Design Considerations for free falling particle receivers and experimental setup for 5m falling test

PTWG Workshop, Riyadh

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Background

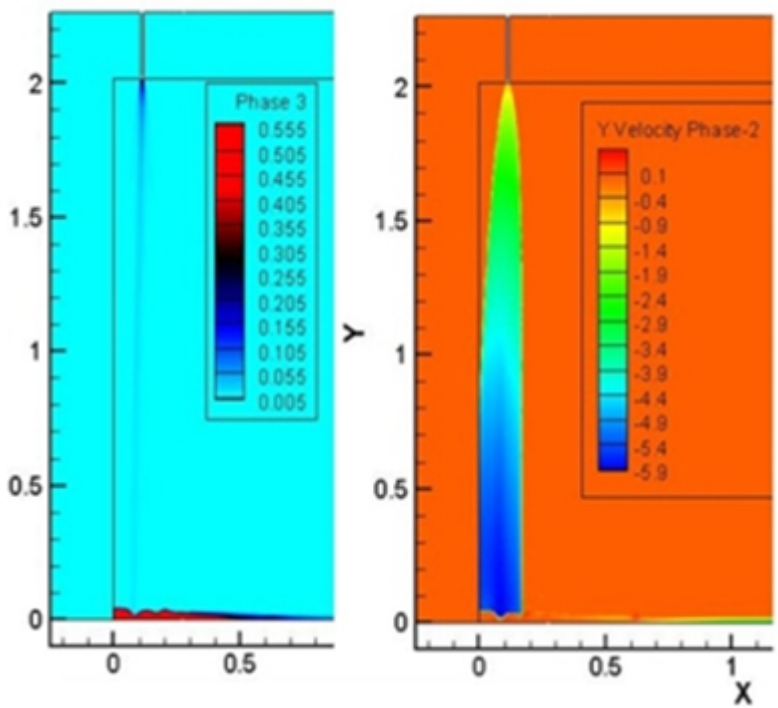
- One of two receiver concept streams scoped by ASTRI program
- For high temperature s-CO_2 Brayton cycle
- Started with an indirect heating concept
- Moved to the directly heated free falling
- Investigated key design considerations
- Full scale hydrodynamics test rig (cold falling) under construction
- For developing and validating new ideas

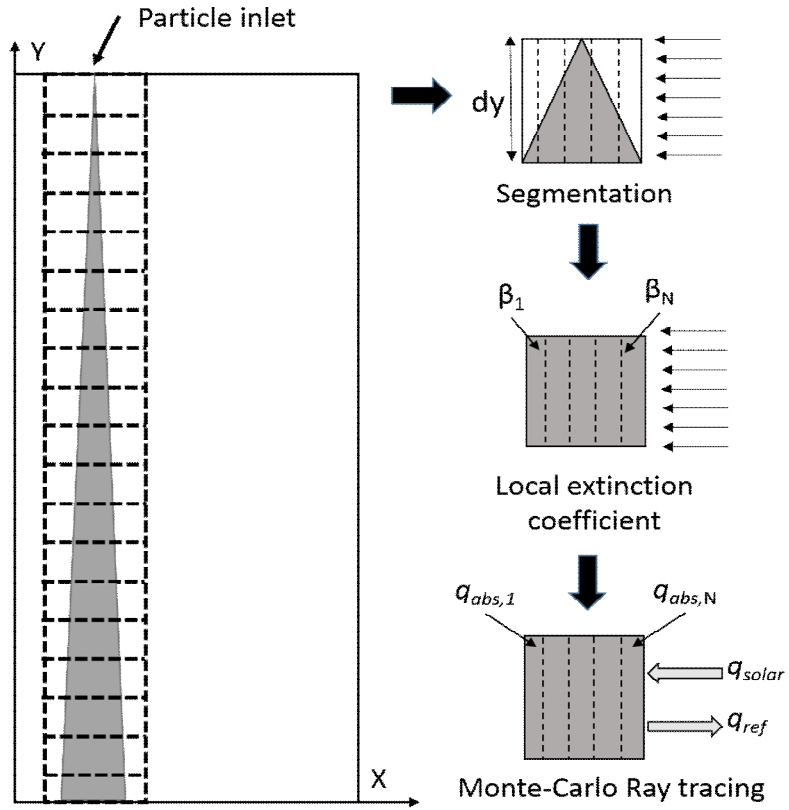
Design considerations for free falling particle receivers

Modelling of Hydrodynamics and Radiation absorption

CFD simulation
ANSYS Fluent
Eulerian-Eulerian multiphase model

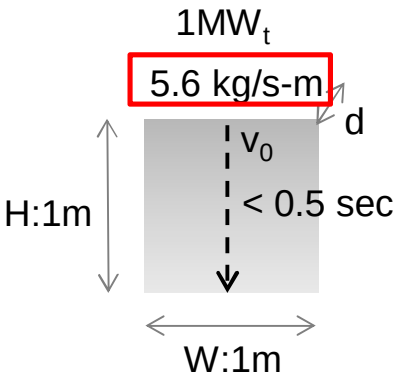
Monte-Carlo (MC) Ray tracing
Matlab

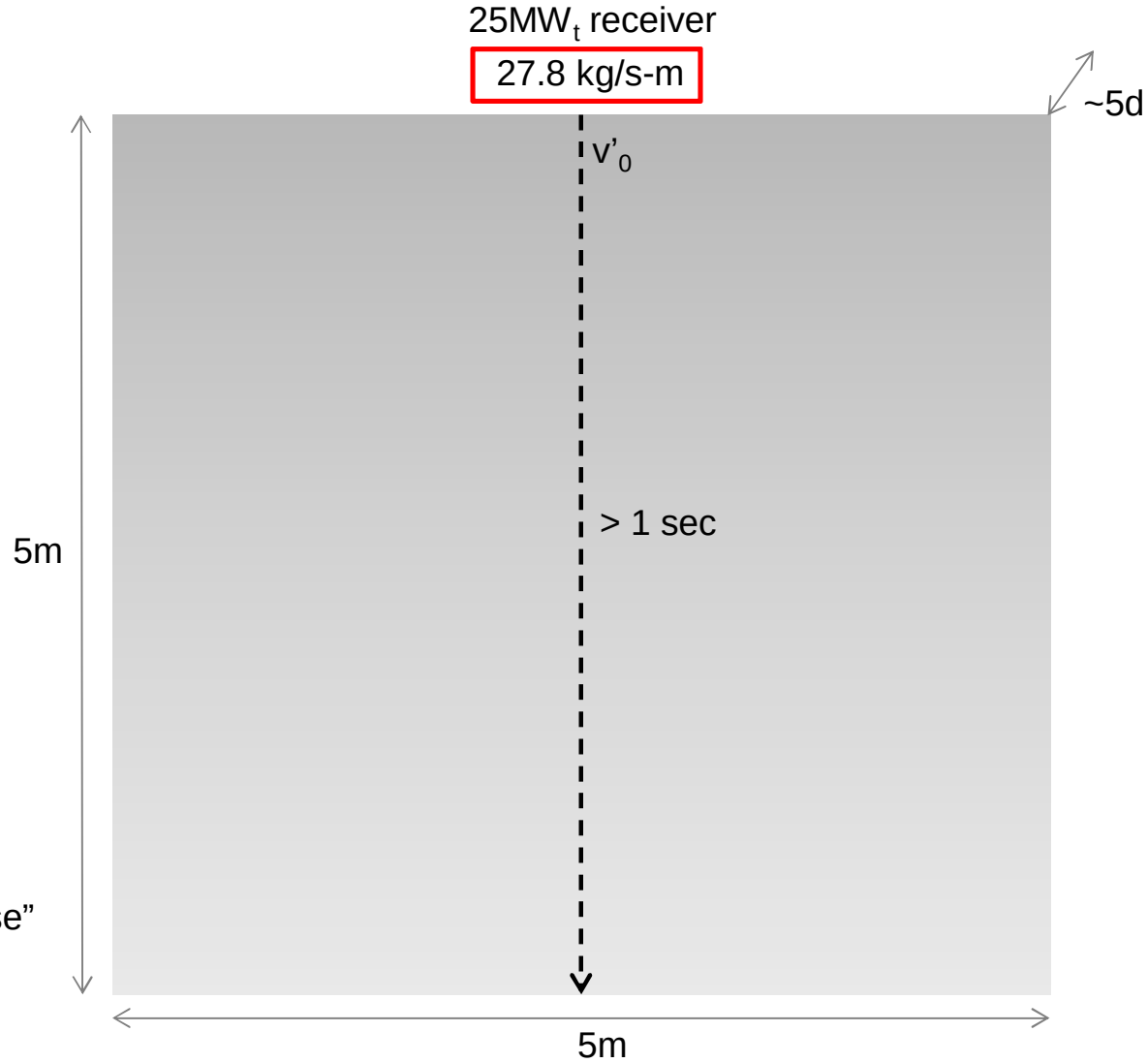




1. Receiver geometry and particle flow rate

Ave flux: $1MW_t / m^2$
Temp. difference: 150 K
Particle C_p: 1.2kJ / kg K

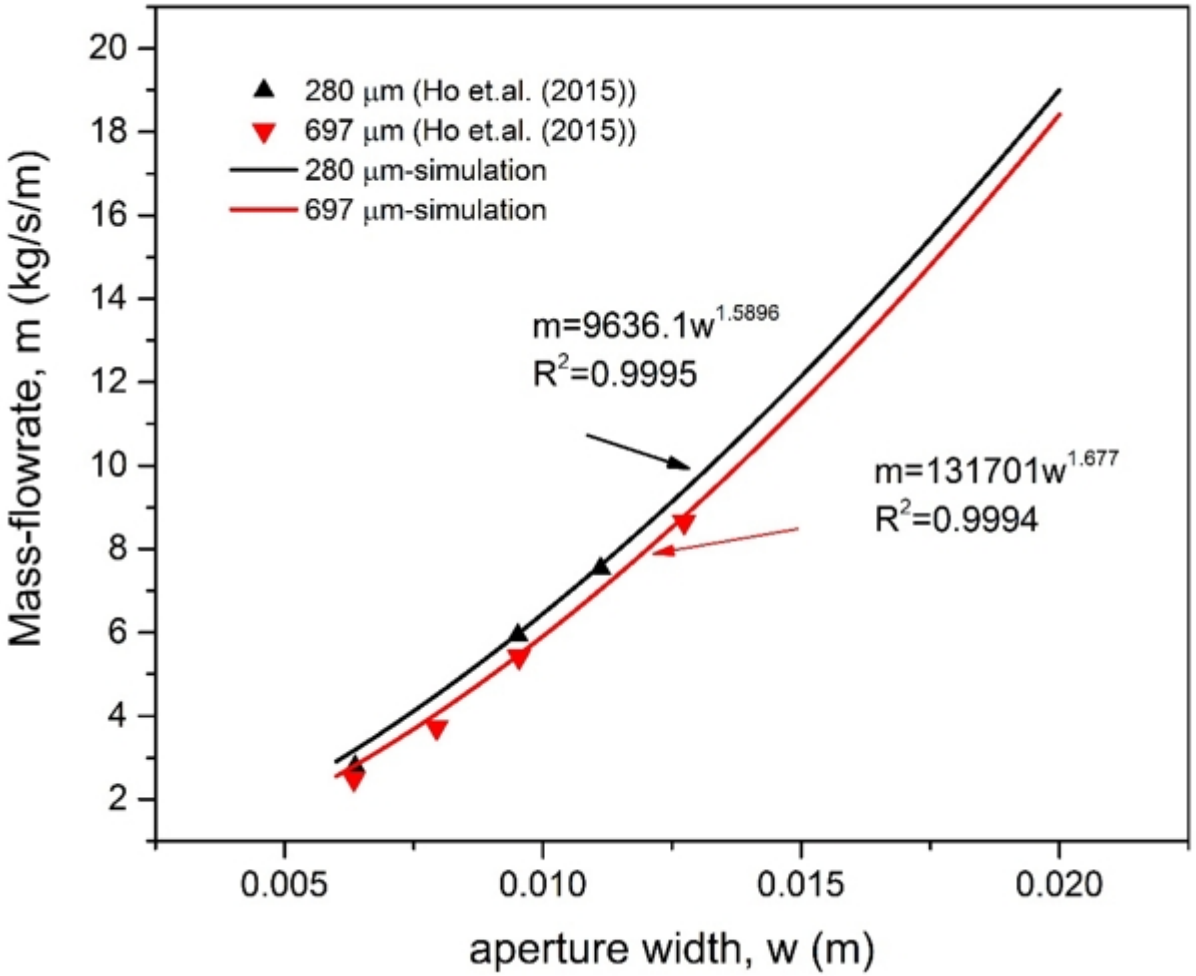




"Flow rate per curtain width

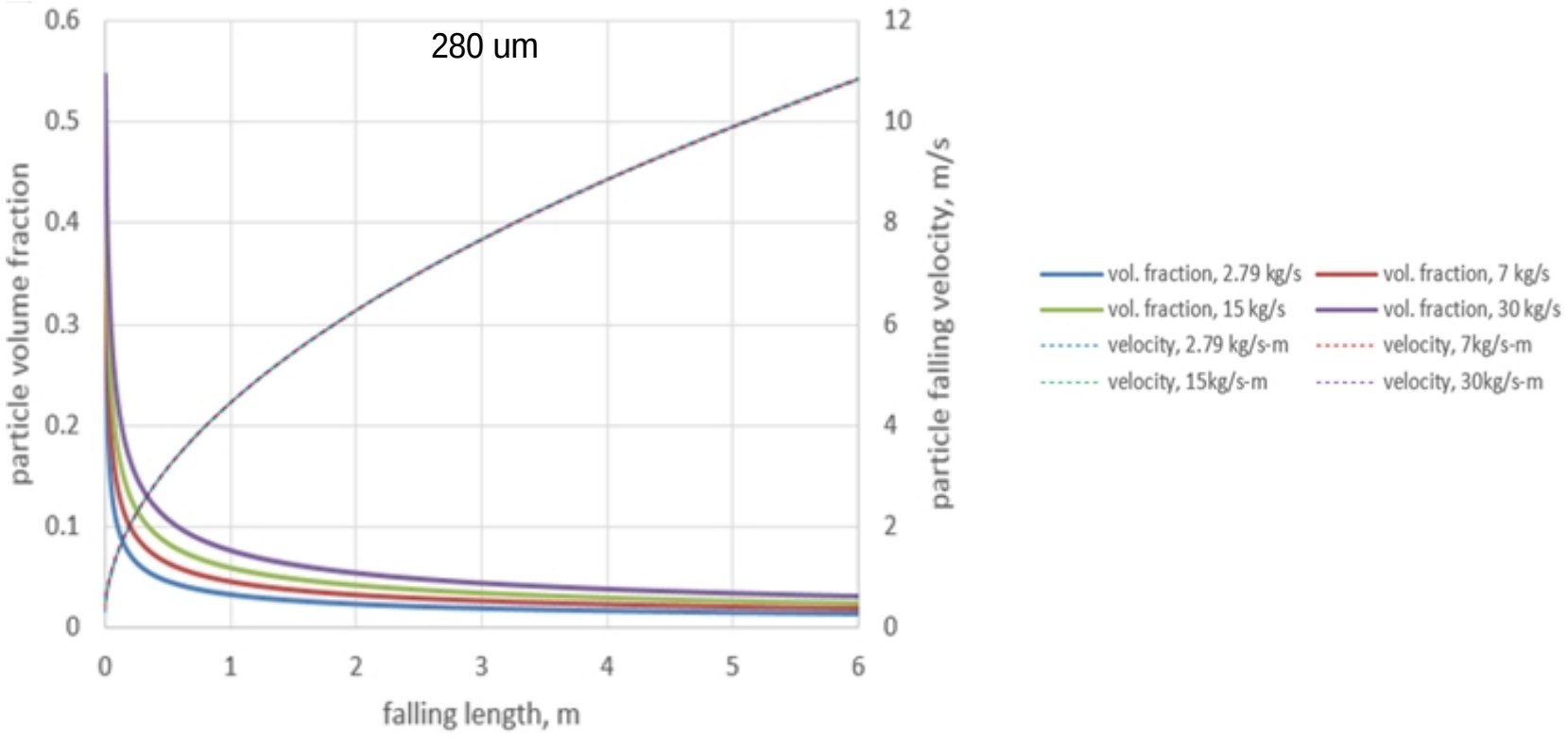
increases as flux & capacity increase
decreases as dT, Cp and W/H increase"

2. Particle discharge aperture width, initial velocity and initial volume fraction



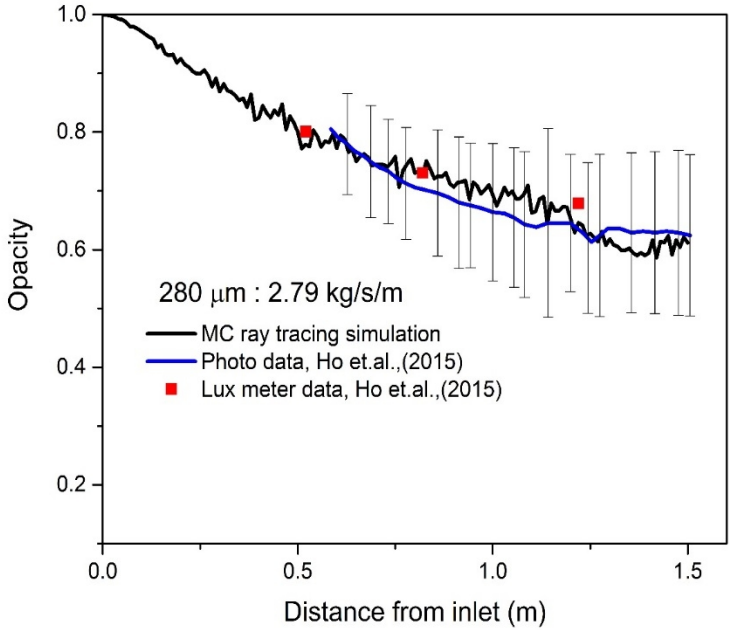
CFD simulation
CARBO Accucast ID50

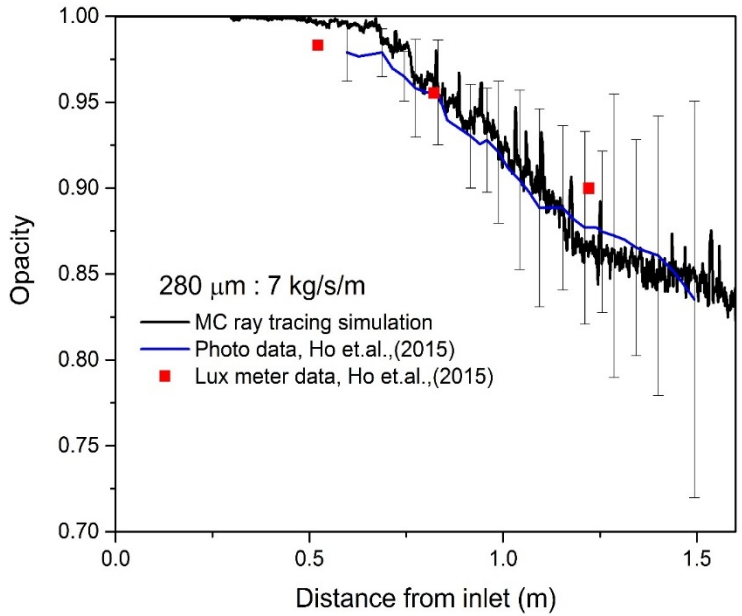
3. Particle falling velocity and volume fraction



4. Absorption and transmission of solar energy

Validation of MC ray tracing





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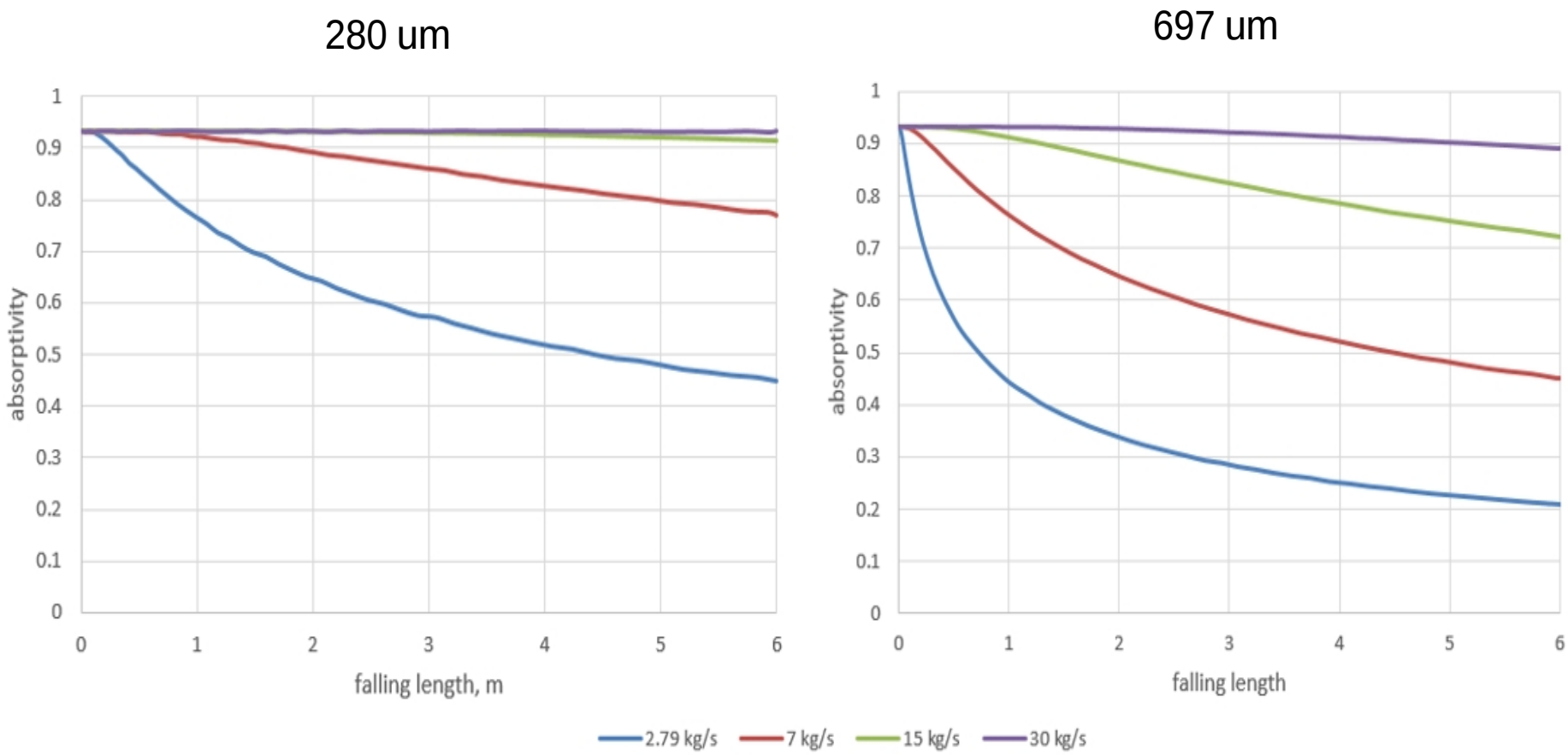
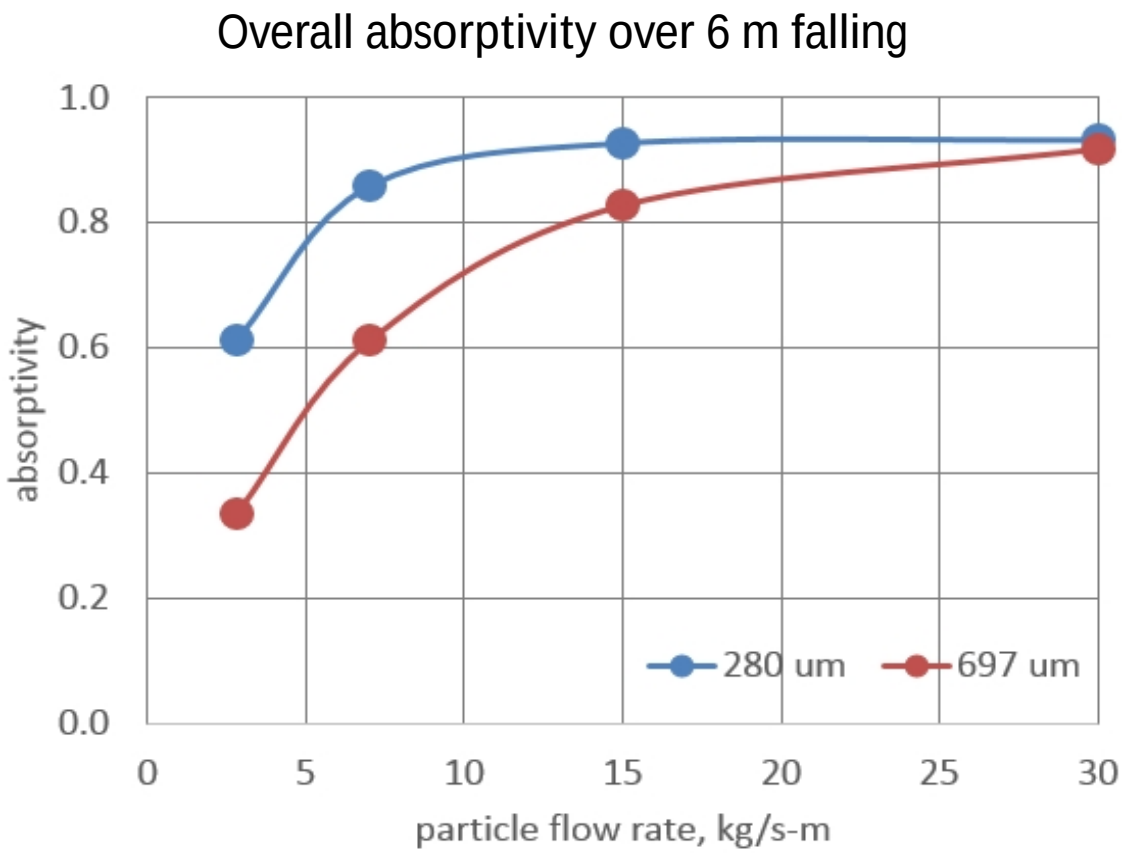
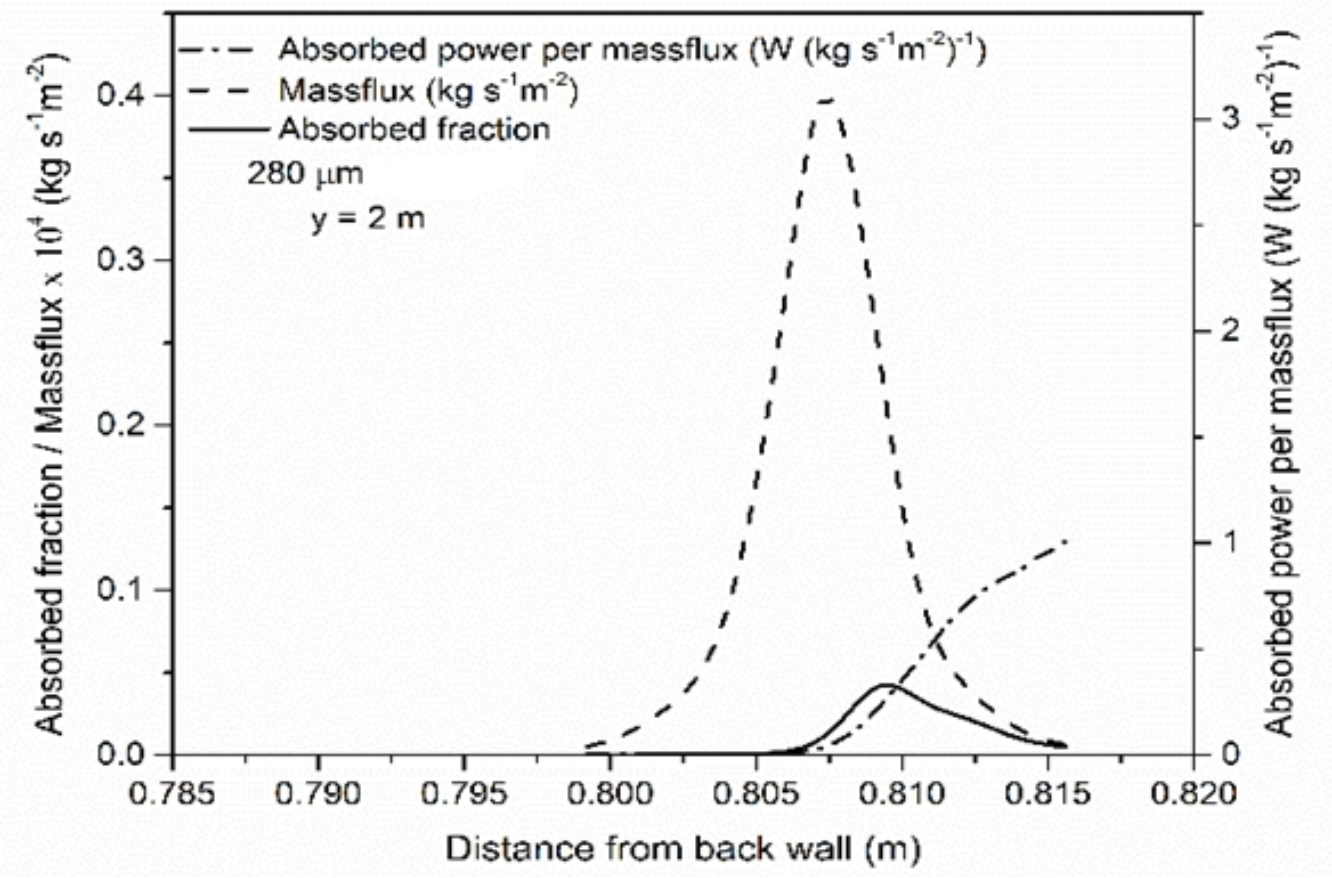


5. Absorption and transmission of solar energy



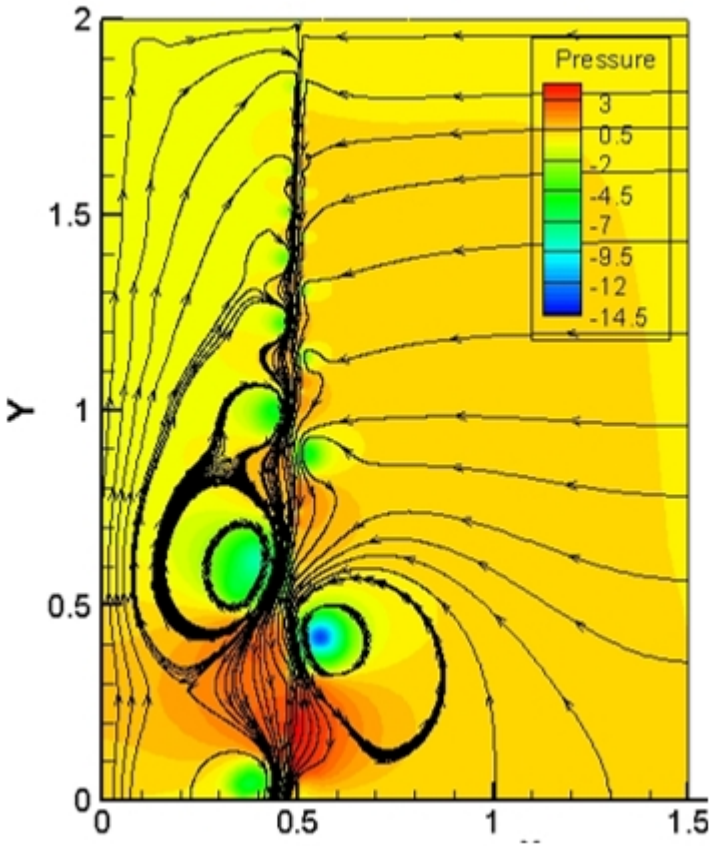
Characteristics
of particle receiver only

6. Uneven absorption of solar energy

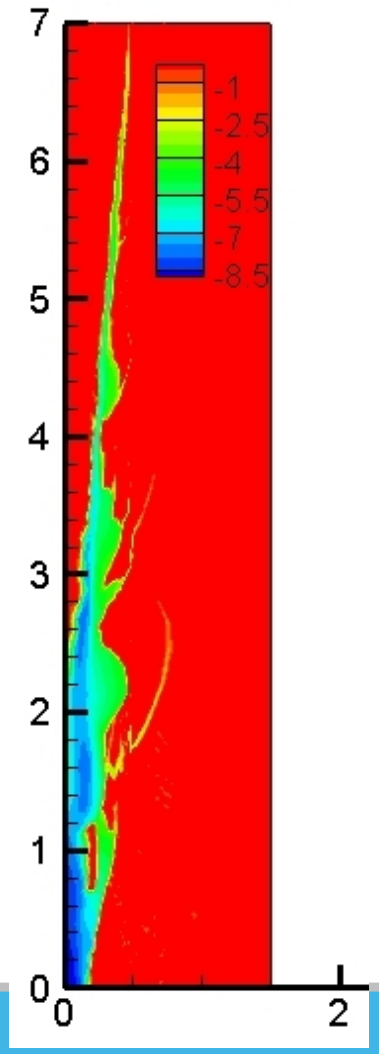


7. Particle flow instability

Pressure distribution airstream trace



Y Velocity distribution



Summary of key design issues

- High transmission loss with bigger particle size, when low flow or part load operation, and in lower section of falling
- Uneven absorption of solar energy across the curtain may cause material problem
- Flow instability increases as falling length increases.

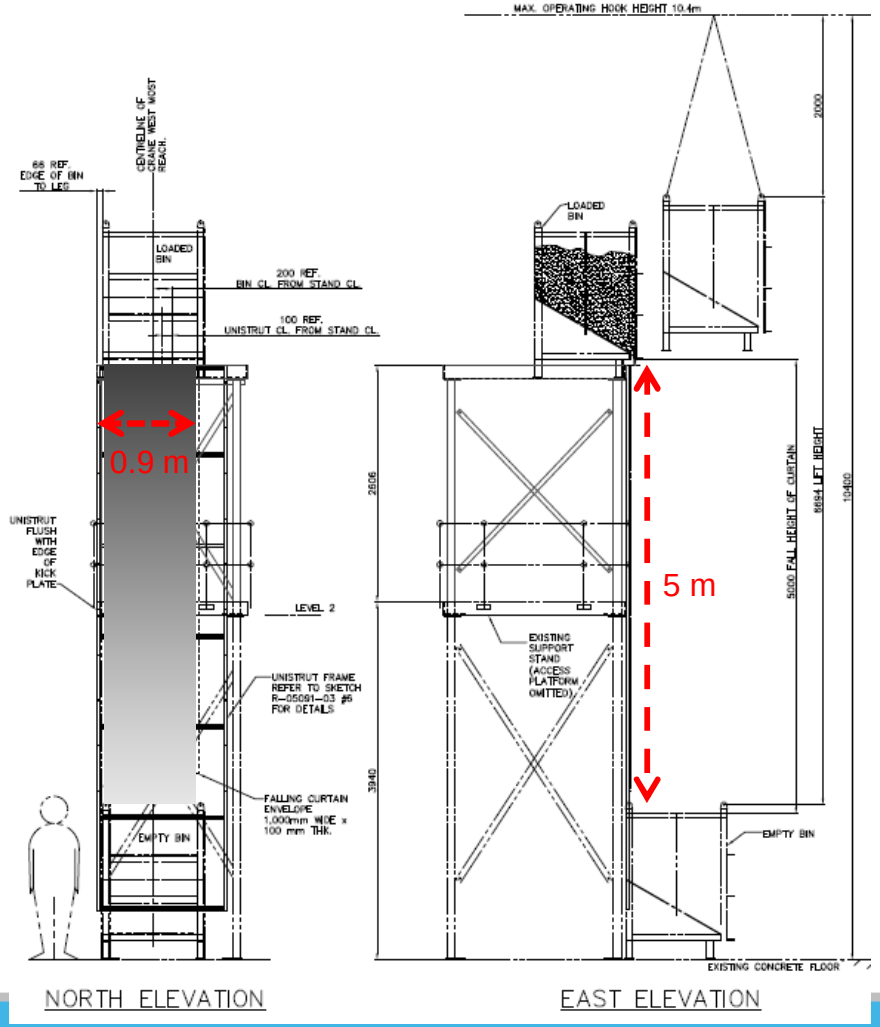
- To do
  - Full heat transfer modelling including emission and convection
  - Exp. hydrodynamics test for developing/validating ideas
  - On-sun heat transfer test

5m falling experimental setup

- To investigate full-scale falling hydrodynamics
- To develop and validate new free falling concepts
- Flow rate up to 30kg/s-m, Different particles

- To be investigated through camera image analysis
  - Overall falling pattern and flow stability
  - Opacity at different height
  - Falling velocity at different heights and depths
  - Particle volume fraction at different locations (?)

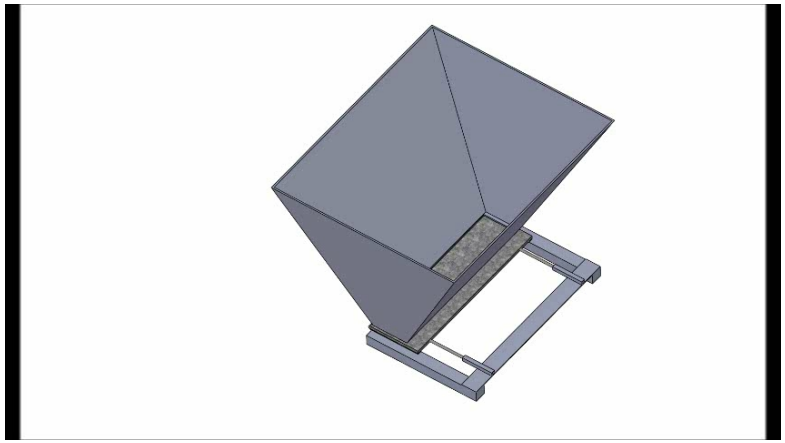
5m falling particle test rig

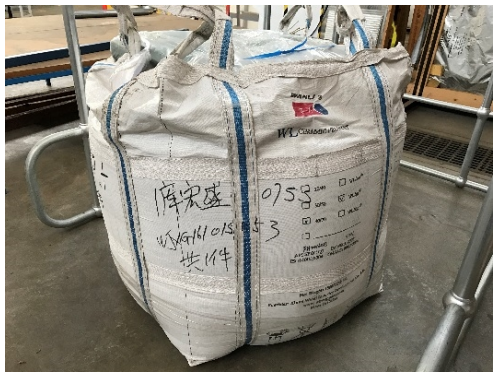


5m falling particle test rig

Bins for containing particle

Sliding gate for particle discharge (SNL)



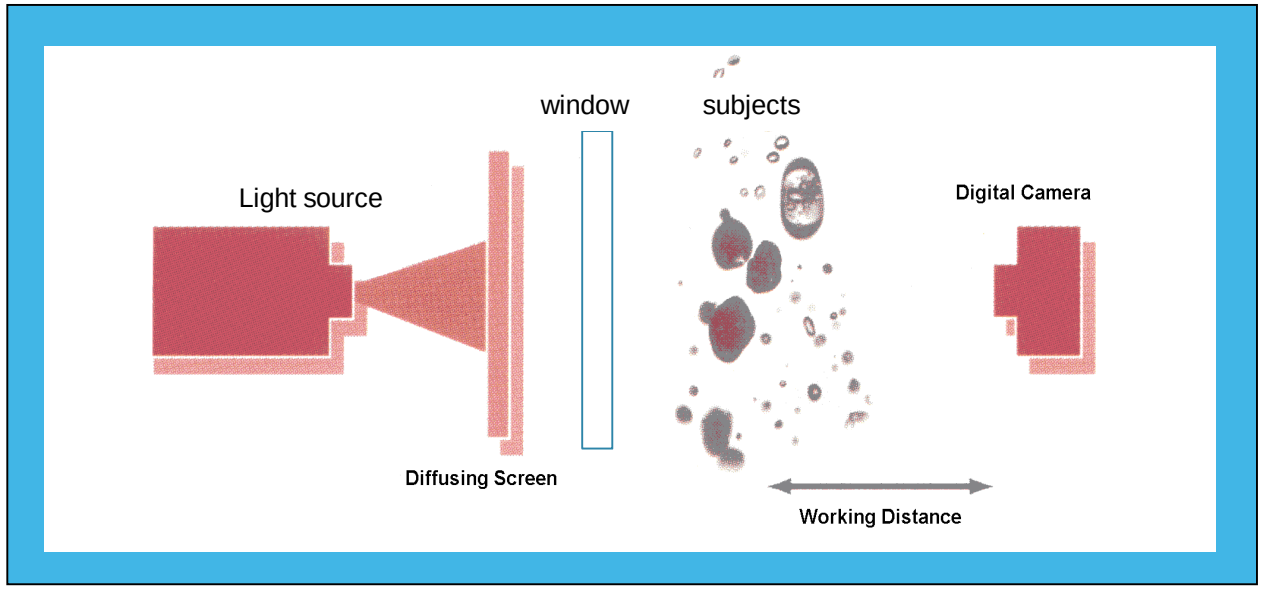


Particles (1.5 ton)
40/70 mesh ceramic proppant

Particle/Droplet Image Analyser (PDIA)

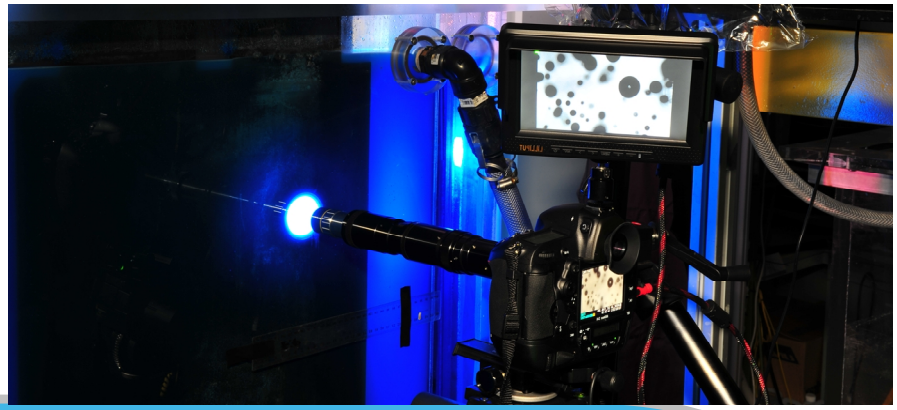
lighting systems

Continuous ARRI® lighting
In-built HID lighting
LED lighting
Broncolor ® Scoro E power pack (flash)



Digital camera

4,928 x 3,280 pixels
Shutter speed = 1/8000 sec
ISO 100 to 12800

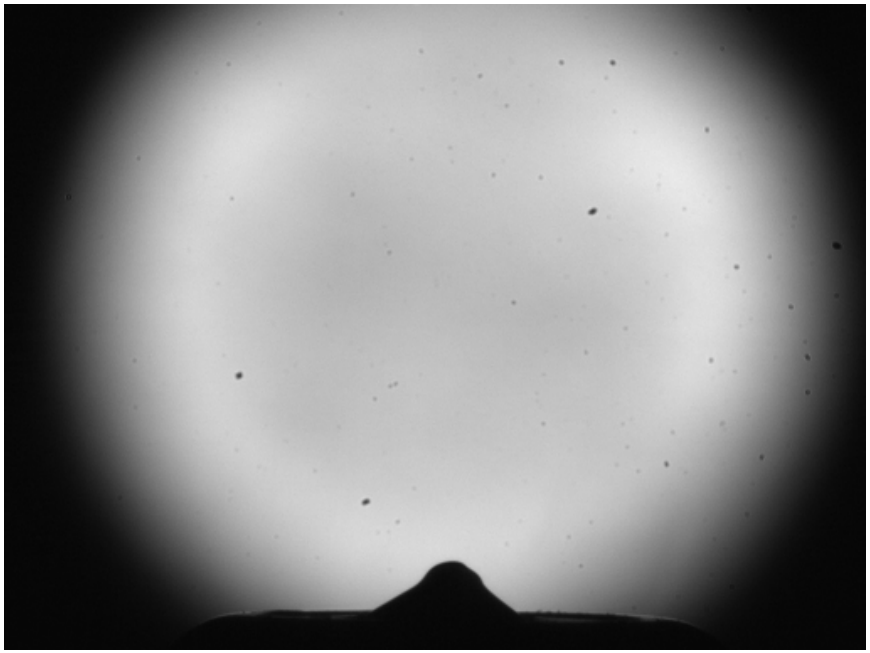


High Speed Diagnostics

Phantom v210 high speed camera

- Resolution: 1280 x 800 pixel
- Max Frame rate: 2,200 fps
- Minimum shutter : 2 µsec

High speed video of Nasal spray



Research team has access to
- v310 (3300 fps) and
- v710 (7500 fps)

Thank you

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