The DONES Programme and an Overview of the IFMIF-DONES Facility

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DONES Business Info Day

Spanish Embassy, Tokyo (Japan),December 4th 2023

Outline

- IFMIF-DONES Facility Description
- DONES Programme Governance and Management
- IFMIF-DONES Experimental Capabilities and Exploitation
- DONES and Japan

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- **DONES Programme Governance and Management**
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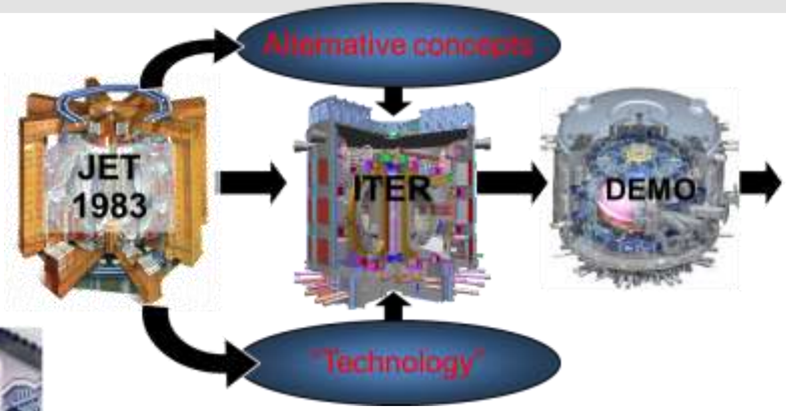
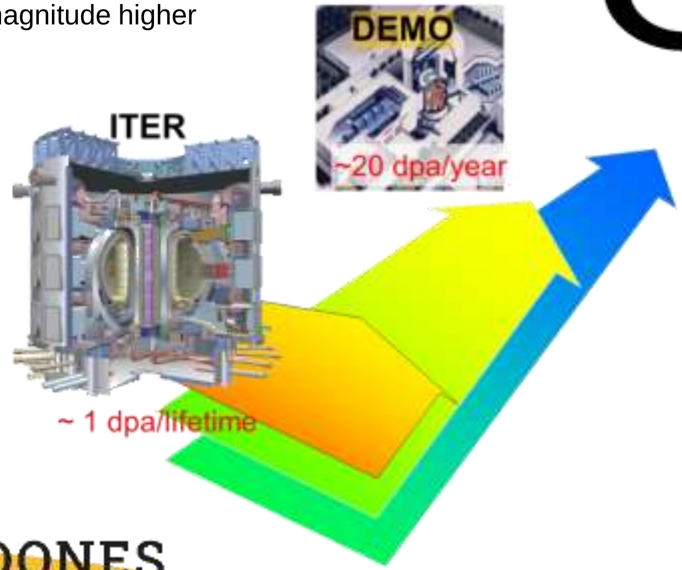
Why DONES?



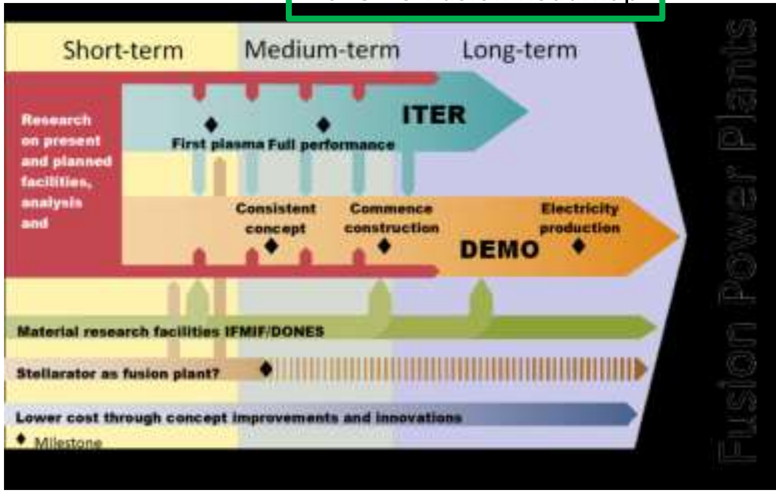
The power plant

EU strategy towards fusion energy

One of the main differences between ITER and DEMO is the radiation dose: at DEMO more that two orders of magnitude higher



2018 EU Fusion Roadmap

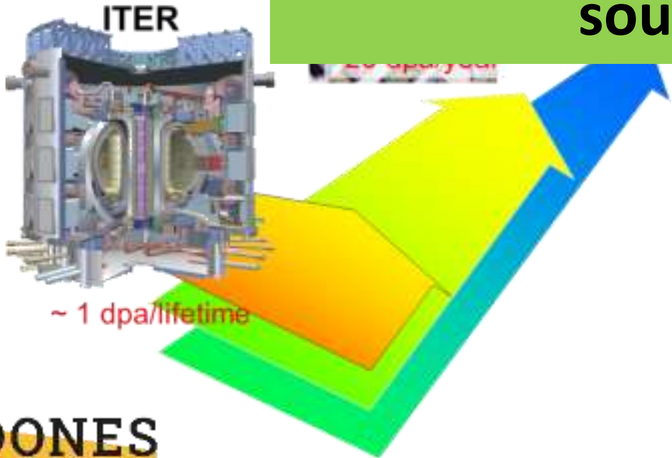


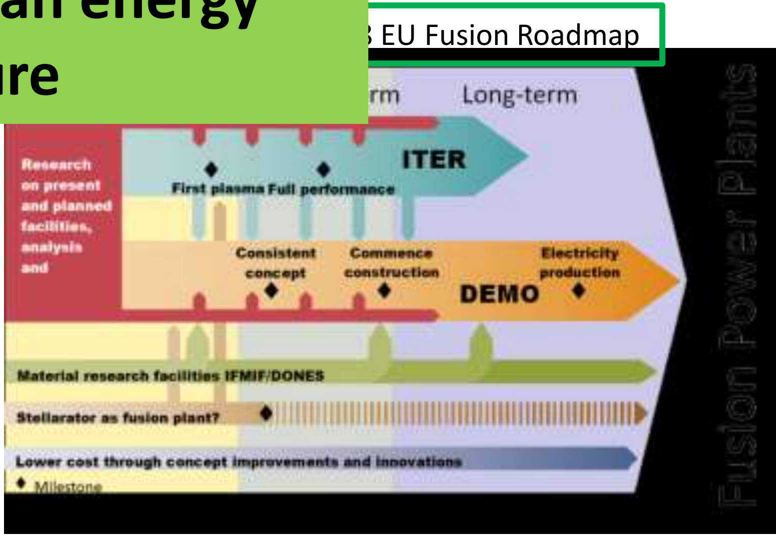
Why DONES?

EU strategy towards fusion energy

One of the main differences between ITER and DEMO is the rad dose: at DEMO more that t of magnitude higher

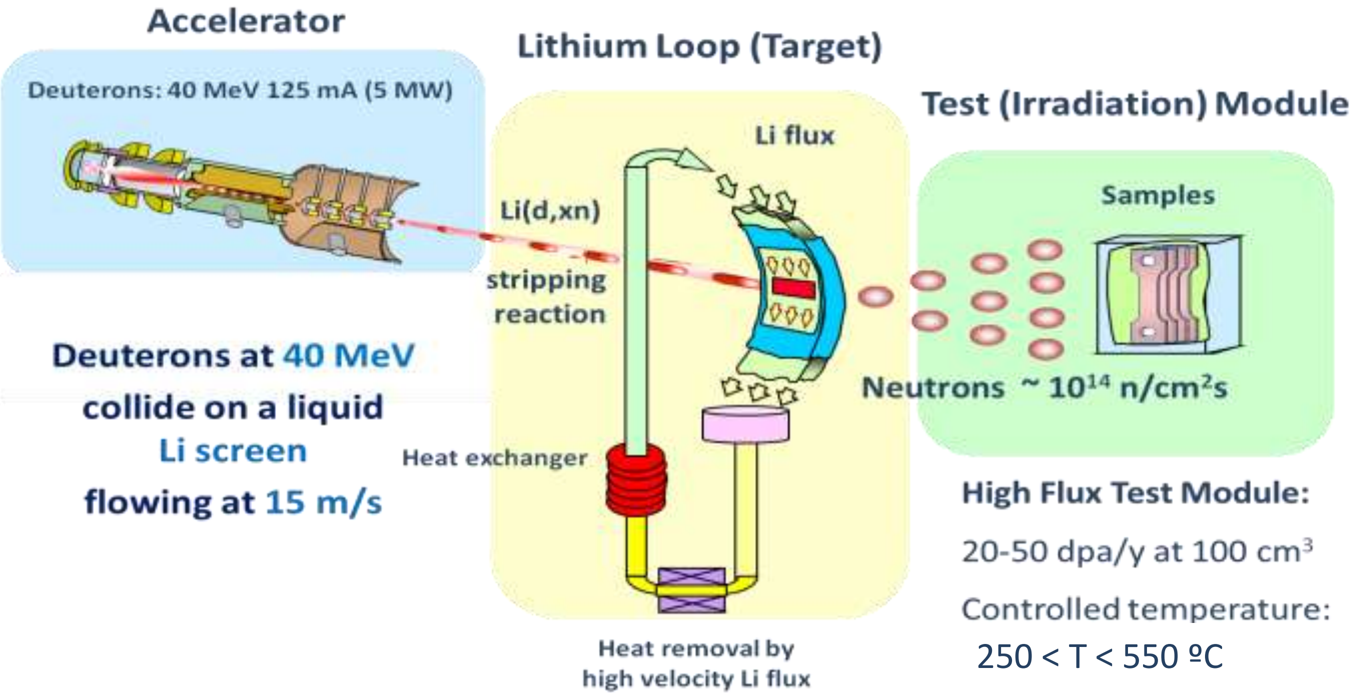
DONES will be a key element in the development of fusion as an energy source for the future





What is IFMIF-DONES?

A fusion-like neutron source required for the qualification of the materials to be used in the EU DEMO



Identified as high priority in the EU Fusion Roadmap
Included in the ESFRI Roadmap as a EU strategic facility

What is IFMIF-DONES?

A fusion-like neutron source required for the qualification of the materials to be used in the EU DEMO

One of the more powerful accelerators in the world

Challenges:high power, high space charge, cw wave operation, high reability, longest RFQ,…

Biggest Li loop in the world

Challenges: Biggest Li loop in the world, power management, impurities management –corrosion risks-, reability, lifetime,...

Challenges: RH, reability and long term control,…

Identified as high priority in the EU Fusion Roadmap
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Based on widely spread efforts!!!

The need for a facility of this type was identified long time ago and work has been carried out by using different frameworks. **In the last 15 years**, **key projects** are:

IFMIF/EVEDA (included in the BA)	⇨	Design and Validation Activities	⇨ **design seems feasible**
WPENS (EUROfusion WP)	⇨	Design and Validation Activities	⇨ **Defining the design: ready for construction!!!**
DONES-PreP (EURATOM CSA)	⇨	Elaborate and draft the international consortium agreement	⇨ **international implementing scheme defined**
DONES-PRIME/UGR (Spanish projects)	DONES-PRIME DONES-UGR ⇨	Engineering and Construction Activities	⇨ **Starting the work on site (first auxiliary buildings)**

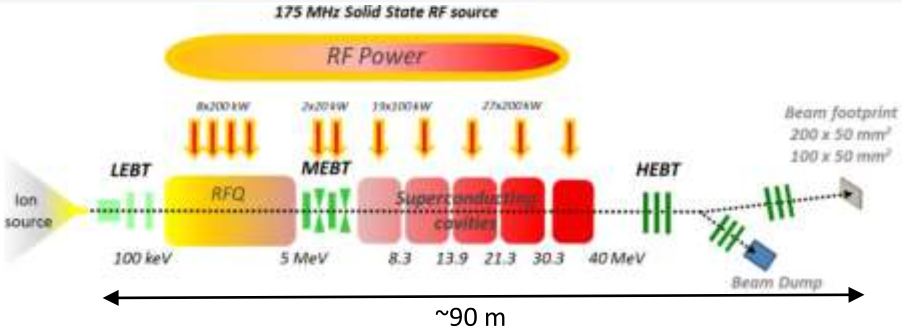
The Site

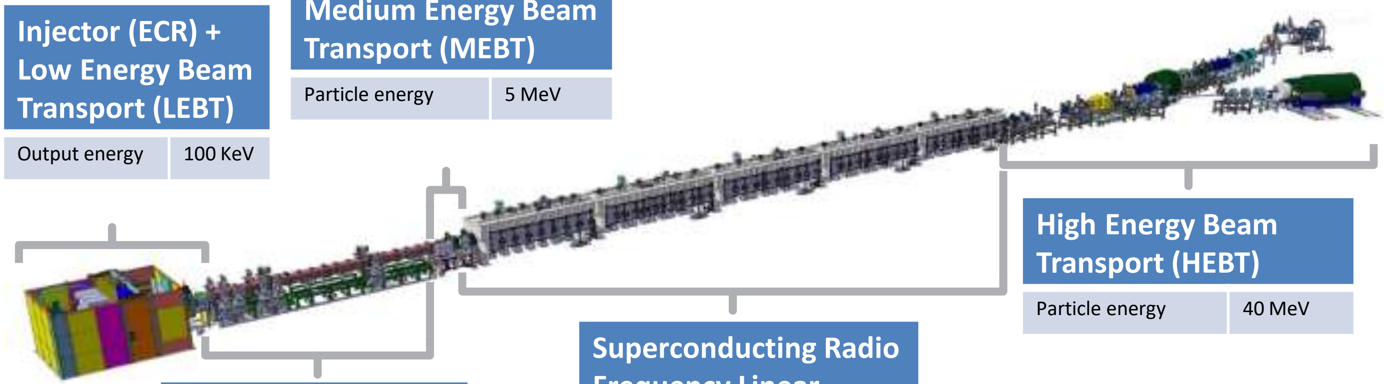
It is be located in the Granada province (Andalusia region – southern Spain), 18 km southwest from Granada city in the Granada Metropolitan park (Escúzar)

Accelerator systems summary

175 MHz, 5MW, 125 mA, CW, high availability: One of the more powerful accelerators in the world

Waiting for validation results from IFMIF-EVEDA: LIPAc Prototype (Rokkasho)





Injector (ECR) + Low Energy Beam Transport (LEBT)

Output energy	100 KeV

Medium Energy Beam Transport (MEBT)

Particle energy	5 MeV

Radio Frequency Quadrupole (RFQ)

Output energy	5 MeV

Superconducting Radio Frequency Linear Accelerator (SRF-Linac)

Output energy	40 MeV

High Energy Beam Transport (HEBT)

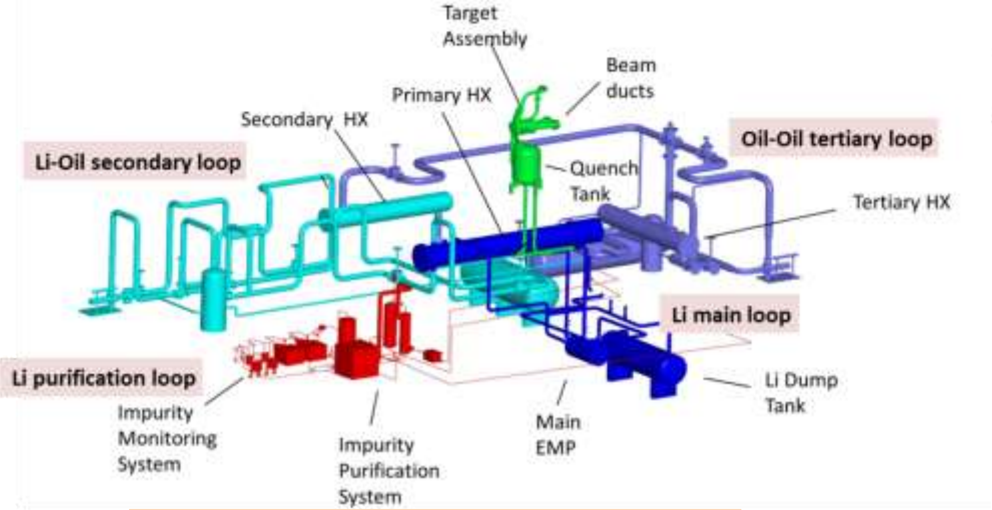
Particle energy	40 MeV

Main involved technologies

- RF
- Cavities
- Magnets
- Mecatronics (Cu, Nb, Al,…)
- Criogenics
- Vacuum
- Power supplies
- Cooling technologies
- Sensors and diagnostics
- Control (hardware and software)

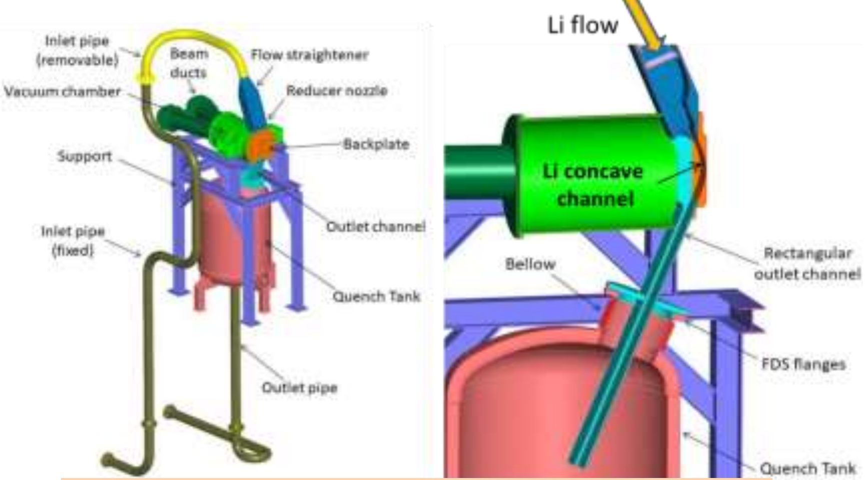
Li systems summary

5 MW power handling, 15 m/s Li velocity, remote handling
Main requirements: Li flow stability and Li impurities control



Li volume ~14 m³ Li flow rate ~100 l/s
Temperature (cold side) ~300 °C

Lithium target



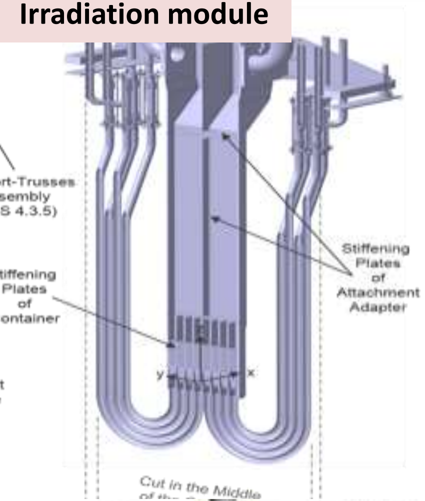
Jet thickness: 25±1 mm Li flow velocity: 15 m/s
Chamber pressure: 10^{-3} Pa Heat flux: 500 MW/m²

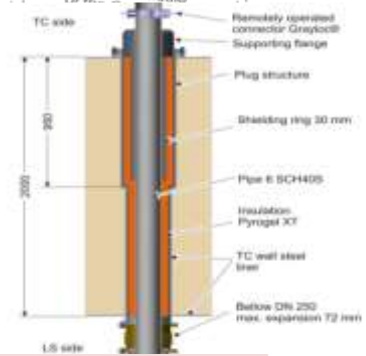
Main involved technologies

- **Liquid metals (fluids, monitoring and purification)**
- **Complex cooling loops**
- **Diagnostics**
- **Remote maintenance**
- **Control (hardware and software)**

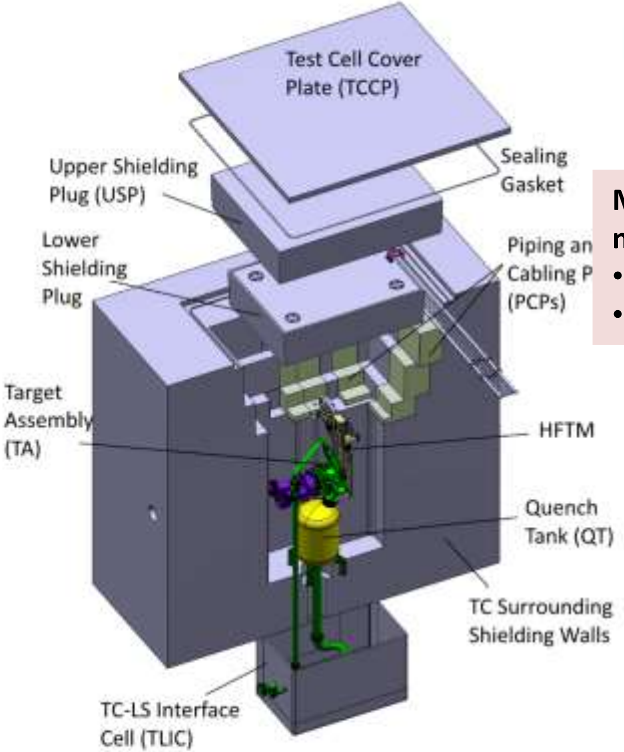
Test Systems summary

Irradiation module

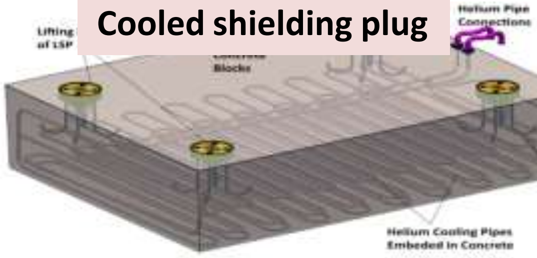




Duct penetration



Cooled shielding plug



Main characteristics driven by the presence of neutrons and Li

- Internal components cooling by He
- Remote Maintenance required

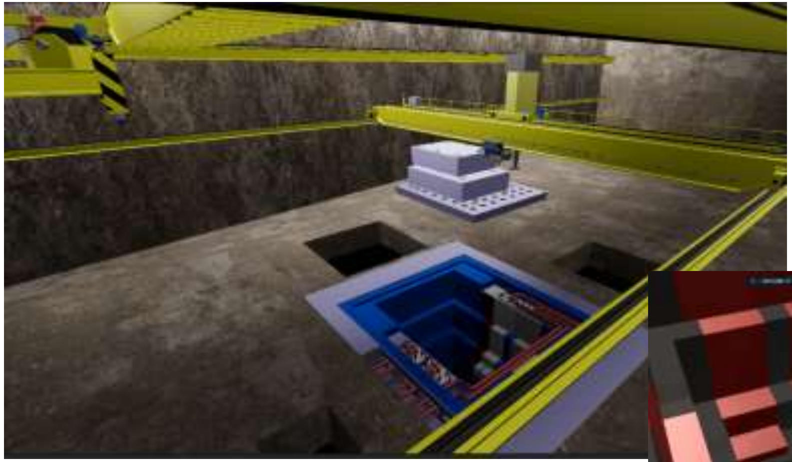
Main involved technologies

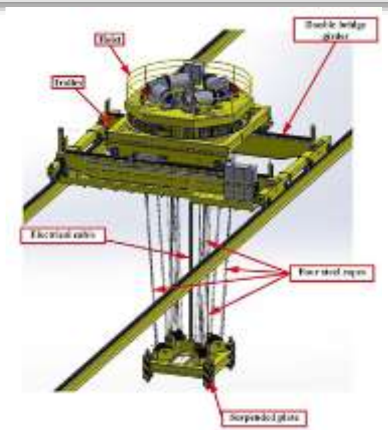
- Mecatronics
- He and water cooling
- He, Ar and water systems
- Shielding materials and technologies
- Remote maintenance
- Vacuum
- Diagnostics
- Control (hardware and sofware)

Remote Handling system

- ❑ Main Remote Handling Equipment : HROC and ACMC
- ❑ Access Cell big enough for storage of all components

Access Cell





Main involved technologies

- Special cranes
- Telemanipulators
- RH tools
- Radiation monitoring

Others systems and transversal topics

- Do not forget "conventional" systems: half budget will go to buildings and conventional systems

- Do not forget "transversal" activities: maintenance, safety, security, control,… they will be continuos activities all along the time of the facility

Main involved technologies

- **Buildings**
- **Cooling**
- **HVAC**
- **Control (hardware and software)**
- **Gas management**
- **Electrical systems**
- **Electronics**
- **Waste management**

- **Maintenance**
- **Safety and security**
- **….**

Posible DONES upgrades and/or acceleration strategies

Discussions are presently going on in order to define posible acceleration strategies for fusion development. They can have some impact on DONES future baseline

Add reloading capabilities:

- It will allow to go over to 50 dpa limit
- It will be required additional hot cell capabilities to manage reloading of irradiatied materials in a new irradiation module

Add partial on-site facilities:

- It will allow acceleration to obtain critical results after the irradiation (1-2 years faster)
- It will be required additional hot cell capabilities for PIE

Add a second Accelerator:

- It will allow a significant acceleration (results to be obtained a factor around 1,75 faster)
- it will be required an additional complete Accelerator, some addtional AS+TS auxiliaries systems, bigger building, upgrade of some Plant Systems

Others….

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Project Organization

Aim is DONES Programme, not only the IFMIF-DONES Facility

DONES Programme Mission

The mission of the DONES Programme is to develop a database of fusion-like neutron irradiation effects in the materials required for the construction of fusion power reactors

DONES Programme Objectives

- To provide a neutron source producing fusión-like neutrons at sufficient intensity and irradiation volume.
- Generate materials irradiation test data for DEMO
- Generate data base for benchmarking with computational material science
- To develop a "Complementary Experiments" work program

The IFMIF-DONES Facility

The fusion relevant neutron source and that will allow to fulfill the objectives of the Programme

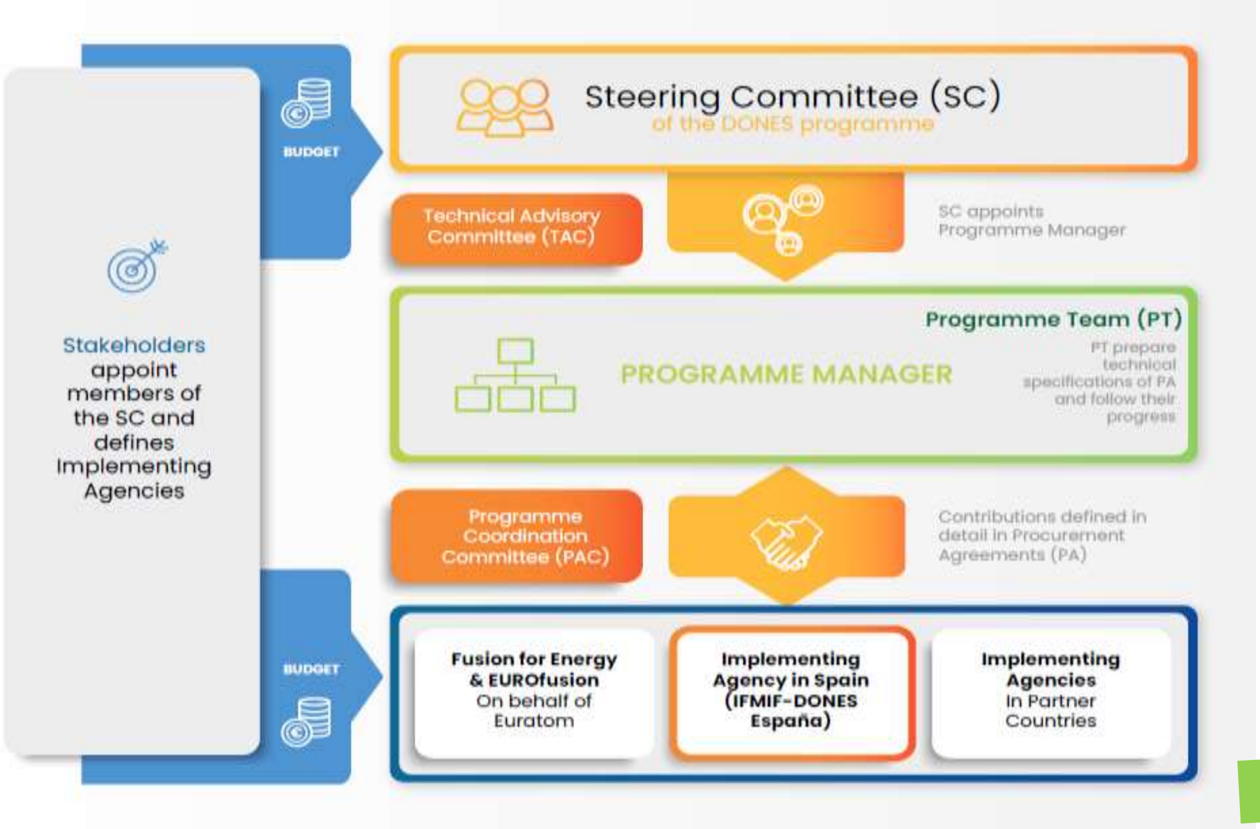
The DONES Program includes:

- The construction and operation (including running the irradiation experiments) of the DONES Facility — On-site
- The preparation of irradiation experiments (for fusion but also other applications)
- The analysis of the irradiation results
- The development of a qualified irradiation database, and of the required modelling and extrapolation capabilities

Off-site

Applications for fusion and for other scientific areas
(radioisotopes production for medical applications, nuclear physics, industrial applications)

Governance and Management



Fast and flexible implementation

Project run by flexible Project Team and relying on In-Kind Manpower contributions from different partners

Design Authority with the Programme Team

Owner/Operator responsibility on the Spanish Legal Entity

Similar to the Broader Approach model

1st DONES Steering Committee was held in Granada, March 16th 2023

(it means the start of the Construction Phase of the DONES Programme)

DONES

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Summary of IFMIF-DONES experimental capabilities

- ## Materials qualification

Experiments to be developed in the irradiation area with the highest neutron flux are managed by specific irradiation modules that can be replaced (and modified) after each irradiation campaign

Present baseline design activities focuses on the High Flux Test Module (HFTM) for high-priority structural materials irradiation

Steel irradiation

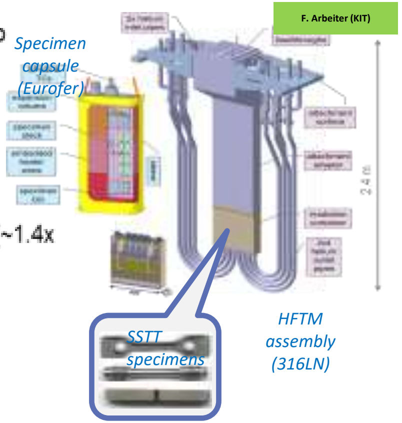
- 13-35 dpa/fpy up to 300 cm³ (22-50 dpa/fpy with two accelerators)
- 10-15 appmHe/dpa, 45-55 appmH/dpa.
- 250 – 550 °C, (~ 1000 specimens)

Copper irradiation (divertor heat sink)

- 5–30 dpa/fpy
- 6–8 appm He/dpa is (~DEMO), 48–50 appmH/dpa (~1.4x DEMO)
- >100°C, helium immersed specimens

Tungsten irradiation (armor)

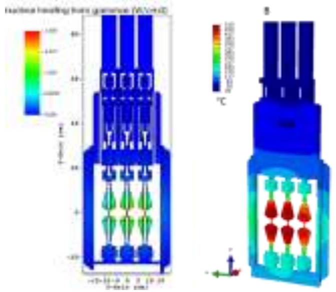
- Up to 800°C, assisted by self-heating
- 8x20 cm³ (cylindrical HT capsules)
- 1–3 dpa/fpy in W
- 9–10 appm He / dpa, (2x of DEMO), 20–29 appm H / fpy, (3x of DEMO)



Adaptation for ODS-steels and vanadium materials can be easily implemented

Prospective irradiation modules for other materials properties characterization are feasible and proposed

- **In-Situ Creep Fatigue Test Module (ICFTM)**



In-situ creep/fatigue/crack-growth loading & measurement

Temperature range 250 – 550 °C in the high flux zone

Base materials, welds, dissimilar welds ; optionally multiaxial loads

- **In-Situ Irradiation Module for Diagnostics (IIMD)**
- **In-situ Irradiation Module for Superconductor materials** (probably outside of Test Cell)
- **In-situ Irradiation Module for corrosion testing in flowing media**

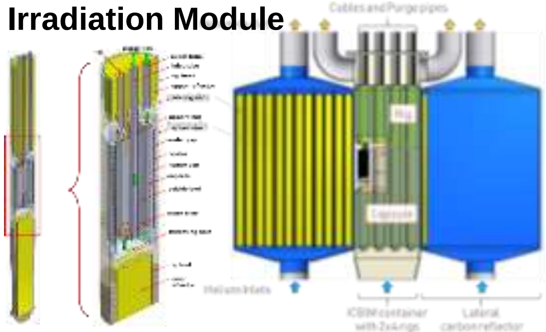
• Breeding Blankets relevant technologies

The different types of irradiation modules allow to address BB technologies issues which are key pending ones for accelerating fusion as an energy source. The facility design allows the installation of other materials or other irradiation modules (sequentially or simultaneously with the HFTM)

Prospective irradiation modules for tritium technologies validation

• In-Situ Ceramic Breeder Irradiation Module

In-situ irradiation and testing of ceramic breeder materials or Be in the temperature range 300 – 1000 °C in the high flux zone, measuring (time resolved) tritium release



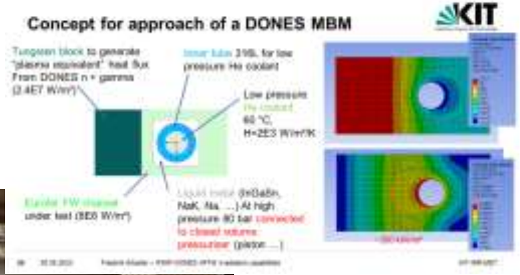
• In-Situ Liquid Breeder Validation Module

In-situ irradiation and testing of different containers of PbLi in the temperature range 300 – 600 °C in the high flux zone, measuring (time resolved) tritium release, permeation and extraction techniques

Prospective irradiation modules for functional testing of Model Blanket Module

Interest raised based on:

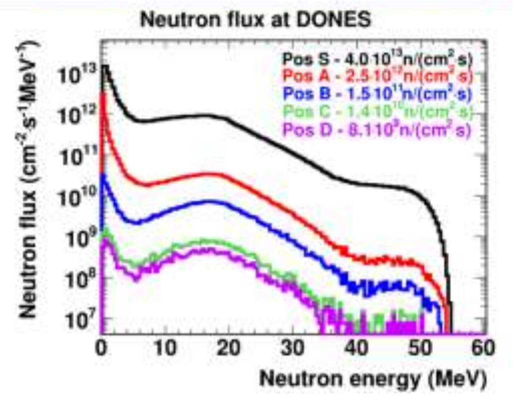
- an irradiation area similar in size to the typical "unit size" of different BB
- Neutron axial gradient similar to the one in DEMO
- Feasibility of heat loads similar to the one in DEMO first wall

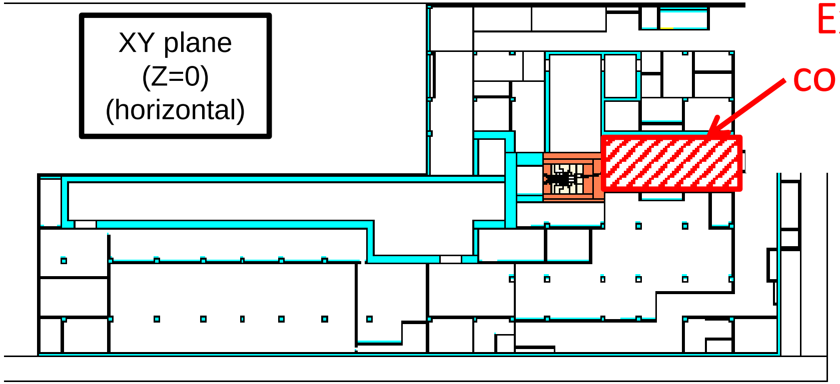


DONES ConP1

Additional experimental areas

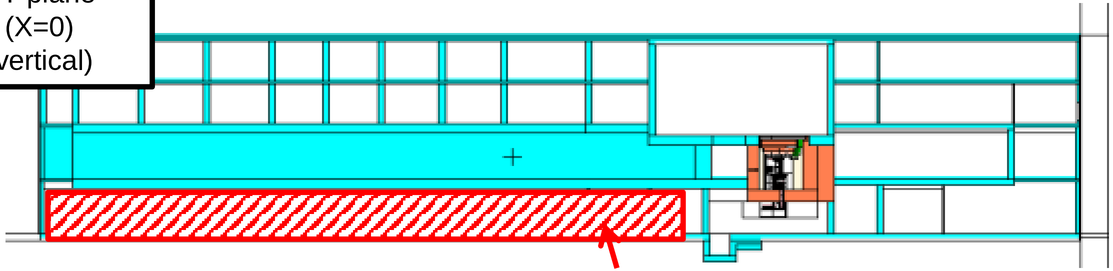
Very high neutron flux at very high energies!!!





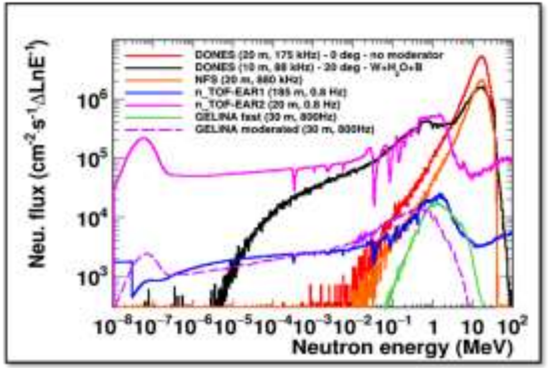
Experiments with continuous neutron beams

ZY plane
(X=0)
(vertical)



Experiments with pulsed neutron + deuteron beams

TOF DONES would be world's highest intensity TOF neutron source



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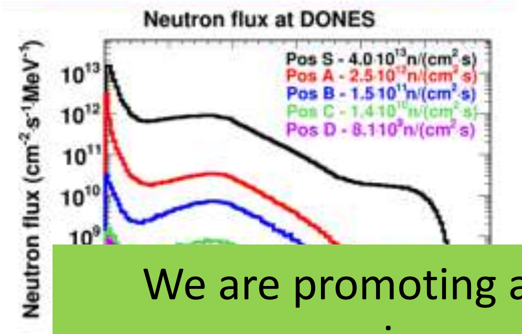
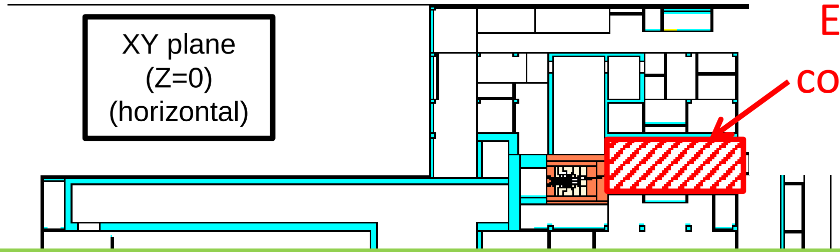




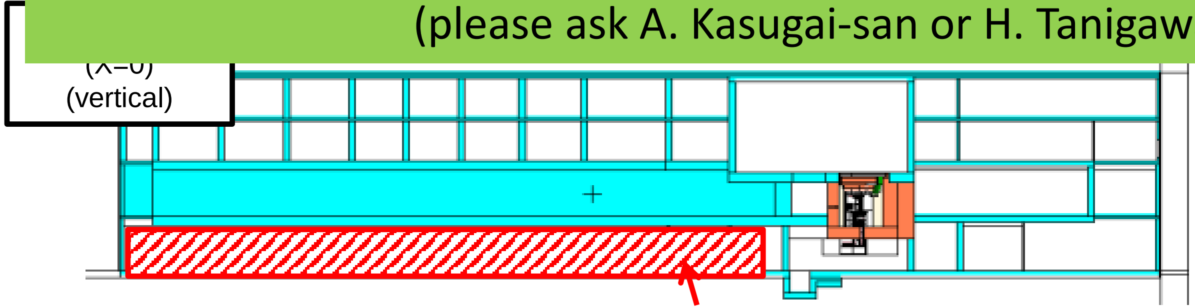
Experiments with continuous neutron beams

We are promoting a Users Community in order to identify all posible ideas to improve the experimental capabilities of the facility:

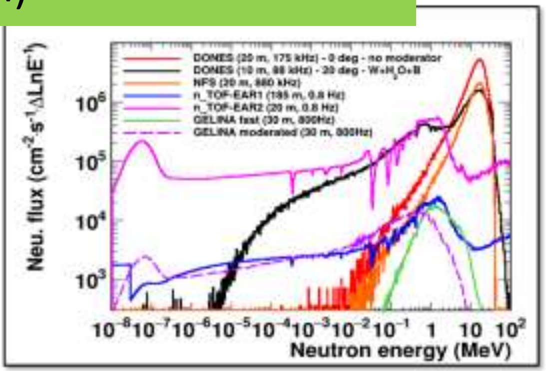
Yearly workshops are organized and you are invited to join!!!

(please ask A. Kasugai-san or H. Tanigawa-san)

intensity



Experiments with pulsed neutron + deuteron beams



DONES Programme Joint Exploitation

Three separate experimental programs (EP) are defined:

- **EP.1 focused on high-priority fusion-related experiments**
- **EP.2 focused on other fusion-related experiments**, and
- **EP.3 focused on Complementary Research activity**

- Each Party shall have a reserved share of "experimental capacity," to develop its own experiments (alone or in consortium with other Parties).
- The "experimental capacity" available for each party shall be in the **proportion of their respective total credits**.

"Experimental capacity" is defined as the "*amount of neutrons per unit of time per unit of volume multiplied by irradiation time multiplied by irradiation volume*"

- Such credits, calculated year by year, shall be the **sum of the annual passive cost of the contributions** (based on an agreed nominal lifetime of the Facility) and the **annual contributions to the operation budget**
- The Parties shall agree on a multiannual operation budget for the DONES Facility, which should be approved annually. This budget shall be shared amongst the Parties according to their agreed contributions.
- The additional budget required for experiment preparation and later exploitation (both on-site and off-site) is incumbent to the Party (or consortium of Parties) in charge of the experiment.

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Why Japan?

Taking into account:

- The needs of the JA fusion programme
- More than 15 years of EU-JA collaboration on Fusion Neutron Sources development
- Even longer EU(and SP)-JA collaboration on fusion materials characterization
- JA expertise in a number of relevant technologies (liquid metals, accelerators technology, remote handling, seismic technology,…)

JA should be involved in the DONES Programme

Collaboration of JA and EU (and specifically SP) industry should be promoted

Opportunities for the industry

In all the Big-Science projects, industry must be involved in the Programme as soon as posible (both for the benefit of the Programme and for the benefit of the industry)

- A specific effort has been made in the DONES Programme to promote the participation of the industry since the beginning:
  - Industry was involved in the Validation Activities (IFMIF/EVEDA Project) during the last 15 years: most of the contributions were developed by industry both in EU and in JA
  - Industry is being involved very significantly in the engineering design and prototyping work developed up to now
  - Collaboration projects with industry are being strongly promoted (ACTECA, FUSION FUTURE, EVO or NEXT projects in the Spanish case)

But this is also a work for you!!!:

If you are interested you must start to be familiar with the Programme as soon as possible

Next year are planned a number of calls:

- (Spain) for engineering support on safety, PLM installation, buildings engineering and manufacturing some accelerator (MEBT, HEBT, BD) and Test Systems (TC) components
- (F4E) for manufacturing some Accelerator components (couplers, sc cavity,…)

Summary

The DONES Programme is a unique opportunity to contribute to a key problem of the humanity (energy) and to participate in high-technology development at relatively low investments

We would like to promote the participation of Japan in the DONES Project

We would like to promote the collaboration of Spanish and Japanese industry in this (and other) big-science project


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