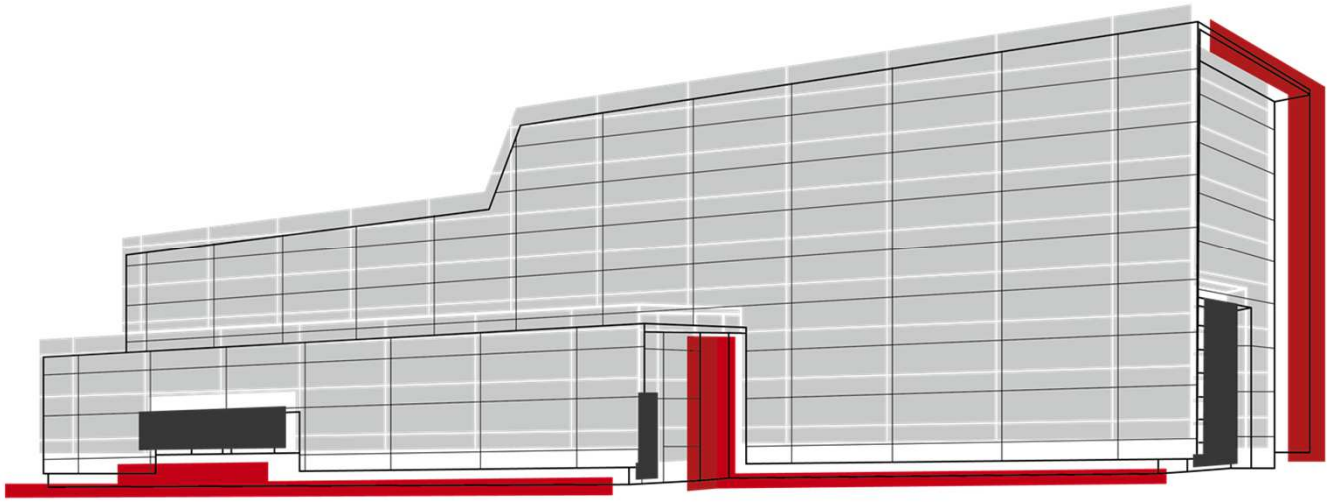
Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin
Nationales Metrologieinstitut

Bistatic wind lidar system for traceable wind vector measurements with high spatial and temporal resolution

Stefan Oertel



Competence Center for Wind Energy (CCW)

Why wind lidar systems?

Lidar – Light detection and ranging

Wind energy sector:

Traceable wind speed measurements necessary for

- Wind potential analysis (site assessment)
- Power curve testing

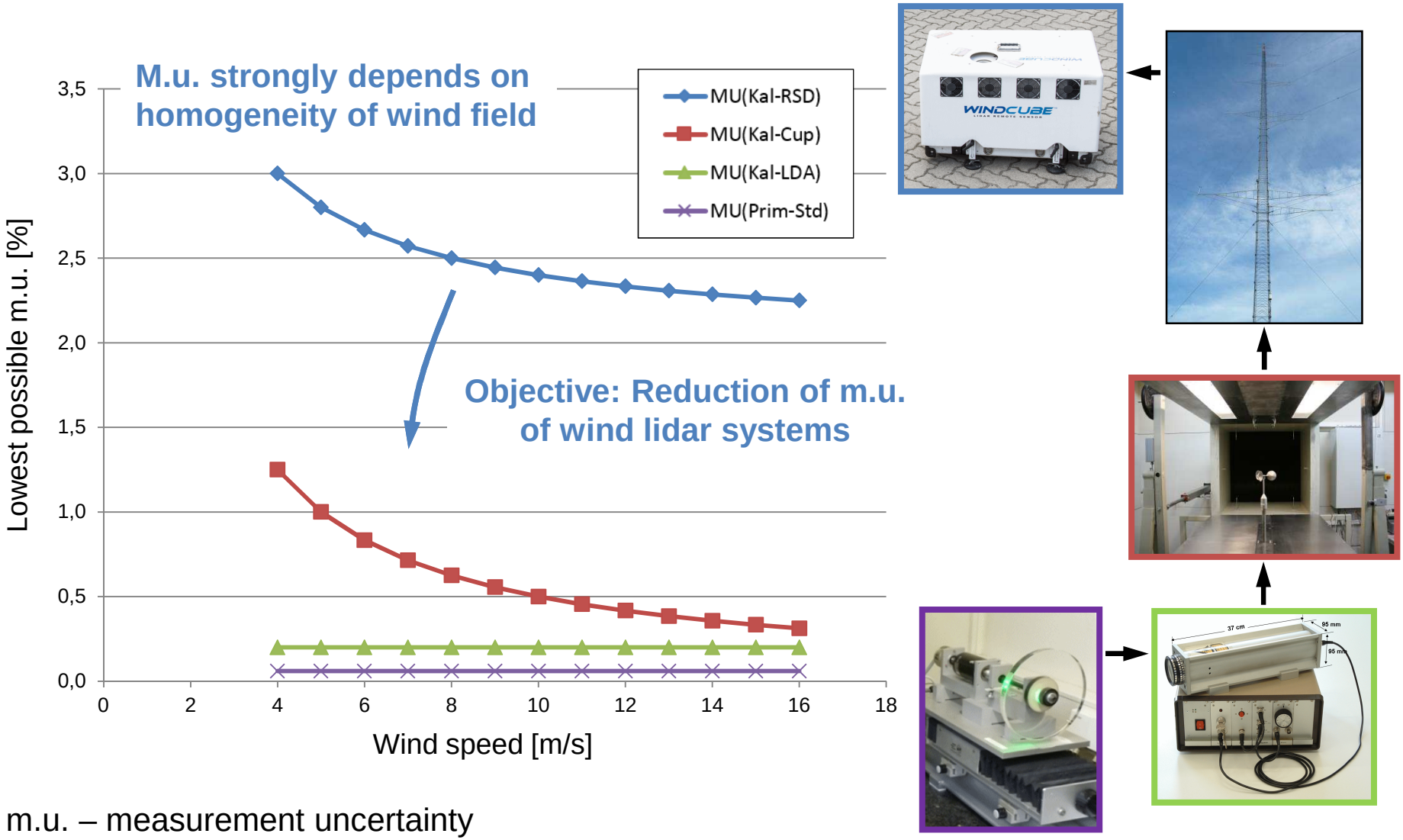
Most precise wind speed measurements:
Wind met masts with cup anemometers

- High effort for mast heights > 100 m
- Expensive

Wind lidar (optical wind remote sensing devices)

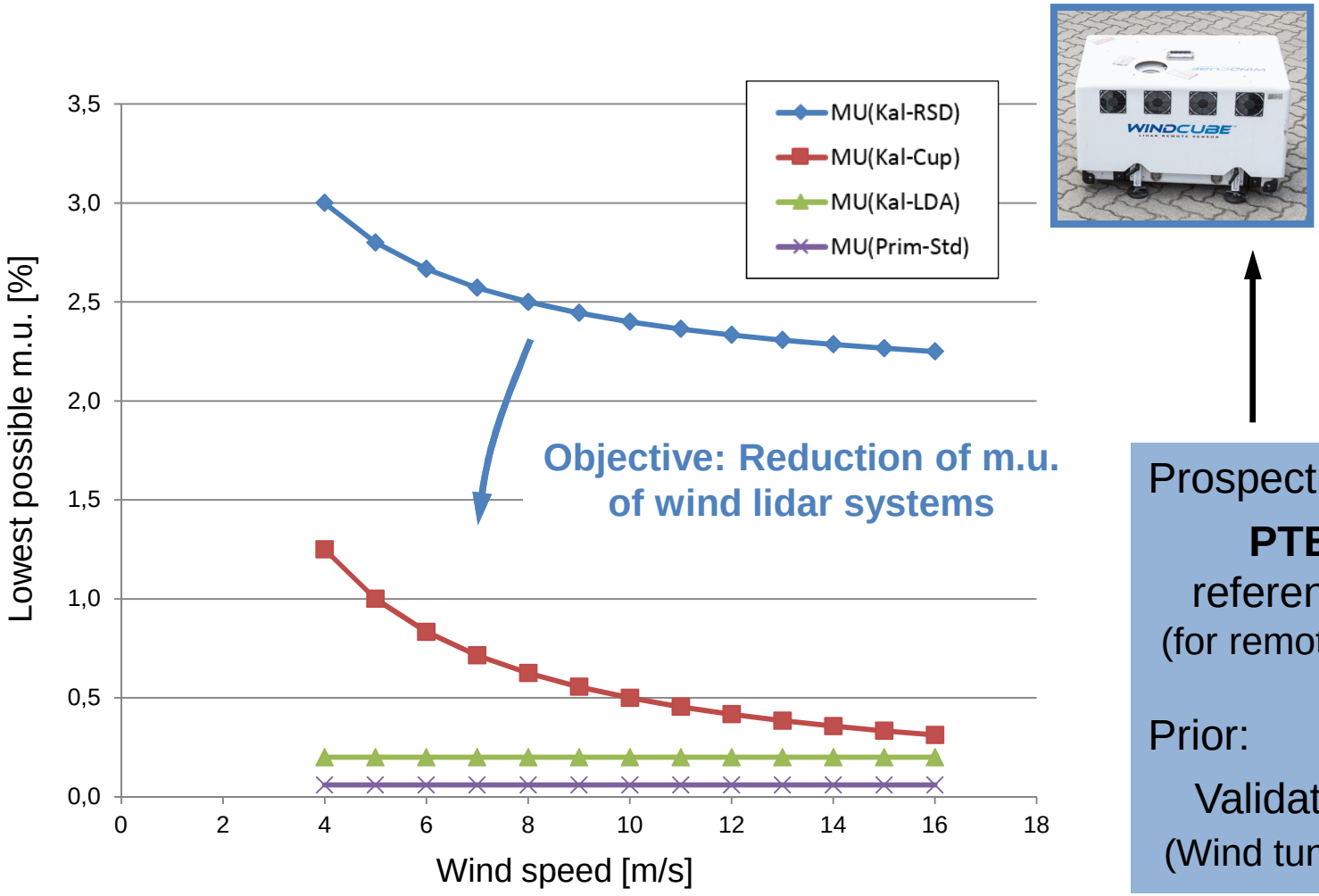
- Technical and economical more reasonable
- **Traceability ?**

Traceability of wind lidar systems



m.u. – measurement uncertainty

Traceability of wind lidar systems



Prospective:

PTB lidar as reference standard (for remote sensing dev.)

Prior:

Validation required (Wind tunnel test facility)

m.u. – measurement uncertainty

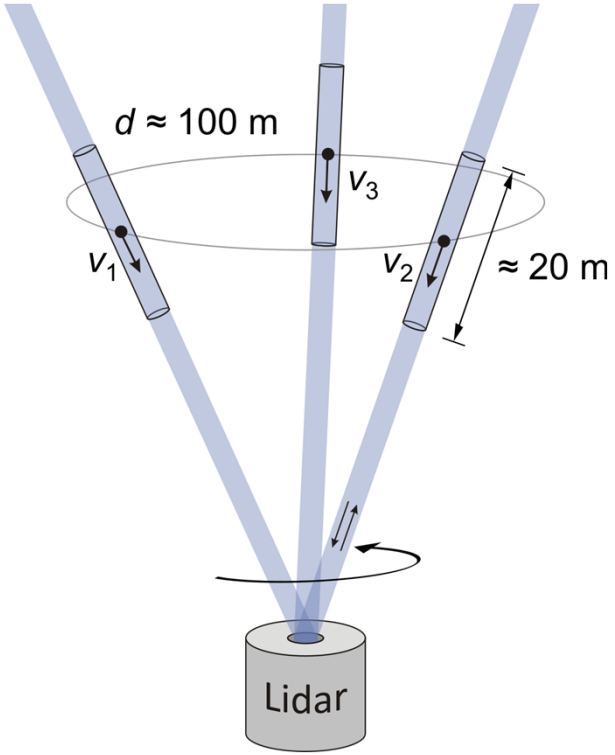
Monostatic measurement principle

Conventional lidar systems

Large measurement volume

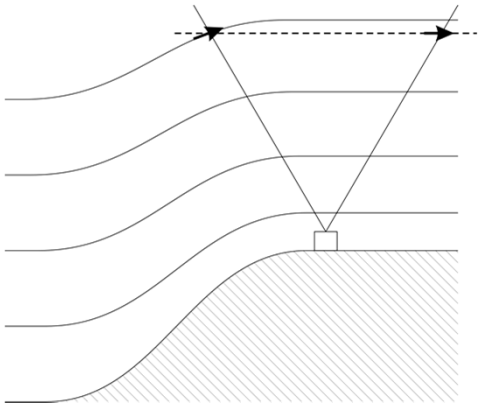
Determination of velocity vector by tilting the transmitting/receiving unit

→ **High spatial and temporal averaging**



One common transmitting and receiving unit

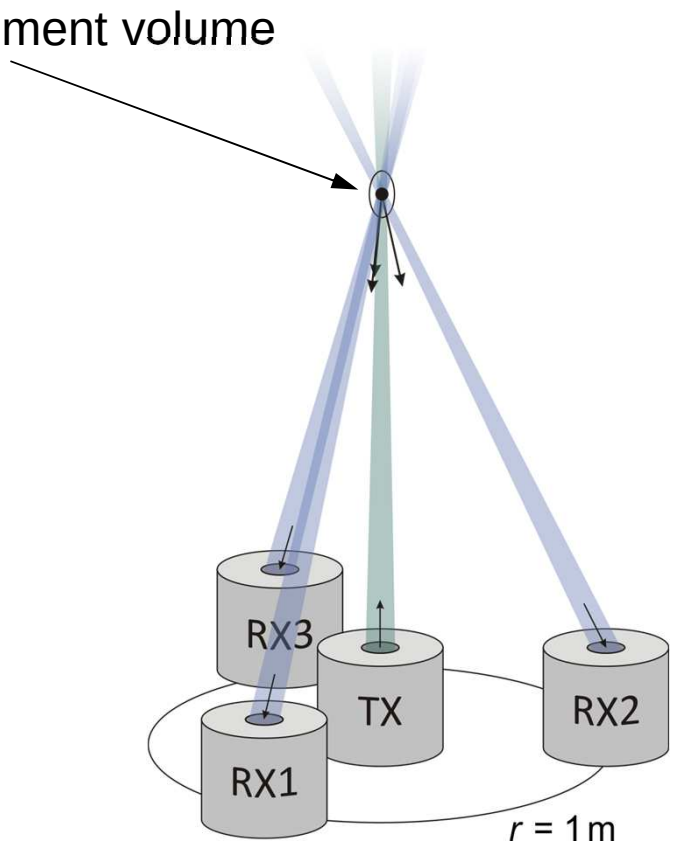
Complex terrain (inhomogeneous wind field)



Measurement failure up to 10 % possible

Bistatic measurement principle

PTB lidar



One transmitting and three receiving units

Advantages

- High spatial resolution / small meas. volume:
  - 100 m: length 0.6 m; ø 6 mm
  - 200 m: length 2.4 m; ø 12 mm
- Measurement of complete velocity vector by means of single aerosols („3C simultaneous“)

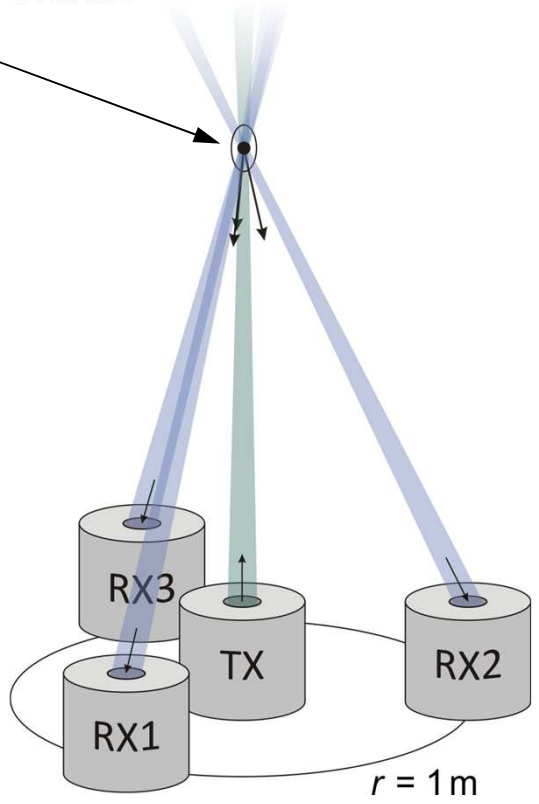
Challanges

- **Adjustment very sensitive**
- Little scattering light (low SNR)
- High frequency resolution necessary (acute angle)

Bistatic measurement principle

PTB lidar

Small measurement volume



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Comparison measurements with wind met mast (WMM):

Deviation within measurement uncertainty of cup anemometers of WMM

for homogeneous **and inhomgneous** wind fileds

Wind tunnel test facility for PTB lidar

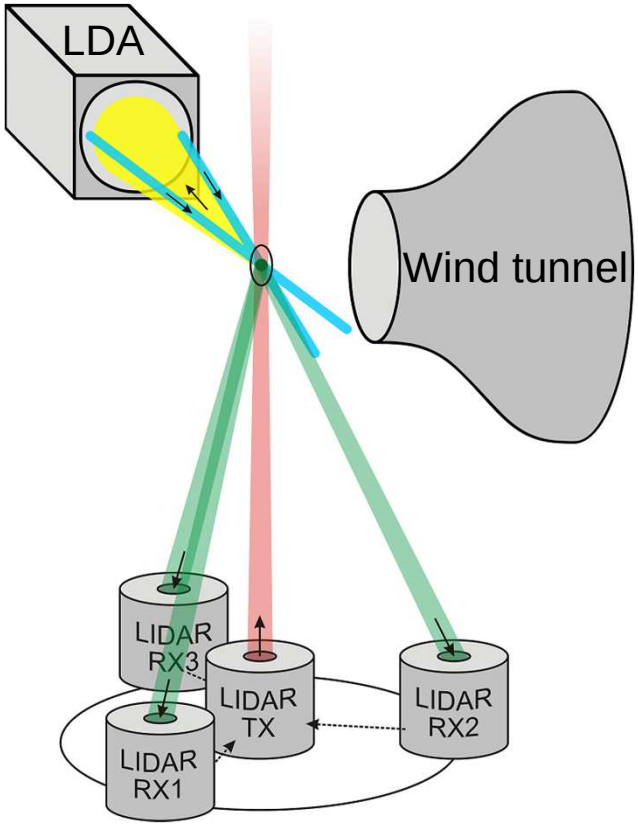
Controllable and well-defined wind flow fields and

precise flow speed reference traceable to SI units (LDA)

for

- Analysis
- Validation

of the bistatic PTB lidar



Wind tunnel test facility (WTTF)

WTTF requirements

- Minimum working distance: 5 m between PTB lidar and wind tunnel test section
- High flow quality (low turbulence level ≤ 0.5 %, high homogeneity)
- Cross section (nozzle): 50 x 50 cm², test section length: 75 cm
- Flow velocity: 4 m/s to 20 m/s
- Flow velocity traceable with laser Doppler anemometer (m.u. ≈ 0.15 %)
- Accurate localization of lidar measurement volume within the test section

Buildup of the WTTF on intermediate level in EULER-Building I (Competence Center for Wind Energy)

Wind tunnel:

- Maximum dimensions: 3,50 m x 6,70 m
- Test section position: → Diffusor, settling chamber

PTB lidar and wind tunnel test facility

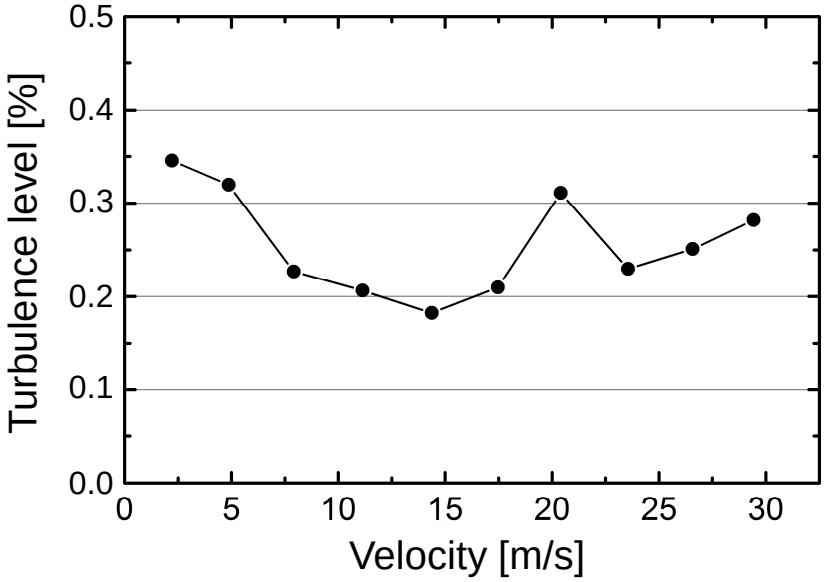
Wind tunnel: DEUTSCHE WINDGUARD

Measurement platform:

- Height: 8 m
- Dimensions: 8 x 5 m²
- Hatch under test section

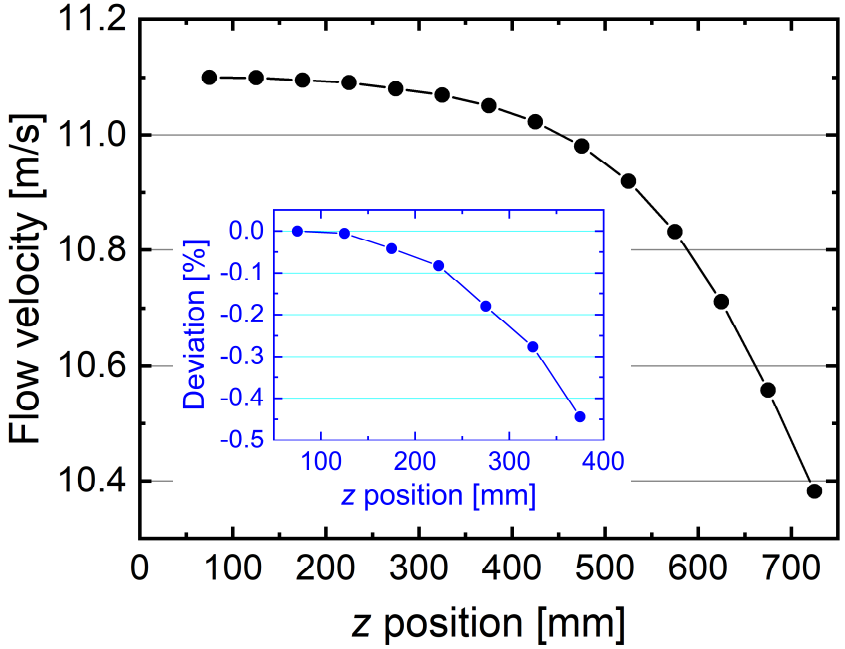
WTTF: Characterization

Turbulence level



- Flow velocity up to 30 m/s
- Turbulence level ≤ 0.35 %

Flow velocity (along test section)



- Open test section

WTTF: Characterization (Lateral homogeneity)

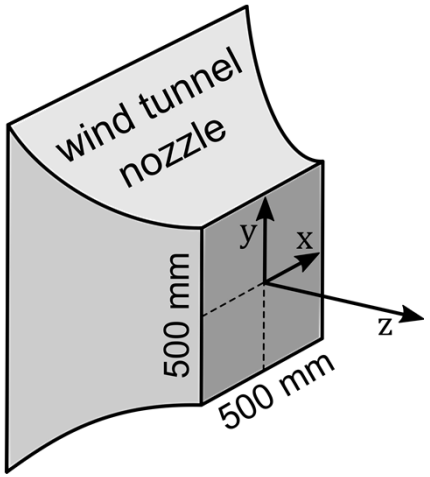
2D flow profiles along the test section

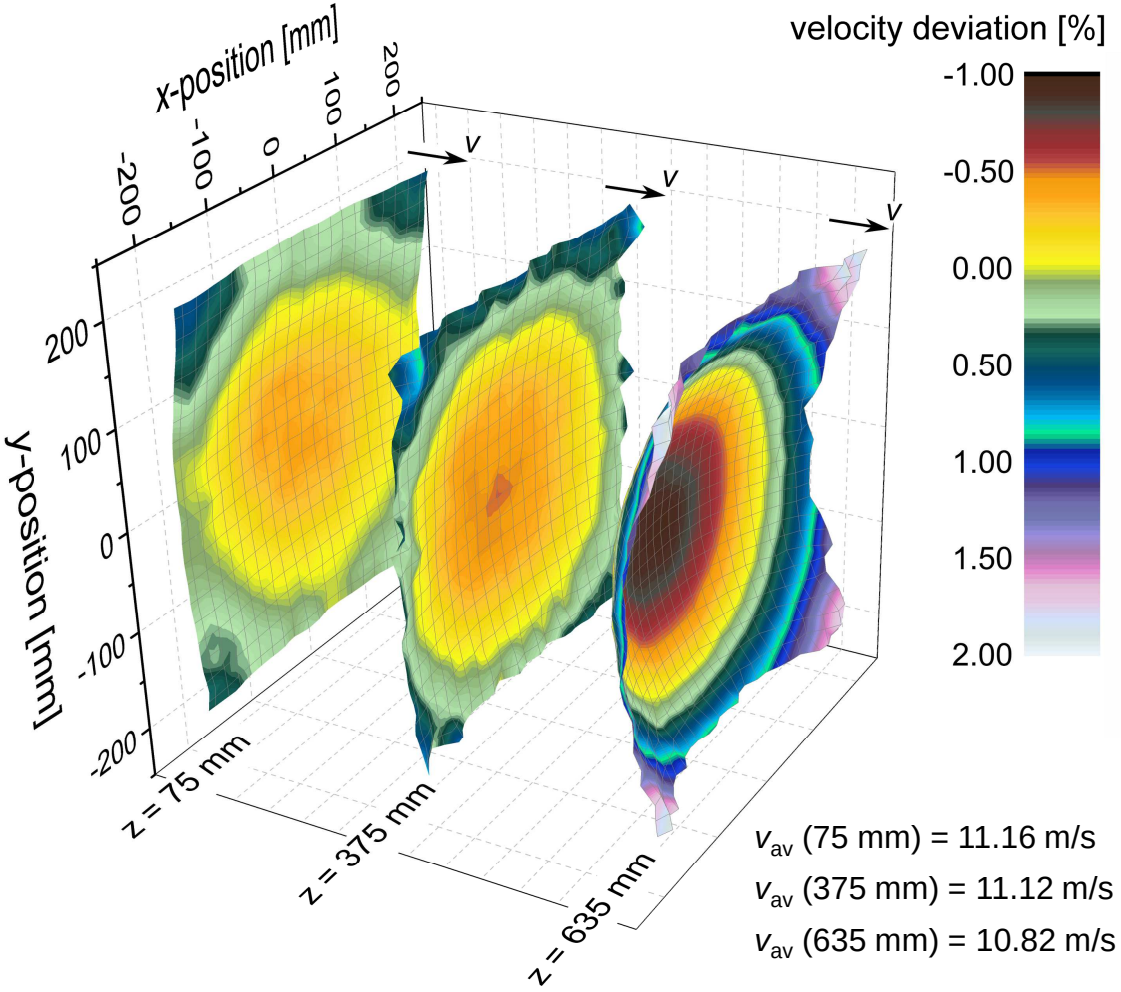
- Cross section: 400 x 400 mm^2
- 10 x 10 mm^2 steps

1st half of test section:

High homogeneity,

0.1 % per dm (r ≤ 100 mm)





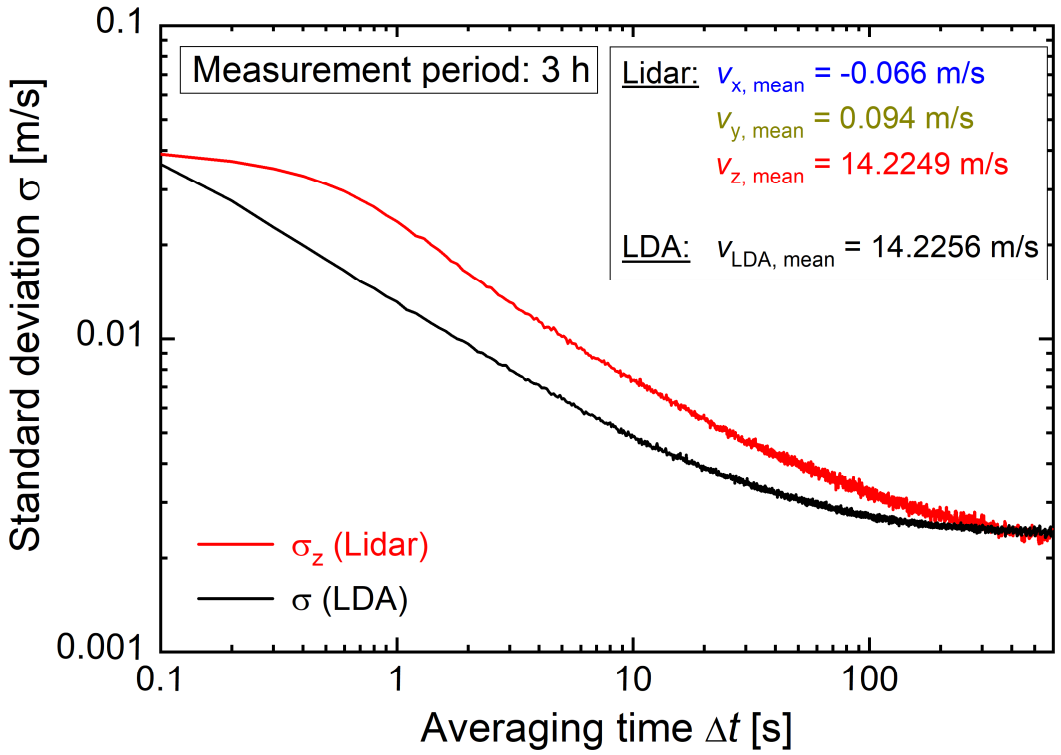
v_{av} (75 mm) = 11.16 m/s

v_{av} (375 mm) = 11.12 m/s

v_{av} (635 mm) = 10.82 m/s

First validation measurements I

PTB lidar vs. LDA



1. Averaging the acquired data over different time slots Δt
2. Calculation of standard deviation σ for each Δt

- small Δt: → 0,04 m/s
  Turbulence of WT
- large Δt: → const.
  Long-term drift of WT
- Deviation of mean values (3 h)
  Lidar ↔ LDA:
  0.05 ‰

Oertel et al., "Validation of three-component wind lidar sensor for traceable highly resolved wind vector measurements", *J. Sens. Sens. Syst.*, **8**, 9-17, 2019
DOI: 10.5194/jsss-8-9-2019

First validation measurements I

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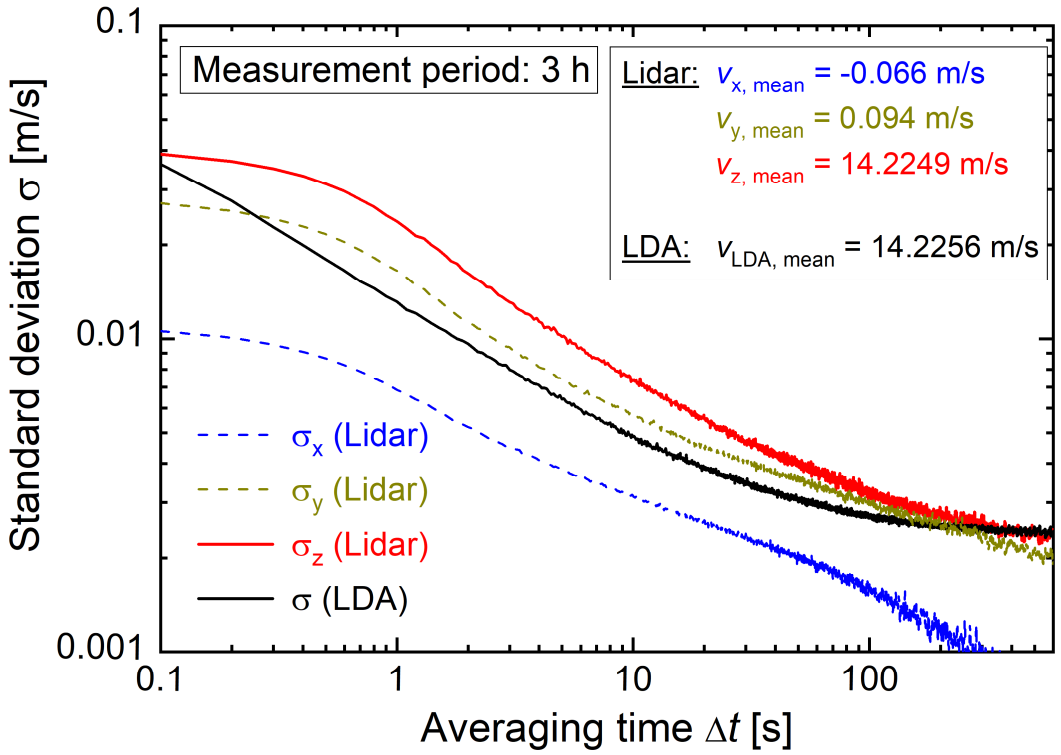

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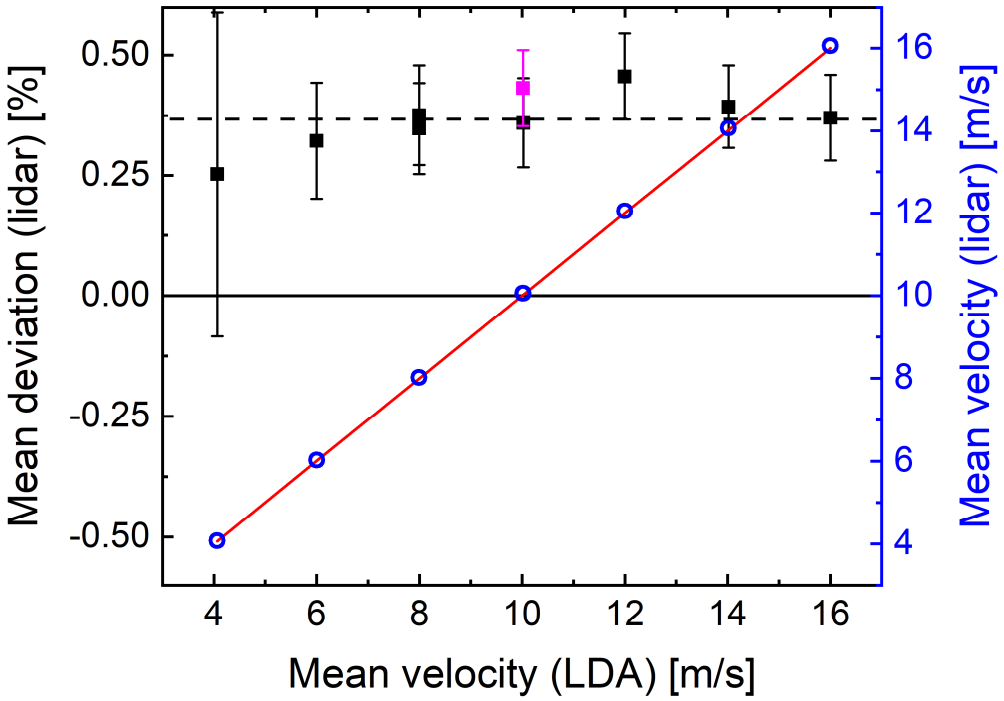
First validation measurements II

PTB lidar vs. LDA

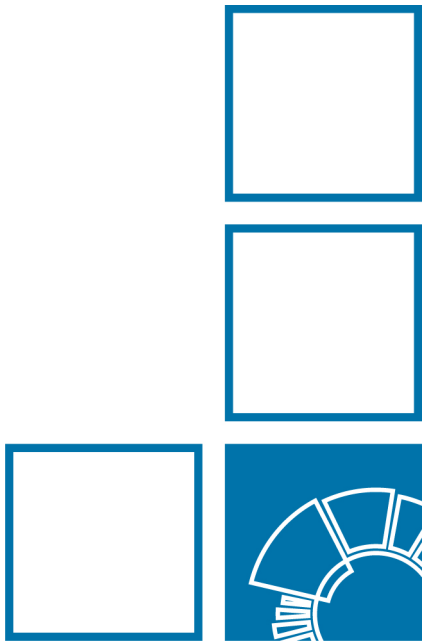


- Measurement time: 1 h
- Averaging time Δ*t:* 1 s

- 90° rotation

- Mean deviation: < 0.5 %
- Average mean deviation:
  0.37 % ± 0.06 %

→ Measurement height



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