

4TH DONES USERS WORKSHOP



Book of Abstracts

October
13-15, 2026

Users Workshop Organizing Committee:

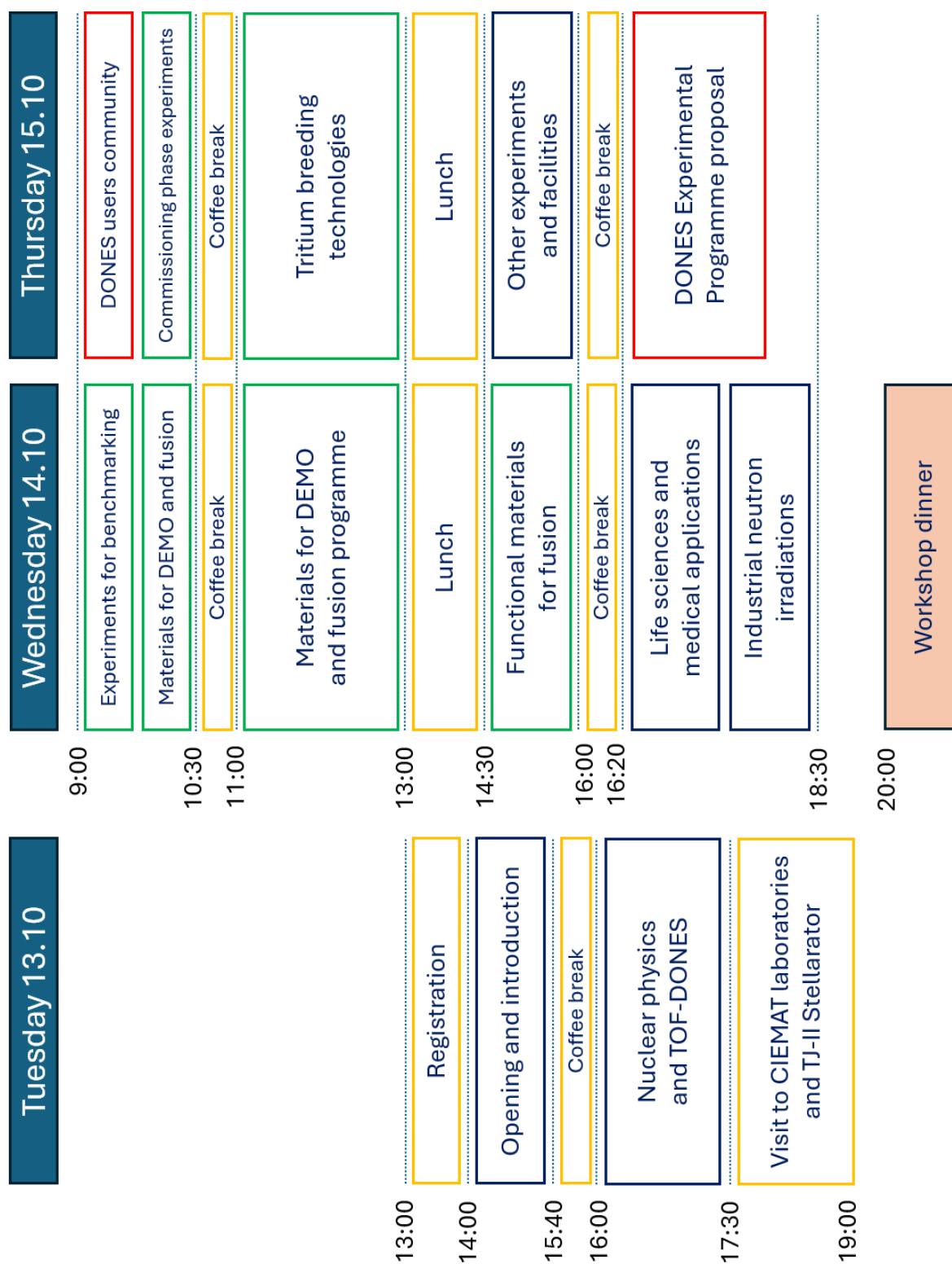
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- Wojciech Królas, secretary of the UC (IFJ PAN)



Programme overview



Opening and Introductory session

Tuesday 14:00 – 15:40

Welcome from CIEMAT management –

Director of the National Fusion Laboratory, Raúl Sánchez (CIEMAT)

*Workshop practical information**Welcome from the users community – Marek Lewitowicz (GANIL)**Status of the DONES programme – Philippe Cara (DONES Programme Team)**IFMIF-DONES design and construction status – Iván Podadera (DONES Programme Team)**Assessment of the IFMIF-DONES irradiation capabilities – Irene Álvarez Castro (esDONES)*

Coffee break 15:40 – 16:00

Nuclear physics: TOF-DONES facility and other experiments

Tuesday 16:00 – 17:30

Conveners: Daniel Cano-Ott, Emilio Mendoza

*Presentation of TOF-DONES – Emilio Mendoza (CIEMAT)**The n_TOF Facility at CERN: A Quarter Century of Unique Contributions to Neutron Physics – Nikolaos Patronis (CERN)**Key Nuclear Data Needs for Fusion Applications: A Selective Review – Yuefeng Qiu (KIT)**Scintillator-based fast neutron diagnostics systems and neutron/gamma discrimination studies at the ToF-DONES – Agnieszka Syntfeld-Kazuch (NCBJ)***Visit to CIEMAT laboratories and the TJ-II Stellarator**

Tuesday 17:30 – 19:00

Experiments for benchmarking of computational materials science

Wednesday 9:00 – 9:25

Convener: María José Caturla

Multiscale models for materials and DONES: microstructural observables, environmental conditions, and interpretation of observations – Sergei Dudarev (UKAEA and University of Oxford)

Qualification of materials for the fusion programme, DEMO and fusion power plant

Wednesday 9:25 – 10:30, 11:00 – 13:00

Conveners: Luis Monasterio and Moisés Weber

EUROfusion material development and qualification roadmap for baseline and advanced materials for fusion in-vessel components – Gerald Pintsuk (FZ Julich)

Fracture Data Acquisition Approach for Reliability Assessment of RAFM Steel in Fusion DEMO Reactors – Takashi Nozawa (QST)

Small Specimen Test Technique to investigate neutron irradiation effects: development performed within EUROfusion project in 2021-2025 – Dmitry Terentyev (SCK CEN)

Coffee break 10:30 – 11:00

Bridging the Gap: Fusion-Fission Synergies to Accelerate Material Qualification for DEMO and Fusion Power Plants – Marta Serrano (CIEMAT)

Pre-Qualification of Small-Scale Tensile Testing Methodologies for EUROFER97 and CuCrZr Towards Future IFMIF-DONES Irradiation Campaigns – Francisco Canillas (CIEMAT)

Materials selection for the DONES High Flux Test Module – Frederik Arbeiter (KIT)

Development Challenges for Tungsten-Based Materials and Joints Under Fusion-Relevant Neutron Loading in Plasma-Facing Components – Hanns Gietl (Max Planck Institute for Plasma Physics)

Fusion-relevant materials studies IRFM: insights on microstructure evolution in WEST first-wall components and hydrogen isotope behaviour studies – Elodie Bernard (CEA IRFM)

Study of the W-based High Entropy Alloy in DiFU as support facility for pre-selection of materials for DONES – Andreja Gajović (Ruđer Bošković Institute)

Towards Fusion-Relevant Materials Qualification: Insights from the UK NEURONE Programme – Slava Kuksenko (UKAEA)

Lunch 13:00 – 14:30

Studies of functional materials and other fusion technologies

Wednesday 14:30 – 16:00

Convener: Frederik Arbeiter

Functional materials and sensors in fusion environments – Rafael Vila (CIEMAT)

Enlarging the Perspectives of IFMIF-DONES by Neutronics Qualification of Functional Materials for the Breeding Blankets and Fusion Reactors – Arkady Serikov (KIT)

DONES as a Key Infrastructure for the Validation of Advanced Fusion Coatings – Elisabetta Carella (CIEMAT)

Advanced Superconducting Components and Materials Testing Laboratory at IFMIF-DONES (DONES-SCMag) - Andrzej J. Zaleski (ILT&SR PAS, Poland)

Coffee break 16:00 - 16:20

Life sciences and medical applications

Wednesday 16:20 – 17:20

Convener: M. Carmen Ruiz

IFMIF-DONES role in Personalized Nuclear Medicine – Marta Oteo (CIEMAT)

Radiobiology at DONES: Current Status and Future Perspectives – Cristina Méndez Malagón (University of de Granada)

High-Power Target Technology for Deuteron-Induced Medical Radioisotope Production at IFMIF-DONES – María Elena López Melero (University of Granada)

Neutron irradiation of electronics and other industrial applications

Wednesday 17:20 – 18:30

Conveners: Santiago Becerril, Luis Monasterio

RADNEXT: Beyond a European Project, a Sustainable Network for Irradiation Infrastructure
– Yolanda Morilla (Universidad de Sevilla / CNA)

CNA as a Combined Irradiation Testing Center: Fostering Academia and Industry Symbiosis
– Yolanda Morilla (Universidad de Sevilla / CNA)

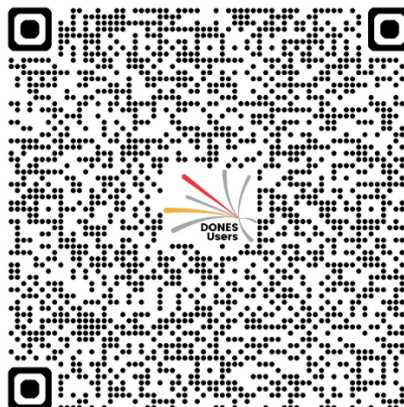
Synergies HiSPANoS-DONES: Recent user experiments at HiSPANoS and plans for the new compact 14 MeV DT generator – Carlos Guerrero (Universidad de Sevilla / CNA)

Characteristics of the neutron source at the entrance to the DONES Complementary Experiments Room R160 – Arkady Serikov (KIT)

Conference dinner

Thursday 20:00 – 23:00

Picalagartos · Restaurant & Azotea Bar
Entrance via NH Collection Hotel
Gran Vía 21, Madrid



DONES users community: the Users Committee and future activities

Thursday 9:00 – 9:45

Conveners: Andreja Gajović, Marek Lewitowicz

Experiments during the commissioning phase of DONES

Thursday 9:45 – 10:30

Convener: Stefan Wikman

Current Status of the European TBM Project and a Possible Use of DONES for Preliminary Testing – Milan Zmitko (Fusion for Energy - External Expert)

Qualification of EUROFER97 within EUROfusion: supporting material validation strategies for IFMIF-DONES and future fusion power plants – Marta Serrano (CIEMAT)

Coffee break 10:30 – 11:00

Tritium breeding technologies: validation at DONES

Thursday 11:00 – 13:00

Convener: David Rapisarda

Interest of the Eurofusion breeding blanket community in DONES irradiations – Gaetano Bongiovi (University of Pisa)

IFMIF-DONES as a key facility for HEXA breeding blanket qualification – Jacobo Zegrí Reiriz (Gauss Fusion)

Recent Progress in Kyoto Fusioneering's R&D on Fusion Blanket Components and Materials for IFMIF-DONES Testing – Mario Oliver (Kyoto Fusioneering UK)

TBU-WCLL radiation parameters assessment on IFMIF-DONES facility – Fernando Mota, María Isabel Ortiz Gandía (CIEMAT)

LBVM geometrical configuration for permeation control optimization – Fernando Arranz (CIEMAT)

Nuclear Reaction Analysis as a Qualification Tool for Hydrogen Isotope Retention in Lithium-Based Functional Materials for Fusion Application – Norberto José Sobral Catarino (IPFN, University of Lisbon, IST)

Technical Comments for Blanket Neutronics Study with Neutron Source like DONES – Kentaro Ochiai (National Institutes for Quantum Science and Technology (QST))

Lunch 13:00 – 14:30

Other experiments and facilities relevant for DONES

Thursday 14:30 – 16:00

Structural and environmental compatibility of 316L/316Ti–EUROFER97 TIG welds for DONES Target Assembly Backplate – Nerea García Rodríguez (CIEMAT)

Test and Validation of a Neutron Measurement System based on Thin-foil Proton Recoil at the DONES Neutron Source – Urszula Wiącek (IFJ PAN)

Dual-beam facility for advanced emulation of neutron-induced damage in nuclear materials using ions – Mario Matic, Tonci Tadic (Ruder Boskovic Institute)

Lithium-6: fuel for future D-T fusion power plants – Magali Rego (University of Manchester)

RF Timer Based Photoelectron Emission Spectrometer – Hasmik Rostomyan (A.I. Alikhanyan National Science Laboratory)

Water in cement: molecular-scale insights from neutron scattering – Alexander Van Driessche (IACT-CSIC)

Coffee break 16:00 – 16:20

Discussion of the DONES experimental programme proposal

Thursday 16:20 – 18:00

Convener: Ángel Ibarra

Abstracts by session

Opening and Introductory session

Overview of the DONES Programme

Philippe Cara, José Aguilar, Juan Cantero Corpas, Pierre Gavouyere-Lasserre, Francesco Grespan, Atsushi Kasugai, Patricia Martin Maderuelo, Antonio Moreno Cortes, Iván Podadera, Tonci Tadic, Claudio Torregrosa-Martin, Moisés Weber

IFMIF-DONES (International Fusion Materials Irradiation Facility, DEMO-Oriented Neutron Early Source) is a cutting-edge neutron irradiation facility designed for the study and qualification of materials intended for use in fusion reactors. It also contributes to the development of tritium and breeding blanket technologies. As part of the European roadmap to fusion electricity, its primary objective is to create a comprehensive database of material properties under intense neutron irradiation conditions, similar to those encountered in a fusion reactor. The neutron source is generated by an accelerated deuteron beam striking a liquid lithium curtain, producing neutrons with an energy spectrum and flux comparable to those experienced by the first wall of a fusion reactor.

The IFMIF-DONES facility has moved from the preliminary design to the detailed design phase, with some components already in production. The construction phase officially began with the first DONES Steering Committee on 16 March 2023, ensuring a smooth transition of design activities handover to the DONES Programme Team. This paper summarizes the current status of the DONES Programme and the IFMIF-DONES design.

The focus will be on the design status of the DONES Facility and its Accelerator Systems, which are designed for delivering the 5 MW D⁺ beam at 40 MeV with high availability. Additionally, it will provide an update on the status of hardware procurement through the In-Kind Contribution of the engaged parties and include an overview of the facility's experimental capabilities.

IFMIF-DONES design and construction status

Iván Podadera, for the DONES Programme Team

The DONES Programme is fully into the construction phase. This talk will provide insights on the latest design changes and the status of the technical construction activities of the different systems, focusing into the impact on the experimental capabilities provided to the users.

Assessment of the IFMIF-DONES irradiation capabilities

Irene Álvarez Castro, Miguel Macías, Arkady Serikov, Ángel Ibarra, Iván Podadera, Claudio Torregrosa-Martin, Moisés Weber

International Fusion Materials Irradiation Facility—DEMO Oriented Neutron Source (IFMIF-DONES) is a research facility primarily designed for the investigation and qualification of materials for future fusion reactors. To this end, IFMIF-DONES has been designed to achieve material damage levels equivalent to those expected in the walls of future fusion reactors. Beyond its primary mission, the intense neutron fields generated by the accelerator also offer significant opportunities for a wide range of complementary scientific and technological applications, whether related to fusion environments or to other research fields. This work presents an analysis of the neutron fluence rate obtained in the Test Cell area and in other complimentary experimental rooms. The sensitivity study was carried out by varying the number of modules installed in the Test Cell area and considering operating scenarios with one or two accelerators. So far, the modules considered in the Test Cell area are the High Flux Test Module (HFTM) and the Tritium Breeder Unit (TBU). The results provide valuable insights into the optimization of IFMIF-DONES operation and its capability to support a wide range of scientific and technological activities.

Nuclear physics: TOF-DONES facility and other experiments

Conveners: Daniel Cano-Ott, Emilio Mendoza

TOF-DONES and other complementary experimental areas will allow to deliver key nuclear data for fission and fusion technology development, including precise (n,γ) , (n,f) , (n,tot) , (n,n') , and $(n,charged-particle)$ cross sections, as well as benchmark measurements for radiation damage, shielding, dosimetry, and detector response. Beyond technological applications, it will also support nuclear astrophysics, medical isotope research, space radiation studies, and nuclear structure investigations using neutrons as probes. The session will be dedicated to present the characteristics of the complementary areas and the measurements to be carried out in them

Presentation of TOF-DONES

Daniel Cano-Ott, Emilio Mendoza Cembranos (CIEMAT)

TOF-DONES is a high intensity neutron time-of-flight facility designed for IFMIF-DONES. The idea is to extract, in a pulsed way, 0.1% of the deuteron beam and send it to room R026. There, the deuteron pulses will impact a target, possibly made of graphite or beryllium, generating neutrons. These neutrons will then travel along different time-of-flight beam lines in vacuum to the experimental areas. The objective of the installation is to perform neutron measurements of interest to fission and fusion technologies, astrophysics, medical physics, nuclear structure, dosimetry, and other fields.

In this workshop we will present the preliminary design of TOF-DONES, completed in the context of the DONES Consolidation Phase 1 project (2023-2025), including the description of the neutron converter, the different beam lines, shielding, collimators and the characteristics of the neutron beam in the different experimental areas.

The n_TOF Facility at CERN: A Quarter Century of Unique Contributions to Neutron Physics

Nikolaos Patronis (CERN)

In this contribution, the n_TOF facility at CERN will be presented, with emphasis on the unique characteristics that make it a leading neutron time-of-flight facility worldwide.

The integration of n_TOF within the CERN ecosystem and the strategic advantages this positioning offers will be discussed, including access to world-class infrastructure, expertise, and collaborative networks. During the quarter century of operation, highly specialized and well-tailored experimental setups have been developed, optimized for precision measurements across a broad-energy range. More recently, advances in detector R&D and newly established experimental techniques have further enhanced the measurement capabilities of the Collaboration, opening exciting new physics avenues. In this talk, the most important setups and techniques developed at n_TOF will be highlighted.

The n_TOF Collaboration is, since the beginning, the largest neutron physics collaboration globally, continuously attracting new participants over the years, reflecting the facility's central role in the field. Selected achievements demonstrating the facility's impact on nuclear data for applications ranging from nuclear energy to astrophysics will be presented.

Finally, the general principle that critical measurements for emerging nuclear technologies and other applications benefit from independent verification at multiple facilities will be addressed. In this context, potential areas where complementary measurements between established facilities like n_TOF and future facilities could serve the broader nuclear physics community will be briefly discussed.

Key Nuclear Data Needs for Fusion Applications: A Selective Review

Yuefeng Qiu, Axel Klix, Dieter Leichte (KIT)

Nuclear data underpin the design and analysis of fusion systems. Nuclear analyses provide key performance metrics — tritium production, heat deposition, material irradiation, and radiation distributions — through simulations based on fusion-relevant nuclear data, including neutron transport, activation, and displacement cross sections, and gas production data. This talk offers a review of existing nuclear and experimental data for fusion applications, focusing on the critical cross sections governing tritium production, neutron multiplication, material damage, and gas production, as well as dosimetry data for detectors of key elements and materials. Drawing on current fusion-specific libraries (e.g., FENDL-3.2, JEFF-4, TENDL-2025) and additional recommended nuclear data, we identify remaining nuclear data development needs and experimental needs and discuss the potential of time-of-flight (TOF) facilities to deliver the high-quality data, which is required to support the coming decade of fusion development.

Scintillator-based fast neutron diagnostics systems and neutron/gamma discrimination studies at the ToF-DONES

Agnieszka Syntfeld-Kazuch, Martyna Grodzicka-Kobylka, Lukasz Swiderski, Tomasz Szczesniak, Lukasz Adamowski, Marcin Bielewicz (National Centre for Nuclear Research (NCBJ))

The Radiation Detectors and Plasma Diagnostics Division at the National Centre for Nuclear Research has been conducting research on scintillation detectors for neutron–gamma discrimination for over two decades. The team’s recent work included characterization of the Organic Glass Scintillator (OGS) and evaluation of its neutron–gamma discrimination performance compared to organic scintillators EJ-276, EJ-309, M600, and stilbene [1]. While single-crystal stilbene still provides the best overall discrimination, OGS is a strong competitor. Parallel studies examined the effect of light self-absorption on pulse-shape discrimination in OGS samples of different sizes [2], and these effects are taken into account when scaling detector dimensions. In 2023, extensive studies were conducted on a novel polyurethane-based plastic scintillator, M600, and compared with the classic EJ-200 [3]. M600 proved to be a durable and cost-effective material for radiation detection in harsh environments, offering reliable neutron–gamma separation and increased resistance to ageing and humidity. Thanks to the group’s long-standing expertise, the NCBJ team is actively participating in the construction of the Vertical Neutron Camera (VNC) for the JT-60SA tokamak in Japan. At the workshop, a short presentation will be given on building neutron diagnostics for ToF-DONES and on performance tests of new scintillator compositions to be conducted using neutron beams at ToF-DONES.

[1] M. Grodzicka-Kobylka et al. Nucl. Instr. Meth. A Vol. 1077 (2025) 170559, DOI: 10.1016/j.nima.2025.170559

[2] L. Adamowski et al. ArXiv Vol. 2504.11963 (2025) 1-21, DOI: 10.48550/arXiv.2504.11963

[3] A. Syntfeld-Kazuch et al. Nucl. Instr. Meth. Phys. Res. A Vol. 1068 (2024) 169764, DOI: 10.1016/j.nima.2024.169764

Experiments for benchmarking of computational materials science

Convener: María José Caturla

The development of irradiation-resistant materials can greatly benefit from predictive models that accelerate materials discovery and provide long-term insight into material behavior. IFMIF-DONES offers a unique opportunity to validate these computational models. The aim of this session is to define the methods—ranging from atomistic to continuum scales—and identify the materials best suited for this validation, considering a broad spectrum of materials relevant to fusion energy and other applications involving neutron irradiation.

Multiscale models for materials and DONES: microstructural observables, environmental conditions, and interpretation of observations

Sergei Dudarev (UKAEA and University of Oxford)

Multiscale models for nuclear materials have now become sufficiently advanced to enable simulations of microstructures of irradiated materials at the level of fidelity, where predictions, derived from models involving no adjustable parameters, can be quantitatively compared with experimental observations. Defect and dislocation microstructures predicted by simulations, have recently been compared with transmission electron microscopy images, X-ray diffraction, Rutherford backscattering spectroscopy and hydrogen desorption spectroscopy measurements, producing surprisingly favourable outcomes. The results extended beyond the interpretation of observations, leading to fundamentally new insights into microstructural processes driven by impacts of energetic particles. Models for radiation effects have also been extended to reactor component scale, providing a foundation for the holistic assessment of materials performance in an operating fusion power plant.

The availability of an intense source of neutrons, with the spectrum matching that of the D-T fusion plasma, provides new opportunities for testing and developing materials, extending the capabilities provided by ion and fission irradiation experiments and broadening the range of testing conditions, to match the fusion power plant conditions. Full tokamak simulations are already able to define the spectrum of mechanical stress and irradiation doses expected at various spatial locations in an operating fusion tokamak, with further effort aiming at providing a quantitative definition of dynamically evolving space of operating conditions for materials in a fusion device. Presently available literature data provide only highly approximate estimates, whereas engineering design studies require a database detailing the evolution of materials in a multi-dimensional space of environmental variables including the neutron irradiation dose rate, time, temperature, tensorial stress, hydrogen isotope atmosphere, generation of transmutation elements, interaction with coolants, corrosion, occurrence of transients etc.

The presentation outlines the areas, where combining DONES capabilities with predictive materials simulations might prove most impactful, offering a comprehensive view of materials testing and validation, linked to reactor design studies and involving the assessment of data derived from complementary ion irradiation and fission reactor irradiation experiments.

Qualification of materials for the fusion programme, DEMO and fusion power plant

Convener: Luis Monasterio, Moisés Weber

Materials qualification is a crucial step on the path from fusion research materials to DEMO and future fusion power plants, where components must resist extreme neutron, thermal, and mechanical loads. This session will explore how IFMIF-DONES will contribute to solve the data gaps by providing fusion-relevant irradiation conditions to validate structural, plasma-facing, and high-heat-flux materials for safe, reliable operation.

EUROfusion material development and qualification roadmap for baseline and advanced materials for fusion in-vessel components

Gerald Pintsuk, Giacomo Aiello, Jean Henry, Michael Rieth, Dmitry Terentyev, Rafael Vila, Marius Wirtz

The first objective of the EUROfusion Work Package Materials is the characterization and qualification of the three baseline materials, i.e. EUROFER97 steel for blankets and divertor cassette structure, tungsten as plasma facing armor material, and copper-chromium-zirconium (CuCrZr) for divertor heat-sinks. Qualification of the industrially available baseline materials, up to a level sufficient for nuclear licensing, is pursued by means of experimental testing and characterization activities before and after exposure to fusion reactor relevant neutron irradiation conditions with strong emphasis on traceability and quality assurance. This also comprises the preparation for neutron irradiation campaigns to be performed in IFMIF-DONES, by the qualification of testing methods and definition of testing standards.

The second objective is the development, characterization and industrialization of few risk-mitigation alternative structural, heat-sink and plasma-facing materials with improved operational performance - i.e. radiation resistance, increased design window and/or other risk minimizing features. This is an essential part of the risk-mitigation strategy towards a Fusion Power Plant, in case baseline materials would not meet future operational requirements. This requires substantial involvement from industry partners and the qualification of the materials under neutron irradiation in parallel to the activities performed for the baseline materials.

The third pillar concerns the selection, characterization and qualification under operation relevant neutron loading conditions of functional materials, i.e. optical and dielectric materials for diagnostics and H&CD as well as insulator materials for breeding blanket and divertor applications.

Tracking of the advancement of material maturity is done by the assessment of the Materials Technology Readiness Level (MTRL) with the aim to advance material maturity to level 7 (System prototype demonstration in an operational environment). Thereby, baseline materials currently exhibit maturity levels between 4-5 where system integration issues become increasingly important. Therefore, maturation of materials to level 7 cannot only be done by tests using basic material specimens but also is dependent on the maturation of the system for which it will be used. The actual roadmap towards MTRL 7 will be sketched and existing obstacles and time-constraints outlined.

Fracture Data Acquisition Approach for Reliability Assessment of RAFM Steel in Fusion DEMO Reactors

Takashi Nozawa, Mitsuru Ohata, Hiroyasu Tanigawa (QST)

The qualification assessment of low-activation ferritic-martensitic steel (RAFM), a key structural material for fusion DEMO reactors, is a critical challenge for the realization of such reactors. The IFMIF-DONES program identifies the acquisition of neutron irradiation data as a key strategy to support this qualification assessment. The design of future in-vessel components will be verified according to structural design codes that have not yet been fully established. In particular, non-inspectable regions are expected to be evaluated through probabilistic fracture analysis based on hypothetical defects. Therefore, the application of probabilistic risk assessment (PRA) incorporating the statistical distribution of fracture characteristics is essential. This approach requires reliable fracture toughness and strength data that capture material variability under relevant conditions. In this study, we present a framework for acquiring such fracture mechanics data using small-scale specimen technology, which is particularly advantageous

Small Specimen Test Technique to investigate neutron irradiation effects: development performed within EUROfusion project in 2021-2025

D. Terentyev^{1,2}, E. Gaganidze³, Mario Walter³, M. Carrington⁴, K. Amjad⁴, D. Cinger⁵, A. Zinovev¹, D. Bermudez^{1,6}, M. Serrano⁷, R. Hernández⁷, R. Molak⁸, G. Pintsuk⁹, G. Aiello¹⁰

1 Belgian Nuclear Research Centre, SCK CEN, Mol, 2400, Belgium

2 Ghent University, Department of Materials, Textiles and Chemical Engineering, Ghent, Belgium

3 Karlsruhe Institute of Technology (KIT), Institute for Applied Materials, Germany

4 United Kingdom Atomic Energy Authority, Culham Centre for Fusion Energy, United Kingdom

5 HUN-REN CER, KFKI Campus, 1121, Budapest, Konkoly-Thege Miklós út 29-33, Hungary

6 Institute of Mechanics, Materials and Civil Engineering, UCLouvain, Belgium

7 CIEMAT. Avd. Complutense 40, 28040 Madrid, Spain

8 Warsaw University of Technology, Faculty of Materials Science and Engineering, Poland

9 Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management – Plasma Physics, 52425 Jülich, Germany

10 EUROfusion PMU, Boltzmannstraße 2, 85749, Garching, Germany

Within the EUROfusion programme, the Work Package “Materials”, among various objectives, pursues the development of validation of so-called “Small Specimen Test Techniques” (SSTT) to enable cost-efficient use of irradiation facilities. The main issue to be resolved is to elaborate a prudent approach for the inclusion of the sub-sized geometries of specimens, which are currently out validity range or not specified in the existing test standards. Six labs are contributing to this subject, focussing the efforts on:

- i. review on the currently available SSTT methods and samples geometries used in previous programmes;
- ii. identify and propose small size geometries for tensile, fatigue, creep and fracture tests;
- iii. execute experimental programs to validate (minimum) allowable size and transferability of the properties extracted using SSTT;
- iv. prepare the guidelines (and recommendations) to establish the basis for a standard of “fusion specific SSTT”;
- v. execute Pilot Run and Interlaboratory study on down-selected test configurations.

This contribution presents an overview of the current status, example of achieved tasks and near-term action plan.

Bridging the Gap: Fusion-Fission Synergies to Accelerate Material Qualification for DEMO and Fusion Power Plant

Marta Serrano García and Lorenzo Malerba (CIEMAT)

Future fusion power systems will expose materials to some of the harshest operating conditions ever considered in nuclear engineering, combining intense neutron irradiation, helium production, thermal cycling, high temperatures, and chemically aggressive environments. While fusion introduces unique challenges, many of the underlying degradation mechanisms and qualification needs are closely connected to those already faced in advanced fission systems. This creates a strong opportunity for deeper collaboration between fusion and fission materials communities. This contribution discusses how shared approaches to materials qualification can help accelerate the deployment of both future fusion reactors and advanced nuclear systems. In particular, it highlights recent efforts within European collaborative initiatives such as CONNECT-NM to develop integrated methodologies for the qualification of materials under extreme environments. Key topics include the development of structured experimental test-beds, accelerated screening and qualification routes, and multi-scale experimental platforms capable of reproducing complex irradiation and thermo-mechanical conditions. The role of major irradiation infrastructures, especially IFMIF-DONES, is discussed in the context of bridging the gap between laboratory materials development and reactor-relevant qualification. The contribution also explores emerging approaches for materials health monitoring based on advanced non-destructive examination and testing techniques, combined with physics-based modelling, data-driven methods, and AI-assisted analysis. These digital approaches, together with interoperable “smart” databases for nuclear materials, can support more predictive and adaptive qualification strategies for both fusion and fission applications. Overall, the presentation aims to highlight how fusion–fission synergies can significantly shorten qualification timelines, improve confidence in materials performance, and strengthen the scientific foundations needed for the next generation of nuclear energy systems.

Pre-Qualification of Small-Scale Tensile Testing Methodologies for EUROFER97 and CuCrZr Towards Future IFMIF-DONES Irradiation Campaigns

Francisco Canillas (CIEMAT), Antonio Fernández-Viña (CIEMAT), Rafael Gallego (University of Granada), Nerea García-Rodríguez (CIEMAT), Rebeca Hernández (CIEMAT), Edgar León-Gutiérrez (CIEMAT), Marcelo Roldán (CIEMA), Marta Serrano (CIEMAT)

The qualification of structural and functional materials for fusion reactors requires extensive mechanical testing under neutron irradiation. However, the limited irradiation volume available in current facilities and in future neutron sources such as IFMIF-DONES makes the use of conventional tensile specimens impractical. Small Specimen Test Technology (SSTT) has therefore emerged as a key approach for maximizing the amount of mechanical information obtained from irradiated material volumes. Nevertheless, the reduced dimensions of these specimens raise questions regarding transferability and the equivalence of the measured properties with respect to standard-sized specimens.

Within the framework of a EUROfusion Engineering Grant, an ongoing interlaboratory programme is being conducted to validate miniature tensile testing methodologies for two fusion-relevant materials: EUROFER97 and CuCrZr. The study includes several SSTT geometries, namely the European EUFLAT, the Japanese SSJ3, and the SCK-CEN cylindrical tensile specimen geometry, tested at different laboratories and temperatures. Particular attention is devoted to the development of robust testing procedures, specimen metrology, machine compliance correction and data processing methodologies, together with the assessment of the influence of microstructure, grain size, specimen dimensions and surface roughness on the reproducibility and transferability of key tensile properties such as yield strength, ultimate tensile strength and elongation.

The ultimate objective of this work is to contribute to the qualification of SSTT methodologies that can be reliably applied to future irradiated materials campaigns. The results obtained will support the future exploitation of IFMIF-DONES by providing validated mechanical testing procedures capable of extracting meaningful tensile properties from the limited material volumes available after irradiation. In this sense, the work represents a necessary step towards the generation of qualification data for fusion structural and high-heat-flux materials under representative irradiation conditions.

Materials selection for the DONES High Flux Test Module

Frederik Arbeiter (KIT)

The DONES High Flux Test Module shall serve to irradiate material samples up to 50 dpa in a temperature range of 250 - 550 °C in a 14 MeV type neutron spectrum. Inevitably, the same and even slightly higher structural damage will be effected in the HFTM's structural and functional components. The HFTM design responds to this challenge by separation of functions and avoiding the most critical combination of loads (i.e., adjusting temperature and stresses in a beneficial way) where possible. Still, the pressure bearing container of the HFTM is challenged by swelling and loss of ductility, the capsules at low temperatures could face embrittlement, and the ceramic insulators of the electrical heaters and sensors are affected by Radiation Induced Conductivity and Radiation Induced Electrical Degradation. The contribution discusses quality and magnitude of the effects, measures to mitigate detrimental effects in the design of the HFTM, and steps towards an optimized materials selection.

Development Challenges for Tungsten-Based Materials and Joints Under Fusion-Relevant Neutron Loading in Plasma-Facing Components

Hanns Gietl (Max Planck Institute for Plasma Physics), A. Ambrogini, T. Fox, R. Lürbke, R. Neu, J. Riesch, G. Savvidis, J. Schachter, T. Schwarz-Selinger, J.-H. You, A. v. Müller (Max Planck Institute for Plasma Physics, Technical University of Munich)

A key challenge in the development of magnetic confinement fusion power plants is the reliable exhaust of heat and particles. Divertor plasma-facing components (PFCs) must therefore withstand extreme thermal and particle loads, including neutron irradiation, which progressively degrades critical material properties. Current divertor PFC concepts typically rely on a monolithic tungsten (W) armor joined to a copper (Cu) alloy heat sink. This architecture combines the plasma compatibility of tungsten with the high thermal conductivity of a copper-based heat-sink structure. Ensuring the thermomechanical integrity of the individual constituents and their joints throughout the operational lifetime of the PFC is essential.

For this reason, advanced material concepts, such as W-fiber-reinforced composites, as well as optimized joining and manufacturing routes, are being pursued. These approaches will be combined with modelling in the future to understand irradiation-induced microstructural changes in the individual constituents and their consequences for mechanical properties. However, the degradation of material and interface properties under fusion-relevant neutron irradiation remains a major challenge and an open question for reliable PFC design. Current modelling approaches and experimental databases still rely largely on non-fusion-prototypic irradiation conditions, such as ion bombardment or neutron irradiation in fission reactors. For complex materials and joints, neutron irradiation is particularly important for assessing mechanical properties, because only neutrons provide the required bulk penetration and volume damage representative of component-relevant conditions. In addition, such irradiation data are essential for validating predictive computational models. Against this background, this contribution will present materials and PFC design concepts as well as planned computational model developments conducted at the Plasma Material Interaction and Components (P2W) division at the Max Planck Institute for Plasma Physics. In this context, gaps for fusion material qualification will be addressed from a neutron irradiation requirements perspective.

Fusion-relevant materials studies IRFM: insights on microstructure evolution in WEST first-wall components and hydrogen isotope behaviour studies

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Exposure to light particles and neutrons bombardment can create activation or microstructure damage in plasma-exposed materials, compromising properties conservation and functionality. This is particularly significant for the divertor components, where the most intense particles (He, hydrogen isotopes, neutrons) and thermal flux are expected, and for which tungsten (W) is the first-choice material thanks to its low sputtering yield, low HI retention and high melting point. Plasma-wall interactions could jeopardize conservation of these key properties throughout long-pulse operation, triggering concerns for the reactor efficiency and safety as soon as tritium (T, hydrogen radioactive isotope) is used: notably, incident He particles can drastically affect the surface, with the formation of dislocation loops, bubbles or W-fuzz. Surface properties play a major role on hydrogen isotopes (HI) retention/permeation, a crucial process for reactor efficiency and safety if enhanced mobility of hydrogen isotopes allow tritium access to structural materials such as Eurofer and potentially its release to the environment; it is therefore of prime importance to characterize both material ageing with hydrogen isotope behavior in the materials envisioned for future fusion power plants

The presentation will tackle activities carried out at CEA-IRFM (Research Institute for Magnetic Fusion, CEA Cadarache) to anticipate material behavior in fusion-relevant conditions. First, evolution of W divertor-tiles from the WEST tokamak is addressed: pre/post mortem studies allow a unique insight on material migration, microstructure evolution and impact on fuel retention throughout the various experimental campaigns, via a large scale multi-technique analysis, with a particular focus on the He campaign impact. In a second part, we will address laboratory studies carried out to anticipate hydrogen trapping and permeation for both the reactor materials (tungsten, Eurofer) and the tritium plant piping (stainless steel), thanks to a coupling between experiments and modelling. Characterizing the behaviour of H isotopes in the materials relies on a large range of experiments, with the rare insight of isotopic behaviour. H and D behaviour studies are based on gas-driven permeation experiments coupled to Thermal Desorption Spectrometry (TDS) measurements of deuterium-loaded samples to get an understanding of both transport and trapping. On the other hand, T behaviour is specifically investigated at the Saclay Tritium Laboratory. These experiments take into account the distinct properties of tritium such as its β decay, which brings us closer to actual tokamak conditions. They also allow us to access experimental conditions that are out of reach with H or D measurements thanks to the high sensitivity of tritium measurements. Finally, experimental activities are performed in the triple beam facility JANus in Saclay to mimic 14 MeV neutrons irradiation and collect important data to feed CEA-modelling tools on retention/permeation on relevant fusion materials.

Study of the W-based High Entropy Alloy in DiFU as support facility for pre-selection of materials for DONES

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The two processes relevant when testing a material for fusion environments are its response to (1) displacement damage and (2) transmutation reactions [1] can be mirrored by ion beam irradiation by heavy ion irradiation, and by helium implantation. The best effect can be achieved when these two types of ion irradiations are applied simultaneously in the dual-beam irradiation setup, like the Dual-Beam Ion Irradiation Facility for Fusion Materials (DiFU) at Ruđer Bošković Institute [2], which is one of only a dozen worldwide. DiFU was built at RBI as support facility for pre-selection of materials for DONES, so the chosen materials will be prepared as small bulk samples for DONES study.

For fusion applications, W and W-based alloys, especially refractory high entropy alloys (RHEA), are known as high heat flux (about 10 MW/m²) materials for plasma facing components e.g. first wall and divertor [3]. To prepare and study larger number of different compositions of alloys as candidates for fusion materials, magnetron sputtering is shown as method of choice, so we used this method to deposit WTaVCr thin films. Their structural properties and chemical composition on atomic scales were studied before and after irradiation in DiFU by dual or single beam.

WTaVCr films were deposited on a silicon substrate. Films were irradiated in DiFU with dual beam of 8 MeV Cu³⁺ and 200 keV He⁺ to dose 1 dpa and 6 dpa (for Cu³⁺), and with single beam of 8 MeV Cu³⁺ to dose 1 dpa. The films were characterized using X-ray diffraction (XRD), scanning electron microscopy (SEM), energy-dispersive X-ray spectroscopy (EDS) and atomic resolution scanning transmission electron microscopy (STEM), both before and after irradiation. Moreover, a highly-performant machine-learned interatomic potential [4] was employed to perform atomistic simulations of bulk and surface WTaVCr.

As-deposited WTaVCr film dominantly contains body-centered cubic (bcc) structure with a unit-cell parameter $a=3.191(2)$ Å and interplanar distance $d_{011}=2.25$ Å, and a second, minority bcc phase with unit-cell parameter $a=3.126(3)$ Å and interplanar distance of $d_{011}=2.21$ Å. While the appearance of the second phase indicates a possible phase segregation of lighter element (V or Cr), this assumption has been disproved by atomic resolution STEM imaging in combination with EDS which show that all the elements (W, Ta, V and Cr) are homogeneously distributed in all the crystal grains. These results led to the conclusion that both bcc phases were the high entropy alloys lattices containing all four metals. After irradiation with dual beam in DiFU, narrower bcc phase with a unit-cell parameter $a=3.126$ Å becomes dominant crystalline phase, although the bcc with $a=3.191$ Å can still be observed. Moreover, after irradiating as-deposited sample of thickness with single beam of 8 MeV Cu ions in dose of 1 dpa we observed that it caused complete transition of the film in the bcc phase with the smaller unit cell ($a=3.126(3)$ Å), initially found in the minority of the as-deposited samples. These results indicated that irradiation induce ordering of the crystal lattice instead of an expected increase of the defects. To elucidate the observed phenomena and confirm whether irradiation really induce the relaxation of crystal lattice, theoretical simulations of bulk and surface WTaVCr were performed. Probability of

WTaVCr to form a bcc bulk crystal of unit cell length "a" was calculated using the tabGAP [5] machine-learning interatomic potential. The simulation indicated that 3.12 is the global minimum of WTaVCr BCC crystal lattice. This statement has been approved experimentally by atomic resolution STEM imaging in combination with EDS which confirmed that all the elements are homogeneously distributed in bcc crystal lattice of WTaVCr. Moreover, the Rietveld refinements of XRD measurements show that the micro-strain value ϵ in as deposited samples was significantly larger compared to the micro-strain present in the irradiated WTaVCr having smaller unit-cell. Observed decrease in micro-strain indicates that the irradiation causes the significant reduction in number of distortions and the relaxation of deformations originally present within the as-prepared crystal lattice finally leading to the observed decrease of unit-cell parameters.

From experimental observations and theoretical analysis, we conclude that the system, as initially deposited, is located in a substrate-induced local minimum, while irradiation of the quaternary W-based alloy WTaVCr induce relaxation in thermodynamically stable phase. Therefore, the irradiation-induced ordering observed in WTaVCr under dual-beam conditions in DiFU provides a clear basis for selecting this alloy system as a promising candidate for neutron exposure in IFMIF-DONES.

The DiFU results can identify which compositions exhibit structural stability and reduced micro-strain under displacement damage and helium implantation, making them suitable for further investigation under fusion-relevant neutron spectra. Based on these findings, we propose the preparation of miniature mechanical-test specimens that would enable the assessment of the materials properties following their irradiation in IFMIF-DONES (small scale mechanical testing samples: for tensile testing, nanoindentation etc.). These small-scale samples, linking post-irradiation mechanical characterization with DiFU pre-screening and DONES neutron-induced material evolution would ultimately support the development of W-based RHEAs for plasma-facing applications.

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Towards Fusion-Relevant Materials Qualification: Insights from the UK NEURONE Programme

Slava Kuksenko (United Kingdom Atomic Energy Authority)

The UK Atomic Energy Authority-led NEURONE programme is a multi-year initiative aimed at accelerating the development and deployment of advanced nuclear steels. Its primary objective is to fast-track the development, screening, and qualification of next-generation reduced-activation steels for both fusion and fission applications. These materials are designed to withstand the extreme conditions expected in future reactors, including high neutron flux, elevated temperatures, and long service lifetimes, while minimising long-term radioactive waste.

The programme integrates advanced modelling, experimental characterisation, mechanical testing, and irradiation campaigns to significantly reduce the time required to validate structural materials and enable their transition to industrial use.

A key element of NEURONE is the irradiation work package, which focuses on understanding radiation-induced microstructural evolution and the resulting changes in mechanical properties under fusion-relevant conditions. To date, this work has relied primarily on ion irradiation to simulate radiation damage and accelerate data generation. In parallel, neutron irradiation campaigns have been conducted at the High Flux Isotope Reactor (HFIR), and irradiation has recently commenced at BR2 to obtain engineering-relevant material properties.

These studies provide important insights into defect formation, phase stability, and hardening mechanisms, including the role of nano-oxide dispersions in enhancing microstructural stability. Ongoing efforts aim to quantify irradiation effects across a range of temperatures and doses, supported by advanced post-irradiation examination techniques. Future work will increase the dataset and strengthen its reliability.

Despite this progress, important limitations remain. Ion and fission neutron irradiation cannot fully reproduce the combined effects of displacement damage and transmutation reactions characteristic of fusion environments. In particular, the lack of high-energy neutron irradiation limits the ability to accurately assess transmutation products and their impact on long-term material performance. Addressing these challenges will require access to dedicated fusion-relevant neutron sources, such as IFMIF-DONES, which are essential for the next phase of materials qualification.

Studies of functional materials and other fusion technologies

Convener: Frederik Arbeiter

Diagnostics and plasma heating of fusion reactors rely on optical and electrical properties of functional materials. Functional materials used in In-Vessel components encompass electrical insulators for sensors, active materials of sensors, electrical insulators of liquid-metal channel inserts, windows (plasma heating), mirrors, optical fibres. Superconducting coils service shielded by the blanket but still receive neutron fluences that can be detrimental for their function. The session aims at exploring the application-relevant (DEMO and beyond) irradiation conditions, operation environment and physical properties of candidate functional materials, and corresponding irradiation capabilities in IFMIF-DONES.

Functional materials and sensors in fusion environments

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This contribution reviews the performance requirements and radiation-induced degradation mechanisms of functional materials intended for operation in fusion reactors, including optical elements, electrical insulators and materials used in sensing systems. Building on the activities of the EUROfusion Functional Materials group, we identify the key irradiation needs for future fusion devices and assess how they could be addressed by IFMIF-DONES.

Particular attention is given to extending irradiation experiments from bulk materials to functional elements, interfaces and small instrumented mock-ups. This is essential for validating magnetic and optical sensors, diagnostic components, and heating and control systems, whose performance also depends on cables, optical fibres and feedthroughs.

Finally, we discuss the experimental interfaces that may be required in the DONES irradiation area for the future qualification of functional components and integrated sensor systems

Enlarging the Perspectives of IFMIF-DONES by Neutronics Qualification of Functional Materials for the Breeding Blankets and Fusion Reactors

Arkady Serikov, Frederik Arbeiter, Dieter Leichtle, Yuefeng Qiu (Karlsruhe Institute of Technology (KIT))

Responding to the growing interest from the DONES users community, this work provides a comparative neutronics assessment of key diagnostic and control components to address the critical needs of future facilities. While structural materials often dominate radiation damage discussions, functional components face unique operational limits under intense neutron fields. This paper addresses the specific challenge of evaluating these neutronics responses in a power-plant environment and maps those requirements directly to the experimental volumes and irradiation conditions provided by the IFMIF-DONES facility.

To provide a comprehensive neutronics evaluation, this study defines and analyzes key categories of functional materials:

- **Tritium breeding and Neutron multiplication materials**, analyzing advanced ceramic breeder (ACB) pebbles (lithium orthosilicate with 35 mol% lithium metatitanate) and Li_8PbO_6 octalithium plumbate, alongside neutron multipliers, including TiBe_{12} in the Helium-Cooled Pebble Bed (HCPB) and the stagnant liquid lead of the Water-Cooled Lead-Lithium Ceramic Breeder (WLCB) blanket concepts;
- **Electrical Insulators**, specifically investigating MgO and Al_2O_3 ;
- **LTS and HTS superconducting coil materials**: Nb_3Sn , REBCO, stabilizer matrix;
- **Optical Elements**, incorporating irradiation studies of chemical vapor deposition (CVD) diamond windows and fiber optic cables.

Comprehensive radiation transport and activation calculations were performed for both MgO and Al_2O_3 to evaluate their suitability in intense neutron fields. The simulations characterize the specific spatial distribution of neutron flux and fluence, nuclear heating, and neutron damage (dpa), directly comparing the irradiation conditions within the DONES High Flux Test Module (HFTM) and Medium Flux Test Module (MFTM) against the expected exposure at the DEMO First Wall (FW). Furthermore, the long-term activation behavior, decay heat profiles, and specific transmutation pathways—such as the generation of sodium (Na) isotopes—were systematically analyzed.

Neutrons degrade superconductors through lattice displacement (reducing critical temperature and critical field) and resistivity spikes in the copper stabilizer matrix due to transmutations. We analyzed the Low-Temperature Superconductor (LTS) Niobium-Tin material (Nb_3Sn) defined in ITER, DEMO/VNS, and the High-Temperature Superconductor (HTS) Rare-Earth Barium Copper Oxide (REBCO) materials used in SPARC, ARC, Proxima Fusion (Stellaris concept), and Gauss-Fusion (GIGA plant). To quantify and predict resistivity spikes in the stabilizer matrix made of highly pure copper surrounding the superconductor, we calculated neutron fluence, neutron damage, and nuclear transmutation. We applied the MCNP6.2 and McDeLicious-17 radiation transport and FISPACT-II inventory codes and the actual MCNP neutronics models of DONES. The materials are irradiated by the neutron spectra of HFTM and the MFTM versions, such as the In-Situ Ceramic Breeder Irradiation Module (ICBIM) and BLanket fUnctional Materials module (BLUME).

Special emphasis is placed on identifying how closely the high-energy deuteron-lithium neutron spectrum can emulate the specific degradation mechanisms—such as Radiation-Induced Conductivity (RIC) in ceramic insulators and transmission loss in optical diagnostics — expected in a commercial fusion environment. Ultimately, this work quantifies the capabilities of IFMIF-DONES to accelerate the qualification of essential functional technologies, providing the fusion community with the predictive data necessary for robust engineering design finalization of breeding blankets and auxiliary systems.

DONES as a Key Infrastructure for the Validation of Advanced Fusion Coatings

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Advanced coatings and permeation barriers are increasingly recognized as enabling technologies for the deployment of liquid breeder blankets in future fusion reactors. In PbLi-based systems, coatings are expected to play a critical role in mitigating corrosion, controlling tritium permeation, improving material compatibility, and extending component lifetime under the extreme thermo-mechanical and irradiation conditions foreseen in DEMO.

Recent developments in coating technologies have focused on the fabrication and optimization of oxide, ceramic and multifunctional barriers compatible with liquid breeder environments. Significant progress has been achieved in understanding coating behaviour under thermal exposure, flowing PbLi conditions and coupled corrosion-permeation phenomena. In parallel, current research is evolving toward more technologically relevant approaches, including coating integration in complex geometries, scalability of deposition methods and assessment under representative operational conditions.

Despite these advances, the qualification of coatings for fusion applications still faces major challenges due to the limited availability of irradiation facilities capable of reproducing fusion-relevant neutron spectra and damage levels. In this context, DONES will provide a unique opportunity to bridge the gap between laboratory-scale developments and reactor-oriented validation. This contribution discusses ongoing coating developments for liquid breeder applications and analyses how DONES could become a key infrastructure for their qualification through dedicated experimental campaigns.

Advanced Superconducting Components and Materials Testing Laboratory at IFMIF-DONES (DONES-SCMag)

Author: Andrzej J. Zaleski (ILT&SR PAS, Poland)

The commercial viability of next-generation fusion reactors, such as DEMO and Fusion Pilot Plant, relies heavily on high-field superconducting magnets. During operation, these systems will be exposed to an unprecedented, intense flux of fast (14 MeV) neutrons, which cause severe radiation damage, microstructural degradation, and a subsequent decline in critical parameters T_c , H_{c2} , J_c .

To address this critical issue, we propose to establish DONES-SCMag, a dedicated research facility integrated into the IFMIF-DONES infrastructure in Granada. Moving beyond standard post-irradiation examinations (PIE), this laboratory will feature a pioneering capability for realtime, in-operando characterization of both superconducting materials (HTS/LTS) and functional components (e.g. prototype coils, high-current cables, and joints) directly exposed to the neutron flux. The facility will allow continuous monitoring of the voltage-current V-I characteristics, magnetic flux penetration, and quench dynamics under high magnetic fields and cryogenic temperatures (4.2 K – 77 K) during ongoing neutron irradiation.

A key engineering focus of the laboratory will be addressing the extreme conditions of in-situ testing, specifically mitigating intense nuclear heating within the insertion cryostats and monitoring the severe activation of stabilizer and structural materials (e.g. copper, silver, and steel alloys) under the fast neutron flux.

This initiative is envisioned to be driven by a Polish-led scientific collaboration combining expertise in low-temperature physics, materials science, and cryogenic engineering, which could in the future form the nucleus of a broader consortium. The Institute of Low Temperature and Structure Research in Wrocław (INTiBS), incorporating research groups specializing in superconductivity and high magnetic fields, would take a leading role, together with potential partners such as the Wrocław University of Science and Technology (WUST), in developing specialized cryogenic transport systems, insertion cryostats, and advanced magnetometry. The collaboration could be further complemented by the Institute of Nuclear Physics in Kraków (IFJ PAN), which would contribute expertise in nuclear engineering, radiation transport modelling, and neutron dosimetry. Such a group could subsequently seek collaboration with leading international fusion laboratories, with the long-term aim of creating a global hub for the validation of superconducting magnet technologies for clean energy generation.

The forthcoming presentation will detail the physical challenges associated with deploying superconducting materials (HTS/LTS) and functional components within a fast neutron irradiation environment. Furthermore, it will outline the critical parameters that must be monitored to accurately characterize the degradation of their functional properties. Finally, a conceptual design for the DONES-SCMag facility, along with a strategy for its integration into the IFMIF-DONES infrastructure, will be proposed.

Life sciences and medical applications

Convener: M. Carmen Ruiz

The wide energy range, high intensity, and versatility of the IFMIF-DONES neutron flux make it possible to carry out a variety of studies relevant to numerous biomedical applications. This session aims to discuss how IFMIF-DONES can serve as a leading facility for health research, ranging from radiobiological studies that provide data relevant to radiation protection and neutron-based cancer therapies, to the use of radioisotopes produced by neutron irradiation as markers of biological processes and for clinical applications in nuclear medicine, including diagnosis and treatment.

IFMIF-DONES role in Personalized Nuclear Medicine

Marta Oteo (CIEMAT)

Nuclear medicine is moving steadily toward a personalized approach, driven by the development of Targeted Radionuclide Therapy (TRT) and theranostic strategies that allow diagnosis and treatment to be tailored to the molecular profile of each patient's disease. TRT relies on radiolabeled compounds that accumulate selectively in tumors or other pathological tissue, delivering cytotoxic radiation while sparing healthy organs. Theranostics goes a step further, pairing diagnostic and therapeutic radiopharmaceuticals against the same biological target, which makes it possible to select patients, plan treatment, monitor response and calculate individualized dosimetry.

None of this reaches the clinic without solid preclinical work behind it. Animal and cellular models remain essential to evaluate biodistribution, pharmacokinetics, dosimetry, efficacy and toxicity of new radiopharmaceuticals before they move into clinical trials — this is the bridge between isotope production and the patient, and it's where safety and efficacy actually get tested.

IFMIF-DONES, although conceived primarily for fusion research, offers a real opportunity here. Its fast neutron source — deuterons of 40 MeV hitting a liquid lithium target — reaches energies of 14–20 MeV, opening up nuclear reactions such as (n,2n) that conventional thermal reactors simply cannot access, since their energy thresholds are too low (for instance, ⁹⁹Mo production via ¹⁰⁰Mo (n,2n) requires around 8.4 MeV). This matters for medicine because these fast-neutron routes give access to isotopes such as ⁴⁷Sc and ⁶⁷Cu with the specific activity and isotopic purity needed for safe clinical use.

It's also possible to divert part of the 40 MeV deuteron beam to produce other promising theranostic isotopes, like ¹⁶⁵Er or ¹⁷⁷Lu. This accelerator-based route is particularly relevant for reaching the high specific activity and no-carrier-added purity that efficient radiolabeling demands, so that the radioactive atoms bind to their molecular targets without competing against stable isotopes.

Taken together, IFMIF-DONES could complement existing reactor and cyclotron infrastructure and help reinforce Europe's capacity to produce radioisotopes, securing supply for advanced imaging and targeted therapies. Access to high-quality isotopes would also benefit preclinical research at centers like CIEMAT, supporting the development of new radiopharmaceuticals and, ultimately, the progress of precision oncology and personalized medicine.

Radiobiology at DONES: Current Status and Future Perspectives

Cristina Méndez Malagón (Universidad de Granada), María José Ruiz Magaña (Universidad de Granada), Ignacio Porras (Universidad de Granada), María Pedrosa Rivera (IFMIF-DONES), María Isabel Porras Quesada (Universidad de Granada), Laura Pla Guillén (Universidad de Granada), Roberto Méndez Villafañe (CIEMAT), Marta Oteo Vives (CIEMAT), M. Carmen Ruiz Ruiz (Universidad de Granada)

Studying the effects of neutrons on the human body is a topic of great current interest. Neutrons can be regarded as a double-edged sword: depending on the context, they may pose a health risk (in occupational environments, space missions, etc.) or serve as a therapeutic tool, as in treatments such as Boron Neutron Capture Therapy (BNCT).

Despite the significant scientific interest in understanding the biological effects induced by these particles, a major limitation persists: the number of neutron facilities where biological experiments can be performed remains very scarce, and many of those currently in operation are approaching closure. Against this background, DONES represents a key opportunity, as it will enable radiobiology experiments focused on the irradiation of biological samples and the subsequent assessment of the radiation-induced damage.

Although these activities are classified within the Complementary Experiments of DONES, a comprehensive strategy for both the irradiation and the processing of biological samples within the facility is currently under development. Based on the group's experience gained at other international neutron facilities — such as the Institut Laue-Langevin (ILL) and the ISIS Neutron and Muon Source — the most suitable irradiation rooms for biological experiments at DONES have been identified. Moreover, a dedicated radiobiology laboratory ("Bio-DONES lab") has been designed, which can be located within the Main Building and will house all the instrumentation and materials required for post-irradiation sample processing.

In conclusion, the present work demonstrates the current potential of DONES for radiobiology studies and outlines future perspectives.

High-Power Target Technology for Deuteron-Induced Medical Radioisotope Production at IFMIF-DONES

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The unique neutron environment available at IFMIF-DONES offers significant opportunities for life-science and medical applications, including radiobiological research, neutron-based therapies, and the production of radioisotopes for nuclear medicine. In particular, the growing demand for diagnostic and therapeutic radionuclides has motivated the exploration of innovative production routes that can complement existing reactor- and accelerator-based facilities [1].

Beyond neutron-induced production pathways, the high-current deuteron accelerator at IFMIF-DONES may also provide access to alternative radioisotope production schemes based on charged-particle reactions. Such an approach could enable the production of emerging and novel medical isotopes while taking advantage of the unique capabilities of the facility. A key technological challenge for the implementation of these deuteron-induced production routes is the development of target systems capable of operating under the extreme thermal loads generated by high-intensity deuteron beams while maintaining structural integrity and reliable performance.

To address this challenge, the University of Granada has developed an innovative high-power target technology specifically conceived for applications intense charged-particle beams. The concept combines enhanced heat-removal capabilities with robust thermo-mechanical design, enabling efficient operation under beam power densities relevant to next-generation accelerator facilities. Such characteristics make this technology particularly attractive for future medical isotope production systems associated with high-current deuteron accelerators.

In this work, we present the first experimental validation of this technology performed within the framework of a collaboration between the University of Granada and the Laboratoire de Physique Subatomique et de Cosmologie (LPSC, Grenoble, France). Irradiation tests were carried out at the LPSC high-power electron beam facility to assess the thermal dissipation capability and structural robustness of the target under representative operating conditions [2]. Experimental results are compared with Monte Carlo particle transport simulations and thermo-mechanical calculations developed for the target design.

The potential application of this technology to deuteron-induced medical isotope production at IFMIF-DONES is discussed through two representative case studies. The theranostic radionuclide ^{177}Lu , one of the most relevant radioisotopes for targeted radionuclide therapy, along with its SPECT imaging capabilities [3-5], and the emerging therapeutic radionuclide ^{165}Er from natural holmium targets [6,7] is also considered as a complementary example. The results demonstrate the feasibility of advanced high-power target concepts for future medical isotope production systems and highlight a promising pathway to expand the scientific and societal impact of IFMIF-DONES beyond its primary fusion mission.

Industrial neutron irradiations and societal applications

Conveners: Santiago Becerril, Luis Monasterio

Industrial neutron irradiations and societal applications focus on how IFMIF-DONES complementary experimental areas can address industrial and societal needs beyond fusion, using continuous and pulsed deuteron and neutron beams. The session will cover applications ranging from superconducting materials characterization and irradiation, cultural heritage, characterization of sensitive samples, technologies for advanced industry, and broader scientific use.

RADNEXT: Beyond a European Project, a Sustainable Network for Irradiation Infrastructure

Yolanda Morilla García (Universidad de Sevilla / Centro Nacional de Aceleradores (CNA)) for the RADNEXT collaboration

Radiation hardness qualification of electronic components is a critical pillar for the space industry, aviation, safety-critical terrestrial electronics and harsh environments including high-energy accelerators and nuclear reactors. Historically, the access to specialized infrastructures has been a major bottleneck due to limited beam time. Over the last ten years, the demand for irradiation testing has increased significantly across the world, due to technological advances and market growth.

To bridge this gap, the first EU-funded RADNEXT program was launched in 2021 — not merely as an isolated project, but as a strategic initiative to democratize and coordinate free-of-charge transnational access to these facilities. After successfully building an ecosystem of 21 essential facilities, its proven impact has secured its long-term future through the approval of the RADNEXT 2030 continuation program, which has been launched in June 2026. This next phase, with 33 beneficiaries and 26 partners, transcends the original scope by expanding from single event effects (SEE) testing into total ionizing dose (TID) and displacement damage (DD) testing. Moreover, characterization of radiation environment monitors and detectors with a radiation effects focus is also part of its scope.

This presentation provides an updated overview of the RADNEXT network and its technical capabilities across proton, heavy ion, and neutron facilities, as well as complementary gamma, electron, X-Ray machines and laser sources. Ultimately, it highlights how RADNEXT has evolved beyond a standard project into the backbone of the irradiation testing landscape.

CNA as a Combined Irradiation Testing Center: Fostering Academia and Industry Symbiosis

Yolanda Morilla García, Pedro Martín Holgado, M. del Amor Romero Maestre, José de Martín Hernández (Universidad de Sevilla / Centro Nacional de Aceleradores (CNA))

As a recognized Unique Scientific and Technical Infrastructure (ICTS) in Spain, the Centro Nacional de Aceleradores (CNA) is a joint research center operating under the Universidad de Sevilla, the Spanish Research Council (CSIC), and the Andalusian Regional Government. Having pioneered irradiation testing within the country, the infrastructure offers open-access capabilities to both public and private entities. The center has not only strengthened its research and commercial services portfolios but has also established a two-way transfer of knowledge.

The irradiation unit of the CNA coordinates all the research related to reliability testing on devices and materials that could be used in critical radiation environments, such as the space environment or high energy Physics experiments. As well as the irradiation of materials that implies their internal modification for applications in agriculture, medicine or biology. This type of test, in static and/or dynamic mode, is performed in RadLab using gamma photons and in the laboratories of Tandem and Cyclotron particle accelerators.

Last year's escalating demand for Commercial Off-The-Shelf (COTS) and radiation-hardened electronic components in the Aerospace and High Energy Physics sectors has intensified the need for accessible, reliable, and versatile irradiation testing facilities. The CNA is strongly committed to participating in the European applied physics facilities networks. By adapting academic research infrastructure to meet strict industrial standards, CNA not only drives technological innovation but also provides these sectors with an efficient, high-fidelity testing ground to guarantee functional reliability.

This presentation focuses on our group activities related to the effects of radiation on electronics, as well as on the capabilities of the CNA as a combined irradiation testing facility. In addition, we will review some key aspects for facilities design and development, highlighting the compliance with the main radiation specifications and guidelines

Synergies HiSPANoS-DONES: Recent user experiments at HiSPANoS and plans for the new compact 14 MeV DT generator

Carlos Guerrero, Begoña Fernández (Universidad de Sevilla / Centro Nacional de Aceleradores (CNA))

In the context of production and use of accelerator-driven neutrons, Spain hosts the CNA HiSPANoS neutron source in Sevilla. Currently, HiSPANoS produced continuous and pulsed beams of thermal, epithermal and fast neutrons which are used for many different applications, including nuclear physics experiments and industrial applications. Recently, with the support of IFMIF-DONES, the Spanish government has granted the funds necessary to expand the portfolio with a compact DT generator of 14 MeV neutrons, aiming at yields in the $1e9$ - $1e10$ n/s range.

The installation, commissioning and use of the HiSPANoS DT generator offers a unique opportunity for the preparatory work of the commissioning of DONES R-160 and as test-bench for the proposed experiments with continuous beams.

Characteristics of the neutron source at the entrance to the DONES Complementary Experiments Room R160

Arkady Serikov (Karlsruhe Institute of Technology (KIT)), Santiago Becerril Jarque (IFMIF-DONES España), Dieter Leichtle (Karlsruhe Institute of Technology (KIT)), Yuefeng Qiu (Karlsruhe Institute of Technology)

For neutron experiment planning inside the DONES Complementary Experiments Room 160 (CER R160), it is necessary to estimate the variability of the CER R160 neutron source, which is formed by neutrons collimated through the Neutron Beam Tube and Shutter (NBT&S). In the Third DONES Users Workshop 1, we demonstrated the neutron source's dependence on the number and design of the irradiation test modules installed inside the Test Cell (TC). We considered the HFTM and two types of MFTM (BLUME and ICBIM) with the objective of minimizing the impact of the TC modules on neutrons entering the CER R160. In this work, we formulate the concept of neutron source synergy, which amplifies the usability of DONES through the effective distribution of neutrons among several irradiation modules and experiments located in both the TC and the CER. For this Workshop, we provide the results of a study on neutron flux growth at the CER entrance resulting from an increased NBT&S aperture diameter. Additionally, we analyzed modifications to the NBT&S neutron beam-line orientation for extended DONES operation at 250 mA with two accelerators running. The results of these feasibility studies for neutron beam redirection and tube diameter optimization are critical to discuss with potential users setting up neutron experiments in the CER.

The effect of neutron flux growth due to a larger tube diameter depends heavily on the size of the prospective experiments in the CER. The performed parametric analysis showed a quadratic dependence of the total neutron flux on the tube aperture size for a detector with a 30 cm diameter (D30) at the CER entrance. For this fixed-size D30 detector, doubling the tube diameter from D15 to D30 resulted in a 4.44-fold increase in the total neutron flux, while a square root of 2 (1.414) diameter increase from D15 to D21 yielded a 2.01-fold increase. The diameter D21 was chosen because $1.414 \times 15 \approx 21.2$. Conversely, if the CER detector is smaller and scaled to match the collimated tube diameter, the neutron flux dependence on the tube diameter is weaker: increasing from D15 to D30 yields only a 1.25-fold flux increase, and an increase from D15 to D21 yields just a 1.13-fold increase. To finalize the engineering implementation of the NBT&S design, feedback from potential users planning neutron experiments in the CER is highly valuable.

References:

[1] A. Serikov et al., “Updates on the BLUME and TRTM OIMs impact on the collimated neutrons entering Complementary Experiments Room R160 at DONES”, Third DONES Users Workshop, Zagreb, Croatia, October 1-2, 2024, <https://indico.ifmif-dones.es/event/29/contributions/793/>

DONES users community: the Users Committee and future activities

Conveners: Andreja Gajović, Marek Lewitowicz

Experiments during the commissioning phase of DONES

Convener: Stefan Wikman

Current Status of the European TBM Project and a Possible Use of DONES for Preliminary Testing

Milan Zmitko (Fusion for Energy - External Expert), Francesca Fantini (Fusion for Energy (F4E))

The European Test Blanket Module (TBM) programme is a key element of the European fusion roadmap, aiming to demonstrate tritium breeding and heat extraction technologies under fusion-relevant conditions and to support the development of future DEMO breeding blanket systems. Significant progress has been achieved in recent years in the design, safety assessment, manufacturing qualification and integration of the European Water-Cooled Lithium Lead (WCLL) and Helium-Cooled Ceramic Pebble (HCCP) TBM concepts. Ongoing activities focus on design consolidation, safety demonstration, component fabrication, validation of manufacturing routes, material characterization, and the preparation of dedicated experimental campaigns to support licensing and future deployment in ITER.

Despite these advances, several critical challenges remain, particularly related to neutron-induced material degradation, tritium behaviour, instrumentation performance, and thermo-mechanical response under fusion-relevant irradiation conditions. The availability of the IFMIF-DONES facility could provide a unique opportunity to investigate these phenomena under a neutron spectrum representative of future fusion power plants and to generate qualification data for materials and technologies relevant to breeding blanket systems.

This contribution presents an overview of the current status of the European TBM project, with emphasis on outstanding irradiation-related challenges and qualification needs. Potential opportunities for utilizing DONES during its early operational phases are discussed. Preliminary testing activities could include irradiation of structural and functional materials, breeder and multiplier materials, tritium permeation barrier concepts, instrumentation components, and small-scale mock-ups representative of TBM systems. Such experiments would contribute to reducing technological risks, validating predictive models, and preparing a comprehensive irradiation programme supporting both ITER TBM exploitation and the development of DEMO breeding blankets.

Finally, the paper discusses potential synergies between the European TBM programme and the DONES user community and outlines candidate experimental campaigns aligned with the pre-DEMO technology qualification strategy.

Qualification of EUROFER97 within EUROfusion: supporting material validation strategies for IFMIF-DONES and future fusion power plants

Marta Serrano García, Giacomo Aiello, D Bernardi, Yann CARIN, C Caes, M Carrington, D Della Torre, R Donnini, S D'Amico, E Gaganidze, N Garcia-Rodríguez, R Hernandez-Pascual, J. Hure, P Lamagnère, Y Lejeail, Edgar Leon, V Lezard-Chaillieux, z Milan, T. T. M. T. T. M. Nguyen, E Perelli Cippo, G Perez, Gerald Pintsuk, J.B. Pointier, Y. Poitevin, D. Ripamonti, I. Szenthe, Dmitry Terentyev, M. Walter, A. Zinovev

EUROFER97 reduced activation ferritic-martensitic (RAFM) steel is the European reference structural material for breeding blanket applications in future fusion power plants. Its qualification, together with that of its welded joints, under representative fusion operating conditions is a key step towards the deployment of reliable structural components capable of withstanding high neutron fluxes, elevated temperatures and complex thermo-mechanical loading conditions.

EUROfusion's Work Package "Materials" and Fusion for Energy (F4E) have identified the qualification of EUROFER97 and its welded joints as one of the major objectives for the 2021–2027 period. The programme aims to support the ITER-TBM programme through the integration of EUROFER97 into the RCC-MRx code while validating the mechanical behaviour and structural design methodologies required for fusion nuclear technologies. Activities currently underway include low cycle fatigue, creep, fracture toughness and fatigue crack growth testing, together with neutron irradiation campaigns covering temperatures between 275 °C and 550 °C and irradiation doses up to 2 dpa.

The experimental results obtained so far provide important input for the qualification of structural design methodologies relevant to breeding blanket systems and future fusion facilities. In particular, the programme contributes to the assessment of engineering rules addressing ratcheting, creep-fatigue interaction and irradiation-induced plastic flow instability under fusion-relevant conditions. In parallel, the ongoing activities are helping to develop irradiation strategies, testing procedures and post-irradiation examination methodologies that are directly relevant for the future operation of IFMIF-DONES.

This contribution presents an overview of the qualification activities performed during the 2021–2025 period and discusses their relevance for reducing material performance uncertainties in future fusion environments. The experimental database and engineering knowledge generated within the programme represent an important step towards the qualification of structural materials for future fusion power plants, while also providing valuable guidance for the future exploitation of IFMIF-DONES as a fusion-oriented neutron irradiation facility.

Tritium breeding technologies: validation at DONES

Convener: David Rapisarda

Tritium breeding technologies are a key enabling element for fusion reactors, ensuring fuel self-sufficiency through breeding blanket systems. This session will address how IFMIF-DONES can support the pre-qualification of breeding blanket concepts by investigating the behaviour of breeder materials under irradiation, their interaction with neutron multipliers, tritium generation, transport, retention, and release under fusion reactor relevant conditions.

IFMIF-DONES as a key facility for HEXA breeding blanket qualification

Jacobo Zegrí Reiriz, Jan Coenen, Tom Reynolds, Paul Staniec; (Gauss Fusion GmbH)

Gauss Fusion is an industrial fusion company based in Garching, Germany. The company is developing the system architecture and critical enabling technologies required to make fusion power plants buildable, maintainable and deployable. “GIGA”, Gauss Fusion’s gigawatt-class fusion power plant concept, provides the architecture baseline to enable a targeted integrated framework for identifying, validating and maturing systems required for fusion development.

Gauss Fusion is advancing proprietary technologies that address critical constraints in fusion power plant design, integration and operation. A key programme under development is “TRIMAT”: an enabling technology platform and tritium ecosystem covering industrialised material choices (IMAT) and integrable tritium technologies (TRI). This includes HEXA tritium breeding blankets with interfacing tritium and heat extraction systems, applicable to any fusion device concept, and the wider HELIOS tritium fuel cycle for stellarators.

IFMIF-DONES is a significant facility in the HEXA breeding blanket qualification strategy to contribute to achieving TRL-6. From a user’s perspective, two significant outcomes are foreseen using the facility. On the one hand, IFMIF-DONES may act as a qualifying platform, enabling partial integration testing to demonstrate HEXA breeding blanket functions and, therefore, supporting TRL progression. On the other hand, IFMIF-DONES will act as a substantiation device, to obtain material properties under relevant fusion neutron irradiation that will enable End-Of-Life assessments of baseline reactor materials for GIGA. To facilitate the leveraging of IFMIF-DONES for these two critical development programs, it is essential that the facility has the relevant volume and environmental conditions (multiple effects and neutron fluence) for prototype testing, and the appropriate supporting auxiliary systems.

Recent Progress in Kyoto Fusioneering's R&D on Fusion Blanket Components and Materials for IFMIF-DONES Testing

Mario Oliver (Kyoto Fusioneering UK Ltd.), Naoko Ashikawa (Kyoto Fusioneering), Colin Baus (Kyoto Fusioneering UK Ltd.), Luigi Candido (Kyoto Fusioneering UK Ltd.), Reuben Holmes (Kyoto Fusioneering), Satoshi Konishi (Kyoto Fusioneering), Takeo Nishitani (Kyoto Fusioneering)

In the development of breeding blankets for fusion power plants, it is crucial to create material irradiation environments that reproduce fusion-relevant neutron spectra and fluences. IFMIF-DONES will provide an irradiation environment with neutron energies and fluxes relevant to fusion applications, enabling the assessment of materials and components under conditions closer to those expected in future fusion power plants.

Various structural materials are being developed for fusion power plant breeding blankets, including reduced-activation ferritic/martensitic (RAFM) steels, V-alloys, and SiCf/SiC composites. Kyoto Fusioneering (KF) is conducting R&D on these materials, focusing on their interactions with several liquid metal and molten salt coolants, and the effects of neutron irradiation. Since most available irradiation data originate from fission neutron environments, evaluation of material-coolant systems under fusion-relevant environments at IFMIF-DONES is essential.

As one of blanket type, KF's Self-Cooled Yuryo Lithium-Lead Advanced (SCYLLA©) used SiCf/SiC structural material [1] is presented. Recent progress in the blanket are engineering designs, neutronics performance and tritium extraction technologies. In addition, it is conducted the R&D works on the material compatibility of SiCf/SiC. Focus is given to ongoing design maturation activities, including remote handling considerations, manufacturability assessments, and developments aimed at supporting future demonstration-relevant blanket testing and commercial fusion deployment. Through the discussion of neutron irradiation experimental plannings for SiCf/SiC components intended for SCYLLA, it will be established methodologies that can also be applied to other materials, such as RAFM and V-based alloys.

Numerical simulation works of a Neutron Source Package for OpenMC under DONES Irradiation target are also conducted. The source code has been generated from detailed deuterium (D)-lithium (Li) cross-sectional area calculations independently performed using PHITS + JENDL/DEU-2020 and MCNP6 + McDeLicious, and is presented alongside a simple benchmark exercise. The results demonstrate that the strong correlation between neutron energy and emission angle with respect to the Li target can be successfully reproduced in OpenMC, enabling representative IFMIF-DONES neutronics simulations with a practical level of accuracy, based on a joint collaboration by IFMIF-DONES Spain, KIT, and KF.

[1] L. Candido et al., "Preliminary design of the self-cooled lithium-lead SCYLLA blanket for a spherical tokamak," *Fusion Engineering and Design*, vol. 223, Art. no. 115574, Dec. 2025, doi: 10.1016/j.fusengdes.2025.115574.

TBU-WCLL radiation parameters assessment on IFMIF-DONES facility

Fernando Mota (CIEMAT), María Isabel Ortiz Gandía (CIEMAT), Fernando Arranz (CIEMAT), Pietro Arena (ENEA, Nuclear Department, C.R. Brasimone), Beatriz Brañas Lasala (CIEMAT), Elisabetta Carella (CIEMAT - National Fusion Laboratory), Francesca Castrovinci, Ignacio Hernandez (CIEMAT), David Jiménez Rey (CIEMAT), Virginie Lombardi (ENEA, Nuclear Department, C.R. Frascati), Fabio Moro (ENEA, Nuclear Department, C.R. Frascati), Simone Noce (ENEA, Nuclear Department, C.R. Frascati, 00044 Frascati), Paula Ollero (CIEMAT)

The Water-Cooled Lithium-Lead (WCLL) Breeding Blanket (BB) is one of three concepts actively developed by EUROfusion as driver blanket candidates for the EU Fusion Demonstration Plant (EU-FDP). This reference design employs liquid PbLi eutectic as breeder material and water as coolant, integrated with EUROFER structures. Despite significant design progress, critical technologies—including PbLi/EUROFER compatibility, tritium management systems, and thermo-mechanical behavior—require qualification under genuine fusion neutron irradiation.

To achieve this qualification, ENEA and CIEMAT have established a collaborative effort to design and develop a Water-Cooled Lithium-Lead Test Blanket Unit (WCLL-TBU) for irradiation testing at the International Fusion Materials Irradiation Facility – Demo Oriented Neutron Source (IFMIF-DONES). The TBU-WCLL targets a neutron irradiation environment representative of the WCLL EU-FDP breeder zone.

This work presents a sensitivity study of irradiation effects on WCLL-TBU materials considering the first conceptual design, as a function of different IFMIF-DONES Test Cell configurations. Parametric analyses identified optimal configurations that maximize tritium breeding performance, irradiation uniformity, and damage metrics. This study provides clear guidance on the most appropriate Test Cell configurations to achieve optimal irradiation conditions for validating breeding blanket technology under FDP-relevant neutron environments.

LBVM geometrical configuration for permeation control optimization

Fernando Arranz (CIEMAT), Paula M. Ollero (UAM), María Isabel Ortiz Gandía (CIEMAT), Beatriz Brañas Lasala (CIEMAT), Fernando Mota (Laboratorio Nacional de Fusión, CIEMAT), David Jiménez Rey (CIEMAT), Ignacio Hernández (CIEMAT, Fusion Technology Division), Marta Malo (CIEMAT), María Sánchez Arenillas (CIEMAT)

One of the most relevant objectives of the Liquid Breeder Validation Module is the study of tritium permeation through structural materials considered for future nuclear fusion power plants, as well as the effect of permeation barriers applied to these materials.

Permeation is mainly affected by the temperature of the wall through which it occurs, following Arrhenius-type relationships. Therefore, temperature control is of utmost importance in order to maintain high temperatures at surfaces where permeation is desired, while keeping low temperatures at other surfaces intended to act as confinement barriers.

On the other hand, a capsule design for the module should be as compact as possible, so that the largest possible number of capsules can be accommodated, thus maximizing the utilization of the irradiation volume available in the Test Cell of IFMIF DONES.

The geometric configuration, including capsule dimensions, experimental tube geometry, and container dimensions, together with purge He and cooling He flow rates involves multiple design requirements. These include consideration of different heat transfer mechanisms (conduction, convection, and radiation), as well as a realistic and adjustable electrical power input.

The presentation will describe the considered factors, boundary conditions, governing equations, and the results obtained.

Nuclear Reaction Analysis as a Qualification Tool for Hydrogen Isotope Retention in Lithium-Based Functional Materials for Fusion Application

Norberto José Sobral Catarino (IPFN, University of Lisbon, Instituto Superior Técnico), Rui Coelho da Silva (IPFN, University of Lisbon, Instituto Superior Técnico), Alberto Ferro (CeFEMA, University of Lisbon, Instituto Superior Técnico), Rodrigo Mateus (IPFN, University of Lisbon, Instituto Superior Técnico)

The development of fusion reactors beyond ITER requires the qualification of functional materials capable of operating under intense particle and neutron irradiation while maintaining their structural and functional properties. Lithium-based materials are attracting increasing interest for advanced fusion technologies, including liquid-metal plasma-facing concepts [1], due to their ability to mitigate power loads and reduce impurity contamination. However, their strong affinity for hydrogen isotopes may significantly affect fuel retention, material performance, and operational safety.

Accurate quantification of deuterium retained in lithium-containing materials is therefore essential for assessing their suitability under fusion-relevant conditions. Nuclear Reaction Analysis (NRA) using the $^2\text{H}(^3\text{He},\text{p})^4\text{He}$ reaction [2,3] is one of the most sensitive techniques for hydrogen isotope measurements. Nevertheless, the presence of lithium introduces competing nuclear reactions whose emitted particles partially overlap with the deuterium signal, potentially limiting the detection capability.

In this work, the sensitivity limits of NRA for deuterium quantification in lithium-based materials were investigated using a Li-Sn alloy containing 15 at.% Li implanted in situ with 10 keV deuterium ions up to a fluence of 10^{17} ions/cm². Measurements performed with a 2.3 MeV ^3He beam demonstrate that the interference from lithium-induced reactions does not compromise reliable deuterium quantification. The detection limits obtained for the alloy are discussed and extrapolated to pure lithium systems.

These results highlight the capability of ion-beam analysis techniques to support the qualification of lithium-based functional materials for future fusion reactors. The methodology is directly relevant for studying hydrogen isotope retention and irradiation-induced effects in materials expected to operate under DEMO and IFMIF-DONES relevant environments.

References:

- [1] F.L. Tabarés, Plasma Phys. Control. Fusion 58 (2016) 014014
- [2] J.P.S. Loureiro et al., Nucl. Mater Energy 12 (2017) 709
- [3] R. Mateus et al., Nucl. Instrum. Methods Phys. Res. B 486 (2021) 55

Technical Comments for Blanket Neutronics Study with Neutron Source like DONES

Kentaro Ochiai (National Institutes for Quantum Science and Technology (QST))

Blanket tests with neutron, blanket neutronics experiments, are of essential importance for verifying tritium production and recovery, as well as heat generation and recovery. These verifications must be quantitative; therefore, it is essential to have precise providing radiation transport analysis and measurement methods in advance.

Neutron source such as the d-Li neutron source produces neutrons above 20 MeV and a tail of neutrons below 1 MeV due to its reaction process; therefore, its transport processes and tritium production processes differ from those of a DT neutron source. Furthermore, for intense neutron sources such as DONES, it is necessary to examine in advance the measurement methods for neutrons and tritium, as well as for neutron and gamma radiation.

Based on some past experience with blanket neutronics experiments using DT neutron sources, the presenter will propose issues and approaches for blanket neutron engineering experiments using d-Li neutron sources such as DONES.

Other experiments and facilities relevant for DONES

Structural and environmental compatibility of 316L/316Ti–EUROFER97 TIG welds for DONES Target Assembly Backplate

Nerea García Rodríguez (CIEMAT), Elisabetta Carella (CIEMAT), David Jiménez Rey (CIEMAT), Marcelo Roldán Blanco (CIEMAT), Antonio Steenackers (AVS), Iraitz Zubiaga (AVS)

Dissimilar welds between austenitic stainless steels and EUROFER97 are unavoidable in the DEMO Oriented Neutron Source (DONES) Target Assembly (TA), particularly in the Backplate (BP), where 316L/316Ti piping joins EUROFER97 structural components exposed to extreme neutron flux, lithium velocity and thermal gradients that drive BP lifetime. This work assesses thin TIG (GTAW) butt welds in 1G configuration without filler on 2 mm plates, establishing a unified framework for the structural integrity and liquid lithium compatibility of BP relevant joints.

A 316L–316L reference campaign validated the welding configuration and identified the optimal current window balancing penetration, internal defects and heat affected zone (HAZ) extension. Radiographic inspection showed evolution from lack of fusion at low current (32-34 A) to porosity at high current (45-55 A), with 38-42 A providing the best continuity/porosity compromise. Optical microscopy, SEM and EBSD confirmed austenitic solidification with minor delta ferrite and the equiaxed-to-directionally solidified transition, while room temperature tensile tests and Vickers hardness profiling (200 gf) established the mechanical baseline.

Dissimilar 316L–EUROFER97 and 316Ti–EUROFER97 BP representative coupons required higher current (≈ 65 A) for stable fusion due to EUROFER's distinct thermal properties. Metallographic examination and hardness traverses revealed pronounced microstructural/hardness gradients at ferritic–austenitic interfaces, emphasizing robust preparation/etching needs.

The assessment matrix includes radiographic inspection, EBSD phase/texture mapping across interfaces, and tensile testing for joint level strength, ductility and fracture location. Corrosion performance is evaluated through dedicated liquid lithium exposures (ELIOS-CIEMAT) in sealed AISI 316L containers with high purity Li, assembled in inert atmosphere glovebox, pressurized to 5 bar Ar, heated up to 350 °C, and operated under controlled T/P with real time SCADA monitoring. As welded and Li exposed specimens undergo identical microstructural (optical/SEM/EBSD) and mechanical (tensile/hardness) characterization, enabling direct comparison and quantitative appraisal of DONES TA Backplate dissimilar TIG weld integrity under structural and lithium breeder conditions.

Test and Validation of a Neutron Measurement System based on Thin-foil Proton Recoil at the DONES Neutron Source

Urszula Wiącek (Institute of Nuclear Physics Polish Academy of Sciences, Poland), Jan Dankowski, Kamil Dojko, Axel Jardin, Agnieszka Kulińska, Arkadiusz Kurowski, Dariusz Morawski, Marek Scholz, Maciej Turzański ((Institute of Nuclear Physics Polish Academy of Sciences, Poland)

One of the key characteristics of a neutron source is the energy spectrum of emitted neutrons. This allows, for example, inferences about the activation of various materials used to irradiate samples composed of different nuclear isotopes. In the case of fusion reactors, however, it is possible to determine basic parameters of the reactor fuel, i.e., the plasma, such as the Ti ion temperature or the fuel ion ratio nT/nD . Among the available techniques, a promising approach to neutron spectrometry in neutron environments relevant to intense neutron sources is the thin-film proton recoil (TPR) method. The proposed system is based on the detection of recoil protons generated in a thin hydrogen-rich converter exposed to the incident neutron beam. By measuring the energy and angular distribution of recoil protons, the incident neutron spectrum can be reconstructed and compared with the Monte Carlo prediction. Currently, the high-resolution neutron spectrometer based on the TPR method is under development at IFJ PAN in Kraków [1-3].

This contribution presents a proposal for testing and validating a neutron measurement system during the commissioning and early operation phases of DONES. The proposed tests focus on several key aspects, such as selection of the most optimal detectors, optimization of the geometry stand, verification of detector response under realistic DONES neutron flux conditions, assessment of neutron energy reconstruction capabilities, and benchmarking of simulation models against experimental data. Particular attention will be given to the expected 14 MeV neutron component and to the influence of scattered neutrons originating from surrounding structures.

The campaign is intended to provide an experimental basis for qualifying TPR diagnostics as a neutron spectrometry tool for future fusion neutron facilities. The results will contribute to the development of robust neutron monitoring methodologies and support the establishment of validated diagnostic systems for high-intensity fusion-relevant neutron sources. Similar measurements will be possible and planned for other neutron diagnostic concepts. This will enable the qualification and characterization of the parameters of fusion neutron diagnostic systems designed using numerical modelling.

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Dual-beam facility for advanced emulation of neutron-induced damage in nuclear materials using ions

Mario Matic, Tonci Tadic (Ruder Boskovic Institute)

Developing next-generation nuclear technologies, including fusion (ITER, DEMO) and Generation IV reactors, requires a precise understanding of material degradation under intense fast neutron fluxes. Degradations involve atomic displacement damage (dpa) and gas production (such as H or He) via transmutation, which trigger hardening, swelling, and embrittlement. Due to the limitations of fission reactor testing, such as long irradiation time, low damage levels and sample activation, ion beam emulation has become an essential tool for rapid material qualification.

The Dual Beam Ion Irradiation Facility for Fusion Materials (DiFU) at the Ruđer Bošković Institute (Zagreb, Croatia) is one of the few multiple-beam facilities, providing dual-beam irradiation capability to the global nuclear research community.

DiFU utilizes a 6 MV Tandem Van de Graaff and a 1 MV Tandetron, equipped with SNICS and duoplasmatron sources to provide a wide range of ion species. It enables simultaneous heavy-ion and light-ion irradiation where parameters (including ion energy, dose, irradiation area, and temperature) are precisely adjusted to match specific reactor conditions. To facilitate post-irradiation analysis, the facility utilizes energy degraders to widen the ion range, creating a broader and more homogeneous irradiation volume. Furthermore, the system can achieve controlled dose and temperature gradients across a single sample, allowing for multiple data points of material response per single irradiation.

DiFU is highly adjustable for various purposes, including the study of fusion fuel blankets, plasma-facing components, and Gen IV structural materials. Operating at temperatures up to 1000 °C under high vacuum (10^{-8} mbar), the facility provides an accelerated, non-activating method to study the synergy between displacement damage and transmutation products. By offering high-throughput capabilities and precise control over the irradiation environment, DiFU serves as a critical asset for the development of resilient materials for the future nuclear fuel cycle.

Lithium-6: fuel for future D-T fusion power plants

Magali Rego (The University of Manchester), Kathryn George (The University of Manchester)

By 2040, at least 100 tonnes of isotopically pure lithium-6 will be required to fabricate breeder blankets for STEP (Spherical Tokamak for Energy Production), the UK's prototype fusion power plant. There is no currently established supply chain or large-scale lithium isotope enrichment plant to provide the needed quantities of lithium-6.

The industrially proven process for lithium-6 enrichment, COLEX (COlumn EXchange), requires massive quantities of liquid mercury that come with problematic handling issues, hazardous environmental and health implications. Alternative methods with similar separation performance such as liquid-liquid extraction have only been tested at a laboratory scale and lack trials for successful industrial-scale deployment.

This project aims to deliver a mercury-free liquid-liquid solvent extraction method using crown ethers to produce enriched lithium at the scale needed for breeder blanket manufacturing. The best-performing lithium enrichment liquid-liquid extraction system has been identified and the extraction conditions optimised.

Lithium-6 enrichment by liquid-liquid extraction has not been studied in detail and there is a poor understanding of the chemistry, making this research a valuable contribution to the field of liquid-liquid extraction, in addition to facilitating the deployment of fusion power plants.

RF Timer Based Photoelectron Emission Spectrometer

Hasmik Rostomyan (A.I. Alikhanyan National Science Laboratory), Vanik Kakoyan, Amur Margaryan, Hasmik Rostomyan, Simon Zhamkochyan, Sergey Abrahamyan, Hayk Elbakyan, Aram Kakoyan, Samvel Mayilyan, Artashes Papyan (A.I. Alikhanyan National Science Laboratory)

We propose a novel RF Timer based photoelectron emission spectrometer designed for the study of the energy and temporal characteristics of very low energy photoelectrons. In the near threshold regime, emitted electrons have kinetic energies from a few meV to several hundred meV, making their distributions highly sensitive to the work function, surface condition, electronic states near the Fermi level and defect related modifications of the material. The instrument combines very low photon energy photoelectron spectroscopy with RF Timer based electron timing, enabling measurement of photoelectron energy and photoelectron emission time characteristics in the picosecond regime.

A particularly relevant application is the characterization of neutron irradiated materials in the context of IFMIF-DONES and future fusion material qualification programs. Radiation induced vacancies, interstitials, defect clusters and surface modifications can alter the density of states, work function, carrier transport and low energy electron emission properties. By measuring both the low energy photoelectron spectrum and emission time distribution, the proposed instrument could provide complementary information on defect related electron dynamics and radiation damage.

Water in cement: molecular-scale insights from neutron scattering

Zhanar ZHAKIYEVA (Nazarbayev University, Astana, Kazakhstan), Alexander Van Driessche Driessche (IACT-CSIC), Alejandro Fernandez-Martinez (ISTerre, CNRS – Univ. Grenoble-Alpes)

Water plays a central role in the mechanical strength, durability, carbonation dynamics, and ion-driven degradation in cementitious systems. Yet the structure and dynamics of water within the poorly crystalline, nanoporous main binder phases of cement, especially in the newly emerging low-CO₂ cements, are difficult to characterize by conventional techniques. Neutron scattering offers unique advantages: its high sensitivity to hydrogen, combined with H/D isotopic contrast, makes it well suited to probing water at mineral interfaces on the molecular scale. Particularly useful is the complementary use of neutron diffraction with isotopic substitution (NDIS) and inelastic incoherent neutron scattering (IINS). The former provides element-selective resolution of interfacial water ordering, a level of structural detail inaccessible to X-ray diffraction alone. Combined with molecular dynamics simulations, NDIS can reveal distinct wet and dry surface domains and identify water-surface cation coordination as water organizes at cement surfaces. The latter characterizes water dynamics through the vibrational density of states, resolving transitions from surface-adsorbed multilayer water to capillary-condensed ice-like phases—features that calorimetric or spectroscopic methods capture only partially. Together, NDIS and IINS provide a molecularly resolved picture of interfacial water, contributing to a more detailed understanding of the role water plays in governing the performance and durability of cementitious materials.

Discussion of the DONES experimental programme proposal

Convener: Ángel Ibarra

A working group representing all DONES stakeholders has been established to prepare a proposal of the DONES Experimental Programme. In this session the principles for the definition of the Programme, planning of irradiation campaigns, handling of different experimental areas and possible upgrades will be presented. A preliminary draft of the Experimental Programme will be proposed and discussed.