

OUTCOMES OF THE DONES CONSOLIDATION PROJECT ACTIVITIES*

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Abstract

IFMIF-DONES is an ESFRI facility based on a 40 MeV, 5 MW beam power deuteron accelerator and a liquid lithium target currently under construction in Granada (Spain) as part of the European roadmap to fusion electricity. Its main goal is to characterize and qualify materials under a neutron field with an induced damage similar to the one expected in a fusion reactor, developing a material database for the future fusion nuclear power plants. Moreover, a number of medium neutron flux experiments in other irradiation areas for fusion and non-fusion applications have been proposed and are under analysis. Although the construction phase is ramping up, the European EURATOM Project DONES-ConP1 has been directed at the preparation of the key documentation and to consolidate contributions from the parties. In this contribution, the main outcomes of the project, such as the first proposal of the DONES Experimental Programme, consolidation of the DONES users community, users and machine interfaces, the evolution of the ideas for the complementary experiments, organization and project documentation for safety licensing will be presented and described.

INTRODUCTION

The DONES Consolidation Phase 1 Project (DONES-ConP1) [1] was an European Project within the EURATOM Work Programme formed by ten European institutions and observers, key in the area of fusion technology development and interested in the DONES Programme. The main objectives were: 1) Developing an **experimental**

programme in fusion and also expanding to non-fusion areas, associated to widen the DONES Users community, 2) Completing the framework of the in-kind and partnership procurements by assessing the **strategy of the in-Kind Contributions** (IKC's) and 3) Updating **key documentation** for policy-makers about financial, legal and organisational project organisation related to the international character of the IFMIF-DONES Facility.

EXPERIMENTAL PROGRAMME

Fusion Programme

The main goal of the facility [2] is the validation of structural materials for fusion reactor in-vessel components. Several critical parameters were identified for study: temperature, displacement damage (2–50 dpa) and transmutation rates (He/H) shall be characterized for the baseline materials EUROFER97, CuCrZr, and tungsten in order to **create the materials properties database under fusion prototypic irradiations**, prioritized by parameters and conditions originating from EU DEMO requirements. A major methodological advance was the proposal of “flip-and-average” approach for High Flux Test Module (HFTM) specimen boxes (Fig. 1), improving dose uniformity to within $\pm 10\%$ and ensuring high-quality experimental data. The proposed programme includes a first campaign in two phases, covering over 85% of priority objectives: 1) verification of 14 MeV neutron energy damage effects, 2) assessment of transmutation phenomena, and 3) characterization of material properties under DEMO-representative conditions. The results detail planned **neutron irradiation campaigns**, covering both structural and functional materials, and specifies the testing methods to be implemented after exposure—such as tensile, fracture, fatigue, creep, and microstructural analyses using small-specimen techniques. It provides a mapping between irradiation modules and their associated Post Irradiation Experiments (PIE) workflows, defining the sequence of activities from sample retrieval to data validation.

Additionally, a catalogue of irradiation modules and their integration with future Test Blanket Module (TBM)

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developments was included, linking DONES experimental programme with the broader fusion materials qualification roadmap. Finally, the structure and schedule of the PIE programme was proposed ensuring alignment between facility design, experiment planning, and post-irradiation capabilities, targeting first coordinated campaigns in the early 2030s. The outcome establishes DONES as a cornerstone facility providing neutron irradiation and material qualification for a Fusion DEMONstration Plant and beyond, guaranteeing that European fusion R&D benefits from a fully integrated “irradiation-to-examination” workflow.

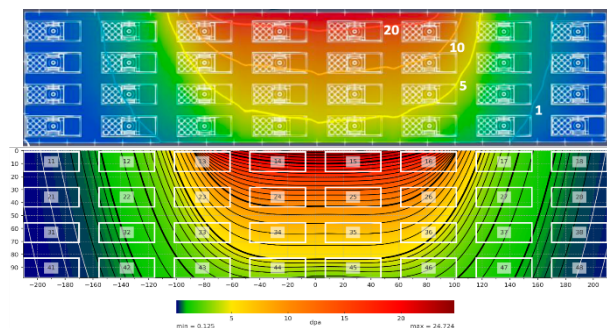


Figure 1: (top) Damage (dpa/fpy) field in horizontal medium plane of the High Flux Test Module (HFTM). (bottom) 2d-model of the damage field.

Non-Fusion Programme

The non-fusion experimental capabilities at IFMIF-DONES were identified during the project, with particular emphasis on nuclear physics, nuclear medicine, and industrial applications. Over 50 proposals across different scientific domains were selected. Special attention was given to pulsed deuteron and neutron beam experiments that leverage DONES' unique capabilities for gamma spectroscopy, fission studies, and reaction cross-section measurements. Key experimental proposals include gamma spectroscopy of nuclei, study of the pygmy dipole resonance with $(n,n'\gamma)$ or $(d,d'\gamma)$ reactions, half-life measurements of long-lived isotopes, and deuteron-induced reactions. IFMIF-DONES has unique capabilities for high-intensity, long-duration experiments that enable high-statistics data collection crucial for detailed nuclear structure studies. Technical requirements have been defined, including the need for approximately 2 ns deuteron beam micro-bunches and the potential integration of state-of-the-art gas-filled magnet spectrometers brought by partner institutions for experimental campaigns. Nine major proposal categories within nuclear medicine were explored, including: radioisotope production (^{225}Ac , ^{177}Lu , $^{99}\text{Mo}/^{99\text{m}}\text{Tc}$, ^{18}F , ^{90}Y , and ^{131}I), elemental analysis techniques, boron neutron capture therapy studies, neutron cross-section measurements for medical isotope production, and cellular response studies.

For the collimated neutron beam experimental area located behind the Test Cell, a layout for two instruments to produce, measure and study radioactive isotopes was proposed. The production rates and the background have been estimated to evaluate the feasibility of such experiments. For the deuteron pulsed beam area, two experimental areas have been proposed: 1) using the extracted pulsed deuteron

beam, and b) Time of Flight Facility (TOF DONES), using the pulsed neutrons from the conversion of pulsed deuterons (Fig. 2). More than ten industrial applications have also been studied with neutron imaging, diffraction, and scattering applications receiving high relevance, using a fast neutron flux of 2×10^{10} n/cm²/s and a thermal one of $4-6 \times 10^7$ n/cm²/s. Among the technological challenges for the implementation of the pulsed deuteron beam experiments, the meander line kicker stands out as the most technically demanding equipment for the deuteron beam extraction [3]. Although this type of device is already in use in other laboratories, the required operating conditions in terms of field strength and beam energy are significantly more stringent. Regarding the beam distribution in the experimental hall, two alternative layouts have been considered: 1) based on pure magnetic distribution, achieving a nominal pulse length of 10 ns, and 2) employing a superconducting buncher able of generating sub-ns pulses.

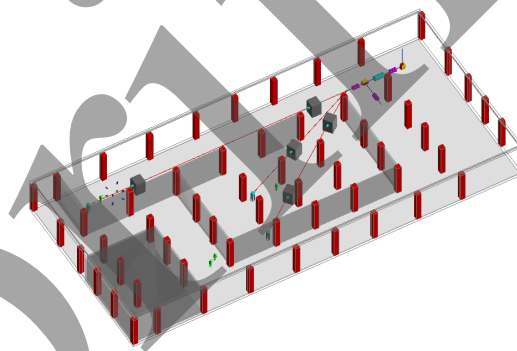


Figure 2: Conceptual design of TOF-DONES

Data Management

First proposal of the Data Management Plan (DMP) to define policies for data access from various users was issued. The DMP aims to outline all aspects of data lifecycle management at IFMIF-DONES, including data source identification, curation and storage processes, user accessibility provisions, and associated data privacy policies. It covers multiple scenarios, such as experiments conducted within the Test Cell, future irradiation modules, complementary experiments, and remote data access during operation campaigns. It also addresses key definitions, such as Digital Object Identifiers (DOIs) and Open Access principles.

DONES Users Community

The DONES Users Committee was established including experts from both fusion and non-fusion science areas interested in performing research activities at DONES, such as: Material qualification for fusion program, Tritium breeding validation technologies, nuclear physics and neutron time-of-flight experiments, Industrial and cultural heritage application of neutrons and Life science application of neutrons. The DONES Users webpage [4] was established, containing basic information about the community. The Third DONES Users Workshop was organized in October 2024 in Zagreb, Croatia, gathering >60 on-site participants and featuring topical sessions.

IKC STRATEGY

A Multilateral International DONES Agreement (MIDA) was signed in November 2025 among esDONES, F4E, INFN, QST and RBI. Other institutes such as ENEA (Italy) and KIT (Germany) have shown interest to join in short term, which secures the full budget for the construction phase. A list of work packages is the basis of the in-kind contribution by the potential parties of DONES Programme. Packages were defined with a technical approach, making them feasible from a technical and organizational point of view. In addition to essential packages, a list of Potential Opportunities (PO) packages which could be implemented to extend the scope and improve the performance of the facility has been reviewed and defined. This includes major improvements such as the addition of a second accelerator to boost significantly the irradiation capabilities. Interactions have been established with several Research Infrastructures such as ESS, XFEL or LIPAc, which were built based on in-kind contributions, to get feedback on their experience of IKC management.

Strategy for Acceptance Tests

Given the large number of components and contributing in-kind partners, the strategy of the acceptance tests must follow a consistent and uniform approach for all systems. The proposal developed under this project is based on the ISO 9001, ISO/IEC 17020, and IAEA guidelines for research reactors. It covers the Organizational structure, Test team staff, Equipment and facilities, Control measures, and Suppliers related to testing. The Testing Plan defines the testing phases, conditions, acceptance criteria, and procedures for developing tests of specific components. The procedure for developing tests was integrated with the Master List of Tests, serving as a centralized database to facilitate a faster and more comprehensive test-creation process.

PROJECT DOCUMENTATION

Organisation Documentation

The documentation related with the Commissioning, Operation and Decommissioning Activities (CODA) was updated: the Schedule, the Cost Estimation, the Risk Assessment, the Integrated Commissioning Plan, together with an update of the organisation. A new structure based on a functional onsite Joint Team between the DONES Programme Team and the esDONES Consortium personnel was proposed to optimize the use of resources.

Safety of Complementary Experiments

The licensing for DONES non-fusion experimental programme has been analysed focusing in three key aspects: Permits of Use and Operational Permits required for complementary experiments, evaluation of Complementary Experiments (CE) proposals from a regulatory perspective, and safety integration of CE within IFMIF-DONES safety design framework. The foreseen experimental areas comply with Spanish nuclear regulatory requirements while maintaining flexibility for diverse experimental configurations. Particular attention was given to integrating safety

aspects already incorporated in the baseline design, including radiological confinement systems, access control protocols, and safety interlock mechanisms (shutter position monitoring, beam shutdown capabilities). A regulatory roadmap for authorization of complementary experiments alongside the primary fusion materials testing mission has been identified. For experiments requiring an extraction of a pulsed deuteron beam, the meander device, magnets, beam dumps (for deuterons and neutrons), the neutron production target, vacuum tubes, cooling systems are considered, while for neutron beam room a shutter, targets, moderators and beam dump are identified.

Samples Transport

Technical and organizational requirements of a transport facility for the distribution of samples to other support facilities off-site for further PIE were analyzed (Fig. 3). Considering the building's characteristics, possible solutions were sought to accommodate all essential elements to accommodate all essential elements and optimize the usage of the available installation space. In doing so, emphasis was placed on a redundant arrangement of necessary capacities, to avoid bottlenecks in the event of revisions, failures or conversion work, but to guarantee always at least 50% of the design capacity. Hints on redundancy, ventilation system, contamination management, support facilities, licensing, radiation protection regime, exposure minimisation, and bottlenecks in the available construction space were given. Specimens to be transported can be relatively easily carried in small type B casks. Their small inner volume might not be a limiting factor and the European laboratories (and thus the number of transports) are numerous. In addition, small pieces like micromechanics specimens can be transported in type A casks or exempt packages.

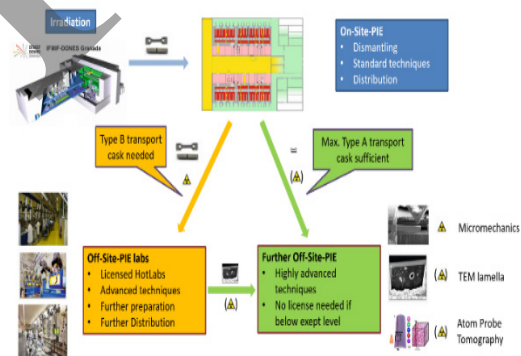


Figure 3: Schematic sketch of the flow of specimens from DONES irradiation to PIE facilities.

CONCLUSIONS

The DONES-ConP1 project has been both an instrumental tool for providing critical documentation for policy makers -such as an updated Programme Team organisation, an Integrated Installation and Commissioning Plan, or a revised Cost Book-, and to make substantial progress in scientific and technological areas of the facility such as the experimental programme definition, the complementary experiments or the transport and safety areas.

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