EUROfusion FSD PB premeeting

WPSA: FP10 and activities in 26-27 towards the future

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FP10 and activities in 26-27 towards the future

- **Lessons learnt from JT-60SA enhancements to be applied to other future devices**
- Background FP10 2028-34: JT-60SA with C wall and transition to W/metal wall

- EFDA/Eurofusion started scientific participation around 2012.
- For several years “marginally” relevant contact. 1 meeting week per year to report on home work, aiming to prepare the research plan issued in 2018.
- General impression of scarce “grip” on the JT-60SA project evolution, even though some EU proposal (e.g. W environment) was difficult to refuse (“accepted” but without clear time plan or committment).
- Situation started to change when
  - WPSA convinced the EuF leadership to support a pilot diagnostics project (EDICAM)
  - QST (likely due to shortage in funding/human resources) asked EU to develop and financially support 2 main diagnostics (EdgeTS and DivVUV)
  - In the wake of this involvement, other proposal triggered by the EU research priorities (W scenario, disruptions and RE, fast ions, RT control) were (not easily) accepted (MGI, FILD)
- From this point,
  - regular involvement in the discussion concerning the project
  - Increased visibility, even though always in the shadow of F4E
  - F4E seeking scientific support

FP10 and activities in 26-27 towards the future

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- Ups:
- Enhancements have helped the scientific partner EuF to enter into the gears of the JT-60SA project (this has not happened before for e.g. the modeling activity, notwithstanding its high quality)
- Developing teams came in close contact with QST counterparts. Seeds for personal and institutional collaborations

- Downs
- Still paying the “original sin” of BA/JT-60SA framework: EU “financing in kind” a JA project, only later changed in EU requiring to be involved in exploitation and operation
- => engineering-dominated (in the EU side): build and go
- => no clear initial plan to be involved in exploitation
- => no adequate funding scheme
- => no adequate engagement rules

- NOTE: previous JET experience has been extremely relevant for participating in the enhancement of a large (and complex) machine => perhaps this can be extrapolated and applied to JT-60SA for future commitments in emerging machines (BEST etc.)

FP10 and activities in 26-27 towards the future

- **Scheme of EU participation to JT-60SA; Science, Operations, Enhancements. Should/Will this go under EuF, or F4E, or hybrid?**
- Background FP10 2028-34: JT-60SA with C wall and transition to W/metal wall
- =>Challenging plans of enhancements on FP10

- 2 (soon 3) entities running fusion in EU difficult to understand. Let's assume this can not be changed, then science should stay in the research institutes and under the good side of EUROfusion (coordination and creation of opportunities)
- At present, (and in future if we take Marco's assumptions) EuF has not a reasonable scheme to support hardware built to be delivered outside EU institutions.
- Then enhancements should stay (as they are at present) hybrid, with EuF providing science case, systems foundations, conceptual design and F4E supporting execution engineering and procurement.
- Operations should be a branch of the scientific exploitation

FP10 and activities in 26-27 towards the future

- **Should there be an Enhancements WP?**
- Background FP10 2028-34: JT-60SA with C wall and transition to W/metal wall

- It could be, however might not be strictly necessary. In any case, in FP10 enhancements activities will be a significant fraction of the whole involvement in JT-60SA
- What should be preserved are
  - Constant and recognizable figure (person) of adequate experience coordinating the enhancements
  - Internal support to gain the necessary visibility with the partners (Ias F4E, QST

- Under such conditions, Enhancements does not need to be a separate WP but a branch of the Scientific Exploitation with strict collaboration with Operations and F4E

FP10 and activities in 26-27 towards the future

- **How to keep competence and at the same time reinforce the operativity and the scientific output of the many subsystems in delivery to QST.**
- The present status is that whatever subsystem has passed the acceptation phase (commissioning) is QST property and EU teams that developed it are treated as a normal user (e.g.: no free access to raw data)

- Bullet 2 is in some extent “natural”: law accountability of a nuclear installation is and should be under the host institution.
- However, EU (and EuF) is paying the absence of an adequate scheme of international collaboration defining a satisfactory way of working
- Presented plan of operations (ETCM5) offer the possibility or participating and possibly after an adequate period of acquaintance.
- However, to make this work:
  - scheme allowing for ***medium*** and long stays (JET style, even if for a more limited number of persons)
  - Negotiate the necessary rules of participation and preservation of the intellectual properties, starting from the highest level (EC-MECS)

Background

- **Scenario integration for long pulse operation would benefit from an earlier transition to Actively Cooled Tungsten divertor.**
- **Transition from the inertially cooled carbon divertor to Actively cooled tungsten divertor was proposed and accepted in BASC-34 (December 2024).**

Research phase	Focus of exploitation	Operation Campaign	Expected operation schedule	[1]	Annual neutron limit	RH	Divertor	Installed NB power	ECRF	Max. usable aux. power[2]
Initial research phase I	Integrated Commissioning	Op-1	2020-2021 (6M) 2023 (6M) First plasma 2023	H	-	R&D	Open upper inertially cooled carbon[3]	0	1.5 MW (2 Gyro.)	1.5MW
	Initial stable and reliable operation • H operation for commissioning towards D operation. • Stable operation at high current heated plasma	Op-2	2026-2027				Lower pumped carbon with intershot cooling [4] (limits high power heating duration)	PNB 8 units, plus NNB Total 16MW (with H) 23.5 MW (with D)	3 MW (4 gyro)	19MW
Initial research phase II	**ITER and DEMO regime access** (high power and high Ip with short pulses) • Access to ITER-relevant high confinement H-mode at high Ip • High beta access • ITER risk mitigation (ELM, disruption)	Op-3	2027-2028 (11M)	D	3.2e19					26.5MW
		Op-4	2029 (11M)				C-wall			33 MW
		No. of campaigns to be confirmed	TBD					PNB 12 units, plus NNB Total 30 MW		
Integrated research phase I	**High beta and metal wall compatibility**	TBD	TBD		4.0e20		W-wall			37MW
Integrated research phase II	**High beta long pulse** **Burning plasma relevant** • ITER standard and hybrid stationary (~2-3τ_R) • High beta steady-state (~2-3τ_R), DEMO contribution	TBD	TBD		1.0e21	Use	Actively cooled lower pumped tungsten		7MW (9 gyro.)	
Extended research phase		TBD	TBD		1.5e21			34MW[5]		41MW

Likely ending 2030

Likely starting 2032

Useful time for ITER Op: until 2034

Likely 1(2?) Exp. Camp.

Update on JT-60SA W wall timeline

"Report on Transition to Tungsten" (TCM44-03-08), November 2025

- Short overview of tungsten wall physics objectives (mission, physics studies in ITER/DEMO relevant regimes, compatibility between high β and metal wall, risk mitigation optimization)
- Additional diagnostics (a further assessment of the diagnostics plan should be done by TCM-45)
- Additional ECRF heating (ECRH powers below 5 MW are predicted to be sufficient to avoid central accumulation with pedestal top) (Modeling result).
- Additional ECRF power supplies
- Additional systems (Boronization: the need of a boronization system; also requirements on cryopumping and vacuum system)
- Additional control systems (Real Time Control: the need for real time diagnostics)
- Status of W divertor and first wall technology development (PA strategy, HHF, NHF and CF)

Modeling results (status at February 2026)

- Argon seeding modelling with SOLEDGE
  - maximum input power that allows detachment with a “reasonable” impurity concentration
- Neon seeding modelling with SOLPS-ITER
  - How much impurity seeding is required for detachment with a given power flux
- Results:
  - Power flux peak is not a major concern, H-mode access ok
  - W erosion is the showstopper
  - detachment threshold is most stringent limit
  - detachment not feasible at low density
  - low pumping throughput likely given by neutral trapping (=> suggested to rise the strike points)
- JINTRAC integrated core/SOL modelling ongoing to establish a core-SOL integrated solutions => coherent results not yet there
- ASTRA-FACIT modeling in progress. Preliminary result: ECRH power below 5 MW (core heating) are predicted to be sufficient to avoid central accumulation with pedestal top
- IMPGYRO (JA) simulations for net W erosion and prompt deposition
- TOTAL (JA) simulations showing plasma rotation and central heating to avoid W accumulation

Status of W-PFCs

JT-60SA Advanced Superconducting Tokamak BA-Satellite Tokamak Program

Next steps

- HHF
  - Testing of small scale tungsten monoblock mockups completed in Q1/25
  - Intermediate scale mockups manufactured and tested in Q2/25
  - 2 full scale mockups manufactured as Q3/25
  - Release of series production in Q2/26
  - Tungsten raw material procurement started (call for tender) in Q3/25
- NHF
  - Design of tungsten PFCs finalized in Q3/25
- CF
  - First 8 units in Q3/25
- Integration
  - PA to be signed by Q4/2025 with call for tender to start by Q1/26

Upgrade of the heating system (ECRF)

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Additional ECRF Heating

- Gyrotron and auxiliaries (2 → 12)
  - 2026-2027 : 2
  - 2027-2030 : 5
  - 2028-2031 : 3
- Launcher
  - 2027-2029 : 2 (Manufacture)
  - 2028-2030 : 1~2 (Manufacture)
  - 2030-2031 : Installation
- Transmission line
  - 2027-2030 : 8 (Procurement)
  - 2030-2031 : Installation
- Control (2 → 12)
  - 2026-2028 : 2 (Modification, testing)
  - 2027-2030 : 5 (Procurement, testing)
  - 2027-2031 : 3 (Procurement, testing)
- Stages (P1/P4, additional)
  - 2027-2028 : P1/P4 (Manufacture)
  - 2028-2029 : additional (Manufacture)
  - ME-3 or ME-4 : P1/P4 Installation
  - ME-4 : additional Installation
- Cooling water, vacuum, auxiliary PS, etc.
  - ME-2, 3, 4 : gyrotron room and PS building
  - 2027-2029 : new gyrotron room (possibly in basement of torus bldg.)

From: ECRF update plan – Koji Takahashi

Upgrade of the heating system (ECRF)

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Additional ECRF power supplies

- Current plan:
  - 3 x ECRF PS with single HVMPS – for gyrotrons 1-6 (2025-2026)
  - 3 x ECRF PS with double HVMPS with outdoor transformers – for gyrotrons 7-12 (2028-2030)
- Alternative plan:
  - 2 x ECRF PS with single HVMPS – for gyrotrons 1-4 (2025)
  - 4 x ECRF PS with double HVMPS with outdoor transformers – for gyrotrons 5-12 (2028-2031)

WPSA draft objectives FP10

- Support design and installation of diagnostics and systems for OP4:
  - Doppler Reflectometry
  - Neutron spectrometer
  - Vertical Neutron Camera
  - Installation/extension of the EC stray detection system
  - Installation/extension of Pellet Launching System and related diagnostics
- Development and installation of the “Edge and SOL” systems (
  - selection to be done
  - Time of installation and operation to be decided (for OP4 or later)
- Support the transfer of the EU know-how for control and protection in a W environment