Annalisa Manera
Nuclear Safety and Multiphase Flows

May 17, 2021

Background

EDUCATION

M.Sc. Nuclear Engineering, University of Pisa, Italy

PhD. Nuclear Engr., Delft University of Technology
The Netherlands

PROFESSIONAL EXPERIENCE

From 07/2021	**Professor, ETH-Zurich**
2017 – present	Professor, University of Michigan
2011 – 2017	Associate Professor, University of Michigan
2006 – 2011	**Head of group “Nuclear Systems Behaviour”, PSI**
2004 – 2006	Research Scientist, Research Center Rossendorf-Dresden
2003 – 2004	Research Scientist, Delft University of Technology

Current trends in nuclear engineering

Toward the "numerical reactor"

First-principle numerical representation of the **multi-physics (multi-scale)** phenomena occurring in nuclear reactors, providing:

- **high-fidelity** simulation capability that can be used for design and safety analysis of LWRs and advanced reactors

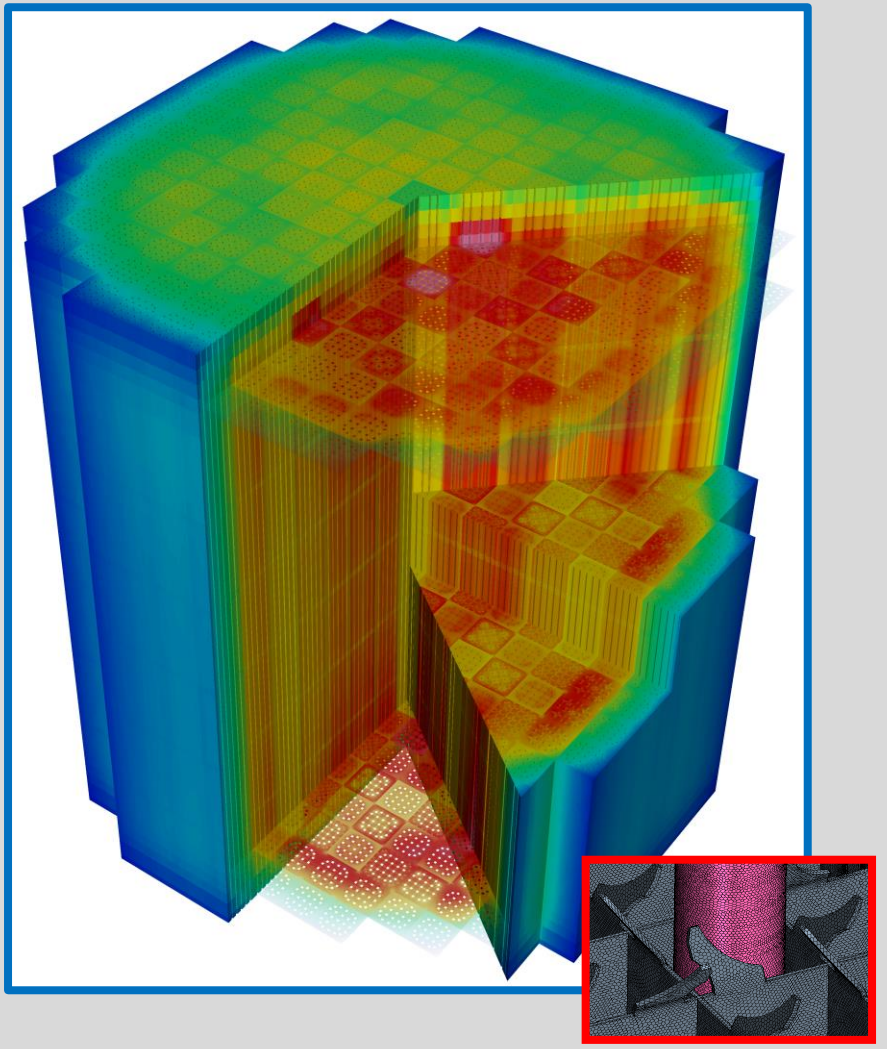
Better prediction of safety margins

↓

improved economics
& life extension

- **Optimization between computations and experimental demonstration** when designing a new reactor systems

(Simulations are cheaper than exp.)

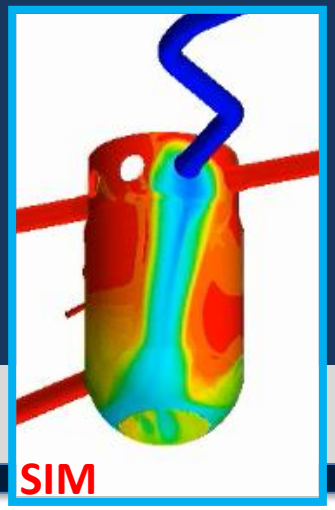


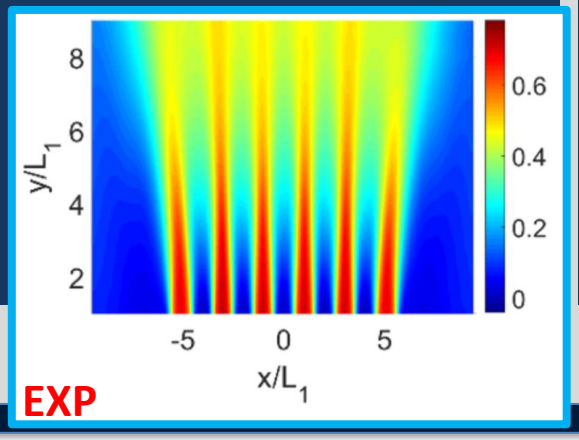
RESEARCH THRUST AREAS

CFD = Computational Fluid Dynamics

Research Thrust #1

Development of CFD-based multi-scale, multi-physics computational tools for nuclear reactor applications





Research Thrust #2

CFD-grade experiments for models development and validation

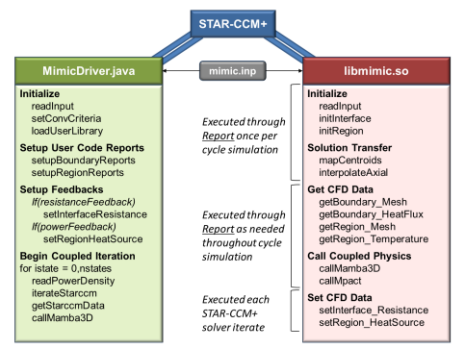
- ❑ Use of high-resolution instrumentation for experiments specifically designed for physics discovery and models development/validation
- ❑ Advance state-of-the-art of high-resolution instrumentation

Thrust #1

DEVELOPMENT OF MULTI-SCALE, MULTI-PHYSICS HIGH-RESOLUTION COMPUTATIONAL TOOLS

HIGH-FIDELITY SIMULATION OF CRUD DEPOSITS ON NUCLEAR FUEL

HIGH-FIDELITY SIMULATIONS



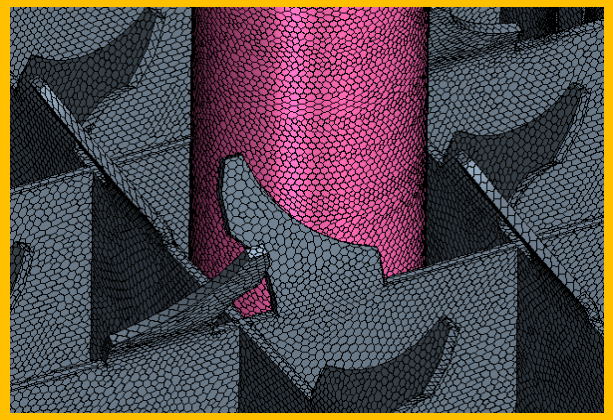
MPACT/STAR-CCM+/MAMBA3D

Neutron transport ⟷ CFD

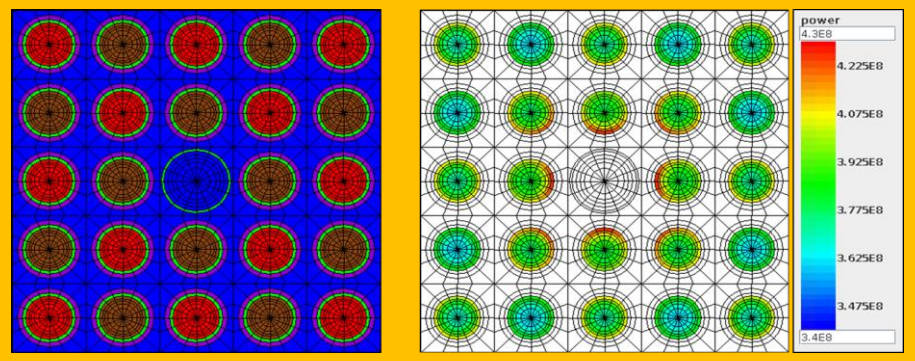
Neutron transport ⟷ Chemistry

CFD ⟷ Chemistry

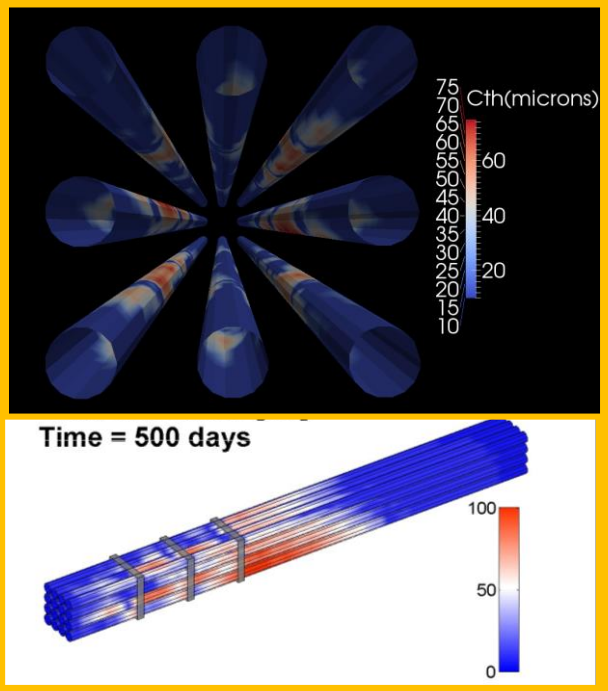
Detailed geometry representation



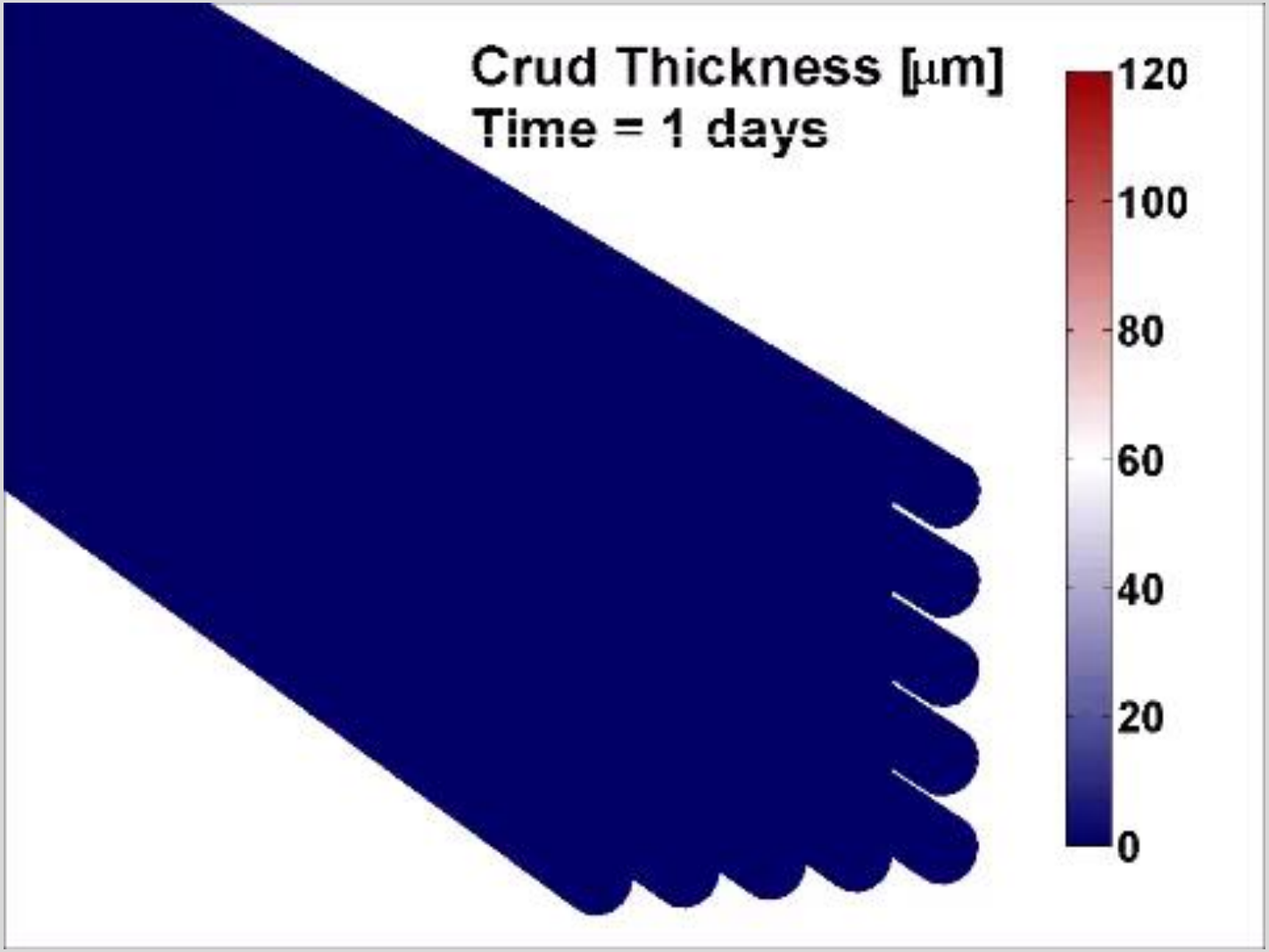
Detailed power/temperature distributions



CRUD DEPOSITION



HIGH-FIDELITY SIMULATION / CRUD



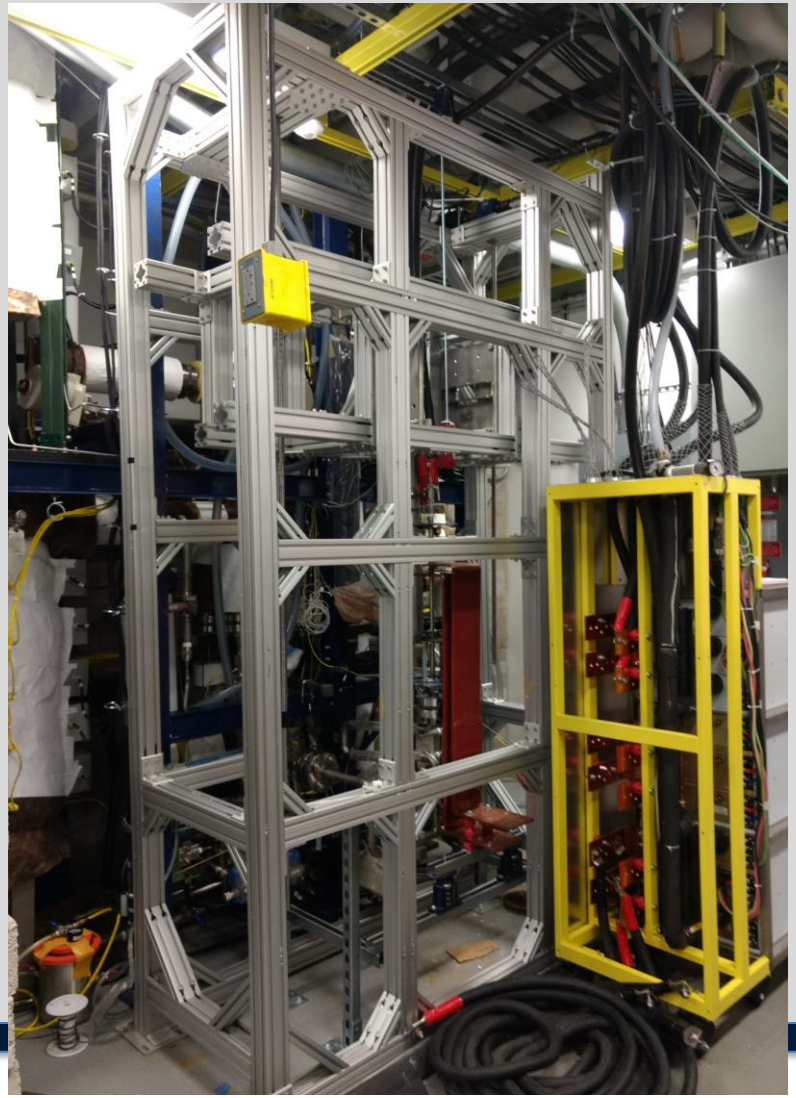
Thrust #2 / A

DEVELOPMENT OF HIGH-RESOLUTION INSTRUMENTATION

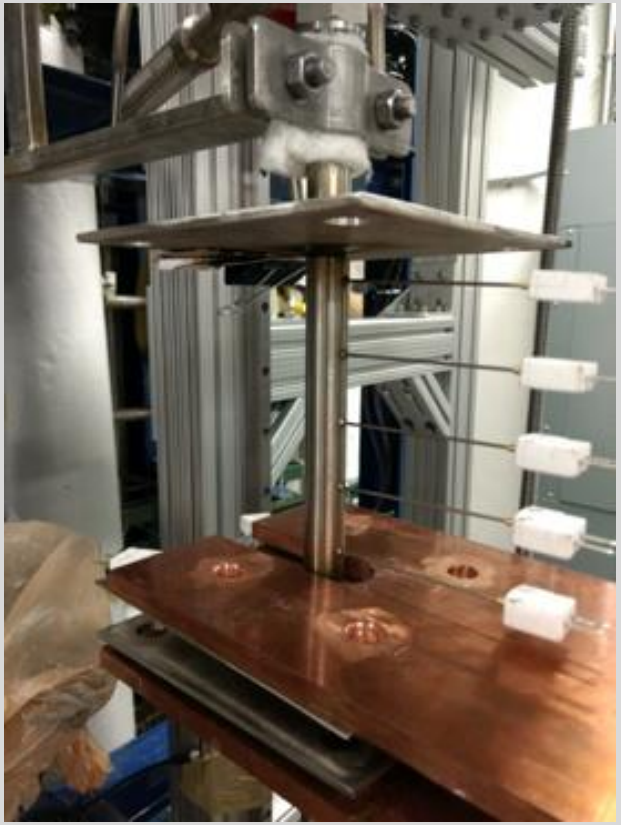
GAMMA TOMOGRAPHY / HIGH-SPEED XRAY RADIOGRAPHY

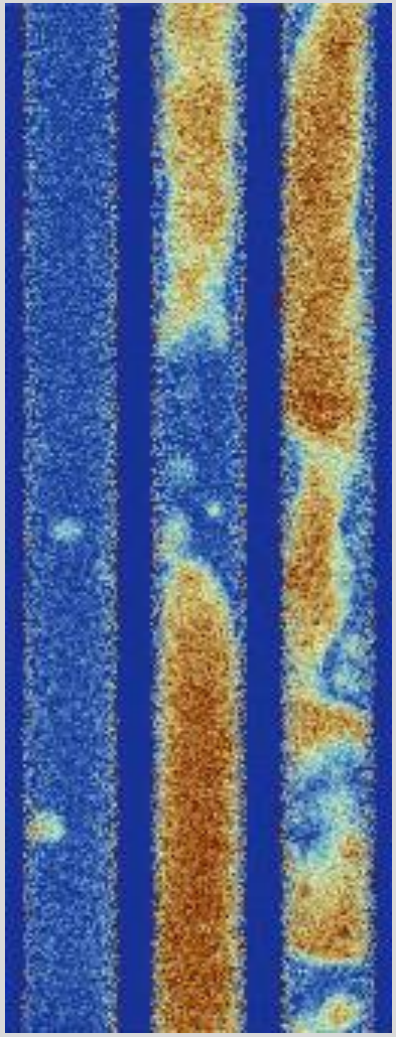
HIGH-SPEED XRAY RADIOGRAPHY

POST-CHF FACILITY (70 bar)

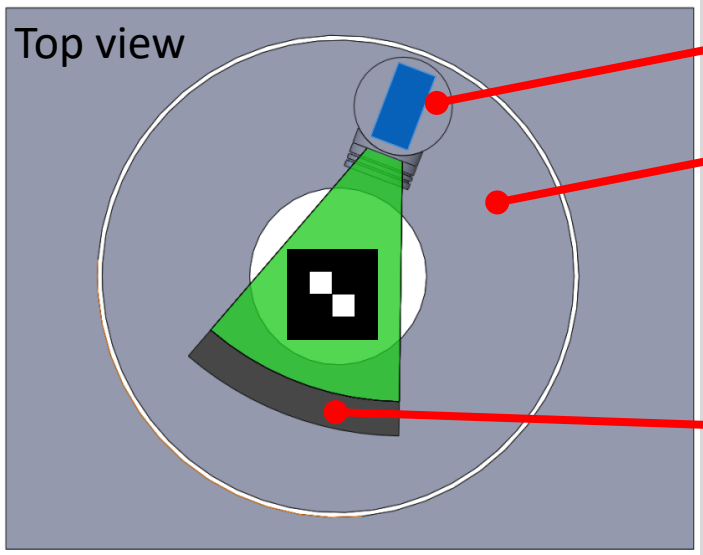


TEST SECTION

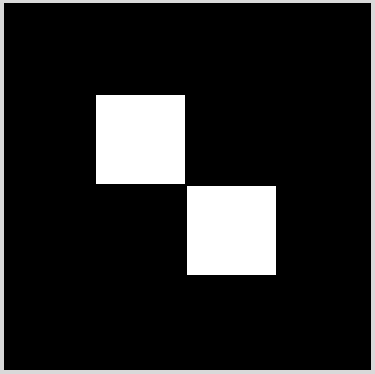




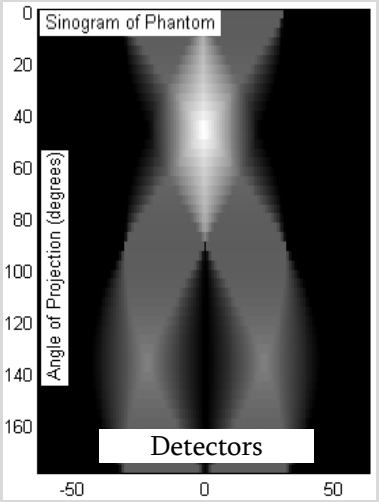
GAMMA-TOMOGRAPHY



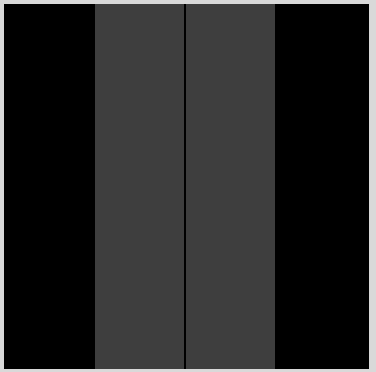
Object cross-section to be measured



Measured sinogram

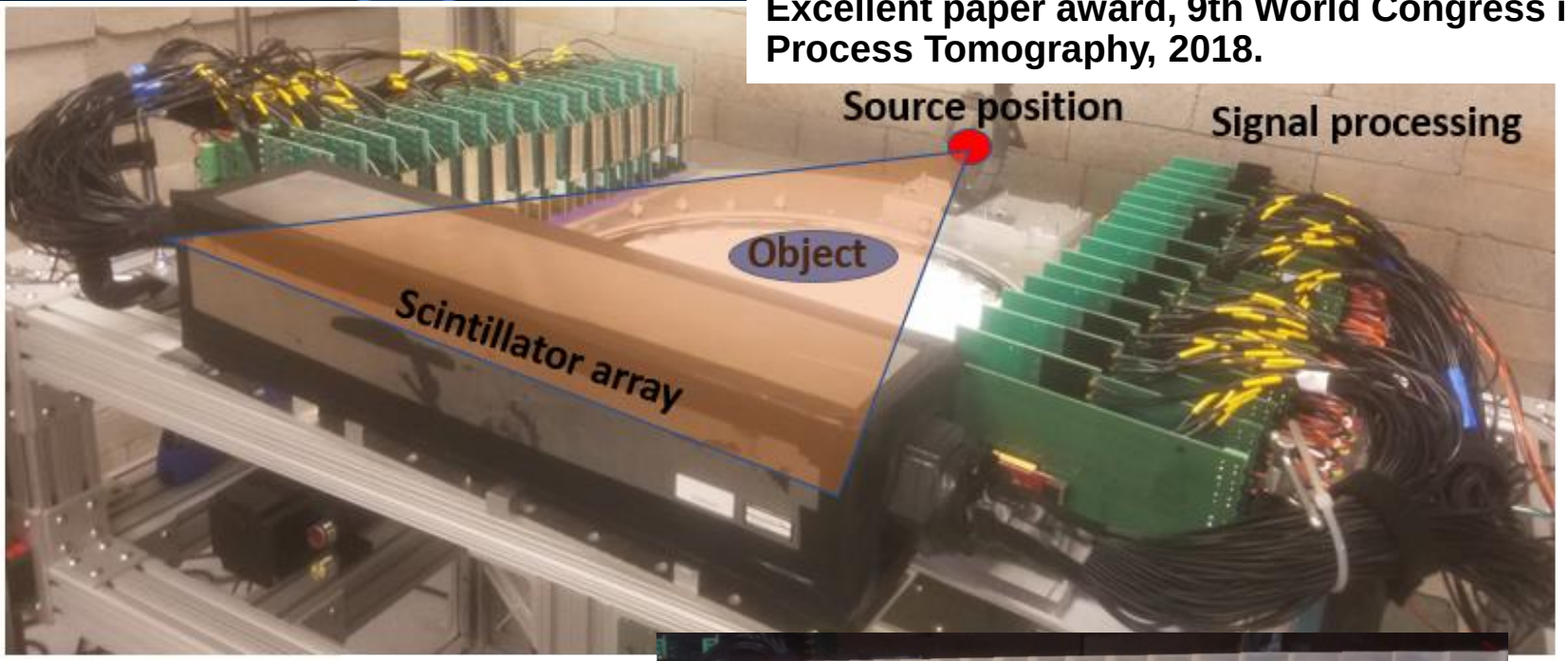


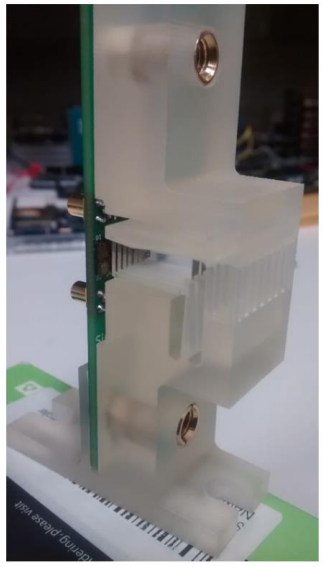
Reconstructed object cross-section

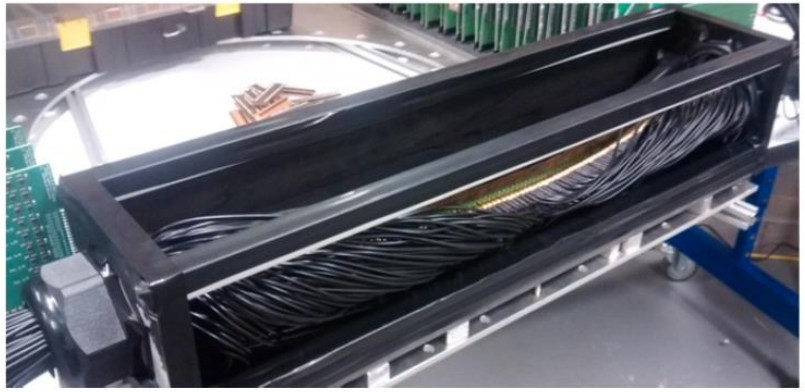


GAMMA-TOMOGRAPHY

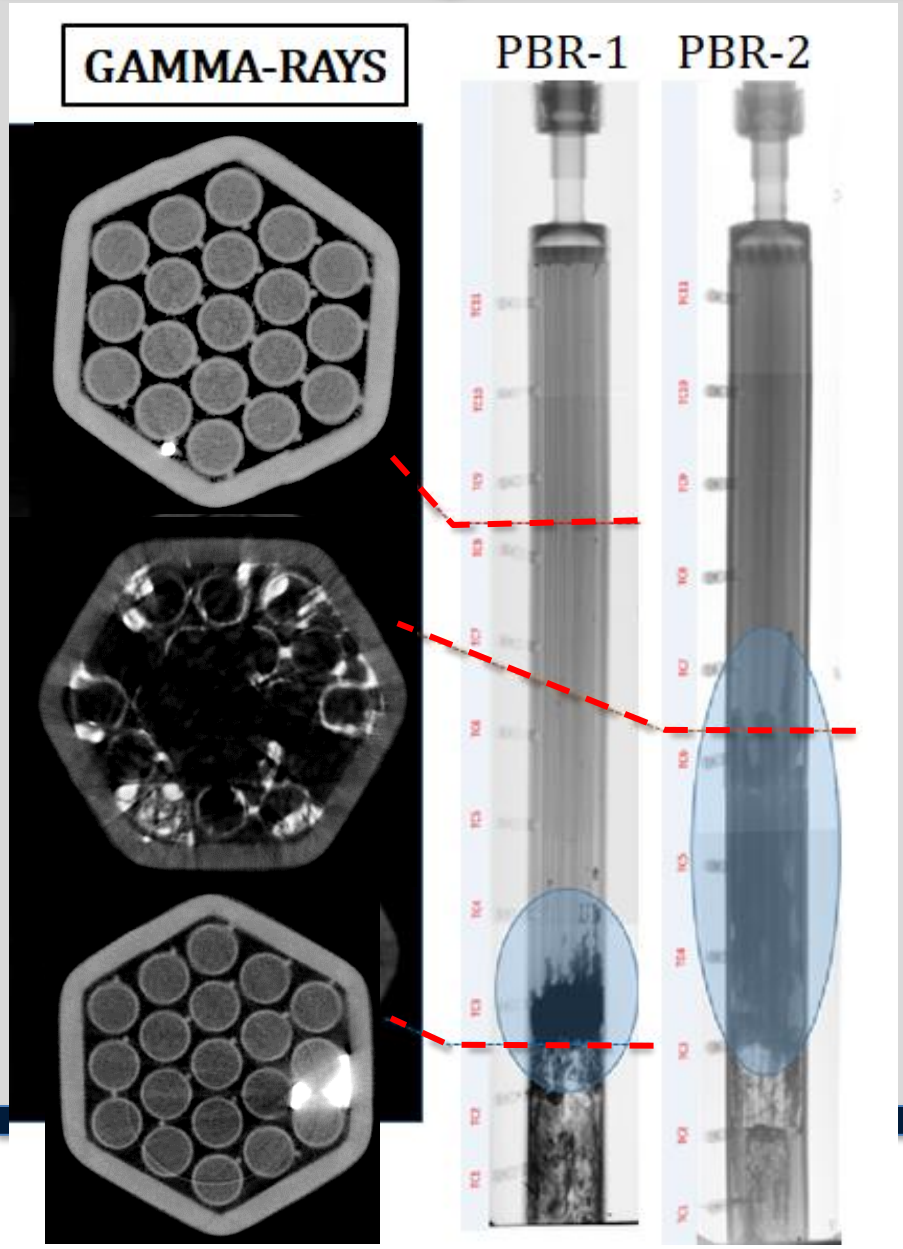
Excellent paper award, 9th World Congress in Industrial Process Tomography, 2018.





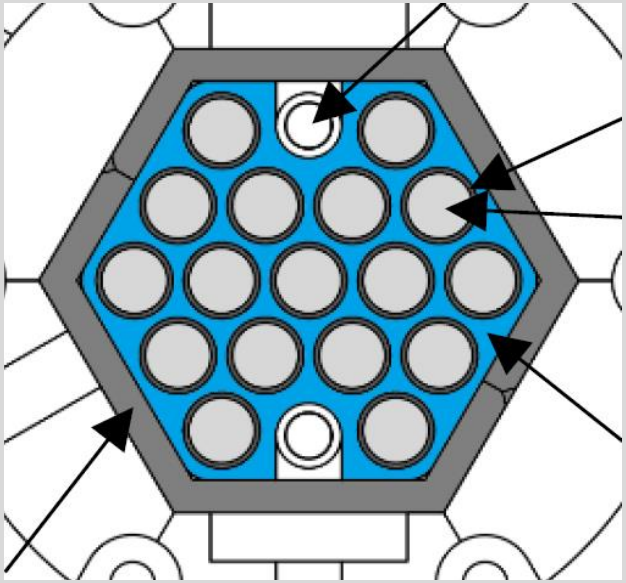


TOMOGRAPHY / IMAGING

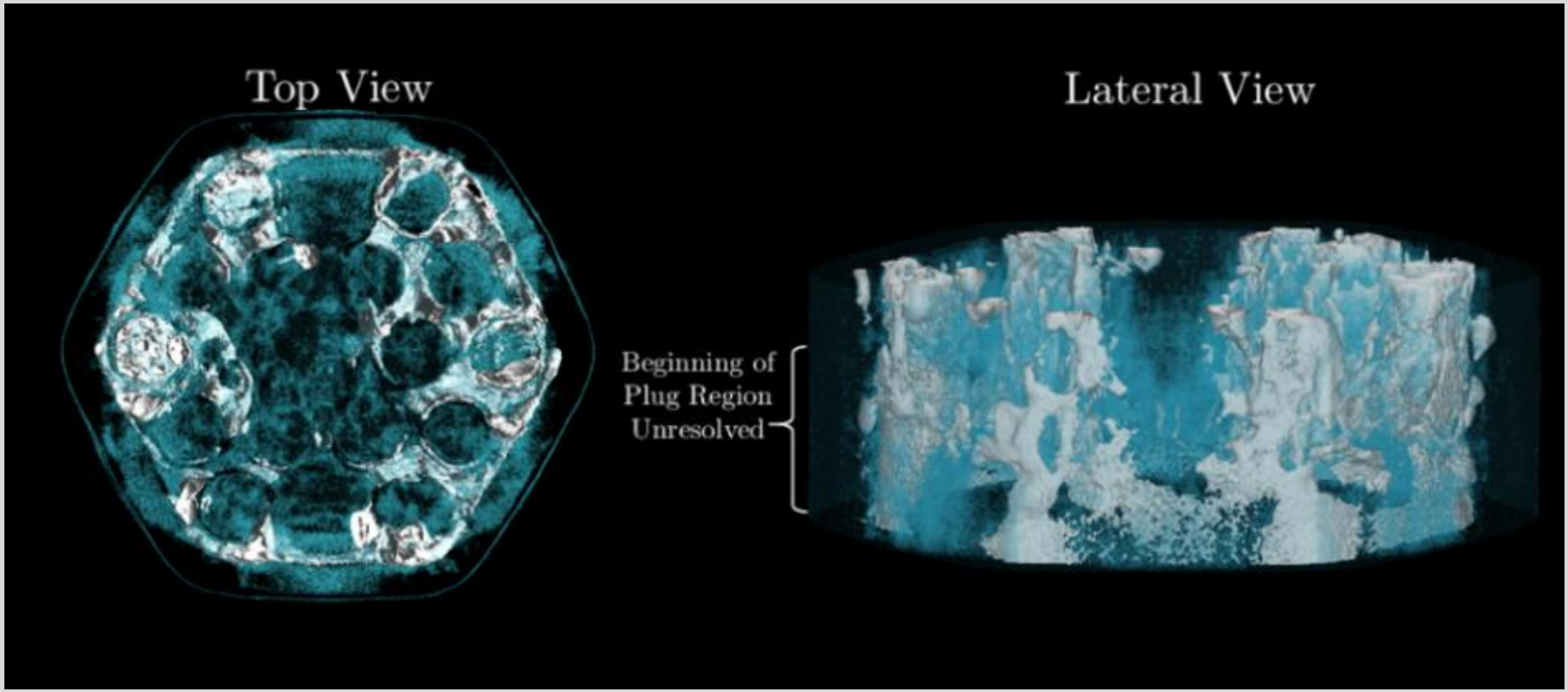


ANL Metallic Uranium Safety Exp (MUSE)

SFR Hexagonal assembly
with 19 fuel pins



TOMOGRAPHY / IMAGING



MSc THESIS RESEARCH TOPIC #1
Development and Characterization of gamma-tomography system v2.0

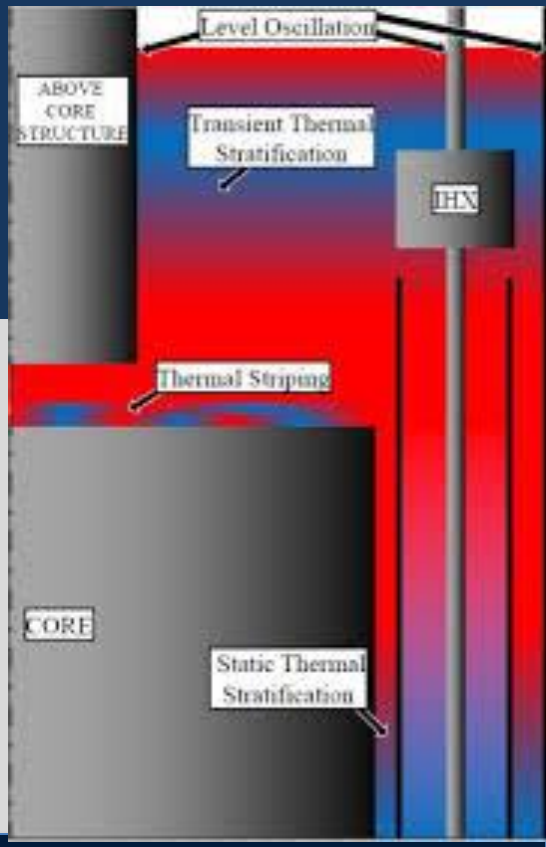
Thrust #2 / B

HIGH-RESOLUTION EXPERIMENTS AND VALIDATION OF CFD MODELS

CFD (computational fluid-dynamics)

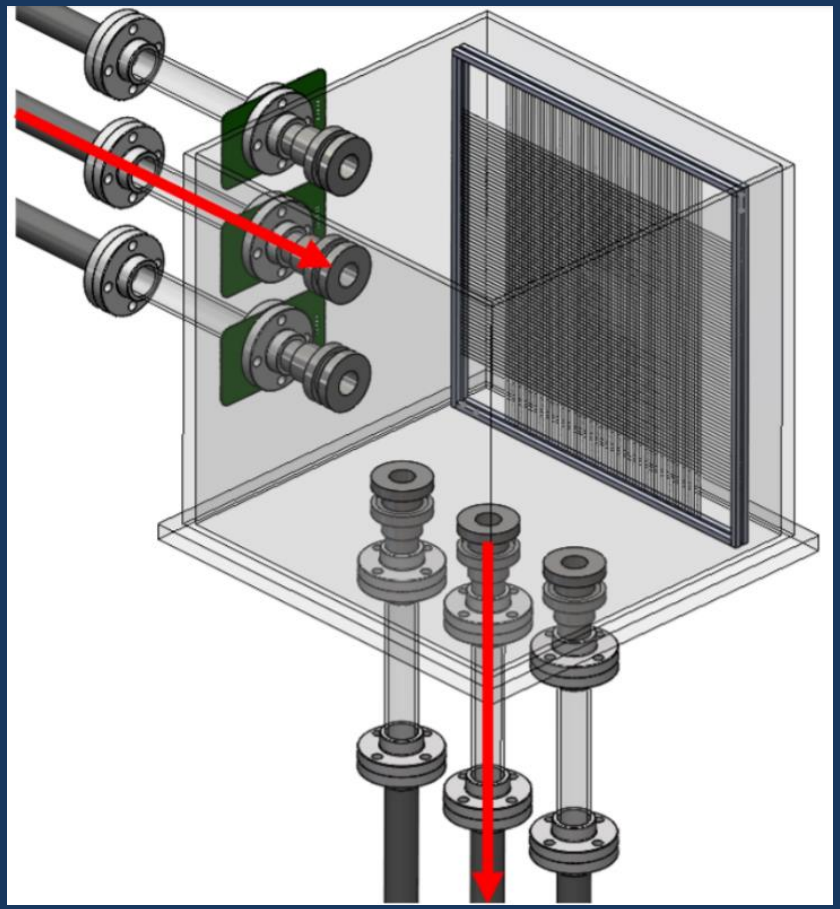
FLOW RELEVANT FOR SFRs

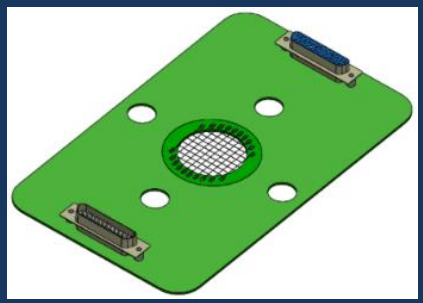
- Buoyant jets in stratified environment
- Propagation of stratification fronts



HIRJet - propagation of stratified fronts

HIRJet FACILITY

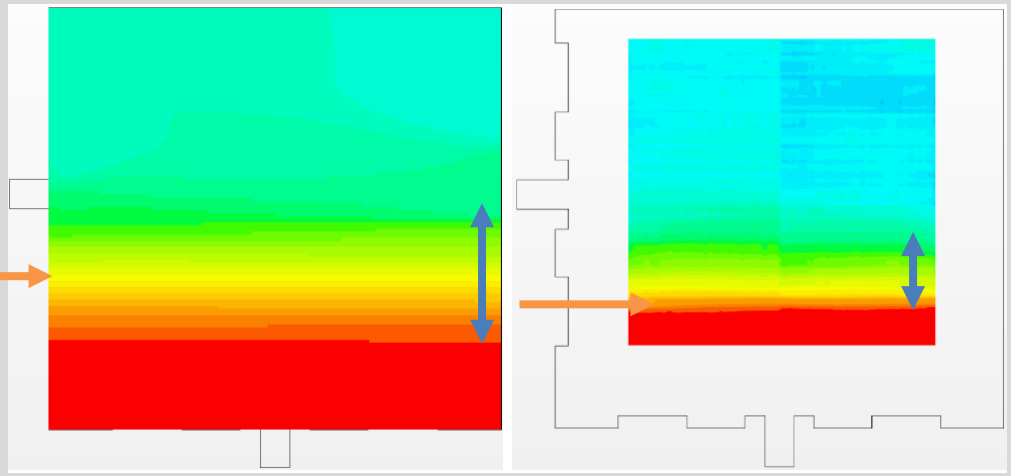




HIRJet – Light fluid into heavy (1.5% Δρ)

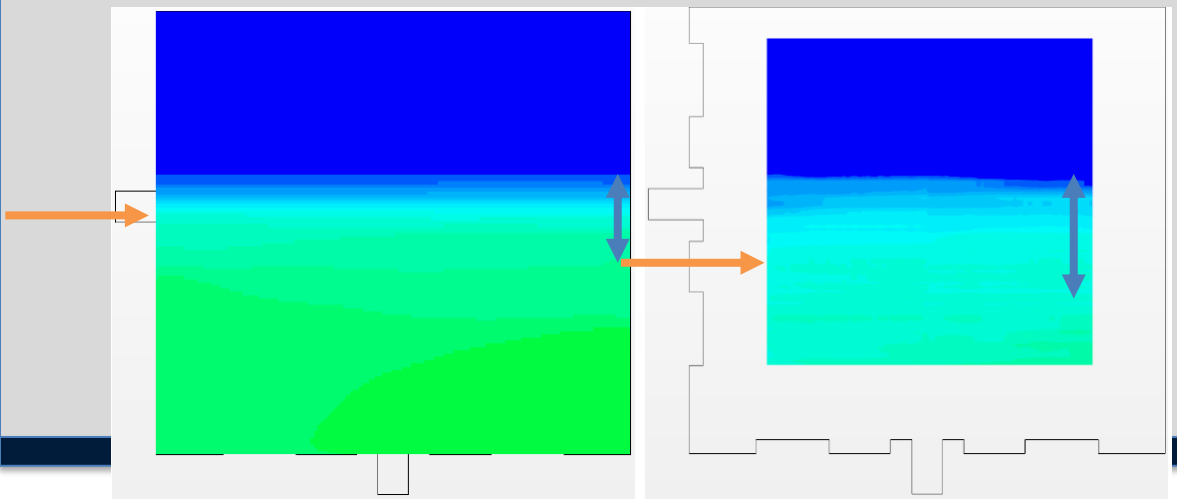
Simulation **Experiment**

MSc THESIS RESEARCH TOPIC #2
Validation of CFD models for thermal stratification



Light into heavy fluid

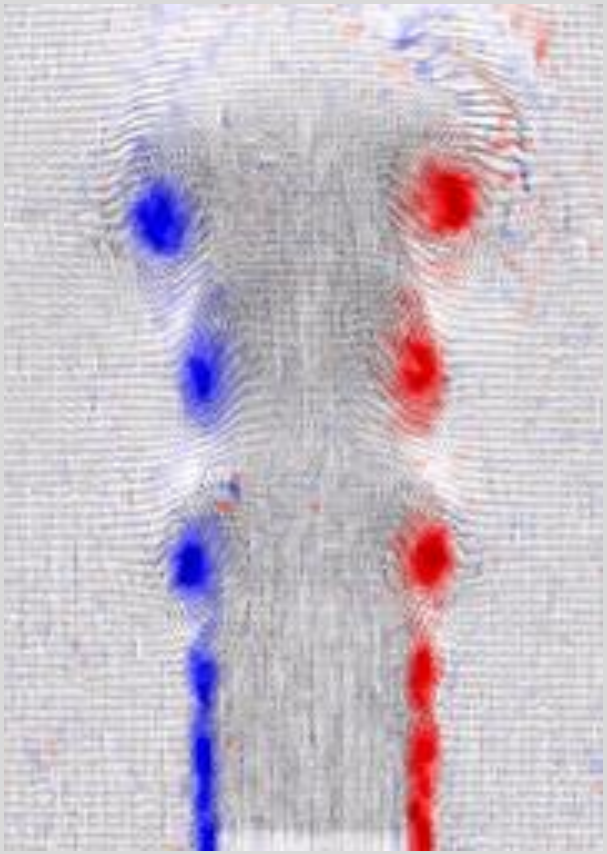
CFD: Front speed is **faster** and has a **broader** mixing region.



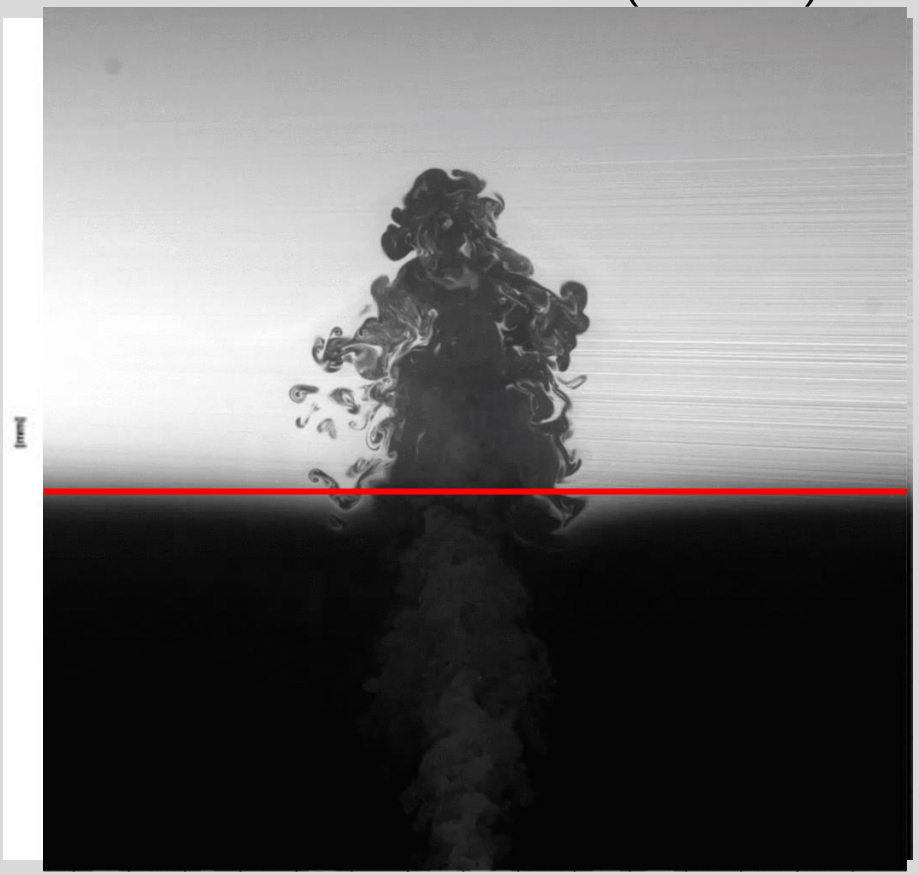
Heavy into light fluid

CFD: Front speed is **faster** and has a **narrower** mixing region

BUOYANT JETS IN STRATIFIED ENVIRONMENTS



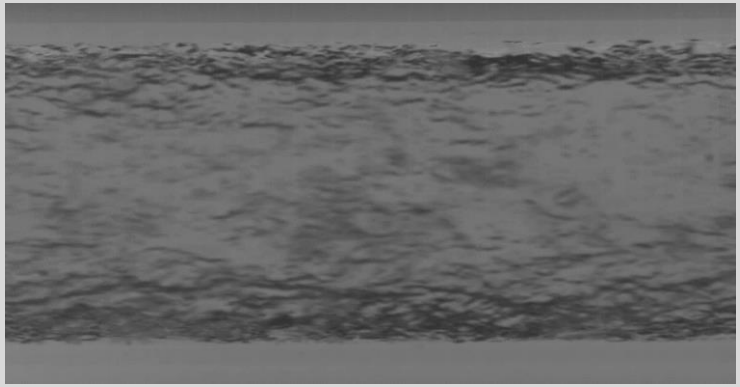
ECMFL Measurements (with RIM)



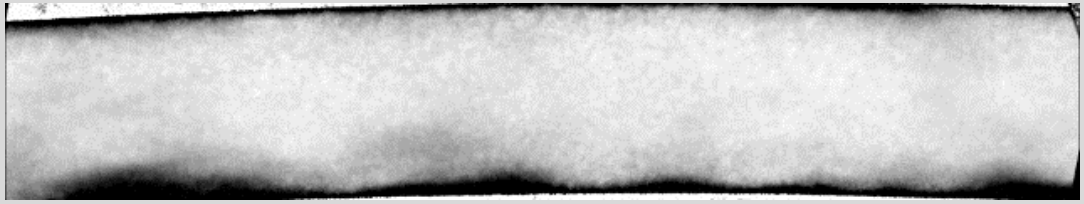
MSc THESIS RESEARCH TOPIC #3
Experiments and CFD simulations of buoyant jets in stratified environments

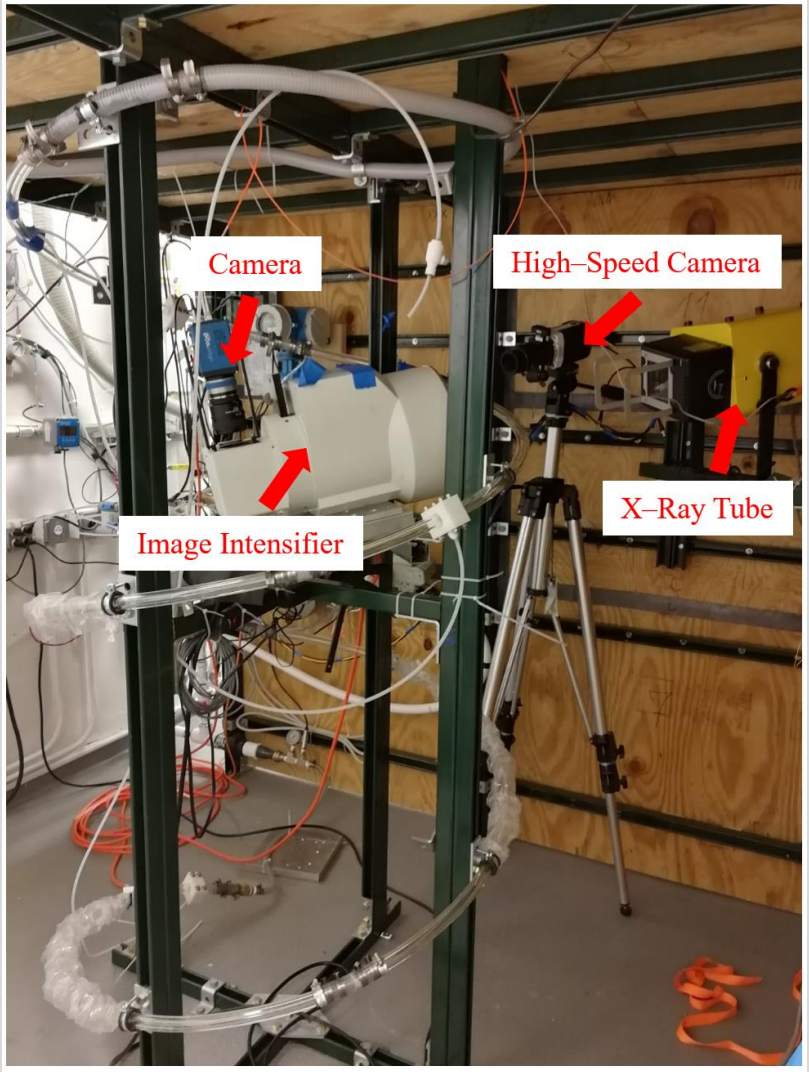
HELICAL COIL LOOP (NuScale SG prototype)

2400 fps, High speed camera



58.35 fps (2ms exposure time), X-ray system

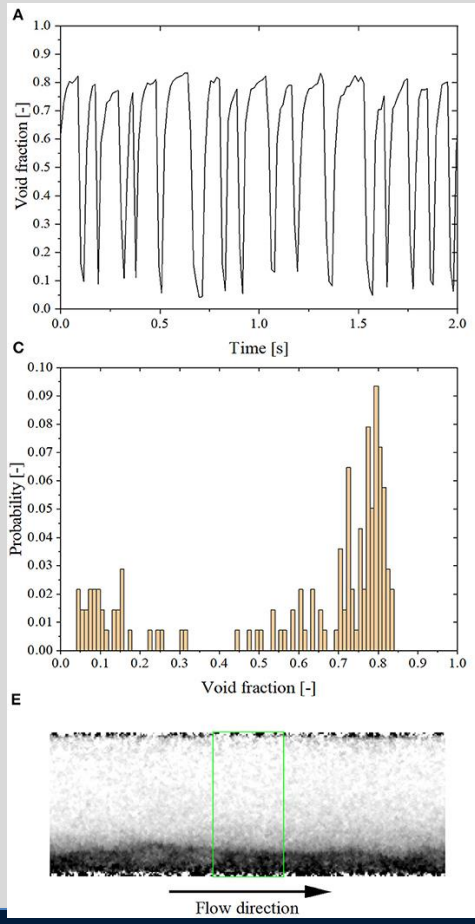




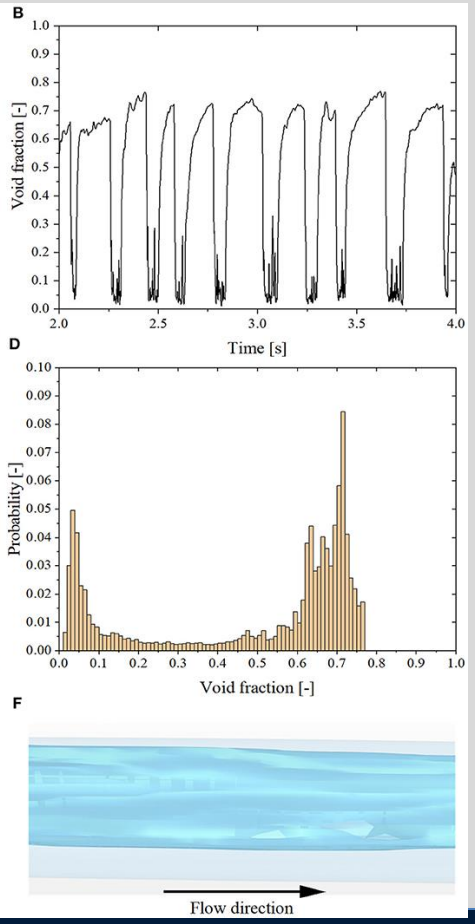
MSc THESIS RESEARCH TOPIC #4
Validation of CFD VOF Models for two-phase flows

SLUG FLOW

Measurements

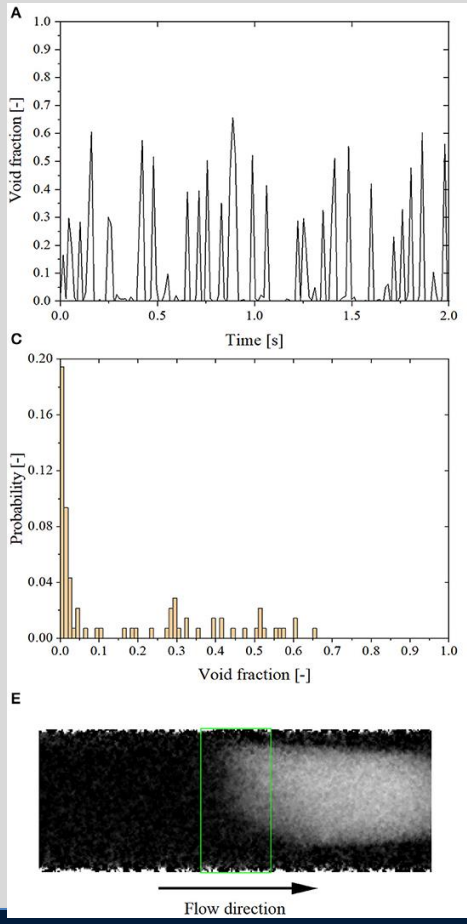


Simulations (VOF)

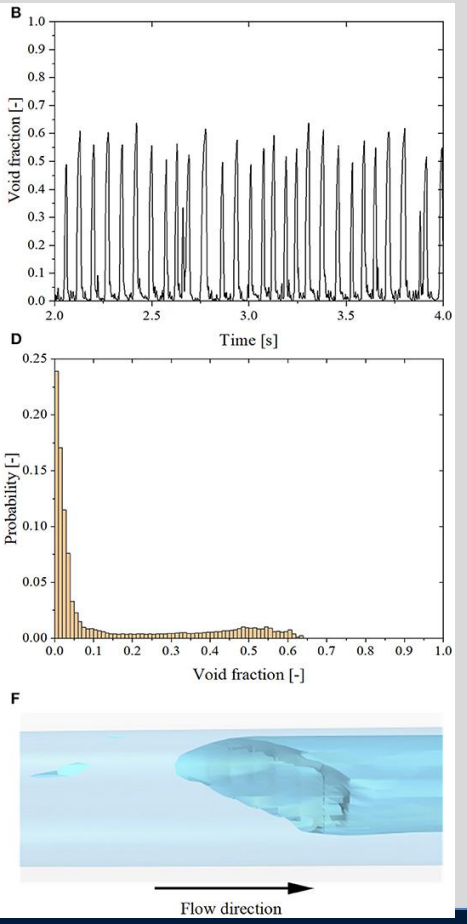


PLUG FLOW

Measurements



Simulations (VOF)



MSc THESIS RESEARCH TOPIC #5
CFD Simulations of thermal fatigue in NPP isolated branch lines