Leica Absolute Laser Tracker operation in magnetic field environment

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Motivation

- Topic of operation of Leica Laser Trackers in magnetic field environment raised by users of accelerator community
- Previous investigations by Laser Tracker users*
- Application: Magnetic field mapping
- Magnetic fields **≤ 200G**

Scope

- Experiment in house
  @ Hexagon MI / Leica Metrology Products Switzerland
- Leica Absolute Laser Tracker AT930/AT960 & AT403
- **3D mode** only – measurements to 1.5"CCR

➢ Give recommendation to users
➢ No hardware modifications / changes

* Friedsam H., "Alignment Aspects of the Mu2e Magnetic Field Mapping System", IWAA 2016, ESRF, Grenoble, (2016); https://indico.cern.ch/event/489498/contributions/2217442/

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Leica Absolute Laser Trackers

AT930 & AT960

- ADM & IFM
- Highly dynamic (1kHz)
- Range up to 60m
- AT930: 3D Measurements
- AT960: 3D & 6DoF Measurements (Range up to 25m)
- 6DoF: T-Probe / T-Scan / LAS / T-Mac

AT403

- ADM only
- Quasi dynamic (5Hz)
- Range up to 160m
- B-Probe

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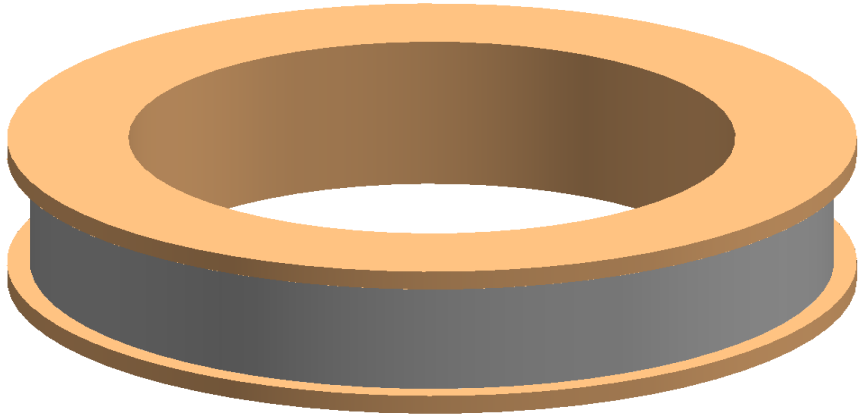
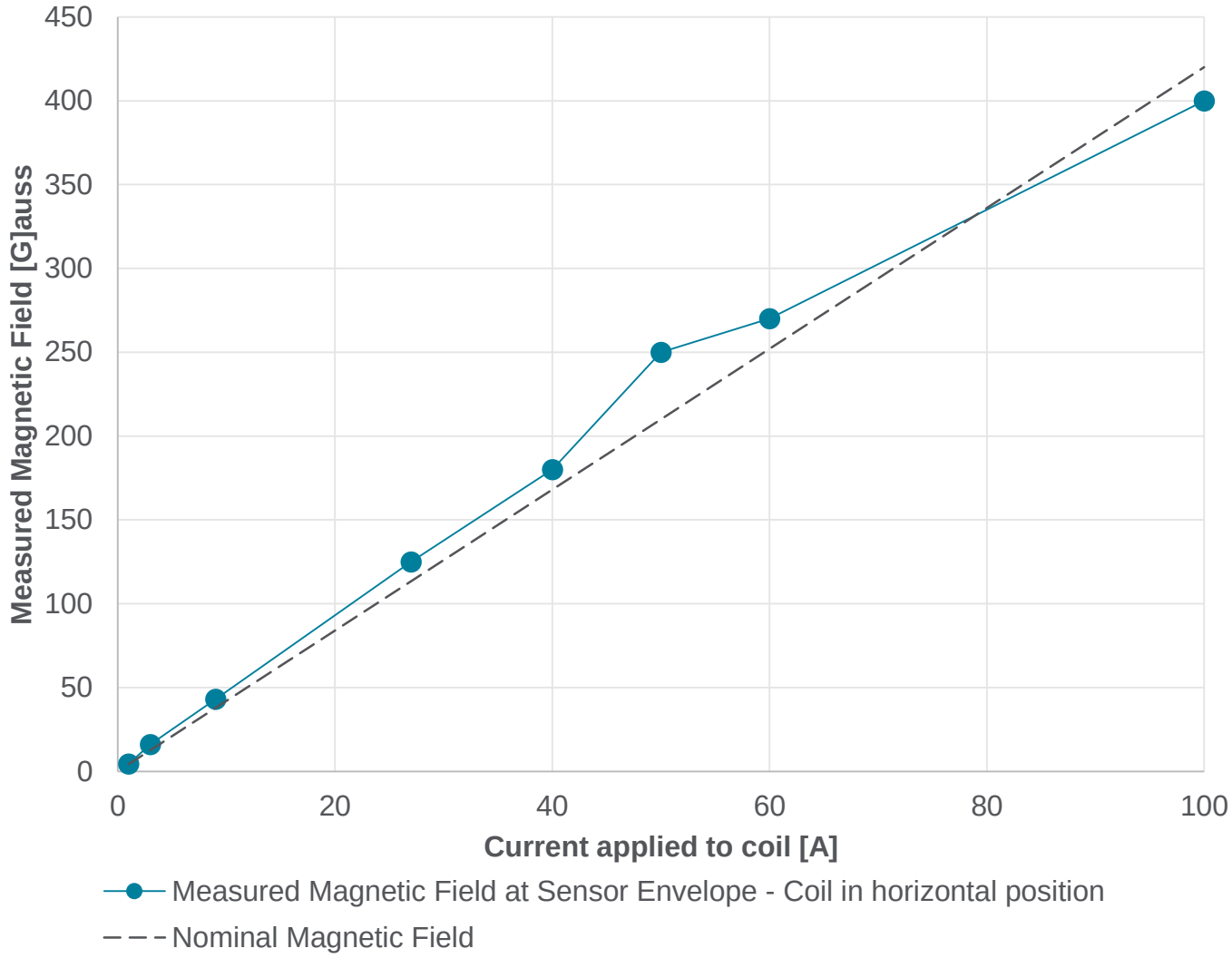
Test Setup - Magnetic Field



- Copper Coil
- 160 Windings
- Ø = 0.482 m
- Height of coil cylinder l = 0.1 m
- Copper cable diameter: 5 mm
- Resistance R_{DC} @22°C: 0.21 Ω
- Inductance L (100Hz) @22°C: 16.7 mH (measured)
- Magnetic flux density B: 4.2 Gauss / A



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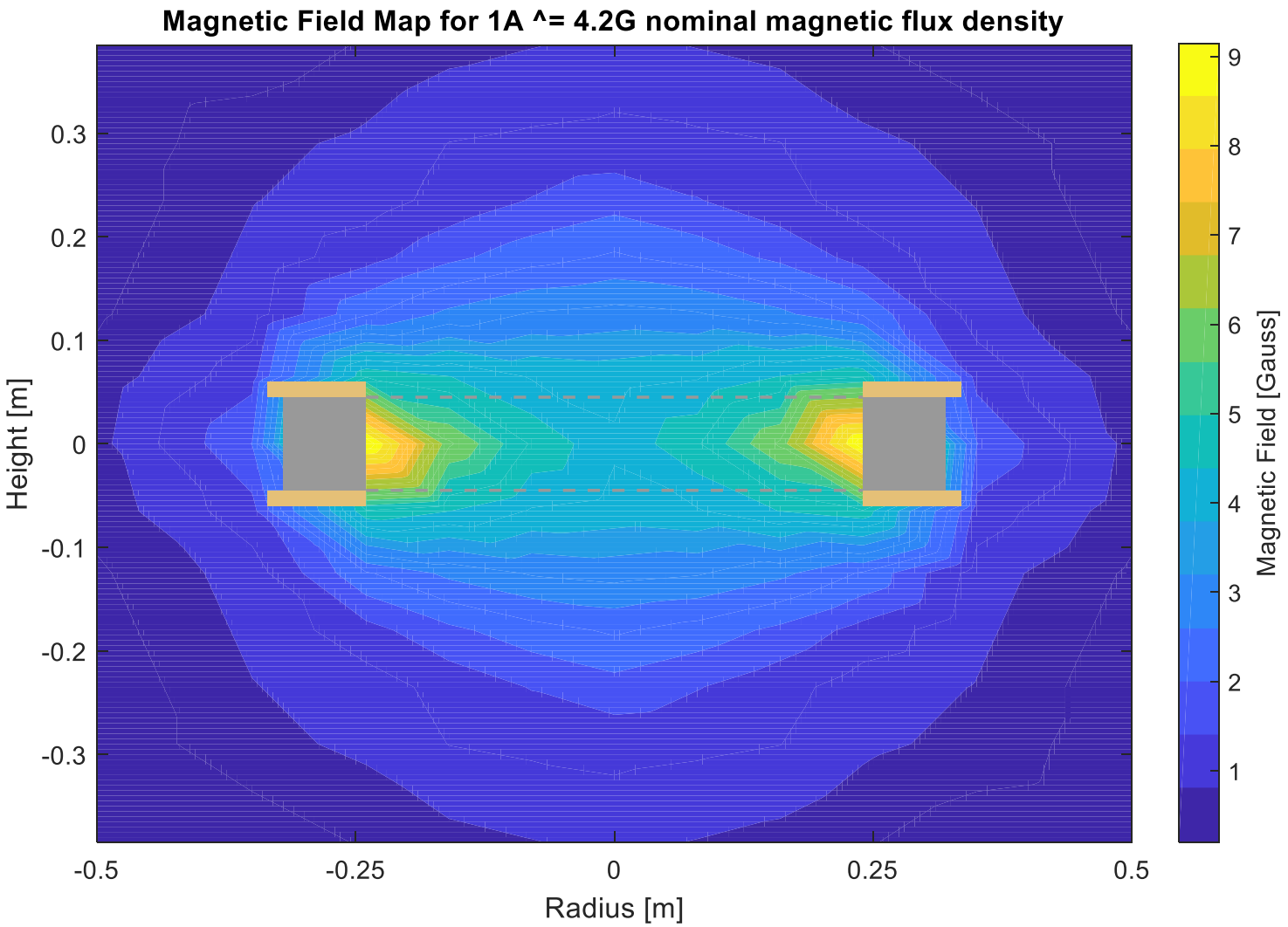
Test Setup - Magnetic Field Measurement



- Coil without Laser Tracker Sensor
- Magnetic field measured with Hall Sensor probe

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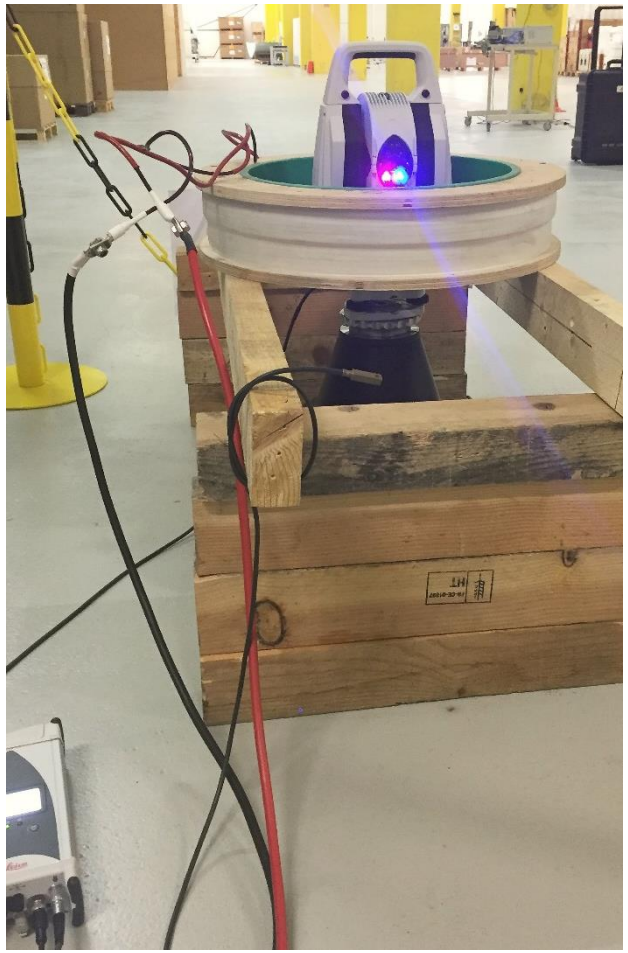
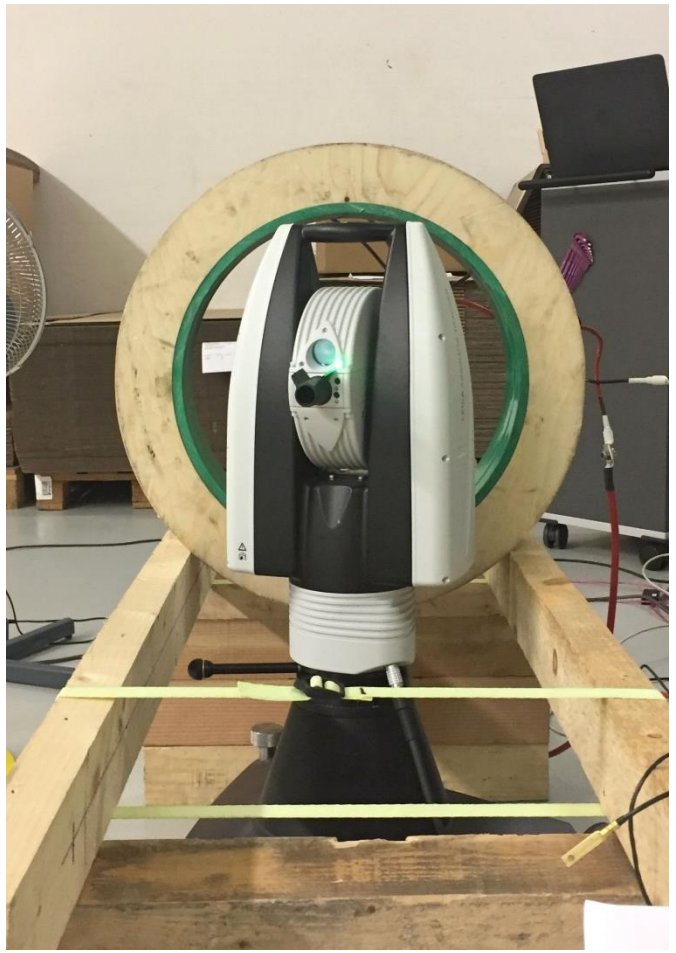
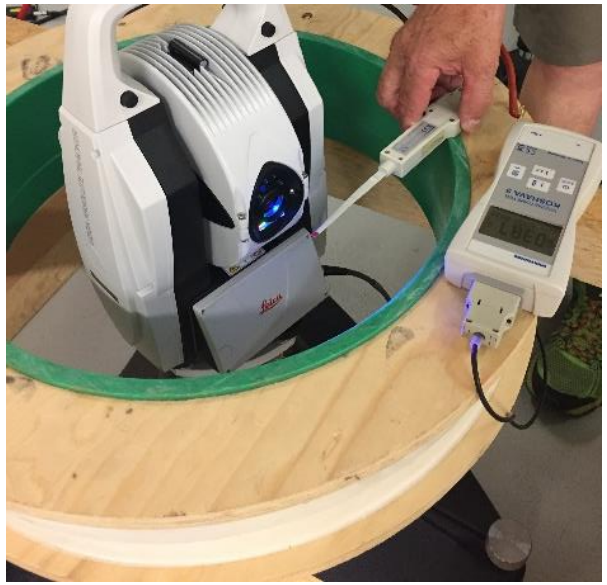
Test Setup – Laser Tracker Position



Coil in horizontal setup



Coil in vertical setup



- Magnetic field checked with Hall Sensor probe
- Controller outside of test zone
- Short time magnetic field (gated) to limit atmospheric disturbances
- Analysis of effects on system by analysing continuous data
- Overall system accuarcy verified before and after experiment (standard Sensor Checks)

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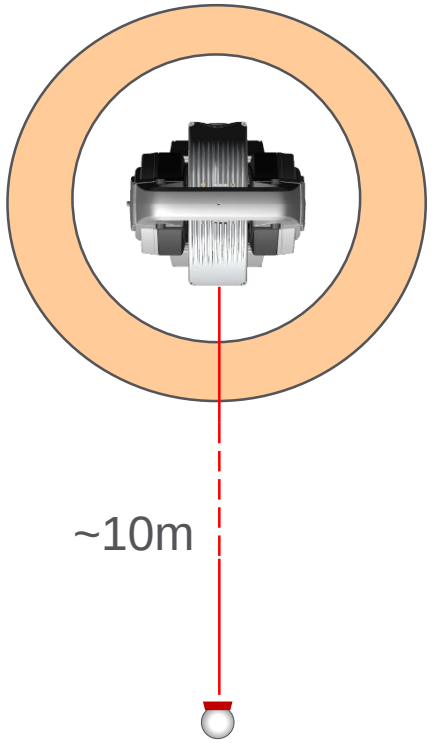
Measurement Setup – Coil in horizontal Position

- Observation of Target at 10m / tilting axis height
- Short time magnetic fields (2-3 sec)



Top View

Front View

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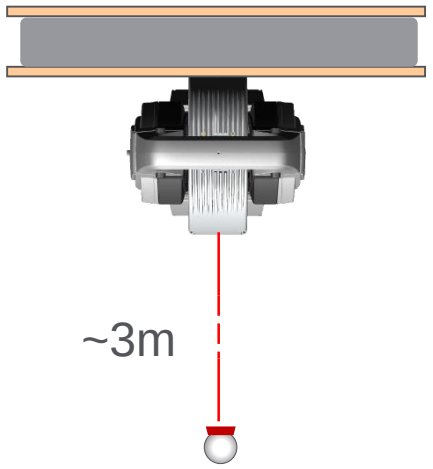
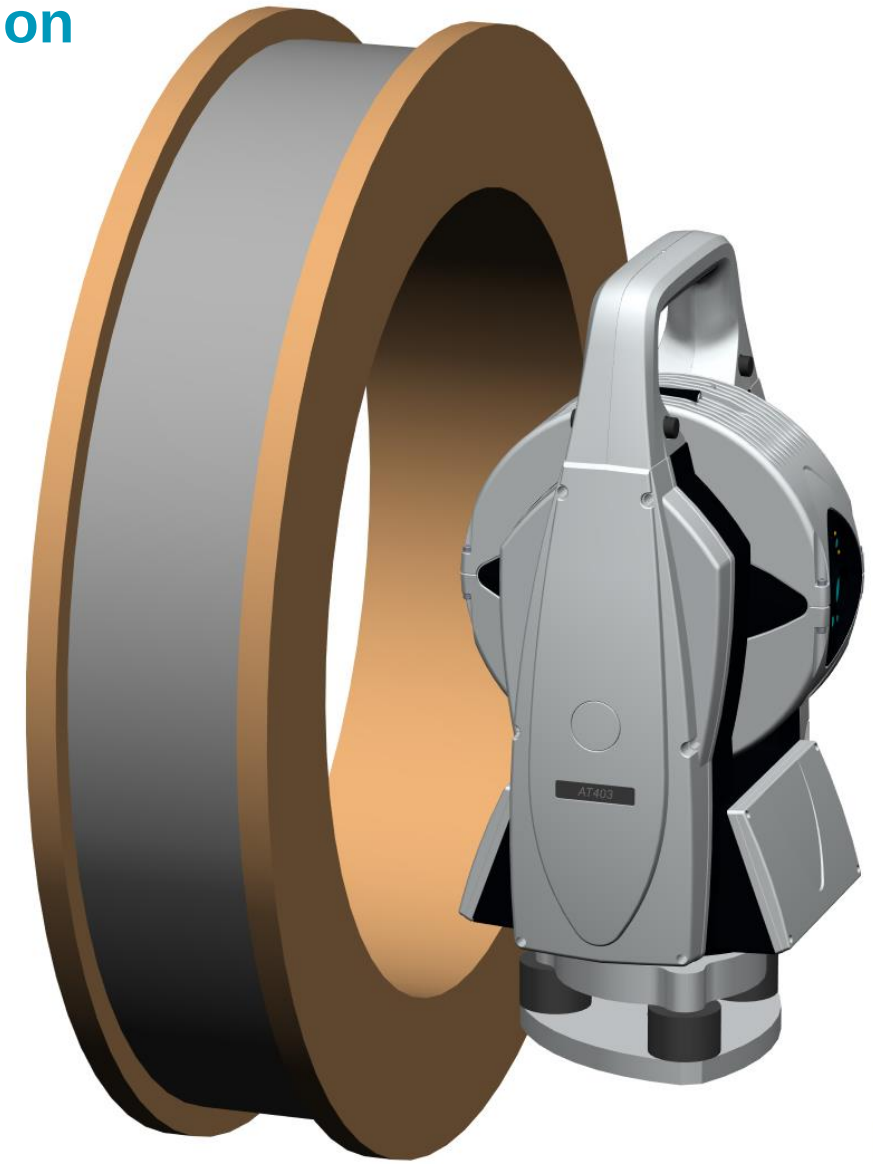
Measurement Setup – Coil in vertical Position

- Observation of Target at 3m / tilting axis height
- Short time magnetic fields (2-3 sec)



Top View

Orientation #1



Side View

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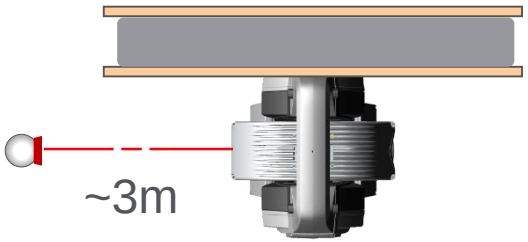
Measurement Setup – Coil in vertical Position

- Observation of Target at 3m / tilting axis height
- Short time magnetic fields (2-3 sec)



Top View

Orientation #2

Side View

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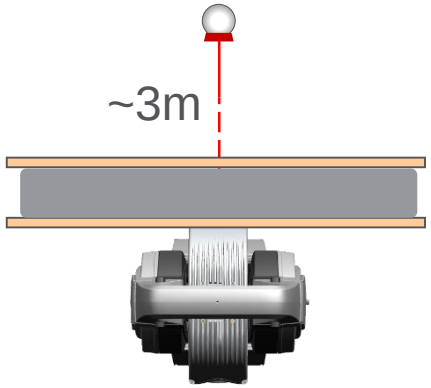
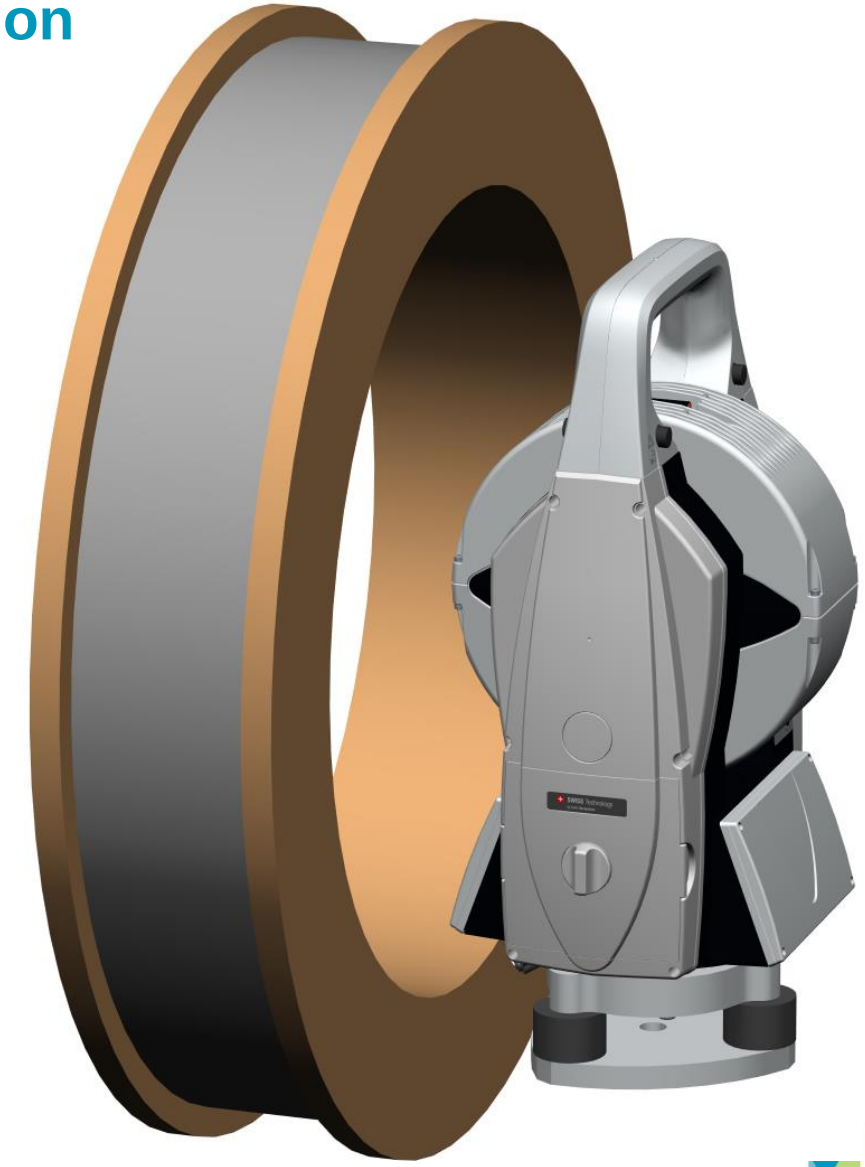
Measurement Setup – Coil in vertical Position

- Observation of Target at 3m / tilting axis height
- Short time magnetic fields (2-3 sec)



Top View

Orientation #3



Side View

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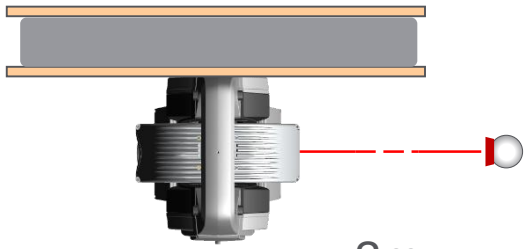
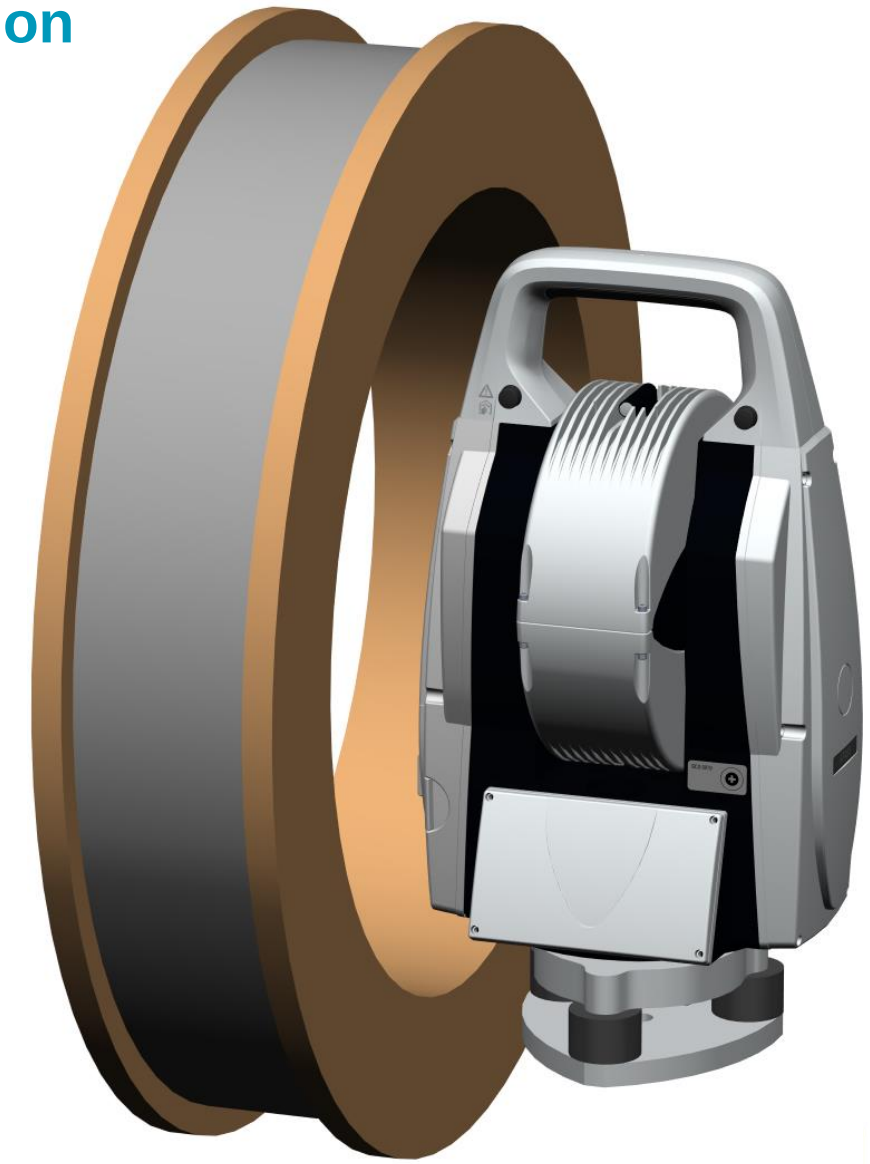
Measurement Setup – Coil in vertical Position

- Observation of Target at 3m / tilting axis height
- Short time magnetic fields (2-3 sec)



Top View

Orientation #4



Side View

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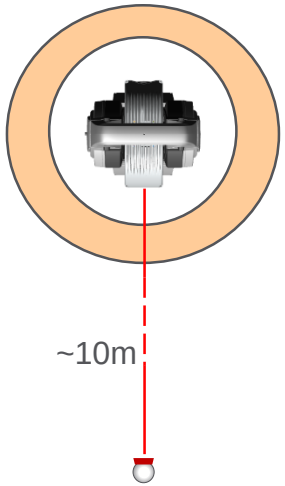
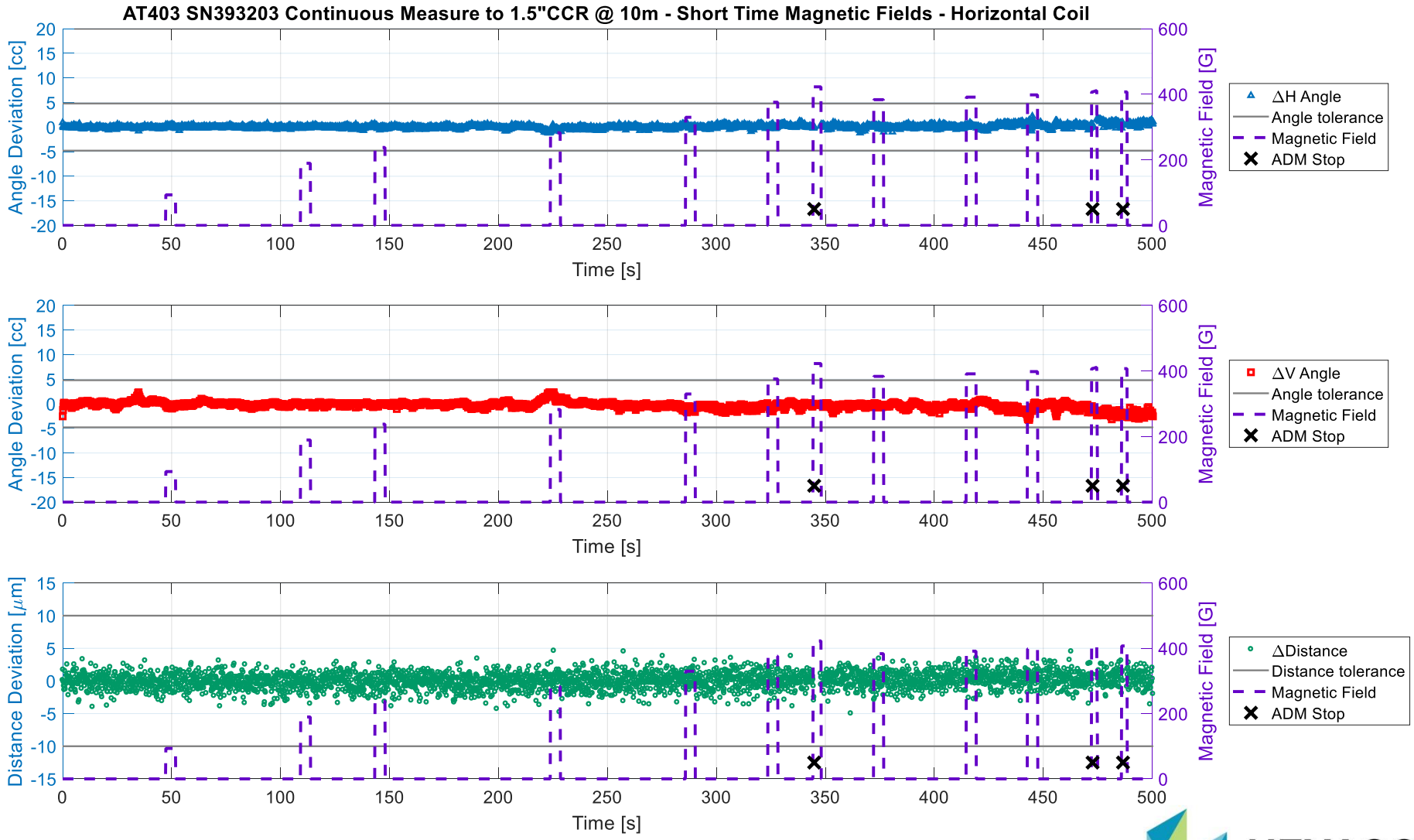
Measurement AT403 – Coil in horizontal Position

- Continuous Measurement of 1.5"CCR @10m
- Short time magnetic fields (3-5 sec) up to 420G



- ADM stops measuring at ≥400G
- System recovers
- No other significant effects



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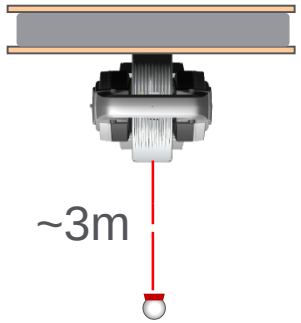
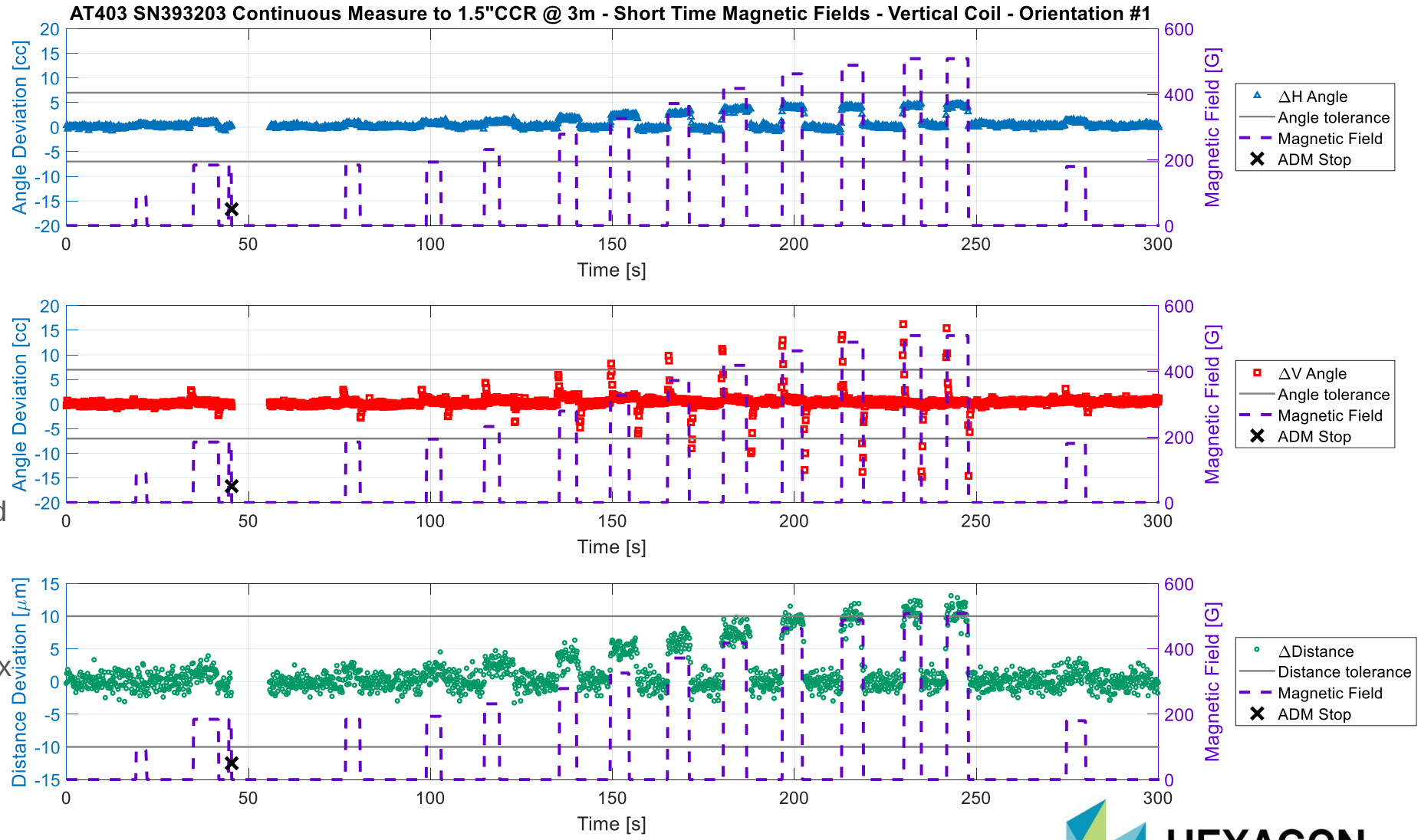
Measurement AT403 – Coil in vertical Position – Orientation #1

- Continuous Measurement of 1.5"CCR @3m
- Short time magnetic fields (3-7 sec) up to 500G



- 1x ADM dropout at ~190G, not reproducable, too fast change of field
- System recovers autonomously
- Effects in angles visible from 200G
- Significant effects in V angles at max change of field
- ADM deviations up to 400G within tolerance



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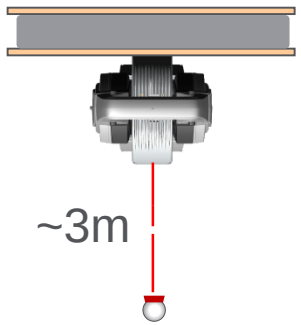
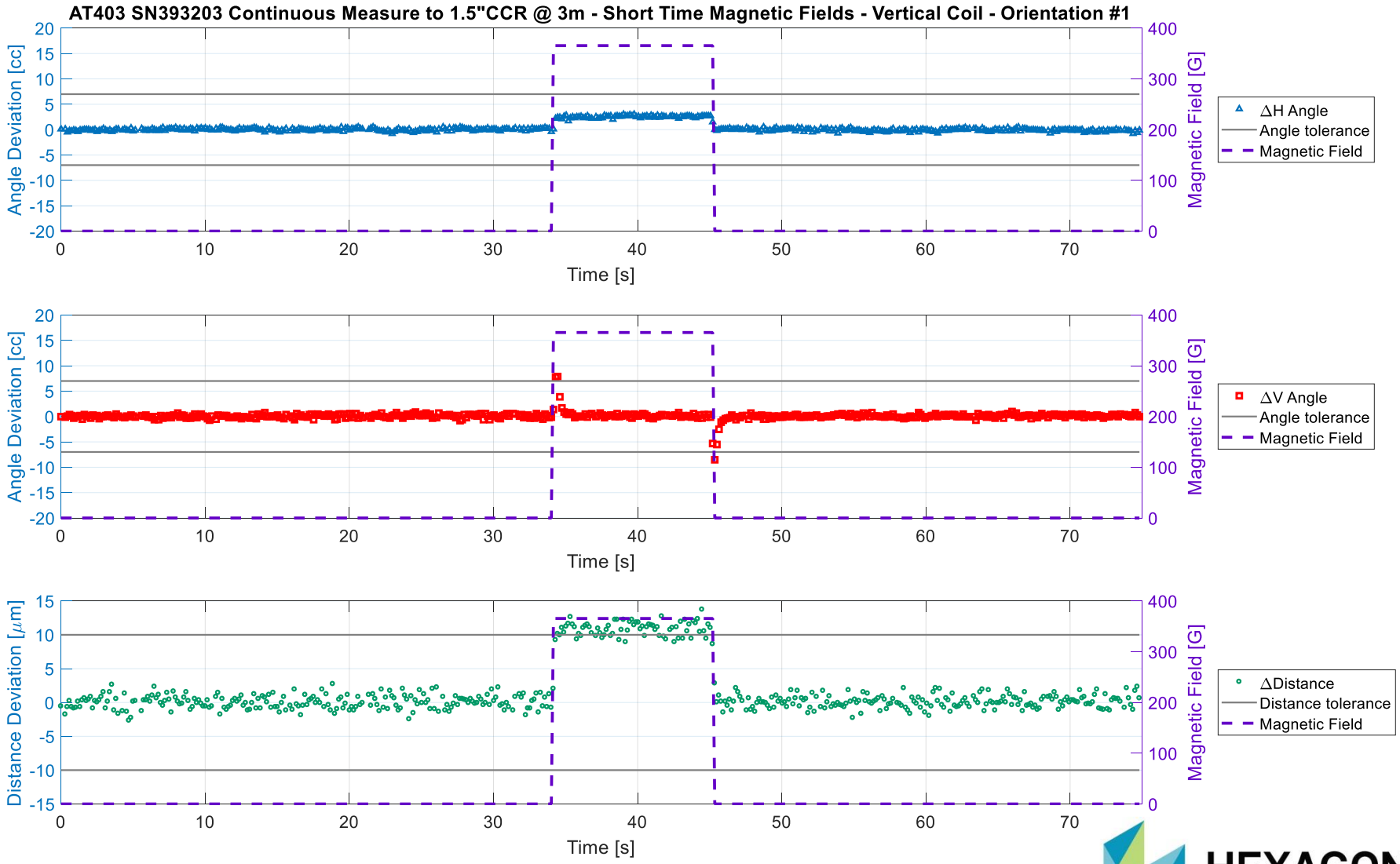
Measurement AT403 – Coil in vertical Position – Orientation #1

- Continuous Measurement of 1.5"CCR @3m
- Magnetic field (10 sec) ~350G





- Significant effect in angles and distance at max change of field
- Effect of Induction

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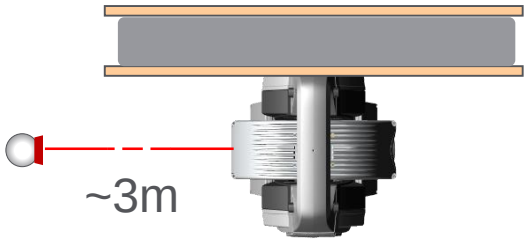
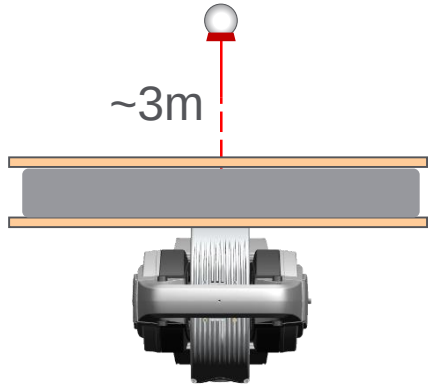
Measurement AT403 – Coil in vertical Position – Orientation #2 - 4

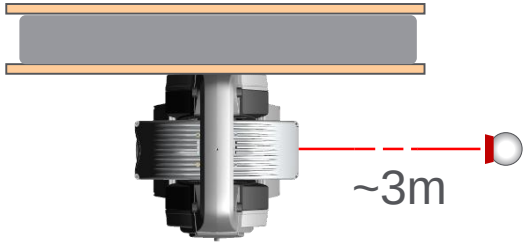
- Continuous Measurement of 1.5"CCR @3m
- Short time magnetic fields (3 - 5 sec) ≤ 350G



Orientation #2



Orientation #3



Orientation #4

- No effect in Orientation #2
- Significant V angle differences in Orientation #3 but small compared to Orientation #1
- Similar effect in V Angle – sensitivity to maximum change of field
- Very little effect seen in Orientation #4 (motors in max exposure)
- No ADM dropouts

AT930 / AT960

Interferometer

- He-Ne (ionized gas) Lasertube
- Inherently sensitive to magnetic fields
- Especially along field lines of tube (vertical, i.e. coil in horizontal position here)
- Large variation between individual sensors (i.e. laser tubes)

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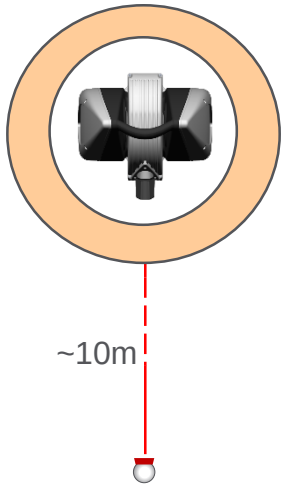
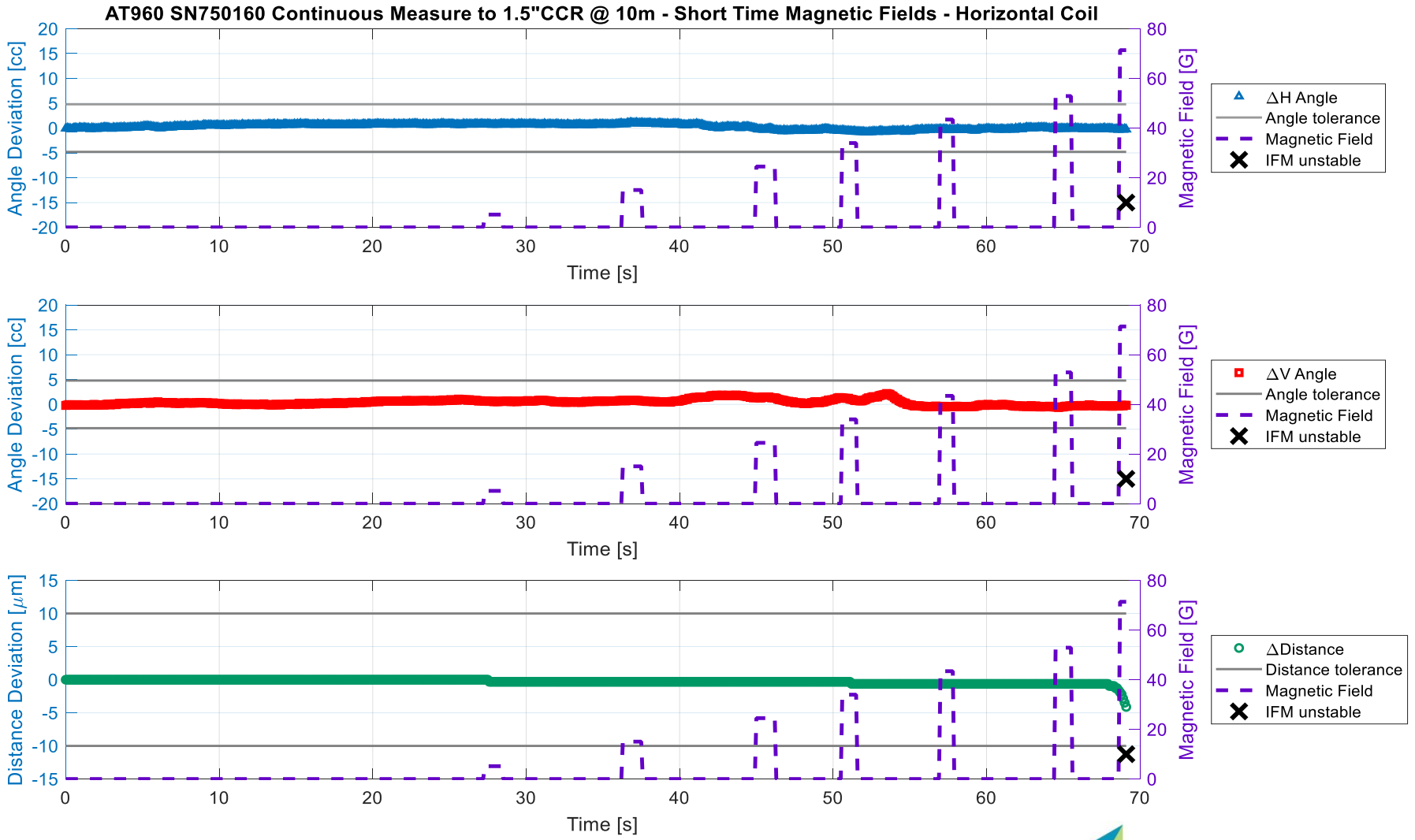
Measurement AT960 – Coil in horizontal Position

- Continuous Measurement of 1.5"CCR @10m
- Short time magnetic fields (2-3 sec) up to 70G



- IFM Lasertube Stabilization interfered at 70G
- System recovers (several minutes)
- No effects before incident



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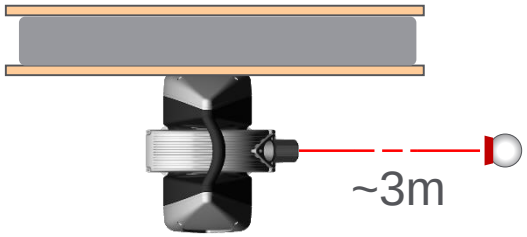
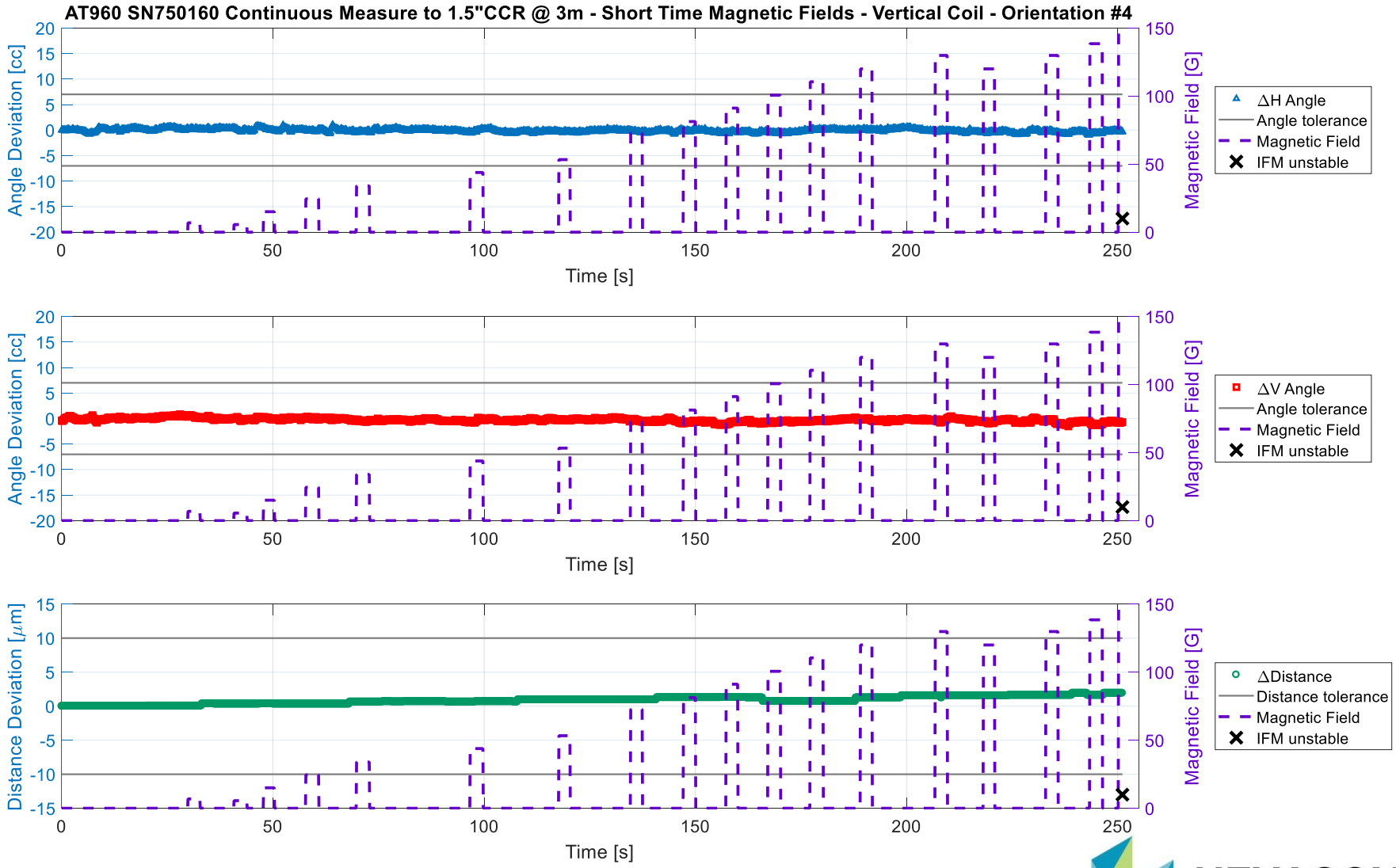
Measurement AT960 – Coil in vertical Position – Orientation #4

- Continuous Measurement of 1.5"CCR @3m
- Short time magnetic fields (3-5 sec) up to 150G



- IFM Lasertube Stabilization interfered at 150G
- System recovers (several minutes)
- No effects before incident



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Conclusion

AT403

- System reacts more sensitive when magnetic field is orthogonal to standing axis, especially when the field changes
- Initialisation tested up to 350G, ADM stops at some point, influence of atmospheric effects on stationary measurements as time magnetic field had to be longer (coil heats up)
- Recommendation (verified with other AT403)
  - **≤ 200G**
    - Full functionality
    - Full accuracy
    - No damage
  - **200 – 300G**
    - Full functionality
    - Accuracy begins to decrease
    - Probably no damage
  - **> 300G**
    - ADM stops measuring at some point
    - System recovers quickly if field is stopped
- **No tests with AT401 / AT402 or B-Probe**
- **No tests for long term exposure to magnetic field**

AT930 / AT960

- Sensitivity of laser tubes to magnetic fields inherent
- Magnetic fields orthogonal to laser tube have less effect
- Large variations in sensitivity of individual laser tubes
- Assumption (from experience of two AT960)
  - **≤ 50G**
    - Full functionality
    - Full accuracy
    - No damage
  - **> 50G**
    - Laser stabilization becoming interfered
    - Need for laser to restabilise if field is stopped
    - Accuracy: small deviations in distance before laser stabilization interfered
    - Probably no damage up to 200-300G

- **No tests regarding 6DoF / T-Products**
- **No tests for long term exposure to magnetic field**

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THANK YOU!

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