PSD Project Board 1 April 2025

Exploitation (Enhancement and Commissioning) of JT-60SA (WPSA)
Status summary of 2024 and changes/status for 2025 compared to AWP

Carlo Sozzi

With contributions of Gloria Falchetto, Matteo Iafrati, Juan Ayllon, Jeronimo Garcia, Alessandra di Bastiano (PSO)

ISTP-CNR (ENEA)

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WPSA Project structure

WPSA
Enhancements and Commissioning of JT-60SA
WP organization

PSO
Alessandra Di Bastiano (ENEA)

Project Management
PL: Carlo Sozzi (ENEA)

W JT-60SA
EUROfusion activities in preparation of the transition to W wall and divertor
Coordination across WPs

JIFS
JT-60SA International Fusion School
Advice & Support

Tasks

Enhancements area aims to promote scoping and feasibility studies up to the level of conceptual design for new enhancement projects, and assist the procurement when approved.
Coordinator: Juan Ayllon-Guerola (CIEMAT)

Code Management aims to provide verified simulation and analysis tools for application to JT-60SA in support to the preparation of the experimental campaigns, data analysis, interpretation of diagnostics and experiments.
Coordinator: Gloria Falchetto (CEA)

Operations supports the commissioning activities and execution of the experimental campaigns providing expertise in plant and plasma operations, vacuum conditioning, real-time control, diagnostics, heating and fuelling systems.
Coordinator: Matteo Iafrati (ENEA)

Overall long-term objective of WPSA:

support for the scientific exploitation of JT-60SA cooperating with Fusion For Energy within the Broader Approach – Satellite Tokamak Project (BA-STP) framework

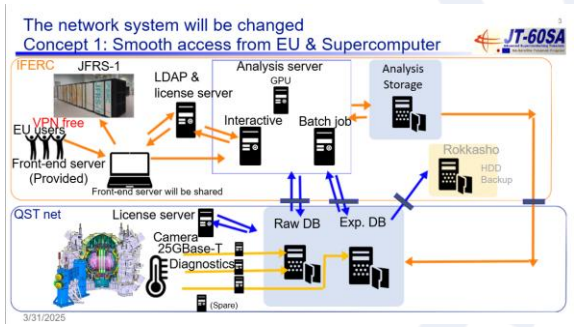
coherently with the needs and the priorities of the European Fusion Roadmap.

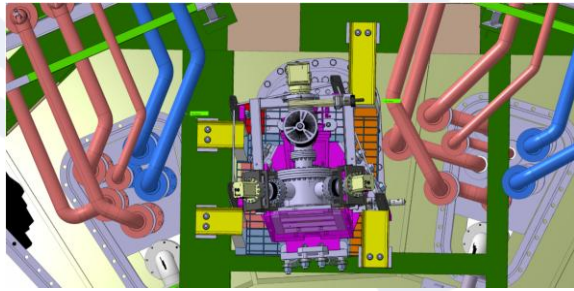
Principal achievements in 2024

Exploitation of the experience of the Integrated Commissioning and preparation of the commissioning of the EU enhancements

The experience gained thanks to the participation of the EUROfusion IC team in the IC/OP1 experimental campaign has been capitalized in several ways:

- introduction to access and analysis to the OP1 JT-60SA data shared by members of the EUROfusion IC team in particular with the participants to the 1st Analysis and Modelling session in October 2024
- contribution to the definition of the requirements for the upgrading of the JT-60SA Analysis Server in view of the next experimental campaigns (see Annex 12, report EFDA_D_2REH3N_v1.0) and to remote participation tools
- continuation and reinforcement of collaborative activities initiated during the IC/OP1 (magnetic diagnostics and plasma control, video diagnostics, MHD analysis, ECRH applications for breakdown and heating).
  - Scientific exploitation => Experiment Team ⇔ WPTE
  - Development, technical preparation, commissioning => WPSA ⇔ Integrated Project Team
- Guidelines for the procedures of installation and commissioning of systems planned to be available for the next operational phase OP2 have been delivered





divVUV spectrometer in the installation position (CAD)

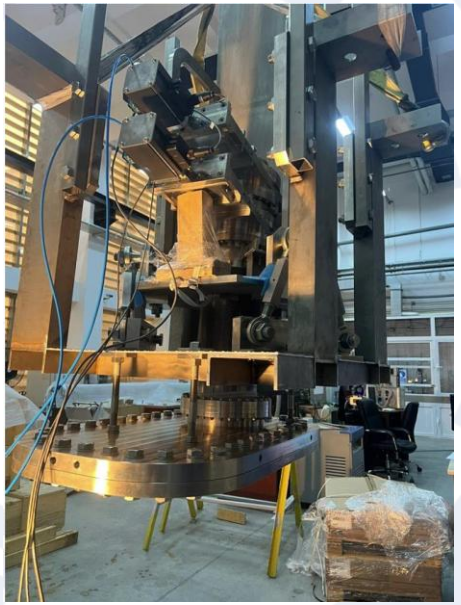
Principal achievements in 2024

Delivery of the components EU led systems under implementation and start of the design phase for a new set of enhancements

- Installation of the four systems below is planned during the present Machine Enhancement 1 period (completion in spring 2026).
  - The Massive Gas Injection system and the Divertor Cryopumping system are on the JT-60SA site (Delivered on site in 2023).
  - The Edge Thomson Scattering system (Delivered 2023-2024) is partially installed and the last set of components is on arrival on site having passed the acceptance test.
  - The Divertor VUV spectrometer is assembled in Europe and the acceptance test is being organized.

F.D'Isa (EEG), SOFT 2024

TS Laser room in Naka

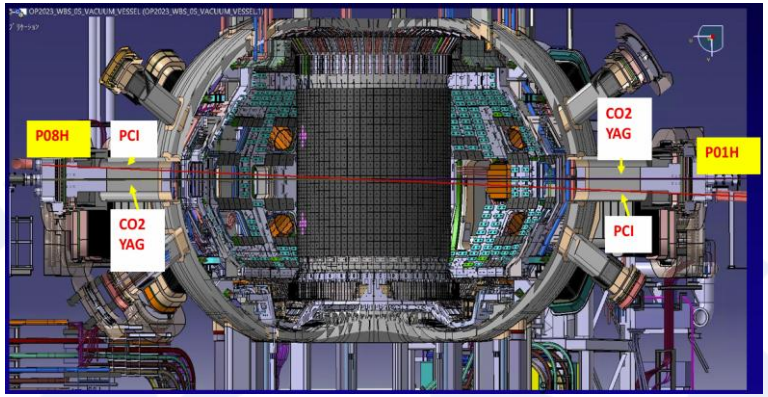


DivVUV structure with the alignment hexapod, gates and the cryostat plug

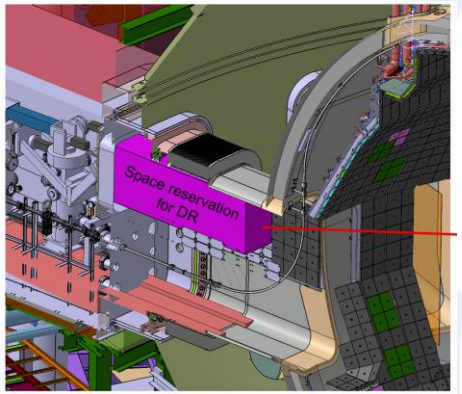
A.Belpane (EEG), SOFT 2024

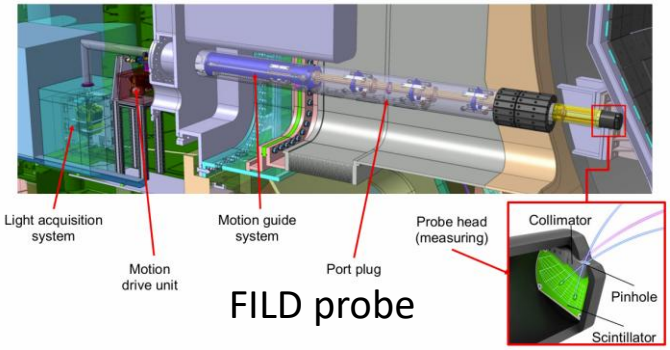
Principal achievements in 2024

- Installation foreseen for following ME periods
  - The TPCI (Ports 1-8) and the FILD (Port 18) systems being planned for installation after the next experimental campaign (ME2) are entering the procurement phase.
  - Another set of diagnostics has entered the detailed design phase
  - Gamma Ray Spectrometer (Port 12, also planned for installation in the ME2), a
  - Compact Neutron Spectrometer and the Dopple Reflectometry systems planned for installation ir the ME3 (assigned Port 12, Port 9)

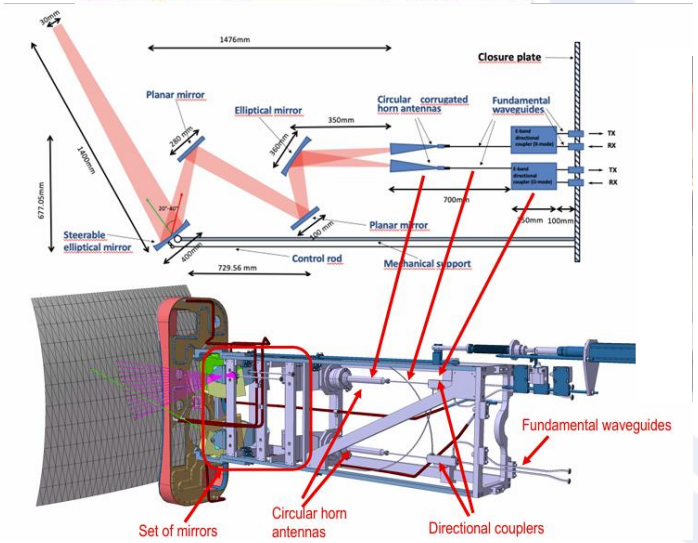


TPCI optical path *Coda, EPS 2024*

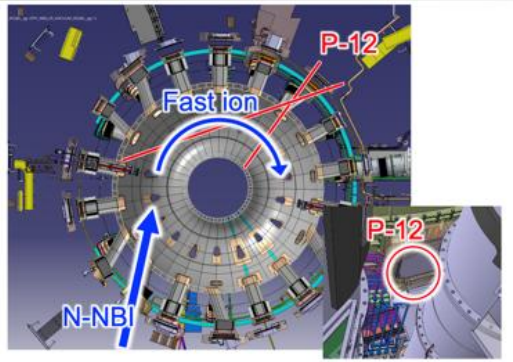


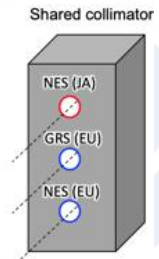


FILD probe



DR design



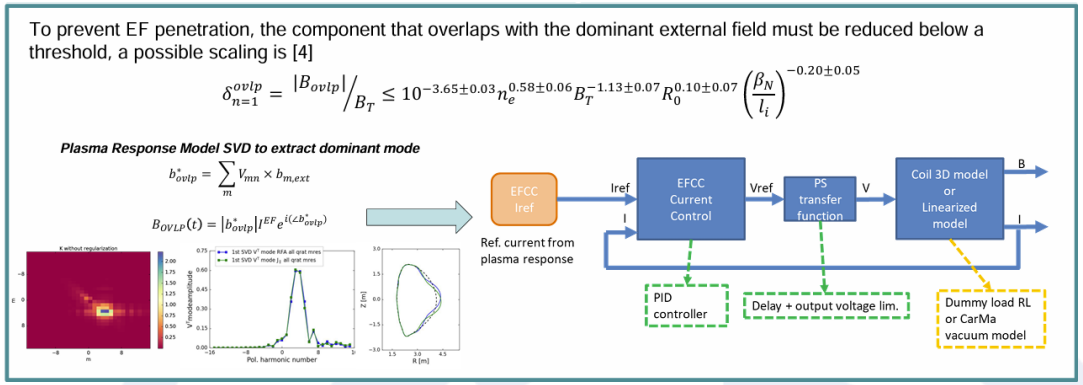


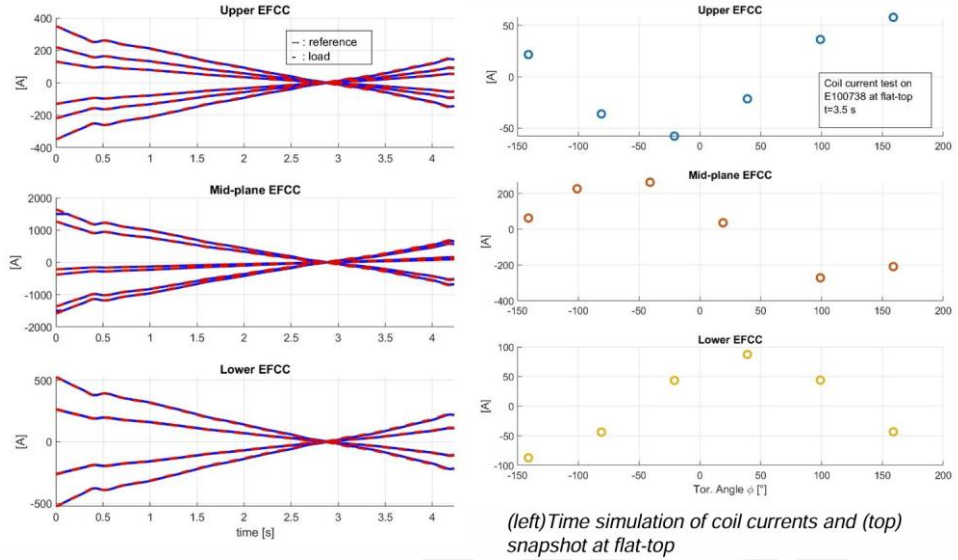
Neutron and Gamma spectrometers

Principal achievements in 2024

Release of analysis tools and training for new users in support of the activity of the JT-60SA Experiment Team

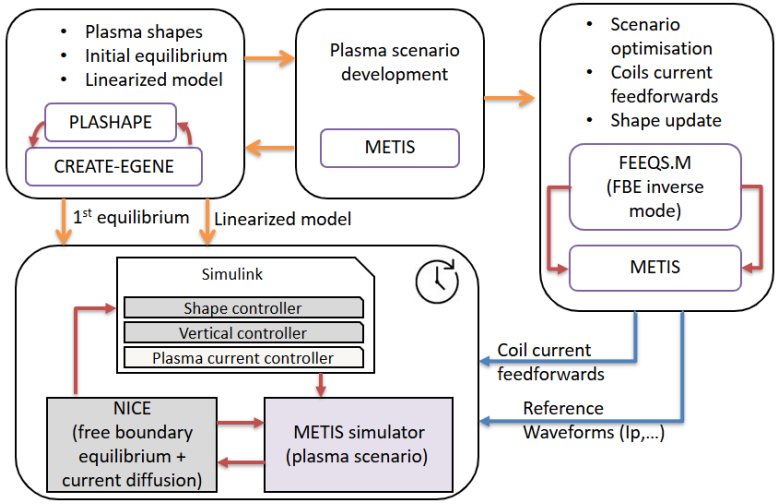
- The following tools for analysis and for experiment preparation have been released and are available for training sessions:
  - Workflows for model-based Error Field correction





(left)Time simulation of coil currents and (top) snapshot at flat-top

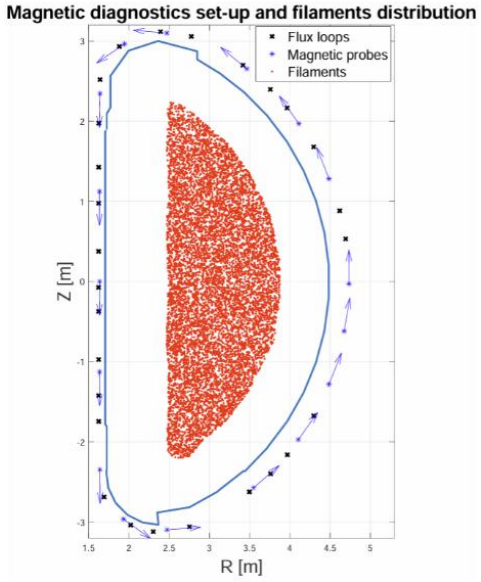
Bolzonella, Pigatto + SOFT 24



Joffrin, Artaud, Mattei IAEA 2025

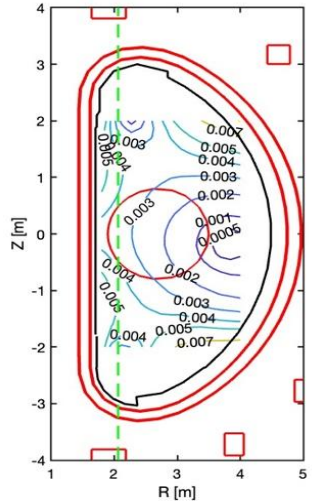
- A Plasma Design Simulator for preparation and development of experimental/operation scenario using CREATE-EGENE (equilibrium solver)-METIS (0-D scaling-law normalized heat and particle transport)-FEEQS.M-FBE (Inverse Free-boundary eq. solver)

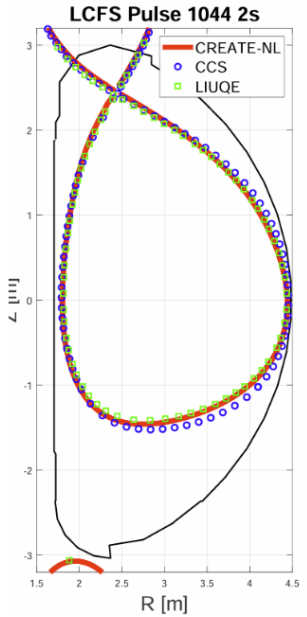
Principal achievements in 2024: operation oriented tools



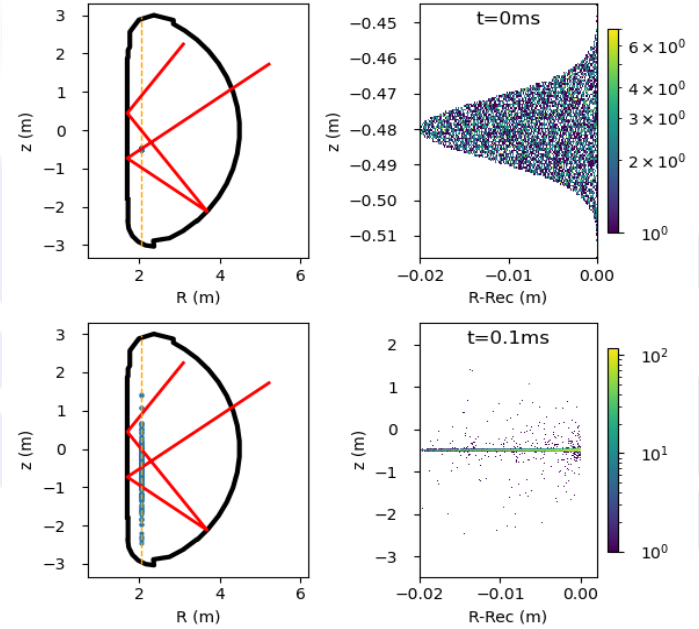
- Moreover, other progresses obtained concerning operation-oriented tools are:
  - upgrade of the breakdown workflow to include the Trapped Particle (magnetic) Configuration extensively used in the JT-60SA OP1
  - validation of the real time algorithms developed for application to ITER for the equilibrium reconstruction based on magnetic diagnostics data. Such activity has been performed using the data collected during the JT-60SA IC and OP1

Poloidal field map calculated by CREATE-BD for E100627 (TPC) at t = 0.085 s (right), corresponding to the breakdown time (with ECH). The vertical dashed green line corresponds to the 82 GHz resonance





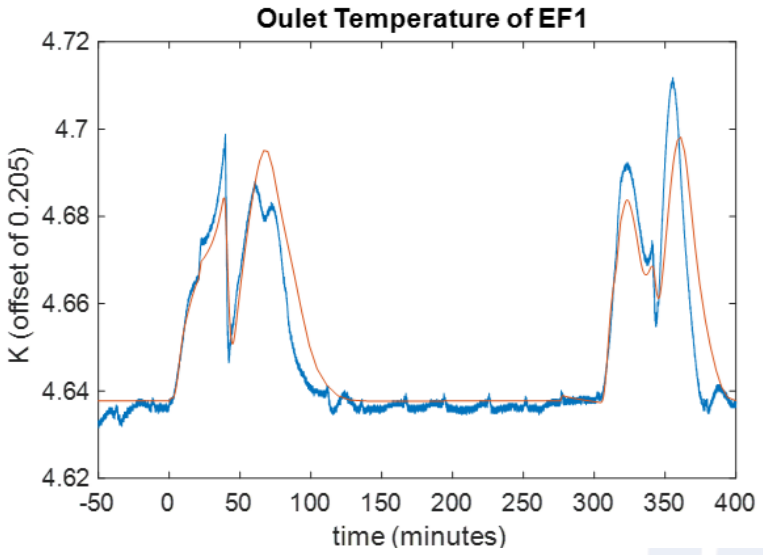
Fiorenza, + SOFT 24
De Tommasi, NF2024



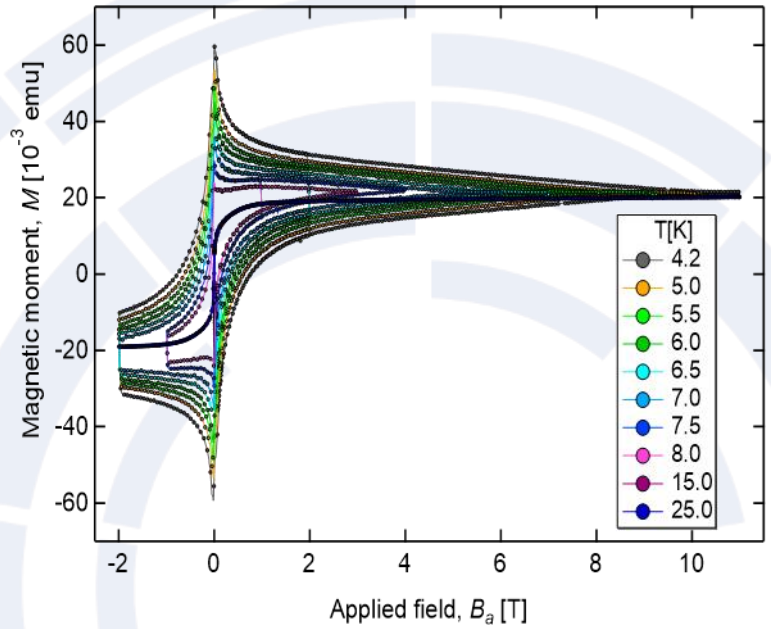
Electrons originate at R = R_{EC} and move towards the high field side (HFS). After a subsequent time, they exhibit vertical spreading due to the drift induced by the B_{pol}.

Principal achievements in 2024: operation oriented tools

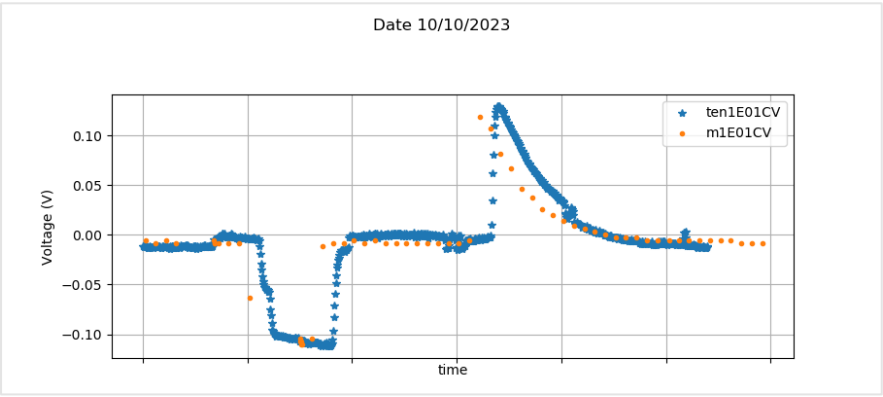
- Modeling of heat loads on the poloidal field coils and central solenoid cryogenic system for reference plasma scenario (double null, full current inductive), including AC losses (DN Full Current Inductive (JT-60SA PID document [1]) f CS3 module on Central Double Pancake).
- Thermal-hydraulic modeling of the cooling circuit for the poloidal field coils and central solenoid.
- Development of a tools for the analysis of the Quench Detection System of the TF coils (resistive voltage detection): synchronization, offset subtraction, noise reduction, data extraction



Temperature results – blue plots are experimental while red plots are simulations.



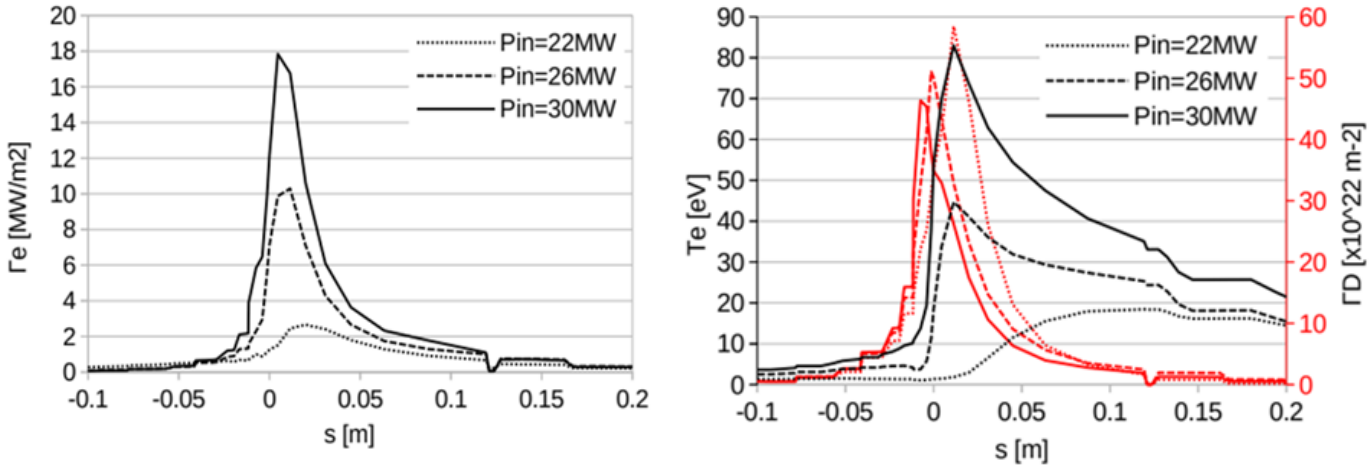
Magnetic characterization of the JT6-0SA NbTi strand (strand ID: TKJ191): field range $-2\ T \leq B_a \leq 11\ T$ at various temperatures.



- *JT-60SA TF1 voltage recorded during a shot in 10/10/2023 and stored in two different databases from PMDB, the "10ms" and the "CryoMag" databases. Time misalignment is present.*

- Characterization of the NbTi and Nb_3Sn superconducting strands used in the JT-60SA magnets, addressing discrepancies in AC losses observed between the JOSEFA facility and the Integrated Commissioning phase.

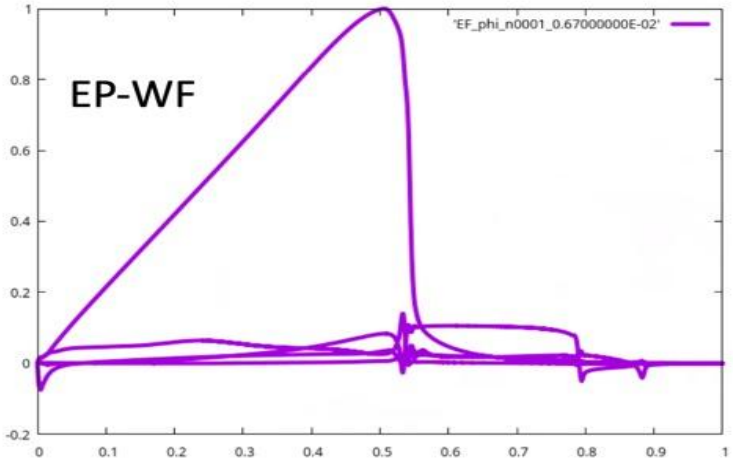
Principal achievements in 2024: modeling



Power density profiles on the OVT on the left; Te profiles (black lines) and ΓD+ (red lines) along the OVT on the right. The results refers to the JT-60SA scenario 2 Ar-seeded cases obtained with SOLEDGE

- Edge/SOL modeling of JT-60SA high performance scenario with tungsten wall and impurity seeding: SOLPS-ITER and SOLEDGE edge codes were used with the common purpose of checking the compatibility of scenario 2 with the first tungsten wall and calculating power and particle fluxes at the first wall and pumping rate.

Rubino, Balbinot, EPS 2025



Electrostatic potential of the internal kink mode showing the n=1, m=1 mode structure close to the q=1 surface

- Upgraded Energetic Particle workflow with embedded transport models extended to include up to 4 different EP specie, reflecting the different combinations of PNBI and NNBI, that have been found to be important for stability and transport considerations in JT-60SA.

2025 objectives

- Prepare and assist machine integration of the EU-led diagnostic systems (OP, ENH) in 2025/26
- Prepare commissioning and first operation of the EU-led diagnostic systems for “delivering” to the scientific community (Experiment Team) (OP) in 2026/2027
- Prepare and verify a suite of tools and codes for the Scientific Exploitation, including operation-oriented tools, synthetic diagnostics, simulation workflows (CM) preparing the subsequent validation on data or benchmarking with/in WPTE
- Support new users in data analysis, leveraging experience gained during commissioning
- Support training for control room tools
- Develop feasibility, design, assist procurement of new subsystems according with the JT-60SA scientific plan (ENH), in particular for 2025 diagnostics for plasma edge and plasma-wall interaction
- Establish a plan for the EU contribution to the transition to W divertor and wall. This might include several lines of work and collection of information of activities performed in other EuroFusion WPs, taking into account the scientific priorities for the C phase and for the W phase and W-related preparation experiments in the C phase of JT-60SA (JT-60SA Experiment Team)
- o Core and impurity transport (WPTE)
- o Modeling of heat load on PFCs (WPTE)
- o Modeling for PFCs shape optimization (WPPWIE)
- o Test of PFCs (WPPWIE)
- o Development and qualification of PFCs (WPDIV)
- o Diagnostics upgrade for W monitoring, wall and divertor protection
- o Upgrade of the heating systems
- o Upgrade of the protection system
- o Review of the wall cleaning systems and procedures
- o Review of the gas injection system

2025 activities

#	Scope	Name	Acronym	Present status	2025 Objective	2025 resources (PMs)
1	Enhancements & subsystem operation	**Edge Thomson Scattering**	ETS	Under installation	Complete installation for plasma commissioning	16
2	Enhancements & subsystem operation	**Divertor VUV**	DivVUV	Under assembly	Delivery to Naka and start installation for plasma commissioning	10
3	Enhancements & subsystem operation	**EDICAM**	ED	Operational	mantainence and further development	3
4	Enhancements & subsystem operation	**Pellet Launching System**	PLS	Centrifuge under procurement; Tender for source being launched	Test of the centrifuge	30
6	Enhancements & subsystem operation	**Tangential Phase Contrast Imaging**	TPCI	Manufacturing Starting	Complete Manufacturing	20
7	Enhancements & subsystem operation	**Fast Ion Loss Detector**	FILD	Manufacturing Starting	Complete Manufacturing	16
8	Enhancements & subsystem operation	**Gamma Ray Spectrometry**	GRS	Conceptual Design	Complete Conceptual Design	14
9	Enhancements & subsystem operation	**Compact Neutron Spectrometry**	CNS	Feasibility Study	Complete Feasibility Study	6
10	Enhancements & subsystem operation	**Vertical Neutron Camera (profile monitor)**	VNC	Feasibility Study	Complete Feasibility Study	6
11	Enhancements & subsystem operation	**Runaway Electron Monitor**	REM	Proposed	Procurement *(on loan)	3
12	Enhancements & subsystem operation	**Edge and SOL diagnostics +**	ESD	Feasibility Study (CALL)	Initial feasibility (Basis for implementation plan)	44
13	Enhancements & subsystem operation	**Neutronics**	Neut	Support to shielding design	Pellet shielding, Neutron and Gamma	4
14	Enhancements & subsystem operation	**Activation foils**	AF	Neutron flux and Spectrometry	Feasibility and support to design	4
15	Enhancements & subsystem operation	**Doppler Reflectometry**	DR	Design	Optical design	18
16	Enhancements & subsystem operation	**EC stray detection**	ECS	feasibility	prototype development	3
17	Enhancements & subsystem operation	**EDICAM**	ED	feasibility and conceptual design	multiple lines of sight	4
18	Operation oriented codes & subsystems modeling	**Electron Cyclotron Waves simulation**	ECW	implementation of ECH and ECE tools	GUI development	2
19	Operation oriented codes & subsystems modeling	**Tools for conditioning and magnetic control**	MAGC	development and training	Benchmarking of CREATE and QST tools and control algorhitms	9
20	Operation oriented codes & subsystems modeling	**Remote access for diagnostics mantainence**	REC	Tested (Pilote)	To be extended	2
21	Operation oriented codes & subsystems modeling	**Criomagnet system simulation and data analysis**	CryoS	Implemented	Extension of the modeling (CS+Scenario with plasma operation), QDV, cooling loop)	10
22	Operation oriented codes & subsystems modeling	**RWM control**	RWM	control system implementation	simulation tool development	2
23	Operation oriented codes & subsystems modeling	**Energetic particle workflow**	HEP	development completed	users training	1
24	Operation oriented codes & subsystems modeling	**pulse discharge simulator**	PDS	finalization	integration of modules	11
25	Operation oriented codes & subsystems modeling	**breakdown modeling**	BRKD	implementation TPC configuration	multi-pass absorption	3
26	Enhancements & subsystem operation	**Test of criomagnet components**	CryoT	Ongoing	Joint resistivity measurements	6
27	Enhancements & subsystem operation	**Design of CS testing tool**	CS	Ongoing	development of a joint testing tool	1
28	Enhancements & subsystem operation	**Preparation of pellet commissioning**	PLSC	Ongoing	development of the commissioning plan	2
29	Management	**Area coordination**	AC			9
30	Enhancements & subsystem operation	**Divertor Cryopumps**	DivCryo	Under installation	Complete installation for operational commissioning	0
34	Management	**Project management and PSO**	MAN			10.8
		TOTAL 2025				**259**

Changes/status for 2025 compared to AWP (October 2024)

- Priority for ME2 enhancement assessed: green light for FILD, TPCI, DR with provisional port assignation (to be confirmed with the standard Design Review process)
- Selection of the diagnostics principle for Neutron spectrometry: Scintillator-based Compact Spectrometer
- Port assignation for Gamma and Neutron spectrometry
- Proposal for a Runaway Electron monitor (on loan from ENEA) for machine protection purposes (under evaluation)
- Pellet Launching System: framework contract for development of pacing and fueling sources being launched by F4E after failure of the PELIN delivery. WPSA to support scientific contribution to support development and procurement.
- Edge and SOL diagnostics feasibility study: Call launched (deadline 4th April)
- Preparation of W transition:
  - First set of (edge) modeling completed, WPTE to coordinate continuation of modeling activity.
  - Next step expected for advancing the preparation:
    - core confinement in coherence with edge modeling
    - Evaluation of needs in term of additional heating (ECRH)
  - Divertor shape optimization organized under WP PWIE (transfer of funding from WPSA)
- Shut-down of remote access due to a cyber attack (duration of several months announced, started in January)

2025 Grant milestones

GA Milestone No.	GA Milestone Title	Due Date [mm/yyyy]
SA.M.05	Participation to the development of scenario at high plasma current in H mode(1)	Dec. 2025 *

2025 Grant deliverables

GA Deliverable No.	GA Deliverable Title	Due Date [mm/yyyy]
SA.D.05	Delivery and final tests of EU-REC completed(2)	June 2024 *
SA.D.06	Installation of the EU systems before the OP2 campaign(3)	Dec. 2024
SA.D.07	Report on participation to the OP.2 campaign. Results and return of experience(1)	Dec. 2025 *
SA.D.10	Delivery of EU procurements (TBD) for the OP3 campaign completed(4)	Dec. 2025

(*)Milestones/Deliverables dependent on external conditions to which the workpackage is constrained, see Risk Table (WPR-04)

(1) To be cancelled in the next GA Amendment: The participation to scientific campaigns is moved to under WPTE.

(2) Expected delivery date is June 2025. To be delayed due to temporary shut-down of remote access. Scope of this deliverable has been redefined. It includes:

- test of remote connection from an EU site with interaction with local systems (e.g. software maintenance of a passive diagnostics)
- test of the tools for data access and remote participation after the upgrade being performed within the JT-60SA project

(3) Installation of the EU lead systems (except Pellet Launching System) before the OP2 campaign will be performed, but the installation date is delayed according with the timeline of JT-60SA, therefore expected delivery date is December 2025.

(4) Installation of the EU lead systems for OP3 campaign is delayed according with the timeline of JT-60SA. Start of the OP3 campaign is presently foreseen in second half of 2027