Status of FSI network development for PACMAN

2nd PACMAN Workshop, Debrecen, Hungary

13th – 15th June 2016

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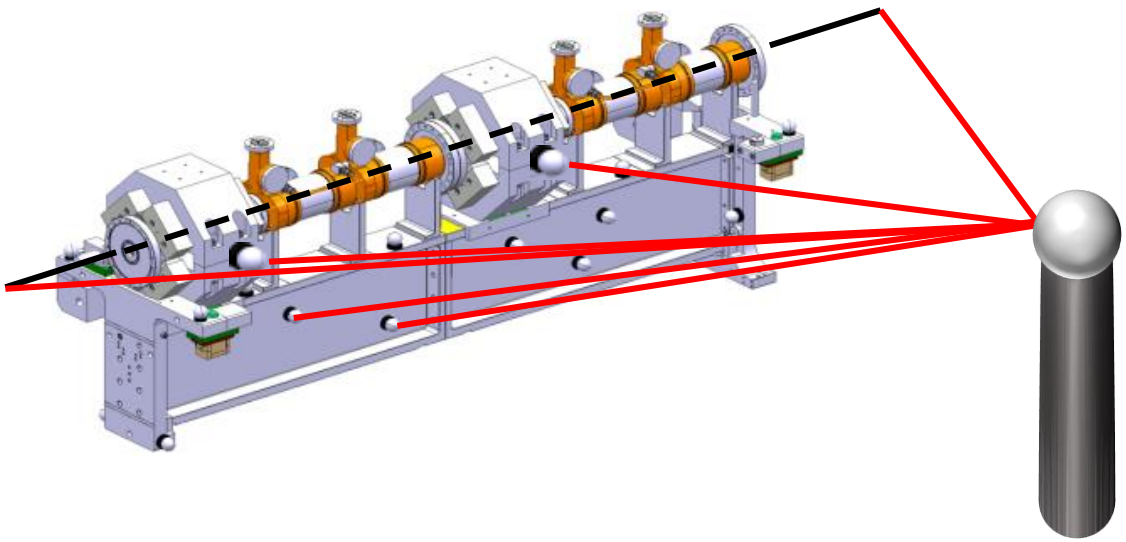
Background

Compact Linear Collider (CLIC) module



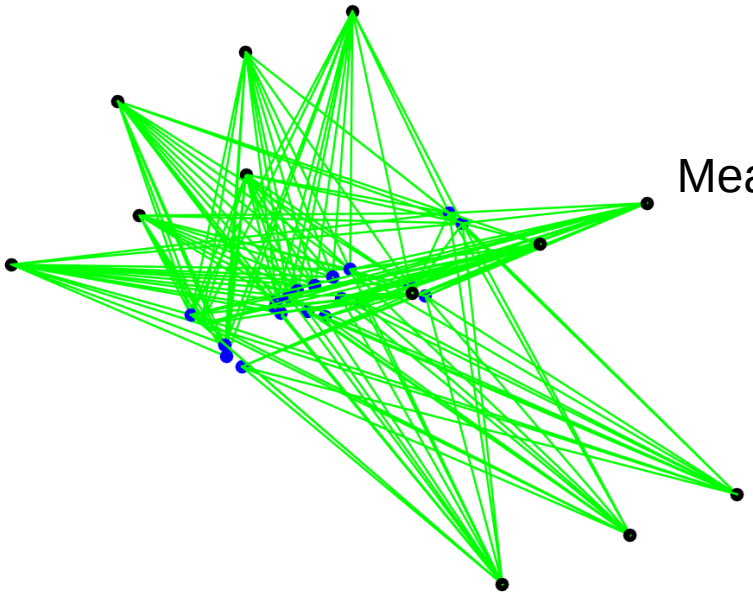
- **Fiducialisation:** Determination of the position of external targets with respect to component functional axis
- Fiducialisation **uncertainty budget**: 10 µm for Main Beam Quadrupole (MBQ)
- Leitz Infinity CMM (0.3 µm + 1 ppm) is the best solution at present

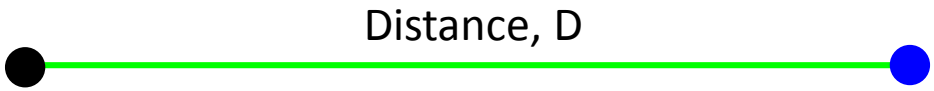
Aim

- Develop a portable alternative that can cope with larger volumes

Multilateration

- Coordinate determination using distances only
- Requires distance measurement from a given point to several points in different directions
- Uncertainty of coordinates depends on that of **distances** and **geometry** of network
- Compensation for systematic errors is possible
- Coordinates & their uncertainties are the output of least squares computation





Measurement station
(X_S, Y_S, Z_S)

Target
(X_T, Y_T, Z_T)

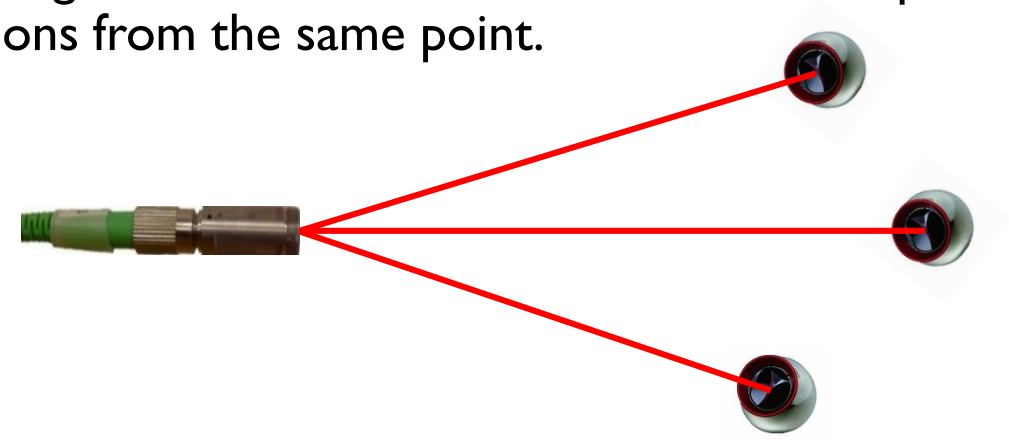
Basic mathematical model

$$D + v = \sqrt{(X_S - X_T)^2 + (Y_S - Y_T)^2 + (Z_S - Z_T)^2}$$

where v is a residual

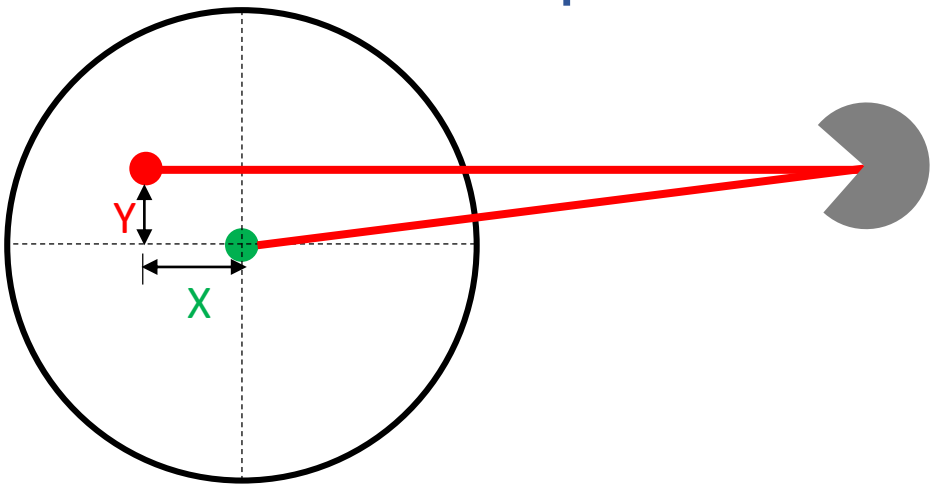
Technology

- Absolute Multiline Technology (AML)
  - Absolute distance measurement based on Frequency Scanning Interferometry (FSI)
  - 0.5 µm per meter measurement uncertainty
  - Not designed to measure distances to different points in different directions from the same point.



- Objective
  - To develop means of making distance measurements in several different directions from same point (using AML)

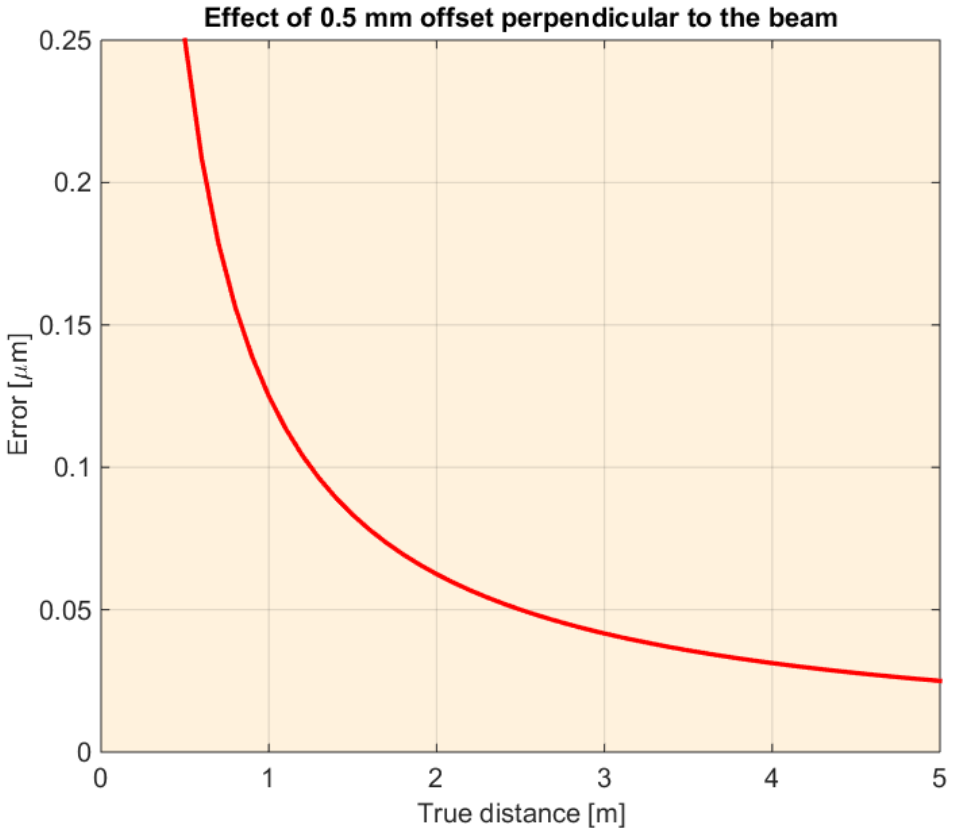
Relate optical fibre tip to centre of sphere



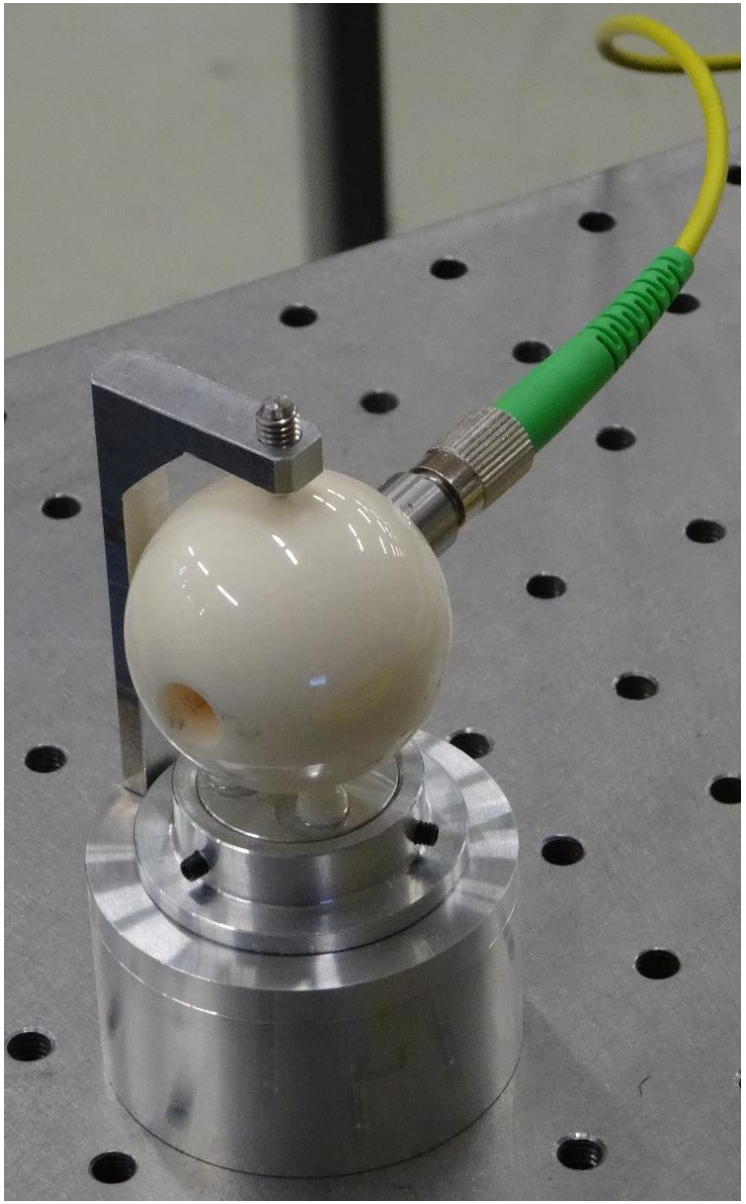
- Optical fibre tip
- Centre of sphere

Two offsets

1. Along the beam, X (constant)
   - Can be easily calibrated
   - Added as a constant in adjustment
2. Perpendicular to beam, Y (negligible- decreases with distance)



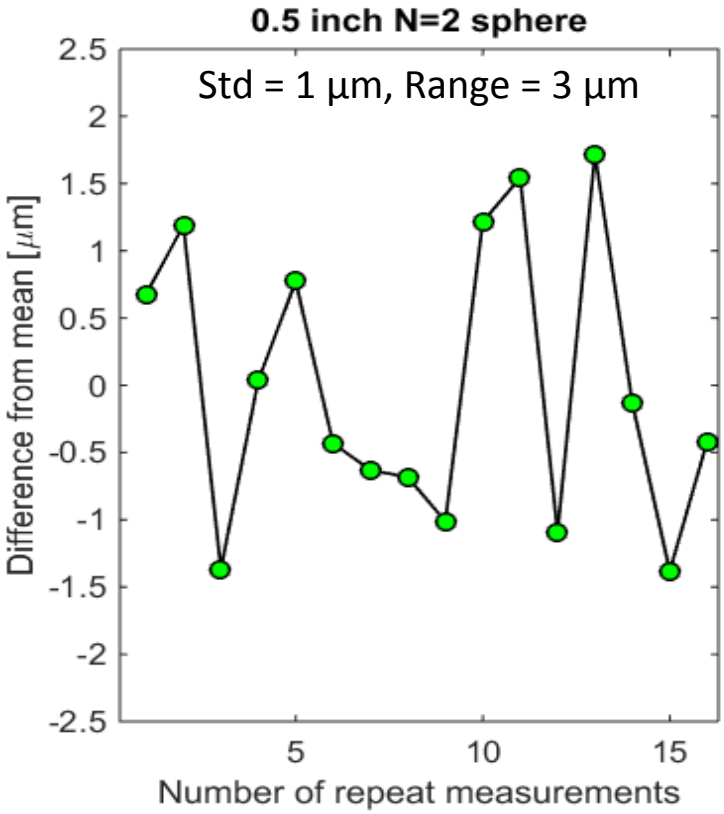
First prototype: Specifications

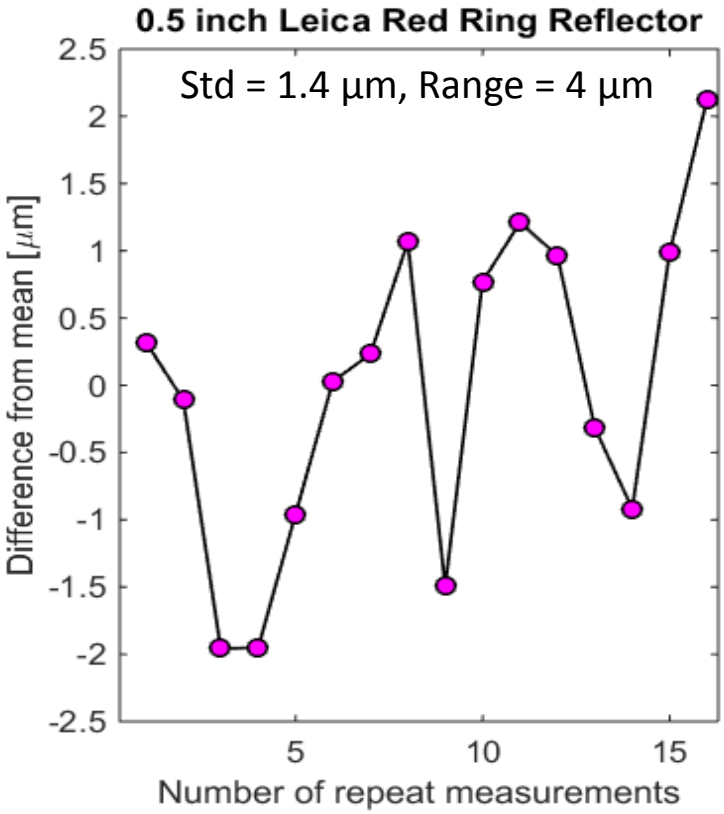


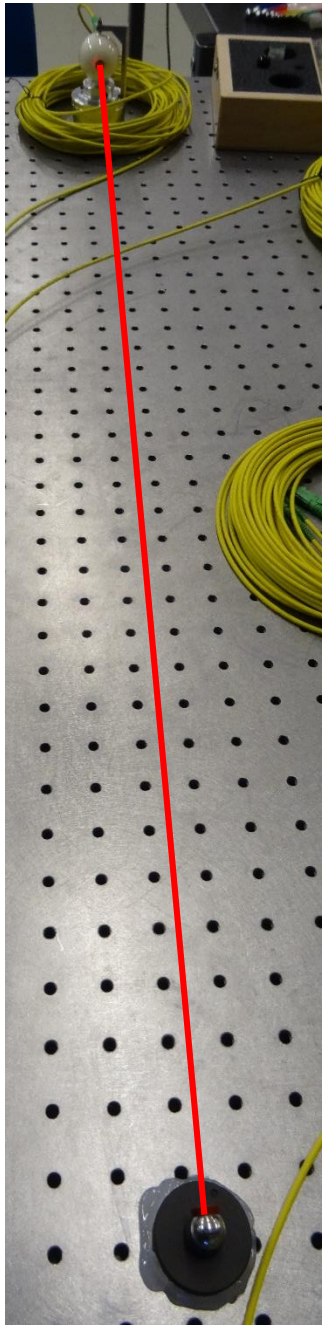
- 3 sphere base allowing repeatable measurements
- Absolute Multiline FSI distances in different directions from the same point
- +/- 44° design vertical angle
- 360° horizontal angle
- Can be mounted on tripod
- CMM measurable
- Measurable by QDaedalus
- Portable

First prototype: Repeatability

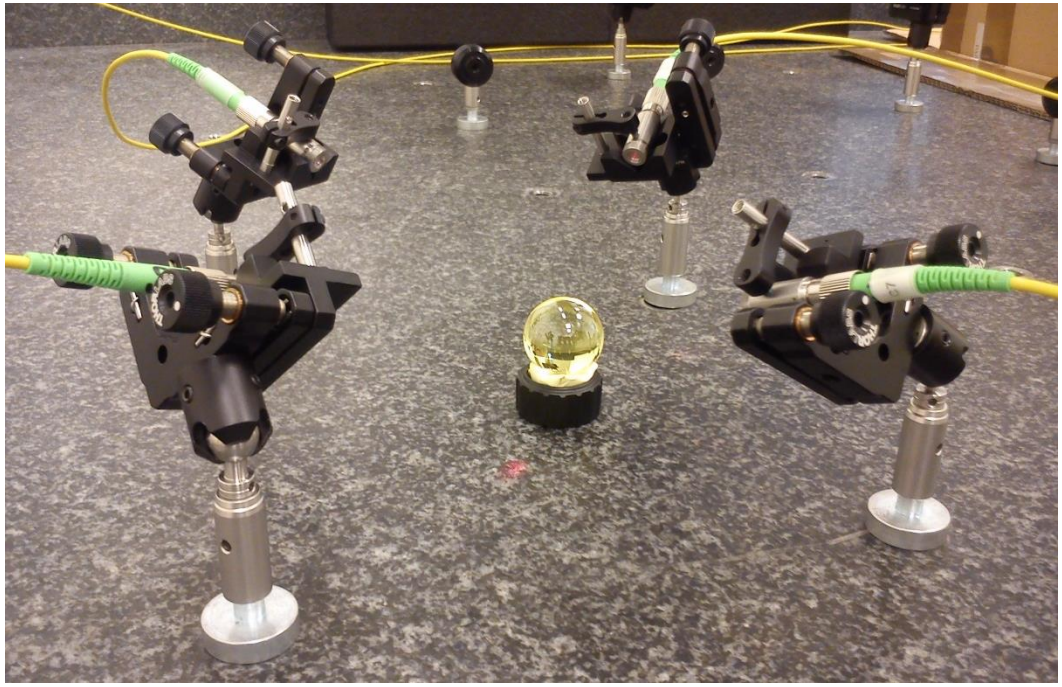
- 1 m distance to a fixed target
- Beam misaligned and then redirected towards target





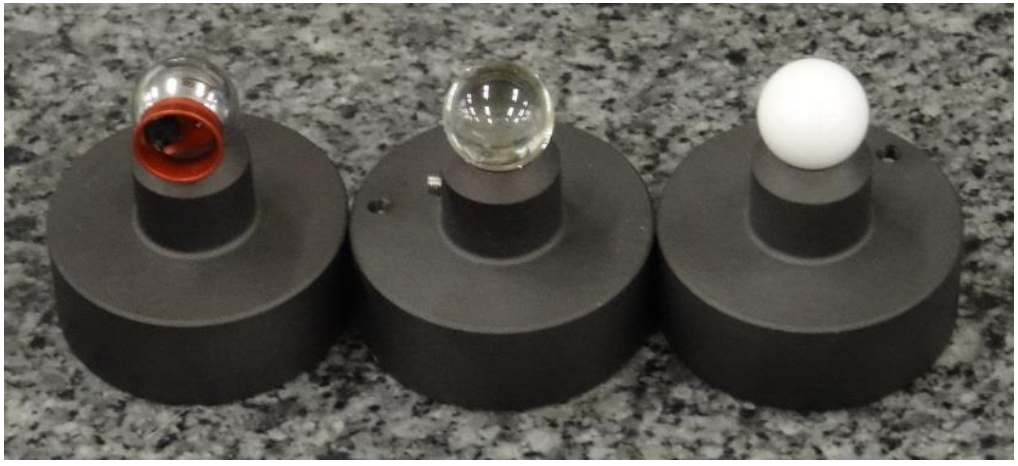


High index (N=2) spheres for improved geometry



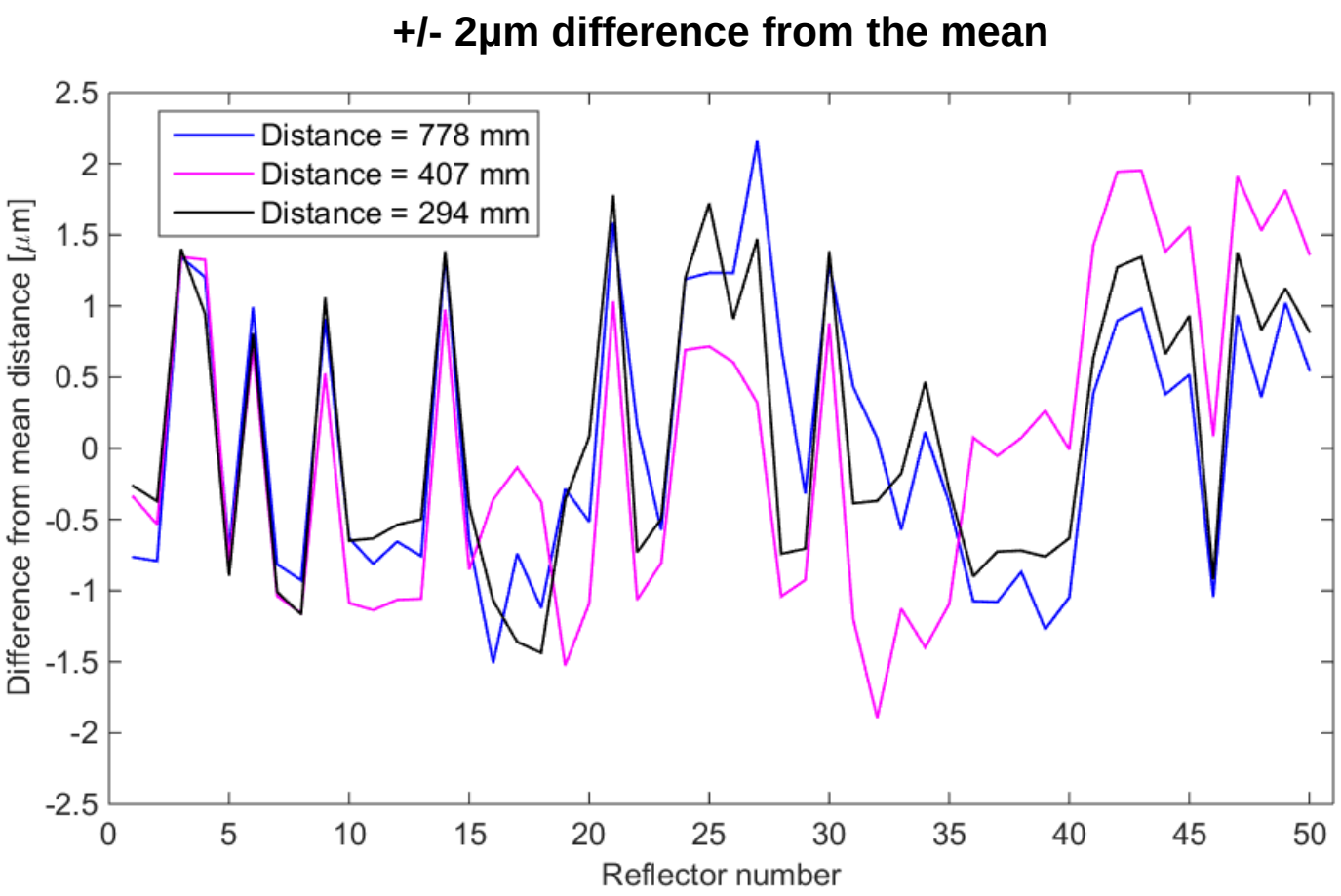
- Wide acceptance angle
- Flexibility in station positioning
- High precision of coordinates

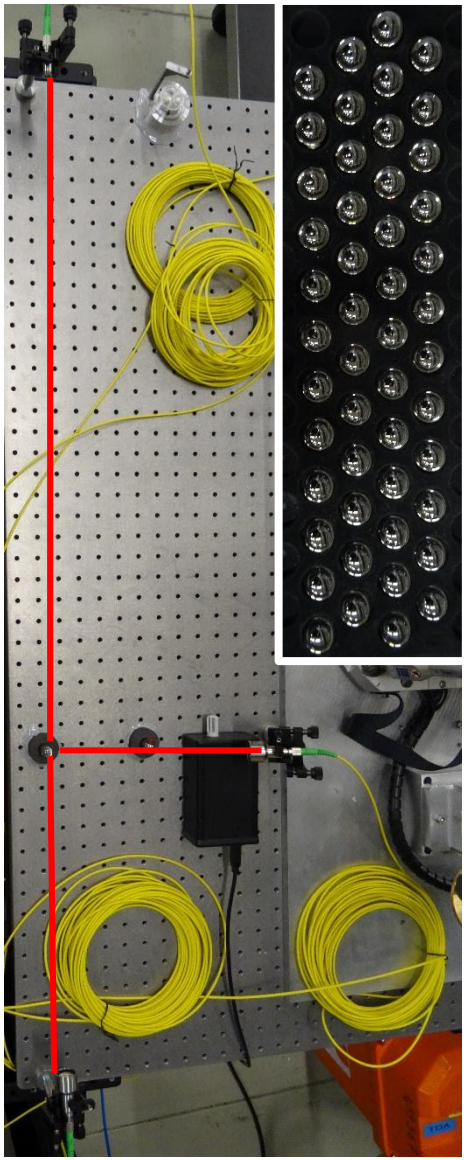
- Standard 0.5 inch (12.7 mm) diameter
- Same support for laser tracker and micro-triangulation targets
- Easy intercomparison
- Vertical mounting possible



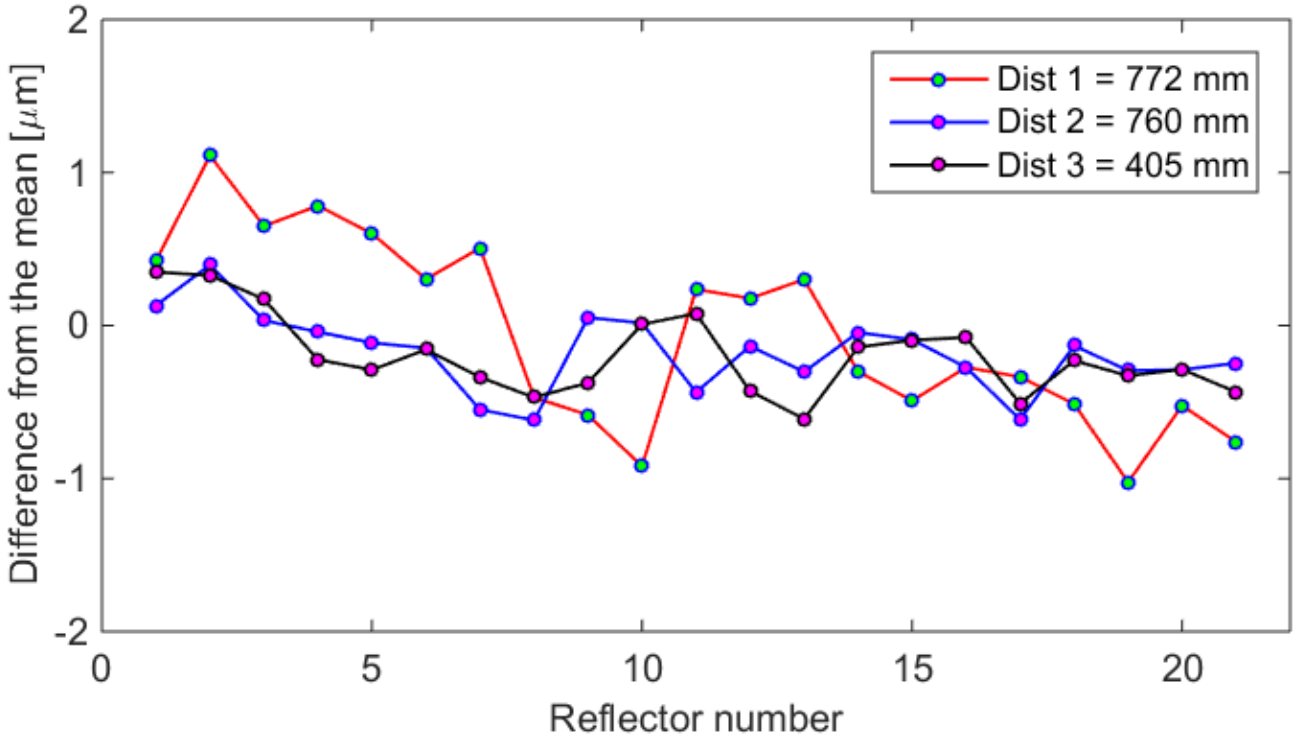
Selection of best sphere subset

- Distance measured to all 50 spheres in batch
- 3 channels perpendicular to each other
- Select spheres whose distances match closely





Repeat measurement of 21 ‘best’ spheres



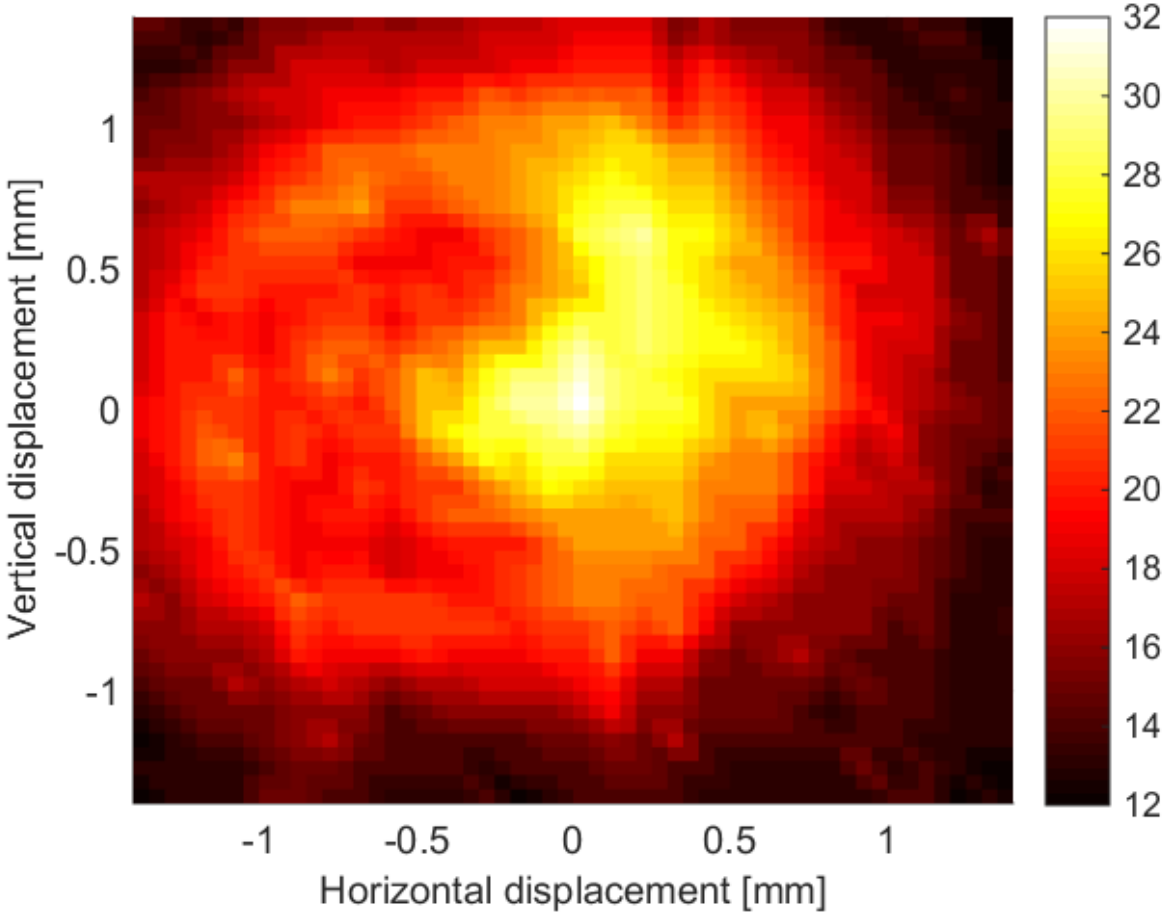
Average [mm]	760.1604	772.333	405.2759
Maximum [mm]	760.161	772.3342	405.2764
Minimum [mm]	760.16	772.332	405.2755
Range [μm]	1.0	2.1	1.0
Standard deviation [μm]	0.3	0.6	0.3

Tolerance to FSI beam misalignment

F280FC-1550 collimator

0.5 inch N=2 target

Intensity map of reflected beam (small collimator)



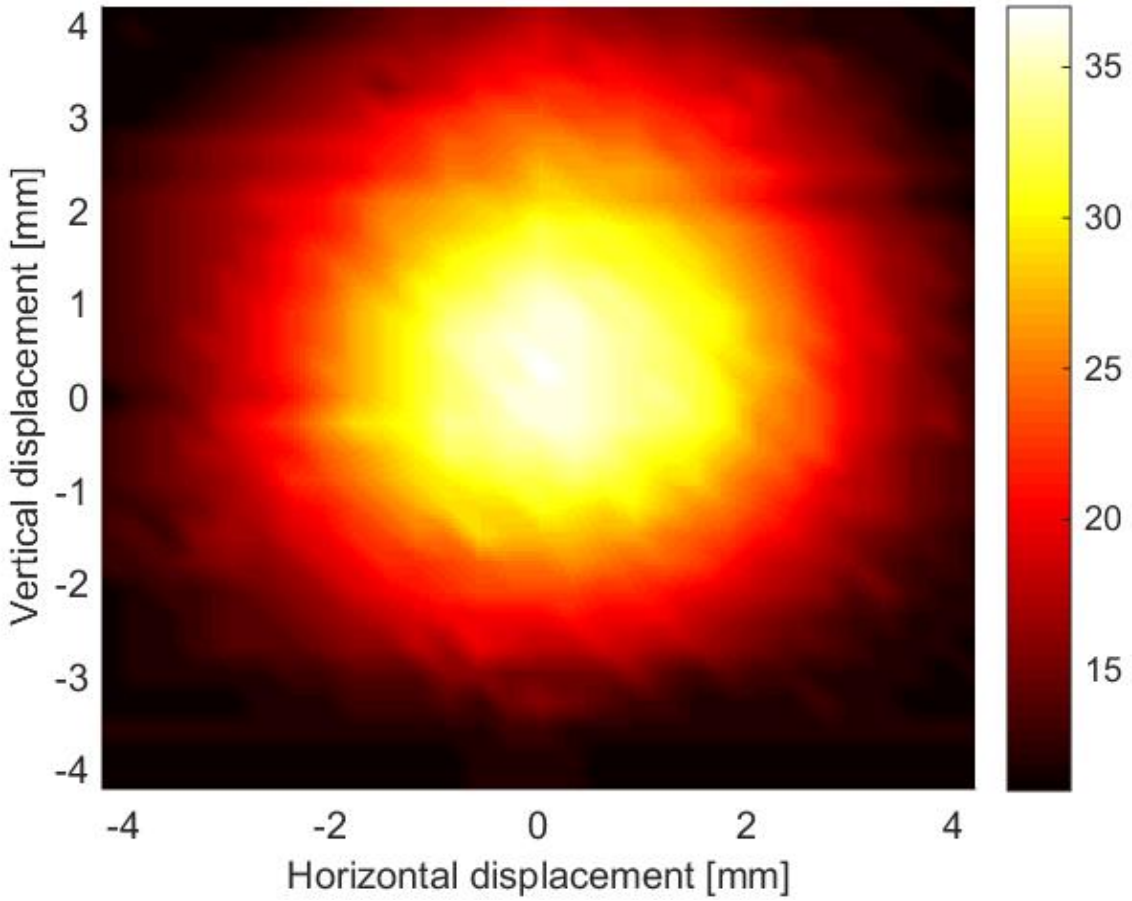
- Tolerance ≈ +/- 0.6 mm (yellow region)

Tolerance to FSI beam misalignment

F810FC-1550 collimator

0.5 inch N=2 target

Intensity map of reflected beam (large collimator)

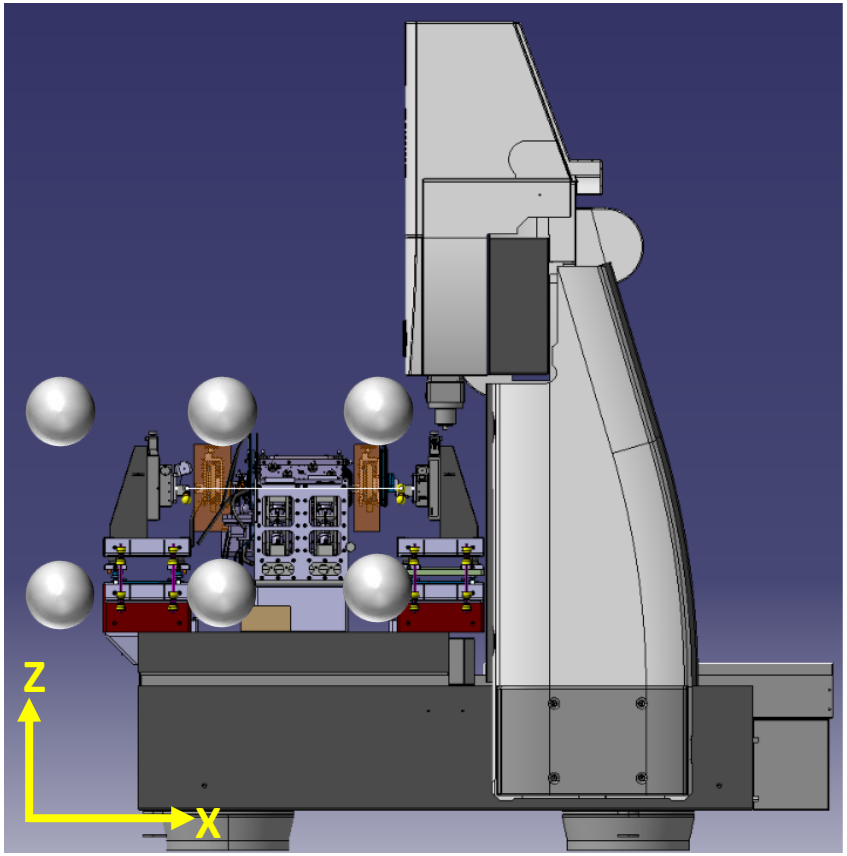


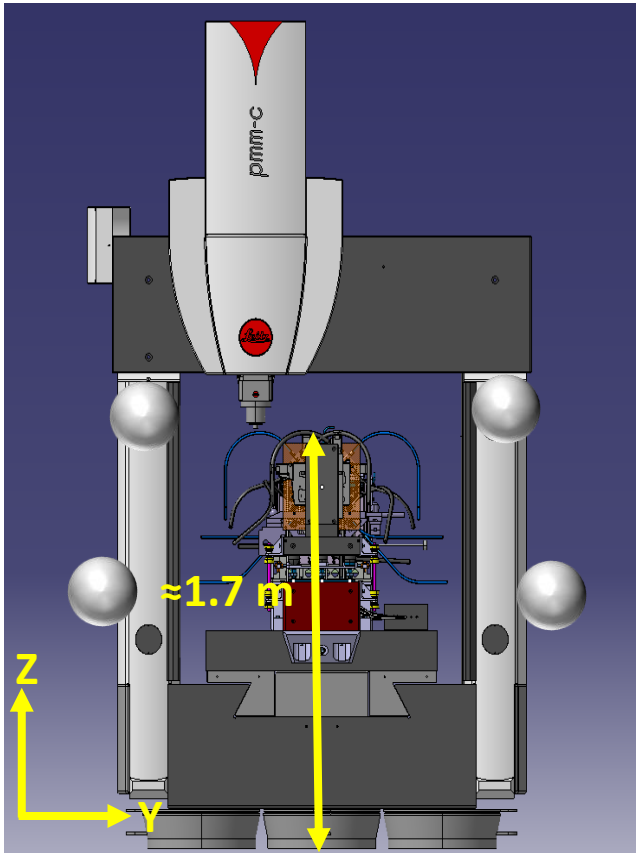
- Tolerance ≈ +/- 2 mm (yellow region)

Positioning of stations in PACMAN bench

- Line of sight problems caused by other components
- Considerable height issues affect practical implementation of stations

Utilising open spaces, dealing with restrictions



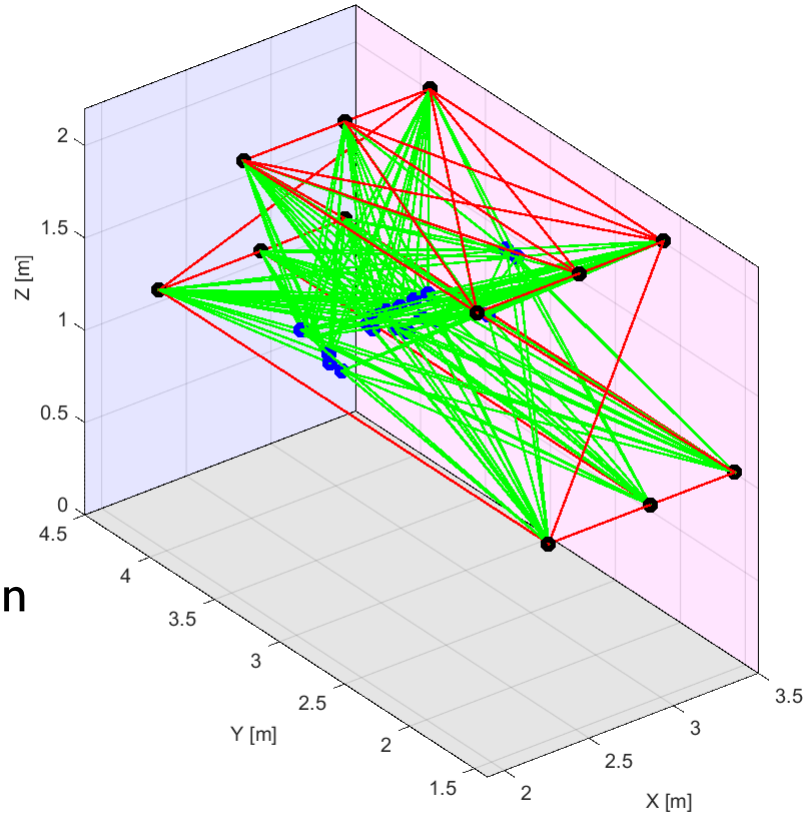


Aim: 10 μm standard deviation in Y & Z.

Approximate station position

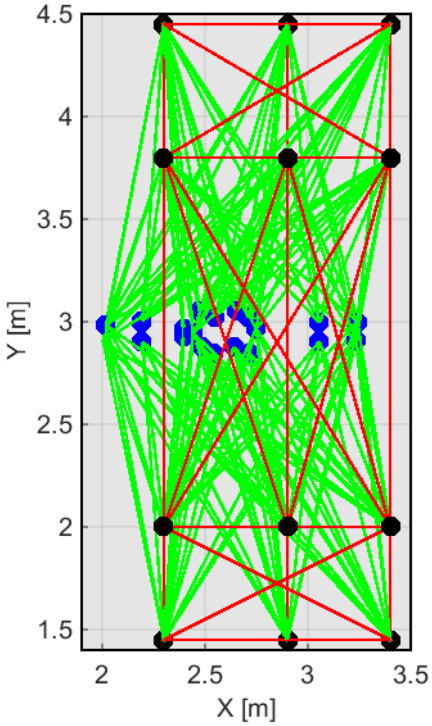
PACMAN bench FSI network simulation

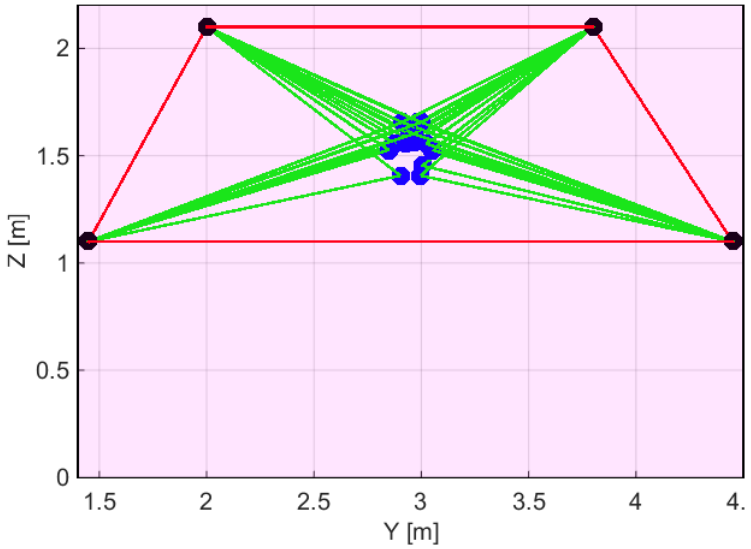
- 12 stations, 6 on each side of module
- 21 fiducials
- 6 fiducials can be 'seen' by all stations
- 6 fiducials on each side of module can only be 'seen' by the 6 stations on that side
- 2 fiducials can only be 'seen' by 2 stations on either side of module
- 20 interstation observations to strengthen network
- 178 observations, 99 unknowns

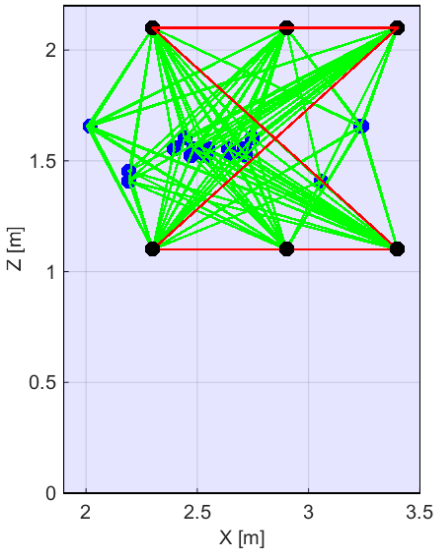


PACMAN bench FSI network simulation

- Negative vertical angle between fiducials and stations is limited by component obstruction
- This limits strength in Z
- Solution is to increase height of top stations and edge them closer to the CMM to increase positive vertical angle

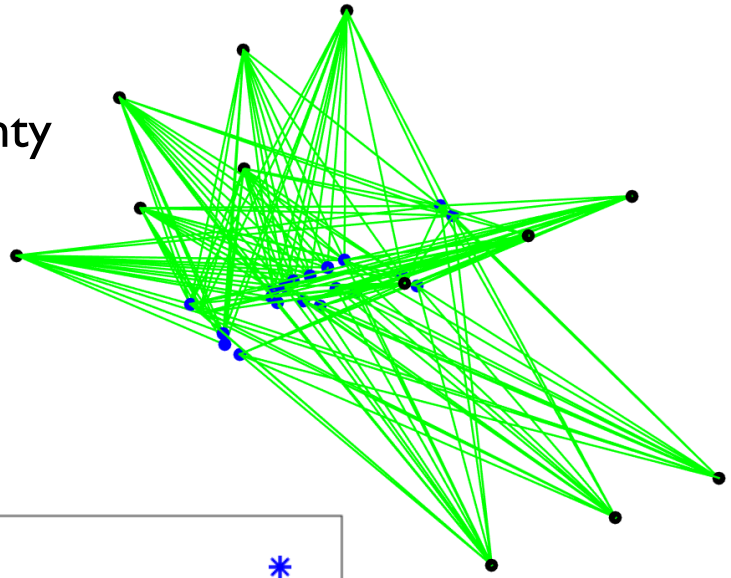


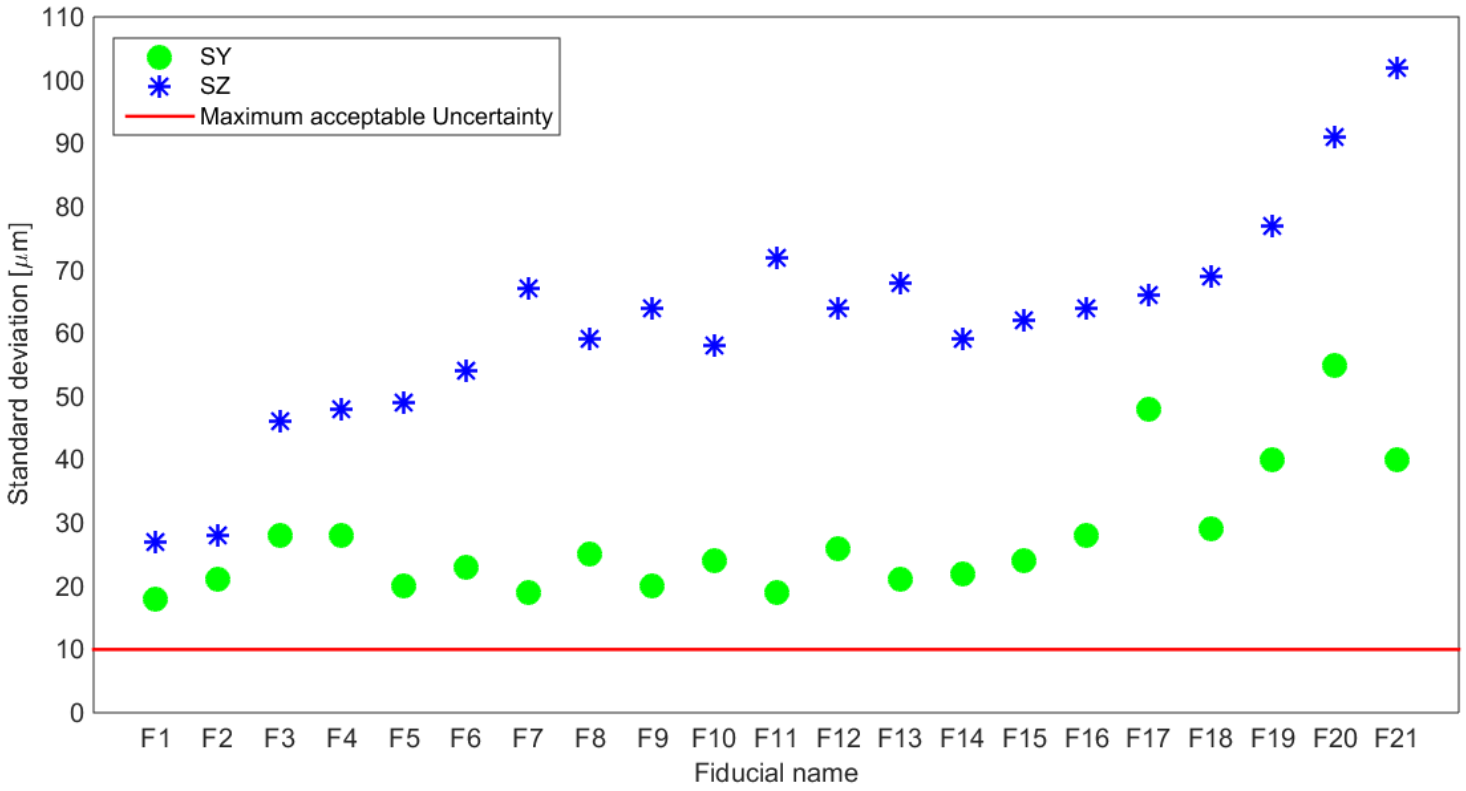




First simulation results – No interstation observations

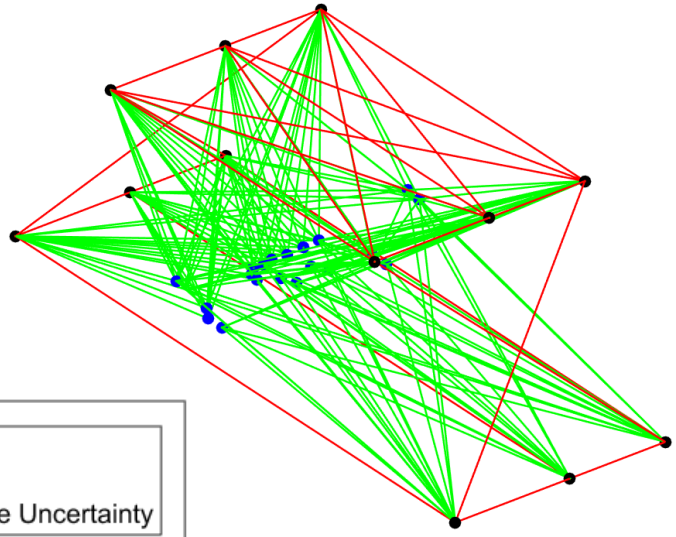
- Simulation based on 10 µm distance uncertainty
- Fully unconstrained network
- 158 observations
- 99 unknowns

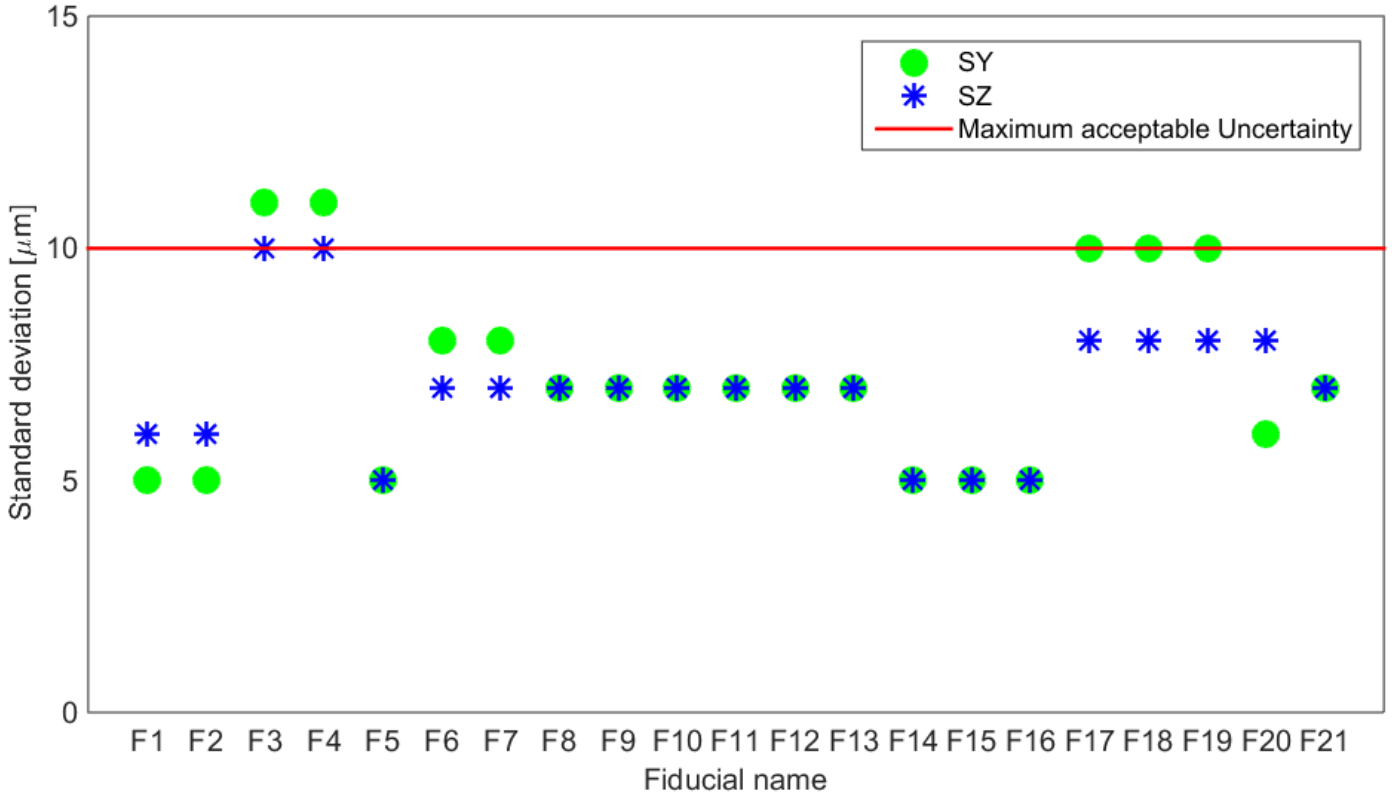




First simulation results – With interstation observations

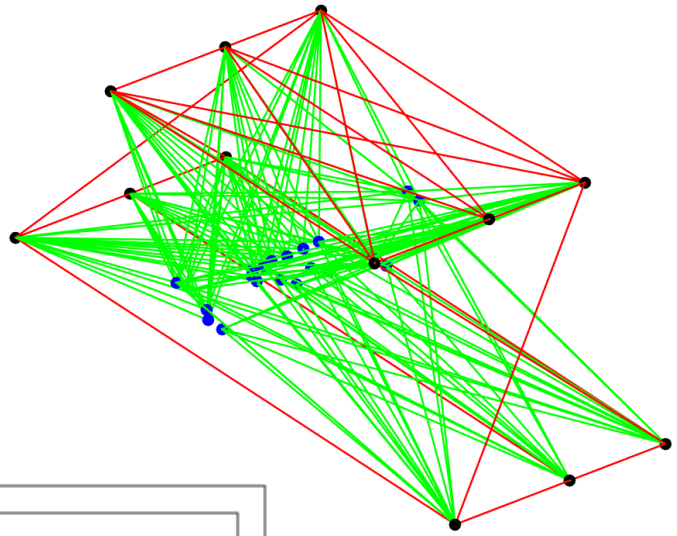
- Simulation based on 10 µm distance uncertainty
- Fully unconstrained network
- 178 observations
- 99 unknowns

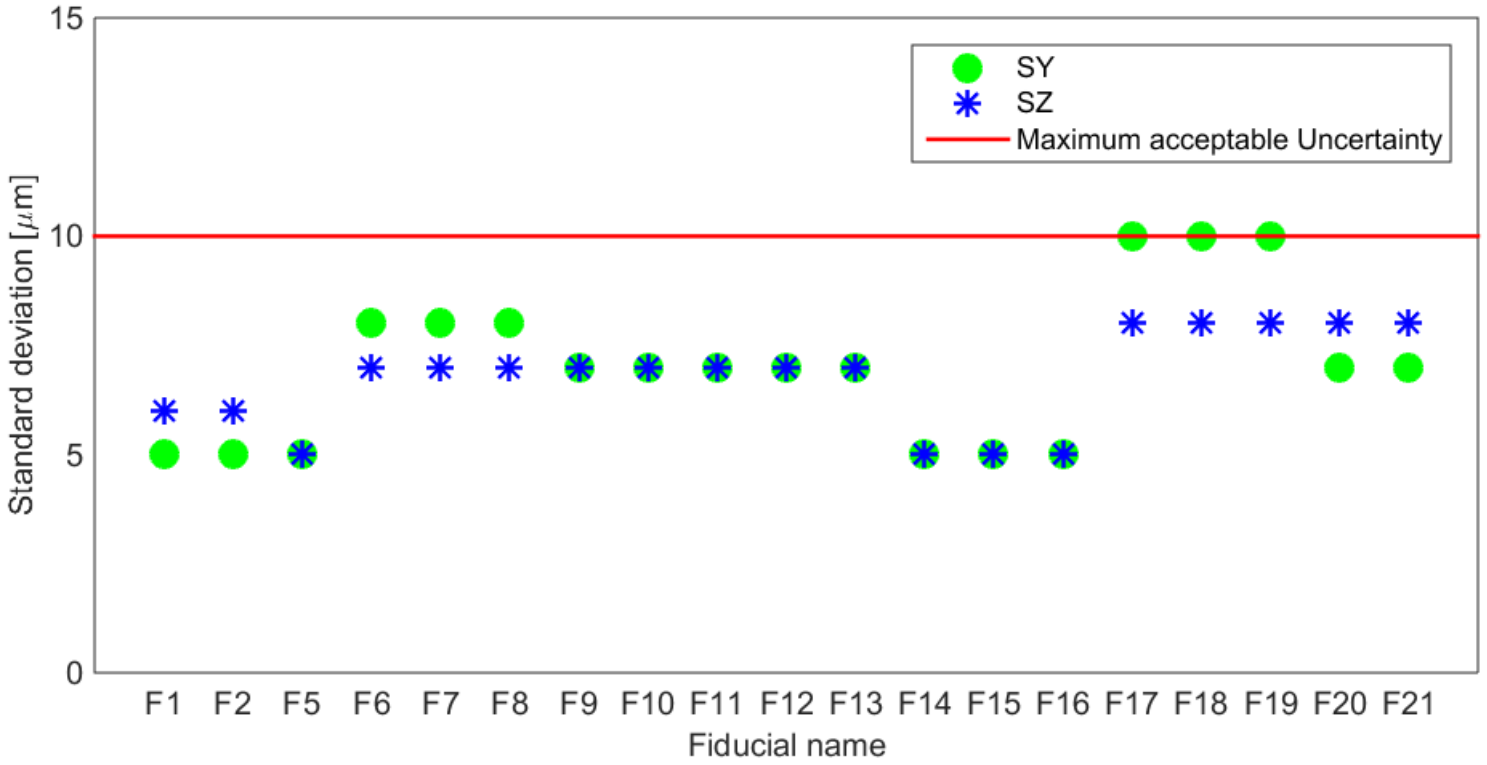




First simulation results – towards optimisation

- Simulation based on 10 µm distance uncertainty
- Fully unconstrained network
- 170 observations (8 fewer)
- 99 unknowns + 1 constant for offset of FSI beam origin w.r.t centre of sphere





Next steps

- Network measurement with prototype
- Further optimisation of network via simulation
- Intercomparison with micro-triangulation & CMM
- Design final measurement setup
- Attempt to build motorised prototype

Supervisors

Mr. Jean-Christophe GAYDE (CERN)

Prof. Dr. Markus ROTHACHER (ETH Zurich)

External Advisor

Dr. Miroslav SULC (Liberec TU)

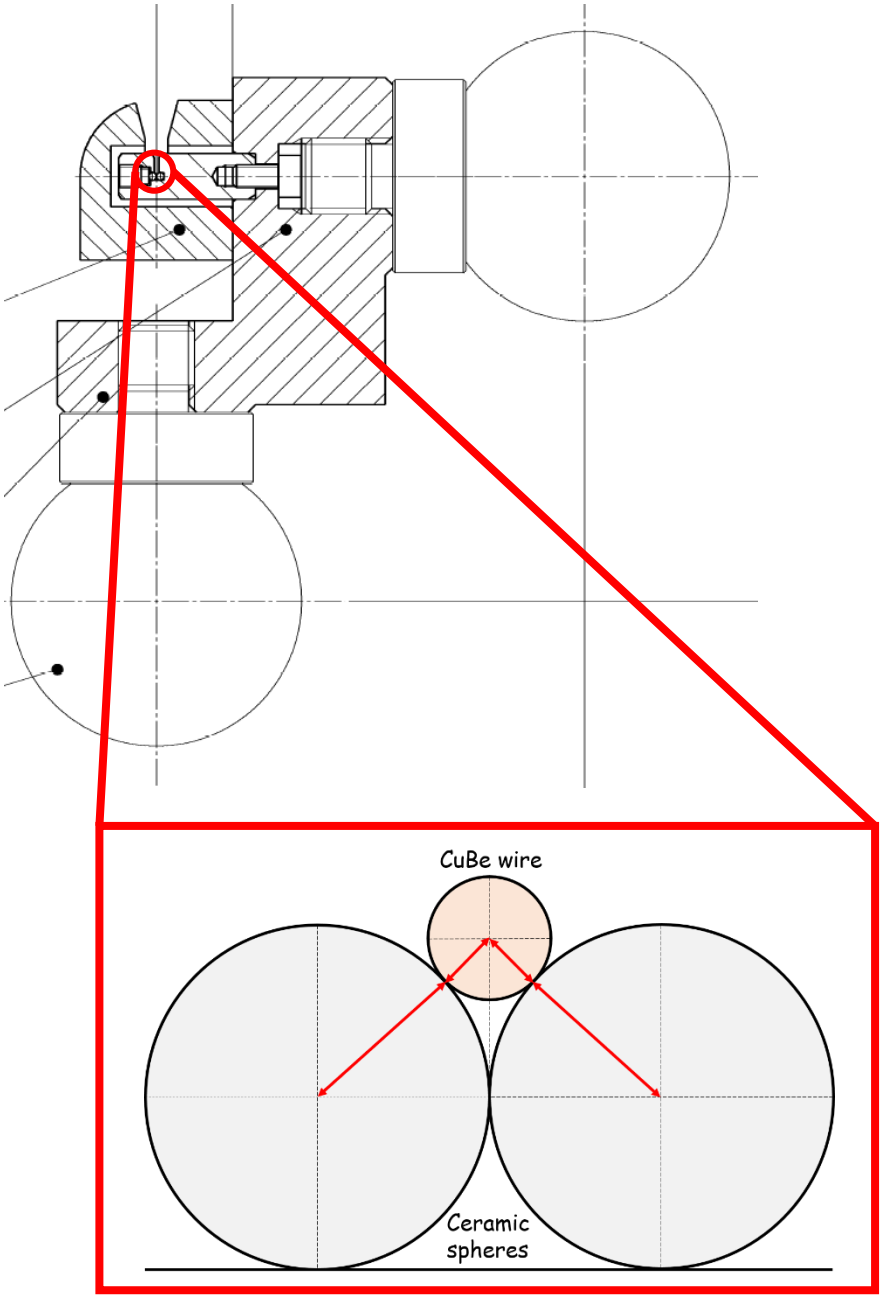
Industrial Partner

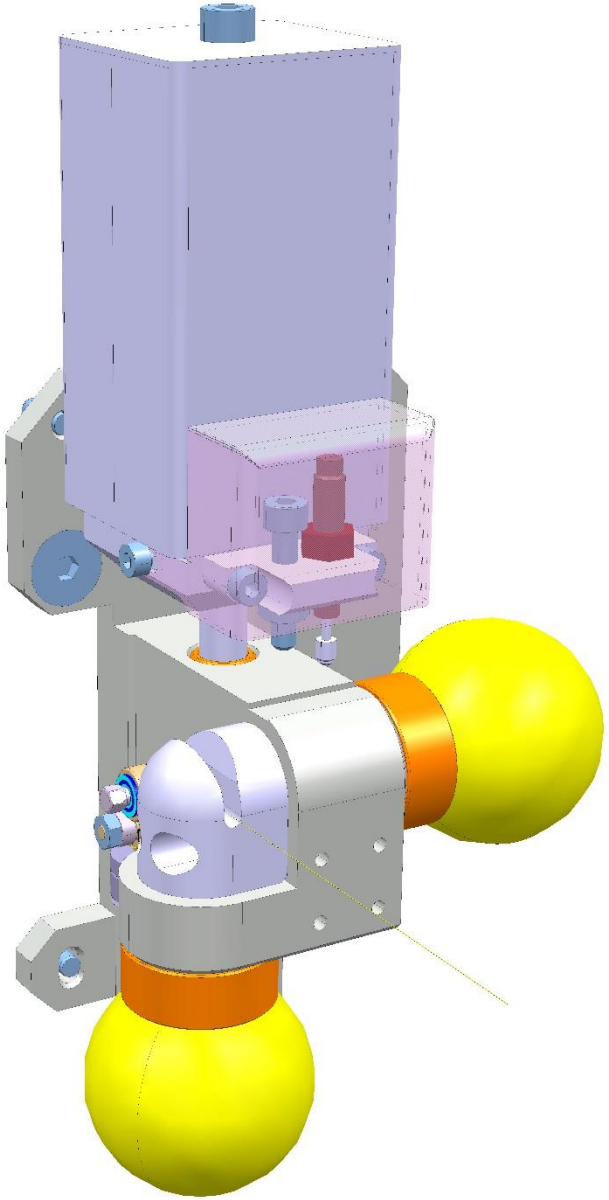
Etalon AG

Special thanks: Francois Morel (CATIA support)

Thank you for your attention.


Indirect measurement of wire w.r.t fiducials with optical CMM





Repeatability in the region of 2 microns