Business from technology

Water Mist Spray Modeling With FDS

Fire and Evacuation Modeling Technical Conference 2011

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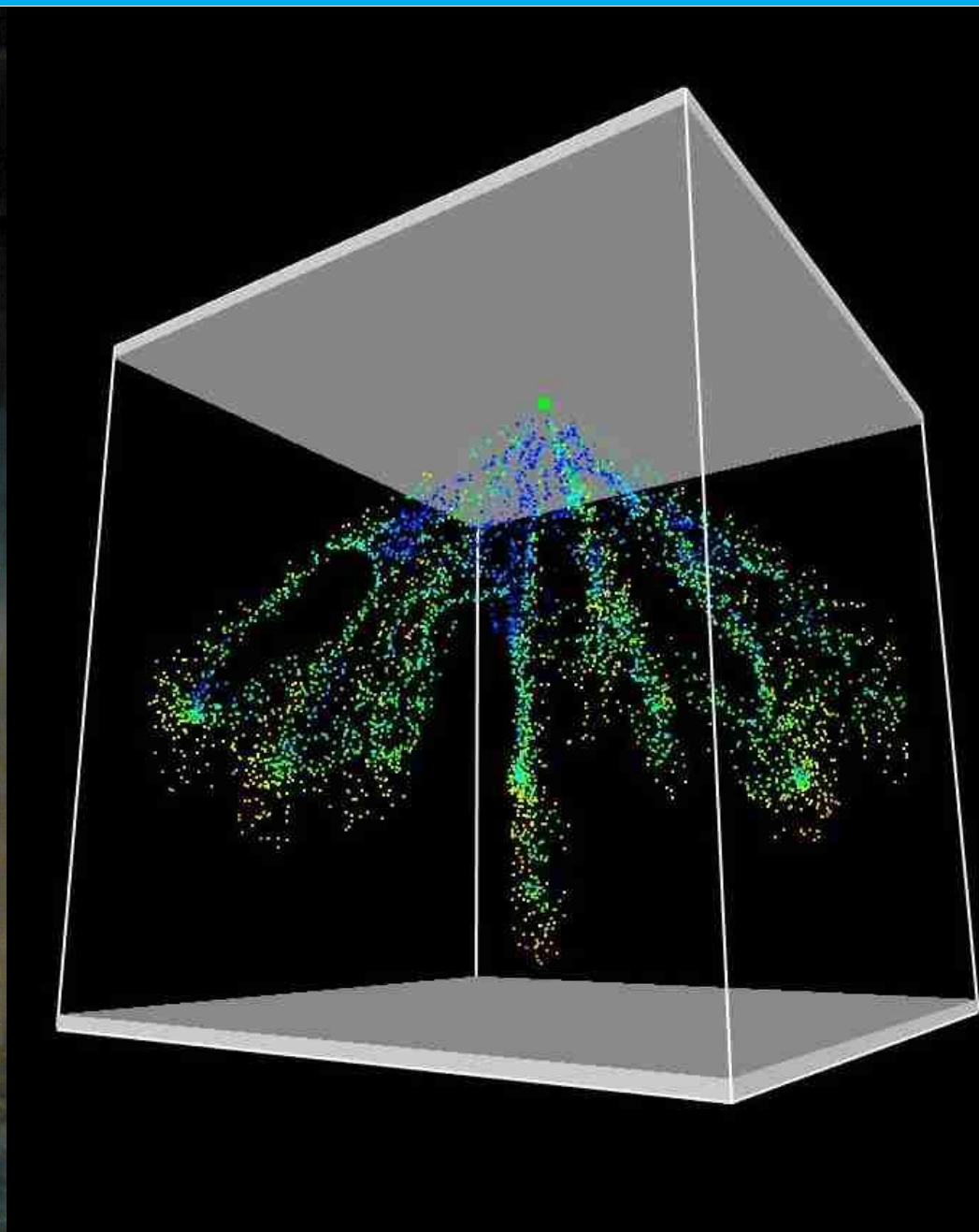
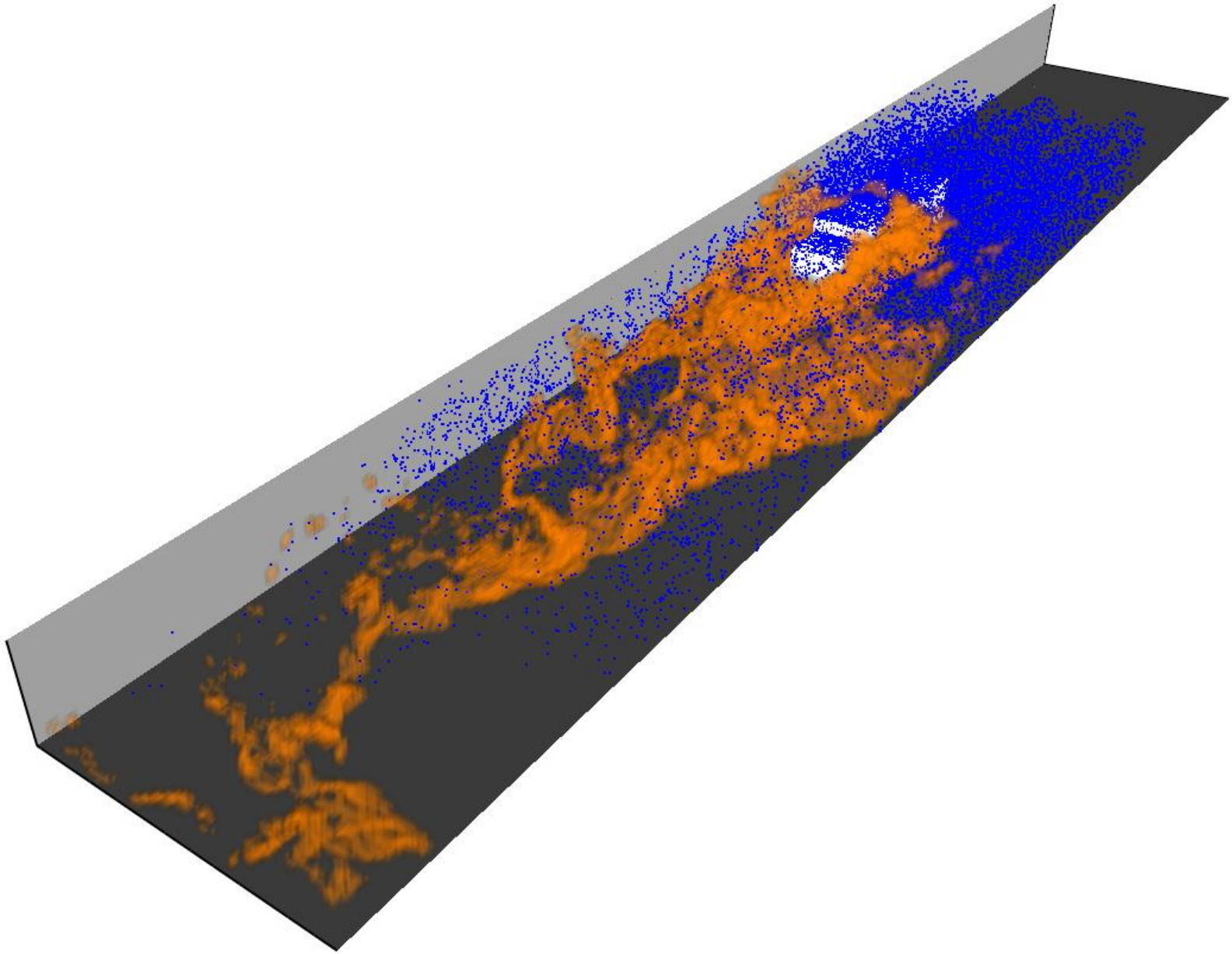
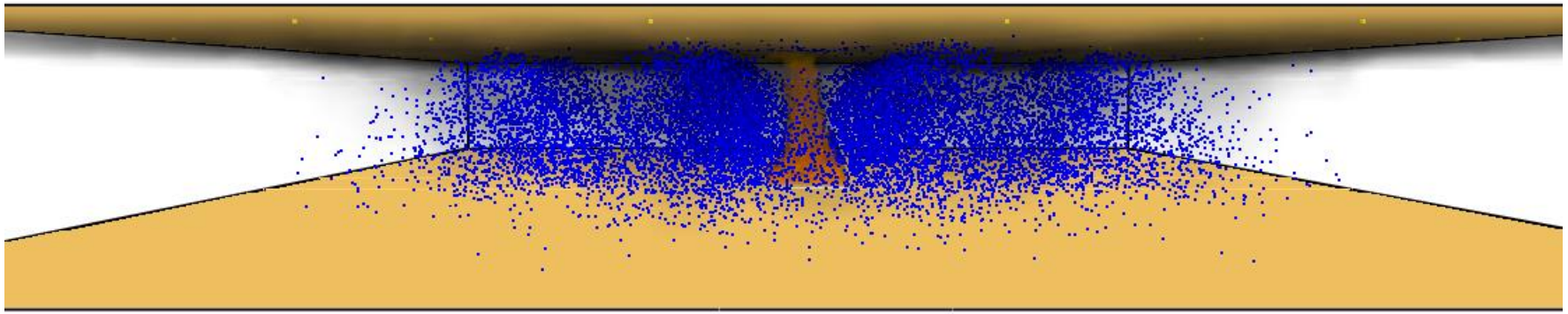
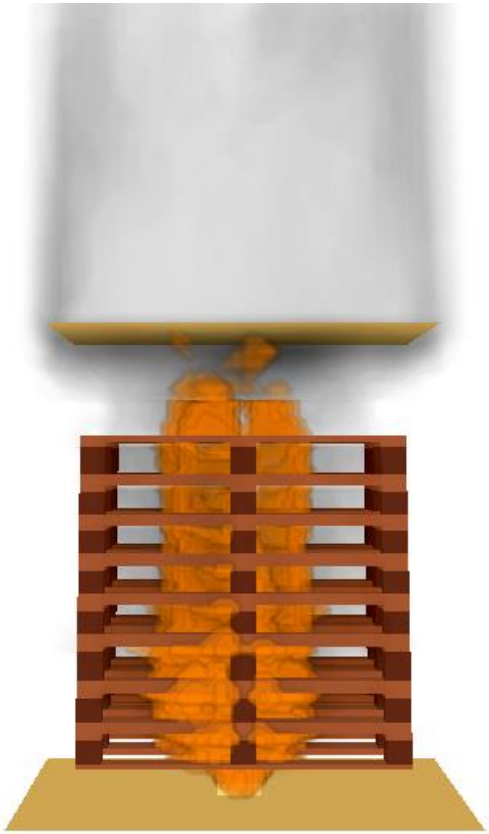
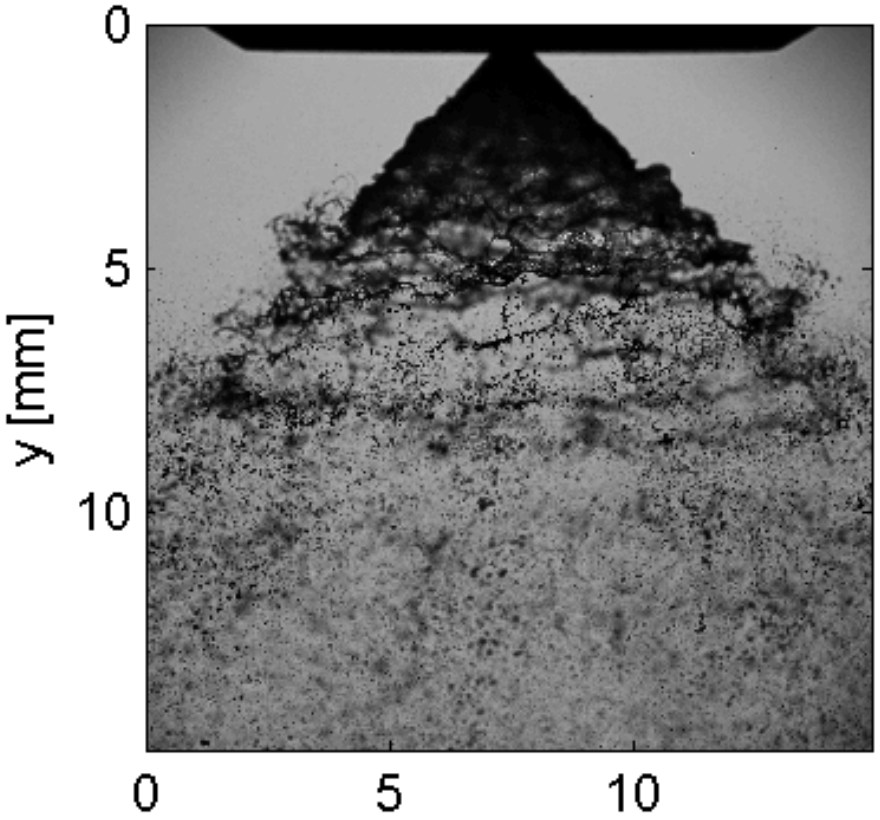






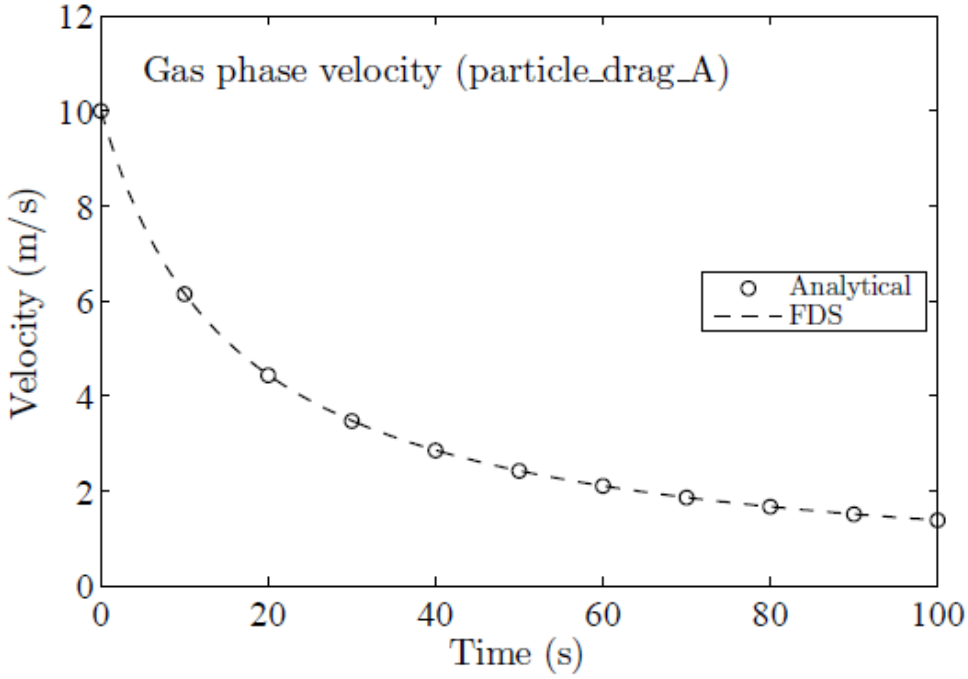



0
5
10
y [mm]
0
5
10

SPRAY COMPUTATIONS IN FDS

Droplet momentum

$$\frac{dm_d\mathbf{u}}{dt} = m_d\mathbf{g} - \frac{1}{2}\rho_g C_D \pi r_d^2 \|\mathbf{u}_{rel}\|\mathbf{u}_{rel}$$



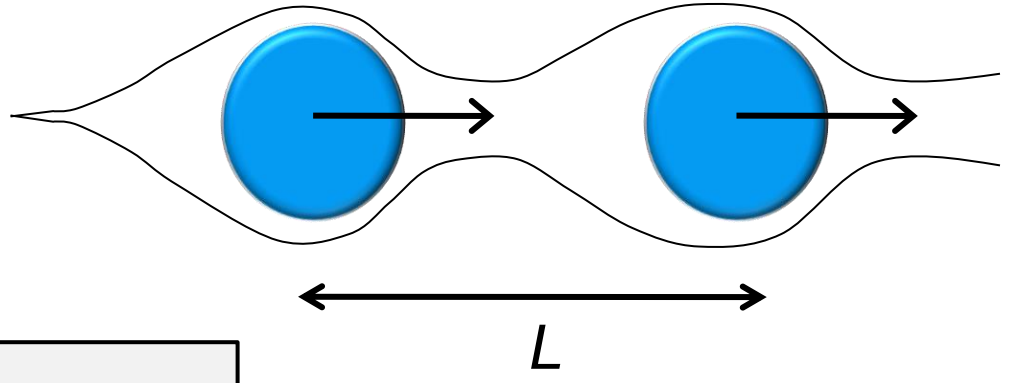
Size distribution

$$F(d) = \begin{cases} \frac{1}{\sqrt{2\pi}} \int_0^d \frac{1}{\sigma d'} e^{-\frac{[\ln(d'/d_m)]^2}{2\sigma^2}} dd' & d \le d_m \\ 1 - e^{-0.693\left(\frac{d}{d_m}\right)^\gamma} & d_m < d \end{cases}$$

$$u = \frac{u_0}{1 + Bu_0 t} \; ; \; B = \frac{1}{2}\frac{\sum C_D \pi r_d^2}{V}$$

DRAG REDUCTION BY WAKE EFFECT

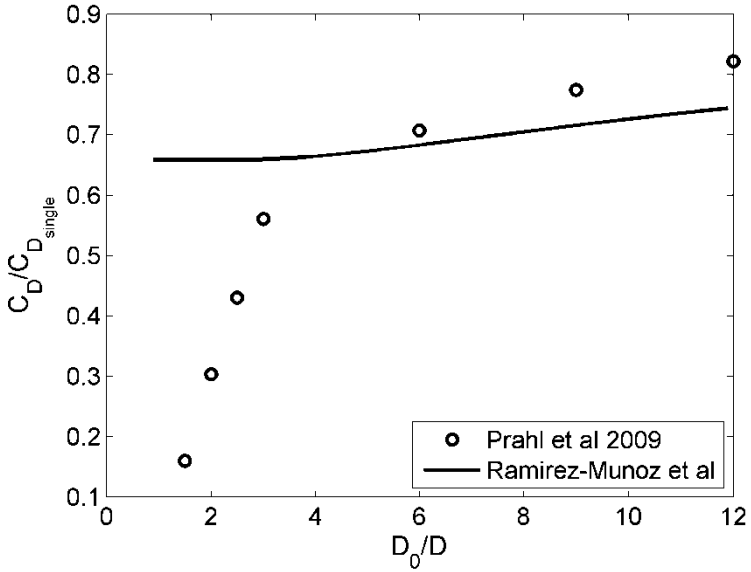
$$C_D = \frac{F}{F_0} C_{D0}$$



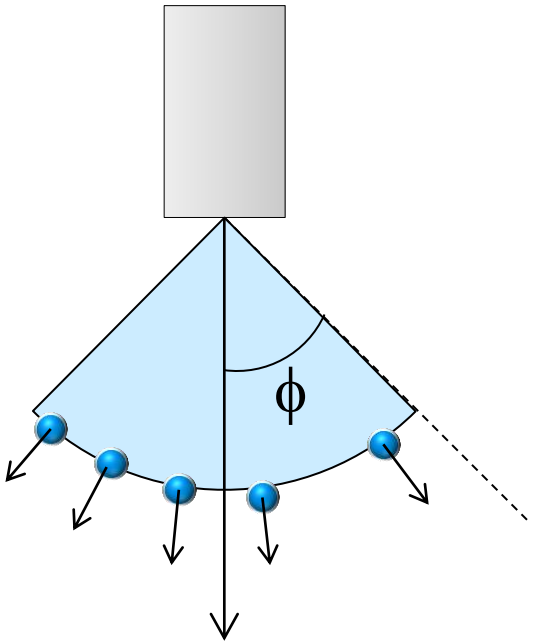
Ramírez-Mũnoz et al. (2007).

$$\frac{F}{F_0} = W\left[1 + \frac{\mathrm{Re}_1}{16}\frac{1}{\left(L/d_d - \frac{1}{2}\right)^2}\exp\left(-\frac{\mathrm{Re}_1}{16}\frac{1}{\left(L/d_d - \frac{1}{2}\right)}\right)\right]$$

$$W = 1 - \frac{C_{D0}}{2}\left[1 - \exp\left(-\frac{\mathrm{Re}_1}{16}\frac{1}{\left(L/d_d - \frac{1}{2}\right)}\right)\right]$$



INTRODUCING THE DROPLETS INTO THE COMPUTATION



- Segment of a spherical surface

$$P_\phi = f(\phi)\sin\phi$$

$$f(\phi) = \exp\left[-\beta(\mu - x)^2\right] \quad , x = \frac{\phi_{\max} - \phi}{\phi_{\max} - \phi_{\min}}$$

- Here: $\beta = 5$ and $\mu = 0$
- Initial velocity: $v_{d,0} = C\sqrt{2\Delta P / \rho_d}$
- User specifies the offset distance

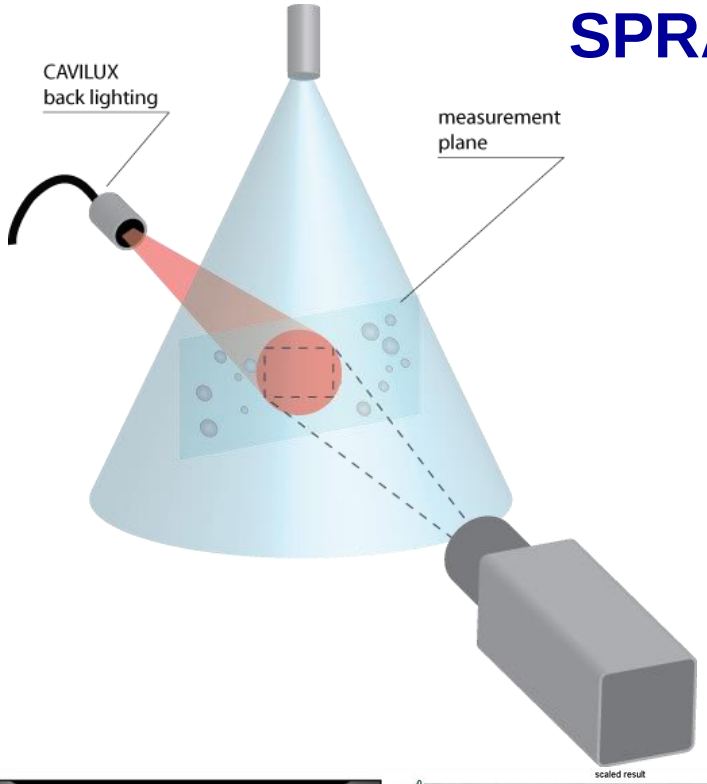
EXAMPLE NOZZLES

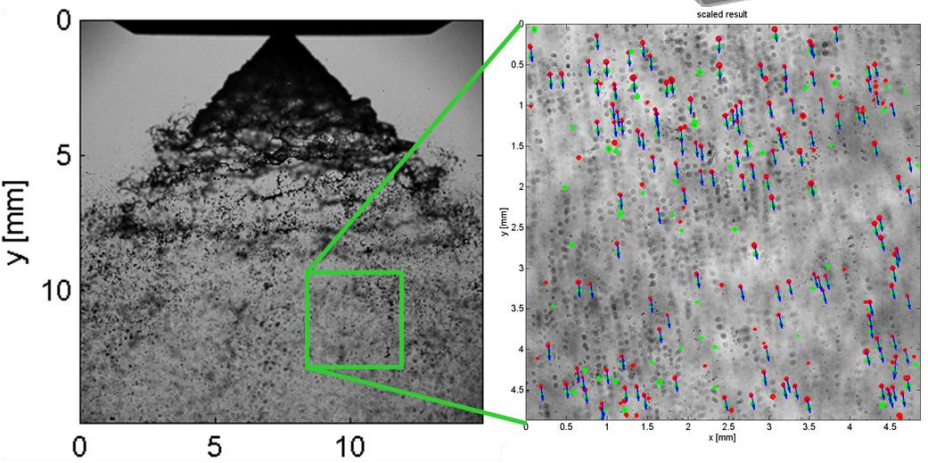
- Spraying systems LN-2
- High-pressure micro-nozzles A, B and C from Marioff.
- Multi-orifice spray heads

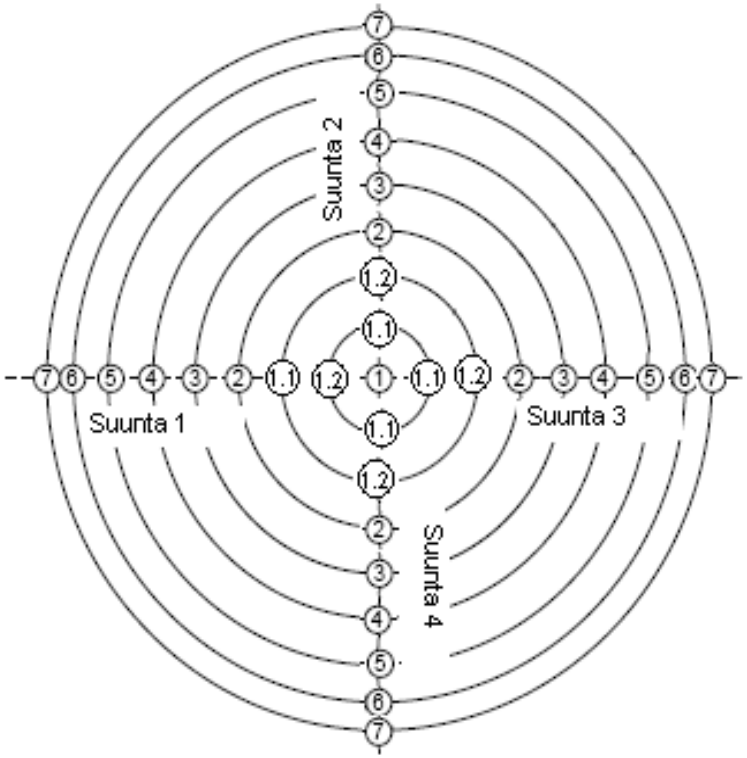
nozzle	K (l/min/bar^{½})	ϕ (deg)	d_m (µm)	γ	σ
LN-2	0.347	38	72	2.1	
A	0.2	10	83	2.9	0.4
B	0.433	12	79	2.26	0.5
C	0.767	14	102	2.59	0.52

	SH1	SH2	SH3	SH4	SH5
Centre nozzle	A	C	B	B	B
Perimeter nozzle	A	B	A	B	B
Number of perimeter nozzles	6	6	8	8	8
Perimeter angle (deg)	60	60	45	45	30

SPRAY PROFILE TESTS

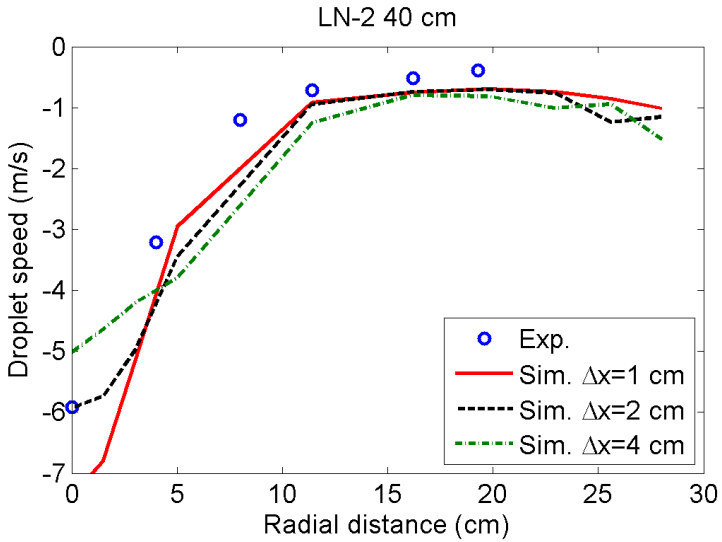


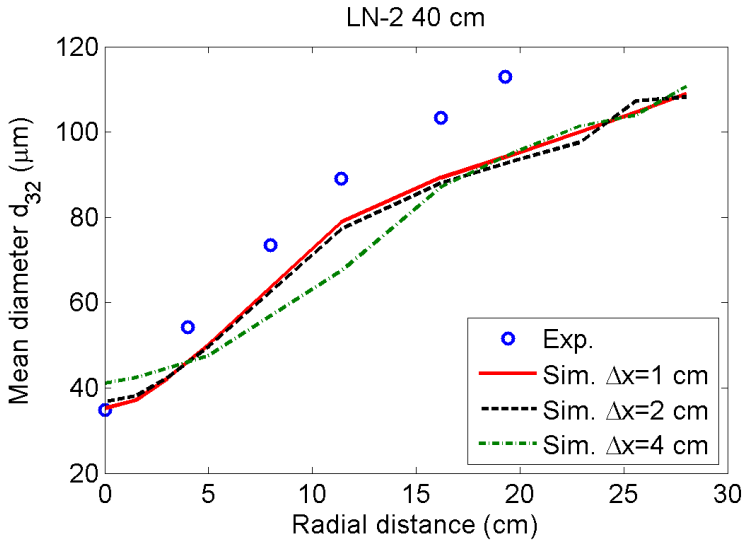


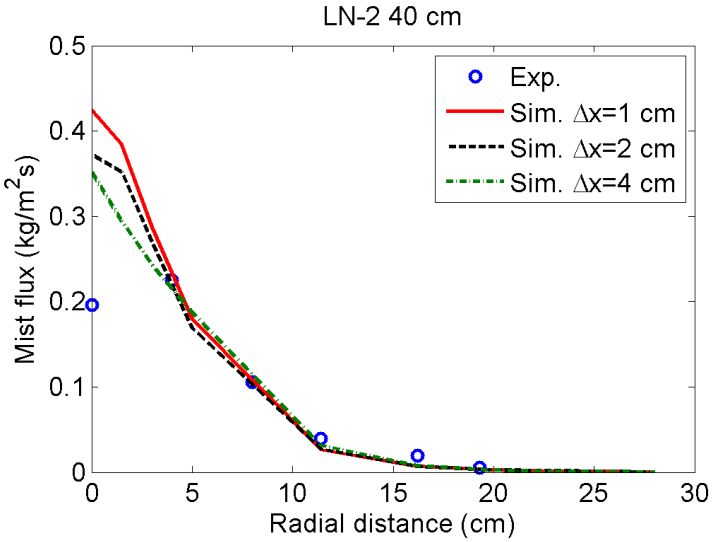


NFPA 750

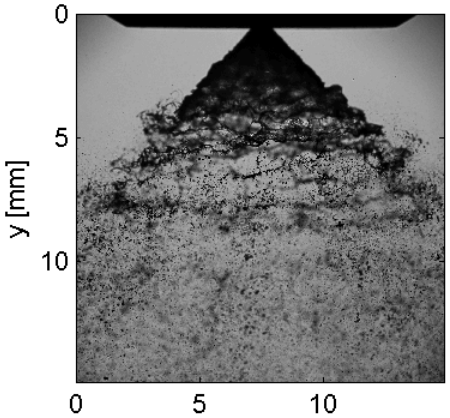
RESULTS: SPRAY PROFILES (LN-2 NOZZLE)



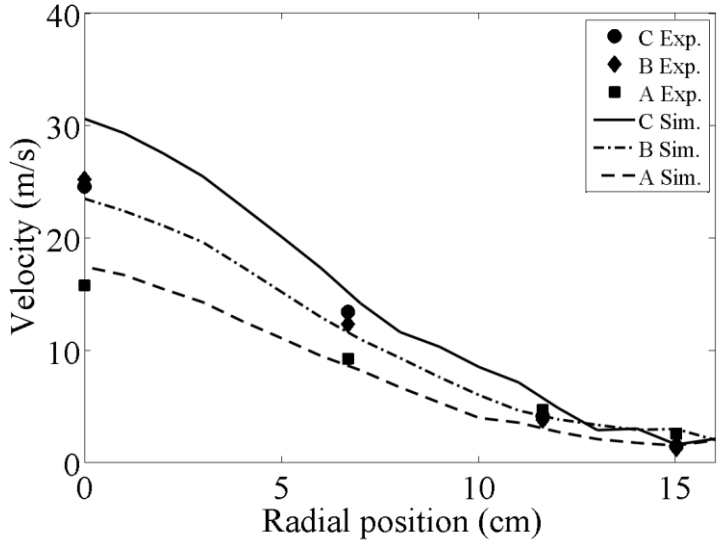


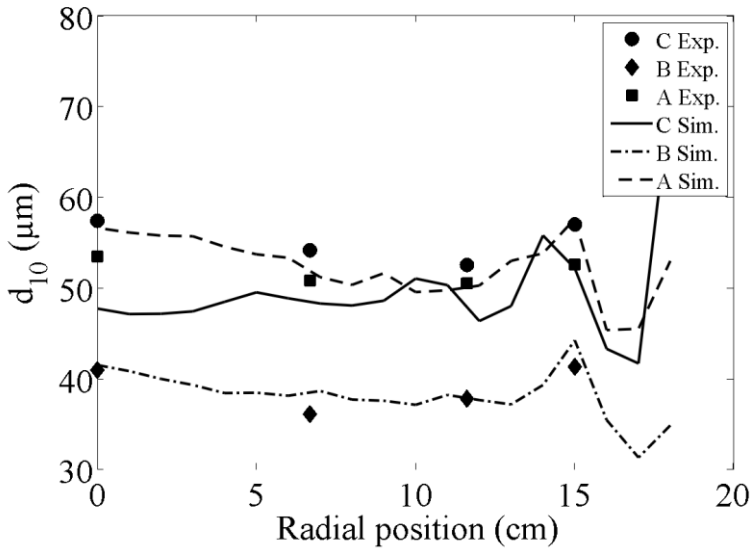


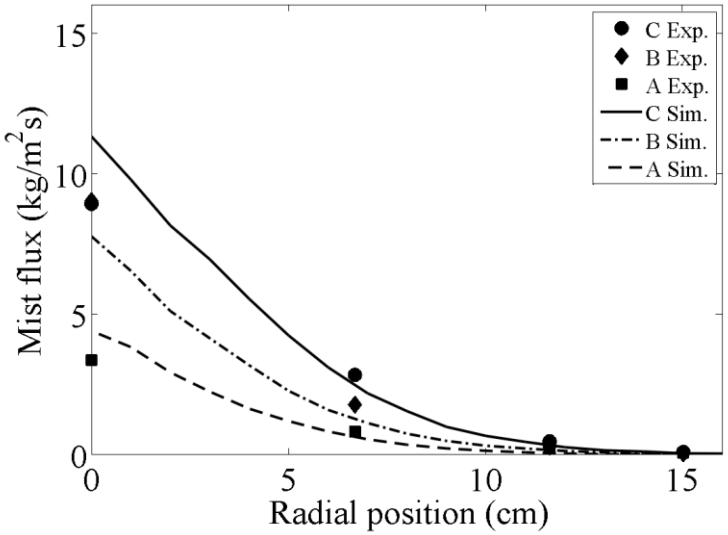
- 0.4 m below the nozzle
- 20 bar pressure



RESULTS: SPRAY PROFILES (A, B, C NOZZLES)

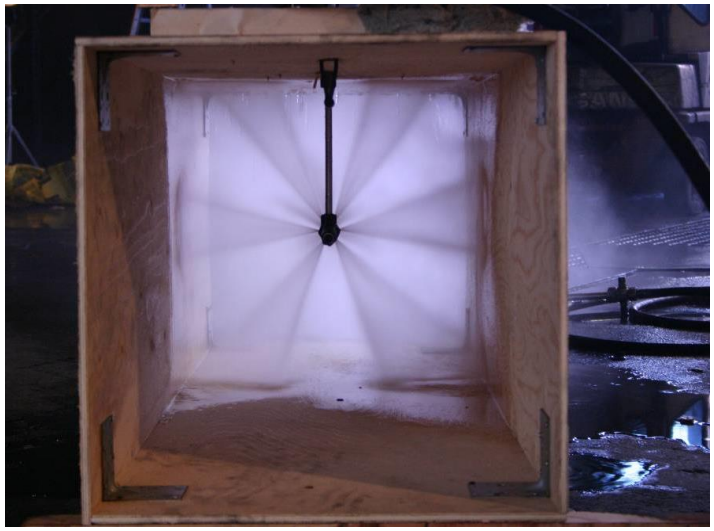


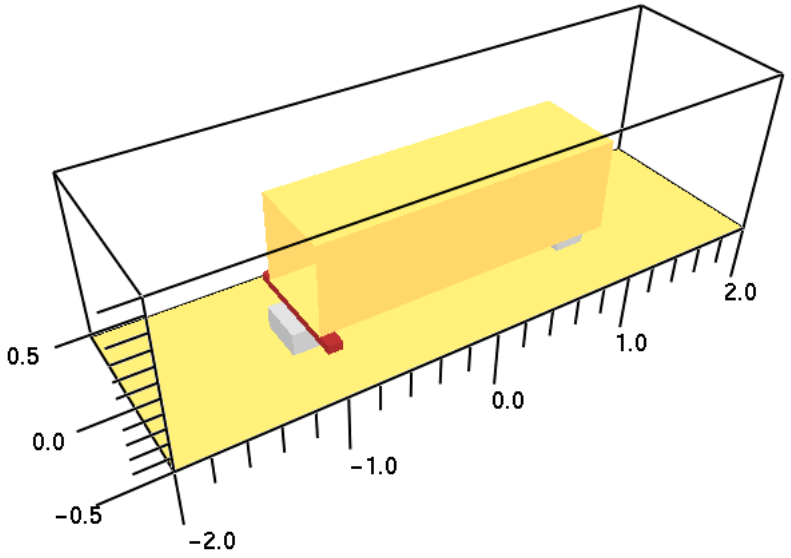




- 1 m below the nozzle
- 70 bar pressure

AIR ENTRAINMENT TESTS

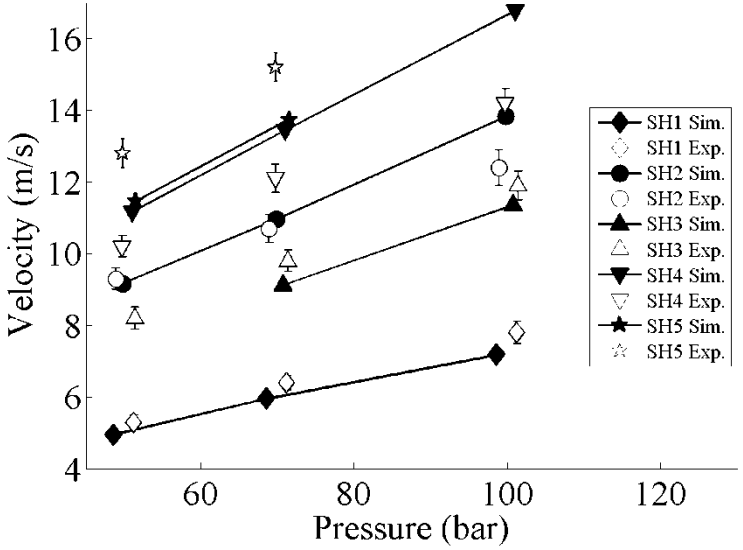




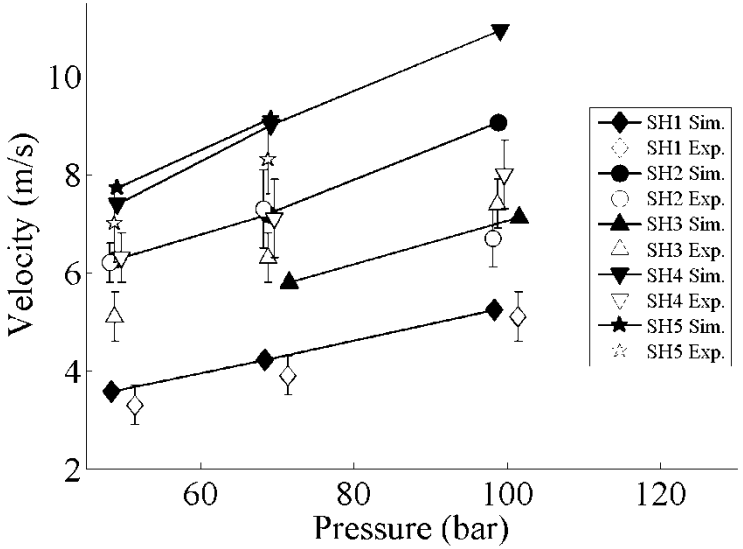
- Rectangular channel 2.0 m × 0.6 m × 0.6 m
- Multi-orifice nozzles in the middle of the channel
- Pressures 50…10 bar
- Air speed measurement 0.5 m upstream (center and 6 cm from wall)

RESULTS: AIR ENTRAINMENT

Channel center

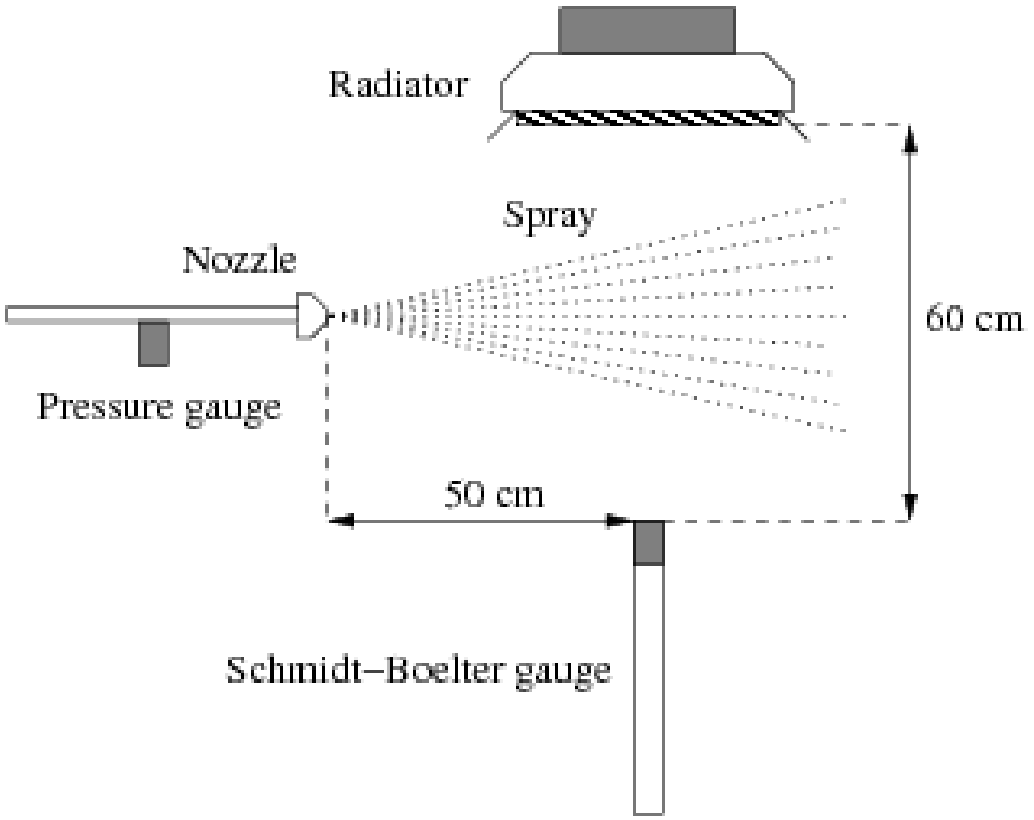


6 cm from wall



- SH4 and SH5 have different perimeter angles
- Difference in momentum transfer difficult to capture
- Results were sensitive to offset value

RADIATION ATTENUATION TESTS



- LPG gas heater
  - 0.2 m × 0.3 m
  - Temperature 950 °C
- Nozzles A, B and C
- 50, 70 and 100 bar
- Experimental uncertainty < 7 %

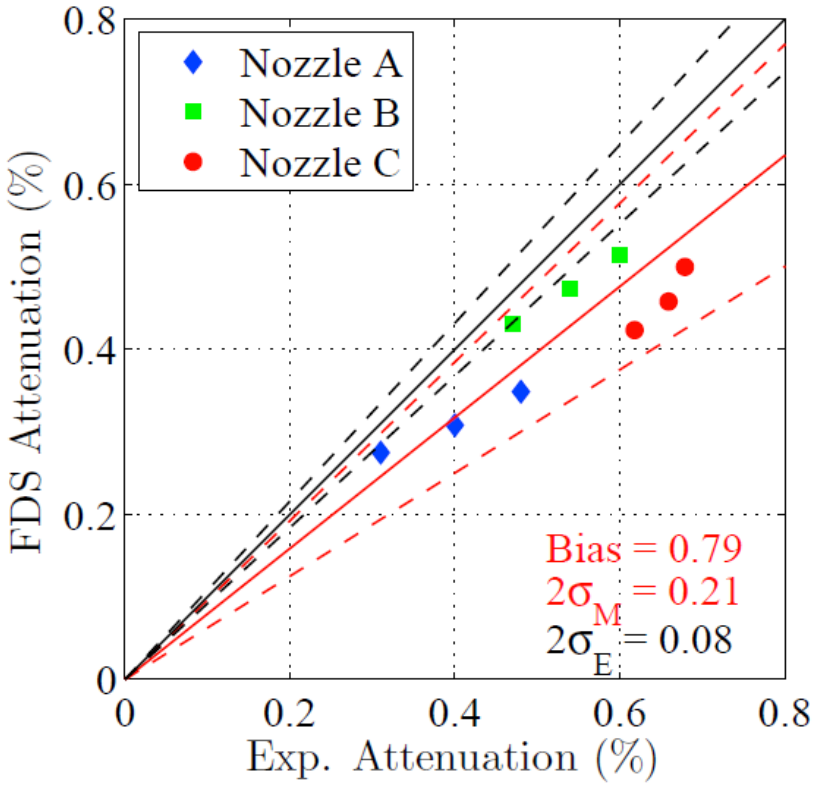
RADIATION ATTENUATION SIMULATIONS

- Two sets of simulations
  - Set 1 = ‘good resolution’
  - Set 2 = ‘even better’

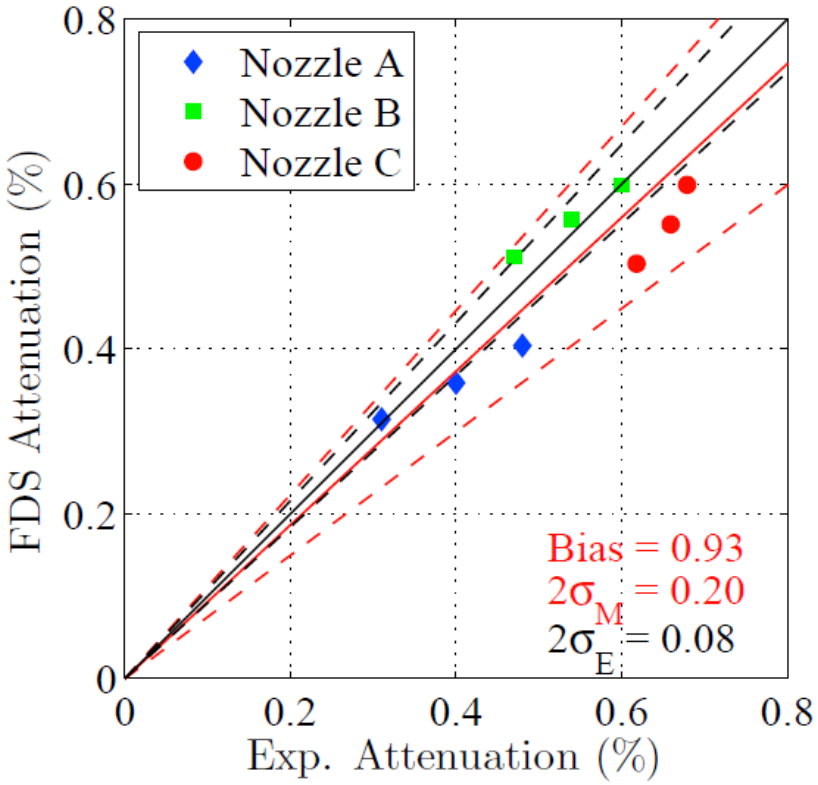
Numerical parameter	Set 1	Set 2
Spatial resolution (Δx)	2.0 cm	1.0 cm
Angular resolution N_Ω	1000	5000
Droplet insertion rate	1×10^5 1/s	1×10^6 1/s
Droplet CFL-condition	∞	1.0

RADIATION ATTENUATION RESULTS

Set 1

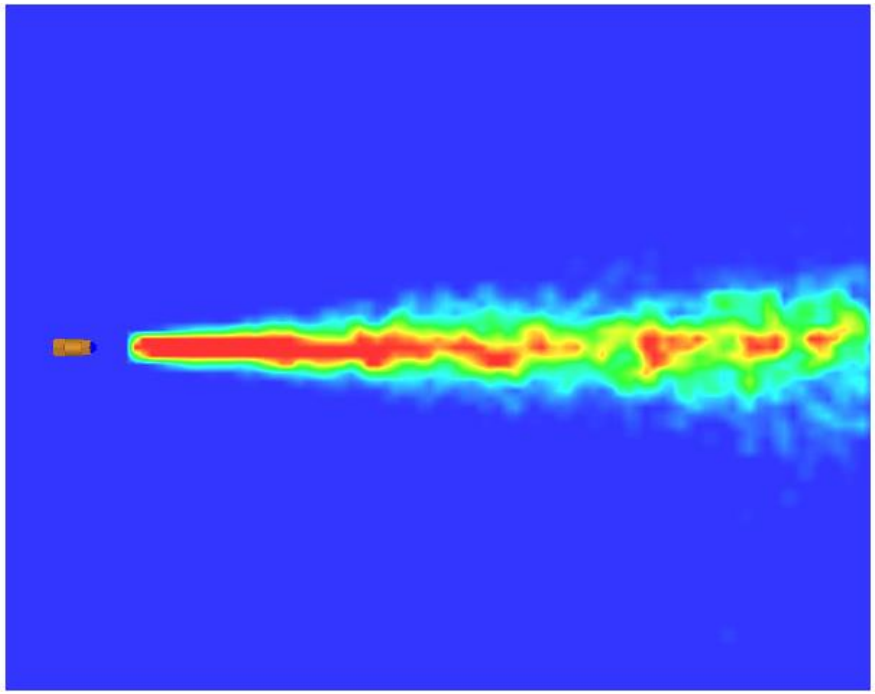


Set 2

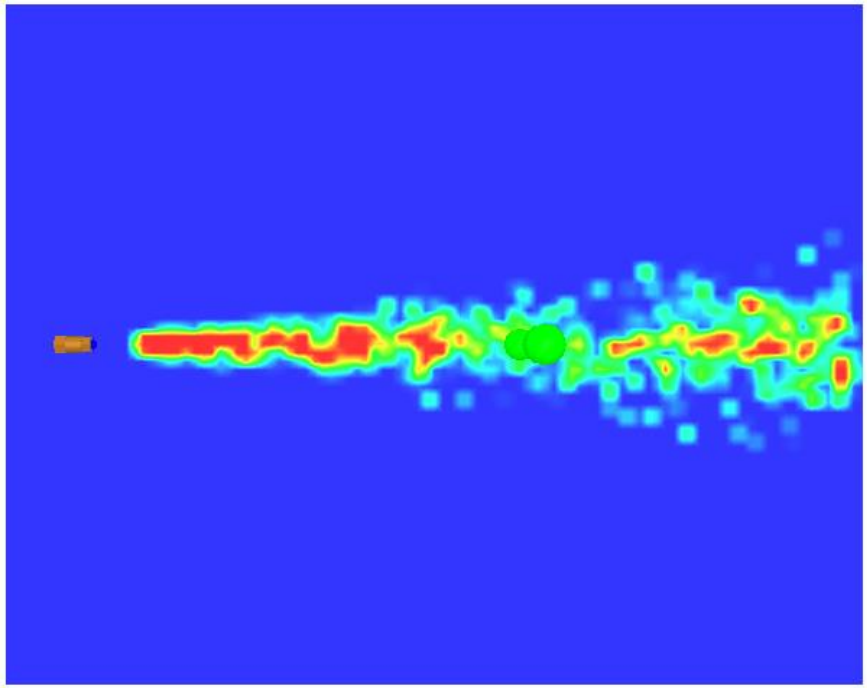


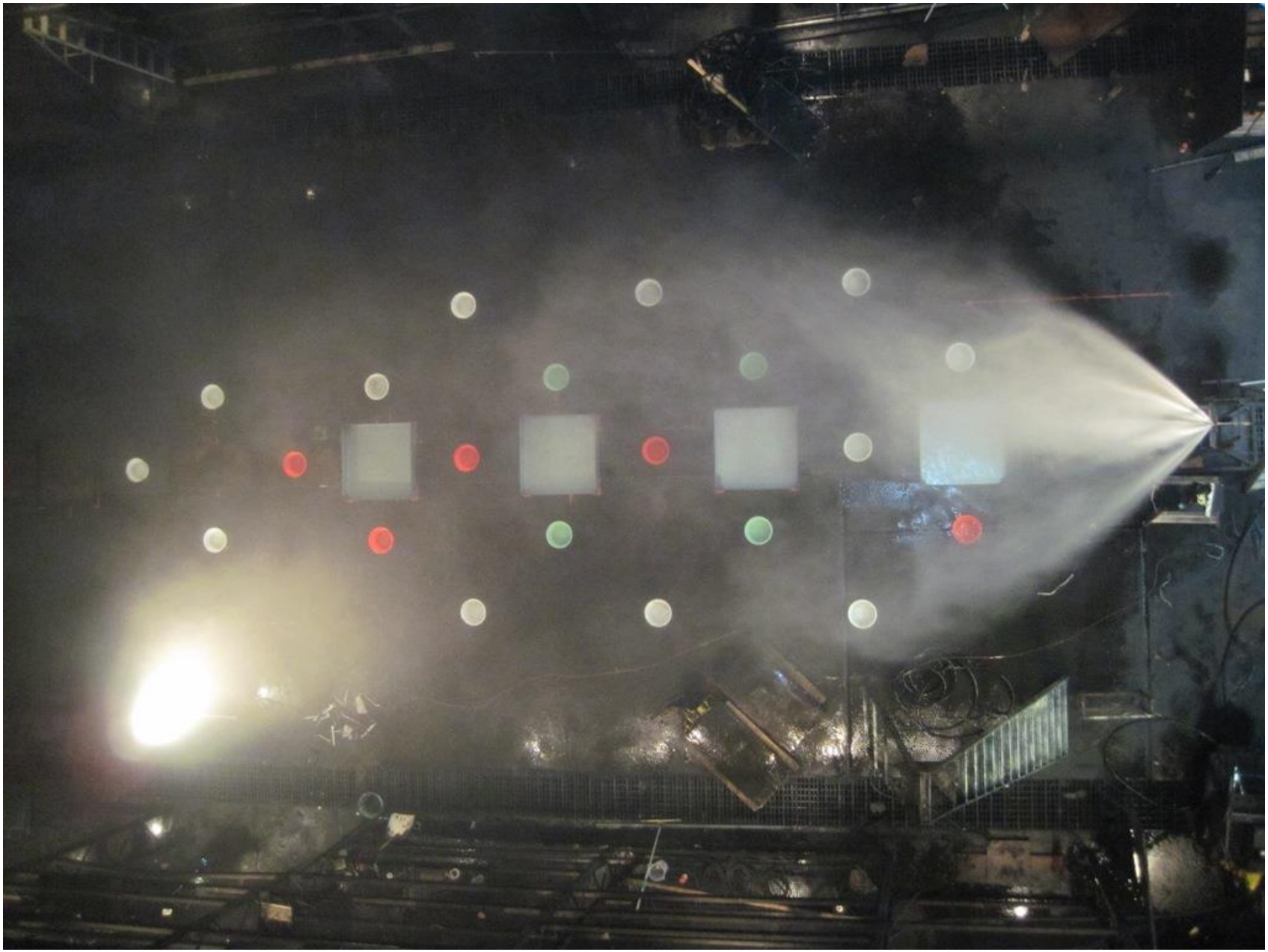
RADIATION ATTENUATION SENSITIVITY STUDY

Δx = 2.0 cm
DROP INSERT RATE = 1×10^5 1/s



Δx = 1.0 cm
DROP INSERT RATE= 1×10^5 1/s





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