

APEX GROUP

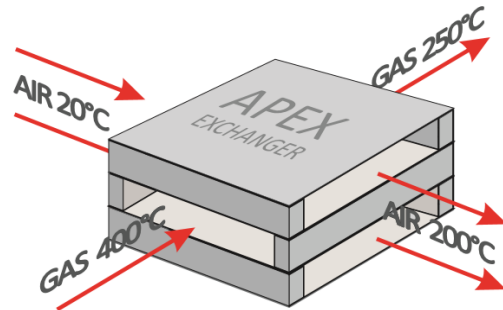
Comparison between experimental and computational results for the transition to turbulence in flat plate channel flow

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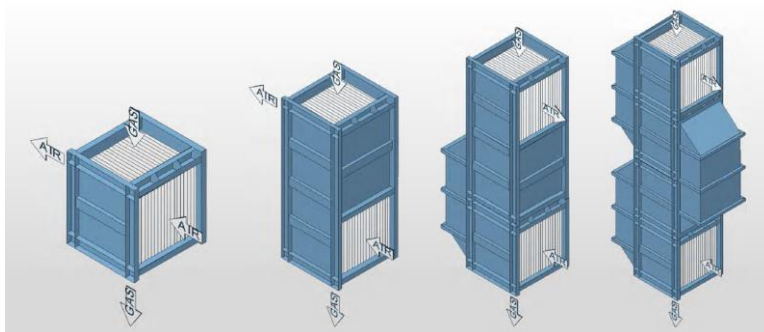
Introduction

- The investigated Heat Exchanger consists of rectangular narrow channels with flat surface operating in the transitional flow regime
- The modular design results in many flow configurations

Heat transfer concept



Modular design



Working range: Transition

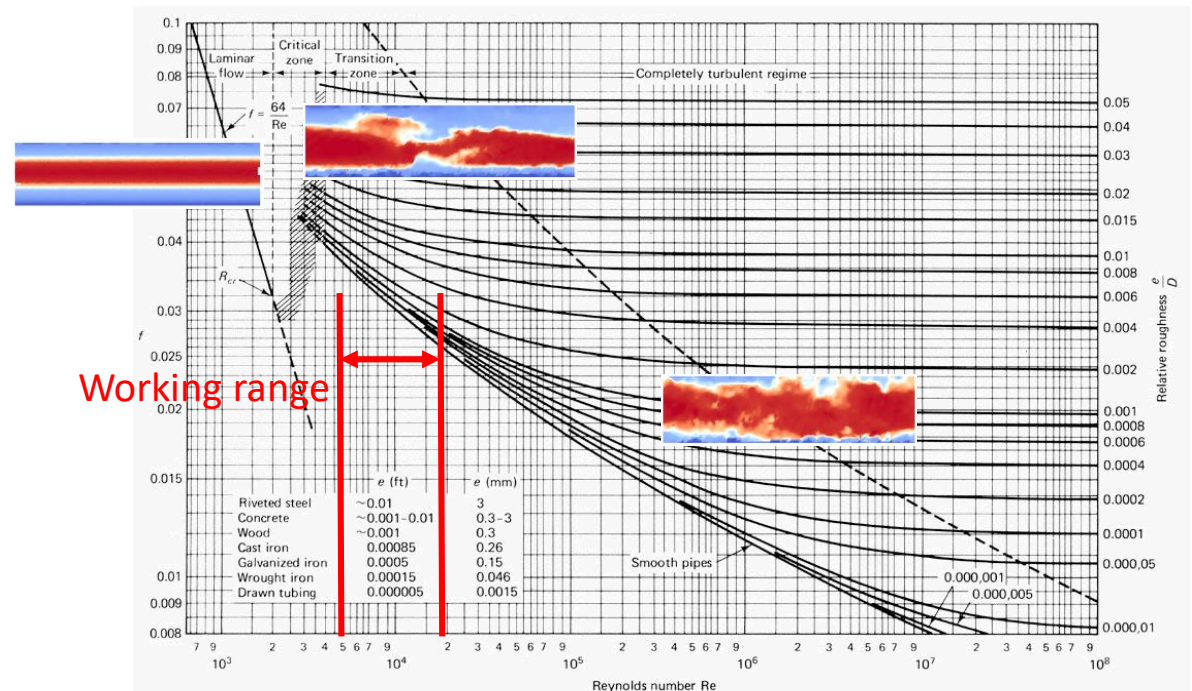


Figure 7.13 Moody diagram. (From L. F. Moody, Trans. ASME, Vol. 66, 1944.)

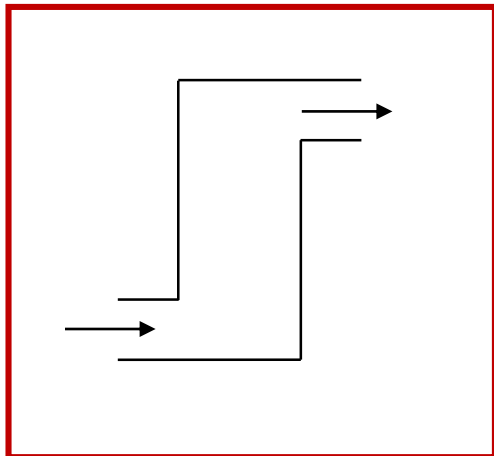
Benchmark comparison – Simulation/Experiment

Why to compare?

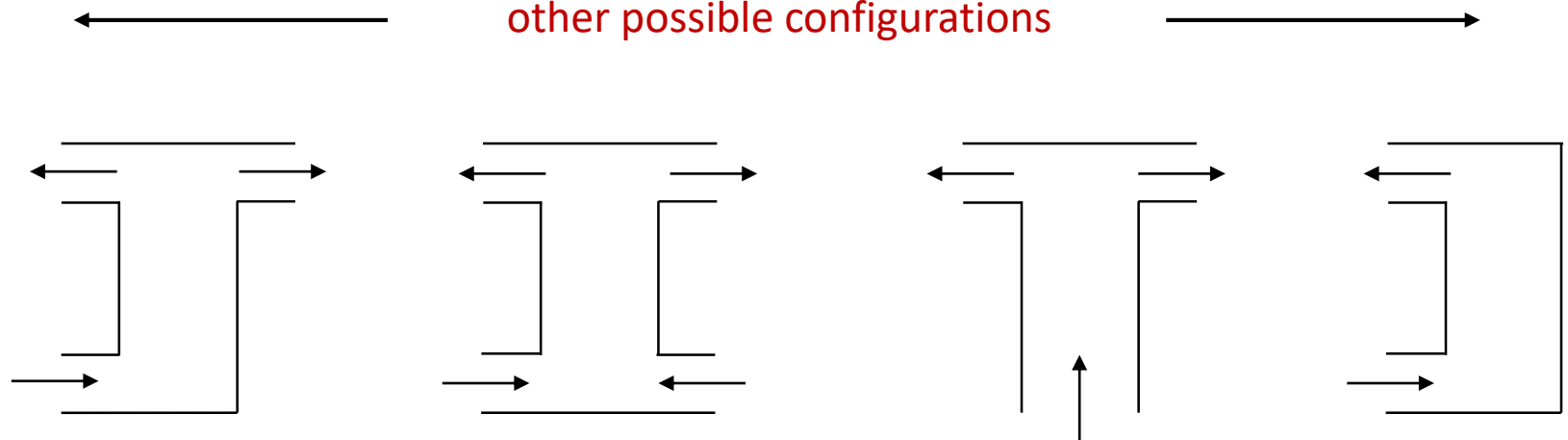
- There are too many design variables like aspect ratio ($AR = \text{channel width} / \text{channel height} > 20$), channel height, Re-numbers, spacers, flow configurations, etc. to allow full experimental analysis.
- **Simulation with FloEFD is a major time saver, but the accuracy is not always predictable.**

To gain confidence in FloEFD simulations, we conducted a benchmark experiment considering a 1:1 scaled Z-configuration channel flow with large aspect ratio in the transitional flow regime ($Re = 5000$ to 20000) under isothermal conditions.

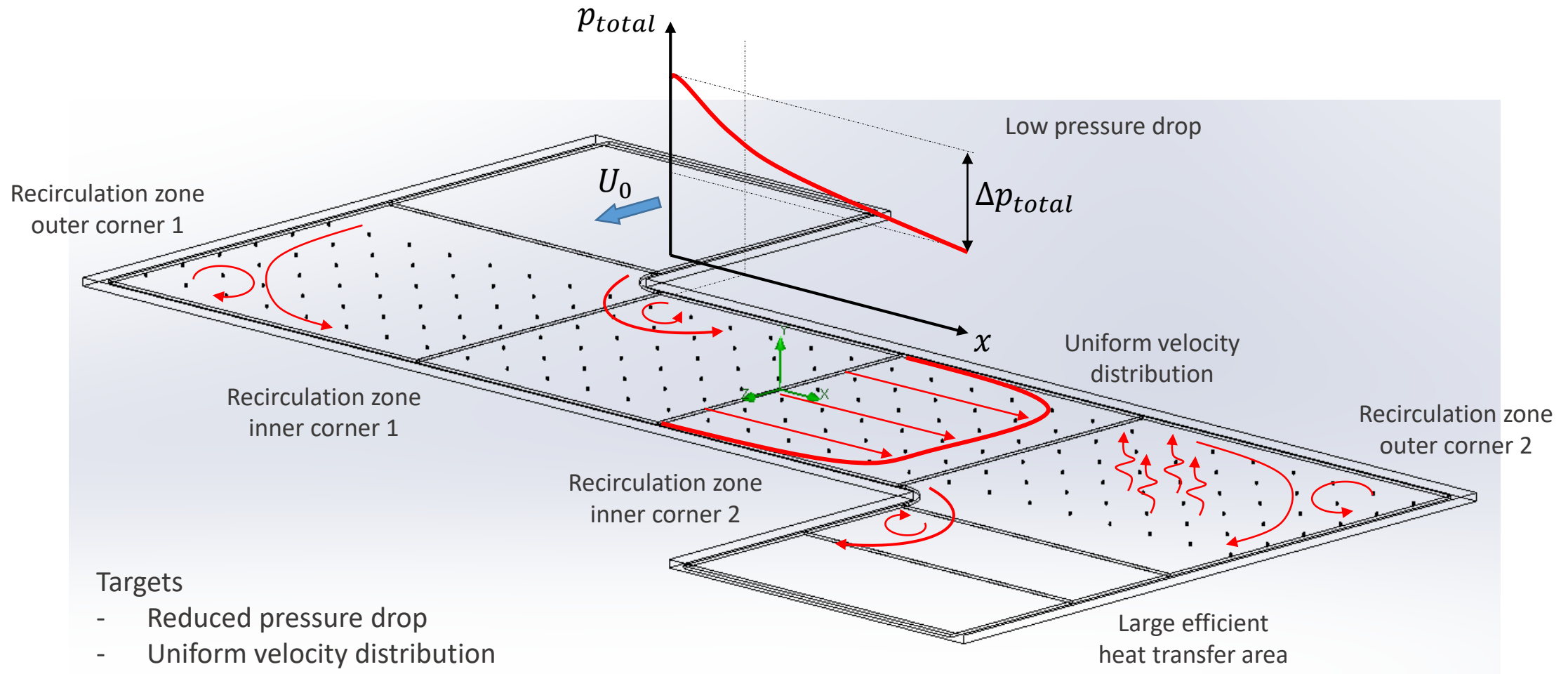
Z-configuration



other possible configurations



Example Z-Configuration



Experimental Set-up:

Transparent plexi-glass facility (1:1 scale)

- optical access
- real dimensions ($L=4\text{ m}$, $W=1\text{ m}$, $h=0.008\text{ m}$)

Centrifugal fan with volume flow rate up to $3500\text{ m}^3/\text{h}$

- Reynolds number up to 30000



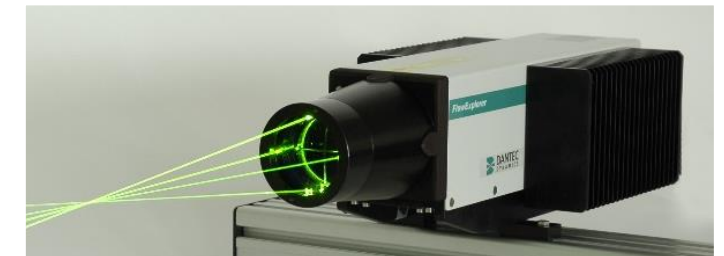
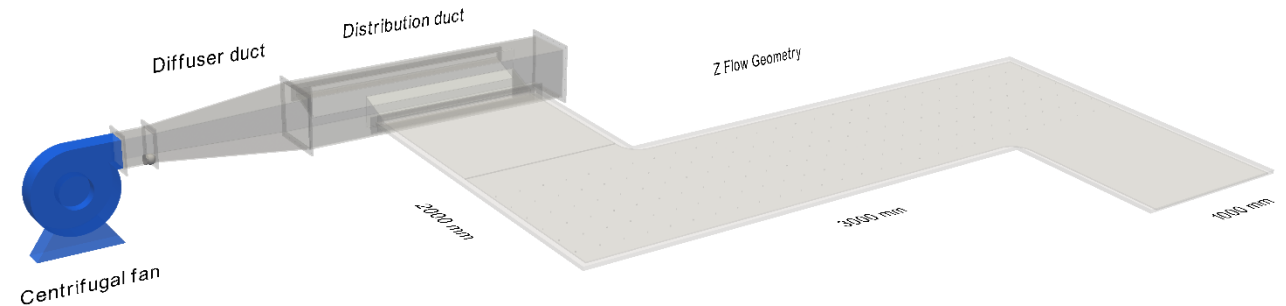
Measurement equipment:

Laser Doppler Anemometry (2D LDA)

- Velocity and turbulence information to define inlet boundary conditions
- Velocity distribution across narrow channel to validate simulation results

Static pressure sensors

- Calculation of pressure drop
- Static pressure distribution across narrow channel



Simulation of experimental conditions with FloEFD

Computational Domain

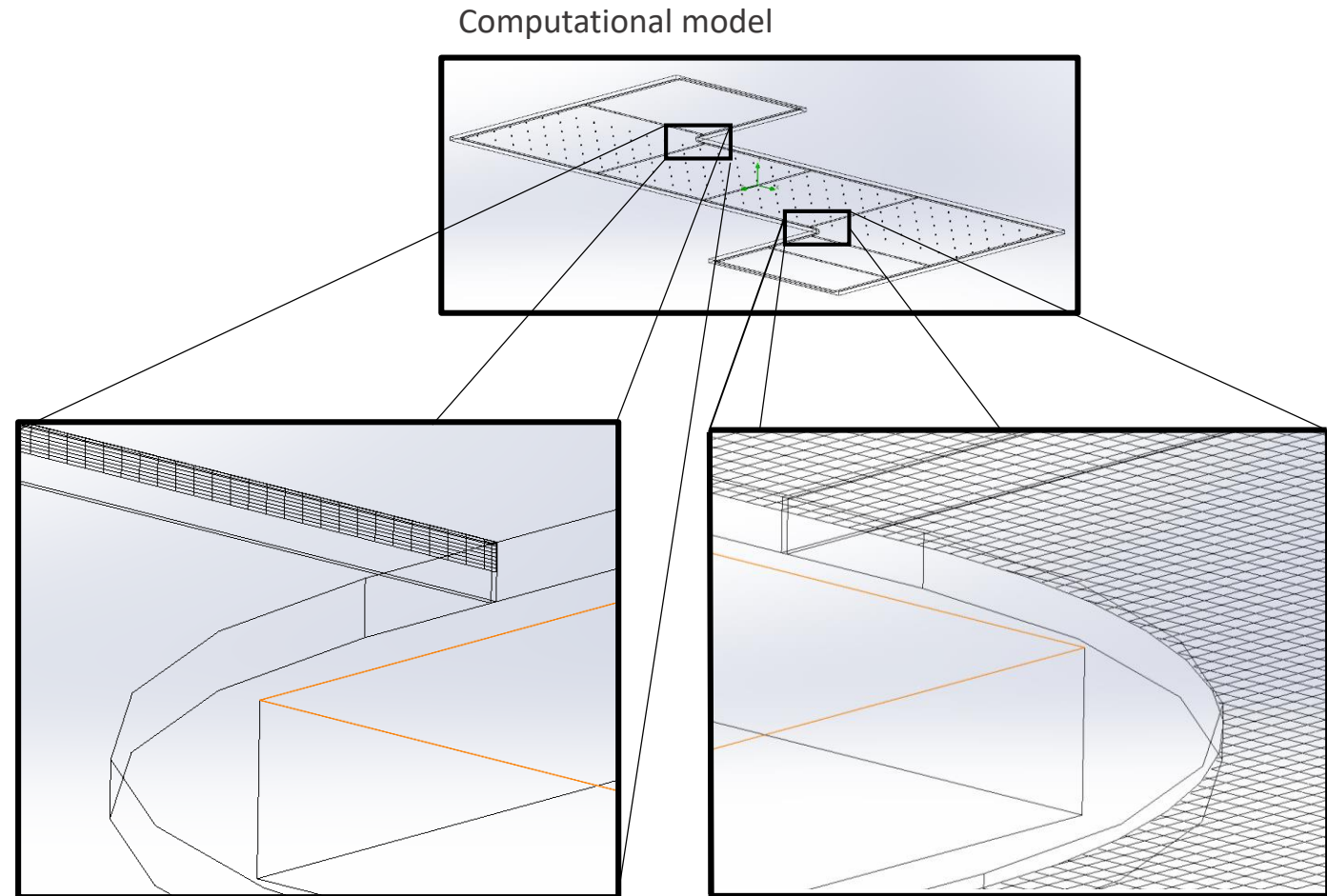
- 1:1 scaled Z-configuration narrow channel
- Applying symmetry, half channel
- Larger possible resolution

Mesh Generation

- Automatic mesh generation
 $dx=0.025$ m, $dy=0.004$ m, $dz=0.03$ m
(final cell size in $z=100$ μm)
- About 4.3 million cells

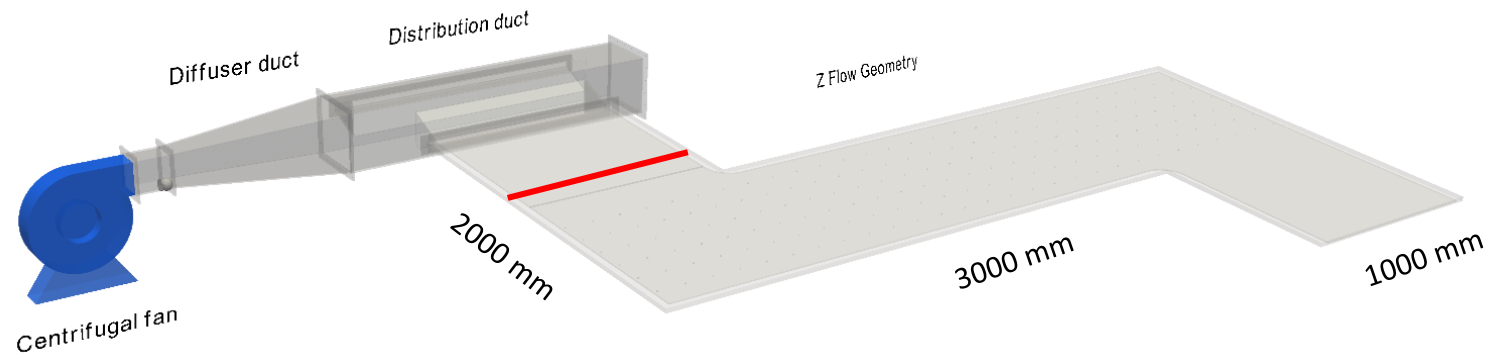
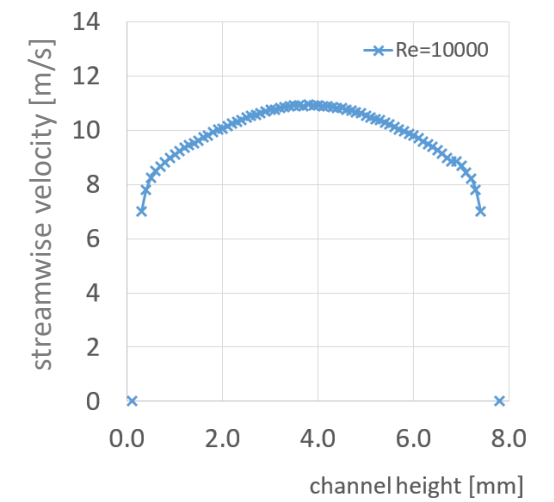
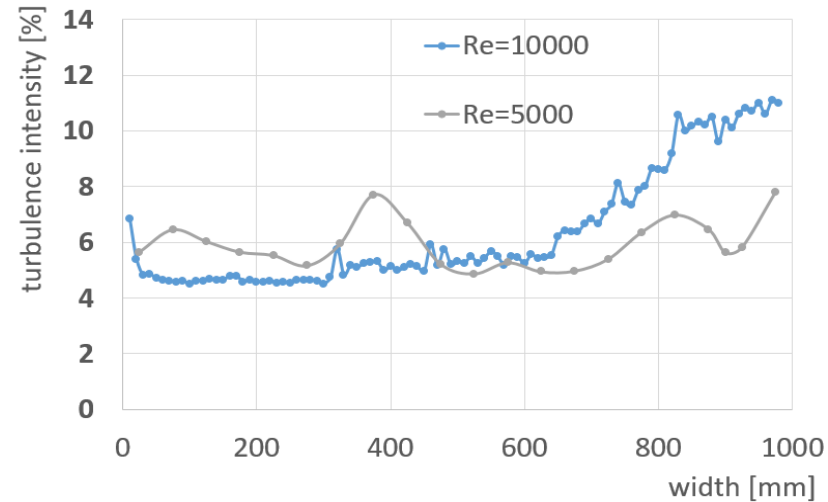
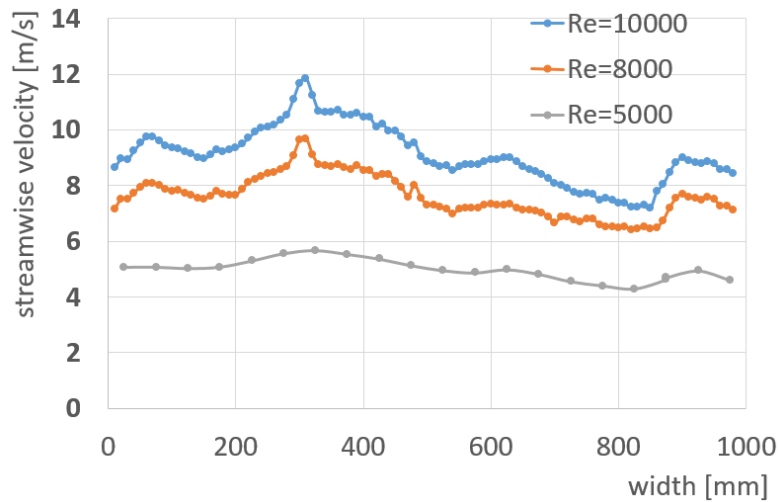
Inlet/Outlet Boundary conditions

- Volume flow rate according measured volume flow rate
- Static pressures at inlet
- Velocity and turbulence intensity profile at inlet by LDA
- **Simulation conditions are set to match the experimental conditions**



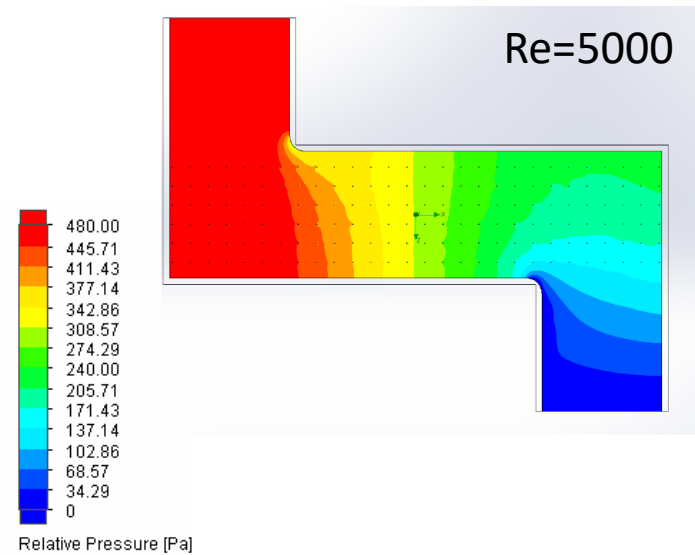
Inlet boundary conditions – Experimental/Simulation

Measurement of boundary conditions with LDA for FloEFD simulation input
 → Link between experiment and simulation

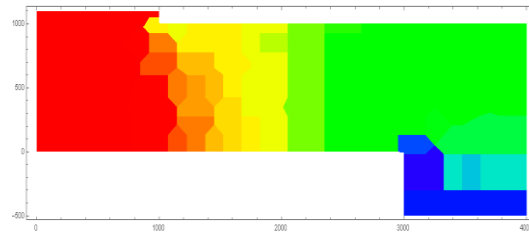


Results – Comparison Simulation/Experiment (static pressure)

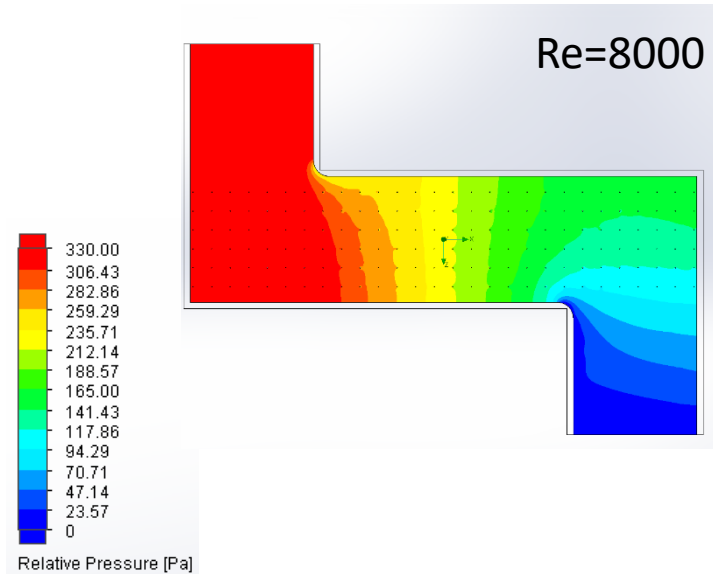
Simulation



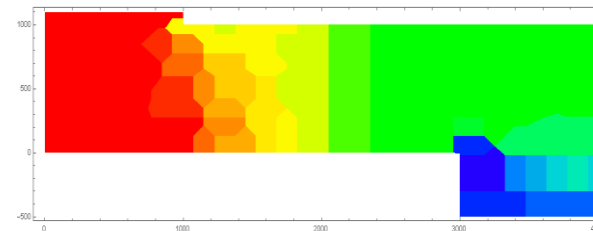
Experiment



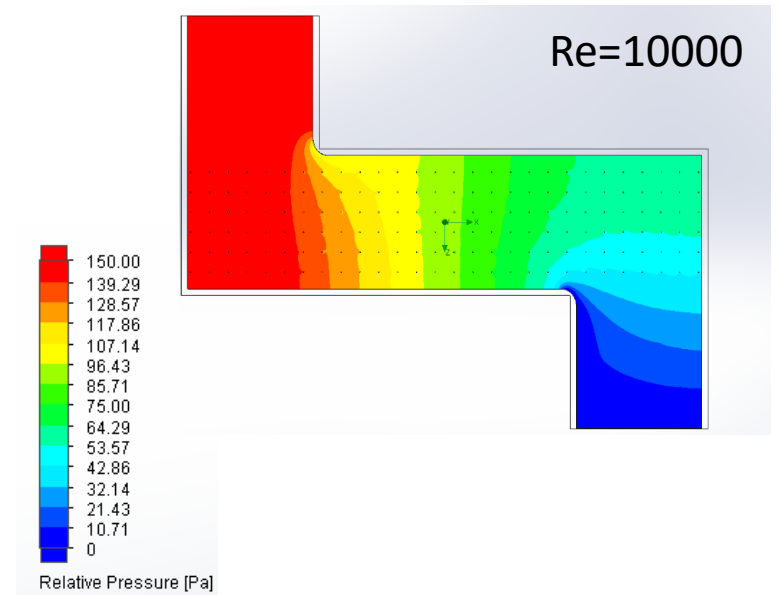
Simulation



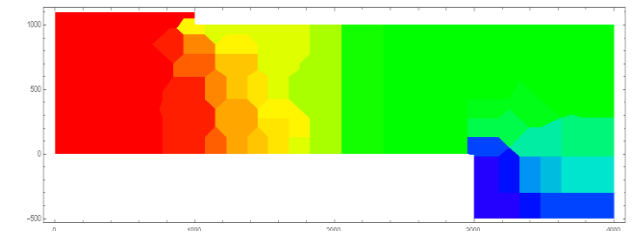
Experiment



Simulation

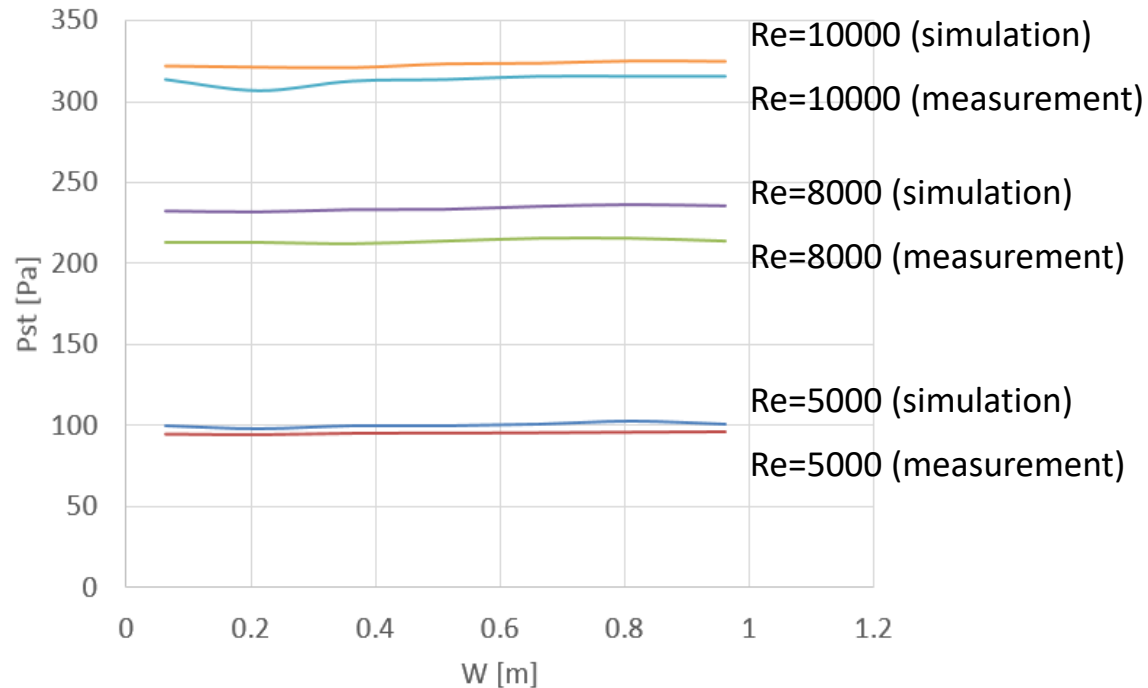


Experiment

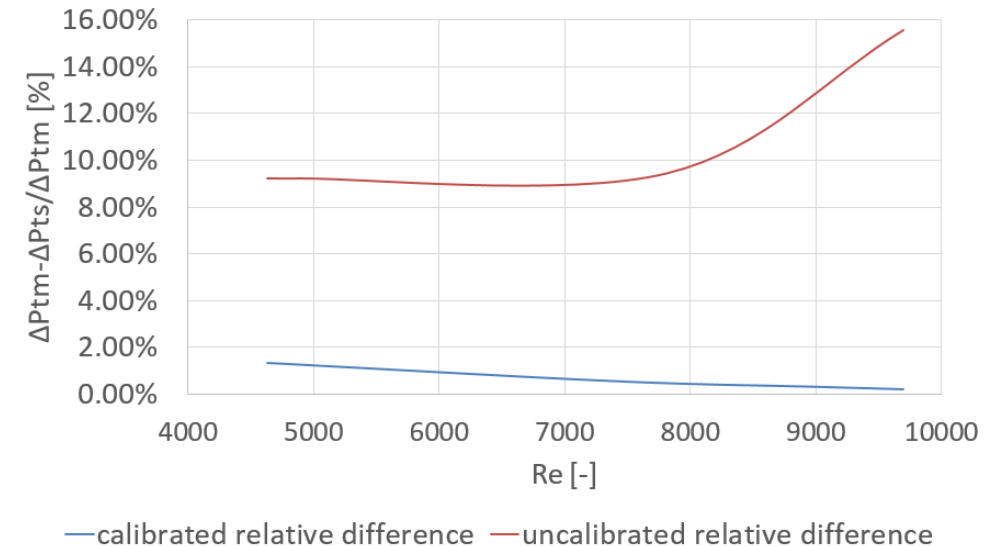


Results – Comparison Simulation/Experiment (static pressure)

Static pressure profile



Pressure drop as f(Re)

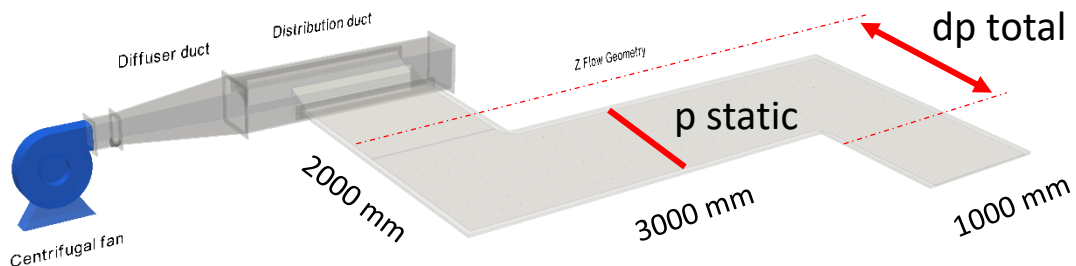


uncalibrated simulation:

- Coarse mesh, estimated inlet flow conditions

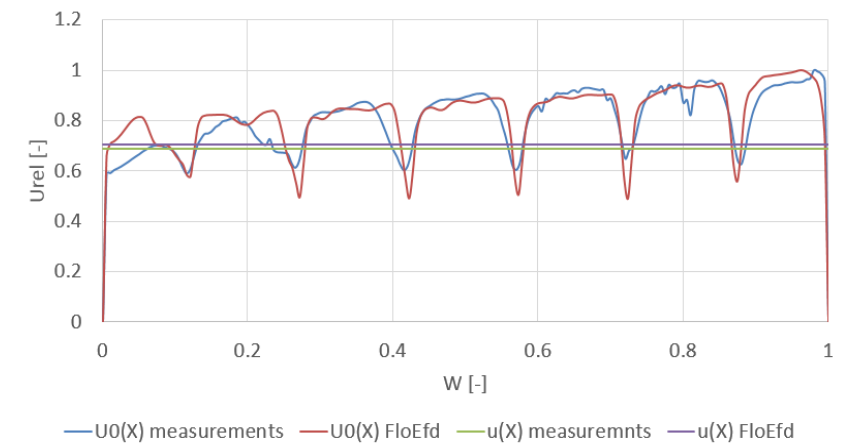
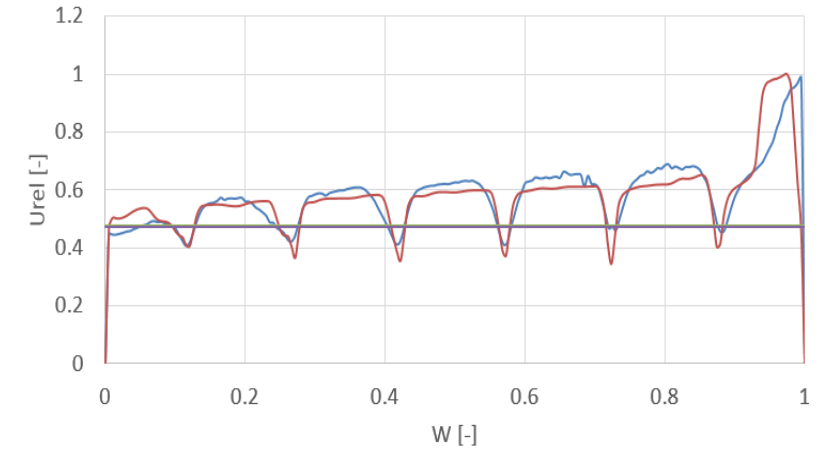
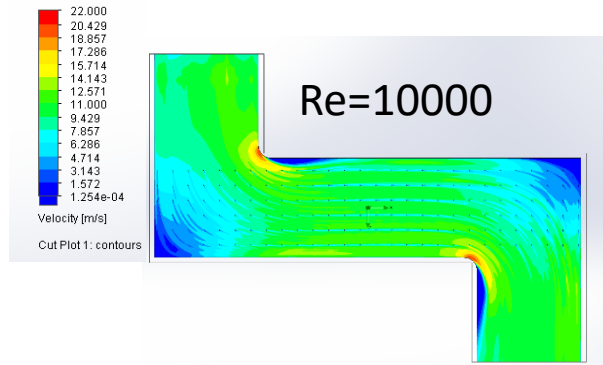
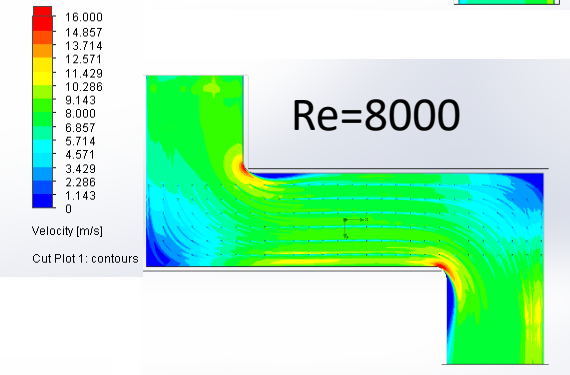
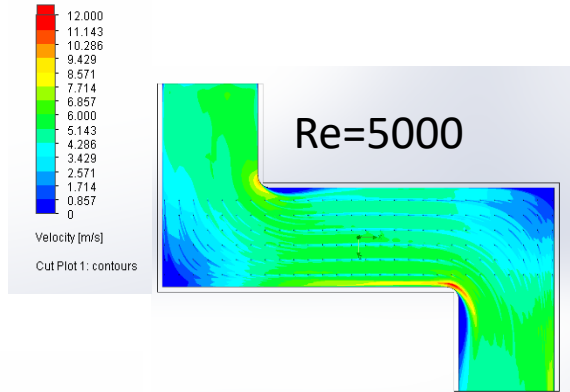
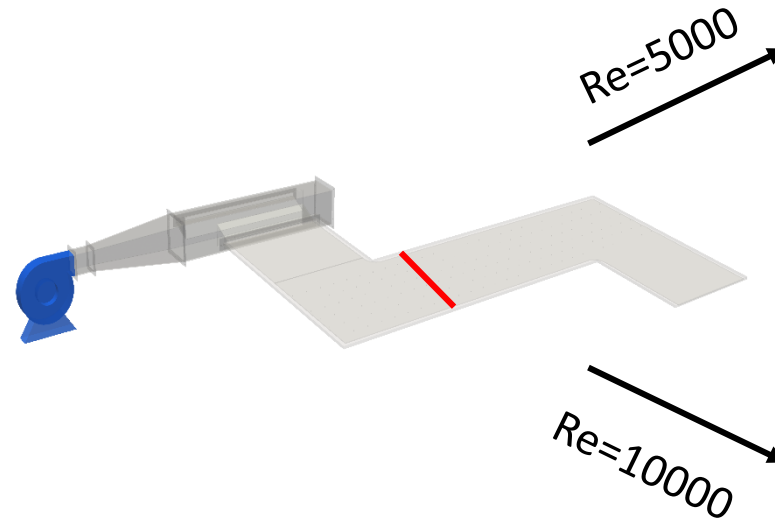
calibrated simulation:

- Refined mesh, measured inlet flow conditions



Results – Comparison Simulation/Experiment (velocity distribution)

Extraction of velocity profile





Conclusion/Outlook – MEASURE ONCE AND SIMULATE MANY TIMES

Conclusion

FloEFD is well suited for the simulation of narrow rectangular channel flow.

- Overall parameters like pressure drop and local parameters like velocity profile are well estimated
- Special care needs to be taken in defining the inlet boundary conditions and the mesh generation
- Without consideration of exact boundary conditions: accuracy of 10% to 20 % can be obtained
- Consideration of exact boundary conditions: accuracy of 2 % can be obtained

Outlook

- Validation of flow structures simulated by FloEFD via 2D Particle Image Velocimetry (e.g. size of recirculation zones).

Variable	Simulation/ Experiment	Range of APEX Group Design
Re number [-]	5000, 8000, 10000	$5000 < Re < 20000$
Aspect ratio [-]	125	$50 < AR < 170$
Channel height [mm]	8	$6 < h < 20$
Flow configuration [-]	Z	Z, C, T ...
Spacer distance [mm]	150	$100 < s < 200$

→ Due to confidence in “calibrated simulation”, we will study numerous configurations via FloEFD (Unlimited number of low-cost, high accuracy simulations) considering the exact boundary conditions obtained from state of the art experimental measurement techniques in a single physical model.