

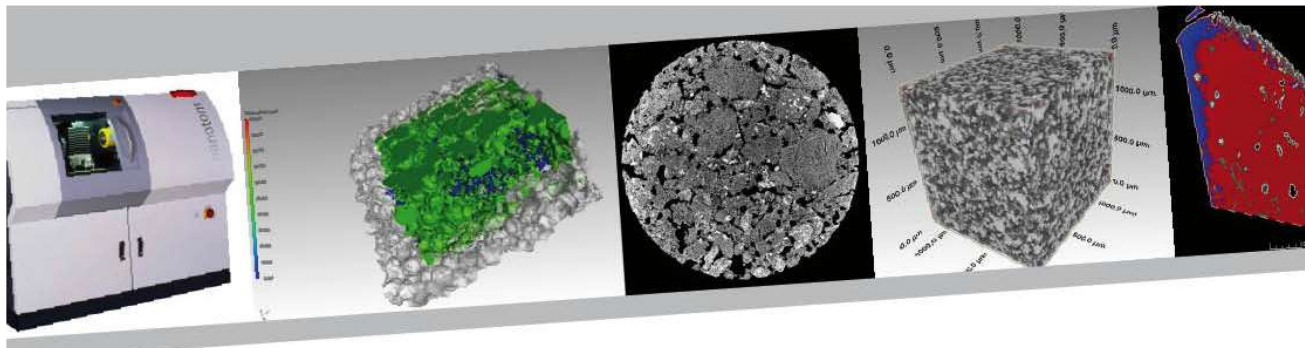
Bubbly flows in FERMaT: research activities, tools and applications



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- 2 LGC, Université de Toulouse, INPT, UPS, Laboratoire de Génie Chimique, Toulouse, France



Promote & develop multi-interdisciplinary research in the field of ENGINEERING at Toulouse University.



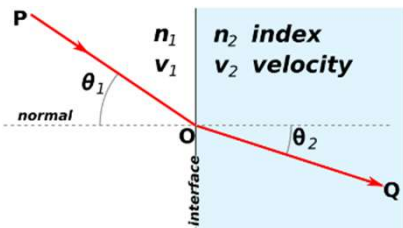
Pierre de Fermat

1607-1665

*French lawyer at the
Parliament of
Toulouse and a
mathematician*



Fermat's principle

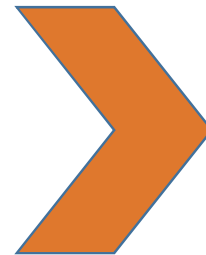


Fermat's Last theorem

There are no three positive integers
 x , y , and z for which

$$x^n + y^n = z^n$$

for any integer $n > 2$



FERMaT FEDERATION

Fluids, Energy, Reactors, Materials, Transfers

FERMaT FEDERATION: a brief history



Dir. Martine Meireles (LGC)

1998: Creation of a collaborative platform between IMFT, LBB and LGC

Center of gravity: multiscale processes coupling fluids and phenomena

2000: Transformation into a Federative Structure

2007: Recognition by the CNRS (FR 3089), extension to the energy and materials sectors -

2007-2013: Grant for equipment by the CPER (2 M€)

2009: AERES Evaluation - renewal

2014: Evaluation HCERES - renewal

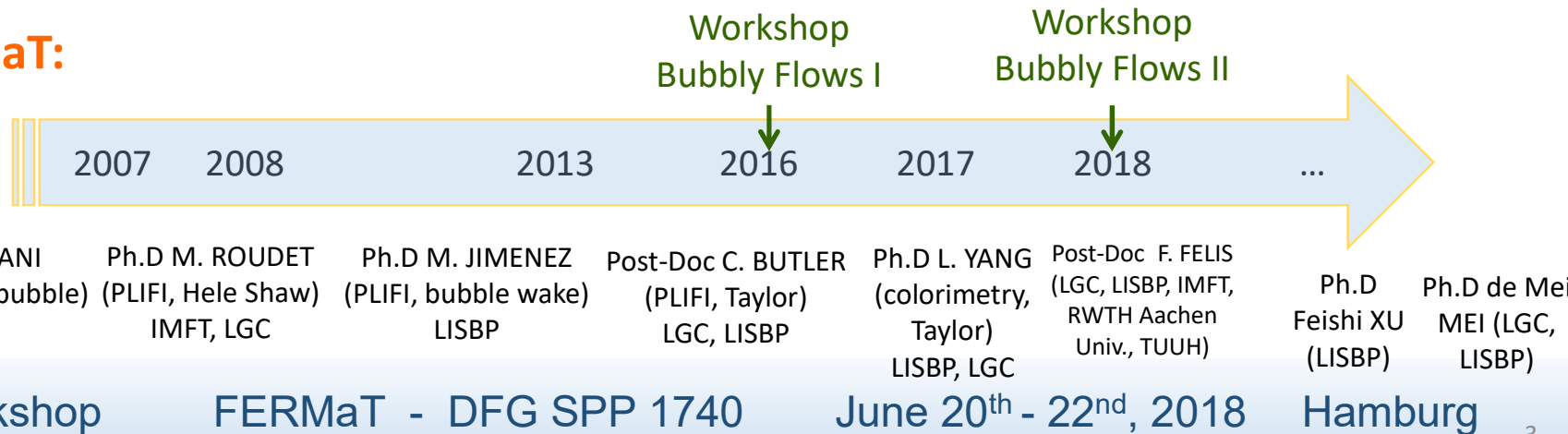
2014-2019: Grant for equipment by the CPER (2 M€)

+ annual budget from academic institutions: 100 k€



Bubbly flows in FERMaT: a brief history

> 20 papers and
> 15 PhD
defended



FERMaT: Fluids, Energy, Reactors, Materials, Transfers

4 academic supporting institutions:

INPT, CNRS, INSAT, UT3



9 laboratories from the field of engineering :

CIRIMAT, IMFT, LAAS, LAPLACE, LGC, LISBP

ICA, LMDC, RAPSODEE



5 laboratories from the field of chemistry/physics

CEMES, LCC, LGP, IMRCP, LPCNO



FERMaT: Fluids, Energy, Reactors, Materials & Transfers

- **Promote/support cooperation**
 - Supports inter-laboratory collaborations ($\geq 2!$) Based on the methodological / technical complementarity of academic partners, focused on scientific locks rather than on a specific application
- **Share equipment**
 - Two metrological "platforms" dedicated to experimentation for Fluids and flows, and for Materials and particulate media:
 - platform for small angles X-ray diffusion « SAXS »
 - imaging and velocimetry platform
- **Scientific events**
- **Training through research**

FERMaT's experimental platforms

INVESTIGATION OF MATERIALS AND PARTICULATE MEDIA

3D imaging by X-ray tomography – GE and RX solutions (CIRIMAT and IMFT)

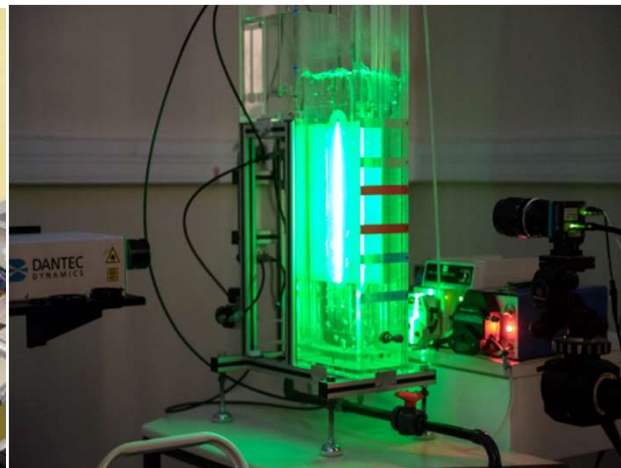
Structure of nanometric objects by X-ray scattering – XENOCES SAXS Platform (LGC)



INVESTIGATION OF FLUIDS AND FLOWS

Acquisition of flow fields by laser velocimetry: 2D, 3D and 4D **Tomo PIV 4D!**

Concentration field measurements and interface monitoring by laser-imaging – La Vision- Dantec- Fluorescence /Optical imaging (LGC) NKT photonics/ Opotek laser



FERMaT: Fluids, Energy, Reactors, Materials & Transfers

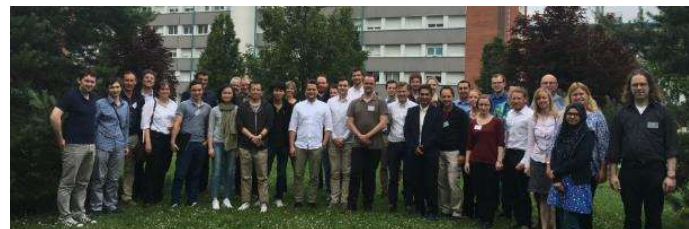
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 - platform for small angles X-ray diffusion « SAXS »
 - imaging and velocimetry platform

- **Scientific events**



- Organize scientific meetings and workshops (colloquium FERMaT – SPP1740, Toulouse, 2016)

- **Training through research**

- Over a 5-year period : around 40 PhD and 25 post-doc fellowships
- Funds 1 to 2 post-doc per year

Human resources funded by CNRS (2010-2016) : Ph D, Post-docs

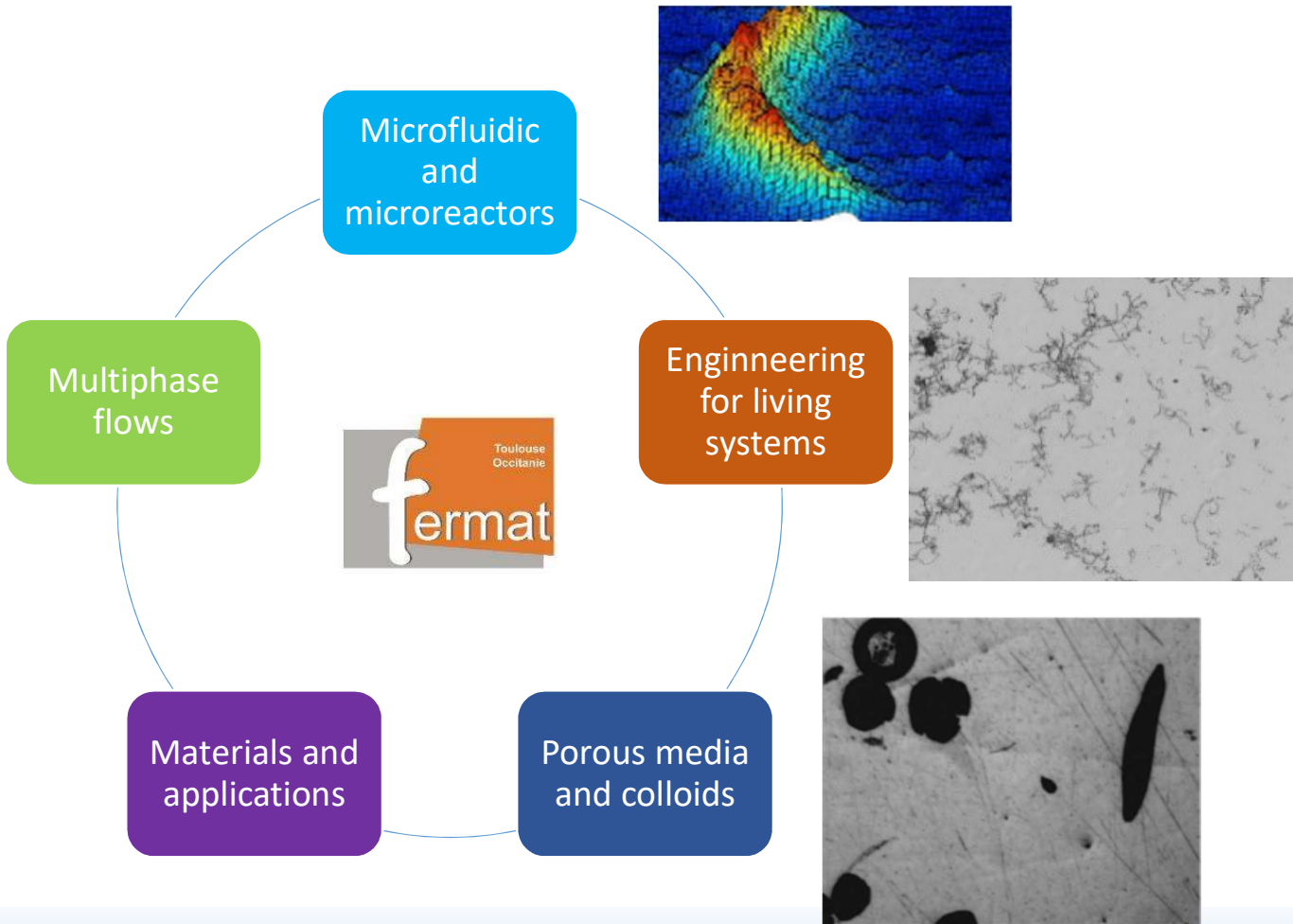
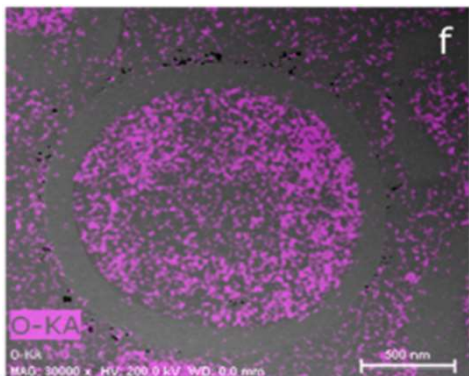
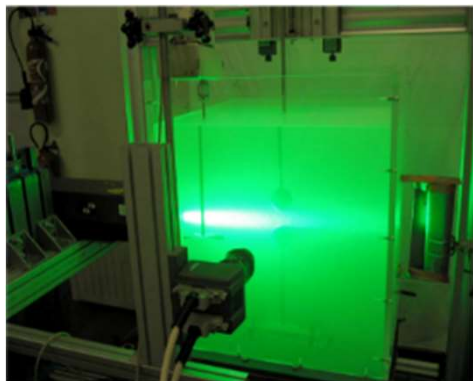
Post-doc on bubbly flows, exp & num.: Colin BUTLER (2017), David LAUPTSIEN (2018), Francisco FELIS (2018).
Software: DIVA, Saturne@polyphasique, Workbench Ansys

Human resources funded by IDEX (2016-2019) / Programme for excellence/ 2 chairs

BIREM : Hydrodynamics of Bioreactors , Rodney FOX (Iowa state , USA) 650 k€

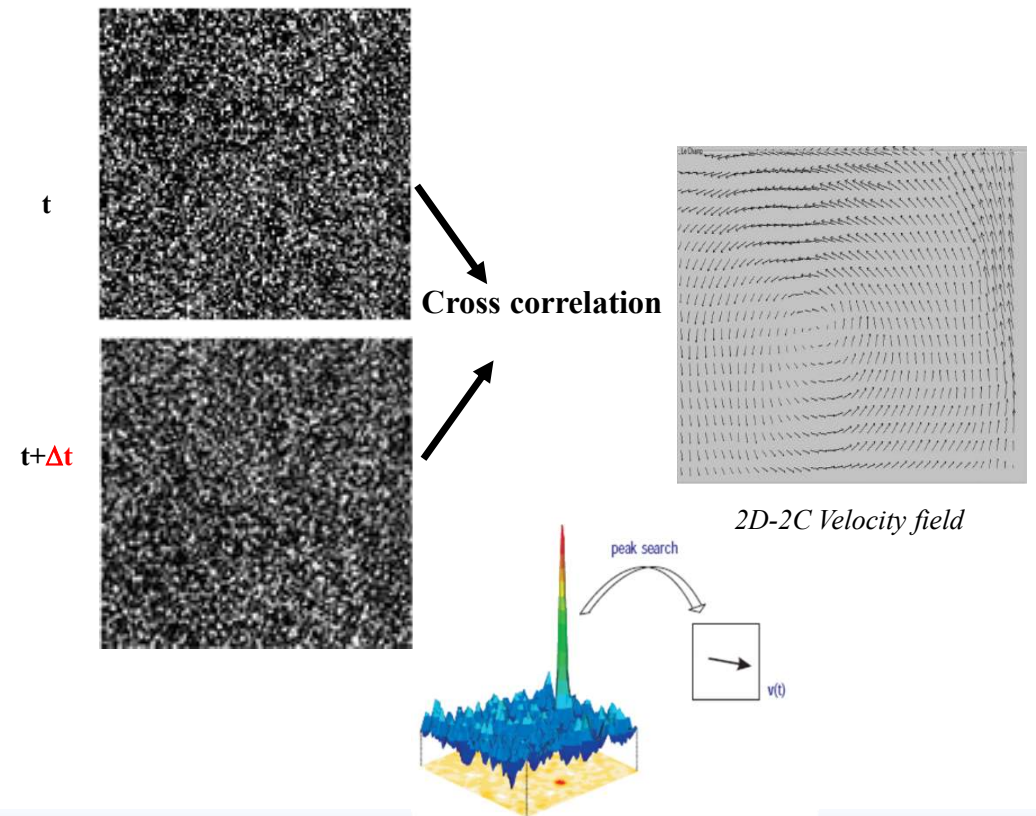
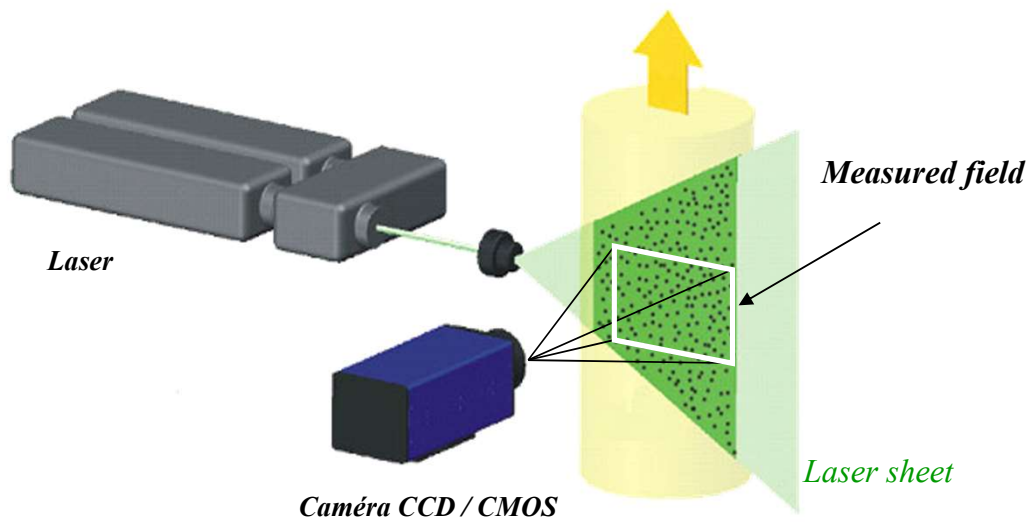
NEMESIS : Rheology of suspensions, Jeff MORRIS (CUNY, USA) 750 k€.

5 active research topics

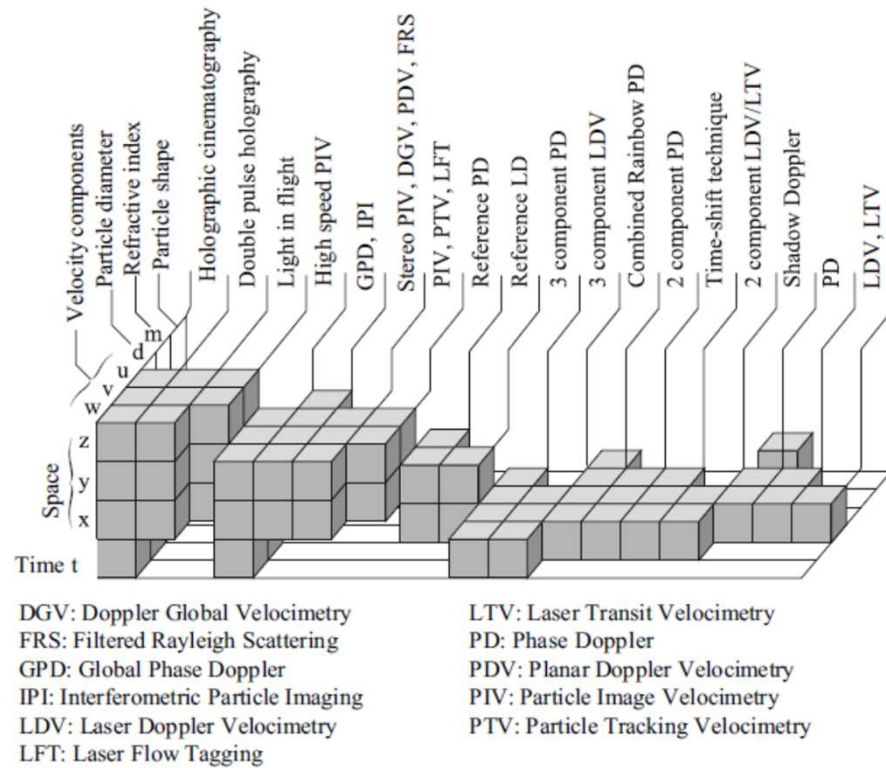


Focus on :
Tomo-PIV 4D

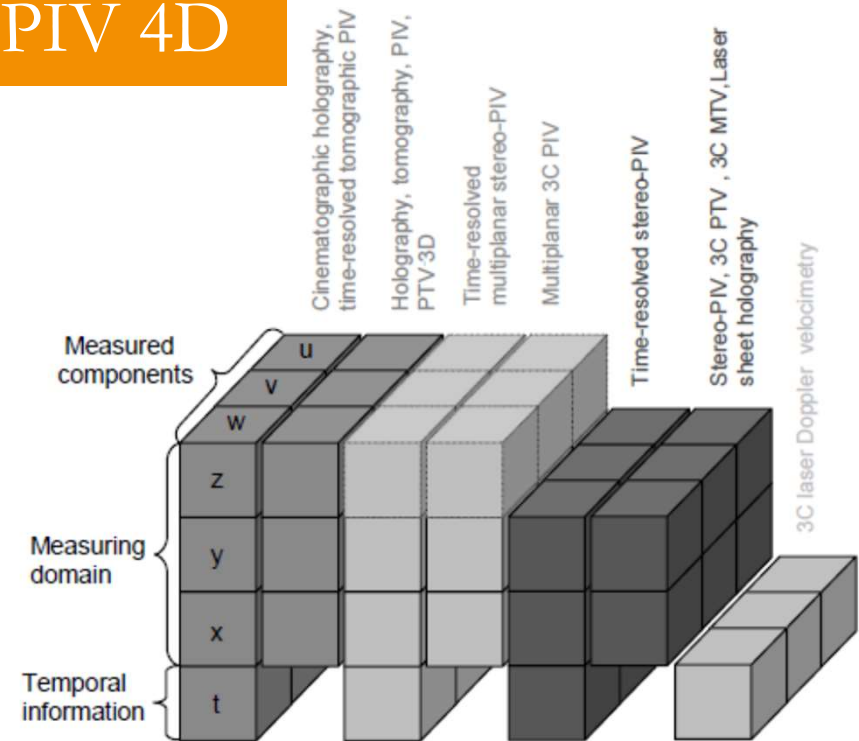
2D PARTICLE IMAGE VELOCIMETRY: Principle



Optical measuring techniques using light scattering



Focus on :
Tomo-PIV 4D

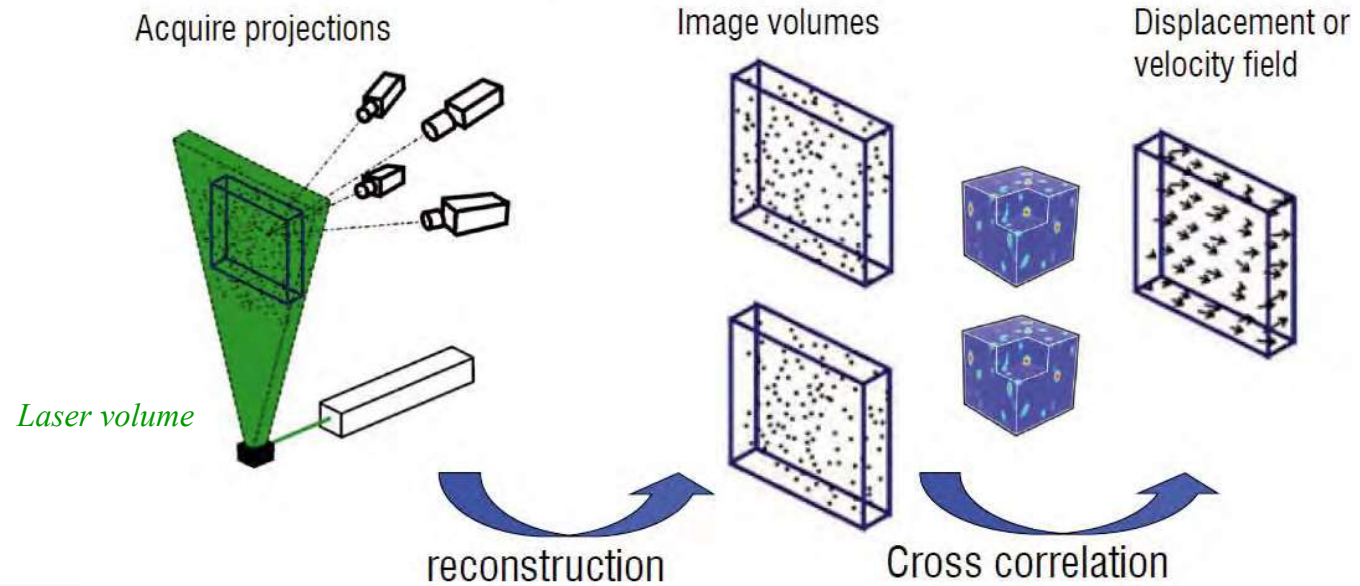
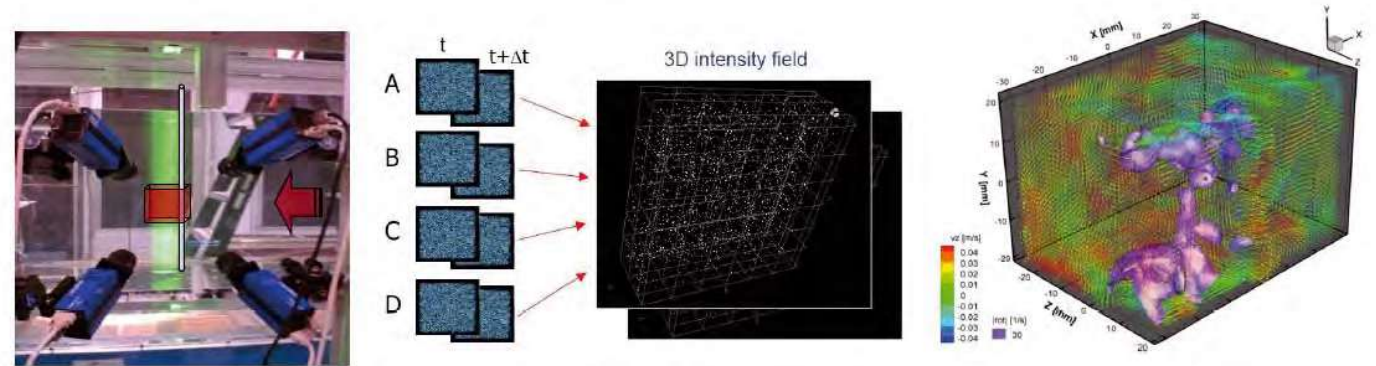


Laser Velocimetry in Fluid Mechanics by Alain Boutier

Representation of the methods of 3D velocimetry

Focus on :
Tomo-PIV 4D

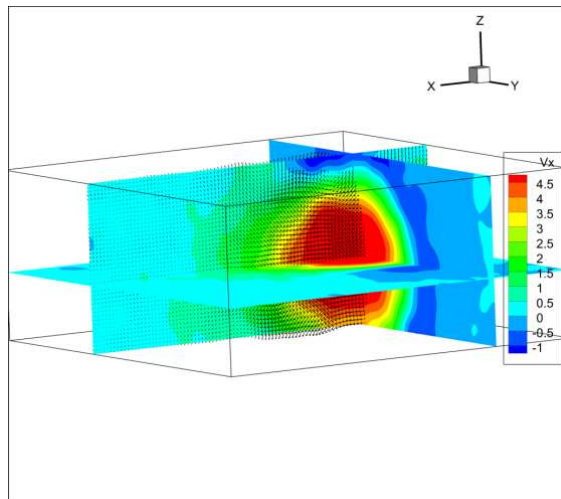
4D PARTICLE
IMAGE
VELOCIMETRY:
Principle



Focus on : Tomo-PIV 4D

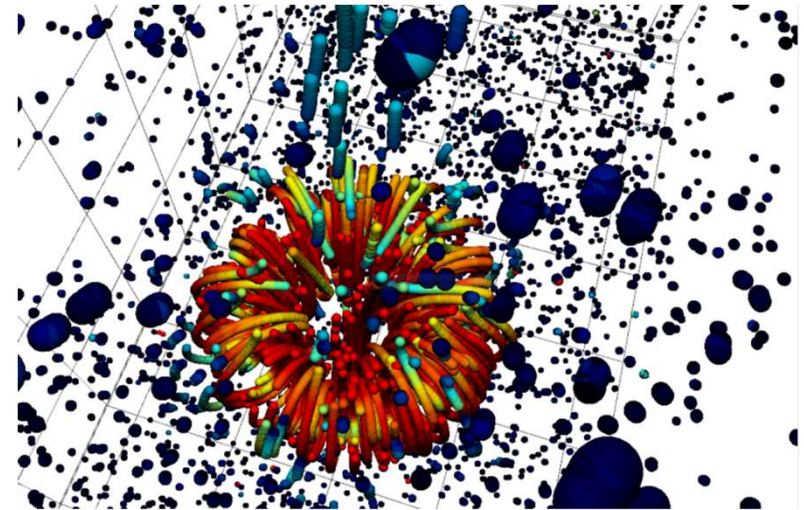
Lagrangian and Eulerian specification of the flow field

Eulerian specification of a field:
function of position x and time t .



Time Resolved TOMO PIV

Lagrangian specification : individual fluid
particles are followed through time



Iterative Reconstruction of Particle Position

Focus on : Tomo-PIV 4D

Lagrangian and Eulerian specification of the flow field



FERMAT PIV TOMO configuration :

- Laser Nd-Ylf : 527nm 2x60mJ.
- Volume: 30cm x 20cm x 10cm.
- 4 caméras VEO 2560x1600 pixels
- + filter 540nm.
- Freq Acq 1000Hz.
- Fluorescent dyes: PMMA Rh. B 20-50 μ m

Experiment: Moving grid in a tank
Sébastien Cazin - IMFT



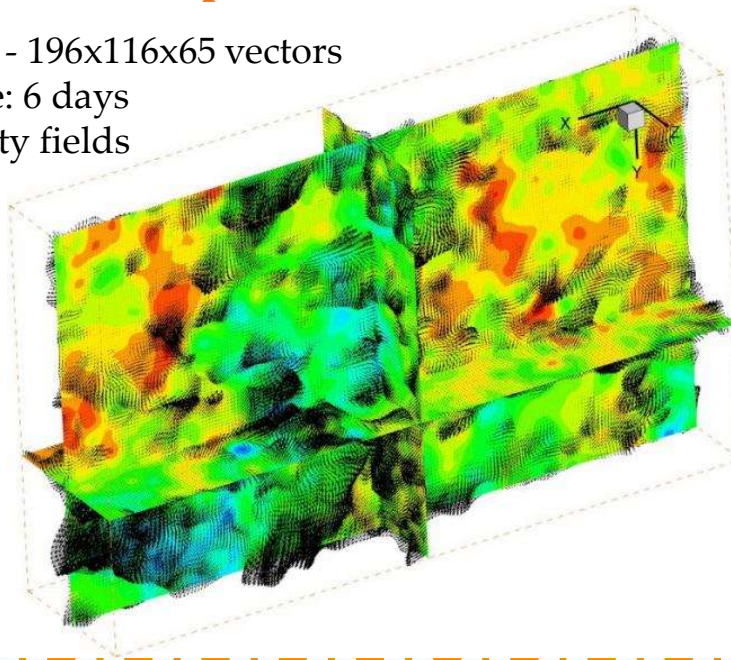
Focus on :
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Lagrangian and Eulerian specification of the flow field

Experiment: Moving grid in a tank – Sébastien Cazin IMFT

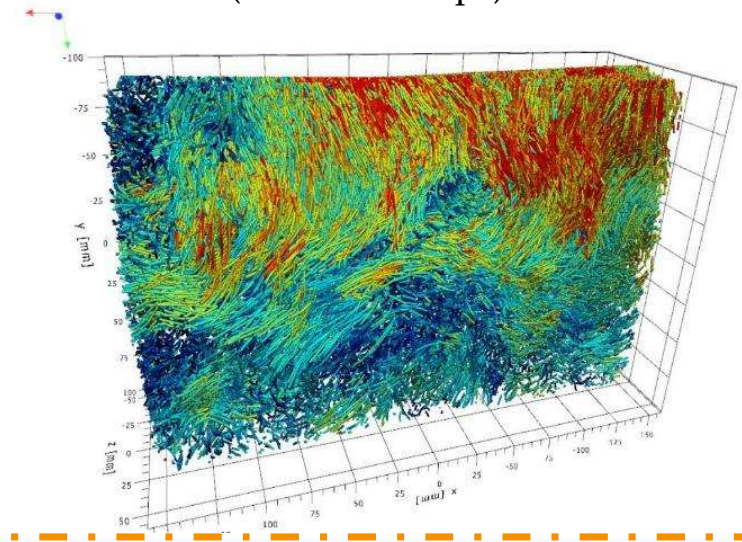
Eulerian specification

48x48x48 voxels - 196x116x65 vectors
Calculation time: 6 days
3000 × 3D velocity fields



Lagrangian specification

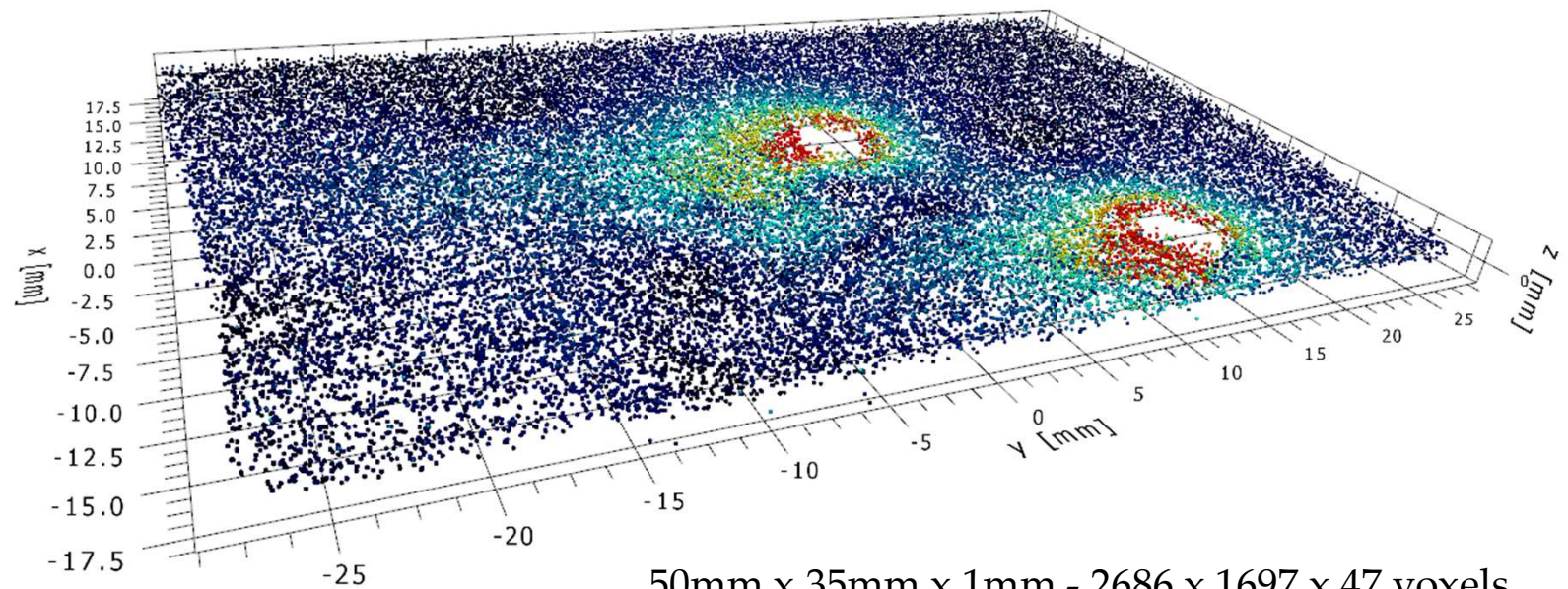
30 000 particles in the volume
Calculation time: 3 hours (3000 time steps)



Focus on :
Tomo-PIV 4D

Lagrangian and Eulerian specification of the flow field

3D Experimental study of bubble rising in a Hele Shaw cell (Roig, Rida, Cazin - IMFT)



50mm x 35mm x 1mm - 2686 x 1697 x 47 voxels

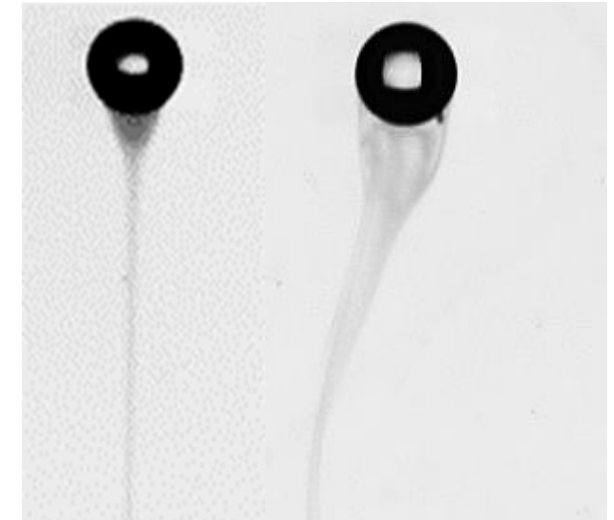
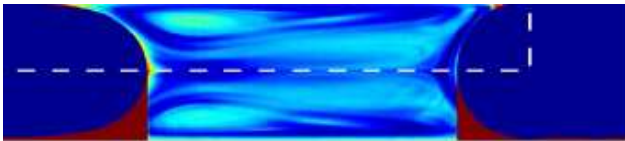
FERMaT
BUBBLY FLOWS: Mass transfer & Hydrodynamic
With or without reaction

3D Rising Flow

Hele-Shaw Flow

Taylor Flow

Microfluidic



Experimental

High speed & Very high speed Imaging, Colorimetry, MTV, PLIF/PLIFI, PIV 2D/2C, PIV 2D/3C, TOMO PIV 4D

Numerical

COMSOL, FLUENT, JADIM, DIVA, NEPTUN, SATURN, DIVA 1&2

Let's share our dreams and tools for future projects !