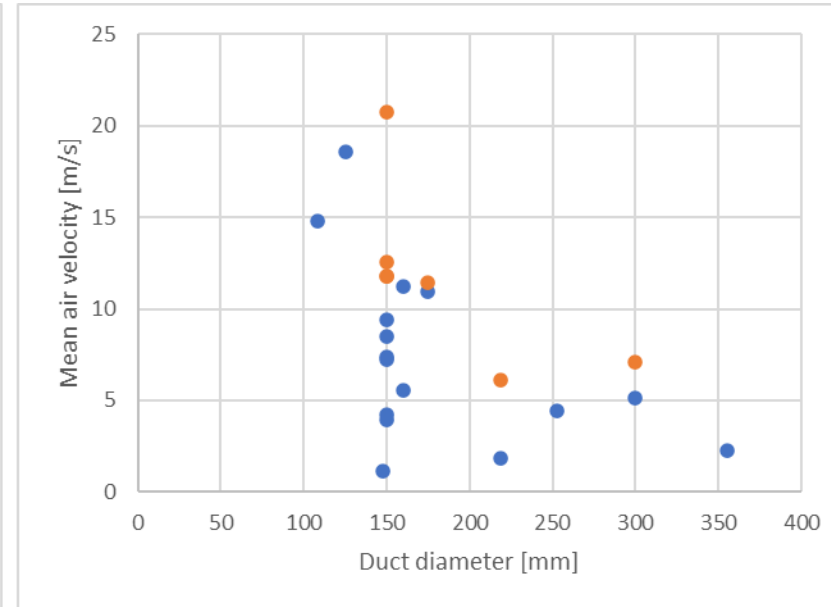
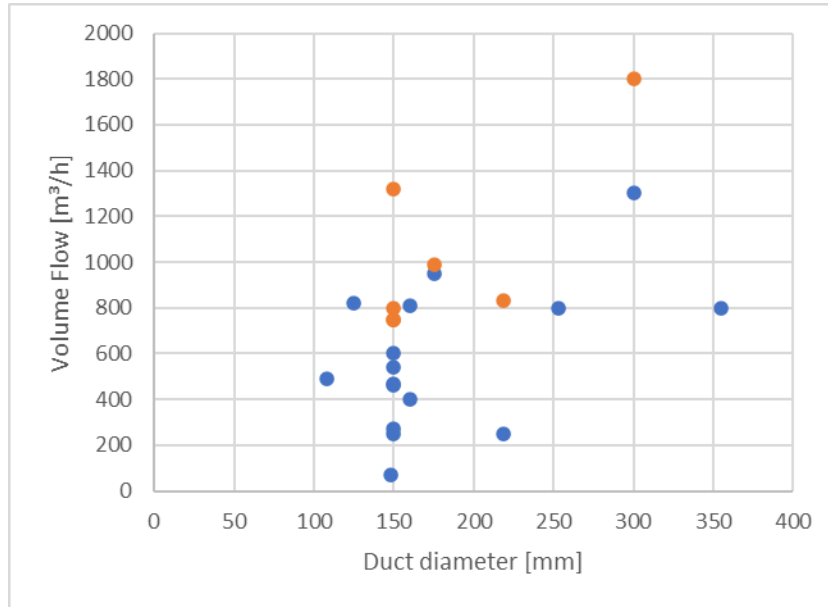




Brake particle losses in ducts

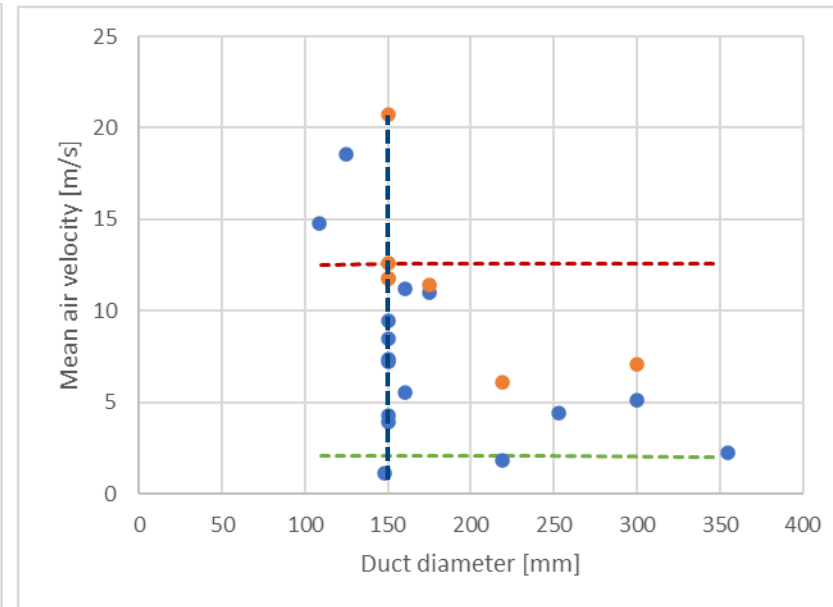
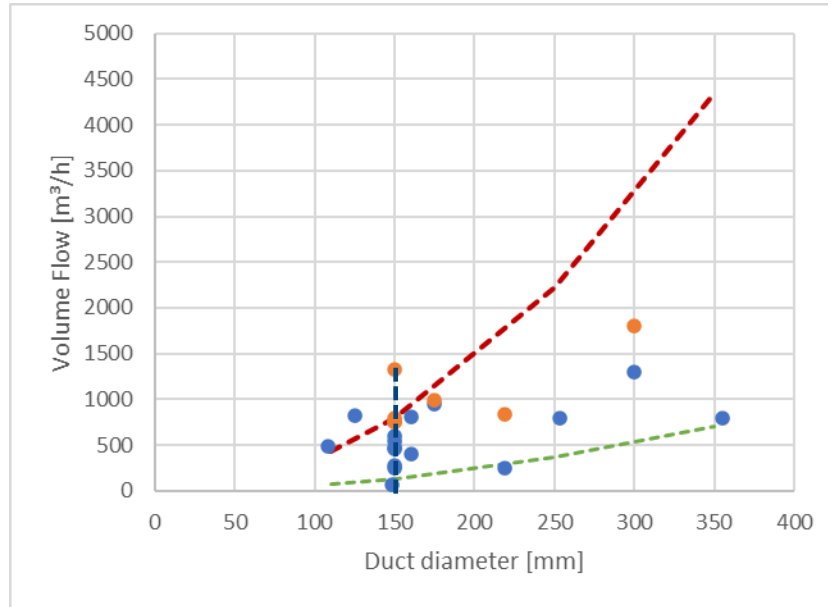
April 2022

ILS: Overview Duct diameter/Volume flow



- Duct diameters ranging from 110 mm - 355 mm
- Majority of labs at duct diameters of about 150 mm

ILS: Overview Duct diameter/Volume flow



Three flow scenarios:

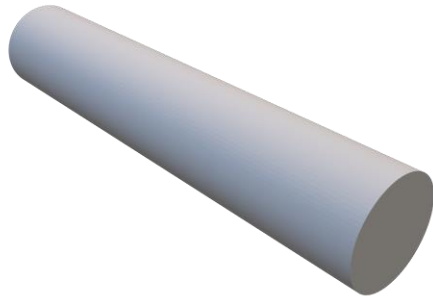
Low Velocity/Low Flow		
Diameter	Flows	Velocities [m/s]
110	70	2,0
150	130	2,0
250	361	2,0
350	707	2,0

High Velocity/Flow		
Diameter	Flows	Velocities [m/s]
110	430	12,6
150	800	12,6
250	2222	12,6
350	4355	12,6

Ducting constant		
Diameter	Flows	Velocities [m/s]
150	70	1,10033
150	300	4,715702
150	800	12,57521
150	1320	20,74909

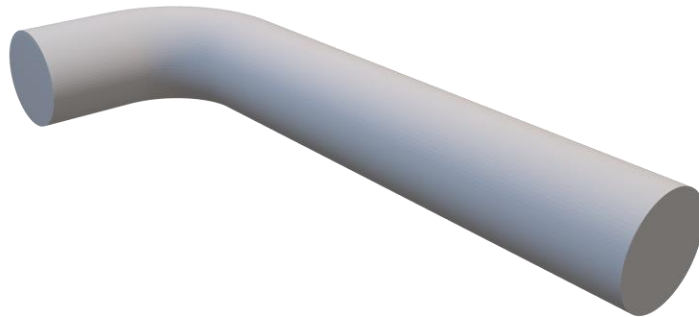
Duct Layouts

Three exemplary layouts are considered (all horizontal):



Layout 1:

5 diameters straight



Layout 2

1 diameter straight,
90° bend ($r=2d$)
5 diameters straight



Layout 3

1 diameter straight,
2 x 90° bend ($r=2d$)
5 diameters straight

Particle loss models

Particle penetration calculation based on empirical equations.

Diffusional losses:

laminar: Holman (1972)

turbulent: Friedlander (1977)

Gravitational losses:

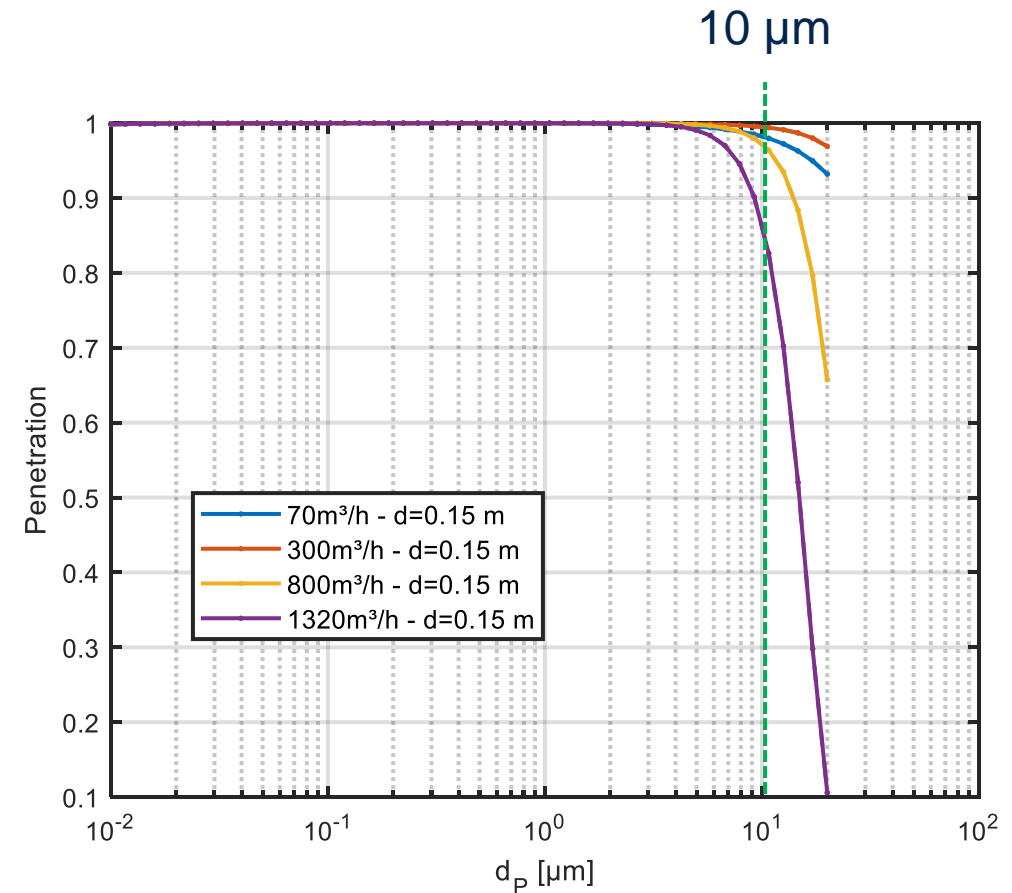
laminar: Heyder&Gebhart (1977)

Turbulent: Schwendiman, Stegen & Glissmeyer (1975)

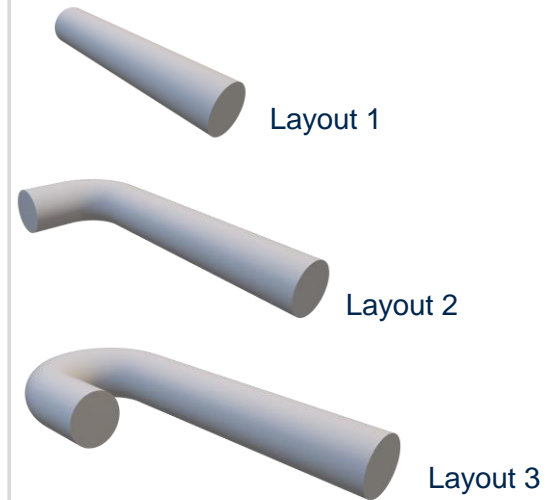
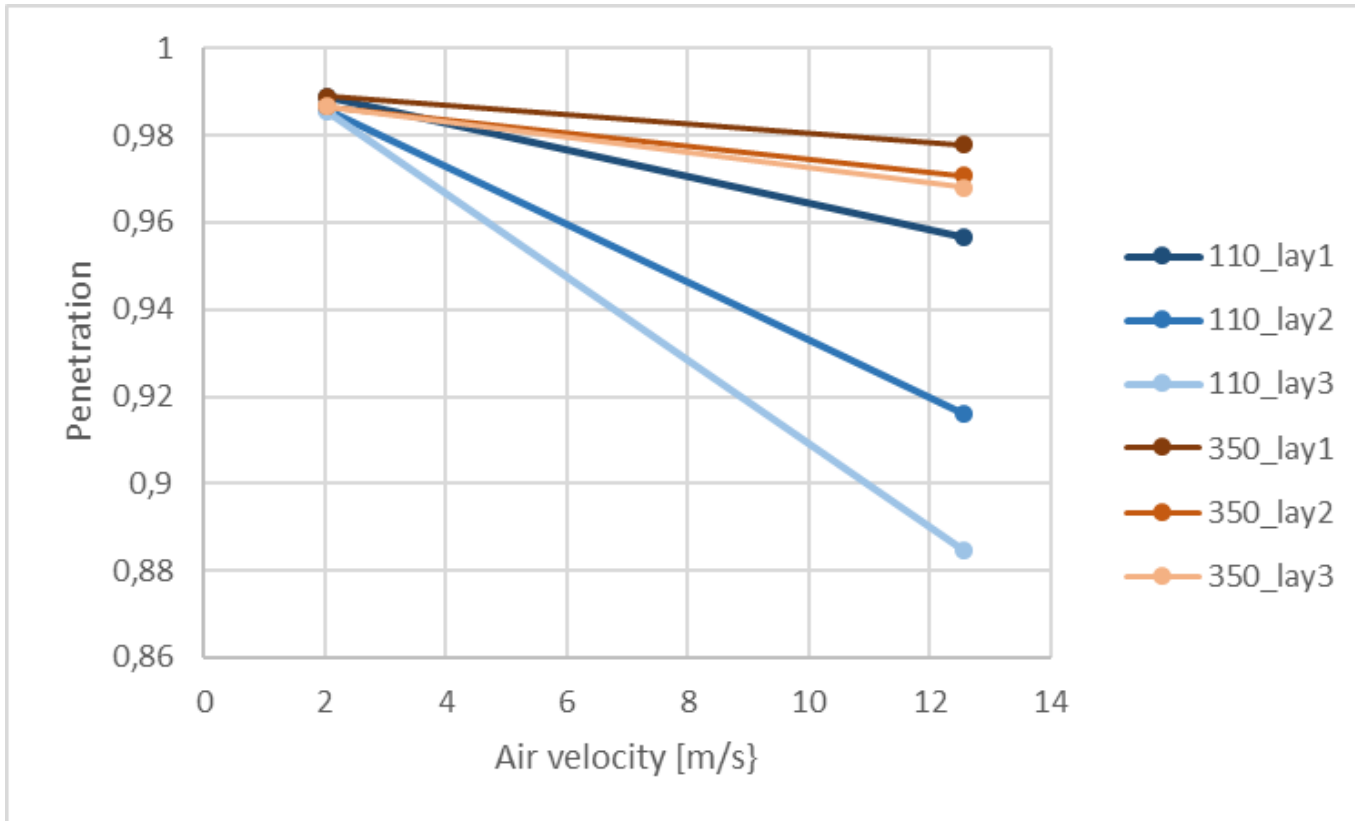
Inertial Deposition

Tube: Liu&Agarwal (1974)

Bend: Pui,Romay-Novas & Liu (1987)

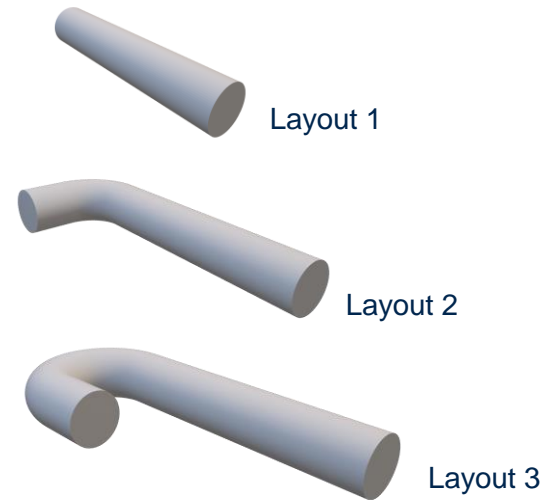
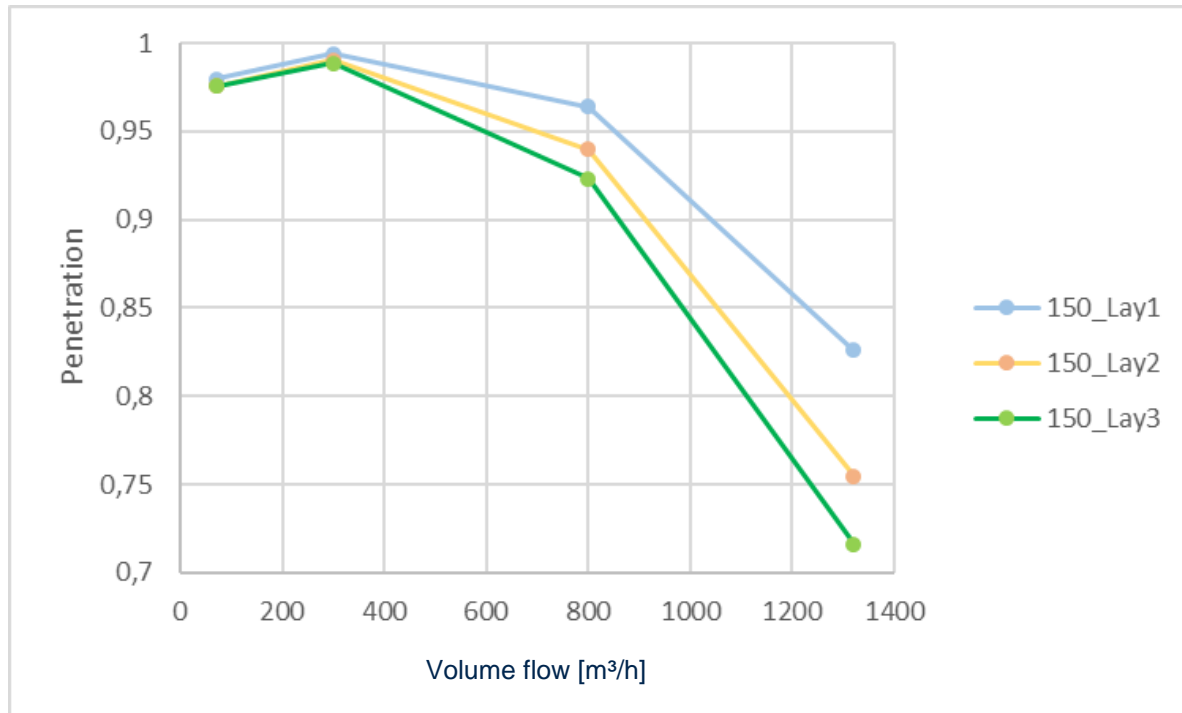


Penetration at particle diameter of $10.7\mu\text{m}$, 110 mm \rightarrow 350 mm



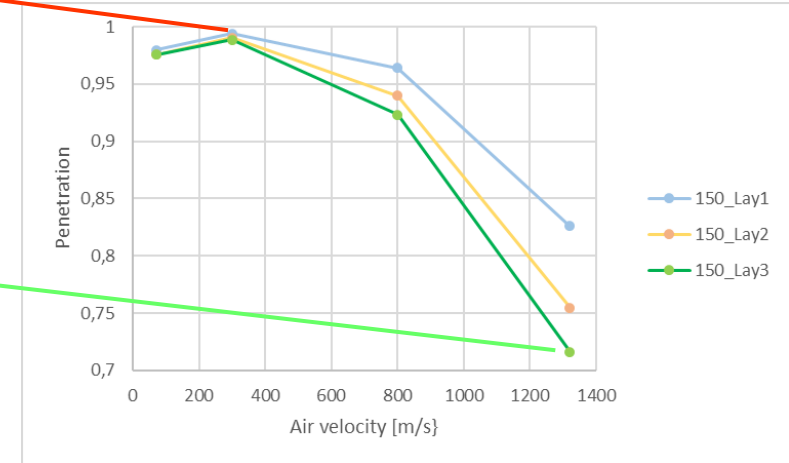
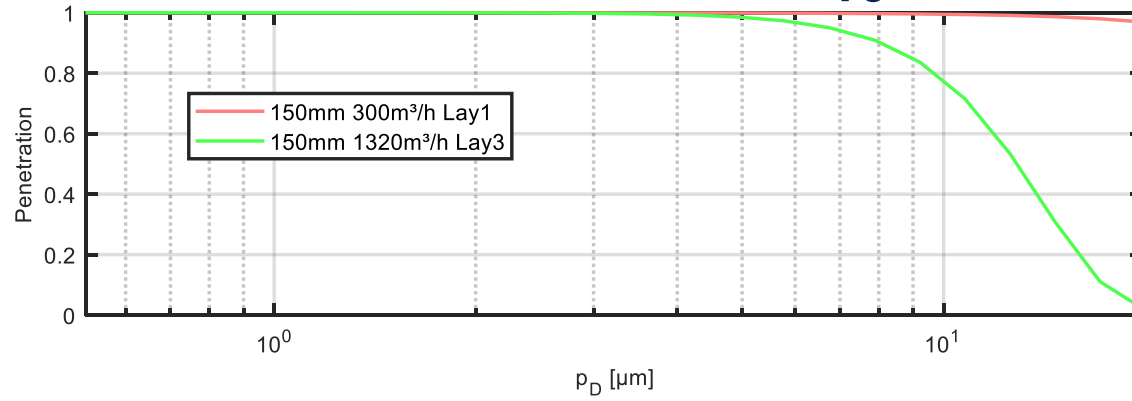
- Larger duct diameters show higher penetration (but result in larger space requirements for installation).
- Low velocity scenarios show higher penetration than high velocity scenarios.
- Duct losses are low (e.g. for $5\mu\text{m}$ particles worst case ca. 1.5%)

Penetration @ 10.7 μm for 150 mm ducting diameter

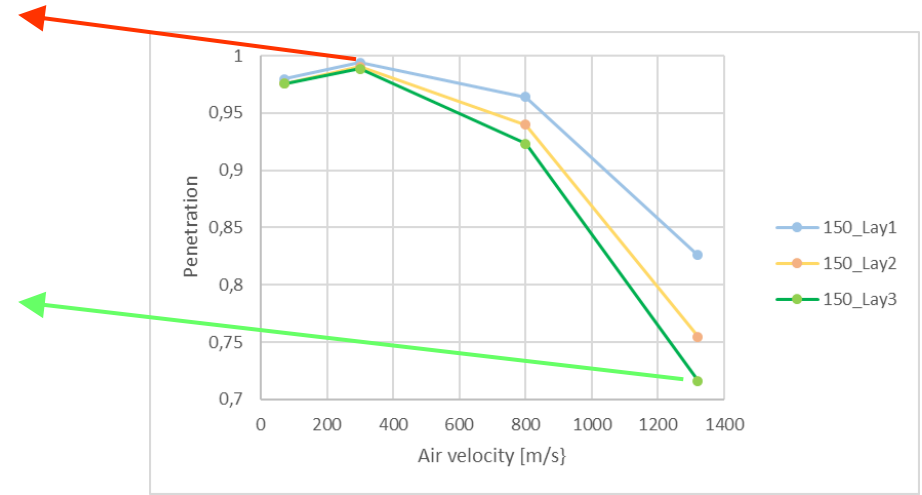
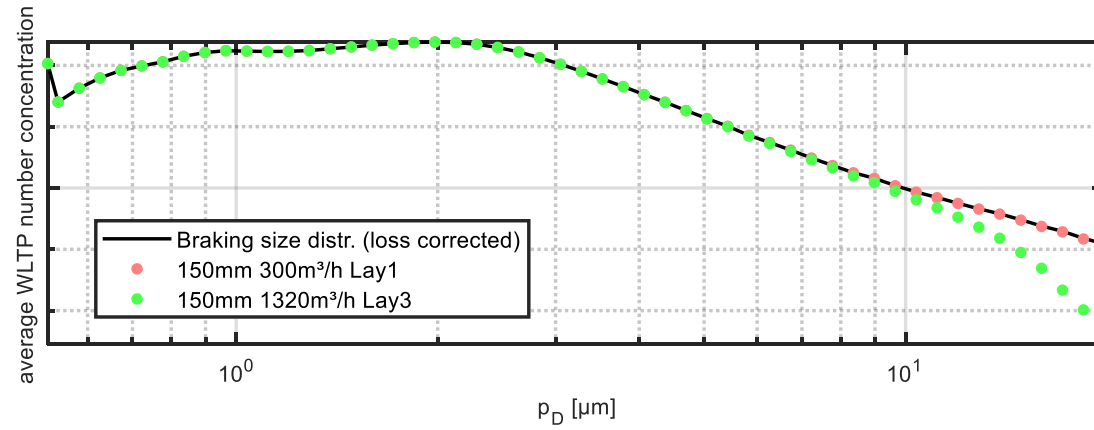
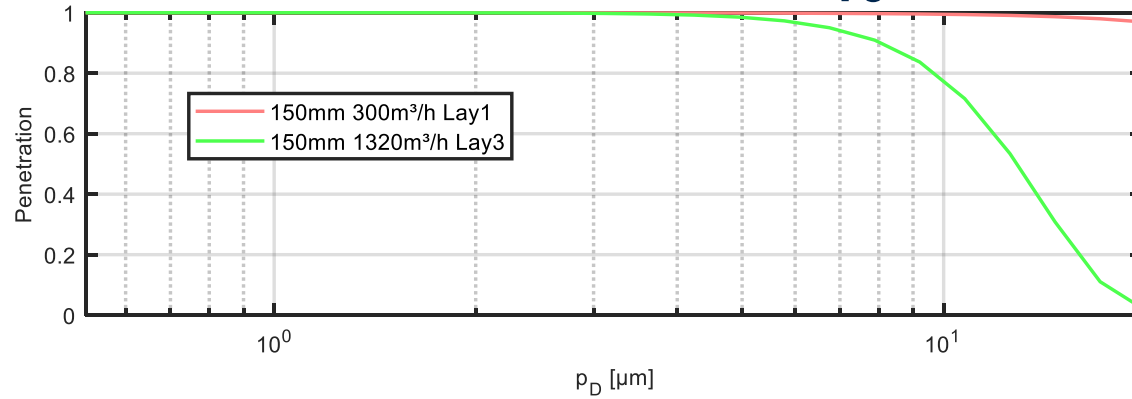


- At a given duct diameter, particle losses increase for high and low airflows.
- Particle losses increase for layouts with higher complexity.

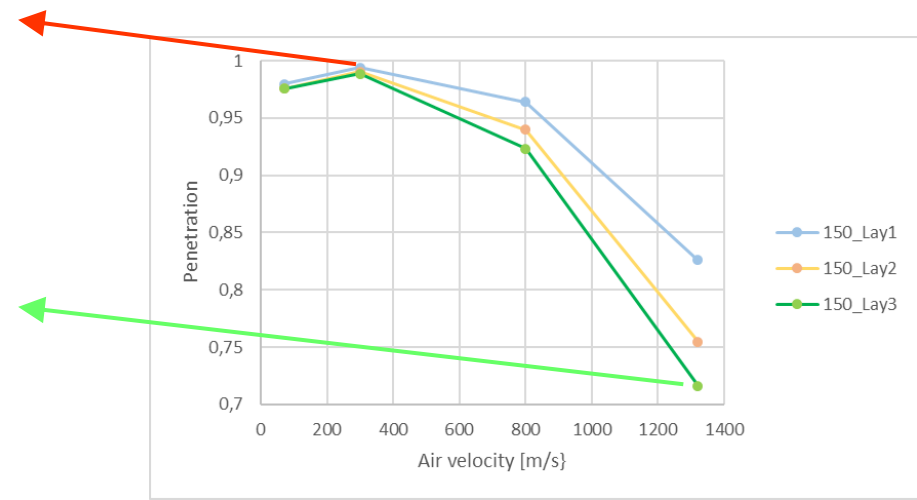
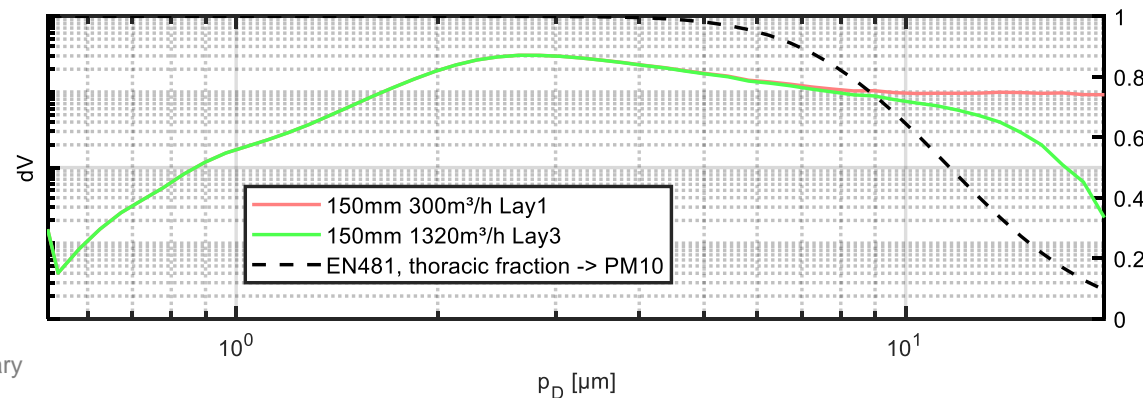
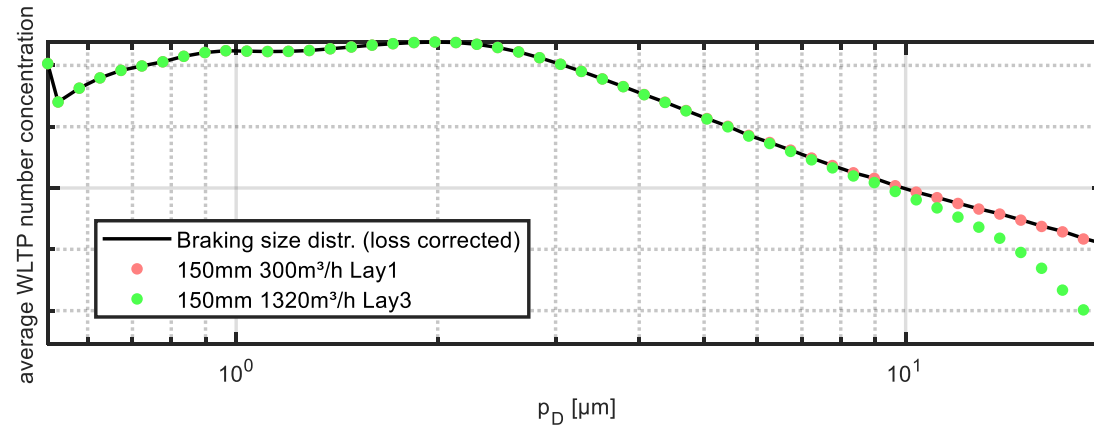
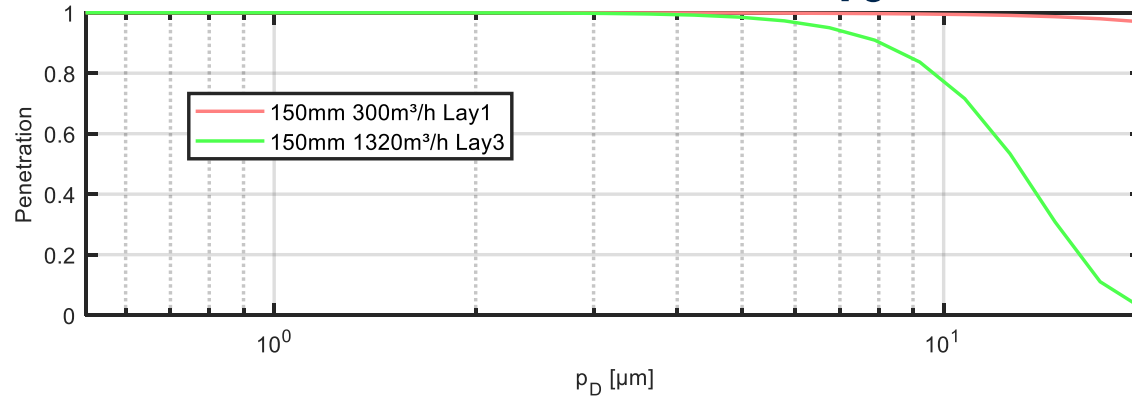
Estimated impact on PM₁₀ emissions



Estimated impact on PM₁₀ emissions



Estimated impact on PM₁₀ emissions



Even for worst case assumptions (from ILS),
The expected difference in PM₁₀ is low (about 2.5%)