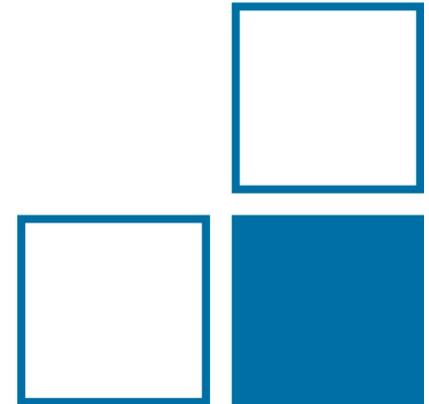


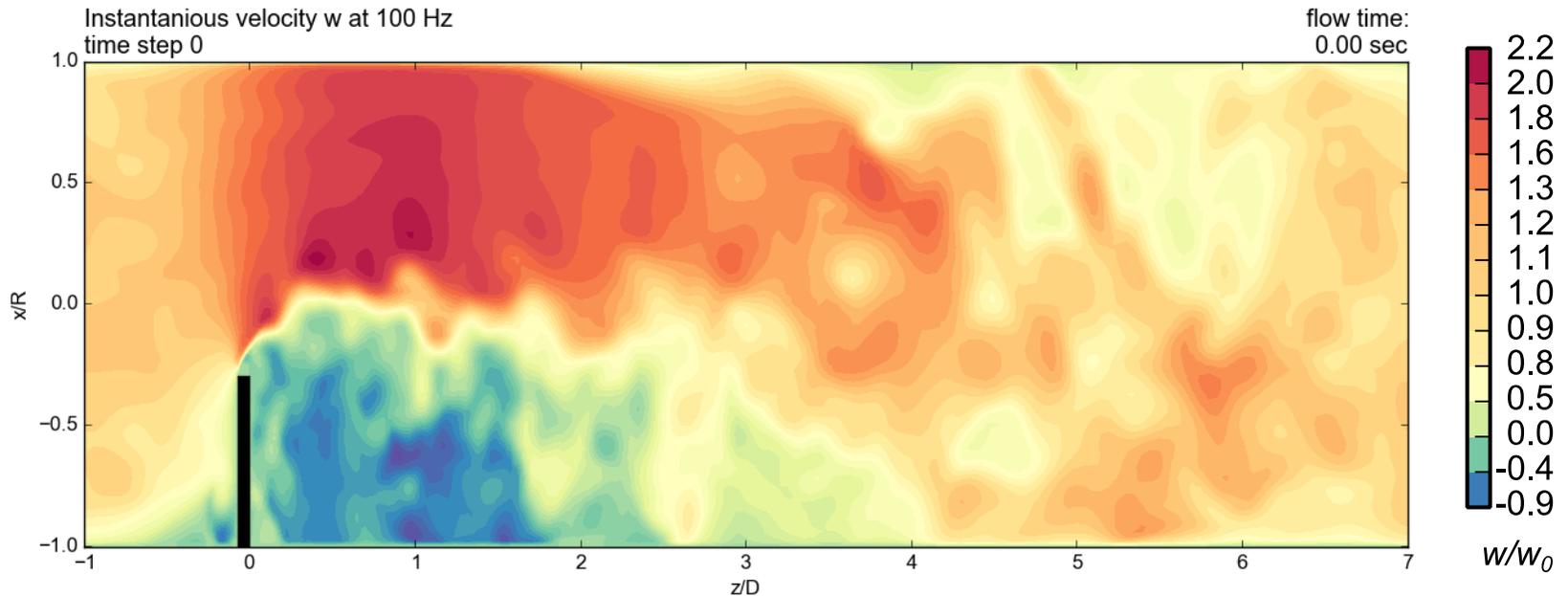
Segmental orifice plates and their practical relevance on flow meter test rigs

14. international EMATEM seminar
Gråsten, Sept. 18th – 21st 2018

Martin Straka, Thomas Eichler



- Analysis of disturbed pipe flows by means of hybrid CFD methods
- CFD & LDV results of 33% orifice DN 200
- Validation of the SBES turbulence model



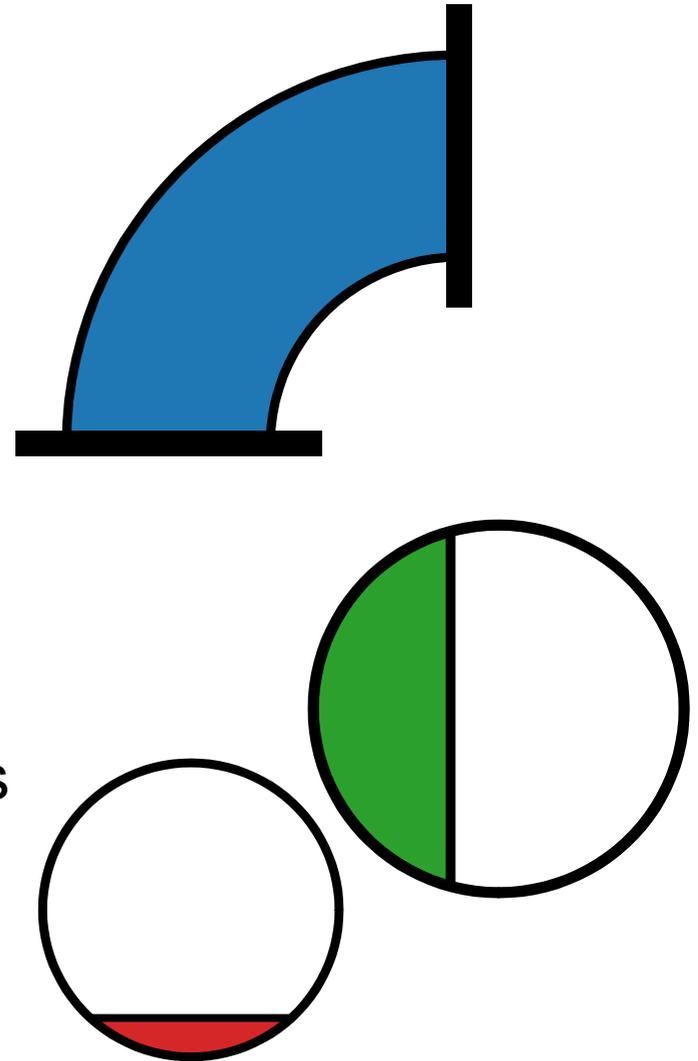
- Approval process due to standards
 - EN 1434 ^[1] : **swirl generator** (to be replaced in 2020)
 - EN ISO 4064 ^[2] / OIML R 49 ^[3] : **swirl generator + 7% orifice**
 - “ [..] *creates an asymmetric velocity profile usually found downstream of a protruding pipe joint, **single bend** or a gate valve not fully opened.*”
- R&D: Optimization / correction for real disturbances
 - Most common: **single bend**, **double bend configurations**, ..
 - Comparability with **orifices**, **new swirl generator**

[1] EN 1434-4, 2016. Heat meters - Part 4: Pattern approval tests

[2] ISO 4064-2, 2014. Water meters for cold potable water and hot water - Part 2: Test methods

[3] OIML R 49-2, 2013. Water meters for cold potable water and hot water - Part 2: Test methods

- **single bends & orifices**
- Geometrical specifications
- Qualitative flow development
- Quantitative description
 - performance indicators
 - errors of analytical flow meters
- Comparison of different designs
- Valuation of the orifice acc. standards
- Alternatives for the near & far field



- Single bend → EN 10253 [4] & [5]

Models	2D	3D	5D
$r_K/D \approx$	1	1.5	2.5

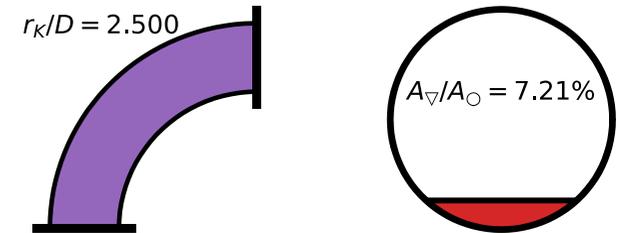
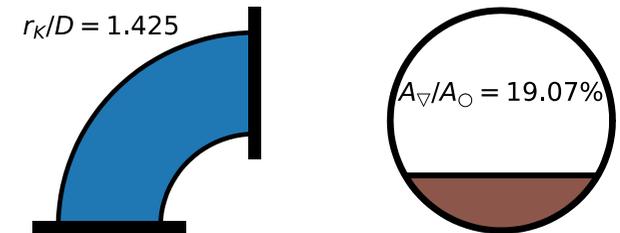
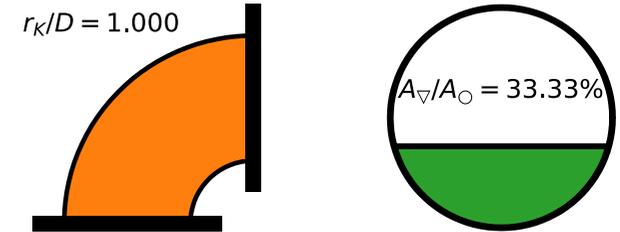
- 3D in DN 50 – DN 400

$$\rightarrow r_K/D = 1.303 \dots 1.545$$

- Orifice → ISO 4064 [2] / OIML R 49 [3]

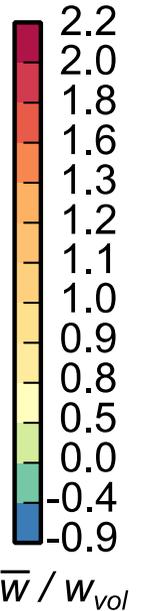
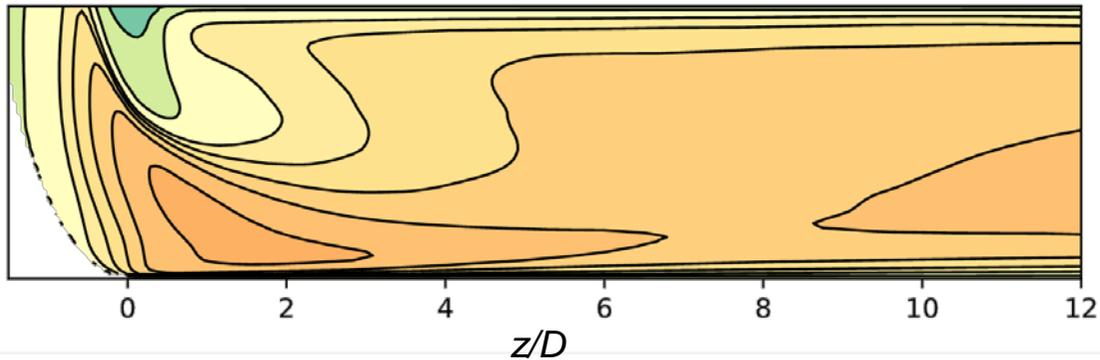
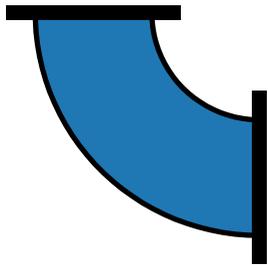
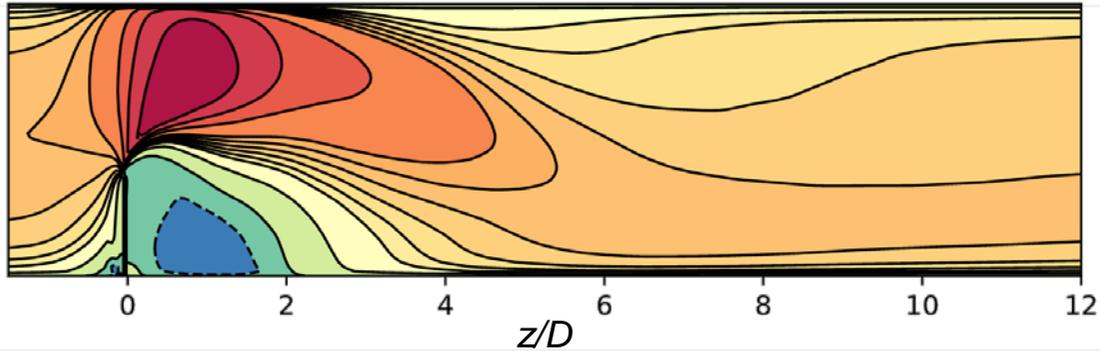
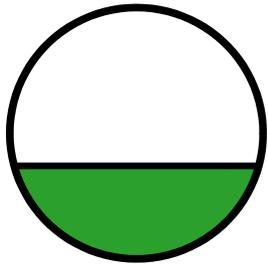
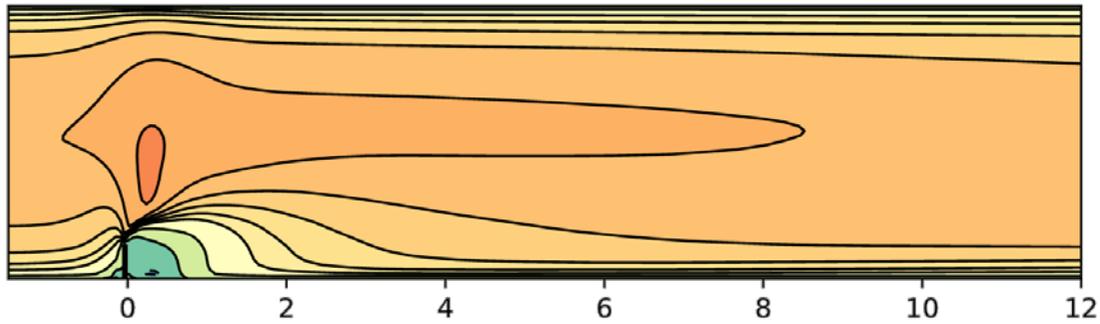
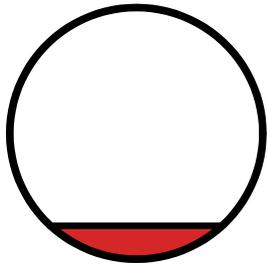
- Sagitta → A_{seg}/A_0

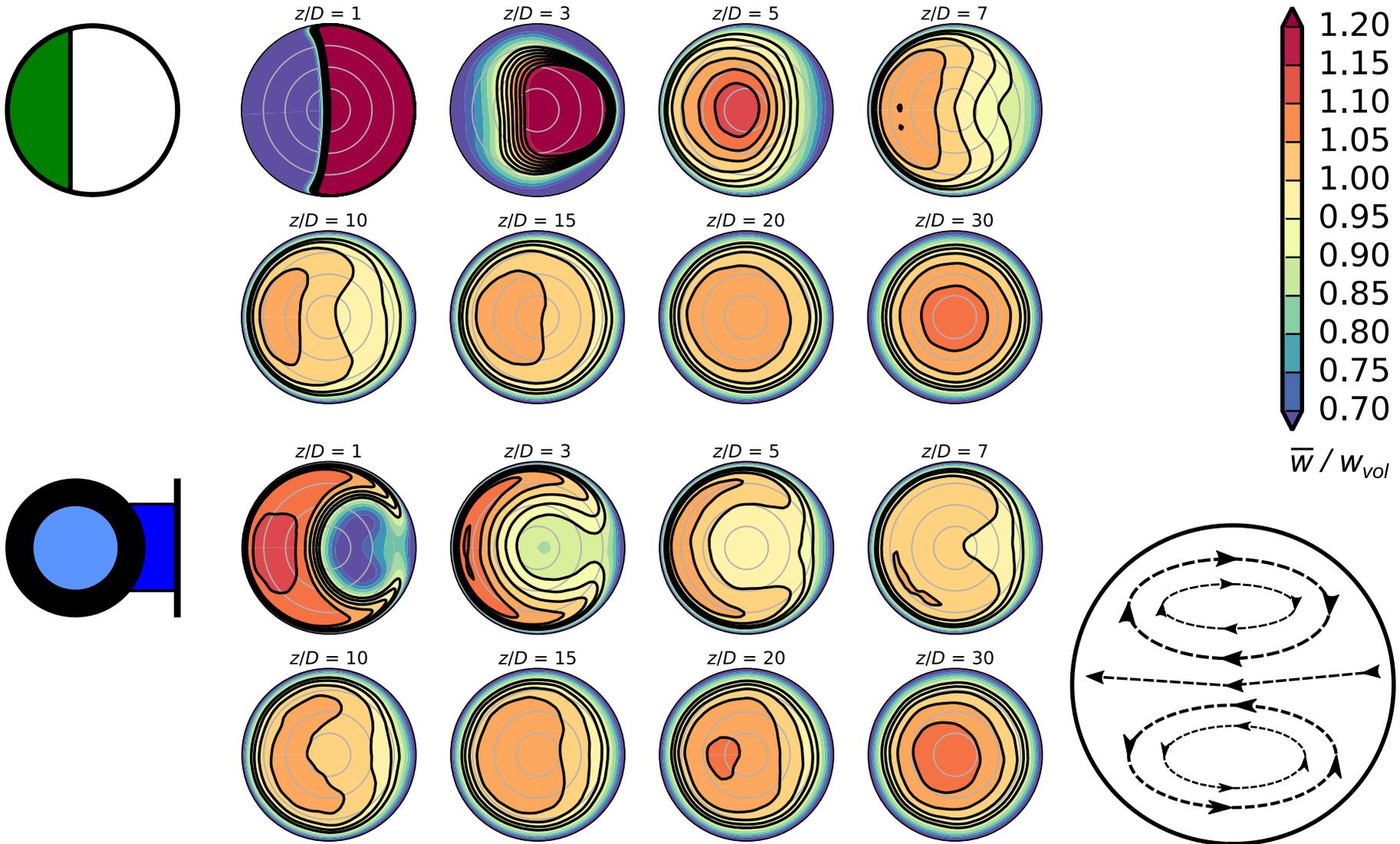
- 7.21 % in DN 100



[4] EN 10253-2, 2017. Butt-welding pipe fittings - Part 2: Non alloy and ferritic alloy steels with specific inspection requirements

[5] EN 10253-4, 2017. Butt-welding pipe fittings - Part 4: Wrought austenitic and austenitic-ferritic (duplex) stainless steels with specific inspection requirements



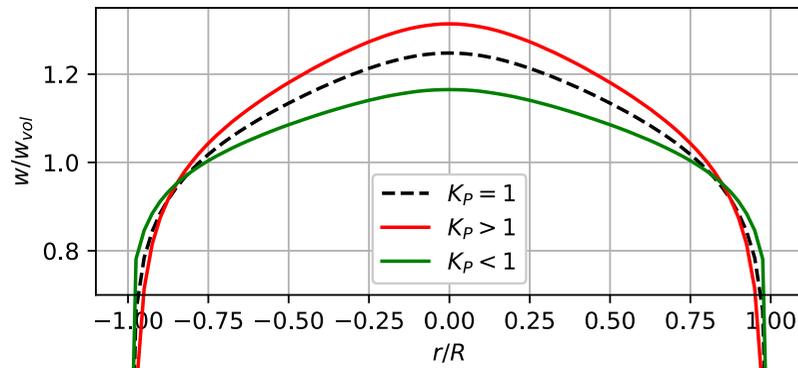


- Defined by Yeh and Mattingly [6]
- Utilized by Müller [7] to evaluate test rigs for EN 1434 [1]

- **Profile factor K_P**

- $$K_P = \frac{\int_{-1}^1 (w_m - w) \cdot \frac{dr}{R}}{\int_{-1}^1 (w_{s.m} - w_s) \cdot \frac{dr}{R}}$$

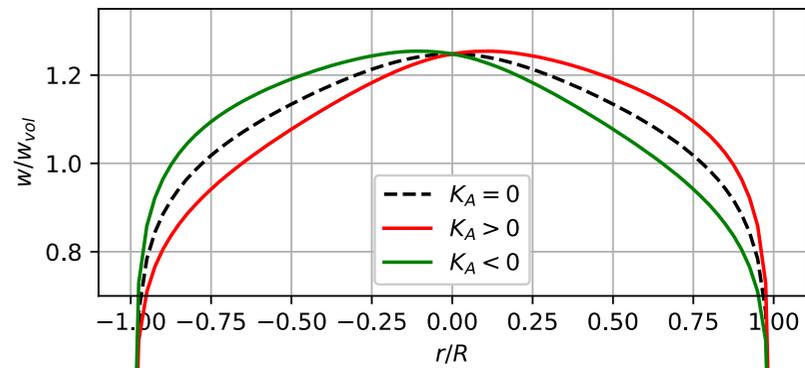
- **Peakness / Flatness**



- **Asymmetry factor K_A**

- $$K_A = \frac{\int_{-1}^1 \frac{r}{R} \cdot w \cdot \frac{dr}{R}}{\int_{-1}^1 w \cdot \frac{dr}{R}} [\%]$$

- **Radial displacement**



[6] T.T. Yeh, G. Mattingly, Pipeflow downstream of a reducer and its effects on flowmeters, Flow Meas. Instrum. 5 (1994) 181–187

[7] Müller, U., 2009. Guidelines for the Fluid Mechanical Validation of Calibration Test-Benches in the Framework of EN 1434

- Defined by Yeh and Mattingly [6]
- Utilized by Müller [7] to evaluate test rigs for EN 1434 [1]

- **Turbulence factor K_{Tu}**

$$Tu_{max} \begin{cases} \frac{r}{R} = -0.2 \\ \frac{r}{R} = 0.2 \end{cases}$$

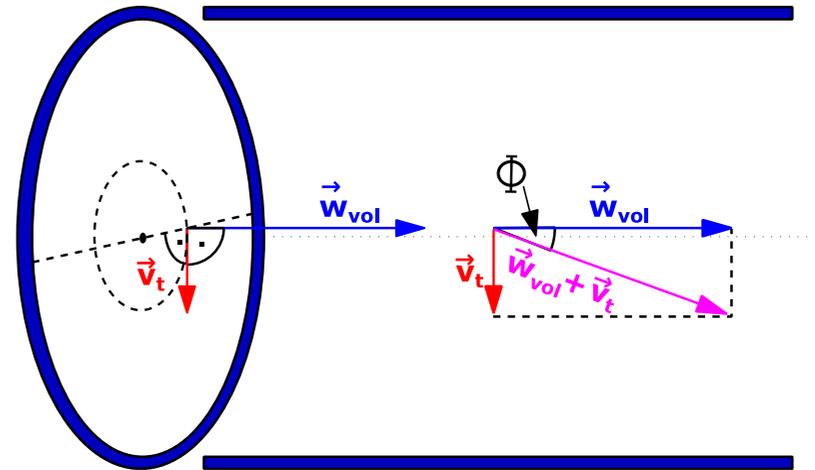
$$K_{Tu} = \frac{Tu_{max}}{Tu_s}$$

- Extent of turbulence

- **Max. swirl angle ϕ_{max}**

- $\phi_{max} = \text{atan}(|v_t|_{max}/w_{vol}) [^\circ]$

- Extent of non-axial flow



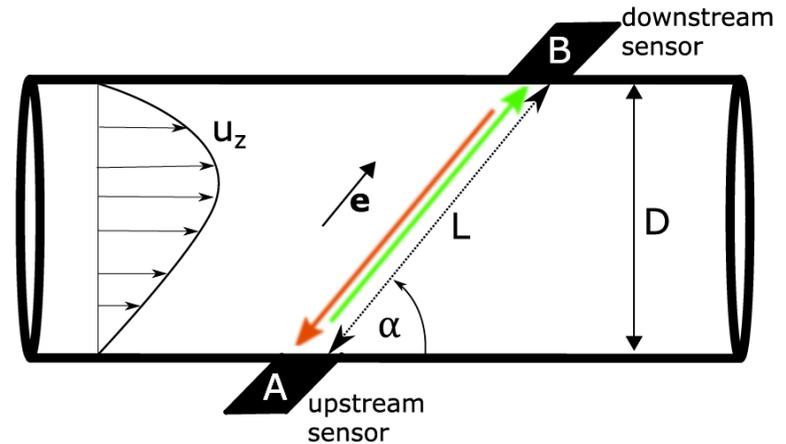
[6] T.T. Yeh, G. Mattingly, Pipeflow downstream of a reducer and its effects on flowmeters, Flow Meas. Instrum. 5 (1994) 181–187

[7] Müller, U., 2009. Guidelines for the Fluid Mechanical Validation of Calibration Test-Benches in the Framework of EN 1434

- **Ultrasonic flow meter (UFM)**

- $Q_{UFM} = k \cdot A \cdot \frac{1}{L \cdot e_z} \int_A^B \vec{u} \cdot \vec{e} \cdot dl$

- Single beam rotating around ϕ

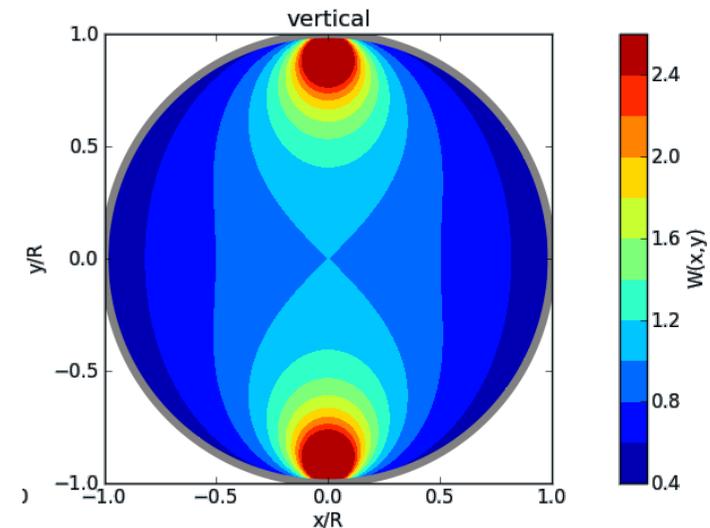


- **Electromagnetic flow meter (EMF)**

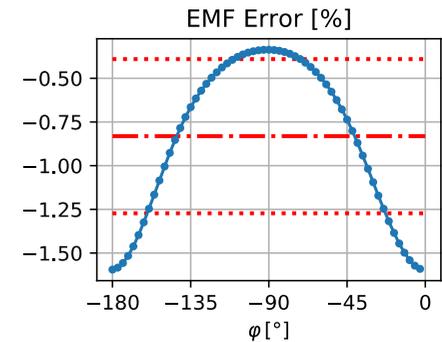
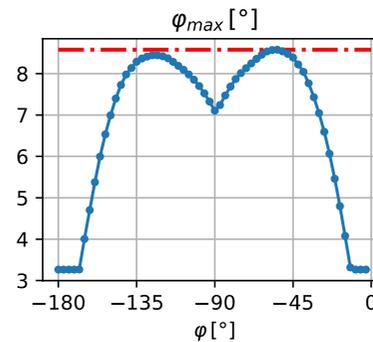
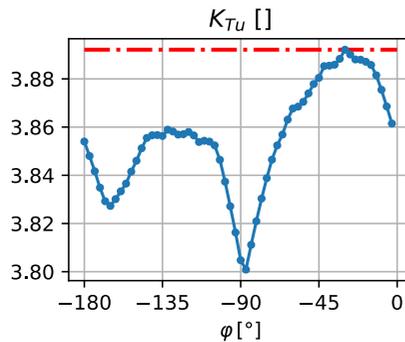
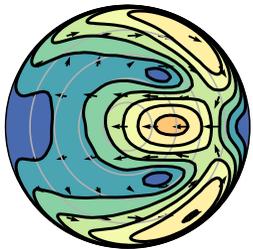
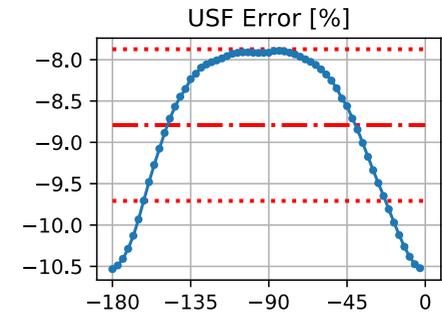
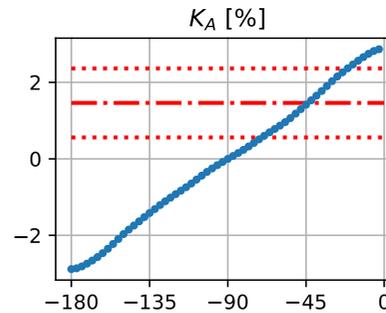
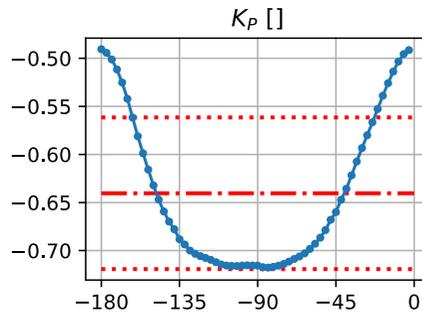
- $Q_{EMF} = k \cdot \iint W(x, y) \cdot w(x, y) \cdot dA$

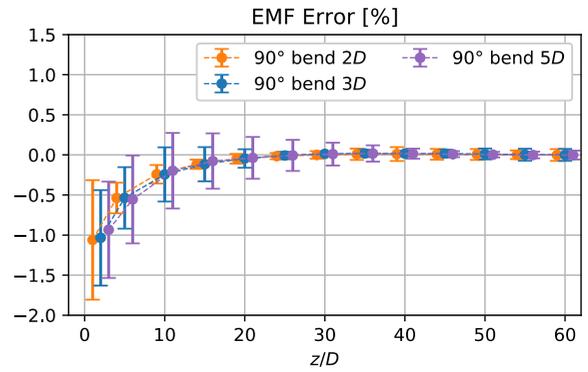
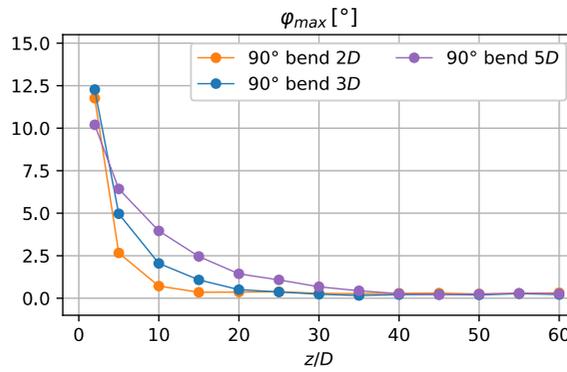
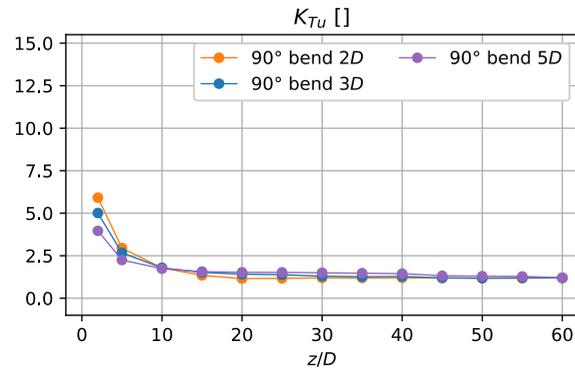
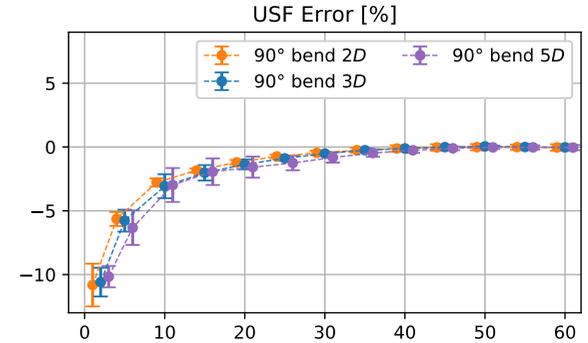
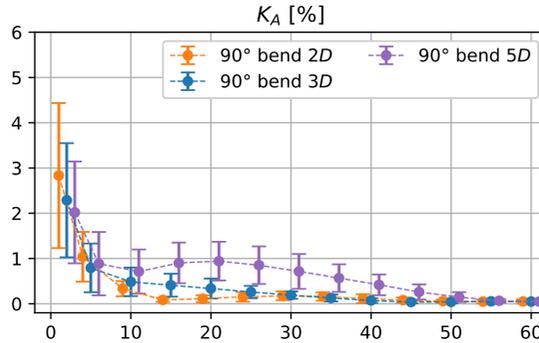
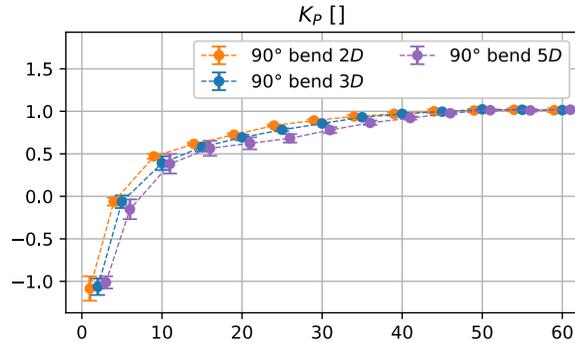
- $W(x, y)$: Shercliff weighting function

- Electrode rotating around ϕ

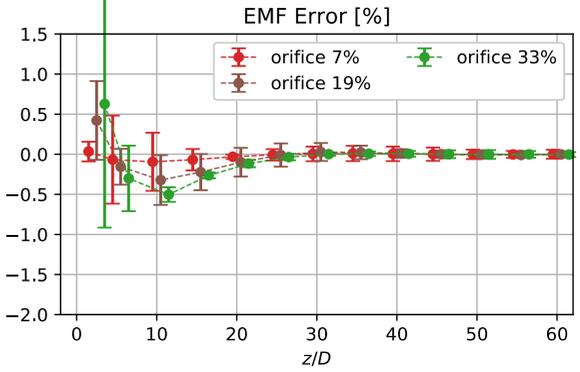
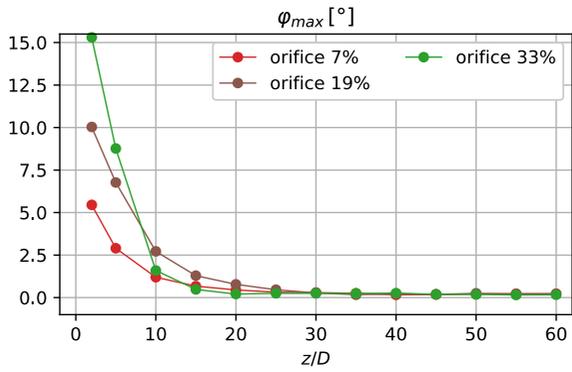
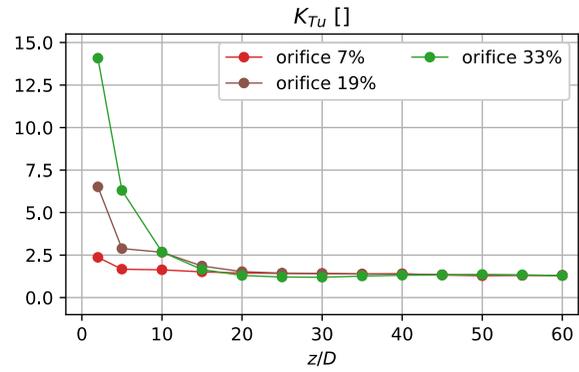
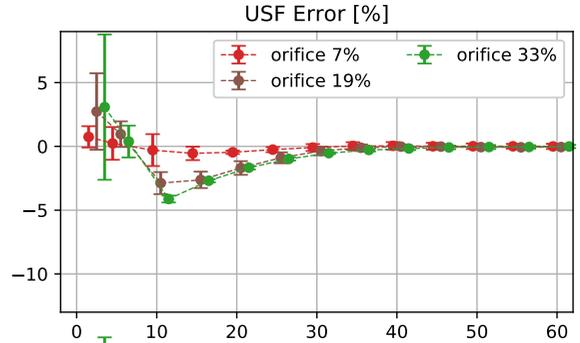
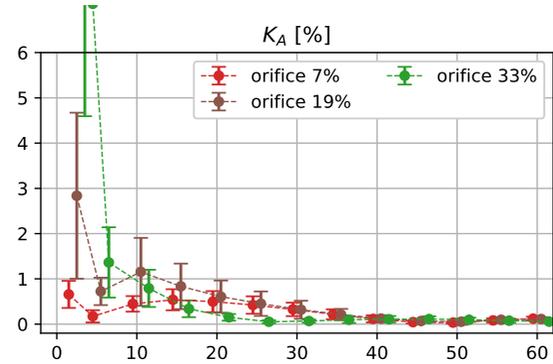
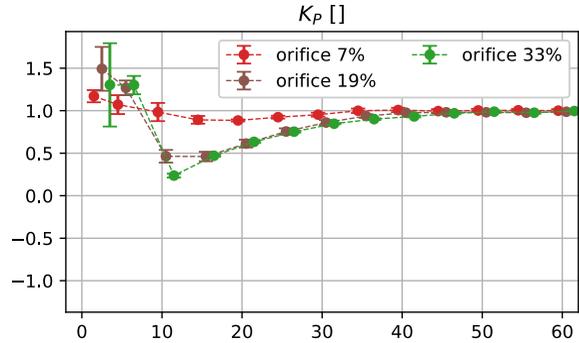


UFM figure from: <https://de.wikipedia.org/wiki/Ultraschallz%C3%A4hler>

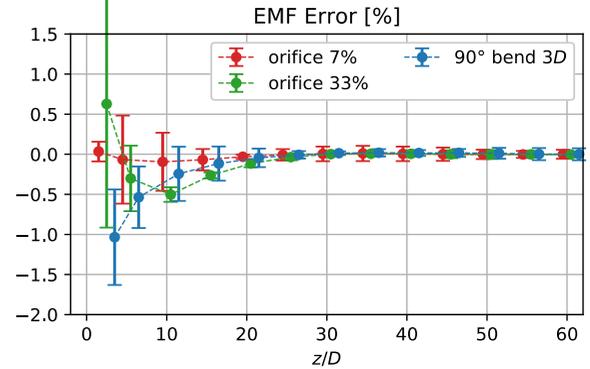
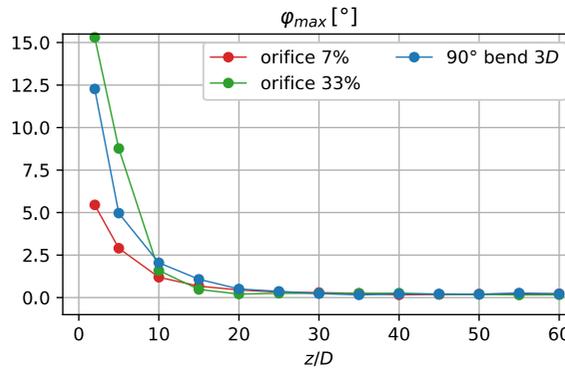
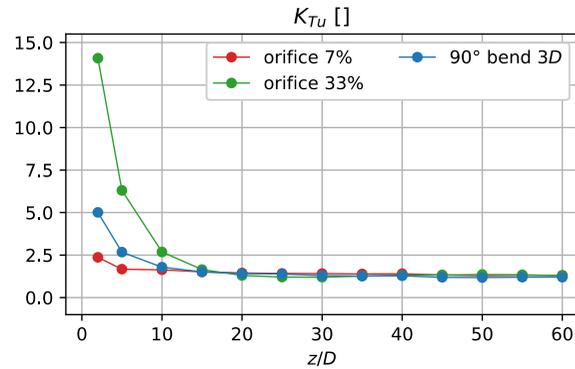
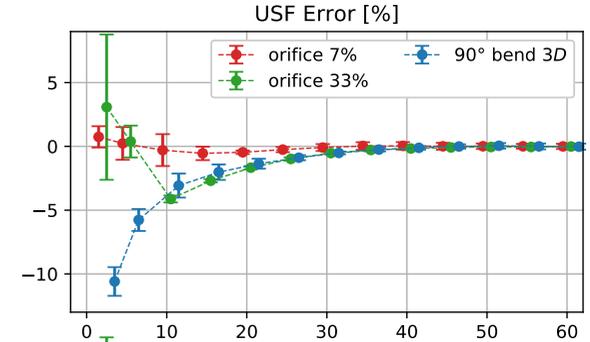
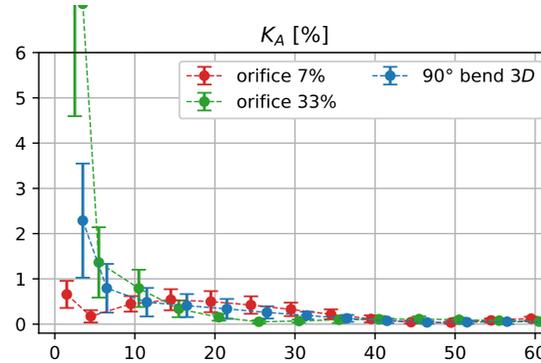
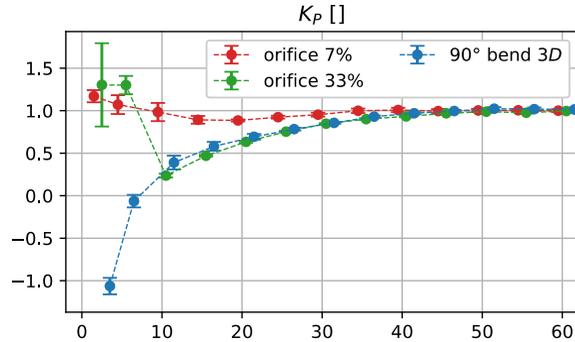


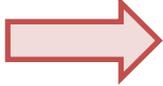


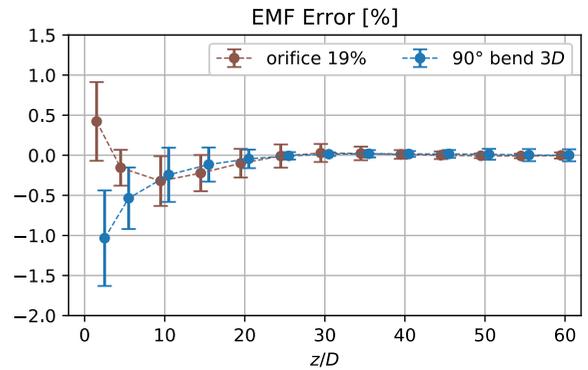
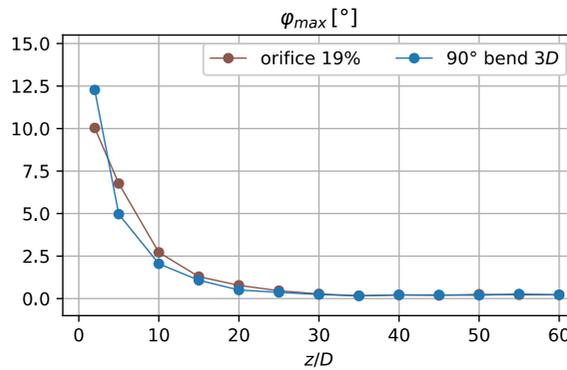
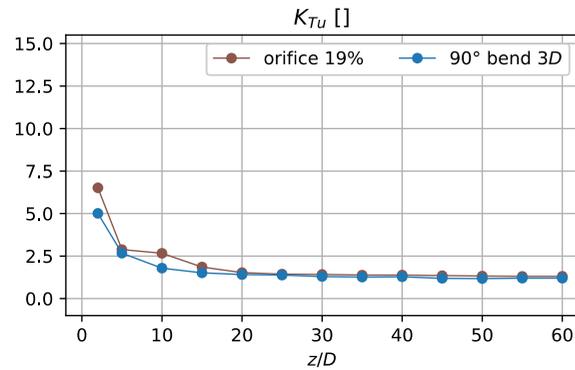
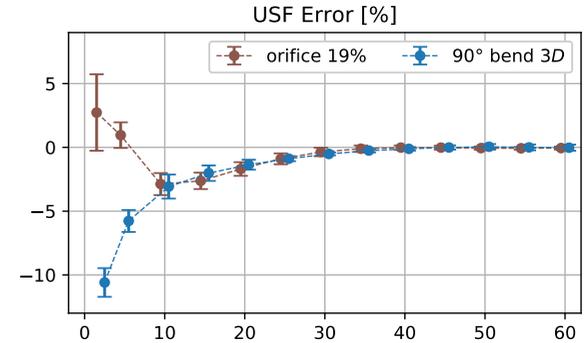
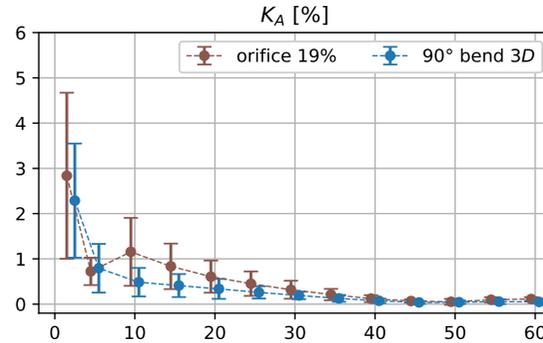
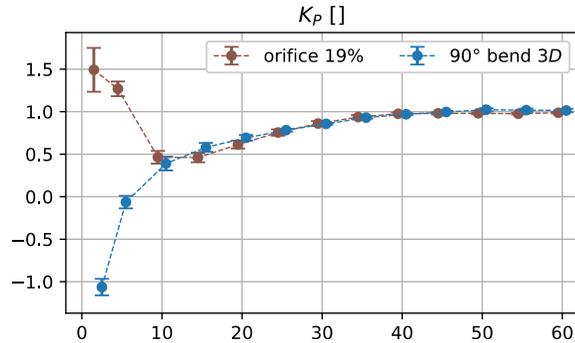
- $r_K/D \uparrow$ ➔ impact on flow developement
- ➔ persistence of disturbance \uparrow



- $A_{seg}/A_0 \uparrow$ \Rightarrow impact on flow developement
 \Rightarrow persistence of disturbance \downarrow

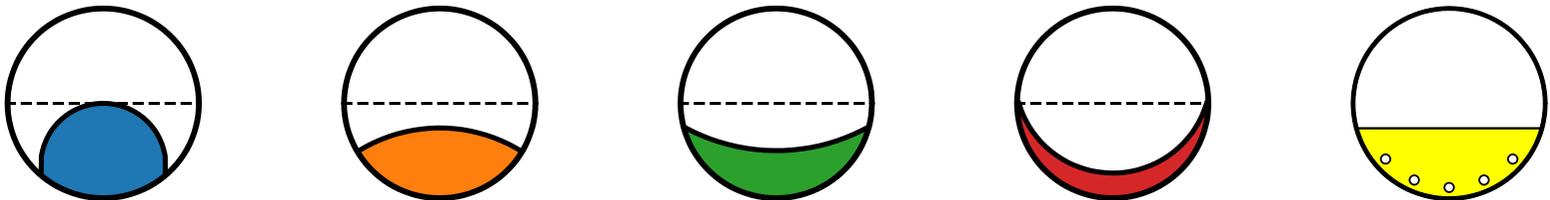


- Orifice 7 %  insufficient extent of disturbance
- Orifice 33 %  slightly exceeds influence of 3D model
-  $z/D > 10 !$



- Orifice 19 %  best match for 3D model
-  $z/D > 10$!

- Validated CFD results for single bends & orifices
- Strong influence of geometrical specifications
- Qualitative and quantitative flow description
- Orifice 7 %  insufficient extent of disturbance
- Orifice 19 %  best match for 3D model, $z/D > 10$
- Optimum orifice for different bend models
- Disturbance generator for the near field



Thank you for your attention!

Vielen Dank für Ihre Aufmerksamkeit!



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