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IFMIF-DONES – neutron irradiation facility

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for the EUROfusion ENS work package and DONES Consolidation Phase project

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International Fusion Materials Irradiation Facility – DEMO Oriented Neutron Source

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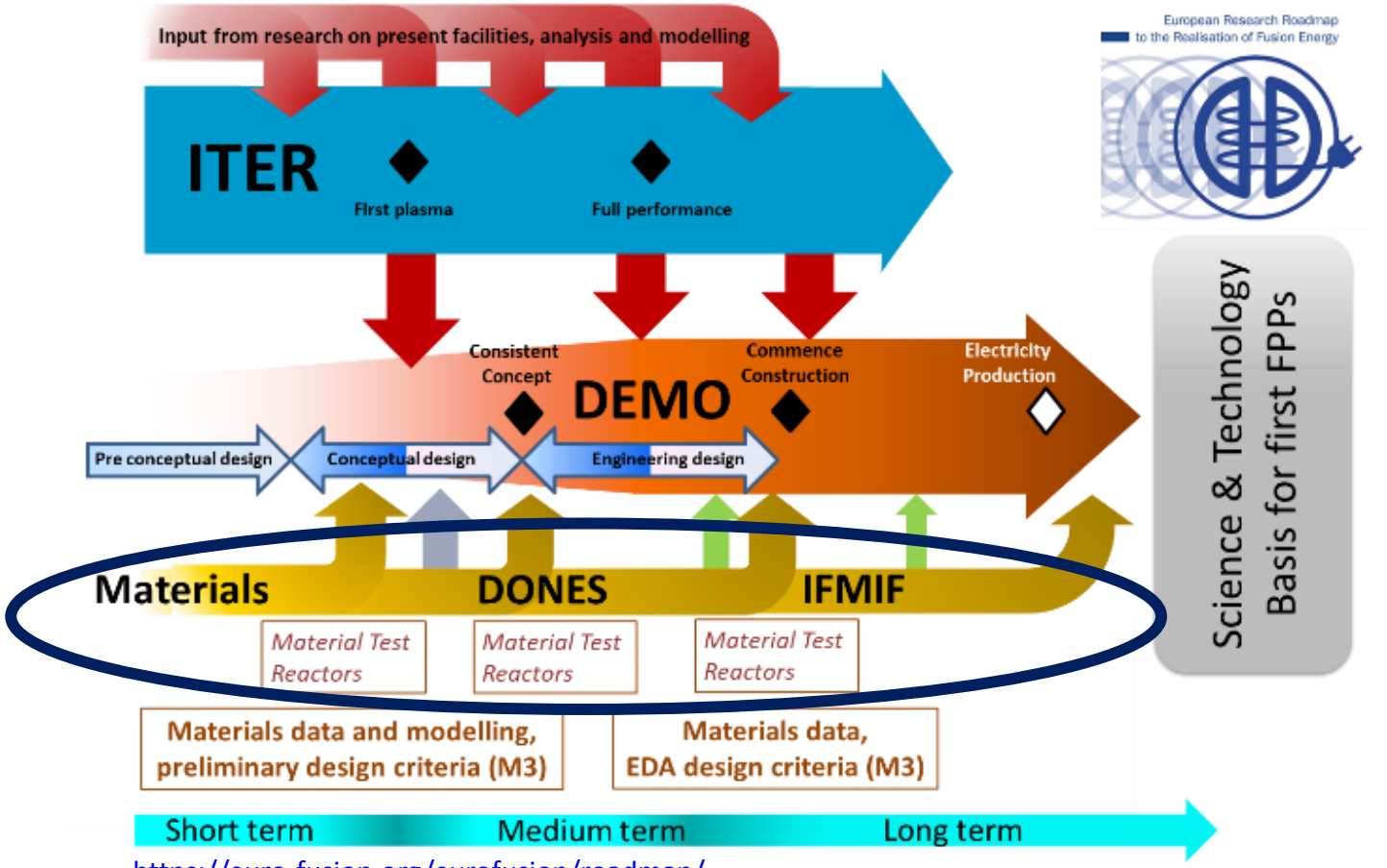
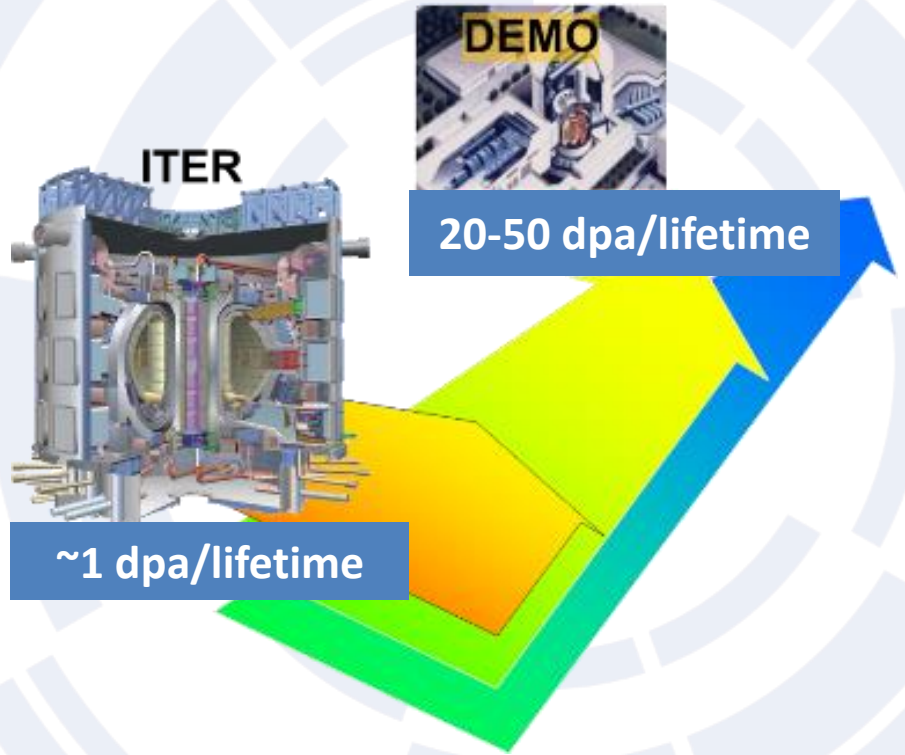
Why IFMIF-DONES? / European roadmap to fusion

One of the main differences between ITER and DEMO is the radiation dose:
at DEMO it is expected one-to-two orders of magnitude higher

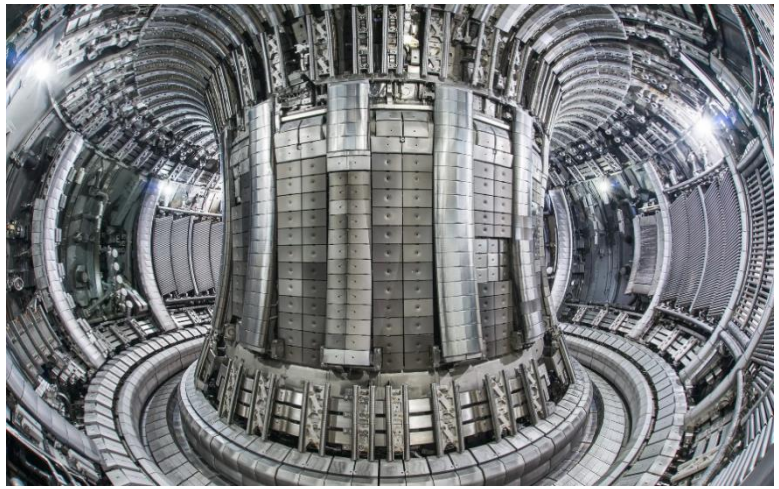


https://euro-fusion.org/eurofusion/roadmap/

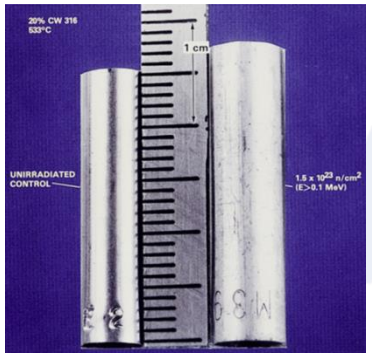


[dpa] displacement per atom in solid

Radiation damage to fusion materials



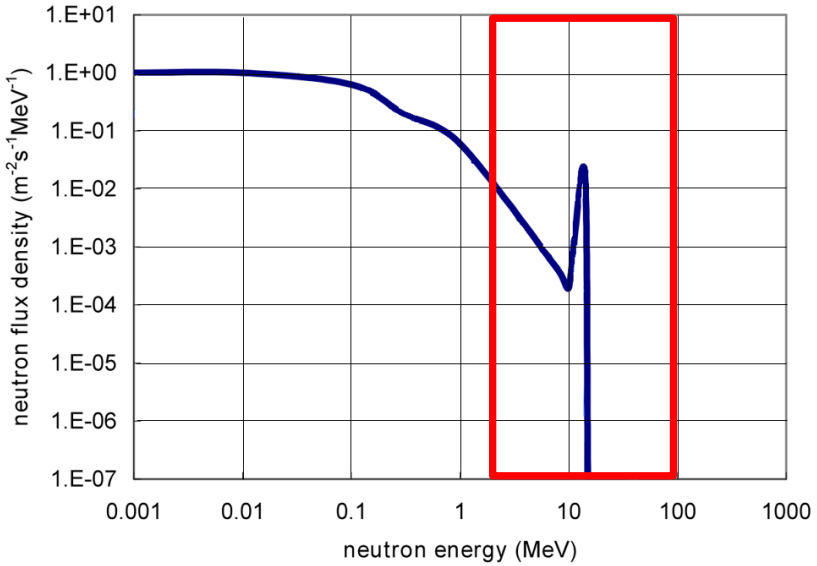
Radiation makes materials swell



It makes them brittle!

Radiation damage processes are very dependent on the neutron energy spectrum

Normalized neutron energy spectrum DEMO first-wall



Fusion neutrons spectrum differ significantly from the ones of **Fission Reactors** and **Spallation Neutron Sources**

A fusion-like neutron source is needed!

A fusion like neutron source

We need to produce **fusion-like neutrons** with:

1) **Intensity** large enough for accelerated testing (as compared to DEMO)
2) **Damage level** above the expected operational lifetime
3) **Irradiation volume** large enough for the characterization of the macroscopic properties of the materials of interest required for the engineering design of DEMO (and the Power Plant)

The most feasible approach based on
Li(d,xn) accelerator based source

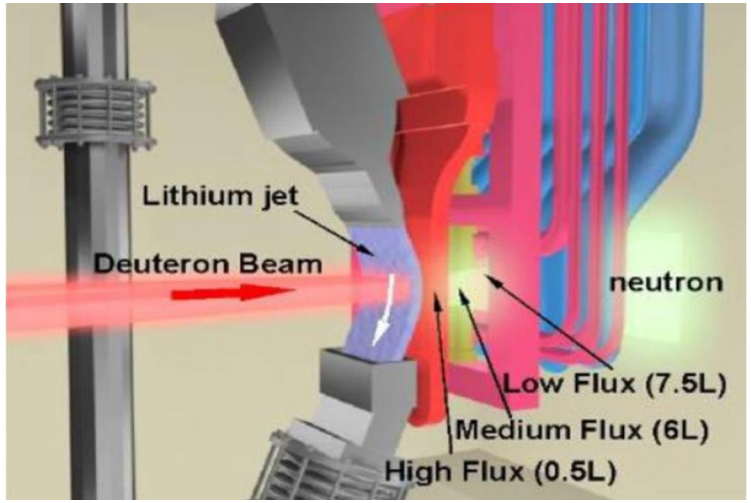
Requirements based on EU DEMO needs:

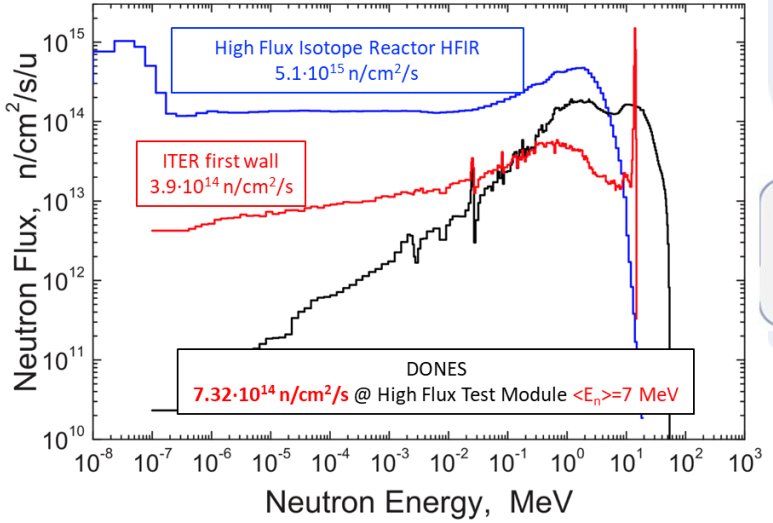
- **10 dpa(Fe)/fpy**

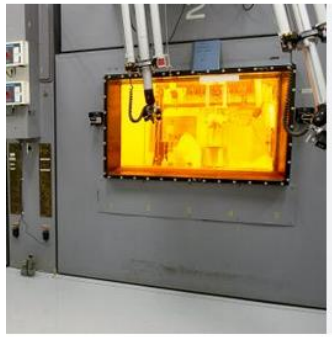
20 dpa(Fe) in 2.5 y volume 300 cm³

50 dpa(Fe) in 3.5 y volume 100 cm³

IFMIF-DONES is an **accelerator-based fusion-like neutron source** to be used for the qualification of the materials for the DEMO Fusion Reactor

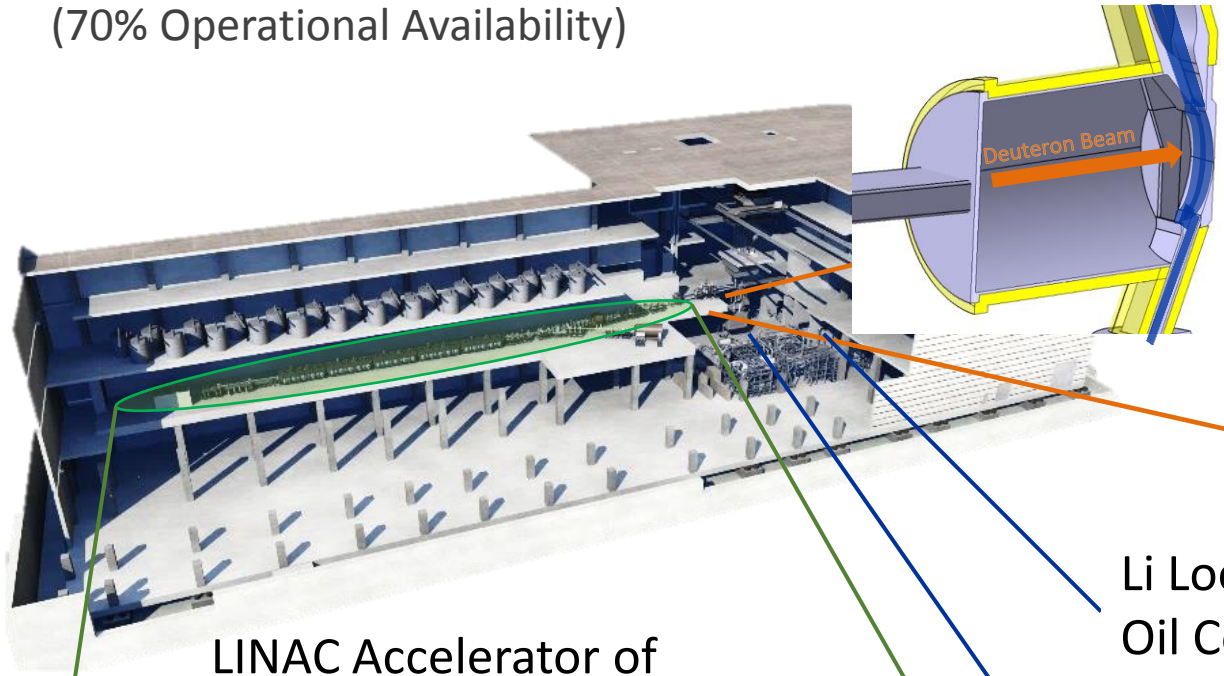




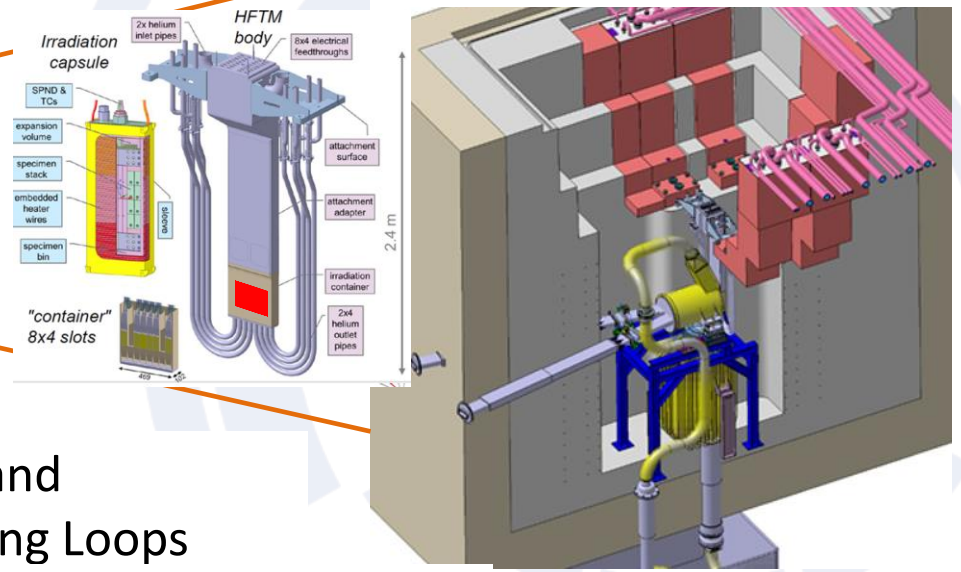


The IFMIF-DONES facility

- Irradiation Facility delivering up to **10^{15} n/cm²/s** (**10^{17} n/s**) with a broad peak at 14 MeV
- Operational at least 255 days/year
  (70% Operational Availability)

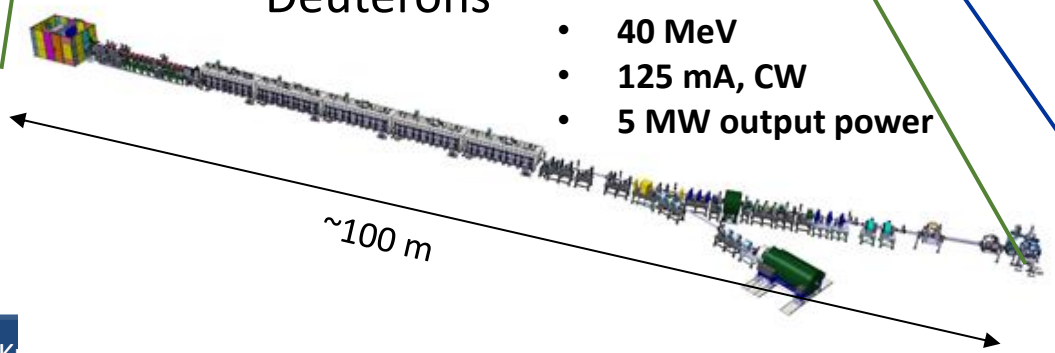


Li Target, Test Cell and Irradiation Modules

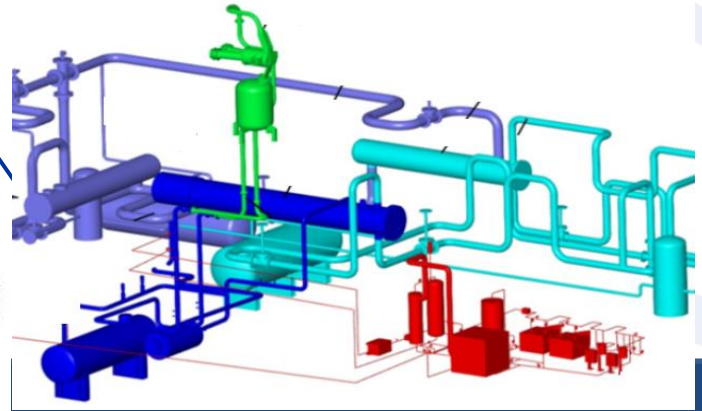


LINAC Accelerator of Deuterons

- **40 MeV**
- **125 mA, CW**
- **5 MW output power**



Li Loop and Oil Cooling Loops

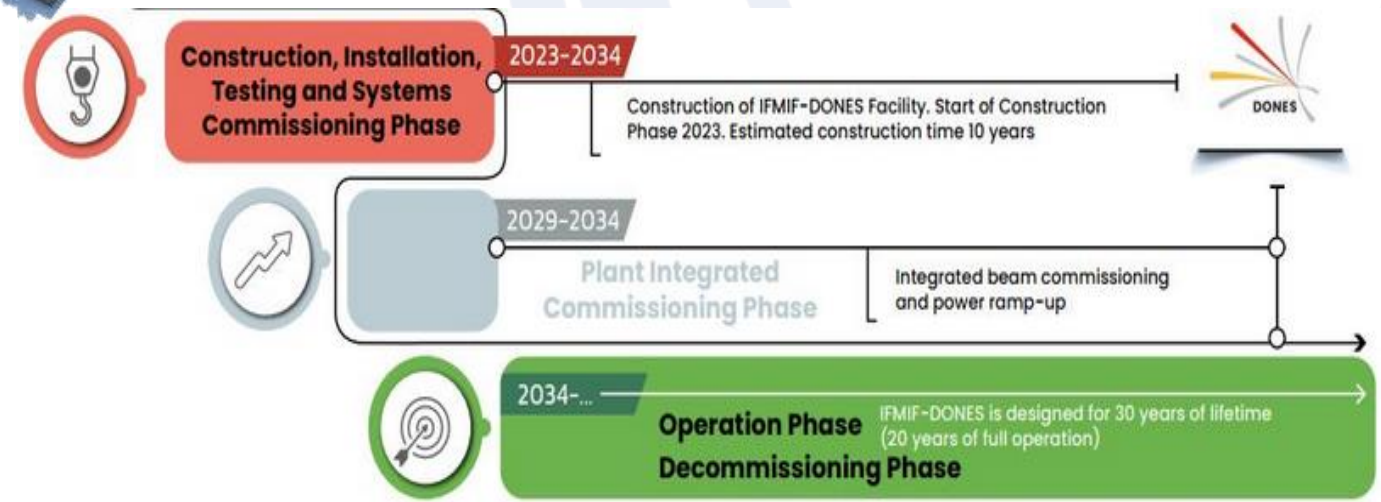


Li(d,xn)

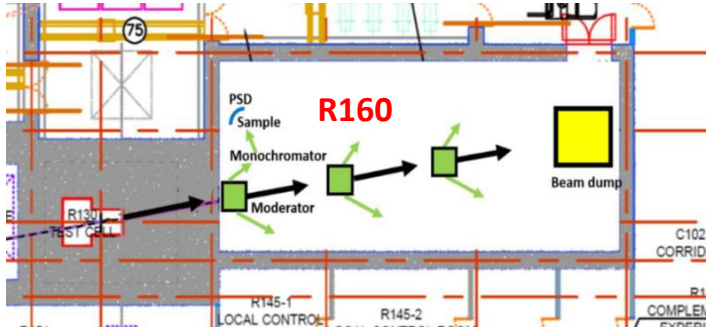
The IFMIF-DONES site in Granada, Spain

Construction phase started in March 2023

First auxilliary buildings in construction since 2021

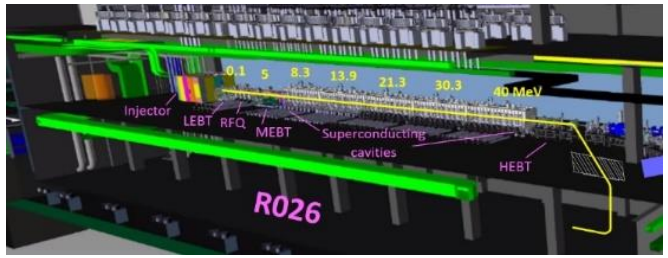


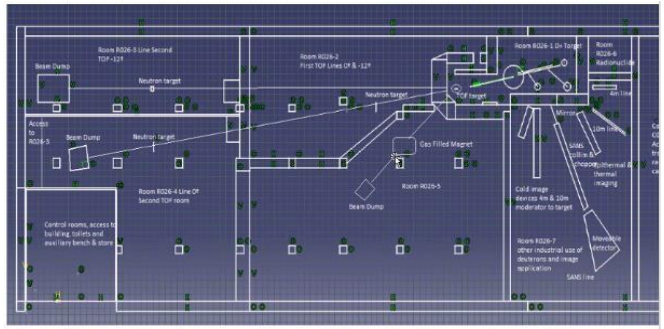
Areas for non-fusion experiments



R160: 300 m² Area

- **Same floor as the Test Cell**
- Profiting from a **continuous neutron beam** **from the TC** via a **Neutron Beam Aperture/Collimator** **(Ø20-12 cm)**
- Estimated **neutron flux at the duct exit**: **$2 \cdot 10^{10}$ n/cm²/s, 99.5% of fast neutrons**, En > 100 keV

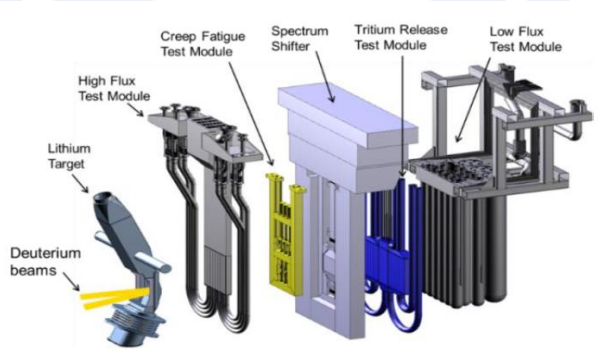




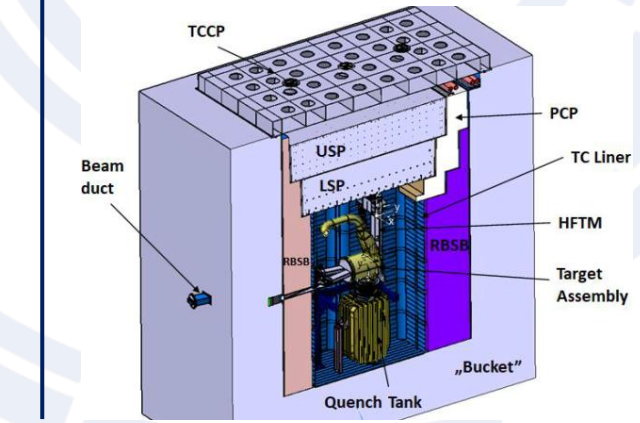
R026: 2100 m² Area

- Ground floor, below the Accelerator Vault
- Profiting from **pulsed Deuterons beam** via a beam extraction from the accelerator
- **Deuteron extraction at 40 MeV** (0.1 % intensity)
- Experiments **using deuterons & pulsed neutrons** (by neutron production with a target)
- Neutron Time-of-flight facility TOF-DONES

Other fusion test modules

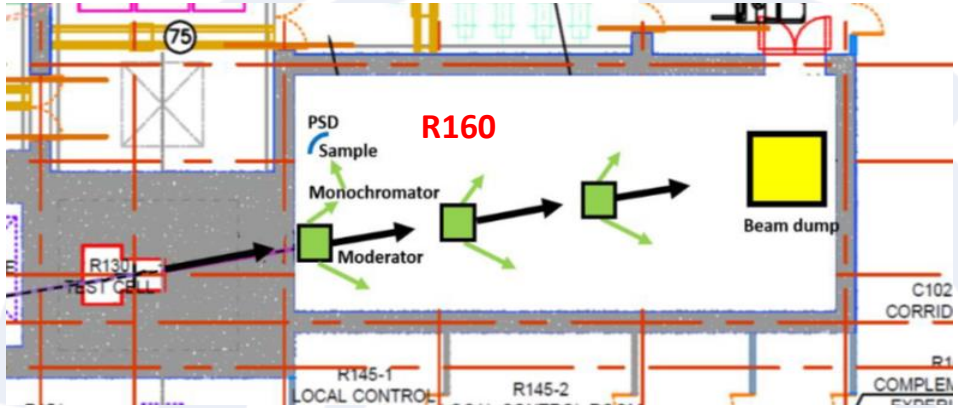


- In Test Cell, behind the HFTM
- Testing e.g. Tritium breeding technologies



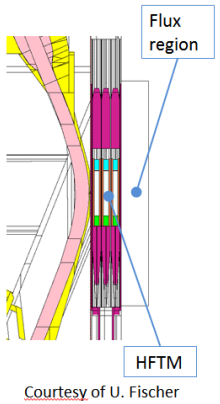
Collimated neutron beam facility

Continuous neutron beam $2 \cdot 10^{10}$ n/cm²/s,
99.5% of fast neutrons, E_n > 100 keV

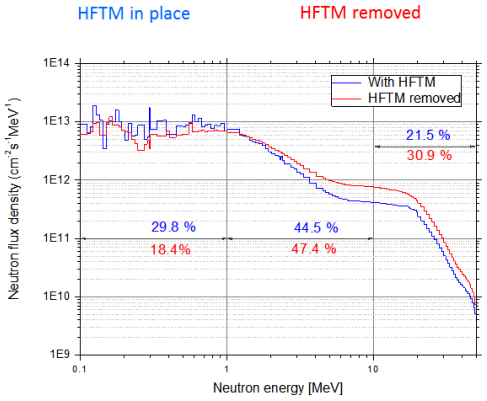


1) **Experiments** with **samples exposed to neutrons:**

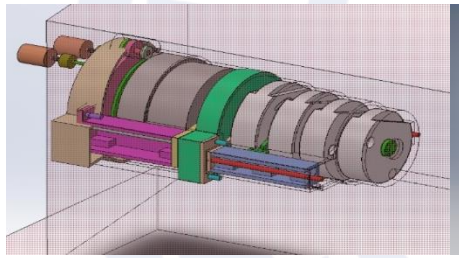
- Activation of small samples by neutrons
- **Characterization of materials** by radiation analysis
- **Neutron imaging**
- **Fast neutron irradiation of components**, devices or bio-samples

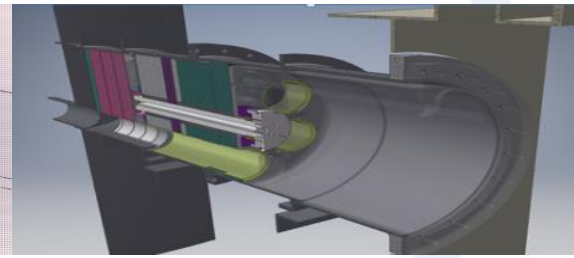


Courtesy of U. Fischer



Continuous energy spectrum,
collimated beam
~ 98% neutrons, θ < 1°

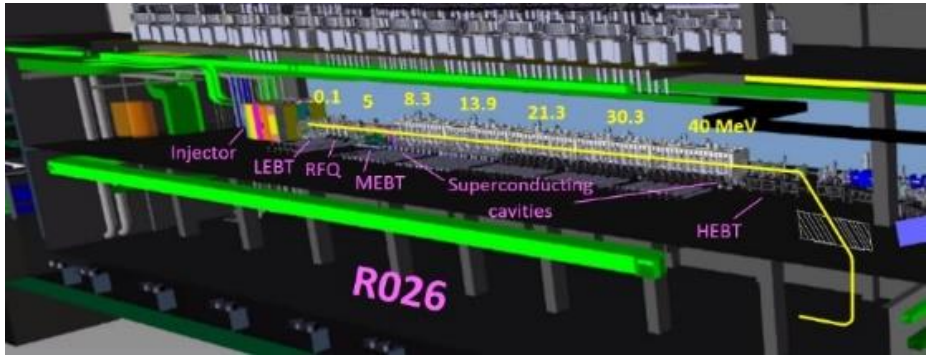


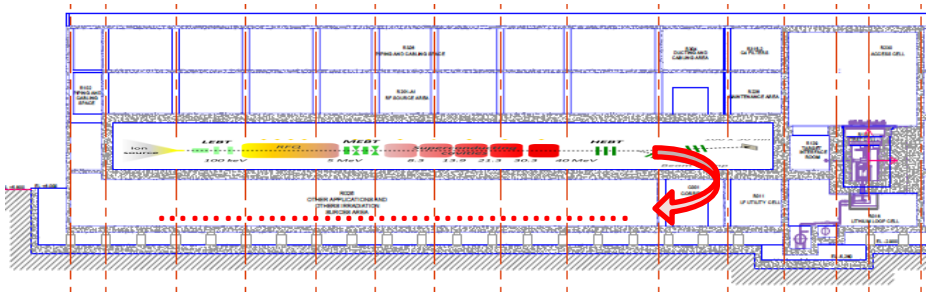


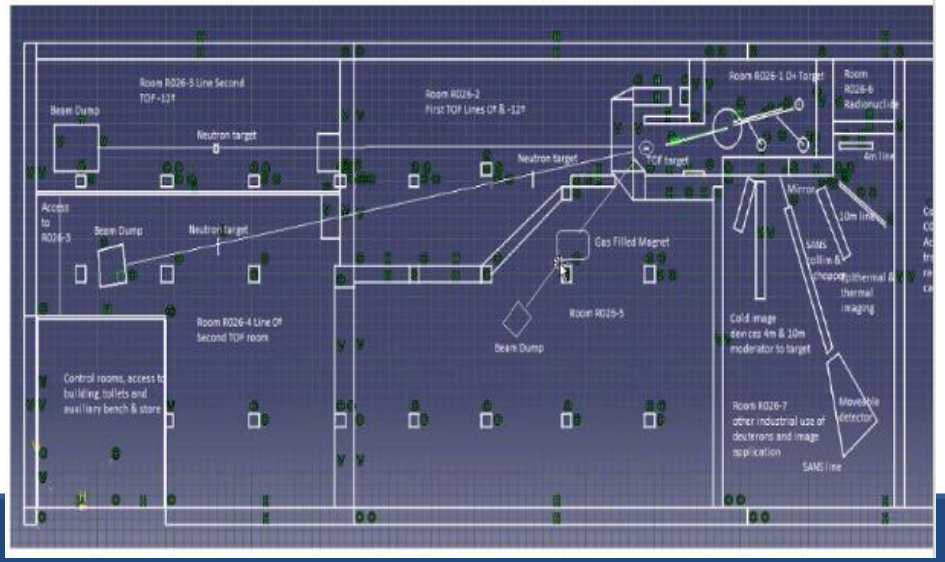
A neutron transport line with shutter is designed to operate experiments in this area independently of the Test Cell

2) Neutron scattering experiments with moderated beams
3) **Fundamental** particle **physics** studies

TOF-DONES Neutron time-of-flight facility







Extracting a **pulsed Deuteron beam at 40 MeV**
(meander line of 3.5 m + electrostatic septum + septum magnet)
Planned at 0.1 % total intensity → 0.125 mA

Secondary neutron target (C target considered)
Timing characteristics: 5.6 μs pulsing (1.9 ns beam-on)

1) Experiments using Pulsed Neutron Beams (nTOF):

- **Cross-section** measurements for neutron induced reactions, for nuclear technologies/fission reactors, fusion, astrophysics

  Ca. 52 isotopes listed in the **High Priority Request List** for nuclear technologies
  Over **35 (n,γ) prioritary cross-section measurements** for astrophysics

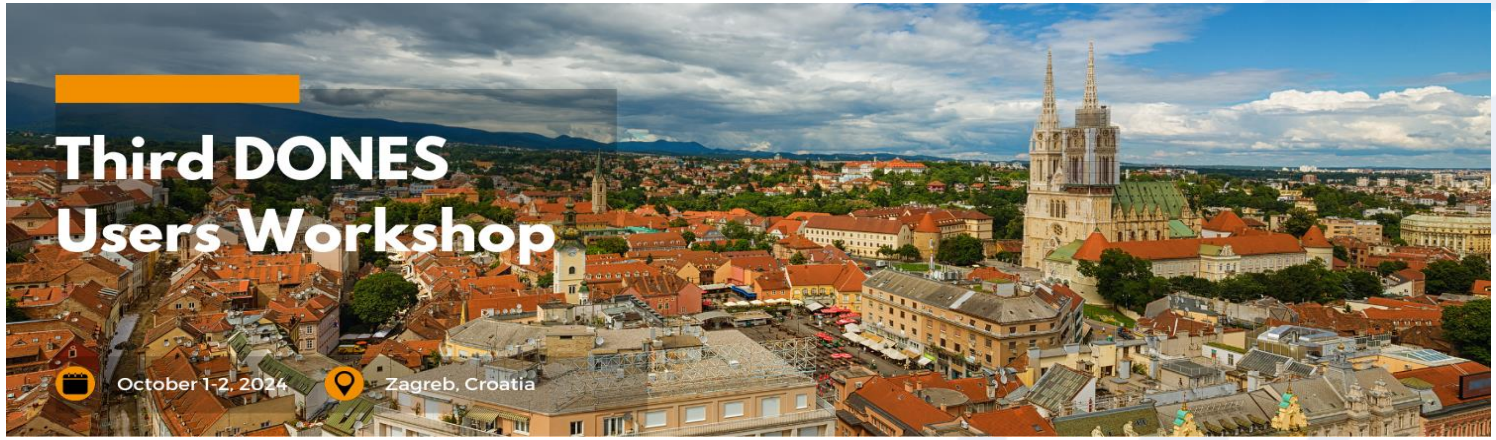
- **Gamma-spectroscopy** of the nuclei produced in fast-neutron-induced fission reaction
- **Half-life measurements** of long-lived isotopes

2) Experiments with pulsed Deuteron beam also possible

IFMIF-DONES Users Community

Zagreb, Croatia
October 1-2, 2024

Registration and call for abstracts are open



Planned sessions and open discussions:

- Material qualification for DEMO and the fusion program
- Tritium breeding technologies validation at DONES
- Irradiation program proposal

fusion

- Collimated neutron beam facility at DONES
- Nuclear physics and neutron time-of-flight facility
- Life science - medical and biological application of neutrons
- Industrial and cultural heritage application of neutrons
- Consolidation of DONES users community

non-fusion

https://indico.ifmif-dones.es/e/DONES-UsersWS3

Contact: users@ifmif-dones.es

Summary and outlook

„Materials qualification is one of the key pending issues in the development of fusion as an energy source”

1. The IFMIF-DONES facility will be built for the irradiation and qualification of fusion reactor materials
   → *the construction phase has started!*

2. The IFMIF-DONES will also host state-of-the-art experimental activities in other scientific areas

- ***A collimated neutron beam facility*** allows IFMIF-DONES to be a first class laboratory for techniques using fast neutrons and an *irradiation facility using mixed neutron/gamma radiation fields*

- The extraction of a deuteron pulsed beam will make IFMIF-DONES into a ***first class nTOF facility***

3. Your ideas and inputs to the DONES Users community are encouraged!

EUROfusion DONES ConP1 IFMIF DONES GRANADA

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