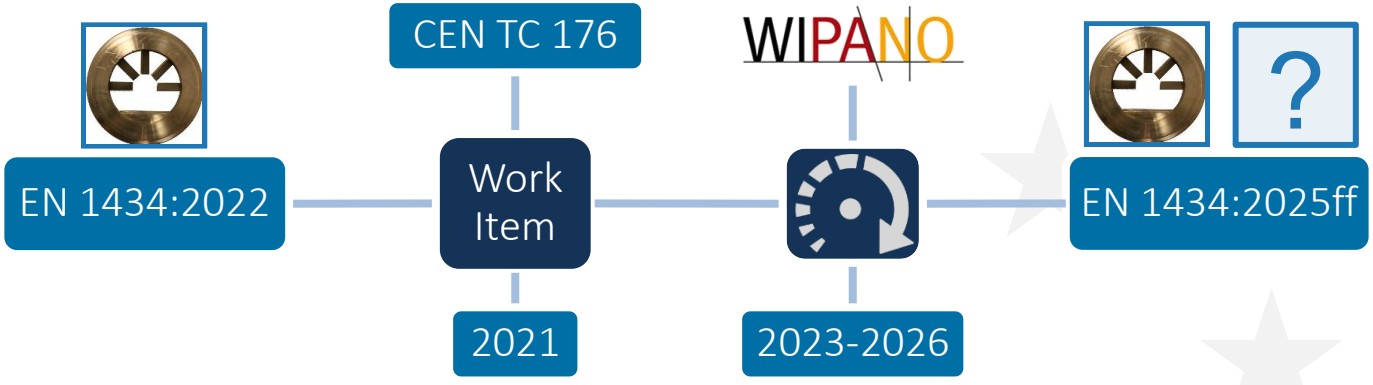

EMATEM
European Metrology Association
for Thermal Energy Measurement

# Entwicklung eines Störkörpers für die EN 1434

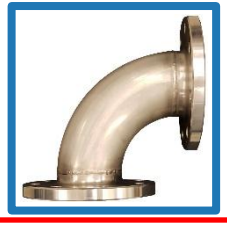
# Projektvorstellung

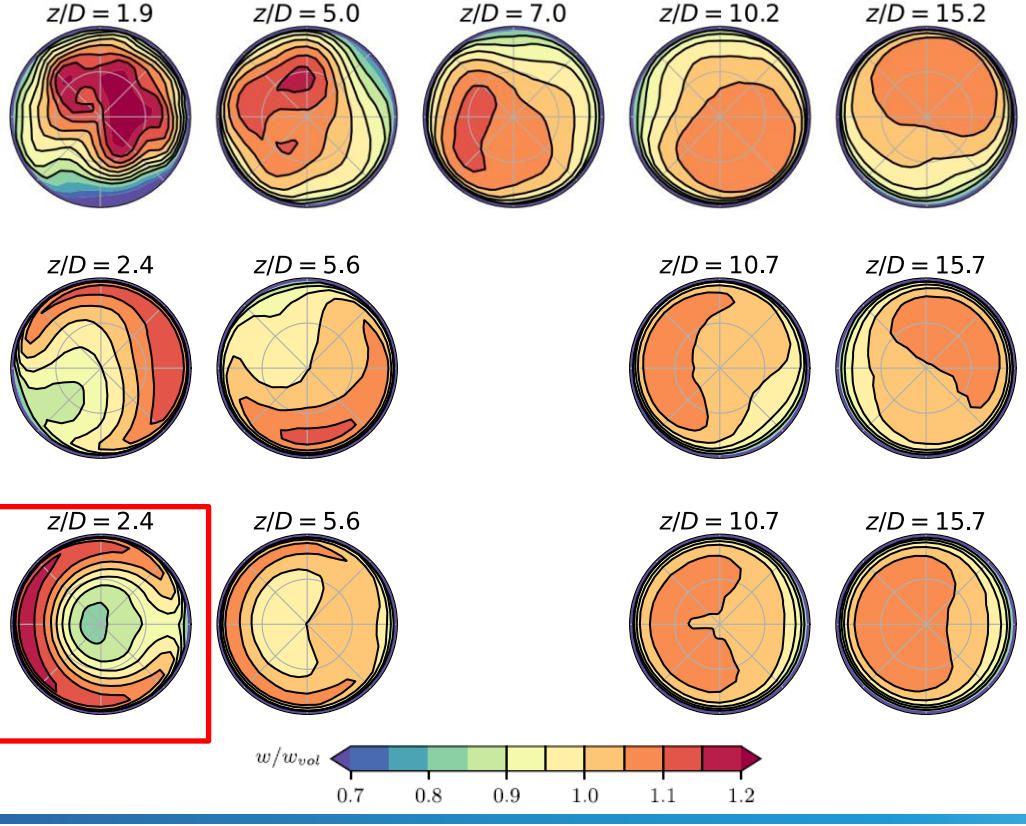



- **WIPANO** (BMWE) - Wissens- und Technologietransfer durch Patente und Normen
- **Work item**: Flow profiles in water and water glycol solution networks, e.g. 90° bend and double bend out of plane
- **Laufzeit**: September 2023 – April 2026
- **Projektpartner**: Physikalisch-Technische Bundesanstalt (PTB), Wärmezähler-Service-GmbH (WSG)
- **Zielstellung**
  - Messtechnische Validierung der Zulassung ohne Einlaufstrecke („0D-Zulassung“) im Durchflusstest der EN 1434
  - Entwicklung eines Störkörpers zur Darstellung des Nahfeldbereichs hinter Krümmer-Konfigurationen
  - Ggf. Erweiterung des Durchflusstests um neuen Störkörper

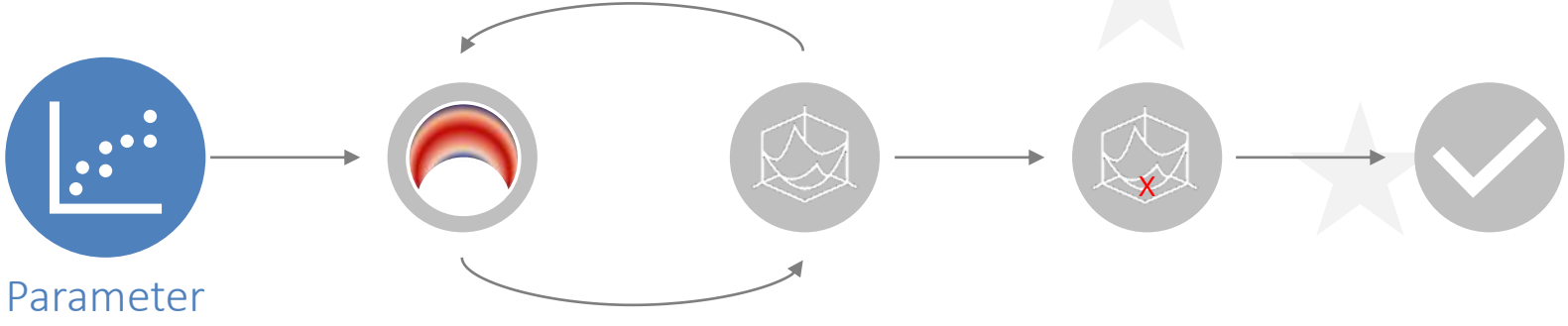
PTB WSG Wärmezähler-Service

# Vergleich der Strömungsprofile





# Designprozess



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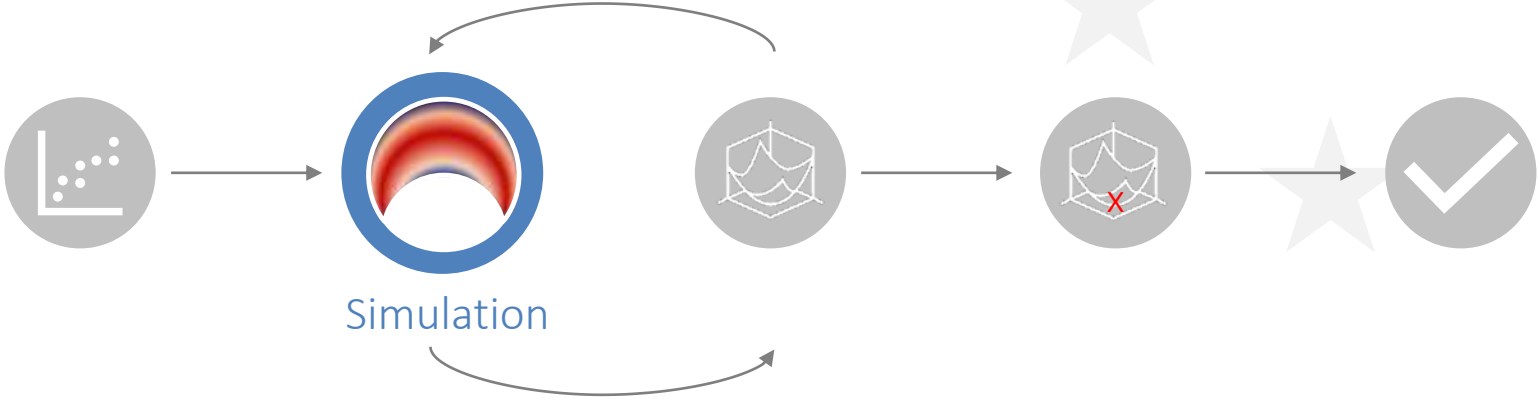
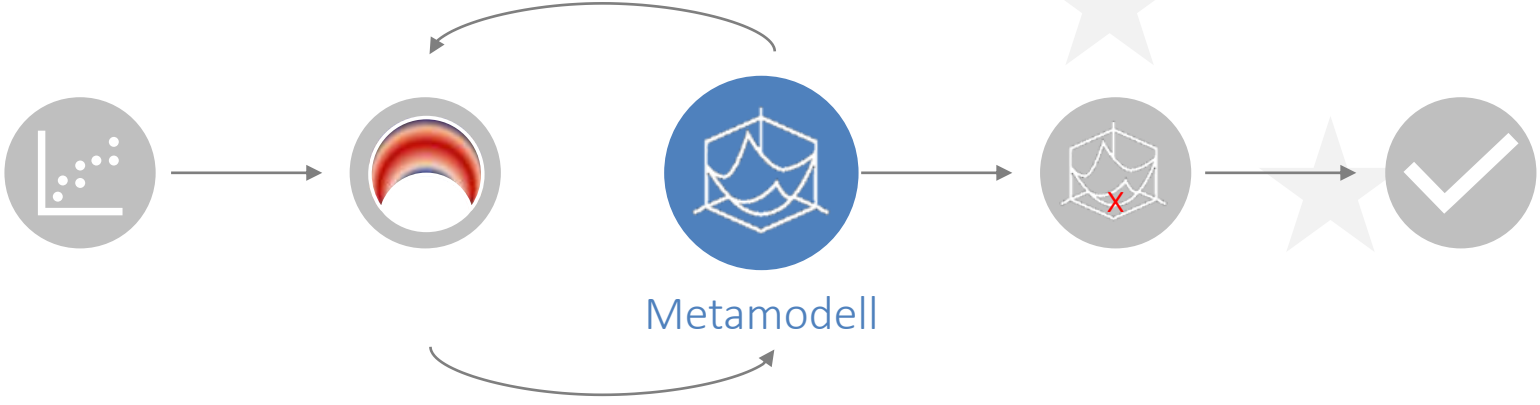


# Designprozess



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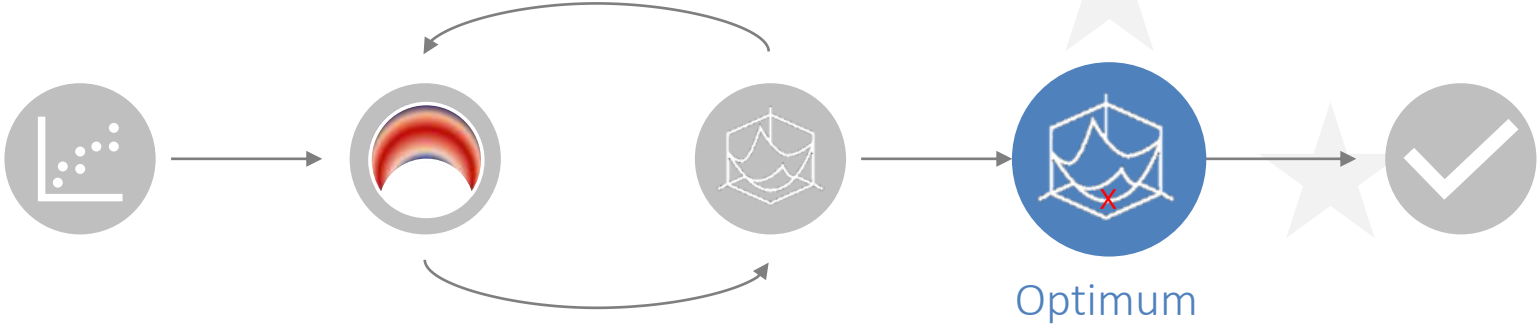

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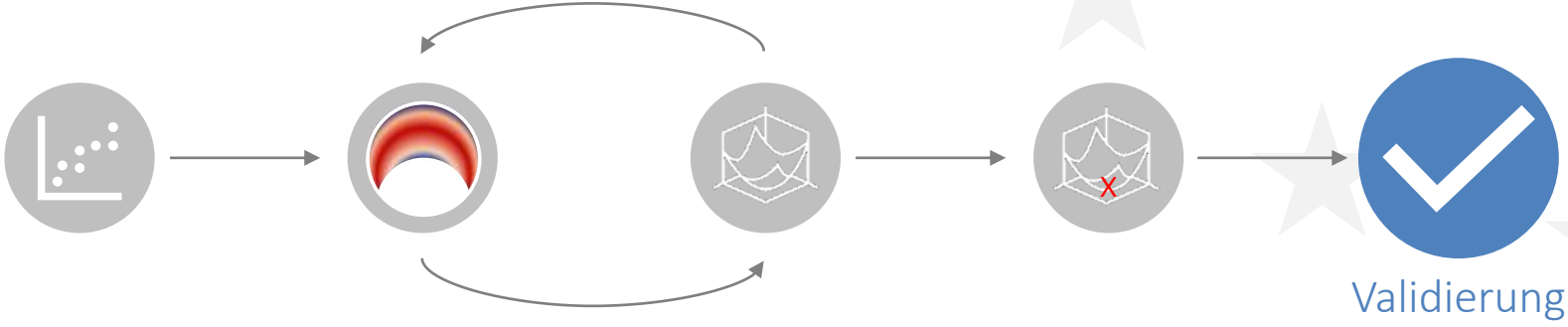
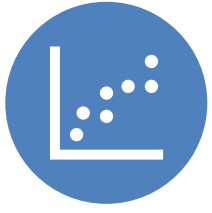




Parameter

# Parameter

## Eingangsgrößen

- Geometrieparameter (Dicke, Durchmesser, …)
- Randbedingungen (Durchflussgeschwindigkeit)

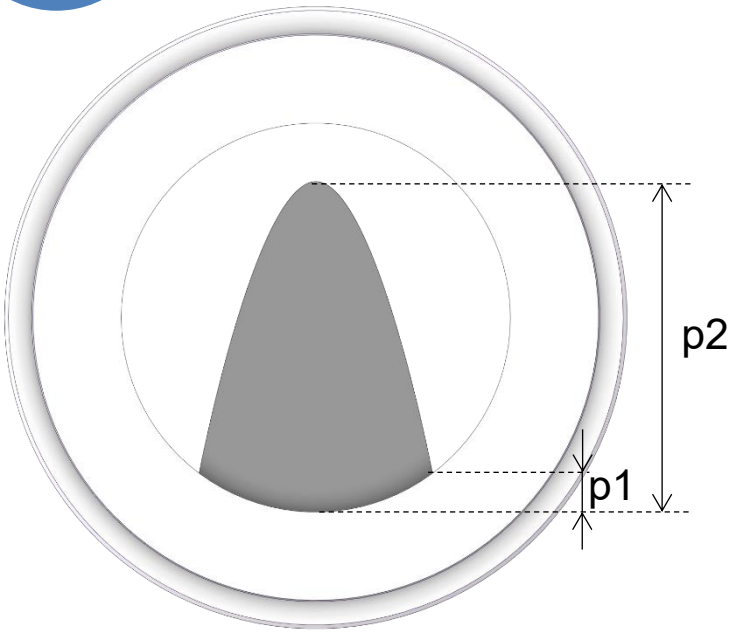
## Zielgröße

- Unterschied zweier Strömungsprofile
- Temperaturverteilung
- Kombination verschiedener Größen

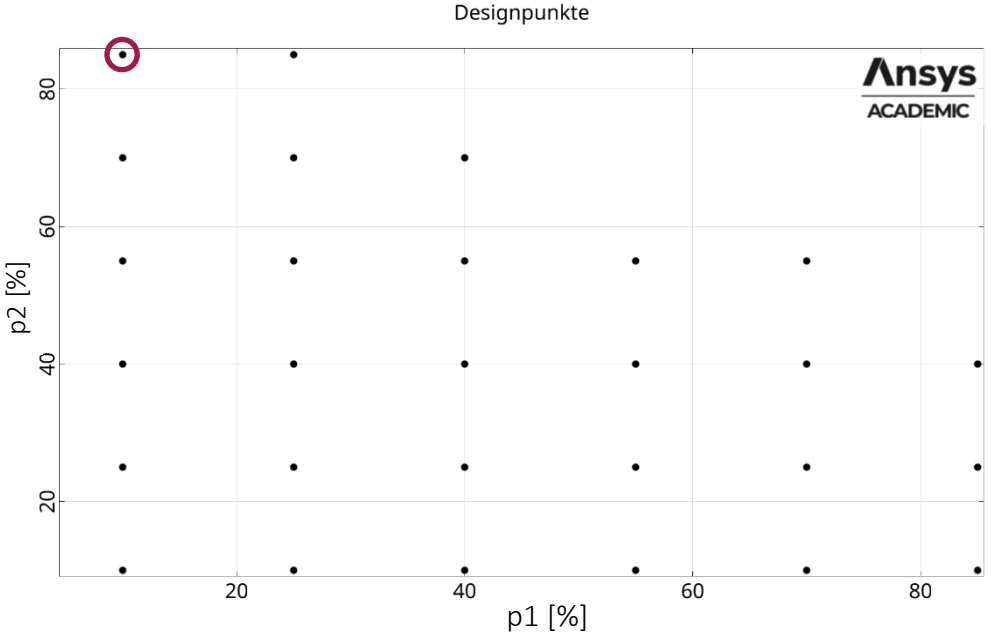
## Nebenbedingung

- Einbauplatz
- Fertigungsmöglichkeiten

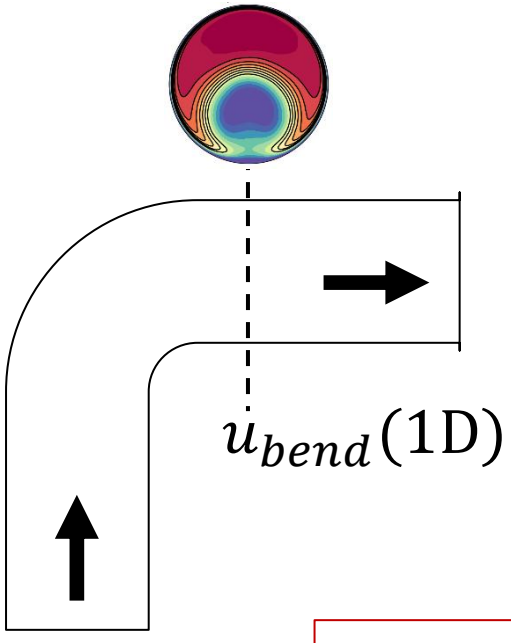
# Parameter

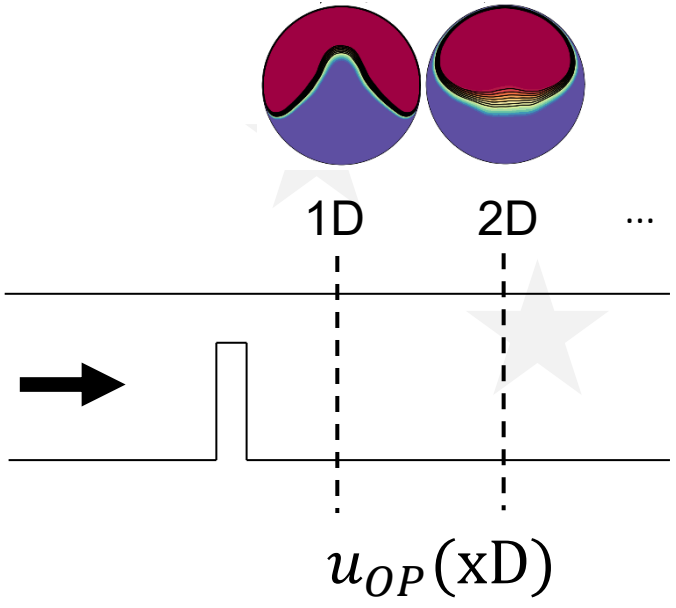



$$A_{OP} \leq \frac{2}{3} A_{Pipe}$$

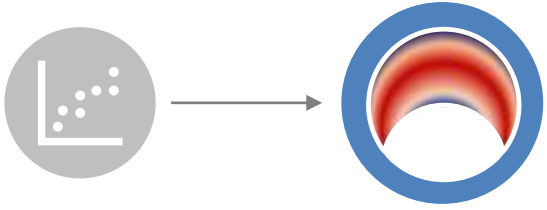


# Parameter



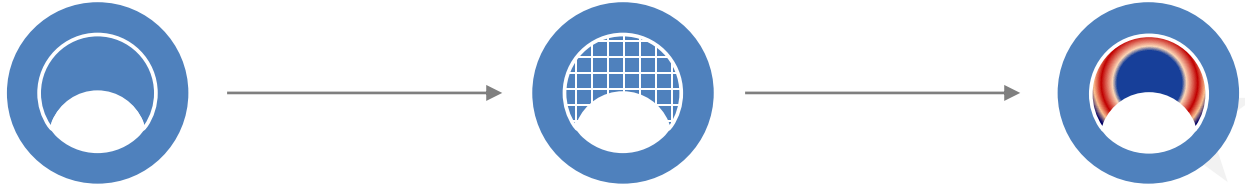




$$L^1 = \frac{4}{\pi D^2} \int_0^{2\pi} \int_0^{D} |u_{bend} - u_{OP}| r \, dr d\phi$$



Simulation

# Simulation



Geometrie

# Simulation

Vernetzung

# Simulation

# Simulation

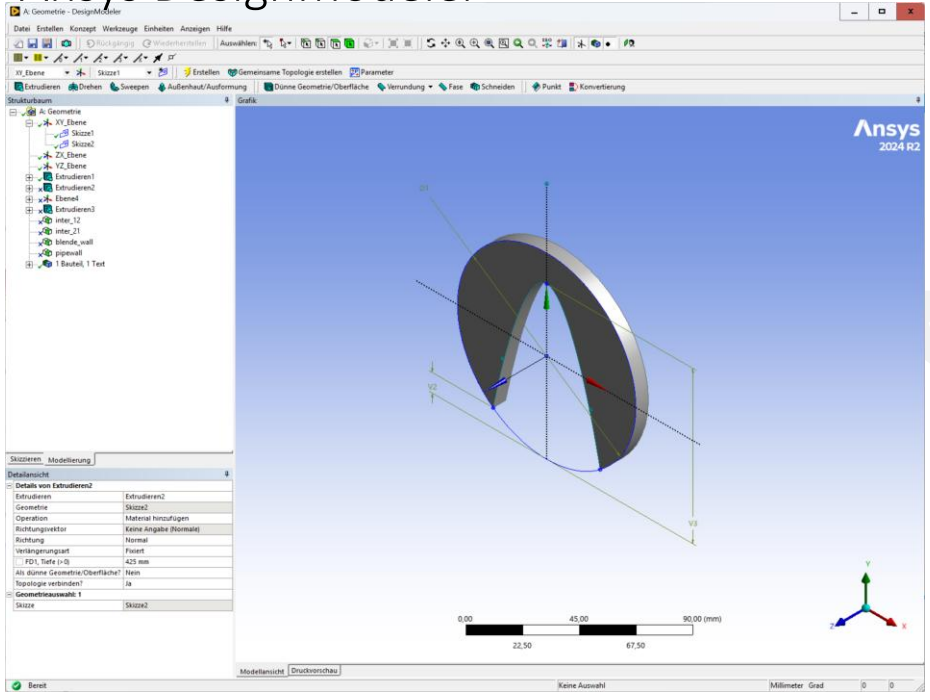
# Geometrie

## Ansys Workbench

Tabelle von Design Points

| | A | B | C | D | E |
|---|---|---|---|---|---|
| 1 | Name | P1 - p11 | P2 - p13 | Beibehalten | Beibehaltene Daten |
| 2 | Maßeinheiten | mm | mm | | |
| 3 | DP 0 | 10 | 10 | | |
| 4 | DP 1 | 10 | 25 | | |
| 5 | DP 2 | 10 | 40 | | |
| 6 | DP 3 | 10 | 55 | | |
| 7 | DP 4 | 10 | 70 | | |
| 8 | DP 5 | 10 | 85 | | |
| 9 | DP 6 | 25 | 10 | | |
| 10 | DP 7 | 25 | 25 | | |
| 11 | DP 8 | 25 | 40 | | |
| 12 | DP 9 | 25 | 55 | | |
| 13 | DP 10 | 25 | 70 | | |
| 14 | DP 11 | 25 | 85 | | |
| 15 | DP 12 | 40 | 10 | | |
| 16 | DP 13 | 40 | 25 | | |
| 17 | DP 14 | 40 | 40 | | |
| 18 | DP 15 | 40 | 55 | | |
| 19 | DP 16 | 40 | 70 | | |
| 20 | DP 17 | 40 | 85 | | |
| 21 | DP 18 | 55 | 10 | | |
| 22 | DP 19 | 55 | 25 | | |
| 23 | DP 20 | 55 | 40 | | |
| 24 | DP 21 | 55 | 55 | | |
| 25 | DP 22 | 55 | 70 | | |
| 26 | DP 23 | 55 | 85 | | |
| 27 | DP 24 | 70 | 10 | | |
| 28 | DP 25 | 70 | 25 | | |
| 29 | DP 26 | 70 | 40 | | |
| 30 | DP 27 | 70 | 55 | | |
| 31 | DP 28 | 70 | 70 | | |
| 32 | DP 29 | 70 | 85 | | |
| 33 | DP 30 | 85 | 10 | | |
| 34 | DP 31 | 85 | 25 | | |
| 35 | DP 32 | 85 | 40 | | |
| 36 | DP 33 | 85 | 55 | | |
| 37 | DP 34 | 85 | 70 | | |
| 38 | DP 35 | 85 | 85 | | |

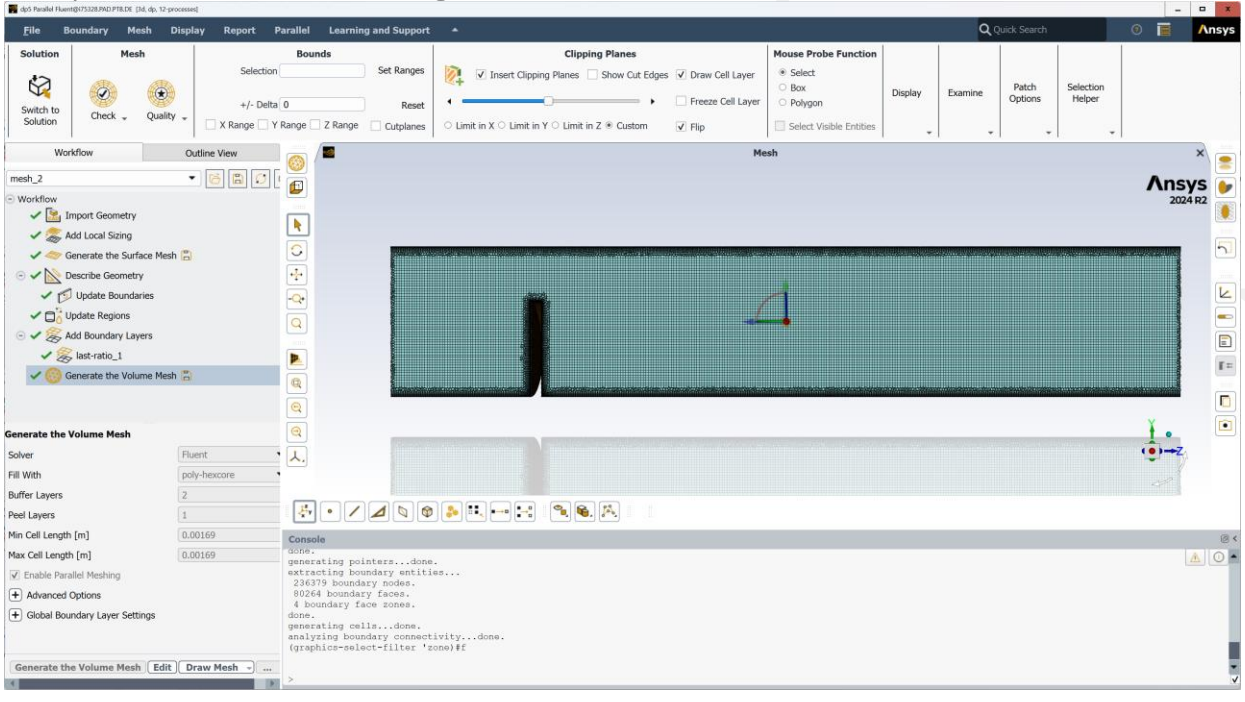
## Ansys DesignModeler



# Simulation

## Vernetzung

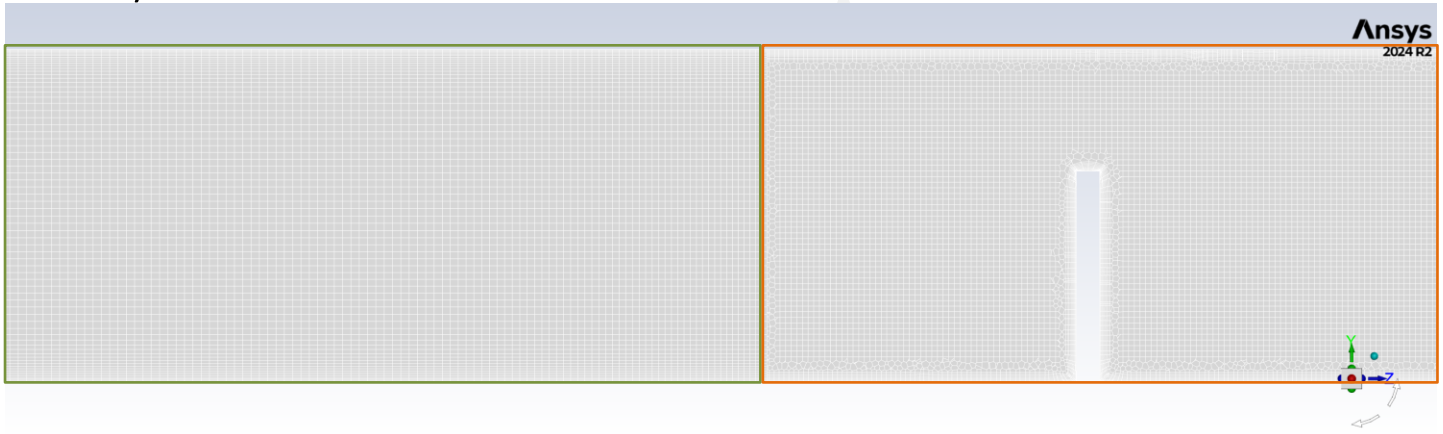
### Ansys Fluent Meshing



# Simulation

## Vernetzung

Ansys Fluent

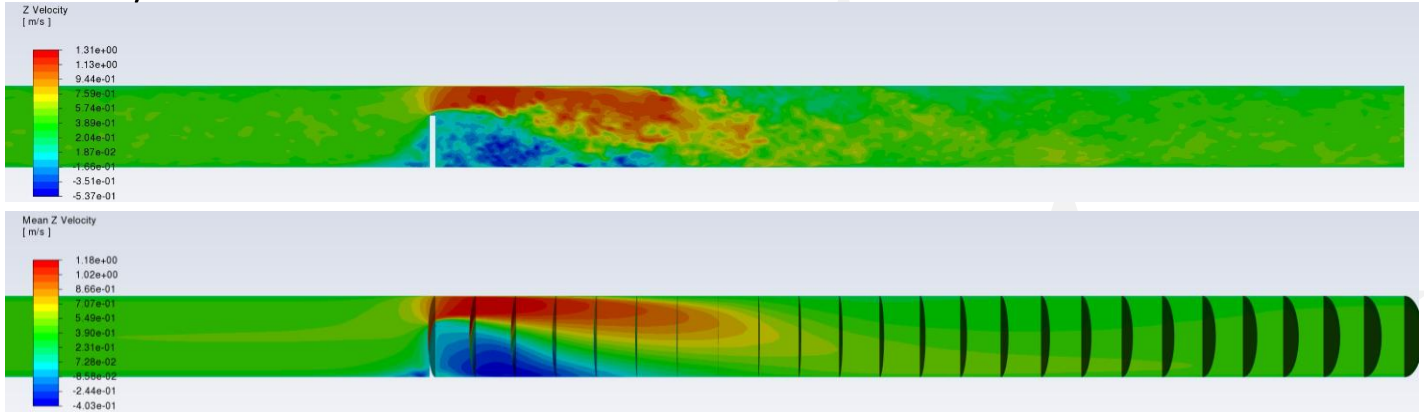



- Kombination von strukturiertem und unstrukturiertem Gitter
- Gittergröße ca. 5,5 Mio Punkte

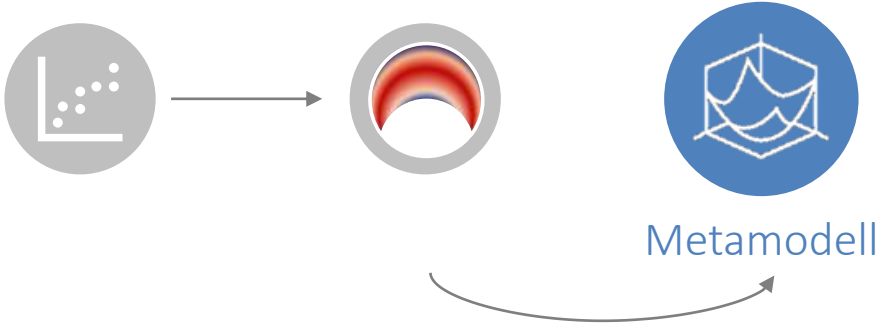
# Simulation

CFD

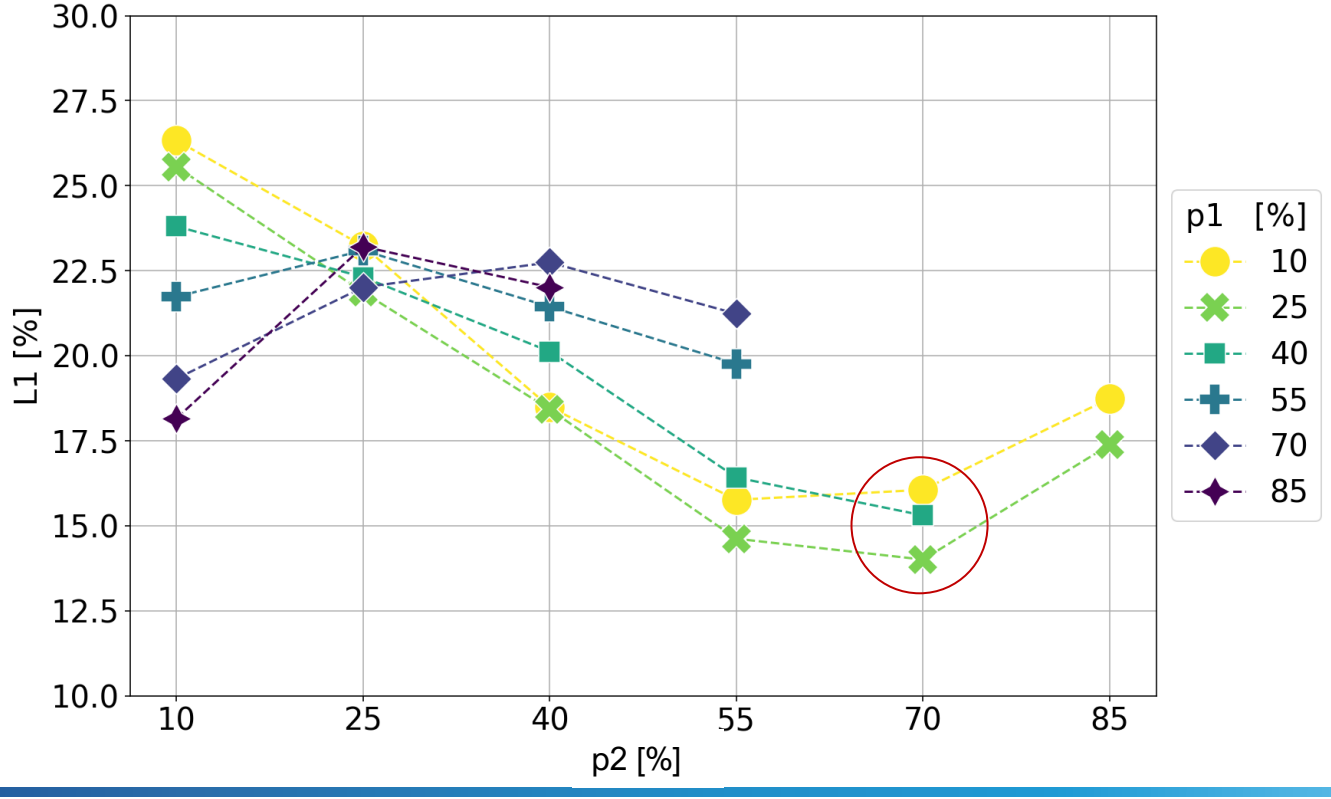
Ansys Fluent




- Hybride RANS/LES-Rechnung bei $Re = 5 \cdot 10^4$
- Zeit pro Simulation = 4 Tage auf 28 CPUs (Intel Xeon Gold 6132)
- Auswertung an 25 Abständen stromabwärts der Blende

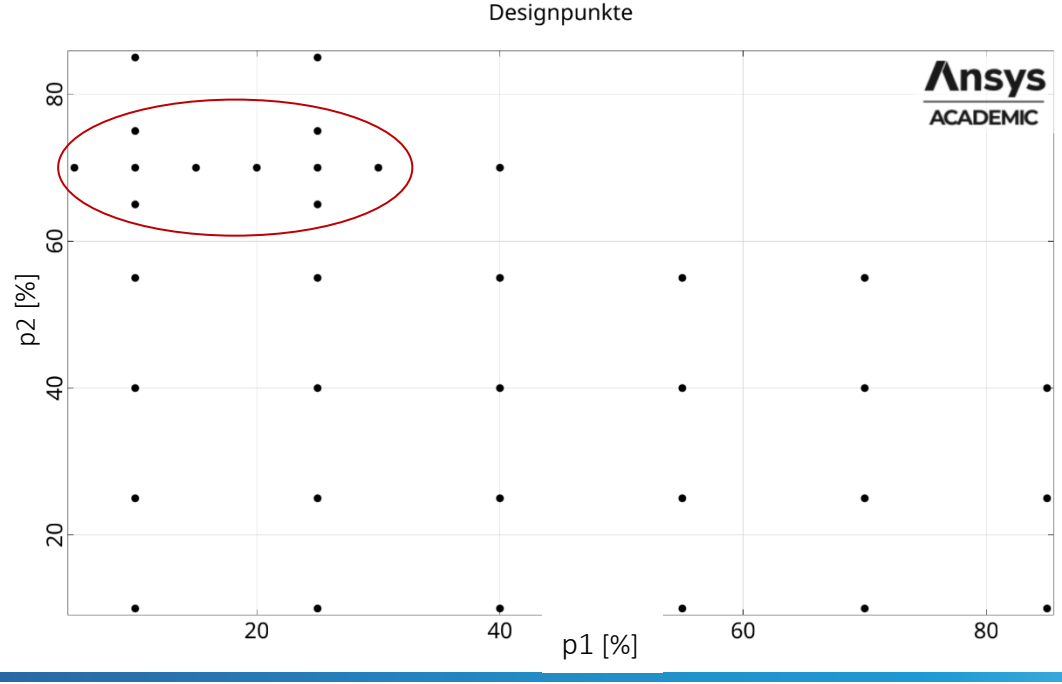

Metamodell

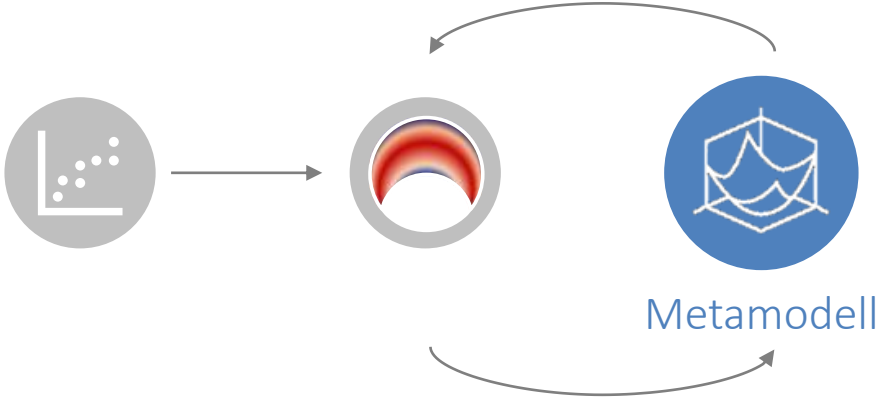
# Metamodell


30.0
27.5
25.0
22.5
20.0
17.5
15.0
12.5
10.0
L1 [%]
10
25
40
55
70
85
p2 [%]
p1 [%]
10
25
40
55
70
85

# Metamodell

- Hinzufügen von Designpunkten




Metamodell

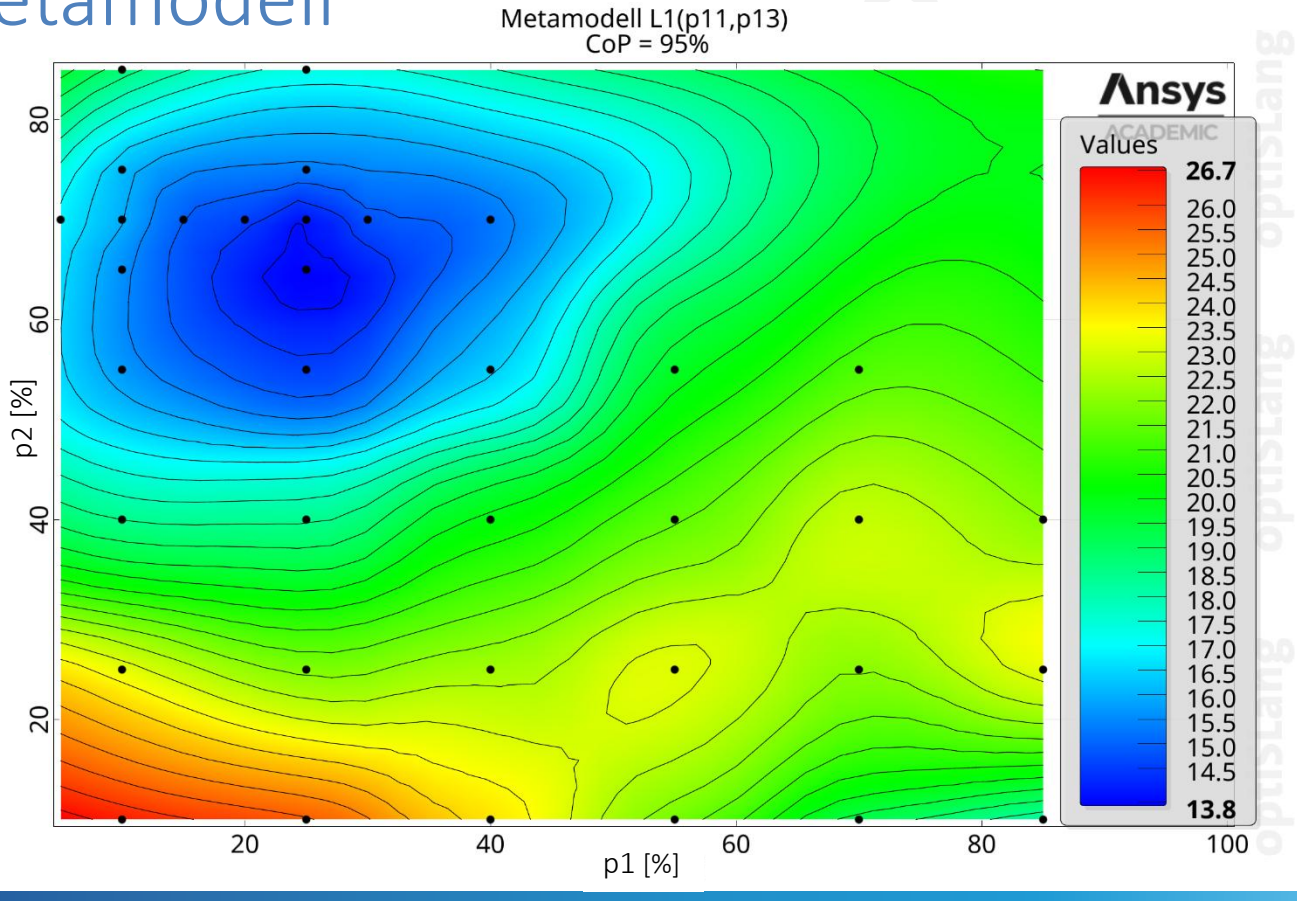
# Metamodell

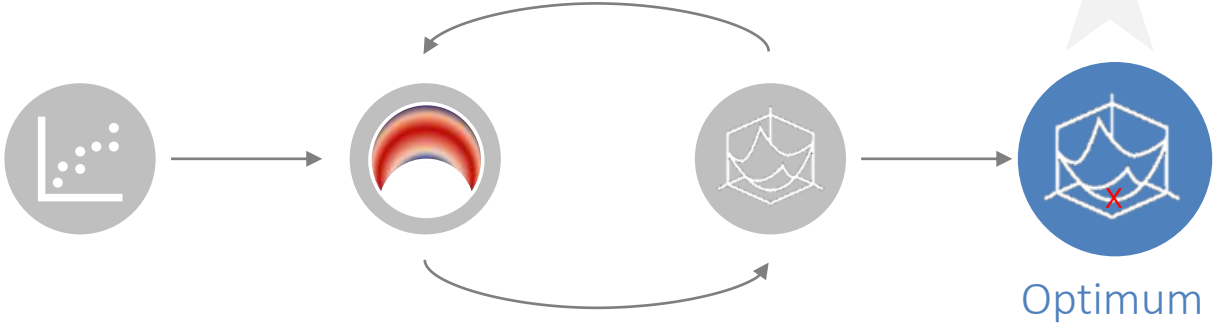
- Mathematische Approximation der Zielgröße durch Eingangsgrößen

$$L^1(p11, p13)$$

- verschiedene Modelle werden gegeneinander getestet
- Auswahl des Modells nach Kennzahl **Coefficient of Prognosis (CoP)**

# Metamodell


Metamodell L1(p11,p13)
CoP = 95%
Ansys
ACADEMIC
Values
26.7
26.0
25.5
25.0
24.5
24.0
23.5
23.0
22.5
22.0
21.5
21.0
20.5
20.0
19.5
19.0
18.5
18.0
17.5
17.0
16.5
16.0
15.5
15.0
14.5
13.8
p2 [%]
20
40
60
80
p1 [%]
20
40
60
80
100

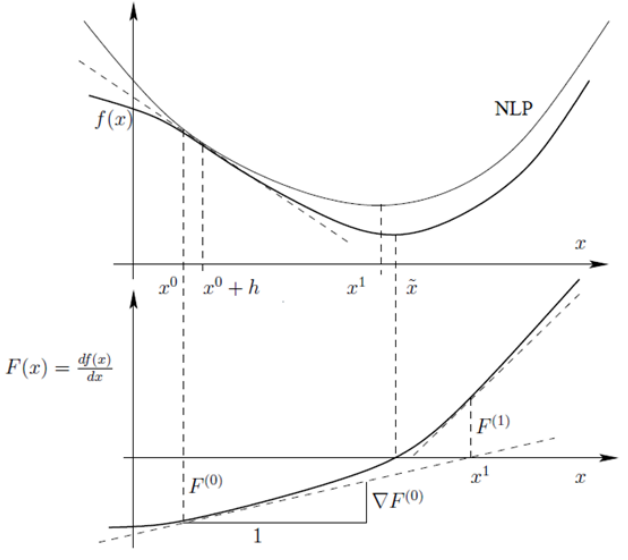

Optimum

# Optimum

- Suche des globalen Maximums oder Minimums

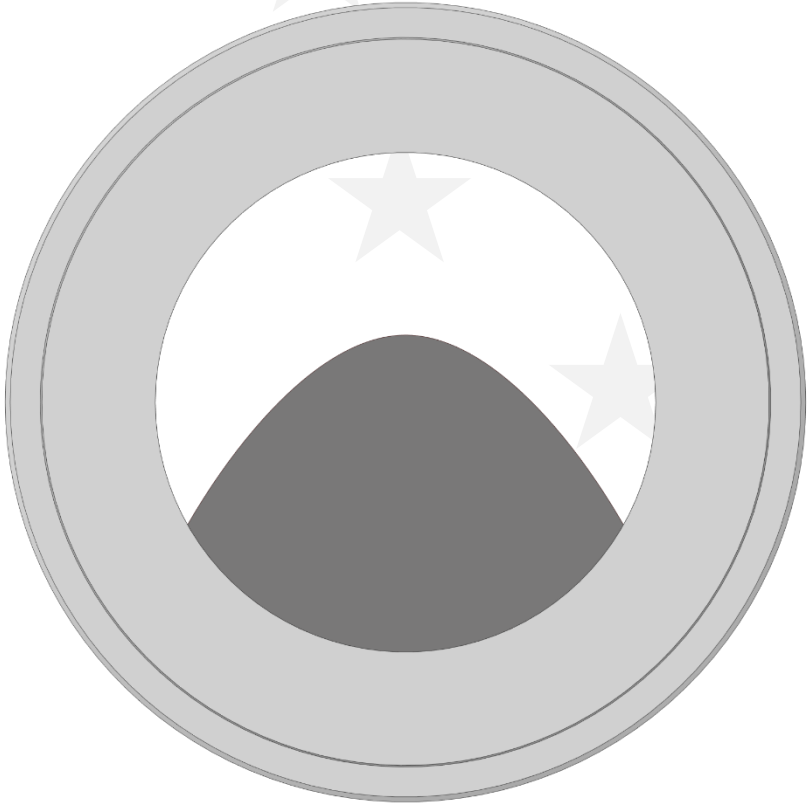
  Minimierungsproblem $\mathbf{min}(L^1)$

- Iteratives Finden des Optimums



# Optimum

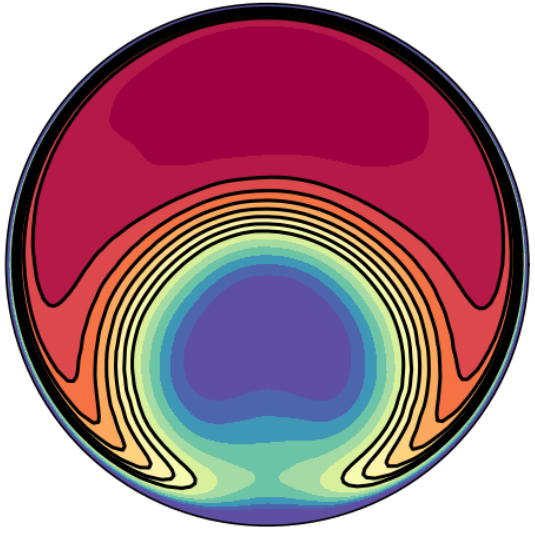
p1 = 25,47 mm
p2 = 63,45 mm

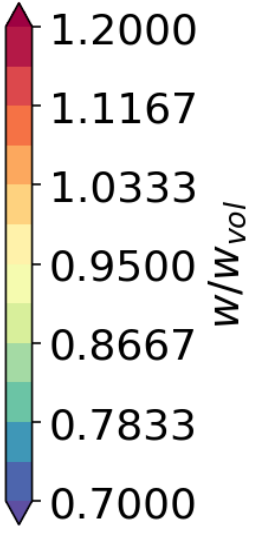


# Optimum

90°-Krümmer (CFD)

$z/D = 1.0$

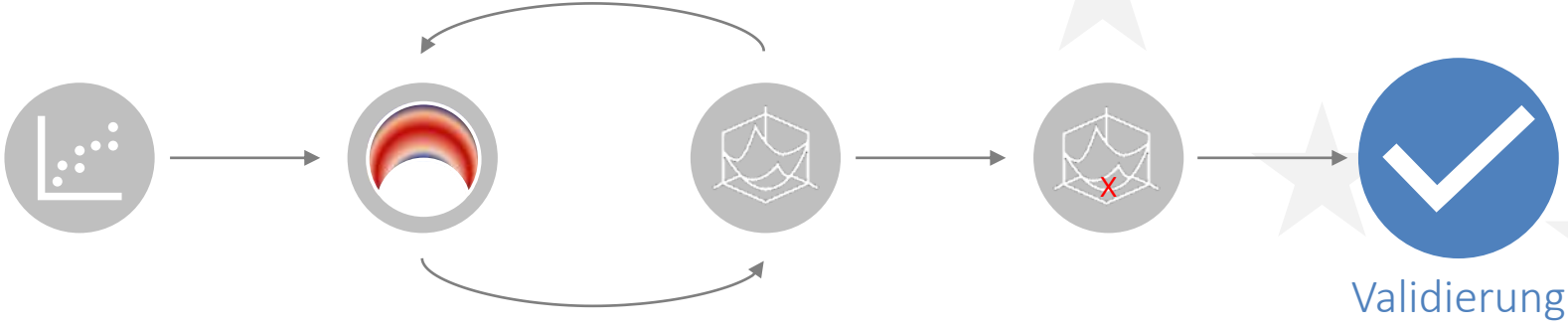





Blende (CFD)

$z/D = 7.0$

$$L^1 = 13,97\%$$


Validierung

# Validierung

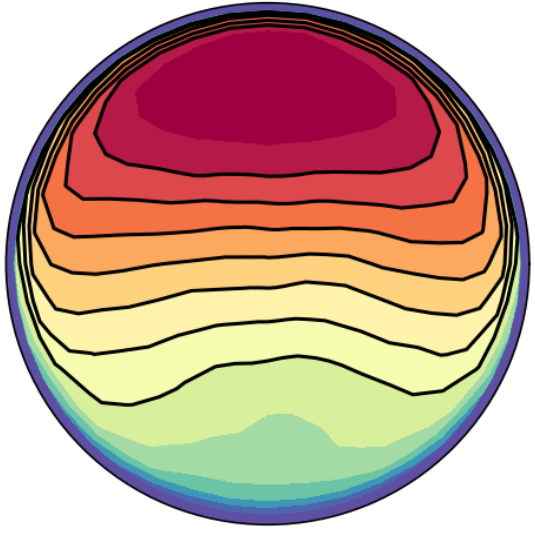
- LDV-Messungen am Wärmezähler-Prüfstand der PTB in DN100
- $Re = 5 \cdot 10^4$
- $\frac{z}{D} = 6.75$

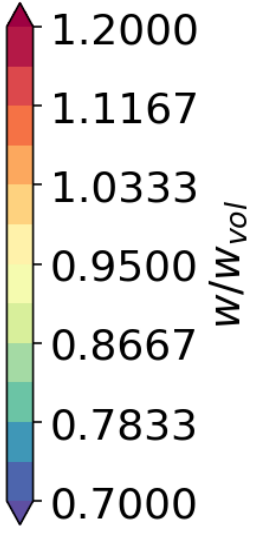
# Validierung

## Re = 50 000

Blende (CFD)

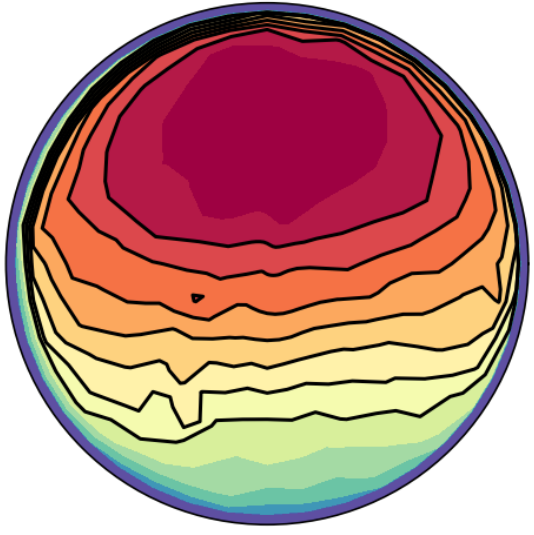
$z/D = 6.75$






Blende (Messung)

$z/D = 6.75$



# Zusammenfassung & Ausblick

- ✓ Erfolgreiche Optimierung mit 2 Geometrieparametern
- ✓ Gute Übereinstimmung in der Validierung
- Variation der Eingangsparameter → Minimierung des L1-Fehlers