Validation of the real-time-response ProCap system for full field wake scans behind a yawed model wind turbine

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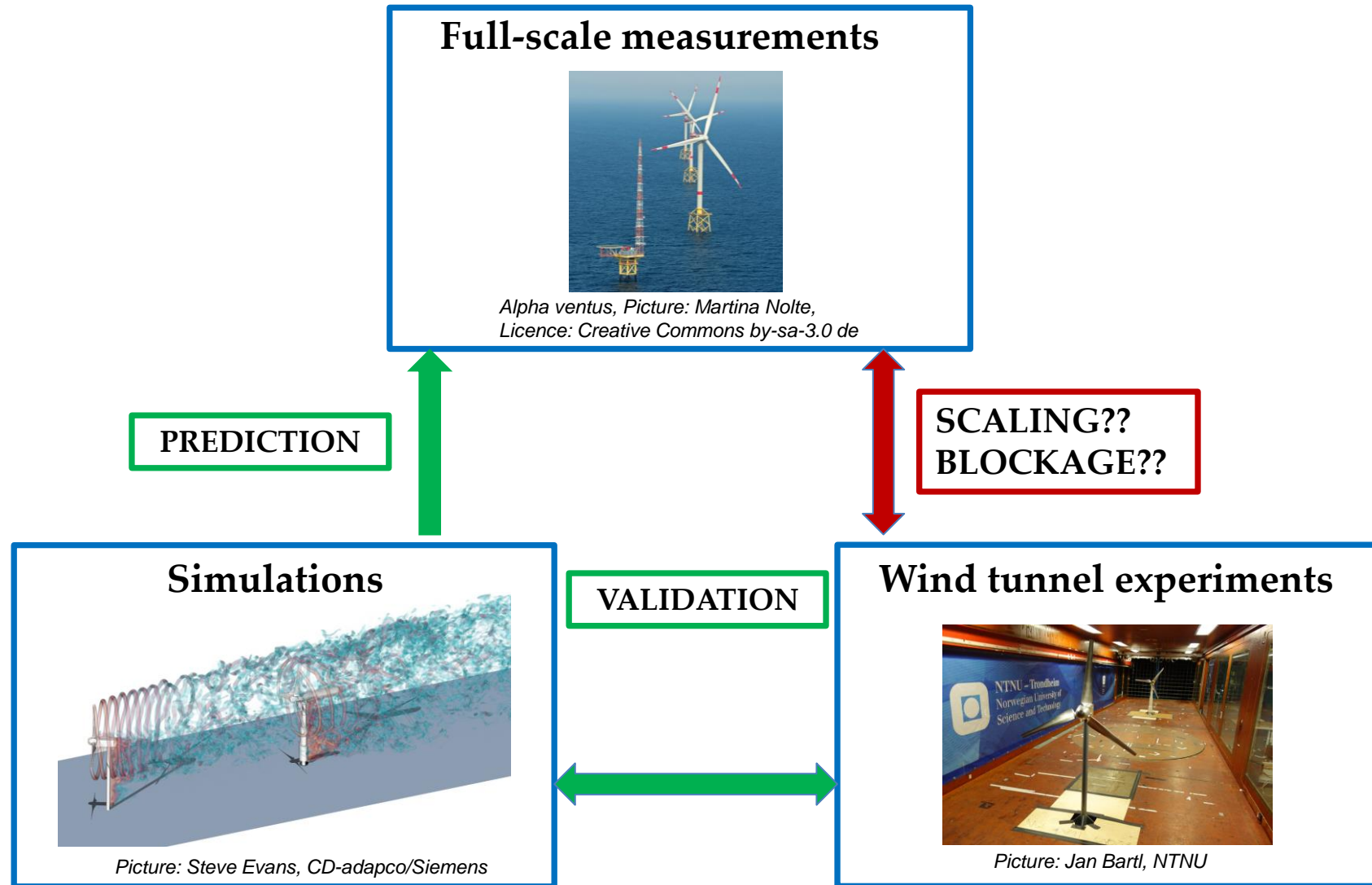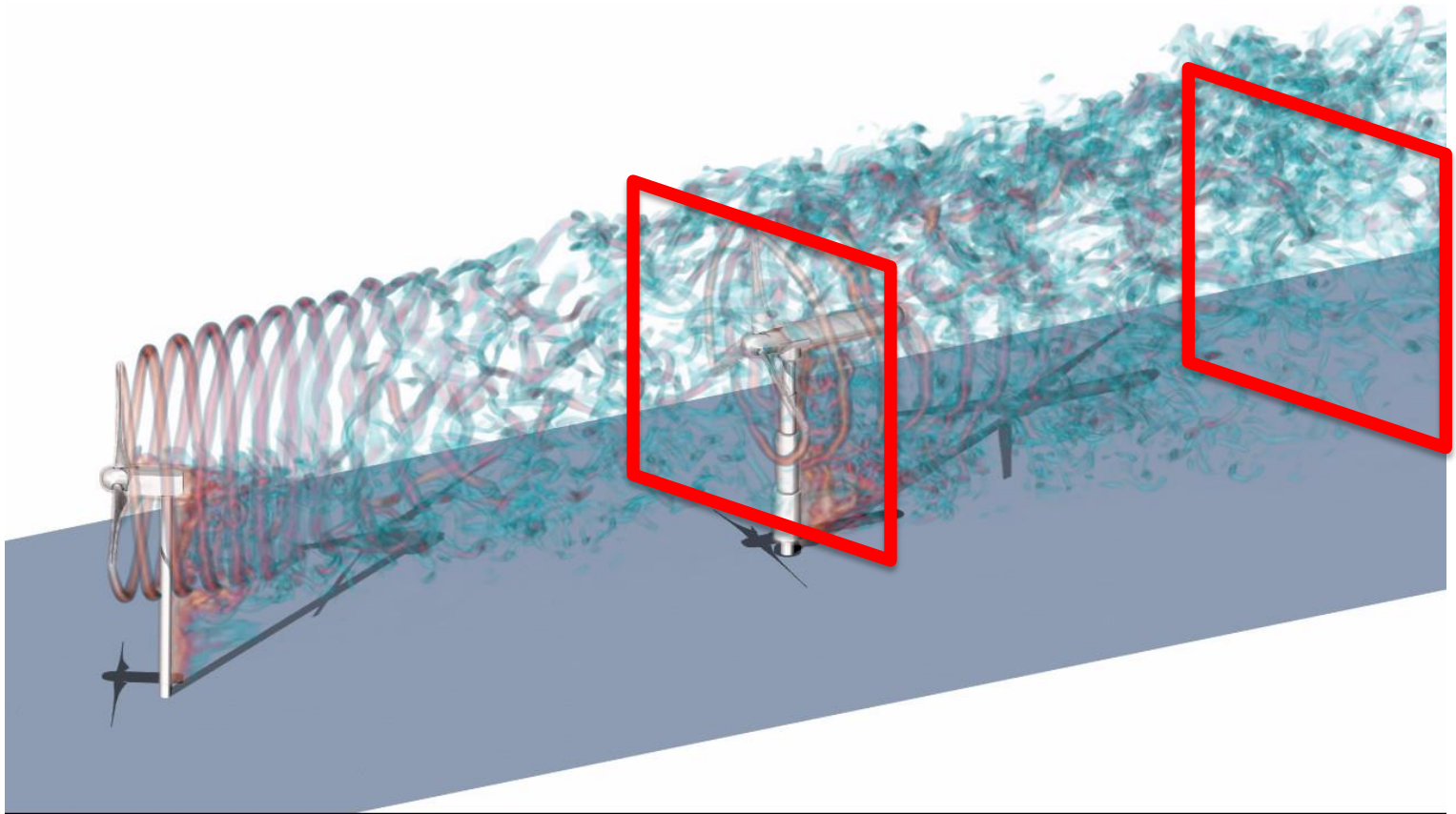1   NTNU   2   **ETH** *zürich*   3   STREAMWISE   4   NMBU   5   IFE

Norwegian University of Science and Technology

Wake model validation across the scales

Full-scale measurements

Alpha ventus, Picture: Martina Nolte,
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PREDICTION

SCALING??
BLOCKAGE??

Simulations

Picture: Steve Evans, CD-adapco/Siemens

VALIDATION

Wind tunnel experiments

Picture: Jan Bartl, NTNU

# Turbine interaction & Wake flow prediction

© Simulation by Siemens/CD-Adapco

This presentation: Comparsion of two flow measurement techniques

Laser-Doppler Anemometry (LDA) *vs* Probe Capture (ProCap)

Wake velocity measurement techniques

Single point measurements

- Pressure measurements (Pitot tube)

- Hot-wire measurements

- Laser-Doppler measurements (LDA)

- ➢ Traverse of single grid points
- ➢ Interpolation in post-processing
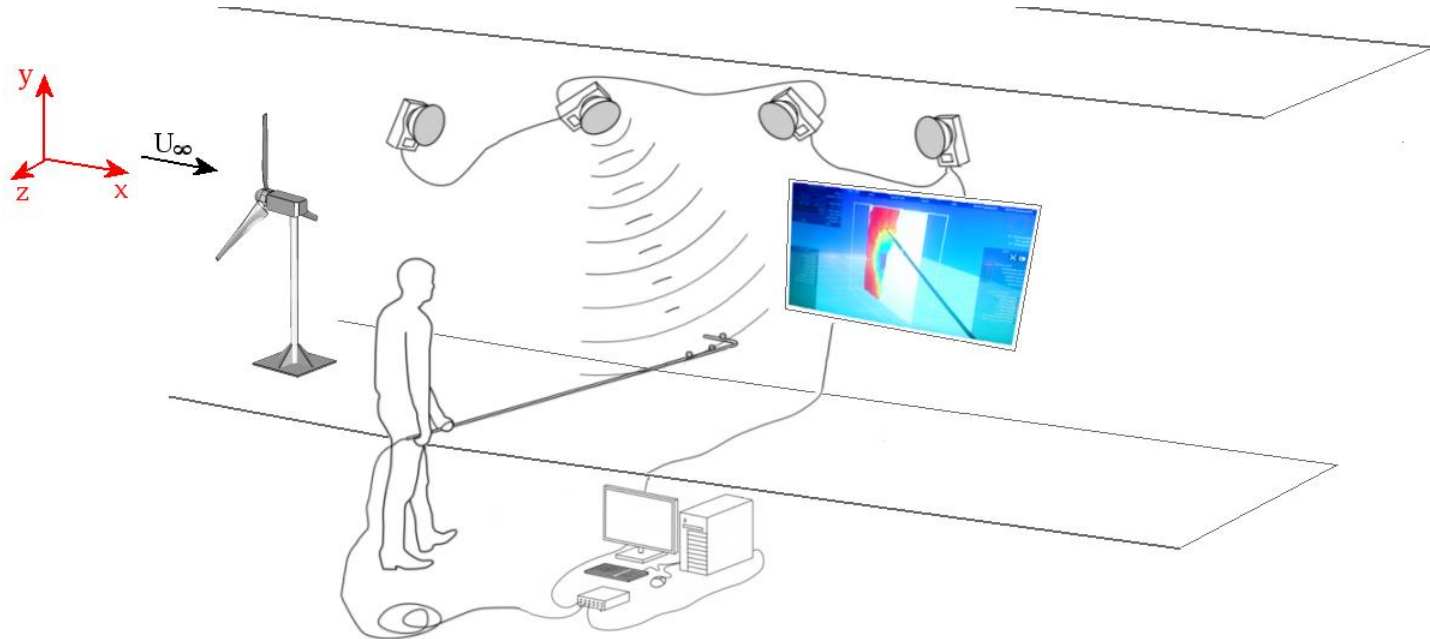- ➢ *Measurement time full wake (2m x 1m) ≈ 5 hours*
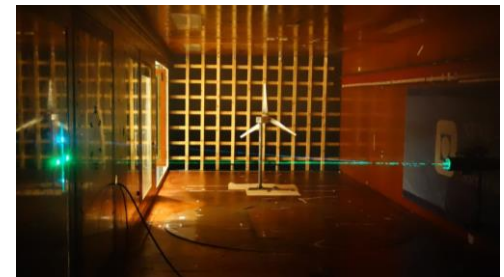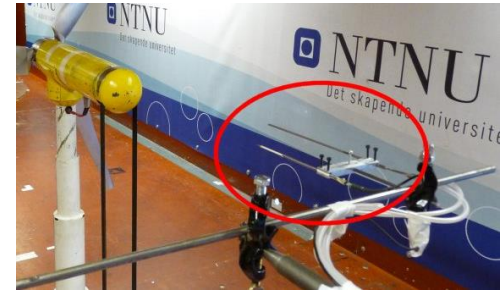
Flow field measurements

- Particle Image Velocimetry (PIV)

- ➢ Limited measurement window

L.E.M. Lignarolo et al. / Renewable Energy 70 (2014) 31–46
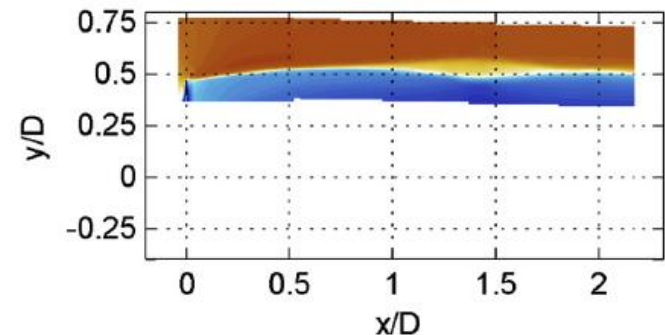
Experimental setup ProCap

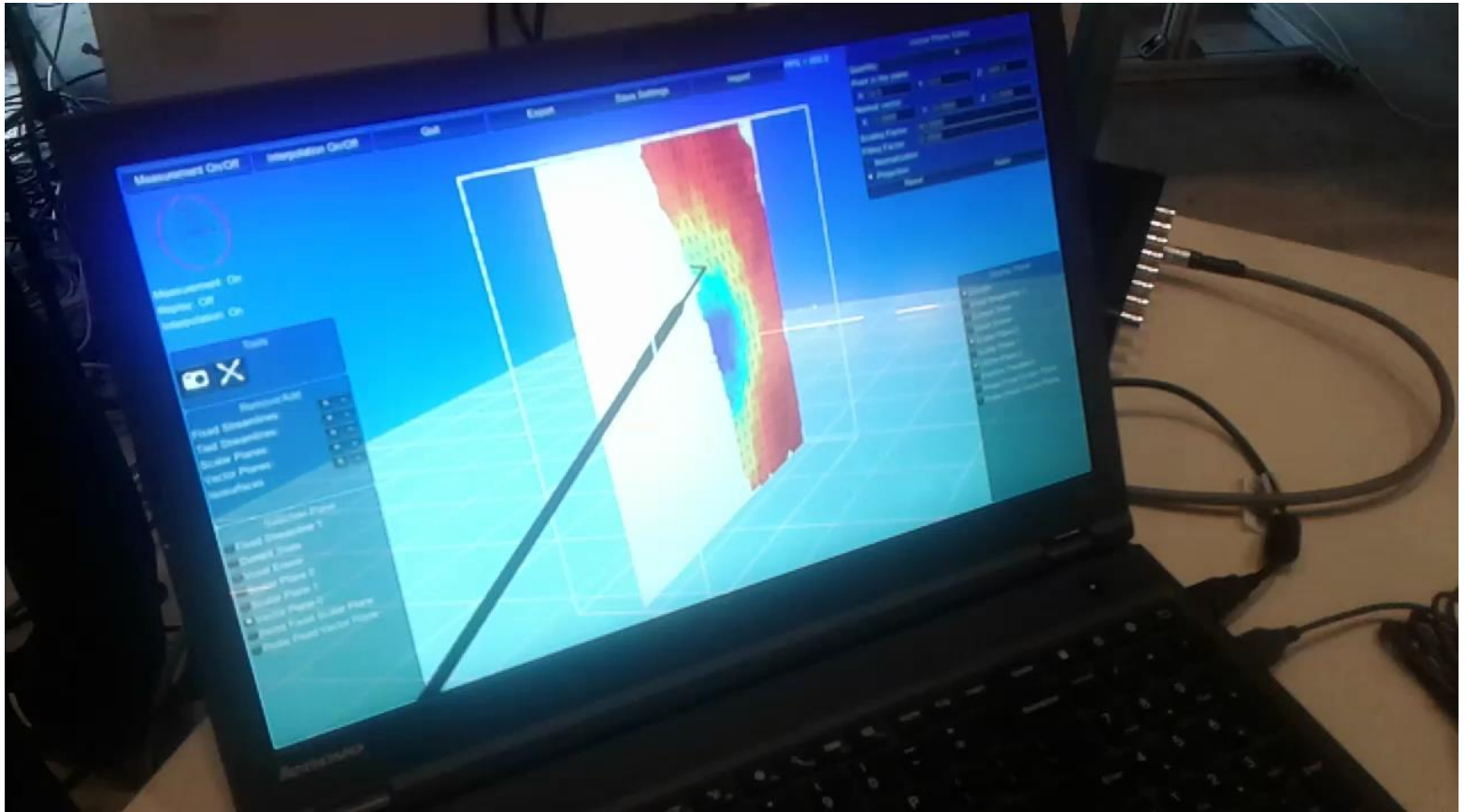➢ Developed at ETH Zürich and its spin-off *streamwise*

The ProCap system consists of
- a hand-guided 5-hole pressure probe equipped with three markers
- a motion capture camera system
- a real-time data processing and visualization system
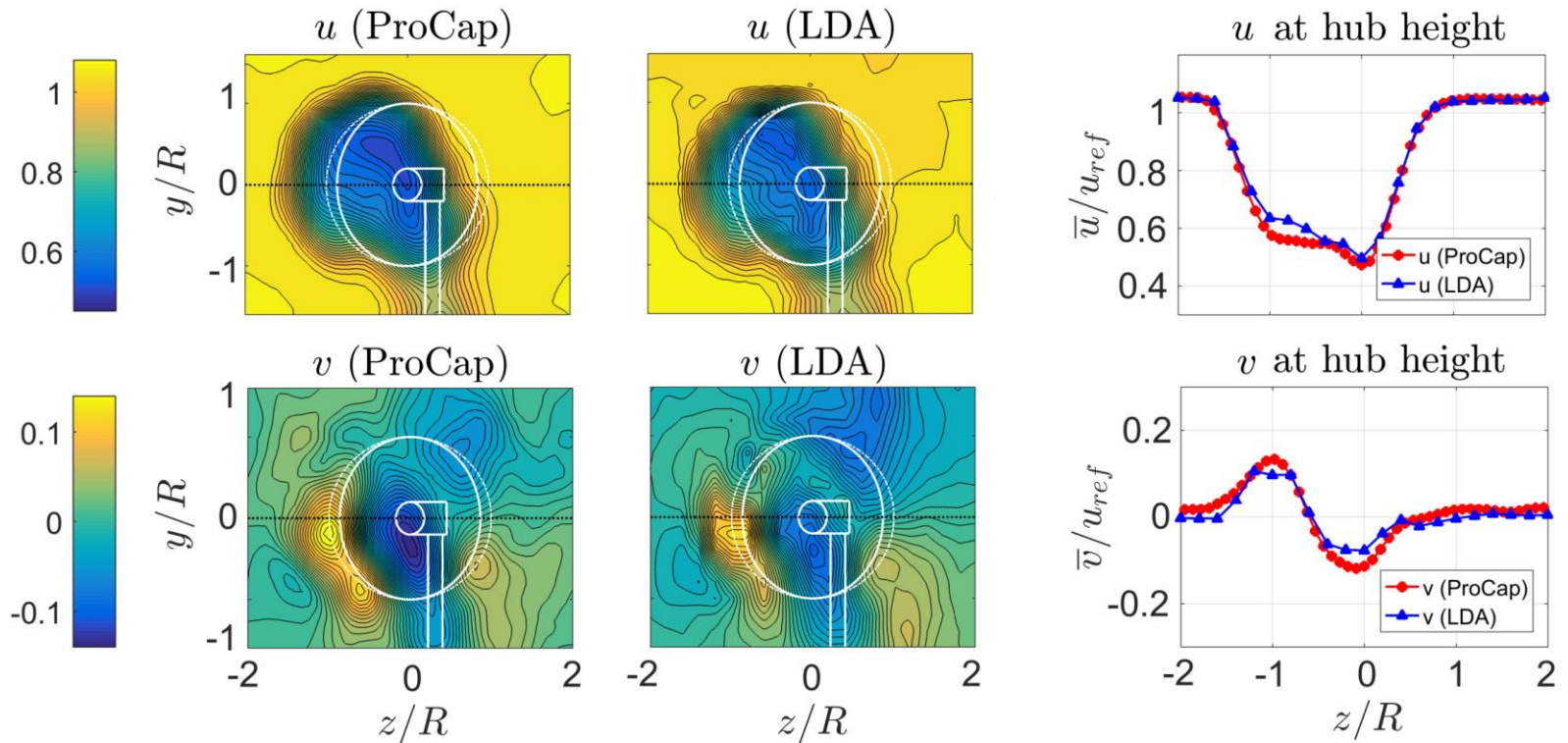
ProCap: Experimental setup
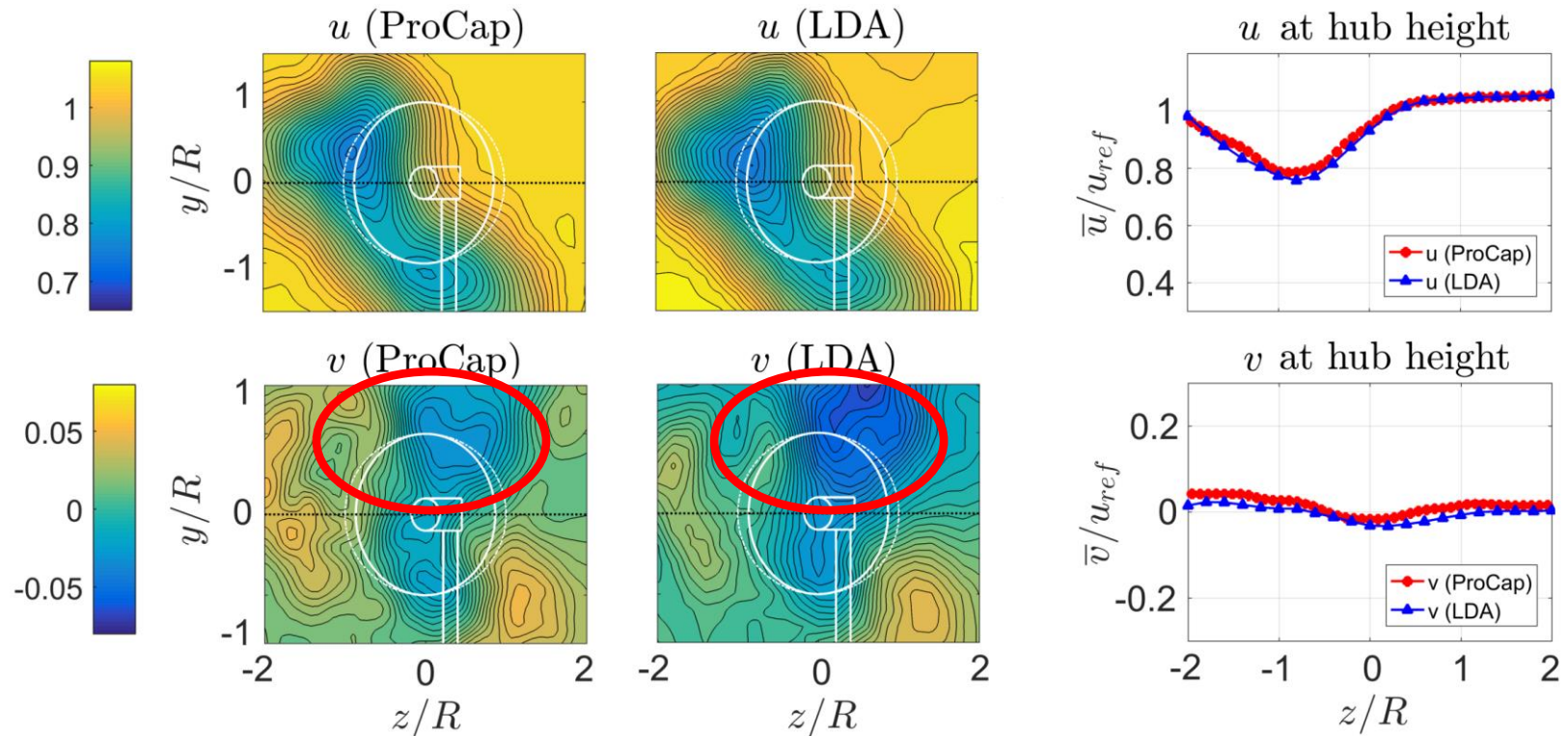
Real-time response data acquisition

> *Measurement time full wake (2m x 1m) ≈ 10 minutes*

Comparison of results: *u* and *v* at 3D, γ=30°

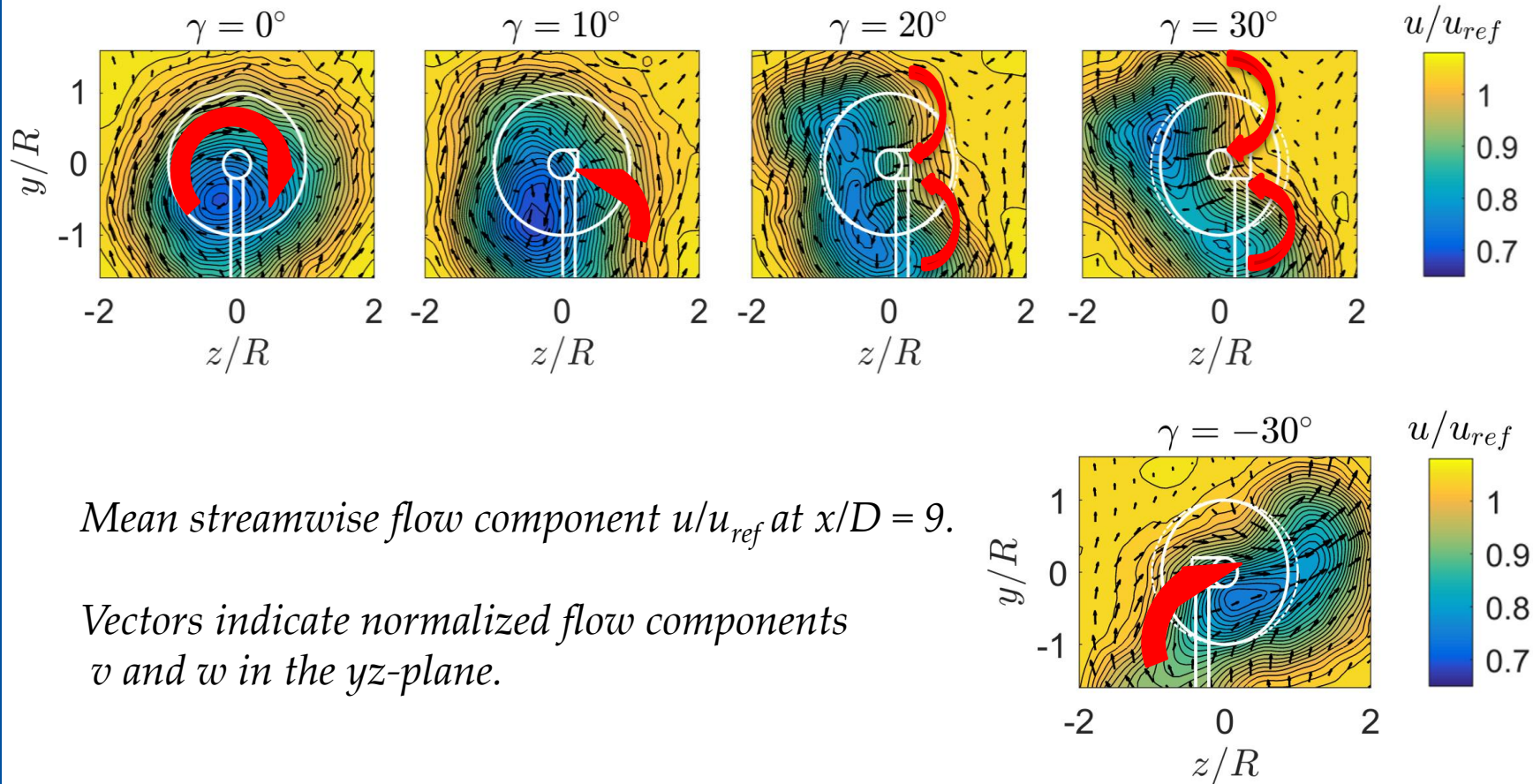*Comparison of the measured flow component u and v at x/D = 3 and γ= 30°. First column: ProCap results. Second column: LDA results.*

Comparison of results: u and v at 9D, $\gamma=30°$

Comparison of the measured flow component u and v at x/D = 6 and γ= 30°. First column: ProCap results. Second column: LDA results.

Further results: wake flow at 9D for different yaw angles

Mean streamwise flow component u/u$_{ref}$ at x/D = 9.

Vectors indicate normalized flow components v and w in the yz-plane.

Conclusions

- Successfully validation of ProCap measurement system for multiple wake scans

- Precise capture of strong velocity gradients and flow circulation

- Significantly shorter recording time

  $t_{ProCap} = 10\ min\ \ vs\ \ t_{LDA} = 6\ h.$

- Real-time data acquisition

  + Review and discussion of the results during measurement

➡ **Fast & accurate system for wind turbine wake measurements**

Thank you for your attention.

MORE INFORMATION ON ProCap:
http://www.streamwise.ch