The CLIC main linac installation and alignment strategy after PACMAN

Hélène MAINAUD DURAND

Based on
LCWS'17 Strasbourg

May 2023

Introduction

PACMAN = a study on Particle Accelerator Components' Metrology and Alignment to the Nanometre scale

It is an Innovative Doctoral Program, hosted by CERN, funded by EU, providing training to 10 Early Stage Researchers (ESRs).

- Start-end dates: 01/09/2013-31/08/2017
- 10 ESRs, working towards a PhD thesis
- 8 PhD theses
- Web-site: PACMAN

Total EU contribution: 2.67 M€

CLIC budget: 1.6 MCHF

PACMAN: intro & main achievements

5DOF adjustment system

2 scenarios of installation & alignment

Objectives

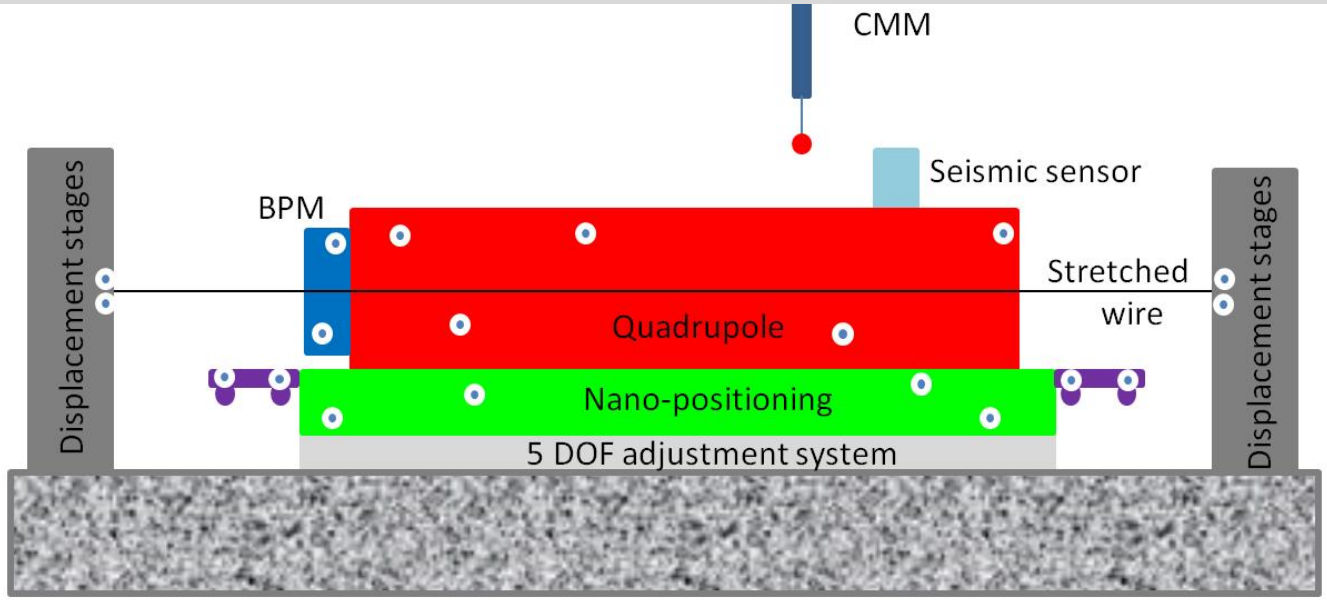
Propose an alternative solution for the high accuracy alignment of the accelerator components:

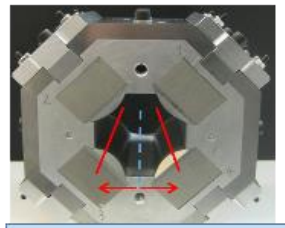
- using a stretched wire acting as a beam for the fiducialisation of components.
- combining references & methods of measurements in the same place to gain time and accuracy

To get this:

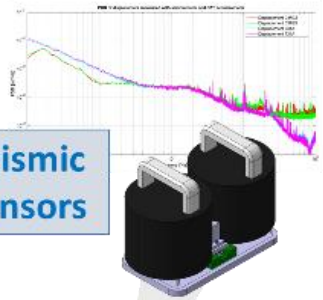
- develop very high accuracy metrology and alignment tools
- Validate them on a final bench: the Final PACMAN Alignment Bench

Extrapolate tools & methods developed to other projects

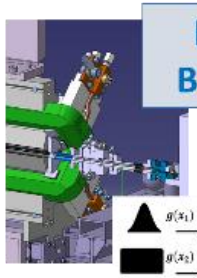




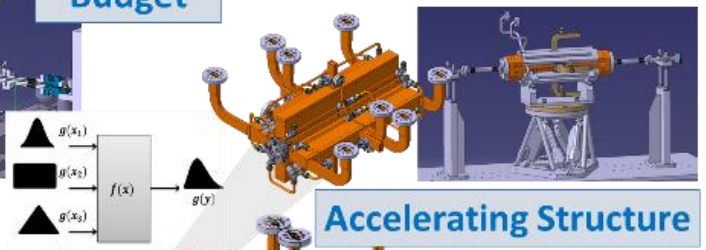
Vibrating Wire



Seismic Sensors

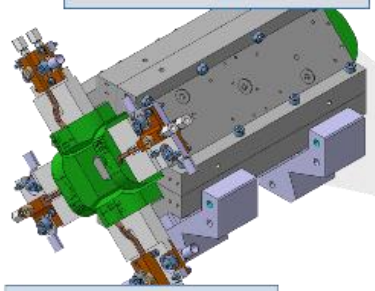


Error Budget

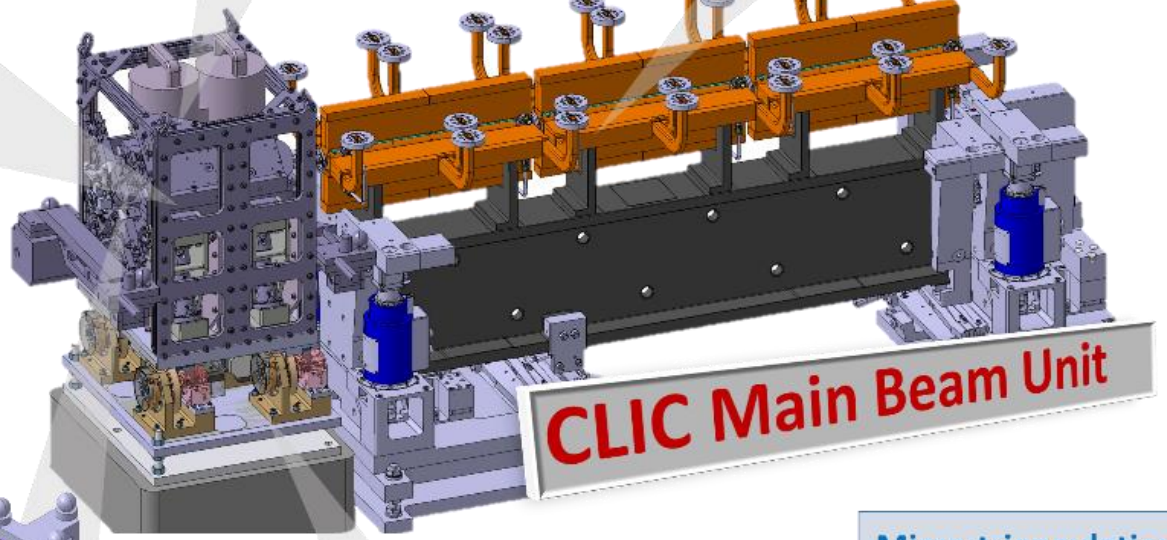


Accelerating Structure

CMM

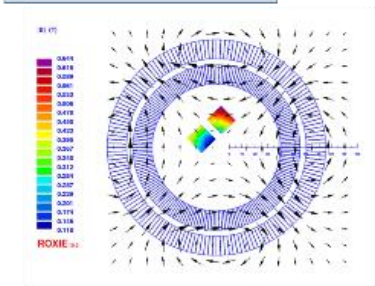


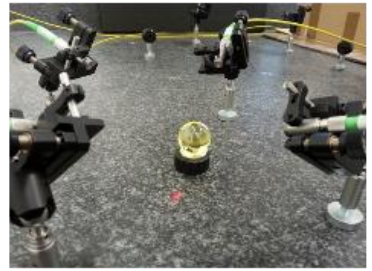
Rotating Coils

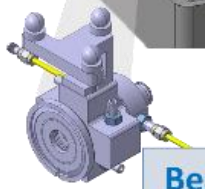


CLIC Main Beam Unit

Frequency Scanning Interferometry

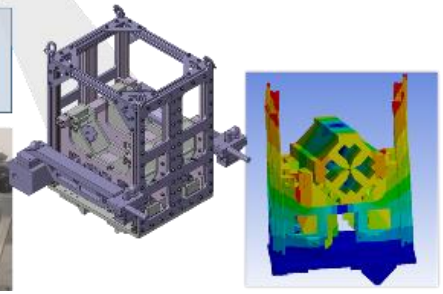




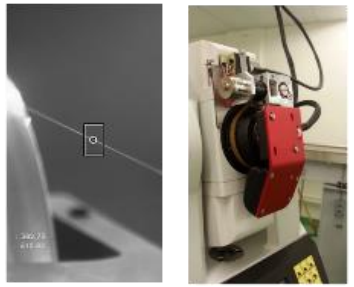


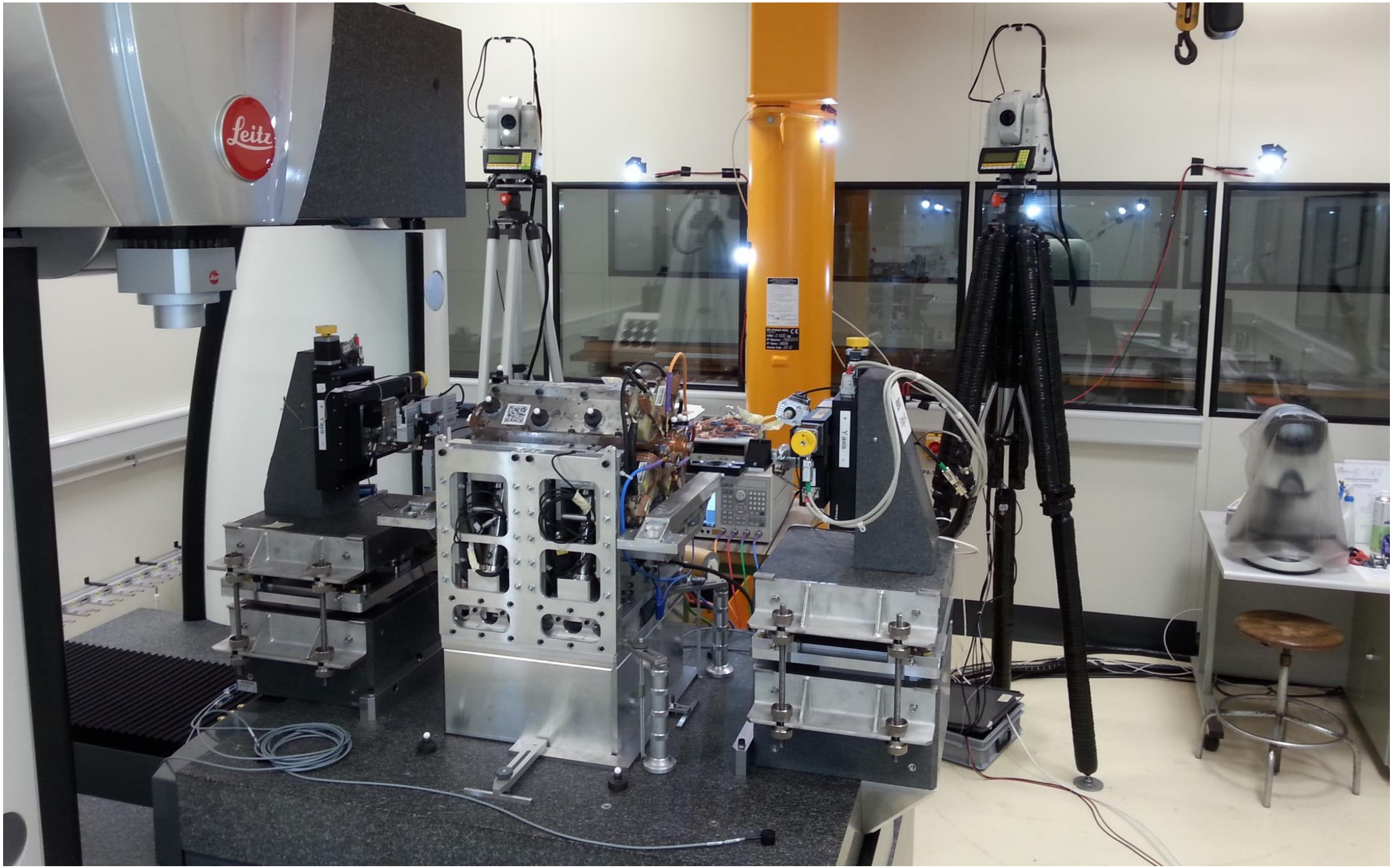
Beam Position Monitor

Nanopositioning



Micro-triangulation

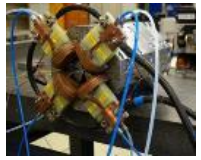



Leitz

Main achievements dealing with installation and alignment

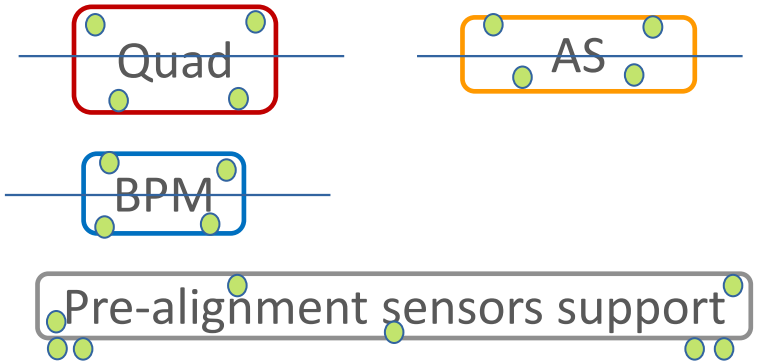
Determination of the reference axis of components by using a stretched wire, positioned at the reference axis thanks to displacement tables.

BPM



Quad

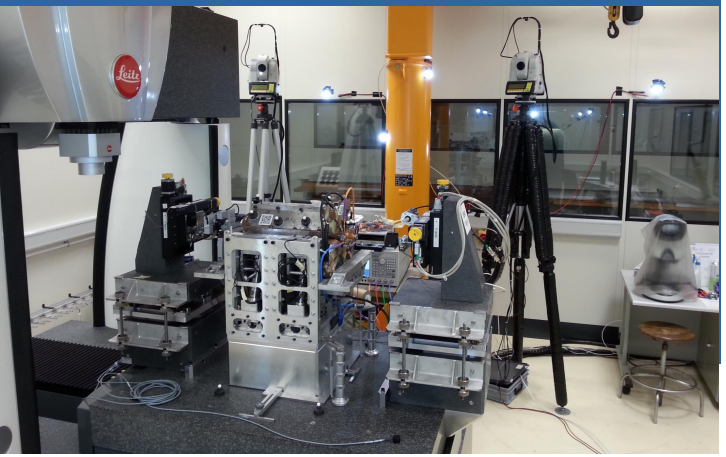
AS



Results achieved:

- 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.

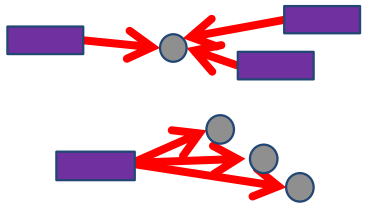
Main achievements dealing with installation and alignment

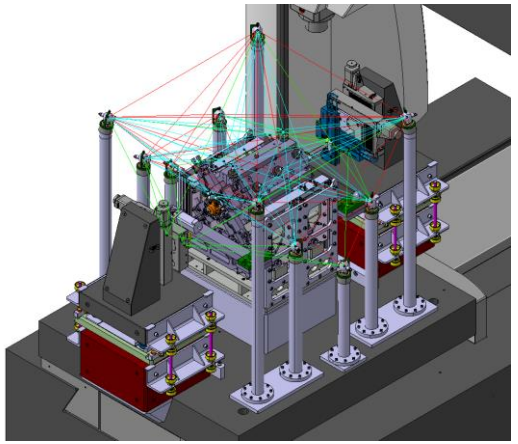


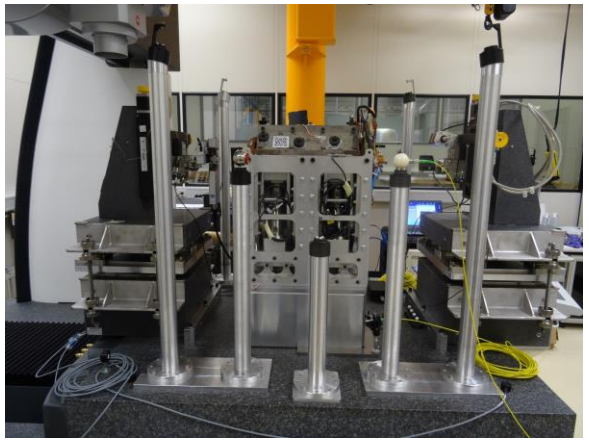
Determination of the position of the stretched wire, w.r.t. external targets: 3 methods:

- Coordinate Measuring Machine measurements (+wire measured using confocal sensor plugged on the CMM head): uncertainty ~ 2 µm
- Frequency Scanning Interferometry (absolute distance measurements)
- Micro-triangulation (angle measurements)

FSI demonstrated a very high accuracy: difference between FSI & CMM measurement on coordinates < 2.5 µm. Portable & self calibrating method!







Micro-triangulation: after comparison with CMM measurements, 85% of the measured coordinates < 15 µm, 75% < 10 µm, 42 % < 5 µm, in a not optimal configuration.

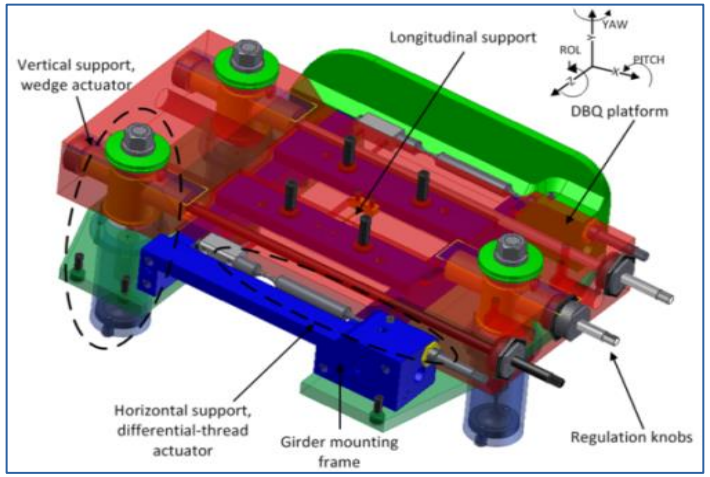
Combined with a 5DOF adjustment platform

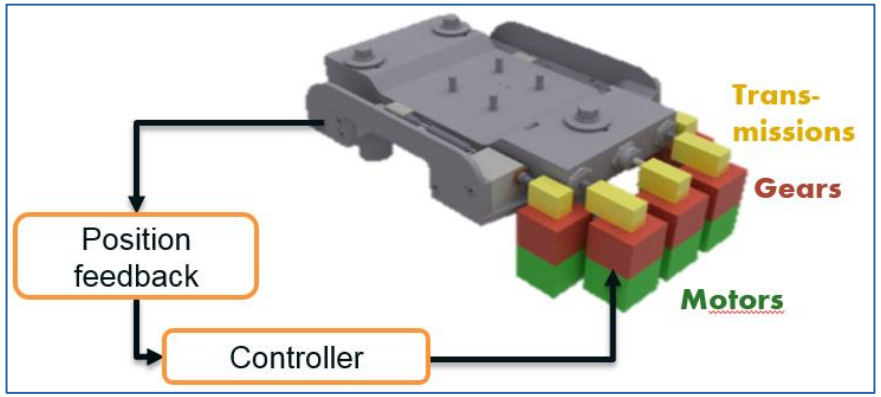
Why a 5 DOF adjustment platform?

- More than 40 000 DB quadrupoles to be aligned 2 per 2 on a common support within a budget of error < 20 µm
- First tests used shims for the adjustment: the alignment took more than 1 day per quadrupole!
- Decision to develop a specific platform, with all adjustment knobs on the same side, in a limited volume.

Design proposed:

- 5 degrees of freedom, 3 adjustment knobs for vertical, based on wedge, 2 adjustment knobs for radial, based on differential threads
- Adjustment within 10', final alignment better than 10 µm.





Combined with a 5DOF adjustment platform

Two scenarios of installation & alignment

Scenario 1

Strategy also applicable in the tunnel, after transport

Scenario 1:

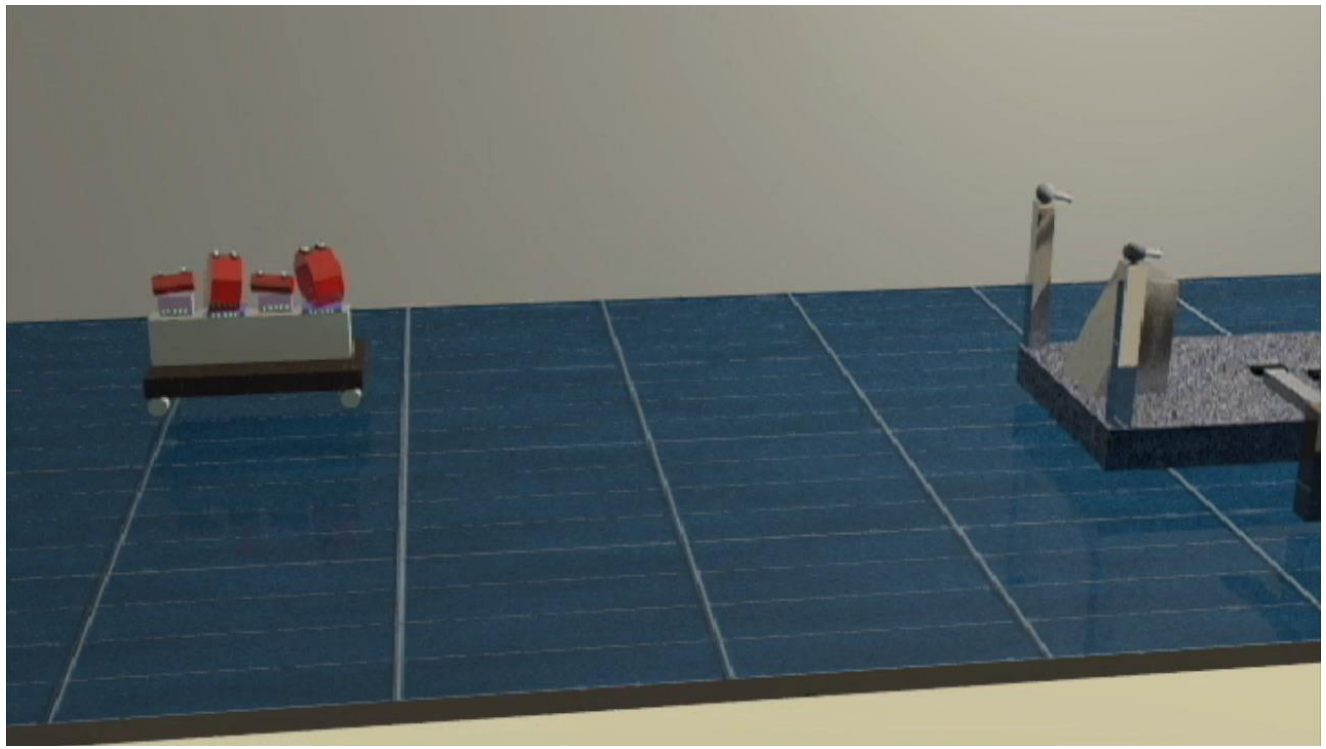
- All components individually fiducialised (PACMAN process using stretched wire)
- Alignment on a common support using plug-in system, knowing the position of the targets.

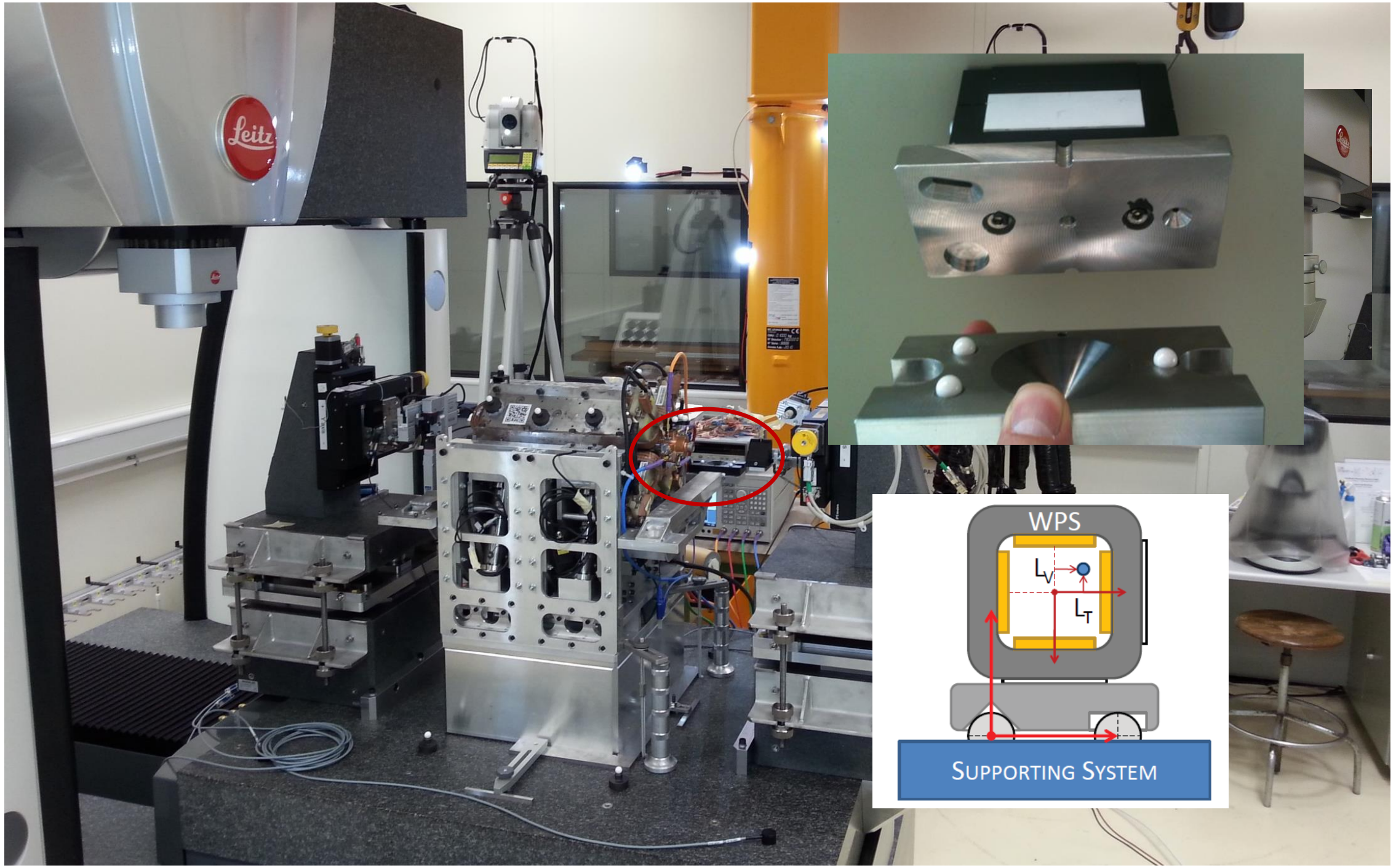
Two scenarios of installation & alignment

Scenario 2

Scenario 2:

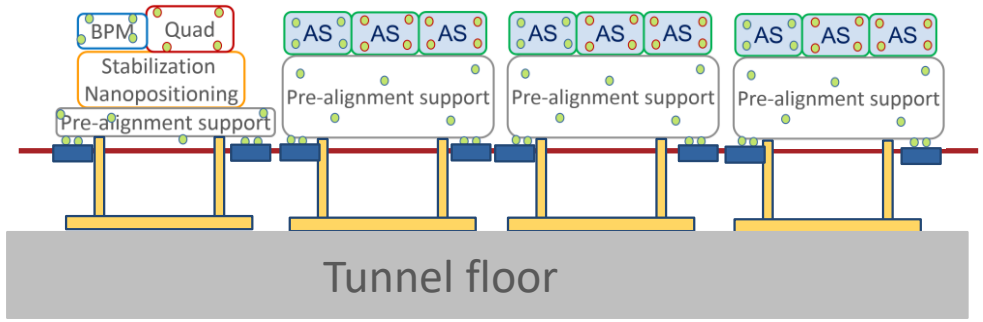
- All components installed roughly on a common support
- Installation of a stretched wire to align all the components reference axes at a theoretical position on the common support (PACMAN process + 5 DOF adjustment system)
- Determination of the position of the alignment targets once all the components are at the theoretical position

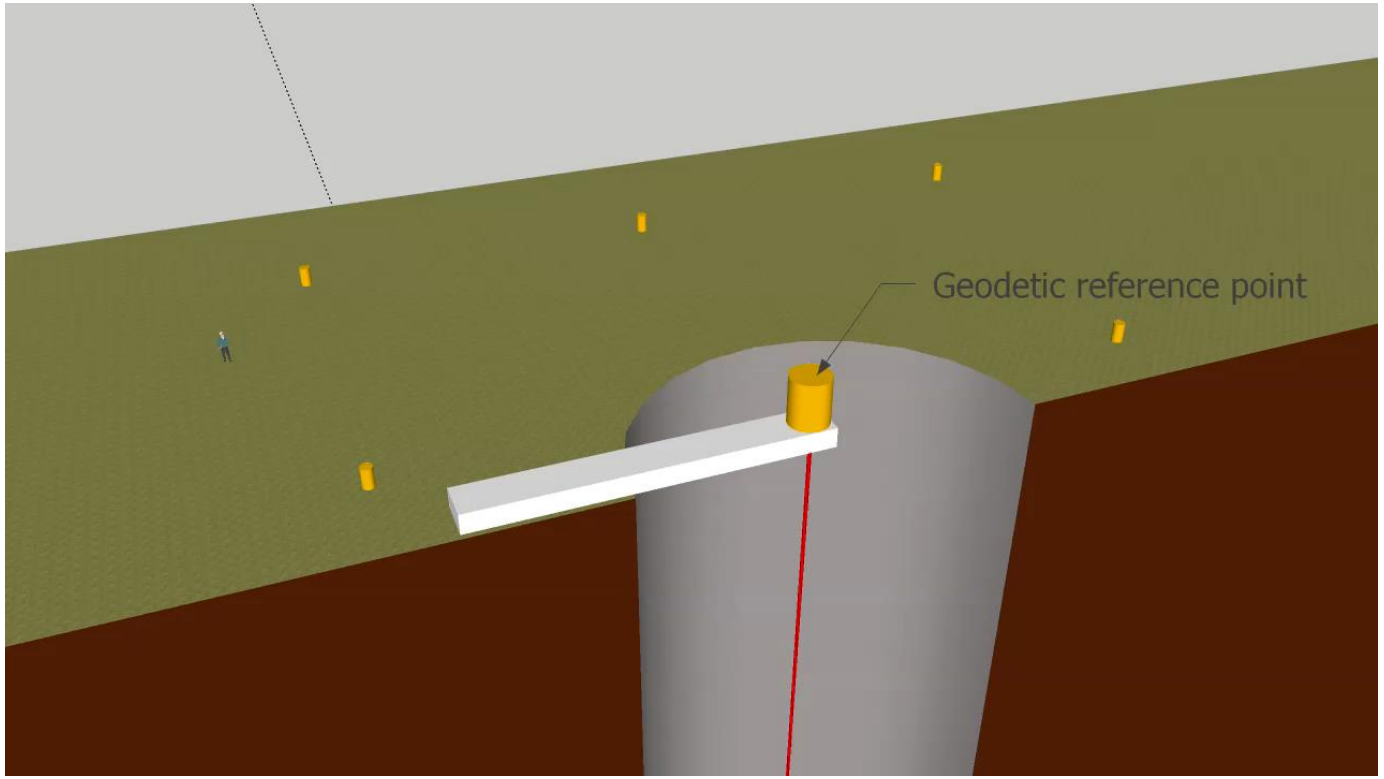



Leitz

WPS
L_V
L_T
SUPPORTING SYSTEM

Alignment in the tunnel





Summary

- The PACMAN project allowed to perform a micrometric determination of the reference axis of CLIC components w.r.t to external targets, using a stretched wire to materialize the beam position
- Portable measurements methods have been developed, providing a similar accuracy: FSI and micro-triangulation.
- A micrometric 5 DOF adjustment system, compact and robust, has been developed, with all adjustment knobs located on same side, on which plug-in motors can be installed in a very limited duration
- The combination of these 3 achievements provide very interesting perspectives for the installation and alignment of the CLIC components.

PACMAN is a team work :

The students:

- Claude Sanz
- Vasileios Vlachakis
- Solomon Kamugasa
- Domenico Caiazza
- Giordana Severino
- Iordan Doytchinov
- Peter Novotny
- David Tshilumba
- Silvia Zorzetti
- Natalia Galindo Munoz

The academic supervisors:

- Paul Shore
- Paul Morantz
- Markus Rothacher
- Pasquale Arpaia
- Xavier Tonnelier
- Laurent Brunetti
- Bernard Caron
- Jo Spronck
- Luca Fanucci
- Angeles Faus-Golfe

The CERN supervisors:

- Ahmed Cherif
- Jean-Christophe Gayde
- Jean-Frédéric Fuchs
- Stefan Russenschuck
- Marco Buzio
- Michele Modena
- Andrea Gaddi
- Kurt Artoos
- Manfred Wendt
- Nuria Catalan Lasheras

The industrial partners:

- Jürgen Schneider, Norbert Steffens, Heinrich Schwenke, Marie-Julie Leray, Pascal Lequerre, Alicia Gomez, Teun van den Dool, Joe Woodford, Jacques Tinembart, Philip Keller, Miroslav Sulc

CERN support:

- Seamus Hegarty, Charlyne Rabe, Karen Ernst, Gregory Cavallo, Nicolas Friedli, David Mazur, Cécile Granier

Thank you for your attention

Based on
LCWS'17 Strasbourg

May 2023

Special acknowledgements to Mateusz Sosin, Jakub Jaros, Anna Zemanek, Vivien Rude and Mathieu Duquenne for their work on the CLIC project.

6 DOF Estimation Based on FSI 3D Reconstruction and Digital Twin