IFMIF-DONES Industrial Opportunities

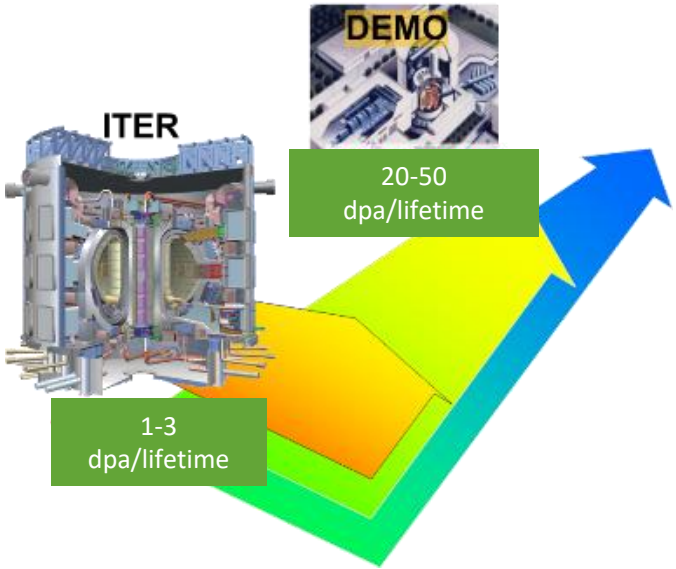
P. Cara (DONES Programme Manager)

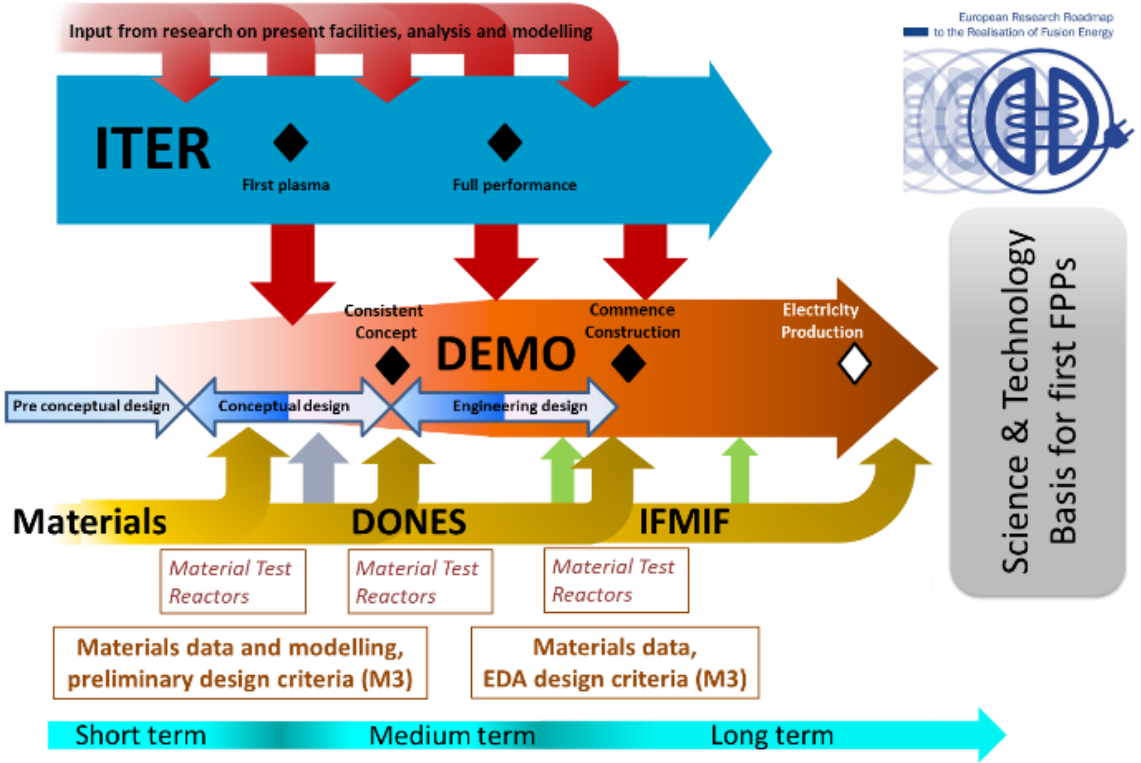
DONES

Dutch Fusion Day
Eindhoven, May 8th 2026

Why IFMIF-DONES ?

One of the main differences between **ITER** and **DEMO** is the radiation dose: at DEMO more than one order of magnitude higher

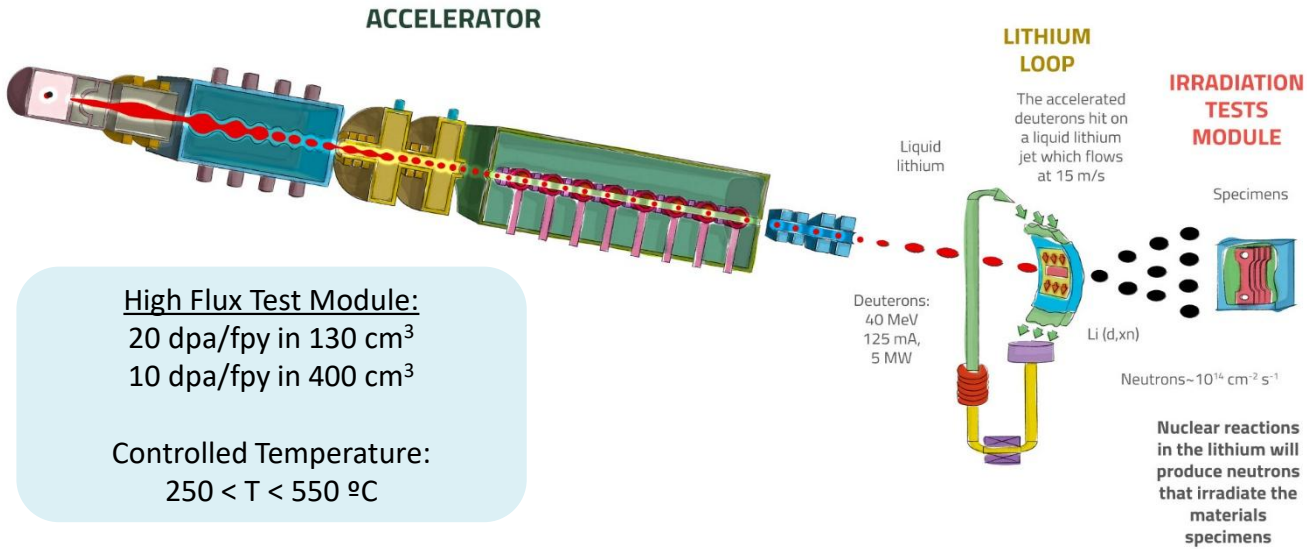


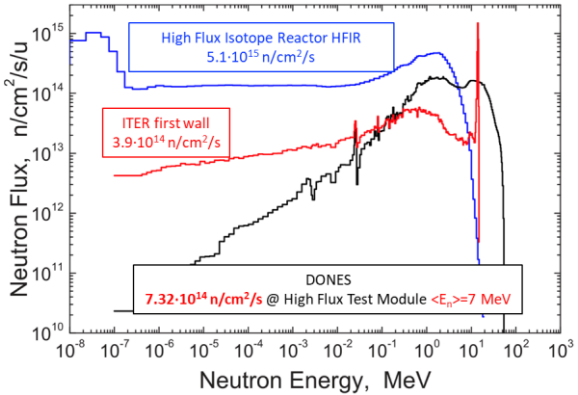


What is IFMIF-DONES?

Challenging!!!

An accelerator-based fusion-like neutron source required for the qualification of the materials to be used in the DEMO reactor





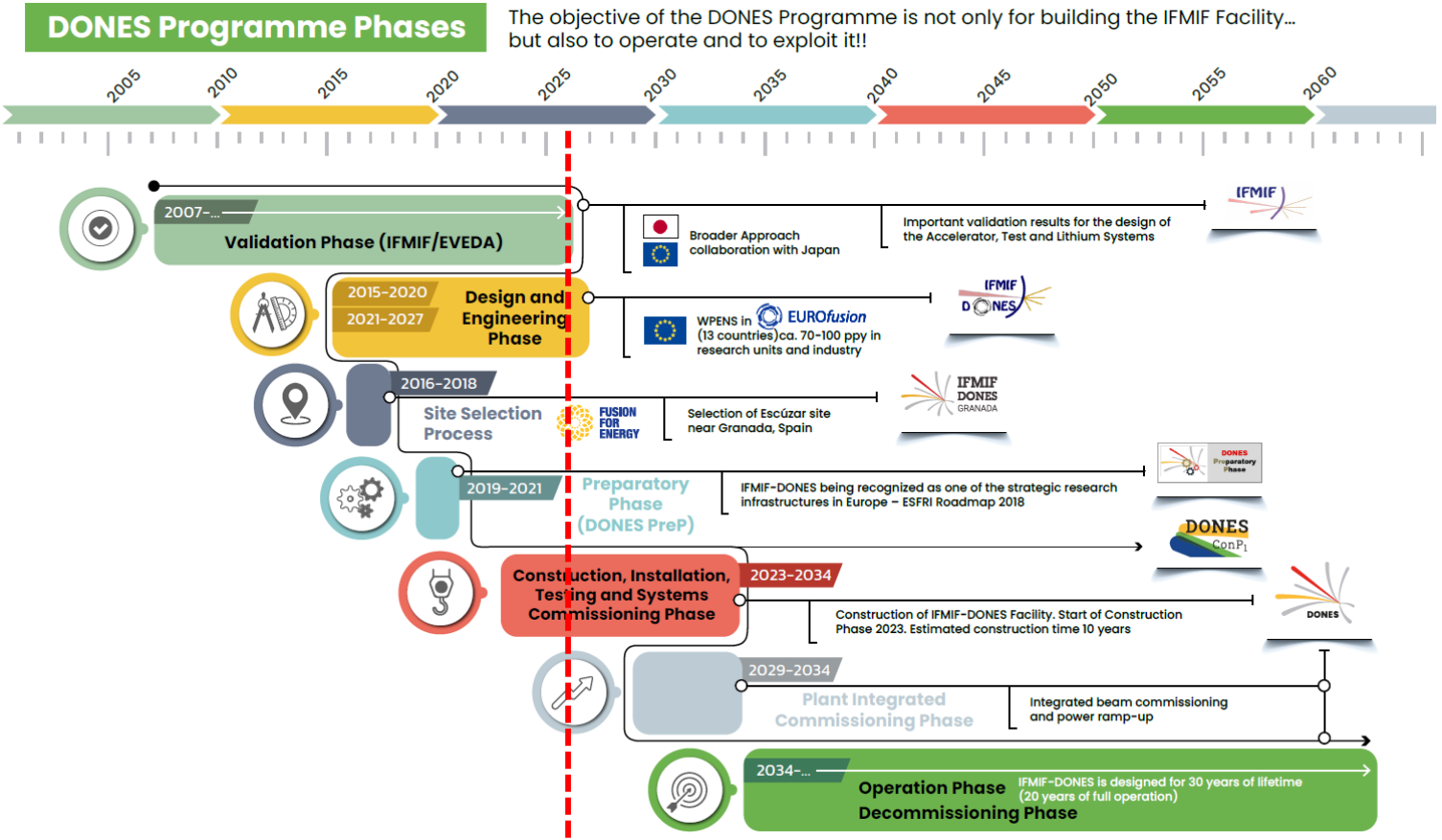
High Flux Test Module:
20 dpa/fpy in 130 cm^3
10 dpa/fpy in 400 cm^3

Controlled Temperature:
250 < T < 550 ºC

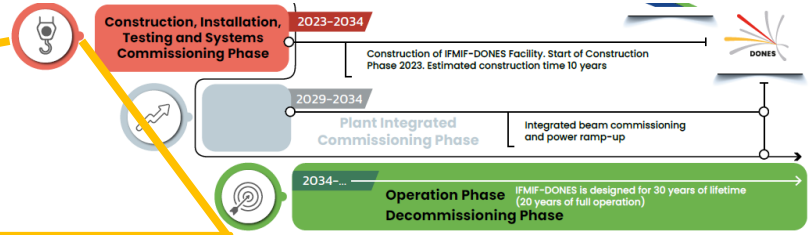
A neutron flux of **~ 10^{15} n/cm^2/s** is generated with a neutron spectrum up to **55 MeV** energy

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

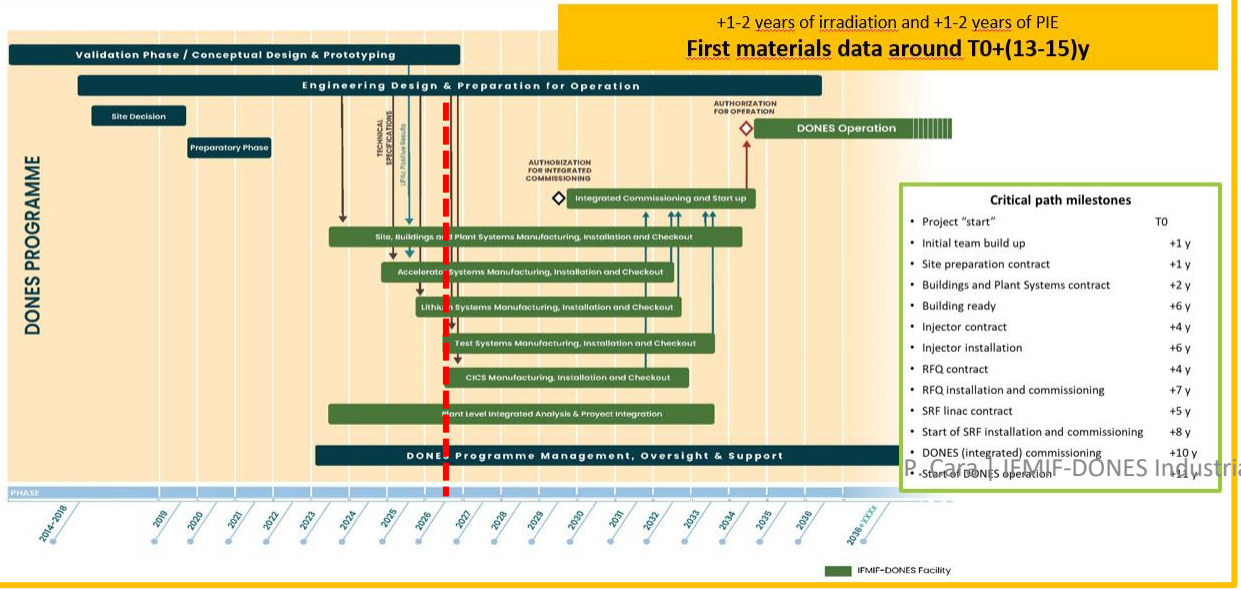
DONES Programme Timeline



DONES Programme Timeline



DONES Programme Schedule



Programme Organization & Experimental Capabilities

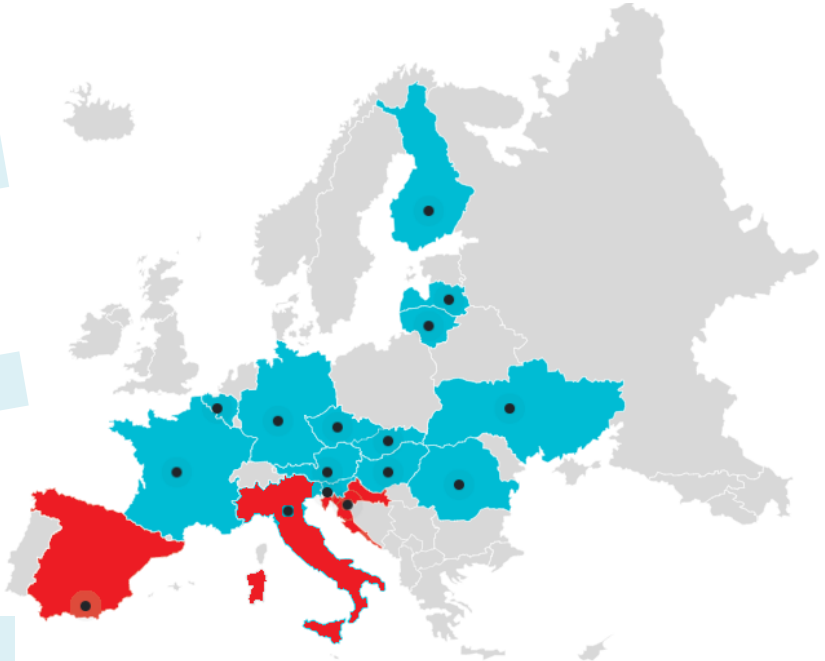
Aim is DONES Programme, not only the IFMIF-DONES Facility

The DONES Programme includes:

- The construction and operation (including running the irradiation experiments) of the DONES Facility
- 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

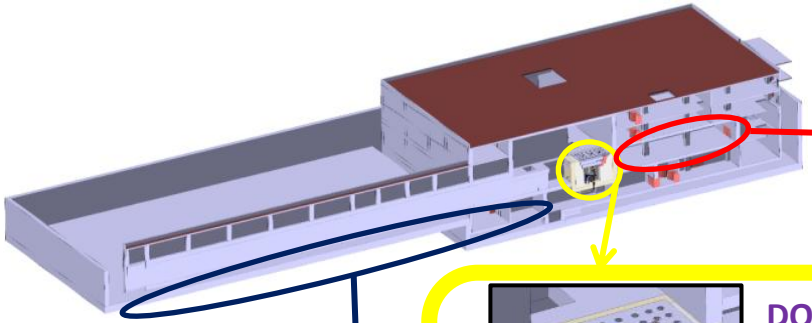
On-site

Off-site

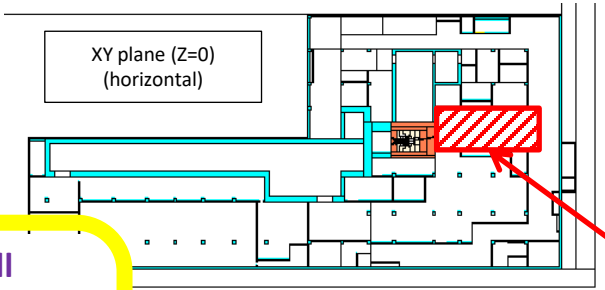


Applications for fusion and for other scientific areas
(radioisotopes production for medical applications, nuclear physics, industrial applications)

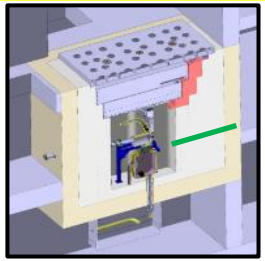
IFMIF-DONES Experimental Capabilities



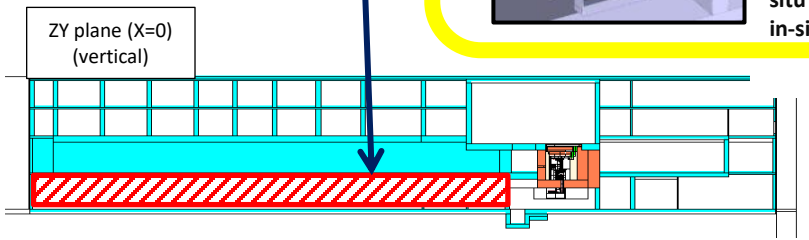
Collimated neutron beam facility – behind the Test Cell



Experiments with continuous neutron beam



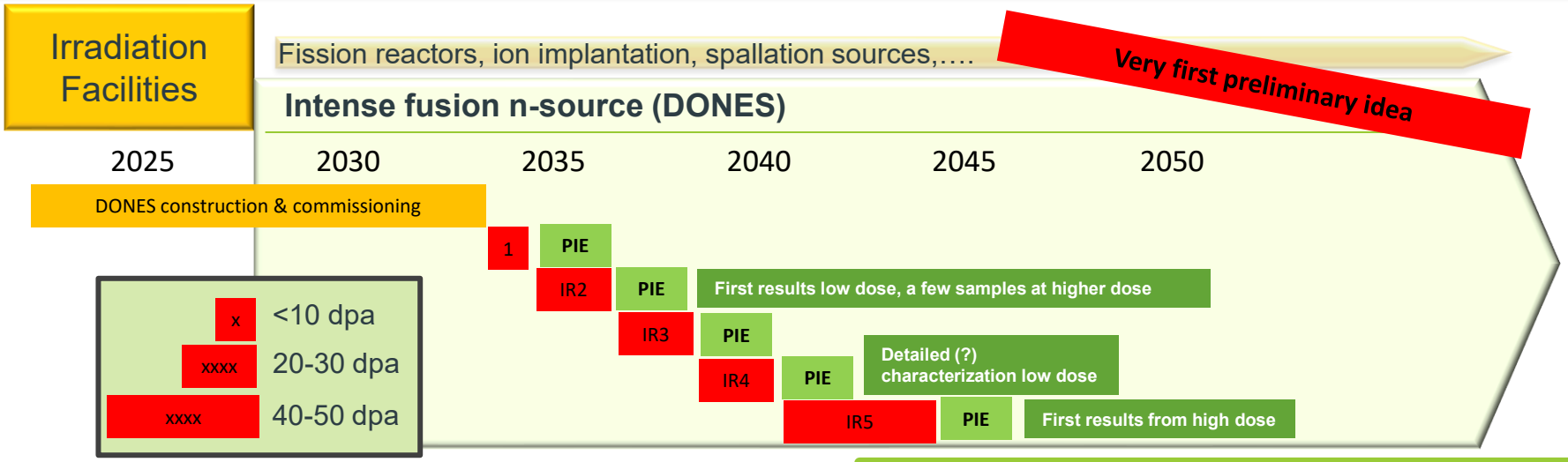
DONES Test Cell
(highest neutron flux)
For other materials properties **(in-situ creep-fatigue, in-situ diagnostics, in-situ superconducting materials, in-situ corrosion testing,…)**



Experiments with pulsed deuteron & neutron beams
(one level below the accelerator vault) E.g. nTOF

- Under consideration for tritium technologies validation (**in-situ ceramic breeder, in-situ liquid breeder,…**) which could start during the phase 4 of the integrated commissioning

DONES-ConP1 Fusion Experimental Plan



Several irradiations campaigns will be needed!!!
Priorities to be defined
Loading flexibility will be important
Reloading capability will be also implemented

Is it possible to speed up?

- Most effective way: add second Accelerator (x2 faster from 2035)
- Some improvement: additional parallelization of the construction and commissioning phase
- Some improvement: Implementation of some optional upgrades

6th DONES Steering Committee held on 21/11/25

DONES-SC Parties (<u>after MIDA signature</u>):

- *IFMIF-DONES España (Spain)*
- *RBI (Croatia)*
- *QST (Japan)*
- *F4E (European Commission)*
- *INFN (Italy)*

DONES-SC Observers:

- *Austria*
- *Belgium*
- *Czech Republic*
- *Finland*
- *France*
- *Germany*
- *Hungary*
- *Latvia*
- *Lithuania*
- *Romania*
- *Slovakia*
- *Slovenia*
- *Ukraine*

Agreements reached:

- Key *Governance and Management documents agreed.*
- *Reference document for Cost estimation for the DONES Programme agreed ("Value estimated for DONES Programme phases").*
- *Establishment of the DONES Programme Team & Programme Manager*
- *Draft Procurement Agreement template ready*
- *Outcome of the DONES Baseline review and recommendations*
- *IP rules agreed (at least partly)*

Mission and Governance

DONES Programme Mission

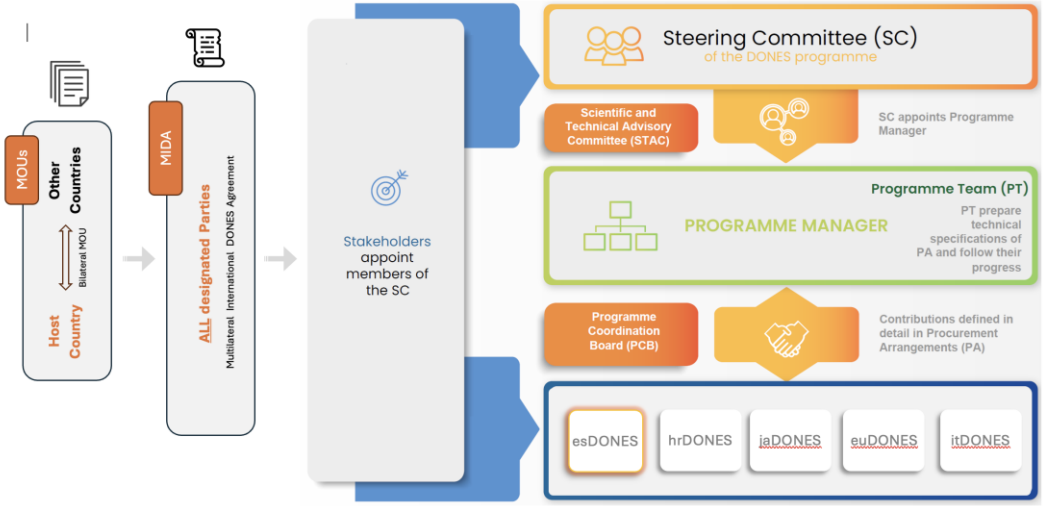
The mission of the DONES Programme is to develop a database of fusion-like neutron irradiation effects in the materials required for the construction of fusion power reactors

DONES Programme Objectives

- To provide a neutron source producing fusion-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.



- Project run by flexible Programme 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.

Site Status

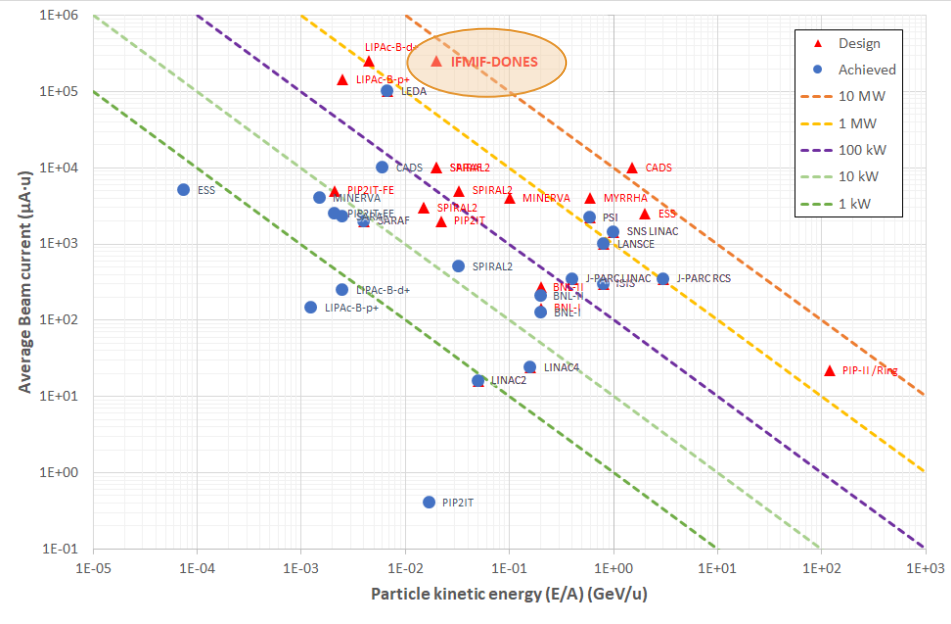
Escúzar (18 Km from Granada)

IFMIF-DONES a Powerful Challenge

One of the World´s most powerful accelerators

High 125 mA beam current

Very high 5 MW beam power on target



5MW CW LINAC

Biggest Li loop management (e.g. Impurities, corrosion…)

70 % availability (whole facility)

IFMIF-DONES: Backed by IFMIF-EVEDA & WPENS

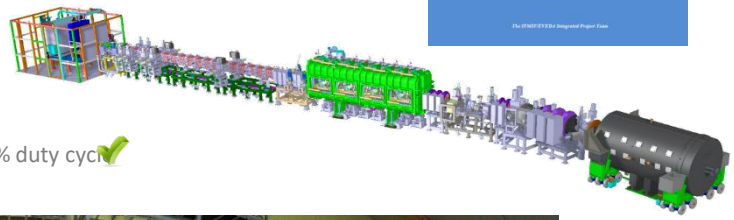
Engineering Design

IFMIF Intermediate Engineering Design Report (2013) ✔

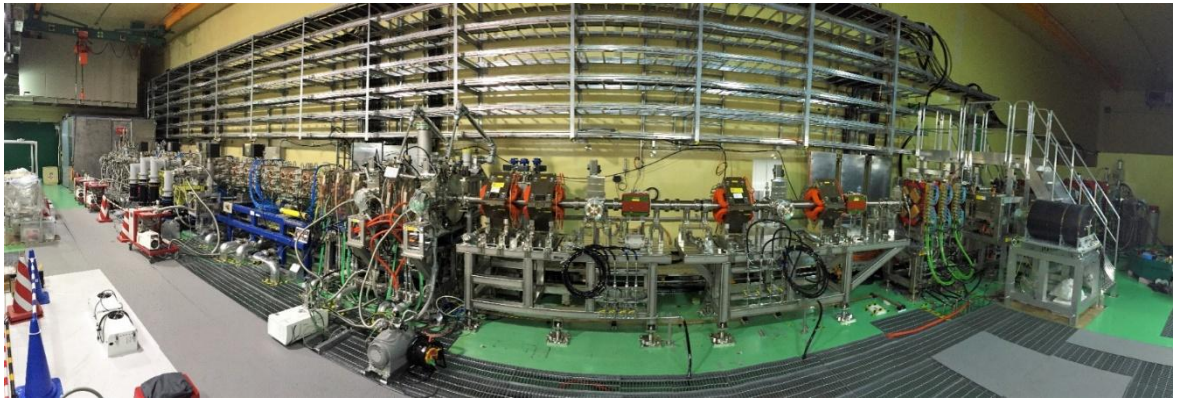
Engineering Validation

Broader Approach Activities — IFMIF/EVEDA IFERC JT-60SA

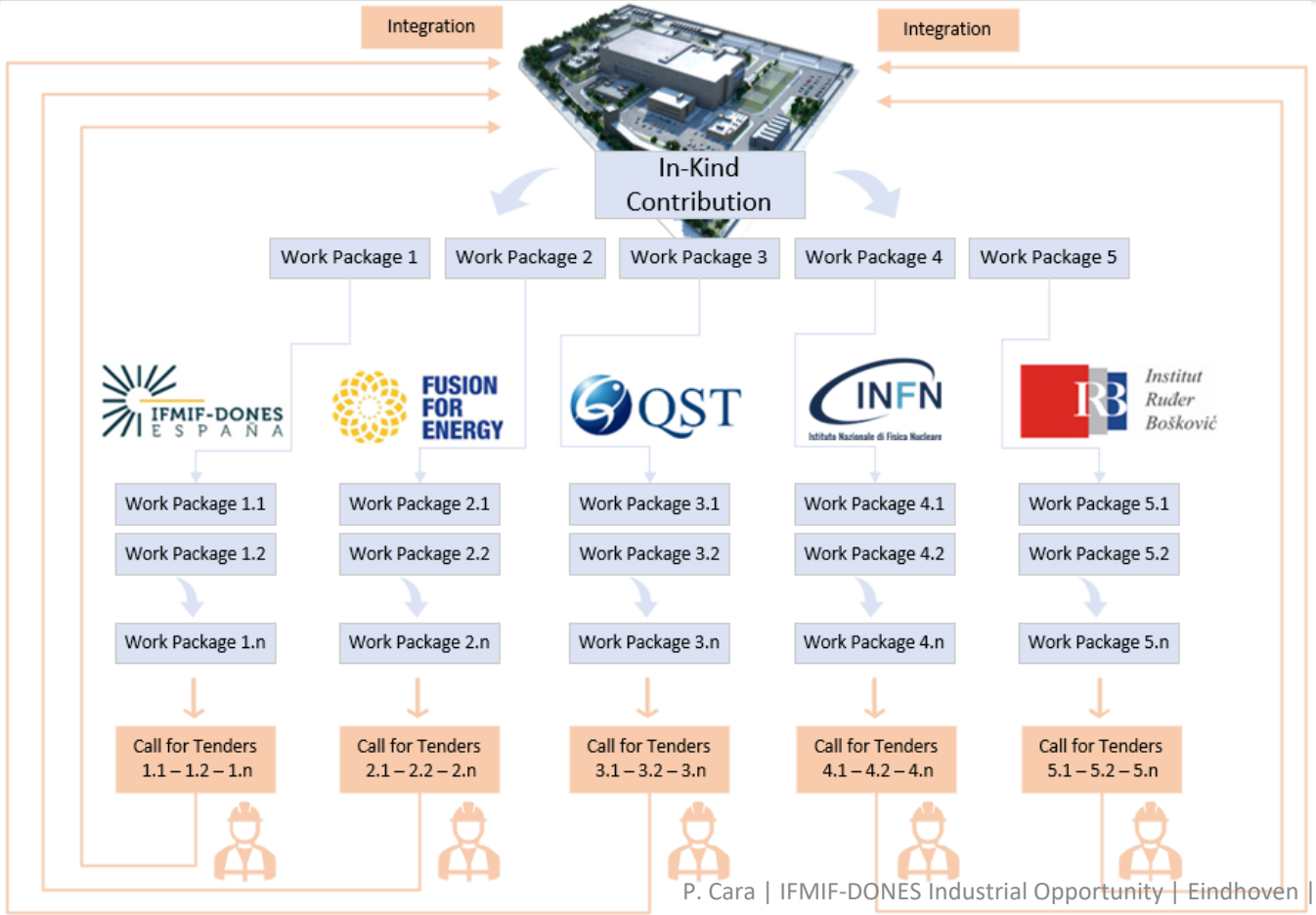
- Test Facility (2015) ✔
- Target Facility (2017) ✔
- Linear IFMIF Prototype Accelerator (LIPAc)
  - 9 MeV, 125 mA CW, 1.125 MW (36 m)
  - Phase A (2017) ✔
  - Phase B (2019) ✔
  - Phase B+ (2024): 5 MeV, 118 mA, 10% duty cycle ✔



DONES Plant Description Document (07/2023) ✔



DONES In-Kind Contribution Framework



Site, Buildings and Plant Systems

1 **Main Building**
Housing of all irradiation systems (Accelerator, Lithium & Test Systems)

Auxiliary Buildings

2 Main Building Access Bldg

EPS [Electric Power System]

3 Main Electrical Bldg
4 Electrical Switchyard Bldg
5 Emergency Power Bldg (Train A)
6 Emergency Power Bldg (Train B)
7 Cooling Towers & Chillers Electrical Bldg

8 Water Treatment Plant
SWS [Service Water System]

9 Boiler for HVAC
10 Chillers & Pumps Bldgs for HVAC
HVAC System

11 Cooling Towers Bldgs
HRS System [Heat Rejection System]

12 Fire Water Pumps Bldg
FPS [Fire Protection System]

13 Empty Casks Storage Area
RWTS [Radioactive Waste Treatment System]

14 Service Gas Areas
SGS [Service Gas System]

15 Administration Bldg
16 Access Gate Bldg
17 Warehouse

Under Construction

Estimated Value Range

D

A Less than 2M
B Between 2M and 5M
C Between 5M and 10M
D Above 10M

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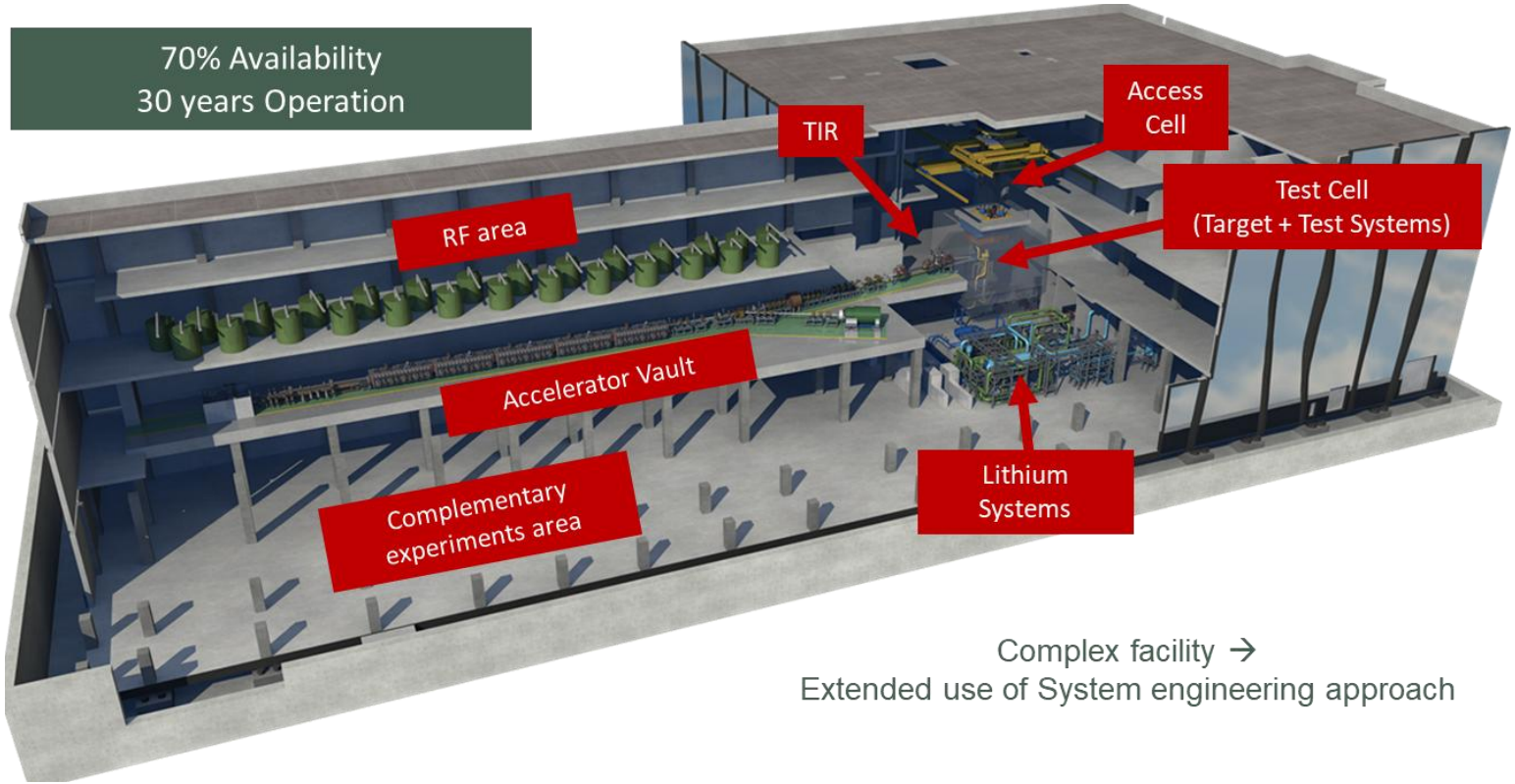
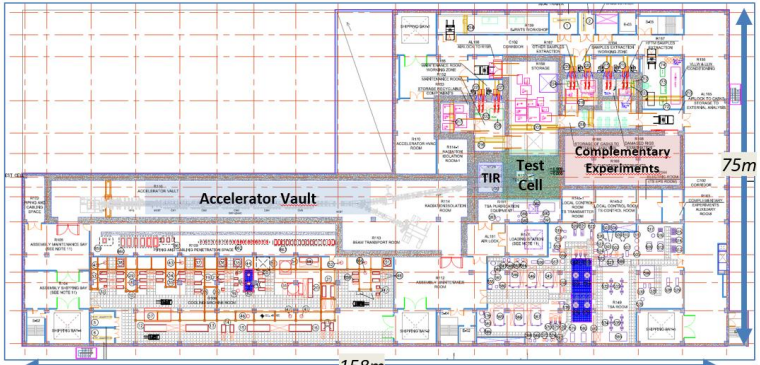
Site, Buildings and Plant Systems

70% Availability
30 years Operation

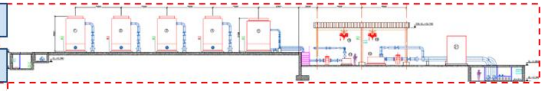


Complex facility →
Extended use of System engineering approach

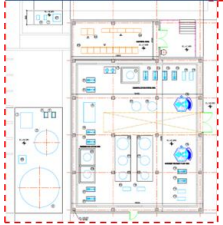
Site, Buildings and Plant Systems



Heat Rejection System

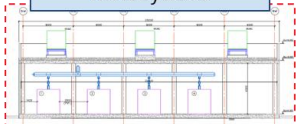


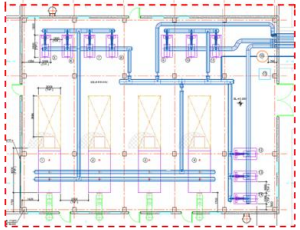
Water Treatment Plant



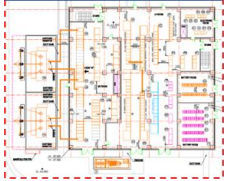
Warehouse

HVAC Systems





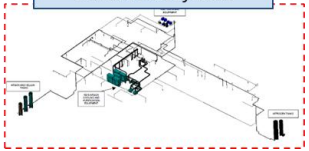
Electric Power System



Access Gate

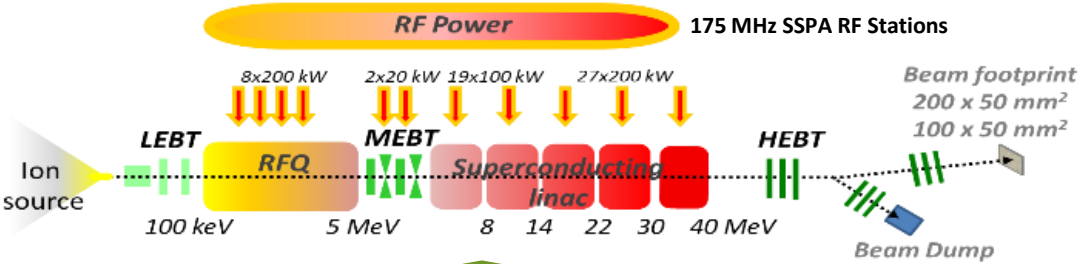
Administration Building

Service Gas System



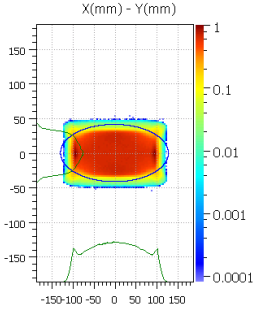
Accelerator Systems

Accelerator based on IFMIF design with
Beam incident at 9° angle →
possibility to upgrade to IFMIF with 2nd mirror accelerator (10 MW)

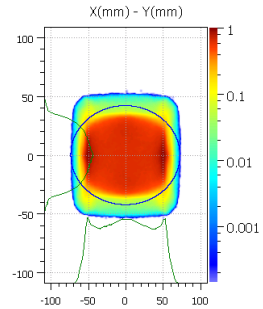


Auxiliaries
Vacuum, Cryogenics, Water cooling,
Gas and electric distribution…

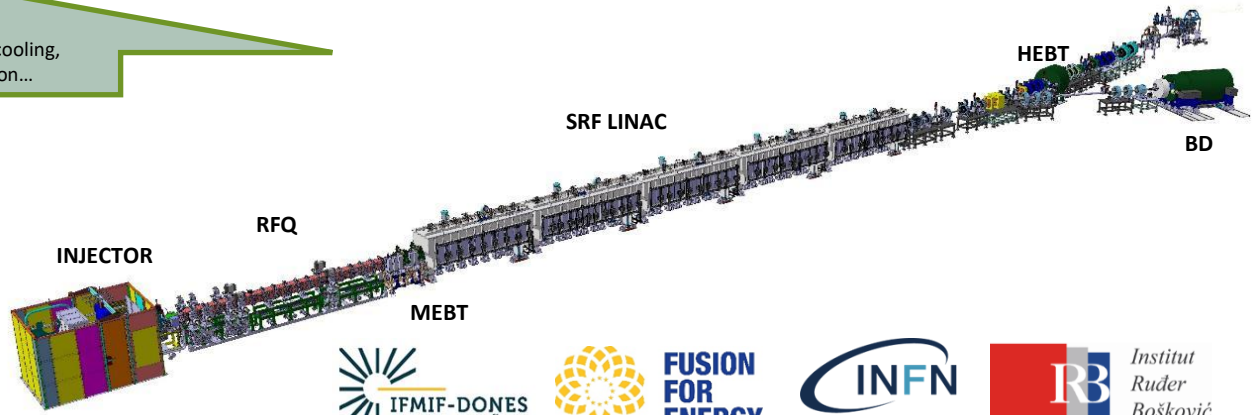
Beam footprint @ target



20x5 cm² footprint
(reference)



10x5 cm² footprint
(optional)



D+ CW 175 MHz SC LINAC
125 mA / 40 MeV → **5 MW**
Total length of ~**100 m**
Windowless liquid **Li target**
20 y, 87% **availability**
Hands-on **maintenance (<1 W/m)**

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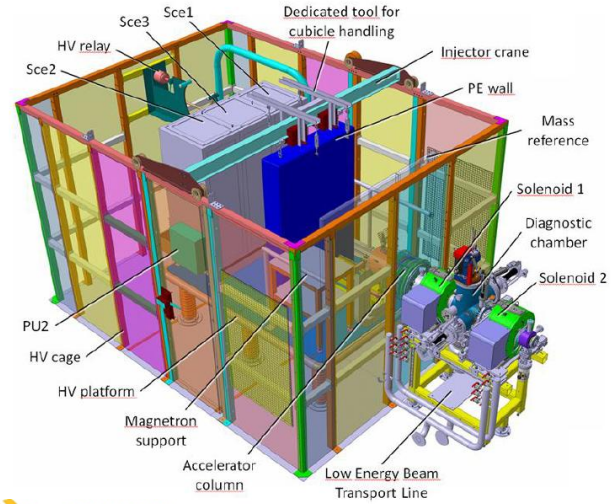
Accelerator Systems (Injector)

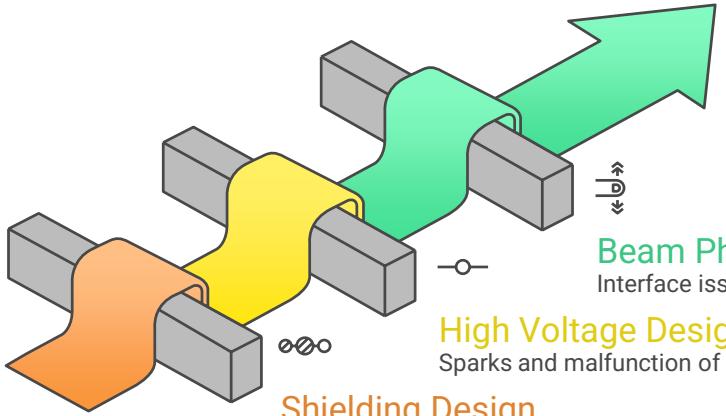
Based on LIPAc design and commissioning (117 mA / 5 MeV / 8.75% DC)

140 mA Continuous Wave deuteron beam at 100 keV
Electron Cyclotron Resonance ion source

Injector enhancement based on LIPAc operational feedback in the frame of IFMIF/EVEDA



Injector Design Risks



Beam Physics Design
Interface issues with RFQ

High Voltage Design
Sparks and malfunction of LEBT

Shielding Design
Radiation during tests and operation

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Accelerator Systems (Injector)

Needed Skills / Key Technologies

- **RF Source Design** — Conceptualizing the RF source
- **Beam Dynamics Modelling** — Simulating beam behavior
- **Mechanical Machining** — Crafting physical components
- **Material Selection** — Choosing appropriate materials
- **High Voltage and Electronics** — Integrating electrical systems
- **Instrumentation for Diagnostics** — Adding diagnostic tools

Estimated Value Range

B

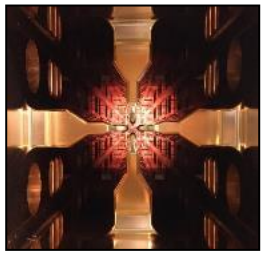
A Less than 2M
B Between 2M and 5M
C Between 5M and 10M
D Above 10M

Accelerator Systems (Radio Frequency Quadrupole)

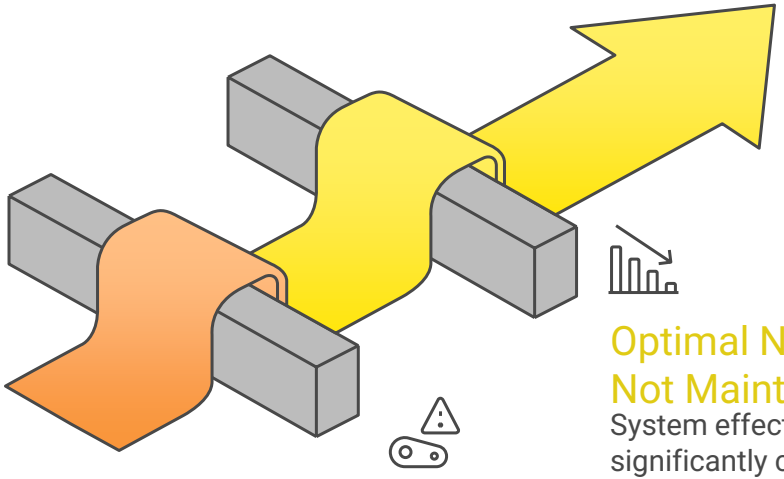
Based on LIPAc design and commissioning (117 mA / 5 MeV / 8.75% DC)

RFQ

- **Vanes erosion model** based on sputtering. Other phenomena under study (ion implantation, …)
- **RFQ mechanical engineering upgrade** to ease the maintenance
- **Power coupler with brazed windows** under prototyping



Project Risks: Transmission Factor Failure



Optimal Neutron Levels Not Maintained
System effectiveness is significantly challenged

Transmission Factor Not Achieved
Neutron flux is insufficient

Accelerator Systems (Radio Frequency Quadrupole)

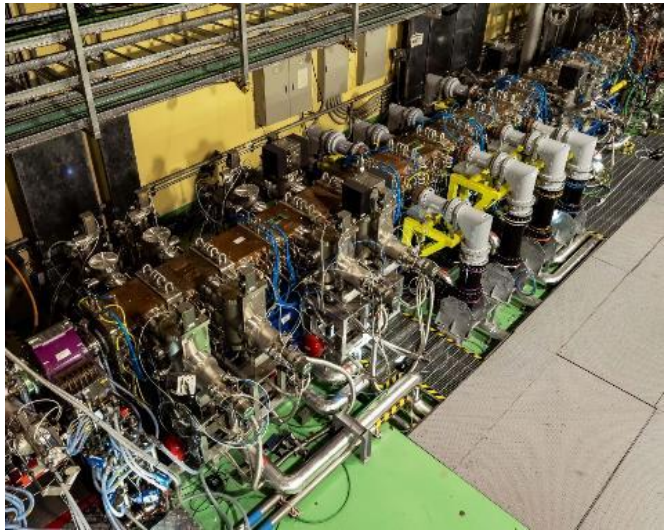
Needed Skills / Key Technologies

- **RF Source Expertise** — Knowledge in generating radio frequency
- **Beam Dynamics Modelling** — Skills in simulating particle beam behavior
- **Mechanical Machining** — Proficiency in shaping and assembling components
- **High Voltage and Electronics** — Understanding of electrical systems
- **Instrumentation for Diagnostics** — Experience in measuring and monitoring

Estimated Value Range

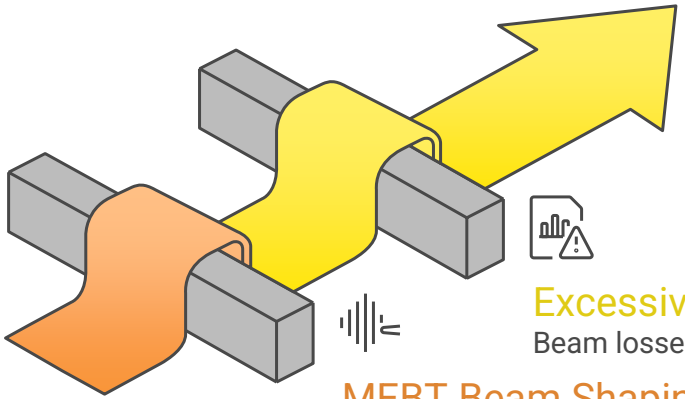
- A Less than 2M
- B Between 2M and 5M
- C Between 5M and 10M
- D Above 10M

C



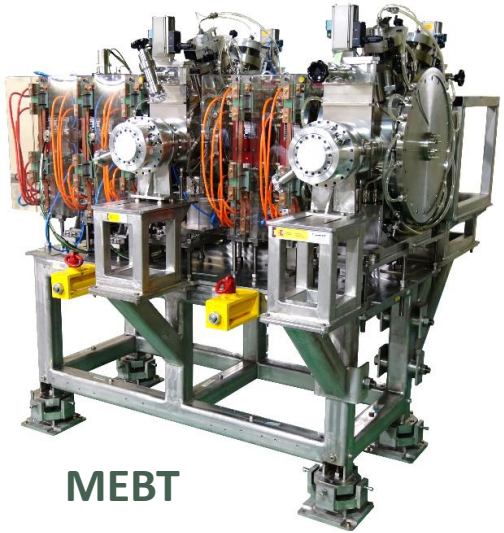
Accelerator Systems (Medium Energy Beam Transport)

Based on LIPAc design and commissioning (117 mA / 5 MeV / 8.75% DC)



Excessive Scraper Losses
Beam losses go undetected

MEBT Beam Shaping
Inability to shape beam as required



MEBT

- Modifications to improve the **maintainability**
- Enhancement of the **Beam Diagnostics** (DC measurement) and **Vacuum package**

Accelerator Systems (Medium Energy Beam Transport)

Needed Skills / Key Technologies

- **RF Source Proficiency** — Understanding and utilizing RF sources
- **Beam Dynamics Modelling** — Optimizing particle behavior
- **Mechanical Machining** — Precise fabrication of components
- **High Voltage and Electronics** — Safe handling of electrical systems
- **Instrumentation for Diagnostics** — Monitoring and analyzing system performance

Estimated Value Range

- A Less than 2M
- B Between 2M and 5M
- C Between 5M and 10M
- D Above 10M

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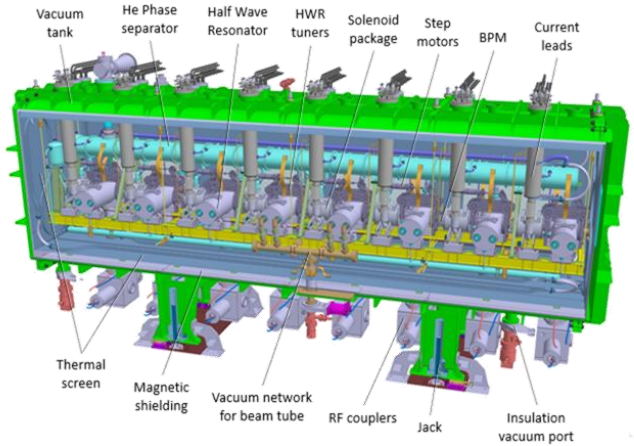
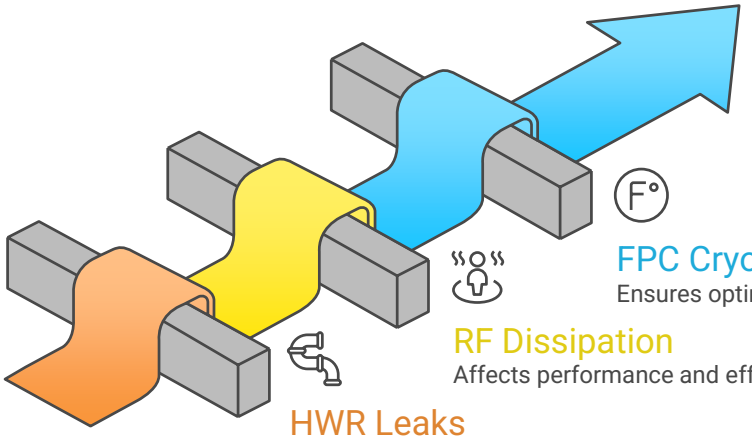
Accelerator Systems (SRF LINAC)

- **Five Cryomodules** top-loaded → integration in the vault
- Two types of HWR's cavities: 19 x low-β and 27 x high- β
- <200 kW RF couplers. Biased T-box design
- **29 x solenoids packages** (with steerers, BPM's & BLM's)
- **4 x Short Warm Sections**
- Complete study of **cryogenic hazards**
- **Studies of assembly and transport**
- **Prototyping and tests of cavities, RF couplers and microloss monitors**



System Risks and Challenges



FPC Cryo-Cooling
Ensures optimal functionality

RF Dissipation
Affects performance and efficiency

HWR Leaks
Significant operational challenges

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Accelerator Systems (SRF LINAC)

Needed skills / Key Technologies

- **Simulation and Design** — Creating blueprints and models
- **Material Procurement** — Sourcing specialized materials
- **Cryogenic Component Design** — Engineering cooling systems
- **Machining** — Shaping components with precision
- **Cleanroom Assembly** — Assembling in a sterile environment
- **Solenoid Manufacturing** — Producing and testing solenoids

Estimated Value Range

D

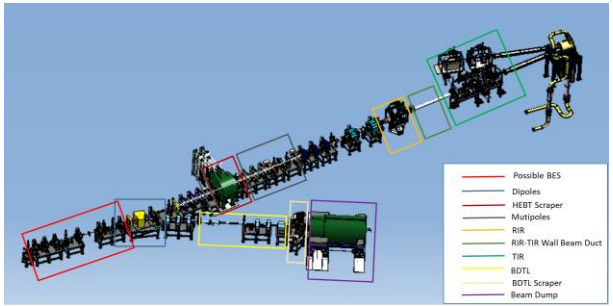
A. Less than 2M
B. Between 2M and 5M
C. Between 5M and 10M
D. Above 10M

Cavity - Coupler

Solenoids

Accelerator Systems (HEBT, Beam Dump & Diagnostics)

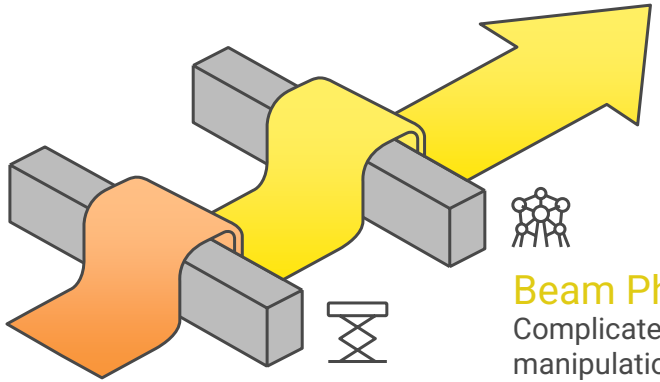
Beam Dump



- **Multipole magnets** (oct/dodec) for rectangular shape
- **Beam Dump** for commissioning and tuning
- Safety-credit and machine protection **Fast valves**
- **Aluminium beampipe** to minimize the activation
- CuCrZr water-cooled RH **Scraper**
- RH He-cooled **Collimator** at TIR
- 1% DC RH **Beam Dump** (LIPAc modified design)
- **Beam diagnostics** for all beam modes → prototypes and tests of critical diagnostics in TIR area (such as profile monitors)
- **Argon cold trap** in the main beamline
- Secondary beamline for **IFMIF upgrade** with **target diagnostics**
- Possibility of **beam extraction** under assessment

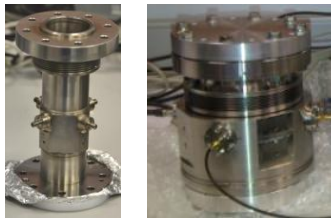
Accelerator Systems (HEBT, Beam Dump & Diagnostics)

Beam Shaping and Physics Risks

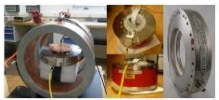


Beam Physics Complexity
Complicates understanding and manipulation

Beam Shaping Problems
Inefficiencies and inaccuracies



Beam Profile Monitor

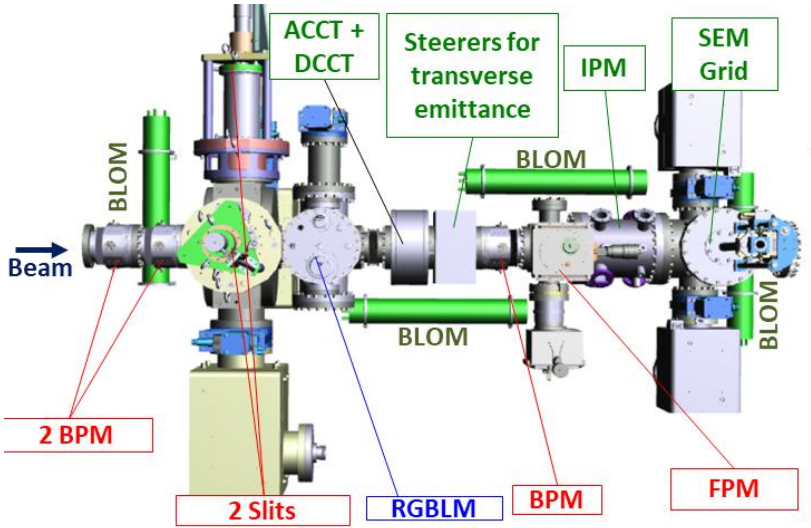


AC-CT

Estimated Value Range

D

- A Less than 2M
- B Between 2M and 5M
- C Between 5M and 10M
- D Above 10M

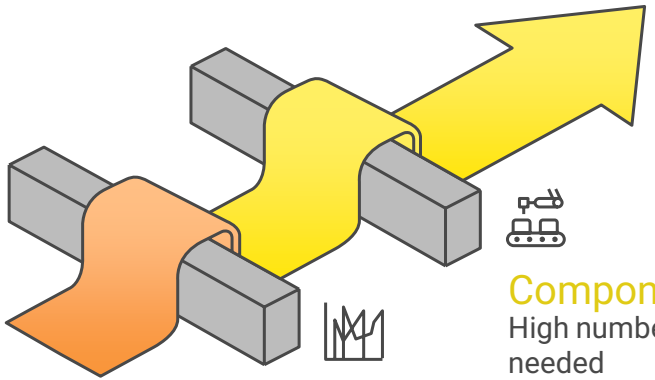


Accelerator Systems (RF Power System)

56 RF Stations to supply the RFQ (8), MEBT (2) & SRF (8;11;9;9;9) cavities including the respective coaxial lines

- Based on **SSPA** (LIPAc Tetrode Based) to improve the reliability and maintainability
- The design of the RF System well advanced by improving the **efficiency** (>60%) and architecture with respect to the LIPAc one
- Requirements for a powerful **LLRF** based on LIPAc experience
- Challenging design of the **coaxial lines**
- Assessment of **circulator** requirements and **transistors** technologies
- Several prototypes have obtained so far 200 kW CW w/ hydrid combiners or 100 kW CW w/ cavity combiners

EMC and Component Supply Chain Risks



Component Supply Chain
High number of components needed

EMC Radiated Emissions
Limits exceeded at 175 MHz

Accelerator Systems (RF Power System)

Needed Skills / Key Technologies

Estimated Value Range

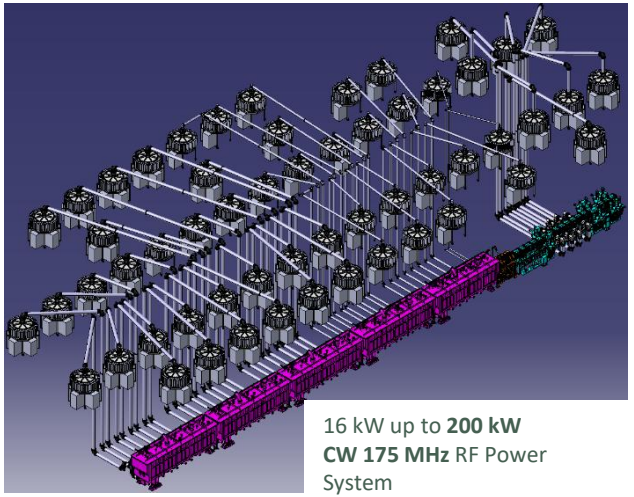
D

- A Less than 2M
- B Between 2M and 5M
- C Between 5M and 10M
- D Above 10M

Power Amplifier Technology — Enhances signal strength

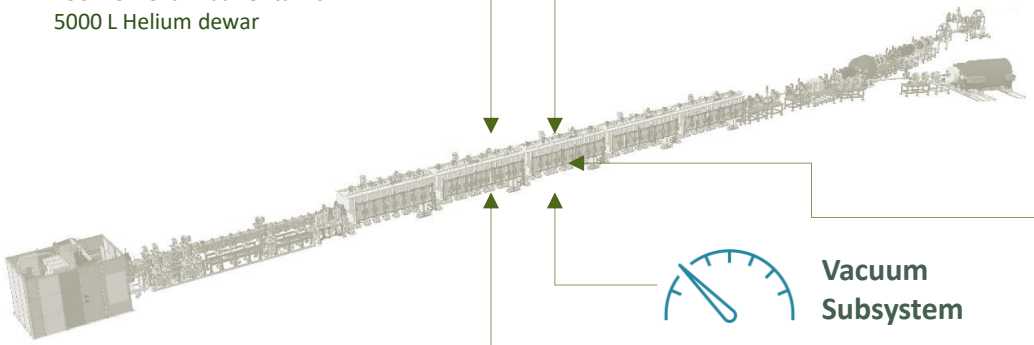
Circulator Technology — Ensures unidirectional signal flow

Coaxial Line Technology — Minimizes signal loss



16 kW up to **200 kW**
CW 175 MHz RF Power System
12 MVA electric consumption

Accelerator Systems (Accelerator System Ancillaries)



Cryoplant

Liquid He 4.45 K and 0.125 Mpa
Superconducting cavities, solenoids
60 K Thermal shielding
150 m3 Helium buffer tanks
5000 L Helium dewar

Gas Distribution

Ar - Argon (dry pumps)
He - Helium (leak testing)
N - Nitrogen (maintenance)
Compressed air (electro-pneumatic devices)
Breathable Air

Water Primary Cooling Loops

Heat load ~10 MW.
15ºC < Temperatures < 27ºC
±0.1ºC < Regulation < ±3ºC

Vacuum Subsystem

Pumping down & protection
of accelerator vacuum chamber
High vacuum pumps
Operating pressure < 5.10^{-6} Pa
4.4 K < Temperature < 540 K

Electrical Distribution

Low & medium voltage
Total apparent power ~25 MVA

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Accelerator Systems (Accelerator System Ancillaries)

Needed Skills / Key Technologies

Electrical Distribution — Power management and engineering

Water Cooling — Temperature maintenance

Vacuum Technologies — Industrial applications

Gas Distribution — Safe and efficient gas management

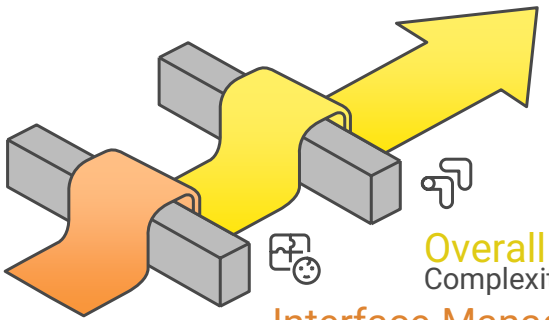
Cryogenic Production — Low-temperature processes

Estimated Value Range

D

- A Less than 2M
- B Between 2M and 5M
- C Between 5M and 10M
- D Above 10M

Project Integration Risks

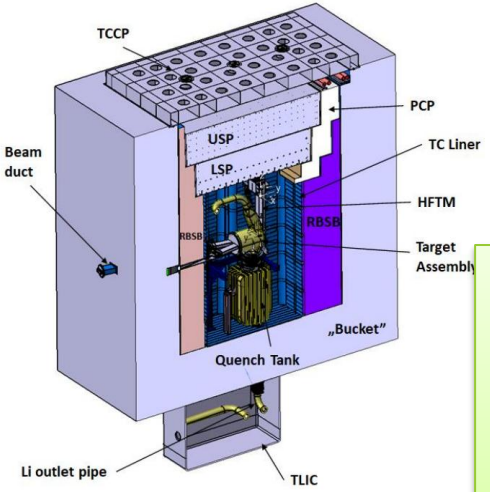


Overall Integration
Complexities of system integration

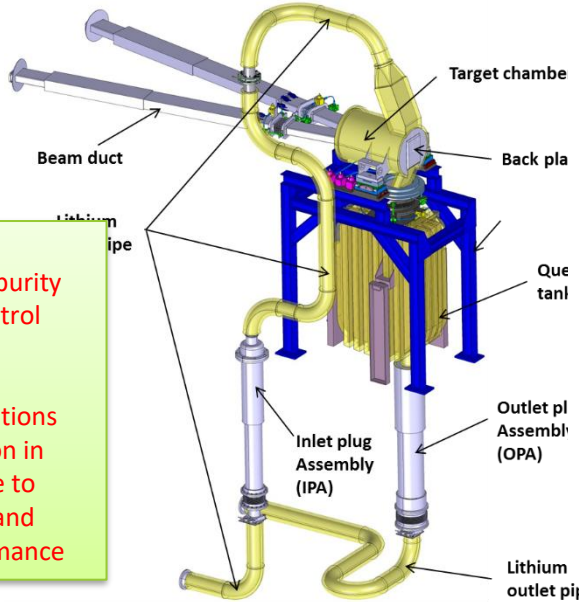
Interface Management
Coordination between components

Lithium Systems (Target, HR, Impurity Control, Ancillaries)

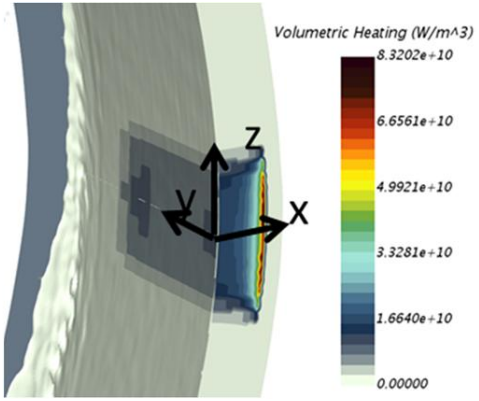
Target System : devoted to creating and steadily maintaining a liquid lithium jet with the required characteristics in front of the D+ beam (footprint 20 x 5 or 10 x 5 cm^2)

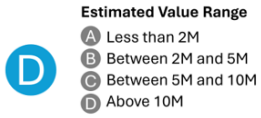


Main risks:
- High Levels of impurity in Li Impurity Control System
- Assembly under operational conditions
- Tritium Desorption in Lithium Traps due to limited research and uncertain performance



Li jet





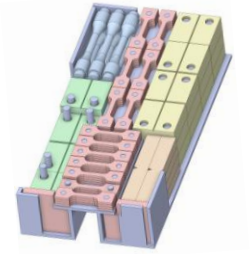
Characteristics:
- Connected to the Beam line
- Li jet speed: 15 m/s
- Li jet thickness: 25 mm
- Removed power: ~ 5 MW
- Li working temperature: 300 °C

Test Systems (Test Cell, Irradiation Modules, Ancillaries)

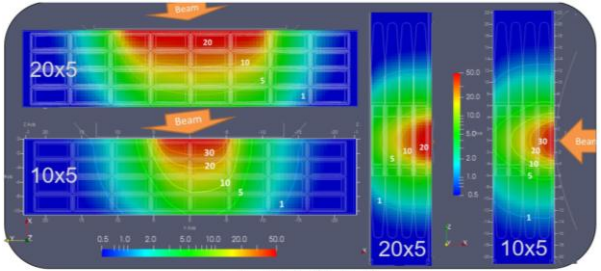
Testing and understanding the degradation of the materials and components properties throughout their operational life in DEMO and future fusion power plants

- Fluences of 20-30 dpaNRT in less than 2.5 years applicable to 0.3 litre volume and fluences of 50 dpaNRT in less than 3 years applicable to 0.1 litre volume
- Temperature range: 250 - 550 °C; temperature gradient < 3%
- High-flux region: Up to 5e^{14} n/cm2/s fast-neutron flux (> 10 MeV)

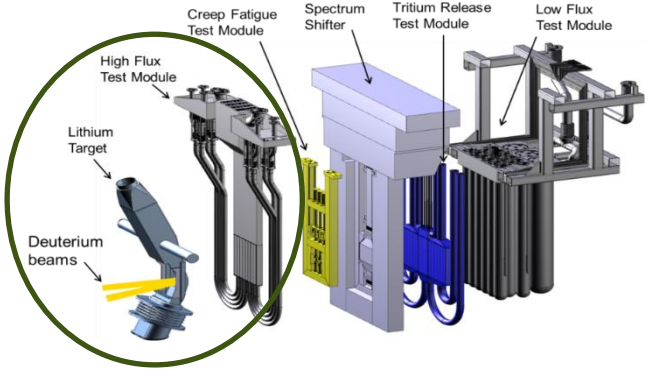
Main risk:
- Failure of critical functions in irradiation systems due to the harsh neutron and temperature environment during irradiation campaigns



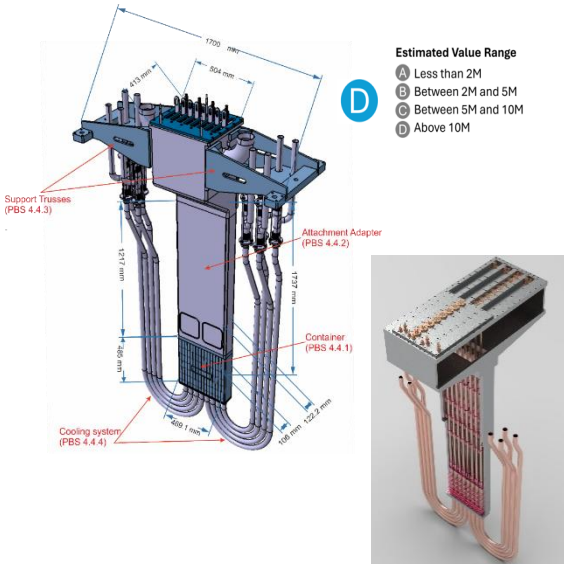
- 120 specimens per capsule
- Around 1000 specimens in the high-flux region
- Almost 3000 specimens per irradiation campaign



DPA (dpa/fpy) distribution



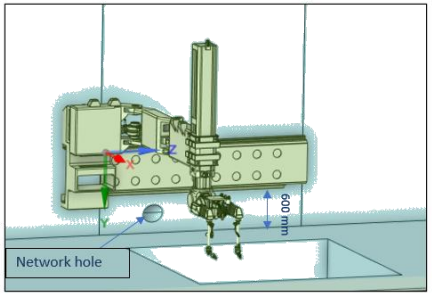
Irradiation Modules



STUMM

- Key role during the commissioning with beam and target
- Benchmarking of the neutronics models of the neutron and gamma fields
- Filled with tens of ionization chambers, micro-fission chambers, SPNDs (Self-Powered Neutron Devices), gamma thermometers and activation specimens

Remote Handling Systems



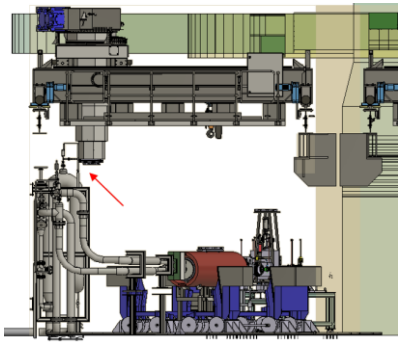
Telescopic mast crane
Robotic Arm

Estimated Value Range

D

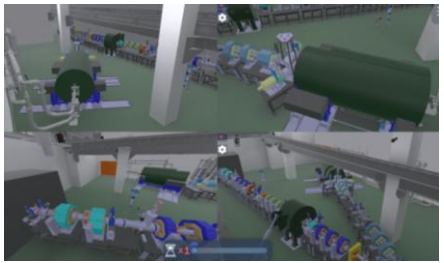
A Less than 2M
B Between 2M and 5M
C Between 5M and 10M
D Above 10M

FUSION FOR ENERGY

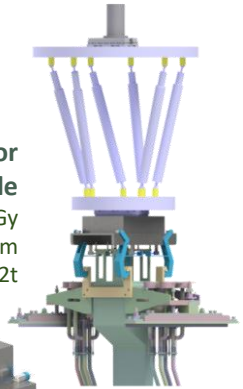


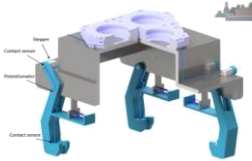
Cranes + Robotic Arms
Gripper system
3 t capacity
8 m crane span

Viewing Systems



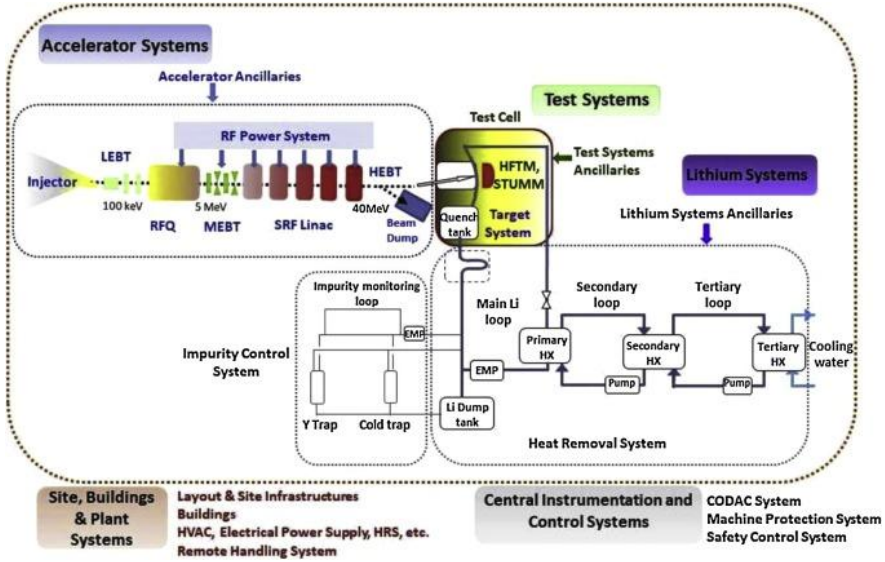
Multipurpose system for High Flux Test Module
Total absorbed dose ~1 MGy
Precision < ±1 mm
Payload 2t

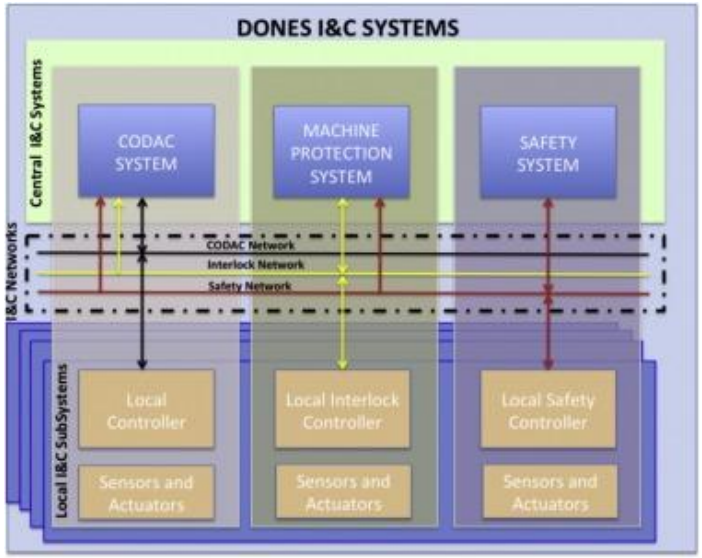




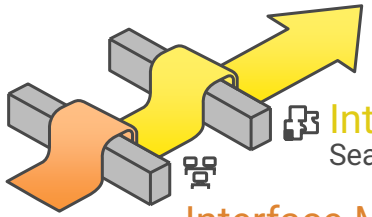
Decontamination Stations

Central Instrumentation and Control Systems





Project Integration Challenges



Integration Complexities
Seamless integration processes

Interface Management
Coordination between components

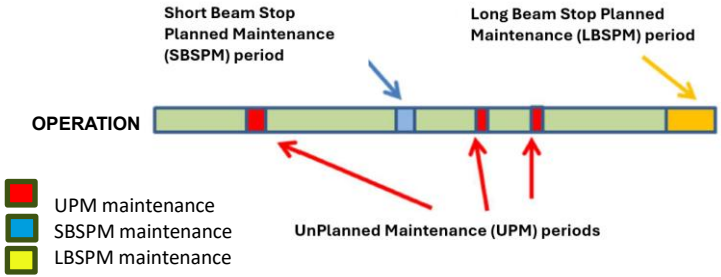
Estimated Value Range

- A Less than 2M
- B Between 2M and 5M
- C Between 5M and 10M
- D Above 10M

D

IFMIF-DONES ESPAÑA

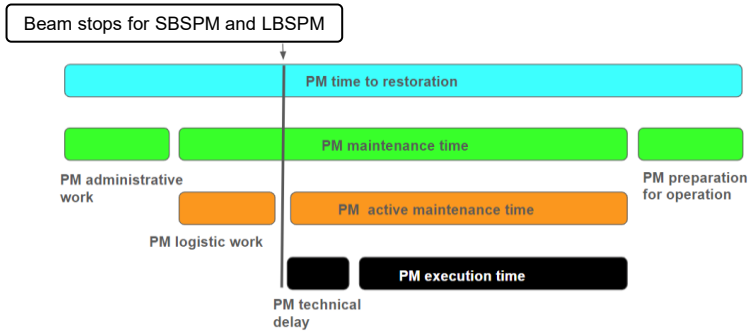
Maintenance strategy



- **OBJECTIVES:**
  - ✓ SAFETY
  - ✓ AVAILABILITY
  - ✓ EFFICIENCY
- **REQUIREMENTS:**
  - ✓ Long Stop (480h) and Short Stop (3 days) along 1-year irradiation
  - ✓ Systems availability exceeding 90% is needed to achieve the overall goal of 70% availability for DONES

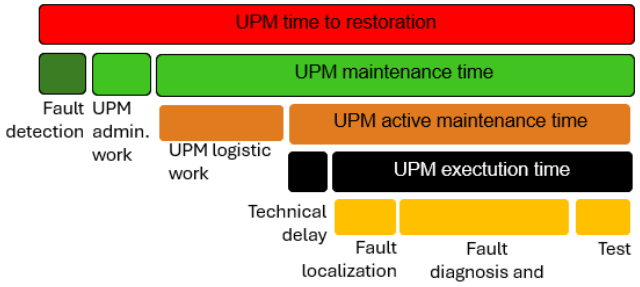
PLANNED MAINTENANCE (PM)

- **NO FAULT DETECTION:** Preventive / Condition-based Predictive
- **FAULT DETECTION:** Corrective Deferred or Opportunistic
- **SCHEDULED**
- **OPERATIONAL TIME WINDOWs**: Type 1 (LBSPM), Type 2 (SBSPM), Type 3 (ICPM)

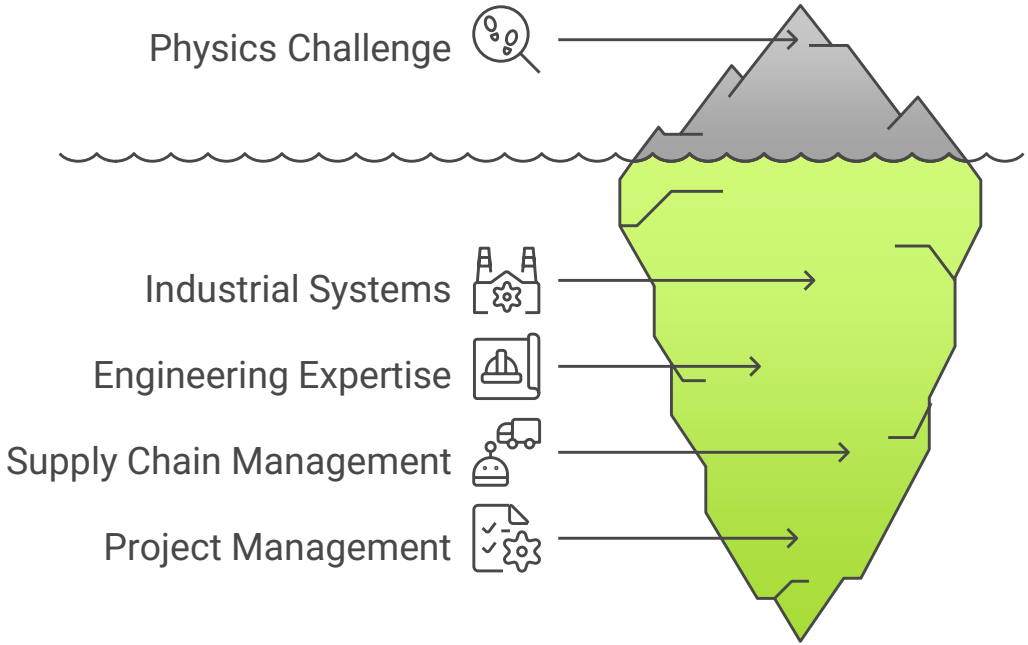


UNPLANNED MAINTENANCE (UPM)

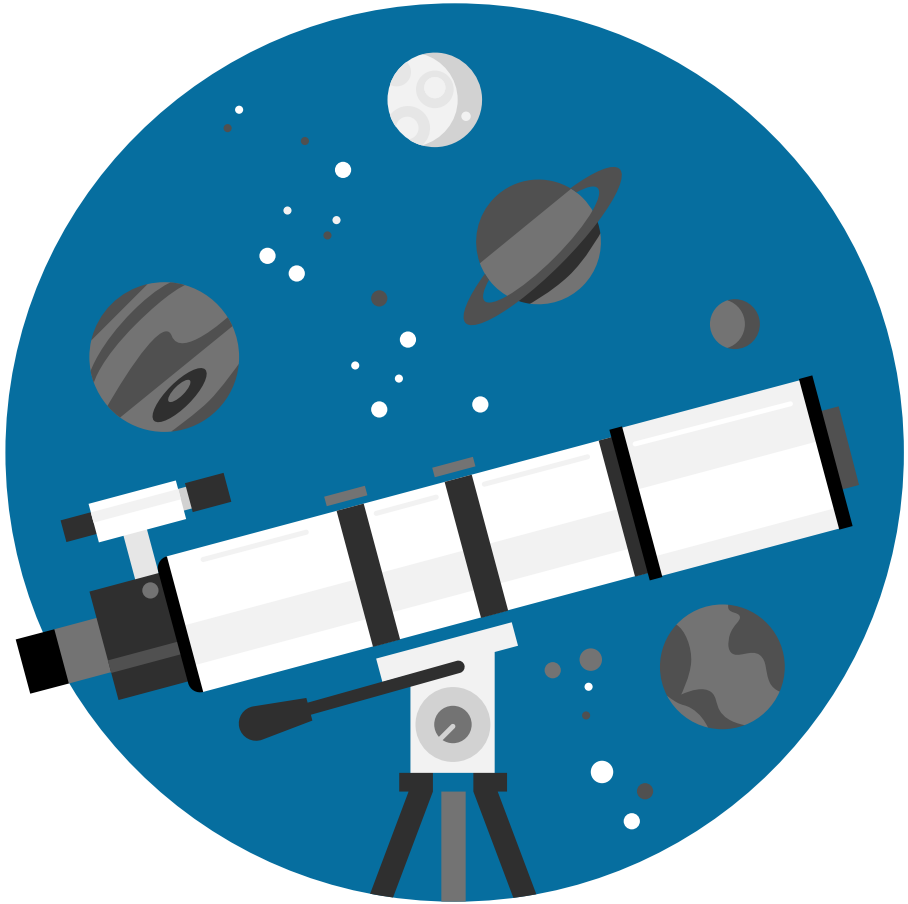
- **FAULT DETECTION:** Corrective
- **UN-SCHEDULED**
- **OPERATIONAL TIME WINDOW**: Type 4 (UPM)



IFMIF-DONES – A Challenge beyond Physics



How to get involved in DONES



DONES website

Call for Tenders Section

https://ifmif-dones.es/ifmif-dones-spain/call-for-tenders/

Fusion for Energy

Industry Portal

https://industryportal.f4e.europa.eu/

Belén del Cerro

Spanish ILO (Industrial Liaison Officer) for ITER and IFMIF-DONES

anabelen.delcerro@cdti.es

Industry Office

Big Science Industry Association

info@industryoffice.org


DONES
www.ifmifdones.org