Relevant parameters during anemometer calibration

Dieter Westermann & Peter Busche

Deutsche WindGuard

Relevant parameters during anemometer calibration

- Find out what kind of wind tunnel induced parameters will influence the wind tunnel calibration
- Evaluate these parameters
- Assess the influence and indicate limits

tested parameters / influence

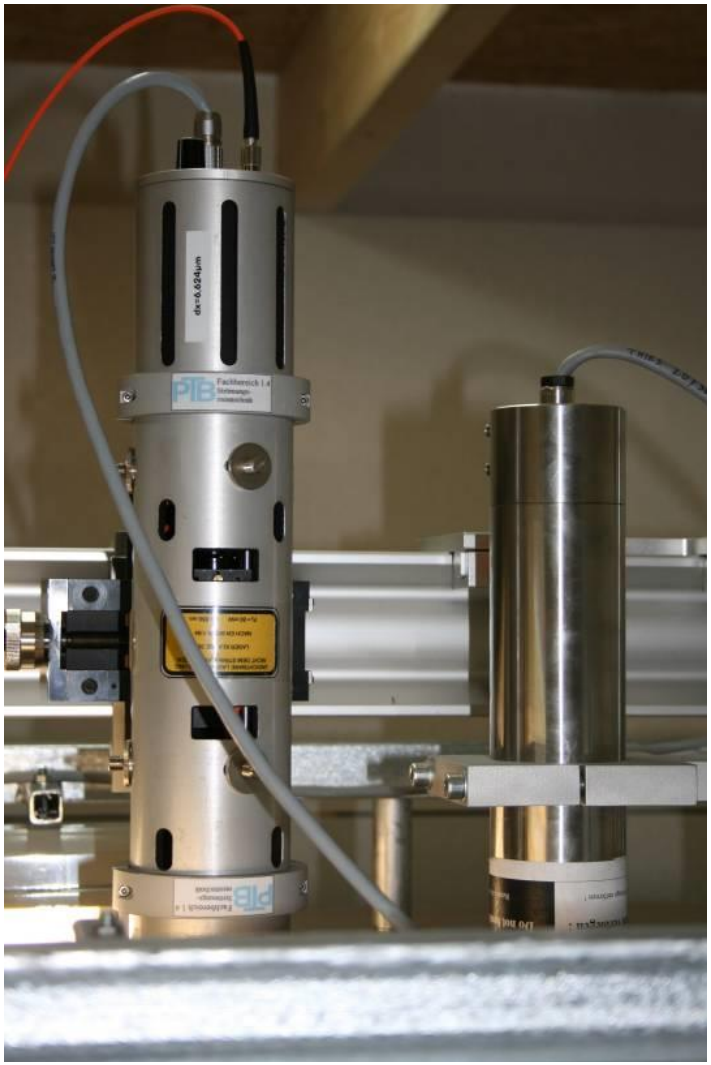
- Measurement of reference wind speed
- Repeatability of measurement results
- **Flow quality**;
  - wind tunnel design
  - Flow homogeneity
  - turbulence
  - flow conditioners
- Test section boundaries
- Positioning of anemometer within test section
- Air density / temperature

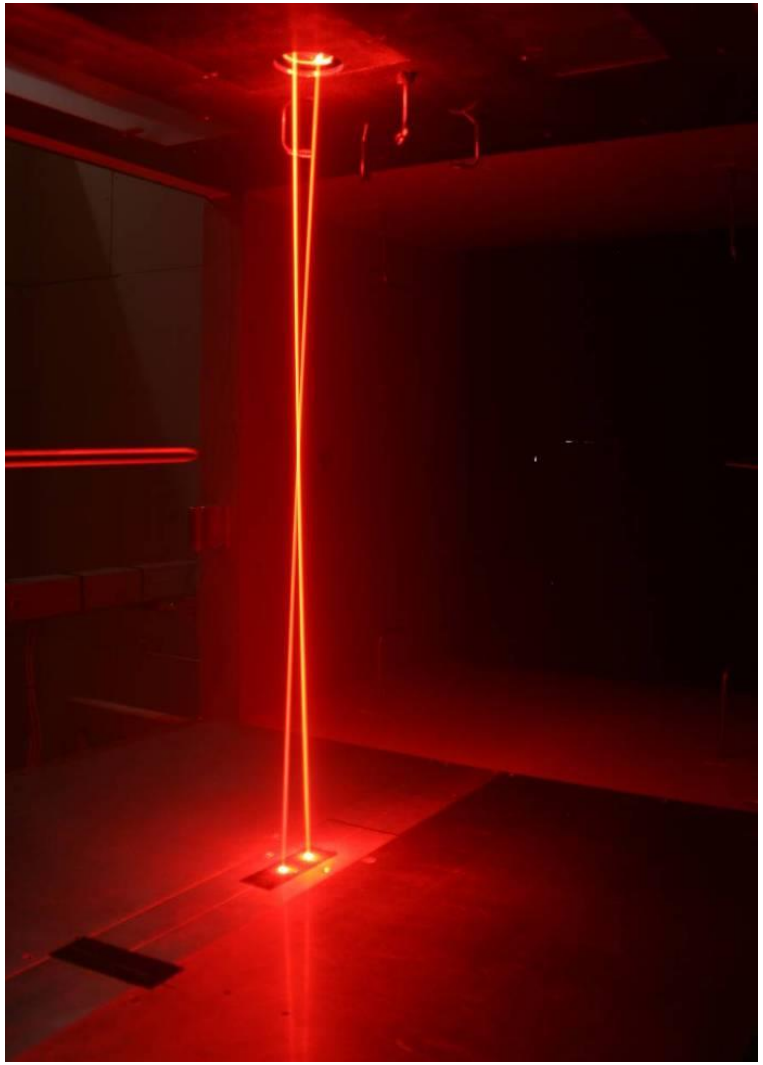
WindGuard Wind Tunnel Research

Documented Wind Tunnel Investigations since 2003

Year	Title	Topic
2003-2007	Westermann D.; Internal investigation Geometrical interference	
2006	N. Balaresque; Master thesis Blockage effects on Anemometer Calibration	Blockage
2008	U. Tolle; Bachelor thesis Untersuchung zur Strömungsrichtungsbestimmung im Windkanal	Flow direction
2009	C.Herold; Bachelor thesis Messunsicherheiten bei der Kalibrierung von Schalensternanemometern im Windkanal	Uncertainty due anemometer mounting
2009->	R. Mueller; NMI Germany (PTB) Comparison between national flow standard and WindGuard wind tunnel speed	Reference speed accuracy
2010	J. Kopmann; Bachelor thesis Vermessung der Strömung in der halboffenen Messstrecke eines Windkanals mittels Pitot- Sonden	Flow quality
2010	J. Wilkening; Master thesis Ausarbeitung und Verifizierung eines Klassifikationsmodells für Ultraschallanemometer im Windkanal	Classification of sonic
2011	P. Löst; Bachelor thesis Untersuchungen der Anzeigegenauigkeit von Staudrucksonden	Comparison between LDA and ISO 3966 Calibration factor
2011	H. Westermann; Bachelor thesis Entwicklung und Test eines Sensors zur Untersuchung der Sprungantwort eines Cup Anemometers	Step response
2011-2012	P.Busche; D.Westermann; Internal MEASNET document Intercomparison Test of MEASNET Wind Tunnels	MEASNET uncertainty
2012	F. Sczesny; Bachelor thesis Experimentelle Untersuchung des dynamischen Verhaltens von Schalensternanemometern	Step response; Classification
2013	R. Kuhlemann; Master thesis Untersuchung zum Einfluss turbulenter Strömungen im Windkanal auf das	Wind tunnel turbulence
2013	L.Büttelbrunn; Bachelor thesis Untersuchungen des Einflusses der Messstrecke eines Windkanals auf das	Influence due to test section boundaries
2013	Y. Zuelfikar; Master thesis Untersuchungen zur Beeinflussung der Strömungsqualität in Windkanälen durch Siebe	Wind tunnel turbulence

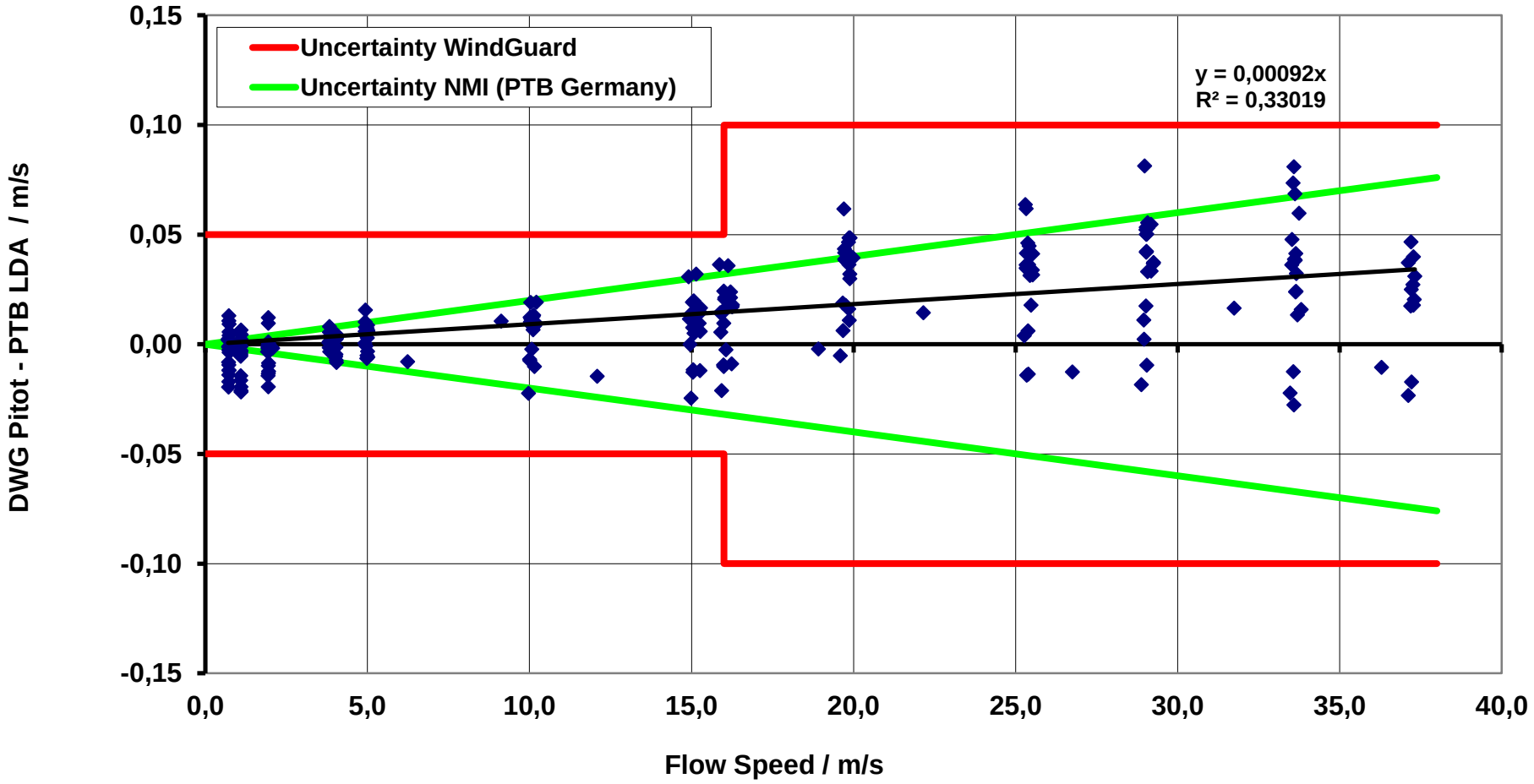
Project reference speed measurement with German National Metrology Institute (PTB)



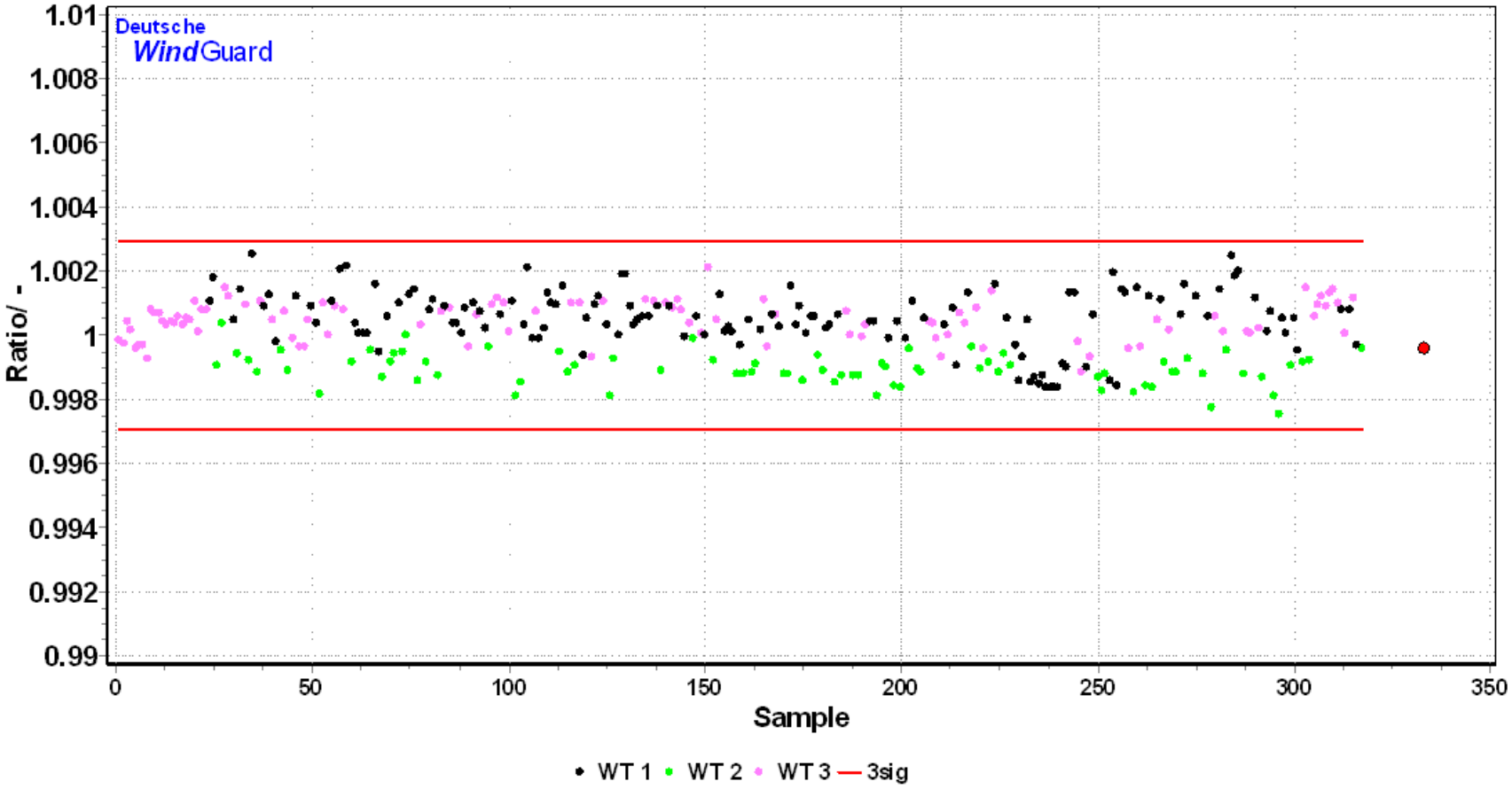


Project reference speed measurement with German National Metrology Institute (PTB)

Deviation WindGuard - German NMI (PTB)

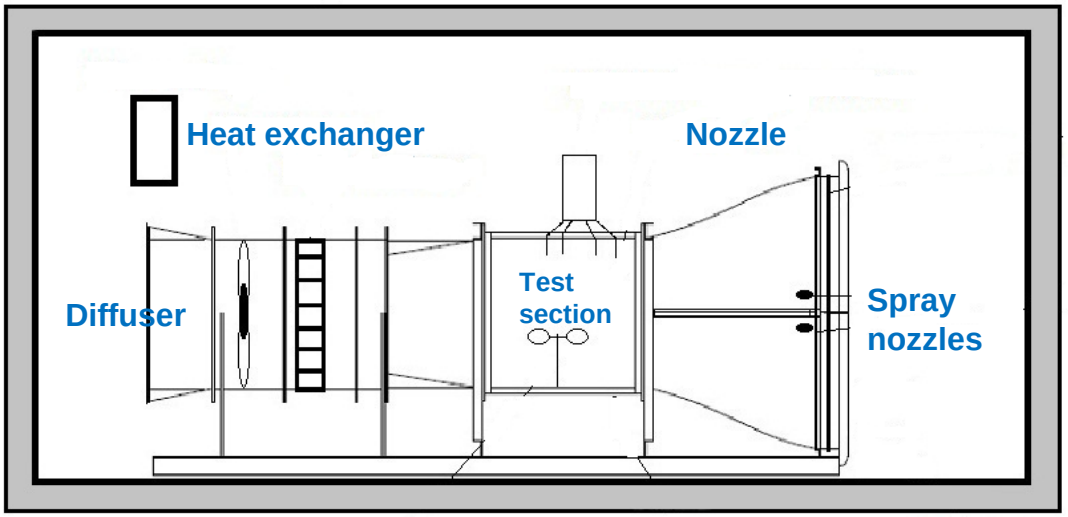


Repeatability during anemometer calibration

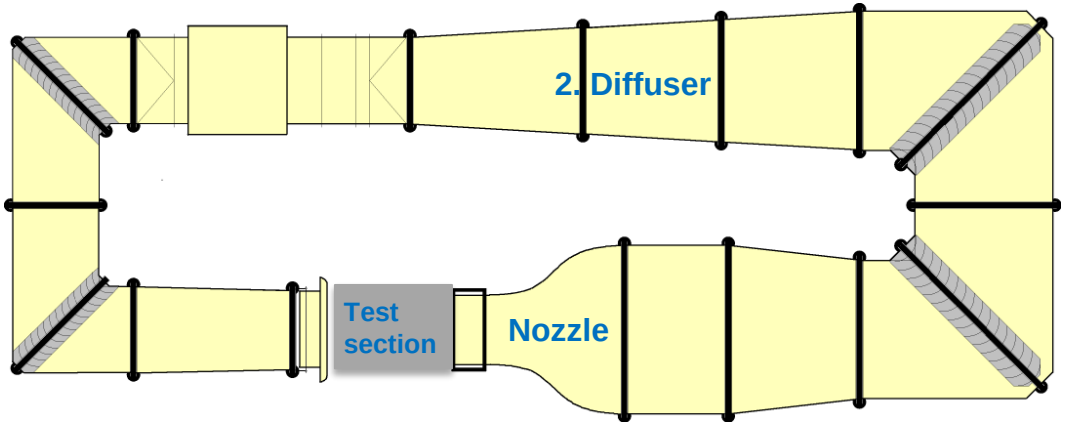


Tests Performed in Wind Tunnel of Different Design

1. Eiffel Wind Tunnel
   - Speed up 25 m/s
   - Closed test section
   - Test section 0.6 x 0.8 m
   - Contraction ratio 2.5
   - Temperature -20˚ - 40˚
   - Turbulence 1.0% - 6%



2. Closed Return Wind Tunnel
   - Speed up to 18 (30, 40) m/s
   - Semi open test section
   - Test section 1.0 x 1.0 m
   - Contraction ratio 5.0
   - Turbulence 0.2% – 1.0 %



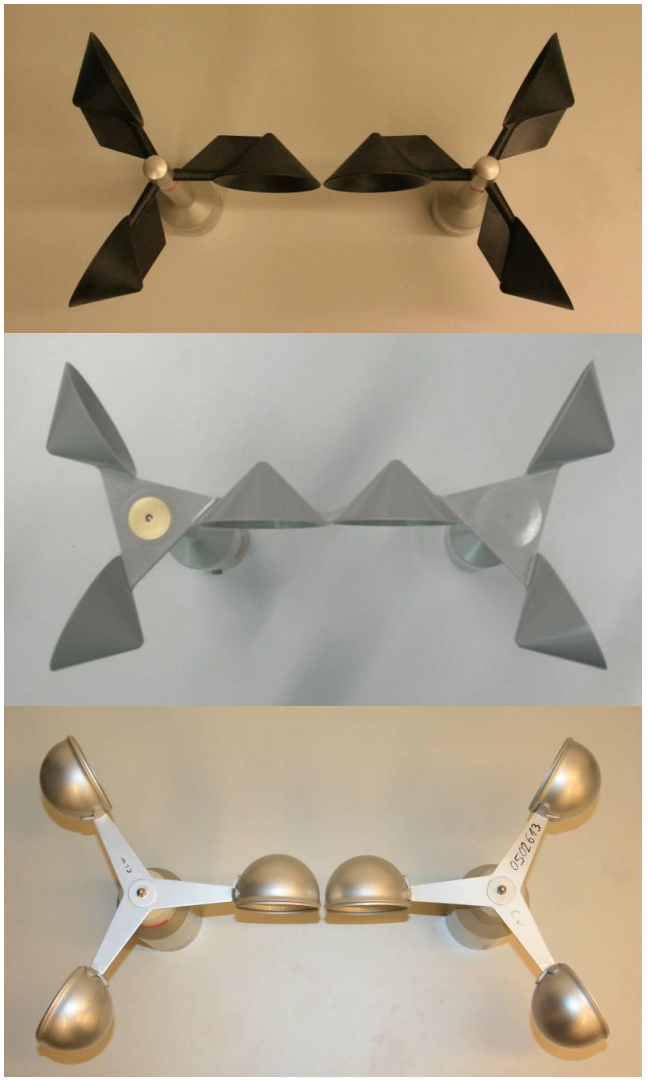
Test Program – Anemometers tested

Anemometers tested

- Vector A 100
- Thies FC
- Thies Classic
- Thies 2 D Sonic
- Big Cup
- Windspeed A100
- Windsensor P2546
- Propeller big
- Propeller small

Test Program – Anemometers tested

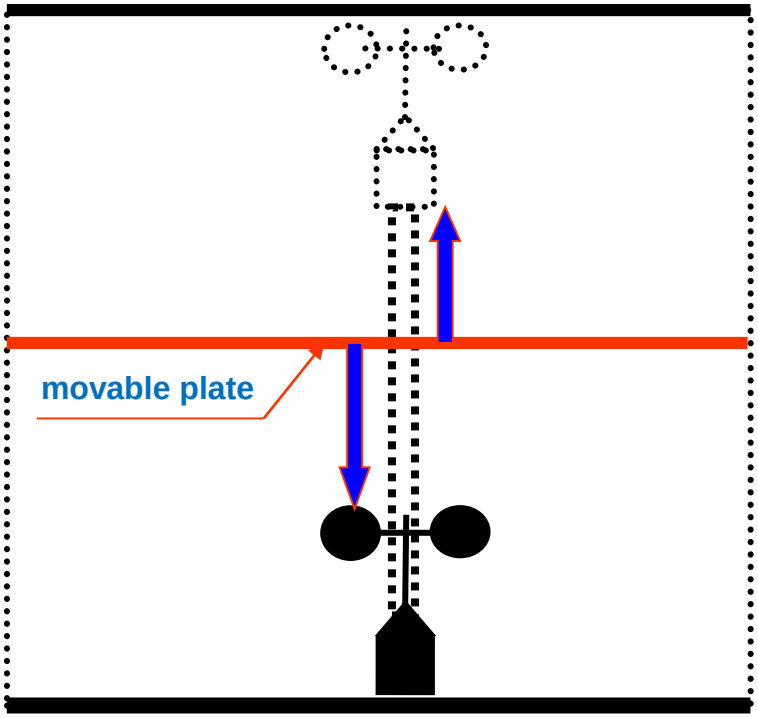
- cw and ccw rotor of each cup anemometer was tested
- easy way to identify horizontal flow gradient: **Ratio cw/ccw** should be the same for all tested setups

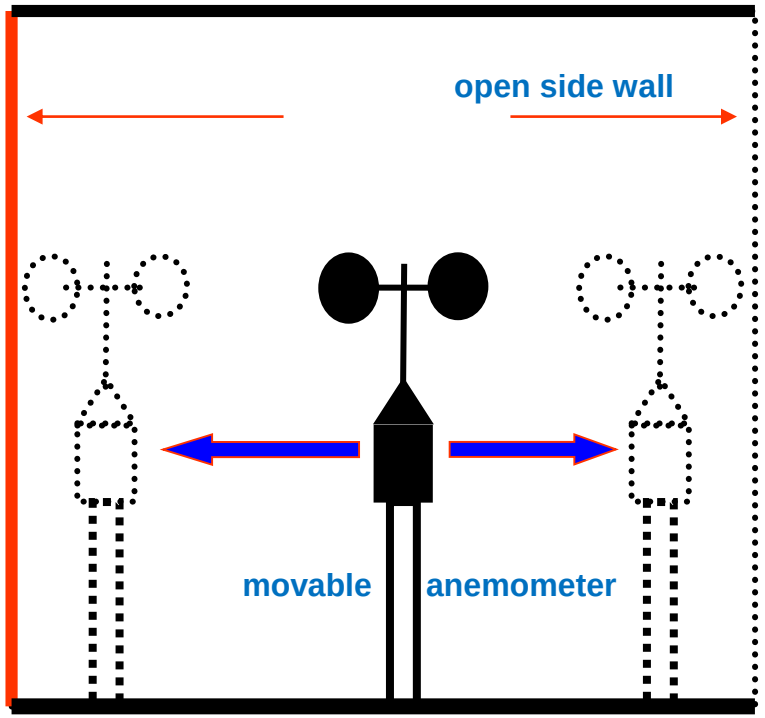


Test Program – Influence of tunnel boundaries

Influence due to limited test section

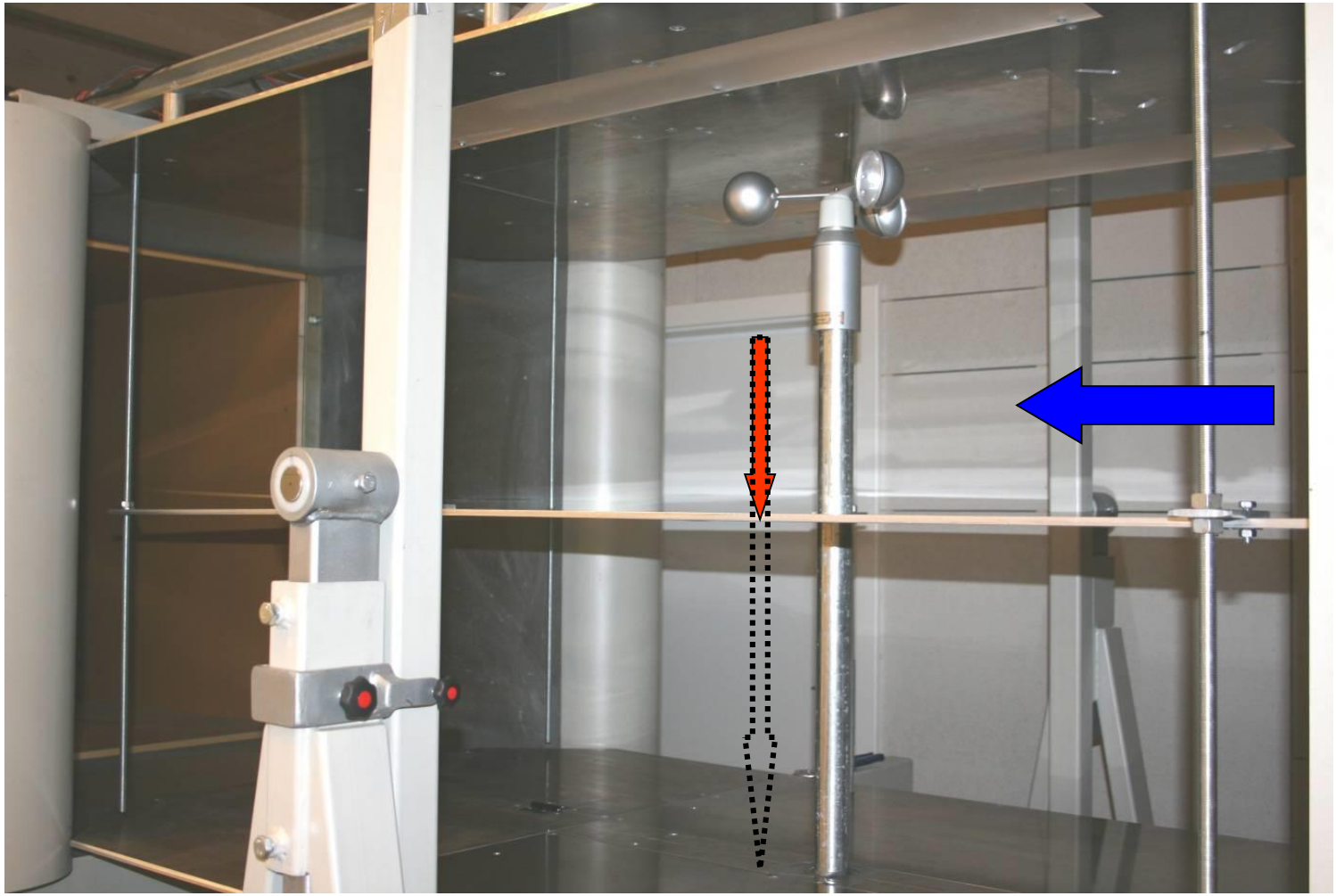
View into the nozzle





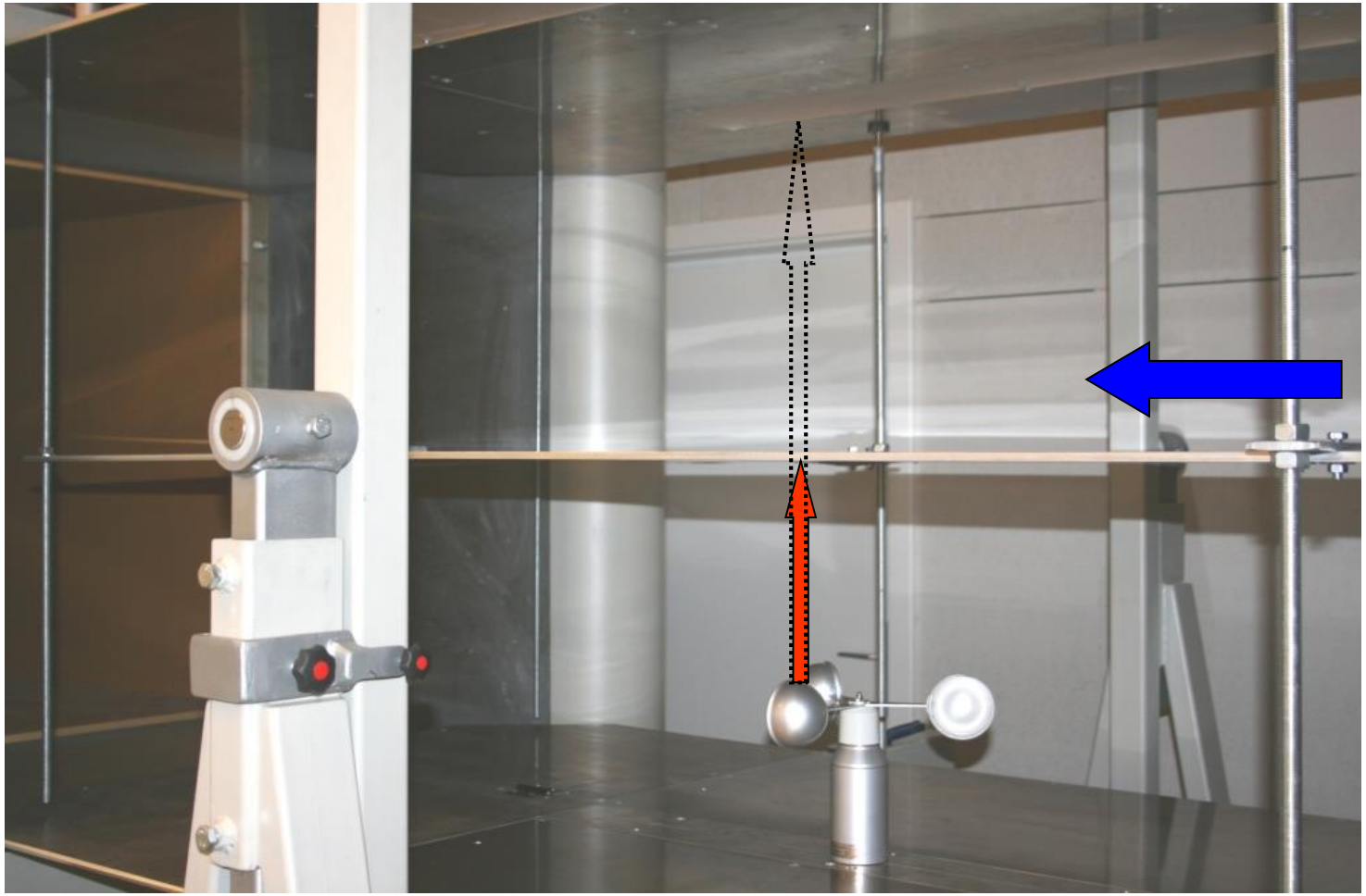
Test Program – Influence of tunnel boundaries

Influence of distance to bottom plate



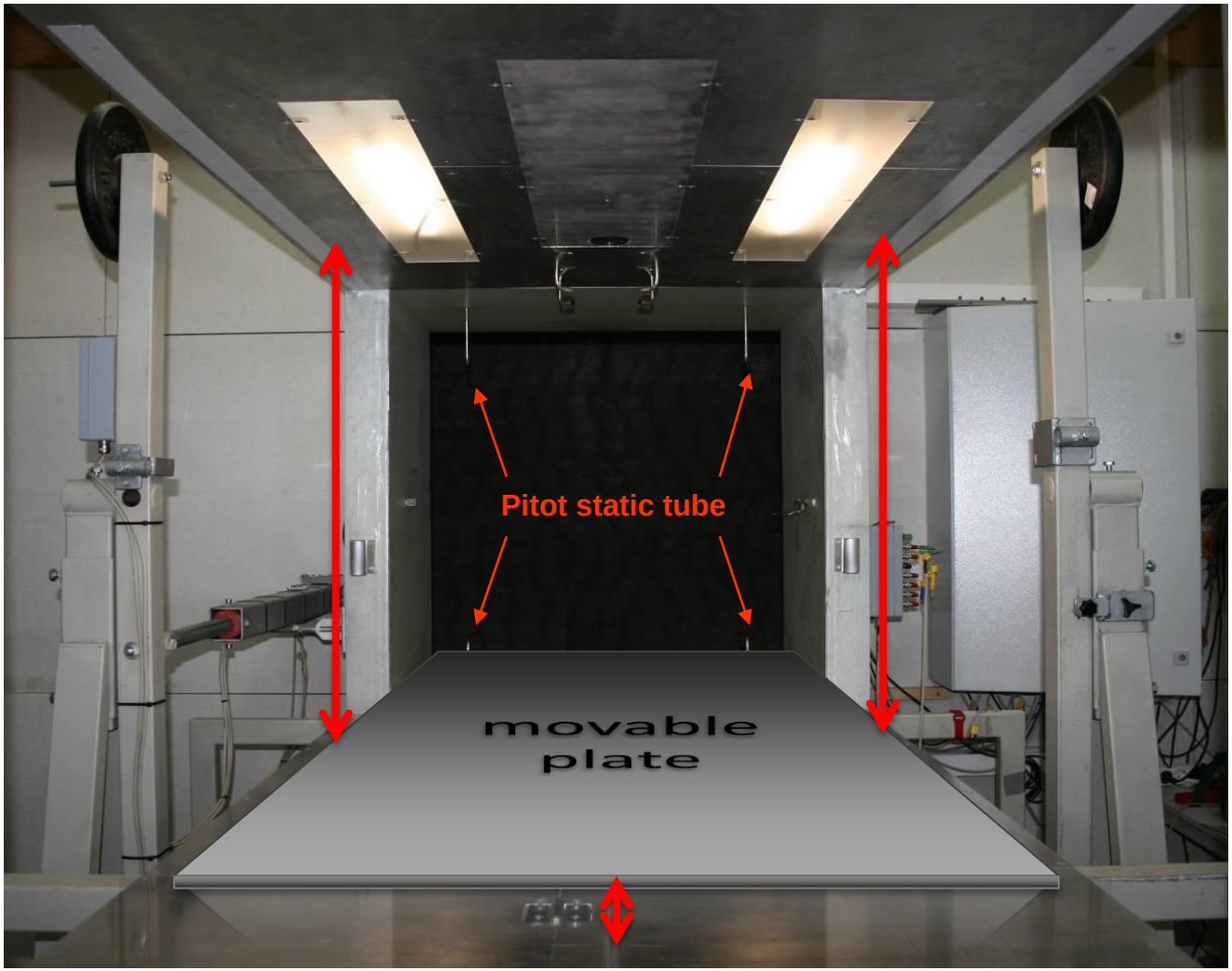
Test Program – Influence of tunnel boundaries

Influence of distance to top plate



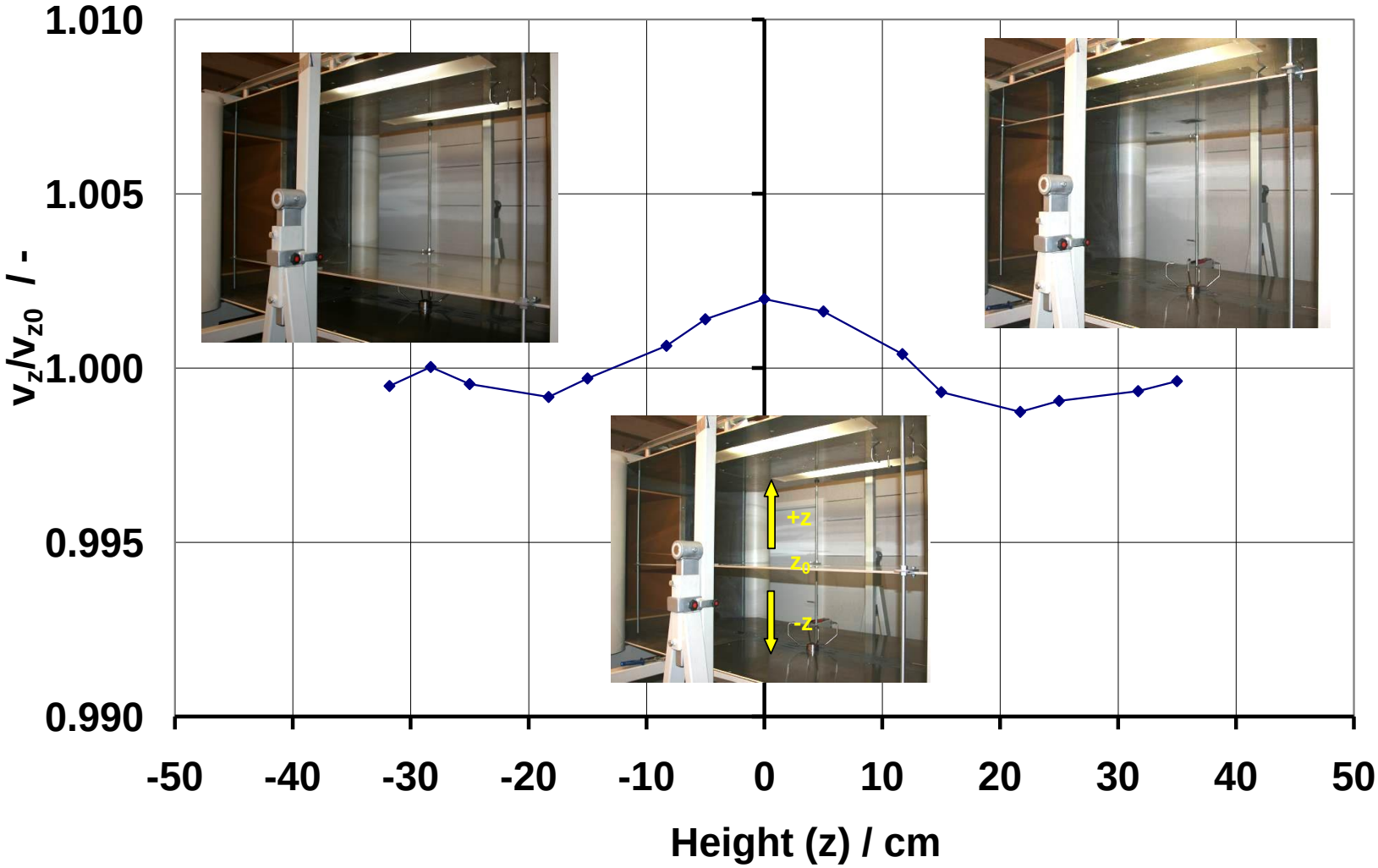
Test Program – Influence of tunnel boundaries

Influence in wind tunnel reference speed due to moving plate



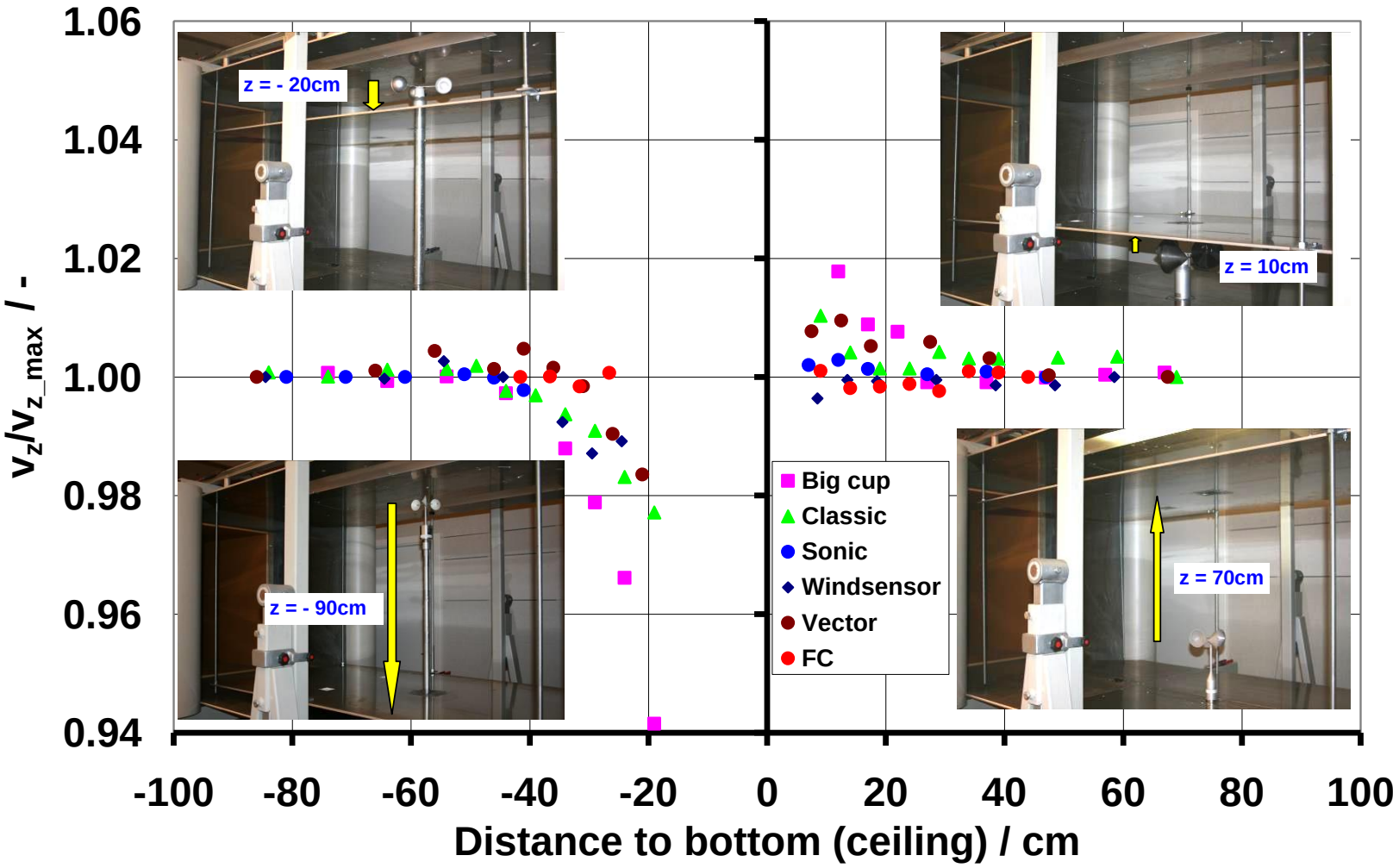
Test Program – Influence of tunnel boundaries

Influence in wind tunnel reference speed due to moving plate measured with Prandlt tubes



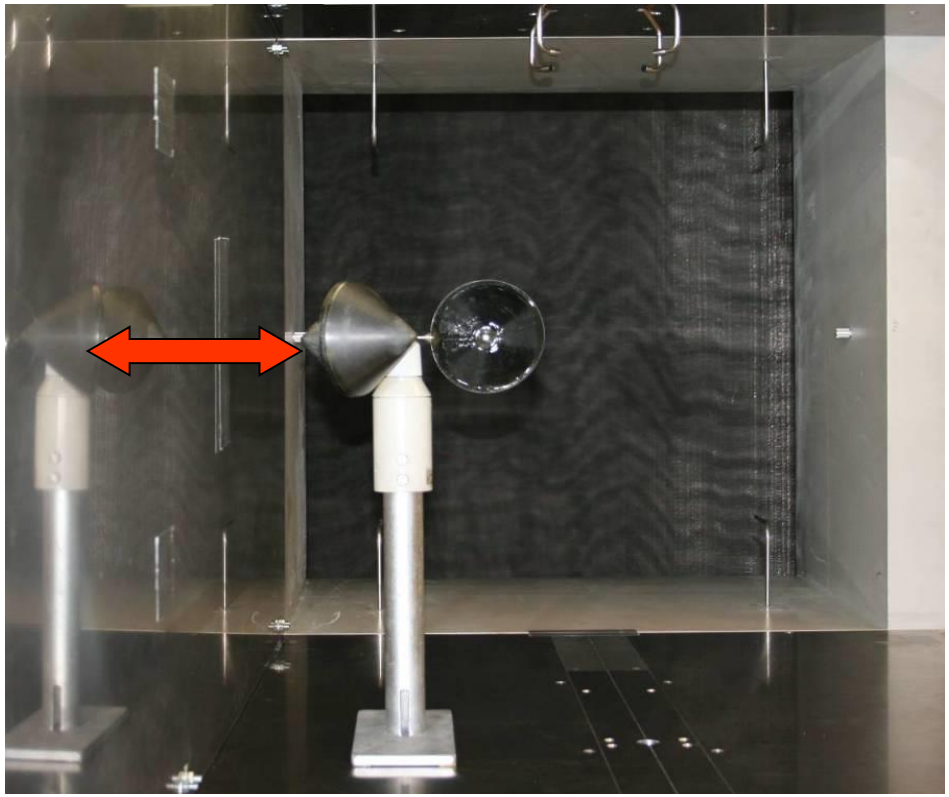
Test Program – Influence of tunnel boundaries

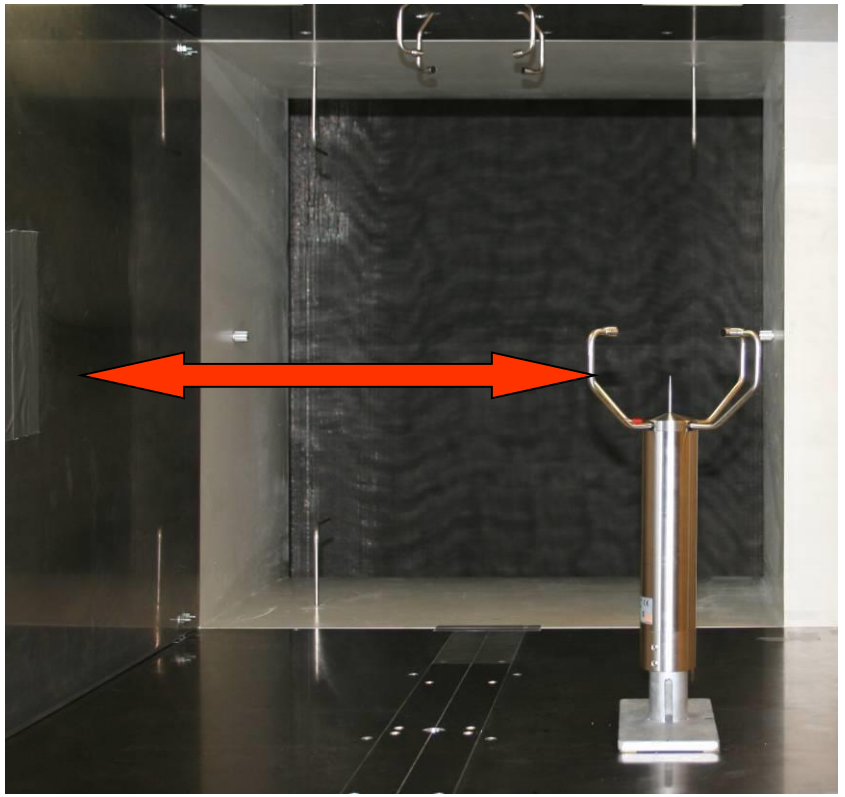
Influence of distance → anemometer to top or bottom plate



Test Program – Influence of tunnel boundaries

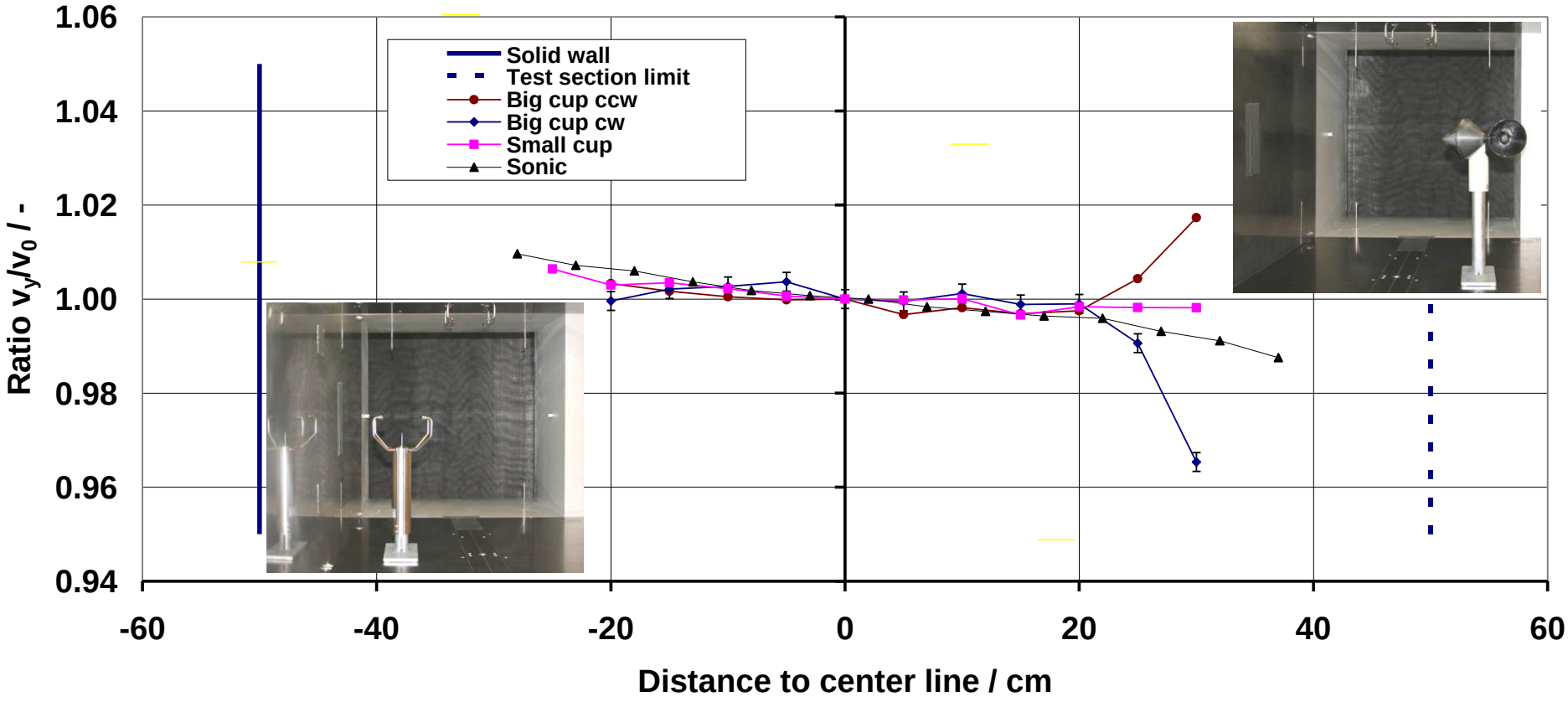
Influence due to side walls (right open; left closed)





Test Program – Influence of tunnel boundaries

Influence due to side walls (right open; left closed)

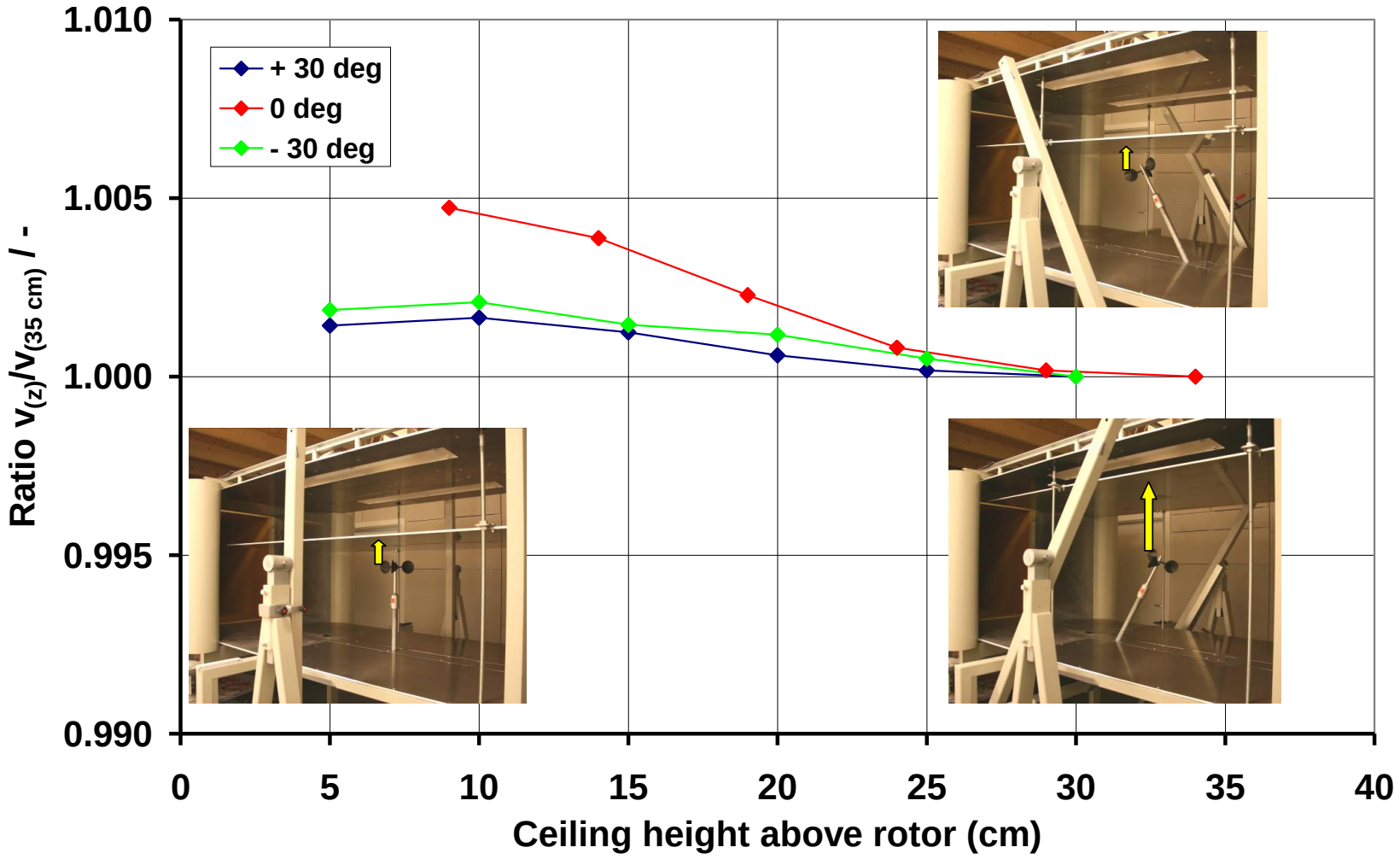


Test Program – Influence of tunnel boundaries

Minimum distances → anemometer to top plate for tilt measurements

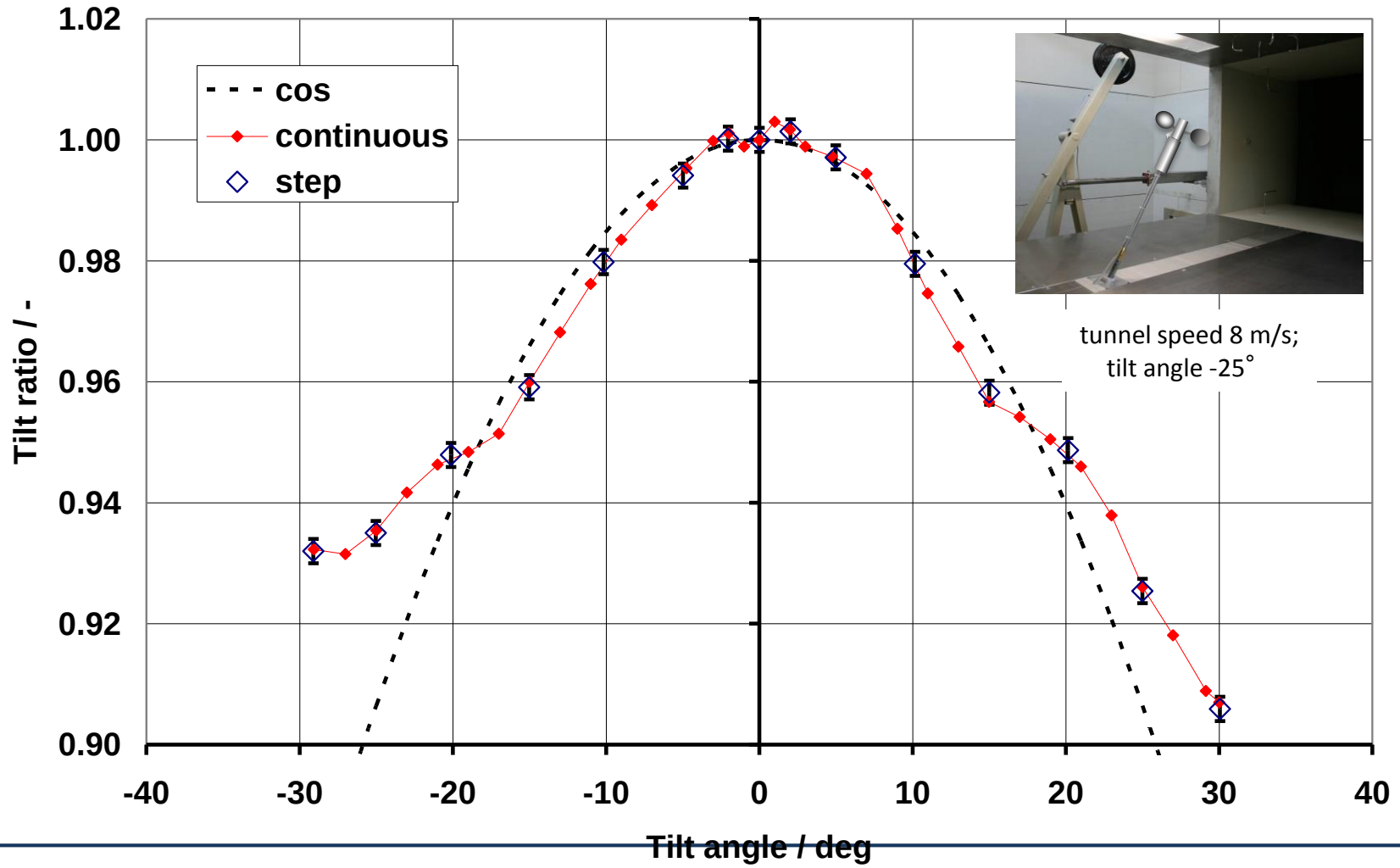
Test Program – Influence of tunnel boundaries

Minimum distances → anemometer to top plate for tilt measurements



Test Program – Procedure for Tilt measurements

Comparison between step wise and continuous measurements



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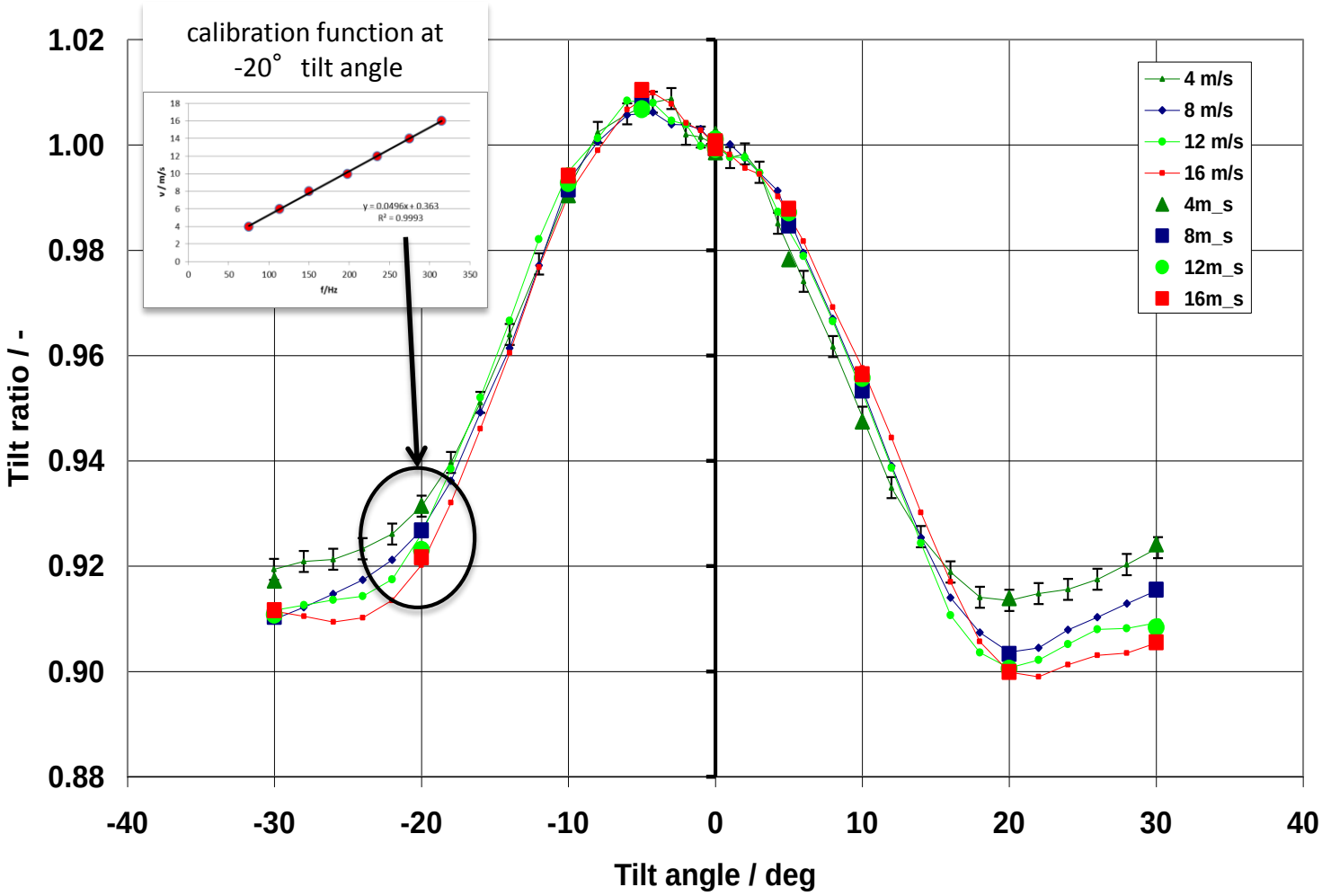
Test Program – Procedure for Tilt measurements II

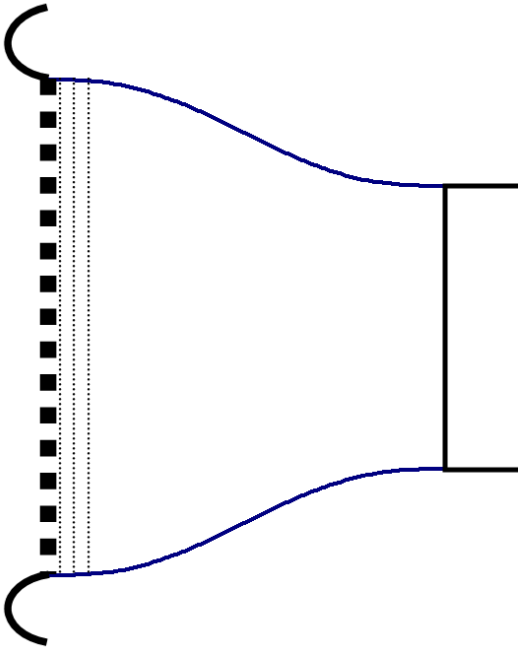
Tilt comparison between continuous and via calibration function

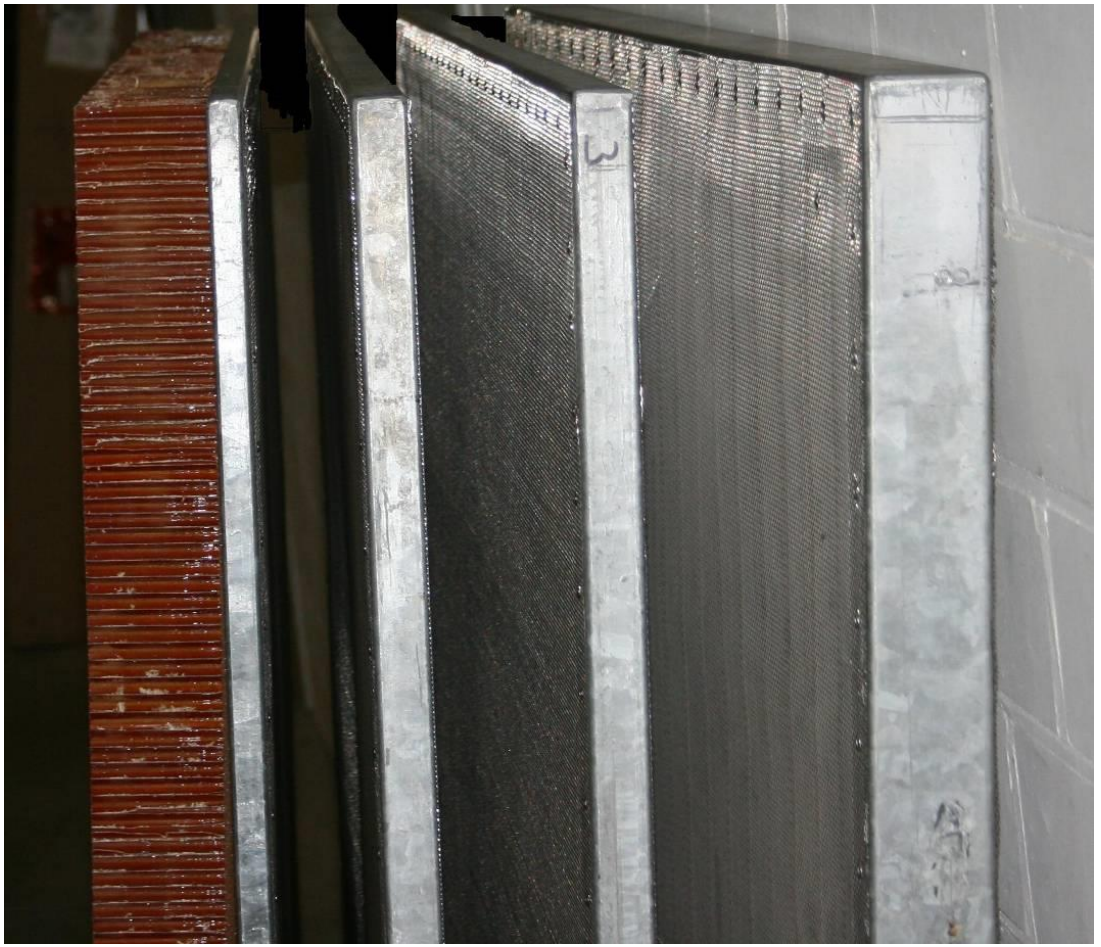
(attained at fixed tilt angles)



Test Program – Test Section Turbulence

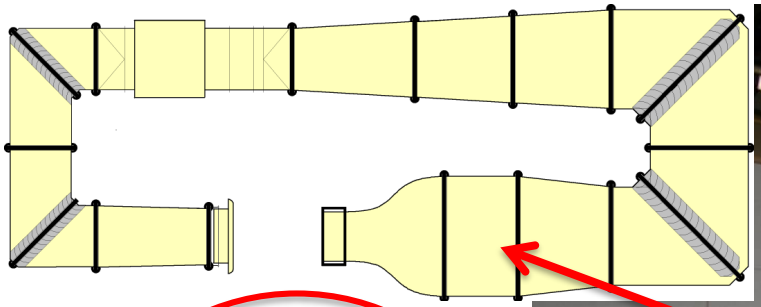
Flow conditioners in open circuit wind tunnel

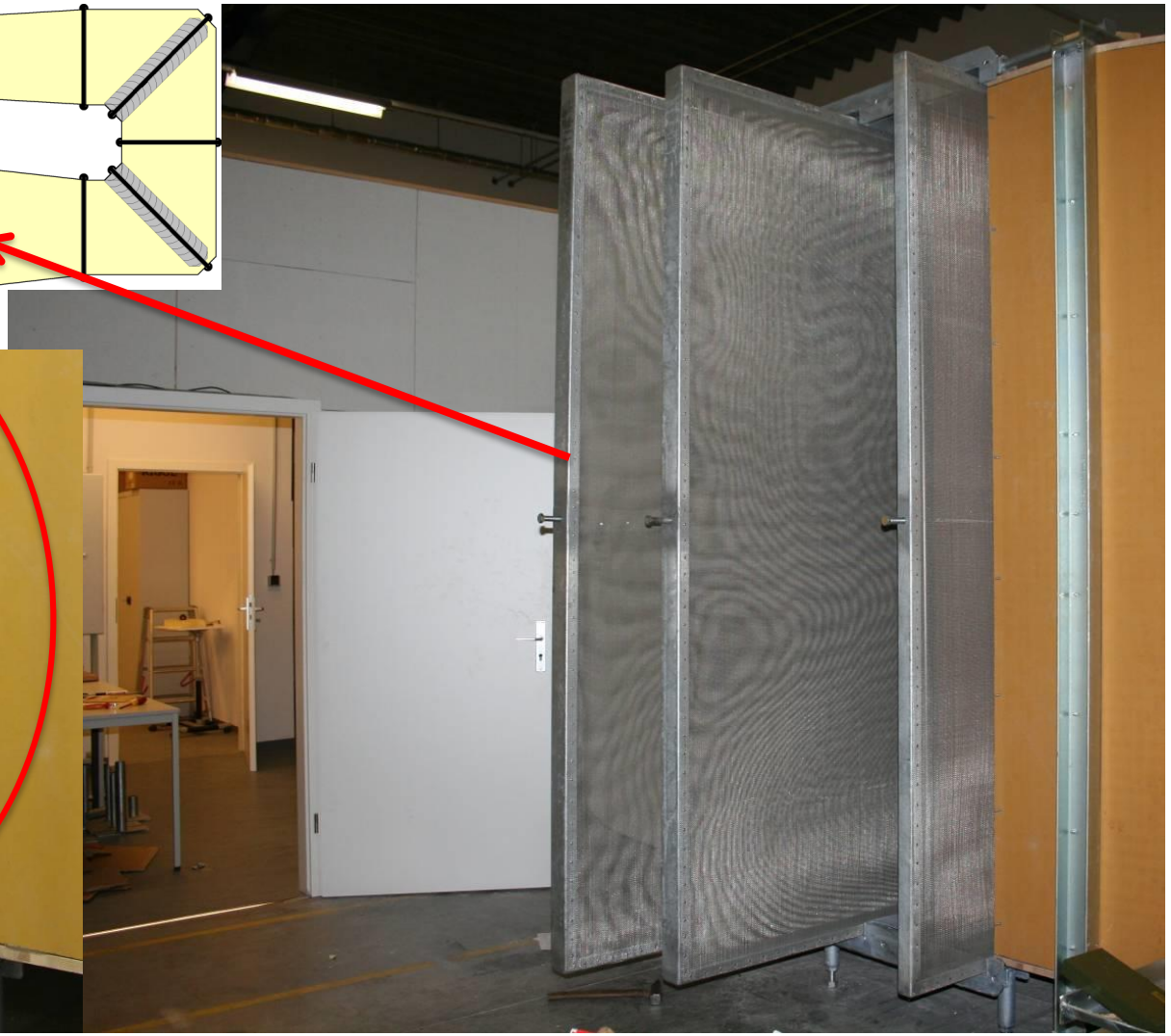




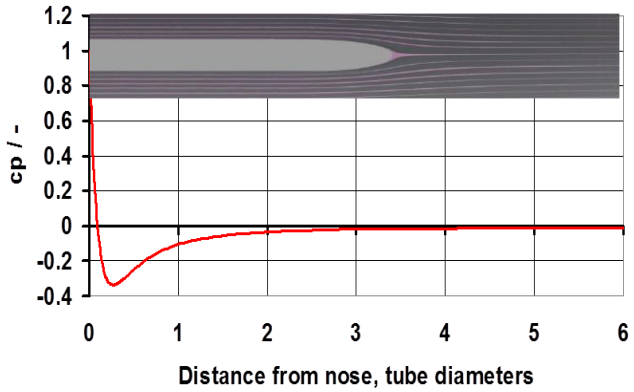
Test Program – Test Section Turbulence

Flow conditioners in closed return circuit wind tunnel





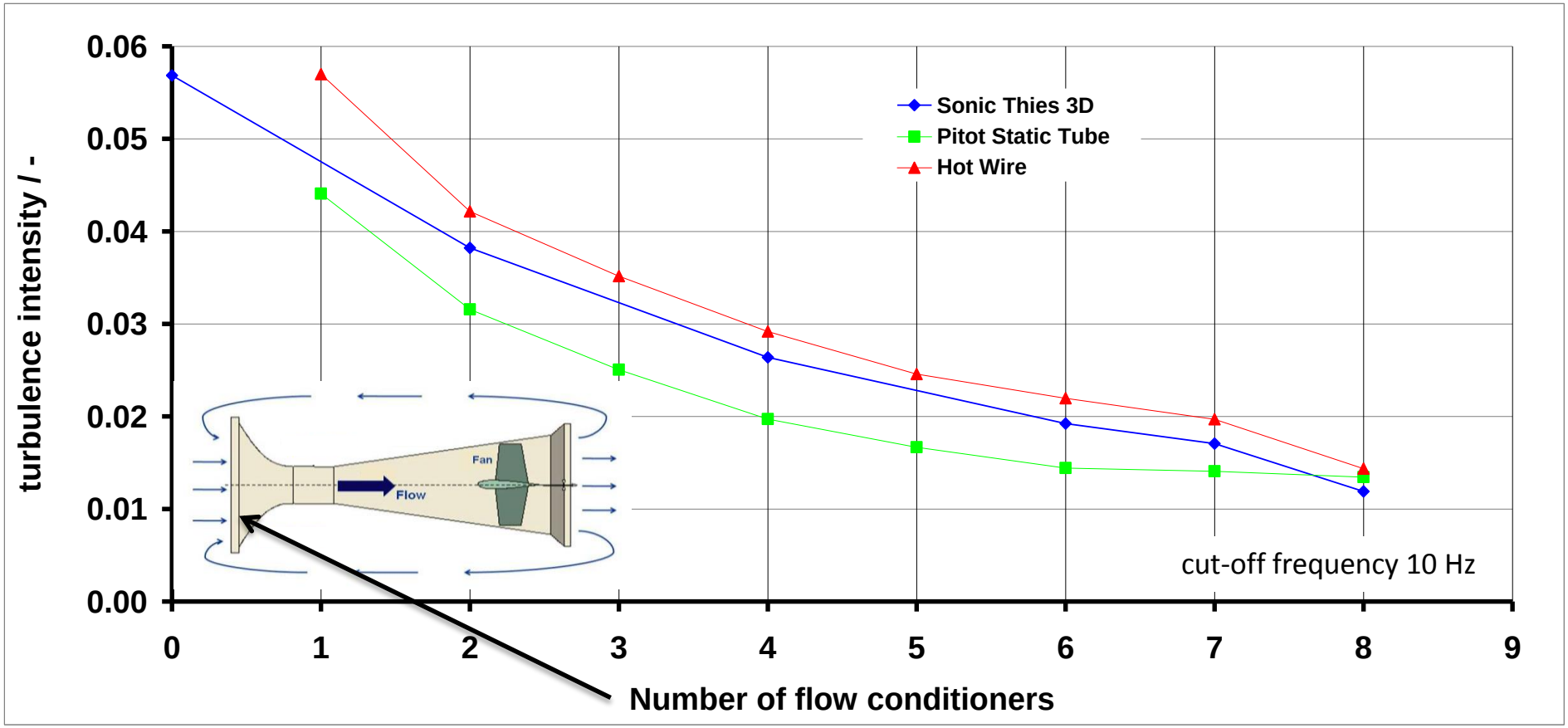
Test Program – Test Section Turbulence



Pitot static tube array

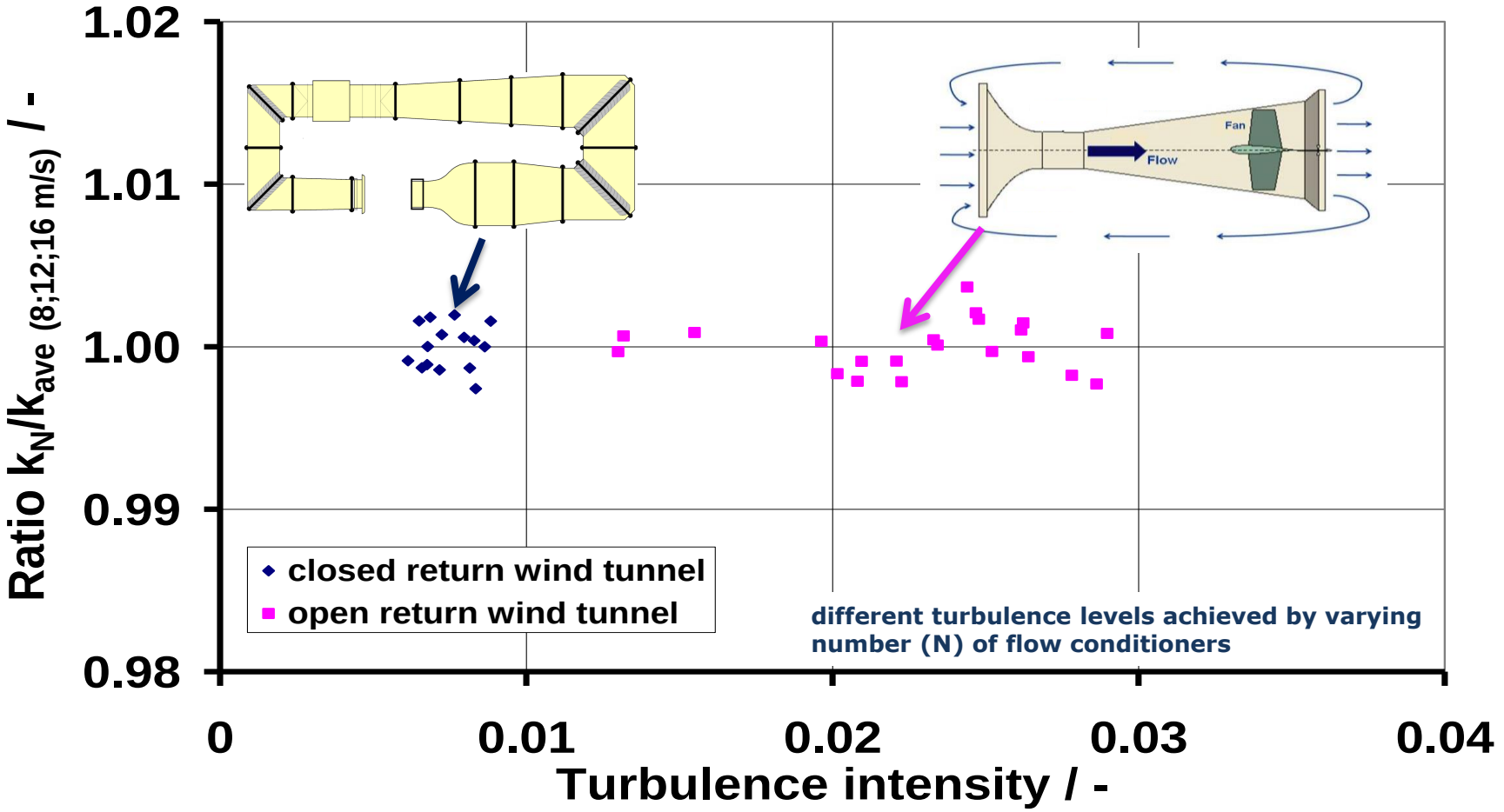
Test Program – Test Section Turbulence

Turbulence intensity in open return wind tunnel



Test Program – Test Section Turbulence

Influence of calibration result upon varying degrees of wind tunnel turbulence (Thies FCA; 8;12;16 m/s)



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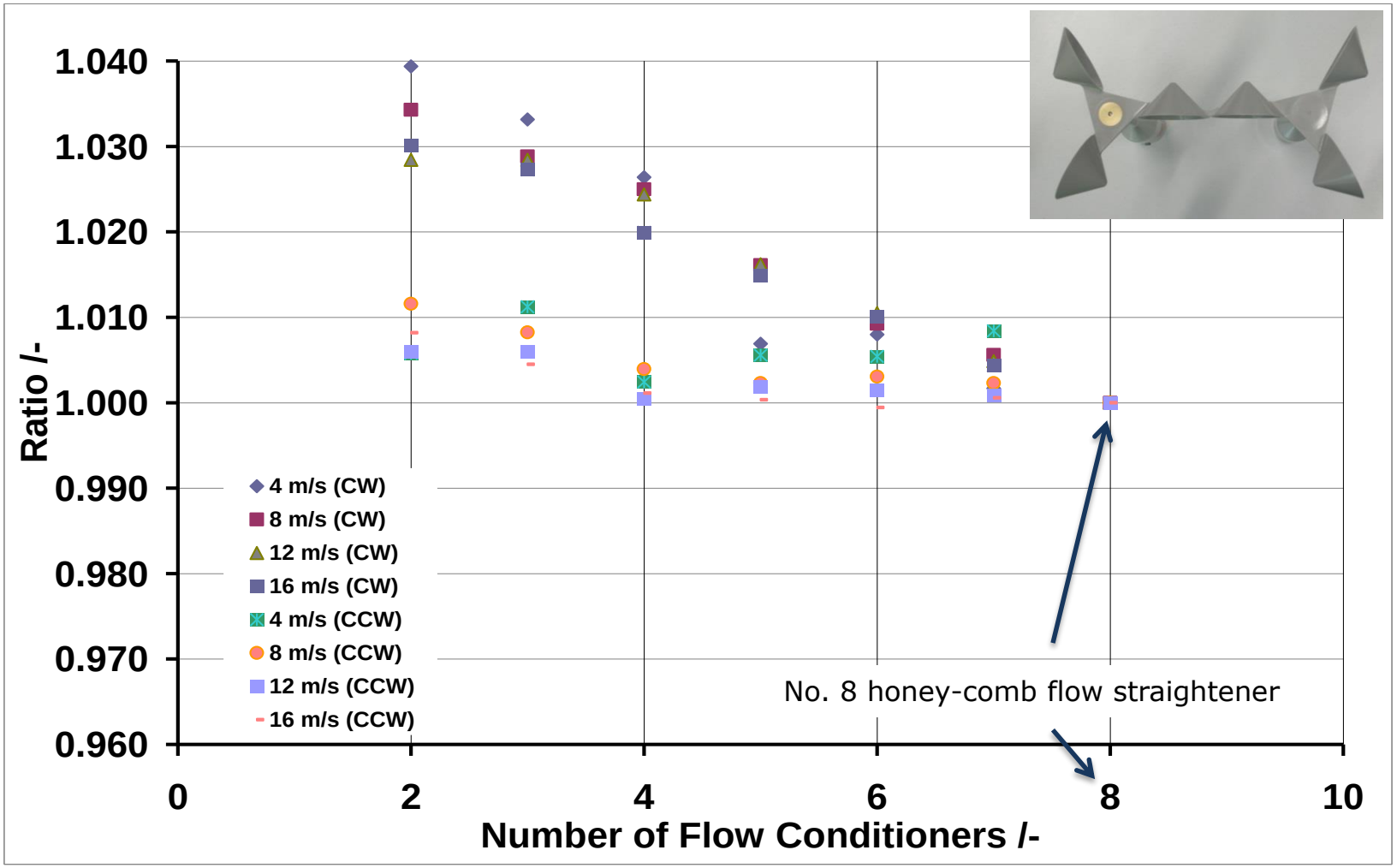
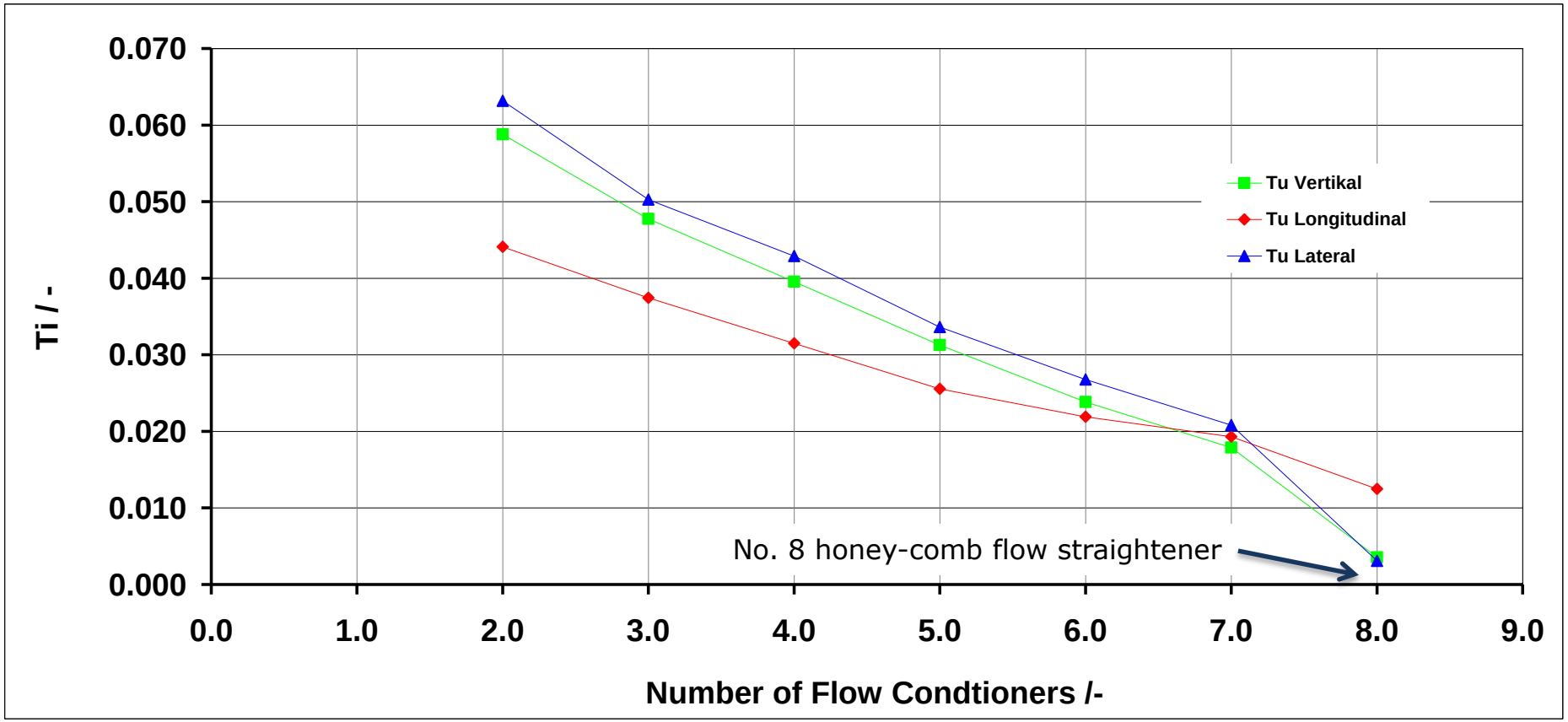
Test Program – Test Section Turbulence / Flow Quality

Calibration results of Windsensor P2546A anemometer **cw/ccw** in open return (Eiffel) wind tunnel



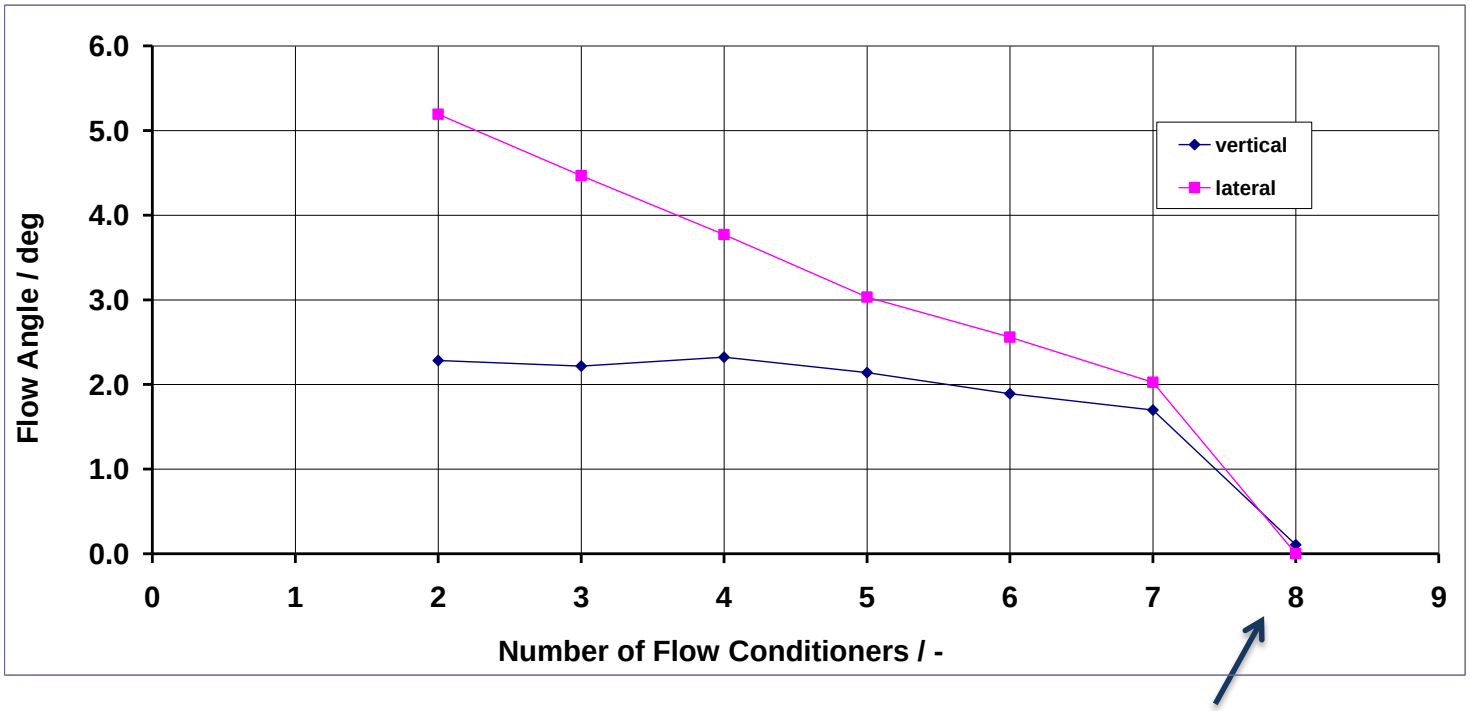
Test Program – Influence of Flow Turbulence

Turbulence intensity measured with 3D sonic (8 m/s) in open return (Eiffel) wind tunnel

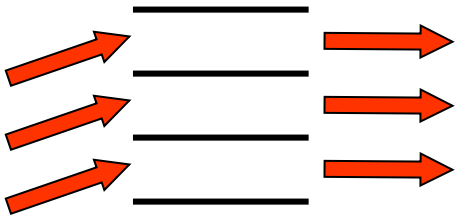


Test Program – Influence of Flow Turbulence

Reduction of flow angle deviation due to honey comb

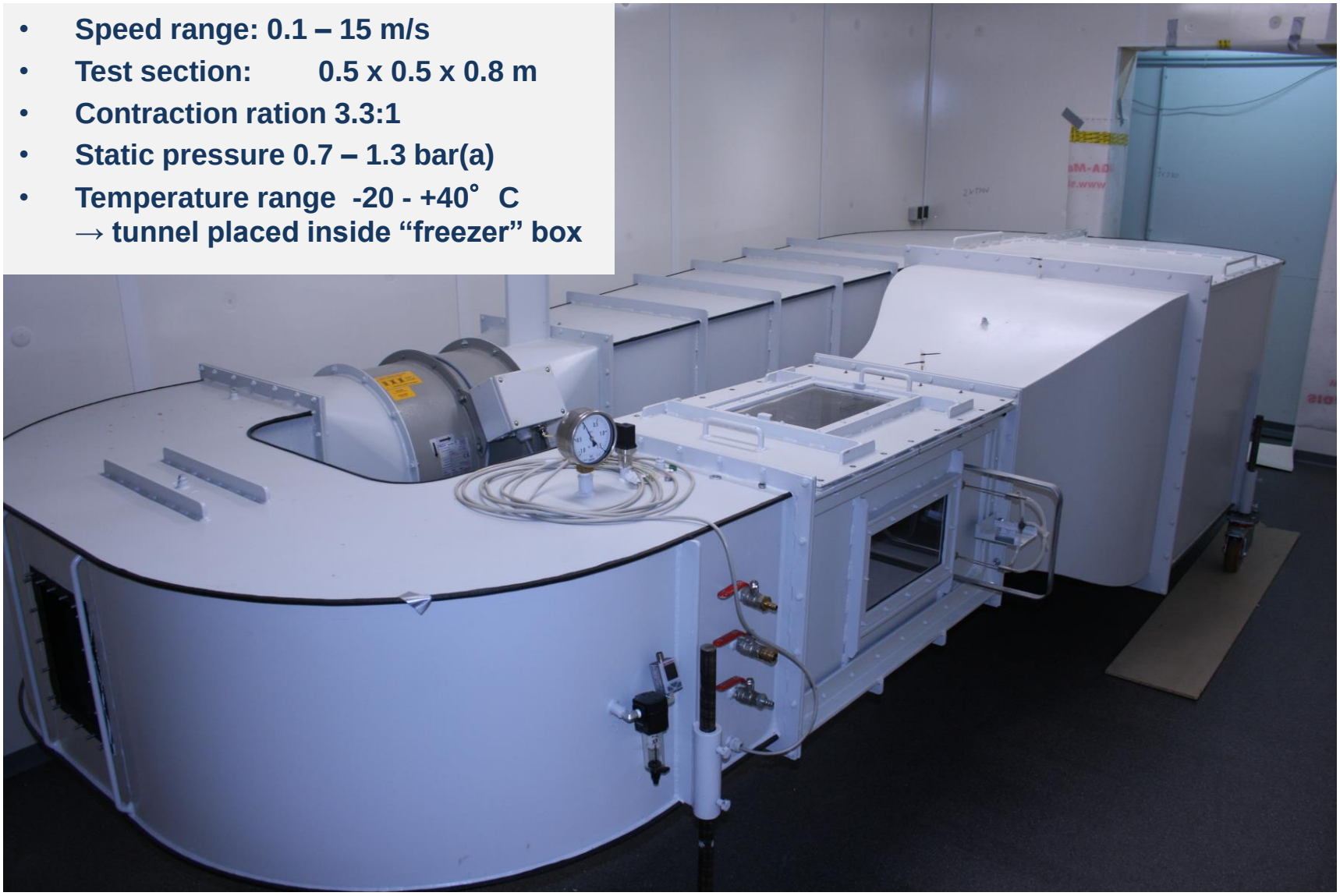


No. 8 honey-comb flow straightener

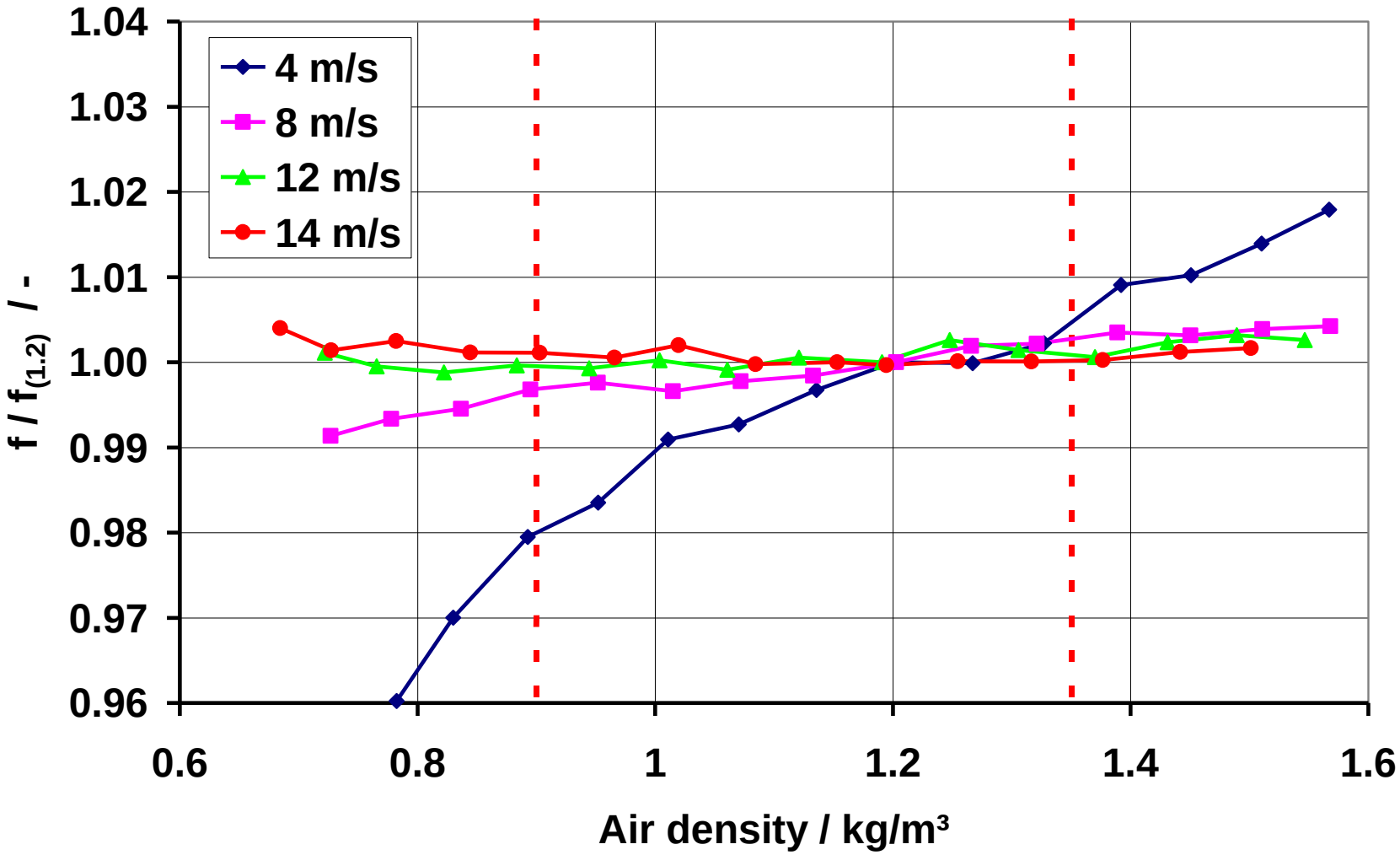


Test Program – Influence of Air Density / Temperatur

- Speed range: 0.1 – 15 m/s
- Test section: 0.5 x 0.5 x 0.8 m
- Contraction ration 3.3:1
- Static pressure 0.7 – 1.3 bar(a)
- Temperature range -20 - +40° C
  → tunnel placed inside “freezer” box

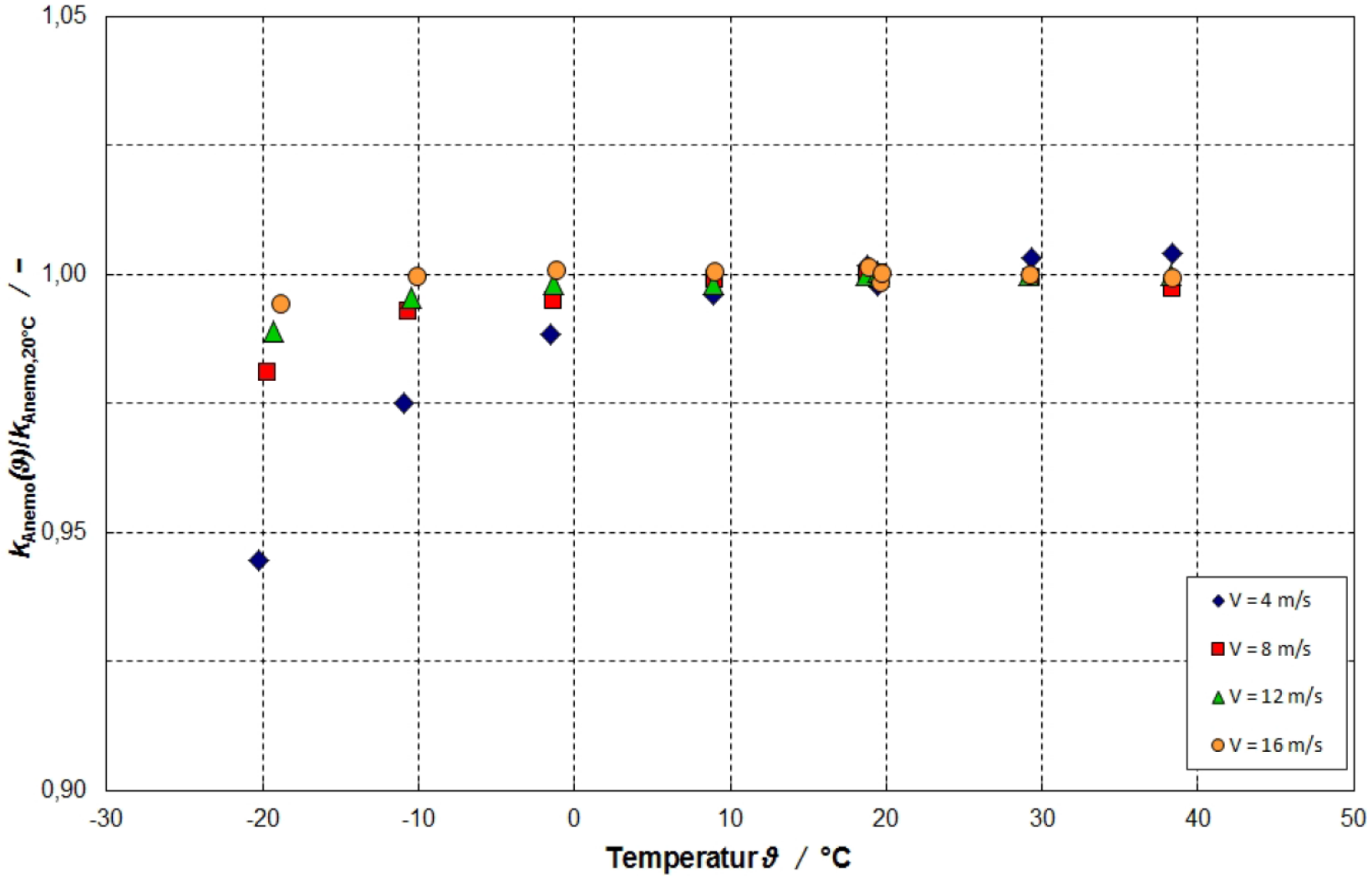


Test Program – Influence of Air Density



Test Program – Influence of Air Temperature

Anemometer type “A”



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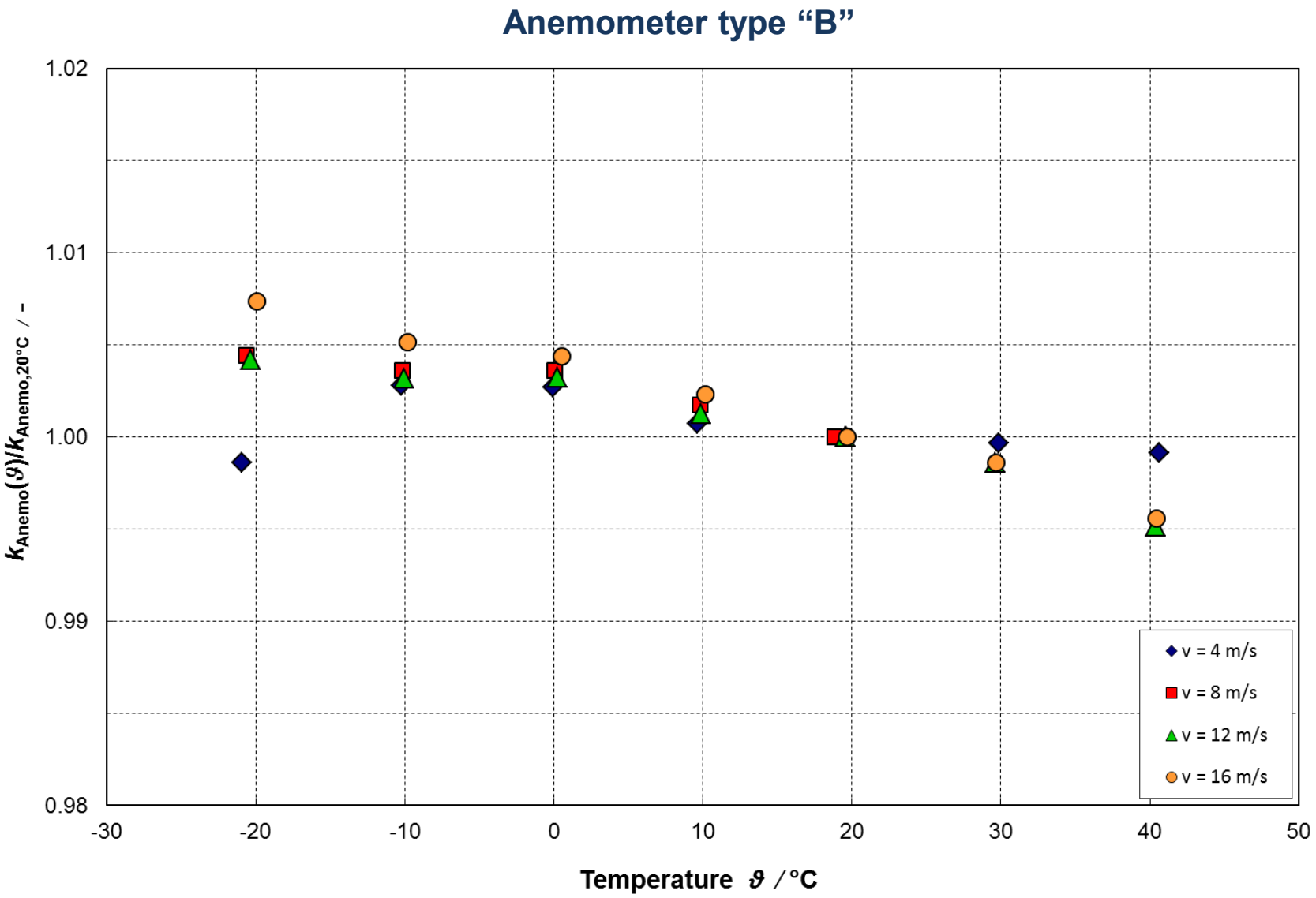
Test Program – Influence of Air Temperature



Outcome

- Test section width 0.8 m better 1.0 m
- Test section size 0.4 m above anemometer
- Test section size minimum 0.5 m below anemometer
- The calibration results are unaffected by turbulence intensity in the range 0.5 – 3.0 %
- Flow conditioners (incl. screens and honey comb) are absolutely necessary
- Closed return wind tunnel produces much better flow conditions
- Tilt measurement are possible using step wise, continuous or through calibration functions (attained fixed tilt angles!) Steep gradients in tilt response are possible → a continuous sweep of the tilt angel is preferred.

Remark: All the results presented are based on measurements in WindGuard Eiffel wind tunnel and Göttinger wind tunnel no 3 with semi open test section

The instrument should be read every morning at 9 o’clock

Dr. Robinson 1849

Thank you for your attention