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QDaedalus

Augmentation of Total Stations by CCD Sensor for Automated Contactless High-Precision Metrology

Sébastien Guillaume[1], Beat Bürki[1], Sylvain Griffet[2], Hélène Mainaud-Durand[2]

1. Institut für Geodäsie und Photogrammetrie, **ETH Zurich**, Switzerland
2. European Organization for Nuclear Research, **CERN Geneva**, Switzerland

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A Very Short Overview of

3D Commercial

Metrological Systems

CMM: Coordinates Measurement Machine

σ < 1 µm/m range < 1-2 m

@ Leitz

Measurement Arm

σ ~ 10 µm/m range < 5 m

@ Romer

Laser Tracker with Absolute EDM

σ ~ 7.5+3 µm/m range < 100 m

@ Leica Geosystems

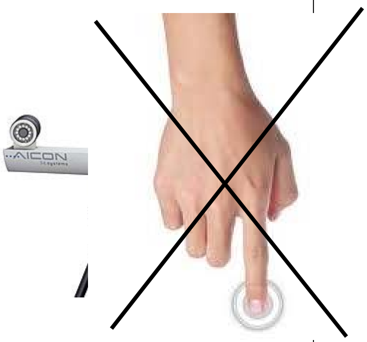
Laser Tracker with Interferometer

σ ~ 7.5+3 µm/m range ~ 150 m

@ Leica Geosystems

Close-Range Photogrammetry

σ ~ 15 µm/m range < 50 m



@ Aicon

Laser Scanner

σ ~ 1 mm range ~ 100 m

@ Leica Geosystems

The Measurement System

QDaedalus

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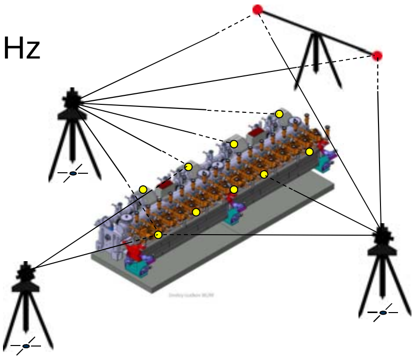
QDaedalus

- High Precise : < 10 µm/m
- Touchless
- Fully Automated
- High Rate Measurements : 30 Hz
- Low-cost
- Open & Flexible Software



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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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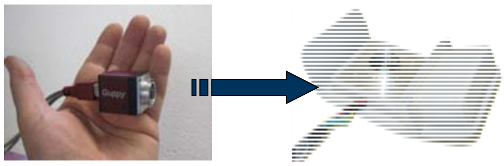

- 1024 x 768 pixel (4.65 x 4.65 µm)
- Fire Wire connection (30 fps)
- External Trigger
- Black and White

1 pixel = 4 arcsec

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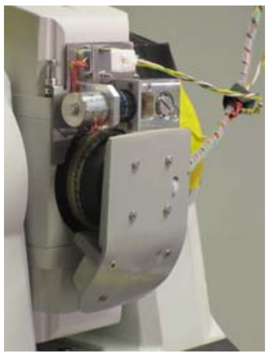

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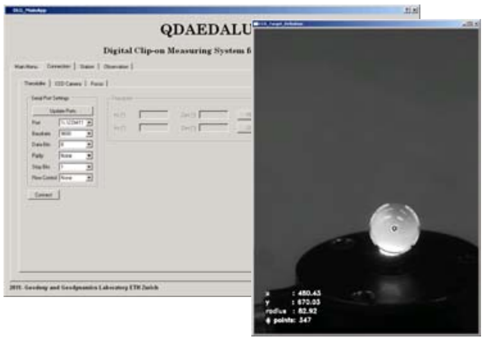

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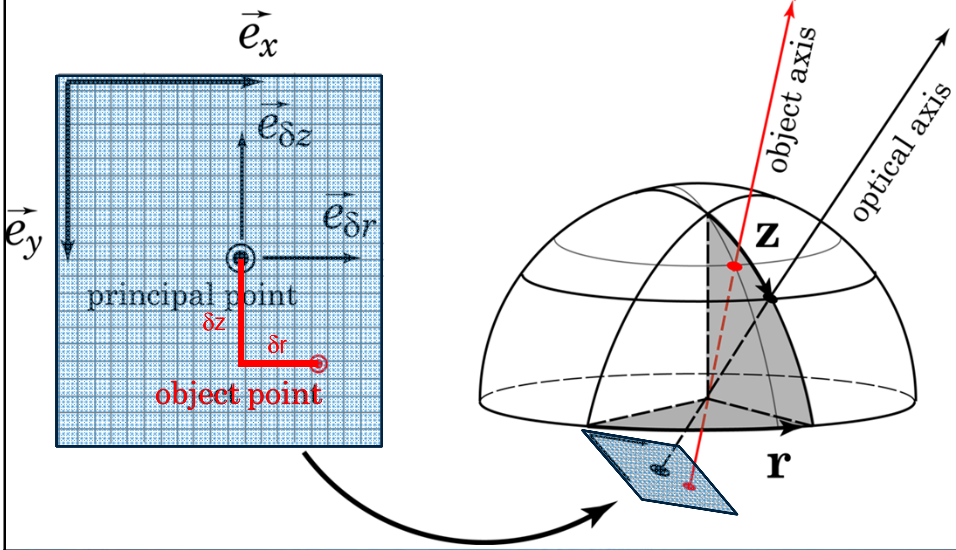
CCD-Space ⟷ Theodolite-Space

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

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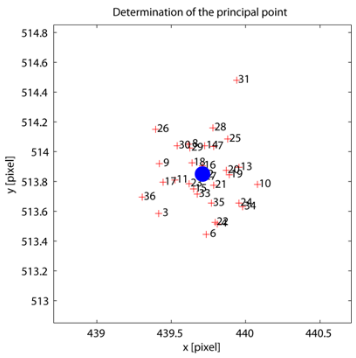
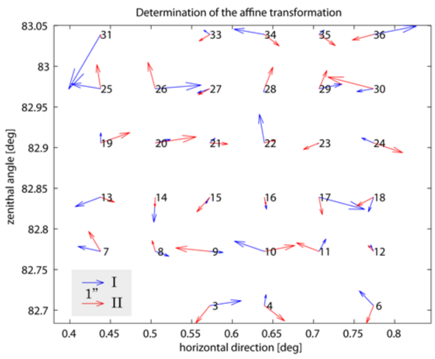
Calibration





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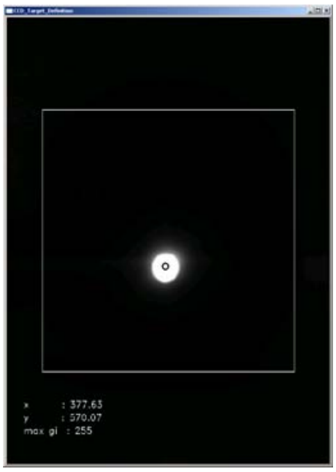
Identification & Extraction of Objects

Optical Target Recognition

OTR: Least-Squares Template Matching

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

OTR: Centroid Operator



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

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OTR: Robust Circle Matching Operator

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

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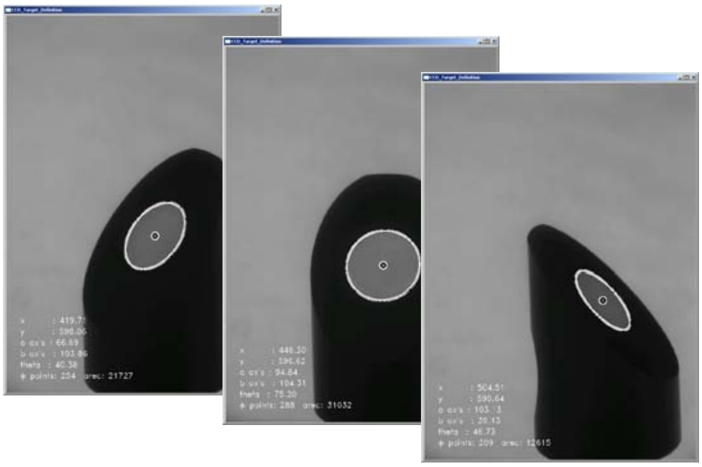
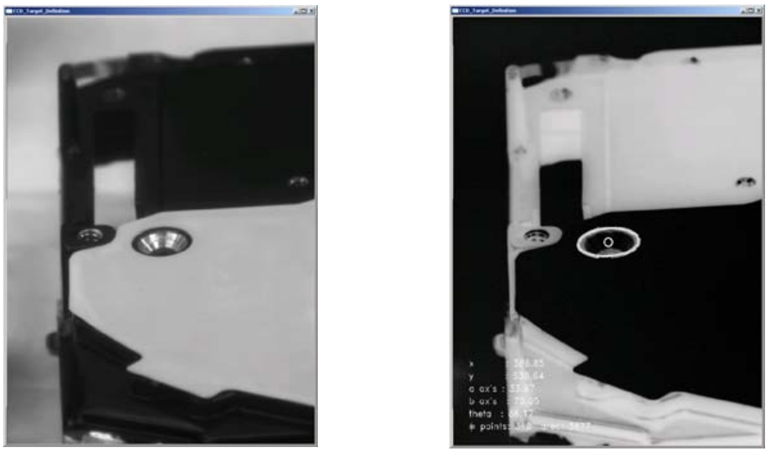
OTR: Robust Ellipse Matching Operator



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

OTR: Robust Ellipse Matching Operator



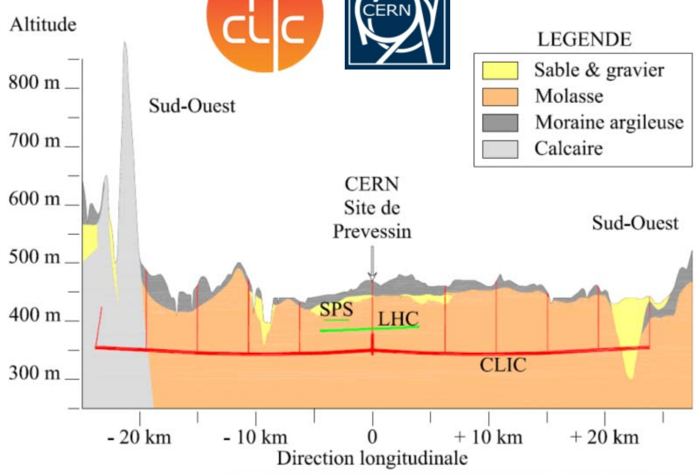
precision < 0.1 pixel = 0.4 arcsec = 2.5 μm/m

Practical Experiment of QDaealus at CERN

Automatic Microtriangulation

of Linear Collider Components

Future = electron-positron Linear Collider



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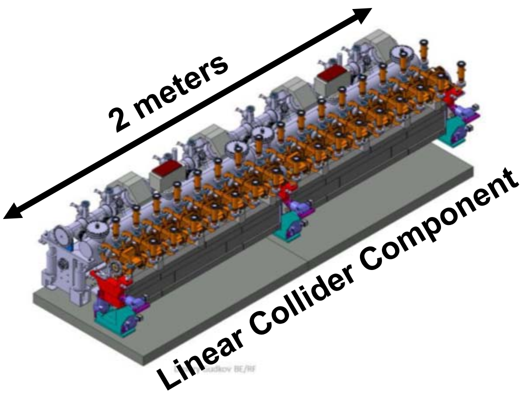

➔ more than 20 000 modules in total to be measured !

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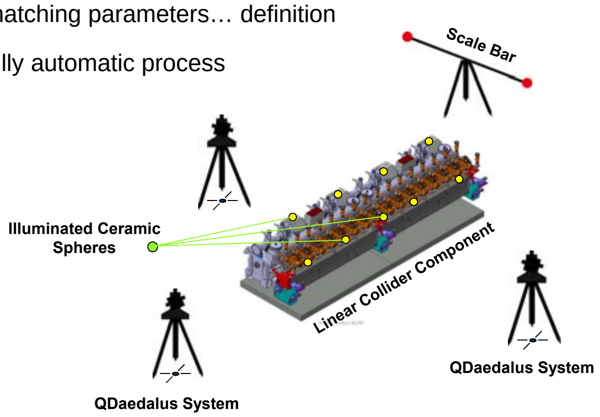
Automatic Microtriangulation

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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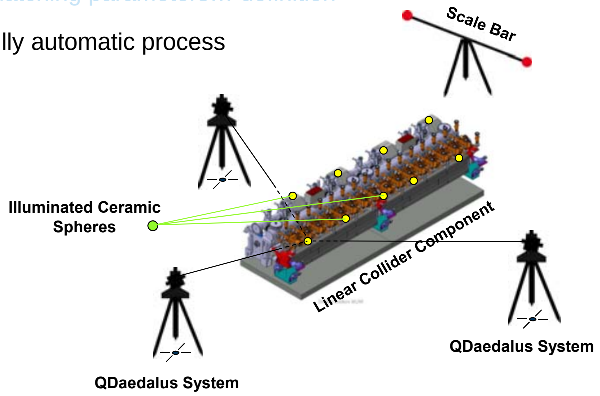

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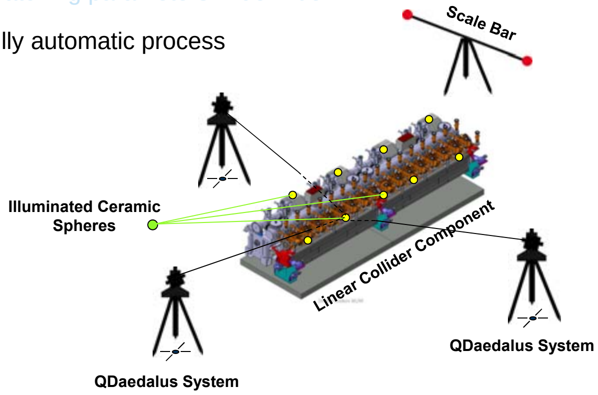

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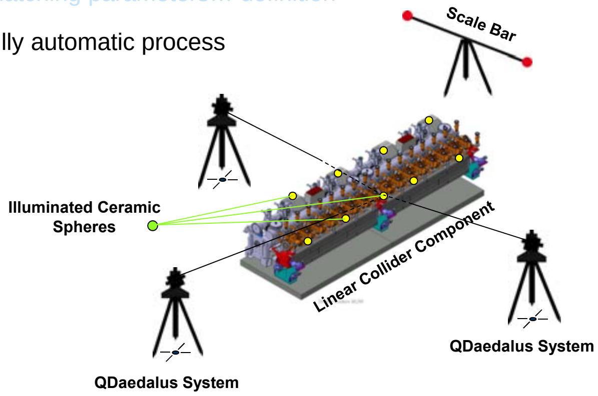

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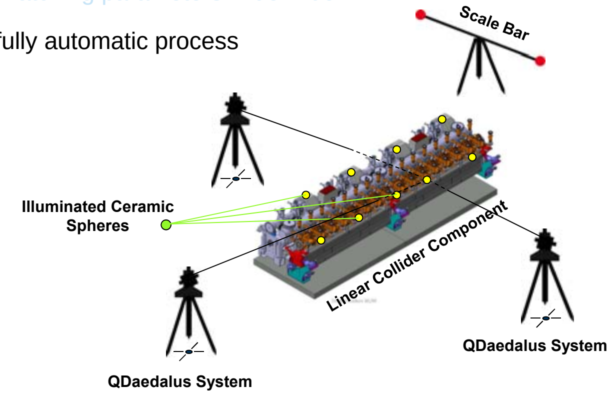

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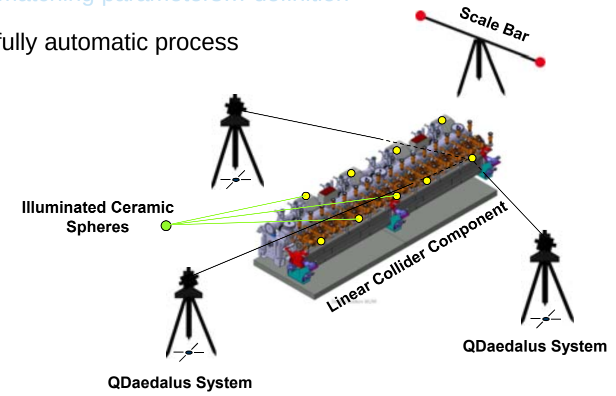

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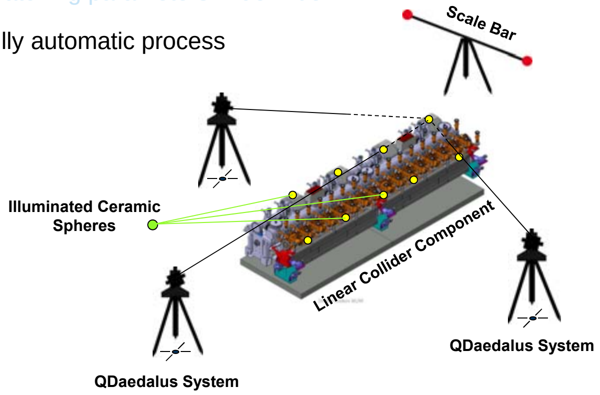

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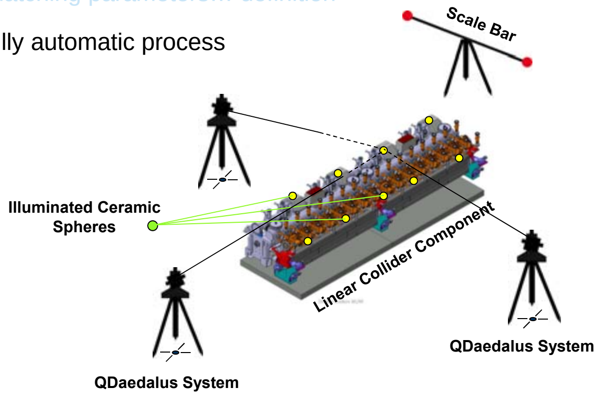

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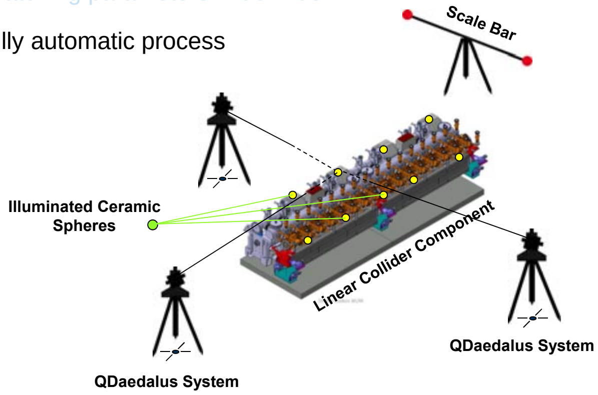

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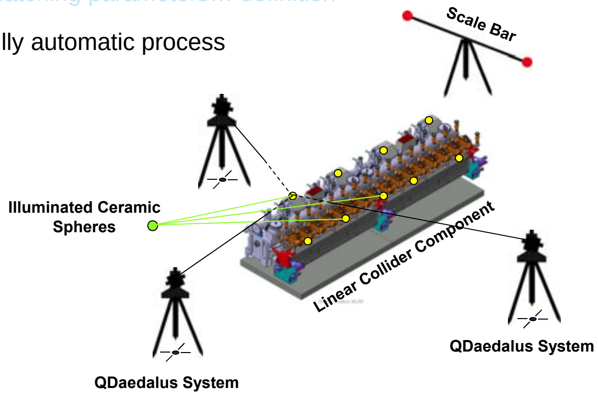

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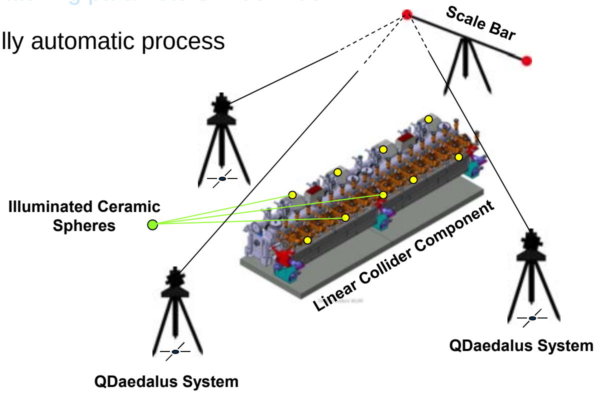

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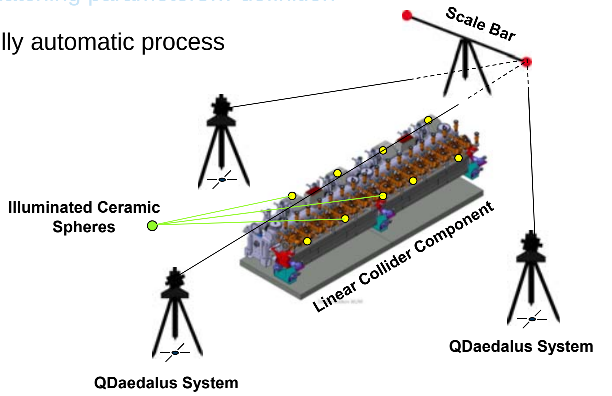

Automatic Microtriangulation

1. Import approximate positions of station and targets
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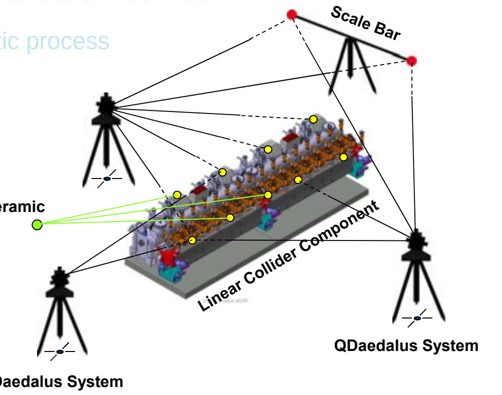
3. Start measurements, fully automatic process
4. Adjust micro-triangulation network



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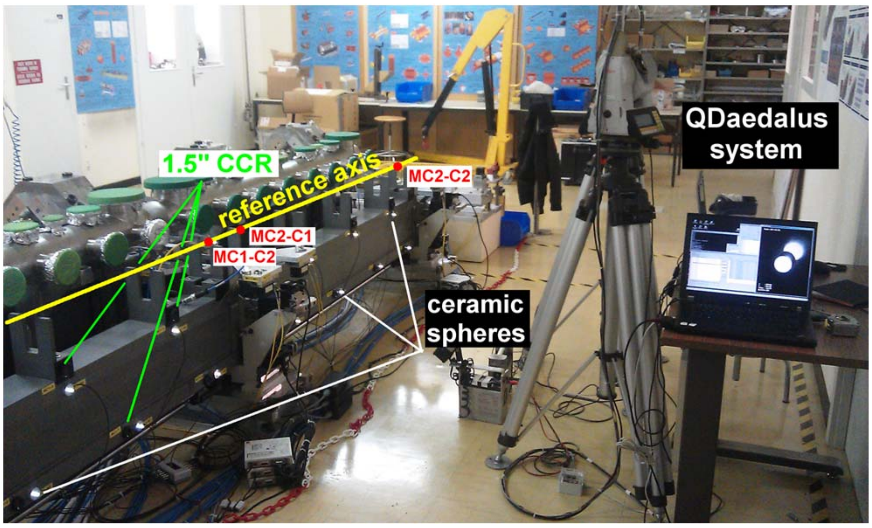

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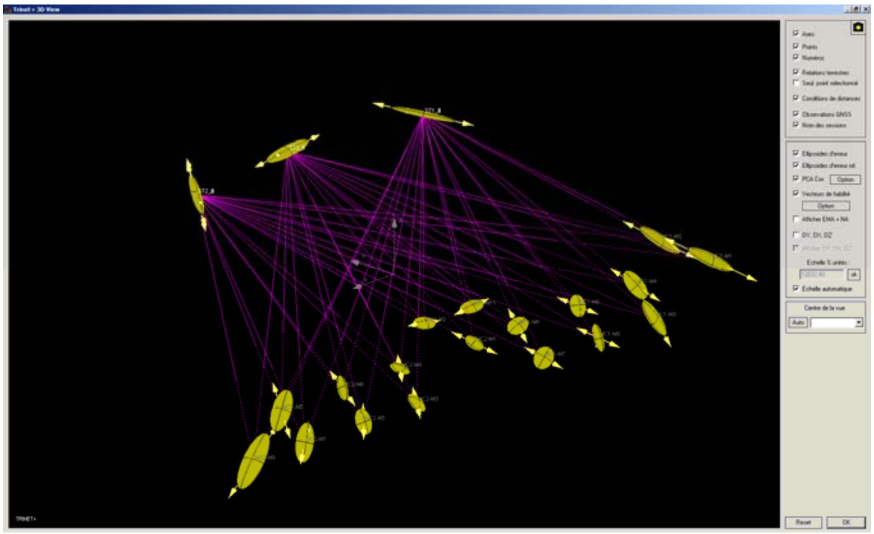

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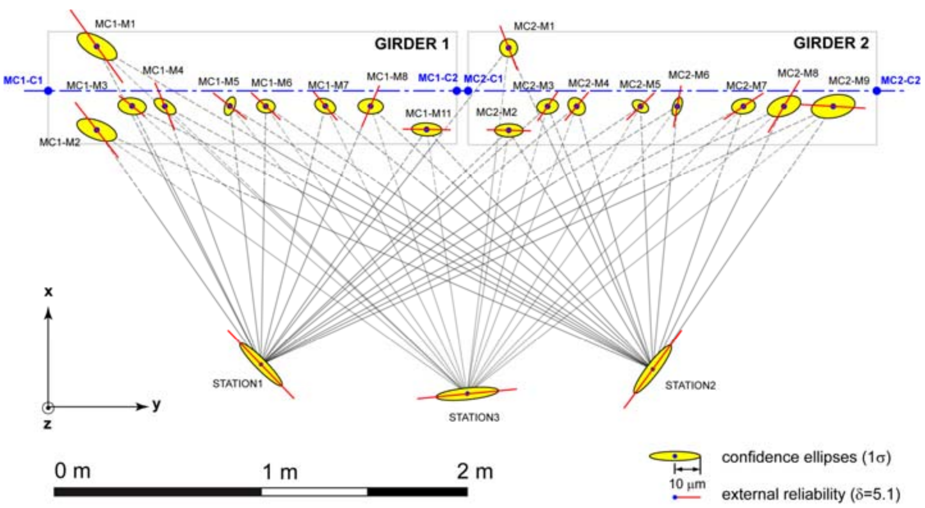

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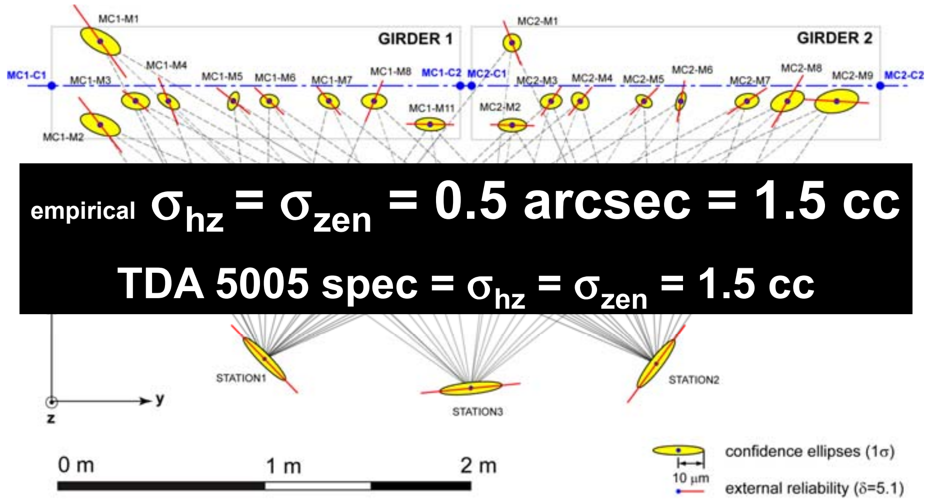

empirical $\sigma_{hz} = \sigma_{zen}$ = 0.5 arcsec = 1.5 cc

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

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

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Oscillation of a Bridge after Passage of a Truck

Kinematic Measurements with QDaedalus

Measurements carried out by HEIG-VD

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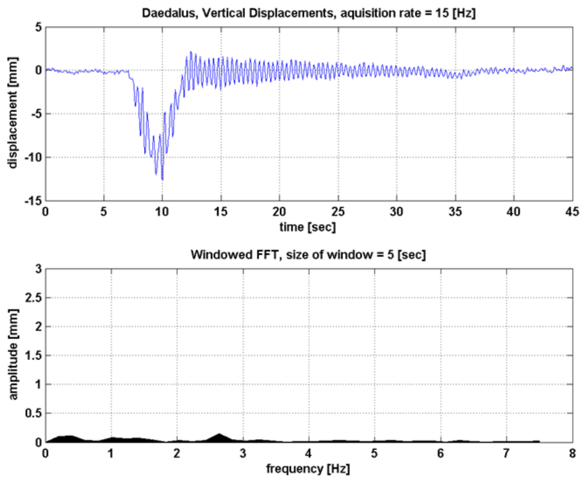
Kinematic Measurements

Kinematic Measurements



S.Guillaume. GGL-ETHZ. 2010

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Summary and Conclusions

The system QDaedalus

- can be mounted without mechanical changes at the Total Station
- enables Optical Target Recognition (OTR) using circle operator and pattern matching
- enables accurate time tagging of the observations
- enables real-time dynamic monitoring of displacements, vibrations, and scintillations
- enables tracking of moving objects with a frame rate of up to 30 Hz including time stamps
- is a versatile tool for numerous indoor and outdoor applications
- further object operators and other improvements are under development

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Thanks for attention

guillaume@geod.baug.ethz.ch

www.ggl.ethz.ch

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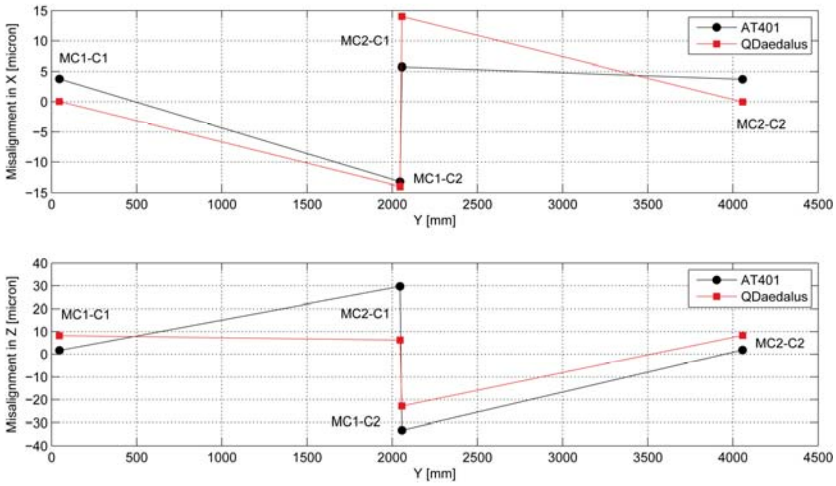
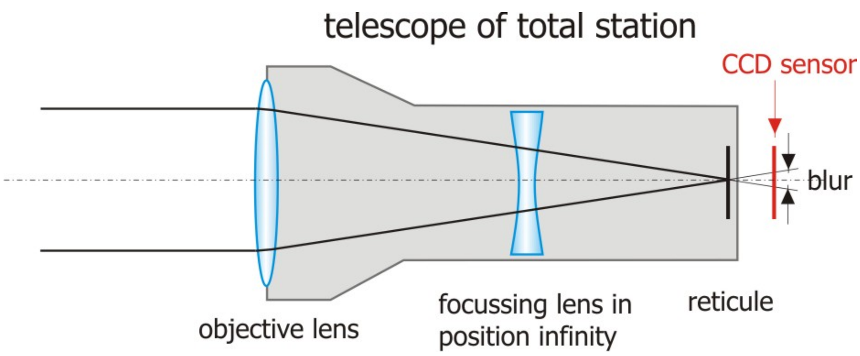


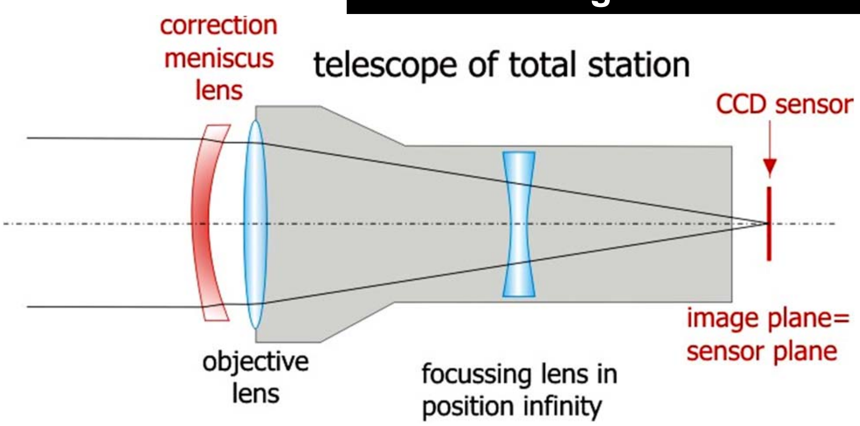
Removing the eyepiece and mounting a CCD camera evokes optical blur

Meas. Range = 1.5 to 13 m



Mounting a divergent lens in front of the objective

Meas. Range = 2 m to ∞



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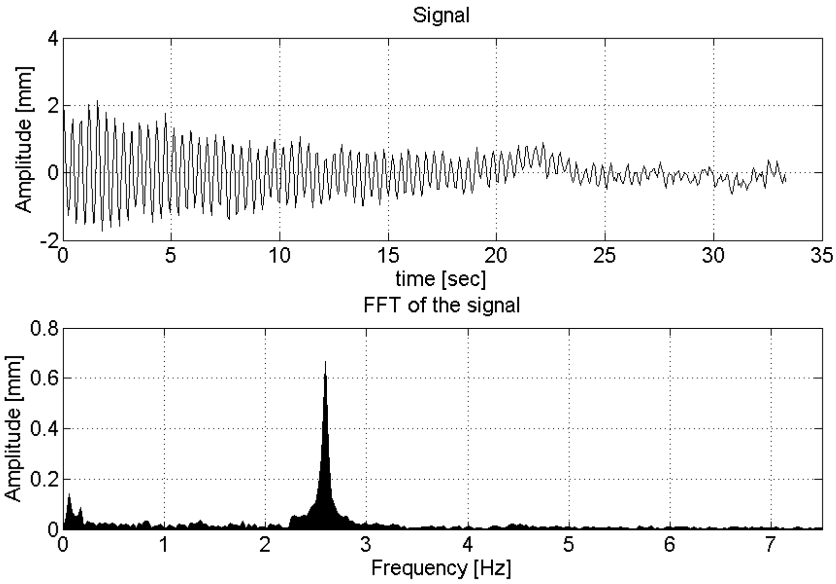
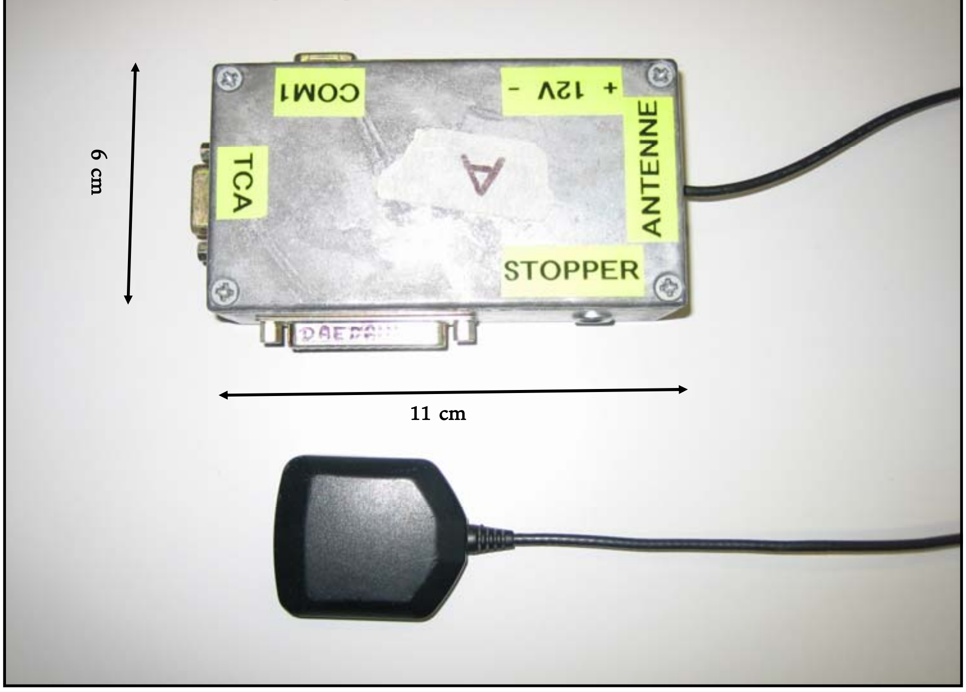
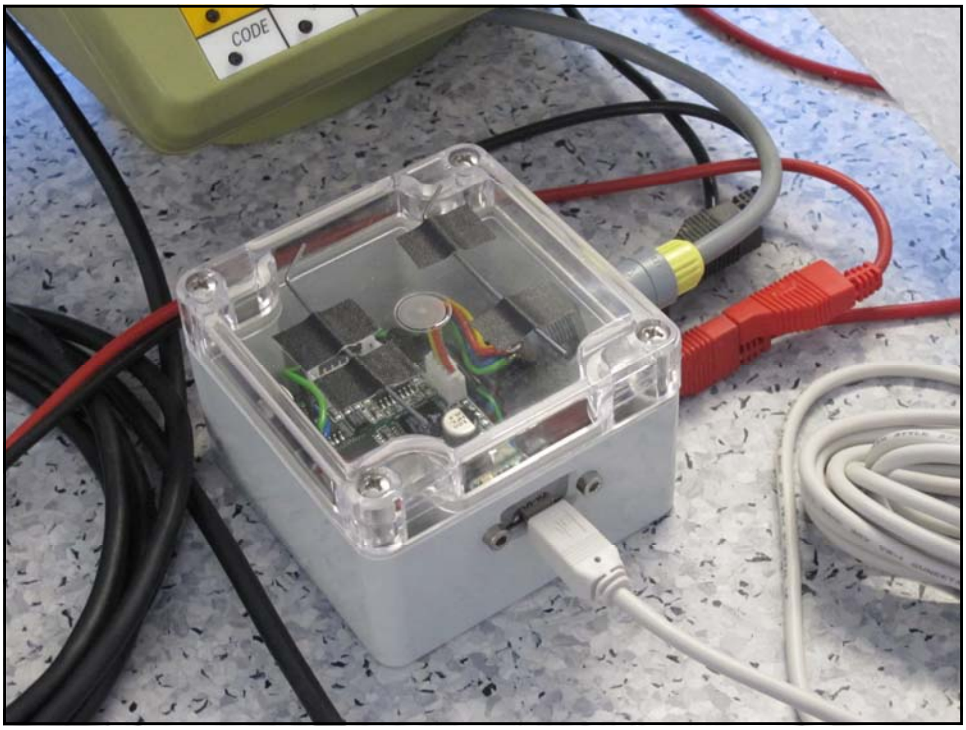


External box for GPS receiver, power input, and Interface cable connections

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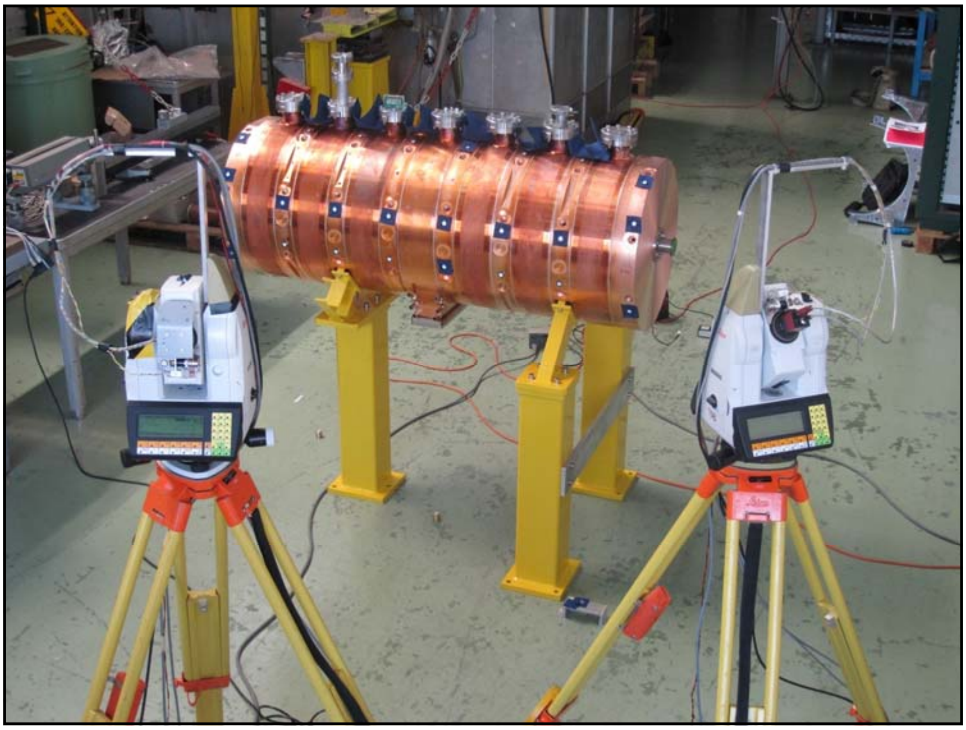

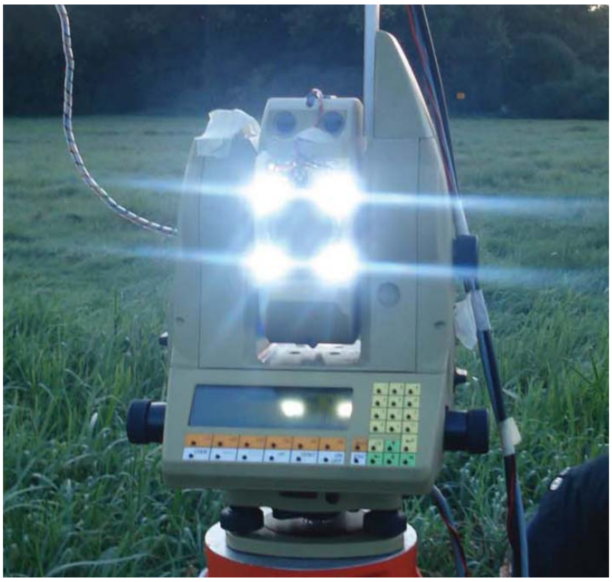

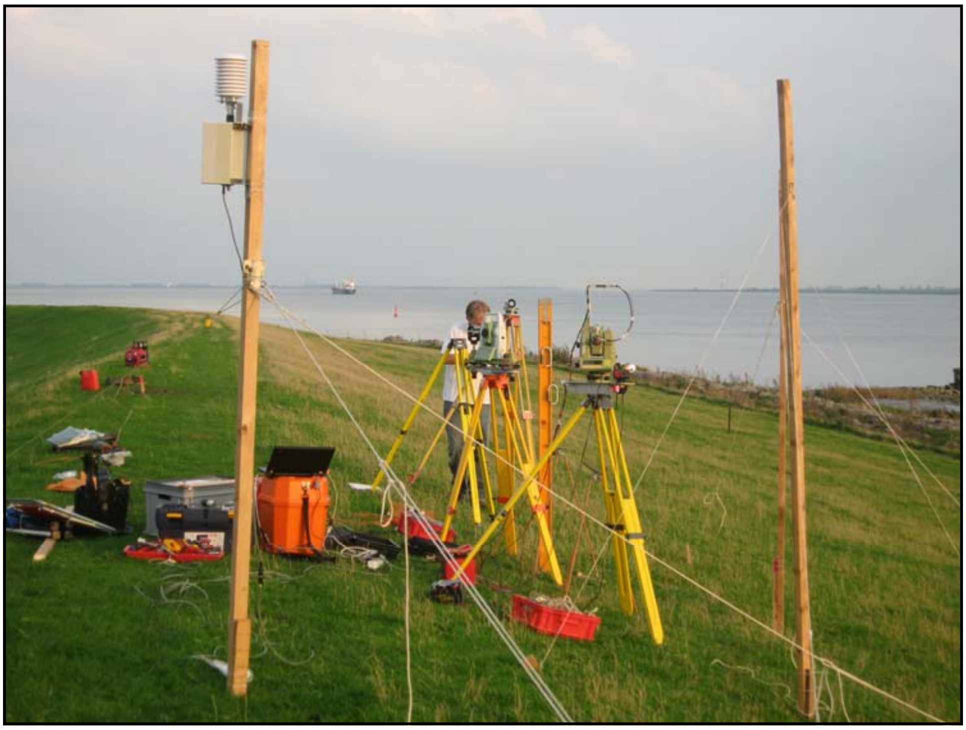

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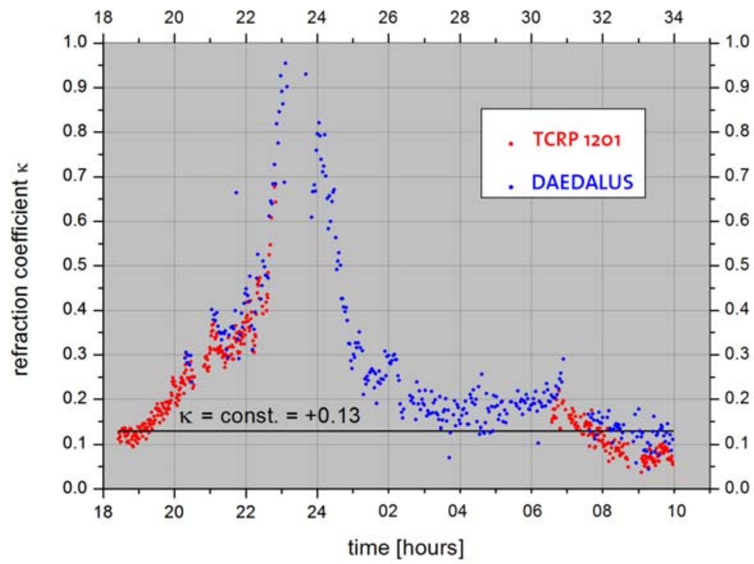
European Organization for Nuclear Research
Accelerators and Beam Physics Group

Evolution of the refraction coefficient κ during 16 hours across Elbe River



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Variations of ΔH during 16 hours across Elbe River due to Refraction