Status and plans of edge/SOL modelling activities in WPSA in support to JT-60SA transition to W

G. Falchetto WPSA Code Management Area Coordinator

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JT-60SA Research Plan v4.0 2018, Sec. 3, page 58

3.3.3. Preparation of the transition to the tungsten wall

The transition to the tungsten wall will imply a large number of additional technical and operational requirements for the main scenarios of JT-60SA. As drawn from the experience in JET and AUG, the following prerequisite should be examined prior to the transition to the tungsten wall:

- High density/large gas puff will be required in the W-wall to avoid W influx and accumulation. This needs to be tested well in non-inductive scenarios in particular.
- Some of the ECRH power will be dedicated to W control and this needs to be tested in advance in relevant scenarios by injecting W or high Z species.
- Shine-through with the available NB power needs to be re-assessed for scenarios.
- Integrated disruption control and mitigation system will be required systematically to avoid or mitigate electro-magnetic and heat loads in high performance scenarios. This will need to be prepared in advance of the transition to W.
- New wall protection system and associated set of diagnostics (IR camera, thermocouple, Langmuir probes, pyrometers, spectroscopy, etc) will need to be installed and commissioned.
- ELM energy impact assessment, ELM mitigation and control or small ELM regime should be established before the installation of the new wall.
- Tungsten sputtering and erosion in the main chamber need to be minimized by careful plasma control clearance.
- Physics of low collisionality will be more difficult to access with the metallic-wall, therefore this part of the program should be done before the transition.

Many of these points are also related to ITER and DEMO research issues and therefore should strongly contribute to the development of DEMO scenario design.

EU publications on W divertor modelling for JT-60SA

- K. Gałązka et al., *"Numerical analyses of JT-60SA with tungsten divertor by COREDIV code"*, Plasma Phys. Contr. Fusion **59** (2017) 045011.
- R. Zagórski et al., *"Numerical analyses of baseline JT-60SA design concepts with the COREDIV code"*, Nucl. Fusion **57** (2017) 066035.
- G. Rubino et al., *"Assessment of Scrape-Off Layer and divertor plasma conditions in JT-60SA with tungsten wall and nitrogen injection"*, Nuclear Materials and Energy **26** (2021) 100895.

	#2	#3
	Full Current Inductive SN, 41MW	Full Current Inductive SN, 30MW High dens.
Plasma current (MA)	5.5	5.5
Toroidal field (T)	2.25	2.25
q_{95}	~3	~3
R/a (m)	2.96 / 1.18	2.96 / 1.18
Elongation / Triangul.	1.87 /0.50	1.86 /0.50
Normalised beta, β_N	3.1	2.6
Line-av. Density ($10^{19}m^{-3}$)	6.3	10.
Greenwald fract. f_G	0.5	0.8
P_{add} (MW) $P_{NNB}/P_{PNB}/P_{EC}$ (MW)	41 10/24/7	30 10/20/0

Modelling with COREDIV : W-PFC

- K. Gałązka et al., *"Numerical analyses of JT-60SA with tungsten divertor by COREDIV code"*, Plasma Phys. Contr. Fusion **59** (2017) 045011.

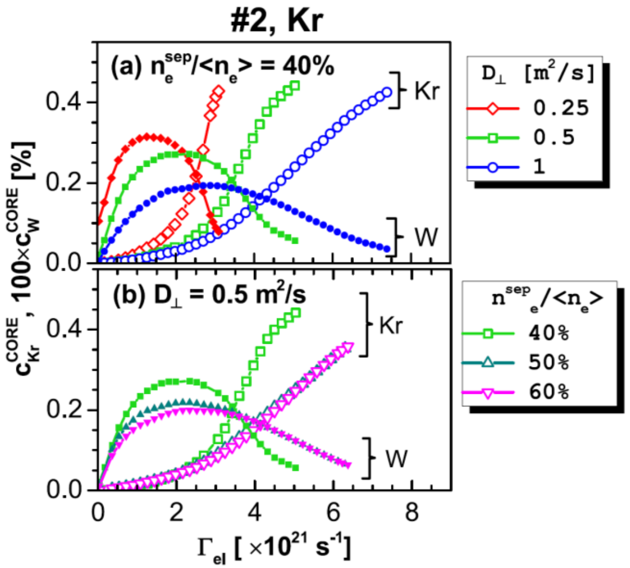
Parameter name	Unit	Scn #2	Scn #3
I_p	(MA)	5.5	5.5
B_T	(T)	2.25	2.25
R_T/a	(m)	2.96/1.18	2.96/1.18
κ	(—)	1.87	1.86
P_{aux}	(MW)	41	30
$\langle n_e \rangle_{LIN}/\langle n_e \rangle_{VOL}/n_e(0)$	$(\times 10^{19}\ m^{-3})$	6.3/5.6/7.7	10/9/12.3
$\langle T_e \rangle_{VOL}/T_e(0)$	(keV)	6.3/13.5	3.7/7.9
$\langle T_i \rangle_{VOL}/T_i(0)$	(keV)	6.3/13.5	3.7/7.9
$H_{98(y,2)}$	(—)	1.3	1.1

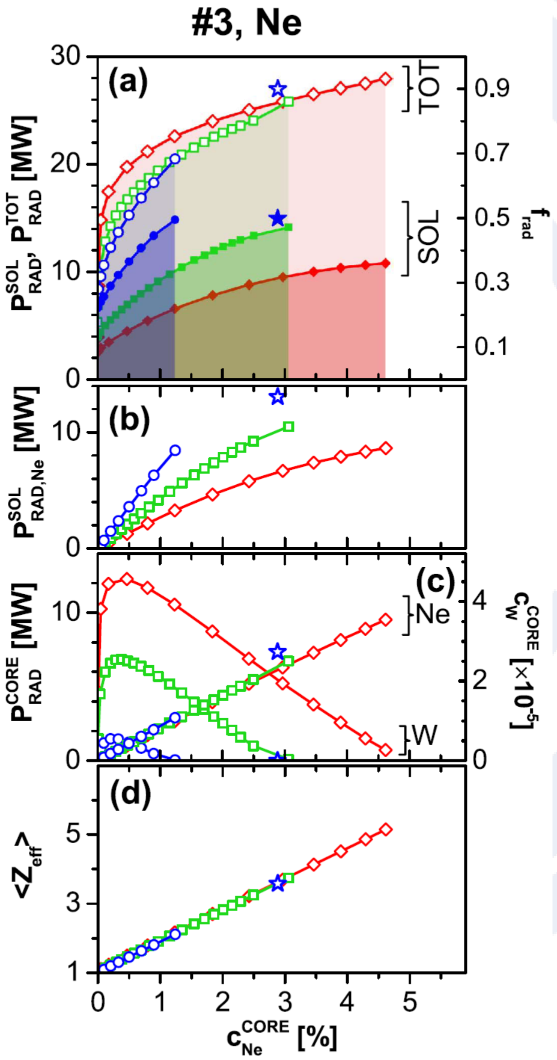
$n_e^{sep}/\langle n_e \rangle \downarrow$	$D_\perp$ / $m^2\ s^{-1}$		
	0.25	0.5	1
40%	✓	✓	✓
50%		✓	
60%		✓	

Main conclusions:

Scenario #2: strong seeding, possibly by Kr, mandatory →however with high Z_{eff}
→ very narrow operation window

Scenario #3: comfortable operation window, similar to the C-PFC case, moderate Ne seeding



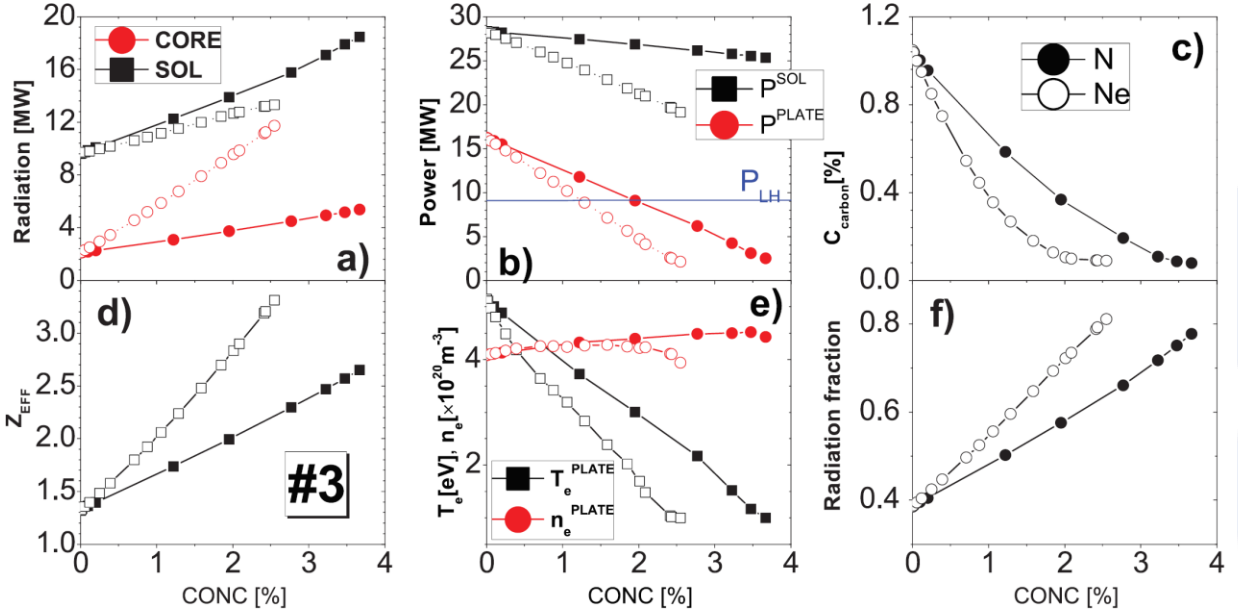


Modelling with COREDIV : C/W comparison

- R. Zagórski et al., *"Numerical analyses of baseline JT-60SA design concepts with the COREDIV code"*, Nucl. Fusion **57** (2017) 066035.

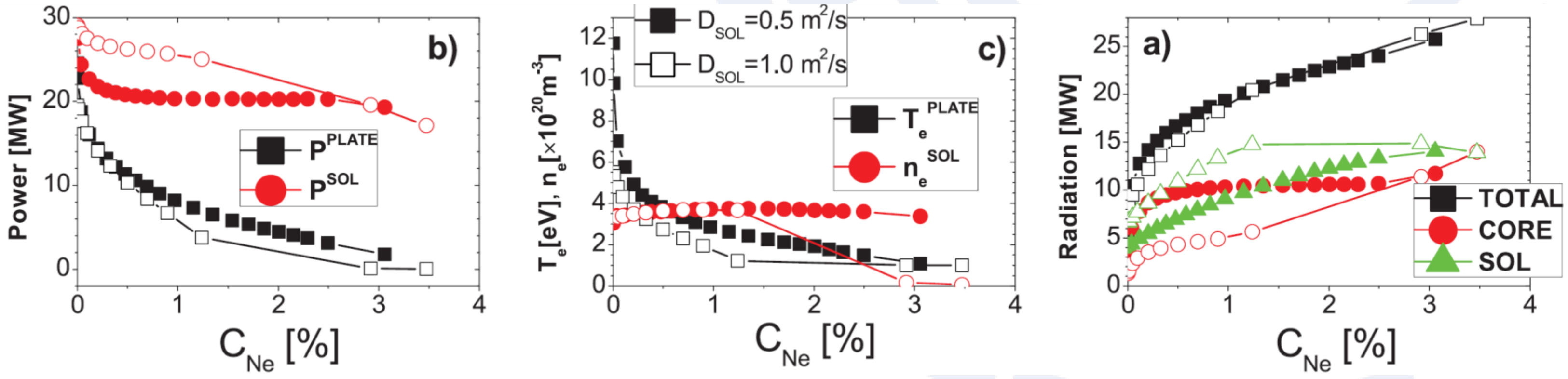
For **scenario #3** in **C,** the regime of detachment on divertor plates can be achieved with N or Ne seeding.
For **scenario #2**, the C and seeding impurity radiation does not effectively reduce power to the targets.
Kr seeding might help to get semi-detached conditions.

C



For a **W divertor,** the power load to the plate is mitigated by seeding and the central plasma dilution is smaller compared to the C divertor.
For **scenario #3** with **Ne seeding, full detachment is predicted.**
For **scenario #2**, **Ar** seems to be an optimal choice

W



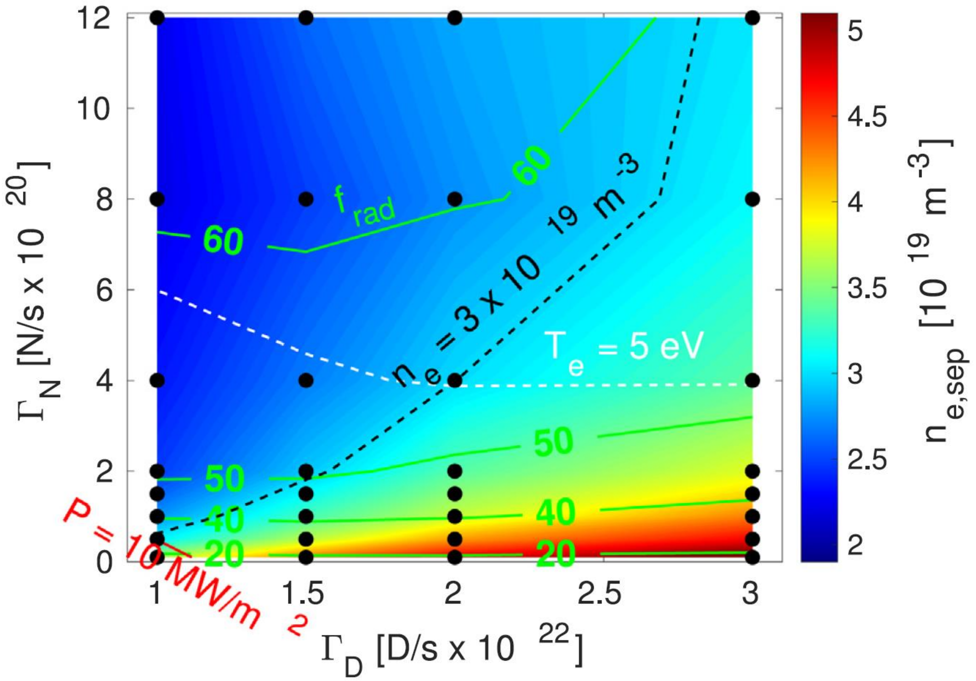
Modelling with SOLPS-ITER : W-PFC

- G. Rubino et al., *"Assessment of Scrape-Off Layer and divertor plasma conditions in JT-60SA with tungsten wall and nitrogen injection"*, Nuclear Materials and Energy **26** (2021) 100895.

Main plasma parameters of the Scenario 3 of JT-60SA [3] and JET experiment 85 419 at $t = 18$ s.

	B_T [T]	I_p [MA]	R [m]	r [m]	k_x –	δ –	q_{95} –	$\langle n_e \rangle$ [10^{19} m^{-3}]	P_{aux} [MW]	P_{in} [MW]	$\lambda_{q,Eich}$ [mm]
JT-60SA	2.25	5.5	2.96	1.18	1.86	0.4	3	10	30	20	1.4
JET	2.7	2.5	3	0.9	1.72	0.4	3.2	7	18	12.5	1.7

engineering limits in steady state defined by $P_{OT} < 10$ MW/m^2 and $T_e = 5$ eV at outer target.
N seeding considered



P_{max} condition is fulfilled for all plasma conditions, except a small region in the left bottom corner. A wide operational window can be defined for upstream density in a neighborhood of the nominal value $n_{e,sep} = 3 \times 10^{19}$ m^{-3} and with $f_{rad} > 50\%$. In these conditions, we have $3 < Z_{eff,sep} < 4$.

Fig. 6. Operational window showing contour of $n_{e,sep}$ for JT-60SA Scenario 3. Contour levels at $n_{e,sep} = 3 \times 10^{19}$ m^{-3}, $P = 10$ MW/m^2 and $T_e = 5$ eV are respectively shown in black, red and white. Green lines represent contour lines for f_{rad}. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

2024 – New task

SA-SE.CM.M.03-T007: Assessment of SOL and divertor plasma conditions in JT-60SA with W wall in high performance scenarios

Plasma edge/SOL modelling of JT-60SA scenario with SOLEDGE3X and SOLPS-ITER transport codes -in support to PFC design - under request of F4E

The modelling with SOL/edge codes will have as objective:

1) Define the radiative patterns necessary to ensure a sustainable load to the divertor, that will guarantee achievement of the performance required by the core plasma.
2) Generate a set of fundamental parameters for optimising core scenarios (<Te>sep, neutral penetration, impurity concentration).
3) Evaluate the thermal loads at the divertor and first wall.

KOM 19/03 with F4E :

agreed to start from technical constraints on PFC

investigate most challenging scenario – using core BC from integrated modelling (eg Romanelli NF 57, 2017)

Modelling can first provide: CX & photons to the dome, power fluxes using optical approximation

Deliverable : provide thermal loads at the divertor and wall in support to PFC design.

D1 - ***SOLPS-ITER*** modeling of a provided JT-60SA high performance scenario with tungsten wall and Ne or mixed impurity seeding (without drifts). - G Rubino (ISTP CNR Bari)

D2 – ***SOLEDGE3X*** modeling of a provided JT-60SA high performance scenario with tungsten wall and Ar or mixed impurity seeding - L Balbinot (Univ Tuscia) + CEA

+ IPPLM K Galazka – COREDIV/TECXY

- Technical constraints from F4E:

Engineering loads in the tungsten divertor PFCs (except targets).
Ensuring T< 1000 °C for steady state operation everywhere.

	Inner& outer baffle	Private dome			Outer cover
Heat flux (MW/m^2)	0.3-1	1	2	10	0.3
Duration (s)	100	100	100	5	100
No. cycles	13000	1000	3000	3000	13000

- Inputs from QST Nakano san:

JT-60SA DMS https://users.jt60sa.org/?uid=238J7D

Scenario 2

Geometry: https://users.jt60sa.org/?uid=25KZ3G

Equilibrium and other data:
https://users.jt60sa.org/?uid=24VEMJ

Gas puff ports not in DMS/from PID.

First Task technical meeting tomorrow
Periodic monthly follow up with F4E/WPDIV