CLIC alignment plan for BDS and QD0

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BDS alignment strategy at CLIC

Determination of the geodetic network on surface

Transfer of reference into tunnel

Determination of the geodetic network in the tunnel

Absolute alignment of the elements

Fiducialisation

Relative alignment of the elements

Active pre-alignment

Control and maintenance of the alignment

From surface to underground

| Determination of the geodetic network on surface |
| Transfer of reference into tunnel |
| Determination of the geodetic network in tunnel |

Distance < 2.5 km

✓ Combination of 3D triangulation and trilateration coupled with measurements of vertical plumb wires

✓ Methods validated on an LHC pit in 2010 (depth of 65 m): precision of 0.1 mm and accuracy of 0.5 mm

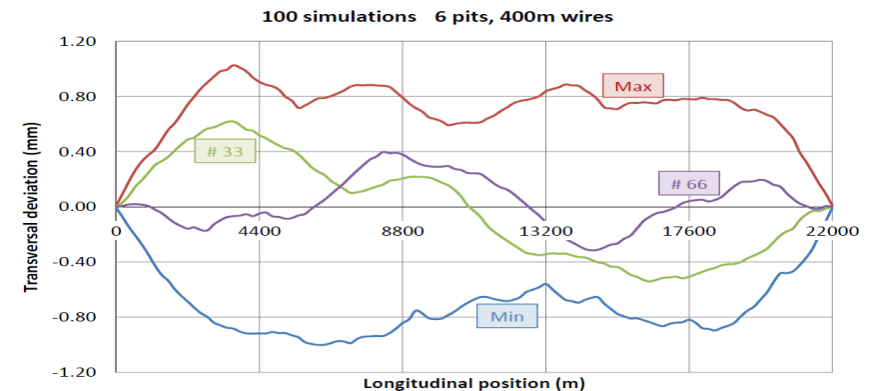✓ Hypothesis decided for CLIC: absolute position at the bottom of each pit: ± 2 mm (depth > 100 m)
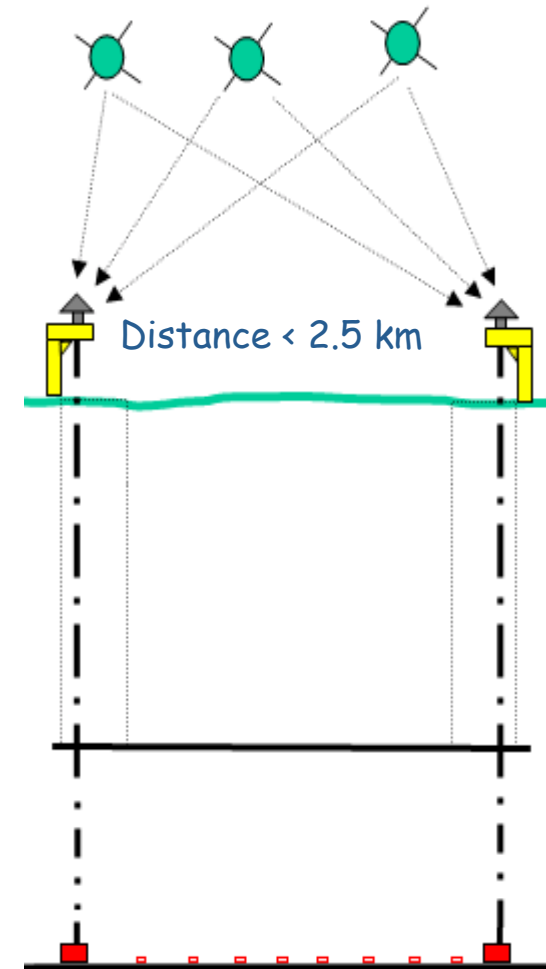
Stretched wire as perfect straight line, MRN

Absolute alignment of the elements
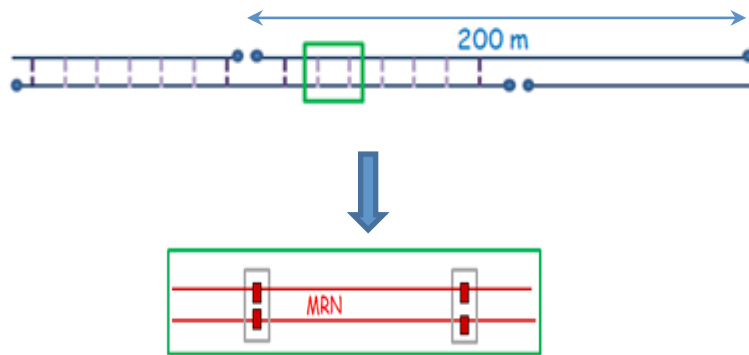
**Metrological Reference Network (MRN)**

Propagation network simulations: max deviation along the linac below 1 mm

✓ Installed w.r.t the <u>tunnel network</u>. Overlapping stretched wires propagating the precision over long distances

✓ Simulations in 2009:
- Precision at the bottom of the shaft of ± 2 mm
- Calibration of metrological plates: ± 5 μm
- Distance between pits: 3.5 km
- Wires: 400m long (for the simulations
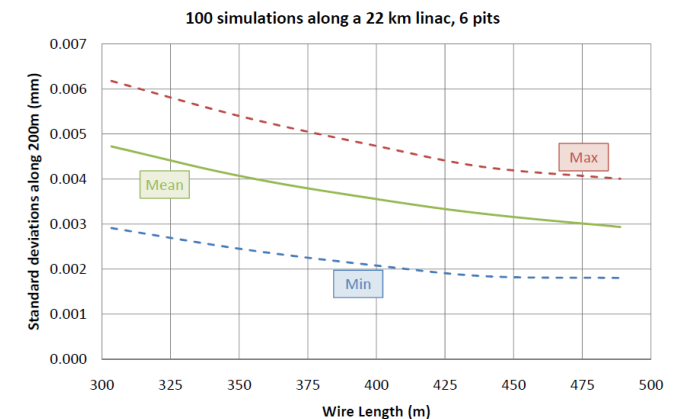
Deviation along 200m according to wire length ~ 3 to 5 μm

Fiducialisation at the micron level

✓ Fiducialisation and dimensional control of objects < 2m: CMM measurements (Tolerances of measurement of Leitz Infinity: 0.3 μm + 1 ppm)

✓ For objects > 2m or as control after transport or during specific tests: combination of « mobile » means:

Laser tracker: AT 401

Micro triangulation

Romer arm

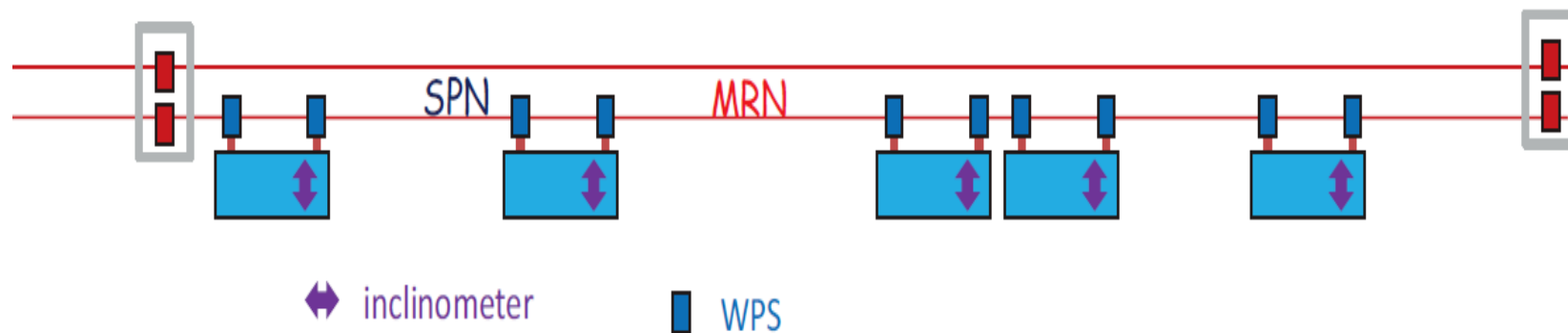| Instrument	Standard deviation between instruments and CMM measurements
AT401	< 5 μm
Micro triangulation	< 5 μm
Romer arm	< 10 μm
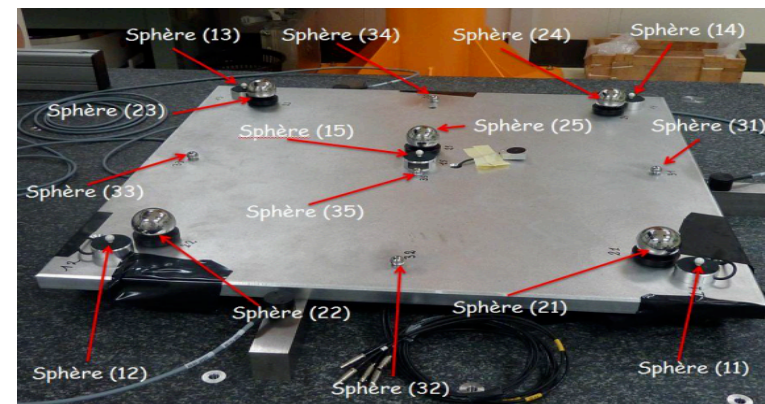
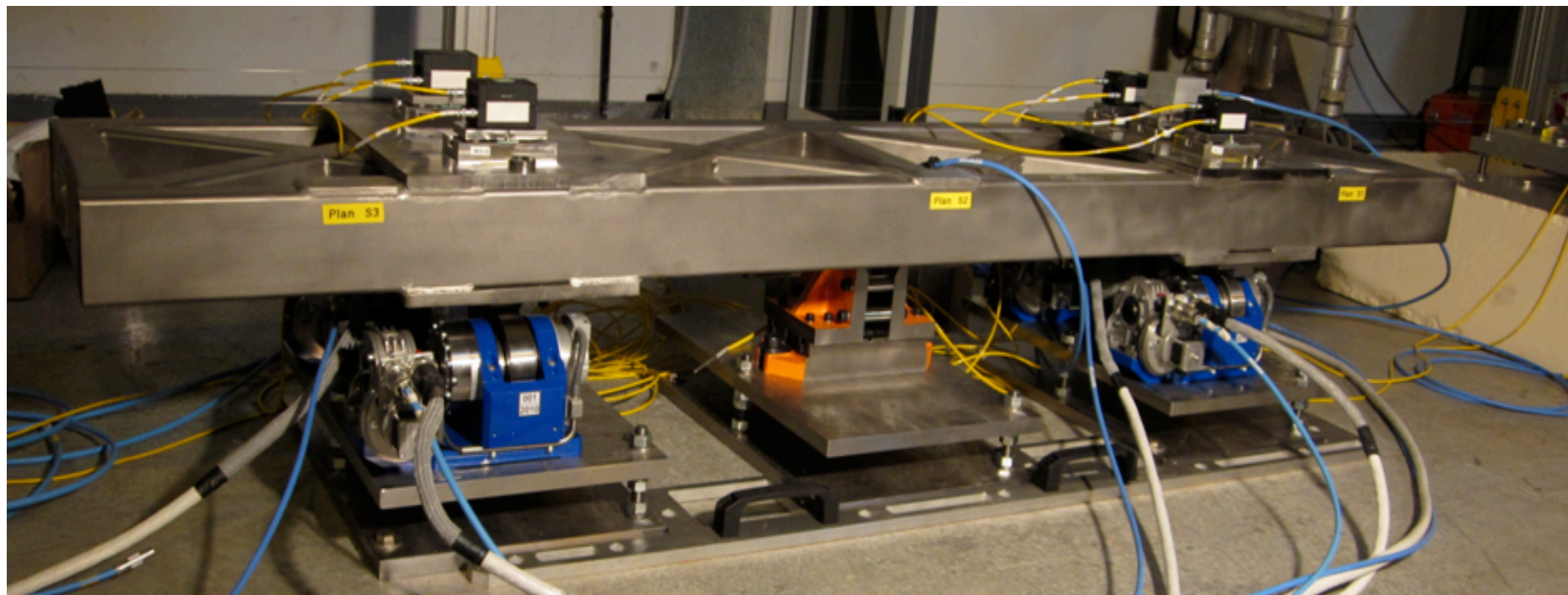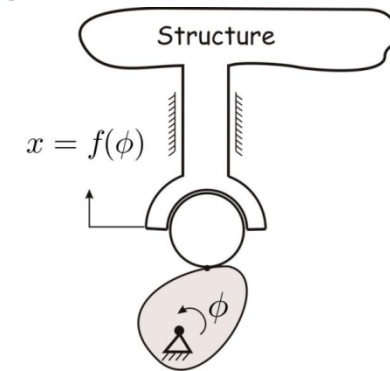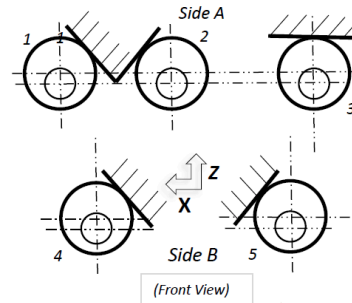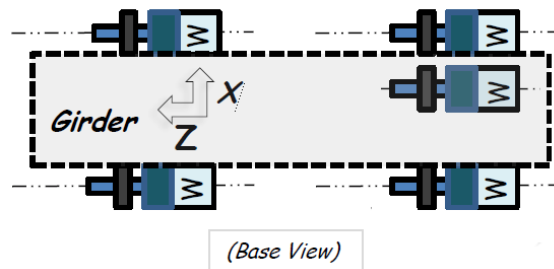# The Support Pre-alignment Network (SPN)

- ✓ Sensors that are part to the component
- ✓ Micrometric measurements between zero of the component and sensors interfaces
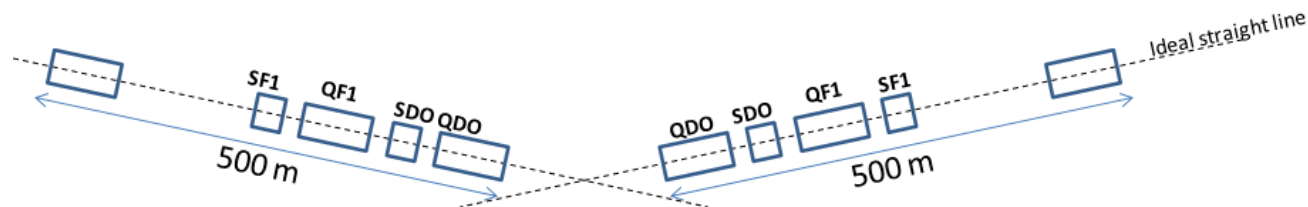
Summary:

Active pre-alignment with CAM movers

Determination of the position → Adjustment with cam movers

Alignment approach in MDI area

## Determination of the position of QD0 w.r.t other components of the BDS (1)

Requirements:

- ✓ Position of the zero of QD0 w.r.t ideal straight line of the 500 last meters of BDS: ± 10 μm rms (including fiducialisation)
- ✓ Longitudinal relative position between QD0 and QF1: ± 20 μm rms

Solutions:
- ✓ Main difference concerns the MRN network (due to lack of space):
  - o No overlapping of stretched wires in the last 250 m
  - o No HLS system needed for modeling of the sag; will be extrapolated on the last 250 m.
  - o Longitudinal monitoring of QD0 w.r.t QF1: capacitive sensors and CFRP bar
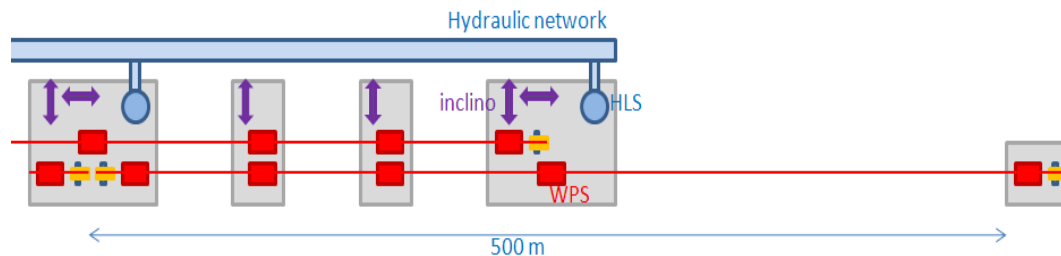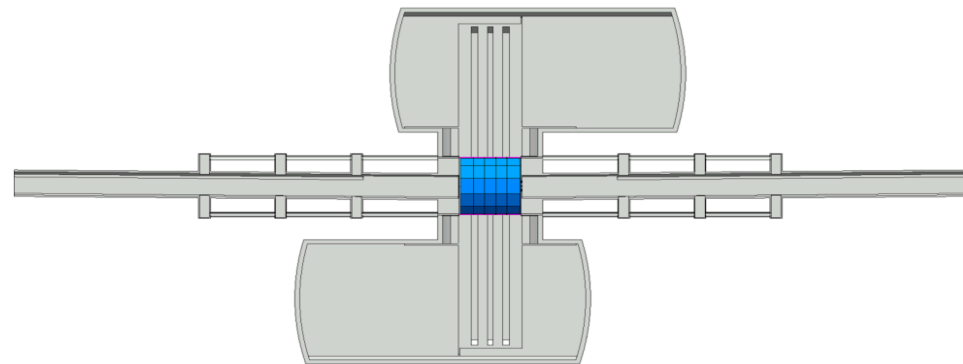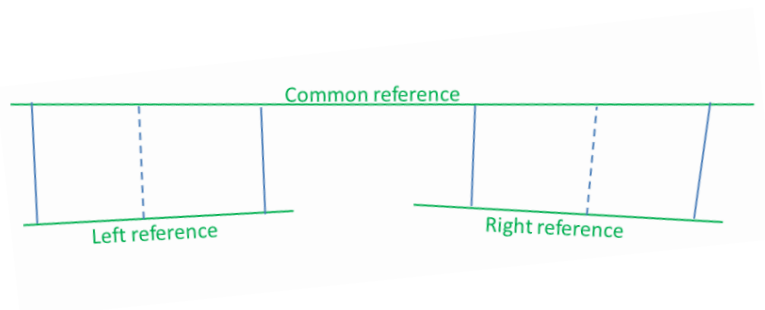
MDI - Survey mini galleries
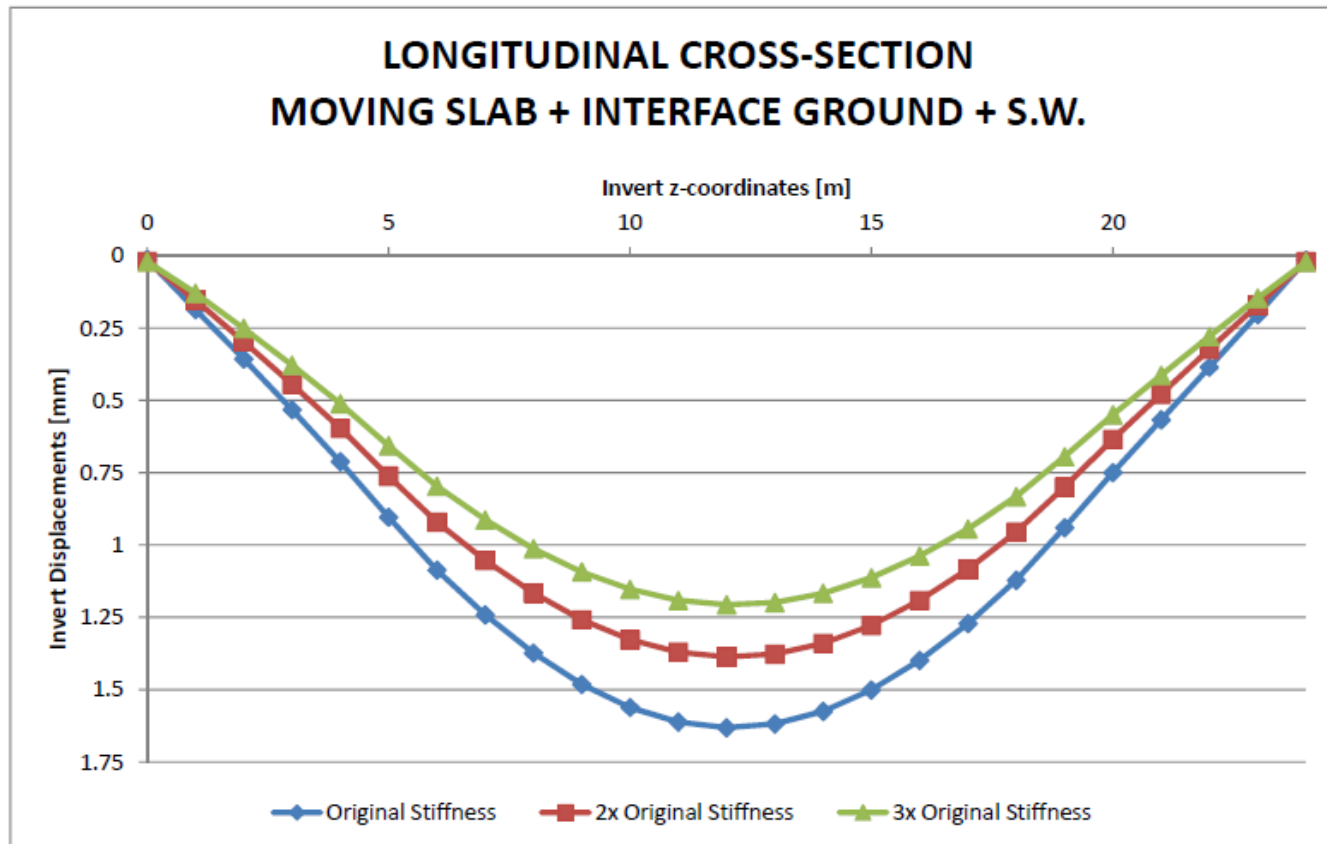
Left side w.r.t right side

Requirements:

- ✓ Determination of left reference line w.r.t right reference line : within ± 0.1 mm rms
- ✓ Monitoring of left reference line w.r.t right reference line : within a few microns
- ✓ Monitoring of the position of left QD0 / right QD0 within ± 5 μ m rms

Solutions:

- ✓ Determination of left reference w.r.t right reference line & monitoring of one BDS w.r.t other:

- ✓ stretched wires/optical system on both side by a common reference (as in the LHC), using the survey galleries
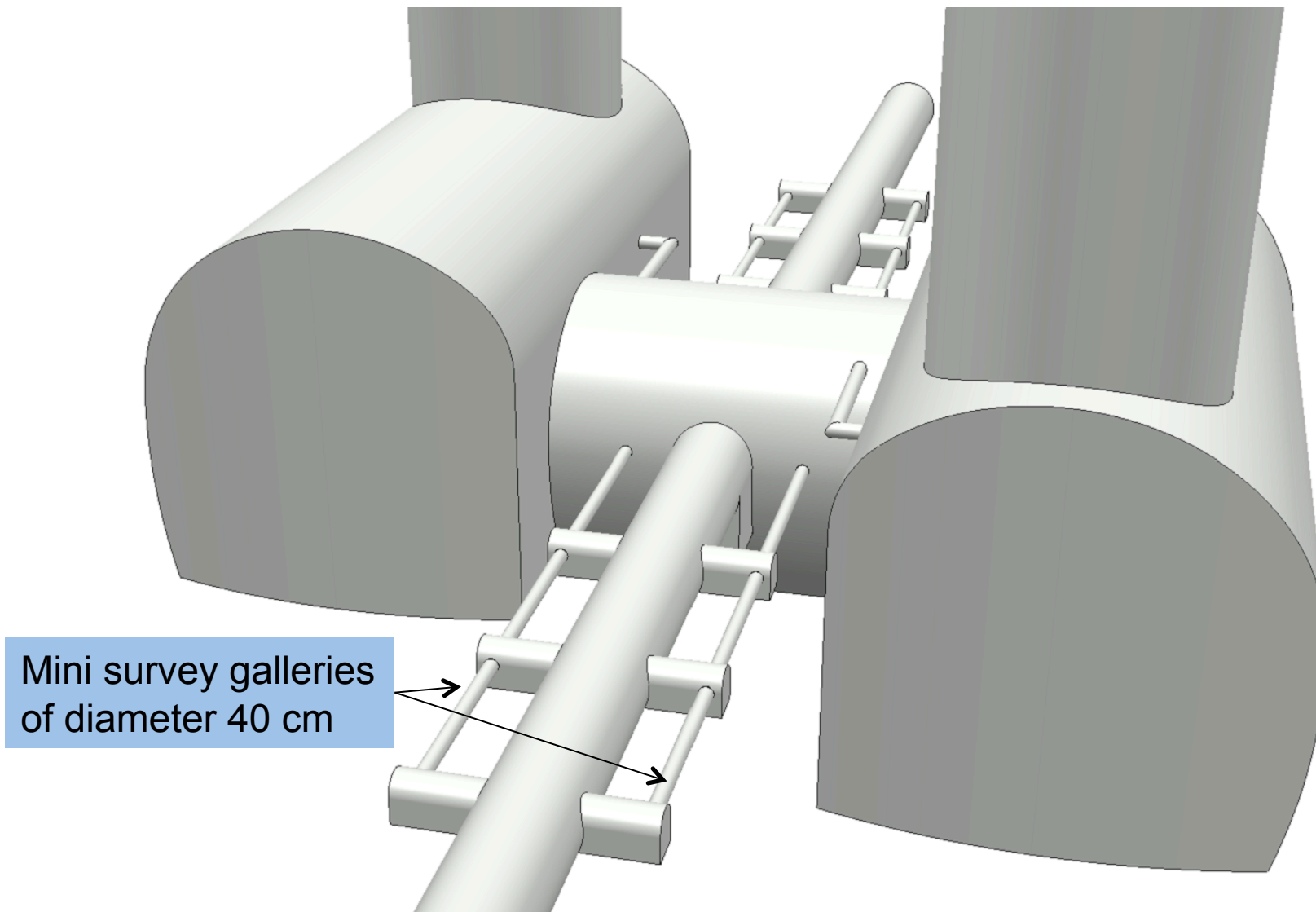
MDI area – remember Invert deformation

LONGITUDINAL CROSS-SECTION
MOVING SLAB + INTERFACE GROUND + S.W.

Invert z-coordinates [m]

Invert Displacements [mm]

— Original Stiffness   — 2x Original Stiffness   — 3x Original Stiffness

2D FE model stiffness	2x FE Stiffness	3x FE Stiffness
1.6 mm	**1.4 mm**	**1.2 mm**

Mini survey galleries of diameter 40 cm

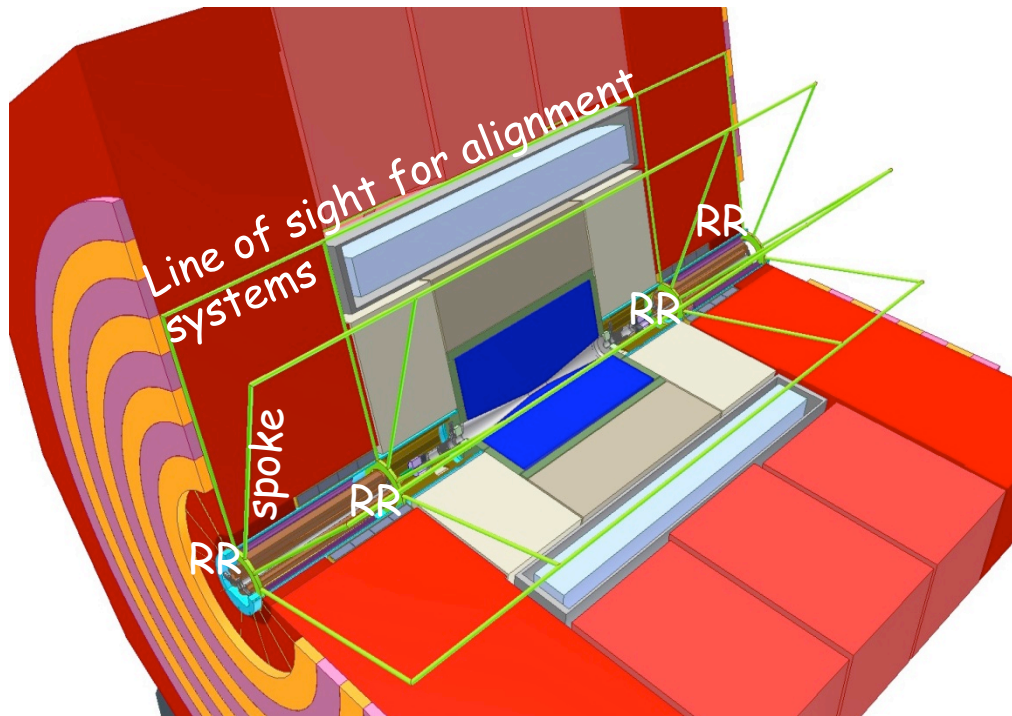# Push-pull ground deflection easily monitored
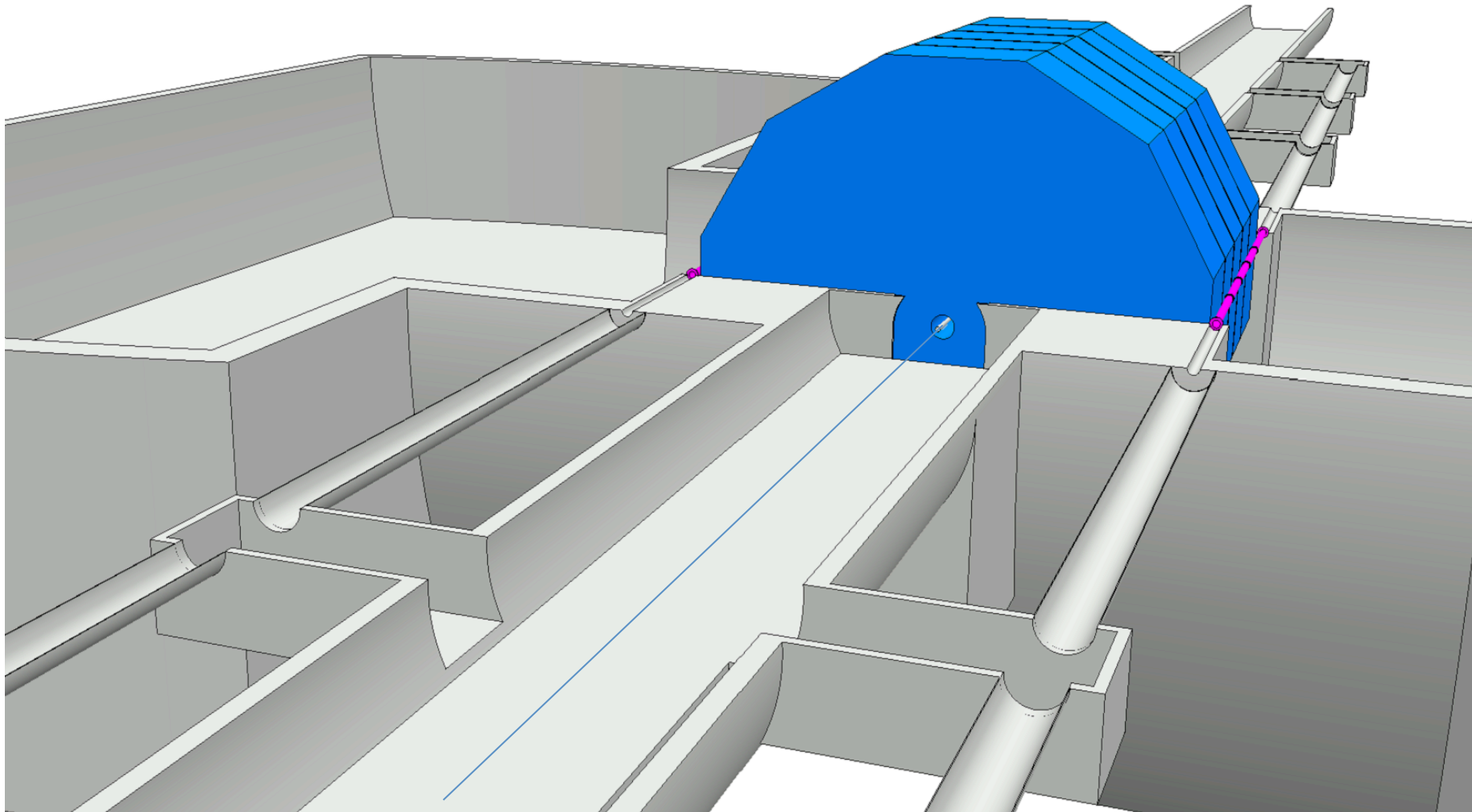
QD0's relative position

Left side w.r.t right side

Monitoring of the position of left QD0 /right QD0: Concept

- ✓ 4 Reference Rings (RR) located at each extremity of QD0, supported from outer tube
- ✓ 6 radial spokes per RR

In two steps:

- ✓ A monitoring of the position of QD0 w.r.t RR thanks to proximity sensors. (initial calibration of their position performed on a CMM)
- ✓ A transfer of the position of RR thanks to 6 spokes to alignment systems. By combination of redundant information, the position of the center of 4 RR is computed.

QD0's relative position – basic principle (idea)

Alignment of two objects:
- omit Z
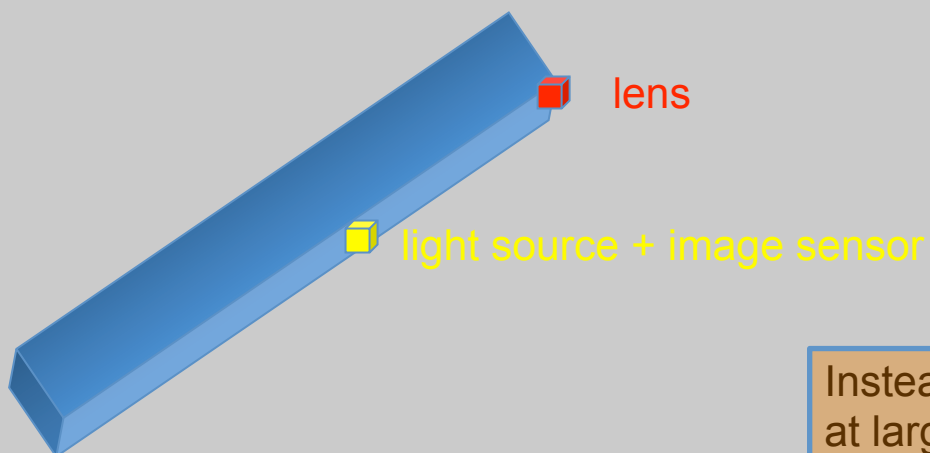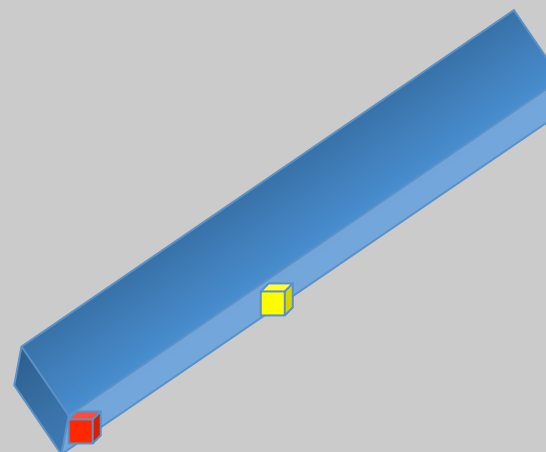- omit rotZ

Y

X

Y

X

Y

X

Y

X
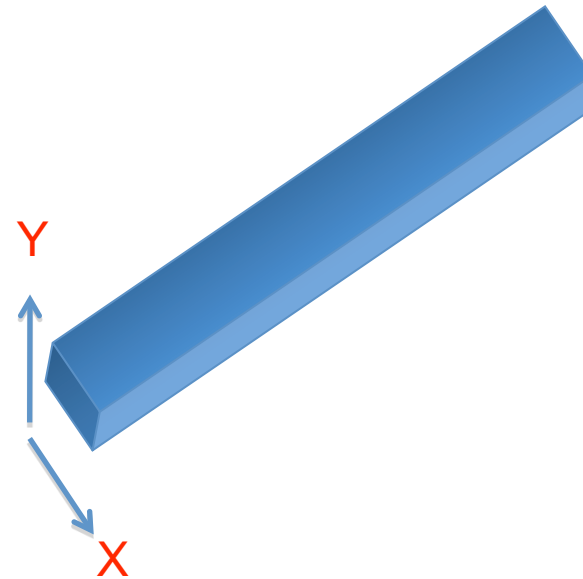
Measure:
- translation X
- translation Y
- Rot X
- Rot Y

QD0 relative position

Direct measurement with 2 anti // Rasniks would only require path of sight of 20 mm^2 along beampipe!

lens

light source + image sensor

Instead: use space away from beam tube, at larger R and do alignment in two steps:

- Reference Rings & radial spokes

- (double) anti // Rasniks

QD0 - Relative alignment

Alignment is NOT influenced by:

- **(common) deformation of RRs (sag, spoke load)**
- **temperature of individual RR**
- **temperature of individual spoke wheel**
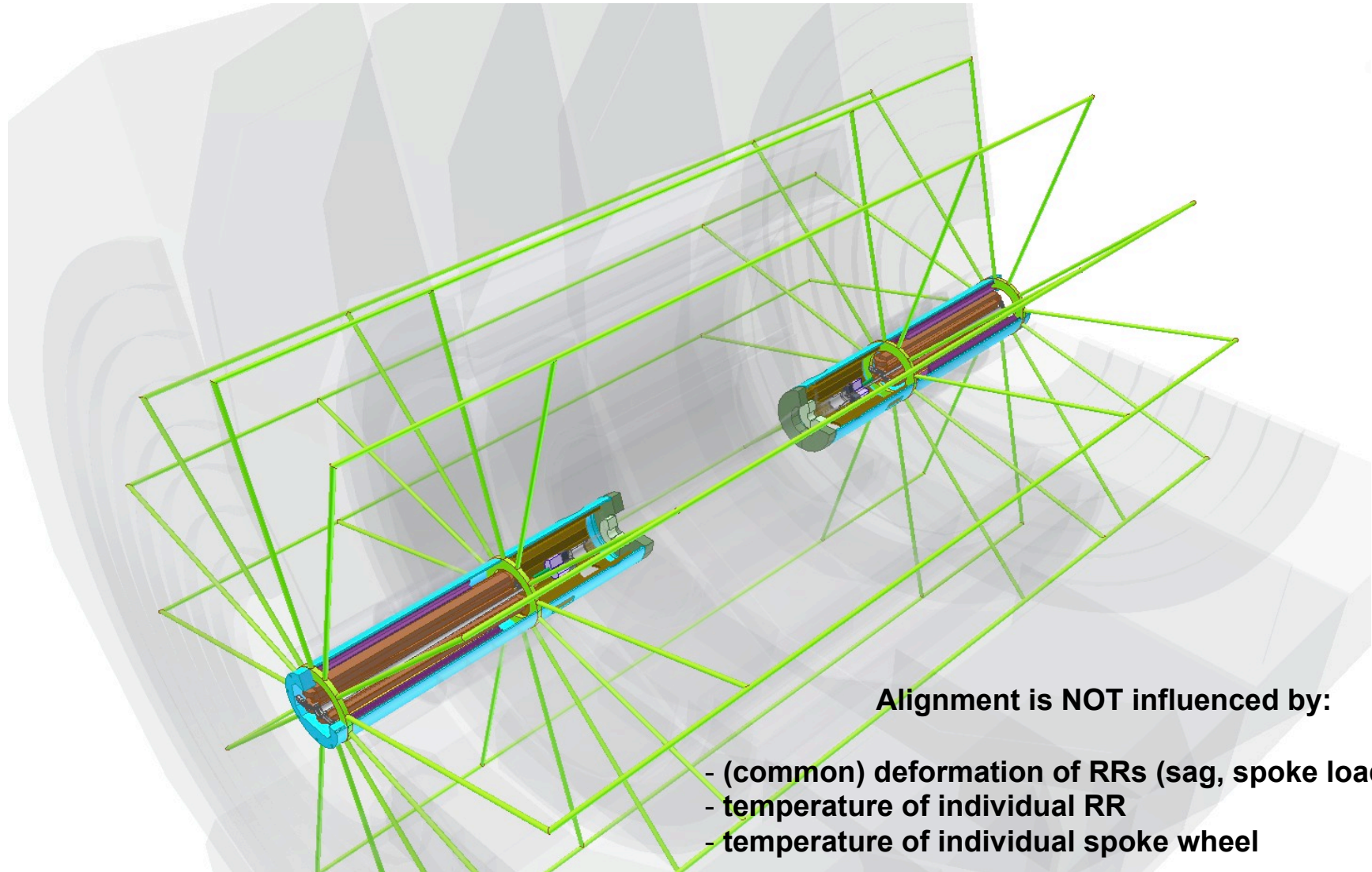
Conclusion

✓ Same strategy of pre-alignment in BDS and main linac (stretched wire, overlap)

✓ tighter requirements for position and adjustments in BDS

✓ Active pre-alignment with cam movers

✓ Special solutions required for final focus and stretched wire around QD0

✓ Relative position of QD0 monitored through detector by Rasnik/ Rasdiff (NIKHEF)

✓ Due to ground movements induced by push-pull CLIC prefers a solution with mini survey galleries

✓ Allows survey link of both BDS ends when detector is on IP