INFLUENCE OF INITIAL TURBULENCE AND CONCENTRATION ON DUST EXPLOSIONS:

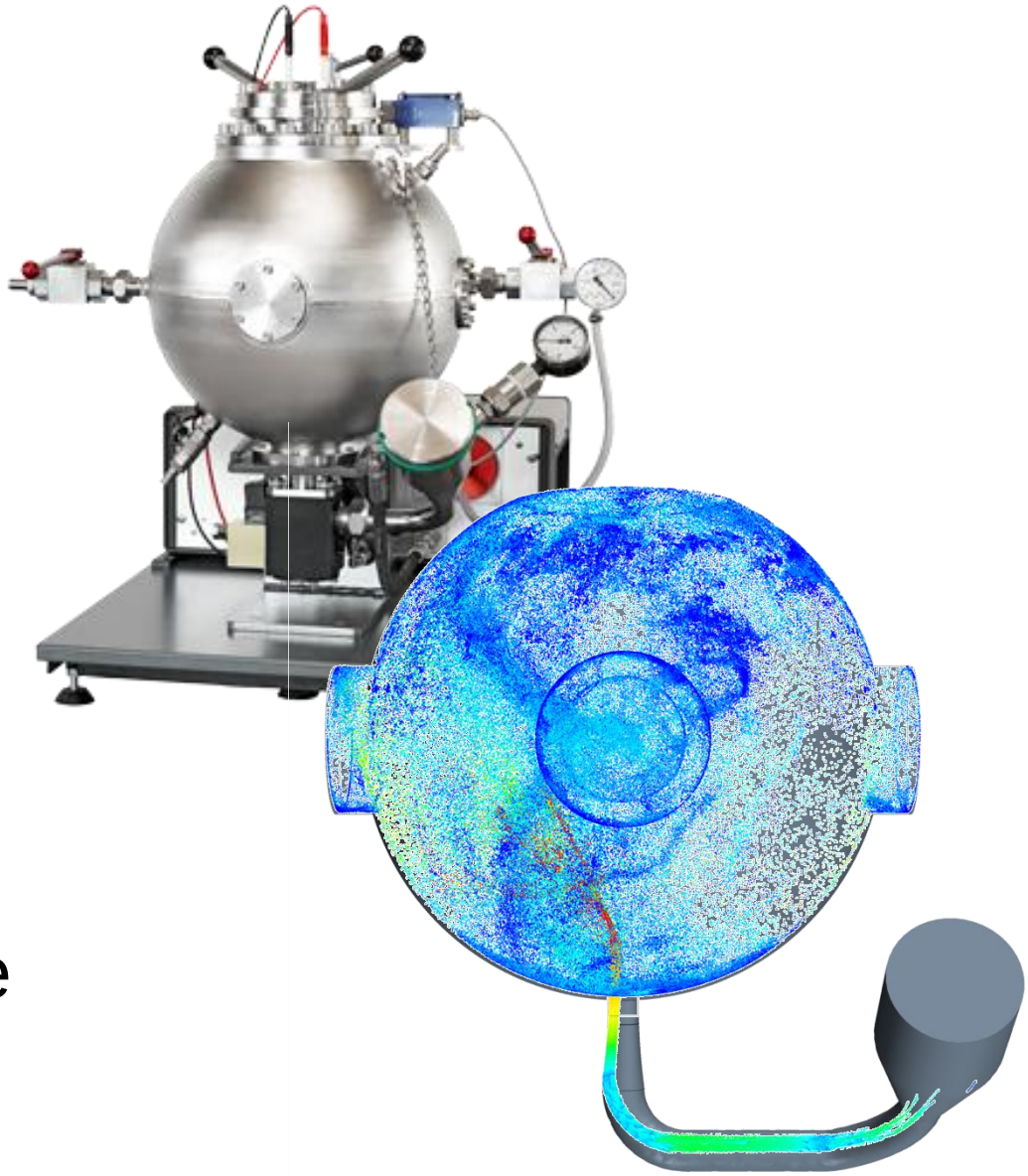
A Combination of Computational and Experimental Approaches

Presented by:

Carlos Murillo, Nathalie Bardin-Monnier, Felipe Muñoz, Daniel Vizcaya, Christian Blanchard & Olivier Dufaud

Outline

- Introduction
- Experimental description of dust dispersion
- Computational description of dust dispersion
- Conclusions & Future Work



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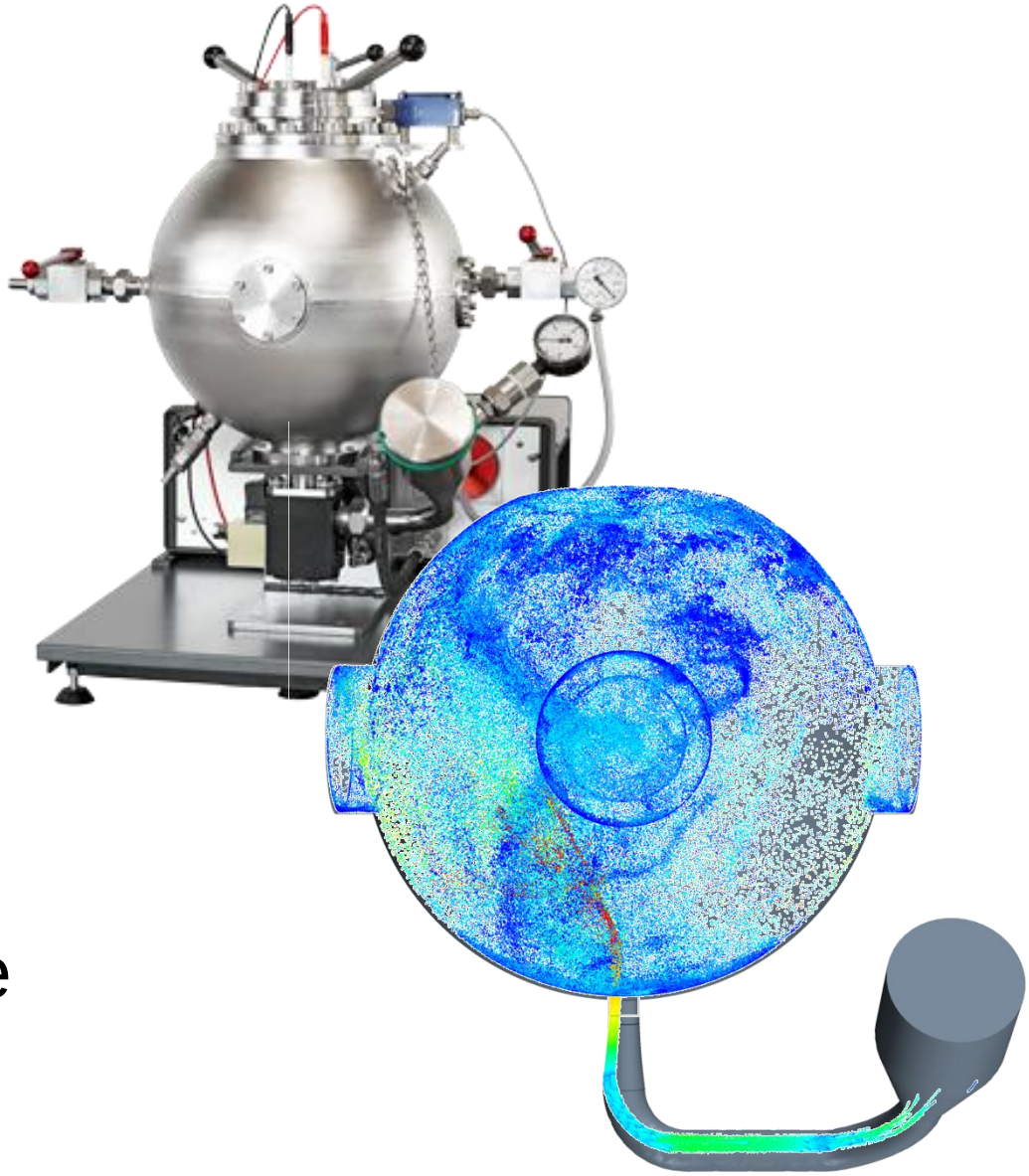
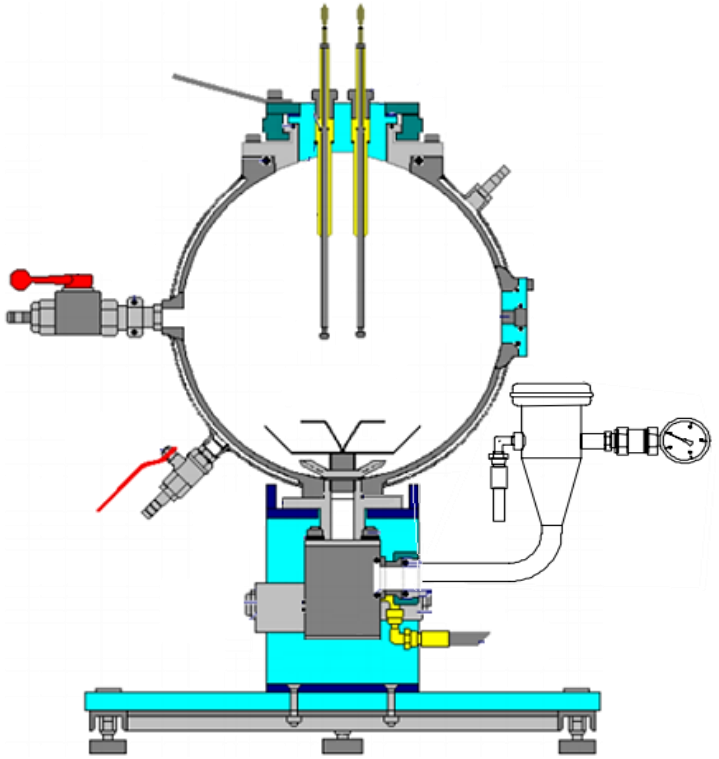


Flammability tests in the 20-L sphere

Determination of flammability parameters of combustible dusts:

- Minimum Explosible Concentration (MEC)
- Maximum pressure rise (P_{max})
- Maximum rate of pressure rise $(dP/dt)_{max}$



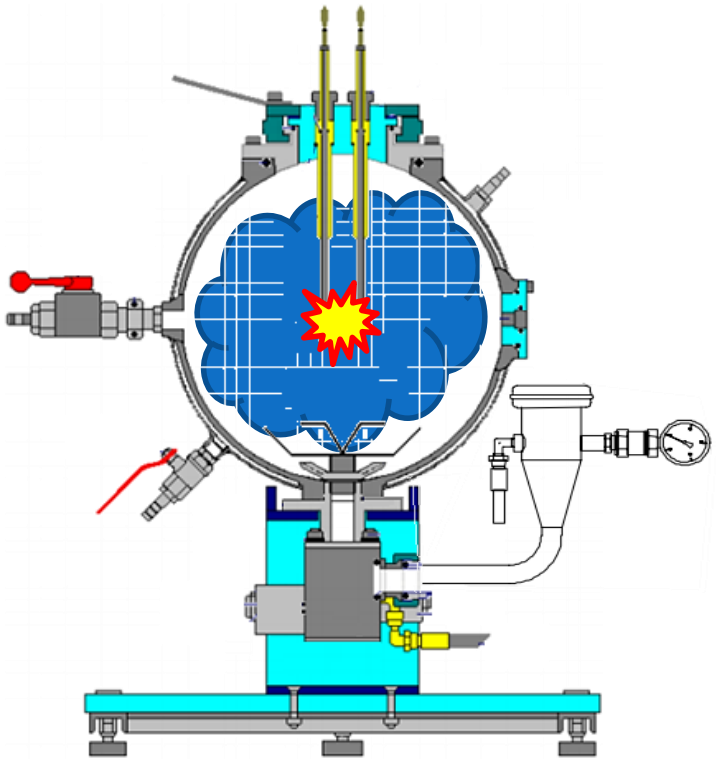
20-L Apparatus
ASTM E2019-03
IEC 241-2-3, 1994

Flammability tests in the 20-L sphere

- Fairly **uniform** dust cloud of the material
- **Injection** of the dust-air mixture in a spherical vessel.
- Ignition of the dust cloud (60 ms)

CHARACTERIZATION OF DUST DISPERSION

- Aerodynamics of the two-phase flow
- Uncertainty levels of the test
- Propagation of the combustion flame



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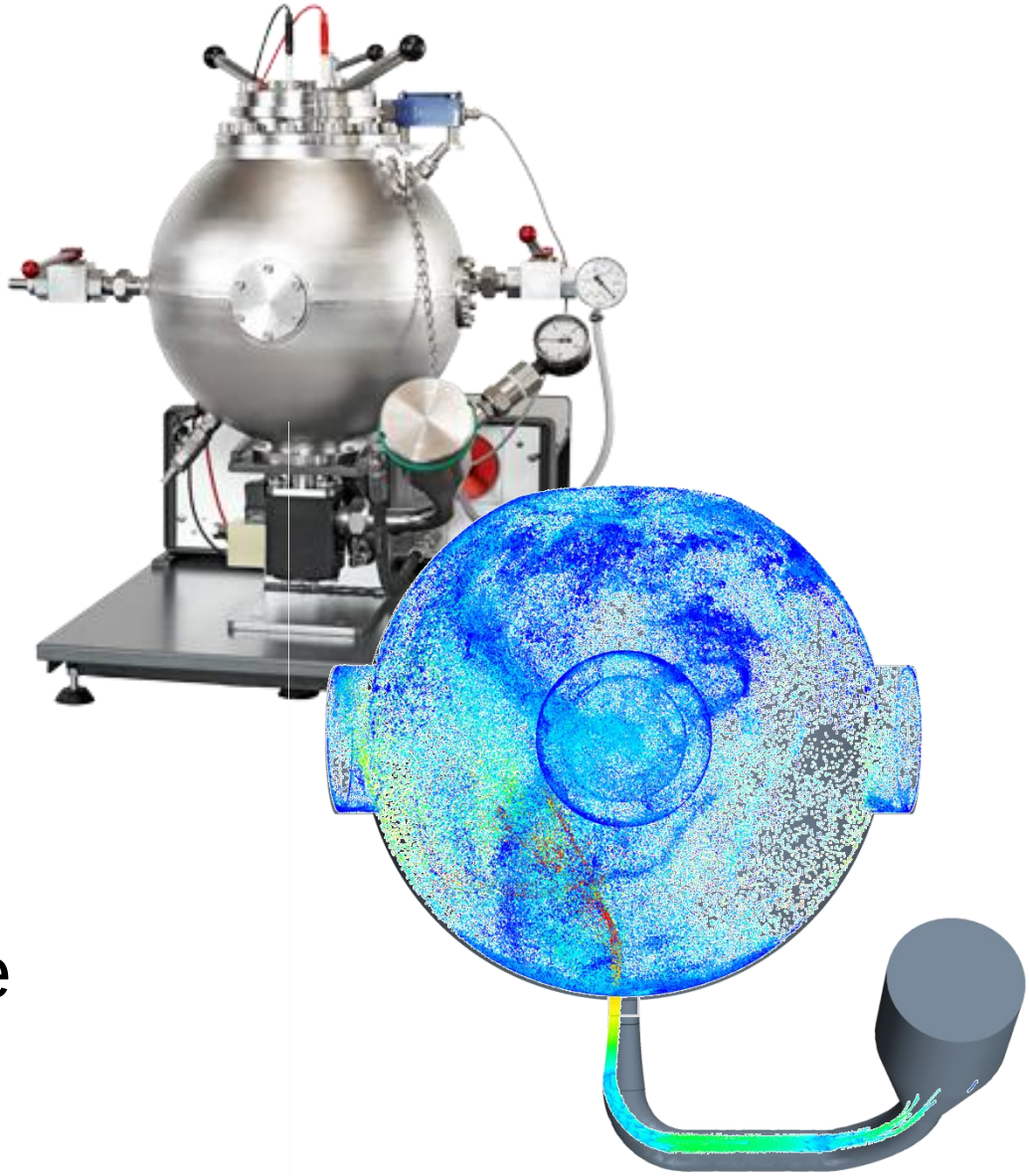


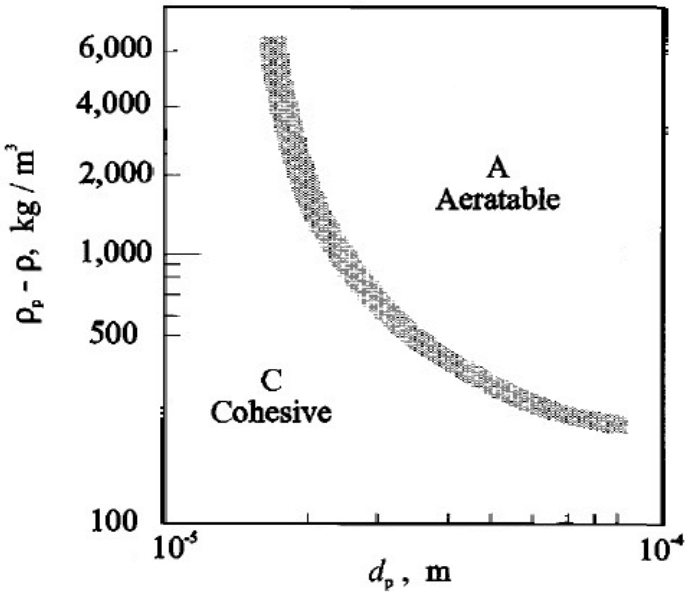
Fluidization of wheat starch

Particle's diameter (μm)	Archimedes Number (Ar)
29	3.3
37	7.5
65	41.2
81	78.1
83	85.2
87	96.6

$$Ar = \frac{d_p^3 \rho_f \ \rho_p - \rho_f \ g}{\mu^2}$$

$$\rho_{ad} = \ \rho_p - \rho_f \ / \rho_f$$

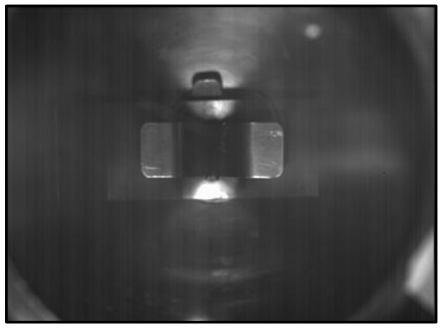
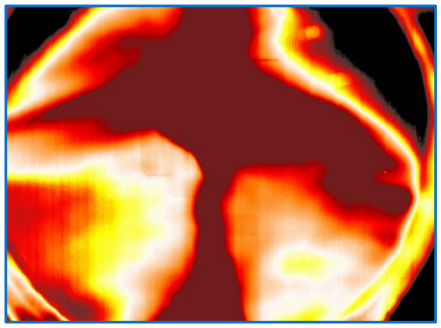
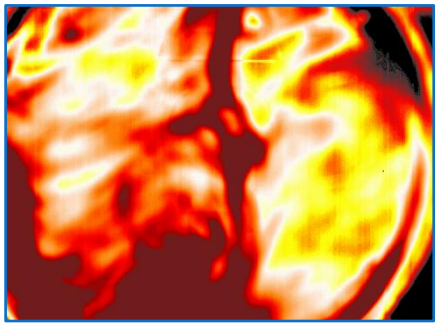
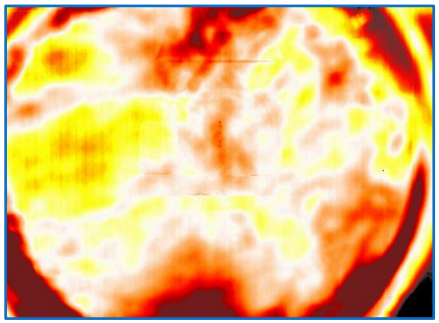
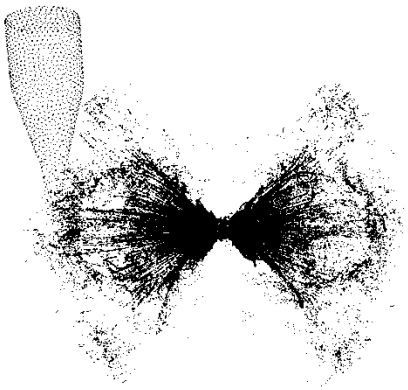
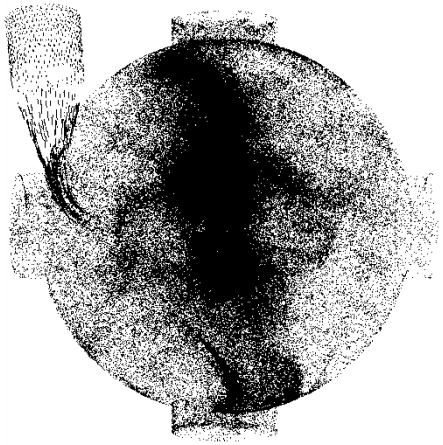
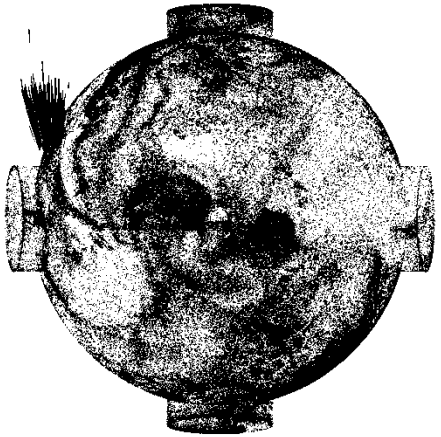
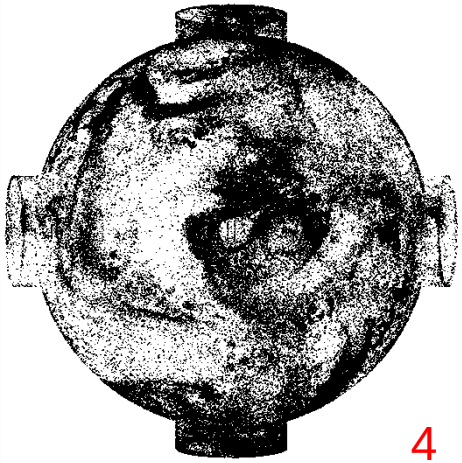
MODIFIED GELDART'S CLASSIFICATION OF POWDERS



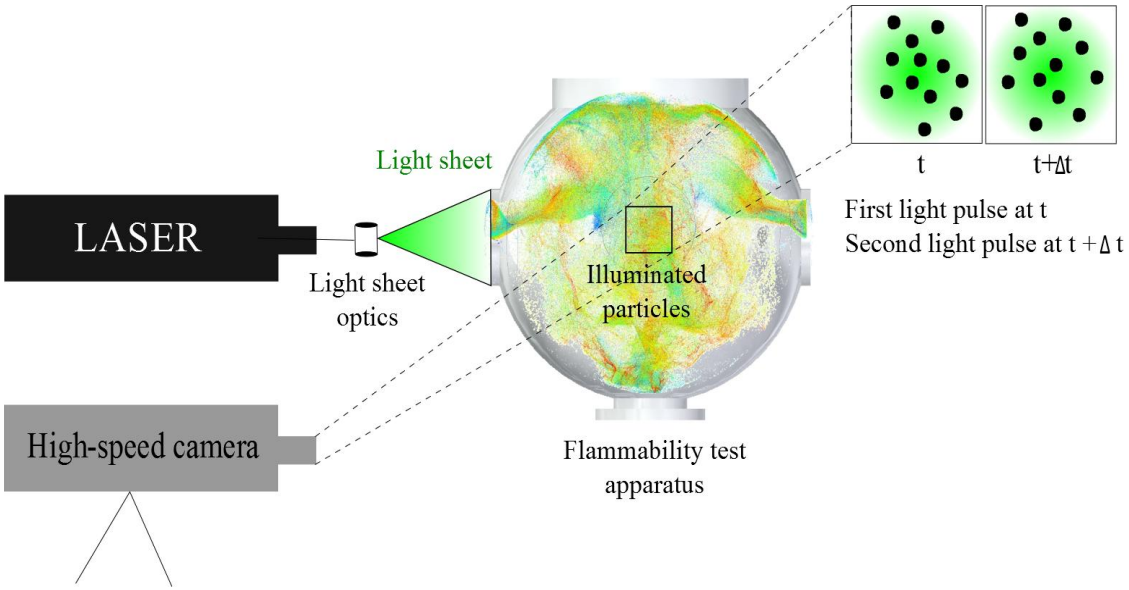
Group A:
Several desirable fluidization characteristics. They expand homogeneously in fluidized beds.

Group C:
Difficult fluidization characteristics. Cohesive behavior

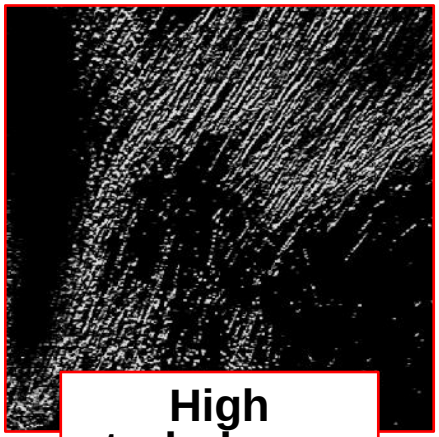
Dispersion of micrometric wheat starch within the 20-liter sphere

		10 ms	**60 ms**	**100 ms**
	Injection	Jets collision	Standard ignition delay	Extended ignition delay
High speed video				
CFD simulation				

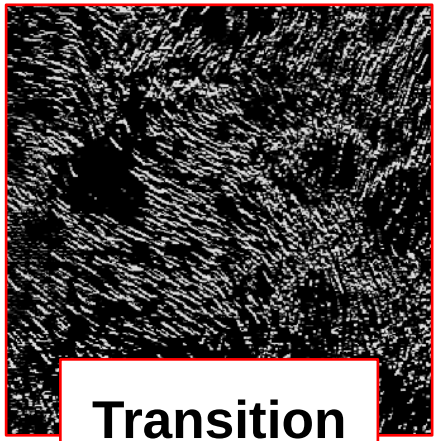
Particle Image Velocimetry



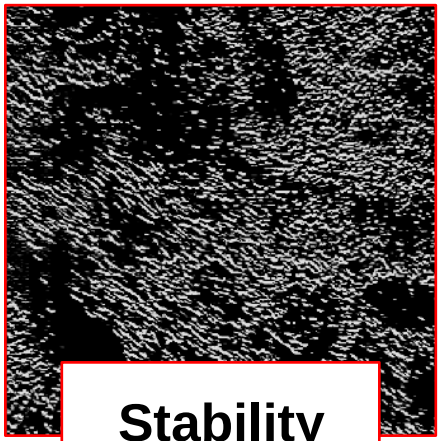
- The settings of the camera were adjusted to visualize a region of 3.0 cm x 3.0 cm.
- Framerate: 6,400 fps (0.16 ms).



High turbulence

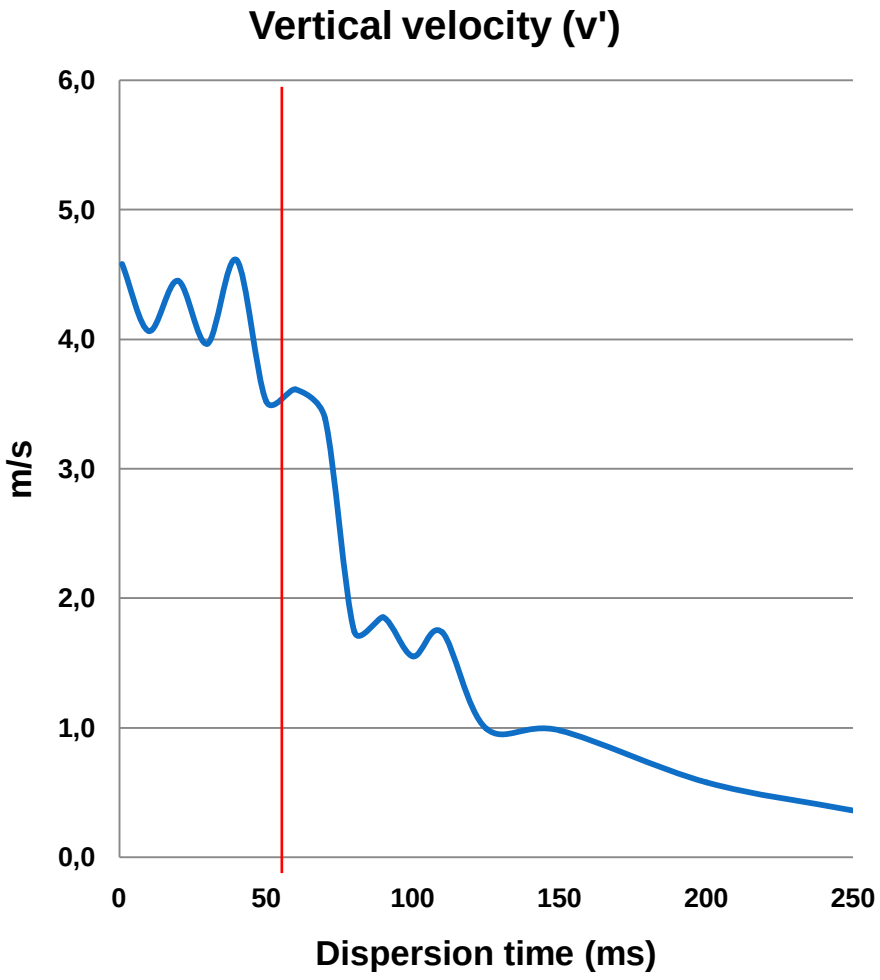


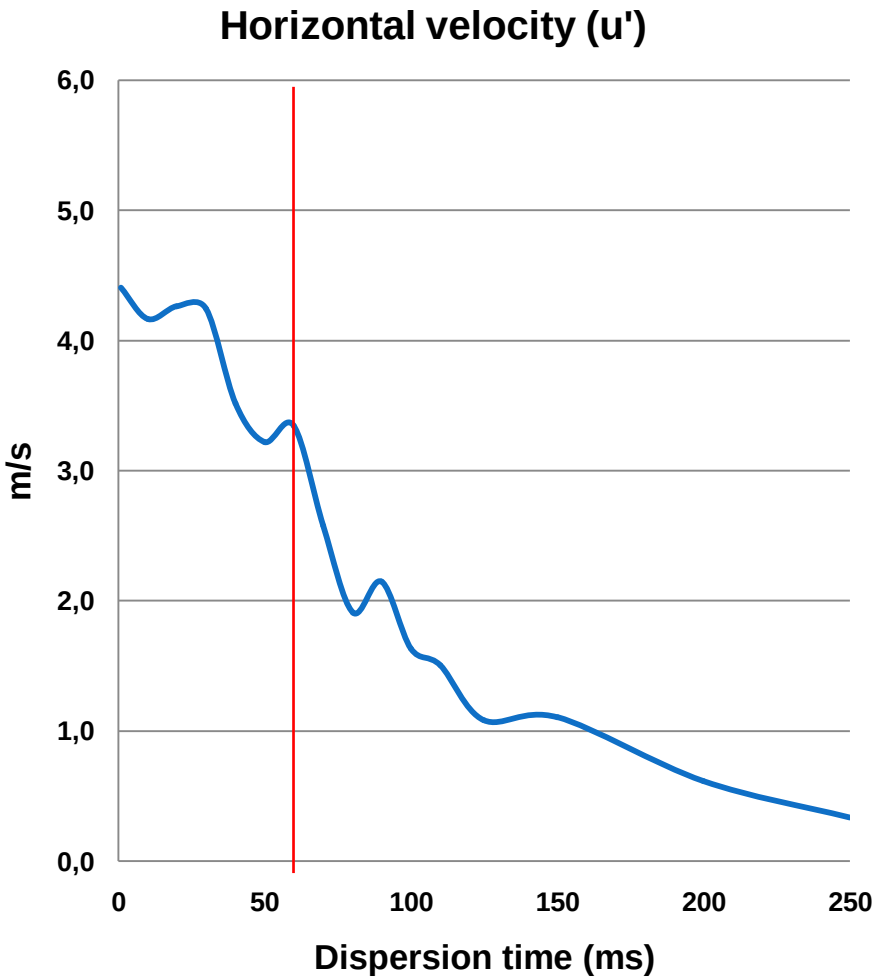
Transition



Stability

Particle Image Velocimetry





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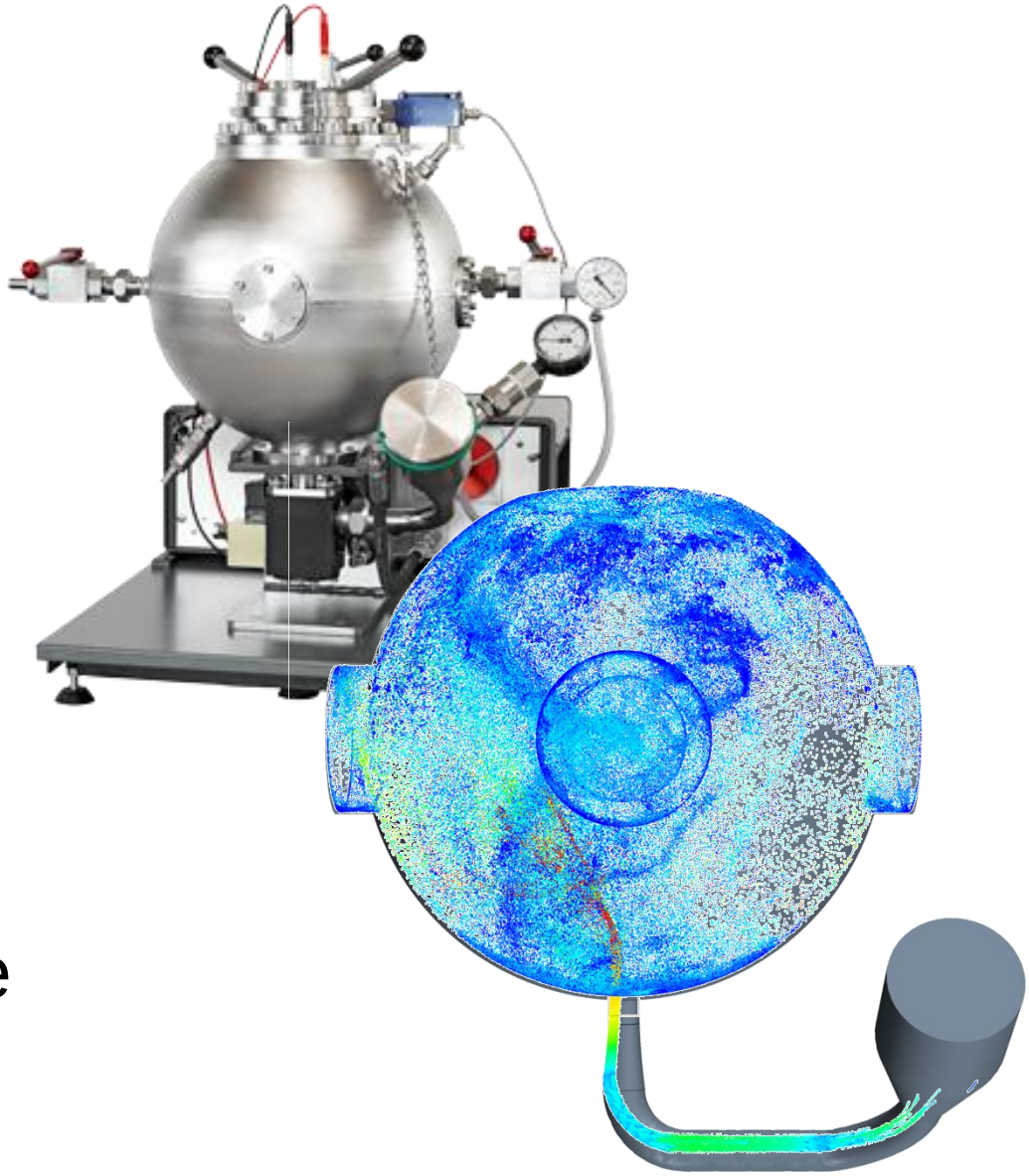


Computational Fluid Dynamics

EULER-LAGRANGE APPROACH
(Φ_{SOLIDS} < 10%)

CONTINUOUS PHASE (EULERIAN)
Dispersion gas

Navier-Stokes equations

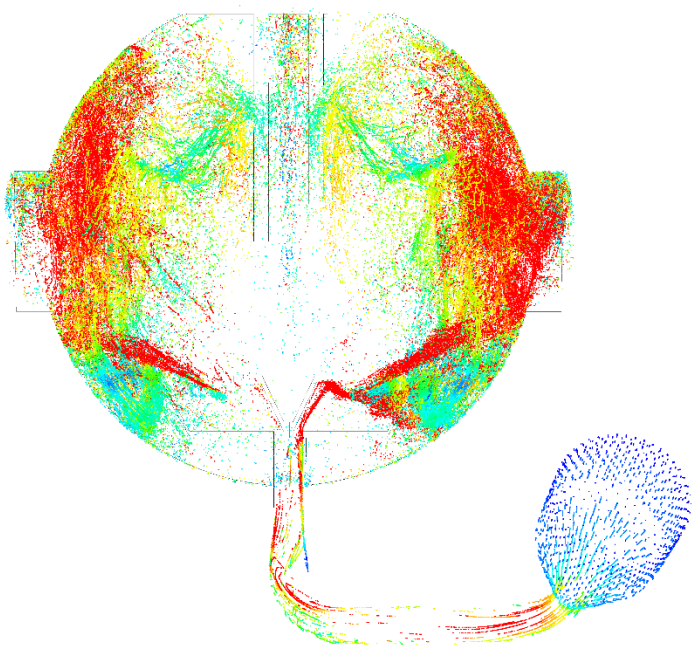
Turbulence model: Detached Eddy Simulations.
RANS model: Boundary layer
LES model: Core region of the fluid flow

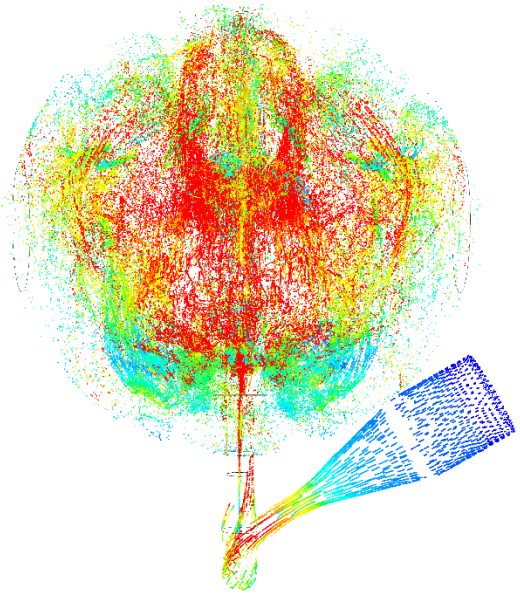
DISCRETE PHASE (LAGRANGIAN)
Combustible dust

Momentum balance
-Drag force (Relative velocity)
-Shear lift force
-Pressure gradients

-Coefficients of restitution (particles & walls)
Normal:0,25
Tangential:0,20

Computational results

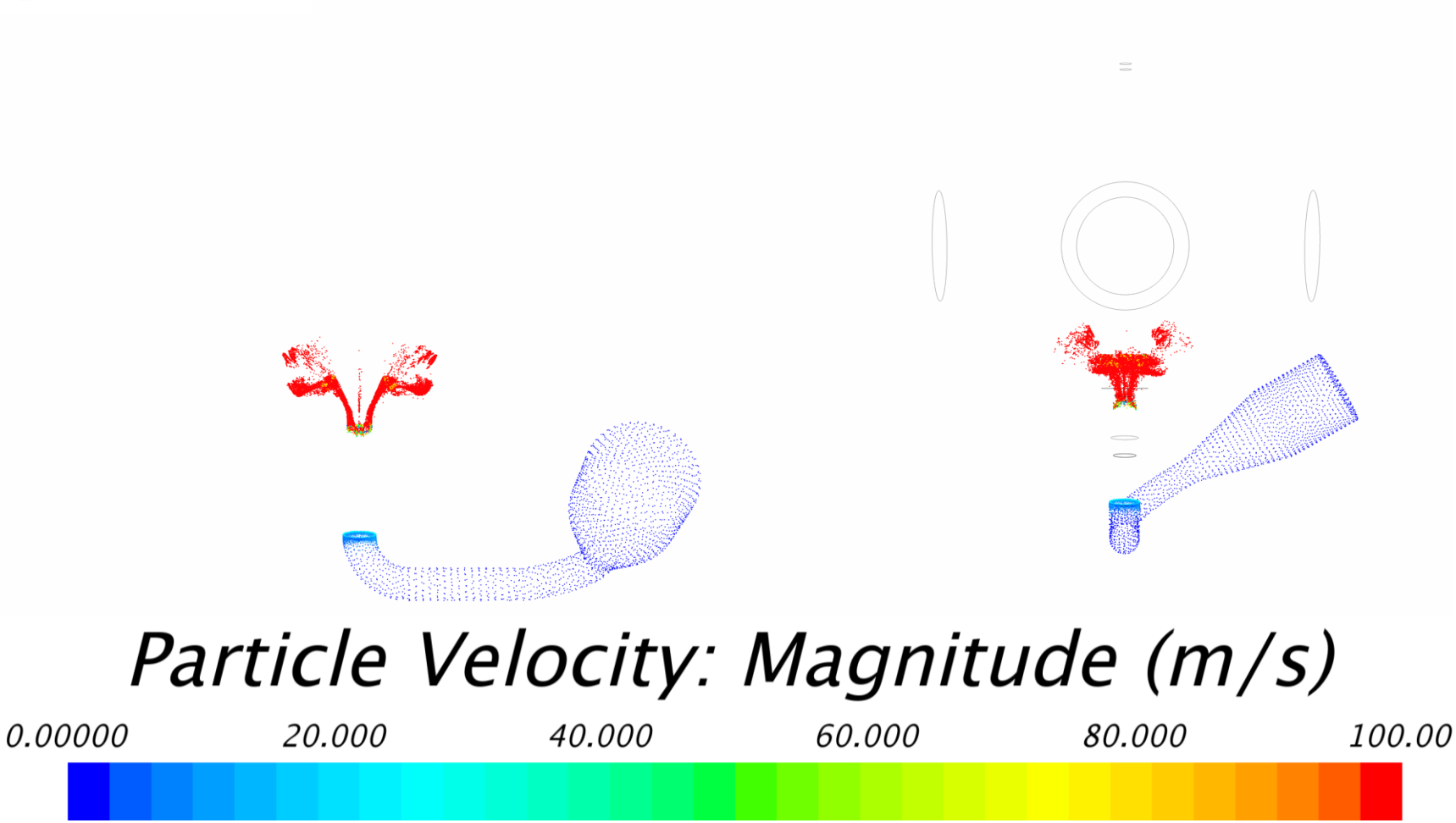




Computational results

STAR-CCM+

0.5 ms



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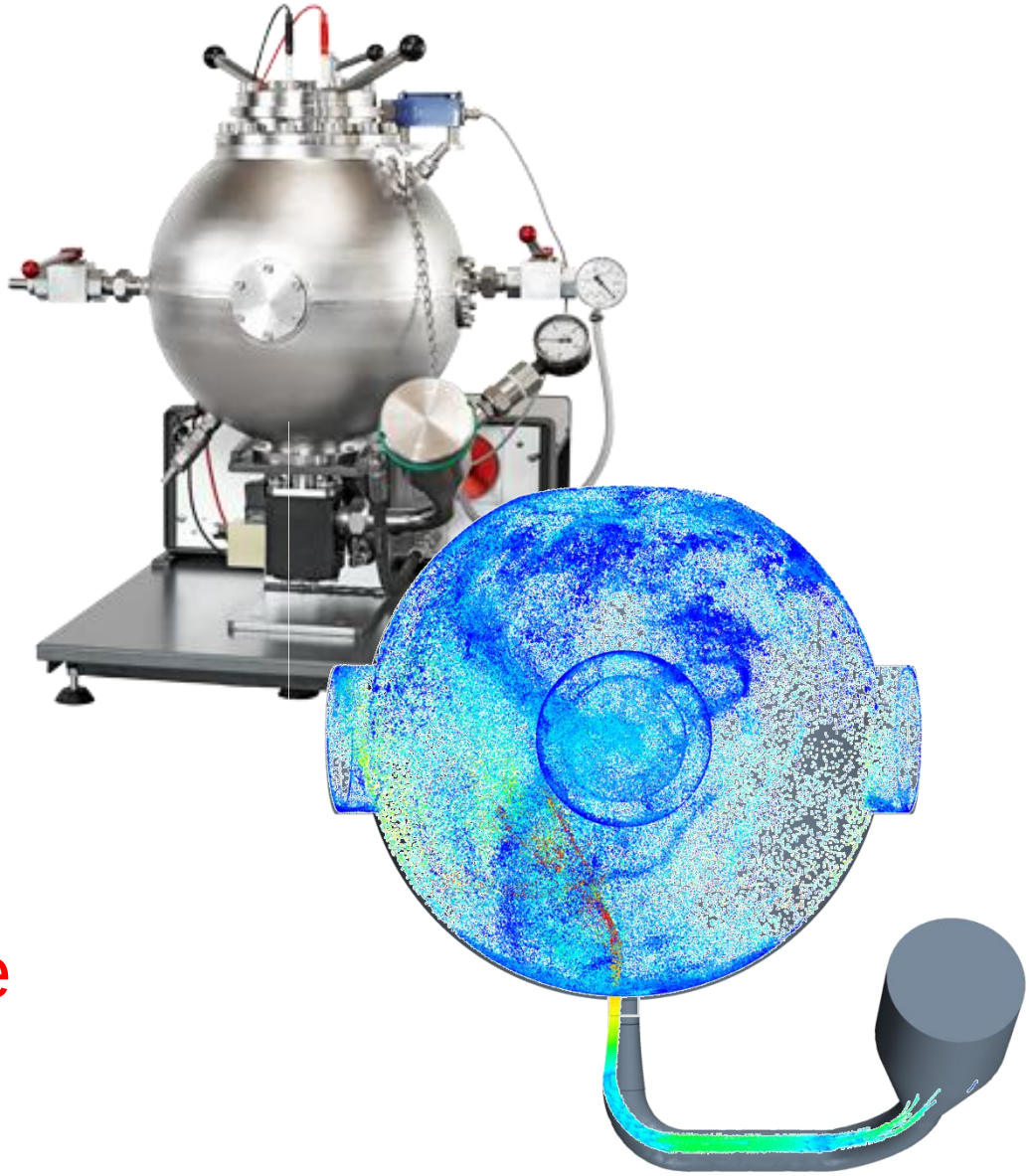


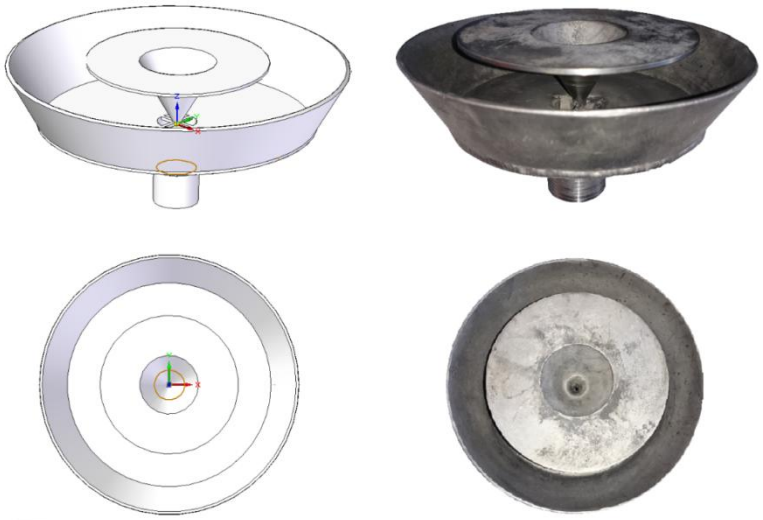
- The ignition delay for micrometric wheat starch must be established between 60 and 80 ms.
- The computational analyses can become a useful tool for the development of a flammability test due to their capability of describing the development of a combustible cloud.

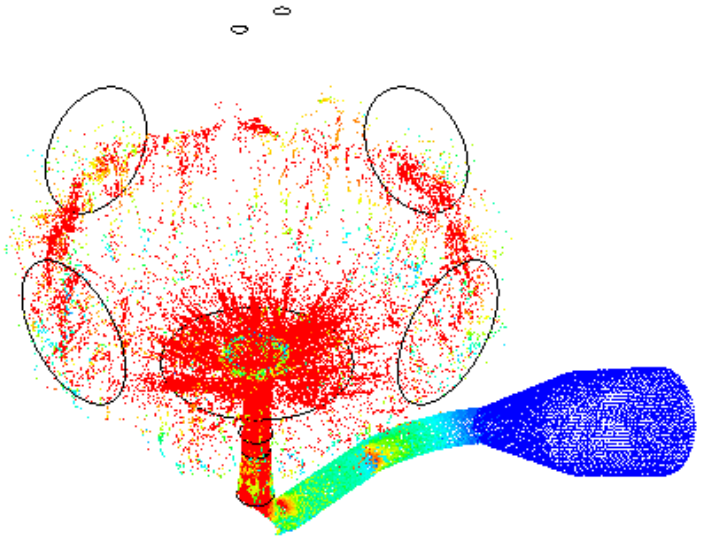
➡ Ignition delay

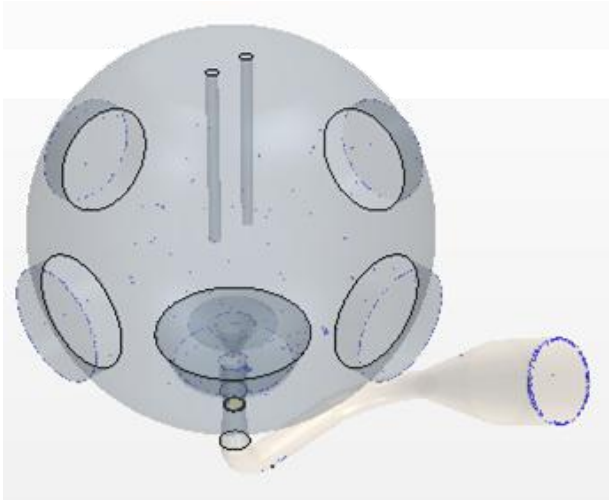
Perspective

- Compare different types of combustible dusts in order to characterize properly the influence of their physical properties
- Develop a comparative analysis of diverse injection nozzles to identify new alternatives that provide more uniformity and stability to the dust cloud

Perspective







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