Status of pre-alignment studies

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Outline

- Pre-alignment requirements
- Solution proposed
- Results obtained
- Summary

Introduction

Beam off

Mechanical pre-alignment — ~0.2 - 0.3 mm over 200 m

Active pre-alignment — 14 - 17 µm over 200 m

Beam on

Beam based Alignment & Beam based feedbacks

One to one steering	Dispersion Free Steering	Minimization of AS offsets
Make the beam pass through	Optimize the position of BPM & quads by varying the beam energy	Using wakefield monitors & girders actuators

Minimization of the emittance growth

Introduction

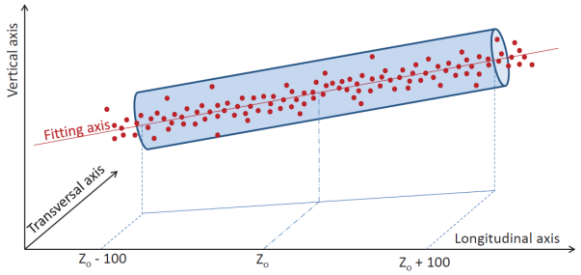
Considering the number of components to be aligned, ground motion, such tight tolerances can not be obtained by a static on-time alignment system.

➔active pre-alignment: we associate movers and sensors to the components to maintain them in place.

Total budget error allocated to the associate positioning of the reference axes of the major accelerator components can be represented by points inside a cylinder over a sliding window of 200m.

<u>Along BDS:</u>

Radius equals to 10 µm over sliding windows of 500 m

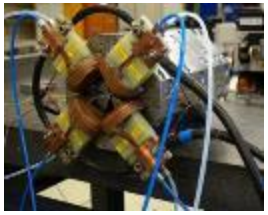


<u>Along Main Linac</u>: over sliding windows of 200 m

Component type	AS	BPM	MB Quad	DB quad
Radius (µm)	14	14	17	20

Introduction

Components to be aligned:



	BPM	Quad	AS
Number of components	~ 4000	~ 4000	~ 140 000
Budget of error	14 μm	17 μm	17 μm

Strategy:

2 steps:

- Fiducialisation & initial alignment of the components and their support
- Transfer in tunnel and alignment in tunnel

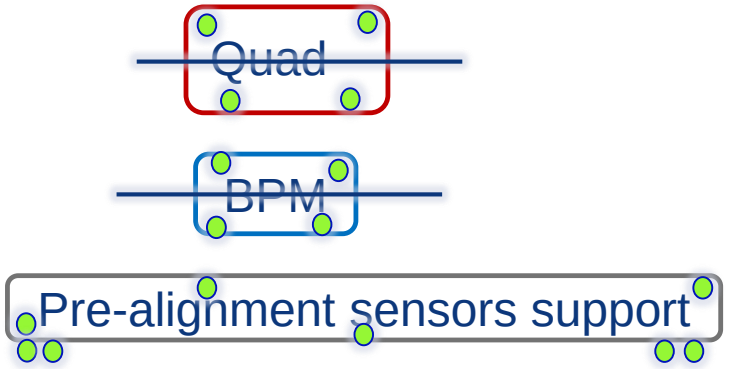
Pre-alignment steps

PETS

Quad

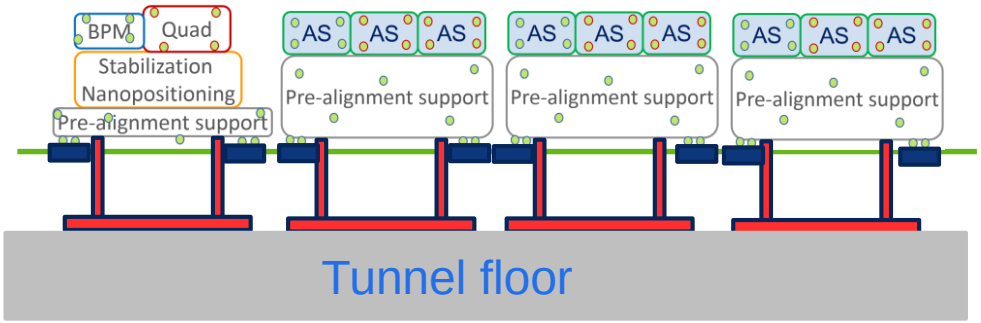
Pre-alignment sensors support

Fiducialisation:



Initial alignment:

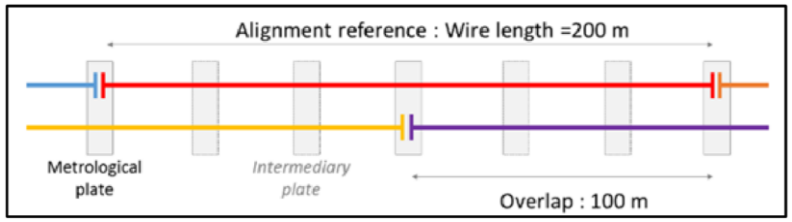
Transfer in the tunnel:

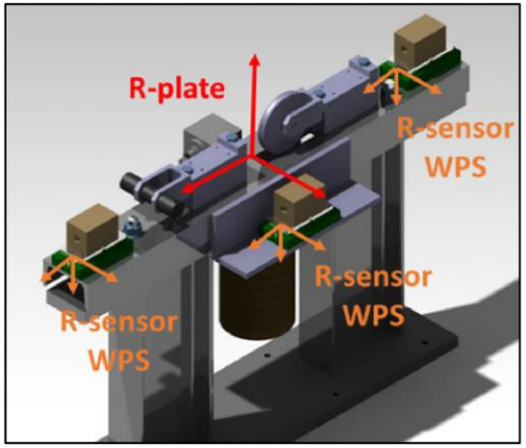


H. Mainaud Durand et al., "The new CLIC main linac installation and alignment strategy", 9th IPAC, Vancouver, Canada, 2018.

Strategy proposed & results obtained

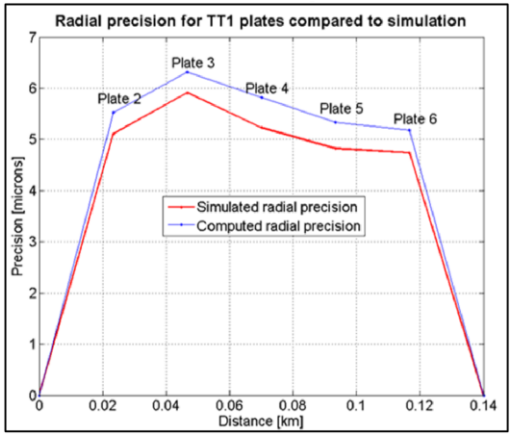
Absolute alignment using overlapping reference lines

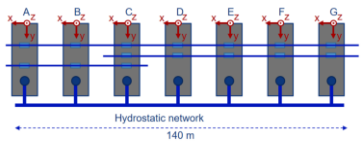




MRN = Metrological Reference Network

Very good correlation between simulated data and TT1 results





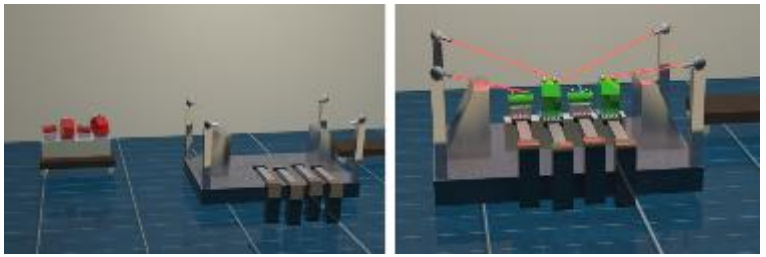
Propagation error over the CLIC collider simulated using the variance-covariance matrix as estimator of parameters:

- For a sliding window of 200m, the standard deviation of the transverse position of each component w.r.t. a straight line is included in a cylinder with a radius below 7 µm
- Maximum standard deviation of 1.1 mm computed along the 25 km of linacs

H. Mainaud Durand et al., "Micrometric propagation of error using overlapping stretched wires for the CLIC pre-alignment", 8th IPAC, Copenhagen, Denmark, 14-19 May 2017, pp.TUPIK098.

Strategy proposed & results obtained

Fiducialisation & alignment on common support



- ✓ Results achieved in the PACMAN project:
  - Sub-micrometric repeatability to determine the magnetic axis of quadrupole, the electro-magnetic center of the middle cell of AS, the electrical center of BPM
  - Relative position of BPM versus quadrupole determined within an uncertainty of measurement below 5 µm.
  - Fiducialisation (determination of the position of the reference axis w.r.t. external targets) for the 3 types of components < 5 µm.
  - Referential frame of the pre-alignment sensors determined w.r.t. references axes within an accuracy of 2.5 µm

PACMAN project website: http://pacman.web.cern.ch

D. Caiazza et al., “New solution for the high accuracy alignment of accelerator components", Phys. Accel. Beams 20 (2017) 083501.

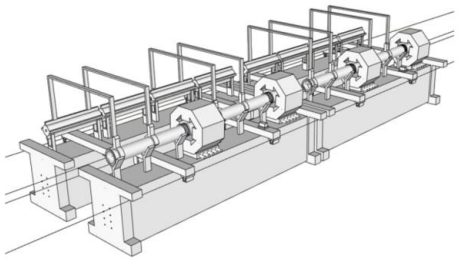
Strategy proposed & results obtained

Relative alignment of the components

SPN = Support Pre-alignment Network

✓ Determination of the position: sensors associated to each components support:

3. Conclusion on estimated precision



2 wires
- Precision < 15 µm
- 8 observations (each sensor gives 2 values)
- 5 parameters to define (2 translations and 3 rotations of the girder)
- Difficult access between MB and DB girders – small distance, a lot of components which connect the two sides

1 wire + tilt meter (10 µrad)
- Precision < 14 µm
- 5 observations (2 cWPS + angle from the tilt meter)
- 5 parameters to define
- No redundancy

Shorter distance between sensors (-80 cm)
⇩
Lower precision of the axis' position (+2 µm)

1 wire + tilt meter (60 µrad)
- Precision < 25 µm
- 5 observations
- 5 parameters to define
- No redundancy

CLIC Workshop 2018
22-26 January 2018

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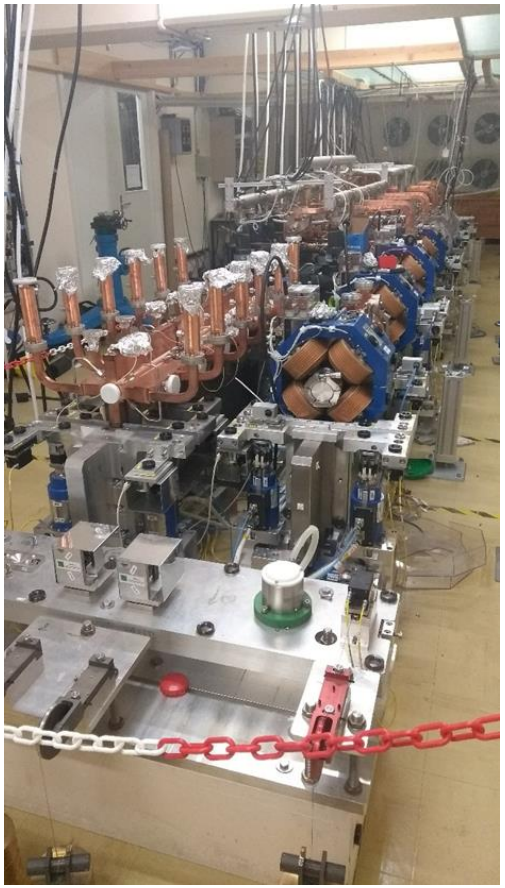
8

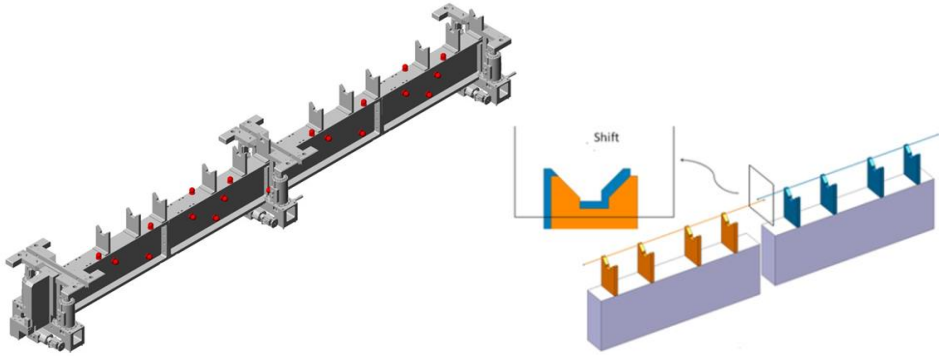


Strategy proposed & results obtained

Relative alignment of the components: adjustment ➔ 2 cases

Articulation point + linear actuators (3DOF):

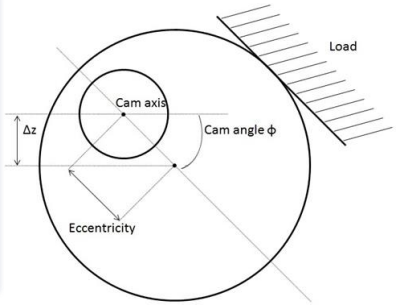
- Snake configuration kept for the DB side, allowing a natural smoothing
- Adjustable articulation point, controlled by FSI measurements within an accuracy of 5 µm
- 3 linear actuators supporting the master cradle will perform the alignment
- Ves replaced by adjustable platforms

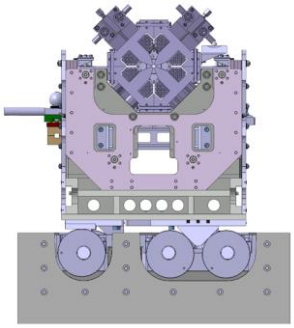


Cam movers (5 to 6 DOF):

- 5 DOF configuration validated for 2 lengths of quadrupoles: 0.5m and 2m (sensors offsets below 1 µm and roll below 5 µrad), met in one movement using feedback from alignment sensors.
- Proposition to add a 6th cam mover

See Juha's presentation this afternoon



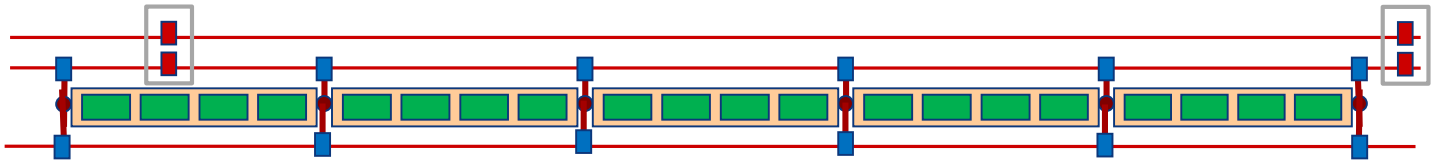


M. Sosin et al., "Issues and feasibility demonstration of CLIC supporting system chain active pre-alignment using a module test setup (mock-up)", CERN-ACC-Note-2016-0063, 2016

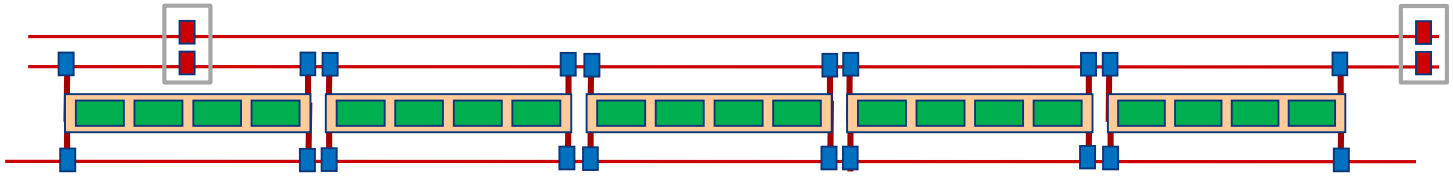
J. Kemppinen et al., "cam mover alignment system positioning with Wire Position Sensor feedback for CLIC", MEDSI, Barcelona, Spain, 2016, CERN-ACC-2016-0339, CLIC Note 1072.

Strategy proposed & results obtained

If you combine long & short systems

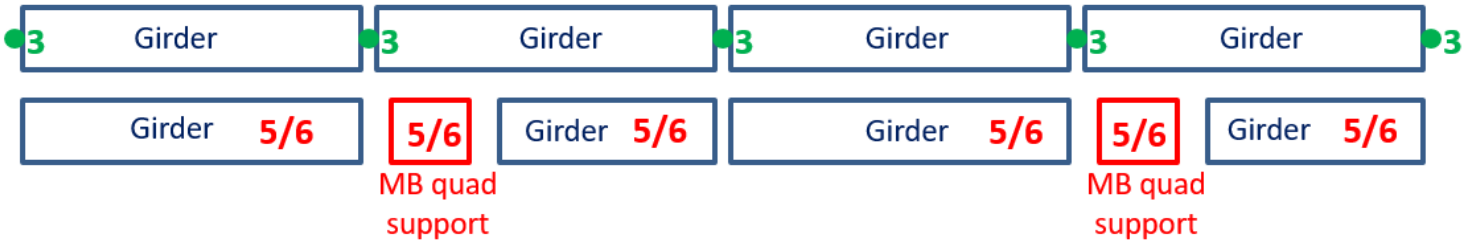


or



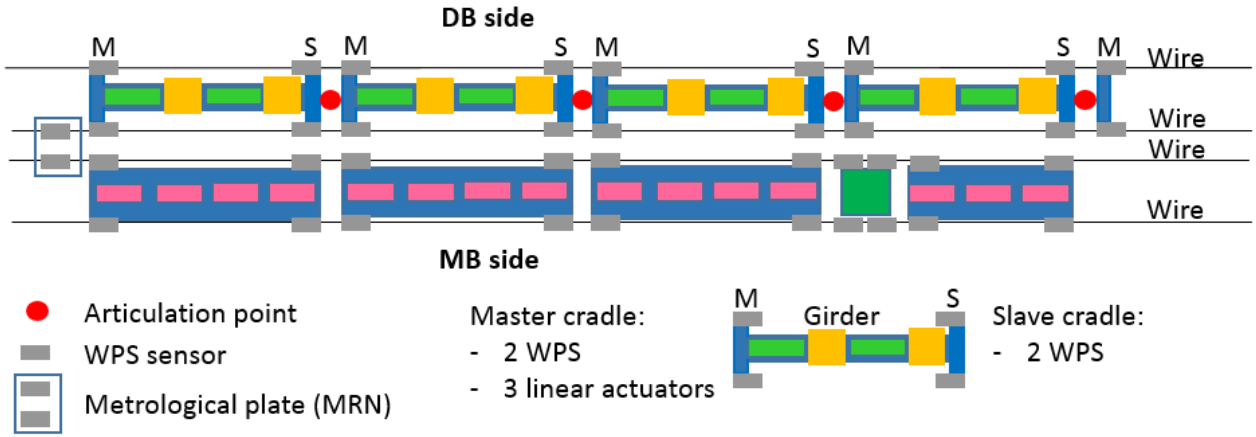
Adjustment configuration

Degrees of freedom: 3 / 5 to 6

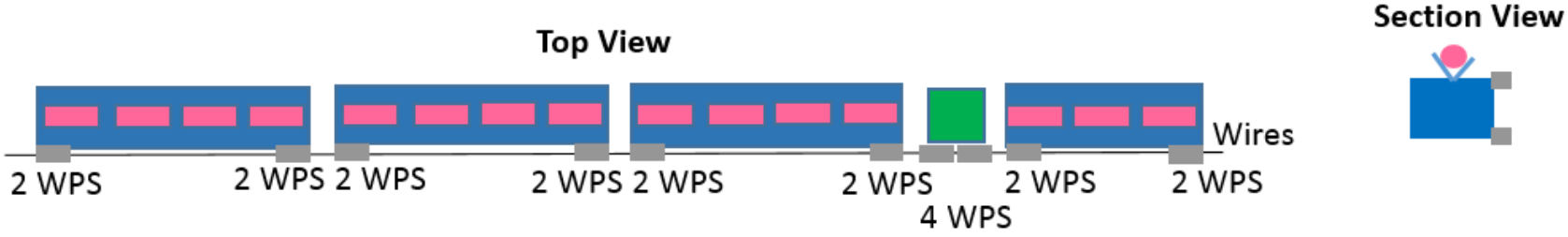


Summary of the configurations proposed

Sensors configuration for 380 GeV DB option



Sensors configuration for 380 GeV Klystrons option



Summary of the results achieved

Components type	AS, BPM (μm)		MB quad (μm)		DB quad (μm)	
YEAR	2012	2018	2012	2018	2012	2018
Fiducialisation	5 (TBC)		10 (TBC)		10 (TBC)	
Fiducials to pre-alignment sensor interface	5	5	5	5	5	5
Pre-alignment sensor accuracy	5	5	5	5	5	5
Sensor linearity	5	5	5	5	5	5
Straight reference	10 (TBC)	7 (in radial, TBC in vert.)	10 (TBC)	7 (in radial, TBC in vert.)	10 (TBC)	7 (in radial, TBC in vert.)
Total error budget	14	11	17	11	20	11

BUT… Active pre-alignment strategy validated only at 20°C, not at 30°C!

Next steps

common with HL-LHC

common with FCC

Geodesy	Study of MRN	Study of SPN	Fiducialisation
Relative determination of vertical deflection	Modelisation of a wire using Eigenfrequencies	Study of low cost sensors and industrialization	PACMAN studies on AS structures
New methods for vertical deflection measurements in pits	Development of corresponding least squares algorithms	Development of low cost linear actuators and industrialization	Development of a FSI bench for in-situ fiducialisation
Impact of gravitational fields on wires	Sensors configuration optimization, simulations over long distances	Impact of an operation at 30°C on alignment systems	Development of low cost adjustment platforms and industrialization
	Development of a new wire	FSI R&D on sensors	Improve adjustment solution for the BPM on the quadrupole
	Development of a laser based solution	Development of a WPS with 2 wires	
		Development of 6 DOF cam movers	

Conclusion

- A lot of studies and developments carried out since 30 years on CLIC active pre-alignment, leading to a realistic and robust solution.
- All achievements are being documented in a CLIC note under preparation.
- These achievements are directly applied on other projects (LHC low beta quadrupoles and HL-LHC components).
- But still important studies have to be undertaken, especially concerning the impact of CLIC temperature operation of 30°C on the active pre-alignment.
- For the first time in 30 years, we won't have a CLIC budget: so no possibility to perform R&D this year on alignment.
- It's dangerous to stop such an activity that will be difficult to be reactivated, independently of the next project chosen.

Thank you very much