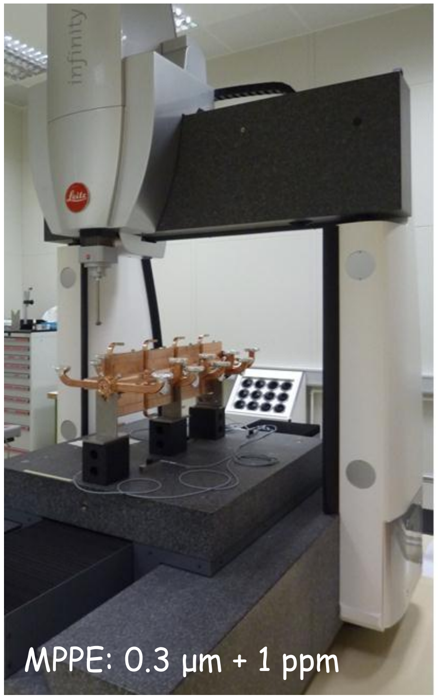
- ✓ The trajectory following test based on a list of coordinates of points as targets of displacements was succesfull, even though sensor noise was affecting the final regulation quality

	Solution 1		Solution 2	
	Vertical	Horizontal	Vertical	Horizontal
Range accepted	+/- 1 mm	+/- 1 mm	+/- 2 mm	+/- 3 mm
Backlash	+/- 1 micron	+/- 1 micron	+/- 1 micron	+/- 2 microns
Long-term operation	50 cycles without problem	50 cycles without problem	2H30 (10 cycles)	40 cycles without problem
Linearity	3 microns	2 microns	1 micron	3 microns
Hysteresis	+/- 1 micron	+/- 1 micron	+/- 1 micron	+/- 1 micron
Resolution	<0.1 micron	<0.1 micron	0.2 micron	0.2 micron

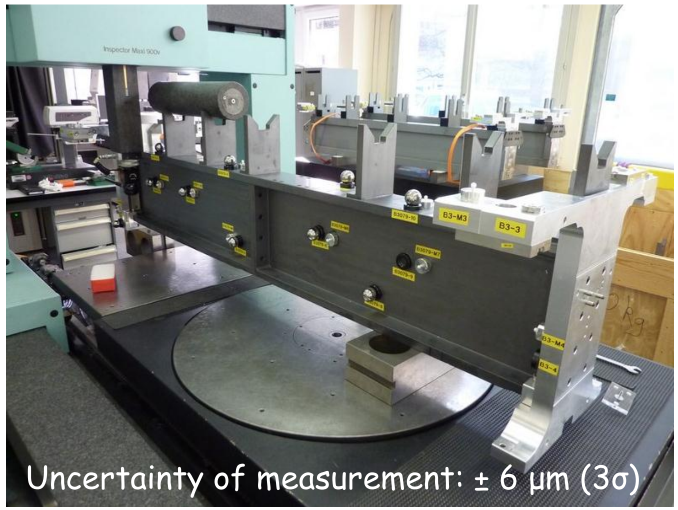


Fiducialisation and alignment on a common support

✓ Fiducialisation of components by 3D Coordinate Measurements Machine (CMM), according to the length of components



MPPE: 0.3 µm + 1 ppm



Uncertainty of measurement: ± 6 µm (3σ)

Mean axis of the V-supports (radius of the cylinder containing the center of the V-shaped supports)

- Solution 1:
  - radius = 6 µm (radial),
  - radius = 4µm (vertical)
- Solution 2:
  - radius = 7.5 µm (radial)
  - radius = 5.5 µm (vertical)

✓ Fiducialisation of the girder assembly : accuracy of measurement estimated to ± 15µm as the volume of measurement of the CMM is not sufficient.

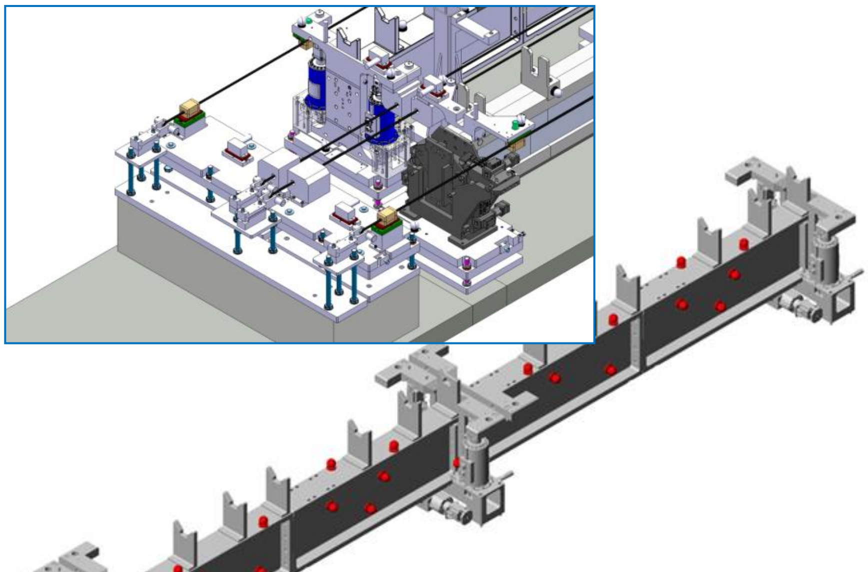
✓ Alignment on site: combination of AT401 (laser tracker) and Romer arm measurements, allowing a precision and accuracy below 10 µm

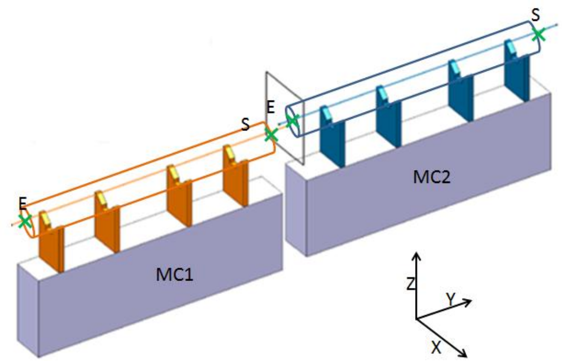
✓ In some cases, the adjustment system on support did not allow a sufficient resolution (not better than 20 µm)

Validation of the global strategy

Determination of the mean axis of the V-shaped supports by two different methods:

- AT401 (laser tracker) measurements on the fiducials measured by CMM [*mean axis w.r.t. fiducials*]
- WPS measurements readings on the 3 balls sensor interfaces measured by CMM [*mean axis w.r.t balls*]





	X (µm)	Z (µm)
MC1-E	-5	12
MC1-S	10	-5
MC2-E	-1	-4
MC2-S	-11	-7

Difference between coordinates of mean axis extremities calculated by 2 different methods

Such results demonstrate the high accuracy and precision measurements performed by:

- ✓ CMM
- ✓ WPS sensors
- ✓ AT401 measurements

Summary: first lessons learnt

- The alignment strategy on short range consists of a very accurate determination of the coordinate systems of:
  - The components
  - Their supports assembly
  - The sensors

  combined with a micrometric adjustment

- First lessons learnt:
  - CMM measurements are the most precise and accurate, provided that the component or its support is shorter than the volume of measurement
  - CMM measurements of fiducials as a first step combined with AT401 + Romer arm measurements as a second step provide the best solution for micrometric alignments on site. The determination of the position of components was better than 10 μm in a stable environment.
  - Standard means of adjustment (shimming,…) cannot be applied without added value to micrometric alignment.

- The first obtained results show that the followed strategy can be successful. The problem is that only the mechanical axis of the components was considered and not their electrical zero or magnetic axis.
  - ➔ one solution: perform at the same time the determination of the magnetic axis and electrical zero and the CMM measurements.