

# Building Openings – Smoke Testing vs CFD Modelling

30 April 2014 @ UCL

# About the speaker



## Jannick Roth

- Civil Engineer
- Educated at the Technical University of Denmark
- Started at WindowMaster in 2009
- Team member of Ventilation Institute
- Responsible for calculations  
(dynamic simulations, CFD modelling,  
energy calculations etc.)

# Agenda

- About WindowMaster – briefly.
- Real cases showing the use of CFD in our daily life.
- Smoke Test – conducted by Aalborg University

# Agenda

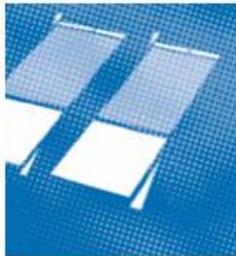
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# VKR Holding

## Group overview



VKR Holding owns companies in four business areas:



### Roof windows & skylights

VELUX  
Altaterra



### Vertical windows

DOVISTA  
VELFAC  
Rationel Vinduer  
SP Fönster  
Traryd Fönster  
Mockfjärds Fönster  
Snidex  
Natre Gruppen  
Lian Trevarefabrikk  
O.H. Industri  
West Port



### Solar thermal energy

SolarCAP  
General Solar Systems  
SONNENKRAFT  
ARCON Solar  
Heliodyne  
EMMVEE Solar Systems  
GREENoneTEC Solarindustrie



### Ventilation & indoor climate

WindowMaster  
Monodraught



# Business Areas

**Smoke &  
Heat  
Ventilation**

**Natural  
Ventilation**

**Hybrid  
Ventilation**

# Solutions

## NV Comfort™



**Intelligent control** based on touch screen.  
(Natural + Hybrid Ventilation)

## NV Advance™

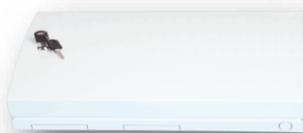


**Top end solution** based on PC interface.  
(Natural + Hybrid Ventilation)



# Solutions

## MotorLink™



Window automation  
via the BMS  
(natural ventilation)

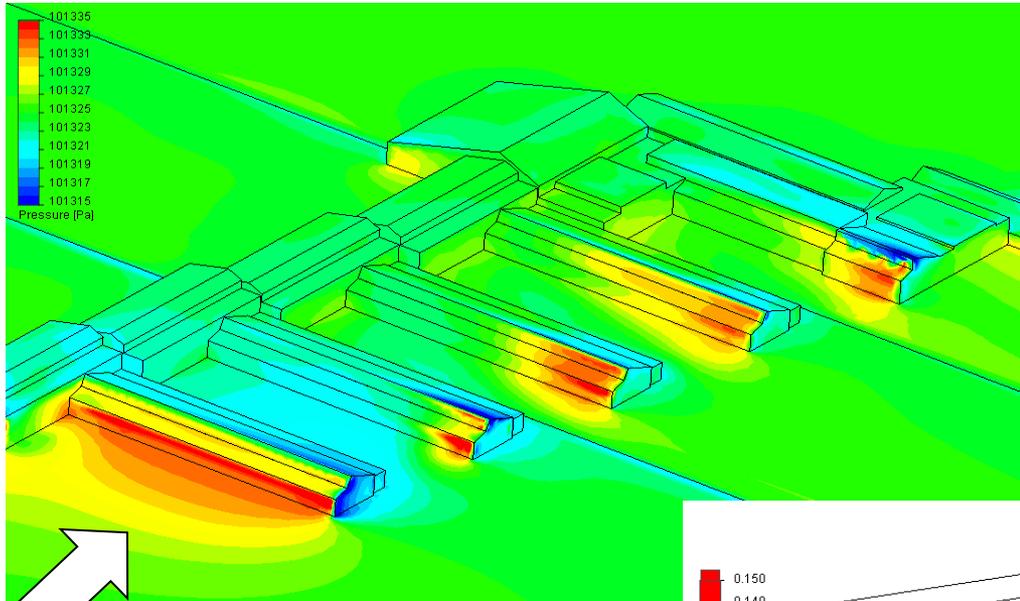
## MotorLink™ features

- *Millimetre-by-millimetre control*
- *Absolute position feedback*
- *Pressure safety feature*
- *3 Speed operation*

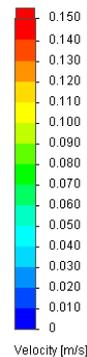
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# Natural ventilation vs. CFD

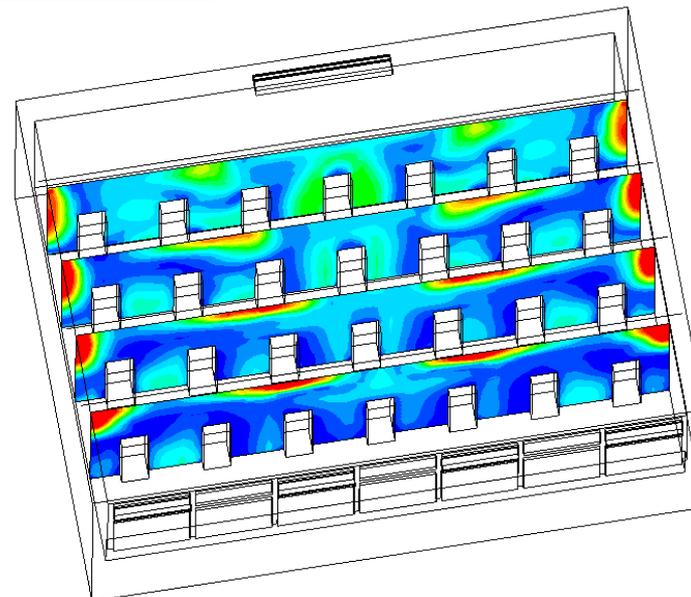


- External CFD (Cp values) are used in our algorithm to control the windows and find the optimum position.
- Internal CFD used to prove the Indoor Environment.

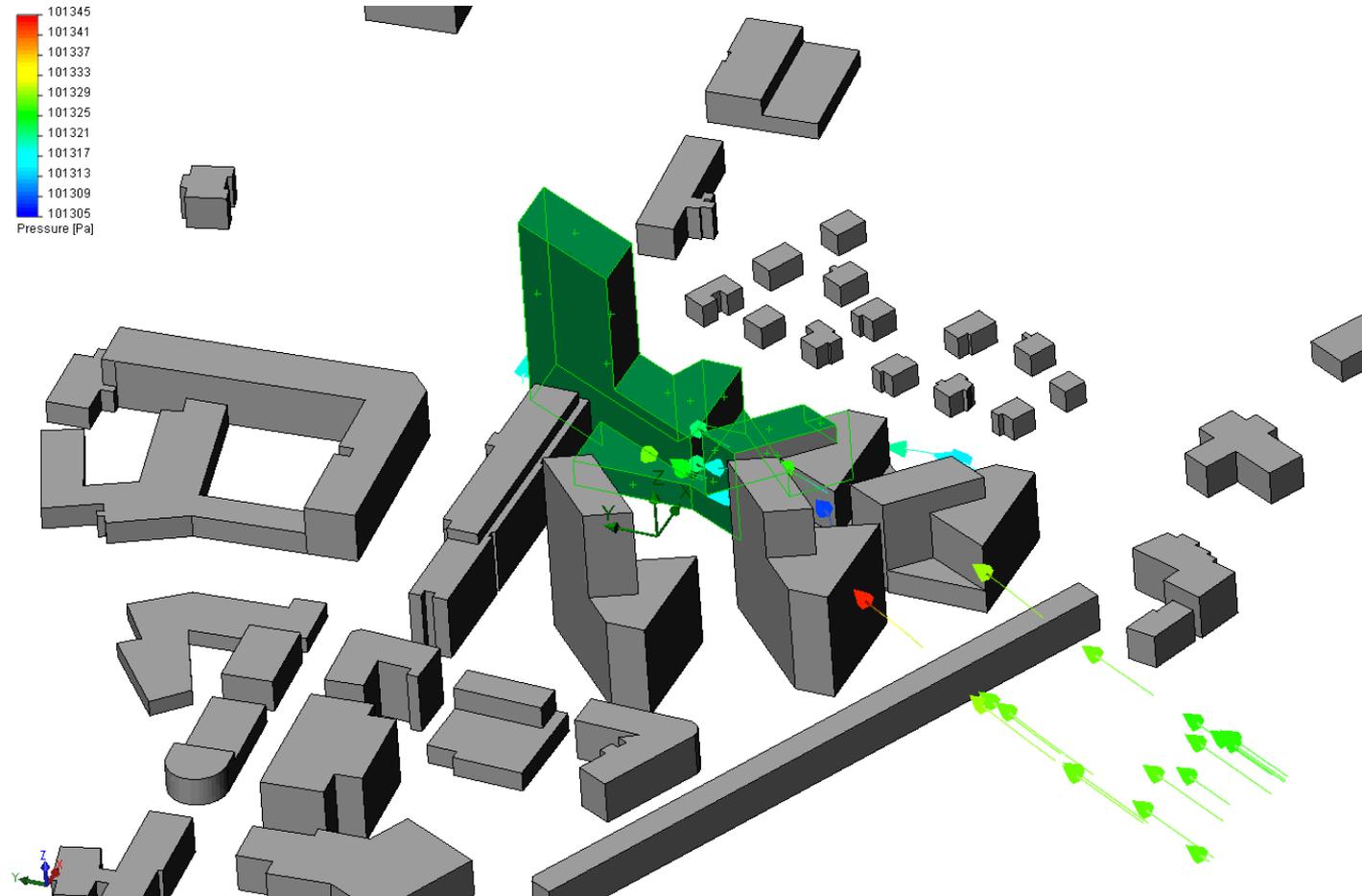


Velocity [m/s]

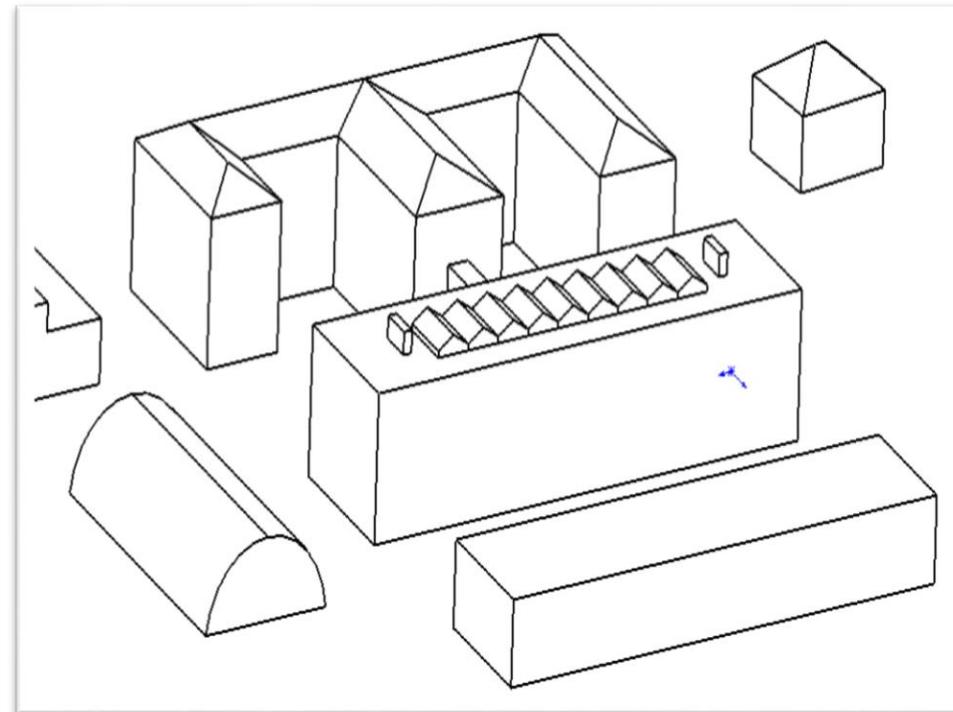
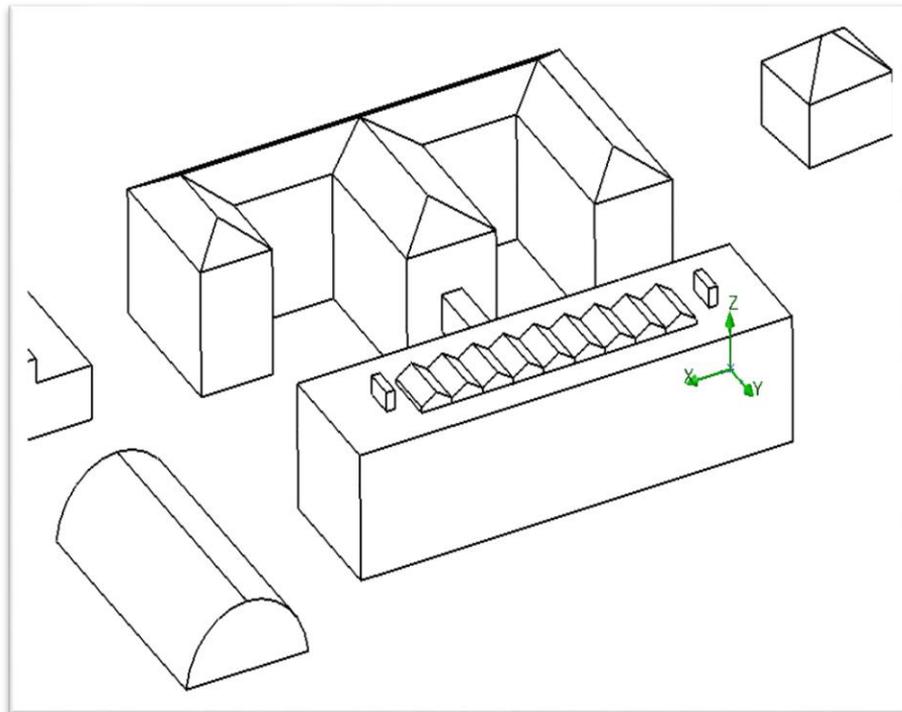
Cut Plot 2: contours  
 Cut Plot 3: contours  
 Cut Plot 4: contours  
 Cut Plot 5: contours



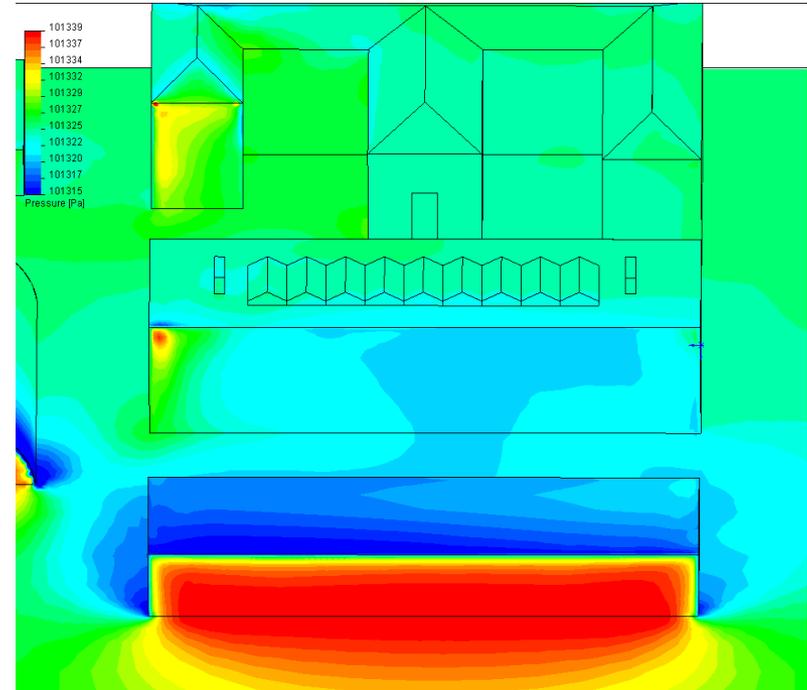
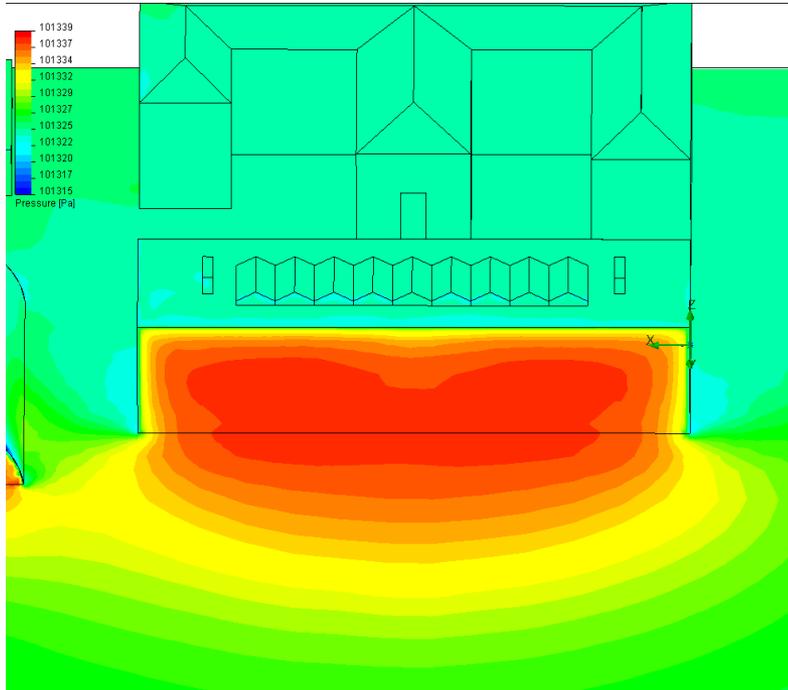
# External CFD – surrounding buildings



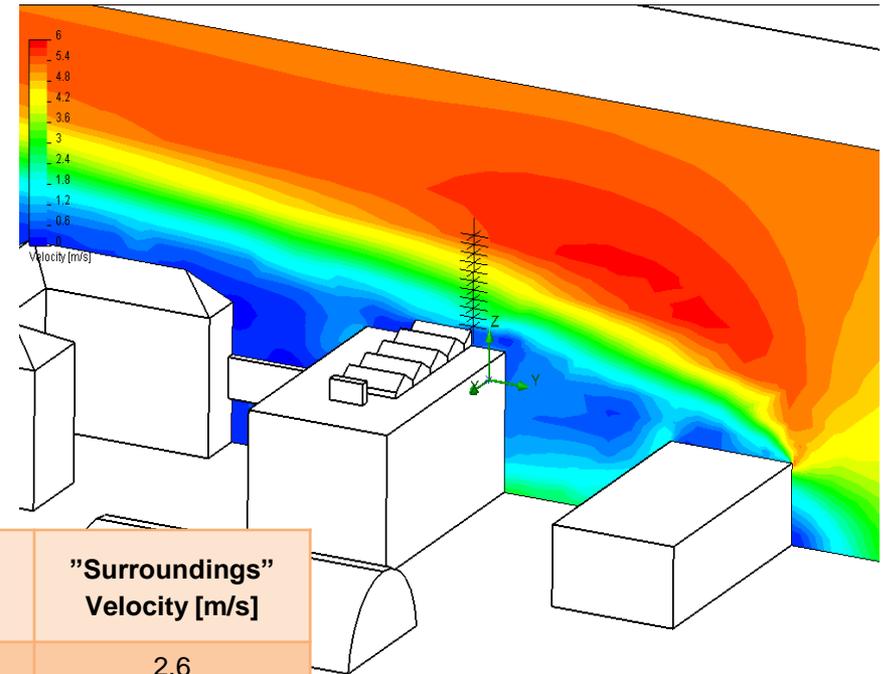
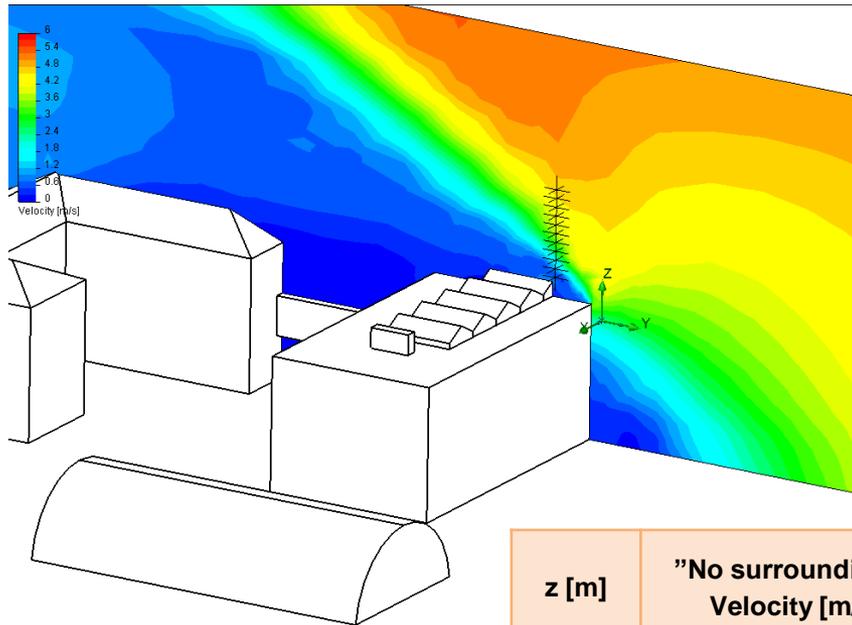
# External CFD – surrounding buildings



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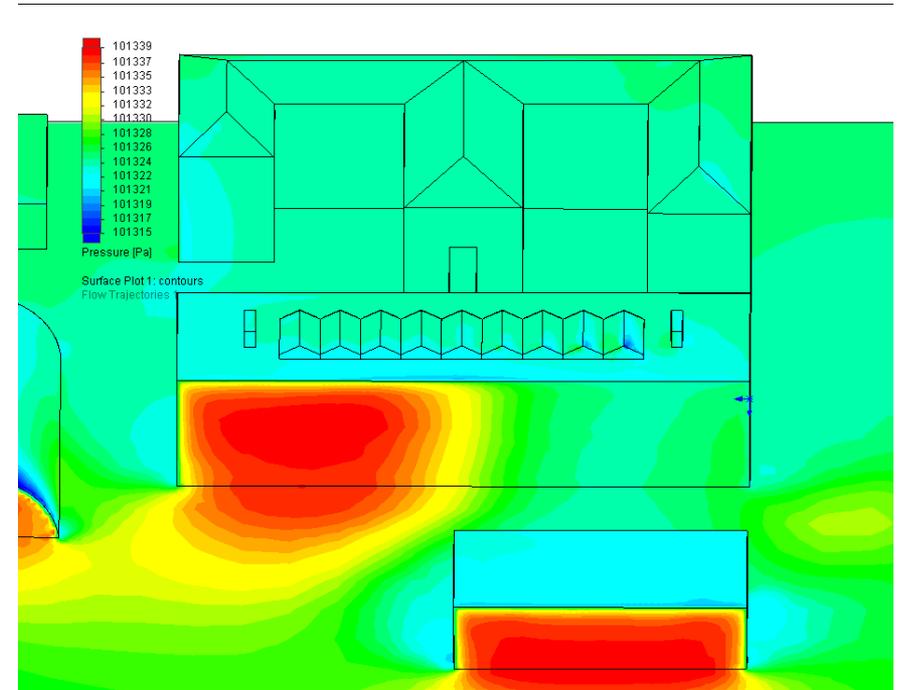
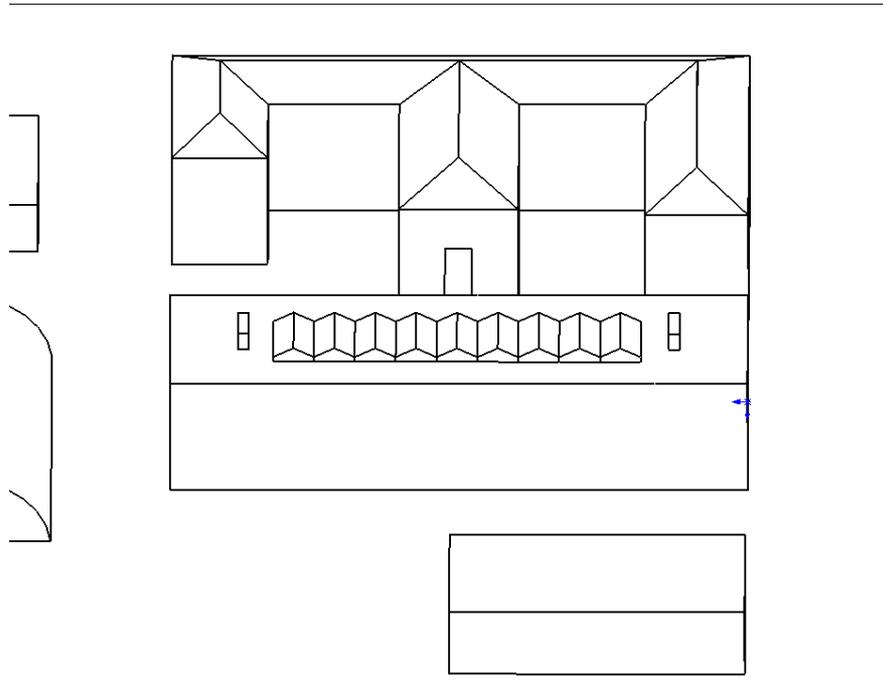


# External CFD – surrounding buildings

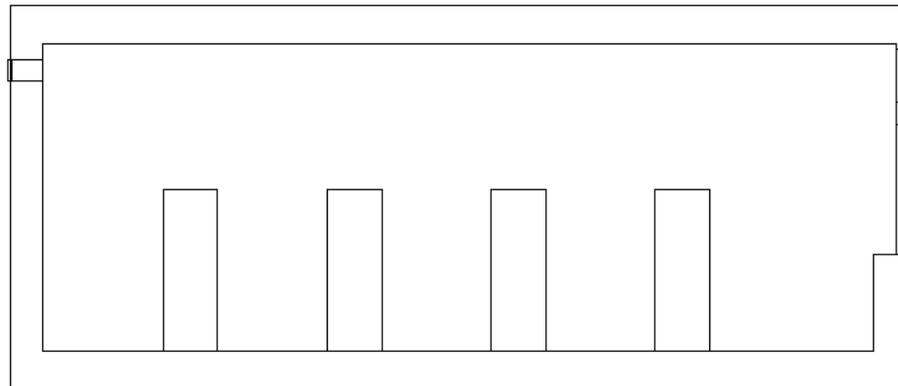
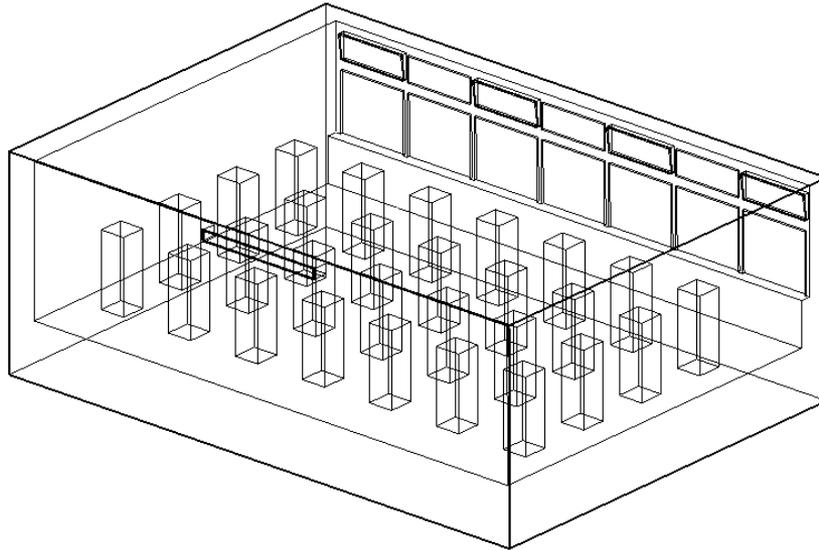


| z [m] | "No surroundings"<br>Velocity [m/s] | "Surroundings"<br>Velocity [m/s] |
|-------|-------------------------------------|----------------------------------|
| 3     | 2,4                                 | 2,6                              |
| 4     | 3,0                                 | 3,1                              |
| 5     | 3,6                                 | 3,6                              |
| 6     | 3,8                                 | 3,9                              |
| 7     | 4,1                                 | 4,3                              |
| 8     | 4,3                                 | 4,7                              |

# External CFD – surrounding buildings



# Mixing of air during colder periods



The result presented is for a typical winter day with an **external temperature of 5°C** and a flow rate of approx. **5 l/s per person (158 l/s)**.

Each of the **28 pupils** gives a heat source of 75 W.

**Lighting of 8 W/m<sup>2</sup>** is simulated. 2/3 of this load is attached to the ceiling and 1/3 to the floor.

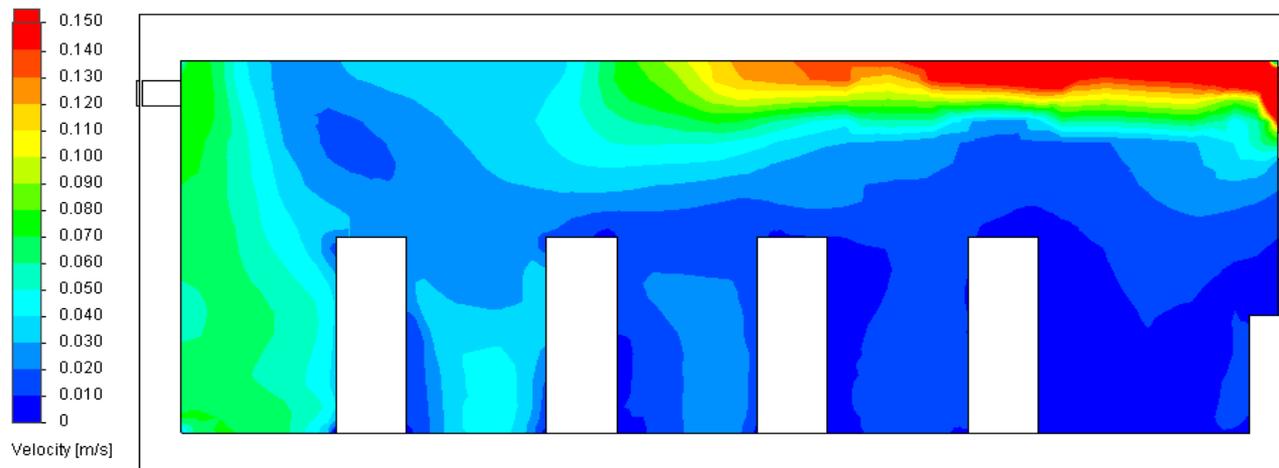
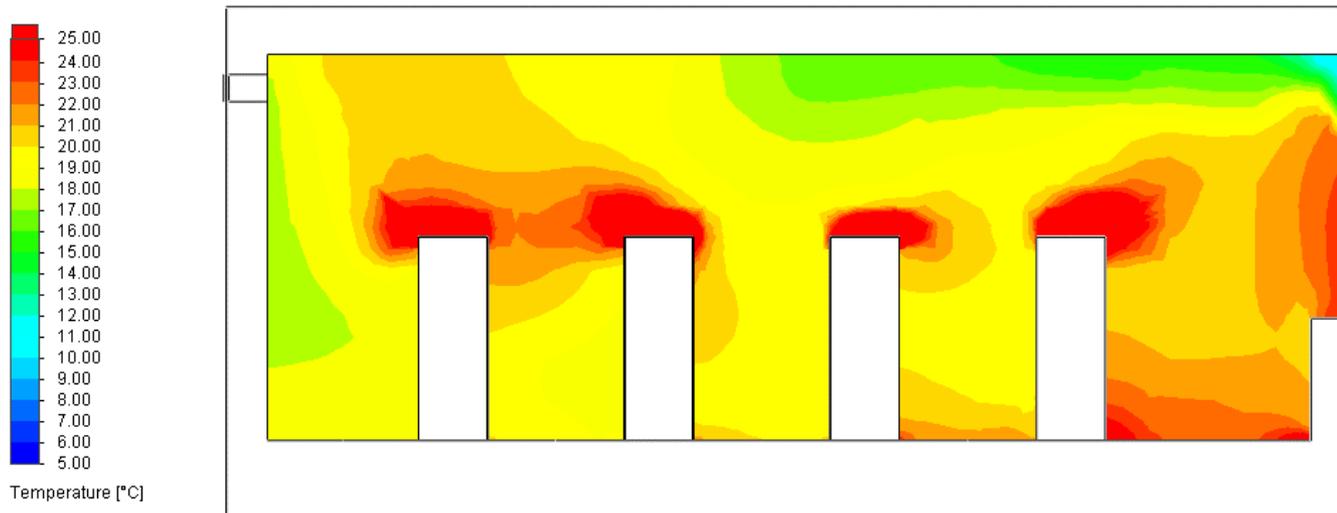
The dimensions of the room is; 7.6 x 10.6 x 2.85 m (w x l x h).

**Four façade windows** can be opened and an **air transfer grill (0.5m<sup>2</sup>)** in the back of the room. Each window has the dimensions 500 x 1400mm (h x w).

**No other heat sources** (e.g. radiators) are assumed in the calculations.

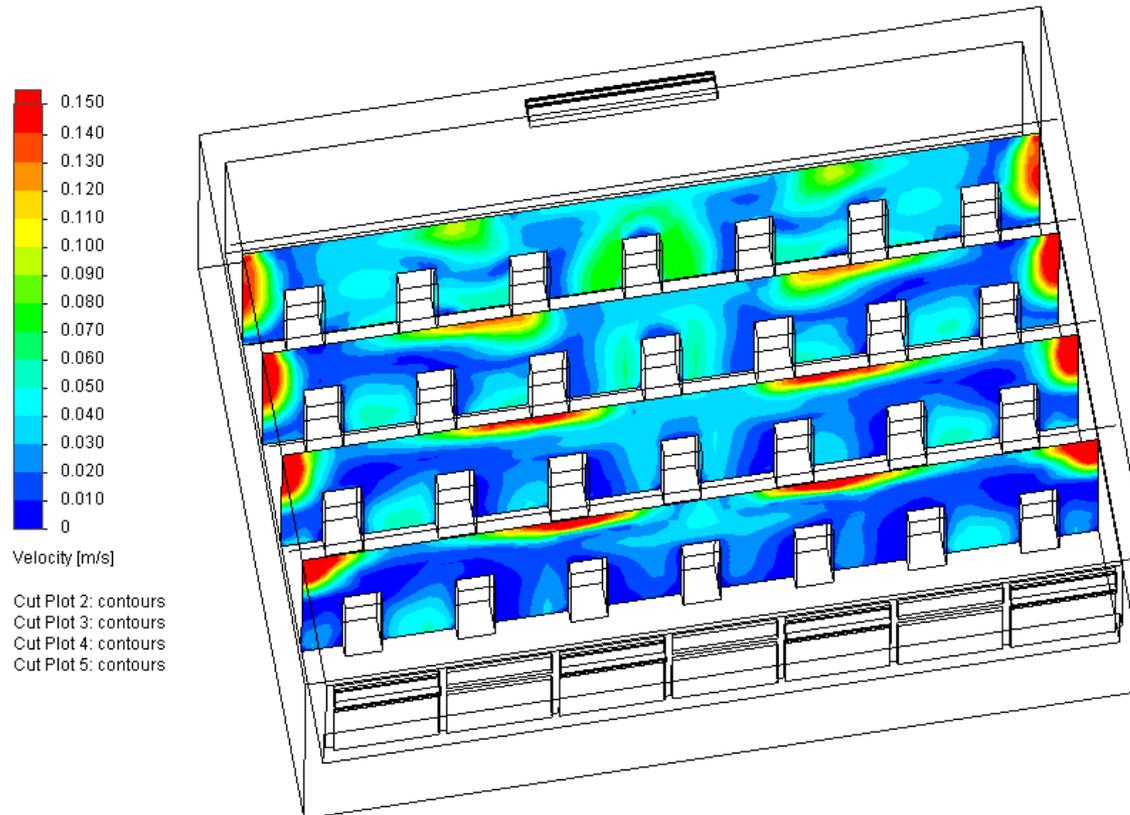
Note: Use of these images is permitted on the condition that WindowMaster are credited in writing, unless agreed in writing by WindowMaster

# Results – temperature and velocity



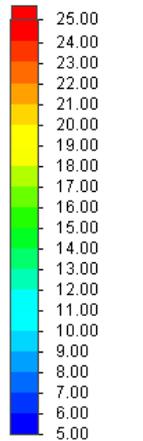
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# Velocity plot

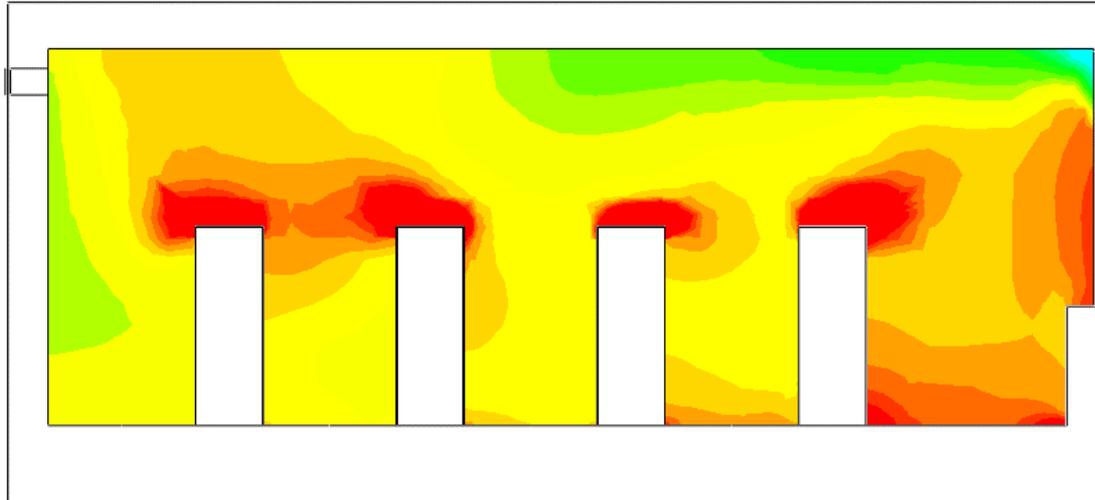


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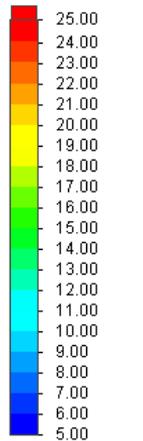
# Optimal window position



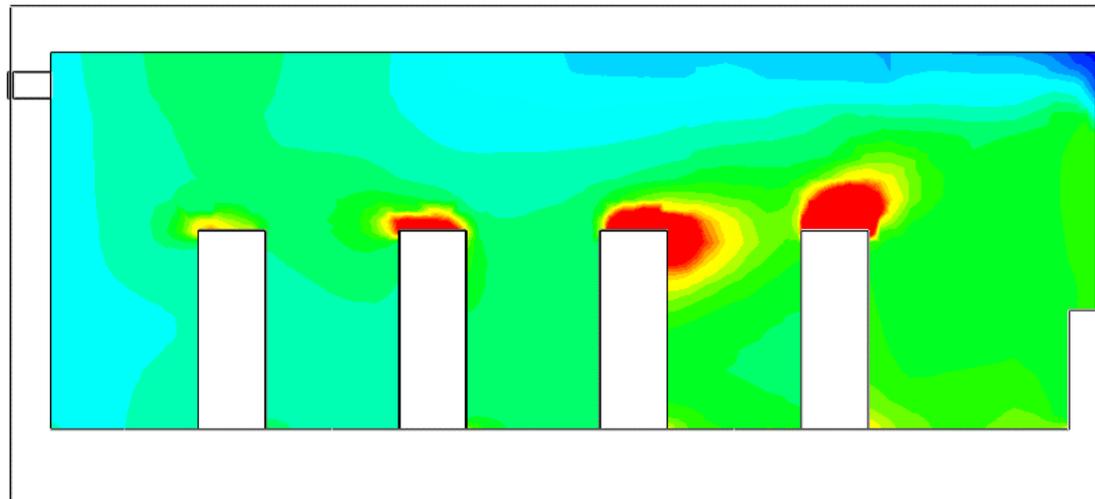
Temperature [°C]



**Optimal position  
= 8 degree of opening**

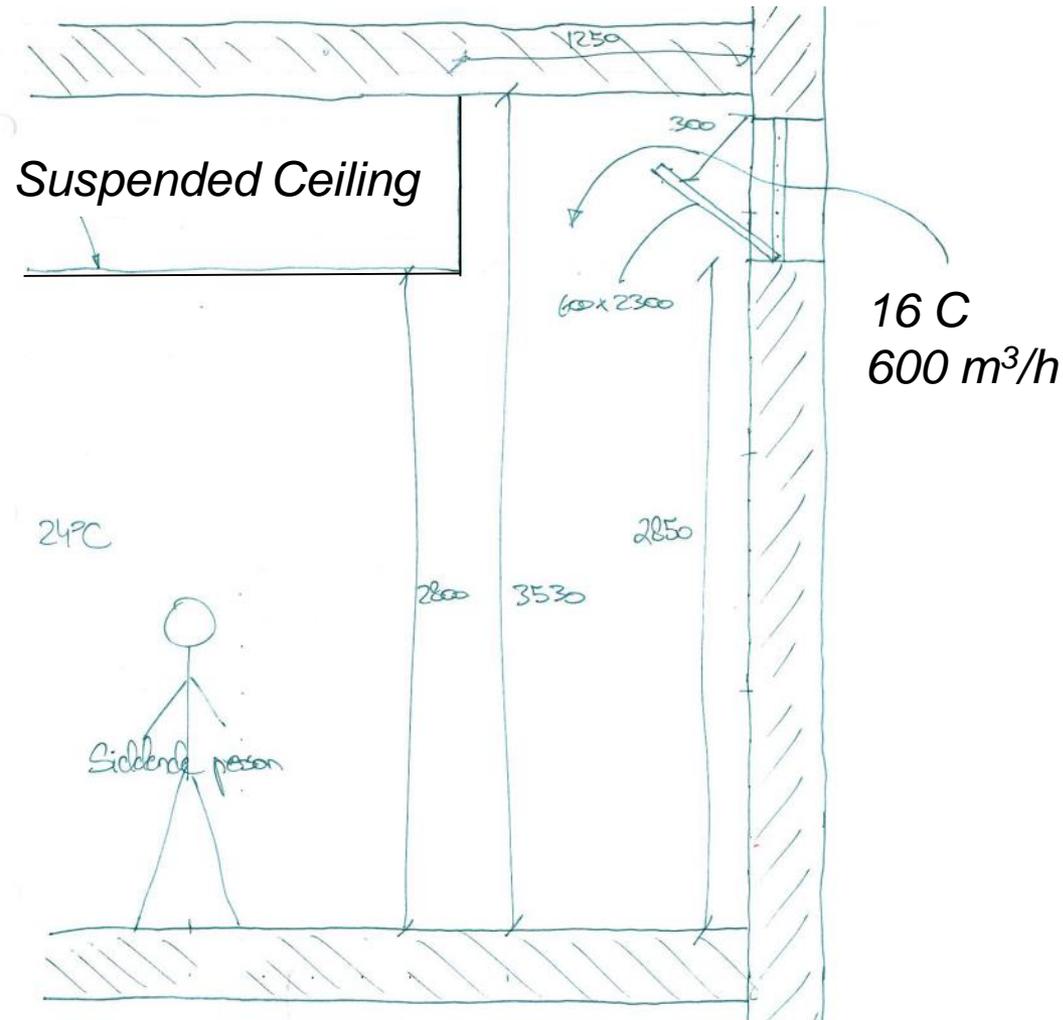


Temperature [°C]

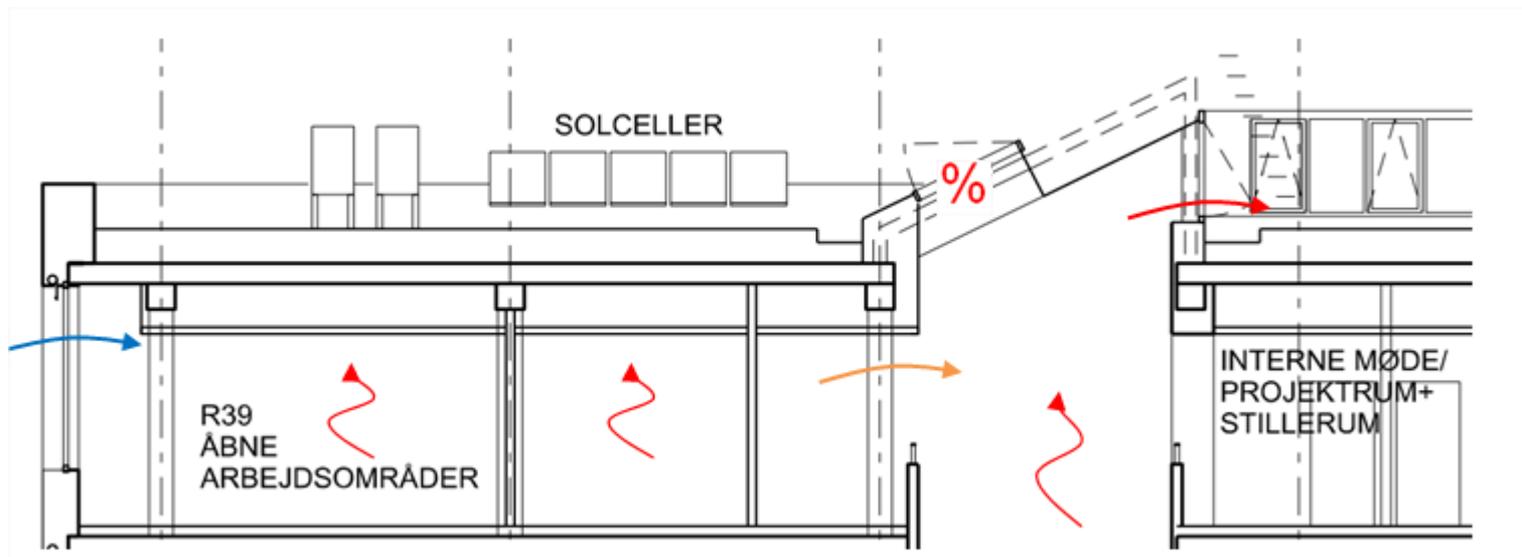


**Non optimal position  
=12 degree of opening**

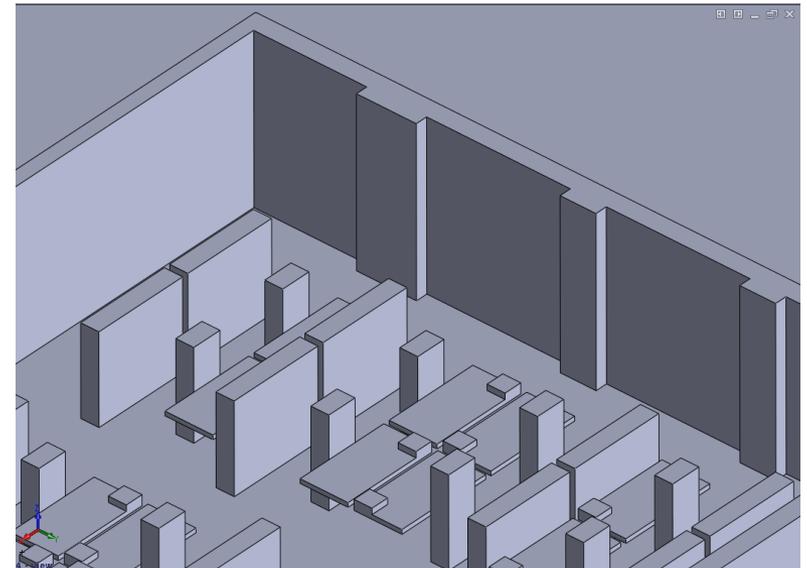
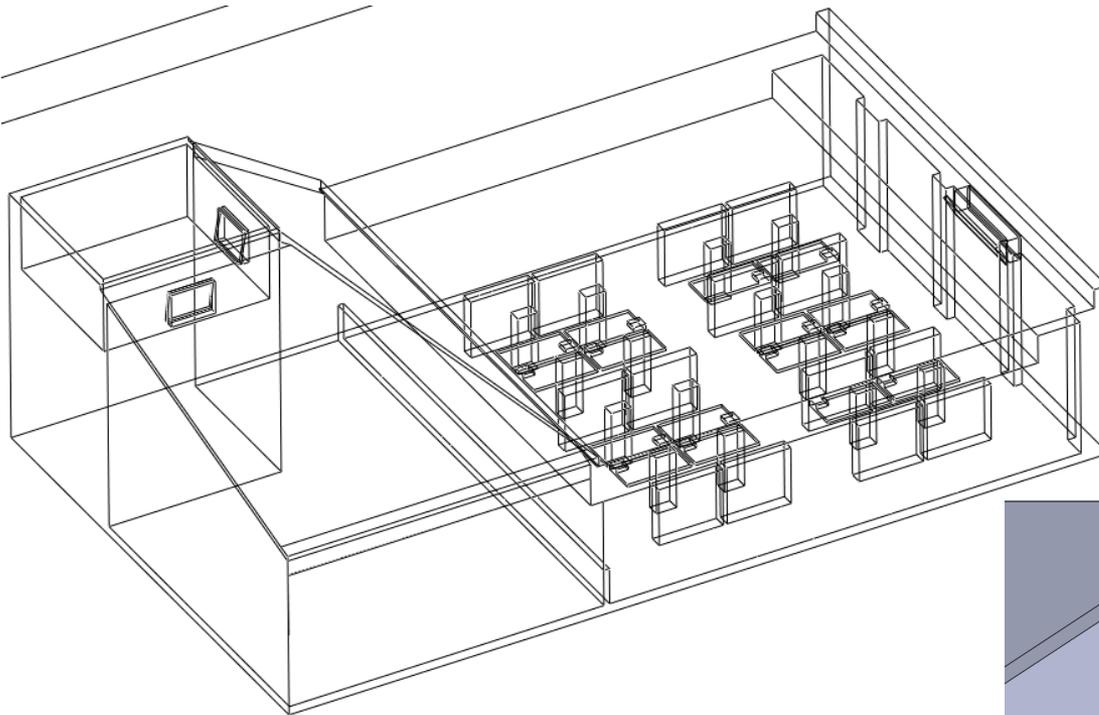
# Office building - suspended ceiling



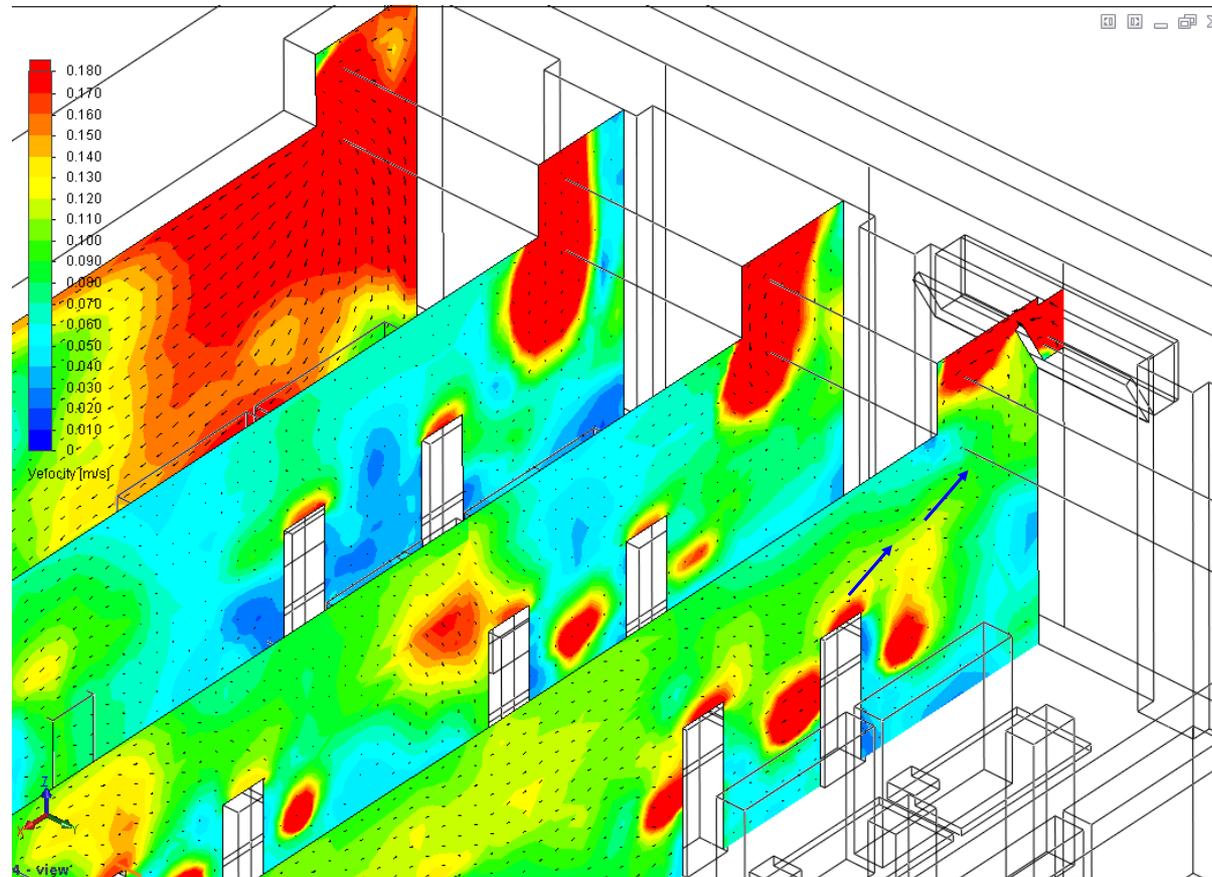
# Office building – ventilation principle



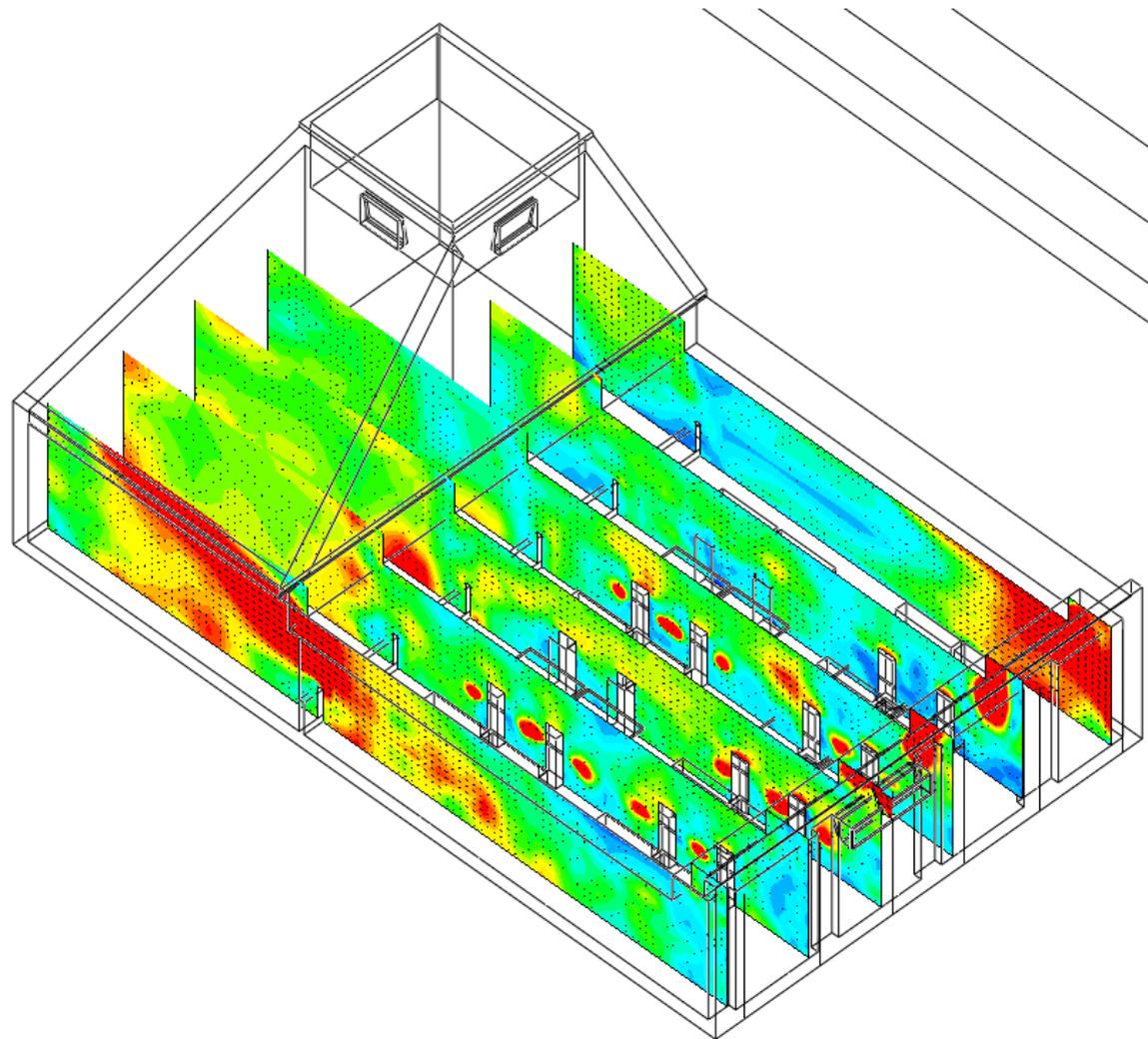
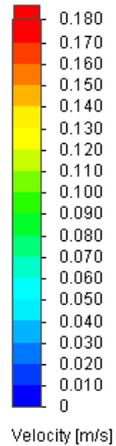
# Office building – CFD model



# Office building – CFD results



# Office building – CFD results



# Agenda

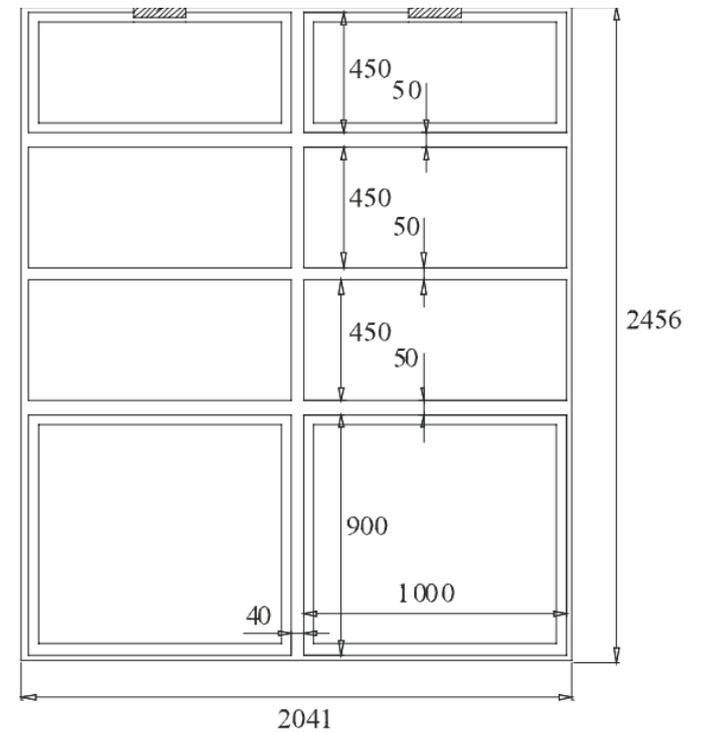
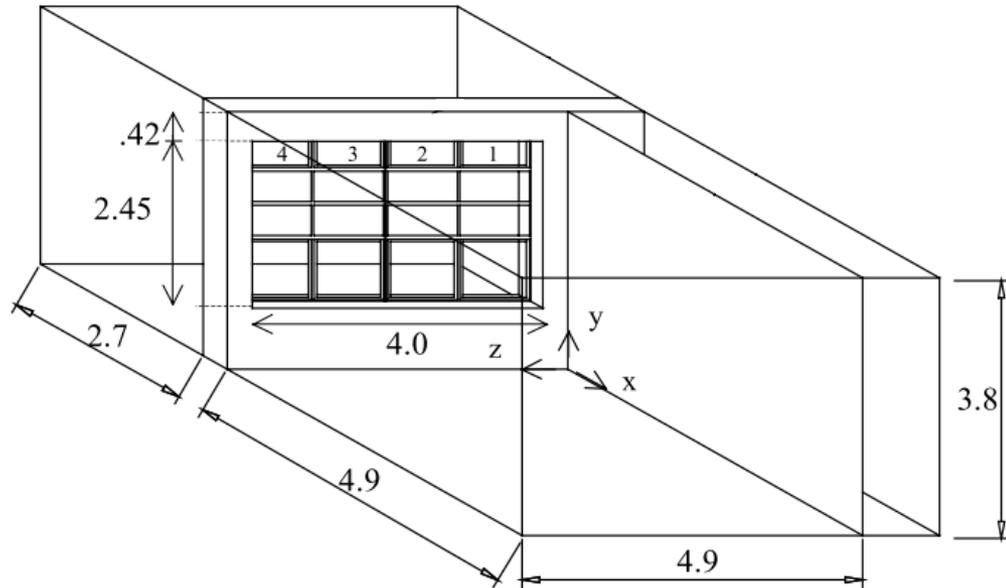
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- **Smoke Test – Conducted by Aalborg University**

# Smoke Test

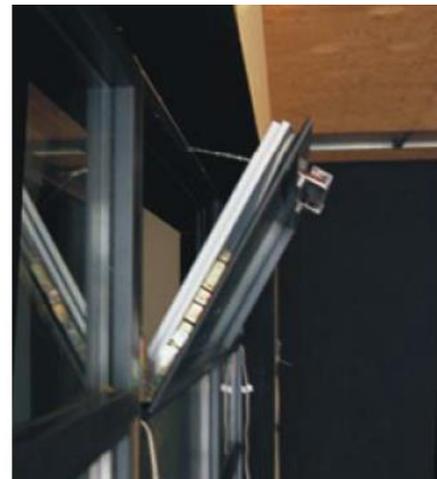


- Office building with natural ventilation via automated controlled windows.
- Conducted in Aalborg Universities test facilities
- Full scale measurements compared to CFD results

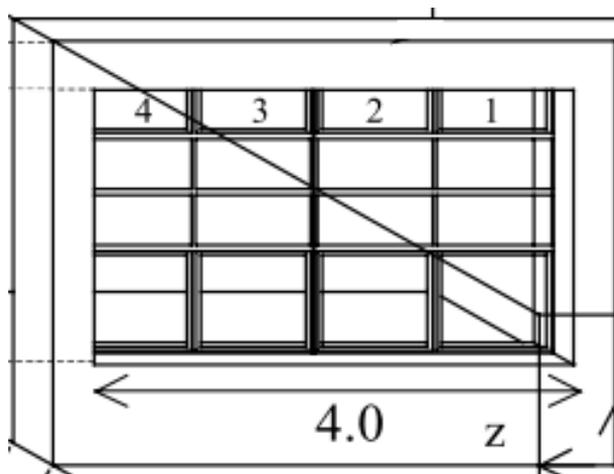
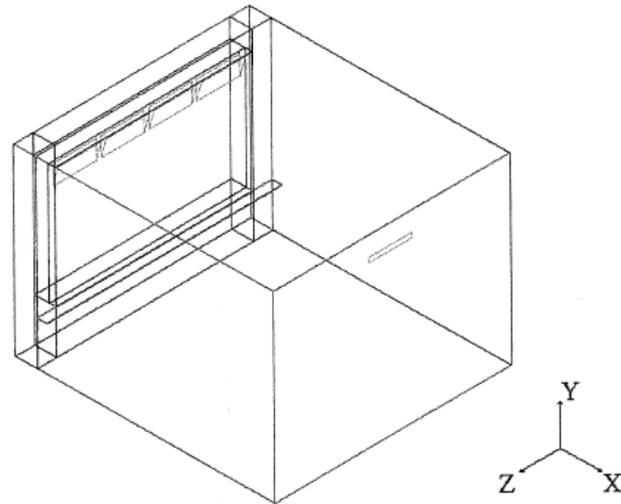
# Test Facilities



# Test Facilities



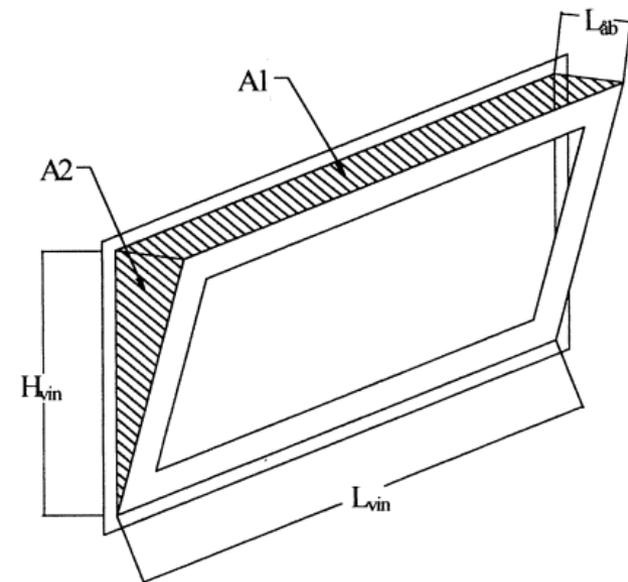
# CFD model - Flovent



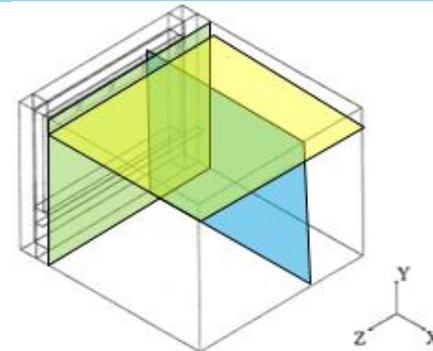
- Four openable windows
- Air flow from window 1 and 4 are symmetric.
- Air flow from window 2 and 3 are symmetric.
- Further analysis are made for window 1 and 2

# Different setups @ 2 m/s

| Test | Chain length [m] | Opening angle [°] | Window 1 [m <sup>3</sup> /s] | Window 2 [m <sup>3</sup> /s] |
|------|------------------|-------------------|------------------------------|------------------------------|
| 1    | 0.063            | 3.7               | 0.050                        | 0.049                        |
| 2    | 0.113            | 11.6              | 0.123                        | 0.135                        |
| 3    | 0.163            | 18.8              | 0.184                        | 0.210                        |
| 4    | 0.213            | 26.1              | 0.240                        | 0.290                        |
| 5    | 0.263            | 33.6              | 0.343                        | 0.414                        |



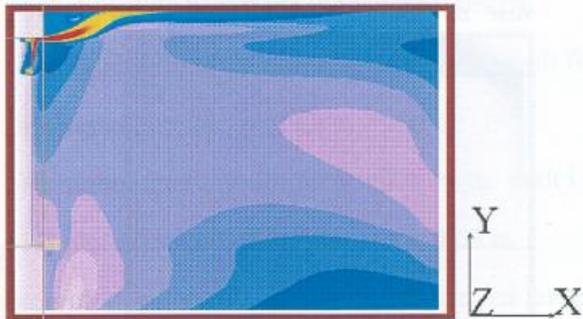
# CFD - window 1



## Blue section

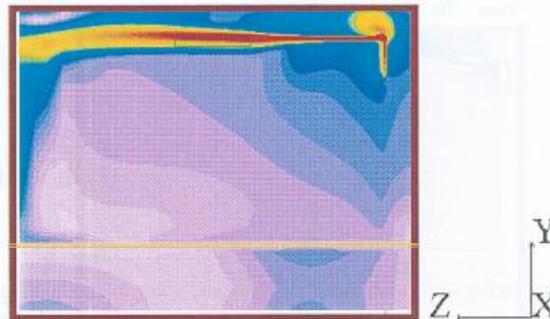
Chain length 0.113m

View: 2D+Z



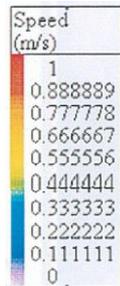
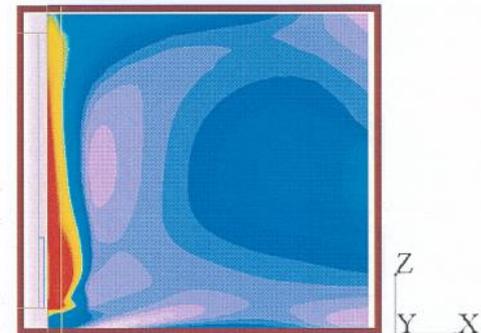
## Green section

View: 2D+X



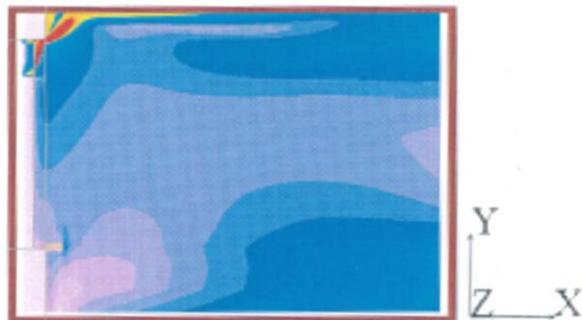
## Yellow section

View: 2D-Y

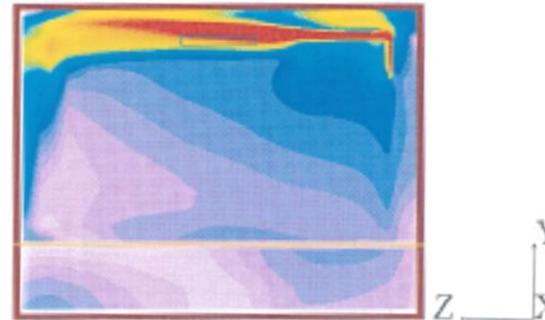


Chain length 0.163m

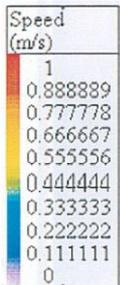
View: 2D+Z



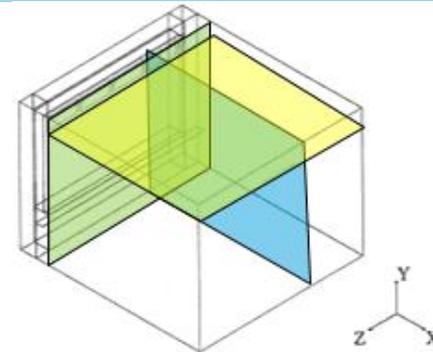
View: 2D+X



View: 2D-Y



# CFD - window 2

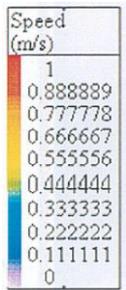
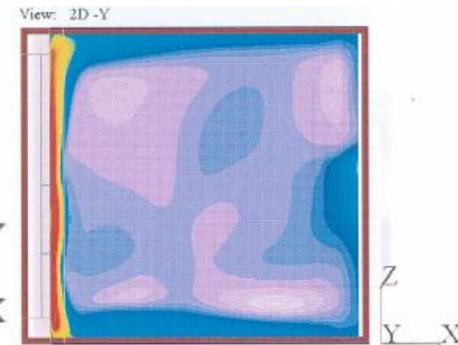
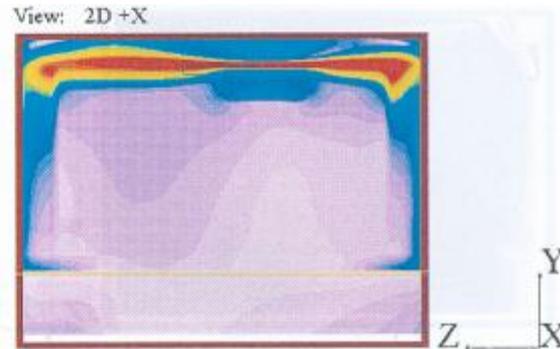
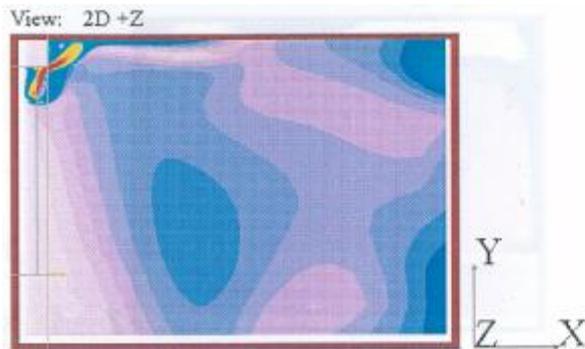


Blue section

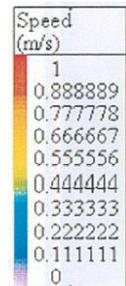
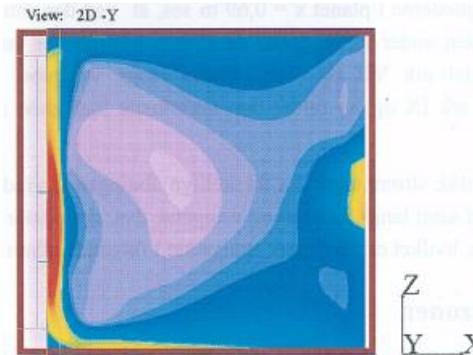
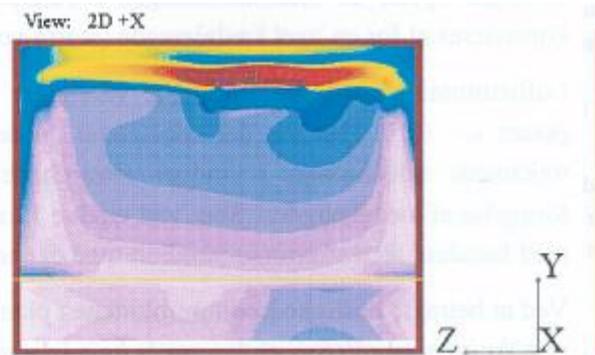
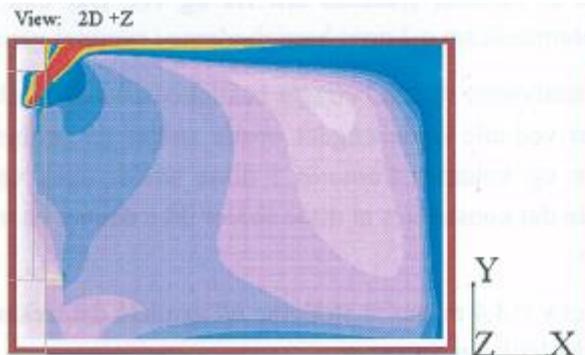
Green section

Yellow section

Chain length 0.163m



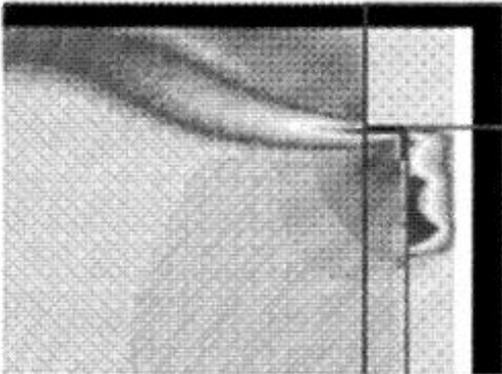
Chain length 0.263m



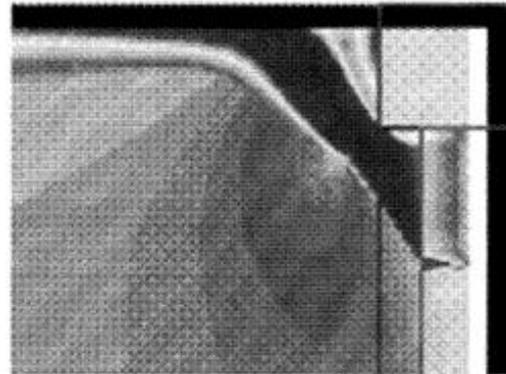
# Comparison of Smoke Test and CFD

# Visual comparison

Vindue 1,  $L_{k\ddot{a}de} = 0,063$  m

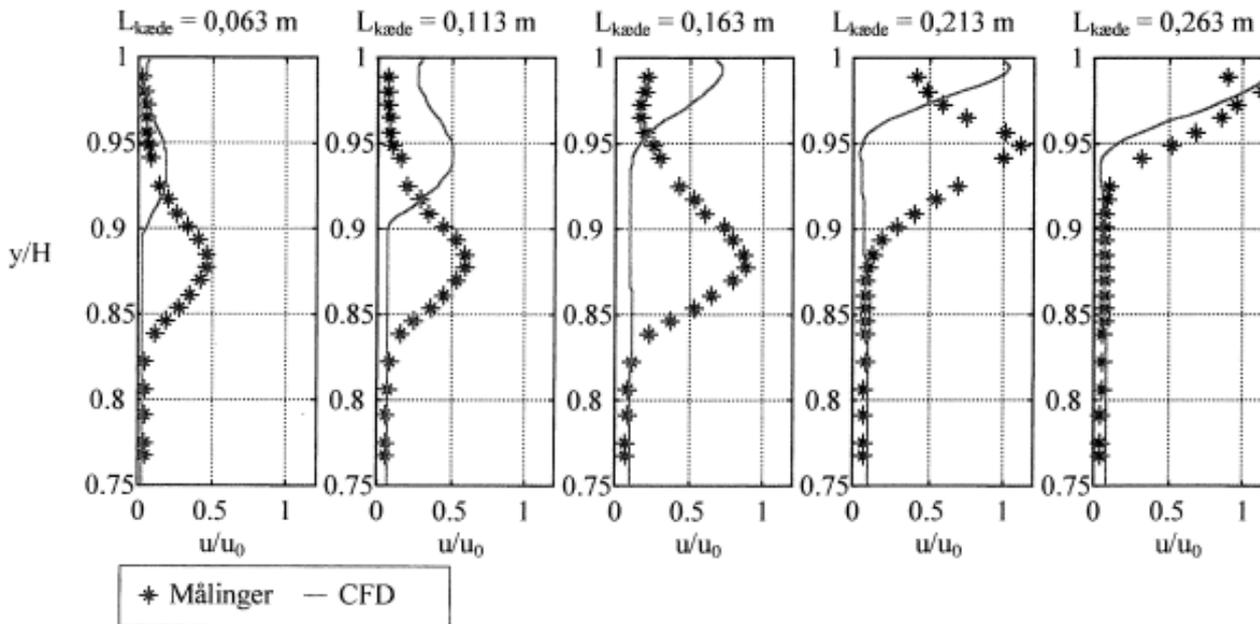


Vindue 1,  $L_{k\ddot{a}de} = 0,263$  m



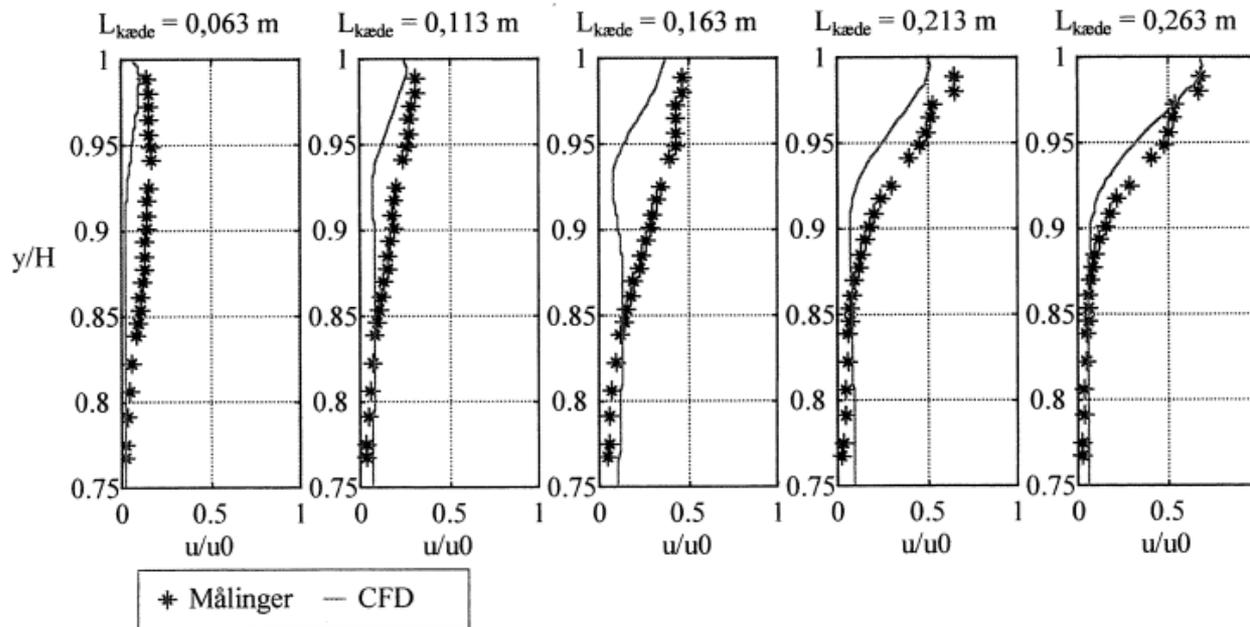
- Relatively good correlation.
- For the “0.063m” the air stream in the CFD sticks to the ceiling before the measured.

# Velocity profiles – window 1



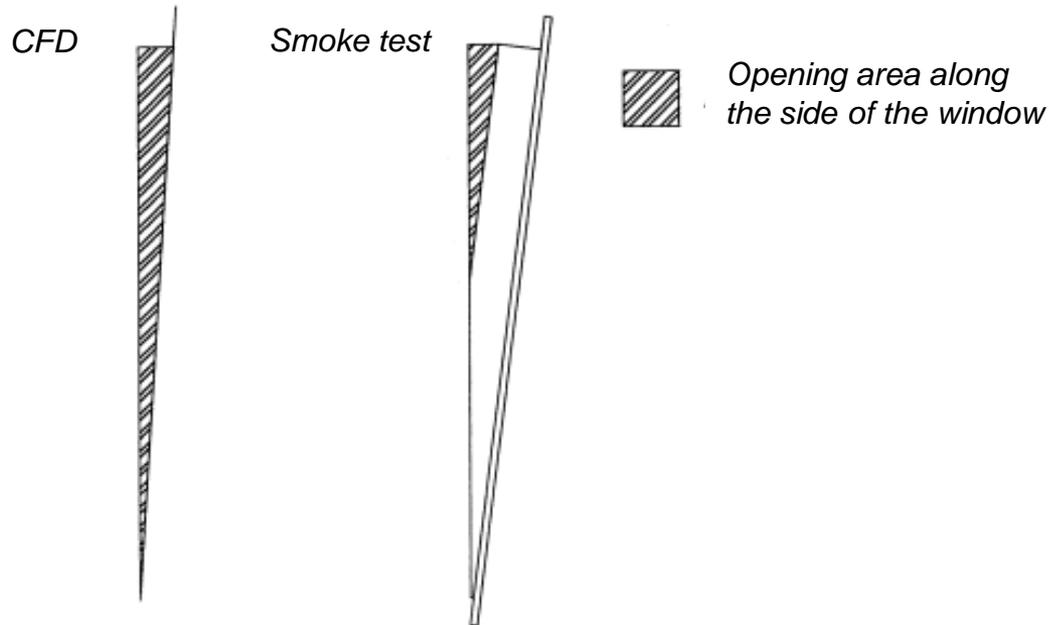
- 0.82m from the window
- Three “smallest openings” doesn’t fit that well to the CFD
- Only the 0.263 chain measurements predicted that the air sticks to the ceiling

# Velocity profiles – window 1



- 2.5 m from the window
- Better agreement, but still not a proper fit.

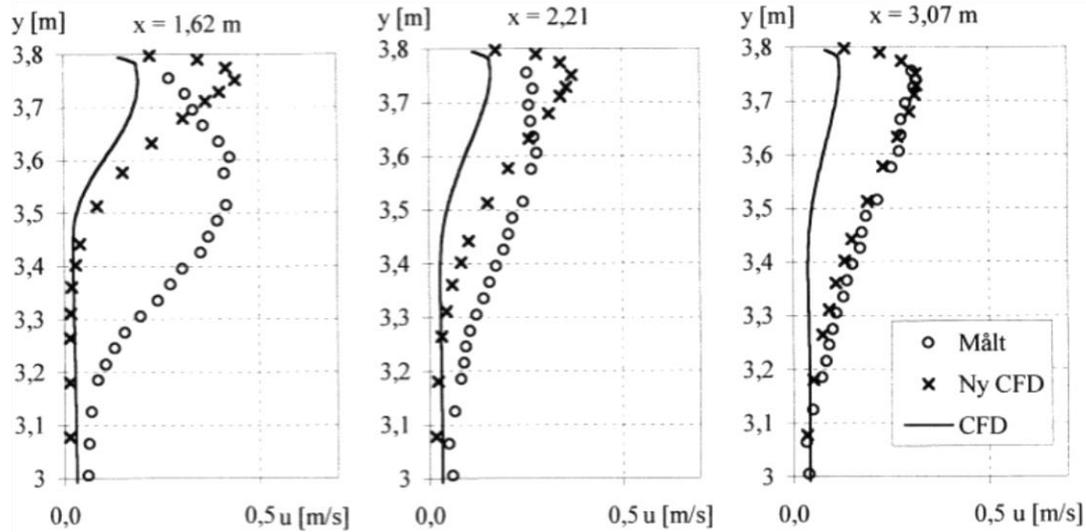
# One of the errors...



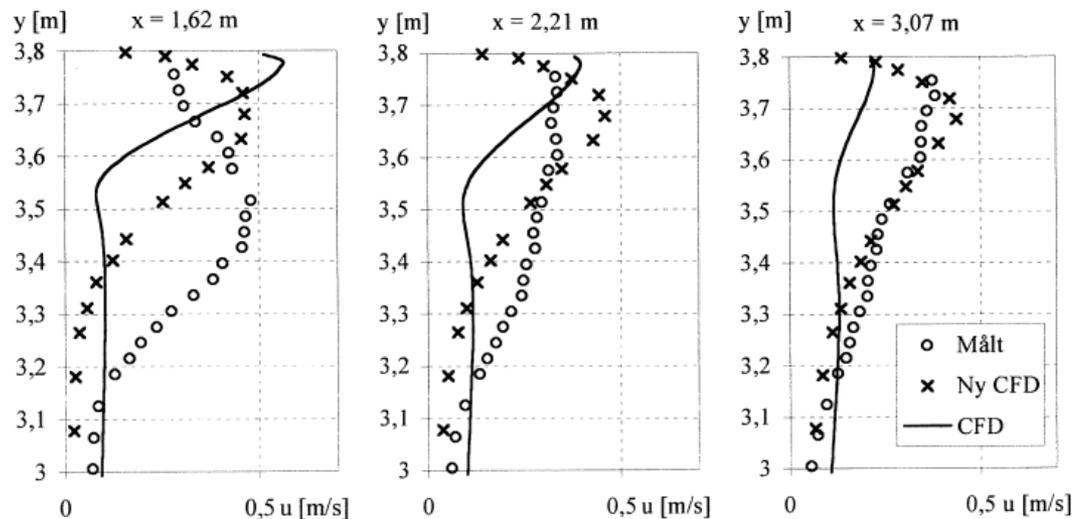
- E.g. for the 0.063m chain.
- CFD didn't comply with the "real world" (test room).
- + The CFD simulation of the wind speed wasn't 100% in line with the Smoke Test.

CFD was modified

# Modified CFD vs Smoke Test - window 1

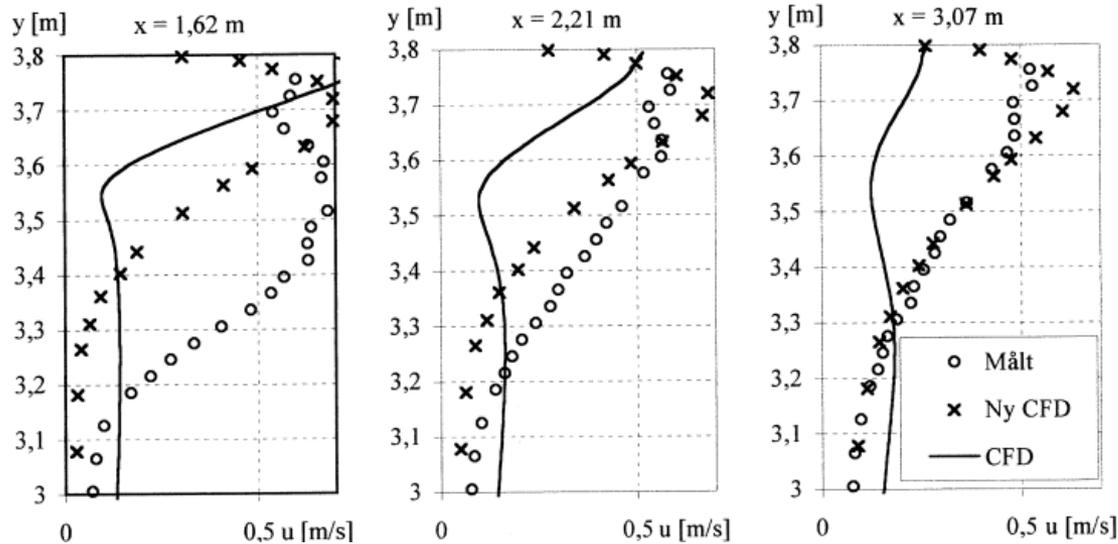


- Chain length 0.063m



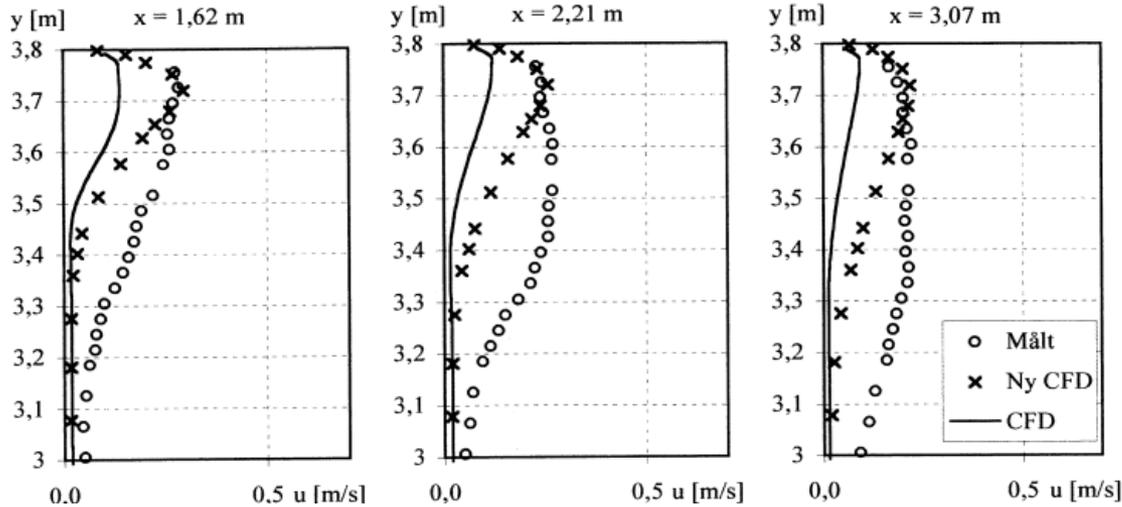
- Chain length 0.113

# Modified CFD vs Smoke Test - window 1

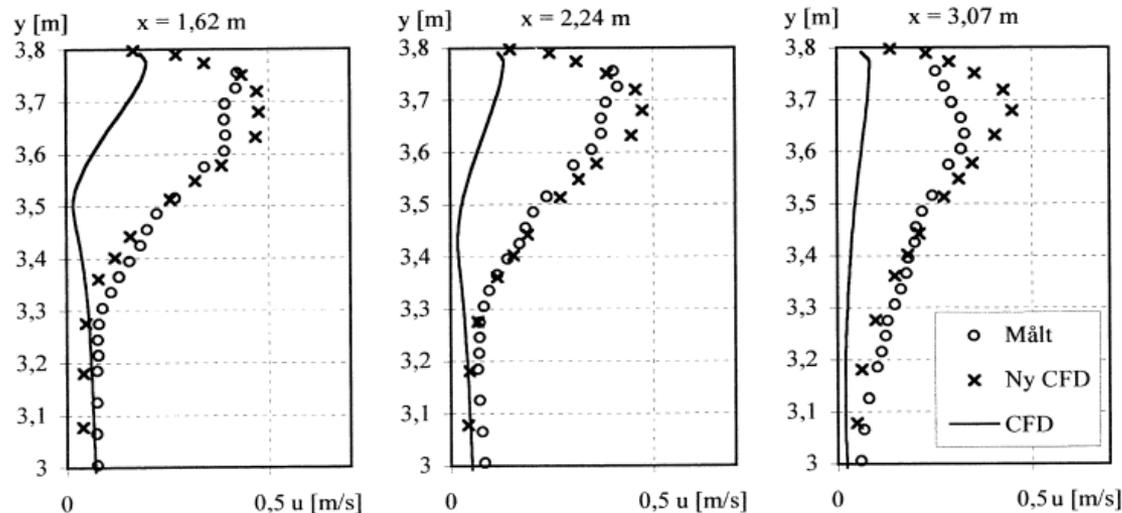


- Chain length 0.163m

# Modified CFD vs Smoke Test - window 2

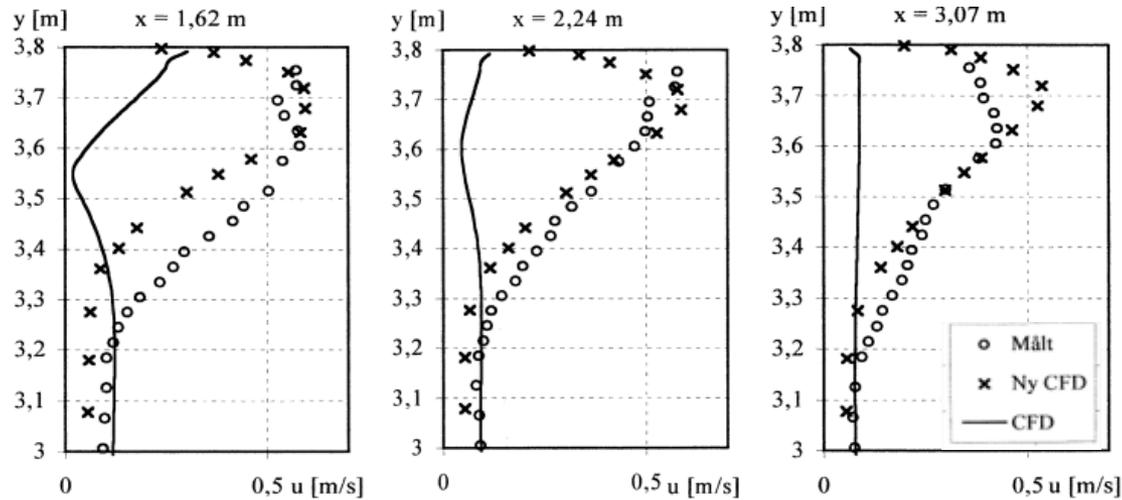


- Chain length 0.063m



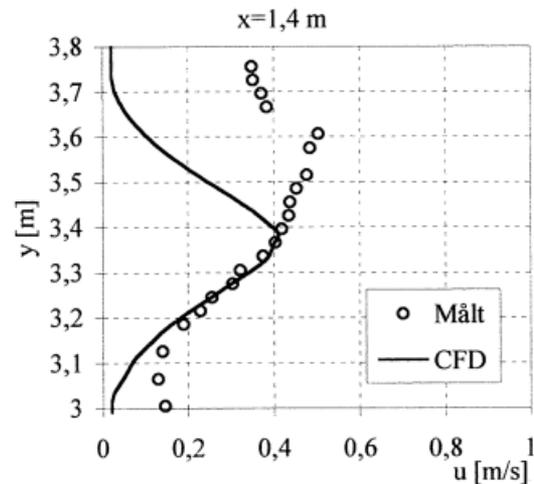
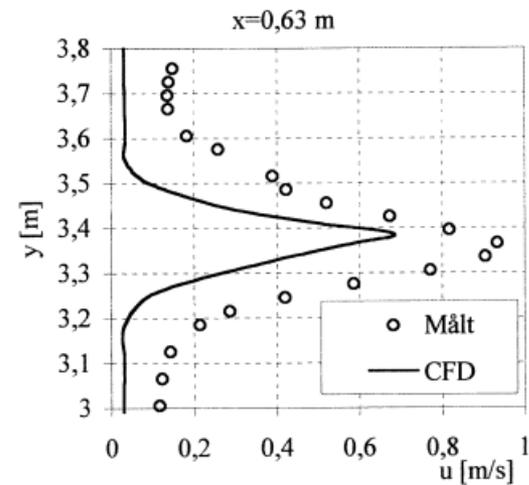
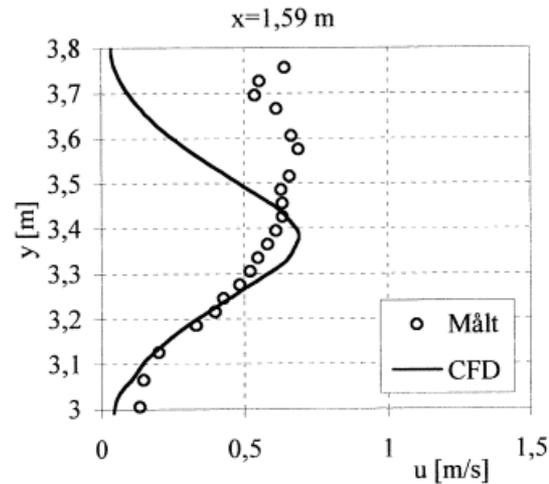
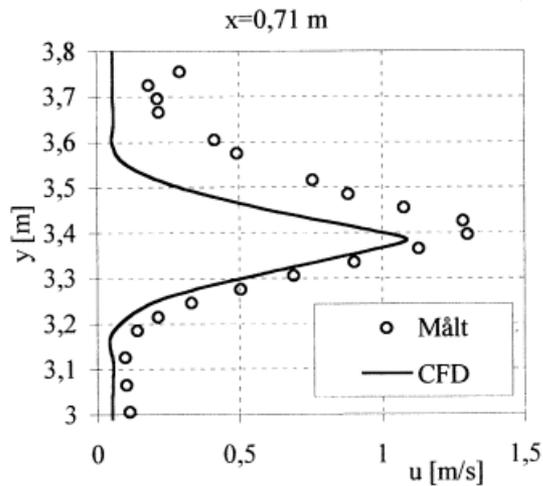
- Chain length 0.113

# Modified CFD vs Smoke Test - window 2



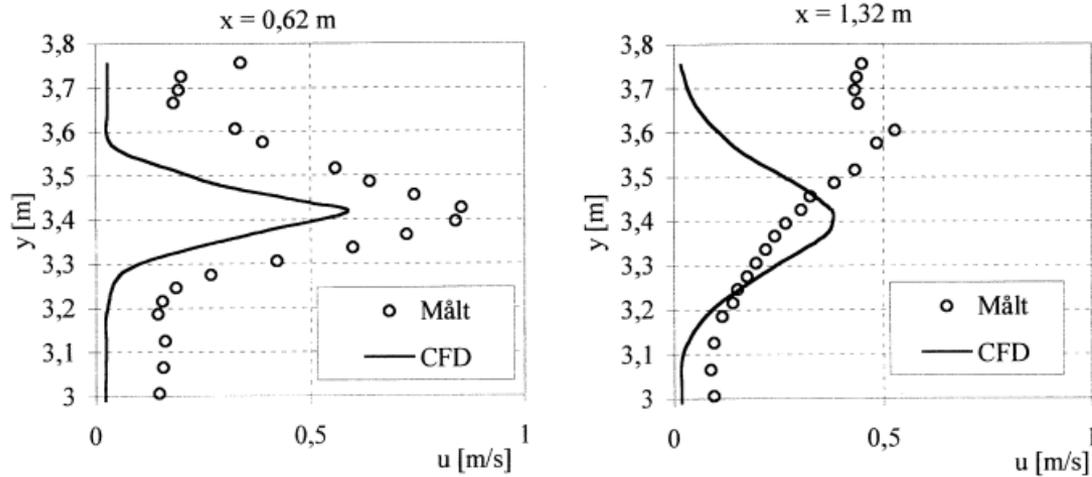
■ Chain length 0.163m

# Velocity profiles close to the ceiling



- Chain length 0.063m
  - @ 0.71m very good agreement
  - @ 1.59 CFD doesn't stick to the ceiling
  
- Chain length 0.113
  - Same conclusion as above

# Velocity profiles close to the ceiling



- Chain length 0.163m

# Conclusion

- The correlation between the CFD results and the Smoke Test was better after the modification.
- Not 100% in line but acceptable in most of the cases.
- The air stream close to the ceiling in the CFD didn't match the smoke test result perfectly. It didn't develop into a “wall air stream” as expected.

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