Karlsruher Institut für Technologie

NUGENIA
NUclear GENeration II & III Association
www.nugenia.org

McSAFE – High Performance Monte Carlo Methods for SAFEty Demonstration

NUGENIA Annual Forum
March 28-30, 2017 (Amsterdam, Netherlands)

From Proof of Concept to Industry-like Applications

V. Sánchez (KIT), L. Mercatali (KIT), F. Malvagi (CEA), P. Smith (AMEC), J. Dufek (KTH), M. Seidl (Preussen Elektra), L. Milisdorfer (CEZ), J. Leppanen (VTT), E. Hoogenboom (DNC), R. Vocka (UJV), S. Kliem (HZDR), P. Van Uffelen (JRC), N. Kerkar (EDF)

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

SNETP
Sustainable Nuclear Energy Technology Platform
www.snetp.eu

Content

- Scientific gaps
- McSAFE Technical goals
- McSAFE Main Concept
- McSAFE WPs, Partners and Structure
- McSAFE Tools

Scientific Gaps

- **Core analysis relies mainly on deterministic neutronic codes (daily work)**
  - Diffusion codes include multiple approximations (energy, angle, homogenized geometry)
  - Pin power approximately reconstructed from 2D lattice calculations
  - SP_3 and S_N solvers are still under development.
    - *Currently very time and memory expensive*
    - *Parallel versions under development*
- **Experimental data at pin level is scarce and not easy to be measured (pin power)**
- **Alternative option:**
  - Use of MC codes capable of simulating the neutron transport without approximations
  - Potential use taking advantage of HPC and parallelization

Innovative solutions needed to pave the way for industry-like applications

McSAFE: Technical Goals

- **McSAFE is based on innovative ideas developed within the EU 7. FP HPMC Project (High Performance Monte Carlo Core Analysis: 2011-2014)**
  - Optimal MC/TH coupling, stable MC-based depletion, **dynamic MC**
  - Many more ideas to simulate whole cores using HPC: UFS, Wieland Shift, Stochastic implicit Euler, …

(Proof of concept)

- **Goal: Move MC methods towards industrial applications**
  - **Generalize N/TH coupling to provided reference solutions**
  - Optimize depletion simulations (stability, CPU)
  - **Analysis of transients such as RIA and others (Safety)**
  - Solve whole cores making use of HPC (improve statistics, reduced CPU)
  - **Validate MC tools using experimental data**

(Industry-like applications➔ McSAFE)

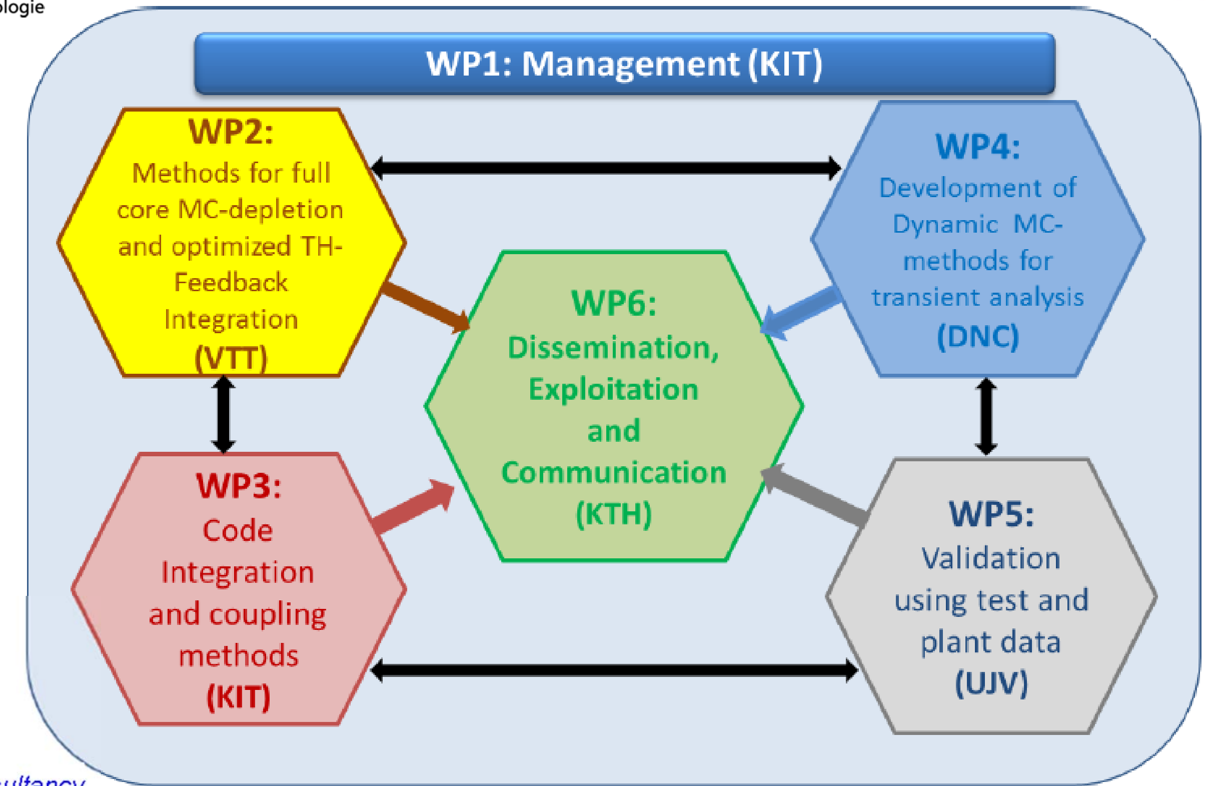
McSAFE: Time Frame

- **Phase 1: 2011 (10)-2014 (9), 7 FP EU HPMC project**

- **Phase 2: 2017 (9)-2020 (8) → McSAFE**
  - Consolidation of the methods for MC-TH coupling
  - Advance validation using exp. Data
  - Consolidate dynamic MC under HPC

- **Phase 3: 2020-2023 (9): McSAFE II NOIP**
  - Benchmarking of MC with high-fidelity deterministic core solvers for REFERENCE SOLUTIONS
  - Benchmarking of dynamic Monte Carlo solutions with transient deterministic codes for SAFETY CASES (pin level, steady-state and transient)
  - Uncertainty quantifications
  - Extension to Gen-IV reactors, research reactors

McSAFE: Work Packages



KIT Karlsruher Institut für Technologie

VTT

ÚJV

NUGENIA NUclear GENeration II & III Association

amec

Preussen Elektra

cea DE LA RECHERCHE À L'INDUSTRIE

HZDR HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

Delft Nuclear Consultancy

JRC EUROPEAN COMMISSION

CEZ GROUP

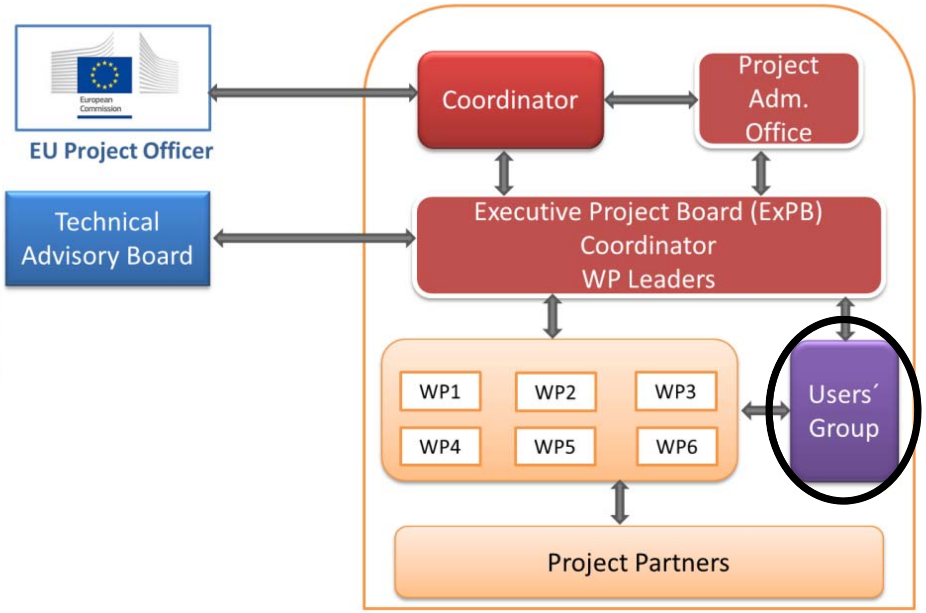
KTH ROYAL INSTITUTE OF TECHNOLOGY

eDF

www.nugenia.org

McSAFE: Management Structure and Partners

NUGENIA
NUclear GENeration II & III Association



A Users Group will be created

Confirmed institutions:

- North Carolina State University (USA)
- National Institute for Nuclear Research (Mexico)
- University of Michigan, (USA)
- University of Illinois, (USA)
- Argonne National Laboratory (USA)
- Canadian Nuclear Laboratories, (Canada)
- Idaho National Laboratory (USA)
- Westinghouse Electric (Sweden)
- SCK-CEN (Belgium)
- IRSN (France)
- POLIMI (Italy)

RESEARCH

KIT Karlsruher Institut für Technologie
KTH ROYAL INSTITUTE OF TECHNOLOGY
VTT
cea
JRC EUROPEAN COMMISSION
HZDR HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF
ÚJV

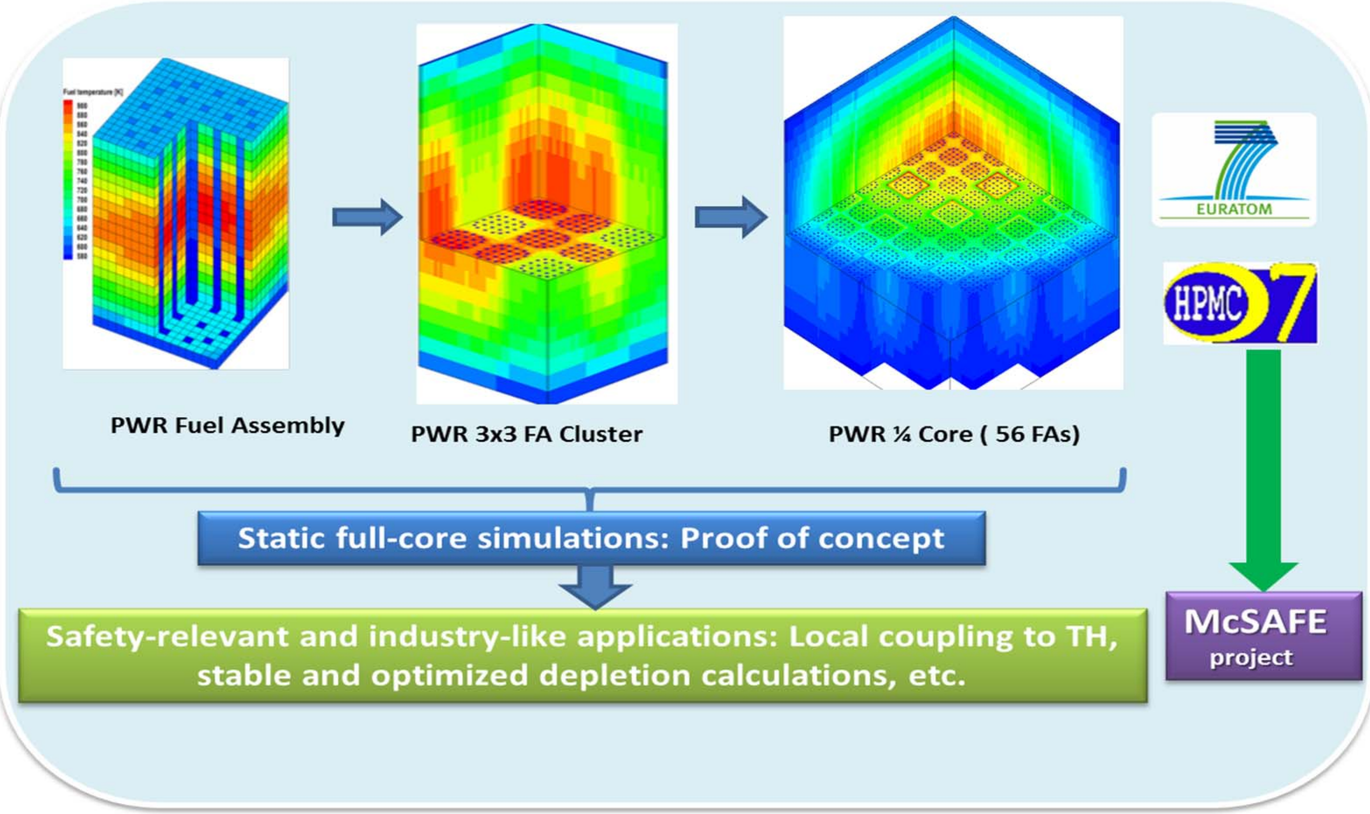
INDUSTRY

Delft Nuclear Consultanc
Preussen Elektra
EDF
amec
CEZ GROUP

www.nugenia.org

McSAFE: Main Concept (1)

❑ MCNP/SUBCHANFLOW Pin-wise Core Simulations



PWR Core Problem

Size: 193x265x30 = 1 534 350 cells

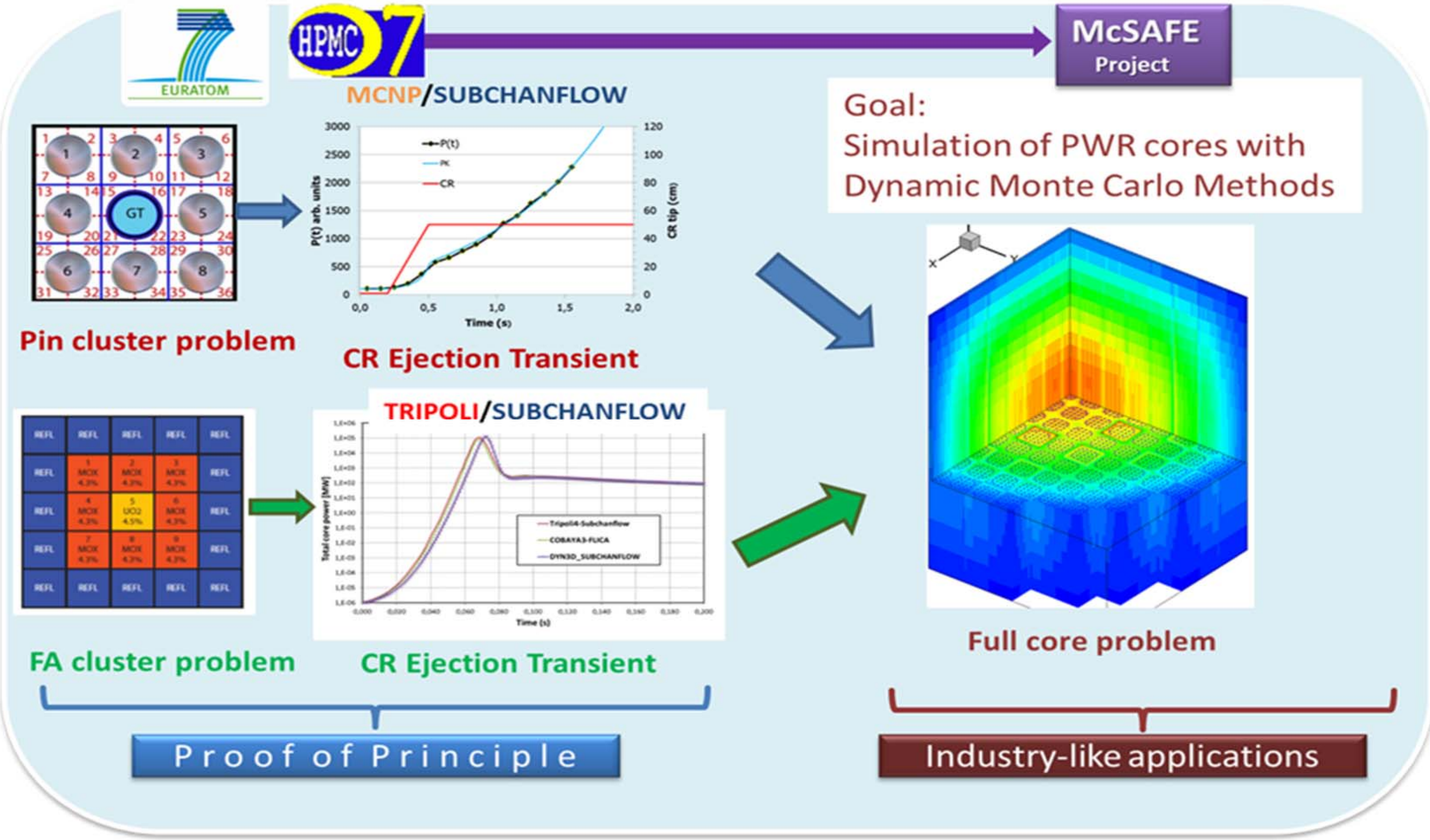
MC/TH simulation: 1.3 E9 histories, **240 cores**, Data Storage: 2.5 GB

Input preparation: < 5 min

Convergence: 20 N/TH iterations, 5600 min **(3.88 days)**

McSAFE: Main Concept (2)

Transient analysis with MC/Sub-channel Codes



DynMCNP: 3x3 Rod problem

DynMCNP Simulation

1E06 particles

DynMCNP run

- 35 cores (MPI/openMP)
- 2.5 days

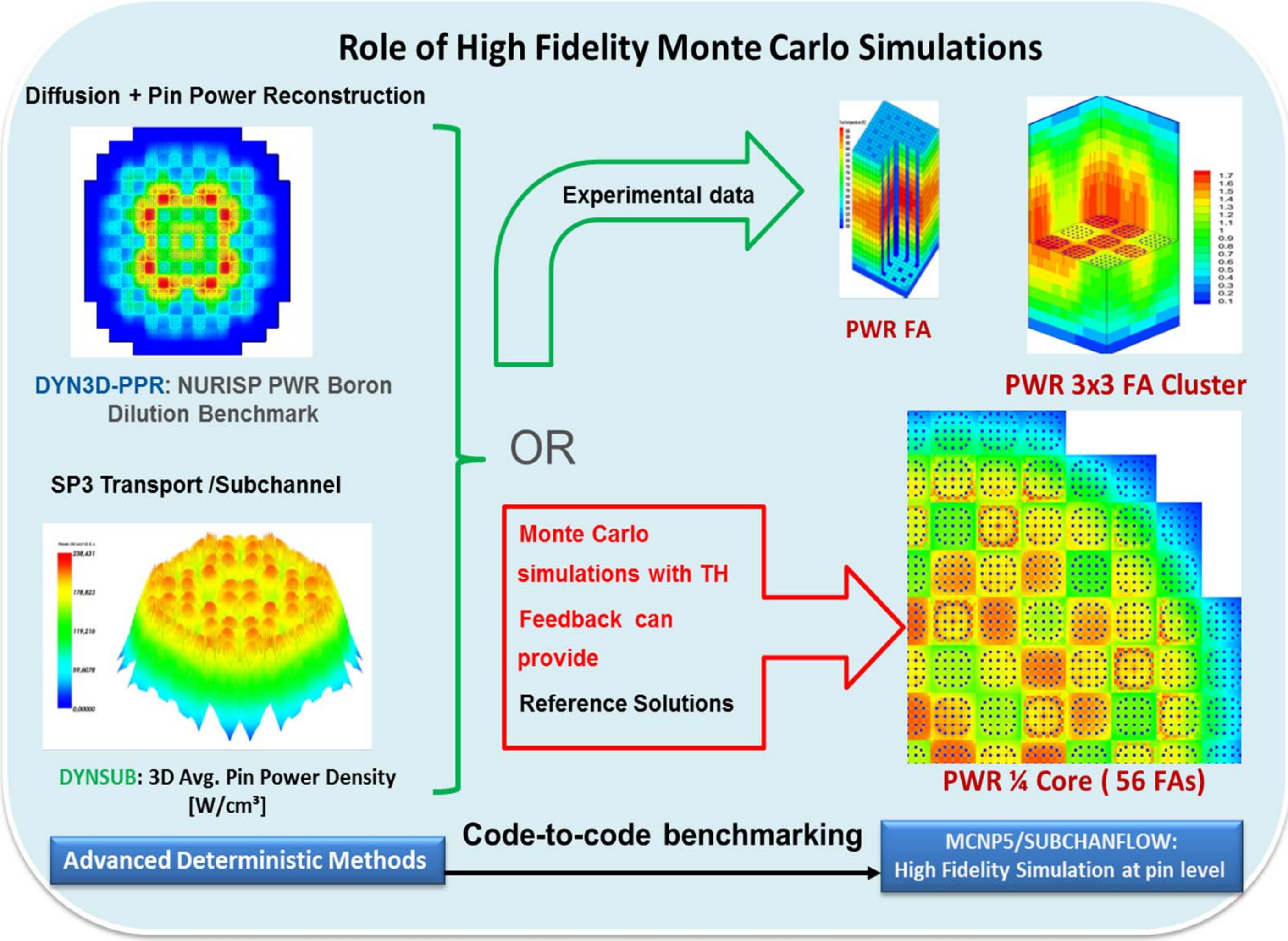
TRIPOLI/SCF : 3x3 Rod problem

Small cluster (28 cores): one week

www.nugenia.org

McSAFE: Validation

- High-fidelity coupled MC-TH simulations as reference solutions



McSAFE: Numerical Tools and Coupling approaches

NUGENIA
NUclear GENeration II & III Association

- Focus on the **further development of European MC, TH and TM codes and on the coupled systems** already developed during the 7FP EU project HPMC to make possible **industry-like simulations of both fuel depletion with stable and accurate depletion methods and LWR transients** (safety-related) with the developed dynamic MC solutions

Methods	Monte Carlo (MC)	Thermal Hydraulic (TH)	Thermo Mechanics (TM)
Static MC-TH	TRIPOLI SERPENT MCNP MONK	SCF, FLICA, TRUST SCF, COSI SCF SCF	
Static MC-TH with depletion	TRIPOLI SERPENT MONK	SCF, FLICA, TRUST SCF, COSI SCF	TU TU, FINIX TU
Dynamic MC-TH	DynTRIPOLI Dyn SERPENT DynMCNP	SCF SCF, COSI SCF	
Dynamic MC-TH-TM	DynTRIPOLI DynSERPENT	SCF, FLICA, TRUST SCF, COSI	TU TU, FINIX

McSAFE: WP5 – Validation Matrix

- **Newly available plant data** in the frame of international benchmarks or in the single initiatives by utilities (e.g. PreussenElektra or CEZ) pave the way **for the validation of the improved capability of multi-physics tools based on Monte Carlo codes** regarding e.g. local safety parameters, depletion, and fuel behaviour

Plant Data	Static MC-TH Problem	Static MC-TH-TM Depletion Problem	Dynamic Problem
VVER-1000	TRIPOLI SERPENT/SCF MCNP/SCF	SERPENT/SCF/TU	
PWR Konvoi	TRIPOLI/SCF SERPENT/SCF MCNP/SCF	SERPENT/SCF/TU	
SPERT III E REA			DynTRIPOLI/SCF DynSERPENT/SCF DynMCNP/SCF

McSAFE: Expected Contribution

- The project will deliver **improved** and **validated high-fidelity numerical simulation tools** that can be used by different end-users (industry, regulators, research centres, etc.) to provide **reference solutions to deterministic codes for safety demonstration.**

- The McSAFE **tools** are **essential to design reactor systems with improved safety features keeping sufficient safety margins**. The project will **reinforce the European leadership's nuclear engineering methods** to better assess the safety of NPP and make NPP operation more flexible while keeping high safety standards

- The **McSAFE calculation schemes** are **applicable to any reactor type**, current or future, **provided the thermal-hydraulics codes are capable of dealing with the specific reactor type**. For future nuclear reactors verification of design calculation methods is even more important as reference data are not available

Thank you for your attention!

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

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

www.nugenia.org

www.snetp.eu