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PSI

H. Ferroukhi:: LRT :: NES :: PSI

Laboratory for Reactor Physics and Thermal-Hydraulics (LRT)

EPFL/ETHZ Nuc. Eng. Master Student **Virtual** Visit, PSI, May 17, 2021

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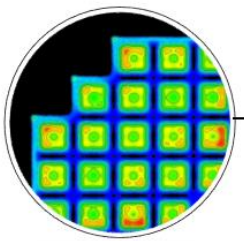
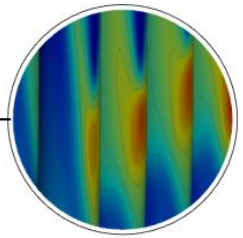
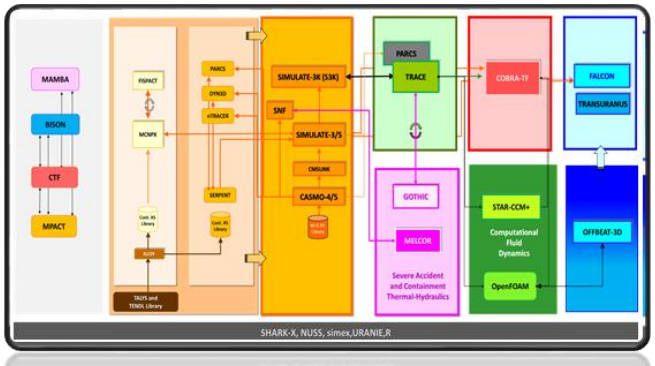
The LRT Laboratory
Overview

Reactor Physics and Thermal-Hydraulics





Modelling



Experiments

PWR BWR VVER SMR

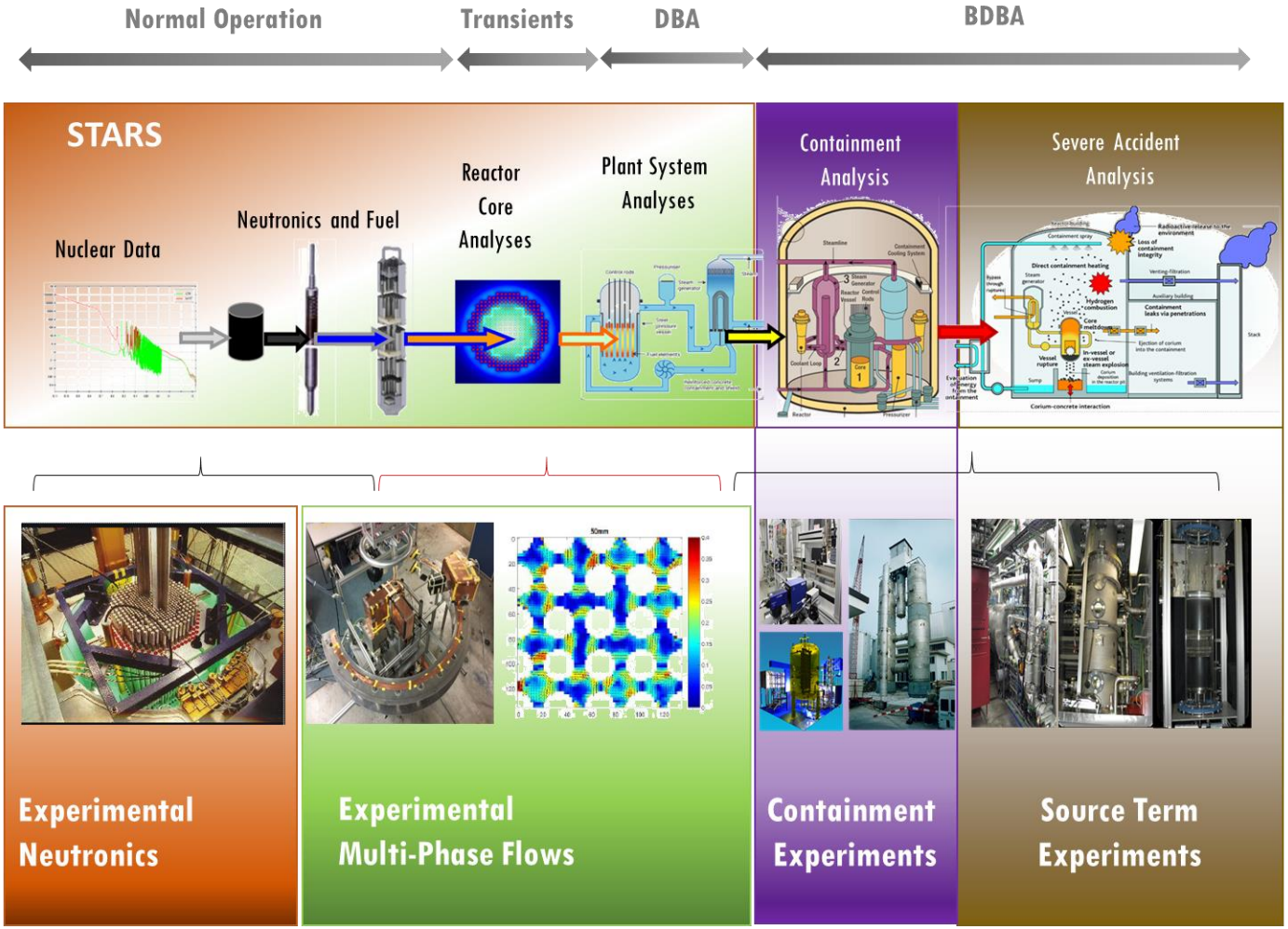
"Hand-in-Hand" Experimental and Analytical **Nuclear Safety** Research

from Reactors to Spent Fuel Systems

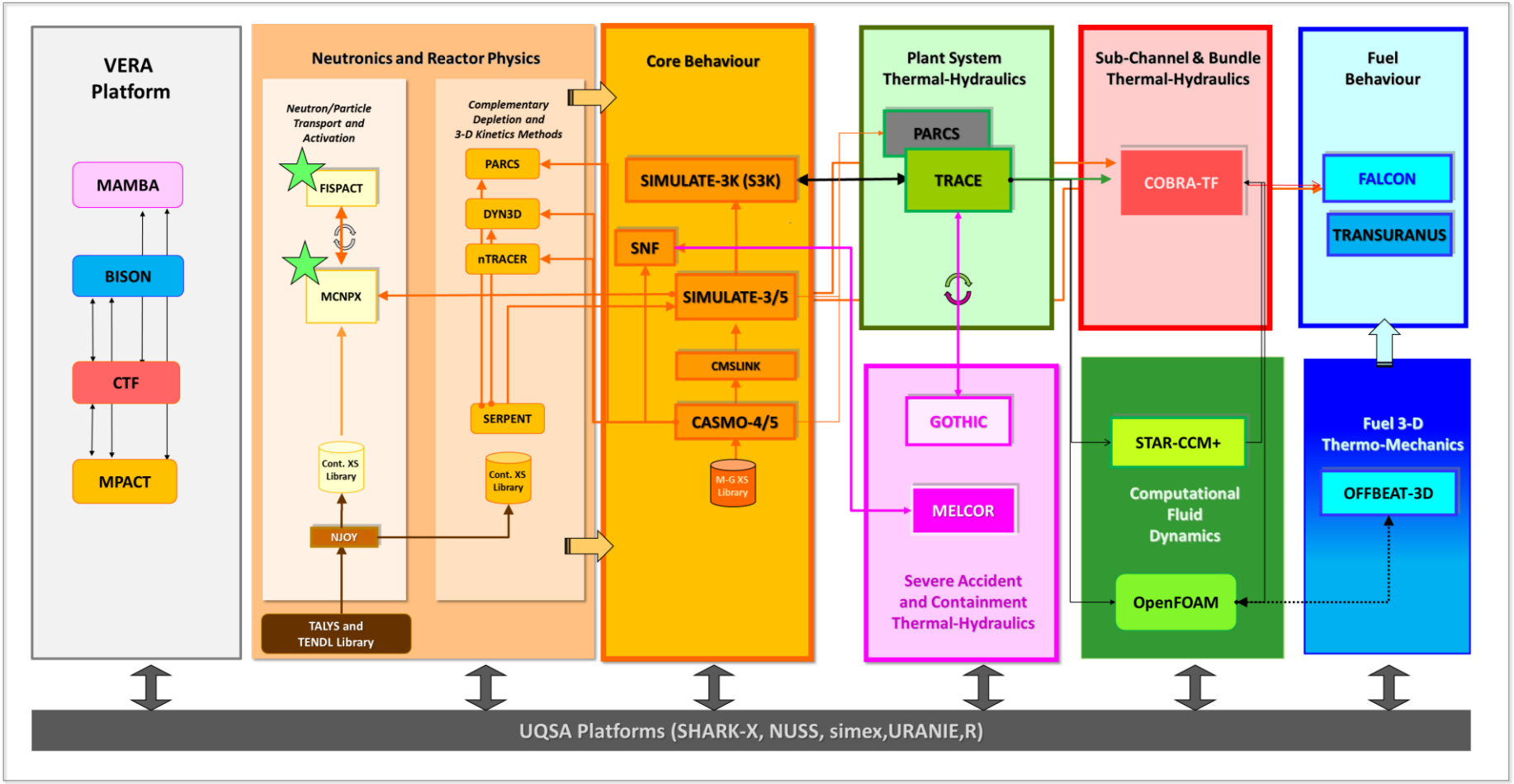
Modelling

Experiments

with Neutrons and Fluids



Integral Swiss Simulation Platform



Experimental Fluid Facilities

Phenomenology

Integral Effects

Separate Effects

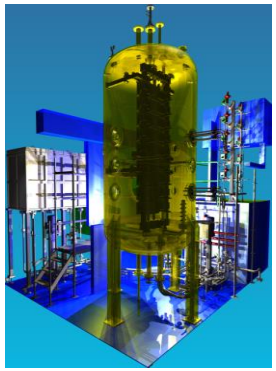
PANDA

Hydrogen Behaviour

VEFITA

FCVS Performance

LINX



Wall Condensation/Evaporation

TRISTAN

Hydrodynamics

HOMER

Gas Mixing and Stratification

miniVEFITA

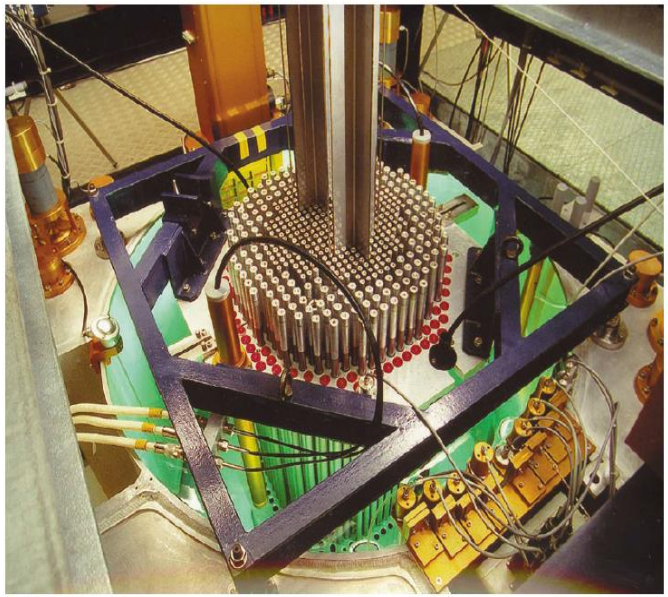
Iodine Retention

Small — **Medium** — **Large** → *Scale*

Experimental Neutron Facilities

EPFL

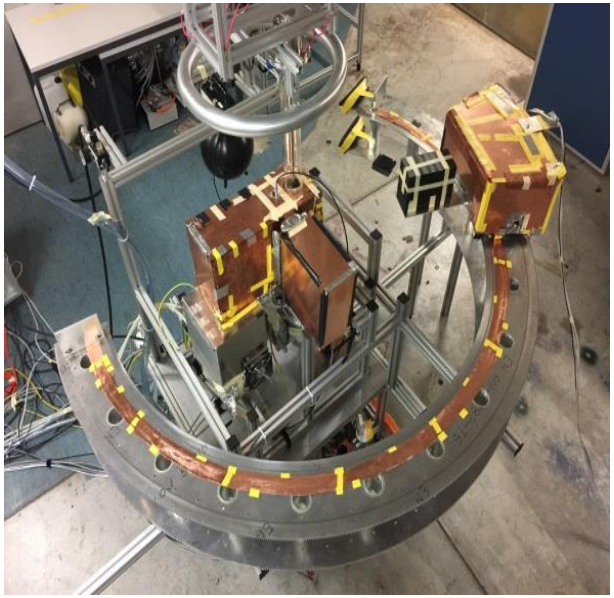
CROCUS



Reactor Physics and Nuclear Data

PSI

Fast Neutron Lab



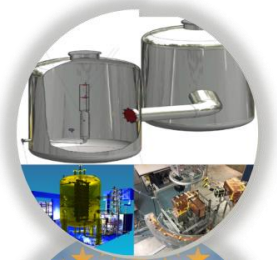
Neutron Tomography and Imaging

HotLab

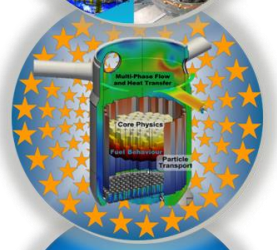
Spent Fuel Measurements

For MSc topics, see next Presentation by Mathieu Hursin

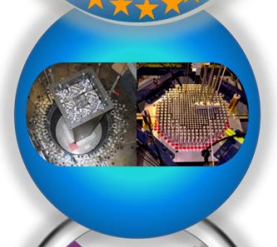
Research Programs



TEG
Experimental Thermal-Hydraulics

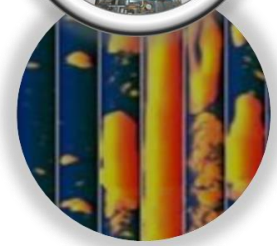


STARS
Multi-Physics Reactor and Spent Fuel Simulations



ERP
Experimental Reactor Physics and Neutrons

SACRE
Severe Accident Modelling and Experiments



ECMFL
Experimental and Computational Fluid Dynamics

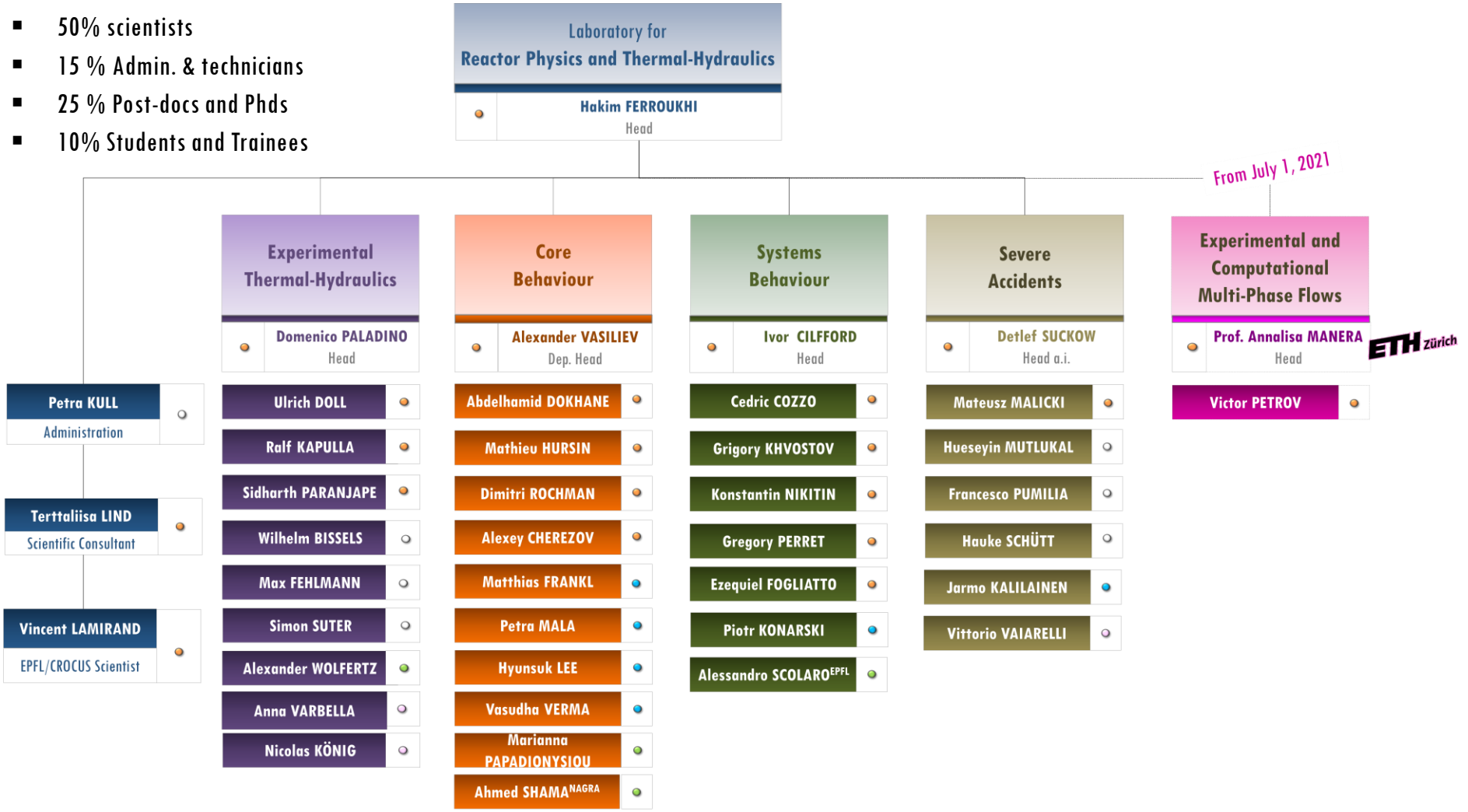
LRT Groups

- Experimental Thermal Hydraulics
- Core Behavior
- System Behaviour
- Severe Accidents
- Multi-Phase Flows

Team

40 Collaborators

- 50% scientists
- 15 % Admin. & technicians
- 25 % Post-docs and Phds
- 10% Students and Trainees



As of 17th May, 2021

Scientist · Administration/Technician · Post-Doc · PhD · Master Student/Trainee · Guest Scientist

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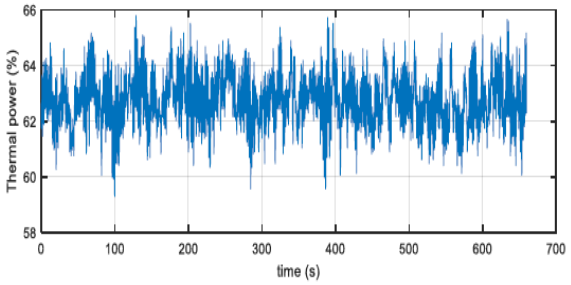
Master Projects 2021/2022
Proposals

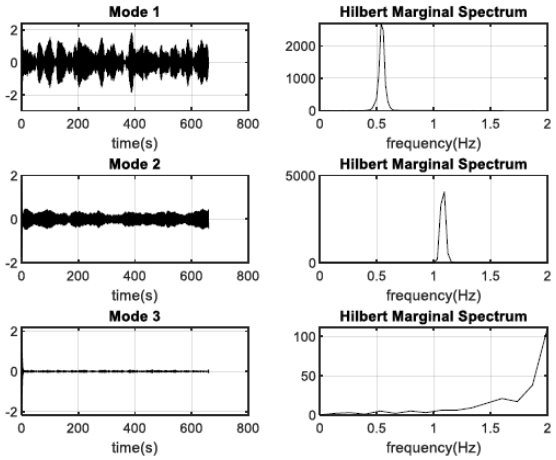
BWR Stability and Time Series Analysis

- **Background**
  - PSI Methodology based on ARMA models has some limitations in evaluating DR at certain conditions
  - Variational Mode Decomposition (VMD) method is promising Algorithm dealing with most limitations, e.g. mode mixing problems, non-stationary signals
  - VDM method decomposes the signal to system intrinsic modes on which DR estimation will be based

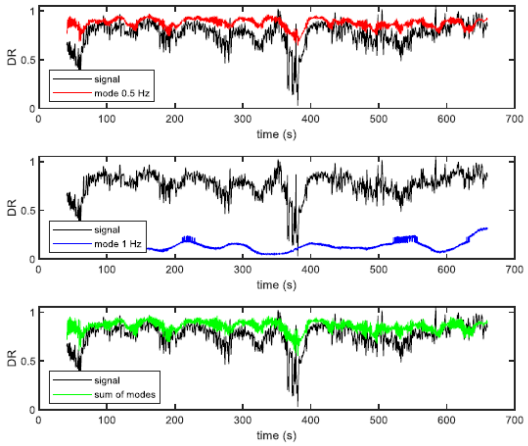
- **Semester and Master's Project**
  - Development of MATLAB program based on VMD method to evaluate the dominant intrinsic modes and evaluation of DR based on these modes
  - Assessment of VMD method against KKL GETARS/COSMOS signals and simulated signals
  - Integration of the new method in the STARS TSAR methodology



Detector Signal



Mode Decomposition



DR Mode estimation

Contact: Hamid  Abdelhamid.Dokhane@psi.ch

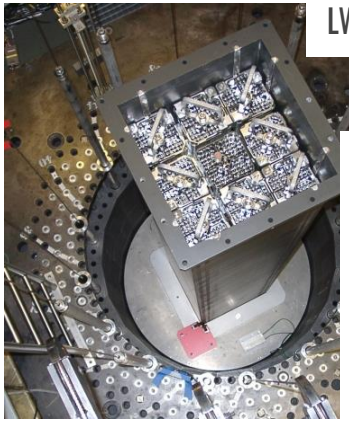
Monte-Carlo Modelling and Criticality Safety

Background

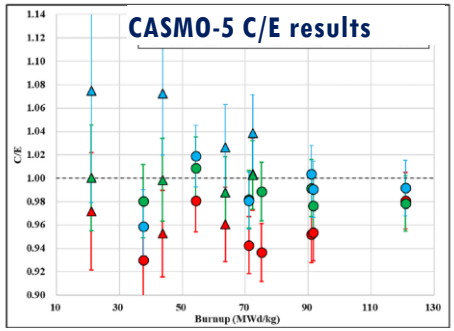
- Nuclear Criticality Safety must be guaranteed for the Disposal of Used Nuclear Fuel (UNF) in Deep Geological Repositories
- PSI reference criticality safety evaluation (CSE) and burnup credit (BUC) scheme: CASMO5 Fuel Burnup/Decay +Monte-Carlo Neutron Transport (MCNP)
- Some components of K-eff biases come from 1) UNF composition and 2) Criticality calculations for UNF

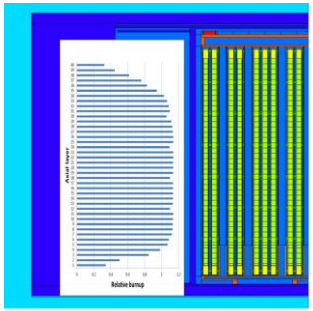
Semester and Master Project

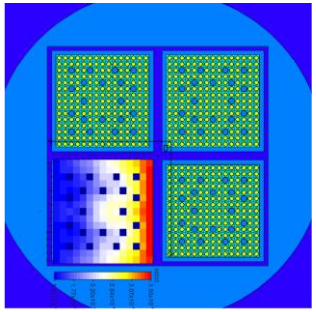
- Based on CASMO C/E obtained for PIE data, derive isotopic correction factors to be used in MCNP criticality calculations with UNF
- Using nuclear data- related correlation analysis and based on CASMO C/E results obtained for reactivity ($\Delta\rho$) measurements performed at PROTEUS experimental reactor, derive correction factors for MCNP K-eff for UNF
- Calculate penalties for MCNP k-eff predictions for UNF configurations for different initial enrichments and discharged burnups



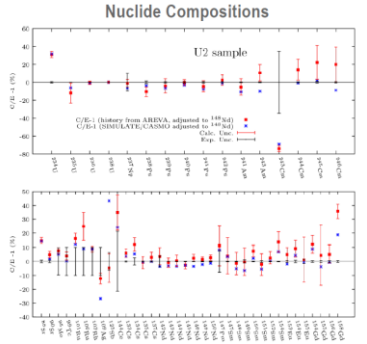
LWR-PROTEUS Programme







MCNP UNF disposal canister model



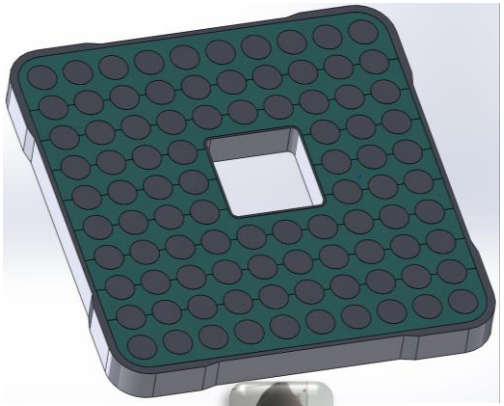
Contact: Mathias  Matthias.Frankl@psi.ch

Machine Learning supported Critical Power Ratio

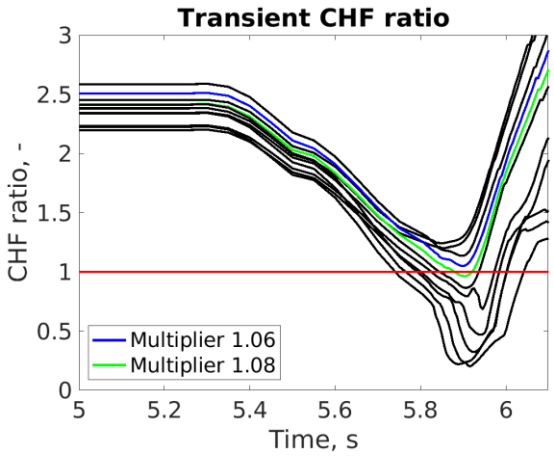
- **Background**
  - LRT developed the methodology of Critical Power Ratio (CPR) prediction with Subchannel Code CTF
  - The methodology is complex (big data?) and slow ⟹ improvements are necessary with ML methods

- **Semester and Master Project**
  - Construct and test a metamodel for the CTF prediction of CPR for BWR fuel assemblies
    - Application of ML or regression methods
    - Train and verify using existing CTF simulation data
    - Apply metamodel to accelerate CPR prediction
  - Methodology expansion to past cycles of a Swiss BWR, including development of a database for all cycles.
  - Methodology improvement using ML/regression/sensitivity analysis with respect to CTF physical models, system BCs, nodalization, etc.

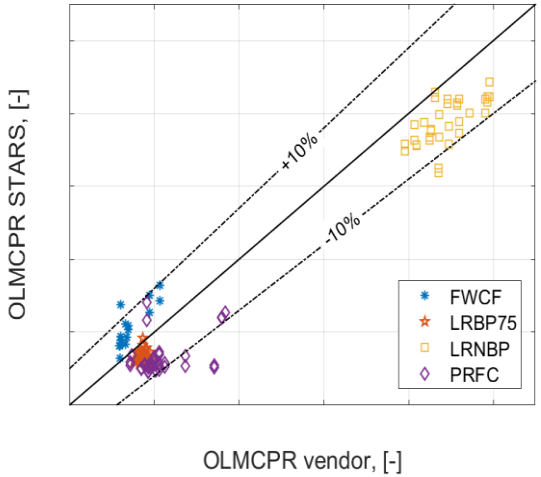
CAD model of BWR fuel assembly



CPR prediction with CTF



Application for BWR safety assessment

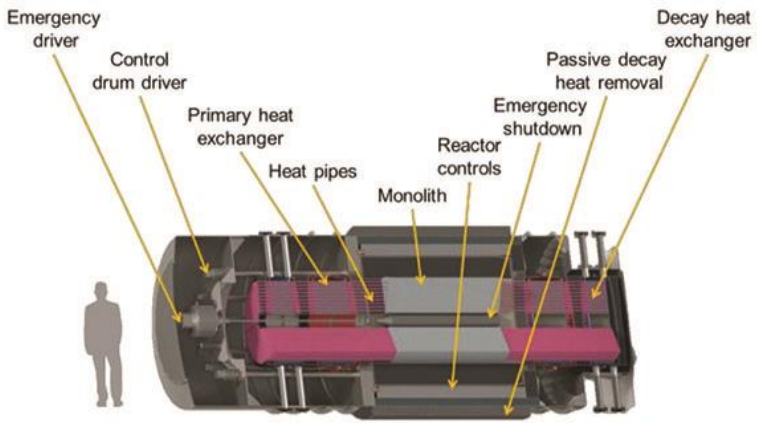


Contact: Konstantin  Konstantin.Nikitin@psi.ch)

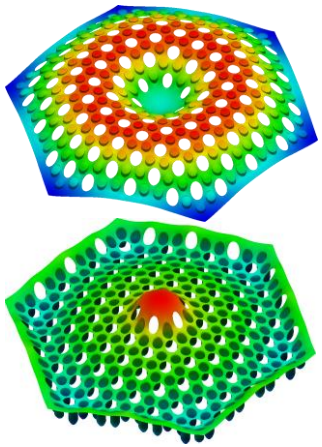
Multiscale Modelling of Heat Transfer in Micro-Reactors

- **Background**
  - Several micro-reactors are in an advanced stage of design around the world
  - OECD/NEA is currently preparing a benchmark on micro-reactor simulations to assess current methods- PSI intends to participate
  - Multiscale methods originally developed for HTGRs may be applied to this design

- **Semester and Master's Project**
  - Develop and multiscale models for the heat transfer in the core of a micro-reactor
    - Modelling of heat conduction in fuel assemblies using OpenFOAM
    - Homogenization to obtain macroscopic properties
    - Reduced order modelling to develop metamodels for fine-scale behaviour
  - Demonstration, testing and verification of full-core behaviour

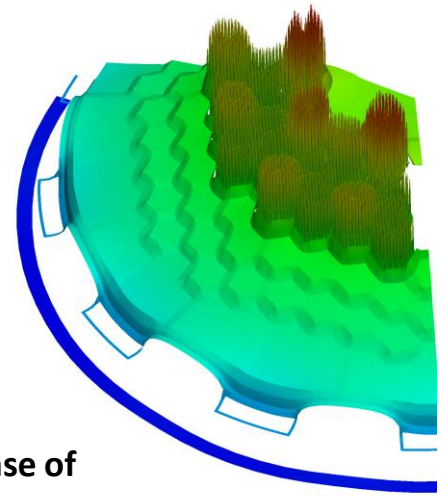


Westinghouse's eVinci micro-reactor design



Basis functions for thermal response of a MHTGR fuel block

Full-core temperature Reconstruction in the MHTGR



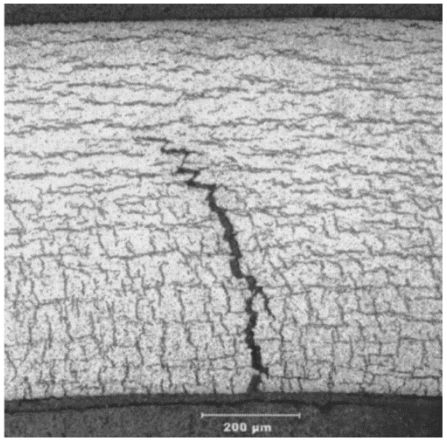
Contact: Ivor  (ivor.clifford@psi.ch)

Hydride reorientation modelling during dry storage

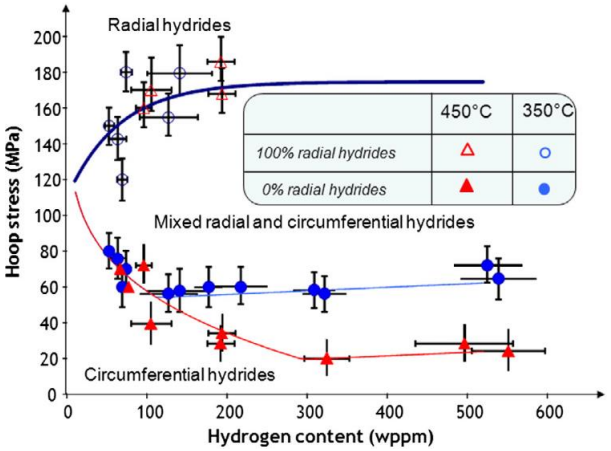
- **Radial hydrides quantification is crucial for the cladding integrity**
  - During base irradiation, hydrogen ingresses the cladding, precipitates and forms hydrides
  - During dry storage, high temperatures and tensile stresses provoke precipitation of radial hydrides
  - Radially oriented hydrides activate degradation mechanisms such as embrittlement and delayed hydride cracking that may lead to cladding failure
- **Semester and/or Master's Project**
  - Literature survey on hydride reorientation modelling
  - Model implementation into the PSI's hydrogen behaviour tool
  - Simulations of fuel rods with real data from the Swiss plants using the code Falcon
  - Testing and validation against available experimental data
  - Studying rod integrity in dry storage conditions

Swiss dry storage facility ZWILAG

Cladding crack along radial hydrides



Implementation of a hydride reorientation model

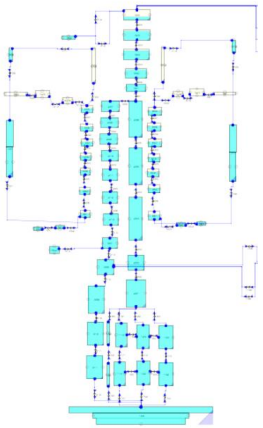


Contact: Piotr (piotr.konarski@psi.ch)

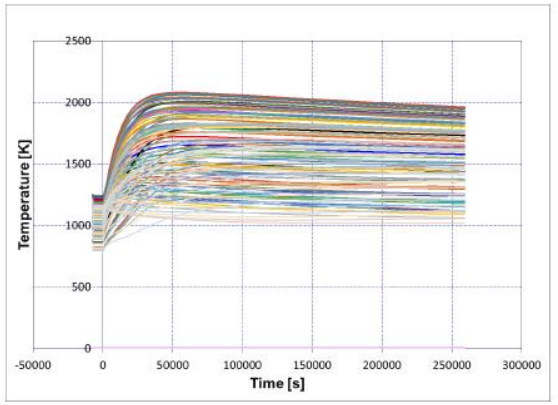
Modelling and Sensitivity Analyses of Water Cooled SMRs

- **Background**
  - MELCOR is an integral computer code for modeling severe accidents in nuclear power plants
  - New concept of NPPs e.g. integrated PWR, helical SGs, passivity of NPP or integrated designs
  - Demand of new model implementations into MELCOR
- **Semester and Master Project**
  - Estimation the influence of different models and parameters to Severe Accident progression
  - Literature study, investigation of unique scenarios and new models, best practices for SA MELCOR analysis, specifically dedicated to SMRs, analysis of the usability
  - Implementation of new models and best practices to an available SMR input deck
  - Performing sensitivity study on SMR input deck on a SA scenario
  - Analyze differences of accident progression as function of used model and parameters

Literature study



Input deck update/implementation of new models



Sensitivity analysis

Contact: Mateusz  mateusz.malicki@psi.ch)

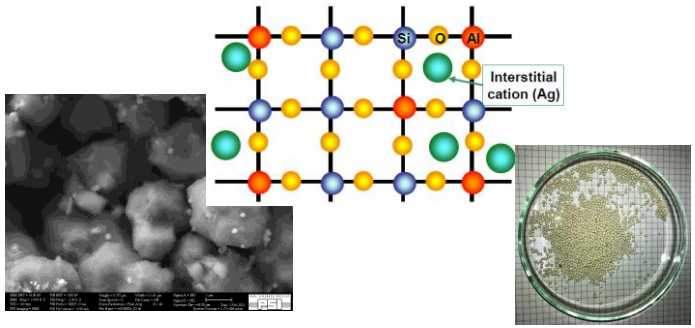
Catalytic Recombination Experiments of Hydrogen with Zeolites

Background

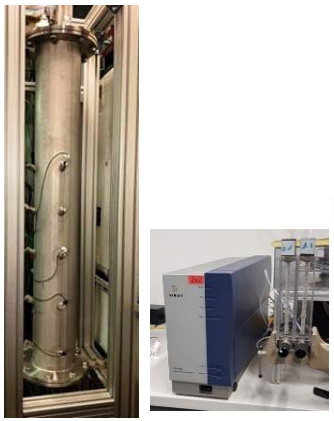
- In severe accidents toxic iodine species can be released, but retained by silver (Ag)-Zeolites
- Zeolites are highly crystalline alumina-silicate frameworks. Ag^+ ions serve to attract iodine/iodides
- Different Zeolites already used in filtered containment venting systems (FCVS) of BWR and PWR NPP
- High adsorption capabilities of some specific filter materials
  - → High potential to inherently remove/recombine hydrogen (H_2)
  - → Reduce risk of a detonation in the containment atmosphere and in FCVS

Semester and Master Project

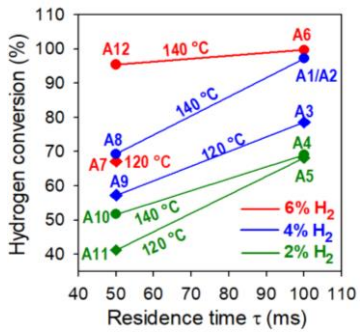
- Perform experiments to characterize H_2 conversion rate under selected severe accident conditions
- Literature study, introduction to analytical instrumentation and analysis
- Study effect of H_2 concentration, pressure, steam fraction and contaminants in the gas stream
- Determine conversion rate for two different Zeolites (AgX, AgR)
- Data analysis and compare experiments; study kinetics behavior



Literature study, introduction to instrumentation



Experiments in test facility



Data analysis, reporting

Contact: Detlef [ef.suckow@psi.ch)](mailto:ef.suckow@psi.ch)

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Master Projects 2021/2022
Final Remarks

- Additional projects available or can be proposed/discussed.
  - Do not hesitate o contact any of us @any time

- For additional info on LRT and its research programs
  - Please consult www.psi.ch/lrt

- LRT Tradition
  - Integrate EPFL/ETHZ Master Projects in On-Going Work OR to kick-off New Activities
  - Use Semester Work as "Heat-Up" phase for Master Project and opportunity for first conference paper
  - Take Master Project as opportunity for first Journal article

B. Jung (MSc Student 2017-2018), A. Vasiliev, M. Pecchia, H. Ferroukhi;
Optimization And Sensitivity Studies Towards PWR Structures Activation Characterization Using the MCNP Code
ANS Student Conference 2018, University of Florida, Gainesville Florida, USA, April 5 - 7 , 2018

M. Papadionysiou (MSc Student 2016-2017) G. Perret, R. Zboray, R. Adams, J.-B. Mosset;
Monte Carlo Simulation Of A Scintillation Detector For Spent Fuel Characterization In A Hot Cell;
Nuclear Engineering And Design 332 (2018) 119 126; doi: 10.1016/j.nucengdes.2018.03.033

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Thank You ! *And Looking Forward to Warmly Welcome You at the LRT for Your Semester/Master project !*