Early Neutron Source IFMIF-DONES: Status and validation activities phase

D. Jimenez-Rey[1], A. Ibarra[2], W. Krolas[3], R. Roman[1], F. Arbeiter[5], F. Arranz[1], S. Becerril[2], D. Bernardi[4], M. Cappelli[4], P. Cara[6], J. Castellanos[7], K. Kowal[8], M. Luque[2], J. Maestre[2], F. Martin-Fuertes[1,2], G. Micciche[4], F.S. Nitti[4], T. Pina[4], I. Podadera[2], Y. Qiu[5], D. Regidor[1], C. Torregrosa[2], M. Weber[1,2], and the full IFMIF-DONES &WPENS Team*

[1]*CIEMAT Madrid, Spain*
[2]*IFMIF-DONES España, Granada, Spain*
[3]*IFJ PAN Kraków, Poland*
[4]*ENEA Brasimone and ENEA Frascati, Italy*
[5]*Karlsruhe Institute of Technology, Germany*
[6]*Fusion for Energy, Garching, Germany*
[7]*INAIA, Univ. Castilla-La Mancha, Toledo, Spain*
[8]*NCBJ Warsaw, Poland*
**E-mail: d.jimenez@ciemat.es*

The development of nuclear fusion as a sustainable and nearly limitless energy source depends heavily on the availability of radiation-resistant materials. The International Fusion Materials Irradiation Facility - DEMO Oriented Neutron Source, IFMIF-DONES, is a cutting-edge neutron irradiation facility aimed to test and qualify materials under conditions relevant to future reactors [1], such as DEMO. IFMIF-DONES is designed to generate high-intensity neutron fluxes (in the order of 10^{14} n/cm^{2}s) with a fusion-like energy spectrum, utilizing deuterium-lithium stripping reactions [2]. The neutron source core components include a high–power linear accelerator (superconductive LINAC type, with a possible extension to a configuration of two similar accelerators) accelerating deuterons to an energy of 40 MeV and operating with a beam current of 125 mA, a lithium target system, irradiation (test) modules, and associated remote handling systems, central instrumentation and control systems, ancillary systems, and radiation shielding infrastructure.

The European Roadmap identifies the need of an Early Neutron Source (ENS) based on the IFMIF-DONES concept. This essential facility has been under design since 2015 in the framework of EUROfusion activities [3], taking as a starting point a preliminary design prepared in the IFMIF Engineering Validation and Engineering Design Activities (IFMIF/EVEDA) project [4], but limited to a single LINAC accelerator. Until 2023, the EUROfusion Early Neutron Source Work Package (WPENS) has been mainly focused on the design and consolidation of the facility and its systems, along with transversal studies and analyses, with special emphasis on safety and operation aspects, relevant to the licensing process, as well as critical technical studies for allowing the starting of the construction in the selected location [5]. In 2023, an important milestone for the fusion-like neutron source was achieved with the establishment of the DONES Steering Committee, formally initiating the construction process in Escuzar-Granada (Spain). Following this significant milestone, the implementation of the WPENS design and construction activities is being carried out by the DONES Joint Project team, located in Escuzar, taking over the responsibility for the activities hitherto developed in the framework of the WPENS.

For that reason, the objectives of the WPENS were redefined in 2024, in such a way that the prototyping & validation activities of the systems and components required for the construction and operation of DONES are continued, together with the assessments of potential upgrades and extension options for the final configuration of the IFMIF-DONES, such as the addition of the second accelerator, increasing beam performance, studying the implementation of the Post Irradiation Examination (PIE) facility and hot cells, and defining the experimental programme for the operation of the facility. The design of the other irradiation modules will be conducted, and modules for testing under relevant irradiation conditions mock-ups (divertor and breeding blanket units for tritium technologies studies) for validating critical DEMO technologies.

The activities within WPENS are structured into eight key areas: Project Integration; Project Level Analyses (encompassing Safety, Neutronics, RAMI, and Logistics & Maintenance); Site, Building and

Plant Systems; Test Systems; Lithium Systems; Accelerator Systems; Central Instrumentation and Control Systems; and the Project Management. In this new phase, a significant emphasis has been fostered on R&D studies and the experimental validation of IFMIF-DONES systems, reinforcing the technological readiness of the facility across all the areas. This approach will be pursued and further strengthened by taking advantage of the various experimental facilities and IFMIF-DONES system prototypes that have been assembled and commissioned during the last few years [5]. This validation phase will be performed at the Multipurpose Vacuum Accident Scenarios (MuVaCaS), LIFIRE, and purification Lithium Technologies CIEMAT (LITEC) experimental facility and the Start-Up Monitoring Module (STUMM) prototype, while other experimental activities will continue at different participating laboratories of the WPENS-Research Units and Affiliated Entities, i.e.: CIEMAT, KIT, at the DRP and Lifus-6 facilities at ENEA, the MARIA reactor at NCBJ and the cyclotron at NPI/Czech Academy of Sciences [5]. It is important to highlight the support to the Linear IFMIF Prototype Accelerator, LIPAc, under continuous testing and progressive assembly in Japan, participating in the operation with the deuteron beam at 9 MeV energy, 125 mA current, in the continuous wave mode through the Cryomodule SRF-LINAc up to the beam dump, as the last IFMIF-DONES system to be validated, to obtain feedback and develop operational expertise for IFMIF-DONES accelerator and carry out activities of common interest with QST for a generic Fusion Neutron Source development [6].

This contribution presents an updated status report on the fusion-relevant neutron source IFMIF-DONES, detailing recent key developments in its design and construction, and highlighting significant technical and engineering progress. The transition to the validation phase marks a critical milestone in ensuring the operational readiness and scientific reliability of the Neutron Source. This work outlines ongoing validation and prototyping activities, summarizing the most relevant R&D studies related to the processes and technologies required for the commissioning and operational phases. Additionally, progress in the mock-up design for validating critical DEMO technologies is presented, including tritium technology validation and divertor testing under fast neutron irradiation. Finally, the initial design for post-irradiation examination (PIE) implementation and the definition of the experimental operational matrix are discussed.

ACKNOWLEDGEMENTS

This work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them. This work has been co-financed by the Polish Ministry of Science and Higher Education in the framework of the International Co-financed Projects (PMW) programme.

REFERENCES

[1] J. Knaster *et al.*, Materials research for fusion, Nature Physics 12, 424–434 (2016).
[2] A. Ibarra *et al.*, The European approach to the fusion-like neutron source: the IFMIF-DONES project, Nuclear Fusion 59, 065002 (2019).
[3] W. Królas *et al.*, The IFMIF-DONES fusion oriented neutron source: evolution of the design, Nuclear Fusion 61 (12), 125002 (2021).
[4] J. Knaster *et al.*, Overview of the IFMIF/EVEDA project, Nuclear Fusion 57, 102016 (2017).
[5] D. Bernardi *et al.*, The IFMIF-DONES Project: Design Status and Main Achievements Within the EUROfusion FP8 Work Programme, J. Fusion Energy 41, 24 (2022).
[6] Y. Carin *et al.*, IFMIF/EVEDA achievements overview, Fusion Engineering and Design 201, 114258 (2024).