Comparison of experiments and numerical simulations of a high pressure water mist curtain as a radiation shield

Bjarne P. Husted
Jasper Ho
Daniel Martin

The Fire Safety Engineering Group at Lund University in Sweden

- 7 members of research staff and 17 PhD-students (6 internal and 11 industrial at the moment)
- More than 25 years of experience
  - One of the firsts universities to start FSE education in Europe

BSc. FSE	MSc. Risk Management	International Master of Science in FSE
• Responsible for education • ~50 students/year • Swedish program	• Course participation • 20-30 students/year • Swedish	• Erasmus mundus • University of Edinburgh and Ghent University • ~20 students/year • International background • English

LUND UNIVERSITY

Acknowledgement

- This presentation is largely build on two M.Sc. Thesis done at Lund University by Jasper Ho and by Daniel Martin (my co-authors)

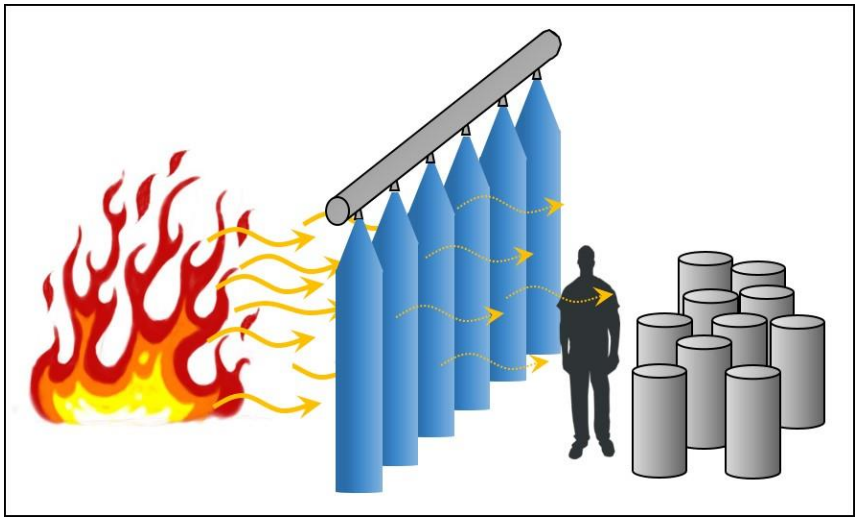
- Ho, J. (2015). Effect of water mist system on a controlled fire. (M.Sc. thesis M.Sc. thesis), Lund University, Lund. (Report 5498)
- Martin, D. A. (2015). *The Use of a Water Mist Curtain as a Radiation Shield.* (M.Sc. thesis M.Sc. thesis), Lund University, Lund. (Report 5497)
- Danfoss and Danfoss Semco for pump and pipework

LUND UNIVERSITY

Contents

Potential uses of a water mist curtain shield

- Protect operational control rooms
- Protecting high value targets from radiation exposure
- Prevent fire spread; i.e. compartmentation



LUND UNIVERSITY

Objectives of the research

- Measure the radiation attenuation through a high pressure low flow rate single nozzle water mist curtain
- Find the different radiation attenuation levels based on:
  - The vertical position within the water mist column
  - Vertical plane angle of the heat flux gauge
  - Radiation source

LUND UNIVERSITY

Previous experimental research

- Nozzle sizes tested:
  - Firefighting nozzles, sprinkler heads, and water mist heads
- Pressures and nozzle flow rate:
  - 0.076 - 10 bars
  - 0.12 – 4.7 L/min (mist), 360 – 1363 L/min (fire nozzle)
- Sources of radiation:
  - Gas radiant panel, liquid pool fire, wood crib fire, Fourier Spectrometer
- $D_v0.5$ sizes:
  - Varied by location in the spray column and the nozzle (24 – 550+ µm)
- 10-70% attenuation

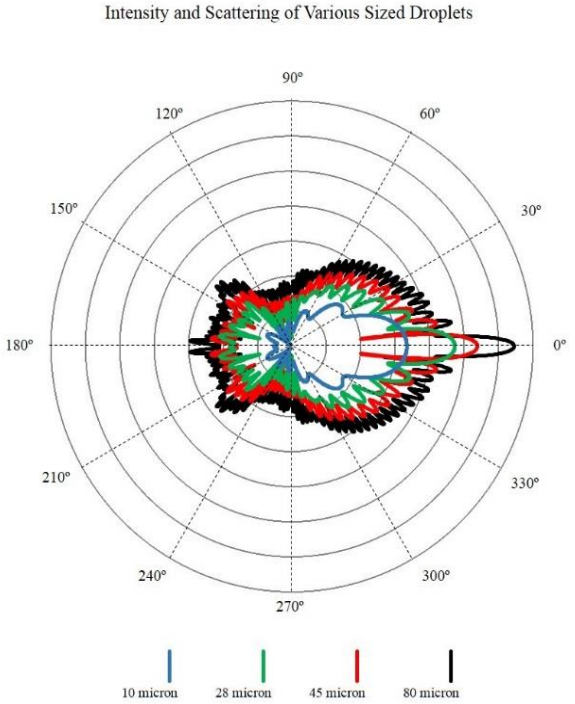
LUND UNIVERSITY

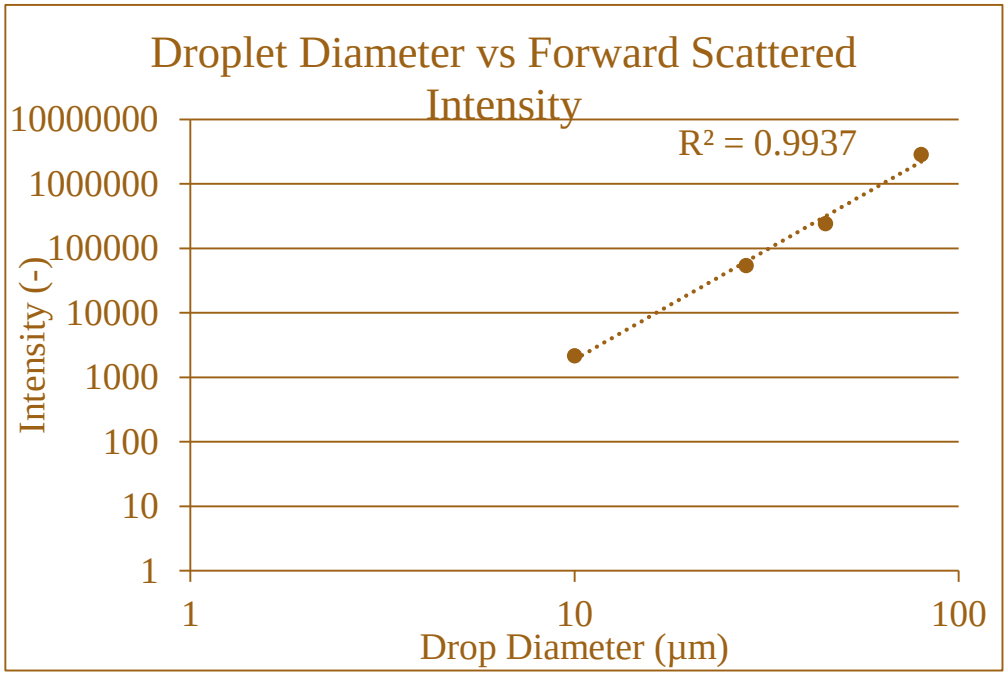
Theoretical Mie scattering

- Simplified method for solving the complex radiation transfer equation
- Physics approach to solving the scattering and extinction of an electromagnetic wave hitting a spherical particle
- MiePlot (a program by Phillip Laven)
  - Single source point, scattering analysis of a single droplet
  - Input: wavelength, droplet size/distribution, refractive indices
  - Outputs: several options but Intensity vs Scattering Angle of greatest interest

LUND UNIVERSITY

Theoretical Mie scattering for a single droplet

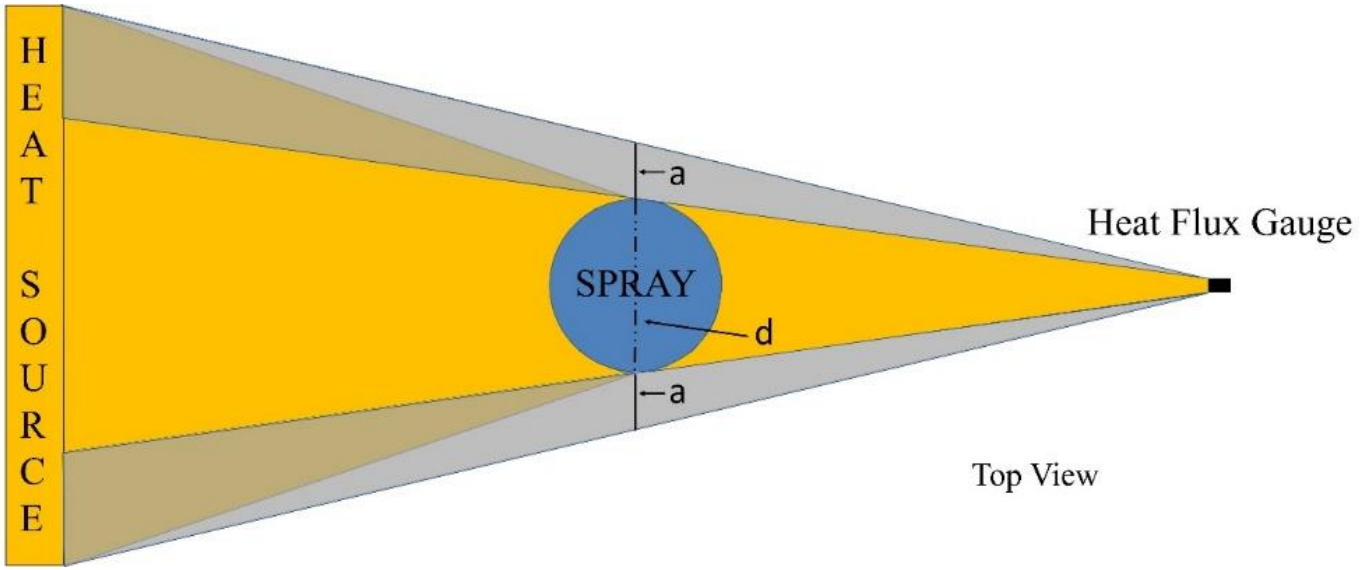




LUND UNIVERSITY

Attenuation calculation

$$Attenuation = 1 - \frac{Measured\ radiation\ \boldsymbol{with}\ water\ mist}{Measured\ radiation\ \boldsymbol{without}\ water\ mist}$$



LUND UNIVERSITY

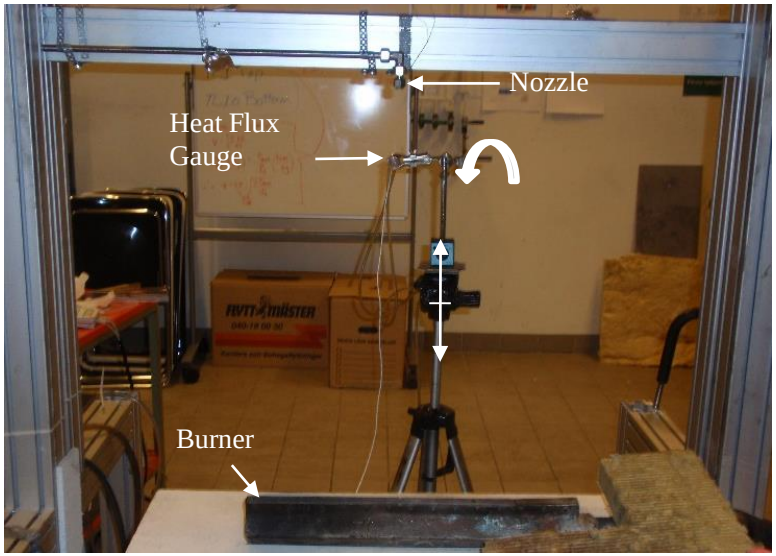
Experimental setup

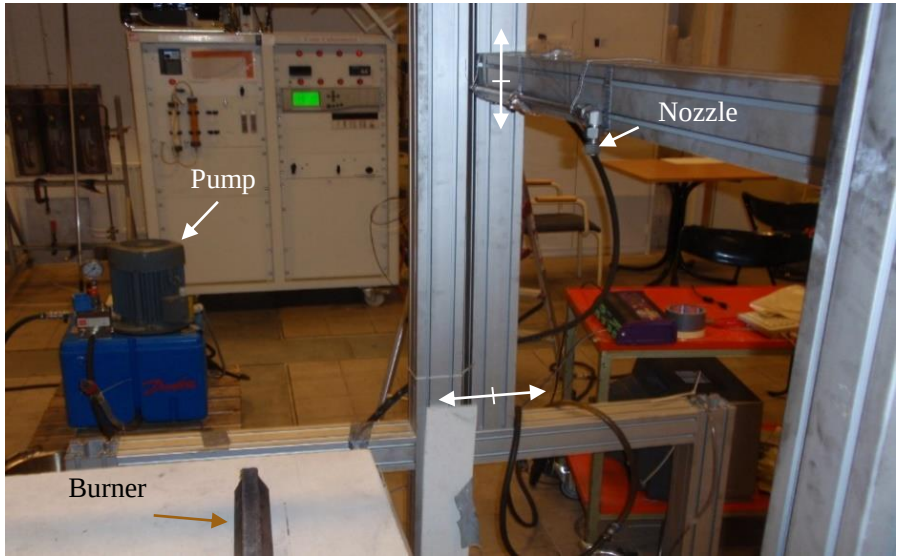
- Danfoss Water Mist System
  - Power Pack PPH 6.3 with a piston pump (4 L/min)
  - Single nozzle: 1910 Hollow Cone Nozzle (0.42 L/min)
  - Operating pressure: 100 Bars
  - Single fluid spray

https://stateofgreen.com/en/profiles/danfoss/solutions/fire-suppression-with-water-mist-in-microbiological-laboratory

LUND UNIVERSITY

Experimental setup

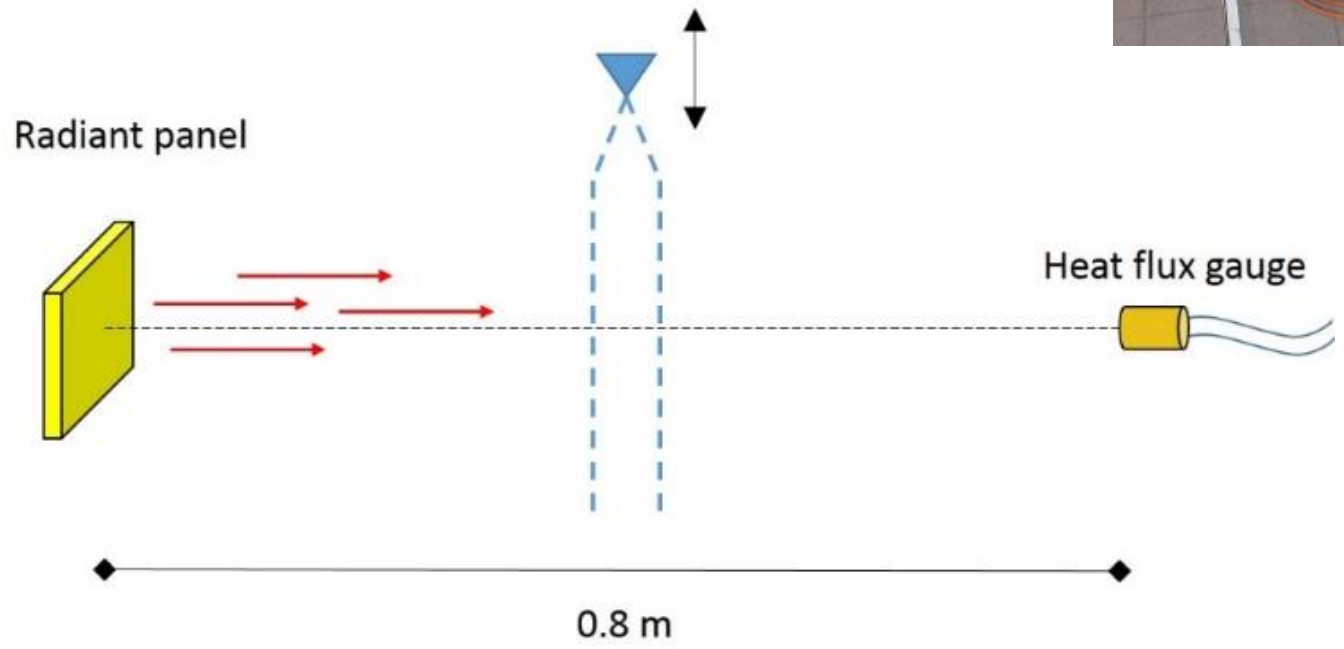




LUND UNIVERSITY

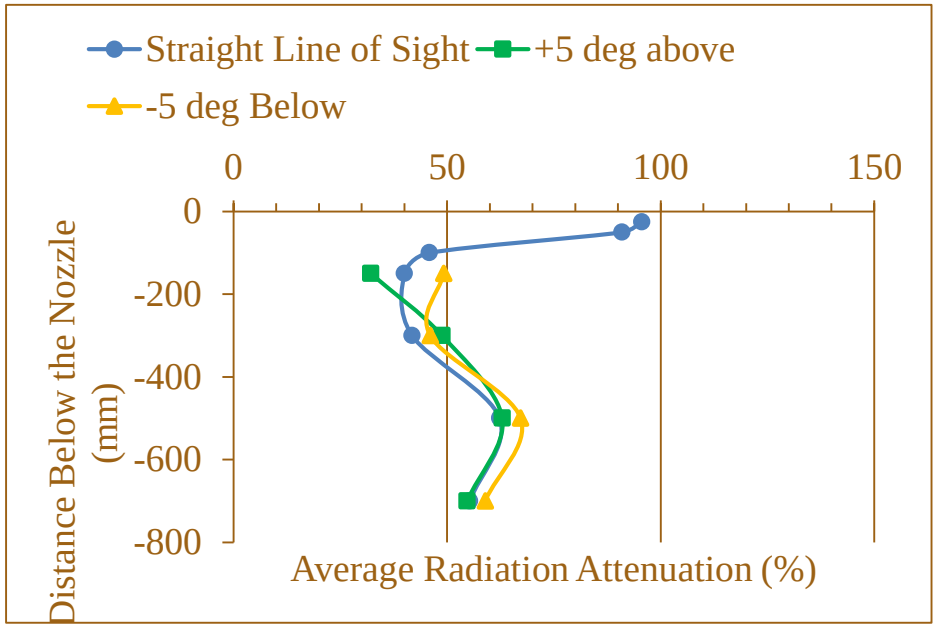
Experimental setup

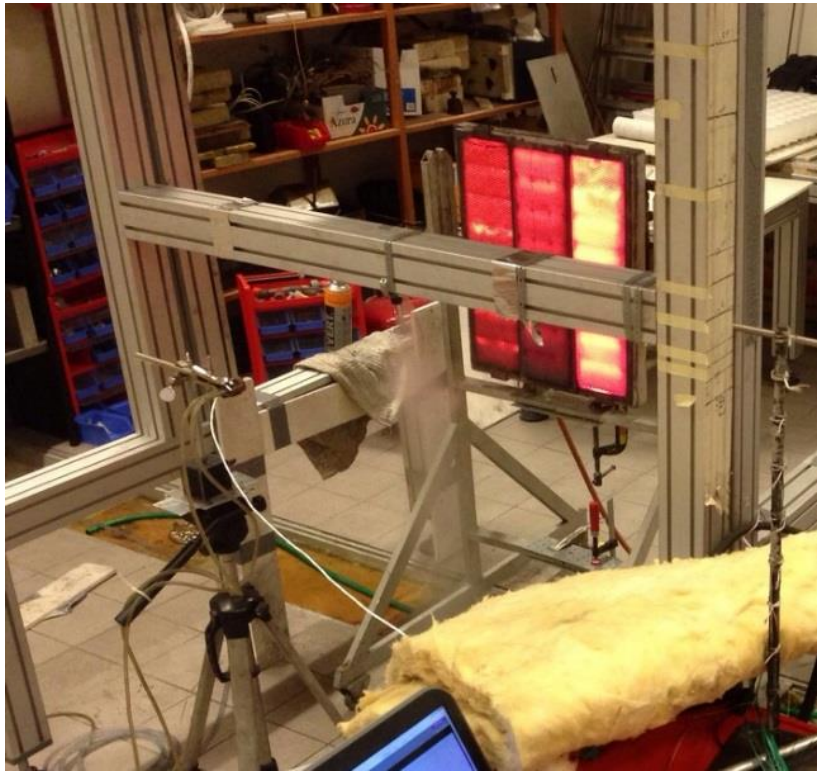
3 burner propane radiant panel: 39 x 47 cm



LUND UNIVERSITY

Results (radiant panel)

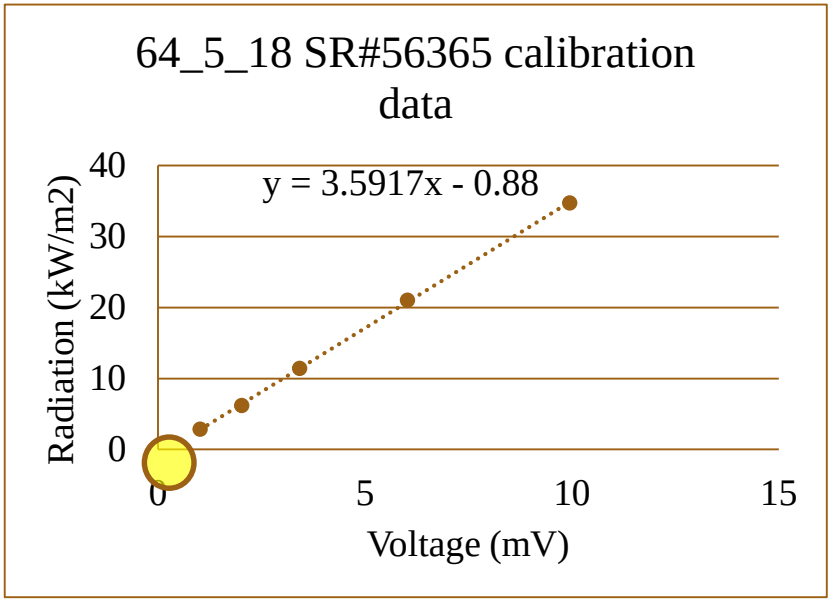




LUND UNIVERSITY

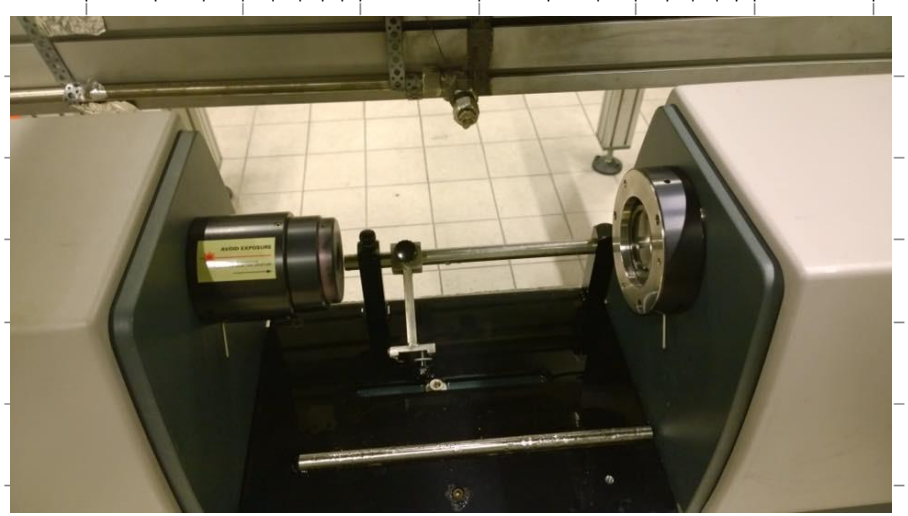
Uncertainties affecting the experimental results

- Misalignment between the heat source, centerline of the spray, and the heat flux gauge
- Radiation levels measured fall below the known calibration curve of the heat flux gauge
- Equipment reading uncertainties
- Water mist/heat source interaction



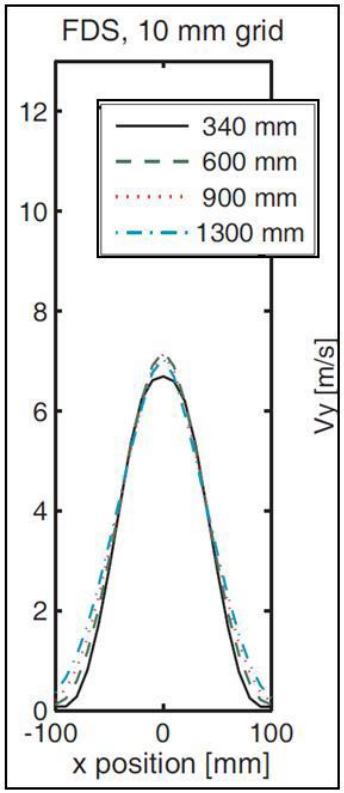
LUND UNIVERSITY

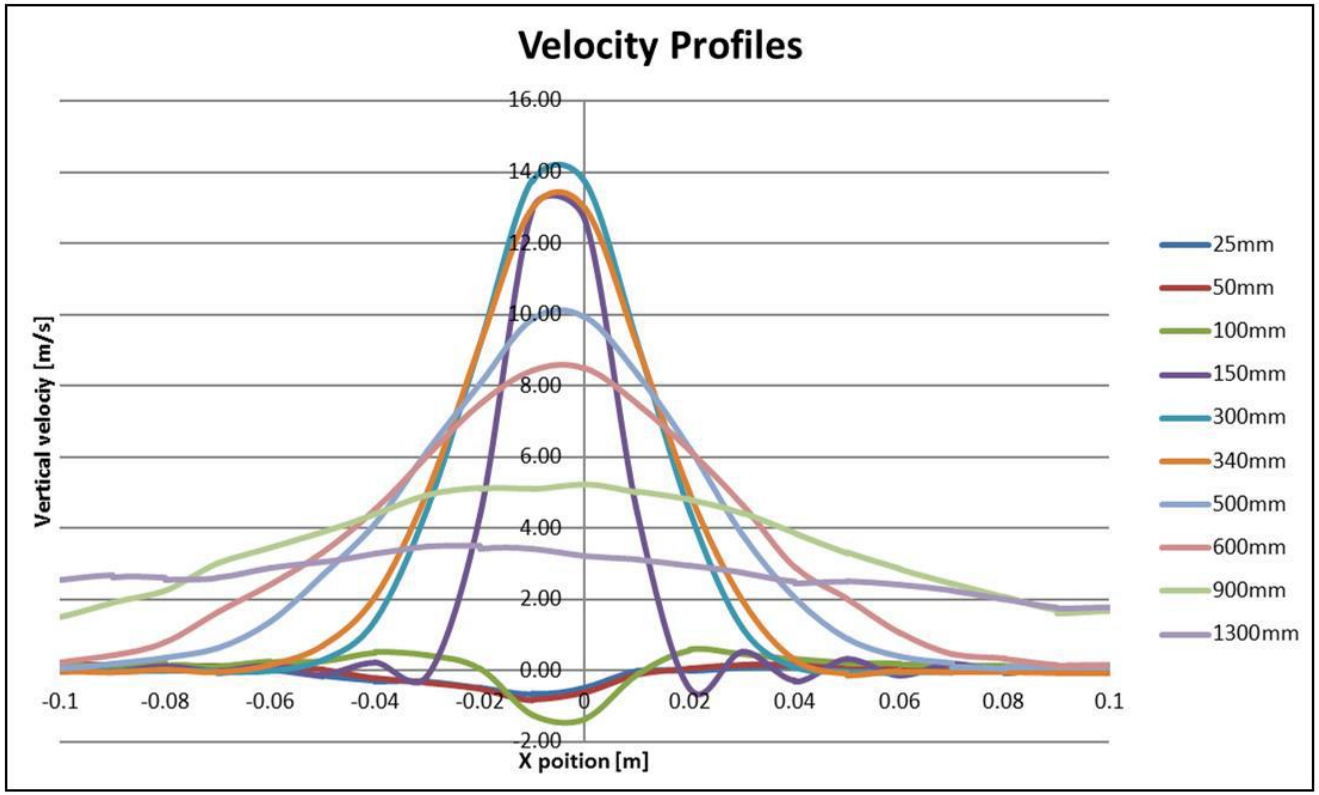
Malvern to verify previous experiments with Phase Doppler Anemometry (PDA)



LUND UNIVERSITY

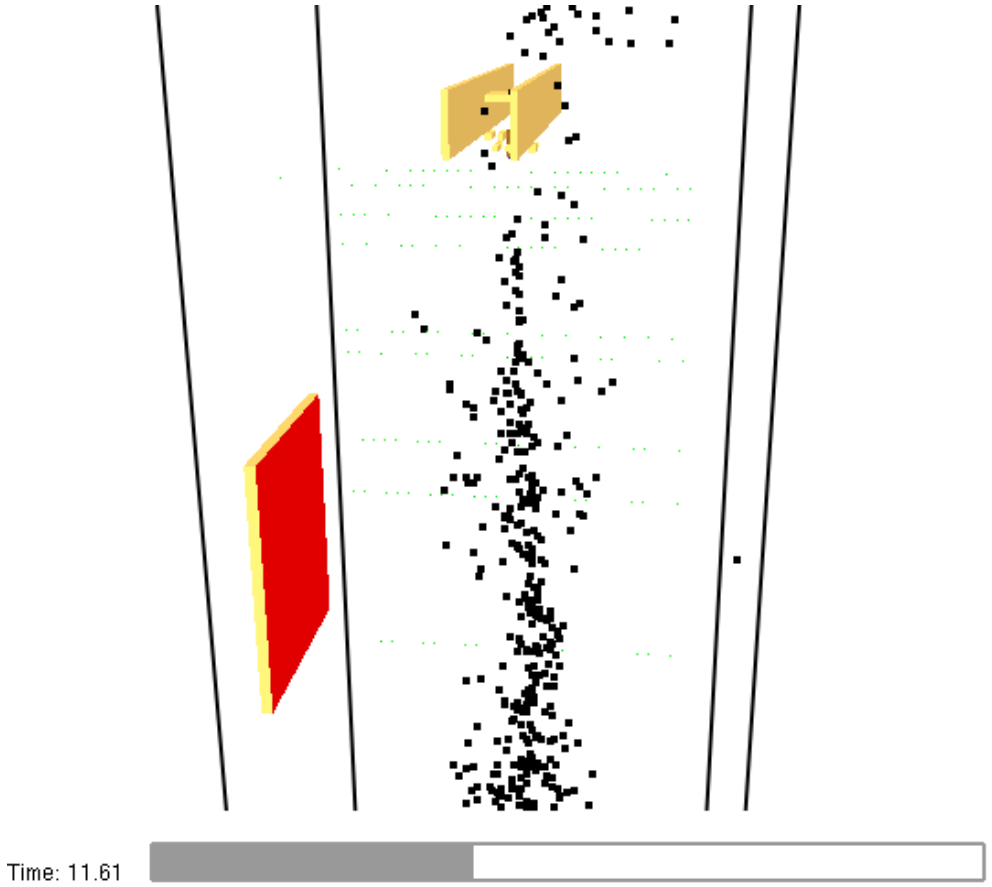
Previous simulation (Husted 2007) FDS 4.07





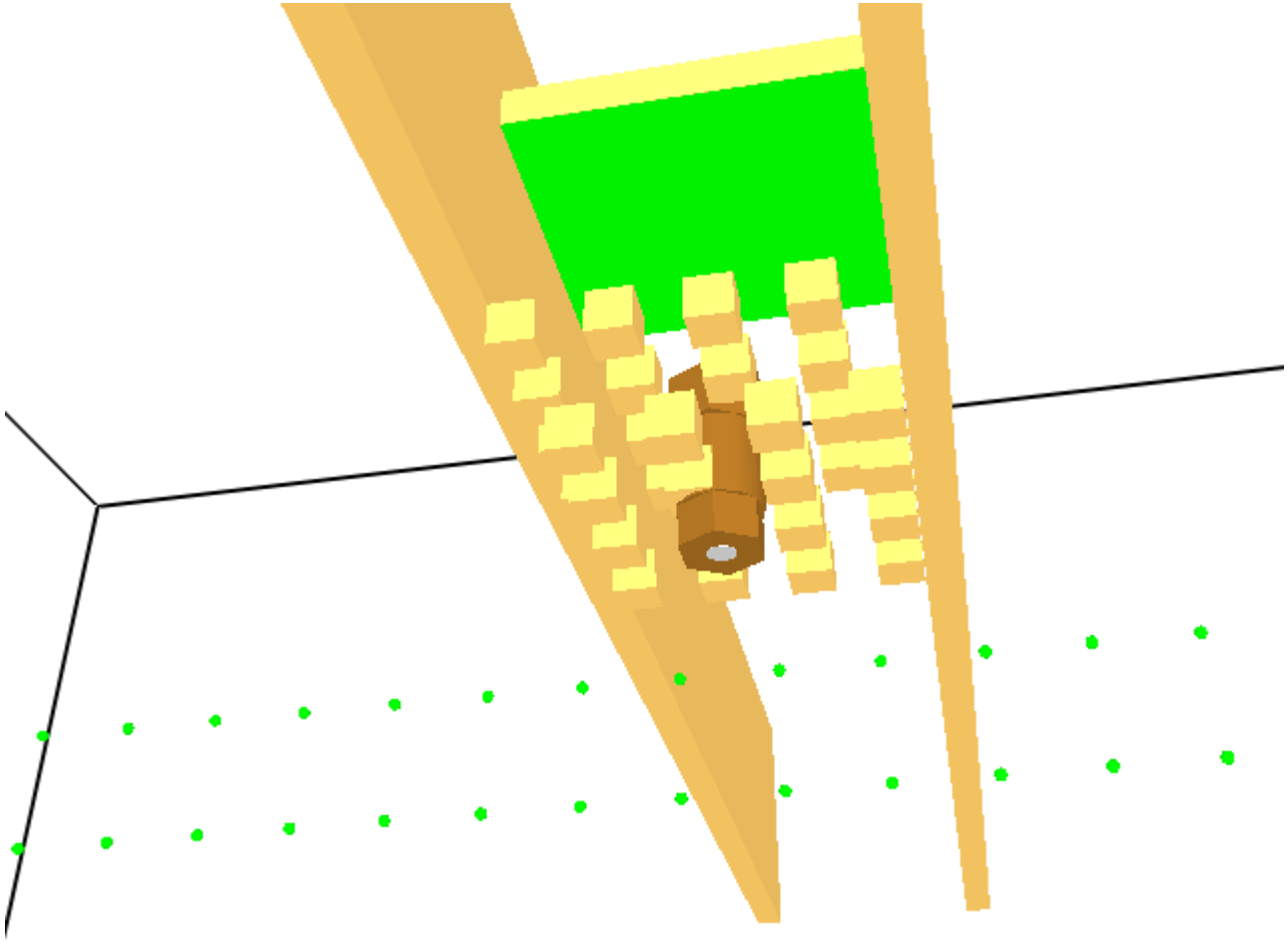
LUND UNIVERSITY

Simulation setup (FDS 6.2 and 6.3)



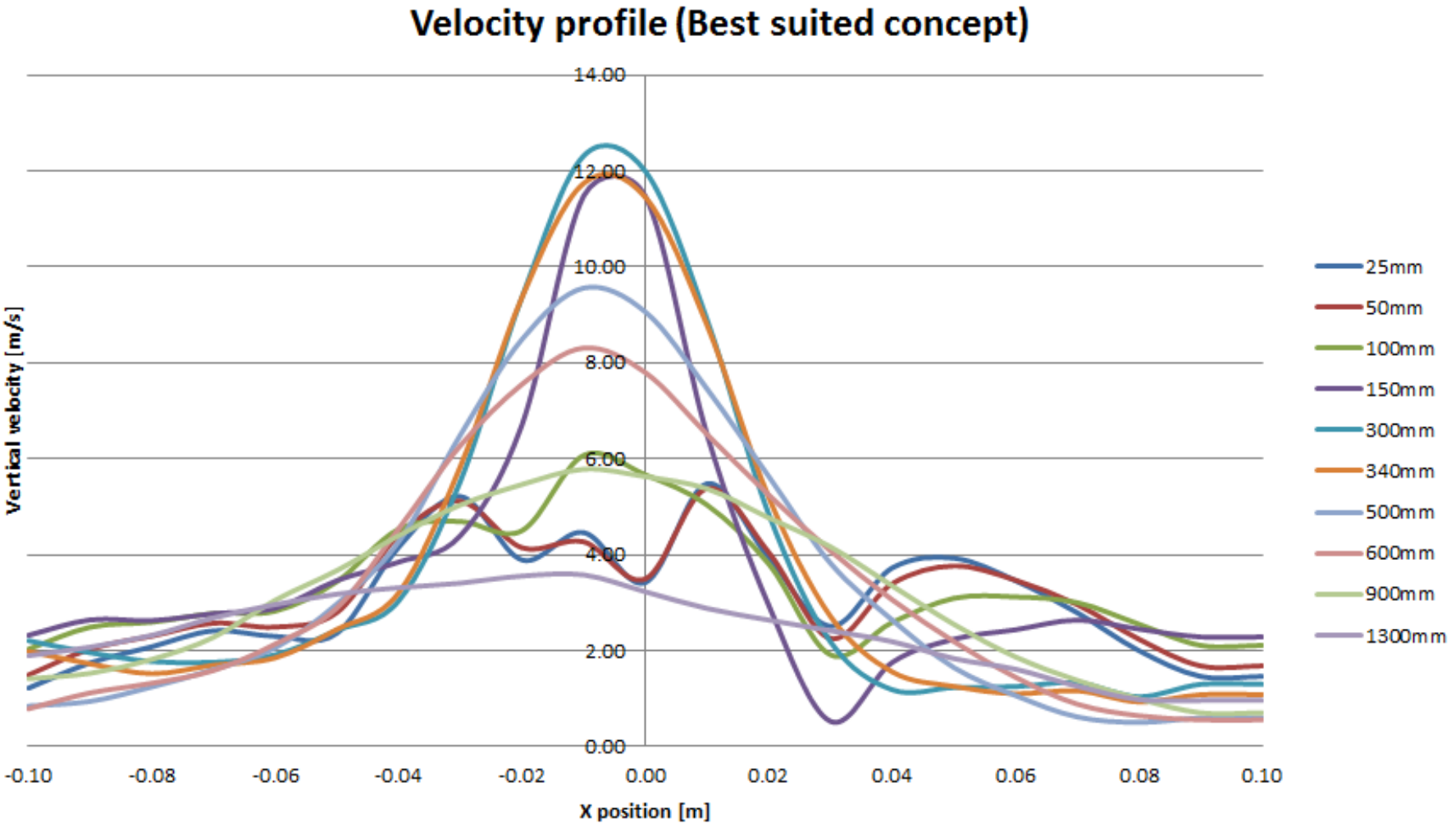
LUND UNIVERSITY

Modelling of spray

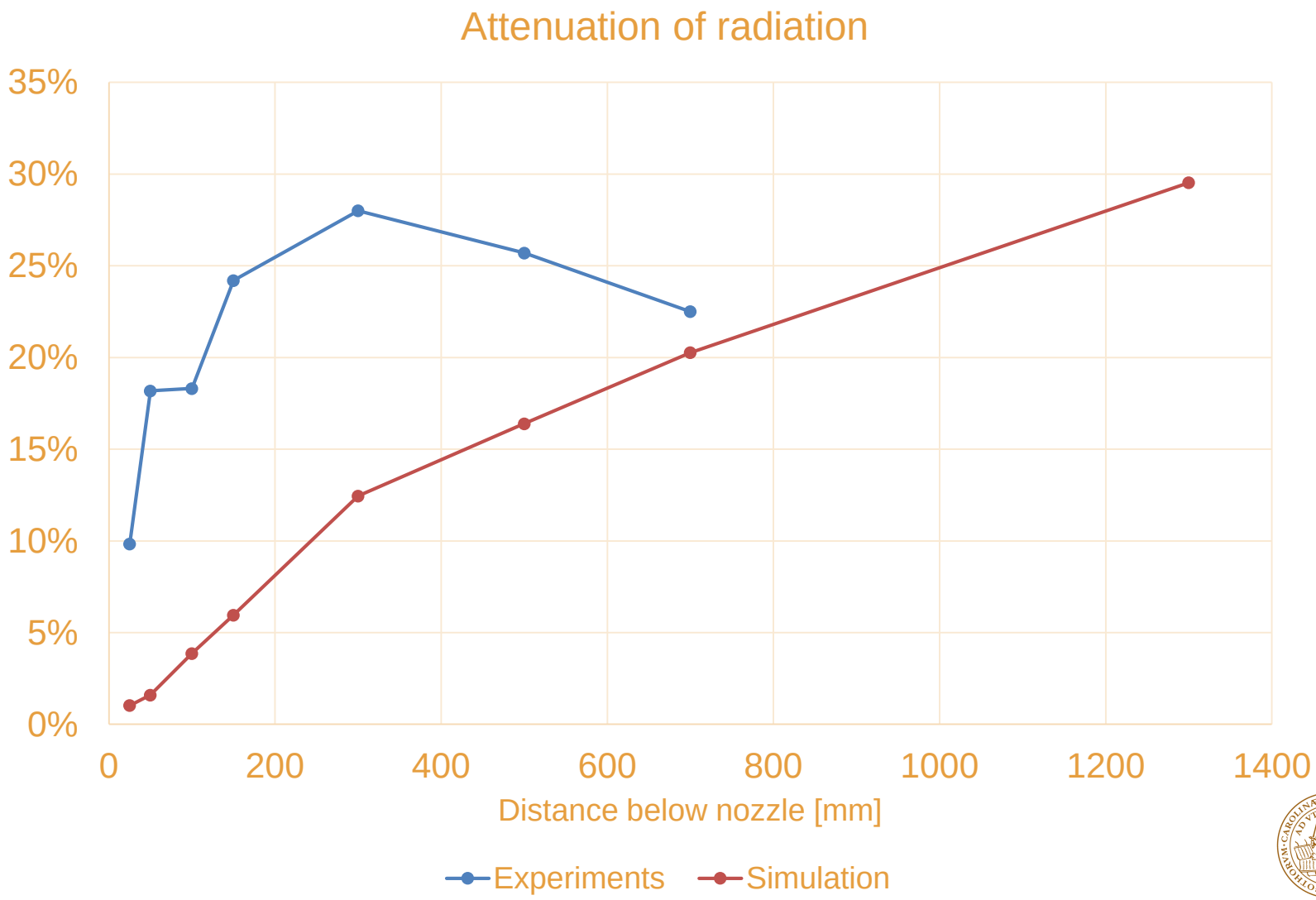


LUND UNIVERSITY

Velocity profile



Results



LUND UNIVERSITY

Sensitivity of simulation results

- Version of FDS
- Parameter for MIE scattering calculation

	Number of Mie angles	Attenuation
Experiment (700 mm)	-	23%
FDS 6.2.0	15	20%
FDS 6.3.0	15	20%
FDS 6.2.0	30	12%
FDS 6.3.0	30	11%

LUND UNIVERSITY

Future work

- Integration of multiple nozzles
- Larger diffusion flame to increase separation distances
- Various nozzle orientations
- Incorporating various nozzle types

LUND UNIVERSITY

LUND
UNIVERSITY