EUROfusion

Soledge2D/3X-Eirene modelling of C-wall Initial research phase scenarios

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UNIVERSITÀ DEGLI STUDI DELLA TUSCIA DIPARTIMENTO DI ECONOMIA, INGEGNERIA, SOCIETÀ E IMPRESA

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Objectives

- Defining an *operational window* ($n_{e,sep}$, P_{in}, impurity concentration …) as it was done for Scenarios #2 and #3
- Predicting *power* and *particle flux profiles* to the divertor targets (applications)

} *Consistently with core and pedestal modelling*

- Understanding the influence of *sub-divertor neutral flux*
  - Estimating neutral particle flux
  - Provide reasonable *neutral penetration* to core modelling
- Support to scenario development (s.p. position, power fluxes etc.)
- Provide plasma background for *diagnostic* R&D (*VUV*, *Langmuir probes*, Visible spectr., Thomson scattering…)
- Code comparison and *benchmarking*

What was previously done: Scenario #2

1) Transport parameters derived from rescaling transport profiles derived from compatible JET pulse modelling
2) Equal input power sharing between D^+ and e^- channel
3) Carbon recycling tested on C-wall JET pulses
4) Used an external model to estimate sub-divertor neutral transport

- An *operational window* was defined
  - Separatrix density was doubled ($1x10^{19}m^{-3} \rightarrow 2x10^{19}m^{-3}$)
  - Plasma purity was reduced (n_D/n_e=0.80→0.72)
- Predicted *power* and *particle flux profiles* to the divertor targets
- Modelled *argon* and neon cooling combined with intrinsic carbon in scenario #2 condition
- First estimation of influence of sub-divertor neutral flux

What we are doing: Initial res. phase II

	Phase	Expected operation schedule		Annual Neutron Limit	Remote Handling	Lower Divertor (wall material)	P-NB Perp.	P-NB Tang.	N-NB	NB Energy Limit	ECRF 110 GHz & 138 GHz	Max Power
Initial Research Phase	phase I	2020-2023	H	-		-	0	0	0	0	1.5MWx5s	1.5MW
		2025		(N2)			3MW	3MW				19MW
	phase II	2025	D	3.2E19		Carbon Div. Pumping (Carbon)	6.5MW			23MW x 14s duty = 1/30	1.5MWx100s + 1.5MWx5s	26.5MW*
		2026		(N2)	R&D							
	phase III	2027										33MW*
Integrated Research Phase	phase I	2029 - 2032	D	4E20 (water)		Actively cooled Carbon Div.Pumping (10MW/m2 ss, 15MW/m2x5s) (Carbon)	13MW	7MW	10MW	20MW x 100s 30MW x 60s duty = 1/30	7MW x 100s	37MW
	phase II	2033 -	D	1E21 (water)		Actively cooled Tungsten Div.Pumping (Tungsten)						
Extended Research Phase		>5y	D	1.5E21 (Boron)	Use	Actively cooled Tungsten Advanced Structure (U. Div. to be considered) (Tungsten)	16MW	8MW		34MW x 100s		41MW

(filler in the VV double wall)

Upper Open Carbon Divertor (very limited heat handling capability) is always ready

*Real Injection: ~26MW x 2-3 sec limited by divertor cooling

Div. Relevant quantities
- Lower input power
- NO actively cooled divertor
- We need to operate in detached/high recycling conditions

How we are modelling Initial res. phase II

1) Transport parameters derived from rescaling transport profiles derived from compatible JET pulse modelling

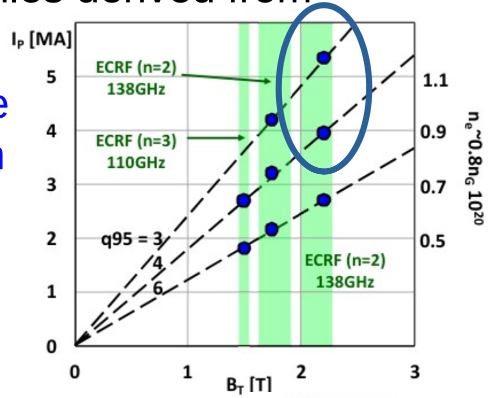
2) Equal input power sharing between D^+ and e^- channel

3) Carbon recycling tested on C-wall JET pulses
4) Used an external model to estimate sub-divertor neutral transport

How we are modelling Initial res. phase II

1) Transport parameters derived from rescaling transport profiles derived from compatible JET pulse modelling

- Included pedestal effective transport profiles from core modelling → better estimation of ped./ped. top radiation



2) Equal input power sharing between D^+ and e^- channel

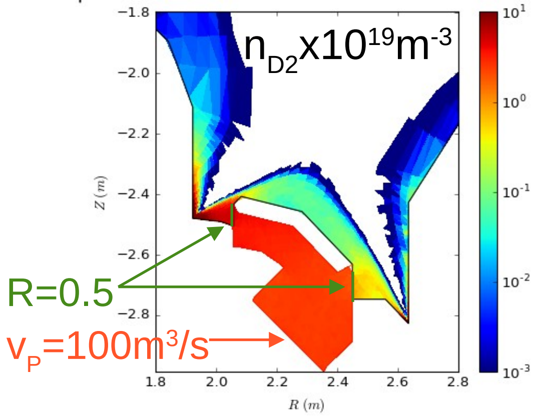
- Total power flux and its sharing at SOLEDGE2D inner boundary derived from core modelling

3) Carbon recycling tested on C-wall JET pulses

4) Used an external model to estimate sub-divertor neutral transport

- Subdivertor modelling included in SOLEDGE2D including semi-transparent surfaces → better evaluation of pumped fluxes and neutral penetration

- Tuned puffing to obtain $<n_e>_{sep}=2.0\times10^{19}m^{-3}$

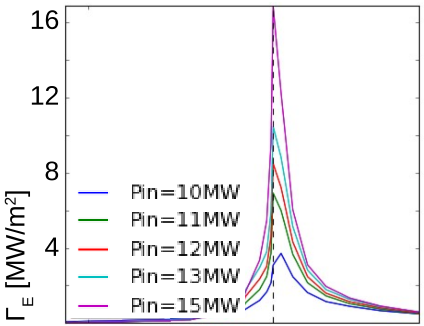


Some early results with $\langle n_e \rangle_{sep}$=2x10^{19}m^{-3}

The maximum P_{in} to obtain sustainable divertor conditions is lower than the input power of initial research phase II/III

$P_{in}=P_{aux}-P_{rad,in}-P_{ELM}$

The power to the outer divertor will be a limiting factor in this phase



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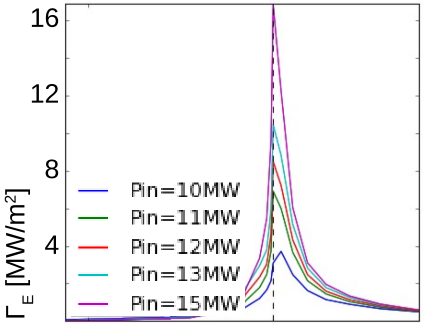
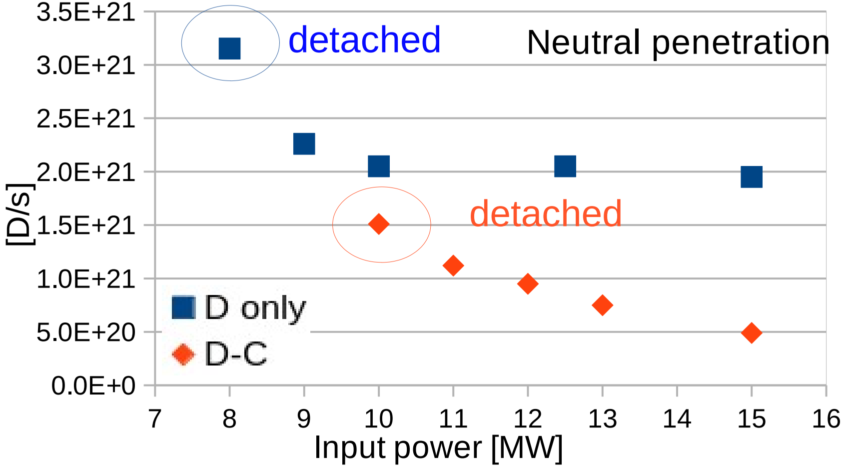


It is not just a power exhaust issue...



Higher separatrix density is needed to obtain sustainable conditions
We would need new input from core modelling if possible

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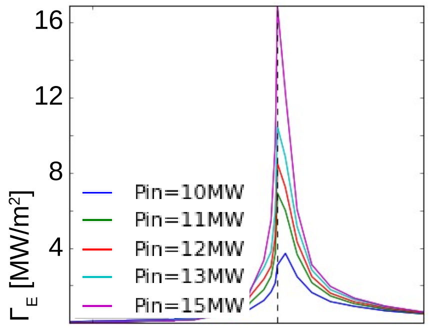

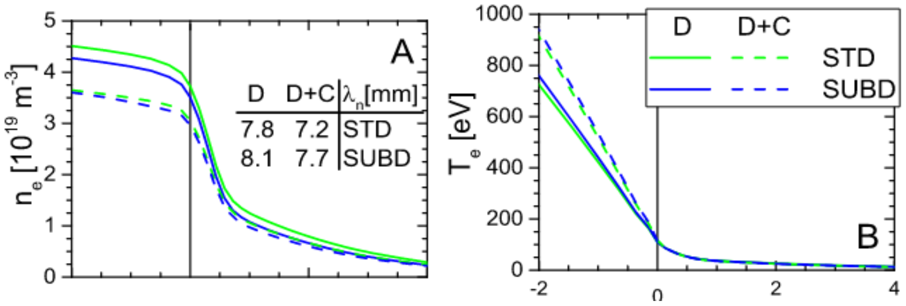

K.Galazka et al, 48th EPS (2022)

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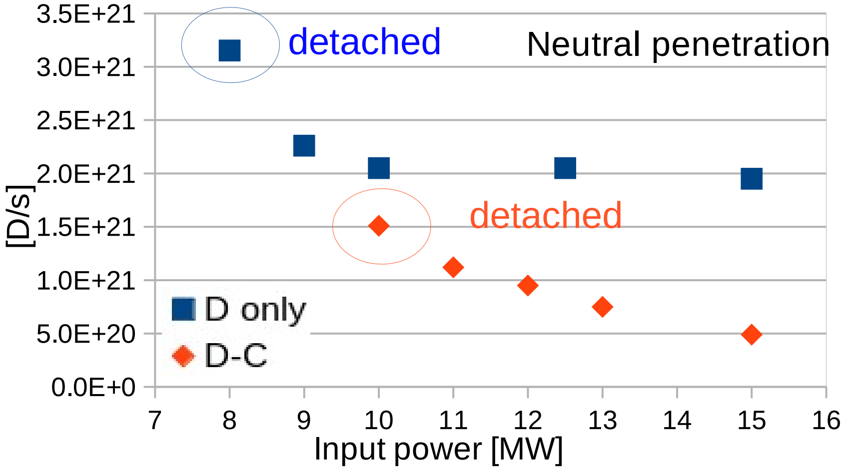

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What we need to improve our modelling

- Information from core and pedestal modelling:
  - Which parameter must be maintained?
    - Separatrix density?
    - Neutral penetration (ionization source)?
    - Pedestal top density?
  - If core simulations are run with higher $\langle n_e \rangle_{sep}$ and *“correct”* neutral penetration, what does append? (Tranp. coef., power sharing etc.)
  - If impurity puffing is included in core modelling
    - Estimation of impurity radiation inside SOLEDGE2D boundary
    - Estimation of impurity transport
- Pumping capabilities
- Pellet particle flux

What information we can provide

- Operational range
  - Estimate power flow to the targets, required density and/or impurity concentration
- Estimate puffing, neutral penetration and pumped flux
- Influence of strike point position on power exhaust and pumping
- Provide plasma background for diagnostic R&D
  - *VUV*
  - Thomson scattering
  - Interferometer
  - *Langmuir probes*
- Ramp-up simulations
  - Initial research phase (no active cooling)
  - Integrated research phase

Possible **future** work

- Complete the assessment on *initial research phase II/III* scenario (this year)
- Complete code benchmarking (this year)
- Execute a second iteration if new data from core modelling are available in order to converge to an integrated simulation (this year, beginning of next year)
- Iterate this process with other interesting scenarios (initial res. Phase I or integrated res. phase scenarios)
- Investigating the influence of strike point position on power exhaust and particle pumping
- Checking power fluxes during the ramp-up, especially during the initial research phase scenario