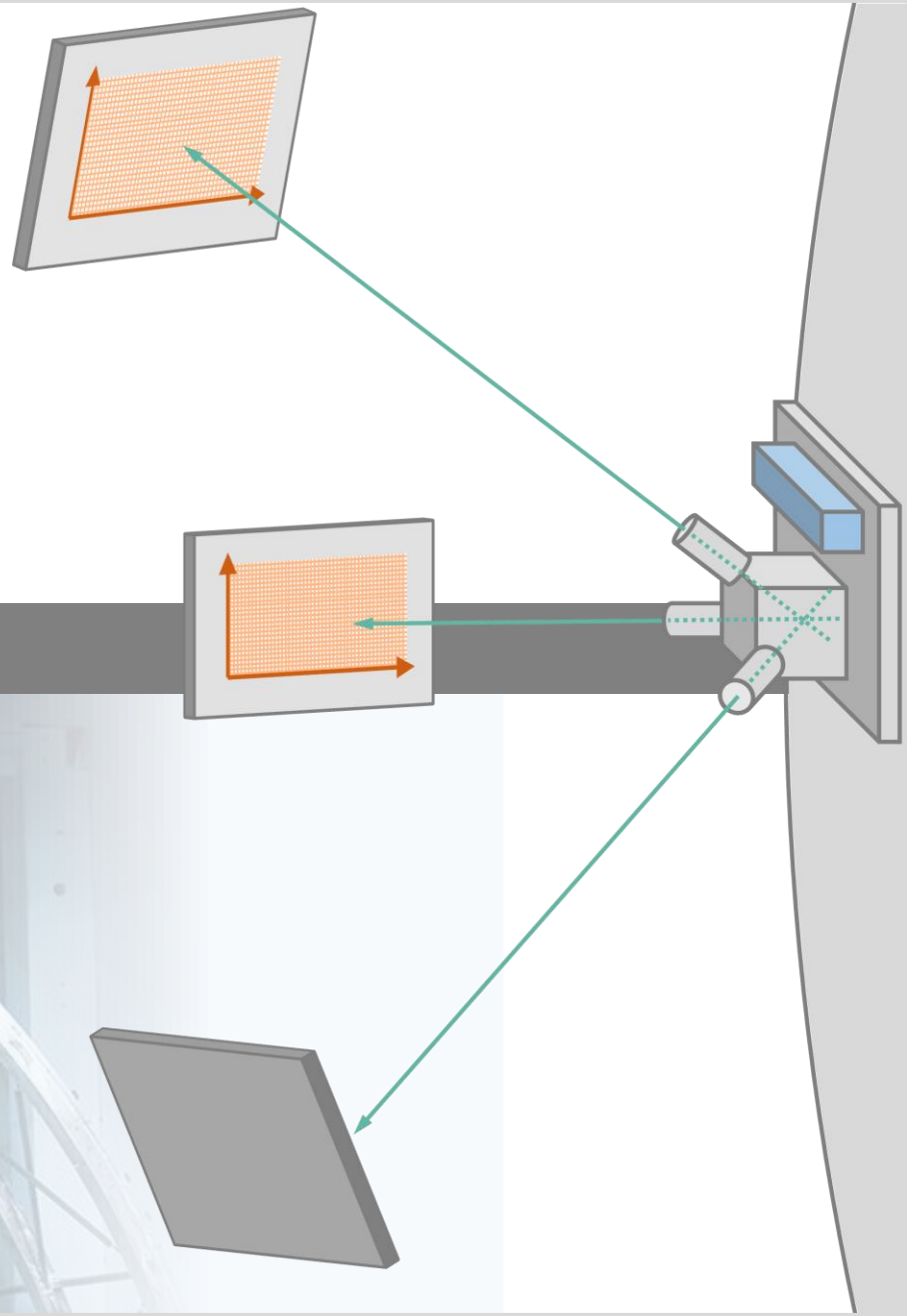
Karlsruher Institut für Technologie

Optimizing the Orientation Determination of the Bartington Magnetometers

Bachelor Thesis of Tizian Römer

INSTITUTE OF EXPERIMENTAL PARTICLE PHYSICS



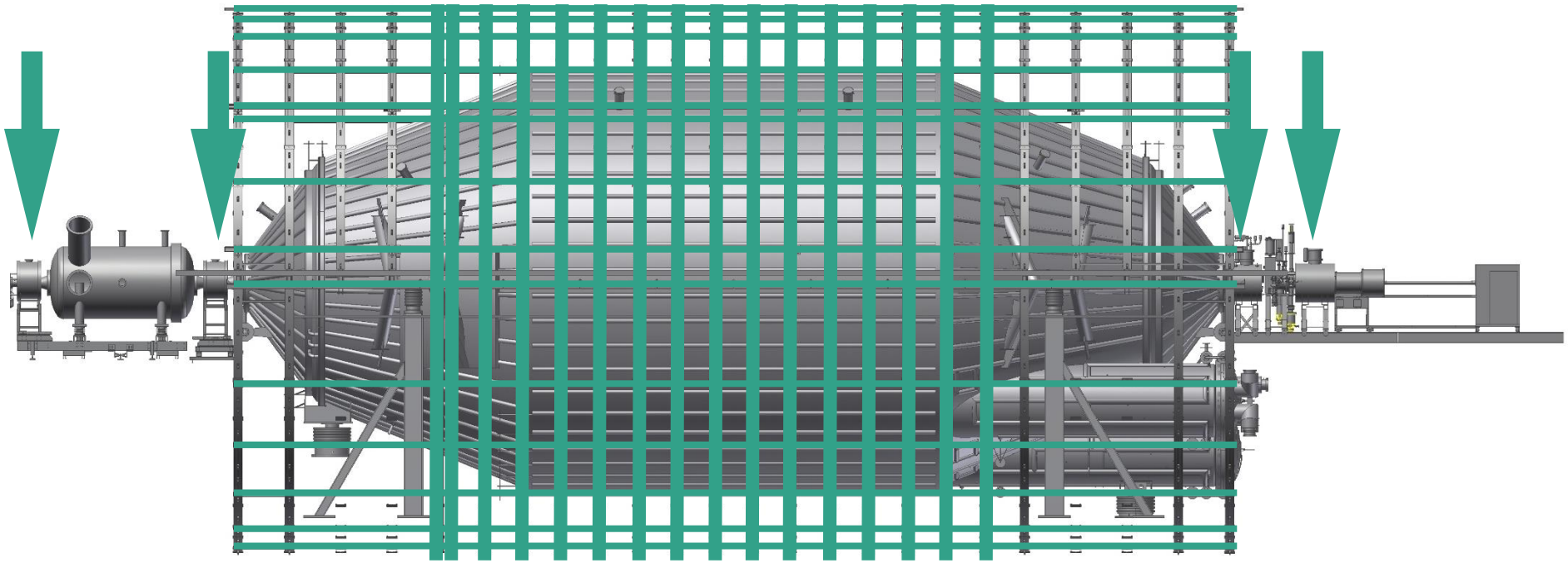
Outline

- Magnetic fields at the KATRIN main spectrometer
- Determine the position and orientation of the Bartington magnetometers
- Precision of this determination
- Comparison to laser tracker measurement
- Magnetic field analysis

Magnetic Field Systems at the Main Spectrometer

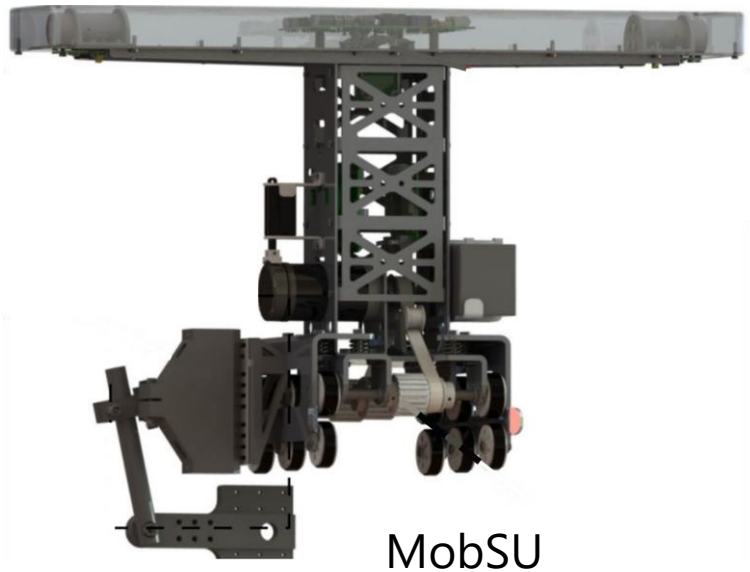
- Superconducting Magnets
- Earth Magnetic Field Compensation System (EMCS)
- Low Field Correction System (LFCS)

} Air Coil System

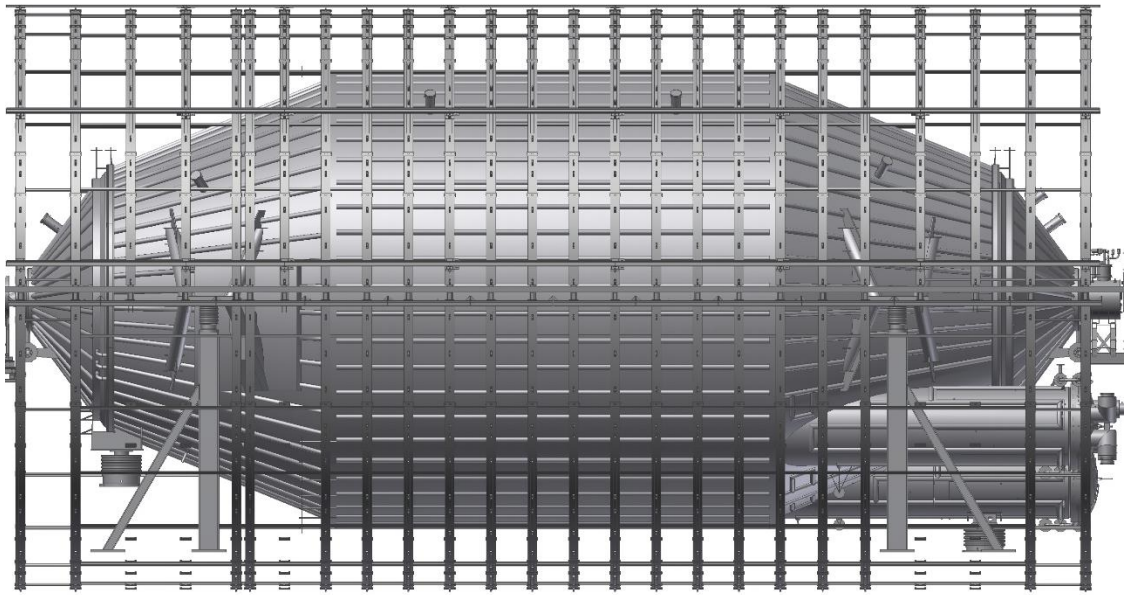


Systems for Measuring the Magnetic Field

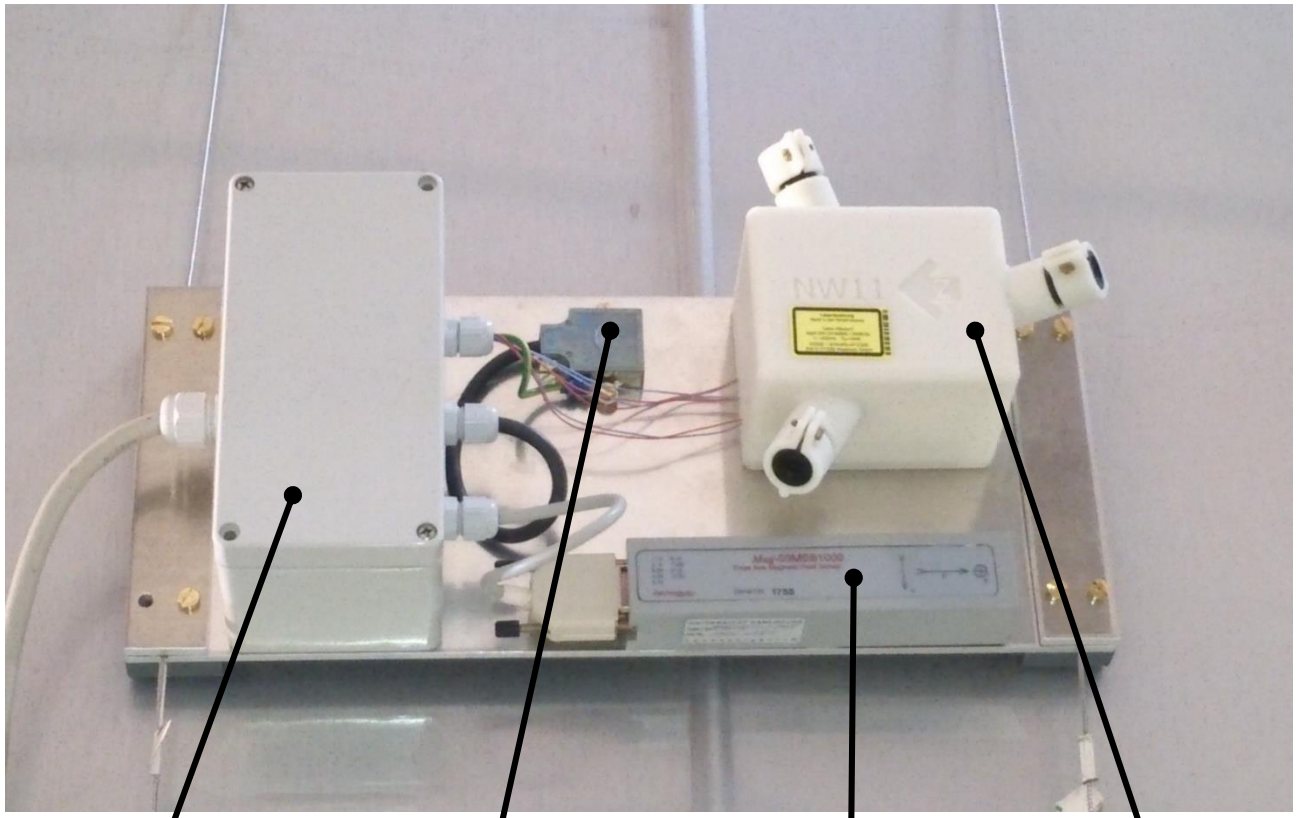
- 4 x Mobile Sensor Units (MobSU)
- Vertical Magnetic Field Sensor System (MagSen-V)
- 24 x IPE Magnetic Field Sensors
- 14 x Bartington Magnetometers

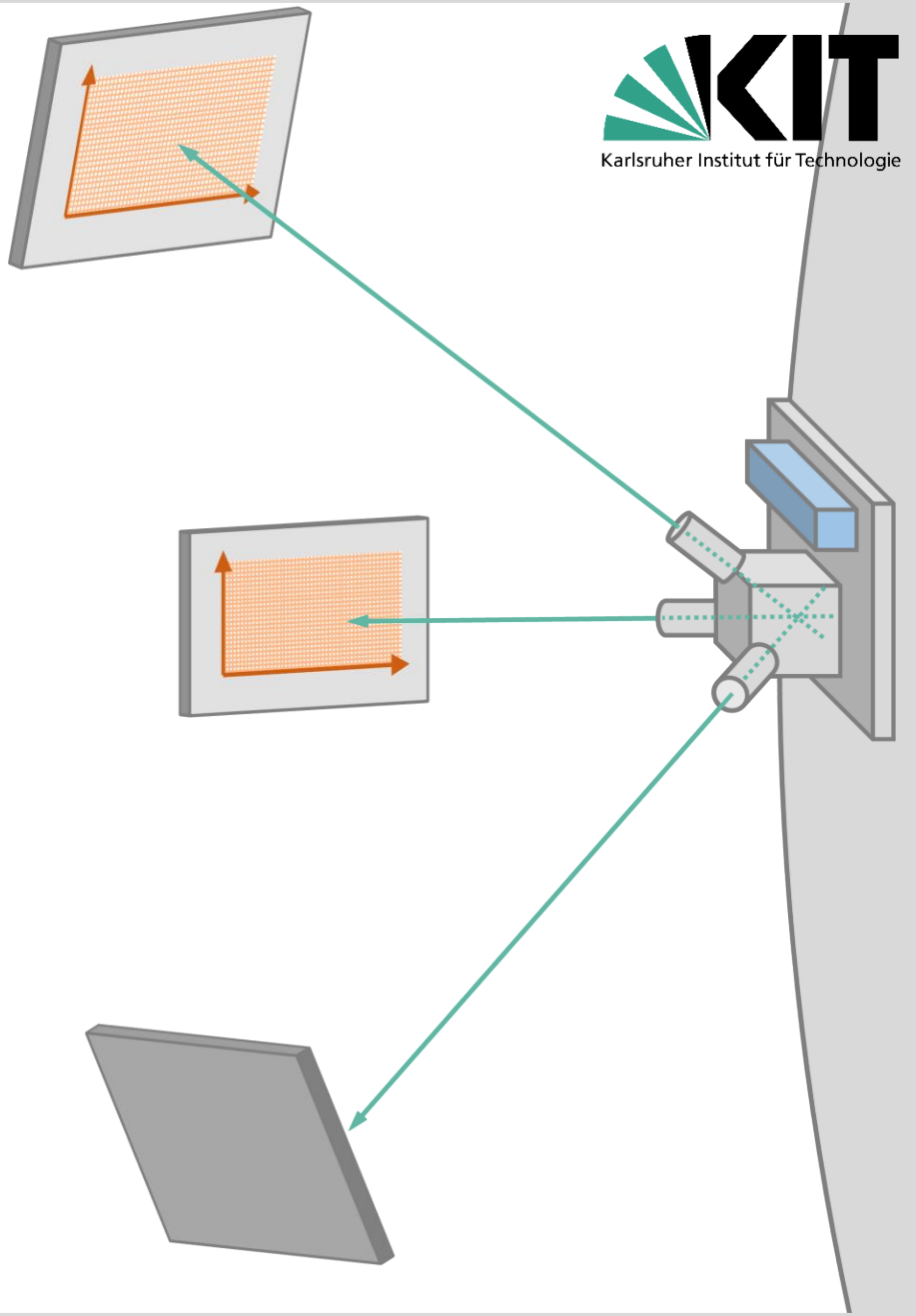


MobSU



Sensor Islands





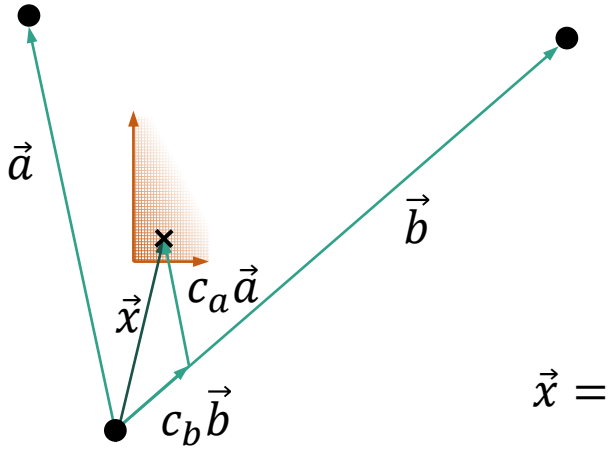
Determine the Position and Orientation

- Determine laser origin from laser point coordinates:

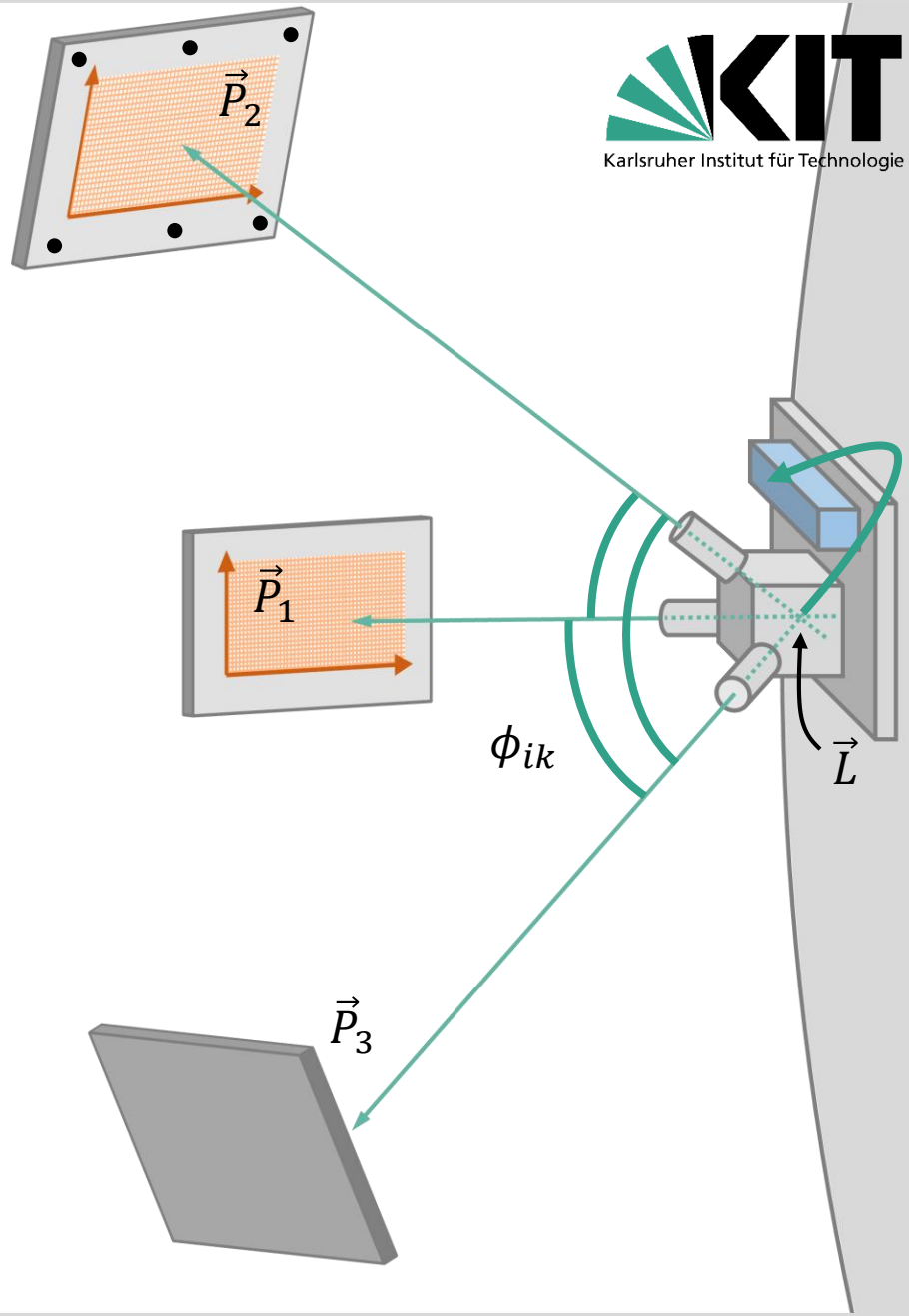
  KLaPoS *(KATRIN Laser Positioning System)*

  $$U(\vec{X}) := \sum_{i \neq k} (\phi_{ik} - \measuredangle P_i X P_k)^2$$

- Determine magnetometer origin from laser origin
- Determine Euler angles from measurement axes
- Determine 3D laser point coordinates



$$\vec{x} = c_a\vec{a} + c_b\vec{b}$$



Precision of the Method

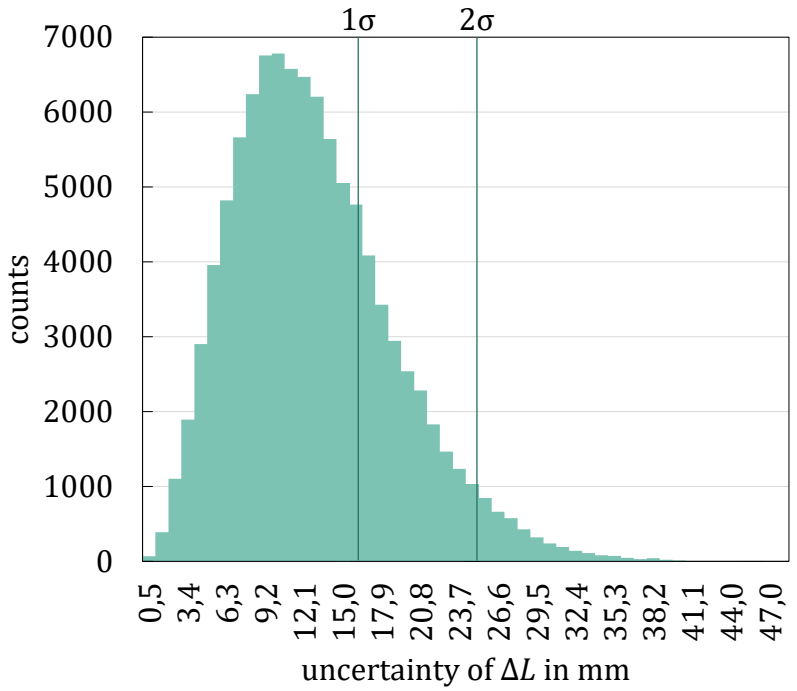
- Position uncertainty

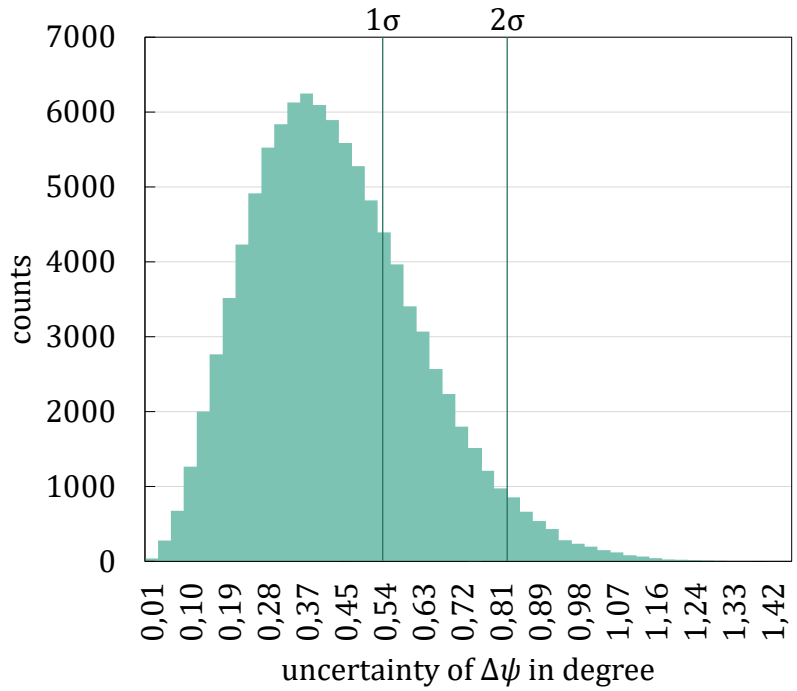
$$\Delta L = \max_{i=x,y,z} |L_i - L_i'|$$

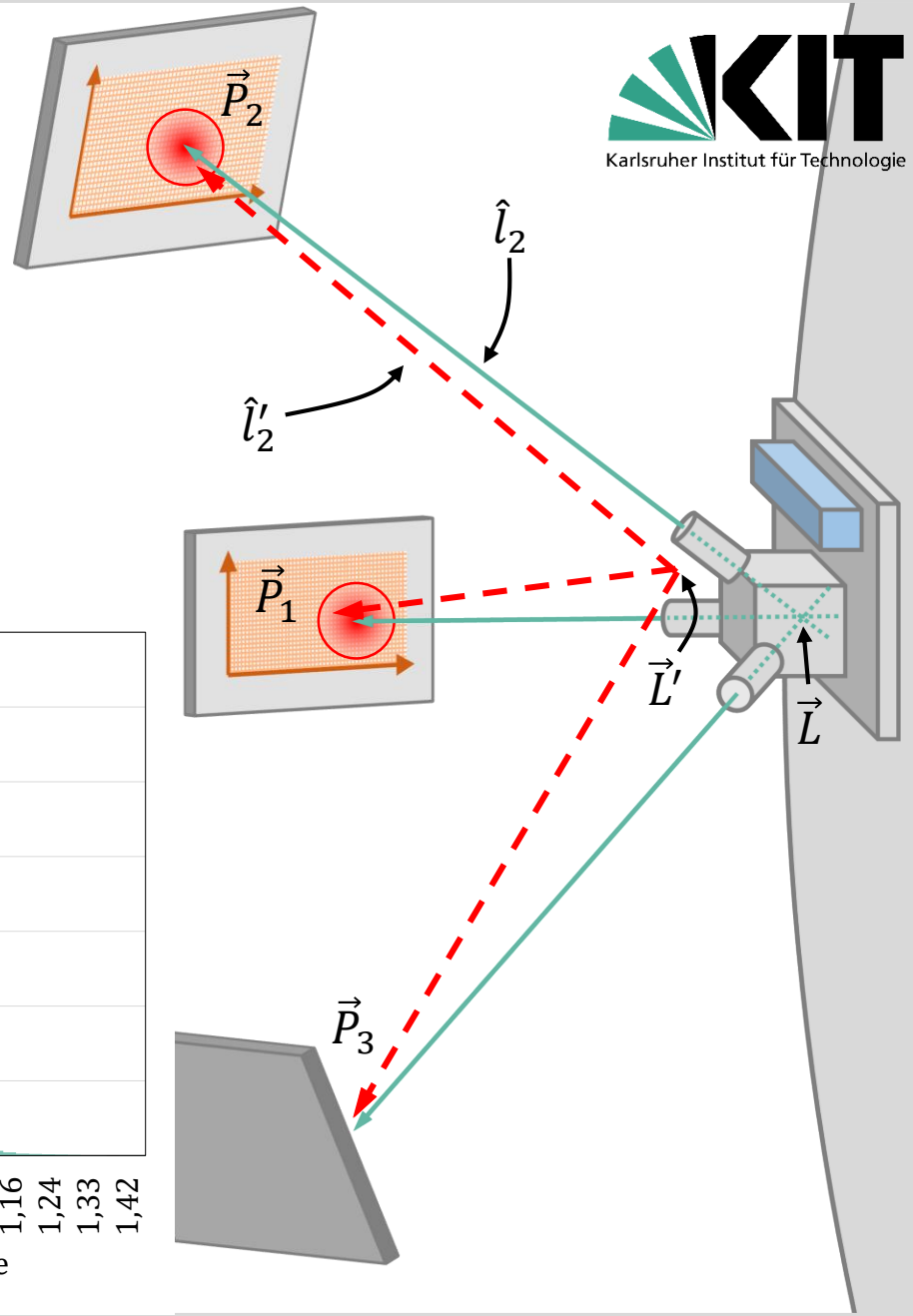
- Orientation uncertainty

$$\Delta\psi = \max_{i=1,2,3} \arccos \hat{l}_i \cdot \hat{l}_i'$$

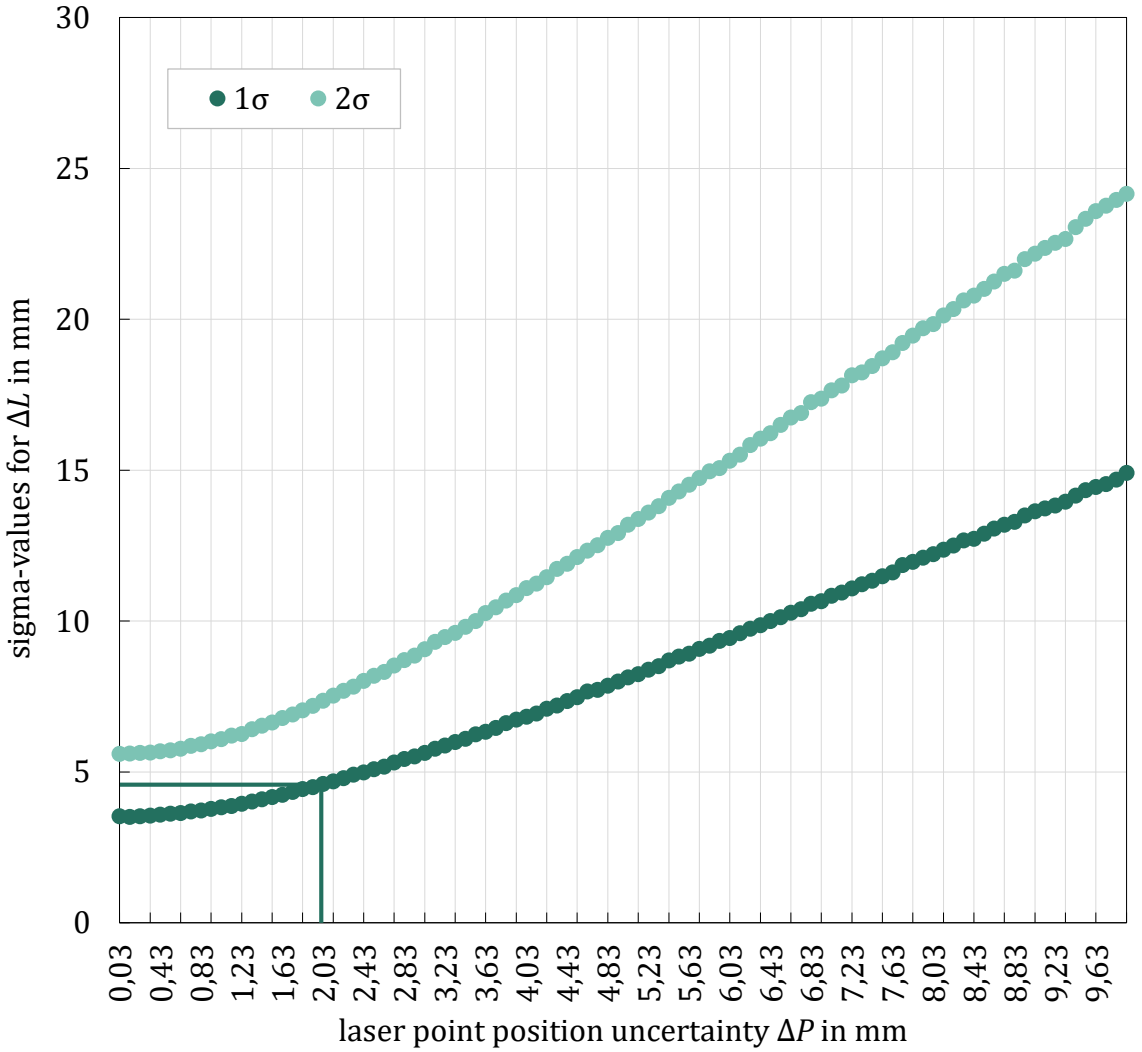
$n = 100\,000$
$\Delta P = \pm 1\ \text{cm}$
$\Delta\phi_{ik} = \pm 0.095°$

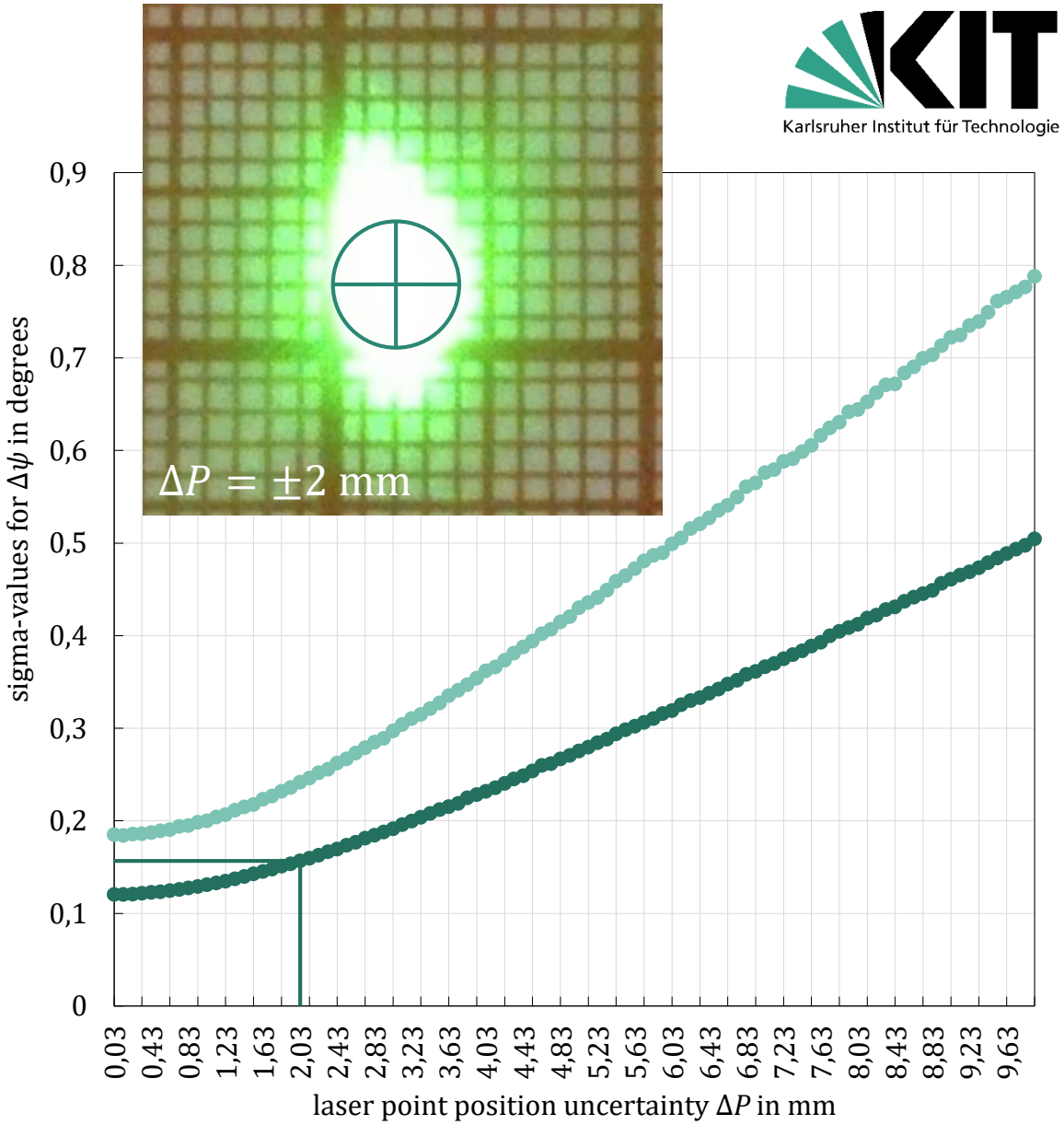






Precision of the Method





KLaPoS User Interface

```
roemer@kalinka4:~/Kasperinstall/bin$ MagnetometerLaserPositioning BU32 112 157


usage: ./MagnetometerLaserPositioning <Sensor> <laser1 x> <laser1 y> <laser2 x>
<laser2 y> <laser3 x> <laser3 y>
'Sensor' is for example 'BU32'. The 2D laser coordinates need to be given in the
 target plate system (graph paper) as double values in millimeter.


roemer@kalinka4:~/Kasperinstall/bin$ MagnetometerLaserPositioning BU32 112 157 7
6 97 354 154
```

KLaPoS User Interface

```
KLaPoS: KATRIN Laser Positioning System
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Magnetometer Position:
M = (-900.1642046, -5214.841657, -4454.74545) mm

Magnetometer Axes:
m1 = (-0.986125006, 0.1649784553, -0.01891209338)
m2 = (0.1650685506, 0.9862190288, 0.01070657922)
m3 = (0.01987959007, 0.008874536004, -0.9997564577)
Euler Angles (zy'z'') in Degrees: (22.03622864, 178.7544848, 31.53546303)

Calculate error sigma values? (1/0): 1
What is the error of each component of the position of the laser points in mm?
Error Delta P = 10
How many trials do you want to be calculated?
(1000 usually takes a few seconds, 10000 a few minutes, 100000 a few hours)
Trials n = 2000

The errors are calculated now ...
Error calculation finished:
One Sigma Error for L:   14.99167179 mm
Two Sigma Error for L:   24.17779741 mm
One Sigma Error for Psi: 0.5061761339 degrees
Two Sigma Error for Psi: 0.8006101848 degrees
```
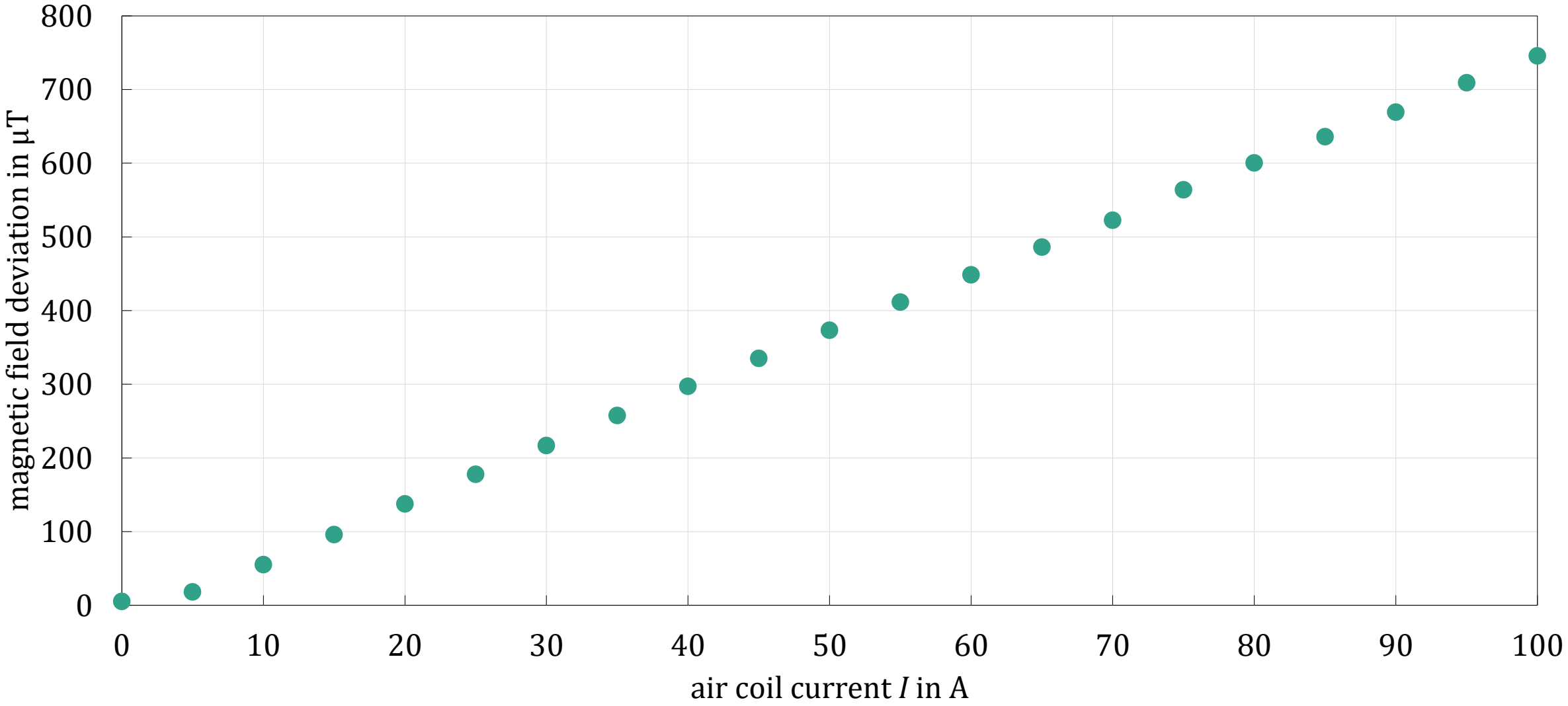

Comparison to Laser Tracker Test Measurements

	x	y	z
Difference of position in mm:	1.9	−1.2	7.0

Difference of measurement axis 1:	0.18°
Difference of measurement axis 2:	0.23°
Difference of measurement axis 3:	0.19°

Magnetic Field Analysis



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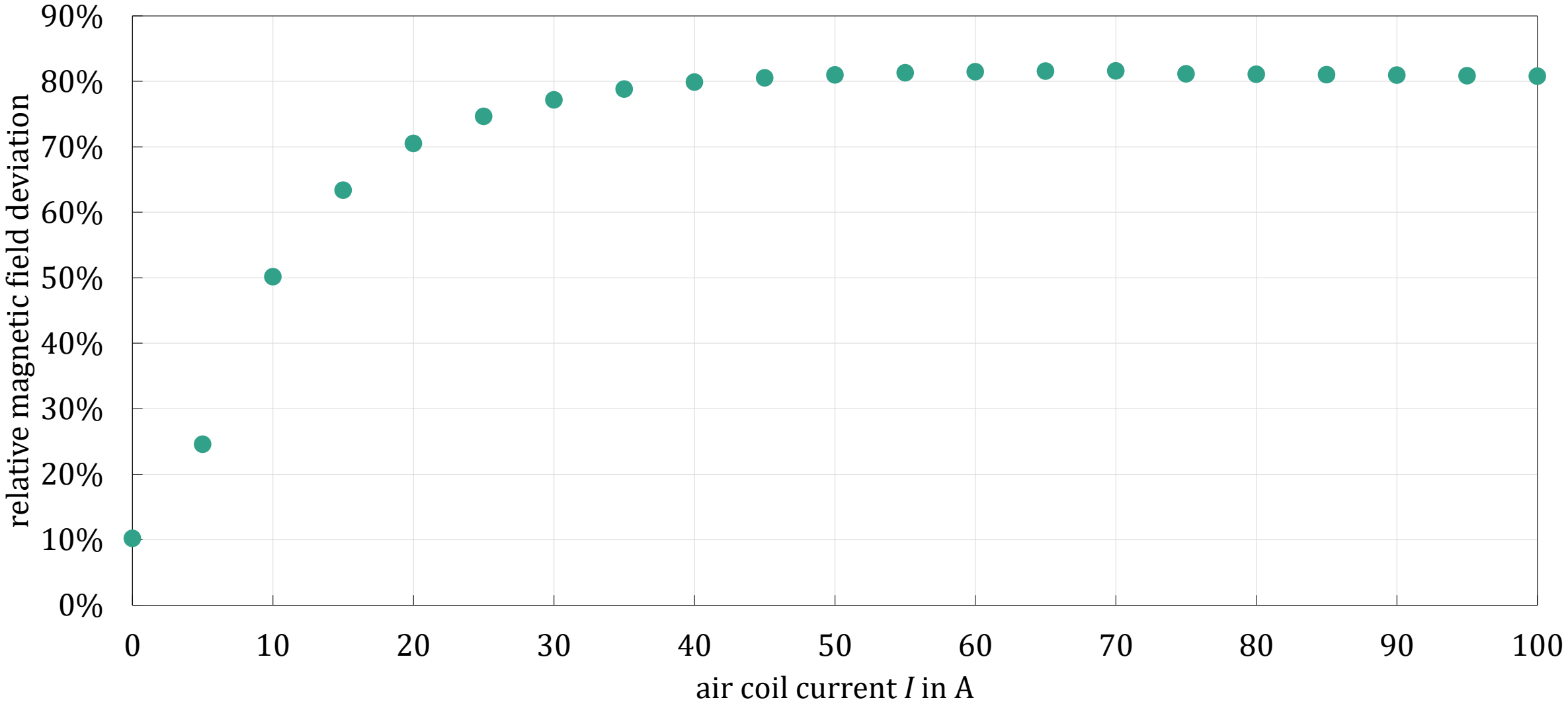
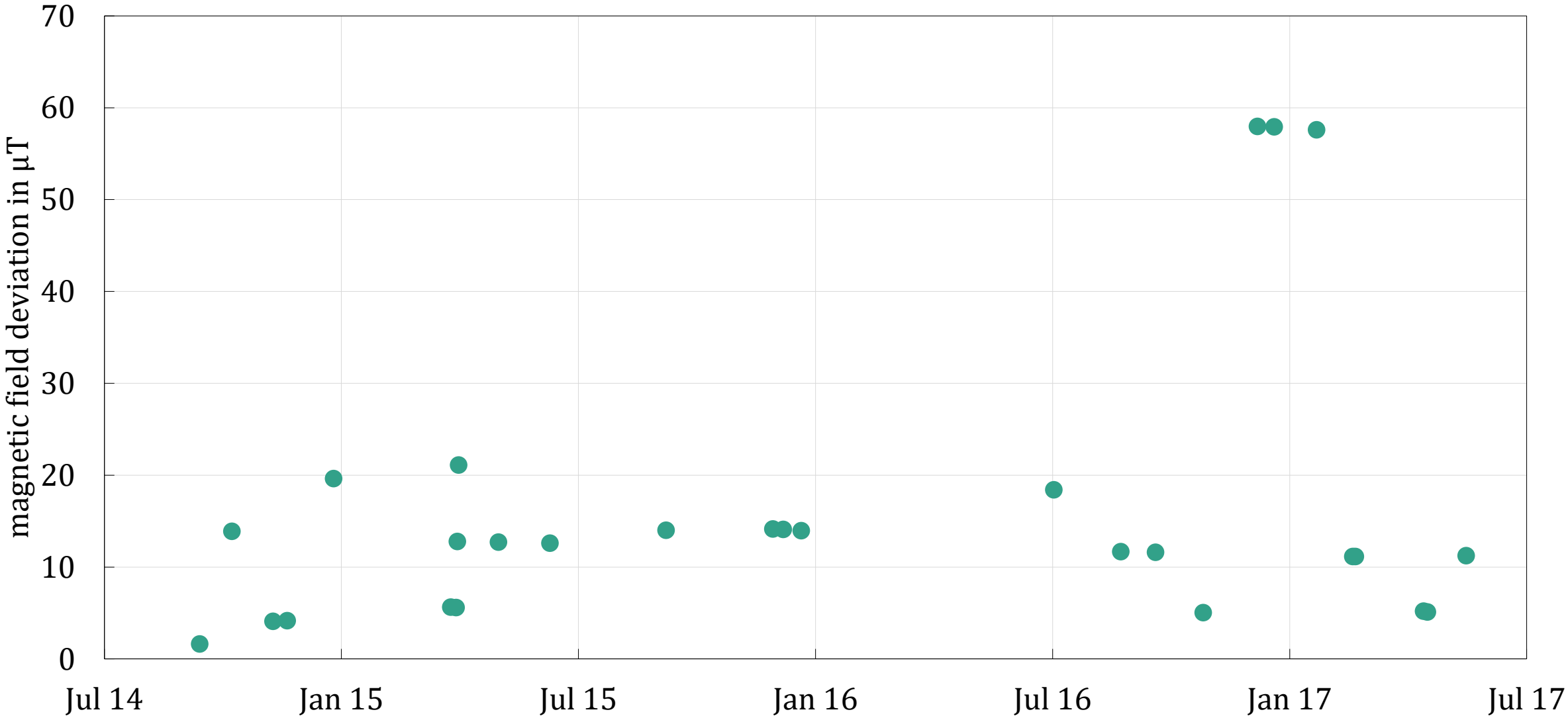


Magnetic Field Analysis



Summary

- Equipped KLaPoS with all necessary features
- Developed error calculation
- Successfully tested method of position/orientation determination
- Found discrepancies in magnetic field analysis