

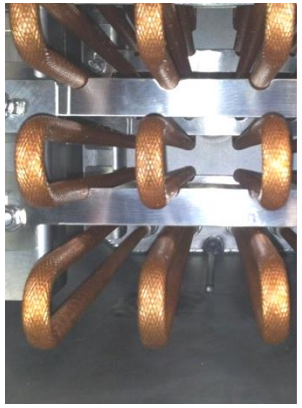


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Enhanced Measuring with Ultrasonic Clamp-On Flow Meters under Disturbed Flow Conditions

(preliminary version)

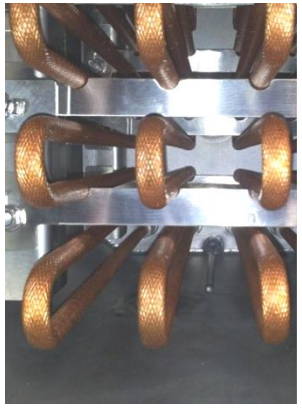
Supported by:

Federal Ministry for Economic Affairs and Energy

on the basis of a decision by the German Bundestag

O. Buchin, N. Berns | Institute of Energy Engineering – TU Berlin | EMATEM 2018



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1. Motivation and objectives of "nivEx"-project
2. Introduction to clamp-on ultrasonic flow metering
3. Test facility and experiments
4. Parameter analysis
5. Field application and limitations

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Motivation of "nivEx"-Project

Drenthen et al. 2009

- The vast majority of heat exchangers run under off-design conditions, hence are less efficient.
- A lack of inline sensors in most facilities yield a demand for mobile non-invasive highly accurate flow meters and thermometers.
- The uncertainty of ultrasonic clamp-on flow meters (USFM) strongly depends on the flow conditions (flow field).
- Thus, behind disturbances, e.g. elbows, the uncertainty exceeds 10 % in most instances.

Objectives of "nivEx"-Project

Drenthen et al. 2009

- Correcting the bias which corresponds to the uncertainty of the flow conditions.
- Correcting the bias of the temperature measurement.
- Development of an uncertainty budget for field applications.
- Joint research project:

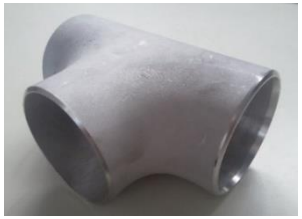
PTB

nivEx Expertensystem

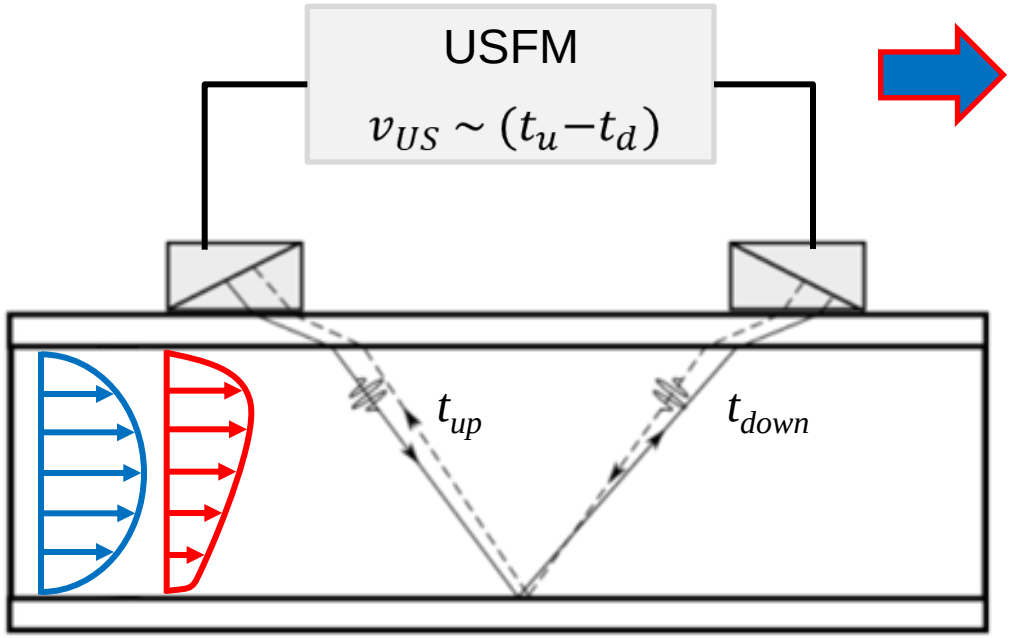
ADAKOM

Transit Time Method

US flow meters (USFM) using the transit time method obtain integral values presuming a fully developed flow profile.

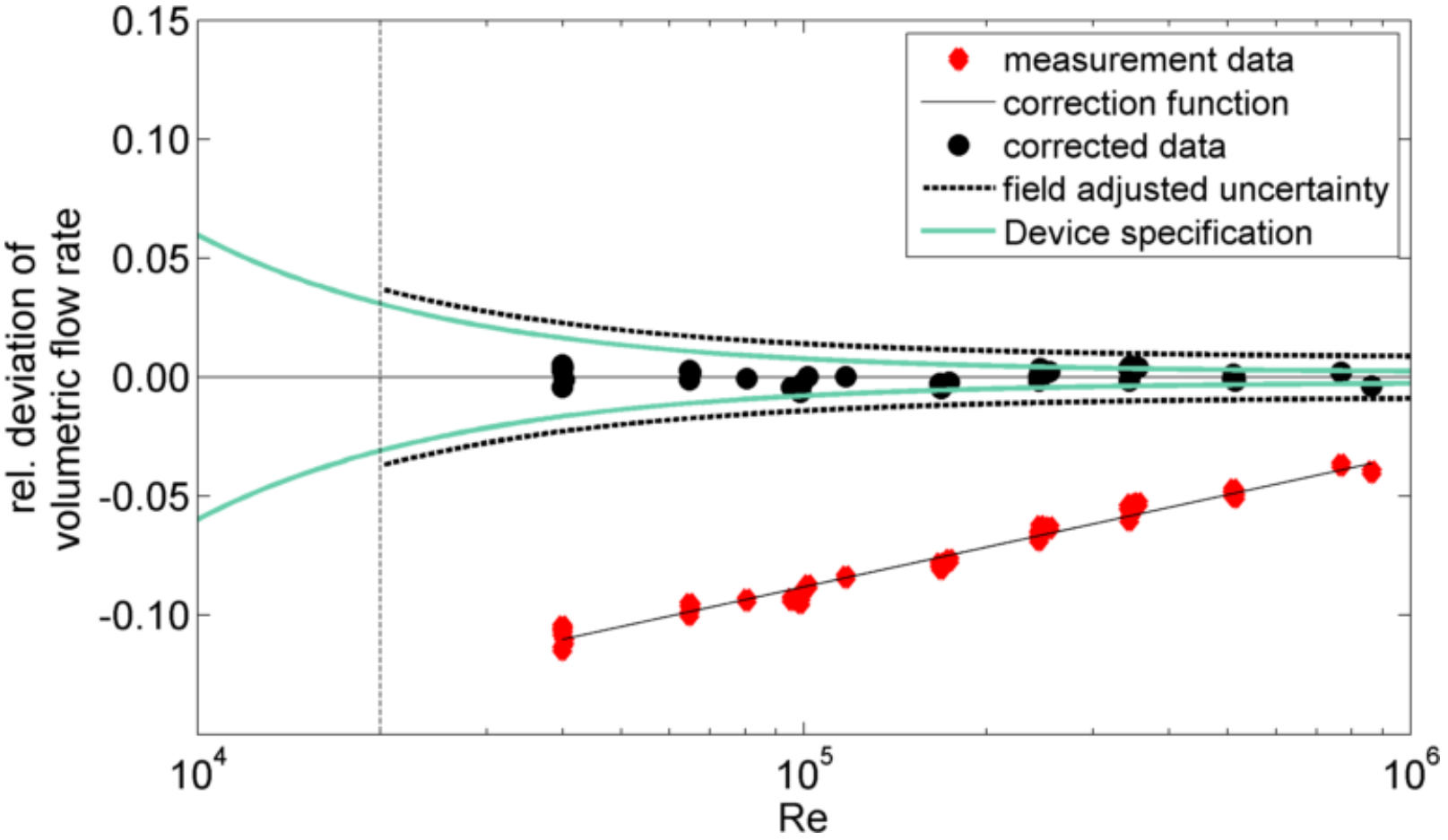


disturbed flow



$t_{up/down}$ – transit time up/downstream

Correction of Bias



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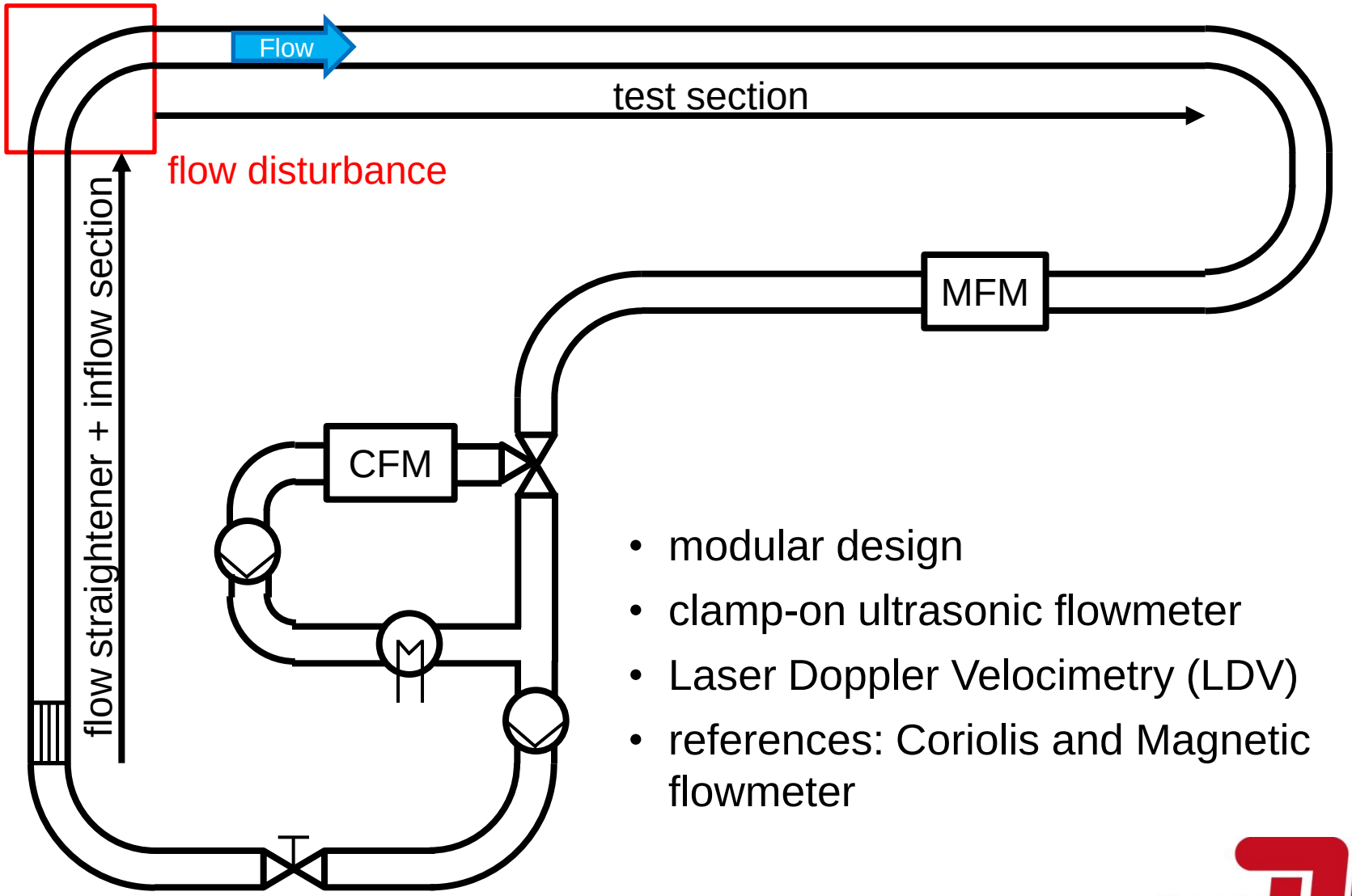
Contributors to the Uncertainty

- flow field (known and unknown disturbances)
- inaccuracy during the installation
- wall roughness
- inaccuracies in the geometry
- properties of the media and corresponding model assumptions
- uncertainty estimation

Test Facility at TU Berlin



- modular design
- clamp-on ultrasonic flowmeter
- Laser Doppler Velocimetry (LDV)
- references: Coriolis and Magnetic flowmeter

Investigations at TU Berlin

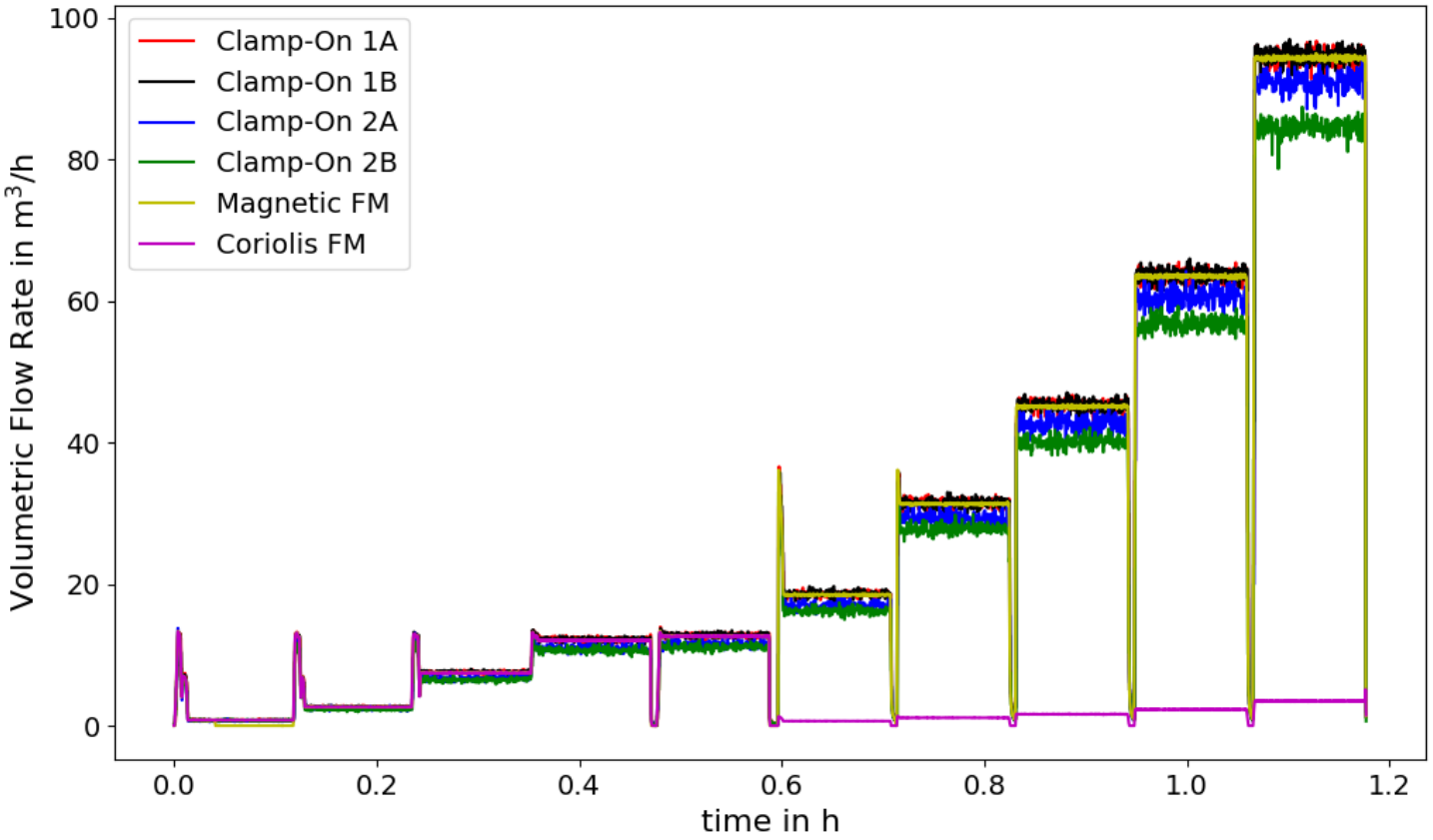
With LDV:

- Analysis of the initial flow field (symmetry, turbulence)
- Disturbed flow field at 5.8D

With USFM (clamp-on):

- Disturbances: 90°-bend (3 aspect ratios), double bend, T-junktion
- Reynolds numbers: $5x10^3$ to $1x10^6$
- Various locations downstream of the disturbance (angle and location)
- Fluids: water, (glycol)
- Fluid temperatures: 15 to 60 ºC

Typical "nivEx" Experiment



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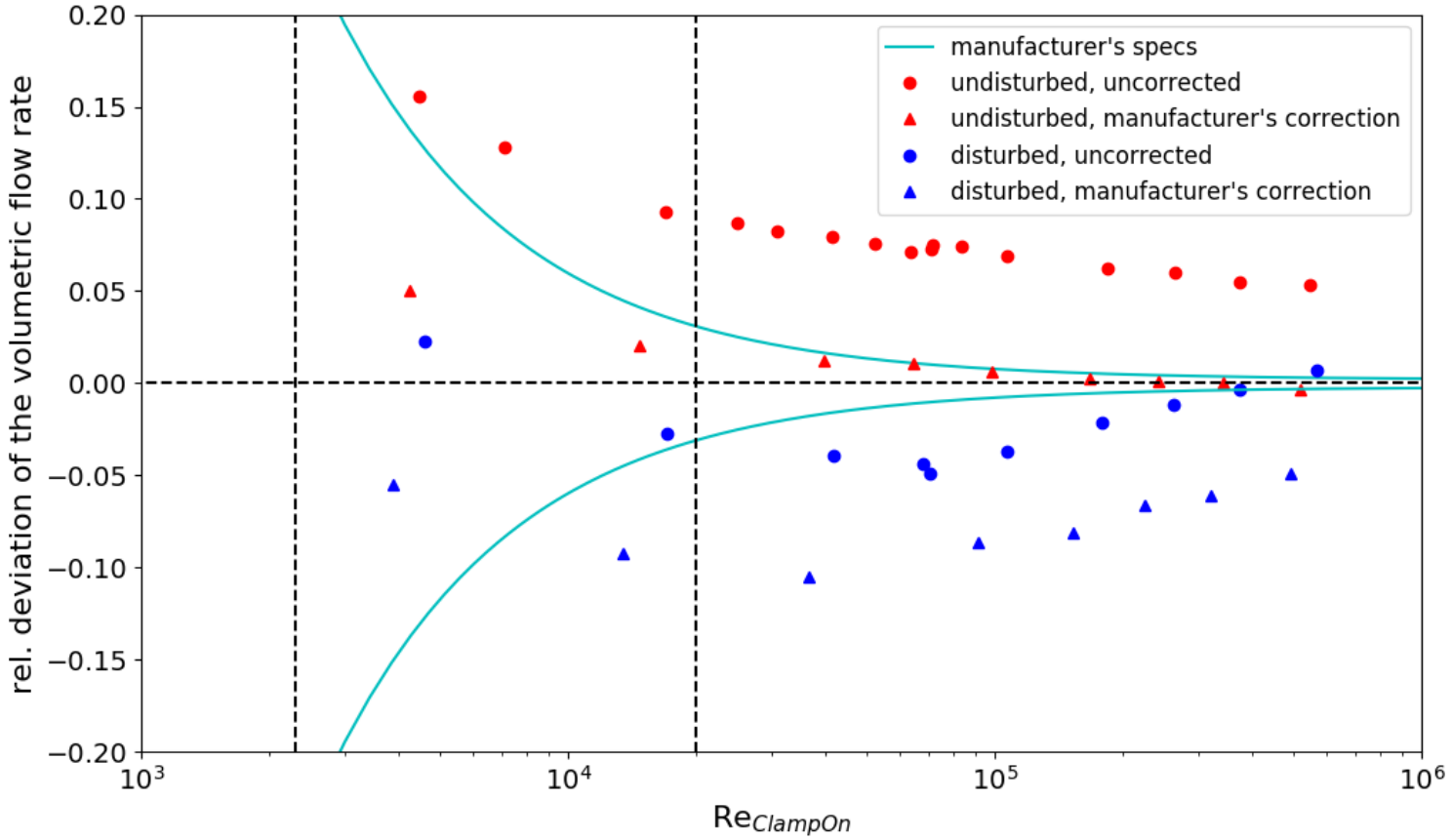
Measurement under Unfavourable Conditions

elbow, 90°-plane



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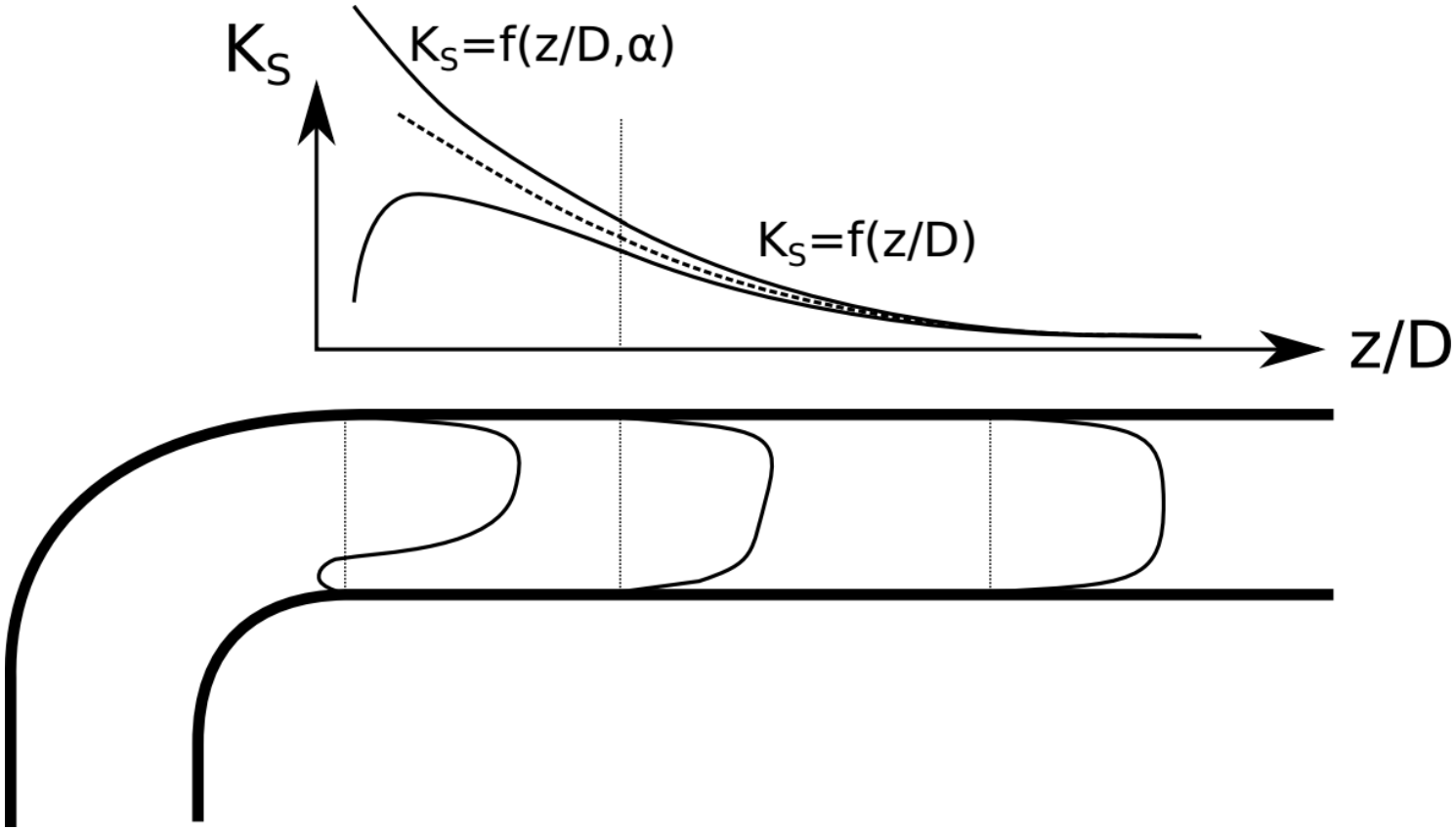
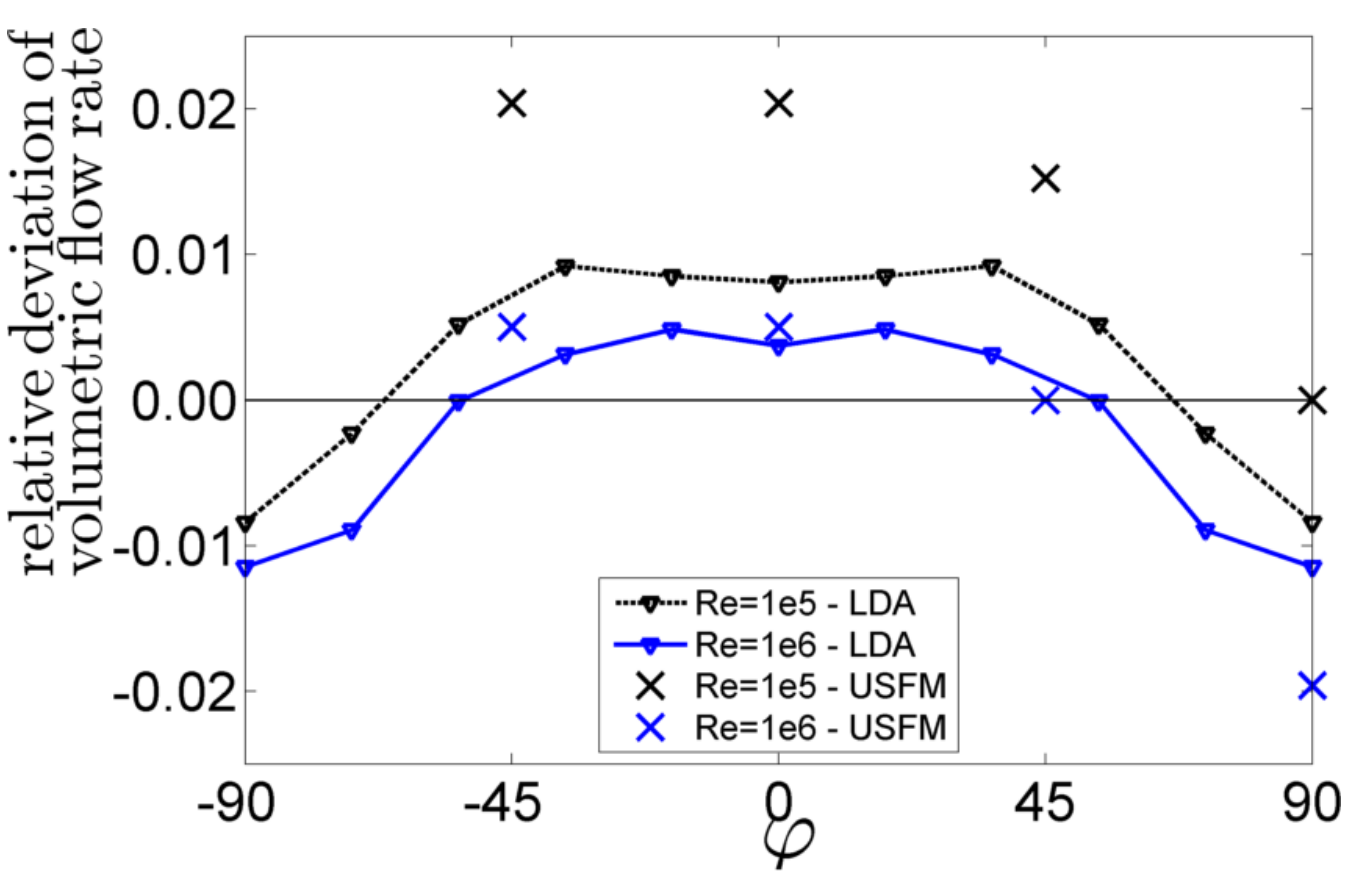
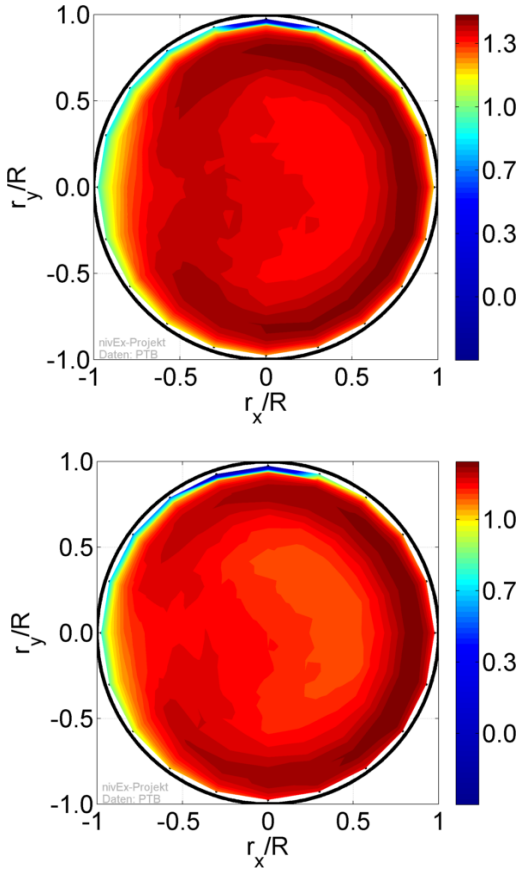
Decay Downstream of the Disturbance



Angular Influence

elbow, z/D=5.8





Conclusions

- Systematic influences of secondary flow structures yield maximum deviation
- 0°-plane is benefitial for accurate measurements in most constellations
- Weighted uncertainty estimates are necessary for appropriate regression
- Highest uncertainties in the transition region
- „nivEx“ correction function yields correction parameters and measure for uncertainty

Field Application and Limitations

- In-situ application of the correction function to improve the measurement set-up
- Application of the correction function to combined measurements for plausibility check and improved measuring

- Influence of pre-disturbed flow unknown
- Highest uncertainty for combination of slow and disturbed flow
- Transfer to gaseous fluids unknown
- Sensitive to user expertise and measurement installation