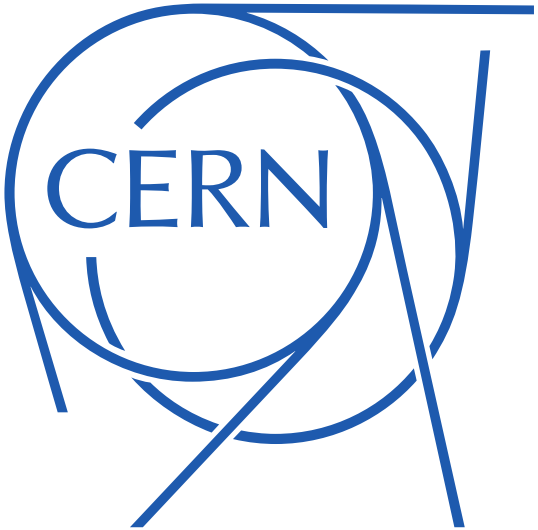

CERN

Juha Kemppinen

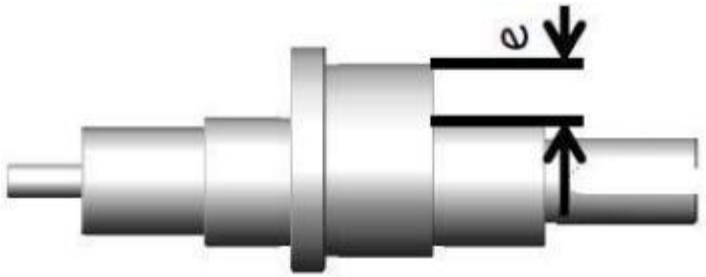
CLIC Main Beam quadrupole active pre-alignment based on cam movers

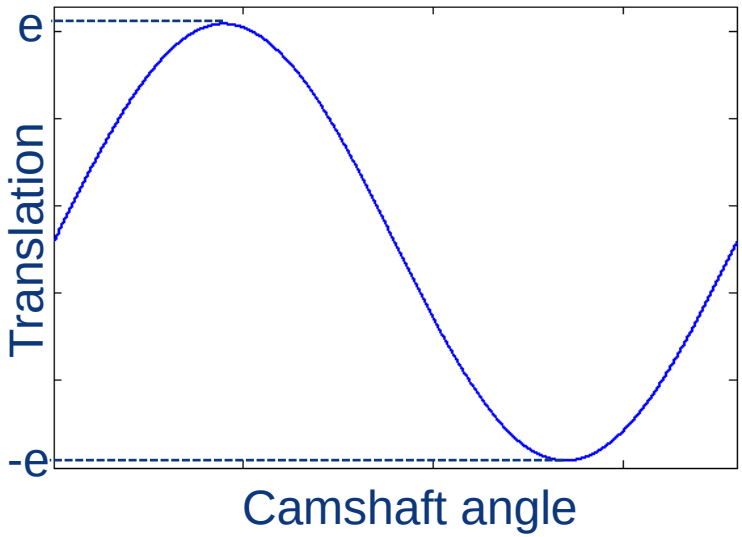
Main Beam Quadrupole (MB Quad) pre-alignment requirements

- Pre-alignment within 17 µm in sliding windows of 200 m
  - → active pre-alignment on single MB Quads within 1 µm / 100 µrad in 5 d.o.f. (stroke +/- 3 mm)
- Provide rigid support for the nano-stabilization system
  - High first eigenfrequency (preferably above 100 Hz)

Approach: cam movers

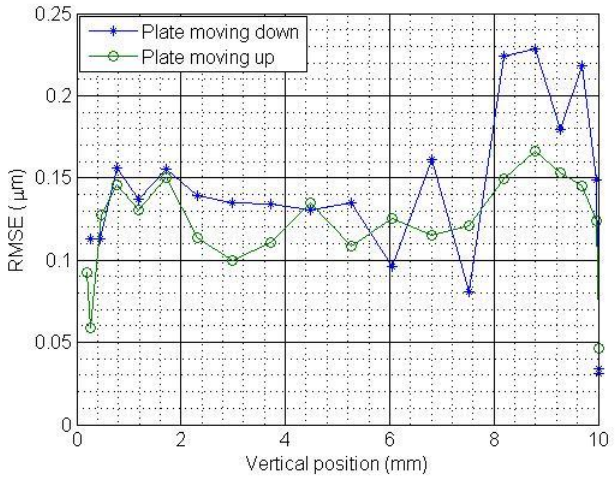
- Originally developed at SLAC and since then successfully deployed in several synchrotrons and light sources
- Transforms camshaft rotation to translation
- Very high movement resolution can be achieved

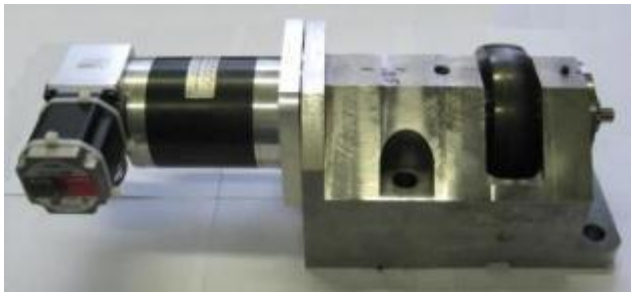


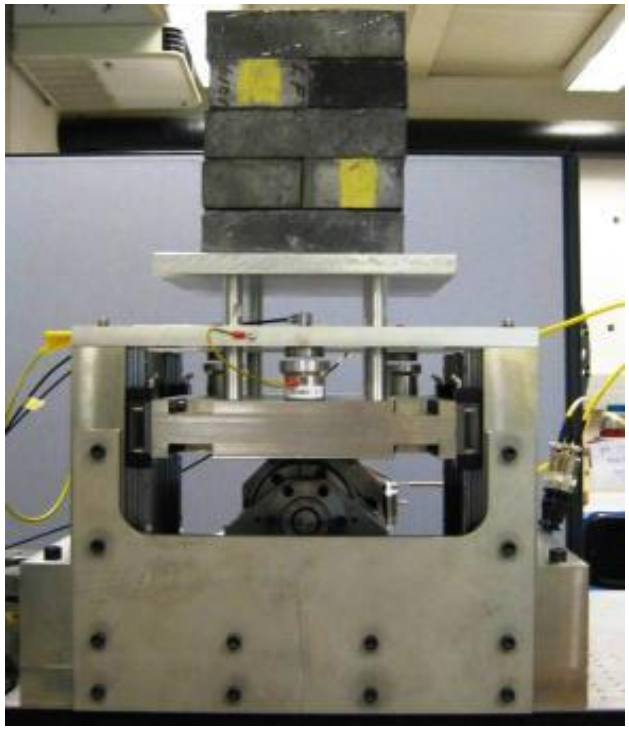


Cam mover prototype

- Based on PSI design
- 1 d.o.f. tests verified sub-micron movement resolution and repeatability
- Stroke +/- 5 mm

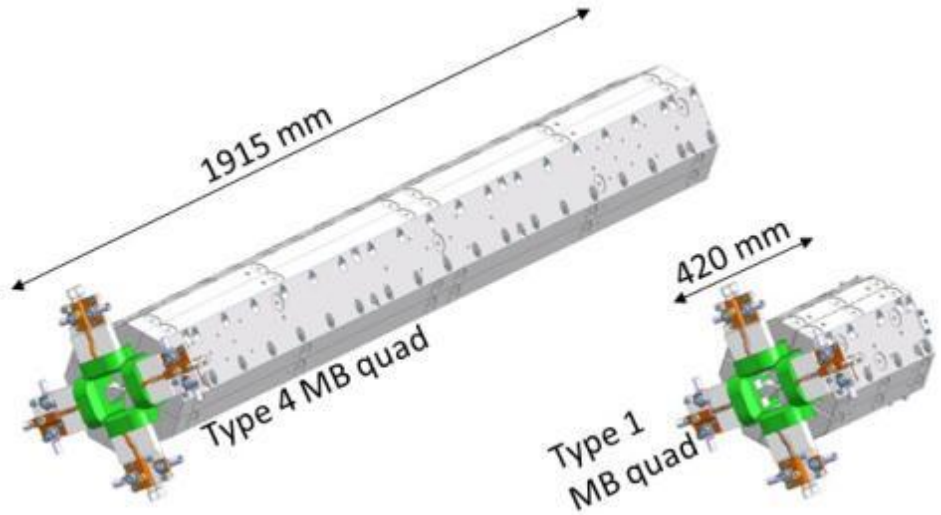






MB Quad types

- CLIC will have 4 types of MB Quads
- At least two different cam mover types will be needed



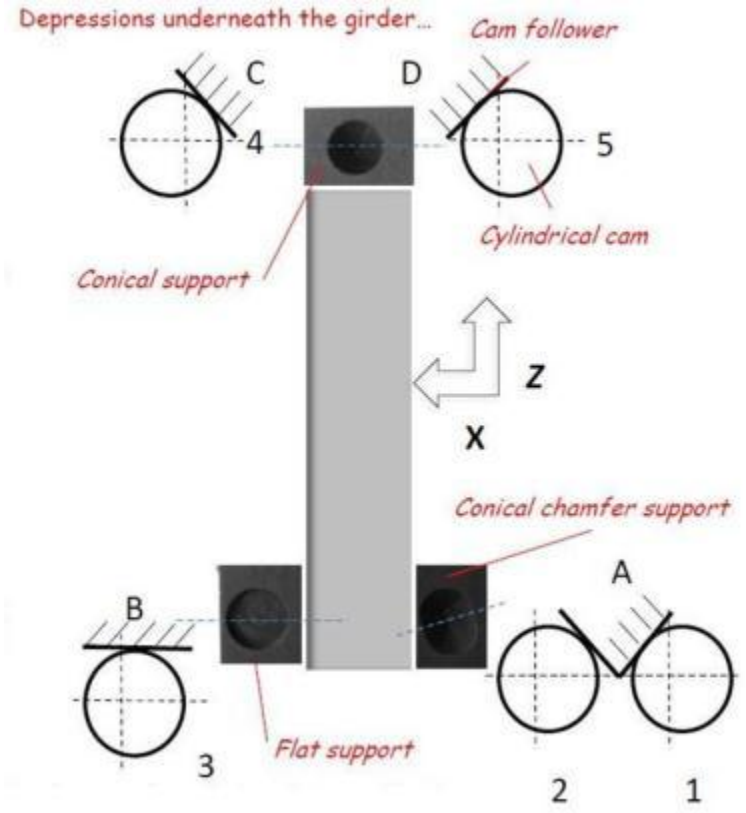
- Estimated masses (quadrupole + stabilization system)
  - Type 1: 300 kg
  - Type 4: 800 kg

Type 4 cam mover

- Manufacturer: ZTS VVU Kosice from Slovakia
- Design was optimized in an iterative process
- 6 cams were manufactured, then tested and calibrated in the 1 d.o.f. mock-up

5 d.o.f. mock-up for type 4

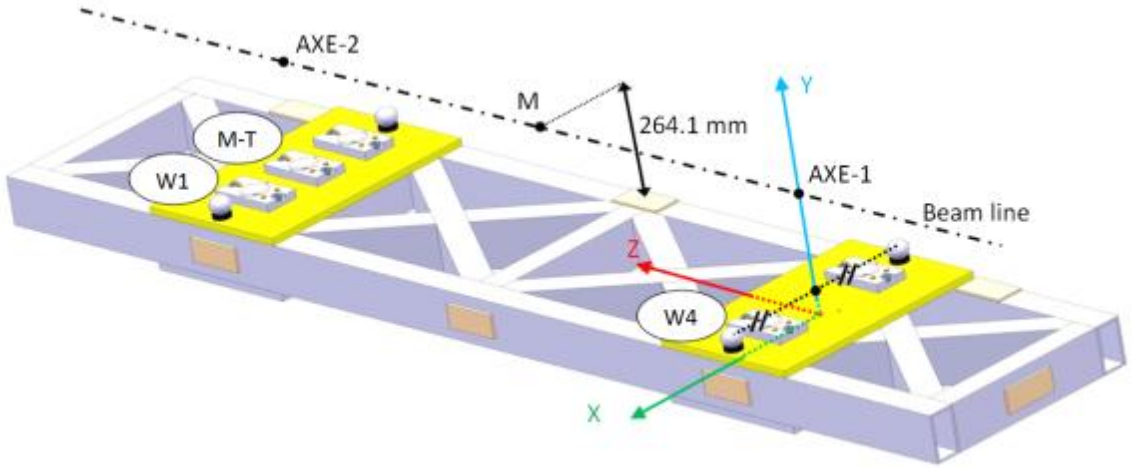
- 5 d.o.f. mock-up was built in the old ISR tunnel
- 5 cam movers with appropriate interfaces can handle the 5 d.o.f. movements
  - All except longitudinal movement (blocked)



5 d.o.f. mock-up for type 4

5 d.o.f. mock-up for type 4

- Chassis orientation is measured using a stretched wire, 2 WPS (W1, W4) and an inclinometer (M-T)
- Cam reference angles are calculated based on Dr. Andreas Streun's (PSI) formulas



5 d.o.f. results for type 4

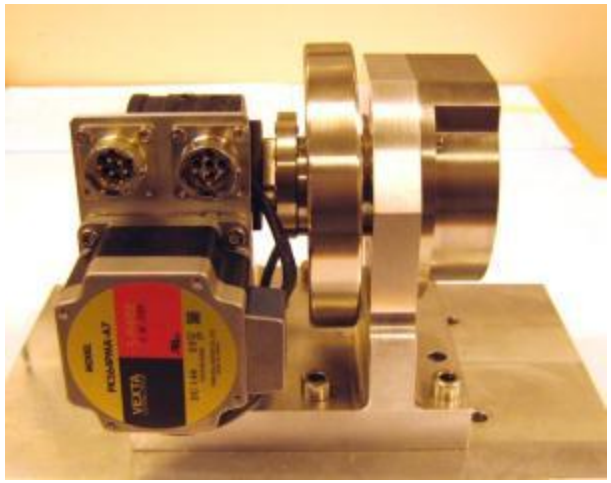
- Positioning repeatability below 5 µm (AXE-1 and AXE-2) and below 5 µrad (roll)
- Movement accuracy (with respect to a reference position)
  - 10 – 20 µm/µrad for simple movements
  - Up to 100 µm/µrad for complex movements
- Iterative method was applied (search position until the chassis is within 1 µm / 5 µrad from reference position)
  - 3 – 5 iterations without load
  - 5 – 10 iterations with load

5 d.o.f. results for type 4

- CERN Mechanical Measurement Lab (EN-MME) performed the experimental modal analysis of the 5 d.o.f. mock-up
  - The lowest natural frequency was found at 15 Hz which is lower than expected
  - This might be due to the support under cam movers → small test setup to verify this will be built shortly

Type 1 cam mover

- Was developed at CERN
- Very tight space restriction
  - No space for two gearboxes → challenging to achieve high movement resolution
    - Sub-micron resolution was realized using Oriental Motor high resolution stepper motor and Davall Gears custom Spiradrive® gearbox



R. Leuxe

Type 1 cam mover

- The first Spiradrive® series is equipped with high tensile brass pinion to have negligible backlash
  - The pinion broke down while the first cam mover was under 1 d.o.f. tests with 100 kg additional weight
  - Remaining gearboxes should be tested with reduced load in 1 d.o.f. and with full load in 5 d.o.f. to finally determine if they can be used

Type 1 cam mover

- A new series of Spiradrive® gearboxes, equipped with steel pinions, was manufactured
  - Better wear and torque resistance but introduces up to 5 arc minutes of backlash → requires more complex positioning algorithms

Next steps – type 4

- 5 d.o.f. tests using different bearing type in cam movers
  - Spherical roller bearing with cylindrical housing instead of a roller follower with spherical housing

    → Line contact instead of point contact
- Integration with the nano-stabilization system
- Improvement of control software and positioning algorithms

Next steps – type 1

- Assembly of 10 cam movers
  - 5 with steel pinion (priority) and 5 with brass pinion
- 1 d.o.f. tests and calibration
- 5 d.o.f. mock-up
  - Finalize design and build in ISR
  - Adapt positioning algorithms to new dimensions and backlash
  - Adapt software to new hardware

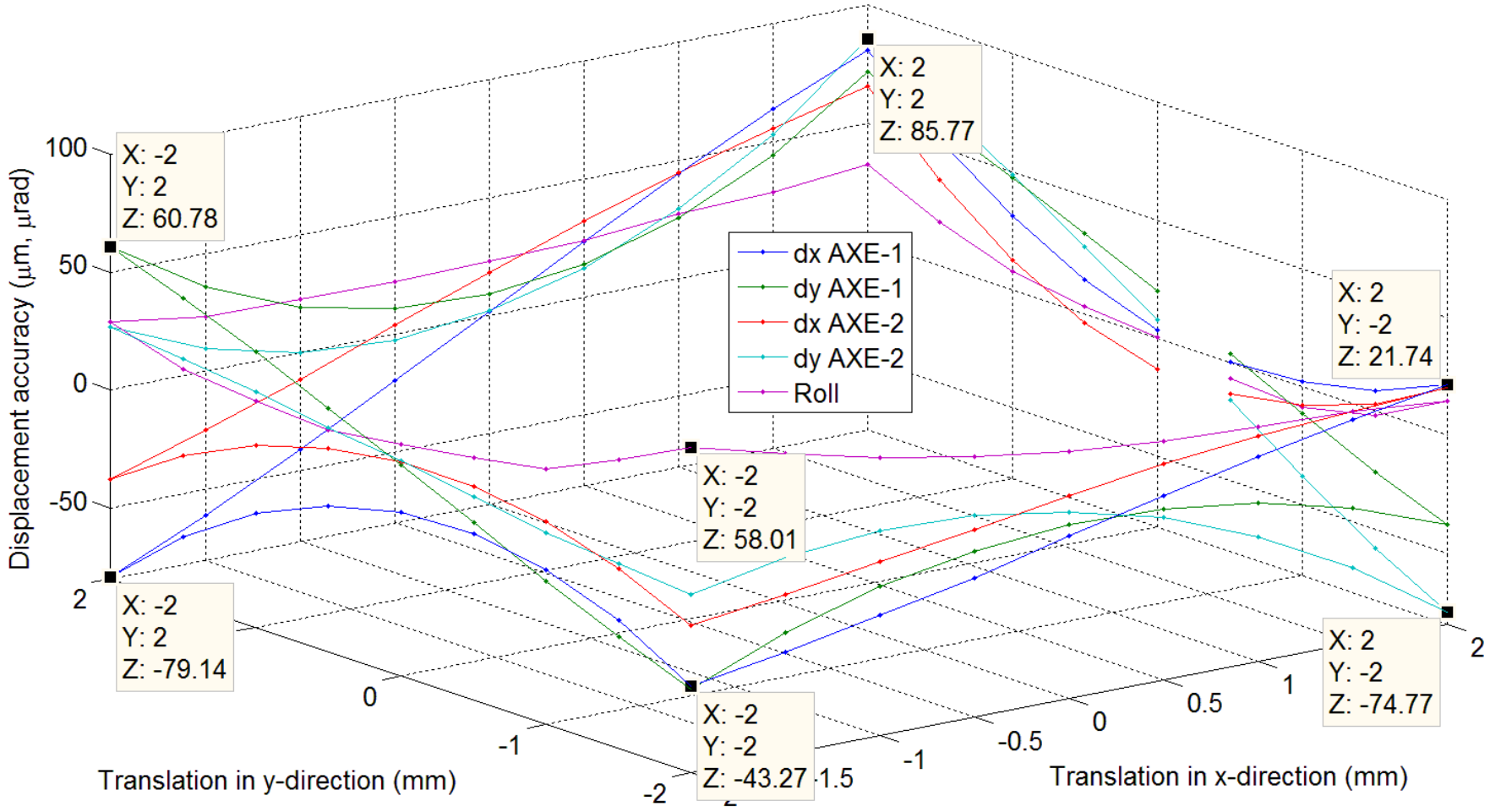
Long term (all types)

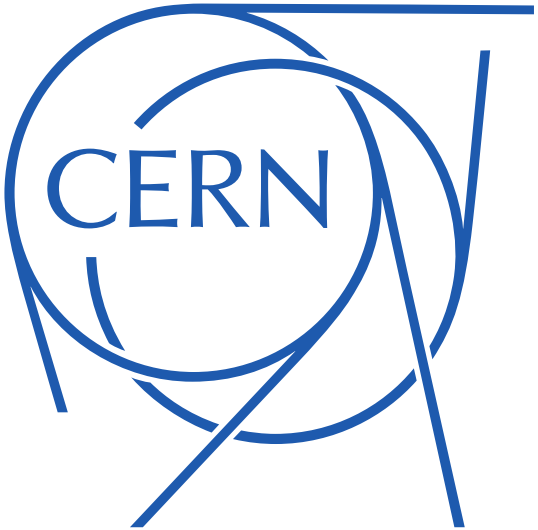
- Replace expensive absolute encoders with a simpler system to recover position data
- Link MB quad coordinate system to CLIC coordinate system → absolute positioning
- Study the possibility of fast WPS data acquisition → positioning feedback directly from alignment sensors (no need for iterations)
- Development of a 5 d.o.f. calibration process which can handle all 4 types of MB quads and their associated alignment sensors and cam movers

Questions?

- Credits
  - Pre-alignment team
    - Michail Anastasopoulos
    - Mathieu Duquenne
    - Sylvain Griffet
    - Andreas Herty
    - Hélène Mainaud Durand
    - Antonio Marin
    - Sylvain Mico
    - Michel Rousseau
    - Vivien Rude
    - Jacek Sandomierski
    - Mateusz Sosin
  - Kurt Artoos
  - Friedrich Lackner
  - Raphaël Leuxe
  - Michael Guinchard
  - Paul Scherrer Institute
  - Andreas Streun
  - ZTS VVU Kosice

5 d.o.f. results for type 4




CERN