von KARMAN INSTITUTE
FOR FLUID DYNAMICS

OpenFoam Seminar

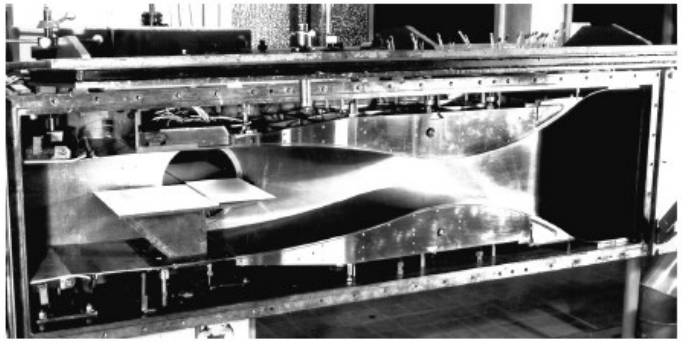
Von Karman Institute for Fluid Dynamics

Maria Faruoli

6th December 2023

THE VON KARMAN INSTITUTE

THE HORIZONTAL CLOSED TEST SECTION OF THE SUBSONIC WIND TUNNEL



THE NEW SUPERSONIC NOZZLE

"Training in Research through Research"

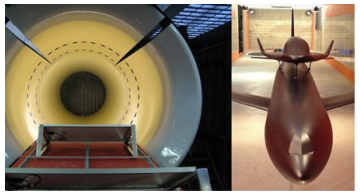
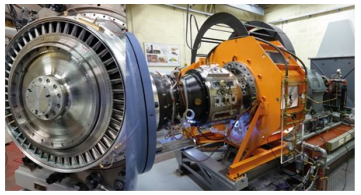
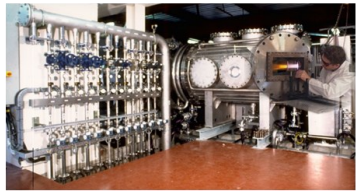
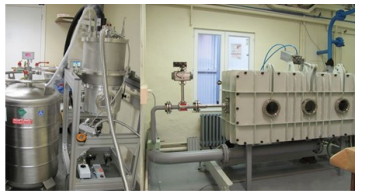
- Founded in 1956
- as Belgian-American Training Center for Experimental Aerodynamics (TCEA)
- renamed von Karman Institute in 1963

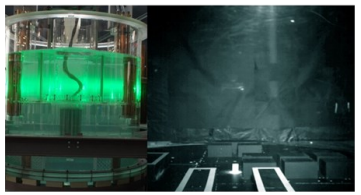
THEODORE VON KÁRMÁN RECEIVING THE NATIONAL MEDAL OF SCIENCE FROM PRESIDENT KENNEDY IN 1963

VKI IN NUMBERS

130

130 staff members, agile organization



48

- 48 experimental facilities
- 3 unique in the world

22

- 22 nations on-the-spot
- A melting pot for research & education

242

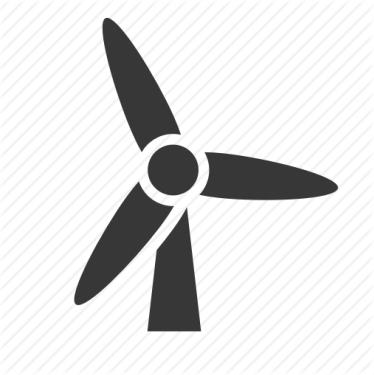
- 242 students
- Research Master: 39
- Short Training program + Belgian Master Thesis: 95
- PhD: 84
- Postdoc: 24

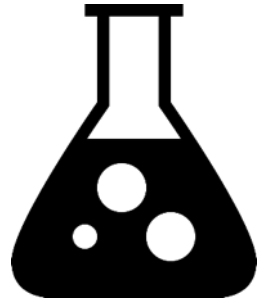
1811

- 1811 alumni
- Dedicated network for international development

von KARMAN INSTITUTE FOR FLUID DYNAMICS

RESEARCH FOCUS





AEROSPACE	TURBOMACHINERY	INDUSTRIAL PROCESSES	ENVIRONMENTAL FLOWS	FLUID ENGINEERING & MEASUREMENT
1. Hypersonics	1. Propulsion	1. Liquid metal flows	1. Wind energy	1. Instrumentation
2. Space exploration	2. Turbines	2. Hydrogen	2. Atmospheric flows	2. Artificial Intelligence
3. Re-entry/debris	3. Compressors	3. Multiphase flows	3. Pollution dispersion	3. Calibration
4. Aeronautics	4. Energy Systems	4. Cryogenic flows	4. Explosion impact	

ORGANIZATION

Education

- Research Master Program
- Doctoral Program
- Short Training Program

Lecture Series

- courses on special topics
- For industry, academics, military participation
- Invited international lectures

Research activities

- Aerospace
- Turbomachinery
- Industrial Processes
- Environmental Flows
- Fluid Engineering & Measurements

TRAINING IN OPENFOAM

Onsite Introductory course to OpenFOAM®

- *March 19-20, 2024*

The **on-site course** gives on the first day a practical introduction to the structure and usability of OpenFoam and OpenFOAM related applications. Besides the general introduction the participants will perform a complete numerical simulation starting from choosing the solver till post-processing.

The second day will be dedicated to the open-source mesh generator snappyHexMesh and a multiphase simulation will be performed with the obtained mesh

Programming in OpenFOAM course

- *March 21, 2024*

The Programming course shows how to start modifying existing libraries in OpenFOAM. Four applications are tested with the participants: modification of a solver, implementation of a post-processing utility, modification of a turbulence model and creation of a boundary condition.

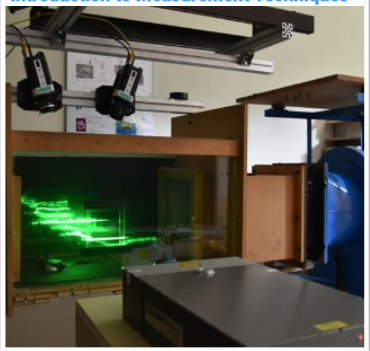
Lectures: VKI PhDs and Research Engineers

von KARMAN INSTITUTE FOR FLUID DYNAMICS

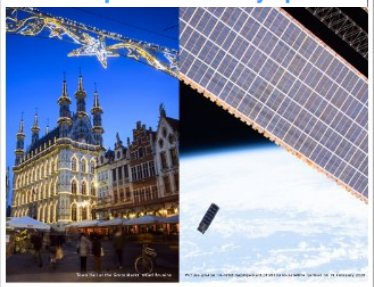
LECTURE SERIES

Multidisciplinary Simulation of Wind Farms in Complex Environments

Introduction to Measurement Techniques

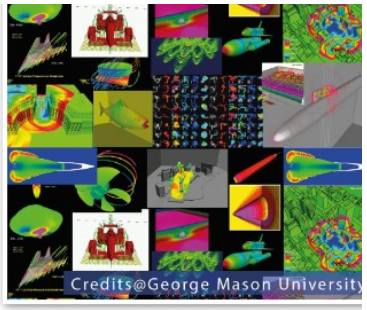


13th European CubeSat Symposium

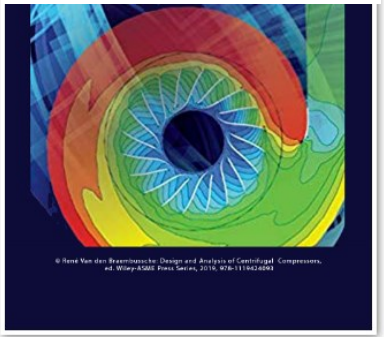


Introduction to Ground Testing Facilities

Introduction to Computational Fluid Dynamics

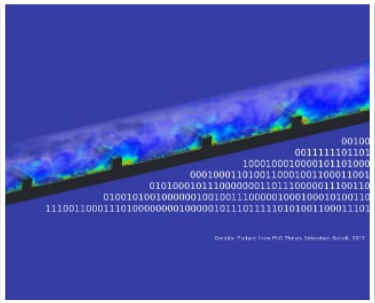


Radial Compressor Design and Optimization

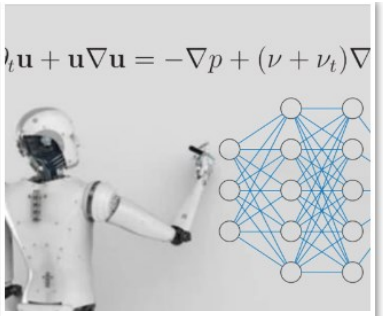


VKI Course on Introduction to Aeroelasticity - Aircraft & Turbomachinery (2.0 ECTS)

15th VKI PHD Symposium

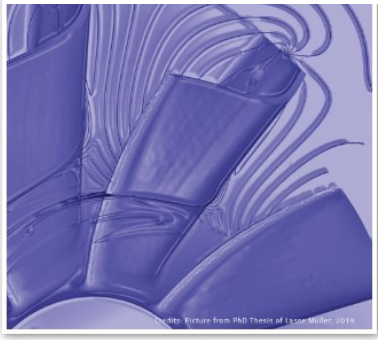


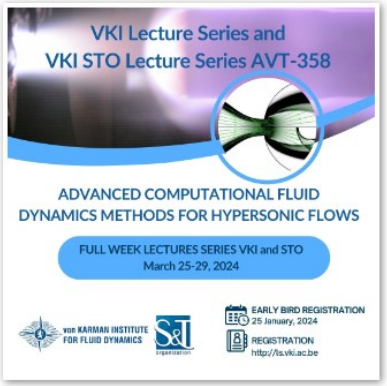
Large Eddy Simulation and Related Techniques



Hands on Machine Learning for Fluid Dynamics

Multidisciplinary Design Optimization



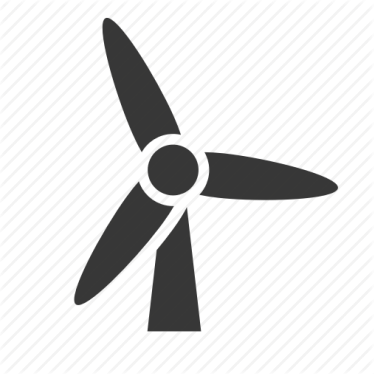
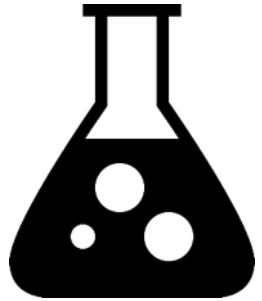


https://www.vki.ac.be/index.php/events-ls

von KARMAN INSTITUTE FOR FLUID DYNAMICS

RESEARCH ACTIVITIES WITH OPENFOAM



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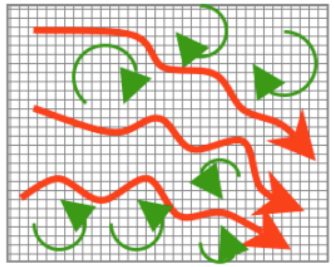
LES OF FORCED CONVECTION THROUGH BACKWARD FACING STEP

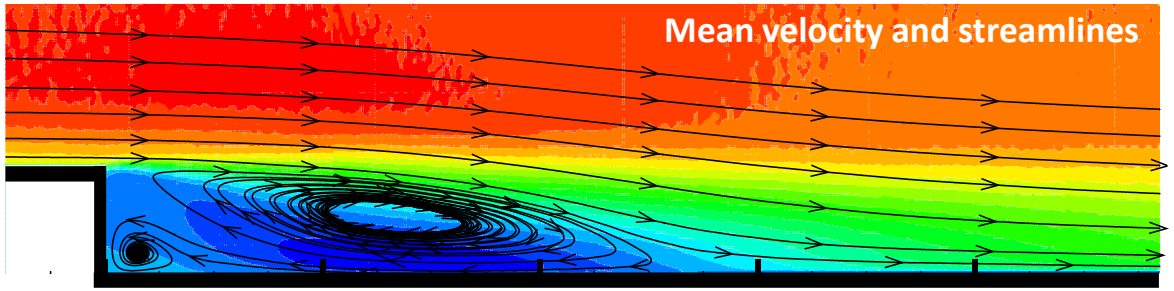
Sealed wind tunnel



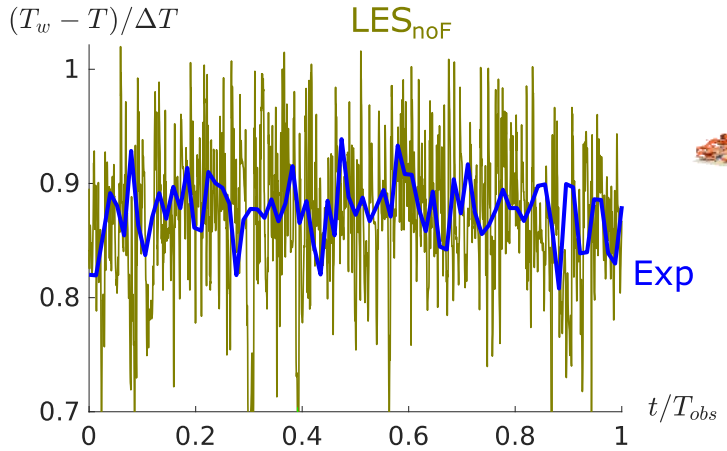
LES

Fluid	Pr
Air	0.71
He-Xe	0.2
LBE	0.025

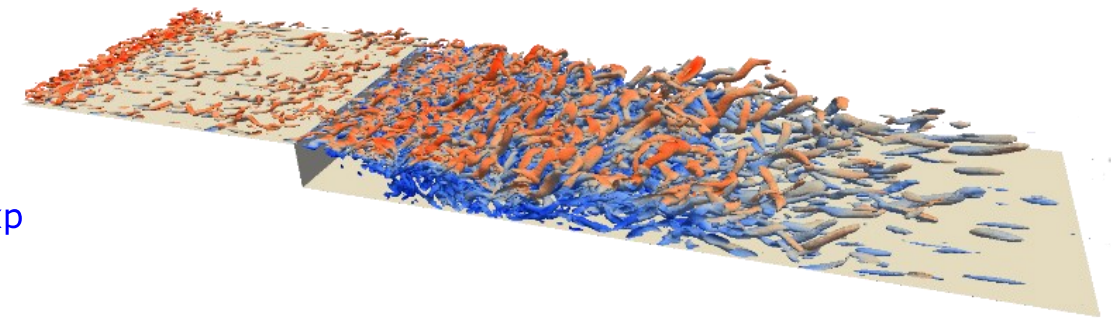
Experiment with He-Xe gas, $Pr \sim 0.2$



Excellent prediction of flow reattachment (+1.3 %)



LES



PhD Thesis of Sophia Buckingham

von KARMAN INSTITUTE FOR FLUID DYNAMICS

LES OF NATURAL CONVECTION BOUNDARY LAYER

Sealed wind tunnel

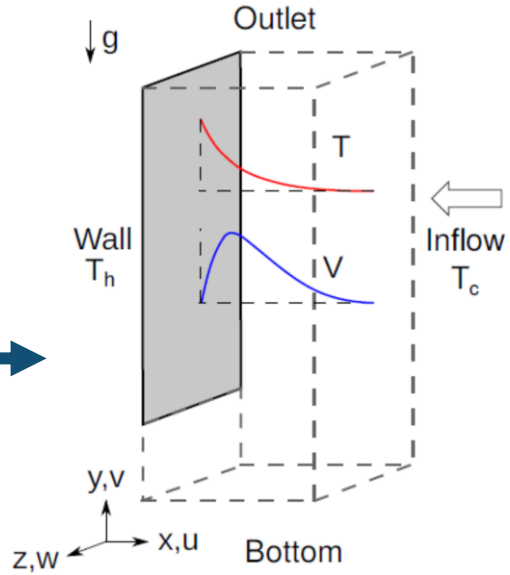
Experiment with air

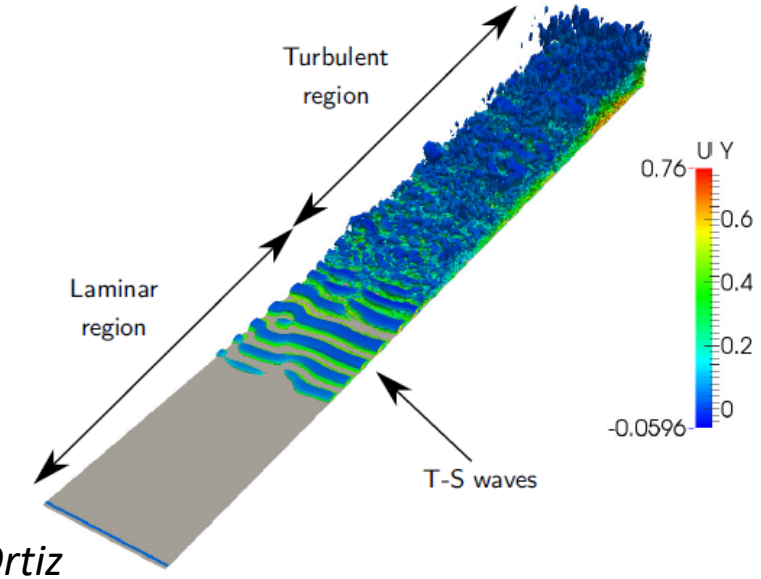
$Pr = 0.71$

$Gr = 4.1 \times 10^{11}$

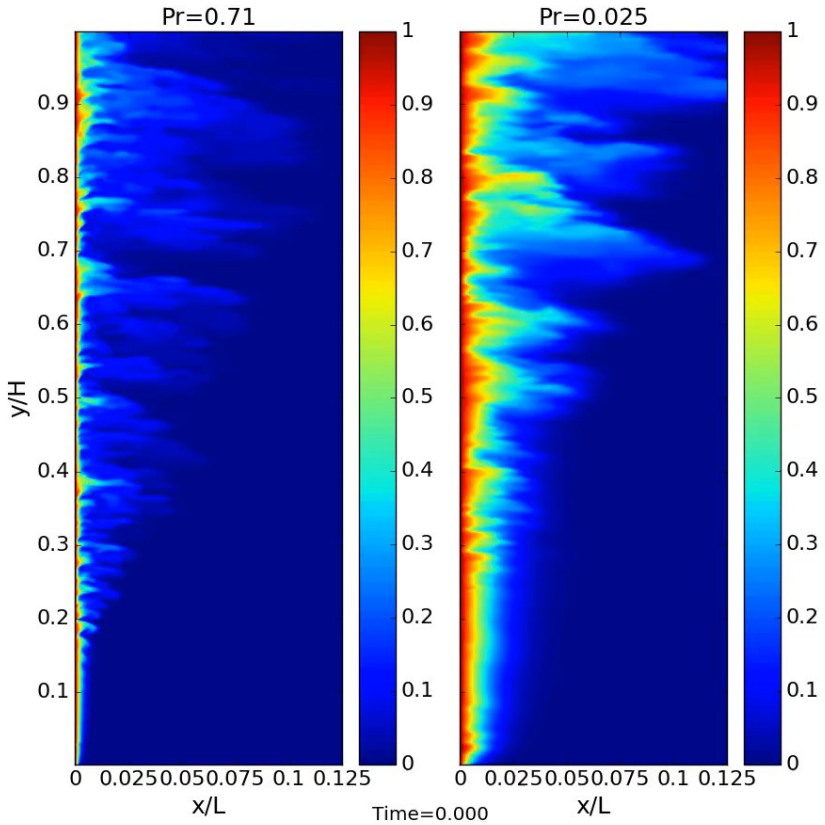
$Ra = 2.9 \times 10^{11}$

LES setup





Temperature

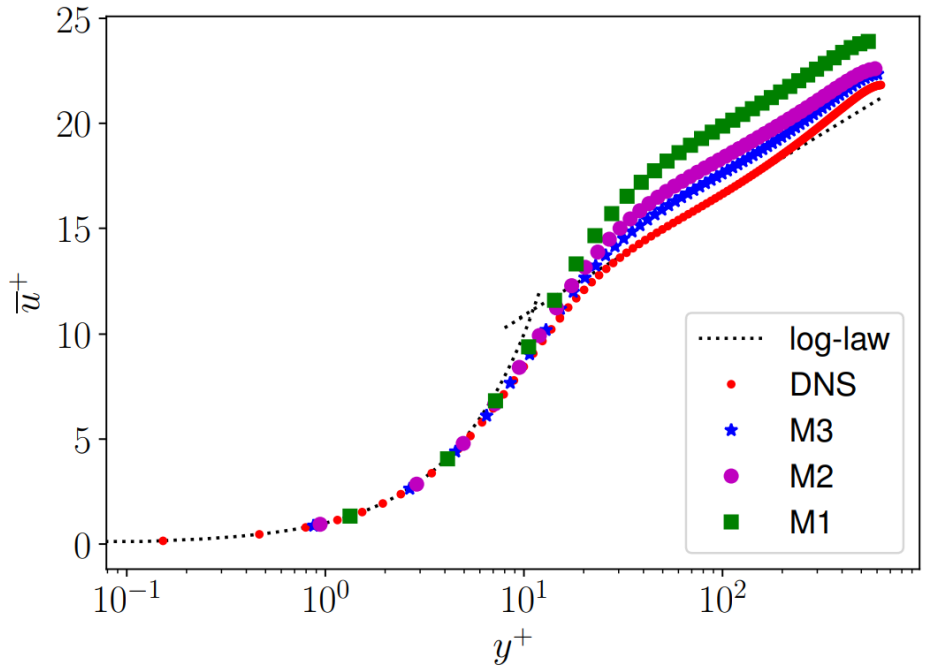


PhD Thesis of Augustin Villa Ortiz

von KARMAN INSTITUTE FOR FLUID DYNAMICS

LES OF LOW PRANDTL NUMBER CHANNEL FLOW

Generation of variable fidelity data for the training of a data-driven turbulent heat transfer model



$Re_\tau = 640\ (M3)$

Spanwise

Streamwise

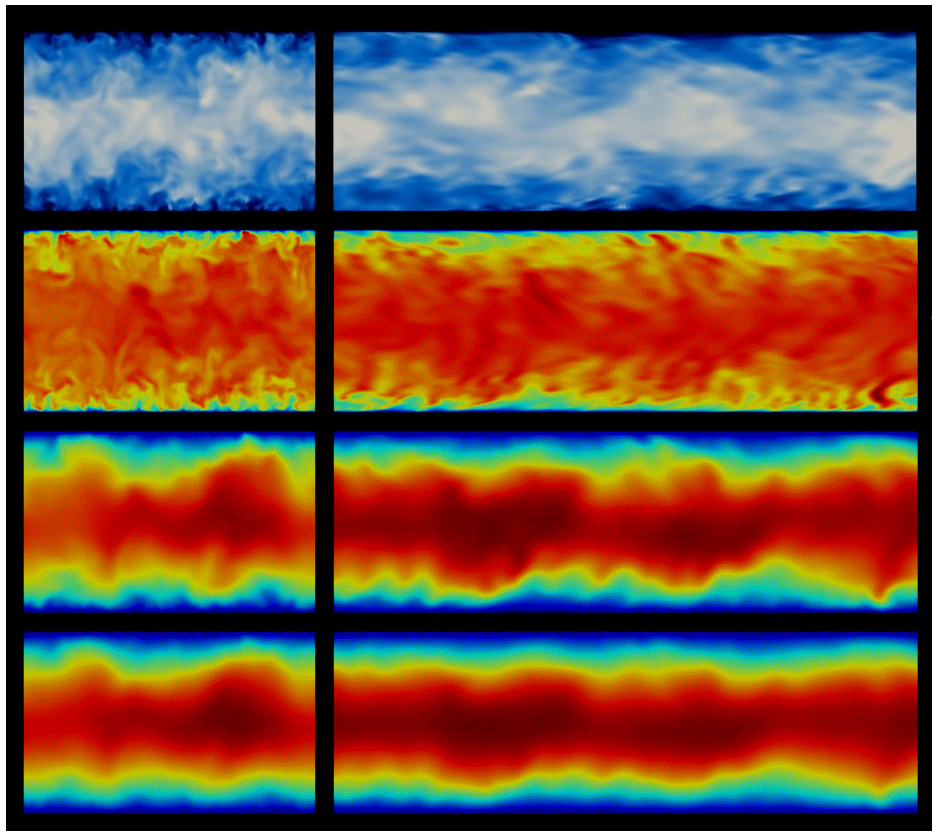
Velocity

Temperature

$\mathrm{Pr} = 0.71$

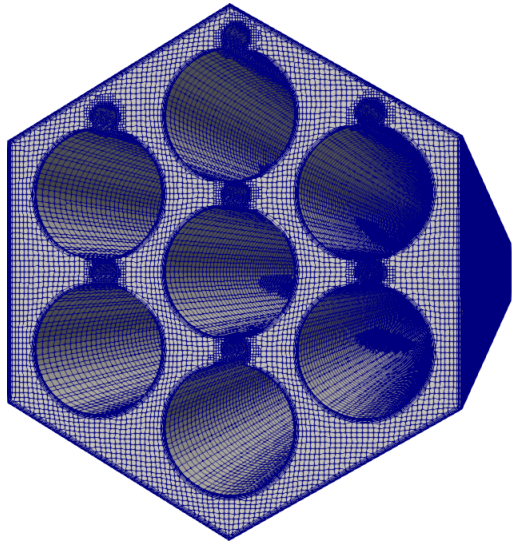
$\mathrm{Pr} = 0.025$

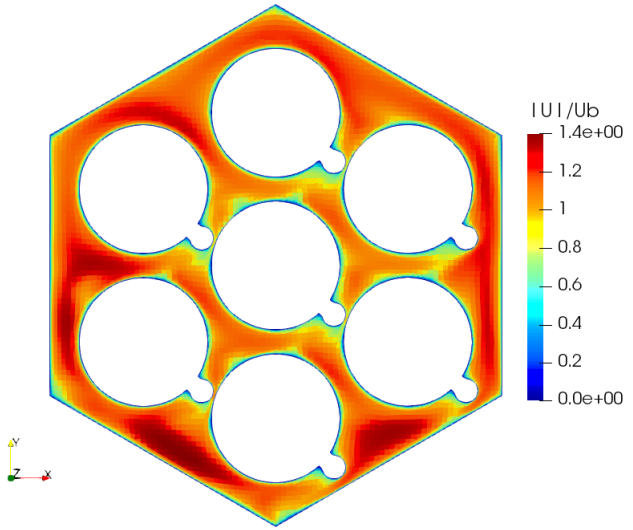
$\mathrm{Pr} = 0.01$

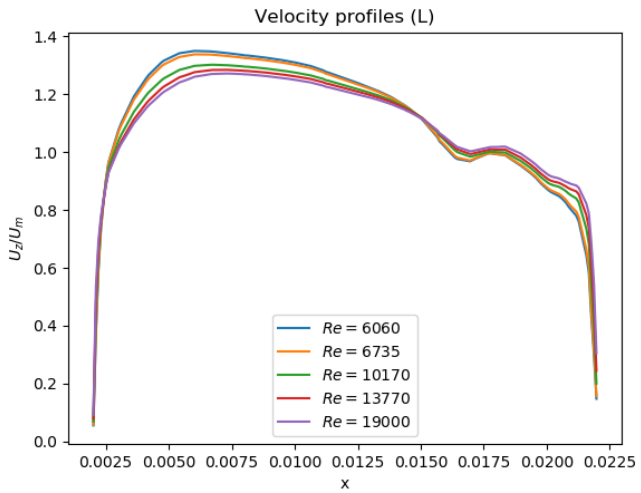


Florentin Prud'homme

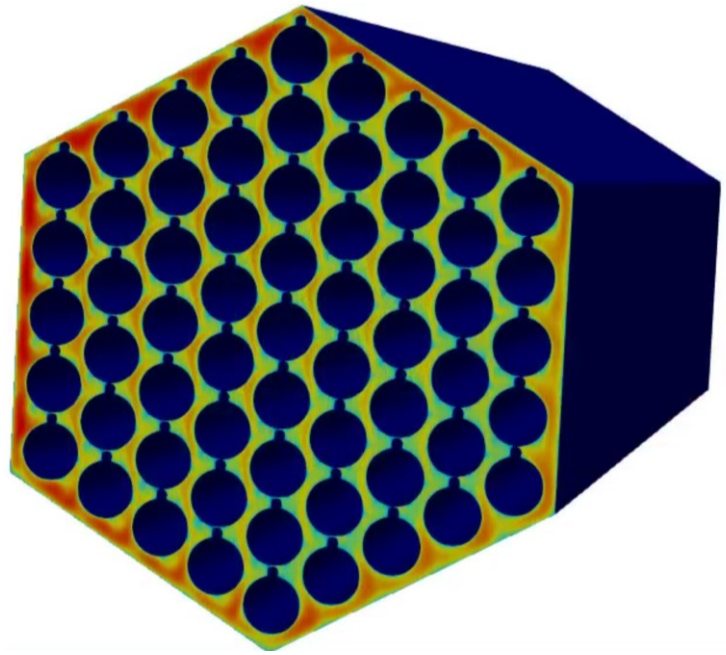
Fuel Bundle Wire Wrapped Simulations







Prediction of the pressure drop and of the flow field and comparison with experiments in FA



Florentin Prud'homme and Maria Faruoli

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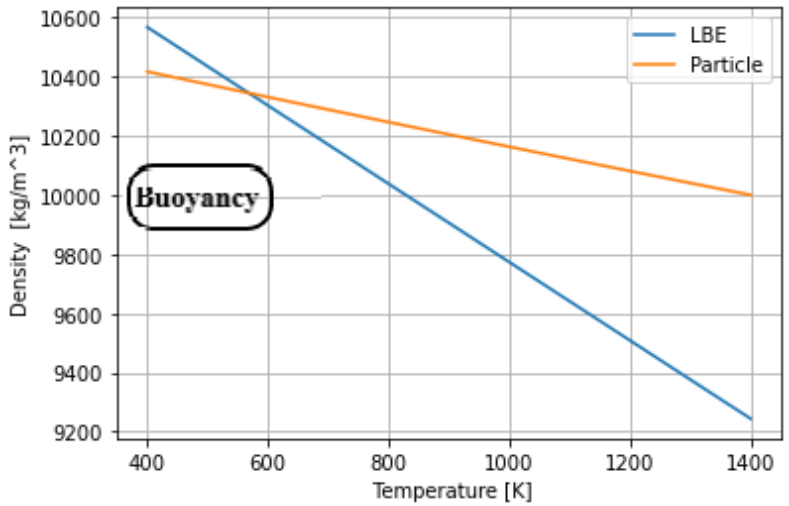
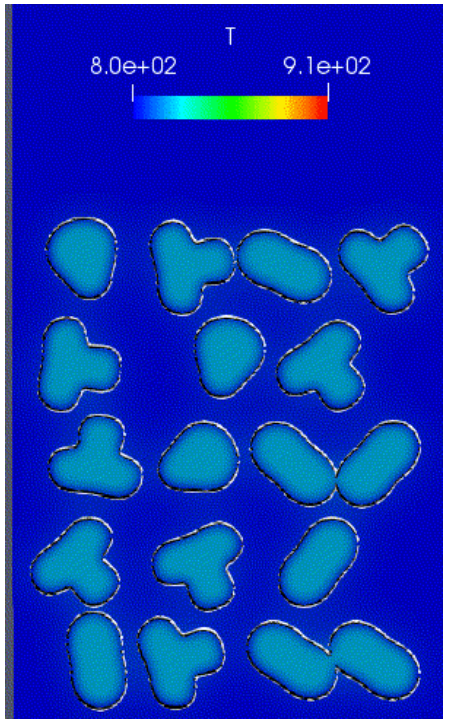
PARTICLE MODELLING

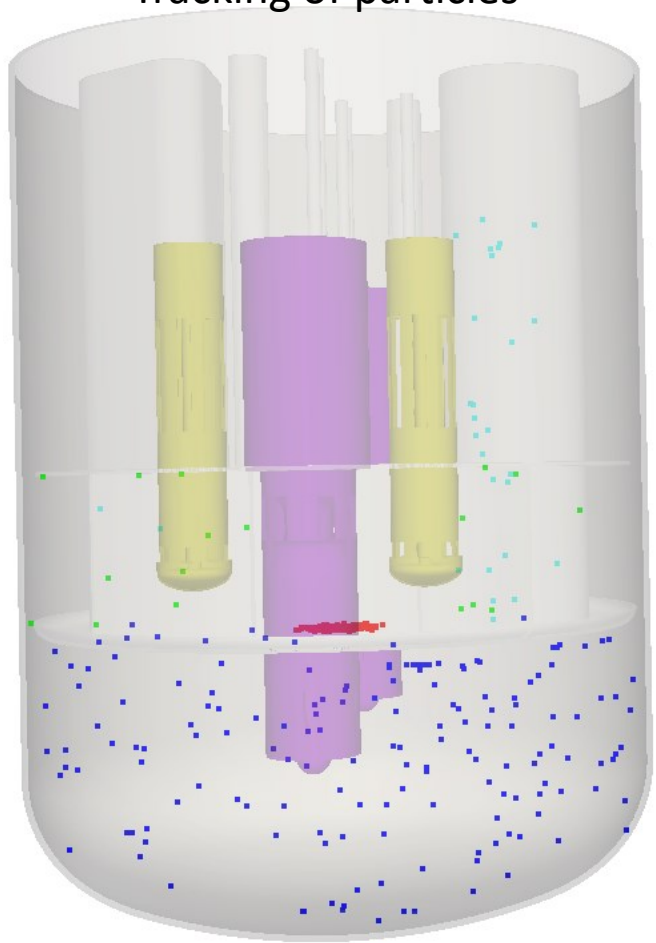
Failure of fuel pin cladding - Release of radioactive particles from the fuel



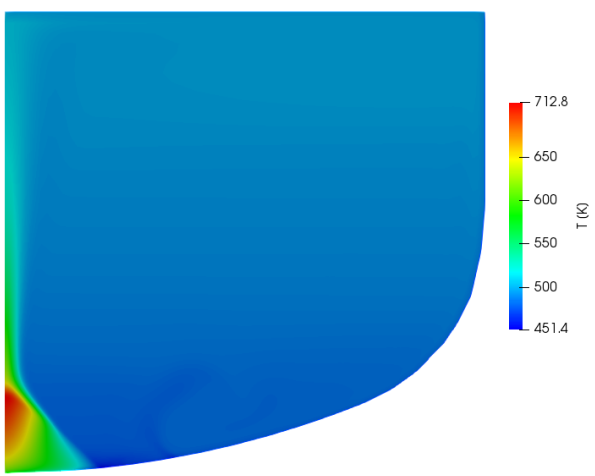
Hot particles

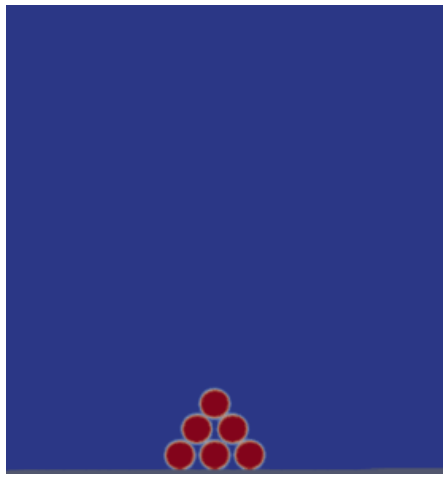


Tracking of particles



Agglomeration of particles at the bottom





Cold particles

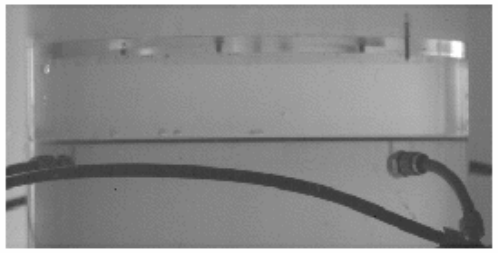
Lorenzo Vallisa and Silvania Lopes

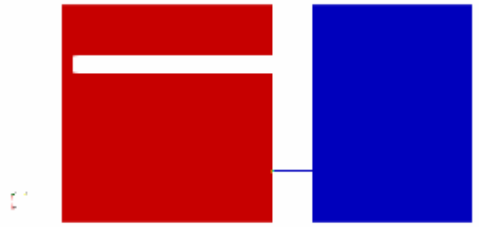
von KARMAN INSTITUTE
FOR FLUID DYNAMICS

Air Ingress from a Side Break

Dynamic mesh is used to study the air ingress in case of the side break of a vessel. The verification of the model is done against experimental results obtained with water.

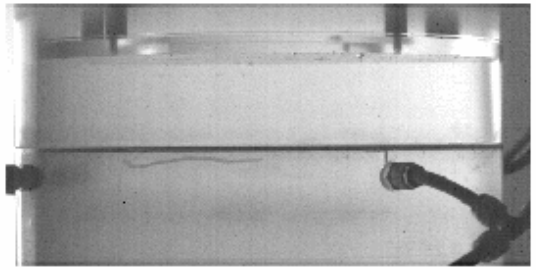
Time=0s

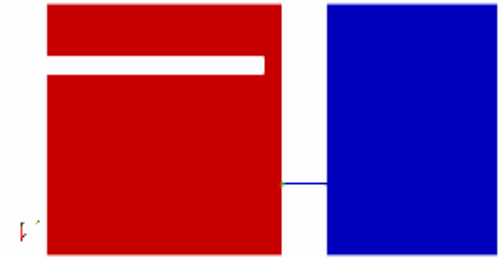




Air ingress

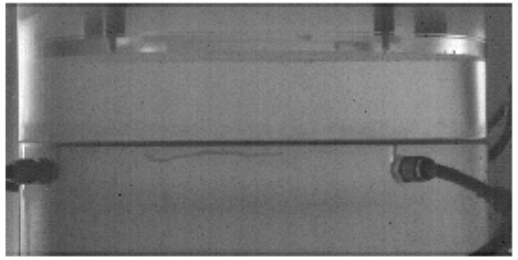
Time=0s

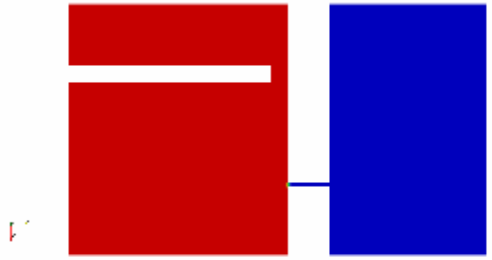




Air ingress

Time=0s

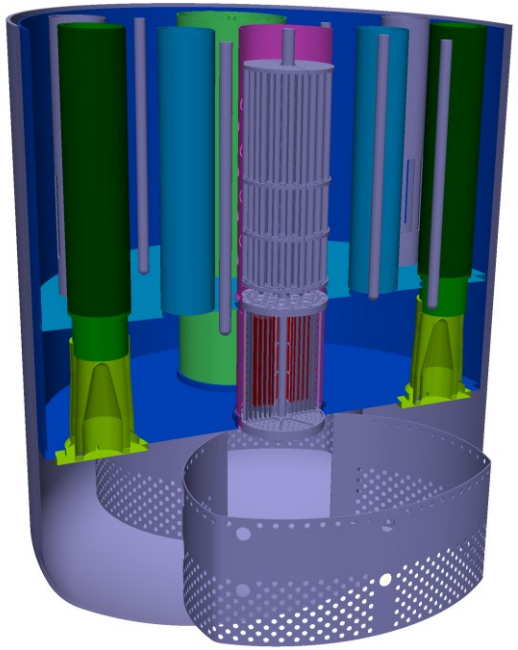


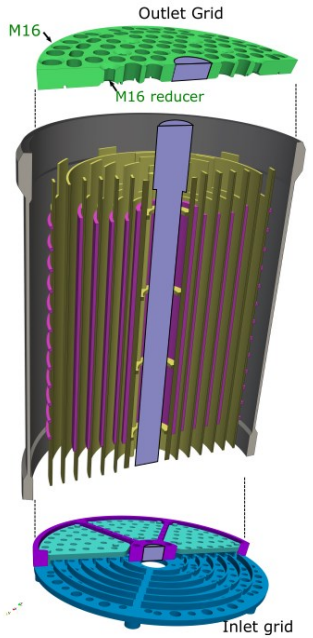


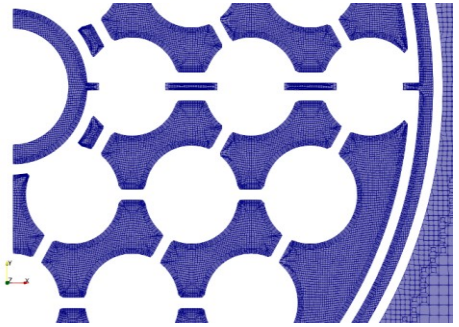
No Air ingress

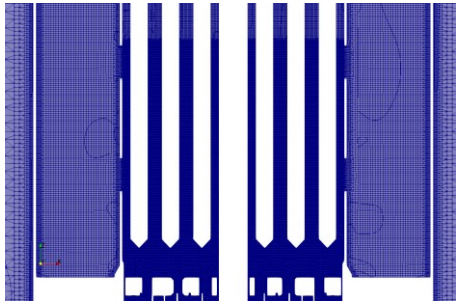
THE E-SCAPE FACILITY

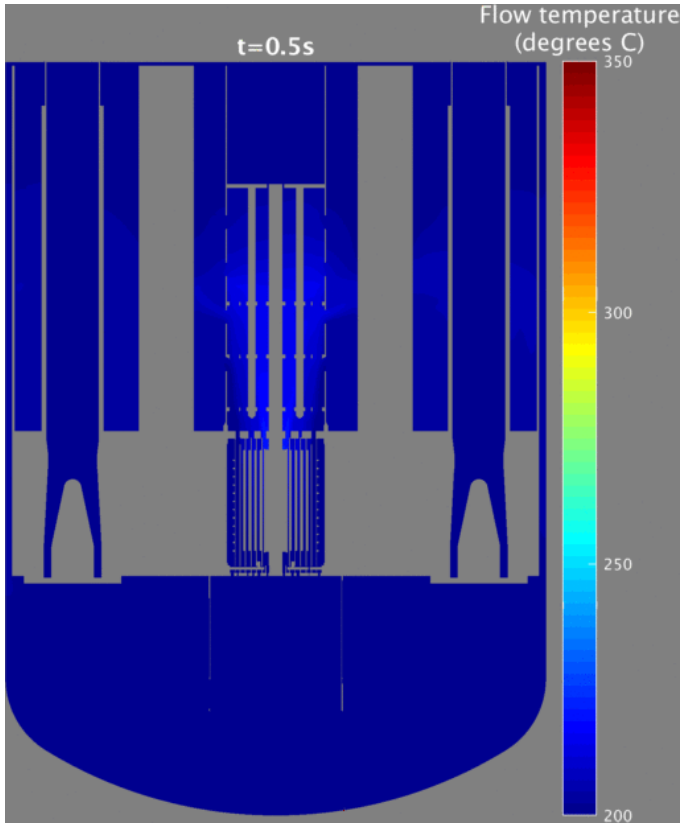
The E-SCAPE (European SCAled Pool Experiment) facility is a thermal hydraulic 1/6-scale model of the primary system of the MYRRHA reactor pool, cooled by LBE.

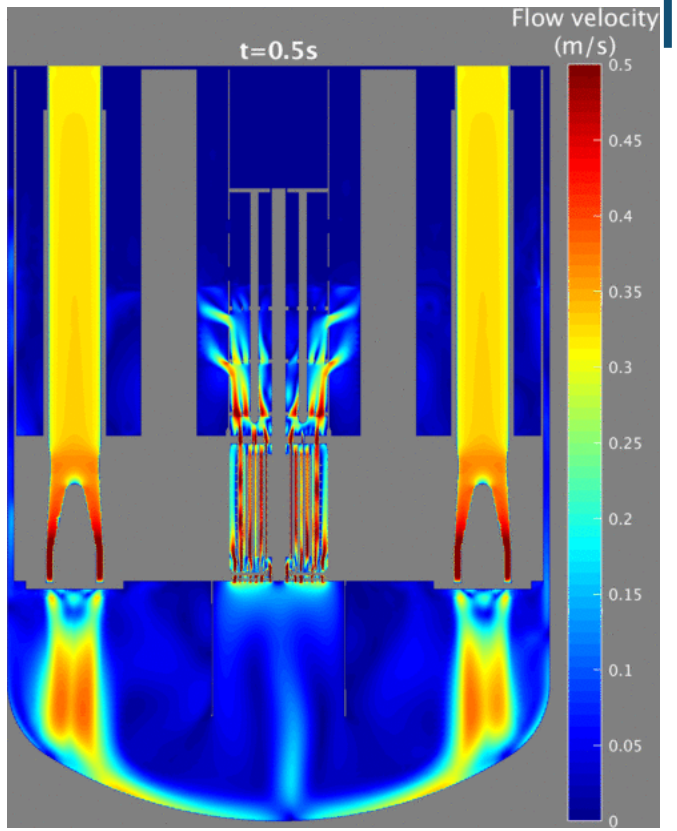








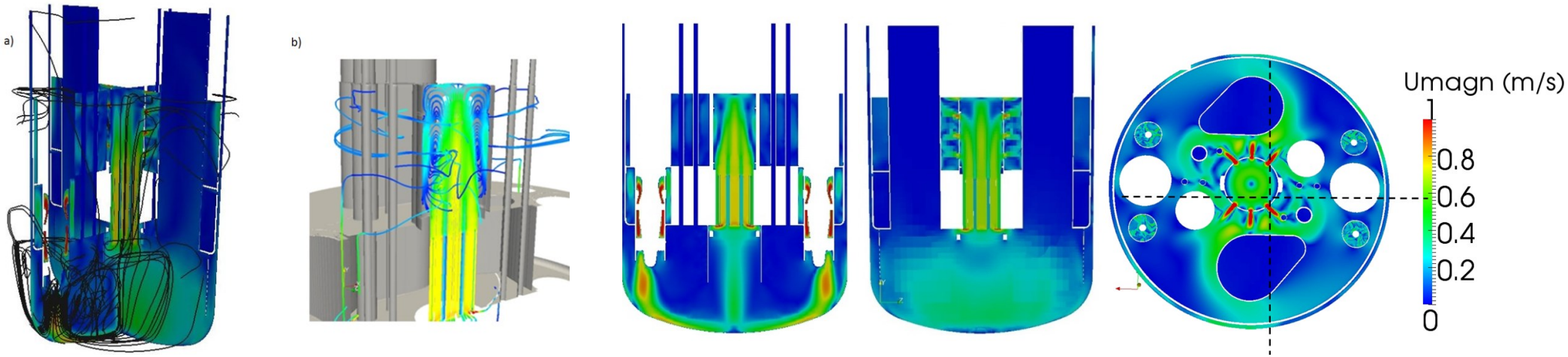


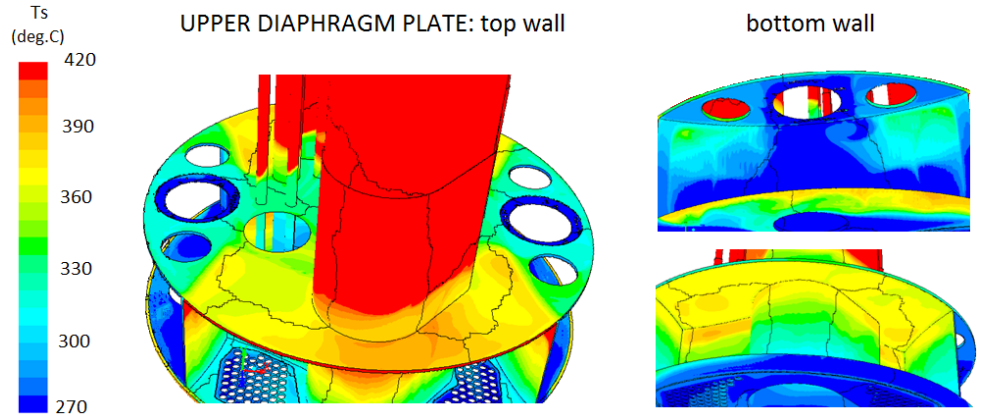


Silvania Lopes

MYRRHA

The developed models are applied to the design of the MYRRHA reactor to study nominal and transient scenario



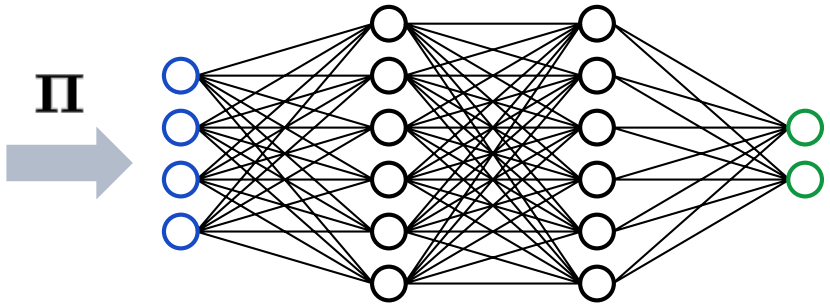


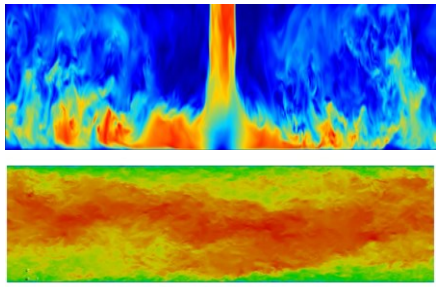
DATA-DRIVEN TURBULENCE MODELLING

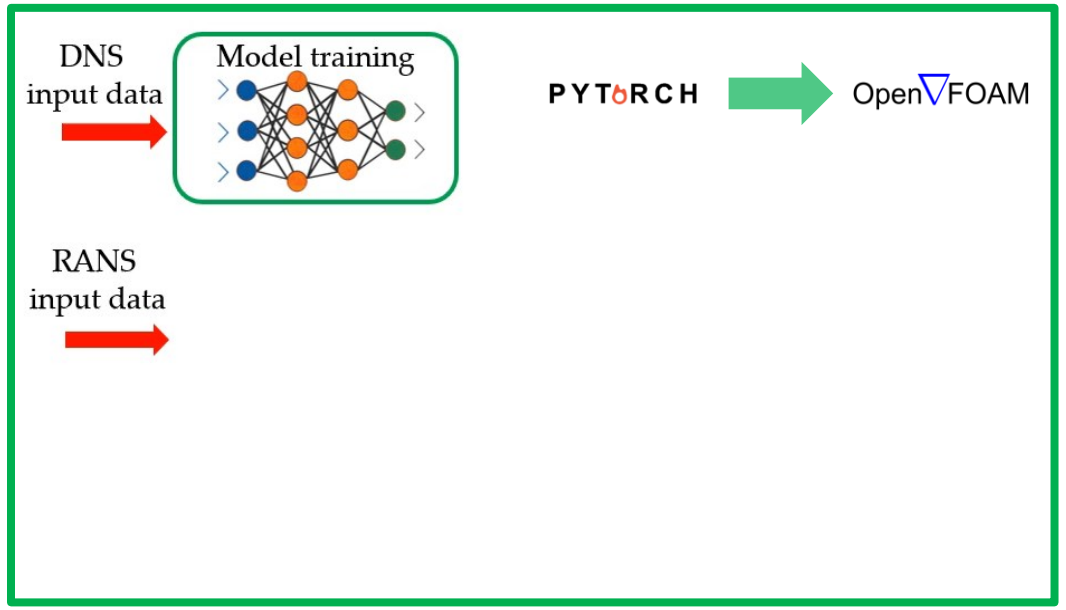
Field Inversion and regression

$\mathbf{q} = \mathcal{F}(\mathbf{\Pi}, \mathcal{W})$ $\mathbf{\Pi}$ Input parameters

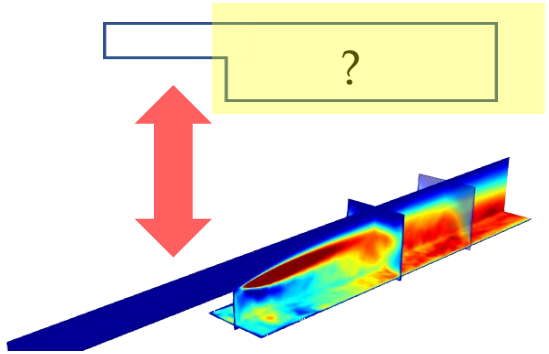
Reference data $\{\Pi_i, \hat{\mathbf{q}}_i\}$







Which $\boldsymbol{\beta}$ gives $\hat{\mathbf{q}}$?



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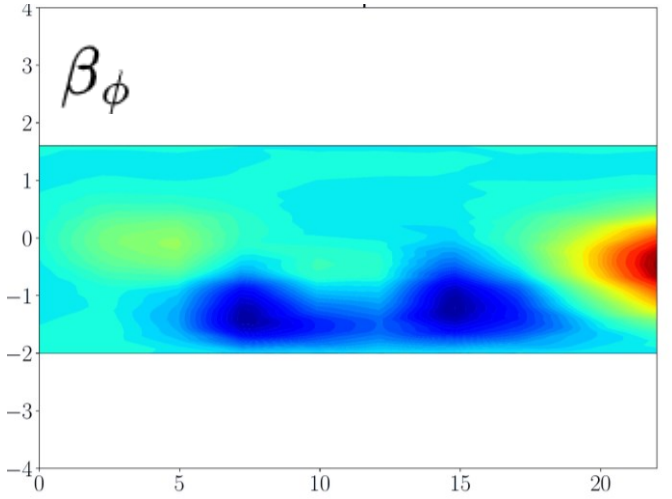
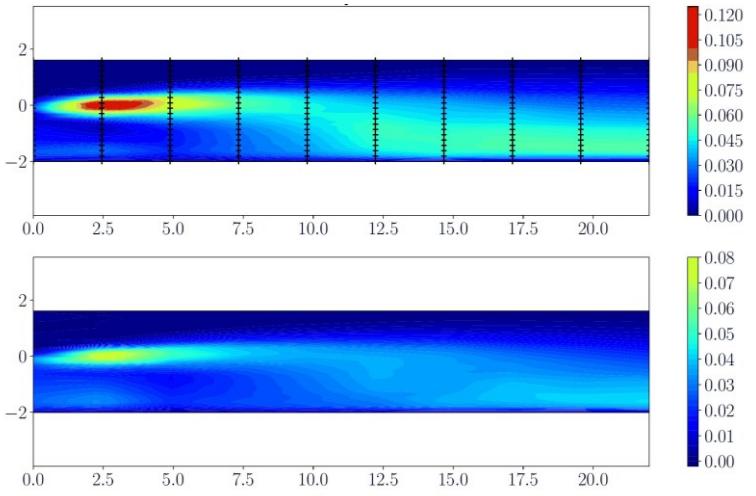
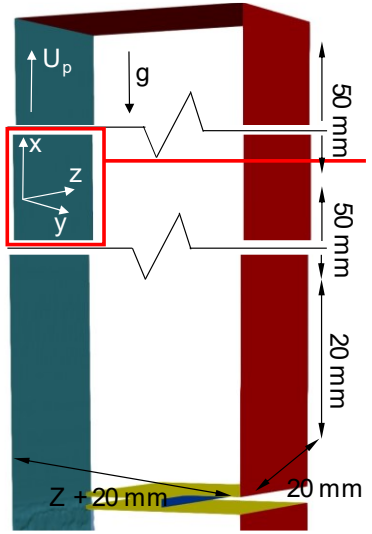
Iteration 1

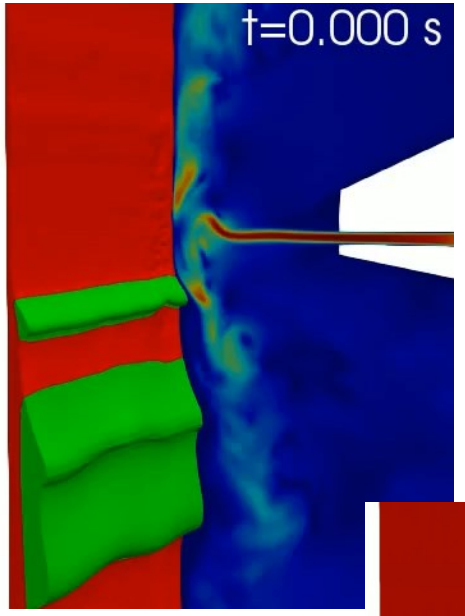


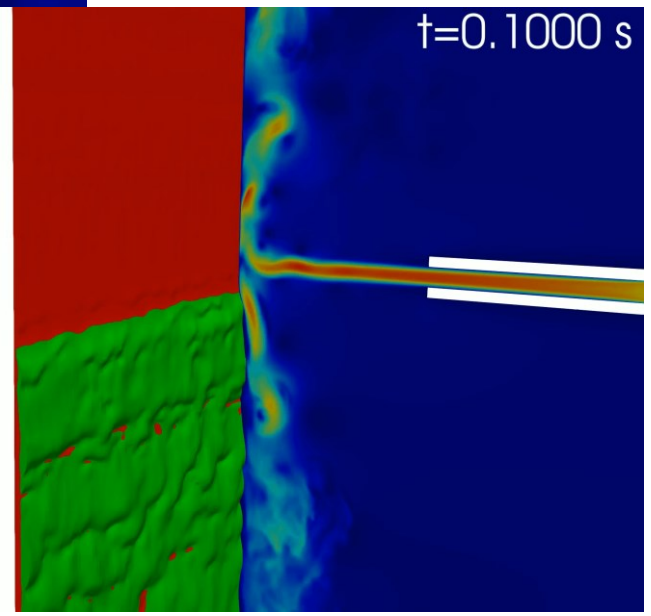
q

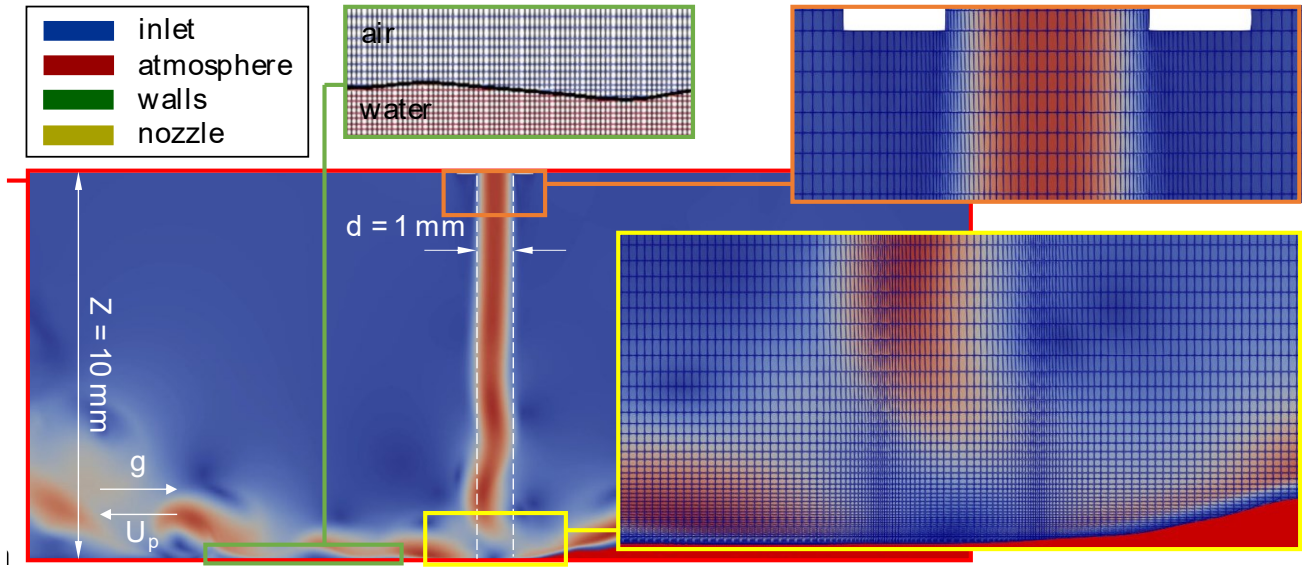


HIGH-FIDELITY CFD TO DESCRIBE THE UNDULATION MECHANISM



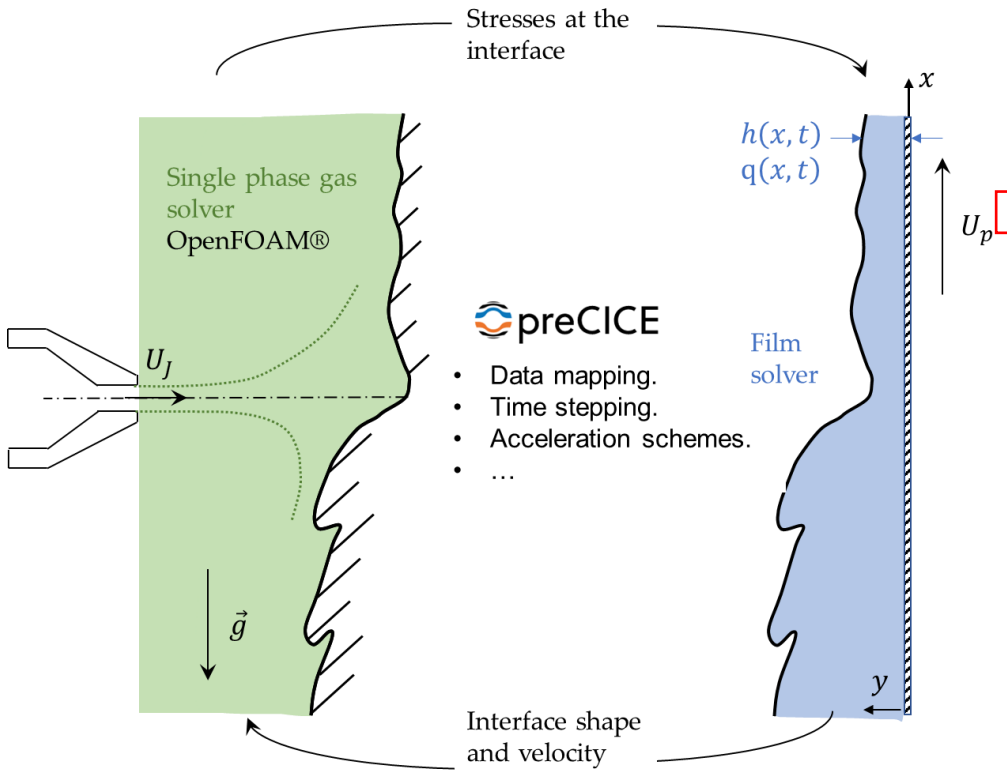


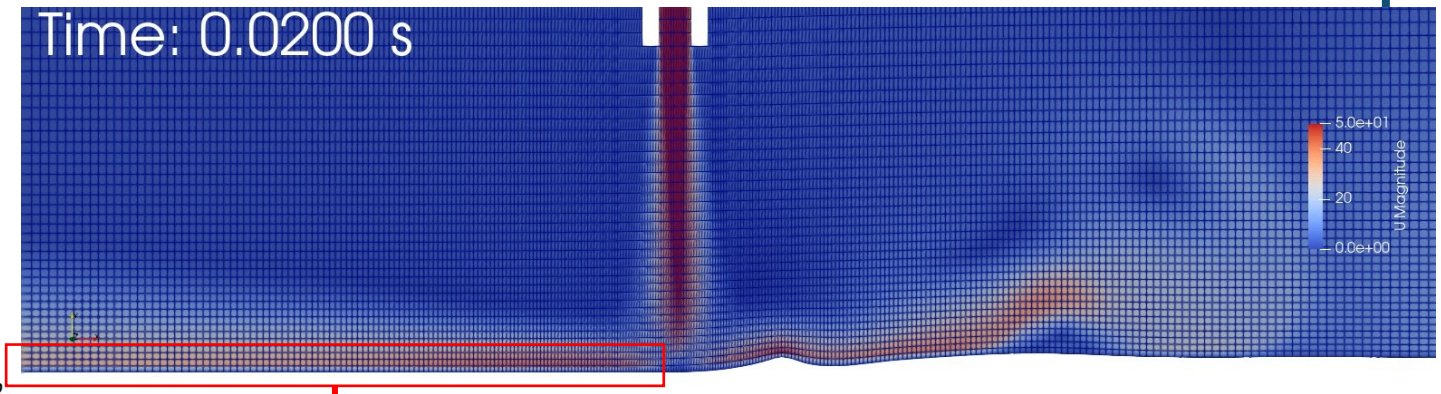


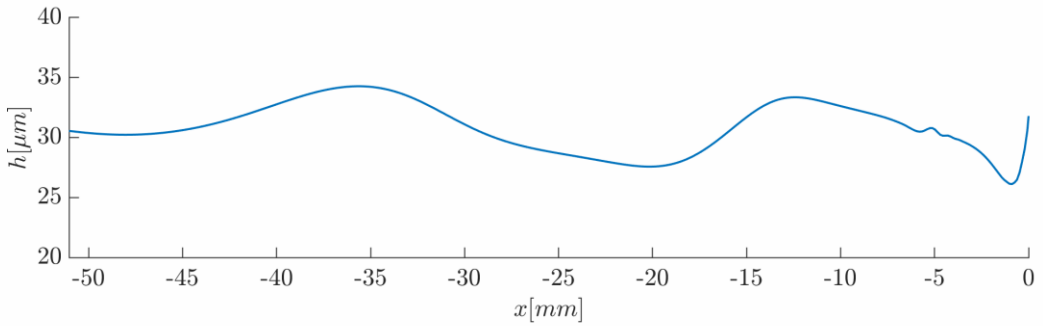


David Barreiro

INTERACTIONS BETWEEN LIQUID FILMS AND GAS FLOWS



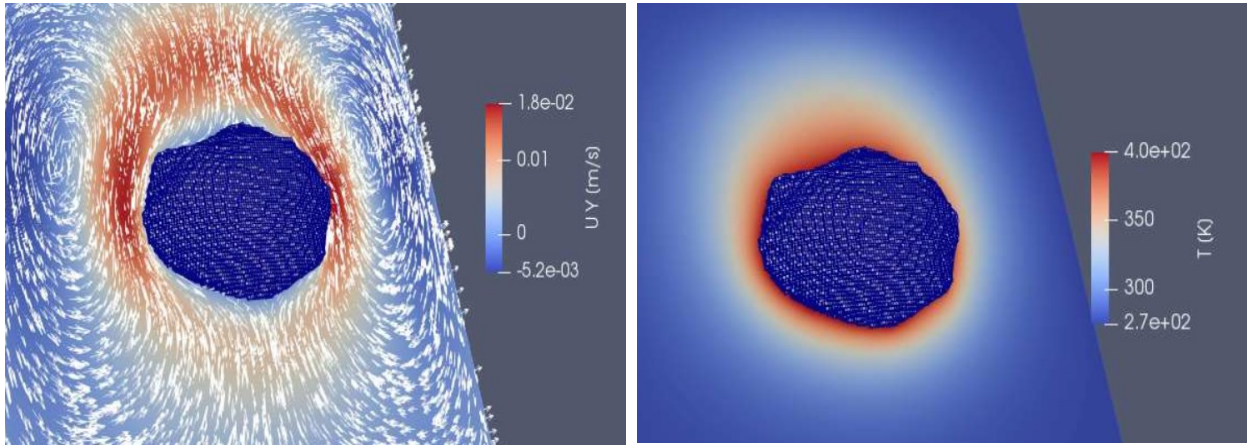




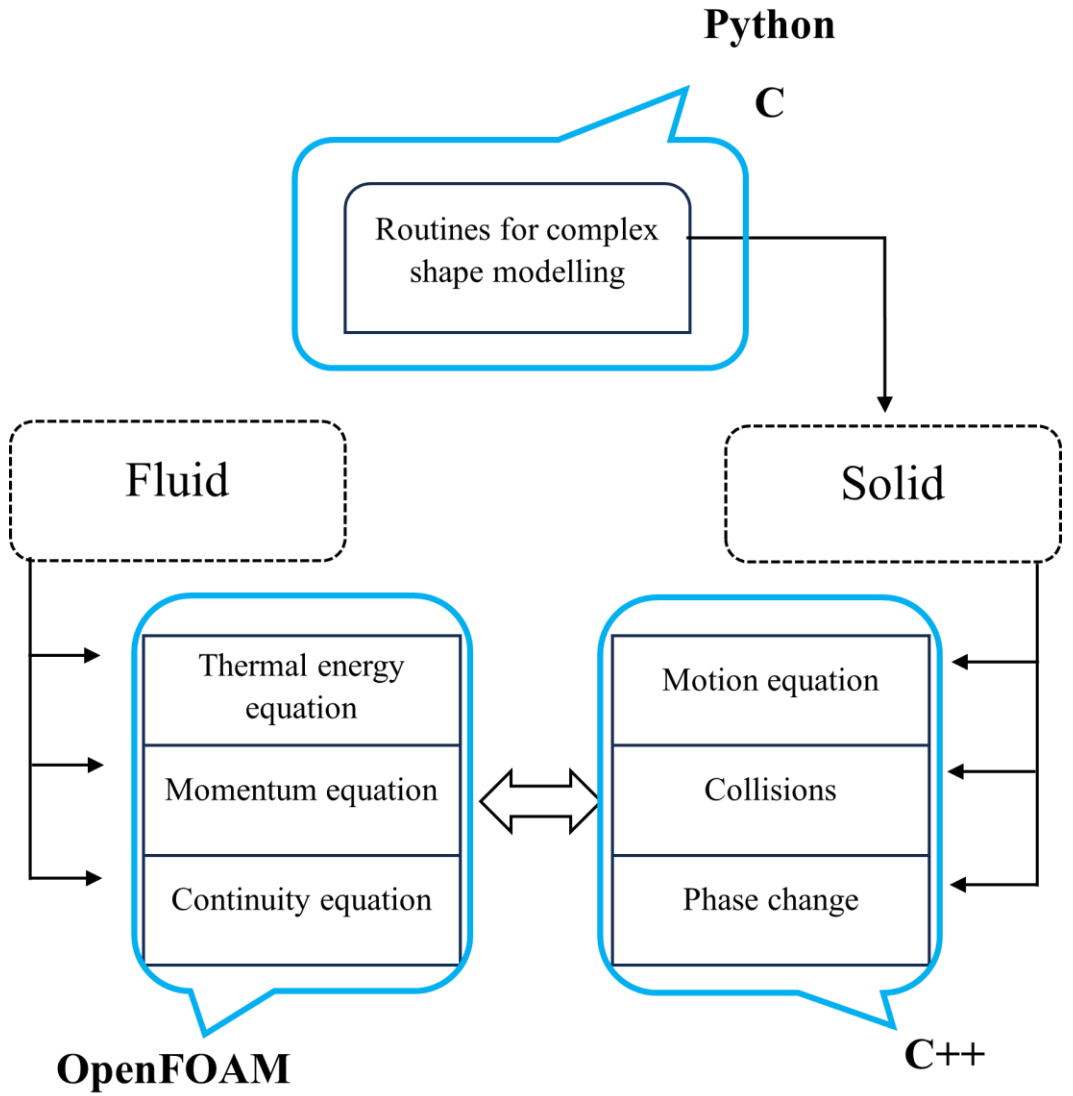
David Barreiro

ADVANCED CHARACTERIZATION OF DENSIFIED CRYOGENIC HYDROGEN

Multiphase solver for thermal interaction modelling of melting particles and the surrounding fluid



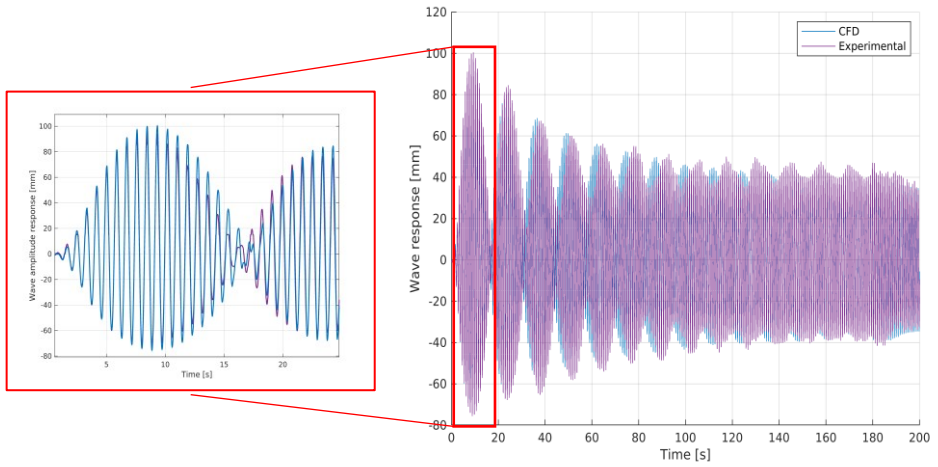
Velocity and temperature profile of free-falling stone into water

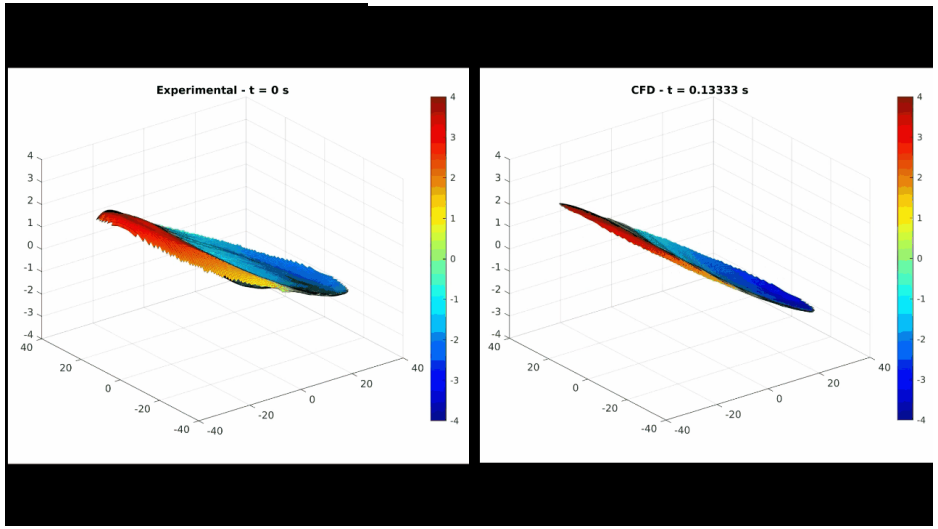


Lorenzo Vallisa

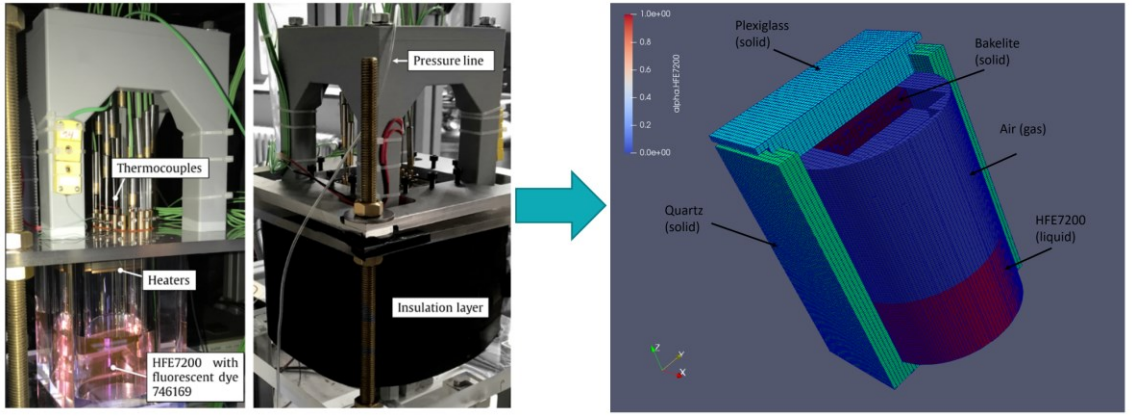
CRYOGENIC PROPELLANT STORAGE TANKS MODELLING

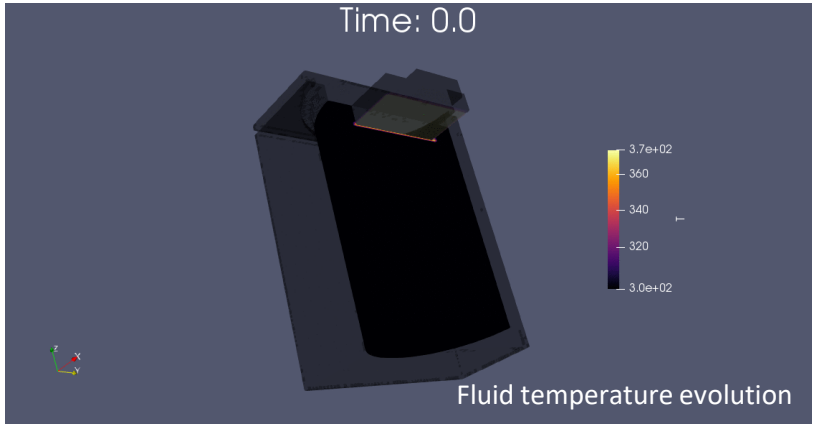
Isothermal sloshing





Interfacial evaporation/condensation (with CHT)

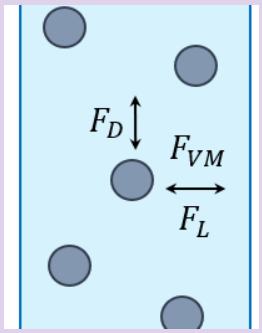


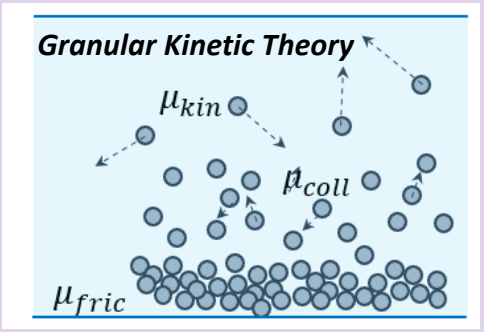


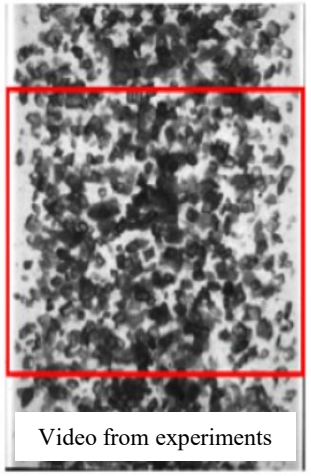
Antonio Cantiani

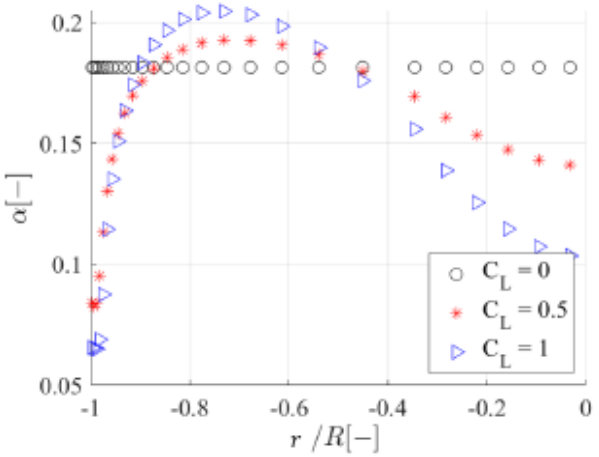
EULER-EULER SIMULATION OF SLURRY PIPE FLOWS

α≤35%, 4-way coupling between liquid and solid







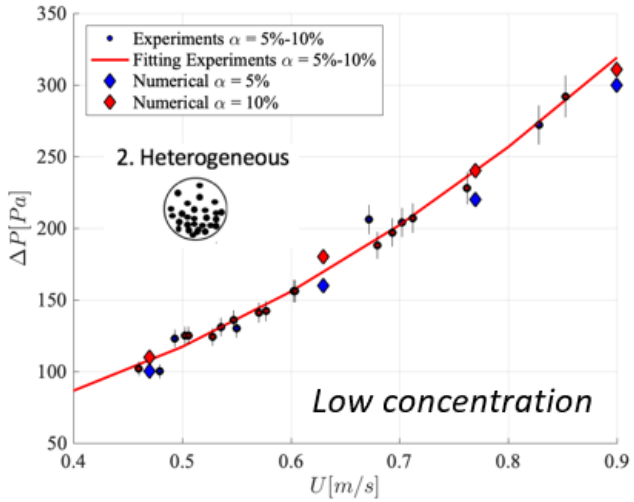


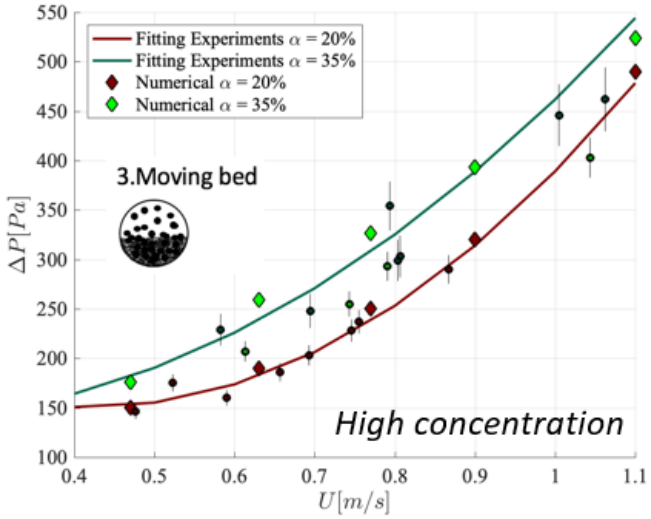
Effect of lift force on solid particles distribution

Vertical pipe section

Horizontal pipe section

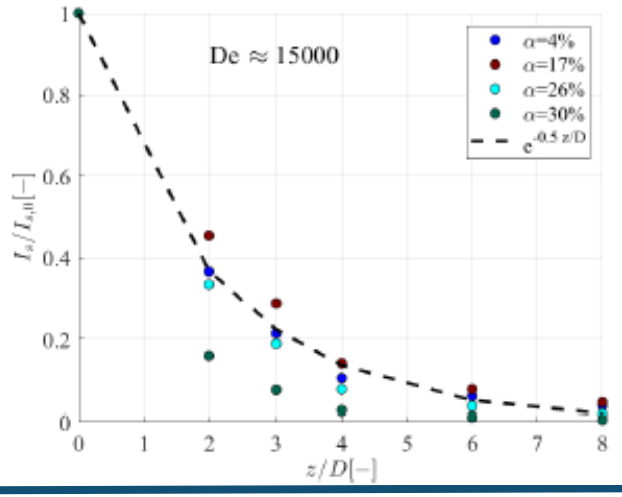
Simulation of several slurry regimes (i.e. particles distribution) and validation against experimental result.

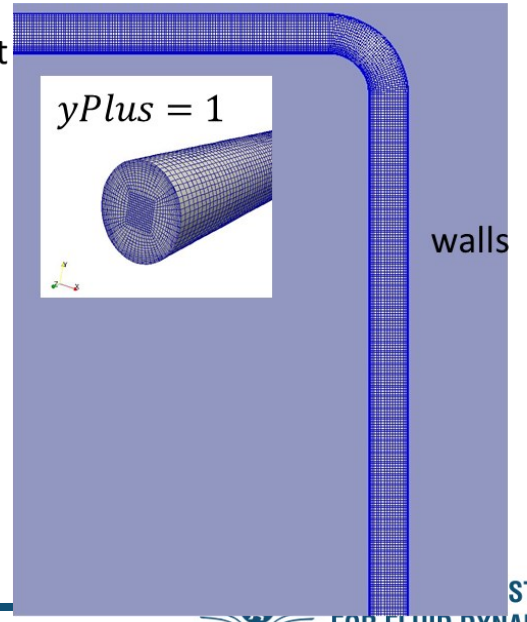




Vertical bend section

Effect of particles on the bend swirl intensity decay





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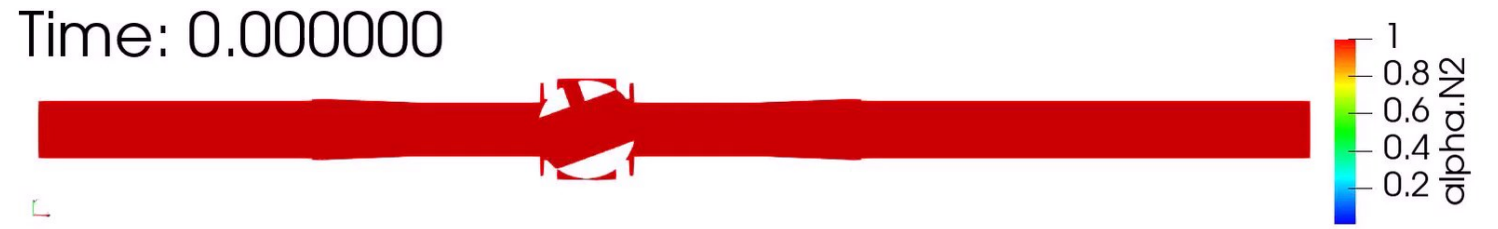
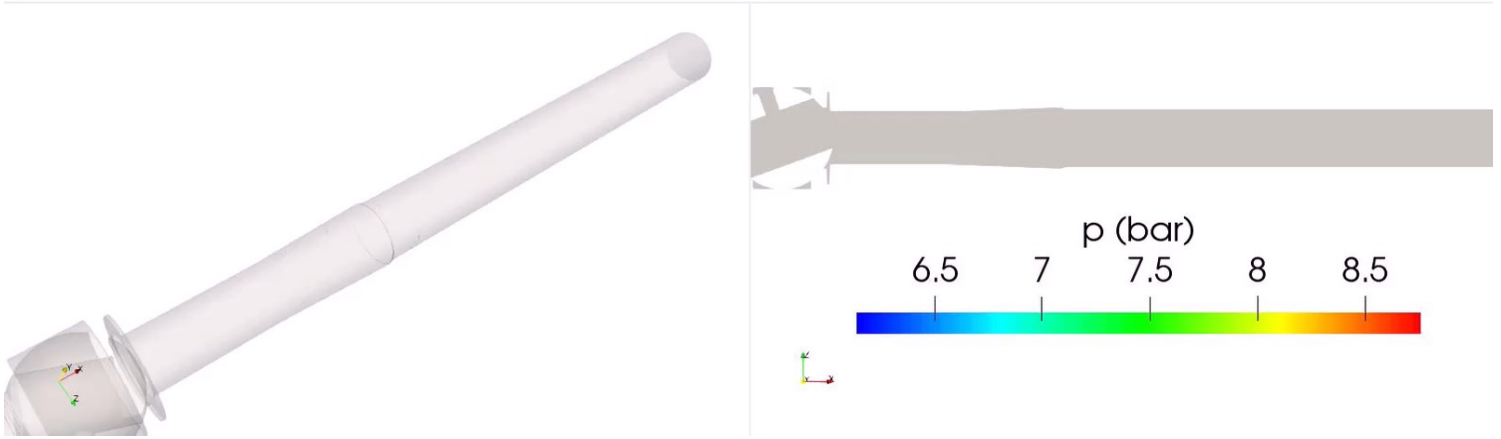
LIQUID NITROGEN CAVITATION

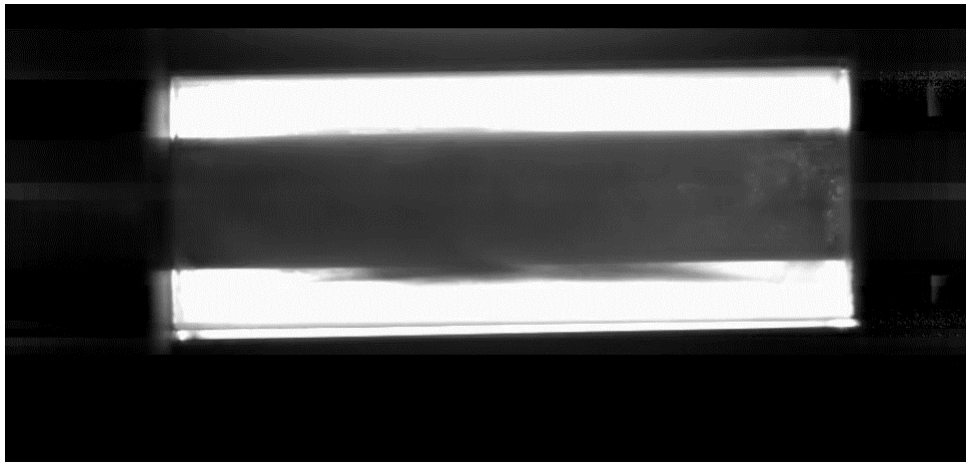




Opening angle: 70 degrees

Total simulation time: 0.08 s
Time step: 5e-7 s

$p_1 = 6.8\ bar$
$p_2 = 8.7\ bar$
$Q = 0.365 \frac{kg}{s}$
$p_{sat} = 6.9\ bar$



Experiment time= 1.3s
$p_1 = 6.6\ bar$
$p_2 = 8.9\ bar$
$Q = 0.42 \frac{kg}{s}$
$p_{sat} = 7.11\ bar$

Maria Faruoli and Maria Teresa Scelzo

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- **“A hybrid solver to resolve strong interactions between liquid films and gas flows”** , D. Barreiro-Villaverde, A. Gosset , M. Lema, M. A. Mendez, FOAM@Iberia 2023
- **“High and low fidelity models to understand the physics of air-knife coating”** , D. Barreiro-Villaverde, A. Gosset , M. Lema, M. A. Mendez, European Coating symposim 2023
- **“Experimental and Numerical Study of a Cryogenic Ball Valve Using Liquid Nitrogen”,** M.T. Scelzo, M. Faruoli, H. Lejeune, S. Varin, J. Pinho, 8th World Congress on Momentum, Heat and Mass Transfer (MHMT’23)
- **“Analysis of the Scaling Between Model Experimental Facilities MYRRHABELLE and E-SCAPE and the MYRRHA Reactor Augmented by CFD”**, L. Koloszar , S. Lopes, M. Faruoli , Ph. Planquart , K. Van Tichelen , J. Pacio , S. Keijers , NURETH 20 (2023)
- **“Gas Ingress During Side Vessel Break: Experiments and Numerical Simulations with a Simplified Pool-Type Scaled Water Model”,** M. Faruoli , M. Delsipee , Ph. Planquart, G. Scheveneels , B. Yamaji, NURETH20 (2023)
- **“Experimental and numerical investigation of slurry flows in pipelines: a contribution towards slush propellants for future rockets' engines”,** M. T. Scelzo, PhD Dissertation at Université Libre de Bruxelles (2021)
- **“Physics-constrained machine learning for thermal turbulence modelling at low Prandtl numbers.”,** M. Fiore et al. , International Journal of Heat and Mass Transfer 194 (2022)
- **“Data-Driven Augmentation of a Second Order Heat Flux Model to Extend it to Heavy Liquid Metals”,** M. Fiore et al., 20th International Topical Meeting on Nuclear Reactor Thermal Hydraulics (NURETH20) (2023).

Thanks for your attention and enjoy the next part of the seminar!