14TH INTERNATIONAL CONFERENCE OF THE CROATIAN NUCLEAR SOCIETY

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ITER and DONES projects overview and perspective

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Content

- Introduction EURO fusion
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- ITER Project
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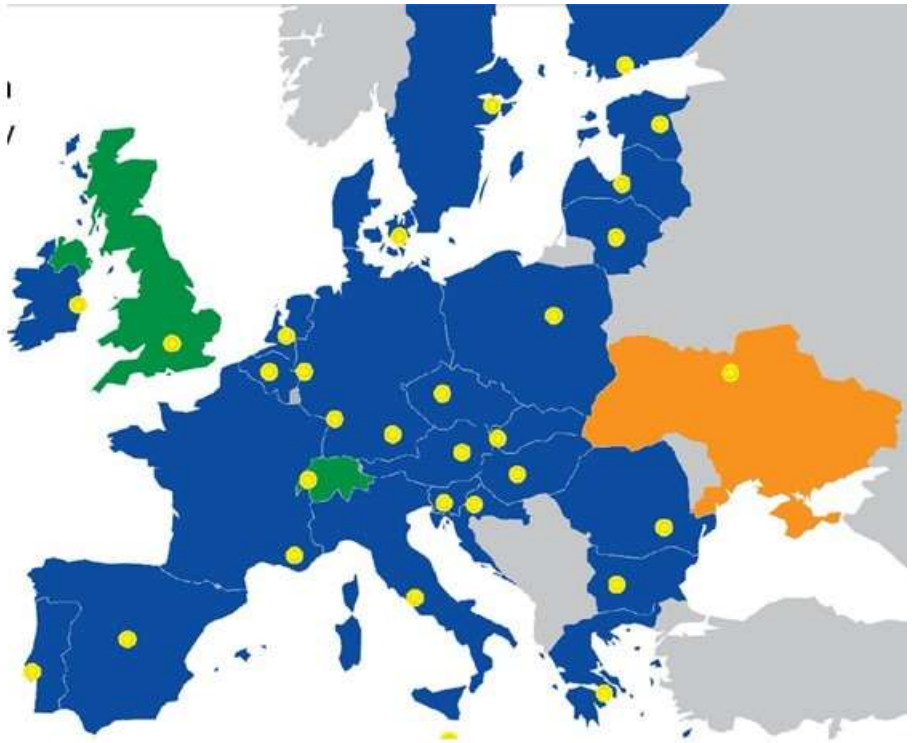
- Conclusions

EUROFusion

- The idea of the ITER project was outlined in **1985**
- On October 9th, 2014, fusion **30 research organisation bodies** from European Union member states and Switzerland signed an agreement to cement European collaboration on fusion research (Ukraine joined 2017).
- **Budget:** €440 million from EURATOM H2020 AND €410 million from member states

Croatia actively participates in EURO fusion research

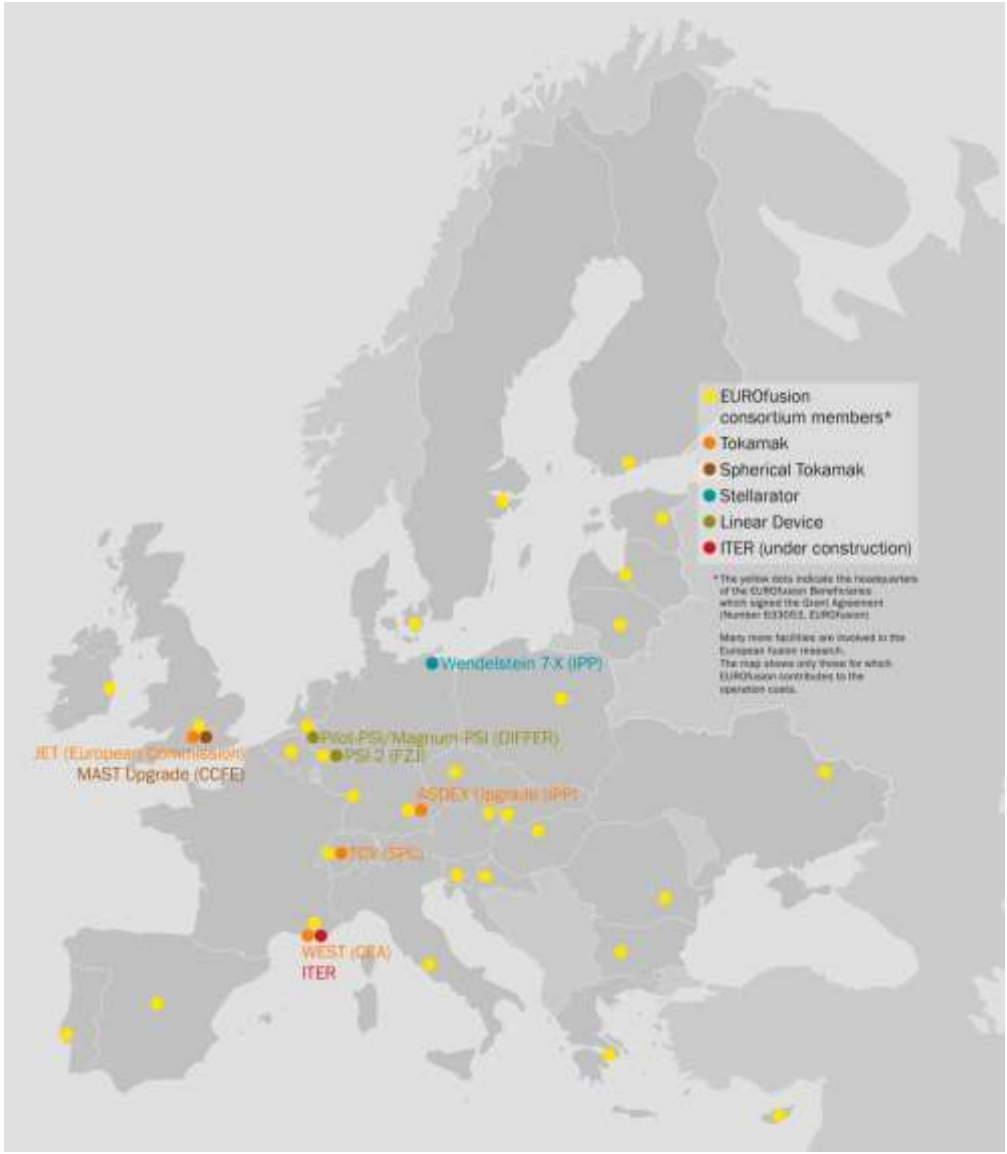
CROATIAN FUSION RESEARCH UNIT



Industrial Partners

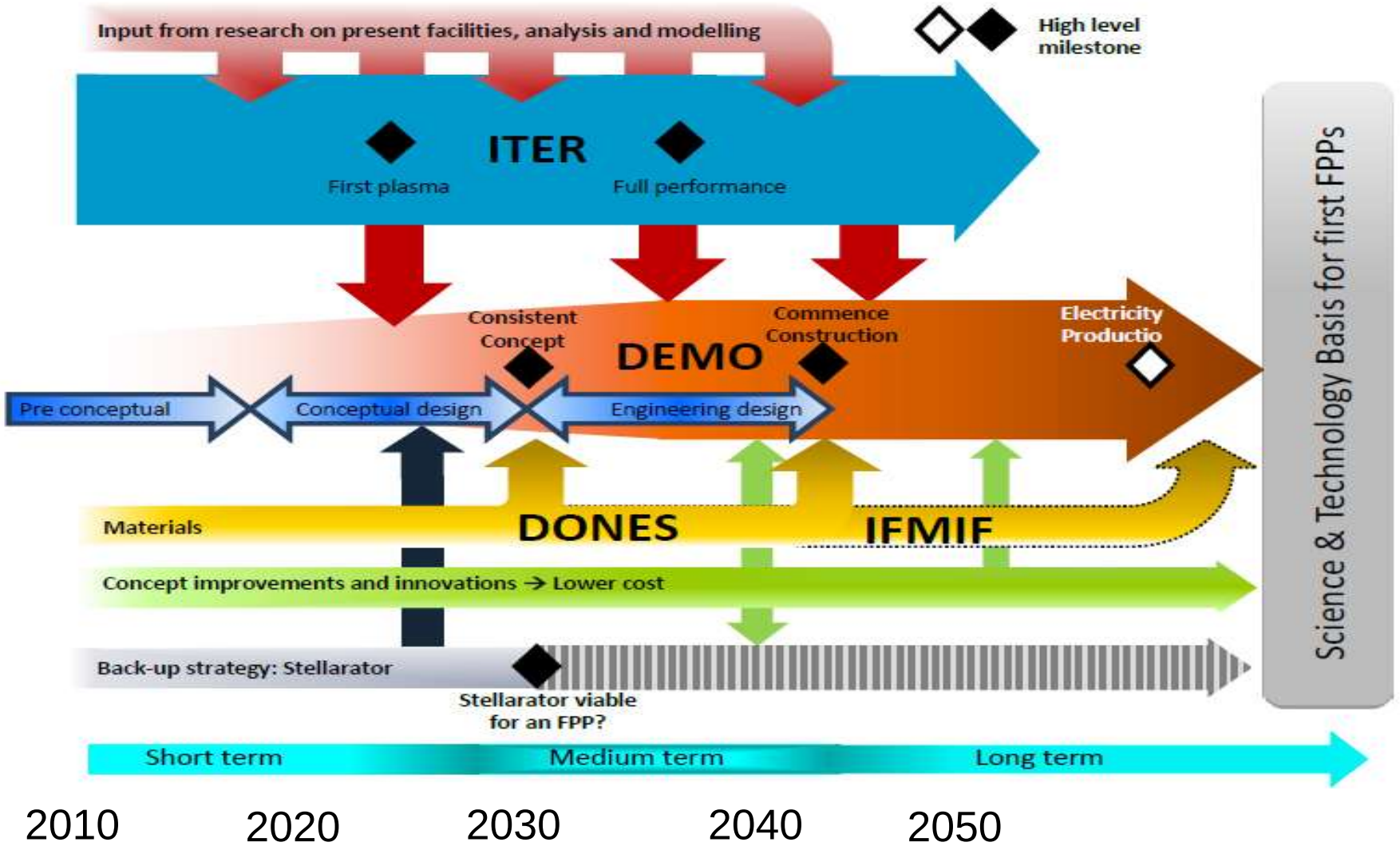
Fusion experiments

- JET, the Joint European Torus is EUROfusion's flagship device
- Other experiments that contribute directly to the Roadmap missions:
  - Medium Sized-Tokamaks: ASDEX Upgrade, MAST Upgrade, and TCV.
  - Linear Devices: Magnum PSI, PSI-2
  - Other tokamaks: WEST
  - Stellarator: Wendelstein7-X



EU Fusion Roadmap to Fusion Electricity (v2.0)

APoS



ITER Project

- At the heart of all EURO fusion activities lies ITER, the next generation fusion experiment which is currently being built in France.
- Once built, ITER will pave the way to making fusion energy a reality
- **Cost:**
  - Construction cost **€15 billion**
  - Europe's Domestic Agency 'Fusion for Energy' manages **€6.6 billion**

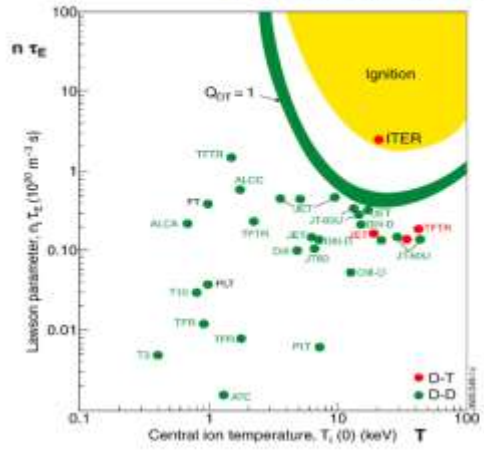
ITER BUDGET

ITER – the new generation

Scientific goals:

- to demonstrate the feasibility of fusion as an energy source
- to prove integrated operation of technologies for a fusion power plant
- to test concepts for a tritium breeding module
- to produce **500MW** of fusion power, **10 times the input power**

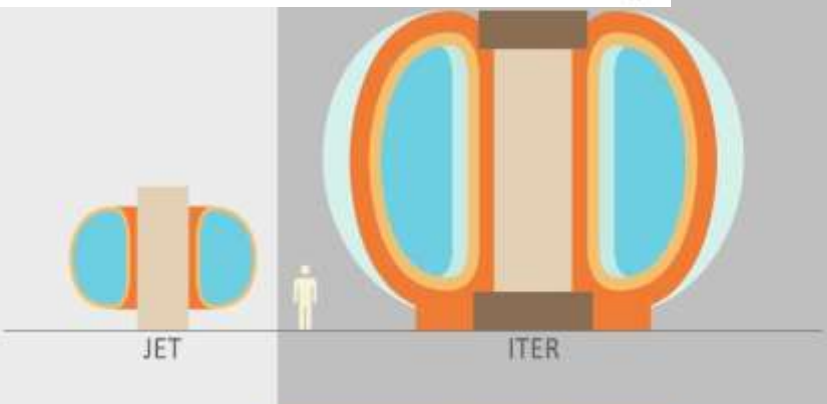
Lawson Criterium



Triple product criterium to achieve ignition:
the fusion of D+T

$$n_e T \tau_E \geq 10^{21} \mathrm{keV\ s/m^3}$$

n_e – density
T – temperature
τ_E – confinement time

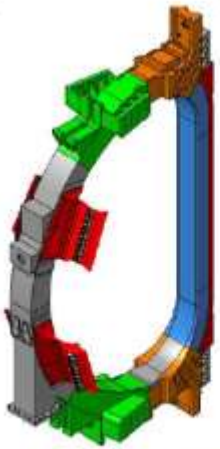


	JET	ITER
Radius	3 m	6.2 m
Volume	90 m^3	840 m^3
Power factor Q	0.65	10
Fusion Power	16 MW	500 MW

Illustration of complexity

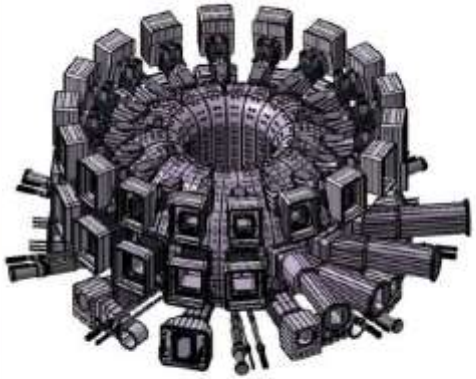
APoS

TF Coil – Mass



Mass of 1 TF Coil:
16 m Tall x 9 m Wide, ~360 t

Boeing 747-300
(Maximum Takeoff Weight) ~377 t

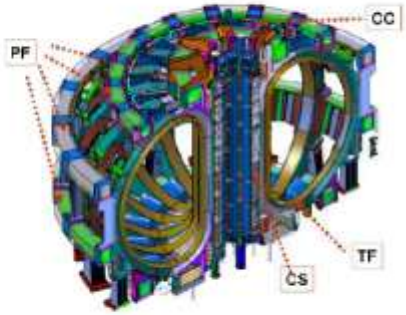


VV & In-vessel components mass:
~8000 t
19.4 m outside diameter x 11.3 m tall

Eiffel Tower mass:
~7300 t
324 m tall

ITER Magnetic Field

Earths Magnetic Field
~ 0.5 gauss or 0.5×10^{-4} Tesla



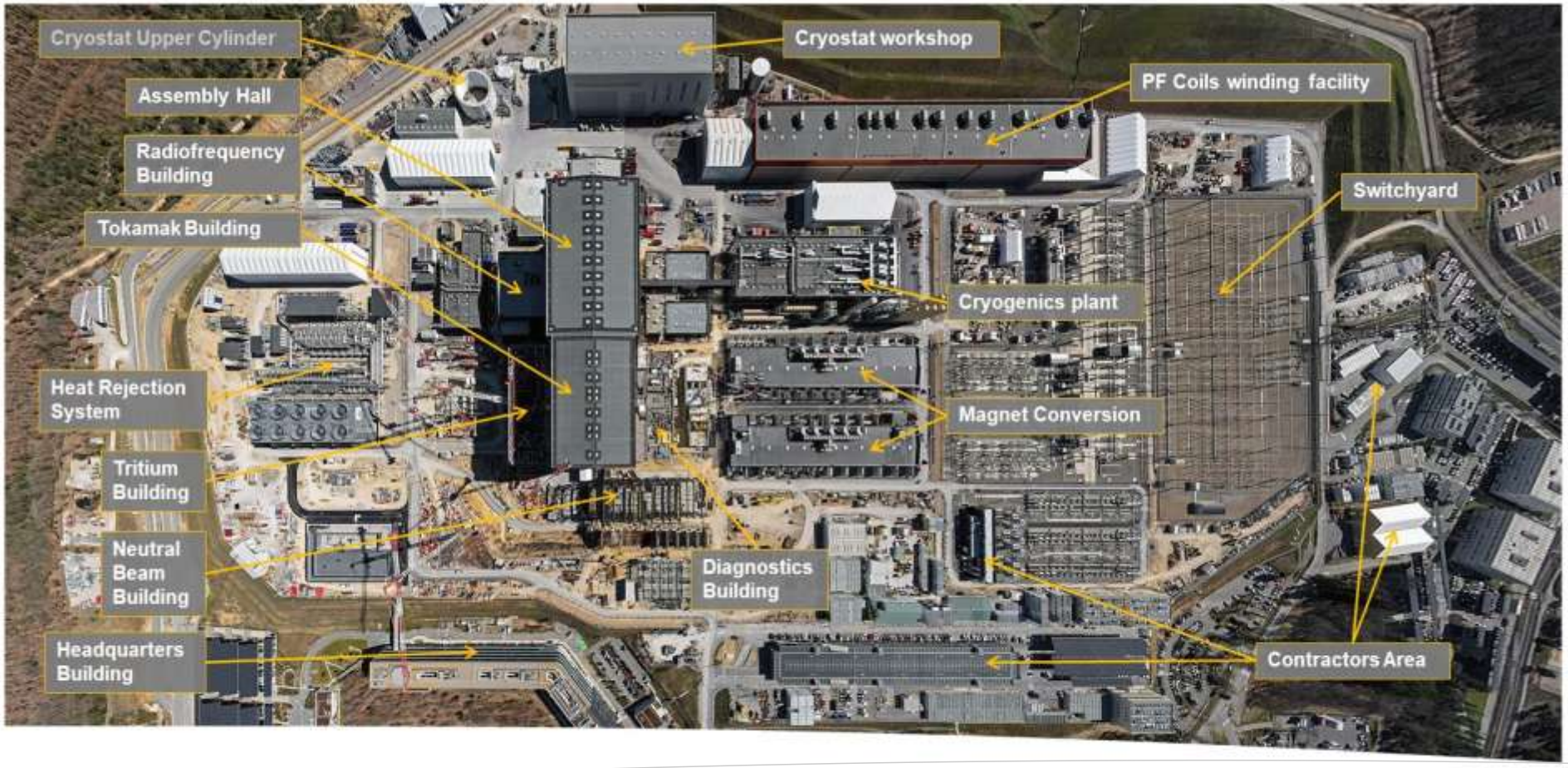
ITER Field
~10 Tesla or 200,000 x Higher

Realising fusion electricity

- Looking beyond ITER, EUROfusion researchers and engineers are working on designing DEMO, the demonstration power plant that will hook fusion electricity to the grid and show that fusion can help meet our future energy needs

ITER WORKSITE CONSTRUCTION

Aerial perspective, June 2024

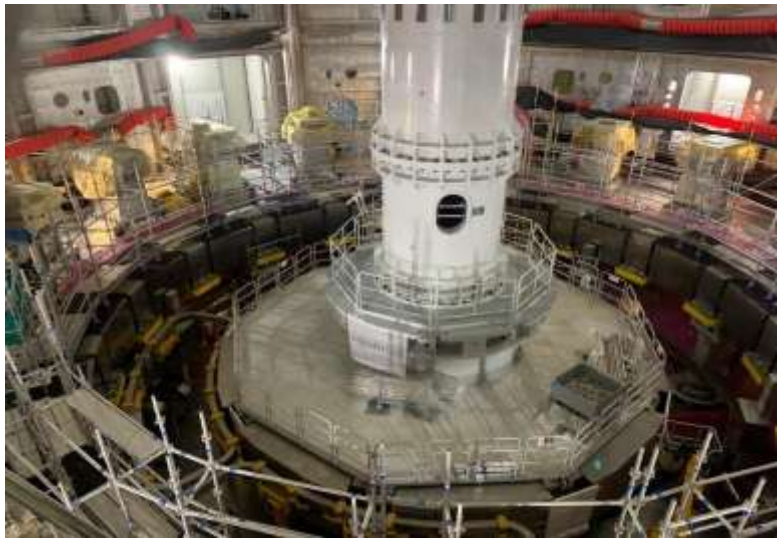


Components Delivery

- Main components delivered since 2020:
  - 16 TF coils (out of 18+1 spare)
  - 4 PF coils (plus 2 close to be manufactured)
  - 3 vacuum vessel sectors (out of 9)
  - 2 Central solenoid modules (out of 6+1 spare)
- All main Cryostat components manufactured
  - Cryostat Base and Lower Cylinder are installed in the tokamak pit
  - Last item manufactured was Cryostat Top Lid
  - Upper Cylinder and Top Lid in storage positions, April 2023

ASSEMBLING THE MACHINE

- Tokamak Pit shown ready to receive the first Vacuum Sector Module, November 2021
- Preparation of two Vacuum Sector Modules in Assembly hall in parallel (Sectors 6 & 7), 2022
- First complete Vacuum Vessel Sector Module installation, May 2022



CHALLENGES OF FIRST-OF-A-KIND COMPONENTS

FROM BERYLLIUM TO TUNGSTEN

The ITER Organization is currently advocating to change the First Wall material from Beryllium to Tungsten. The final choice is pending the ITER Council's decision.

OVERBUDGETING & DELAYS ?

- A common phenomenon for projects funded in the Public Sector

Graphic: EUROfusion, Reinald Fenke, CC BY 4.0, www.euro-fusion.org, data: ITER Organization

Original schedule (current delay 3-5 years)

- ITER will start operation in the 2020's.
- ITER will run experiments with real fusion fuel in the 2030's.

ADDRESSING CHALLENGES

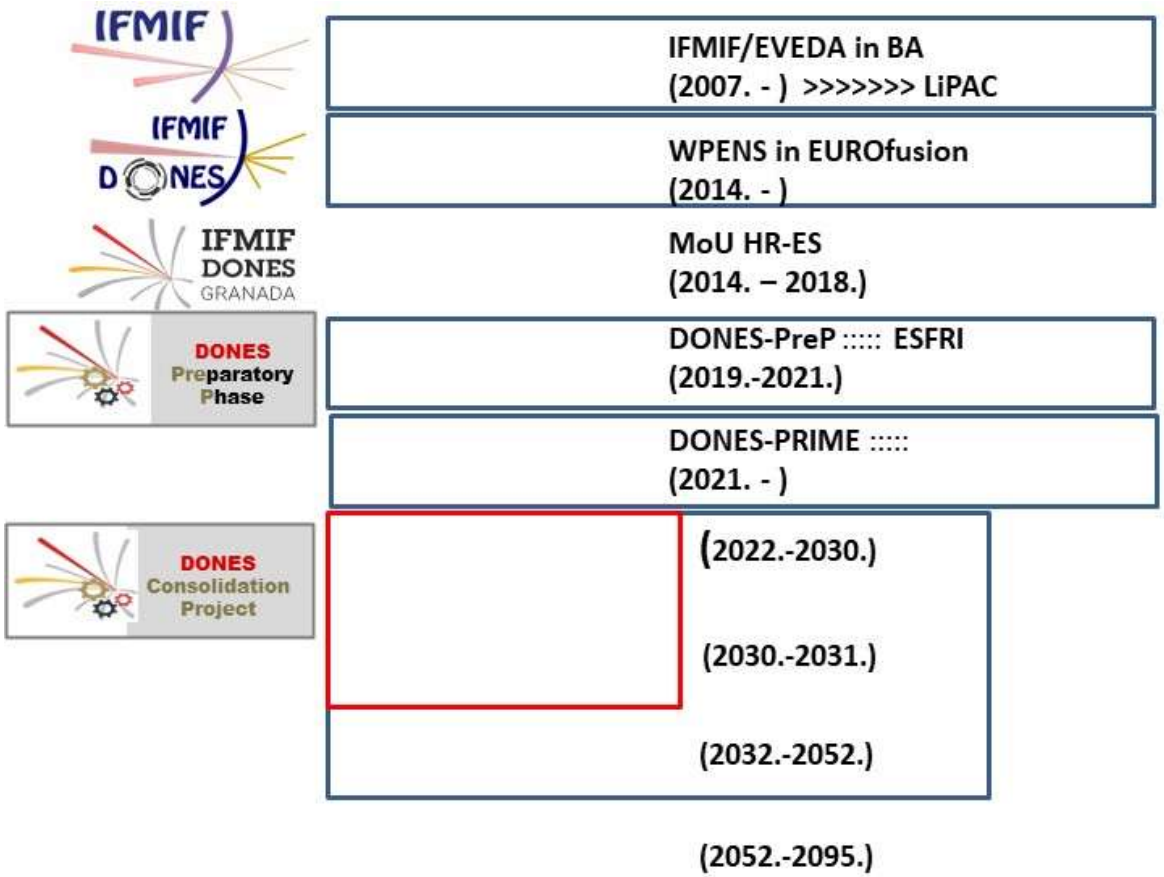
The current ITER cost and schedule “baseline” was set in 2016. Given recent challenges, a review of the baseline is underway, and a new baseline proposal will be presented to the ITER Council in 2024.

Key challenges and considerations include Known delays created by the Covid-19 pandemic and First-of-a-Kind technical challenges.

- Repairs to the Vacuum Vessel sectors and Thermal Shield cooling pipes, as described earlier.
- Ensuring mutual alignment with ASN, the French nuclear safety regulator, on any concerns.
- Ensuring a strong quality culture, project-wide.
- Opportunities to offset future risks by further testing of completed components.
- Adjustments to the scope of First Plasma (the first experimental campaign) or machine design elements that could add efficiency while preserving performance goals.

A new baseline proposal will be presented to the ITER Council in 2024.

IFMIF-DONES Facility



DONES Program Mission

To develop a data base of fusion-like neutron irradiation effects in materials materials

DONES Program Objectives

- To provide a neutron source producing high energy 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 workprogram

The DONES Facility

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

DONES Basis
DEMO Oriented Neutron Source

APoS

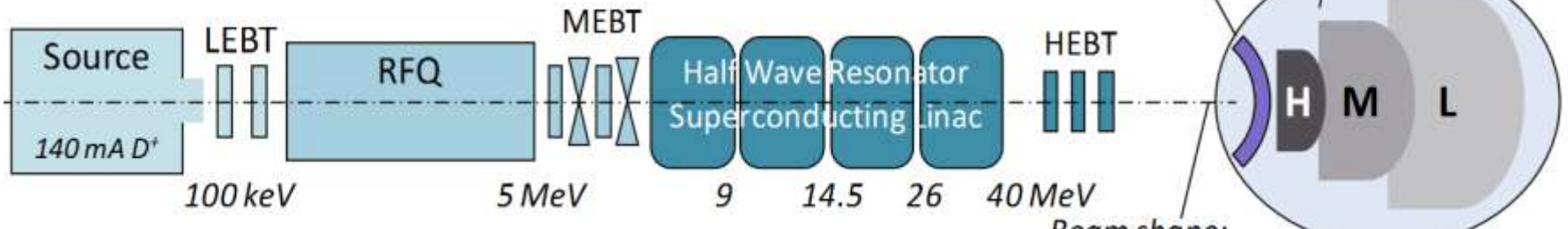
Accelerator beam

(125 mA)

"Waterfall" of liquid lithium

$25^{\pm 1}$ mm thick, 15 m/s

Target Chamber

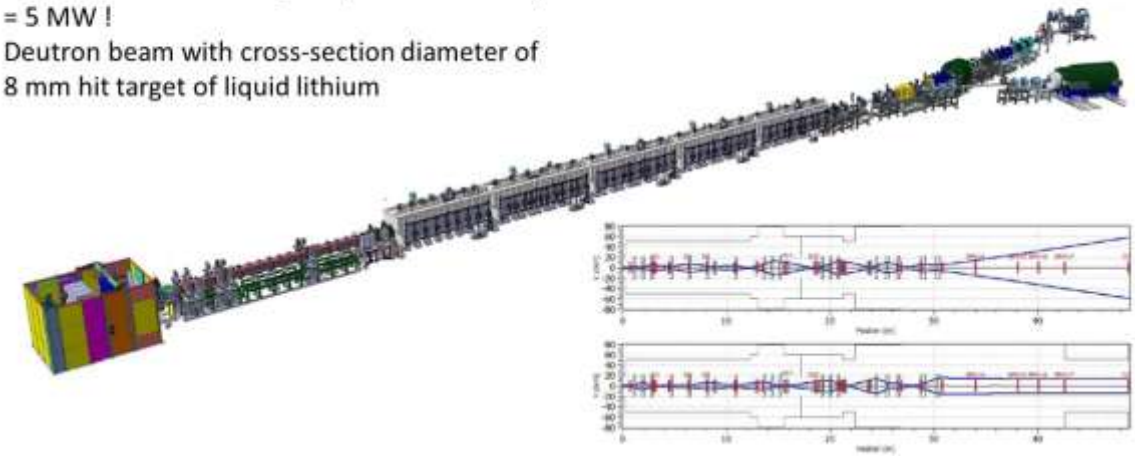


Beam shape:
200 x 50 mm²

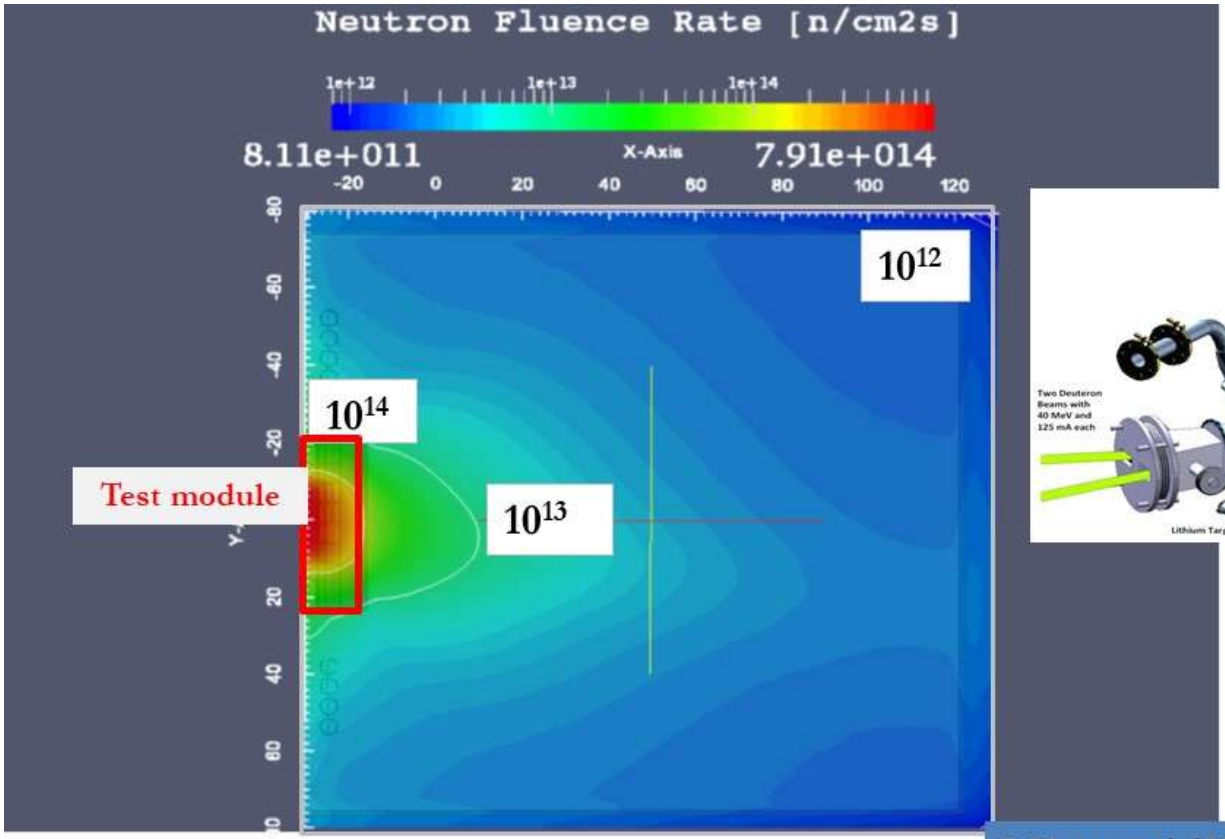
High (>20 dpa/y, 0.5 L)
Medium (>1 dpa/y, 6 L)
Low (<1 dpa/y, > 8 L)

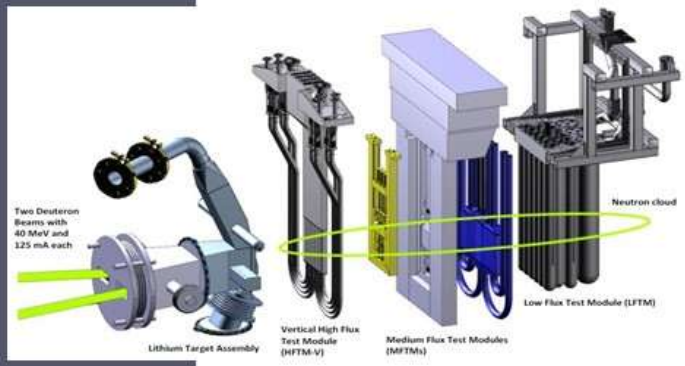
Fast neutrons around 10^{14} n/cm²s

Accelerator DONES-a highest power in history
= 5 MW !
Deutron beam with cross-section diameter of
8 mm hit target of liquid lithium



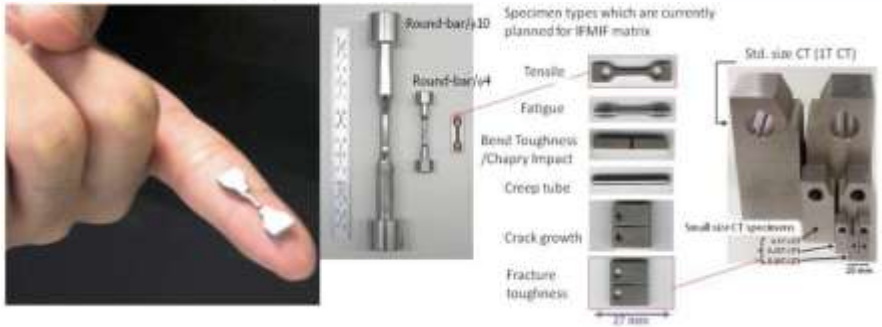
DONES Basis
DEMO Oriented Neutron Source





F. Mota et al. (2015)

DONES

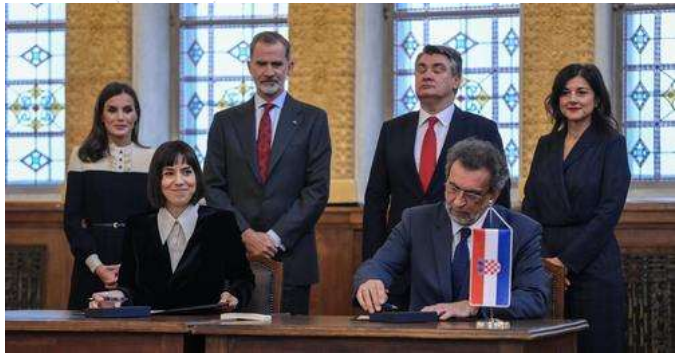


IFMIF-DONES Facility

The site is located at Escúzar - 18 km southwest from Granada city- Spain

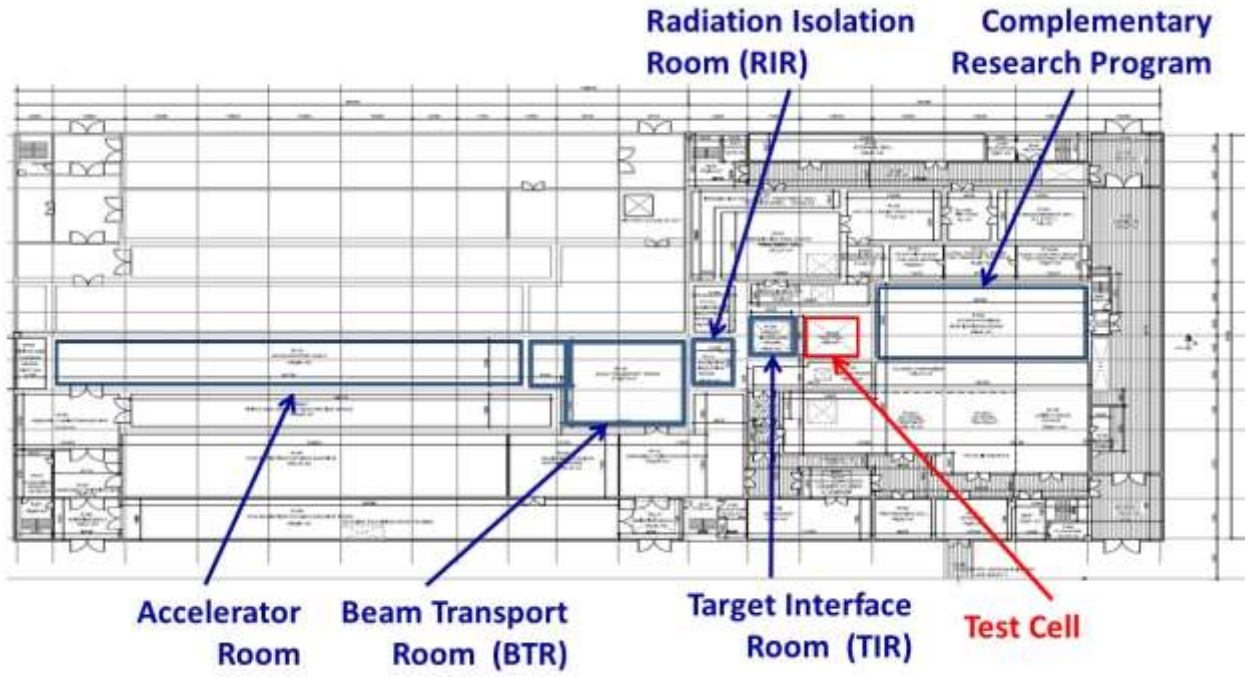
Spanish - Croatian site selected by EU

DONES



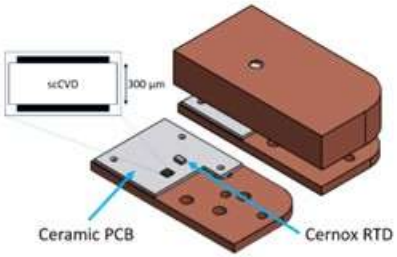
Project DONES started officially by signing the agreement HR-ES on 17.11.2022 in Zagreb

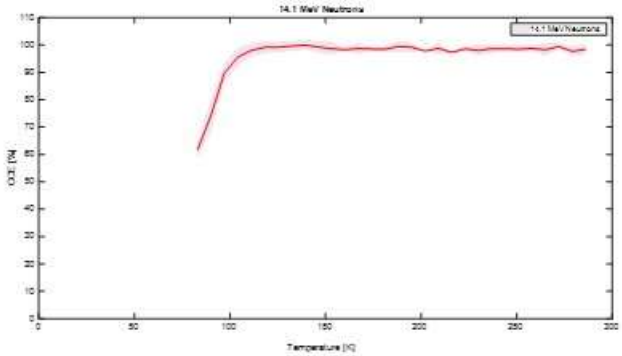
IFMIF-DONES Facility



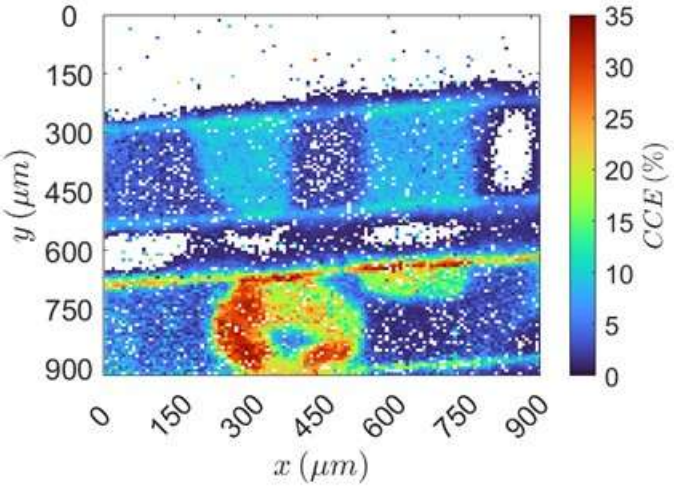
Croatian fusion research highlights @ IFMIF-DONES

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





Assessmentof neutron induced damage in electronics at DONES

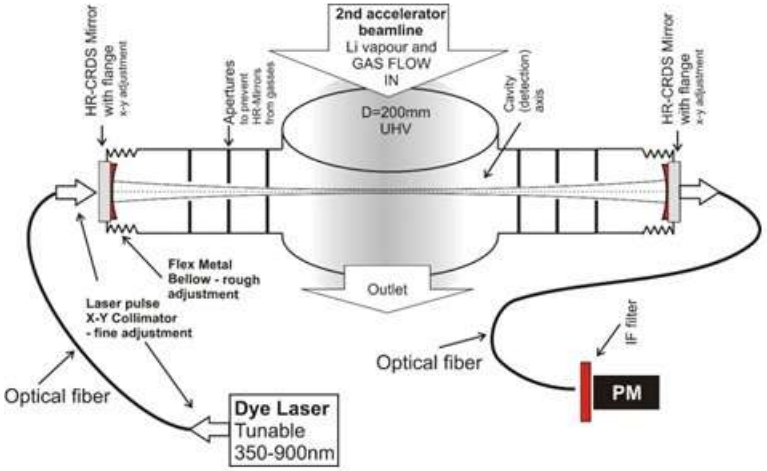


IRB Zagreb

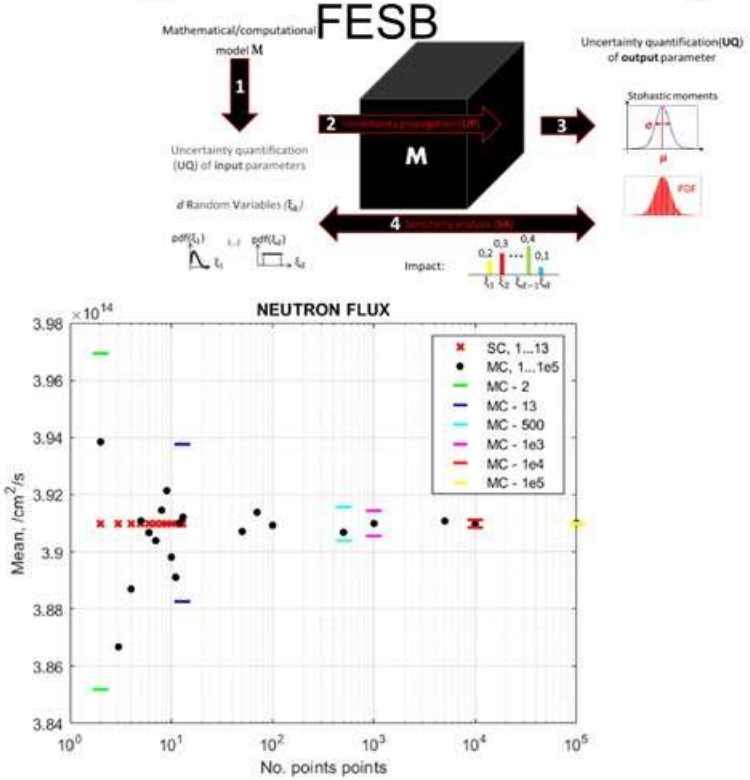
Croatian fusion research highlights @ IFMIF-DONES

APoS

Cavity Ring-Down Spectroscopy laser systems for lithium evaporation monitoring by IF



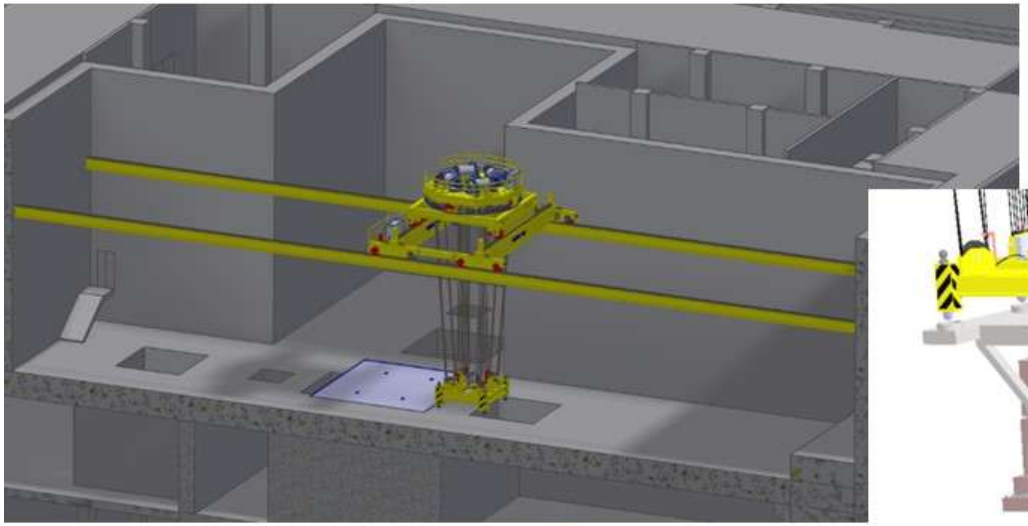
Assessment of error propagation in tuning of DONES accelerator by FESB

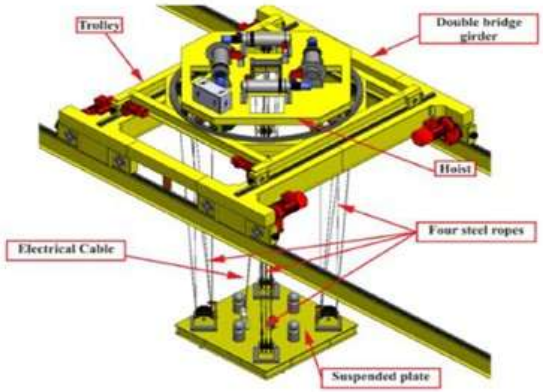


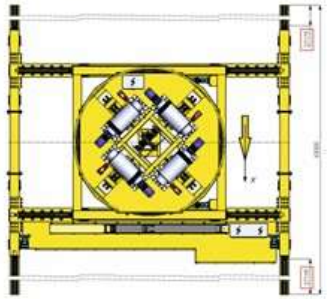
Croatian fusion research highlights @ IFMIF-DONES

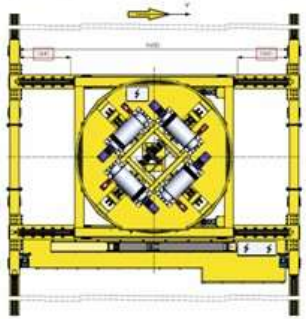
APoS

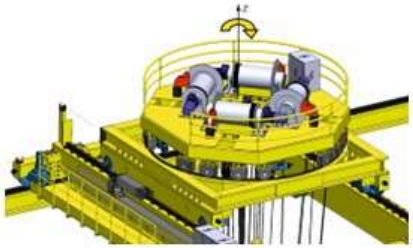
Heavy Rope Crane – HROC INETEC & FSB

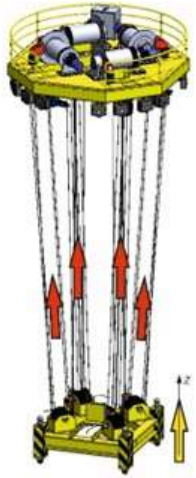


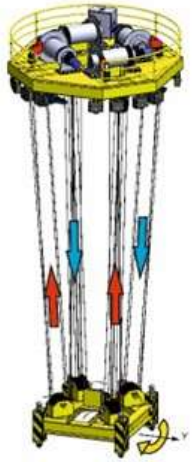






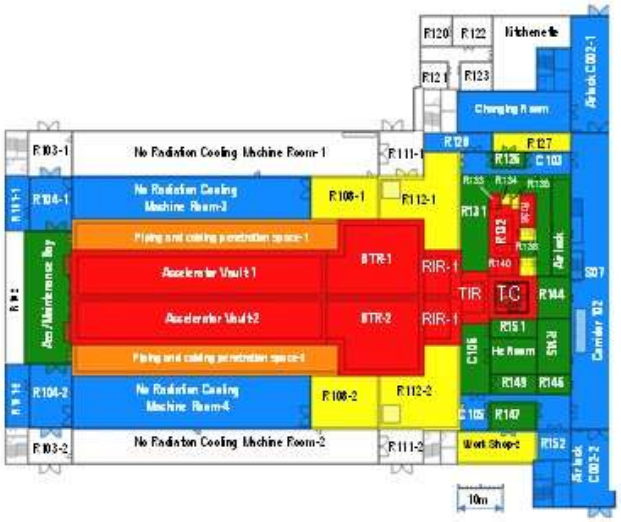




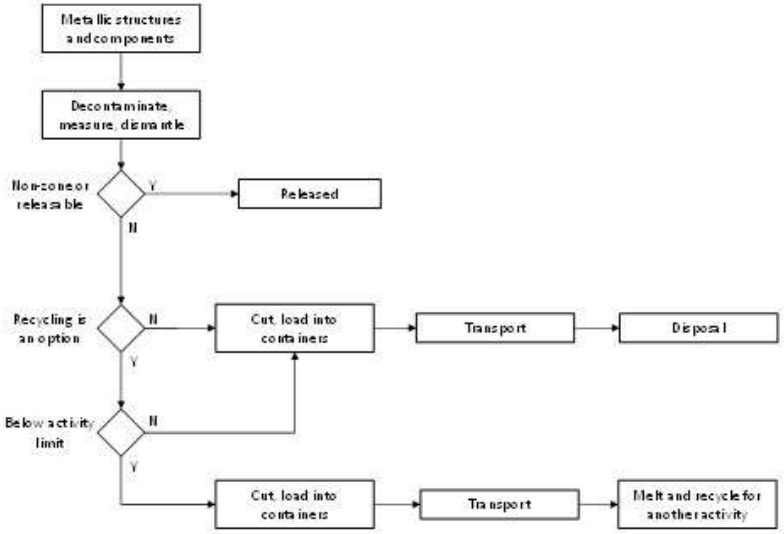


Croatian fusion research highlights @ IFMIF-DONES

Radiation monitoring and personnel dosimetry at DONES



DONES decommissioning strategy RBI in partnership with APOSS



Croatian fusion research highlights @ IFMIF-DONES

Preliminary assessment of radiation induced damage at components in TIR, IRB & APOSS

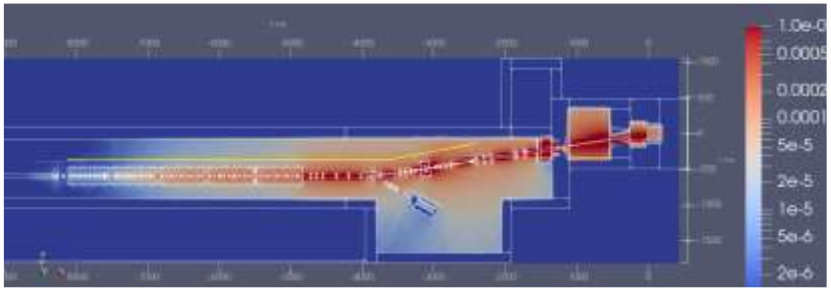


Figure 1: Dose rate [μSv/h] calculated using stainless steel as tube material

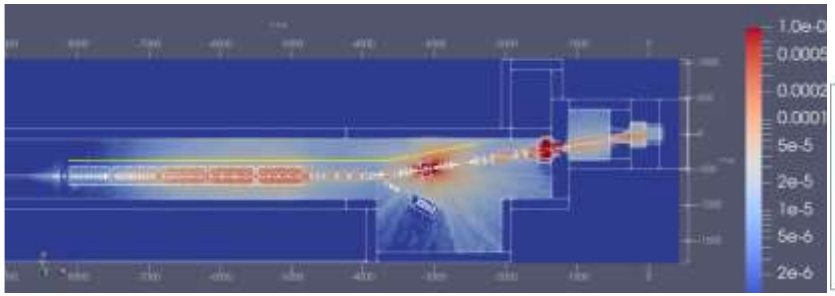
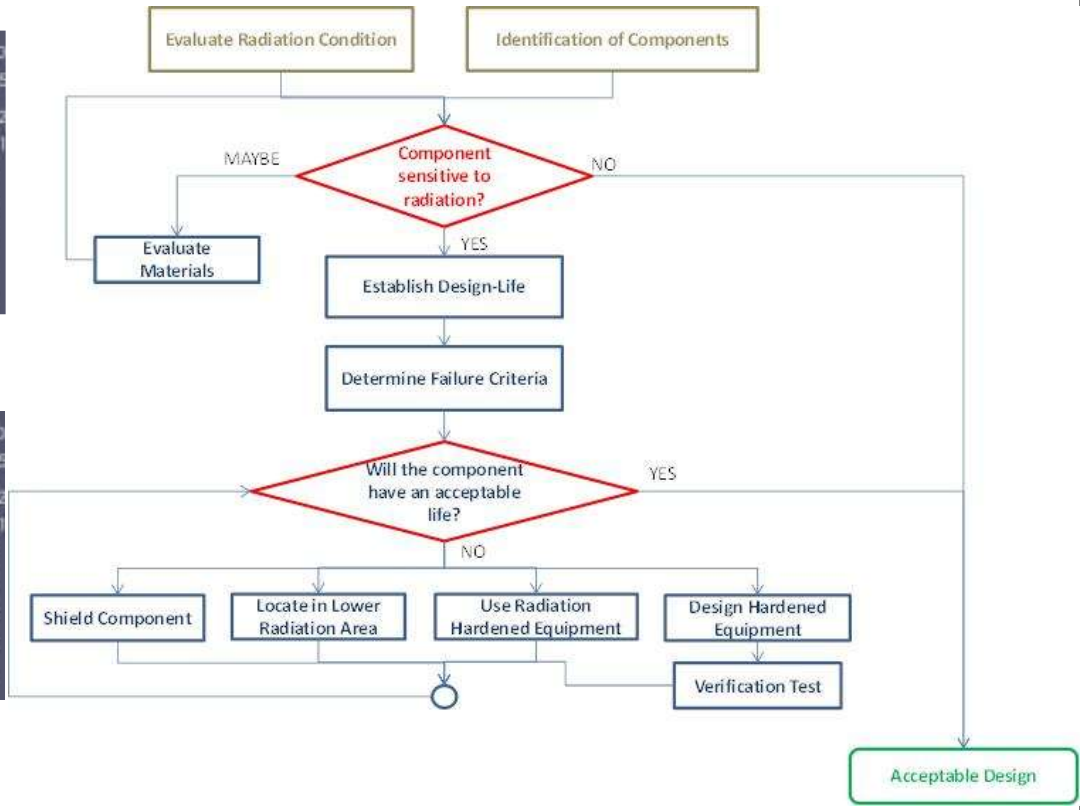


Figure 2: Dose rate [μSv/h] calculated using Aluminum as tube material



Conclusions

- ITER has addressed major technical issues (e.g., non-conformance report on delivered components) and made huge efforts to implement corrective actions on repair work. A new baseline will be established in June 2024.
- In participating to the ITER Project with the IO and/or the Domestic Agencies, the Industry develops competencies that will be key for the next steps of the fusion programme.
- The ITER Project and Industry together have to find economically efficient solutions to a great technical challenge requiring high skills and experience with the latest technologies, nuclear fabrication, and construction.
- IFMIF-DONES project started successfully, civil works on going, final design are polishing…

END

Questions?
Comments?

Thanks for your attention!