

Preparation of ITER Operation, WPPrIO

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DE LA RECHERCHE À L'INDUSTRIE

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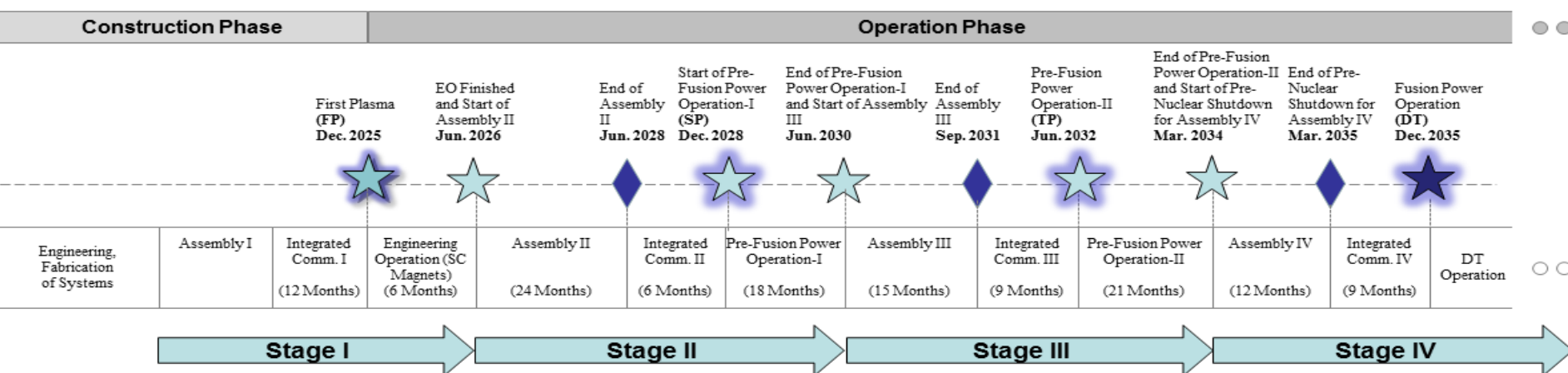


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Major evolution during Horizon Europe



- From ITER Design, Construction to **Operation**
- **Maximise EU return for the large EU investment into ITER with a strategic vision towards DEMO**
- **Guide the DEMO design**
- As a consequence EU programme will strengthen
 - Operational aspects (Engineering and Physics)
 - Operational tools and simulation capability: ITER and extrapolation to DEMO





Horizon Europe: from ITER Construction to Operation

- **Nuclear facility** with safety and nuclear licensing issues
- Complex **integrated operation** and Big Data era
- Goal driven programme towards ITER objectives
- Scenario optimisation in D-T mix once in nuclear phase
- **Sustained burning plasma** with dominant alpha heating
- Test DEMO technologies
- **Master operation** with systematic simulation and RT control (machine protection/safety)

EUROfusion role in ITER operation and scientific exploitation ?



- **2 Sub-Groups* set by the GA :**
 - **Scientific and organizational aspects**
 - **Recommendations to GA (2020) may lead to some evolution of WPPrIO**
- **EU involvement in terms of activities that will**
 - **lead to strong EU involvement in ITER operation for ITER success**
 - **impact significantly the EU DEMO studies (design and operation)**
- **Ongoing analysis of “ITER sub-systems” procured by EU in which European team must be involved during the operation**
 - **maximize return on investment and the lessons learned**

[*A. Grosman/J. Pamela et al]

Analysis on the required involvement for relevant EU implication in ITER operation and Impact on DEMO



- **TF & PF Magnets, Cryoplant**
- **Remote Handling Equipment**
- **Divertor and Plasma Facing Components**
- **Heating and CD systems**
 - Electron Cyclotron resonance heating, Neutral Beam and Ion Cyclotron resonance heating systems
- **Vacuum Pumping & fueling**
- **Diagnostics and control**
- **Tritium Plant**
- **Test Blanket Module (TBM)**
- **Waste and Radiological Protection**
- **ITER Integrated Modelling & Analysis Suite (IMAS) and development of analysis/operational/simulation tools**

[Working Group's "EUROfusion role in ITER operation and scientific exploitation"]



- Contribute to lay the foundation of a **coordinated significant EU participation in the ITER Team** benefiting from the strength of the EU programme in **operation, technology and simulation**
- Contribute to position EU as a leading actor in ITER scientific exploitation
- Integrate EUROfusion activities in line with the Roadmap priorities in liaison with F4E and ITER-CT
 - Prepare ITER operation
 - Develop validated tools for exploiting ITER
 - Train operational team on EU facilities



- **European participation in ITER operation and scientific exploitation**
 - Shared EU strategy towards ITER operation and scientific exploitation
 - Integrated actions between EU labs (EUROfusion), ITER-IO & F4E
- **Map EU labs activities in support to ITER**
 - Contracts with ITER-IO , F4E
 - Scientific activities: ITPA, Operation Network , fellowship ...
- **Map EUROfusion WP activities in support to ITER**
- **Contribute to develop a coordinated training scheme for ITER (operation, Engineering) in consultation with ITER-IO and F4E**

Prepare ITER operation

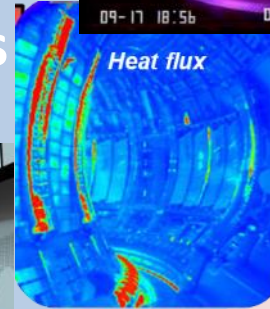
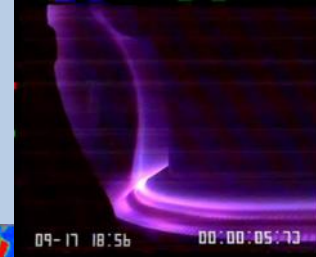


Operation

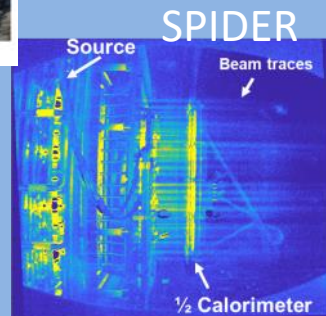
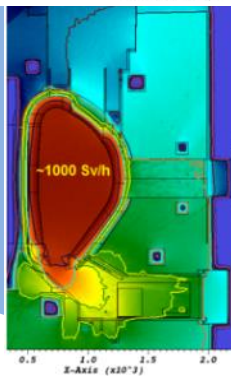
Scenario and RT Control

Operational tools

Training on EU facilities

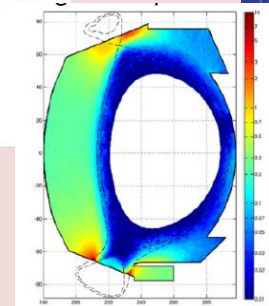
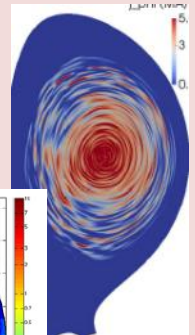
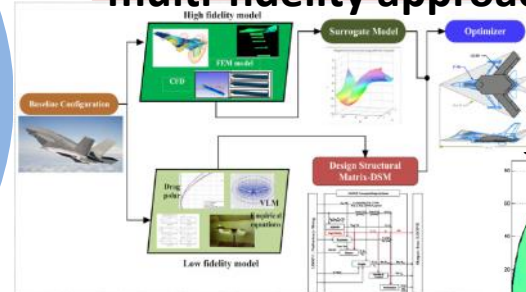


Technology



Simulation

multi-fidelity approach



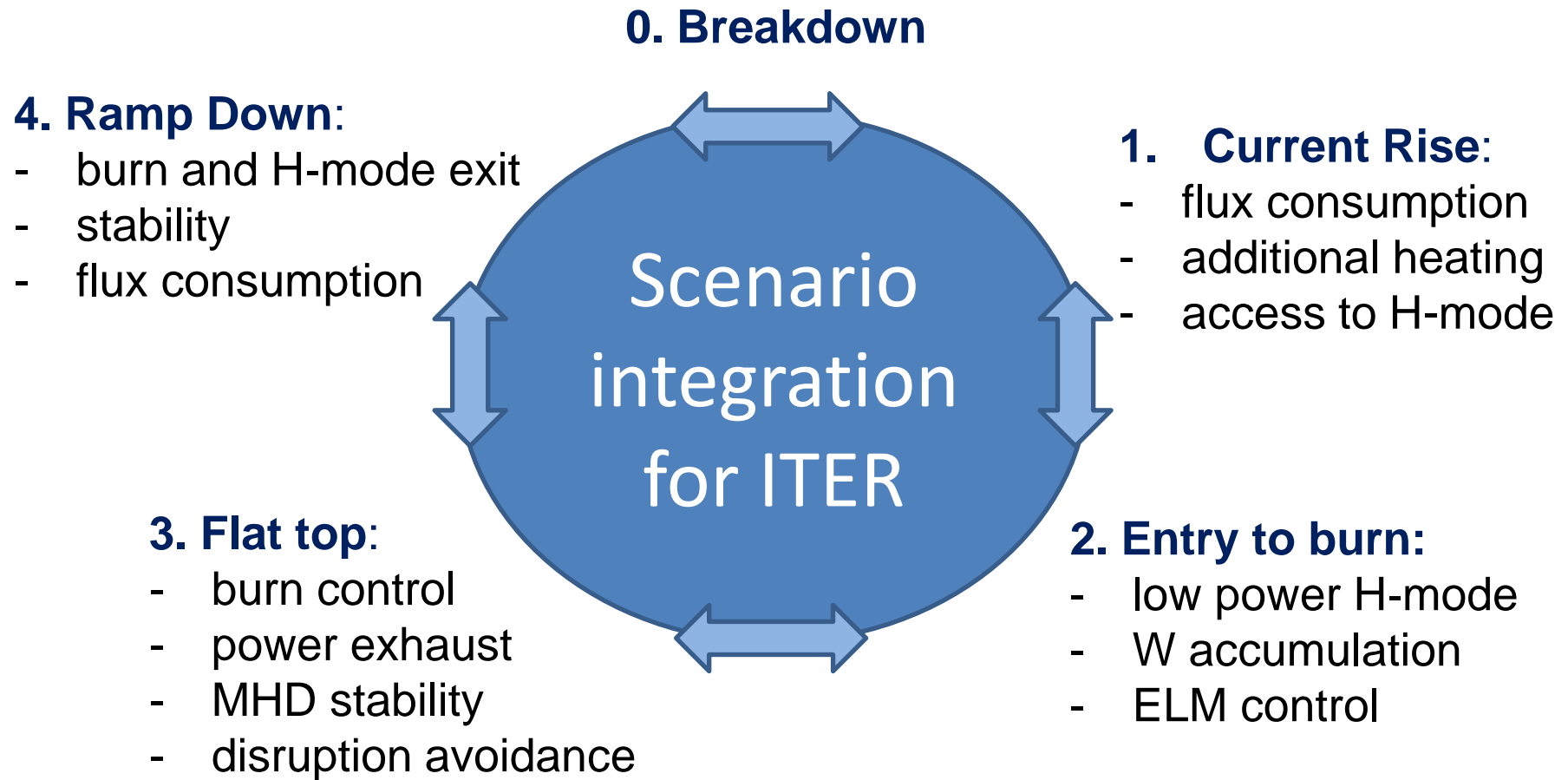


Three sub-projects :

- 1. Operation, simulation and analysis/operational tools**
 - 2. ITER nuclear technology**
 - 3. Technology and R&D for the ITER Neutral Beam**
- For each sub-project a EUROfusion task coordinator or sub-project leader should be nominated**
 - 1 Project Support Officer at CEA/Cadarache**
 - Liaise with EUROfusion WPs, F4E and ITER-CT**
 - Ready for pragmatic evolution during Horizon Europe**



Individual parts that are inter-linked





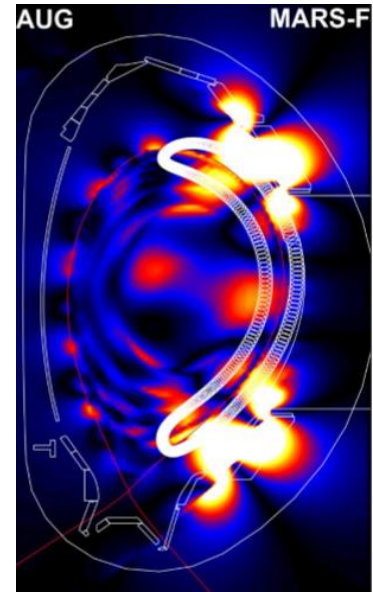
- **EUROfusion tools development and validation for**
 - ITER data consistency and interpretative data analysis
 - analysis of Big Data (~ 2 PB per day !)
 - first plasmas and initial operation
 - ITER pulse preparation taking into account the machine limits
- **Contribute to the implementation, exploitation and validation of IMAS in the EU facilities**
- **Provide integrated simulations of plasma scenarios for the various operation phases of the ITER schedule**
 - from initial plasmas to non-nuclear and nuclear phases of operation
- **Develop training in support to ITER operation on activities related to future EU involvement in ITER**



- **Predictive workflows for simulations of ITER operation from breakdown to termination respecting plant limitations**
 - continuous cycle of improvement with validation on EU facilities
 - different levels of sophistication (multi-fidelity approach): free-boundary equilibrium, core-edge coupling, H&CD , fuelling, wall protection
 - synthetic diagnostics
- **Fast simulators for pulse preparation and real-time control**
 - reduced models implemented in IMAS
 - Implementation and validation on EU facilities
- **Simulation tools for ITER initial operation for optimizing breakdown conditions, wall conditioning including machine protection**
 - test tools and train EU staff on facilities
- **Data analysis tools to handle Big Data**
 - develop automated data processing
 - implement IMAS data analysis/visualisation tools on EU facilities

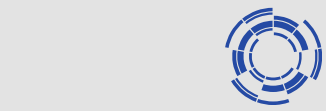
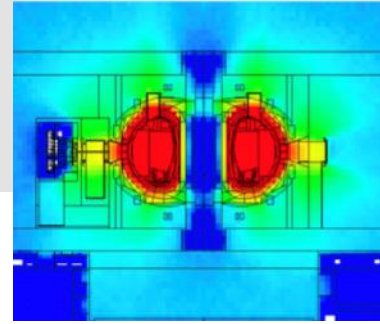


- **Develop an integrated vision from measurement, operation, control, data consistency and simulation**
- **Participation in ITER Diagnostics design activities**
 - Based on EU expertise to provide relevant ITER assistance
 - EUROfusion participation in the design of ITER Fast Ions Lost Detectors (University of Seville) jointly with ITER-CT (agreement to be finalised)
- **Development of synthetic diagnostics and operational tools in support of the EU diagnostic procurements in liaison with F4E/ITER-CT**
 - E.g. Wide-Angle Viewing System, neutron camera, bolometers, charge exchange recombination spectrometer, collective Thomson scattering,

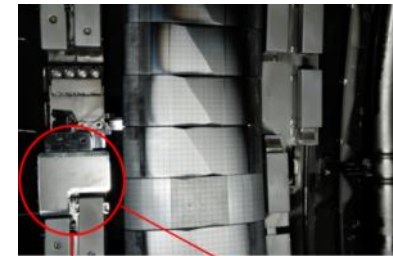
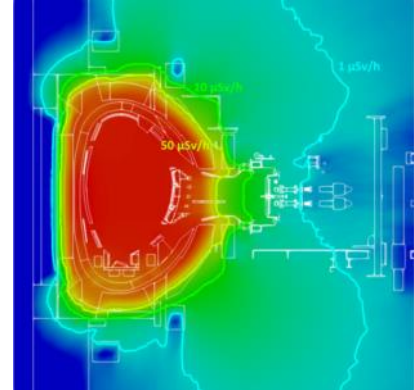


ITER nuclear technology [1/2]

- **Transfer knowledge from JET to ITER**
 - JET D-T 14 MeV neutrons: consistent fusion tokamak nuclear test prior to ITER
 - Operating a tritium plant
- **Validated nuclear codes for ITER licensing, operation, machine activation: neutron transport code, neutron streaming, shutdown dose rate**
- **Neutron induced activation in ITER materials (sim./exp.)**
- **Measure tritium production rate inside a TBM mock-up**
- **Water Activation experiment for ITER cooling system**
- **Validated methods to measure accurately ($\leq 10\%$) the fusion power on ITER and Tritium accountancy**



Activation map



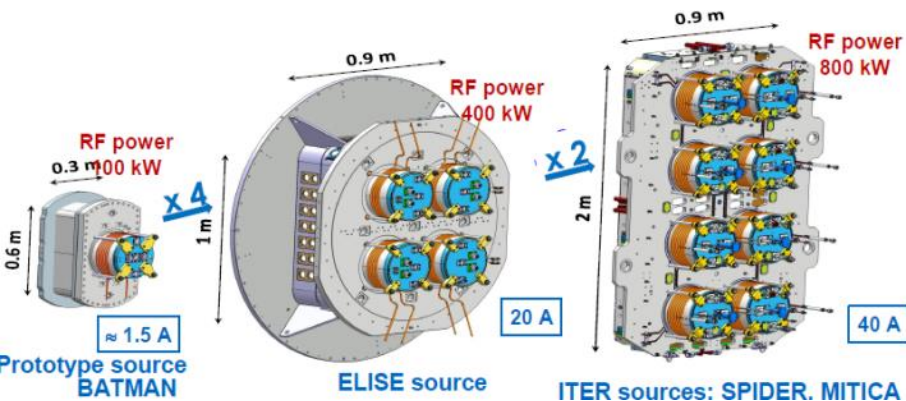


- **Support JET DT programme with two planned DT campaigns in 2021 and in 2023**
 - With 14 MeV neutrons budget of 13×10^{20} (2021) and 3×10^{20} (2023)
 - Programme beyond 2021 subject to decisions for the budget planning for FP9 (and Brexit decision)
- **Activities to be extended beyond the support to JET programme addressing direct ITER needs including nuclear waste management and characterization**
- **Develop synergy with the fission R&D expertise**

Technology and R&D for ITER Neutral Beam [1/2]



- Contribution to the optimisation of the ITER 1MeV NB operation
 - extracted ion current of 40 A, 16.5 MW for 1h!
 - Experiments and simulation programme
- Coordination of the EUROfusion participation in the NBTF operation at Padova (Consorzio RFX)
 - full-size ITER negative ion sources (SPIDER)
 - full-size ITER 1 MV NB (MITICA) (1MV holding in the accelerator & injector)
- Coordination of the scientific exploitation of RF driven sources (IPP-Garching) in synergy with NBTF
 - size scaling and source behaviour in long pulses
 - BATMAN Upgrade (1/8th size ITER-like)
 - ELISE (half ITER-like source) with 4 RF drivers



Technology and R&D for ITER Neutral Beam [2/2]



- **Cooperation Agreement signed with the ITER Organization Consorzio RFX and EUROfusion**
 - experts from European labs (up to 14 ppy/y) to work on the neutral beam project at ITER's facility in Padua
- **NBTF Advisory Committee :**
 - to evaluate the implementation plan and the progresses of the NBTF
 - EUROfusion has proposed experts to be officially nominated in November during next NBTF Steering Committee
- **In addition, 6 ppy/y for activities on ELISE (and when required on BATMAN Upgrade) in IPP/Garching in support for NBTF**
- **WPRIO set-up periodic meetings to coordinate activities in ELISE in support to the ITER NB development performed in NBTF**



- **Transverse activities in support to ITER, e.g.**
 - Tokamak Exploitation, JT-60SA, W7-X: ITER experiments, validation of the ITER tools, JET D-T, long pulse operation, operation of JT-60SA Negative NBI
 - Adv. Computing Hubs: IMAS implementation in EU facilities, Big Data
 - PWI & Exhaust: ITER first wall issues and heat exhaust modelling
 - E-TASC: code development and validation in support to ITER
 - Heating & CD: Neutral Beam system
 - Design-assist Activities: consequences on DEMO design, neutronics
 - Breeding Blanket: ITER TBM, neutronics
- **Liaise with F4E and ITER-CT for ITER operation and training aspects**
 - Training of EU ITER operational team (e.g. session leaders, diagnostic, RT, H&CD systems) in EU multi-facilities and JT-60SA
- **EUROfusion participation in present structure (ITPA, fellow, ITER operation network...) and in future Topical Groups /Task Forces**
- **EUROfusion participation in ITER Research Plan revision (a la JT-60SA)**

E-TASCs projects addressing ITER high priority items (red) in FP-9



Dep.	WP	#	Title
FSD	TE	1	Physics of the L-H Transition and Pedestals
FSD	TE	2	Physics Properties of Strongly Shaped Configurations
FSD	TE/ PWIE	3	Plasma Particle/Heat Exhaust: Fluid/Gyrofluid Edge Codes
FSD	TE/ PWIE	4	Plasma Particle/Heat Exhaust: Gyrokinetic/Kinetic Edge Codes
FSD	PWIE	5	Neutral Gas Dynamics in the Edge
FSD	PWIE	6	Impurity Sources, Transport, and Screening
FSD	PWIE	7	Plasma-Wall Interaction in DEMO
FSD	TE	8	Integrated Modelling of Transient MHD Events
FSD	TE	9	Dynamics of Runaway Electrons in Tokamak Disruptions
FSD	TE	10	Physics of Burning Plasmas
FSD	PrIO	11	Validated Frameworks for the Reliable Prediction of Plasma Performance and Operational Limits in Tokamaks
FSD	W7X	12	Stellarator Optimization
FSD	W7X	13	Stellarator Turbulence Simulation
FTD	DES	14	Multi-Fidelity Systems Code for DEMO



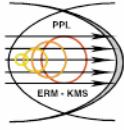
- **Call for Participation in**
 - ITER operational tools and ITER simulation (TSVV#11 under analysis)
 - Nuclear technology (beyond October 2021)
 - Confirmation of EUROfusion participation in NBTF and ELISE
- **Set-up EU contact persons network**
 - Map ITER activities within EU labs
- **Make a proposal for coordination meeting EUROfusion, F4E and ITER-CT on ITER operation (to be agreed)**
- **Develop topics on EUROfusion Engineering Grants on joint engineering activities between EU labs and ITER-IO/F4E (pending eligibility criteria)**
- **Develop training in support to ITER operation on activities related to future EU involvement in ITER**
 - E.g. IMAS, wall protection, Infra Red diagnostic operation, RF heating...
 - Develop European Operations Network

Prepare EU labs and scientists to have an active role in ITER operation

Thank you for your participation



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Laboratory for Plasma Physics
BELGIUM



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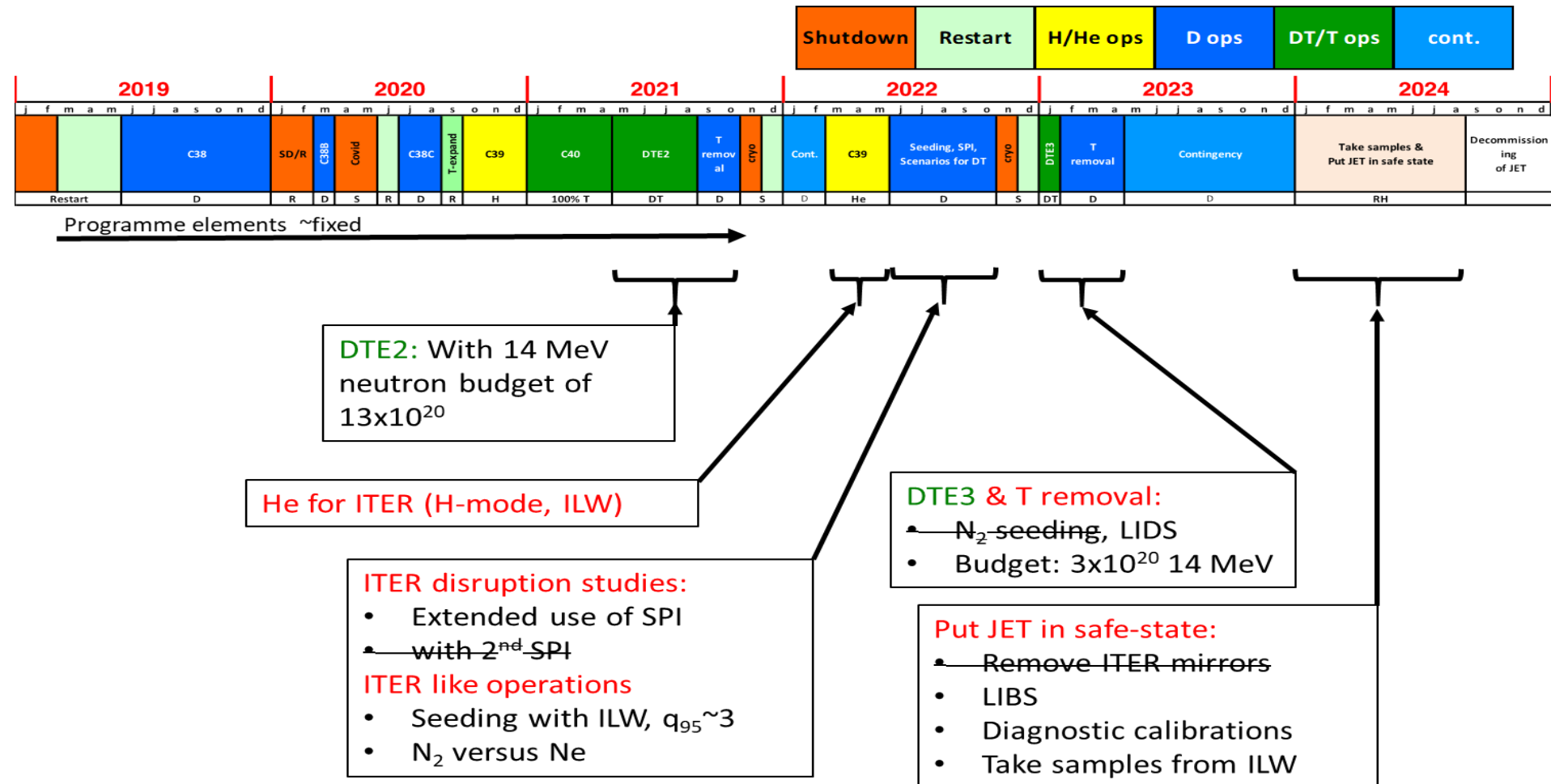
UKRAINE



Revised JET programme 2022-2024



- 10 months of contingency by removing the shutdown foreseen after the DTE2 and the installation of SPI2 and related diagnostics, ITER mirror
- Programme subject to decisions for the budget planning for FP9



Water activation experiment



Water circulating in cooling pipes activated by neutrons $\rightarrow {}^{16}\text{O}(n,p){}^{16}\text{N}$ & ${}^{17}\text{O}(n,p){}^{17}\text{N}$ reactions

- ${}^{16}\text{N}$ $T_{1/2}$ 7.13 s β decay: γ 6.13 MeV (69%) and 7.12 MeV (5%)
- ${}^{17}\text{N}$ $T_{1/2}$ 4.173 s β decay: delayed n decay (95%) and γ 871 keV (3.34%)

OBJECTIVE OF THE EXPERIMENT & ITER RELEVANCY

Validation of the **full methodology for water activation assessment used for ITER**, possibly within $\pm 30\%$, and to reduce the safety factors applied to the calculations results outside bio-shield which have large impact on the schedule, commissioning and licensing.

QUANTITIES OF INTEREST : ${}^{16}\text{N}$ decay γ spectra & dose rate

2017-2018 Feasibility study

Position

NBI scraper cooling loop located in the basement under Octant 8

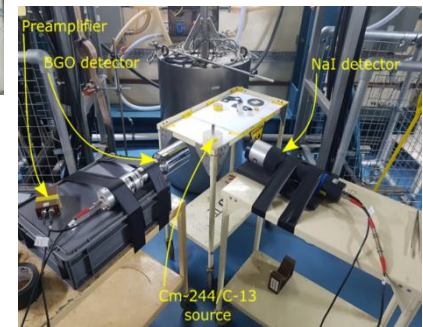
Detectors

- **Decay gamma spectra**
BGO 3" x 3" and a **NaI** 5"x6" (already available)
- **Dose rate**

1 l air-vented Ionization chamber

Pre-analysis: Calculation of expected responses from ${}^{16}\text{N}$ (counts & dose rate) at the selected position for DTE2 + preliminary background assessment

Calibration of BGO & NaI carried-out in Culham



WACT experiment «frozen» in FP8