Validation of the CLIC alignment strategy on short range

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on behalf of the CLIC active pre-alignment team

OUTLINE

✓ Introduction: CLIC project & active pre-alignment
✓ Alignment strategy on short range
✓ Module test setup and associated results
  o Description
  o Fiducialisation & alignment on a common support
  o Adjustment
  o Validation of the global strategy
✓ Conclusion
CLIC = Compact Linear Collider

Study for an e- e+ collider, with a center of mass energy of 3 TeV

Length > 40 km for 3TeV

Based on the two beam acceleration concept

The main linacs consist of more than 20 000 modules (2 m length)
Problem and solution proposed

PRE-ALIGNMENT (beam off)

Mechanical pre-alignment

Within +/- 0.1 mm (1σ)

Active pre-alignment

Within a few microns

Beam based alignment

Beam based feedbacks

Active pre-alignment =

Determination of the position of the components in a general coordinate system by alignment systems

+ 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
Solution proposed

- Several components will be pre-aligned on supports or girders:

- Configuration of girders and supports:

  Degrees of freedom: 3 / 5

- Reference of alignment: overlapping reference lines
Solution proposed for CDR

✓ Sensors & actuators are associated to each support / articulation point of girder:

✓ As a summary:

For CDR: - straight reference = stretched wires
- sensors = Wire Positioning Sensors (WPS)
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Short range strategy (1)

- Different types of fiducials that are glued on the components or supports

- Reference system of alignment sensors: 3 balls mechanical interface
Short range strategy (2)

✓ **Means**

- **AT401**
- **Micro triangulation**
- **Romer arm**

<table>
<thead>
<tr>
<th>Instrument</th>
<th>$\sigma$ ($\mu$m)</th>
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<tbody>
<tr>
<td>AT401</td>
<td>$&lt; 5$</td>
</tr>
<tr>
<td>Micro triangulation</td>
<td>$&lt; 5$</td>
</tr>
<tr>
<td>Romer arm</td>
<td>$&lt; 10$</td>
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</tbody>
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$\sigma$ = Standard deviation between instruments and CMM measurement

**FERRANTI**
- 750x500x500 mm
- Uncertainty of measurement: 6 $\mu$m (3\sigma)

**LEITZ**
- 1200x1000x700 mm
- MPE: 0.3 $\mu$m + 1 ppm

**OLIVETTI**
- 1600x900x600 mm
- Uncertainty of measurement: 6 $\mu$m (3\sigma)
Short range strategy (3) — determination of the position

Fiducialisation of components

Fiducialisation of their common support

Alignment on a common support

Whole assembly ready to be aligned
Short range strategy (4) ➔ adjustment
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✓ Conclusion
✓ **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 module test setup

- **Configuration:**

- **Components:**
Fiducialisation

✓ Means of measurements chosen according to the length & accuracy required
Alignment on a common support

In situ, by combination of mobile means

Case of the DB quad
(alignment of the other components under progress)

Determination of the position of the DB quad on its interface plane w.r.t. the mean axis of the V-shaped supports

✓ performed by AT401 and Micro-triangulation measurements, with a precision and accuracy better than 10 μm

✓ Adjustment system based on shims did not provide the required resolution of adjustment (not better than 20 μm)
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 successful, even though sensor noise was affecting the final regulation quality.
Validation of the global strategy

Determination of the mean axis of the V-shaped supports by two different methods:
- AT401 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]

<table>
<thead>
<tr>
<th></th>
<th>X (µm)</th>
<th>Z (µm)</th>
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<tbody>
<tr>
<td>MC1-E</td>
<td>-5</td>
<td>12</td>
</tr>
<tr>
<td>MC1-S</td>
<td>10</td>
<td>-5</td>
</tr>
<tr>
<td>MC2-E</td>
<td>-1</td>
<td>-4</td>
</tr>
<tr>
<td>MC2-S</td>
<td>-11</td>
<td>-7</td>
</tr>
</tbody>
</table>

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

• 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 \( \mu m \) 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.