Microtriangulation for Automated Contactless High-Precision Metrology

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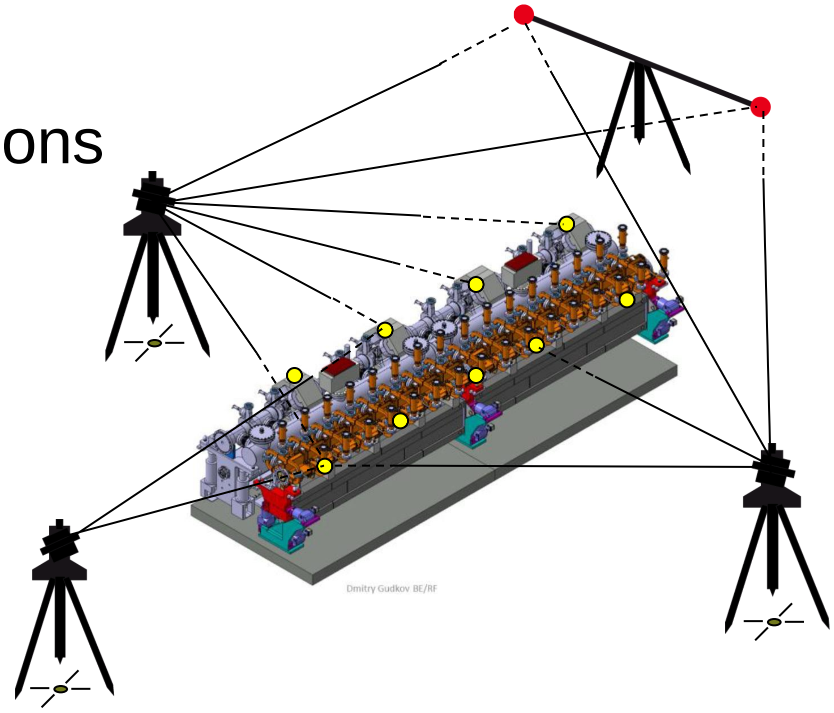
The Measurement System

QDaedalus

Qdaedalus for Microtriangulation

- Traditional geodetic network
- High Precise : < 10 µm/m
- Touchless
- Fully Automated
- Static and Kinematic Applications
- Low-cost
- Open & Flexible Software



QDaedalus: System Components

- Main Components
  - **Total Station**
  - CCD Sensor
  - Focusing Mechanics
  - Software (Qt c++)

- Additional Components
  - Front Lens (for long range obs. > 13 m)
  - Interface box (CCD Triggering synchronization of multiple system)
  - External GPS Receiver (for Absolute CCD Timing)

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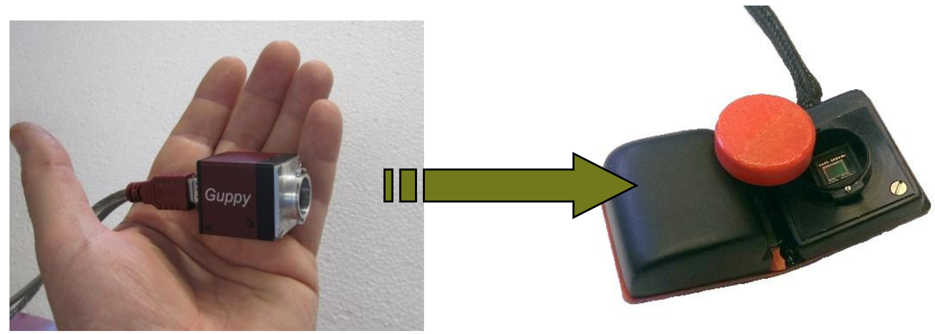

- 1024 x 768 pixel (4.65 x 4.65 μm)
- Fire Wire connection (30 fps)
- External Trigger
- Black and White

1 pixel = 4 arcsec

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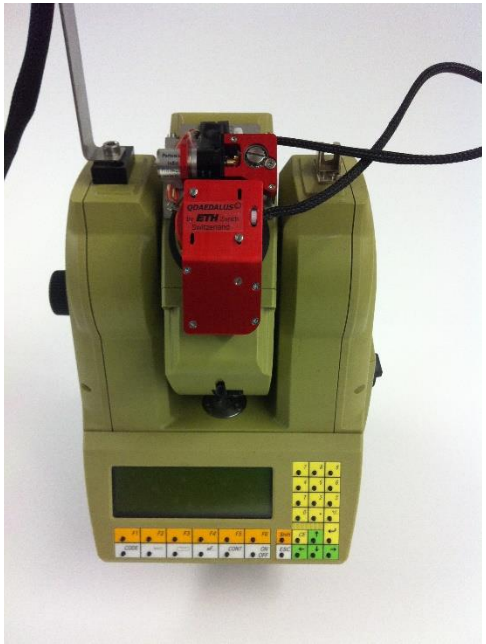

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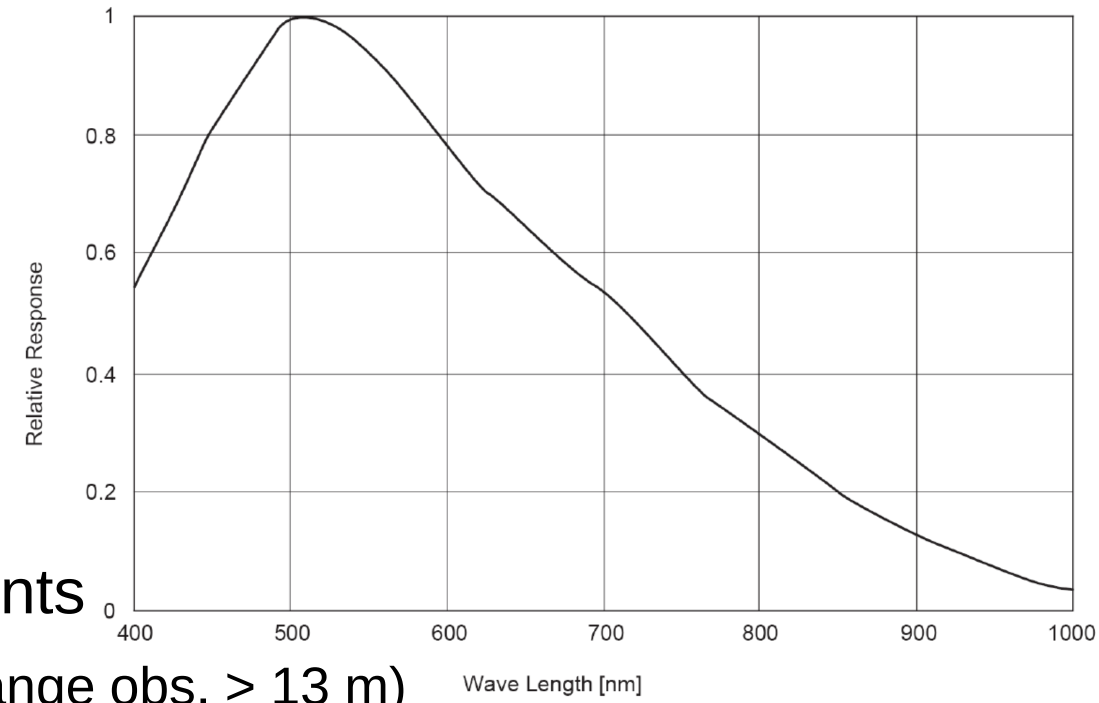

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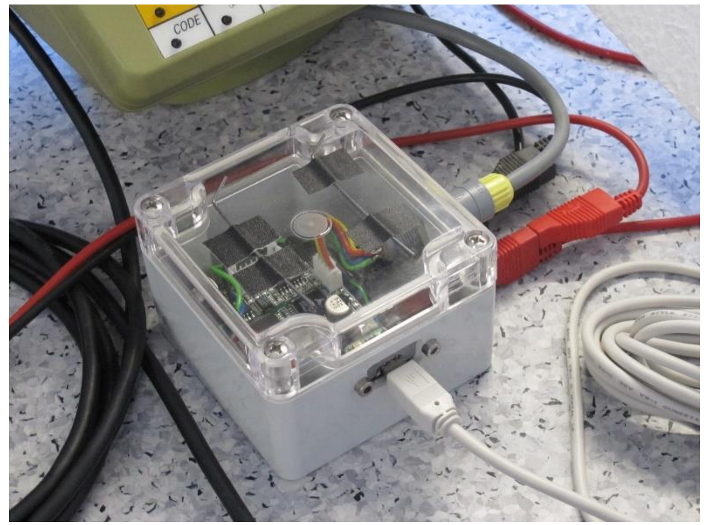

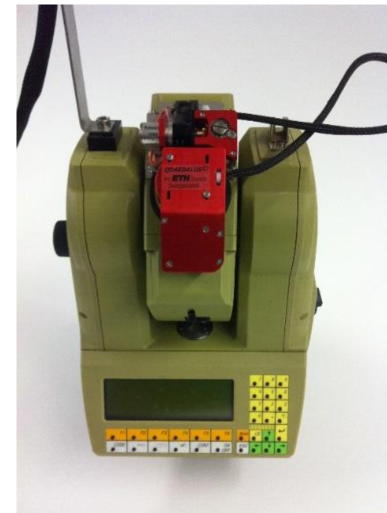

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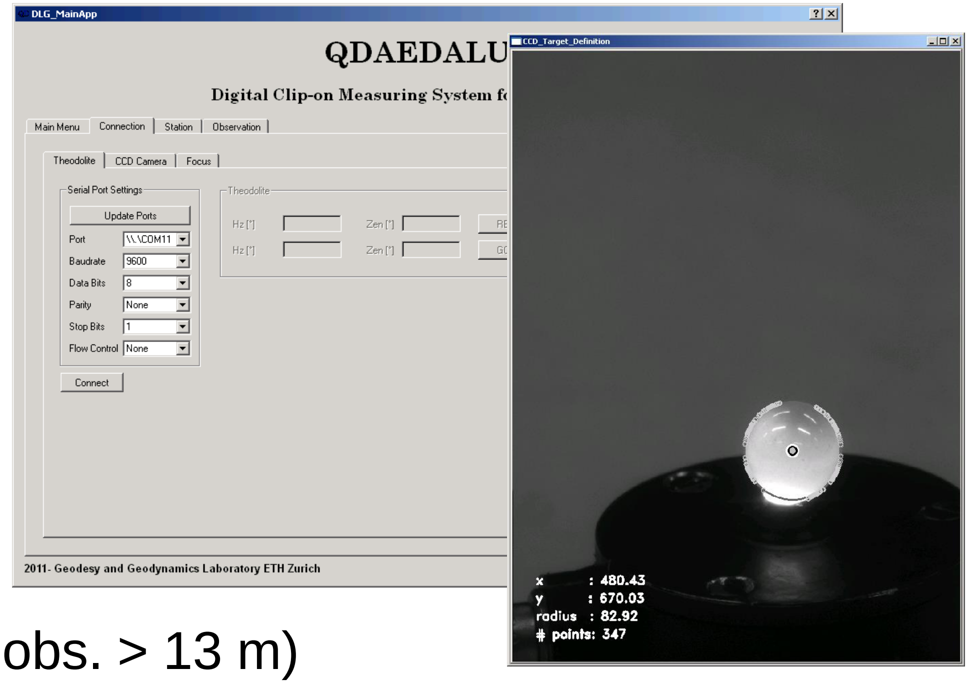

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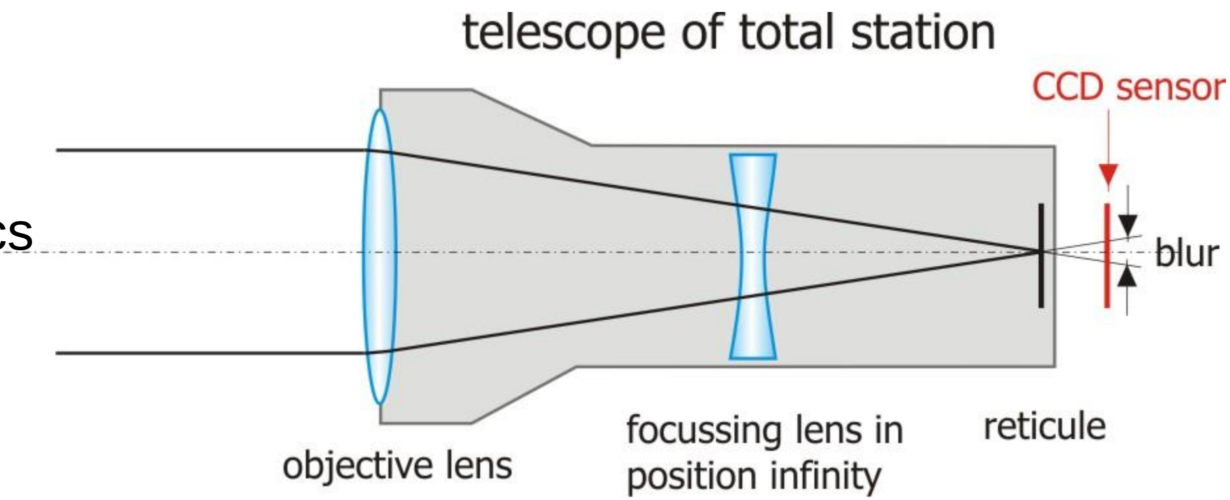

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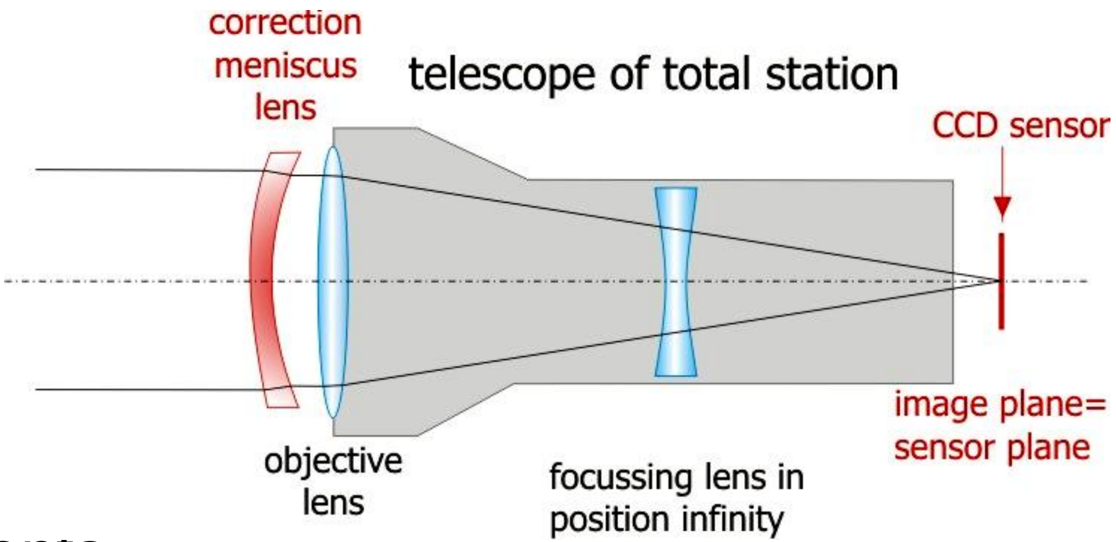

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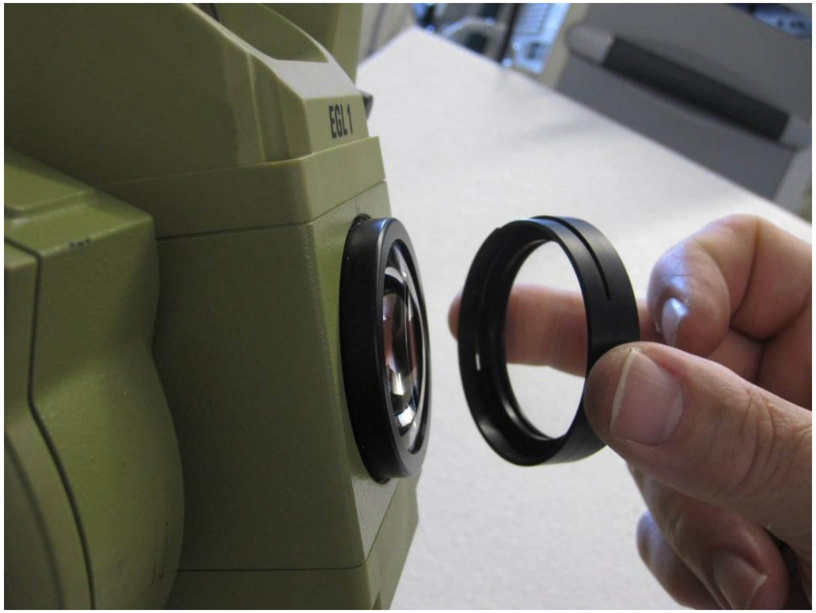

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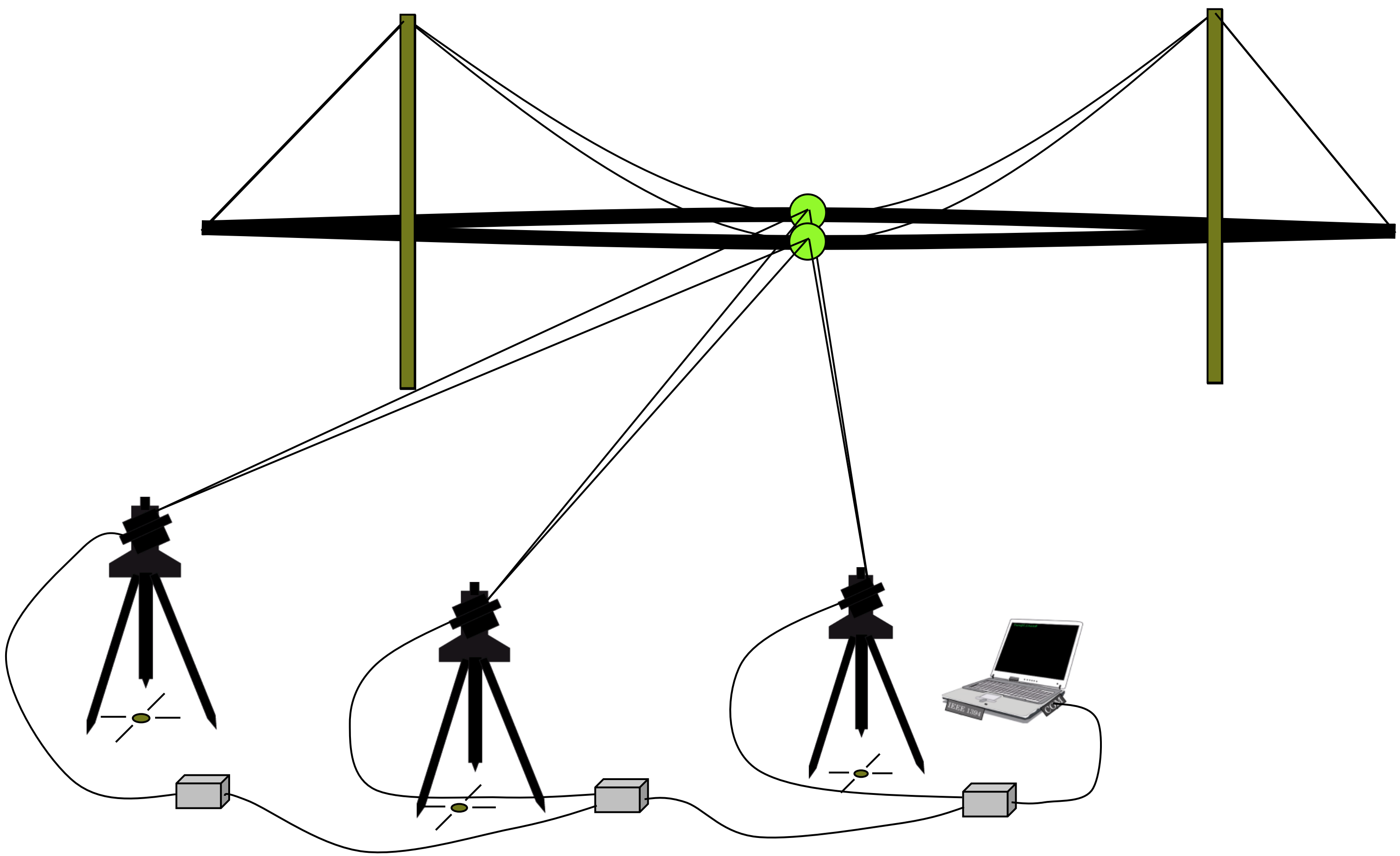

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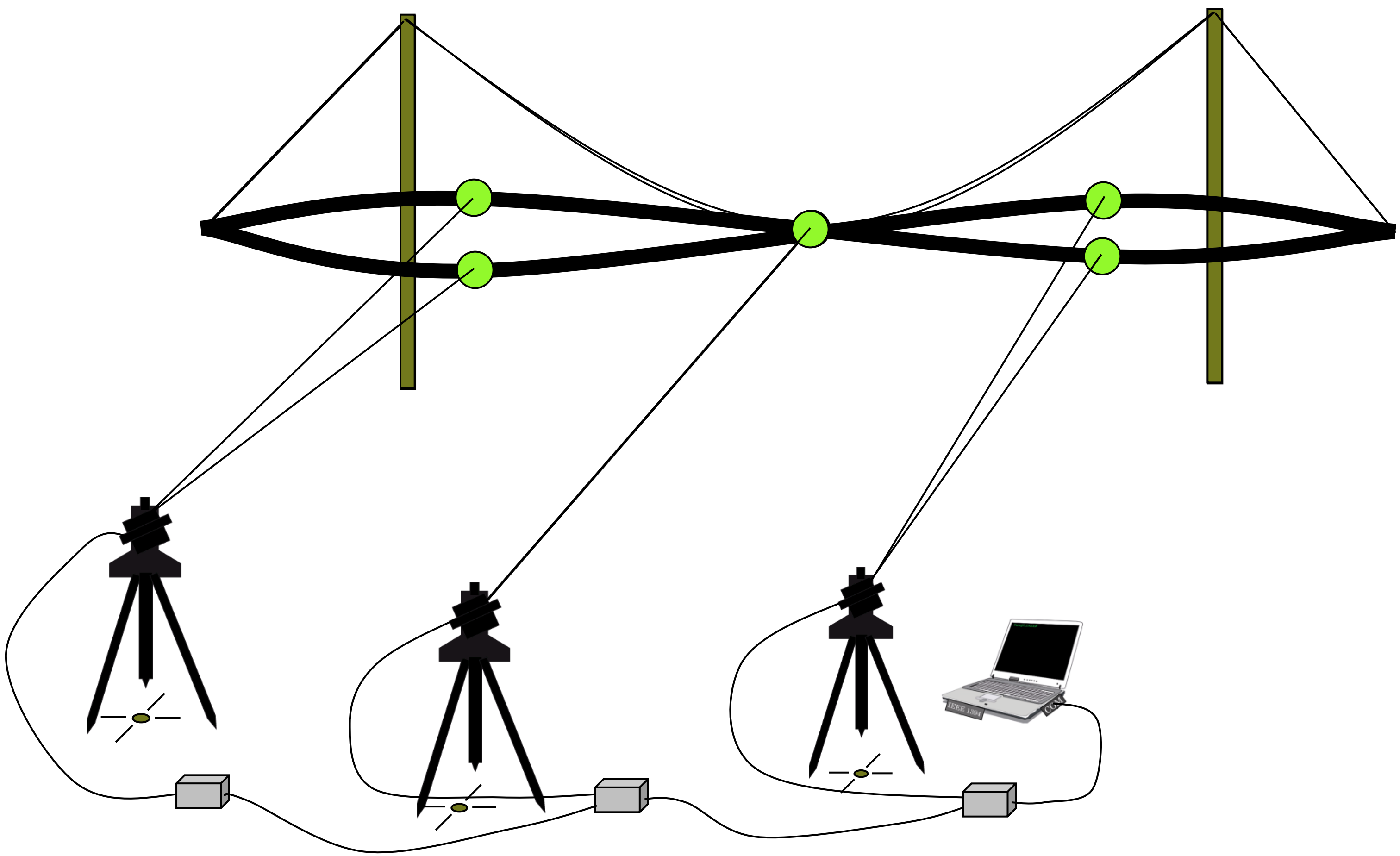

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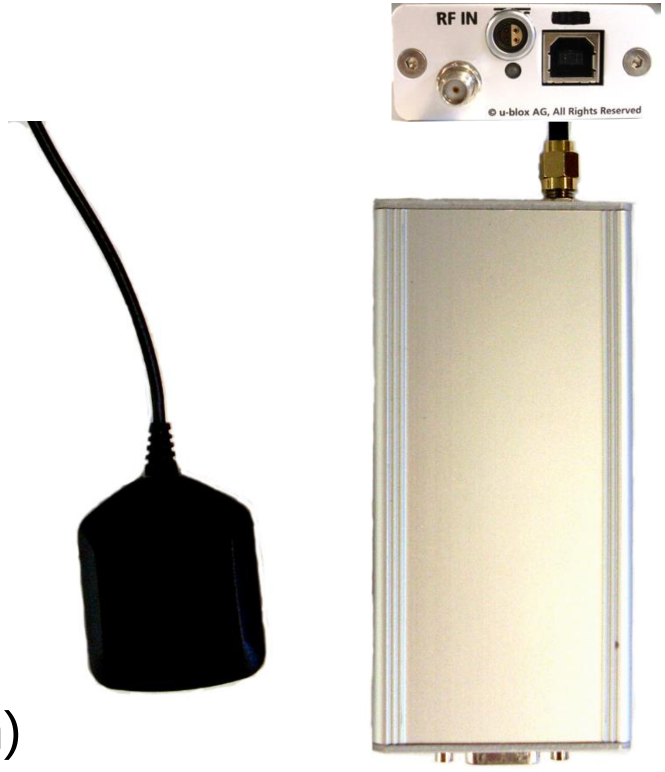

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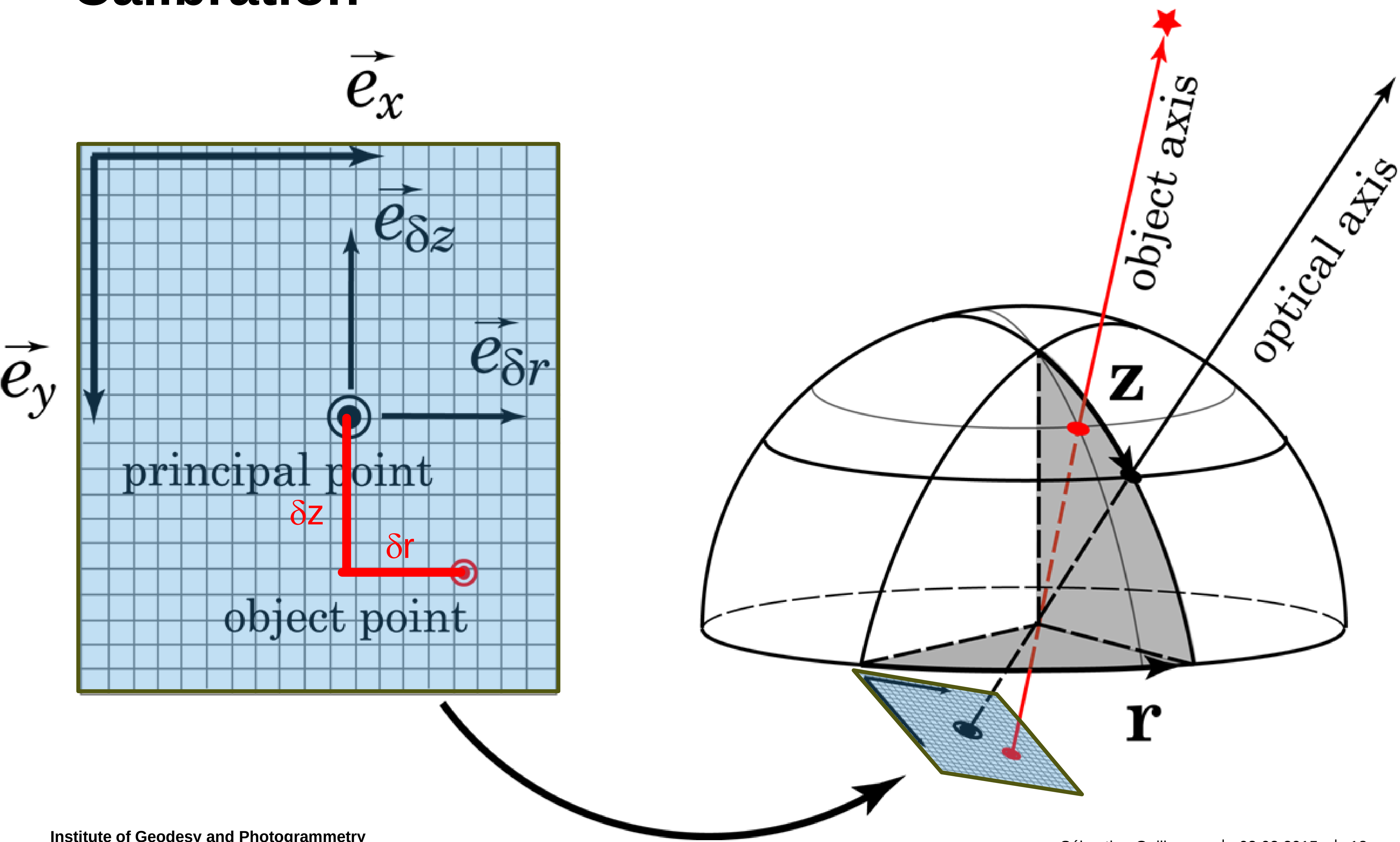
CCD-Space ⟷ Theodolite-Space

Calibration

Calibration



Calibration

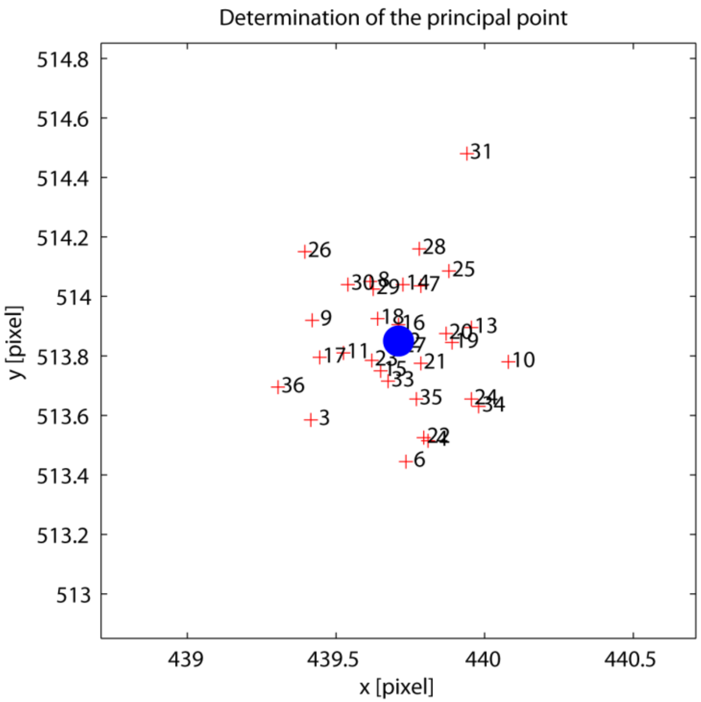
Affine Transformation (6 parameters)

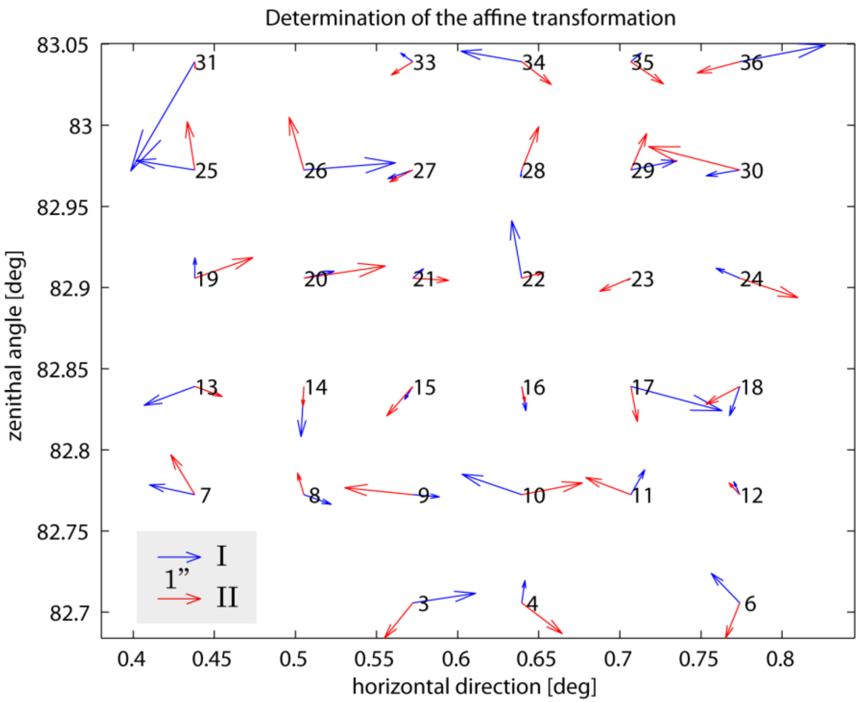
$$r_{object} = r_p \underbrace{- \frac{1}{\sin z_p} \left[a_{11} \cdot (x_{object} - x_p) + a_{12} \cdot (y_{object} - y_p) \right]}_{\delta r}$$

$$z_{object} = z_p \underbrace{- a_{21} \cdot (x_{object} - x_p) - a_{22} \cdot (y_{object} - y_p)}_{\delta z}$$

object angles | **telescope readings** | **calculated Hz and V corrections**

Calibration



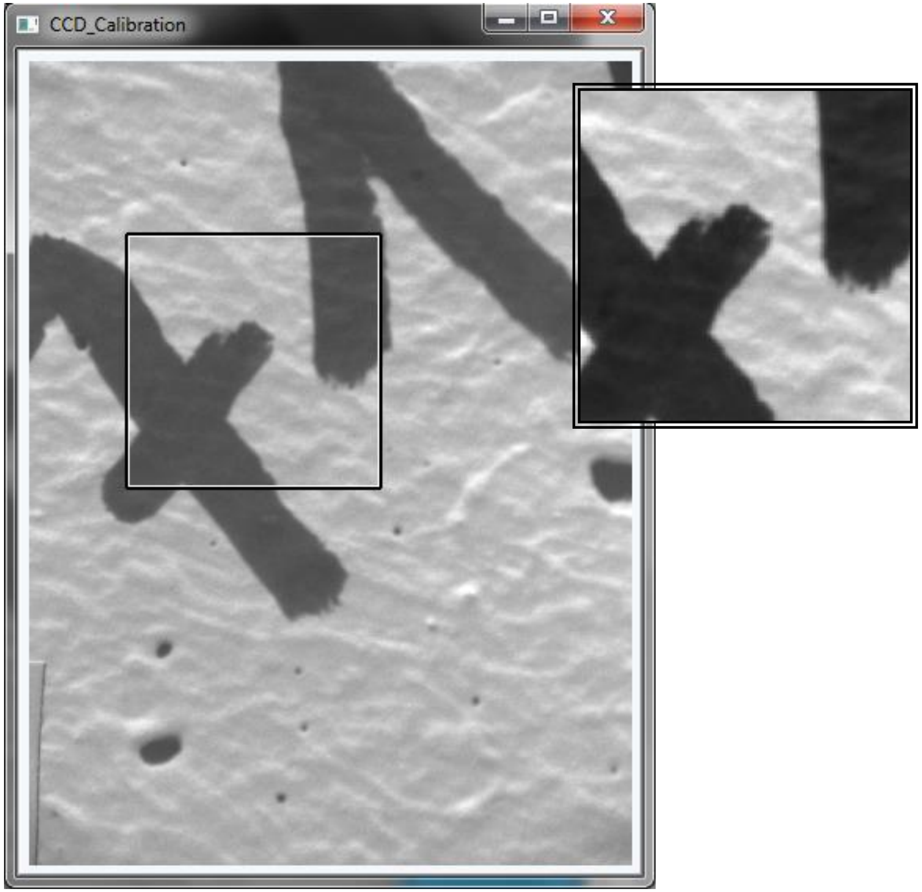


Identification & Extraction of Objects

Optical Target Recognition

- Least-squares template matching.
- Centroid operator.
- Robust circle matching.
- Robust ellipse matching.

OTR: Least-Squares Template Matching



PARAMETERS

- template

ADVANTAGES

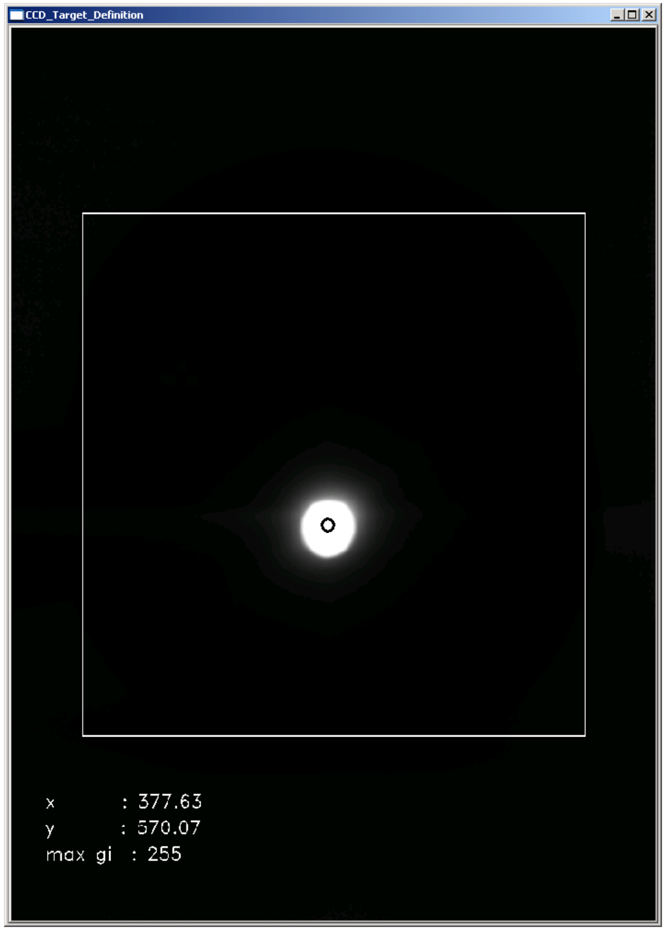
- arbitrary objects with texture
- very accurate

DESADVANTAGES

- systematic bias in the target definition
- time computation for real-time tracking
- not invariant with respect to view

precision < 0.1 pixel = 0.4 arcsec = 2.5 μm/m

OTR: Centroid Operator



PARAMETERS

- automatic threshold for the background (inverse image also)
- minimal area of target
- center of mass or 2D gaussian

ADVANTAGES

- robust and reliable segmentation
- short computation time (real-time)
- very accurate
- simple targets (lamps, diodes, ...)
- precise focusing not needed

DESADVANTAGES

- usually mandatory active targets
- mechanical reference not optimal
- not invariant with respect to view

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- automatic threshold for the background (inverse image also)
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OTR: Robust Circle Matching Operator

PARAMETERS

- canny edge detector sensitivity
- minimal point for adjustment
- minimal and maximal radius

ADVANTAGES

- optimal for spherical objects
  => optimal mechanical reference
- very accurate
- simple passiv target
- well adapted for automated microtriangulation

DESADVANTAGES

- mandatory focusing
- range limited (>> sphere, >> dist.)

precision < 0.1 pixel = 0.4 arcsec = 2.5 μm/m

OTR: Robust Ellipse Matching Operator

PARAMETERS

- automatic threshold for the background (inverse image also)
- minimal area of target
- minimal number of points

ADVANTAGES

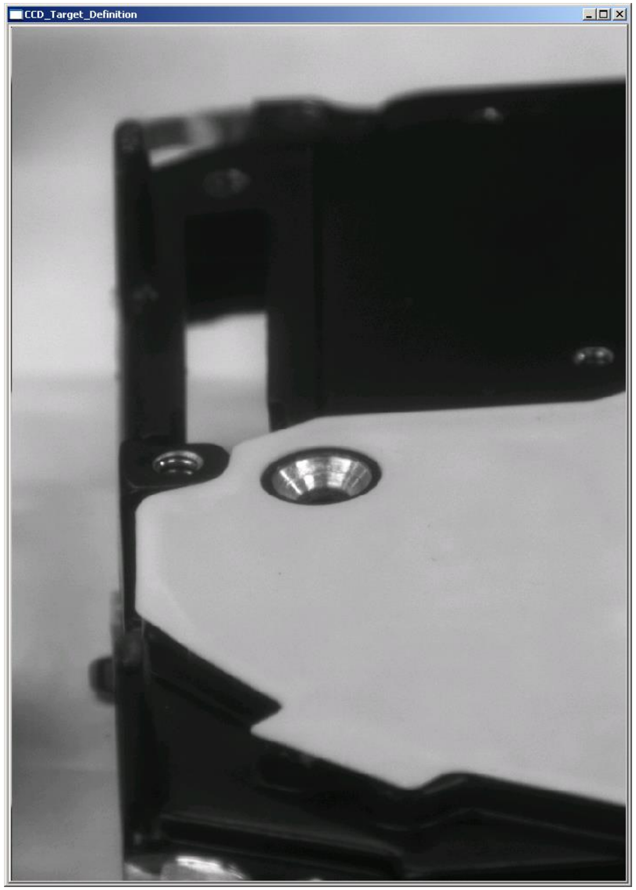
- optimal for circular objects
  => optimal mechanical reference
- simple passiv targets (hole, black circle on white background)

DESADVANTAGES

- mandatory precise focusing
- range limitation (>> circle, >> dist.)

precision < 0.1 pixel = 0.4 arcsec = 2.5 μm/m

OTR: Robust Ellipse Matching Operator



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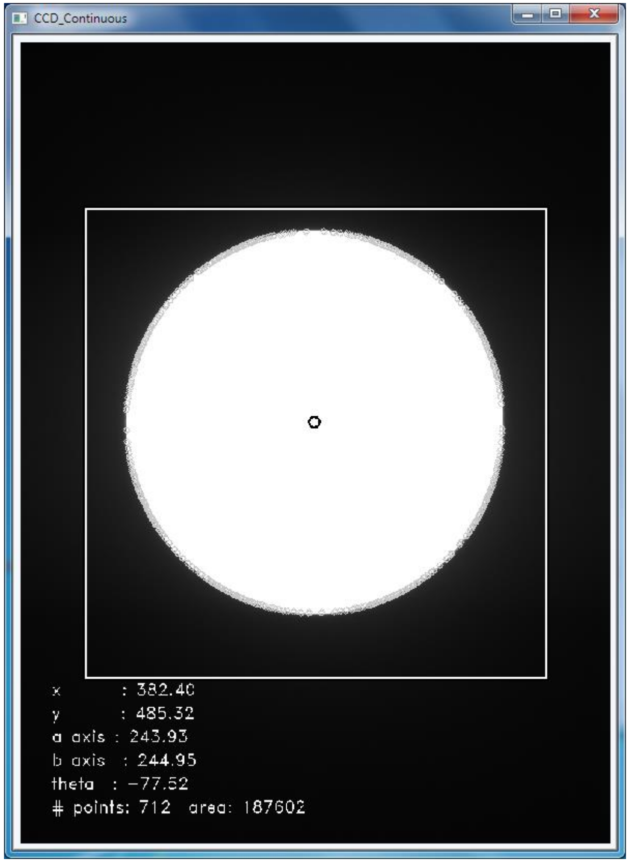
OTR: Robust Ellipse Matching Operator



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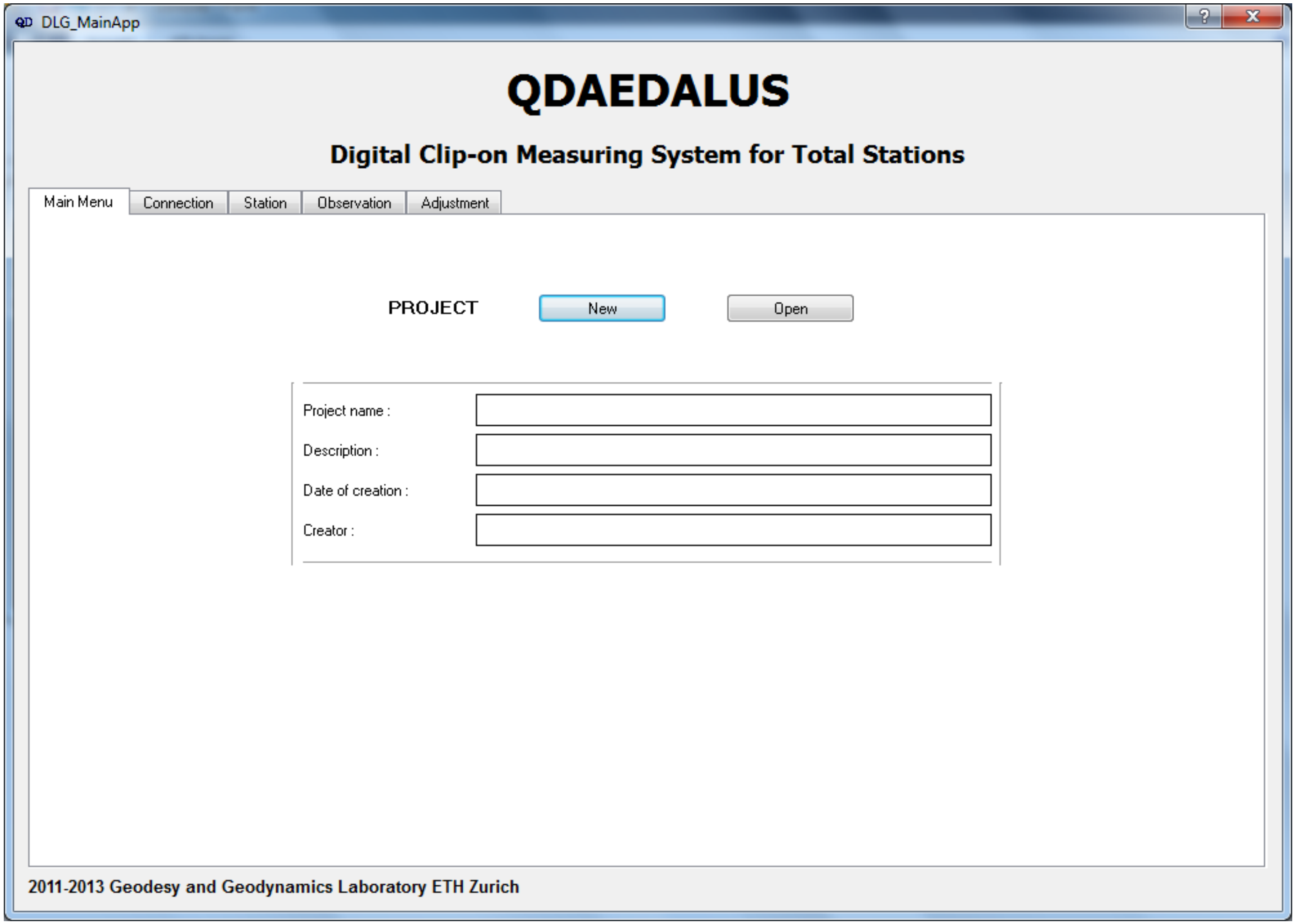
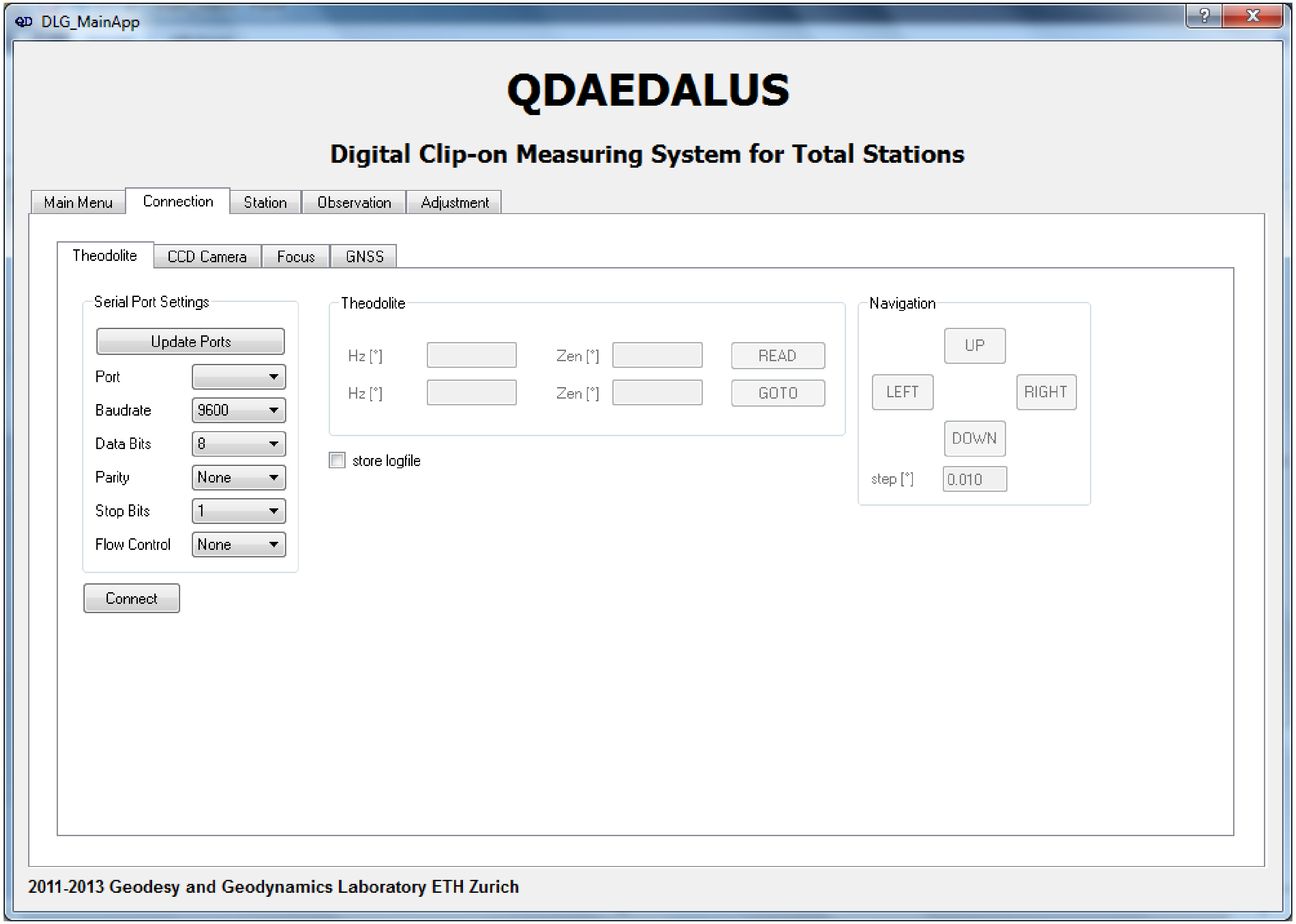
Measuring with QDaedalus

Measuring with QDaedalus (Start)



Measuring with QDaedalus (Connection)



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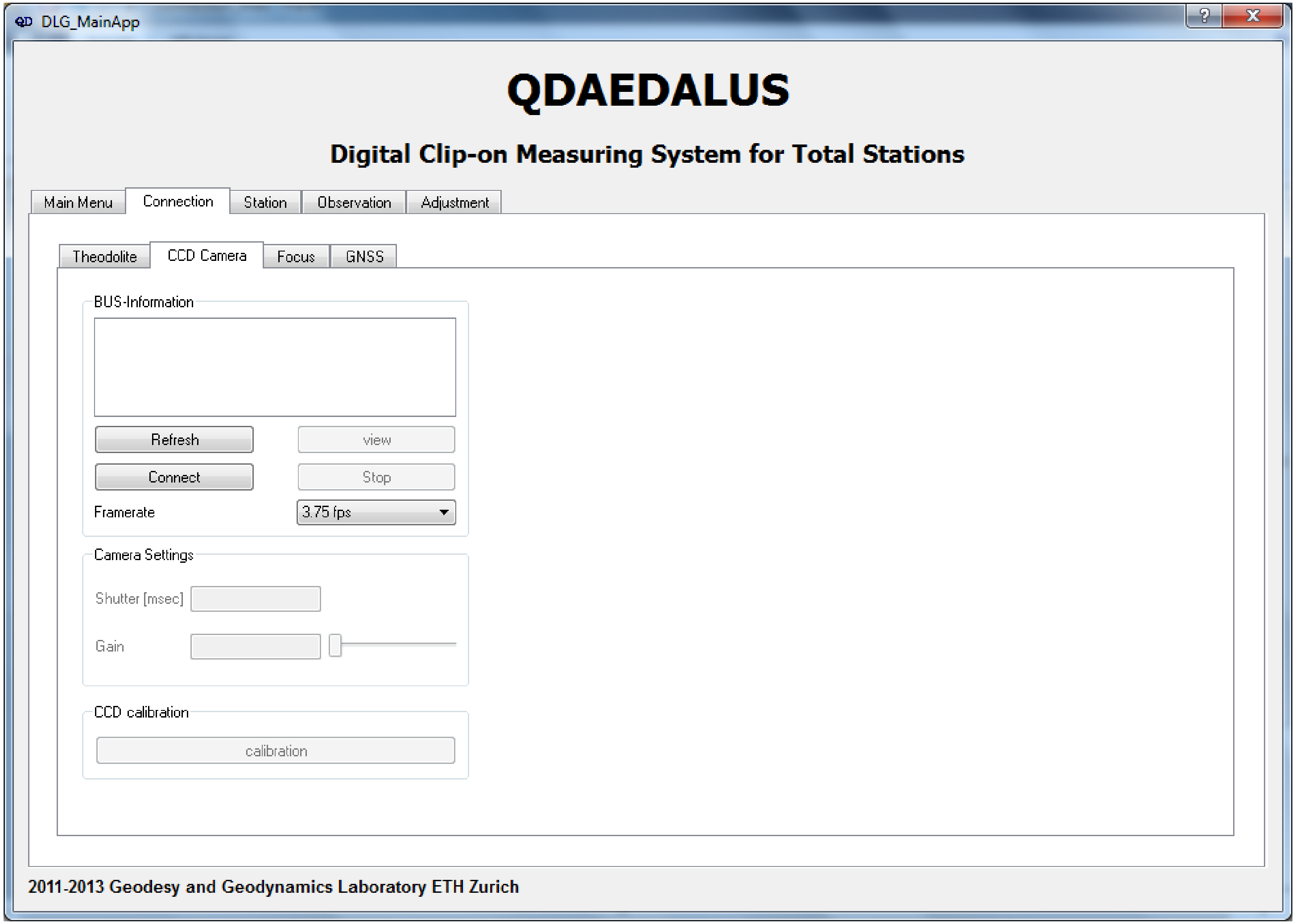
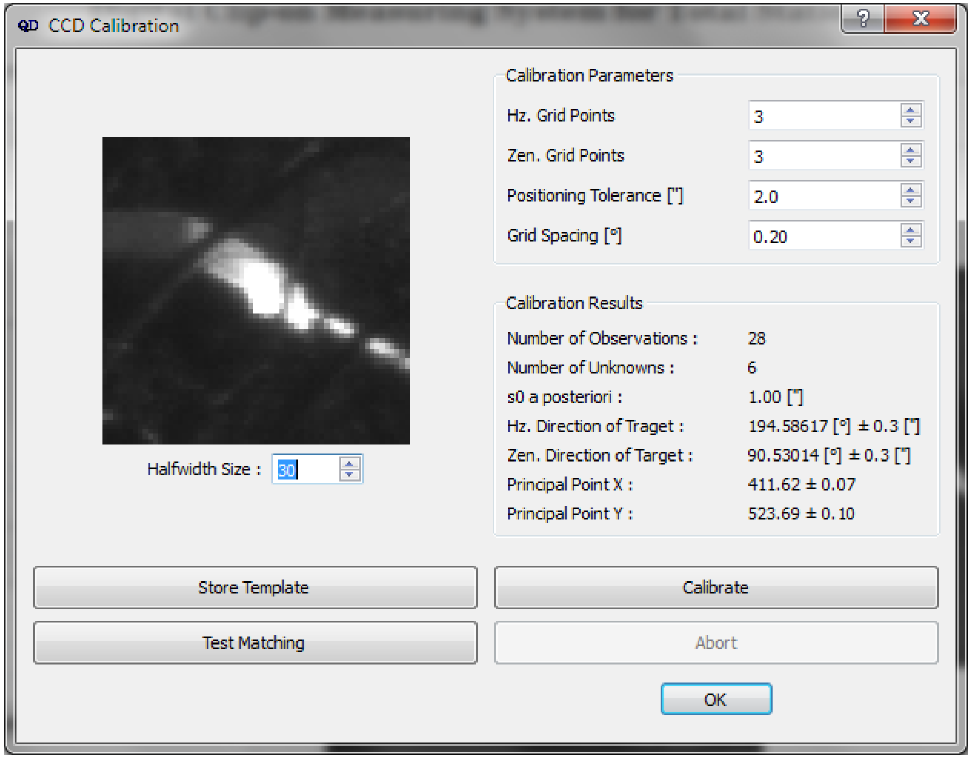
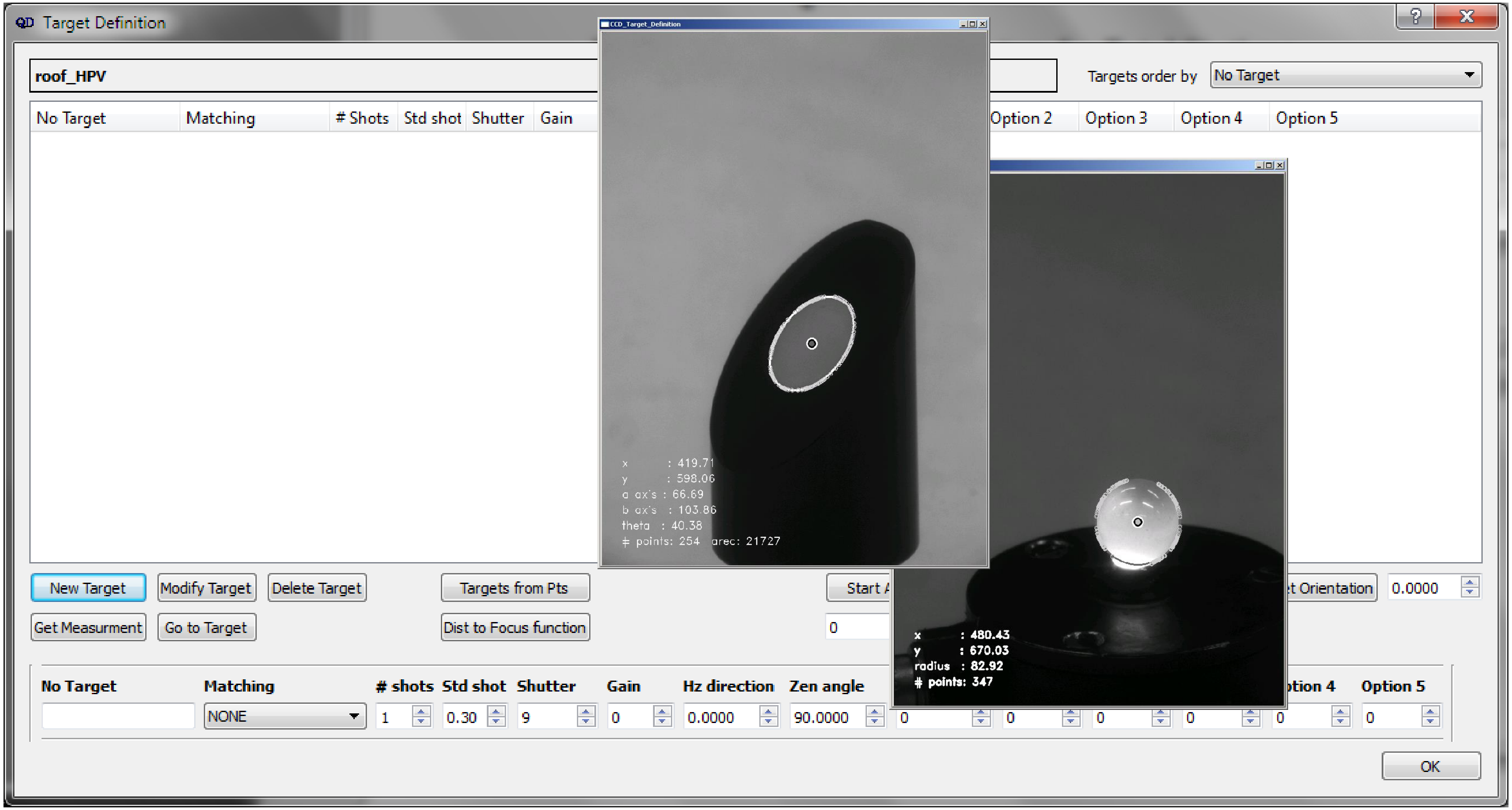


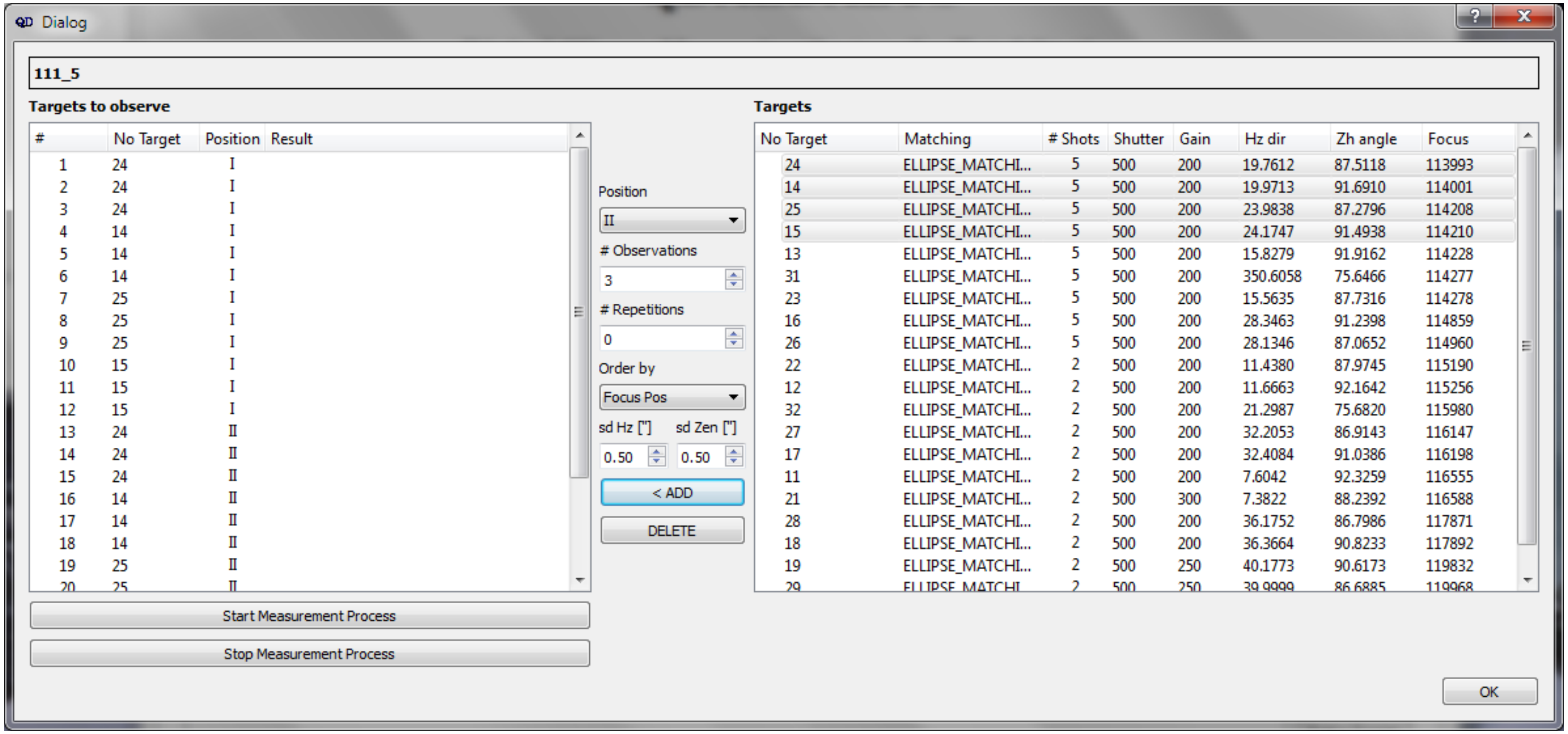
Measuring with QDaedalus (Calibration)



Measuring with QDaedalus (Target Def.)



Measuring with QDaedalus (Meas. Process)



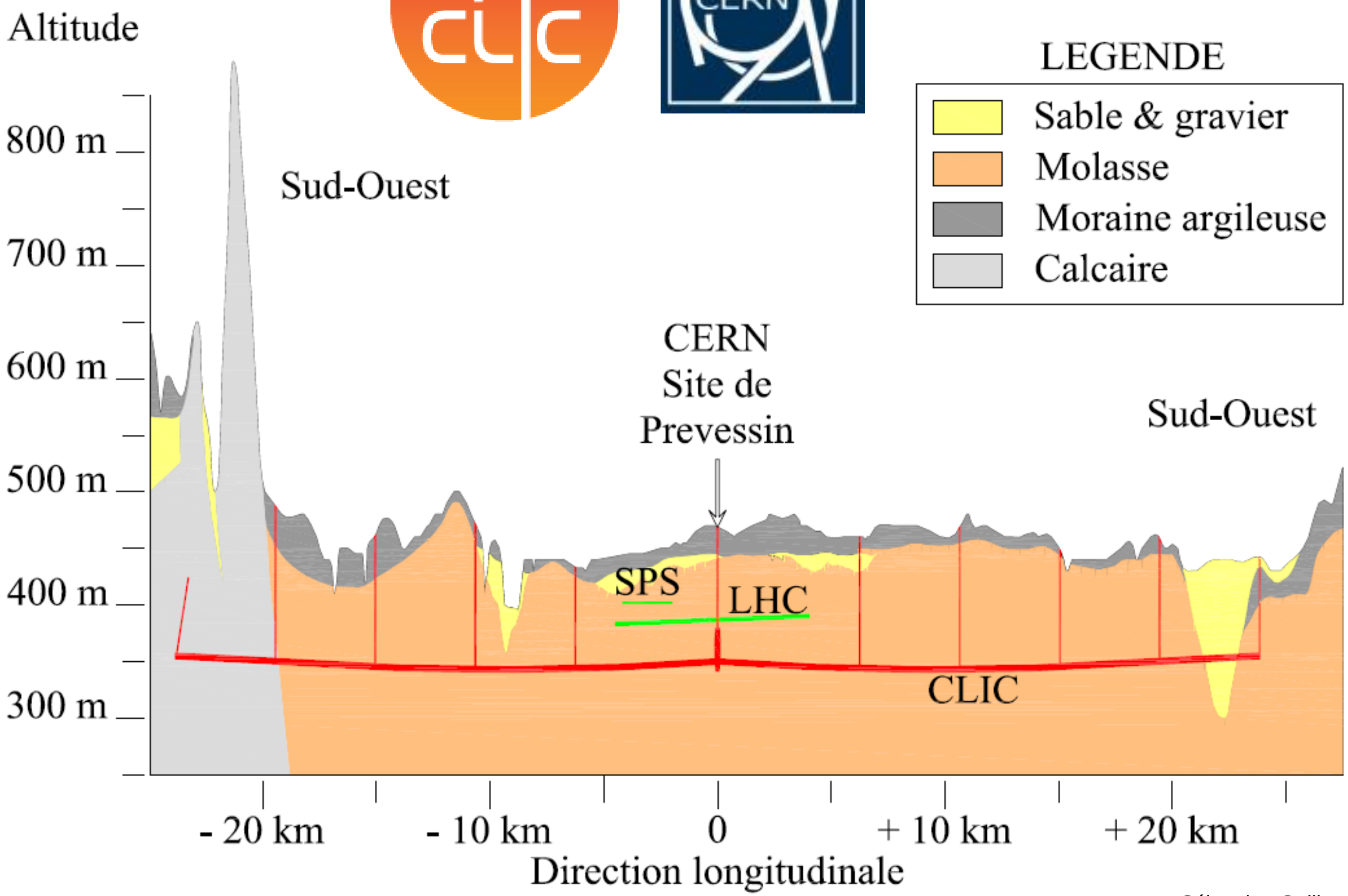
Practical Experiment of QDaealus at CERN

Automatic Microtriangulation of Linear Collider Components

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

CERN

Automatic Microtriangulation



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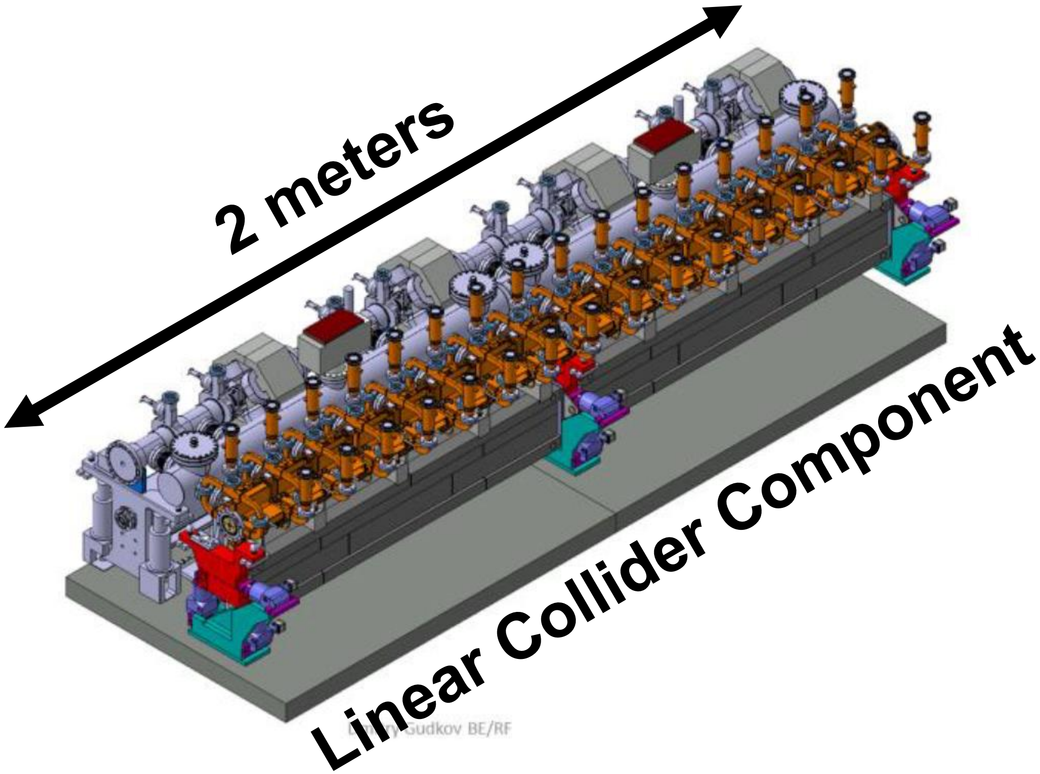
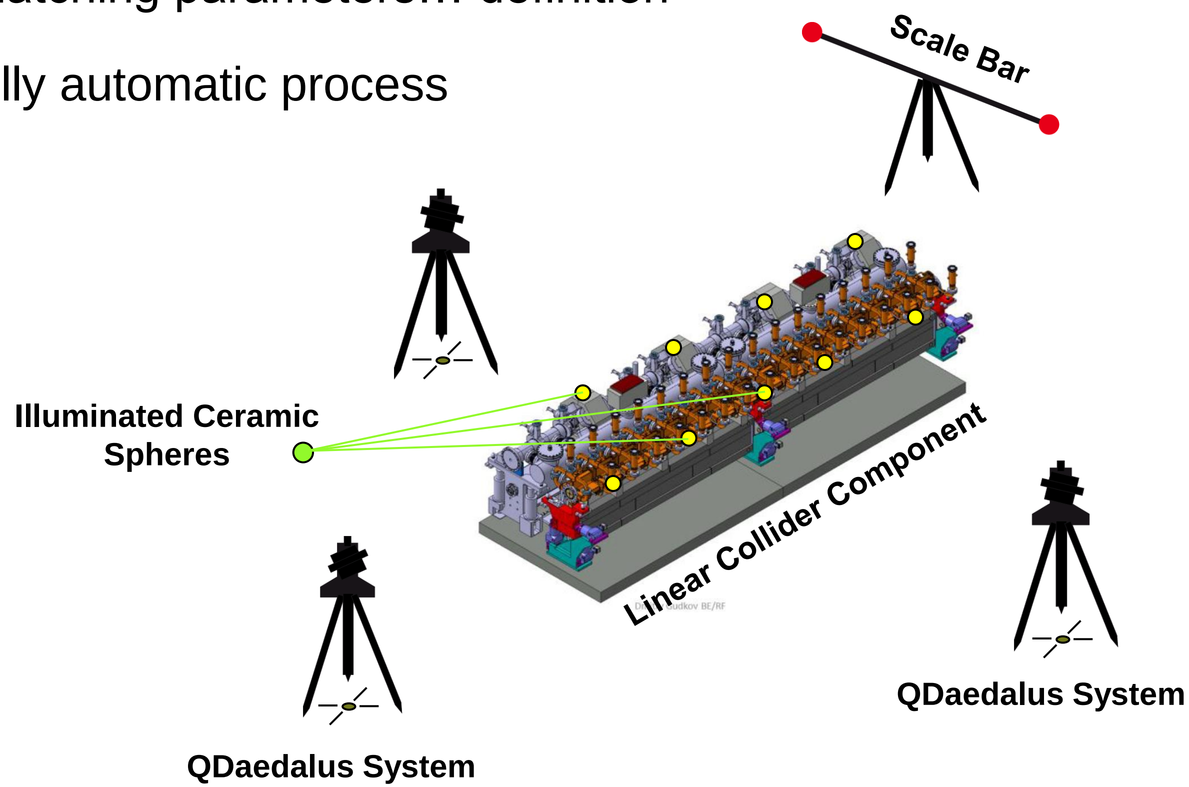


➔ more than 20 000 modules in total to be measured !

Automatic Microtriangulation

1. Import approximate positions of station and targets
2. Camera, focus, circle matching parameters… definition
3. Start measurements, fully automatic process



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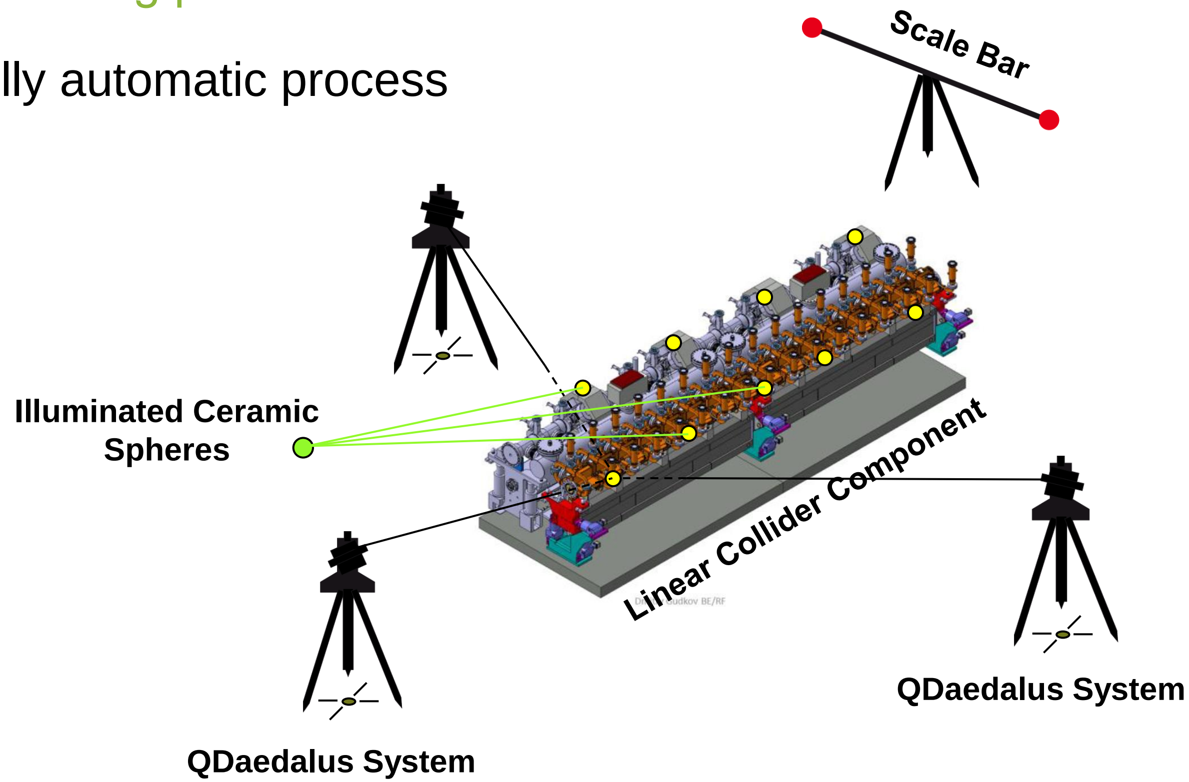

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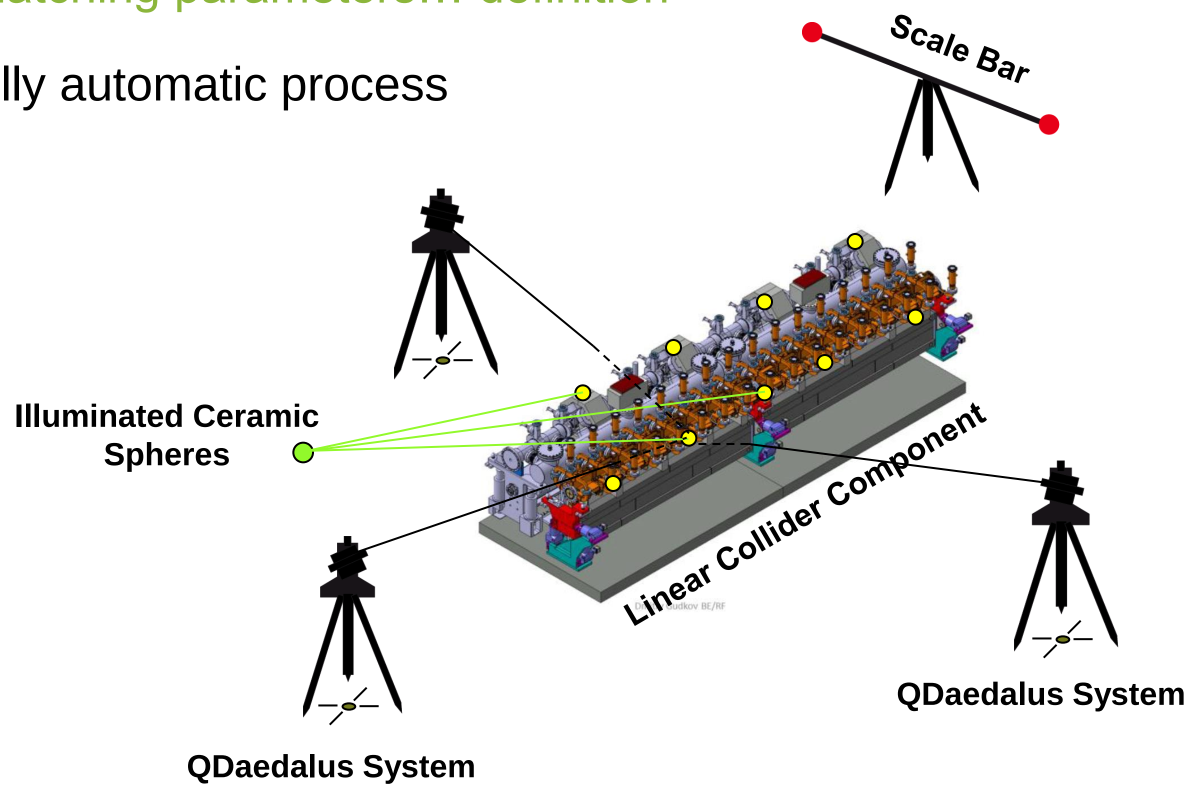

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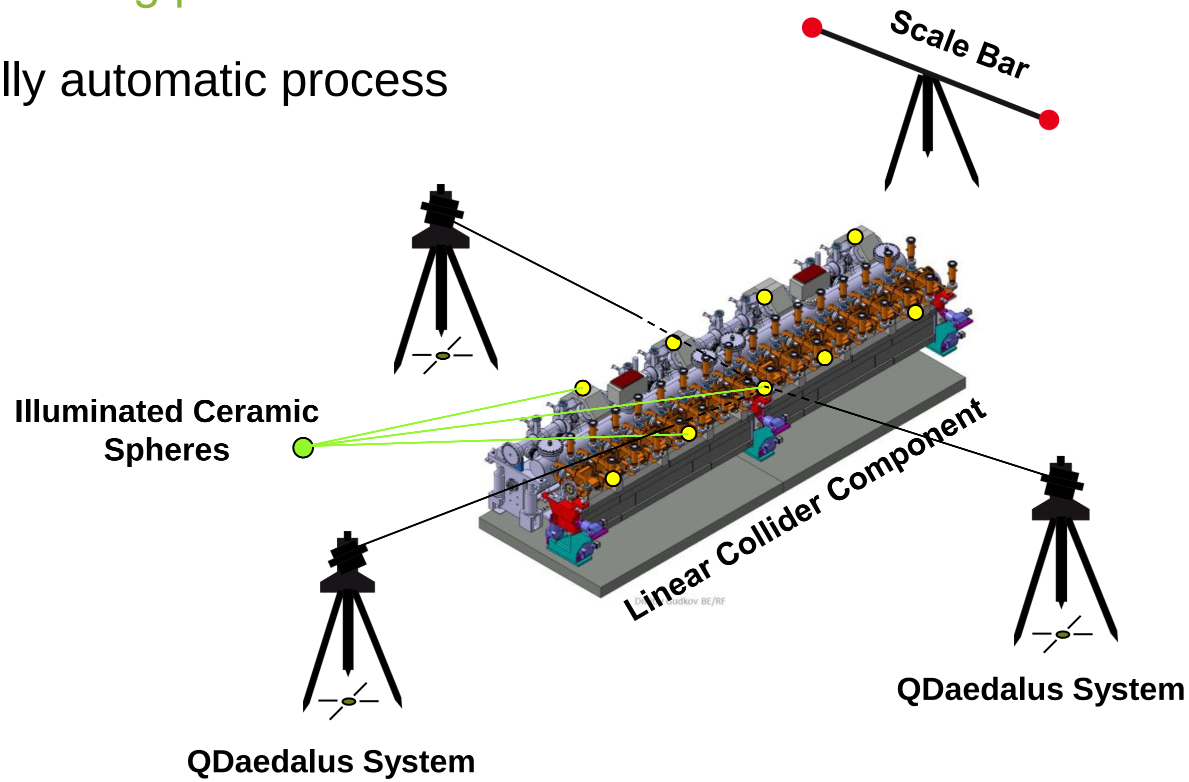

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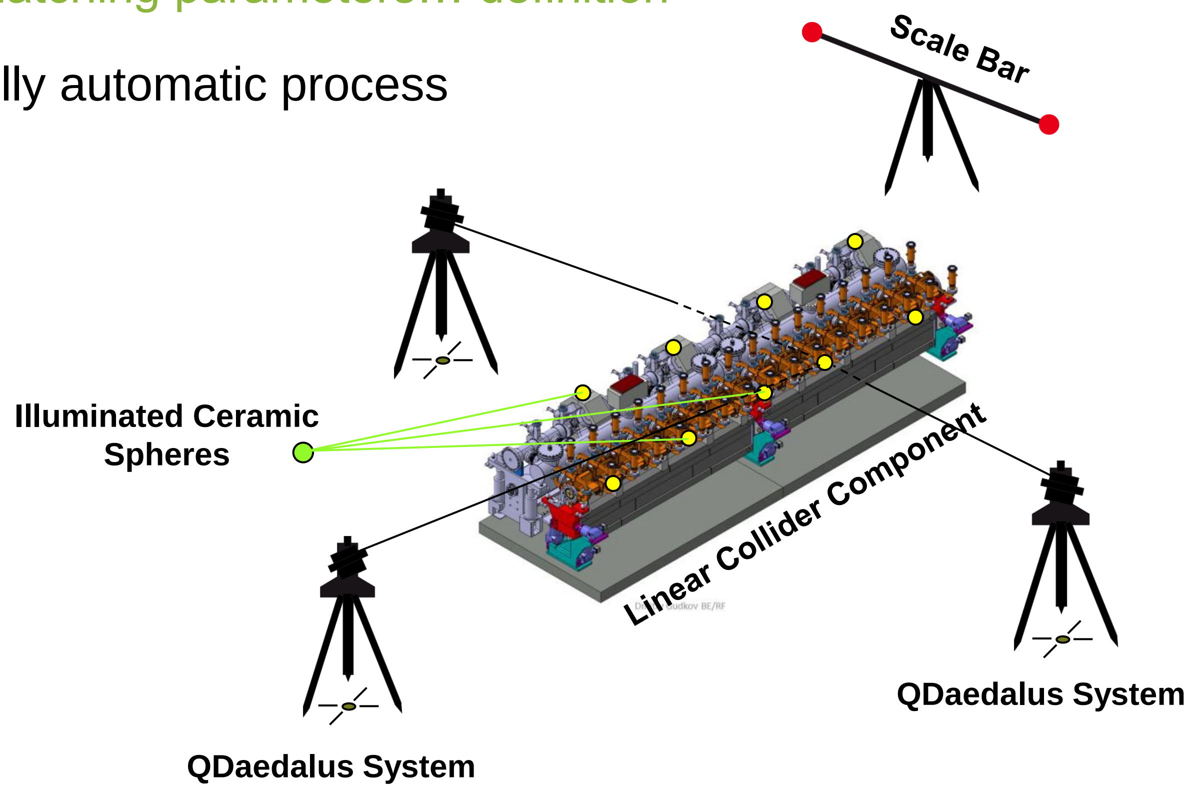

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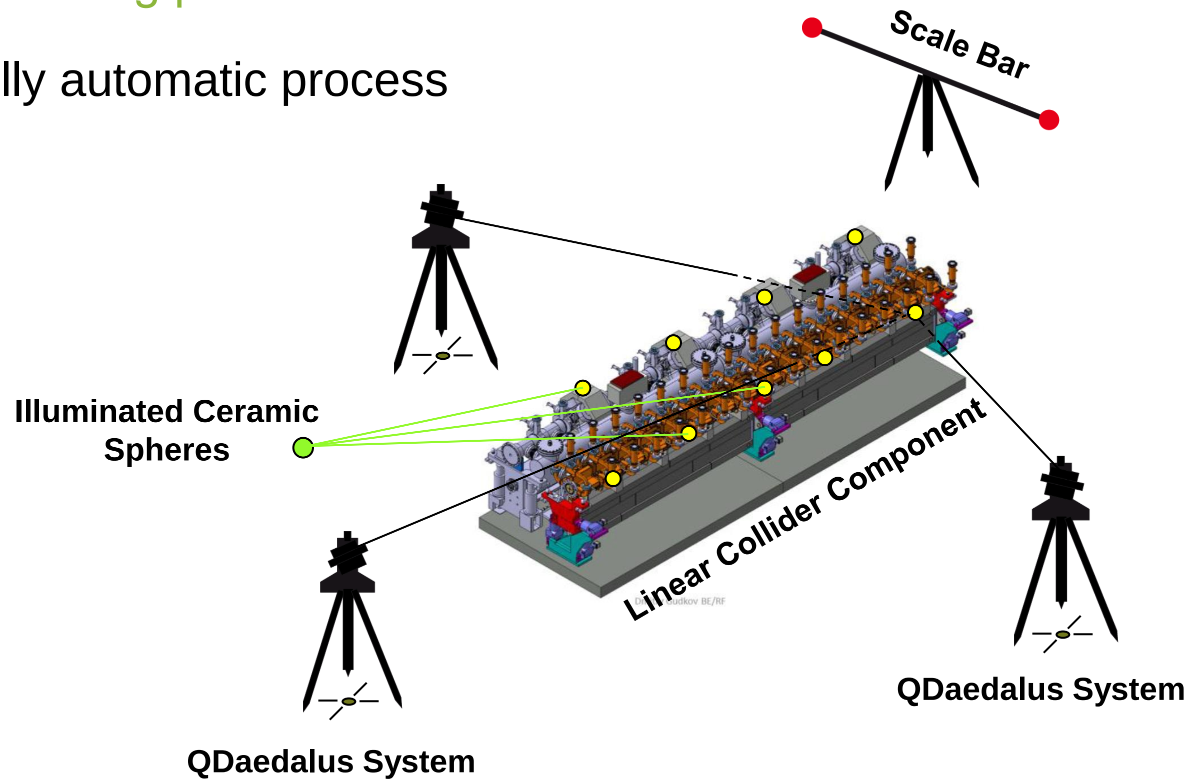

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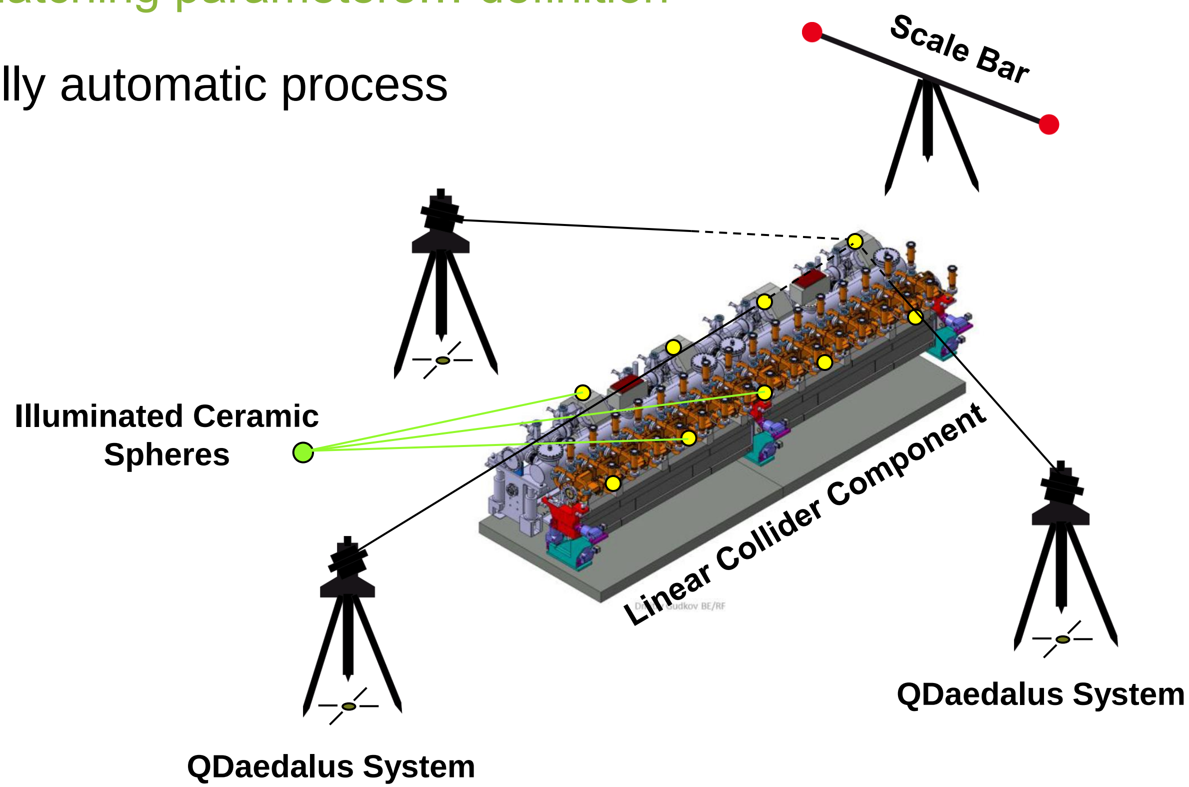

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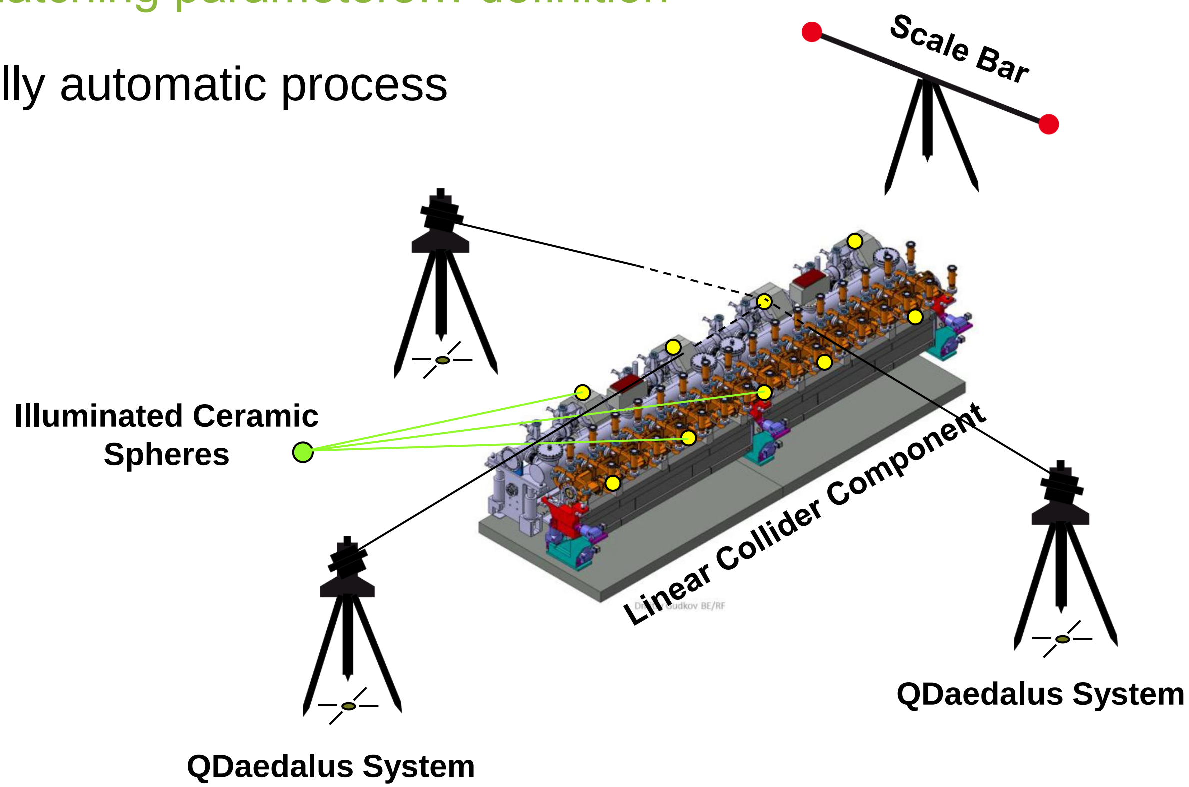

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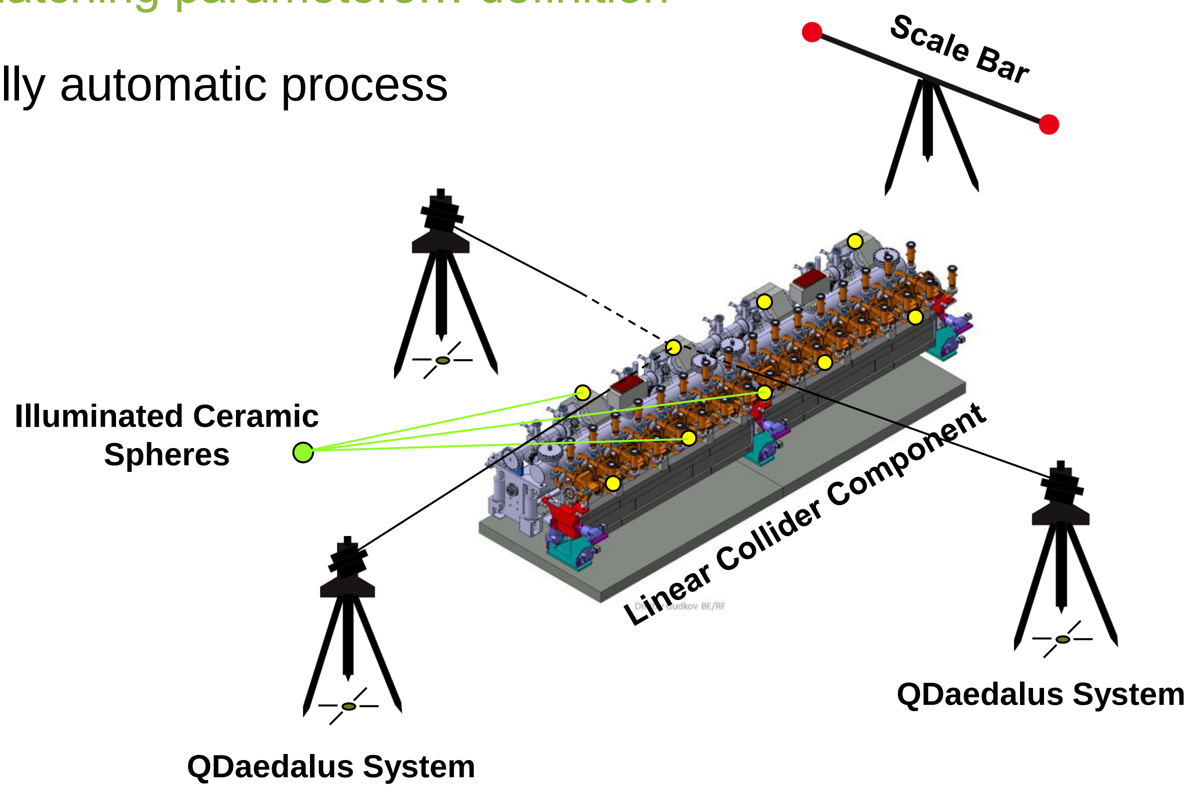

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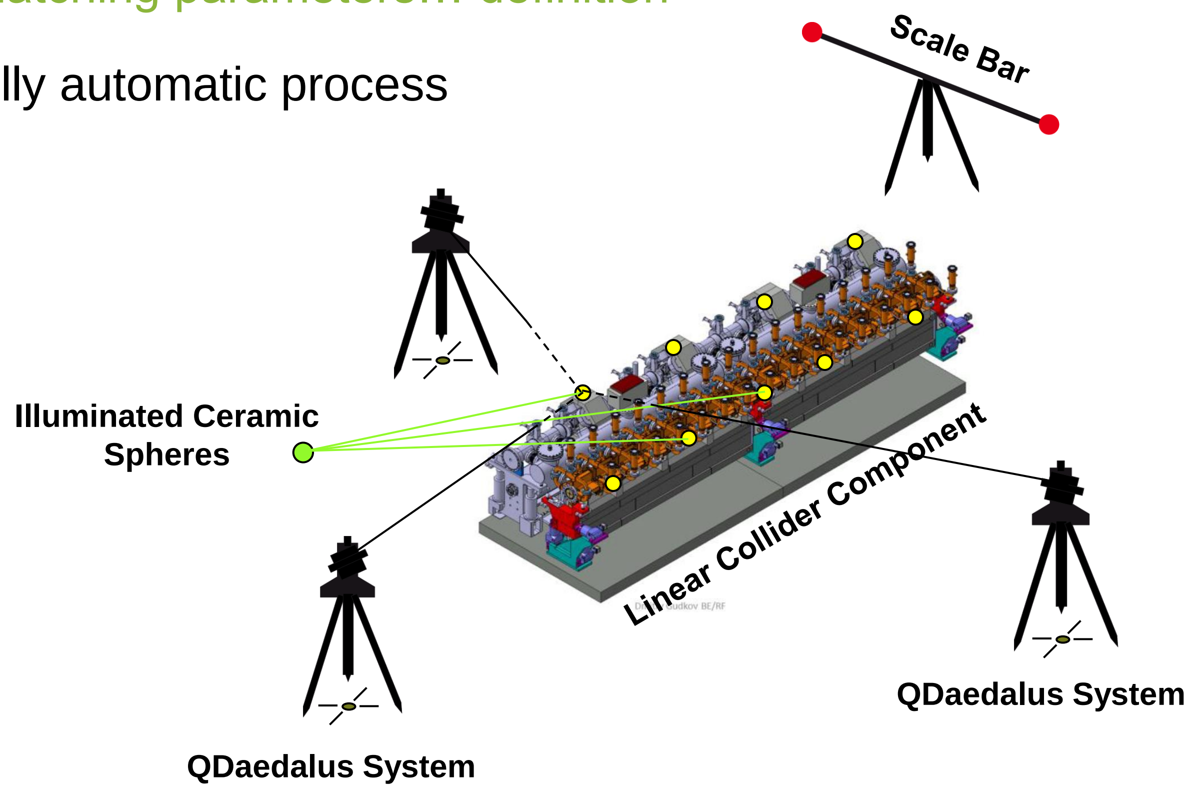

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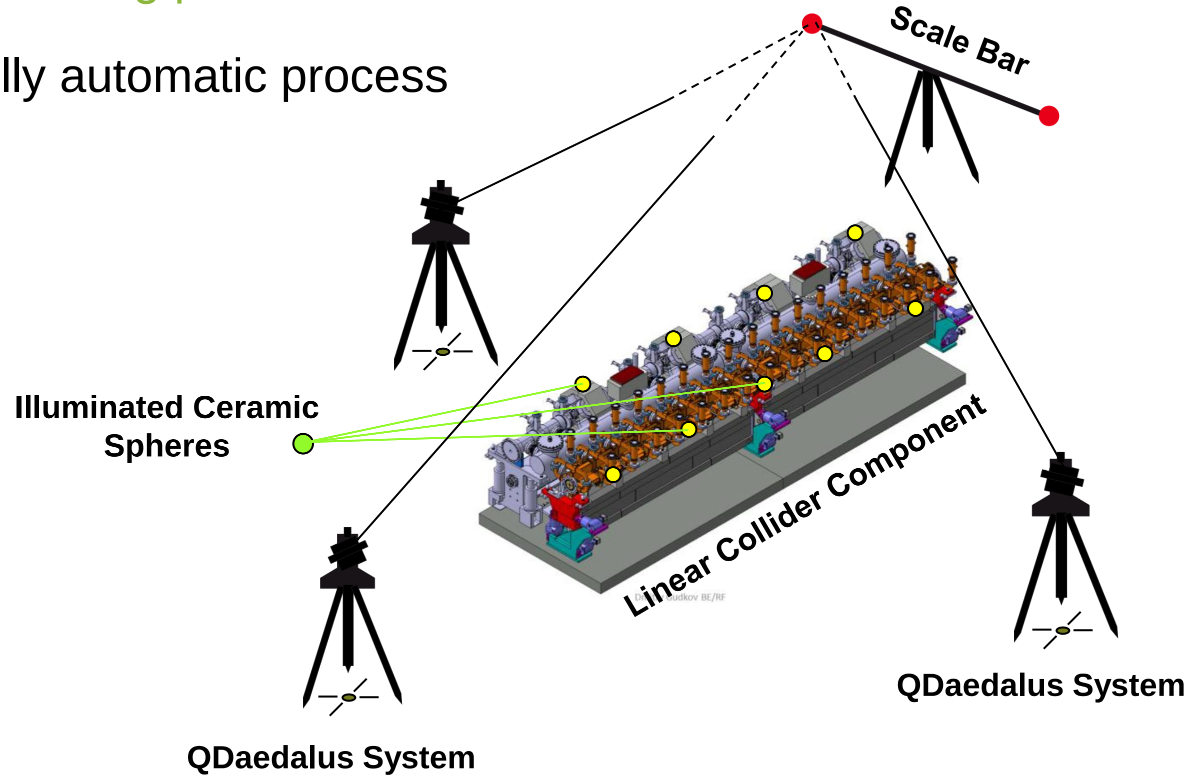

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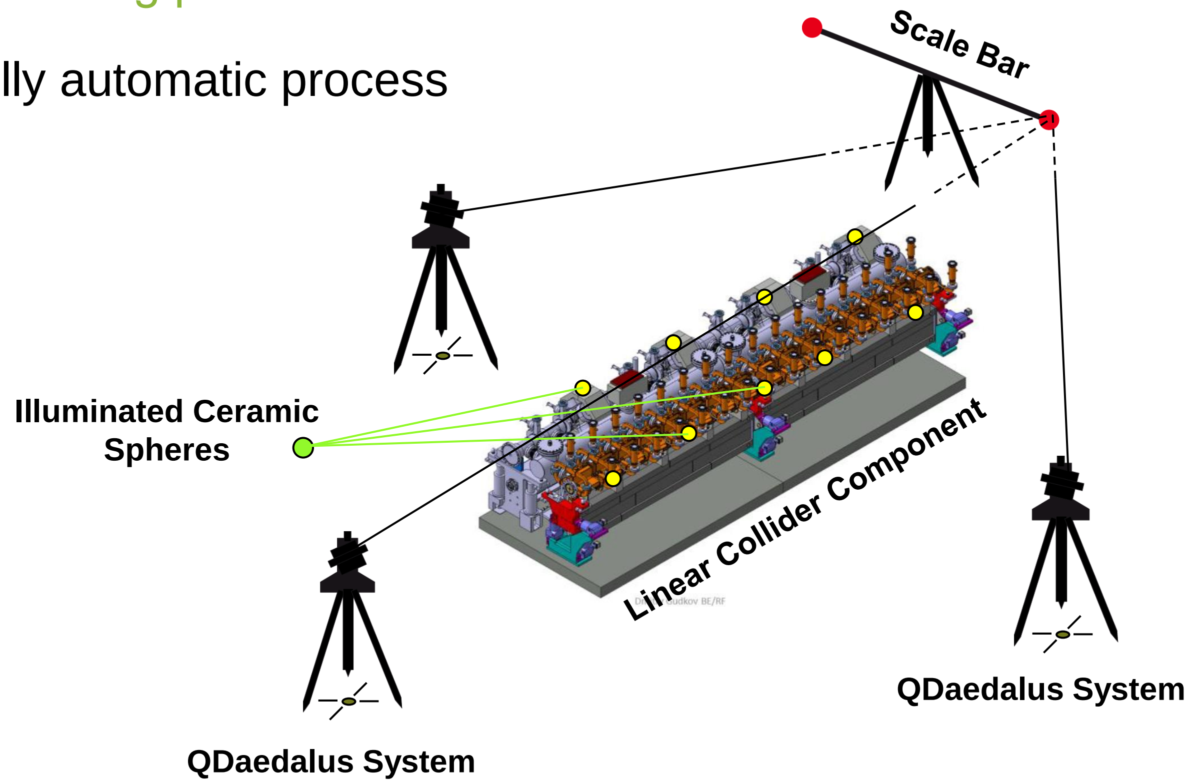

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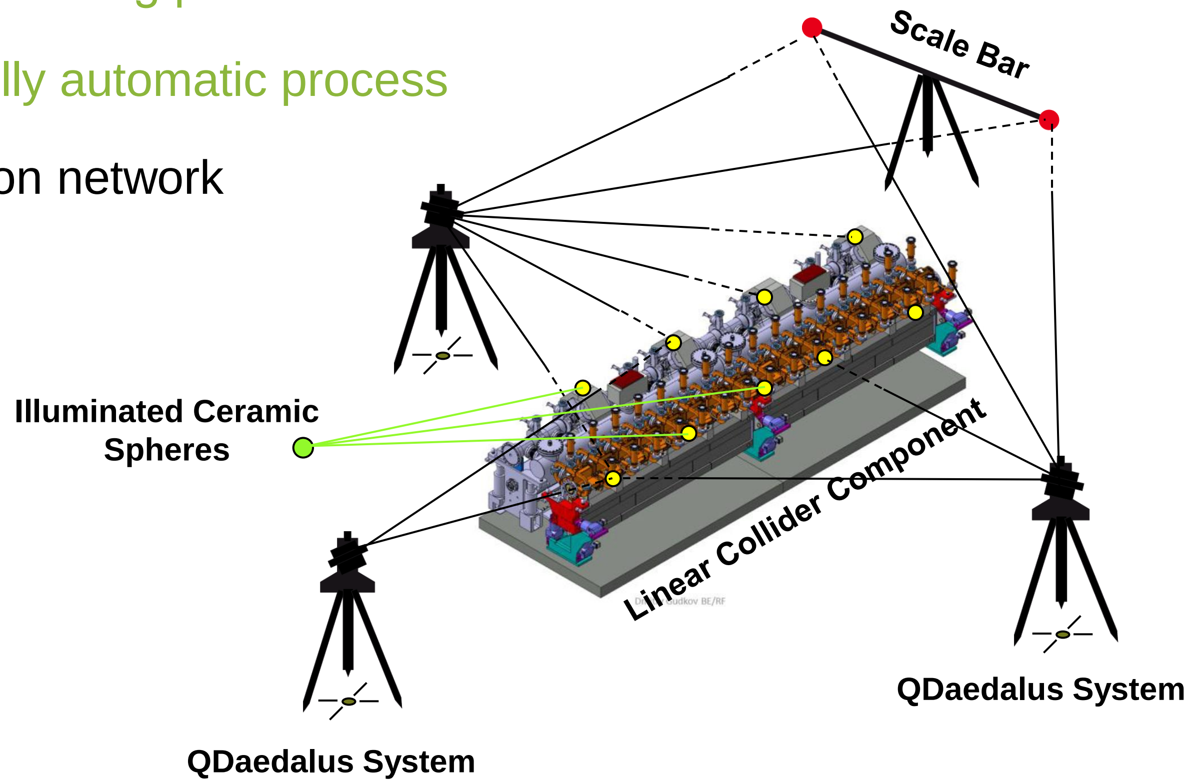
4. Adjust micro-triangulation network



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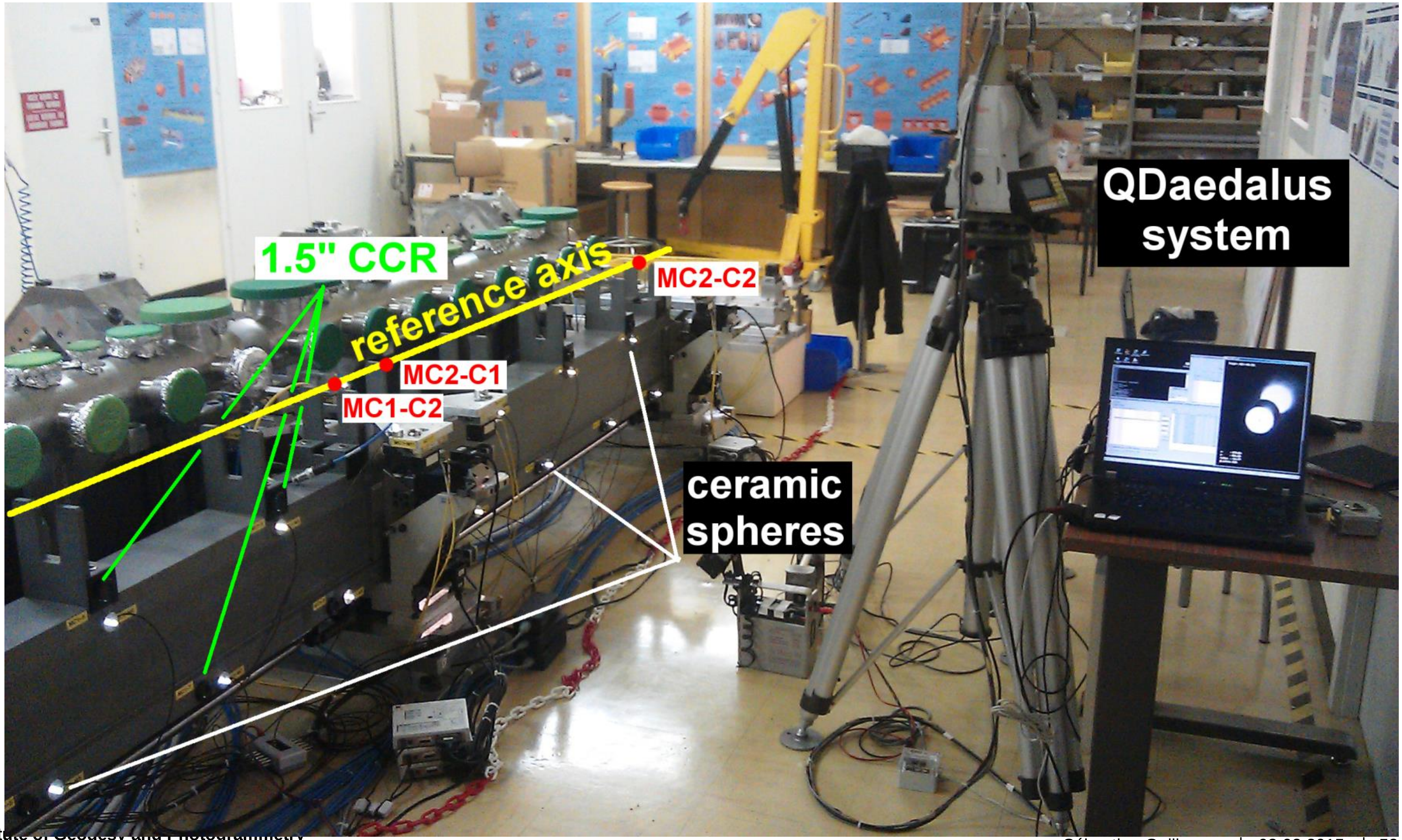

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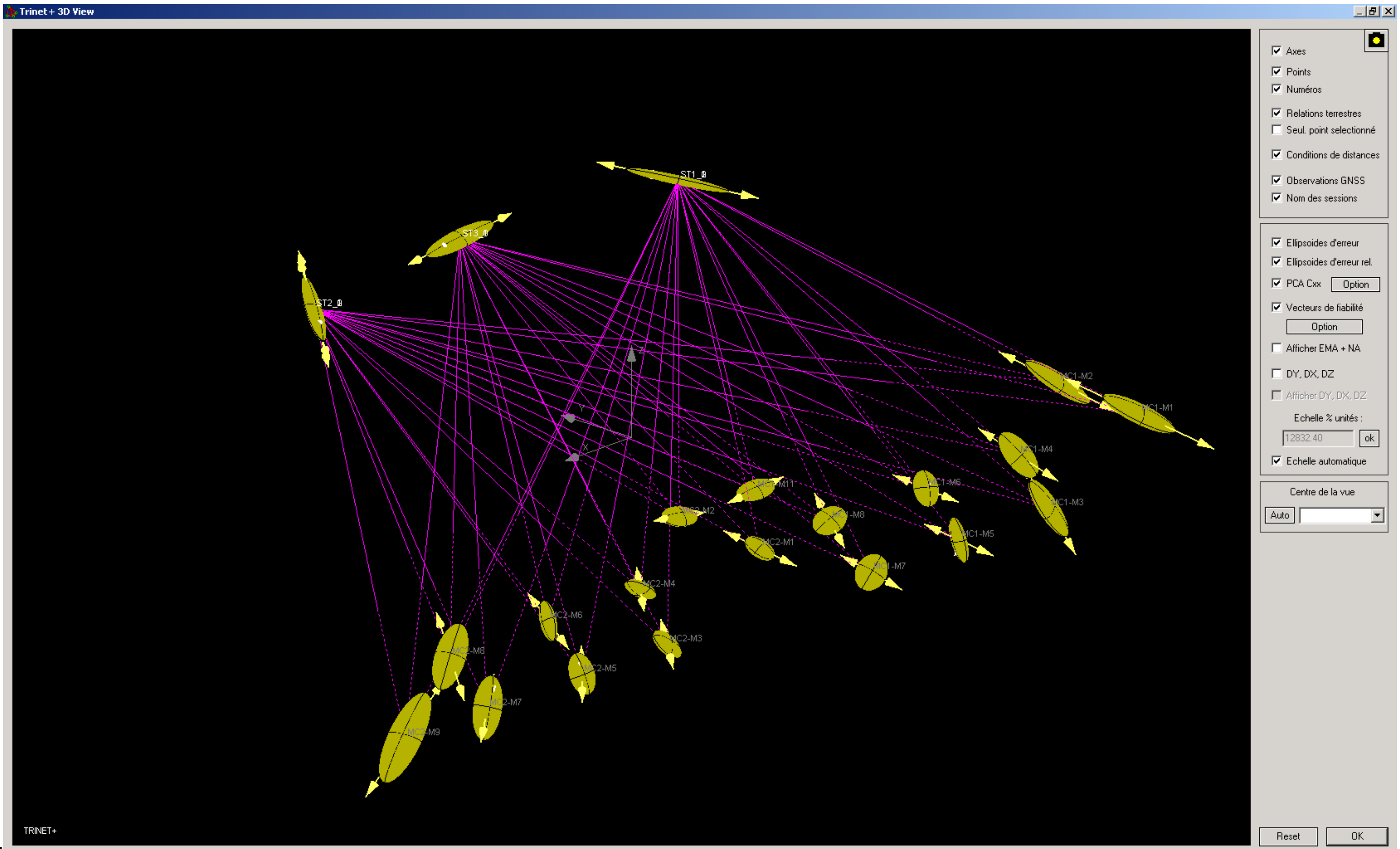

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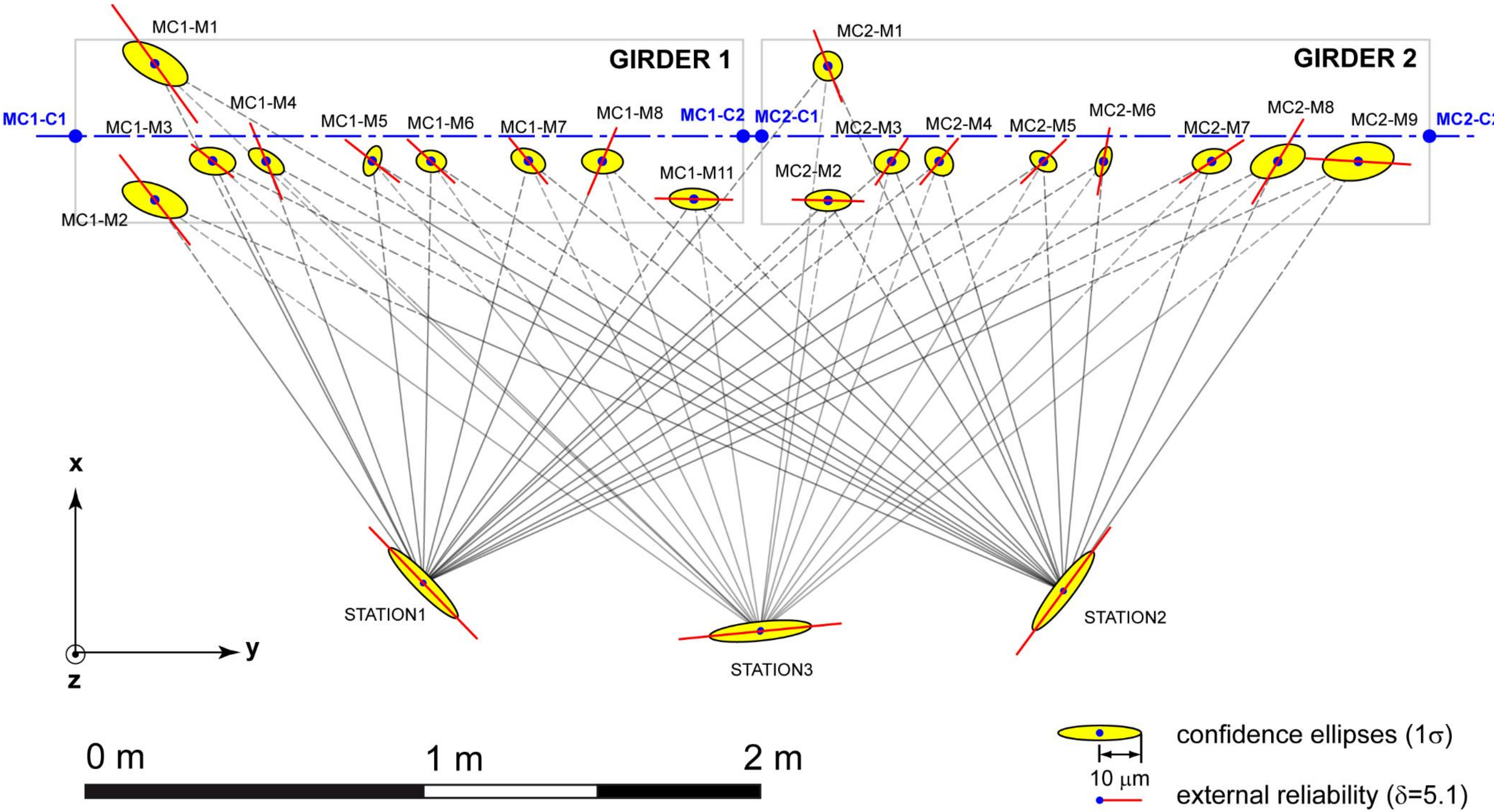

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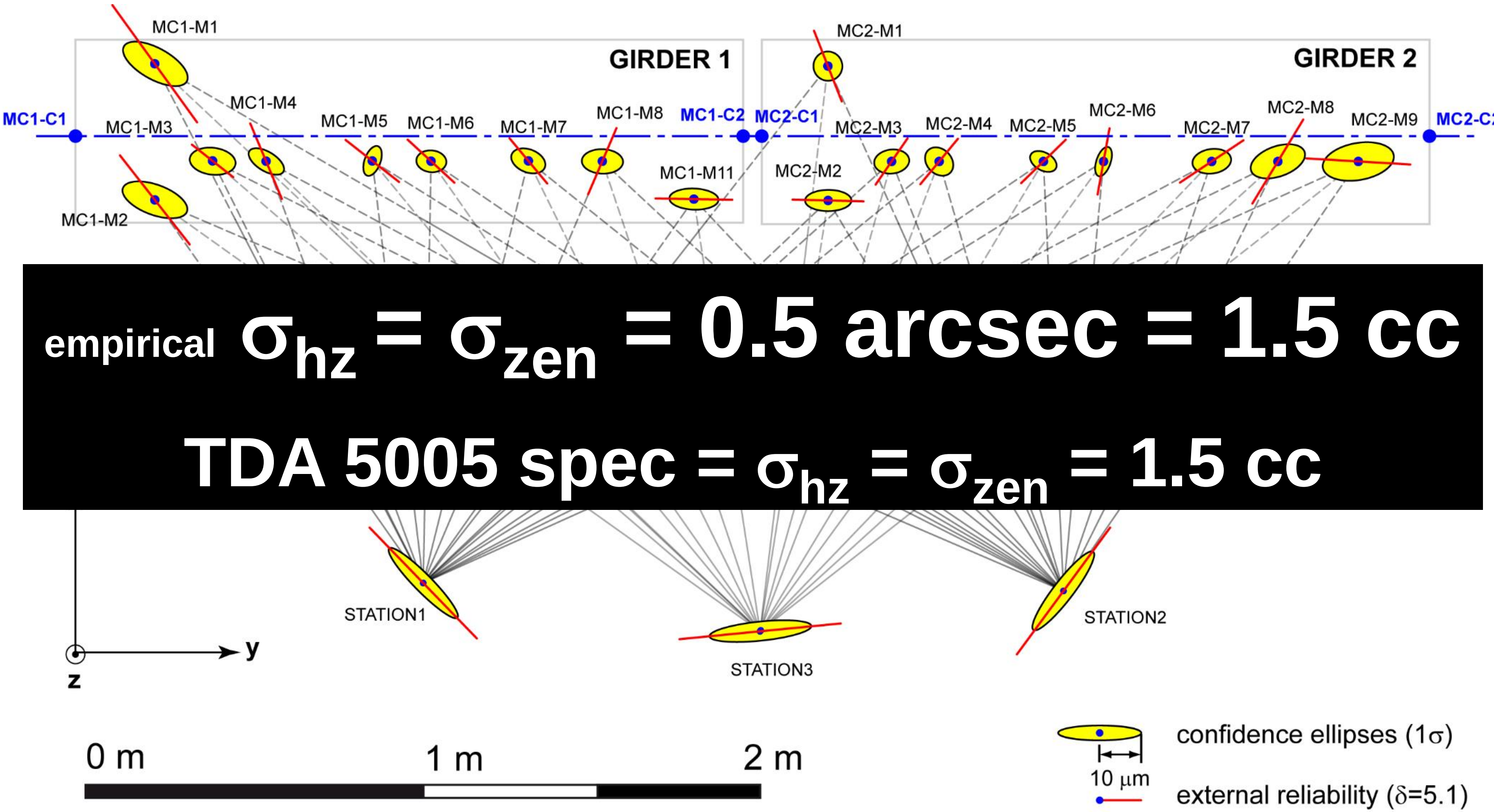

empirical $\sigma_{hz} = \sigma_{zen} = 0.5$ arcsec $= 1.5$ cc

TDA 5005 spec $= \sigma_{hz} = \sigma_{zen} = 1.5$ cc

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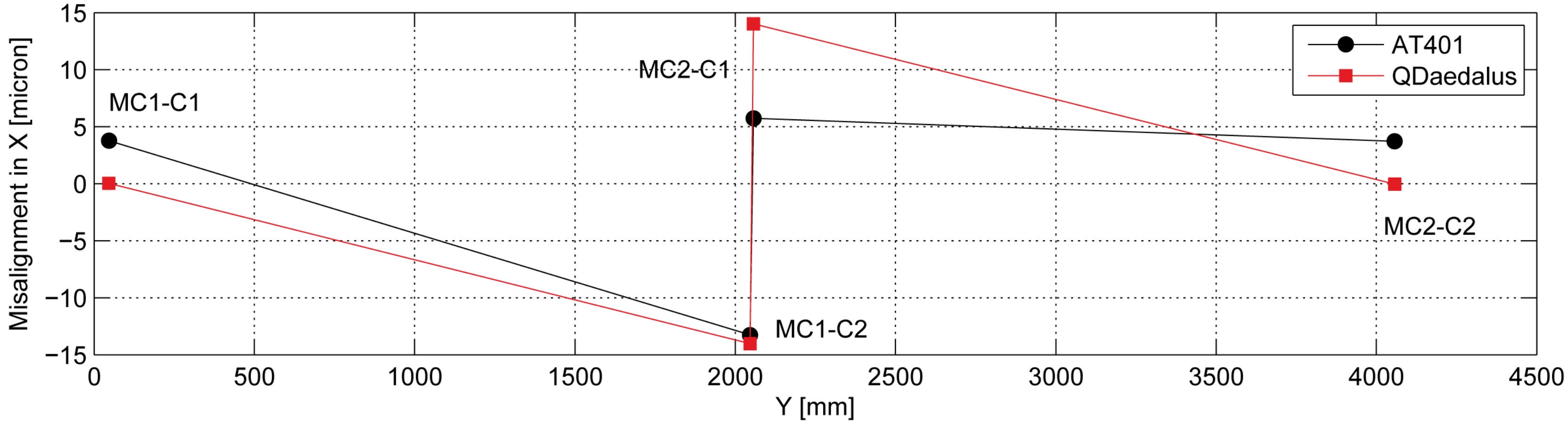
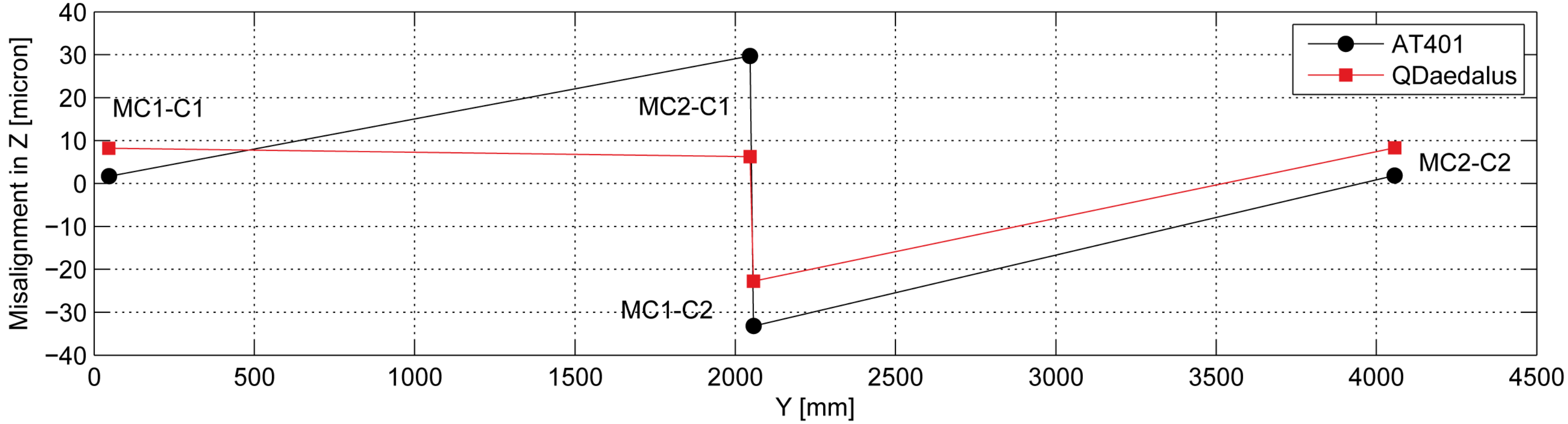
Automatic Microtriangulation

Empirical standard deviation and differences with respect to the Coordinates Measurement Machine (CMM σ = 1μm) of the points measured with the system QDaedalus.

	Empirical Standard Deviation			Differences with Coordinate Measurement Machine			
	sX [microns]	sY [microns]	sZ [microns]	dX [microns]	dY [microns]	dZ [microns]	d3D [microns]
MC1-M3	5	6	9	-3	-2	1	4
MC1-M4	5	4	7	8	-6	7	12
MC1-M5	4	3	6	1	-5	-10	11
MC1-M6	4	4	5	**-11**	9	-5	15
MC1-M7	4	5	4	2	7	4	8
MC1-M8	4	6	3	3	-3	3	5
MC2-M3	3	5	4	1	8	2	9
MC2-M4	3	4	4	5	**16**	0	17
MC2-M5	4	3	6	0	8	-7	11
MC2-M6	4	3	5	-5	-2	4	7
MC2-M7	5	5	8	-8	-8	-4	12
MC2-M9	6	11	10	7	**-23**	6	24

Automatic Microtriangulation

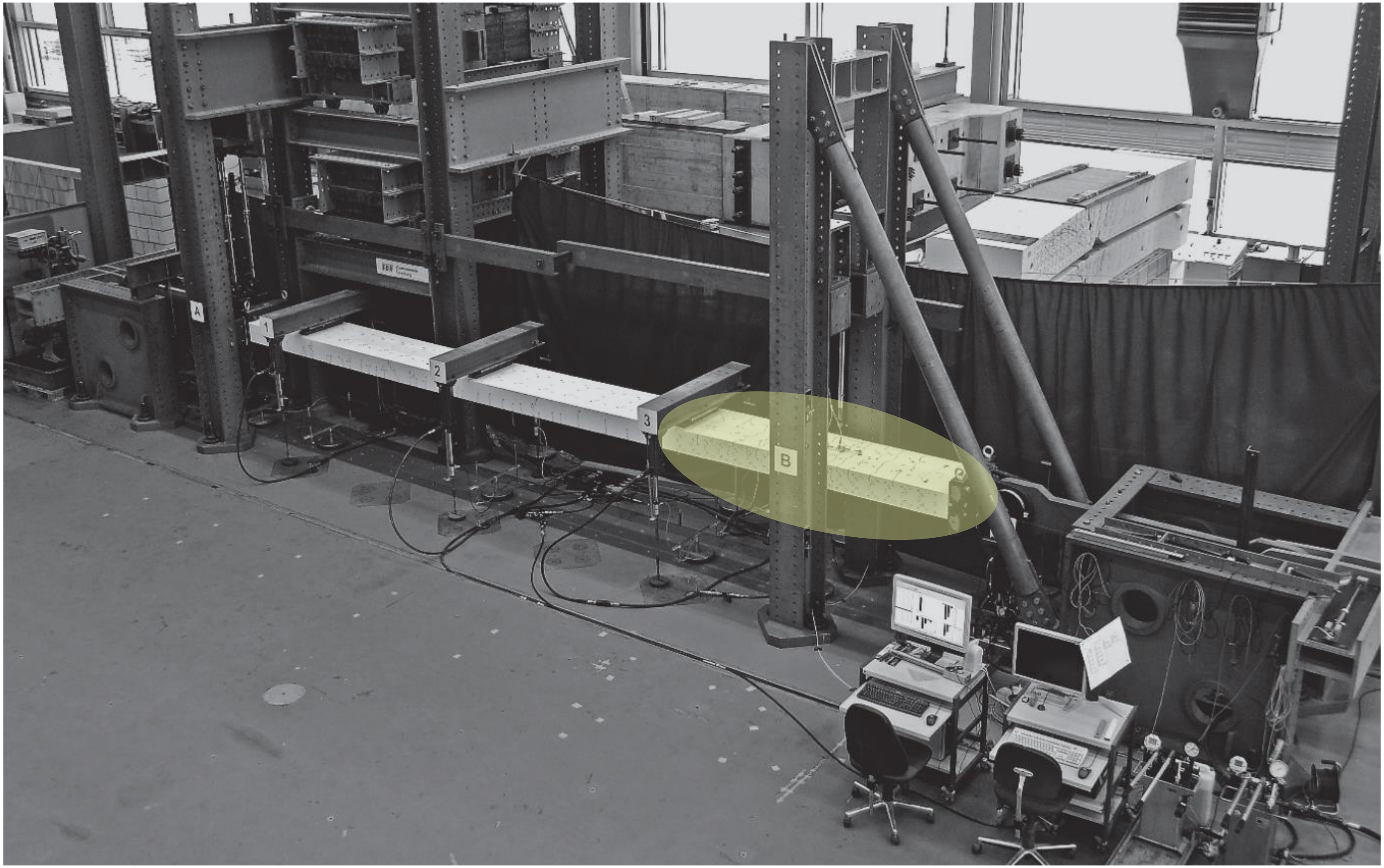




Automatic Microtriangulation for Stress Analysis in Reinforced Concrete Beams

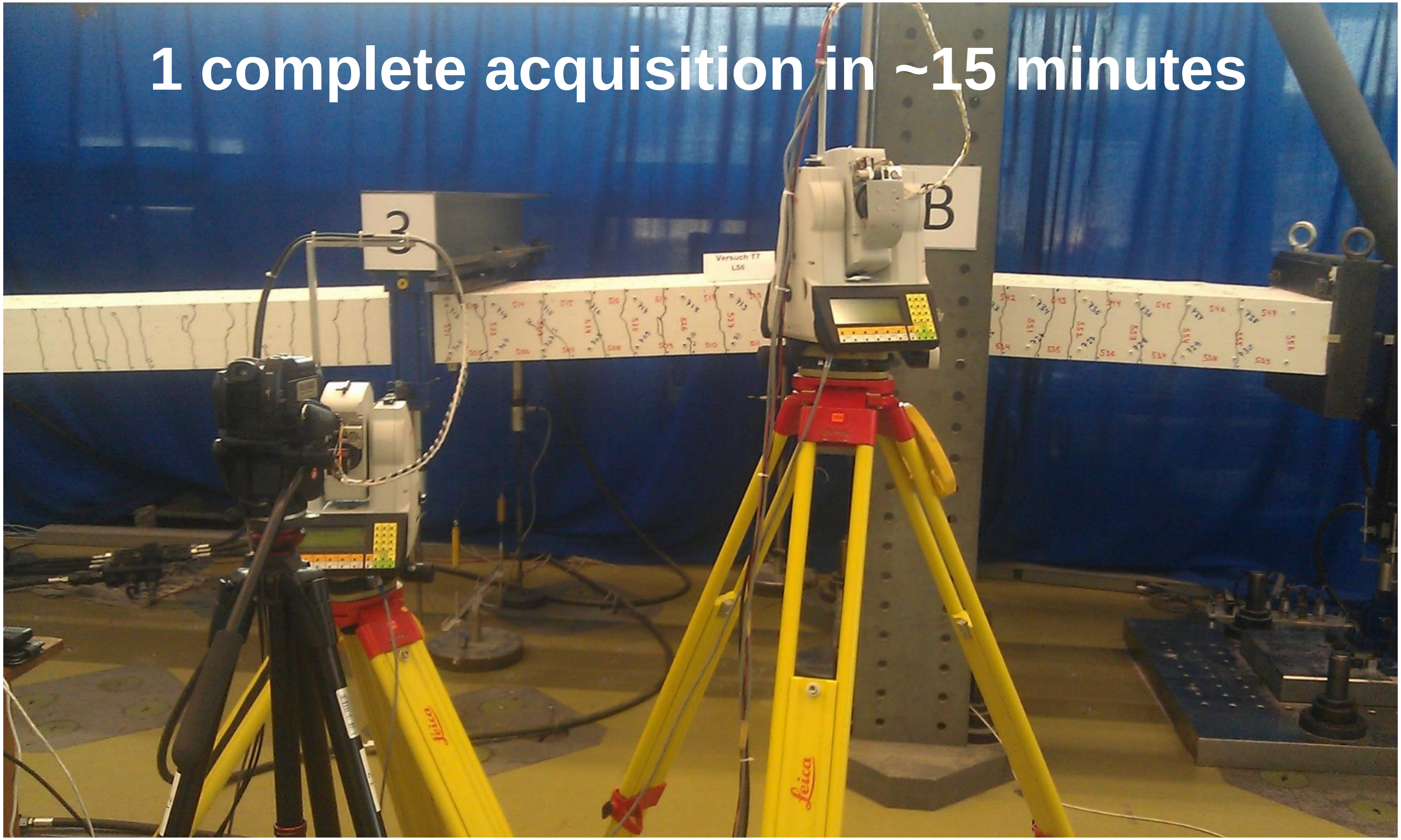
ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Stress in Reinforced Concrete Beam

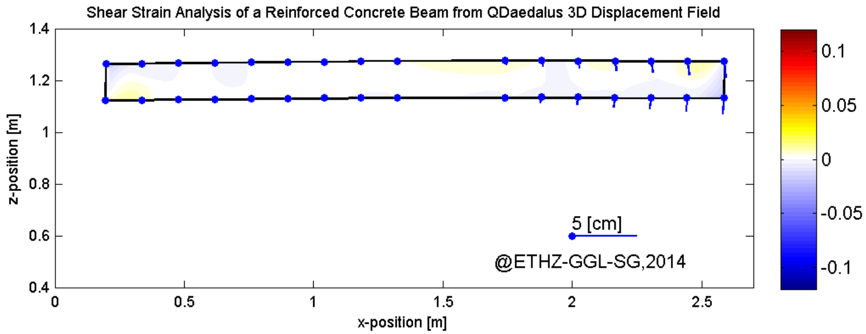


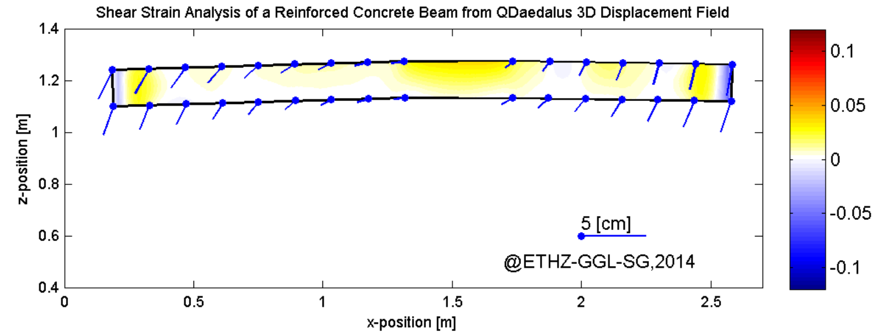
ETH zürich

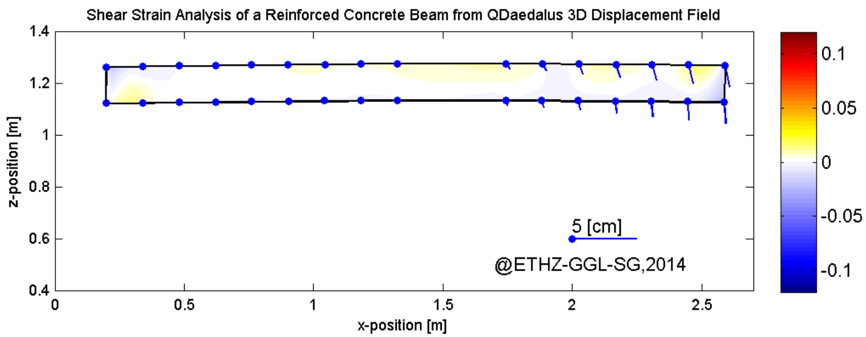
Stress in Reinforced Concrete Beam

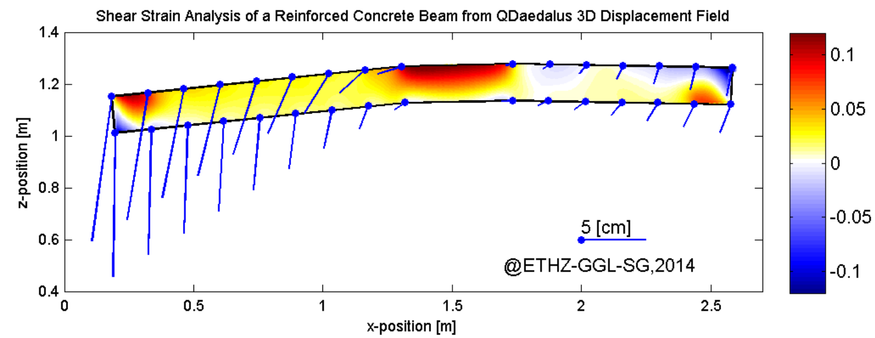


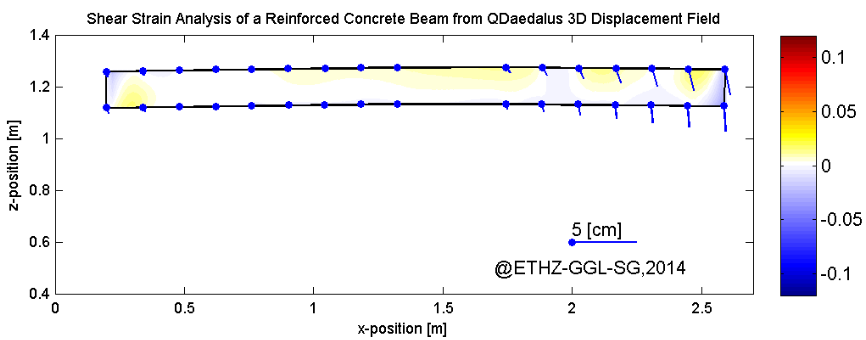
Stress in Reinforced Concrete Beam

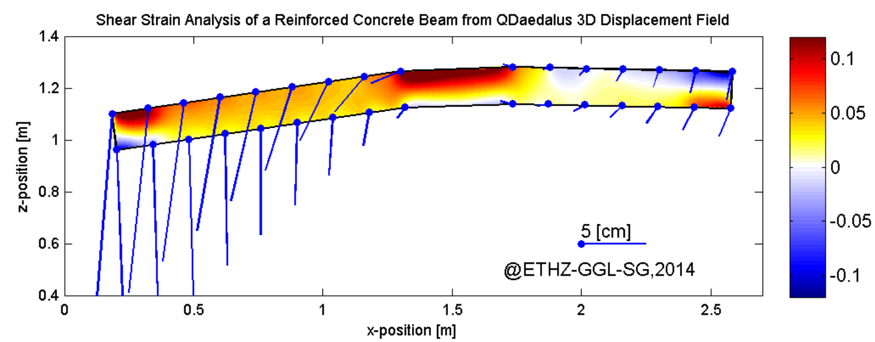












Kinematic Measurements with QDaedalus

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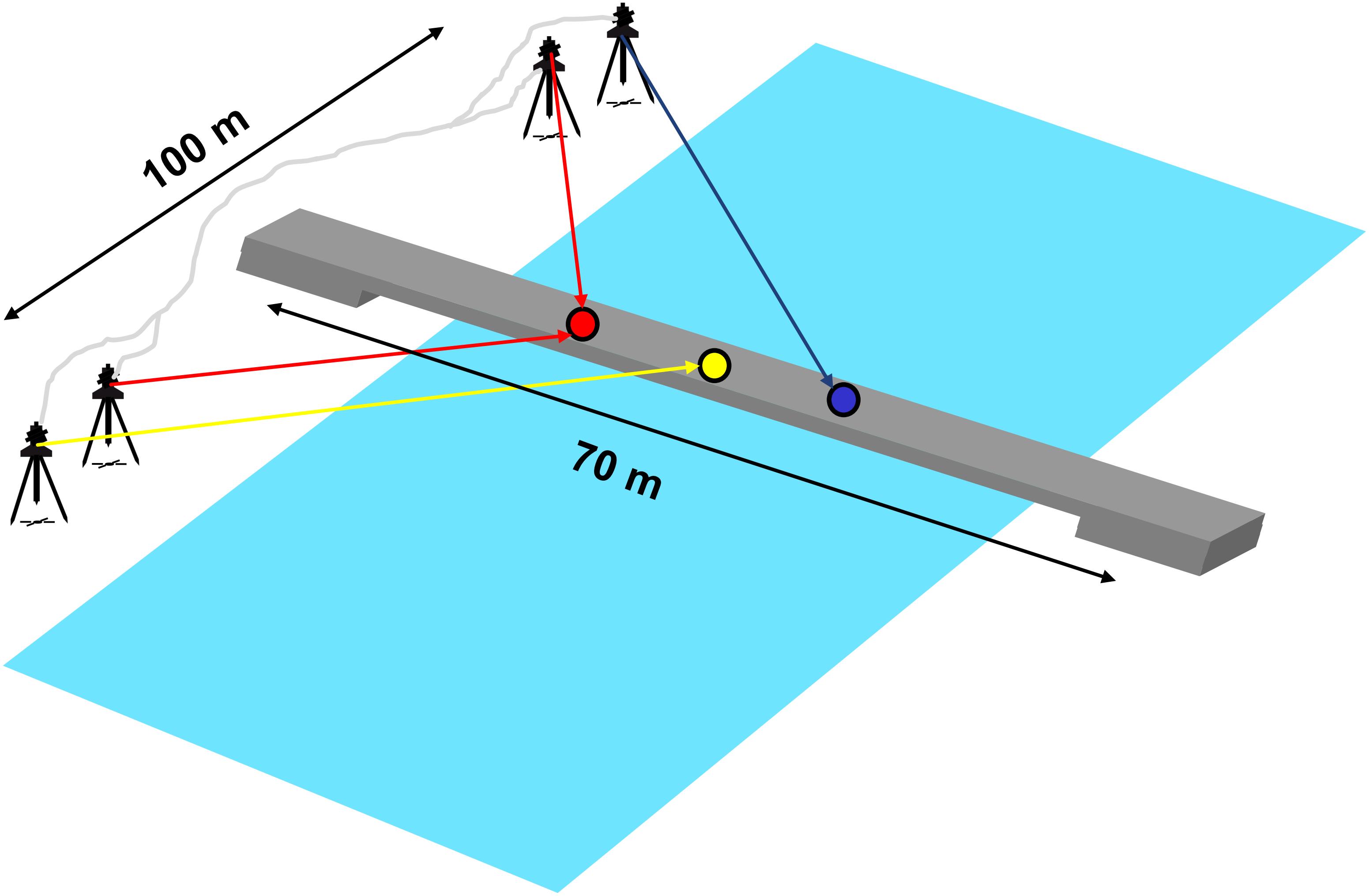
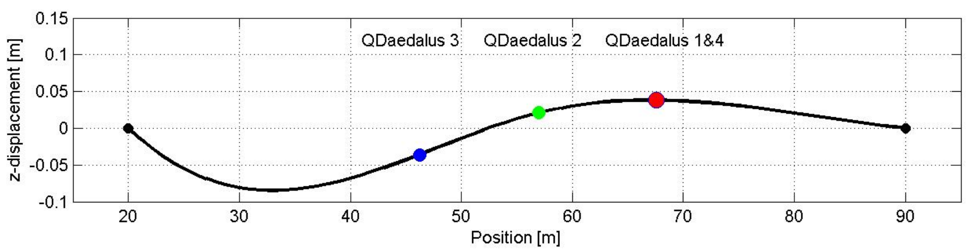
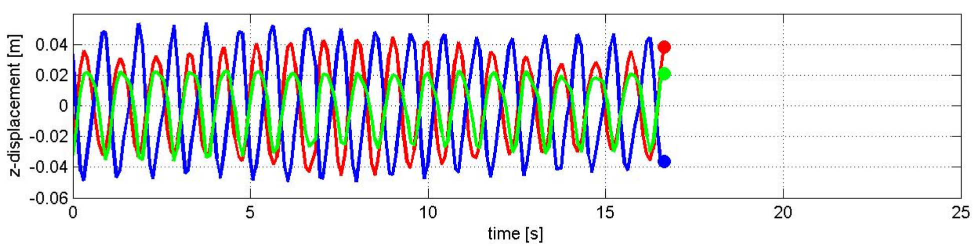
Kinematic Measurements

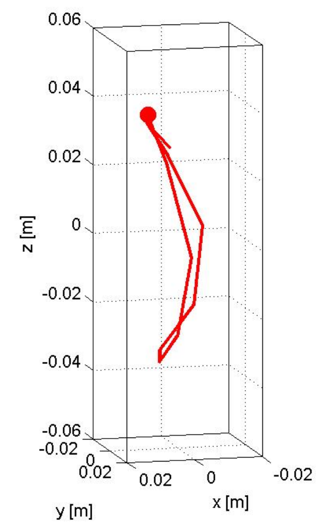
Kinematic Measurements



Kinematic Measurements







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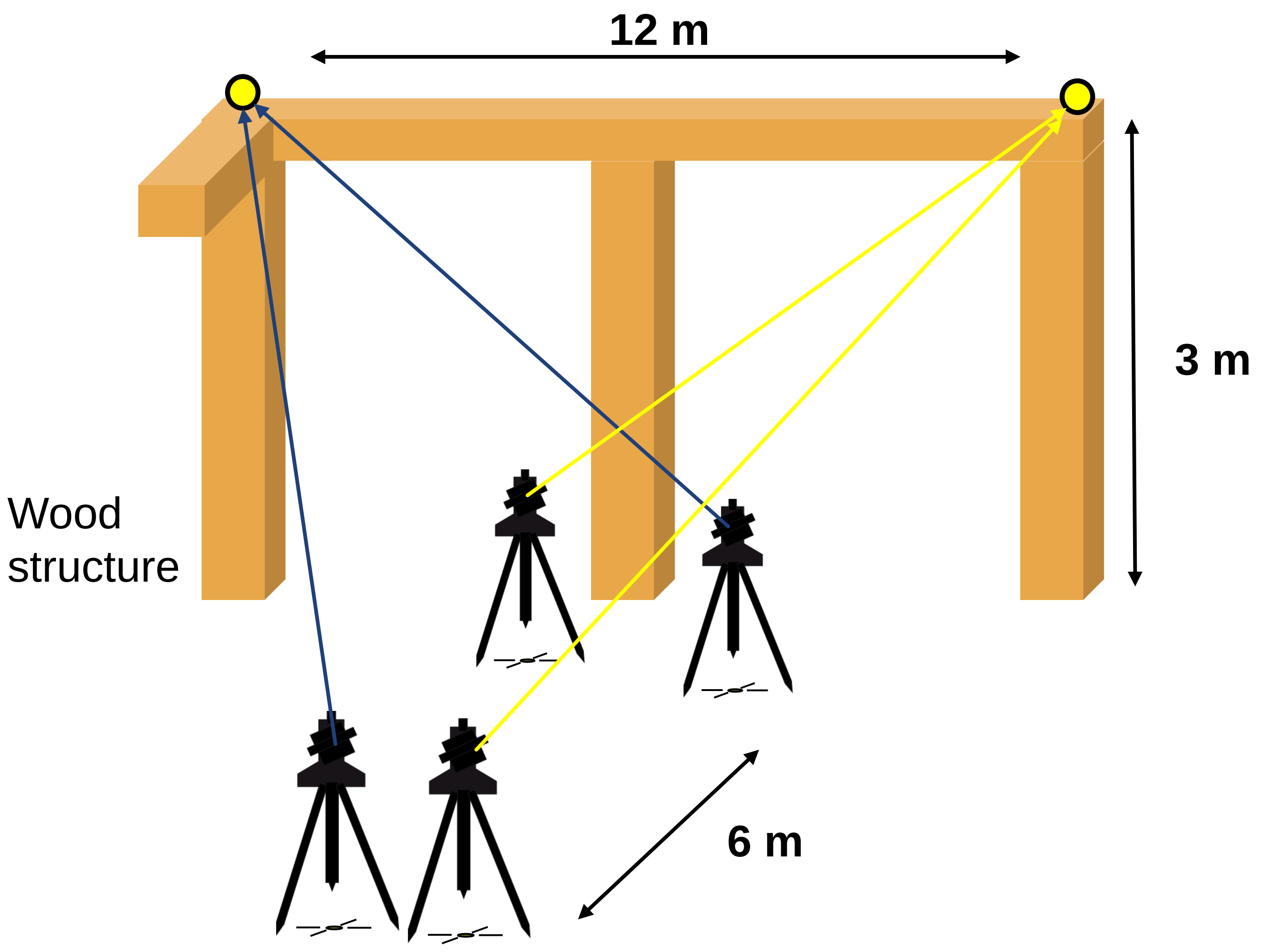

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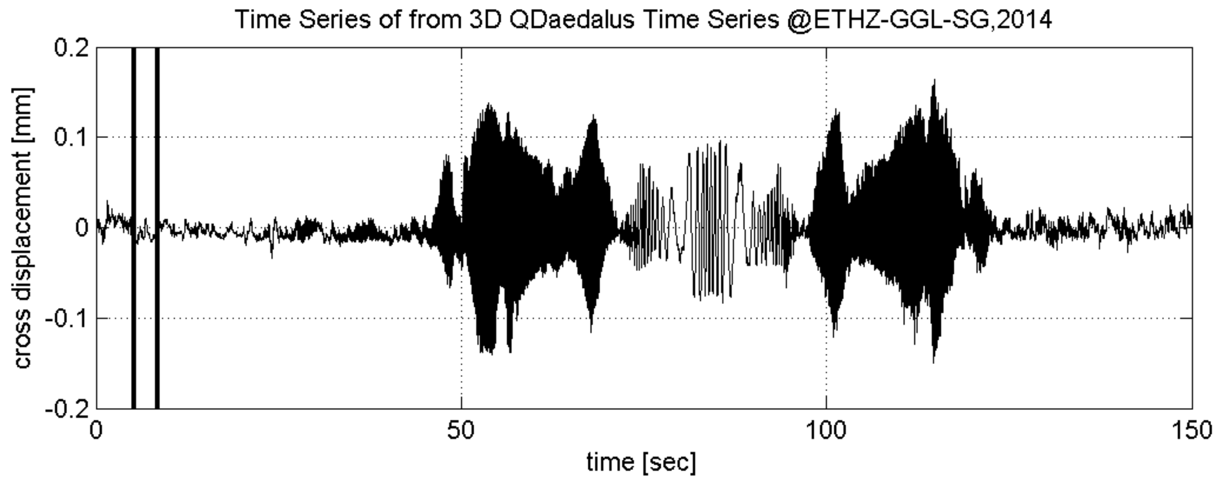
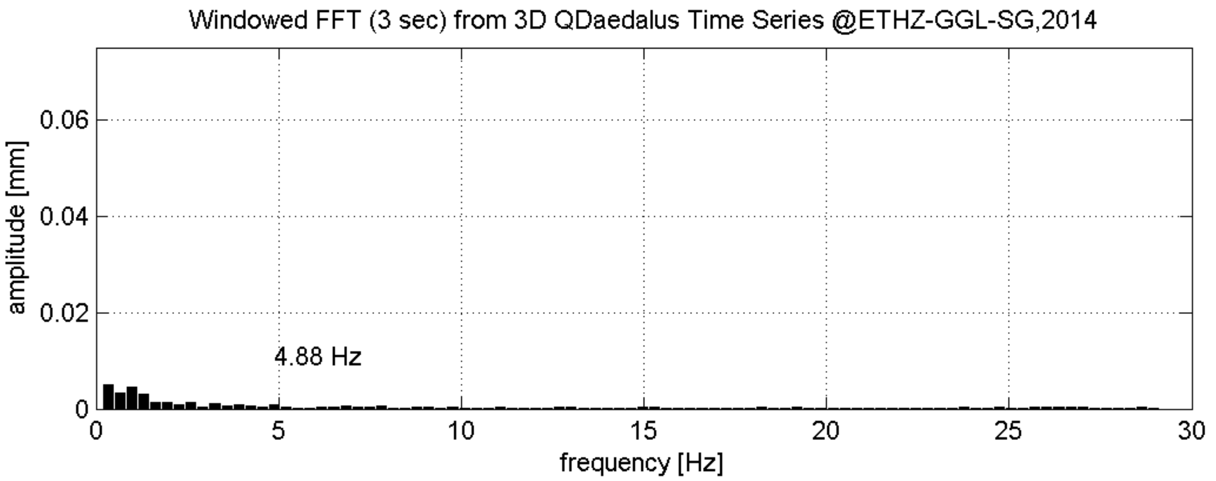
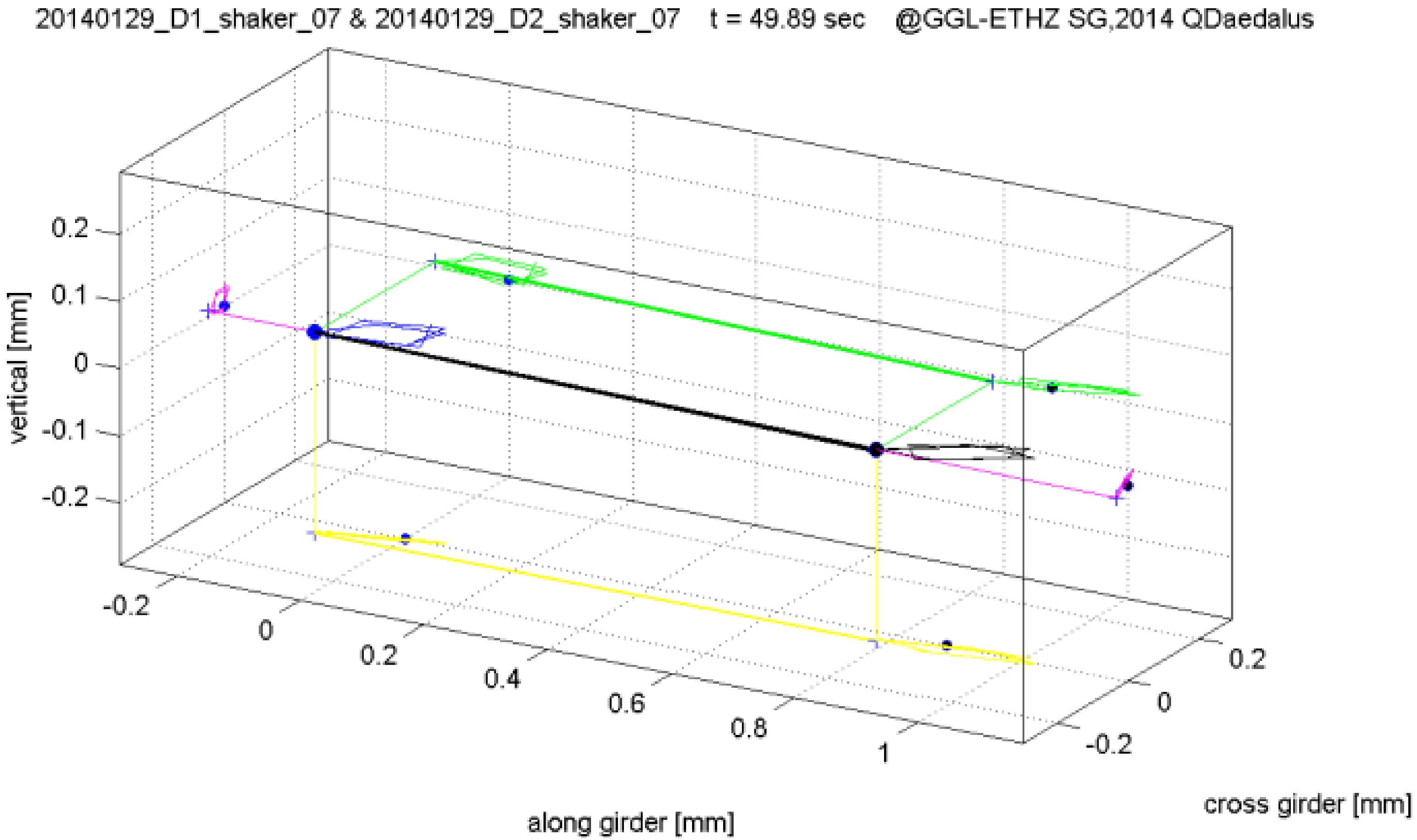




Kinematic Measurements



Thanks for attention

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