Train-Localization in Tunnels using Magnetic Signatures

INTELLIGENT MAGNETIC POSITIONING FOR AVOIDING COLLISIONS OF TRAINS

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Intelligence on Wheels (IoW) & German Aerospace Center (DLR)

DLR

Motivation

Improving safety and efficiency …


Wolfsburg (D) 1.4.21

Süderlügum (D) 20.4.21


Arch (CH) 23.4.21


Cazis (CH) 8.4.21

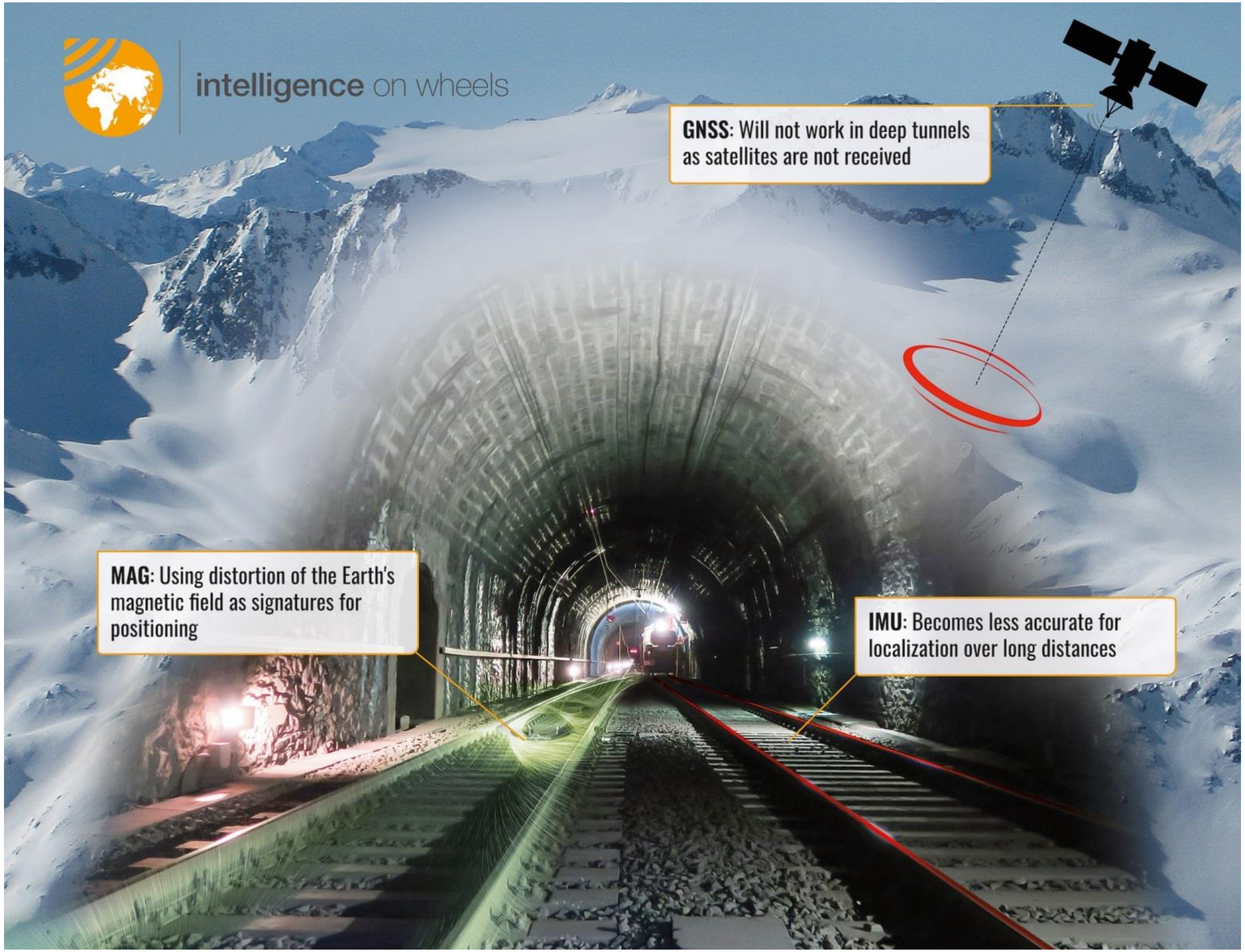

Světec (CZ) 4.4.21

intelligence on wheels

- TrainCAS Virtual Infrastructure
- Collision Avoidance based on Location Beaconing via Train2Train Communication

… of future railway transportation

Why Localization with Magnetic Signatures?



Research Questions

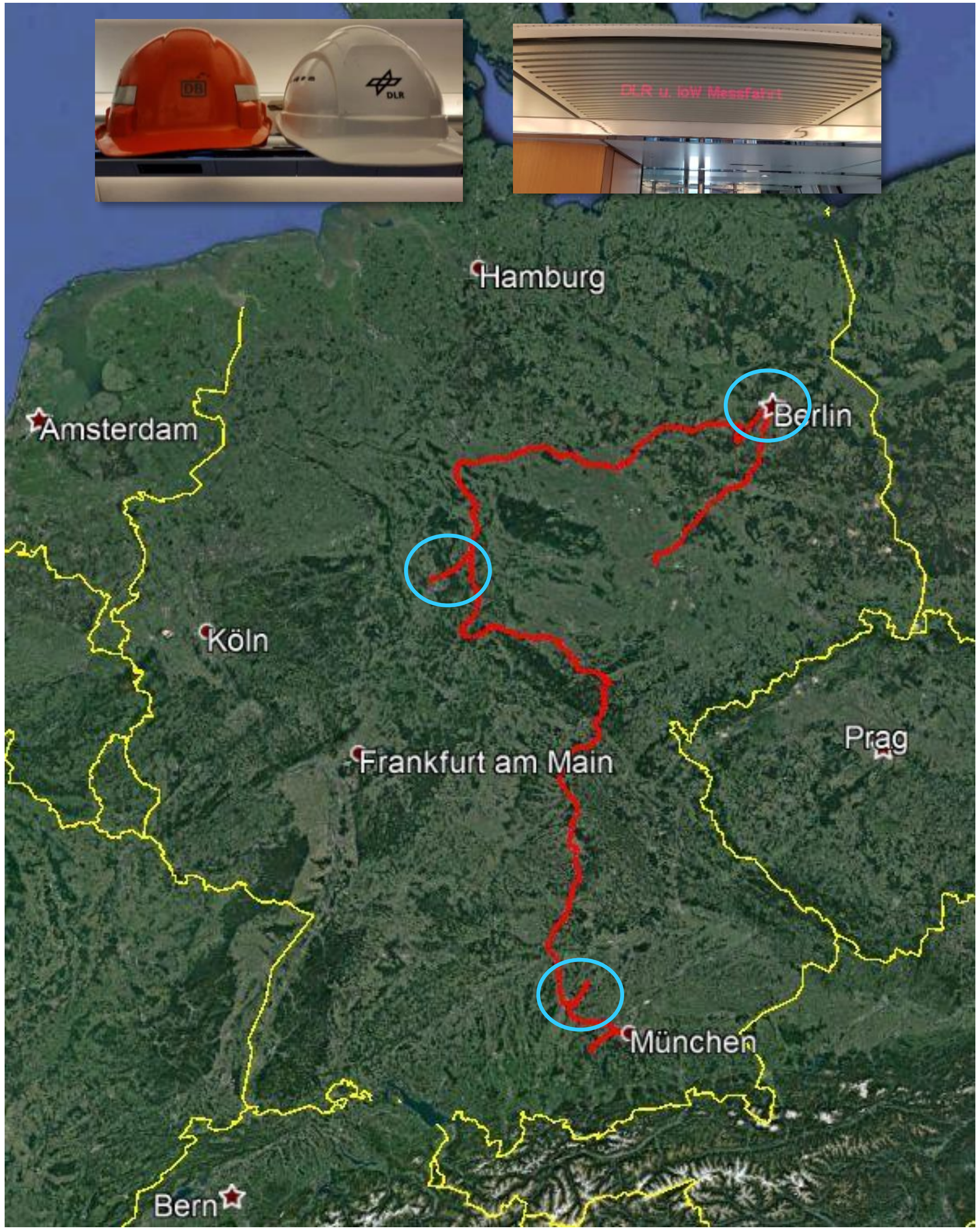
- Which sensor positions are most suitable?
  - Noise analysis
  - Understanding contributions to the signature
  - Cross section dependencies
- What is the influence of magnetic track brakes?
- How about the long term stability of magnetic signatures?
- How good is the velocity determination from synchronized sensors without map?
- Which accuracy can be achieved with magnetic localization alone and if fused with other sensors?

Measurement Campaign

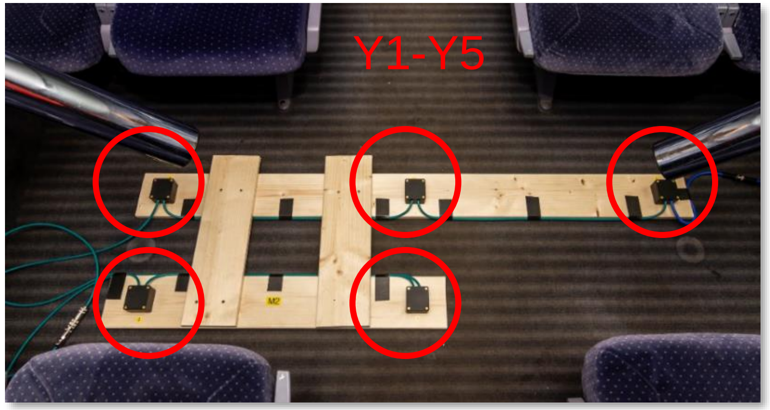
Campaign Overview
(early 2021)

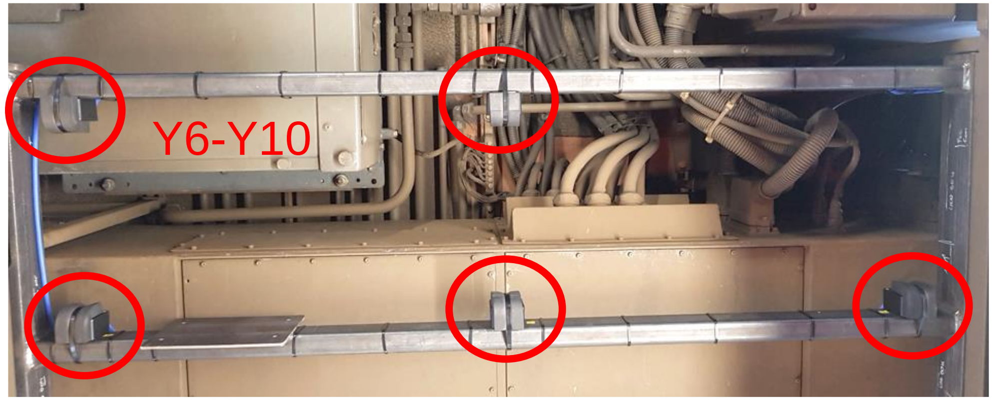
- <u>Berlin</u>
  - Urban and suburban, bridges, underpasses, crossing road and rail traffic
- <u>Göttingen – Kassel</u>
  - High speed, tunnels incl. switchways, cargo trains
- <u>Dasing – Radersdorf</u>
  - Rural, not electrified, single track

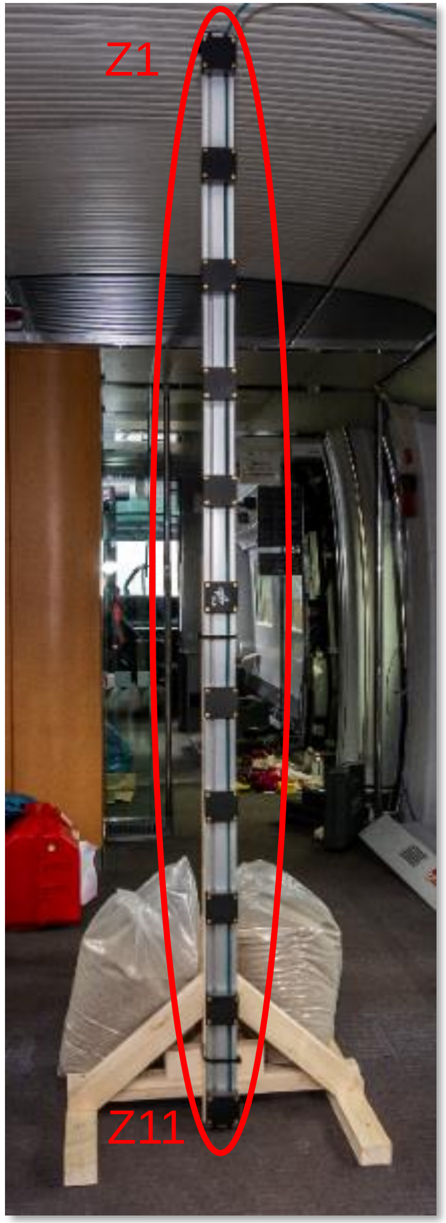
- 2.242 km in 8 measurement days (with track repetitions)
- 1.450 km of magnetic track signatures recorded
- 98 km trajectories referenced by Leica-stations (cm accuracy range)



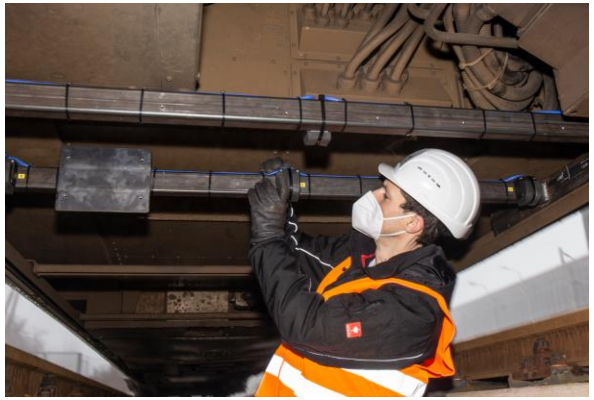
Magnetic Sensor Arrays







Antenna and sensor relative positions

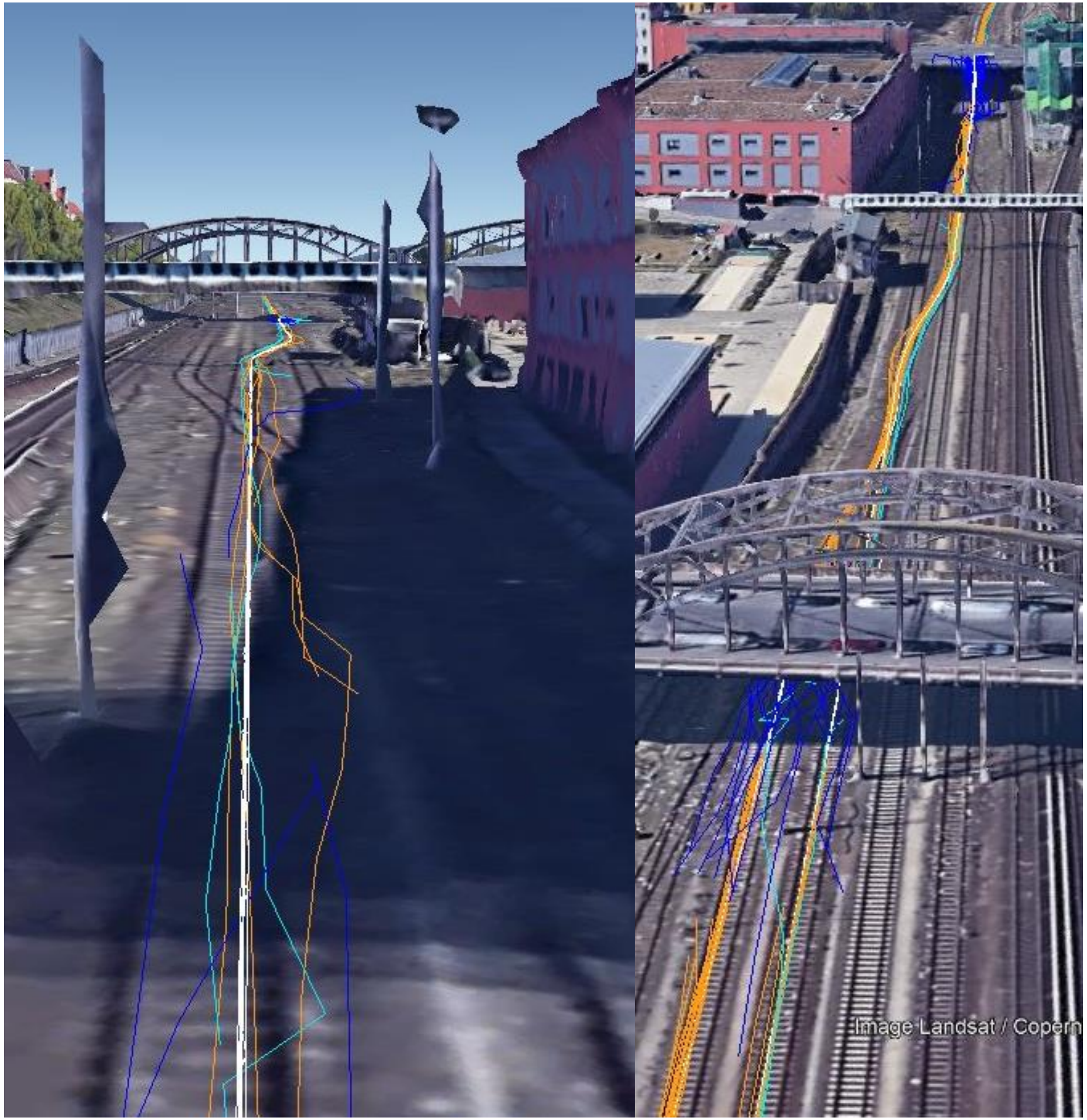


Data Analysis

Reference Trajectories

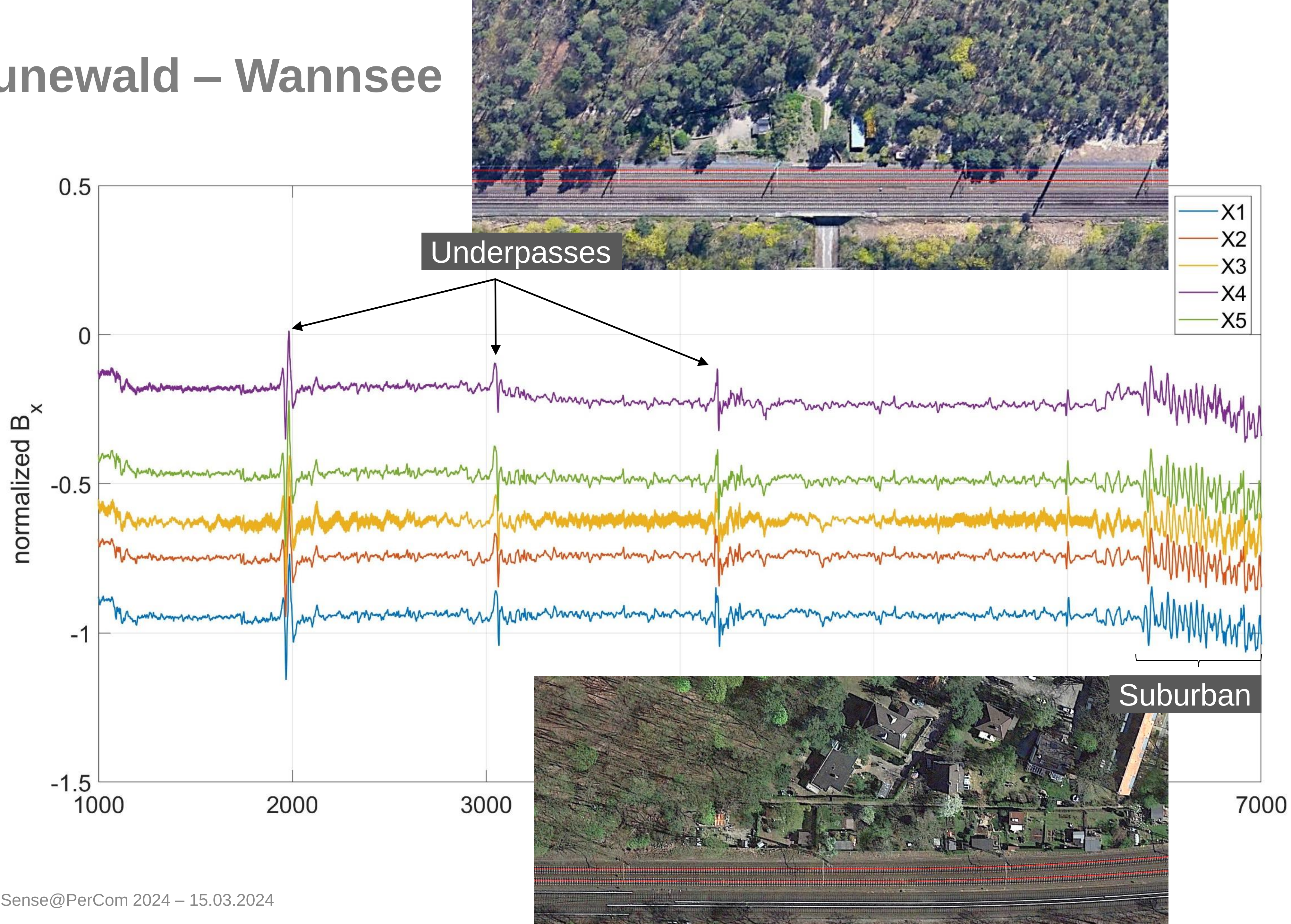
- No PVT 8.1%
- GNSS Standalone (3.5%)
- SBAS (15.0%)
- DGPS (73.4%)
- Leica1 (3.2%)
- Leica2 (1.1%)

of 2.242 km

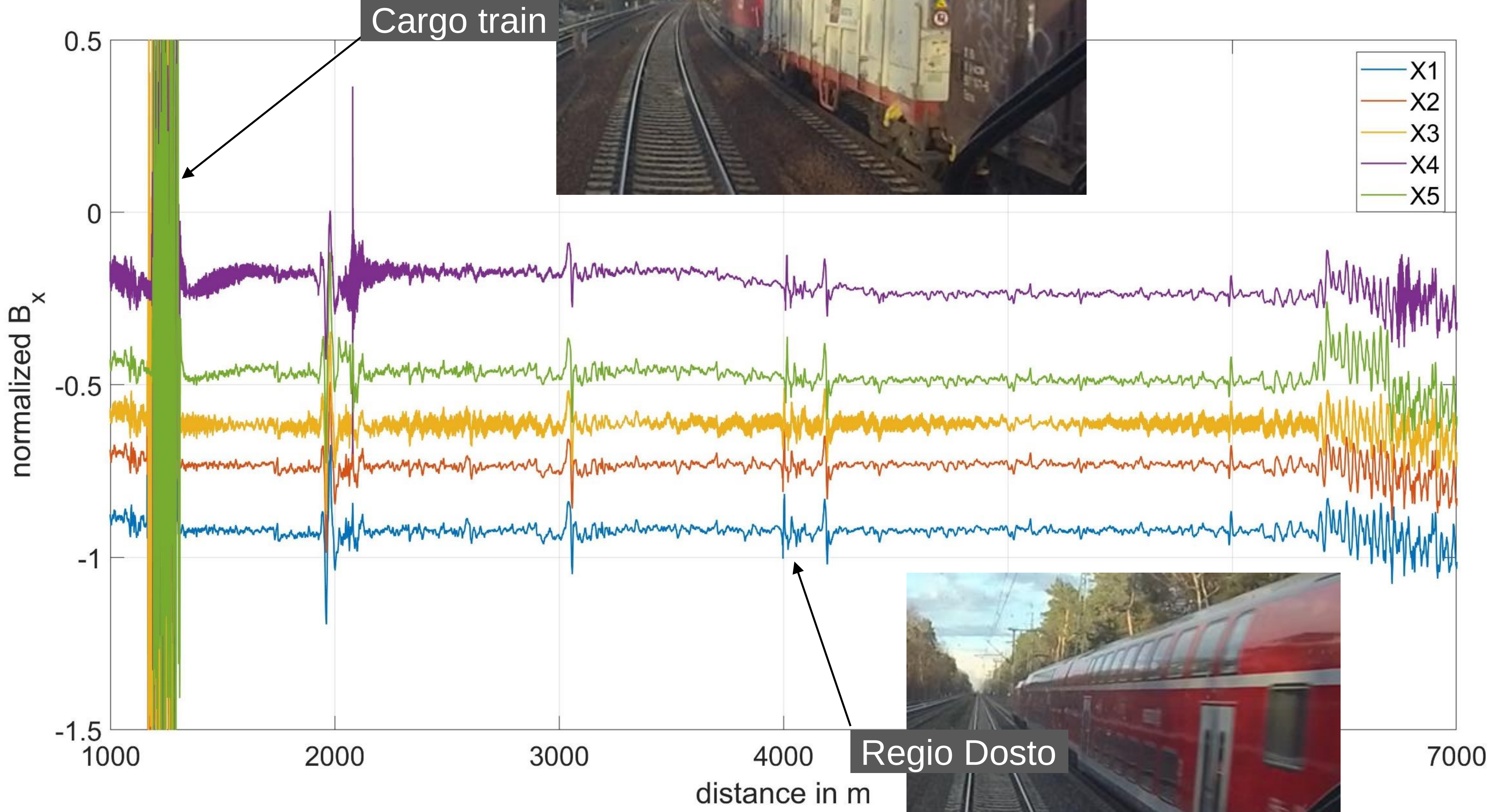


DLR

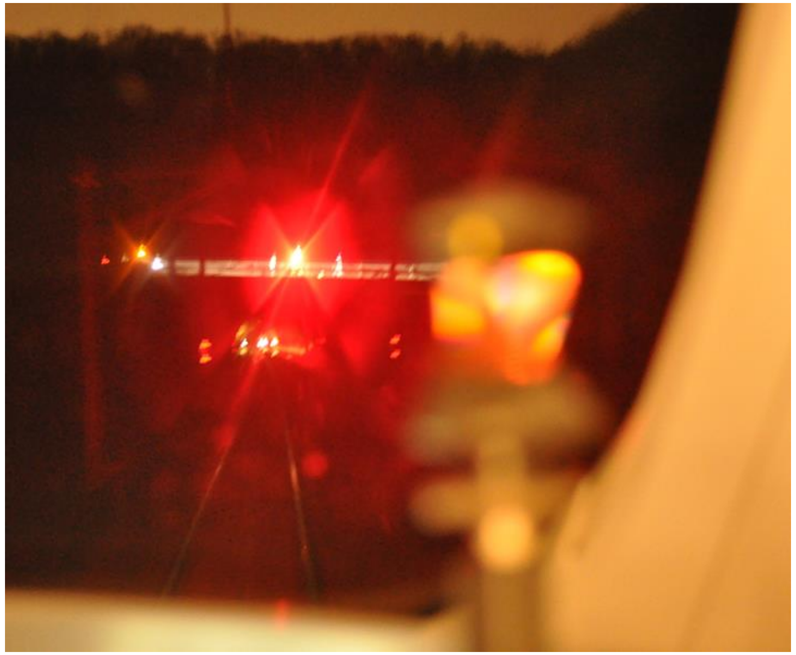
Expl: Grunewald – Wannsee
Features



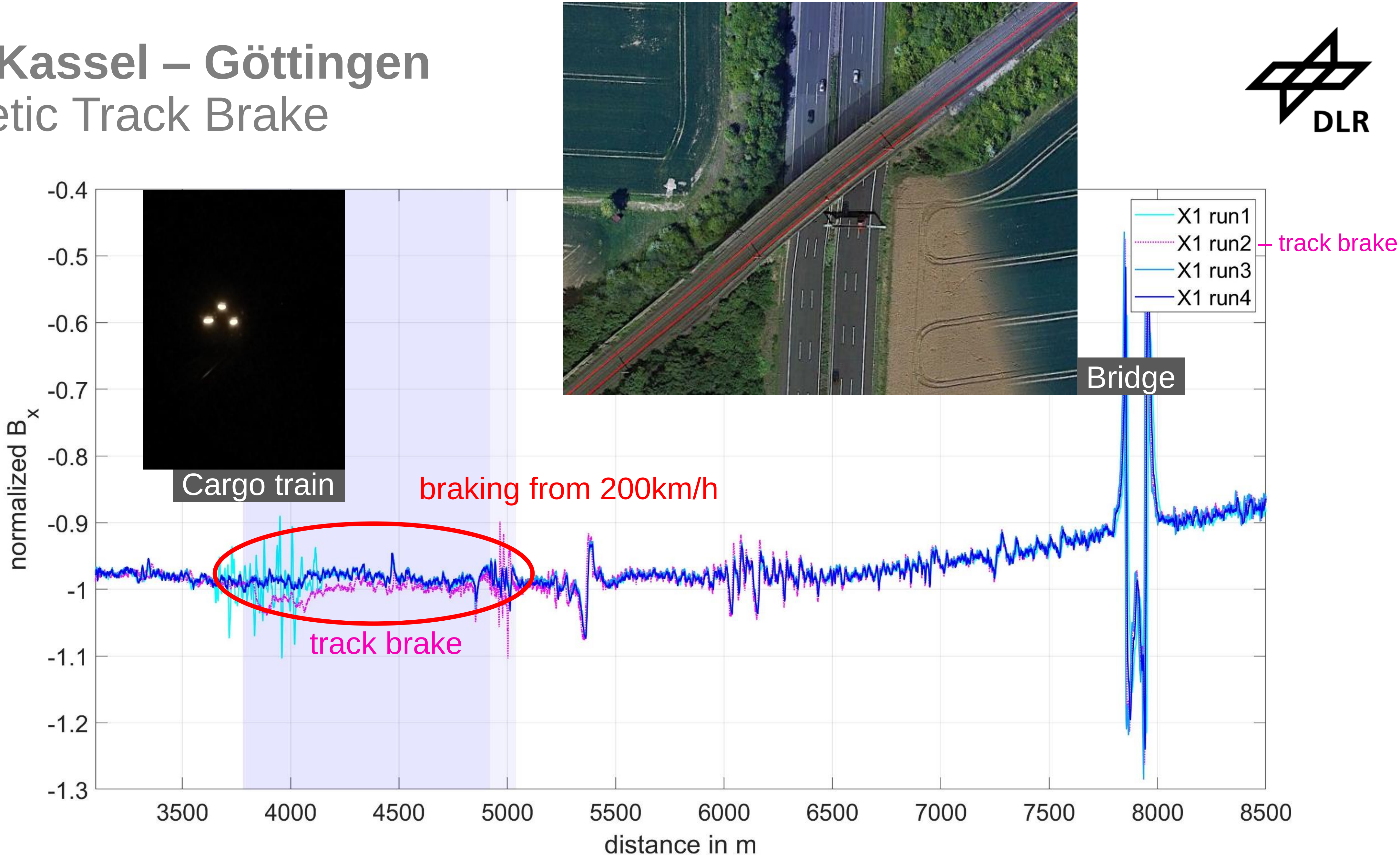
Expl: Grunewald – Wannsee
Other trains



Expl: Kassel – Göttingen: High Speed and Long Tunnels!

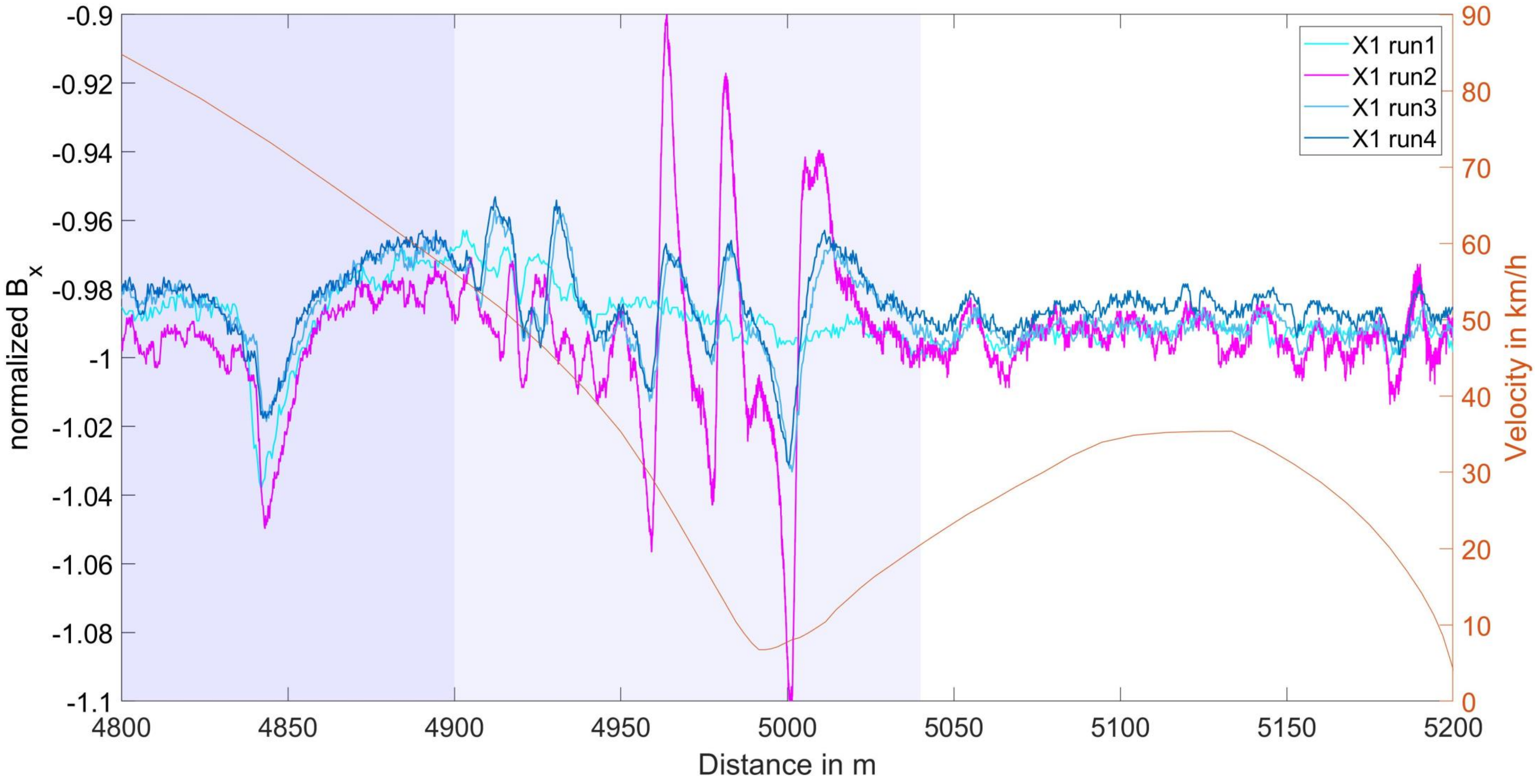


Expl: Kassel – Göttingen
Magnetic Track Brake

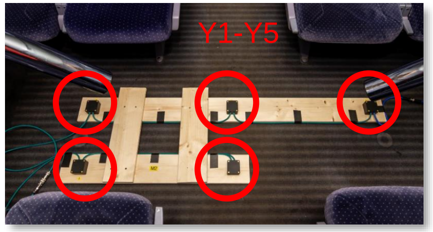


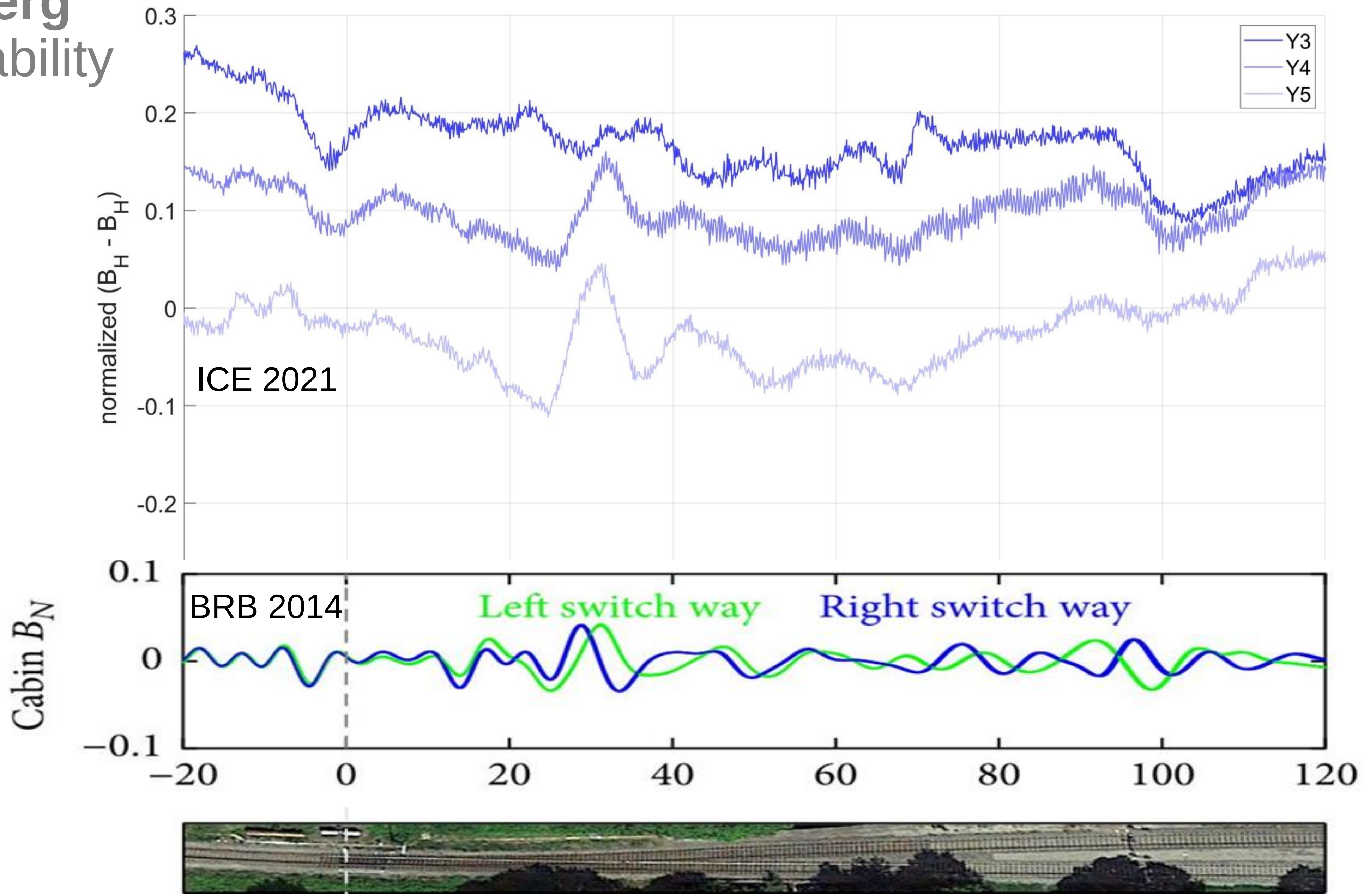
Expl: Kassel – Göttingen
Magnetic Track Brake

A. Lehner, T. Strang, O. Heirich, B. Siebler, S. Sand, P. Unterhuber, D. Bousdar Ahmed, C. Gentner, R. Karasek, S. Kaiser: ***Impact of Track Brakes on Magnetic Signatures for Localization of Trains.*** 5th International Conference on Railway Technology: Research, Development and Maintenance 2022, Montpellier, France



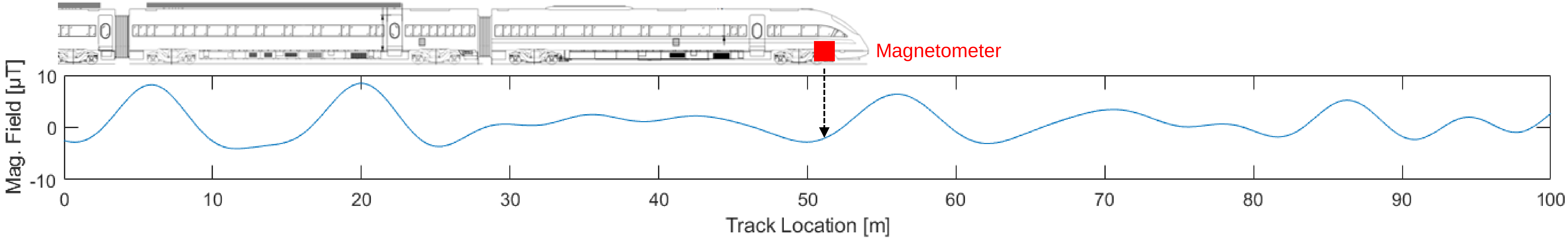
Expl: Friedberg
Long term stability

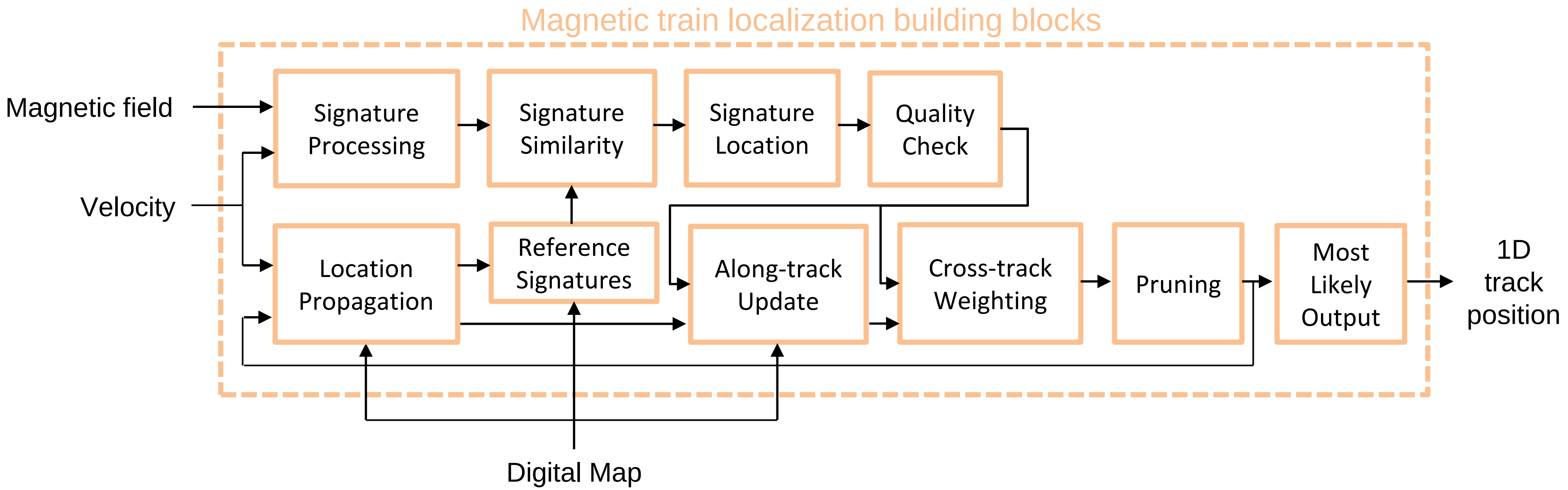




Magnetic Localization

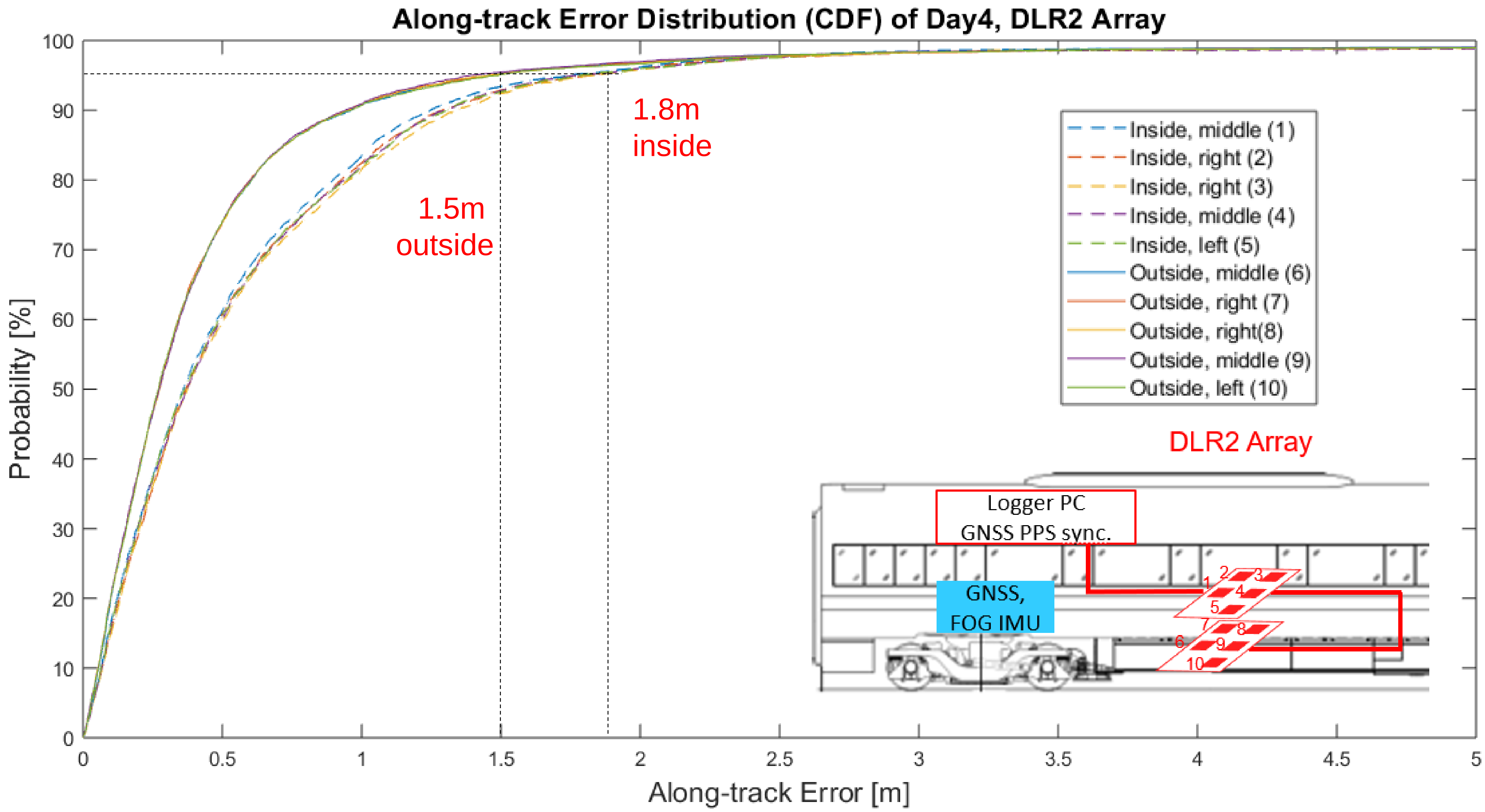
Magnetic localization





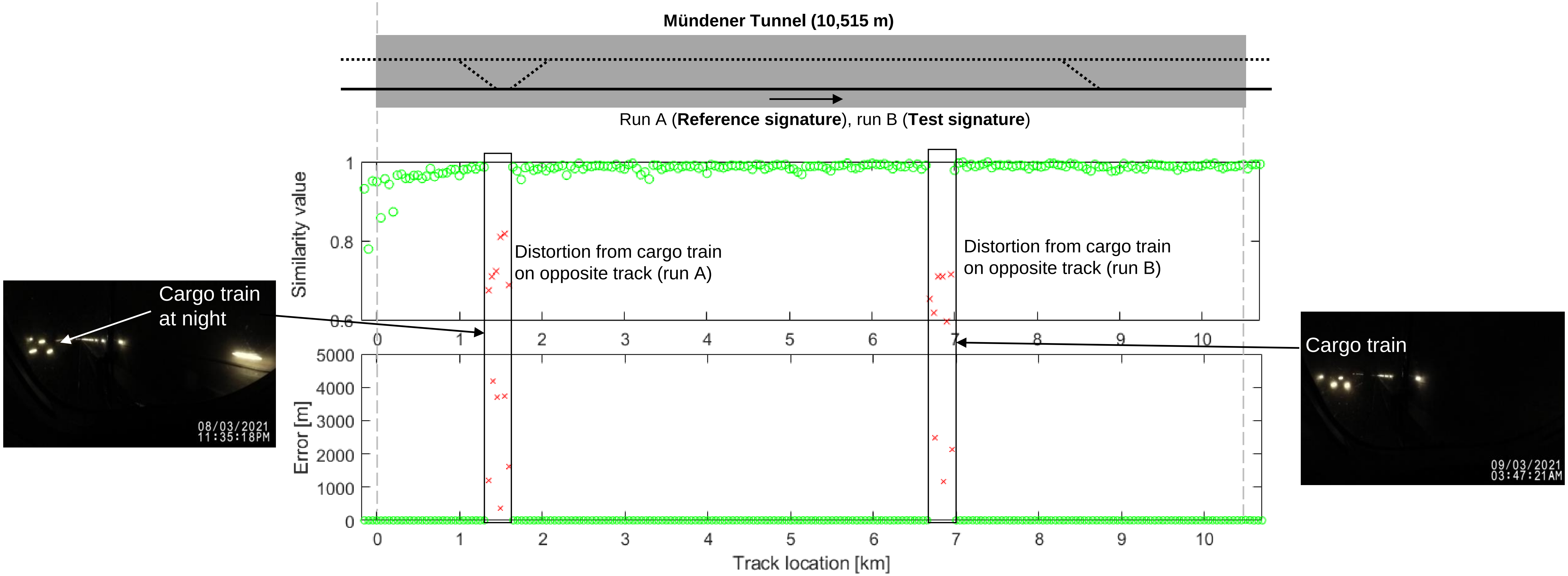
Along-track accuracy

Heirich, Oliver und Siebler, Benjamin und Lehner, Andreas und Strang, Thomas und Sand, Stephan (2022) *Magnetic Train Localization: High-Speed and Tunnel, Experiment and Evaluation.* ION GNSS+ Conference 2022, 21.-23.Sept.2022, Denver CO, USA.



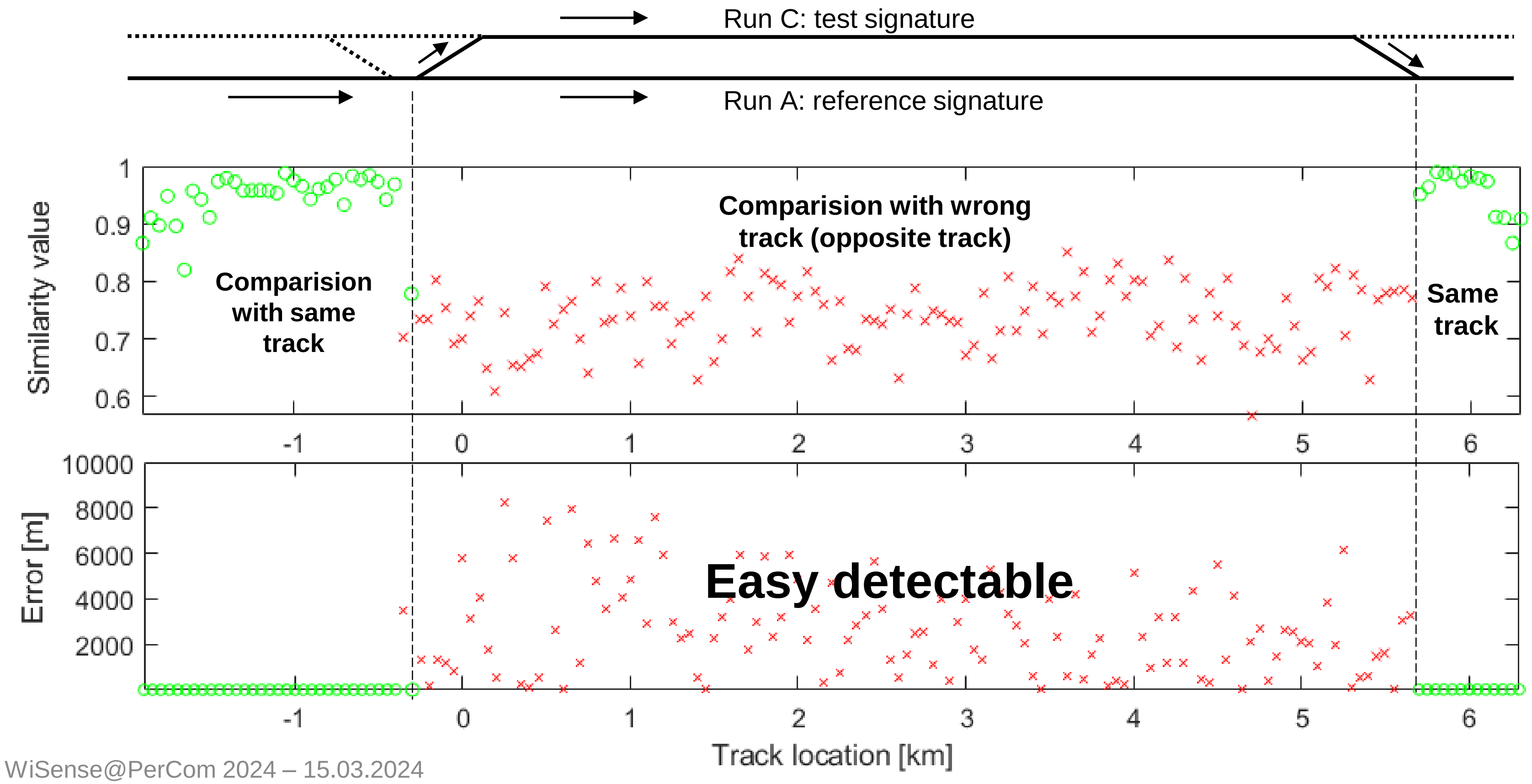
Track-selective magnetic localization

- Along-track localization: positioning availability with detected and excluded distortions is > 98%
- O, X is from a detector, not from data labeling



Track-selective magnetic localization

- Cross-track: switch & track identification inside tunnel
- O, X is from a detector, not from data labeling



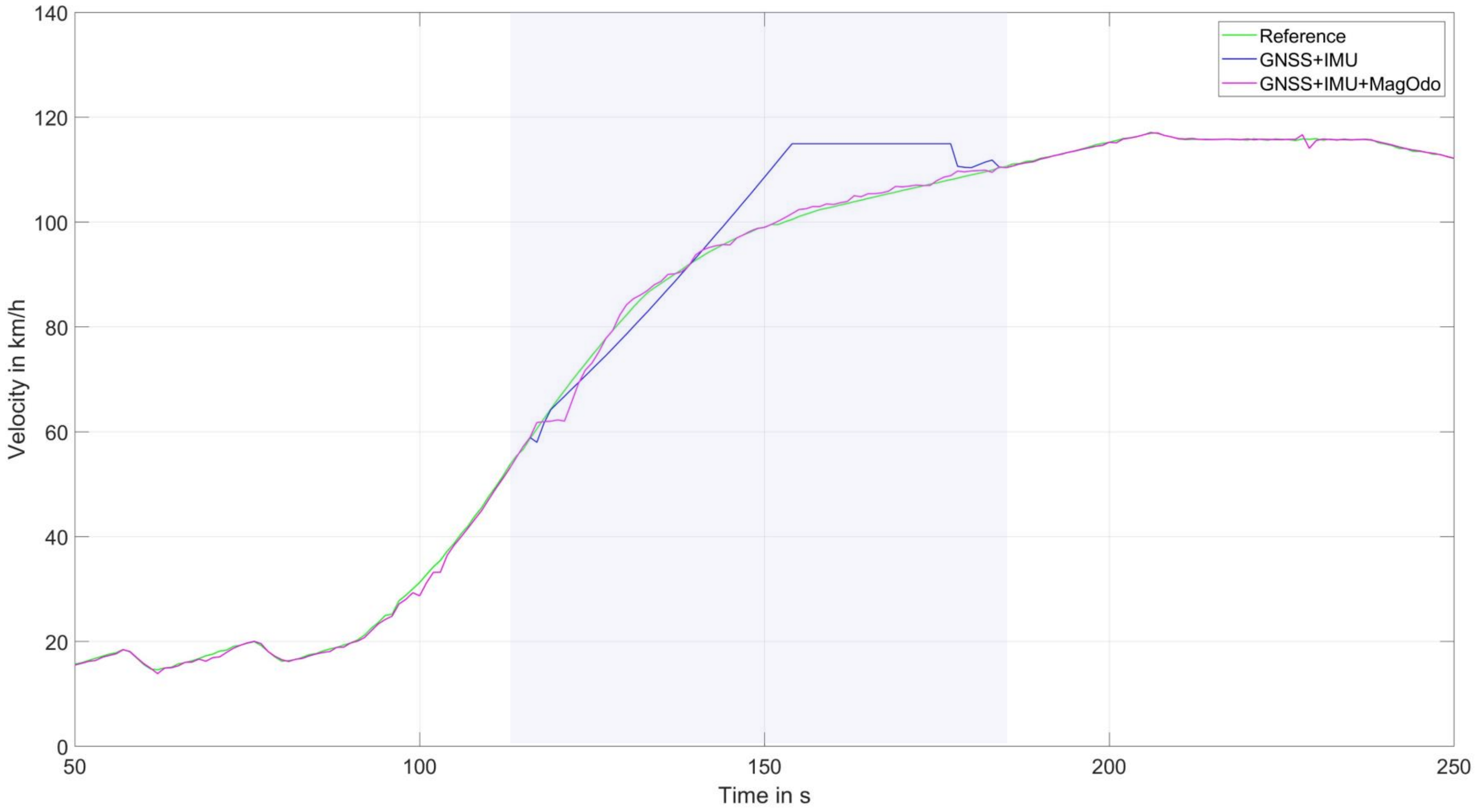
Integration

Magnetic Odometry integrated into TrainCAS

Example:

Speed estimation inside Leinebuschtunnel (1.740m)

with magnetic odometry speed error < 1.7 km/h (RMSE) in tunnel, even less along the entire track outside tunnels

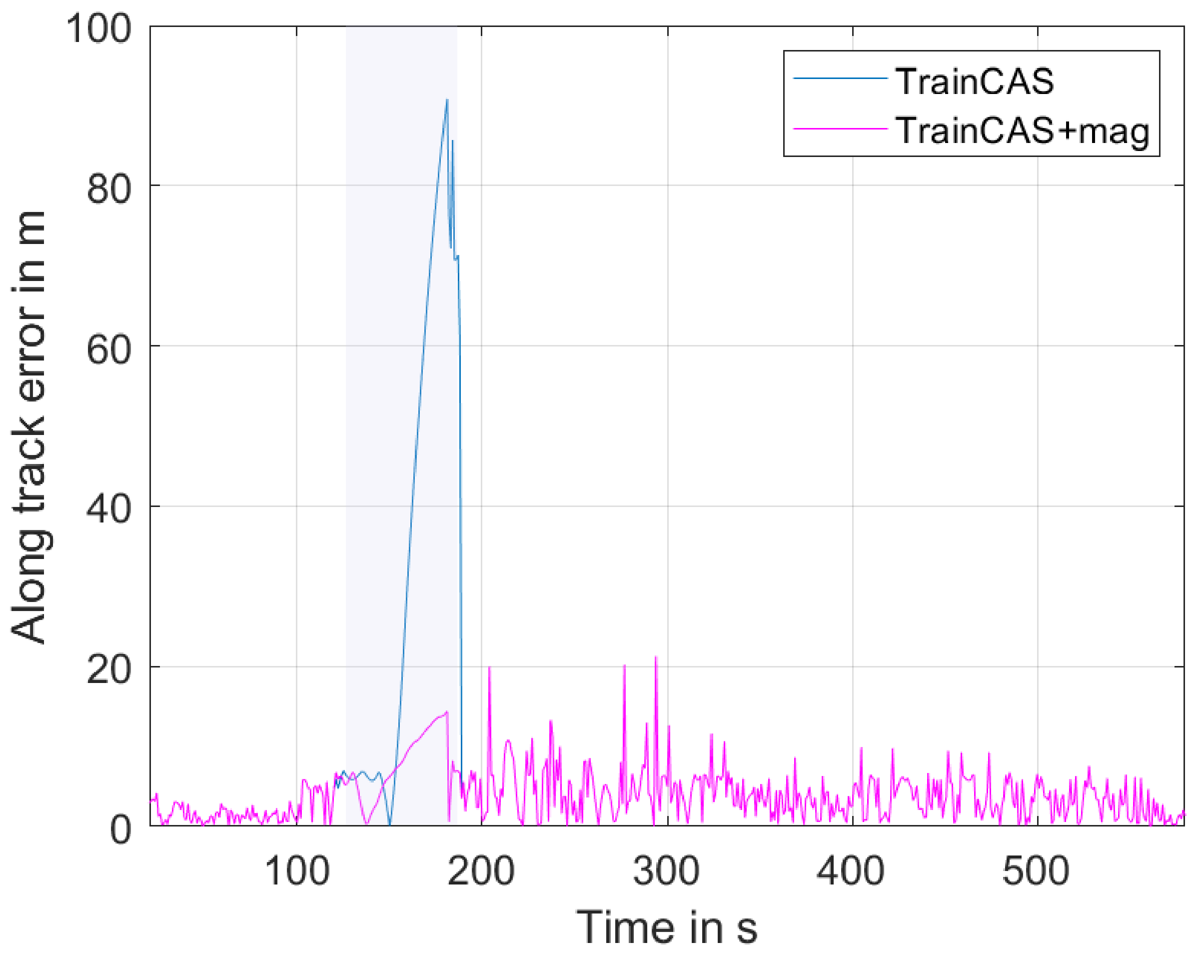


Magnetic Localization integrated into TrainCAS

Example:

Localization error inside Leinebuschtunnel (1.740m)

with magnetic localization < ~20m



Summary and Outlook

Findings

- Localization accuracy in along-direction is comparable to GNSS (95%: 1.5m sensor outside, 1.8m sensor inside)
- 100% track-selectivity: It is possible to re-identify the correct track and a track change at a switch, also inside tunnels of arbitrary length
- Other trains causing distortions: can be handled with fault detection
- Speed error was below 1.7 km/h (RMSE) in integrated system with support of magnetic signatures

Conclusion

- Magnetic signatures are a major improvement to train localization and odometry
- Best results if magnetic odometry & localization combined with GNSS, IMU and digital track map for continuous train localization and integrity monitoring

Teamwork

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