H2020 McSAFE High Performance Monte Carlo for Safety

NUGENIA NUclear GENeration II & III Association

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McSAFE – High Performance Monte Carlo Methods for SAFEty Demonstration

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V. Sánchez (KIT), L. Mercatali (KIT), Dufek (KTH), J. Leppanen (VTT), E. Hoogenboom (DNC), R. Vocka (NRI)

Presented by Dr. F. Gabrielli on behalf of McSAFE Consortium

Contact the coordinator: Victor.sanchez@kit.edu

www.mcsafe-h2020.eu

NUGENIA is mandated by SNETP to coordinate nuclear Generation II & III R&D

SNETP Sustainable Nuclear Energy Technology Platform

www.snetp.eu

Content

- Project goals
- Structure and partners
- Status of mulit-physic tools
- Status of dynamic MC-codes
- HPC Requirements for high-fidelity simulations
- Validation approach
- Outlook
- Invitation to join the USER GROUP

Project Goals

- **McSAFE is based on innovative ideas developed within the EU 7. FP HPMC Project (2011-2014)**
  - Optimal MC/TH coupling, stable MC-based depletion, **dynamic MC**
  - Many more ideas to simulate whole cores using HPC: further optimisation, use of Stochastic implicit Euler, …

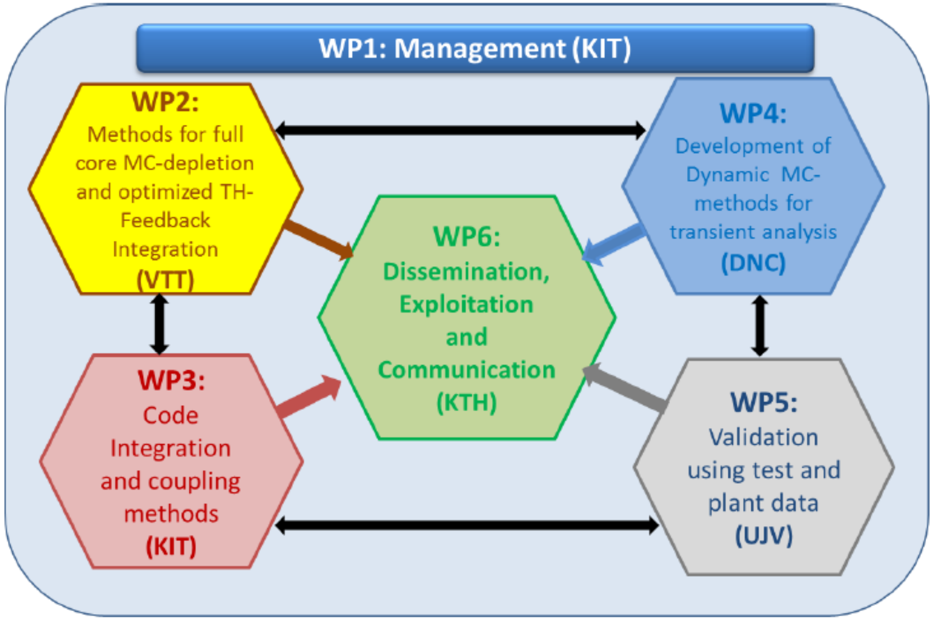
  (Proof of concept)

- **Goal: Move MC methods towards industrial applications**
  - **Generalize and optimized N/TH/TM coupling**
  - Optimize depletion simulations (stability, CPU, memory requirements)
  - **Extension of MC-codes for transient analysis e.g. RIA (Safety)**
  - **Validate MC tools using experimental data**
  - Full core simulations at pin-level using HPC
  - Provide reference solutions for low-order solvers

→Industry-like applications

Project Structure &Partners

Key-partners:
Code developers, utilities, R&D, Universities…



Interconnected work packages

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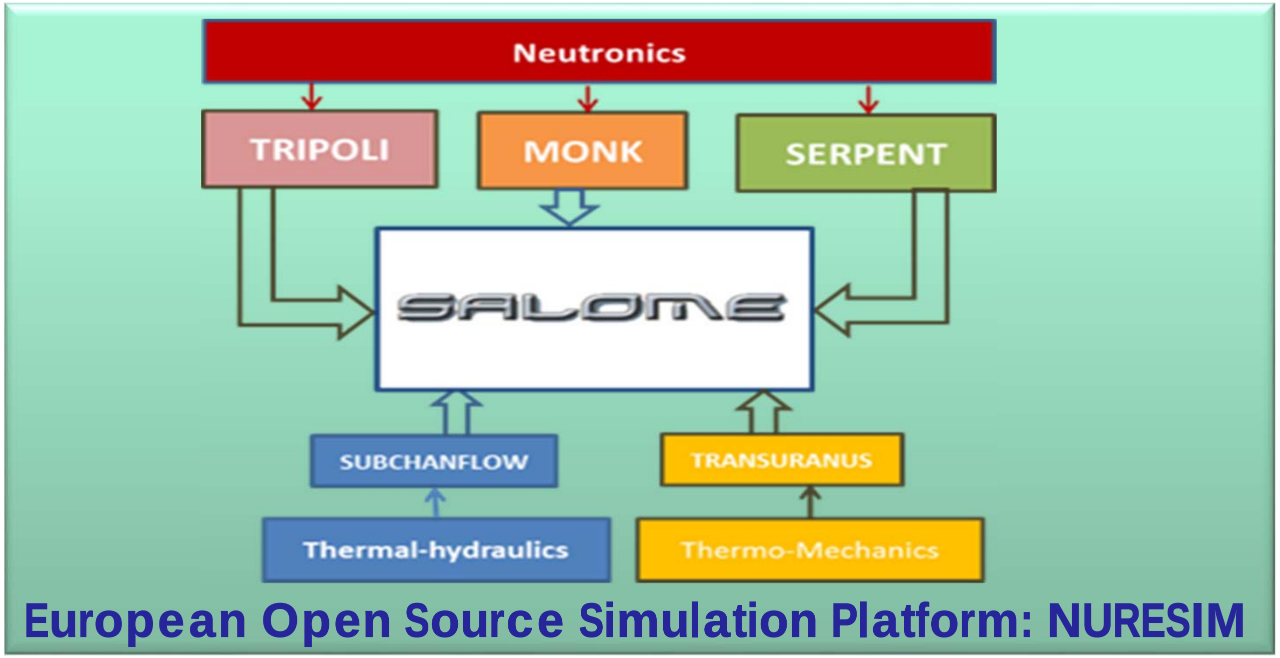
Status of Multiphysics Tools

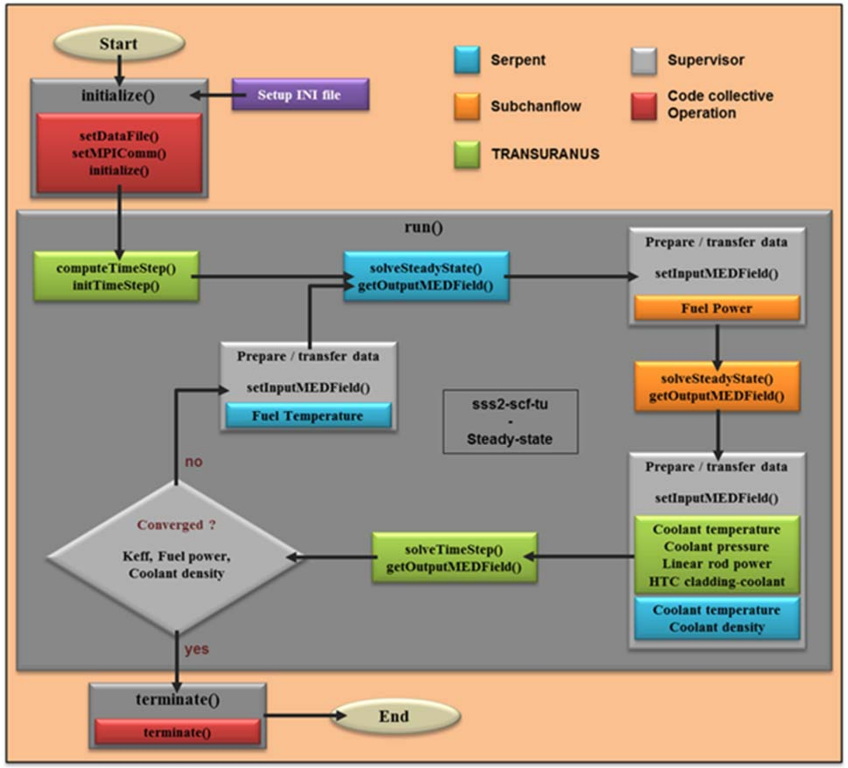
- **NURESIM Platform: Code coupling based on ICOCO**



- **Two coupling approaches:**
  - ICOCO-based approach
  - Internal coupling based on Multi-physics interface

MC-TH Coupling using ICOCO

▪ SERPENT/SUBCHANFLOW/TRANSURANUS Coupling

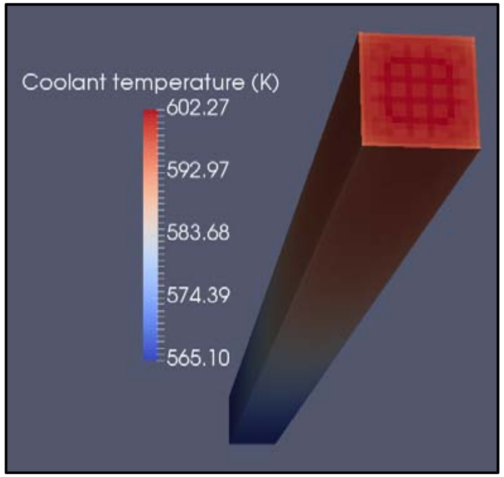


Coupling flowchart of Serpent, SCF and TU

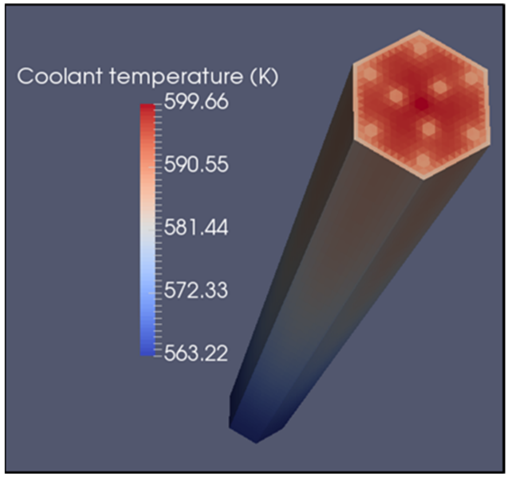
- **Supervisor written in C++**
- **Class definition ICoCo API based on abstract base class**
- **Each code is linked as dynamic libraries**
- **MEDCoupling used for domain interpolation**
- **Supervision program controls the calculation and data flow**

Analysis with coupled MC/TH/TM

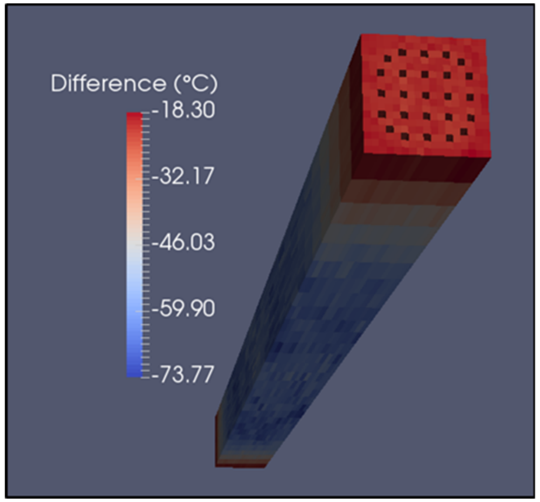
PWR FA: SERPENT/SCF/TU

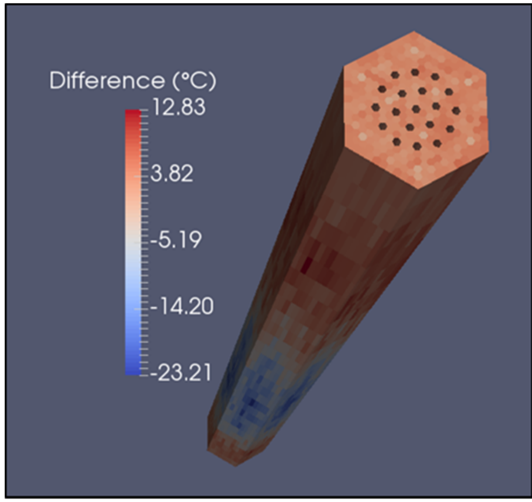


HEX FA: SERPENT/SCF/TU



- **Difference: SERPENT/SCFTU-SERPENT/SCF:**





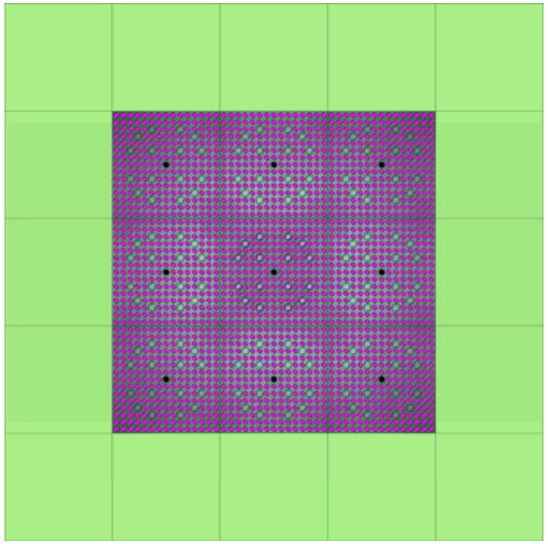
Dynamic Monte Carlo for transient analysis

Dynamic MC Codes under development

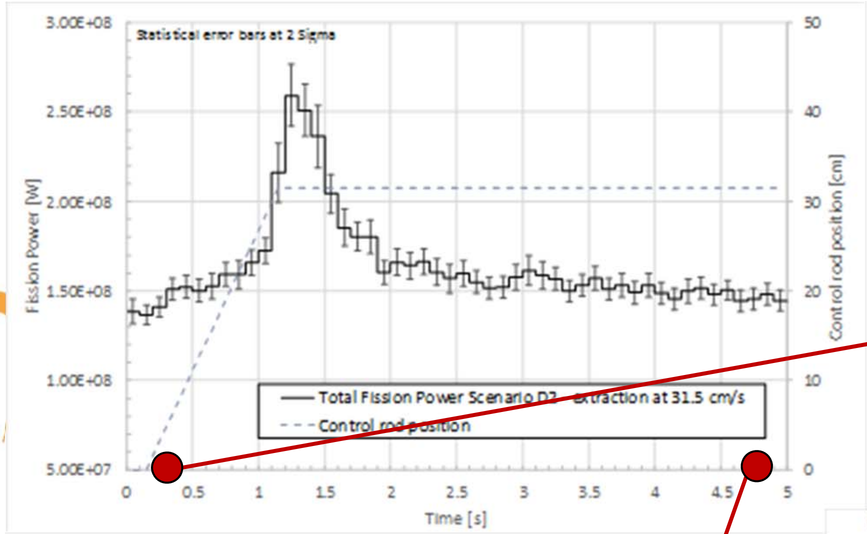
- dynSERPENT/SUBCHANFLOW
- dynTRIPOLI/SUBCHANFLOW
- dynMCNP6/SUBCHANFLOW

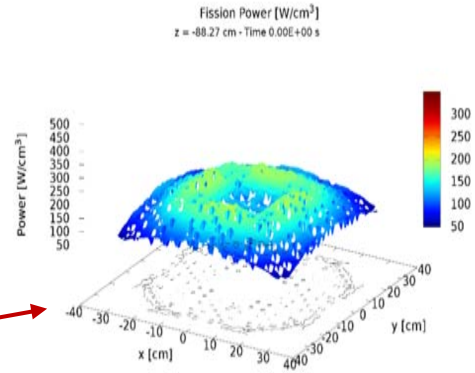
Problem:

- PWR 3x3 Minicore
- Rod ejection (REA) problem



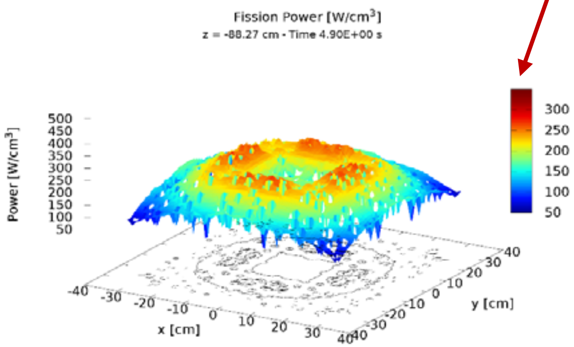
dynSERPENT/SCF REA Analysis



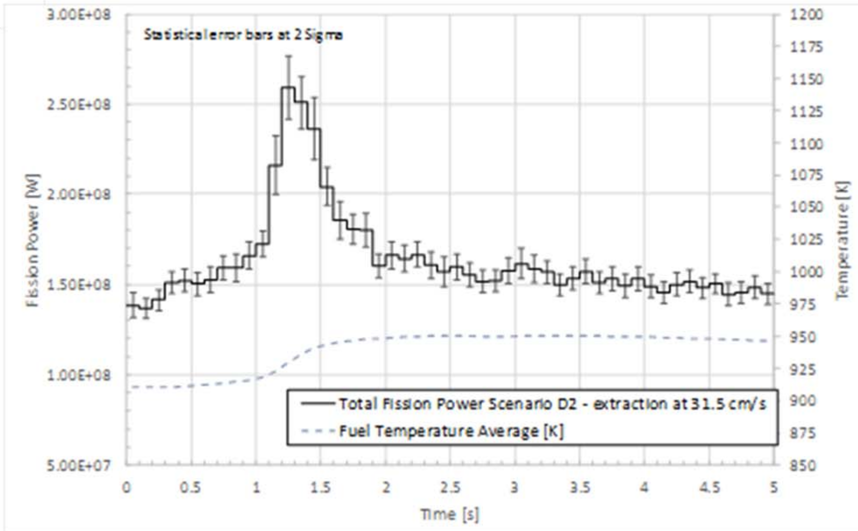


X-Y power distribution at Time: 0.1 s

Power evolution after CR-ejection



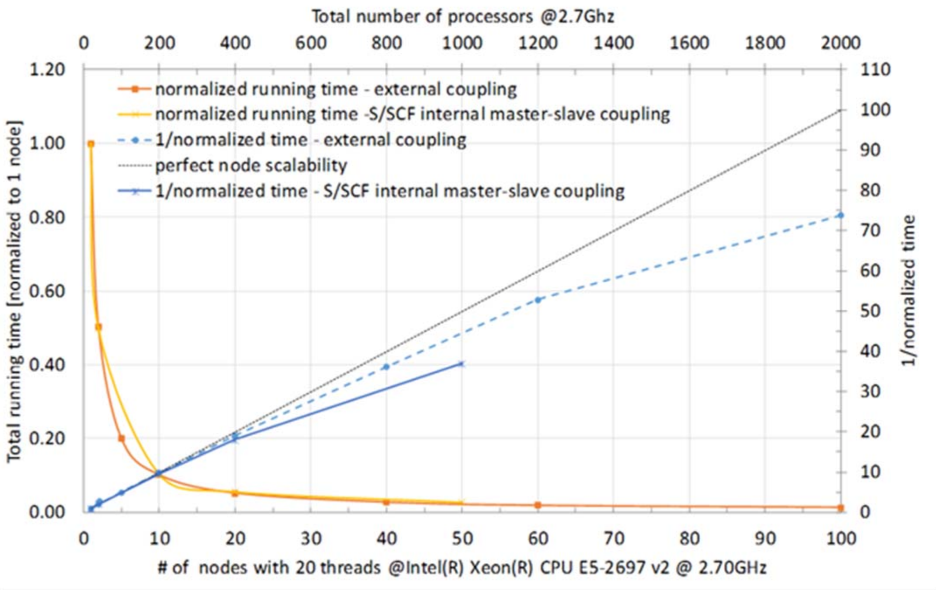
X-Y power distribution at Time: 4.9 s



Fission power evolution and avg fuel temperature

Requirements for HPC for High-Fidelity Simulations

- **Massive use of HPC required for**
  - MC-depletion with Thermla hydraulic feedback
  - pin/subchannel level MC/TH-simulations
- **Scalability of SERPENT/SCF (internal Coupling)**



- **Use of KIT infrastructure (HPC HLfor2) ~ 10 0000 processors**
- **PRACE-Application for European HPC under preparation**

Validation of Multiphysics Codes

- **Depletion problem in LWR-cores**
  - **Plant data of VVER-1000 and PWR Konvoi cores (startup cycle: criticality, rod worth, temperature feedback), Zero burnup on-power (power distribution, boron) and Fuel cycle burnup (power distribution, boron letdown)**

Plant Data	Static MC-TH Problem	Static MC-TH-TM Depletion Problem
VVER-1000	TRIPOLI SERPENT/SCF	SERPENT/SCF/TU
PWR Konvoi	TRIPOLI/SCF SERPENT/SCF MONK/SCF	SERPENT/SCF/TU

- **Dynamic capability of Monte Carlo codes coupled with TH-solvers: Experimental data of SPERT III-E REA Tests**

Codes	Organisation
DynTRIPOLI/SCF	CEA, KIT
DynMCNP/SCF	DNC, KIT
DynSERPENT/SCF	VTT, KIT

Outlook

- **Main methods and multi-physics codes development completed**

- **Next steps:**
  - Validation using plant data and tests
  - Optimization of codes/methods for HPC-simulations
  - Optimizations to reduce
    - *Problem size for full core depletion at pin-level*
    - *statistical uncertainties of MC-codes*
  - Applications to PWR, VVER and SMR

- **User Group will start the use of the codes**

McSAFE User Group

- **Any organisation is welcome to join the USER GROUP**
  - **Test and apply developed codes**
  - **Perform code-to-code benchmarking**
  - **Provide feedbacks to the consortium**
  - **Depletion problem in LWR-cores**

- **How to apply to become a UG member?**
  - **Just contact the Coordinator:**
    - **victor.sanchez@kit.edu**
  - **Sign UG Agreement**
  - **Get access to the tools**

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Thank you for your attention!

For more information:
Victor.Sanchez@kit.edu
Mobile: +4915201547532
+4972160822283

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