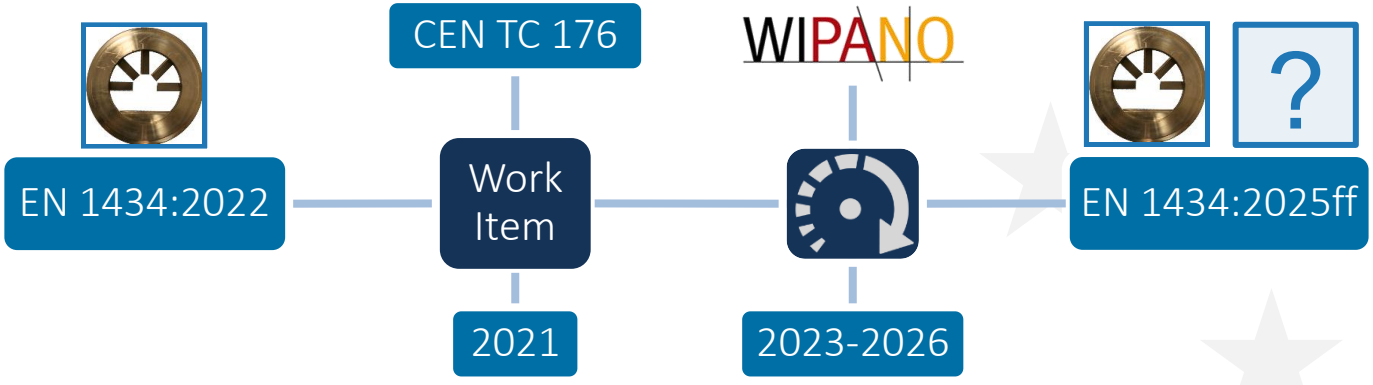

EMATEM
European Metrology Association
for Thermal Energy Measurement

Development of a flow disturbance generator

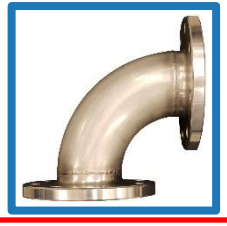
Project introduction

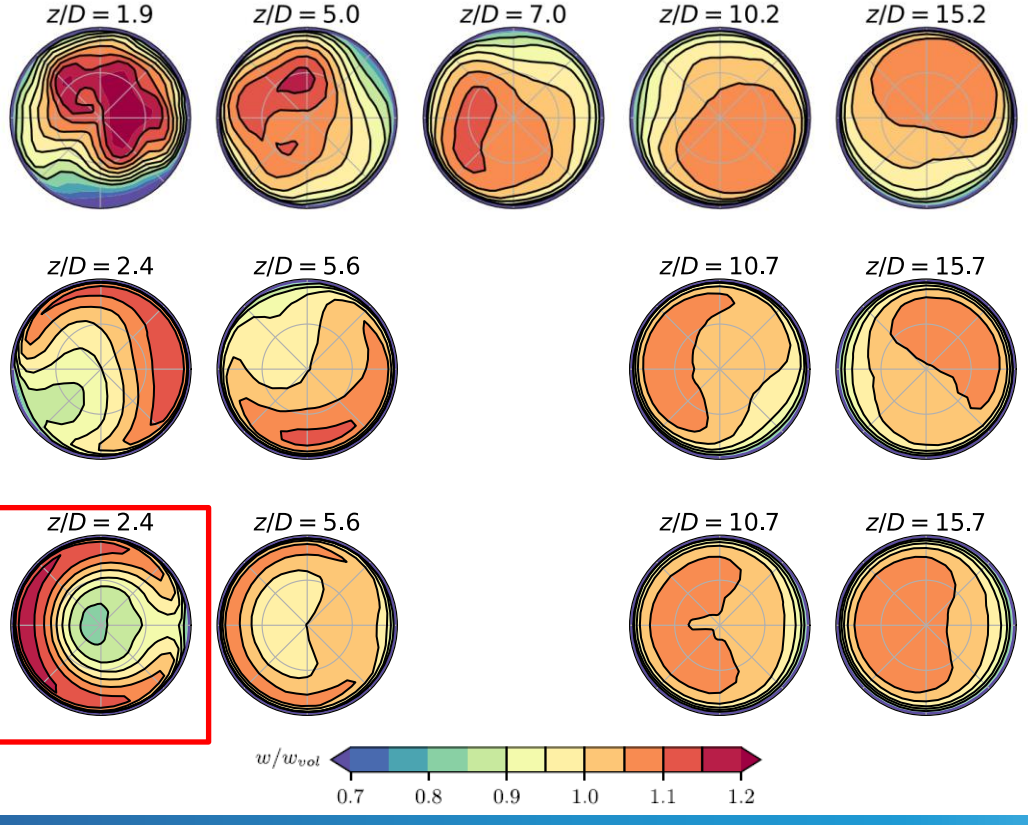


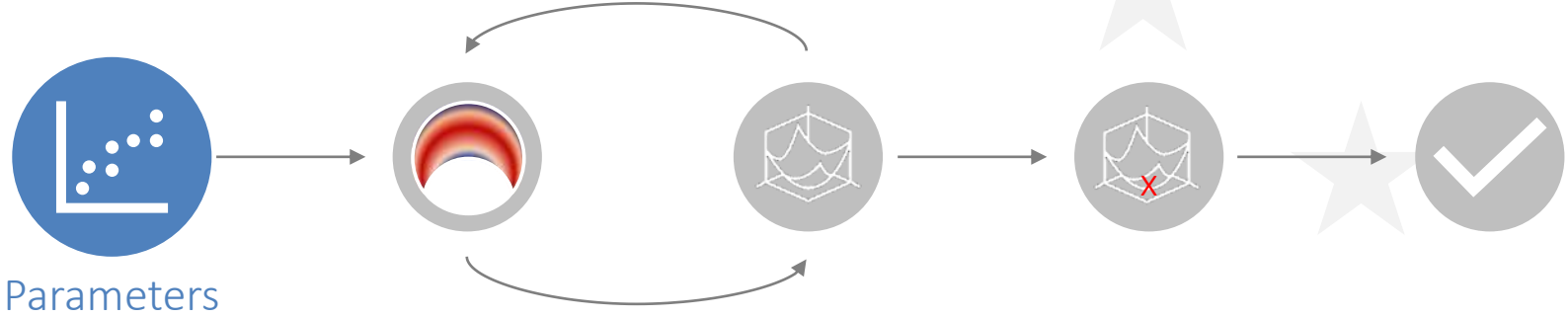
- **WIPANO** (BMWK) - Wissens- und Technologietransfer durch Patente und Normen
- **Work item**: Flow profiles in water and water glycol solution networks, e.g. 90° bend and double bend out of plane
- **Duration**: September 2023 – April 2026
- **Project partners**: Physikalisch-Technische Bundesanstalt (PTB), Wärmezähler-Service-GmbH (WSG)
- **Objectives**
  - Metrological validation of type approval without inlet section (“0D approval”) in the flow disturbance test of EN 1434
  - Development of a disturbance generator to represent the near-field range downstream of bend configurations
  - If necessary, extension of the flow disturbance test to include new disturbance generator

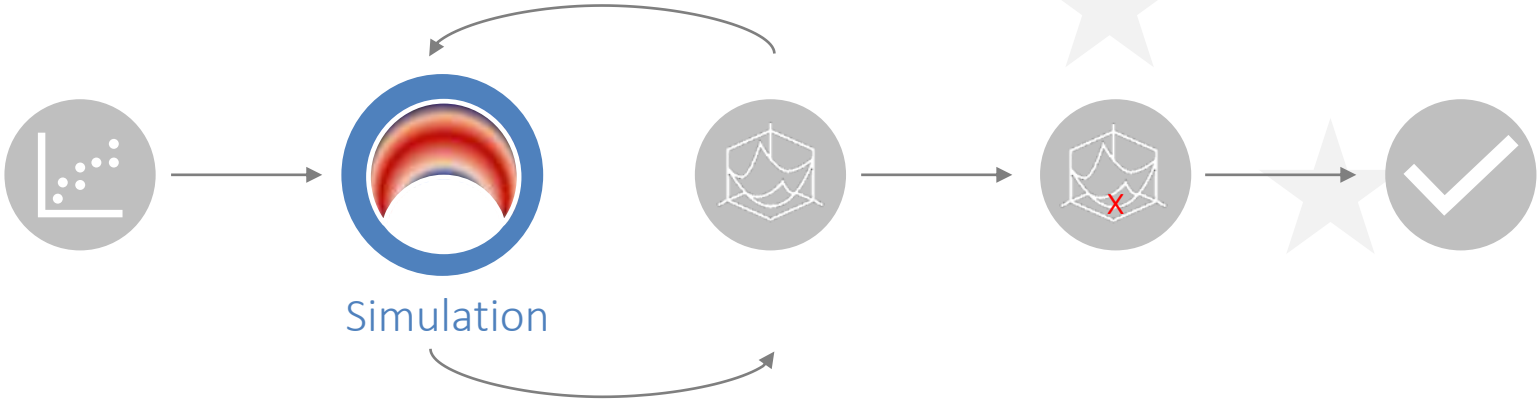
PTB WSG Wärmezähler-Service

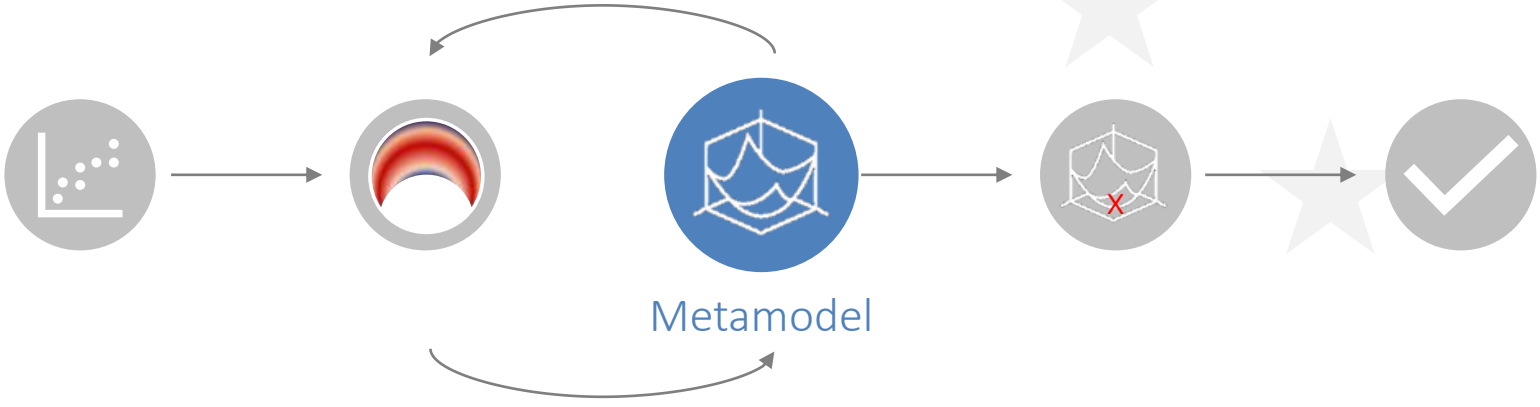
Comparison of flow profiles

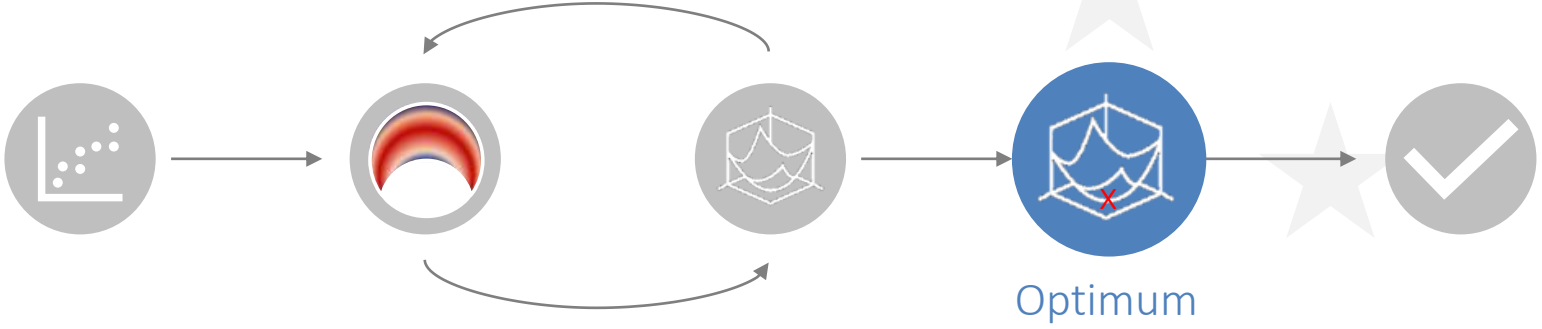


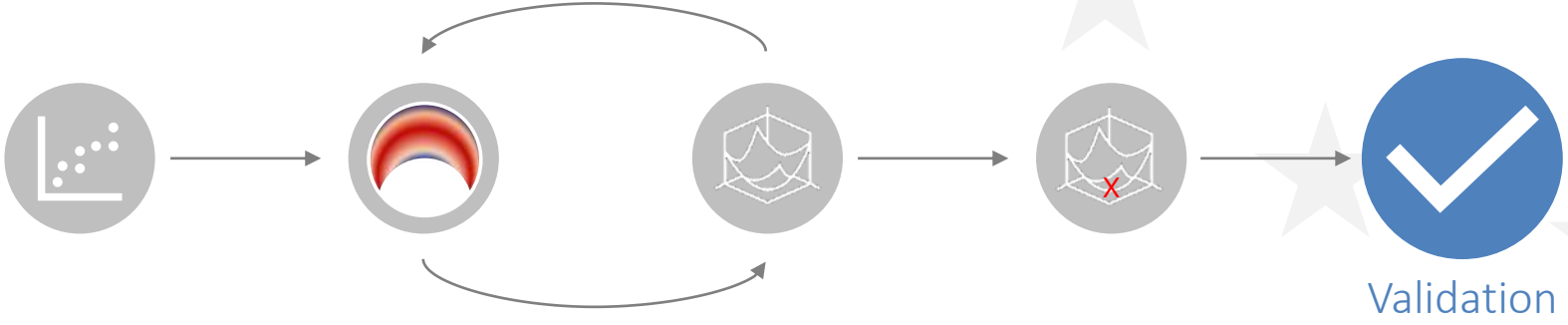


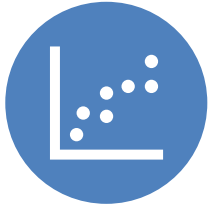

Parameters


Simulation


Metamodel


Optimum


Validation



Parameters

Parameters

Input parameters

- Geometry parameters (thickness, diameter, …)
- Boundary conditions (flowrate)

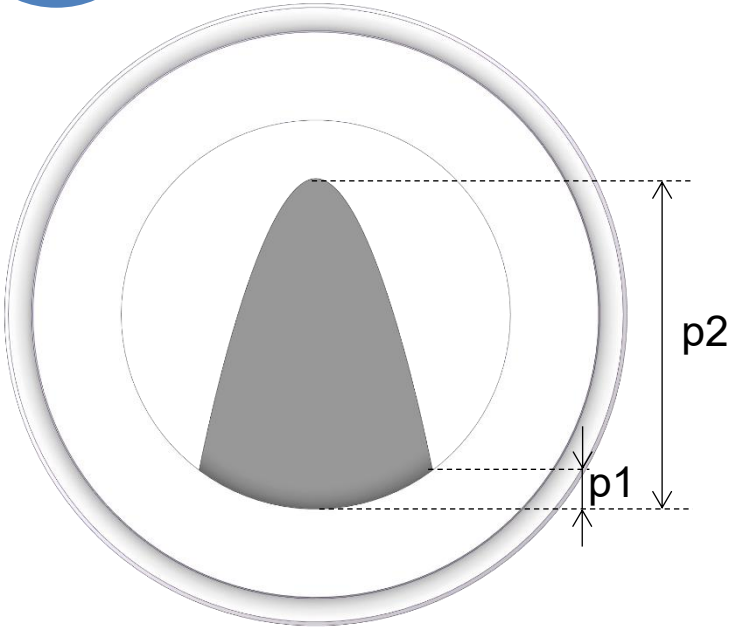
Objective

- Difference between two flow profiles
- Temperature distributions
- Combination of different objectives

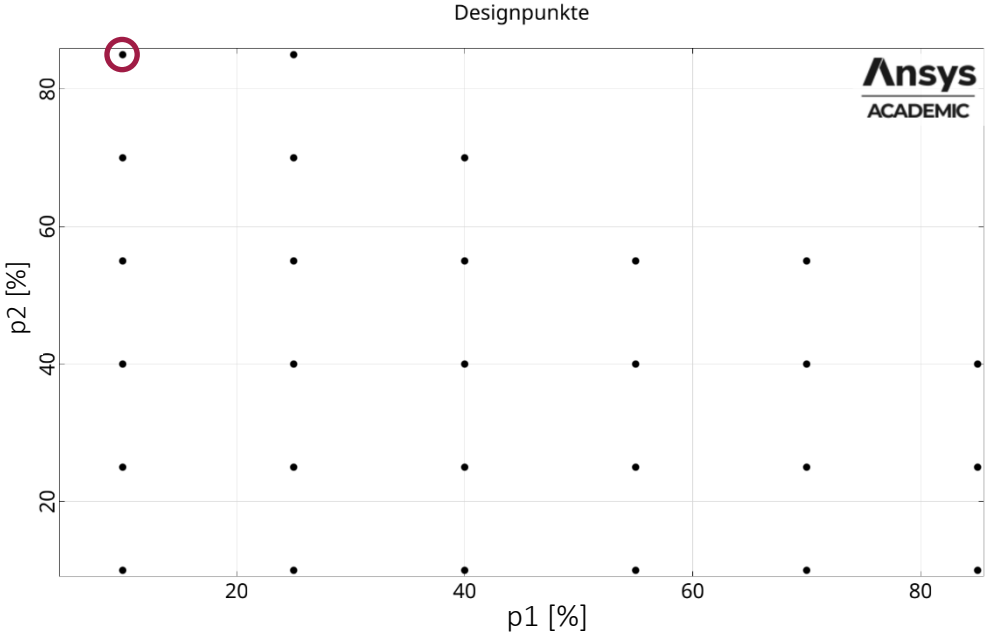
Constraints

- Installation space
- Manufacturing possibilities

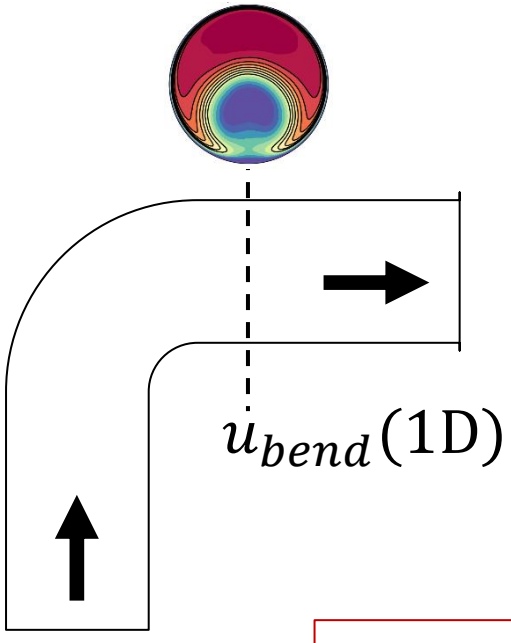
Parameters

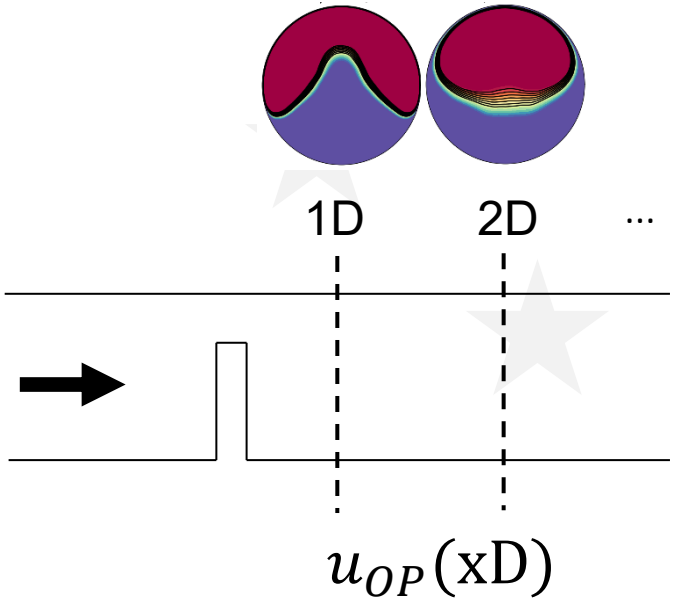


$$A_{OP} \leq \frac{2}{3} A_{Pipe}$$

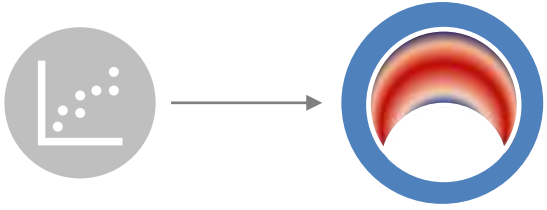


Parameters



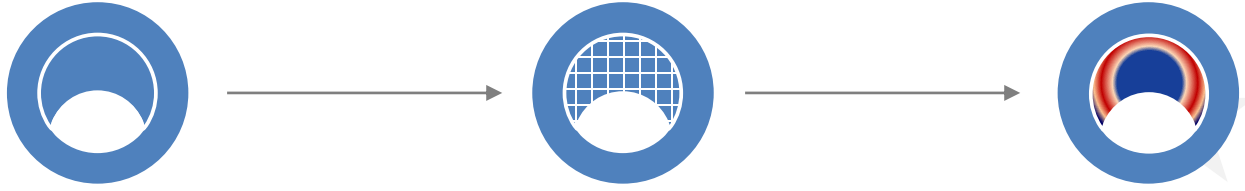


$$L^1 = \frac{4}{\pi D^2} \int_0^{2\pi} \int_0^{D} |u_{bend} - u_{OP}| r \, dr d\phi$$



Simulation

Simulation



Geometry

Simulation

Simulation

Simulation

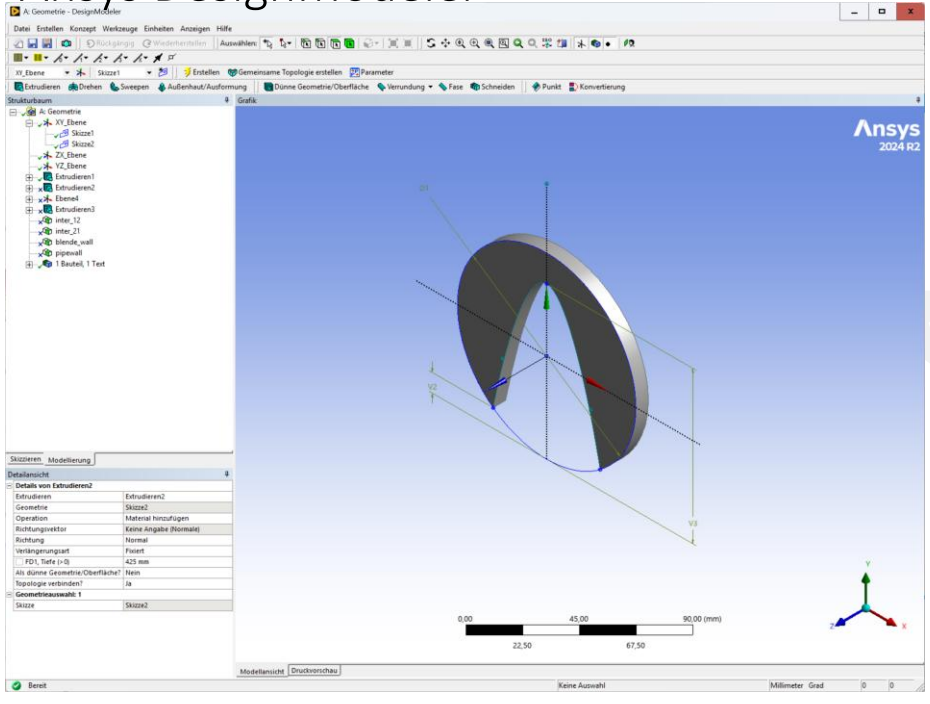
Ansys Workbench

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		

Geometry

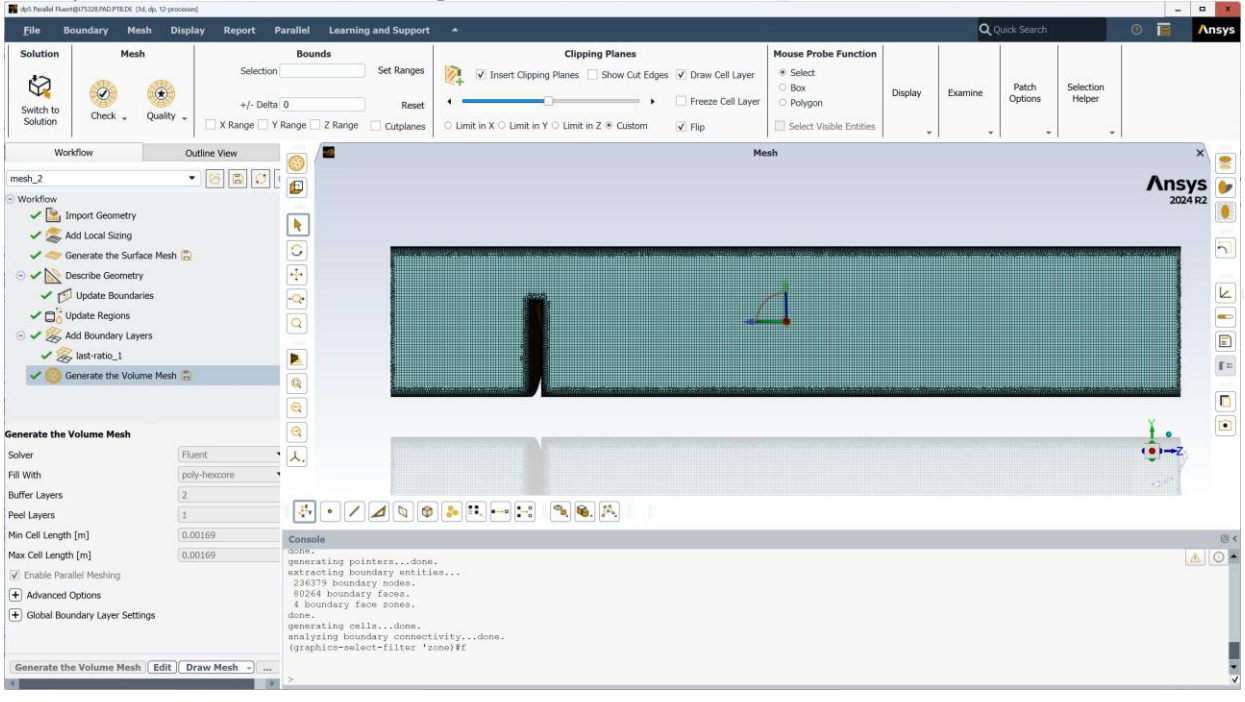
Ansys DesignModeler



Simulation

Meshing

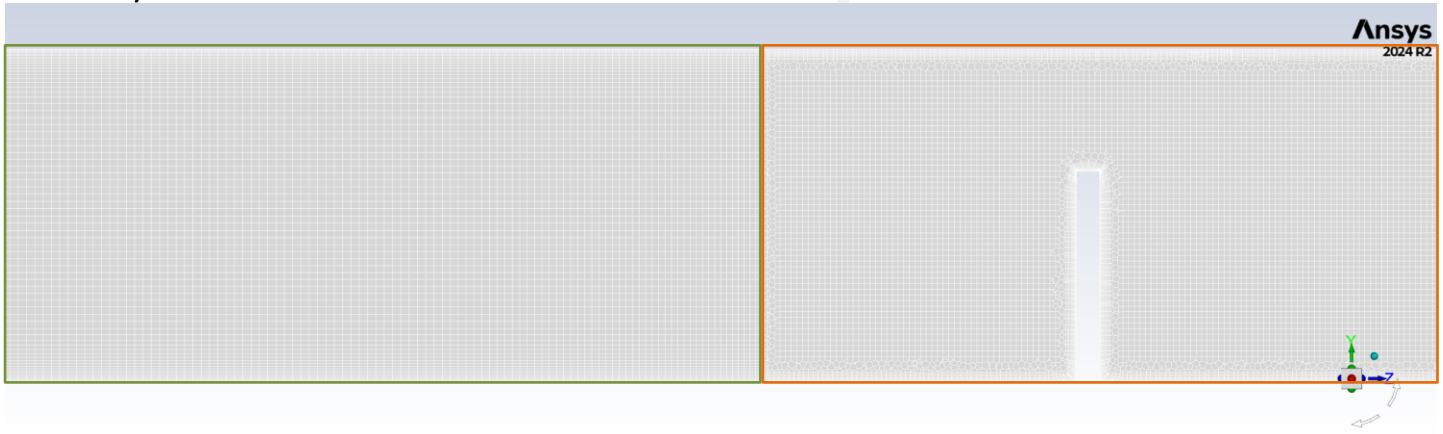
Ansys Fluent Meshing



Simulation

Meshing

Ansys Fluent

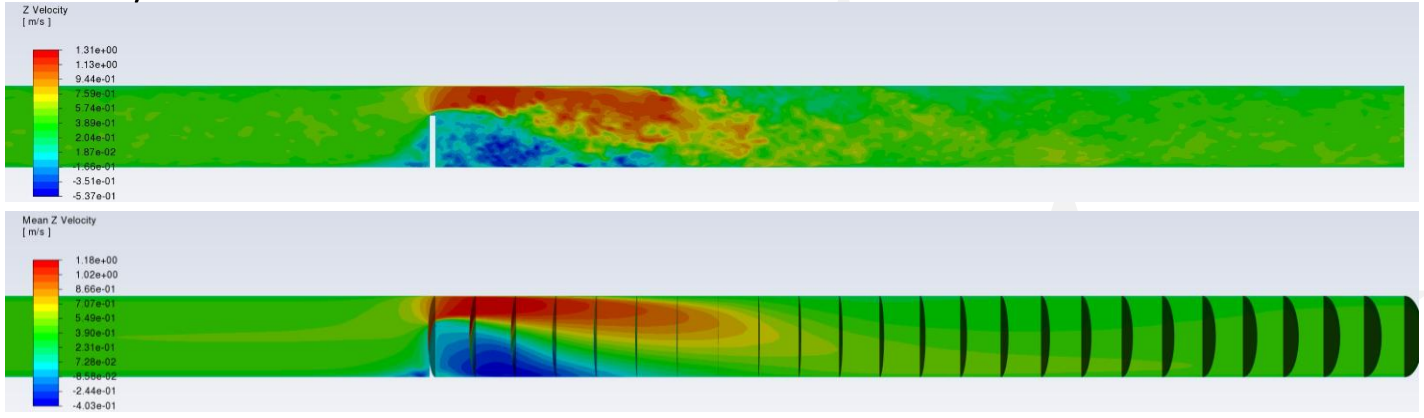


- Combination of structured and unstructured grid
- 5,5 million grid points

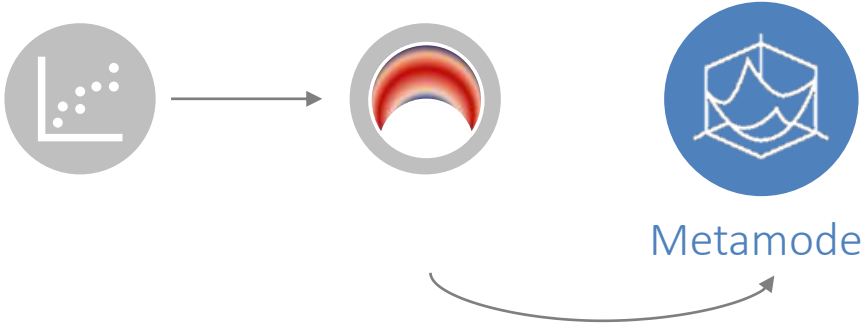
Simulation

CFD

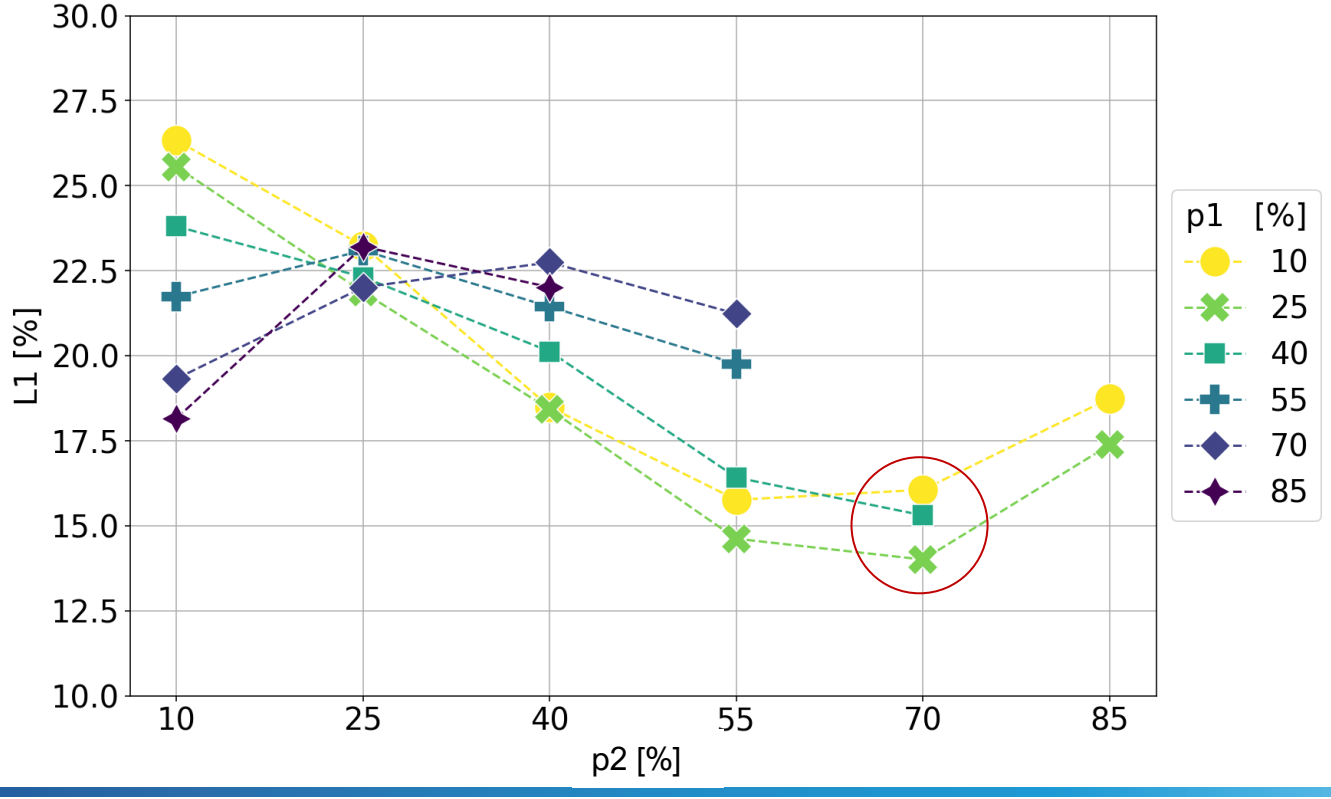
Ansys Fluent



- hybrid RANS/LES-simulations at $Re = 5 \cdot 10^4$
- time per simulation = 4 days on 28 CPUs (Intel Xeon Gold 6132)
- Evaluation at 25 positions downstream of the orifice

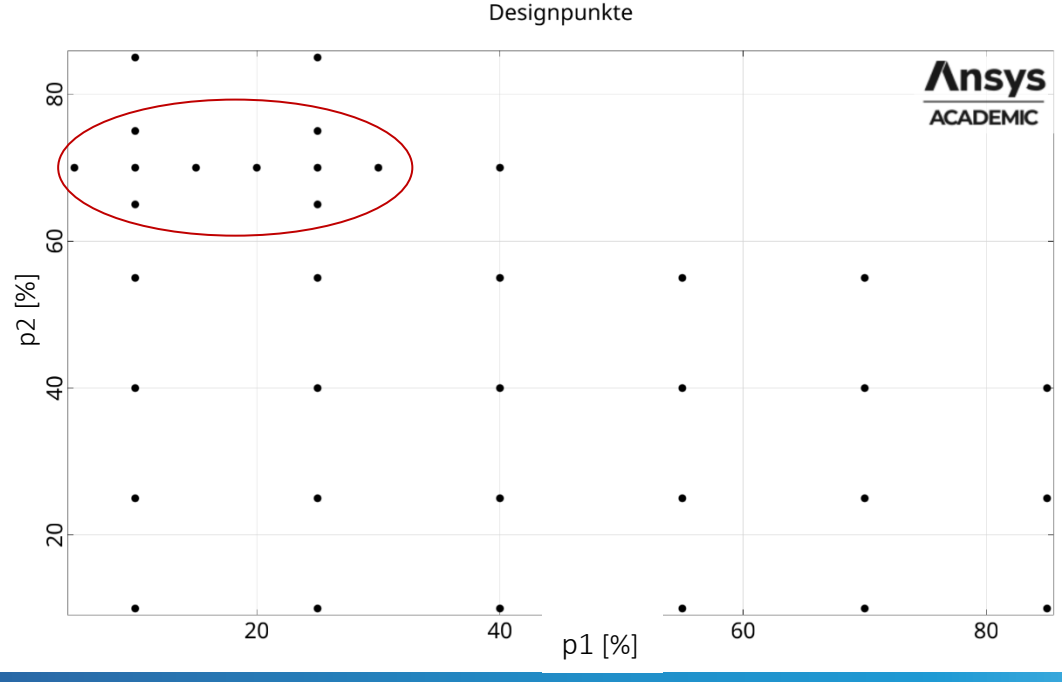

Metamodel

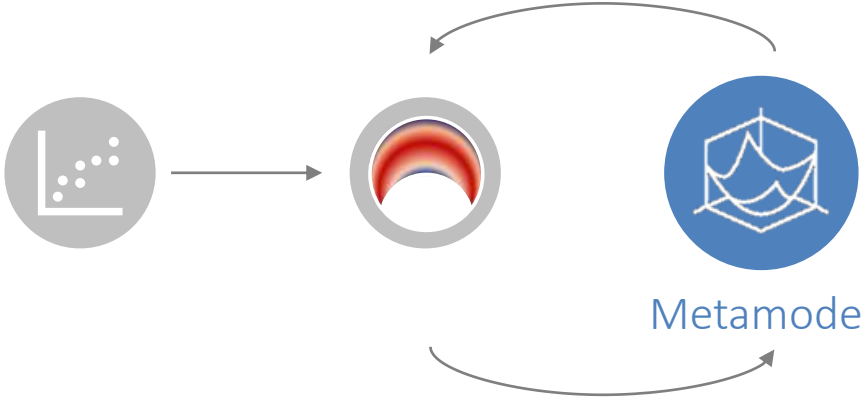
Metamodel


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

Metamodel

- Adding design points




Metamodel

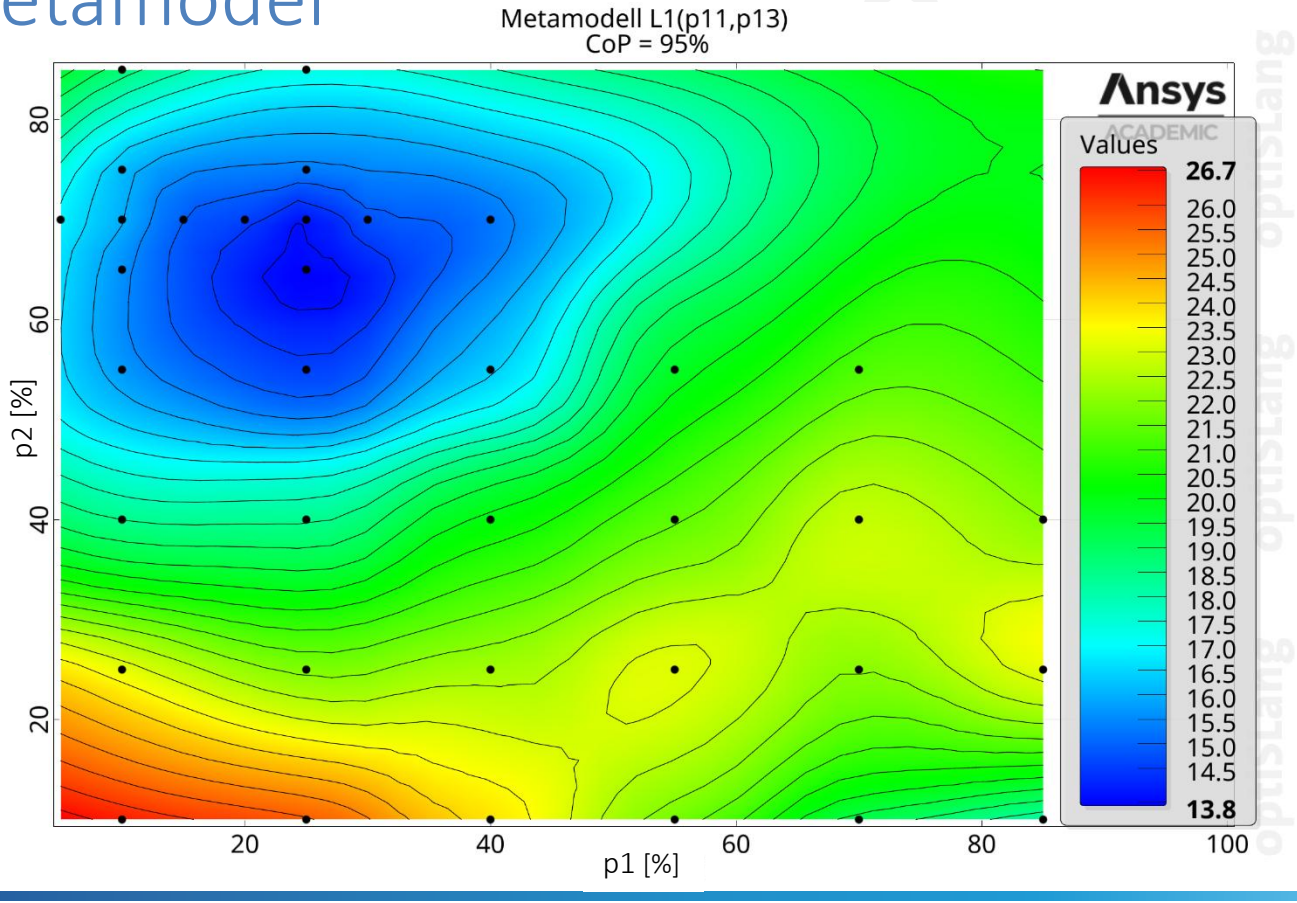
Metamodel

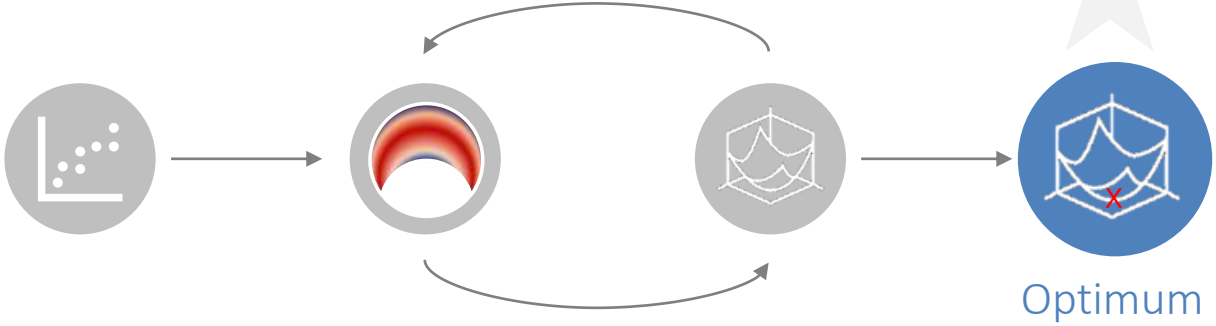
- Mathematical approximation of the objective using input parameters

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

- Various models are tested against each other
- Selection of the model based on the **Coefficient of Prognosis (CoP)**

Metamodel


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

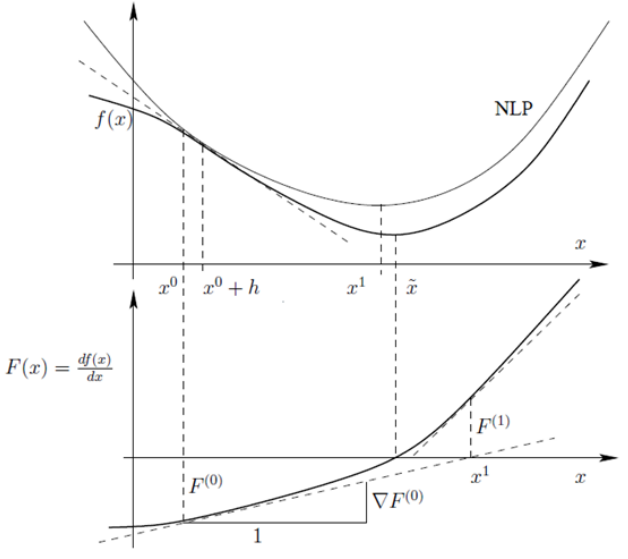

Optimum

Optimum

- Search for the global maximum or minimum

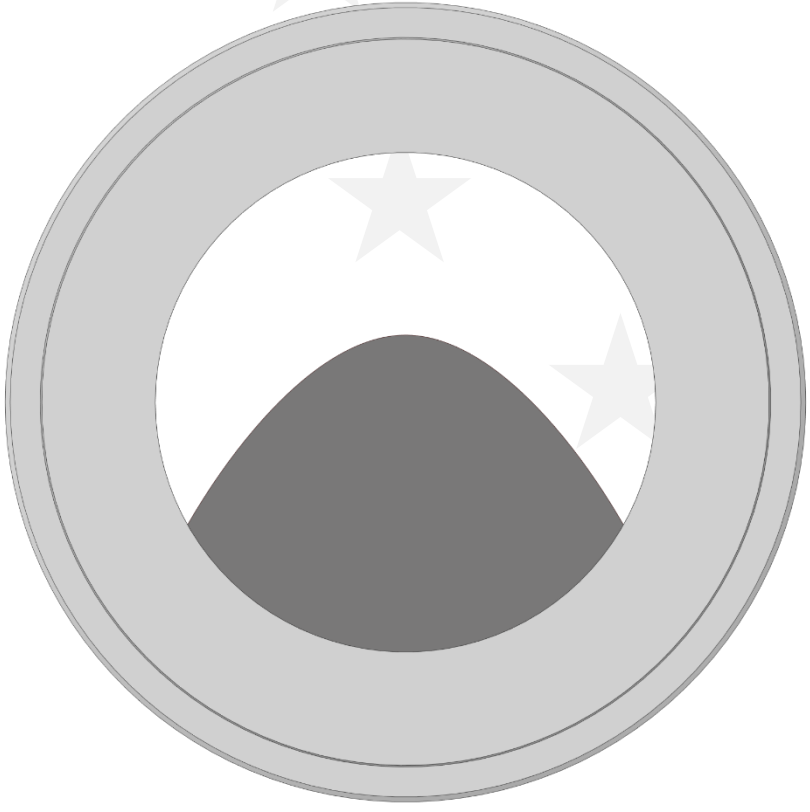
  Minimization problem $\mathbf{min}(L^1)$

- Iterative search for the optimum



Optimum

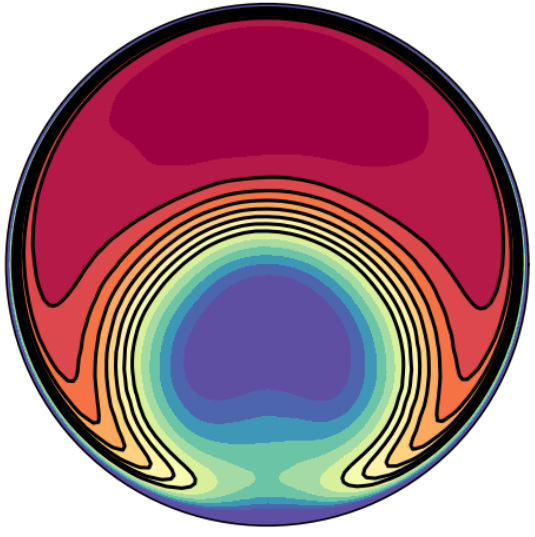
p1 = 25,47 mm
p2 = 63,45 mm

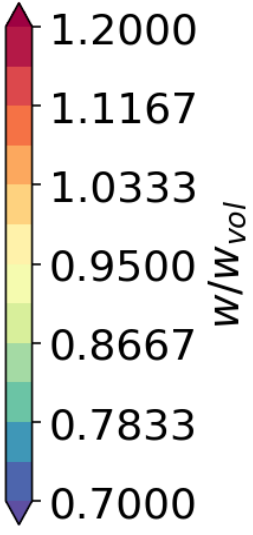


Optimum

90° bend (CFD)

$z/D = 1.0$

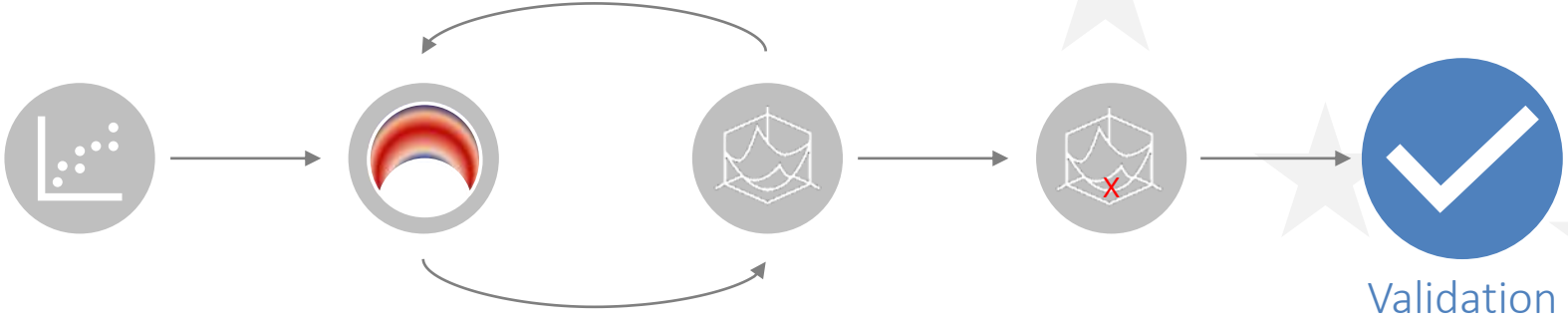




orifice (CFD)

$z/D = 7.0$

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


Validation

Validation

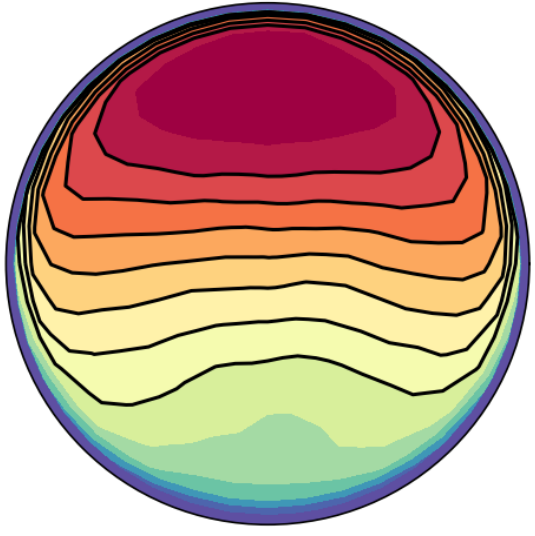
- LDV measurements on the PTB heat meter test bench in DN100
- $Re = 5 \cdot 10^4$
- $\frac{z}{D} = 6.75$

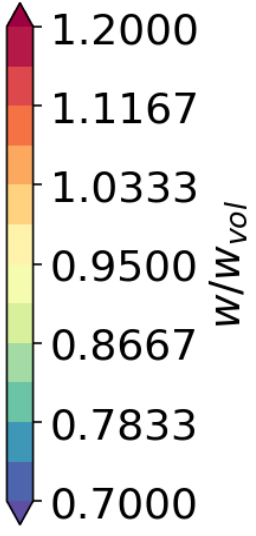
Validation

Re = 50 000

orifice (CFD)

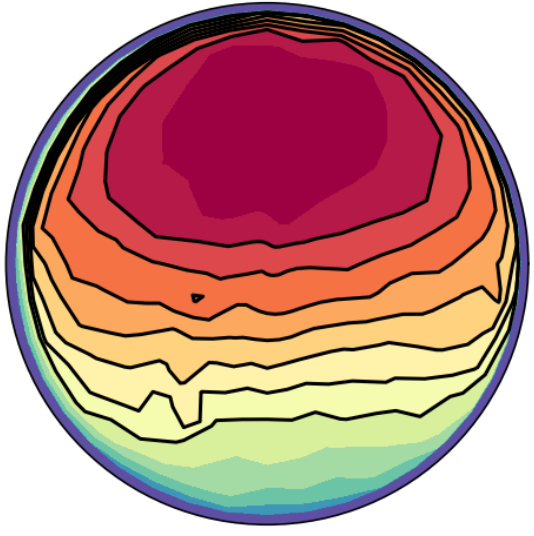
$z/D = 6.75$





orifice (LDV)

$z/D = 6.75$



Summary & Outlook

- ✓ Successful optimization with 2 geometry parameters
- ✓ Good agreement in validation
- ○ Variation of input parameters→ Minimization of L1 error