Gruppo di Ingegneria Chimica

PRocess Intensification in Multiphase Equipment (PRIME)

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ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

Chemical Engineering Research Group

## Process Intensification in Multiphase Equipment (PRIME)

Our research group is focused on process intensification in multiphase equipment, and it consists of the following:

A computational focused activity

- ✓ Computational Fluid Dynamics for equipment modelling, design and scale-up
- ✓ Multiscale modelling coupling different computational techniques

An experimental focused activity

- ✓ Particle Image Velocimetry for Fluid flow measurements
- ✓ Planar Laser induced Fluoresce and Electrical (Capacitance) Resistance Tomography for mixing time and concentration field measurements in single and multi-phase systems.
- ✓ Malvern Mastersizer for drops or solid particles size distribution measurement
- ✓ Rheometer Anton Paar MCR 92 for Rheological characterization
- ✓ Other imaging techniques for visualization and characterization

UNDERSTAND PREDICT INNOVATE
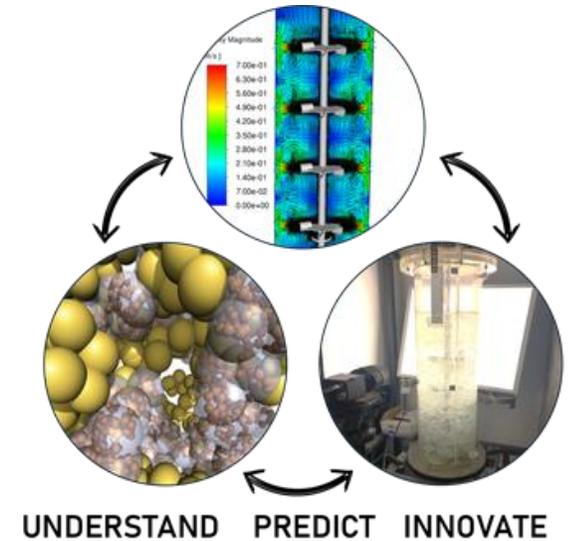
Experimental investigation support understanding of fundamental physical phenomena and their interaction with chemical and biochemical reactions for model development and validation.

People, Activities, Expertise and Research Topics

Prof. Alessandro Paglianti: Development of optical and tomographic experimental techniques and modelling methods for innovative equipment for the chemical and biochemical industry.

Prof. Giuseppina Montante: Development of modelling technique based on Computational Fluid Dynamics supported by experimental investigation for the study of innovative processes in the chemical and biochemical industry

Prof. Nicodemo Di Pasquale: Development of multi-scale models with approaches ranging from microscopic (Molecular Dynamics) to macroscopic (CFD) applied to chemical processes and systems

Prof. Francesco Maluta: Development of multi-scale approach using numerical simulations of innovative processes in the chemical and biochemical sector including Open- Source software.

Prof. Federico Alberini: Development of experimental techniques (PIV, ERT, passive acoustic), coupling traditional and Machine Learning methodologies.

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Experimental techniques based on optical methods

Particle Image Velocimetry (PIV)

Laser source

Continuous phase
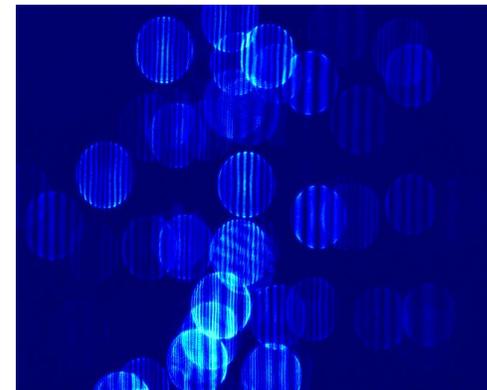
Dispersed phase

Size Distribution of Bubbles, Droplets and Particles

Digital image analysis
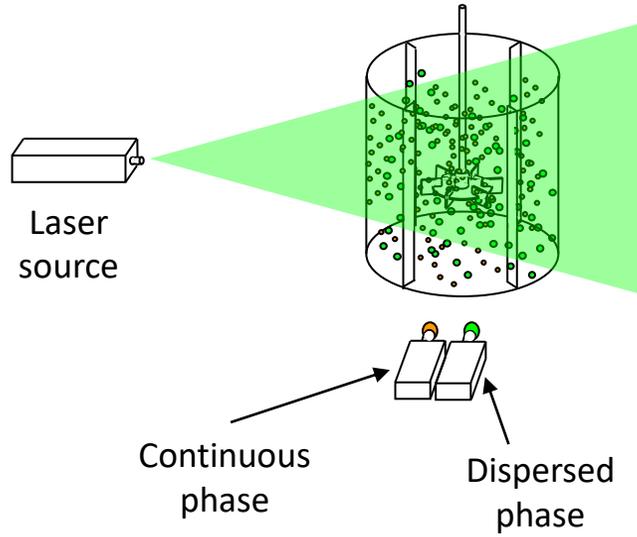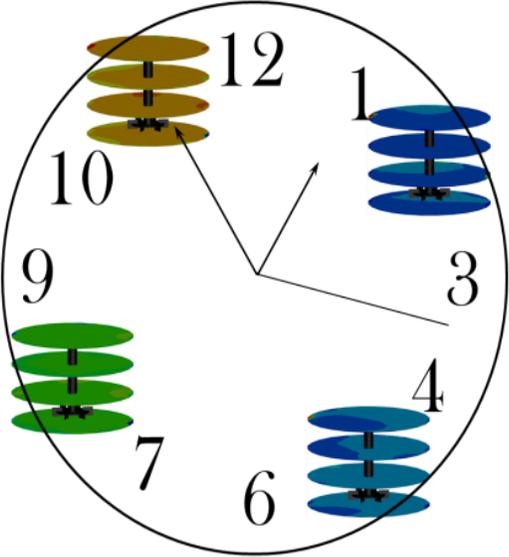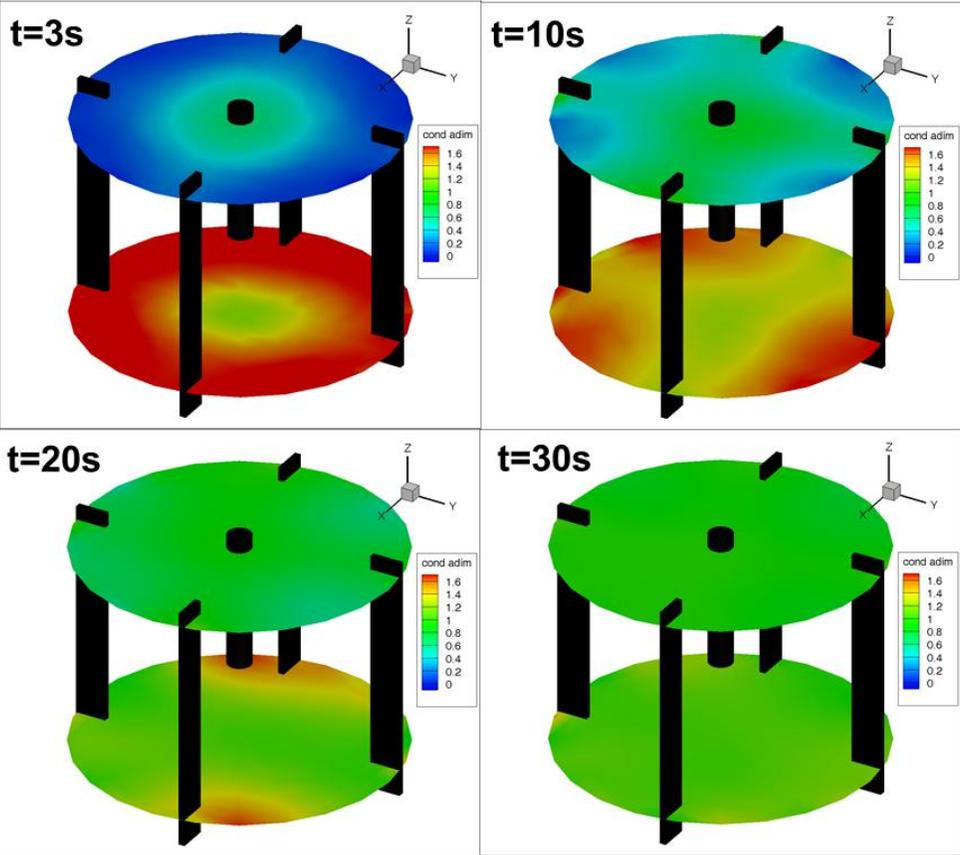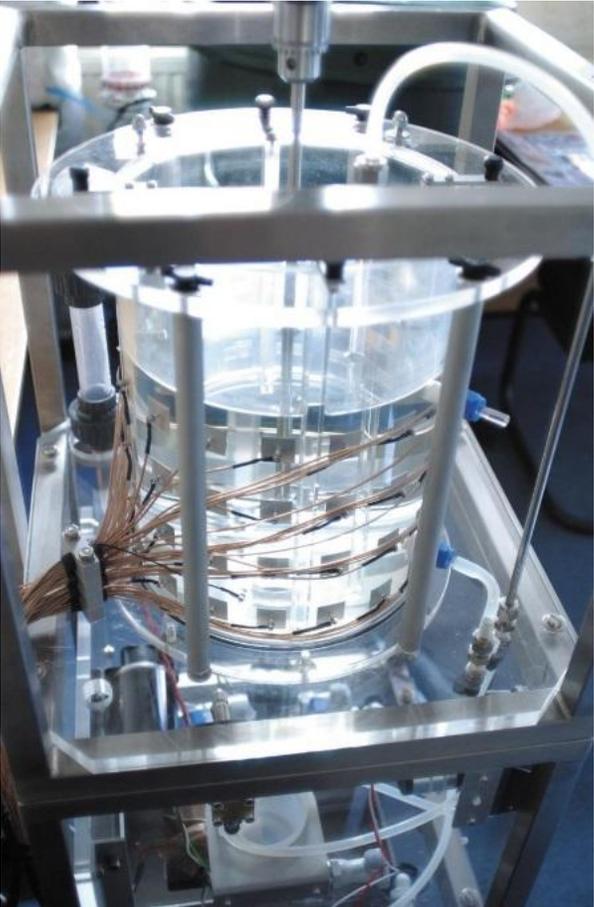

Laser diffraction

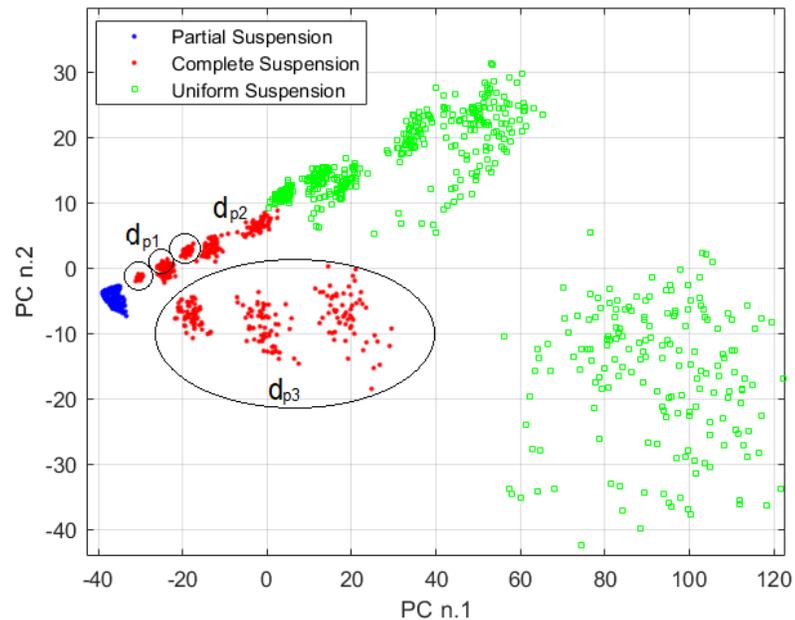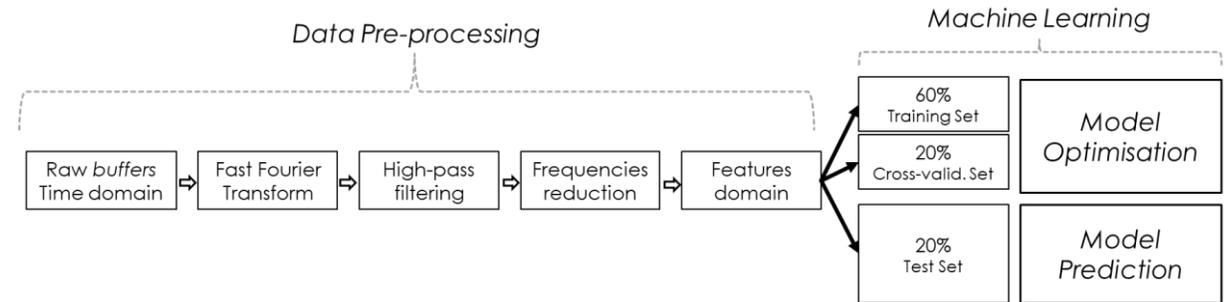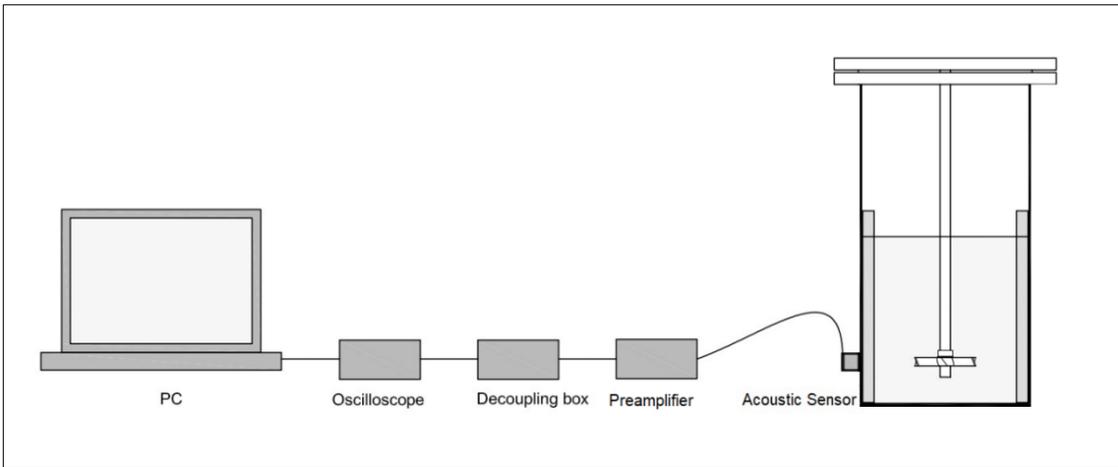## Planar Laser Induced Fluorescence (PLIF)

BAFFLE

IMP

Laser Plane
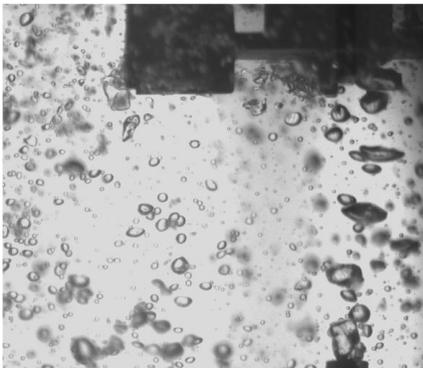
Interferometric Particle Imaging

Experimental techniques based on Tomographic methods

Concentration distribution and mixing time measured by Electrical Resistance Tomography (ERT)

Experimental techniques based on acustic methods

Passive Acoustic Emission and Machine Learning


Same approach can be used:
- Monitoring gas-liquid mixture;
- Monitoring solid-liquid mixture;
- Monitoring of pressurized vessels behavior;
- In pipe or vessel systems;
- Coupling different sensor technologies including PAE for digital twin;

Experimental investigation for complex fluids characterization

Rheological Characterization for the Study of Non-Newtonian Fluids
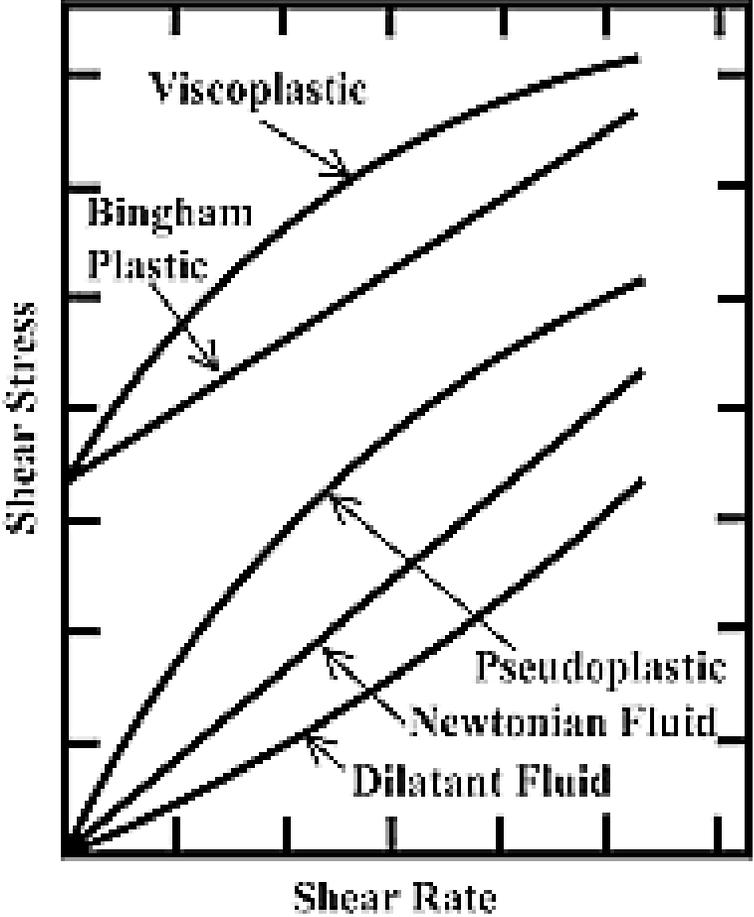
Applied to Complex (Multiphase) Systems, such as Emulsions

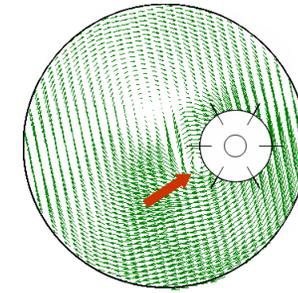# Equipment simulation based on Computational Fluid Dynamics modelling
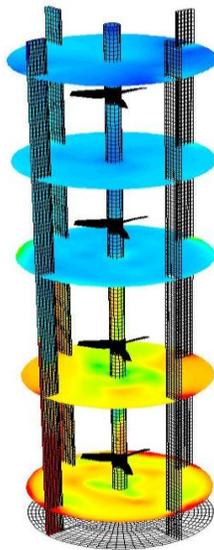
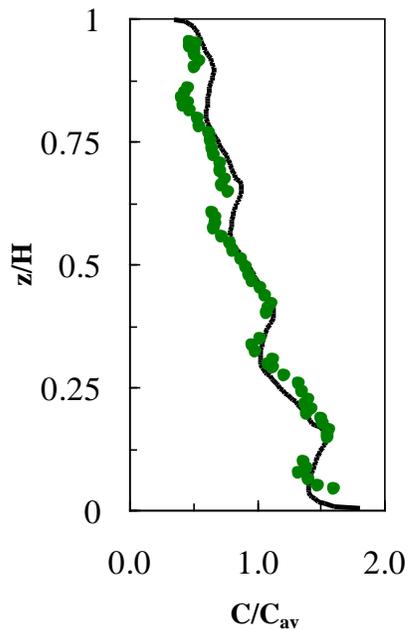## Gas-solid fluidized beds
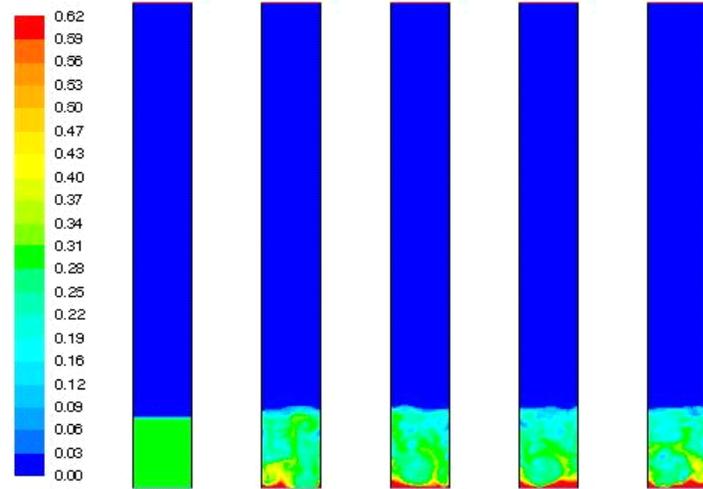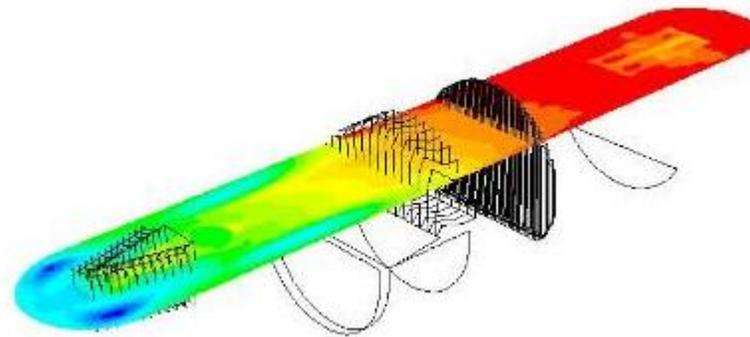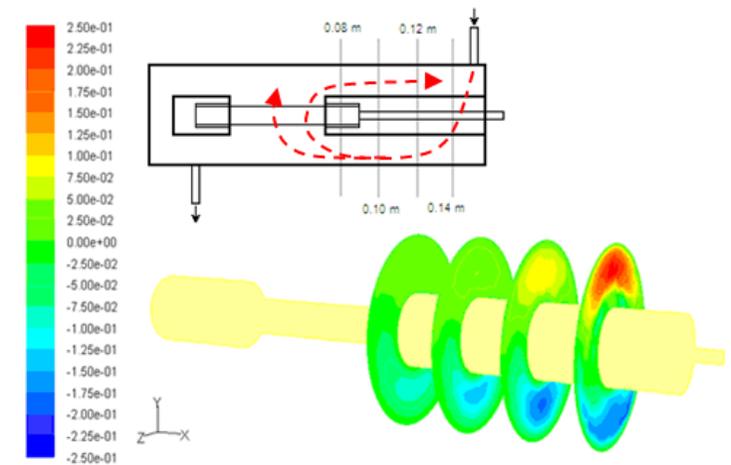
Turbulent liquid mixing
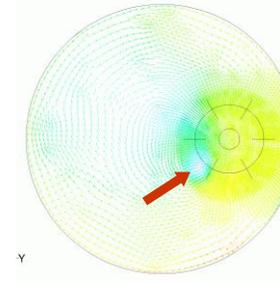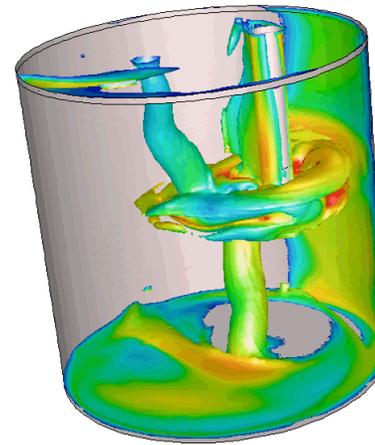
CFD

PIV data

Multiphase stirred reactors

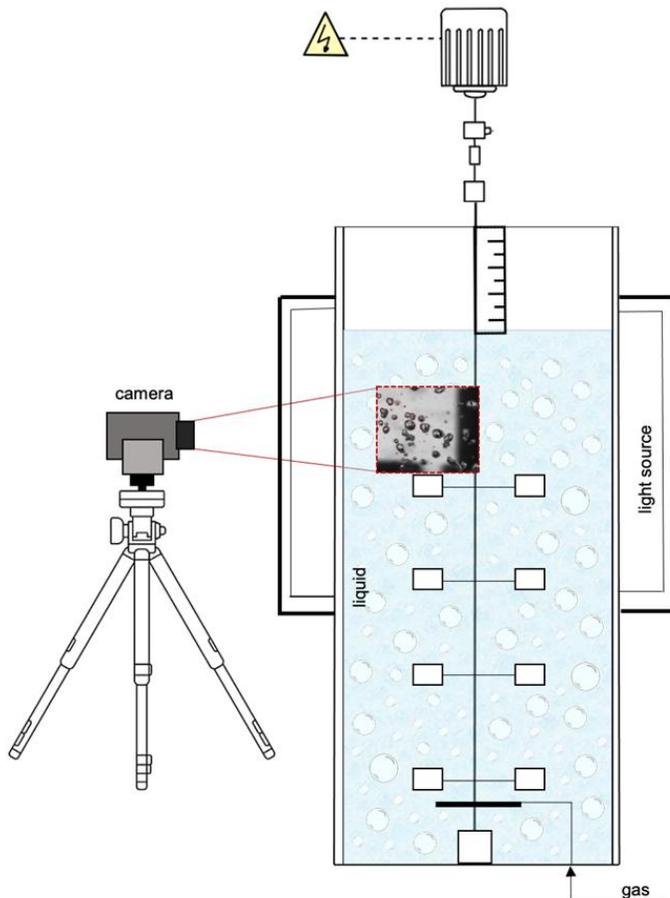## Inertial separator for oil and gas applications

Membrane modules

1. Modelling Methods For Improving The Scale-up Of Industrial Gas-liquid Stirred Reactors
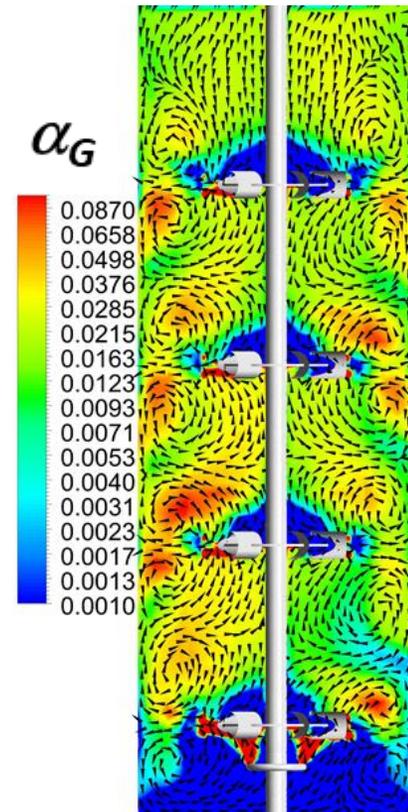
Main target of the project: scale-up of multiphase reactors for <u>gas-liquid mass transfer-limited chemical processes</u> based on Computational Fluid Dynamics.

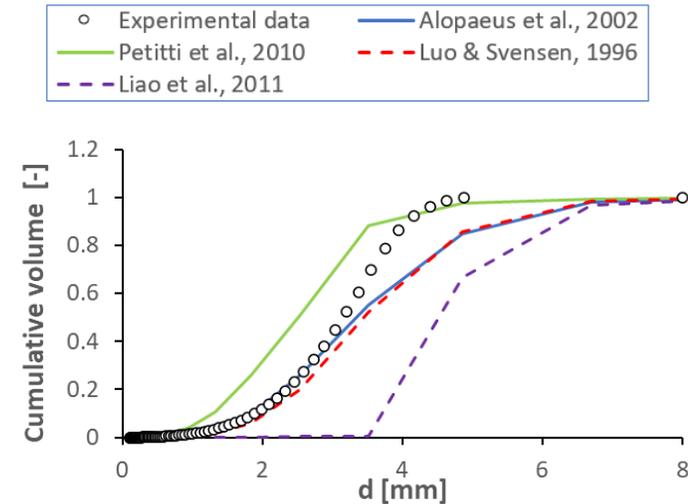Application: Scale-up of a lab scale reactor for CO_2 capture and storage

Experimental characterization

Modelling and simulation

α_G

0.0870
0.0658
0.0498
0.0376
0.0285
0.0215
0.0163
0.0123
0.0093
0.0071
0.0053
0.0040
0.0031
0.0023
0.0017
0.0013
0.0010

Model validation

	Experimental data	Alopaeus et al., 2002
Petitti et al., 2010	Luo & Svensen, 1996
Liao et al., 2011	

Experimental P_G: 9.3 W
Experimental α_G: 1.7%

	(1)	(2)	(3)
$P_{G,\varepsilon}$ (W)	7.7	9.1	7.9
$P_{G,T}$ (W)	9.7	11.0	11.2
α %	1.5	1.5	1.6

2. Study and Characterization of Non-Conventional Stirred Reactors Used in the Pharmaceutical Industry in Single-Phase or Solid–Liquid Systems
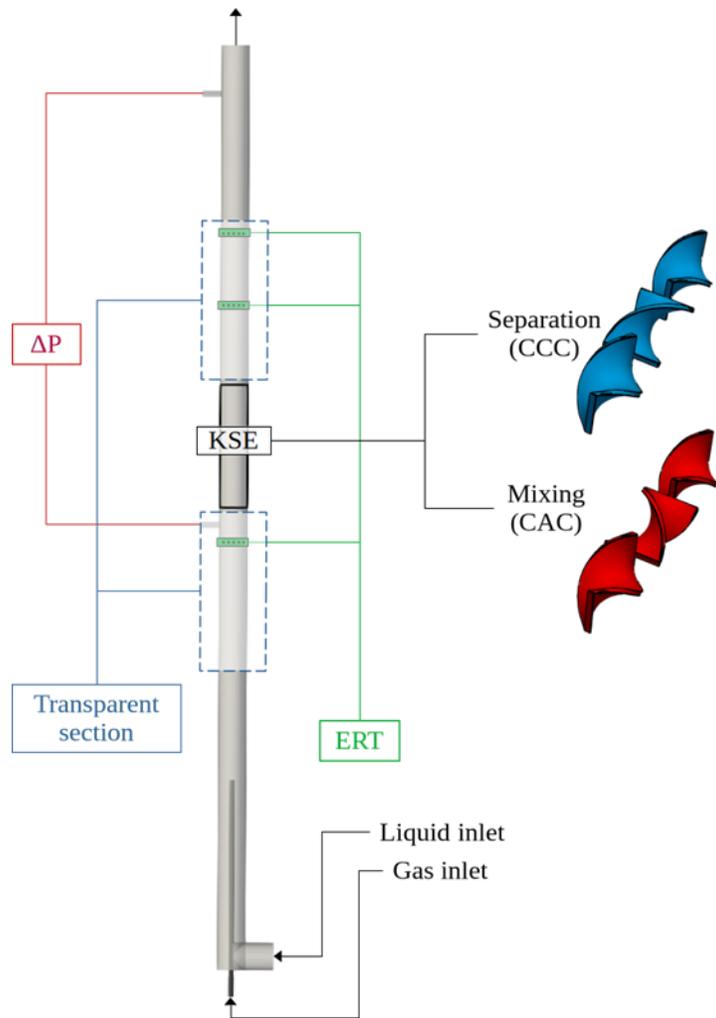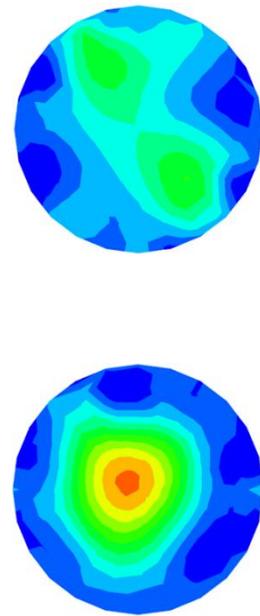
Optical Techniques
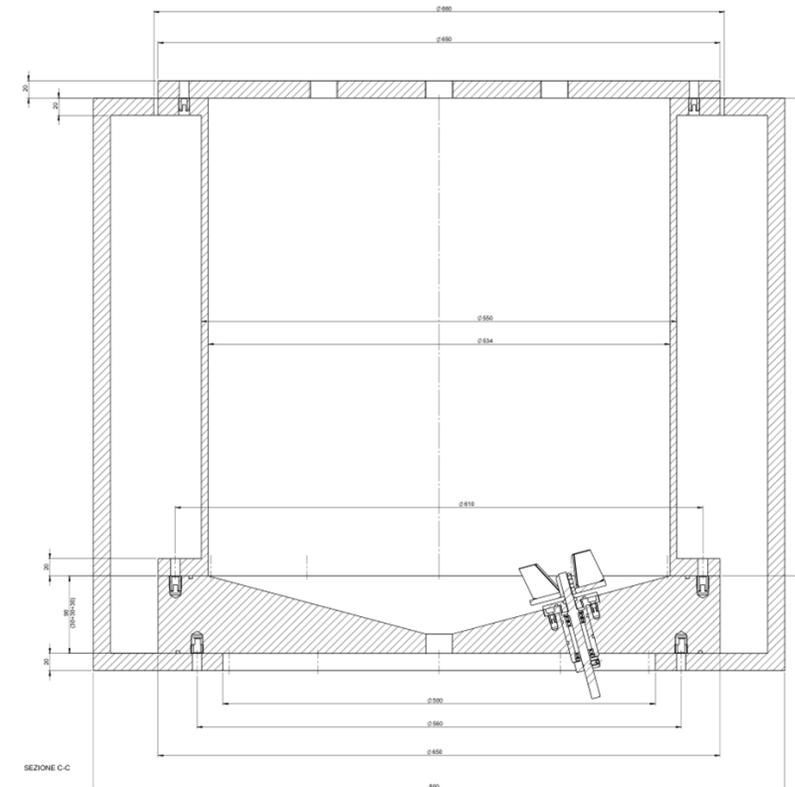
Industrial sensor (Torque meter) / Analysis of signal in time or in frequency

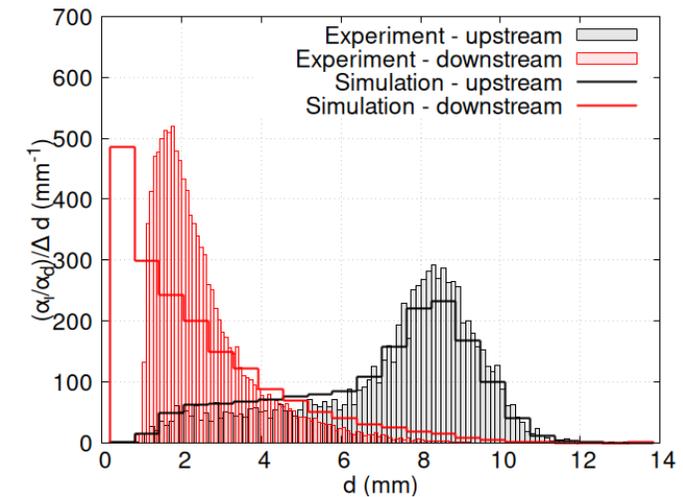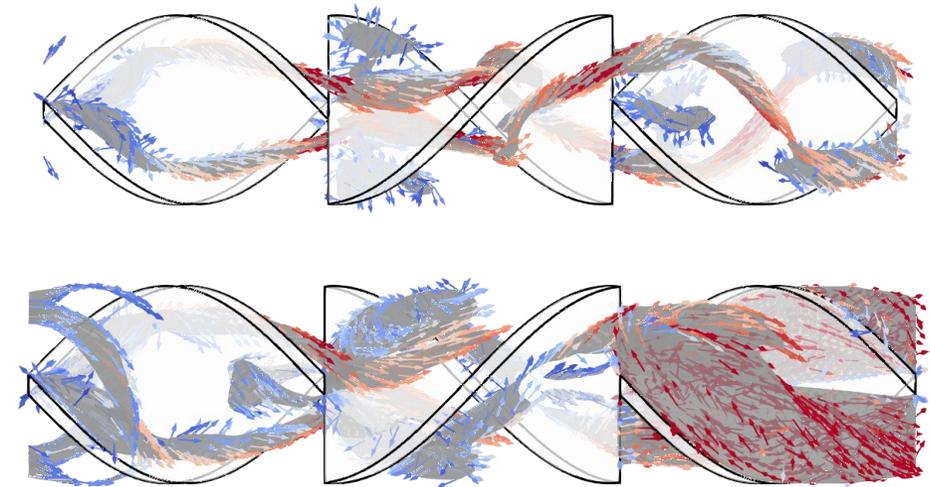# 3. Experimental Investigation and Modeling af Gas-liquid Mixing, Absorption and Separation In Continuos Reactors

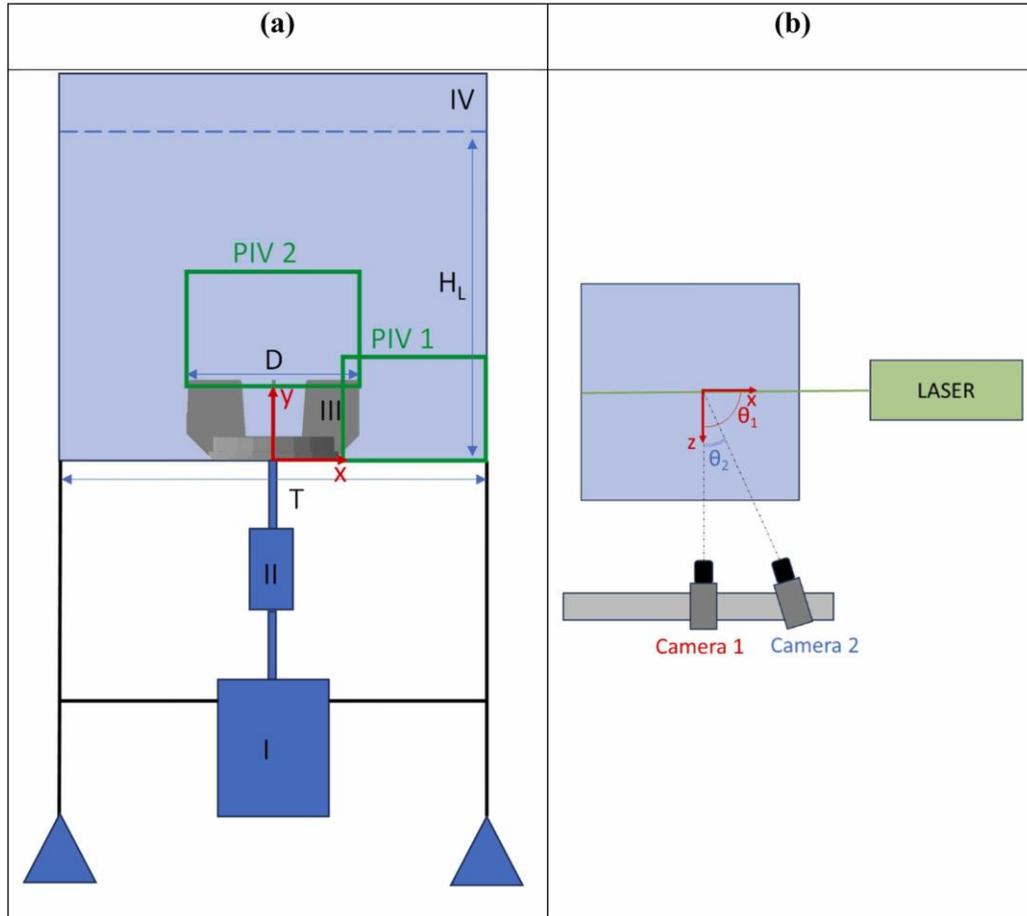Optical Techniques / Industrial sensors (Pressure drop) /signal analysis
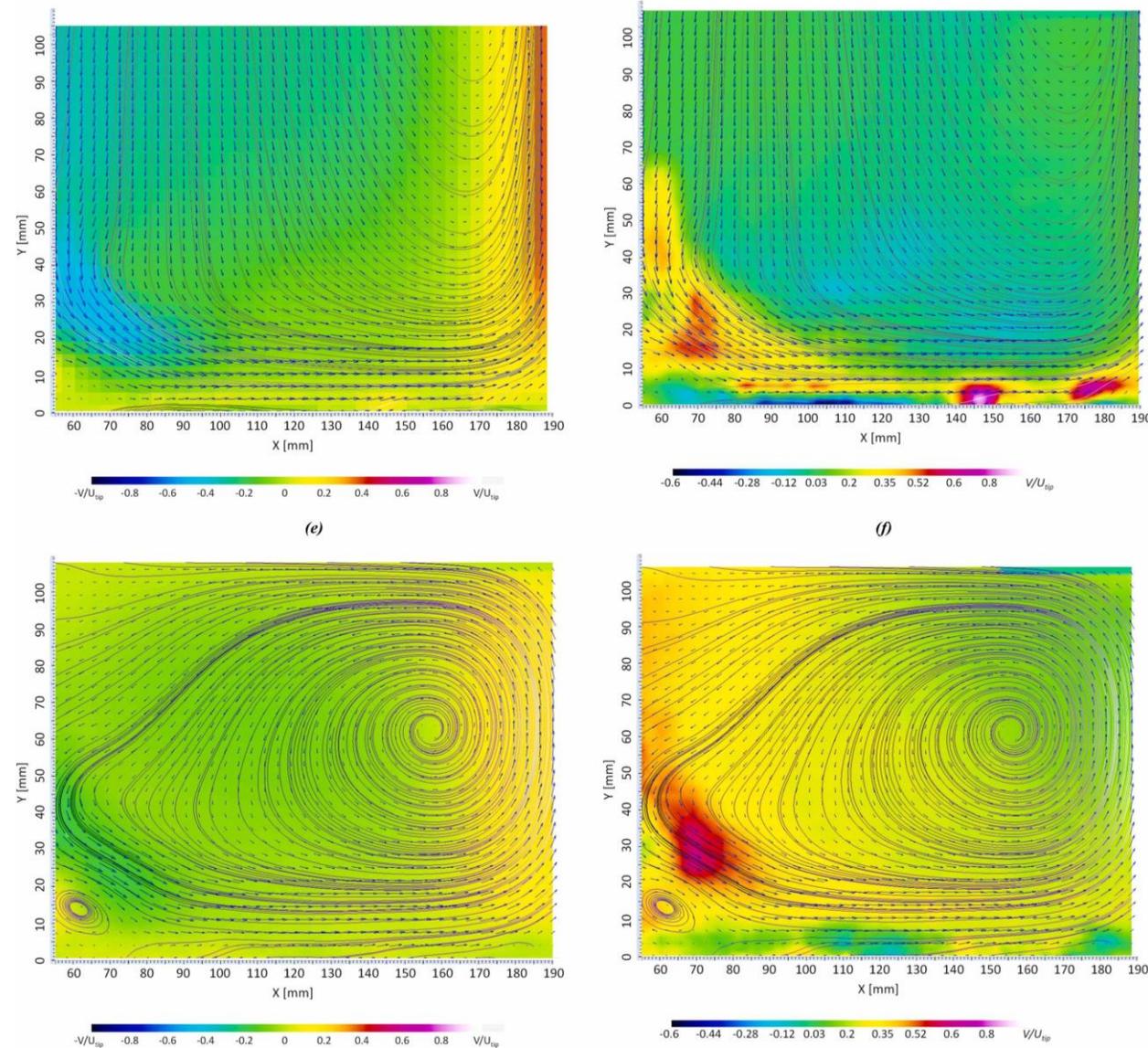
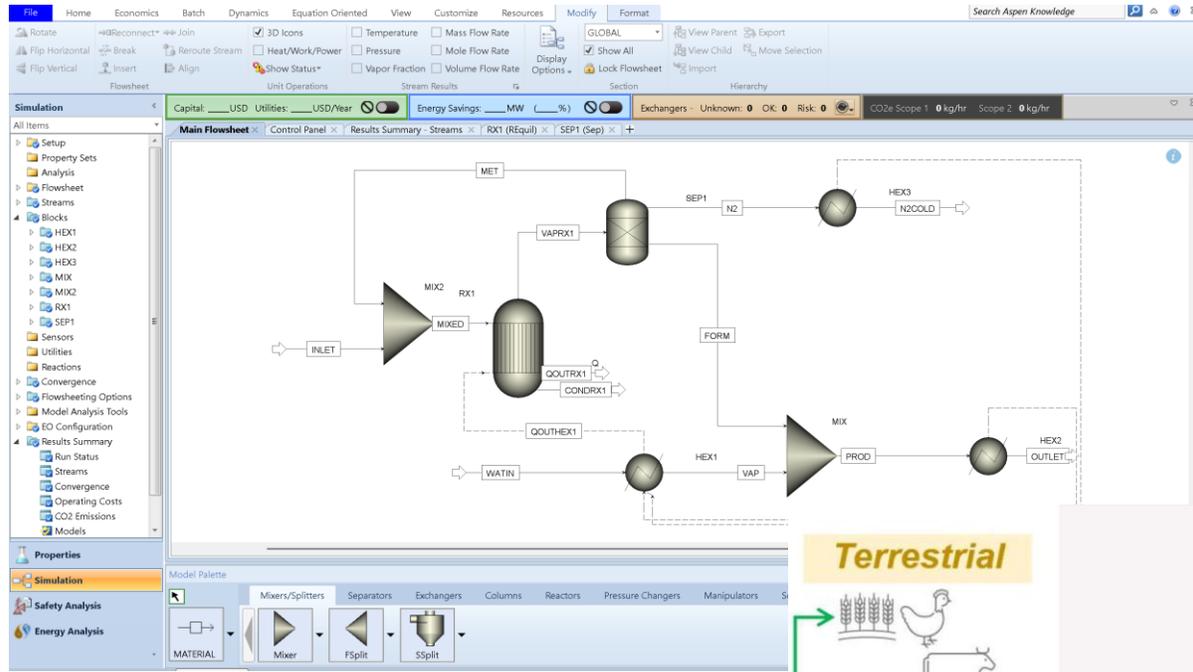Conductivity tomograms

CFD simulation and model validation

4. Study and Characterization of the Flow Field Inside Stirred Reactors
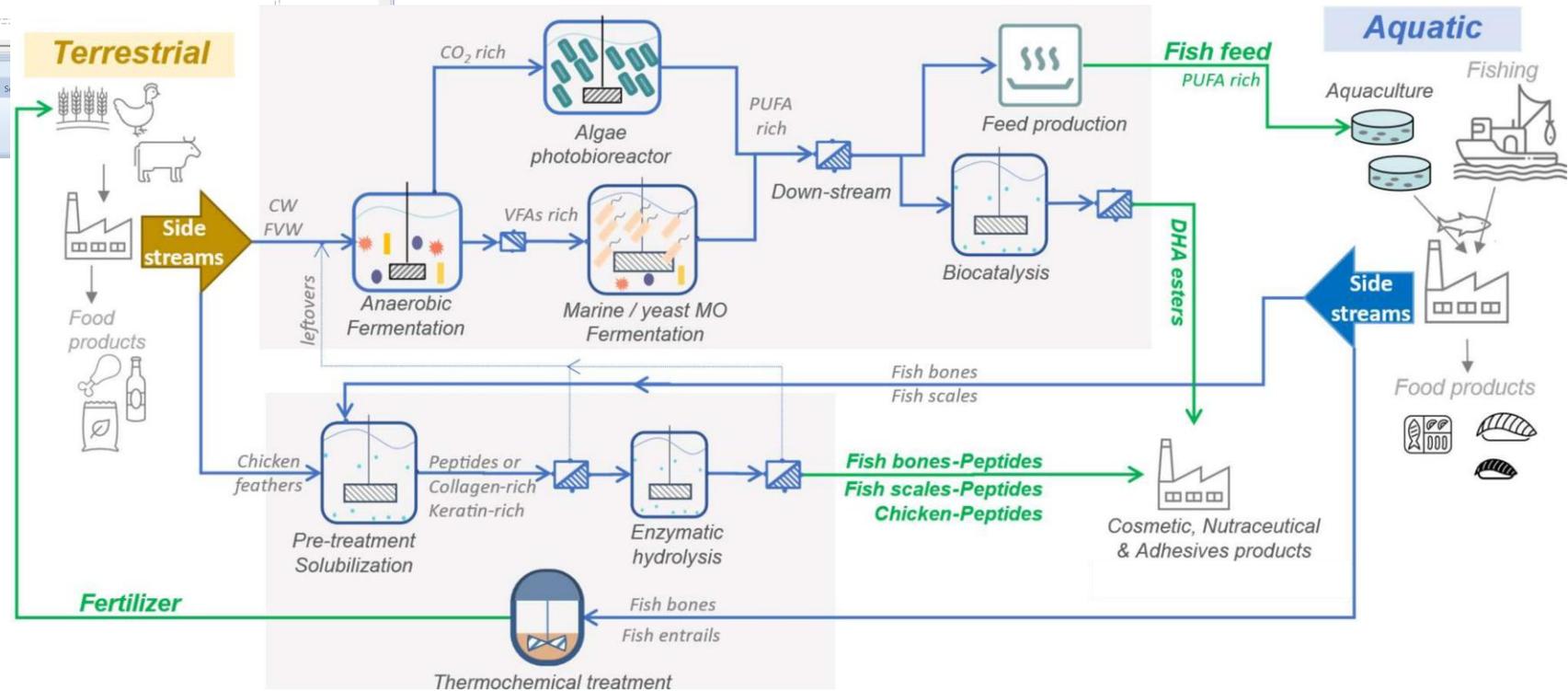

Optical techniques/ PIV & PLIF
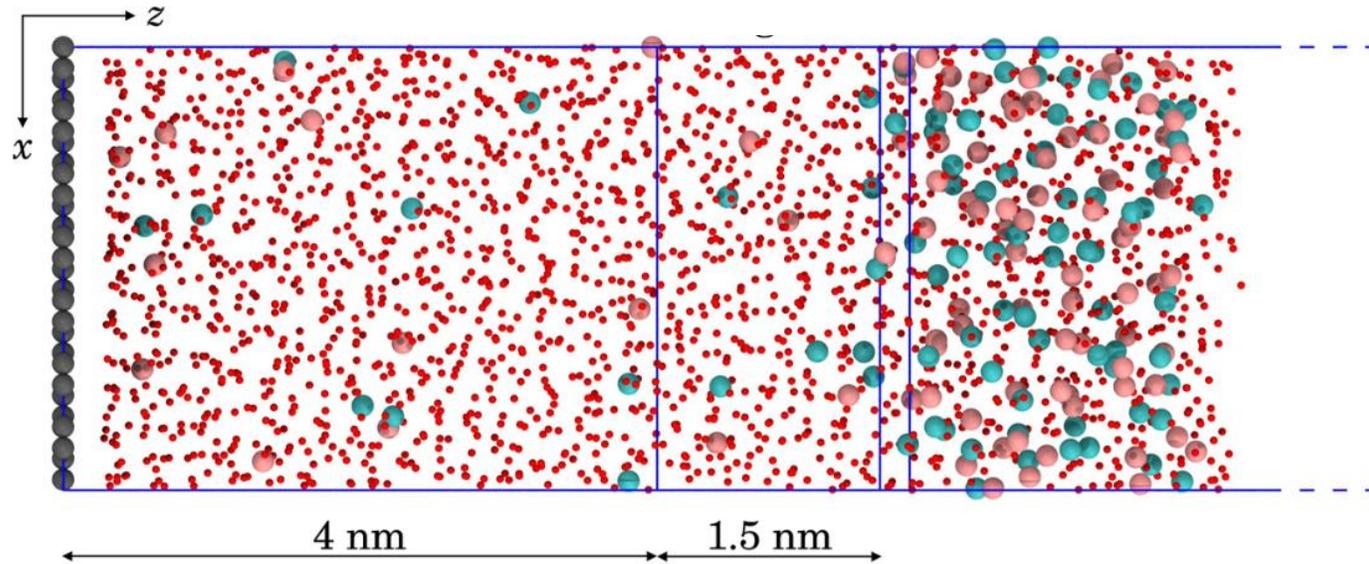
5. Process Simulation Using Aspen Plus

Material and energy balances and phase equilibria

- Definition of the system boundaries;

- Selection of the thermodynamic model;

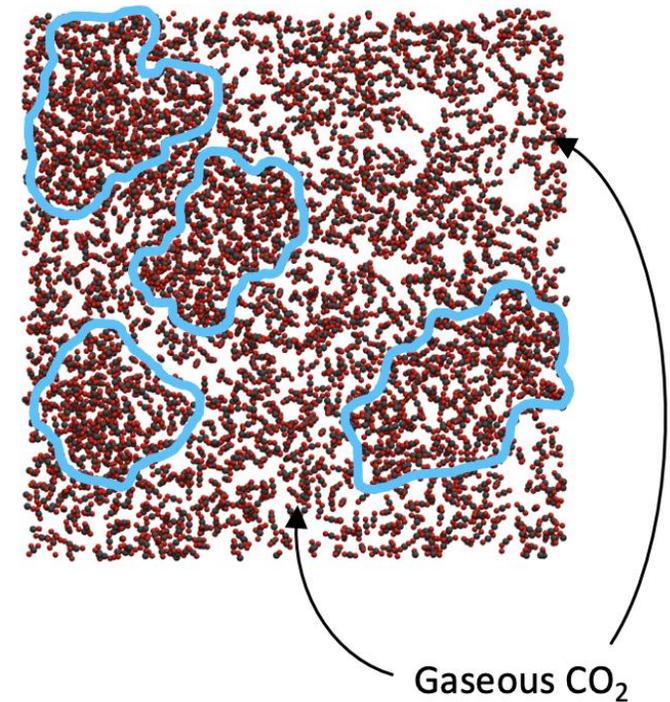- Sensitivity analysis on assumptions and models.

6. Modeling: Molecular Dynamics (MD)

4 nm   1.5 nm

Systems with Phase Change and Supercritical Fluids

Systems with Interfaces

Liquid CO$_2$ clusters

Gaseous CO$_2$

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