IFMIF-DONES Project, Status and Opportunities

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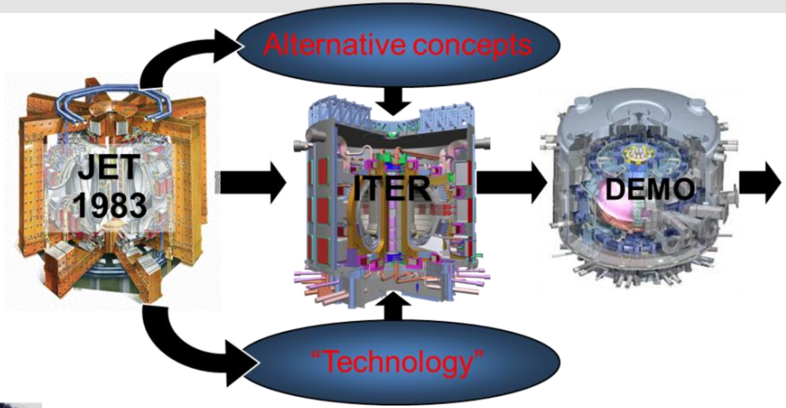
Virtual Workshop Croatia-Spain (IFMIF-DONES)
February 24th 2023

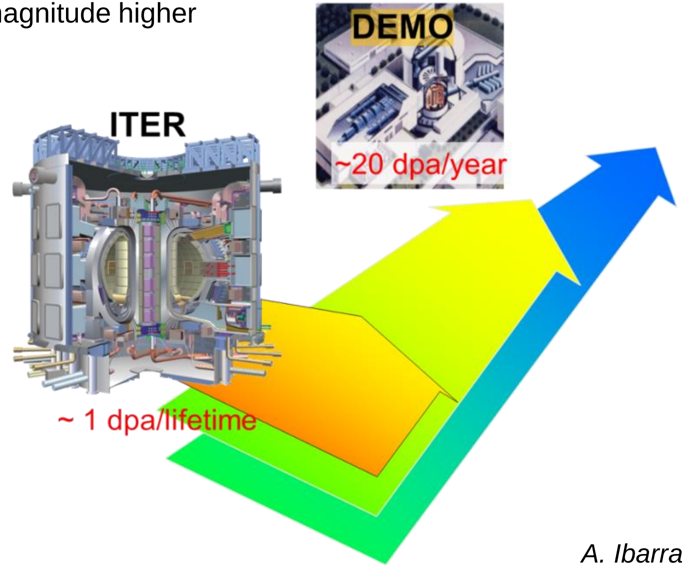
Why DONES?



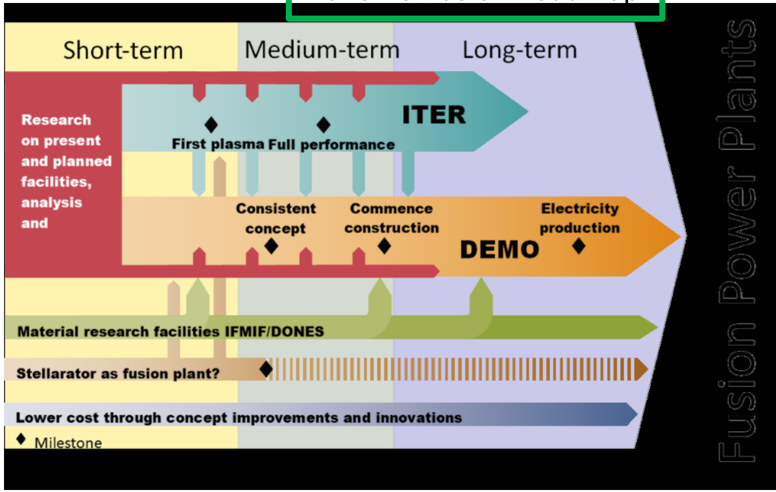
The power plant

EU strategy towards fusion energy

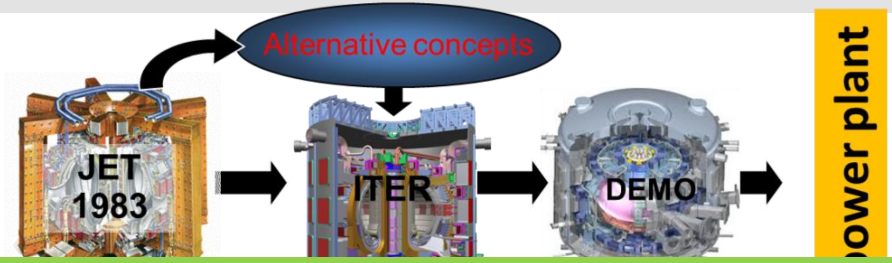
One of the main differences between ITER and DEMO is the radiation dose: at DEMO more that two orders of magnitude higher



2018 EU Fusion Roadmap



Why DONES?



EU strategy towards fusion energy

One of the main difference
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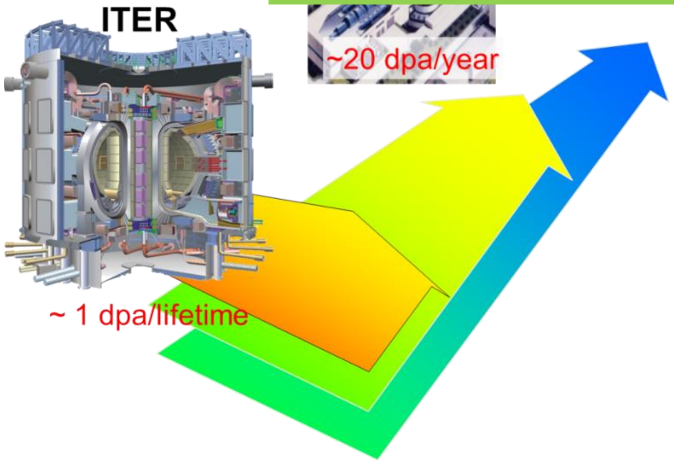
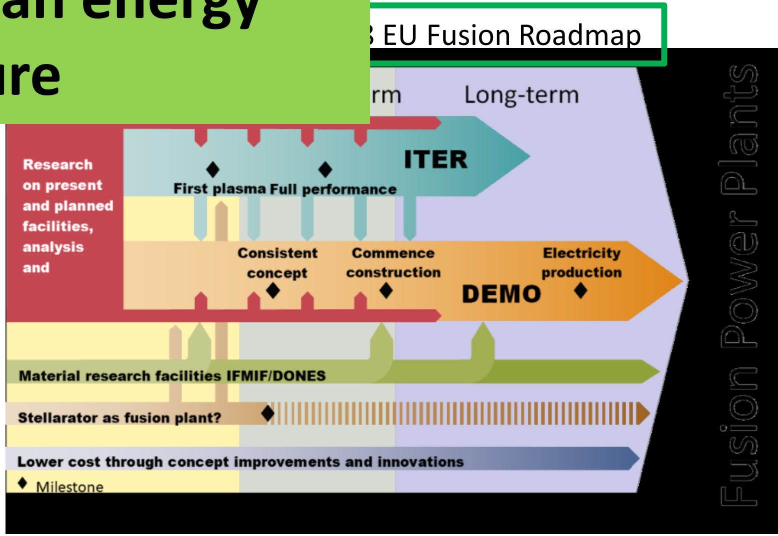
dose: at DEMO more that t
of magnitude higher

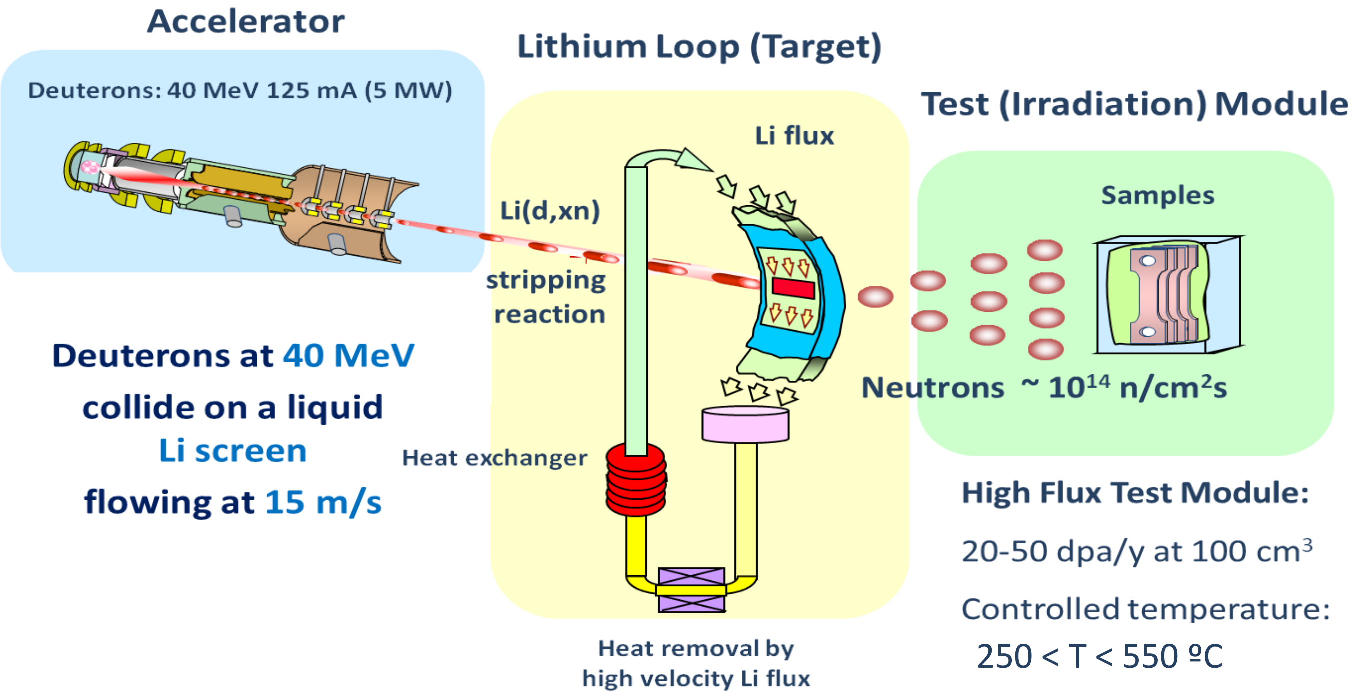
DONES will be a key element in the development of fusion as an energy source for the future





What is IFMIF-DONES?

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



Deuterons at 40 MeV collide on a liquid Li screen flowing at 15 m/s

High Flux Test Module:

20-50 dpa/y at 100 cm^3

Controlled temperature:

250 < T < 550 ºC

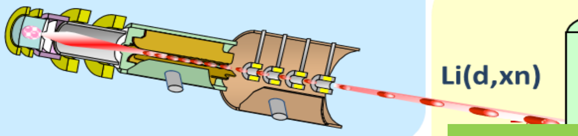
Identified as high priority in the EU Fusion Roadmap
Included in the ESFRI Roadmap as a EU strategic facility

What is IFMIF-DONES?

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

Accelerator

Deuterons: 40 MeV 125 mA (5 MW)



Lithium Loop (Target)

Li flux

Li(d,xn)

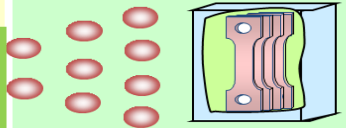
st

r

exc

Test (Irradiation) Module

Samples



utrons ~ 10^{14} n/cm^{2}s

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,...

A neutron flux
generated w
up to

:

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

Site

Well characterized from the geotechnical, seismic,radiological and meteorological point of view
(some further detailed studies presently going on)

Work on-site already started!!!

Key technologies involved

Accelerator Systems

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

Test Systems

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

Remote Handling

- Special cranes
- Telemanipulators
- RH tools
- Radiation monitoring
- Viewing systems
- Control (hardware and software)

Lithium Systems

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

"Conventional" Systems & Transversal Topics

- Buildings
- Cooling
- HVAC
- Control (hardware and software)
- Gas management
- Electrical systems
- Electronics
- Maintenance
- Safety and security
- Seismic systems
- ….

Project Implementation

Around 75% of the construction Budget is (close to be) assured

The DONES-Steering Committee will be stablish in the next few weeks

(and that means the “official” start of the DONES construction Phase)

Opportunities for the industry-I

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

- A specific effort has been made in the DONES Project 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 EU contributions were developed by EU industry
  - 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 Project as soon as possible

Some examples

Accelerators and related technologies for Big Science Facilities (ACTECA project)

Strategic objective: developm... Spanish involvement in the co... project, as well as...

ACTECA

2017-2020
7-8 M€

New materials, technologies and advanced processes to contribute to the new era of fusion energy (FUSION FUTURE Project)

Strategic objective: To con... to fusion en...

FUSION FUTURE

2020-2023
6 M€

Research on Technologies and Processes for IFMIF-DONES (DONES EVO Project)

Strategic objective: Mitiga...

DONES EVO

2021-2024
6 M€

Neutron Exposed Technologies for the IFMIF-DONES Test Cell (DONES NEXT Project)

Strategic objective: ... exposed c...

DONES NEXT

2021-2023
2 M€

Research on Big Science Facilities Efficiency (DONES FLUX Project)

Strategic objecti...

DONES FLUX

2022-2024
3 M€

Research on Big Science Facilities Industrialization (NEURON DONES Project)

NEURON DONES

Strategic objective: Optimization of the facility operation and maintenance

APPROVED in Dic 2022!!!

Foreseen activities

- White Rabbit + TSN based high performance synchronization
- Smart Electric System (AI + Micronetwork modelling)
- H2 + Supercapacitors based Emergency power cell
- Lithium purification systems and techniques
- Safety Critical parts monitoring
- Low cost / fast commissioning Cybersecurity tools
- AI based Smart Assistant (anomalies, predictive maintenance)
- Quantum computing for AI applications
- Immersive & gestural tele-control of quadruped based robotic arm + hand
- Quadruped robot based BIM and Thermographic surveillance
- AI based Post Mortem Analyses Assistant
- High frequency LLRF (GHz)

2022-2025
9 M€

Opportunities for the industry-II

- The institutions involved (and to be involved in the near future) in the Project are starting to issue a number of contracts to develop a number of different activities
- Initially a small number of relatively small contracts but they will grow up step by step

- Last year contracts:
  - Spain (CIEMAT, UGR, IFMIF-DONES España): Calls for auxiliary building construction (12 M€), DONES research building (8 M€), three different prototypes construction (0,5-1,5 M€ each), some labs under development
  - F4E: Solid State RF System,…

now running!!!

- Short term (2023-2024) contracts:
  - Spain: Innovative Public Adquisiton (CPI) presently under preparation
  - F4E: *To be defined in the next few months*

In definition

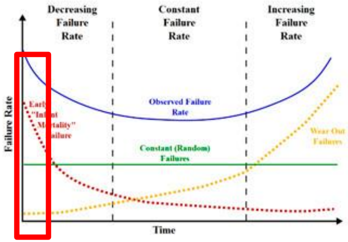
Most of them will require Industry Consortia to be developed!!!

Public Procurement of Innovation (CPI)

Phases

1. Call for expressions of interest on the market (CPM)
2. Report on CPM results
3. If positive ⟹ call for tenders (R&D+Prototypes)

Two mock-up validators to test:
- (Manufacturing technologies)
- RAMI parameters
- Behavior under pre-operational conditions



Identified Challenges:

DONES VATIAC
- RFPS2
- RFPS cryo
- MEBT
- HEBT + BD

DONES VATIST
- TSYS
- ICS
- HX1
- TC

Challenge 1: Integrated Validator for Accelerator Systems **(DONES VATIAC)**

Challenge 2: Integrated Validator for Test Systems and Lithium Systems **(DONES VATIST)**

Opportunities for the industry-II

- The institutions involved (and to be involved in the near future) in the Project are starting to issue a number of contracts to develop a number of different activities
- Initially a small number of relatively small contracts but they will grow up step by step

- Medium term contracts (linked to the initial steps of the program):
  - Spain:
    - Engineering support (expected end 2023- early 2024)
    - Buildings and other plant systems (several contracts maybe from 2024-2025)
  - Others *(To be defined):*
    - Accelerator systems (injector, RFQ, RF, SRF,…) (expected maybe from 2024-…)
    - Li systems (Li loop others…) (expected maybe from 2025-…)

Still to be defined

Most of them will require Industry Consortia to be developed!!!

Croatian contribution to IFMIF-DONES

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Croatian development of IFMIF-DONES

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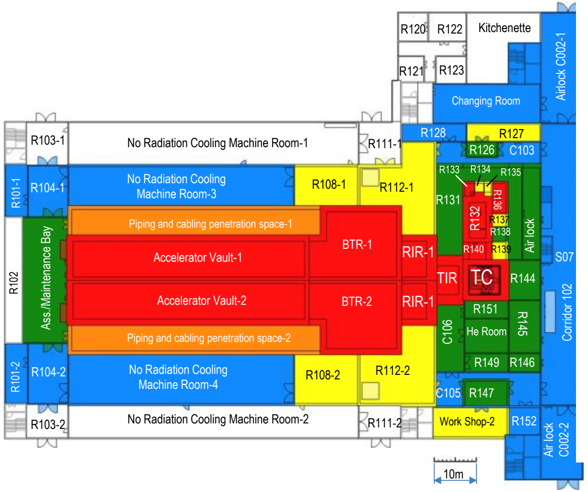
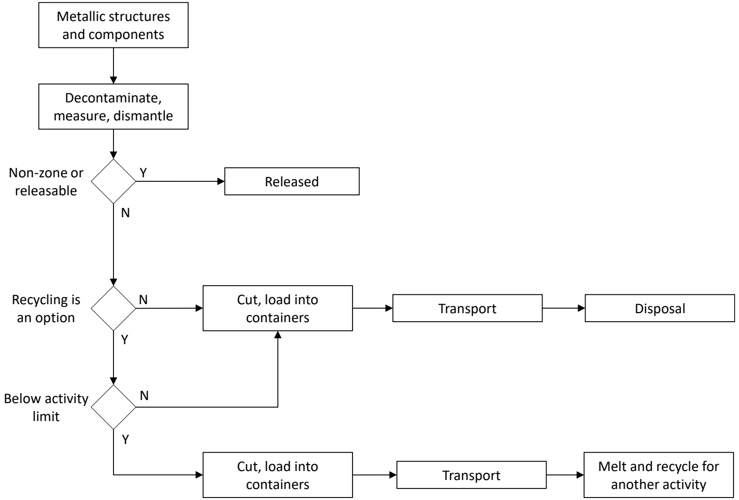
Radiation monitoring and personnel dosimetry at DONES



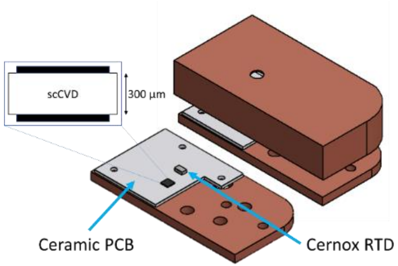
DONES decommissioning strategy

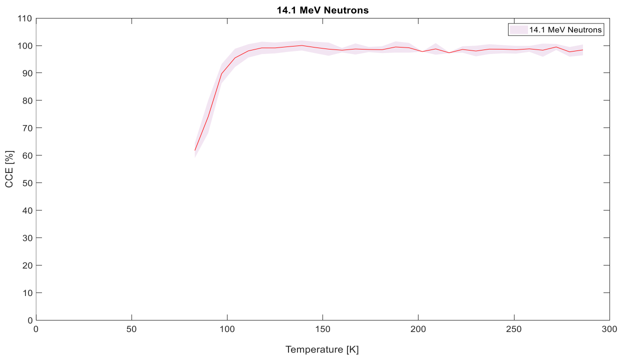
RBI in partnership with APOSS



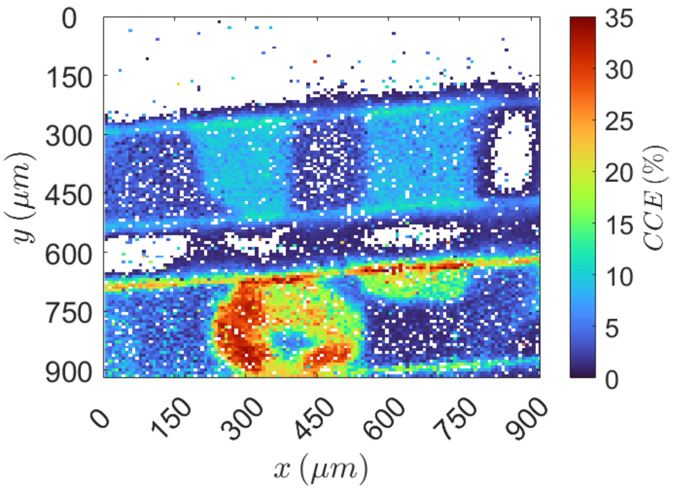
Croatian development of IFMIF-DONES

Development of Micro-Loss Monitors – neutron detectors for DONES accelerator





Assessmentof neutron induced damage in electronics at DONES



Croatian development of IFMIF-DONES

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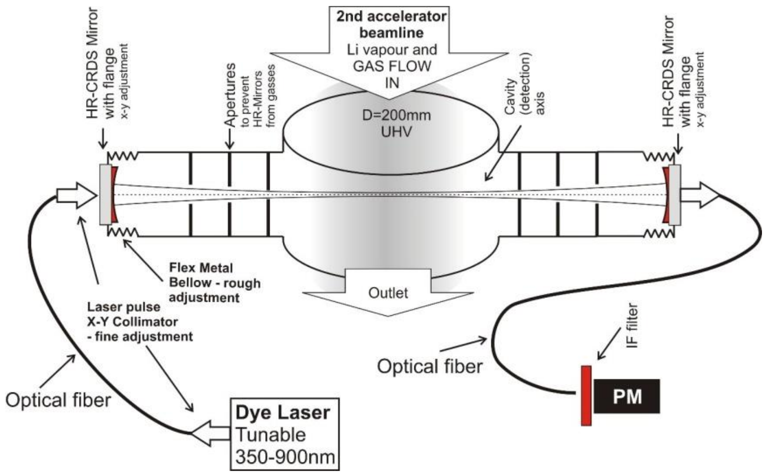
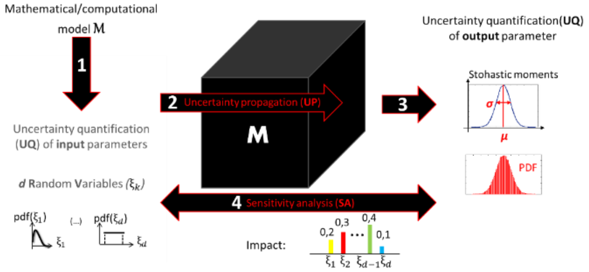
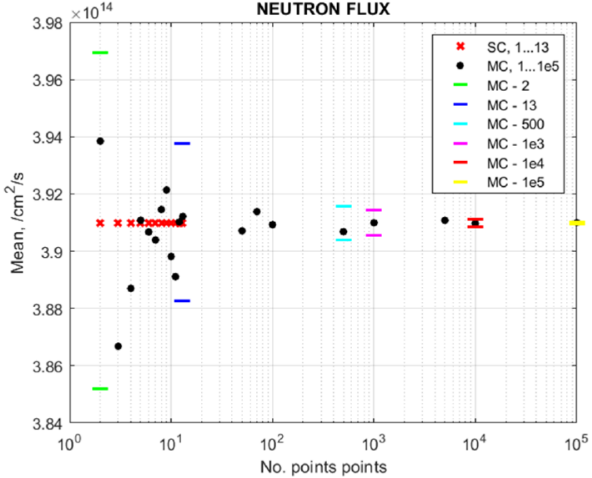
Cavity Ring-Down Spectroscopy laser systems for lithium evaporation monitoring



Assessment of error propagation in tuning of DONES accelerator





Croatian development of IFMIF-DONES

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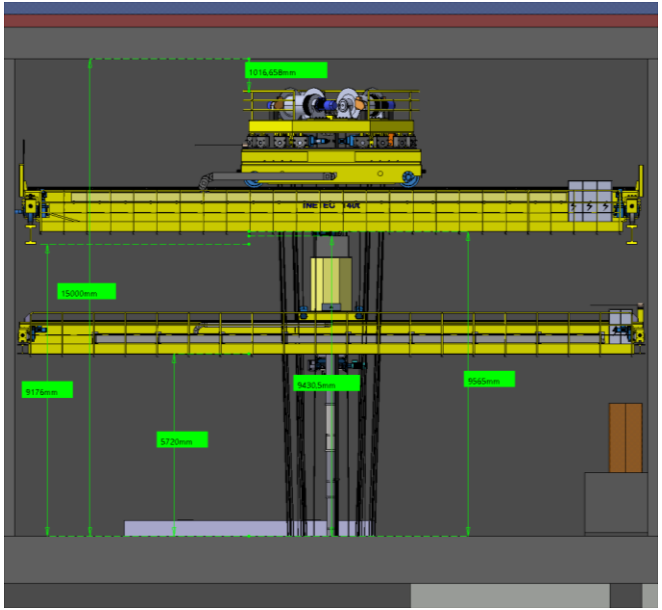
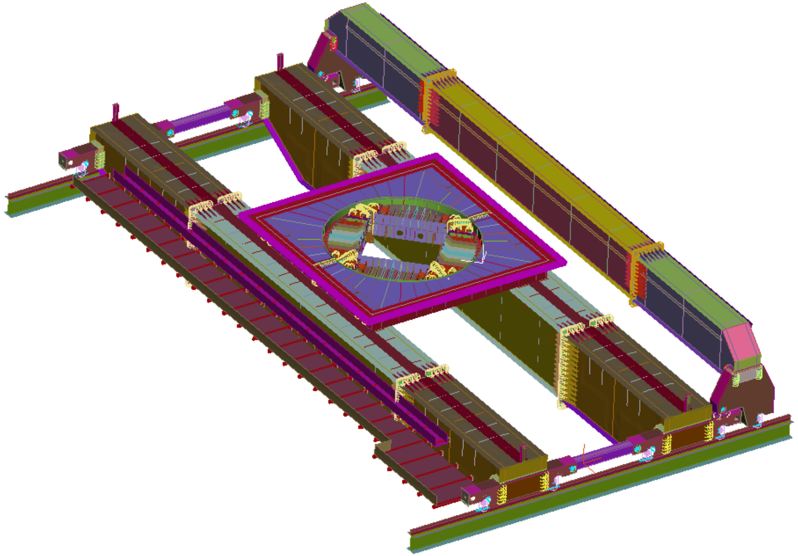
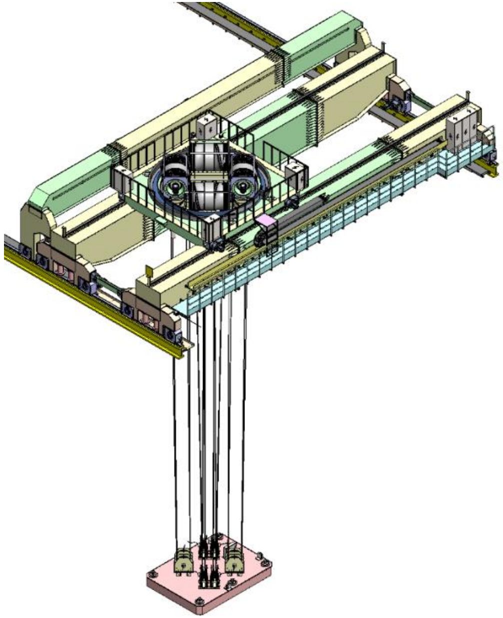
Remote Handling integration RBI & FSB in partnership with INETEC



Seismic assessment for cranes

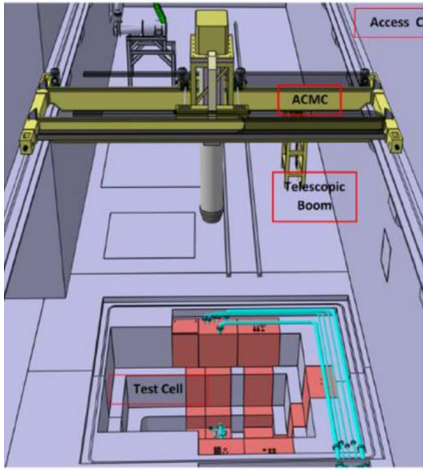


Key Remote Handling Systems



Heavy Rope Crane (HROC) for precise positioning of 100+ tons concrete lids at Test Cell of DONES

Designed by RBI, FSB & INETEC



Access Cell Mast Crane (ACMC) for sample manipulation

Designed by RBI, FSB & INETEC

Croatian Contribution

Target Interface Room

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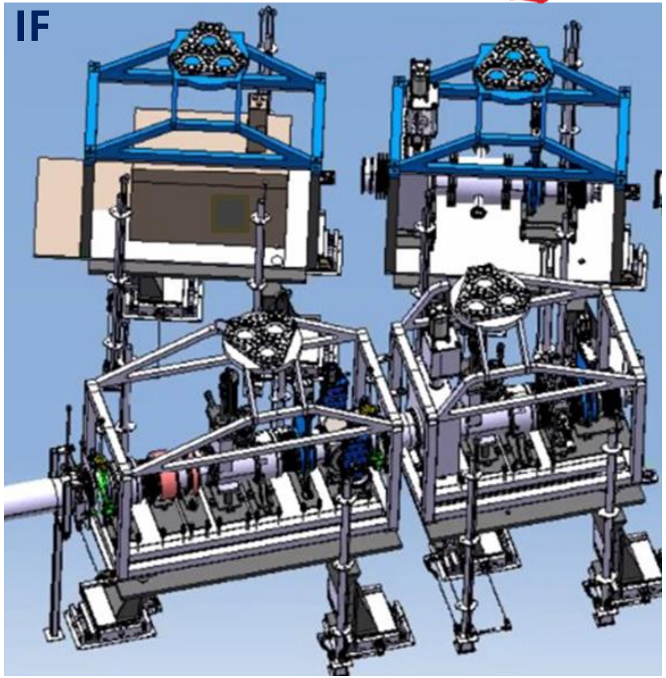
The key TIR section of the IFMIF-DONES accelerator consists of four modules, with all sorts of sensor systems to diagnose the incredibly powerful ion beam of 5 MW and laser systems for characterization of “waterfall” of molten lithium.

CRDS Laser system for lithium evaporation monitoring Designed by IF



Croatian Contribution

Heat Exchangers for molten lithium loop

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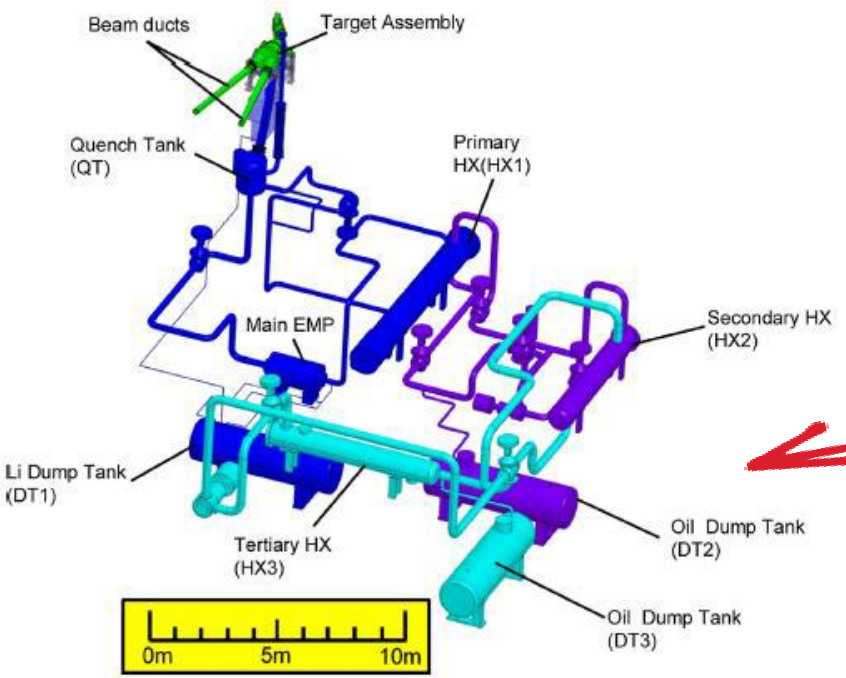
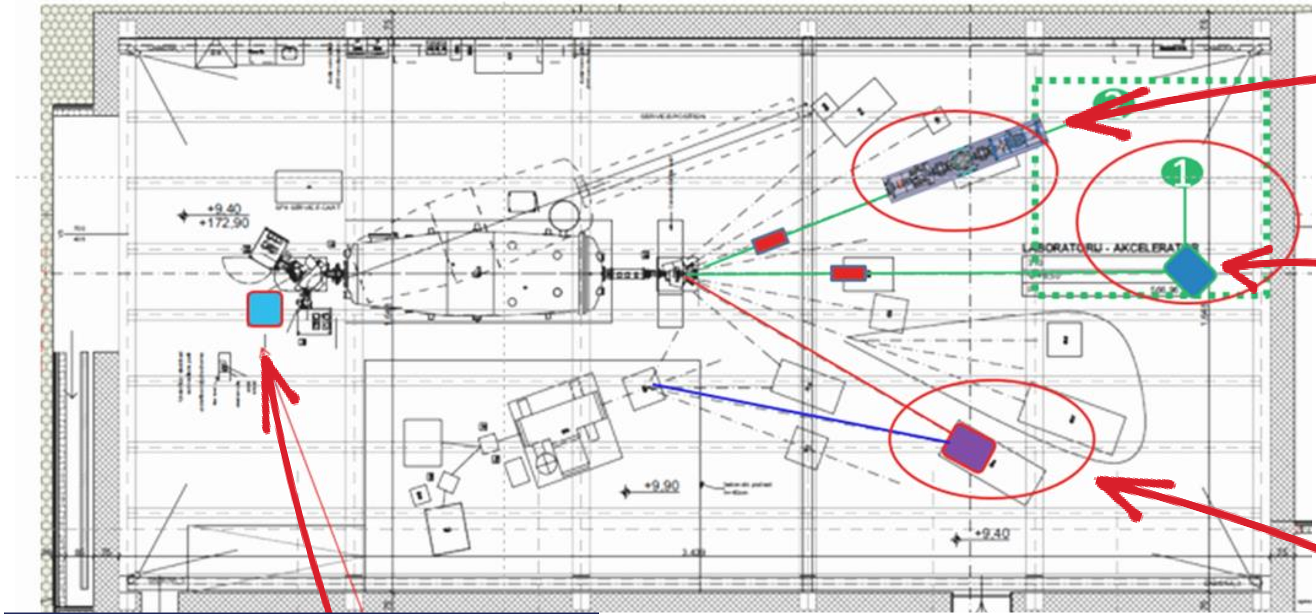


Oil-Oil and Oil-Water 10 MW Heat Exchangers with related diagnostics and Oil Dumps

Croatian Contribution



Setup for DONES Accelerator System Ion Beam Diagnostics Testing

Setup for DONES Accelerator System Radiation Detectors Testing

DiFU dual-beam facility for ion beam irradiaton and pre-selection of fusion materials

Multi-cusp High-power ion source

Croatian Contribution

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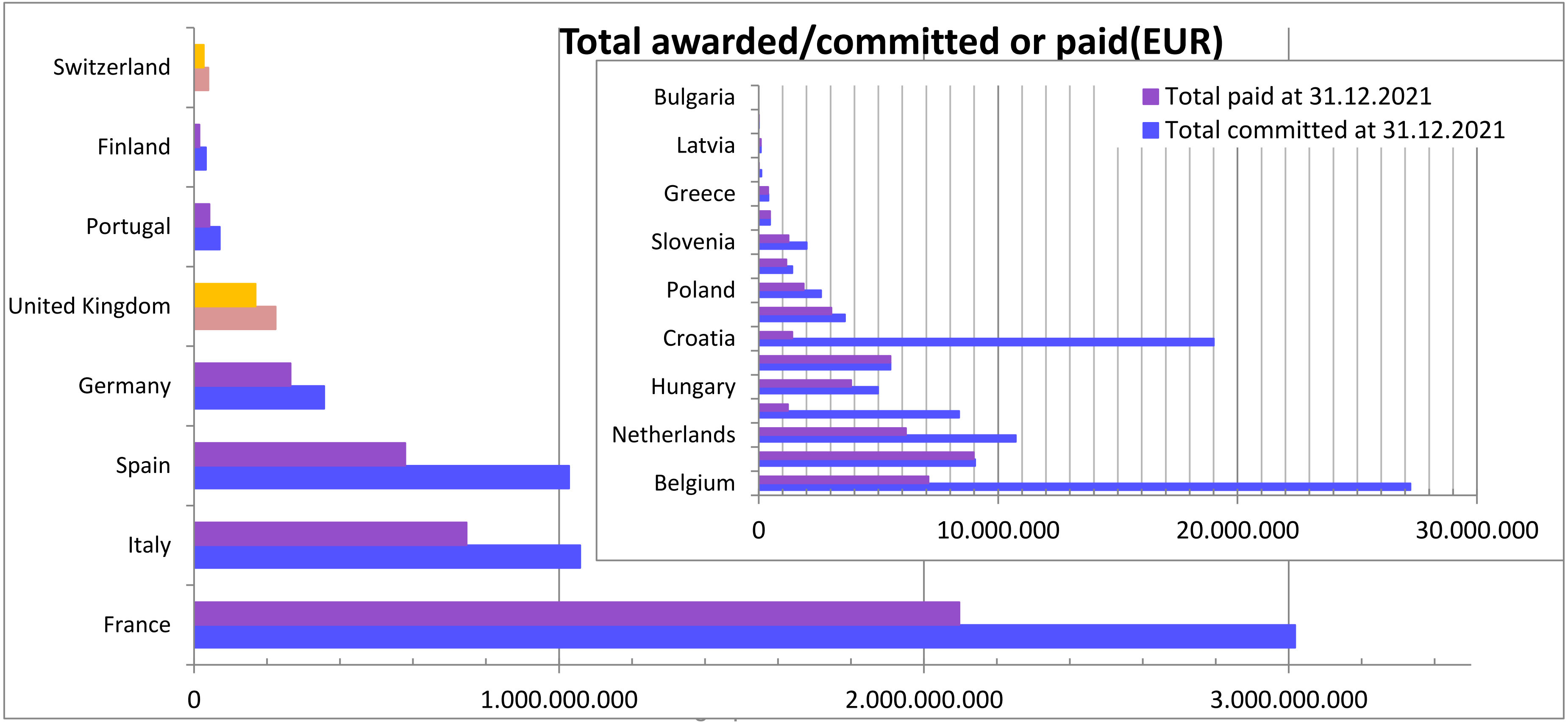
After O-ZIP Project - new RBI accelerator center will host the DONES Support Facilities

And other Support Facilities required by our Spanish partners

TOTAL DISTRIBUTION OF CONTRACTS



Summary

- The DONES Project 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 are open to new partners and collaborators!!!

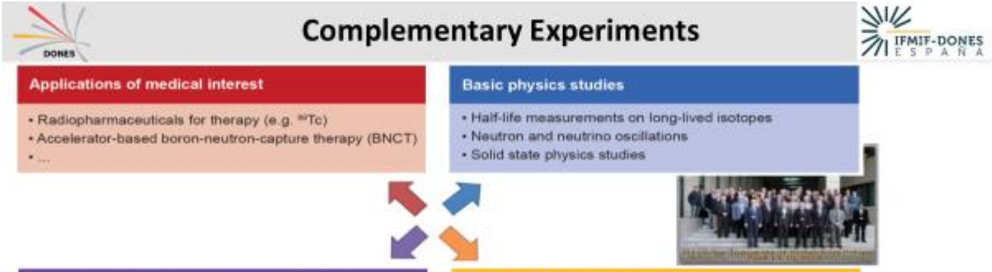
visit www.ifmifdones.org

or

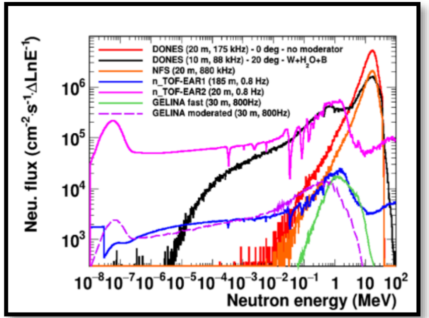
contact@ifmif-dones.es

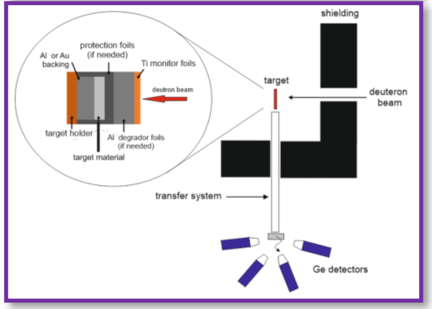
Complementary info

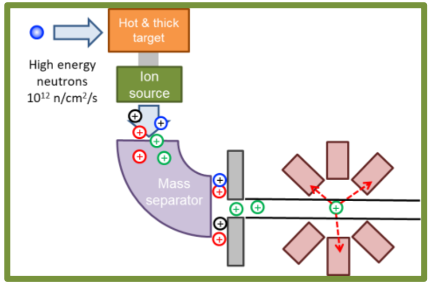
Complementary experiments



❖ **Deuterons** extracted from the accelerator beam but only a small fraction (a few percent)
❖ **Neutrons** available behind the Irradiation Module either inside or outside the Test Cell



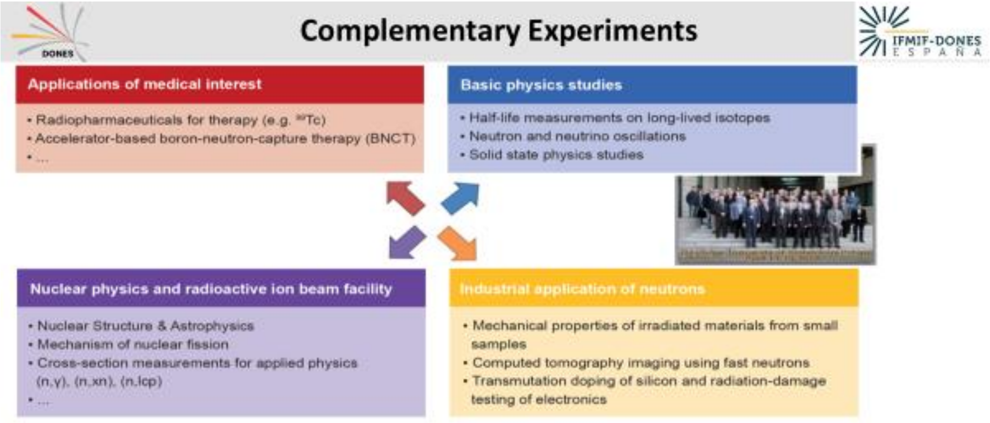


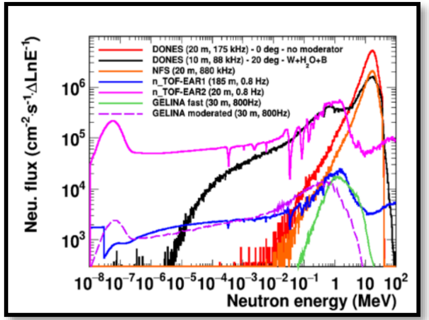


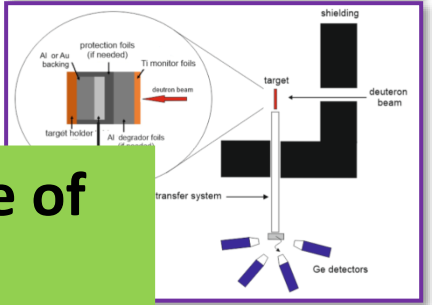
It will allow the construction of:

- **the most intense deuteron TOF facility for nuclear physics studies**
- **a first class facility for techniques using fast neutrons**
- **the production of radioisotopes of medical interest**

Complementary experiments

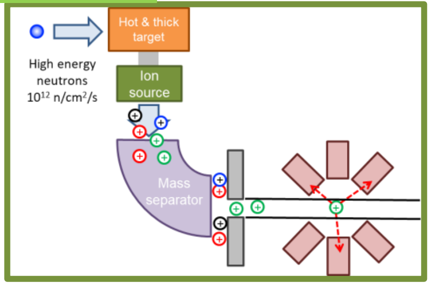






DONES will be a unique facility and new type of experiments will be feasible

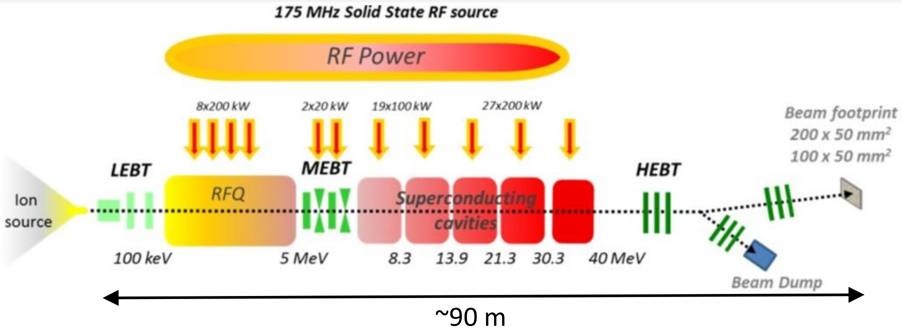
- the most intense deuteron TOF facility for nuclear physics studies
- a first class facility for techniques using fast neutrons
- the production of radioisotopes of medical interest

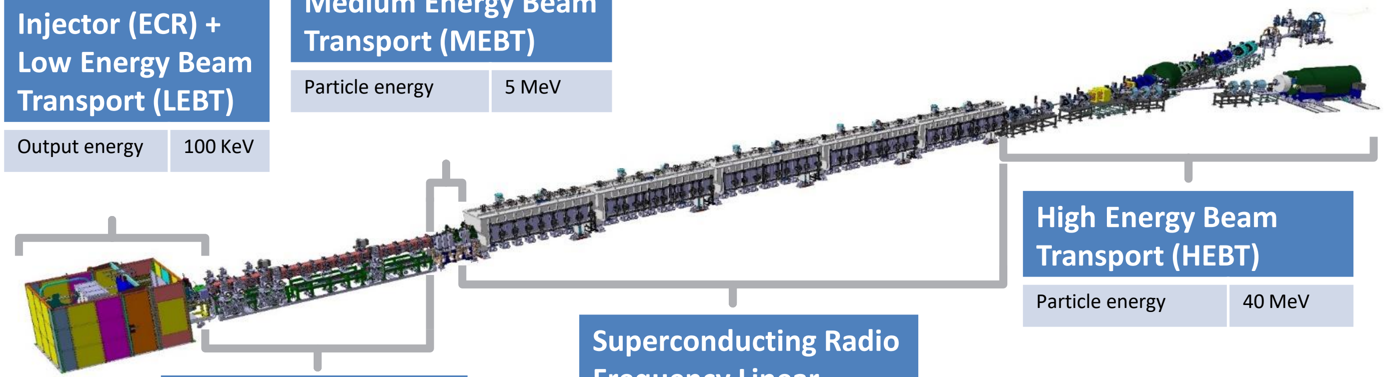


Accelerator systems summary

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)

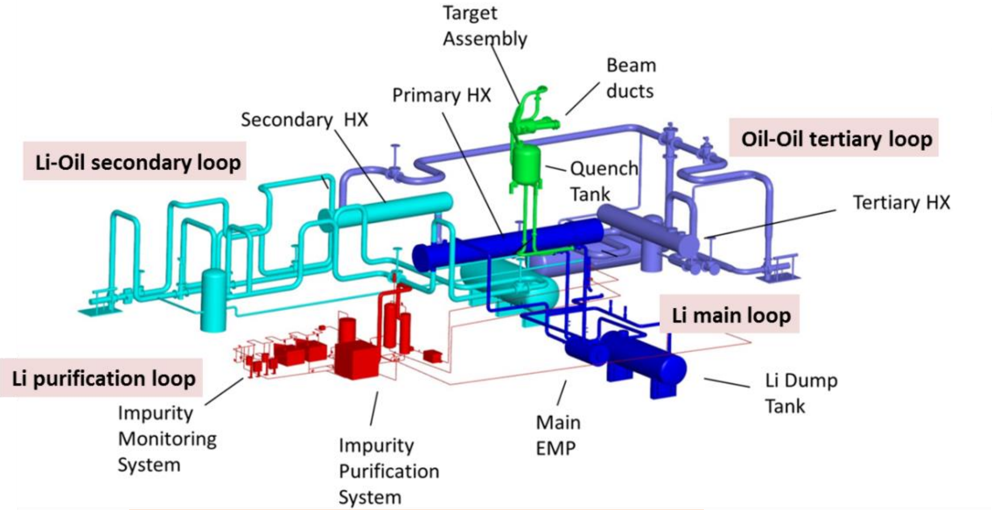
Particle energy	40 MeV

Main involved technologies

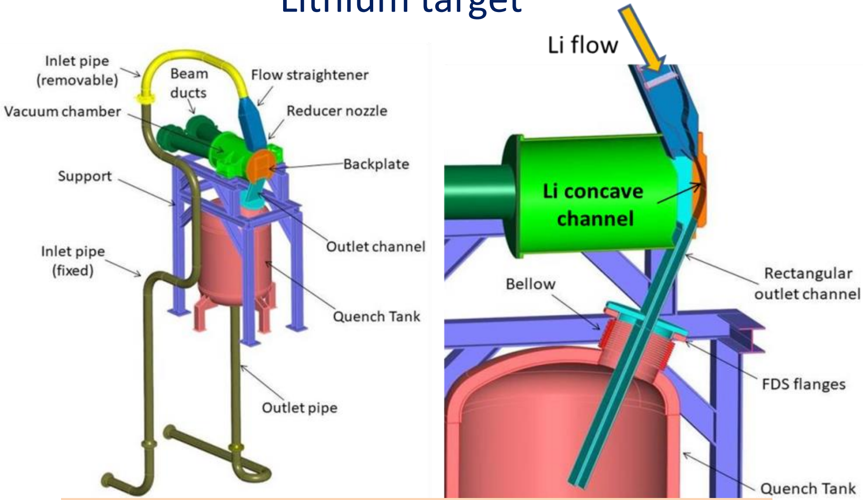
- RF
- Cavities
- Magnets
- Mecatronics (Cu, Nb, Al,…)
- Criogenics
- Vacuum
- Power supplies
- Cooling technologies
- Sensors and diagnostics
- Control (hardware and software)

Li systems summary

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



Lithium target



Li volume ~8 m^3 Li flow rate ~100 l/s
Temperature (cold side) ~300 °C

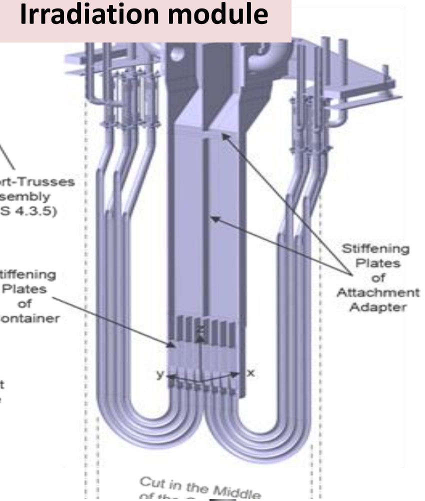
Jet thickness: 25±1 mm Li flow velocity: 15 m/s
Chamber pressure: 10^{-3} Pa Heat flux: 500 MW/m^2

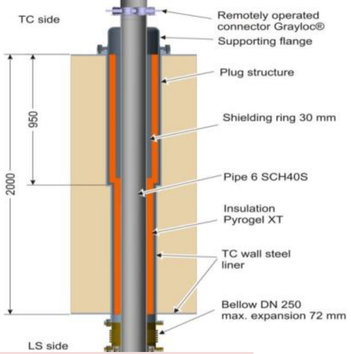
Main involved technologies

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

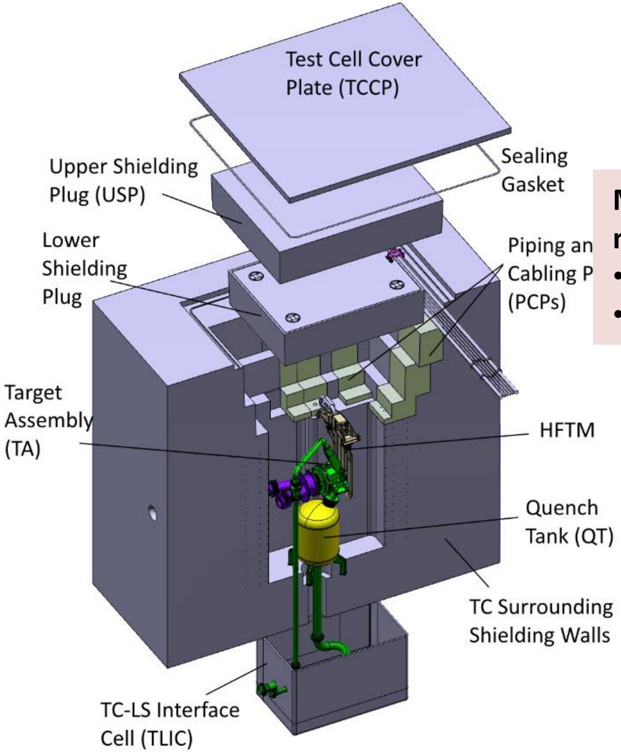
Test Systems summary

Irradiation module

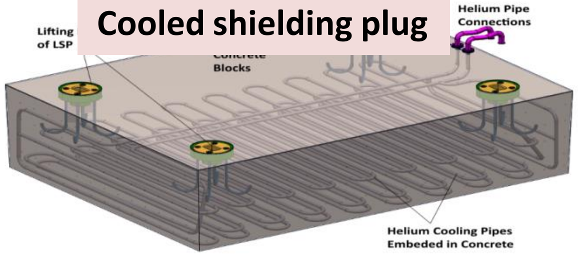




Duct penetration



Cooled shielding plug



Main characteristics driven by the presence of neutrons and Li

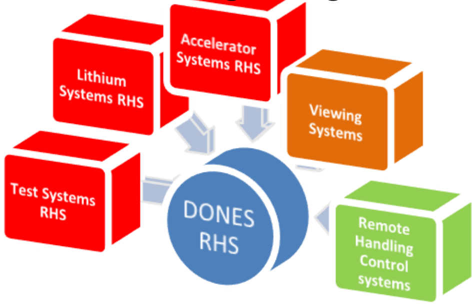
- Internal components cooling by He
- Remote Maintenance required

Main involved technologies

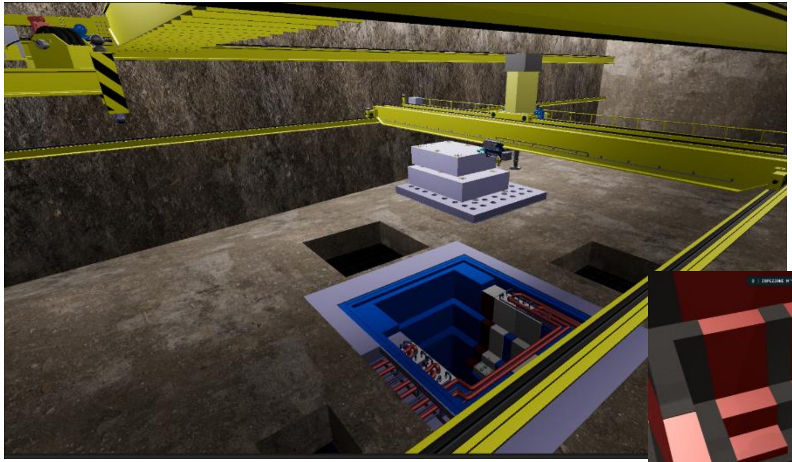
- Mecatronics
- He and water cooling
- He, Ar and water systems
- Shielding materials and technologies
- Remote maintenance
- Vacuum
- Diagnostics
- Control (hardware and sofware)

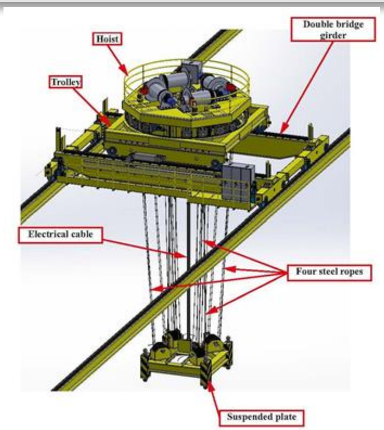
Remote Handling system

- ❑ **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

- Maintenance
- Safety and security
- ….