Machine report: TJ-II 25th Stellarator/Heliotron Working Group Meeting June 3-5, 2025

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Machine report: TJ-II

- 1. TJ-II in the CIEMAT-LNF Strategic Research Plan 2025-2028
- 2. Highlights and recent publications
- 3. Scientific objectives for TJ-II
- 4. Next experimental campaign

Strategic Research Plan 2025-2028

ICTS Strategic Plan 2025–2028 Laboratorio Nacional de Fusión



- 4-year reference document for research conducted at CIEMAT-LNF (Mission, SWOT, objectives, resources, etc.).
- Required by the Ministry and evaluated by an external international panel.
- Organised in 8 Strategic Research Lines (SRLs)
 ...
 - SRL2. Broadening of the stellarator physics basis
 - SRL3. Plasma theory and advanced simulations
 - SRL4. Stellarator Reactor Design
 - . . .
- TJ-II exploitation is the main part of SRL2.

Strategic Research Plan 2025-2028

- The exploitation of TJ-II in this period will concentrate on areas of the stellarator physics basis for which its diagnostic and operational capabilities can be leveraged for contributing to the Wendelstein 7-X (W7-X) preparation and exploitation and for addressing stellarator reactor physics gaps.
- The national and international fusion context is evolving.
- In any conceivable scenario, the continuation of the exploitation of the TJ-II stellarator in the next planning period is considered strategic.
 - Important investment to replace the Power Supply Monitoring and Control System.
 - Other upgrades are expected for improving or extending the diagnostic capability (HIBP, Thomson, sFILD, GEM camera, Boron dropper).

TJ-II operational highlight from 2021-2024

Record energy content and confinement at TJ-II.

- Pellet injection on NBI plasmas resulted in record energies and confinement values at TJ-II (PiEC, see García-Cortes et al. PoP 2023).
- Similar to W7-X high performance after pellet injection.
- A quantitative girokinetic interpretation of the experimental profiles is in progress (IAEA 2025)



Some TJ-II recent publications (2023-2025)

	Garcia-Cortes et al.	Enhanced confinement induced by pellet injection in the stellarator TJ-II
Pellet	McCarthy et al.	Multi-pellet injection into the NBI-heated phase of TJ-II plasmas
physics and PiEC	Alonso et al.	Density profiles in stellarators: an overview of particle transport, fuelling and profile shaping studies at TJ-II
	Panadero et al.	Using rational surfaces to improve pellet fuelling in stellarators
	van Milligen et al.	Rational surfaces, flows and radial structure in the TJ-II stellarator
Transport analysis and sim. NBI phys. and AEs	Estrada et al.	H-mode transition in the TJ-II stellarator plasmas
	van Milligen et al.	Importance of the Rotational Transform for L-H Transitions in the TJ-II Stellarator
	Thienpondt et al.	Influence of the density gradient on turbulent heat transport at ion-scales: an inter- machine study with the gyrokinetic code stella
	Ghiozzi et al.	Modeling of frequency-sweeping Alfvén modes in the TJ-II stellarator
	Mulas et al.	Validating neutral-beam current drive simulations in the TJ-II stellarator
	Zapata-Cornejo et al.	A novel unsupervised machine learning algorithm for automatic Alfvénic activity detection in the TJ-II stellarator
	Varela et al.	Stability optimization of energetic particle driven modes in nuclear fusion devices: the FAR3d gyro-fluid code

SRL2.01. Diagnose and model fast ion transport and energetic particle interaction with turbulence and MHD waves in NBI heated TJ-II plasmas.

- Validation of Alfvén Eigenmode excitation/saturation models and current drive and NBI power deposition calculations.
- Characterisation NBI heating scenarios with forward and reversed magnetic field.
- Re-design and installation of an improved scintillating Fast Ion Loss
 Detector head and camera system for fast ion studies.
- Experimental strategies for assessing the interplay: fast ions MHD waves – broadband turbulence.

SRL2.O2. Quantify turbulent transport and validate turbulence models in TJ-II.

- Development of power-balance analysis capabilities in ECRH and NBI plasmas, with profile diagnostics and validated power deposition calculations
- Validation of gyrokinetic simulations in optimal experimental core scenarios.
- Deployment of the full diagnostic capabilities of the dual HIBP system (5 additional sample volumes).
- Characterisation of Edge-SOL turbulence in limiter and island-divertor-like SOL configurations with electric probe and spectroscopic diagnostics.

SRL2.O3. Characterise and interpret pellet fueling and profile shaping effects on global confinement in TJ-II.

- Validation of pellet ablation/deposition physics and models in the TJ-II magnetic configuration space.
- Characterisation of the effects of density profile shaping by pellet injection on plasma turbulence, transport and enhanced performance
- Conduct power-balance analysis and use first-principles models to interpret the heat and particle flux in enhanced confinemen regimes –relevance for the W7-X HP program



SRL2.04. Characterise and interpret impurity transport, plasma radiation and light impurity effects on plasma performance in TJ-II.

- Qualification of the TESPEL and LBO perturbative techniques and data analysis for impurity transport studies
- Characterisation and interpretation of impurity transport and total radiated power in NBI heating scenarios
- Installation and test of a GEM camera (IPPLM) for its possible use at W7-3
- Installation of a boron dropper (PPPL) and assessment plasma performance improvement
- Characterisation and interpretation of the effect of light impurities (Li, B), both in wall coatings and injected into the plasma, on the performance of plasma
 S. Jablonski et al. PoP 2024



SRL2.05. Develop low-field scenarios for scaling studies at TJ-II.

- Adaptation of the 28GHz gyrotron line for X2 plasma start-up at 0.5T and development of NBI take-over scenarios.
- Documentation of the TJ-II operational space at reduced field and extend its confinement and scaling database.
- Characterisation of B-field scaling properties of plasma turbulence, operational density limit and SOL e-folding length for inter-machine comparisons

SRL2.06. Exploit Machine Learning techniques and generative Artificial Intelligence for their application in TJ-II and W7-X.

- Develop machine learning algorithms for automated analysis of large data volume diagnostics in TJ-II and W7-X.
- Assess of the use of generative Al services for human/database interfacing and experiment planning and conduction.

Next experimental campaign at TJ-II

- Presently renovating the fire protection system in the power suply building (last campaign in May 2024).
- Depending on progress campaign will start in Oct. 2025 or early 2026.
- Working on diagnostic and system upgrades:
 - HIBP, Thomson, sFILD, GEM camera, Boron dropper.
 - Upgrade of the ECH mirror for the 28GHz gyrotron (0.5T operation).
- Call for Participation will be distributed through the CWGM list.
- Your proposals will be most welcome!

onso for the TJ-II team | Machine report : TJ-II | 25th CWGM, PPPL | 3/06/20