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WPSA Code Management Area Progress Meeting

Assessment of SOL and divertor plasma conditions in JT-60SA with W wall in high performance scenarios

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Objectives

- Evaluate **power exhaust** and impurity concentration of JT-60SA high performance scenario (scenario 2) with W first wall
  - Which **plasma conditions** obtain **sustainable power fluxes** the divertor?
  - Under which conditions detachment can be obtained?
    - Argon seeding (SOLEDGE – Università della Tuscia)
    - Neon seeding (SOLEDGE/SOLPS running - CEA/CNR)

- Evaluate **pumping** efficency and divertor geometry effect
    - SOLPS → evaluate the effect of pumping speed
    - SOLEDGE → evaluate the effect of divertor geoemtry and s.p. position

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Discharge and physical parameters

JT60-SA scenario #2	
R [m]	2.96
a [m]	1.17
I_p [MA]	5.5
B [T]	2.25
P_{aux} [MW]	**41 MW**
$<n_e>_{sep}$ [m^{-3}]	**$2.0x10^{19}m^{-3}$**
$<n_e>_{ped}$ [m^{-3}]	$5.0x10^{19}m^{-3}$
$<n_e>_l$ [m^{-3}]	$6.0x10^{19}m^{-3}$
D^+ flux [s^{-1}]	$1.8x10^{21}$ s^{-1}
Transport parameters	Derived from experiments and scalings ($\lambda_q \approx$ 1.5 mm)

Target **P_{in}=30MW**

Corresponds to **P_{aux}~40MW** with realistic/derirable impurity concentration from COREDIV prediction

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Integrated modeling predictions

- COREDIV – integrated 1D core + 2D SOL (simplified slab SOL geometry, analytical neutrals background)
- P_{aux}=41MW, n_e^{sep}=2.24 10^{19} m^{-3}, H-mode, far SOL D = 1m^2/s,

- When increasing Ar concentration the W radiation rises due to increased sputtering,
- then it lowers due to lower temperature on the targets (not shown, see Q_{target}).
- P_{sep} drops quickly to around 22 MW already at 0.5% of Ar
- Total power to both targets hardly falls to 6 MW

BC condition for the SOL transport codes

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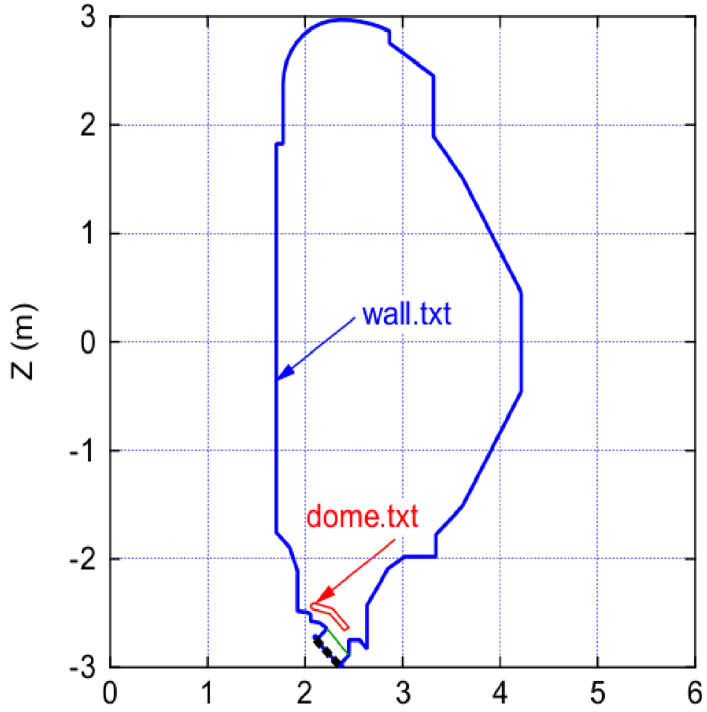
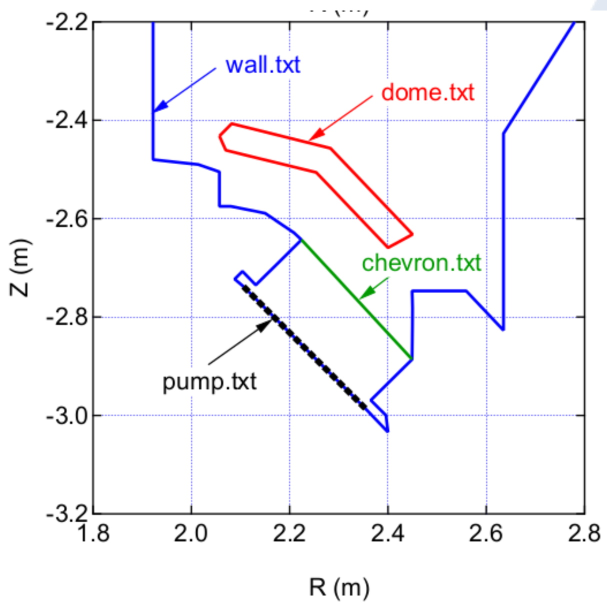
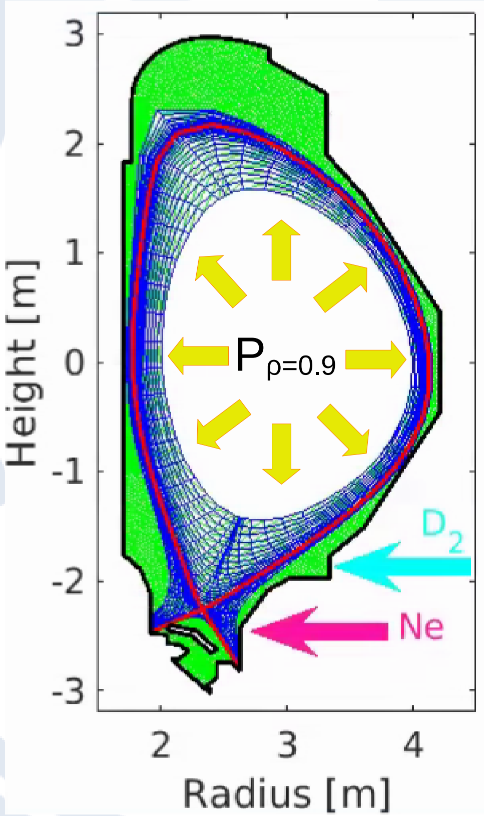
Geometrical parameters

Wall, pumping and puffing taken from IDM repositories







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1.1) Power exhaust in argon seeded simulations

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Ar seeded case (SOLEDGE)

- We can not directly correlate $P_{\rho=0.9}$ (our input) to P_{aux}
- Performed an **input power scan** (22-26-30MW)
- **Set inpurity content** by tuning seeding
  - Check which conditions allowed for detachment

$P_{\rho=0.9}$ (in. bound.)	22 MW		26 MW		30 MW	
Div. Plasma status	inner det.	outer det.	inner det.	outer att.	inner det.	outer att.
$P_{rad,tot}$	18.5		18.9		17.5	
$P_{rad\ 0.9<\rho<1}$	5.4		5.6		4.7	
$P_{rad,SOL\ (\rho>1)}$	13.1		13.3		12.8	
$P_{sep,\rho=1}$	16.6		20.4		25.3	
$P_{part,wall}$	**3.5**		**7.1**		**12.5**	

Detachment could only be obtained in the P_{in}=22MW case

Key parameter
If we want the outer target to be detached, we can afford only ~4MW of power not radiated

$P_{sep,L\text{-}H}$=10MW → H-mode **access is guaranteed**; detachment is obtained with double P_{sep}

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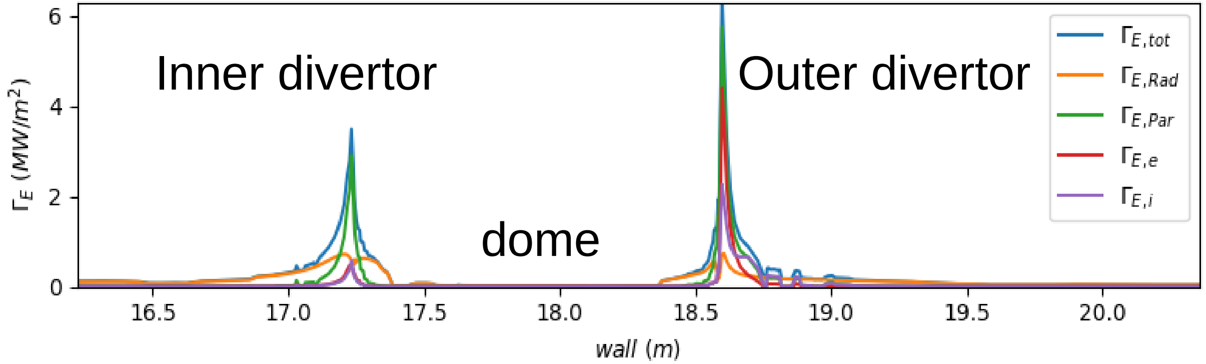
Power exhaust issue is critical (1/2)

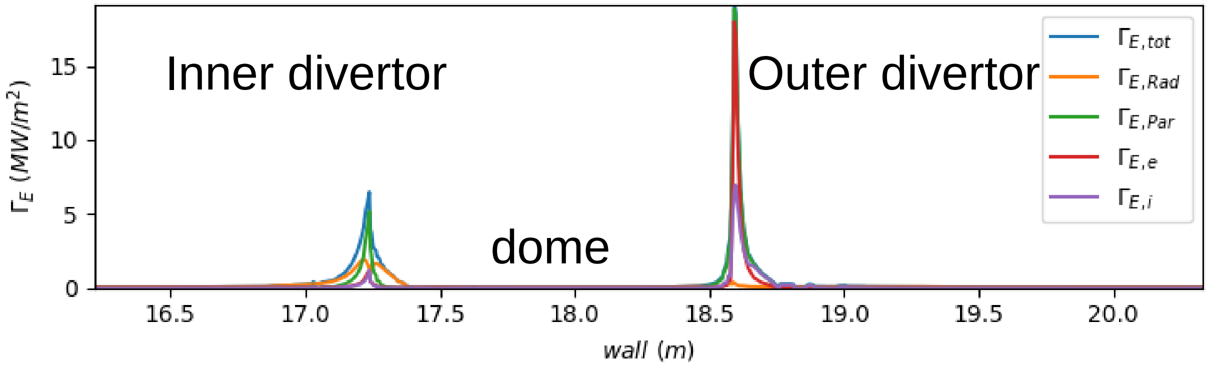
P_{in}=22MW

Power density flux to the inner and outer target is below 10MW/m^2



P_{in}=30MW

Power density flux peaks at 20MW/m^2 and outer target is attached → high sputtering rate is expected



Power flux to the dome and other sections of the first wall is negligible

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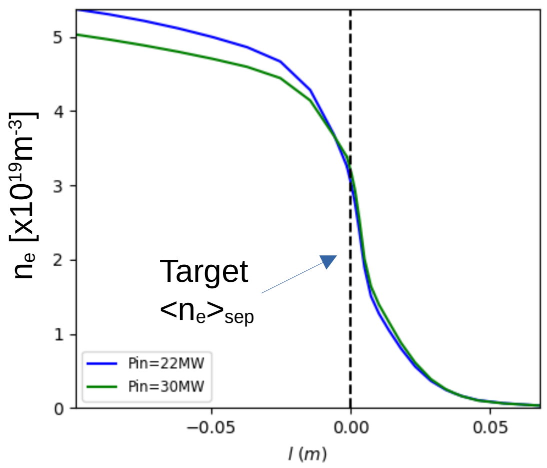
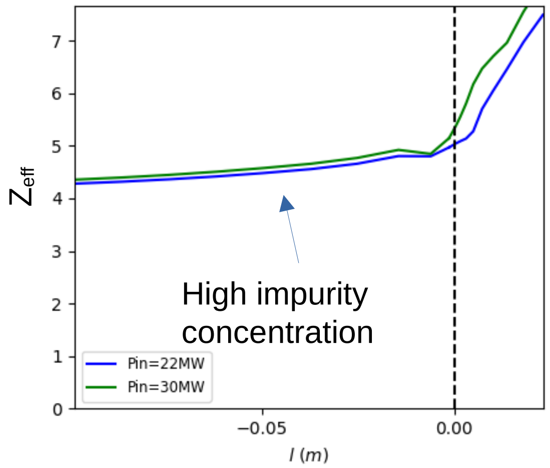
Power exhaust issue is critical (2/2)

… and there may be some consequences on machine performances

Radial outer mid-plane profiles





Pumping rate is slow, $\langle n_e \rangle_{sep}$ decreases slowly

- Sustainable divertor conditions where obtained with **higher $\langle n_e \rangle_{sep}$** and with **high impurity concentration**
- **Previous Ar** seeded simulations included carbon and showed slightly lesser power exhaust issue
- **Maximum P_{aux} sustainable** under these conditions **is ~30MW** which is consistent to what was recently presented at 26th PSI conference
- **High radiation fraction** are required to sustain detachment in the scenario

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1.2) Power exhaust in neon seeded simulations

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Ne seeded case (SOLPS)

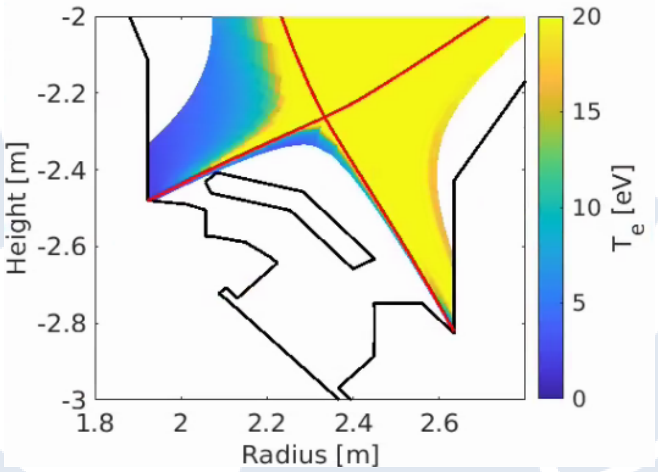
- Performed an **input power scan** (26 and 30MW) @$n_{e,OMP}$ ~ 2e19 m^{-3}
- Simuation are converging
- **Set inpurity content** by tuning seeding
  - Decrease power levlel to allowable values

$P_{\rho=0.9\ (in.\ bound.)}$	26 MW		30 MW	
Div. Plasma status	inner det.	Onset Det.	inner det.	Onset Det.
$P_{part,wall}$	3.21		4.7	
$P_{sep,\rho=1}$	21.6		25.3	
$P_{rad\ 0.9<\rho<1}$	3.19		3.1	
$P_{rad,SOL\ (\rho>1)}$	14.4		17.7	
$P_{rad,tot}$	17.4		20.8	

Similar $P_{part,wall}$ to obtain detachment onset

$f_{rad} = P_{rad,tot}/P_{\rho=0.9} > 65\%$

Outer target start to detach in a region close to Strike Point



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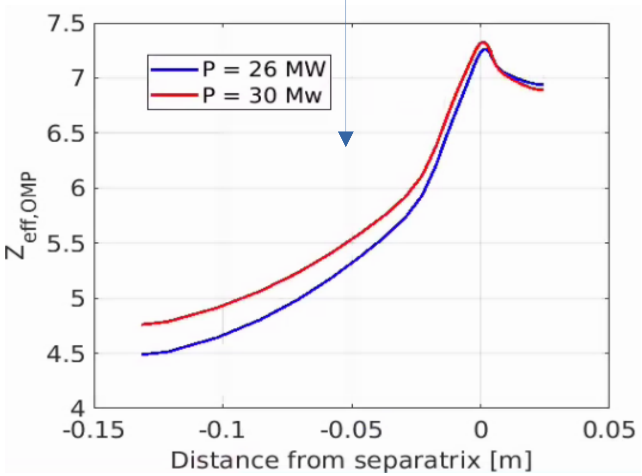
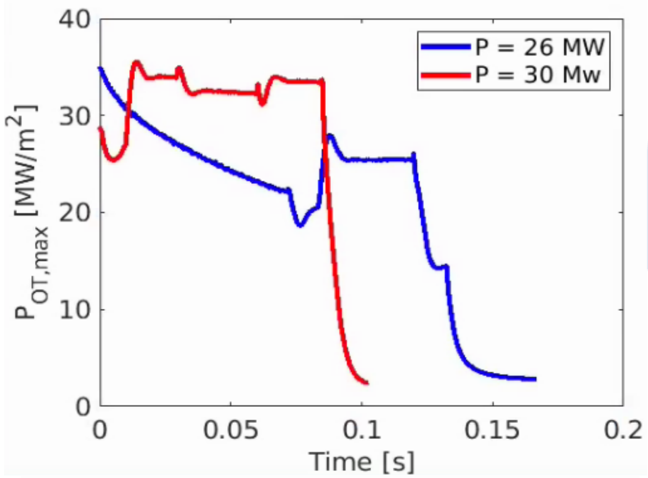
P=30 MW with Ne – SOLPS

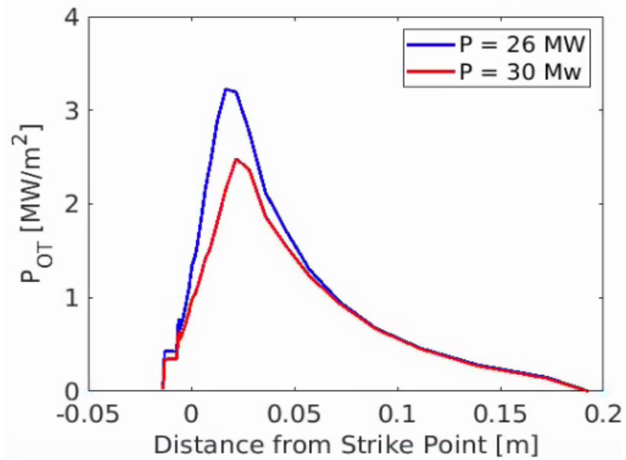
Simulation are converging

Very high plasma contamination required for f_{rad}>65%

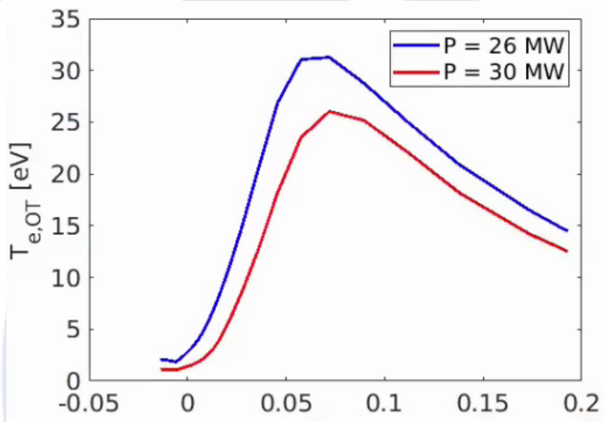


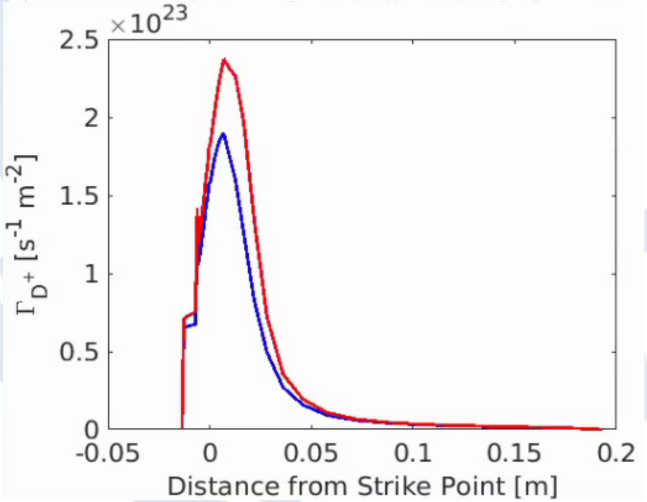
“No” power exhaust issue





Sputtering issue in far-SOL?





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Conclusions on power exhaust mitigation

- Power exhaust is a critical issue
- To obtain detachment with high input power, high density and high impurity concentration is required
  - Is such separatrix density compatible with target core performance?
  - What is the inpact on core performance?
  - Core modelling is foreseen
- The effect of λ_q predictability will be addressed
- Can detachment be obtained?
- Can power density flux be
- reduced below 10MW?

YES, but the inpact on machine performace must be addressed: YOU mught be able to help us

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2) Pumping

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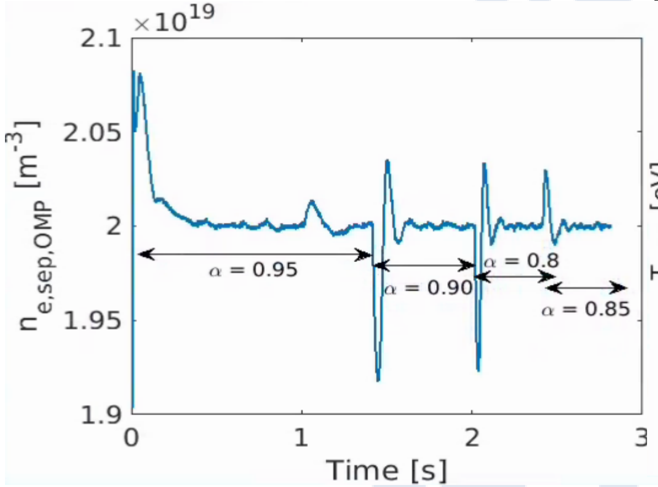
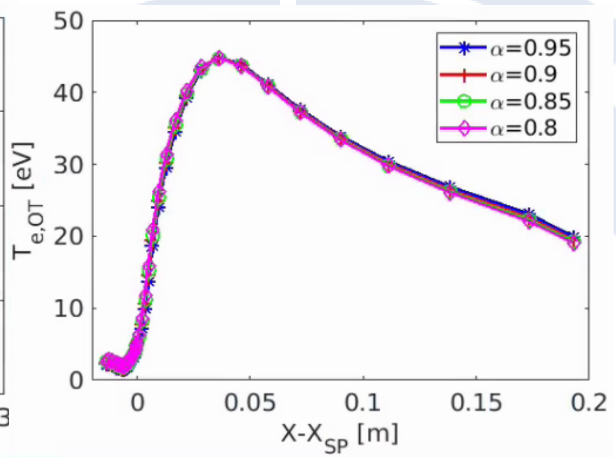
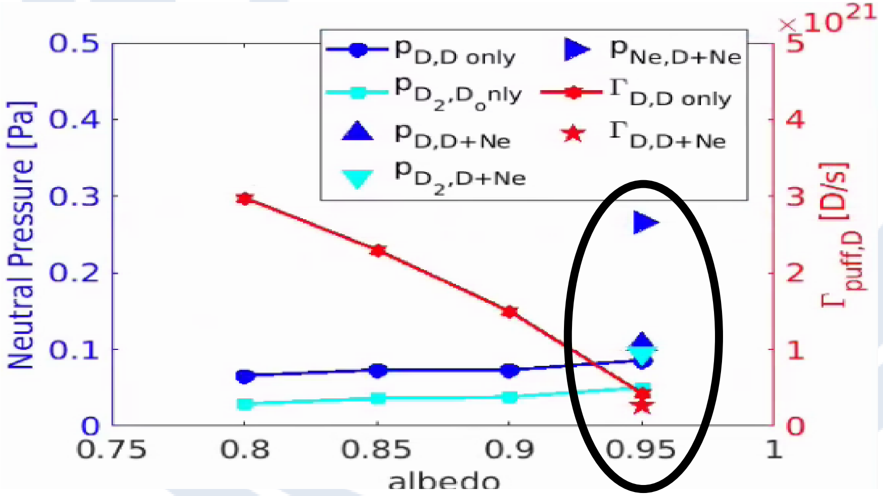
Accessing pumping rate

- Scan in D pumping albedo 0.8-0.85-0.9-0.95
- Pure D plasma (for fast scan)
- **Attached condition** on OT (P_{in} = 10 MW)
- $n_{esep,OMP}$ = 2e19 m^{-3} **feedback controlled by Γ_{puff}**
- Same OT plasma conditions
- Pressure averaged in front of the pump (both P_D and P_{D2})

No power exhaust effect







Sub-divertor pressure doesn't change drastically even if the albedo il changed → **this is the pumping system working range in attached regime**

Pumping speed ~100m^3/s

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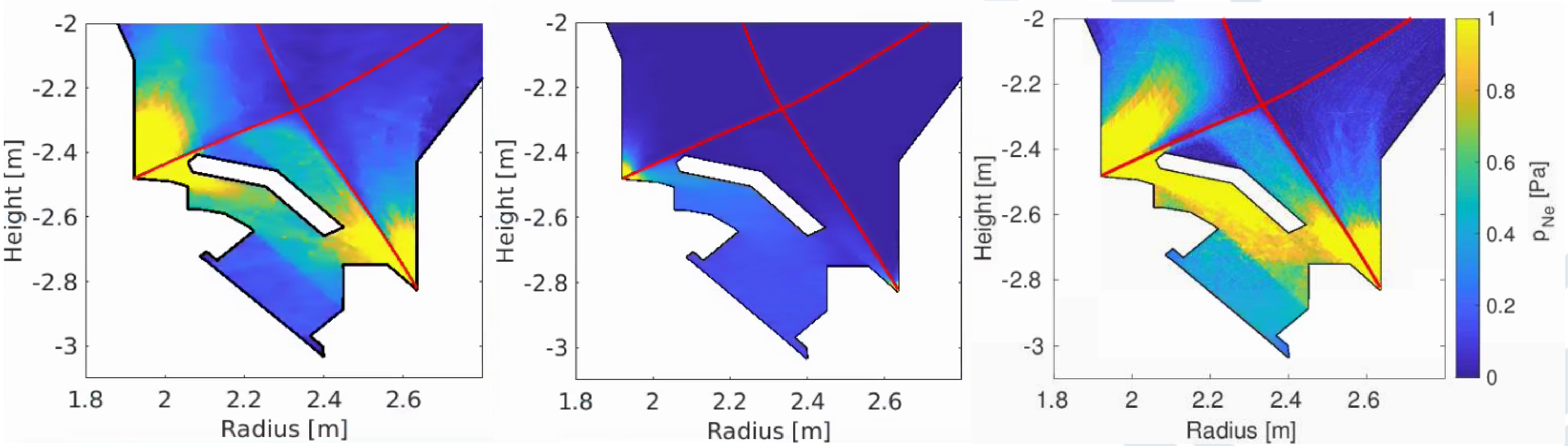
Neutral Pressure Ne seeed

Sub-divertor pressure doesn’t change drastically even if the plasma is deeply detached from IT and strat to detache on OT

→ **Difficult leakage of D neutrals from divertor chamber towards the subdverto region (better for Ne)**



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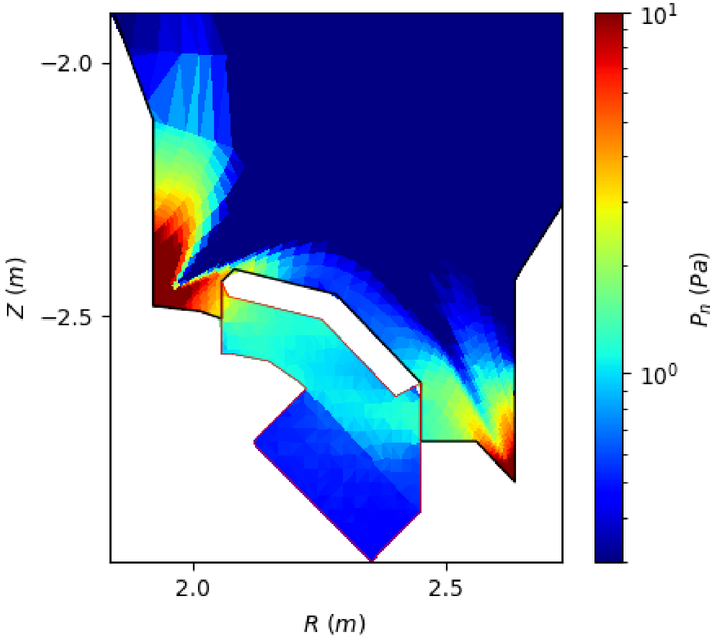
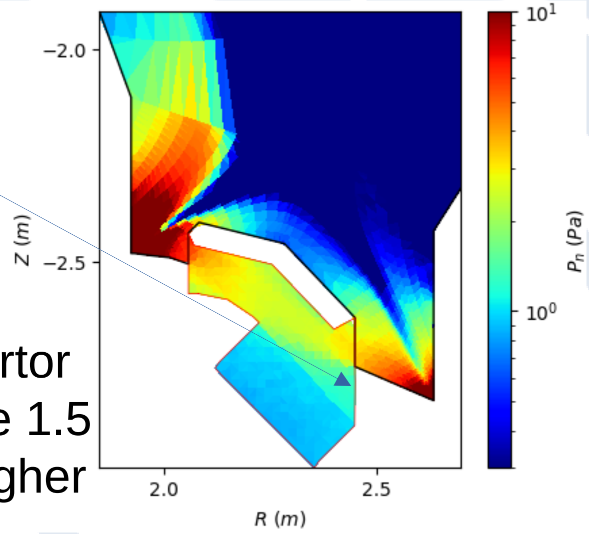
How can pumping rate be increased?



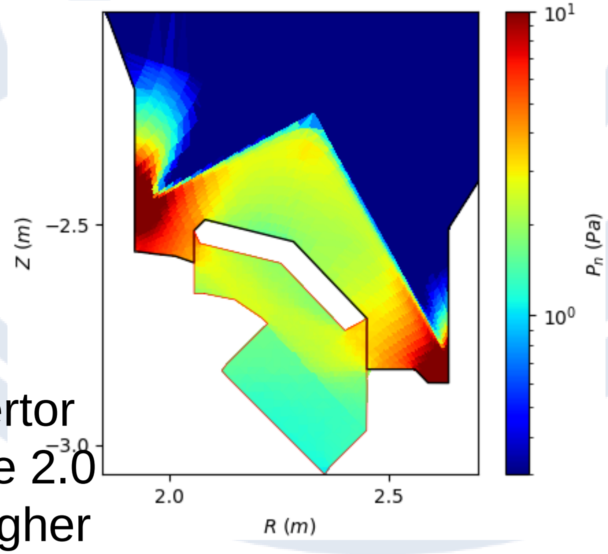
Standard divertor geometry → **low sub-divertor pressure** even when outer target is detached

Change divertor shape



Subdivertor pressure 1.5 times higher

Change s.p. location
(obtained by lowering the first wall position by 8 cm)



Subdivertor pressure 2.0 times higher

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Can pumping rate be increased?

- No final results yet, simulations are slowly converging
- BUT
- Neutral pressure is a **factor 1.5/2 higher** in the no-corner and high s.p. simulation respectivelly
- **Pumping rate can be increased with both solutions**
- No inpact on power exhaust is observed at the moment

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Ongoing activity

- Edge modelling will be completed soon
- Core modelling will be performed to complete the integrated modelling

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