Scientists and Professionals from all around the World in Karlsruhe: The 28th Edition of the Frédéric Joliot/Otto Hahn Summer School on Nuclear Reactors "Physics, Fuels and Systems"

The Institute of Neutron Physics and Reactor Technology (INR) of the Karlsruhe Institute of Technology (KIT) together with the Commissariat à l'Énergie Atomique (CEA) hosted this year the "Frédéric Joliot/Otto Hahn (FJOH) Summer School" at the GenoHotel in Karlsruhe from August 23rd to September 1st 2023. The topic of this year's school was "**Digital Twins: New Horizons in Nuclear Reactor Design and Optimisation".**

It was organized in six technical blocks and one seminar devoted to "Digital Twins in Aerospace and Nuclear Industries" given by Dr. V. Badalassi from ORNL, USA.

The first introductory block was devoted to "**Opportunities in Developing Digital Twins for Near-Term and Future Nuclear Reactors"** and consisted in two lectures. The first one entitle "Digital Twins : from Basic Concepts to Application to Nuclear Reactors - A Power Utility Perspective" was given by Dr. É. Décossin (EDF, France) and the second one entitled "The Promise of AI and the 4th Industrial Revolution for Generation-IV Reactor Design" given by Prof. Dr. N. K. Prinja (Jacobs Clean Energy, UK).

The second block was focus on the topic "**Methods for Data Management and High-Performance Computing"** and it consisted of three lectures as follows. The first lecture was given by Prof. Dr. R. McClaren (University of Notre Dame, USA) and it was subdivided into three topics: "Uncertainty Quantification and Predictive Science", "Sensitivity Analysis for Computer Simulations", and "Sampling Based Methods for Uncertainty Quantification". The second lecture was entitled "Data-driven Surrogate Modelling, Artificial Intelligence and Machine Learning" given by Prof. Dr. M. Frank (KIT, Germany) and finally the third lecture was entitled "Data Asssimilation, Machine Learning, and Digital Twins" presented by Prof. Dr. M. Asch (Université de Picardie Jules Verne, France).

The third block was dedicated to the topic "**Computer-based Materials and Fuel Developments**" and it was organized as two lectures. The first lecture was entitled "Computer-Based Materials and Fuel Developments" given by Dr. L. Messina (CEA, France) and by Dr. P. Grigorev (Université d'Aix-Marseille, France). The second lecture was devoted to "From Nuclear Fuel Element Simulation Towards the use of Digital Twins" given by Dr. K. A. Gamble (INL, USA) and Dr. D. Pizzocri (Politecnico di Milano, Italy).

The fourth block was devoted to "**Advanced Methods in Nuclear Data and Reactor Physics**" and it consisted of two lectures. The first one entitled "Recent trends in Applying Machine Learning Methods to the Nuclear Data Life Cycle" given by Prof. Dr. O. Cabellos (Universidad Politécnica de Madrid, Spain) and the second one entitled "How can modern artificial intelligence serve reactor physics" given by Dr. L. Fiorito (SCK-CEN, Belgium).

The fifth block was devoted to "**High-fidelity Nuclear Thermal-Hydraulics**" and it consisted of two lectures. Dr. M. A. Mendez (von Karman Institute for Fluid Dynamics, Belgium) gave the first lecture, which was subdivided into three chapters: "What is Machine Learning? Trends and Challenges", "An introduction to deep learning and physics informed learning", and "Deep learning for turbulence modeling". Dr. A. Gerschenfeld (CEA, France) gave the second lecture, which was subdivided into three chapters: "Modelling scales and their interactions", "Code coupling and multiscale simulations", and "Applications".

The sixth block was devoted to "**Nuclear Design and Optimisation Using Multi-physics Modelling and Simulation**" and it consisted of two lectures. Dr. F. Bertrand (CEA, France) gave the first one and Dr. V. Yadav (INL, USA) gave the second one entitled "Regulatory Aspects of Digital Twin Application in Nuclear".

A technical visit to the Energy Lab 2.0 and to the Tritium Laboratory Karlsruhe (TLK) at KIT has been organized.

The 2023's edition of the FJOH Summer school was attended by 49 participants from 18 countries (Europe, Asia, Middle East, and North America). Recognized experts of 7 different countries from EU, USA, and UK from Academia, industry, and research gave high-level lectures on topics of their expertise. During the ten days, the participants had the opportunity to exhaustive discussions with the

lecturers and other participants. Apart from the technical issues, another goal of the FJOH Summer School is to intensify the networking among the participants of different continents and nationalities with the common objective of enhancing the nuclear reactor design and optimization processes worldwide.

A well-recognized tradition during the FJOH Summer School is an extensive and diverse program with social events to get familiar with the German culture and way of life as well as to foster the exchange among the participants. This year, the Sunday trip consisted in the guided tour of the castle ruins "Weinsberg" and of the "Kerner Haus". Then a guided canoe tour of Heilbronn was organized. The Sunday trip ended with a dinner at the Gasthaus LöwenThor in Gondelsheim.

The next Summer School will be hosted by CEA in Aix-en-Provence, from August 21st to August 30th, 2024 and it will be devoted to **"Innovative Approaches for Streamlining the Design, Deployment, and Operation of Near-term and Emerging Reactors"**.

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